# Report of Activities in the Divisions



## Annual Report 1989 - Volume II

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

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Thirty-fifth Annual Report (Volume II) of the European Organization for Nuclear Research

Publications Section

The CERN Annual Report is produced in three Volumes :

Volume 1, entitled 'CERN 1989', selects the highlights from the year and presents them in a non-technical style with ample illustration. There are English and French editions and it is anticipated that this will be the Volume that most readers will wish to see.

Volume 2, entitled 'Report of Activities in the Divisions', gives a detailed description of the year's work in technical language and without illustration. English and French editions, produced in limited quantities, are available on request.

Volume 3, entitled 'List of CERN Publications', groups all known publications coming from the research at CERN during the year. It is produced in a single edition in limited quantity, available on request.

# Contents

# Theory Division

The TH division consists of the Theoretical Physics Division and the Scientific Information Service. Their activities in 1989 are presented separately below.

## Theoretical Physics

The TH division consists of 21 staff members, 12 of them with indefinite contracts; 31 fellows from Member States on two-year fellowships; up to 100 visitors, most of them short-term; and 4 secretaries. The telephone list of CERN-TH had 125 names in June 1989, reaching 137 a little later, a predictable value for the busy summer months. During 1989, TH-preprints surpassed the average birth-rate of one a day. The grand total of 367 was not a very easy number to handle, given the Division's modest secretarial pool and limited computer-terminal facilities.

The main line of research, following a trend already visible in the previous two years, gravitated around LEP physics and other timely phenomenological endeavors. The swing is back from the Planck scale, in whose ambitious avatars some 20 to 30% of the effort was still involved. Lattice QCD, nuclear physics, cosmology and astroparticle physics were the other main topics of activity.

### Fundamental theory

*Conformal theories* is the present name of the game in the forefront of formal field theory. Conformal theories encompass many systems, from the intrinsically two-dimensional fundamental strings (one dimension is time) to 'real' planar critical systems with two space dimensions. Some highlights in this direction include :

- the consistent covariant quantization of the manifestly space-time supersymmetric Green-Schwartz action, a step in the proof (or disproof) of the finiteness of string theory;
- further support for the existence of a fundamental length in string theory, relevant to the final stages of black hole evaporation;
- the systematic construction of modular invariants and vacuum solutions to string field theories;
- further struggle with the construction of realistic four-dimensional string models, with three generations, both in the orbifold and in the free-fermion approaches;
- the analysis and quantization of Chern-Simons theories, a field related to the classification of knots and links, and whose connection with physics is vehemently prophesied;
- quantum groups : a symmetry tool to classify rational two-dimensional conformal field theories, and to analyse quasi-two dimensional condensed matter systems, fractional spins and fractional statistic excitations, etc.

### Phenomenology within the Standard Model

Most of the 1989 activity centred around the preparation of the start-up of LEP. EP and TH Divisions jointly sponsored a workshop 'Z Physics at LEP1', actively attended by most in-house phenomenologists and large numbers of invitees. New results concerned Z decays into four fermions, into pairs of light scalars, and into states of non-null flavor; top mass effects on radiative corrections; the treatment of multi-photon initial state radiation and its applications to event generators; a model-independent approach to the Z line shape; radiative corrections to asymmetries, effects of new gauge bosons; and a long *et cetera*. Some of this effort materialized in the form of a three-volume 'Yellow' report on LEP physics.

Away from LEP, progress was perceptible in various fronts. Among them, the QCD effective Lagrangian at long distances, the masses of heavy-flavoured hadrons, the decays $b \to s\gamma$, the prospects to measure the $WW\gamma$ vertex at ep and pp colliders and their hopes to observe new vector bosons, the understanding of a hypothetical strongly interacting Higgs sector, and the chances to see CP violation in $\Phi$ decays. The questions on the proton spin structure raised by the EMC measurements of polarized structure functions continued to be debated, and new light was shed on the subject by the derivation of generalized Goldberger-Treiman relations for singlet currents. Efforts have been made to gauge the impact of nuclear physics on the analysis of solar neutrino experiments, as well as that of collective pionic modes on neutrino scattering.

### Lattice gauge theory

As in 1988, unrestricted access to the newly installed CRAY Y-MP was a phenomenal asset. The large amount of available computer time made it possible to launch or to participate in ambitious large-scale projects. These include a high-statistics study of the 3-d, 3-state Potts model and an analysis of the chiral phase transition in QCD with light quarks. The latter simulation gave a strong evidence for the decrease of the chiral transition temperature with increasing number of flavours. Members of the lattice community also participated in the quantitative determination of weak matrix elements and of the hadron spectrum in quenched QCD, efforts not yet crowned with complete satisfaction.

### Interface with Astrophysics, Cosmology & Cosmogony

'We are all in the gutter, but some of us are looking at the stars'. Thus may a contemporary Oscar Wilde have expressed the fact that some of the effort of the TH division is diverted from the analysis and forecast of data from the LEP pits, and directed straight upwards. The issues dealt with in this section ranged from the rapidly testable, such as the unsuspected possibility that the non-luminous matter of our galaxy be made of very heavy stable charged particles, to the numerically most serious problem in our understanding of the Universe : the smallness of today's cosmological constant (the energy density of the vaccum, as a source of a gravitational field). Even more far-reaching may have been the study of chaotic inflation scenarios for ever-replicating universes, and the study of the unlikely global conditions under which the human race, and the Theory Division, may last forever.

### Conclusion

As can be seen from the above brief description, the work of the Division has extended over a broad range of Theoretical Physics. This reflects the growing symbiosis between different areas of physics ranging from statistical mechanics through nuclear physics and particle physics to astrophysics. Mathematical physics and field theory provide a common language for describing these various phenomena. The activity of the Division reflects a healthy balance between work close to experiment and studies of a more fundamental theoretical nature.

## Scientific Information Service

The community of CERN users is still growing, implying an increasing demand for SIS services, availability of literature and copy facilities. In a situation of a fixed low level of staffing and operational budget, this situation requires a systematic use of modern technological aids and increasing efficiency.

In order to meet these challenges, a development plan was elaborated and submitted to the Director-General. It presents three main projects : the implementation and elaboration of a computerized library management system, the creation of an international clearinghouse for HEP preprints, based on optical disk storage, on-demand printing and on-line ordering, and extension of library space. There were also a number of policy issues, relating to the financial basis of services.

The activities and development plans were reviewed by consultants from France and the UK at the end of the year. The reports raise a number of policy issues and give strong support to the three main projects : Library system, Optical disk for preprints, and Library space extension.

A contract for the library system ALICE (Aleph Library Information at CERN) was signed in November 1988. The cataloguing and retrieval modules were installed for testing late in the summer of 1989. Further developments were carried out in the autumn, and the full conversion of records for some 25 000 books and 11 000 preprints and reports is scheduled for the start of 1990. The query language is CCL (Common Command Language, ISO 8777). Next to follow will be the loans module (based on bar-coded items and the official CERN magnetic card for user identification), periodicals control and acquisition with accounting. A query and SDI (Selective Dissemination of Information) system based on electronic mail was developed at SIS by a research associate from ISTIC, Beijing.

An initiative was taken towards an international cooperation scheme for efficient management of preprints databases. The present overlap of input should be replaced by a system of distributed responsibilities, with electronic transfer and merging of data. A stand-alone system for decentralized input, based on UNESCO's MicroISIS software was developed and distributed to Dubna and Beijing. A first international co-ordination meeting is scheduled for May 1990 at CERN.

The optical disk project for the creation of a clearinghouse for preprints is now being submitted for funding. With the release of 6.4 GB disks, it is now realistic to keep images of one full year's preprints on-line for local access on screen (in the library) and for dissemination to users world-wide by mail or telefax. The use of LANs for full-text transmission on-site is restricted by the limited capacity of present Ethernets and the priority given to transmission of experimental data.

A new policy was decided at the end of 1988 for the CERN Historical Archive. During 1989, an archive version of the library system was installed and the archive files converted to AMC-MARC format (a standard for archives and manuscripts developed by the Society of American Archivists). The Archive can now easily take care of and make available all documents considered to be of archival interest. The manpower problem remains to be solved.

# Experimental Physics Division

## The LEP Programme

### ALEPH

1989 was an exciting year for LEP and the ALEPH collaboration (Annecy, Athens, Barcelona, Bari, Beijing, CERN, Clermond-Ferrand, Copenhagen, Ecole Polytechnique, Edinburgh, Florence, Florida State, Frascati, Glasgow, Heidelberg, Imperial College, Innsbruck, Lancaster, Mainz, Marseille, Munich, Orsay, Pisa, Royal Holloway College, Rutherford, Saclay, Sheffield, Siegen, Trieste, and Wisconsin). Mid-August saw the first collisions, in a 5-day 'pilot run'. ALEPH was ready except for the solid state micro vertex detector, of which only fragments were in place, and the outer muon detection layer. It was the culmination of 15 months of intensive installation effort, made especially nerve-racking by the relatively short period of time available between completion of the civil engineering work for the underground cathedral and the startup of LEP. Many problems had to be solved, not the least of them learning to work together on one detector after constructing the components in many laboratories by semi-autonomous teams. One of the most challenging jobs, successfully accomplished, was that of data aquisition in a coherent way from the several subdetectors.

A first in the history of particle physics experiments was the successful implementation of data reconstruction essentially on-line. The reconstructed data were available in the Computer Centre as well as in two additional clusters within two hours of the arrival of the events. Altogether, the ALEPH off-line system was a major success. Track reconstruction efficiency was 99% from the very beginning. This permitted rapid analysis of the first data.

In this first year of LEP operation ALEPH accumulated ~35 000 Z decays and 55 000 Bhabha luminosity events, in a scan of the Z resonance. Fig. ALEPH–1 shows a Z decay to hadrons. The performance of the detector was in large part excellent, in other areas improved operation is still to be expected. The spatial and energy resolutions of the electromagnetic calorimeter are at their design values. The momentum resolution of the tracking, even at the highest momentum of 46 GeV/c, is $\Delta p/p^2 = 0.0010/\mathrm{GeV}$, quite close to the design value. Fig. ALEPH–2 shows a scatter plot of $p_T$ vs. $(p_1^2 - p_2^2)/|\vec{p}_1 + \vec{p}_2|^2$, for neutral secondary vertices, the historical 'Thompson plot' of the discovery of the $K^0$, as an illustration of the performance of the tracking. The overall performance of ALEPH was entirely sufficient to permit the studies and particle searches indicated for this first data set. The four decay modes : $q\bar{q}$, $e^+e^-$, $\mu^+\mu^-$ and $\tau^+\tau^-$ could be well separated. Perhaps the most important physics result for this first period was the determination of the number of fermion families on the basis of the missing decays into neutrinos. This required a systematically precise measurement of the total cross-sections, and therefore of the luminosity. Fortunately the excellent design and construction of the ALEPH luminosity monitor permitted, even for this first round of data and analysis, systematic errors in the luminosity measurement at the 1% level, a factor of two or more better than was possible in the experiments at PEP and PETRA. As an illustration of this systematic understanding of the luminosity determination, fig. ALEPH–3 shows the agreement between data and simulation for the azimuthal acceptance of luminosity events. Fig. ALEPH–4 shows the measured cross-sections together with the expectation for 3 neutrino families.

Some of the numerical results are as follows :

– From the shape of the Z resonance :

$$m_Z = 91.182 \pm 0.040 \text{ GeV}$$

$$\Gamma_Z = 2.541 \pm 0.056 \text{ GeV}$$

in good agreement with the standard model.

– From the cross-section at the peak,

$$N_\nu = 3.01 \pm 0.15$$

- The partial width for leptonic decay,

$$\Gamma_{\ell\bar{\ell}} = 83.9 \pm 2.2 \text{ MeV}$$

in good agreement with the standard model.

- From this value of $\Gamma_{\ell\bar{\ell}}$ a purely leptonic value of $\sin^2\theta_W$ can be derived

$$\sin^2\theta_W = 0.231 \pm 0.008.$$

- Searches for the minimal Higgs exclude this particle in the mass range

$$32 \text{ MeV} < M_H < 15 \text{ GeV}$$

with 95% confidence.

- Searches for new heavy quarks, heavy leptons, supersymmetry particles, excited leptons and the Higgs bosons of the minimal supersymmetric model are all negative and give lower bounds for the masses of such particles only slightly below one-half of the mass of the Z.

**DELPHI**

DELPHI (Ames, Amsterdam, Athens, Athens National University, Belgium, Bergen, Bologna, CERN, Copenhagen, Cracow, Demokritos, Dubna, Genoa, Helsinki, Karlsruhe, Lisbon, Liverpool, Lund, Milan, Orsay, Oslo, Oxford, Padua, Paris, Rome, Rutherford, Saclay, Santander, Serpukhov, Stockholm, Strasbourg, Trieste, Turin, Udine, Uppsala, Valencia, Vienna, Warsaw, Wuppertal) is a general purpose detector, offering three-dimensional tracking and energy deposition with fine granularity as well as identification of leptons and hadrons over most of the solid angle. In October 1988, the superconducting coil, which provides a 1.2 T field in the 6.2 m bore of the cryostat, developed a leak in one of the turrets. The repair caused a delay of 21 weeks in the magnetic field mapping and thus in the installation of the detectors mounted inside the cryostat. For this reason the magnetic field could be mapped only at the beginning of March 1989. After optimization of the two compensating currents, both the homogeneity and the alignment with respect to the cryostat were substantially better than the specifications.

The Collaboration had to work very hard to complete the installation and the cabling in less than half of the time initially foreseen and have the detector ready for installation of the beam pipe by 20 May. The cabling could be completed by working overtime and at weekends. At the start of June, DELPHI was moved to the final position equipped with all the detectors, including the barrel and forward muon chambers. The Barrel RICH was installed with all the liquid radiators and the mirrors, but half (i.e. 12/24) of the quartz bitubes; the remaining 12 bitubes will be introduced at the end of 1990. Only a few cells of the vertex silicon strip detector were mounted during the pilot run to study background problems. A full inner layer and four outer layer sectors were installed in September. More details on the installed sub-detectors can be found in the EF chapter of this volume of the Annual Report.

The first event was seen on 14 August. Initial running was disturbed by some problems with the efficiency of the data acquisition system. By the end of the year, about 13 000 hadronic Z events were collected. The track chambers worked immediately very well and with no background. The calorimeters were operational few weeks later. Within a few hours the events were passed through the VAX farm and looked at on workstations in the DELPHI Interactive Center DELICE. Fig. DELPHI–1 shows a hadronic event.

Fig. DELPHI–2 shows the line-shape as measured with the hadronic decays of the Z boson. A Standard Model two-parameter fit gave for the number of neutrino species $N_\nu = 2.97 \pm 0.26$. The Z parameters obtained without assuming the Standard Model are :

$$M_z = 91.171 \pm 0.030 \pm 0.030 \text{ (LEP) GeV}$$

$$\Gamma_z = 2.511 \pm 0.065 \text{ GeV}$$

$$\Gamma_{ee}\,\Gamma_h = 0.148 \pm 0.07 \text{ GeV}^2$$

The study of the leptonic decays of the Z bosons gave, assuming universality, the partial widths :

$$\Gamma_{ee} = 83.2 \pm 3.0 \pm 2.4 \text{ MeV}$$

$$\Gamma_{\mu\mu} = 84.6 \pm 3.0 \pm 2.4 \text{ MeV}$$

$$\Gamma_{\tau\tau} = 82.6 \pm 3.3 \pm 3.2 \text{ MeV.}$$

Figure DELPHI–3 gives the energy dependence of the cross-sections of the Z leptonic modes. They are compatible with the Standard Model and universality.

The ratio of the average leptonic width to the hadronic width was found to be $\Gamma_l/\Gamma_h = (4.89 \pm 0.20 \pm 0.12) \times 10^{-2}$. This result, combined with the hadronic data on the line shape provided values for the hadronic, leptonic and invisible widths :

$$\Gamma_h = 1741 \pm 61 \text{ MeV}$$

$$\Gamma_l = 85.1 \pm 2.9 \text{ MeV}$$

$$\Gamma_{inv} = 515 \pm 54 \text{ MeV}$$

which are in good agreement with the Standard Model.

The study of the properties of the hadronic final states allowed a careful comparison with the models which are usually used to describe the hadronization process. The Lund parton shower model tuned at lower energy was found to reproduce well the measured distributions, except for the average value of the transverse momentum $p_T^{in}$ with respect to the sphericity axis in the event plane, which appears to be smaller than expected. Matrix element models had to be retuned at LEP energy to reproduce, in particular, the rapidity distribution. Average values of the most important variables were obtained :

Sphericity : $\langle S \rangle = 0.073 \pm 0.004$
Aplanarity : $\langle A \rangle = 0.0121 \pm 0.0014$
Thrust : $\langle T \rangle = 0.934 \pm 0.003$
Transverse momenta : $\langle p_T^{in} \rangle = 0.434 \pm 0.010$ GeV; $\langle p_T^{out} \rangle = 0.231 \pm 0.005$ GeV

The Collaboration has searched for new particles and put limits on the masses of many of them. In particular standard Higgs have been searched and excluded with 95% confidence level in the mass range 0.2 ÷ 14 GeV. Production of the SUSY Higgs $h^0$ has been excluded up to about 35 GeV (95% CL), and the same limit applies for charged Higgs which decays to τν with a branching ratio larger than 40%. For smaller branching ratios the mass limit varies between 35 and 30 GeV. Selectrons have been excluded up to the kinematical limit.

## L3

The aim of the L3 experiment (Aachen, Amsterdam, Ann Arbor, Annecy, Baltimore, Beijing, Bombay, Boston, Budapest, Caltech, CERN, Florence, Geneva, Harvard, Hofei, Lausanne, Leningrad, Lyon, Madrid, MIT, Moscow, Naples, Pittsburgh, Princeton, PSI, Rome, San Diego, Schenectady, Shanghai, Sofia, Taiwan, World Laboratory, Zeuthen, Zurich) is to detect, measure and analyse $e^+e^-$ collisions at LEP with emphasis on reaching good energy resolution for electrons, photons and muons (1%). The detectors are installed within a 7800 t conventional magnet providing a 0.5 T field. A relatively low field in a large volume was chosen to optimize the muon momentum resolution, which improves quadratically with the track length.

From the interaction point outwards, the following detectors are installed (Fig. L3–1) :

- A central tracking device, the Time Expansion Chamber (TEC), which has been designed with the main goals of determining the transverse momentum and the sign of the charge for particles up to 50 GeV, as well as charged multiplicities and secondary vertices for particles with lifetimes greater than $10^{-13}$ s.
- An electromagnetic calorimeter using a new type of crystals (BGO) to measure photon and electron energies with an accuracy better than 1% above 2 GeV.
- A hadron calorimeter measuring hadron energies with energy resolution $(55/\sqrt{E} + 5)\%$ and $\Delta\theta = 2.5°$, $\Delta\phi = 3.5°$ angular resolution for jets, which also provides a clean muon sample by absorbing hadrons close to the $e^+e^-$ interaction point, thus minimizing pion decays in flight, and by tracking muons through the uranium absorber. A forward-backward system extends the coverage of the hadron calorimetry to 99.5% of 4π.
- A muon detector composed of large drift chambers, which measures the sagitta of the outgoing muon tracks over a length of 2.8 m and provides a momentum resolution $\Delta p/p < 2\%$ at p = 50 GeV/c.

The above detectors are complemented by a luminosity monitor which is made of a cylindrically symmetric array of BGO crystals. It provides a precision better than 2% on the integrated luminosity on a run to run basis.

During 1989, testing of components and assembling of the L3 detector was finished, the experiment being ready to start data taking for 14 August, when LEP started. Runs taken before the end of 1989 have served to test the performances of the subdetectors and set up the appropriate level 2 and 3 triggers. During those runs the muon subdetector and the hadron calorimeter have worked as expected, the electromagnetic calorimeter did not reach yet the design resolution, mainly for low energy electrons and photons, and the time expansion chamber had problems due to the breaking of several wires. All the problems are being fixed for the run in 1990. The total number of interactions taken with the L3 detector has been 17 000. Figures L3–2, L3–3 and L3–4 show some sample events. Using these data, the following results have been obtained and have been submitted for publication :

$$M_Z = 91.160 \pm 0.024 \text{ (exp.)} \pm 0.030 \text{ (LEP) GeV}$$

$$\Gamma_Z = 2.539 \pm 0.054 \text{ GeV}$$

$$N_\nu = 3.29 \pm 0.17$$

$$\Gamma_{ee} = 81.1 \pm 2.8 \text{ (stat.)} \pm 1.2 \text{ (syst.)} \pm 0.7 \text{ (theory) MeV}$$

$$\Gamma_{\mu\mu} = 87.6 \pm 5.6 \text{ MeV}$$

The partial width for decays into b quark pairs

$$\Gamma_{bb} = 353 \pm 26 \pm 30 \pm 35 \text{ MeV}$$

has been measured by making use of the transverse momentum of their semileptonic decays into muons. By measuring the cross-sections and the forward-backward charge assymmetry of muon and tau pairs, the neutral coupling constants to leptons have been constrained to

$$g_A = -0.495 \pm 0.007$$

$$g_V = -0.066 \pm 0.04$$

Also, lower limits on masses of scalar muons $\tilde{\mu}$, scalar electrons $\tilde{e}$, and winos $\tilde{W}$ have been set which are

$$M_{\tilde{\mu}} \geq 41 \text{ GeV}$$

$$M_{\tilde{e}} \geq 41 \text{ GeV}$$

$$M_{\tilde{W}} \geq 44 \text{ GeV}$$

at 95% confidence level.

## OPAL

The OPAL experiment (Birmingham, Bologna, Bonn, Cambridge, Carleton, CERN, Chicago, Freiburg, Haifa, Heidelberg, Kobe, London, Manchester, Maryland, Montreal, Ottawa, Rehovot, Riverside, Rutherford, Saclay, Tel Aviv, Tokyo) is a general purpose detector which aims to make precise measurements at LEP on and above the $Z^0$.

1989 saw the completion of the OPAL detector, apart from some end cap muon chambers, its testing and commissioning followed by several months of successful data taking during which 30500 multihadron $Z^0$ decays, plus ≈ 10% lepton pair decays, were recorded and analysed. Fig. OPAL–1 shows a typical mutihadron event.

This report concentrates on activities which have involved support from EP division. A small team of EP physicists designed, built, commissioned and operates the end cap presampler, with the exception of the construction of the multiwire chambers which were built at the Weizmann Institute in Israel. They improve substantially the position and energy resolution for particles producing electromagnetic showers in the material between the interaction point and the lead glass electromagnetic calorimeter. This material thickness lies between 1.3 and 4 radiation lengths. The endcap presampler consists of an umbrella type arrangement of 32 chambers in 16 wedges (sectors). Each sector has one large and one small trapezoidal chamber. The anode wire plane consists of 2 mm spaced 50 μm wires. The cathode planes are thin G10 sheets covered with resistive carbon paint and are readout by means of strips and pads etched on the side of further 1.6 mm thick G10 boards. The total thickness of the chamber is only 6.8 mm.

Data taking started after the pilot run, once the gas safety system was available, and continued until the end of the physics running. Only one chamber had serious high voltage problems. First performance indications of the presampler for detecting minimum ionizing particles, as well as showering particles, have lived up to expectations. Fig. OPAL–2 shows the response of one presampler sector to a 45 GeV electron. Position and pulse-height information are given by pads and perpendicular strips and wires.

CERN provided valuable technical backup to the outside groups during the installation, testing and operation of their detectors. Supervision of the planning, coordination and excecution of the installation work, help on mechanical aspects of the assembly work and major contributions to the gas systems were provided by the CERN groups.

The cabling was finished in the first half of 1989. In May the magnet was closed, fully equipped with all detectors, and transported to the beam position to be connected to the LEP vacuum system. Installation work on the final magnet cooling pipes and bus bars, the gas building and gas distribution network, safety devices such as fire and gas detection continued under the supervision of CERN personnel.

CERN personnel acted as coordinators for many roles, including running the detector, supervising the online and offline systems, technical and safety aspects.

A particularly critical area in 1989 was the commissioning and operation of the online data aquisition system. While many individual detector groups had already produced independent data aquisition systems for test purposes, the task of guiding the group representatives in the work of putting these into standard form and arranging for the synthesis of OPAL-wide events occupied a considerable effort in the first part of the year, as did the connection to the centralised trigger system. Coordinated control of the run, central diagnosis and the process of routing and writing out the events all used a number of CERN-supplied facilities.

The commissioning of the online system in the weeks leading up to the first collisions was organized and overseen by CERN personnel, as was the work of running the system and encouraging its improvement during the rest of the year's running. A small group of CERN Fellows made exceptional contributions in this field.

OPAL was well prepared for the LEP pilot run and observed $Z^0$ events in the first minutes of LEP operation on 13 August. The first energy scanning over the $Z^0$ peak was made in September, rapidly followed by OPAL's first publication on the mass, width and peak cross-sections of the $Z^0$. The LEP run continued until the Christmas shutdown by which time OPAL had collected 30 500 multihadronic $Z^0$ events. Further publications followed on the decay of the $Z^0$ into lepton pairs, a study of jet production rates and a test of QCD on the $Z^0$, a search for the top and b′ quarks in hadronic $Z^0$ decays, mass limits for a standard model Higgs boson, global event properties, evidence for final photon bremsstrahlung in $Z^0$ multihadron decays, a search for supersymmetric particles and a higher statistics measurement of the mass, width and peak cross-sections of the $Z^0$.

Fig. OPAL–3 shows the results of OPAL's 1989 measurement of the $Z^0$ line shape through observation of the cross-sections for $e^+e^- \rightarrow$ hadrons at 11 energies around the $Z^0$ pole. The trigger was based mainly on information from three independent detectors : the electromagnetic calorimeters, the time-of-flight system and the jet chamber. Two components of the forward detector were used to measure the integrated luminosity, namely the calorimeter and the tube chambers which are used to define a fiducial volume. The resulting systematic point-to-point error on the luminosity measurement was 1% and the overall error 2.2%. Taking into account the LEP energy uncertainty of 30 MeV, we obtain a mass of $m_Z = 91.145 \pm 0.022 \pm 0.030$ GeV, a width of $\Gamma_Z = 2.526 \pm 0.047$ GeV and a hadronic pole cross-section $\sigma_{had}^{pole} = 41.2 \pm 1.1$ nb are obtained from a model independent fit. A Standard Model 2 parameter fit yields $3.09 \pm 0.19$ (exp.) $^{+.06}_{-.12}$ light neutrino generations.

A particularly novel result concerned a measurement of the strong coupling constant $\alpha_S$ The relative production rates of multijet events are determined by the value of $\alpha_S$ which, according to the concept of asymptotic freedom, is expected to decrease with increasing energy. Fig. OPAL–4 shows OPAL's measured 3-jet fractions compared with the corresponding results at lower centre of mass energies, showing clear evidence for a 'running' coupling constant. The possibility of an energy independent coupling constant can be excluded with a significance of 5.7 standard deviations.

A search for the minimal Standard Model Higgs boson was performed using 1259 $nb^{-1}$ of data. No Higgs candidates were observed in the reactions $e^+e^- \rightarrow (e^+e^-, \mu^+\mu^-, \nu\bar{\nu}) H^0$, $H^0 \rightarrow (q\bar{q}$ or $\tau^+\tau^-)$, thus excluding a Standard Model $H^0$ in the range $3.0 \leq m_H \leq 25.3$ GeV at the 95% confidence level.

Supersymmetric scalar leptons and the chargino $\chi$ tilde$^{\pm}$ were sought through their decays into pairs of acoplanar leptons and jets. Model independent limits were determined on branching ratios for the $Z^0$ to decay into pairs of heavy particles with subsequent decays leading to the above topologies. Mass limits for the scalar leptons e tilde, mu tilde and tau tilde of about 43 GeV were obtained at the 95% confidence level, and of 45.0 – 45.7 GeV for the $\chi$ tilde, depending on the photino mass.

The partial widths for $Z^0$ decays into charged lepton final states were derived from measurements of the corresponding $\ell^{\pm}$ channels. A combined fit with the multihadron final state gave the following results for the widths : $\Gamma_Z = 2.536 \pm 0.045$ GeV, $\Gamma_e = 81.2 \pm 2.6$ MeV, $\Gamma_\mu = 82.6 \pm 5.8$ MeV, $\Gamma_\tau = 85.7 \pm 7.1$ MeV and $\Gamma_{hadrons} = 1836 \pm 46$ MeV. The above results are consistent with lepton universality, and the computed invisible width, $\Gamma_{invisible} = 453 \pm 44$ MeV, gives $2.73 \pm 0.26$ (exp.) $^{+0.02}_{-0.04}$ (theor.) light neutrino generations. A rough measurement of Forward-Backward Asymmetry ($A_{FB}$) is consistent with the standard model.

A direct search for a heavy, charged, sequential lepton used 2 independent methods, one based on visible energy and missing $p_T$, the other on isolated high momentum e or $\mu$. The combined result gave $m_{L\pm} > 44.3$ GeV.

The number of hard isolated photons observed in the reaction $e^+e^- \to \gamma +$ hadrons is significantly larger than expected from initial state radiation. Both the yield and the momentum distribution are in agreement with final state photon bremsstrahlung from quarks. In conjunction with the hadronic decay width, the measured $q\bar{q}\gamma$ rate provided a determination of the weak couplings of charge 1/3 and charge 2/3 quarks.

A search for new quarks, on a relatively small sample of 2185 hadronic $Z^0$ decays gave no evidence for top or b′ quarks. Limits for the top and b′ quark masses were derived assuming various standard and non-standard model decay schemes. At the 95% confidence level, these are 44.5 GeV for the top and 45.2 GeV for the b′ quark mass.

# The $p\bar{p}$ Collider Programme

## UA1

During 1989 the UA1 Collaboration (Aachen, Amsterdam, Annecy, Birmingham, Boston, CERN, Helsinki, Kiel, London, Madrid, MIT, Padua, Paris, Rome, Rutherford, Saclay, UCLA, Vienna) completed data taking at the CERN $p\bar{p}$ collider. In the running period from March to June about 3.3 $pb^{-1}$ of data were collected, giving a total of about 4.6 $pb^{-1}$ from the high luminosity runs with ACOL in 1988 plus 1989. Typical luminosities were in excess of $10^{30}$ $cm^{-2}$ $s^{-1}$.

UA1's main objective in the recent runs has been the search for the top quark through its muonic decay channel. However the increased luminosity also allows more precise measurements of, for example, beauty quark production and decay and $B^0\bar{B}^0$ mixing. Compared to earlier runs, the muon detection system was substantially improved by additional iron shielding, equipped with planes of Iarocci gas tubes. An upgraded data acquisition system, based on VME, provided three flexible levels of trigger, making it possible to record data at luminosities above $10^{30} cm^{-2} s^{-1}$ with less than 15% of dead time. For luminosities in excess of $2 \times 10^{30} cm^{-2} s^{-1}$, the single muon and jet triggers were combined to further reduce the trigger rate. Due to the sharp response in transverse energy of the new trigger processor, this combined trigger does not reduce the efficiency for the top search.

During data taking, events containing one or two clean muon candidates were written on a special output stream for immediate 'express-line' reconstruction at the CERN computer centre. The first priority was the selection of clean samples of events with expected topologies for decay of a top quark, namely an isolated high $p_T$ muon accompanied by a second muon or by at least two jets. The kinematical properties of these samples are then compared with those expected from a combination of background (non-prompt muons from $K/\pi$ decay) and 'standard' physics processes, in particular production of beauty and charm quarks. Maximum likelihood analysis gives an upper limit for production of a top quark with standard semi-leptonic decay. Using theoretical calculations, a lower mass limit of around 60 GeV is derived. Similarly a lower limit of around 45 GeV is obtained for the mass of a 4 th generation, charge 1/3, b′ quark.

If the standard model is extended by a second Higgs doublet, and $m(t) > m(H^+) + m(b)$, the dominant top quark decay should be $t \to H^+b$. The standard top analysis is not sufficiently sensitive to this decay mode. However a more dedicated analysis is in progress which could lead to mass reaches of the charged Higgs beyond the expectations from LEP.

In the second half of 1989 reconstruction of the non 'express-line' data samples, containing in particular low $p_T$ dimuons, has continued at CERN and outside and will be completed early in 1990. Analysis is in progress on W and Z production properties and on b quark studies. The UA1 published result on $B^0\bar{B}^0$ mixing has been confirmed and further analysis should lead to a more precise measurement when studies of muon background at low $p_T$ have been completed. Likewise the previous measurement of the beauty production cross-sections as a function of $p_T$ is being repeated with higher statistics.

Studies of high $p_T$ charmonium production in the dimuon channel are already well advanced. Fig. UA1–1 shows the invariant dimuon mass spectrum in the range 2 to 5 GeV from the 1989 data. The $J/\psi$ peak is clearly visible and a common fit to a gaussian peak and a linear background gives a $J/\psi$ mass of $3.13 \pm 0.07$ GeV. From the event topologies it is deduced that about 2/3 of the charmonium production comes from $\chi$ states and 1/3 from B decays. A topology independent signature of charmonium production from B decays is the observation of a $\psi'$ signal. In contrast to the $J/\psi$, the $\psi'$ is dominantly produced via B decays since heavier charmonium states would decay directly into open charm quarks. From Monte Carlo calculations, about 15-20 events are expected with a $\psi' \to J/\psi\,\pi^+\pi^-$ decay. Fig. UA1–2 shows the mass difference $M(J/\psi\,\pi^+\pi^-) - M(J/\psi)$, together with a Monte Carlo simulation of the combinatorial background from B decays into $J/\psi$ and $\psi'$. A significant signal is observed, in good agreement with the expected mass difference of 0.589 GeV. The number of $\psi'$ decays, about 16, is compatible with the B cross-section published by UA1, times the published branching ratio.

The new data are also being used to search for the rare B meson decays, $B^0 \to \mu^+\mu^-$ and $B^0 \to \mu^+\mu^- X$. A preliminary upper limit for $B^0 \to \mu^+\mu^-$ of $8 \times 10^{-6}$ at 90% confidence level has been obtained which is a factor of 5 better than the current world limit. For the channel $B^0 \to \mu^+\mu^- X$, Monte Carlo studies are in progress, concentrating on the loop-induced FCNC decay of the b quark. A branching fraction sensitivity of the order of $10^{-4}$ is anticipated. A limit at this level would imply an upper limit on the top quark mass of around 400 GeV. For the future a limit of $10^{-5}$ would constrain the top quark mass to be less than about 150 GeV.

## UA2

The upgraded UA2 detector took data between September 1988 and June 1989 during a very successful run of the CERN $p\bar{p}$ Collider. A total integrated luminosity of 7.4 $pb^{-1}$ was recorded on tape, corresponding to ~ 80% of the amount delivered by the machine. This illustrates the smooth operation of the detector and, in particular, the high efficiency and small dead-time of the data acquisition system at peak luminosities as high as $3 \times 10^{30} cm^{-2}s^{-1}$.

In 1989 the UA2 Collaboration consisted of ~ 100 physicists from ten Institutes : Bern, Cambridge, CERN, Heidelberg, Milan, Orsay (LAL), Pavia, Perugia, Pisa and CEN Saclay. The main goals of the experiment are the following :

- The search for the sixth, as yet undiscovered quark, the top quark.
- A precision measurement of the W and Z mass ratio, $m_W/ m_Z$.
- A study of W and Z production properties.
- A search for supersymmetric particles.
- Studies of jet production at high transverse momentum, including the search for the signal expected from W and Z hadronic decays.

Data analysis on these subjects is almost complete and several papers have been already submitted for publication in scientific journals. The main physics results achieved so far are as follows :

- The search for the top quark, based on the detection of its leptonic decay mode $t \to be\nu$, has provided no evidence for such a process. Using the expected top production rate and decay branching ratio, this negative result implies that the top quark mass is greater than 69 GeV at the 95% confidence level. This result also excludes the existence of a b′ quark, i.e. a member of a hypothetical fourth fermion family, with a mass lighter than 54 GeV.
- A total of 1206 $W \to e\nu$ and 148 $Z \to e^+e^-$ events have been used to perform a new measurement of the boson masses :

$$m_W = 80.8 \pm 0.3\ \%\ \text{(stat.)} \pm 0.2\ \text{(syst.)} \pm 0.8\ \text{(scale) GeV;}$$

$$m_Z = 91.5 \pm 0.4\ \text{(stat.)} \pm 0.1\ \text{(syst.)} \pm 0.9\ \text{(scale) GeV.}$$

The transverse mass distribution for $e^-\nu$ pairs from W decay is shown in Fig. UA2–1. Fig. UA2–2 displays the invariant mass distribution of a sample of $Z \to e^+e^-$ decays. From the measured values of $m_W$ and $m_Z$ a precise measurement of the mass ratio $m_W/m_Z$ is obtained which is not affected by the 1% scale error :

$$m_W/m_Z = 0.883 \pm 0.005\ \text{(stat.)} \pm 0.003\ \text{(syst.).}$$

This can be combined with recent, precise measurements of the Z mass from SLC and LEP to remove the mass scale uncertainty from the determination of the W mass :

$$m_W = 80.4 \pm 0.4\ \text{(stat.)} \pm 0.2\ \text{(syst.) GeV.}$$

This result and the Z mass value from SLC and LEP are compared with the Standard Model predictions in Fig. UA2–3. The experimental point lies within the region allowed by the minimal Standard Model and supports the hypothesis that the top quark is heavier than the W. At the same time, the measurement of $m_W/m_Z$ can be converted into a precise measurement of $\sin^2\theta_W$ :

$$\sin^2\theta_W = 0.221 \pm 0.009\ \text{(stat.)} \pm 0.005\ \text{(syst.),}$$

in agreement with previous results.

- The large samples of $W \to e\nu$ and $Z \to e^+e^-$ events have been used to measure the W and Z production cross-sections multiplied by the electron decay branching ratio, $\sigma_W^e$ and $\sigma_Z^e$, respectively, with higher precision than previous experiments. These results are found to be in good agreement with theoretical predictions, which include $O(\alpha_s)$ QCD corrections. In the framework of the Standard Model, the ratio $\sigma_W^e / \sigma_Z^e$, together with the measurement of the Z width from SLC and LEP, can be used to provide the first determination of the W width :

$$\Gamma_W = 2.30^{+0.19}_{-0.18} \text{ GeV}.$$

The W and Z transverse momentum distributions, which are determined from the same event samples, are also found to be in agreement with theoretical predictions.

- Searches for supersymmetric (SUSY) particles are based on the detection of the large transverse momentum imbalance expected from the presence of non-interacting photinos, which are assumed to be the lightest stable SUSY particle. The upgraded UA2 detector is particularly suited to search for such event configurations because of its good calorimeter hermeticity. No significant excess of events with large transverse momentum imbalance has been found above the expected rate from conventional sources, either in purely hadronic events or in events containing electron pairs. This negative result provides the following 90% confidence level bounds :
  - $m(\tilde{q}) > 74$ GeV independent of $m(\tilde{g})$;
  - $m(\tilde{g}) > 79$ GeV independent of $m(\tilde{q})$;
  - $m > 106$ GeV for $m(\tilde{q}) = m(\tilde{g}) = m$;
  - $m(\tilde{e}) > 40$ GeV in the case of a light $\tilde{\gamma}$;
  - $m(\tilde{W}) > 45$ GeV in the case of a light $\tilde{\nu}$.

- Results on jet physics include a measurement of the single jet inclusive cross-section as well as studies of two- and four-jet events. In all cases QCD has been found to describe the data well. An exclusive sample of $\sim 4.5 \times 10^6$ two-jet events has been used to search for the hadronic decays of the W and Z bosons via a pair of light quarks. A significant signal, at the level of 5 standard deviations, has been observed above the large background from parton-parton scattering (Fig. UA2–4).

A new running period is scheduled to take place at the $p\bar{p}$ Collider during the last four months of 1990. In order to further increase the luminosity by a factor of ~2, additional quadrupoles will be used to reduce the $\beta$ functions at the beam crossing point. This improvement should provide data samples comparable to those collected during the 1988-89 run, with the effect of reducing the statistical error on the ratio $m_W/m_Z$ by a factor of $\sqrt{2}$. The measurement of this ratio is the main goal of the 1990 run for the UA2 experiment. It represents a precision test of the Standard Model and will provide a significant constraint to the range of possible mass values for the top quark.

## UA6

The apparatus of the UA6 Collaboration (CERN, Lausanne, Michigan, Rockefeller) is a double arm spectrometer where each arm is equipped with 5 MWPCs, a TRD, and a fine-grained electromagnetic calorimeter built of lead and proportional tubes. During the shutdown in early 1989, this spectrometer was rotated in the SPS tunnel to view the products of collisions of the SPS proton beam with protons from the internal molecular hydrogen jet target. The experiment studies high $p_T$ $\pi^0$, $\eta$, and direct $\gamma$ production, as well as inclusive $J/\psi$ production through its $e^+e^-$ decay mode, $\gamma\gamma$ pairs, etc., at $\sqrt{s} = 24.3$ GeV. In particular, high $p_T$ direct $\gamma$ production at such relatively low $\sqrt{s}$ corresponds to high $x_T = 2\,p_T/\sqrt{s}$, a region which other collider experiments do not probe. This fact, together with the availability of both $p\bar{p}$ and pp data taken with the same detector, should enable us to extract a good measurement of the gluon distribution within the nucleon.

During the 1989 collider running period UA6 accumulated an integrated luminosity of 3.3 $pb^{-1}$ on tape for $p\bar{p}$ collisions to be added to the 3.0 $pb^{-1}$ collected in 1988 in pp collisions. Analysis of the 1988 and 1989 data is about to start.

Analysis of the data from 1985 (0.5 $pb^{-1}$ in $p\bar{p}$) and 1986 (1.6 $pb^{-1}$ in pp) is now nearing completion :

- $J/\psi$ results were submitted to the Madrid conference. It is found that $\sigma(pp \to J/\psi + X)/\sigma(p\bar{p} \to J/\psi + X) = 0.73 \pm 0.13 \pm 0.18$. This seems to indicate that gluon processes, which are expected to be the same in $p\bar{p}$ and pp interactions, dominate in $J/\psi$ production rather than quark-antiquark annihilation. The transverse momentum distributions in pp and $p\bar{p}$ collisions are consistent with being the same.

- The $\pi^0$ invariant cross-sections now span the range $0.75 < p_T < 6.0$ GeV/c. The ratio of the $p\bar{p}$/pp cross-sections is consistent with unity throughout this range of $p_T$. The $\eta/\pi$ ratio is measured to be 0.5 in both pp and $p\bar{p}$ interactions.

- Both the $p\bar{p}$ and pp direct photon cross-sections extend up to $p_T = 6$ GeV/c. They are both in excellent agreement with a Next-to-Leading-Order calculation by Aurenche et al. using Duke-Owens structure functions with a soft gluon distribution. The ratio $\sigma(p\bar{p} \to \gamma + X)/\sigma(pp \to \gamma + X)$ has a tendency to rise with $p_T$, demonstrating the increasing importance of the $q\bar{q}$ annihilation term in $p\bar{p}$ interactions as $p_T$ increases. The difference $\sigma(p\bar{p} \to \gamma + X) - \sigma(pp \to \gamma + X)$ is a direct measure of this annihilation contribution and is independent of the gluon structure function. The UA6 measurement of this difference is the first such measurement in $p\bar{p}$ collisions and is shown in Fig. UA6–1 together with the prediction by Aurenche et al.

The analysis of the larger data samples collected in 1988 and 1989 should allow the errors on the $J/\psi$, $\pi^0$, $\eta$, and direct photon ratios to be decreased significantly.

## UA8

UA8 uses a small-angle spectrometer coupled with the UA2 calorimeter to study the structure of events which contain a leading ('beam-like') hadron. The experiment studies the properties of jets produced in events which contain leading protons, lambdas and their anti-particles in order to obtain information on the soft structure components of the proton. It also studies general properties of diffractively produced systems such as energy flow in high-mass diffractively excited systems and energy flow in inelastic events which contain both a leading proton and a leading anti-proton. The experiment is performed by a group from the University of California, Los Angeles (UCLA) with Ph.D. students from Cukurova University (Adana, Turkey) and the Middle East Technical University (Ankara, Turkey).

The experiment triggered on events containing energetic particles scattered into one of four small angle Roman pot spectrometers located in the same intersection region as the UA2 experiment. These spectrometers accepted protons, antiprotons, lambdas and antilambdas with Feynman x above about 0.7. Four Data-Driven Trigger Processors calculated the momenta of spectrometer tracks in real time and furnished a Level 2 trigger 1.3 μs after a bunch crossing for readout by the UA2 data acquisition system. This trigger operated in parallel with the lambda trigger which used hit information from the small-angle minidrift chambers to trigger on events in which a forward lambda was produced and decayed in the quadrupole between the first and second measuring stations on the outgoing antiproton arm. For some triggers, the energy deposition in the UA2 calorimeter was required to be above a threshold of typically 15 GeV.

During the 1988 and 1989 collider runs a sample of approximately one million triggers has been amassed. Since the end of data taking, work has been spent primarily on fine-tuning the spectrometer alignment, background studies and studies of the response of the UA2 calorimeter to the relatively low energy deposition typical of the UA8 events.

Preliminary results on a variety of topics were presented at the 8th Topical Workshop on Proton-Antiproton Collider Physics in Castiglione della Pescaia, Italy, in September 1989 and will be published in the Workshop Proceedings. The results presented include a study of two-jet coplanarity, a study of jet production as a function of momentum transfer to the leading proton or antiproton, a study of longitudinal energy flow in diffractive systems and a study of events containing leading lambdas. Fig. UA8–1 demonstrates the longitudinal structure of diffractive systems with a mass of 210 GeV. In this figure, $dE_{CM}/ d\cos(\theta_{CM})$ is plotted in the centre of mass of the diffractive system, where $E_{CM}$ is the average energy in the UA2 calorimeter transformed to the diffractive system's rest frame, and $\theta_{CM}$ is the centre of mass polar angle.

Fig. UA8–2 shows a preliminary $\bar{\Lambda}$ mass spectrum from a subset of the 4000 events $\bar{\Lambda}$ sample. Events containing a leading $\bar{\Lambda}$ may be particularly interesting for a study of structure functions since the $\bar{\Lambda}$ lacks at least one of the valence quarks of its parent beam particle. The missing valence quark must be a part of the system whose structure function is under study. The presence of this valence quark may lead to a difference in the jet production rate or jet energy distribution between events containing a leading $\bar{\Lambda}$ and events containing a leading proton. This study is in progress.

# The SPS Fixed Target Programme

## Neutrino Experiments

### *WA18*

The CHARM collaboration (CERN, Hamburg, Amsterdam, Rome, Moscow) has pursued the analysis of high statistics data obtained in an exposure in a 160 GeV narrow band beam in 1984. Differential cross-sections $d\sigma/dy$ have been measured in semileptonic neutral- and charged-current reactions on isoscalar nuclei induced by neutrinos and antineutrinos. The y-distributions measured in this experiment can be used to demonstrate directly the coupling of the neutral current to the right-handed quarks in the nucleon. 'You need a nut to find the sense of a screw'.

The angular distribution of elementary $\nu(\bar{\nu})$ quark scattering process is composed of two components, an isotropic one ($J = 0$) for $\nu_L q_L$ and $\bar{\nu}_R q_R$ scattering and an anisotropic $(1 - y)^2$ component ($J = 1$) for $\nu_L q_R$ and $\bar{\nu}_R q_L$ scattering. Because of the polarization of neutrinos the y distributions are sensitive to the relative coupling of left- and right-handed quarks in the nucleon. By comparison of neutral and charged current y distributions the coupling of neutral currents to right-handed quarks can be extracted. Llewellyn-Smith has derived a fundamental relation between NC and CC differential cross-sections of $\nu(\bar{\nu})$ on isoscalar target :

$$\left(\frac{d\sigma}{dy}\right)^{\nu}_{NC} = g_L^2\left(\frac{d\sigma}{dy}\right)^{\nu}_{CC} + g_R^2\left(\frac{d\sigma}{dy}\right)^{\bar{\nu}}_{CC}$$

$$\left(\frac{d\sigma}{dy}\right)^{\bar{\nu}}_{NC} = g_L^2\left(\frac{d\sigma}{dy}\right)^{\bar{\nu}}_{CC} + g_R^2\left(\frac{d\sigma}{dy}\right)^{\nu}_{CC}$$

This relation is valid for nucleons composed of u and d quarks (and $\bar{u}$ and $\bar{d}$ antiquarks) only, and its validity depends on the assumption of weak isospin invariance.

The value of $g_R^2 = 0.042 \pm 0.010$, thus determined, demonstrates for the first time directly the existence of a non-vanishing coupling of the $\nu\bar{\nu}$ current to the right-handed quarks with a statistical significance of more than four standard deviations.

### *WA79*

The CHARM II Collaboration (Brussels, CERN, Hamburg, Louvain, Moscow, Munich, Naples, Rome) is conducting a measurement of the ratio of the cross-sections of the elastic muon-neutrino and antineutrino scattering on electrons with the aim of a precise determination of the electroweak mixing parameter $\sin^2\theta_W$. Because of the purely leptonic nature of these reactions this determination is free from uncertainties which are affecting the measurement of the ratio of cross-sections of semileptonic reactions.

Approximately one-half of the statistics aimed at was recorded in 1987 and 1988, yielding 762 $\nu_\mu e$ and 1017 $\bar{\nu}_\mu e$ events (Fig. WA79–1).

The ratio of the energy weighted neutrino and antineutrino fluxes was determined in four independent ways, from quasielastic scattering, from the muon flux recorded in the iron shield, from the rate of inclusive NC and CC reactions and from single $\pi^0$ production in NC induced reactions. The four normalizations are in good agreement with each other, their weighted mean has a fractional error of ± 2.3 % corresponding to an uncertainty of $\Delta\sin^2\theta_W = \pm 0.003$.

From the cross-sections ratio thus determined a value of

$$(\sin^2\theta_W)_{Born} = 0.233 \pm 0.012\ \text{(stat.)} \pm 0.008\ \text{(syst.)}$$

was derived in the Born approximation. Applying electroweak radiative corrections with $m_t = m_H = 100$ GeV gives

$$\sin^2\theta_W = 0.232 \pm 0.012\ \text{(stat.)} \pm 0.008\ \text{(syst.)}$$

This value can be directly compared to that derived from a measurement of the decay width of the $Z^0$ to lepton pairs, $\Gamma_{ll}$, performed at LEP by the ALEPH Collaboration which yielded

$$\sin^2\theta_W = 0.231 \pm 0.008$$

From this close agreement limits on small contributions due to the exchange of states other than the $Z^0$, e.g. $Z'$ or photon (magnetic moment, anomalous electric charge radius of the neutrino) can be derived.

Data taking continued in 1989 and will be completed in 1990. A calibration run in electron and pion beams has been performed to reduce the systematic errors. The statistical and the systematic errors are expected to reduce by a factor of 2 to 2.5 in the final analysis.

*WA21*

The BEBC Hydrogen Collaboration WA21 (Birmingham University, CERN, Imperial College, MPI Munich, Oxford University, University College London) completed data taking in December 1983. The samples include approximately 19000 $\nu$ and 11000 $\bar{\nu}$ charged current events. These constitute the largest data set of neutrino interactions on free protons. Work published to date includes studies of inclusive structure functions and final state properties, exclusive final states, neutral current cross-sections and production of strange and charmed particles.

During 1989, more work was published on the proton structure functions in $\nu$ and $\bar{\nu}$ charged current interactions. The study of $\nu p$ and $\bar{\nu}p$ charged current structure functions allows the separate determination of the distribution of the different flavours of quark and antiquarks in the proton. Using the complete data sample and absolute flux normalizations the structure functions were measured in the range $0 < x < 0.7$ where x is the Bjorken scaling variable. The valence quark ratio $d_v/u_v$ is a measure of the violations of SU(6) symmetry in the proton. The results show a dominance of the isospin zero state of the spectator diquark. No evidence is found for direct scattering from diquarks and the data are in disagreement with published models.

Furthermore, the collaboration has published an experimental test of the PCAC hypothesis in single pion production. The pure target and good measurement precision of the hydrogen bubble chamber allow a clean separation of the final states $\mu^- p\pi^+$ and $\mu^+ p\pi^-$. The samples consist of 1081 $\nu p$ and 180 $\bar{\nu}p$ interactions with hadronic mass $W < 1.4$ GeV. This process is well understood theoretically and previous results have shown a disagreement at low $Q^2$. However, this has been shown to be due to an inadequate treatment of the pion 'off mass shell' correction. The data yield a value of $m_\alpha = 1.31 \pm 0.12$ GeV for the parameter in the axial vector form factor of the proton.

**Muon Experiments**

*NA4*

The NA4 Collaboration (Bologna, CERN, Dubna, Munich, Saclay) has completed the analysis of their high statistics measurements of the structure functions $F_2(x, Q^2)$ and $R = \sigma_L/\sigma_T$. Results for muon interactions on deuterium have recently been finalized (Fig. NA4–1). They are in good agreement with earlier results from SLAC measured at lower four-momentum transfer $Q^2$ but exhibit a discrepancy with data from the EMC (NA2) experiment, similar to the one observed in the comparison of earlier hydrogen target data. Scaling violations are observed in the deuterium data and are in good agreement with perturbative QCD predictions. The QCD mass scale parameter determined from these data is $\Lambda_{\overline{MS}} = 230 \pm 40 \pm 70$ MeV, in agreement with earlier results from muon-carbon and muon-hydrogen scattering. The structure function ratio $F_2^n / F_2^p$ obtained from the combined hydrogen and deuterium data is in excellent agreement with earlier results from the EMC and with recent preliminary results from the NA37 experiments.

*NA37*

In 1989 the NMC collaboration (NA37 : Amsterdam, Bielefeld, Freiburg, Heidelberg, Los Angeles, Mainz, Mons, Neuchatel, PSI, Saclay, Santa Cruz, Turin, Uppsala, Warsaw) has continued its experimental program with a series of high luminosity runs to measure the cross-sections ratios of Be, Al, Ca, Fe and Pb relative to Carbon. These data were taken with a calorimetric trigger setup and a concrete absorber in front of the spectrometer which had been installed in 1988. In a short run of two weeks, about 14 million physics triggers were recorded.

For most of the running time in 1989, the calorimeter and absorber were dismantled and the movable platform supporting the $H_2$ and $D_2$ targets was re-installed. Hydrogen and deuterium target data were taken at beam energies of 280, 200 and 120 GeV to complete the program for the determination of the neutron and proton structure function. To access interesting physics topics at very low Bjorken x, e.g. shadowing in $D_2$ and a possible violation of the Gottfried sum rule, an extension of the trigger to very low scattering angles (2.5 mrad) was introduced. With this trigger, the kinematic range is expected to extend down to x = 0.001. Extra planes of drift and proportional chambers were added to ensure adequate acceptance and resolution in the extended kinematical domain.

The final run was dedicated to a direct comparison of deep inelastic scattering from $^6$Li and $^2$D at 200 GeV. Previous data on Li/C/Ca and D/C/Ca suggest that the ratio Li/D exhibits only shadowing and very little of the EMC effect which would indicate a decoupling of these two effects.

### CP Violation

*NA31*

A first evidence has been published in 1988 by the CERN-Edinburgh-Mainz-Orsay-Pisa-Siegen Collaboration for a CP violating transition of the CP-odd neutral kaon $K_2$ into two pions at a level corresponding to a value of the CP violation parameter Re $\varepsilon'/\varepsilon = (3.3 \pm 1.1) \times 10^{-3}$. The strength of direct CP violation is therefore small compared to the CP violating effects generated by state mixing and compatible with predictions based on the Standard Model for three generations of quarks.

In the years 1988-1989 new data have been taken with an improved set-up in an effort to improve the significance of this initial observation. The statistics accumulated exceed the original sample by more than a factor of two. These data are being analysed.

A search for a neutral Higgs particle in the decay $K_S^0 \rightarrow \pi^0 H^0$ followed by $H^0 \rightarrow e^+e^-$ has been performed using data taken concurrently with the original $\varepsilon'/\varepsilon$ measurement. Allowing for a non-zero Higgs lifetime, three candidates have been seen, consistent with an expected background of 3.3 events. Limits on the branching ratio product of kaon and Higgs decays in the range $10^{-8}$ to $10^{-7}$ are presented as a function of the mass and the lifetime of the Higgs particle in Fig. NA31–1. These limits severely constrain the neutral Higgs of the minimal Standard Model in the mass region 15 MeV $< m_H <$ 211 MeV.

Data were taken in 1987 with a modified beam to be sensitive in the $K_S - K_L$ interference region for a measurement of phases of the CP-violating amplitudes in both $K^0 \rightarrow 2\pi^0$ and $K^0 \rightarrow \pi^+\pi^-$ decays in the same experiment. The observed interference pattern is demonstrated in Fig. NA31–2. The phases are obtained from a comparison of the rate of decay for two target positions corresponding to different kaon lifetime intervals. The final result is $\phi_{00} = 47.1° \pm 2.8°$ and $\phi_{+-} = 46.9° \pm 2.2°$. A direct comparison gives the phase difference $\phi_{00} - \phi_{+-} = 0.2° \pm 2.9°$. This in turn leads to an upper limit on possible CPT violations in the $K^0$ mass matrix of $|m_{\bar{K}^0} - m_{K^0}|/m_{K^0} < 5 \times 10^{-18}$ which is the most stringent test of the equality of particle and antiparticle masses to date.

### Lepton Pair Production

*NA34*

The HELIOS-1 experiment (Bari, Brookhaven, CERN, Heidelberg, London, Los Alamos, Lund, Montreal, Moscow, Novosibirsk,Pittsburgh, Rome, Rutherford, Saclay, Stockholm, Tel Aviv, Turin) on hadroproduction of leptons and photons ended three years of data-taking in December 1989. It contains an electron spectrometer, a muon spectrometer and photon and charged particle detection over a large solid angle, as well as a hermetic high resolution calorimeter for missing energy detection. The last year was particularly fruitful : a long smooth run under optimised conditions increased the statistics in all channels by more than a factor of ten. Fortunately, it was possible to keep up to date with the data processing concurrently with the data taking, so that the analysis is now in the stage of physics evaluation.

Large samples of electron pairs and muon pairs are available with better statistics, better mass resolution, much wider range of the kinematic variables and for the first time, complete information on the associated event. For example, it is now possible to associate to the lepton pair, the photon from the Dalitz decay of a meson. Fig. NA34–1 shows the mass spectra of $\mu\mu\gamma$ and $ee\gamma$ as well as the inclusive spectra, from about one third of the data. One notes the prominent peak from the $\eta$ showing that it can be measured directly, eliminating one of the weakest points of the previous experiments. The electron and muon reactions are complementary, covering different regions of rapidity and mass, with a considerable region of overlap.

For each event the missing energy is also available, obtained by a high resolution measurement of the total visible energy in a hermetic calorimeter. The inclusive spectrum of missing energy has been measured out to 200 GeV allowing us to see the neutrinos from charm decay, another first (Fig. NA34–2). These data provide a novel measurement of the cross-section for charm production and improved limits on the production of new sources of missing energy. The study of muon pairs correlated with missing energy allows an answer to the old question of how much of inclusive muon production from proton collisions comes from Drell-Yan, from charm production, and from decays of mesons.

New results are emerging concerning the production of the low mass 'anomalous' lepton pair. The mass resolution in the muon data is much better than in previous experiments, and this together with better statistics, allows one to see possible structures in the mass spectrum which would not have been visible previously. By using both electron and muon reactions, the dependence of the lepton pair production on the charged particle multiplicity in the associated event is being studied as a function of rapidity and effective mass. It is expected that these results will allow a good understanding of the mechanism for this unusual process.

## Spectroscopy and Heavy Flavour Production

### *NA12/2*

1989 has been a year of transition and consolidation for the GAMS collaboration (NA12/2 at CERN and VIth Joint Experiment at IHEP Serpukhov : LAPP Annecy, KEK, Los Alamos, Pisa, Serpukhov). The main activities have been :

- upgrading of GAMS-4$\pi$, the setup of the VIth joint experiment;
- global assessment of the observable mesons in NA12/2 central production data;
- further analysis of the 38 GeV and in 100 GeV $\pi^- p$ charge exchange reaction data.

Some striking results have been obtained. The first is the observation, in central collisions, of a tensor state with a mass of 2180 MeV and a width of about 150 MeV, which decays into $\eta\eta$ (Fig. NA12–1). Coming after the scalar $f_0(1590)$, this new state is a glueball candidate. As the $f_0(1590)$, it is not observed to decay into K pairs significantly. The ratio of the masses of these two mesons is in agreement with the present state of lattice calculations for scalar and tensor glueball ground states.

The second is the abundant production of the $a_0(980)$, in comparison with the production of the $a_2(1320)$ in central collisions. This is in contradiction with the dominance of the $a_2$ in charge exchange reactions. It is another element of evidence that the $a_0$ is an exotic state.

Next are the confirmations of the presence of states that decay into $\omega\omega$ at 1640 MeV and 1960 MeV, supported by the observation of the same decay channel for $f_4(2050)$, and of the existence of a 1920 MeV state which decays into $\eta'\eta$ with very unusual properties. The spin and parity assignments $J^{PC}$ of the latter might be the exotic combination $1^{-+}$ besides $0^{++}$ and $2^{++}$. It is produced at large $|t|$ values with a rather narrow width.

The GAMS programme has now collected two 'solid' glueball candidates, a scalar and a tensor one, one intrinsic exotic meson, another intrinsic exotic candidate, a new scalar meson and a few other phenomena which complicate the light meson spectrum. The need to come to a coherent picture of this spectrum encourages further efforts in the next years.

### *WA82*

Experiment WA82 (Bologna, CERN, Genoa, Milan, Mons, Moscow) aims at studying charm hadroproduction with large, unbiased samples of charmed particles. For this purpose, it uses a Microstrip Vertex Detector (MVD) in front of the $\Omega'$ spectrometer. The MVD is made of 15 silicon planes, of pitch and size varying from 10 to 50 $\mu$m, and from $5 \times 5$ mm$^2$ to $5 \times 5$ cm$^2$; in addition eight 20 $\mu$m pitch planes detect the incident beam particle, thus measuring the position of the impact on the target. The MVD provides an impact parameter trigger which enriches the charm content of the recorded interactions by a factor of about 15. It measures track angles with a precision of about 0.1 mrad and impact parameters to about 10 $\mu$m, thus allowing good recognition of secondary vertices. The $\Omega'$ spectrometer identifies protons and kaons up to 50 GeV, and detects electrons and neutral mesons, kaons and hyperons.

In former runs about 30 million triggers were recorded, two thirds of them with a 340 GeV $\pi^-$ beam and one third with a 370 GeV proton beam striking a thin tungsten/silicon target. In 1989, 25 million triggers were added, using the $\pi^-$ beam on a tungsten-copper target. The data from the 1987 run (1/5 of the total data) have been processed. Fig. WA82–1 shows a mass spectrum from $K^-\pi^+$, $K^-\pi^+\pi^-$, $K^-\pi^+\pi^-\pi^+$, and charge conjugate channels. A sharp D peak of ~ 800 events is observed above a rather small background; this background is reduced by a factor of ~ 3 using particle identification. From the $K^-\pi^+\pi^+$ and charge conjugate channels, the parameters of the production law $d^2\sigma / dx_F dp_T^2 = (1 - x_F)^n e^{-bp_T}$ have been found to be n = 3.40 ± 0.45, b = 2.00 ± 0.12 $GeV^{-1}$ (up to $p_T$ = 4 GeV). No significant 'leading particle' effect was observed.

The ratio of the production rates in Si and W yields a direct determination of the parameter α in σ(charm) ~ $A^\alpha$ : α = 0.89 ± 0.05 ± 0.05. With the full data, all those errors should be reduced by a factor 2 at least and precise lifetime and branching ratio measurements should be possible, as well as studies of rarer decays states such as $D_s$ and $\Lambda_C$.

*WA84*

A new high resolution vertex detector using scintillating fibres is being developed by the WA84 Collaboration (CERN, IC London, Pisa, Rome, Southampton). The aim is to study $B\bar{B}$ production by 350 GeV pions in a fibre target and also observe the decay of the $B\bar{B}$ pair and of the 2 resultant charm particles in the target. The target is placed at the entry to the Omega spectrometer and the outgoing particles are measured also by a silicon microstrip detector and by the spectrometer. The scintillation light in the fibres is transmitted by a long opto-electronic chain with 5 image intensifiers to a CCD having a fast clear and readout electronics. The output can be analysed automatically. The plastic fibres of 15 to 30 μm diameter use PMP which is a newly developed scintillator with a very large Stokes' shift. The spatial resolution obtained with plastic fibres is as good as that found with the previous glass ones but the time resolution is far superior. It is of the order of nanoseconds, so that an interaction rate of $10^5$ per second is now possible. The light transmission is also better and more than 2 hits/mm are obtained along the track of a minimum ionizing particle.

Background noise has been a problem which has been studied and understood. It comes from low energy delta rays (≈ 10%), from the opto-electronic chain (back scattering in the image intensifiers) (10%), and from cross-talk between fibres (20%). Technical solutions to reduce the last two sources have been found and new equipment and fibre targets have been ordered.

The light from the fibres was previously transported out of the beam line using a bent bundle of non-scintillating fibres which were not radiation hard. This system has now been successfully replaced by a special optical system. The complete new system is shown in Fig. WA84–1.

Tests have been carried out with 6 and 200 GeV test beams and a full trial made of the target, opto-electronic chain, and data acquisition system with the new Ω' spectrometer and a high $p_T$ trigger, with a 350 Gev $\pi^-$ beam. The data are being analysed automatically with vertex-finding and track measuring routines. It is found that typical values of the impact parameter of fitted tracks from the fitted vertex are about 30 microns which would be adequate for the search for beauty and charm decays. A systematic analysis is being carried on to determine the efficiency of the full system studying the matching of the track reconstructed from the CCD information and those obtained from the Ω' Spectrometer. An example of an event is shown in Fig. WA84–2.

In conclusion, great progress has been made in developing high resolution scintillating fibre detectors. Clear tracks are obtained and can be measured automatically. The collaboration is now working to define a detailed program for an efficient fixed target beauty search.

*WA89*

WA89 (Bologna, CERN, Genoa, Grenoble, Heidelberg MPI, Heidelberg University, Mainz, Mons, Moscow) is a new hyperon beam experiment using the Omega Facility. The experiment exploits the large hyperon fluxes available in the new charged hyperon beam installed in the West Hall at the Omega facility. In a first phase beginning now, $\Sigma^-$ of about 350 GeV will be used to produce large samples of charmed-strange baryons and to measure their lifetimes, branching ratios, production cross-sections, etc. The lowest excited states are expected to decay radiatively to the ground states, and will be searched for using a leadglass calorimeter. The same data should also provide large samples of the exotic U(3100) states observed in the previous CERN SPS hyperon beam experiment WA62, if these states exist. More speculatively, baryons with beauty or double charm may be accessible through their charmed decay products. Also the postulated double-strange dibaryon H (uuddss) and the pentaquark P ($\bar{c}$suud, $\bar{c}$sudd) will be searched for.

In a second phase, $\Xi^-$ and possibly $\Omega^-$, tagged by a ring-imaging Cherenkov counter, will be used to search for the H, to study Ξ and Ω resonances, low $p_T$ processes and possibly rare hyperon decays.

The apparatus is based on the existing Omega spectrometer, including an enlarged set of microstrip detectors for detection of charm decay vertices, and an additional set of drift chambers for detection of Λ decays. A new leadglass calorimeter with 650 elements, and a new set of transition radiation detectors for suppression of beam pions have been added. The trigger and on-line system have been equipped with new spill-buffers, μVAXes and a system of seven RISC computers. The MBNIM trigger system has been extended to provide on-line selection of Λ decays. The existing wide-angle RICH counter is being upgraded to provide π/K/p separation up to 150 GeV.

In a first run at the end of the year, the beamline, the apparatus with the exception of the RICH counter, and the trigger system were set up and tested. The beam was found to provide $10^5$ $\Sigma^-$ at 340 GeV per SPS pulse with a π/Σ ratio of about 2.5, in good agreement with predictions. A first sample of six million interactions was recorded and is used for a detailed study of trigger and event rates. The experiment will continue in spring of 1990.

**Particle Production in Crystals**

*NA42*

The NA42 Collaboration (LAPP Annecy, IPNL Lyons) studies unexplained hard photon production by electrons channeled in a crystal. A previous experiment (NA33) designed to study the pair creation process in the interaction of high energy photons with a crystal in alignement conditions had revealed the existence of an unexpected peak in the radiation of a 150 GeV $e^-$ beam incident along the <110> axis of a 185 μm Ge crystal, at $x = E_\gamma / E_{e^-} = 0.85$. The photon multiplicity for the peak events has been measured to be $M \approx 5.7$. In NA42, in a 76 μm crystal of the same crystallographic quality, the peak nearly disappears and the photon multiplicity at $x = 0.85$ is only $M \approx 2.0$ (Fig. NA42–1). The thickness dependence of the effect shows that the extrapolated multiplicity in the peak in a very thin crystal tends to unity. The high energy radiation peak emitted by axially channelled electrons in a thick crystal is then interpreted by the radiation cooling mechanism.

The extrapolation to zero thickness of these results will allow us to extract from the data the single γ radiation spectrum. The comparison of this spectrum with the constant field one will give evidence for the reduction effect of the radiation intensity, important for $x \leq 0.4$, due to the radiation formation length. At higher energies, in the TeV region, this effect will dominate this interaction in such a way that these results predict an electron-photon energy conversion near $x \approx 1$ with a single photon only in the final state.

*NA43*

The aim of experiment NA43 (Aarhus, CERN, Strasbourg, Stuttgart) was to continue the investigation of the gamma radiation from high energy electrons and positrons traversing single crystals.

Improvements of the experimental setup have been achieved with a new goniometer and a plastic hut around the vacuum chamber containing the goniometer with the crystal so that this was thermally stable. With two drift chambers, one placed behind the crystal and one 50 m upstream, the angular resolution together with the goniometer was about 2 microradians and long-time stability was strongly improved.

Photon spectra were recorded for various incidence angles of the beam to major crystallographic axes and planes. The energies of the beam were 70, 150 and 240 GeV for electrons and 150 GeV for positrons. The crystals were : 0.10, 0.17, 0.50, 0.60 and 1.4 mm Si; 0.20, 0.40 and 0.60 mm Ge and 0.15 mm diamond. The results obtained from this variety of measurements allow a detailed study of the dependence of the radiation on the crystal thickness, on the angle between the beam direction and the crystal axis (or plane) and on the energy of the incident particles.

Fig. NA43–1 shows the obtained photon spectra at 150 GeV for different crystals. It can be seen that the peak structure only appears in the spectrum for particles aligned within less than half the critical angle for channeling. The effect furthermore only exists if the crystal is not too thin as can be seen from Fig. NA43–1 (a). Other data from the experiment show that the peak gets narrower with increasing energy and moves to higher photon energy.

For 0.4 mm Ge, 150 GeV (Fig. NA43–1 (c)), the total energy loss for incident angles within 0–7 μrad is about twice as much as for angles within 27-31 μrad. The peak for 0–7 μrad contains about 24% of the radiation events shown in the spectrum.

Fig. NA43–2 shows the difference in radiation between electrons and positrons for the same energy, crystal and incident angles. While the radiation is greatly enhanced for electrons near the axis, it is strongly suppressed for positrons. This is due to the fact that electrons under channeling conditions are focussed around the strings and therefore into the strong field, while positrons are repelled and thereby move far from the strings.

Three days of beam time were spent to investigate the feasibility of a search for neutral particles ('Darmstadt events'). The number of electron-positron pairs was measured at three distances from the crystal with a multiplicity detector. The primary beam was deflected immediately after the crystal so that only charged particles created after the bending magnet were counted. Such pairs can be produced from a neutral particle produced in the crystal and decaying in flight in the vacuum tube installed after the crystal. A strong one-charged-particle background was identified coming from showers being produced in the vacuum chamber wall. The tail from this one-particle Landau distribution limits the sensitivity of the measurements which were performed in an aligned (<110> axis) and in random direction.

### The Heavy Ion Beam Programme

*NA35*

The NA35 Collaboration (Athens, Bari, CERN, Cracow, Frankfurt, Freiburg, LBL Berkeley, GSI Darmstadt, MPI Munich, Warsaw and Zagreb) continued the analysis of streamer chamber data from nucleus-nucleus and hadron-nucleus interactions. The aim is to study the behaviour of hadronic matter at high density and temperature.

From the study of oxygen- and sulphur-induced interactions with various targets the following picture of the reaction emerges :

- In S+S collisions the energy of the incoming baryons is degraded more than anticipated in some existing N-N superposition models (e.g. FRITIOF). This fact results in an enhancement of the observed number of baryons at midrapidity compared with the predictions of this model (Fig. NA35–1).
- The transverse mass distributions of pions, kaons, protons and lambdas in oxygen- and sulphur-induced reactions are not in contradiction with a model in which a fireball is created during the reaction that expands isentropically and radially. The temperature at the freeze-out time is about T = 115 MeV and the radial expansion velocity $\beta = 0.78 \cdot c$ for all particles, independent of the projectile-target system (Fig. NA35–2).
- Earlier findings of NA35 have shown that the transverse radius parameter of the fireball at midrapidity is about twice the radius of the incoming projectile in central collisions of O+Au and S+Ag reactions. In central S+S collisions this phenomena is not observed.
- The production of strangeness ($\Lambda$, $K^0$) increases, like the pion production, with the violence of the collision. Most important, the increase of strangeness production in S+S collisions is much stronger than the one of pion production resulting in an enhancement of particle production with strangeness or anti-strangeness content by a factor of two compared with a linear superposition model like FRITIOF (Fig. NA35–3).

Studies are underway to learn more about the difference in strangeness production in systems that are symmetric in projectile and target mass (e.g. S+S) and systems that are asymmetric (O+Au).

Strong efforts are currently undertaken by the collaboration to speed up further the analysis of the streamer chamber pictures by implementing new algorithms and techniques for automatic image processing.

Beyond this, the collaboration is heavily involved in the development of a large area Ring Image Cherenkov Counter and a Time Projection Chamber with particle identification capabilities. These developments are essential for further experiments with lead beams, which are planned to cover a large fraction of the phase space with identified particles.

*NA36*

NA36 (Bergen, Berkeley, Birmingham, Carnegie-Mellon, Chandigarh, CERN, Cracow, Madrid, Santiago de Compostela, Strasbourg, Vienna, York) has continued the analysis of data taken with sulphur and proton beams. The aim of the experiment is a measurement, using a TPC, of the production especially of (multi-) strange (anti–) baryons, proposed as a signature of the Quark-Gluon Plasma.

While it was demonstrated in the previous year, that decays of neutral strange particles can be reconstructed in central events of very high multiplicity (Fig. NA36–1), the current effort focuses on a detailed quantitative understanding of systematics, such as non-uniformities of the magnetic field, optimization of pattern recognition and track reconstruction, vertex reconstruction for multiple targets, acceptance calculations involving simulations of the drift process and of TPC electronics, improvement of momentum resolution using additional tracking chambers, etc. At the same time, a substantial fraction of all data has already been processed.

In parallel, the analysis of forward energy flow continues, based upon better calibrations and simulations. Furthermore, electromagnetic dissociation processes are investigated using a forward Cerenkov counter and large angle calorimetry.

Proton beams were used in 1989 to prepare the experiment for data taking with proton and sulphur beams in 1990. On-line hardware had to be reconfigured. Also the operation of the NA36 TPC was optimized, and a new approach for the TPC read-out was tried in view of a forthcoming new experiment. A new scheme of analogue read out of multiplexed sense wires should give a much better spatial resolution.

*NA38*

The NA38 collaboration (Annecy, CERN, Clermont-Ferrand, Lisbon, Lyon, Orsay, Palaiseau, Strasbourg, Valencia) studies dimuons produced in nucleus-nucleus collisions.

An improved procedure for subtraction of the huge dimuon background originating from meson decays has been implemented, which is based on accepting muons only if the muon of identical four-momentum but opposite charge would also have been accepted by the apparatus. This procedure has enabled us to exploit the mass region between 0.5 and 1.5 GeV and to identify a $\rho/\omega$ and a $\phi$ signal (Fig. NA38–1 (a,b)). With the $\rho$ to $\omega$ ratio fixed at 1 :1, the $\phi$ to $\omega$ ratio was found to increase markedly when going from p-U to high $E_T$ O-U and S-U reactions (Fig. NA38–1 (c)). The events used here have $p_T > 1.2$ GeV.

This subtraction procedure will also allow a more rigorous comparison of the $J/\psi$ to continuum ratio for different systems. This ratio has been found to decrease both with $E_T$ for a given system, and with the product of beam and target atomic numbers when going from p-Cu (a system which was newly studied using 1988 data) via p-U, O-Cu and O-U to S-U reactions. Papers on $J/\psi$ to continuum ratios, on the A-dependence of the cross-sections of $J/\psi$ and of continuum production, on the $p_T$ distributions of the $J/\psi$, on $E_T$ distributions, and on the $\phi$ to $\rho + \omega$ ratio and its A-dependence are in preparation.

For the forthcoming sulphur beam runs in 1990 and 1991, the layout of the target region is being restructured with the aim of halving the relative number of background dimuons originating from meson decays. Both the Pb-fibre calorimeter which measures $E_T$, and the cylindrical hodoscope which surrounds the target and has given reasonable estimates of the charged particle rapidity density, are being rebuilt and upgraded.

*WA80*

The aim of the WA80 experiment (Berkeley, Darmstadt, Lund, Münster, Oak Ridge, Tennessee) is to study the reaction mechanism of nuclear collisions. It features calorimetry over a large fraction of $4\pi$, baryon identification in a pseudo-rapidity range between –1.7 and 1.5 units, and measurement of photons and $\pi^0$s in a pseudo-rapidity range between 1.5 and 2.4. The distribution and the multiplicity of charged particles is measured in the pseudo-rapidity range between –1.7 and 4.2 with high spatial resolution. The data taking with oxygen beams of 60 and 200 GeV/nucleon in 1986 and with 200 GeV/nucleon sulphur beams in 1987 were most successful. More than 10 million events have been collected and are mostly analysed. Many results have already been published; the following results were obtained mainly in 1989.

The leadglass detector SAPHIR can measure photons and furthermore $\pi^0$ and $\eta$ mesons. The ratio of direct photons to neutral pions can be determined by calculating those photons which result from meson and baryon decays by means of Monte Carlo simulations. The main contribution for the hadronic background stems from the following decays : $\pi^0 \to 2\gamma$, $\eta \to 2\gamma$, $\omega \to \pi^0\gamma$, and $\psi' \to 2\gamma$. Weak decays like $K_s^0 \to 2\pi^0$ do have minor influence in this calculation. Most of the trivial photons are produced by neutral pions. Due to systematic errors it is, therefore, of great advantage to use the measured neutral pion data instead of applying model calculations or data from different detectors. The photon distributions from the other three mesons have been calculated by the following $m_T$ scaling : $f(m_T, \pi^0) = f(m_T, h)$ with $m_T = \sqrt{m^2 + p_T^2}$, $h = \psi, \omega, \psi'$, and m denotes the respective rest mass. With the present analysis an upper limit of 15% for the direct $\gamma/\pi^0$ ratio could be extracted for central and peripheral O+Au collisions at 200 A · GeV (Fig. WA80–1).

Global and local fluctuations in the distributions of transverse energy and of charged particle multiplicity have been investigated in a comparison between experimental data and model calculations. The results indicate that the observed fluctuations originate predominantly from the distribution of sources, i.e. either the number of participating nucleons or the number of binary collisions. The apparently larger widths of the distributions observed in restricted regions of phase space are explained to be of purely statistical nature. As a result of this analysis the cross-sections for events with energy densities much larger than the typical value for central collisions is limited (Fig. WA80–2).

Charged pion yields and transverse energies of baryons are measured in the target rapidity region employing the Plastic Ball detector. Only little dependence of the measured quantities on the bombarding energy is observed. It was found that a leading order formation zone cascade is not sufficient to explain the baryon yield and the transverse energies of baryons in the target fragmentation region (Fig. WA80–3).

*WA85*

The WA85 Collaboration (Athens, Bari, Birmingham, CERN, College de France, Trieste) studies strange baryon and antibaryon production in high energy nucleus-nucleus interactions. The aim is to search for a quark gluon plasma signature in the increase of strange baryons and antibaryon production with respect to 'normal' hadronic interactions. The Ω spectrometer is used equipped with a multiparticle high $p_T$ detector, together with sulphur and proton beams at 200 GeV/c per nucleon incident on a tungsten target. Cascade and Λ decays are fully reconstructed. This is made possible by using a narrow phase space region ($p_T > 0.6$ GeV/c, $2 < Y_{lab} < 3$ ) for charged particles which reduces the observed multiplicity to a few tracks out of a few hundred. Two arrays of silicon microstrips sample the overall multiplicity for central rapidities.

