Report of Activities in the Divisions and Departments

Annual Report 1985 - Volume II

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

The CERN Annual Report appears in a new format this year with the aims of increasing the readability of some of the most important information from the year's activity at the Laboratory and, at the same time, of reducing the production costs.

Volume 1 of the Report, entitled 'CERN 1985', selects highlights from the year and presents them in a non-technical style with ample illustration. This volume is being produced both in English and in French in the same quantities as in previous years since it is anticipated that this is the volume most readers will wish to see.

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

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

Report of Activities in the Divisions and Departments

Annual Report 1985 – Volume II

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

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

Contents

Theoretical Physics Division

The November telephone list of the CERN Theory division had 123 names. The August list had 149. In addition there were as always many visitors not staying long enough (at least one month) to be so listed. There are 21 Staff physicists, and 29 Fellows. In 1985, 262 TH preprints were registered. These were spread over the whole range of elementary particle theory, and even a little further. They are listed at the end of this report. Only a few main themes can be mentioned in what follows.

Unified theories

Theoretical physicists are increasingly optimistic about the possible production of a theory unifying the strong, electromagnetic, weak, and gravitational interactions. In this respect, at CERN-TH as elsewhere, 1985 was the year of the 'superstring'.

The superstring theory brings together three main themes. The first two, supergravity and Kaluza-Klein theory, were already much pursued at CERN. Supergravity is an extension of Einstein's general relativity based on the supersymmetric unification of bosons with fermions. In Kaluza-Klein theory, originally put forward in the 1920's but revived in recent years, spacetime has more than four dimensions. The extra dimensions are curled up to be be very compact (on a scale of some 10^{-33} cm, corresponding to an energy of 10^{19} GeV). What we see as internal symmetries (charge conservation, colour symmetry, etc.) are in this picture really spacetime symmetries in the extra dimensions. The third essential element of the superstring theories is a revival from the 1960's, the string itself. The idea then, to explain the Veneziano spectrum of hadrons, was that hadrons were excitations of a basic string-like object which rotated and vibrated. Many of the important developments in this connection came from CERN. The idea now is that it is not hadrons, but their constituent quarks, and leptons, intermediate bosons, etc., which are such excitations of strings. This possibility was considered already in 1974. But the present wave of activity was triggered by the discovery last year that in certain superstring theories in 10 dimensions apparently miraculous cancellation of certain anomalies occurred, so that such schemes might yield finite theories of all interactions including gravity.

A crucial property of the most popular superstring theories (the 'heterotic') is that they exhibit huge internal gauge symmetries. The gauge group is much larger than expected on the basis of standard Kaluza-Klein considerations. A reformulation of $d = 10$ superstrings in terms of an even larger space (a $d = 506$ group manifold) has been proposed at CERN. It makes the relation to the Kaluza-Klein idea more transparent, and may facilitate calculations. In another development at CERN four out of the five known types of consistent $d = 10$ superstring theories were found to be contained in a single theory, that of bosonic closed strings in $d = 26$, corresponding to different vacuum states. (In these high dimension bosonic string theories, the fermions emerge as solitons!) The question of the origin of all these local symmetries has also been looked at from the point of view of general coordinate transformations in phase space. And a completely covariant formulation of both open and closed string and superstring theories has been pioneered. This may open a way towards a complete proof of finiteness, and a solution to the vacuum degeneracy problem.

Other aspects of supergravity and Kaluza-Klein theory which have been studied include: hidden symmetries in $d = 11$, the structure of extended supergravity theories in four dimensions, supergravity and new compactifications to $d = 4$, and the consistency of the Kaluza-Klein ansatz.

The fundamental superstring structure is immediately relevant only on a scale of some 10^{19} GeV, far removed from laboratory experience. Nevertheless some progress has been made towards extracting phenomenological implications. The first step is to compactify the six surplus spacetime dimensions. Initially this was done via an intermediate 10-dimensional field theory. But doubt has arisen about the consistency of this approach. More recently it has proved possible to compactify directly to a 4-dimensional field theory which is a variant of the no-scale supergravity models introduced at CERN previously. The problem of supersymmetry breaking in the model has been studied. It has been shown that gaugino condensation would break supersymmetry and generate a gravitino mass, and sufficient conditions for gaugino condensation have been found. Progress has been made in showing how this supersymmetry breaking scheme can lead to masses for the supersymmetric partners of the known particles. The problem of gauge symmetry breaking has also been studied, and various possibilities enumerated. They all involve extension of the low-energy standard model gauge group with at least one new neutral gauge boson, i.e. a new heavier Z^0. The phenomenology of some of these possibilities has been pursued in more detail, in particular the version with just one extra neutral gauge boson. The generation of low mass scales in this model through some variant of a no-scale model has been considered, and its possible effects at the CERN $p\bar{p}$ collider, at LEP, and in electron and neutrino scattering.

Cosmology

There continues a strong interaction between elementary particle physics and cosmology. In particular, scenarios for the very hot early universe bring into play the high energy features of unified theories, providing a critical testing ground for such theories.

In CERN-TH more work has been done on inflation in supergravity models, and on quantum cosmology in higher dimensional field theories (Kaluza–Klein). Astrophysical constraints on supersymmetric theories have been developed, notably on unstable gravitinos. Work on superstring cosmology has started, with studies of the evolution with temperature of the effective potential in four dimensions, and an exploration of the constraints on models from primordial nucleosynthesis limits on light particles akin to neutrinos. Contacts with astrophysicists interested in similar problems are being developed, and several are now visitors in the division. Division members have taken a leading role in the ESO–CERN symposia, the second of which will be held in 1986. And the division has joined with ESO in planning a summer school on 'astroparticle physics' for 1987.

Collider physics

A vigourous interaction between theorists and experimenters has led to new progress in the interpretation of the bulk of the collider data in terms of the standard model,with a refined treatment of W and Z production. (In fact, over the last five years work in CERN-TH correctly predicted all the effects so far observed, in particular with jets, which are very prominent at collider energies: yields, branching, fragmentation, and the production of mini-jets now clearly seen by UA1). This, and new data, has ended hopes of last year that some of the events found in earlier runs might be clear-cut manifestations of new physics beyond the standard model, and in particular of supersymmetry. Nevertheless, superstring theories suggest the existence of many new particles with masses not much larger than those of W and Z, and theorists are working out some of their experimental signatures, at LEP and at LHC's.

LEP physics

Theorists have been active in the thorough review of LEP physics made during the year. In addition to updating traditional aspects of LEP physics, such as precision measurements at the Z, QCD tests, high energy running with LEP phase II, and searches for new particles, emphasis has been placed on physics at the toponium resonance. In particular, this is a good place to look for Higgs bosons, and perhaps supersymmetric particles.

Quantum field theory

In quantum field theory, new results have been obtained on anomalies, on Nicolai mapping, on instantons, and on stochastic quantization of chiral theories.

Lattice gauge theory

Substantial effort has again been devoted to the direct numerical simulation of gauge theories.

It has been found that with the inclusion of Kogut–Susskind fermions, in quenched approximation, it is more than ever important to use sufficiently large lattices. A linear extension of at least 10 sites is required for reliable calculation. The hadron mass spectrum has been studied on a lattice with 16 sites in each space direction, and 32 in the temporal. The results are in satisfactory agreement with experiment, and the value of the scale parameter, from the calculated mass of the ϱ meson, is consistent with independent determinations based on the calculation of the string tension.

Further exploratory studies of the masses of glueball states have been made. The influence of fermions on the deconfinement transition in SU(2) lattice gauge theory has been examined.

The susceptibility of the 3-dimensional Ising system on a 24^3 lattice was measured. The result is in disagreement with one obtained with a special purpose machine. It has been pointed out that the discrepancy could originate in the difference of algorithms for generating pseudo random numbers.

The Monte Carlo renormalization group (the numerical approach to the real space renormalization group) has been applied to the question of triviality or nontriviality of the SU(2) Higgs model. The preliminary results show no evidence for a nontrivial continuum theory.

Remarkable progress has been made in connection with the specialized parallel computer to be realized in collaboration with a group of member states. A prototype of one of the CPU modules has been built, and is under test. This has been done in the framework of a joint TH–DD venture.

A few years ago it was realised that some coordination was needed between the many groups engaged in lattice gauge theory calculations, so that computing facilities could be efficiently used. TH division initiated a yearly meeting of experts, held at CERN in 83 and 84. This is now continued by member state universities, in 1985 at Wuppertal.

Composite systems

Hadrons are held to be composites of quarks, and it is speculated that quarks, leptons, and gauge bosons, might themselves be composite. So the dynamics of binding is of continuing importance.

A quark model analysis of low energy K^+N and $\bar{N}N$ interactions has been made, in anticipation of experiments at LEAR. In the first case quark-gluon exchange determines quantitatively the S- and P-wave phase shifts. In the second case quark rearrangement contributes a large part of the short range potential.

A colourdielectric effective field theory has been developed to simulate gauge gluon effects. It gives quark confinement in the free nucleon, and gives nuclear binding by spreading of quark wavefunctions in nuclei. This spreading has been calculated by a Monte Carlo percolation study. The model leads to an understanding of the EMC effect, and of the nuclear size dependence of deep inelastic structure functions.

The importance of measurement at LEAR of the charmonium and bottomium states not accessible to e^-e^+ machines has been stressed. Regge trajectories of mesons and baryons have been successfully analysed in potential models with relativistic kinematics.

Signatures for the formation of droplets of quark–gluon plasma in heavy ion collisions have been further investigated, with emphasis on deflagration effects. Over the past three years TH division has had an important role in connection with the oxygen beam programme soon to start at CERN. It may offer a first look at the quark–gluon plasma which should form in high energy heavy ion collisions.

Other

Among experimental results which have been analysed are the high energy atmospheric and underground signals from Cygnus X3. They appear incomprehensible in terms of presently known or conjectured particles or interactions.

Tentative schemes for detection of hypothetical 'cosmions' (which might cool the sun's interior and reduce its high energy neutrino flux) have been devised. In collaboration with an Isolde group, an experiment has been devised and performed to search for Simpson's m = 17 keV companion to the electron neutrino. The experiment involves the electron capture decay of ^{125}I and is complementary to the ^{35}S beta-decay experiments performed elsewhere, and gives again a negative result.

The main roles of TH division, as always, were original research and collaboration with the experimenters. Only a fraction of the year's research production was mentioned above. The collaboration with experimenters seemed to go very well. The Division also has an educative role. Many members gave lecture courses, in the Division, in the CERN Academic Training programme, in summer schools and winter schools and workshops. Many individual seminars were delivered, in Europe and abroad. And the Division contributed as usual to the management of CERN, participating in the work of the various committees.

'The Theory Division is of undoubted high quality and provides important support to the experimental programme at the laboratory. In addition it has also become a focus for European theoretical particle physics. All the British theoreticians we have met have stressed its value, and many have spent one or more sabbatical periods there.' (Kendrew Report).

Experimental Physics Division

$\bar{p}p$ Collider Programme

UA1

The Aachen - Amsterdam - Annecy - Birmingham - CERN - Harvard - Helsinki - Kiel - London (QMC) - Padova - Paris (CdF) - Riverside - Rome - Rutherford - Saclay - Vienna - Wisconsin (UA1) Collaboration have presented new results based on data taken in 1984 at 630 GeV (integrated luminosity 263 nb^{-1}) combined with earlier data (136 nb^{-1}) from 1982 and 1983 at 546 GeV. They have also results from the 1985 ramped collider run between 200 and 900 GeV.

Current values of the W and Z masses, based on 172 $W^{\pm} \rightarrow e^{\pm} \nu_e$ and 16 $Z^0 \rightarrow e^+ e^-$ decays, are shown in fig. 1. They are in excellent agreement with current expectations for the standard model. The improved determination of the parameter $\varrho = m_w^2/(m_z \cos \theta_w)^2$ gives

$$\varrho = 1.026 \pm 0.037 \text{ (stat)} \pm 0.019 \text{ (syst)}.$$

The standard electroweak model in its simplest form predicts $\varrho = 1$. The W decay angular distribution (fig. 2) confirms the expected parity violating asymmetry and the spin-1 assignement of the W. The W and Z production cross sections are in agreement with QCD expectations, and their ratio allows a limit to be set on the number of light neutrino species, $N_\nu \leqslant 10$ at 90% confidence level.

The decay $W \rightarrow \tau\nu_\tau$ has been observed in hadronic events (fig. 3). Limits are placed on the decay of the W into supersymmetric particles, $W \rightarrow \tilde{e}\,\tilde{\nu}$, leading to $m_{\tilde{e}} > 32$ GeV at 90% confidence level.

The inclusive jet cross sections at 546 and 630 GeV are in good agreement with QCD and show the expected scaling behaviour between the two energies. The angular distribution for two-jet events exhibits the Rutherford scattering shape, $\sin^{-4} \theta/2$, with important deviations arising from the variation of the strong coupling constant α_s with four-momentum transfer squared. A determination of α_s at $Q^2 \sim 4000$ GeV^2 has been made from the ratio of the rates of 3-jet and 2-jet events yielding the value

$$\alpha_s = 0.16 \pm 0.02 \pm 0.03.$$

In addition to the Z^0 production in which 9 $\mu^+\mu^-$ events have now been observed, dimuons are an important source of information about heavy flavours. A particularly interesting topic is $B\bar{B}$ mixing, a property of neutral B-mesons expected to occur particularly for B_s^0 mesons which consist of beauty (b) and strange (s) quarks. Transitions between B and $\bar{B}$ lead to events with like-sign dimuons which can otherwise occur as a result of flavour-cascade decays. After removing Υ and Drell-Yan events, the like-sign/unlike sign ratio is 0.46 ± 0.10 to be compared to an expected ratio without mixing of 0.28 and with mixing of 0.51. The potential ability to measure this ratio more accurately has provoked a large amount of theoretical interest.

Hadronic events with significant missing transverse energy continue to attract large interest because of their potential to reveal new physics. UA1 has observed $\sim$ 30 of such 'monojet' events. While the existence of such events is not in question, their interpretation has become a centre of intense activity, specifically on whether it is possible to account for them in terms of the standard model.

The preparation of the UA1 upgrade for the time when the Antiproton Collector (ACOL) operation starts, are described in the EF Division section.

UA2

The work on the Bern -CERN-Copenhagen -Heidelberg-Orsay (LAL) -Pavia-Perugia-Pisa-Saclay (UA2) Collaboration has been concentrating on three main fronts: (a) the analysis of data collected during 1984 (integrated luminosity of ~ 310 nb $^{-1}$); (b) the preparation and operation of the UA2 detector during the 1985 data taking period (450 nb $^{-1}$); (c) the design and construction of the new detector parts to be used in connection with ACOL operation, described in the EF section.

On the first front a number of important results have been obtained: production and decay properties of the weak bosons $W^{\pm}$ and Z have been studied with increased accuracy and generally found in excellent agreement with the predictions of the standard model, as shown in fig. 4 for the W and Z masses. The hints for possible manifestations of non-standard phenomena which were noted in 1984 have received no confirmation and are most likely explainable in terms of events containing a very high transverse momentum W or Z boson.

The cross sections for jet production and for direct photon production have been measured and their scaling properties have been studied. The results are in good agreement with QCD predictions. A detailed study of events containing three jets in the final state has been performed and has been used to measure the strong coupling constant α_s (fig. 5).

UA4

The Amsterdam-CERN -Genoa-Naples-Pisa (UA4) Collaboration had a special dedicated run to measure the elastic $\bar{p}p$ scattering in the Coulomb interference region. The data are now being analysed. The aim is to obtain a measurement of the ratio of the real to the imaginary part of the forward elastic scattering amplitude with an error of 5-10%.

Progress was also made in the analysis of the data collected in the previous runs. Final results on elastic scattering up to $-t = 1.5$ GeV^2 were obtained. The analysis of these results clearly show an increase with energy of the effective size of the proton.

UA5

1985 has seen the first, very successful, operation of the pulsed $\bar{p}p$ collider, in which the beams were cycled between 100 GeV and 450 GeV, so giving interactions at a centre-of-mass energy up to 900 GeV, higher than any previous accelerator. The Bonn-Brussels (FU)-Cambridge-CERN-Stockholm (UA5) Collaboration have taken data at $\sqrt{s} = 900$ GeV, 200 GeV and intermediate energies and have presented the first physics results.

The value for the cross section at 900 GeV is found to be $\sigma_{inel} = 50.9 \pm 1.3 \pm 1.3$ mb.

UA5 has previously observed a strong violation of KNO scaling in the charged particle multiplicity distribution of non single-diffractive events at 540 GeV. The new data at 900 GeV confirm this result. The multiplicity distributions can be fitted by a negative binomial distribution, $p_n = \binom{n+K-1}{n}(\langle n\rangle/K)^n/(1+\langle n\rangle/K)^{n+k}$ over a wide range of energies (11.5 GeV $< \sqrt{s} <$ 900 GeV). The parameters of the distribution, $\langle n\rangle$ is the mean multiplicity, K determines the shape, both vary smoothly with energy. Thus fig. 6 shows that K^{-1} varies linearly with log s over the energy range, and there is no approach to scaling at high energies (which would be indicated by $K \rightarrow$ constant).

One of the main aims of the UA5 experiment is to search for the 'Centauro' events seen in cosmic ray experiments. These have a large number of charged particles but no photons. A preliminary study has shown that such phenomena, if present at all, are at the level of less than 0.5% of normal events at $\sqrt{s} = 900$ GeV.

UA6

The CERN - Lausanne - Michigan - Rockefeller - Lund (UA6) Collaboration aims to a comparison of the elementary processes involved in $\bar{p}p$ and pp collisions. The experiment is designed to look for the interaction of stored p or stored $\bar{p}$ with the protons of an internal jet target. In particular it will look for the production of single photons or electron-positron pairs which should both be enhanced in the $\bar{p}p$ interaction because of quark–anti-quark annihilation. The experiment has run for the whole 1985 collider period. Data have been collected on $\bar{p}p$ interactions for an integrated luminosity of 1000 nb^{-1} which is 30 times more than the whole integrated luminosity accumulated at the ISR in the $\bar{p}p$ mode. pp collisions will be measured in 1986. A direct comparison between the two reactions will then be possible.

UA8

A UCLA (UA8) Collaboration aims to study $\bar{p}p$ events which have a quasi-elastic recoil proton or antiproton. After a test period, a short physics run was made in 1985 yielding 40 nb^{-1} of data which are now being analysed.

ISR Experiments

The analysis of data collected at the ISR before its closing down in 1984 has continued.

The Ames-Bologna-CERN-Dortmund-Heidelberg-LBL-Lund-Warsaw (R418) Collaboration have presented results from the light ions runs. The very soft nucleus-nucleus interactions, where nuclei fragment into their nucleon constituents or nuclei with smaller mass number without accompanying created particles, have been interpreted in terms of quasi-elastic nucleon–nucleon scattering. The study of high p_T nucleus-nucleus interactions has instead provided new data on the atomic mass dependence of the final state particle composition and more evidence for a contribution of valence quarks to the high p_T trigger hadron.

The Ames-Bologna-CERN-Dortmund-Heidelberg-Warsaw (R419) Collaboration using the Split Field Magnet (SFM) have continued their study of deep inelastic events and comparison with hard scattering models. In particular further evidence has been obtained that the yield of high p_T protons observed, results from the hard scattering of diquarks which then fragment into protons.

The CERN-Clermont Ferrand-UCLA-Saclay (R608) Collaboration have presented evidence for Pomeron single-quark interactions in diffractive processes. Other results concern (a) the comparison of $\bar{p}p$ and pp elastic scattering; (b) a test of CP invariance in Λ° decay; (c) the longitudinal event structure in proton diffraction.

The Brookhaven-Cambridge-CERN-Copenhagen (NBI)-London (QMC)-Lund-Pennsylvania-Pittsburgh-Rutherford-Tel-Aviv (R807) Collaboration and the Athens-Bonn-Brookhaven-CERN-Moscow (LPI + EPI)-Novosibirsk-Pisa (R808) Collaboration using the Axial Field Spectrometer (AFS) have determined the gluon structure function in the proton from a study of events with a direct photon and a jet in the final state. Preliminary results indicate that the gluon structure function is steeper than generally assumed. This observation is in qualitative agreement with a previous result from the same collaboration based on a measurement of the charge correlations and showing that quark jets dominate more than expected over gluon jets.

In addition a study of 3-jet events allowed a determination of the strong coupling, α_s. They in fact demonstrated that gluon bremsstrahlung is the source of these events and their value for the strong coupling is $\alpha_s = 0.19 \pm 0.03 \pm 0.03$. A comparison with results from UA1 and UA2 a nice agreement with QCD.

The same Collaborations have presented a measurement with much improved statistics of the e^+/π^+ ratio at low p_T showing that this ratio increases from 10^{-4} to 10^{-3} when p_T decreases to 100 MeV/c. This effect is not yet understood in terms of the presently used model of conventional sources.

SPS Programme

Muon beam experiments

The BCDMS Collaboration, Bologna-CERN-Dubna-Munich-Saclay (NA4) Collaboration have studied 'wrong-sign' dimuon events in deep inelastic muon-carbon scattering. These are rare events with three muons in the final state, two of which have a sign opposite to the one of the incoming beam. The observed spectrum of such events is fully compatible with background. This measurement allows to set an improved upper limit of 1.2% on the D^0–$\bar{D}^0$ transition probability and of 9 pbarn for the $B\bar{B}$ pair production cross section.

Final results have been presented from a study of nuclear effects, e.g. the EMC effect, in deep inelastic muon scattering with deuterium (A = 2) nitrogen (A = 14) and iron (A = 56) targets. No Q^2 dependence of the structure function ratio $F_2{}^A(x, Q^2)/(F_2{}^D{}_2(x, Q^2)$ is observed over the kinematic range of this measurement. The dependence of this ratio on the Bjorken x variable is shown in fig. 7. The iron data are in agreement with earlier EMC results. For the N_2 data which cover a wider kinematic range than the iron data, no significant effect is observed for small $x < 0.3$, in agreement with the low Q^2 SLAC measurements.

The European Muon Collaboration (EMC), Aachen - Annecy - CERN - Freiburg - Hamburg - Heidelberg - Kiel - Lancaster - Liverpool - Marseilles - Mons - Oxford - Sheffield - Turin - Uppsala - Warsaw - Wuppertal - Yale have been looking at those deep inelastic muon scattering processes where a virtual photon knocks a ϱ^0 meson out of the target protons $\gamma^* p \rightarrow \varrho^0 p$. In the framework the Vector Dominance Model (VDM) one would expect the decay angular distribution of the produced ϱ^0 to have a $\sin^2 \theta$ behaviour. Fig. 8 shows the observed angular distribution whose $\cos^2 \theta$ behaviour is totally different from the VDM prediction. Furthermore one finds that the four momentum transfer between the virtual photon and the proton has a shallow distribution typical of a hard scattering process. These observations, indicate that at high Q^2, ϱ^0's are produced by hard photon scattering off the point like constituents of the proton and that the soft hadron like properties of the photon disappear. The Collaboration has also presented results on: (a) the proton structure function F_2 which is found to be approximately independent on Q^2 at fixed x, as expected if the nucleon is made up of point like charges; small deviation from such a behaviour have been understood in the framework of QCD. (b) Hadron multiplicities as a function of Q^2. (c) Charm production. (d) Azimuthal distribution of the produced hadrons. (e) J/ψ production. The cross sections for the J/ψ have been measured in hydrogen and deuterium targets and compared with those measured in iron. The comparison indicates that the J/ψ cross section is larger for bound nucleons (iron) than for free nucleons.

Neutrino experiments

The CDHS Collaboration, CERN - Dortmund - Heidelberg - Saclay - Warsaw, has continued the analysis of the data from the WA1 and WA1/2 experiments. The efforts concentrated on four different areas where significantly better results could be achieved than were available before: (a) Samples of 367 $\mu^-\mu^-$ and 73 $\mu^+\mu^+$ like-sign dimuon events have been analysed. The magnitude of a prompt like-sign signal has been controversial in the past. The new analysis yields a signal of prompt like-sign dimuon events originating from $\nu_\mu(\bar{\nu}_\mu)$ nucleon scattering; its significance is of 2.8 (2.4) standard deviations. (b) The total cross section of $\nu_\mu(\bar{\nu})$ nucleon scattering has been remeasured. The new results for the cross section slopes are

$$\sigma^\nu/E = 0.702 \pm 0.002\,(\text{stat.}) \pm 0.017\,(\text{syst.}) \cdot 10^{-38}\ \text{cm}^2/\text{GeV. nucleon}$$

$$\sigma^{\bar{\nu}}/E = 0.334 \pm 0.004\,(\text{stat.}) \pm 0.008\,(\text{syst.}) \cdot 10^{-38}\ \text{cm}^2\,/\text{GeV. nucleon}$$

consistent with a linear rise of ν_μ and $\bar{\nu}_\nu$ total cross sections with energy (fig. 9). (c) A large sample of events obtained in Wide-Band neutrino beams has been analyzed to obtain more precise structure functions of the nucleon. The analysis of the Q^2 dependence of the structure functions in terms of QCD is in progress. (d) The analysis of the dedicated run to measure precisely $\sin^2 \theta_W$ from the ratio of Neutral Current (NC) to Charged Current (CC) cross sections has been largely completed. From $R_\nu = (NC/CC)_\nu = 0.3059 \pm 0.0025$ (stat.) ± 0.0020 (syst.) for hadronic energy greater than 10 GeV, a radiatively corrected value $\sin^2 \theta_W = 0.227 \pm 0.005$ (exp.) ± 0.005 (theor.) has been obtained.

The CHARM Collaboration, CERN - Hamburg - Amsterdam - Rome - Moscow (WA18) have measured the cross section of coherent π^0 production by muon-neutrino and antineutrino neutral current interactions on nuclei. In neutral current reactions, neutrinos can radiate in the forward direction a virtual Z^0, which can transform inside the nucleus into a neutral pion. The existence of this process proves that the Z^0 is transmitting an axial vector force and not a scalar force. Comparing the cross section with that measured for the corresponding charged current reaction recently observed in BEBC one can determine a linear relation of the axial vector coupling constants of u and d quarks and hence their relative sign. The result $|u_a - d_a| = 1.10 \pm 0.23$ agrees with the prediction $|u_a - d_a| = 1$ of the Electroweak Theory.

The same Collaboration have also obtained a precision measurement of the electroweak mixing angle from semileptonic neutrino scattering. From a measurement of the ratio of semileptonic deep inelastic cross sections by neutral and charged current reactions a value of

$$\sin^2 \theta_w = 0.236 \pm 0.005 \text{ (exp)} \pm 0.005 \text{ (theor.)}$$

has been derived. The following values of boson masses are predicted (experimental errors only)

$$M_W = 83.3 \pm 1.0 \text{ GeV}$$
$$M_Z = 94.0 \pm 0.8 \text{ GeV.}$$

Direct measurements of these boson masses are in excellent agreement with these predictions.

The CHARM II Collaboration, Brussels - CERN - Hamburg - Louvain - Moscow (ITEP) - Munich (Univ.) - Naples - Rome (WA79) are preparing a new detector to repeat these measurements with higher precision. Development and prototype work is finished and the construction of the detector is well under way.

CP violation

The NA31 experiment carried out by the CERN - Dortmund - Edinburgh - Orsay - Pisa - Siegen Collaboration aims to contribute to the understanding of CP violation in neutral kaon decays. It is planned to compare with precision the rates of CP violating decays of the long lived kaon into two pions with the corresponding CP allowed decay rate of the short lived kaon, for both the decays into neutral and into charged pions. To this end a new beam line and detector has been constructed in the North Area for neutral kaons of typically 100 GeV in energy. The set-up of the experiment is now complete, and this year's run was used for extensive tuning of various components including the beam, detector elements and the trigger. During a final but short period, the experiment performed satisfactorily with more than 20 000 $K_L \rightarrow 2\pi^0$ and 50 000 $K_L \rightarrow \pi^+\pi^-$ decays logged onto tape. This is substantially more than ever achieved before, but still only a small fraction of the total statistics expected. The data are being analysed. An example of a mass spectrum showing $K_S \rightarrow 2\pi^0$ decays reconstructed from the four observed photons is given in figs 10(a) and 10(b).

Search for new particles

Numerous scalar particles have been predicted which can be characterized as the collective modes which accompany spontaneous breakdown of symmetries. Among them is the Higgs sector responsible for spontaneous symmetry breaking of the electroweak force and the axion suggested to circumvent parity and CP violation in Quantum-Chromo-Dynamics. Such scalar particles would decay predominantly into $\gamma\gamma$, e^+e^- or $\mu^+\mu^-$ states. A sensitive search in a beam dump experiment by the CHARM Collaboration did not reveal any candidate events. Earlier claims for detection of axions have also been shown to be invalid.

The CHARM Collaboration have also made a search for decays of heavy neutrinos in the mass range 0.5–2.8 GeV. Neutrinos may have non-zero mass. If mass eigenstates do exist they do not necessarily coincide with the weak flavour eigenstates but rather with a linear superposition of them. Depending on the magnitude of the mass differences neutrino oscillation and neutrino decays may be induced. A search for various decay modes has not revealed candidate events. Limits on interfamily mixing of neutrinos have been extended to $|U_{ei}|^2$, $|U_{\mu i}|^2 < 10^{-7}$ for $m_{\nu i} \sim 1.5$ GeV and to $|U_{\mu i}| < 3.10^{-4}$ for $m_{\nu i} \sim 2.5$ GeV.

The Athens - Bari - Birmingham - CERN - Paris (VI + CdF) (WA77) Collaboration are studying π^- N interactions at 300 GeV using the Ω' spectrometer equipped with a multiparticle high-p_T trigger. They search for high p_T prompt production of resonances amongst which gluonium states could be expected. Such processes have not been previously isolated experimentally. They are predicted to proceed via QCD higher twist mechanisms. The Collaboration have reported evidence for such mechanisms in the high p_T production of the ϱ^0 meson. A detailed comparison with QCD predictions is in progress.

Nuclear beam experiments

A programme of experiments using high energy nuclear beams will start at CERN in 1986. For this purpose the GSI in Darmstadt and the Nuclear Science Division at LBL Berkeley are providing an ion source for ^{16}0, ^{32}S and perhaps ^{40}Ca projectiles for injection into the CERN PS-SPS accelerator. The source has been assembled and successfully tested at GSI. The energy range of the external SPS beams will be 60 to 225 GeV per projectile nucleon. The preparation of several dedicated experiments is well under way.

LEAR Experiments

The LEAR $\bar{p}$ storage ring has made it possible for the first time to perform very large statistics experiments with high intensity beams of excellent quality: very good resolution over a large momentum range, pencil like dimensions and without any contamination whatsoever. To derive the best possible results from these ideal conditions it is necessary, however, that both the performances of the detectors and of the analysis programs used to interpret the data be properly understood. Many of the experiments are still deeply involved in this preparatory phase; for these reasons final results are coming out very slowly at the moment.

In the following, published or about to be published results will be given first. They will be followed by short summaries of the progress being made in some experiments.

$\bar{p}$-Nucleus interactions

Experiment PS184 (Grenoble - CEN, Saclay - CEN, Strasbourg - CRN, Tel - Aviv University Collaboration).

The above collaboration has measured angular distributions for the elastic scattering of antiprotons on ^{12}C, ^{16}0, ^{18}O and ^{40}Ca nuclei at incident energies of 47 and 180 MeV. Different models have been used to interpret the data. Simple black-body calculations fail to reproduce the results mainly because they give diffraction minima deeper than those observed. More elaborate analyses within the framework of the optical model have also been made. Extensive searches on the relative sensitivities to the different potential parameters have been carried out. Optical potentials having the geometry of the charge distribution failed to reproduce the data; the finite range of the interaction had to be taken into account. The corresponding optical potentials have shallow real parts, 5 MeV $\lesssim V_0 \lesssim$ 105 MeV while the imaginary parts are at least twice as deep.

Target mass and energy dependence of the strong absorption radius and reaction cross section confirm that the antiproton penetrates deeper inside the target nucleus as the incident energy increases.

Experiment PS173 (Max-Plank Institute-Heidelberg and Heidelberg University Collaboration) has measured the differential cross sections for $\bar{p}p$ elastic scattering in the full angular range at incident momenta 181, 219, 239, 261, 287, 505 and 590 MeV/c.

From a fit to these cross sections with an optical potential with a real and imaginary part of the Wood-Saxon type, values for the $\bar{p}p$ total, elastic and inelastic cross sections have been obtained for momenta below 300 MeV/c. The elastic and inelastic cross sections and their S-wave components are shown in fig. 15a. The S-wave contributions account for about 70% of the elastic cross section and

40% of the inelastic cross section. For comparison the partial-wave cross sections that would correspond to a black disk are shown by the dotted curves in fig. 15b.

In the inelastic cross section the inelastic S-wave component is close to the unitary limit while the P-wave component is less than 60% of the unitary limit. In the elastic cross section the S-wave component is pabout 60% of the black-disk value and the P-wave even smaller. D-wave contribution to the cross section is estimated to be less than 10%.

This collaboration has also measured the differential cross section over the complete angular range of the charge exchange reaction $\bar{p}p \rightarrow \bar{n}n$ at incident momenta of 183, 287, 505 and 590 MeV/c. The results were compared to predictions of different models but none gave satisfactory fits.

The integrated cross section (shown in fig. 16) as a function of the incident momentum agrees well above 260 MeV/c with an older Brookhaven experiment but poorly below that value, where the LEAR cross section falls faster.

Spin effects in $\bar{p}$ interactions

Experiment PS172 (Amsterdam NIKHEF-Geneva University-Queen Mary College-Surrey University and Trieste University Collaboration).

Historically, polarised proton beams were first produced by scattering from carbon and hydrogen at small angles. Experiment PS172 has attempted to repeat this trick with anti-protons of 550 MeV/c scattered through angles up to 20°. Results were disappointing. Polarisations were measured in a double scattering measurement where the asymmetry is equal to the product of polarisations P_1 and P_2 at the first and second scatters. Observed asymmetries were $\leqslant$ 1%, corresponding to polarisations $\leqslant$ 10%. Thus it appears that this technique is not useful for $\bar{p}$ of this momentum. Using Glauber theory, the result sets limits on the polarisation in $\bar{p}n$ scattering as well as $\bar{p}p$.

During most of 1985, data were taken on the reactions $\bar{p}p \rightarrow \pi^-\pi^+$, K^-K^+ and $\bar{p}p$, using a polarised target to measure simultaneously cross sections and polarisations over the full angular range. Data vastly superior statistically to previous data were taken at 12 momenta from 450 to 1550 MeV/c and are presently being analysed.

Preliminary unpublished results from other experiments are given now.

Electromagnetic form factor of the proton

Experiment PS170 (Ferrara University-Padua University-Saclay and Turin University Collaboration).

More data continue to be taken on the very rare annihilation $\bar{p}p \rightarrow e^+e^-$ from which to derive the electromagnetic form factors of the proton in the time-like region. About 1900 events coming from annihilations at rest and 400 from annihilations in flight up to 600 MeV/c have now been observed. For the form factor at rest a value $|G_e| = |G_m| = 0.70 \pm 0.04$ is obtained. At 600 MeV/c, assuming that the equality of the two form factors holds, a value $|G| = 0.26 \pm 0.03$ is measured. This value is smaller than that predicted by the standard 'vector dominance model' on the basis of previously obtained data in the time- and space-like regions and the well established vector mesons.

$\bar{p}$ Nucleus interactions

Experiment PS176 (Basel-Karlsruhe-Stockholm-Strasbourg and Thessaloniki Collaboration).

Through the observation of X- and γ-rays emission this collaboration studies strong interaction effects aimed at the study of hadronic shifts and widths in light antiprotonic atoms — from lithium to calcium — to help in establishing a universal $\bar{p}A$ potential.

Amongst other things, a first search for spin-orbit dependences in the $\bar{p}A$ interaction was attempted in a measurement on $\bar{p}^{138}$ Ba and ^{174}Yb through the measurement of hadronic shifts and widths in separated fine structure components. The results from ^{174}Yb show a significant indication of spin-orbit effects which manifests itself as a stronger absorption in the atomic level with spin and angular momentum parallel as compared to the opposite case.

Antiproton absorption was studied in three different ways. Firstly a spectroscopy of gammas emitted from excited residual nuclei left over after $\bar{p}$ absorption was performed; secondly, the spectrum of the emitted neutrons was measured; and thirdly, high-energy gammas in the range between a few tens of MeV and 1 GeV were detected. Already at the present stage of evaluation one can state that the observed $\bar{p}$ annihilation in light nuclei on a single nucleon with an intact residual nucleus left over in an excited state is unexpectedly frequent. The measured neutron spectra in the range between 1 MeV and 100 MeV show essentially three regions: evaporation neutrons corresponding to a temperature of about 7 MeV; faster neutrons with temperatures around 45 MeV; and a few very fast neutrons. The high energy gamma spectrum shows no clear evidence for possible $\bar{p}$-nucleon or $\bar{p}$-nucleus bound states.

They have also measured the magnetic moment of the antiproton with a precision of the order of 3×10^{-3} i.e. a factor of 2 better than the actual world average. The fine structure splitting in the 11–10 and 10–9 transitions (unaffected by the strong interaction) in $\bar{p}\ ^{208}Pb$ was observed and gives the result: $\bar{p}$ magnetic moment = 2.801 μ_N, where μ_N is the Bohr magneton.

Experiment PS176–186 (Karlsruhe - Los Alamos - Mississippi University - Munich T.U. - Strasbourg University - Stockholm University and Thessaloniki University Collaboration).

This collaboration has measured antiprotonic X-ray spectra from different molybdenum isotopes using G_e detectors. They have observed for the first time the nuclear quadrupole moment (E2) mixing of nuclei and atomic states. This effect occurs when an atomic de-excitation energy matches a nuclear excitation energy and the electric quadrupole coupling induces configuration mixing.

In the case of ^{94}Mo the spacing between antiprotonic (n,ℓ) = (7,6) and (5,4) levels (844.8 keV) is sufficiently close to the first $1^{\pi} = 2^{+}$ nuclear excitation energy (871.1 keV) to allow configuration mixing of the (7,6; $1^{\pi} = 0^{+}$) and (5,4; $1^{\pi} = 2^{+}$) states. The admixture of the lower antiprotonic level causes an increase of the strong absorption width for the upper level which reduces the ($n = 7 \rightarrow n = 6$) X-ray intensity compared to ^{92}Mo; in the latter this is ruled out because the excitation energy of the first nuclear 2^{+} state is 1.51 MeV. From the reduction one can deduce the width of the 'hidden' (5,4) level. The values found for different Mo isotopes is given below, where those predicted with a phenomenological optical potential using an effective $\bar{p}$-nucleon scattering length $\bar{a}$ are also given.

	^{94}Mo	^{95}Mo	^{98}Mo
$\Gamma^{0}_{Si}\ (5,4)_{exp}$ (keV)	42.6 ± 9.2	49.9 ± 19.8	45.1 ± 10.0
$\Gamma^{0}_{Si}\ (5,4)_{calc}$ (keV)$^{(a)}$	32.6 (40.8)	32.8 (41.2)	33.7 (42.4)

(a) Calculated with a phenomenological optical potential using $\bar{a}$ = (0.30 + 3.10i) fm and, in parentheses, $\bar{a}$ = (1.53 + 2.50i) fm.

Experiment PS186 (Technical University (Munich) - Mississippi University and KFA Jülich Collaboration).

In the study of nuclear processes induced by the annihilation of antiprotons, they have measured the energy spectra of charged particles (π, p, d, ...) emitted from nuclides with mass numbers ranging from A = 6 to A = 232. A telescope consisting of 8 Ge detectors was used. The multiplicity of charged particles was also measured using an array of scintillation counters. The multiplicities range up to 15, the mean value being about 3 with a slight increase with A. Activation analysis of residual nuclei with ^{165}Ho as target show that more than 45 nucleons may be emitted after annihilation; the lightest identified nuclide was ^{116}Te. Odd-even effects of residual nuclei were observed.

Heavy hypernuclei production

Experiment PS177 (Amsterdam NIKHEF - CERN - Darmstadt GSI - Grenoble CEN - Orsay C.S.N.S.M. - Saclay CEN - Uppsala University and Warsaw University Collaboration).

The experiment aims at producing heavy hypernuclei and to measure their lifetimes. The novelty of the method is that instead of using incident negative kaons to produce them, the K^{-} results from the annihilation of antiprotons at rest in heavy nuclei. The kaon is then supposed to interact with the residual nucleus producing a Λ hyperon which attaches itself to a nucleus forming a hypernucleus.

The first data obtained, still with low statistics, show that hypernuclei are effectively produced and with an unexpected high efficiency. A likely interpretation is that, in addition to the interaction of secondary kaons, a new mechanism takes place: direct formation of Λ in the annihilation of a $\bar{p}$ by 2 nucleons as proposed by theoreticians. The analysis, still in progress, seems to indicate that these hypernuclei belong to 2 different ranges of masses, $_{\Lambda}A \sim 200$ as expected but also $_{\Lambda}A \sim 100$, the Λ being attached to fission fragments resulting from the decay of the target nucleus excited by the annihilation.

Further increase of statistics will permit to disentangle these two effects and to evaluate the respective lifetimes.

$\bar{p}p \to \pi^0, \eta$ Inclusive production

Experiment PS182 (Basel University-Stockholm University-Stockholm Research Institute-Thessaloniki University and CERN Collaboration).

The experiment investigates possible production of exotic narrow states in $p\bar{p}$ annihilations at rest through the spectroscopy of γ 's and π^0's. Results, although not final yet, are the following :

a) Narrow peaks in the inclusive γ-spectra are absent. A high statistics measurement using BGO-detectors yields upper limits for production of neutral narrow states $< 10^{-3}$ per annihilation at 90% confidence level.

b) The inclusive π^0 spectrum shows, apart from expected structures, three candidates for narrow states at a level of 3σ. The significance is low and statistics insufficient for making the necessary cross checks.

c) The η-spectrum for $p\bar{p}$ annihilations at rest was measured for the first time.

Branching ratios for the following mesonic final states were found for annihilations in liquid hydrogen:

$$\Gamma(p\bar{p} \to \pi^0\varrho)/\Gamma(p\bar{p} \to \pi^0\omega) = 2$$

$$\Gamma(p\bar{p} \to \eta\varrho/\Gamma(p\bar{p} \to \eta\omega) \leqslant 0.2$$

$$\Gamma(p\bar{p} \to \pi^0\gamma)/\Gamma(p\bar{p} \to \pi^0\pi^0) = 0.10 \ .$$

$\bar{p}p \to \bar{\Lambda}\Lambda$

Experiment PS185 (Carnegie-Mellon University, Erlangen-Nuernberg University-Freiburg University-Illinois University-Julich KFA-Rice University-Saclay CEN-Uppsala University and Vienna Akad. Wiss. Collaboration).

The purpose of the experiment is to extract information on quantum numbers and spin dynamics in the creation process of the $\bar{s}s$ pair contributing to the formation of $\bar{Y}Y$ hyperons in the final state of the annihilation. A plausible scheme for the annihilation $\bar{p}p \to \bar{\Lambda}\Lambda$ is shown in fig. 17. The ud ($\bar{u}\bar{d}$) diquark acts as a spectator while the u quark in the proton and the $\bar{u}$ quark in the antiproton annihilate into an $\bar{s}s$ pair. The spin S and the isospin I of a light diquark in the baryon 56-plet are related by a symmetry condition which for the Λ hyperon (I = 0) leads for the diquark: I = S = 0 and similarly for the $\bar{\Lambda}$ hyperon. The hyperons therefore reveal spin quantities of their strange quark and also the dynamics of the reaction $u\bar{u} \to s\bar{s}$. It can then be shown that if the $\bar{\Lambda}\Lambda$ pair is produced with orbital angular momentum $\ell = 0$, a gluon mediates the $u\bar{u} \to s\bar{s}$ transition while if $\ell = 1$ the exchange is mediated by a particle with vacuum quantum numbers O^+ or $1^+, 2^+$.

Because of the parity violation in the $\Lambda(\bar{\Lambda})$ decays their polarization and the spin correlations between the two hyperons can be measured. Together with the total and the differential cross sections data these measurements allow an almost unambiguous determination of the amplitudes intervening in the process.

Measurements have already been made at incident momenta: 1442, 1450 and 1550 MeV/c. Because of the high quality of the LEAR beam, the modular structure of the target together with the use of a degrader a scan in small momentum steps is possible; in particular near the threshold (1435 MeV/c) measurements in 0.8 MeV/c steps have been made.

The total cross section measurements are shown in fig. 18, together with results from older experiments. The inset shows the measurements close to threshold: they are based on 10% of the data.

The behaviour of the total and of the differential cross sections (not shown) indicate that the $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ reaction proceeds mainly via P-wave.

Data has also been taken at 1700 MeV/c to get a first insight into the $\bar{p}p \rightarrow \bar{\Lambda}\Sigma^0$ + c.c. reaction.

Resonance search

Experiment PS171 (CERN-Mainz University-Munich University-Orsay (LAL)-Vancouvert University-Victoria University and Zurich University Collaboration). The main efforts of this Collaboration are oriented towards the identification of the different final states resulting from the annihilation of antiprotons stopped in gaseous hydrogen and establishing the intermediate resonant channels contributing to them.

The following example illustrates the progress being made in the analyses.

Through a combination of dE/dx information and the results of a kinematic fit, the final state $K^+K^- \pi^+\pi^-$ has been separated from annihilations into four charged particles. When different mass combinations are studied strong $K^*\bar{K}^*$ and $\phi\pi^+\pi^-$ production are observed (fig. 19). The $\phi\pi^\pm$ mass distribution (fig. 20) shows a statistically significant enhancement at a mass corresponding to the Zweig-rule violating decay $B^\pm \rightarrow \phi\pi^\pm$, hitherto undetected in other experiments. Detailed analysis indicates the enhancement to be real and not to occur as a reflection of some other effect.

S.C. PROGRAMME

Isolde

The staging of a second experimental area to be served by a high-resolution, high-current electromagnetic separator known as ISOLDE-3 is going ahead. The first beam is scheduled for the second half of 1986.

In the following some of the physics results are reported which were obtained during 1985 at ISOLDE-2.

A broad program is performed at ISOLDE comprising particle, nuclear, atomic, solid-state, surface, astro, and applied physics. The larger and long-term experiments approved by the PSCC and Research Board are listed in the Grey-book 'Experiments at CERN'. However, it is characteristic of ISOLDE that many experiments require relatively little machine time. These are grouped under the code IS01-x subject to approval by the ISOLDE Committee.

Target-ion source development

The development of new target-ion source systems is a quintessential part of ISOLDE's research effort. The last years work has been concentrated on the introduction of an improved plasma discharge ion-source and a series of new high temperature target materials. By combining the new source with targets of magnesium oxide, calcium oxide, and barium oxide, greatly increased beam intensities of the most neutron-deficient neon, argon and xenon isotopes have been obtained. The use of a thick thorium carbide target in conjunction with different ion sources gave improved yields of a variety of elements, including three new isotopes of radon, ^{198}Rn, ^{227}Rn and ^{228}Rn. Fig. 21 shows the status of elements available as on-line beams at ISOLDE. In addition, further elements are available by the decay of primarily produced radioactive beams.

Particle and nuclear physics

Experiment IS10 has investigated the possibility of using low-energy bremsstrahlung as a tool for measuring neutrino masses. A more accurate approximation to the theory of internal bremsstrahlung was developed. In this, screening is taken fully into account. In order to test this theory and prompted by a recent suggestion of a neutrino having a mass of 17 keV and an admixed intensity of 3%, the internal bremsstrahlung spectrum of ^{125}I was measured. The experiment sets strict limits in the mass and admixed intensity of a hypothetical heavy-neutrino component (fig. 22).

A new region of deformation at $A \simeq 100$ was discovered several years ago. Experiment IS01-5 was undertaken to examine the possibility of extracting information on Nilsson configurations and shape transitions in fission products far from stability by means of a novel approach. Easily measurable gross β-decay properties such as the half-life and neutron emission probability were studied in this new region of strongly deformed nuclei. Comparison of the results with RPA calculations permitted to assign Nilsson states to the unpaired nucleons in ^{101}Sr and ^{101}Y. A quadrupole deformation of $\epsilon_2 = 0.35 \pm 0.03$ could be deduced for these isotopes.

Experiment IS01-10 demonstrated the feasibility of using ISOLDE beams to prepare radioactive targets for charged-particle nuclear reaction spectroscopy. For such experiments, samples with a thickness of $\geqslant 10\ \mu g/cm^2$ must be formed on very thin carbon foils, which must then be transported to a laboratory having the appropriate facilities for the reaction studies. Targets of ^{131}Cs ($T_{1/2}$ = 9.7 d) and ^{134}Cs ($T_{1/2}$ = 2.1 y) were successfully collected on carbon foils and shipped to the tandem Van de Graaff accelerator laboratory at the Technical University of Munich. The 9.7 d ^{131}Cs sample is believed to be the shortest-lived target of this type which has been produced and used in a nuclear reaction experiment.

Atomic spectroscopy of short-lived isotopes by means of laser techniques is one of the main lines of research at ISOLDE and is the subject of the experiments IS70, IS80, IS81, IS82, IS150, IS01-c, IS01-9, IS01-11 and IS01-16. Measurements of nuclear spins, moments and changes of the mean square charge radii were performed for the isotopic chains ^{220}Fr-^{228}Fr (IS70), ^{208}Ra-^{232}Ra, and ^{202}Rn-^{222}Rn (IS80). These experiments were prompted by the evidence for stable octupole (pear-shaped) deformation in the neutron-rich Ra isotopes. The measured spins and magnetic moments in this region can only be explained by taking octupole deformation into account. Furthermore, the odd-even staggering of the charge radii is inverted in the case of nuclei with strong octupole deformation. This is a very peculiar and until now unexplained observation, but possibly correlated with the octupole deformation.

The experiment IS150 has for the first time applied resonance ionization mass spectroscopy (RIMS) to study the hyperfine structure and the isotope shift of short-lived isotopes. The basic idea of this technique is to excite the atom under investigation resonantly via atomic levels by several lasers and to ionize it in a last step. The ions created in resonance by this stepwise excitation and ionization are then separated in mass by a time-of-flight technique. This results in a large enhancement of the signal-to-background ratio. Measurements on gold isotopes were performed at ISOLDE down to mass number A = 185, in order to study the phenomena of shape transitions and shape coexistence which were first observed in 1971 at ISOLDE in the case of the neighbouring Hg isotopes.

Collinear spectroscopy has been proved to be the most powerful general technique to measure spins, moments and charge radii of unstable nuclei. For example experiment IS81 exploited this technique to study the isotopes ^{111}In - ^{127}In where up to three nuclear states per isotope are long lived enough to be accessible for laser spectroscopy. Nevetheless, there is in some cases the need to improve the sensitivity of collinear spectroscopy. In the experiment IS01-9 the collinear set up was modified by replacing the standard detection of resonant photons by a detector for the anisotropy of nuclear radiation. A β-asymmetry is obtained when the nuclei are polarized by optical pumping and stopped in a crystal. Nuclear magnetic resonance was performed in the case of ^{8}Li and ^{9}Li. In the case of most neutron-rich isotope the spectra strongly favour evidence 1 = 3/2 for the unknown spin of ^{11}Li. A further run has to be performed but already now the high sensitivity of this new variant of collinear technique has been proven.

The most proton-rich radioactivity observed up to now, ^{32}Ar, has been used in experiment IS140 to measure the axial-vector coupling in beta decay, the quantity (g'_A/g_A). The result 0.49 ± 0.05 implies a strong reduction relative to the free-nucleon value g_A and is, at least in part, linked to the subnuclear degrees of freedom. The experiments have become possible through the development of diameter ($\sim$25 μm). The fibres have a core material of scintillating cerium glass and an optical cladding of a non-scintillating glass of a lower refractive index. When a particle crosses the bundle, about 7% of the scintillation light generated along its path is trapped inside fibres. (The remaining light is absorbed by an opaque 'extra mural absorber' surrounding each fibre). The trapped light is transported to an output face and then amplified by a gated image intensification system before recording on a CCD or film (fig. 24).

The experimental interest in this development is twofold. Firstly, the device can be used as an active target for direct observation and measurement of short-lived particles, such as those containing charm or beauty. Secondly, it holds good promise for compact, precise particle tracking in the high rate, particle density and radiation levels of future collider detectors. The first application is already within reach and tests are under way to demonstrate the feasibility of this detector to operate and produce clear interactions in beams at high energy and high flux (10^6 Hz). The second application requires improvement in the attenuation length (presently $\lambda \sim 20$ cm) of the scintillating glass before chambers of $\sim$ 1 m length can be considered. Based on present studies the source of the poor attenuation length appears to be understood and an improvement programme is underway with the glass manufacturer.

Electronics group

The major goals of the group over the year have been FASTBUS developments and support, development of electronics systems for LEP experiments, the collider experiments and fixed target experiments. The application of advanced technologies in design such as semi-custom VLSI and programmable logic devices has been intensified.

Some details on the major projects are given below.

FASTBUS development and support has continued in close collaboration with the LEP experiments, outside laboratories and other groups. The range of general purpose devices is continually being expanded, with e.g. a kluge card including the semi-custom VLSI circuit (ADI chip), a backplane indicator, ancillary logic for the cable segment, a high speed test memory (in collaboration with NA31), etc. Design is in progress of a dual slave memory (DSM, in collaboration with DELPHI and L3), and of an 'elastic' segment interconnect for linking FASTBUS equipment over a long distance (e.g. LEP underground to surface).

The development of a read-out system (in collaboration with MPI, Pisa, University of Wisconsin) for the TPC of ALEPH has advanced well. The amplitude conversion is based on an 8 bit Flash ADC, for which a close collaboration with European industry has taken place to improve the performance of their devices and to meet CERN requirements. Tests with prototypes have been successfully concluded on a prototype TPC. Final models have been made of some parts and tendering for production by European industry of this 50,000 channel FASTBUS system has started.

Much progress has also been made with the development of the LTD (LEP Time Digitizer) system. It is being designed in close collaboration with the DELPHI 'Channel electronics standardization group' . This general purpose time digitizing system features a high resolution (2 ns time bins), a wide dynamic range (32 μs) and accepts high multiplicities. It covers the needs of virtually all detectors of DELPHI in this field. The development with European industry of a monolithic 2 ns time interpolator chip for this project is in preparation.

Development has continued of additional VME based hardware for the upgrade of the data acquisition system of UA1. The upgrade of the central detector and muon detector electronics has been completed.

Work has started on a CCD based read-out system for scintillating fibers, as part of the upgrade of UA2. A buffered REMUS-FASTBUS interface is also being developed for the upgrade in FASTBUS of the data acquisition system of this experiment.

After completion of the development a large spectrum of analog and digital devices has been produced and commissioned for NA34.

The collaboration with NA32 and DELPHI on electronics for silicon strip detectors has continued.

Some work has started on electronics for the calorimeter of PS195.

Finally, the group has continued to give the traditional support to new experiments, and to experiments with extensions, modifications and upgrades of their electronics.

Engineering and projects group

Most of the activity of the group was devoted to ALEPH and DELPHI in close collaboration with the many collaborating groups and institutes. The construction of the two iron yokes (~ 2800 tons each) is nearly completed; their supporting structures and hydraulic ram system for their opening and displacement in the experimental areas has been ordered and has been partially delivered. A new data acquisition system for mapping the magnetic field in the large inside volumes (~ 120 m^3) has been developed. The ALEPH access platform has been designed as well as the huge structure supporting the muon chambers and the large amount of cables. ALEPH TPC front end electronic prototypes have been thoroughly tested.

The group has also contributed to WA79 (construction of the 700 t glass target, low voltage power distribution and monitoring); to PS189 (H^- source, mapping and correction of the spectrometer) and has provided assistance to the users of the East Area test beams.

Technical assistance group

The bulk of the group's effort is directed towards the construction of the outer and inner field cages for the ALEPH detector which is now well under way.

Other activities during the year were scanning platform for calorimeter modules in the UA2 detector; technical coordination of the endcap RICH counter and construction of paraboloidal mirrors for the barrel RICH counter of the Delphi detector.

Design of a multiwire proportional chamber for the Medical Research Council in Cambridge (England).

Routine technical assistance was provided for many different groups.

The preparation of LEP Experiments

The preparation of the four LEP experiments involves both the EP and the EF Division. To avoid duplication most of these activities are reported in the EF section. Here we mention only some prototype investigation and important tests for each experiment.

- The ALEPH Collaboration have completed the design and prototype work and are now in the construction phase.
- The DELPHI Collaboration have successfully tested the first prototype module of the High-density Projection Chamber (HPC).

The results obtained by the prototype of the Barrel Ring Imaging Cerenkov (RICH) are better than foreseen in the Technical Proposal. Cerenkov Rings have been measured both in the liquid and in the gas radiators.

An important step forward was made in the electronics for the Vertex Detector. The VLSI chip, which can muliplex 128 analog channels, has been tested and proven to work in a test beam with minimum ionizing particles.

- The OPAL Collaboration have performed prototype work on the central detector, the calorimeter and the microprocessor tree of the data acquisition system.

A method to improve the space resolution of the jet detector has been tested.

Calorimeter prototype set ups including all detectors in their final configuration have produced an extensive set of data at various energy confirming previous results on performances.

- The L3 Collaboration have performed full scale tests with the first completed octant of the central muon detector; an individual wire resolution of 136 microns has been obtained i.e. a factor two better than originally proposed.

Extensive tests have been performed with the first matrix-arrangement consisting of Bismuth Germanate Oxide (BGO) crystals and photodiodes as well as associated electronics in final configuration. The energy resolution of better than $(5.7 \pm 0.5)\%$ at 100 MeV and the measured $1/\sqrt{E}$ dependence confirms the expected resolution of better than 2% for the GeV range.

An operational Time Expansion Chamber (TEC) consisting of the mechanics, electronics, readout system and gas system has been installed at the MARK-J detector at DESY. Beam tests performed during 1985 have shown a resolution below 50 μm over 1.5 cm drift range.

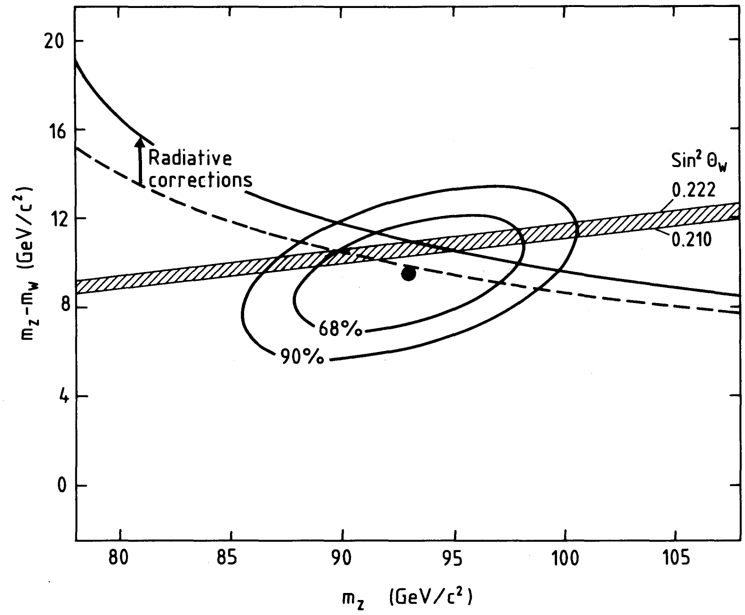


Figure 1—A plot of the Z-W mass difference against the mass of the Z. The two curves (solid and broken) show the standard model predictions for $\varrho = 1$ as function of M_w, with and without radiative corrections respectively. The shaded band shows the expectation from low energy neutrino interactions. The error ellipses are for 68% and 90% confidence (UA1).

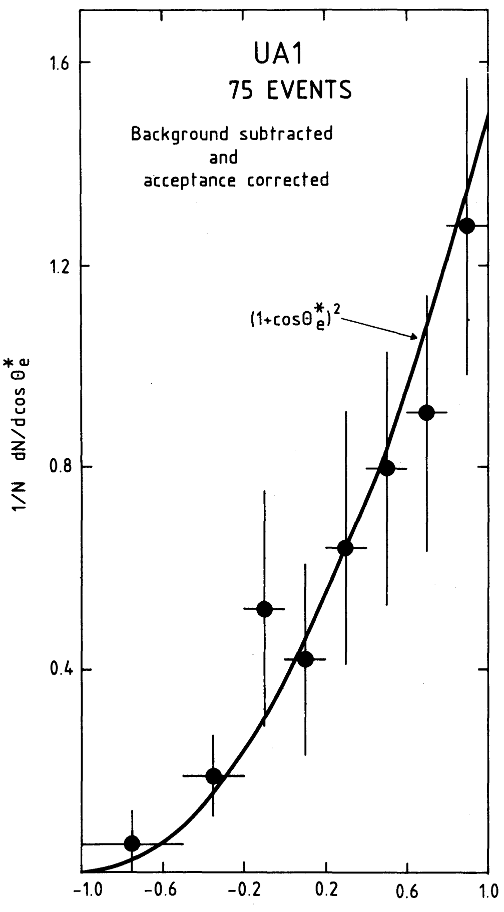


Figure 2—The W decay angular distribution. θ_e^* is the emission angle of the electron (positron) with respect to the proton (antiproton) direction in the rest frame of the W. The curve shows the (V–A) expectation of $(1 + \cos\theta_e^*)^2$ (UA1).

