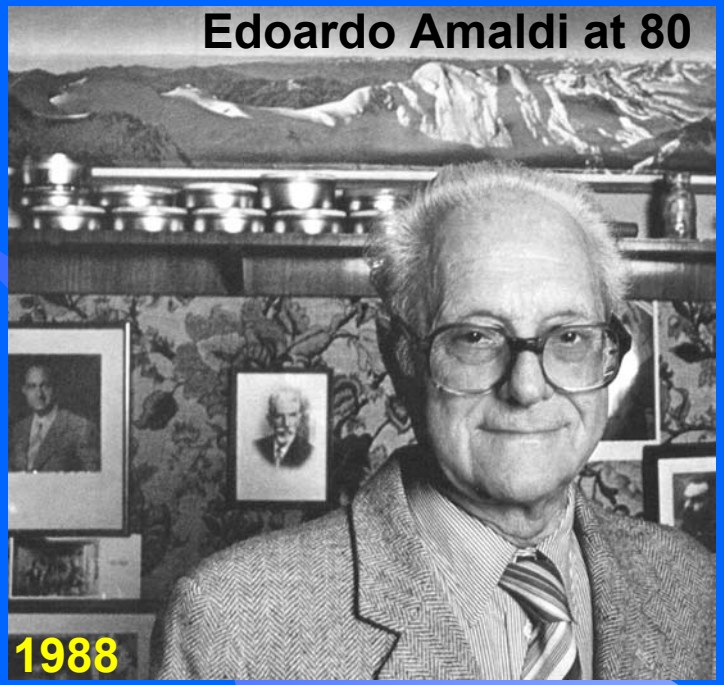
INFLUENCE OF FERMI AND HIS ROMAN GROUP ON NUCLEAR AND MEDICAL PHYSICS

Ugo Amaldi

Universitày Milano Bicocca and TERA Foundation

Photo of a photo



The discovery of neutron induced radioactivity

January-March 1934

1933 Christmas holidays:

Enrico Fermi and the other "ragazzi di Via Panisperna"