Ten million triggers were obtained in the sulphur beam run in September 1987. Results based on around 8000 Λs, 2000 $\bar{\Lambda}$s, 100 $\Xi^-$ and 50 $\bar{\Xi}^-$ decays (Fig. WA85–1), were presented at the Madrid Conference. This corresponds to 85 % of the total statistics.

The multiplicity dependence for Λ, $\bar{\Lambda}$ and negative hadrons has been studied. The average number of negative hadrons, Λs and $\bar{\Lambda}$s are plotted as a function of the multiplicity in the central rapidity region in Fig. WA85–2. In each case a behaviour compatible with a linear rise is seen over the range accessible to the experiment ($dN/dY_{lab} > 70$). The FRITIOF model, which is based on a superposition of NN collisions, predicts a linear rise in all three cases. A comparison of these Λ yields to those from the proton-tungsten reference data taken in 1988 is underway.

The proton-tungsten reference data taken in 1989 are being processed through the pattern recognition and track reconstruction programs. More proton data have been requested to have enough $\Xi^-$ and $\bar{\Xi}^-$, in order to make a significant comparison with the sulphur data.

Multistrange baryons are expected to be an especially good indicator of the onset of a quark gluon plasma and WA85 is the only experiment to successfully identify them in ultrarelativistic nucleus-nucleus interactions.

*WA86*

In the WA86 experiment (Bologna University and INFN), five stacks of CR39 sheets were exposed to oxygen and sulphur ions of 60 and 200 GeV at the CERN SPS. It is planned to expose at least 8 more stacks to the highest energy oxygen, sulphur and heavier ions.

The main purpose of the exposures is the calibration of the CR39 sheets to be used for a large area experimental search for magnetic monopoles at the Gran Sasso Laboratory (experiment MACRO). Almost one half of the CR39 detector has been installed and CR39 sheets for one more quarter are presently being manufactured. Relativistic ions provide a tool for testing the response of CR39 sheets to ions of different charges. Incident ions are measured in the first layer and tracks of fragments in the next sheets. As a byproduct of the measurements, good limits are obtained on the production of nuclei with a fractional charge attached to them.

The stacks have 20 layers of CR39, each layer $10 \times 7$ cm$^2$ and 1.4 mm thick. There is a copper absorber after 6 layers and a second one after 8 more. One exposure has been performed to oxygen and one to sulphur ions and the tracks are presently measured with an Elbeck image analyser. A sensitivity down to $Z = 6$ has been obtained and the peaks due to different ions are clearly separated.

*EMU01*

In the EMU01 experiment (Alma-Ata, Beijing, LBL-Berkeley, Chandigarh, Jaipur, Jammu, Lund, Linfen, Marburg, Moscow, Ottawa, Seattle, Tashkent, Wuhan) nuclear emulsions are used as detectors to study ultrarelativistic heavy-ion interactions. The main aim of the experiment is to investigate global aspects of the multiparticle production like the mass and energy dependence of charged particle multiplicities, angular distributions of charged particles, and target and projectile break-up. The experiment, however, also focuses on local particle density fluctuations. Indications of a Quark Gluon Plasma phase transition in terms of high overall particle densities combined with large local fluctuations are studied.

Within the collaboration two complementary techniques are used, each with its own advantage. The conventional technique with horizontally exposed stacks is predominantly used for obtaining minimum bias data, and for special studies of the target break-up. In order to gain maximal resolution in interactions of extreme multiplicities, where many particles are produced in a narrow forward cone, the usage of vertically exposed emulsion chambers facilitates the measurements.

Fig. EMU01–1 shows pseudo-rapidity distributions and particle density distributions obtained for central Sulphur-induced interactions. The distributions are in good agreement with FRITIOF calculations.

Fig. EMU01–2 shows the dispersion of the multiplicity distribution as a function of average multiplicity for increasing rapidity-windows, centred around the nucleon-nucleon centre-of-mass system, for Oxygen-induced interactions at three different energies. The solid line is a linear fit to the 60 A GeV data. Statistical calculations reveal that the intercept should be equal to one over twice the slope. As can be seen from the figure the slope is weakly dependent of the incident energy, and the asymptotic slope is given by the dashed line.

Fluctuations in particle densities of non-statistical nature is one of the proposed signatures for deconfinement of quarks into a quark gluon plasma. Such fluctuations are studied in the emulsion chambers. The technique with chambers is highly suitable for these studies due to its supreme resolution. For example, particles produced in the region $1 < \eta < 7$ can be measured with an accuracy of about 0.01 units of pseudo-rapidity.

*EMU03*

The EMU03 experiment (Cairo University) has until now obtained 70 $e^+e^-$ pairs emitted in the interaction of 200 A · GeV nuclei and its relativistic fragments $2 \le Z \le 16$ in emulsion.

The kinematic analysis of 10 electron pairs from eight fully measured events suggests the emission of intermediate neutral bosons of masses $1.50 \pm 0.29$ MeV and $9.82 \pm 1.52$ MeV, with lifetimes in the region $10^{-16}$ – $10^{-15}$ s, decaying into the observed $e^+e^-$pairs. The distribution of the energy partition $y = |E^+ - E^-| / (E^+ + E^-)$ is similar to previous results, peaking strongly forward and deviating significantly from the distribution expected for Dalitz decays and $\gamma$ conversion. The mass-lifetime plot (Fig. EMU03–1) indicates the presence of two clusters 'A' and 'C', observed also in earlier data together with a third cluster 'B'. These particles may be identical to those producing the low-mass electron pairs observed at GSI Darmstadt.

*EMU07*

The KLM Collaboration (Krakow, Louisiana State, Minneapolis) has been analysing the data on central nucleus-nucleus collisions obtained from the 1986 exposure of emulsion stacks to oxygen beams at 60 and 200 GeV/nucleon and from the 1987 exposure to a sulphur beam at 200 GeV/nucleon.

Following the first results on the multiplicities and the pseudorapidity distributions, which showed consistency with the predictions of superposition models, a major effort has been devoted to analysing the structure in the angular distributions, searching for particle correlations, collective phenomena and evidence for non-statistical fluctuations. Study of the two-particle azimuthal and pseudorapidity distributions provided no evidence for correlations. The results were found to be consistent with independent emission of secondaries. The same conclusion was obtained from examination of the pseudorapidity gap distributions. On the other hand, using the method of scaled factorial moments, definitive evidence for the pseudorapidity density fluctuations of intermittent type was found. Observed intermittent patterns become less pronounced for the collisions of heavier projectiles. The factorial moment analysis was then extended into a two-dimensional phase space of pseudorapidity and azimuth angle (Fig. EMU07–1). The two-dimensional analysis reveals an enhancement of the intermittency effect compared to a one-dimensional investigation. This observation suggests that formation and cascading of minijets may be the mechanism responsible for the intermittent behaviour observed in multiparticle production.

Supplementing the analysis of central nucleus-nucleus collisions, a minimum bias sample of oxygen interactions has been examined to search for an energy dependence of the fragmentation of oxygen nuclei. An apparent increase in the yields of heavy fragments with increasing energy can be attributed to the sharp increase of the cross-section for electromagnetic dissociation. Yields of helium fragments were observed to decrease with increasing energy.

# LEAR

In 1989, LEAR delivered antiprotons for 3483 hours to the various experiments. The total number of extracted antiprotons was $4.5 \times 10^{12}$, in an energy range from 105 MeV/c to 1.9 GeV/c. In preparation for future operation at even lower momenta, $10^9$ antiprotons were decelerated to 61.2 MeV/c and stored for 20 min. Finally, $1.8 \times 10^9$ fully stripped Oxygen ions were successfully injected and stored at 147 MeV/c/nucleon. After cooling in longitudinal and transverse phase space, the ion beam was accelerated and ejected at 408 MeV/c/nucleon.

**Fundamental Symmetries**

The CPLEAR experiment PS195 (Athens, Basel, Boston, CERN, Coimbra, Delft-TU, Fribourg, Ioannina, Liverpool, Ljubljana, Marseilles-CPPM, Orsay-CSNSM, PSI-Villigen, Saclay-DPhPE, Stockholm, Thessaloniki, ETH-Zürich) is studying with high precision the CP-T violating phenomena in the neutral kaon system by measuring the interference effects and the asymmetries between $K^0$ and $\bar{K}^0$ of the three main different decay modes. The possibility of tagging the strangeness of the initial and final states is a unique feature of this experiment allowing the possibility of testing consequences of CP,T and CPT invariance in decay modes not accessible by the $K_L$, $K_S$ experiments. In particular the measurement of direct CP violation is one of the important goals of this experiment. This measurement is performed in PS195 in an independent and complementary way to the standard experiments and its importance is proven with the recent results of the NA31 experiment at CERN and the E731 experiment at Fermilab. Even if the results are only as good as the $K_L$, $K_S$ experiments, the systematic errors will be completely different. The high rate of the stopping antiprotons and the low branching ratio of the interesting reactions require a filter mechanism to select only those events of potential physics interest. A sophisticated system of on-line trigger processors has been developed. The detector has been installed and data have been collected (500 tapes) in the last months of 1989. All detectors (tracking chambers, particle identification detectors and the electromagnetic calorimeter with high position resolution (62000 channels)) are performing according to the designed specifications, even at a flux of $1.3 \times 10^6$ antiprotons per second. The group is processing the data and looks forward to a high statistics run in 1990.

The aim of experiment PS189 (CERN,Orsay CSNSM) is to reduce the present upper limit on a hypothetical CPT violation in baryon-antibaryon pairs in order to reach an accuracy of $10^{-9}$. A radiofrequency mass-spectrometer (RFMS) has been designed and constructed to make a comparison of the charge to mass ratio of proton and antiproton. The design parameters are adjusted in order to couple a high resolving power of $10^6$ with an acceptance as large as possible. The charge to mass ratios of antiproton and proton are compared by measuring the ratio of the cyclotron frequencies of antiproton and $H^-$ ions rotating in the same very homogeneous magnetic field. This ratio is determined by applying a RF modulation which allows the ions to be ejected only when the frequency is tuned at (N+1/2) times the cyclotron frequency. The resolving power depends on N and on the energy selection which is achieved using electrostatic energy filters set in the injection and ejection lines of the device. Due to fundamental and technical limitations the $\bar{p}$ momentum cannot exceed 20 MeV/c in the RFMS, that is, nowadays, a challenge to the LEAR machine. The set-up has been assembled and tuned at Orsay using a $H^-$ beam line. From July 1988 up to the end of the year the equipment has been moved to and reinstalled in the LEAR experimental area. The first half of 1989 has been mainly devoted to the feasibility test of energy degradation as a suitable way to match the LEAR lowest momentum to the spectrometer acceptance at 20 MeV/c. Then, new beam visualisation devices adapted to very low momentum have been tested and the RFMS transmission was improved. The conclusion about energy degradation was negative, and consequently, the CERN and IN2P3 management have decided the construction of a PS189-dedicated RFQ decelerator. The decelerator should be installed by fall 1990 in order to test the equipment before the end of the year. Then, data taking should take place and be completed as soon as possible, depending on antiproton beam availability.

The TRAP Collaboration PS196 (Harvard, Mainz, Washington) has lowered the energy at which antiprotons can be stored and studied by almost ten orders of magnitude, starting with 6 MeV particles from LEAR. PS196 has held cryogenic antiprotons a few degrees above absolute zero for more than a month, longer than the previous storage time of one week achieved at the ICE ring. With cold antiprotons, the team has been able to make a comparison of the inertial masses of the proton and antiproton with an accuracy already more than fifty times better than previous measurements. The resolution of the apparatus is now such that an improvement of another factor of one hundred is within sight, bringing closer the main objective of the experiment: to compare the inertial masses of protons and antiprotons to an accuracy of $10^{-9}$.

In recent months the resolution of the apparatus was improved to one part in $10^8$, opening a new series of systematic tests to improve the accuracy in the near future. Antiprotons at cryogenic temperatures are now available to study and compare their inertial mass with that of the proton. Today this is one of the few precise tests of CPT invariance and the most precise with baryons.

A collaboration consisting of participants from the Los Alamos National Laboratory, Texas A&M University, NASA Ames Research Center, and the University of Colorado at Boulder (PS200) has been formed to perform a fundamental measurement in gravity that has not been done before: the measurement of the gravitational force on individual particles of anti-matter. In certain extended supergravity models, specific particles have different gravitational masses than their associated antiparticles. However as yet there has been no direct test of this prediction.

It is proposed to directly test the equality of particle and anti-particle gravitational masses in the baryon sector with antiprotons and negative hydrogen ions. The distribution of times of flight (TOF) of particles launched vertically up into a shield drift tube will exhibit a cut-off independent of the initial velocities. This cut-off time gives a direct measure of the gravitational force on the particles. Negative hydrogen ions will be used in comparison and as a calibration standard. A statistical precision better than one percent is anticipated and can be achieved by launching a few million particles.

During 1989 detailed studies of the degrader technique have been performed using antiprotons and protons from LEAR as well as 2 – 5 MeV protons from the Van de Graaff accelerator at Los Alamos. A 50 keV trap with an axial dimension of 30 cm has been tested. A model of the drift-tube set-up has been built for detailed testing of the patch effect and the coulomb-explosion. A superconducting magnet producing a field between 0.5 and 2 Tesla at a homogeneity of 1 part in a million over a cylindrical volume of 50 cm length by 1 cm diameter has been received and commissioned. In March 1990 the technical feasibility of the drift-tube part of the experiment using ions from an ECR source will be tested. The electron cooling of trapped antiprotons will then be tested at LEAR towards the end of next year.

### Soft QCD phenomena

*Hadron Spectroscopy and $N\bar{N}$ Annihilation*

Three years after the start of the project, the Crystal Barrel detector at CERN's LEAR low energy antiproton ring is now assembled and has taken its first batch of data. This experiment (PS197) aims at a detailed study of proton-antiproton annihilations, especially for the production of neutral particles. Covering nearly the full solid angle and sensitive to both charged and neutral particles, the Crystal Barrel detector is one of a new generation of magnetic detectors and the first of its kind to be used in low energy proton-antiproton physics. The detector employs crystal calorimetry to measure the energy of photons and a jet drift chamber to analyse the momenta of charged particles. Antiprotons of 200 MeV/c momentum from LEAR annihilate in the detector's liquid hydrogen target, which is surrounded by two cylindrical multiwire proportional chambers with a total of 300 wires and a cylindrical jet drift chamber with 690 sense wires. The proportional chambers are used for a fast charged particle multiplicity trigger. The jet chamber measures the momenta of charged particles with an accuracy of ± 3% at 1 GeV/c momentum. The energy loss of particles in the chamber will be used to discriminate pions from kaons up to momenta of 500 MeV/c. The chambers are surrounded by an electromagnetic calorimeter made of 1380 individually sealed cesium iodide crystals of 16 radiation lengths thickness. The light produced in each crystal is read out with only one photodiode mounted on the side of a wavelength shifter. The resulting excellent light collection yields a good energy resolution (± 4 MeV at 100 MeV photon energy) and angle resolution (± 1°). Covering 98% of the full solid angle, the calorimeter allows efficient reconstruction even for final states with large multiplicities. The surrounding coil provides a homogeneous magnetic field of 1.5 T along the beam axis. The Crystal Barrel's ability to reconstruct charged particles as well as photons allows a complete kinematical reconstruction of all annihilation channels, especially those with several neutrals ($\pi^0$ or $\eta$) which have not been observed so far. Particular emphasis will be on meson spectroscopy and the search for glueballs, hybrids and particles with exotic quantum numbers which are predicted in the Standard Model of high energy physics, but which have not yet been unambiguously identified. In the first two physics runs in October and December 1989 more than four million proton-antiproton annihilations were recorded, including one million with a special trigger on all-neutral events. Also recorded were test runs with triggers based on charged particle multiplicity as well as photon multiplicity. All these data are presently under analysis and first physics results are hoped for in the near future. In forthcoming runs it is planned to further increase the statistics, but also use fast triggers on charged and neutral multiplicity and on invariant photon-photon masses, in order to collect data samples for particularly interesting final states. Runs with gaseous hydrogen, deuterium and with antiprotons in flight (up to 2 GeV/c) are also planned.

The OBELIX experiment PS201 ( Bologna, Brescia, Cagliari, CERN, Dubna, Frascati, Legnaro, Orsay, Padova, Pavia, Trieste, Torino, Udine) is designed to study exclusive final states of antiproton and antineutron annihilations at low energies with protons and nuclei. The physics motivations of the experiment are the search for glueballs, hybrids, multiquarks and light mesons produced in $N\bar{N}$ annihilations and study of their spectroscopy and decays, the study of the dynamics of $N\bar{N}$ interactions and the investigation of the quark-gluon aspects of nuclear matter. During 1989 the construction of the apparatus was speeded up, and parts of the detector in the final configuration were tested with the $\bar{p}$ beam in two period of running. In particular the time-of-flight system, nearly completed, was succesfully operated, as well as the new electronics for the jet drift chambers, based on 8-bit FADCs. The spiral projection chamber used as vertex detector was succesfully installed on the beam and the assembling of the first supermodule of the electromagnetic calorimeter is in progress. The acquisition system, based on VAX 6250 and operating under the MODEL package in the full version, is operational. An attempt of measuring annihilation cross-sections for $\bar{p}$ of 70 – 80 MeV/c on protons with a new technique gave encouraging results.

The purpose of the JETSET experiment is to search for new, as yet unobserved, states of matter ('glueballs', 'exotics', and 'hybrids') predicted by current models of hadronic structure. This will be achieved by scanning the mass range above $2M_p$ using in-flight annihilations of antiprotons on protons of a hydrogen gas jet target inside the machine. The supersonic jet is capable of providing target densities of about $10^{14}$ atoms/cm$^2$. In conjunction with the LEAR $\bar{p}$ beam, which contains about $10^{10}$ particles circulating at a frequency of $3.2 \times 10^6$ s$^{-1}$, luminosities of about $10^{31}$ cm$^{-2}$ s$^{-1}$ can be achieved. The first reaction to be studied will be the gluon-rich reaction $\bar{p}p \rightarrow \phi\phi$. The signature of the $\phi\phi$ final state will be the production of four charged kaons to be selected in about 1 MHz of annihilation rate. The forward detector consists of :

- a charged particle tracking element constructed of self-supporting 'straw' drift tubes;
- a layer of silicon pad detectors;
- a segmented, 24-element threshold Cerenkov detector;
- a RICH counter;
- a segmented scintillator counter to provide the fast trigger signal for the detector; and
- a segmented 'Pb-Scintillating fibre' e/$\gamma$ calorimeter.

The barrel detector is instrumented similarly, except that the RICH and e/$\gamma$ calorimeter counters will not be present in the first phase of the detector. The first data taking in JETSET is expected to be in the summer of 1990.

The purpose of the LEAR experiment PS185 (Carnegie Mellon, Erlangen, Freiburg, Illinois, Jülich, Uppsala, Vienna) is the measurement of cross-sections and spin variables in the 'neutral hyperon' reactions, $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ and $\bar{p}p \rightarrow \bar{\Lambda}\Sigma^0$ ($\bar{\Sigma}^0\Lambda$), as well as in the 'charged hyperon' reactions, $\bar{p}p \rightarrow \bar{\Sigma}^+\Sigma^+$ and $\bar{p}p \rightarrow \Sigma^-\Sigma^-$. The polarization distribution (combined from $\Lambda$ and $\bar{\Lambda}$) exhibits large negative values of up to 50 % over most of the angular range. The aim of another run on $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ at 1.645 GeV/c beam momentum has been to obtain first data on the scattering of (polarized) $\Lambda$ and $\bar{\Lambda}$ from protons and carbon. With a newly developed silicon-microstrip telescope the experiment has also begun to measure the 'charged' channels $\bar{p}p \rightarrow \bar{\Sigma}^+\Sigma^+$ and $\bar{p}p \rightarrow \Sigma^-\Sigma^-$. The $\bar{p}$ beam momenta used for this, slightly below and above 1.90 GeV/c, are the highest ones ever extracted from the LEAR machine.

*$N\bar{N}$ interactions*

The aim of the experiment PS199 (Cagliari,Geneva,Trieste,Torino) is the study of the spin structure of the charge-exchange reaction $\bar{p}p \rightarrow \bar{n}n$ at LEAR energies; in particular it measures the differential cross-section, the polarization parameter P, and the spin transfer parameter D from 500 to 1500 MeV/c in the full angular range.

The experiment is fully installed and working. After a few days of calibration runs with a liquid hydrogen target in April and May, data have been taken with a frozen spin polarized proton target in September at three different momenta, 700, 800 and 900 MeV/c. The data at the lowest momentum have already been analysed, and a remarkable polarization signal has been observed, with maxima of about 0.20 both in the forward and in the backward hemisphere. This is the first time such a parameter is ever measured for the charge-exchange reaction at low energies.

A complete energy scan is foreseen in 1990, as well as at least one measurement of D, the polarization transfer to the neutron.

*Nuclear physics with $\bar{p}$*

It has been suggested for a long time that antiproton annihilation would deposit very high energy in the nucleus, thereby possibly creating special nuclear matter states. The PS203 measurement is ultimately aiming at observing if such exotic phenomena occur. As a first approach particle spectra and the distribution of the residual nuclei after the annihilation have been measured. As a second approach, the fission fragment distribution will be studied.

The measurement was performed in May 1989. A double-arm time-of-flight fission spectrometer was used, which consists of a channel plate detector and two $12 \times 12$ PIN diode arrays at both sides. Two targets ($^{238}$U and $^{197}$Au) were exposed to stopped antiprotons. The mass, energy and angular correlations of coincident fragments were measured. In the case of uranium, the average mass is 106(1) with FWHM of 46 and the average total kinetic energy is 154(1) with FWHM of 35. The average momentum of the fissioning nucleus calculated from the angle, masses and energies of the coincident fragments was around 610 MeV/c. It is seen that the total mass and the total kinetic energy decrease as the momentum of the fissioning nucleus increases. Our result suggests that the excitation energy produced by antiproton annihilation is large on average compared with that by 96 MeV pion and 1 GeV proton projectiles.

### Solid state physics

In 1989, experiment PS194/2 (Aarhus, CERN, SIN, Stockholm) continued its investigations of ionization, energy-loss and X-ray emission by antiproton impact, covering the range of 40 keV to 5 MeV antiproton energies. Major progress was made in K-shell excitation by antiprotons of 3.5 MeV energy impinging on targets of Ti, Cu, Se and Nb. The corresponding X-ray spectra were measured for the first time. In all spectra the K-line arising from the radiative filling of the vacancy could be observed. The comparison with equivelocity proton yields shows that antiprotons are more effective than protons in producing inner shell vacancies (Fig. PS194/2–1). This reflects the 'antibinding' effect produced by negative projectiles on the target electron. In the investigation of the Barkas effect in energy loss, antiproton dE/dx in a thin silicon detector was measured down to 250 keV antiproton energy. The deviation from the proton energy loss increases and reaches 50 % in the velocity region of the maximum (proton) energy loss. Measurements to even lower energies seem feasible. This unexplored region is particularly interesting since mechanisms other than the ones responsible for the Barkas effect are expected to play a role. The first single ionization measurements of helium by antiprotons was reported in a broad energy region from 40 keV to 2 MeV. A comparison with protons and with theoretical calculations (Fig. PS194/2–2) shows reasonable agreement with the estimated cross-sections. The apparent difference between antiproton and proton cross sections can be explained qualitatively by the polarization of the electron cloud in the region 100 to 500 keV (cf. Barkas effect!), and by the 'antibinding' effect below 50 keV. Progress in ionization to even lower energies demands the development of new deceleration techniques, other than foil degradation.

Electrons produced in several 100 keV antiproton-foil collisions through atomic process have been studied in experiment PS204 (Tokyo, Aarhus, CERN). The purpose of this experiment is to investigate the existence or non-existence of the 'wake-riding electron', which is an electron trapped in an attractive part of 'wake' potential induced in solids by a swift antiproton. Incidentally, this experiment provides a unique chance to investigate charge asymmetry effects in electron emission phenomena. We have measured the energy distributions of electrons emitted in the forward direction from a carbon foil by slow antiprotons. Figure PS204–1 shows an example of the zero-degree electron spectra for (a) 600 keV protons and (b) 610 keV antiprotons bombarding a 2 $\mu g/cm^2$ carbon foil. A drastic difference between antiprotons and protons is observed around (anti-)cusp region, where an electron has a velocity around the projectile velocity. An ordinary sharp cusp-shaped peak for protons is replaced by a broad shallow dip for antiprotons. Figure PS204-2 shows the electron spectrum around the 'anti-cusp' region. To reduce the statistical scatter of the data, electron spectra belonging to different antiproton energies are added together after the abscissa is properly shifted to keep a structure around the anti-cusp region. The raw data are shown by the solid circles. The histogram is the result of an average over neighbouring channels (± 1 channel). Although the statistics are still not very good, one can notice, about –50 eV below the anticusp, a broad bump, the energy position of which is consistent with that of electrons released from the wake-riding states.

## SC programme

### ISOLDE

The ISOLDE installation provides high quality secondary beams of radioactive isotopes, derived from primary beams of 600 MeV protons or 910 MeV $^3$He from the SC. The larger ISOLDE experiments are approved by the PSCC and the Research Board and are listed in 'Experiments at CERN in 1989'. However, it is characteristic of ISOLDE that many experiments require relatively little machine time. These small or test experiments are grouped under the code IS01-x and are approved by the ISOLDE Committee.

The SC-ISOLDE facility has been operational for 5 periods of about one month each in 1989. The two on-line isotope separators ISOLDE-2 and ISOLDE-3 as well as the Synchrocyclotron have been operating very reliably. This resulted for 1989 in a new record number of 306 shifts of radioactive beams available for experiments. There were 38 runs scheduled and in 36 of these data were taken by a total of 76 groups. A broad programme was performed, comprising nuclear, atomic, solid-state, surface, astro-, and applied physics.

*Target/ion Source & Separator Development*

The development of new target/ion source systems (IS01) is an essential part of the ISOLDE research. Since completion of the ISOLDE-3 construction the necessary effort could again be devoted to this task. In 1989 a number of new systems have been tested with proton or helium-3 beam. In particular the hot plasma ion source for less volatile elements could be greatly improved in reliability and several elements (Au, Ag, Cu, Mn, Mg, Be) could for the first time be produced on line with good yields. The use of reactive gases fed into the targets or ion sources via newly installed gas lines allowed a controlled production of molecular ion species. Beams of $SrF_2^+$, $YF^+$, $HfF_3^+$, $FAl^+$, and $SeCO^+$ could be used for elements that were not available at ISOLDE in a chemically pure form before.

In collaboration with the SC group the higher order components necessary for the high resolving power expected of ISOLDE-3 have been installed and successfully tested. Off-line tests of an electron cyclotron resonance (ECR) source showed promisingly high efficiencies for several gaseous elements. Also a new chemically selective way of laser ionization in a three step process (IS01-29) gave very encouraging results and the equipment shall soon be moved to an on-line separator.

*Nuclear Physics*

The ISOLDE separators allow the production of long chains of isotopes extending to regions very far from β-stability. Because of this unique feature the properties of such nuclei – in particular masses, electromagnetic moments, excitation levels, and nuclear decay characteristics – are a natural focus of the experimental studies.

In the measurement of nuclear masses with the ion trap cyclotron resonance technique developped by experiment IS130 an important breakthrough has been achieved. The reconstructed apparatus now reaches a resolving power of $2 \times 10^6$. It was used to determine the masses of the long series of isotopes between $^{138}$Cs and $^{137}$Cs to an accuracy of 10 keV. The results are compared to earlier values in Fig. IS130-1. More conventional $Q_\beta$ measurements were performed for $^{93}$Br (IS01-21) with a highly efficient scintillator spectrometer and for several Cs isotopes with a germanium spectrometer coupled to a specially designed magnetic electron separator (IS01–20).

The systematic study of electromagnetic properties of nuclear ground states (mean charge radius, magnetic moment, electric quadrupole moment) was continued using various optical methods. With collinear laser spectroscopy the systematic study of rare earth elements was extended to the isotopes $^{147-159}$Tb and $^{167-171}$Lu. The chain of In isotopes was measured up to mass number 130 (IS81), close to the doubly magic nucleus $^{132}$Sn. Using the recently introduced ion counting techniques (IS84), several far off stability isotopes, $^{96}$Kr, $^{77}$Sr, $^{100}$Sr, could be added to earlier measured series. In order to study the phenomena of shape transitions and coexistence which were first observed in 1971 at ISOLDE in the case of the neighbouring Hg isotopes, the static quadrupole moments of $^{191-194}$Au were measured by collinear spectroscopy (IS01-30). This information, not available from the earlier pulsed laser desorption measurements (IS150), is consistent with prolate shapes.

At the low temperature nuclear orientation facility NICOLE, installed at ISOLDE-3, the nuclear moments and decay multipolarities of short-lived isotopes in the Os-Hg region have been studied (IS120). The spectroscopic data clearly point to triaxial shapes for many of the Ir and Pt isotopes.

Significant progress has been made in the spectroscopic study of nuclei in the $N \propto 20$, $Z \propto 11$ region, where earlier mass measurements at CERN had demonstrated anomalous binding energies. The level schemes measured by γ- and neutron spectroscopy (IS230) cannot be explained for within the sd shell-model space, but fp intruder states in some cases even make up the ground state. The great similarity of the excitation scheme of $^{34}$Si (Fig. IS230–1) to a doubly magic nucleus can be explained in this way. Spectroscopy in the $Z \propto 40$, $N \propto 60$ region, where earlier data have demonstrated a very pronounced nuclear deformation, was extended to $^{89,91,93}$Kr produced in decay of Br (IS220). The level schemes cannot be understood with a stable deformation, but indicate transitional shapes.

The study of the $^{98}$Cd decay was completed (IS200), the closest approach yet to the doubly magic $^{100}$Sn. The determined quenching of the Gamow-Teller strength is in line with the data from the heavier isotopes. The proton emission in β-decay of $^{115}$Xe was restudied. The extremely complex spectrum is being analysed using the concept of chaos in quantum systems.

*Atomic Physics*

ISOLDE allows the study of electronic properties of elements where nature does not provide an amount sufficient for conventional optical investigations. In 1989 the study of Rydberg states in francium was completed using the collinear laser spectroscopy technique with a two-photon excitation scheme (IS01-16). The energies of 39 levels of d and s type are now known to high precision. The high resolution of the measurement allowed a determination of the fine structure of the nd levels and also the hyperfine coupling for 8d, 9d, 10s, and 11s. These data for a simple but highly relativistic atom represent a unique testing ground for relativistic Dirac-Fock calculations to high precision.

*Solid State Physics*

Nuclear methods allow the investigaton of impurities in condensed matter at very low concentration. The intense pure beams of radioactive ions from ISOLDE are ideal for such research, as evidenced by the increasing number of users in this field. The solid state experiments take advantage of the practically unlimited choice of isotopes at ISOLDE which can be implanted into the matrix under investigation.

The most straightforward application of radioactive tracers is in the study of diffusion. The new data for Te in Si determined with a classical sectioning method (IS170) show that at least two mechanisms contribute. For the simple system Fr in K and Rb an enhanced diffusion of the oversized impurity was found in experiments using $\alpha$-spectroscopic depth profiling (IS01-23), as illustrated by the broad spectrum in Fig. IS01-23–1. The sharp line is due to the At daughter atoms that have diffused back to the sample surface. This process actually occurs at least 1000 times faster than self-diffusion, a phenomenon yet to be explained.

The major effort of the solid state programme was the study of impurity implantation into semiconductors, a process of high technological importance. Combining the results of Mossbauer spectroscopy (IS20), channeling (IS181), and perturbed angular correlation (PAC) (IS01-32) it was found that implantation of Cd and In into GaAs leads to amorphization of the implantation track region that anneals out at $\propto$ 300K. Such experiments could only be performed at ISOLDE, since the three different techniques required each different nuclear properties of the implanted isotopes. Mossbauer spectroscopy was further used to study the anomalous diffusion of Sb in Si, the channeling technique to study vacancy motion in GaAs, and PAC to observe donor-acceptor pairs in Si and III-V compounds as well as hydrogen passivation in semiconductors. Using site selective doping the local density of states at $^{73}$Ge and $^{119}$Sn impurities in GaAs and InP could be studied with conversion electron spectroscopy (IS240).

*Astrophysics*

ISOLDE-2 was used to implant $^{22}$Na at high dose into Ni, to be used as a target for nuclear reactions (IS01-35). The cross section measured for the $^{22}$Na(p,$\gamma$) reaction indicates that the hot NeNa cycle can be of importance at stellar temperatures above $10^8$ K.

*Applications*

Radioisotopes of rare earth elements were produced to investigate possible medical uses (IS01-22). Also a new generator for $^{71}$Kr was used in a first clinical test. Several samples of $^{83}$Rb were prepared for tests of the ALEPH and DELPHI detectors. As in previous years, parasitic irradiations to produce test activities or calibration sources were performed.

*Developments of experimental Techniques*

The deceleration of ions from $\propto$ 50 keV and subsequent trapping in a radiofrequency quadrupole (RFQ) trap has been tested successfully. This process, when installed at ISOLDE, will allow the injection of any type of ion into the cyclotron trap mass measurement apparatus (IS130), thus overcoming the present need for surface ionization.

The sensitivity of the collinear laser technique could be greatly improved by using multiphoton ionization, thus opening the possibility to study elements with small production yield (IS82). Also the polarization achievable for Li in the collinear setup (IS01-36) could be increased with the use of an electro-optical modulator.

The efficiency of channeling measurements could be greatly improved by the use of a particle detector with 2-dimensional position readout (IS01-23). A UHV switchyard is being installed at ISOLDE-3. It will feed the newly designed multi-purpose UHV chamber (IS31) for surface physics experiments.

**Muon Spin Rotation ($\mu$SR) Experiments**

These experiments are related to the diffusion of positive muons in metal lattices at low temperatures and address the question of the conditions for quantum mechanical tunneling processes. Earlier work has included the motion of positive muons in aluminium in the temperature range 0.03 to 20 K, and evidence for tunneling without phonon excitation was found below 1 K. The results were in agreement with a theory presented by

J. Kondo, which explained the temperature dependence (having the exponent –0.7) of the mobility as the result of 'friction' caused by conduction electrons. In 1989 the main activity was around the project SC76. It was proved that muons in superconducting aluminium behave quite differently than in metals in the normal state. The friction is less in the superconducting state due to the presence of the energy gap in the conduction electron distribution. This can also be explained in terms of the Kondo theory for tunneling with dissipation.

## Technical Developments

### Detector Development Group

The group has continued his activity in the development of various kinds of gaseous detectors; two will be described here, aimed at rather different applications.

*Microstrip Gas Detector*

In a collaboration between the teams of R. Bellazzini (INFN Pisa) and F. Sauli (Detectors Development at CERN), a new kind of gas detector is being investigated, in view of its very promising performances at high rates (Fig. Micro–1). Conductive strip are laid on a thin glass substrate and alternatively connected to potentials to achieve multiplication of charges released in an overlaying gas. The picture shows one edge of a microstrip detector, with 10 microns wide anodes interlaced with thicker, 30 microns wide cathodes, fanned for readout. Using an electron beam lithography process, large active surfaces ($10 \times 10$ cm$^2$) can be realized rather inexpensively. The group has demonstrated gas gains in excess of $10^4$, uniform over the surface of the detector, high rate capabilities (no gain drop at equivalent particle rates above $10^7$/s.cm$^2$) and localization accuracies of 30 microns or better obtained recording the induced charge on cathode strips (Fig. Micro–2). More important in view of high luminosity applications, the expected two-track resolution is comparable to the pitch, 200 microns in the present design. These performances compare rather well with those of the silicon strip detectors, at a fraction of the cost. Note that for the readout one can make full use of the high density electronics developed for solid state devices, with however a considerably better signal to noise ratio (signals are at least an order of magnitude larger in the microstrip chamber, and detector capacitances are smaller). Work is in progress to study the radiation resistance of the new detector, expected to be less sensitive to ageing than thin-wire proportional chambers.

*Imaging Chamber for Microcosm*

Imaging chambers are gaseous devices in which detection of the ionization is obtained observing the light emitted in the multiplication process; using as recording device a high- resolution solid state camera, granularities in the megapixel region can be easily obtained, unthinkable when using a more conventional electronic readout. Some applications of the imaging chamber have already been described in last year's Annual Report; G. Charpak is actively pursuing the development of a device capable of high-resolution mapping of two-dimensional activity distributions (a diagnostic method named radio-chromatography). The light emission in the chamber is, under normal condition, relatively small and detection requires the use of an electronic image intensifier. The Detector Development group, with P. Fonte and D. Sauvage as main investigators, has found ways to enhance the light yield so much as to make tracks directly visible by naked eye; this has led to the idea to build an imaging chamber for the Microcosm permanent exposition at CERN. When installed, the device will allow visitors to see alpha-particle tracks in helium both directly and, on a monitor screen, after digital recording and mapping; the increase in energy loss due to straggling and, occasionally, Rutherford scattering of an alpha particle off helium can be observed. Fig. Imag-1 shows an example of digitized tracks. The work for the development of the detector has shed more light in the mechanism of photon emission and propagation in gas discharges; built at a much larger scale, and thanks to the simplicity of the readout, an imaging chamber may be the ideal tool to study rare events of a certain complexity, such as the double beta decay.

### Radiation Resistance of Scintillating Fibres

This LAA project, carried by LIP/Lisbon and CFNUL/Lisbon and one CERN physicist, aims primarily at evaluating scintillating optical fibres supplied by industries, often at the prototype stage, in view of assessing their suitability for the SPACAL fibre calorimeter project. Emphasis is on scintillation light emission and transmission and, mainly, radiation sensitivity. The dependence on type of radiation, dose, and dose rate are studied. Fibres are irradiated at the LNETI laboratories near Lisbon by $^{60}Co$ sources as well as neutrons from a research reactor, and measured on site, starting minutes after the end of irradiation, using collimated electrons from a beta source. The fibres are all made of polystyrene (acrylic scintillators are much less radiation resistent, and PVT fibres are not currently available). Irradiation under controlled atmospheres (oxygen, nitrogen, dry air, argon, vacuum) is used in order to define the best working conditions and to gain some insight into the underlying physical mechanisms. Results obtained so far indicate that the best available fibres can stand several megarads provided they are in contact with air and no glue is used to keep them in place. Damage done by reactor neutrons is comparable to the effect of the same dose of photons.

### Low Temperature Detectors Group

*Superconducting Strip Detector Development*

Ultrafast signals were first time seen in a 3.4 micron wide NbN strip detector. These signals feature over 5 mV amplitudes and less than 300 picosecond risetimes. The signals can be understood by taking into account non-equilibrium properties of the superconducting material.

*Calorimetric Detectors*

New athermal calorimetric detector principles were theoretically investigated, with views on setting improved experimental limits on galactic cold dark matter, and on studying astrophysical and cosmological neutrinos. The feasibility of determining the dipole moment of the electron-neutrino was also investigated, using such a detector.

*Polarized Targets*

The SMC NA47 Polarized Targets project was launched, aiming at setting up and operating in 1991 the world largest polarized target, which was built in 1982 for the EMC NA2 experiment and which led to the 'proton spin crisis'. The project team is simultaneously designing and constructing an improved target, which is planned to be installed in the experiment in 1992. The Group installed and operated a Frozen Spin polarized target, as a technical support, for the LEAR PS199 experiment. The first tests of another Frozen Spin target proved very successful, in a newly commissioned polarized neutron beam of the GKSS laboratory in Geesthacht, Germany. The new facility will be used for the studies of the structure of large biomolecules using the spin contrast variation method. The quantum tunneling and diffusion studies of positive muons in aluminium at ultralow temperatures were continued at TRIUMF, Vancouver. These experiments, which seem to confirm the general features of the Kondo theory of quantum tunneling, also show enhanced local tunneling at the lowest temperatures.

### Technical Assistance Group

The main activities of the group during the past year are summarized below.

- NA34 : design and manufacture of various high precision micro targets.
- NA31 : refurbishment and operation of the helium gas system. Assistance in setting up detectors.
- DELPHI Forward RICH : the Group has responsibility for the technical coordination of this project. A test rig for the drift gas system for a portion of detector was installed.
- Obelix : design and manufacture of a prototype converter with incorporated potential degrader for the lateral calorimeter chambers. Development of a method for constructing 6 micron thick cylindrical windows for the inner wall of the SPC.
- ALEPH : development of electronics for monitoring gas flow.
- PS202 : the Group is responsible for the technical coordination of this experiment. In addition, the following specific tasks were accomplished : design and development of a series of prototype straw chambers leading

to the manufacture of the final barrel detector; design and manufacture of the barrel trigger counters; development and operation of prototype RICH detectors; design of the various support structures.

- NA45 : manufacture of a large mirror assembly (diameter 1.7m focal length 4m) using the mirror slumping technique developed in the group. Tests have also been carried out on the feasibility of producing such mirrors using various other techniques.
- Pad chambers : as part of a collaboration within NA34 the group is concerned with the mechanical design, development and construction of prototype pad chambers. These use the principle of resistive charge division to obtain a precision measurement of the position of through passing ionizing tracks.
- NA46 : design and manufacture of a series of precision proportional chambers.
- EMU09 : design and construction of an emulsion transport system.

The following general services are also provided by the group :

- Scintillator workshop : scintillator and light guide systems are constructed for experimental groups both from CERN and outside institutes.
- Wire stretching facility : the Group's wire stretching machines have been used to produce planes of wires to be used by user groups in the manufacture and maintenance of various types of wire chambers.
- Mirror slumping : apart from the work for NA45 described above the group has continued to produce high quality mirrors using this technique for various CERN and outside user groups.

**Engineering & Projects Group**

The activities of the group have been mainly related to the final installation and commissioning of equipment for the LEP experiments in the underground areas. In ALEPH, coordination at various levels and mechanical support have been provided. The mobile access platforms have been commissioned. In DELPHI, a substantial contribution has been given to the installation and commissioning of the hadron calorimeter and of the high voltage current monitors. The complex cooling system for the front end electronics has been designed, installed and operated successfully. The DELPHI and L3 magnetic fields have been mapped with the gears and the instrumentation already used in ALEPH and OPAL. Several activities have also been carried out in the framework of collaboration with outside laboratories. For the ELETTRA (Trieste) synchrotron light source, the design of the ring magnet elements has been provided and prototypes have been constructed and tested. For this purpose, a very accurate field measuring system has been developed. Consultancy in machine design and operation has been given to CELSIUS (Uppsala) and to KFA. The LEP detectors field mapping gears, together with their data acquisition instrumentation and software, have been installed and operated in DESY for measuring the H1 and ZEUS magnets. Finally, the usual assistance has been given to the users of the East Hall test beams.

**Thin Films and Glass Group**

The Group has three main fields of activity, namely vacuum deposition of thin films, machining of glass and ceramics, and glassblowing. Vacuum deposition consisted of the evaporation of UV mirrors, photo cathodes, lightweight foam glass mirrors and various wavelength shifters. Machining work included the preparation of foam glass substrates and various ceramic parts. Glassblowing consisted mainly of fabrication of the ever-popular H2 flash tubes and special gas bubblers.

**Mechanical Engineering Group**

The Technical Office is involved in the magnetic refrigeration and loop test project for helium at 1.8 K in collaboration with CENG, Grenoble, and the pre-project for the LEP 200 cryogenics installations. It is also taking part in testing the access aprons for the ALEPH Experiment, in the final stages of work on the hoisting points for the OPAL poles and in assembling the RICH Barrel for DELPHI. In addition, it has studied the prototype quadrupole, sextupole and bending magnets for the ELETTRA Ring in Trieste. The sub-section continues to provide figures and photoreproductions for scientific publications. Its staff are at present being trained in CAD for using Macintosh for figures and graphs. The Mechanical Workshop has produced the coils for ELETTRA and assembled prototype magnets for it. It is working on the final touches to Experiments PS195 and UA6, and has provided technical support to the MICROCOSM Exhibition. The Mechanical Assistance Section handles the maintenance for the standard EP gas mixers and has made specialized ones for the ALEPH, PS195 and OBELIX Experiments. It manages the independent workshops and seconds its staff to help in setting up experiments.

**Tests & Instrumentation Group**

The Test and Instrumentation Group is responsible for a broad range of activities associated with the Electronics Pool. The Electronics Pool contains approximately 38000 instruments. They are use by LEP, UA, LEAR experiments, CERN divisions outside EP and by a large number of Visiting teams. Approximately 150 groups are Pool users, the average movement of Pool equipment was approximately 800 per month in 1989. Main Pool policies are decided by EPAC (Electronics Pool Advisory Committee), where internal CERN users and visitors are represented. The group has continued its collaboration with European manufacturers to develop jointly standardized electronics instruments for the EP Pool. Several manufacturers from France, Germany and Italy have worked at CERN together with the group staff to complete the development of FASTBUS supplies for ALEPH, DELPHI, UA2 and LEAR experiments. Approximately 500 of these units have been delivered and tested by the Pool before equipping the experiments. This joint development made one German manufacturer able to use the same technology in a series of commercial units now being marketed in Europe for industrial applications. In the field of activities related to the VMEbus standard, the joint development of a VMEbus crate done in collaboration with a German manufacturer was completed. The production units are now being tested at the Pool premises with the support the LEP-SPS Controls group. The development of a VMEbus crate containing options particularly adapted for high energy physics research was discussed and approved by EPAC. A specification for the units is being prepared in view of stimulating European manufacturers to the production. A series of VMEbus units, particularly suited to HEP experiments have been tested. Some of these units have been developed by a French Laboratory in collaboration with OPAL and subsequently produced by European manufacturers. Others have been developed on industry initiative or suggested by CERN. The units tested were a pulse height discriminator, a VMEbus-GPIB interface, a CAMAC-VMEbus interface, a display unit and a system for interconnecting several VMEbus crates. Moreover the quality test of commercial instruments recently appeared on the market was performed on the following units : a Snoop FASTBUS Diagnostic Slave module (SFDM), a CAMAC time to digital converter (FERET TDC), a Precision Charge Source type 7120 and a Quad Discriminator type 704.

**Electronics Research & Development Group**

The activities of the group in 1989 have centred on production and commissioning of electronic systems for the LEP experiments, in close collaboration with institutes and industry in the member states. In parallel, collaboration with experiments in other areas of CERN has continued in development, design, production and commissioning of detector signal processing and acquisition systems.

After successful completion of the design, in collaboration with the DELPHI 'Channel Electronics Standardization Group', of a high performance general purpose nsec time digitizer LTD (LEP Time Digitizer), companies in Austria, Greece and Portugal have produced 300 of these FASTBUS modules. They are performing according to specifications with a variety of detectors in the experiment. A futher production of 300 of these units is scheduled. Commercialisation is foreseen by a number of companies because of its attractive features, such as 2 ns time bins based on an ASIC, 32 μs dynamic range, and multihit capability.

The commissioning of electronics for the Time Projection Chamber and the minivertex detector of ALEPH, and the barrel muon chambers of OPAL – designed in collaboration with MPI-München, Univ. of PISA and Univ. of Wisconsin and produced by companies in France, Germany and Italy – has been completed and has successfully taken data from the detectors. The system for the ALEPH TPC processes signals from 6408 wires and 41004 pads. It consists of 47412 thick film hybrid charge preamplifiers, 800 64-channel amplitude and time sampling (8 bit, 12,5 MHz) modules (TPD) with thick film gaussian shaping (FWHM = 220 ns) amplifiers, 72 read-out processors (TPP) based on 68020 microprocessors, and a calibration system. A set up with another 100 TPD modules is in preparation for the read-out of a TPC in the experiment NA35. For ALEPH some complementary devices are in the process of design.

The design of a read-out system for silicon strip detectors, in collaboration with the DELPHI microvertex detector group, has virtually been completed. Its basic element is a FASTBUS module (SIROCCO IV) which has two channels, each capable of sampling analogue signals (by a 10 bit FADC at 5 MHz) from up to 2048 strips.

Preprocessing is done on board by a 56001 DSP. Production has started by a company in Italy to cover the read-out of 55000 strips in the first phase of the DELPHI detector. Although the system has been developed to process signals from the MICROPLEX chip, it can easily be adapted to other multichannel preamplifier- sample-hold circuits. An implementation with the SVX chip (designed at LBL) for use with the Si strip microvertex detector of the Forward Beauty detector (P238) is in preparation.

The group has taken over the responsibility to complete the design of the electronics for the Forward RICH detector of DELPHI. This system amplifies, discriminates and timemultiplexes detector wire signals before time measurement by LTDs. A review of the design is in progress.

The design of a read-out system for the ministreamer tube calorimeter of PS195 (75000 channels) – in collaboration with the Univ. of Basel, Demokritos Athens, ETH-Zürich, PSI and the Univ. of Thessaloniki – has advanced well. Production of 3000 SMD based preamplifiers and 1100 high voltage distribution cards has been completed by companies in Greece and Italy, and subsequently installed and tested. A pilot quantity of 50 CRAM's (Calorimeter Receiver And Memory, based on an ASIC) has been tested with the detector and a production of a further 950 of these FASTBUS modules is in preparation. The design of the other basic elements of the system (three different types of FASTBUS module) is nearing completion. Participation in the development and design of the fast trigger and processor system, and of the VME based data acquisition system has continued. Prototypes of a number of modules for these have been completed and tested in the experiment.

The design of electronics which allows to incorporate information from a TRD in the trigger of NA31, with the aim of rejecting electrons with a very small loss of pions, has been completed. Fifty CAMAC modules of three different types were produced and installed in the experiment. The design work has completely been done on DAZIX and VISULA work stations.

MACVEE development and support has continued. The total number in use at the end of 1989 is more than 600. The system, which is manufactured in France, Germany and Italy, was adapted for use with the 68030-based Macintosh IIcx and Macintosh IIci computers which were introduced during the year. A large installation was implemented at DESY for the control and monitoring of the H1 experiment using MacVEE tools integrated with Apple's Macintosh Programmer's Workshop. At CERN enhanced MacSYS features, including a CAMAC list translator for Mac-CC, were developed by the UA1 online team.

After ten years of service to the community of 184 users, SuperCAVIAR support by Wylbur EXEC files was closed down at the end of 1989. Introductory information, applications notes, technical documentation and upgrade news for MacVEE are kept available on the CERNDOC scheme.

The development has continued, in collaboration with the EP-DET group, of a read-out system for multidrift tube vertex detectors based on 150 MHz-8 bit FADCs and SMD components. The theoretical study on the optimisation of a complete detector signal processing chain has advanced well, this takes into account signal formation at the detector, noise, signal shaping, sampling clock frequency, ADC resolution and dynamic range, and digital signal processing. A program has been developed by which circuit components can easily be defined for required shaping time constants.

A considerable amount of effort has further gone into the following projects : the design and commissioning of a gas and water flow alarm and monitoring system for ALEPH, the design and production of charge sensitive preamplifiers (1600) for the TPC of NA36, the evaluation of the CAMEX chip for read-out of Si strip detectors and high precision pad wire chambers, the design of a Sigma-Delta analog to digital converter chip, the production and implementation of CCD based scintillating fiber read out systems – originally designed for UA2 – in a number of other applications.

The year has been a crucial one for FASTBUS development and support, because of the start up of the large FASTBUS systems in the LEP experiments. The great effort made in designing and providing a coherent infrastructure of hardware has paid off, as all systems were brought to taking data with relatively little difficulties. The development of some complementary devices, and investigations on further increasing the system speed are in progress.

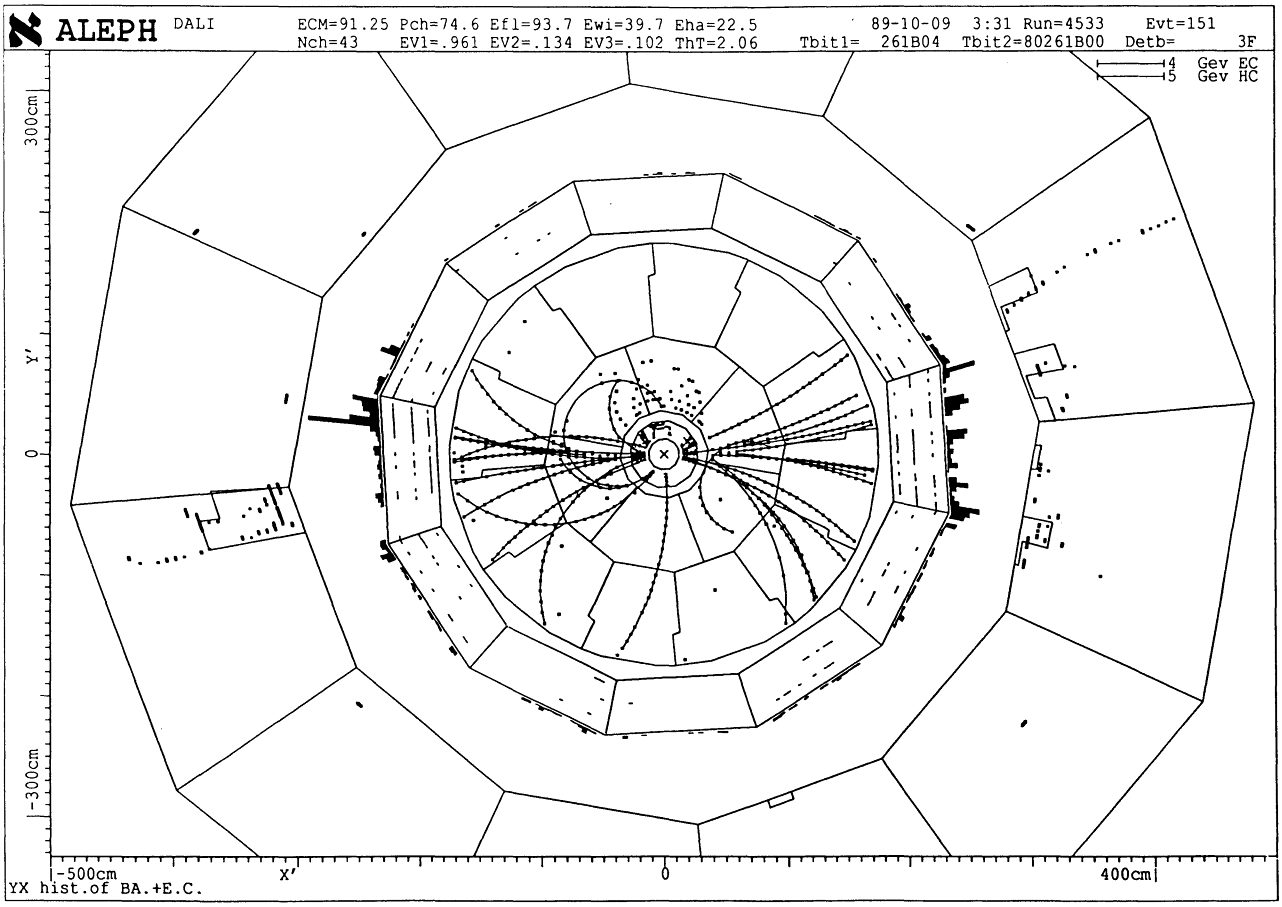



*Fig. ALEPH–1*
*Hadronic decay of a Z seen in the ALEPH detector.*

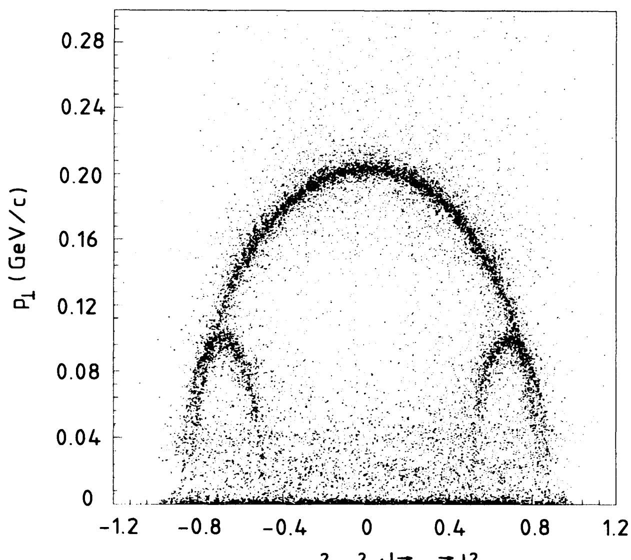



*Fig. ALEPH–2*
*'Thompson' plot : scatterplot of $p_T$ vs. $(p_1^2 - p_2^2) / |\vec{p}_1 + \vec{p}_2|^2$ for neutral $V^0$ decays. This plot illustrates the performance of the tracking in the ALEPH detector.*

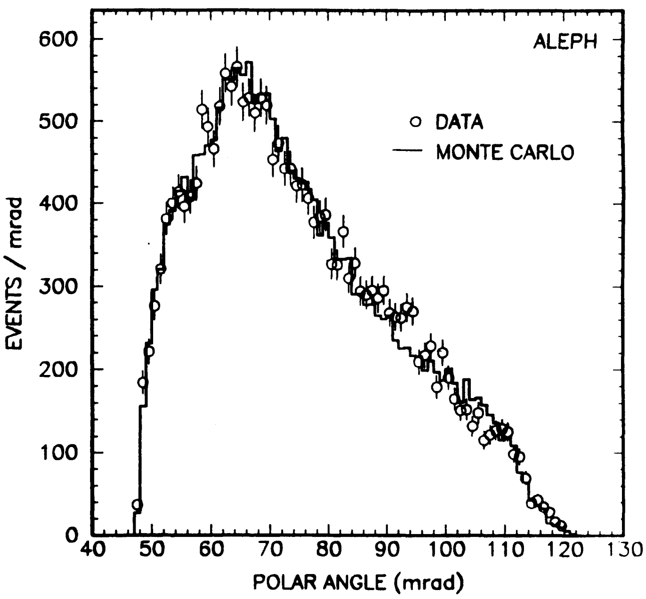



*Fig. ALEPH–3*
*Comparison of data and simulation for the azimuthal dependence of luminosity events (ALEPH).*

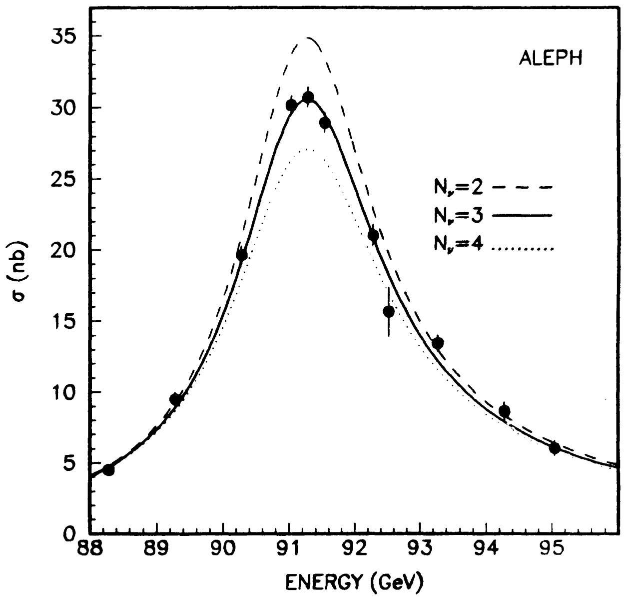



*Fig. ALEPH–4*
*Cross-sections for hadronic decay as function of LEP energy. The solid curve is the theoretical expectation for three neutrino families, with the mass of the Z as only free parameter (ALEPH).*

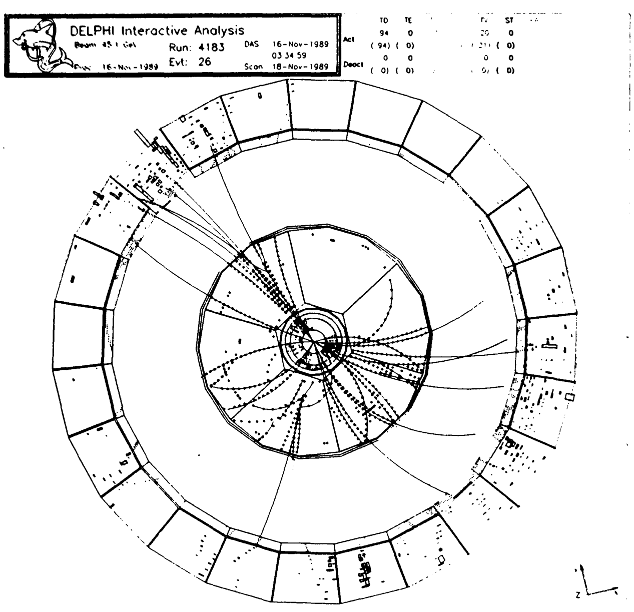



*Fig. DELPHI–1*
*Hadronic Z decay as seen by the DELPHI detector.*

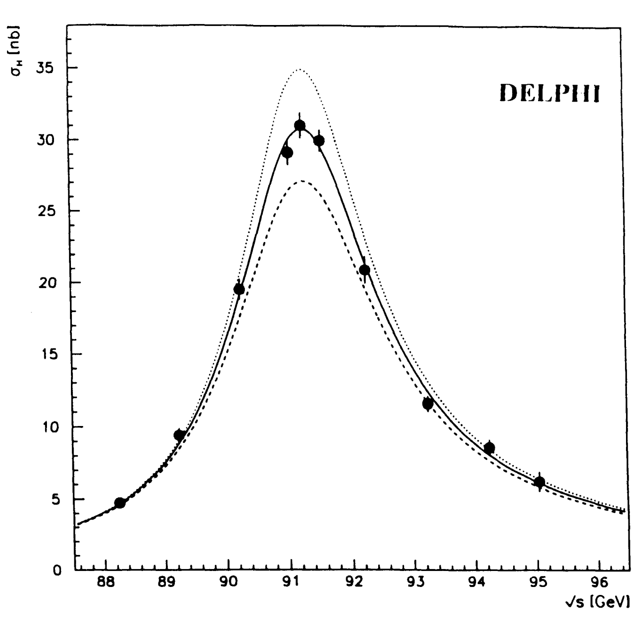



*Fig. DELPHI–2*
*Line shape of the Z measured by DELPHI from hadronic decays.*

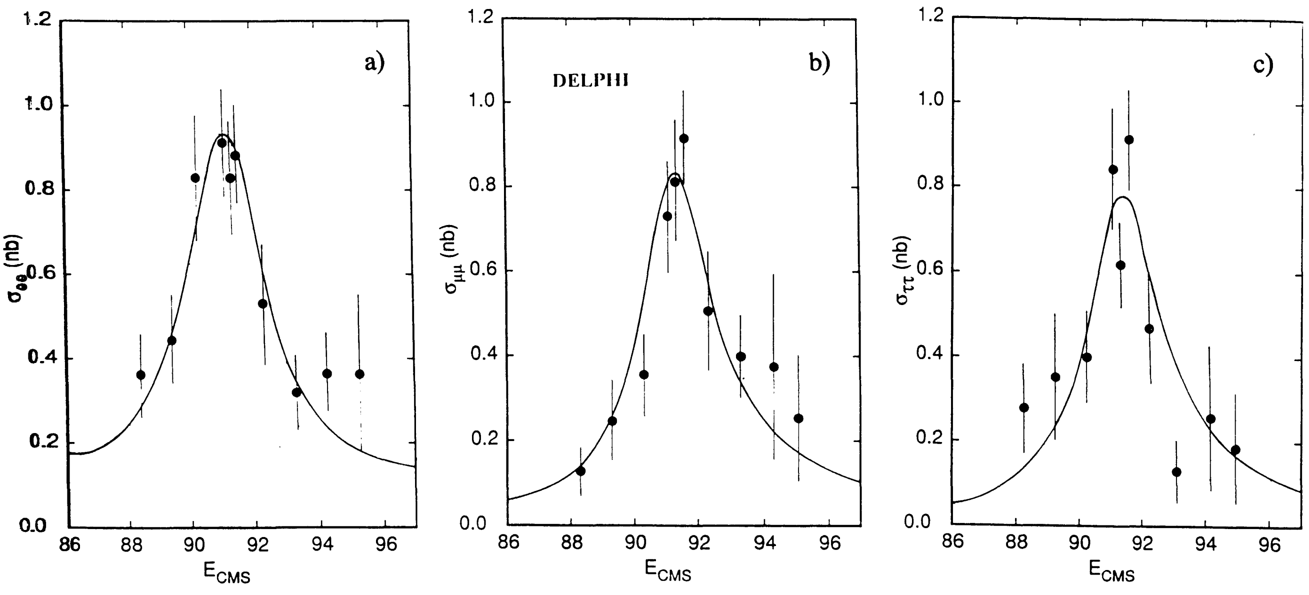



*Fig. DELPHI–3*
*Line shape of the Z measured by DELPHI for the three leptonic decay modes : (a) electron decays; (b) muon decays; (c) tau decays.*

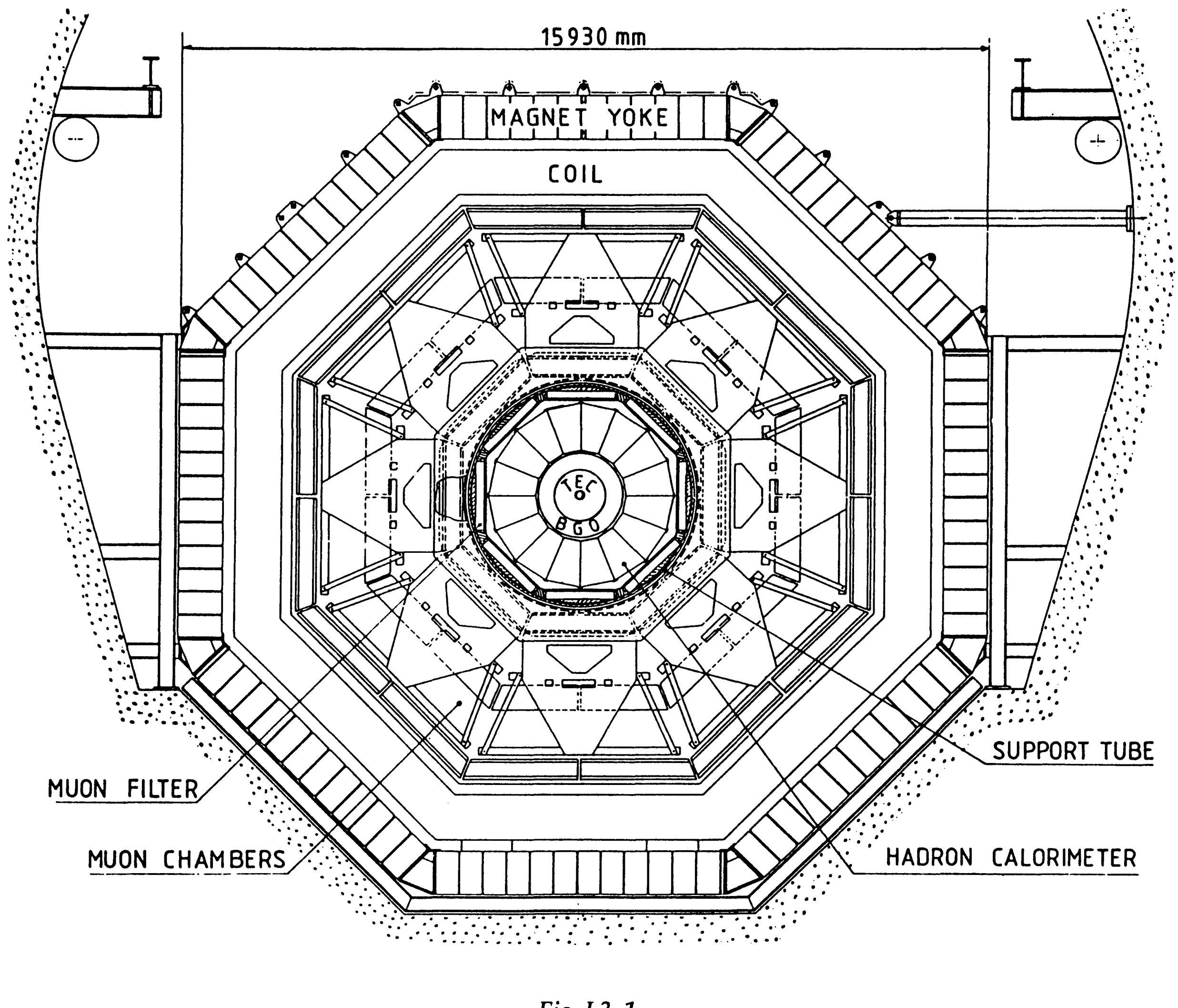



*Fig. L3–1*
*Transverse view of the L3 detector.*

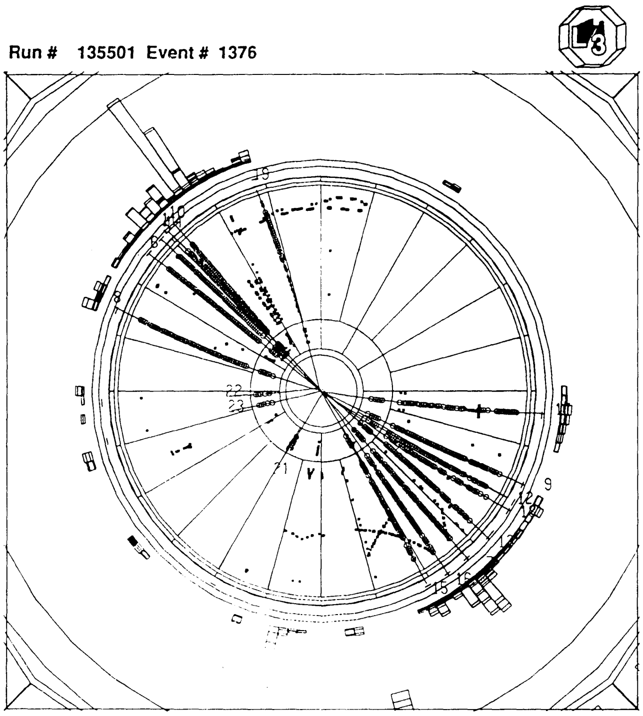



*Fig. L3–2*
*Display of an event $e^+e^- \rightarrow$ 2 jets + $\mu$ seen by the L3 detector.*

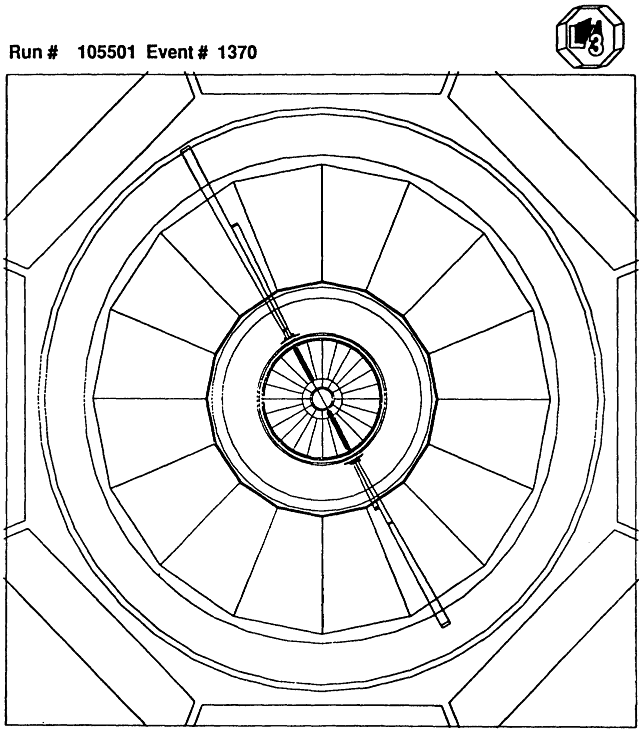



*Fig. L3–3*
*Leptonic Z decay Z $\rightarrow e^+e^-$ seen by the L3 detector.*

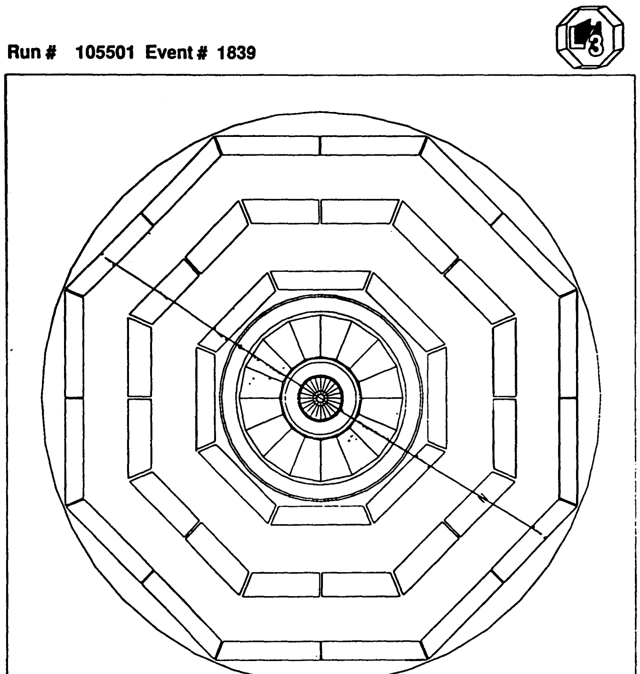



*Fig. L3–4*
*Leptonic Z decay $\rightarrow \mu^+\mu^-$ seen by the L3 detector.*

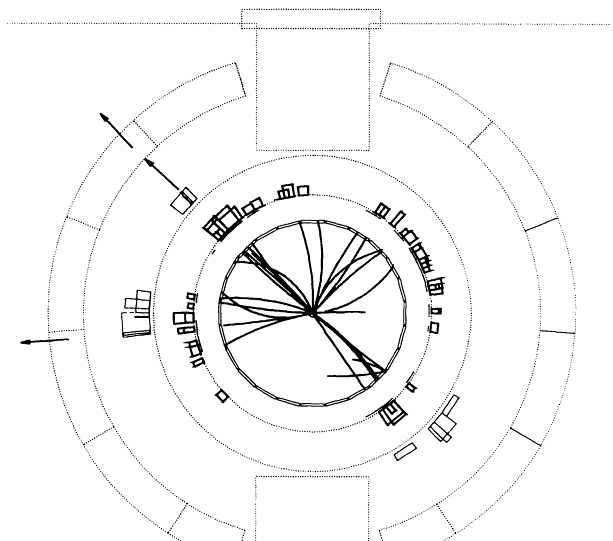


*Fig. OPAL–1*
*Typical multihadron Z decay seen by the OPAL detector.*

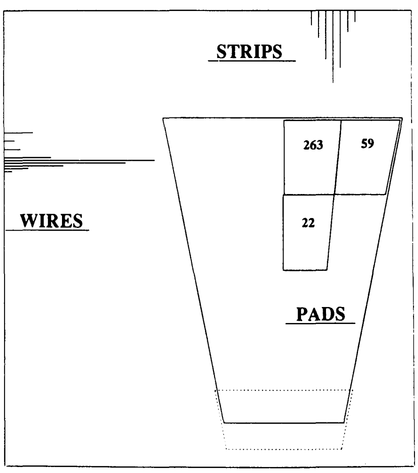



*Fig. OPAL–2*
*The response of an end cap presampler sector to a 45 GeV electron (OPAL).*

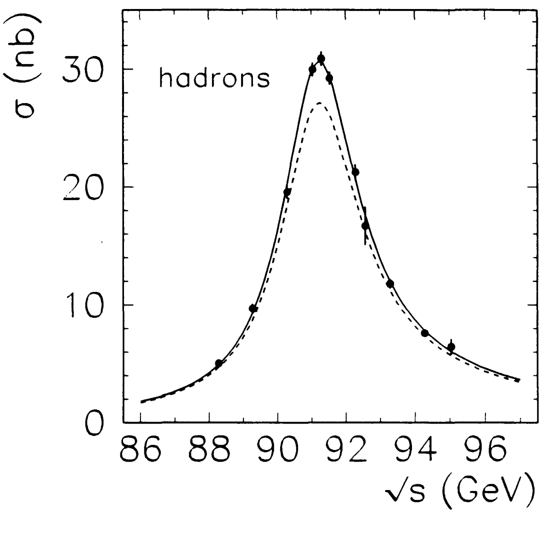



*Fig. OPAL–3*
*Multihadron cross-section vs. centre-of-mass energy measured by OPAL. The solid and dashed curves are Standard Model predictions for 3 and 4 light neutrino generations, respectively.*

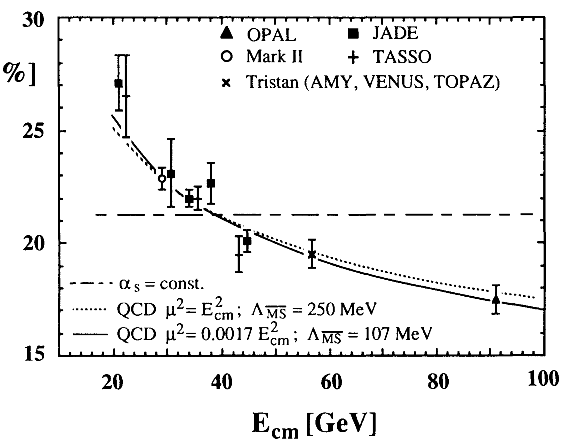



*Fig. OPAL–4*
*Three-jet event production rates. The energy dependence of the measured rates is compared to several different assumptions about the energy dependence of the strong coupling constant $\alpha_s$ (OPAL).*

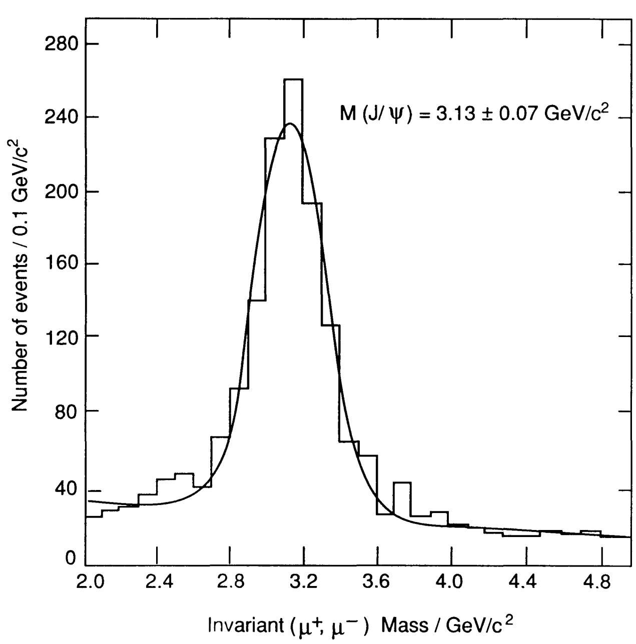



*Fig. UA1–1*
*Invariant mass spectrum of dimuons in the J/ψ mass region, measured by UA1. The solid line shows a fit which is a combination of a Gaussian peak with a linear background.*

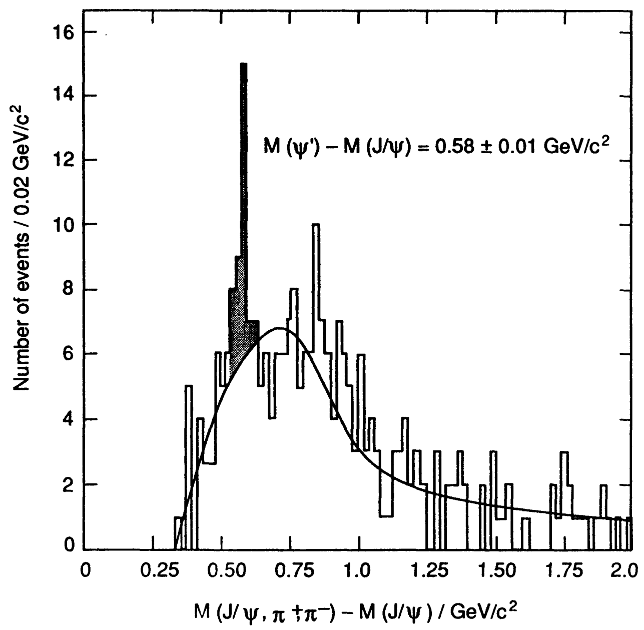



*Fig. UA1–2*
*The invariant mass difference $M(J/\psi\pi^+\pi^-) - M(J/\psi)$ (UA1). The solid line shows a Monte Carlo simulation of the combinatorial background from B decays.*

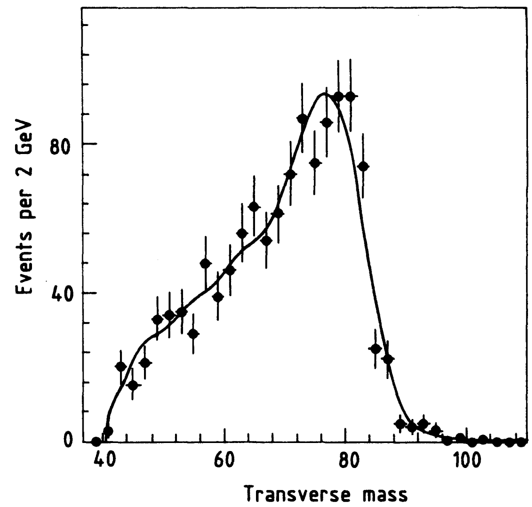



*Fig. UA2–1*
*Transverse mass distribution for e-ν pairs from W decays where the electron is detected in the UA2 central calorimeter. The curve is the best fit to the data.*