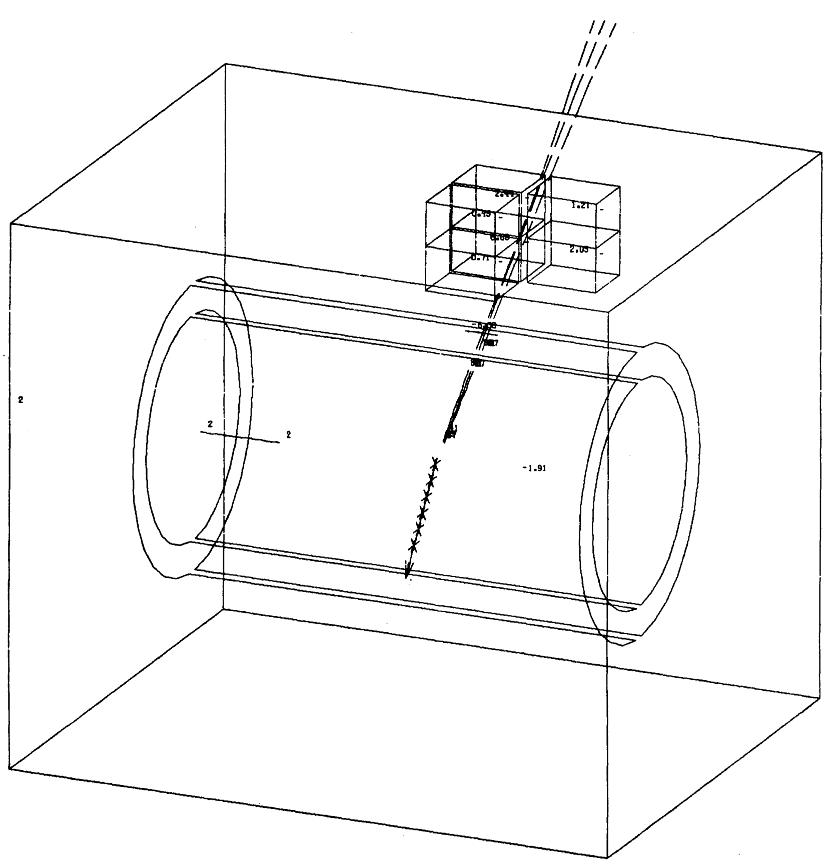


Figure 3—Computer display of an event which has been interpreted in terms of W production with subsequent decay into → $\nu_\tau \tau$. The τ-lepton then decays into ν_τ and 3 charged hadrons. The three tracks shown in the central detector are from the decay of the τ and the arrow shows the direction of the missing transverse energy (UA1).

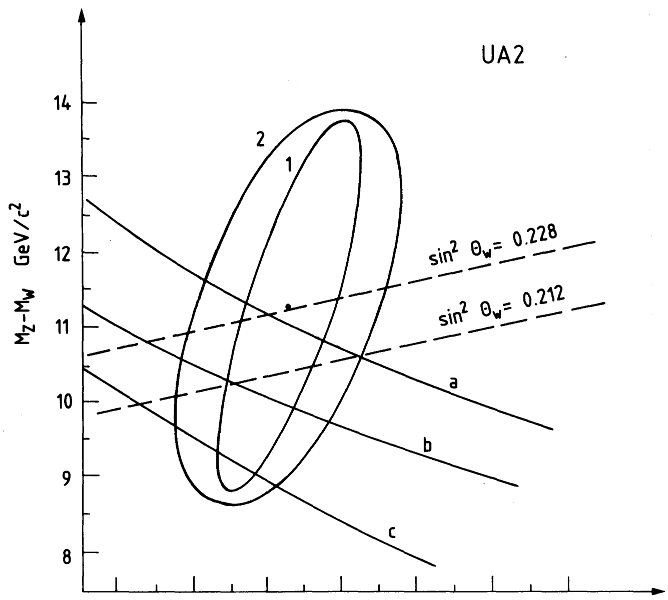


Figure 4—68% confidence contours in the (M_z − M_w) vs M_z plane, taking into account the statistical errors only (1), and with statistical and systematic errors combined in quadrature (2). Curve (a) is the Standard Model prediction for $\varrho = 1$ with radiative corrections. Curve (b) is the same prediction without radiative corrections. The band defined by curves (a) and (c) corresponds to the region allowed by the low energy result, $\varrho = 1.02 \pm 0.02$. The curves corresponding to two different values of $\sin^2 \theta_w$, define the region allowed by the world average of low energy results, $\sin^2 \theta_w = 0.220 \pm 0.008$ (UA2).

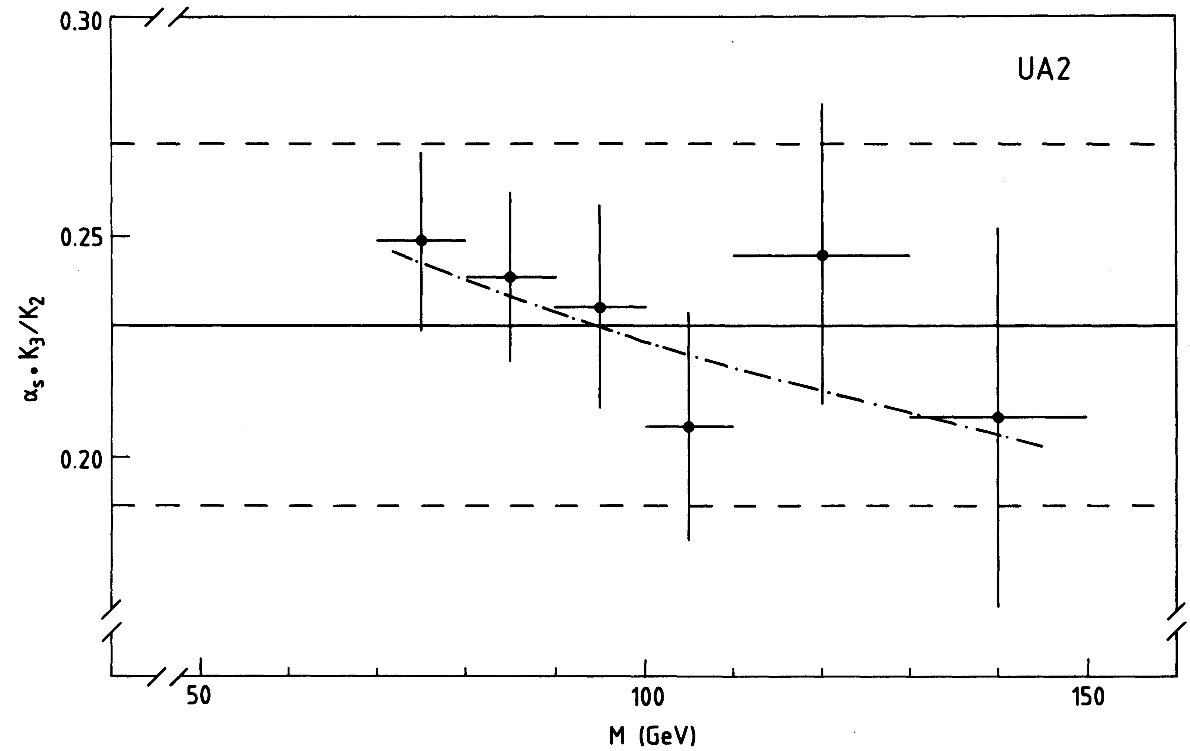


Figure 5 — $\alpha_s K_3/K_2$ evaluated in bins of the mass of the multi-jet system M. α_s is the strong coupling constant, K_2 and K_3 represent the contributions arising from higher order corrections to the two and the three jet cross sections. The full line shows the final result and the dashed lines indicate the overall statistical and systematic error. The curve represents the variation of α_s predicted by QCD (UA2).

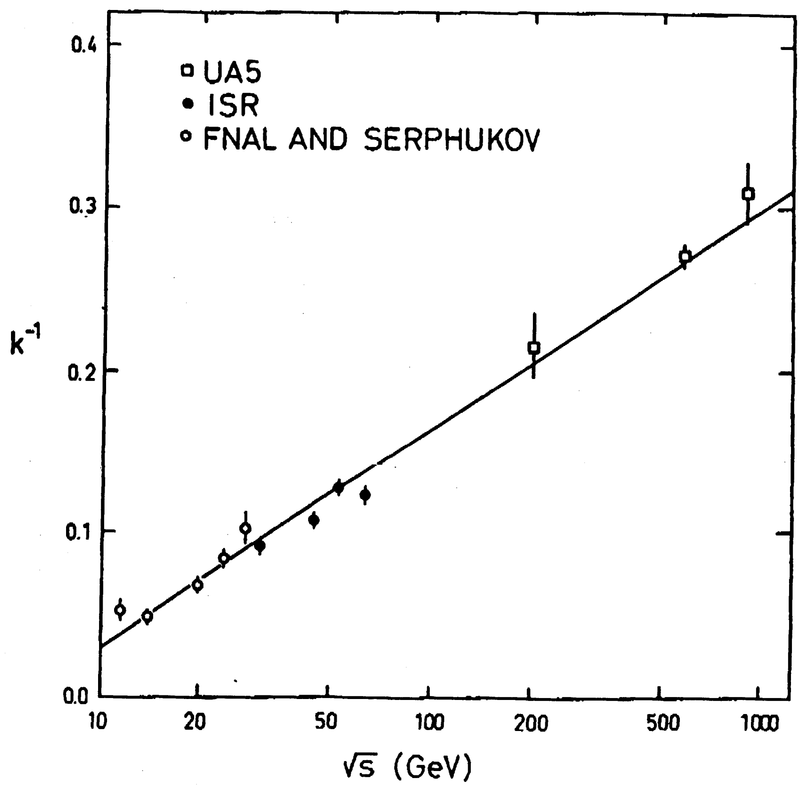


Figure 6 — The parameter k^{-1} of negative binomial fits to non single-diffractive multiplicity distributions as a function of $\sqrt{s}$. A linear dependence of this parameter with log s is seen up to $\sqrt{s}$ = 900 GeV (UA5).

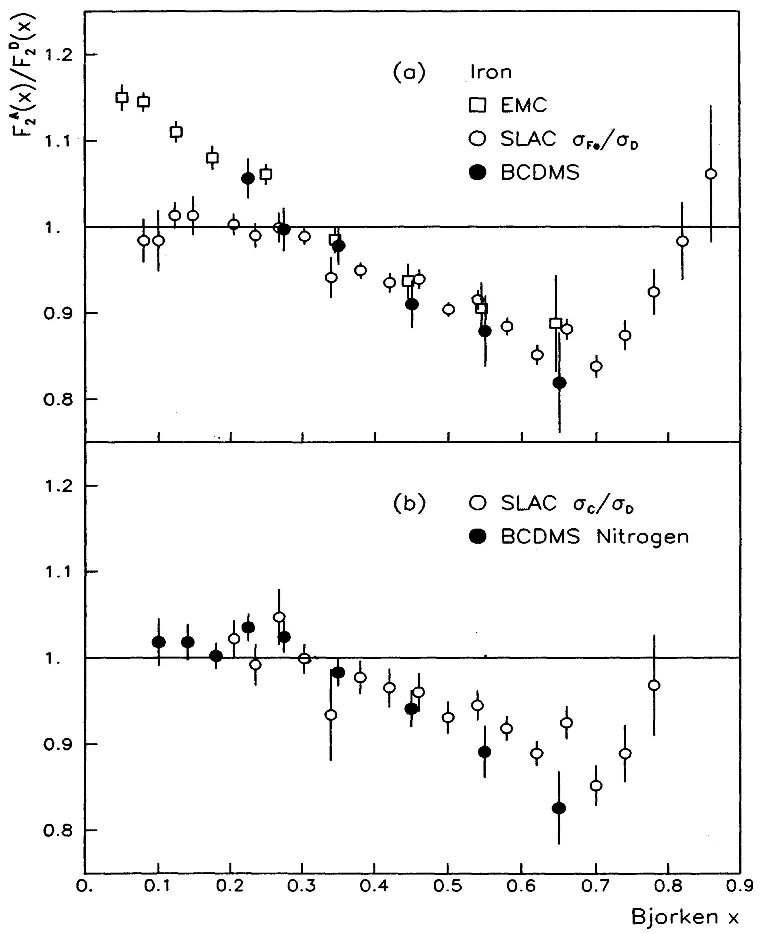


Figure 7—Q^2 averaged data for structure function ratios as a function of x. Only statistical errors are shown. Systematic errors of the BCDMS data are typically 50% of the statistical ones. (a) Data for F_2^{Fe}/F_2^{D2} compared to EMC and SLAC results. (b) Data for F_2^{N2}/F_2^{D2} compared to results of SLAC for carbon (NA4).

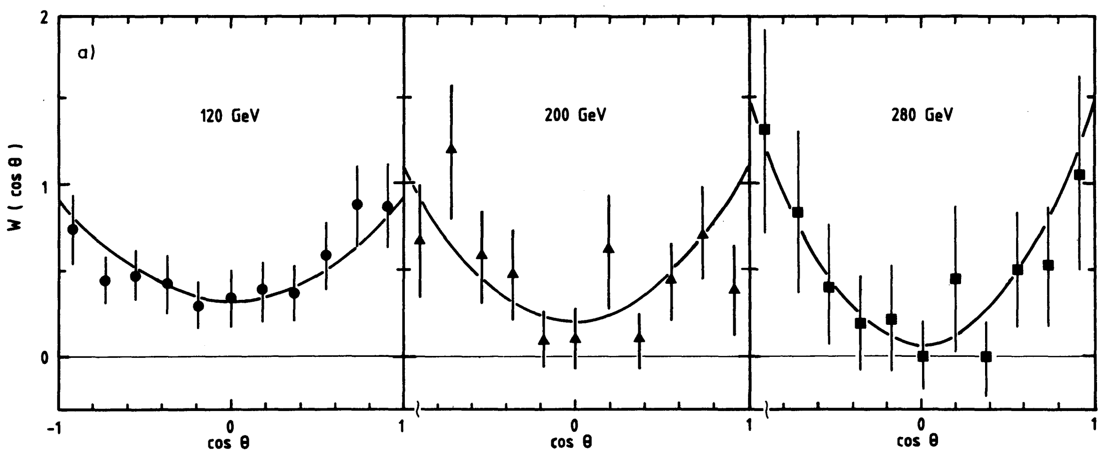


Figure 8—ϱ^0 decay angular distribution, in 120,200 and 280 GeV muon proton interactions at high Q^2. θ is the polar angle of the decay π^+ in the ϱ^0 CMS (the distributions are normalized to 1). The curves are the fitted angular distributions (EMC).

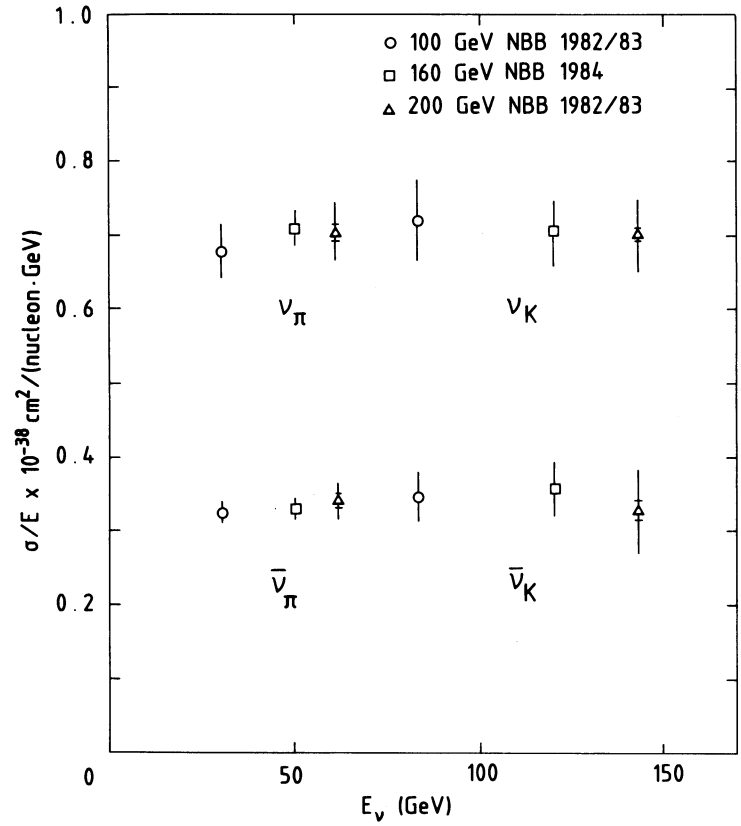


Figure 9—($^1/_{E_\nu}$) × (total cross section for ν_μ ($\bar{\nu}_\mu$) nucleon scattering) versus E_ν (WA1/2).

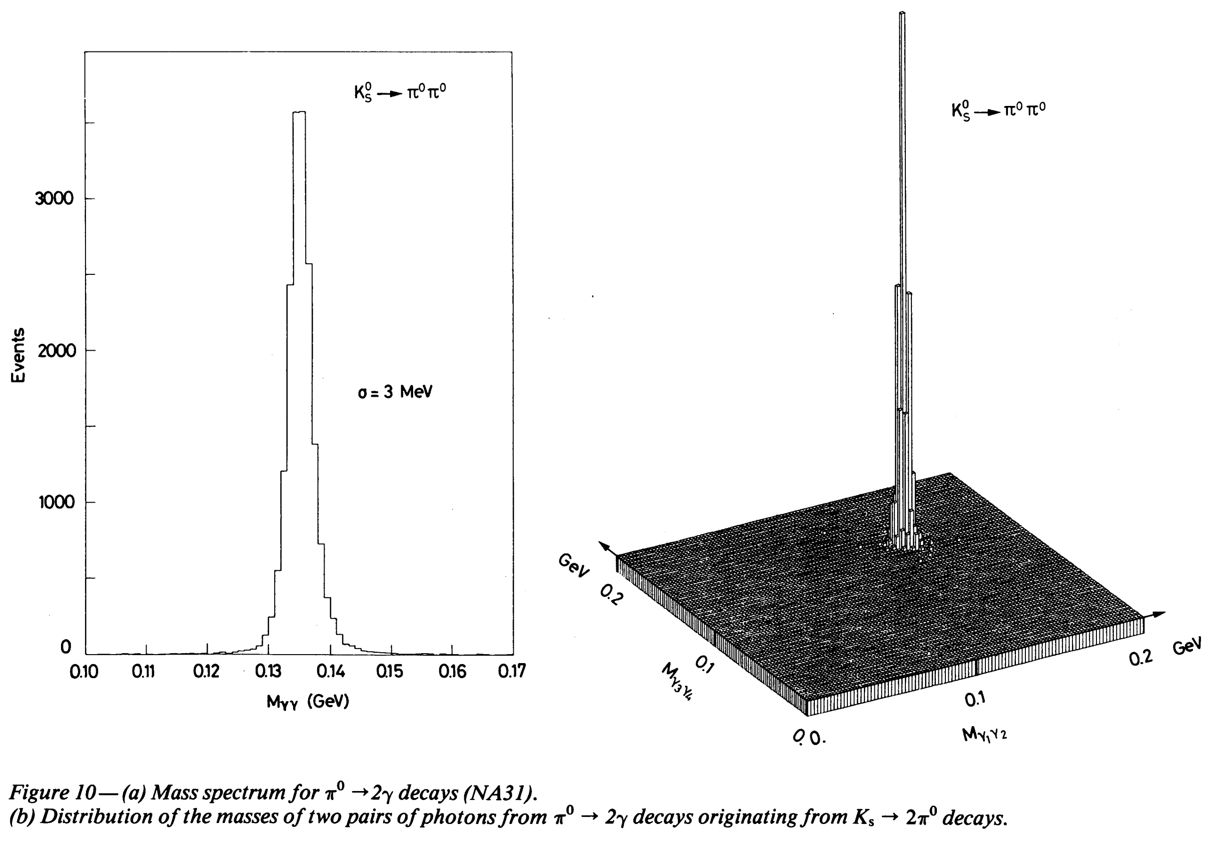


Figure 10—(a) Mass spectrum for $\pi^0 \rightarrow 2\gamma$ decays (NA31).
(b) Distribution of the masses of two pairs of photons from $\pi^0 \rightarrow 2\gamma$ decays originating from $K_s \rightarrow 2\pi^0$ decays.

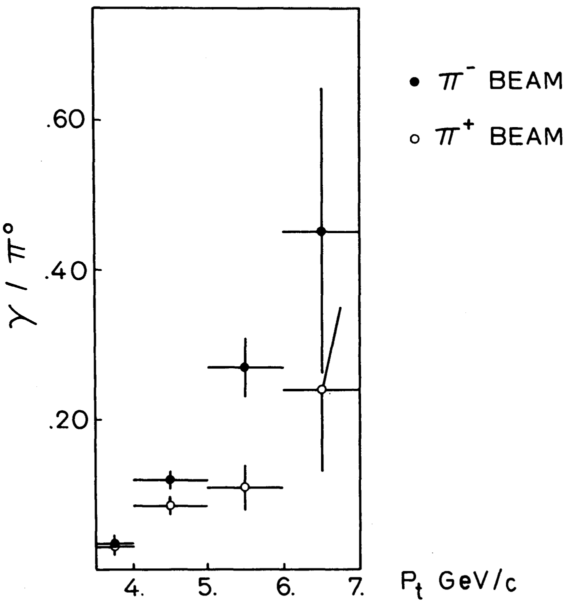


Figure 11 — The ratios of γ to π^0 production for π^- proton and π^+ proton interactions (after background subtraction and correction for acceptance and efficiencies) (WA70).

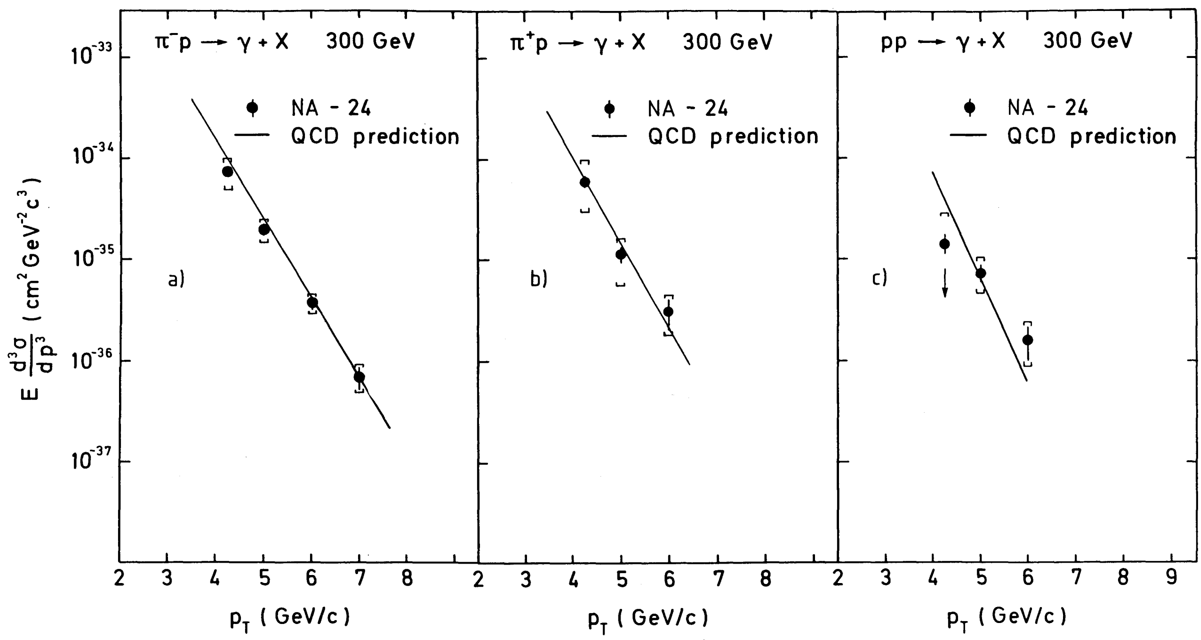


Figure 12—Direct photon cross sections for (a) $\pi^- p$, (b) $\pi^+ p$ and (c) pp collisions. The solid lines represent QCD calculations (NA24).

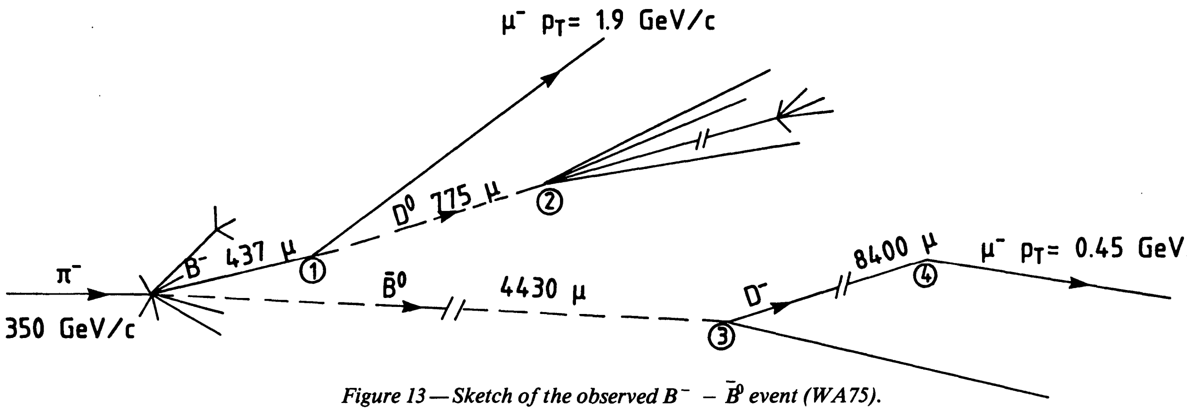


Figure 13 — Sketch of the observed B^- – $\bar{B}^0$ event (WA75).

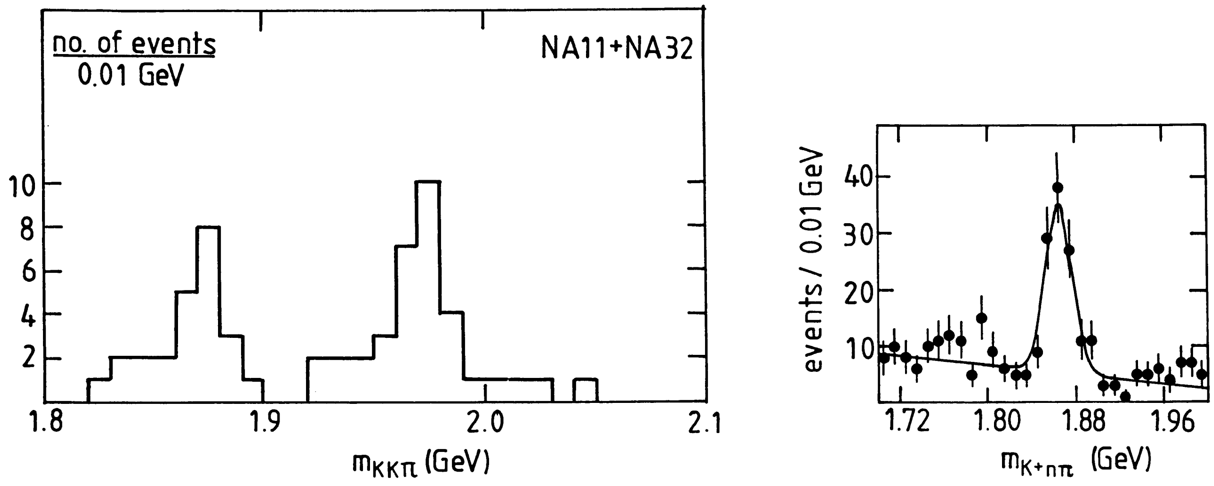


Figure 14 — (a) $KK\pi$ mass spectrum. The two peaks are $F^{\pm}$ decays and Cabibbo forbidden $D^{\pm}$ decays.
(b) D-meson signal in the combined $K\pi$ and $K\pi\pi$ mass spectrum (NA32).

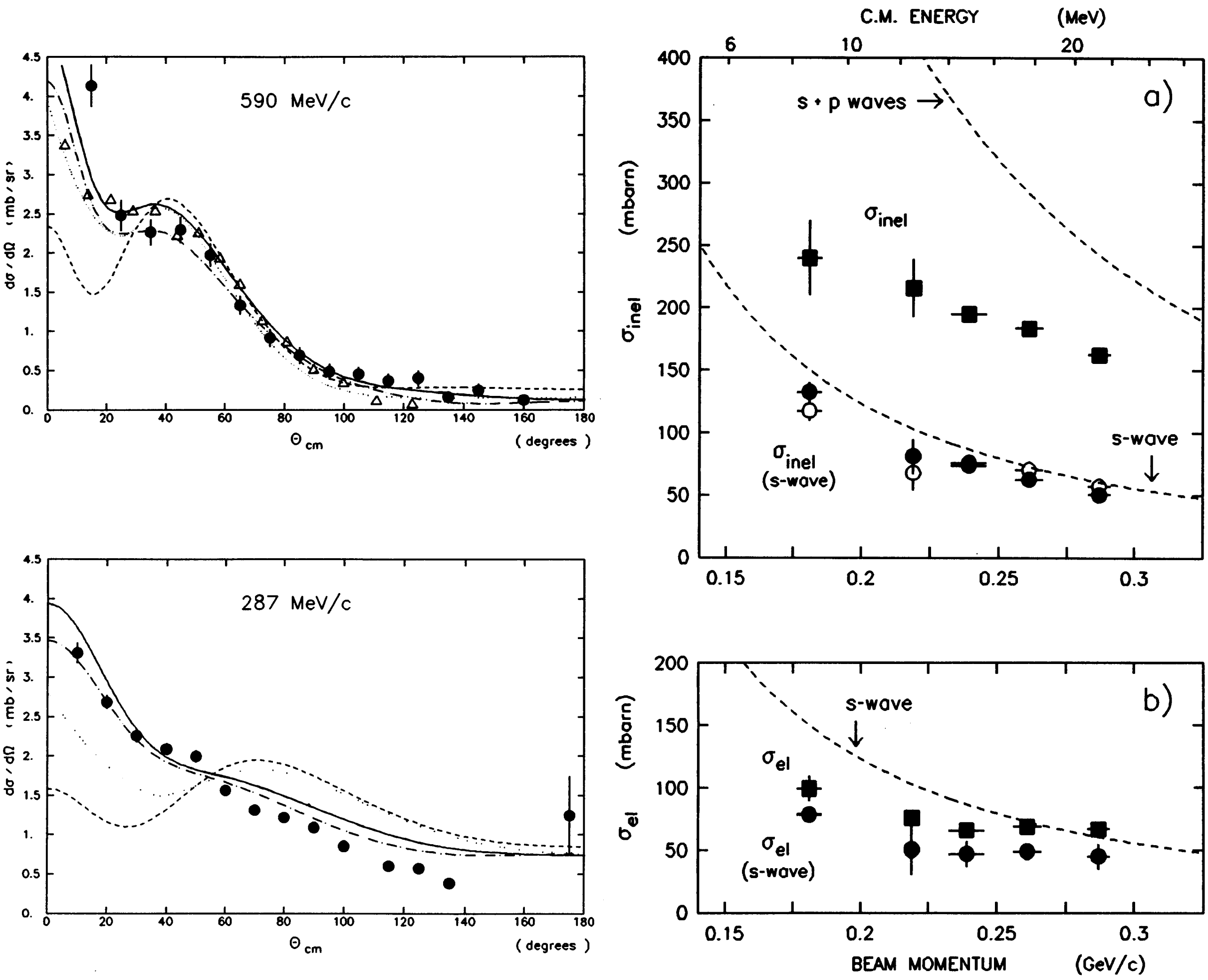


Figure 15 — (a) The differential $\bar{p}p$ elastic cross sections at incident $\bar{p}$ momenta: 590 and 287 MeV/c. The superimposed curves are the results of different model calculations.
(b) Elastic and inelastic $\bar{p}p$ cross sections as a function of the incident momentum. The results of a partial wave analysis for the s-wave contribution are also shown. Assimilating the proton to a black sphere would give the results indicated by the dotted curves.

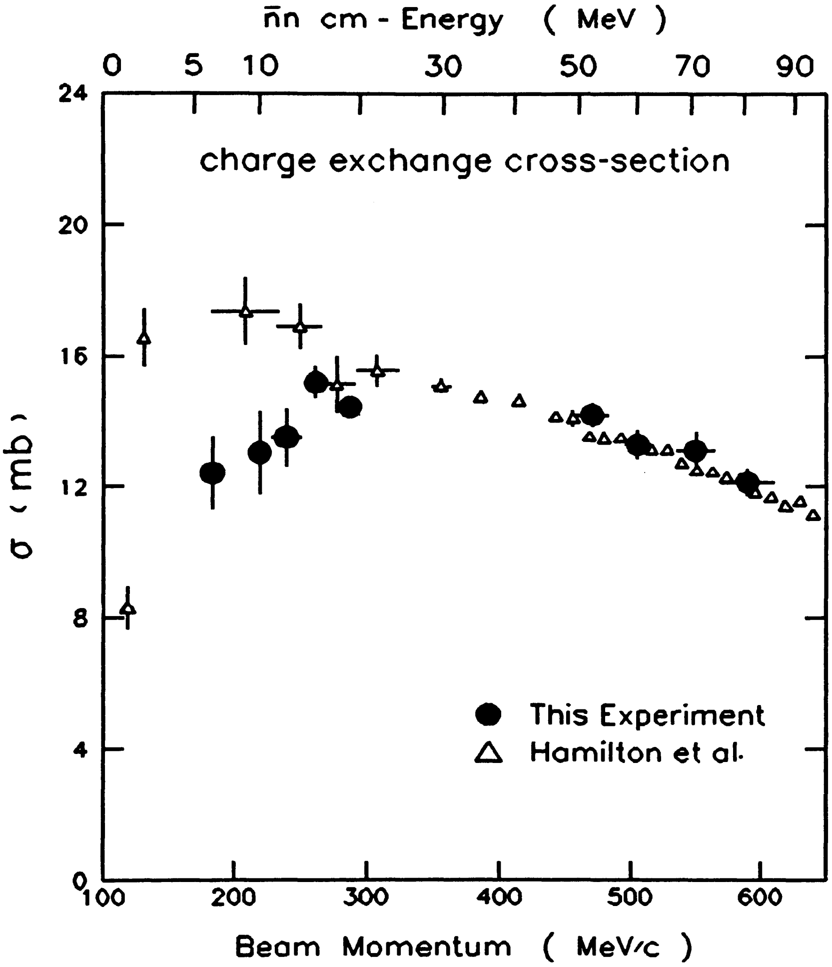


Figure 16—The $\bar{p}p \rightarrow \bar{n}n$ cross section as a function of the $\bar{p}$ momentum.

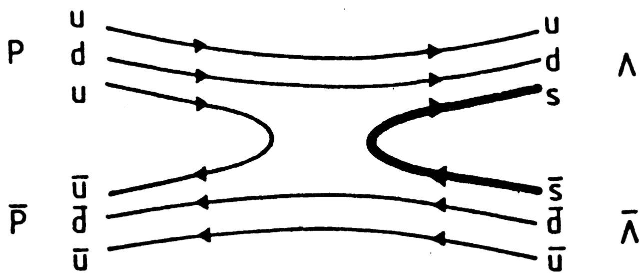


Figure 17—A quark-line diagram for the annihilation $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$.

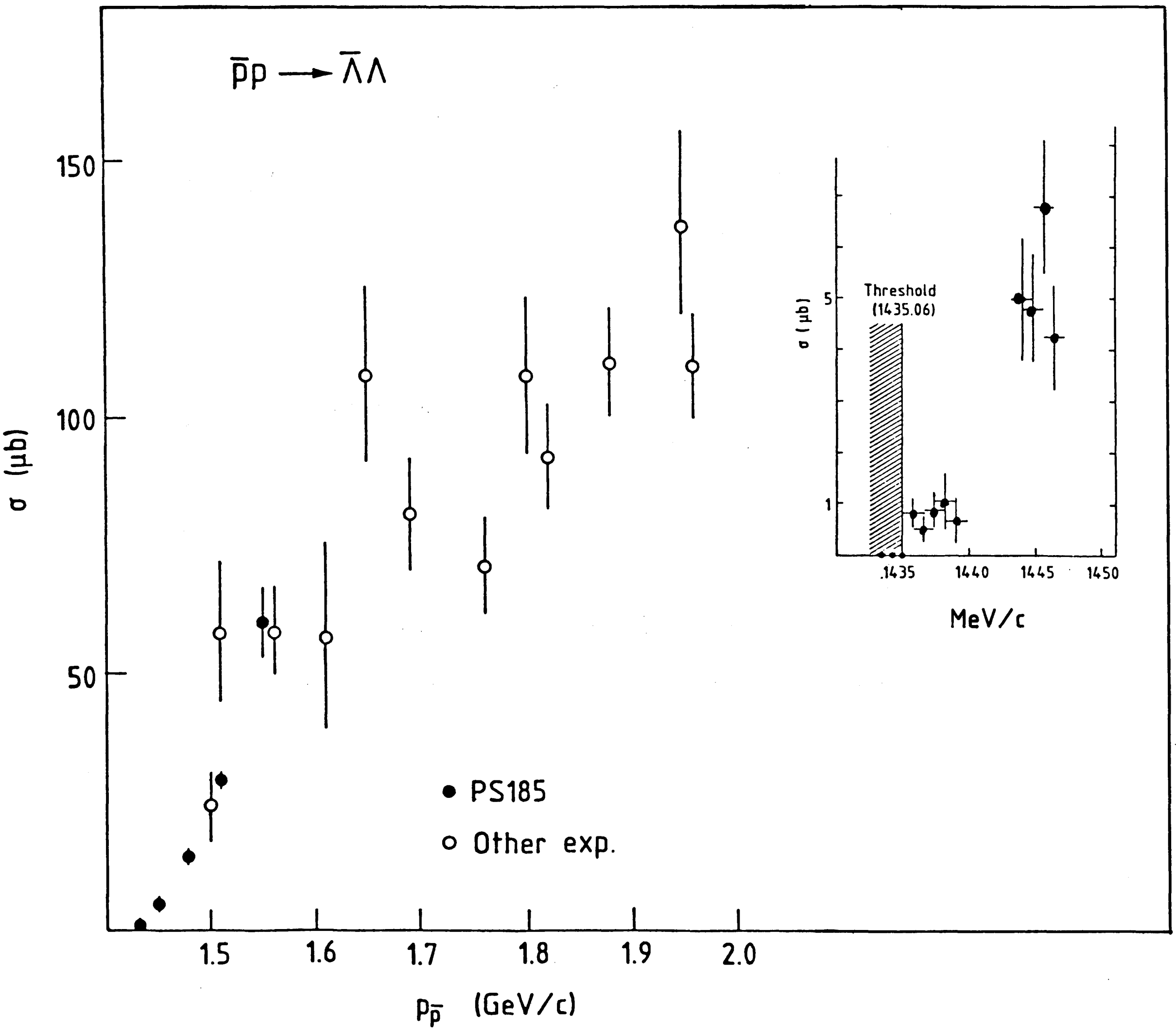


Figure 18— Total cross section for the annihilation $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ in the momentum range accessible at LEAR.

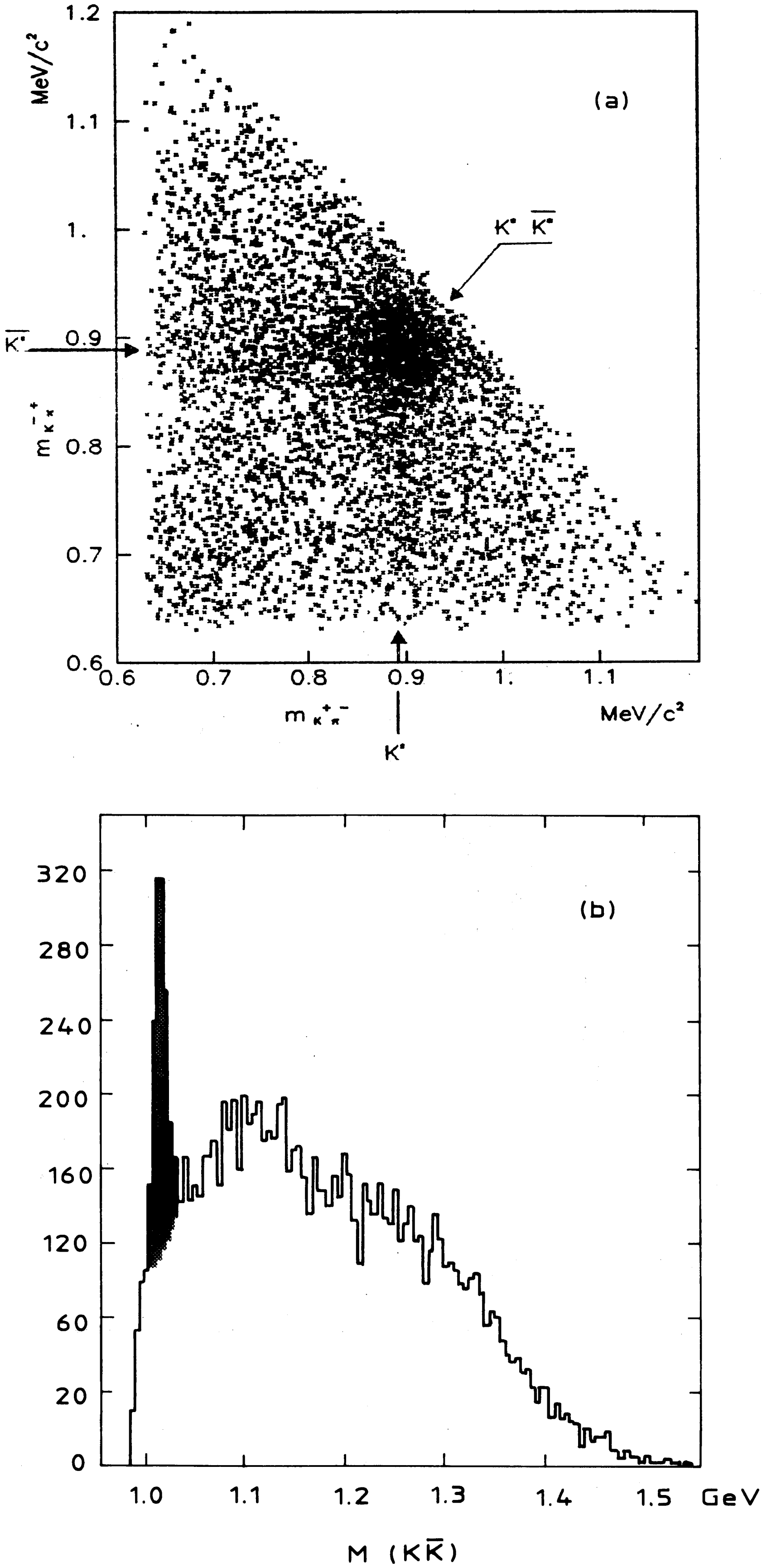


Figure 19—Results from the annihilation $\bar{p}p \rightarrow K^+K^-\pi^+\pi^-$.
(a) Strong $K^*\bar{K}^*$ production is seen when in each event the $(K^+\pi^-)$ mass is plotted against the $(K^-\pi^+)$ mass.
(b) The (K^+K^-) mass distribution shows strong ϕ production.

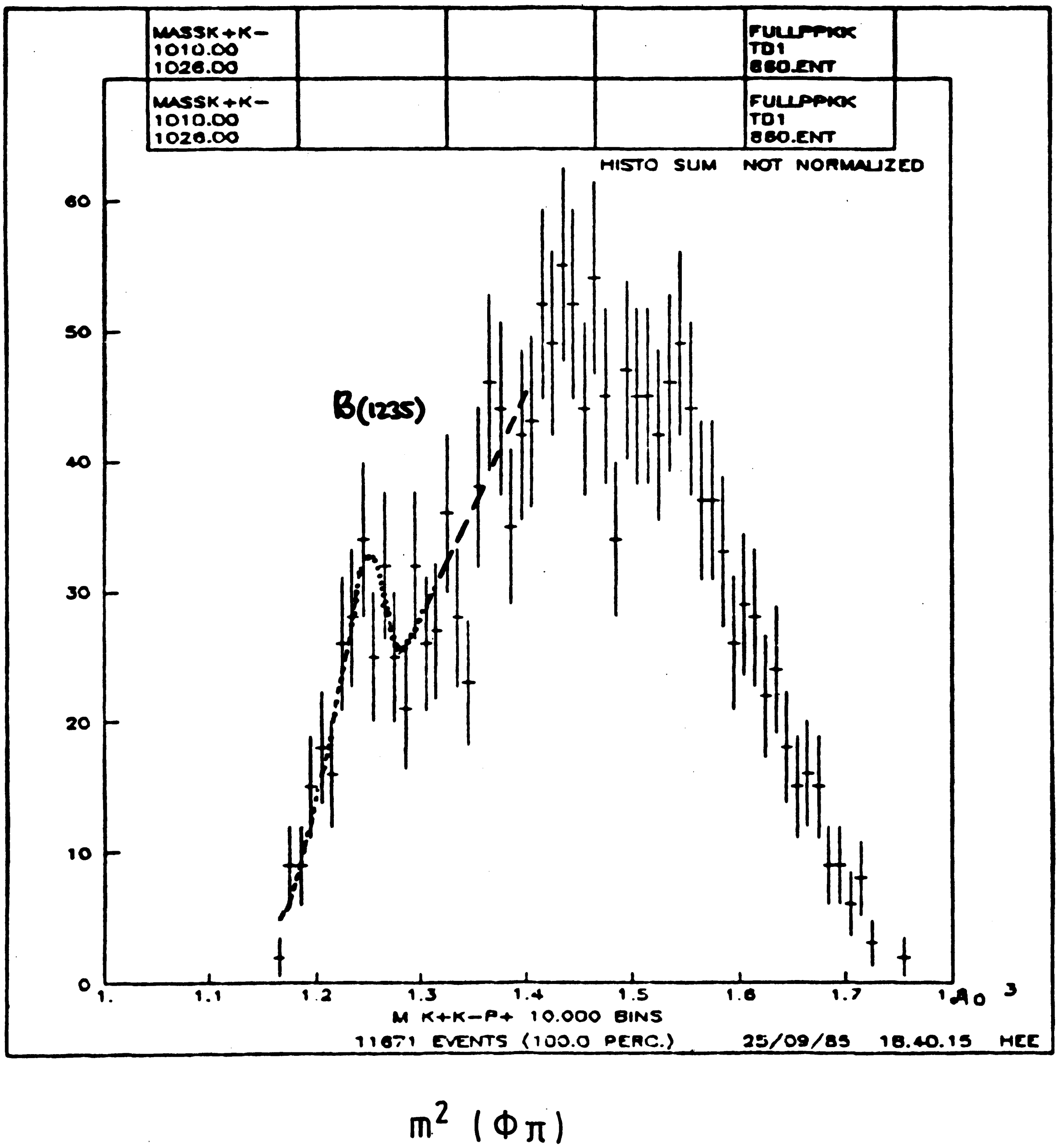


Figure 20—The $\phi\pi^{\pm}$ mass distribution for events with a $(K^{+}K^{-})$ mass in the ϕ region. An enhancement with the mass and width expected for the decay $B(1235) \rightarrow \phi\pi$ can be seen.

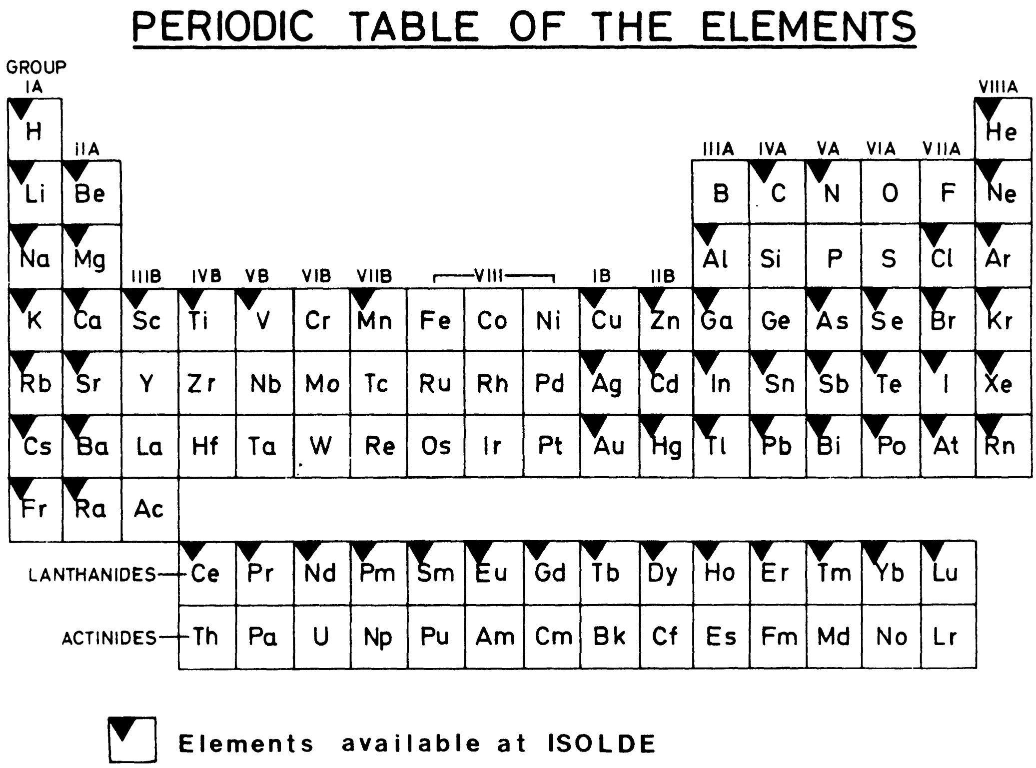


Figure 21—Periodic table of elements. Elements available as on-line beams at ISOLDE are marked by a triangle.

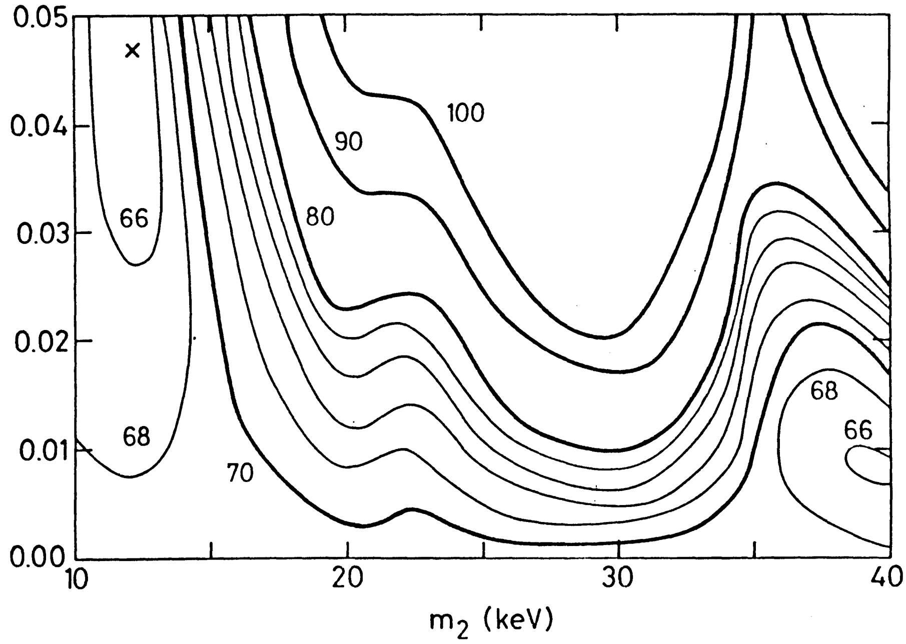


Figure 22—Contour plot of χ^2 as a function of the mass m_2 of a heavy neutrino and its admixed intensity c_2. The measurement is compatible with $c_2 = 0$, and a 17 keV neutrino with an admixed intensity of 1% is excluded at 90% confidence level.

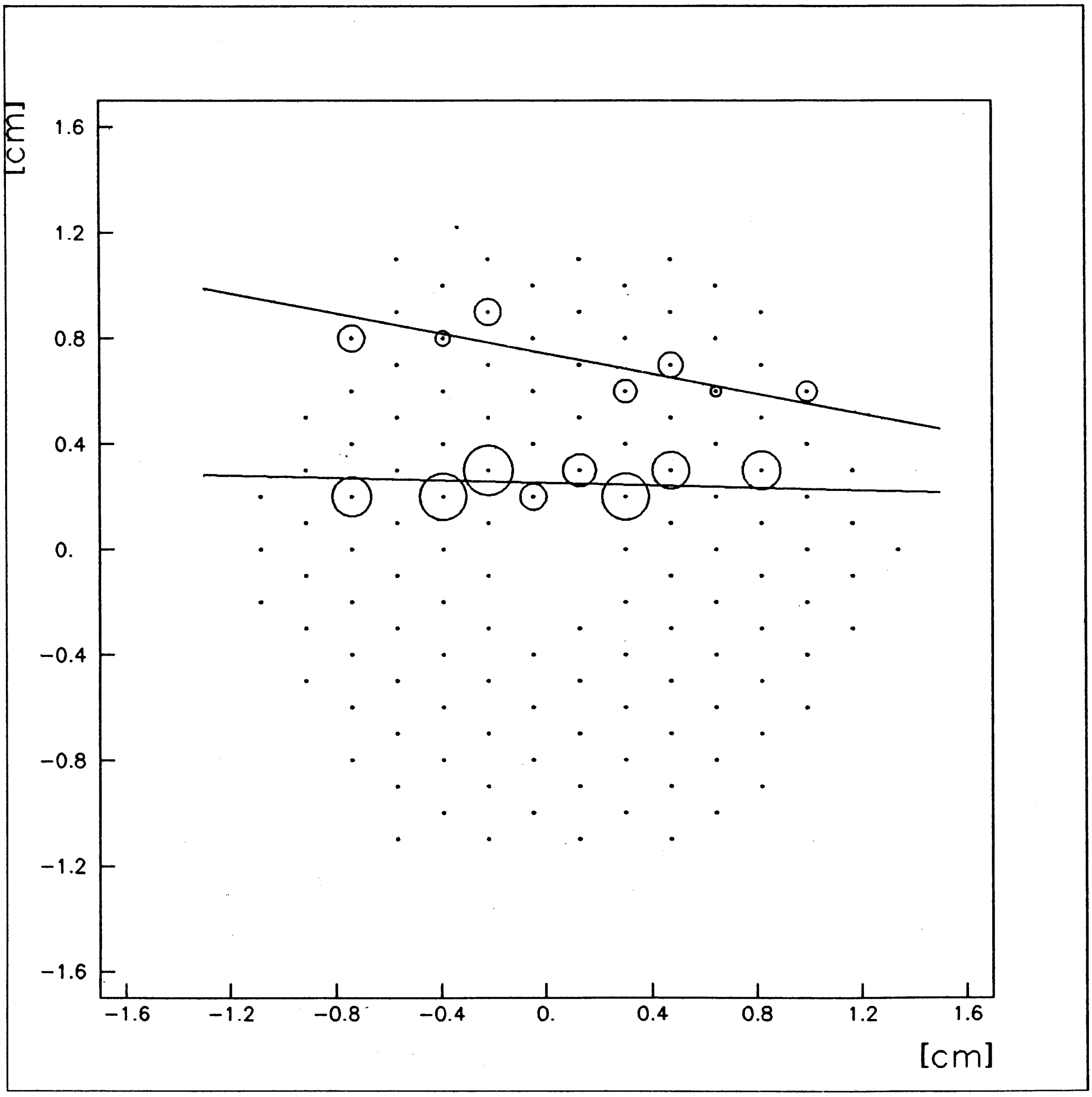


Figure 23—A double track event recorded in a new detector developped at CERN.

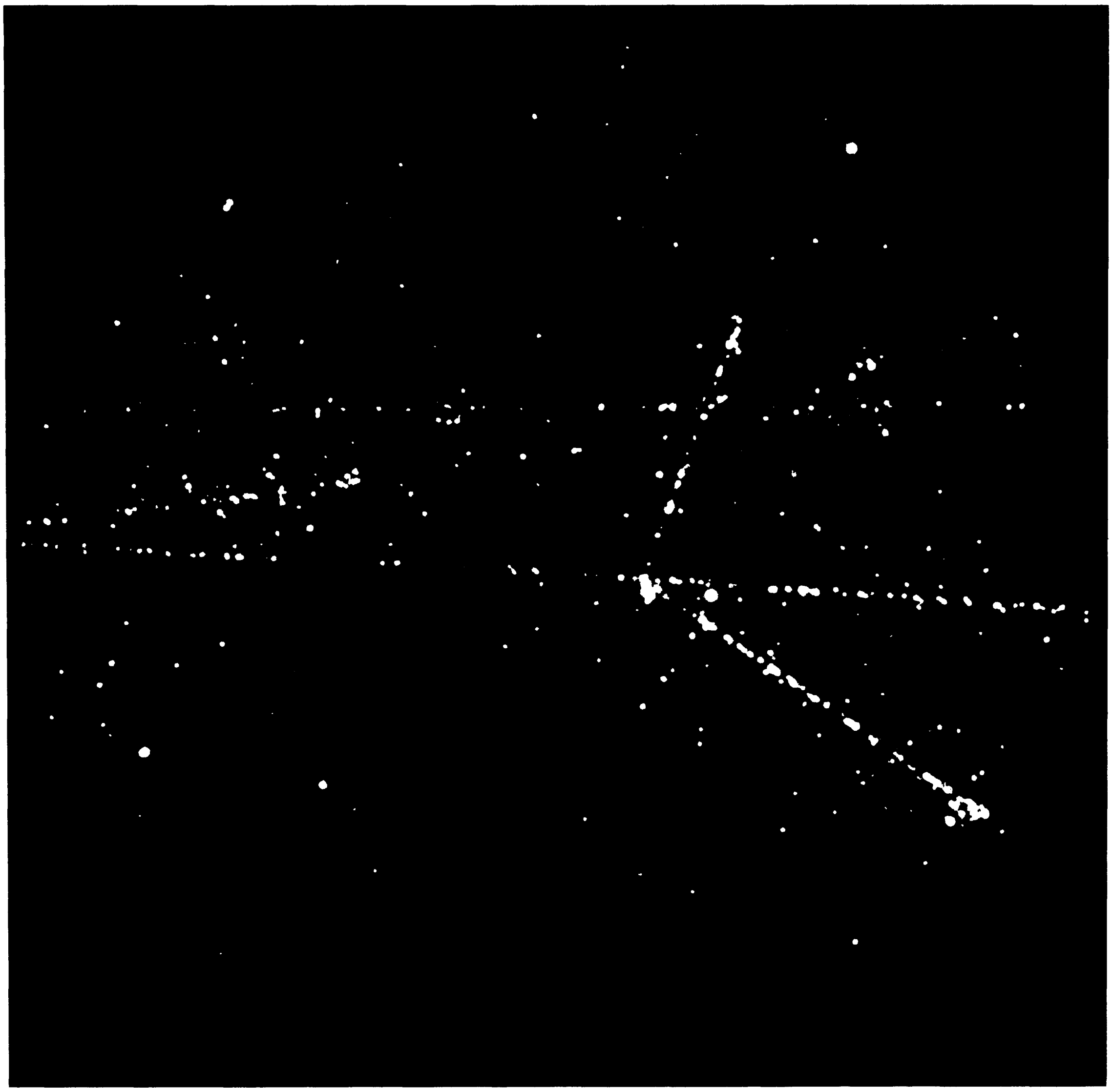


Figure 24—Example of a 5 GeV/c π^- interaction in the CERN-RAL-MPI (Munich) 'scintillation chamber'. The longest track length is 18 mm and the typical spot diameters are 80 μm. The track residuals are $\sigma \sim 20\ \mu$m.