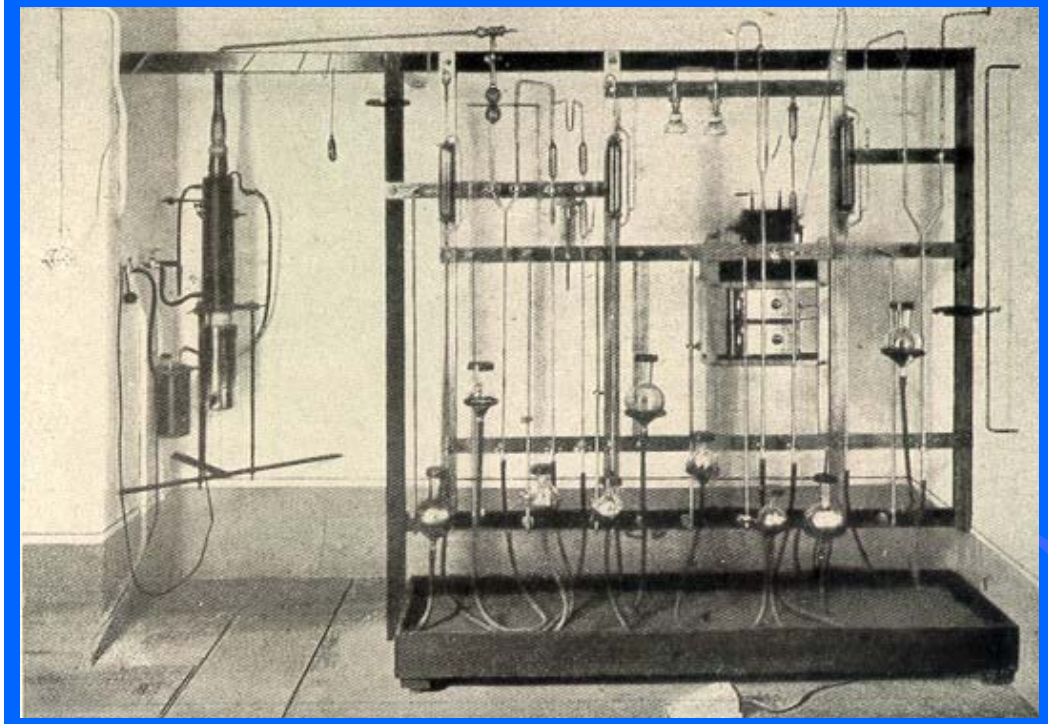
at Santa Cristina

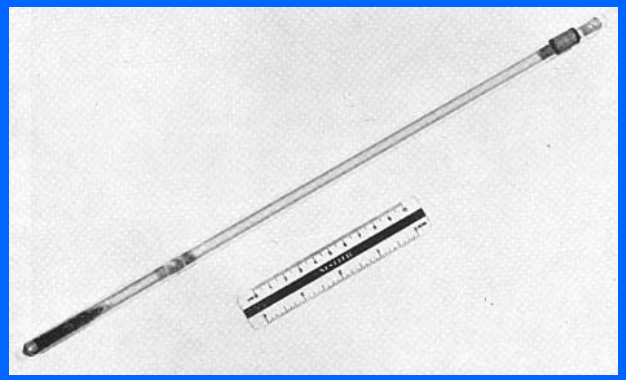
March 1934: The Joliot-Curies discover artificial radioactivity

induced by alfa particles

The Institute of Via Panisperna

1934 : Fermi discovery was made with a Be-Rn source. Radon extracted at Laboratorio Fisico della Sanità Pubblica





The “Divine Providence”

The third paper

RADIOATTIVITÀ « BETA » PROVOCATA DA BOMBARDAMENTO DI NEUTRONI. — III.

E. AMALDI, O. D'AGOSTINO, E. FERMI, F. RASETTI, E. SEGRÈ

« Ric. Scientifica », 5 (I), 452–453 (1934).

Sono state proseguite ed estese le esperienze di cui alle Note precedenti [1] coi risultati che ricordiamo appresso.

Idrogeno – Carbonio – Azoto – Ossigeno. – Non dànno effetto apprezzabile. Sono stati esaminati paraffina irradiata al solito modo per 15 ore con una sorgente di 220 mC, acqua irradiata per 14 ore con 670 mC e carbonato di guanidina irradiato per 14 ore con 500 mC.

Fluoro. – Il periodo del Fluoro è sensibilmente minore di quanto indicato precedentemente e cioè di pochi secondi.

Magnesio. – Il Magnesio ha due periodi, uno di circa 40 secondi e uno più lungo.

Bromo. – Ha due periodi, uno di 30 minuti e l'altro di 6 ore. L'attività corrispondente al periodo lungo e probabilmente anche l'altra, seguono chimicamente il Br.

Palladio. – Periodo di alcune ore.

Jodio. – Periodo 30 minuti. L'attività segue chimicamente lo Jodio.

Praseodimio. – Ha due periodi. Uno di 5 minuti e l'altro più lungo.

Neodimio. – Periodo 55 minuti.

Samario. – Ha due periodi uno di 40 minuti e uno più lungo.

Oro. – Periodo dell'ordine di grandezza di 1 o 2 giorni.

(1) E. FERMI, « Ricerca Scientifica », 5 (1) p. 283, p. 330 (1934).