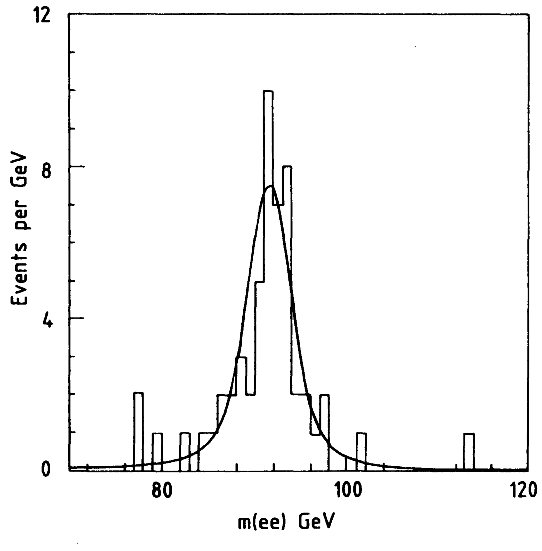



*Fig. UA2–2*
*Invariant mass distribution of a sample of electron pairs for which both electrons are detected in the UA2 central calorimeter. The curve is the best fit to the data.*

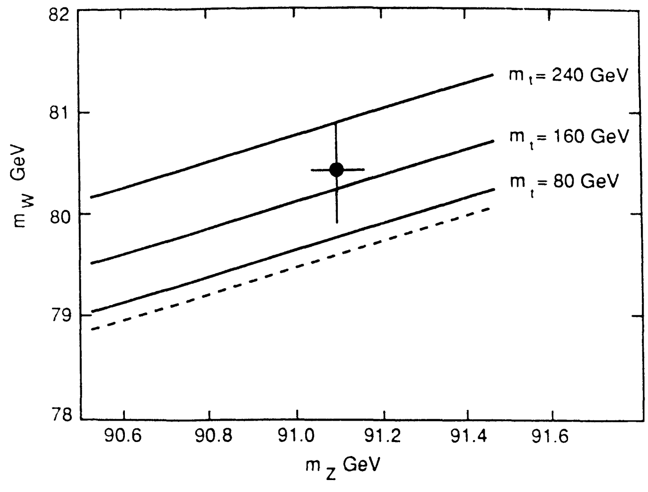



*Fig. UA2–3*
*Comparison between the Standard Model predictions for $m_W$ and $m_Z$ and the experimental values. The solid lines show the allowed values for $m_W$ and $m_Z$ for different masses of the top quark $m_t$, with a Higgs boson mass $m_H$ = 100 GeV. The dotted line shows the prediction for $m_t$ = 80 GeV and $m_H$ = 1000 GeV.*

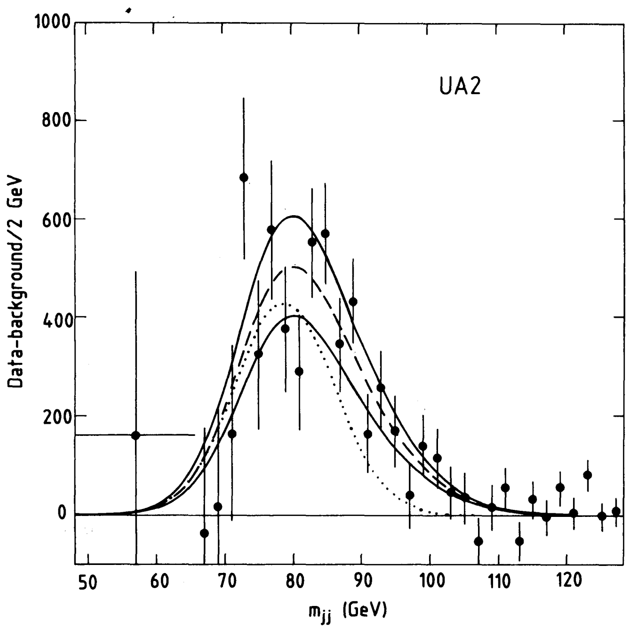



*Fig. UA2–4*
*Background-subtracted signal in the mass spectrum of 2-jet events. The dashed line is the best fit to the data and the two full lines represent the ±1σ bounds. The dotted line is the best fit using only the W contribution.*

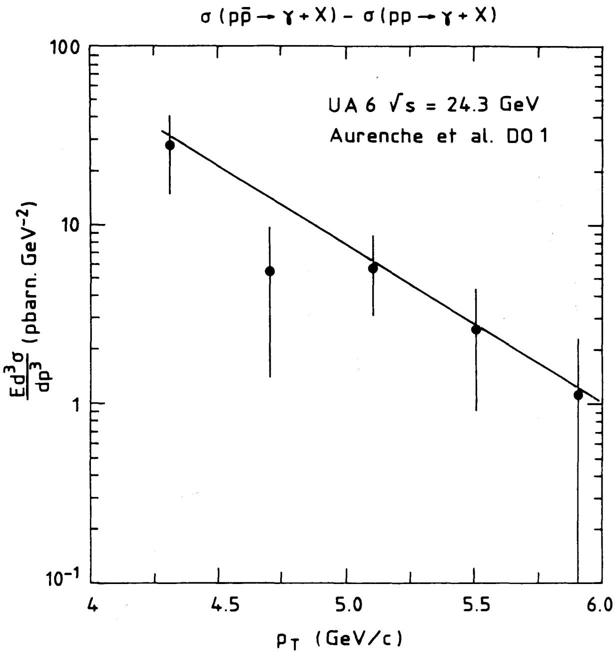



*Fig. UA6–1*
*The cross-section difference*
*$\sigma(p\bar{p} \to \gamma + X) - \sigma(pp \to \gamma + X)$ measured by the UA6 experiment. The solid line is a theoretical prediction by Aurenche et al.*

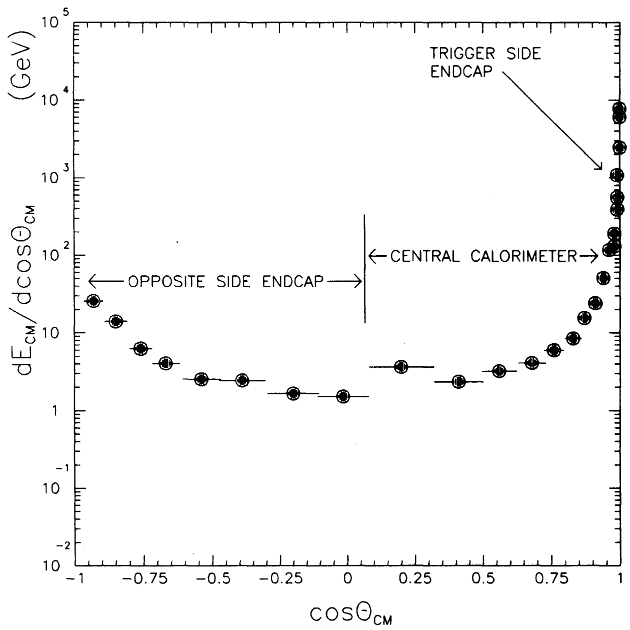



*Fig. UA8–1*
*Energy flow in the diffractive centre of mass measured in the UA8 experiment. The average $dE_{CM}/d\cos(\theta_{CM})$ is shown for events with a diffractive mass of 210 GeV. The trigger particle is near $\cos(\theta_{CM}) = 1$. The first 8 points from the left correspond to the cells of the UA2 end-cap calorimeter opposite the trigger; the middle 10 points are from the central calorimeter and the 8 points on the right are from the end-cap calorimeter on the trigger side.*

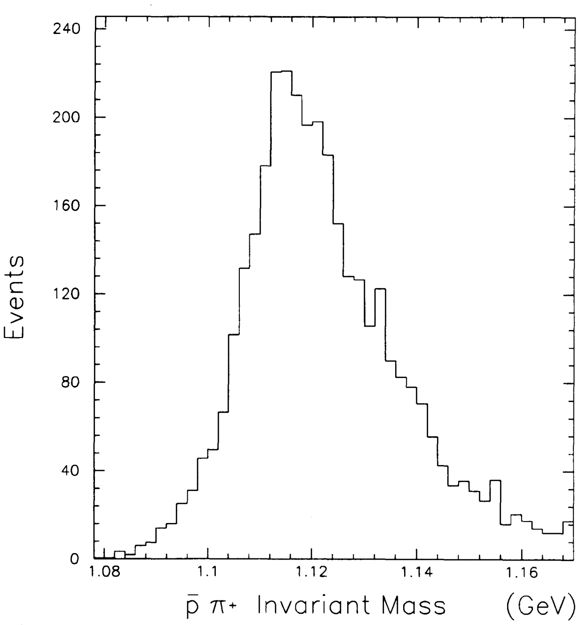



*Fig. UA8–2*
*Preliminary $\bar{\Lambda}$ invariant mass spectrum.*

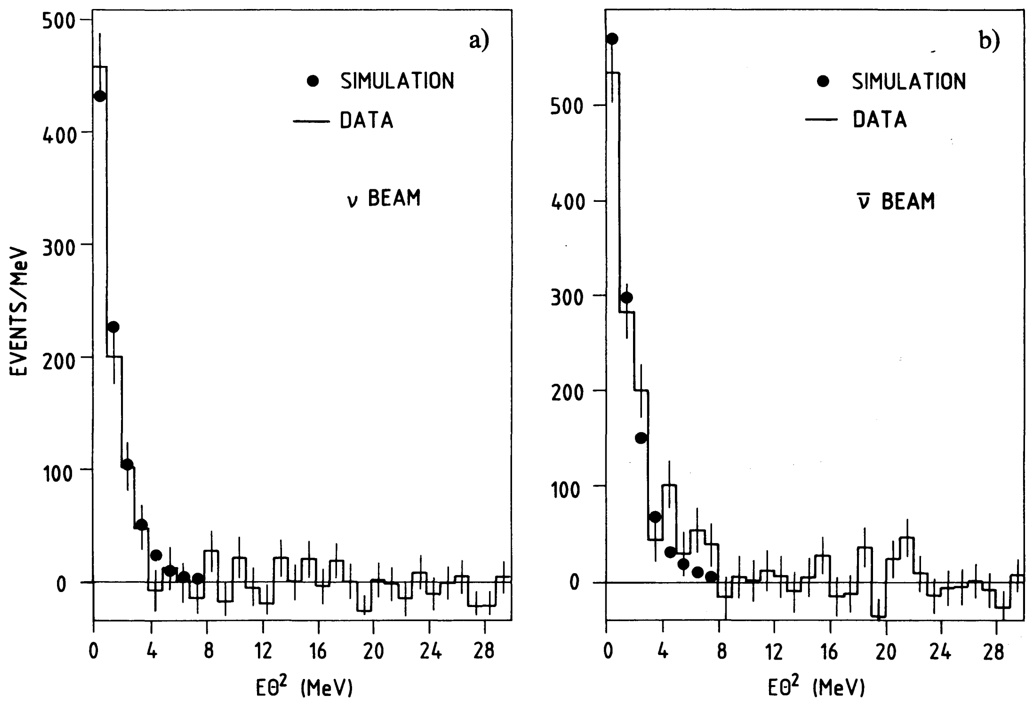



*Fig. WA79–1*
*Distribution of neutrino-electron scattering events observed by the CHARM II Collaboration in 1987 and 1988 as a function of $E\theta^2$, (a) in the neutrino and (b) in the antineutrino beam, after subtraction of the background. The points represent the expected distributions.*

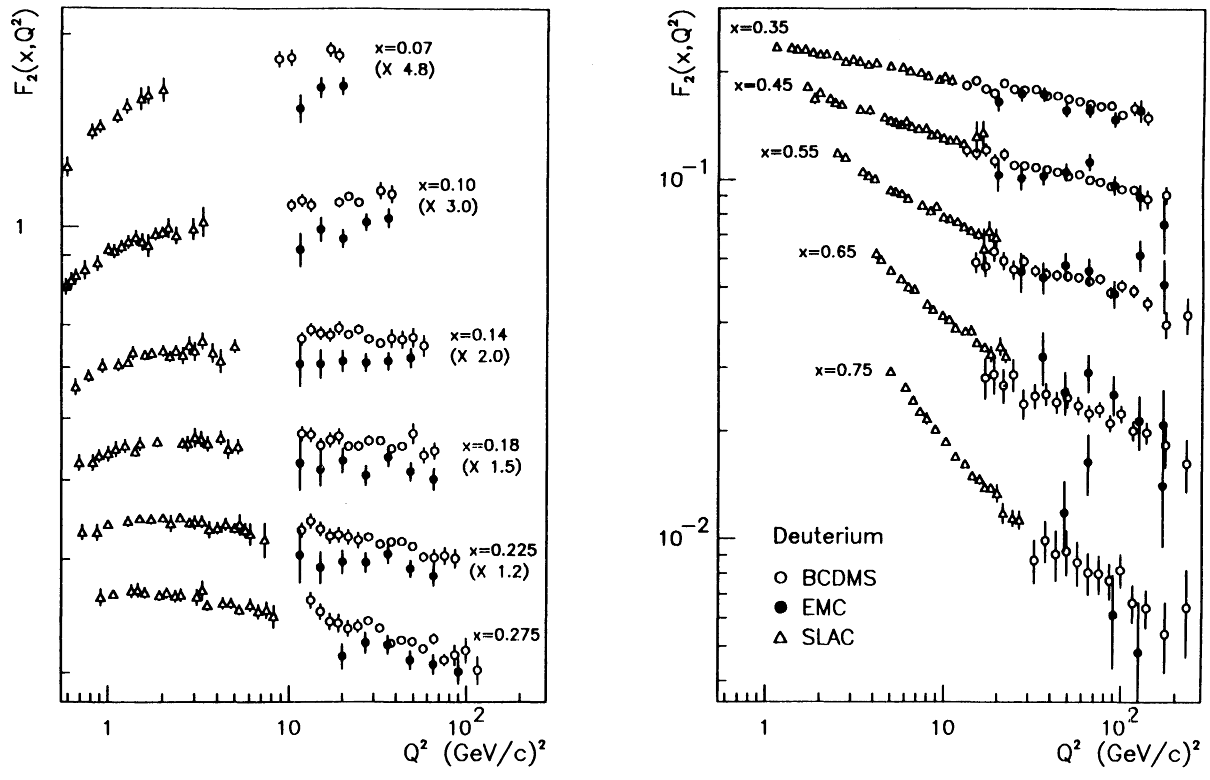



*Fig. NA4–1*
*The nucleon structure function $F_2(x, Q^2)$ measured in the NA4 experiment with a deuterium target. Also shown are earlier electron scattering data from SLAC and data from the EMC experiment.*

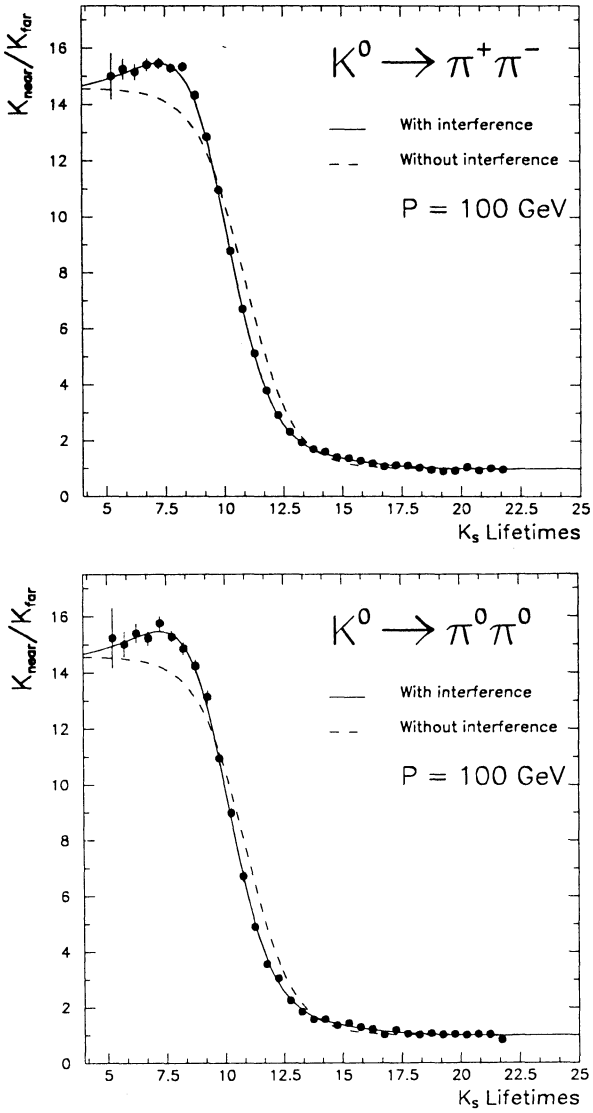



*Fig. NA31–1*
*Ratio distributions of the kaon decay rates into neutral and charged pions for two different target positions, measured by the NA31 experiment. The solid line is the result of a fit with interference between $K_S$ and $K_L$ decays; the dashed line is the expectation without interference.*

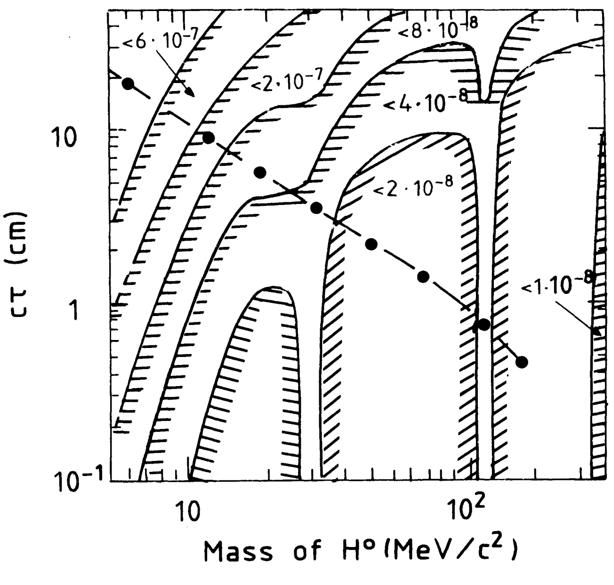



*Fig. NA31–2*
*The 90% confidence limits on the product of the branching ratios $BR(K_L^0 \rightarrow \pi^0 H^0) \times BR(H^0 \rightarrow e^+e^-)$ as a function of the $H^0$ mass interval and lifetime interval. Contour lines of equal limit, as a function of mean lifetime and $m_{ee}$, are shown. Also shown are values for the lifetime as a function of mass for the single neutral Standard Model Higgs particle.*

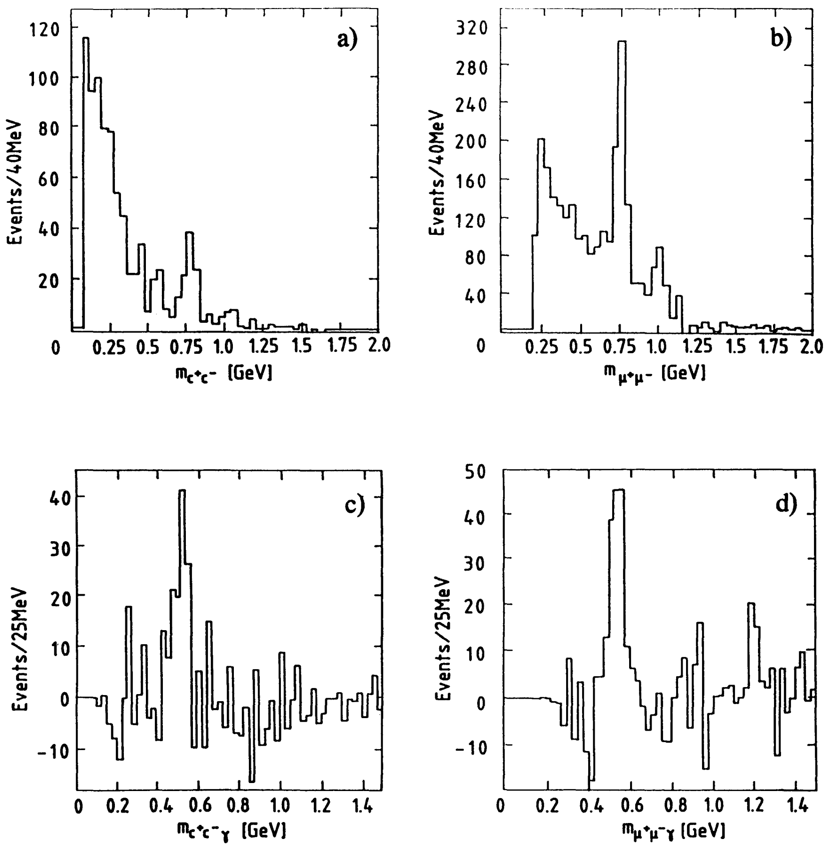



*Fig. NA34–1*

*Invariant mass spectra measured by the NA34 experiment : (a) shows the electron mass spectrum from about one third of the recorded data; (c) shows the mass spectrum of electron pairs and one additional photon, with a 100 MeV mass cut on the pair to exclude pions. There is a prominent peak from the decay of the η meson. Figures (b) and (d) are the corresponding spectra for the subsample of muon pairs with the same angular selection as for the electron pairs, from about one third of the data.*

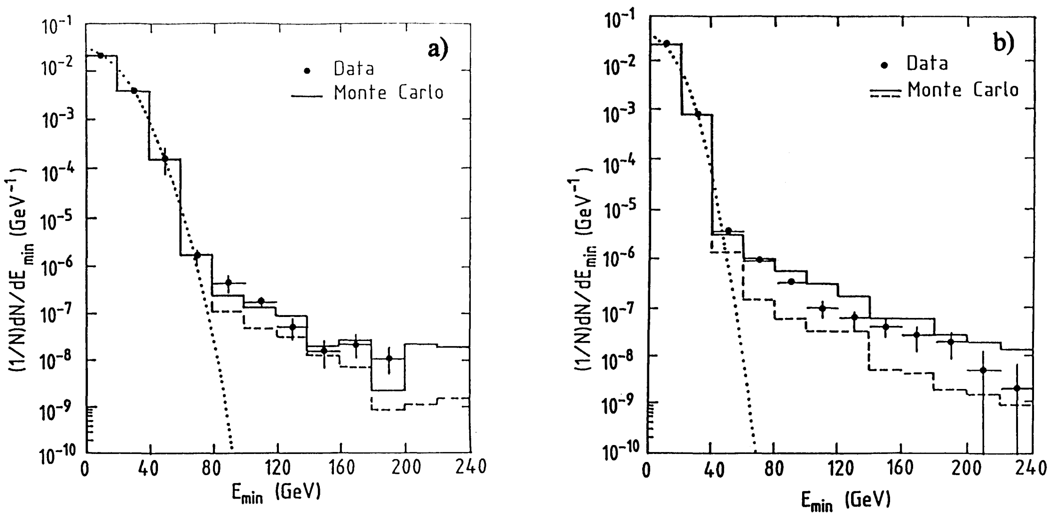



*Fig. NA34–2*

*Missing energy spectra measured by the NA34 experiment : (a) shows the inclusive spectrum of missing energy for 450 GeV protons on a beryllium target. The dotted line shows the distribution for events with no missing energy, due to calorimeter resolution. The dashed line is an extrapolation of the EHS results for proton-proton collisions, added to the resolution curve. The solid line uses the Fermilab beam dump neutrino cross-sections instead. (b) is the same as (a) but for a uranium target in a different 'beam dump' configuration.*

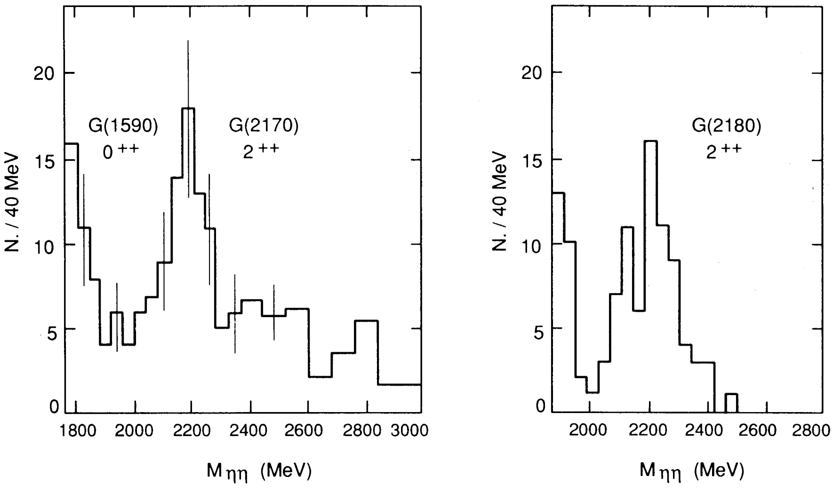



*Fig. NA12/2–1*
*Central production of a tensor meson decaying into ηη, measured in the GAMS experiment. Left : measurement with a 300 GeV π⁻ beam; right : with 450 GeV protons.*

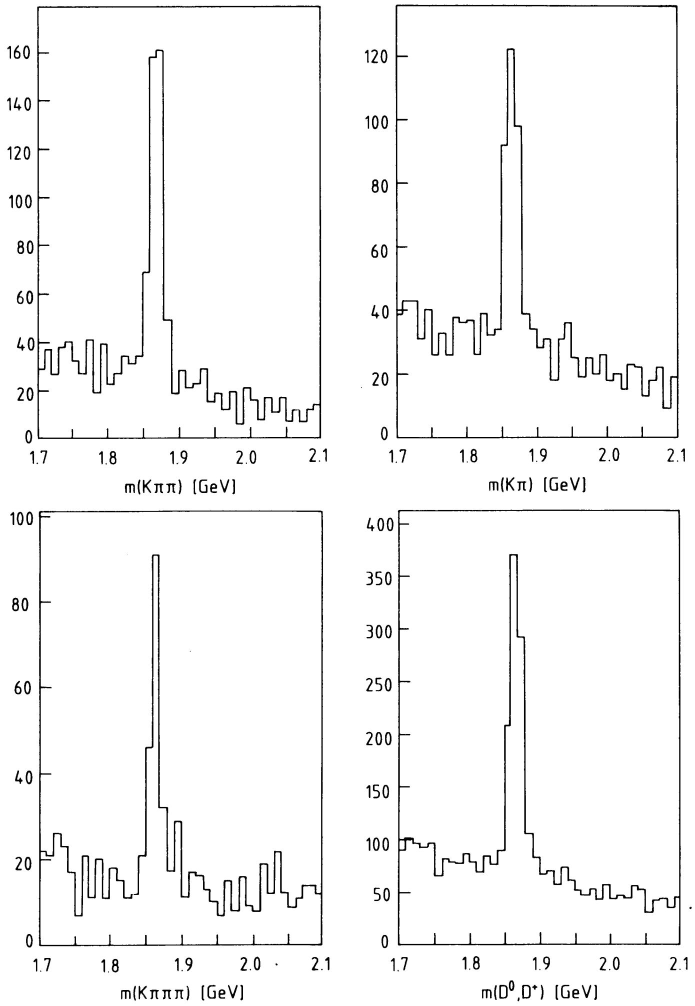



*Fig. WA82–1*
*Invariant mass spectra of D meson decays measured in the WA82 experiment.*

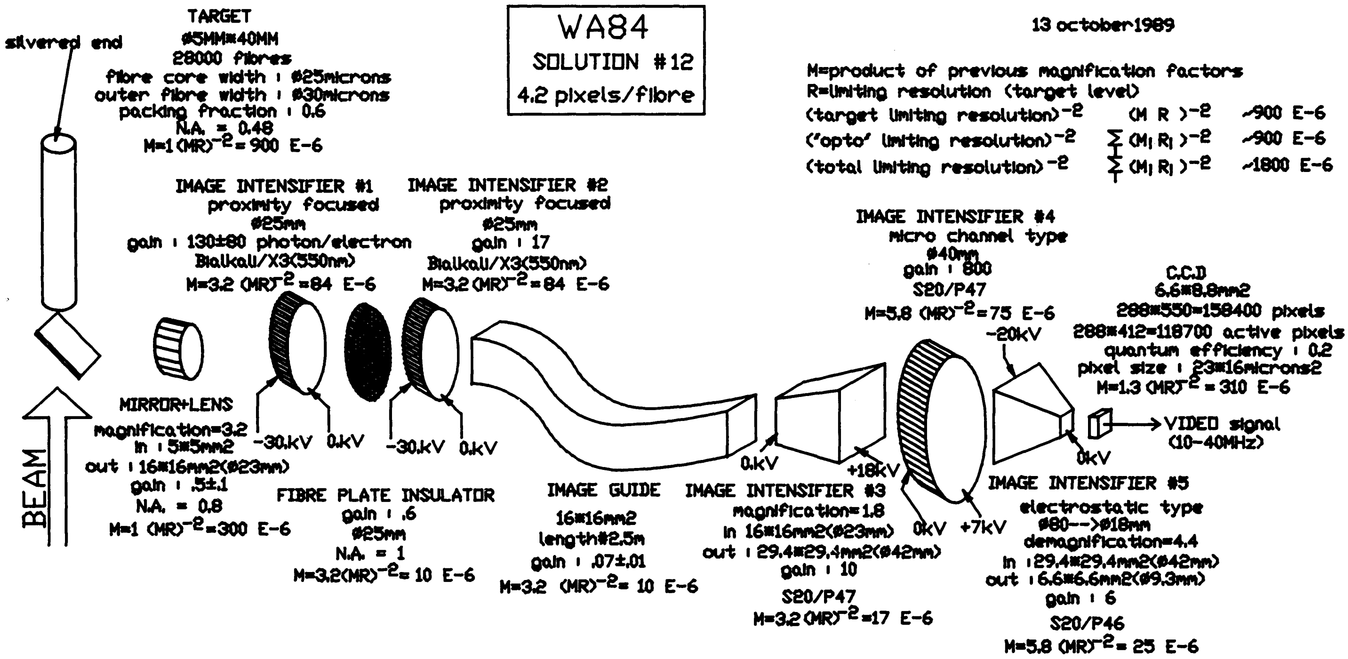



*Fig. WA84–1*
*Fibre target and opto-electronic read-out chain of the WA84 apparatus.*

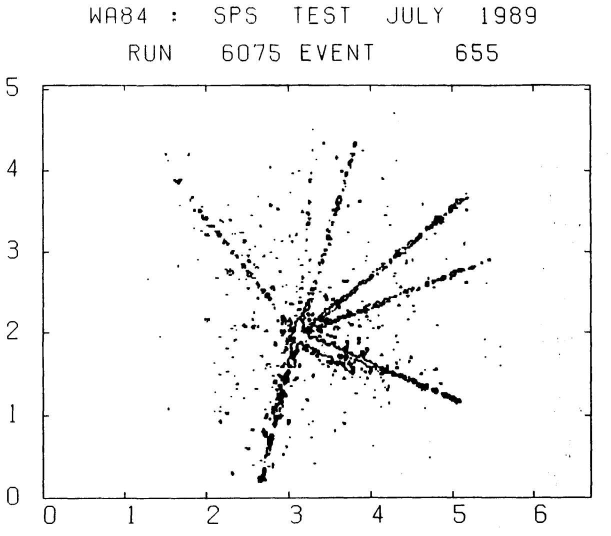



*Fig. WA84–2*
*Example of an interaction in the WA84 scintillating fibre target. The 5 × 5 × 50 mm³ target is viewed transversely such that the beam enters perpendicular to the page.*

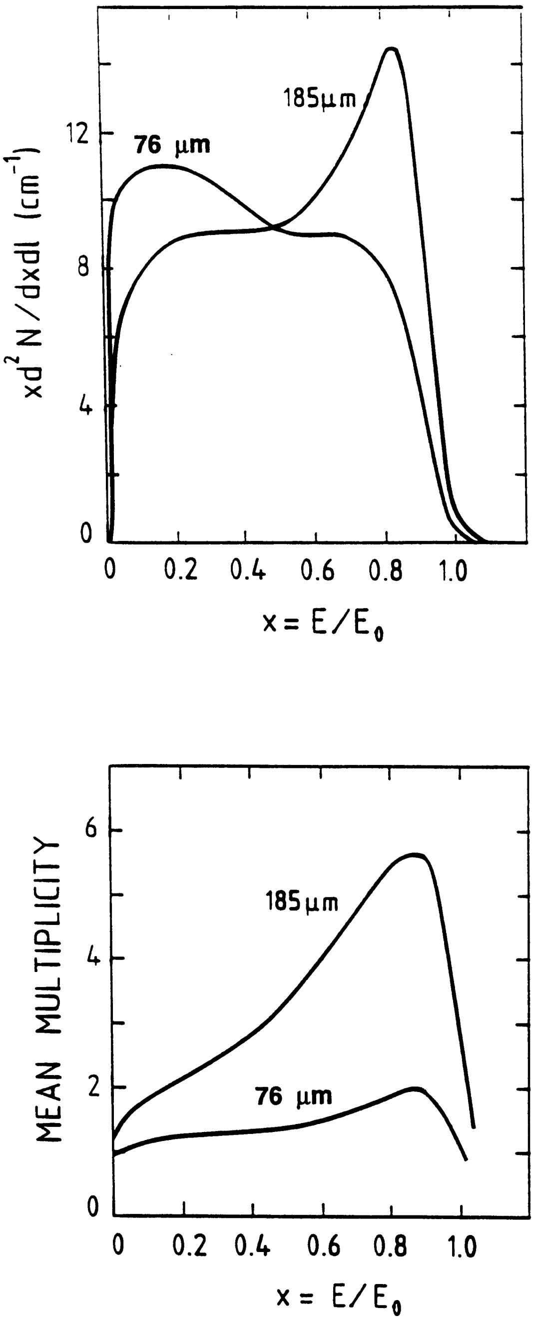



*Fig. NA42–1*
***Photon interactions in aligned crystals, measured in the NA33 and NA42 experiments. Top : radiative energy spectra for 150 GeV electrons incident at exact alignment with the <110> axis of Ge crystals of 185 and 76 µm thickness, cooled to 100 K; bottom : mean photon multiplicity.***

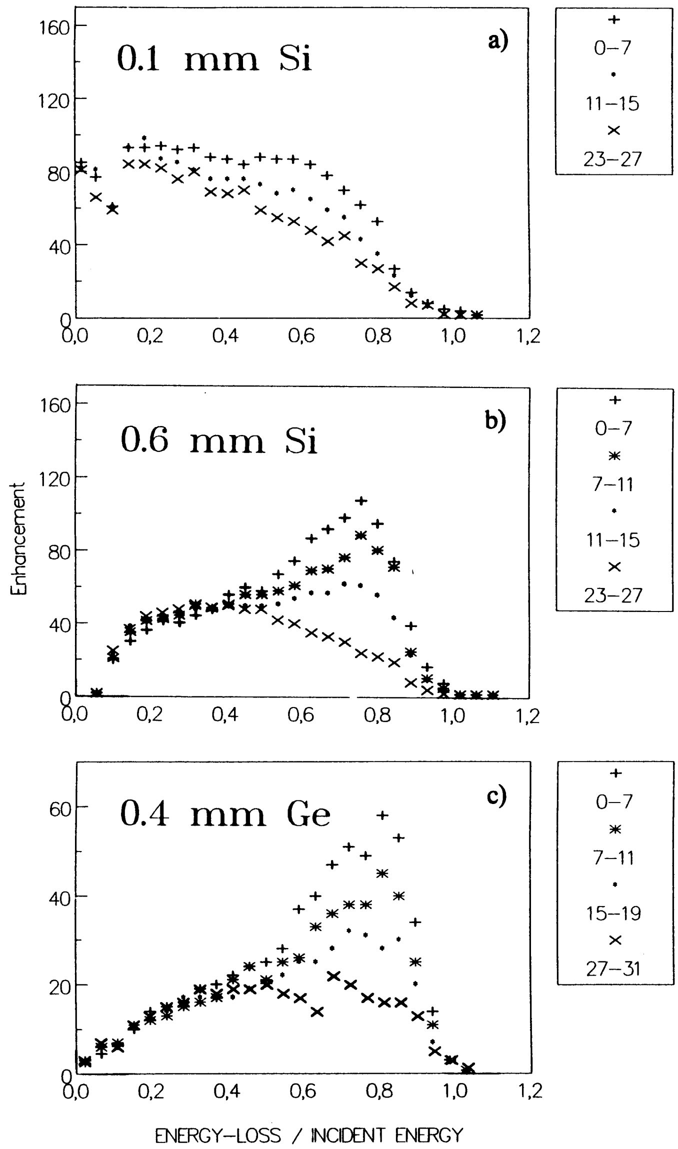



*Fig. NA43–1*
***Photon spectra obtained from a 150 GeV electron beam interacting in Si and Ge crystals of different thickness. The different symbols correspond to different incident angles of the beam.***

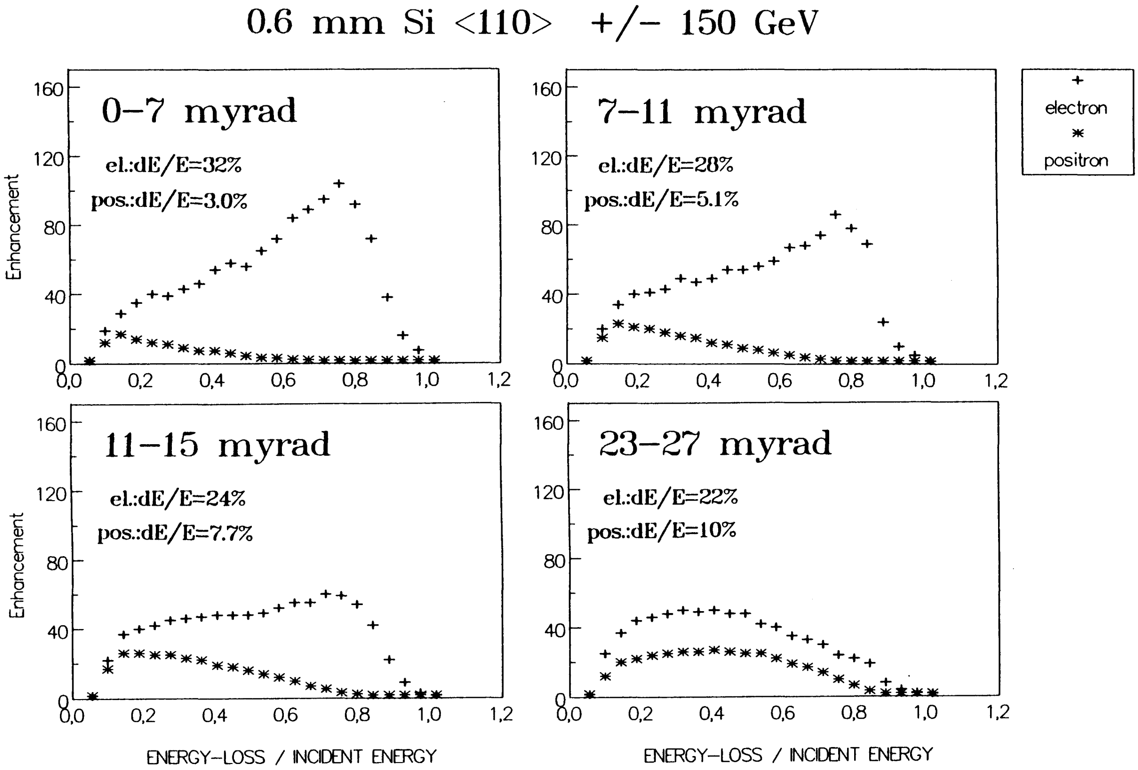



*Fig. NA43–2*
***Radiation spectra from 150 GeV electron and positron beams interacting in a 0.6 mm Si crystal, for different incident angles.***

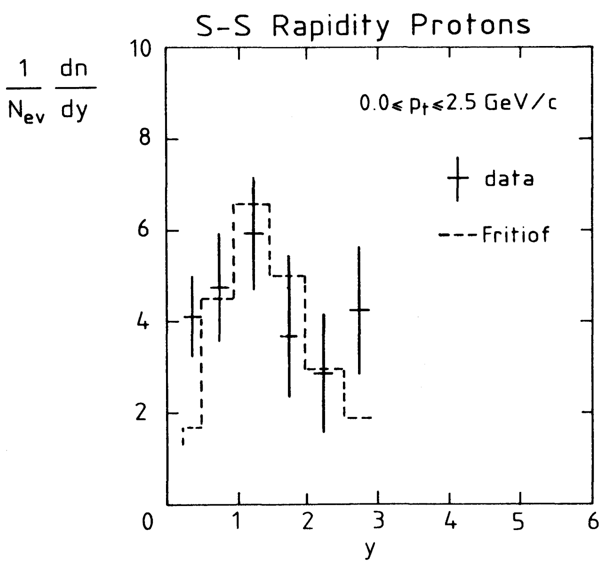



*Fig. NA35–1*
***Rapidity distribution of protons in sulphur-sulphur collisions at 200 GeV/nucleon, measured in the NA35 experiment. The dashed line is a prediction by the FRITIOF Monte Carlo program.***

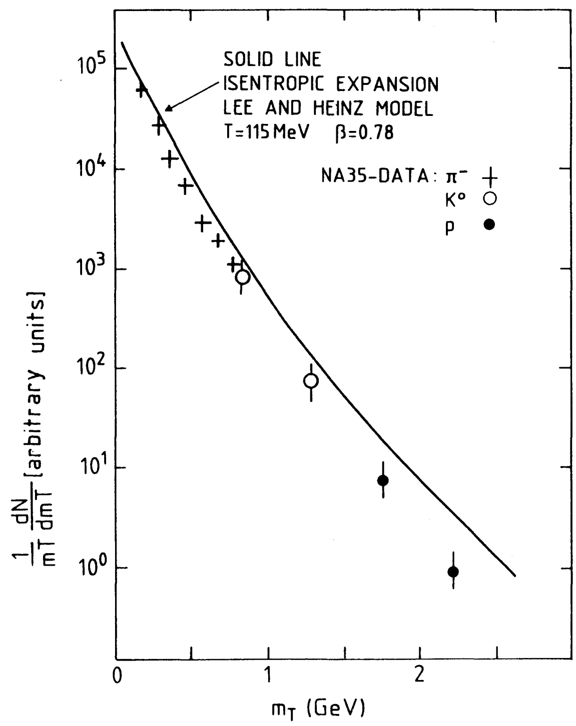



*Fig. NA35–2*
***Transverse mass distribution in sulphur-sulphur collisions at 200 GeV/nucleon.***

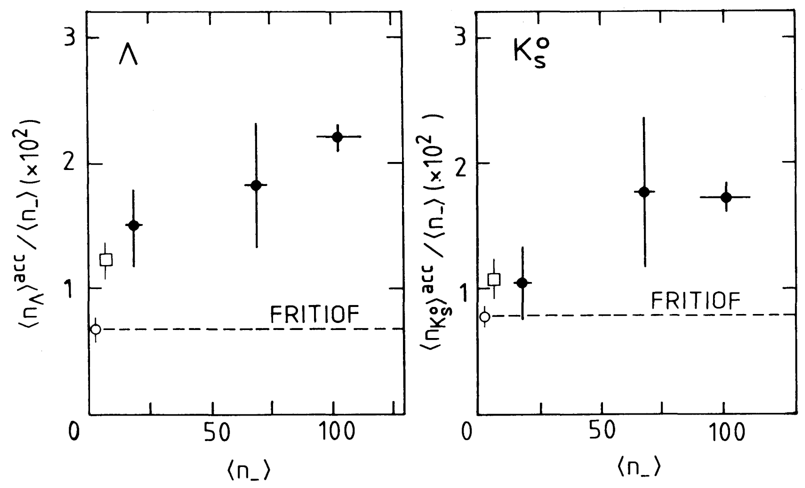



*Fig. NA35–3*
*Strangeness production measured in the NA35 experiment. The ratios of the average $\Lambda$ and $K^0$ multiplicities to the average negative hadron multiplicities per event are shown for sulphur-sulphur collisions at 200 GeV/nucleon (full circles). The open circles are proton-proton data and the dashed line is a prediction of the FRITIOF Monte Carlo.*

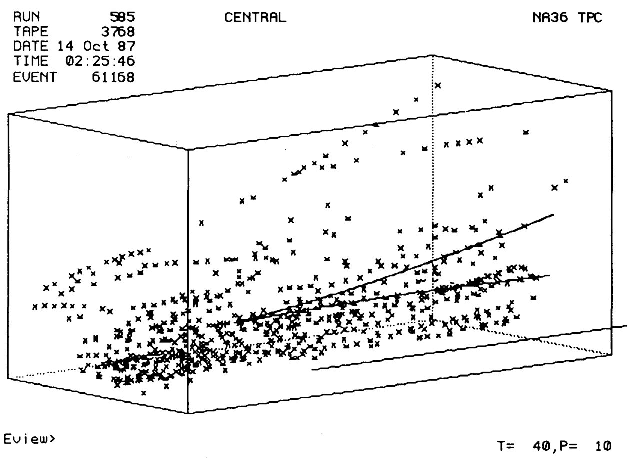



*Fig. NA36–1*
*Three-dimensional view of charged tracks from sulphur-sulphur collisions measured in the Time Projection Chamber (TPC) of the NA36 experiment.*

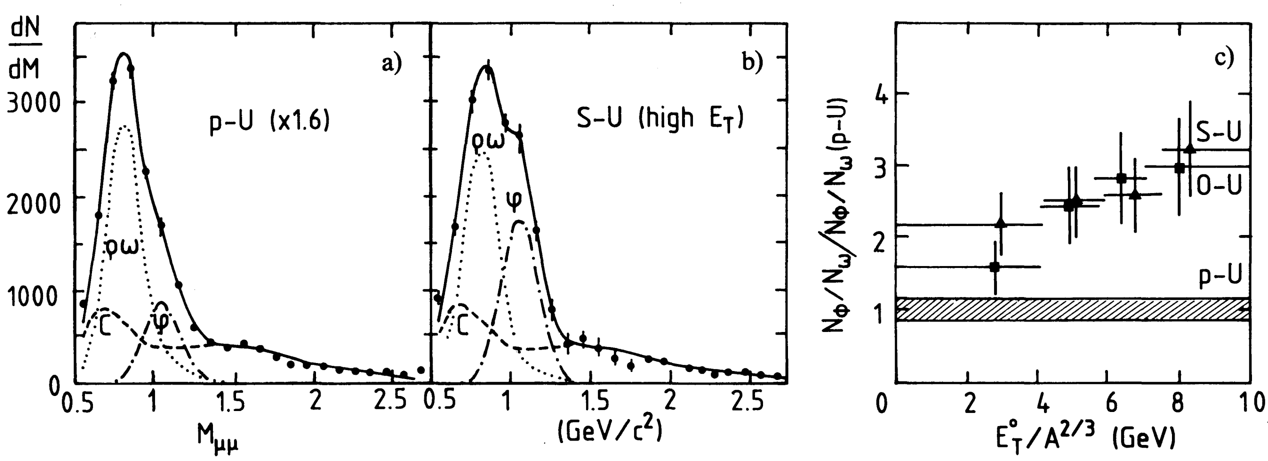



*Fig. NA38–1*
*(a) The dimuon mass distribution in the low mass region for p-U reactions, meassured in the NA38 experiment. The fit shown by a solid line is a superposition of a parametrized continuum, $\rho + \omega$, and $\phi$ distributions, with the $\rho$ to $\omega$ ratio being fixed to 1 :1; (b) the same for high $E_T$ S-U reactions, with a much more prominent $\phi$ signal than in (a); (c) the $\phi$ to $\omega$ ratio as a function of $E_T / A^{2/3}_{beam}$ for O–U and S–U interactions, normalized to the same ratio as found for p–U reactions.*

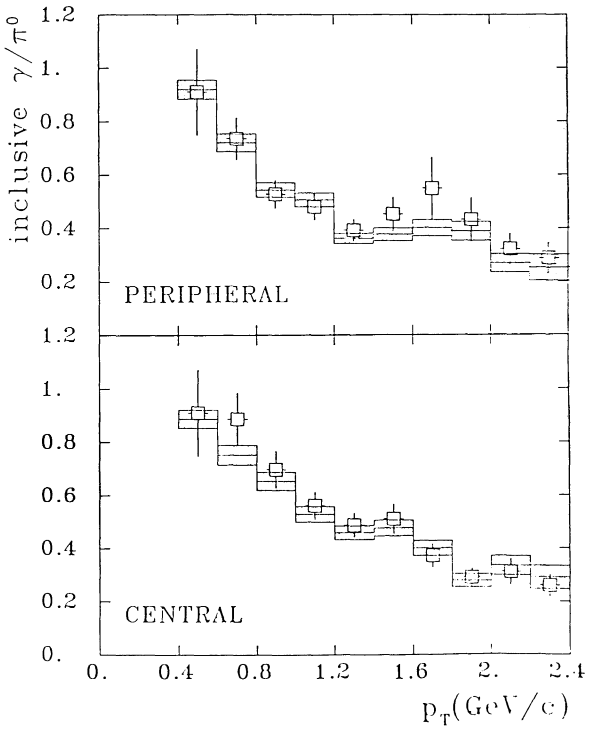



*Fig. WA80–1*
*$\gamma/\pi^0$ ratio for central and peripheral 200 A · GeV O+Au reactions as a function of transverse momentum. The histogram shows the Monte Carlo Simulation whereas the data are represented by the open squares.*

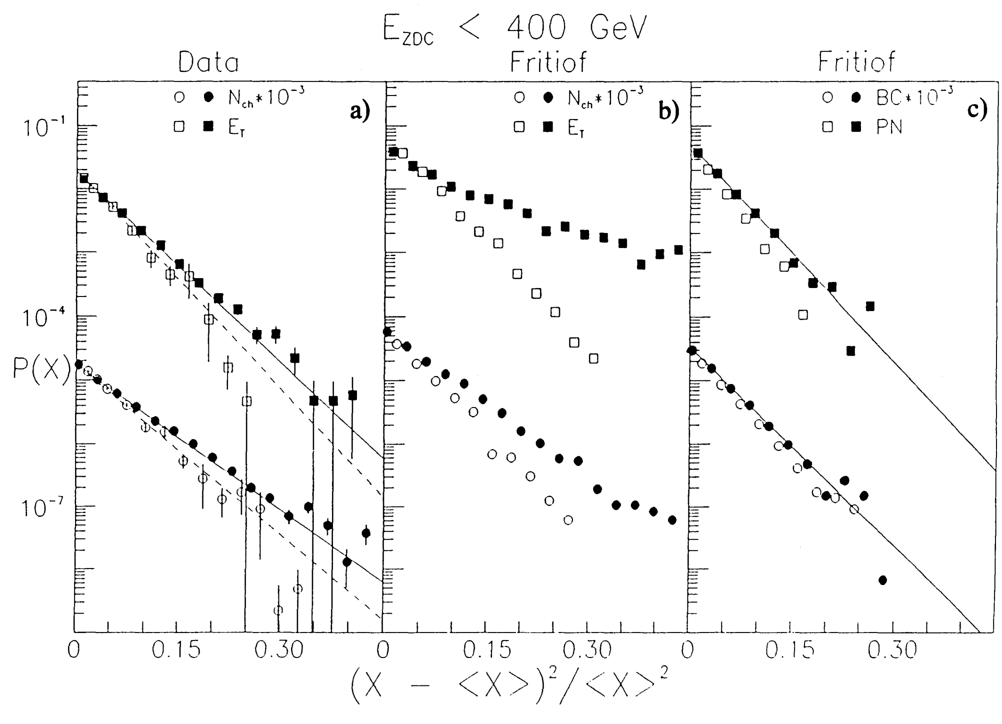



*Fig. WA80–2*
*Gaussian representations of (a) experimental $n_{ch}$ and $E_T$ distributions, (b) $n_{ch}$ and $E_T$ distributions from the FRITIOF sample and (c) the source distributions (participants and binary collisions). The best line fits to the points are indicated in (a) for the region $(X-<X>)^2/<X>^2 < 0.4$ for both tails, and in c) for the region $(X-<X>)^2/<X>^2 < 0.16$ but only for the tail extending to higher values. Filled symbols always indicate the tails reaching higher values, whereas the open symbols represent the low value tails.*

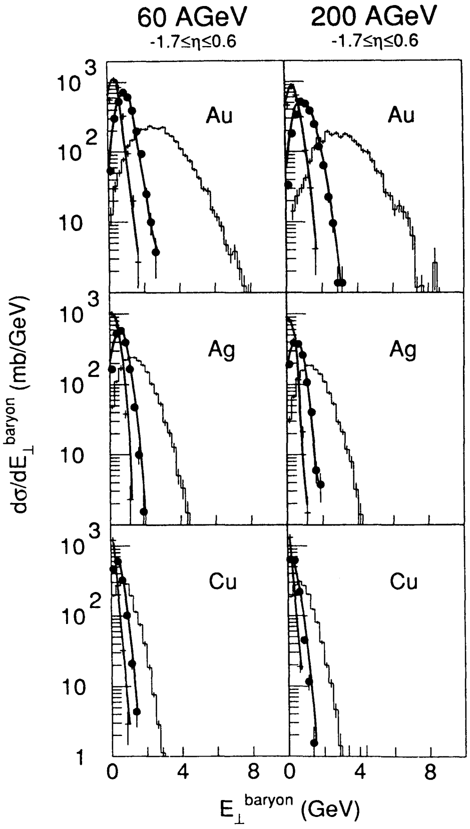



*Fig. WA80–3*
*Transverse energy spectra of baryons in the rapidity range $-1.7 \leq \eta \leq 0.6$. The histogram represents the measured data while the circles and crosses show calculations within Ranft's MCFM assuming formation zone parameters $\tau_{zero}$ of 5 and 10 fm/c. The solid lines are only meant to guide the eye.*

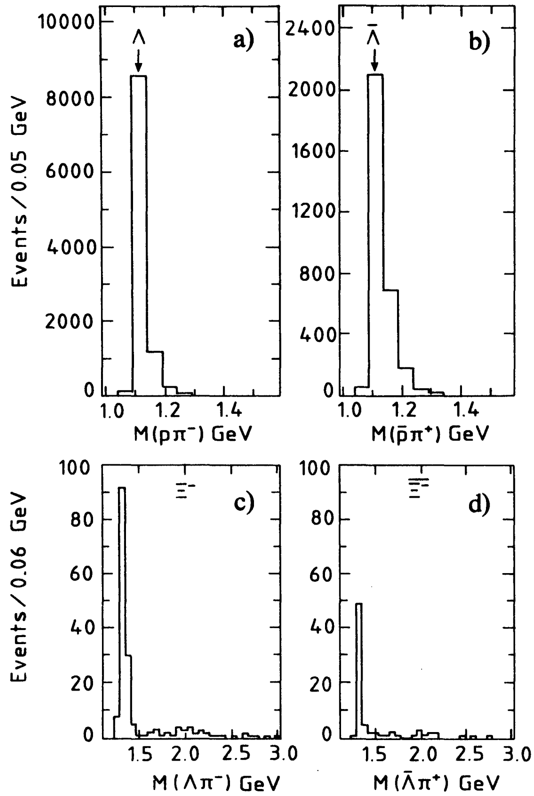



*Fig. WA85–1*
*Effective mass distributions for $V^0$ candidates measured in the WA85 experiment, assuming the two decay tracks to be (a) p and $\pi^-$, (b) $\bar{p}$ and $\pi^+$. Effective mass distribution for the cascade candidates are shown assuming the decay to proceed via (c) $\Lambda$ and $\pi^-$, (d) $\bar{\Lambda}$ and $\pi^+$. Clean $\Lambda$ (a), $\bar{\Lambda}$ (b), $\Xi^-$ (c) and $\bar{\Xi}^-$ (d) signals are visible at the expected mass values.*

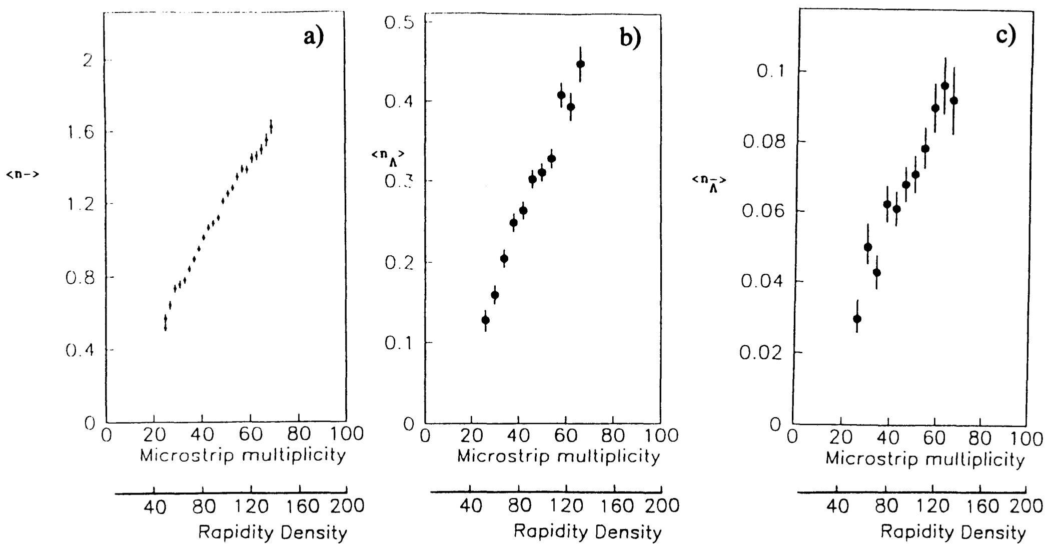



*Fig. WA85–2*
*Average number of negative particles (a), Λs (b) and $\bar{\Lambda}$ (c), produced at $p_T > 1$ GeV and laboratory rapidities $2.2 < Y_{lab} < 3$, as a function of the multiplicity measured by the microstrips. The lower horizontal scale shows the average rapidity density evaluated in the interval $2.2 < Y_{lab} < 3$ which corresponds to the measured multiplicity.*

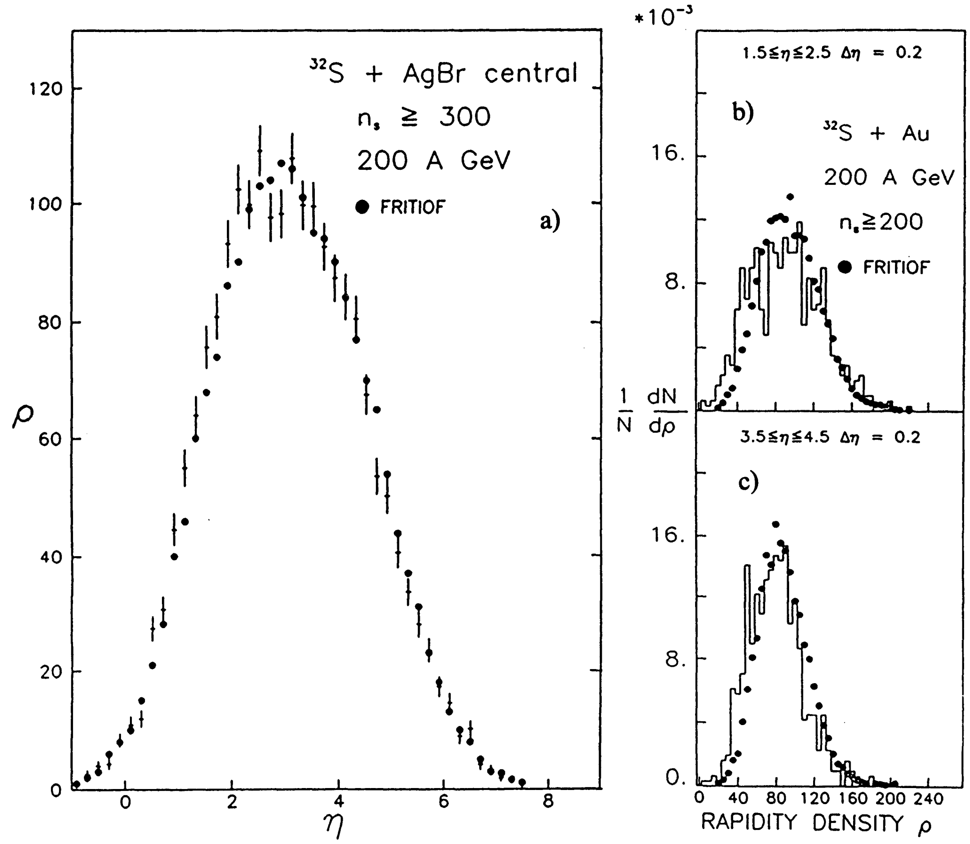



*Fig. EMU01–1*
*(a) Pseudo-rapidity distributions for shower particles in central sulphur-silver (bromine) interactions, measured in the EMU01 experiment. The dots indicate the results from FRITIOF calculations. (b) Particle density distributions in bins of 0.2 rapidity units in central sulphur-gold interactions.*

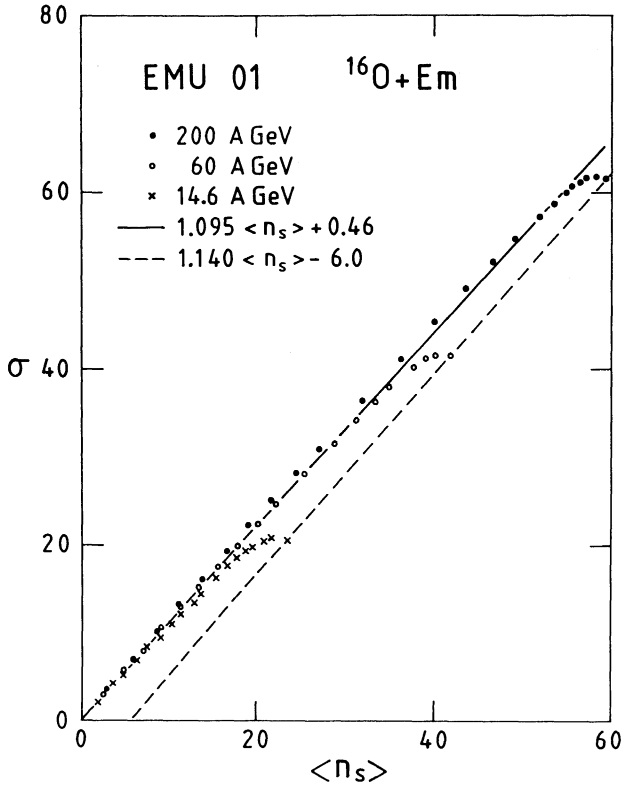



*Fig. EMU01–2*
*Dispersion of multiplicity distributions versus the average multiplicity for increasing rapidity-windows, centered around the nucleon-nucleon center-of-mass system, for oxygen-induced interactions at three different energies.*

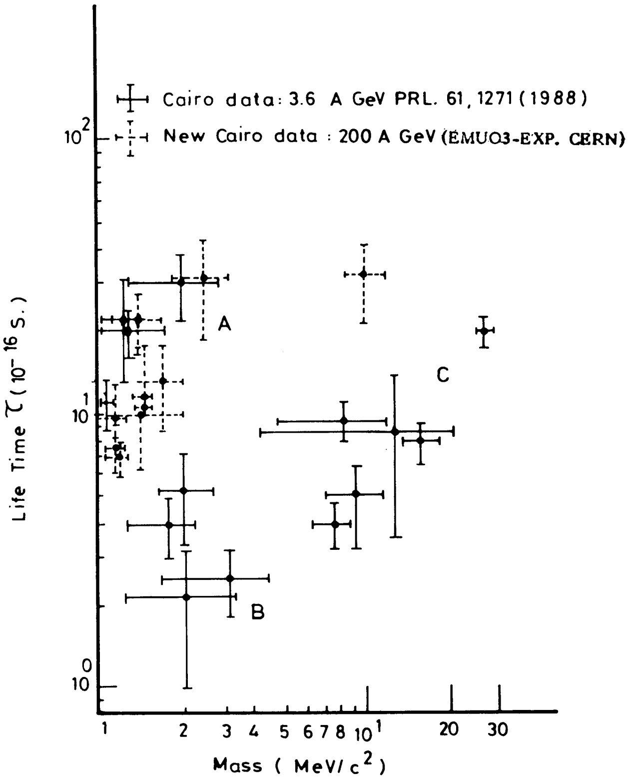



*Fig. EMU03–1*
*Mass-lifetime plot of $e^+e^-$ pairs observed in experiment EMU03.*

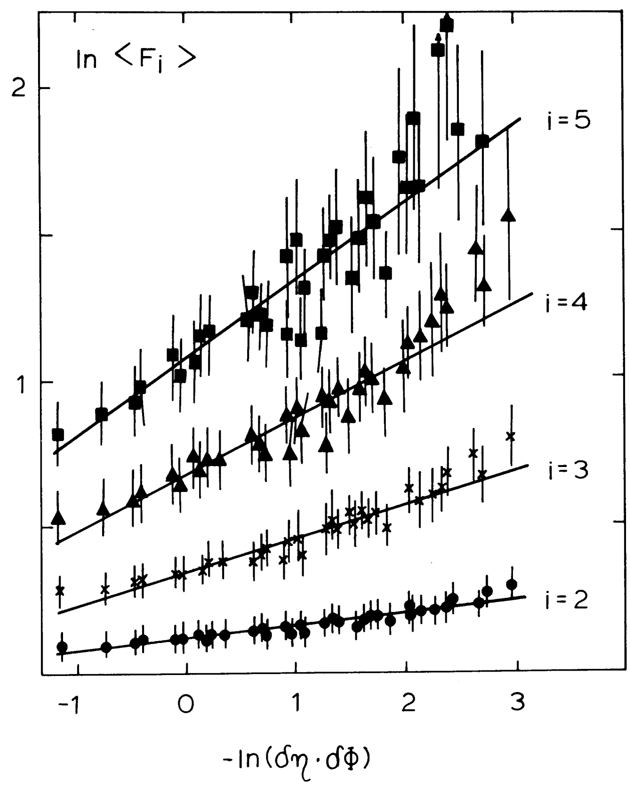



*Fig. EMU07–1*
*Factorial moments obtained from a two-dimensional analysis in pseudorapidity and azimuthal angle as a function of cell size, for oxygen interactions at 200 GeV/nucleon with Ag or Br nuclei in emulsions.*

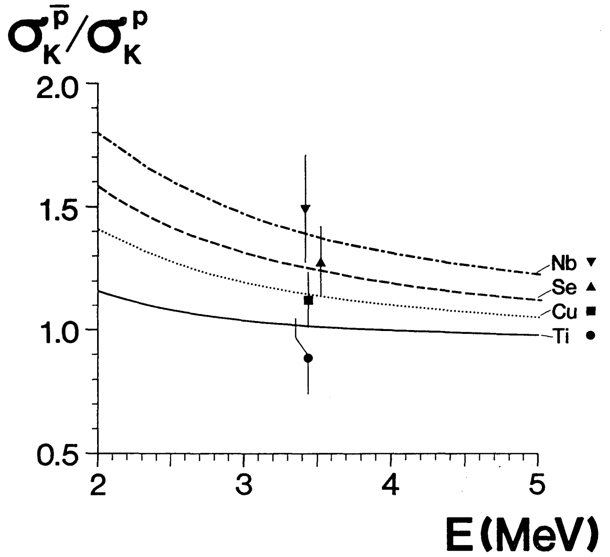



*Fig. PS194/2–1*
*Measured ratio of K-shell ionization cross-section by antiproton and proton impact. Values for Ti, Cu, Se and Nb targets are compared to theoretical calculations.*

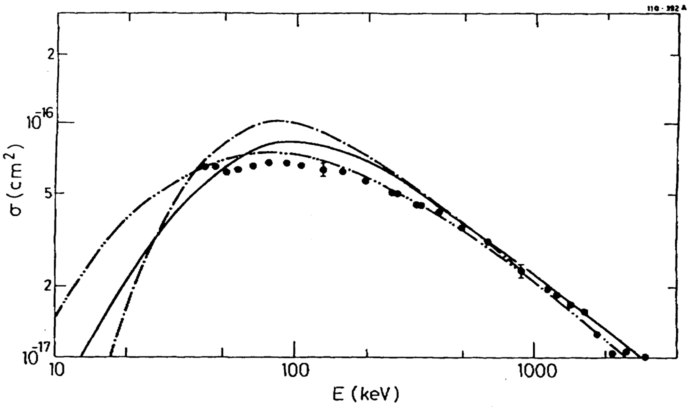



*Fig. PS194/2–2*
*The energy dependence of single ionization of Helium by antiprotons (dots) compared to proton data (solid line). The dashed lines are theoretical calculations, showing particularly good agreement in the antiproton case.*

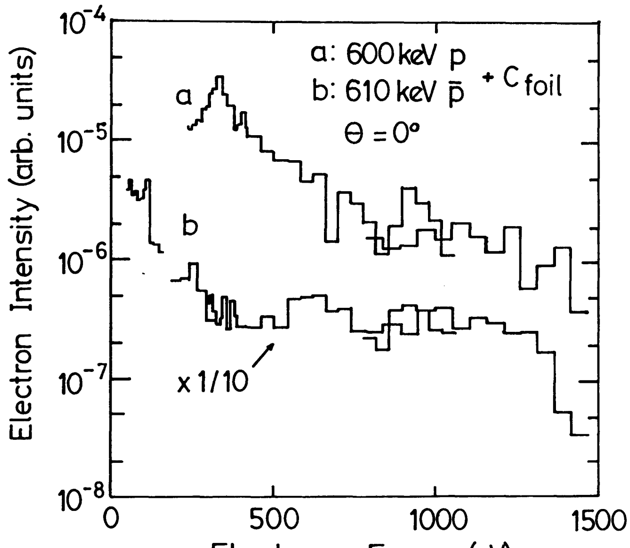



*Fig. PS204–1*
*Electron spectra $d^2/dE_e d\Omega$ multiplied by the electron energy $E_e$ at 0° for (a) 600 keV (± 15keV) protons and (b) 610 keV (± 15 keV) antiprotons bombarding 2 μg/cm² carbon foil.*

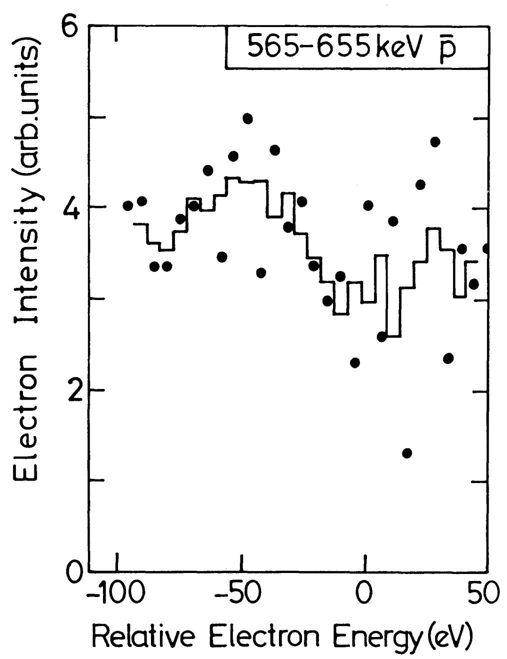



*Fig. PS204–2*
*Electron spectra $d^2/dE_e d\Omega$ at 0° for 565-655 keV antiprotons. The solid circles show raw data. The histogram is a result of a channel average over neighbouring channels (± 1 channel).*

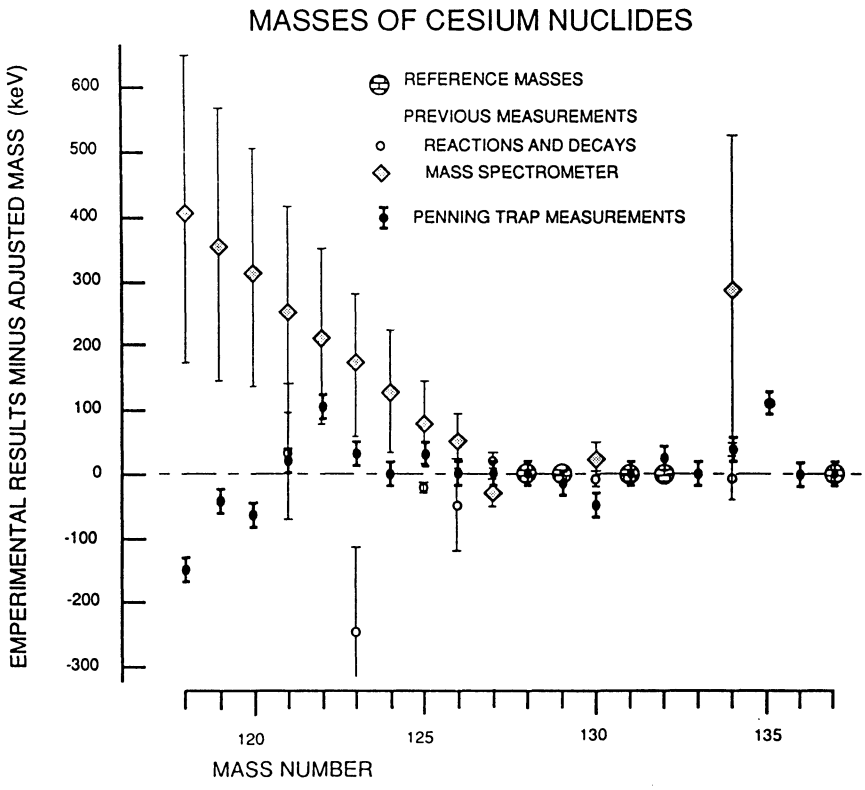



*Fig. IS130–1*
*Masses measured for Cs isotopes. The zero line corresponds to the adjusted (Wapstra) mass values previously published.*

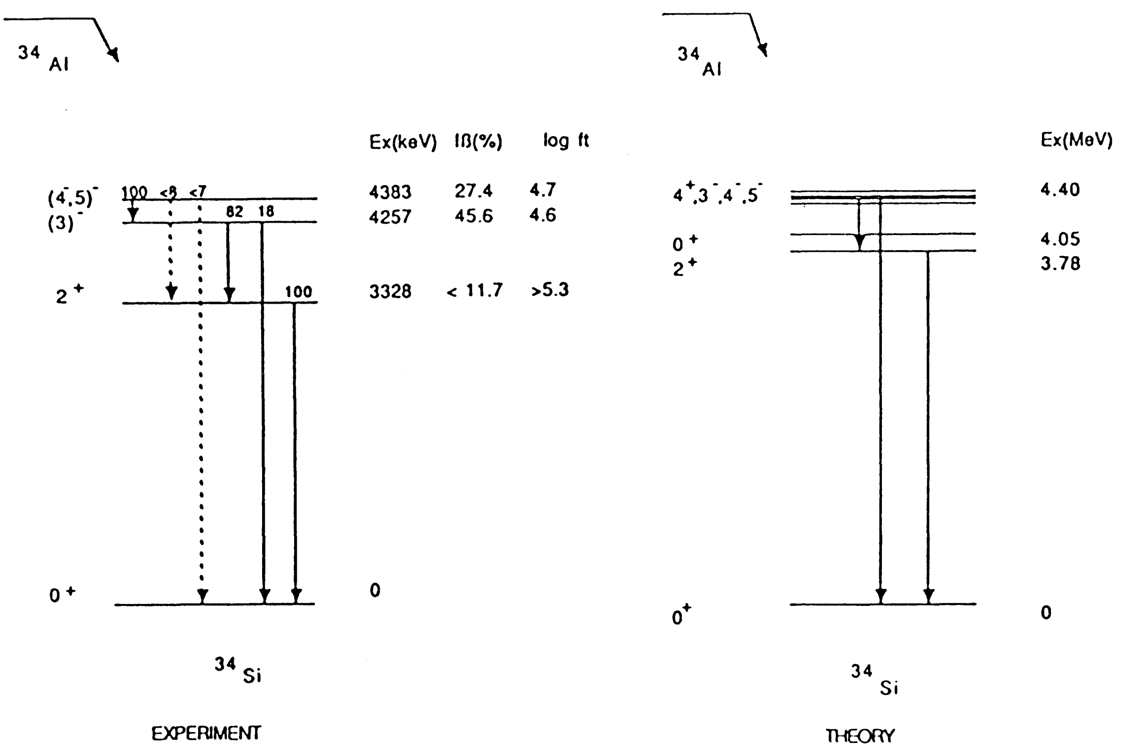



*Fig. IS230–1*
*Experimental and calculated level scheme of $^{34}Si$, showing remarkably high position of first $2^{+}$ state, characteristic for doubly magic nuclei.*

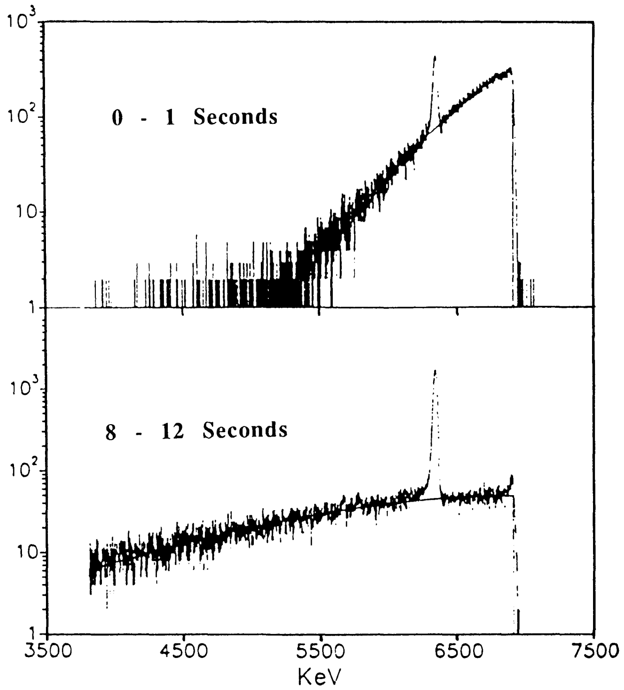



*Fig. IS01-23-1*
*α-spectrum of $^{205}$Fr implanted into K at 35.4°C. The characteristic broad distribution is due to diffusion even in 1 second. The peak originates from $^{201}$At daughter nuclei that have migrated to the sample surface.*

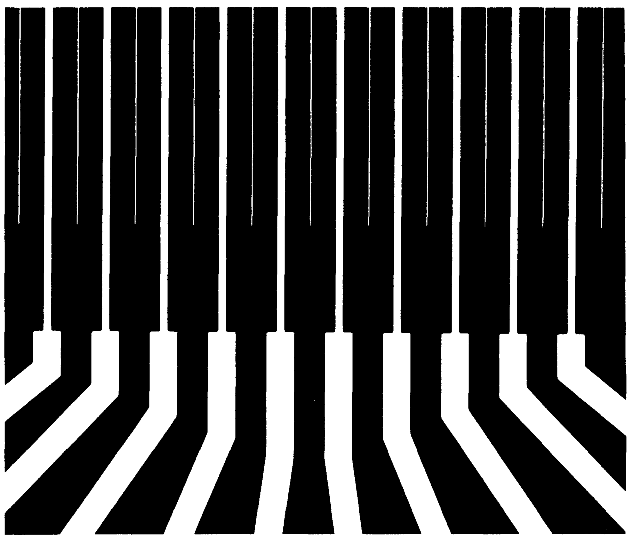


*Fig. Micro–1*
*Close view of the microstrip chamber. Thin anode and cathode strips alternate to produce a pattern capable, under suitable conditions, to amplify and detect ionization. Localization is achieved recording the induced charge profile on cathode strips for each event.*

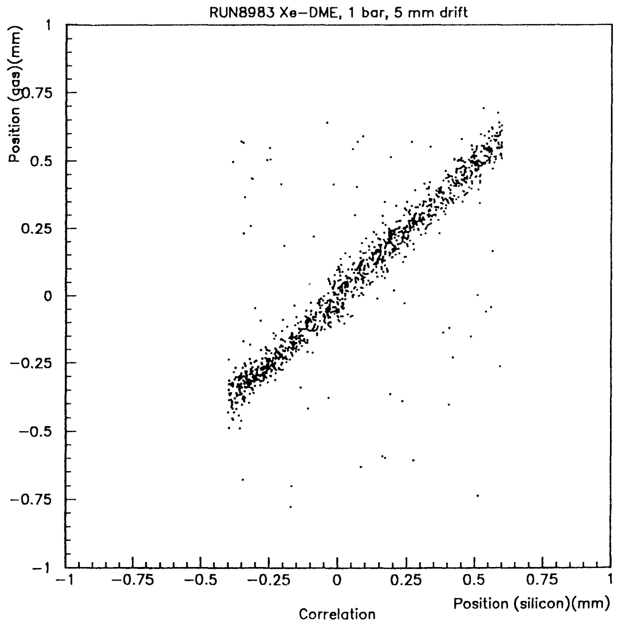



*Fig. Micro–2*
*Correlation between the real position of minimum ionizing tracks (measured with a pair of silicon strip detectors), and the position recorded using the microstrip gas chamber. The correlation is linear, and its dispersion suggests an intrinsic localization accuracy of 30 μm rms.*