SPS EXPERIMENTS IN 1985

Experiment number	*Experiment*	*Collaboration*	*Status*
WA69	Photoproduction in the energy range 70–200 GeV	Bonn–CERN–Erevan–Lancaster–Manchester–Rutherford–Sheffield	Data-taking
WA70	Study of direct photon events in hadronic collisions	Geneva–Glasgow–Liverpool–Milan–Neuchâtel	Data-taking
WA76	Study of the mesons produced centrally in the reaction pp giving pp + X^0 and π^-p giving π^-p + X^0 at 340 GeV/c	Athens–Bari–Birmingham–CERN–Paris	Preparation
WA77	Search for direct production of gluonium states in high p_T π^-N collisions at 350 GeV/c	Athens–Bari–Birmingham–CERN–Paris	Data-taking
WA78	Search for the hadroproduction of B/anti-B pairs	Bari–Brussels–CERN–London–Rome–Turin	Completed 16.8.1985
WA79	Study of neutrino-electron scattering at the SPS	Brussels–CERN–Hamburg–Louvain–Moscow–Munich–Naples–Rome	Setting-up
WA80	Study of relativistic nucleus-nucleus collisions at the CERN SPS	Darmstadt–Lawrence–Lund–Marburg–Munster–Oak Ridge–Warsaw	Preparation
WA81	Measurements of pair production under channelling conditions by 70–180 GeV photons incident on single crystals	Aarhus–CERN–Strasbourg	Preparation
NA2	Electromagnetic interactions of muons	Aachen–Annecy–CERN–Freiburg–Hamburg–Heidelberg–Lancaster–Liverpool–Marseilles–Mons–Oxford–Rutherford–Sheffield–Turin–Uppsala–Warsaw–Wuppertal–Yale	Completed 15.8.85
NA4	Inclusive deep-inelastic muon scattering	Bologna–CERN–Dubna–Munich Saclay	Completed 16.8.1985
NA10	High resolution study of the inclusive production of massive muon pairs by intense pion beams	CERN–Naples–Palaiseau–Strasbourg–Zurich	Completed 15.8.1985
NA24	Investigation of deep-inelastic scattering processes involving large p_T direct photons in the final state	Bari–Freiburg–Moscow–Munich	Completed 15.8.1985
NA31	Measurement of $\lvert\eta_{00}\rvert^2\lvert\eta_{+-}\rvert^2$	CERN–Dortmund–Edinburgh–Orsay–Pisa–Siegen	Data-taking
NA32	Investigation of charm production in hadronic interactions using high-resolution silicon detectors	Amsterdam–Bristol–CERN –Cracow–Munich–Rutherford–Santander–Valencia	Data-taking
NA33	An experimental study of single-vertex e^+e^- pair creation in a crystal	Albany–Annecy–Frascati–Lyon	Completed 07/1985
NA34	Lepton production	Brookhaven–CERN–Heidelberg–London–Los Alamos–Lund–Montreal–Moscow–Novosibirsk–Pittsburgh–Rutherford–Saclay–Syracuse–Tel-Aviv	Setting-up
NA35	Study of relativistic nucleus-nucleus collisions	Athens–Bari–CERN–Cracow–Darmstadt–Frankfurt–Freiburg–Heidelberg–LBL–Marburg–Munich–Texas–Warsaw –Zagreb	Preparation
NA36	The production of strange baryons and antibaryons in relativistic light ion collisions	Bergen–Birmingham–Brookhaven–CERN–Chandigarh–Cracow–LBL–New York–Pittsburgh–Strasbourg–Vienna	Preparation
NA37	Detailed measurements of structure functions from nucleons and nuclei	Bielefeld–Bloomington–Freiburg–Heidelberg–Mainz–Mons–Neuchâtel–Oxford–Santa Cruz–Torino–Uppsala–Warsaw–Wuppertal–Zurich	Preparation
NA38	Study of high-energy nucleus-nucleus interactions with the enlarged NA10 dimuon spectrometer	Bergen–CERN–Clermont-Ferrand–Lisbon–Lyon–Neuchâtel–Orsay–Palaiseau–Strasbourg–Valencia	Preparation
NA14/2	A program of heavy flavour photoproduction	Athens–CERN –London–Orsay–Paris–Saclay–Southampton–Strasbourg–Warsaw	Data-taking
NA34/2	Study of high energy densities over extended nuclear volumes via nucleus-nucleus collisions at the SPS	Brookhaven–CERN–Heidelberg–Los Alamos–Lund–Montreal–Moscow–Novosibirsk–Pittsburg–Saclay–Stockholm–Tel-Aviv	Preparation

SPS EXPERIMENTS IN 1985 (Cont.)

Experiment number	*Experiment*	*Collaboration*	*Status*
UA1	A 4π solid-angle detector for the SPS used as a proton–antiproton collider at a c.m. energy of 630 GeV	Aachen–Amsterdam–Annecy–Birmingham CERN–Harvard–Helsinki–Kiel–London–Padua–Paris–Riverside–Rome–Rutherford–Saclay–Vienna–Wisconsin	Data-taking
UA2	Study of antiproton–proton interactions at 630 GeV c.m. energy	Bern–Cambridge–CERN–Copenhagen–Heidelberg–Milan–Orsay–Pavia–Perugia–Pisa–Saclay	Data-taking
UA4	Measurement of the elastic scattering in the Coulomb interference region at the antiproton–proton collider	Amsterdam–CERN–Genoa–Naples–Palaiseau–Pisa	Completed 18.6.85
UA5/2	An exploratory investigation of proton anti-proton interactions at 800–900 GeV cm energy at the SPS collider	Bonn–Brussels–Cambridge–CERN–Stockholm	Completed 4.4.1985
UA6	An internal hydrogen jet target in the SPS to study inclusive electromagnetic final states and Λ production in $p\bar{p}$ and pp interactions at 24.3 GeV c.m.	CERN–Lausanne –Michigan–Rockefeller	Data-taking
UA7	Measurement by silicon shower detectors of the invariant cross-section of π^0's emitted close to zero degree	Japan–Naples	Completed 9.12.1985
UA8	Study of jet structure in high mass diffraction at the SPS Collider	U.C.L.A.	Data-taking
EMU01	Study of particle production and nuclear fragmentation in collisions of ^{16}O beams with emulsion nuclei at 13–200 GeV	Beijing–Jaipur–Jammu–LBL–Lund–Ottawa–Shanxi–Tashkent–Washington–Wuhan	Preparation
EMU02	Search for fractionally charged nuclei in high-energy oxygen-lead collisions	U.C. Berkeley –CERN	Preparation
EMU03	Interactions of ^{16}O projectile and its fragments in nuclear emulsion at about 50 and 225 GeV/c	Cairo	Preparation

LEP EXPERIMENTS in preparation in 1985

The ALEPH Detector	Athens – Bari – Beijing – CERN – Clermont-Ferrand – Copenhagen – Dortmund – Edinburgh – Egham – Frascati – Glasgow – Heidelberg – Innsbruck – Lancaster – London – Marseilles – Munich – Orsay – Palaiseau – Pisa – Rutherford – Saclay – Sheffield –Siegen – Tallahassee – Trieste – Wisconsin
OPAL Collaboration	Birmingham – Bologna – Bonn – Cambridge – Carleton – CERN – Chicago – Freiburg – Heidelberg – Israël – London (Birkbeck + QMC + UC) – Manchester – Maryland – Ottawa – Rehovot (Weizmann Inst.) – Rutherford – Saclay – Tel-Aviv – Tokyo
L3 Experiment	Aachen (I + III) – Amsterdam – Annecy – Beijing – Bombay – Budapest – CALTEC – Carnegie-Mellon – CERN – EIR Würenlingen – Florence – Frascati – Geneva – Harvard – Hawaii – Hofei– John Hopkins Univ. – Lausanne – Lund – Lyons – Madrid – Michigan – MIT – Moscow – Naples – Northeastern – Ohio State Univ. – Oklahoma Univ. – Princeton – Rome – Siegen – Yale – Zeuthen – Zurich
DELPHI	Ames – Amsterdam (NIKHEF) – Athens (Univ. + Nat.Tech.Univ.) – Belgium – Bergen – Bologna – CERN – Copenhagen – Cracow – Dubna – Genova – Helsinki – Karlsruhe – Liverpool – Lund – Milan – Orsay – Oslo – Oxford – Padoua – Paris (Coll. de France + LPNHE) – Rome – Rutherford – Saclay – Santander – Serpukhov – Stockholm – Strasbourg – Trieste – Turin – Uppsala – Valencia – Vienna – Warsaw – Wuppertal

PS EXPERIMENTS IN 1985

Experiment number	*Experiment*	*Collaboration*	*Status*
PS170	Precision measurements of the proton electromagnetic form factors in the time-like region and vector meson spectroscopy (LEAR)	Ferrara–Padua–Saclay–Turin	Data-taking
PS171	Study of $\bar{p}p$ interactions at rest in a hydrogen gas target at LEAR (ASTERIX)	CERN–Mainz–Munich–Orsay–Vancouver (TRIUMF)–Victoria–Vienna–Zurich	Data-taking
PS172	$\bar{p}p$ cross-sections and spin effects in $\bar{p}p = K^+K^-$, $\pi^+\pi^-$, $\bar{p}p$ above 200 MeV/c (LEAR)	Amsterdam–Geneva–London–Surrey–Trieste	Data-taking
PS173	Measurement of $\bar{p}p$ cross-sections at low $\bar{p}$ momenta (LEAR)	Heidelberg (MPI + Univ.) - Laval - Mainz - Rutgers	Data-taking
PS174	Precision survey of X-rays from $\bar{p}p$ ($\bar{p}d$) atoms using the initial LEAR beam	Amsterdam–Birmingham–Delft–Rutherford–Williamsburg	Data-taking
PS175	Measurement of the antiprotonic Lyman and Balmer X-rays of $\bar{p}$H and $\bar{p}$D atoms at very low target pressures	Karlsruhe	Data-taking
PS176	Study of X-ray and γ-ray spectra from antiprotonic atoms at the slowly extracted antiproton beam of LEAR	Basle–Karlsruhe–Stockholm–Strasbourg–Thessaloniki	Completed Dec. 1985
PS177	Search for heavy hypernuclei at LEAR	Amsterdam–CERN–Darmstadt–Grenoble–Orsay–Saclay–Uppsala–Warsaw	Data-taking
PS178	Study of antineutron production at LEAR	Cagliari–Padua–Turin	Data-taking
PS179	Study of the interaction of low-energy antiprotons with H^2, He^3, He^4, Ne-nuclei using a streamer chamber in a magnetic field	Bergen–Brescia–Dubna–Frascati–Oslo–Padua–Pavia–Turin	Data-taking
PS182	Investigations on baryonium and other rare $\bar{p}p$ annihilation modes using high-resolution π^0 spectrometers	Basle–Stockholm–Thessaloniki	Data-taking
PS183	Search for bound $N\bar{N}$ states using a precision gamma and charged pion spectrometer at LEAR	Athens–Irvine–Karlsruhe–New Mexico–Pennsylvania–Strasbourg	Data-taking
PS184	Study of $\bar{p}$-nucleus interaction with a high-resolution magnetic spectrometer	Grenoble–Saclay–Strasbourg–Tel-Aviv	Completed Dec. 1985
PS185	Study of threshold production of hyperon-antihyperon pairs in antiproton–proton interactions at LEAR	Carnegie-Mellon–Champaign–Erlangen–Freiburg–Houston–Julich–Saclay–Uppsala–Vienna	Data-taking
PS186	Nuclear excitations by antiprotons and antiprotonic atoms	Munich (Technical Univ.)	Data-taking
PS188	Measurements of channelling radiation and its polarization, X-ray excitation, together with deviations from Landau distributions	Aarhus–CERN–Strasbourg	Completed 19.8.1985
PS189	High precision mass measurements with a radiofrequency mass spectrometer – Application to the measurement of the proton–antiproton mass difference	CERN–Orsay	Preparation
PS194	Measurements of the ratio between double and single ionization of helium for antiprotons	Aarhus–CERN–Stockholm	Preparation
PS195	Test of CP violation with K^0 and anti-K^0 at LEAR	Athens–Basel–Fribourg–Liverpool–Saclay -SIN–Stockholm–Thessaloni–Zurich	Preparation
PS196	Precision comparison of antiproton and proton masses in a penning trap	Fermilab–Mainz–Washington	Preparation

SC EXPERIMENTS IN 1985

Experiment number	*Experiment*	*Collaboration*	*Status*
ISOLDE	ISOLDE programme	ISOLDE	Data-taking
IS 10	Determination of the mass of the electron-neutrino from experiments on electron capture beta-decay (EC)	Aarhus–CERN–Lund–Roskilde	Data-taking
IS20	Mössbauer studies of implanted impurities in solids	Aarhus–Groningen	Data-taking
IS30	PAC experiments at ISOLDE	Berlin–CERN	Data-taking
IS40	ABMR experiments at ISOLDE	Göteborg–CERN	Data-taking
IS70	Continuation of atomic spectroscopy on alkali isotopes at ISOLDE	CERN–Orsay	Completed 07.1985
IS80	Study of nuclear moments and mean-square charge radii by collinear fast-beam laser spectroscopy	Bombay–Göteborg–Mainz–CERN–New York	Data-taking
IS81	Laser spectroscopy at Z = 50	CERN–Darmstadt –Mainz	Data-taking
IS82	Multiphoton ionization detection in collinear laser spectroscopy of ISOLDE beams	CERN–Mainz–Troltzk	Preparation
IS100	Studies of stable octupole deformations in the radium region	Bergen–CERN–Chalmers–Mainz–Warsaw	Data-taking
IS110	Nuclear orientation studies and measurements of magnetic moments of radon isotopes proton-rich nuclei	CERN–Kingston–Mainz–Princeton–Zurich	Data-taking
IS120	Nuclear implantation into cold on line equipment	Bonn–CERN–Daresbury–Delft–Gent–Louvain–Lyon–Munich–Orsay–Oxford–Paris–Strasbourg	Preparation
IS130	High-precision direct mass determination of unstable isotopes	CERN–Mainz–Montreal	Preparation
IS140	Study of the beta-decay properties of extremely proton-rich nuclei	Aarhus–CERN–Copenhagen–Darmstadt–Gothenburg	Data-taking
IS150	Nuclear charge radii in the region of shape isomerism at Z < or = 80	Atlanta–CERN–Madrid–Mainz	Data-taking
SC65	Local magnetic fields in ferromagnetics studied by positive muon precession	CERN–Grenoble–Uppsala	Data-taking
SC68	Muonic chemistry in condensed matter	Parma	Data-taking
SC76	Impurity trapping of positive muons in metals	CERN–Geneva–Jülich–Uppsala	Data-taking
SC81	Formation and interaction of muonic in insulators and semiconductors	Parma–Rutherford	Data-taking
SC82	μSR in organic and free radical chemistry	CERN–Parma–Rutherford	Data-taking
SC83	Study of particle production in ^{12}C induced heavy ion reactions at 86 MeV/N	Bergen–Copenhagen–Grenoble–Lund–Saclay	Completed 02.1985
SC85	Element distribution and multiplicity of heavy fragments	Darmstadt–Heidelberg–Münster	Data-taking
SC87	Study of target fragmentation in the interaction of 86 MeV/N ^{12}C with tantalum, bismuth, and uranium	Berkeley–Oregon–Studsvik	Data-taking
SC92	Subthreshold production of neutral pions in heavy ion collisions	Darmstadt–Frankfurt	Data-taking
SC93	μSR measurements under high pressure and at low temperatures	Grenoble–Munich–Uppsala	Data-taking
SC95	Muons and muonium in molecular physics	CERN–Leicester–Rutherford	Data-taking

Experimental Physics Facilities Division

Neutrino Beam

Neutrino beam N1 was overhauled in 1985 for experiment WA79 (CHARM II). As well as the replacement and repair of radiation-damaged materials and equipment, a new horn was built to provide the optimum neutrino flux for WA79's running conditions. Also with the aim of obtaining optimum experimental conditions, the electric power supply was modified by the addition of a delay line to provide a rectangular current pulse in the horn and thus keep the current constant at 120 kA for 6 ms. This system is now operational.

Detectors For Fixed Target Experiments

BEBC

The Big European Bubble Chamber BEBC, which had completed its last physics run in summer 1984, was dismantled in 1985 to free the BEBC hall for pre-assembly and testing of components for the LEP experiments Opal and Aleph. BEBC material was, as far as possible, re-used at CERN or sold for re-use by others or as scrap.

A particular problem was posed by the cryogenic liquids having served as working fluids in the chamber (hydrogen, deuterium and neon-hydrogen mixtures). The most valuable of these, deuterium, was reconverted to heavy water by combustion in a catalytic 'burner' provided by industry. Such conversion to an easily storable and transportable liquid is, unfortunately, not possible for neon and not of commercial interest for hydrogen, but it is hoped that all these liquids will nevertheless find buyers in 1986.

It is noteworthy that the total loss of deuterium during the entire operation period of BEBC was of the order of 6%, which is very low, considering the complex operations undertaken during eight years (electrolysis, many transfers, use in a large bubble chamber in extended runs and finally reconversion to heavy water).

The main survivor of the BEBC complex is the large helium refrigeration plant. It will be used for testing the Aleph superconducting magnet and for studies of two-phase liquid helium flow, one of the major problems encountered in extended superconducting systems such as superconducting accelerating cavities or magnet strings in particle accelerators.

Omega Spectrometer

The Omega spectrometer is made up of a set of wire and drift chambers in and around the 1.8 tesla field of a superconducting magnet, and of Cherenkov counters and counter hodoscopes, all backed up by powerful software for event reconstruction.

Two collaborations made use of the Omega facility in 1985 for taking data with high statistics:
WA69: photo-production in the energy range from 70 to 200 GeV, and
WA70: study of direct photon events in hadronic collisions.
WA70 complemented the basic spectrometer with their electromagnetic calorimeter, while WA69 used this calorimeter and their Ring Imaging CHerenkov counter (RICH).

The Omega facility with its wire chambers, electronics and read-out systems has proved to be very reliable these last years, so that the Omega group has been able to tackle other problems of experimental apparatus. For the RICH, constructed by the Rutherford–Appleton Laboratory, a recirculating gas system was constructed which kept water vapour and oxygen at ppm levels and controlled the chamber pressure with a precision of 0.1 mbar. Possibilities for the focussing of drifting electrons in the RICH were studied, and a practical focussing system was installed on the central chambers.

Since late summer 1985, the group has accepted some responsibility for the transformation of the apparatus of the European Muon Collaboration into the set-up of experiment NA37 (detailed measurements of structure functions from nucleons and nuclei).

The Omega electronics group participated in development work for other detectors; their work is described under the heading Detector Developments.

European Hybrid Spectrometer EHS and Experiment NA36

Many of the EHS spectrometer detectors, including magnet M2 but excluding ISIS and SAD, have been rearranged behind superconducting magnet M1 along beam line H2. An active target and a TPC now under construction will be installed in M1. This experiment, approved as NA36, will use a light ion beam in November and December 1986 and later in the spring of 1987 to study baryon and strange anti-baryon production.

The bubble chamber LEBC

During the first four months of the year, the rapid-cycling LExan Bubble Chamber LEBC developed and built by EF Division in earlier years was installed and tested as the vertex detector of the Multiple Particle Spectrometer MPS at the Fermi National Laboratory, USA, for experiment E743 (charm production in proton–proton interactions at 800 GeV/c beam momentum). Data-taking started on 5 May, less than one year after LEBC completed data taking for Experiment NA27 at CERN.

The run ended on 27 August when the Tevatron finished 1985 operation for fixed-target physics. During this period LEBC took 1.26 million pictures with 75 bubbles per centimetre and a bubble diameter of 22 micrometres.

Experiment NA31

In 1985 the large liquid argon photon calorimeter designed and constructed by EF Division for Experiment NA31 came into service. This shower detector measures some 2.4 m $\times$ 2.4 m across the incident photon direction and extends 0.6 m, or 25 radiation lengths, in depth.

The calorimeter has a fine structure of 80 cells, each having walls of 1.5 mm lead thinly clad with aluminium, with a 5 mm gap filled with liquid argon. The readout electrodes are placed centrally in these gaps. Readout plates for X and Y co-ordinates are made as double-sided printed-circuit boards with 11.3 mm wide strips; the 1.2 mm spacing between strips was obtained by an etching technique. X and Y readout plates alternate from cell to cell. Corresponding X and Y strips are longitudinally connected together, but the front and rear halves of the calorimeter are separated, to facilitate photon/hadron distinction. The readout strips are operated at a voltage of 2 kV with respect to the lead plates, which are at ground potential. Each longitudinal group of readout strips forms a channel, and is connected via a low-impedance flat cable to the room-temperature pre-amplifier sited on top of the cryostat. There are 1536 channels, whose signals, after amplification, are transmitted by twisted pair cables to the control room some 30 m away.

A fast trigger signal is provided by a scintillator plane with wavelength-shifter readout, inserted between the front and rear halves of the calorimeter. The associated photomultipliers are placed outside the cryostat near to the preamplifers, and the light signals are transmitted to them by acrylic light guides.

The calorimeter is housed in a cryostat which for reasons of space is in the form of a rectangular box whose flat double walls of many square metres area must withstand the differential forces between the insulating vacuum and the pressure generated by the hydrostatic head of the liquid argon and the overpressure in the gas above. Since the particles to be measured must pass through these walls, it was essential to keep to a minimum the material used for them. With industrial collaboration, structures were developed to fulfil these conflicting requirements with a material thickness corresponding to 0.7 radiation lengths.

The cooling system consists of two liquefiers each able to extract 1 kW at 80 K, plus an emergency system drawing liquid nitrogen from a storage dewar. No major faults occured during the experimental period of four months with the calorimeter continuously operational. The energy resolution was found to be 8% divided by the square root of the energy in GeV, and the spatial resolution around 2 mm, both in agreement with design figures.

Experiment NA34 (HELIOS)

Experiment NA34 (HELIOS) is designed to measure lepton production in proton-nucleus collisions at the SPS with a high degree of precision. It is intended to use a 450 GeV proton beam 30 micrometres in diameter interacting in a target consisting of a wire 50 micrometres in diameter and 20 mm long. HELIOS will use an electron spectrometer, a muon spectrometer and several calorimeters.

EF Division is responsible for the development and construction of:

- the 'target' area, involving a beam hodoscope (silicon micro-strip), a micro-target/beam servo-system and an active target;
- three drift chambers and high-resolution vertex detectors (DC1–DC2–DC3) associated with the electron spectrometer;
- the electronic equipment associated with a 400-component silicon pad detector.

By means of a dipole magnet inserted between DC1 and DC2, the drift chambers measure the momentum of secondary particles. Using a set of silicon micro-strip detectors, DC1 also contributes to reconstructing the interaction vertex. The chamber design was optimised to ensure both excellent spatial resolution (50 micrometres after 10 mm of drift) and the best possible spatial separation of two consecutive tracks (600 micrometres) at a rate of 10^5 interactions per burst. The performance was measured in 1985 on various prototypes and with drift chamber DC1. These results are obtained by using projection geometry improved by (a) a 'slow' gas (carbon dioxide, 10 micrometres per nanosecond), (b) limited primary ionization collection (focussing geometry), (c) fast signal shaping (20 nanoseconds) and (d) highly accurate positioning of the sensitive wires. The acceptance of the drift chambers corresponds to a production cone of 6°. There will be a maximum of 118 measuring points over a 3-metre track length, distributed in 5 projections: 0°, 15°, +45°, −45°, and 90°. The assembly comprises 1400 measuring and 16000 field wires. One chamber, DC1, is operational, while DC2 and DC3 will be available in February and May 1986 respectively.

The silicon pad detector measures the charged multiplicity of events used for rapid decision (less than 100 ns) and is required to show whether one or two particles have passed any component affected. This information makes it possible to distinguish between a single electron emitted from the target and an electron pair (Dalitz conversion) and consequently to reject the pairs in an on-line decision (less than 10 microseconds). A correlator has been built to identify a 'single electron' candidate on the basis of the data from various detectors, i.e. the electromagnetic calorimeter, the transition radiation detector and the silicon pad detector. This fast identification is made possible by the segmentation of different detectors defining routes leading towards the microtarget.

Detectors For Proton–Antiproton Collider Experiments

The proton–antiproton collider experiments UA1, UA2, UA4 and UA5 have been taking data from time to time since the second half of 1981.

Having in the past been involved in the design, construction and operation of the various detectors, EF Division is now participating in the respective upgrading programmes of experiments UA1 and UA2.

Experiment UA1

The detector of experiment UA1 consists of a cylindrical drift chamber in a magnetic field of 0.7 tesla, around which is a lead-scintillator calorimeter for electromagnetic shower detection ('gondolas'). Hadron calorimetry is integrated into the magnet yoke; large planar drift chambers and newly built Iarocci chambers at the outer circumference of the detector serve for muon identification. With calorimetry in the forward and very forward directions the detector covers almost the full solid angle, making it highly suitable for the detection of missing energy.

At the end of 1985 the UA1 detector has completed its fifth year of proton–antiproton running. EF Division is deeply involved in four major aspects of the improvement program:

- Central detector
- Calorimeter upgrade
- Data acquisition system
- Engineering and mechanical support.

In March the central detector, a true imaging chamber with the high spatial resolution necessary for the complex events in proton–antiproton collisions, was exposed for the first time to the 450 + 450 GeV beams attainable with the new ramping mode of the SPS collider magnets. In close cooperation with SPS Division, the UA1 team assured stable operation of the detector, which, in spite of some difficulties with background successfully completed the run. In the summer the detector was prepared for the autumn collider period (at 315 + 315 GeV continuous), the longest ever experienced by the group. During this period the engineering and mechanical support of EF Division was greatly appreciated, when another novelty to this experiment, the microvertex chamber, had to be installed in the central detector. Because of this dedicated help from strongly committed and motivated people the UA1 installation schedule did not slip by a single day.

In parallel to these hardware activities other members of the UA1–EF team worked on the improvement of the data acquisition, since the higher luminosities tend to increase the event rate beyond the data handling capacity. In September 1985 a new, VME-based acquisition program combined with a double-buffering scheme in the data flow came into operation. This new system allows a tenfold increase in the data rate, simultaneously reducing the overall error rate in data processing by a factor of three. By the time the run is finished, the UA1 detector will have collected more than 350 inverse nanobarns despite a three and a half week break in the run when the microvertex chamber was removed.

All this improvement work together with the maintainance of an excellent standard of detector operation has led to a high degree of reliability and efficiency, adding to our family of W and Z particles other new and exciting physics prospects.

1985 is also a step into the future of UA1. The approval of the calorimeter upgrade by the SPS Committee in November has encouraged a new line of instrument research in the field of warm liquid calorimetry. Following the proposal for a uranium calorimeter, it was convincingly shown that room temperature liquids such as tetramethyl-silane (TMS) and 2, 2, 4, 4-tetramethyl-pentane (TMP) can be used as active media for ionization instead of the well-known and widely used liquefied noble gases. Most of the effort was spent in extending the 'lifetime' of drifting electrons by means of an elaborate purification of these liquids. Only then would sufficient charge be seen by the sensitive preamplifiers necessary in such a device. Figure 1 shows pulses observed with a set of TMP-filled cells and metal plates exposed to a beam of electrons and muons.

In view of the five to tenfold increase in proton–antiproton luminosity which will be provided by the new antiproton collector (ACOL) due to operate in late 1987, the central detector team, besides assuring the current physics program, is seeking new methods for the safe operation of the detector at the higher background levels to be expected. Special tests of laser calibration have already begun, to cope with field distortions caused by a high accumulation of space charge. It appears that the only way to map these distortions is by means of straight (infinite momentum) tracks, which directly measure the sagitta errors. A high concentration of background charge multiplied by the wire gain (10^5) will also inexorably effect the long term stability of the chamber and reduce its life. This ageing phenomenon is presently under much debate. A systematic investigation has therefore been started to study the effect of radiation damage to wire chambers. These results will help to assess the possible dangers of operating the central detector in the ACOL era. In the event that the wire chamber amplification has to be reduced (for the above reasons), 12 000 preamplifiers will need to be modified to compensate for the loss in gain without significantly degrading the design performance of the detector, and this problem also is being investigated.

Experiment UA2

Up to the end of 1985, the detector system of experiment UA2 consisted of a cylindrical vertex detector (four proportional and two drift chambers and a preshower detector), surrounded by a highly segmented 'central' calorimeter (lead-scintillator and iron-scintillator stacks for the electromagnetic and hadronic shower components, respectively). The forward and backward cones were equipped with magnetic spectrometers (toroidal magnets and drift chambers) and electromagnetic calorimeters.

The improvement programme, approved in 1984 by the Research Board, is designed to cope with the increase in luminosity of the proton–antiproton collider expected in 1987 with the start-up of the new Antiproton COLlector ACOL.

The upgrade consists essentially of the replacement of the present forward-backward spectrometers by two segmented calorimeter end-caps (lead-scintillator and iron-scintillator sandwiches for electromagnetic and hadronic showers), largely improving the solid angle coverage for the calorimetry, and of the complete redesign of the present vertex detector.

Improved electron discrimination will be achieved in the new vertex detector by the use of two cylindrical transition radiation detectors and of a 3024-element silicon counter array. Precise tracking — within the severely restricted radial space available — is obtained by a mini-vertex chamber, and — around the transition radiation detectors — by a scintillating fibre tracking and pre-shower detector consisting of 60 000 fibres arranged in 24 cylindrical layers.

Technical support by several EF groups for the upgrade programme mainly concerns the following items:

- the image intensifier and CCD (Charge Coupled Device) readout system (32 read-out chains) of the scintillating fibre detector,
- the silicon counter array (1 m^2),
- the control systems of a scanning table for the calorimeter modules and of the end-cap support chariot movements,
- the high-voltage system for the end-cap calorimeters,
- a 100 MHz Flash Analog-Digital Converter (FADC) system for the readout of the mini-vertex chamber and of the transition radiation detector.

These FADCs have already been used during the 1985 UA2 run for the readout of the existing vertex drift chambers, in order to improve their multitrack resolution.

All these activities are performed in very close collaboration with EP Division and with outside members of the UA2 Collaboration.

Experiment UA5/2

Experiment UA5/2 provides for fast visual examination of highly complex events taking place during proton–antiproton collisions in the SPS.

The detector consists essentially of two large streamer chambers 6 m long, a set of triggering hodoscopes and six stereoscopic cameras which photograph the chambers via image intensifiers.

The UA5 detector, which took its first photographs in 1981, has been reinstated for the purposes of observing the 450 + 450 GeV proton–antiproton collisions produced in March/April 1985 by the SPS collider operating in the pulsed mode.

During this period the detector took 115 000 photographs which are now being analysed in the collaboration's five laboratories.

After the data-taking, the detector was withdrawn from experimental area LSS4 and dismantled.

Lepton Asymmetry Analyser

In the context of exploratory work concerning Proposal SPSC 84-33/P200 (installation of a Lepton Asymmetry Analyser, LAA, at the SPS collider), the installation of such a device in the UA1 area is being investigated.

For this purpose two muon spectrometers have been built and installed in the forward region, one on the proton and one on the antiproton side. The spectrometers have operated satisfactorily since the beginning of the collider period in September 1985, and data from about 50 000 events have been accumulated.

Each arm of the spectrometer consists of three 2.5 tonne C-shaped iron toroids magnetised to 1.7 tesla, eight time-of-flight counters, 28 finger counters, four veto counters and four drift chambers with 27 sense wires per chamber. They are installed at 7.5 degrees from the beam axis and cover the pseudo-rapidity range from 2.6 to 3.0 and azimuthal angles from -10 to $+10$ degrees.

When triggering without a transverse-momentum cut on particles crossing the whole spectrometer (1.5 m of iron), the measured rates at a luminosity of 2.10^{29} cm^{-2} s^{-1} are:

incoming proton side: 0.11 Hz $+/-$ 0.01 Hz;

incoming antiproton side: 0.30 Hz $+/-$ 0.01 Hz.

Using in addition the UA1 minimum bias signal, the measured rates remain the same on the proton side and are reduced to 0.16 $+/-$ 0.01 Hz on the antiproton side. These results show that the halo of the proton beam in the collider is eliminated by timing. On the antiproton side, the halo coming from the proton beam is eliminated by directionality.

All the trigger rates observed fit the expected values calculated by Monte Carlo methods. When a transverse-momentum cut is imposed, the trigger rates are reduced by about two orders of magnitude.

Extrapolation of these results for the experimental conditions expected when ACOL comes into use (design luminosity 4×10^{30} $cm^{-2}s^{-1}$) indicates that the final LAA project will meet the requirements of UA1.

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),

OPAL (Omni-Purpose Apparatus for LEP),

L3 (Letter of intent number 3), and

DELPHI (DEtector with Lepton, Photon and Hadron Identification).

ALEPH and OPAL are sometimes referred to as classical experiments, because their layout conforms to some extent with trends at existing colliders. ALEPH plans to use a time projection chamber as the central detector and a lead and wire-chamber sandwich calorimeter as the electromagnetic shower counter, the two surrounded by the superconducting coil of the magnet, whose iron yoke is equipped with Iarocci tubes and which doubles as a hadron calorimeter. In OPAL, the central detector will be a cylindrical drift chamber and the electromagnetic shower counter a lead-glass calorimeter, with the coil of the magnet in the annular space between them.

L3 emphasises accurate tracking and high precision in energy measurement of leptons, aiming at a mass resolution better than 2% in dilepton final states. Notable features of this experiment are the enormous size of the magnet and the muon detectors, and the envisaged use of a calorimeter incorporating 12 000 bismuth germanate (BGO) crystals for electromagnetic shower detection.

DELPHI proposes to employ the novel technique of Ring Imaging CHerenkov counters (RICH) for better hadron identification. The RICH detectors will be installed around the central detector, a time projection chamber. A High-Density Projection Chamber will serve for electromagnetic calorimetry. All these detectors are mounted inside the superconducting magnet coil.

EF Division is, together with EP and other divisions, involved in all four experiments, and the two divisions are jointly developing and constructing particular components. EF Division is, in particular, providing general technical support, such as co-ordination of detector design, preparation of the CERN infrastructure, elaboration of the installation programme, study of safety questions, and so on. A LEP interface group was formed in EF early in 1984 with particular responsibility for all installation problems concerning these experiments.

ALEPH experiment

EF Division is involved with CEN, Saclay, in work connected with the cryogenic system of the superconducting magnet. Together with EP Division and a large number of laboratories in the collaboration, it is examining the structure of the magnet iron and the development of the prototype central detector TPC. One of EF's special interests is the field cage producing a highly uniform electrostatic field throughout the TPC volume.

The central part of the magnetic circuit, the 'barrel', has been fully assembled at the works. Delivery of the 24 modules will begin on 6 January 1986; they are to be fitted up as avalanche tubes ('Iarocci tubes') prepared by the Italian members of the collaboration.

Tests on the prototype TPC 90/2 have been continuing and have made it possible to demonstrate and eliminate certain problems in detector construction in Munich (MPI). The detectors are being series-produced and good progress is being made.

Tests on winding the TPC electrostatic cage have been performed and winding has started.

The final development of the digitization circuits is virtually complete and these circuits are ready for industrial quantity-production.

The electronics huts have been ordered and half of them delivered and fitted with their water and electricity supplies. They are ready to house the racks, half of which have arrived at CERN, a quarter of them fitted out and ready for the FASTBUS modules.

The drawings for the cooler support have been made.

The specifications for the fire-detection installations and extinguisher systems in the huts and electronic racks have been drawn up and a call for tenders has been issued.

Experiment OPAL

Contributions by EP and EF Divisions to Opal during 1985 have included the full responsibility for the construction of the magnet iron yoke and coil, engineering and construction of the Jet detector in collaboration with German and Canadian institutions, and engineering and assembly work of the electromagnetic lead glass barrel calorimeter.

For the magnet the provisional assembly of the first half of the iron yoke has been completed by industry; delivery to CERN will start at the beginning of 1986. The main parts of the coil winding machine have been delivered to CERN. Preparatory work for the winding of the coil has continued according to schedule: the complete coil is expected to become available by the end of 1986.

All the main orders for the mechanical parts of the Jet detectors have been placed. The design of the tooling system for handling the Jet detector has been completed and the tendering procedure has started. In parallel to the construction of the Jet detector the corresponding full size prototype has been used for studies aiming at the definition of an optimal set of operation parameters to ensure the best possible detector resolution.

Concerning the lead glass calorimeter, the construction of which is largely taken care of by Japanese members of the collaboration and industry, series production has started of all elements both for the lead glass counters and for the complex 'pointing geometry' mechanical support structure. Delivery of a significant fraction of these elements started in early 1985 and assembly of counters in module elements has already been performed on a large scale. The design and construction of the large calibration stage has been completed; it is expected to reach CERN by end of January 1986.

Experiment L3

In 1985 manufacture started of most of the various L3 detectors. At the same time the installation scheme was studied in detail and major improvements introduced to match the installation program to the available time between gaining access to the underground area and the

LEP beam start-up. EF continued to furnish a technical support team for L3 with design and construction responsibilities in the fields of general engineering, infrastructure, safety and installation as well as for the magnet, the support tubes and the BGO detectors.

Infrastructure studies

The design of the general equipment in the L3 pit PX24 and the underground area was frozen for many important items, in particular for the lifts and stairs, the gangway system and the shielded counting houses close to the L3 detector. Considerable progress was made in finalizing the layout of the ventilation system, the pressurized reception areas for personnel access and many other details. The system using four or five stacked counting houses in the pit was studied, a specification prepared and a call for tenders sent to some 40 firms. The order will be placed in Spring 1986.

Magnet construction

The construction of the 336 'half-windings' for the big water-cooled magnet of L3 in hall 867 was terminated on schedule in mid November. The 1000 t of aluminum conductor and the special welding equipment will soon be transported into the recently finished assembly hall SXL2 at LEP point 2, close to the access shaft for the future underground experimental area of L3. The iron yoke of the magnet is composed of 1100 t of precision welded and machined pole elements, filled with 4500 t of steel from the Soviet Union. The delivery of this steel, flame-cut from cheap 40 or 50 mm thick plates and pre-assembled in suitable packages in plants near Moscow and Novosibirsk, proceeded throughout the second half of 1985 as planned; now almost 50% of the total quantity is stored on a CERN parking-lot. The manufacture of the pole elements was sub-contracted by L3 in spring 1985 to a Swiss company using plates rolled in France. All plates were delivered to Zurich this summer and the construction is progressing well, closely monitored by EF technicians. Another contract will be placed for the preparation and installation of the cooling lines for this magnet; a preliminary consultation with industry took place this spring and now the final tender action is under way. Design work is currently concentrating on the power supply, a cooled radiation screen to stabilize the temperature seen by the sensitive detectors in the magnet, the system of magneto-resistors for the field monitoring and the general operation monitoring using a VME-based microprocessor.

Magnet assembly and detector support tube

Because of lack of manpower, the assembly of the 6600 t magnet for L3 will have to be sub-contracted to a specialized firm. After a careful study of the sequence of operations a detailed specification has been prepared and 50 European firms were contacted in September, and more than 20 offers received; the selection of the best proposal is under way in order to allow at least 1 year of preparation to the successful bidder, before assembly starts in May 1987. All the L3 detectors will be mounted on a 32 m long, 4.5 m diameter support tube. After finite-element calculations of the stresses and a detailed study of the detector installation, it was possible to simplify the design of the support tube considerably. The project includes now also the so-called torque-tube, cylinders to which the muon chamber octants will be attached and with which they can be moved along the support tube into the magnet or rotated around it for easier loading. In order to save critical installation time in the underground area, it was decided to assemble the support tube on the surface and to lower it down the pit as one piece using a heavy crane. The drawings and specifications for the support tube were finalized in autumn and a call for tenders sent to more than 70 firms.

Beam tests

The EF team organized and supported the beam tests carried out by the different L3 detector groups in the X3 beam of the CERN West Experimental Hall, comprising systematic studies on a

10 × 10 matrix of BGO crystals for the barrel detector, 3 sectors of the luminosity monitor with 57 narrower BGO crystals, 1 module of the hadron calorimeter and various protoypes. Valuable information was obtained concerning the optimisation of the read-out system, the possibilities of an on-line calibration and also concerning the importance of gaps between crystals.

BGO work

The L3 project has now placed orders in China for the bulk manufacture of BGO crystals. In 1985 some 2.5 t of germanium oxide and 3 t of polycrystalline BGO were handled by EF as part of the crystal production process. Facilities for materials handling and for reception testing of crystals have been established in building 27, including an automated spectrophotometer for the rapid measurement and analysis of light transmission properties of crystals. Two examples of this machine ordered by the BGO crystal manufacturer in Shanghai for quality control during production have been built and delivered and are in use.

Muon chamber assembly at CERN and gas system work

The assembly space given to L3 in hall 867 was extended and a clean area was created for the assembly of the L3 muon chambers. The first 2 precision drift chambers were assembled and other chambers and stand components received from Holland, Spain and the USA. The EF team helped with infrastructure work and, being in charge of the final gas system, provided prototype gas systems, ventilation and leak detection for testing the new chambers.

Installation program

A careful examination of the L3 installation program showed clearly that the time available in the LEP machine planning for the fitting-out of the pit and underground area, and for the assembly of the magnet, the support tube, detectors and beam elements (18 months) was far too short. As a result of a study carried out by a consultant firm, L3 requested that the construction work for the L3 area be decoupled from the tunnel building early enough to gain 9 months, and offered to finance for this a third access shaft. The proposal was accepted by the LEP management, but a gain of only 6 months could be achieved. However, by simplifying the support tube design and by planning its assembly at the surface before its installation underground, by carefully organizing the sequence of parallel installation work and by staging some of the L3 detectors (BGO end caps in particular) a realistic installation program was achieved, compatible with the 2 years available between the end of civil engineering at point 2 end 1986 and the planned start of the LEP operation at the beginning of 1989.

Experiment DELPHI

EF Division is working on the ‘end cap’ sectors of the Time Projection Chamber (TPC) which will serve as the DELPHI central detector, on the cylindrical part (‘barrel’) of the RICH and on the cylindrical part (‘barrel’) of the electromagnetic calorimeter, a High density Projection Chamber (HPC). The division is also involved in the cryogenic system for the superconducting magnet.

Prototype work for the TPC sector plates, including further beam tests concerning the circular arrangement of cathode pads and gating efficiency, has been completed. Series production has started, and the first of twelve sector plates is close to completion.

For all three levels of the TPC trigger, many details have been finalised after hardware tests and software simulation. Block diagrams, control schemes and software were defined both for the development of the integrated circuits (gate arrays) and for the control logic (bit slice processor). The design of the gate array prototype is currently being implemented in a CMOS multiproject chip.

The prototype of the Barrel RICH—containing three full-length drift tubes—has given the number of photoelectrons in the gas and liquid radiators which was anticipated in the Technical proposal. Numerous studies were carried out in parallel with these beam tests. Field distortions, edge effects, and electron capture due to freon contamination have been studied in detail in a special test system using single electrons produced by an ultraviolet laser. The complete order for quartz plates was placed, and UV transparency was checked on the first samples. The problem of TMAE stratification has been clarified (TMAE = tetrakis-dimethylamine ethylene, the photo-ionizable additive used in RICH drift chambers). The apparatus for measuring outgassing of materials is operational. First tests with the wound Mylar high-voltage insulator were successful. As a result of these tests, the detailed design of the Barrel RICH has been completed.

Development and construction work in preparation of the HPC production continued through the year. A spooling system to store the large quantity (4000 km) of lead wire required was brought into operation. A production machine for the continuous fabrication of lead ribbon was designed and run in; this machine glues 60 lead wires with high precision onto a fibreglass epoxy substrate. It operates at a production rate of typically 1 m of ribbon per minute. Three of these machines will be used during the production phase.

A full scale prototype of the final HPC design was tried out in test beams at DESY and at CERN. These tests concerned energy resolution, charge attenuation length with and without magnetic field, response to minimum ionizing particles, and electron-pion separation.

A new analog pulse processor for signals from multi-wire proportional chambers was developed. It uses a simple integrator/differentiator network to suppress the 1/t tail of these signals to a 'permille' level. Pulse formation down to 10 ns full width at half maximum (FWHM) is feasible without undershoot.

A pilot project on electronic CAD/CAM has been carried out in collaboration with DD and EP Divisions. Schematic diagrams were prepared, and two CAMAC boards were designed, which are now operational. The project clearly demonstrated the power and usefulness of the CAD technique, especially for FASTBUS developments.

A FASTBUS prototype data acquisition system is being assembled around modules partly developed in the Delphi group, such as the General Purpose Master (GPM) and the FASTBUS Diagnostic Module (FDM). This system will be controlled by a 'microVAXII' In parallel, a 3081E emulator provided by DD Division was installed and its control software adapted to a VAX environment. Interfacing to FASTBUS is underway.

The layout of the infrastructure has been defined in detail. Work on full-scale models for cabling, piping, and detector compatibility is continuing. The cryogenics system for the solenoid was finalized in collaboration with the Rutherford–Appleton Laboratory, and tenders have been received.

DELPHI contains an unprecedented number of different detector components and therefore gas systems. Standardization and high reliability are mandatory. A prototype gas system and its microprocessor control have been constructed.

Technical Support for the Construction of the LEP Machine

EF Division is engaged in many activities in connection with the construction of the LEP machine:

Automated field measurements on selected bending magnets;

Development of automated surveying instruments;

Assembly and adjustment of the special low-field bending magnets and injection magnets;

Preparations for supervisory work concerning the beam vacuum system and the magnet bus-bar connections and cooling systems, following the installation of the bending magnets in the LEP tunnel starting in 1987;

Supervisory and other work at the various sites around the LEP ring;

Responsibility for the monorail transport in the ring;

Assistance, including electronics development work, to various projects in the LEP instrumentation group;

Assistance in the development and application of the technique for the lead shielding of the vacuum chamber;

A major effort goes into the development of superconducting RF cavities, whose use could increase the beam energy of LEP to much higher values in later phases of the project.

The total divisional manpower engaged in these activities is in excess of 100 people.

Automated survey instruments

An EF/LEP team is now working on the automation and improvement of several survey instruments needed for the building of LEP.

CERN has developed the DISTINVAR, an instrument capable of measuring distances from 0.4 to 50 m with a resolution of a few micrometres. A batch order was placed with a European firm which delivered the last of the fifteen instruments ordered in December.

This group designed an automatic gyroscopic theodolite capable of indicating geographic north with an accuracy of 10 seconds of arc, and three of these instruments have been made at CERN. It is now in use in piloting the boring of the LEP tunnel.

A self-contained, portable land computer based on the use of a powerful micro-processor has been developed. It collects the data provided by survey instruments, and a dozen will be produced in collaboration with industry.

A self-contained, portable terminal with graphic display and a touch screen is now being developed. It will be used for dialogue with the land computer.

Superconducting Accelerating Cavities

Activities in 1985 have been concentrated mainly on the prototype cavities for LEP. A four-cell 350 MHz cavity fabricated from niobium sheet material of improved thermal conductivity has been successfully tested; long term operation (more than 2000 hours) at an accelerating field of 7.5 MV/m and a quality factor in excess of 3×10^9 was possible without major problems. Such values for the field and quality factor substantially exceed the design values upon which plans for a first upgrading of the LEP machine are based. No degradation of the quality factor Q was observed in the test.

Single-cell 500 MHz copper cavities with a sputtered niobium layer a few micrometres thick have yielded fields above 10 MV/m and quality factors comparable to those of niobium sheet cavities (a few times 10^9). A four-cell cavity of this kind for LEP is in preparation.

A model has been built and tested of a simple and economical design of cryostat providing ready access to all the vital parts such as couplers, tuners and beam tube connections.

High power radio-frequency couplers have been constructed and tested on a superconducting cavity powered by a 60 kW RF tetrode. Development work is in progress on higher order mode couplers and frequency tuners; facilities for electron-beam welding with an internal gun, for chemical treatment of large four-cell cavities, and for dust-free rinsing and assembly have been developed and set up.

Cryogenics

Cryogenic activities in EF Division are very widespread, covering operation of cryogenic detectors and superconducting detector magnets (Omega, experiments WA75, WA78 and NA3), cooling of polarised targets, development of cooling systems for LEP detector magnets, studies and technical support for the cooling of superconducting cavities, participation in tests involving cryogenic techniques of all kinds, production and procurement of cryogenic fluids and participation in theoretical studies for future superconducting accelerators.

West Area helium refrigeration

The superconducting detector magnets for Omega and for experiments WA75 and WA78 were in service during the SPS fixed-target run.

The BOC refrigerator, which in the past was used for the cooling of a superconducting RF separator at 1.8 K, was revived and used for the development of superconducting RF accelerating cavities for LEP. In the second half of 1985, this plant ran for more than 2000 hours in a first 4-cell prototype cavity test for LEP.

The screw compressor installed in the West Hall was connected to a modified 400 W cold-box of the standard 'North Area' type. This installation is now used as a pilot plant for studies on microprocessor control of refrigerators for LEP experiments.

North Area helium refrigeration

The superconducting dipole magnet of experiment NA34 and the polarized target used in experiments NA2/NA9 were cooled for fixed target physics.

In the second half of 1985, when the SPS operated in collider mode, the cold-box for the polarized target was removed from Hall EHN 2. With the rearrangement of the EHS detectors for experiment NA36, the cold-box for the EHS magnet was moved to a new position inside Hall EHN 1. The vertex magnet used in experiments WA75/WA78 was moved from the West Hall to Hall EHN 1, where it will serve for experiment NA35. Reinstallation of corresponding cryogenic equipment is under way.

Helium refrigeration for LEP experiments

After extensive technical studies, a technical specification was drawn up for a multi-purpose helium refrigerator suitable for simultaneous cooling of a superconducting solenoid magnet for a LEP experiment and for a set of superconducting quadrupole magnets forming a so-called low-beta insertion in the LEP lattice before and after beam intersections. This specification was submitted to industry, and tenders were received in November.

Central Services

Central helium liquefiers reliquefied about 17 0000 litres of helium. About 1.9 million litres of liquid nitrogen were purchased from outside suppliers and delivered to the users.

Detector Developments

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

Silicon detectors and microelectronics

Most effort has been concentrated on the installation of the 1 m^2 silicon array for experiment UA2. Because of manufacturing problems the detector supplier cannot meet the original delivery schedule. Extensive testing is required to identify the sources of the problems, and CERN asked external research institutions for help. The findings helped to improve the reliability of the detectors.

Preparations were also started for a new silicon detector telescope in the Omega spectrometer, to be used by experiment WA76 (ext). One development, notable in this context, has been the miniaturized support structure for a 1000 strip silicon detector.

A fast (100 ns) low-noise (800 electrons RMS) preamplifier has been developed in collaboration with INFN, Milano, and is now commercialized by industry. It is used by experiments WA76 and E687 (Fermi National Laboratory, USA).

Practical training in the use of microelectronics techniques was organized with the Inter-University Micro-Electronics Center IMEC in Belgium. Participants from EF, EP, DD and LEP Divisions are preparing a few pilot projects, to be produced as chips by IMEC.

High-density digitization modules for FASTBUS

In the context of participation in the Omega, UA2 and OPAL experiments, two FASTBUS standard high-density digitization modules have been built. The first, GATHER, a Flash Analog-Digital Converter (FADC) with a sampling frequency of up to 100 MHz, was brought into use at the beginning of August on the UA2 vertex detector. The 640 channels were produced and commissioned in collaboration with INFN, Pisa, Italy. The system made it possible to double the detector's double-pulse resolution when it was re-started at the beginning of September.

The second, CIAFB, a charge integration converter with a 15-bit dynamic range, 12 precision bits and 96 channels, is now being assessed by the experimental groups in the OPAL collaboration. The cost price per channel will be very low, and it will be possible to sub-contract 90% of the manufacture to industrial firms in CERN's Member States.

Holographic recording of particle tracks

Tests of holographic recording of particle tracks, based on earlier experience in BEBC, continued during a technical run of the 15-foot bubble chamber at the Fermi National Laboratory, USA, at the end of 1984. A five month physics run in 1985 at the Tevatron in a wide-band neutrino beam (800 GeV protons on target) followed. An European-American-Indian collaboration will process the useful holograms on newly-built measuring machines at the Rutherford–Appleton Laboratory, Hawaii and Rutgers.

Film Processing, Scanning, and Measurement

The EF Division film processing service was formally closed down at the end of 1985, having developed some 40 000 km of film from all manner of optical detectors using film, such as bubble, spark and streamer chambers. Basic facilities will be kept in operational condition for emergency use. In 1985, 550 km of film from the bubble chamber LEBC (Experiment E743), and from the LEAR streamer chamber experiment PS 179 were developed, while help was given to experiment NA35, scheduled to take pictures in a streamer chamber late in 1986.

In 1985 the ERASME/Bessymatic film measuring facility finished the analysis of film from BEBC (WA21) and the EHS bubble chamber (NA27). The experimental teams involved in these experiments are continuing their research program at Fermilab at increased beam energies. They produced film using the 15 foot bubble chamber for neutrino interactions in a heavy neon-hydrogen mixture (E632) and pictures of hadronic interactions (pion–proton and proton–proton) in LEBC (E743). The ERASME/Bessymatic system proved flexible enough to adapt easily to these types of film and scanning and measuring is in progress.

Similarly, the UA5 experiment produced streamer chamber pictures of proton-antiproton interactions at a total center-of-mass energy of 900 GeV. These pictures were measured with top priority to evaluate multiplicity and rapidity distributions in this new energy range. Parallel to classical recording on film the UA5 experiment used CCD cameras to digitize the optical signal on-line. Off-line the tracks were reconstructed, visualised and analysed semi-automatically with the help of a digital image processing unit.

EF SEMINARS

The following seminars were organized by EF Division in 1985:
T. Jensen (Ohio State University), 21 January
The CLEO vertex detector: construction and initial running experience
E. Heijne (CERN), 15 April
Microdetectors and microelectronics
D. Treille (CERN), 6 May
The Physics at LEP
W. Dahme (University of Munich), 13 May
Survey of the experiments at LEAR
R. Heuer (CERN), 20 May
The Jet Chamber of OPAL
W.C. Middelkoop (CERN), 3 June
The SPS: recent performance and future use
E. Amaldi (University of Rome), 10 June
Search for gravitational waves
Ph. Gavillet (CERN), 17 June
Personal computers in physics environments: Why and for what?
H. Ing (Chalk River Nuclear Laboratory), 19 September
A bubble damage polymer detector
G. Mickenberg (Weizman Institute, Rehovot), 14 October
Development of calorimeters using thin chambers operating in a high-gain mode
W. Hoffmann (LBL Berkeley), 25 October
Results from the TPC at PEP: What we learned about parton fragmentation
A. Minten (CERN), 28 October
The Stanford Linear Collider (SLC)
C. Prescott (SLAC), 4 November
Detectors and experiments at SLAC
J. Eades (CERN), 11 November
The Omega Ring Imaging Cherenkov detector
F. Piuz (CERN), 18 November
Results and developments of micro-vertex detection
E. Jones (CERN), 25 November
Progress on ACOL
O. Gildemeister (CERN), 2 December
The UA2 upgrade
M. Demoulin (CERN), 9 December
Utilisation de VME dans le système d'acquisition de données de UA1

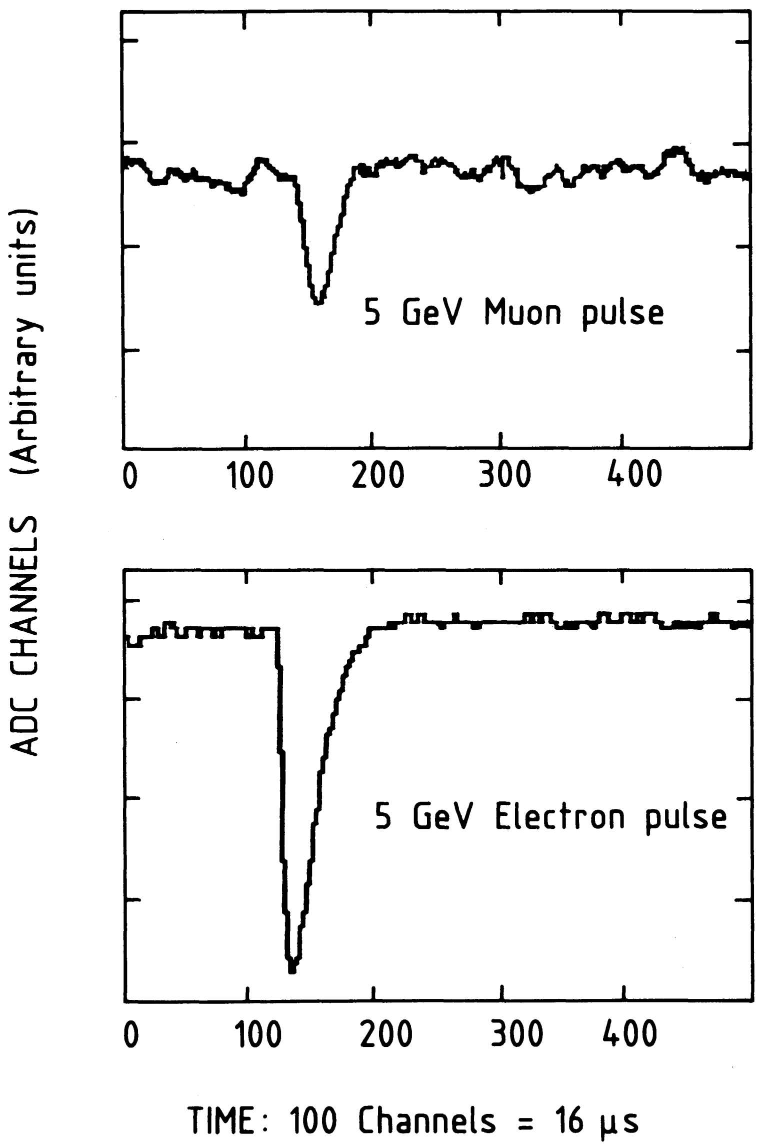


Figure 1 — Wave-form analyzer pulses

Data Handling Division

Introduction

It has almost become a rule that the Central Computer installation undergoes big changes during the week preceding Christmas. 1985 was no exception: the IBM 3081 was replaced by an IBM 3090-200, the most powerful machine available from this manufacturer. As usual, the change-over was carefully planned and the whole operation was finished in 30 hours. Nonetheless, most IBM/Siemens services remained available throughout the installation, though at reduced capacity. The 3090 took over immediately, without the slightest trouble.

All in all, the Computer Centre provided its services smoothly, breaking here and there new records in CPU hours delivered or jobs processed. The DEC services were greatly enhanced with the installation of three VAX 8600s and a central Apollo service was started.

The software support activities went hand in hand with the enhancements and diversification of the hardware. The VM/CMS operating system supports 80 simultaneous users at peak times. To achieve this, large efforts were required to adapt software and to produce documentation.

In related fields also considerable efforts were made to provide the facilities required by the user community. A wide range of activities was covered: microprocessor support, relational data-base services, mechanics CAD/CAM and personal work stations and personal computers.

Data Communications play an ever increasing role and 1985 saw a large growth in the workload. This is due in part to the increase in the number of installations and in part to the diversity of the networks in use, necessitating gateways, bridges and interfaces. Examples of new installations are: a new large INDEX switch, needed to cope with the growth of the terminal network (15% in a single year) and the installation of eight local Ethernets and nine Frigate (Ethernet/Cernet bridges) throughout CERN. The internal X-25 network was doubled, and the GIFT file transfer gateway put into operation. The EARN connectivity was improved and the traffic increased considerably.

In the Data Handling field the software support to experiments continued, leaving little time for new developments. The latter concentrated around the simulation program GEANT3 and the ZEBRA memory management package. A first level of the GKS (Graphics Kernel System) was introduced and a user guide written. Several additions and improvements were made to PIONS.

A number of new on-line computers were installed: two VAXes for LEP experiments and another for Isolde, a ND-570/CX for Delphi and several microVAXes for lab use and for NMC and Delphi. A major upgrade of the VAX Data Acquisition System has been released and substantial changes were made to the NORD data acquisition software to adapt to SINTRAN III version J.

The new, modular VMEbus-based VALET-Plus test system was succesfully introduced in spring and some 50 systems are now on order by various groups at CERN and other Institutes.

The 3081/E emulator was improved as more and more complex software was run on the machine. Several large simulation and analysis programs now run on the 3081/E, at the predicted performance of one IBM 370/168. A total of 14 machines were built in 1985, using wirewrap and multiwire technologies. A project was started to evaluate the performance of a cluster of five 3081/E processors attached to an IBM 4361 host for the bulk processing of event data.

Four XOP fast processors were built for L3 and UA2. The use of Fastbus has been steadily increasing and the CFI interface, originally foreseen for Camac only, now has VMEbus, Unibus and Q-bus hardware and software added. The Fastbus hardware specification was adopted as the ANSI-IEEE Standard 960.

The division contributed to the development of the new VMEbus-based data acquisition system for UA1.

Central Computing Services

CDC Services

1985 has been a year of consolidation on the CDC machines and services.

Hardware stability has improved drastically on the 875/MFB system with an availability of 98.5% and an MTBI of 141.1 hours (respectively 96.6% and 50.7 hours in 1984). The weekly CPU record has been broken 4 times in 1985 to reach a maximum of 315.3 user hours during the week of 09–12–85.

On the 835 side, the engineering work done in 1985 in the area of cache and control store has paid off. The machine has performed well with an availability of 99.3% and an MTBI of 186.1 hours.

New communications processors were introduced for the CDC service, along with a new version of the interactive support software, INTERCOM. Several modifications were made to the operating system of the CDC Cyber 875 to improve reliabiliy and performance. This completes the development of the CDC service.

IBM and Siemens Services

During the twelve month period ending at Christmas 1985, both of the IBM-compatible systems in the Computer Centre were replaced, with the introduction of a Siemens 7890S and an IBM 3090-200, together with 90 GigaBytes of disk storage, 8 new cartridge tape drives, new communications controllers and other minor peripherals. This has involved an immense amount of planning and preparatory work in order to achieve smooth installation and ensure suitable service back-up for this increasingly complex configuration and service.

A new interactive and batch service using the VM/CMS operating system was developed, in collaboration with other HEP laboratories. This service is now supporting more than 80 simultaneous users at peak times.