iodine isotopes

used in nuclear medicine

The efficacy of slow neutrons

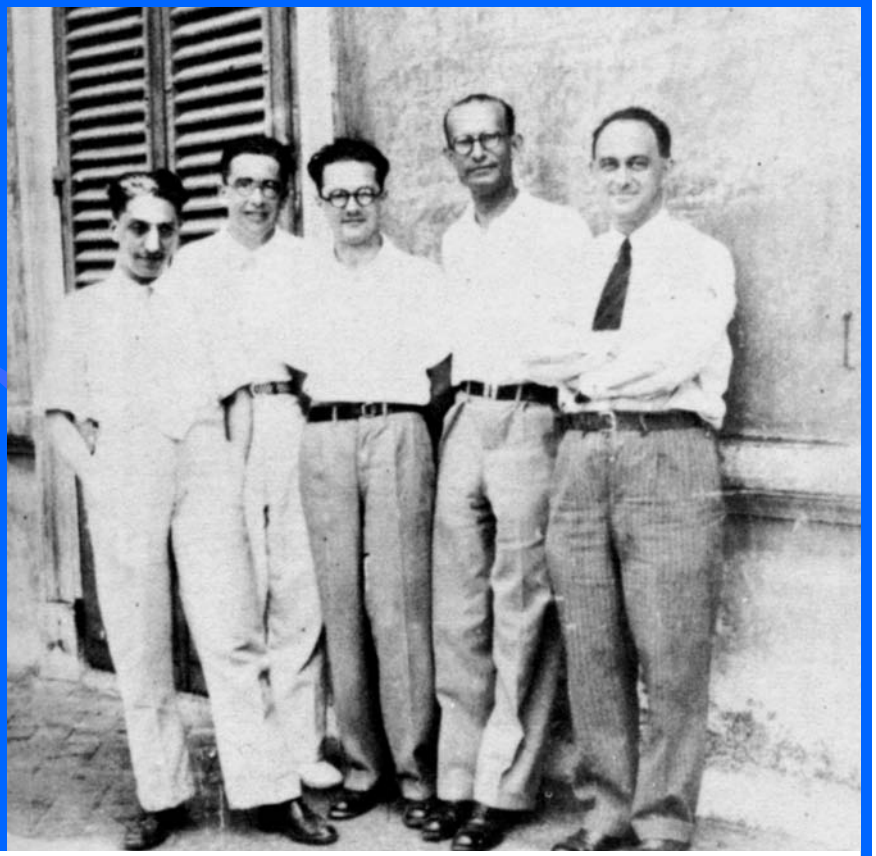
October 20, 1934

Many years later Fermi himself told Chandrasekhar how it had happened [11]. "*We were working very intensely on radioactivity induced by neutrons and the results did not make sense at all. One day while I was going to the laboratory, it occurred to me to study what would happen if I placed some lead in front of the source of neutrons. I took a long time to work the piece of lead very carefully on the lathe, which was unusual for me; I was clearly dissatisfied with something and was looking for every possible excuse for delaying the moment for putting the lead in place. At a certain point I said to myself: 'No, I do not want a piece of lead here: what I want is a piece of paraffin.' And that is how it was, without prior warning or conscious reasoning. I immediately took any old piece of paraffin and put it there where I should have put the piece of lead.*"

October 1934: discovery of artificial radioactivity induced by slow neutrons

Discovery:	**Saturday**	**20.10.34 (*)**
First paper:	**Monday**	**22.10.34**
Patent:	**Friday**	**26.10.34**

(*) A. De Gregorio : not on October 22!



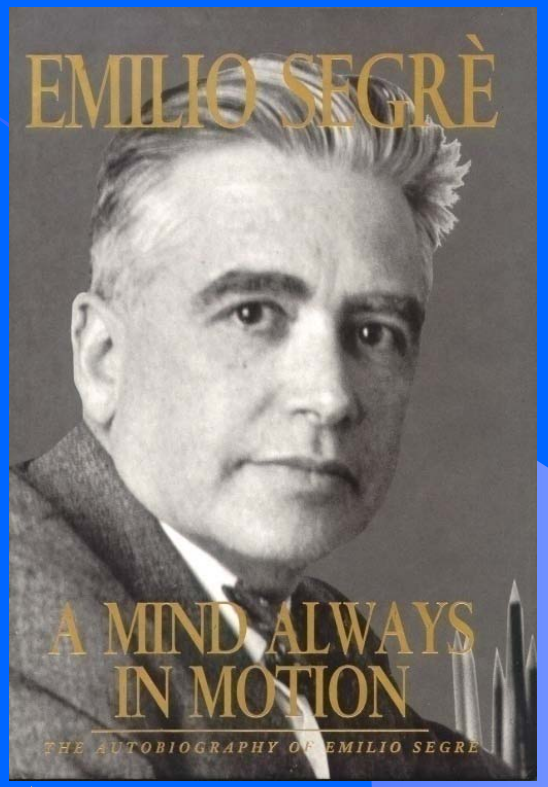
O. D'Agostino E. Segrè E. Amaldi F. Rasetti E. Fermi

+ B. Pontecorvo = The boys of Via Panisperna

Writing the paper

Emilio Segrè: "*Enrico Fermi physicist*" – 1970

Fermi dictated while I wrote. He stood by me; Rasetti, Amaldi and Pontecorvo paced the room excitedly, all making comments at the same time. The din was such that when we left, Amaldi's maid discreetly asked whether the evening guests were tipsy. Ginestra Amaldi handed the paper to her boss at *La Ricerca Scientifica* the following morning.