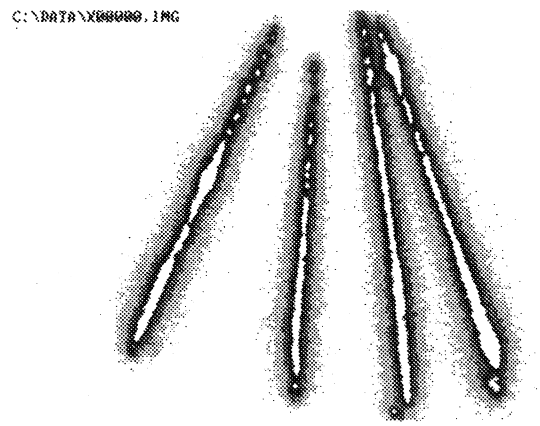


*Fig. Imag–1*
*An alpha particle detected with the imaging chamber, as recorded by a digitizing CCD camera; the color shade maps the light intensity in each pixel, proportional to the ionization density in the original track. A device of this kind, allowing visual detection of tracks, will be installed in the Microcosm permanent exposition.*

# SPS EXPERIMENTS IN 1989

| *Experiment number* | *Experiment* | *Collaboration* | *Status* |
|---|---|---|---|
| WA79 | Study of neutrino–electron scattering at the SPS | Brussels – CERN – Hamburg – Louvain – Moscow ITEP – Munich – Naples – Rome | Data-taking |
| WA80 | Study of relativistic nucleus–nucleus collisions at the CERN SPS | Darmstadt GSI – LBL – Lund – Munster – Oak Ridge Nat. Lab. | Data-taking |
| WA82 | High statistics study of charm hadroproduction using an impact parameter trigger | Bologna – CERN – Genoa – Milan – Mons – Moscow Lebedev | Completed 27.9.89 |
| WA84 | Study of the production and decay properties of Beauty flavoured hadrons | Brussels – CERN – Genoa – London IC – Pisa – Rome – RAL – Southampton | Data-taking |
| WA85 | Study of high energy nucleus–nucleus interactions using the $\Omega'$ spectrometer equipped with a multiparticle high $p_T$ detector | Athens – Bari – Birmingham – CERN – Paris (Collège de France) – Paris LPNHE – Trieste | Data-taking |
| WA86 | Exposure of CR39 stacks to oxygen and/or sulphur beams at the CERN-SPS | Bologna | Preparation |
| WA89 | Hyperon beam experiment | Bologna – CERN – Genoa – Grenoble ISN – Heidelberg (MPI + Univ.) – Mainz (Inst. of Nuclear Physics) – Mons – Moscow Lebedev | Data-taking |
| NA12/2 | Search for mesons and glueballs decaying into multiphoton final states produced in central hadron collisions and study of inclusive production of heavy quark mesons | Annecy LAPP – KEK – Los Alamos Nat. Lab. – Pisa – Serpukhov IHEP | Data-taking |
| NA31 | Measurement of $\|\eta_{00}\|^2/\|\eta_{+-}\|^2$ | CERN – Edinburgh – Mainz – Orsay LAL – Pisa – Siegen | Data-taking |
| NA34 | Lepton production | Bari – Brookhaven – CERN – Heidelberg – London UC – Los Alamos – Lund – Montreal (McGill + Univ.) – Moscow (Lebedev + EPI) – Novosibirsk – Pittsburgh – Rome – RAL – Saclay – Stockholm – Tel Aviv – Turin | Completed 22.12.89 |
| NA34/3 | Measurement of low mass muon pairs in sulphur–nucleus collisions with an optimized HELIOS muon spectrometer | Bari – CERN – Montreal (McGill + Univ.) – Moscow (Lebedev + EPI) – Rome – Saclay – Stockholm – Turin | Preparation |
| NA35 | Study of nucleus–nucleus collisions | Athens – Bari – CERN – Cracow (INP) – Darmstadt GSI – Frankfurt – Freiburg – LBL – Marburg – Munich MPI – Warsaw (INS + Univ.) – Zagreb Rudjer Boskovic Inst. | Data-taking |
| NA36 | Production of strange baryons and anti-baryons in relativistic ion collisions | Bergen – Birmingham – Carnegie Mellon – CERN – Chandigarh – Cracow INP – LBL – Madrid CIEMAT – Santiago de Compostela – Strasbourg – Vienna | Data-taking |
| NA37 | Detailed measurements of structure functions from nucleons and nuclei | Amsterdam NIKHEF – Bielefeld – Freiburg – Heidelberg MPI – Mainz – Mons – Neuchâtel – UC Santa Cruz – PSI – Turin – UCLA – Uppsala – Warsaw | Completed 22.12.89 |
| NA38 | Study of high-energy nucleus–nucleus interactions with the enlarged NA10 dimuon spectrometer | Annecy LAPP – CERN – Clermont-Ferrand – Lisbon LIP – Lyons IPNL – Orsay IPN – Palaiseau – Strasbourg – Valencia | Data-taking |
| NA43 | Investigations of the energy and angular dependence of ultrashort radiation lengths in Si, Ge and W single crystals | Aarhus – Strasbourg – Stuttgart MPI f. Metallf. | Completed 2.10.89 |
| NA44 | A focusing spectrometer for one and two particles | Brookhaven – CERN – Columbia – Copenhagen – Hiroshima – KEK – Los Alamos Nat. Lab. – Lund – Pittsburgh | Preparation |
| NA45 | Study of electron pair production in hadron and nuclear collisions at the CERN SPS | Brookhaven – CERN – Heidelberg (MPI + Univ.) – Milan Ec. Poly. – Weizmann Inst. | Preparation |
| NA46 | Darmstadton hunting in the interaction $\gamma$-crystal | Annecy LAPP – Lyon IPNL – Turin Univ./INFN | Preparation |
| NA47 | Measurement of the spin-dependent structure functions of the neutron and proton | Amsterdam NIKHEF – Bielefeld – Buenos Aires – CERN – Delft Tech. Univ. – Dubna JINR – Freiburg – Houston – UCLA – Mons – Nagoya – Northeastern – Rice – Saclay CEN DPhN – Trieste Univ./INFN – Uppsala – Univ. of Virginia – Warsaw Inst. Nucl. Studies – Yale – Zurich ETH | Preparation |

## SPS EXPERIMENTS IN 1989 (Cont.)

| *Experiment number* | *Experiment* | *Collaboration* | *Status* |
|---|---|---|---|
| UA1 | A $4\pi$ solid-angle detector for the SPS used as a $p\bar{p}$ collider at a c.m. energy of 630 GeV | Aachen TH - Amsterdam NIKHEF - Annecy LAPP - Birmingham - Boston - CERN - Helsinki - Kiel - London (IC + QMC + Westfield) - Madrid CIEMAT - MIT - Padua - Paris (Coll. de France) - Rome - RAL - Saclay DPhPE UCLA - Vienna HEPHY | Data-taking |
| UA2 | Study of antiproton–proton interactions at 630 GeV c.m. energy | Bern - Cambridge - CERN - Heidelberg - Milan - Orsay LAL - Pavia - Perugia - Pisa - Saclay DPhPE | Data-taking |
| UA6 | An internal hydrogen jet target in the SPS to study inclusive electromagnetic final states at large transverse momentum and $\Lambda$ production in $\bar{p}p$ and pp interactions at $\sqrt{s}$ = 24.3 GeV | CERN - Lausanne - Michigan - Rockefeller | Completed 22.11.89 |
| UA8 | Study of jet structure in high mass diffraction at the SPS Collider | UCLA | Completed 26.06.89 |

## LEP EXPERIMENTS IN 1989

| *Experiment number* | *Experiment* | *Collaboration* | *Status* |
|---|---|---|---|
| | ALEPH | Annecy LAPP - Athens Demokritos - Barcelona Autonomous Univ. - Bari Univ. - Beijing HEP Inst. - CERN - Clermont-Ferrand - Copenhagen Niels Bohr Inst. - Edinburgh - Florence - Florida State - Frascati Nat. Lab. - Glasgow - Heidelberg - Innsbruck - Lancaster - London IC - Mainz - Marseilles CPPM - Munich MPI - Orsay LAL - Palaiseau - Pisa - Royal Holloway College - RAL - Saclay DPhPE - Sheffield - Siegen - Trieste - Wisconsin | Data-taking |
| | OPAL | Birmingham - Bologna - Bonn - Cambridge - Carleton - CERN - Chicago - Freiburg - Heidelberg - London (Birkbeck + Brunel + QM and Westfield + UC) - Manchester - Maryland - Montreal - NRCC - UC Riverside - RAL - Saclay DPhPE - Technion - Tel-Aviv - Tokyo - Weizmann Inst. | Data-taking |
| | L3 | Aachen TH (I + III) - Amsterdam NIKHEF - Annecy LAPP - Beijing HEP Inst. - Bombay TIRF - Budapest Res. Inst. - CALTECH - Carnegie-Mellon - CERN - EIR Würenlingen - Florence - Frascati Nat. Lab. - Geneva - Harvard - Hawaii - Hofei Science and Tech. - Johns Hopkins - Lausanne - Leningrad NPI - Lyons IPNL - Madrid CIEMAT - Univ. of Michigan - MIT - Moscow ITEP - Naples - Nijmegen NIKHEF - Northeastern - Ohio State - Oklahoma - Princeton - Rome - Siegen - Sofia INRNE - UC Schenectady - UC San Diego - World Lab. - Yale - Zeuthen IHEP - Zurich ETH | Data-taking |

## LEP EXPERIMENTS IN 1989 (Cont.)

| *Experiment number* | *Experiment* | *Collaboration* | *Status* |
|---|---|---|---|
| | DELPHI | Ames Lab. Iowa State Univ. – Amsterdam NIKHEF – Athens (Demokritos + Univ. + Nat. Tech. Univ.) – Belgium (DELPHI) – Bergen – Bologna – CERN – Copenhagen Niels Bohr Inst., – Cracow INP – Dubna JINR – Genoa – Helsinki – Karlsruhe IEKP – Lisbon LIP – Liverpool – London (Birkbeck Coll. + Brunel Univ. + QMC + Westfield + UCL) – Lund – Milan – Orsay LAL – Oslo – Oxford – Padua – Paris (Coll. de France + LPNHE + P. et M. Curie Univ.) – Rome Sanita/INFN – RAL – Saclay DPhPE – Santander – Serpukhov IHEP – Stockholm – Strasbourg – Trieste – Turin – Uppsala – Valencia – Vienna OeAW – Warsaw – Wuppertal | Data-taking |
| LEP5 | A single Bremsstrahlung monitor to measure luminosity at LEP | Rome Univ./INFN | Preparation |
| LEP6 | The search for highly ionizing particles in $e^+e^-$ collisions at LEP using MODAL (MOnopole Detector At Lep) | Bologna Univ./INFN – Harvard – Weizmann Inst. | Preparation |

## SC EXPERIMENTS IN 1989

| *Experiment number* | *Experiment* | *Collaboration* | *Status* |
|---|---|---|---|
| ISOLDE : | | | |
| IS01 | Target and ion-source developments | Bergen – Burnaby – CERN – Gothenburg – Mainz – Montreal – Orsay CSNSM – Oslo – Sheffield – Strasbourg – Zurich | Data-taking |
| IS01-a | Studies of the low energy structure of neutron-rich odd-mass Indium isotopes | CERN – Studsvik – Gent | Preparation |
| IS01-3 | Study of particle unstable states in $^9Be$ by time of spectroscopy of beta-delayed neutrons from $^9Li$ | Aarhus – CERN – Darmstadt GSI – Gothenburg – Madrid – Toronto | Data-taking |
| IS01-6 | Test of off-line beta-ray spectrometer using radioactive sources produced at ISOLDE | CERN – Madrid – Gothenburg | Data-taking |
| IS01-9 | Nuclear radiation detected optical pumping of an on-line implanted atomic beam | CERN – Mainz | Completed 1.3.89 |
| IS01-11 | Spectroscopy in the near-UV resonance line $7s^2S_{1/2} - 7p^2P_{3/2}$ of Ra | CERN – Kassel – Mainz | Data-taking |
| IS01-13 | Hyperfine interaction studies of implanted radioactive probes by e–$\gamma$ time differential perturbed angular correlations | Berlin HMI – Lisbon (SACAVEM + CFN) | Data-taking |
| IS01-16 | Study of Rydberg states in Fr isotopes | Orsay CSNSM – Lyons | Completed 1.6.89 |
| IS01-17 | The construction of a fast neutral beam line for colinear laser spectroscopy at ISOLDE-3 | CERN – Orsay CSNSM – Lyons – Mainz | Preparation |
| IS01-18 | Precision spectroscopy of unstable isotopes of ion traps | Mainz | Data-taking |
| IS01-20 | $\beta$ end point determination of the Rb and Cs isotopes with a magnetic electron separator in conjunction with a germanium hyperpure detector | Giessen – Grenoble ILL | Data-taking |
| IS01-250 | ISOL technique for nuclear medicine | CERN – Rossendorf ZIK | Data-taking |

## SC EXPERIMENTS IN 1989 (Cont.)

| *Experiment number* | *Experiment* | *Collaboration* | *Status* |
|---|---|---|---|
| IS01-23 | Atomic diffusion in alkali metals | Argonne Nat. Lab. - Berlin HMI - Kuwait ISR - CERN | Data-taking |
| IS01-25 | Direct mass measurements with the ISOLDE-3 separator | Giessen - CERN | Preparation |
| IS01-27 | Surface analysis by delayed desorption | Saclay - Berlin - CERN - Tel Aviv | Data-taking |
| IS01-28 | Measurement of the beta-decay energy of $^{101}Y$ and $^{102}Y$ | Braunschweig - CERN | Data-taking |
| IS01-29 | Development of a laser ion source | Mainz - Troitzk - CERN | Data-taking |
| IS01-30 | Quadrupole moments of radioactive gold isotopes | CERN - Mainz - Oslo | Completed |
| IS0-31 | Study of the neon and carbon neutron drip line nuclei | Aarhus - CERN - Gothenburg - Madrid | Data-taking |
| IS0-32 | Microscopical studies of structural and electronic properties of semiconductors | Konstanz - Erlangen | Data-taking |
| IS0-33 | Investigation of the $^{97}Cd$ and $^{99}In$ decay | Berlin - CERN - Warsaw - Manchester - Gothenburg | Data-taking |
| IS0-34 | Complete beta-delayed one and two proton emission study of $^{22}Al$ | Berkeley - Jyvaskya - Bonn - Manchester | Preparation |
| IS0-35 | Manufacture of a $^{22}Na$ target | CERN - Munster - Bochum - Caltech | Data-taking |
| IS0-36 | Measurement of the quadrupole moment of the exotic $^{11}Li$ nucleus | Mainz - Marburg - CERN | Data-taking |
| IS20 | Mössbauer studies of implanted impurities in solids | Aarhus - CERN - Groningen - Leuven | Data-taking |
| IS31 | Radioactive ions for surface characterization | Aarhus - Berlin (FU + HMI) - CERN - Konstanz | Data-taking |
| IS80 | Study of nuclear moments and mean-square charge radii by collinear fast-beam laser spectroscopy | Bombay BARC - CERN - Leuven - Mainz | Data-taking |
| IS81 | Laser spectroscopy at Z = 50 | CERN - Darmstadt GSI - Mainz | Data-taking |
| IS82 | Multiphoton ionization detection in collinear laser spectroscopy of ISOLDE beams | CERN - Mainz - Troitzk Inst. of Spect. | Data-taking |
| IS83 | Nuclear ground state properties in Strontium by fast beam laser spectroscopy | CERN - Leuven - Mainz - McMaster - McGill | Data-taking |
| IS84 | Nuclear ground state properties of alkaline-earth ions by optical pumping, state-selective neutralization and particle detection in fast ion-beam collinear laser spectroscopy | CERN - Leuven - Mainz - McGill | Data-taking |
| IS120 | Nuclear Implantation into Cold On Line Equipment (NICOLE) | Berlin FU - Bonn - CERN - Daresbury - Delft TU - Gent - Leuven - Lyons INPL - Manchester - Munich TU - Orsay CSNSM - Oxford - Paris IN2P3 - Strasbourg CRN | Data-taking |
| IS130 | High-precision direct mass determination of unstable isotopes | CERN - Darmstadt - Mainz - McGill - Orsay CSNSM | Data-taking |
| IS140 | Study of the beta-decay properties of extremely proton-rich nuclei | Aarhus - CERN - Darmstadt TH - Gothenburg - Madrid | Data-taking |
| IS160 | Nuclear structure of neutron deficient $Z \geqslant 64$ rare earth nuclei from Gamow-Teller decays | CERN - Darmstadt GSI - Jülich IKP/KFA - Orsay CSNSM - Paris IN2P3 - Strasbourg CRN/ULP - Valencia | Data-taking |
| IS170 | Diffusion of implanted radioisotopes in solids | Munster | Data-taking |
| IS181 | Localization of implanted radioactive probes by channelling and blocking of emitted charged particles | Konstanz | Data-taking |
| IS190 | Systematic measurements of the Bohr-Weisskopf effect at ISOLDE | Bonn - Chalmers UT - CNAM Paris - Lund - Lyons ASIM - Mainz - New York - Orsay Aimé Cotton - Uppsala | Preparation |
| IS200 | Investigation of the Gamow-Teller decay of $^{98}Cd$ | CERN - Chalmers UT - Darmstadt GSI - Manchester - Warsaw | Completed 31.10.89 |
| IS210 | Search for beta decay of the neutron halo in light nuclei | Aarhus - Darmstadt TH - Gothenburg - Madrid | Preparation |

## SC EXPERIMENTS IN 1989 (Cont.)

| *Experiment number* | *Experiment* | *Collaboration* | *Status* |
|---|---|---|---|
| IS220 | Nuclear structure of N ≃ 56 Krypton isotopes | Brunswick TU – Lund – Mainz (Inst. Nucl. Chemistry) | Preparation |
| IS230 | Study of fp states in nuclei with high neutron excess | Lyons IPNL – Madrid Autonomous Univ. – Paris IN2P3 – Strasbourg CRN/ULP | Data-taking |
| IS240 | High resolution conversion electron spectroscopy of valence electron configurations (CESVEC) in solids | Aarhus – CERN – Zurich | Data-taking |
| SC65 | Local magnetic fields in ferromagnetics studied by positive muon precession | CERN – Grenoble CEN – Munich TU – Uppsala | Data-taking |
| SC76 | Impurity trapping of positive muons in metals | CERN – Jülich IFF/KFA – Uppsala | Data-taking |
| SC81 | Formation and interaction of muonium in insulators and semiconductors | Parma – RAL | Data-taking |
| SC93 | $\mu$SR measurements under high pressure and at low temperatures | Grenoble CEN – Munich TU – Uppsala | Data-taking |
| SC97 | Hydrogen mobility in disordered metals studied by $\mu$SR | Grenoble ILL – Jülich IFF/KFA – Uppsala | Preparation |
| SC98 | Production of $^{18}$Fluorine at the CERN SC | Geneva – CERN | Preparation |

## EMULSION EXPERIMENTS IN 1989

| *Experiment number* | *Experiment* | *Collaboration* | *Status* |
|---|---|---|---|
| EMU01 | Study of particle production and nuclear fragmentation in collisions of $^{16}$O beams with emulsion nuclei at 13–200 A GeV | Alma-Ata HEPI – Beijing HEPI – Chandigarh Punjab Univ. – Grenoble CEN – Jaipur-Jammu – LBL – Lund – Marburg – Moscow (Lebedev) – NRCC – Shanxi – Tashkent INP + LHEP – Washington Univ. – Wuhan | Preparation |
| EMU03 | Interactions of $^{16}$O projectile and its fragments in nuclear emulsion at about 60 and 200 GeV/nucleon | Cairo Univ. | Preparation |
| EMU05 | Study of extremely short-range particle correlations in high-energy ion collisions | Univ. of Alabama – NASA/MSFC – Tokyo | Preparation |
| EMU07 | Interactions of 60–200 GeV/nucleon $^{16}$O and $^{32}$S (Pb) nuclei in light and heavy absorbers | Cracow INP – Louisiana State – Univ. of Minnesota | Preparation |
| EMU09 | An emulsion hybrid set-up for the study of sulphur–nucleus collisions at 200 GeV/N | Bari Univ./INFN – CERN – Univ. Coll. Dublin – Univ. Alabama-NASA MSFC – London UCL – Nagoya Univ. – Rome Univ./INFN – Salerno Univ./INFN – Turin Univ./INFN | Preparation |

# PS EXPERIMENTS IN 1989

| *Experiment number* | *Experiment* | *Collaboration* | *Status* |
|---|---|---|---|
| PS185 | Study of threshold production of $\bar{p}p \to \bar{Y}Y$ at LEAR | Carnegie Mellon – Erlangen-Freiburg – Univ. of Illinois – Jülich IKP/KFA – Uppsala – Vienna IMEP/OeAW | Data-taking |
| PS189 | High precision mass measurements with a radiofrequency mass spectrometer – Application to the measurement of the $p\bar{p}$ mass difference | CERN – Orsay CSNSM | Preparation |
| PS194/2 | New measurements of antiproton–atom collisions : ionization, dE/dX, X-rays and channelling | Aarhus – PSI | Data-taking |
| PS195 | Test of CP violation with $\bar{K}^0$ and $K^0$ at LEAR | Athens (Demokritos + Univ.) – Basle – Boston – CERN – Coimbra – Delft TU – Fribourg – Ioannina – Liverpool – Ljubljana – Marseilles CPPM – Orsay CSNSM – PSI – Saclay DPhPE – Stockholm MSI – Thessaloniki – Zurich ETH | Preparation |
| PS196 | Precision comparison of $\bar{p}$ and p masses in a Penning trap | Harvard – Mainz – Washington | Data-taking |
| PS197 | The Crystal Barrel : meson spectroscopy at LEAR with a $4\pi$ neutral and charged detector | CERN – Hamburg – Karlsruhe KfK/Univ. – LBL – QMC – Mainz – Munich – RAL – Strasbourg CRN – UCLA – Zurich | Preparation |
| PS199 | Study of the spin structure of the $\bar{p}p \to \bar{n}n$ channel at LEAR | Cagliari – Geneva – Saclay (DPhN + LNS) – Trieste – Turin (Polytechnic + Univ. + INFN) | Data-taking |
| PS200 | A measurement of the gravitational acceleration of the antiproton | Los Alamos Nat. Lab. – NASA/ARC – Texas A&M – Univ. Colorado/Boulder | Preparation |
| PS201 | Study of $\bar{p}$ and $\bar{n}$ annihilations at LEAR with OBELIX, a large acceptance and high resolution detector based on the Open Axial Field Spectrometer | Bologna – Brescia – Cagliari – CERN – Dubna – Frascati Nat. Lab. – Legnaro Nat. Lab. – Padua – Pavia – Trieste – Turin Polytechnic/INFN – Udine | Preparation |
| PS202 | JETSET : Physics at LEAR with an internal gas jet target and an advanced general purpose detector | CERN – Freiburg – Genoa – Univ. of Illinois – Jülich IKP/KFA – Oslo – Uppsala | Preparation |
| PS203 | Antiproton induced fission and fragmentation of nuclei | Bonn – Florida State – Jülich IKP/KFA – Munich TU – Univ. of Mississippi – Univ. of Virginia | Data-taking |
| PS204 | Measurements of wake-riding electrons in antiproton–carbon-foil collisions | Aarhus – Tokyo | Preparation |

# Experimental Physics Facilities Division

This year's report on the activities of the Experimental Physics Facilities (EF) Division is the last such report before the Division ceases to exist as the proposed changes in the CERN Divisional structure come into effect at the end of the year.

The Division was set up in 1976 at the start of the physics programme at the new CERN SPS accelerator, to build and operate major CERN experimental facilities such as bubble chambers and large general-purpose spectrometers and to provide advanced equipment for experimental physics such as detectors, magnets, measuring machines and cryogenics apparatus.

Activities at first centered around the 2-metre Bubble Chamber HBC200, the Big European Bubble Chamber BEBC, the Heavy Liquid Bubble Chamber Gargamelle, the Rapid Cycling Bubble Chamber RCBC, the Holographic Bubble Chamber HOBC, the Lexan Bubble Chamber LEBC and spectrometers such as OMEGA, the European Hybrid Spectrometer EHS, the Split Field Magnet SFM, and the Axial Field Spectrometer AFS, all of which were constructed and operated with major EF support. The Division also participated largely in the construction and operation of large electronic detectors for neutrino physics (Experiment WA1) and streamer chambers (Experiment WA44) and last but by no means least, in the proton-antiproton collider experiments UA1, UA2 and UA5, building the streamer chamber for the last named. Furthermore the Division constructed and operated neutrino beam lines and RF-separated hadron beam lines and began the development of superconducting radiofrequency accelerating cavities as part of its accelerator technology activities.

For all 14 years of its existence the Division has provided continuous support to the SPS fixed target and proton-antiproton collider programmes, and has supplied a CERN-wide cryogenics service, for example in constructing and operating liquid argon calorimeters and operating superconducting solenoids. In addition to this, a substantial redeployment of EF staff was initiated in the early 1980s, when the bubble chamber programme was phased out and the ISR was closed down, to help in the construction of the LEP accelerator and its four experiments. EF staff played a major role in the design, construction, co-ordination and installation of all four LEP detectors and in the preparation of the experimental areas and a good number of EF staff assisted in the construction of the LEP accelerator.

At the same time the R&D work on superconducting accelerating cavities was vigourously pursued and is now the basis of the LEP energy upgrade programme; the Division is also involved in R&D work for detectors for future hadron colliders in the context of the LAA programme.

This year's report on EF activities is mostly concerned with the successful completion, installation and start-up for physics of the LEP machine and of the four LEP experiments.

## Fixed Target Experiments

### OMEGA Spectrometer

OMEGA is a multi-particle spectrometer with some fifty planes of proportional wire chambers in a 1.8 Tesla magnetic field. Powerful software allows the reconstruction of typically twenty tracks in a wide solid angle. This basic equipment can run with a high asynchronous rate of interactions – it is possible to attain luminosities of $5 \times 10^{31}$ during spill and $8 \times 10^{30}$ ($s^{-1}cm^{-2}$) on average. However, the interesting charm and beauty events do not have characteristics which allow them to be easily distinguished from the other hadronic interactions. There are, none the less, limited possibilities for enriching the sample of interesting events with a fast trigger, and some of them have been put to work. For a given trigger, the number of interesting events is proportional to the total sample, and in this way the speed of the data acquisition has been substantially increased.

This year's series of experiments started with a long final run for WA82 (Charm Hadro-production Using an Impact Parameter Trigger). The spectrometer was already suitably set up at the end of the 1988 fixed target period so that no reconfiguration was required. The efficiency of the system then improved reasonably rapidly, and WA82 collected the planned number of events.

After the WA82 run, WA84 tested the latest version of the scintillating fibre target. This test was intended to establish the influence of the magnetic field on the background produced in the first image intensifier. Moreover, some new data were needed for a study of bridging the tracks between the fibres and the OMEGA system.

The next experiment on the list, WA85, needed the OMEGA chambers sensitive in the 'Butterfly' region only. For this purpose the cathode planes of the proportional chambers had to be replaced. Experiment WA85 (OMEGA/Ions) studies the production of Lambdas, Xis and their antiparticles induced by protons on a tungsten target. This is to be compared in 1990 with the same production induced by sulphur ions, the strangeness signal being a possible sign of the existence of the quark-gluon plasma.

The last part of the year (from 9 November to Christmas) was devoted to the installation and set-up of the Hyperon Experiment WA89. As it turned out the hyperon beam behaved as expected whereas the set-up of the experiment and of the trigger took rather more time than WA89 had hoped for. By mid-December all the subsystems were debugged and ready for data taking. The data taken so far should allow WA89 to study the performance of the experiment with real data and to design a more selective trigger. For technical reasons, the drift chamber for detecting the photons of the RICH could not be finished in Heidelberg, so that the performance of the upgraded RICH is still unknown. So far as the improvement in the optics is concerned,11 new spherical mirrors have been suspended in the central region. They are perfectly spherical and of the same curvature.

### Experiment WA79 – CHARM II

The Division's Instrumentation Group prepared the electromechanical systems used to calibrate the neutrino beam (NFM). A new type of beam position control was installed involving considerable mechanical work (dismantling, removal from the shafts, modifications). New electronic equipment (VME modules and OS9 system) were installed in the control room. The programmes needed to operate the system were developed in collaboration with the physicists working on experiment CHARM II.

During the run from August to December 1989, the T9 target was bombarded by $7.95 \times 10^{18}$ protons, at an average intensity of $1.8 \times 10^{13}$ protons per pulse every 14.4 seconds.

### Experiment WA84

The fixed-target experiment WA84 (search for mesons carrying a beauty quark) uses a detector with high spatial resolution designed and built by the EF Division. It was tested in a high-energy SPS beam and in a 340 GeV pion beam in the OMEGA spectrometer.

In this detector a $4 \times 4 \times 40$ mm$^3$ target, consisting of an assembly of plastic scintillating optic fibres 20 $\mu$m in diameter, delivers images of interactions to an opto-electronic chain, containing light-guides, image intensifiers and a CCD camera.

As tests showed that the opto-electronic chain and the target worked well, work concentrated on improving the radiation resistance. A new optical image transfer system was developed and is proving entirely satisfactory, offering the prospect of improved data-taking in the near future.

### Experiment NA31

The two drift chambers of experiment NA31, each consisting of four wire planes, have been repaired and partially rebuilt. The large liquid argon calorimeter, designed and constructed by EF Division, was removed from its cryostat for a number of modifications. During some six months of data-taking after reinstallation in the experiment, all three detectors gave excellent performance.

### Experiment NA35

Some 12 km of film was developed for Experiment NA35, a study of nucleus-nucleus collisions. Technical support was provided for the streamer chamber cameras.

# Detectors for LEAR Experiments

### Experiment PS195

The CP-violation experiment PS195 on LEAR had its first run in may 1989. Technical support by EF Division included, for example, help with the cabling of the calorimeter, in the commissioning of the 30 electronic racks and in safety matters.

# Detectors for SPS $p\bar{p}$ Experiments

The proton-antiproton collider experiments UA1 and UA2 have been taking data since the second half of 1981.

Having been involved in the design and construction of these two experiments, the Division continues to participate in upgrading and running them.

### Experiment UA1

During the Spring collider run, the UA1 experiment collected mainly data based on muon triggers, furthering the search for the top quark. During 1988 and 1989 data corresponding to 4.69 inverse picobarns have been collected for further analysis.

*Uranium-TMP Calorimeter Construction*

The U-TMP (uranium-tetramethylpentane) calorimeter consists of ten 'Gondolas', each made up of 16 'modules'. A module is made up from two stacks of 62 'boxes', which are TMP containers, stacked side-by-side and interleaved with uranium plates. A full description of the calorimeter together with an account of its performance may be found in Nuclear Instruments and Methods, A265 (1988) 303 – 318.

Module Testing

The first Gondola module, M1, was filled with TMP at the end of June 1989 along with two forward detectors and a 'very forward' unit. A great improvement in cross-talk and electronic noise was observed. Early tests revealed high voltage problems also found in position detectors, which imposed a production slow-down for systematic high voltage tests during the summer. Various factors such as non-flatness and non-uniform thickness of uranium plates and the presence of dust and particles were shown to be responsible for the problems. With finer filters in all gas and TMP lines (pore sizes 0.2 µm and 0.5 µm, respectively), with stack assembly in a clean room, and with a new rinsing procedure using ultra-pure water, four modules are being prepared with high voltage testing throughout the different stages of construction. A trial stack has already been satisfactorily tested at high voltage, and the four will be filled for testing early in 1990. Series production should then be resumed.

### Experiment UA2

The UA2 experiment ran for data-taking on the proton-antiproton collider from March to June 1989, carrying the total integrated luminosity to a value of 7.4 inverse picobarns.

The rest of the year was devoted to a recalibration in the test beam of samples of calorimeter modules and to the dismantling for repair and maintenance of the central detectors. In parallel with this work a small research and development project was started, aiming to produce silicon detectors with a double-sided readout in view of a possible replacement of the inner layer detectors to improve its granularity. This project is being conducted in collaboration with the EF Silicon Detector Group.

# LEP Experiments

In November 1982, the Research Board, following the recommendation of the LEP Experiments Committee, approved four experiments for LEP :

| | |
|---|---|
| ALEPH | Apparatus for LEP PHysics |
| DELPHI | DEtector with Lepton, Photon and Hadron Identification |
| L3 | Letter of intent number 3 |
| OPAL | Omni-Purpose Apparatus for Lep |

All four experiments were operational when the first LEP colliding beam for physics use was established in August 1989, and all recorded $Z^0$ events within a few hours. By the end of the year, each experiment had published results. Between them the four experiments have collected some 100 000 $Z^0$ events.

EF Division has participated in each experiment, notably in the coordination of design, construction and installation of detectors, in the preparation of the CERN infrastructure, and in the implementation of safety systems.

### LEP Interface

The installation of the four LEP experiments was terminated successfully by the beginning of July, in time for the first LEP beam tests.

No major setbacks were encountered, apart from the helium leak in the cryostat of the DELPHI solenoid, which occurred in October 1988, and required four and a half months of repairs and tests, severely reducing the time available for the mounting of the detectors. Rearrangement of the installation sequence, however, and a lot of extra shift-work and overtime permitted the DELPHI experiment to be on-beam in time – a remarkable achievement. The various services (electricity, water cooling, ventilation, etc.), being all very new installations, required some de-bugging and caused several unscheduled interruptions in the operation of the detectors.

The essential safety systems (mainly flammable gas alarms and fire alarms) were operational for the first LEP physics runs.

### Experiment ALEPH

In the first half of 1989, installation work on ALEPH was completed and it was positioned in LEP shaft 4. Cables were also laid between the detectors and the counter rooms and from there to the central computers. All the services, alarm and command systems were commissioned and tested and thereafter worked satisfactorily. The same was true for the various gas distribution systems.

The superconducting coil was cooled without any particular problems and the magnet, with a rated current of 5000 A, worked on the whole extremely well, despite some minor faults in the electrical power supply during the magnet's two thousand hours of operation.

The final tests on the Time Projection Chamber (TPC), a detector for which CERN has special responsibility, started at the end of February. The gas system was perfectly stable from the start and right up to the Christmas shutdown. Between February and August many tests and measurements of all types and calibration of the TPC were carried out. They showed that the chamber worked well from the start of data-taking to the expected degree of accuracy.

Once all the detectors had been tested and commissioned by the groups responsible for construction, the central data-acquisition system, based on a cluster of three VAX 8200 and one VAX 8700, recorded and stored the data from all the sub-detectors. This was done very efficiently throughout the experimental run from August and December 1989, once the difficulties inherent in the start-up of such a complex system had been overcome.

The second half of the year, from August to December, was devoted to data-taking. The first $Z^0$s were observed a few hours after the LEP machine succeeded in colliding the electron and positron beams. A total of about 12 000 $Z^0$ were recorded during this period – this demonstrates that a very high standard of efficiency was reached for the first operating run of such a complex detector and should be seen as a great success. (See for general reference : 'ALEPH : a detector for electron-positron annihilation at LEP', D. Decamp *et al.*, submitted to Nuclear Instruments and Methods).

**Experiment DELPHI**

EF Division was responsible for the overall co-ordination of the project, for the assembly of the detector in the pit and for the standardisation and construction of the gas systems (with the exception of those for the Ring Imaging Cherenkov counter RICH). The Division was also involved in the 'end-cap' sectors and the trigger of the Time Projection Chamber (TPC), and carried major responsibility in the cylindrical parts – the barrel – of the RICH and of the electromagnetic calorimeter (a High-density Projection Chamber or HPC), and in the data acquisition system.

Most of the detector components were available for the start-up of LEP, including the 144 modules of the HPC, all the liquid radiators and half of the drift tubes and read-out chambers for the Barrel RICH. A complete inner layer and four sectors of the outer layer of the silicon vertex detector were added in September. The fluid systems for the liquid radiators and drift tubes came into operation in December in time to register $Z^0$ events during the last physics run in 1989.

The data acquisition system was necessarily commissioned gradually, as the tight installation schedule had allowed practically no time for testing before beam turn-on. During the 1989/1990 shutdown, the missing sectors of the outer layer of the vertex detector and one tracker of the Small Angle Tagger will be installed, and various maintenance tasks will be carried out. The remaining 50% of the Barrel-RICH drift tubes are all manufactured and tested, but will only be installed during the longer shut-down at the end of 1990.

**Experiment L3**

*Completion of Detector Installation*

At the start of 1989, L3 detector installation continued with the assembly of the muon chamber octants, loaded vertically onto an auxiliary tube and then rotated by means of an air bearing and counter-weight system into position. The two so-called ferris wheels, approximately 13 m in diameter and 6 m wide, were then pulled into the magnet and interconnected using an hydraulic 'person access device' (PAD) fixed to the top of the magnet. A cradle carried by a horizontal arm with a stroke of 6 m inserts the operator between the chamber layers and gives him access to the jumper cables.

At the same time, installation of the detectors inside the support tube continued; the BGO barrel was lowered and taken by a 14 tonne crane to the opening inside the hadron calorimeter barrel already installed with the support tube in 1988. The assembly was then placed on pre-aligned rails, positioned inside the calorimeter, and connected. This was followed by insertion of the TEC (Time Expansion Chamber) complete with the 7 m long central vacuum chamber, again using a system of pre-aligned rails, this time directed to the BGO barrel aperture. Next the LEP beam components were lowered and their supporting structures connected permitting the installation of the forward luminosity monitors consisting of an array of BGO crystals. At a later stage the hadron calorimeter endcaps were added to complete phase 1 of the installation of the L3 detector. (See for general reference: 'The Construction of the L3 Experiment', submitted to Nuclear Instruments and Methods).

*Infrastructure, Counting Rooms & Cabling*

At the start of the year, an intense effort was made to install the services, comprising gas, water, silicone oil cooling, optical fibres and thousands of cables. The bulk of the cables runs from the various detectors into the 'Blockhouse' where most of the front line electronics is installed. This work was performed in parallel with the installation of the detectors, so that each detector could be tested as soon as possible after its installation. All the connections were satisfactorily made and tested by EF, EP and LEP personnel with a supplementary staff of at least 70 people. The increased testing activity led to a rapid increase in the electricity and cooling consumption, which permitted a test and adjustment of these systems under full load.

One of the counting room areas was converted into an L3 'run-control centre' and equipped with work consoles, from which the entire experiment can be monitored and controlled.

A number of different safety systems was installed in the experimental hall and in the various counting room areas. Gas, water and smoke detectors were connected to the GSS (General Safety System) and alarm signals relayed to the CERN fire-station. The Slow-Control System, which monitors above all safe operational conditions in detectors, was put into service.

The gas systems were installed and commissioned for flammable gas, first to test the detectors in situ, then for operation, when all the required safety conditions were fulfilled.

*Magnet Tests*

In the first half of the year, the magnet was run at full field strength for about 40 hours so that some readjustments could be made in collaboration with researchers and LEP teams responsible for finalizing the beam line. From the start-up proper on 6 August to the machine shutdown on 21 December, the magnet has operated at its design level for more than 1500 hours without any particular problems.

*L3 Operations in 1989 & Plans for 1990*

As a result of a tremendous collective effort, preparations were sufficiently advanced at the beginning of August for L3 to be able to play a full part in the LEP pilot run, during which $Z^0$s were detected from the very first collisions.

After some initial work with the beam, operating difficulties causing loss of beam time were analysed and, as a result, staff in EF-L3 intensified overall monitoring of the installations and developed an extension to the slow control system. These modifications, which will be installed during the shutdown at the beginning of 1990, will, in the long run, allow such close monitoring to be relaxed. The following important Slow-Control functions aim to achieve this objective.

The minimal safety network for L3's critical parameters (Black Box L3 or BBL3) proved very effective throughout the 1989 run. By this means, in the event of an alarm, the systems were automatically cut out. It was decided to extend this network to cover all the parameters that might damage the detector in the event of a fault.

Parallel to that, a real-time Expert System installed on a microVAX 3200 has enabled all the BBL3 parameters to be centralized, recorded, distributed and monitored, as well as a large number of analog parameters (2.5 Mbytes/day) relating to the gas systems, the L3 magnet and the ionization chambers. A series of utility programmes for data presentation and histograms using graphic-mode terminals allows the current status of the detector to be consulted from a remote station and a log of the previous three days may be consulted for all the parameters. A record of all analog data is kept on tape and a paper record of all the alarms raised is kept for consultation purposes and for subsequent analysis. Information on LEP services, a VME/VAX procedure supervisor which automatically restarts part of the system when one of the L3 computers breaks down and a new portable graphic presentation system are in the process of being integrated into the system. This will facilitate standby monitoring and remote consultation of the experiment's parameters.

With regard to the magnet, work is concentrating on the temperature regulation of the active casing which protects the detectors from heat lost in the coil and on summarizing the large volume of information available on the status of the magnet and its peripherals. The software for the control system is being adapted so that less local monitoring during operation is required.

**Experiment OPAL**

In 1989 the OPAL detector, with the exception of the muon end cap 'patch' chambers, was completed and commissioned, and achieved several months of successful data taking during which 30 500 multi-hadron $Z^0$ decays, of which some 10% were accompanied by lepton pair decays were recorded and analysed. OPAL was well prepared for the LEP pilot run and observed its first $Z^0$ events on 13 August during the first minutes of LEP operation.

The magnet field had already been mapped by the beginning of the year, most of the cabling had been installed, most detectors were in place although untested, and the electronics huts were supplied with power, ventilation and cooling. The magnet was open, that is to say separated into its three parts, to give access to the detectors. We mention here some activities which involved support from EF Division.

*The Jet Chamber*

CERN has played an important role in all the mechanical aspects of the Jet chamber construction and in the central detector assembly. Parts of the laser calibration system were also designed, including precision mirror mountings and the 'distribution wheel'. The Jet chamber itself, about 4 m long and 4 m in diameter, consisting of 24 identical sectors each containing 159 sense wires, 161 potential wires and about 500 field wires, was wired at CERN. Cosmic and laser beam data were recorded early in the year in a combined run with the Vertex and Z chambers, using parts of the final on-line data acquisition system.

After several weeks of preparation following the cosmic ray run, a test tank containing the beam pipe and the Vertex, Jet and Z chambers was transported to pit 6 and lowered into the underground experimental area where it was transferred into its final pressure vessel. After intensive cabling work, the pressure vessel was closed by the pressure bells and vacuum tests were carried out. The magnet was closed in May and moved to the beam position where a successful pressure test of the central detectors was effected.

### *The Electromagnetic Barrel Detector*

This detector, whose mechanical design was carried out in CERN, consists of 9440 lead-glass crystals, each with its photomultiplier, mounted on ten half-ring supports. The last five half-rings were transported to pit 6 in the first weeks of the year, where they were installed in the 'near' side of the magnet. After connection to the high voltage and front-end readout system, all the counters were monitored using the gain tracking system. One counter only was found to be out of operation and has been replaced. Later, in order to keep the photomultiplier temperatures constant, ventilation and heat exchangers were installed on the half-ring structures.

In April, when the OPAL detector was temporarily closed, the gaps between opposite half-rings were measured. They were later adjusted, with the detector open, to have values of 2-3 mm when closed; thus, with its slightly non-pointing geometry, the barrel calorimeter is completely hermetic.

### *Slow Controls*

The OPAL Slow Controls System supervises the operation of the 14 subdetectors, the general infrastructure of the whole detector, and safety aspects around the experiment in conjunction with the LEP-wide safety services. These functions are performed by autonomous micro-processor based stations distributed around the OPAL experiment. A dedicated station in the Control Room provides the operator with a coherent picture of the whole detector, displays warnings and alarms and enables interaction with the detector. The system, designed and implemented by CERN staff, was ready on time and has proven to be both user friendly and very reliable.

### *General Technical Support*

CERN, mainly EF Division, provided valuable technical backup to the outside groups during the installation, testing and operation of their detectors.

Supervision of the planning, coordination and excecution of the installation work, and help on mechanical aspects of the assembly work, were provided by CERN groups. The EF mechanical workshop gave very substantial help in the manufacture of the different mechanical parts of the detector.

The trigger electronics for the electromagnetic calorimeters was designed and built in 1989 by the OME-EF group. It is based on a 40 input/32 output analog matrix in Fastbus for the fast part of the trigger, and on a pointer finding processor for the second level trigger. Both systems are now in operation on the detector (about 20 Fastbus modules each). This group also participated in the physical implementation of the Fastbus-to-VSB interface designed by the Freiburg (D) group. Twenty interfaces were successfully used for the readout and control of the electromagnetic calorimeters, the jet-chamber track trigger and the muon chambers.

In May the magnet was again closed, this time fully equipped with all its detectors, and transported to the beam position to be connected to the LEP vacuum system. The closing of the detector was a delicate operation – although the magnet had been closed previously in the pit for magnetic measurements, this was the first time it had been closed with all the detectors and cabling in place.

Cabling was finished in the first half of 1989. Installation work on the final magnet cooling pipes and bus bars, the gas building and gas distribution network, safety devices such as fire and gas detection continued under the supervision of CERN personnel. The neccessary infrastructure for safely delivering flammable gases to the detectors was in place only shortly before first beams from LEP in July and delayed somewhat the commissioning of certain detectors.

### *Operating OPAL & Physics Analysis*

CERN personnel acted as coordinators for many roles, including running the detector, supervising the on-line and off-line systems, and technical and safety aspects.

A particularly critical matter in 1989 was the commissioning and operation of the on-line data acquisition system. While many individual detector groups had already produced independent data acquisition systems for test purposes, the task of guiding the group representatives in the work of putting these into standard form and arranging for the synthesis of OPAL-wide events required a considerable effort in the first part of the year, as did the connection to the centralized trigger system. Coordinated control of the run, central diagnosis and the process of routing and writing out the events all used a number of CERN-supplied facilities. The commissioning of the on-line system in the weeks leading up to the first collisions was organized and overseen by CERN personnel, as was the work of running the system and encouraging its improvement during the rest of the year's running.

## Technical Support for the Construction of the LEP Machine

### LEP Vacuum

The Instrumentation Group continued to collaborate with the LEP Vacuum Group on the control system for the LEP sector valves. In the first half of the year, all the equipment was installed, tested *in situ* and commissioned. The second half of the year was devoted to the development of new equipment (interlocks for high-speed valves, multi-valve systems) and to modifying and upgrading programmes.

### Superconducting Accelerating Cavities

Work in 1989 has been concentrated on the production and testing of the first superconducting accelerating cavity modules for LEP and for the SPS.

Four 350 MHz, four-cell niobium cavities have been manufactured, two by private industry and two by CERN, and assembled in a four-cavity module. Such a module has been chosen as the basic unit for installation in LEP.

This first module has been fully equipped with auxiliaries, such as cryostats, couplers and tuners, necessary for LEP operation. To test and operate the module, maximum use has been made of the existing test string for copper cavities with its radiofrequency, control and cryogenic equipment. Each cavity exceeded its design accelerating field of 5 MV/m and the module has been run at a total voltage of 32 MV. Installation in LEP is planned for the beginning of next year.

An order has been placed with industry for the manufacture of twenty niobium cavities.

Development of niobium-sputtered copper cavities for LEP has continued. Five 4-cell cavities have been made at CERN and have exceeded their design values for accelerating fields and quality factors.

For the SPS work, two niobium-copper cavities have been assembled, made ready and tested for operation. It is planned to replace the existing superconducting LEP cavity with this 2-cavity module.

Other activities have included continued development work on higher order mode couplers and on magnetic shielding. In addition, improved facilities for the chemical treatment of cavities and a new clean-room facility have been installed.

The latest results are presented in more detail in the paper 'Superconducting Cavities for LEP', C.Arnaud et al, XIV International Conference on High-Energy Accelerators 1989, Tsukuba, Japan.

## Cryogenics

The main EF activities in cryogenics comprised fixed target experiments, LEP experiments, superconducting quadrupole magnets for high luminosity ('low beta') insertions in LEP, superconducting RF cavities for the LEP-200 upgrade to energies sufficient for $W^+W^-$ pair production, LHC superconducting magnets, and the supply of cryogenic liquids to various users.

### Fixed Target Experiments

The CERN cryoplant network provided refrigeration for the superconducting magnets of the following experiments or detectors : NA34 (superconducting dipole of the former NA3 spectrometer), NA35 (superconducting vertex magnet formerly used in experiment NA9), NA36 (superconducting magnet formerly used with the EHS-RCBC bubble chamber and now housing a time-projection chamber), and OMEGA. Work included, besides operation and maintenance of cryoplants, a general modernization of controls aiming at a future coherent centralized control system for all CERN cryoplants, including those of LEP.

### LEP Experiments & Low-Beta Quadrupole Magnets

Liquid helium refrigeration is required at all four LEP experimental areas so that the cryoplants at Points 2, 4, 6 and 8 were in operation for most of the time following the LEP startup. The operating crews had an immense task in operating the four new cryoplants at four different sites, and at the same time looking after the existing four plants for the fixed target experiments in the West and North area, the plant for the test facilities of superconducting cavities in the West area and the plant for the superconducting magnets in the North Area.

In the first half of the year, work concentrated on the assembly, test and installation of the valve boxes, transfer lines and ancillary equipment (service panels etc.) for the quadrupole magnets, on the installation and commissioning of the gas handling equipment (purifiers, storage tanks, and distribution networks), on installation of and equipment for the local control rooms at Points 2 and 6, and on the installation of the quadrupole power supplies at Points 4 and 8. Much work was invested in programming the installed industrial process control system for data acquisition, display of process status, automatic control procedures and alarm circuits. Preparations have started for remote supervision and control of LEP cryoplants from a main cryogenics control room in the North Area.

### Cryogenics for Superconducting Accelerating Cavities

EF Division cryogenics work in 1989 for the superconducting accelerating cavities included the design, construction, testing and running of cryogenic equipment for the cavity test area in Hall 180, for the LEP test cavity in the SPS ring and for the first operation of eight superconducting cavities in the LEP tunnel. In addition, the design concept for the future cooling of up to 256 superconducting cavities in the upgraded LEP was established, and tenders were invited for a 6 kW compact refrigerator, suitable for underground installation and able to cool at least 32 superconducting cavities at Point 2 of LEP.

The LEP2 solid niobium cavity continued to run in the SPS tunnel at BA4, its total running time advancing from 7000 to 12 000 hours. Its stable operation from a small automatic 120 W refrigerator and its high accelerating field contributed to the success of the quick start-up of LEP. It was therefore decided to augment the acceleration contributed by superconducting cavities and to replace LEP2 by two cavities made from niobium-sputtered copper and assembled in a common cryostat. The required additional refrigeration was gained by a careful redesign of the entire cooling system, in particular of the liquid helium distribution and controls.

For the cavity test area in Hall 180, a special distribution system was built and installed to supply cooling at 4.5 K from the existing 500 W refrigerator to the area equipped for testing up to eight superconducting cavities. Here the double-cavity module for the SPS and the first 4-cavity module for LEP were tested, their cryogenic performances evaluated and ideas for future simplifications developed. Further safety tests were carried out to determine worst-case conditions for the pressure rise in case of accident in the liquid helium vessel surrounding the superconducting cavities for LEP.

An ex-ISR helium liquifier was modified to serve as refrigerator for the first superconducting cavities in LEP and installed at Point 2, with the compressor in the surface building SUH2 and the cold box underground in the klystron gallery near the cavities. A system of screened transfer lines was built and put in place to connect an increasing number of cavity cryostats, first to this refrigerator, and from the end of 1991 to the new 6 kW cryoplant.

### LHC Superconducting Magnets

The helium liquifier in the North Area continued to provide liquid helium for the superconducting magnet development program for LHC.

### Cryogenic Liquid Supply to various Users

In total, about 180 000 litres of liquid helium, liquefied at CERN, and about 1.7 million litres of liquid nitrogen, purchased from outside, but stored and distributed by CERN services, were delivered to users all over the CERN site.

# Detector Developments

This section summarizes a number of current developments in particle detectors, mostly undertaken with a specific application in view.

### Silicon Detectors & Custom-Built Microelectronics

The silicon group has provided support on a continuous basis for running the inner and outer silicon arrays in Experiment UA2 and for installing additional silicon detectors and readout electronics in the OMEGA Spectrometer. On a smaller scale, mounting services have been organized for a number of other projects, such as the LEP luminosity monitors, the DELPHI SAT, and so on. At the request of several groups, a new production run of the 16-channel AMPLEX integrated circuit was initiated.

Results in the fields of electronics and of detector development have been obtained in the context of the LAA project :

- several front-end amplifier circuits, two different analog pipeline chips, and a new type of ADC have been tested and can now be used as high-performance building blocks in more complex readout chips for various types of detector;
- high-resistivity silicon detector manufacturing technology has been further developed in collaboration with IMEC in Leuven (B). As an alternative, hybrid approach, an experimental pixel detector readout chip with a one-bit digital output has been made and tested in collaboration with EPFL in Lausanne. This pixel detector achieves noise better than 400 electrons rms for a response time of 100 ns, a power dissipation of 30 μW and a pixel size of 200 μm × 200 μm.

### Scintillating Fibres

In addition to the Silicon detector work described above, R&D work on scintillating optical fibres for tracking and calorimetry was pursued.

# Accelerator Developments

### CLIC Project

Collaboration between the Instrumentation group and the CLIC study project was maintained throughout the year, mainly in developing the laser PICOLA (PICOsecond LAser), an excimer-pumped dye laser generating extremely short (a few picosecond) light pulses. After assembly and tests this laser has been moved to the PS Division photocathode preparation laboratory to serve as the light source driving the experimental photocathodes being investigated in the search for a source of short bunches of electrons for the CLIC accelerator.

Specifications for a highly complex phase-stabilised picosecond solid-state laser system also for the CLILC Test Facility programme have been worked out and preparations for the call for tenders finalized.

In a collaboration with PS Division a high power flashlamp-pumped laser has been built to study plasma generation by focusing laser light on metal targets, as a possible means of obtaining highly ionized metal atoms.

It has been necessary to develop special instrumentation to measure ultrafast laser pulses, such as, for instance, an optical auto-correlator with measurement capabilities in the picosecond range, and a spectrometer with a CCD on-line readout for bandwidth measurements.

# Data Handling Division

The major event for CERN, and consequently for the Division, was the successful start up of the LEP programme in the second half of the year. Not only was there a very fast turnon of data production but also a rapid increase in the luminosity such that by the end of 1989 all the central computer systems were fully loaded with the LEP experiments taking some 50% of the combined capacities of the CERNVM, CRAY and VXCERN (central VAX cluster) services. Tape mounting, which by year's end was dominated (80%) by cassettes, reached record levels of 2400 mounts per day.

An important milestone at the start of the year was the combined hardware and software upgrade of the CERNVM system to use VM/XA on an IBM 3090-600E. In retrospect, this complex upgrade went very well and a stable service was ready in good time for the LEP startup. The HEPVM collaboration, which aims to provide a uniform user environment at different VM sites, made steady progress with increasing membership and the sharing of important software products such as the Tape Management System written at RAL. The TMS will be integrated with the FATMEN distributed file catalogue system which entered production status at the end of the year.

The VM/XA and VXCERN services experienced user and account growth of between 25 to 30% during the year. The VM interactive service, which saw an increase of simultaneously logged on users from 560 to over 800 in the last six months alone, coped well with the additional load. Very long batch queues were, however, a regular feature of the last months of 1989. VXCERN, on the other hand, continued to be totally saturated and a major source of user dissatisfaction. To preserve a modicum of response, the number of simultaneously logged-on users was limited to 200. By the last quarter of 1989, most of the major CERN experiments were using the CRAY batch service extensively such that the XMP 48 was running to full capacity.

One half of the Siemens 7890S is now dedicated to administrative data processing, whereas the other half runs a dedicated batch service under VM/HPO and the diminishing MVS service.

The budget situation of the Division gave cause for concern. 1989 was a year of very low capital investment and a difficult year for operations' funding. The threat of having to close the Computer Centre by November was fortunately removed when additional funds were made available in September. The lack of normal investment money made it difficult to plan the evolution of the major services.

A study of CERN's computing needs for the early 1990s was published. Six working groups studied the requirements of the different user communities.

This year saw the phasing out of old equipment and services wherever possible. The Mass Storage System, the IBM 3800 laser printer and a number of tape drives were taken out of service and CERNET was closed down definitively. The joint study with IBM, to evaluate the use of a robot for automatic cartridge mounting, was not without problems.

There has been a remarkable, but anticipated, growth in the use of the Interlink facility, used to access VM from a VAX, notably after LEP startup. Workstation support and distributed computing in general absorbed increasing amounts of effort. Database support activity is also growing.

1989 was another year of growth in communications infrastructure, traffic, and services with the consequent heavy pressure on all of the staff involved. The most noteworthy facts are the immense expansion of Ethernet and the growth in leased-line bandwidth and connectivity. Approximately 2000 stations are now connected to 35 Ethernet segments and 90% of the offices requiring an Ethernet connection have now been wired. Several new leased-lines, with bandwidths of up to 2 Mbits/s were put into operation in 1989.

For the Management Information Systems the past year was marked by the introduction and consolidation of standard packages for text processing, spread sheets, databases, etc. The move of the ADP services to the Siemens 7890S was already mentioned.

1989 also saw the improvement and consolidation of various heavily used services, such as XPrint, Who, Phone and others. The program library has been ported to new platforms and a major effort has been made in the area of optimization for advanced architectures. The Physics Analysis Workstation (PAW) package went into full production and proved to be a great success : 1100 different users and 150 000 sessions on VM during 1989.

In the area of online computing, the emphasis in 1989 was on further developing the MODEL software for the LEP experiments. At the same time, new data-acquisition systems were commissioned for OMEGA and for LEAR experiments, based on integrating VME-based VALET-Plus front-ends with host VAXes. Both the Fastbus System Management software and the CERN Host Interface with its associated software went into production use in DELPHI and L3. The growing user community for the Division's online developments generated an increasing support load. Progress was made in evaluating magnetic media, especially 3480-compatible devices. The increase in the number of workstations in use has been explosive : there are now 450 DEC workstations and 100 microVAXes installed, against 50 larger VAX machines.

Commercial deliveries of CERN Host Interface modules were supported by installation work at the LEP experiments and high-speed, noise resistant, optical interconnects were installed as part of the distributed data acquisition systems of three of these experiments.

The emulator farms installed in DELPHI and L3 were used for the first time in real-time, during the first runs of LEP. In collaboration with IBM, the Parallel Processor Compute System is being evaluated. The system consists of 32 VLSI versions of the IBM 370 architecture. Work on transputer arrays is also well underway.

This was the first year in which the Division supported Engineering Computing with a group having this work as its primary rôle. Extensive mechanisms for dialog with the engineering community were put in place and these have been helping to shape future plans in the field. Major upgrades of CAE tools for electronic design were started and the modernisation of the Mechanical CAE tools continued. Central support of tools based on PCs was established with effort transfered from SPS Division.

## Computer Centre Operations

### IBM Operations

The major activities during the year directly affected the services offered to the IBM user community. VM/XA went in as the production operating system on the IBM 3090-600 as of the very beginning of the year and was progressively upgraded throughout the period. These upgrades resulted in serious instability problems at certain times. Whereas VM/HPO did not reappear in January it was re-introduced early in the summer when it was offered as a 'stand alone' service to a small group of users on one half of the Siemens 7890. At the same time the ADP service went 'live' on the other half of that machine and MVS finally moved into 'lodgings' as a second level system under HPO.

Whereas MVS was reduced to small proportions, the Mass Storage System was taken out of service. The MSS mounted its last cartridge during the summer with very little outcry from its faithful users. The number of IBM 3420 tape drives was initially reduced to a mere six (for budgetary reasons), but three more were re-installed later in the year, on user request. The old 3800 laser printer was taken out of service at the end of the year, instead of Easter as originally planned. Also CERNET was definitely closed down.

Very little installation work was done, except for some equipment bought by the users. The ALEPH 3380 disk string was installed late in the summer and the 7171s saw their days numbered with the arrival of TAG++ equipment late in the year. The Christmas shutdown was used to move all the tape media equipment to the Tape Vault, to reconfigure almost every possible channel and to take out about 3 km of unused IBM cables from the false floor.

### Cray & Workstations Operations

*Cray*

Our Cray X-MP48 has been in a stable hardware configuration since the beginning of January. Since then we installed Unicos 5.0.

Having succeeded in providing a highly stable service already at the end of 1988, the major effort has gone this year in maintaining the achieved performance and perfecting the operations.

All necessary operations on the front-end machines have been documented in the Operator's Guide.

The work, started in September, on the automatic operator has progressed very rapidly and we already have a working prototype.

The shift coordination task has taken some effort because of the reorganization of the shift system from a $6 \times 3$ to $6 \times 2$ scheme. We had to write a series of programs to simplify the handling of the shift schedule.

*Workstations*

During 1989 the number of on-site Apollo workstations grew from 130 to 225. We now have 19 DN10000 series workstations, many of which are configured with 4 CPUs. A number of Exabyte units were purchased and used for back-ups. A major reconfiguration of the Domain token rings was carried out.

Apollo operations have been complicated by the foreseen introduction of the new version of the operating system, DomainOS : as a result we had to run (and we still are) two almost incompatible (from the operational point of view) operations.

The daily operations work involves first line user support for hardware/software problems, assisting Apollo in trouble-shooting, new installations, removal of old machines (80 new nodes have been installed and 10 old ones removed), and moving equipment, both DD owned and user owned (20 nodes have been moved during 1989), as well as planning network configuration updates and planning network extensions for new machine installations.

The introduction of DomainOS has been quite smooth, apart from bugs in the O/S itself. L3 already has a large number of machines running DomainOS, and OPAL is scheduled to change at the start of 1990. At that point, only small user groups will be on the old O/S and we will be able to move them more easily.

A high-capacity back-up device (Exabyte) has been acquired, allowing us to run unattended backups for all our servers.

Due to unreliability of our SNA link, its support has been dropped and users now make heavy usage of tn3270, a 3270 emulator that uses Telnet to connect to CERNVM.

**DEC Operations**

The further postponement of the VAX cluster upgrade resulted in a reduced service being available to users on VXCRNA/VXCRNB, with login limits being imposed in an attempt to maintain response times. In spite of replacing the older RA81 disks with RA90 populated storage arrays, the level of disk failures on DEC systems in the Centre remains unacceptably high (on average, we experience three disk failures a month) and five of the newer RA90 disks failed in the 1990 New Year startup. Attempts to use the predictive maintenance tools to diagnose disk failures have so far proved unsuccessful and the problems of poor disk reliability have had to be escalated to the highest levels in DEC.

The majority of the TA90 performance issues have now been resolved and following its formal acceptance, the TA90 subsystem was successfully moved to the vault, allowing us to perform backup operations in a satisfactory manner. The CERN/Digital joint project on automatic operations (CAOS) is progressing well with the test phase about to start shortly. Several new Microvax-based services (local area VAXclusters and the TH library information system) have been integrated into the DEC operations area this year.

**Data Communications**

During 1989 we continued with the installation of 3812 corridor printers. There are now 35 such printers installed, including one printer at OPAL's LEP pit.

The NETsystem project started slowly but by the middle of the year was well established – providing network trouble-shooting tools and a mechanism for problem tracking. More than 10 major problems were passed to NETsystem, all of which were successfully closed. During the Christmas shutdown the major ethernet cables in the computer centre were certified by CERN and NETsystem personnel. The status of the NETsystem project is discussed in a bi-weekly meeting.

Since February, an off-shift communications operator acts as the first-line contact for all operational problems with communications equipment including external X.25 connections, DECservers etc.

The CERNET service finally stopped on 22 December. All CERNET equipment has been removed from the computer room.

A technical student developed a prototype expert system to help the operators solve user problems with connections to the central computers. The prototype was finished and will be put into production in 1990.

**Technical Support**

The Site Committee and EP Division succeeded in providing space in building 186 for the continuing 'archive' of physics data. The equipment for this building was ordered to handle traffic and storing of up to 500K cartridges.

The eventual purchase of the DEC TA90 units combined with a shortage of VM cartridge units prompted preliminary moves to transfer labelling and copying facilities to MVS, where hopper feeds (ACLs) are available and units are under-used during the day.

The installation of the RAL Tape Management System or TMS provides a potential replacement for many pieces of software presently in use for following tape and cartridge usage, but makes it more important than ever that automation of 'inventory' tasks be not just possible, but easy and applicable at other sites too. Discussions with IN2P3 and others started to provide a way to allow cartridge exchange between laboratories equipped with STK silos, other such devices, manual drives only etc. without excessive difficulty in restickering. Tests with a 'new' standard cartridge sticker are in progress, and may solve many of the potential problems.

The System Managed Cartridge Facility (SMCF, an automatic 3480 library) was installed in an enclosure in the Tape Vault. It is hoped to provide sufficient reliability to open a trial service in 1990 : considerable improvements have already been made. This enclosure was also planned to include all remaining manual units, and these are now in place. About 300 $m^2$ of 'extra' computer room space is therefore now available. Mount rates have now reached almost 2000/day, with a peak of 2247/day and 204/hour. The new Vault arrangements should allow us (with the foreseen increase in DCS manpower) to sustain this workload.

## Computer Centre Software Support

### Database support

*ORACLE Services*

The Relational Database Management System, ORACLE, now runs on 30 different computers at CERN ranging from MicroVaxes to the IBM 3090, under diverse operating systems, including flavours of Unix such as AIX and SUN OS. SQL*NET is used routinely to access databases in most of these machines, from each other and from hundreds of other machines, forming a kind of distributed database; though software for the few missing connections is still awaited. The latest PC and Apple Macintosh versions of ORACLE, which now allow SQL*NET connection, are already in use on a limited number of machines. A pilot application showing the capabilities of HYPER*SQL on the Macintosh has been developed. The new, more powerful Version 6 of ORACLE has been tested on VMS, but not yet on VM.

A project based on the expert system, NEXPERT, connected to the LEP ORACLE database of electrical cables, has reached the stage where means are being sought to put it into production. On the whole, the ORACLE database service continues to play an important rôle for LEP, also after production start-up, particularly for control.

*Fastbus System Manager*

In 1989, the production version of the FASTBUS System Manager FSM was successfully commissioned ahead of the LEP start-up. FSM uses a Relational DataBase Management System to describe, configure and initialise any FASTBUS read-out electronics system, and to provide diagnostic tagging of equipment malfunctions. It was installed with ORACLE at DELPHI and at L3, and was ported to an INGRES RDBMS by the MEGA experiment at LAMPF, Los Alamos. A derivative version of FSM is used, with ORACLE, by ALEPH.

The software design and implementation proved to be sufficiently robust to meet the challenge of managing FASTBUS hardware systems ranging in size from the 10 or so crates of the MEGA experiment to the highly complex DELPHI system, which, with over 200 FASTBUS crates and cables, is the largest FASTBUS read-out system in the world.

### Distributed Computing

Remote access to the central ORACLE engineering database from within the LEP control system was implemented. The EMDIR electronic mail directory service was brought up to production quality, including the development of a full-screen interface on VM. We have provided a general FORTRAN-callable interface to the TCP/IP communications system on the major CERN computing platforms. This facility, called TCPAW, has been used to give distributed data access within the PAW system. An efficient remote graphics emulator has been made available for PAW.

The group has been heavily involved in the installation and evaluation of the initial systems connected to the FDDI ring in the Computer Centre.

In the area of Distributed Computing, a significant amount of manpower was devoted to consulting and lecturing.

### Central VAX Services

The situation around the central VAX cluster was unchanged in 1989. The systems, especially the general timesharing service, became increasingly popular and more heavily used. While one of the CAD service computers was upgraded during the year, the timesharing service was not and became more and more overloaded. Much work was spent trying to gain even small improvements in response time but our efforts were continually being overwhelmed by the gradually increasing userbase. One major new version of the VMS software was installed and several minor upgrades. We have continued to provide support for VMS link software such as TCP/IP and the Cray VAX station software. In both cases, we have helped various groups install these network products on their systems. In the case of the Cray software, this included some 10-12 installations for the ALEPH collaboration, four of these in Florida via HEPnet.

The group is responsible for two local Area VAXclusters, one for internal use and the second for some 20 DD programmers (a number which approximately doubled during the year starting at 10-12 in January). The LAVC was used to field test new version of VMS and DECwindows. We continued to offer a LAVC consultancy service which was used by such groups as ALEPH, CAD, OPAL, LEP database and DELPHI.

One member of the group continued to supply system management support to the DELPHI experiment where the major event of the year was the transfer of a large number of VAX systems from the Lab 1 site to the DELPHI pit.

### Apollo Services

On the Apollo side, the group provided first line system software support for the systems outside SPS and L3. The Apollo network increased further during 1989 and the low level of available staffing for overall Apollo support is becoming more acute. The interface to the manufacturer was transferred in January and, after a certain learning curve, seems to be stable. However, the situation was complicated by the Hewlett-Packard takeover of Apollo in the spring.

### IBM Networking

1989 saw a large increase in the installed networking infrastructure providing connectivity both inside the organization and to outside institutes. Networking to the central 3090-600E is facilitated using the TCP/IP, SNA and DECNET protocols (via INTERLINK).

SNA now connects to around 10 external institutes, directly, at speeds ranging from 19.2 kBaud to 512 kBaud. In addition some of these sites act as gateways into regional SNA networks. Potential access to hundreds of institutes is now possible, although only a small fraction are used regularly by physicists to connect to and from CERN.

1989 saw an explosive growth in the use of INTERLINK, particularly during the time of the LEP startup. Currently, more than 120 Vaxes use this service on an intensive basis, submitting around 20000 Jobs/month to VM. This service is now also used for full screen access to VM from Vaxes inside the organization and from the international DECNET. The interfaces to the IBM were upgraded in 1989 to cope with the anticipated increase in load.

The principal use of TCP/IP has been file transfers to and from VM and workstations and the provision of a full screen service to VM. This latter facility provided access to VM for a handful of users at the beginning of the year to around 140 users currently. The introduction of TAG++ has been a large contributor to the use of TCP/IP.

Pilot services were introduced in 1989, including NFS, a file access mechanism, and a remote execution facility, currently used to initiate PAW tasks on VM.

A TCP/IP to DECNET gateway was introduced to provide job submission from TCP/IP to VM, capitalising on the DECNET facilities provided by Interlink. Currently around 100 jobs/day are processed by this facility.

### IBM Services

During the annual shutdown between Christmas and New Year the IBM 3090-400 was upgraded to a six-CPU 3090-600E VF configuration. The new system was launched with VM/XA SP2 software, specially tailored the year before to suit CERN's own needs. After some teething problems, it developed into a very reliable tool, providing simultaneous access to more than 700 users at peak hours.

In the course of 1989, the system was steadily improved in terms of both the services provided and its reliability. For very complex programmes users can now use XA mode, which provides up to 999 Megabytes of virtual memory.

The VMSTAGE system continued to enjoy great success with its method for storing the most widely used tapes on disk. Its useful space was extended to nearly 40 Gigabytes, and it now handles more than 15 000 requests a week. The result has been that more than 12 000 manual loading operations of magnetic tapes have been dispensed with.

The BMON batch treatment system, together with the VMSETUP and VMSTAGE tape management system were improved, paving the way for the future introduction of a 3480 robot cassette loading system.

The Siemens 7890S machine was restarted with one half dedicated to the ADP system and the other still run on the 'old' VM/HPO software. The MVS/WYLBUR which, though still big, is being stripped down to an ever more skeletal remnant, now operates at second level.

The MSS 3850 mass storage facility was finally shut down after the huge number of files it contained (still more than 200 000 at the time of going to press) had been copied onto 3480-type cassettes.

### CRAY service

The event simulation and event processing applications from several large experiments supplanted the pioneering theoretical physics users. Major users were UA1, UA2, NA34, and NA31 with the LEP experiments ALEPH, DELPHI, and OPAL flooding the system in the latter part of the year.

In spite of an intensive development programme, in collaboration with Cray Research, (UNICOS 5 supervised installation, VM station Beta test, and two VMS Station Beta tests) an overall scheduled availability of greater than 99% was achieved. Generic support for Automated Cartridge Libraries was provided and significant improvements to tape staging were implemented.

Interesting systems benchmarked during the year included the APOLLO DN 10000, Cray Y-MP, NEC SX-2, AMDAHL 5990, and the COMPAREX 8/91.

### PRIAM service

The PRIAM service continued to run smoothly and the group participated in the support of two other ULTRIX based systems, DXMINT and TAG++. The transfer of responsibility for the Swiss backbone network to SWITCH was virtually completed.

### DEC Coordination

The major activities of the DEC Coordination Project (DECCO) during the last year have been the following :

- Management of the second phase of the CERN-DEC joint projects. The areas of research covered were : operation of a complex VAX Cluster-based data centre; improvement to the standard DEC VMS operative system; a distributed computing environment for analysis and visualisation of physics data; a visual Entity-Relational data interactive system; application of parallel processing to real-time data acquisition and VAX/VMS to IBM/VM high speed, long distance links. Most of them have by now been successfully completed or will be completed during 1990.
- Coordination of technical and commercial relations between DEC and CERN users, in close cooperation with the other CERN divisions involved (mainly FI and EP).
- Organization of the usual large number of events and visits both at CERN and outside.

## Communication Systems Support

### CERNET

CERNET was definitively switched off at Christmas after more than a decade of reliable and efficient service. CERNET was CERN's first general-purpose local area network, designed and built at CERN in the late 1970s to use high-speed transmission (2 Mbit/s and above) and advanced software principles (multi-layer protocols and a portable high-level language). At its peak in 1984-85, CERNET interconnected more than 100 computers running at least 10 different operating systems, and carried some 4 Gigabytes of data per day.

### Internal Network Infrastructure

Despite serious budgetary problems, the Ethernet local area network was further extended during 1989 to reach an extra 41 buildings (1700 offices). Ethernet is now available to approximately 90% of the rooms requiring it. There are now almost 2000 stations connected to 35 Ethernet segments, themselves inter-connected by bridges. Traffic on the backbone segment increased by a factor four with peaks of 60% utilisation.

The ever-increasing traffic on the Ethernet backbone makes its replacement by the 100 Mbit/s Fibre Distributed Data Interface (FDDI) local area network very urgent. Collaborative agreements with DEC and Apollo were added to the earlier one with IBM, and successful tests with FDDI equipment from IBM, Apollo, and AMD were carried out. Existing fibres were certified for use with FDDI, such that an FDDI backbone can be implemented during 1990.

That the Ethernet system is still working well is due in a large part to major progress on in-house network management and monitoring tools (in the continued absence of adequate industrial products). The Ethernet database continues to be a key element, despite the difficulty of keeping it up to date.

In the laboratory, a compact Device for Ethernet MONitoring (DEMON) was developed using our existing G64 bus Ethernet card. This device has features that are not available commercially, and is already giving useful results. It has aroused industrial interest.

### Transmission Services

The main emphasis for new terminal connections has continued to be the use of Ethernet terminal servers. Only about 230 INDEX lines were installed or moved (less than half the level of recent years), but more than 550 connections to servers were installed or moved. There are now about 300 servers at CERN, more than half managed by DD.

Repair interventions on INDEX and the terminal servers continued normally, as did the coordination and advisory service for terminals. INDEX was available for more than 99.8% of its scheduled up-time. Statistics showed that more than 500 existing INDEX connections were no longer used. With the closure of CERNET, the INDEX monitoring system (SIMON) was transferred to run on a PC connected to Ethernet.

Terminal server coordination and management continued to prove time-consuming, and industrial support is being sought. LEP start-up brought the lack of terminal server connections to the IBM VM service to a head; this was resolved by a terminal access gateway (TAG) which provides access to the IBM via Ethernet and TCP/IP for terminals connected to DEC terminal servers.

Modem support and installation for on-site and off-site connections (including X.25) reached a record level. First-line support for X.25 hardware continued. Support for small printers was dropped during the year, as such printers are now normally part of PC configurations.

### Network Software & Services

The number of stations on Ethernet doubled during the year, mainly spread amongst IBM-compatible PCs, Apple Macintosh PCs, personal workstations, and terminal servers.

The use of the TCP/IP family of protocols has continued to grow, with two major events : the changeover of about 1000 systems in January to use officially allocated addresses, and the opening of the first off-site TCP/IP services to other HEPnet sites towards the end of the year. Today, TCP/IP is indisputably the first choice among vendor-independent protocols, filling the role previously foreseen for the ISO/OSI protocols. Nevertheless, support of the LEP experiments in the form of an OSI Transport Protocol package for both OS9 and G64 systems has been appreciated, with the package delivered to ALEPH, DELPHI, and OPAL.

There are now at least 700 users of Novell Netware (mainly supporting Ethernet-connected IBM-compatible PCs) and probably an equal number of Apple Macintosh users connected directly or indirectly to Ethernet. These user communities have raised unsolved problems of central support.

The world-wide HEP DECnet again grew dramatically (now more than 10 000 nodes), as did the DECnet on the CERN site (more than 500 nodes). Additional dedicated routers were introduced, and various connections were added (ESA, NIKHEF, NORDUNET,...) or enhanced (Italy, Switzerland, Germany, USA,...).

For external services in general, 1989 was the record year so far for growth in leased-line bandwidth and connectivity. A 2 Mbit/s line from INFN/GARR Bologna came into service in July. Another 2 Mbit/s line from

ETH Zurich, and 256 kbit/s lines from IN2P3 Lyon and CEA Grenoble, were ordered. A 1.5 Mbit/s line from NSFnet via Cornell, donated by IBM, was also on order. A 64 kbit/s line from DESY Hamburg was brought into service, among others; at the end of the year a total of 40 lines (including EARN and EASINET) was operational or on order, with a total bandwidth of about 7.5 Mbit/s.

X.25 services continued to develop, notably by the opening of services to NIKHEF and NORDUNET. At present, both TCP/IP and DECnet rely heavily on X.25. A management system for X.25 was purchased and installed, and proved to be useful for both operations and statistics, although increased functionality promised by the manufacturer is still awaited. A survey of the market in high-speed X.25 switches was initiated, and a dedicated X.25 switch was operated in the framework of the migration of EARN to OSI protocols. On request from Belgian and German physicists, CERN agreed to join the X.25 pilot project for the Eureka COSINE network. Finally, documentation and administrative mechanisms were established to assist the use of terminals from home via the French and Swiss public X.25 networks.

EARN services continued normally with sustained growth. CERN was the first site to provide connectivity between the old EARN and its new OSI-based backbone, but progress has been slow. Succesful tests were made of software to run EARN traffic over TCP/IP. Meanwhile, progress was made in plans for EASInet, the IBM-sponsored network intended to link various academic supercomputer centres in Europe.

Support and enhancement of electronic mail services continued to consume much effort. Efficiency was improved by more use of the SMTP protocol over TCP/IP, by various reconfigurations of the gateways, and by upgrading the central mail gateway (MINT) to a modern machine financed by SWITCH (the Swiss university network). A software package from DFN (the German research network) was used to provide external connections fully conforming to the X.400 standard.

To improve organization of the many wide-area network services used by the European HEP community, two HEPnet committees came into operation during the year : the HEPnet Requirements Committee (intended to express physics needs); and the HEPnet Technical Committee (intended to coordinate planning and operation). The latter is currently chaired by CERN, and has set up various specialised sub-committees. In addition to the HEPnet committees, CERN has continued to participate in other relevant international network coordination activities, including RARE (for OSI), RIPE (for TCP/IP), and EARN.

#### Network Management

The sustained growth in all network services means that network management has continued to be of concern throughout the year. The major development has been the provision of a graphical display utility that shows the state of bridges or routers in a given network. Although developed for internal networks this has proved very useful for the external networks also. It is also in use by ALEPH, and has generated considerable interest outside CERN in the continued absence of suitable industrial products. At the same time, the network alarm system has been refined and has come into full use by the Computer Centre operators. An alarm server is under development to allow alarms to be generated for the electronic mail gateways.

Related database work advanced during the year, in particular with the TCP/IP address database becoming operational. However, it did not prove possible to load data from the CERN Ethernet database automatically into a database used by the DEC network management service. It proved necessary for DEC to undertake a detailed equipment census instead.

System management of the various computers used for network management, network databases, and gateways, required continuous effort.

#### Telecommunications

The telephone service again ran normally throughout the year, despite heavy pressure on the operational staff, caused by the simultaneous use of two exchanges, and a high rate of faults on aging equipment. By bad luck, one of the main cables leading to the SPS failed during the first weeks of LEP commissioning, and could not be repaired for some days. The telex service ran smoothly, with increasing use of computerised access, and the use of telefax continued to increase (60 machines now installed).