While the mainframe installations had very little impact on the overall availability of the services, the enhancement of the VM service and the increasing complexity of the systems did take their toll, and as a result all performance figures were lower than in 1984.

The availability figures for the 3081 and 7890 were 98.92% and 99.32% respectively, while the MTBI's were 90 hours and 178 hours.

The increased computer power had a somewhat strange effect on the workload statistics, with the average number of MVS jobs run per week creeping up from 30054 in 1984 to 30178, but the average number of CPU hours jumping from 657 hours in 1984 to 1163 hours last year.

Tape performance has been much the same as previous years with long periods of no problems interspersed with the occasional scare and frantic investigation as to whether it is a hardware/software/media/cleaning/compatibility problem. With the tape mounting rate now well above 6000 per week more of this load ought to be moved on to the cartridge tape units.

DEC Services

During 1985, three VAX 8600's were installed. In addition, the PRIAM VAX was upgraded to an 11/785 and GIFT was moved to an 11/780.

With the exception of the new CAD/CAM 8600, which suffered severe teething problems shortly after installation, all machines performed well. Tape drive performance continued to be lower than expectations, but disk drive performance improved significantly during the year.

A new program development service for physicists was set up on a VAX-8600 in the Computer Centre. The service, which was opened during the summer, already has over 600 registered users. The service has been linked to most of the HEP data networks, and is a focal point for communication between LEP group members throughout the world.

Apollo Services

The number of Apollo workstations available on site has reached 17 at the end of 1985, 9 of them belong to EP groups, the others to DD groups. Currently 3 workstations support the publicly available services that have been made available during last year. These services include a self-service tape unit, a CERNET service, a Versatec A4 plotter, a file server and a diskless server. The availability of most of these exceeded 99%.

Since December the CERNET service uses both the old MECGATE and the new Frigate gateways providing a better degree of availability.

Currently 12 CERN groups (DD + EP + etc.) are actively using the central facilities, the number of registered users is 93. The availability of the Apollo Domain Network has been 98 %.

Infrastructure

During 1985 the tape vault reorganisations were finished. Few changes can now be made to improve users' conditions. A self-service tape drive (for labelling) was introduced, apparently successfully.

A PCNET to connect PC's in Building 513 has been installed and is in permanent use.

Following serious battery degradation on the Emerson Uninterruptable Power Supply in building 513, a new battery was acquired and installed successfully in November. An extra second hand UPS 250 KVA unit was purchased as well in the Fall and this extra capacity will be available in March-April, 1986. This will off-load the present system and allow us to run the centre with protected power until the end of 1989, coping with the extra load imposed by the 875 successor system.

Remote Access to Central Computers

The old CTL printers have all been replaced by ten IBM 3262 line printers, three Xerox 2700 laser printers and two DEC printers. The IBM line printers have had a stacking problem which has been tracked down as a problem with the paper specifications. The paper will be changed to conform to specification and it is expected that this will eliminate the problems.

Terminal Pool

The terminal pool supported by the Division comprises today 1935 units:
298 Graphic terminals
1337 Alpha-numeric terminals
300 Printers/printing terminals
240 terminals and printers were installed during the year, and 27 terminals exchanged.

The IBM-PC hardware assistance (less than full support) covers about 120 IBM configurations, and approximately 50 configurations of the Olivetti M20-series.

A process to select terminals for use at CERN has started. The aim is to select two types of terminals, a cheap as well as a superior terminal, that may be used with the VAX VMS and the IBM VM/CMS operating systems.

User Support Services

Program Enquiry Office

The breadth of services now available on the central computers has continued to expand during the year to the point at which it is no longer possible for all members of the PEO to provide expert help in all areas. Reorganization in order to handle this situation has started and will continue in the coming year.

A major part of the work of the last year has been directed at the introduction of a general user service on VM/CMS. Many utilities have been written both to support commonly used software (Patchy, Historian,...) and to interface with other services available at CERN (file transfer, MVS printers, CDC job submission...). FIND, a powerful search facility based on keywords, has been written to give access to HELP files and other on-line documentation. A User Guide has been produced. A significant amount of work also went into the introduction of the Tektronix version of the GKS standard graphics package on VM. This included the installation and provision of supporting procedures, the documentation and help given to early users, and the conversion of existing graphics applications (e.g. HPLOT).

Another major area of work has been in text processing and printer support. The text processing facilities on the IBM were greatly enhanced by the introduction of the APA6670 laser printer, coming from the IBM research laboratory in San Jose. The necessary support for both this and the Xerox 2700 laser printer was added to the CERNPAPER text processing software. The first step towards graphic hard-copy on laser printers was taken with the introduction of HPLOT output on the Xerox 8700. This printer was primarily installed for economic printing for which a special print format and character set were developed.

Other activities have included

- a CDC procedure (LISTOFF) to make new IBM printers readily available to CDC users
- a revision of EPIO with major improvements for VAX and versions for Apollo and Cray
- organization of DD seminars
- installation and maintenance of Monte Carlo programs for the Program Library
- providing access to individual Computer Newsletter articles via the on-line help facilities.

Program Library

The FORTRAN compiler available under the IBM VM/CMS operating system was changed from that of Siemens to that of IBM (namely VS/FORTRAN).

The complete CERN library was installed using this system including many new system interface routines.

The IBM interactive debugger associated with the VS/FORTRAN compiler was installed in VM/CMS and tailored to CERN usage.

The Program Library manual in a new compact form (taking only 1/3 of the paper of the previous size) was printed by the CERN print-shop.

The manual was made available interactively in the VM/CMS system with an interface to the interactive enquiry system 'FIND'.

There are now 6 implementations of the program library at CERN: for IBM MVS, IBM VM/CMS, CDC NOS-BE, VAX VMS-4 , Nord-500 SINTRAN-3 and Apollo.

A site-wide licence for the Numerical Algorithms Group library was obtained. All the requested versions have been delivered and installed on the appropriate public machines. The interactive HELP facility of the NAG library has been installed in the IBM VM/CMS and VAX VMS-4 systems.

Mathematical consultancy

A comprehensive test program has been provided for the KERNNUM program library. This library has been extended in various ways, including additional facilities for vector processing, double precision versions of most of its function subprograms for low precision computers, and control of error recovery. The Fortran version of KERNNUM is now also available for the Apollo and Cray computers, and for the IBM VM/CMS system. The Fortran source code (but not yet the assembly code) of KERNNUM and its test program have been transferred from CDC to the IBM system, replacing the Author-based maintenance procedures by CMS- and Script-based facilities.

A set of six small benchmark jobs for vector processors has been collected and applied to an investigation of the Siemens VP 200 computer.

Work on electrostatic fields in wire chambers included the following. The method of multipole expansion for the potential of the electrostatic field of doubly-periodic infinite arrays of thick wires has been tested successfully. Improvement in computational efficiency of appropriate recurrence relations for the successive derivatives of terms involving theta functions has been done. Subroutines for plotting equipotentials and field lines in doubly-periodic two-dimensional fields whose complex potential is available, including routines for windowing, handling intersections with conduction surfaces, etc. have been written and tested. For the field in chambers containing both strips and wires, a finite-difference method has been successfully developed. Associated plotting routines are being written.

Work on a new package for nonlinear least-squares fitting and maximum likelihood parameter estimation has continued. The package is ready in its single precision version on CDC.

Fortran routines of the elementary functions for the M68000 mathematical library have been developed and tested. This work will continue.

The development of a new program of a budget simulation model has begun. Work on the Pension Fund and maintenance of the book-keeping programs for the Pension Fund investment continued. The statistical analysis for the CERN Technology Study has been completed. A Yellow Report has been published and two other publications on this matter have been prepared.

Studies on integral equations of the first kind and on a class of definite integrals have continued and have led to publications.

Accounting

Over the past year some 900 VM/CMS accounts were created. A further 1000 accounts were opened on Wylbur/MVS, and 140 on NOS/BE. The corresponding figures for the previous year were 800 and 240, respectively. The external communication service (EXTASE) has 118 registered users and their rate of usage is about 70000 Fr per year, nearly doubling the figure of 1984. This sum is recovered from user accounts at half yearly intervals.

A major revision of the charging algorithms on both IBM and CDC systems was undertaken.

Tools were written to transfer registration information between VM/CMS and MVS, to monitor VM/CMS connect and cpu time usage, to extract and reformat accounting and space usage data, etc.

Computer Science Library

The CSL has expanded its successful ‘closed reference section’ as a way to counter the frequent absence of popular books and periodicals. Although locked up, such books are visible in the computerized catalogues. The latter replace the traditional card catalogues for all books from 1979 onwards, and include references to books in other CERN libraries.

The section on ‘Standards’ has been brought up-to-date (ISO, ANSI, ECMA, CCITT). Efforts are made to include (through contributions from individuals) draft proposals, which are not available through official channels. A new area in which a good number of books has been ordered concerns artificial intelligence.

Documentation Office

The new process of selling computer manuals via a stores cards was introduced for VM/CMS manuals. For this, a new way of working with the CERN stores had to be found and this has been successful to date. Approximately 900 VM manuals have been sold so far by this process, representing 25 KSF (on top of the manuals purchased separately for the computer centre). Whilst this is still reasonable, an extrapolation for the future reveals the importance for the Divisional budget in this way of working which, apart from being the norm in other computer centres, has been well accepted in general by the users.

The Computer Newsletter was distributed last month to 3027 internal and 1240 external addresses, giving about 21 000 copies for the 5 issues of last year. There were 28 DD Reports during 1985, and the number of external subscribers to the list of available reports is currently 164.

Specialized Computing Services

LEP Services

The activities of the mechanics CAD/CAM project are reported in the progress report of the LEP Division.

The ORACLE database management service for LEP construction was expanded, with the installation of a VAX-8600 computer. A VAX-11/780 computer ia also available for application development. The numbers of both applications and users of this service continue to increase. More details can be found in the report of the LEP Division.

Relational Data-Base Management Systems

A relational database management service was made available to all CERN users, with the installation of the ORACLE system on the central IBM service and on the central physics program development VAX-8600 system.

Remote access to ORACLE using a technique based on remote procedure calls was implemented.

Microprocessor Support

Work in this area continues to concentrate on support for the Motorola 68000 family of microprocessors.

Several performance improvements were implemented, particularly in the CUFOM processors (linking and loading routines). A new common code generator for the Pascal and Modula-2 compilers was completed, providing improved optimisation and support for the Motorola 68020 processor. Work was begun on a FORTRAN 77 front-end for the common compiler system, in order to ensure adequate long term support for this important language. The cross-assembler was extended to support the 68020 processor.

A new version of the MoniCa debugging monitor was released, bringing support for additional processors in the Motorola 680xx family, improved modularity, and support for the RMS68K real time kernel.

During the year the IEEE adopted a standard format for object modules, MUFOM, which was largely based on work done at CERN.

The PRIAM program development service was further consolidated, and upgraded to use a VAX-11/785 computer. A number of relatively inexpensive UNIX workstations were evaluated.

1985 has seen a special event in the area of microprocessor support at CERN. The PRIAM project, the Interdivisional Project for Microprocessor Support, organised the first conference 'VMEbus in Physics', which attracted more than 300 participants from all member states, the US, Canada, Finland, and Poland.

The conference provided an excellent opportunity to survey hardware and software applications of the VMEbus standard in physics, to discuss developments in the definition of the standard, and finally to inform industry, participating with more than 50 delegates in the conference, about the needs of the fast growing VMEbus market in the physics community.

Work on promulgating the use of the VMEbus standard at CERN has continued in several Working Groups and by organising presentations and maintaining contacts with industry and out-side users. Technical assessment of VMEbus products and a general consultancy service is also part of this work.

The ABEL and PALASM programs for programmable logic design have been installed on the PRIAM VAX. In addition, hardware and software for the PRIAM self-service PROM programming facility has been acquired and is now available to the users. The system runs on an IBM PC connected to Ethernet. Also, the old PROM service has continued to operate throughout 1985.

Four issues of the Mini and Micro Computer Newsletter have been published this year.

Personal Work Stations

The personal workstation project has moved the emphasis from evaluation to building the infrastructure necessary to run a large network of APOLLO personal workstations.

APOLLO Computer is still the market leader for the development of large Fortran programs that contain advanced graphics. The first Apollo Domain workstations were purchased in 1982. The Apollo is well accepted and is now formally supported by DD.

The number of nodes has expanded from four to seventeen. All 17 have been placed on the Domain network which now spans half of the CERN Meyrin site. This has enabled us to install central services in DD division that are accessible to all APOLLO users. This includes the network access to VAX and the central IBM machines via Ethernet and CERNET, and external access to other APOLLOs using X.25. A central file server has been added and is used to contain the master version of the very large CERN library, access to which is now offered as a service. A set of pro cedures common to all nodes has been installed. These include management of accounts, file protections, backups, hardware and software statistics and network-wide utilities. Site licenses for the principal compilers and operating systems have been purchased. The work is covered by a small team operating in the areas of system management, user support, CERN library installation and networking.

Collaborations have taken place with ICL using two PERQ-2's, DELPHI of Italy and Modulator of Switzerland with two SUNs and Whitechapel with their MG-1 workstation. We have been able to evaluate these machines to ascertain their strengths and to compare them with APOLLO for the principal types of applications at CERN. A Symbolics 3640 is being rented for use as an Algebra machine by Theory Division and for the development of Expert Systems. These Expert Systems should ultimately help in fault diagnosis of accelerators and large experiments. Three VAX-Stations have been purchased.

Personal Computers

The personal workstation project was extended to include the coordination of personal computer activities. The most popular CERN types of personal computers are Apple Macintosh, the IBM PC family and the IBM compatible Olivetti M24. A small team is responsible for giving advice and keeping regular contacts with the relevant companies. The team calls on the expertise available in the different divisions of CERN in order to encompass the large area of software and add-on hardware that is available today.

Evaluation of networks for personal computers has begun with some promising results with the IBM PC network and Ethernet/Cheapernet connections for the IBM PC family and the Olivetti M24. Appletalk has been used successfully to connect Apple Macintoshes together with a Laser Printer. The Kermit protocol for transfering files has become very popular and has become the CERN standard for RS232C lines which includes the Index terminal switching lines. Kermit has now been made available on the three popular personal computers and on a large number of the mini and central mainframe computers.

UNIX

An electronic mail gateway is being developed on a small VAX system, under the UNIX operating system. This uses a number of software packages which have been tailored to CERN's needs. The mail gateway provides connections between many computer services at CERN, and with a substantial number of external networks.

Consultancy and support was provided for networking on small systems, including workstations and personal computers. Much of this work has involved the TCP/IP family of protocols.

Data Communications

1985 has been a busy and exciting year, with growth and progress in all areas. There have, however, also been an unusually high number of staff changes and a severe manpower shortage in all sections, with the available staff being sufficient for only about 75% of the desired programme of work. In particular, the rapid growth of services has led to a heavy load of user education.

In the spring, a data communications policy document was developed and endorsed by the Director for Research responsible for computing. This policy has been presented to the relevant ECFA sub-group (SG5), the inter-laboratory HEPCCC committee, and the 'Computing in High Energy Physics' conference in June. The main points of the policy are: use of ISO/CCITT standards to achieve Open Systems Interconnection in the long term; use of interim protocols meanwhile; and the use of gateways to interconnect incompatible protocols as necessary.

The activities in data communications overlap more and more with those of others (in DD, throughout CERN, and outside), as networks become ubiquitous, so liaison and coordination are continually increasing in importance. A new Divisional committee — CSC, or Communications Systems Coordination — has been established as a forum for policy decisions in the communications area. New mechanisms for liaison with users have also been created during 1985, notably the nomination of contact people for data communications in each Division, and participation in various meetings with experiments. Liaison with external users remains fragmented and unsatisfactory, but the continued activities of ECFA SG5, and the creation of the RARE association (Réseaux Associés pour la Recherche Européenne), have aided us in this area.

Major achievements in 1985 included:

- About 15% growth in INDEX in a single year.
- Installation of the first of two new large INDEX switches (PACX 2) in the Computer Centre.
- Approximate doubling of the internal X.25 network.
- Opening of the GIFT file transfer gateway.
- Large increase in EARN connectivity and traffic.
- Start of upgrade programme for obsolete CERNET node computers.
- Installation (or help with installation) of eight Ethernets throughout CERN.
- Installation of nine Frigate boxes (Ethernet/CERNET bridges), and many improvements in the Frigate software.

The following sections give more details of these and other achievements, and describe on-going work and studies.

Circuit-switching and terminals

Installation Programme

Work carried out during 1985:

- 362 INDEX 'terminal line' installations and moves.
- 215 INDEX 'host interface' connections
- 47 X25 and other 'non-INDEX' connections
- 6 modem installations.

The accumulation of a large backlog of installations led to the use of contract labour in order to reduce the backlog to a more acceptable level.

INDEX system

The following was achieved:

- Replacement of INDEX-2 by a large PACX as the first step of the INDEX upgrade program.
- Replacement of Mini-INDEX-5 by a Standard PACX in the West Area.
- Start of replacement procedure of INDEX-0 and 1 by a second large PACX, the future PACX-1.
- Introduction of the mini-LDS126 as a standard Gandalf data set.

Digital Telephone Exchange

This project (also known as the ISPBX, Integrated Services Private Branch eXchange), is a collaboration between DD Division, the Administration, the PE Department, and LEP and SPS Divisions, in planning a digital telephone exchange to meet the requirements of the LEP site, and eventually to expand to replace the present electro-mechanical exchange. During 1985, a call for tenders was made and a contract is being finalised with STK of Oslo, for delivery and installation during 1986. Initially, the digital exchange should offer a data-switching capability similar to that of INDEX, with which it must be interconnected.

External Networking and High-Level Gateways

X.25 services

The EXTASE service (two-way terminal access to public X.25 networks) and the EXCITE service (CERN local X.25 network connected to JANET, SACLAY and TELEPAC) are now fully integrated and operational. Two new switches from CAMTEC have been installed allowing for some 30 different machines or services to be interconnected. Monitoring panels for test purposes have been implemented and installed successfully. The X.25 data traffic is now approximately 2.5 Gbytes/year, and increasing.

Electronic Mail

During 1984 a study, under the name of COMICS, was carried out on electronic mail and related topics. The major recommendations, as presented in the final report of February 1985 were:

- CERN should use the X.400 series of recommendations adopted by the CCITT in 1984, as a basis for the interconnection of various electronic mail systems in the medium and long term. CERN should press its suppliers to support X.400
- In the short and medium term, an electronic mail gateway should be established at CERN, to allow interchange of mail between the various systems already in use. For technical reasons (availability of suitable software), this should be a VAX computer running the UNIX operating system.

In June 1985, a project, under the title of MINT (Mail INTerchange) was formed, and work began on providing the mail gateways. The goals of MINT are:

- To establish the MINT gateway computer.
- To provide connectivity between recommended mail systems at CERN.
- To provide a uniform addressing syntax for mail.

In order to provide the best service with the limited manpower available, a recommended mail system has been selected for each of the major computer systems in use at CERN.

EARN

The CERN node of the IBM-sponsored European Academic Research Network (EARN) has now become one of the major switching nodes, with 5 international links to Rome, Paris, Darmstadt, Stockholm and Didcot, 4 national links to Swiss Universities and 5 local links within Cern. EARN is now operational in most European countries and the combined EARN/BITNET network, which is exceeding 1200 nodes, doubled its size over the last twelve months. CERN's own traffic on EARN is at a level of about 3 Gbytes/year, and increasing.

Such fast growth does not go without problems and therefore the development of an intra-network Mail Gateway (NETGATE) was carried out together with the University of Zurich. NETGATE was designed to resolve incompatibilities between the various formats in use over EARN/BITNET, for the transfer of files and electronic mail, and is also used as an outgoing mail gateway for Wylbur originated mail.

GIFT

The GIFT (General Internetwork File Transfer) service started officially in August 1985 and since then the usage has grown constantly. The main usage is by the UK physicists needing to access the IBM File Manager. The Italian high-energy physics community have recently started intensive usage converting from the old PDINFN gateway access. Surprisingly enough there is a certain number of users inside CERN (especially from the VXCRNA DECnet node) profiting of the GIFT user interface, more DEC-oriented than the CERNET direct access programs.

Miscellaneous

A project has been started that will lead to the definition, development and installation of an integrated Network Management Center. This will allow the operators to continuously monitor the status of all the physical and logical networks present at CERN (13 different ones plus all the gateway and bridge facilities) and to be alerted on faults. Full statistics on traffic will be available for the network planning.

The Committee Assessing Transport Services (CATS) has been set up in response to the need for unified data communication between computer tasks running in a variety of hardware and software environments. The basic task of CATS is to produce recommendations by March 1986 on ways in which this can be best provided in both the short and long term for the whole CERN community. Estimates must be given of the resources required, consistent with the provision of such a service to meet the needs of LEP and the LEP experiments.

European (and World) Network activities

Following the first European Networkshop held in Luxembourg in May, CERN has become a founder member of the RARE association mentioned above. The aim of this association is to promote OSI (Open Systems Interconnection) networking for the academic and research community, normally by use of ISO/CCITT standards and the public data networks. Apart from liaison with the CEC (Commission of the European Community) and CEPT (Conférence Européenne des Postes et Télécommunications), RARE has launched several technical activities of direct relevance to CERN. A first RARE technical meeting on electronic mail was held at CERN and we will in due course trigger discussions on file transfer problems.

CERN has signed in October the ESPRIT contract for the THORN (THe Obviously Required Name-server) project involving 9 industrial and academic participants (including CERN). The project is intended to produce portable software implementing a general-purpose distributed 'name-server' whose primary application, in the CERN context, is as a directory for electronic mail.

Contacts and technical studies for a dedicated link between CERN and the US are well in progress. The problem of tariffs and third party traffic has been addressed in a number of meetings with the Swiss PTT.

Internal Networking Hardware and Software

CERNET

During 1985 Cernet has continued to work reliably with an overall availability of 98.7%. The total number of packets transferred via Cernet was $562.54*10^6$ which is a significant decrease. CERNET continues to run in a very stable manner. The growth in the number of users has flattened off at rather more than 100 links. What growth there is, i.e. about 10 new connections, consists mostly of Frigate gateways to Ethernets. Thus a shift from CAMAC to VMEbus connections is observed.

Preparatory work has been done to allow the replacement of seven obsolete Modcomp II/45 computers by newer Classic II/15 single-board models. This operation is financed by reduced maintenance costs for the new equipment. The replacement will take place during early 1986, but a first machine was delivered in 1985 and is being equipped to cope with its limited number of I/O processors.

Services on CERNET itself

CERNET can permit connections across an ensemble of CERNET and Ethernet, via gateway software baptised MAID. The CERNET machine-independent Transport Manager has been modified to allow for these new connection possibilities, as have the Transport Managers on CDC and IBM.

Ethernet general support

The DD Ethernet in buildings 31 and 513 has continued to attract new users and uses. Physically, it has also been extended, in the form of Cheapernet, into all offices on the third floor of building 31.

The division has also helped, in varying degrees, with the installation of other Ethernets in CERN. This includes, in particular, public Ethernets in the North and West experimental areas. All of these Ethernets are interconnected via Frigates.

There has been work to evaluate various different hardware and software options for allowing IBM-compatible PCs to attach to Ethernet. Such PCs may wish to communicate between themselves, or with a larger computer such as the PRIAM VAX.

The work to allow the UTInet software and servers to operate on top of Ethernet (or Cheapernet) hardware is nearing completion. A Cheapernet interface for the G64 bus has been designed and implemented, and two prototypes are working correctly. More general software for microprocessors connected to Ethernet (or Cheapernet) is under study.

Frigate and allied subjects

Nine Frigate (Flexible Reconfigurable Internet Gateway) boxes, all based on VMEbus hardware, are in service. Work continues to improve the reliability and performance of the basic AID (Automatic Internet Datagram) service. In particular, an adaptive binary search algorithm has been introduced to accelerate and generalise the AID addressing and routing mechanisms. Table look-up hardware to further accelerate these mechanisms has been proposed and will soon be implemented. A proposal has been made for backup and load-sharing of Frigates on the same Local Area Network.

The FAID (File AID) service has been implemented in the Frigate box. This is compatible with the original Mecgate (Multihost Ethernet-CERNET Gateway) service. It includes as part of it a complete, though not yet entirely satisfactory, implementation of the CERNET Transport Manager and File Access routines.

Backbone Network

The studies for the future backbone network have advanced significantly during the year, following the formation of an **ad hoc** task force. Major points are:

- Choice of a progressive evolution from CERNET to the future backbone, rather than an abrupt changeover.
- Elaboration of a service definition for the backbone, whose main point is that the backbone should offer a Medium Access Control bridge service, in accordance with the ISO 8802 (IEEE 802) standards. This is in fact exactly what is offered today by the Frigate AID service.
- Provisional choice of the 100 Mbit/s token ring draft ANSI standard known as FDDI as the backbone technology, and establishment of related industrial contacts.
- Ordering of equipment for a pilot project using the Proteon 80 Mbit/s proprietary token ring.

Other Hardware Activities

An experiment to use the CMOS standard cell design methods in a Multi Project Chip environment is under way. The first trial was not successful, but it could be traced to a manufacturing error. The result of the second trial are just becoming available and it looks as if the design is working.

Data Handling

Off-Line Processing

The activities can be grouped into three major areas:

1. Direct programming support given to experiments, mainly LEP, whereas the involvement in SPS experiments has decreased further.
2. Development and maintenance of general programs, where 'general' means essentially to be of use to more than one experiment.
3. Graphics in the computer centre, and for current and future event viewing on special hardware devices (graphics work stations).

Any programmer is generally involved in more than one of these items, since many general programs and tools are and have been produced in response to direct needs of experiments.

It should, however, be pointed out that no major new project has been started in 1985, not because there is a lack of ideas, but because the existing man-power is absorbed in developing and maintaining the existing packages.

General Development and Activities

GEANT3

The GEANT simulation program has been continuously improved. The electromagnetic package has been compared with the well known EGS (see CERN/DD/85-1). Physics is now possible at energies down to 10 keV for photons. The hadronic shower package has been optimized. Comparisons with test beam results have given excellent results, including the case of Uranium compensating calorimeters.

The graphics package has been considerably improved. Interfaces with GKS, PIONS and GMR have been produced. With the experience gained in 2-D and 3-D graphics on Megateks, Apollos, and simple graphic terminals, a proposal for a common graphics interface has been presented and discussed in the framework of the graphics committee appointed by MEDDLE.

The memory manager ZBOOK has been replaced by ZEBRA in the version 3.10.

With the growing demand to implement GEANT on systems other than conventional scalar machines, studies have started to modify some algorithms in order to run efficiently on parallel processors and on vector machines. GEANT is now running on the 370/E and 3081/E emulators.

GEANT is now used by more than 20 experiments (CERN, DESY, SLAC, FNAL, LBL, Proton decay experiments, Satellite experiments with the European Space Agency).

ZCEDEX

The ZCEDEX command processor has been upgraded. It is now running on VAX, Apollos and IBM/VM. Among applications, ZCEDEX is the heart of HTV, and of the interactive version of GEANT. It is also used by ROPE, the OPAL Reconstruction Program.

ZEBRA

The first version of the ZEBRA system has been released in Spring. The version 3.40 released in December provides all the facilities proposed by the ZEBRA working group in 1984. The direct access package RZ has been actively discussed.

The Debug package of the ZEBRA memory manager was designed and implemented. Work started on an automatic documentation tool of ZEBRA structures. The direct access package of ZEBRA was designed with representatives of the LEP collaborations. The soundness of the ideas was tested on a model implementation.

FLOP

FLOP has been extended to provide output for a tree analysis program, TREE.

A program called Treeplot has been developed. Treeplot creates a static calling tree for Fortran or Mortran programs on IBM/VM or VAX, and plots this on the IBM/MVS Versatec plotter. Experimental versions exist for 32-character names, graphic terminals and different inputs.

ALEPH has developed an automatic coding convention checker on top of FLOP, called FLOPPY.

Other Developments

The Physics Analysis Workstation (PAW) project has been started in collaboration with people from EP. The aim is to produce in 1986 an improved version of the HTV system. PAW will run not only on mainframes, but also on workstations (Apollos) and on some personal computers (MacIntosh). Improvements to the HBOOK, HPLOT, and ZCEDEX packages have been discussed. A common graphics interface is also required.

Interesting results have been obtained with a new track finding program based on template matching and using fuzzy tracks. Work is presently done on methods yielding filtered tracks ready to be fitted.

Tools were developed to include different fonts (mono spaced) in SCRIPT documentation on the APA6670. This allows the inclusion of FORTRAN code and output listings in the text. Programs and procedures were set up to transport (compressed) bitmaps (produced presently on the Apollo) to the IBM, where they are expanded and rasterized to be output together with other text in a document printed on the APA6670 (the same principle will allow us to include files produced by GKS). Both these tools open up the possibility of producing really professional documentation using SCRIPT on the APA6670 at CERN. Also slides can be easily generated.

A new procedure IBMLIB was written to generate binary libraries on VM/CMS.

Graphics

For general graphics a first level of GKS (Graphical Kernel System) was introduced. Computers initially supported are: IBM under both MVS and VM, VAX/VMS, NORD-500 and Apollo. The GKS software currently supported consists of the Minimal-GKS (MGKS) written at CERN and the Tektronix PLOT-10/GKS. PLOT-10/GKS, as delivered, does not support all graphics devices in use at CERN. Therefore substantial effort went into providing GKS workstation drivers for devices such as Versatec and HP plotters and Pericom terminals. The GKS Metafile was chosen as a basis for shipping and storing graphical pictures. With this it is possible to ship a Metafile generated on one computer via CERNET to any other computer for inspection or plotting by the Metafile interpreter MINTR. It allowed to install a general remote plotting service on the central plotters under IBM/WYLBUR to which any remote computer connected to CERNET can submit a Metafile for plotting. It is intended to extend this service to colour plotting, both for paper and transparency, and to laser plots with combined text and graphics.

A 'CERN GKS User Guide' has been written which serves at the same time as a reference manual for MGKS. The HPLOT program has been interfaced to GKS allowing HPLOT to run on any terminal supported by GKS and to write a GKS Metafile for plotting.

There have been many additions and improvements made to PIONS. In particular a driver has been written for GKS so that PIONS users may produce GKS metafiles, and work has also started on a driver for the new Apollo GMR graphics system. Work has been carried out to reorganize PIONS development and production versions, and the package has been distributed to many sites. An improved Viewing Server has been produced in collaboration with the University of Victoria, Canada.

For 3-dimensional graphics, simple cases of 'hidden line removal' like Lego-plots, SURF3D and painter's algorithm have been written.

For the study of a graphics editor, the work has concentrated on the representation of pictures in memory and in files, on command interpretation and macro processing. An editor can be demonstrated which is at least an interesting try-out object for graphics editor design.

On-Line Processing

Computer Pool and Associated Activities

The rationalisation and standardisation of the on-line computer pool continued throughout 1985. A further dozen of HP Computers were phased out, and all ND-100s were equipped with modern memory to save maintenance costs.

During the year, the following new equipment was installed:
- 2 LEP VAXes, bringing the number of LEP VAXes on-site to 11
- a ND-570/CX, provided by NORSK DATA, was installed in the West Hall for DELPHI
- one more ND-100 Compact was purchased for the Pool
- Micro-VAXes were installed in hardware labs for FASTBUS development and testing and in some experiments such as NMC and DELPHI
- the ISOLDE dual HP configuration was replaced by a VAX 750.

A total of 20 FASTBUS Interfaces are now supported. A couple of Q-bus CAMAC Interfaces for use on Micro-VAXes are under evaluation. Meanwhile, the support effort for CAMAC System Crate has not diminished; many off-site LEP VAXes (Saclay, DESY, Rome, Ottawa) use it. Limited maintenance for OMNET was still provided during 1985 and it will be supported for NMC until the end of the 1986 Fixed Target Period.

Financial constraints have led to a serious consideration of the use of more OEM equipment. There is a wide range of interesting add-on equipment on the market, but careful evaluation is required for each item because of support, maintenance and standardisation problems.

As from December 1985, all Pool CAVIARs are covered by a commercial CAVIAR repair service which is also available to owners of private CAVIARs. A new CAVIAR allocation policy is being introduced whereby users contribute to the operational costs of the service. The DD developed VMEbus-based VALET-Plus System was not introduced as an allocatable Pool system. Nevertheless, the on-line Pool gives VALET-Plus users technical consultancy and administrative support.

The general financial situation, with the trend towards having users pay directly for equipment and services, has resulted in additional administrative efforts for proper accounting and budget control. To ease this expanding task, personal computers have been introduced for pool administration and accounting. In addition, the on-line Pool Data Base is being converted from the HP-based IMAGE system onto the centrally supported ORACLE Data Base Management System.

On-Line Support and Development

A major upgrade of the VAX Data Acquisition System has been released , which fulfills some of the LEP collaboration's requests and removes some limitations. An important new feature is the possibility of recording data on disk files. The CAMAC station booking scheme has been revised and a new facility allowing CAMAC modules to be shared among several processes has been introduced. The tape recovery has been upgraded to cover the case of events spanning more than one record, introduced last year. Many other improvements have been made, involving nearly all the programs of the Data Acquisition suite; moreover some modifications have been introduced to cope with the new release of the VAX operating system (VMS version 4). The procedures for distributing new software via network have been consolidated, in coordination with User Support.

An evaluation of the MicroVAX II has been carried out with the aim of using such machines in experiments. The CAMAC system has been interfaced to the Q-bus using commercial products and the Data Acquisition software has been migrated successfully. Only one component of the Message Reporting was incompatible with MicroVMS, due to architectural discrepancies between the VAX and the MicroVAX: a reduced version of this part has been written for the MicroVAX. Apart from such minor necessary modifications, the VAX software is now frozen.

SINTRAN III version J has been released for the NORD systems; as a consequence substantial changes have been made to the data acquisition software to be compatible with the latest Sintran version and to convert it to standard ANSI Fortran 77. The possibility to write the CAMAC or FASTBUS readout part of the data acquisition in Fortran has been introduced, using standard subroutine calls. A new user-friendly CAMAC testing facility has been developed.

The level of software support has met the requirements of the experiments. In the case of VAX and PDP, support teams, as opposed to single contact persons, have been introduced to cope with the continuous growth of the number of installations. The VAX Data Acquisition System is now in use on 23 VAXes on site (of which 10 are in the LEP collaborations) and the CAMAC software is supported on 13 more VAXes. The software has also been distributed to some 22 groups in their home institutes (both in CERN member states and in other countries, such as USA, Canada, China). A few PDP systems are still supported as data acquisition machines in fixed target experiments. NORD systems have been used extensively for data acquisition applications: a total of 33 NORD systems, 7 ND-500, 17 ND-100 and 9 ND-10S, have been supported in many different types of experiment and test beams. Norsk Data has put a large ND-500 configuration at the disposal of the Delphi collaboration, who are using it in a test beam installation. It has been shared by 5 different users groups, one of which has successfully used FASTBUS in the data acquisition system.

As part of the effort to rationalize support operations, the number of 16 bit processor installations has decreased during 1985: some of the older NORD 10S and PDPs have been retired and more will follow. At the same time, the remaining ND-100 installations have been upgraded to bring them all to the same hardware level (CPU and memory management).

Collaboration with all the four LEP experiments has continued in several fields. Members of the group have been actively participating in the work for the design of each LEP experiment's data acquisition. This has included participation in collaboration meetings, technical discussions, working groups, and software planning bodies. A major evaluation exercise of the CDF Buffer Manager software has been carried out with the Aleph Data Acquisition team. Working groups have been set up to evaluate the requirements and the current proposals of the collaborations and to identify and join in particular projects mainly in the areas of dataflow, human interface, multiprocessor organisation and error reporting. A nucleus team is currently studying the general architecture of the LEP on-line software and the overall specifications for the LEP data acquisition system. To try out this design in a real production environment, a kernel system implementation will be provided in a near future to allow the LEP collaborations test beams with direct FASTBUS/VMEbus readout.

Coordination and participation in the ESSIG (CERN's Expert Systems Special Interest Group) activity led to the launching of some Pilot Projects related to the applicability of Artificial Intelligence and Expert Systems to HEP. An evaluation project of the emerging technology of Lisp machines has been performed in collaboration with other divisions (LEP, TH, PS, SPS). Prototypes of a Prolog Assistant for users of CERN networks and an integrated toolkit aimed at assisting designers and users of the trigger system for the L3 experiment have been developed. Several ESSIG newsletters and technical reports have been published.

Networking activities have continued as well: the EPIC Ethernet Pilot Project has been followed and the software to run CERNET over Ethernet for the Frigate programme has been developed on VAXes. Active participation has taken place in the Transport Service studies (CATS). Installation and support for the UK Janet software and for the VAX emulation of the IBM RSCS software (JNET) have been provided on many VAXes on-site. Many VAXes and the NORD support computer were connected to the CERN X25 gateway. The Cosmos X29 and X25 software was installed and successfully tested. Little progress has been made on the ND Ethernet due to hardware and software problems, however the Cosmos/Ethernet software has now arrived. The CERNET utilities and the

CERNET Transport Manager on the NORD have been modified to use ND's general task-to-task communication software. The incremental backup program from NORD to IBM archive volumes has been completely rewritten.

Several new DEC software products (Common LISP, ADA compiler, the program library manager, the debugger and the language sensitive editor) have been tried out on the central VAX and some evaluation notes have been produced.

VMEbus and VALET-Plus

The VALET-Plus test system was introduced in March and has now been adopted as a CERN supported test system. It consists of a set of VMEbus modules including a 68000 processor running the user application using the PILS (Portable Interpretive Language System) language and the portable standard CERN libraries available in EPROM. This VMEbus system is linked to a personal computer such as an APPLE Macintosh, an IBM-PC, an HP-200, etc, which provides the user interface and the standard peripherals to the 68000.

Some 50 VALET-Plus systems have been ordered by various groups at CERN and in major institutions and laboratories elsewhere as a standard means of testing electronics and sub-detectors ensuring portability of the developed programs between different parts of the collaborations.

The concept and the software of the VALET-Plus have also been adopted and implemented on more specialized hardware by DELPHI in their FASTBUS MAC-GPM and by OPAL in the CAMAC CBA.

A program of work has been carried out to fully benefit from the modularity and expansion possibilities of VALET-Plus both in hardware and software. These efforts have been put into MoniCa, the communication facilities, PILS and the micro- computer BRIDGE utility.

PILS has been widely used on VAX and 68000 (VALET-Plus) systems inside and outside CERN. A compiler option and an error recovery facility have been developed for both the VAX and the 68000. At present in use at some test installations, these new features will be officially introduced early next year. This work was presented at the 1985 Conference on Real-Time Computer Applications in Nuclear and Particle Physics in Chicago.

The HP and CAVIAR systems are still widely used but maintenance constraints and rationalisation of support is leading to a gradual replacement by new systems such as VALET-Plus.

Emulators

168/E Offline Pool

The utilisation of the pool was roughly at the same level as in 1984. Some 4100 jobs were run, representing about 6700 hours of IBM 370/168 equivalent time. As expected, the number of individual users decreased as the existing client experiments completed their analysis. The major user was the SFM experiment with a small amount of time going to R807 and NA12. In view of the unlikelihood of new customers for the 168/E pool emerging, one of the three clusters of the pool was shut down in September, liberating emulators to act as spares for UA1 and UA2 online use and saving maintenance cost and effort. The pool thus presently consists of two clusters of two processors each.

168/Es Online

The six 168/E processors installed at UA1 for online filtering remained in constant use during the runs in 1985, either tagging interesting events for 'Express Line' processing or rejecting uninteresting events so as to improve the data taking efficiency of the experiment. The 120 metre long VMEbus/VMX to CAMAC link, produced for the first stage of the UA1 upgrade, was commissioned during the year and has been operating satisfactorily.

The UA2 third level filter/trigger system was upgraded from two to three 168/Es and their data memories were extended to 0.5 Mbytes. The processors functioned without problems during the runs.

MICE

During 1985 three MICE machines were successfully used in a variety of real-time applications.

3081/E

Development

This high performance emulator of an IBM 370 series machine is being developed in collaboration with SLAC. During the year the major development activities on the processor itself were improvements and debugging as increasingly complex software was tried on the machine. Major physics code now running on the 3081/E includes INGER (R807 event reconstruction), MVFIT (LASS kinematic fitting), GHEISHA (hadronic shower simulation), BINGO (UA1 event reconstruction) and GEANT (Monte Carlo detector simulation). The attained performance meets the goal of one IBM 370/168 unit.

Starting from the netlists for the wirewrapped prototypes, the five boards of the processor have been successfully implemented in Multiwire technology which is suitable for larger scale production.

Much effort was invested in interfacing during the year. A dual port interface board was developed allowing data transfers up to the full processor speed along with flexible control and monitoring of the processor operation. Versions are available with one CAMAC and one VMEbus port or with two VMEbus ports. The CAMAC port communicates with the PAX module developed for the 168/E, while the VMEbus port is connected to a newly developed VMEbus module allowing several modes of DMA transfer. The specification of a dual port FASTBUS interface was agreed with potential users and the design of the unit was started.

On the software side, the interactive diagnostic support package SINEX was substantially extended and successfully ported from its original ND100 environment to VAX, IBM, MC68000, Macintosh and Apollo to meet the needs of the first recipients of 3081/Es. With help from outside institutes the suite of diagnostics running on the processor was greatly enhanced. The translator software which converts IBM object code to 3081/E microcode was debugged and improved, especially in the area of optimisation and pipelining. An extended set of microcodes was developed for pipelined operation.

3081/E based developments going on in other institutes included its use as a VAX emulator at CNAF Bologna and by the Italian APE project in a high performance computing engine for theoretical physics.

Production

To meet the needs of the first users, ten pre-series processors were produced in the same wirewrap technology as the prototype and a further four were built with Multiwire boards. That this was possible in parallel with development was due not only to much hard work by the small team involved but also to the successful involvement of industry in the construction of boards and chassis. This trend will be reinforced in the future.

By the end of the year, three processors and interfaces had been delivered to UA1 for combined online-offline use and two to L3, as well as others for evaluation to Rome, Saclay, Bologna, Pisa, DELPHI and NA34.

Offline Farm Pilot Project

The aim of this project is to evaluate the performance of a cluster of five 3081/E processors attached to an IBM 4361 host for the bulk offline processing of event data. During the year a preliminary farm was constructed with two emulators attached to the 4361 by a temporary interface using an IBM DACU and CAMAC. The necessary system software SYEPAK was written to allow easy communication with the emulators from user tasks running on the 4361. This configuration is now available to users for assessment. Meanwhile the design was finalised of a high performance IBM channel to VMEbus interface which will form the definitive connection to the emulators and the construction of a prototype was started. The MIT-Harvard collaboration in UA1 has decided to reproduce the same farm based at Harvard.

XOP Fast Trigger Processor

During 1985 four XOP trigger processors were built and installed, and the construction of a further three processors launched. These very fast processors, designed for trigger calculation and data compression with performance 10-40 times faster than a MC68000, are being used by the LEP L3 and the UA2 experiments in their trigger systems.

L3 will use 4 XOPs in parallel for the second level trigger, receiving in turn data from the first level trigger electronics, processing them, and sending the trigger decision to the next level. The data transfer will be handled by the dual FASTBUS master logic implemented on each XOP processor.

The UA2 scheme uses one XOP processor as the trigger supervisor. The processor generates and senses NIM signals to control the first level trigger. In the case of a successful first level decision, further data will be written into the XOP buffer memory using the LeCroy ECLine protocol. The XOP processor begins the second level trigger calculations on this data and within 800 microsec. the event will have been rejected or the readout process initiated by using the FASTBUS broadcast facility in order to notify the readout processors.

During the year the major hardware effort has been on interfacing. In collaboration with LAPP Annecy a dual FASTBUS master interface with 40Mbytes/sec throughput has been designed and a prototype is expected by the end of February 1986. For UA2, an XOP buffer memory interfacing directly to the LeCroy ECLine system at 40Mbytes/sec has been designed. The preprocessor on the input port of the buffer memory can perform gain correction and pedestal subtraction without influencing the transfer rate.

On the software side, a complete VMEbus based support package has been produced. This package, which offers debugging facilities as well as downline loading and control, is resident in EPROM and allows the easy installation of XOPs in any environment. Specialised instructions have been implemented to speed up commonly used operations in trigger routines such as cluster and centre of gravity finding. The cross assembler running on the IBM and on VAX computers has been expanded to handle these instructions and also those for the FASTBUS master interface.

FASTBUS

As the LEP experiments began testing parts of their detector read-out systems, the use of FASTBUS increased correspondingly. All extensions to the original CAMAC to FASTBUS Interface (CFI) and also the LeCroy 1821 and FASTBUS Diagnostic Sequencer Interfaces were included in the range of interfaces supported by the CERN FASTBUS Routines. The CFI was used to test ALEPH TPC FASTBUS equipment using the standard VAX CAMAC On-Line system. After the predictable pains of integration, the ensemble worked well. The NA31 experiment successfully completed their first phase of data-taking with the CFI and were quite satisfied with its performance. We have been closely involved in discussions with the LEP and other collaborations on their needs for various system modules.

Preliminary work was started on a FASTBUS database scheme, using ORACLE, for FASTBUS module catalogueing and system initialisation. This will continue through 1986 and will be tried out in one or two pilot projects in the autumn, notably at UA2.

The FASTBUS Hardware Specification, which was developed with a strong CERN participation, achieved international recognition as the ANSI-IEEE Standard 960. The Draft Specification for Standard FASTBUS Routines underwent serious revision in 1985 and it is hoped that work on this document will be completed in the coming year.

The first ever FASTBUS Software Workshop, was held at CERN in October 1985 and the Proceedings published as the Yellow Report CERN 85-15. The Workshop attracted about 150 participants who agreed that it was most beneficial and recommended that it should be repeated annually or bi-annually as a FASTBUS System Workshop. We were pleased to welcome several of our American colleagues on this occasion, and were able to have several fruitful discussions with them, particularly concerning the proposed software standard revisions.

FASTBUS Interfacing

The CERN FASTBUS Interface (CFI)

The CFI has now been fully commercialised and is being produced and supported by European industry. In addition to the original CAMAC I/O register connection, a VMEbus I/O register connection is also now available and an adaptor has been commercialised to allow a UNIBUS I/O register to connect to the CFI. Full testing of this UNIBUS to FASTBUS interface has taken place on a VAX 11/780 and on a VAX 11/750 at Edinburgh University. Both ALEPH and NA31 plan to use this UNIBUS to FASTBUS interface early in 1986.

A version with the UNIBUS I/O register replaced by one for Q-BUS has been installed on a MicroVAX in the FASTBUS lab and has successfully run user programs from NA31 and DELPHI using a pre-release version of the driver. It should be emphasised that the same FASTBUS board is used in all versions of the interface.

A New CERN Host Interface

Experience with the CFI has shown the design to have certain strengths and weaknesses. Discussions have thus started on a possible successor, optimised for 32 bit hosts, to be in service by LEP start-up. Connection to VAX-BI is of importance to some collaborations, but in view of the multiplicity of buses which will be present in LEP experiments (UNIBUS, Q-BUS, VMEbus, CAMAC etc.) a consistent approach is essential. In particular, considerations of modularity and software should radically influence the design since the associated manpower effort will dominate the life-cycle costs of the interface. Several tasks have been accomplished towards this goal.

1. A study group to report on Future Host Interfacing has been initiated. The aims and the timescales for the study group have been presented to a large audience of prospective clients (LEP collaborations, UA2 etc.). The study group has already produced a summary of the requirements and discussed these, individually, with representatives of the collaborations. Members of the group will now analyse the existing interfaces in the light of these requirements and subsequently present their conclusions to the major experiments.
2. A new design has been made for the FASTBUS coupler, in which the sequencer has been replaced by programmable logic. A prototype will soon be built and tested.

Extensions to the CFI/UFI/QFI Family

A new interface, if completely redesigned, would take about two years to produce in quantity. Experiments, both the LEP test beams and UA2, have requirements that must be fulfilled within the next year. Minimal hardware and firmware modifications to the existing FASTBUS card are presently under investigation.

Direct Support to Experiments

LEP experiments

ALEPH

Members of the division were involved in the planning of software specifications and design, the evaluation of software design methodologies, program development tools, hardware/systems environments, and utility software.

A continuing effort is made to coordinate the work on the ALEPH Monte Carlo program, by a team of about 15 people (four permanent at CERN) coming from eight institutions.

The '84 version of the GALEPH program has been used for physics studies (LEPC milestone). The '85 version is an open system making use of various sytems as GEANT3, LUND and BOS77, and maintained under HISTORIAN.

DELPHI

A Software Coordination Panel (SCOOP) had been formed within the context of the overall off-line software effort. In the frame of the Software Management Working Group the following was achieved by members of the division:

1. Writing, with others, a specification for a DELPHI documentation scheme.
2. Introducing the new bit handling package. This was coded in various FORTRAN dialects and in COMPASS.
3. Preparing a partial solution to the Hollerith/ CHARACTER problem.
4. Preparing a clean-up of the CERN Program Library. Recommendations have been made, and a program to make a short summary of the most useful routines automatically from the main document has been written.
5. A program to generate a printed calling tree of FORTRAN programs has been written. It also checks for any inconsistencies in calling sequences.

These last four items were done in a general way, and published as Computer Newsletter articles.

The implementation of all the programs required to store, retrieve and display data describing the Delphi detector has been completed (Spring 85) following the specifications given in the final report of the Delphi software planning group.

The usage of these programs in simulation runs and the definition of a more realistic set-up showed that the original design was insufficient and that there was a lack of flexibility in the available system. A new hierarchical data base management system has therefore been designed and implemented from scratch. It is now under test.

The Delphi Data Base Management System (sometimes called CARGO) is based on KAPACK, can be used to manage any kind of tree structured data and does not depend on any peculiar requirement of Delphi.

L3

Electronics for the L3 central detector

A time expansion chamber (TEC), which has been installed as central detector in the Mark J experiment at DESY, is considered as a prototype for the TEC central detector of L3. For this chamber the electronics for reading out the track signals of the 168 channels and transmitting them over 60 m long cables was developed, constructed and put into operation. In addition, a pulse simulator for the adjustment of the readout system was designed and constructed.

Investigations with a view to implementing charge division readout of the Z-coordinate are under way.

High-density readout electronics.

The collaboration continued with EF division in view of the possible use of silicon microstrips as a complement of the TEC in L3 and the growing interest in miniaturised and integrated analog electronics for reading out signals from particle detectors.

Computer control using a G64 based system is being implemented for the handling and measuring equipment of a special electronics laboratory which includes a clean room.

Special amplifier circuits were developed and their production by industry was closely supervised.

OPAL

A main contribution to the OPAL collaboration has been in the area of pattern recognition in the central detector. For that purpose, a complete simulation of this detector has been developed and used to test a new method of track finding based on a conformal mapping. The method has been successfully applied to the track reconstruction of events generated by the OPAL detector simulation program. In addition, this track finding algorithm has been used in the reconstruction of real data recorded during test runs performed with a full size prototype sector of the OPAL central detector. The pattern recognition program has been working as expected from the simulation studies and has been used also to refine various calibration constants previously obtained by other means.

DD staff has also taken an active part in the design of the overall OPAL reconstruction and analysis program, taking advantage of 'SASD' (Structured Analysis, Structured Design) methods learned during a one-week course offered by the OPAL collaboration.

In the framework of OPAL, the GOPAL program (interface of GEANT for OPAL) has been more or less completed. All detector components are now described, including the digitization process. A first version of the OPAL reconstruction program, ROPE, has been produced. Based on ZBOOK, it has been used by the central detector group. A new version based on ZEBRA has been produced at the end of the year.

Collider Experiments

UA1

The ongoing software support for UA1 consists mainly of online monitoring of the whole experiment in VMEbus (trigger,calorimeters,central detector histograms and event display) and calibrations. This comprises ND-500 system and applications as well as libraries.

During 1985 UA1 completed the installation of a new VMEbus based data acquisition system which ran successfully during the Autumn collider period. Such an improvement provides much flexibility for future upgrades, being modular and expandable in both online data acquisition and offline event data processing.

In order to integrate the new system with existing electronics, several special VMEbus modules needed to be developed both at CERN and at external firms and collaborating institutes. These included general purpose 68010 based CPU boards (CPUA1), VMEbus/VMX dual ported memory boards (DPRX, DPDX), VMEbus/Remus drivers (RVMEX), Crate Interconnects, 168/E links, 3081/E interfaces, Macintosh/VMEbus connections (MacVee), Interrupt Vector Generators, VMEbus I/O boards and Streamer Tube Readout modules (STAR). These were developed between CERN EP and DD Divisions, Data-Sud, Saclay, LAPP/Annecy and the Universities of Helsinki and Padova. The present system consists of 20 VMEbus crates, 60 CPUA1 boards, 12 MacVees and over 100 of the remaining VMEbus modules listed.

More than 200,000 lines of Assembler code have been written and installed using the standard CERN cross-software support. In addition much Fortran code has been written and compiled with the VdS/RTF68K compiler. The software consists of a special CPUA1 monitor/debugger, a data acquisition event manager and readout supervisor, several event unit tasks for data handling and sampling, VMEbus resident libraries and test facilities. In addition the incorporation of MacVee has permitted direct user friendly interfaces with both the VMEbus multiprocessor system and the existing CAMAC crates. Consequently Macintoshes are used as control, monitoring, downloading, display and testing devices. To permit standalone developments, with MacVee, a complete system has been installed including Fortran compiler, 68000 assembler, linker and editor.

Finally two 3081/E processors have been installed and run in the first phase of a program which will consist, finally, of 6 such emulators running both on- and off-line. These provide higher level triggering devices in online data acquisition mode and an extensive offline data processing facility. In connection with using such a system standalone in VMEbus, software and hardware are currently being developed for the introduction of video disc mass storage devices.

UA2

Work continued on the design of the new chain of programs to handle data from the upgraded detector. Coding will start in the spring. The programs will run on the IBM VM system.

The analysis of the 1985 data has to be completed.
Meetings are held at approximately monthly intervals to coordinate on-line DD work.

SPS experiments

NA31

Data taking started in April 1985. A program reconstructing events, making calibrations, and monitoring the quality of hardware and data taking was developed.

The CP-violation experiment is very sensitive to systematics. They have to be understood and reduced as much as possible in hardware and in software. In order to reduce the effect of variations in the calibration constants of the calorimeters, they are constantly monitored, and the different calibration constants are stored in a KAPACK data base, transportable using EPIO.

Studies to determine a fast and good cluster finding algorithm for the calorimeters will continue in 1986. This experiment is using HISTORIAN as code manager on all machines of the collaboration: IBM/MVS, IBM/VM, CDC, VAX and NORD.

NA36 (ex EHS)

The experiment NA36 will use many of the detectors of EHS and will retain the existing ND100 for monitoring. Support continued for extending the associated software and adapting it to the new environment.

WA1

The neutrino experiment stopped data taking in September 84. The production to get final results on total neutrino cross section, structure functions, like-sign dimuons and Weinberg angle was finished in summer 1985.

The pattern recognition program and the Montecarlo program have been used heavily in production but as they turned out to be very reliable they needed only a low level of support.

WA79

The first version of the analysis program CHARON has analysed successfully the data taken during the test run in summer. For convenience and safety, automatic loading of geometry and calibration files has been implemented, based on the random access facility in ZBOOK.

The program is strictly written in ANSI FORTRAN77, and runs on IBM, VAX, and NORD. The code manager is Historian, the graphics package GKS.

OMEGA

Several experiments making use of very high precision micro strip chambers have been approved. Appropriate coding has to be developed and as well a package for the RICH detector which is now part of the Omega detector.

ERASME

The maintenance of the 6 ERASME CRT film measuring tables continued. Assistance was again given for revising and tuning the ERASME measuring table of JEN in Madrid.

Miscellaneous Activities

Divisional Electronic Workshop

During the year further progress was made in improving the working methods of the workshop and integrating them with those of the development groups. Three DAISY Personal Logician Schematic Capture systems were installed, one each for two development teams and one for the drawing office section of the workshop. These systems are now in regular use for the production of schematics and the checking of electrical consistency of designs.

CAD/CAE for Electronics

The software package MDS from PCK for the multiwire technology has been succesfully used in several applications.

A new wirewrap software package, to replace WRAP3, is being written and some jobs have been done with it already.

Interfaces from the DAISY systems to other design packages have been implemented. There have been succesful demonstrations of the transfer of designs from DAISY to the CBDS CAD system used for PC preparation and to the package for semi-automatic wirewrap preparation.

The circuit modelling program SPICE is installed on the ERASME VAX. With the collaboration of an EP division programmer, it was modified to facilitate its use, in particular for the design of discrete and integrated analog circuits.

Training and Conferences

The division continued to organize the Informatics Tutorials. Four tutorials took place, on the C programming language, Prolog, networks and GKS. They met with the usual success. Also the Computer Seminars and the DD seminars have been held at regular intervals.

The division provided lecturers for the summer student programme, the Microprocessor Colleges in Bogota, Trieste and Lisbon (organized by the International Centre for Theoretical Physics in Trieste) the summer school in Czechoslovakia (organized under the auspices of the European Physical Society) and the winter school on Experimental Methods in High Energy Physics in Bombay (organized by the Tata Institute).

Tutorials on the VMEbus were organized in connection with the 'VMEbus in Physics' conference.

The division organized two conferences, which took place at CERN. The first concerned the use of the VMEbus in physics and was mentioned before. The second was a workshop on Fastbus software. In addition, another collaboration meeting on data compilation for high energy physics was held at CERN. A member of the staff is involved in organizing a forthcoming school on advanced techniques in computational physics, to be held in Trieste.

Different members of the division were invited to lecture at other institutes or at user meetings such as DECUS and SEAS.

A member of the staff has published a book and contributed chapters to others.

Standardization

1985 saw the adoption of two standards (IEEE-960, Fastbus and IEEE-695, Standard Object Module Format), to which members of the division had made substantial contributions. A member of the staff participates in the ANSI X3J3 Fortran standard committee. Others are very active in promoting of and contributing to standards, particularly in the Data Communications field and in graphics.

Proton Synchrotron Division

Introduction

The year began with an uncommon kind of removal and ended with a veritable marathon. Moving a complete accelerator is a rather rare event, and the machine concerned was also something of a special case, being the venerable original linear accelerator which first supplied the PS with 50 MeV protons in 1959. Constantly available ever since, it was supplanted as principal preinjector in 1978 by its younger and more vigorous brother, but had found new roles in recent years, first as proton supplier to LEAR, and later as something of a virtuoso in the light ion field. The move could perhaps better be described as a strategic withdrawal, since the principal object was to eliminate a weak point in the PS Ring shielding at the Linac I junction which had been a perennial nuisance ever since the first high intensity beams for the SPS passed that way. The heavy work had to be done when the PS was shut down, and this was—just!—accomplished. More complex was putting the machine together again, but inside six months old faithful Linac I was once again in operation, and a lot more accessible than it had been before.

The marathon was run by the PS Accelerator Complex, operating continuously for an unprecedented seventeen weeks—2800 hours—supplying antiprotons simultaneously to the SPS Collider and to LEAR for its low energy experiments. This was something of a challenge for the machines and their crews, and both proved more than equal to it. The experiments got more than they had asked for, some significant development work was fitted in, and at the end of the marathon the machines were running better than they had at the beginning, although their crews were rather tired. A full account is given under 'Operation' below.

Preparations for the acceleration of oxygen ions, and for first tests with electrons in the PS, both items on the programme for 1986, were well ahead. LEAR expanded its horizons with a wider range of momentum and longer spill times, and plans were being made for the post-ACOL generation of experiments. The Booster stretched itself to produce 1 GeV protons, for a while, with very favourable effects on PS injection, creating an attractive future option. Beam losses and remanent radioactivity in the PS both went down, whilst the available beam intensity went up. The Antiproton Accumulator continued to experiment with ways of stacking more $\bar{p}$'s per p, and the design of the Antiproton Collector (ACOL) made excellent progress, as did the complex plans for installing the new machine around the existing one. The versatile PS controls system successfully absorbed a new process (r.f.) and ACOL and LPI controls were in gestation. After careful studies, renovation of the PS Complex access control system began. At the Synchro-Cyclotron, despite a rather spectacular mechanical breakdown and some other little troubles, a successful experimental programme, embracing both protons and light ions, was carried through. Various improvements were made to obtain better and more reliable future operation. The installation of the new on-line isotope separator, ISOLDE III, was on schedule. All these items are described in greater detail in the sections which follow. Finally, it should not be forgotten that this successful programme depended on a considerable amount of behind-the- scenes work in laboratories, offices and workshops.

PROTON SYNCHROTRON

The Physics Programme

Operation

The year of 1985 duly produced what had come to be regarded as the usual quota of records, but the most striking feature on the operational scene was the extraordinary reliability of all the machines making up the PS accelerator complex even when called upon to display their highest degree of versatility. Overall computer control enabling operational modes to be changed from cycle to cycle allowed ambitiously complex experimental programmes to be imagined and realised — the last running period of the year, when two entirely separate experimental areas were supplied with the rare antiprotons simultaneously and for an unprecedented 2800 hours of continuous operation, was the most brilliant example to date. Yet in the end everything must depend upon the devotion and competence of the staff, and these qualities were often severely tested during the year.