The patent to "increase the production of artificial radioactivity with neutron bombardment"

Patent: Friday 26 October because of

Orso Mario Corbino

REGNO D'ITALIA

MINISTERO DELLE CORPORAZIONI

UFFICIO DELLA PROPRIETÀ INTELLETTUALE

Attestato di Privativa Industriale

№ 324458

Nel Registro degli attestati di privativa industriale di questo Ufficio è stata regolarmente inscritta la domanda depositata, coi documenti voluti dalla legge, all' Ufficio stesso

nel giorno ventisei *del mese di* ottobre *1934 alle ore* 12,15

da Fermi Enrico, Amaldi Edoardo, D'Agostino Oscar, Pontecorvo Bruno, Rasetti Franco, Segrè Emilio e Trabacchi Giulio Cesare { a Roma

per ottenere una privativa industriale per il trovato designato col titolo:

Metodo per accrescere il rendimento dei procedimenti per la produzione di radioattività artificiali mediante il bombardamento con neutroni.

Il presente attestato non garantisce che il trovato abbia i caratteri voluti dalla legge perché la privativa sia valida ed efficace, e viene rilasciato senza esame preliminare del merito e della novità di esso

Roma, li -2 FEB 1935 Anno XIII

Il Direttore

Nei riferimenti al presente *attestato* richiamare *soltanto* il suindicato numero, adottando la dizione PRIVATIVA ITALIANA N. 324458

B

La Tipografica - Roma XII - Ord. 3543 - (5.000)

July 2, 1940. E. FERMI ET AL. 2,206,634

PROCESS FOR THE PRODUCTION OF RADIOACTIVE SUBSTANCES

Filed Oct. 3, 1935

Fig. 1.

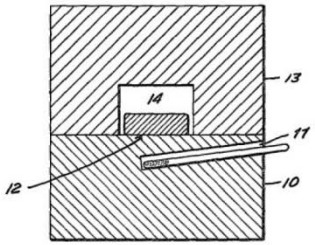
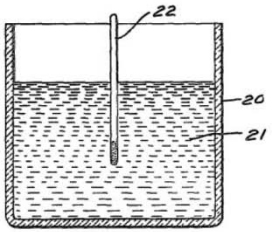


Fig. 2.



INVENTORS

ENRICO FERMI, EDOARDO AMALDI,
BRUNO PONTECORVO, FRANCO RASETTI, EMILIO SEGRE

BY

ATTORNEYS

The American patent was deposited on October 3, 1935

"To obtain radioactive substances in quantities of practical importance"

Patented July 2, 1940 2,206,634

Uranium is explicitly quoted

UNITED STATES PATENT OFFICE

2,206,634

PROCESS FOR THE PRODUCTION OF RADIOACTIVE SUBSTANCES

Enrico Fermi, Edoardo Amaldi, Bruno Pontecorvo, Franco Rasetti, and Emilio Segrè, Rome, Italy, assignors to G. M. Giannini & Co., Inc., New York, N. Y., a corporation of New York

Application October 3, 1935, Serial No. 43,463
In Italy October 26, 1934

7 Claims. (Cl. 204—31)

This invention relates to the production of isotopes of elements from other isotopes of the same or different elements by reaction with neutrons, and especially to the production of artificial radio activity by formation of unstable isotopes.

It has been known for many years that, although each chemical element has always the same atomic number or charge, it may exist in different forms having different atomic weights. These forms of the elements are referred to as isotopes.

It has also been known that the radio-active elements, by disintegration or break down occurring in their nuclei are spontaneously converted into various isotopes of other elements. Thus, for example, the radio-active element uranium may be converted into lead of atomic weight 206, while the element thorium may be converted into a different isotope of atomic weight 208.

It has long been known that such spontaneous used which require tremendous energy to break through the potential barrier surrounding the nucleus; and that if, instead of charged particles, neutrons are used for the nuclear reactions, the greatest efficiencies are in some cases attained with low energy or "slow" neutrons, e. g., of the order of a few hundred electron volts, or even much less down to a small fraction of an electron volt.