The telephone cabling database was successfully implemented to replace the old paper wiring lists, but these proved to contain many errors accumulated over the past decades. An updating campaign has been planned.

Installation of the new digital exchange for LEP was finally completed, under the responsibility of SPS Division, although not without software problems. All the material to extend the LEP exchange to replace CERN's worn-out electro-mechanical exchange was delivered, and partially installed and tested. Good progress was made on the basic software for call accounting and for PC-based operator consoles. A provisional date of 1 July 1990 was set for the final cut-over.

# Management Information

## Administrative Data Processing

*Computer service*

1989 was the year of the migration from our old IBM 4361 computer system located in building 5 to a much bigger SIEMENS 7890 located in the main computer-room in building 513. As a result of the larger computer-power available, we had the opportunity of going to a new release in VM/SP (5.15) and we could do an important step from an obsolete DOSVSE system to the brand new VSE/SP release 3.2 which required a review of all production JCL. An other important fact, in running a more powerful computer, was the significant decrease in the response time for our users.

*Personnel & Pay-roll systems*

The personnel system was confronted with an increasing number of on-line users due to the fact that the leave recording was generalized in 1989 and many group level users where added to the system. This results in an increased user support and maintenance effort. Version 4 of PAYPER was put into production. It implements modified staff rules and introduces some enhancements. For the ORACLE database almost 10 major applications were connected to the central personnel database, which is now updated every night. A new application was worked out to process the outside firms personnel data, in view of a merge into a single view of all persons authorized to access the site.

*Purchasing & Receiving*

The automatic bill checking system (the incoming bill is compared with the corresponding unpacking data and released for payment if the delivery corresponds to the bill) results in accelerated administrative treatment of bills. The link between COPICS and the financial database also improved significantly. The project EFP (Electronic Form Processing) allows some users to handle internal purchase requisition without paper.

*Financial Applications*

The most important development in 1989 was the implementation of the PPA project (Project Program Accounting). The financial system now allows analysis of the financial situation not only by units in the organic structure of CERN (groups, divisions, etc..) but also by program, project, activity, etc. Furthermore, the system now charges personnel costs to the groups and projects, whereas previously personnel cost was only considered on a divisional level. This required the introduction of a mechanism to keep track of personnel assignments to projects. In addition, the CERN plan of accounts has been completely reviewed. The new plan of accounts should allow better analysis of expenditure its economic nature.

## Office Computing Systems Support

Office Computing Systems group continued throughout 1989 to provide basic services in the office area to all of CERN : purchasing of equipment, installation, user training, development.

Text processing support improved and was made considerably more reliable. This trend continued with the introduction at the end of the year of a set of industry-delivered and supported products for the central IBM service. TEX is available and supported on many systems; SGML-compatible macros are being introduced.

A number of corporate databases were delivered to the users or improved, e.g. the Users' Office, the CERN Inventory, the front-end Personnel database. The conversion of the ageing TIS radiation badge database started and is well underway. These services are based on ORACLE and part of the unification policy. The CERN Hostel was equipped with an industrial hotel management system based on our standard Olivetti PCs.

Electronic Forms Processing, even though it remains a solution that needs to be reviewed, spread from the original pilot installation in PS to other divisions.

The PC shop delivered Olivetti and Macintosh PCs as usual. Its service to MIS users was extended to the whole of CERN. A new tender for the acquisition of IBM compatible PCs with fresh evaluation of the market and consultation with the user divisions resulted in renewal of the Olivetti contract. User training was contracted-out under our supervision and at the end of the year the organizational responsibilities were transferred to Technical Training, with MIS continuing to give assistance. A number of seminars for secretaries and for new supervisors were given.

The Departmental server project culminated in the construction of a server for PC and Macintosh type systems giving file sharing, data dissemination, mail, format conversion etc. It was implemented successfully and ported to an industry-standard Unix system. Software was written to make PostScript LaserWriters on AppleTalk networks accessible from non-Macintosh computers. Finally, OCS continued to run the successful public service Desk Top Publishing room and operated computer systems for SIS, ST and DG/AG.

## User Support

### Resource Management

Centralised accounting, budget control and reporting for the IBM VM, Siemens VM, CRAY Unicos and VAX VMS (not budget control) services based on the CCDB ORACLE database have now been completed.

The section collaborates strongly with the other Computer Centre groups and with the physics community in ensuring that the resources are used as efficiently as possible and allocated according to the requirements of the CERN Experimental Program.

The FATMEN (File And Tape Management for Experimental Needs) requirements were specified and the basic system was written and installed on the CERN central systems.

New random number generators have been introduced on all central computers and a completely modernized version of the function minimizer package, MINUIT, has also been installed.

APOLLO support has been given in the form of user guides, training and development of tools. Training programs have been organized and given for PAW and GKS.

### User Interfaces

The Section was reorganized in May 1989. Coordination of the User Consultancy Office was continued. A new stock room for storing self-service documentation was constructed next to the UCO help desks. Obsolete Writeups were deleted from the catalogues, and some other Writeups were converted from Script to SGML. The 'Prologues' used by the FIND command were updated.

New utilities and packages introduced included VMIO (replacing IOPACK), the WHO and PHONE utilities, the VAX versions of XPRINT and XSCRIPT, and a new VAX utility called GRPLOT.

The VM Users Guide was completely revised and rewritten. The CRAY Unicos Users Guide was completed and published. The report 'Computing at CERN in the 1990s' was finally edited and published.

Support of the Central VAX Cluster continued, including maintenance of the Registration programs and the management of disk space.

Work continues on improving the FIND command. The IBM character set problems have been largely resolved.

### Program Library

The CERN Program Library and the related documentation has been distributed to several hundred institutes all over the world, and big improvements have taken place in the support of remote users. News concerning the Program Library is now broadcast to a list of remote users at the same time as they are issued on the CERN Central Services. An electronic copy of the Computer Newsletter is available to remote users. Installation procedures for the Library have been greatly streamlined to help non-local users to export the CERN software environment. Installation guides are in preparation for all the systems.

The Library has been ported to new platforms (ALLIANT, CONVEX) with the active collaboration of the vendors. Particular attention has been devoted to the UNIX world. The UNIX version of the Library is constantly upgraded and C is used to provide portable code in the area of system interface and communication.

A major effort has been made in the area of optimization for advanced architectures. The code of the Library is being analysed in order to find opportunities to enhance its performance via micro-parallelization and vectorization. New routines have been introduced and existing code has been upgraded to take full advantage of the Vector hardware of CERN's mainframes. Work is being done particularly on the GEANT Simulation Monte Carlo where a substantial CPU gain is hoped for. This work is mainly done by IBM personnel presently at CERN in the scope of the European Supercomputer Academic Initiative. CERN has also been actively involved in the European Supercomputers Organization SUP'EUR which held a meeting hosted by CERN in September.

Improvement has continued in all areas, leading to the replacement and removal of obsolete code which, where necessary, has been replaced by newly written software mainly in standard FORTRAN 77. New versions of existing programs have also been installed and distributed, containing fixes and new features, in a constant effort to meet higher software standards.

New physics generator Monte Carlo codes have been introduced and existing codes have been upgraded with the active participation of the authors. Interaction with the authors has been particularly successful in the areas of code standardization and machine portability.

The documentation on the supported programs has been continuously updated to reflect changes in the code and users' feedback. The conversion of the Program Library manual from the old text formatter to new products has begun. This will simplify the extraction of machine readable documentation and the maintenance and enhancement of the existing documentation. An interface with a database for automatic information retrieval is under study. User problems have been analysed and solved, providing active support and advice for the user community and feed-back for the Library staff.

Efforts to improve the service to users of the Computer Science Library are being made.

**Package Development**

*PAW, The Physics Analysis Workstation system*

PAW has been operational for more than a year; a large amount of feedback has been received from an increasing number of users both at CERN and outside. A monitoring program has been developed which shows 1100 different users and 150 000 sessions in one year on the CERN IBM only. A new PAW manual has been produced and more than 4000 copies distributed.

The HBOOK interface to the new MINUIT has been completed. New 2-D and 3-D features have been implemented in HPLOT, and the graphics quality improved in general.

HIGZ, the graphics kernel of PAW, has been substantially developed, and the graphics emulators TELNETG and 3270G released. TELNETG is a utility derived from the standard TELNET program which gives the possibility to run a HIGZ based application on a remote computer (line mode) and to have the user interface and the graphics I/O on the local workstation. The 3270G emulator is similar, but provides full screen support. The HIGZ/PostScript interface has been developed. It is independent of the local graphics package.

The conventional command interface of KUIP has been consolidated and a graphical panel interface developed. There is a new version of the KUIP compiler. An interface with KUIP vectors has been developed for SIGMA.

A complete implementation of FORTRAN I/O is now available in COMIS, and a better communication with the other PAW packages has been achieved (e.g. access to KUIP vectors from FORTRAN routines).

There have been improvements in various areas of ZEBRA (mainly FZ and RZ), and a new package (CZ) to support ZEBRA servers in a heterogeneous network has been developed, as has ZFTP (a ZEBRA file transfer utility) to simplify the transfer of ZEBRA files (both RZ and FZ) in an heterogeneous environment.

More functionality has been introduced in the kernel of PAW, and it has been adapted to the new facilities described above. The fitting package has been upgraded and the robustness improved. There is an implementation on online systems (OS9).

*GEANT*

The current version 3.13 was released in June 1989. The main areas of development were a revision and consolidation of the algorithms for the geometry package and improvements in the hadronic shower package and the tracking system.

*ADAMO*

The version 3.1 of the ADAMO Entity-Relationship data system was offered in beta-test to ALEPH and Zeus. The main changes with respect to version 3.0 are : a portable command interface with KUIP; the TAP package using Zebra (no longer BOS); an extended I/O based on ZEBRA, with extra I/O packages using ORACLE and BOS (for ALEPH); an installation kit based on PATCHY. The TIP, interactive access to ADAMO data and plotting using PAW, was upgraded to 3.1, so that the whole system has a unified command KUIP-like interface. Direct support to various experiments for ADAMO applications continues.

### Experimental Support

The section has given offline support to ALEPH, NA31, OMEGA, OPAL, and UA2. This has been a very interesting year, with the first data from LEP being analysed within hours of being written to tape, and physics publications submitted within the first weeks.

For ALEPH, the Monte Carlo was completed and large event samples generated on various computers. Comparison of generated and real data is in progress. A library of general purpose routines was provided for offline analysis programs. All main software packages are now running on the Cray.

For NA31, the maintenance of the programs and the management of the production continues.

The OPAL reconstruction program chain was ready and operational for the first real data, and has been tuned using this data. The analysis programs were implemented on the Apollo DN 10000, which was then used for event analysis and on-line monitoring.

In OMEGA, work continued to support the WA82, WA85 and WA89 collaborations, in particular to interface software for new detectors. Trident, the offline reconstruction program, was updated to use more modern software packages and utilities, such as Zebra, HIGZ and GKS.

The UA2 production program, modified to handle events with more than one vertex, processed an amount of data equivalent to all the previous years together. The offline software was implemented on the Cray, and a substantial amount of processing was, and is being, done on that machine.

### Graphics

A major new release of GKSGRAL (Version 3.1) has been introduced on all supported operating systems, the list of which has been extended to include UNIX. A staff member has been made responsible for support to CERN-affiliated institutes, of which there are now over 100, and for which a 'NEWS' distribution system also has been set up. Many detailed improvements have been made to device drivers, in particular for Megateks, VAXstations, and the XEROX interface (EPIC); and the metafile plotting, viewing, and editing utilities are in the process of being entirely reorganized with many simplifications and improvements. Various commercial products have been evaluated, including a Tektronix 4236 3D driver, and an emulator package has been selected in order to perform mainframe graphics on IBM PCs. New plotting hardware has been ordered for the Computer Centre. New versions of all the documentation have been produced, two courses on GKS have been organized.

### General

Members of the group have presented various papers, notably at the CHEP conference in Oxford, and editorial work for Computer Physics Communications and Europhysics News was continued.

## Online Computing Support

### Software developments, etc.

Our current software development programme is now generating a substantial support load as the number of users grows. It includes the MODEL data-acquisition suite, VALET-Plus in stand-alone embedded systems, and developments in Remote Procedure Call, FASTBUS and interface software.

The year has been one of intensive preparation for the LEP experiments, whose data-acquisition systems went into physics production in the Autumn. This required a corresponding effort in developing the MODEL data-acquisition suite further, in line with the evolving needs of users. Substantial improvements were made to all the major subsystems, and many of the modules have reached a rather stable state. This software is now in regular use by three of the four LEP collaborations. At the same time, the group was involved in bringing up new data-acquisition systems for several other experiments, notably at LEAR and OMEGA. The State Manager, a powerful new approach to run control developed in conjunction with DELPHI, was implemented and tested during the year and is now in use in several experiments. A substantial effort went into the integration of MODEL with VALET-Plus front-ends, and is now in production in the OMEGA and CP-LEAR data-acquisition systems. A demonstration system for integrated MODEL and VALET-Plus is now available to help new experiments. Work has begun on porting parts of MODEL to UNIX in collaboration with the WA89 experiment, and on preparation for a system-independent version of MODEL.

A major new release of the VALET-Plus software was prepared : this incorporates the developments made for integration with MODEL and VAX hosts. It also includes new libraries, improvements in communications and the user interface, and extensions to the SPIDER data-acquisition system. It is accompanied by a new version of PILS incorporating many improvements. Nearly 200 VALET-Plus systems are now in use world-wide, and high-rate data-acquisition systems based on VALET-Plus are running at OMEGA and PS195. A version of the VME-based VALET-Plus software is now available on the CHI (CERN Host Interface) in FASTBUS. Exploratory work has begun on porting some of the VALET-Plus software to OS9.

The full software for the CHI high-speed FASTBUS to VAX connection is now available : it is in production use by DELPHI, L3 and elsewehere. The same software is used for the HVIOR high-speed VMEbus to VAX link of the OMEGA data-acquisition system. A scheme for support of the VMS driver for CHIs interfaced to the VAX BI is now in operation. In several experiments, data transfers are now made over optical fibre links. Progress has been made on bringing up OS9 on the CHI, and we have begun work with a CHI connection to the DECstation 3100 based on SCSI.

The range and functionality of our Remote Procedure Call facility has been substantially enhanced in new versions released during 1989. Work has begun on gateways to allow interworking with other RPC systems. The first phase of a Transputer-based event-builder for the JETSET experiment is now complete, and has been operated in a test beam.

### Hardware-related Support Activities

Technical and commercial consultancy provided by OC includes : following the OEM market; evaluation and recommendation of add-on equipment; helping to negotiate discounts, conditions of purchase and after-sales service; setting up on-site maintenance; setting up simple and coherent procedures for users etc. In 1989, considerable effort also went into direct user-assistance in installations, system reconfigurations and upgrades. This was particularly the case for DELPHI (multi-microVAX set-up in the pit) and L3 and with the TA90 installations at OMEGA, OPAL and OBELIX.

The year was marked by an enormous increase in the number of DEC workstations. There are now about 450 VAX- and DEC- stations on site, in addition to the 50 or so VAX systems and over 100 microVAXes; there are also 4 NORD 100/500 systems still in use.

The number of supported CFIs has stabilised at about 70 units (of the 100 or so on-site). The new CHI became commercially available by mid 1989, and more than a dozen are already in use at CERN. We have made a proposal for an on-site CHI support service (similar to that for the CFI) with the cooperation of the Electronics Coordinator.

About 40 STC 2925 tape units are now in service or on order, mainly for use with microVAX or VME systems. Many users take advantage of our on-site repair agreement with DEC for this OEM equipment. Evaluation of 3480-compatible drives in online environments has been carried out over the year with a view to solving technical problems, making recommendations and setting up appropriate maintenance arrangements. It has concentrated on Q-bus, VMEbus and SCSI environments.

The microVAX Pool has now been in existence for over two years : a 5th system was added in mid-1989. Up to Christmas 1989, 20 allocation requests were fulfilled : the hardware was allocated for more than 75% of the time, and on average, each configuration is allocated 2 to 3 times per year. The CAVIAR pool operation and the corresponding repair contract were discontinued at the end of 1989, and active pool CAVIARs transferred to their owners.

The group's budget planning and accounting was transferred to a Macintosh, enabling us to make use of the various MIS tools available in that area. The new ORACLE Database for the EP-ELI group was successfully implemented during 1989. Our DECCO database has become a useful tool for the administration of the DEC DOSSIERs and DEC maintenance contract extensions, and we have participated in attempts to harmonise the various related database applications in our area.

### Other Activities

Papers on several aspects of the group's work were presented at the Real-time Conference (Williamsburg) and the Conference on Computing in High-energy Physics (Oxford). During 1989, four issues of the Mini &

Microcomputer Newsletter were edited and distributed by OC; there are over 1200 subscribers, over half of whom are off-site.

## Advanced Computing development

### Introduction

The Advanced Computing (AC) group has been in existence since October 1988. It is structured around three main activities :

- Support and expand 3081E emulator farms in use. Evaluate IBM VLSI /370 Chip Set processors (PPCS) as a possible replacement for the 3081E emulators.
- Become a centre of expertise in the use of Transputers in experiments.
- Evaluate new technology and new methods in order to acquire skills which can contribute to solve data handling problems for the next generation of experiments and accelerators.

### Emulator & IBM Parallel Processor Activities

*Emulators*

3081E emulators have been heavily used in on-line and off-line activities. The March-June 1989 run of UA1, centred on Muon physics, has put the data acquisition system under heavy pressure, with event rates of 25 Hz after the first trigger and 10 Hz after the second trigger (which is the input to the 12 emulators). The average processing time in the emulators was 100 ms for rejected events and 1 s for interesting events. All events were recorded with the interesting ones going on separate tapes.

Many thousands of cartridge tapes have been written on four 3480 cartridge drives controlled by an IBM 9375-60 CPU. During 1989 the interesting events were analysed off-line both on the same 3081E emulator farm and in the computer centre. The Rome-INFN and the MIT farms have been exploited non-stop for both Monte Carlo analysis and data analysis.

With the LEP machine starting summer 1989, DELPHI and L3 collaborations have started to use their farms of emulators. Nine emulators equipped with 5 megabytes of memory and interfaces to FASTBUS have been prepared for the L3 and DELPHI collaborations. Three have been integrated on-line in DELPHI, four have been integrated on-line in L3 and the remaining two are used for program development and on-line support. Within the first weeks of LEP data taking they were already fulfilling their role of event monitoring and data structure checks. The L3 off-line farm of emulators connected to the LEPICS was also operational for analysis.

*IBM PPCS*

In June 1989 the first IBM VLSI /370 Chip Set system has been installed at CERN. It consists of a /370 host system (an IBM 9373-30) and a Parallel Processing Compute Server (PPCS). The PPCS itself is composed of 32 processors (of the type 9373-30) each with an IBM proprietary interface. Our contribution to the Joint Study Project with IBM for this system, known as Stage 2, is the design of a VME interface to the processor ports. The design is finished and we are in the debugging phase. In addition, a simple monitor program (VERMIN) for the processors of the PPCS has been developed and the emulator farm host software package (SYEPAK, VEPAS and VICIS) has been adapted to this platform. The full system once in operation is best suited for an on-line application.

*Emulator-related Activities*

The redesign to put an 3081E emulator on a single board (EMU90), made at CERN by a fellow from the ALEPH Collaboration, has been completed by the APE/INFN of Rome and Pise (EMUAPE). It will be reproduced in quantity as the basic scalar processor for the APE100 (100 GFLOPS QCD engine).

**Transputer Activities**

This is a collaborative effort between one physicist in EP, a MEIKO resident engineer, a SPS fellow, the AC and the OC groups. Details of the projects can be found in the EP section of the annual report. The main objectives are the continuation of the collaboration with MEIKO, the integration and support of the event builder for the JETSET LEAR experiment, collaboration for the trigger system for UA6, continuation of the design of the Transputer/DSP combination (FDPP) intended for very fast front-end processing and the collaboration with Inmos and other European companies to work on the next generation Transputer (proposal submitted to Esprit). 1989 activities include a collaboration with HP(Apollo) and the practical courses given on Occam and Transputers to the CERN school of Computing. New requests for collaboration have been received and are under review.

**Evaluation of new technology & methods**

*Performance Evaluation*

Measurements of the performance of several computer systems using HEP benchmark programs, including the standard CERN benchmarks and GEANT examples, and evaluations of their potential for use in the HEP environment were made. The systems evaluated were :

- T800 Transputer with both the MEIKO and 3L compilers;
- MEIKO Computing Surface;
- ARDENT Titan 2;
- DECstation 3100.

The performance evaluation work necessitated the development of versions of the CERN program library for the Transputer (MEIKO and 3L compilers), and the DECstation 3100. These have been made generally available and are used by several groups at CERN and outside. Support for the libraries is therefore continuing.

*FORTRAN Farming*

The performance evaluation work on the MEIKO Computing Surface led to a detailed study on the possibility of using it for HEP FORTRAN farming, the results of which were presented at the Oxford Conference on Computing in High Energy Physics.

The work on the DECstation 3100 led to a proposal to significantly augment the processing power of existing, VMS based, micro-VAX offline processing farms by the addition of ULTRIX based DECstations. This idea was pursued in collaboration with DEC and has been taken up by the Wisconsin group of the ALEPH collaboration. A West Area heavy ion experiment is also currently considering utilising such a mixed system farm for their offline production.

In addition, a feasibility study of the possibility of FORTRAN farming on a heterogeneous set of network connected workstations using TCPAW for software communication has been undertaken.

*Other Activities*

There have been contacts with SERC projects in the UK, especially those using Apollos and Transputers, and we are now in contact with projects in EPFL, Lausanne. An effort is made to keep up with developments in FermiLab where their ACP developments are far ahead of our own.

We have participated in the integration of HP/Apollo personal workstations with Transputers, and information on the development of software to support the high level languages, C and FORTRAN, and the operating system, Helios. We are participating to the project to design a VLSI FASTBUS interface based on the SPARC coprocessor using VLSI simulation tools (Verilog).

Extra activities center around the theory of parallel systems which are either in use or form part of the future planning of industry. They include :

- tools for Parallel systems : Linda, ISIS
- operating systems, multi threaded tasks, synchronisation, message passing
- valiant theory on non uniform memory access, NUMA, systems

We have helped set up presentations by Multiflow, Convex, Ardent and others in order to stimulate the general awareness of parallel systems.

# Computing Support for Engineering

## General

1989 was the first complete year in which the primary rôle of ED group was Computing Support for Engineering. As such, it saw the creation of many new working contacts and operational environments.

A very important ingredient in this was the establishment, towards the end of 1988, of User Groups in each field of activity, bringing together the support team and engineering representatives from all parts of CERN under chairmen selected from the latter. These groups are a great help in defining future directions and priorities of action.

As a vehicle for informing people on engineering computing matters at CERN, the Computing Support for Engineering Newsletter has grown to have a personal subscription list of over 500. Two issues were produced during the year.

For those involved, the satisfaction of establishing services was often tempered by frustration due to the exceptional financial and staff restrictions at CERN. This has not eased the growth of working relations with the user community. Nevertheless, at the end of the year it is encouraging to see the extent to which rôles have been recognised and partnerships defined. It has proved possible to set up a modest informatics support for Structural Analysis and Field Computation code which is reported on in more detail below. Following a major decision taken near the end of 1989, the support responsibility for CAE tools running on personal computers will move to DD from SPS division along with additional staff.

The interface and high-speed link equipment designed in the group performed essential rôles in LEP experiments. This activity has also been much valued as an 'in-house' user of CAE support.

## Computing Support for Engineering

### *CAE for Analog Systems*

Support continued for ISPICE, the CERN-modified SPICE simulator running on the central VAX-cluster. In collaboration with the CIEMAT institute in Madrid and the division's graphics support team, a new version using the CERN-standard GKS graphics package was introduced. This permits access from GKS-supported graphics terminals and terminal emulators.

The analog analysis and simulation package SABER was introduced as a replacement for the obsolete SCEPTRE and ECAP programs and a complement to ISPICE. It is being used in a number of pilot projects, e.g. for the design study of superconducting magnets for LHC and a plasma lens design. Feedback to the manufacturer, ANALOGY Inc., by continued close contacts and discussions at CERN, has contributed to the inclusion of new features in the simulator and to the setting of directions for its future evolution. Informatics support and applications support for the program is being provided.

Negotiations with the vendor led to an agreement for conversion of the existing three CPU-locked licences to networked licences, allowing SABER to run on any suitable Apollo at CERN. One such conversion was purchased. The implementation of the network licensing scheme foresees the use of SABER on multiple platforms, e.g. Apollo, Sun and DEC, and is planned for the beginning of 1990.

At the request of the Analog Electronic CAE/CAD User Group, conditions for site-wide support of the PC-based analog simulator PSpice were negotiated and grouped ordering has begun.

### *CAE for Digital Electronics & CAD for Electronics*

A network of 5 Racal-Redac Visula workstations, generally operated by layout experts, provides printed circuit board layout facilities for the Research Divisions. For this, the component database was updated and steadily expanded to more than 1400 components, of which 900 are CERN Stores items. There was an ongoing effort to increase layout throughput. A feature was incorporated for the mechanical design of front panels, which is reducing considerably the time spent in specifying the manufacturing data. Skeleton jobs with 'standard boards' are being set up to save time in the initial phases of board layout. Two stations were upgraded to Apollo

DN3500s and network-wide backup on Exabyte cartridges was implemented. Evaluation of the new interactive router was started.

The needs of designers of sophisticated electronics are addressed by a network of 13 DAZIX CAE workstations. A major hardware and software upgrade of this system is in progress. Four Sun SparcStations were received early in order to give the opportunity of familiarisation with the Sun-OS operating system and experimentation with various client/server configurations. The procedure for transferring designs made on DAZIX to Visula for PCB layout was brought to production status. It relies on DAZIX's PCDI package and allows subsequent back-annotation of the DAZIX schematic. The work involved a significant and ongoing effort to harmonise the component libraries of the two systems. In general, efforts were made to pool the work of designers in component model creation and this activity is being reinforced.

The use of programmable logic continues to increase and the two public Unisite programming units received software and hardware upgrades in order to handle new devices. Xilinx and Altera have emerged as programmable logic families of particular interest to CERN. Licence support for the development tools of these products was expanded and the possibility was introduced to include the internal logic of such designs in DAZIX board-level simulations.

*Microprocessor Support (PRIAM)*

A number of the older cross-software tools (the CERN- and ACE-written compilers, the debug monitor MoniCa, and CERN's implementation of the Motorola RMS68K real-time operating system kernel) were consolidated, and now require only minor maintenance work. The manpower made available in this way was invested in more extensive support for the OS-9 real-time system and in investigation of candidate items for future support in both the hardware and software areas.

In 1989 Microware's OS-9 was the most widely used operating system for real-time applications of MC68000-based systems at CERN. This probably will remain the case for several years yet. PRIAM continued licence and update administration for OS-9, served as primary contact to Microware's hotline support and as focus for, and distributor of, every type of OS-9 related information. Specific technical efforts in the OS-9 area were field testing of Internet (Microware's TCP/IP network product), now widely used at CERN, installation and test of Unibridge (an OS-9 cross development tool running on various UNIX systems) and the porting of the X11 windowing package to OS-9.

The investigation of modern, multiprocessor, real-time kernels centred extensive tests of the VMEexec system. This is being developed by Motorola with major contributions from SCG (kernel), Microtec (symbolic debugger), and ACE (compilers). Investigation of new microprocessor architectures concentrated on Motorola's MC88000 RISC chip. The RP88, a MC88000-based co-processor from Tektronix for the Apple Macintosh II, was installed as a convenient test platform and use of the MC88000 with C and FORTRAN compilers was started.

PRIAM continued to administer the VMEbus Blanket Purchase Contracts for CERN. The utility of these arrangements is demonstrated by the turnover of more than 2 MCHF.

The effort in the international working group writing ORKID (the Open Real-Time Kernel Interface Definition) was essentially finished in 1989, with publication of the final document foreseen for February 1990. It is hoped that CERN will be rewarded for this standardisation work through the availability of better and more uniform kernels on the software market. In a further effort which was initiated by PRIAM, the VME Inter-Crate bus, VICbus, had a major success in 1989 with its acceptance by ISO/IEC JTC1 SC26 for official international standardization.

*Mechanical CAE-CAD*

In the last few months, CERN's CAM mechanics project has taken off again, centred on Euclid CAD (marketed by Matra-Datavision), Autocad CAD (distributed by Autodesk), structural analysis (ANSYS and CASTEM), and field calculation (TOSCA).

The present trend in CAD (Euclid) is to distribute use of the CPUs to graphics work stations while benefitting from a centralized data base accessible to all users. The same principle lies behind CAD: grouped around data base servers and software, MS-DOS compatible PCs execute the various modules of the Autocad mechanics system in local mode. Whereas the graphics work stations are entirely dedicated to Euclid, the Autocad PCs are also used for some mechanics structural analysis calculations and generally for office automation purposes (word processors and tabulators, etc.)

During the past year the number of connections to Euclid increased from 31 to 39. The computing power was increased to the equivalent of 50 Digital VAX 11/780 units (the first computer in the VAX range). With the computing power used by the 10 VS 3200 workstations, the Euclid CAD project used the equivalent of 77 VAX 11/780s. The number of Autocad licences gradually rose to 70 in the course of 1989. The range in types of hardware (IBM PC/AT, Olivetti 80386, etc) and the widely differing applications of the PCs prevents any valid comparison between the CAD and CAD in terms of computing power used.

For individual applications, the Central Workshop continued with the CIM (Computer Integrated Manufacturing) of its CNC (Computer Numerical Control) machines. The Autocad and Euclid geometries are regularly transferred onto the CNCs in the workshop. Euclid and Autocad geometries can be converted back and forth between one another using the IGES (Initial Graphic Exchange Standard). The bulk of night-time and weekend computing was used for producing some 800 detailed LEP installation plans. Consisting of 200 000 3D points and 160 000 facets, these plans took up 40 minutes computing time on a VAX 8650 on average. The management of projects like LEP requires the correlation of graphic and alpha-numeric information, and to this end a dedicated interface has been set up between Euclid and the ORACLE relational database management system. Euclid can not only be used for technical data but even for calculating the overall dimensions of an object. When used in conjunction with ORACLE, the data can be used to optimize the spatial handling operations (during installation) of objects in the CAD database. This is just one of the numerous applications of the Euclid-ORACLE interface.

*Training for CAE*

Systematic user training is essential for efficient use of CAE tools. Off-site training was organized in the use of DAZIX and Visula. In collaboration with the training services and User Groups, on-site training was arranged for SABER, Xilinx, Altera, OS/9 and TOSCA and an introductory seminar on the use of PC-based tools was given.

**Interfacing**

The process of turning the production of the CERN Host Interface (CHI) over to industry was largely completed. Examples of this interface family, which allows the complete range of VAX and µVAX computers to be connected to FASTBUS and VMEbus, were installed in the DELPHI, L3 and OMEGA experiments. The FASTBUS versions are being manufactured by Dr. B. STRUCK, Hamburg and the VMEbus versions by Creative Electronic Systems SA, Geneva. Front-line hardware support and general software support is being provided by the division to users at CERN, while DEC supports specially adapted high-performance VAX/VMS drivers.

Six Optical Data Interconnects (ODI), developed in collaboration with the Laboratorio de Instrumentaçâo e Fisica Experimental de Particulas, Lisbon, Portugal, are being used by ALEPH to bring data from the particle detectors, which are 150 meters underground, to the surface. Two more are installed in DELPHI and a 10 km version, using Laser diodes, is in use by L3. The ODI is now also commercially available. In collaboration with Instituto de Engenharia de Sistemas e Computadores, Porto, Portugal, a G703 version of the ODI was designed and prototype tests have begun.

With an eye to the needs of future experiments, investigations were started on the emerging High Performance Parallel Interface (HPPI), a 200 Mbyte/s link with distance-independent protocol, presently under review by ANSI and ISO. Contact has been established with the main backers of HPPI (AMT/DAP, Cray, DEC, IBM, MEIKO and the Los Alamos National Laboratory) and simulation and design work on HPPI has begun.

**Divisional Electronic Prototype Workshop**

The workshop continued to support electronic development activities and the hardware infrastructure of divisional services.

Some 190 construction and wiring jobs were handled, including 90 where the workshop staff managed external sub-contracting. To satisfy the growing need for miniaturisation of electronic equipment, support for construction using surface-mounted devices was established and is now in full operation. On the other hand, a decline was seen in the use of wirewrap as a technique for prototype board construction.

The production of schematic diagrams and the layout of printed circuit boards in the division are now entirely based on computer-aided techniques. While designers themselves were largely responsible for schematics, a significant amount of schematic entry was still done for those reluctant to learn the techniques themselves. The coordination of printed circuit board layout creation among the research divisions was reinforced. In DD some 30 PCB jobs were handled. The majority originated on the DAZIX CAE systems, having been transferred using DAZIX's PCDI interface package.

## Direct Support to Experiments

One engineer continued to support NA36 directly. In view of the small CERN involvement in this experiment and the increasingly rare presence of the external collaborators, he played a key rôle in maintaining the equipment, especially the $\gamma$ detectors and the main spectrometer magnet, in an operational state.

## Other Activities

The group participated in a number of extra activities, both inside and outside CERN : Leading rôles in several standardization activities related to VMEbus (EPAC, ORKID, VICbus); Chairmanship of the EUCLID user group (including organization of their international user meeting); Organization of the Swiss DAZIX user meeting.

Work was presented at the Europhysics Workshop on Real-Time Systems, Chamonix; the Eurobus Conference, Munich; the 'Sixth Conference on Real-Time Computer Applications in Nuclear and Plasma Physics', Williamsburg, Virginia; and 'VMEbus in Industry', Paris.

# Proton Synchrotron Division

The successful operation of the LEP Preinjectors was the year's top priority for the Division and this paid off handsomely for the spectacular start of LEP. The year 1989 also marked the 30th anniversary of the first beams in the PS Ring, and a year in which the 'Particle Sources' Division broke the all time records in various accelerators comprising the PS Complex. The ubiquitous PS Ring broke new records in proton beams for antiproton production, beam for fixed target physics in the SPS as well as in its new role as the Lepton Injector to the SPS. The PS Booster triumphed over previous records in intensity per single ring and the ensemble of Lepton Preinjector Linacs and Electron Positron Accumulator (EPA) produced record intensities in electrons and positrons. The AAC (Antiproton Accumulator and Collector complex) surpassed the mark of $1 \times 10^{12}$ antiprotons stored and, achieved record performances in accumulation rate (Fig. 1). Last but not least, the LEAR ring had the first ever runs with oxygen ($O^{8+}$). For its role as a supplier of protons and antiprotons to the SPS Collider, all time records were broken in the daily production rates (Fig. 2) and the total quantity of antiprotons supplied, leading to record luminosities (Fig. 3). All this was achieved with the different accelerators providing a high degree of availability for physics and, with diminishing human and financial resources. The Division's resources have also been called upon for possible new projects including the construction of a Beauty factory, ISOLDE displacement to the vicinity of PS Booster, CLIC and LHC. Tables 1 to 5 and Fig. 4 illustrate the breakdown of the year's operation of the PS complex. (The figures are on pp 106–109; the tables are on p. 110)

## LEP Pre-Injector – LPI

The five month shut-down of the LPI at the start of the year during the $p\bar{p}$ collider runs was used intensively to repair the end flanges of the accelerating sections of the linac LIL. This was because six of them had sprung a vacuum leak due to chlorine corrosion at the end of the previous year. This major undertaking was carried out in close collaboration with the CERN central workshop. In parallel, some of the high voltage elements of the LIL modulator/klystron stations which had proved less reliable during the commissioning were replaced to give a better overall system reliability.

After a hectic period for re-installation, re-alignement and HF re-conditioning of the whole linac, the LPI was ready, just in time for the start-up of LEP at the beginning of July. It then remained in operation for the rest of the year, performing extremely well and with an overall availability exceeding 95%.

The reliability of the complex was further improved by operating the $e^-$ to $e^+$ converter in a fixed position, thus avoiding the pulse to pulse mechanical movement in a high radiation area.

Finally, the first part of the consolidation programme has been completed by equipping the key LPI elements with adequate spares and rejuvenating the modulated power supply of the electron gun, the unique source of all leptons at CERN.

## Hadron Injectors – HI

During 1989, both Linac1 and Linac2 functioned well in the usual reliable manner. Linac2, the main source of protons at CERN, underwent upgrades of its mechanical tuning system, the water flow monitoring system, and the RF systems. Linac1 continued to fulfil its role as the normal source of protons for LEAR. It was also the scene of an oxygen/sulphur ion run intended to check out the new hardware and carry out some major improvements. The latter included the improvements to the ECR ion source and, in the quality of vacuum. The new hardware included a means to measure the sulphur content by cycle stealing (needing a pulsed de-grader and new optics) and a novel, almost non-destructive, thin-wire ion beam profile monitor.

The latter was also profitable to the PS Booster (PSB) where the upgraded electronics for bunch phase detection proved beneficial for the low-intensity ion performance. This was the first time that ions were accelerated in the PSB to a magnetic rigidity corresponding to 1 GeV protons (326 MeV/amu). On the proton front, the PS Booster continued to pursue its tradition of being involved in record performances :

(i) The SPS fixed target beam intensity was increased (in the PS at 14 GeV/c) to $2.57 \times 10^{13}$ protons/pulse, mainly due to the use of h = 10 cavities in the PSB which allow the squeezing of an increased number of protons in given emittances.

(ii) The antiproton production beam was increased to $1.75 \times 10^{13}$ protons/cycle (PS at 26 GeV/c) by using both the recombination by an RF Dipole in the 1 GeV PSB-PS line (yielding a beam filling half the PS circumference) and the adiabatic harmonic change scheme in the PS (to squeeze the beam into a quarter of the PS circumference).

(iii) A new sum-of-four-rings record of $3.3 \times 10^{13}$ protons/pulse at 1 GeV/c was obtained, auguring well for the proposed ISOLDE operation near the PSB, which would profit from all the Booster cycles not used by the PS machine. Future operation with ISOLDE would imply a 3-5 fold increase in average PSB beam intensity. The studies of the ensuing higher machine irradiation and other aspects are underway.

The high intensity proton RF Quadrupole accelerator, being developed with a view to replace the ageing 750 kV Cockcroft-Walton pre-accelerator of Linac2, was installed on its test bench, by now fully equipped with ancillary devices. RF measurements, at low level, have shown that the accelerator structure meets design specifications and is ready for beam tests. The beam to be injected into the RFQ (90 keV, about 250 mA) has been analysed and found to be satisfactory.

The HI staff continued their involvement with the major beam diagnostics components (current transformers, position monitors, profile monitors) of the PS Complex for which they are responsible. In addition to making the systems work and improving them, new profile monitors were installed in positions which needed them most urgently.

A development of maybe more general interest is a standard 'Diagnostics Protocol', which enables a central control system to meaningfully communicate with local intelligent devices treating a specific beam monitor. Such a protocol was successfully tested with the PSB slow beam-current-transformer used as a potential application.

## Main Proton Synchrotron

### Operations

The year commenced with the necessary preventive maintenance and important installation activities concerning all of the accelerators of the PS complex. The access control systems of the Booster, Linac2 and LEAR were renewed on schedule and the last week of February saw the first beams in the PS as part of the technical running-in week after the long Christmas shutdown.

The first period of the year was virtually dedicated to the SPS Collider operations upto July, with intensities and luminosities increasing steadily (see Fig. 2 & 3), interspersed with breakdowns somewhat expected for such a long run. A series of major electrical failures which coincided with the long Easter weekend, hence reduced staff, meant that the running through the Easter weekend was rather unfruitful for physics. However, the month of May proved out to be spectacular, with the antiproton accumulation rate often exceeding $50 \times 10^9$ antiprotons/hr and, for the first time, the total daily production exceeded the AA design figure of $1 \times 10^{12}$ antiprotons accumulated per day. This led to the figure of 1800 nbarns$^{-1}$ in integrated luminosity achieved over 31 days, an all time record since the birth of the SPS Collider.

The Whitsun weekend running in May saw no major problems as at Easter and the antiproton production beam saw another all time high of $1.55 \times 10^{13}$ protons/pulse on target, using vertical recombination scheme in the PSB-PS transfer line using a RF dipole. This record was further improved in June to $1.63 \times 10^{13}$ protons/pulse. June also saw the first ever production of positrons and electrons by the LEP preinjector; $1.5 \times 10^{11}$ positrons and $1 \times 10^{11}$ electrons in four bunches were injected and circulated in the PS as part of the preparations for the LEP commissioning, which commenced on schedule in July.

The end of the Collider run also enabled further machine development sessions especially for the high intensity, antiproton production beam. In September, using all four Booster rings, vertical recombination in PSB-PS transfer line and longitudinal merging in the PS, a record intensity of $1.75 \times 10^{13}$ protons/pulse in five bunches at 26 GeV/c was achieved. This was an important accomplishment leading to substantial energy savings for the rest of the year because 24 hours were normally sufficient to produce and replenish the Accumulator with antiprotons. For the rest of the year,the Antiproton source complex ran in this energy saving mode with two substantial fills per week sufficient for LEAR consumption. For the remainder of the week, the production chain was usually switched off with the antiproton transfer to LEAR being the only active process.

While the second half of the year was visibly devoted to the LEP commissioning and physics runs, the versatile PS continued the other operations in parallel for the SPS fixed target physics, AAC and LEAR as well as test physics beams for the East Hall Experimental Area. The average availability of the PS complex for leptons was over 91% for the second half of the year. The year's operations ended with several faults due to power cuts beyond CERN's control, causing interruptions in antiproton physics at LEAR and, partly in the lepton transfers to the SPS and LEP.

**Radiofrequency Systems**

The new antiproton production beam systems first set-up in November 1988 were further refined during the long SPS Collider run which started in March. Subsequently, $1.5 \times 10^{13}$ protons per pulse were routinely delivered onto the target. As mentioned earlier, record intensities were finally achieved by combining the two processes of funnelling in the Booster-PS transfer line and, longitudinal merging inside the PS at 3.5 and 26 GeV/c. A lot of minor RF hardware improvements in the Antiproton Collector and in the PS helped to achieve an excellent overall reliability despite these sophisticated and complex operations.

For leptons, the RF systems were ready on time to contribute to the successful commissioning of LEP in July. However in September, a vacuum leak in a bellows of the short circuit arm of the 114 MHz cavity interrupted the beam for 40 hours. No other major faults were experienced later, and a standard beam of 4 bunches was regularly delivered to the downstream machines. The two other types of lepton beams as foreseen ('long bunch expansion' & 'double batch ejection') were also successfully prepared, although not immediately needed by SPS or LEP.

A single bunch proton beam was specially set-up on a PS 'A' cycle and was successfully used for the energy calibration of LEP.

For the proton beam used for fixed target physics in the SPS, new intensity records were achieved due to the improved behaviour of the PS ferrite cavities with respect to beam loading, largely contributed by the RF feedback implemented in 1988.

**Instrumentation**

In the PS, special electronics and coupling networks have been developed and produced to extend the low frequency sensitivity of the normal closed orbit pickup electrodes over the frequency range of 7 kHz to 2 MHz. Moreover, the closed orbit acquisition system has been modified to allow the acquisition of the trace of a selected bunch over two consecutive turns in the PS, independent of the injecting accelerator.

During the October shut-down, ten beam loss monitors have been installed in the TT2 line and interconnected with the associated electronic chains for measurement and display. The signal display of these ten monitors has been incorporated to the existing hardware and software of the 100 beam loss monitors of the PS ring.

Synchrotron light monitors have been designed, manufactured and installed in section 12 of the PS ring.

**Beam Studies**

*Leptons*

Studies have continued to prepare the PS for an expected future demand to provide increased intensity to SPS/LEP, namely :

(i) A technique was developed for accelerating leptons with the 114 MHz cavity and ferrite cavities tuned to 3.8 MHz, so as to produce longer bunches. This will let the SPS run tests to capture bunches of leptons with the same density but higher intensity, with the RF system at 100 MHz.

(ii) The maximum intensity of accelerated electron bunches, which is limited by the instabilities created by the ions captured by the beam, was raised to $4 \times 10^{10} e^-$/bunch using transverse feedback techniques.

(iii) The 3.5 GeV re-synchronization technique was put into operation and can be used to eject two families of four bunches towards the SPS.

Mention should also be made of the contribution of the PS studies team to the LEP start-up and to the orbital correction studies carried out at LEP.

*Hadrons*

Satisfactory trials were carried out for two weeks in May on the first phase of the new slow ejection 62, resulting in the approval of this project.

A special 14 GeV proton beam was prepared for SPS/LEP to make a precise calibration of the nominal running energy of the LEP ring.

*New projects*

Studies were conducted to accelerate lead ion beams in the PS for fixed-target experiments in the SPS and for LHC. In addition, major contributions were made to the 'beauty factory' project in the ISR tunnel, i.e. performance and injector modifications, machine lattice, collective effects, etc.

**PS Ring, Magnets & Septa**

During the long shutdown, refurbishment of the PS Ring continued, with the complete overhaul of Octants 3 and 4. The straight sections were also refitted to take the hardware needed for partial slow ejection tests and for installing the synchrotron light monitor.

Problems with cooling water circulation for the AA septa led to the EPA demineralized water station being shifted to the AA and to a new station being built for the EPA.

The Magnets Section carried out the magnetic measurements for the Group and the Division, overhauling and preparing magnets for the experimental areas and undertaking the acceptance of new magnets (some 20 in all). It also took part in design work for a superconducting sextupole coil for the LHC; it designed, produced and tested various solenoid systems for CLIC, LIL and LEAR, drafted the final technical note for the LEAR PFWs, and did the calculations and designed the bumpers for COSY/Jülich.

## Antiproton Accumulator & Collector – AAC

The first half of the year was dedicated to the SPS Collider with only a small fraction of the $\bar{p}$ production going to LEAR. On several occasions, the daily production exceeded $10^{12}$ $\bar{p}$, thanks to the the good performance and reliability of the AAC. The running during the second half of the year was exclusively for LEAR. The low $\bar{p}$ flux required by LEAR permitted intermittent stacking, with reduced power consumption and lower operating costs. The $\bar{p}$ stacking rate has evolved steadily from $12 \times 10^9$/hr in 1988 to $58 \times 10^9$/hr in 1989, thus achieving a factor ten in improvement over the AA operational stacking rate before ACOL.

**Production & Collection**

A target made of iridium embedded in graphite continues to be used for $\bar{p}$ production . The primary proton beam hitting the target improved substantially during the year, yielding a larger number of antiprotons, thanks to the various RF gymnastics in the Booster and PS. Despite these higher intensities, no yield degradation due to possible target damage has been observed. The improved primary proton beam was kept in operation with reduced intensity for LEAR runs in the second half of the year.

Various developments have been carried out during the year for improving the collector lenses used immediately after the target. A lithium lens of 20 mm in diameter, pulsed at 480 kA, was the principal lens used operationally and yielded $62 \times 10^{-7}$ $\bar{p}$/proton on the AC injection orbit after various optimisations. Early in the year, it was planned to use a larger, 36 mm lithium lens but, after a flange failure at $1.1 \times 10^6$ A in the development laboratory, beam trials was postponed to July 1989. This lens is mounted inside its toroidal transformer which has been developed in collaboration with INP-Novosibirsk, USSR. The related 200 kJ power supply and pulser have been designed at CERN and built, partly in industry, within a record time of six months. This equipment is able to deliver a current pulse in excess of $1.2 \times 10^6$ A within the specifications of 1 ms rise time, 3.5 ms duration and a repetition rate of 2.4 s. After extensive development and life tests, this lens was successfully operated at $1.1 \times 10^6$ A for beam trials in July. These trials were very encouraging with 20% improvement in $\bar{p}$ yield with nominal production beam and a 40 % improvement for lower intensity primary beam. It is hoped that the lens will be robust enough to be fully functional for the $p\bar{p}$ Collider run in 1990.

With the financial help of the German Ministry of Research and Technology (BMFT), the development work of a plasma lens for collecting antiprotons has been restarted in early 1989. A new plasma lens model scaled for the AAC target area installation has been designed and built. The neccessary mechanical support structures compatible with the later installation at the target have been assembled together with the lens in the laboratory. A new, modular pulse generator has also been assembled from existing components. Initial high-current operation and relevant measurements commenced before the end of 1989.

### Debunching Cavities

Antiprotons are normally injected into the AC with the 5-bunch structure and are captured, rotated and debunched by means of two cavities. The isoadiabatic debunching was improved after the commissioning of the closed loop phase feedback of these cavities. The efficiency of this operation, given by the ratio of antiprotons existing in 1.5% momentum spread after bunch rotation divided by antiprotons in the 6% momentum bite of the injected beam was 83 %.

### Stochastic Cooling Systems

Additional cryogenic cooling systems were installed in early 1989, reducing the temperature of the combiner boards from 100 K to 30 K and the thermal noise by 4 dB. Further, the function governing the pickup & kicker movements was modified such that the loop gain is increased during the cycle without the reduction of the initial 200 $\pi$ mm.mrad acceptance. These modifications increased the capabilities of the AAC to work at 2.4 s. After 2.4 s of stochastic cooling in the AC, the measured transverse emittances were about 13 $\pi$ mm.mrad and, 70 % of the antiprotons produced reached the injection orbit of the AA. It was found that the AA precooling and the stack tail systems were the limiting factors for working in the 2.4 s repetition regime. It was proposed to improve the stochastic cooling speed by a factor two by the installation of additional cryogenic systems in the AA. This would have yielded a 10% improvement in stacking rate at 2.4 s over and above what is possible today in the 4.8 s repetition regime. However, financial and other considerations have prevented the management from funding this improvement. The present 4.8 s stochastic cooling time reduces the transverse emittances to 4 $\pi$ mm.mrad in both planes.

For the AA, the precooling system has seen some improvements due to the installation of lower noise preamplifiers and additional band II amplifiers.

### Stack Intensities

Using the technique known as beam 'shaking', high stack intensities were achieved without any appreciable loss in the stacking rate. Shaking of the beam modifies the ion amplitude distribution and reduces the excitation of high order resonances. The AA machine design parameter eta is not well matched for high intensities above $8 \times 10^{11}$ and, the full cooling bandwith is not used. This leads to the heating of the stack edges, increasing the loss rate and the depletion of a large fraction of the stacking rate. Nevertheless, a maximum stack intensity above $1 \times 10^{12}$ was reached with a stacking rate of $30 \times 10^9$ $\bar{p}$/hr. The record stack intensity of $1.31 \times 10^{12}$ was arrived at with somewhat lower stacking rate.

### Quadrupolar pick-up

For beam transfer between two rings, good transverse matching is required to conserve low emittance. To check the AC/AA and the AA/PS matching with proton beams, a quadrupole pick-up has been installed in the AA to observe the coherent quadrupolar injection oscillations. It is also intended for the observation and the eventual damping of the coherent quadrupolar ion-$\bar{p}$ instabilities. The pickup responds to the coherent beam envelope oscillations at second-order betatron frequencies given by $(n \pm 2q)*f_0$. The coherent dipole oscillations have to be carefully compensated before the measurement, analyses and correction are carried out with this pick up. This has been done successfully for the PS/AA transfer line and would be extended to the other transfer lines in the coming year.

## Low Energy Antiproton Ring – LEAR

LEAR provided antiprotons by ultra-slow extraction between 105 MeV/c and 1917 MeV/c, physicists having a preference for extreme momenta (105, 200) and (> 1500). For the first time, antiprotons were extracted alternately in slow (200 or 105 MeV/c) and fast extraction (105 MeV/c) for multifilling the Penning trap in Experiment PS196. Since June, the machine has been controlled entirely from DEC-Stations both in the Main and local LEAR control room.

Several stages in machine development and experiment were completed :

- Semi-slow extraction (< 1 ms) was tested at 105 MeV/c (future operation at 61.2 MeV/c for PS189);
- Deceleration at 61.2 MeV/c (kinetic energy 2 MeV) was improved and stochasttic cooling at this energy used to obtain a lifetime of 20 mins for $1.0 \times 10^9$ circulating antiprotons;
- An experimental 'damper' was installed and successfully tested for stabilizing the very dense beams obtained by electron cooling;
- Hope of bringing the electron cooling to pre-operation phase by the end of the year was ruined by the rapid breakdown in collector performance and associated problems. Depsite these setbacks, stable beams of $2.0 \times 10^9$ circulating particles ($dp/p = 5 \times 10^{-4}$, transverse emittance $\approx 3\pi$ mm.mrad) at 200 and 105 MeV/c were obtained (lifetime 2 h). The cooling speed was a few seconds.

Finally, during a special machine study session in November 1989, LEAR injected, accelerated and extracted oxygen 8 for the first time. Multi-injection in longitudinal phase space coupled with electron cooling and the damping meant that up to $1.4 \times 10^{10}$ circulating charges at 147.4 MeV/c/nucleon could be obtained using multi-injection, storing pulses of $3 \times 10^8$ from the linac. The cooling speeds were 0.3 s and 1 s, respectively in the longitudinal and transverse phase spaces. This experiment augurs well for future development of ions at CERN. Ion beams were accelerated and extracted at 408 MeV/c/nucleon. A TIS team used slow extraction of this type (30 s to 20 mins) to measure energy deposits in material equivalent to human tissue.

So far as projects started in 1989 are concerned, the design and construction of pole-face windings (sextupole + vertical dipole) must first be mentioned. These should make it possible to improve the machine at low energies and provide a more flexible regulating system for experiments inside the machine. Studies to replace the electron collector in the electron cooling system have led to an agreement with Novosibirsk (USSR) to deliver a versatile collector in 1990.

Various improvements were carried out for the controls of the vacuum bakeout system for the LEAR ring as well as the design and installation of a transparent vacuum chamber for the Jetset experiment, using new vacuum components based on NEG pumps.

In order to monitor the intensity, position and profile of the very low momentum proton or antiproton beam extracted from LEAR, two new monitors working under the ultra-high vacuum conditions of LEAR have recently been tested; these were a position-sensitive photomultiplier coupled to a thin inorganic scintillator and a double sided silicon strip detector.

## Synchro-Cyclotron

1989 was a vintage year for the SC. Whereas in previous years there was a merry-go-round of rotating condenser (rotco) changes due to breakdowns, for the first time since records were kept, the only rotco change during the year was when the second rotco, which had been specially prepared for $^3He^{++}$ use, was exchanged for the 'proton' mode rotco – a change necessary for the physics programme.

During the year only 137 hours (1.6%) were lost due to breakdowns compared with 913 hours (8.2%) in the previous year.

As previously indicated, both protons and $^3He^{++}$ were accelerated to the main user ISOLDE. Muon spin rotation (μSR) also took some main beam on occasions and there were several parasitic users. Figure 5 shows the experimental layout at the end of 1989 .

The traditional shutdown at the beginning of the year, when the vacuum control system was modernised, was followed by a trouble free start-up and excellent running until March when the two rotcos were interchanged and $^3He^{++}$ successfully accelerated. Back to protons in May and again after a quick start-up, the RF voltage was pushed up to 23 kV (normally 20 kV) during a technical development with only a correspondingly small increase in discharges. Both ISOLDE 2 and ISOLDE 3 had several extremely good runs both before and after the scheduled shutdown in September, and especially in November when the SC beam intensity was improved by 5% to 10% by changing the gas in the ion source.

ISOLDE made progress with a new radioactive beam of selenium, this being the first time that this element had been produced at the SC. A resolution of 7000 for the full machine was obtained at ISOLDE 3 as the SC continued its excellent progress until the end of the year.

A remarkable feature of 1989 was the performance of Rotco 1. Since its last service it had made a total of $1200 \times 10^6$ revolutions up until the end of the year. This is approximately the equivalent of 500 years of normal use of a domestic washing machine!

## Experimental Areas

As usual, the East Area beams were employed extensively for testing and developing detectors used in current or planned physics programmes (some 40 tests during 1989).

The t9 beam can now be operated up to 15 GeV, thereby expanding the useful range of the four test beams, i.e. the particles can now be obtained with an energy range between a few hundred MeV and 15 GeV (protons, pions, electrons and positrons for the most part). In addition, a new beam stopper has been mounted on beam-line t9 and the useful area expanded by almost 150 m$^2$.

The only shadow to be cast on this was a breakdown on a quadrupole in the SE62 ejection supplying these beams with primary particles which stopped working in the last week of 1989.

In the South Area, which takes its antiprotons from LEAR, the latter's second-generation experiments continued to be set up and the Experimental Planning Section made a significant contribution towards these experiments, which have still not quite reached their desired beam quality.

The 105 MeV/c s3 line was adjusted with protons and then with antiprotons. This line supplies experiment PS 189 (measurement of the antiproton mass). For the first time an antiproton beam 'degraded' to 20 MeV/c was used. Since its intensity is considered insufficient for measuring the mass of the antiproton with the requisite precision ($10^{-9}$), a new line with RF quadrupole deceleration will be studied and set up in 1990.

Antiproton physics operations, which were continued throughout the year (almost 3500 hours), led to the first results from Experiment PS 196 (precision comparison of antiproton mass in a Penning trap). They have already confirmed that the masses of the proton and antiproton are equal to a precision of within $10^{-6}$. Experiments PS 189 and PS 196 are expected to produce even more accurate measurements.

Calculations on new low and very low energy beam lines continued, in particular for the anticyclotron deceleration tests planned for 1990 on the S4 line.

A new system for predetecting inflammable gas leaks and fire outbreaks was set up in the South Hall. It is based on air analysis sampled by aspiration and is used to monitor the interior of the detectors used for PS 195 (beam s1) and PS 201 (beam m2). Particular attention was paid in these areas to general safety since inflammable gas is used in large quantities.

Finally, the specification for controlled access doors to secondary beam areas was drawn up so that they can be overhauled in 1990 and 1991.

## Computer Controls

Controls activities during 1989 have been dominated by the first physics runs for LEP and the introduction of the UNIX operating system in the controls software development environment. In addition, the servicing and exploitation of the running control system also constitutes a major part of the ongoing activities, often under the strained circumstances due to the lack of sufficient staff for on-call duties.

The shutdown at the beginning of 1989 was used for the normal preventive maintenance of the computer and interface hardware. The last of the ND-10 front-end computers were replaced by the new ND-120s, with substantial savings in maintenance costs. With ethernet interface and the latest version of SINTRAN III operating system installed uniformly across all of the ND computers, it has been possible to establish communications using the TCP/IP protocol. A significant effort has gone these aspects in order to meet the performance criteria of the stringent controls environment; however, there are severe constraints that limit the performance and it would be necessary to continue to use the existing TITN Message Exchange System in parallel with the ethernet-TCP/IP communications. In addition, new facilities using TCP/IP had to be developed for the automatic software backup and printing due to the closing down of the central CERNET facilities.

The annual shutdown was also used to carry out major modifications to the PS coarse timing system and, to put into operation the control of the PS main magnet motor-generator power supply directly from the main control room. This joint activity with the power group has resulted in substantial manpower savings by the elimination of the need for a local power house operator. The modifications remove the vicious circle of timing events between the Program Line Sequencer (PLS), the main PS sequences (LBS) and the power house controls and, provide a clear, master timing event generation driven by the PLS only. It also includes better diagnostics and recovery facilities and permit easier programming of the PS complex supercycle. At the same time, a general reorganization of the central timing room (CCR) was carried out to increase the overall reliability of this nerve-centre of the PS complex.

Priority was given to the operation of the LEP Preinjector (LP) complex to be ready for the LEP commissioning. For the July start-up, all the application software work necessary to be able to run from the PS main control room was completed, with the exception of electron gun controls. The LP instrumentation systems performed well upto the improvements and modifications conceived after the first LEP injection tests of 1988; this, amongst other aspects, contributed significantly to the reliability of the LP complex and the spectacular start of LEP.

For the operating systems, the introduction of the UNIX system in the PS controls environment in 1989 was the first step towards the unification of control systems at CERN and a key move towards vendor-independence in this domain. The initial experience with a local UNIX network of servers and VAX workstations has been very promising, particularly for the prototype renewal of the Linac remote controls and the provision of a user interface for the PLS; the latter includes the online use of the ORACLE database management system. Much progress has been made in the development of tools for accelerator control using the industrial, X-11 standards for the workstation window management as well as the tools in UNIX for access to the equipment currently controlled by the front-end ND-120 computers. This is an important step necessary for the graceful transition to the future UNIX-based systems. At the equipment control level, work has started on the development of a future front-end processor using the industrial VME standard. The VME chassis includes a Motorola 68K processor running under the OS-9 operating system and permits communications using the TCP/IP protocol. Using software developed for the LEP OPAL experiment, a first version of the CAMAC equipment access software from VME has been implemented. In addition, the Nodal interpreter has been fully rewritten in the language 'C', with obvious benefits and portability to all UNIX and OS9 systems.

For the applications related software, the NAPS (New Application Program Structure) project has been completed. This involves the complete chain of software generation from the ORACLE database down to loading mechanisms for the specific equipment processors. A major PS application equipment module for controlling the power supplies has been converted to this new structure and, is routinely used for the LP complex. On the database aspects, the ORACLE off-line database as a unique source of read-only controls data has been put into routine use. It is accessible both, from the IBM/VM as well as the DEC/ULTRIX(UNIX) systems.

Much progress has been made in the development of an Expert System with applications to the beam injection line of the PS Booster. The system includes control and acquisition of equipment parameters and, will be used as a test-bed for a new Expert System architecture under the aegis of the ESPRIT II initiative of the European Community.

Several developments, improvements or extensions have been carried out to the various systems which fall within the domain of computer controls. These include the development of a new CAMAC timing surveillance module, extensions to the signal observation system, modernising of test and calibration facilities for instrumentation repair, introduction of remote controls for the sulphur ion source, development of modern techniques for computer-aided hardware design, documentation, and software tools for maintenance and graceful recovery of operational conditions after unforseen destruction. For the controls of beam instrumentation systems, several new features have been added to provide additional capabilities and to improve the reliability of measurements. Notable amongst these are the time-tagging of measurement data with a unique, CERN-wide clock, capability for bunch measurements over two turns in the PS and the implementation of a generalized protocol for the Booster beam measurement transformers.

All the developments in the basic building blocks for the new generation of control systems have been done in close collaboration with the SPS/LEP controls group; this is in line with the aim to have uniform control of all the accelerators at CERN.

The Ethernet cabling for the PS Division has been completed and includes both, the laboratories and the offices. The communications laboratory has been equipped with the necessary software and hardware tools to survey the traffic and, for the fault diagnostics. The high availability of this communications medium augurs well for the future.

The office Personal Computer (PC) network was extended by the installation of about 50 additional PCs, two new Novell file servers, and the installation of four printing cluster points around the various buildings of the division. For the office secretaries, it was decided to converge to the CERN administration standard of Macintosh computers, with a bridge to the PC world by the use of Novell servers.

## Research, Development & Projects

### Lead Ion Linac

The optimization of the parameters for the lead ion accelerating facility has continued and resulted in a considerably higher estimate for the number of ions per SPS pulse needed for the fixed target experiments. It seems possible to achieve an intensity of about $4 \times 10^8$ ions at the exit of SPS. This increase stems mainly from the better transmission efficiency between the PS and the SPS and, from the idea to accelerate several charge states simultaneously in the linac. The main worry, however, has been the question of how to supply the LHC with substantially higher intensities and nevertheless stay compatible with what has already been proposed for fixed target physics. The study has shown that the proposed facility can be upgraded in several ways and that the investment proposed would also be useful for LHC. The different possibilities include upgrading of the ion source, a special low energy end with a low charge state (and therefore high current) ion source with subsequent intermediate stripping, storing with cooling after the linac or, storing with cooling at higher energies.

Both LEAR and AAC have been considered for this purpose and look promising. It seems reasonable to choose the final scheme or a combination of these schemes, only when the straightforward possibility of ion source upgrade becomes more clear over the next few years. Cooling, at least to reduce the horizontal emittance, will probably be needed in any case and could be done in the PS.

The interdigital H-structure is still being followed up in order to assess its possible advantages, in conjunction with GSI/Darmstadt.

### Heavy Ion Source Studies

Modest exploratory work to study the possible application of laser ion sources for heavy ions has started. In experiments at the Technical University in Munich, a flashlamp pumped, Q switched Nd :Yag laser (pulse length = 10ns, pulse energy = 0.3 J, wavelength = 1.06 μm) was focussed on a 50 micron spot. This produced a variety of ions including Au and Pb with charge states up to 12+ (ionization potential < 370 eV). This effort continues at the Munich Max Planck Institute for Quantum Optics at higher pulse powers. At CERN, it is planned to further the R & D on a modest scale with a carbon dioxide laser, following the work at Dubna where such a laser has already produced more $Mg^{9+}$ ions than the CERN electron cyclotron resonance $O^{6+}$ source. This development has just begun in collaboration with the AT division who have lent a 2 Joule dye laser for preliminary studies.

Medium and high power $CO_2$ lasers have been acquired in order to extend the ion producing capability at CERN and, the assembly ot the lasers together with their diagnostic equipment is under way.

### CERN Linear Collider (CLIC) Test Facility

In parallel with the operation of the LEP pre-injector, the electron linac expertise of the LP group is being used to set-up a test facility, aimed at the production of electron bunches of high charge ($10^{12}$ particles) and very short length ($\sigma z$ = 1mm). The interaction of these bunches, with specialized structures developed to extract power at high frequency (30 GHz), will enable the basic problems of CLIC drive beam to be studied. A blockhouse, close to Lep Injector Linacs(LIL), is under construction and will house an HF gun based on photocathodes illuminated by a laser and fed with power from the spare LIL klystron/modulator. A low power prototype of the gun has been machined by the central workshop, measured and readjusted. A high power version is in preparation.

First 10 nsec pulses of $1 \times 10^{12}$ particles have been obtained in a DC gun at 70 kV from a multi-alkaline photocathode, made in an on-line preparation chamber and illuminated by a laser, an excellent example of a close multi-division collaboration.

### Ferro-electric Crystals

It has been the aim to encourage a number of new ideas – at least up to the point of being able to judge if they are likely to be of some use in designing the accelerators which will replace LEP and the LHC. The emission of electrons from ferro-electric crystals during phase transition is one such example. A no-cost collaboration between CERN and the Universities of Katowice in Poland and Thessaloniki in Greece, using borrowed equipment, has given very intense electron emission from a PLZT ceramic with a high zirconium concentration. The zirconium broadens the phase transition so that a high voltage pulse of 40 kV redistributes a large fraction of the ferroelectric structure into a paraferroelectric state, releasing electrons bound to the surface. It is too early to say very much about the perveyance of the beam emerging into the vacuum. See : Pulsed Electron Emission from Ferroelectrics by H. Gundel, H. Riege, J. Handerek, K. Zioutas – CLIC Note 82 and submitted to JAP.

**Open Resonators**

Another collaboration, with Naples University, was originally set up to investigate the use of open resonators (opposing spherical dishes) to produce intense high frequency fields. The open resonator has a high Q and the waist in the standing wave can be very narrow and intense, limited to a few microwave wavelengths. Fields of GeV/m exist over a short distance and, in some modes of the resonator, might be used to focus particles at the final focus of a linear collider. Another application may be to produce an improved version of the interference beating suggested by Hora in 'Nature' (26.05.88) as a means to accelerate in vacuum. Discussions are also underway with Rochester University about the use of open resonators as axion detectors and as a new kind of pickup for cool beams.

There has been a recent interest in using these open resonators as part of a beat-wave experiment in the microwave range. This is part of a collaboration between the Rutherford-Appleton Laboratory (UK) and Naples presently unter the aegis of the EEC.

| MACHINES | INTENSITIES or ACCUMULATION RATES | | | | Dates |
|---|---|---|---|---|---|
| AAC | AA Stack | | | 1.31 E12 pbars | Aug-08 |
| | Accumulation Rate | | | 5.8 E10 pbars/h | May-26 |
| PS | 20 bunches at 14 GeV/c | | (Beam for SPS) | 2.57 E13 protons / pulse | Aug-26 |
| | 5 bunches at 26 GeV/c | | (AAC production) | 1.75 E13 protons / pulse | Sep-12 |
| | Leptons | e- | | 4.5 E10 e-/bunch | Nov-06 |
| | | e+ | | 5 E10 e+/bunch | |
| PSB | 20 bunches to Measurement Line (1 GeV) | | | 3.3 E13 protons / pulse | Nov-13 |
| LPI | Intensities in EPA | | e- | 1 E12 e- | |
| • | (8-bunch mode) | | e+ | 8 E11 e+ | |
| | Accumulation rates | | e- | 1.2 E11 e- / bunch / s | |
| | (8-bunch mode) | | e+ | 8.0 E9 e+/ bunch / s | |
| LEAR | O8+ at 400 MeV / nucl. | | | 1.3 E10 charges | Nov-15 |
| | protons at 2 MeV | | | 1 E9 protons ; lifetime : 18 min. | |

*Figure 1*
*1989 – PS Complex – Records*

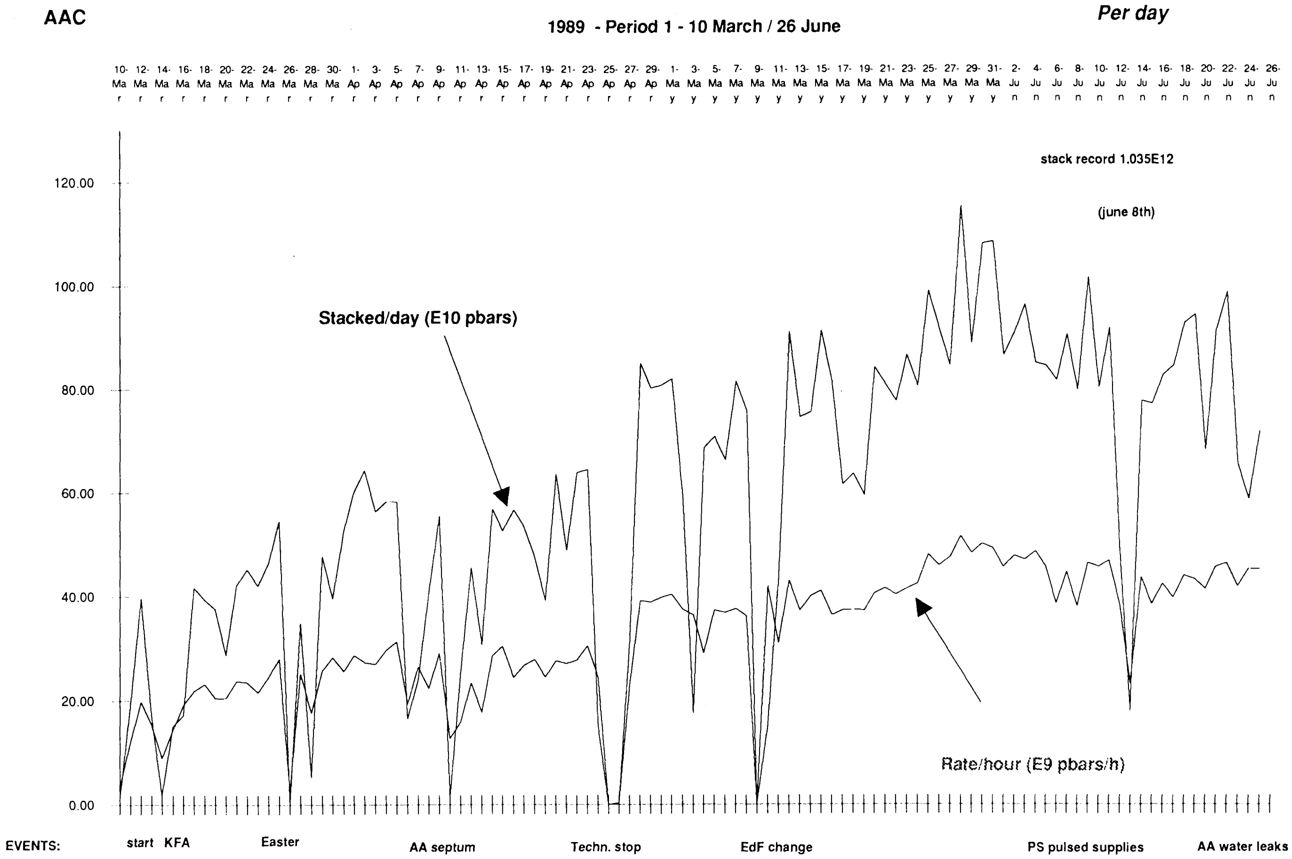



*Figure 2*

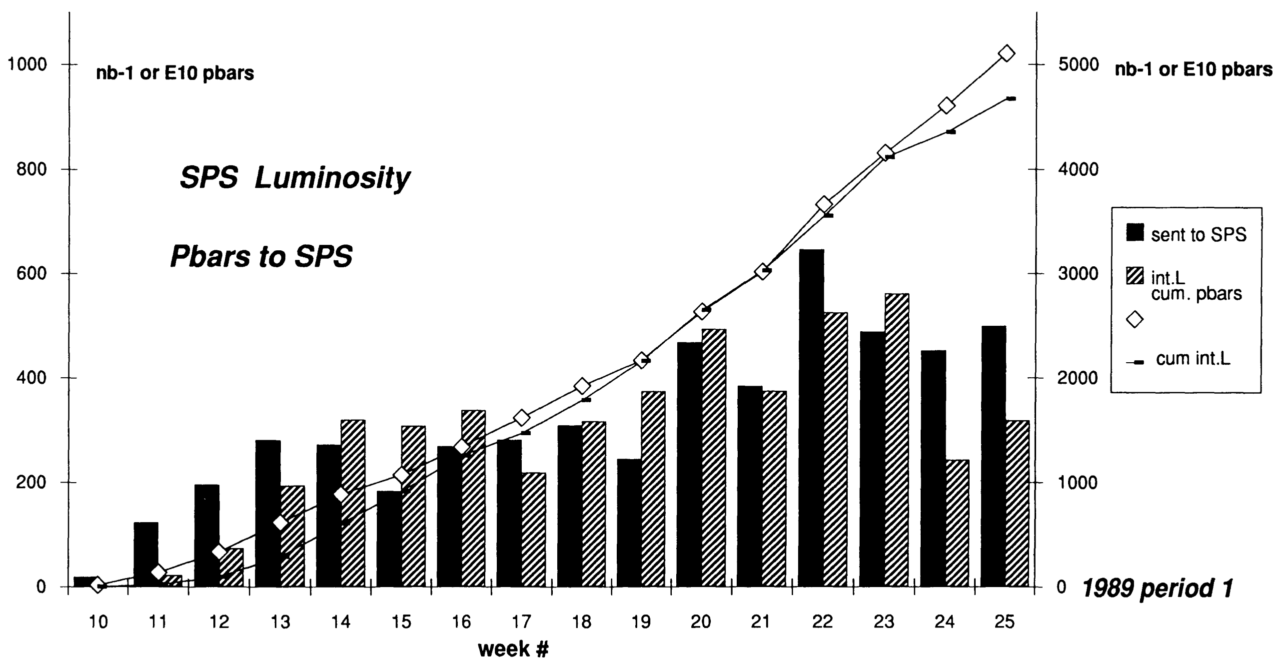
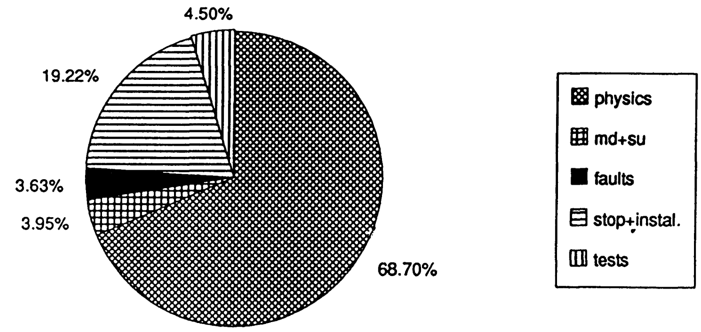
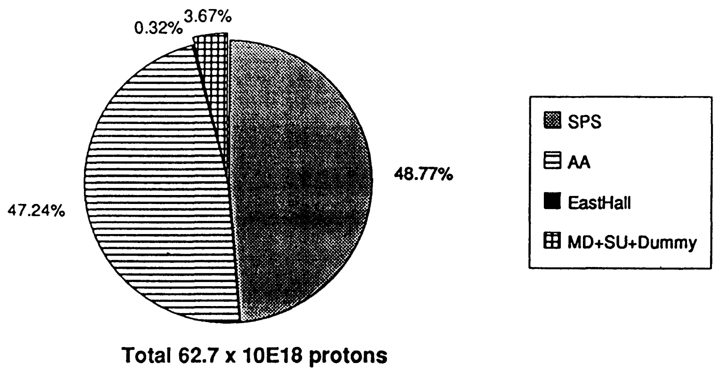



*Figure 3*

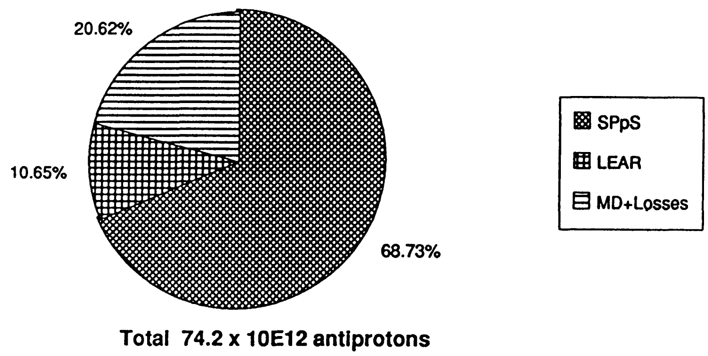
### *1989 PS hours distribution*




### *1989 Protons distribution*




### *1989 Antiprotons distribution*




### *1989 LEPTONS distribution*

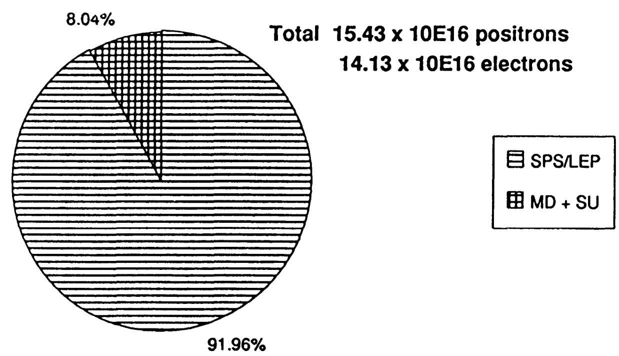



*Figure 4*

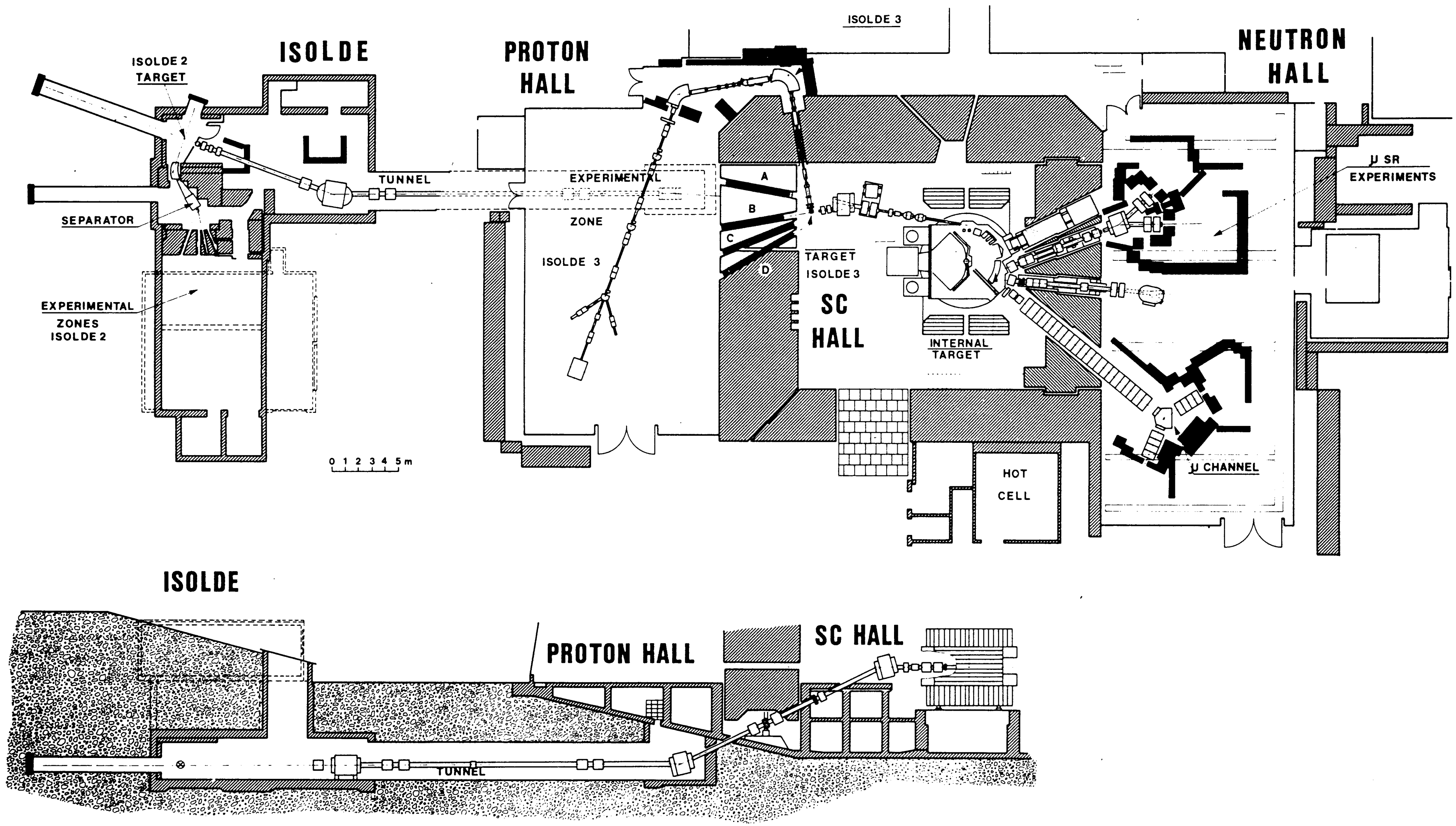



*Figure 5*
*Layout of the SC experimental area at the end of 1989*

*Table 1*
*Statistics for PS Ring operation in 1989*

| | |
|---|---|
| Scheduled physics running time | 6329 hours |
| Achieved physics running time[1] | 6018 " |
| Scheduled setting-up time[1] | 353 " |
| Total ejected proton beam intensities | |
| antiproton production | $2.97 \times 10^{19}$ |
| SPS collider | $4.87 \times 10^{17}$ |
| SPS fixed target | $3.05 \times 10^{19}$ |
| East Hall slow ejection | $2.11 \times 10^{17}$ |
| To beam dump | $0.17 \times 10^{19}$ |

1) Includes some machine development

*Table 2*
*Statistics for AAC operation in 1989*

| | |
|---|---|
| Scheduled running time | 5838 hours |
| Achieved running time | 6037 " |
| Total number of antiprotons produced | $7.4199 \times 10^{13}$ |
| Average production rate | $3.1 \times 10^{10}$/h |
| Maximum stack during 1989 | $1.31 \times 10^{12}$ |
| Total number of antiprotons sent to SPS | $5.1033 \times 10^{13}$ |
| Total number of antiprotons sent to LEAR | $0.7897 \times 10^{13}$ |
| Accidental stack losses | $1.5269 \times 10^{13}$ |

*Table 3*
*Statistics for LEAR operation in 1989*

| | |
|---|---|
| Scheduled physics running time | 3483 hours |
| Scheduled setting-up time | 1820 " |
| Achieved setting-up time[1] | 1848 " |
| Total number of pulses injected | 2070 |
| Total number of pulses extracted for physics | 1656 |
| Total number of antiprotons injected | $7.1 \times 10^{12}$ |
| Total number of antiprotons ready for extraction for physics | $4.5 \times 10^{12}$ |

1) Includes physics, setting-up and machine development

*Table 4*
*Statistics for LEP Preinjector operation in 1989*

| | |
|---|---|
| Scheduled lepton production time | 4050 hours |
| Achieved lepton production time | 3797 " |
| Scheduled production time for LEP | 3624 " |
| Achieved production time for LEP | 3391 " |
| Total number of electrons sent to SPS/LEP | $13.1 \times 10^{16}$ |
| Total number of positrons sent to SPS/LEP | $14.2 \times 10^{16}$ |

*Table 5*
*Statistics for SC operation in 1989*

| | |
|---|---|
| Scheduled physics running time | 4019 hours |
| Achieved physics running time | 3839 " |
| Scheduled machine development & setting-up time | 913 " |
| Achieved machine development & Setting-up time | 934 " |

# Super Proton Synchrotron Division

Following the winter shutdown of January and February, the SPS operated in collider mode for a 16 week period. The operational performance of the machine, in terms of both instantaneous and integrated luminosity, was improved compared to the 1988 run, enabling the experiments to accumulate almost 50% more data from approximately the same running time. For the rest of the year the SPS provided protons for the Fixed Target program and simultaneously supplied LEP with $e^{\pm}$ beams in the interleaved cycling mode. Following the planned ten day startup with protons, the first positrons were injected into LEP, on schedule, on 14 July. The first successful injection of electrons into LEP followed on 25 July, after commissioning of the TI12 transfer line. Leptons were thereafter available to LEP, with little or no perturbation to the SPS physics program. Indeed, the SPS performance, in terms of protons delivered to the targets, compared well with previous years.