All the usual maintenance tasks were completed during the long shutdown at the beginning of the year, but two unexpected additions cropped up. The severe cold spell in January seriously damaged the windings of the 44-ton filter of the PS main magnet power supply, and only a major effort by a firm of specialists and CERN mechanics kept the delay in starting up down to two days. Then, during preliminary tests, an insulation breakdown caused by a leak in the cooling water circuits made it necessary to replace one of the (100) units of the PS magnet. With stout work by SB transport, the exchange of the 40-ton units was smartly done, and the start-up was only delayed by a further day. Unfortunately, Fate was still not on our side, and a succession of power failures, including one to the 'uninterruptible' standby serving vital equipment, chose to occur at crucial moments in the complex start-up procedure. Although the enthusiasm and stamina of operating crews and experts alike were sorely tried, the planned start-up programme was maintained, at the expense of temporarily sacrificing some 30 hours of machine development time. By the end of February, the AA was on stream, and the SPS received its proton beam on March 4th.

The month of March was not a happy one for those responsible for running and repairing the machines. Besides a relatively high breakdown rate and further power failures, resulting in repeated losses of the AA antiproton stack, numerous changes of the experimental programme had to be made in order to cope with the 'critical days' imposed by CERN's contract with the electricity supply authorities (EdF), and this was, to say the least, hard on everyone's nerves. Nevertheless, a successful experimental physics programme was rapidly established; LEAR users had a full week of operation with antiprotons at 300 MeV/c, after setting up the machine as economically as possible since only precious $\bar{p}$ were available for the purpose, Linac I being out of action after its move. Beams of protons and antiprotons with appropriate characteristics were supplied to the SPS at 26 GeV/c for the successful tests of Collider operation in the pulsed mode, and the very first 900 GeV/c collisions were soon observed. The AA tried out a current-carrying target with a lithium lens, and then returned to the standard configuration with the magnetic focusing horn for routine production, rapidly obtaining a satisfactory performance (a maximum of 7×10^9 $\bar{p}$ /hour for 1.3×10^{13} protons per pulse on the target). From 20 March the East Hall test beam users were once again in business (24 GeV/c extracted proton beam). Although the machine complex had not yet returned to optimum performance, all programmed beams were in service, and first tests had been made of the scheme to send antiprotons to two different users and serve the East Hall as well during one PS supercycle. A difficult running period was almost at an end when a breakdown of the magnetic horn abruptly stopped antiproton production — the stack, however, stayed and was used up to the last particle. The Easter holiday was greeted with sighs of relief all round!

During the second period, from April to mid-June, better performances were obtained and the fault rate was comfortingly low. The programme of operations was fairly standard (some would have it that, in the PS environment, the term applied to anything lasting more than a week). The SPS was supplied with 14 GeV/c protons for fixed-target operation, and the East Hall users were able to run during the day (0900–2300), whilst the AA produced and cooled antiprotons for the longest ever run (5.5 weeks) devoted to LEAR experiments. Antiproton accumulation attained a high level; for some of the time, four out of every seven $\bar{p}$'s produced found their way into the stack. The LEAR experiments used four different momenta, and it is indicative of the progress made that the density of the beam at the focus for the lowest momentum (200 MeV/c) was 60 times higher than in the previous year. A better transfer efficiency was also obtained between the AA and LEAR, reaching a maximum of 80% — unfortunately, this did not prove to be readily reproducible. The only serious nuisance in this period was the loss of the AA stack on five occasions for quite unrelated reasons; twice it was voltage fluctuations on the incoming power lines, twice failures of water cooling and once an air-cooling fan which abruptly stopped. Towards the end of the period a development session was devoted to operation with deuterons, in preparation for the future acceleration of oxygen ions, and (exceptionally) whilst this was taking place the AA stack was preserved, to be used afterwards by the SPS returning to its Collider mode. An extension of 48 hours allowed the experiment UA4 to complete its measurements.

The third period, from the end of June to the middle of August, began with three weeks of relatively simple operation supplying protons only to the SPS and the East Hall. A long development session in preparation for future running with oxygen ions took place using deuterons, and these were successfully transferred to the SPS at 10 GeV/c per nucleon using fast extraction. The AA devoted a week to trying out different configurations for antiproton production, finally leaving in operational service a short target and lithium lens combination, which proved to be quite reliable. LEAR was at last able to use protons from Linac I, once again in action after its move. The South Hall experiments were provided with antiprotons at chosen momenta in the region of 1500 MeV/c, and later at around 600 MeV/c. The euphoria generated by this quietly successful period was rapidly dissipated when it was found that the insulation of the AA lithium lens transformer was in a very poor state, and the whole target area was radioactively contaminated as a result of the destruction of targets by overheating. A crash programme for cleaning up was immediately instituted with a good deal of help from SB Division and external firms, including modifications to the drainage to confine the effects of any subsequent similar incident. Start-up of the AA for the next, most important, period was only delayed by five days.

The last period, covering more than a third of the year, truly represented the best that could be done with the machines at our disposal. Operating continuously for more than 2800 hours, serving all the antiproton customers, both high and low energies, as well as the East Hall users, changing modes of operation often in a few minutes and frequently as many as 25 times in a single day, achieving performances better than ever before; this was enough in itself to generate some feeling of satisfaction. But, for once, the Fates were on our side, and the fault rate was amazingly low for so long a run — only just over 5%.

The AA had returned to its standard configuration (plain copper target, magnetic horn) and was stacking a creditable figure of 6.5×10^9 $\bar{p}$/hour. A best-ever transfer efficiency between AA and SPS — 85% — was recorded, although the average was more like 75%. The best performances of 1984 were equalled, a triumph somewhat marred by three stack losses, one of which was caused by a suicidal bird which barbecued itself in the 130 kV substation. An SPS stop to cope with difficulties in the UA1 experiment helped LEAR to provide antiprotons for the South Hall at the exceptionally low momentum of 105 MeV/c (the energy reached only a little way along the Linac injectors). October could be considered as the most efficient month's running ever seen. Everything went according to plan, and the SPS integrated luminosity was 30% higher than at the same stage in 1984. LEAR delivered, as well as 105 MeV/c, other momenta in the 500–600 MeV/c range, chosen at will and produced in short order. Everything continued to run like a good Swiss clock into November, up to the technical stop scheduled for the 10th and 11th; at this moment the AA stack was lost because of a power failure. Some of those lost antiprotons must have been going round and round for nearly a thousand hours. The opportunity was taken to do some hasty maintenance, since nobody had been able to enter the AA enclosure for a month and a half. For the following fortnight the contract with EdF imposing 'critical days' meant that the SPS was almost unable to use antiprotons. LEAR made the most of this opportunity, whilst still remaining within the limits established by the Research Board. Another incidental effect was to produce a new record for the circulating stack intensity in the AA — 4.23×10^{11} $\bar{p}$ — on the very day of the 26th anniversary of PS operation.

Using the short periods of development time available, a new scheme of beam optics at 26 GeV/c in the PS was brought into service. This considerably reduced the losses at beam extraction, both for the SPS and the AA, and its benefits showed up later in the form of a significant reduction in induced radioactivity. Another very promising development was demonstrated in tests of injection from the Booster to the PS at 1 GeV instead of the usual 800 MeV. The only serious fault was related to the chronic problem of cooling circuit blockage in various magnetic elements; the future use of water with a low oxygen content was expected to resolve this problem.

December was another satisfactory month, suitably ending this exceptionally long run. With a regular 1.6×10^{13} protons per pulse on target, the AA was stacking 1.3×10^{11} antiprotons every 24 hours, an excellent performance. A final development session for PSB-PS transfer at 1 GeV went well. LEAR operated at close to its maximum momentum (1.7 GeV/c), delivering its antiprotons stably and reliably in steady streams lasting from one to three hours. During the last two days of the run three users were served simultaneously, namely the SPS, LEAR and the East Hall. This was done in order to accommodate a high priority test for future experiments at LEP and the Collider with ACOL in operation. Statistics of the year's operation are shown in Figures 1, 2 and 3.

Finally, the integrated luminosity in the SPS reached 655 $nbarn^{-1}$, considerably more than had been hoped for, and representing a 30% improvement in overall performance. The constant endeavour to keep beam losses down, coupled with better PS beam optics, showed other benefits. In spite of running for a longer period than ever before, and at high intensity, the induced radioactivity in the PS at the end was found to be relatively low level. This of course directly affects the radiation dose received by maintenance staff. There was certainly an element of chance in the high degree of reliability exhibited during this long run for example, no power cuts due to storms occurred. Even in this fortunate situation there were several occasions when the workload on staff approached unacceptable limits, especially towards the end of the run. It was felt that this factor should be taken into account for future planning, particularly since operations seemed likely to grow more complex without any concomitant increase in the number of staff available.

Experimental Areas

1985 saw a considerable expansion of activities in the PS experimental areas (see fig. 4). In the South Hall, the pure beams of low energy antiprotons provided by LEAR ran for more than 1300 hours (1983: 265 h, 1984: 690 h) at 21 different energies (5 only in 1983/84) with fifteen experiments taking data. On the average, a changeover between experiments, including the associated vacuum systems, took place every 40 hours of running time. The momentum range available operationally stretched from 105 to 1700 MeV/c, and even at the lowest value the beam could be focused down to a spot size of 2 mm^2. For four of the experiments working at 105 MeV/c, thin beryllium windows were introduced to reduce multiple scattering. Various other improvements to simplify operation took place; an additional remotely-controlled wire chamber was installed in the vacuum system of one zone, the allocation of power supplies to beam transport elements was modified for low momentum runs to improve stability and a second beam control point was installed at the far end of the experimental area.

In the East Hall beam t_7, still being used for an experiment at the beginning of the year, was later changed into a two-branch test beam. This, and the three other test beams (t_9, t_{10} and t_{11}), were used by the four LEP experiments, most of the SPS experiments, some detectors for HERA (DESY) and numerous detector prototypes. The number of pieces of equipment under test went up from 10 during the first period to 20 in the last; a total of 50 items were installed.

The centralized gas distribution systems installed in the South and East Halls were fully employed. Ten different gases were available, and about 8,500 m^3 in each Hall was distributed to a total of 38 users. This was equivalent to the contents of some 1700 cylinders!

Besides installation work, repair and renovation of beam transport elements continued, and assistance in this field was also provided in other parts of the Division's territory on several occasions, notably AA and PSB. Thirty-seven breakdowns on the experimental floor were dealt with, representing a fault rate of less than 0.2%.

In addition to running the existing beam monitors (covering both experimental areas and machines), tests began of a new monitor designed for very low energy antiproton beams, using secondary emission followed by electron multiplication. Throughout the year studies continued on requirements for the second generation of LEAR experiments, due to begin with the start of ACOL operation in 1987. These covered plans for installation of experiments as well as the possibility of extension to the North Hall and the development of beam optics.

Machines and Technical Development

Linear Accelerators

In recent years the shielding at the complex junction where the Linac I wing joined the main Ring building had become completely inadequate. This was largely due to the close proximity of the high intensity beam line crossing over to the AA and the SPS and of the extraction system from s-s 16 supplying it. What began as a transfer system for the relatively low intensity and infrequent packets of beam for the ISR had become the main export channel for PS high energy protons at ever-increasing intensities. Even quite small beam losses, difficult to eliminate swiftly, caused undesirable levels of radiation in necessarily accessible areas near the Linac preinjector.

With the introduction of the RFQ in 1984, replacing the former bulky and immovable 500 kV HT set, a solution became feasible, albeit scarcely simple. This was to move the whole machine back by some twelve metres — no small undertaking — and heavily reinforce the shielding at the Ring building junction. Obviously this could only be done during a PS shutdown, so the beginning of 1985 was the first chance — and the last until the following year. Besides the shielding at the junction, it was necessary to reinforce with steel blocks the shielding between the side wall of the Linac and the Ring, which had been weakened by construction of the LEAR injection tunnel. This turned out to be a fairly major piece of civil engineering, because the earth covering had to be removed and replaced. Bad weather brought the PS start-up deadline uncomfortably close, but the freezing temperatures also stabilized the soil enough to permit a steep-sided excavation. Actually moving the three accelerating cavities ('tanks') was a simple enough task, but the dismantling and reinstallation of all the associated equipment — such as r.f. modulators and amplifiers, power supplies for focusing quadrupoles, water and other services — was a massive undertaking. A considerable amount of extra help had to be called upon, both from inside and outside the Division, and even with this willing assistance there was still a marked shortage of manpower. Nevertheless, the job was finished only a little behind schedule, and Linac I was able to start up again early in June.

The opportunity of the move was taken to renew or refurbish some of the older installations, such as parts of the r.f. system, ventilation and electricity supplies. The front end was provided with two beam lines, each with its own ion source, RFQ and matching elements, including cavities for longitudinal matching. One line supplied the Linac with oxygen ions, alpha particles or deuterons, whilst the other provided protons or H^- ions. This installation, as well as measuring equipment elsewhere along the Linac line for the low intensity O^{8+} beam (special secondary emission grids and beam current transformers), required a good deal of development effort. For the H^- ion source, previous attempts had only produced rather unstable beams of a few hundred μA, but a new device developed in collaboration with BNL gave an RFQ output of a few mA.

Linac II continued to provide, with a very high degree of availability, proton (and deuteron) beams for the PS complex. Some changes in the beam optics of the 50 MeV transport line resulted in an appreciable increase in the intensity supplied to the Booster, and the lower beam losses were also expected to reduce the hazard due to radioactivity in this extremely crowded area where the two linac beams passed through the PS Ring. In this same region a new computer-controlled parameter reset facility permitted rapid changeover from protons to deuterons and pulse-to-pulse switching between Linac I (e.g. O^{8+}) and Linac II (protons). This also proved very useful when restarting after a power cut.

Future plans included control of both Linacs and LEAR from the PS Main Control Room for routine operation. Progress was made in this direction with the provision of access to Linac parameters by programs running in the main NORD computers of the PS control system, permitting them to be displayed and controlled from the MCR operator consoles.

Booster Synchrotron

During the long shutdown, the final step was taken in the rejuvenation of the main magnet power supply with the installation of five new rectifier-inverter sets, more compact than the old models and modern in design. The original 300 air-cooled thyristors, dating from the late sixties, were replaced by 80 single-sided water-cooled high-power units. The new system rapidly attained the high degree of reliability which characterised its predecessor.

Using spare cycles during operation, further studies were made on acceleration up to 1 GeV, with the ultimate object of raising PS injection energy from the current 800 MeV and thereby reducing the intensity limit imposed by space-charge effects. Then, in a machine study session towards the end of the year, a 1 GeV beam was actually injected into the PS. To do this, it was necessary to push transfer line beam transport power supplies up to their limits (and in some cases even beyond), putting a time limit on the experiment. However, the results were worth while; up to 2×10^{13} protons per pulse were accelerated, using two of the Booster's four rings, to 1 GeV, and of this number up to 1.77×10^{13} were accelerated in the PS (cp. with $\sim 1.5 \times 10^{13}$ normally for antiproton production). A very welcome by-product was a significant reduction in losses between PSB and PS. On the evidence of this trial, it was quite clear that putting the Booster energy up to 1 GeV for routine operation would give a solid advantage in overall efficiency. However, it would require capital investment to upgrade certain critical components, notably the septum magnets used for extraction, blending the beam from the four rings and injection into the PS.

With the CERN oxygen ion research programme scheduled for 1986, a major effort was devoted to development work for the acceleration of these particles, mainly in the fields of beam instrumentation and r.f. control loops able to handle the very low ion intensity levels and, on alternate cycles, proton beams with intensities of a factor of 10^6 higher. Tests were carried out in summer using a beam of deuterons, reduced to μA levels, from Linac II. The elaborate r.f. 'gymnastics' required for ion acceleration, in particular the change of both harmonic number and circulating bunches from 10 to 5, could be tried out. It was also possible to check the performance of prototype electronic modules for beam control and instrumentation relying upon very small signals blurred by noise. The performance of most systems was encouraging, and indeed a beam as small as 3×10^8 ions per pulse was successfully accelerated through the whole chain of machines including the SPS (as reported elsewhere). Areas where more work would be required were identified, but in the meantime construction of electronic modules to equip all four rings was started.

Blockage of water-cooling passages in the septum magnets of the PSB-PS transfer line, a recurrent problem, had been occurring more and more frequently. First aid treatment consisted of washing out with a weak acid solution, requiring a machine stop of several hours. Since the cause was thought to be a reaction involving dissolved oxygen enhanced by irradiation due to inevitable beam losses, a pilot cooling system using demineralized water with a low oxygen content (< 5 parts in 10^8) was tried out on one of the magnets with the encouraging result that no blockage occurred in nearly a year's operation. It was therefore decided to extend this scheme to all septum magnets in the Booster.

Main Proton Synchrotron

An important part of the year's work was devoted to preparations for the acceleration of electrons, positrons and oxygen ions. New equipment was installed for e^+/e^- injection (kicker, septum magnet, transfer lines) and the closed orbit display system was upgraded to cope with the various trains of bunches coming to the PS from four different machines and rotating in both directions. Final versions of the 'wiggler' magnets, required to stabilize electron/positron beams, were under construction after the previous year's successful tests. The two 600 kV, 114 MHz, r.f. accelerating cavities were being built, and it was planned to install one of these (incomplete) at the beginning of 1986 in order to check possible effects on the proton beam. Magnet field cycles for acceleration of the new particles were established. The existing pick-up electrodes, which had given faithful service through twenty years of continuous development of the PS, would not be compatible with criteria for vacuum equipment in the presence of synchrotron radiation (generated by circulating e^+/e^-), so prototypes of the mechanical and electronic parts of a suitable new model were under development, for tests in 1986. The high sensitivity beam control system for use with ions was tried out successfully. In addition, looking forward to the high intensity beams coming with ACOL operation, electronics for the longitudinal merging of bunches was ready, and development of feedback to compensate beam loading effects on the r.f. cavities was under way.

Main contracts were placed for the new PS vacuum chamber and system. In the design, a big effort was made to minimize the number of components by standardizing as much as possible. The conductors for the new figure-of-eight loop for the PS main magnet pole-pieces (for field correction at high values) were specified and it was anticipated that the order would be placed early in 1986. In the meantime, detailed drawings of the fixations (5000 components) were being finalized, and a prototype assembly was under construction.

Developments in performance are reported under a separate heading below. Particularly noteworthy was the reduction of beam losses and the associated increase in fast extraction efficiency, which reached close on 100%, significantly diminishing levels of radioactivity in important sectors of the machine. A favourite project, in mind for some time already, began at last: renovation of the PS Ring. One sector was repainted and it was planned to start on the major spring-cleaning, including removal of cables etc... no longer in use, in January of 1986. However, with the comparative scarcity of shutdown time, a brand-new Ring could scarcely be expected to emerge in less than ten years.

Antiproton Accumulator

Both performance and reliability continued to improve through 1985. The highest recorded stack intensity was 4.23×10^{11} antiprotons, and the longest continuously circulating stack was held for 42 days ($\sim$ 1000 hours), both new world records. Other statistics appear in figs. 2 and 3.

Several versions of current-carrying (self-focusing) targets were tried out during the year, with excellent results in terms of increased antiproton yield (up to 40%), but reliability was inadequate for regular operation. As theory had predicted, it proved difficult to find a design that would withstand the shock of intense pulses of protons and currents of a few hundred kA simultaneously.

The use of lithium lenses (for a description and illustration, see Annual Report for 1984, p. 108) was tried out, in both pre-focusing and antiproton collecting roles, for some production runs. Such a lens has a focal length somewhat shorter than that of the magnetic horn usually employed to concentrate the antiprotons. The experience was extremely positive for the pre-focusing mode, where the apparatus withstood more than 1.5×10^{6} pulses at 350 kA in a high intensity proton beam without any sign of failure, but less so in the collecting position, where the integral step-down pulse transformer suffered damage to its ceramic insulation due to excessive differential expansion resulting from heating by the intense particle shower (beam loss doubled the heating effect due to electrical losses).

During four weeks of regular operation, a short rhenium target was in use, followed by a lithium lens. Rhenium appeared to have the optimum combination of density and 'transparency' for antiproton production. However, two targets burned up owing to perforation of the steel end windows, although a third, using titanium windows, was still intact at the end of the run. The contamination with radioactive debris resulting from the burned-up targets required a major clean-up operation under expert supervision, in the course of which the target area drainage system was modified to prevent the spread of radioactive contamination in any future similar incident. Antiproton production then reverted to the standard copper target and magnetic focusing horn configuration.

A study programme sought to optimize antiproton accumulation rates by improving transverse acceptance. This was an iterative process, since orbit modifications changed the position of the beam in the cooling system pick-ups, requiring further adjustments. The AA magnets were re-shimmed in order to reduce the tune excursion across the momentum aperture. Following this work, the antiproton accumulation rate reached a new high point of 3.7×10^{-7} per proton on target (with the standard target-horn configuration). The horizontal extraction acceptance was increased from about 2π mm mrad to around 4π mm mrad by a slight displacement of the r.f. cavity. This resulted in an improved extraction efficiency without any reduction in acceptance for the circulating beam.

The efficiency of the electrostatic clearing system in removing ions from the circulating beam was improved by raising the voltage and adding more electrodes. Adverse effects of inadequate clearing showed up as ion-induced non-linear resonances, antiproton/ion coherent instability and the capture of charged microscopic particles, all of which were harmful at high stack intensity. Computer control of the clearing power supplies made elimination of charged particles by ion purging fairly successful. The antiproton/ion instability was still observable, but weaker. Installation of a resonant vertical pick-up made detailed studies easier, and adding the signal from this device to the transverse damper proved effective in reducing the instability.

During the last running period of the year, there were daily transfers of 30% of the stack to the SPS at the same time as slices of as little as 0.3% were being dispatched to LEAR several times each day (see fig. 5). This mode of operation placed particular emphasis on stack core emittances at high intensities and during accumulation. In order to reach the performance necessary, some improvements had to be made to the stack-tail kicker, and a very precise control, to a few parts in 10^{-4}, had to be maintained over Q_H/Q_V tune.

The ACOL (Antiproton Collector—see Annual Report for 1984, p. 108) project gathered considerable momentum. All major systems were ordered, and about half the total budget committed, by the end of the year. Half of the total number of quadrupoles were delivered, measured and shimmed to be well within the specified gradient tolerances. Five of the eight wide dipoles were delivered and measured. Vacuum chambers for dipoles and quadrupoles were all being fabricated and delivered either to CERN or to the magnet manufactures (dipole vacuum chambers had to be installed before the two halves of the magnet were welded together). Microwave power amplifier prototypes were developed, and production orders placed. A laboratory model of a d.c. beam current transformer with a sensitivity of 5 μA (2×10^7 charges in ACOL) was developed within the Division. With a response time of $\sim$ 100 ms, it should be capable of monitoring individual injected bursts of antiprotons. The complex mechanical design problem posed by movable cooling electrodes following the beam shrinkage seemed to have been solved, and prototypes were under construction. Development of magnetic horns, lithium lenses (in collaboration with FNAL) and plasma lenses (in collaboration with European Universities) continued. A lithium lens, designed and built at CERN, successfully withstood more then 5×10^6 pulses in the current range of 320–450 kA. One prototype plasma lens survived 10^5 pulses, which was two orders of magnitude better than any of its predecessors.

Major modifications would be required to the AA for operation with ACOL. Antiprotons arriving in larger quantities and at ten times the previous rate would require a more powerful stochastic cooling system, and to this end a new stack-core system, working in the 4–8 GHz range, was designed and constructed. Laboratory tests were sufficiently encouraging for field trials to be envisaged for early 1986. A comprehensive redesign of the whole target area was undertaken. A 'dog-leg' layout for the beam transport from the production target would considerably reduce penetration of radiation into the accumulation area, and the shielding separation would be greatly improved by providing an independent access gallery. A surface building to house power supplies and other equipment, as well as a zone for handling, by remote control, highly radioactive items, was already under construction. A mock-up of the target area was being built, so that any necessary work in the highly radioactive zone could be rehearsed to minimize doses to personnel. All other systems, such as beam diagnostics, controls, extraction equipment and the beam lines were well advanced. The installation shutdown, starting in September of 1986, had been planned in detail, but some problems remained, mainly related to a dearth of manpower in the design offices; it was also clear that installation would require contract labour from outside. Some stretching of the budget would be necessary to pay for the missing manpower, but it was still hoped that running-in of ACOL could begin in the Spring of 1987.

LEAR

The machine ran for 4,000 hours in 1985, operating concurrently with the SPS Collider during the second half of the year (see Fig. 5). This antiproton sharing proved less hazardous than had been anticipated, principally because of the high levels of reliability attained by all the machines involved, and this was a fortunate circumstance, since LEAR operations during this period became quite complex. 2700 hours were programmed for experimental physics, at 21 different extracted beam momenta between 105 MeV/c and 1700 MeV/c; internal beam was accelerated to 2000 MeV/c but not extracted. A total of 1450 spills went to the beams on the experimental floor, serving 1, 2 or 3 users simultaneously. The remainder of the running time covered all machine studies, with both protons and antiprotons, and setting-up periods.

Considerable effort was devoted to developing the 'momentum scanning' procedure and its associated software, designed so that the extracted beam momentum could be changed quickly, easily and as often as required. This process became fully operational, enabling the momentum to be changed in a few hours using fewer than three small pulses of antiprotons. Other developments in the computer control field included various programs monitoring beam, inside the machine and in the experimental areas, so that stable operation could be supervised from the PS Main Control Room. Work on the next step, remote control from the MCR, was also going ahead.

Developments in stochastic cooling included the completion of continuously variable delays for the transverse systems and filters for the longitudinal system, making it possible to apply transverse cooling during the extraction process at any momentum below 609 MeV/c. This gave a longer beam lifetime, higher extraction efficiency and better extracted beam emittances in the low momentum range. Improvements to the pick-ups, with the addition of cryogenically cooled amplifiers, so that stochastic cooling could be applied down to 100 MeV/c in preparation for deceleration below that momentum, were rapidly moving ahead.

The second r.f. cavity, and the tuning capacitors used to increase the frequency range of both cavities, became operational. A feedback system was being tested out on the second cavity. The system (B-pulse train) generating the frequency of the r.f. from the changing main magnet field was modified to obtain precise reproducibility for all flat-top field values and to take into account saturation effects in the magnet cores at high momenta (> 1300 MeV/c).

The beam observation and measurement systems were augmented by the addition of four current transformers, with an individual accuracy of $\pm 4 \times 10^7$ particles, in the PS-LEAR transfer line (E2). These proved to be extremely useful in detailed matching studies aimed at getting a better acceptance and thus increasing the overall antiproton transfer efficiency. In the machine itself, a new transverse kicker was installed to provide better measurements of betatron tune, and a tank where H^- ions would be stripped to obtain proton injection in the reverse direction.

Developments in Overall Performance

For the 26 GeV/c beam supplied to the AA for antiproton production, a new scheme of beam optics in the PS (permitting a reduction in the values of parameters α_p and β_H at the extraction point), resulted in a highly significant increase in the efficiency of transfer of beam circulating in the PS to the AA target, from 93% to 97%. Further studies of the remaining beam losses at low energy, carried out at both the operational injection energy of 815 MeV and the proposed future figure of 1 GeV, confirmed the interest in making the controlled longitudinal expansion as early as possible after injection and showed the importance of precise control over the Q_H/Q_V working point in terms of the evolution of the bunching factor. This led to the introduction in operation of injection on a magnetic field plateau at 815 MeV, reducing low energy losses for beams of $1.45-1.5 \times 10^{13}$ protons per pulse. The expected reduction in the Laslett Q-shift accompanying injection on a field plateau at 1 GeV gave an immediate improvement of 15%; in terms of current operation, this would mean running at up to 1.75×10^{13} protons per pulse with a reduction of a factor of two in low energy losses or virtually zero loss for the standard intensity of 1.5×10^{13}. A large proportion of the low energy losses occurred during the (controlled) longitudinal expansion; it was therefore proposed to try carrying out this process in the Booster, during 1986, with the aid of an experimental 200 MHz r.f. cavity installed in one of the four rings. Another project for the following year was injection tests at 1 GeV using the r.f. dipole (see Annual Report for 1984, p. 106) to combine the output of two Booster rings; it was feared, however, judging from experience at 800 MeV, that a limit would be set to this type of operation by microwave instabilities. Work continued on the scheme for fusing the bunches from two Booster rings by successive changes of the r.f. harmonic number during acceleration in the PS. This technique will be required when ACOL comes into service, in order to provide the shortest possible bunches.

Transfers of protons and antiprotons to the SPS for Collider operation also benefited from the new scheme of beam optics in the PS. Both efficiency and emittance conservation were better, contributing to the higher SPS luminosity obtained. A continuation of these developments would, it was hoped, lead to a better betatronic matching for the antiprotons, as well as a higher value for $\Delta p/p$ of the extracted beam. The system for damping oscillations occurring at 3.5 GeV/c injection from the AA (see Annual Report for 1984, p. 106), already operational in the horizontal plane, was extended to the vertical, resulting in better conservation of transverse emittances for the antiproton beams supplied to both SPS and LEAR. A new technique was employed to supply the single-bunch proton beam used for SPS Collider operation and for AA tests; by eliminating the four superfluous bunches at the moment of injection, reproducibility of intensity and emittance were both improved.

The beam supplied to the SPS for fixed-target experiments ($1.8-2 \times 10^{13}$ protons per pulse, 5-turn continuous extraction on two consecutive cycles at 14 GeV/c) was not the subject of specific studies, but inevitably benefited from the development of the antiproton production beam.

Reduction of low energy beam losses cuts down radioactivity levels in the PS, and injection at 1 GeV should help still further in this direction. Developments in the Booster, particularly bringing up the performance of all four rings to the level of the best two, will lead to an increase in available intensity. This, in turn, will make it possible to investigate the limits of the present system of beam loading compensation for the r.f cavities, and to study the effects of coupled-bunch instabilities.

In preparation for the planned operation with oxygen ions (0^{8+}) in 1986, several days were spent setting up the Linac II–Booster-PS chain of accelerators to run with deuterons. This involved getting prototype beam control systems to work at the low intensities envisaged ($\sim 10^8$ units of charge per bunch) and testing beam instrumentation under the same conditions. A four-bunch deuteron beam was extracted from the PS at 10 GeV/c per nucleon, with bunch intensity adjustable between 10^8 and 10^{11} particles, and sent to the SPS for studies in that machine. As a result of this work, it was possible to begin construction of the operational versions of beam control systems and to determine the modifications required to instrumentation in the machines and transfer lines that would be required for operation with oxygen ions in 1986. Looking further ahead, the possibility existed of accelerating heavier ions with the same charge-to-mass ratio (e.g. Ca^{20+}) by mixing a very small proportion with the 0^{8+} ions at the source; this might be done in 1987 after tests in 1986.

Computer Controls

The year began with the commissioning of the controls for the PS radio-frequency systems. Thereafter, the major effort was devoted to construction of controls for the LEP Preinjector, although the design and layout of ACOL controls was also being actively pursued. Amongst activities concerned with consolidation of existing systems were commissioning of the link to the Linac/LEAR controls and first operation of an autonomous beam instrumentation system through the new 'intelligent device interface' (IDI). A layout for the controls of the ISOLDE III beam line was produced. In spite of the numerous innovations, no more than 1% of scheduled beam time for the PS complex was lost due to controls system faults.

The computerized controls for the two PS radio-frequency systems, with their multiple modes of operation, comprised a hardware/software package comparable in dimensions with the controls for any of the individual machines, for example one of the Linacs. They included around 5 man-years of work on specialized applications software and the installation of an equivalent amount of existing software, as well as 14 well-filled CAMAC crates. After painstaking preparations lasting throughout 1984, the new system was commissioned and integrated into the overall PS controls during the long shutdown at the beginning of 1985. Bringing this large new package into operation when the accelerators re-started went remarkably smoothly, thanks to excellent collaboration between the various specialized groups and the high degree of modularisation and standardisation which characterises the PS controls system.

The major part of the available effort in 1985 was concentrated on further definition and implementation of the controls for the LEP Preinjector (LPI). Early summer saw completion of the two consoles, one in the Main Control Room and the other adjacent to the machines themselves; they were identical with existing operator consoles and fully integrated into the PS controls network. Detailed definition of the interface layout proceeded as the process equipment and its electronics itself progressed, with installation and check-out following. These activities were still continuing at the end of the year.

Central to the LPI controls system is the SMACC project, outlined in the 1984 Annual Report (p. 111). This is an auxiliary crate controller based on a 32-bit microprocessor (Motorola 68000), which, in contrast to its predecessor, can deal with multiple tasks, is programmed in a high level language and allows local interaction. This requires a fully-fledged operating system, for which the manufacturer's RMS68K was chosen; the high level language is P+. A Macintosh personal computer permits access to the SMACC via the serial crate controller (using MacNODAL) or directly through the front panel (using the SMACC's resident NODAL). The package is completed by an improved message transfer scheme between the SMACC and the main (ND 100) computers, based on a datagram service and a remote procedure call. Development of the hardware was completed early in the year, and it went into series production for delivery by December. The software side also made substantial progress. An important concomitant to this project was the adaptation of existing applications software structures for use in the SMACC in the same way as in the ND 100 process computers. The opportunity was taken to incorporate a number of improvements suggested by five years of operational experience, relating to reliability, productivity and serviceability. The major part of this work was accomplished during 1985, and a milestone was reached before the year's end when some of the equipment in the LPI was controlled through the suite of software modules of the new structures.

A start was made on the formulation of requirements for the operational aspects of the LPI. This is an essential prerequisite for the development of specific applications programs. Timing and sequence control occupies a special place in the hierarchy of the hardware and software designed for the LPI. Various rather intricate filling cycles for the electron/positron storage ring (EPA) and strategies for injection into the PS lead to a very elaborate timing system, which is, in turn, locked into the PS supercycle sequence. Control of the latter is done by the 'PLS', which was in the course of being replaced bit by bit with a modular system to meet the new requirements.

Since it was decided early in 1984 that on-line accelerator modelling would be part of the commissioning strategy for EPA (the LPI storage ring), two modelling programs ('COMFORT' and 'MAD') were installed in the PS program development computer. A file transfer system connected to the console computers and a convenient user interface was under development.

For beam instrumentation needing intricate digital processing algorithms, and where only the final result in a simple format is of interest for operation, it was decided that local processing would be used employing the SMACC (see above). This would be connected to the standard CAMAC interface via a package of communications hardware and software developed during the year and christened IDI (for Intelligent Device Interface).

A layout was prepared for the ACOL interface and an assessment made of the basic applications software requirements. A study began of the future controls aspects of the PS access control system. In the context of the Linac/LEAR control system, apart from further progress towards control of the Linacs from the MCR, help was given to the CELSIUS storage ring at Uppsala and the CRYRING facility at Stockholm, both of which planned to use copies of the LEAR control system. Assistance was given with the definition of the controls required for ISOLDE III, leading to a layout of the system with particular reference to the process interfacing.

Stockholm and Uppsala were not the only beneficiaries of CERN technology transfer. During two ten-day visits to Brookhaven National Laboratory, experts from PS Controls took part in a review of plans for a new controls system for the AGS accelerator complex, including the recently authorized Booster project. Like the PS controls, the system was being designed for pulse-to-pulse setting of beam characteristics. Other consultations on accelerator controls took place at the Centre Lacassagne at Nice, concerning their isochronous cyclotron for neutron therapy (MEDICYC).

The LEP Preinjector

Since it constitutes an important part of the LEP project, this subject is covered in the LEP chapter of this report. However, PS Division is responsible for the construction of the two linear accelerators, the accumulator and the transfer lines which will supply electrons and positrons to the PS for acceleration on their way to LEP via the SPS. Various aspects of the LPI, and necessary modifications to the PS, are mentioned under other headings in this report. For the machines themselves, the injector of the 600 MeV linac produced a 4 MeV beam in December, and it was anticipated that electrons could be sent to the PS for its acceleration trials by the autumn of 1986.

Safety

Efforts continued to maintain a safety-conscious attitude in the Division. The Safety Committee, whose members had particular responsibilites in the field, including dissemination of information, met five times and heard presentations on various topics from the Code for inflammable gases to electrical safety precautions.

With the numerous additions over the years, the PS access control system had become extremely complex in its ramifications and, with further extensions looming on the horizon, an effort was made towards simplification. The objectives were to reduce the chances of any possible confusion by presenting a more straightforward geographical situation to the operator responsible, thereby minimizing the (admittedly small) chances of mishap, and to reduce the amount of hardware requiring maintenance and/or renewal. Independent control of a sector of the Ring (Inflector) was relinquished, resulting in the loss of some operational flexibility (e.g. any access to the Ring stopped beam to the Booster), but producing a major simplification in access control logic and presentation. In addition, a number of little-used doors were eliminated from the system.

First steps were taken in the overall renovation of the access control system with the installation of a prototype for the LEP Preinjector. Before finalizing the design, advice was sought from an agency expert in the appraisal of security systems, which was asked to make a thorough analysis of a typical sub-system controlling access to the PS Ring. The consultants found no fault with the concepts, made some useful suggestions for improvements in reliability, and generally endorsed the plans for renovation. The access control system installed at the LPI comprised four simple interlocked doors and one door fitted for controlled access which used a local microprocessor for key control and the generation of messages for users, with provision for later use of magnetically-coded cards. A mobile console permitted operator control either in the LPI building or from the PS Main Control Room.

General Services

The progress made during the year, and preparation for future projects, placed a heavy load on the services providing mechanical design and development in the technological field. A good deal of this work was concerned with the ACOL project and with construction of the LEP Preinjector (LPI). Vacuum technology occupied an important place, with extensive studies and laboratory tests of a new cryogenic pumping system for stochastic cooling equipment in ACOL, improvements in the Linac I vacuum system to get both higher reliability and a better vacuum for oxygen ion acceleration, and studies for further development of the system producing the very high vacuum required for LEAR. There was also considerable industry in the field of magnetic elements—dipoles, septa, quadrupoles, etc. Excluding the Experimental Areas (dealt with under that heading) some 250 units were either constructed (by industry to CERN designs) or reconditioned (at CERN). A very active magnetic measurement team was sometimes using as many as four measurement benches at the same time. An interesting development in the field of septum magnets, employed for beam extraction and injection mostly, was the use of bakeable cores constructed from laminations with inorganic coatings. These showed a very considerable reduction in outgassing rate under vacuum, of up to two orders of magnitude as compared with the former method using araldite adhesive. When workload and budget should permit, it would be advantageous to replace many existing septum magnets with this type. Of course, many other tasks were performed by general services, and some appear under other headings in this Report.

Office automation for management and administration continued to make progress. All Group secretaries and administrative staff were provided with text processors or terminals with access to the central computer system. Internal use of electronic mail began on an experimental basis. Software was developed to look after administrative aspects of official travel and the management of workshops.

SYNCHRO-CYCLOTRON

Operation and the Experimental Programme

According to plan, the reduced number of hours available for experimental physics was maintained in 1985, in order to provide money and manpower for the ISOLDE III project. The proportion devoted to work with light ions fell from the peak of 30% in 1984 to 16%, leaving 84% for proton acceleration. Apart from the light-ion experiments, main users were ISOLDE and Muon Spin Rotation (μSR) experiments. Figure 7 shows the experimental area layout.

The year had traditionally started with ion acceleration, and 1985 was no exception. After the start-up, r.f. conditioning for the $^{18}O^{6+}$ frequency range went well, but for $^{20}Ne^{5+}$ it was not quite as successful. The experimental programme began on schedule, but was dramatically halted after only one day when a turbo-molecular pump situated directly below the rotary capacitor (Rotco) exploded, rupturing the r.f. vacuum and distributing pieces of metal throughout the Rotco assembly. An identical incident had occurred in 1981, and measures to prevent a recurrence were under investigation. A praiseworthy team effort got the cleaned-up unit going again with a loss of only two weeks to the physics programme. Although, for unexplained reasons, the duty cycle was not as good as usual, the SC continued to function smoothly, delivering beams of $^{18}O^{6+}$, $^{12}C^{4+}$, $^{20}Ne^{5+}$ and $^{12}C^{3+}$ ions until the scheduled shutdown early in March.

During the shutdown advantage was taken of the relatively low level of radioactivity to correct errors in mechanical alignment which had plagued Rotco and transmission line changes for some years, and the transition to proton acceleration consequently went more smoothly than on previous occasions. After start-up the large number of r.f. discharges caused the Rotco to be exchanged for its sister unit. This ran well, and a successful programme of physics with protons was completed. This would be the last time the μSR experiments could run on both sides of the machine; in the future, they would be confined to the 'neutron' side. The summer shutdown began in mid-July and, apart from further preparatory work for the ISOLDE III installation, the main task undertaken was replacement of corroded steel pipework in the primary circuits of the SC heat exchangers by stainless steel.

The start-up, in the proton mode, was somewhat painful. Although the Rotco reached 20 kV with a 1-in-2 duty cycle with relatively few r.f. discharges, good performance was only achieved after thoroughly cleaning some ceramic tubes, in the vacuum duct, which had acquired a conducting layer of contamination. The relatively bad vacuum in the SC (pressure up by a factor of three) was also disquieting, and various tests were made in search of the reason, but no conclusions could be drawn. ISOLDE experienced separator problems, probably due to the long shutdown period. In spite of all this, performance in November and December was good. In addition to the standard experiments, a uranium calorimeter for the SPS experiment NA 34 was tested with 600 MeV protons, and a radioactive isotope of fluorine was made for an experimental programme at the Geneva Cantonal Hospital. Distribution of machine time during the year is shown in Fig. 6.

The Rotco problems meant keeping a standby team of electromechanical experts on hand so that a replacement was always available. The Rotco which was exchanged shortly after the Spring shutdown was found to have a large quantity of oil inside, and this had evidently been the cause of the trouble—somewhat to everyone's relief, since worse had been feared! After reconditioning, this unit performed exceptionally well on the test stand. Since the reliability of a certain rotary turbo-molecular vacuum pump was seriously in question, following two identical catastrophic failures (see above), it was finally decided to replace it with a static cryo-pump. This was planned to take place before the first light-ion run early in 1986.

Development

The filament of the ion source assembly in the SC had to be set in two distinctly different positions, one for proton and the other for light ion acceleration. Changing from one to the other used to take 2–3 days of work in a radiation environment. An adaptor was developed which enabled the changeover to be achieved within minutes by a simple mechanical rotation. Positions were accurate to within a few microns, and radiation doses to personnel were reduced in proportion to the time saved.

The μSR experimental teams had used beams from both sides of the machine. Because of the ISOLDE III installation, the 'proton' side would no longer be available, and an alternative had to be sought. Tests showed that the 125 MeV channel would be suitable, and so plans were made to refurbish it in 1986, involving, among other things, the replacement of two quadrupoles donated for construction of the LEAR experimental areas.

Construction of the second on-line isotope separator, ISOLDE III (illustration fig. 8), continued. Manufacture of the major components was completed and some were installed. These included the front end containing the acceleration section and a triplet of quadrupoles, wall radiation shielding, 90° and 60° bending magnets, a singlet and a doublet of quadrupoles, the Faraday cage and the large coaxial conductor for the 60 kV supply to the target, the robot for hot target handling, sliding lead doors for hot target containment and a moveable shielding door. Vacuum pumps had been delivered, and measurements begun on the 90° magnet.

Most of the hardware for ISOLDE III computer control was delivered and passed acceptance tests, and some of the applications programs had already been tried out. The design divided control tasks into three independent loops, each having a CAMAC crate containing four controllers, with specific tasks, equipped with Motorola 68000 microprocessors. For the software, Equipment Modules, developed for the PS controls, were employed as far as possible. These software packages considerably facilitated the writing of applications programs and offered a variety of other advantages, including easy use by non-specialists.

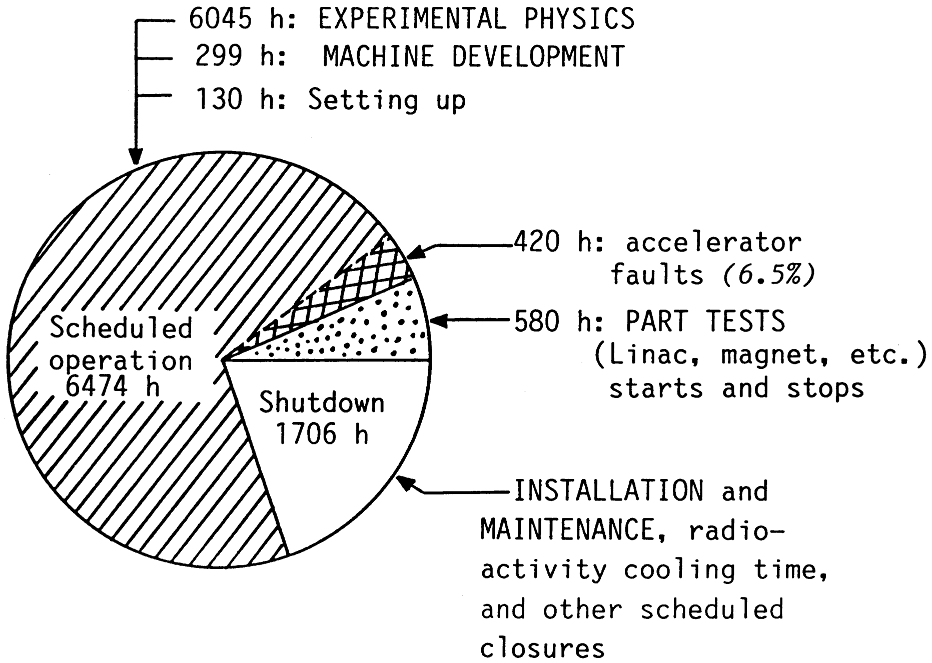


Figure 1—Functional division of the PS year (24 hours per day).

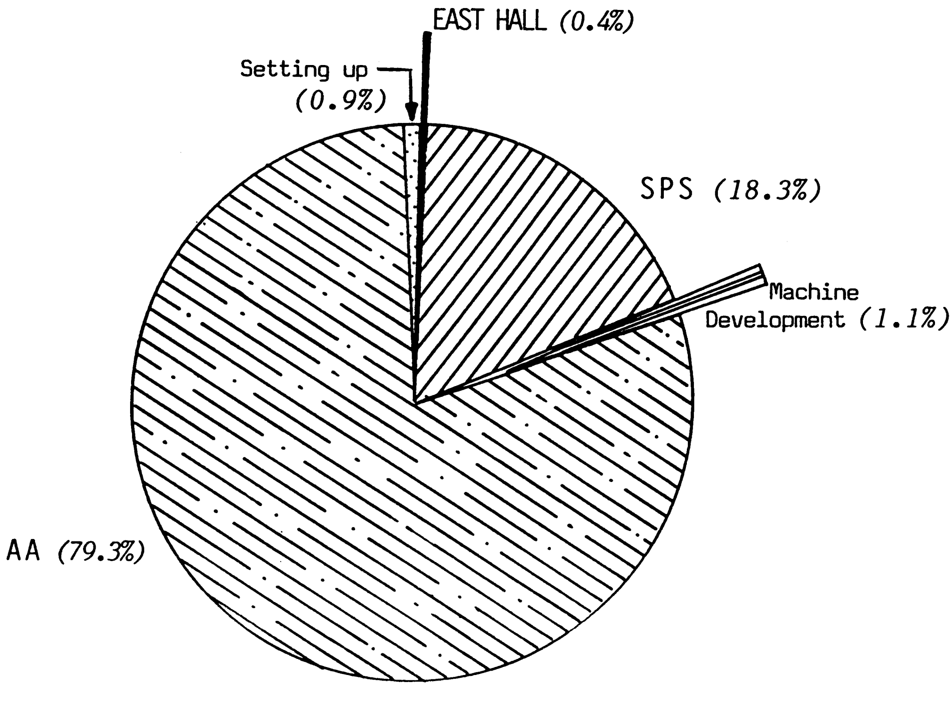


Figure 2—Overall distribution of PS protons in 1985.

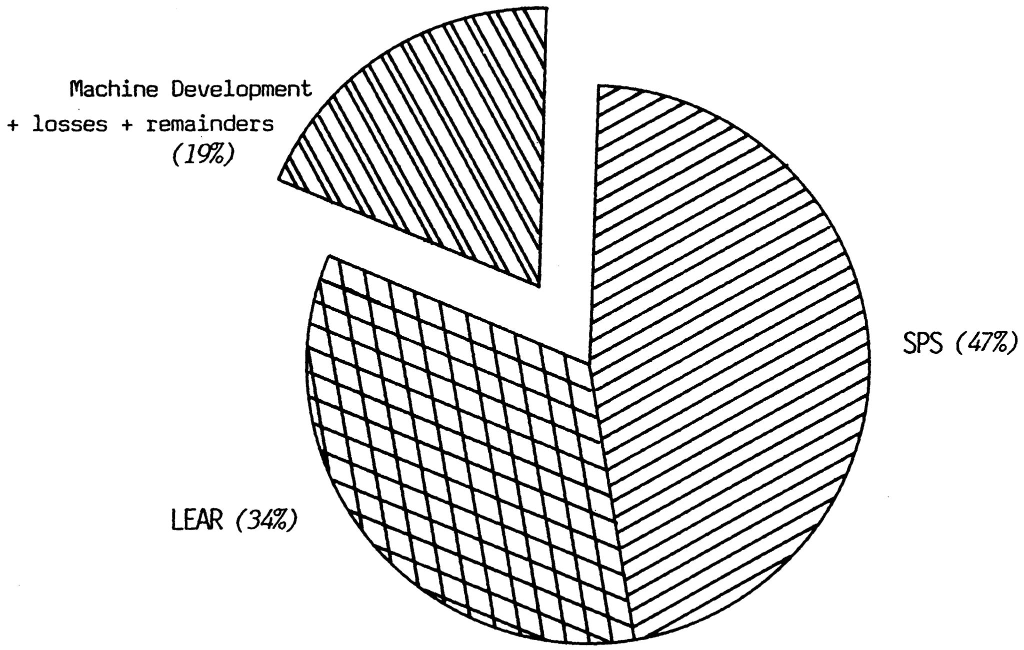
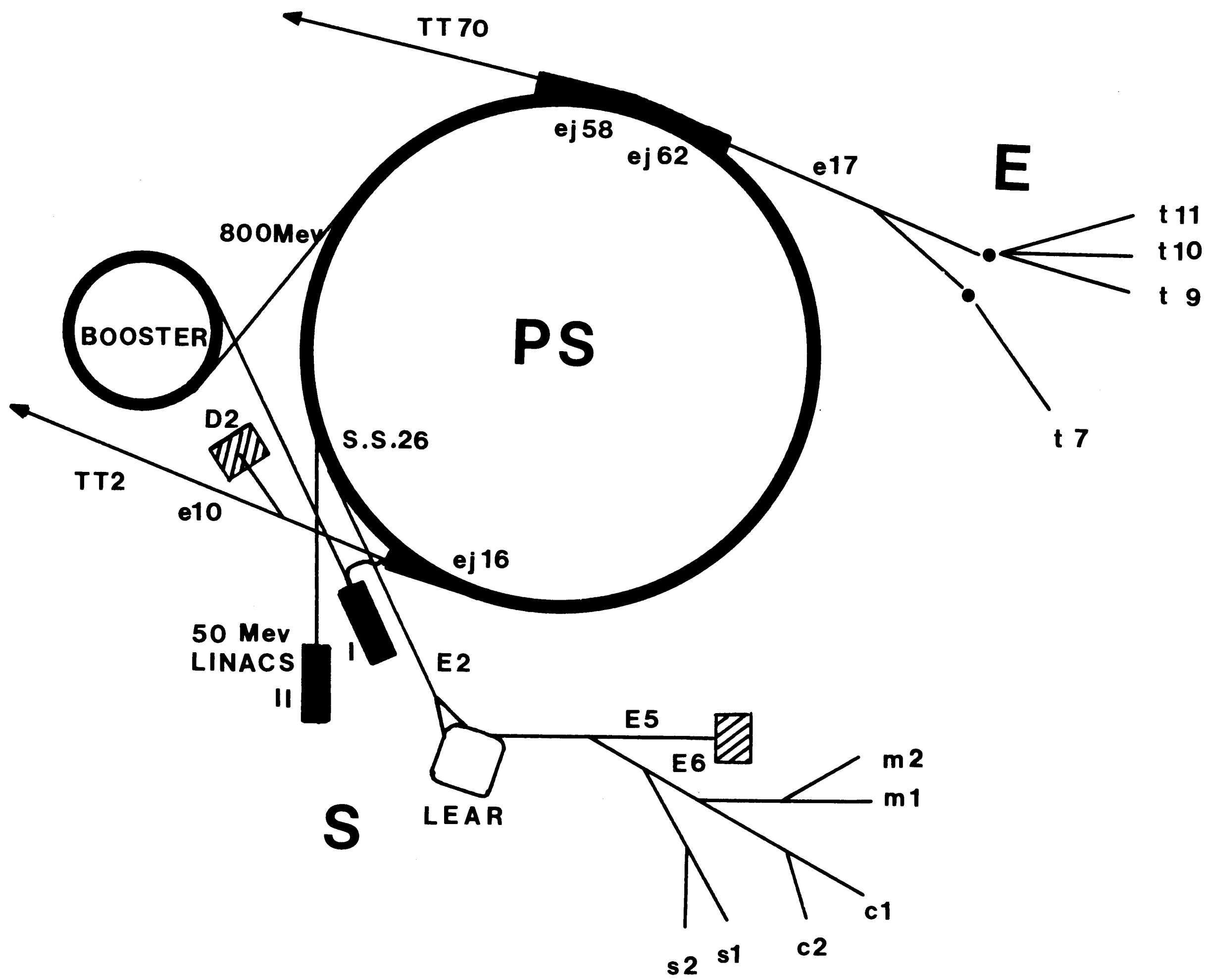


Figure 3 — Distribution of antiprotons in 1985.



LINACS I AND II

Either Linac can supply the Booster, or the PS directly, with 50 MeV protons; Linac II is normally used for regular operation. Linac I also provides a proton test beam and H^- ions for LEAR.

SOUTH HALL (S)

LEAR, the low energy antiproton ring, is designed to provide pure beams of "cooled" antiprotons between 0.1 and 1.7 GeV/c for an experimental area occupying the remainder of the South Hall.

E2 : supplies LEAR with 50 MeV protons and H^- ions from Linac I, or with antiprotons at 0.6 GeV/c extracted from straight section 26 in the PS.

E5 : extracted beam line from LEAR fitted with equipment to measure beam characteristics.

E6 : supplies the experimental areas with continuous streams of antiprotons extracted from the LEAR stack at a rate of about 3×10^5 $\bar{p}$/s. The beam is divided into three branches, each of which can be directed into one of two paths leading to different experimental zones. Relative intensity in the three main branches is adjustable over a range of 20:1. Beams m_1, c_1 and c_2 can operate at up to 2 GeV/c, and beams m_2, s_1 and s_2 at up to about 1 GeV/c.

TRANSFER TUNNELS (TT)

TT2 : takes proton beams for the SPS (via TT10, not shown). It also carries protons for $\bar{p}$ production and for test purposes to the Antiproton Accumulator (AA), and antiprotons returning from the AA to the PS at 3.5 GeV/c.

TT70 : takes antiprotons accelerated in the PS to the SPS for collider experiments; protons can be sent in the opposite direction to check out the beam transport line.

D2 : external dump buried in the earth outside the Ring wall; used for setting up the beams travelling along TT2, and also during PS machine development sessions.

EAST HALL (E)

Slow extraction from straight-section 62; the primary beam, e_{17}, is divided into two branches and targets in each of these provide four secondary beams. The latter can supply intensities of about 10^5 hadrons (or 10^3-10^4 e^+e^-, depending upon momentum), for 10^{11} protons of 24 GeV/c on target, with $\Delta p/p \sim 1\%$. Beams t_7 and t_9 can operate at up to 10 GeV/c, and t_{10} and t_{11} at up to 5 and 3.5 GeV/c respectively.

Figure 4 — Schematic diagram of the PS beams and experimental complexes in 1985.

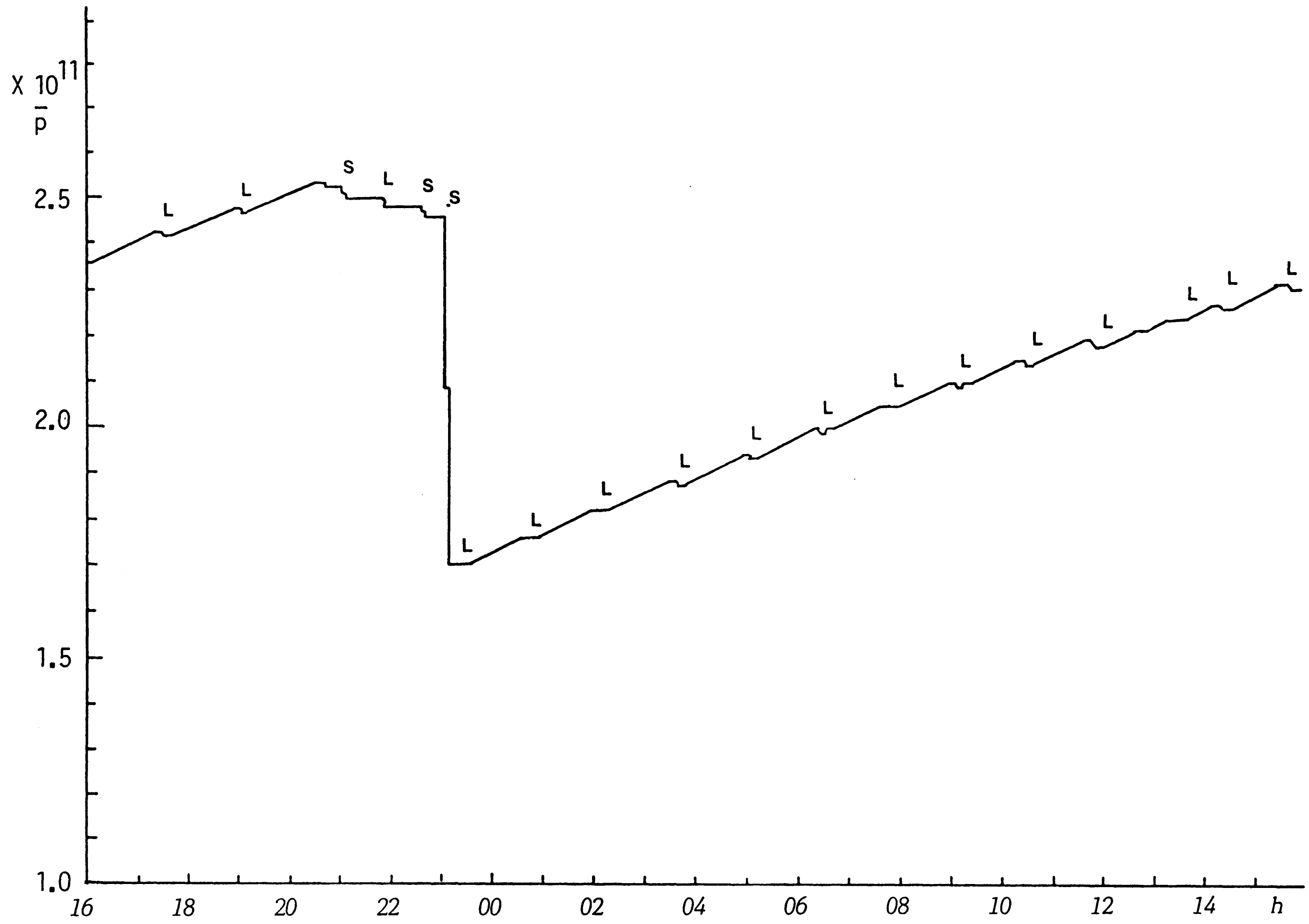


Figure 5—Evolution of the AA antiproton stack over a 24-hour period with regular deliveries to LEAR ('L'), and a single transfer to the SPS Collider ('S'), preceded by two 'pilot' shots. (From a computer print-out 1/2 November 1985).