Neutrons when produced in any ordinary manner, e. g., by the action of radon on beryllium or of polonium on beryllium or by bombardment of atomic nuclei with artificially accelerated particles, might have a very wide range of energies but high average energy. These energies range up to several million volts. It is necessary, therefore, if the greatest efficiency of reaction is to be attained, to reduce by artificial means the energy of these neutrons. We describe below a method for slowing down fast neutrons.

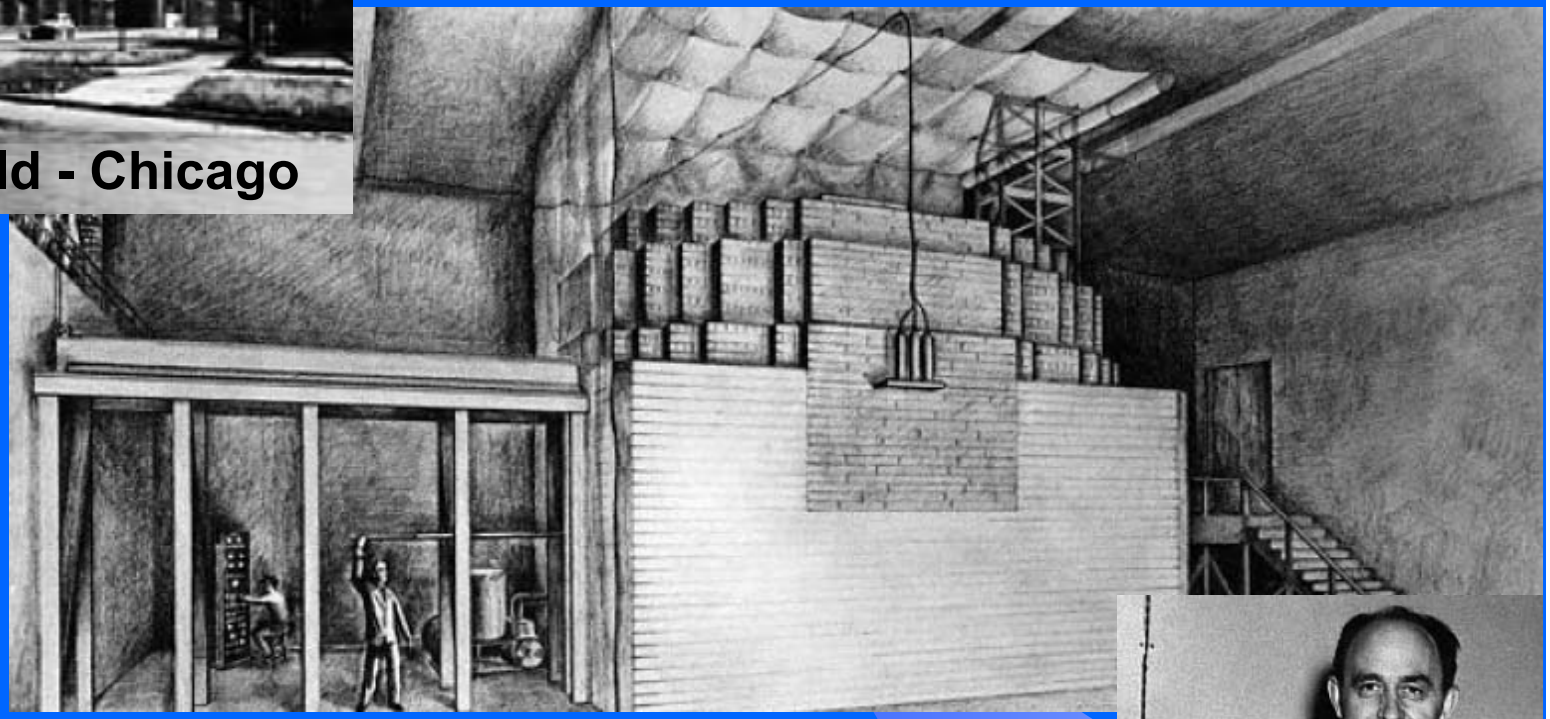
Fifty years later

"We were extremely pleased and amused, not so much because a patent could result in a financial benefit for the 'inventors', but rather because a work, carried out with great energy and dedication, only for its intrinsic merits, had unexpectedly brought us to applications which, in addition, would be mainly of a scientific and a medical nature"

E. Amaldi – Phys. Report 1984

December 2, 1942

Stagg Field - Chicago



Arthur Compton to James Conant:

“The Italian navigator has landed in the New World.”