## The SPS Collider

### Machine Studies

The improvement of the collider performance during the 1989 period came mainly from the use of the 100 MHz RF system which had been commissioned at the end of 1988 and from a systematic study of the causes of the transverse emittance increase of the antiproton bunches on their way from the AA stack to the SPS coast.

As explained in the 1988 report, the 100 MHz system was installed to allow the injection of longer bunches in order to diminish the transverse tune spread which comes primarily from space-charge effects at the 26 GeV/c injection energy.

The combined use of the two RF systems, 100 and 200 MHz, has been refined and finalised. During the injection process, the two RF waveforms are out of phase in order to achieve maximum Landau damping, but they must be in phase during acceleration. The delicate changeover which includes separate programming of the RF voltage in each of the 200 MHz travelling wave cavities to avoid dangerous multipactoring levels, has become part of a fully operational procedure. Operation with the two RF systems not only improved the capture efficiency, but also simplified considerably the tuning of the machine with high precision which is needed on the injection platform and during the early part of the ramp to avoid non-linear resonances. The 100 MHz cavities were also powered in coast at 315 GeV/c to increase the longitudinal acceptance and this resulted in a 50% improvement of the intrabeam scattering limited lifetime.

Single bunch dipole instabilities observed at 26 GeV/c when using the 100 MHz RF system alone have been studied. They are explained by a longitudinal head-tail mechanism, an effect previously unseen in existing accelerators. A theory to predict the growth rate as a function of chromaticity has been developed and agrees well with the observations.

At the beginning of the period a larger than usual (up to a factor 3) increase of the antiproton transverse emittances was noticed along the injection and acceleration chain. This came from a number of minor malfunctions and misadjustments which were identified after patient investigations, and finally suppressed. The emittance increase could eventually be reduced to a factor of only 1.5, the residual problems occurring mainly at the start of the SPS acceleration when the bunches shorten, leading to increased space charge effects.

In 1987 when dense antiproton bunches were made available after the commissioning of the AC, the proton beam lifetime decreased dramatically while enormous background rates from the protons were seen in the physics detectors. This was surprising since the intensity of the antiproton bunches was still several times smaller than that of the proton bunches, and therefore the beam-beam tune shift seen by the protons was smaller than the one suffered by the antiprotons. However, past experience had already shown that the linear tune shift is insufficient to characterize the beam-beam interaction, and that the relative size of the beams has a dominating influence. This effect was therefore explained by the fact that the antiproton beam had smaller transverse dimensions than the proton beam, and the problem could be solved by carefully balancing the emittances of the two beams.

In 1989 a series of experiments was performed to systematically study the influence on beam-beam induced losses of parameters like tune, emittances and intensities, and to identify the effect of 13th and 16th order resonances. In one of these experiments where one proton bunch was colliding against one antiproton bunch, the intensity of the antiproton bunch was reduced by removing a substantial part of the particles with a transverse scraper. This reduces the intensity and the size of the antiproton bunch, as well as the linear tune shift suffered by the protons. However, the lifetime of the proton bunch decreased after the scraping. This can be explained by the change in the transverse dependence of the electromagnetic force exerted by the antiprotons on the protons: when the size of the antiproton bunch is reduced, a larger number of protons find themselves oscillating in the non-linear part of the beam potential and suffer from the effect of enhanced very high order resonances, which cannot be avoided by tune adjustment since the tune spread is larger than the space between resonances. Other experiments provided a measurement of the effect of 13th and 16th order resonances as a function of the transverse separation between the beam centres. The diffusion rate of particles was measured as a function of their amplitude, showing that large amplitude particles diffuse much more rapidly than small amplitude ones. These diffusion phenomena are explained by the onset of stochastic motion in certain regions of the transverse phase space due to overlapping of high order resonances.

Continuing studies on the signals obtained from the 11 GHz stochastic cooling pick up have shown that the smooth Schottky signal is contaminated by stronger synchrotron frequency sidebands. These apparently reflect a macrostructure in the bunch which depends upon previous RF manipulations and is very slow to disappear.

### Collider Operation

The collider restarted after the winter maintenance break, continuing the same physics programme which had started in September 1988. Experiments UA1, UA2, UA6 and UA8 took data. The total time devoted to collider operations was sixteen weeks, including the continuous running over Easter for the first time in the history of the SPS operation. Figures for operation are shown in the table opposite.

A total of 4.8 inverse picobarns of integrated luminosity (compared to 3.4 in 1988) was accumulated from a total of 119 coasts. The average integrated luminosity per coast was 40 inverse nanobarns, a 27% increase on 1988; the peak initial luminosity was $3.0 \times 10^{30} cm^{-2}s^{-1}$. A new record integrated luminosity per week was set at 561 compared to 480 inverse nanobarns in 1988.

The total of 8.36 inverse picobarns for the two years was comparable with the FNAL total of 9.5 inverse picobarns, in spite of a ten week maintenance stop of the SPS over Christmas.

### Technical Developments of the Collider

In all six 100 MHz power amplifiers (20 kW each), a new type of main circuit breaker has been installed to achieve a more reliable operation. The 500 W transistorised driver amplifiers have been upgraded for better linearity.

The transverse feedback system or damper underwent an important overhaul. The use of directional couplers connected to narrow band receivers was abandoned in favour of electrostatic pick-ups and broadband 10 MHz receivers. This and the careful adjustment of signal delays for protons and anti-protons makes the damper act simultaneously on all bunches during the entire accelerating cycle. In the previous configuration each freshly injected bunch was acted upon during only 20 ms. This work was prompted by the observation of coherent beam-beam signals during the injection of anti-proton bunches. The damper can now be used to blow up selectively the transverse emittance of circulating bunches or even eliminate bunches completely. This facility was used extensively during machine study sessions concerning the beam-beam effect.

A new low-beta scheme has been proposed for the collider in order to gain a factor of two in luminosity. This scheme is based on a rearrangement of the central quadrupole doublets of the insertion. These doublets are pushed towards the collision point and the existing quadrupoles are replaced by quadrupoles which have a 10% smaller aperture diameter and a correspondingly larger maximum gradient. The length of the doublet components adjacent to the collision point is increased from 6 m to 7.5 m. The installation of the new scheme for the LSS4 insertion will take place during the long winter shutdown at the beginning of 1990.

As the quadrupole doublets have been displaced, one cannot find a machine type quadrupole at the regular fixed target lattice positions 41810 and 41910 in the new scheme. As a consequence, the SPS will have to work in fixed target mode with 5 quadrupoles powered independently by their own low-beta power supply. These power supplies must therefore be able to work under multicycling conditions. This will imply the redesign of

*Collider performances & typical operational parameters before and after the AA upgrade*

| | 1985 | 1988 | 1989 |
|---|---|---|---|
| Beam energy (GeV) | 315 | 315 | 315 |
| $Beta_H$ (m) | 1.0 | 1.0 | 1.0 |
| $Beta_V$ (m) | 0.5 | 0.5 | 0.5 |
| Number of bunches | 3+3 | 6+6 | 6+6 |
| Separation | no | yes | yes |
| Protons per bunch ($10^{10}$) | 16 | 12 | 12 |
| Antiprotons per bunch ($10^{10}$) | 2 | 4 | 6 |
| Proton emittances ($\times 10^{-6}$ rad.m) | 23 | 12 | 11 |
| Antiproton emittances ($\times 10^{-6}$ rad.m) | 20 | 8 | 10 |
| Initial luminosity ($\times 10^{30}cm^{-2}s^{-1}$) | | | |
| peak | 0.4 | 2.5 | 2.95 |
| average | 0.13 | 1.3 | 1.8 |
| Integrated luminosity ($nb^{-1}$) | | | |
| average per coast | 8.2 | 31.5 | 40 |
| per year | 655 | 3375 | 4759 |
| peak per coast | | 71 | 97 |
| per week | 77 | 480 | 561 |
| Hours scheduled | 2688 | 2415 | 2654 |
| Hours in coast | 1358 | 1206 | 1434 |
| Number of coasts | 80 | 107 | 119 |
| Average coast duration (h) | 17 | 11.3 | 12.1 |
| % of coasts terminated by faults | 18 | 25 | 28 |
| Number of EDF critical days lost | 9 | 7 | 7 |

the cycle generation program to control these supplies from the Apollos and of the programs for trimming the magnetic cycles.

In the new scheme, the maximum betas have increased and at the same time the quadrupole apertures have decreased. The closed orbit correction must therefore be improved. To do so, one will install two more pulsed orbit dipoles (MDPH) in positions 41207 and 42407. The natural chromaticity of the machine will be increased by the increased maximum betas and therefore also the chromaticity correction scheme must be improved. Two sextupoles now belonging to the LSFA family in positions 42805 and 50405 will be connected to the LSFC family, while the two LSFC sextupoles in positions 60805 and 61205 will be connected to the LSFA family.

For the new insertions in LSS4 and eventually later in LSS5, about 80 m of new vacuum chambers of a very special cross section giving a maximum aperture in the low-beta quadrupoles have been supplied by industry.

All the shielding has been redesigned and shielding pieces have also been put inside the gap of the QT quadrupoles to protect the experiment as well as possible against the particle losses on the vacuum chamber.

### The Experimental Areas for Proton-Antiproton Physics

The collider run of 1989 was a direct continuation of the one which ended at Christmas 1988, so that few changes were needed by the experiments. In fact, no changes at all were asked by UA2.

The UA1 collaboration made a request for further improvements in the coverage of the muon filters installed in LSS5 around their detector. Mobile shielding has been built for installation around the magnets which, in both forward regions of UA1, compensate the field of the central spectrometer magnet. Thus the UA1 detector could run with almost hermetic shielding for muon detection in the forward regions. Also for the UA1 detector, a manipulator was developed in order to install the new calorimeters in the forward openings of the spectrometer magnet. This has permitted the successful installation of a number of test modules.

The UA6 experiment was turned around in January 1989, in order to take antiproton-proton data, to be compared with proton-proton data taken earlier. In conjunction with UA2, experiment UA8 accumulated enough data for its programme to be completed.

Preliminary studies have continued in collaboration with the vacuum experts in the Division and the team of physicists who propose to study B-meson physics at the collider (Proposal P238). A prototype for a silicon micro-vertex detector has been worked out in some detail for test purposes.

## The SPS Proton Accelerator

### Fixed Target Operation

After a break of 10 days in the operation, during which the collider experiments were removed from the SPS ring, the fixed target operation started in the first week in July. This year the cycle of 14.4 seconds duration contained four lepton cycles in addition to the 450 GeV proton cycle.

Protons were accelerated to 450 GeV and slow extracted to the North and West Area during a 2.4 s flat top. A double fast resonant extraction of 5ms at 450 GeV, one burst just before the start of the flat top and the second at the end, delivered beam to target T9 in the neutrino cave. On a typical cycle $3.1 \times 10^{13}$ protons were accelerated to 450 GeV of which $1.8 \times 10^{13}$ were delivered to the neutrino target, the principal user of beam in 1989. (See table below). A total of $15 \times 10^{18}$ protons was delivered to all targets with an average of $2.5 \times 10^{13}$ protons per cycle. The peak intensity, averaged over any 15 minute operating period, was $3.5 \times 10^{13}$ protons. At the end of the period, during a one week test run, the intensity on the neutrino target was increased to $2 \times 10^{13}$ protons per cycle without signs of deterioration of the target.

*SPS performance statistics (protons on fixed target)*

| | 1986 | 1987 | 1988 | 1989 |
|---|---|---|---|---|
| Total scheduled hours of operation | 2705 | 2286 | 3067 | 3330 |
| Total scheduled hours for physics | 2163 | 2002 | 2635 | 3240 |
| Efficiency for physics in% | 80 | 80 | 76 | 71 |
| Peak intensity per cycle accelerated to 450 GeV (in units of $10^{13}$) | 3.4 | 3.2 | 3.46 | 3.5 |
| Average intensity per cycle delivered to targets (in units of $10^{13}$) | 2.38 | 2.1 | 2.85 | 2.5 |
| Total number of protons delivered to targets per year (in units of $10^{18}$) | 12.9 | 8.0 | 13.06 | 15.3 |
| Cycle length (s) | 14.4 | 14.4 | 14.4 | 14.4 |

### Technical Developments of the Accelerator

Due to the increasing induced radioactivity of the electrostatic septa (ZS), presently of the order of 10 rad/h just after stopping the beam and 5 rad/h after one week of cooling down, it is imperative to improve the maintenance of the 3M insulating liquid in the feedthroughs. A central circulation system which will be located upstream of ZS1 is under study.

One more electrostatic septum, namely ZS4 in LSS6, failed due to a short circuit in the lower ion trap, stressing the fact that the electrostatic septa are subject to wear.

The extraction system in LSS2 will be overhauled during the shutdown at the beginning of 1990. Most of the controls cables must be renewed because of radiation damage. The girders of the septum magnets MST and MSE will be realigned. Regular realignment is necessary because the floor of this enlarged (8.5 m wide) part of the tunnel continues to move upwards at a rate of about 0.7 mm/year.

The modified version of the internal beam dump (TIDV) installed in the main ring of the SPS in 1988, in which the flexible water hoses for cooling the aluminium core are placed inside the vacuum, has operated since then satisfactorily, without any further leaks. As planned, the additional spare TIDV of the modified design has been completed and tested, providing an essential non-radioactive spare beam dump. In addition the studies of a different, shock resistant design, based on explosion welding of the inner core with the copper housing, have been continued and first results from a reduced scale test sample programme are being evaluated.

After 5 years of operation, the helium cooling station for target T9, located in the neutrino cave, had to be completely overhauled in order to ensure continued safe operation in a highly radioactive environment. Also in the neutrino cave, part of the primary beam line to target T11, which is no longer in use, was dismantled, thus allowing better access to the components of the beam line leading to T9 and freeing magnetic elements for other applications.

In order to assure also in the future the reliable operation of the SPS vacuum system we have started to replace or upgrade certain very old equipment.Seventy-five all-metal sector and roughing valves have been ordered and partially installed to replace the more than 13 years old indium sealed valves. For the power supplies of the sputter-ion pumps which have also been manufactured between 1974 and 1976, an upgrading program was started.Their HV-part will be completely rebuilt and entirely potted in silicon rubber, the current reading will be improved to allow pressure measurements via the sputter-ion pumps even below $10^{-9}$ mbar and the old MPX interface will be replaced by a new one compatible with the future SPS control system.

As far as the Siemens RF power plant is concerned, six 140 kW 200 MHz power amplifiers have been dismantled, cleaned and after replacement of worn-out components, reinstalled. The same maintenance work was done for two 1 kW and two 10 kW predrivers.

One 1 MW high voltage power supply has been modified to permit the installation of a prototype 1.3 MVA dry transformer replacing the existing PCB insulated transformer. Unfortunately, this transformer failed during operation and must be improved and repaired by the manufacturer.

Thirty-five Philips power amplifiers (35 kW, 200 MHz) were completely dismantled, cleaned and reassembled. In addition, extensive work was required to check and clean other components of the 68 power amplifiers, like short-circuit devices and high voltage filter boxes and switches. Some maintenance effort was also required for the 800 MHz klystron plant to keep it in good operational condition.

As in previous years the air and water cooling systems for the different RF plants have been checked carefully. Several pumps and blowers had to be replaced or repaired.

A new technique for the acceleration of heavy ions, at a fixed frequency, has been successfully tested in the SPS accelerator. A wideband voltage controlled oscillator, developed for this purpose, produces the fast phase changes required to keep the beam and RF waveforms in synchronism. Full modulation (at the revolution frequency) of the RF power amplifiers is necessary for this mode of operation. The older Siemens amplifiers in their present condition do not allow such a modulation; an upgrading is under study.

A special monitor was installed in LSS2. Small scintillators were mounted on linear moving mechanisms inside a vacuum chamber. This monitor allowed the study of particles lost from the beam and this in perspective of the LHC.

A new high speed linear wire scanner has been designed and is ready for the test bench.

The programmable amplifiers of the SPS beam position measuring system have been upgraded, using PIN diodes to replace the mechanical relays. This improvement will allow a true multicycle orbit acquisition using the full dynamic range capabilities of the system. The new design has been thoroughly tested after which a pre-series was installed and gave full satisfaction. The final production has been launched and we foresee a progressive installation from the beginning of 1990.

A new versatile timing control unit called sequencer has been developed. It will be used in a variety of beam observation systems: observation of coherent beam oscillations, beam position in the SPS and in the transfer lines, control of the transverse feedback system (damper).

The increased beam intensities and higher radiation levels lead to considerable damage to control cables in critical areas of the SPS tunnel. Some 80 km of cables have been changed in sextant 1 as a first step of a long term consolidation programme.

### Evolution of the SPS Controls System

The activities for upgrading the SPS control system were temporarily reduced to a minimum in 1989, since the Controls Group had to concentrate on the final installation and commissioning of LEP. However, there have been many developments at the levels of equipment control and applications programs.

As a continuation of the evolution which took place in the past years, more MPX driven pieces of equipment have been replaced by microprocessor-based interfaces. All these new devices are managed through the Oracle database by means of a number of packages which are now fully operational.

A powerful VME based acquisition system for analysis of coherent beam oscillations and beam intensity has been designed and installed (BOSC). Its memory capacity is sufficient to store seconds worth of oscillation data. This is the first time at CERN that the control of accelerator equipment has been implemented using the multi-tasking operating system OS-9 in the local crate and the TCP/IP protocol over Ethernet and Token Ring for direct host-to-host communication with the control room workstations. The system has proven its value in machine studies concerning the dynamical aperture.

The replacement of the old function generators by the new VME based μ-processor system (MUGEF) has continued in 1989. The injection and the north transfer lines were completely equipped including the acquisition of power converter status and currents. Some 60 units were concerned. The MUGEF data module subroutine has been restructured and the new version was successfully implemented.

The power converters of the new low-β insertion in LSS4 and those of the existing low-β in LSS5 will from 1990 onwards also be controlled by MUGEF's. The MUGEF crates in BA 4 and 5 also include a 16 bit analogue acquisition system with a 25 μs conversion time. The Nord100 control computers are being replaced by PCs using a XENIX operating system. The MIL-1553 line links the PCs to the MUGEF's while the Token Ring connects the PCs to the Apollo workstations in the control room. This new configuration requires extensive changes to the NODAL programs which will be ported from the Nord 100 computers to the PCs.

A modelling facility for the SPS Beam Transfer lines relying on a new database containing all the relevant information of each beam line element has been implemented in the control room workstations.

An Apollo workstation has been installed in the BA3 Faraday cage to provide a platform for high level application software and the control of the 60 timing modules of the RF systems is now available from the Apollo. The complexity of the triggering for three major RF systems during the SPS supercycle has necessitated analysis software on the Apollo which extracts and displays timing settings according to the particular concern of the operator.

The microprocessor software produced by the RF group has been developed on a G64 development system running the FLEX operating system with a Motorola 6809 CPU. The supplier of the Pascal compiler which is used in this system stopped development effort on this product several years ago. Therefore an upgrade to a VME development system running the OS/9 operating system with a Motorola 68000 CPU is being investigated. A recent version of the Pascal compiler is being tested for the G64 controllers and the system is being evaluated for future developments using the 68000 family of microprocessors.

Work has continued on the development of the application software for controlling the SPS from the new, workstation based, control room consoles. The new software has been used successfully for the lepton cycles of the SPS that were used for LEP commissioning and operation.

The software is now very reliable with few problems occurring in operation. The main work this year has centred on improvement of the operation interface in the following two areas :

- Individual SPS application program interfaces have been re-designed after observation of their performance in operation and after careful discussion with the operators.
- An integrated 'console manager' has been developed in collaboration with the machine operators that provides them with sophisticated control of the various tasks that can run on a workstation. This console manager can also be used to start and control LEP applications programs, thus allowing the operations group to control both machines from the same environment and even from the same workstation.

In addition to this work, the software has been extended in the following areas :

- Control of the SPS supercycle which will lead to the possibility of 'loading' the accelerator for a new supercycle some time in advance of actually using it. This will lead to the possibility of rapid switching between supercycles at the touch of a button.
- The software for control of the SPS timing system has been extended to provide similar functionality for LEP.

**The Experimental Areas for Fixed Target Physics**

As usual, the SPS has delivered fast-extracted protons to produce the neutrino beam, operated under the responsibility of the EF Division, and simultaneous slow extracted protons to serve the North and West Experimental Areas. The layout of beams and experiments for fixed target physics in 1989 are shown in the figures on pages 121 and 122 at the end of this chapter.

## The North Area

In the North Area, the H2 beam has been exploited to provide electrons and hadrons to a crystal channeling experiment NA43, and to the two ion experiments, NA35 and NA36. Furthermore, two $p\bar{p}$ collider groups, UA2 and UA6, used the beam for calibration and detector development.

The K4 beam has been devoted to a highly successful run of the CP-violation experiment NA31, taking data alternately in $K_L^0$ and $K_S^0$ beams produced respectively by 450 GeV/c primary and 360 GeV/c secondary protons.

Tests and calibrations of elements of the DELPHI (LEP) and H1 (HERA) detectors as well as a new micro-strip detector linked to a data-driven processor have occupied the H6 beam.

Meanwhile, the H8 beam has been used exclusively in its micro-focus, primary proton beam mode to enable the lepton-production experiment, NA34/1, to complete data-taking. At the end of the year this beam has served to carry out a test on the deflection and transmission of protons by channeling through a bent crystal. This test profited from a collaboration of groups from the Universities of Aarhus and Strasbourg with the beams group of the SPS Division. The technique is expected to lead to future applications in the design of beams. Thus, it has been incorporated in the studies for the production of simultaneous, nearly-collinear $K_L^0$ and $K_S^0$ beams in relation to an intended new experiment by the NA31 collaboration to determine the CP-violation parameter $\varepsilon'/\varepsilon$ with greater precision.

The M2 muon beam has been exploited at three energies to complete the programme of the Nuclear Muon Collaboration, NA37.

Other studies have led to the design of a scheme to split the primary beam of heavy ions, so far serving experiments NA35 and NA36 in the H2 beam, to allow a new pion-interferometry experiment, NA44, to receive ions simultaneously in the K4 line by 1991. The H8 beam is being prepared for the installation of a new electron-pair spectrometer, NA45, and an improved dimuon detector, NA34/3, for the $^{32}$S-ion run in 1990. Modifications planned for the H2 beam will allow a sensitive search by experiment NA46 for any neutral particles, which may be produced preferentially by a beam of tagged photons incident on a crystal and thereafter decay to $e^+e^-$.

## The West Area

An important part of the activity during 1989 has concentrated around the installation and commissioning of a new hyperon beam that was constructed for experiment WA89 to study the properties of charmed-strange baryons. To perform these studies it was proposed to use the Omega spectrometer in the West Hall and some new experimental equipment installed just upstream of the spectrometer. The most-easily-produced hyperon, the sigma-minus particle, has a lifetime which corresponds to a decay length of 15 metres at 400 GeV/c. Thus the hyperons must be produced close to the experiment to avoid large decay losses. Furthermore, in order to get a reasonable rate of hyperons, at least $10^{10}$ protons per spill must be used. Thus the provision of a hyperon beam implies targeting and dumping some $10^{10}$ protons inside the experimental hall.The large amount of shielding needed interfered with many of the installations in the hall and thus much work has been devoted to modifications of the infrastructure to accommodate this shielding.

In order to allow the transport of 450 GeV/c protons to the hyperon production target, the last 150 metres of the H1 beam line have been reconstructed. To meet the new power requirements it has also been necessary to upgrade the cabling of some upstream beam elements.

The key elements of the hyperon beam itself are three dipole magnets mounted on plug-in units in order to minimize the change-over time between hyperon and normal hadron operation. The dipoles are equipped with tungsten inserts filling the gap between the poles. Each of the 90 tungsten inserts has a unique hole with small transverse dimensions and the ensemble of these inserts defines the beam channel and thus the properties of the beam.

The hyperon beam and the experiment itself were commissioned in November and December and the first results give very promising indications of beam properties which agree with the design figures.

During the first part of the fixed target period the H1 beam operated in its normal hadron mode. The main part of the time was used by the WA82 collaboration continuing their charm production studies with a negative pion beam at 340 GeV/c. Some weeks were also devoted to proton operation at 200 GeV/c giving reference data to the heavy ion experiment WA85.

A full programme was carried out in the four tertiary test beams X1, X3, X5 and X7. Detectors from the UA1, L3, OPAL, ZEUS, ALEPH and DELPHI collaborations as well as a luminosity monitor for LEP have been calibrated and tested.

In addition, the X7 beam has been extended through the former BEBC hall to the neutrino experiment WA79 (CHARM II). For this calibration beam, additional bending magnets and quadrupoles and about 150 m of vacuum pipe were installed in both the West hall and the BEBC hall. Some of the detectors normally present in the beam had to be replaced by vacuum in order to minimize the amount of material traversed by the particles. The performance of the beam was such that WA79 could successfully calibrate its detector with pions and electrons of momenta between 2 and 60 GeV/c and with momentum-selected muons of 60 GeV/c. Even at the lowest energies the pion rates were sufficient to collect adequate statistics in a reasonable time.

The X3 beam has also been prolonged in order to provide the heavy ion experiment WA80 with *in situ* calibration of their calorimeters. Much effort has gone into this project which allows WA80 to take data in the H3 beam and calibrate in the X3 beam without disconnecting any part of their apparatus.

## Other Developments

### Design Studies of the LHC

The importance of obtaining a very high luminosity, i.e. of the order of a few times $10^{34}\,cm^{-2}\,s^{-1}$, in the LHC is increasingly emphasized. In addition, the possibility of producing heavy ion collisions as well as electron proton collisions appears to increase considerably the potential of the CERN accelerator complex. Studies were pursued in 1989 to improve the machine design and better assess the performance of the LHC as a proton-proton collider as well as a heavy ion collider.

In order to ensure the stability of the high intensity large emittance beams which are necessary to reach the design luminosity of $4 \times 10^{34}\,cm^{-2}\,s^{-1}$, a sophisticated multipolar correction scheme including sextupole, octupole, decapole and possibly dodecapole corrections, is necessary. Two possible solutions have been studied in detail. In the first solution long flat super- conducting coils are wound inside the main magnets on the external surface of the vacuum chamber. This provides a correction as close as possible to the source of errors, and therefore holds the promise of the best performance. Unfortunately, it is difficult to implement, especially in the twin aperture magnets of the LHC. In the second solution, space is reserved for lumped correctors between each quadrupole and the following dipole magnet, as well as between dipoles in the middle of each half cell. Both solutions appear to be adequate, and therefore it is proposed to adopt the solution with lumped correctors. However, for this scheme to be effective the diameter of the superconducting filaments in the main magnet coils must not exceed 5μ, in order to minimize the persistent currents at injection energy. Studies are continuing to evaluate the higher order effects induced with this scheme by a non zero closed orbit deviation. New computer programs based on Finite Mapping with Normal Forms approximation of the particle trajectories have been successfully used for these studies, in complement to the classical tracking programs.

Whereas the systematic part of the multipolar errors can be satisfactorily compensated, the only way to minimize the detrimental effects of the random components of the magnet errors is to measure the field of each individual element and to install the magnets in the machine in a prescribed way. Ordering schemes have been devised based on the minimization of the effect of the strong sextupolar errors in the bending magnets. Although the twin aperture character of the LHC makes the ordering sequence more complicated than for ordinary single aperture elements, a sizeable increase of the dynamic aperture can be obtained. However, the gain is limited by the existence of the high order multipolar effects which are strongly dependent on the coil diameter.

Detailed studies of the beam-beam effect have been launched, both experimentally in the SPS and by computer simulation. Studies in the SPS concentrate on the understanding of the behaviour of large amplitude particles in head-on collisions, and are described in the chapter on collider studies. A specific problem of the LHC is that bunches are separated from each other by 4.5 m, while the space between the magnets which recombine the two beams in each interaction area is around 200 m. The beams must therefore be made to cross at an angle in order to avoid multiple bunch collisions. The crossing angle must be sufficiently large to minimize the long range interaction of the bunches. However, this may induce synchrobetatron resonances and reduce the effective beam aperture in the quadrupole triplets. Extensive computer simulations are being made to determine the optimum value of the crossing angle. The tune spread which affects the large amplitude particles ($6\sigma$) due to the multiple long-range interactions is determined, as well as the amplitude growth of these particles on the synchrobetatron sidebands of high order resonances. In the cases where there is more than one interaction region, alternating vertical and horizontal crossings considerably reduces the tune spread due to the long range interactions.

The design of the low beta insertions and of two different solutions for the dispersion suppressors have been further refined, in particular to optimize the transverse acceptance in the quadrupole triplets and to reduce the number of special elements. The work to build a database using IBM/VM files and the standard MAD language has been started.

The performance of the LHC as a heavy ion collider has been assessed. For lead-lead collisions the luminosity is limited by fundamental phenomena like electromagnetic nuclear dissociation and pair production followed by electron capture. Emittance growth due to intrabeam scattering is also a serious limitation, but machine parameters can be adjusted so as to make the operation possible at a luminosity of $10^{28}$ cm$^{-2}$ s$^{-1}$.

Experiments have been pursued to simulate the non-linear dynamics of particles in the LHC by powering strong sextupoles in the SPS. Attention has been focussed on the effect of small but unavoidable tune modulations. A controlled modulation of the horizontal tune was induced by powering a special quadrupole. The modulation depth was of the same order of magnitude as that of the natural modulation measured in the SPS and the frequency was varied from 9 to 200 Hz. The diffusion rate was measured in the presence of sextupole non-linearities as a function of beam diameter, modulation frequency and depth. The effect of modulation is dramatic, considerably enhancing the diffusion rates and particle losses. However the experiment did not reveal a clear dependence on the modulating frequency, in contradiction with some theoretical predictions.

One of the most serious problems concerning the operation of the LHC, especially at high luminosity, is that of controlling the particles in the beam halo so that only a small fraction of them eventually hits the magnet system, where they can induce quenches. From SPS experience it is known that different phenomena, in particular the beam-beam interaction, cause a fraction of the beam particles to slowly acquire large oscillation amplitudes, forming a thin halo around the beam core. In the halo particles diffuse outward faster and faster until they hit the collimators, the diffusion rate being governed by non-linearities arising from the beam-beam interaction as well as from the errors in the main magnetic field. Systematic studies, including experiments and computer tracking, are being made to better understand this diffusion mechanism as well as the particle behaviour in a collimation system. In the SPS collider the transverse flow of particles has been measured at different distances from the beam centre. The results allow the calculation of the impact parameter distribution on the collimators, a necessary ingredient in the assessment of collimation efficiency.

Following the decision to increase the design luminosity of LHC, a review of the LHC RF system is in progress. The superconducting cavity version has been abandoned, because of the large peak power required anyhow to handle the heavy beam loading. Multi-cell copper cavities with rectangular shape determined by the two beam's distance are being actively studied. An optimization of the cavity cell with a three dimensional computer code has been made, and model measurements will follow soon. Possible RF sources are being discussed with European manufacturers. The critical parameters are modulation speed, efficiency and phase linearity.

A more realistic pre-bunching scheme to produce the 15 ns bunch spacing in the LHC has been worked out in its preliminary form. It involves two low frequency (66.7 MHz) RF systems in the PS and SPS accelerators.

The studies on the beam transfer to LHC have continued. A scheme, which avoids the polarity reversal of the SPS has been worked out and adopted .

More work has also been done on the beam dumping system and preliminary designs were made for the kicker systems and for the beam dump itself. Computer calculations and model measurements were made to find a suitable design for the kicker pulse generators which must produce very high current and long duration pulses for the extraction of the 8 TeV beam. A collaboration with the University of Erlangen was started on the development and testing of pseudospark high current switches which have for this application advantages compared to thyratrons. A study, comparing different types of high field kicker magnets, was continued in order to determine the most suitable magnetic material and magnet configuration.

## Development of High Field Superconducting Magnets

The development of high field superconducting magnets for a possible Large Hadron Collider in the LEP tunnel has been marked by the successful testing of several one-metre long single aperture dipoles.

A dipole magnet made with $Nb_3Sn$ cables reached a 9.5 T magnetic field in the bore at a temperature of 4.3 K. This magnet has been built as a joint project of CERN and the firm ELIN (Austria). The $Nb_3Sn$ compound in the cables is formed when the wound coils are reacted at 675° during 144 hrs. Technologies related to the insulating materials and the high temperature of reaction have been developed and the successful test shows that the 'wind and react' route is technically feasible. The first 8 T one-metre long single aperture magnet, made with NbTi cable, which had already been tested in 1988, has been enclosed in a horizontal cryostat and measured again at Saclay (F). After 6 months at room temperature, the magnet has shown again its very good behaviour and reached 9.3 T after two quenches. Magnetic measurements and protection tests have also been performed. A second 8 T model of the same design was built by ANSALDO and tested. It has shown a similar behaviour as the first one reaching a 9.45 T field. Several twin aperture dipoles are under construction in industrial firms and are expected to be tested in 1990.

The research and development activity on high field super-conducting magnets is spread in various national laboratories and in various firms either by normal contracts or by collaboration agreements between CERN and firms or laboratories. Industry is also involved in the earliest stage of the design and construction of magnet models and prototypes.

The development in European industries (five firms are involved in five different countries) of superconducting wires and cables has progressed to obtain high current densities in thin NbTi filaments. A current density of 1190 A/mm$^2$ at 11 T, 1.8 K, has been obtained in a NbTi composite strand of 1.29 mm diameter having 5 µm filaments. Composite wires with $Nb_3Sn$ compound, produced by special powder metallurgy, have reached current densities of 1600 A/mm$^2$ in the non-copper part at 11 T, 4.2 K. High current cold diode assemblies for by-passing quenching magnets have been tested. At 77 K, they can easily carry a current of 16.5 kA during 52 s without damage and with a current sharing ratio of about 40% to 60%.

### Operation of a Superconducting Cavity in the SPS

The superconducting cavity was cooled down at the end of the January-February shut-down for a period of about two months. It was left at room temperature during most of the $p\bar{p}$ period, until the end of June 1989, when the cavity was made ready for lepton acceleration. The cavity has been in operation since the start-up of LEP in July and has proven to be very reliable. It provides an additional voltage for lepton acceleration of about 9 to 10 MV. During the summer period, when the 200 MHz single cell cavities system suffered a large number of vacuum bellows failures, this extra voltage was absolutely necessary to accelerate leptons for injection into LEP.

Some minor improvements on the low level circuitry were necessary to obtain the present degree of reliability. In particular the thyristor controlled regulation circuitry for the liquid helium level is now switched off during the RF pulses. This suppresses the unwanted tuning vibrations induced by the sharp thyristor pulses. Automatic switching from magnetostrictive (RF driven) to thermal (temperature driven) tuning when the RF is off for long periods ensures now an automatic restart of the cavity, thanks to the very large dynamic range of the tuner phase detector circuitry. The RF pulses for lepton acceleration now start halfway along the ramp of the magnetic cycle, and not before injection. In this way the tuner transients have become much more reproducible and consequently the cavity can safely handle larger beam currents.

After more than 10 000 h at low temperature in the SPS accelerator, no significant degradation of the performance of the cavity has been observed. During normal operation, the cavity field is between 5 and 5.5 MV/m. No conditioning of the cavity has been necessary since June 1989. The quality factor is estimated to be between 1 and $2 \times 10^9$. This relatively low value (which does not affect the SPS operation, because of the very small RF duty cycle) can be explained by trapped magnetic fields, for which no special precautions have been taken.

A motor-driven waveguide switch has been installed between the tetrode power amplifier and the superconducting cavity. It allows the cavity to be connected to a passive damping device in case of a breakdown of the power amplifier or feedback loop, thus permitting to continue the high intensity proton beam operation. Tests with beam have shown that this damping is sufficient for stability of the fixed target proton beam. Since the superconducting system has changed from an experimental to an operational version (permanent use for lepton acceleration), the provisional layout of mains distribution and amplifier software had to be adapted to the new conditions.

A new radiation resistant fibre optics link has been installed between BA3 and BA4 to synchronise the superconducting cavity. Transmitters and receivers have been developed. A measurement program to monitor possible radiation damage has been established in collaboration with the TIS Division.

Following the excellent results of the cavity in summer 1989, it was decided to install a second superconducting cavity in the SPS, during the 1990 shut-down. The basic reason is to improve the reliability of the overall lepton acceleration system (copper and superconducting cavities). This will make a better use of the existing refrigerator, which should be able to cope with a double cavity during steady operation. During the filling of the cryostat with liquid helium, the refrigerator capacity will be boosted with an additional supply of liquid nitrogen, using the existing transfer line which runs from BA4 to LSS4. After detailed discussions with the EF division, it was decided that the present cavity will be taken out of the SPS during the 1990 shut down and replaced by a twin cavity, already assembled and tested. In this way, a better insurance against possible contamination of a cavity is achieved. The twin cavity to be installed in the SPS will be of the niobium coated copper type, with the advantage of its insensitivity to stray magnetic fields. New types of high order mode couplers have been developed for this cavity by the EF division.

A complete new RF chain, from the low level electronics to the final power amplifier is being prepared for the second cavity. This includes new power supplies, cabling and modifications of the infrastructure in the SPS tunnel and in BA4. New driver amplifiers, using tetrodes, will replace the existing one. The control of the future cavities will be fully integrated in the SPS control system. All orders for RF power amplifiers, power supplies, cooling systems, interlocks and controls have been placed.

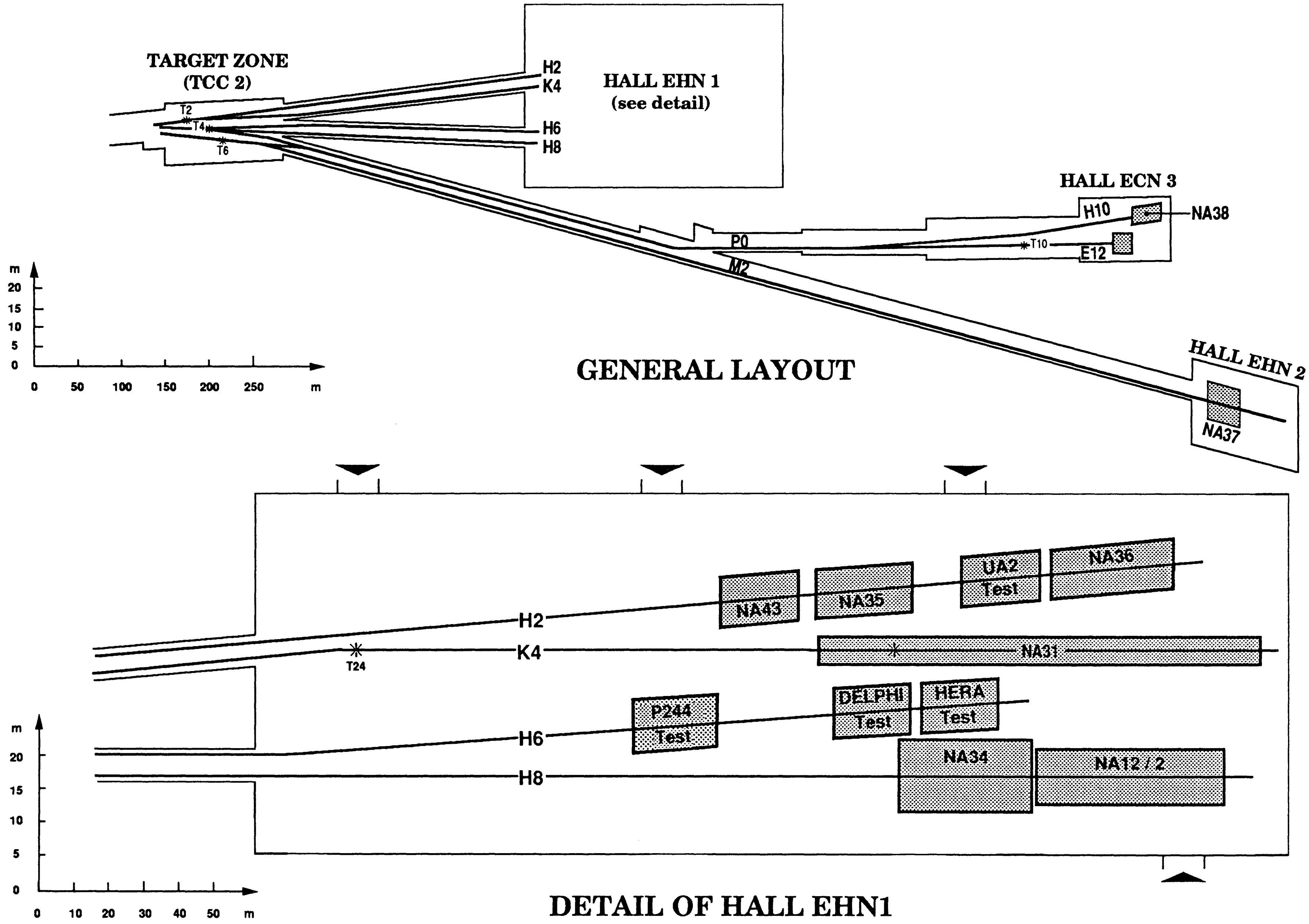



*Figure 1 SPS North experimental area*

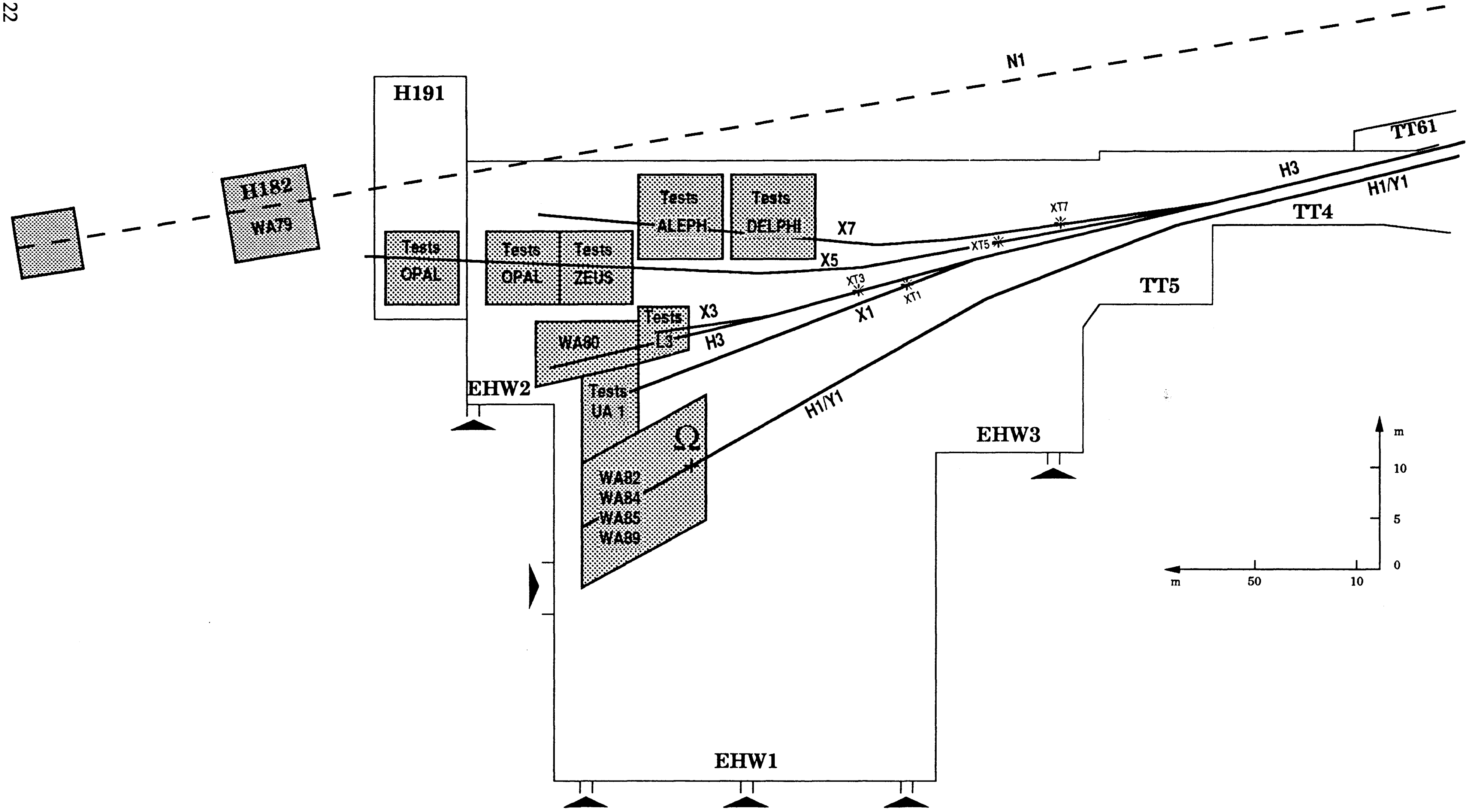



*Figure 2* *SPS West experimental area*

# LEP Division

From now on historians will remember the date of the French Revolution as being exactly 200 years, day for day, before the first beams circulated in LEP : 14 July 1989. They will also remember that the first $e^+e^-$ beam collisions occurred in the machine on 13 August 1989, only 5 years 11 months after the official ground-breaking ceremony on 13 September 1983, and that the official inauguration was celebrated on 13 November of the same year in the presence of some 1500 guests including Heads of State and Government and Ministers from CERN's 14 Member States as well as representatives of many other countries. All of this culminated in experiments installed around the machine witnessing some 100 000 $Z^0$ particles by the end of the year.

With so much success to report, it was sad that the completion of the LEP construction project entailed the dissolution of the LEP Division. However, the tremendous effort made by the Division's staff since its foundation in 1983, together with the very important help so willingly given by all the other CERN Divisions, as well as the very essential part played by European Industry, is sincerely acknowledged.

## LEP Commissioning & Operation

As part of the preparation for the LEP commissioning with beam all installed components were tested in place. Working groups were formed to deal with beam optics problems, beam instabilities, synchrotron radiation effects and to prepare the main commissioning procedures for injection, energy ramping and luminosity optimization as well as the necessary application programs. Before the start-up a cold check-out of all the systems was carried out.

On 14 July, positrons were injected and a full turn was achieved within less than one hour. The next days were spent commissioning the trajectory measurement and correction system and other beam monitoring instruments. Thereafter, many turns were obtained, particles were trapped with the RF system and the machine tunes were measured. Early in August, beam was accumulated by off-axis injection, the energy was ramped to 45 GeV, the beta functions in the interaction points were reduced and the effects of the detector solenoids were compensated. On 13 August, a pilot physics run was started which gave over 50 $Z^0$ in all experiments, sufficient for a first check of the detectors.

Already during the early commissioning phase strong betatron coupling was observed. This was reduced by changing the horizontal and vertical tunes such that their difference was no longer close to the eighth integer and by using the rotated quadrupoles of the solenoid compensation scheme. With this and some other improvements a physics run in September gave luminosities in the $10^{29}$ $cm^{-2}s^{-1}$ range. The superconducting quadrupoles were commissioned and the vertical beta function in the four interaction points was reduced from 21 to 7 cm resulting in luminosities of over $10^{30}$ $cm^{-2}s^{-1}$ in the following runs. By the end of the year there had been 85 fills for physics with a total of 453 hours of coasting beams at a range of energies. Half of the physics time was spent around the expected $Z^0$ mass. An estimated total of about 1.8 inverse picobarns of accumulated luminosity was recorded and over 100 000 $Z^0$ particles were detected in all four experiments.

During machine development runs, more work was aimed at understanding the betatron coupling which decreased with increasing beam energy and seemed to be caused by some ferromagnetic materials in the dipole magnet vacuum chambers. Rotated quadrupoles were installed in the arcs to reduce this coupling and the related vertical dispersion. Among the collective effects, betatron and synchrotron frequency shifts, parasitic mode losses and bunch lengthening were measured indicating a rather low impedance of $|Z/n| \sim 0.25\ \Omega$. Currents of over 0.5 mA per bunch were achieved which is 2/3 of the design value. However, most of the time the intensity was limited to lower values by synchro-betatron resonances caused by dispersion in the cavities. The energy of LEP was frequently calibrated from the voltage induced in a flux loop during magnet cycling. As an independent energy measurement, protons were injected and stored on the nominal orbit where they have the same momentum as the electrons. From the measured revolution frequency the velocity and momentum of the protons were obtained.

## The LEP Project

### Injector System

Installation and development work on the pre-injectors and on the PS on behalf of the LEP Project are reported in the PS Division chapter. The following paragraphs describe the work carried out by the SPS Division for LEP.

During the winter shutdown the upstream part of the 20 GeV $e^-$ beam line TI12 in the SPS tunnel was completed. At the same time the last 8 (out of 32) single-cell accelerating cavities, each with its damping loop, tuner, higher-order-mode suppressors and power amplifiers (60 kW, 200 MHz) were installed and commissioned. Furthermore, an important improvement was made to the power converters of the SPS main dipoles. Instead of operating with one station in current control and all other stations in voltage control, all stations are now current controlled. This resulted in better stability and reproducibility of the current at the 3.5 GeV level. Also an NMR-calibrated magnetic measurement was introduced so that the energy of the leptons extracted from the SPS could be better defined.

For all SPS systems involved in lepton acceleration, especially the RF, beam transfer and beam monitoring systems, a major effort was made during the first half of the year to complete and improve their data acquisition and control systems. Using the experience from the lepton beam tests in 1988, much of the high-level software was rewritten and better adapted to the operation with interleaved proton and lepton cycles.

The difficulties with the industrially-manufactured high-voltage coils of the LEP injection kickers were solved. The end connections of the epoxy-impregnated glass-mica insulation were moulded at CERN and the coils successfully tested at their design voltage. The six kicker magnets and the two eddy-current septum magnets were installed in the LEP tunnel and connected to their respective pulse generators located in the restricted space behind the LEP magnets. A digital waveform acquisition system was developed for the transmission of signals of lepton bunches and kicker pulses to the Prévessin Control Room. This facility proved very useful for the synchronization between lepton bunches and kicker pulses.

After the SPS proton-antiproton run in the first half of the year, the startup of the operating mode with interleaved proton and lepton cycles in July proceeded quite smoothly and the SPS fixed target program has not at all been affected by the interleaved lepton acceleration. The electron transfer line TI12 was commissioned without difficulty. On average an intensity of $1.2 \times 10^{10}$ particles per bunch for both positrons and leptons could be sent to LEP. The transmission from the CPS through the SPS to LEP was about 80% for $e^+$ and 60% for $e^-$. The electrons are mainly lost at injection into the SPS when they pass through the channel that is also used for 450 GeV proton extraction and has an aperture of 20 mm × 20 mm. Better beam position control should enable the beam loss to be reduced.

Difficulties occurred with leaks in the bellows of the damping loops of the single-cell lepton accelerating cavities. These damping loops need to be moved into and out of the cavities under vacuum to permit the alternate acceleration of high intensity proton beams and low intensity lepton beams. The failure rate was reduced by slowing down the movement of the bellows and cycling the bellows only when lepton acceleration is needed. A new type of bellows with a guaranteed lifetime of 1.5 million cycles has been ordered and will be installed in 1990.

The average vacuum pressure in the SPS was about $7 \times 10^{-10}$ mbar before lepton acceleration started and no pressure rise due to outgassing caused by synchrotron radiation could be observed. during the October shutdown some replacement chambers were installed which had never been in the machine before.

### Main Ring

Underground construction work was completed in March with the concreting of the final section at the base of pit PZ 33 at Crozet. Immediately afterwards, the surface building above this pit was started in order that its electrical sub-station and access control point could be equipped in June. This completed the programme of 71 LEP surface buildings representing a covered surface of 55 000 $m^2$ interconnected by 2500 m of service tunnels together with access roads, parking areas and platforms having a total surface area of some 160 000 $m^2$.

The second half of the year was devoted to the finishing touches of the vast surface buildings' programme : constructing roads, adding fences, landscaping, planting trees, etc., all of this with the desire to blend into the environment according to the proposals of the consultant architects.

*Applied geodesy*

Most of the activity was focussed on the completion and alignment checks of LEP, its injectors and experiments. After termination of the civil engineering and its control surveys, the installation and alignment of the last octant, TI12 and all of the components installed late, was carried out. Moreover, a full re-measurement of the machine was undertaken to detect and correct all misalignments related to micro- or macro-movements : vertical and radial smoothing survey of the quadrupoles, check of the dipoles. Concerning the injectors, LIL was fully re-aligned and the SPS subjected to a complete smoothing survey. In the experimental areas, after assembly and positioning of the detectors, the experiments were surveyed in their beam data-taking position. Then, by computation, all the geometrical parameters of the inner detectors were determined and transferred into the corresponding databases. In addition, underground cables installed between five of the pits were surveyed to confirm their location and conformity with local bye-laws and rights of way.

Apart from LEP, other work including site surveys, metrology of secondary beams or of PS, LEAR and SPS experiments required a considerable effort.

*Theory*

The LEP Theory Group was strongly involved in the LEP commissioning. The beam optics team prepared 80 schemes necessary to describe the LEP cycles, and participated in the elaboration of the control software. The following items were completed : LEP parameter database, interfaces between MAD and Oracle, beam dynamics tables under Oracle, their transfer to the control system. This was used in the LEP commissioning proper, first obtaining a circulating beam, then performing orbit and tune adjustments, retuning of the high-beta insertions, etc. The effects of the unexpected nonlinear field components in dipoles and quadrupoles were studied, and the LEP model adapted accordingly. Coupling due to solenoids and other coupling sources was carefully compensated. Finally, $\beta_y^*$ was reduced from 7 to less than 4 cm, with the prospect of a corresponding luminosity increase. A new shorter spin rotator for LEP was designed.

For LEP commissioning, the BBI program was made available in the LEP control system. Experiments on bunch lengthening were made and the longitudinal and transverse impedances measured and compared with theoretical predictions.

The accelerator design program MAD was rewritten to enhance its reliability and adapted to permit its use with the naming scheme used in the LEP control system, to read and write files in the LEP control format TFS, and to allow new constructs such as the element class. With graphics facilities it was implemented on the Apollos in the control system. The program BEAMPARAM was incorporated in MAD and work started on a menu-driven user interface to MAD on Apollo. In collaboration with BNL and DESY, the SMILE program was corrected and expanded to allow calculation of the equilibrium polarization in circulating electron beams for betatron and synchrotron resonances of (in principle) arbitrary high orders.

*Magnets*

The assembly and installation of the magnets progressed at the highest rate of four half-cells per day without major difficulties. In order to correct the vertical field perturbation induced by the nickel layer of the vacuum chamber, shims punched in 0.5 mm thick galvanized steel were installed at the ends of the dipole pairs in April.

For the beam test of mid-July, the whole magnet system was commissioned, except the two superconducting quadrupoles of point 6 which were tested with their dedicated liquefier in August. The eight superconducting quadrupoles quenched at current levels above 1900 A showing no retraining.

The beam tests showed that the whole magnet system behaved satisfactorily. Combined with a measurement of the revolution frequencies of electrons and protons at injection, the flux loop and field display system allowed the calibration of beam momentum to within $\pm 3 \times 10^{-4}$ at 46.5 GeV/c (one sigma value).

The beam tests also revealed anomalous coupling between horizontal and vertical betatron oscillations. Very precise magnetic measurements inside samples of vacuum chambers showed this to be mainly due to horizontal field components associated with the above-mentioned nickel layer. These fields, of the order of a few hundredths of a gauss, but with a gradient of 1 to 2 $\mathrm{Gm}^{-1}$, are produced by a permanent magnetization of the nickel layer. Sixteen short skew quadrupoles of 1400 G integrated gradient were built and installed in the arcs in November to improve the betatron coupling compensation. A programme has also been launched to find ways of demagnetizing the vacuum chambers in the tunnel.

*Radiofrequency*

Installation and commissioning of the remaining 64 RF cavities continued in sectors 27 and 67 so that by the end of May, the total copper cavity system was installed and operational. However, it was not fully conditioned up to maximum RF power, since this is a time-consuming process and requires access to the RF area to be restricted. When the first beams were injected into LEP, the RF system was ready to store and accelerate both electrons and positrons. This was successfully achieved on 13 August, with colliding beams at 45 GeV. Unexpected longitudinal instabilities of both the electron and the positron beams were observed at rather low beam intensities and a crash programme was undertaken to build a longitudinal feedback system to cure them. This was achieved by using the existing RF system with the addition of some sophisticated electronics at the lower-power and controls levels.

The dedicated systems for damping transverse beam instabilities were made operational during the latter part of the year. At the present beam intensities, these instabilities do not occur but the efficiency of the feedback system was demonstrated by damping externally provoked transverse oscillations of the circulating beams.

In preparation of the LEP energy upgrading, a test area for superconducting cavity modules at cryogenic temperature was prepared. This was used to condition and test the 4-cavity module planned for installation in LEP, together with the 2-cavity module for the SPS. LEP ring half-cells 244 and 245 were prepared for the upgrading pilot test and are ready to receive the first 4-cavity module. A third RF unit with one klystron and the associated control racks was installed for powering these cavities in sector 23.

*Vacuum*

Efforts during the first half of 1989 were entirely devoted to the installation of the vacuum system in the tunnel and its commissioning. By mid-June, the last joint was tightened and on 9 July bake-out of the last vacuum sector was successfully completed, i.e. all the vacuum system except the RF cavities and the interaction regions had been baked *in situ* before start-up. The failure rate of the vacuum components was very low; less than 0.5% of more than 30 000 joints had to be re-made during installation and only very few small leaks were detected and sealed after bake-out. This confirmed the sound design of the system and the careful work executed by personnel from CERN and outside contractors.

The static pressure reached $8 \times 10^{-12}$ Torr in more than half of the machine and only slightly more elsewhere; a promising sign that the system was clean to UHV standards, in spite of its size and complexity. The initial dynamic pressure rise in the presence of beam was indeed $1 \times 10^{-7}$ Torr/mA as expected. Progressive cleaning due to gas desorption by the synchrotron radiation reduced it by more than three orders of magnitude, yielding a beam lifetime of 35 hours (for 1 mA) in December.

The non-evaporable getter performed extremely well. Only two conditioning campaigns were required (short heating to 450 °C) in order to restore the maximum pumping speed, one in September after a beam dose of 100 mA × hours and one in November after 1100 mA × hours.

*Beam instrumentation*

Installation of instruments in the vacuum chamber, and of electronic equipment in the 24 underground stations, was only terminated at the end of June due to the late delivery of the Jura octant, leaving little time for tests. Following circulation of the first beams, synchronization of the first-turn trajectory measurements, expected to be performed simultaneously at the 504 pick-ups, was started. The accuracy of beam position measurements improved steadily since that time and has already provided a corrected closed orbit showing r.m.s. deviations of less than 1 mm in both planes. Measurement of the betatron frequencies was one of the most used facilities during the commissioning stage. It offers different modes of data treatment and has the powerful option of exciting then observing selected bunches, yielding opportunities for sophisticated machine physics experiments.

Another very positive achievement was the large reduction of backgrounds to the four experiments due to the extensive LEP collimator system.

Bunch-current monitoring was also available from the beginning to allow the injection stacking progress and beam life-time to be monitored. Bunch lengths were measured with the help of a broad-band sampling oscilloscope located in the machine tunnel, until a streak camera could be tried out on single-bunch passages towards the end of the year. Transverse profile monitors have yet to achieve their final performance. Although synchrotron-light telescopes provided two-dimensional beam images relayed by TV, reliable emittance values could not be deduced from them. Wire scanners were operational during some machine development periods and yielded promising measurements.

The mini-calorimeters installed in the collimators at ± 15 m from each experiment counted Bhabha events at the expected rate and operated, together with the electrostatic deflectors, to scan the beams at the crossing points and to check for perfect vertical overlap which leads to maximum luminosity.

*Electrostatic separators*

By the start-up on 14 July, the separation system was fully operational, and since then it has operated with high reliability. In the even collision points, where eight separator units were suppressed for economic reasons, it has run at voltages of as much as 25% above the design values in order to reduce the beam-beam forces by an increased separation. Up to now, the higher field has not led to beam losses due to electrical breakdowns.

In several commissioning experiments, the main parameters of the separation system were carefully studied. Firstly, is was shown that the amplitude of the closed orbit deformation corresponds accurately to the values calculated from beam optics. Secondly, it was verified that the nominal kick ratio between the two pairs of independently powered separator units corresponds to a minimum disturbance of the vertical closed orbit in the arcs for both the back-up and the low-beta optics. Thirdly, the vernier adjustment of the beam collisions made it possible to verify that at current energies and 7 cm low-beta optics the bunches collide head-on to within about + $1\sigma_y$ (± 7 μm). Furthermore, it was demonstrated that without separation $e^+e^-$currents higher than a few 10 μA could not be accumulated.

*Power converters*

During the first months of the year, industry delivered the very last power converters for powering the magnet system, the RF klystrons and the sputter-ion pumps for the vacuum system. In parallel, equipment was installed and tested in the eight equipment buildings, four underground areas and one experimental hall. In the gaps of the installation schedule, commissioning took place and tests from Prévessin Control Room were carried out. This gave confidence that all the equipment would be ready for the start-up of LEP with beam. Since that time, all the power converters have worked to full satisfaction and meet their specification. Their reliable operation has contributed in an essential way to the very rapid start-up of LEP and the full success of the physics runs.

Operational experience since July has shown that the design options taken to achieve a reliable and very performant system were correct. This result was reached within the given tight budget and short time schedule.

*Electrical installation*

LEP's electrical network had been brought into service progressively since 1987 and was completely ready for the first beam tests in July. Increasing the power carried by the network, especially during the second half of the year caused no particular difficulty. The power consumed attained 45 MW, raising to 131 MW the total power drawn from EDF by the SPS/LEP complex.

At the completion of the construction phase, a total of 4750 km of control and power cables had been installed representing some 50 000 individual cables.

*Controls*

This work is reported in the SPS Division's chapter, see pp 115–116.

*Cooling & ventilation*

For the first half of the year the activities were focussed on the preparation of the installations for the machine start-up. The machine cooling water circuits (80 MW capacity) were all completed : cooling towers, underground heat exchange and pump stations together with the primary, demineralized and raw water circuits, have now all been installed. Also completed were the fire detection systems and the underground air conditioning installations for the technical and experimental areas. All of the above systems are connected to the main control room. The chilled water production plants were completed at the even points and 80% completed at the odd points.

The provisional air treatment installations spent their fourth and last year in operation whilst the definitive installations reached 85% completion. In addition, the final duct network reached 95% completion bringing up to some 32 km the length of ductwork now installed.

*Installation & mechanical engineering*

The year saw the end of LEP installation work in good time for the first circulating beams on 14 July, exactly the date planned at the beginning of 1987. The second half of 1989 was mainly devoted to the organization and the follow-up of the LEP shut-down in September, October and November and the preparation of the main shut-down of the beginning of 1990. Installation work continued in a few surface buildings until the end of the year. The LEP site surveillance team was organized and set up during the year.

In the field of mechanical engineering, the design, manufacturing and installation of the remaining beam observation equipment and the optical laboratory were completed; the workshop being intensively involved in the manufacturing process. The four thin-wall vacuum chambers for the LEP experiments were inserted into the detectors and connected to the LEP machine. In collaboration with the EF division, the design of 20 superconducting cavities was completed and an order for their construction awarded to industry. Studies were performed to prepare the transport and installation of the first set of four cavities of this type in the LEP tunnel.

In the field of R&D and new technologies, the hydroforming development for building 1.5 GHz copper cavities was completed and studies started on the application of this technique to 352 MHz cavities. Studies for the LHC components started during the last part of 1989.

*Radiation control*

During the first six months of the year all monitors, apart from those in the air release system, were installed and tested. When operation started in July, the LEP radiation protection system was ready and the transition from the installation to the exploitation phase went smoothly. Radiation measurements performed during the second half of the year confirmed the estimated low levels of radiation.

Operating LEP did not change any radiation parameter monitored by the environmental measurements. Concentrations of radioactivity and noxious compounds in air, the stray radiation levels near the access pits, as well as the radioactivity measured in small streams in the LEP area remained inside the fluctuations of the values measured during the four years of pre-operational measurements.

*Personnel access*

The access control system for LEP was completed and put into service just before the start up of the machine. Before LEP can be switched on it is necessary to execute a tunnel search which requires nine teams. They ensure that all persons have left the tunnel and that doors and gates are properly locked electrically. When the search is completed it is possible ro remove the inhibits from the so-called 'safe elements', which can then be switched on. These elements are: the main-dipole supply, the RF system, a beam stopper in the ring vacuum chamber, and the beam transfer lines coming from the SPS injector. LEP is then ready to operate.

Due to the long distances in LEP, the access control system is fully dependent on the general controls system and on special software. It was formally checked out by inspectors from the French safety authority in the framework of the convention signed with them.

## LEP 200

The main activity concerned the production, testing and installation of a superconducting LEP 4-cavity module. This consists of a string of four bulk-niobium 4-cell cavities with individual helium tank but in a common insulation vacuum. Each cavity is equipped with tuners and power and higher-order-mode couplers. Two cavities were produced by industry and two at the CERN workshops. All cavities were tested individually and the module itself assembled under clean conditions at CERN. Successful tests were made in a facility used earlier for the LEP copper cavities, adding a liquid helium supply system based on an existing refrigerator. All four cavities exceeded the specified accelerating field of 5 MV/m, a total voltage of 32 MV was obtained.

The operation in LEP was prepared by moving and refurbishing an existing ISR refrigerator, adding a 1 MW RF power system similar to the existing ones and, by using a model, checking the method of transportation.

Twenty new bulk-niobium cavities were ordered with their couplers, a main coupler test stand is under preparation and offers for a 6 kW refrigerator were requested. A further set of eight Nb/Cu-sputtered cavities are in production at CERN, already partly equipped for the machine operation and successfully tested. Two more of these have been rearranged as a double module for the SPS so as to provide spare capacity for the RF system. It is expected to have a total of 32 superconducting cavities in LEP by the end of 1991.

## Other Divisional Activities

### The CLIC Study

The study of a possible linear $e^+e^-$ collider in the TeV range (CLIC) continued, with contributions from several CERN divisions as well as from outside laboratories.

A main item of this study is the development and construction of a test facility permitting the generation of a high-intensity drive beam for the two-beam acceleration scheme envisaged. Most items for this test facility are ordered or at hand and the building for shielding and housing the facility has been erected. The development of suitable laser-driven photocathodes – one of the most critical items of this facility – has started and already resulted in the production of substantial photocurrents (12 A), which will, however, remain limited by space charge until the RF gun of the facility is ready.

Another key item of the study is the development of a high-gradient accelerating structure in the 30 GHz range. This work, which includes the design and development of input and output couplers as well as brazing tests, has progressed to the point where the manufacture of accelerating structures, ready for tests at the test facility mentioned above, can be envisaged. This work includes the development of alignment methods in the micrometre range of reproducibility and of beam-position monitors of similar accuracy.

The theoretical studies of a final focus system, including the radiation effects therein, have progressed and resulted in the proposal of an actual design.

### CERN Accelerator School (CAS)

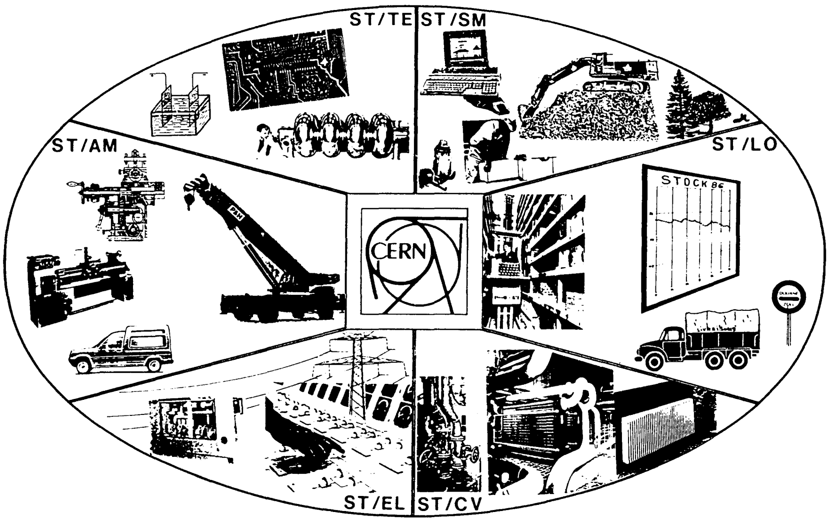
CAS started the year with a specialized course on 'Synchrotron Radiation and Free Electron Lasers' with the collaboration of the Daresbury Laboratory in England (6-13 April). Synchrotron light sources are a rapidly expanding sector in accelerators and are major recruiters of staff. This course was an opportunity to improve communications and to demonstrate the mutual benefits of such contacts.

In the autumn, CAS joined with the University of Uppsala to hold a very successful Advanced Accelerator Physics course in Uppsala, Sweden (18-29 September). The General and Advanced courses form a biennial programme that has now been repeated three times. It is now clear that the attendances are settling down to about 100 students for the General course and about 80 students for the Advanced and within these numbers around 80% are from Member States, 10% from North America and 10% from the rest of the world.

Courses must be planned well in advance and accommodation booked. In varying stages of preparation, CAS has three course for 1990, two for 1991 and one for 1992.

CAS also ran five seminars, which included the John Adams' Memorial Lecture.

# Technical Support Division




The objectives defined when ST Division was created and which were approved by the Council in December 1985 were achieved. The operations budget was reduced by a total of 6 MCHF for 1989. The Division comprises seven main groups : the Mechanical Support Group (mechanical and sheet-metal workshops, handling and heavy transport), the Special Technologies Group (metal spinning, printed circuits, surface treatment, chemical treatment, etc.), the Electrical Installations Group (high- and low-voltage networks, design studies and works), the Monitoring and Communications Group (power distribution system, alarms, design studies and works), the Heating, Cooling, Ventilation and Air-Conditioning Group (heating plants, pumping stations, regulating work, design studies and works), the Site Management Group (civil-engineering design studies and works, maintenance, mail and cleaning) and the Logistics Group (transport and distribution of equipment, stores). For administrative purposes, TIS Commission is linked to ST Division.

The following table shows the distribution of personnel at the end of 1989 together with expenditure under the 'Materials' Budget broken down by major activity of the Division.

| | *Personnel* | *MCHF* |
|---|---|---|
| – Division Leader's Office, organization, management | 16 | 0.5 |
| – Mechanical support : | | |
| Mechanical, sheet-metal and similar work | 57 | 1.0 |
| handling and heavy transport | 37 | 4.4 |
| – Special technologies : | | |
| electrochemistry, special welding, surface treatments | 62 | 0.8 |
| – Installations : | | |
| electrical, operation, maintenance and works | 79 | 3.3 (79 + 34) |
| – Monitoring and communications, alarms, maintenance and works | 34 | |
| – Installations : | | |
| heating, cooling, ventilation, operation, maintenance and works | 50 | 3.9 |
| – Site management : | | |
| civil-engineering work, maintenance, cleaning, gardening, mail | 53 | 5.8 |
| – Logistics : | | |
| transport/distribution of equipment, stores, stock control | 60 | 1.4 |
| – Equipment alterations and minor modifications | - | 0.3 |
| **Total operational budget** | **448** | **21.4** |

*Personnel movements in 1989*

| | |
|---|---|
| – Recruitment | + 3 people |
| – Re-organization of electrical activities in August, and partial re-organization of heating and ventilation, transfers between divisions as part of restructuring | + 55 people |
| – Retirements, early retirements, end of contract | – 26 people |
| – Special leave at the end of 1989 | 11 people |

The budget amounts given above do not give a full picture of the ST Division's activities. The various groups operated on project or Divisional budgets as follows:

| *Projects* | *MCHF* |
|---|---|
| Projects and infrastructure consolidation | |
| **Total** | **3.2** |

| *Operations on divisional budgets* | |
|---|---|
| Civil-engineering installations and modifications | 3.9 |
| Electrical installations and alterations | 3.2 |
| Installations and alterations: heating, cooling and ventilation | 3.5 |
| Subcontracted work (mechanical engineering) | 2.6 |
| Subcontracted work (special technologies) | 0.8 |
| **Total** | **14.0** |
| Water and power consumption (for the whole of CERN) | 51.5 |
| Replacement of polychlorinated oils (PCBs) in compliance with legislation in the two Host States | 1.0 |

In addition to calls for tenders to industry, ST Division has recourse, subject to demand, to several renewable one-year contracts to maintain all its services and fulfil its work commitments. A breakdown of these contracts is given below.

| | | *No.* | *1989 MCHF* |
|---|---|---|---|
| A. | Maintenance contracts (infrastructure maintenance and cleaning) | 7 | 7.1 |
| B. | Service contracts | | |
| | for site operation and handling | 8 | 6.2 |
| | for large-scale projects | 5* +2 (LEP) | 5.9 |
| C. | Work and minor work contracts | | |
| | on the Site | 12 | 9.5 |
| | off the Site | 10 | 3.4 |
| **Total** | | **39** | **32.1** |

* management of site operation and handling service contracts for other Divisions

ST Division has continued its efforts to draw up results-based contracts such as those in categories A and C, i.e. contracts based on specifications with technical parameters setting out the clear responsibilities of the firm in the technical, social and financial fields. 'Service contracts based on hourly rates' (Category 3) will be limited to an absolute minimum and almost entirely restricted to the fields of transport and handling.

## Mechanical Support Group

### Transport & heavy handling

*Vehicles*

At 31 December 1989, the vehicle fleet amounted to 834 vehicles or heavy lifting devices and 270 mopeds.
Since the beginning of 1989, the entire fleet has been maintained under minor work contracts by four firms outside CERN. Maintenance improved considerably during the year.

*Transport*

The transport service (personnel, on site and long distance for equipment) continues to operate successfully, particularly:

- all transport for the last phase of installation for LEP and its experiments;
- transport of equipment and assistance with assembly work for the exhibitions in Milan, Aquila, Lyons, Sheffield, Martigny, Stockholm, Turin and Grenoble;
- transport of prefabricated units and counting rooms for the four LEP experiments (exceptional loads);
- LEP inauguration
- assembly of CLIC shielding
- fitting-out of building 188
- shuttle for LEP experiments provided by a subcontracted firm

*Handling*

- the January and February shutdown of the machines
- completion of the installation of the LEP machine and experiments, and reduction of contracted personnel to normal operational level
- miscellaneous handling work for the UA1 and UA2 experiments
- HYPERON (Hall 180)
- annual beam-modification programme (PS and SPS)
- office removals for members of the personnel and refurbishing of premises

## Main Workshop

The goal to complete the LEP installation for mid-1989 produced hectic activity for all sections of the Main Workshop during the first half of the year. Among the outstanding jobs were the completion of nine collimators for the LEP machine including precision spatial (3D) measurements and alignment of critical internal components and the very successful repair* of 17 LIL accelerating structures which required the combined effort and know-how of delicate machining, brazing, welding and handling in a clean environment. This latter job gave rise to a number of internal publications produced by the PS Division.

* The origin of this trouble was a fault due to incorrect manufacturing processes in industry

The very high level of activity in the Main Workshop continued also for the second half of 1989 thanks to a number of interesting jobs coming mainly from the PS Division and where the workshop sections participated actively in the development and manufacture of a complete radio-frequency quadrupole, a model for producing pole-face winding for the LEAR consolidation programme and a prototype linac structure for the acceleration of lead ions.

Out of a total available workshop capacity of 72 880 hours (17% less than the previous year), some 45 120 hours were made available as machine tool hours on user jobs and some 11250 hours for technical activities and supervision directly related to these jobs. Like last year, the main users were LEP main ring, the LEP injector inside the PS complex and the four LEP experiments which together represented about 70% of the total.

The machine tool maintenance team which keeps in operation a widely dispersed machine tool park was assisted this year by a new performance based contract covering all prevention maintenance activities. The results of the first year operation of the new contract can be rated as a considerable improvement over the previous situations without a significant increase in costs.

## Technology Group

Work in the Special Technologies Group was largely dominated by finalizing and commissioning components for the LEP accelerator and its experiments. However, a marked effort had also to be dedicated to future projects like the LHC, CLIC and LAA where often close collaborations with outside Institutes and Industry, associated with these programmes, were established.

As in previous years, the development of superconducting cavities was pursued actively. In particular, it required the support of our electron-beam welding specialists as well as of our personnel assisting in the chemical treatment and polishing of the cavity surfaces and in their analysis and inspection. In total, 17 four-cell units and 6 single-cell cavities were treated.