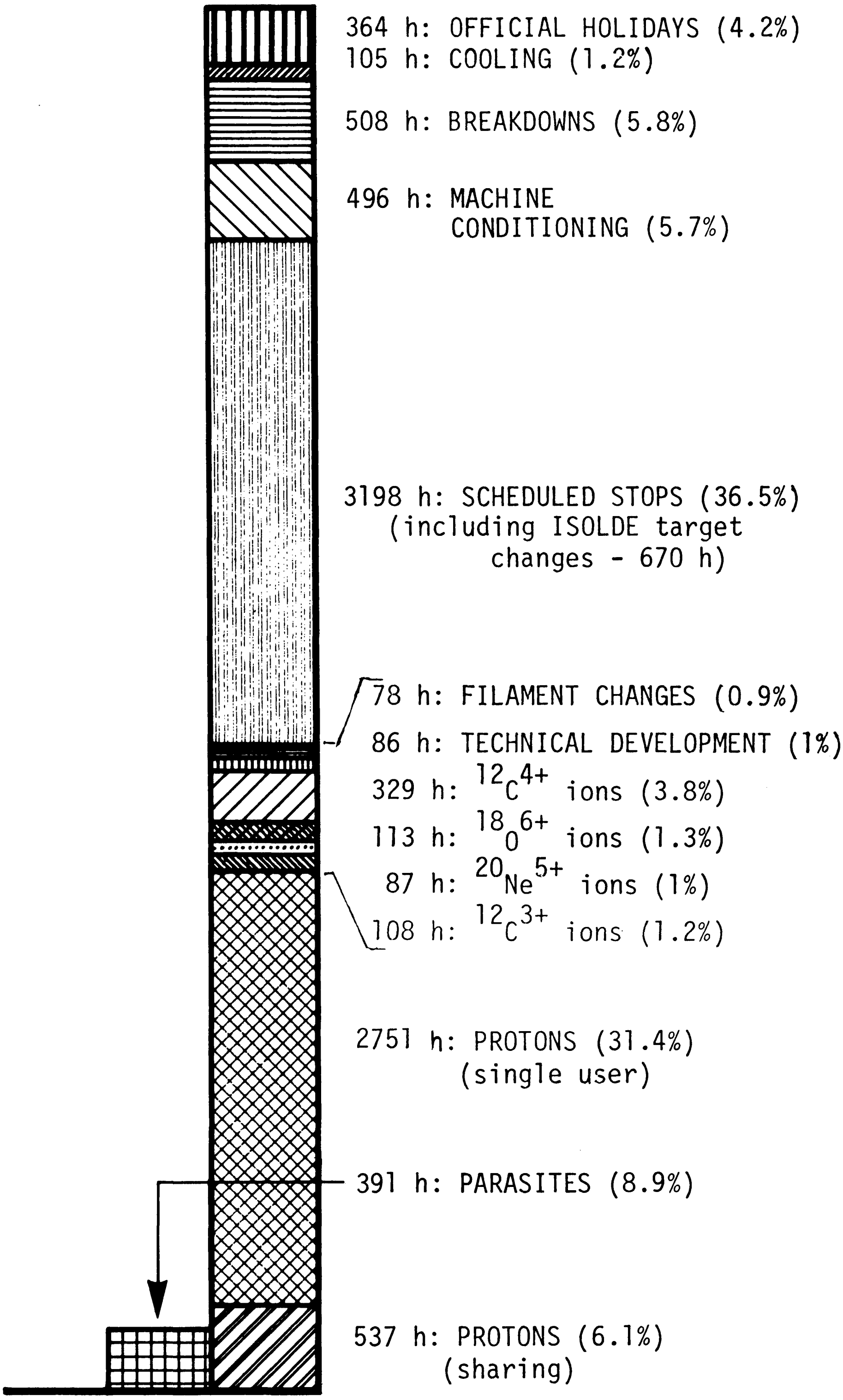


Figure 6— The allocation of SC machine time in 1985 (24 hours per day).

Proton Hall

μSR experiments are carried out in the "C" zone, sharing the beam with similar experiments in the Neutron Hall. This is also the zone where the experiments are housed which use beams of light ions. The remainder of this area has been set aside for ISOLDE 3.

Neutron Hall

μSR experiments are carried out in the zone indicated, and the two arms of the μ channel are used for parasitic tests employing low-intensity π^- and μ^- beams.

SC Hall

This is where the pion production target in the extracted proton beam is housed. Irradiations are often carried out in the extracted beam, using both protons and ions.

Underground Zone

This is the on-line isotope separator facility, ISOLDE. Irradiations are also occasionally made at the centre of the tunnel.

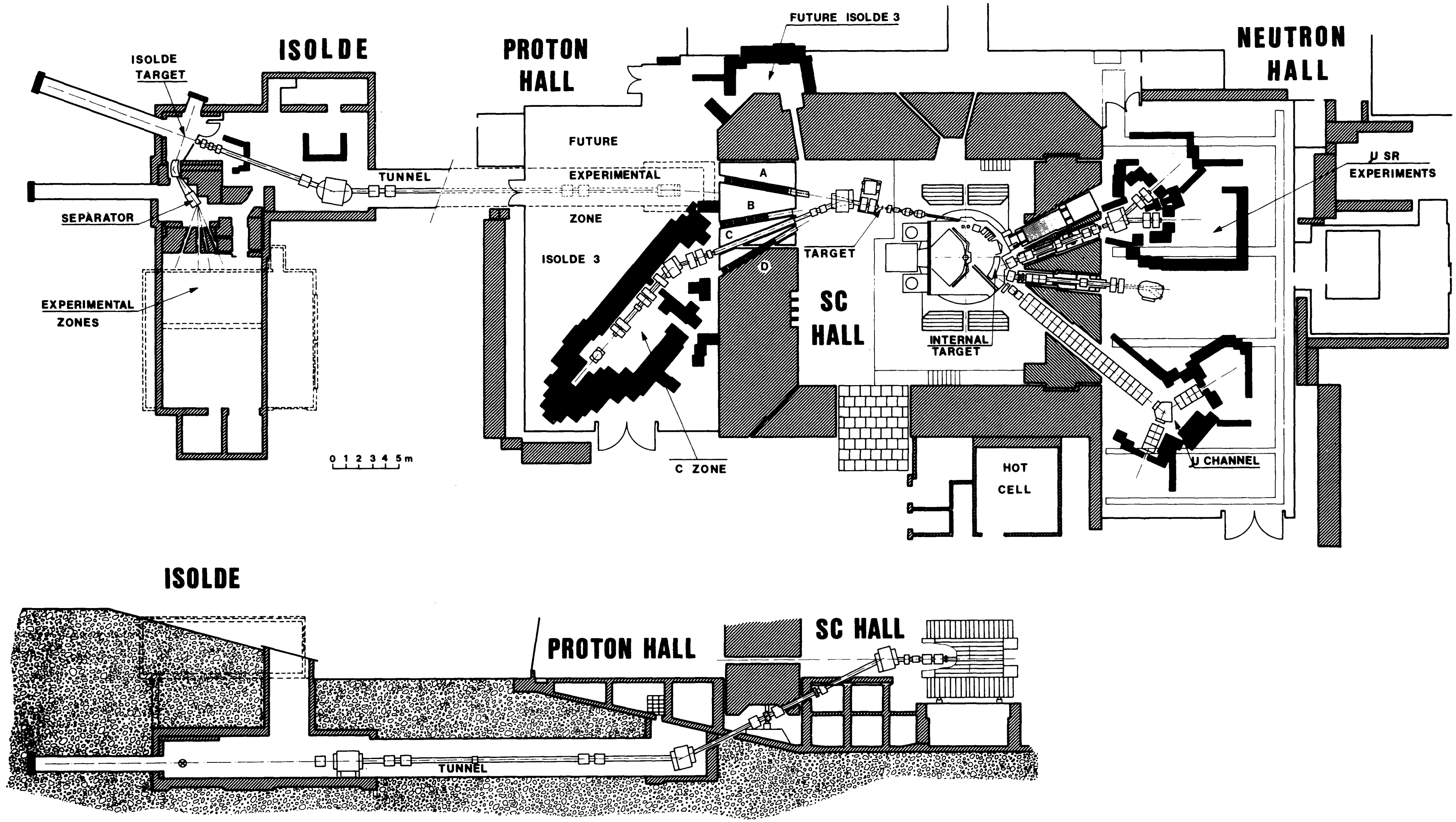
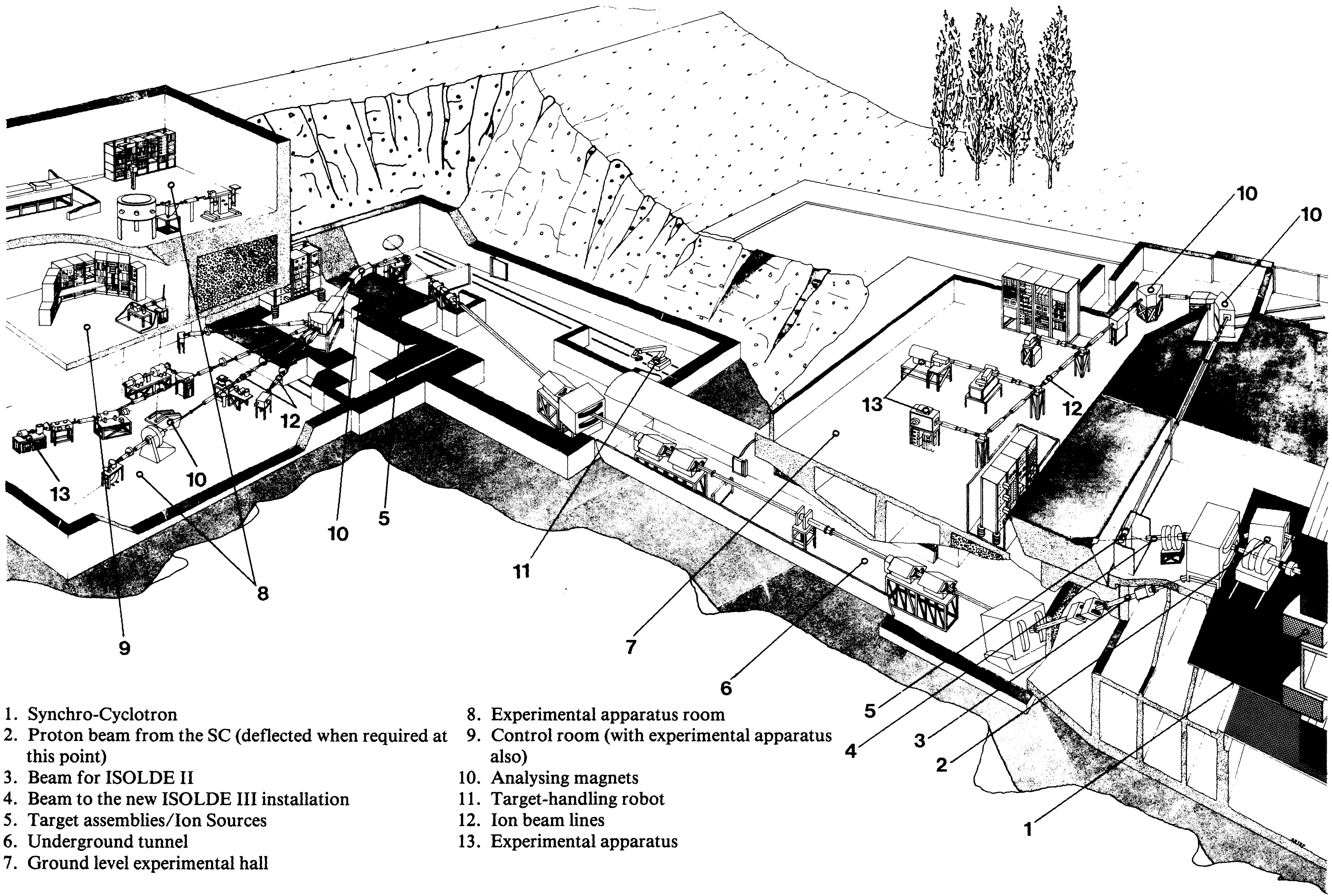


Figure 7—Layout of the SC experimental areas at the end of 1985.



1. Synchro-Cyclotron
2. Proton beam from the SC (deflected when required at this point)
3. Beam for ISOLDE II
4. Beam to the new ISOLDE III installation
5. Target assemblies/Ion Sources
6. Underground tunnel
7. Ground level experimental hall
8. Experimental apparatus room
9. Control room (with experimental apparatus also)
10. Analysing magnets
11. Target-handling robot
12. Ion beam lines
13. Experimental apparatus

Figure 8 — The 'ISOLDE' on-line isotope separator facilities at the SC. The new ground-level installation, ISOLDE III, was due to come into operation in 1986.

Super Proton Synchrotron Division

Introduction

During the year 1985 the SPS collider has operated in the following three very different modes:

i) Pulsed collider mode, cycling the magnets between beam energies of 100 GeV and 450 GeV for $p\bar{p}$ data taking at 900 GeV cms energy.

ii) High beta operation, with $\beta_H^* = 1080$ m to collect data on elastic $p\bar{p}$ scattering at angles down to 0.1 mrad.

iii) High luminosity operation, during the last 4 months of the year, yielding an integrated luminosity of 655 nb^{-1}, which is more than the 576 nb^{-1} integrated luminosity accumulated in all previous years together.

The operation of the collider with the present beam intensities is now well understood and the machine development studies and construction of equipment (separators, 100 MHz RF system) were aimed at the much more intense antiproton beams expected when ACOL comes into operation.

From April to August, 4 months were devoted to fixed target operation. A machine development session was devoted successfully to the acceleration of deuterons in preparation for the operation with 0^{16} ions at the end of 1986.

The experimental areas were fully exploited with all available secondary beams in full use and up to 10 experiments taking data during the same period. Furthermore, a very intense activity is going on in the zones for the tests and calibration of detector modules for the two UA experiments and the four LEP experiments.

About 35% of the SPS staff was working for the LEP project in 1985. Some 100 man years were devoted to the adaptation of the SPS as injector for LEP and another 50 man-years to LEP main ring systems which are being built by the SPS Division, i.e. the controls system, the electrostatic separators and the access system for LEP.

The Magnet Group was involved in a great variety of work for different purposes such as the dipoles for ACOL, the magnets for the transfer lines from SPS to LEP, magnetic measurements of the LEP sextupoles and design studies of high field superconducting magnets for the Large Hadron Collider in the LEP tunnel.

The SPS Collider

Machine Studies and Collider Performance

For the first time in the history of the collider no major changes were introduced between the operating periods of 1984 and 1985. As a consequence the peak performance was not significantly increased this year, but the integrated luminosity was a factor 1.6 larger due to the operational use of the progress made during the machine development sessions of the 1984 run. The development effort in 1985 was aimed essentially at the preparation of the high luminosity operation with ACOL when the accumulation rate of antiprotons should be an order of magnitude higher than at present.

The momentum spread of a full AA stack corresponds to a longitudinal emittance of 6 eVs, whereas the longitudinal acceptance of the beam transfer system and of the SPS is only 0.5 eVs. In the present operation with 3 antiproton bunches we can therefore withdraw only 1.5 eVs, that is 25%, of the full stack core per SPS fill. This is not a limitation since it takes about one day for the AA with its present accumulation rate to replenish its stack. However, to make full use of ACOL, the entire stack core will have to be transferred to the SPS once per day. This can be achieved by doubling the longitudinal emittance of each bunch from 0.5 eVs to 1 eVs and by increasing the number of bunches from 3 to 6.

Doubling the longitudinal emittance can be done either by lengthening the bunches or by increasing their momentum spread. Since the allowable momentum spread at 26 GeV/c is limited by the compression scheme in the CPS and by the transfer line, longer bunches must be accommodated at injection in the SPS. This will be possible with the 100 MHz RF system which is being constructed. However, at high energy, short bunches are needed since the analysing power of the UA experiments is optimum for secondaries from proton–antiproton collisions which occur near the centre of the detectors. It is planned to keep the bunch length at 315 GeV equal to the present value of about 1 m, by using part of the additional RF voltage provided by the 200 MHz single cell cavities for e^+e^- acceleration. This will entail a two times larger momentum spread of the bunches, which makes it necessary to double the momentum acceptance of the collider. The latter is limited by the strong chromatic aberrations induced by the low-beta insertions. The present correction scheme, which comprises four sextupole families regularly distributed around the machine, cannot cope with an increased momentum spread. A systematic search for more powerful correction schemes has shown that the momentum acceptance can be doubled by rearranging the existing sextupoles, in their present positions, into five circuits instead of four, the new family being localized around the insertions.

With 6 antiproton bunches colliding against 6 proton bunches the beam-beam induced tune spread would double with respect to the present situation, leading to an unacceptably low lifetime of the beams. An electrostatic separation system is being built to separate the beams during storage at high energy in 9 of the 12 interaction points. The first proposal for a practical separation scheme was made in 1983. Further studies in 1985 have lead to an improved layout which allows a separation in the horizontal plane by a distance of 3 times the beam dimension and uses only 6 separator units, each 3m long, and 3 high voltage supplies. This arrangement is, however, limited to the presently used lattice configuration. By adding 3 more units at a later stage, combined vertical and horizontal separation would be provided, allowing greater operational flexibility.

A prototype version, comprising only two pairs of separators, but sufficient for the case of 3 bunches had been successfully tested in 1984, giving convincing evidence of the validity of the final scheme. Additional use of this system in 1985 confirmed this result.

At the injection momentum of 26 GeV/c, the beam–beam tune spread affecting the antiprotons adds to the direct space-charge tune spread of the dense proton bunches so that it is impossible to avoid at the same time the third and fourth order resonances for the protons and antiprotons respectively. Attempts to suppress these resonances with the help of the existing sextupole and octupole circuits were successful in reducing significantly the losses of particles with tunes close to the resonance lines. However, the improvement resulting from these corrections was not sufficient, as some losses and an increase of the emittances still occurred for the particles which cross the resonances. It is now considered more promising to reduce the beam-beam tune spread also at injection by separation, in which case all particles can be kept away from the dangerous zones. An experiment was made in which one bunch of antiprotons was injected in the presence of six dense proton bunches. As anticipated, it was impossible to capture and accelerate this bunch without heavy losses.

However, with the beams separated over most of the circumference of the machine by the use of a single electrostatic separator, the transmission improved considerably. It is planned to use this scheme for the future operation with six bunches.

In order to provide a larger momentum acceptance and to reduce the transfer losses at ejection, a new lattice configuration has been set up in the CPS. After careful matching of the transfer lines to the new parameters, the density of the beams injected into the SPS was significantly improved. However the matching of the antiproton line posed some problems, due to insufficient precision in the measurement of the betatron parameters. Better monitors will be installed during the next shutdown for this purpose.

Pulsed Collider Operation

In order to exploit the maximum possible beam energy for proton–antiproton collisions while remaining within the maximum allowed power dissipation of the magnet coils, a run was made in which the magnets were cycled for several hours between the beam energies of 100 and 450 GeV in a cycle of 21.6 s repetition time, with the same circulating beams.

Tests with protons had shown in 1984 that this mode of operation was indeed possible, although extremely acrobatic. In particular, the machine tunes had to be controlled over the entire cycle to an unprecedented accuracy of ± 0.005. To achieve this precision two continuous tune measuring systems had been developed, the results of the measurements being fed automatically to the power supplies computer for correction of the tunes.

Two different magnetic cycles are necessary, one for injection at 26 GeV/c and acceleration to 100 GeV/c and one for cycling between 100 GeV/c and 450 GeV/c. These cycles have been programmed in such a way that they can be combined in any sequence to form a supercycle, a notion which is new to the SPS. To achieve this, a new central timing generator was built, and other hardware as well as software facilities were extended.

During the physics run, the duty cycle was 19% for data taking at the maximum energy of 450 GeV and 38% at 100 GeV. In order to avoid excessive complications, the low beta insertions were not used and there were only two bunches of protons and one bunch of antiprotons circulating in the machine. This type of operation took place in March 1985 with a total of about 100 hours of data taking by each of the experiments UA1 and UA5.

High Beta Operation

In order to allow the experiment UA4 to collect data on elastic scattering at small angles, a few dedicated runs have been made in previous years with the betas at the collision point increased from the normal value of 50 m up to 100 m, whereas for high luminosity operation they are decreased down to 1 m horizontally and 0.5 m vertically. This year a dedicated run of one week took place in June with a horizontal beta of 1080 m to allow data to be taken at considerably smaller scattering angles.

This has been made possible by the installation of an additional short quadrupole in position 416. The maximum of the beta function occurs in the middle of quadrupole Q418, and the collision point was displaced to this position. The vertical beta at this location was 20 m. At the beginning of the coasts the beam halo was carefully cleaned by inserting the scrapers in a well defined sequence, so that the detectors could closely approach the beam and observe collisions at an angle down to 0.13 mrad in the antiproton direction and 0.1 mrad in the proton direction, with good background conditions. The initial luminosity was around 3.10^{26} cm^{-2} s^{-1}, providing trigger rates from 2 to 10 Hz depending on the position of the detectors. Around 150 000 elastic events were collected by UA4 in 95 hours of data taking during an SPS run of 154 hours, thus allowing a successful completion of this experiment.

High Luminosity Operation

This year 17 weeks were devoted to high luminosity collider operation compared to 13 weeks in 1983 and 1984. The week of machine development which traditionally preceded the installation of the experiments was no longer considered necessary since on the one hand the mode of operation was largely unchanged, and on the other, the new orbit measuring system allowed to start the machine in single bunch mode. The latter reduces the danger of irradiation of the sensitive detectors of the UA experiments compared to the 20 bunch mode previously necessary for correcting the orbit.

From the start initial luminosities of about 2×10^{29} cm^{-2} s^{-1} were recorded and the improved luminosity lifetimes of the later part of the 1984 run were maintained at around 24 hours throughout the period. In good conditions the beams were colliding for 120 hours per week. This figure alone indicates the degree of operational reliability reached by the SPS.

Long coasts of more than 24 hours were normal and with the high initial luminosities and long luminosity lifetime the integrated luminosity per fill increased from an average of 5.3 nb^{-1} in 1984 to 8.2 nb^{-1} in 1985. This reflected the reduction in the number of coasts prematurely lost due to technical faults of the SPS equipment; in 1984 32% of all coasts were lost in this way whilst in 1985 it was only 18%.

Because of the unusually low temperatures and industrial action near the end of November, 9 days of physics production were lost when the electricity supplier Electricite de France claimed those days as days of low power consumption. The supplier can make this request for 22 days between the 1st November and 31st March.

The integrated luminosity for the 1985 run was 655 nb^{-1} which is more than the 576 nb^{-1} integrated luminosity accumulated in all previous years together. There were 80 coasts with a total of 1358 hours of coasting beams.

Technical Developments of the Collider

The existing provisional SPS separation system which was tested successfully during the last months of 1984, has been upgraded. Its high voltage generators were replaced by more reliable units of a modern design and the control electronics was improved. Installation of two additional separators and redeployment of the existing units during the 1986 shutdown will lead to the final layout in the SPS which can then be tested well before the commissioning of ACOL. The power supplies for the main machine quadrupoles have been modified so that it will be possible, without changing manually any connections, to control independently the tune in the two halves of the machine, as is necessary for separating 6 proton from 6 antiproton bunches.

The effort to fully exploit the Schottky signals for beam monitoring has been pursued. After a considerable reduction in the noise level of the electrodes and of the receivers, the main contaminating signals now come from tiny coherent beam excitations at high harmonics of the mains frequency. Their amplitude was reduced last year by a better filtering of the main magnet power supplies. In order to eliminate the remaining signals, a comb rejection filter with very narrow 1 Hz notches spaced at 50 Hz intervals and locked to the distributed mains has been built. Using this, the Schottky signals are much cleaner and it is hoped that computer algorithms can be applied to the acquired Schottky data from individual proton bunches to separate their coherent and incoherent spectra. Preliminary tests have been encouraging. The Schottky information from individual bunches is presently only available for the horizontal plane, using the second passband of the travelling wave accelerating cavities at a frequency of 460 MHz. To obtain information from the vertical plane a sensitive multi-stripline transverse pick-up, with 10 electrodes in series on either side of the beam, has been designed and is being built. This pick-up will also operate at 460 MHz and will be installed in the shutdown of 1986.

In order to exploit the high intensity antiproton beam from ACOL, the construction of a new 2MV, 100 MHz RF system was approved in 1984. The first cavity was expected by end 1985, but due to difficulties encountered with electron beam welding on the single cell cavities for e^+e^- acceleration it was decided to replace electron beam welding by brazing, and this led to some delay in the delivery of the first cavity. Reduced scale model tests have continued in order to analyse the higher modes of the cavity with the aim of constructing a suitable damping system for these modes.

The infrastructure in the tunnel for the installation of the cavities has been designed and a large fraction of the work will be done in the 1986 shutdown. It is still expected that the cavities can be installed in LSS4 during the 1987 shutdown.

Five RF amplifiers (20 kW, FM broadcasting type) have been ordered. The first amplifier is being tested at CERN and has already delivered its nominal power, while the others will be commissioned at the beginning of 1986.

The electronics necessary to provide beam control with the five cavities in $p\bar{p}$ operation has been defined. All signal processing will be done at the fundamental frequency rather than at a lower intermediate frequency. Since this is a new project to be installed in 1987, the interface between the computer and hardware will use the G64 and MIL 1553B standards. A study of the RF system control in G64 has been made and the final design of the actual cards and micro-processor software will begin in 1986. The equipment designed for this purpose will also be used in the 200 MHz e^+e^- beam control system.

The project for the stochastic cooling experiment aimed at demonstrating the feasibility of transverse cooling of bunches in a large storage ring is progressing well. Following the preliminary studies already started in 1984, the layout has been finalized with a horizontal pick-up in LSS3 and a kicker in LSS1. The study of the infrastructure for the atmospheric optical link transmission between BA1 and BA3 has been completed and work has already started on the extension of the geodetic pillar on top of BA1. Experiments with an infrared link between BA3 and the ISR water tower were made during 1985 and have confirmed the feasibility of such a transmission, using a laser modulated at 500 MHz.

The cooling pick-up with 10 GHz as centre frequency is now in its final design phase, and should be installed in LSS3 by the end of the 1986 shutdown, so that preliminary tests with beam can take place during the next $p\bar{p}$ run. Model measurements have confirmed the results of the theoretical studies. A good sensitivity (70 Ω/mm) and sufficient bandwidth (~ 1 GHz) for the cooling experiment have been obtained with a pick-up of the rectangular corrugated waveguide type.

For the future operation with electrons, it is imperative to be able to correct the orbit with single bunches. The transformation of the closed orbit measurement system which was needed for this purpose is also of major interest for the operation of the collider. Fortunately, it could be finished in time for the start up of the collider in September, which greatly profited from this. The new system also allowed the slow drifts of the orbit during long coasts to be monitored all around the machine.

The continued development, in close collaboration with industry, on highly transparent vacuum chambers for collider experiments led to the construction of a 12 m long test system made of composite materials based on carbon fibres. This system withstood repeated bakeouts to 120°C which resulted in residual gas pressures in the 10^{-10} mbar range. The moderate cost of these chambers compared to beryllium chambers offers the possibility of large scale use in major detector arrays. It was decided to equip the UA1 central detector region with a carbon fibre vacuum chamber already for the 1986 collider run.

The Proton–Antiproton Experimental Areas

After completion of the pulsed collider run, the UA5 detector was demounted and removed from LSS4. The 'roman pots' of experiment UA4, which was completed at the end of the short dedicated period with a high beta configuration in June, are now used by two new experiments, UA7 and UA8. It is intended that the latter will have its main run in conjunction with UA2 during the collider operation with ACOL in 1987 and 1988.

The UA2 experiment will undergo major upgrading and extension before autumn 1987. This requires modifications to the infrastructure of the LSS4 area, the study of which is now well advanced. In LSS5, two instrumented and magnetized muon filters have been installed, one on each side of UA1, as a test for the Lepton Asymmetry Analyser (LAA) proposal.

A large effort has been made to reduce the background on the proton-upstream side of UA1, in order to permit simultaneous operation of UA1 and UA6, and also to reduce the beam-gas background seen by UA1. Two collimators and three sections of shielding closely surrounding the vacuum pipe at strategic positions along the low-β insertion have been installed. Furthermore, a double wall of scintillators covering the tunnel section has been built to monitor the background level and to allow UA1 to eliminate the events accompanied by charged background particles.

Measurements indicate that the background has been decreased by more than an order of and also that the remaining background events can be detected by the scintillator wall with an efficiency greater than 90%. On the proton-upstream side of UA1, the contamination by background is now reduced by a factor greater than one hundred. This has permitted the UA6 experiment to run its jet target at full intensity during the whole collider run. A project is under study to install similar equipment on each side of both UA1 and UA2 for 1987, when operation with ACOL will provide more intense antiproton beams.

The SPS Accelerator

Machine Studies and Accelerator Performances

A machine development session was devoted to the acceleration of deuterons in preparation for the forthcoming operation with 0^{16} ions. The magnetic cycle was adjusted for injection at 10 GeV/c per nucleon of two consecutive CPS batches, 1.2 s apart, followed by acceleration up to 225 GeV/c per nucleon. The main problem in this case is the performance limit of the RF system for very low intensity beams, especially around the very critical transition energy. A previous experiment had shown that it is possible to cross transition using a frequency loop instead of a radial loop, the latter being impractical at very low beam intensity. The frequency programme had therefore been redesigned to cover the range from 10 GeV/c per nucleon to 225 GeV/c per nucleon. It was shown that in order to avoid losses, the relative error in frequency at transition should be smaller than $\pm 6 \times 10^{-8}$. A sensitive resonant phase pick-up allowed capture and acceleration of down to 10^8 particles per pulse, although parasitic signals coming from cavity number 1 made phase adjustments very critical. Without this cavity in operation intensities down to 10^7 particles were successfully accelerated and this is well below the anticipated intensity of the 0^{16} beams.

Accelerator Operation

The fixed target operation consisted of periods 2 and 3, from 21st April to 16th August. At the end of the first period, just before the usual short shutdown, there was one week of high-beta collider operation. Exceptionally, there was no neutrino operation in 1985, apart from a low intensity test beam in part of period 3.

The repetition time, as in most of 1984, was 14.4 seconds with a flat top of 2.8 seconds at 450 GeV. The absence of the neutrino extraction gave a slightly increased duty cycle to the other experiments. The good transmission efficiency achieved in 1984 by increasing the injection energy from 10 GeV to 14 GeV was again evident from the beginning of operation.

The overall efficiency, actual beam-time/scheduled beam-time, was 80%.

The ratio of protons on target to protons accelerated was 80% in 1985 compared to 90% in 1984. This was partly because the highly efficient (~ 97%) neutrino extraction was not used and partly because there was much more beam extracted to the North Area, where 10% of the protons are lost on the splitters before the targets.

Technical Developments of the Accelerator

Two more new sweeper magnets for the beam dumping system have been built. These magnets, which are made of 0.2 mm thick laminations with an improved insulation, will replace the last two of the three original magnets whose performance had been steadily decreasing during nearly 10 years of operation.

Until 1984, the performance of the SPS extraction systems had been severely limited by thermal deformation of the supporting structure of the electrostatic wire septa due to radiation heating. In July 1984, the first septum in LSS6 was therefore replaced by a unit with an improved version of a wire supporting structure made of invar instead of stainless steel and with the diameter of the wires reduced from 100 μm to 65 μm. At the beginning of 1985, also the second unit in LSS6 and the first two units in LSS2 were replaced. As a result, the losses in both SPS extraction channels were reduced by almost a factor 3 and are now as low as they were during the first years of SPS operation at much lower beam intensities.

The last part of the beam transfer line in the neutrino cave was upgraded, to provide more flexible steering and monitoring facilities for the targeting of the proton beam on T9 for the CHARM II experiment (WA 79). The software for operating this line was also adapted to ensure the required steering and focussing properties for the beam as well as the correct transmission of beam data to the experiment.

One of the remotely adjustable supports of the target station T9, which had suffered severe radiation damage, was exchanged. This work required careful planning and preparation because of the high level of radioactivity in the neutrino target area.

During a test run, which took place in May/June, the modified beam line and the repaired target station T9 were commissioned successfully; target and beam were adjusted for maximum multiplicity and for the correct direction of the secondary particles with respect to the detector.

Further improvements were made to the RF system. In the Siemens plant, the new type of isolation and grounding switches for the anode voltage has been installed in one of the high voltage power supplies and is operating well. The anode capacitors for several tetrode amplifiers in the Philips plant have been modified and have given very reliable operation during the 1985 run. As a consequence, all 68 amplifiers will be modified during 1986.

In order to make tests for the project of a new cavity monitoring and interlock system, one of the travelling wave structures (cavity 1) has been equipped with a programmable controller which showed fault-free operation during the 1985 run. In the 1986 shutdown the other three cavities will be equipped with the same type of controller. An RF test set-up which is completely independent of the operational power plant, has been installed, permitting permanent testing of the different tetrode amplifier units after overhaul or repair, even during SPS operation.

The capability of the beam monitoring system is being extended to cope with the new demands of the low intensity beams of oxygen ions. A beam intensity measuring system using a resonant directional coupler is under development. At the same time the dynamic range of the beam current transformer is being extended downward in order to be able to calibrate the new system with deuteron beams of an intensity suitable for both devices. New electronics for the secondary emission monitors in the external beam lines have been tested. They will allow the measurement of the intensity and of the position of the slow extracted beams but not of their profile. Orders for the series production are being sent out.

The damper in sextant 3 has been moved to sextant 2 during the 1985 shutdown to leave space for the future 200 MHz single cell cavities for e^+e^- acceleration. Its feedback loop has been equipped with a digital delay line which increases the bandwidth from 3 MHz up to 10 MHz and with a digital notch filter which prevents overloading of the power amplifiers by eliminating the unwanted signals caused by a deformed closed orbit. With these improvements the damper can also be used to provide a continuous tune measurement system for the high intensity proton beam for fixed target operation which is prone to transverse instabilities. This is done by using the damper in a nonlinear regime where the beam oscillation amplitude is allowed to grow up to 0.2 mm but is strongly damped above this value.

The first interlocked access doors separating the SPS from the future LEP injection tunnels TI12 and TI18 were installed at the beginning of the year, in order to prepare for the excavation work approaching from the LEP side. The two access doors between the UA1 area and the SPS tunnel were also moved and modified, including their TV supervision, in order to liberate a maximum amount of space for equipment of the experiments. The access control system serving the North experimental area was replaced by equipment identical to that serving the West area. By interconnecting the two systems through the computer network, it is now possible to operate both areas from either the North or West control rooms.

An error logging and software interlock computer has been added to the SPS computer network in order to relieve the ALARM computer from some of its many tasks. Changes have been made to the computer network. Several computers have been moved from the message handling nodes directly concerned with the accelerator operation to a message handling node dealing primarily with hardware and software developments. This reconfiguration was needed to liberate message handling space for additional computers for accelerator operation. Some 40 installations of Data-Module software have taken place in various on-line computers. A MIL–1553B software driver has been installed in GP6 allowing LEP equipment already installed in SR1 to be surveyed via the SPS network. Furthermore, all the message handling computers have been updated with a new system.

Since the SPS was commissioned about 10 years ago it has continuously been adapted to many new and challenging demands. After the operation for fixed target physics had been mastered with ever changing cycles and beam utilisation, the machine had to be converted for its part-time use as a proton antiproton collider, first in a continuous and then in a pulsed mode, and in 1986 the SPS will accelerate oxygen ions. All these changes could be made within the framework of the SPS computer control system which was unique in 1975 and whose contribution to the technological advance in this area has been largely acknowledged.

However, in the near future the SPS will also be used to accelerate electrons and positrons for injection into LEP. In order to maintain a viable fixed target physics programme, protons will be accelerated in between the electron and positron cycles. This multicycling mode, now standard in the CPS, will be new to the SPS. Furthermore, the existing hardware and software is becoming obsolete and its maintenance will get more difficult every year. On the other hand, tools and methods in the domain of computer control have greatly evolved since 1975. For these reasons and in view of the future combined operation of the SPS and LEP from the same main control room (MCR), a new infrastructure for the MCR has been designed together with an upgrading of the SPS control system and an intensive effort has been started to produce the software necessary for the multicycling mode of operation.

The main guideline for the upgrading of the MCR has been, to preserve the essential features of the existing control room based on N-100 computers driving CAMAC based consoles while starting to make use of modern technology, existing standards and commercial products.

The new control room environment will consist of an autonomous Local Area Network (LAN) with a number of personal workstations acting as consoles and a number of servers which provide shared resources.

Access from the MCR-LAN to the machine control network and vice versa is performed through a gateway computer. For the implementation of this new infrastructure it has been decided to make use of the UNIX (AT & T trademark) operating system. The personal workstations are the IBM PC/AT running under XENIX, a UNIX system III implementation from Microsoft Corporation. The basis for the man-machine interface is provided by the Graphic Kernel System defined by ISO standard. Several programming languages are available, as Fortran 77, C and NODAL which will be supported under XENIX from early 1986 onward. The Local Area Network has largely benefitted from the CERN/IBM collaboration on networking which was launched in the fall of 1983 for the LEP control system. The access protocol is the IEEE 802.5 standard, better known as the token passing ring. The high level network protocols are the Internet Protocol (IP) and the Transmission Control Protocol (TCP) as defined by the U.S. Department of Defense DARPA for all its packet switched networks. A token ring network has been installed in the MCR, and is currently under test.

As for the LEP control system all the new equipment interfaces for the 0^{16} and the e^+e^- are microprocessor driven; the standards chosen are the G64 and the VME crate and bus system with respectively the M6809 and M68000 microprocessors. These equipment control assemblies will be connected to the existing N-100 based SPS control system through the MIL-1553 B multidrop by means of a VME crate, thus making use of the VME module developed for the LEP Process Control Assembly. A VME to Nord I/O bus interface has been designed, the software is currently under development and will be available early 1986. This software is developed in such a way that the equipment control assemblies can be moved at a later stage from the N-100/VME to the PCA which are identical to those of the LEP control system.

The need for handling of e^+e^- cycles combined with a proton cycle in the SPS has lead to the definition of multicycle facilities. The essential idea is that the microprocessor driven equipment control assemblies will handle the individual elementary e^+e^-, or p cycles while the control system will take care of the supercycles which consist of a combination of the elementary cycles. The implementation of these principles has required the development of a new machine timing system; G64 timing cards are now available and the VME implementation has reached the prototype phase. All this SPS control upgrading will demand new communication links to be installed around the SPS machine. In order to reduce the cost and increase the flexibility, it has been decided to follow the LEP control choice and to make use of the Time Division Multiplex system; TDM equipment, covering all the SPS control buildings, has been ordered.

In multicycling mode 60 power supplies and RF equipments as well as 250 closed orbit correctors will have to be pulsed with a specific function for each elementary cycle. A common kernel for all these applications has been defined on a VME crate basis, and suitable industrial products have been found. The corresponding software is being written.

Structured approaches in the analysis and design phases of software projects have become current practice. In order to profit from recent progress in software engineering, training sessions have been held for the staff involved. Among the advantages already emerging is the common language that the system provides for better definition and understanding of the problems.

The Experimental Areas for Fixed Target Physics

The full exploitation of all 7 principal secondary beams in the North Area has served 9 experiments, of which 5 have been completed. In addition, two new test zones have been provided in Hall EHN1; one for experiment UA2, which is preparing for the upgrade of the $p\bar{p}$ collider, and the other for the DELPHI experiment at LEP.

The principal new facility to be completed and successfully commissioned has been the alternate K^0_L and K^0_S beam for the precision comparison of the CP-violating decay mode by experiment NA31. The K^0_S beam is composed of a target unit mounted between two dipole magnets and followed by a beam dump which is carrying a mobile collimator and beam instrumentation. These elements are assembled on a train which, supplied with power and cooling water, travels on rails over a length of 50 m inside a 2 m diameter vacuum tank, pumped down to a pressure of 10^{-3} Torr. Inside the vacuum tank the train can be stopped at any of 41 stations to allow K^0_S decay data to be collected over the whole region in which, alternately, decays of K^0_L can be detected. The downstream end of the vacuum tank is separated from the detectors of the experiment by a membrane, only 0.8 mm thick, made of epoxy-impregnated Kevlar fibres, specially constructed and tested by the industry.

Progress has been made in the design of special collimators and interlocks to permit the new lepton experiment NA34, which has so far been setting up in the H8 beam, to receive in 1986 a 450 GeV/c primary proton beam with a final spot size matched to a target of only 50 μm diameter.

Another project, related to the requirements of this experiment and to the planned programme of physics with oxygen beams, has been approved and is being prepared for installation. It concerns the provision of a beam link from the beginning of the M2 muon beam to the Po line serving the high-intensity area ECN3. The primary beam (protons or oxygen) can then be switched to reach ECN3 via target station T6, whenever the branch through T4 is required by experiment NA34 in the H8 beam.

Following the completion of experiments NA2 and NA4 in Hall EHN2, extensive modifications are under way to prepare for the new muon experiment NA37, which will make use of a downstream spectrometer to calibrate the absolute momentum of the incident muon beam.

The West Area has likewise seen a very full programme of experiments, tests and calibrations. In the H1 beam to Omega, the tagged photon experiment (WA69) was completed. In order to increase the electron intensity in the beam, an orientable single crystal of silicon was inserted downstream of the target to enhance the yield of e^+e^- pairs by coherent pair production. The extra intensity gained in this way was about 30%.

Experiment WA78, a search for beauty particles, was completed in the main branch of the H3 beam. The other two branches, from which tertiary particle beams are derived, were used continuously for tests and calibrations for ALEPH, DELPHI, OPAL and UA1. In the original West Area design, the X3 test beam to L3 and the experiment in H3 could not receive beam at the same time. A solution has been found which relieved this constraint and allowed a large amount of simultaneous operation.

The last two weeks of fixed target operation saw another new feature in the West Area. The X7 test beam was extended through the former BEBC hall to the neutrino building, where it was used to calibrate the WA79 (CHARM II) detector. Extra magnets on top of high concrete pyramids were installed in the BEBC hall and an extra 250 m of vacuum tube was provided to transport the beam.

In the field of beam instrumentation, a new type of multiwire proportional chamber, using a delay line readout, has been developed and provided to several experimental groups in the low intensity test beams. The device is both cheap and simple to operate. Another project concerns the conversion of standard filament counters, normally used for beam profile measurements, to allow nuclear fragments to be identified in ^{16}0 ion beams.

Twelve hydrogen targets were operated in the SPS experimental areas of SPS and LEAR, while four new targets were constructed.

Other Developments

A considerable effort has been devoted to the construction of the lithium lenses for ACOL. A first prototype lens with a diameter of 20 mm was assembled and filled with lithium by means of a specially designed filling station at the KERNFORSCHUNGSZENTRUM at Karlsruhe/FRG. This lens was then brought back to CERN and connected to its power supply which has been constructed by the PS Division.

Initial tests showed that the resistance and the inductance of the lens were as expected, so that pulsing tests with half sine wave current pulses of 320 kA peak and a repetition time of 2.4 s could start. During a test run of about 4 months, 3 million pulses were achieved without any failure. Thereafter, the peak current was raised to 400 kA and until the end of 1985 a further 2 million pulses have been accumulated, still without any failure. This performance gives confidence that the adopted design is adequate for the use of this lens in the proton beam upstream of the target. In the near future, the peak current will be raised to 450 kA to check if this lens, at least during an initial phase, could also be used as a $\bar{p}$-collecting lens downstream of the target instead of the originally foreseen 40 mm diameter lens. In parallel with complementary theoretical studies, involving materials other than lithium and commercial finite element programmes for detailed stress analysis, further prototypes made of different steel qualities have been built. These tests revealed that the material used for the first prototype was in fact the most suitable. Therefore, a second lens was assembled and filled in November. It will undergo electrical tests at the beginning of 1986.

The first Wide Bending Magnet for ACOL has been delivered to CERN with some delay due to difficulties in industry with tooling, materials and labour. Magnetic measurements and field shimming are under way in order to meet the very tight requirements on homogeneity and low multipole content of the magnetic field. The fabrication of the 8 remaining bending magnets is well advanced, and the magnets should be delivered according to schedule.

The tooling for the series of 15 Narrow Bending Magnets is being prepared and the materials have been accepted. Due to space restrictions the lattice bending magnets and quadrupoles cannot be used in the injection region of ACOL. Therefore a special magnet leaving passage for the injected beam and a half-quadrupole have been designed and were ordered by the end of the year.

The final system for gas purification and distribution for the central detector of the LEP experiment OPAL is being designed. Several parts of the equipment for the general gas distribution systems have been delivered and tested, and specifications for most of the remaining parts have been sent out.

After completion in early 1985 of the first report on the feasibility of a Large Hadron Collider to be installed in the LEP tunnel, theoretical studies have been pursued, in collaboration with the LEP Division, in order to better define and optimize the different lattice modules of the machine. Most of the effort has been aimed at finding the maximum possible cell length, since this determines the maximum energy for a given bending field, while at the same time keeping the magnet aperture small to minimize the cost. In parallel a research and development program on high field superconducting magnets is being set up. Several national laboratories and industries are collaborating with CERN in the studies for highly performing NbTi and Nb_3Sn wires and cables as well as on a number of options of magnet design.

As to the superconductors, the aim is to obtain large aspect ratio cables made of filaments with a diameter of 2 to 5 μm and operating at 2°K for NbTi or at 4.5°K for Nb_3Sn. In this context small quantities of 5 μm diameter NbTi wires have been ordered, while Nb_3Sn wires of appropriate performance are expected to become available in the next few years. The magnet design options being investigated comprise a single bore 8T, NbTi wound magnet, single bore 9.5 T magnets wound with either NbTi or Nb_3Sn and operated at 2°K, resp. at 4.5°K, as well as a twin bore 'two in one' 10 T magnet with NbTi or Nb_3Sn windings. For all options, the magnet design is at present based on two layer windings made with two different cables with graded current densities. Small lengths of dummy cables with such a large aspect ratio have been ordered for practical investigations of winding configurations.

In parallel, quench protection studies and field error calculations are being pursued and magnetic error compensation schemes are being investigated. For Nb_3Sn magnets to be made according to the 'wind and react' method, preliminary promising resu lts have been obtained with a high temperature resistant mica-glass tape.

The superconducting magnets, which had been installed in 1978 in the H6 secondary beam were removed after 6 years of entirely satisfactory operation. It is recalled that these two 2 m long, 4.5 T dipoles had been developed by a combined team of CEA–Saclay and CERN.

A feasibility study has been carried out in relation to the air conditioning system for the SPS magnet enclosure and beam transfer tunnels. It has been shown that by a relatively simple and inexpensive extension the three air treatment plants forming part of this system could be turned into heat pumps allowing the recovery of waste heat from the SPS magnet for winter heating. The system thus upgraded would allow a yearly saving of electric energy of at least 1000 MWh, worth about 100 kSF. The investment involved would be paid back within less than two years.

LEP Division

Introduction

Progress on the LEP construction project was highly satisfactory throughout the year. Excavation of all the access shafts, almost a third of the main ring tunnel, many auxiliary galleries and the larger underground halls were completed while, on the surface, many buildings were completed and others commenced. The rate of delivery of machine components started to take on impressive proportions and already a third of all the dipole cores and the RF accelerating structure, and much vacuum and other equipment is in stock ready for preparation and installation as soon as the tunnel sections are completed. Installation work in the first machine shaft started in October and the first sub-station was completed in December.

With some three-quarters of all LEP work and equipment already ordered it was possible to make a more accurate estimate of the overall project cost. This showed that, excluding contingencies and infrastructure for experiments, about 1100 MSF (in 1985 prices) will be required for the LEP machine construction compared to the original authorization of 1030 MSF.

For the convenience of the reader, all aspects of LEP construction are reported in the following paragraphs. However, it must not be forgotten that much of the work was carried out in divisions other than LEP; PS for the pre-injectors and initial beam acceleration, SPS for beam transfer and injection into the main ring, EF for help with the survey, magnet and vacuum systems, and not forgetting the less glamorous but equally important help from the service divisions. The contributions of all these divisions and particularly the staff concerned are gratefully acknowledged.

The vast amount of effort required for LEP leaves little available for other activites. Nevertheless, the division devoted time to CERN's future via the studies on linear electron and circular proton colliders, the laser-plasma beat-wave experiment at RAL, by being host to the CERN Accelerator School and by providing lecturers for the US Accelerator School.

The LEP Project

Injector System

LEP Injector Linacs (LIL)

In the convention of the collaboration with the Laboratoire de l'Accélérateur Linéaire (LAL) at Orsay, signed in 1982, a first beam in the 600 MeV linac (LIL-W) was scheduled for the end of 1985. This target was partly attained since on 17 December, a 4 MeV electron beam was produced in its injection system. The latter consists of a 60 keV electron gun, a prebuncher-buncher system, focusing and steering elements, together with beam monitors. The properties of the 4 MeV beam were good though the high-power RF distribution system (waveguides filled with SF_6) posed some operational problems.

The accelerating sections for both linacs are installed with the exception of the first section of LIL–W which was left aside to allow the use of a spectrometer at the end of the 4 MeV beam line. The focusing elements on the sections are in place and connected while the intersections will be installed only in early 1986. Two high-power klystron modulator assemblies were put into operation. However, the completion of the remaining four modulators, the RF distribution system and the associated low-power systems were delayed due to lack of manpower and late deliveries. Delays were also encountered with the construction of the LIPS systems (RF peak-power enhancement by pulse compression) though the power supplies, vacuum system and beam monitors were completed and performed reliably during the 4 MeV beam tests. The first computer controls of a number of elements became available.

Work on LIL–V (200 MeV high current) also progressed. Its injection system was commissioned at LAL ready for installation in the LIL–tunnel.

The Electron-Positron Accumulator (EPA) and the Transfer Lines

Progress on EPA construction and installation continued with the aim to inject an e^- beam from LIL-W at the beginning of June 1986. All bending magnets were shimmed, tested and are available for installation. Of the lenses, one series of quadrupoles remains to be delivered, but all others are ready. The majority of the vacuum chambers, supports and alignment systems were designed and manufactured, assembly and testing of the kickers and their generators progressed well and the injection and ejection septa were installed together with their power supplies. The RF cavity successfully passed its first test.

Measurements on the beam equipment impedance of the different machine components were continued. The main contribution to the overall impedance is due to the kickers and ways to reduce it were investigated.

The PS Modifications

Injection of e^- beams into the PS should start in September 1986. Consequently, the injection septa and kickers, the RF cavity and the wigglers were completed for installation in the early 1986 shutdown.

Adaptation of the SPS as Injector for LEP

In July it was discovered that all 24 cavities for e^+ and e^- acceleration in the SPS which had been completed (out of a total of 34 cavities) had deep cracks, starting from the inside of the cavity, in the main circumferential weld which holds the two halves of the cavity together. A repair procedure is being implemented. The first power tetrodes for 65 kW CW at 200 MHz produced by the manufacturer suffered from overheating of parts of the supporting structure of the cathode and grid. Following modifications, two pre-production tetrodes were tested successfully at full power so that the series production of the modified tetrodes could be resumed. All other main components of the accelerating modules have been ordered and about one third of the required cables, cooling systems and supports installed.

Tests showed that with minor modifications and additions, the existing SPS main ring power supplies can just be made to operate with the required accuracy at the 3.5 GeV injection energy of e^+ and e^-. The new single-bunch electronics of the SPS beam position monitors was commissioned and successfully operated during the autumn $p\bar{p}$ run. Design work started on the closed orbit acquisition system for the supercycles with interleaved p, e^+ and e^- acceleration and will be based on VME crates linked by MIL 1553 B to the SPS control system. The shielding against synchrotron radiation consists of a combination of 3 mm thick diaphragms made of tungsten alloy attached to special gaskets inserted in between the SPS flanges, and lead shields clamped to the outside of the vacuum chambers. All shielding for the regular arcs of the SPS was ordered, while the design of that for the long straight sections was started.

Beam Transfer from SPS to LEP and Injection into LEP

The major components of the two new kicker magnets for e^- injection/e^+ extraction and for e^- extraction as well as the new septum magnets for e^- extraction were delivered and assembly will start at the beginning of 1986. Construction was started of the thyristor controlled commutator switch which will permit the e^- septum magnets to be powered by the 25 kA power supply already used for 450 GeV proton extraction. The pulse generators for the SPS extraction kickers and the LEP injection kickers are of similar design. A prototype capable of producing a burst of 8 pulses, 2.5 μs long, 90 μs apart and with an amplitude of 5 kA, has performed reliably for more than 10 pulses.

Starting from the SPS side, openings were pierced in the tunnel wall of LSS6, and a few metres of the upper parts of the new beam transfer tunnels TI12 and TI18 from SPS to LEP constructed. Excavation of the latter will continue from the LEP side and will be completed during the 1986 and 1987 shutdowns. The twelve 2.8 m long dipoles for TI12 and TI18 were delivered, about half of the 100 or so dipoles and quadrupoles recuperated for these beam lines overhauled and the steel septum magnets for LEP injection ordered. Some 70 power supplies recuperated for TI12 and TI18 were installed in the LEP auxiliary building SR1.

The design of the two kicker septum magnets and of the six injection kicker magnets was completed and components for prototypes delivered for assembly early in 1986. The septum magnets are housed in vacuum tanks, whereas the injection kickers operate in air and have a ceramic vacuum chamber. A prototype of the latter with an oval aperture of 70 mm × 220 mm and a length of 1.3 m has been produced by industry and is being equipped with specially developed ceramic flanges which permit reliable and bakable vacuum connections to be made to stainless steel flanges. The chamber will be covered internally by a 5 μm thick layer of titanium applied by means of a magnetically assisted DC sputtering system built at CERN.

Main Ring

Construction

During the year all of the 18 pits giving access to the underground system were excavated to their final depth, this varying between 52 and 148 m. The major underground halls were also excavated together with the secondary galleries at points 2, 4, 6 and 8. But perhaps the most exciting event occured on 26 July when the tunnelling machine no. 1 arrived at point 2 a month in advance, having covered the 2.5 km from PM 18 at an average rate of 26.6 m per day. This same machine was then transferred to point 6 and by the end of the year had bored 1 km towards point 5.

Results with tunnelling machine No. 2 have been less satisfactory so far. Starting from point 8 in August it was scheduled to reach point 7 by the end of the year but, in fact, only managed 2 km due to a series of difficulties and accidents. Tunneling machine no. 3, brought into operation only towards the end of the year, started on its route from point 8 to point 1.

Serious difficulties were experienced in the Jura section of the tunnel due to geological faults and fissures filled with sand or clay. On three occasions work had to be stopped for up to one-and-a-half months for sealing operations using cement injections or to introduce reinforcing rings. Nevertheless, 2 km of excavation has been achieved in this region and the rate of progress is satisfactory.

Progress on LEP's 70 surface buildings was very good. Of the six groups of buildings, three were under construction during the year while the tendering procedure was prepared for a fourth. Many buildings were completed and handed over to their users during the year, notably at sites 15 and 18, while the construction of buildings at sites 2, 4, 6 and 8 was started.

Applied Geodesy

The intense mapping effort required to furnish maps for studies and the civil engineering work continued during the year, as well as the constitution of the land registration documents to establish owner and third party rights for the LEP in general and for over 50 km of trenches for cables and optical fibres in particular. The efficiency of these operations was improved by the installation of a digital mapping system compatible with the computer aided design (CAD) system Euclid.

Geodetic control of the civil engineering work continued, following closely the advance of the main tunnel as well as the excavation of the caverns and adjacent galleries. The use of a gyro to pilot the boring machines proved very successful so that, for example, after the excavation of 3 km of tunnel between pit 1 and pit 2 the tunnelling machine was only 4 mm from the theoretical radial position. The cross-section of the tunnel was also regularly controlled using photogrammetric and electronic distance measurement (EDM) profiles.

The surface geodetic network was remeasured using the Terrameter, so that the first underground control point, which will be used to install the elements of LEP, could be accurately determined. A check of the surface network using the global positioning system (NAVSTAR satellites) produced excellent results; the difference between the coordinates XYZ being around 4 mm (1σ) for the seven points determined by the two methods. The receiver manufacturers were very interested in the precision of the LEP geodetic network and requested a second series of measurements in October.

The development of the instruments needed to cope efficiently with some 20,000 measurements required for the installation and alignment of the LEP machine components continued.

An intense survey programme was also required for the PS, SPS, AA, ACOL and LEAR machines as well as for the fixed target and $p\bar{p}$ experiments of the SPS.

Theory and Parameters

The study continued on adjustment facilities of the machine's linear optics by estimating the residual dispersion and evaluating its correction. The constraints on the beams' optics which have to be satisfied during energy ramping made it necessary to establish numerically the possibility of adequate continuous adjustment of the insertion betatron functions and the chromaticity between the machine configurations for injection and operating energy. New analytical methods were developed for calculating amplitude variations and stability limits of individual particles subjected to the non-linear field of the sextupoles used for chromaticity correction. At the same time these values were calculated by numeric simulation of the trajectories over several turns. The effects of imperfections in the magnetic field and of alignment errors on the beam stability continued to be examined. The development of the Methodical Accelerator Design (MAD) program into a flexible framework for beam optical calculations has been pursued in collaboration with staff of the Brookhaven National Laboratory.

The transverse impedance of the shielded bellows was still a major factor in the expected limitation of beam current in LEP by transverse mode-coupling. In conjunction with the Vacuum Group, their transverse impedance was reduced by optimizing their geometry and is now about a third of that of the RF cavities, which seems acceptable. The theory of transverse mode-coupling was extended to include Landau damping by betatron frequency spread. Coupled-bunch oscillations of counter-rotating beams in LEP were calculated and found to be stable if the spread in higher-mode resonant frequencies of the RF cavities is sufficiently large. The electromagnetic fields in a vacuum chamber of toroidal geometry and their effects on the beam continue to be studied.

Magnets

About 1200 cores for the LEP main-ring dipoles, i.e. more than one third of the complement, were received and accepted. Despite the novelty of the manufacturing technique, the rejection rate was less than one per cent. According to magnetic measurements, performed in the EF Division on a statistical sample, the field pattern in the gaps is within tolerance but the spread of the bending strengths is excessive, because the magnetic permeability of the steel laminations is influenced by the internal stresses produced by mortar shrinkage. Therefore, after twelve months ageing, the cores are stress relieved by mechanical strain and their overall excitation characteristics are then systematically measured by means of a fixed set of excitation and measuring coils, into which the cores are moved on rails. These operations take place in a part of the old ISR tunnel, where the cores are temporarily stored. During installation, the cores will be grouped according to the results of the measurements, to improve the uniformity of the bending strength around the LEP ring. Prototypes of the dipole excitation bars have been used to assemble a test six-core magnet unit.

Some 80 quadrupoles for the machine arcs and 120 sextupoles were received and three quarters of them have been measured with satisfactory results using the harmonic-coil method. The reception and measurement of the sextupoles are performed by a team in the SPS Division. Series deliveries of the quadrupoles for the long straight sections and of the correction dipoles started towards the end of the year. For electrical and mechanical components, such as excitation bars, bus bars and water-cooled cables, girders and jacks, clamps and hydraulic fittings, production was started but delivery will take place only when they are needed for assembly and installation. New contract adjudications concerned special magnets, such as the eight dipole wigglers and the 64 weak-field bending magnets, and the welding in situ of the dipole excitation bars and of the bus bars for quadrupoles and sextupoles. Preparatory work for assembly and installation was continued.

Radio-Frequency

Series production by industry of all components of the accelerating structure continued smoothly throughout the year. At CERN these components are being assembled into complete coupled-cavity units, adjusted and conditioned to full power in two semi-automatic conditioning stands. This part of production too was brought up to full rate, resulting in about one finished unit per week. By the end of the year, 42 of the required total of 128 units were complete and in store.

A complete RF unit, consisting of 16 coupled cavities, two 1 MW klystrons, the waveguides for RF power distribution and all the necessary drive and control electronics, was tested. This permitted the finalization of all prototype electronic equipment which is part of such a unit, the preparation and issue of calls for tender, as well as the placing of some orders for the electronic modules. High power tests with the 16-cavity unit confirmed all aspects of the design but did reveal the need for circulator protection of the klystrons.

The development work concerning the difficult problem of synchronization of two pairs of RF stations and the injector continued and an order was placed with industry for the delivery and laying of the monomode optical fibres which will link the geographically separated parts of the RF system.

Vacuum

Considerable effort went into the production of the main ring vacuum chambers. Aluminium tubes, 12 m long and extruded to acceptable tolerances, were achieved only after lengthy trials and technical improvements. Chemical cleaning of the tubes and the manufacture of chambers still required much development by the contractors until a pre-series of satisfactory performance was obtained. Series production was started and reached the scheduled rate of four dipole and two quadrupole chambers per day. Many chambers were tested to ultra-high vacuum: the ultimate static vacuum of some 10^{-9} Pa and the composition of the residual gas were almost as specified and mounting and operation of the NEG getter pumps presented no problems. To check whether this static vacuum has implications for the dynamic outgassing in LEP, a short chamber of each type was exposed to synchrotron radiation at the DCI storage ring at Saclay. It was confirmed that the initial outgassing will be stronger, but also that the initial beam cleaning rate will be higher such that the LEP performance (in terms of beam lifetime) will be reached as specified. The production line for the lead shielding of the vacuum chambers was set up and commissioned, the pre-series of chambers being clad successfully. The first UHV stand for commissioning of the finished chambers was commissioned in the new hall on the Prévessin site.

In addition to the 2662 standard vacuum chambers there will be about 270 special ones; prototype chambers for the physics experiments and the injection regions were manufactured and optimization started. Vacuum conditioning of the RF cavities continued at a regular rate of about 1 unit per week and the delivery of components (pumps, valves etc.) was maintained without any major problem. The design of the bellows complete with RF bridges was finalized and the contract placed after successful prototype tests. Prototypes of many items for the controls system were designed, optimised and manufacture of series items started.

Beam Instrumentation

Half of the 450 aluminium blocks to hold pick-up buttons for the orbit measuring system were delivered and accepted. However, button electrode prototypes of the same material did not meet the requirements and only after deciding to replace them with a stainless steel version could the final order for 2500 buttons be placed. The design of electronics for signal treatment received close attention and was reviewed by experts from various laboratories. Two different schemes will be adopted: i) for beam position monitors (BPM) located close to the eight crossing points where a full signal treatment will be made using components recuperated from the ISR; ii) for BPMs where e^+/e^- signals are separated by more than 600 ns button signals will be multiplexed and the measurement made via the very cheap 8-bit flash ADC's now available on the market. Over 300 km of coaxial cable will be needed to route the signals toward 24 electronic stations. Cable samples were tested at DESY for their noise immunity in a high synchrotron radiation environment, and in a reactor for their mechanical resistance to high radiation. Final specifications were written and tendering started.