The American patent

American Patent:	3 October 35 2 July 40	Gabriello Giannini & Co. granted
Request to the military patent office of ORSD	14 June 46	Giannini and L. Bernard 0.45 M$
Request to the civil patent office of USAEC	13 October 48	Giannini and L. Bernard 1,9 M$

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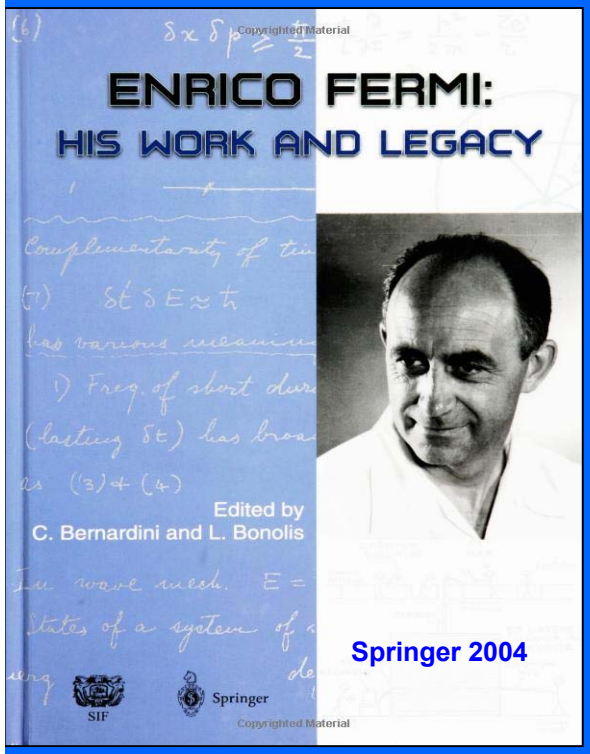
Trial against USA Government	15 August 50	Giannini and L. Bernard 10 M$
Pontecorvo disappears	1 September 50	

November 52 : each inventor receives 28,000$

Nuclear physics

1935: E. Fermi and E. Amaldi in the Rome Institute

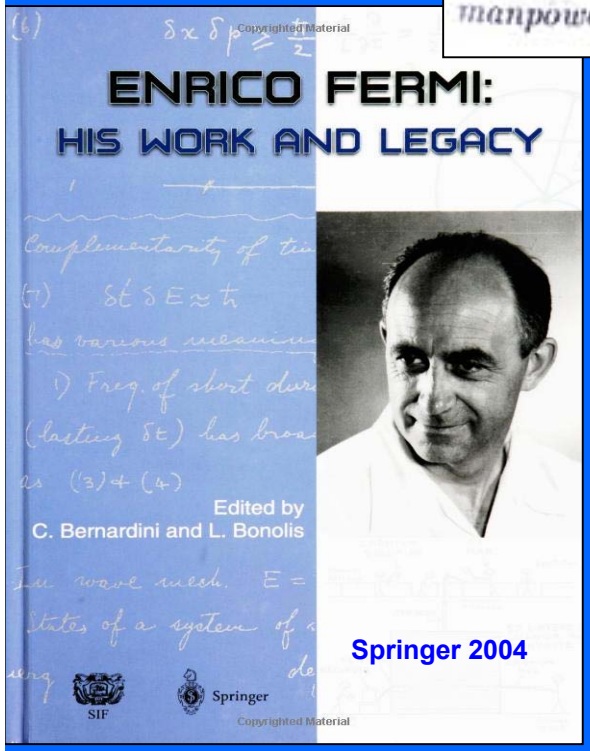


UA:

Nuclear physics from the nineteen thirties to the present day

1935: E. Fermi and E. Amaldi in the Rome Institute

Amaldi and Fermi worked with enormous energy and concentration for many months "...[...] *as if by our own more intensive efforts we wanted to compensate for the loss of manpower in our group*" [15], and within a few months they had published six papers