Development for the components, associated with RF cavities, like RF-couplers, ceramic to metal brazings and Ti-sputtering of ceramics continued, partially in connection with Industry involved with production of cavities for CERN.

Again, our large vacuum furnace was charged mainly with the bake-out of components for high vacuum application. An increasing number of outside institutes and firms have requested the use of this installation to prepare components for accelerators at their home institutes (MPI-Heidelberg, COSY-Jülich, DESY-Hamburg, HERAEUS). The income through these activities was immediately re-invested to replace the cooling water manifold and the original, by now obsolete, control systems by a modern PC-controlled unit. This project was successfully terminated with the support of the ST-CV and ST-EL groups.

Major investments were also made in the field of electron-beam welding technology where a new highly sophisticated CNC-controlled facility was purchased and successfully commissioned in 1989. This replaces the 20 years old HAMILTON which was transferred free of charge to the Institute for Welding and Quality of Portugal (ISQ) at Lisbon for training purposes.

Moreover, an ultra-precise CNC-milling machine with a precision of a few microns was purchased to respond to the increasing requests for high precision parts for accelerator components (e.g. CLIC) as well as for detectors (LAA).

Among the more important accelerator components passing through the hands of ST-TE or being manufactured entirely by this Group were a prototype of the RF-Quadrupole for the PS, RF-structures and model work for a high strength, pulsed quadrupole for CLIC, development work for correction sextupoles for LHC, a liquid helium pump, four cryostats for LEP-superconducting cavities, plasma lens for ACOL, electroforming and welding of components for 25 BIMO-LEP-collimators, impregnation and inspection of various magnet coils for the PS-LEAR and LHC.

A great effort had to be devoted to the development of second generation large Lithium lenses for ACOL, requiring a current of 1.3 MA, 60% above the initial design value, in preparation for the next $p\bar{p}$ run in 1990. All the above efforts were strongly supported by our chemical and surface treatment laboratories as well as the materials inspection sections.

Finally, the services of ST-TE were continuously sollicited for the development and manufacture of components for the CERN experiments, like the electroforming of Cu-bellows for DELPHI, detector development within the frame of LAA and for JETSET at LEAR, coating of Cherenkov mirrors for an INFN-Fermilab-CERN collaboration and as in the past, the heat and surface treatment of components for the new UA1 calorimeter.

The printed circuit workshop continued to support the development of electronics and fabricated in 1989 about 8300 printed circuits (prototypes and small series) where an increasing demand for hybrid circuits on ceramic substrates could be recognized in 1989. In order to reduce further the production time of prototype circuits, a second CNC-drilling machine was purchased which is operated in parallel with the existing one, thus eliminating one of the major bottlenecks in the production chain.

## Monitoring & Communications Group

The Monitoring and Communications Group was set up in 1989 to centralize all such activities for the technical infrastructure on all the CERN sites.

These activities and the related operations are based on the Technical Control Room (TCR). In this context, a project to integrate technical alarm systems in the LEP/SPS control system was set up prior to coverage of all sites on the lines adopted at LEP, with greater communication with the Prévessin Control Room (PCR).

The Control Room replied to approximately 8300 requests for help relating to the technical installations, including 2000 outside normal working hours.

A considerable amount of support was provided by the Group for the project to replace the present Hasler telephone system by STK digital switchboards.

The radio and paging tasks were merged and organized under the Radio- Communications Committee on which all the Divisions are represented.

The Safety Alarms, Fire and Gas Detection Section was very busy in connection with the completion, handover and integration of LEP equipment into the existing system.

In the Computer Centre mention should be made of the work done to install robotic handling of cassettes.

The work done by the Group totalled more than 2.2 million Swiss francs, and to this should be added work charged directly to Divisional budget codes.

## Electrical Distribution Group

The Electrical Service was restructured in August 1989 and replaced by an Electrical Service for the whole of CERN with responsibility for operation and extension of the electrical network and cabling connected with the accelerators. Personnel from ST, SPS, PS and LEP Divisions who had been involved in work of this nature were incorporated into the new service. In the second half of 1989, this service concentrated on developing the necessary computerized tools to achieve standardized management of databases for operations, installation and cabling. Owing to a considerable amount of development work, a link was established between the ORACLE databases and the three-dimensional CAD EUCLID and in this way automated drawings and cable-laying surveys are available. Industry has shown interest in sharing costs for this.

The budget for improvements to the non-LEP electrical equipment was cut back extensively to provide resources for the LEP Project, so only a very restricted amount of work was possible. The project to replace equipment with PCB (polychlorate oils) as a dielectric was temporarily suspended to free resources to meet the LEP energy budget. Network maintenance was progressively extended to include the LEP network. The latter now comprises a 400 kV station, a 70 kV transport system to LEP, an 18 kV distribution network with 7 large compensation and filter units totalling 540 MVA and 12 generating sets supplying the emergency supply networks.

The computerized network control system that was installed for LEP is to be extended to cover the rest of the site.

## Cooling & Ventilation Group

### Main tasks

The main tasks in 1989 were the operation, maintenance, improvements and alterations, design and construction of new installations, in the field of cooling, ventilation, air-conditioning, heating and fluids distribution. Some of the main activities will now be described.

*Water supply*

Three pumping stations, built exclusively for CERN use, (Peney 1,2,3) together with a station for joint use, CERN-Services Industriels de Genève the Vengeron, pumping lake water, are operated by 'Services Industriels' personnel. The CV Group is in charge of the technical follow-up of these installations.

The total water consumption of CERN in 1989 was 27 million cubic metres.

*Accelerators & experimental areas*

The Group had to operate, maintain, improve and alter the cooling equipment of the SPS, PS and SC accelerators, supplying primary water, producing demineralized cooling water and ensuring its distribution through heat exchangers to the main magnet, RF equipment, power supplies, beam dumps, beam transfer magnets, experimental area devices, etc.

CV Group ensured the air-conditioning in these accelerator tunnels, and in experimental areas such as SPS, PS and LEP experiment counting rooms, excluding OPAL. Air-conditioning (cooling and heating) was also provided in the SPS, PS and LEP surface buildings complex, with the exception of those situated over the LEP pits, and also for accelerator control and computer rooms, including LEP.

*Computer Centre*

A significant part of the air-conditioning activity was devoted to the Computer Centre. The equipment includes a chilled water production station (5 MW) and sophisticated air-conditioning installations which meet the precise requirements of modern computers.

*Central heating*

A considerable proportion of the Group's time was devoted to the operation of central heating installations. Two power houses (66 MW in all) burn heavy fuel to produce and distribute superheated water to both the Meyrin and Prévessin sites (40 km of piping). Local heat exchange stations supply hot water to radiators for office buildings or heated air to the experimental halls.

New plans have been drawn up to convert the heating station on the Prévessin site to natural gas; this operation should be followed soon after by a similar conversion of the Meyrin plant.

The CV Group also ensured :

- *Supply and distribution of compressed air and drinking water*

- ***Fire-fighting water supply*** : four pumping stations supply water for fire-fighting purposes distributed over the Sites by approximately 12 km of piping. Diesel-powered generators were constantly available in case of emergency.
- ***Gas distribution*** : about 2 km of piping supplies gas to restaurants on the Meyrin Site and to a few other users. Stringent safety precautions were observed for the operation of this supply system.

**Design & construction work : new projects in 1989**

The more important projects of the Group were :

- *in situ* cooling of detector electronics (ALEPH, DELPHI);
- cooling electronics for LEP experiments (DELPHI and L3) and air-conditioning for ALEPH, DELPHI and L3 counting rooms;
- pumping station for LEP raw water supply;
- air-conditioning equipment for LEP surface buildings (excluding those built over the pits);
- Computer Centre extensions and air-conditioning for the four LEP experiment computers;
- cryogenics installations for the four LEP experiments;
- automation of the SPS demineralizer and of the North Area cooling Tower system;
- cooling facilities overhaul of the PS experimental areas, South, East and LEAR.

### Industrial support technical follow-up

The Group has a general purpose maintenance contract with a large firm which carries out routine maintenance work on electro-mechanical equipment on Meyrin, Prévessin and LEP sites, according to the Group's technical specifications and quality standards.

'Strategic' equipment such as cooling and air-conditioning systems for the accelerators, and also Power Houses, was maintained and operated by the Group's own personnel.

## Site Management Group

The SM Group's activities covered the following fields :

- civil engineering design studies and work (conversions and constructions other than LEP, underground networks, roads and car parks);
- upkeep of building structures and infrastructure; improvement and conversion of old structures to comply with regulations;
- grounds management, including upkeep of green areas, cleaning of buildings, roads and car parks and the locking schedules; The Group is continuing work on the inventory and on the implementation of a site management system and on the design of a computerized maintenance programme.
- the Mail Office (franking and distribution) has liaised with the Divisions to complete the installation of the computerized programme for external address lists with its centralized update system.

### Mail Section

The new programme of computerized external address-lists was completed and became operational as scheduled in the course of 1989. 20 000 external addresses for the some 30 000 documents sent out are on file in one database. The database is kept updated by the secretariats chiefly responsible for external documents and by the addressing service of the Mail Office. Computerization of internal addresses is scheduled for 1990.

### Design Studies & Works

During 1989, the Design Studies and Works Section handled 411 work requests for an amount of some 2.1 million Swiss francs, compared to 3 million Swiss francs in 1988. In addition to these requests mostly concerned with minor works, the Section was involved in the construction of buildings 929 and 2013.

The system for the site management in general and of office, laboratory and hall space in particular and for diagram handling is now in place. This system, which was the subject of an internal report, centralizes diagram and alphanumeric information on all aspects of the site. A link has been set up between the graphics system and the ORACLE database, use of which is gradually being extended to all Divisions, to simplify input of data and avoid duplication.

### Site Management Section

The inventory started in 1988 of office and laboratory buildings with their various equipment is now virtually complete. All the information concerning these premises is now available to the Divisions via ORACLE. At the same time, updating of the databases concerned and of the database for the huts continues.

Despite the meagre resources available, particular attention was paid to keeping the outside areas clean and attractive. A considerable amount of work was done in the grounds particularly on the LEP site including planting out, spreading topsoil and turfing.

This year, the cleaning service was particularly busy on the LEP site and involved in preparations for the Inauguration Ceremony on 13 November. It also worked on a preliminary draft of a new call for tenders for existing contracts. In future, contracts will be chiefly performance-related entailing considerable reappraisal of the responsibilities of each of the parties and thus help to sustain the improvements that are already apparent in the standards of services provided.

Centralized computerized control of some locking schedules and the monitoring of the allocation of keys for these schedules has started. This initiative should be extended gradually to all the locking schedules in force at CERN.

Improvements to and essential replacement of equipment and facilities in the various restaurants have been carried out. One example is a new drinking water distribution point that has been installed in Restaurant No 2. This has reduced queueing which used to interfere with the efficiency of the self-service food counters.

### Maintenance & Emergency Repairs

With a budget of 700 000 Swiss francs, the Maintenance and Emergency Repairs Section was not able to carry out more than routine repairs of buildings, roads and car parks. However, an additional 300 000 Swiss francs was made available for roof repairs on two buildings (buildings No. 358 and 269).

The systematic cuts in financial resources for building maintenance ultimately creates a considerable backlog of work and gives rise to all sorts of tensions between the various services and the users.

A study and three-year work programme has enabled an overall view to be gained of the work needing to be done through investment in the upkeep of old buildings.

## Logistics Group

### Stores

In 1989 :

- the total value of standardized items issued from the stores was 25 million francs, a decrease of 13% over the 1988 figure;
- the value of items of equipment issued via the three self-service points represented 12% of total issues;
- the annual turnover rate of the central stores was 2;
- the stock value varied between +10.3% and –1.4% in relation to the authorized limit of 13.6 million francs, the level at 31 December 1989 being 1.4% below the authorized level.

### Transport & Distribution

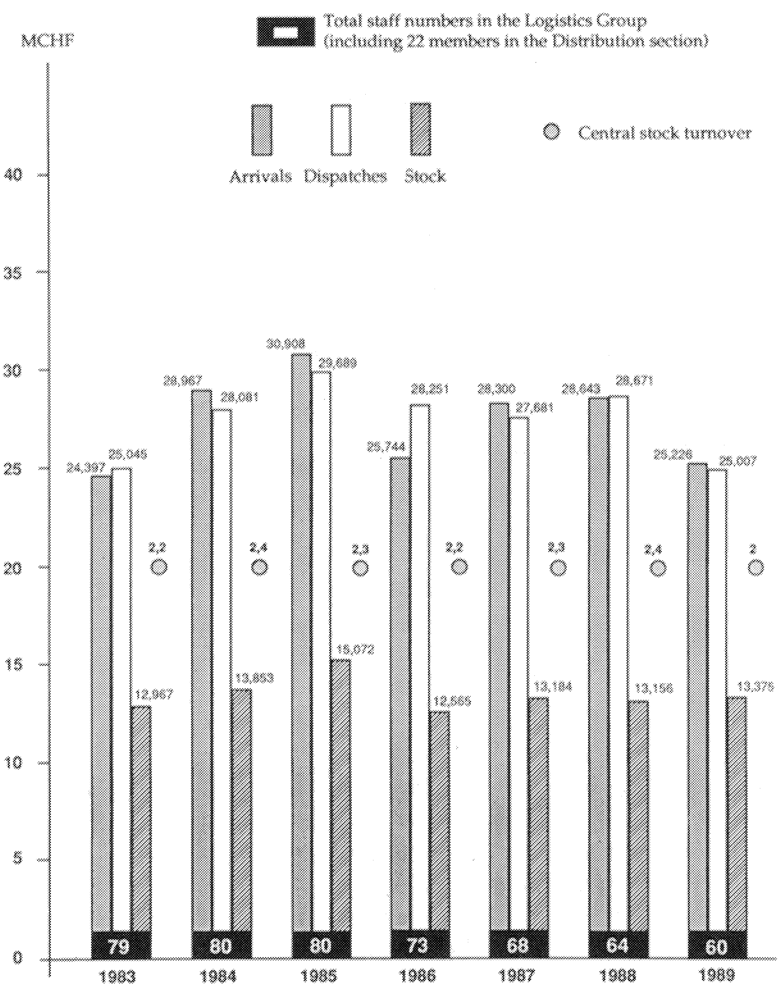
Following lengthy discussions with the French Customs Authorities, a revised customs and fiscal regime was introduced in May. The main benefits of this regime are the harmonization and simplification of procedures between CERN and the two Host States.

Considerable progress was made in the preparation for the introduction of Electronic Data Interchange (EDI), at CERN. Three pilot projects have been set up and CERN's suppliers had an opportunity to see how EDI will be used in practice at a conference hosted by CERN in November 1989.

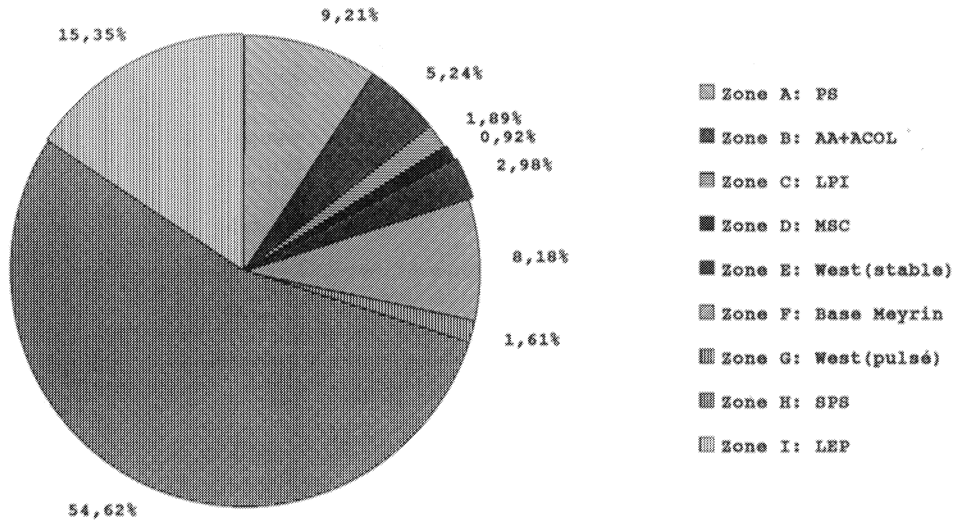
During the year the Section handled 44 889 arrivals and 8340 shipments.

The sales of obsolete equipment amounted to 1.29 MCHF.

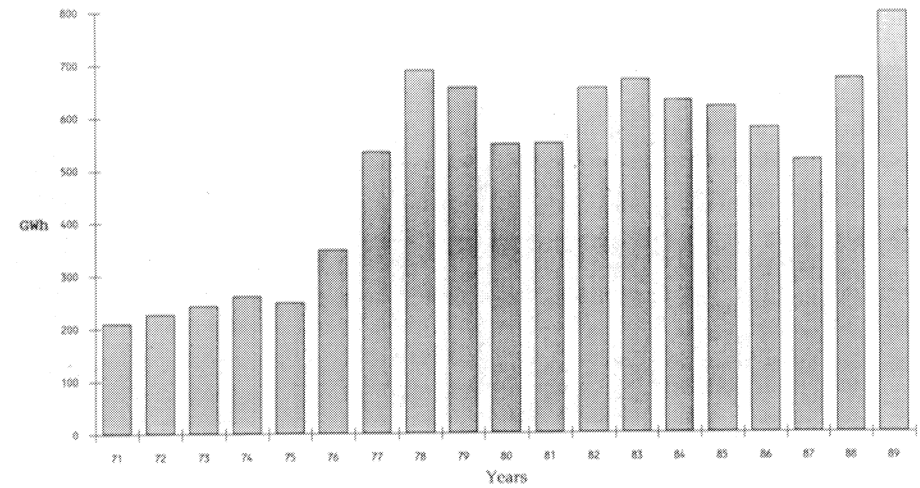
*Stock movements*



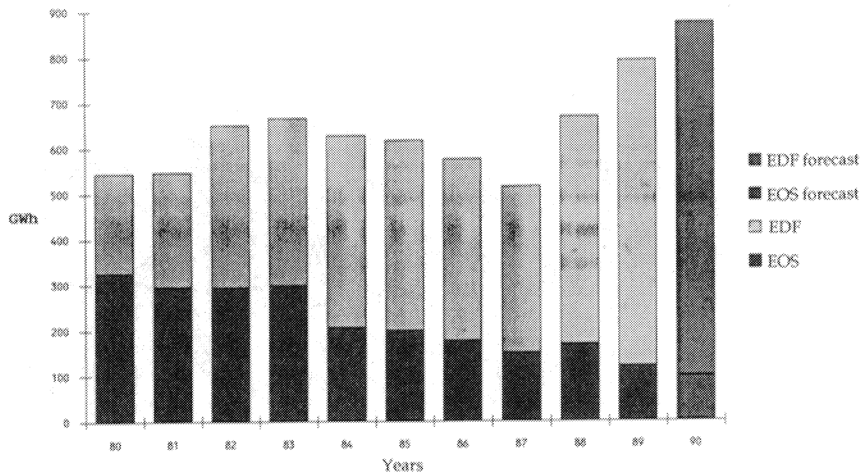

*Total electrical power consumption at CERN in 1989 = 796 GWh*



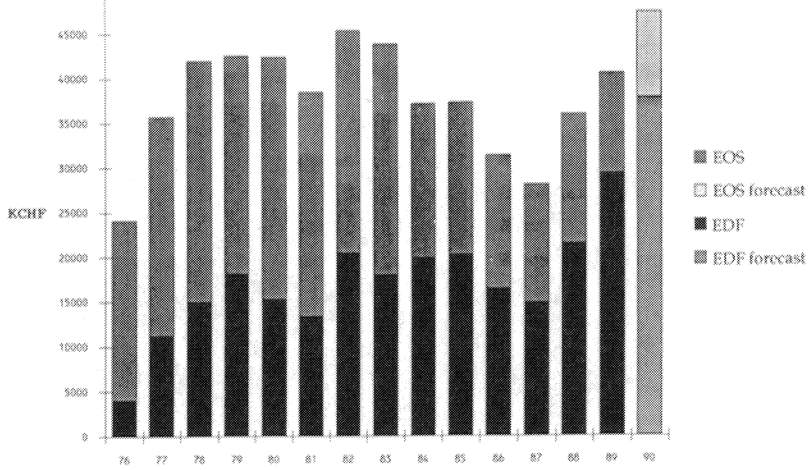
*Total electrical power consumption at CERN*

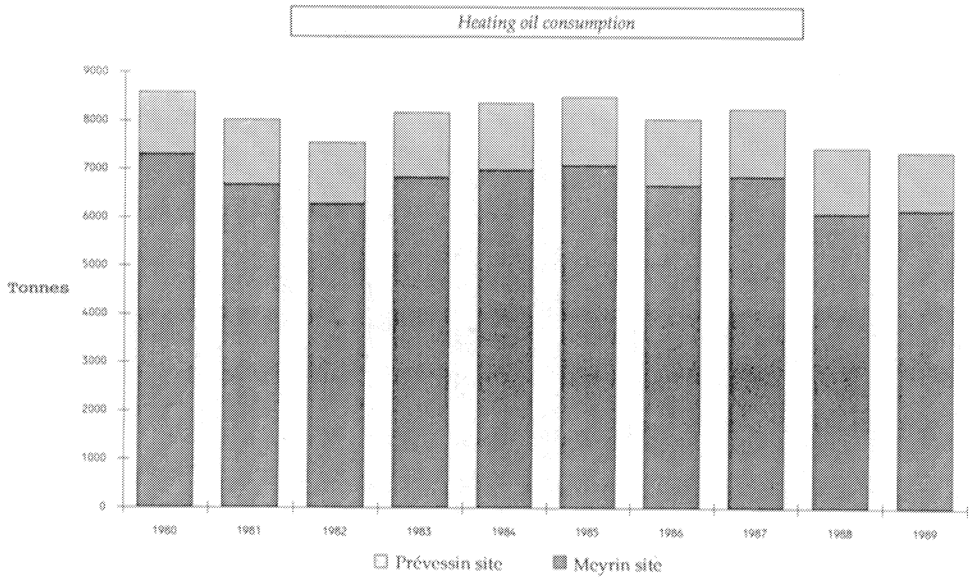


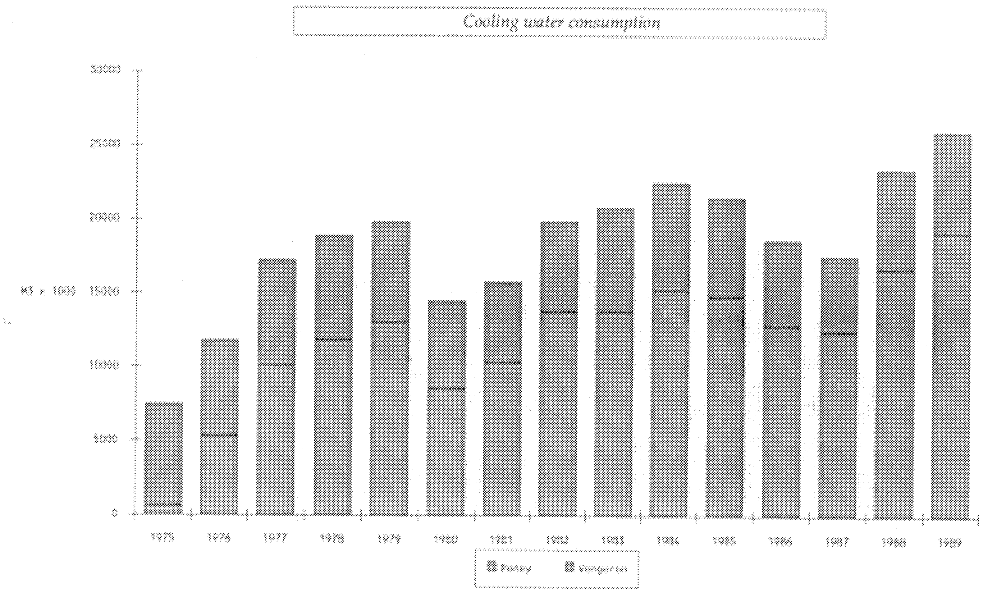

*Electrical power consumption at CERN : energy*

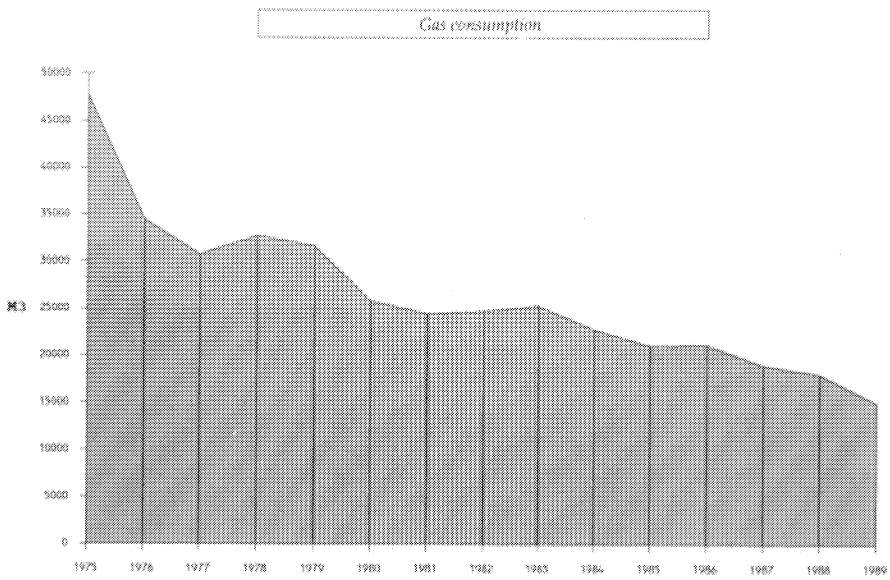



*Electrical power consumption at CERN : cost*




Heating oil consumption
Tonnes
Prévessin site
Meyrin site


Cooling water consumption
M3 x 1000
Peney
Vengeron


Gas consumption
M3

# Finance Division

As predicted in the last Annual Report, 1989 was a difficult year financially for the Organization, requiring an almost unprecedented degree of financial discipline.

However, these efforts have borne fruit since carry-over of outstanding commitments were reduced from 42 million Swiss francs between 1988 and 1989, to 24 million Swiss francs between 1989 and 1990, i.e. a reduction of some 18 million Swiss francs.

In parallel to this strict financial discipline and to the exceptional demands made on the staff concerned, the Budget and Accounting Reform got under way, with the approval of Phase I by the Finance Committee in June 1989, followed by the preparation of Phase II in 1990.

The financial problems linked to LEP construction are gradually being resolved. Some 14.95 million Swiss francs were used to reduce the LEP debts in 1989. LEP construction will continue to put pressure on the Organization's financial resources throughout 1990 and 1991, and for part of 1992.

The slight reduction in the Procurement Service's work load following completion of LEP has allowed time for preparatory work for the restructuring of the Finance Division to enable the Organization to take account of the recommendations and wishes of the Member States and to meet the Laboratory's future needs. The planned restructuring of the Procurement Service will commence in 1990.

In view of budget constraints and following the conclusions of the CERN Review Committee, staff who have retired or resigned cannot be replaced and the personnel of the Division is therefore having to absorb the additional work load.

## Financial & Accounting Services

The depreciation of the Swiss franc with respect to most European currencies, which began in the spring of 1989, continued throughout the year, as shown in Table 1 below, with a consequent reduction of several million Swiss francs in the Organization's purchasing power for materials over the same period.

*Table 1 : Rates of exchange*

| Rates as at 03-01-1989 | | 01-03-1989 % | 02-05-1989 % | 03-07-1989 % | 02-10-1989 % | 29-12-1989 % | Highest | Lowest |
|---|---|---|---|---|---|---|---|---|
| ATS | 12.00 | + 1.25 | + 5.33 | + 1.42 | + 2.50 | + 7.83 | 12.97 | 12.00 |
| BEF | 4.02 | + 1.24 | + 5.72 | + 1.74 | + 2.74 | + 7.71 | 4.33 | 4.02 |
| DEM | 84.60 | + 0.95 | + 5.32 | + 1.30 | + 2.42 | + 7.68 | 91.20 | 84.60 |
| DKK | 21.75 | + 0.92 | + 5.52 | + 1.15 | + 2.30 | + 7.36 | 23.48 | 21.75 |
| ESP | 1.32 | + 3.79 | + 9.09 | + 1.89 | + 3.79 | + 6.63 | 1.44 | 1.32 |
| FRF | 24.75 | + 1.41 | + 6.46 | + 2.02 | + 3.23 | + 7.68 | 26.69 | 24.75 |
| GBP | 2.72 | + 0.28 | + 3.96 | - 4.33 | - 3.22 | - 8.93 | 2.85 | 2.47 |
| GRD | 1.00 | + 0.00 | + 2.00 | + 0.00 | - 3.00 | - 5.00 | 1.04 | 0.95 |
| ITL | 0.11475 | + 0.87 | + 6.10 | + 3.49 | + 3.49 | + 5.66 | 0.12300 | 0.11475 |
| NLG | 74.80 | + 1.14 | + 5.61 | + 1.60 | + 2.61 | + 7.82 | 80.80 | 74.80 |
| NOK | 22.80 | + 2.19 | + 7.68 | + 2.85 | + 3.07 | + 2.63 | 24.85 | 22.80 |
| PTE | 1.02 | + 1.96 | + 5.88 | + 0.98 | + 0.49 | + 1.96 | 1.09 | 1.02 |
| SEK | 24.40 | + 1.84 | + 7.58 | + 3.28 | + 3.69 | + 1.43 | 26.61 | 24.40 |
| USD | 1.49 | + 5.37 | + 12.75 | + 11.74 | + 9.06 | + 3.36 | 1.79 | 1.49 |

### Cash position

The cash position was difficult, owing mainly to the large sums paid for the LEP project. With the agreement of the Finance Committee, short-term bank overdrafts were necessary towards the end of the year.

It should be noted that in spite of the fact that two Member States failed to pay the balance of their contributions (8 MCHF), the sum borrowed, i.e. 81 MCHF, was below the authorized total amount.

The overdrafts were partly repaid to the bank concerned in January/February 1990 as soon as the first contributions were received.

*Table 2 : Contributions outstanding on 31 December 1989*

| *Member State* | *CHF* |
|---|---|
| United Kingdom | 1 062 737* |
| Greece | 6 992 070 |
| Total | 8 054 807 |

* was received on 3 January 1990

| | |
|---|---|
| **Income** | MCHF |
| Contributions from Member States | 802.97 |
| Interest and compensatory income | 13.55 |
| Unused provisions + miscellaneous | 0.74 |
| | **817.26** |
| **Expenditure** | **816.31** |

Excess income amounted to 0.95 MCHF (817.26 MCHF – 816.31 MCHF). From this excess income, 0.43 MCHF was transferred to the Special Reserve Account, and an amount of 0.52 MCHF was carried forward to 1990.

### Visiting Teams

570 visiting teams have open accounts in our books. During the financial year 1989, about 5400 invoices were made out for a total of some 61 million Swiss francs. These monthly invoices relate mainly to issues from stores, work done in the workshops or outside, orders sent to suppliers and miscellaneous expenditure.

## Planning & Budget Service

The main task of the Planning and Budget Service is to prepare and publish the Organization's official budget documents (annual and medium-term budgets, cost-variation index, scales of contributions, etc.) together with the necessary background information for the decisions of the CERN Management.

A new budget layout (by Programme/Project/Activity) was prepared in the framework of Phase I of the Budget and Accounting Reform. Approved by the Finance Committee in June 1989, it was presented for the first time in October 1989.

## Procurement Service

With LEP inaugurated and operating to the satisfaction of its users, the Organization is now containing expenditure to ease the financial pressure. New investments were kept to a minimum and the number of calls for tenders fell from 51 in 1988 to 19 in 1989. The number of major supply contracts fell from 79 in 1988 to 29 in 1989.

It should be noted, however, that the implementation of the Organization's new commercial policy led to the finalization of a new type of contract aimed at co-operation with industry, termed 'Joint Development Agreements', as distinct from supply contracts. Owing to their flexibility, these new contracts, which are directly based on ordinary partnership deeds in the Swiss Code of Obligations, are suitable for virtually any context. Some 15 agreements of this type were concluded in 1989. It is still too early to draw any conclusions but they would appear to have a bright future in store.

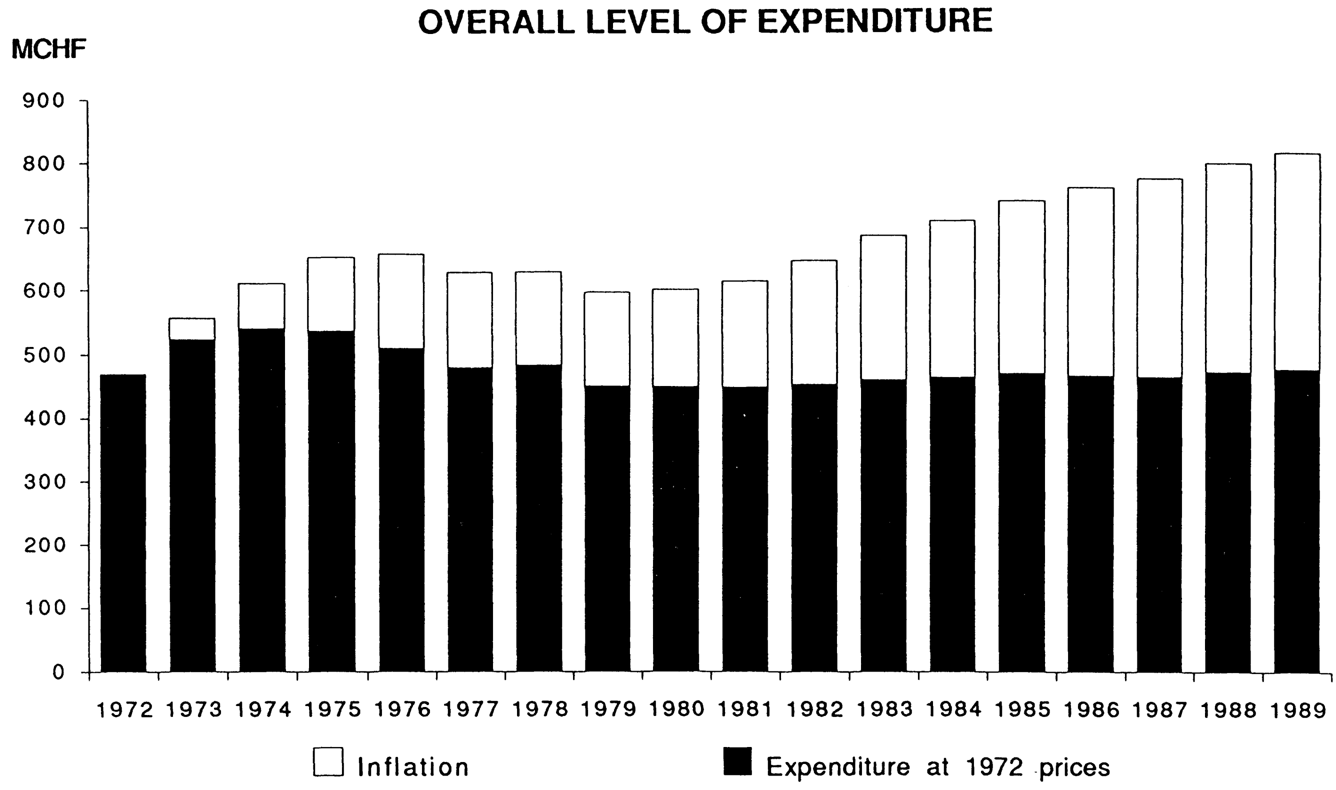
The situation with regard to orders tended to ease off. 27552 orders were recorded in 1989 as against 33421 during the previous financial year. This fall was the result of a new policy designed to contain the Organization's expenditure over the period required to clear the LEP accounts. Many operating costs were either reduced or cut altogether even though this may mean sacrificing lesser priorities.

Studies were carried out with a view to restructuring the Procurement Service. At the end of 1989, it was decided to allow the first few months of 1990 to take stock of the conclusions with a view to their implementation during the summer of 1990.

Technical presentations, typically lasting a single day, continued to be well supported and involved 97 firms from nine Member States over a total of 46 sessions. There were two exhibitions organized by individual Member States, involving 13 firms from Spain (31 January to 3 February 1989) and 27 firms from the Federal Republic of Germany (23 to 25 May 1989).

*Table 3 : 1989 Expenditure (in thousands of Swiss francs)*

| Budget headings and sub-headings | 1989 Expenditure | Directorate - general | Administration (AG,FI,PE) | Research Divisions | LEP Project | Technical Division |
|---|---|---|---|---|---|---|
| TOTALS | **816 311** | **34 654** | **62 654** | **199 347** | **239 934** | **279 722** |
| **1 Personnel** | **408 136** | **28 155** | **47 109** | **123 353** | **57 330** | **152 189** |
| 10 Staff members | 382 769 | 5 528 | 46 625 | 122 259 | 56 410 | 151 947 |
| 14 Fellows | 15 460 | 14 485 | 0 | 565 | 215 | 195 |
| 15 Research Associates | 9 907 | 8 142 | 484 | 529 | 705 | 47 |
| **2 Maintenance, general expenses and consumable items** | **169 232** | **4 349** | **14 530** | **33 084** | **17 000** | **100 269** |
| 20 Site and buildings | 18 184 | 8 | 248 | 1 730 | 3 754 | 12 444 |
| 21 Service equipment | 16 396 | 58 | 1 551 | 4 174 | 2 371 | 8 242 |
| 22 Equipment for accelerators and beams | 29 136 | 207 | 0 | 365 | 6 374 | 22 190 |
| 23 Experimental equipment | 6 066 | 0 | 24 | 5 518 | 314 | 210 |
| 25 Data handling equipment | 15 815 | 44 | 359 | 13 175 | 1 086 | 1 151 |
| 27 Power and water | 51 495 | 0 | 0 | 0 | 0 | 51 495 |
| 28 Administrative expenses / Consultants | 27 614 | 3 657 | 12 016 | 6 122 | 2 470 | 3 349 |
| 29 Travel | 4 526 | 375 | 332 | 2 000 | 631 | 1 188 |
| **3 Capital outlays** | **238 943** | **2 150** | **1 015** | **42 910** | **165 604** | **27 264** |
| 30 Site and buildings | 47 847 | 200 | 51 | 1 105 | 41 773 | 4 718 |
| 31 Service equipment | 19 222 | 511 | 214 | 6 497 | 7 695 | 4 305 |
| 32 Equipment for accelerators and beams | 127 014 | 748 | 0 | 1 361 | 108 943 | 15 962 |
| 33 Experimental equipment | 24 956 | 0 | 0 | 22 234 | 2 554 | 168 |
| 35 Data handling equipment | 19 904 | 691 | 750 | 11 713 | 4 639 | 2 111 |


OVERALL LEVEL OF EXPENDITURE
MCHF
900
800
700
600
500
400
300
200
100
0
1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989
Inflation
Expenditure at 1972 prices

# Personnel Division
# Human Resources Management

## New Personnel Policy Proposals

In accordance with the recommendations of the CERN Review Committee, considerable effort was devoted to the preparation of new policy proposals which received the support of Finance Committee and the Committee of Council in April. Work began on the planning and implementation of several features including performance appraisal, skills inventory, succession plans, individual career plans, manpower planning, career paths, rejuvenation of the staff and Fellowship stipends.

Detailed discussions took place with Divisional representatives and the Staff Association to clarify the Organization's employment structure and contract policy, and proposals were submitted to Council in December concerning recruitment, fixed-term and indefinite contracts, secondments and detachments and the Fellowship programme.

Finance Committee and the Committee of Council also recognized the need for the Organization to prepare for the future by recruiting well-qualified young people to meet the challenges of new projects and the related new technologies.

## Employment

### Staff Recruitment in 1989

| | | |
|---|---|---|
| Applications received : | 280 | (following newspaper advertisements) |
| | 1010 | (others, e.g. in response to vacancy notices, and spontaneous applications) |
| *Total* | *1290* | |
| Candidates invited : | 167 | |
| Selection Boards : | 46 | |

*Nationality of external candidates appointed as a result of Selection boards held in 1989*
*(the number of staff actually started in 1989 was 44)*

| *Basic CERN Programme* | | | |
|---|---|---|---|
| Austria | – | Norway | – |
| Belgium | 4 | Portugal | 1 |
| Denmark | 1 | Spain | 2 |
| France | 8 | Sweden | 2 |
| Germany (Federal Republic of) | 6 | Switzerland | 5 |
| Greece | – | United Kingdom | 5 |
| Italy | 3 | Non-member State | 2 |
| Netherlands | 1 | *Total* | *40* |

Recruitment activity on the basic programme was severely limited by budgetary constraints. For several 1989 vacancies, recruitment action was delayed until 1990. Special funding of the LAA project enabled two further staff members to be appointed on posts of strictly limited duration.

### Internal mobility

Fifty nine staff members moved from one division to another following internal transfer, reassignment, etc. (excluding changes that occurred as a result of the restructuring exercise).

### Departures

One hundred and forty four staff members left the Organization for the following reasons :

| | |
|---|---|
| Early departure | 69 |
| Resignation | 23 |
| Retirement | 19 |
| Fixed-term contract expiration | 20 |
| Death | 3 |
| Disability | 6 |
| Others | 4 |

## Tripartite Advisory Committee on Conditions of Employment

Three meetings of this new Committee established by Council to replace the CCEC were held during the year to examine the results of the 5-yearly salary review, in the presence of representatives of the Member States, the Management and the Staff Association. The results showed that CERN salaries were lower than those of the agreed reference Organizations; proposals for adjustments were held over until the first meeting of the Committee in 1990.

## Training

During the academic year 1988/1989 staff members spent an average of 3.4 days per person on organized training activities. While this represents a modest increase on the previous year, the Management accepts that the figure should be increased to at least 5 days as an objective for all staff. In a changing environment with rapidly evolving technologies, there is a new awareness at all levels of the need for training.

In this context particular attention is being given to developing the Technical Training and Management and Communications programmes, both by building on existing seminars and by new initiatives. The stimulus of dialogue with discussion partners in industry and academia is being actively sought.

The successful Academic Training, General Education and Apprenticeship programmes continued at the level of previous years, while the demand for Language Teaching remained high.

## Fellows, Associates & Students

The number of Fellows increased slightly, with the emphasis on participation in the LEP experiments. In December Council decided to extend the Associates programme for the years 1990 and 1991 to allow an additional number of scientists and engineers from Eastern European countries to work at CERN. A total of 1650 applications were received for appointments as Fellow, Paid Associate or Student, of which 580 were successful. The registration of Unpaid Associates continued to increase, reaching a total of 5700 by the end of the year.

## Office Automation

An ORACLE database system is now routinely used for the management of the entire Staff recruitment process.

The database for the management of candidates for posts as Fellows, Associates and Students has been extended by adding a module to support the selection process during Selection Committee meetings and calculate the relevant budget consequences.

The Personnel Skills Inventory became operational in April, and data input started in May, to be nearly completed by the end of the year. This new tool is proving very valuable in identifying possible internal candidates and planning redeployment of the staff.

## Social Security & Integration

The Joint Advisory Rehabilitation and Disability Board considered 18 cases in 1989. Taking these together with the cases pending from 1988, it made recommendations in 15 cases, including 6 dismissals and 2 partial incapacity pensions. The remainder involved rehabilitation and/or adaption of posts.

## Divisional Organization

The Divisional structure has been reshaped to correspond more closely to the needs expressed by the user Divisions, notably by the creation of personnel coordinators for each major sector of activity – scientific, technical and administrative.

## Staff Review

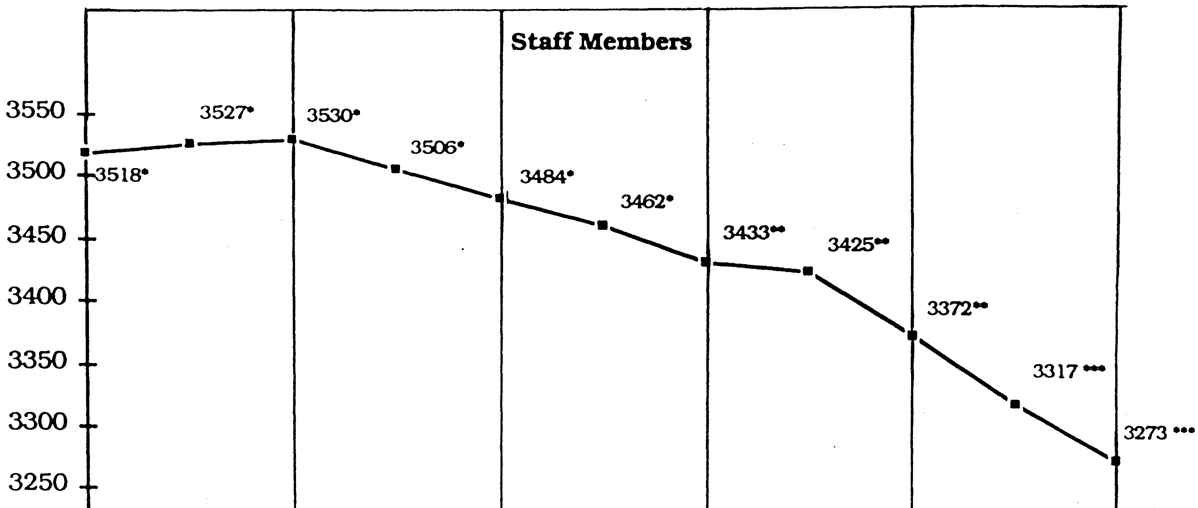
During the Staff Review, 264 promotions (including 61 grade commitments from previous years) were approved, of which 34 were out-of-career promotions and 15 senior staff promotions.

A total of 284 posts were examined (excluding categories 1, 2 and 5a) of which 138 were classified at the next higher grade. Following 51 appeals concerning classification and non-promotion, 4 posts were classified at the next higher grade by Personnel Division, and 11 on the recommendation of the Appeals Board.

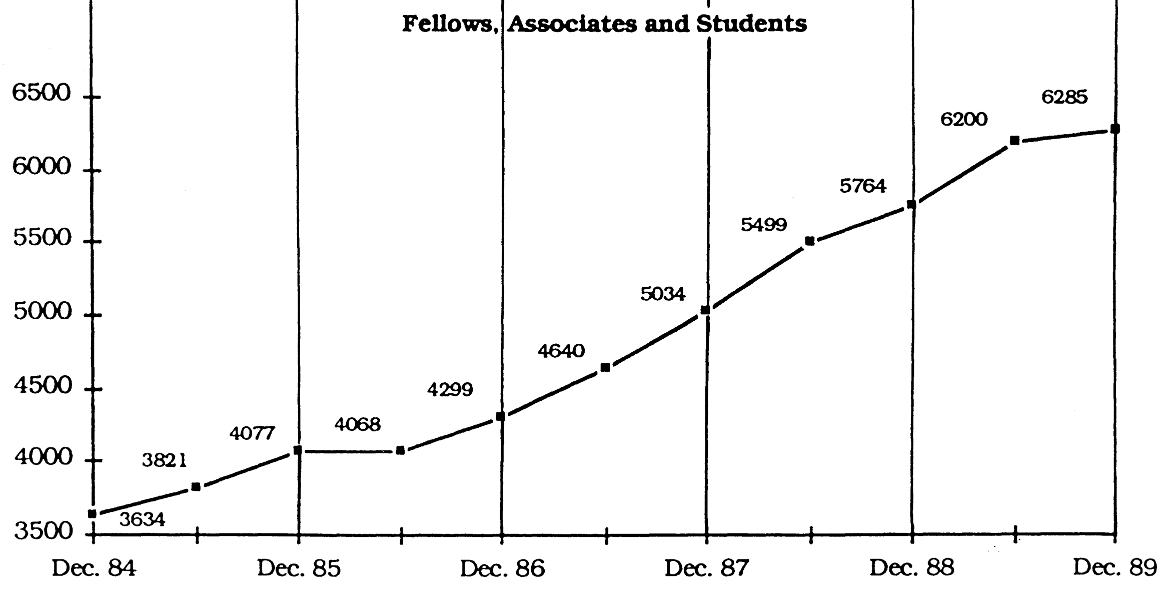
## Performance Appraisal

The first formal Performance Appraisal Scheme was introduced in 1989. Its format and use is to be reviewed in 1990.

*Staff Members, Fellows, Associates and Students with a CERN contract - 1984-1989*




| | | | | | |
|---|---|---|---|---|---|
| SM arr. | +59 | +47 | +54 | +79 b) | +42 |
| SM dep. | -47 | -93 | -105 | -140 | -141 |




* excluding ACOL project recruits
** excluding ACOL project and LAA recruits
*** excluding LAA recruits
b) including 24 staff members transferred from ACOL project to basic programme

N.B. In this table, staff members leaving on 31 December are counted as present on that date, and included in the departures of the following year.

# Technical Inspection & Safety Commission

## Introduction

The TIS Commission activities in 1989 were strongly affected by the final period of installation of the LEP machine and experiments. In spite of this pressure of work the Groups were able to fulfil their normal tasks and remained very active for other approved CERN programmes. Where monitoring systems were being installed for LEP, they were operational for the start-up in July.

A safety campaign on the 'Dangers of chemicals and protection of the environment' was organized at CERN in collaboration with the Environment Delegate of the Republic and Canton of Geneva and other Geneva services (OCIRT, SIS, Civil Protection), as well as some firms of the region. The campaign devoted to the prevention of domestic and industrial risks consisted of an exhibition of safety documentation posters, projection of video films, demonstrations and a series of lectures by various European specialists. It included a simulated emergency exercise on the CERN site with the participation of the Geneva services (fire brigade, anti-pollution service, police and helicopter for the transport of a supposed casualty to the Cantonal Hospital).

In the frame of prevention, a special effort was made by the Medical Service with the help of the Divisional Safety Officers (DSO) to update the information on occupational risks for the CERN personnel. The new information form summarizing the various possible exposures to noxious agents, completed by the staff members and sent to the Medical Service, was analysed and used to determine the frequency of medical examinations, while the General Safety Group arranged visits to working places and prepared an inventory of laboratories and workshops presenting special risks.

Due to the important safety role played by supervisors, a guide reminding them of their safety duties was drawn up for the courses organized by the Training Service for CERN supervisors.

Active prevention remained the essential role of TIS. This is illustrated by the Groups' progress reports published in detailed annual reports available from TIS secretariats. The present report only summarizes the main activities and gives more detailed information in tables and graphs.

### Training & Documentation

In addition to the training activities reported by the Fire and Rescue Group, the year was devoted to the preparation of a video film available on self-service in the Users' Office, to give any visitors coming at weekends or nights an initiation to safety and safety procedures in force in the Laboratory. The film, 20 minutes long, is available in French and English, and the Italian and German versions will be ready for the first half of 1990. Furthermore, a campaign, devoted to publicise the need to dial '18' from any internal CERN exchange in case of emergency, led to the printing of a sticker in 18 of the languages spoken on the sites. Emergency procedures for LEP underground areas were also drafted and evacuation exercises held.

The list of all safety documentation is now available for consultation via VM; one Safety Instruction and three Safety Bulletins were published during the year and the Fire Safety Code was completed and sent for approval to SAPOCO.

## Radiation Protection Group

During the first production runs of LEP, RP surveyed carefully the experimental areas. The radiation levels found were everywhere below 2.5 mSv/h, except near the junction between the mobile shielding and the detectors. The RP Group also surveyed the magnetic fields, the use of radioactive sources and searched for induced activity. All monitor equipment and control equipment worked satisfactorily, apart from the radiation monitors installed in magnetic fields of the large detectors. The data acquisition system for RP measurements in the LEP control system is operational, the alarm transmission into the LEP alarm server is progressing. RP operation at LEP included the surveillance of many thousands of gammagraphies of welds and the transport of radioactive sources and uranium.

Radiation protection at the SPS followed, during the first half of 1989, the $p\bar{p}$ collider programme which was interlinked with tests for $e^+e^-$ operation and the tests with new superconducting cavities. The doses to the UA1 and UA2 detectors, and the ambient dose rates in accessible underground areas, were closely monitored when $p\bar{p}$ luminosities reached very high values.

During the second half of 1989, the fixed-target physics programme required an adaptation of the monitor system to new beams and layouts in the North and West experimental areas and a continuous follow-up of the experiments running with high intensity and primary beams (e.g. neutrino cave, hyperon beam). Radiation levels and exposure of individuals could be kept lower than in 1988.

Radiation levels around the PS continue to decrease, mainly on account of the improved shielding of the ACOL machine. The LIL-EPA complex operated at full intensity for LEP filling when dose rates outside the shield were well within those specified. The principal source of external radiation appears to come from the inflector region, where high levels over short periods, due to faults in the fast extracted beam line, required investigation on several occasions.

The procedure for access to controlled radiation areas in the PS was made uniform and the necessary equipment provided, including the production of a video film detailing the procedures. The dose received by maintenance personnel from radioactivity induced in the machine remains about the same as last year, although it should be noted that some 40% of this dose was from maintenance and improvements in the ACOL target area, carried out under supervision of an RP technician.

Radiation protection at the SC and the two ISOLDE areas was mainly directed to improvements of the ventilation systems to ensure a better control of the airborne radioactivity.

### Radiation Protection on the Site

On the site, the RP waste disposal service had to cope with a large influx of active materials during the long machine shutdown. A plant to evaporate hydrous solutions was completed and 7 $m^3$ treated.

The TLD measuring programme to estimate the dose rate on the CERN sites continued and the network of measuring points was extended to new LEP surface areas. The doses measured in 1989 are below 1.5 mSv everywhere along the fence. The isodose rate patterns were in general identical to those found in 1988, showing only small changes due to differences in the beams installed in West and North experimental areas. The operation of LEP did not affect significantly the natural background dose at the LEP islands.

The Site Radiation Survey Section had also to register and check more than 1400 mobile radioactive sources and supervised the installation of 4000 small sources in the LEP detectors. The number of registered lasers amounted to almost 300 and a number of magnetic field surveys were made, showing the need to reinforce the recommendations made for persons working in the presence of magnetic fields. A survey of the RF stray fields near high-power RF equipment was made in LEP.

### Environmental Radiation Control

The routine measurements of the environmental monitoring radiation comprised also LEP. The 1985-1988 pre-operational background measurements were published in 1989 and, when compared with the results for 1989, showed no changes during the first half-year of operation.

The overall emission of effluent radioactivity from CERN remains approximately the same as for 1988.

### Individual Dosimetry

The start of LEP operation significantly increased the number of personal dosimeters to be distributed (now more than 5000 per period). Individual doses ($\gamma$ and n) remained below the CERN reference limit of 15 mSv/y. Nobody received more than 10 mSv and only 21 people more than 5 mSv. The collective dose of all persons at CERN was 1122 mSv, fairly equally distributed between CERN staff (including unpaid associates) and contractors. The total neutron dose was 20.1% of the total collective dose and only five persons received neutron doses above 1 mSv, the highest dose being 1.3 mSv.

No accidental exposure was discovered by or reported to the RP Group.

### Calibration & Instrumentation

In spite of the staff shortages, 418 instruments of a total of more than 800 were calibrated, in addition to many exposures of TL dosimeters and routine and special exposure of dosimeter films, but this shortage caused serious limitations to other activities of the Section and tests of new types of radiation instruments ceased.

This Section is also in charge of the TIS inventory, control and updating of which took considerably more time than in previous years in order to incorporate it into the ORACLE database for CERN inventories.

### General Activities

In spite of involvement in the LEP project (design, calculations, exploitation and operation), the collaboration in the LHC studies was intensified : an international ad hoc working group met during spring and established a report, pointing out the radiation protection and radiation physics problems the Group will have to tackle on this project. The RP Group also took part in a working group on detectors for future colliders and continued radiation studies for CLIC and participation in CEBAF, the Kaon project at TRIUMF and the MEDICYC project in Nice. Work was also devoted to the continuous improvements of the cascade and shower simulation codes (FLUKA and EGS) and collaboration with other European institutes within an EEC research programme for developing new detectors for active personal monitors.

## General & Electrical Safety & Technical Support Group

### Safety Inspections

The programme for periodic safety inspections of buildings and technical installations launched in 1987 continued. Due to staff shortage, these inspections concentrated in 1989 on buildings and installations of higher risks. Special attention was given to the LEP project, which was carefully followed with respect to all safety aspects.

### Electrical Safety

Besides safety inspections of electrical installations in operation, the Section was heavily involved in the control and inspection of all electrical installations of the LEP accelerator during the test period prior to the LEP start-up. Continuous efforts were made on training and informing personnel on electrical risks and hazards. A special seminar was organized to inform personnel directly concerned with electrical installations, on the new safety regulations in force in the CERN host countries.

### Ergonomy & Environmental Protection

Following the campaign for updating the questionnaire on occupational hazards, many measurements were made in working places where complaints concerning lighting, noise and other nuisances were reported. Several proposals for improving conditions at the work places were made in conjunction with the Medical Service.

The programme for measuring noise levels around the different LEP sites confirmed that the installations will not affect the comfort of people living in the vicinity and that noise levels are below the regulation limits as requested by the INB procedure.

### Safety of Experiments

In 1989 this Section was mainly concerned with the tests and running-in of the four LEP experiments requiring continuous supervision. Regular meetings were organized within TIS Commission and with the experimental teams to set up safety procedures for testing and operating the experiments.

Attention was also given to the UA1 and the LEAR experiments, whereas the control of fixed-target physics experiments was totally inadequate due to lack of available manpower.

**Technical Support**

Maintenance, modifications and improvements of various radiation monitor systems for the SC, PS and SPS accelerators and experiments continued. The LEP radiation monitor systems were successfully put into operation, including all the links to the LEP controls network. An ORACLE database for long-term storage of radiation monitor data was set up and application programs for monitors were written. Support was given to other TIS Groups, mainly for software and communication problems.

*Statistics of accidents reported at CERN in 1989*
*(CERN staff only)*

| Total declared accidents : | 183 | Lost days : | 1169 |
|---|---|---|---|
| a) Lost time injuries (*) | 59 | | 650 |
| b) Accidents on journey to and from work (*) | 19 | | 406 |
| c) Road accidents on duty (*) | 5 | | 113 |
| (*) accidents entailing absence from work of at least one day | | | |

## Fire & Rescue Service

In 1989, the number of operations increased as expected, owing to the final period of installation of the LEP. The table opposite shows how the number of operations increased throughout the entire LEP installation period. Because of the greater distances and increased complication of LEP operations, the same figures expressed in man-hours demonstrate how the Service's workload has increased.

The inadequate transmission from LEP of supplementary information on automatic alarms and the abnormal increase in operations linked with lift breakdowns will require efficient corrective or preventive measures as soon as possible.

Continued efforts in training and retraining courses for new arrivals, first-aid workers and auxiliary firemen have been maintained. Safety instruction courses for underground workers have been updated and improved.

The programme to improve the Service's administration and management structure is being carried out determinedly. Definite progress has been made and positive results obtained in the computerization of operation reports.

The number of firemen on permanent standby has had to be reduced from 14 to 12 for social reasons linked to the difficulties of working shifts. As it stands, the Service's manpower is fully stretched and the replacement of staff by people of the same ability is of constant concern.

## Medical Service

Health care at work is being developed in all the Member States of CERN. Multi-disciplinary health services are being set up and occupational medical officers (OMO) are becoming important figures in personnel management (as has always been the case, but to differing degrees).

The primary objective of an OMO is to prevent occupational accidents and illnesses. The way this has been approached has changed somewhat over the years, mainly owing to advances in technology. The nature of occupational hazards and health risks is changing: cases of exposure to them are becoming more complex and more difficult to detect, hence the refinement of biological surveillance techniques, for example.

An additional concern at CERN is the gradual ageing of staff. Certain by no means minor problems arise as a result of this, for example in all operating zones requiring round the clock supervision. For many people, physical and psychological stamina tend to decrease with age.

*Breakdown of operations for 1989*

*Statistics for 1983 to 1989 – LEP construction period*

| *operations* | *1983** | *1984* | *1985* | *1986* | *1987* | *1988* | *1989* |
|---|---|---|---|---|---|---|---|
| total | 1192 | 1488 | 1605 | 1876 | 1917 | 2032 | 2466 |
| LEP | 1 | 28 | 58 | 125 | 335 | 473 | 637 |
| *emergency* | | | | | | | |
| ambulances | 174 | 432 | 443 | 467 | 458 | 431 | 469 |
| fires | 31 | 30 | 20 | 18 | 17 | 25 | 27 |
| floods-pumping | 149 | 134 | 158 | 115 | 178 | 221 | 129 |
| lifts | 76 | 81 | 53 | 77 | 73 | 133 | 270 |
| emergency shutdowns | 10 | 14 | 16 | 25 | 24 | 19 | 37 |
| problems due to animals | 26 | 41 | 30 | 26 | 23 | 41 | 55 |
| pollution | 17 | 14 | 23 | 12 | 8 | 7 | 11 |
| *automatic alarm* | | | | | | | |
| fire detection** | 362 | 415 | 482 | 375 | 466 | 487 | 457 |
| gas detection | 95 | 125 | 145 | 147 | 132 | 193 | 113 |
| flood detection | 0 | 0 | 0 | 0 | 0 | 2 | 23 |
| burglary detection | 1 | 11 | 12 | 40 | 12 | 42 | 38 |
| helium compressor alarm | 0 | 2 | 4 | 2 | 5 | 1 | 0 |
| chlorine detection | 2 | 5 | 10 | 0 | 7 | 3 | 9 |
| general | 0 | 0 | 4 | 0 | 4 | 1 | 217 |
| *direct prevention* | | | | | | | |
| monitoring in confined spaces | 4 | 2 | 9 | 20 | 27 | 34 | 45 |
| supervision of high-risk work | 7 | 32 | 17 | 8 | 21 | 37 | 24 |
| escorts for dangerous loads | 29 | 15 | 10 | 7 | 23 | 17 | 17 |
| transport of chemicals | 5 | 2 | 8 | 8 | 4 | 4 | 4 |
| installation of electric fans | 1 | 10 | 10 | 5 | 6 | 5 | 4 |
| patrols around the machines | 1 | 1 | 2 | 3 | 2 | 2 | 15 |
| guard duty machine access | 0 | 0 | 1 | 0 | 16 | 0 | 4 |
| felling of dangerous trees | 0 | 1 | 2 | 6 | 4 | 6 | 4 |
| traffic accident reports | 0 | 3 | 2 | 0 | 0 | 0 | 38 |
| *exercises* | | | | | | | |
| auxiliary firemen | 0 | 0 | 0 | 6 | 4 | 11 | 18 |
| professional firemen | 0 | 2 | 7 | 1 | 3 | 6 | 69 |
| with local emergency services | 1 | 0 | 3 | 0 | 1 | 2 | 1 |
| training of auxiliary first-aid workers | 2 | 3 | 4 | 3 | 4 | 3 | 5 |
| fire detection equipment tests | 1 | 0 | 1 | 2 | 2 | 1 | 2 |
| *logistic support* | | | | | | | |
| opening of the customs tunnel | 0 | 9 | 15 | 0 | 47 | 28 | 110 |
| opening of stores | 0 | 0 | 0 | 0 | 11 | 30 | 37 |
| breakdowns | 4 | 14 | 24 | 28 | 16 | 17 | 24 |
| official visits | 0 | 0 | 3 | 17 | 1 | 4 | 19 |
| local openings/closures *** | 5642 | 5877 | 4239 | 4592 | ? | ? | 45 |
| 'taxi' service *** | 2440 | 2022 | 1611 | 1314 | 1244 | 1010 | 918 |
| *miscellaneous* | 194 | 90 | 87 | 458 | 318 | 219 | 171 |

* for 1983, the figures for 'external operations' are incomplete

** for actual fires, see 'fires'

*** not regarded as operations (transport outside of CERN's normal working hours only)

To guarantee the best possible supervision of all these factors, the Medical Service has continued its efforts in the various areas within its province. Routine supervision has led to the performance of numerous clinical and supplementary examinations, in particular for people who had not had a check-up for more than 10 years. Particular attention was also paid to operators.

In its overall evaluation of staff health, the laboratory was able to carry out an increased number of biological tests which are extremely useful in the prevention of cardiovascular complaints. Inspections of work stations have been made as frequently as possible, often in liaison with other TIS Commission Groups.

The Secretariat's work has been assisted by the development of a computerized system ( links with ADP, for instance ). The transfer of all medical files to microfilm was also completed this year, a task begun more than a year ago. In January 1990, the Service dealt with 15,566 files, 6159 'active' and 9405 from the archives, of which 9049 were on microfilm.

First-aid and check-ups in the infirmary still rank highly among the Service's traditional activities, as does the regular preparation of 500 first-aid boxes distributed around the site. Participation in first-aid courses has continued without respite.

The figures opposite (top & middle) give more detailed information on the Service's activities.

## Chemistry, Fire & Materials Group

### Chemistry & Materials

The collection, conditioning and despatch of hazardous wastes from the CERN sites to agreed disposal or recovery plants in the Host States continued to be one of the major tasks. In particular, electrical equipment containing PolyChlorinated Biphenyls (PCB), such as transformers, condensers and rheostats, was despatched to the approved French treatment station in the Department of Ain with the full agreement of the Swiss and French authorities. In all, six deliveries were made and certificates of destruction obtained.

Other types of waste were despatched to the Geneva treatment plant at Chéneviers or to the sewage plant at Aïre. The task of packaging has become more onerous as the authorities insist on increased labelling to reduce the possibility of confusion at the treatment plant.

The storage area for hazardous materials in the centre of the PS ring, building 262, has been modified to increase the storage area under cover and to avoid accidental spillages reaching the drains and hence the rivers.

#### *Industrial Hygiene*

The control of possible toxic contaminants in the work-place has continued to play a large rôle. The general trend showing that certain products are more dangerous than at first thought, for either the environment or human beings, means that alternative products or work methods have to be worked out in collaboration with those concerned.

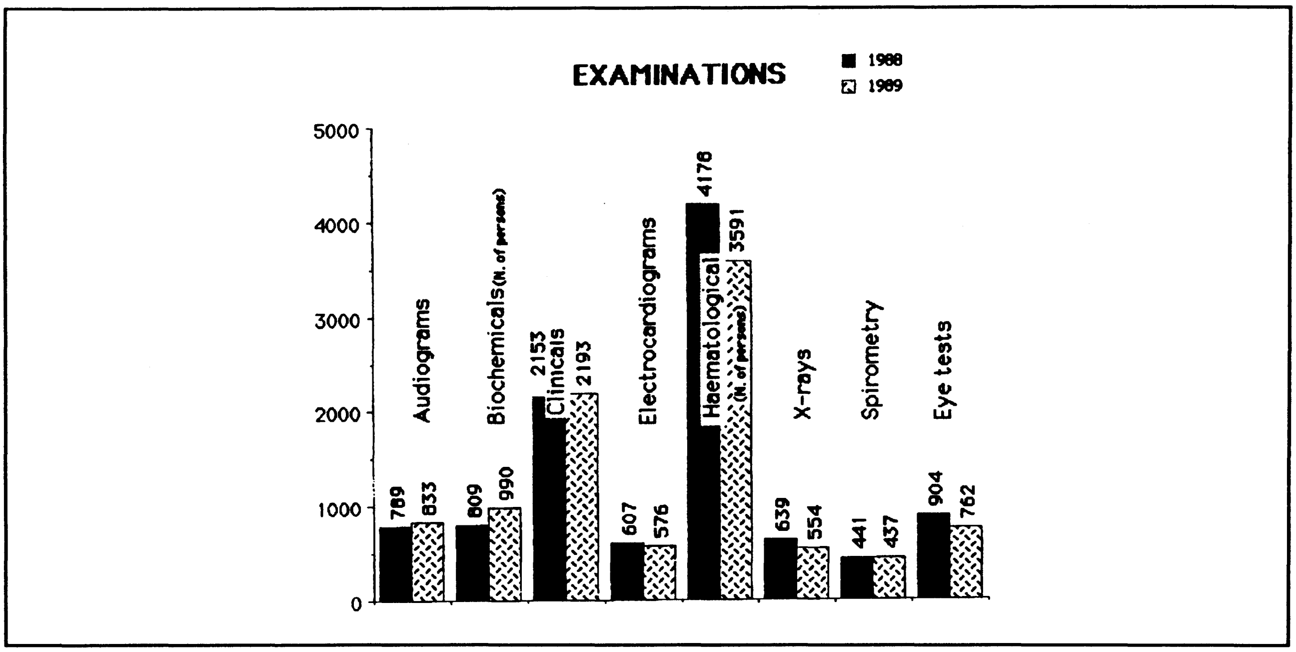
#### *Pollution Control*

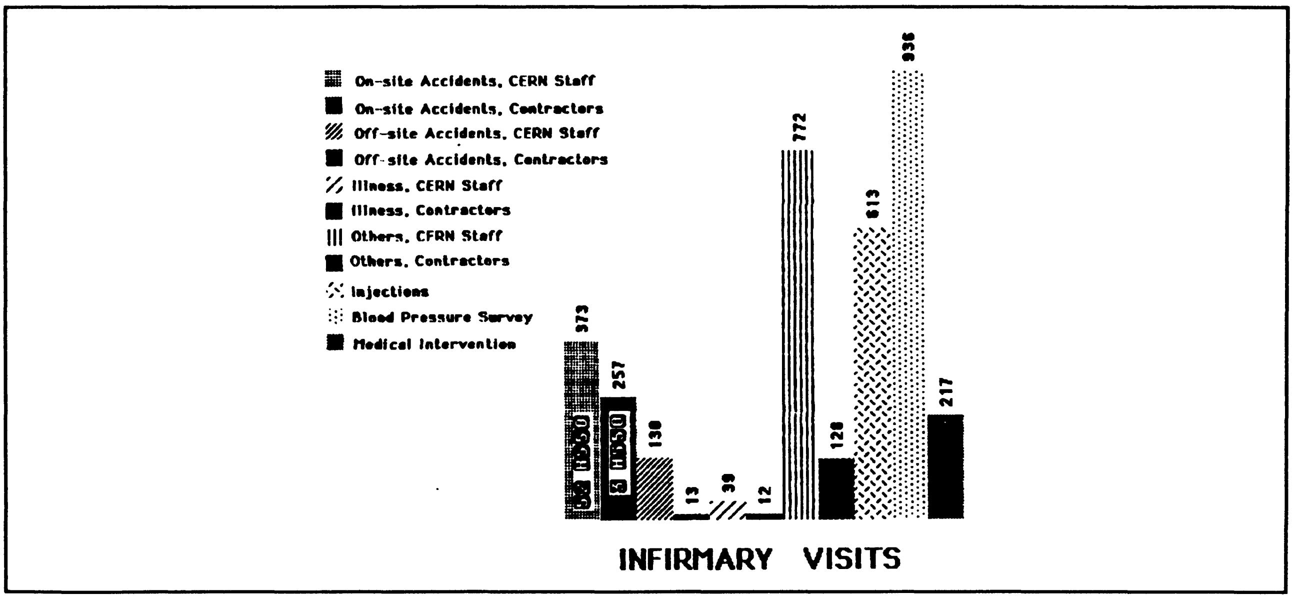
The long hot summer made the task of checking the local rivers, to which CERN's surface and cooling waters run, more imperative than normal. The effluent monitoring stations were visited 41 times, and 24 breakdowns or malfunctions were reported to ST Division. Checks on the state of the local rivers, the Nant d'Avril in Switzerland and the Lion in France, were carried out on 30 occasions to ensure their continued well being. Measurements of pH, dissolved oxygen, temperature, conductivity and turbidity were made both upstream and downstream of the CERN outlets. No serious pollution was recorded during the year. The figure opposite (bottom) shows the annual temperature and pH variations in the two rivers after the last CERN outlet.

Ozone and oxides of nitrogen (NOx) continued to be monitored at the two control stations (Cessy and Meyrin). The treatment of information by computer worked well. Preparations were made to install ozone and NOx meters at LEP Points 1 and 5.

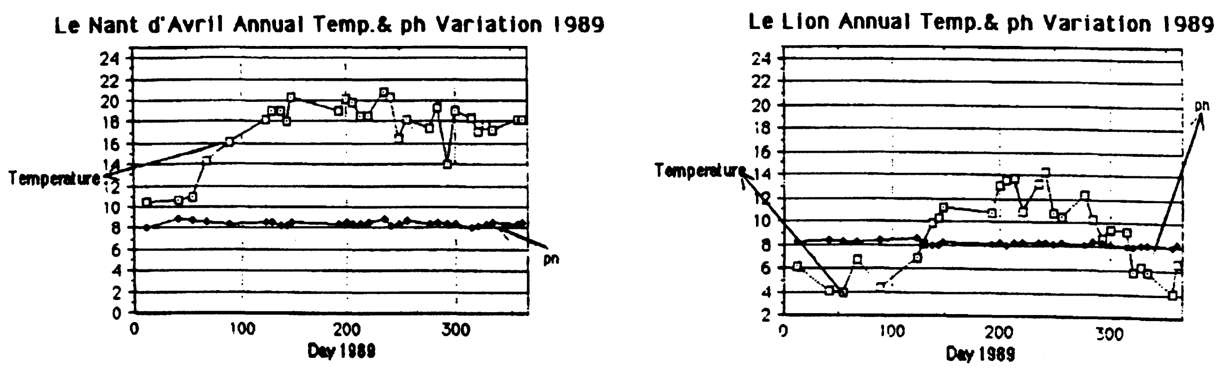
#### *Gas & Chemical Safety*

Gas safety continued to take up a large amount of time as the LEP experiments came into use at the same time as the LEAR experiments. Furthermore the safety of small test installations had also to be ensured.




*Annual variation in temperature and pH in the rivers Nant d'Avril and Lion*



More intensive studies, including Hazops (*HAZ*ard and *OP*erability *S*tudies) were carried out on a number of systems, including :

- DELPHI Barrel RICH gas distribution system
- DELPHI Forward RICH gas system
- ALEPH inner track chamber gas system
- OPAL muon end caps gas system
- operating instructions for the OPAL central detector, hadron pole tip and end-cap pre-sampler gas system
- L3 TEC gas system
- OBELIX experiment at LEAR
- PS 195 experiment at LEAR
- JETSET experiment at LEAR

Advice was given to groups setting up small test experiments and visits were paid to ensure that they continued to conform to CERN requirements.

All orders (380) for chemicals and products containing chemicals (e.g. paints, adhesives and cleaning agents, etc.) were examined and action taken where necessary. Details on all these orders, including toxicity class and flammability rating, were put onto a computerized list, distributed monthly to Divisional Safety Officers and the Medical Service. The same was done for CERN Stores products classified in toxic classes 1 and 2 or ordered in 200 litre drums.

About twenty transports of dangerous goods by air and several others by surface were arranged. This involved the preparation of correct documentation, packaging and labelling of the items concerned.

*Material Testing*

The test programme for many materials and components continued during the year to establish the behaviour under flame and fire, and to determine the resistance against ionizing radiation. The tests were mainly carried out on cables, or cable insulating materials, but also on other organic insulations, structural materials, optic and electronic components. Most of the fire tests were required for the LEP experimental areas, whereas most of the radiation tests were for the LEP main ring, LAA or LHC.

The search for safer furniture to be used in underground areas resulted in tests on upholstered office chairs, carried out at an independent fire testing laboratory.

At the next generation of high-energy proton colliders, detectors will have to operate in conditions where radiation effects on scintillators, optical fibres and electronics become very important, and therefore the Group continued to co-ordinate radiation hardness studies for the LAA project.

Radiation test studies of long-term ageing effects on insulating materials continued, either on production materials or on development compounds. A study is in progress on the dose rate effect on mechanical properties of some production insulating cables and sheath materials and on the extrapolation to lower dose rates.

Preliminary results of long-term irradiation tests showed that epoxy resins used for magnet coil insulations were much less sensitive to dose rate effects. Irradiations are still in progress. Samples will be installed in the LEP tunnel during the 1990 winter shutdown.

**Fire Prevention**

A total of 180 fire prevention inspection reports were issued. Very important are the instructions to the fire brigade following the reception of new installations such as fire and gas detection systems, hydraulic systems, etc.

Despite the heavy routine work load described above, fire prevention studies were carried out for UA1 of a fire extinguishing installation using high expansion foam.

The installation of fire fighting equipment in LEP was terminated during 1989. This included 1200 portable fire extinguishers filled with 6 kg halon 1211 each, and 25 extinguishers on a trolley filled with 50 kg halon. In addition, 85 fixed installations covering 13 300 m3 exist in LEP experimental areas.

A revision of 1000 fire extinguishers took place in 1989, covering almost the whole of the Meyrin and Prévessin sites, during which the extinguishers were completely dismantled, each element inspected and replaced if necessary.

*High-dose Dosimetry*

In May and June 1989, ~ 1000 dosimeters were placed in the LEP main ring in octants 1 and 2, in the two RF zones in octants 2 and 6, in the injection tunnels TI12 and TI18, as well as around the wiggler and the mini-wiggler magnets.

A 1.5 km long alanine cable dosimeter (ELCUGRAY) was made by Kabelmetal Elektro (Hanover) and delivered to CERN in February. A part of this cable was cut in short pieces to obtain dosimeters for routine measurements, other parts were used for dose distribution measurements at the SPS and in LEP.

During the October shutdown of LEP, 54 dosimeters were taken from representative places to know the integrated doses of the first two months of operation. The main results showed that the doses exceed 200 Gy on dipoles and quadrupoles for 150 hours of operation and 200 mAh beam intensity.

Field experience was gained with colour dosimeter films in the different radiation fields of the PS Booster, the SPS ring and target areas, up to $10^6$ Gy. Comparison with radio-photoluminescent dosimeters (RPL) gave very good agreement.

## Mechanical Engineering Group

The Group's main activities for 1989 centred around the final period of installation of the LEP machine and its four experiments, operations concerning CERN's other current experiments and the Laboratory's infrastructures, advice on engineering matters, and participation in new projects coming under the 'Active Safety' programme.

The new Mechanical Engineering Section has worked closely with the Inspection Section in safety matters. 110 studies were devoted to monitoring the installation of the LEP detectors and analysing other projects such as OBELIX and JETSET. 2694 inspection reports concerned controlling and testing experimental equipment, infrastructure equipment and fluid distribution systems during production, installation and commissioning, and to periodic inspections and numerous operations and tests upon request.

Special enquiries were held on the three handling accidents which took place at the Laboratory in 1989.

The following 'Active Safety' programme activities should be mentioned: participation in the 1 m, 10 T LHC prototype magnet project, assistance and advice for users of ANSYS computer programmes and the organisation of two technical seminars on structure calculation with the collaboration of Professor Ostergaard, USA, and Professor Zinkievicz, GB.

*Number of inspections and periodic tests made in 1989*

| | |
|---|---|
| Heavy hoisting gear (cranes etc.) | 714 |
| Light hoisting gear (hoists, winches etc.) | 1139 |
| Heavy hoisting gear (rudder bars ) | 1803 |
| Light hoisting gear (slings, chains etc. )* | 6906 |
| Lifts and freight elevators | 370 |
| Other handling devices (transpalets ) | 339 |
| Automatic doors | 253 |
| Industrial pressure vessels | 747 |
| Special vessels for experiments | 370 |
| Safety valves** | 1379 |
| Chimneys | 10 |
| X-ray examinations done by TIS/MC/MI*** | 220 |
| Welders' qualifying tests | 33 |
| Mobile supports for experiments | 13 |
| LEP monorail (motor units etc.) | 132 |

* inspections are carried out twice per year for the Transport Group and once for other users.
** inspections are carried out twice per year.
*** X-ray inspections of welds in the pipework of the LEP machine itself and its experiments were carried out by an external contractor under the TIS/MC/MI's control.

# General Administration

General Administration, set up during 1989, comprises the Office of the Head of Administration, the Services of the Director-General, the Central Services and the Pension Fund.

## Office of the Head of Administration

Under the heading of relations with the Host States, the Administration pursued its task of representing the Organization in contacts with all levels of the French and Swiss administrative authorities. In particular it dealt with the following: residence and employment of spouses and children of members of the personnel, journeys through the tunnel between the sites and via border posts, customs arrangements, transport and traffic matters and the status of contractors and their staff.

The Office also continued to deal with financial management of all the units comprising the central Administration.

## Services of the Director-General

### Internal Audit Service

The Internal Audit was integrated into the new structure spearheading the Administration at the beginning of 1989 when its main task was to check the Accounts of the Organization and the Pension Fund, where account was taken of the concern expressed by the Auditors.

The audits carried out during the year included various aspects of the Organization's day-to-day administrative activities. In addition, the Service carried out various studies at the request in particular of the Head of Administration.

Throughout the year the Internal Audit Service also gave sustained theoretical and practical support to studies undertaken for a new budget system by project, programme and activity (PPA) and to discussions aimed at drawing up the Organization's future financial and accounting system.