Aperture collimators will be needed to localize beam losses away from the four experimental detectors. The specifications for this system were optimized with the help of a Monte-Carlo study. Other collimators used to reduce the synchrotron radiation background to experiments were also reviewed and will allow, in their new position, a measurement of relative luminosity fully compatible with experimental set-ups. Further improvement of the high-permeability cores for beam current transformers was achieved and the design started of a prototype unit.

A new layout of the beam polarimeter was prepared while the detailed design of polarization measurements received renewed attention. Work also progressed steadily on other diagnostic equipment mentioned in previous reports.

Electrostatic Separators

During the year, a full size prototype separator, with 4 m long stainless steel electrodes, was thoroughly tested and its high-voltage performance found to be excellent. From spark rate measurements at fields in the range from 38 to 53 kV/cm it was concluded that a separator unit will only spark once or twice per year at the design field of 20 kV/cm, at least under laboratory conditions. Parasitic mode loss measurements on the prototype confirmed results obtained earlier with a simplified model. Heating of the electrodes by parasitic mode losses was simulated in the vacuum tank and the resulting deformation found to be so small that it will not be necessary to directly cool them during the initial operation of LEP at currents of up to 3 mA per beam. A contract for 33 vacuum tanks of 4.5 m length and 0.5 m diameter was placed and calls for tenders sent to industry for all other major components of the separator units.

Prototypes were built of several components to be used in the 160 kV circuits, the plugs and resistors successfully withstanding voltages exceeding 240 kV. The first 2000 m of high voltage cable was delivered to CERN and passed severe acceptance tests, notably DC operation at 400 kV with rapid discharges at 240 kV. Early in the year 36 high voltage generators were ordered while development of the control electronics made good progress. More than half of the microprocessor cards were ordered.

Power Converters

Replies to the preliminary inquiries covering the power converters and the associated electronics for the LEP Main Ring magnet system were analysed in detail so that the majority of the final specifications could be written and issued to industry. By the end of the year six major contracts were placed, covering roughly half of the equipment involved.

The various components of the 100 kV, 40 A pre-series power converter for the klystrons were delivered by industry during the year. The final assembly of the converter, as well as the dummy loads, was carried out and tests started on them.

Electrical Installation

All of the contracts for electrical equipment were issued other than those for generators, filters and compensators. The two electrical installation contracts for the surface buildings and underground areas were also awarded.

Installation work in the buildings and sub-stations of points 1, 2 and 8 continued, the point 1 sub-station being commissioned before the end of the year. The assembly was also started of the 66 kV switchboard at Prévessin and which is the source of the LEP distribution system.

Controls

Calls for tender were sent out for the supply of Time-Division Multiplex (TDM) equipment for communications between LEP sites, and for the supply and installation of their optical fibres and coaxial cables. The contract for the supply and installation of a radio communication system for the LEP tunnel and other underground areas, and for the supply of a digital telephone exchange for both voice and data were adjudicated while the definition of other communications projects continued to progress. A contract was also awarded for the supply of the hardware and software of the Process Control Assemblies (PCAs) which consist of multiprocessors housed in a standard crate, connected to microprocessors in the field by a multidrop highway and interconnected by a network.

In order to permit software development and hardware tests prior to delivery of the first PCA in 1987, a number of test systems were made available which emulate functions of the PCA. Work was then started on the details of the communication protocol between the PCA and microprocessor based equipment in the field. Interfaces of the multidrop highway to a number of microprocessor systems were designed and tests carried out at various transmission speeds over a length of several kilometres and for use in the early installation phase.

In view of the future use of e^+e^- beams in the SPS and of the combined operation of the SPS and LEP machines from the Main Control Room (MCR), a new infra structure for the latter was designed. The main guidelines were to preserve the essential features of the existing control room, based on Nord-100 computers driving CAMAC based consoles, while making use of modern technology, existing standards and commercial products. The new system will consist of an autonomous local area network with a number of personal work stations acting as consoles and a number of servers which provide shared resources.

This project largely benefitted from the CERN/IBM collaboration which allowed tests to be started on a token ring network installed in the MCR.

Cooling and Ventilation

The main effort was concentrated on the preparation of the technical specification for cooling, ventilation, heating and fire detection equipment for LEP. This allowed five contracts to be placed for piping and ducting at point 1, for heating and ventilation of some surface buildings and for the whole fire detection system of the LEP underground areas. Eight calls for tender were also prepared and seven others partly completed.

Progress on the construction work at point 1 made it possible to start the underground pipework and ducting together with the temporary ventilation, heating, permanent ventilation and fire detection of some surface buildings.

Installation, Planning and Engineering

The year saw the start of LEP's installation phase. The work of equipping the surface buildings SE1, SR1, SXL2, SE2, SE8 was either completed or under way while that of the first machine pit PM15 started in October. Ordering of all the main transport and handling devices was completed and prefabrication of the underground infrastructure (concrete modules and metal-frame crates) was started ready for installation in pit PM15 early in 1986.

The ORACLE data base facility and the related application program were brought into operation in the field to enable close follow-up of the work planning. The site management and coordinating teams were also set up. Over 50,000 hours of mechanical engineering design effort was provided for the LEP Groups, either by the staff or by subcontracting, of which about 60% by CAD. On the new technology side, a great effort was devoted to the design and testing of ultra-thin vacuum chambers using aerospace techniques, as well as to participation in development projects such as RF superconducting cavities with a niobium inner coating, experimental vacuum chambers and a 4 MW RF load.

Computer Services

The installation of a VAX 8600 and the introduction of Version 5 of the relational database management system ORACLE in the summer greatly improved the response time for the users of LEP database applications. The planning and installation software under development over the past two years was brought into full production and is responding well, as is the LEP cables management facility. Applications under development included a budget information query facility and space allocation management system. Discussions on the use of ORACLE for the commissioning and operation of LEP were started.

After three years of operation, the CAD Project entered the consolidation phase. All designers and draughtsmen have received basic training so that new machine elements are now automatically studied using CAD in order to facilitate future studies and maintenance. The stability of EUCLID software over the last year led to better exploitation but more work stations will need to be added in order to tackle the increasing work load.

Radiation Control

Calculations on shielding effects of labyrinths, access shafts and a shadow shield in the cavity area were completed. First results of a newly developed paint dosimeter were promising and other dosimeters to be used in LEP were studied further. Radiation resistance tests continued for many items to be used in the LEP main ring while, for cable insulation and other plastic materials to be used in large quantities, tests on flame propagation, oxygen index and production of corrosive gases were made. A radiation monitor system for the RF test areas was completed and the installation of monitors in LIL and EPA started. The layout of LEP radiation monitor systems was defined, the specification of their new control unit finalized and the development of the microprocessor software started.

Routine radiation protection commenced for the LEP RF test areas, the e^- guns and first sections of LIL, and for many test beams used exclusively for the LEP detector development. The programme to measure pre-operational radiation parameters continued. It included the operation of two environmental monitor stations, the determination of radiactivity in different samples of air, water, mud and vegetation, background radiation measurements in collaboration with the Commission Fédéral de Surveillance de la Radioactivité, and the measurements of radon in underground tunnels.

Personnel Access System

For safety reasons the access of personnel to the LEP facilities must be strictly controlled at two levels. Firstly, persons going underground are recorded at the top of the 14 access shafts by means of magnetically coded identity cards which also operate a turnstile and release an automatic door. A prototype of this equipment was installed in an SPS shaft and performed satisfactorily under realistic conditions. This permitted a specification to be written for further equipment, the first installation being scheduled for 1986 in the shaft PM 15. Persons wishing to enter the LEP radiation zones are subjected to a second control using the identity cards and classical procedures. By means of CCTV, an operator in the machine control room surveys the passage of personnel into or out of the zone. To enter, personnel must also collect a special interlock key whose absence ensures that the particle beams cannot be injected.

Other Divisional Activities

CERN Accelerator School (CAS)

The year started with the distribution of the first proceedings to be published by CAS for its course on "Antiprotons for Colliding Beam Facilites". Later, the proceedings appeared for the

CAS-ECFA-INFN workshop on the "Generation of High Fields for Particle Acceleration to Very High Energies" and by the end of the year those for the "General Accelerator Physics" course held at Gif-sur-Yvette were also printed.

Two events were organized: the first, a joint US–CERN topical course on "Non-Linear Dynamics" was held in Sardinia in February and the second, "Advanced Accelerator Physics", at Oxford in September. The former will hopefully lead to a long and productive collaboration with the US School and, indeed, preparations were started for the next joint course, to be held in America and entitled "Frontiers of Particle Beams". The Oxford course completed the first biennial cycle of the basic CAS programme to cover general accelerator physics topics in two, two-week courses. Preparations were also made for a specialised course "Applied Geodesy for Particle Accelerators" to be held at CERN in April, 1986 and the next "Basic Course on General Accelerator Physics" to be held in Aarhus, Denmark in September, 1986. Over the year CAS also organised 11 seminars on accelerator physics topics.

Future Studies and Collaborations

Many members of the Division continued studies on the possibility of constructing a Large Hadron Collider in the LEP tunnel, in collaboration with the SPS Division. A member of the LEP staff took on the setting-up and chairing of a panel to advise the Long Range Planning Committee (chaired by C. Rubbia) on the feasibility of linear electron-positron colliders at CERN, and many other members of the LEP staff also contributed to this study.

The Division ensured some CERN participation in the laser-plasma beat-wave experiment undertaken by a Rutherford Appleton Laboratory–Imperial College–Oxford Collaboration.

Technical Services and Buildings Division

Introduction

The very large number of negotiated departures (totalling 80) between 1980 and 1983, together with a few regular retirements, deaths, and the transfer of personnel to other Divisions, has made it possible, while adhering to the staff ceiling set by the Directorate- General, to recruit some younger staff. This has helped improve the technical competence of certain teams, stabilize the average age of the Division and improve its ability to tackle the Division's additional workload (civil engineering for LEP, maintenance and operation of the site and mechanical engineering and related work).

From the peak of 616 in 1974, staff numbers have now fallen to around 475, comparable with the figure for 1964; however, the Division's workload has more than quadrupled during the same period through the considerable extension of the sites and the concomitant increase in the number of buildings and general technical installations. It has been possible to cope with this tremendous increase as a result of better organization, albeit coupled with a reduction in the rate of maintenance operations, the acceptance of certain risks with regard to the reliability and operational security of installations and, above all, the farming out of a large number of maintenance, service and minor work contracts.

Some operations are therefore now completely in the hands of outside firms, including cleaning, on-site handling, maintenance and minor work in the buildings, and maintenance of the general electromechanical installations. About 450 employees of outside firms are now working permanently on the site. The figure does not include the teams responsible for new building work, which vary considerably according to the extent of the work to be done.

The Division's expenditure (personnel and material) amounted to 119.7 million Swiss francs, broken down under the following main headings:

	Number of people	Forecast expenditure (MCHF)
Construction department	63	17.3
Energy, water	–	46.3
Site maintenance, operation and cleaning	189	29.5
Central Workshops	150	13.8
Transport, equipment handling	53	10.6
Management and administration	20	2.2

These amounts do not include the following items charged to the budgets of other Divisions but which were the technical and financial responsibility of the SB Division:

		MCHF
New construction work (ACOL, etc.)		1.8
LEP construction:		65.0
Underground work	54.8	
Surface buildings	10.2	
Alterations to existing installations		13.4
Central Workshops: jobs put out to contract		4.0

New Works and Alterations

The three groups of the Division responsible for new works (Civil Engineering, Technical Installations, Co-ordination) have, since 1983, formed the Civil Engineering Department SB/LE.

This department's prime task is to complete the LEP civil engineering programme (underground works in the plain, including connections with the SPS Tunnel, underground works under the slopes of the Jura, surface buildings at the eight LEP access points, the Pre-injector Building) under the supervision of the Director of the LEP project and in close collaboration with the various groups of the LEP Main Ring Division. The Department's available manpower has resulted in its being made responsible for the erection of the other buildings on the Meyrin Site (Buildings Z and O, building for the ACOL project).

Although its staff total has been sharply reduced through the many transfers to the LEP Division, the Technical Installations Group also provides technical support for certain parts of the project connected with civil engineering (electricity, ventilation, air-conditioning and pipework).

Finally, the Co-ordination Group undertakes a considerable amount of work for the planning and financial monitoring of the various operations of the Department's Civil Engineering and Technical Installations Groups.

The staff total of this department at the end of the year was 63, including 12 engineers and supervisory staff.

Design Studies and Civil Engineering Work for the LEP project

The work for the LEP programme undertaken by the SB/LE Department is described in detail under the sub-heading Civil Engineering in the section of the report dealing with the LEP Division.

Meyrin site

A loan of slightly under ten million Swiss francs granted by the Swiss Confederation via FIPOI (Fondation des Immeubles pour les Organisations Internationales) has enabled work to continue on erecting two buildings: Building Z or 32, near the Administration Building, to house the steadily increasing number of physicists from outside the Organization; and Building 0 or 33, for various units serving visitors from outside (physicists, contractors' staff, suppliers, pensioners, journalists, visitors, etc.). Building 32 is scheduled for completion in February and Building 33 in March 1986.

The ACOL project has made considerable alterations necessary to Hall 193 (the antiproton accumulator hall), including civil engineering work in the target area, changes to the electricity supply and piping, the construction of a 320 m^2 hall, a 160 m^2 building for radioactive materials, and a 100 m^2 target chamber model building, and the building of a target area access tunnel 4 m in diameter by 42 m long and of an access shaft 3 m in diameter by 6 m deep. All this work was completed in 1985, while connections to the existing installations are scheduled for the machine shutdown at the beginning of 1986.

Work on a multi-purpose surface treatment building located near the existing surface treatment shop and the effluent treatment station, begun in 1984, was almost complete by the end of the year, except for some internal fitting-out. It is primarily intended for the cleaning of LEP's 12 m vacuum chambers and for treating superconducting accelerating cavities. It will also permit the surface treatment of large items which, with the old installations, was only possible using temporary rigs, in conditions that were unacceptable from the safety standpoint. The dimensions of the two-storey building are 25.5 × 13.5 m, and it houses all the equipment (large tanks, a cleaning tunnel for vacuum chambers, etc.) and technical installations needed for the work to be performed in the greatest safety for both personnel and the environment.

Prévessin site

A 4800 m^2 hall for fitting the lead shielding and testing vacuum chambers for the LEP project was built and made available to users.

The draft plan and detailed design studies for an 860 m^2 radioactive store were completed and a call for tenders issued. Building work began in November.

Various Alterations to Buildings and Technical Installations

The extremely heavy increase in 1983 (+30%) and 1984 (+14%) in the number of requests from other Divisions for the fitting out of buildings and work on technical installations gave way to a stable situation in 1985 (+2%).

The total number of requests, including those from within the SB Division, rose to 2854, and the value of the work done reached a total of 14.8 million Swiss francs.

The most extensive work included :

- design studies for and the laying of foundations for the ALEPH magnet (Building 191);
- fitting-out of a LASER area (Building 100);
- construction of a high-voltage test area (Building 268) for LEP Division;
- fitting-out of a vacuum area (Building 181) and the 4800 m^2 storage area (1026) for LEP Division;
- numerous alterations in LINAC I (Building 351);
- construction of offices and laboratories (150 m^2) in Building 600 for the staff of DD Division;
- construction of offices and laboratories: buildings 601 (70 m^2) and 602 (450 m^2) for the staff of EP Division, and the fitting-out of workshops in Building 115;
- the fitting-out of a hall and gas areas (Building 175) for EF Division;
- the design study for the LPI project - supplies building (Building 278).

Maintenance and Operation

Site maintenance

The sums used for maintenance of the buildings and grounds amounted to 950000 CHF for day to day maintenance and 350000 CHF for major overhaul work.

These sums, which were drastically reduced in 1978 following a strict economy drive, are clearly inadequate to cover the maintenance of over 520000 m^2 of building ground-area and 350000 m^2 of roads, car parks and storage areas, which are on average more than 13 years old.

Assessment of the present condition of the buildings has continued. Its aim is to allow maintenance of the buildings to be computerized and to draw up a realistic maintenance programme for the future.

Work on improving road signs and the flow of traffic has continued, as well as the day-to-day maintenance programme for open spaces and green areas.

Cleaning

A call for tenders for the renewal of the cleaning contracts on both sites has been issued, and new contractors started work in 1985.

In this field, optimum frequency has been reached in the cleaning of offices, laboratories, workshops and halls, and any further savings would be difficult to envisage.

Technical maintenance

Technical installations were serviced according to schedule, with no major incidents.

The policy of reducing preventive maintenance in favour of keeping equipment in working order was continued.

During the renewal procedure for the three maintenance contracts (electro-mechanical, low-voltage electricity and heat and fluids), a full analysis, resulting in the establishment of priorities and a change of methods, made possible a considerable reduction in costs.

Several buildings (Buildings 927, 32, 33, etc.) with their various electrical switchboards, heating or air-conditioning plants, etc., were completed in 1985. The first sets of fittings for LEP area 1 were also commissioned and thus have to be included in the new operational and maintenance charges.

The alterations, improvements and renewals of old equipment included :
- replacement of 25 electricity distribution switchboards (over 25 years old);
- improvements to the SPS tunnel fire-detection equipment (1st section);
- continuation of the programme to renew the heating and air-conditioning controls as part of the centralized, computer-controlled operating system;
- renewal of the heating sub-plants in Buldings 55, 57 and 101;
- renewal of the low-voltage part of Sub-station 8 (PS machine East Area);
- replacement of the automatic control system for the pumps in Pumping Station 2.
- assistance to DD Division in installing the new IBM-3090;

Maintenance operations included :
- replacement of the SPS cooling tower fan blades;
- general overhaul of a motor-generator set.

New projects included the installation of neutral point coils and the fitting of 300 zero-sequence protective devices as part of the programme for earthing the MEYRIN site's 18 kV mains.

Annual variation in power, water, and fuel oil consumption from 1978 to 1985

	1978	*1979*	*1980*	*1981*	*1982*	*1983*	*1984*	*1985*
MEYRIN SITE								
Active power consumption (MWh)								
- grid supply	361930	306904	323713	295291	293837	297258	205227	198947
- stand-by generators	22194	22278	2595	2030	2085	3620	1215	546
Total	384124	329182	326308	297321	295922	300878	206442	199493
Maximum instantaneous power (kW)	77400	71000	69500	60000	61000	64000	38000	36000
Cooling water (1000 m^3)	7114	6808	5964	5494	6123	7047	7328	6722
Drinking water (m^3)	208315	59276	45967	40883	45201	26539	45001	23362
Heavy and light fuel oil (metric tons)	13162	13334	8195	7493	6576	7092	7112	7132
Gas (m^3)	26723	31755	25831	24486	24548	25343	22748	21104
	1978	*1979*	*1980*	*1981*	*1982*	*1983*	*1984*	*1985*
PRÉVESSIN SITE								
Electricity (controlled by SPS Division):								
- Active power consumption (MWh)	303556	327038	221966	252146	357988	369037	424106	418445
- Peak power (kW)	246000	212000	192280	177603	182877	236403	206530	233800
- Average power (over 10 min) (kW)	73000	71400	80800	83000	82000	88200	76570	75790
Cooling water (1000 m^3)	11989	13043	8554	10662	13760	13788	15115	14675
Heavy fuel oil (metric tons)	1281	1302	1245	1348	1278	1348	1014	1420

Central Workshops

The average workload on the Central Workshops in 1985 remained considerable, most of the work's being for LEP Division and work from the other Divisions linked to the LEP project.

Mechanical Engineering Section, Free Workshops, Fitting work

The Mechanical Engineering Section widened its scope by providing a considerably wider range of technical support for various projects. Close collaboration made it possible to optimize the methods and production equipment selected.

The services provided included the work done in developing the TPC chambers for DELPHI, the assistance given to the L3 coil operations, the parabolic mirror moulds for DELPHI's Rich Barrel, the assembly of the prototype HPC module for DELPHI and the machining of various types of base-plate for the ALEPH calorimeter.

Various other types of work were done which required the use of the workshop's different installations. The most important were the milling on numerically-controlled machines of h.v.-l.v. plates for EPA injection kicker magnets leading to the PS, the highly sophisticated turning of three internal conductors for the neutrino 86 horn, the complete manufacture, including machining, assembly and testing, of two kicker and pick-up sets for ACOL's stack core cooling and a prototype pick-up vacuum tank with its two supporting electrodes. Two 114 MHz cavities for PS-LEP were also completed in a very short time. The numerically controlled turning equipment was used for four 100 MHz drift-tube assemblies for SPS-LEP, while titanium and nickel grids for a 4 MW load were machined by spark erosion for LEP. The planing, numerically-controlled milling and assembly work was performed for the prototype UA2 hadron calorimeter module. Vacuum tanks for the injection lines and several vacuum chambers of various shapes and sizes for EPA were made for SPS-LEP.

The team of engineering fitters carried out repairs and machining work in situ on the PS inductance coils and assembly work on the WA 79 chambers and for experiments UA6, UA2 and NA 31.

Sheet-Metalwork/Welding Section

Various examples of the work done by this Section deserve mention:

- The manufacture of 114 MHz r.f. cavities for LEP/PS. These are double-walled stainless steel components 1.8 m in diameter and 1.2 m high, consisting of 15 mm gauge cylinders and convex ends with an outer casing, itself made up by welding 60 'orange-segment-shaped' components together. The MIG and/or TIG welds gave rise to considerable stresses requiring heat treatment at 950C in vacuo. Two cavities of this type were made.
- The shaping and welding of a 5 mm gauge stainless steel pick-up vacuum tank, 2.5 m in overall length, with a copper heat screen. The tolerances were very close, especially between the extruded tank outlets and the heat screen.
- The manufacture of a 0.5 and 1 mm gauge stainless steel 2.4 GHz kicker shielding tube, octogonal in shape, to tolerances of 0.05 mm between it and the positioning of the rails supporting the ferrites.

The Section has acquired a new portable welding set for use at the PS during the replacement of the elliptical vacuum chambers. The welding set was designed by the Group's Design and Projects Office.

Thin Sheet-Metalwork Section

LEP project:

- Manufacture of a 350 MHz, four-cell niobium cavity (LEP Phase I) and a 2 mm gauge 316 LN stainless steel helium cryostat to house it.
- Shaping of a 350 MHz copper cavity with four cells and three cathode and niobium screen assemblies (Photograph 007–05–85) for providing cathodically sputtered niobium coatings (LEP Phase II).
- The manufacture of 25 copper domes 400 mm in diameter and 1.5 mm thick for the power couplers of the superconducting cavities. These cold-spun components were brazed in vacuo.

SPS Division:

- A prototype higher-mode filter (HOM) for the electron acceleration system made by swaging copper (6 mm gauge) and cold-spinning stainless steel (2 mm gauge).

- The cold-spinning of 60 copper clamps for a Siemens amplifier filament for the proton acceleration system.
- The manufacture of 30 stainless steel and aluminium deflectors and 4 titanium screens (1 mm gauge) for the electrostatic septa of the separators.

Special Techniques Section

Mechanical engineering support

By and large, the workload has been heavy, with an increase in demand for special work, especially the truing of ceramics: insulators (UA1), sealed grommets and ferrites (ACOL). Three-quarters of the work was for the LEP project and the associated machines.

Special items of work included:
- prototype vacuum chambers for the LEP intersection region;
- sophisticated mechanical components for the 'A$\bar{A}$ flexible line' (stochastic cooling);
- ceramic insulators for the niobium cathodic sputtering system inside copper r.f. cavities for LEP;
- various types of accelerator beam monitors;
- solid copper u/v mirrors for synchrotron radiation for EPA;
- high-precision thin targets for experiment PS 177;
- the development of evaporation masks for prototype drift tubes for DELPHI.

Synthetic resins

Heavy demands were made here, with almost two-thirds of the work done for LEP and the associated machines. The operations included:
- the solid-casting of high-voltage components for PS and LEP, involving over four tonnes of epoxy resin mixes;
- the manufacture of more than 5000 optical joints for EP, EF and visiting teams;
- making over a hundred glass-polyimide insulating components for LEP;
- the potting of coils, magnets and transformers for PS, SPS and LEP;
- casting insulating lead-throughs for connectors for SPS and LEP;

Some more unusual work also deserves mention:
- the casting of a microwave absorber, 900 mm in diameter, for LEP;
- the manufacture of flexible polyurethane inserts for the LEP steel-concrete magnets;
- design studies and tests on the 'F + 964' mixture (report SB/AC/ST/3206) and on the effect of fillers on the properties of epoxy mixtures (in progress).

Detectors

In view of the staff numbers available, the workload was heavy, and concerned mainly experiments UA1 and UA2, the LEP machine and experiments (LIL, BWS, DELPHI, L3, OPAL and ALEPH, amounting to almost 25% of the work), and OMEGA and LEAR.

Besides the traditional hodoscopes and couplers (e.g. prototype large scintillators for DELPHI and L3), there was a great deal of development in the use of optical fibres: transparent fibres (LIL), scintillating fibres (NA38) and WLS (wave-length shifter) fibres (UA1).

Thin films

A wide variety of operations was performed, including an increasing amount of work on resistive layers (titanium, nickel- chrome and tantalum) deposited on temperature- and radiation-resistant bases (Kapton R, quartz and alumina).

Some particularly unusual work deserves mention:
- vapour-deposition of aluminium on optical fibres for UA2;

- vapour-deposition of copper strips through a mask on large quartz plates for the prototype drift chamber for DELPHI;
- vapour-deposition of Al, Ti, Au, Pd and Ge on glass plates for SPS.

In addition, there was a considerable increase in the 'doping' of ceramics associated with various components of the LEP vacuum chamber: a thin cathodically sputtered film of titanium constitutes a resistive coating which is permeable to radio-frequencies and allows the beam image current to pass, thus reducing the vacuum chamber impedance.

Metallurgy

In addition to the large number of inspections performed throughout the year, the Section often handled work concerning:
- the solid copper or niobium r.f. cavities for LEP;
- tin-lead deposits linked to the LEP vacuum chamber shielding;
- the contamination of the anode wires of wire chambers by quartz or polymer deposits (EF, EP, UA1);
- magnet cooling circuit corrosion (PS, SPS, L3 collaboration).

Laser

The main aims of concentrating the electron beam welding equipment and laser installations were to broaden the engineering environment of the laser equipment (thus reducing tooling and maintenance costs) and to make a substantial improvement in work organisation.

The laser has increasingly proved itself as a practical tool. A large number of feasibility tests on cutting out (e.g. UA2 insulating joints) and micro-welding (e.g. stainless steel containers for the UA1 uranium calorimeter) were performed this year.

Surface Treatment Section

The most significant work done by this section included:
- Chemical polishing, anodization and de-oxidation (500 and 350 MHz cavities) treatment of niobium superconducting cavities for the LEP project, and chemical polishing of 350 MHz, four-cell cavities using a slower-operating bath than in the past.
- The preparation of sheet-metal (degreasing, scouring) before shaping and tribo-finishing treatments for 350 and 500 MHz copper cavities.
- The electro-forming of conductors in nickel and selective silver-plating on aluminium alloy components for the PS magnet horn and the $A\bar{A}$ power supply line.
- The surface preparation of LEP storage cavities and the development of a palladium-plating bath for treating components of the 200 MHz amplifier module.
- The chemical nickel and hard-chromium plating of the bodies of the lithium lenses (FERMI and CERN) and the selective tinning of the contacting surfaces for the antiproton source.
- Silver-plating before heat treatment of various atomic clock components for the University of Neuchâtel.
- Copper plating for r.f. applications and preparation before brazing for the MEDICIS project.

Finally, work continued on building and fitting out the new multi-purpose surface treatment shop, which is due for commissioning on 1 March 1986.

Printed-Circuit Board Section

This section carried a very heavy workload.

In addition to conventional circuits, demand for multi-layer types still continued to increase, with an average of 2–3 items of the same type made, since the Section is required to produce a new model almost every day.

A new CNC drilling machine has been obtained and in future manufacturing precision will be such that holes 0.3 mm in diameter can be internally metallized.

In the field of hybrid circuits, the various facilities available to the Group made it possible to produce noteworthy items (project WA 76/EF: Kapton R fan-out, silicon detector supports, project MSP2/EF).

Examples of special work included:

- metallized-hole circuits measuring 0.2 × 0.58 m drilled on a numerically controlled machine for exeriment NA 36;
- Kapton R circuits for the DELPHI experiment, measuring 2.4 × 0.55 m, with metallized holes;
- aluminium-cored multi-layer circuits for the Collège de France, made with the assistance of the Surface Treatment Section.

Chemical Laboratory Section

The Section made a considerable contribution to the various experimental or machine Divisions in the field of corrosion, with special reference to cooling circuits. Several reports have been published.

At the same time, for the HVDC Power Converters/LEP project, tests have made it possible to specify the most suitable coating for protecting electrodes made by the spark erosion of titanium. These tests also showed the need to replace the electrolyte which it was initially intended to use by a less reactive formula containing no chlorine ions.

A new and original low-cost bath has been developed for the chemical polishing of copper superconducting cavities which are subsequently cathodically sputter-coated with niobium. A report on this innovation is now being drawn up. It has been possible to use this bath successfully to treat several single-cell cavities of 500 MHz and one four-cell cavity of 350 MHz.

Heat Treatment Section

Even more than in previous years, this Section's work showed a clear bias towards jobs for LEP. Only about 10% of the workload was for other Divisions, visiting teams or national institutes.

The main work in which the members of this Section took part concerned:

- LIL brazing of 38 r.f. cavity couplers;
  brazing of copper/stainless steel waveguides for bunching and pre-bunching;
- LIPS brazing of alumina/metal insulating components for magnetic pick-ups;
- LEP piston synchroniser brazing;
  production of 100 kW coaxial loads and brazing the copper/stainless steel terminal load;
  storage cavities (coaxial windows), prototype higher-mode filters for the 200 MHz module, plus constant technical support for the contractor;
- PS, EPA } brazing in vacuo on septum magnet coils and alumina/metal;
  coaxial power supplies; heat treatments on new prototype vacuum chambers;
- ACOL, LEAR projects heat treatments in vacuo;
- EF various metal-ceramic, copper niobium, stainless steel/niobium and alumina/niobium brazing operations on superconducting cavity components, and the annealing in vacuo of niobium components;
- SPS production of 80 assemblies for septum magnets (MSE, MST, MSL, etc.).

Other work included heat treatments on NEG pump components, niobium stress-relieving annealing, outgassing of chambers in vacuo (PS, EPA, ACOL, LEAR), truing of titanium electrodes (L = 3 m) for separators and the treatment of 18 stainless steel tanks (L = 4 m) for r.f. cavities (LIL). Finally, there were various conventional heat treatments (hardening, salt-bath and gas cementation and light-alloy treatment).

For the sake of completeness, it should be noted that the Section played a considerable part in work for various institutes or universities [the Neuchâtel Watchmaking Institute, EPF Lausanne, SIN Villigen and the Universities of Heidelberg (D), Aarhus (DK) and Uppsala (S)].

Quality Control Section

The 11903 hours worked by the Section during the year covered:

- 5199 hours in the Metallurgical Service, including 2926 hours for LEP;
- 6704 hours in Metrology Service, including 3813 hours for LEP.

It took an active part in inspections of the components of the four scheduled LEP experiments: DELPHI, OPAL, L3 and ALEPH. Its services were also required for other projects like ACOL – PS (new vacuum chamber).

The numerically controlled measurement centre commissioned in October 1984 alone worked for nearly 2000 hours, requiring the drawing up of 67 programmes, 52 of which were put on memory for repeated use in the future. This measurement centre performed work which would have taken at least 8000 hours on conventional equipment. It was thus possible to limit recruitment to the Service to one person engaged under an industrial support contract.

Services and Projects

For the L3 collaboration, this Service designed an improvement for the electron-beam welding machine (suction-cup on lifting device, turn-table) and a milling machine for weld beads, a chisel for bath-bearers, a grinding machine for aligning the half-turn ends, drilling machines for 70 mm holes and a half-turn transport frame.

For the SPS Division, it designed and built an internal electron-beam welding machine for finishing the beads on 200 MHz ACM modules.

For the DELPHI experiment, it performed on-load tests for the HPC module securing system, and developed a special roller bearing and a new, more suitable assembly for the rocking motion linked to the extension of the rails for inserting and withdrawing the modules (simultaneous transport of 12 modules).

For experiment WA 70, it designed a new hydraulic control system using four pumps to adjust the height of the calorimeter.

PS Division asked for the design and manufacture of an internal welding machine for the new elliptical vacuum chambers, with remote-control facilities.

For the Group's own requirements, the Design and Projects Service made a 3-axis table (movements over 1400 × 1000 × 500 mm) for the laser welding set, a surface-plate adjustable at 3 points for the Quality Control Section, rail supporting frames for the LEP vacuum chamber cleaning machine; it designed and built a new pumping installation using the vacuum pumps salvaged after the dismantling of BEBC for the electron-beam welding machine and it improved the precision of the 3-axis table (Hamilton gun surround).

Sub-Contracting Section

This Section continued to work steadily in 1985 in its usual technological fields :

Mechanical engineering

- $\bar{A}A$, ACOL, L3 coil, DELPHI, ALEPH and UA2 projects: manufacture of components for vacuum chambers, special tanks and electrodes by spark erosion, large test scanning assemblies and the complete manufacture of pick-ups and kickers for ACOL.

Heat treatment

- Treatment of chambers and cavities in vacuo.

Bellows manufacture

- The sub-contractor is now engaged in the full manufacture of bellows.

Surface treatment

- Treatment of the LEP chambers and special coatings (copper plating, etc.); continued work on panels (silk-screen printing and anodization).

Printed circuits

- Sub-contracting of a large number of multi-layer and multi- wire circuits, large double-sided, metallized-hole and multi-layer circuits (with a considerable increase in demand), all for the DELPHI, OPAL, L3 and UA1 experiments.

Transport and Equipment Handling

Efforts towards rationalisation have resulted in a reversal of the noticeable trend in the past few years for the number of vehicles to increase considerably.

At the end of the year the vehicle fleet numbered 799, including 418 passenger cars, 102 utility vehicles, 25 lorries, 13 tractors, 26 trailers, 85 fork-lift trucks, 4 cranes, 12 cross-country vehicles, 12 items of civil engineering plant, 53 horticultural machines and 49 machines of various kinds for the Cleaning Section and the Fire Brigade.

The distance covered inside the Organization's grounds and in Europe by all registered vehicles has reached the impressive figure of 3 187 000 km.

The vehicle fleet also includes 240 mopeds and 338 machines specifically designed for handling equipment in the accelerator tunnels (tractors, trailers, bogies, etc.).

Studies conducted with the LEP Division installation groups and the experimental groups have resulted in making the fullest possible use of the existing fleet. It will be necessary only to make specific purchases of machines for the transport, handling and installation of the various components of the LEP machine and its experiments.

Whilst the entire fleet of vehicles and plant is maintained by the garage workshops of the Transport and Equipment Handling Group, some of the routine work is carried out under a servicing contract.

The Group provides transport for official meetings at CERN, conferences, visits and journeys off the sites; moves equipment over long and short distances on the sites or elsewhere; operates general services (refuse collection, the large number of removals resulting from staff transfers to the LEP Division, etc.); and moves all the equipment needed in all the assembly and experimental halls and in the machine tunnels.

The most important removals of equipment included:
- transport of equipment and assembly work for exhibitions in Hanover, Paris, Lund, Stockholm, Strasbourg and Trondheim;
- transport of LEP pre-injector structures and acceleration sections between CERN, Munich, Paris and CERN.

Special equipment-handling activities on the site included:
- handling work during the machine shutdowns in January, February and throughout the year, as scheduled;
- the dismantling of the ISR and BEBC;
- the assembly of the Neutrino experiment;
- further work on the installation of PS/LPI (LEP pre-injector);
- the start of LEP installation (SM 18, PM 15, Point 2);
- the regular beam modification programme (throughout the year);
- removals, for personnel seconded to LEP, from their existing Divisions and re-fitting of premises;
- removals for SB, EF, EP and PS Divisions.

Documentation Department

Introduction

In addition to furnishing the usual services to the CERN community, the Department continued its efforts to adapt the services to the evolving needs. Computer-based abilities have had a great impact in almost every area of the Department's work, resulting in greater efficiency, lower costs and reduced man-power. In the course of the year, for example, there were moves to implement computerized address lists CERN-wide, to introduce electronic mail on the NOTIS office automation system and to have all transactions in the printshop handled on a computer, also via the NOTIS system.

The Work of the Sections

The workload in the printshop dropped in the last months of the year, possibly related to budgetary restraints being experienced in the Divisions, and the output for the year was just over 50 million A4 pages. The only change in the printshop equipment was the replacement of a Xerox highspeed photocopier by a second Kodak 200 AF machine so as to benefit from lower tariffs.

Printshop production statistics had been held on computer in previous years and during 1985 the NOTIS system was used to prepare a straightforward method of billing all printshop transactions to the customers should this become Laboratory policy. The price of all the major documents which are printed can now be automatically compiled and indicated on the documents. Contact was made with external experts with a view to their participation in a study of the feasibility of passing responsibility for printshop operations to an outside concessionaire.

For the NOTIS system it was largely a year of consolidation rather than further development although an improved version of word processing was introduced and preparations for the introduction of electronic mail, linked to other systems on the CERN site, were well advanced. The number of terminals connected to the NOTIS computers continued to increase.

In the Library, space has become a major preoccupation and the less-used holdings were moved to enlarged basement storage areas. Much effort went into studying how a closed reference collection could be established which would only be accessible under the supervision of Library staff. The latest version of the ISIS computer system for Library holdings was installed; a new database to handle book acquisitions was implemented as well as a major update of the corporate authors database. Abridged cataloguing of books which had been acquired before the introduction of the ISIS system continued and preparations were made to implement a database of Conference information, working in collaboration with the European Physical Society. Following the introduction of the VM/CS operating system, studies are underway to implement ISIS under the system so that the interactive facilities of ISIS can be used from any terminal connected to the IBM.

Several collections of documents from long-standing members of CERN were made available to the CERN Archive and were inventoried in an abbreviated way so as to be of use to the Study Team for CERN History. The Team is writing up, on the basis of reports already produced, the first volume of the history which will cover the period from 1949 to 1954. This volume will be published towards the end of 1986.

The Translation and Minutes Section handled a wide variety of material and the workload was at a consistently high level with an ever larger number of pages being translated or drafted in English, French or German. The Section also embarked on a new venture in providing simultaneous interpretation at some internal CERN meetings. It is anticipated that this work will increase in the coming years.

The Scientific Reports Section had a particularly busy year since, in addition to the usual throughput of scientific papers, editorial work was required on the CERN Users Guide and many papers for LEAR, Collider Workshops and an Accelerator School Symposium. In the Publications Section the journal CERN COURIER reinforced its role as a major means of communication in the field of particle physics. World-wide circulation now exceeds 19000 copies. An improved presentation of the 'Images' in-house journal was well received.

The CERN Exhibition visited Scandinavian countries for the first time being present at the Tekniska Museet in Stockholm, the Norwegian Institute of Technology in Trondheim and the Ideon Research Park in Lund. Each of these exhibitions attracted many thousands of visitors and there were associated events such as lecture series, press conferences, visits by schools and teachers and contacts with industry. The CERN exhibition team was greatly helped by the collaboration of our Swedish and Norwegian colleagues. There were other more specialized exhibitions in the course of the year such as one presenting new LEP technologies at the SFP exhibition in Paris, and one in collaboration with AGF at the Hannover Fair. There were also smaller presentations at the ILO in Geneva and at Strasbourg.

A study of the implications of CERN-wide computerized address lists which can be accessed from the Mail Office expedition room resulted in the replacement of the antiquated Addressograph machine by modern machines which can print onto labels or directly onto envelopes or paper. The corresponding computer programs should be ready early in 1986.

The Documentation Department was disbanded at the end of 1985. The services provided by almost all its Sections had been transformed during the four years of existence of the Department and the throughput of work had increased by some 50% with less staff and with only modest increased budgetary requirements. The personnel of the Department deserve recognition for their considerable efforts to respond to the changing circumstances of the Laboratory.

Finance Department

Introduction

As in previous years, the construction of LEP and of the four large detectors around the collider determined the activity of the Finance Department as a whole. The problems posed by this important and complex project were further complicated by the economic situation both within the Organization and outside it. Without the increasing use of data processing and the dedication of staff at all levels, it would not have been possible, with current staffing levels and the budget allocated, to meet the needs of the service without a serious deterioration in quality.

Financial and Accounting Services

The exchange rates between various currencies and the Swiss franc were rather erratic during 1985 due to the considerable changes in the value of the US dollar. Table 1 below shows variations at certain dates.

Table 1 — Rates of exchange

	Rate as at 3.1.1985	*3.1.1985 %*	*1.3.1985 %*	*1.7.1985 %*	*2.9.1985 %*	*1.11.1985 %*	*30.12.1985 %*	*Highest*	*Lowest*
FRF	27.–	+ 3.52	+ 1.85	+ 1.85	– 0.19	– 0.19	+ 1.85	27.99	26.79
DEM	82.70	+ 3.50	+ 1.39	+ 1.33	– 0.37	– 0.73	+ 1.93	85.69	81.66
ITL	0.13525	+ 1.66	– 2.96	– 2.96	– 8.88	– 10.36	– 8.84	0.1390	0.1206
GBP	2.995	+ 3.–	+ 7.68	+ 11.01	+ 7.34	+ 2.33	+ 0.50	3.3937	2.96
ATS	11.77	+ 3.65	+ 1.36	+ 1.36	– 0.51	– 0.77	+ 1.78	12.20	11.61
BEF	4.13	+ 2.90	+ 0.73	+ 0.73	– 1.46	– 1.94	– 0.25	4.2670	4.0179
DKK	23.15	+ 3.45	+ 0.21	+ 1.08	– 2.16	– 2.16	–	23.95	22.45
NOK	28.65	+ 4.18	+ 1.55	+ 1.39	– 2.45	– 4.54	– 4.02	29.89	27.24
SEK	29.05	+ 4.13	– 0.35	– 0.20	– 4.48	– 5.86	– 5.51	30.13	27.25
NLG	73.30	+ 3.41	+ 1.09	+ 1.29	– 0.28	– 0.69	+ 2.04	75.84	72.54
GRD	2.0310	+ 0.05	– 7.78	– 7.59	– 14.87	– 31.42	– 30.93	2.0330	1.3920
USD	2.625	+ 8.95	+ 0.19	– 3.43	– 11.43	– 18.29	– 20.–	2.9295	2.0843

The treasury position of the Organization was satisfactory during the year as most Member States paid their contributions earlier than in 1984.

The rates of interest available on the Swiss money market went up during the first half of the year due to increased rates in the USA and decreased during the period July/December. The favourable cash position and the higher interest rates available on the Swiss franc and other currencies enabled the Organization to increase considerably the amount of income received as shown under 'Income' in this report.

As shown in Table 2, on 31 December, the contributions outstanding amounted to 4.6 million Swiss francs, including a balance for 1984 from one Member State.

Table 2 — Contributions outstanding on 31.12.1985

Member States	*Swiss francs*
Belgium Greece Spain	255'089.14 3'079'258.03 1'290'781.–
Total	4'625'128.17

Income	*Accounts (millions of Swiss francs)*
Contributions from Member States	717.83
Interest	13.02
Unused provisions + miscellaneous	0.50
Compensatory income	14.18
Supplementary income for $p\bar{p}$ improvement project and loan from FIPOI	19.38
	764.91
Expenditure	758.03

Excess income amounted to 6.88 MCHF (764.91 - 758.03).

6.83 MCHF were transferred to the Special Reserve Account, and an amount of 0.05 MCHF was carried forward to 1986.

Visiting Teams

The number of visiting teams' accounts increased to 400 in 1985. On 31 December, the total invoiced was approximately 30 million Swiss francs.

LEP Experiments

Experiments at the LEP accelerator will be undertaken by four collaborations known as the ALEPH, DELPHI, L3 and OPAL collaborations. They are very large, involving about 200 physicists on each experiment and a similar number of technical staff coming from almost every Member State and also from some ten non-Member States.

Accounts were opened in 1984 for the Common Fund items of ALEPH, DELPHI and OPAL.

On 31 December 1985, commitments, payments and balances available were as follows (in millions of Swiss francs):

	Commitments	*Payments*	*Balance of funds available*
ALEPH	15.248	9.483	2.970
DELPHI	9.295	4.214	4.806
OPAL	7.931	2.959	5.967

Purchasing Service

The Purchasing Service benefited greatly from the introduction of COPICS, a data processing system for orders and other similar documents (particularly release orders). Thanks to COPICS, it was possible to place more emphasis than in the past on professionally important matters.

In 1985, 137 calls for tender were issued for contracts estimated to amount to more than 200000 Swiss francs. This represented an increase of 44% compared to 1984, a year when the number of calls for tender had already reached an unprecedented level. Similarly, the number of price enquiries for contracts of lower amounts rose from 1912 last year to 2047 in 1985. The number of contracts increased from 100 in 1984 to 114 in 1985, whereas the overall number of orders during the same period increased from 27324 to 29435. The Invoice Office dealt with 64698 related documents in 1985, compared to 63254 in 1984.

Overall the activities described here were carried out without prejudicing enquiries to potential suppliers. In this area, contacts established as a result of efforts made over the last ten years were maintained and developed. They allow the Service to have a relatively up-to-date knowledge of the production capacities available in the various Member States of the Organization.

The development of products and methods, technological research and innovations necessitate constant reappraisals of the technical aspects of the contracts. This is one of the reasons which led, in 1985, to the organization of 76 technical presentations on the CERN site. They enabled 109 firms from 11 Member States to demonstrate the products that they considered essential in their relations with the Organization.

Apart from these presentations which rarely lasted more than a day, exhibitions at CERN held from Tuesdays to Fridays allowed CERN scientists and technicians to acquaint themselves with the products of 11 Norwegian, 26 Austrian and 39 Italian companies. These meetings enabled all those interested to meet and many useful contacts were established. They proved to be all the more fruitful as the exhibitions took place at the same time as conferences or colloquiums enabling the specialists to benefit from each other's knowledge and gain a clearer picture of their own needs.

Stores Service

Various special customs and tax procedures were negotiated. In particular:

- A tax procedure concerning the delivery of goods intended for the part of LEP on Swiss territory.
- A procedure for temporary imports of CERN equipment into the United Kingdom and Italy.

The transport of magnet modules from the USSR for the DELPHI and L3 experiments were studied and the first deliveries took place.

Gas quality control, carried out by the Technical Section, became fully operational.

The Recuperation Service continued to be very busy, with a greater workload than usual owing to the dismantling of the BEBC.

During the year:

- The total value of issues of standardized equipment was 29.7 million Swiss francs, an increase of 5.7% over 1984.
- The value of items issued via the three self-service points represented 8.7% of total issues.
- The annual central stores turnover rate was 2.3.
- The stores value (central and self-service) varied between −0.8% and +14% of the authorized limit of 13.6 million Swiss francs, whilst the average level was 10% above the authorized stores limit.
- Delivery of 52120 items was taken and 9933 despatches of goods were carried out for the Organization as a whole.
- There were 12045 release orders and orders for standardized items.
- 250345 requests for equipment were processed and met from central stores.
- As a result of decisions taken by the Standardization Groups, 769 in all, 259 new items were stocked and 510 articles were declared obsolete; 135 of these with a value of 71 950 Swiss francs were transferred to the Recuperation Service.
- The Quality Control Service checked the conformity of 1631 deliveries (6.8% of the articles ordered worth approximately 5.6 million Swiss francs).
- The Recuperation Service sold equipment outside the Organization for approximately 2.6 million Swiss francs (including 4796 tonnes of scrap metal and 236 tonnes of scrap paper).

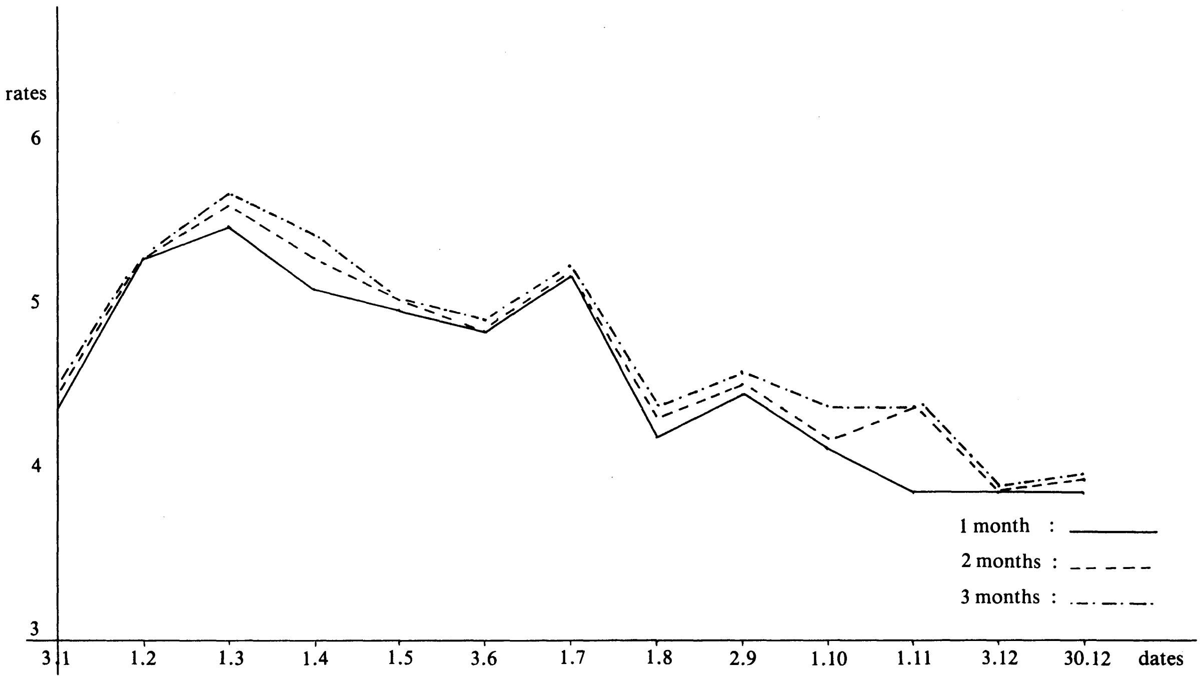


Figure 1 — Development of the expenditure of the Organization

Expenditure 1985

(in thousands of Swiss francs)

Budget headings and sub-headings	Expenditure 1985	Directorate-General and CIS	Research Directorate	Technical Directorate	LEP Project	Administration and TIS
TOTALS	**758032**	**33093**	**185880**	**280154**	**193651**	**65254**
1. Personnel	**360074**	**26641**	**108363**	**133721**	**42835**	**48514**
10) Staff members	337461	5864	107736	133610	42656	47595
14) Fellows	11580	11282	232	43	23	–
15) Research associates	11033	9495	395	68	156	919
2. Maintenance, general expenses and consumable items	**162875**	**6373**	**33153**	**99604**	**8690**	**15055**
20) Site and buildings	16803	15	1639	14374	500	275
21) Service equipment	18087	153	2309	10862	1673	3090
22) Equipment for accelerators and beams	27318	–	709	25104	1461	44
23) Experimental equipment	7790	–	7484	181	108	17
25) Data handling equipment	15450	49	12988	346	898	1169
27) Power and water	45905	–	–	45905	–	–
28) Administration/Consultants	24397	5818	4746	1629	2119	10085
29) Travel	7125	338	3278	1203	1931	375
3. Capital outlays	**235083**	**79**	**44364**	**46829**	**142126**	**1685**
30) Site and buildings	87029	–	5'564	11'100	70190	175
31) Service equipment	15088	21	3381	3640	7129	917
32) Equipment for accelerators and beams	94078	–	1773	31869	60436	–
33) Experimental equipment	21184	–	21062	–	122	–
35) Data handling equipment	17704	58	12584	220	4249	593

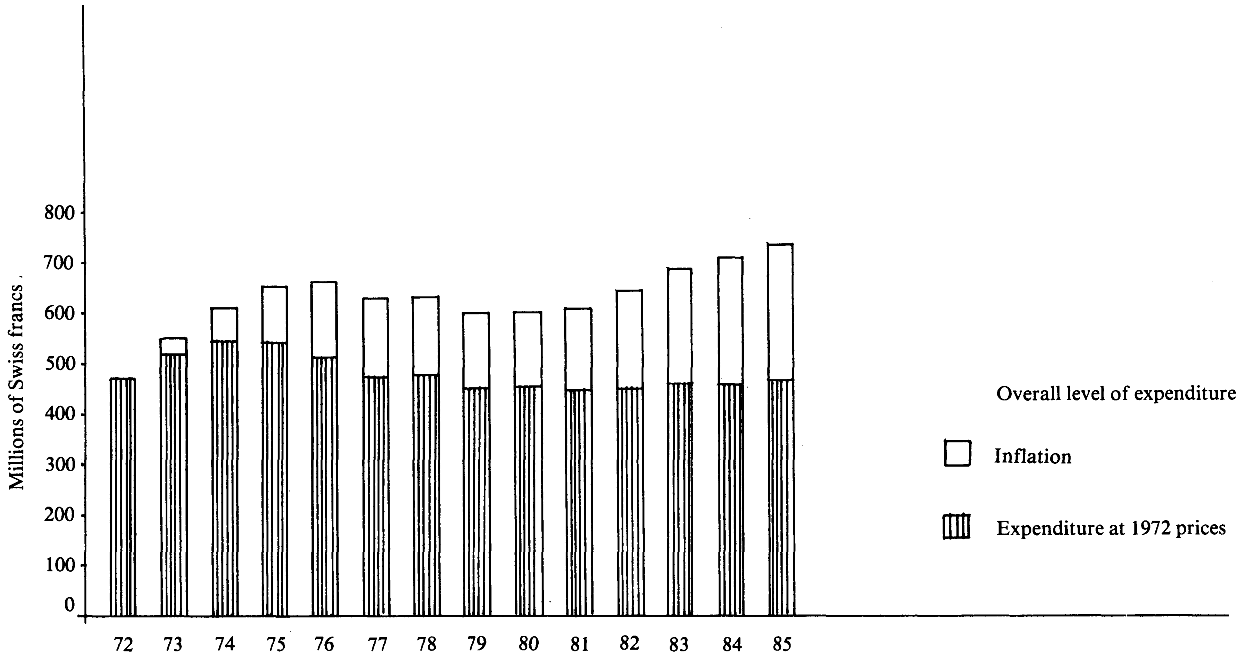


Figure 2 – Rates of interest 1985

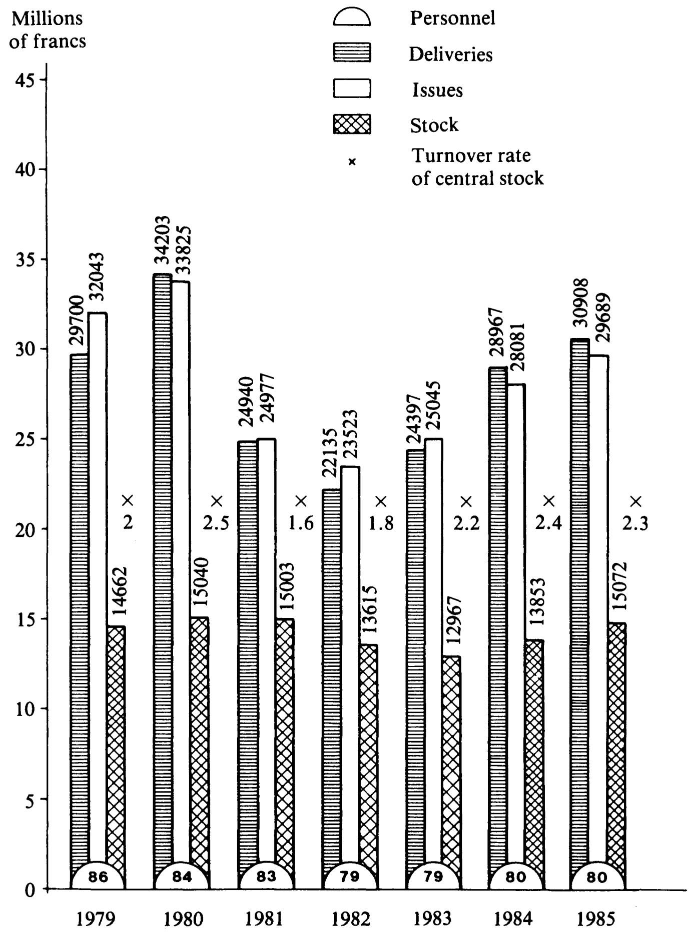


Figure 3 — Development of stock movements since 1979

Management Information Department

The industrial support co-ordinator took a number of steps which resulted in the re-negotiation of a large number of contracts with a view to curbing the inflation caused by the annual application of the price indices, in the award of industrial design contracts to local firms, and in the organization of seminars to provide information for the staff.

Forecasts and Statistics Group

This Group is responsible for preparing and publishing the Organization's budget documents (annual and long-term budgets) including those relating to the cost variation calculations. It also took part in the work of the informal group set up at the request of the Finance Committee to study budget documents and procedures.

At the central level, the Group is responsible for monitoring the authorized operations budgets and publishing a graphic management report, as well as for various special studies on a range of matters including contributions from the Member States, forecasts of personnel costs (including costs relating to the Pension Fund), and cost variations. Another of the Group's tasks is the co-ordination of management information users; in this respect the Group played a particularly active part in setting up the IFIS project (Interactive Financial Interrogation system, for LEP) and in developing the new financial data-base.

Data-Processing Group

As was agreed, this Group implemented the personnel management software package as from 1 April 1985. On the basis of EP Division's experience with this product and especially with leave control, a working group gave a list of recommendations with a view to adopting this system in the divisional secretariats. The 'Salaries' application was further developed and will be completed in 1986.

The Organization's financial data-base was set up. The user community has access to the data via inquiry systems that were developed in 1985 for use by financial Services and Divisional administrators. A detailed users' manual was published. In addition, two sessions were organized to provide users with information and practical experience, thus familiarizing them with these new products.

The computerized management system of the Purchasing Service, which was developed in close co-operation with the latter, is now fully operational. The Group also set up a system of retrieving and transferring, via the INDEX network, data required for the financial monitoring of the LEP project.

In addition, acquisition of an intelligent concentrator has made it possible to make access by terminal to the administrative data-processing centre, via the INDEX network, available to all users.

Technical Support Group

With respect to management of the industrial support office, for which this Service is responsible, the workload remained at last year's level as regards both contract monitoring and data entry of weekly reports.

With regard to personnel movements, which are monitored by the Group, the regular provision of data by PE and the Divisions made possible short-term personnel cost forecasts.

The personnel cost forecast model developed in 1984 was used to prepare the profile of estimated personnel expenditure over the next fifteen years, which was presented to the Council in June 1985.

This year saw the entry into operation of a computerized system, defined, implemented and operated by this Group, for the supervision of signature rights. In the context of its efforts to improve the level of information available to the personnel, the Service compiled the first section of the Supervisor's manual, which will be issued soon.

Personnel Department

Recruitment

Some 2400 employment applications were received and processed and some 300 candidates were invited to 80 selection boards. 61 candidates were selected for appointment; their average age was 28 years. The nationality distribution was as follows : Austria (1), Belgium (4), Denmark (2), France (20), Great Britain (11), Italy (8), Federal Republic of Germany (3), the Netherlands (2), Norway (1), Spain (5), Sweden (1), Switzerland (2), non-Member States (1).

Staff Review

306 posts were examined, of which 136 were classified at the next higher grade, and the Change of Category Committee for Senior Technical and Administrative Assistants approved 5 of the 11 cases submitted. There were 26 appeals concerning classification and non-promotion, following which one promotion was granted and in another 7 cases the posts were classified at the next higher grade.

Consultative Committee on Employment Conditions ('CCEC')

Members of Personnel Department made significant contributions to the preparation of the report by this tripartite body on the review of CERN salaries, which was the principal topic of its meetings during 1985. They also participated in the preparation of CCEC documents concerning the CERN salary index award for 1986, the Education Grant and the review of the Staff Rules and Regulations. At the end of the year CCEC was confirmed as a Standing Committee by Council.

Social Work

In addition to its normal work of helping members of the personnel and their families with personal problems the Section collaborated in matters of social integration, especially concerning residence and work authorisations, and social security. It participated in a working group on alcohol abuse which produced recommendations for a policy on this subject, shortly to be introduced. In the field of health care, the Section prepared a new procedure for handling applications for cures following professional accidents or illnesses.

Staff Policy

Under the Early Departure Scheme, 25 members of the personnel left the Organization during 1985 before reaching the compulsory retirement age. In the next few years some 30-40 staff per year are expected to leave under this scheme.

In agreement with the Standing Concertation Committee, it was decided to introduce a formal programme of periodic review discussions between supervisors and their staff, with a series of training courses beginning in 1986. Among the many other topics considered by the Standing Concertation Committee were the conditions for staff who perform stand-by duty, and senior staff promotion procedures.