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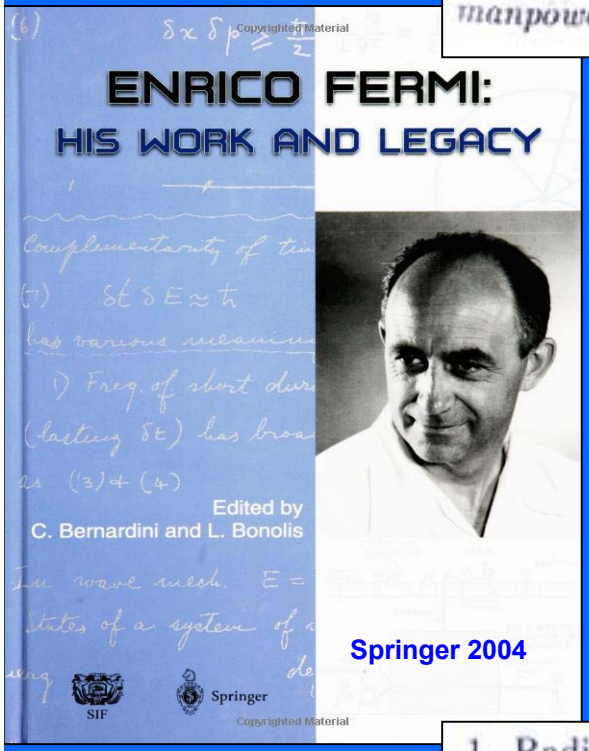


Springer 2004

UA:

Nuclear physics from the nineteen thirties to the present day

29 May 1936: paper submitted to Physical Review

1. Radioactivity produced by neutrons slowed down by impact with hydrogen and other light nuclei.
2. The $1/v$ law according to which the slower the speed v of neutrons, the more they are absorbed by nuclei.
3. The huge cross-section of cadmium and the existence, in cadmium, and in many other nuclides, of bands of absorption of slow neutrons.
4. The effect of the chemical bond on the absorption of neutrons.

Medical isotopes and the ISS (*) "tube"

(*) ISS = Istituto Superiore di Sanità = Italian National Health Institutes

Letter by D. Marotta to E. Fermi – 16.11.36

I nuovi orizzonti che ha aperto per la terapia dei tumori maligni la possibilità di fabbricare sostanze radioattive artificiali in quantità considerevoli mi fa pensare alla convenienza che l'Istituto di Sanità faccia il possibile per organizzare i mezzi tecnici per tali preparazioni. Prima però di prendere in considerazione il progetto proposto dal Capo del Labratorio di Fisica di questo Istituto desidererei avere il parere di Vostra Eccellenza.

The new vistas opened for tumour therapy by the possibility of producing large quantities of radioactive substances convince me that it is convenient for 'Istituto di Sanità' to procure the technical means for such productions. However , before considering the project proposed by the Chief of the Physics Laboratory (G. C. Trabacchi), I would like to have the opinion of Your Excellency.

Domenico Marotta, Director of Istituto di Sanitá (1936) and the Queen Maria Josè of Savoia

Visits to the States in 1935 and 1936

To obtain information on accelerators

1935: Rasetti went to Pasadena and Berkeley

1936: Segrè went to Berkeley (27-inch cyclotron)