### Council Secretariat

During the year, the Council Secretariat made the practical arrangements for 15 meetings and 2 Council Sessions. Between 1 January and 31 December 1989, the Service coordinated the preparation and distribution of 231 English, 190 French, 41 German and 14 bilingual documents.

The Service, as well as catering for the needs of the Delegates of Council and the Members of the the various Committees during the meetings, also looked after the requirements of the President of Council and the Chairmen of the other bodies.

The Secretariat also made the necessary arrangements for 5 Restricted and 2 Plenary Sessions of ECFA and prepared the relevant documents.

In addition, the Secretariat helped in the preparation of the conference 'ECFA Study Week on Instrumentation Technology for Future High Luminosity Hadron Colliders', Barcelona, September 1989.

*Document Statistics - Council Secretariat*
*1 January - 31 December 1989*

| | Number of Documents | | | | |
|---|---|---|---|---|---|
| | English | French | German | Bilingual | Total |
| Council and Committee of Council | 80 | 80 | 7 | 8 | 175 |
| Finance Committee | 110 | 110 | 34 | 6 | 260 |
| Scientific Policy Committee | 14 | – | – | – | 14 |
| ECFA | 27 | – | – | – | 27 |
| | 231 | 190 | 41 | 14 | 476 |

### Legal Service

The Legal Service continued to act as legal adviser to the Organization. It took part in the work of the Task Force on the participation of non-Member States in CERN's activities and in negotiations relating to scientific and technical co-operation between CERN and the European Communities.

It took part in studying the problems of technology transfer in the context of CERN's relations with industry, was involved in the work relating to the taking out of patents and helped to draw up co- operation agreements with other laboratories.

It took part in the work of the Organization's Pension Fund, with particular regard to pension guarantees in the event of dissolution, to the new status of the Pension Fund and to legal matters relating to the management of its assets.

The Service was represented on various committees (in particular the Safety Policy Committee and the Pension Group) and working groups.

It defended the interests of the Organization in litigation procedures and continued its work in the field of insurance. It also headed the CERN team in the EUROLEP/CERN affair.

### Translation & Minutes Services

The Translation and Minutes Service continued its normal tasks of preparing the records of all CERN's major meetings and many internal ones, in some cases providing simultaneous interpretation as well. Translations were mainly among the two official languages and German, but texts for translation into and out of Dutch, Italian, Russian and Spanish were also received. Major users included the Finance and Personnel Divisions, the Pension Fund, Publications Section, the Legal Service and the Council Secretariat, though the scientific and technical divisions were also well represented. The final statistics for the year show there was a slight increase in the volume of work handled despite reductions in staff.

### Strategic Information Unit

This unit was set up in 1989 with the task of providing the Management with strategic information on matters inside and outside the Organization. It was heavily involved in the studies on indefinite contracts and on the cost of CERN Users, in the acquisition of data on CERN purchases in the Member States and on ECFA and in various work requested by the Management (organizational chart, statistics, etc.).

### Public Relations

To ensure that the completion and the official inauguration of LEP received maximum coverage in newspapers, on the radio and television throughout the world, the Media Service, with the advice of Communications Consultants Saatchi and Saatchi, drew up a communications strategy for the year.

The first event was a Press Day in June which over 100 media representatives attended. After a visit to LEP and the experiments a Press Conference was given by the Director General. Interest in CERN and LEP snowballed after the Press Day right up to the official Inauguration Ceremony in November.

The Ceremony was attended by 212 media representatives including 18 television crews. The whole event was broadcast live on television throughout Switzerland and two special 5-page supplements on LEP were published in the 'Financial Times' and in the 'International Herald Tribune'.

In 1989 CERN featured in the world's most prestigious publications and as a result of programmes on 58 television channels the LEP story reached hundred of millions of viewers all round the world. CERN's image as a leader in high energy physics and strong force for advance through collaboration has been greatly enhanced.

The number of visitors to CERN has again shown an upward evolution during 1989 reaching a total of over 23 300; without taking into consideration the LEP inauguration day, which saw approximately 1300 visitors.

As in the past, the younger generation is greatly attracted by our scientific world and by the technological innovations present in our machines and detectors, their number has reached over 12 000. The opening of Microcosm has given greater scope to our visits, particularly since the LEP has closed up for a long running period and the detectors have been 'out of bounds' since their commissioning.

### Publications & Exhibitions Group

The Publications Section continued the regular production of the CERN Courier, Weekly Bulletin, Images and Annual Report, with increasing emphasis on computer file transfer, text formatting and page make-up. The popular documentation for CERN visitors was up-dated to bring it into line with the advent of LEP. This was available in four languages in time for the inauguration of the Collider. The Section also participated in the preparation of other documentation related to the LEP inauguration. A new version of the cartoon album 'Hunting Particles' was almost completed and there was also work, together with Austrian physicists, to prepare a set of posters on particle physics and accelerators for use in schools.

The Exhibitions Section was involved in exhibitions in Italy at the Milan Fair and in L'Aquila in collaboration with INFN and the nearby Gran Sasso Laboratory. Other major events were at the British Association for the Advancement of Science meeting in Sheffield, UK, and at the Foire du Valais in Switzerland. Several exhibitions during the year had particular emphasis on technology and collaboration with industry. These included the Tekniska Massan in Stockholm, Salone Nuove Technologie in Turin and Il Futuro Remoto in Naples. Discussions began with colleagues from ESO, ESA and EMBL on the possibility of an itinerent joint European science exhibition in a few years time.

## Central Services

### Composition & Printing

In 1989 the output of the print-shop was a total of 60 million A4 pages, which is a 20% increase over 1988. The output of the print-shop during the past four years in numbers of pages is shown below :

*Output of the print-shop in numbers of pages*

| 1986 | 1987 | 1988 | 1989 |
|---|---|---|---|
| 52 million | 76 million | 51 million | 60 million |

The annual budget (970 000.- francs) is worked into a free quota for each division and accounts for 50 million pages. The remainder is billed directly to the customer. Demand for colour work has continued to grow. Out of the 60 million A4 pages, almost 20% represents work in two and four colours.

The equipment has been maintained at a relatively low cost, the most noteable repair job being that of the compressed air system which is used in all folding and sorting machines. The introduction of a colour copier installed on trial has proven very popular. The copies are charged.

Macintoshes are introduced where possible and the staff are tought to use standard CERN text processing products, i.e. (La)Tex and MS-Word. Phase-out of Norsk Data equipment has started. All offices are equipped with LocalTalk and Ethernet to provide the necessary connectivity.

**General Services Group**

The installation was completed at entrance A of audio-visual links to the Reception building; this allows both the operation of the gates outside working hours by staff members holding the CERN identity/access card, and the necessary remote control.

Proposals for simplifications have been prepared for the use of the inter-site tunnel, notably the addition of a second, access-card operated lane, and an appreciable reduction in the number of documents to be presented to the guard.

A security seminar was held at CERN in September, with the participation of experts from Harwell and Saclay. A number of propositions made by the experts are being evaluated in close collaboration with user representatives (Users' Office and ACCU).

The Housing Service accommodation facilities (hostel, flats) continue to operate at very high occupancy rates. Supplementary accommodation was secured in the private sector as from October 1989. The search continues for low-priced accommodation near the main CERN sites.

Offers from private owners of studios and flats, which continue to provide a very precious source of accommodation at prices most CERN users can afford, have increased thanks to adverts placed by the Housing Service.

A computerized reservations and billing system was finally installed in the Hostel reception office. Though generally satisfactory for the huge volume of transactions this office has to deal with, some additional improvements are being investigated. Reservation world-wide by means of electronic mail and longer office opening hours were appreciated improvements to the desk services offered to numerous users.

# Technological Developments at CERN

## Accelerator Technology

**Subject** Four-turn dc septum magnet
**Institute** MPI, Heidelberg (D)
**Contact** P. Pearce / CERN–PS

After looking at the injection conditions for the Heidelberg Heavy Ion Storage Ring (TSR), it was found that the 0.55 T, 4-turn dc septum magnet, designed for the EPA injection scheme, fitted the requirments exactly. It was agreed to transfer the complete design and manufacturing documentation, together with the prototype septum coil to MPI Heidelberg. The special tooling developed to manufacture this coil was also used to make a spare coil for the Heidelberg installation.

**Subject** Sectorial septum magnet and vacuum chamber
**Institute** GANIL,Caen, (F)
**Contact** P. Pearce / CERN–PS

CERN agreed to a request from the CEA to collaborate with GANIL in designing, constructing and testing a dc sectorial septum magnet system, used as the main extraction element for their Medium Energy Beam project. The 12-turn, 1 T magnet with a water-cooled vacuum chamber produces a maximum bending of 28° and a stray field of $< 2 \times 10^{-4}$ on the non-deflected closed-beam orbit. The septum magnet ensures that intermediate energy heavy ions with specific electric charges are directed towards the Medium Energy Beam exit for use in the Heavy Ion Research laboratory (CIRIL) in non-nuclear physics research.

**Subject** Kickers, septa & bumper magnets for Booster and Storage Rings
**Institute** ESRF, Grenoble (F)
**Contact** D. Blechschmidt / CERN–PS

A collaboration has been established whereby CERN is designing and manufacturing the kicker magnets and their associated high voltage pulse generators for both the Booster and Storage rings of the ESRF. Low voltage control electronics is to be provided by ESRF and the systems commissioned as a joint effort. Completion scheduled 1991. In addition, three types of septum, fast bumpers and associated power supplies are also being built by CERN for ESRF. Special coated ceramic vacuum chambers are also considered as part of this collaboration.

**Subject** Plasma lens for CERN AAC source
**Institute** Phys. Institute, University of Erlangen
**Contacts** H. Riege /CERN–PS
J. Christiansen, K. Frank, M. Stetter, R. Tkotz / University of Erlangen

A new plasma lens was designed, built and integrated into a modular pulse generator compatible with the AAC target area installation. First laboratory tests and measurements started before the end of the year. The project has been supported by the German Ministry of Research & Technology with 1 MDM.

**Subject** Lead ion linac design
**Institute** GSI Darmstadt (D)
Lawrence Berkeley Laboratory (USA)
Centre d'Etudes nucléaires, Saclay (F)
**Contacts** H. Haseroth / CERN–PS
N. Angert, J. Klabunde & U. Rathinger /GSI
K. Berkner, R. Gough, B. Feinberg & H. Gould / LBL
S. Valero / Saclay

Collaboration with GSI concerned mainly cross-sections for ion charge exchange and stripping. (This statement is equally true for LBL, Berkeley.) The design of an interdigital H-structure is another topic where we profit from a special program developed at Saclay.

**Subject** Lead ion linac design Institute
Institute for Applied Physics, Frankfurt (D)
**Contacts** H. Haseroth / CERN–PS
H. Klein, A. Schempp, H. Deitinghoff, R.Becker / Frankfurt

The collaboration concerns low velocity structures for ion acceleration in the context of the design of accelerating structures for a lead ion linac, including the ion source. There is also a collaboration with CEN Grenoble (R. Geller) for ECR source development and with GSI (N. Angert, B. Wolf) and Techn. University Munich (G. Korschineck) concerning ion source studies.

**Subject** Magnet measurement instrumentation
**Firm** Metrolab (CH)
**Contact** K. Henrichsen / CERN–SPS

A digital integrator for high accuracy flux measurements was needed for the various magnet measurement systems for the thousands of magnets in LEP. No such instrument was commercially available and so it was developed at CERN and used extensively during the period of magnet manufacture and tests. The integrator is mounted as a plug-in card meeting G-64 specifications, the standard chosen for LEP instrumentation. Many laboratories outside CERN showed an interest in this integrator. It was therefore decided to hand it out to industry. The company Metrolab specializes in the field of magnet measurement equipment and is now manufacturing and selling the original integrator. This company has now developed a stand-alone integrator using the same basic principle. It also features some very useful functions and the instrument has been provided with industry compatible standards for interfacing.

**Subject** Electromagnet design
**Firms** Ansaldo (I) & Cockerill-Sambre (B)
**Contact** K. Henrichsen / CERN–SPS

Contracts for collaboration have been signed with these two firms to develop low-carbon steel for electromagnets. The magnetic properties of samples of low-carbon steel are measured to high accuracy at CERN using a split coil permeameter.

**Subject** Magnet design
**Institute** ESRF, France
**Contact** K. Henrichsen / CERN–SPS

The LEP Magnet Group has been consulted on various questions related to magnet design and magnetic measurements. The harmonic coil measurements of the magnetic lenses were of particular interest. Consultation was provided during the testing of the measurement benches which were manufactured by the Danish firm Danfysik.

# Computing

**Subject** Cartridge tape robot
**Firm** IBM (USA)
**Contact** J.-C. Juvet / CERN–DD

The increasing burden of manually mounting 3480-type cartridges in the Computer Centre led to a study in the area of robotics. Following negotiations early in the year, CERN agreed to take part in a two-year joint study with IBM, which started on 1 April, with the aim of providing an on-line robotics subsystem with a 40000 cartridge capacity and sustained rate of 160 mounts per hour on-line. Installation of half of the automatic library capacity was complete by the autumn as well as all the tape drive hardware components. Progress on the project was somehow delayed for a period but performance half way into the joint study is now very promising. It is planned to provide an experimental service for the LEP experiments during the first quarter of 1990 and to open up the service to the whole user community by the summer.

**Subject** Networks and distributed computing
**Institute** European Commission
**Contact** B. Carpenter / CERN–DD

CERN agreed to participate in the X.25 pilot project for the Eureka project COSINE (Cooperation for Open Systems Interconnection in Europe), intended to provide international networking facilities for the research and development community in 19 European countries. CERN also contributed to a Working Group set up by DG XIII of the European Commission to make proposals for future networking activities to be sponsored by DG XIII. Our joint study with IBM on the use of Fibre Distributed Data Interface (FDDI, the future OSI standard IS 9314) continued and was complemented by FDDI product testing agreements with DEC and Apollo. We contributed actively to the resolution of problems in the standards defining the use of FDDI to carry TCP/IP protocols, and in those defining the interconnection of FDDI and Ethernet via MAC-level bridges.
Two remaining joint projects with DEC in the communications area (network management, and OSI file transfer) were brought to a close. However, CERN became a trial site for DEC's commercial network management service (NETsystem). An electronic mail connection to DEC, using the X.400 standard, was opened.
A new network management collaboration with Hewlett Packard Laboratories (Bristol, UK) was launched.
1989 saw a significant increase in the interest in distributed and cooperative processing. Two medium term projects were initiated with IBM to improve the communications bandwidth and the development environment required for effective distributed computing. The emergence of the FDDI fibre technology promises several times the bandwidth capability between the IBM and workstations. The announcement of the AIX operating system, IBM's version of UN*X, will provide a platform for program development in order to exploit the new era of distributed computing.
A EDI (Electronic Document Interchange) pilot study was developed in collaboration with IBM and FABRIMEX to introduce a paper less data exchange with some outside suppliers.

**Subject** Parallel Computing
**Firm** IBM Böblingen (D)
**Contact** A. Fucci / CERN–DD

In June 1989 the first IBM VLSI /370 Chip Set system was installed at CERN. It consists of a /370 host system (an IBM 9373-30) and a Parallel Processing Compute Server (PPCS). The PPCS itself is composed of 32 processors (of the type 9373-30) each with an IBM proprietary interface. Our contribution to the Joint Study Project with IBM for this system, known as Stage 2, is the design of a VME interface to the processor ports. The design is finished and we are in the debugging phase. In addition, a simple monitor program (VERMIN) for the processors of the PPCS has been developed and the emulator farm host software package (SYEPAK, VEPAS and VICIS) has been adapted to this platform. Once in operation, the full system is best suited for an on-line application.
The Joint Study Project agreement includes a Stage 3 system with the same number of processors interconnected through an IBM network switch capable of parallel operation under a parallel VM operating system. This system is intended for off-line applications and parallel software studies.

**Subject** Interfacing
**Firms** Various
**Contact** R. McLaren / CERN–DD

The process of turning the production of the CERN Host Interface (CHI) over to industry was largely completed. Examples of this interface family, which allows the complete range of VAX and μVAX computers to be connected to FASTBUS and VMEbus, were installed in the DELPHI, L3 and OMEGA experiments. The FASTBUS versions are being manufactured by Dr B. STRUCK, Hamburg and the VMEbus versions by Creative Electronic Systems SA, Geneva. Front-line hardware support and general software support is being provided by the division to users at CERN, while DEC supports specially adapted high-performance VAX/VMS drivers.
Academic partners, for the development of the Optical Data Interconnect (ODI), at present in use in ALEPH, DELPHI and L3, have been the LIP and INESC institutes in Portugal. The ODI is now also commercially available from Dr B. Struck.
Another Joint Study with the IBM T.J. Watson Research Center in Yorktown Heights, USA, covers the design of an updated version (VICAR) of the VICI (VME to IBM Channel Interface) used in emulator farms and now in PPCS systems. The design phase is complete and few prototypes are currently being constructed. The new interface will be constructed and tested according to the standards set by IBM. The software package for the basic hardware tests is currently under development.

**Subject** Microprocessor Support
**Firm** Motorola (D)
**Contact** D. Sendall / CERN–DD

In the software area, various field tests of software from ACE, Microware, and Motorola have been undertaken. The Division participates actively in the development of the ORKID (Open Real-Time Kernel Interface Definition) standard, in collaboration with VITA (VME International Trade Association).
In the hardware area, we provide the convenor and secretary to the VICbus (VME Inter-Crate bus) Working Group: WG8 of ISO/IEC JTC1 SC26.

**Subject** Mechanical CAE
**Firm** Matra-Datavision (F)
**Contact** R. Messerli / CERN–DD

Collaborative ventures with MATRA DATAVISION, the supplier of the EUCLID CAD software include: an agreement on field tests (β-site tests) of new releases of EUCLID, and the joint development of software to allow Apple's Macintosh II computer to be used as an access station for EUCLID.

**Subject** Software Standards
**Institute** ISO
**Contact** D. Sendall / CERN–DD

Work continued within the Swiss standards organization's Group 149/UK9 and ISO JTC1/SC24/WG1 and WG2, as well as in the maintenance update of GKS, and in the investigation of how graphics application program interface standards may be used within a windowing environment.
Work on the future FORTRAN standard has continued, and active participation in the work of X3J3 has been directed towards the preparation of a final draft for anticipated acceptance in the near future.

**Subject** ESPRIT Projects
**Institute** European Communities
**Contact** I.M. Willers / CERN–DD
R.W. Dobinson / CERN–EP

The following proposals have been submitted to ESPRIT :

- a large multiprocessor computer based on the next generation Transputer with INMOS, PARSYS, PARSITEC, MEIKO and TELMAT
- a database server for large amounts of data with HP/Apollo, Anamartic, NTSC, and Cresco Data. Anamartic supplies wafer scale memories

## Controls

**Subject** Cooperation between Expert Systems (ARCHON)
European Community ESPRIT II project 2256
**Institutes** Various
**Contacts** F. Perriollat & P. Skarek / CERN–PS

EEC ESPRIT II project for the development of an architecture for distributed Expert Systems with industrial applications.

**Subject** Portable Nodal
**Institute** Sincrotrone Trieste (I)
**Contacts** G. Cuisinier / CERN–PS
F. Pottepan / Sincrotrone Trieste

Build portable accelerator control interpretor language Nodal for various workstations and front end processor platforms.

**Subject** X windows
**Institute** ESRF Grenoble (F)
**Contacts** F. di Maio / CERN–PS
A. Goetz / ESRF

Develop X-window tools and methods for the user interface in accelerator controls.

**Subject** TRIUMF, Kaon factory controls
**Institute** TRIUMF, British Columbia, Canada
**Contacts** H. Lustig, F. Perriollat, Ch. Serre / CERN–PS
D. Dohan / TRIUMF

Design and implementation methodology for the Kaon factory controls system.

**Subject** The EPS Interdivisional Group on Experimental Physics Control Systems and its collaboration with research institutes and industry
**Institutes** Various
**Contact** A. Daneels / CERN–PS

EPCS was founded in March 1986 under the auspices of the European Physical Society, as a response to controls specialists' request for a platform for exchanging information, sharing experiences and initiating studies and collaboration in their field of technology.
To date, the group has grown to include 31 laboratories worldwide. The European Member Institutes are CEN Saclay (F); CERN Geneva (CH); CRN Strasbourg (F); CRPP Lausanne (CH); CTU Prague (CS); Daresbury Warrington (GB); ESRF Grenoble (F); GANIL Caen (F); GSI Darmstadt (D); HMI Berlin (D); IHEP Serpukhov (USSR); JET Culham (GB); KFA Jülich (D); LNF Frascati (I); NIKHEF Amsterdam (NL); PSI Villigen (CH); RAL Chilton (GB); Sincrotrone Trieste (I). In Africa there is NAC Faure (SA). In North America : BNL Upton,Long Island; CEBAF Newport News (VI); FNAL Batavia (IL); LANL Los Alamos (NM); SLAC Stanford (CA); TRIUMF Vancouver (BC). In Asia: BARC Calcutta (India); IHEP Beijing (PRC); INP Novosibirsk (USSR); IRAQI AEC Baghdad (Iraq); JAERI Naka-Machi (Japan); KEK Tsukuba (Japan).

The group sponsored a major international conference on accelerator and large experimental physics control systems in Vancouver, Canada, in autumn 1989); it attracted a large number of industrial exhibitors. The Group also sponsored topical workshops and seminars that were also attended by computer manufacturers, and negotiated and obtained particularly favourable conditions for its European member Institutes for CASE products.
EPCS also provided assistance to JET Culham, by loaning its workstations, donated by Digital Equipment Corporation and Hewlett Packard, to enable JET to initiate a study on its future controls.

**Subject** Operational protocols for power converters
**Institutes** Various
**Contact** G.Baribaud / CERN–SL

The Power Converter Control Protocols working group benefits from the continuous participation of 7 laboratories: CEN, Saclay; CERN, Geneva; ESRF, Grenoble; GANIL, Caen; GSI, Darmstadt; KFA, Jülich; PSI, Villigen; with occasional contributions from KEK, Tsukuba; CTU, Prague; LNF, Frascati; CNR, Strasbourg; HMI, Berlin; Daresbury Laboratory, Warrington; IRAQI-AEC, Baghdad; SINCROTRONE, Trieste. So far a general concensus has been obtained on a standard model describing the behaviour of power converters.

**Subject** Operational protocols for beam instrumentation
**Contact** G.P. Benincasa / CERN–PS

Despite the great variety of instrumentation that exists around accelerators, the working group for instrumentation protocols has come to the promising indication that it might be possible to reach a common protocol for a large fraction of instrumentation devices. To date CERN, ESRF HMI Berlin, PSI Villigen and LNF Frascati are involved. After an initial successful implementation at CERN, the group will attempt to prove the validity of their protocol on a large number of practical cases.

## Detectors

**Subject** UV mirrors for Cherenkov light
**Firm** Bofors Aerotronics AB (S) )
**Contact** T. Ekelöf / CERN–EP

The focussing UV mirrors for the Barrel and the Forward RICH were all delivered in 1988 and 1989. See also :
1. P. Baillon et al., Nucl. Instruments & Methods in Phys. Res. A277 (1989) 338–346
2 S. Walles, Particle World, 1 (1989); 2,35

## Electrical Engineering

**Subject** Development project for a geological radar on tunnel boring machines
**Firm** ETH-Zurich-EEK
**Contact** F. Caspers / CERN–PS

Project in preparation.

**Subject** Development project for general purpose geological radar based on synthetic pulse techniques
**Firm** Bureau de Recherches géologiques et Minières, Orléans (F)
**Contact** F. Caspers / CERN–PS

The project has been running since 1988.

**Subject** Magnetometer design
**Firm** Danfysik (DK)
**Contact** K. Henrichsen / CERN–SPS

Highly automated measurement benches for the precise measurements of the LEP magnetic lenses were developed and built at CERN. The measurement principle was based on rotating harmonic coils with Fourier analysis of the measured flux signals. Several laboratories have shown an interest in this development. The Danish firm Danfysik is now manufacturing and selling this bench to the European Synchrotron Radiation Facility and Argonne National Laboratory; there are other potential customers.

## Electronics

**Subject** Silicon on sapphire circuits
**Firm** ABB Hafö (S)
**Contacts** T. Ekelöf / CERN–EP

Work supported by the LAA project and the Swedish Board for Technical Development. For details see :
T. Ekelöf, Megarad-hard read-out electronics in SOS, Proc. ECFA Study Week on Instrumentation Technology for High-Luminosity Hadron Colliders, CERN 89-10, p.361

**Subject** Application specific integrated circuits
**Firm** MIETEC NV (B)
**Contacts** H. Heijne & P. Jarron / CERN–EF

AMPLEX : a 16-channel analog front-end chip with 600–800 ns peaking time, 1000 electrons r.m.s. noise, track-hold and multiplexing, technology : 3 μm CMOS.

**Subject** Low noise front-end circuit
**Firm** FASELEC AG (CH)
**Contacts** H. Heijne & P. Jarron / CERN–EF

AMPLEXF : a 4-channel version of AMPLEX with 200 ns peaking time for 1000 electrons rms noise, technology: 3 μm CMOS .

**Subject** Analog readout processor for silicon calorimetry application
**Firm** IMEC-Invomec Division (B)
**Contacts** H. Heijne & P. Jarron / CERN–EF

AMPLEX 2 : with extended dynamic range and ECL compatible, faster readout, technology: 3 μm CMOS.

**Subject** Low noise BICMOS front-end circuit
**Firm** FASELEC AG (CH)
**Contacts** H. Heijne & P. Jarron / CERN–EF

BIPOLTEST : a fast preamplifier block for use with 10–20 pF detector elements, with 15–20 ns peaking time, using the lateral bipolar effect in 3 μm CMOS FASELEC. Power 2 mW for 1000 electrons noise.

**Subject** Analog pipeline chip for high rate detector signal
**Firm** Rutherford Appleton Laboratory (GB)
Senter for Industriforskn (N)
**Contacts** H. Heijne & P. Jarron / CERN–EF

SAPE : two different 10 MHz analog pipeline chips with simultaneous write and read operation, developed in collaboration with RAL and SI Oslo. These units are not yet fully tested.

**Subject** Microelectronic circuits
**Firm** Mead SA (CH)
FASELEC
**Contacts** H. Heijne & P. Jarron / CERN–EF

PIPAD : an ADC based on the pipeline principle. 12 bits, of which 11 were found to be significant. After 12 initial cycles, a new conversion is delivered each cycle at a rate of 1 MHz. Developed in collaboration with MEAD SA, Lausanne and processed in 3 μm CMOS by FASELEC.

**Subject** Low noise CMOS front-end circuit
**Firm** IMEC – Invomec Division (B)
**Contacts** H. Heijne & P. Jarron / CERN–EF

A CMOS current-sensitive preamplifier with 100 ns peaking time and 3 mW power consumption for use with 100 pF detector capacitance.

**Subject** Low noise front-end circuit
**Institutes** ETHZ (CH)
EPFL (CH)
**Firm** Smart Silicon Systems SA (CH)
**Contacts** H. Heijne & P. Jarron / CERN–EF

PIXEL : An experimental pixel detector readout circuit, 200 μm × 200 μm, with a 65 μm × 65 μm bonding pad for bump bonding. R.m.s. noise less than 400 electrons at 100 ns response of 1 bit. Threshold adjustable between 5000 electrons and 20000 electrons. Developed in collaboration with ETHZ, EPFL and Smart Silicon Systems SA, Lausanne.

## Superconducting Technology

*Continuation of work reported in 1988*

**Subject** Design and construction of a prototype superconducting quadrupole
**Institute** CEA (F)
**Contact** R. Perin / CERN–SPS

**Subject** Development of NbTi conductors with 5 mm diameter filaments
**Institute** INFN (Italy)
**Contact** R. Perin / CERN–SPS

**Subject** Construction of 10 T, twin-aperture, 10 m long dipoles
**Institute** INFN (Italy)
**Contact** R. Perin / CERN–SPS

**Subject** Development of a 10 T twin-aperture dipole model magnet with $Nb_3Sn$ conductor
**Institute** FOM-UT-NIKHEF (NL)
**Contact** R. Perin / CERN–SPS

**Subject** 1 m long, 8 T, NbTi single-aperture dipole models
**Firm** ANSALDO (I)
**Contact** R. Perin / CERN–SPS

Common development contract concluded.

**Subject** 1 m long, 10 T, $Nb_3Sn$, single-aperture dipole model
**Firm** ELIN-UNION (A)
**Contact** R. Perin / CERN–SPS

Common development concluded.

**Subject** 9 m long, 7.5 T, NbTi twin-aperture prototype using HERA coils
**Firm** ABB (D)
**Contact** R. Perin / CERN–SPS

Contract in progress.

**Subject** 1 m long, 10 T, NbTi, twin-aperture dipole model for LHC
**Firms** Ansaldo (I)
Elin (A)
Holec (NL)
Jeumont-Schneider (F)
**Contact** R. Perin / CERN–SPS

Contract in progress.

**Subject** Superconducting sextupole and dipole corrector
**Firm** Tesla Engineering (GB)
**Contact** R. Perin / CERN–SPS

Common development in progress.

**Subject** Superconducting tuning quadrupole
**Firm** ACICA Consortium (E)
**Contact** R. Perin / CERN–SPS

Common development in progress.

**Subject** High current diodes for superconducting magnet protoection
**Firm** ABB (CH)
**Contact** R. Perin / CERN–SPS

Common development in progress.

## Technology

**Subject** Applications of Ferroelectrics
**Institutes** Physics Department, Silesian University of Katowice
Institute of Nuclear Physics, University of Thessaloniki
**Contacts** H. Riege /CERN–PS
J. Handerek /University of Katowice
K. Zioutas /University of Thessaloniki

Several new methods of pulsed, charged particle emission have been successfully demonstrated with ferroelectrics within the framework of the collaboration :

- by field-induced polarization change;
- by laser illumination; and
- by beam-plasma-surface interaction.

These new emission methods are, in several ways, superior to conventional electron emission methods. Potential applications are envisaged in accelerator technology fields such as electron and ion beam sources, X-ray and microwave sources, laser pre-ionizers, high-power gas switches and plasma lenses as well as in the industrial areas of microelectronics and vacuum microelectronics.

**Subject** Test station for dipole magnets
**Institute** CEA (F)
**Contact** R. Perin / CERN–SPS

**Subject** 1.8 K helium circulation test installation
**Institute** CEA (F)
**Contact** R. Perin / CERN–SPS

**Subject** Survey collaboration
**Institutes** Geodesy Department, University of Stuttgart (D)
Geographical Institute, Lisbon (P)
**Contact** M. Mayoud / CERN–LEP

The one and only European example of the Terrameter, a very high precision ($10^{-7}$) electro-optical distance meter, is intended for use by the Member States whenever required.
The Department of Geodesy of the University of Stuttgart asked to use the instrument to carry out measurements on movements in the earth's crust. Owing to adverse meteorological conditions, the measurements could not be completed and will continue at a later date. The Geographical Institute of Lisbon and CERN drew up a joint collaboration protocol for the installation and measurement of a geodetic calibration base at Estremoz. Work went well and remarkable results have been obtained owing to the excellent atmospheric conditions.

**Subject** Gyroscope collaboration
**Firm** Bertin (F)
**Contact** M. Mayoud / CERN–LEP

Bertin has shown a certain amount of interest in the development work carried out on the WILD/CERN gyroscope. After testing of the instrument, we await their final decision.

**Subject** Distinvar construction
**Firm** Baechler (CH)
**Contact** M. Mayoud / CERN–LEP

Baechler is interested in carrying out the complete independent manufacture of various geodetic metrology instruments which have been designed and developed at CERN. Discussions will begin shortly.

# Seminars & Colloquia*

## CAS ACCELERATOR SEMINARS

S.R. Mane (Fermilab) (20.02.1989)
Electron spin polarization in storage rings : the SMILE algorithm

G. Bonvicini (SLAC) (01.03.1989)
Observation of beamstrahlung at the SLC

A. Sessler (LBL) (19.04.1989)
Plasma suppression for beamstrahlung and the plasma adiabatic focuser

N. Kroll (SLAC) (04.07.1989)
Coherent electron-positron pair production in the final focus of a linear collider

## CERN COLLOQUIA

C. Rubbia, W. Kittel, V. Soergel (CERN) (20.02.1989)
Special Symposium in honour of Leon van Hove for his 65th birthday

R.M. Bonnet (European Space Agency) (20.04.1989)
Probing the interior of a star

N. White (SAE ESTEC, Noordwijk) (18.05.1989)
X-ray binaries

O.V. Lounasmaa (Helsinki University of Technology) (25.05.1989)
Magnetoencephalography : a non-invasive method of experimental brain research

B. Pontecorvo (JINR, Dubna) (14.09.1989)
Autobiographical notes

I.J. Danziger (ESO) (28.09.1989)
SN 1987A – the second year

L. Okun (ITEP) (12.10.1989)
The concept of mass

P. Shaver (ESO) (16.11.1989)
The large scale structure of the Universe

H. G. Dehmelt, Nobel Prize for Physics 1989 (University of Washington, Seattle) (18.12.1989)
Experiments with an isolated subatomic particle at rest

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* unpublished



## COMPUTER SEMINARS

M. Katevenis (Computer Science Institute, Forth, Crete) (25.01.1989)
The design of the Berkeley RISC II processor

P.-E. Danielsson (Linköping University, Sweden) (08.02.1989)
Parallel processors and algorithms for image processing

R. Dawkins (New College, Oxford University) (19.04.1989)
The evolution of evolvability

C. Adams (Rutherford Appleton Laboratory) (10.05.1989)
Multi-media networking

B. Sufrin (University of Oxford) (14.06.1989)
The design of human-computer interfaces

S. Scarci (IBM, Rome) (18.10.1989)
Automatic speech recognition

R. D. Cowles (Cornell University, USA) (01.11.1989)
SuperStorage

P. Smith (IBM, Boulder) (29.11.1989)
The Personal Science Laboratory

## DD SEMINARS

J. Fr. Hake (KFA Germany) (15.02.1989)
Mathematical software at KFA

C. G. Harrison (IBM Yorktown) (22.02.1989)
The ACE multiprocessor workstation

F. Chevrier (CERN) (15.03.1989)
La sécurité sur site d'expérience en physique des hautes énergies par système expert

J. .M. Vermaseren (NIKHEFH) (22.03.1989)
FORM, a new symbolic manipulation program for large expressions

S. J. Mullender (CWI Amsterdam) (29.03.1989)
AMOEBA – High performance distributed computing

L. Cottrell (Stanford Linear Accelerator Center) (05.04.1989)
Computing at SLAC

T. Killian (A&T Bell Laboratories, USA) (12.04.1989)
Plan 9 : it looks familiar, but it's gnot

R. Knerr (A&T Bell Laboratories, USA) (19.04.1989)
Lightwave communications

J. A. Fisher (Multiflow Computer, Inc.) (19.04.1989)
Building the fastest possible uniprocessors : trace scheduling compilers and VLIW architectures

J. A. Fisher (Multiflow Computer, Inc.) (19.04.1989)
The Multiflow Trace / 300 series

Iwaya & Fukuda (NEC) (21.04.1989)
Supercomputer NEC SX-3 announcement

B. White (Stanford Linear Accelerator Center) (17.05.1989)
IBM GroupTalk and computer conferencing at CERN

D. Summers (Fermilab) (24.05.1989)
A high-speed data acquisition and off-line reconstruction system

P. Vu (Cray Research Mendota Heights) (07.06.1989)
High performance linear algebra kernels and their applications

W. Kluge (University of Kiel) (23.06.1989)
Concurrent processing in reduction systems

S. Lone (CERN) (28.06.1989)
Parallel architectures as part of the fast trigger?

A. Agrawal (SUN Microsystems) (01.11.1989)
80 MHz bipolar ECL SPARC

S. Adler (IBM Publishing Systems Business Unit) (06.11.1989)
IBM and SGML

B. Autin (CERN) (15.11.1989)
MATHEMATICA, the standard program for symbolic computation?

J. Barton (Silicon Graphics Mountain View) (06.12.1989)
Tools and mechanisms for different levels of parallelism for multiprocessor computers

### EF ELECTRONICS SEMINARS

F. Formenti (CERN) (16.10.1989)
Techniques du blindage et mise à la masse

F. Bourgeois (CERN) (27.11.1989)
Introduction aux standards modernes d'acquisition

P. Jarron (CERN) (11.12.1989)
ASICs pour les expériences au CERN

### EF SEMINARS

D.R. Quarrie (Fermilab) (20.01.1989)
The CDF online system

J. Eades (CERN) (06.03.1989)
Gravity and other matters

E. Heijne (CERN) (13.03.1989)
R&D in silicon detectors and micro-electronics

J.-M. Le Goff (CERN) (03.04.1989)
Use of an expert system for monitoring and control of the L3 experiment

J. Conway (University of Wisconsin) (17.04.1989)
The ALEPH TPC

L. Borne (CERN) (24.04.1989)
A new generation of computational tools in structural engineering

F. Piuz (CERN) (22.05.1989)
Fast RICH with VLSI electronics

A. Marchioro (CERN) (29.05.1989)
Architectural design of a new VLSI Fastbus integrated master

P. Baehler (CERN) (19.06.1989)
Les PC IBM ou compatibles dans l'environnement du développement électronique

D.R.O. Morrison (CERN) (03.07.1989)
Cold fusion : Science or biopsy science?

A. Hofmann (CERN) (23.10.1989)
LEP : an overview

S. Majewski (University of Florida, Gainesville) (01.11.1989)
Radiation damage studies of plastic scintillators and plastic scintillating fibres

D. Delikaris (CERN) (06.11.1989)
The DELPHI TPC : construction, working parameters, performance and first results

I. Lehraus (CERN) (10.11.1989)
The ALEPH TPC : gas system

A. Cattai (CERN) (20.11.1989)
The High Density Projection Calorimeter of DELPHI – status and operational experience at LEP

E. Chiaveri (CERN) (04.12.1989)
LEP 200 : superconducting cavities on the way

### ELECTRONICS SEMINARS

Y. Arai (KEK, Japan) (26.01.1989)
Custom VLSI development and data acquisition system for VENUS

### EP SEMINARS

A. Penzo (INFN, Trieste) (09.01.1989)
The new Tevatron polarized $\bar{p}$ beam facility : first results and physics outlook

A. Onuchin (Novosibirsk) (30.01.1989)
The liquid krypton calorimeter for the KEDR detector

A. Peisert (CERN) (06.02.1989)
Development and tests of a new silicon microstrip detector

R. Landua (CERN) (13.02.1989)
New results from $p\bar{p}$ annihilation at rest

G. Bonvicini (SLAC) (27.02.1989)
Solution to all QED radiative correction problems

A. de Roeck (University of Antwerp) (06.03.1989)
Particle production in low $p_T$ hadronic collisions (results from the CERN-EHS experiments)

S.R. Wasserbach (Stanford University) (13.03.1989)
Results on D and $D_s$ decays from Mark III

B. Hubbard (LBL) (20.03.1989)
Jet fragmentation properties from CDF

N. Wainer (Weizmann Institute) (22.03.1989)
Comparison of inclusive fractional momentum distributions of quark and gluon jets produced in $e^+e^-$ annihilation

A. Palano (Dipartimento di Fisica e Sezione INFN, Bari) (22.05.1989)
New results on central meson production in WA76 and observation of the $Q/f_2(1720)$

C. Haber (LBL) (31.05.1989)
The CDF silicon vertex detector

K. Fransson (University of Uppsala) (05.06.1989)
A measurement of low-$p_T$ prompt-electron production at the $p\bar{p}$ collider using a RICH counter

E. Klempt (Institute of Physics, University of Mainz) (19.06.1989)
Observation of a new $2^{++}$ resonance at $M = 1.565$ GeV$/c^2$ in $p\bar{p}$ annihilation at rest

M.A. Botje (PSI, Villingen) (26.06.1989)
New results from the NMC

A. Staude & H. Wahl (CERN) (03.07.1989)
Report on the Workshop on Physics at the Main Injector held at Fermilab in May 1989

V. Chaloupka (University of Washington, Seattle) (24.07.1989)
High energy physics with no target, fixed target, and a slowly moving target

C.D. Buchanan (CERN) (21.08.1989)
Evidence indicating that meson and baryon formation are controlled by phase space and a linear confining quark potential

W. Molzon (University of California) (04.09.1989)
Study of lepton flavour violating and other rare decays of neutral kaons

S. Bethke (University of Heidelberg) (18.09.1989)
Recent results on jet physics and tests of QCD in $e^+e^-$ annihilations

V.J.D. Kekelidze (University of Tbilisi, USSR) (09.10.1989)
A fixed-target target experiment to study CP-violation in B-meson decay

M. Boutemeur (CERN) (04.12.1989)
Light quark meson spectroscopy

C.A. Heusch (University of California, Santa Cruz) (20.12.1989)
First measurement of limits on non-diagonal lepton pairs at high $q^2$ involving tau leptons

## SPECIAL EP SEMINAR

A. Richard Newton (University of California, Berkeley) (23.11.1989)
Integrated electronics : trends in technologies and CAD tools

## ISOLDE SEMINARS

R.K. Sheline (Florida State University) (26.05.1989)
Evidence for octupole deformation in nuclei

C. Rolfs (Münster), J. Vervier (Louvain-la-Neuve), P. Aguer (Orsay), H. Rebel (Karlsruhe), M. Arnould (Brussels), K. Langanke (Münster) & H. Haas (CERN) (19 & 20.06.1989)
Nuclear astrophysics with radioactive beams

H. Stroke (University of New York) (02.09.1989)
Cooled composite calorimeter spectrometers and detectors : a primer and progress

D. J. Vieira (Los Alamos National Laboratory, USA) (07.12.1989)
Exploring the frontier of exotic nuclei : recent measurements using the TOFI spectrometer

M. Hass (NSRL, University of Rochester) (14.12.1989)
Tilted foil polarization of separated reaction products and radioactive beams

## LEAR DISCUSSION MEETINGS

(01.08.1989)
Very low energy antiprotons

## PARTICLE PHYSICS SEMINARS

S. Stone (Cornell University) (10.01.1989)
A pot-pourri of new Cleo results : the $\Xi_c^0$, $\gamma(1s) \rightarrow J/\Psi + X$, and $b \rightarrow u$ : limits

C. Wetterich (DESY) (31.01.1989)
A new intermediate range force?

(09.02.1989)
Physics at UNK

V. Blobel (University of Hamburg) (02.03.1989)
Neutral-current neutrino interactions and the Standard Model

T. Nozaki (KEK, Japan) (14.03.1989)
Recent results of the TRISTAN experiments

B. Gavela (Univ. Autonoma de Madrid) (04.04.1989)
The electric dipole moment of the neutron

H. Nelson (CERN) (06.04.1989)
Search for a neutral Higgs particle in the decay sequence $K_L^0 \rightarrow \pi^0 H^0$, $H^0 \rightarrow e^+e^-$

G. Belletini (Pisa), L. Fayard (Orsay) & M. della Negra (CERN) (18.04.1989)
New results from the p$\bar{p}$ collider experiments : the search for Top

Y. Nir (SLAC) (09.05.1989)
What do we know (and how) about the CKM matrix?

R. Schwitters (SSC) (13.06.1989)
Status of the SSC laboratory

V. Gibson (CERN) (15.06.1989)
New results from NA31 on CP violation and CPT

D.O. Caldwell (University of California) (18.07.1989)
Recent results in the search for dark matter

J. Kirkby (CERN) (29.08.1989)
Summary of the SLAC Lepton-Photon Symposium

J. Nash (SLAC) (15.09.1989)
First results from the Mark-II at the SLC

T. Yamanaka (Fermilab) (19.09.1989)
A new measurement of $\varepsilon'/\varepsilon$ by FNAL E731

J. Yoh (Fermilab) (26.09.1989)
Recent results from CDF and future prospects

J. F. Wilkerson (Los Alamos National Laboratory) (17.10.1989)
New limits on neutrino mass from tritium beta decay measurements

H. Schroeder (DESY) (31.10.1989)
The measurement of quark couplings in B decays

C. Rubbia (CERN) (02.11.1989)
Perspectives for a Hadron Collider in the LEP tunnel

R. van Kooten (SLAC) (07.11.1989)
New particle searches in Z decays using the Mark II at the SLC

A. Melissinos (University of Rochester) (14.11.1989)
The search for cosmic axions

A. Rozanov (ITEP & CERN) (28.11.1989)
Determination of the electroweak mixing angle from neutrino-electron scattering

Charm II Collaboration

D. Froidevaux (LAL, Orsay) (30.11.1989)
Search for new particles with the UA2 detector

J. Steinberger (Scuola normale, Pisa) (05.12.1989)
Three families : results of the ALEPH collaboration at the $Z^0$

D. Nanopoulos (College Station, A&M University, Texas) (07.12.1989)
Three generations, past, present and future : a theorist view

K. Einsweiler (CERN) (12.12.1989)
Measurement of W and Z parameters in UA2

## MEETINGS ON PARTICLE PHYSICS PHENOMENOLOGY

G. Bertsch (Michigan State University) (20.01.1989)
Detecting the quark-gluon plasma

V.A. Khoze (Leningrad Institute for Nuclear Physics, Gatchina, USSR) (03.03.1989)
QCD coherence in hadronic jets

B. Andersson (University of Lund) (28.04.1989)
The QCD cascades : parton-hadron duality, fractal nature and intermittency

W. van Neerven (University of Leiden) (19.05.1989)
Order $\alpha_S^2$ contributions to the Drell-Yan K-factor

B. Mele (CERN) (30.06.1989)
New heavy vector bosons at p$\bar{p}$ colliders

A. Sirlin (University of New York) (25.08.1989)
Considerations concerning the renormalization of the electroweak sector of the standard model

R.F. Jaffe (MIT) (15.09.1989)
Flavour and spin structure of the proton

M. Shifman (Bern) (10.11.1989)
Light Higgs particle in the decays of the K and eta-mesons

## PS SEMINARS

J. Handerek (Institute of Physics, Silesian University Katowice, Poland) (15.02.1989)
Copious electron emission from PLZT ceramics with a high zirconium concentration

R.B. Moore (Department of Nuclear Physics, McGill University, Montreal) (22.02.1989)
RFQ traps as beam coolers and bunchers

H. Satz (University of Bielefeld) (01.03.1989)
Quark deconfinement in nuclear collisions

G. Silverstrov (Institute of Nuclear Physics, Novosibirsk, USSR) (29.03.1989)
Use of high currents and liquid metals – particle focusing devices

K.N. Leung (LBL) (03.04.1989)
Development of high brightness $H^-$ sources

P. Skarek (CERN) (05.04.1989)
ARCHON – Architecture for cooperative heterogeneous on-line systems : a CERN-PS ESPRIT-2 collaboration

F. Peyrin (Laboratoire de traitement du signal et ultrasons INSA, Villeurbanne, France) (12.04.1989)
Représentation temps fréquence des signaux numériques: du spectrogramme à la représentation de Wigner-Ville

J. Stovall (LANL, Los Alamos) (17.04.1989)
FEL and RFQ accelerator activities in Los Alamos

R. Becker (University of Frankfurt) (19.04.1989)
Status of the electron beam ion source

E. Harms & B. Hanna (FNAL) (07.06.1989)
Accelerator operations at Fermilab

Y. Baconnier (CERN) (11.10.1989)
New techniques of acceleration : from CLIC (CERN Linear Collider) to CTF (CLIC Test Facility)

A. Thiessen (Los Alamos National Laboratory, New Mexico) (16.10.1989)
Status of Los Alamos PSR instability studies

D. Hoffmann (GSI, Darmstadt) (22.11.1989)
Beam plasma experiments with heavy ions

I. Wilkie (CERN) (06.12.1989)
Experience with workstations for accelerator control at the CERN SPS

### SPECIAL PS SEMINARS

H. Ikegami (Research Centre for Nuclear Physics, University of Osaka) (08.06.1989)

F. Dothan (Hebrew University of Jerusalem) (24.07.1989)
The brush discharge or how to get cheaply amps of kilovolt electrons

E.J.N. Wilson (CERN) (31.07 M 10.08.1989)
An introduction to accelerators (7 lectures)

M. Tigner (Cornell) (30.10.1989)
Plans for a B-factory

### SCIENCE & SOCIETY SEMINARS

R. Sené (Collège de France) (07.03.1989)
Fast neutron breeders – Super-Phénix : from physics to reality

P. Tanguy (Electricité de France) (16.03.1989)
Super-Phénix : some aspects of the safety of LMFBRs

### SPECIAL SEMINARS

L. Rosenberg (University of Chicago) (30.03.1989)
Status of the Chicago Air Shower Array

R.L. Garwin (IBM Thomas J. Watson Research Center) (05.06.1989)
The Cold Nuclear Fusion Workshop at Santa Fe

(13.10.89)
Results from the first physics run at LEP

### *JOHN ADAMS' MEMORIAL LECTURE*

R. Erickson (SLAC) (17.11.1989)
Making beams collide at the SLC

### *RADIATIVE CORRECTIONS FOR EXPERIMENTALISTS*

W. Hollik (CERN) (30.05.1989)
Introduction and renormalization

D. Bardine (JINR, Dubna) (01.06.1989)
Weak corrections in $e^+e^- \rightarrow \mu^+\mu^-$

B. Ward (Tenessee) (02.06.1989)
QED corrections in $e^+e^- \rightarrow \mu^+\mu^-$

T. Riemann (DAW, Berlin) (02.06.1989)
The $Z^0$ line shape

### SPS SEMINARS

M. Berz (SSC-CDG) (03.02.1989)
High-order perturbative description and analysis of beam dynamics using differential algebra

M. Furman (SSC-CDG) (26.05.1989)
Self-consistent beam beam model

A. Norton (CERN) (23.06.1989)
Physics from UA1 to UA2 : today and tomorrow

R. Perin & L. Oberli (CERN) (30.06.1989)
Development of high-field superconducting magnets for the LHC

A. Rosowsky (CERN) (28.09.1989)
Single shot longitudinal profile of short bunches (100 ps) : preliminary studies

H. Schönbacher (CERN) (01.12.1989)
Radiation doses to the SPS and an estimate of radiation damage

### THEORETICAL SEMINARS

A. Patel (CERN) (11.01.1989)
Hadronic matrix elements in lattice QCD

C. Verzegnassi (CERN) (18.01.1989)
Special features of Z couplings to fermions and new physics detection

D. Zeppenfeld (Madison) (25.01.1989)
Signals for new and old physics in $p\bar{p}$ collisions

J. L. Petersen (CERN) (01.02.1989)
On representations and realizations of $N = 4$ and other superconformal algebras

G. Veneziano (CERN) (08.02.1989)
Do wormholes kill the cosmological constant?

T. Sjöstrand (CERN) (15.02.1989)
An evaluation of high-$p_T$ physics Monte Carlos

S. Ferrara (CERN) (22.02.1989)
Effective Lagrangians for superstring compactifications

E. Martinec (E. Fermi Institute, Chicago & ENS, Paris) (01.03.1989)
Singularities, catastrophes and mean field theories

R. Iengo (SISSA, Trieste) (08.03.1989)
Quantum gravity corrections from superstring theory

B. Lampe (CERN) (15.03.1989)
Heavy quark jets in $p\bar{p}$ collisions

Z. Ryzak (MIT) (22.03.1989)
Spin content of the proton and the breaking of axial U(3)

W. Thirring (Vienna) (29.03.1989)
Stability of matter

L.E. Ibanez (CERN) (12.04.1989)
The zoology of four-dimensional heterotic string

R. Kleiss (CERN) (26.04.1989)
Structure function Monte Carlos

A.N. Schellekens (CERN) (03.05.1989)
Extended chiral algebras and modular invariant partition functions

J. Distler (Cornell) (17.05.1989)
Who's afraid of Joseph Liouville?

D. Lüst (24.05.1989)
Modular invariance in supersymmetric field theories

I. Shapiro (Lebedev Institute) (26.05.1989)
Some important topics in low-energy $\pi$ physics and their relation to experiments at LEAR

P. West (CERN) (31.05.1989)
N = 2 superconformal models, Landau-Ginsberg Hamiltonians and the epsilon-expansion

S.M. Roy (CERN) (07.06.1989)
The Einstein-Podolsky-Rosen paradox, Bell's inequalities and tests of the no-faster-than-light signalling hypothesis

R. Jackiw (MIT) (14.06.1989)
Quantum gravity on flatland

J.S. Hagelin (Maharishi International University, USA) (21.06.1989)
Deriving with flipped SU(5) from the string

D.V. Nanopoulos (Texas A&M University) (28.06.1989)
Quantum gravity and the collapse of the wave function

D. Gross (Princeton University) (05.07.1989)
High energy behaviour of string amplitudes : looking for the string symmetry

E. Lomon (MIT) (06.07.1989)
Experimental and theoretical developments about exotic dibaryons

J. Smith (Marseiles & Stony Brook) (12.07.1989)
QCD corrections to the reaction $p + \bar{p} \rightarrow W + \gamma + X$

H. Fritzsch (University of Munich) (19.07.1989)
QCD and the spins inside the proton

T. Matsui (IPN, Orsay) (02.08.1989)
How to compute the $J/\psi$ suppression in ultrarelativistic nucleus-nucleus collisions

E.W.N. Glover (CERN) (09.08.1989)
Windows on new physics from rare Z decays

A.V. Ramallo (CERN) (26.07.1989)
Chern-Simons and conformal field theories

L. Maiani (University of Rome 1 'La Sapienza') (23.08.1989)
The Z line-shape in $e^+e^-$ annihilation

A. de Rújula (CERN) (30.08.1989)
Charged dark matter

L. Baulieu (Paris) (06.09.1989)
On topological quantum field theories : ghost phenomenology

J.-L. Basdevant (Orsay & Paris), A. Martin (CERN) & J.-M. Richard (Grenoble) (13.09.1989)
New lower bounds on many-body Hamiltonians

F. Feruglio (University of Padua) (20.09.1989)
Gravitino interactions and non-linear realization of supersymmetry

G. Veneziano (CERN) (27.09.1989)
Anomalous currents and anomalous structure functions in QCD

J. Donoghue (CERN) (04.10.1989)
On the origin of chiral Lagrangians

I. Antoniadis (Ecole Polytechnique, Palaiseau) (11.10.1989)
An expanding Universe in string theory

R. Barbieri (Scuola normale superiore, Pisa) (25.10.1989)
Solar neutrinos : facts and speculations

G. Martinelli (Università di Roma 'La Sapienza') (01.11.1989)
Weak decays on the lattice

I. Khalatnikov (Landau Institute, Moscow) (08.11.1989)
Qualitative inflationary cosmology

D. Espriu (CERN) (15.11.1989)
Chiral Lagrangians and chiral perturbation theory : can we derive them from QCD?

B.W. Lynn (Stanford University) (22.11.1989)
Q-stars

M.M. Salomaa (Helsinki University of Technology & ETH Zurich) (29.11.1989)
Quantized vortices in superfluid $^3$He : 'superconducting cosmic strings' in the laboratory

S. Petcov (CERN & Institute for Nuclear Research and Nuclear Energy, Bulgaria) (06.12.1989)
The silver neutrino problem : an update

F. Karsch (CERN) (13.12.1989)
QCD phase transitions at finite temperature

## TIS SEMINARS

A.H. Sullivan (CERN) (20.03.1989)
Effects of small doses of radiation

O.C. Zienkiewicz (University College Swansea) (14.09.1989)
New developments in the finite element method and adaptive refinement procedures

# Training Programmes 1988/89*

## ACADEMIC TRAINING

*18 lecture series (70 lectures – 20 lecturers)*

Accurate tests of the standard electroweak model at LEP. The case for polarized beams.
A. Blondel (CERN/EP) (4 lectures)

Object-orienteted programming
O. Nierstrasz & D. Tsichritzis (Centre Universitaire d'Informatique, Geneva) (4 lectures)

Semiconductor devices for high energy intrumentation
G. Lutz (MPI, Munich & CERN–EP) (4 lectures)

Superconductivity, hot and cold
M. Cyrot (CNRS University of Grenoble) (5 lectures)

Experimental tests of quantum mechanics in quantum optics
A. Aspect (Ecole Normale Supérieure, Paris) (2 lectures)

Elementary introduction to supersymmetry
S. Ferrara (CERN/TH) (4 lectures)

Theory of RF waveguides & cavities
G. Dôme (CERN–SPS) (5 lectures)

Elementary introduction to anomalies and superstrings
L. Alvarez-Gaume (CERN–TH) (4 lectures)

Calorimetry in high energy physics
R. Wigmans (CERN–EF) (3 lectures)

Models of the brain memory
M. Mezard (Ecole Normale Supérieure, Paris) (4 lectures)

Introduction to particle physics for non particle physicists
M. Jacob (CERN–TH) (4 lectures)

Space technology
W. Kröll (DFVLR, Cologne) (2 lectures)

Image processing
M. Kunt (EPF, Lausanne) (4 lectures)

Materials for advances technologies
M. van de Voorde (Joint Research Centre, Petten) (3 lectures)

Major mathematical achievements of recent years. Fractals
R.F. Churchhouse (Department of Computing Maths, University of Wales, Cardiff) (5 lectures)

Antimatter
J.S. Bell (CERN–TH ) & H. POTH (GSI, Darmstadt) (4 lectures)

The physics with ion beams: basic concepts, present status, future plans
P. Sonderegger (CERN–EP) (4 lectures)

Accelerator physics for pedestrians
M. Hine (5 lectures)

## TECHNICAL TRAINING

*Mathematics*

Notion de dérivées et ses applications
J.-L. Périnet-Marquet (40 hrs)

Groupes et algèbres de Lie I
P. Sorba (40 hrs)

Groupes et algèbres de Lie II
P. Sorba (40 hrs)

Traitement numérique du signal
M. Martini (40 hrs)

Systèmes dynamiques
H. Epstein (40 hrs)

*Electronics*

Electronique analogique
G. Baribaud & C. Bertuzzi (88 hrs)

Systèmes d'exploitation OS 9
Ecrin Automatismes (6 sessions × 40 hrs)

Microprocesseurs 8 bits
J. Feyt & G. Mugnai (88 hrs)

Laboratoire d'électronique II
P. Cennini & R. Platteaux (88 hrs)

* The titles of the courses and lectures are given in the language used.

De la logique câblée au microprocesseur
J.-P. Bertuzzi & J.-L. Perinet-Marquet (128 hrs)

Unix
(2 sessions × 32 hrs)

*Computing*

Système d'exploitation MS-DOS
H. Michel (9 sessions × 8 hrs)

Initiation à l'informatique et aux techniques de programmation (1er module)
E. D'Amico & H. Michel (2 sessions × 20 hrs)

Initiation à l'informatique (2ème module)
E. D'Amico & H. Michel (2 sessions × 20 hrs)

Programmation en PASCAL
M. Cousin (40 hrs)

Programming in PASCAL
H. Slettenhaar (80 hrs)

On-line and real time programming on VAX/VMS
A. Lacourt & J. Bourotte (132 hrs)

Oracle I
Equinoxe (3 sessions × 24 hrs)

Oracle II
Equinoxe (2 sessions × 24 hrs)

Oracle III
Equinoxe (2 sessions × 16 hrs)

VM/CMS I (français & anglais)
A. Ballanti, D. Duret, L. Esteveny, A. Krige, J.-M. St-Viteux
(6 sessions × 30 hrs)

VM/CMS II
E. van Herwijnen (30 hrs)

Programming in C
J. Brazier (2 sessions × 40 hrs)

Programmation en langage C
M. Pauze (40 hrs)

*Mechanics*

Théorie des éléments finis
CAST (40 hrs)

Introduction à Castem
L. Borne & A. Lefrançois (40 hrs)

Ansys PC et Ansys-Full
AS&I Dataid (40 hrs)

Autocad
M. Bert (40 hrs)

*Administration – Management*

Microsoft Word
Informatique Maquet (2 sessions × 16 hrs)

Pagemaker-Windows
Informatique Maquet (2 sessions × 16 hrs)

Microsoft Excel
Informatique Maquet (3 sessions × 16 hrs)

Gestion de projets
INSA (2 sessions x 80 hrs)

*Special courses*

Blindage et mise à la terre
M. Mardiguian (32 hrs)

CAE in electronics
L. Odess (2 jours)

(707 people attended the courses and seminars)

## PERSONAL SKILLS MANAGEMENT TRAINING AND SECRETARIAL DEVELOPMENT

Techniques d'encadrement
P. Artigues (3 sessions × 40 hrs)

Animer et diriger une équipe
P. Artigues (24 hrs)

Managing people
T. Attwood (16 hrs)

Managing change
T. Attwood (16 hrs)

Conduire une réunion
V. Skorokhodoff (16 hrs)

Communiquer efficacement
F. Labro (5 sessions × 32 hrs)

Precision communication
S. Datta (3 sessions × 32 hrs)

Les relations interpersonnelles dans le cadre du travail
P. Artigues, V. Dubos (5 sessions × 24 hrs)

Interpersonal communication in the work environment
Ch. Bruce-Thompson (24 hrs)

Les relations interpersonnelles dans le cadre du travail, niveau 2
P. Artigues (24 hrs)

Interpersonnal communication in the work environment, level 2
Ch. Bruce-Thompson (24 hrs)

Méthodes et pratique de la négociation
P. Pigallet (2 sessions × 32 hrs)

Managing time
T. Attwood (16 hrs)

## CERN SUMMER STUDENT LECTURE PROGRAMME

*Introduction*

Physics at CERN – past, present and future (2 lectures)
P. Darriulat

*Courses*

Detectors, electronics and data acquisition for particle experiments (4 lectures)
C. Fabjan

Detectors, electronics and data acquisition for particle experiments (1 lecture)
W. Bell

Detectors, electronics and data acquisition for particle experiments (7 lectures)
D. Sendall

$e^+e^-$ physics (6 lectures)
J. Haissinski

An introduction to accelerators – past, present and future (6 lectures)
E. Wilson

Main concepts of particle physics – QCD, QED and standard model (6 lectures)
C. Jarlskog

Hard hadronic interactions (4 lectures)
V. Cavasinni

Soft hadronic interactions (2 lectures)
M. Albrow

Event recognition and reconstruction in large detectors
A. Norton

*Seminars*

Isolated particles trapped in minuscule accelerators (2 lectures)
G. Gabrielse

Electron positron colliders in the TeV energy range
W. Schnell

Monte Carlo and random numbers (2 lectures)
F. James

The Supernova 1987A in the Large Magellanic Cloud
W. Hillebrandt

A new force weaker than gravity ?
C. Wetterich

Status of CP violation – theory and experiment (2 lectures)
M. Calvetti

Ultrarelativistic ion beams and the quest of the quark-gluon plasma (2 lectures)
P. Sonderegger

High energy neutrino astronomy and astrophysics (2 lectures)
P. Grieder

Self-reproducing universe
A. Linde

*Other*

Student session

## APPRENTICESHIPS

*Number of apprentices*
*from September 1988 to August 1989 : 29*

| Profession | 1st year | 2nd year | 3rd year | 4th year | Total |
|---|---|---|---|---|---|
| Laborant en Physique | 4 | 2 | 3 | 4 | 13 |
| Electronicien | 4 | 4 | 4 | 4 | 16 |

The 3 'Electroniciens' apprentices and the 4 'Laborants en Physique' apprentices who completed their apprenticeships in 1989 obtained the Swiss 'Certificat Fédéral de Capacité' (CFC).

## GENERAL EDUCATION

1. **Talks**

   **Science pour tous** (R. Carreras) :
   a series of 31 talks (in French) intended primarily for people with no scientific training.

   About 100 people attended each talk.

2. **Publications**

   **Picked up for you this week** (R. Carreras) :
   A weekly sheet in English of press cuttings of general scientific interest.

   About 1400 copies per weekly edition and about 3200 of the comprehensive edition for the year

## LANGUAGE COURSES

| *Description of classes* | *English* | | | *French* | | | *German* | | |
|---|---|---|---|---|---|---|---|---|---|
| | *No of classes* | *No of hours* | *No of students* | *No of classes* | *No hours* | *No of students* | *No of classes* | *No of hours* | *No of students* |
| *Extensive course (1 – 6 h/week)* | 21 | 834 | 245 | 28 | 1437 | 347 | 3 | 124 | 35 |
| *Special extensive course (Phonetics, follow-up, etc.) (2 – 6 h/week)* | 5 | 113 | 19 | 1 | 30 | 8 | – | – | – |
| Semi-intensive course (7 – 12 h/week) | 8 | 472 | 64 | – | – | – | – | – | – |
| Total | 34 | 1419 | 328 | 29 | 1467 | 355 | 3 | 124 | 35 |

Total number of enrolments English + French + German : 718

# CERN Schools

In the series of schools on specialized topics, the CERN Accelerator School (CAS) in conjunction with the Daresbury Laboratory, UK organized a course on Synchrotron Radiation and Free Electron Lasers. This was held at Chester College, Chester from 6-13 April and attracted 89 students from no less than 17 different countries, with industry being well represented.

The lecture and seminar programme was as follows:

**Lectures**

M. Cornacchia (LBL)
Requirements and limitations on beam quality I, II

G. Dattoli (ENEA)
Introduction to Free Electron Lasers (FEL)

P. Elleaume (ESRF)
Theory of wigglers and undulators I, II

A. Hofmann (CERN)
Characteristics of synchrotron radiation

M.H. Key (RAL)
X-ray plasma laser

J. Lawson (RAL)
Particle photon interactions

G. Mühlhaupt (ESRF)
Hardware limitations on storage ring sources

J.M. Ortega (LURE)
Optical FEL cavities

M.W. Poole (Daresbury Laboratory)
Design and technology of undulators

G. Rees (RAL)
Review of elementary accelerator theory I, II, III

A. Ropert (ESRF)
High brilliance lattices and the effects of insertions I, II

A. Sessler (LBL)
High power, high efficiency FELs

V.P. Suller (Daresbury Laboratory)
Temporal structure of the Beam

**Seminars**

J. Bordas (Daresbury Laboratory)
User requirements for synchrotron radiation sources

P. Marin (LAL)
State-of-the-art synchrotron radiation source

R. Reininger (DESY)
Monochromators and associated optical equipment

E. Weihreter (BESSY)
Compact synchrotron radiation source

The 1989 CERN-JINR School of Physics took place at the Hotel 't Zuiderduin in Egmond-aan-Zee, the Netherlands, from 25 June to 8 July 1989 and was organized in collaboration with the Joint Institute for Nuclear Research, Dubna, and NIKHEF, Amsterdam. It was attended by 60 students from nine CERN Member States, including 11 students from the host country, 38 students from 6 Member States of JINR, and 6 students who came from countries which are members neither of CERN nor of JINR.

The lecture programme included :

P. Darriulat (CERN)
The CERN scientific programme

B. de Wit (University of Utrecht)
Gauge theories and applications

K. Ellis (FNAL)
QCD and collider physics

W. Hollik (University of Hamburg) and R. Kleiss (University of Leiden)
Precision tests of electro-weak theory

D. Kazakov (JINR)
Beyond the standard model

V.A. Rubakov (INR, Moscow)
Cosmology and high-energy physics

R. Rückl (University of Munich/DESY)
Heavy flavours and CP violation

Yu.G. Ryabov (IHEP, Serpukhov)
The IHEP scientific programme

A.N. Sissakian (JINR)
The JINR scientific programme

Ch. Wetterich (DESY)
A new force weaker than gravity?

The 1989 CERN School of Computing was organized in collaboration with the Institut für Hochenergiephysik der Universität Heidelberg. It took place in Bad Herrenalb, Federal Republic of Germany from 20 August to 2 September 1989 and was attended by 72 students from 44 institutes in 18 countries. Eight of the students came from countries which are not Member States of CERN.

The main lecture programme was as follows :

K.-H. Becks (Wuppertal University)
Artificial intelligence and expert systems – Applications in data acquisition

G. Bednorz (IBM Research Laboratory, Zurich)
Special lecture

M. Birrittella (Cray Research, Inc., Chippewa Falls)
Integrated circuit design for Supercomputers, GaAs vs. silicon, theory and practice

K. Bowler (Edinburgh University)
Applications of large transputer arrays

A. Bradier (CEC, Brussels)
ESPRIT – European strategic programme for research and development in information technology

F. Carminati (CERN)
Experience with vector processors in HEP

B. Carpenter (CERN)
HEPnet: where we are and where we are going

R.F. Churchhouse (University of Wales, Cardiff)
Ciphering algorithms

R.F. Churchhouse (University of Wales, Cardiff)
Fractals

R.W. Dobinson (CERN)
Future trigger and data acquisition systems

R. Frühwirth (Institut für Hochenergiephysik, Vienna)
Track and vertex fitting

W.J. Haynes (DESY, Hamburg)
Microprocessor-based data acquisition systems for HERA experiments

A.J.G. Hey (Southampton University)
Scientific computing with transputers

H.F. Hoffmann (DESY, Hamburg)
Deutsches Forschungs Netz – wide band communications and their use by German HEP institutes

E. Malandain (CERN)
Application of diagnostic expert systems in the accelerator domain

G. Müller and M. Salmony (IBM, Heidelberg)
The future of fast networks

A. Norton (CERN)
Pattern recognition and event reconstruction in large detectors

E. Picasso (CERN)
The status of the LEP machine

L.M. Robertson (CERN)
Introduction to operating systems

P.C. Treleaven (University College London)
Neural networks and neurocomputers

H.M. Wacker (Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt, Oberpfaffenhofen)
The services concept of the DLR Central Data Processing Division

H.M. Wacker (Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt, Oberpfaffenhofen)
The use of Amdahl's scalar law in determining the power of vector computers

D.O. Williams (CERN)
Computing at CERN in the nineties

P. Zanella (CERN)
30 years of computing at CERN

R.W. Dobinson (CERN), A. Hamilton (INMOS, Bristol), A.J. Jackson (Transputer Support Centre, Southampton) and D. Jeffery (CERN)
Tutorials and practical sessions on the use of transputers and OCCAM.

The third of the CAS courses on Advanced Accelerator Physics was jointly organized with the The Svedberg Laboratory, Sweden. It was held in Uppsala University from 18-29 September and was attended by 81 students of whom 9 were from the USA and 6 from countries relatively new to the field such as Brazil, Finland, Iraq and Korea.

**Lectures**

B. Autin (CERN)
Chromaticity

S. Baird (CERN)
Schottky noise on very cold beams

E. Bonderup (Aarhus University)
Laser cooling

D. Boussard (CERN)
Schottky noise and BTF diagnostics

G. Dôme (CERN)
Longitudinal motion I, II, III

B. Franzke (GSI)
Interactions with the residual gas

R.-D. Kohaupt (DESY)
Landau damping

J.-L. Laclare (ESRF)
Bunched beam coherent instabilities I, II, III

L. Lindgren (Max-lab, Univ. of Lund)
Hamiltonian mechanics I, II, III

D. Möhl (CERN)
Stochastic cooling I, II

L. Palumbo (La Sapienza, Rome)
Wake fields

A. Poncet (CERN)
Ion trapping and clearing

H. Poth (GSI)
Electron cooling I, II, III

A. Ropert (ESRF)
Dynamic aperture

F. Ruggiero (CERN)
Kinetic theory and Vlasov equation

A. Sørensen (Aarhus University)
Intra-beam scattering
Liouville theorem and emittance

E. Steffens (MPI)
Introduction to polarisation of protons

E. Wilson (CERN)
Lattice and lens design

**Seminars**

A. Brahme (Karolinska Institutet)
Radio-therapy

C. Ekstrom (The Svedberg Lab.)
Internal targets

I. Hofmann (GSI)
Intensity limits in storage rings
Crystalline ion beams

S. Kullander (Uppsala University)
Living with radiation

F. Willeke (DESY)
Interpretation of numerical tracking

# Distinguished Visitors in 1989

**January**

09 Mr Tieying LI, State Councillor, Chairman of the State Committee for Education, People's Republic of China

12 Mr Robert WALKER, House of Representatives Science, Space & Technology Committee, USA

14 Mr Stanley HAGEN, Minister, British Columbia, Canada

18 Mr V. MARINO, Head of Private Office of Mr C. MILLON, Deputy of the Ain, France

18 Prof. Sergio BARABASCHI, Vice Director-General, Italy

20 Mr Karel ZAVAZAL, Deputy Minister for Research, Czechoslovakia

23 Basque Delegation, Ministry of Industry, France

28 Mr Roald Z. SAGDEEV, Director, Cosmic Research Institute Moscow, USSR

S. Ginsburg

**February**

02 Prof. Giampolo BELLINI, Director INFN, Italy

Prof. A. AIRAGHI, Director 'Finmeccanica', Italy

07 – 14 The IHEP Delegation to CERN, Serpukhov, USSR

09 Mr Jean-Claude MARTIN, Councillor, Rhône-Alpes Region, France

13 Personnel Department of the French Senate, France

20 Heads of Industry, Federal Republic of Germany

20 Prof. R. LÜST, Director-General, European Space Agency, Paris, France

23 Dr K. ROOT, Department of Education & Science, United Kingdom

Mr Piers BAKER, Foreign & Commonwealth Office, United Kingdom

Dr N. WINGFIELD, Cabinet Office, United Kingdom

Mr Stephen BOWDEN, H.M. Treasury, United Kingdom

Mr Robin P. RITZEMA, Department of Education & Science, United Kingdom

24 Dr B. OKKERSE, Director-General for Higher Education & Scientific Research, Netherlands

His Excellency R.J. Van SCHAIK, Permanent Representative, Netherlands

Mr Van ALDERWEGEN, Director for Research Organizations, Netherlands

Mr J.W.C. ZANDVLIET, Deputy Permanent Representative, Netherlands

Mr J. BEZEMER, Dutch Delegate to the CERN Finance Committee

**March**

01 Mr Pin ZHOU, Vice-Chairman of the State Committee for Science and Technology, People's Republic of China

Mr Shuguang MENG, State Committee for Science and Technology, People's Republic of China

His Excellency, M. Fangbo CAI, Ambassador Extraordinary and Plenipotentiary, People's Republic of China

Mr Zhao Qi ZHANG, Permanent Mission of the People's Republic of China to the United Nations and other international organizations in Geneva

Mr Guanghua ZENG, Second Secretary, People's Republic of China

Mrs Ruoli HU, Embassy of the People's Republic of China

06 Mr A. TUROT, Consul General in Geneva, France

16 Mr J.R. PATERSON, Consul General in Geneva, United Kingdom

22 Mr Charles MILLON, President of the General Council, Rhône-Alpes, France

**April**

04 Mr E. DE LA GARZA, Congressman, USA

Mr W. STENHOLE, Congressman, USA

Mr P. HILLBURN, US Mission, Geneva, USA

05 Mr Fulvio CACCIA, Member for Ticino of the Swiss National Council, Switzerland

11 Mr Yves MANSILLON, Prefect of the Ain Département, France

13 Finmeccanica Group, Italy

18 Mr Noël LEBEL, Commissaire at the Commissariat for the Development of the Northern Alps, France

Mr François GILLET, France

20 Mr J. VEREKER, Deputy Secretary, Department of Education & Science, United Kingdom

Mr T. CLARK, Accountant General & Head of Finance Branch, United Kingdom

Mr R. RITZEMA, Head of International Science Division, United Kingdom

21 Mr J.-L. MATHIEU, Audit Office, France

**May**

09 Mr Claude EVIN, Minister for Solidarity, Health and Social Services, France

11 Mr F. KOURILSKY, Director-General of the CNRS, France

12 Mr O. VODOZ, Geneva Council of State, Switzerland

Mr G.D. KOLMOGOROV, Minister of Standards, USSR

19 Professor J.P. SUCENA PAIVA, Minister of State responsible for Science and Technology, Portugal

Participants at the AGM of Intercantonal Office of Pharmaceuticals Testing, the Conference of Cantonal Directors of Health and Swiss Institute of Public Health and Hospitals

25 Mr CADOT, Sub-prefect, St. Julien-en-Genevois, France

Mr V. CASSONI, Olivetti, Italy

29 Members of the Japan Atomic Industrial Forum, Japan

**June**

02 Members of the Intercantonal Conference for Scholarships, Geneva

05 Dr S. SZATMARY, Deputy Director-General, Central Research Institute for Physics, Budapest, Hungary

07 Jury of the Award for Industry, City of Geneva, Switzerland

08 Norwegian Council for Scientific and Technical Research (NTNF), Norway

08 Group of Senators of the French Republic

10 Dr ORSENIGO, President of Como Province, Italy

20 Mr De KONING, Minister for Social Affairs, Netherlands & Mrs DE KONING

30 Professor A. SAKHAROV, Academician, USSR et Mrs. E. BONNER, USSR

**July**

11 Delegation from the Japanese Development Planning Institute, Japan

13 His Excellency Messaoud AIT CHAALAL, Permanent Representative of the Democratic and Popular Republic of Algeria to the United Nations and other international organizations in Geneva

31 Prof. Rolando VALIANI, Chairman of the Board of Directors of EFIM - Manufacturing Industries, Italy

**August**

22 Mr M. PARAMELLE, Director of ALAFTA, France

25 Mr Rino FORMICA, Finance Minister, Italy

**September**

04 /05 IAPS Centre, Budapest, Hungary

07 Prof. Dave BROBECK, LBL, USA

Dr Keizo SHIMIZU, Ohbayashi Corp., Japan

08 ENI Research Committee, Italy

11/12 Secretaries of the Research and Technology Working Groups of the West German Federal Parliament

12 His Excellency and Mrs Nguyên COTHACH, Deputy Prime Minister of the Socialist Republic of Viet Nam

His Excellency Trân HOAN, Permanent Representative of the Socialist Republic of Viet Nam to the United Nations and other international organizations in Geneva

13 His Excellency Morris ABRAM, Permanent Representative of the United States of America to the United Nations and other international organizations in Geneva

His Excellency Richard KENNEDY, Ambassador-at-large, USA

15 His Excellency Gerald CLARKE, Permanent Representative of the United Kingdom to the IAEA, UNIDO & the United Nations in Vienna

Dr C. GROTE, Sec.Gen. Acad. of Sciences, Federal Republic of Germany

Dr R. LEISTE, Director Inst. for High-Energy Physics, Zeuthen, East Berlin, German Democratic Republic

19 Mr V. SYTCHEV, Minister of Standards, USSR

27/28 Mr Markku LINNA, Director-General, Department of Higher Education & Research, Helsinki, Finland

Mr Matti LÄHDEOJA, Assistant Director-General, Department of Higher Education & Research, Helsinki, Finland

28 His Excellency Jean-Pierre KEUSCH, Director, International Organizations Department, Berne, Switzerland

His Excellency Bernard de RIEDMATTEN, Permanent Representative of Switzerland to the United Nations and other international organizations in Geneva

**October**

03 Mr John CARLETON, Department of Trade & Industry, United Kingdom

Mr Ulrich MARTHALER, Department of Trade & Industry, United Kingdom

13 Mr Alain CATTA, Deputy Under Secretary of Cultural, Scientific and Technological Affairs in the Ministry for Foreign Affairs, Paris, France

and Mr GRASSIN, his deputy

Mr Jacques VERNET, Councillor of State, Geneva, Switzerland

Members of the International Committee for the Protection of Lake Geneva's Water, Switzerland

16 Mr & Mrs Fred BUCY, Former President & Chief Executive Office, Texas Instruments, USA

18 Mrs Irène SAVOY, Member of the Grand Council and members of the Development Committee, Grand Council, Department of Public Works, Geneva, Switzerland

21 Mr Tadeusz SYRYJCZYK, Minister for Industry, Poland

**November**

03 Mr Jozef LENÁRT, Secretary of the Central Committee of the Communist Party of Czechoslavakia, Czechoslovakia

06 H.R.H. Prince of the Asturias, Don Felipe of Bourbon and Greece

Mr Pierre CHEVALIER, Secretary of State for Political Science, Belgium

09 Research Committee, Italy

13 Official Inauguration of LEP

14 Mr V.F. KONOVALOV, Soviet Minister for Nuclear Energy & Industry, USSR

16 Members of the Swiss Society of Machine Builders (VSM), Zurich, Suisse

17 Mr & Mrs YE YI and party, Commercial Counsellor in Berne for the People's Republic of China

18 Dr Heinrich ROHRER, Nobel Laureate

23 Mr Guy-Olivier SEGOND and officials from the Municipal Department of Social Affairs, City of Geneva, Switzerland

27 Dr Van BILJON, Commercial Attaché & Mr T.G. VISSER, Minister, South Africa

**December**

01 His Excellency Richard BURT, Ambassador and, USA

His Excellency Yuri NAZARKIN, Ambassador

The American & Soviet Delegations to the Nuclear & Space Talks in Geneva

18 Prof. Hans DEHMELT, 1989 Nobel Laureate in Physics, University of Washington, Seattle, USA

19 Mr Coby CHASE, Texas Nat. Research Laboratory, USA

*Corrigendum*

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**Volume II**

On page 187 of Volume II of the Annual Report, please read under 6 November :



H.R.H. Don Felipe of Bourbon, Prince of the Asturias