Fellows, Associates and Students

These programmes were the subject of a report to Council reviewing their development in the period 1980-1984 and proposing some modifications for the five years to come. Council agreed that, within a constant budget level, higher priority should be given to the Fellowship programme (the number of Fellowships increasing from 135 in 1985 to 148 in 1987) at the expense of a reduction in the Member States' and non-Member States' Associates programmes. Council also agreed to strengthen the Technical Student programme. In the framework of this programme an agreement was reached with the French authorities to appoint French engineers under the Service National de la Coopération scheme at CERN and the first four engineers arrived in 1985. Unpaid Associates' registrations continued to increase, reaching 3700 by the year-end.

Training

Technical Training

The technical seminars of several full days' duration which were introduced last year proved to fill a real need. The response of the staff was so great that the number of seminars had to be increased. A growing fraction of the participants are engineers and applied physicists (60 out of 430).

Management Training and Personal Skills Development

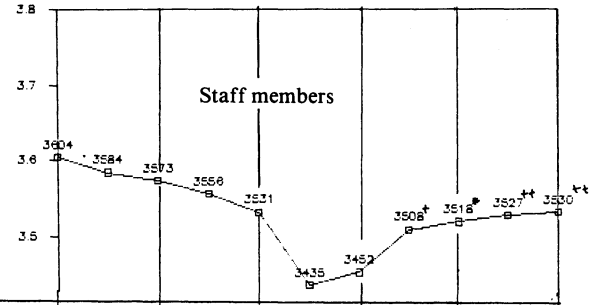
There is a continuous increase in the number of requests for enrolment into the management training and personal skills development programme and more seminars had to be organized. 181 days of training could be offered in academic year 1984/85, compared to 100 in 1983/84. Of the 367 staff members who attended them 188 were enrolled in supervisory courses, 95 in personal skills development seminars and 84 in courses for secretaries.

Other programmes

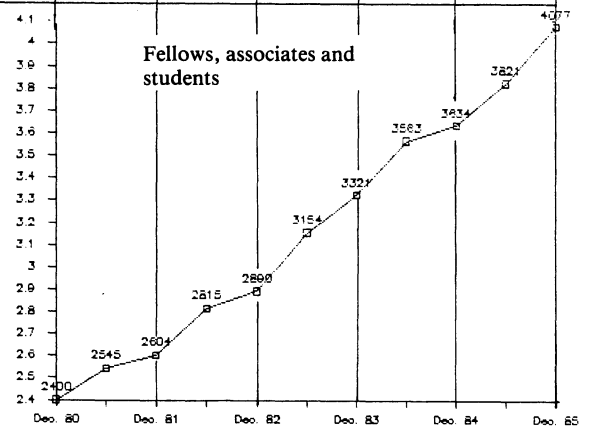
The Language and Acadamic Training programmes continued as in previous years or increased slightly. In total 9846 man-days of training were administered in academic year 1984/85, compared to 8596 in 1983/84 and 6889 in 1980/81.

Restaurants Supervisory Committee

The availability of nourishing meals at reasonable cost has continued to receive the attention it deserves. A dietician employed at a local hospital was appointed to inspect the kitchens of the three restaurants regularly and advise the concessionnaires on such matters as the composition of balanced meals. Preparations for a call for offers for the operation of all three restaurants have progressed well and it is hoped that the new contracts will come into force at the beginning of 1987.



SM arr.	+ 46	+ 41	+ 78	+ 108	+ 59
SM dep.	- 77	- 83	- 157	- 42	- 47



* excluding 32 ACOL project recruits
++ excluding 33 ACOL project recruits
\+ excluding 7 ACOL project recruits

Figure 1—Monthly totals of Fellows, Associates and students with a CERN contract in 1983, 1984 and 1985.

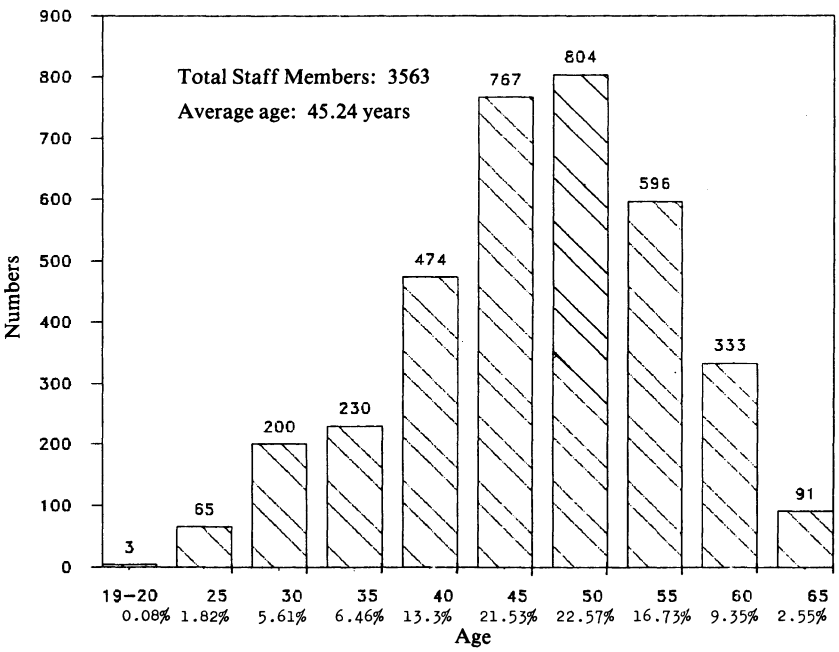


Figure 2—Staff members by age group, as at end 1985.

Technical Inspection and Safety Commission

General Safety and Electricity Group

Electricity and electrical installations

Electrical safety code C1 was supplemented this year by the publication of appendices dealing with special subjects (emergency stops, electronic laboratories and test rigs).

Safety bulletins were also issued to draw attention to points which have caused incidents or accidents (rack fans, connectors). The other controls and inspections at the various stages of projects and installations have continued, especially for LEP, while training campaigns have been conducted and preventive inspections made of existing installations. A special effort was made in the field of electricity to highlight technical safety matters. A very great deal of attention will also have to be paid to this field in future owing to the increasing number of visitors involved in the assembly of the LEP experiments.

It is intended to intensify this work in the future with the aid of acquired computer data.

General Safety

LEP experiments

In the four LEP experiments stress has of course been laid on safety, which is handled together with the members of various collaborations. The final touches are put to safety matters at specific CERN meetings, which have been marked by excellent communication between the different Groups of the TIS Commision and the four experiments.

Periodic safety inspections

Safety inspections performed on all the sites with safety officers and co-ordinators and analyses of accidents have again proved their worth by revealing various hazards. Safety bulletins, notes and instructions have been drawn up on the basis of the information obtained from these inspections and analyses. However, the effects of staff shortages are increasingly being felt, particularly on account of continuous site expansion.

Publications

The General Safety and Electricity Group has published safety instructions relating to electrical hazards and also a number of safety notes, especially one drawn up in collaboration with the Medical Service concerning display screens. Safety bulletins have dealt with the use of overhead travelling cranes, electrical rack fans and protective helmets. The Group also took part in the preparation of documents concerning the hazards involved in the use of certain plastic components of electric cables and other equipment.

A working group examined the CERN's basic safety document, 'SAPOCO 42'. The examination revealed the differences between the present situation and that described in the document, and its results have been sent to SAPOCO to help in an overall review of the document.

Working environment, work station ergonomics

The TIS ergonomics service has, jointly with the Medical Service, helped in making noise measurements and has put forward proposals for dealing with several instances of noise pollution.

Heat conditions have been improved in some air-conditioning installations and power savings have been made while maintaining a comfortable environment.

The equipment available to us has made it possible to check vibration levels in some installations.

We have introduced a new type of safety helmet with adaptable lighting for the use of those required to enter the tunnels or work sites.

The 805 visits by patients to the infirmary included 269 reported accidents, distributed as follows:

Table 1 — Statistics for known accidents at CERN for the period from 1.11.84 to 31.10.85

Number of accidents reported	*Total number of accidents involving absence from work*	*Total number of days lost*
214 for CERN and equivalent personnel (including 34 occurring on journeys to and from work) 55 for contractors' personnel (including 4 occurring on journeys to and from work)	79 for CERN and equivalent personnel (including 21 occurring on journeys to and from work) 29 for contractors' personnel (including 2 occurring on journeys to and from work)	1643 for CERN and equivalent personnel (including 604 occurring on journeys to and from work) 237 for contractors' personnel (including 11 occurring on journeys to and from work)
269 (38)	108 (23)	1880 (615)

Figures in brackets refer to accidents occurring on journeys to and from work.

Rescue and Fire Service

Organisation

The broad lines of the programme of emergency rescue defined in 1983 were continued, i.e.:

- with the ordering and delivery of equipment suitable for the new requirements, mainly the fitting on a lorry chassis of a rescue unit for LEP's deepest shafts (-150 m) for bringing a seriously injured person back to the surface in complete safety;
- training for staff, especially leading firemen, aimed at obtaining the ambulance-man's certificate issued by the Centre Fernand Martignoni in Lausanne and at technical courses for one fireman per duty shift in (1) the maintenance and inspection of the 3500 fire extinguishers on the sites and (2) the maintenance and reconditioning of the self-contained breathing apparatuses in use at CERN.
- very close collaboration with the professional and volunteer emergency services in the Host Countries has very perceptibly improved the quality and coordination of rescue work through effective mutual assistance. The services concerned include the Geneva Fire and Rescue Service, the Airport Safety Service, the Meyrin First-Aid Association, the 'SMUR' (Service Mobile d'Urgences et de Réanimation = Mobile Emergency and Resuscitation Service) of the St. Julien hospital, the emergency service of the La Tour hospital, the Civil Defence air-base at Annecy and the Departmental Fire Services of the Ain;
- the programme of monthly visits to the LEP shafts together with the local rescue services was carried out according to schedule.

Emergency Action

Clarification of the firemen's duties continued. The control and customs post at the tunnel has been taken over by a company under contract and the last guard duties performed by the firemen at the entrance to the Prévessin site are due to end during 1986.

The firemen's equipment has been centralised and their availability for emergency action increased, with a staff held constant at 12 firemen on shift duty 24 hours a day throughout the year, in order to meet the new requirements brought about by the LEP work site and the large distances to be covered in extreme cases.

The overall breakdown of actions is given below :

	1983	1984	1985
Fire alarms (false or otherwise)	362	425	482
Fires	23	25	17
Ambulance calls: CERN	174	228	240
Host countries	134	190	177
Gas alarms	95	125	145
Miscellaneous alarms	43	72	61
Pumping out leaks of water or miscellaneous liquids	134	143	158
Lift alarms	29	43	30
Persons trapped in lifts	47	38	23
Misc. technical assistance	172	203	193
	1190	1488	1526

Fire Prevention Service

Progress with the LEP project meant that this Service was required to take a considerable part in drawing up a wide variety of opinions and experts' reports which were often wanted at very short notice.

Close collaboration with the General Safety Group is essential to periodic inspections. The Service's work can be summarized to a certain extent by the figures given below:

Safety inspections of buildings	145	
Acceptance tests for technical installation	14	fire detection
	5	gas detection
Examinations of drawings (sites 1 and 2)	21	
Examinations of LEP drawings	480	
Evacuation drills	4	
Smoke-removal tests	11	
Miscellaneous tests	14	
Safety instruction sessions (essentially for LEP)	33	
Technical demonstrations	13	

Four specific tasks were completed this year, viz:

1) The running of LEP safety information sessions for all future users, both certain CERN staff and contractors' personnel.

2) In view of the lengthy times needed before assistance can be given at distant LEP points, the specification of the number of people working on the spot and trained as auxiliary firemen for immediate action in the event of damage and accidents.

3) The drawing up of an official agreement formalising the action by the French and CERN emergency services in each other's support.

4) Work on a similar agreement with the Republic and Canton of Geneva is in hand.

Flammable Gases and Chemistry Group

General

The Chemical Safety Code was accepted by SAPOCO and was put into force by the Director-General. Safety Notes have been written on the use of non-metallic materials in underground areas as well as a guide to national and international regulations and test procedures on fire hazards.

The physics and engineering groups have continued to request help in using potentially hazardous materials such as diethylaniline, sulphurhexa fluoride, trichloroethylene, lead, silica, epoxy resins and many solvants.

The waste disposal service offered by the group continued to expand with the dispatch, for recuperation or neutralisation, of 150 tons of aqueous solutions of acids, bases, photographic solutions etc., 30 tons of sol vents, 15 tons of waste oils, 190 tons of oil/water mixtures and about 6 tons of various wastes such as asbestos, resins and divers chemicals. Silver continued to be recovered from photographic fixing solutions collected on the site.

Plastics

Analyses and fire tests on electrical cables and other items containing non-metallic parts (mainly plastics) were carried out at CERN or were arranged at laboratories in the Member States. Based on the results, advice was given to LEP users, particularly experimental groups on the suitability of such materials.

To aid such work a conference on this subject was arranged with experts from London Transport and Rubber and Plastics Research Association of Great Britain.

Environmental Monitoring

The quality of the water discharged to local rivers continued to be monitored and regular visits were paid to the rivers to ensure that they remain in good condition. Cooperation with the LEP Division was maintained and several inspections and enquiries were carried out.

On the LEP ring the two monitoring stations for ozone and oxides of nitrogen continued to run and had to be maintained.

Personnel Monitoring against Chemical Hazards

The effort in this field continued to be considerable and some of the important monitoring work included:

- Silica in resin filling operation
- Lead in soldering work
- Trichlorothylene in vacuum pump cleaning
- Perchloroethylene in vacuum tube cleaning

- Toluene in magnet painting operations
- Ozone in a cable testing installation.

Gas Safety

Inspections were made of many experimental test stations where inflammable gases are used. Advice was given on many aspects of gas safety but especially on detection and analysis of gases, and the safe ventilation of installations.

Training

A course on gas technology and safety was arranged for technicians at the request of several users. Talks were given at seminars in Switzerland at official meetings, on aspects of industrial hygiene and flammable gas detection.

The group contined to participate in the Safety Briefings organized monthly for Newcomers to CERN.

Mechanical Engineering Group

This Group's workload increased substantially in 1985.

Technical assistance for the accelerator and experimental programmes has been maintained at a satisfactory level of efficiency owing to the spirit of collaboration shown by the staff of the TIS/MC Group and of the other Divisions at all levels.

The forms taken by this assistance included:

- advice on safety, the correctness of a design and the reliability and economics of new equipment at the stages of design and the drawing up of the specifications;
- inspection during manufacture and acceptance testing;
- periodic inspection and testing of existing equipment;
- training and qualification of staff in the use of hoisting gear.

The Group has often been called upon to provide verbal advice and instructions on equipment during its design and has drawn up about 200 design study reports on new projects or major alterations to existing equipment. Most of the evaluation studies dealt with pressure or vacuum vessels, cryostats, hoisting gear, electro-mechanically operated heavy plant, monorails and other transport and installation equipment.

A great deal of the equipment for the LEP machine and experiments is now being built and work sites have been opened for the ancillary facilities.

A large number of items of equipment has been inspected and tested both at CERN and at the manufacturers' premises. This work has included in particular the acceptance inspections of the superconducting magnet for DELPHI, the definition of control and inspection procedures with the manufacturers and the monitoring of the manufacture of the ALEPH cryostat, the OPAL central detector and the handling and transport system for the L3 solenoid coils.

The components of a test tank for applying overpressure to the outside of vacuum containers were acceptance-tested and the installation, now being assembled, will be available during the first half of 1986.

The table shows the number of periodic inspections performed at CERN. This workload becomes heavier every year owing to the increasing complexity of the Laboratory's work and equipment.

In the field of training, the Mechanical Engineering Group organised a series of courses, run by the Host Countries, on the use of overhead travelling cranes. The courses had become necessary following a number of incidents with hoisting gear. They were taken by 280 members of CERN's personnel and 120 people from industrial support firms.

Table 2—Number of routine inspections and tests carried out in 1985

Large lifting equipment (cranes, etc.)	578
Small lifting equipment (winches, hoists, etc.)	809
Large lifting accessories	1252
Small lifting accessories	18302
Lifts	318
Other means of transport	260
Automatically closing doors	185
Industrial pressure vessels	492
Experimental pressure vessels	340
Safety valves	2563
Chimneys	10
Radiographic inspections	173
Welders' examinations	43

Medical Service

Work continued in 1985 to maintain a high-grade occupational medical service within the Organization. Several items deserve mention, although it should not be forgotten that problems are arising which pose a serious threat to the policy so far pursued.

In the field of *regulations,* CERN's Medical Code has been drawn up and examined by the various authorities concerned. It has been submitted to the Organization's joint bodies for approval. It constitutes an updated specification and is designed to fit occupational medicine better into the Laboratory's daily life.

The clinical *medical examinations* and a large number of laboratory and paramedical tests performed by the Medical Service together with medical experts and laboratories outside the Organization have been continued with the limited means available to the service.

The 2200 clinical examinations, 3800 blood tests, 5900 biological analyses, 900 audiograms, 400 electro-cardiograms, 900 sight tests and 700 X-ray examinations of the thorax and skeleton form a vital source of information for the medical officers who are required to assess whether those dealt with by the Service are medically fit for work.

Several cases of serious illness (not necessarily linked to working conditions) were discovered during the year.

An important step in our *epidemiological* work is the *computerization* of all our results. Our extensive databases have once again been greatly supplemented by further information. This work involves a high proportion of the Service's staff and colleagues from neighbouring services. By the end of 1985, the Service held information on over 21000 people and the database represents more than 220000 records, some of them in the archives, some active. In addition, the Medical Service handles 7000 conventional active records, not to mention about 9000 in the archives.

First aid to the victims of illness and accidents was rendered as in the past. The infirmary recorded 805 cases of accidents occurring on the site, 107 of them serious (fractures, electric shock, etc.).

The Service took an active part in developing first aid procedures in the context of the construction of LEP. First aid instructors from the Fire Brigade gave initial courses to personnel from the LEP/IM Group.

Visits to work stations were continued. The visits made, about a hundred, gave a better insight into problems linked to industrial hygiene and working conditions. The excellent co-operation provided for many years by the general and chemical work safety groups must be stressed here.

Links with the outside medical world were maintained as far as possible. There have been numerous exchanges of correspondence with doctors and hospital departments, participation in medical information sessions over the lunch hour (once a week at the La Tour hospital), and participation in the work of the Swiss medical commission on rescue and first aid and that of the working group for industrial first aid training.

Radiation Protection Group

Radiation protection activities continued to increase throughout 1985 despite the shutting down of the ISR, which was more than offset by the growing work for the LEP project (described in the LEP annual report). The preparation and discussions with the authorities of the Host States concerning reports and procedures connected for example with the authorization for LEP to function as a French 'Installation nucléaire de base' and the handling and inspection of nuclear materials, which are more and more used for large detectors, required such additional administrative and technical work.

Radiation Control of Accelerators

In addition to taking care of the routine radiation safety problems, the RP Group was actively involved in the many projects going on in the PS Division. These projects included making measurements to justify improvements in the interlock system, the shielding and displacement of the old Linac, and the design and testing of a new beam dump, as well as testing internal dump targets. Progress was made in installing the infrastructure necessary for ACOL with AA working at record intensities, which required that the whole work site be declared a radiation area and kept under close control. The section was involved in the ACOL programme where precautions for the ACOL target area will be to some extent dictated by experience gained when two heavy metal targets melted while being tested in the AA target area. The RP-PS section supervised the clean-up and investigated the consequences and implications of these incidents for the design of experimental target stations.

Radiation was also produced for the first time in LIL. Tests with the electron guns required improvisation to assure adequate radiation safety with minimum disturbance to the LIL/EPA installation programme. Many minor points related to radiation safety in LIL/EPA were investigated and the recommendations given incorporated into the layout.

At the SPS during fixed target physics the Group was mainly involved in coping with the changing situation in the West Area with its many test beams and the high intensities of secondary beams in the North Area EHN1 and primary beams in NAHIF. During colliding beam experiments the help of the Group was required to control unwanted beam losses upstream of the UA experiments. Also, work in the radiation controlled areas of the assembly hall at the SPS site occupied much of the RP-SPS section. With the aging of the machine and the more complicated SPS operations, the need for modifications and tests on activated components increased considerably.

Site Surveillance and Control

During 1985 two new storage facilities for radioactive material became available: in the RP storage area in the centre of the PS ring, building 225 with a surface of 400 m^2 was put into use for the storage of radioactive items for reuse, while for the storage of radioactive scrap tunnel TT7 was made available. The construction of a new shielded storage building on the Prévessin site started at the end of the year. Much work went into the control of the use of depleted uranium. An area to assemble uranium modules was installed in the RP building 573. Radioactive waste (1.5 m^3) was eliminated this year for the first time via ANDRA, France. Research activities were carried out mainly in the field of thermoluminescence (TL) detectors to study in particular the fading and annealing properties of various TL materials, and at the SC the Group participated in the production of ^{18}F for medical research in the Cantonal Hospital. The radiation control around the SC was mainly determined by the ISOLDE operation and its related problems, such as for example transport of radioactive samples outside CERN. The number of radioactive sources remained constant at about 1300 sources, requiring a large number of inspections and the replacement of old sources.

Environmental Monitoring

Radiation levels at the CERN boundaries remained below the reference values laid down in the CERN Radiation Protection Policy statement ($<$ 1.5 mSv at the CERN fences), except in one location, where a yearly dose just reached the reference values, within the error limit. The authorities were informed by quarterly reports of all environmental radioactivity found in samples on the site, the activity released, and the doses measured at the fences. The measurements to determine the preoperational levels on the future LEP site continued. By the time LEP starts its operation, more than four years of records of radiation measurements on the LEP site will be available, also showing the natural fluctuations of these radiation levels.

Personnel Monitoring

A new data handling system for the film-badge service was introduced in the first half of 1985. After the usual teething troubles direct access to personal dosimetry information contained in the database became possible, but improvements to the system are still needed and are under way.

Due to the reduced fading of the nuclear emulsion sealed under N_2 it became possible to increase the wearing period for personnel dosimeters from one to two months for EP and LEP Divisions in view of the small radiation risk for persons working in experimental areas.

The detectors presently in use at CERN were investigated with respect to their ability to cope with the radiation environment of LEP and with new dosimetric quantities proposed by ICRU. Tests with new detectors continued in order to find a possible replacement for the NTA emulsion in the field of hadron personnel monitoring.

Technical support

Work continued to replace electronics for radiation monitors and other RP equipment as far as funds would allow.

Development activities were concentrated on the LEP radiation protection system. The RP control equipment to be developed for LEP will, however, also eventually replace the data loggers now in use at PS, SPS and for site monitoring.

The UTINET LAN was extended to link more RP measuring equipment to the central data acquisition system and to allow for more terminals to be connected for text processing and/or database interrogation. The storage space was considerably increased by the installation of a 140 Mbyte Winchester disc.

General Activities

The work on testing the radiation resistivity of many different types of materials and on the development of reliable high-level dosimeters continued. A collaboration with the Istituto Superiore di Sanità in Rome was initiated to investigate the application of various types of dosimeters, collaboration with industry. RP staff were consulted on material and dosimeter matters and participated in international working groups.

In many other fields, such as personnel dosimetry, radioactive waste disposal, training, environmental protection, non-ionizing radiation, and TLD, members of the RP Group were actively engaged in national and international working groups.

International collaboration to develop Monte Carlo simulation codes for hadron cascades continued. The Group participated in the CERN Radiation Protection Committee and in discussions with Host State authorities concerning CERN radiation protection, CERN as a French 'Installation Nucléaire de Base', the control of nuclear material, and the disposal of radioactive waste.

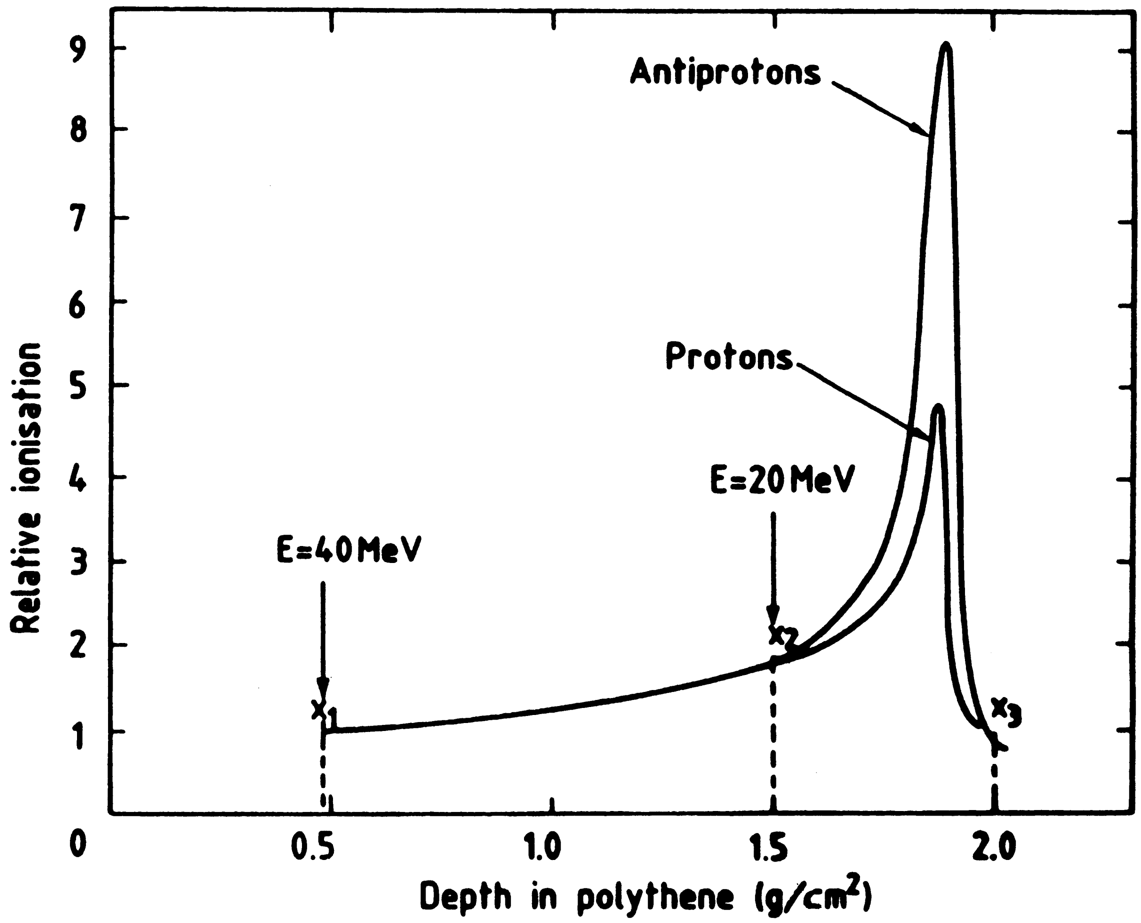


Figure 1 — With the advent of antiproton machines, and the availability of antiprotons for research, there is interest in possible biological effects of antiproton annihilations. A comparison made in the dump line for LEAR, of the depth dose curve in a low energy antiproton beam with that of protons of the same energy, shows that the energy deposited by antiprotons is only about twice that of protons.

Services of the Director-General

The Services of the Director-General consist of the following units:
- Council Secretariat
- Public Relations
- Internal Audit
- Legal Service
- Relations with the Host States

Council Secretariat

During the year, the Council Secretariat made the practical arrangements for 17 Committee Meetings and 2 Council Sessions (4 meetings). Between 1 January and 31 December 1985, the Service co-ordinated the preparation and distribution of 203 English, 162 French, 70 German and 18 bilingual documents.

The Secretariat also made the necessary arrangements for four Restricted and two Plenary Meetings of ECFA and prepared the relevant documents.

Public Relations

The Public Relations Service covers information to the media and the presentation of CERN to the general public.

The contacts established with the daily and scientific media have been actively maintained: visits by journalists to CERN, including a number of interviews with the Director-General and with physicists, were organized, as well as a press conference for representatives of the international and local press in Geneva and its surrounding area. In addition, press conferences were given on the occasion of exhibitions arranged by CERN in Europe at the request of various institutions in its Member States (Hanover Fair, Stockholm, Trondheim and Lund).

Document statistics—Council Secretariat
1 January-31 December 1985

	Number of Documents				
	English	*French*	*German*	*Bilingual*	*Total*
Council and Committee of Council	53	53	4	6	116
Finance Committee	107	107	65	12	291
Scientific Policy Committee	20	2	1	-	23
ECFA	23	-	-	-	23
	203	162	70	18	453

The number of visitors to the Laboratory continued to increase during the year and exceeded 21'000, compared with 20'000 in 1984. Very keen interest is shown by young people; the technological and industrial content of the visit is growing as a result of the technologies which are being developed for LEP. The cultural aspect, in the presentation of fundamental research, needs to be improved; various projects are being studied, in particular the creation of a Visitors' Centre open to the public, providing a general introduction to particle physics and the work of the Laboratory.

Eminent personalities who visited CERN in 1985 are listed in the Appendix.

Internal Audit

The Internal Audit Service carried out checks on the accounts of the Organization and of the Staff Insurance Scheme, wherever these were felt necessary or where they had been agreed with the External Auditors. Whenever possible some of these checks were performed during the year.

In accordance with an agreed programme, spot-checks and individual investigations were also carried out in respect of certain activities or services. The difficulties encountered and suggested solutions were discussed with those in charge of the areas concerned with a view to possible improvements.

Certain issues relating to administration of the Staff Insurance Scheme were examined because of the growing size and greater spread of the Scheme's assets.

Legal Service

The Legal Service carried out its task as adviser to the Organization. It prepared documents and gave legal opinions on questions raised by the Director-General and the Directorate. It also maintained the necessary contacts over legal matters with the authorities of the Member States and the Host States and took part in the work of the Council and its Committees.

It played an active part in drawing up documents relating to the LEP project, co-operation between CERN and the European Communities, and the accession of Portugal.

In addition, it contributed to the establishment of the legal code governing uranium imports and exports to and from the Organization's Host States. It examined matters concerning membership of the AVS in Switzerland by members of the personnel who are of Swiss nationality, and prepared the legal actions concerned with this matter.

It participated in various committees, in particular the Safety Policy Committee, Working Group on Pensions, working groups and inquiries. The Legal Service provides the secretariat for the newly-created Committee for Relations with the Host States.

The Legal Service played an active part in work concerning the Organization's Staff Insurance Scheme, inter alia as regards pension guarantees in case of the dissolution of the Organization and financial administration of the Scheme's assets.

In respect of litigation, it represented the Organization's interests before national courts, managed its insurance policies, attended to the recovery of sums owed to the Organization by external debtors, and helped in the settlement of commercial disputes.

The Service also provided members of the personnel, particularly the Scientific Associates, with the necessary legal guidance on such matters as legislation concerning the family, taxation, nationality and residence.

Relations with the Host States

The Service for Relations with the Host States continued its task of representing the Organization's interests before the French and Swiss authorities at local, departmental or cantonal, and national or federal levels. It also kept in constant touch with the French and Swiss elected representatives at all levels and with numerous representative organizations.

In the latter half of the year an internal Committee for Relations with the Host States was created under the leadership of the Director of Administration and the Director and Leader of the LEP Project, with the senior staff of the Organization concerned as its members.

The Service's work covered problems connected with both the LEP project and general administrative matters.

LEP project

Activities relating to LEP concentrated essentially on solving two significant problems.

The imminent commencement of work on the LEP installation sites resulted in a thorough search being made for possible accommodation for the 1000 or so contractors' staff expected. Planning surveys were made of ten sites which might prove suitable for temporary housing.

In addition, from an examination of the high-voltage power lines and the optical fibre links that were announced at the time of the original project study, it proved possible to select precise alignments with no adverse environmental impact. An application for a 'déclaration d'utilité publique' was drawn up for the French authorities.

Finally, in the sphere of safety, the French authorities and CERN reached an agreement on intervention by emergency services whereby the roles to be played by each of the services in various potential situations were defined. A similar agreement with the Swiss authorities is being discussed.

General Administrative Matters

The task of managing those parts of the French site under agricultural use was continued. Two meetings were held by the Advisory Committee set up to enable the Prefecture, locally elected representatives and representatives of the farmers' unions to express their views on problems arising as a result of CERN's establishment in a rural area.

Seminars and Colloquia *

EXPERIMENTAL PHYSICS SEMINARS

H. Aihara (Berkeley) (21.1.85).
Heavy quark production in the PEP-4 experiment at SLAC.

T. Wyatt (CERN) (28.1.85).
A study of the production of b quarks in e^+e^- annihilation with the TASSO detector at PETRA.

M. Atac (Fermilab) (4.2.85).
Progress in instrumenting the CDF at Fermilab.

E. Gatti (Politecnico, Milan) (11.2.85).
Semiconductor drift chambers.

V. Hedberg (CERN) (18.2.85).
Prompt positrons at low Pt in 63 GeV pp collisions.

N. Isgur (University de Toronto) (4.3.85).
Gluonic degrees of freedom and where to find them.

R.A. Lee (Stanford University) (18.3.85).
Radiative decays of the Psi-prime (3685) to all-photon final states.

Suh Urk Chung (Brookhaven National Laboratory) (20.3.85).
New results on E/Iota meson.

D. Anderson (Fermilab) (1.4.85).
Fast calorimeter with BaF_2 and effect of dopes in liquid argon.

A. Gurtu (CERN) (15.4.85).
New results on charm production and decay in 360 GeV/c negative pion-production interactions.

S. Jadach (Cracow University) (20.5.85).
Monte Carlo techniques for precise calculations of the QED radiative corrections.

W. Smith (Columbia University) (15.7.85).
Neutrino production of dimuons by CCFRR.

C. Fernandez (CERN) (12.8.85).
Charm production and decay properties in 400 GeV/c pp interactions.

M. Dittmar (CERN) (2.9.85).
Investigation of baryon production in jets from e^+e^- annihilation.

K. Hamacher (Wuppertal University) (9.9.85).
Aspects of fragmentation in deep inelastic muon scattering results from the EMC.

M. Whalley (University of Durham) (16.9.85).
What the Durham/RAL HEP database can offer the CERN physicist.

S. Erhan (University of California, Los Angeles) (30.9.85).
Evidence for Pomeron single-quark interactions and longitudinal event structure in proton diffraction at the ISR.

P. Hughes (Rutherford Laboratory) (9.10.85).
Micro vertex detection and heavy flavour physics using scintillating optical fibres.

S. Kwan (Bristol University) (14.10.85).
Study of hadronically produced charmed particles using high resolution silicon detectors (ACCMOR collaboration).

P. Reimer (JINR, Dubna) (21.10.85).
Measurement of nuclear effects in deep inelastic muon scattering deuterium, nitrogen and iron targets.

H.H. Thodberg (Niels Bohr Institute, Copenhagen) (28.10.85).
Triple jet production at the ISR and determination of the coupling according to the lowest order QCD.

P. Sherwood (CERN) (4.11.85).
New lambda and antilambda hyperon spin polarization results from the ISR.

A. Jacholkowska (CERN) (11.11.85).
First observation of Q^2 dependence in hadron production in deep inelastic scattering.

N. Wermes (CERN) (18.11.85).
The pseudoscalar puzzle in radiative J/psi decays.

D.R. Ward (Cambridge) (25.11.85).
Results from the UA5 experiment at the pulsed SPS collider.

S. Cooper (CERN) (2.12.85).
Hadron spectroscopy - From upsilon to pi-zero.

H. Keilwerth (Heidelberg University) (9.12.85).
New neutrino and antineutrino total cross section measurements from CDHS.

COLLOQUIA

S.F. Mason (King's College, London) (29.1.85).
An electroweak origin for biomolecular handedness.

A.W. Lohmann (University of Erlangen) (12.2.85).
The digital optical super computer.

W. Paul (Bonn University) (7.3.85).
History and tales of the invention and the development of particle accelerators.

C.F. Ehret (Division of Biological and Medical Research, Argonne National Laboratory) (30.4.85).
Recent advances in chronobiology and chronobiotechnology: applications for shift workers and for world travelers.

A tribute to Niels Bohr on the 100th anniversary of his birthday. (6.5.85)
H. Schopper (CERN): Opening address,
A. Pais (Rockefeller University): Niels Bohr and the development of physics,
L. Van Hove (CERN): Niels Bohr and the creation of CERN.

V.F. Weisskopf (MIT) (12.9.85)
Niels Bohr, the quantum and the world.

* Not published.

G.A. Tammann (Astronomical Institute, Basle) (15.10.85).
The cosmic expansion field.

G. Setti (European Southern Observatory, Garching) (24.10.85).
Present and future instrumental projects at the European Southern Observatory.

C.N. Yang (University of Stony Brook, New York) (30.10.85).
Hermann Weyl's contribution to physics.

R.J. Tayler (Astronomy Centre, University of Sussex, Brighton) (5.11.85).
Dark matter in the Universe.

R.L. Mössbauer (Technische Universität, Munich) (14.11.85).
The rest mass of the neutrino.

W. Kohn (University of California, Santa Barbara) (26.11.85).
Electronic structure of matter - an alternative view point.

G. Morfill (MPI, Institut für extraterrestrische Physik, Garching) (10.12.85).
On the origin of high energy cosmic rays.

SCIENCE AND SOCIETY SEMINARS

J. Ziman (Dept. of Social and Economic Studies, Imperial College, London) (2.4.85).
On being a physicist.

S.P. Worden (Technical Advisor, U.S. Delegation, Geneva) (17.6.85).
Technologies for strategic defense.

S.D. Drell (SLAC) (11.7.85).
Star wars and arms control: Problems and prospects.

PARTICLE PHYSICS SEMINAR

A.G. Chilingarov (Novosibirsk) (10.1.85).
Recent results from Novosibirsk.

V. Hughes (Yale University) (15.1.85).
Measurements of the Lamb shift in Muonium.

G. Kalmus (Rutherford Appleton Laboratory) (22.1.85).
Photoproduction and decay of charmed particles at 20 GeV.

P. McIntyre (Texas A and M University) (24.1.85).
The Texas accelerator center.

V. Luth (SLAC) (31.1.85).
Lifetime measurements of heavy leptons and mesons (results from PEP).

C. Santoni (CERN and INFN Sez. Sanità, Rome).
(CHARM Collaboration) (14.2.85).
Final results on the determination of the electroweak mixing angle from the measurement of the ratio of cross-sections for elastic scattering of muon neutrinos and antineutrinos off electrons.

F. Vannucci (LPNHE, University of Paris VI et Paris VII) (19.2.85).
Do neutrinos decay? Do they oscillate?

P. Grafstrom (CERN and University of Uppsala) (21.2.85).
Measurement of the electron asymmetry in the beta decay of the polarized sigma-minus hyperon. Results from a Tevatron experiment at Fermilab.

J.P. Guillaud (LAPP, Annecy) (28.2.85).
Charmonium spectroscopy at the ISR.

C. Prescott (SLAC) (5.3.85).
Present status of the SLC project.

H.-Ch. Walter (Institut für Mittelenergiephysik, Villigen) (7.5.85).
Search for the decay of the positive muon into three electrons.

M. Koshiba (Tokyo University) (8.5.85).
New results from Kamioka proton decay experiment.

A. Böhm (III. Physikalisches Institut, RWTH Aachen) (14.5.85).
Recent results from MARK J on electron-positron annihilation into two muons and into one muon plus hadron.

B. D'Ettorre-Piazzoli (Istituto di Cosmogeofisica del CNR, Torino) (23.5.85).
Observation of a time modulated muon flux in the direction of CYGNUS X-3.

J.R. Hansen (CERN) (30.5.85).
Latest results on jet physics from UA2.

P. Musset (CERN) (4.6.85).
The first direct observation of beauty decays.

L. Mapelli (CERN) (11.6.85).
W and Z in UA2.

S. Stone (Cornell) (25.6.85).
Recent developments at Cornell: b quark studies and the CLEO II project.

Ling-Lie Chau (Brookhaven National Laboratory) (2.7.85).
Physics of charm and beauty, and beyond.

D. Hitlin (Caltech, Pasadena) (4.7.85).
D-meson studies with the MARK- III.

H. Dijkstra (NIKHEF-H, Amsterdam) (9.7.85).
High statistics inclusive phi-meson production at SPS energies.

W. Schmidt-Parzefall (DESY) (11.7.85).
Electron-positron physics in the upsilon region.

B. Renk (University of Dortmund) (16.7.85).
Are there prompt like sign dimuon events in neutrino interactions?

J.H. Schwarz (Caltech, Pasadena) (23.7.85).
Towards a unified field theory of all interactions.

C. Hojvat (Fermilab) (30.7.85).
Perspectives for 1.6 TeV collisions this summer at Fermilab.

A. De Rujula (CERN) (6.8.85).
Some snapshots of the 1985 HEP panorama.

G. von Dardel (University of Lund) (13.8.85).
A precision determination of the life-time of the neutral pion.

M.J. Jonker (SLAC) (11.10.85).
Results from the anomalous single photon (ASP) collaboration at PEP.

J. Rafelski (University of Cape Town) (30.10.85).
Strange quarks and quark plasma in nuclear collisions at CERN.

D. Caplin (Imperial College, London) (31.10.85).
Hunting the Monopole.

A. Hahn (University of California, Irvine) (12.11.85).
Recent results from the Irvine selenium double beta decay experiment.

J. Panman (CERN) (12.12.85).
A precise determination of the electroweak mixing angle from semi-leptonic neutrino scattering.

COMPUTER SEMINARS

S. Himbaud (Groupe d'Intelligence Artificielle de Luminy, Marseilles, France) and G. Le Guillou (Commissariat à l'Energie Atomique, Cadarache, France) (6.2.85).
Système Expert en Diagnostic de Panne pour le Réacteur Nucléaire Super Phénix

P. Freeman (University of California, Irvine, USA) (13.3.85).
Software Construction using Components and Special Purpose Languages : The Draco Approach

A.S. Tanenbaum (Vrije Universiteit, Amsterdam, The Netherlands) (17.4.85).
Distributed Operating Systems

Y. Kanada (Computer Centre, University of Tokyo, Japan) (24.4.85).
Japanese Supercomputers

K. Hornbach (Lear Siegler Inc./Instrument Division, Grand Rapids, USA) (23.9.85).
Improving Productivity with Software Tools

D.R. Quarrie (Fermi National Accelerator Laboratory, Batavia, USA) (16.10.85).
The CDF Data Acquisition System

R. Taylor (INMOS Ltd., Bristol, U.K.) (30.10.85).
Occam, the Transputer and its Applications

M.M. Kay (Stanford University and XEROX Palo Alto Research Center, California, USA) (4.12.85).
Expert Systems: Artificial Intelligence or Artificial Stupidity?

Training Programmes 1984/85 *

ACADEMIC TRAINING

18 Lecture Series (70 lectures - 29 Lecturers)

The Universe at t $\gtrsim 10^6$ years; galaxy formation, clustering, and the unseen mass
M.J. Rees (Institute of Astronomy, Cambridge) (3 lectures).

Critical phenomena
E. Brezin (CEN, Saclay) (4 lectures).

A new branch of research: astronomy of the most energetic gamma rays
G. Cocconi (CERN) (2 lectures).

Mécanique des roches et stabilité des cavités souterraines
G. Lombardi (Conseil des Ecoles Polytechniques Fédérales) (3 lectures).

The very early Universe
D. Nanopoulos (CERN) (3 lectures).

Lasers: technology and applications
L. Woste (EPFL and CNRS) (5 lectures).

Base de données and systèmes relationnels.
C. Delobel (Université de Grenoble and IMAG) (5 lectures).

Composite models of leptons and quarks
R. Peccei (DESY, Hamburg) (3 lectures).

Superconducting components for accelerators
H. Lengeler, J. Tückmantel, R. Perin and M. Morpurgo (CERN) (5 lectures).

From the photons to the neuronal signals: visual transduction and related biological problems
M. Chabre (CNRS and CEN, Grenoble) (3 lectures).

Heavy flavours
R. Rückl (University of Munich) and S. Reucroft (CERN) (5 lectures).

e^+e^- physics
G. Flügge (Institut für Kernphysik, Karlsruhe) (5 lectures).

Beam interaction with the vacuum in acclerators and storage rings
R. Calder, O. Grobner, A. Poncet (CERN) (5 lectures).

A short introduction to the theory of numbers
R.F. Churchhouse (University College, Cardiff) (5 lectures)

Highlights on $p\bar{p}$ collider results
L. Di Lella (CERN) (3 lectures)

Hamiltonian mechanics, J.S. Bell (CERN) (3 lectures)

Physics at LEAR
R. Armenteros and P. Lefevre (CERN) (3 lectures)

Control systems for accelerators and storage rings
G. Benincasa, J. Boillot, J. Gamble, G. Shering, P. Wolstenholme (CERN) (5 lectures)

(Audience: maximum 170 - minimum 20.)

* The titles of the courses and lectures are given in the language used.

TECHNICAL TRAINING

Courses

Mathematics - Physics

Introduction à la physique des particules
J.P. Lagnaux (84 h).

Champs magnétiques et aimants
F. Rohner (60 h).

Computer Science

Initiation à l'informatique et aux techniques de programmation
H. Michel, J. Philippe, E. D'Amico, Y. Perrin (80 h).

Initiation à l'informatique
H. Michel, J. Philippe, E. D'Amico, Y. Perrin (40 h).

Initiation aux techniques de programmation
H. Michel, J. Philippe, E. D'Amico, Y. Perrin (40 h).

Introduction to computing and programming techniques
H. Slettenhaar (80 h).

Introduction to computing techniques
H. Slettenhaar (40 h)

Introduction au matériel informatique
H. Slettenhaar (40 h).

Introduction to computers hardware
H. Slettenhaar (40 h).

Programmation en ligne et temps réel
J.A. Bogaerts, A. Lacourt (140 h).

Méthodologie de la programmation
L. Zaffalon (40 h).

Programmation en PASCAL
M. Cousin (2 sessions of 36 h).

Microprocesseurs 16 bits: fonctionnement et utilisation
C. Guillaume (80 h).

Electronics

Laboratoire d'électronique I
P. Cennini (88 h).

Laboratoire d'électronique II
R. Platteaux (88 h).

Laboratoire d'électronique III
J.P. Bertuzzi, J.L. Périnet (84 h).

Électronique et régulation
G. Baribaud, Ch. Bertuzzi (72 h).

Microprocesseurs 8 bits: étude, fonctionnement et application
J. Feyt, G. Mugnai (88 h).

Mechanics and courses for mechanicians

Électromécanique
J. Belleville, A. Ranieri (88 h).

Soudure: Initiation
Lycée de Bellegarde (2 sessions of 70 h).

Soudure: Perfectionnement
Lycée de Bellegarde (2 sessions of 70 h).

Connaissances pratiques des matériaux
R. Barraud, L. Haenny (64 h).

Administration

Techniques d'organisation et de statistiques
A. Brissonnaud, A. Lecomte, G. Lindecker (88 h).

Informatique administrative: introduction à WYLBUR
N. Blackburne (2 sessions of 32 h).

Dactylographie '10 doigts'
J. Lepagnot (2 sessions de 40 h).

436 people attended the technical courses.

Seminars (Calendar year)

Chapitres choisis de mathématiques:
- Transformations d'égalités et équations du 1er degré
  A. Chouvelon, J.L. Périnet (20 h)
- Eléments de trigonométrie plane
  A. Chouvelon, J.L. Périnet (20 h)
- Introduction au calcul différentiel
  J.P. Dufey, B. Frammery (20 h)
- Séries et transformations de Fourier
  L. Rinolfi, M. Martini (32 h).

Les pompes: technologie et entretien
CAST-INSA Lyon

Traitement statistique des erreurs expérimentales
C. Leluc, W. Leo (2 sessions of 32 h).

Les fibres optiques
G. Chartier, P. Facq (2 sessions of 12 h).

Ajustement de courbes aux points expérimentaux
C. Leluc, W. Leo (16 h).

Connaissance de nos accélérateurs I (2 sessions of 21 h).

Connaissance de nos accélérateurs II (2 sessions of 21 h).

133 people attended the technical seminars.

TECHNOLOGICAL FORUMS

Les lentilles au lithium, P. Sievers

Fenêtre en Kevlar pour l'expérience NA31, M.L. Mathieu

For these 2 forums about 30 people attended each time.

PERSONAL SKILLS, MANAGEMENT TRAINING AND SECRETARIAL DEVELOPMENT

Management training

Techniques d'encadrement du personnel
P. Artigues (IDEP-CELER) (5 seminars of 5 days),
54 participants.

Management des groupes
P. Artigues (IDEP-CELER) (3 seminars of 4 days),
29 participants.

Relation Interpersonnelles dans le travail (Niveau 1)
P. Artigues (IDEP-CELER) (3 seminars of 3 days),
30 participants.

Relations Interpersonnelles (Niveau 2)
P. Artigues (IDEP-CELER) (1 seminar of 3 days),
10 participants.

Méthodes et Pratique de la Négociation
Ph. Pigallet (IDEP-CELER) (2 seminars of 4 days),
18 participants.

Supervision, Delegation, Leadership and Communication
(D. Gration) (3 seminars of 5 days), 26 participants.

Communication
(D. Gration) (1 seminar of 4 days), 15 participants.

Secretarial development

Cours pour secrétaires (Niveau 1)
Shelle Rose (IDEP-CELER) (3 seminars of 3 days),
32 participants.

Cours pour secrétaires (Niveau 2)
Niven Charvet (ITC) (2 seminars of 3 days), 23 participants.

Secretarial development Level 2,
Shelle Rose (IDEP-CELER) (2 seminars of 3 days),
16 participants.

Personal Skills

Lecture efficace,
Pierre Artigues (IDEP-CELER) (1 seminar of 6 days),
14 participants.

Gestion du Temps et de soi-même
G. Curetti, (1 seminar of 3 days), 13 participants.

Time and Self Management
G. Curetti (1 seminar of 3 days), 12 participants.

Savoir prendre des notes en rèunion
M.J. Couchaère (IDEP-CELER) (1 seminar of 3 days),
12 participants.

Report Writing
Piers Campbell (ITC) (2 seminars of 4 days), 16 participants.

Effective Reading
Shelle Rose (IDEP-CELER) (1 seminar of 6 days),
8 participants.

Questioning and Listening Skills
J. Townsend (1 seminar of 3 days), 8 participants.

Producing Creative Ideas
J. Townsend (1 seminar of 2 days), 7 participants.

Assertive Communication Workshop
J. Townsend (1 seminar of 1 day), 10 participants.

CERN SUMMER STUDENT LECTURE PROGRAMME

Introduction

Introduction to particle physics
J. Ellis (1 lecture).

Courses

Hadronic Interactions
L. Camilleri (4 lectures)

Electronic Detectors, instrumentation and data acquisition
C. Fabjan (3 lectures), W. Bell (1 lecture)
D. Burckhart (1.5 lectures), A. Bogaerts (1.5 lectures)
and all together (1 demonstration).

Highlights in e^+e^- physics
W.D. Schlatter (4 lectures).

Introduction to the Concepts of Particle Physics
V.L. Telegdi (4 lectures), V.F. Weisskopf (7 lectures)

An Introduction to Accelerators
E. Wilson (5 lectures)

Seminars

The Physics of $\bar{p}p$ Colliders
P. Darriulat (1 lecture).

Searches for Magnetic Monopoles
G. Giacomeli (1 lecture).

Monte Carlo
F. James (2 lectures)

Silicon Detectors
R. Klanner (2 lectures).

Physics at LEAR
R. Klapisch (2 lectures).

Proton Decay
H. Meyer (1 lecture).

An Introduction to Stochastic Cooling
S. van der Meer (1 lecture).

Neutrino Experiments beyond the Standard Model
F. Vannucci (1 lecture).

Melting the Vacuum
W. Willis (1 lecture).

Other

Physics and Society
V.F. Weisskopf (1 discussion session).

Students Session
H. Dabbous, J.L. Doumont, A. Sevrin (3 presentations).

(Average attendance: 135; maximum: 225; minimum: 75.)

APPRENTICESHIPS

Number of apprentices from September 1984 to August 1985: 27

Profession	*1st year*	*2nd year*	*3rd year*	*4th year*	*Total*
Laborant en Physique	3	3	3	3	12
Mécanicien-Électronicien	4	4	4	3	15

Two apprentices "Laborants en physique" and two apprentices "Mécaniciens-Electroniciens" who completed their apprenticeship in 1985 obtained the "Certificat fédéral de Capacité".

GENERAL EDUCATION

1. Talks

- **"Science pour tous"**, by 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 1200 copies per weekly edition and about 3500 copies of the comprehensive edition for the year.

LANGUAGE COURSES

	English			*French*			*German*		
Description of classes	*Number of classes*	*Number of hours*	*Number of students*	*Number of classes*	*Number of hours*	*Number of students*	*Number of classes*	*Number of hours*	*Number of students*
Extensive course (1-6 hours per week)	12	966	115	24	1256.5	261	–	–	–
Special extensive course (Follow-up, phonetics, drafting, etc.) (2-6 hours per week)	9	167	51	2	105	18	–	–	–
Semi-intensive course (7-12 hours per week)	16	1058	119	9	666.5	83	5	355.5	50
Total	37	2191	285	35	2028	362	5	355.5	50

Total number of inscriptions English + French + German 697

Scientific Conferences and Schools

The 1985 CERN–JINR School of Physics was organized in collaboration with JINR, Dubna and the Institute of Physics of the University of Bologna. It was held at Urbino, Italy, from 1–14 September 1985. In addition to 10 students from 6 laboratories in the host country, the School was attended by 14 students from JINR, Dubna and by 19 students from 14 institutes in 6 of the Member States of JINR, together with 1 student from CERN and 46 students from 34 institutes in 12 CERN Member States. Nine students came from countries which are neither Member States of JINR nor of CERN.

The lecture programme was as follows:

- E. Amaldi (Rome University): *Gravitational waves*
- N. Cabibbo (Rome University): *Physics in Italy*
- J. Ellis (CERN): *Supersymmetry*
- M. Ferro-Luzzi (CERN): *Physics at CERN*
- S.B. Gerasimov (JINR): *Quark distribution in nuclei*
- G. Giacomelli (Bologna University): *Lepton-hadron interactions*
- G. Giacomelli (Bologna University): *Underground physics and the search for magnetic monopoles*
- P.I.P. Kalmus (Queen Mary College, London): *Proton-antiproton collider physics*
- R. Klanner (DESY): *Experiments on weak decays of leptons and quarks; basis and tests of the standard model*
- V.A. Kuzmin (Institute for Nuclear Research, Moscow): *Grand unified theories and cosmology*
- Yu.M. Makeenko (ITEP, Moscow): *Lattice quantum field theories*
- V.N. Popov (Leningrad Department, Moscow Steklov Mathematical Institute): *Introduction to gauge fields*
- A.V. Radyushkin (JINR): *Perturbative QCD*
- G. Setti (ESO, Garching): *Recent results in astrophysics*
- M.E. Shaposhnikov (Institute for Nuclear Research, Moscow): *Gauge theories with scalar fields*
- A.N. Sissakian (JINR): *The JINR experimental programme in high energy physics*

Distinguished visitors in 1985

JANUARY

17 UN-ECE Electrical Energy Committee (70 persons)

28–29 The Heads of Eight Leading Finnish Industries
Messrs – Timo RELANDER, Managing Director, Confederation of Finnish Industries
Pentti KORKKA, Executive Vice President, NOKIA CORP.
Matti ILMARI, Executive Vice President, KYMMENE-STRÖMBERG CORP
Lauri PREPULA, Executive Vice President, Finnish Foreign Trade Association
Yrjö TOIVOLA, Managing Director, VIASALA CORP.
Gerhard WENDT, Corporate Vice President, KONE CORP.
Pertti VOUTILAINEN, President-Managing Director, OUTOKUMPU CORP.
R. JUNNILA, Director of Research and Development, NESTE CORP.

30 West European Ambassadors in Berne,
H.E. Mr Jean RETTEL, Ambassador of Luxembourg
H.E. Mr R. PAULUCCI di CALBOLI, Ambassador of Italy
H.E. Mr Patrick F. POWER, Ambassador of Ireland
H.E. Mr Dimitri VELISSAROPOULOS, Ambassador of Greece
H.E. Mr John E. POWELL-JONES, Ambassador of the United Kingdom
H.E. Mr Georges EGAL, Ambassador of France
H.E. Mrs Janine C. FERRINGA, Ambassador of the Netherlands
H.E. Mr Armand COESENS, Ambassador of Belgium
H.E. Mr Gerhard FISCHER, Ambassador of the Federal Republic of Germany
Mr Pasquale A. BALDOCCI, Minister Counsellor at the Italian Embassy
Mr Vincente GIRBAU LEON, Minister Counsellor at the Spanish Embassy
Mr Göran WIDE, Counsellor at the Swedish Embassy
Mrs Tove KIJEWSKI, Second Secretary at the Norwegian Embassy

FEBRUARY

14 H.E. Mr Kazuo CHIBA (Japanese Mission in Geneva) (3 persons)

18–19 Swedish Physics Committee (3 persons)

19 Scientific Policy Committee (17 persons)

MARCH

06 Representatives of the PHILIPS Directorate Messrs. EDLINGER, GELLING, ROMBERT

11 Dr. Jonathan JOHNSTON, High Sheriff of Surrey (United Kingdom)

14 Representatives of the National Council for Scientific Research and Technology (Portugal) (4 persons)

22 Mr Henri KRASUCKI, Secretary-General of CGT (France)

APRIL

18 Group from the World Council of Churches led by His Grace Dr John S. HABGOOD, Archbishop of York (20 persons)

26 Mr Jaime GAMA, Portuguese Minister for Foreign Affairs (6 persons)

MAY

07 Mr. Dean MORTON, Executive Vice-President, Hewlett Packard (4 persons)

22 Mr Claude GUIZARD, Prefect of the Ain (4 persons)

30 'Strategy' Group of the Swiss Army General Staff (13 persons)

31 Dr E. van SPIEGEL and Dr Th. SISKENS, respectively Director General and Director for Science Policy in the Ministry of Education and Science (Netherlands)

JUNE

05 Dr E. BLOCK, Director, National Science Foundation, USA

12 Professor R. HAENSEL and Professor A. MICHAUDON, Directors of Institute Max von Laue-Paul Langevin (ILL) (France)

18 Mr Giulio ANDREOTTI, Italian Minister for Foreign Affairs

19 Parliamentarians from the People's Republic of China (20 persons)

JULY

26 Mr BERTHOLON, Assistant to the Prefect of the Ain for Research and Technology

26 Directorate and Board of Management of Bayernwerk AG, Munich (Federal Republic of Germany) (40 persons)

AUGUST

13 Delegation, Finance Board, Swiss National Council
Members of the Board:
Mrs Yvette JAGGI
Mr Karl FLUBACHER
Mr Gottlieb GEISSBÜHLER
Mr Bernard MEISOZ
Mr Hans SCHÄRLI
Mr Georg STUCKY
Mr Fritz BUCHER
Mr Christian AYER

Other participants:
Professor B. HAHN, Swiss Delegate to the CERN Council
Mr O. UHL, Minister, Mr J. STÄHELIN, Mr P. CREOLA } Federal Department of Foreign Affairs
Mr M. CONSTANTIN, Director of FIPOI, Geneva
Mr J.P. VETTOVAGLIA, Chargé d'Affaires at the Swiss Permanent Mission in Geneva

SEPTEMBER

03 Her Majesty Queen Beatrix and His Royal High-ness Prince Claus of the Netherlands, accompanied by:
Mrs M.P. van KARNEBEEK-van LEDE
Lt-col. P.J. JANSEN
H.E. Mr van SCHAIK, Ambassador
H.E. Mr FERRINGA, Ambassador
Minister HEINEMANN

04–06 Professor Yan DONG-SHENG, Vice-President, Chinese Academy of Science accompanied by Mrs. LU BEI LEI

10 United Nations Institute for Training and Research (UNITAR) (50 persons)

18 LEP Components and LEP Experimental Equipment by the CERN Scientific Policy Committee (SPC)

20 Professor Juhani KUUSI, Director-General TEKES (Technology Development Centre of Finland)

26 Professor PORTER, Houston Area Research Center – HARC (USA)

OCTOBER

04 H.E. Mr J.G. TOWER, Ambassador, H.E. Mr CLARK, Ambassador and party (USA) (10 persons)

09 Mr Luigi GRANELLI, Italian Minister of Research and Technology

11 'Passport to Research' (Around the France of the Infinitely Small) (30 persons)

12 Dr W. SAXON, President of M.I.T. and M.I.T. Club of Switzerland

15 Dr Ernst HOFMEISTER, SIEMENS A.G., Federal Republic of Germany

16 Mr. Timothy EGGAR, British Parliamentary Under-Secretary at the Foreign and Common-wealth Office

NOVEMBER

11 H.E. Mr Yves PAGNIEZ, Ambassador (France)

12 H.E. Mr John RICH, British Ambassador and Mr John S. CHICK, H.M. Consul General

28 Mr George WALDEN, British Parliamentary Under-Secretary at the Department of Education and Science

DECEMBER

20 Mr Hubert CURIEN, French Minister of Research and Technology (9 persons)