1936: Amaldi went to Columbia and Carnegie Mellon

"Probleme der Atomkernphysik" in Copenhagen
June 1936: Bohr's compound nucleus

Bohr Rosenfeld Amaldi Wick

Pauli Jordan Heisenberg Born Meitner Stern Franck

The “tube” was built on the last floor of Istituto di Sanità

Lecture by Enrico Fermi at Istituto di Sanità Pubblica 29 .5.1938

PROSPETTIVE DI APPLICAZIONE DELLA RADIOATTIVITÀ ARTIFICIALE

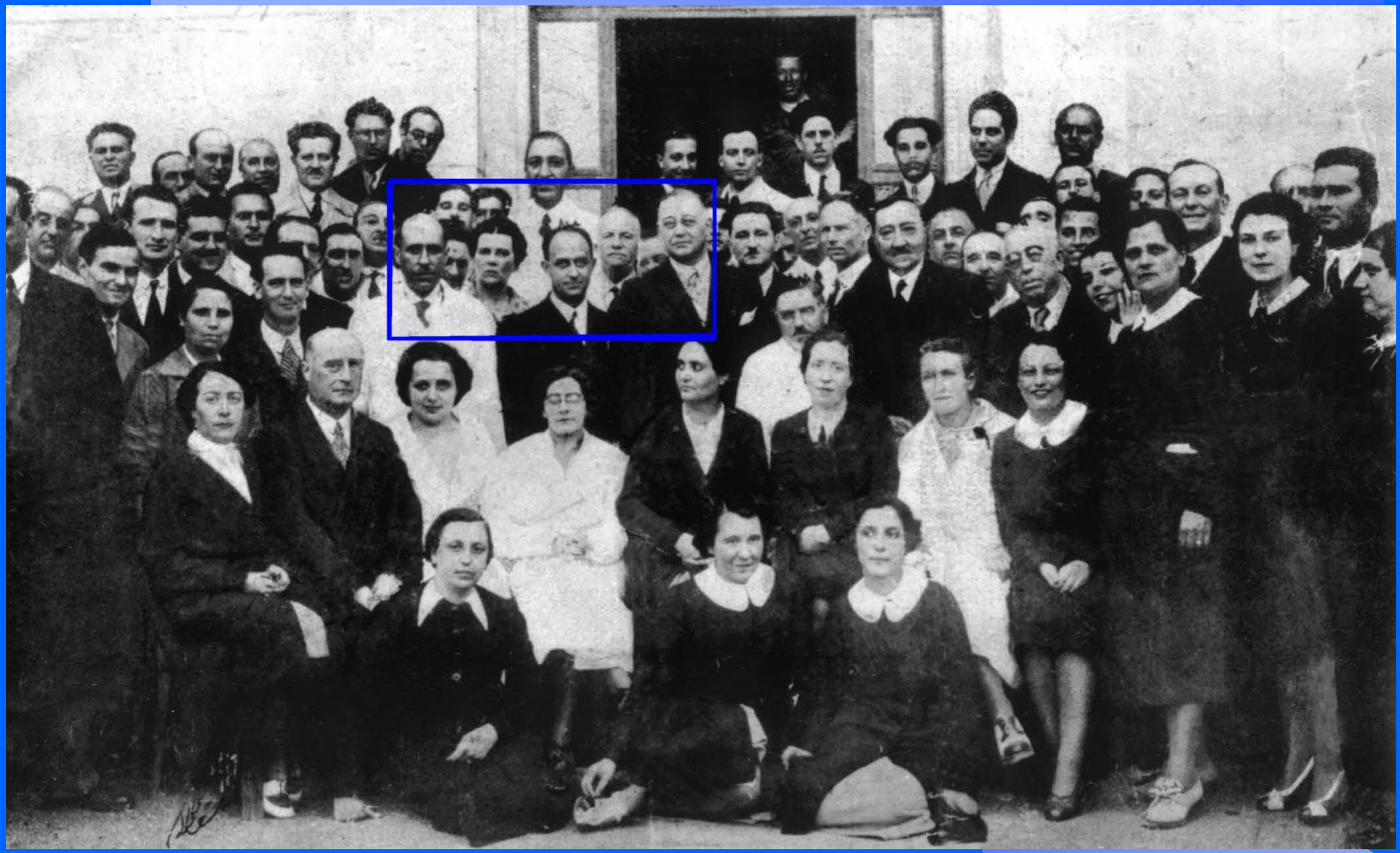
"It can be forseen WITHOUT DOUBTS that the (new) radioactive substances will find THERAPEUTICAL APPLICATIONS similar to the one of natural occurring radioactive substances.

Moreover and independently, the use of large quantities of radioactive substances will open, I HOPE, the way to many interesting studies in biology and chemistry through the use of radioelements as 'INDICATORS' "

È da prevedere senz'altro che le sostanze radioattive artificiali troveranno un impiego terapeutico analogo a quello delle sostanze radioattive naturale.

Ma anche indipendentemente da queste possibilità, l'uso delle sostanze radioattive artificiali in quantità rilevanti renderà possibili, io spero, anche molte interessanti ricerche nel campo della biologia e della chimica, usando i radioelementi come " indicatori".

Lecture by Enrico Fermi at Istituto di Sanità Pubblica 29 .5.1938



G.C. TRABACCHI – E.FERMI – D.MAROTTA

The 1 MeV Cockcroft-Walton

Fotografia d'insieme dell'impianto a 1 milione di volt per la accelerazione di ioni dell'Istituto Superiore di Sanità (Laboratorio Fisico) in Roma.

Built by

Ageno, Amaldi,

Bocciarelli, Trabacchi

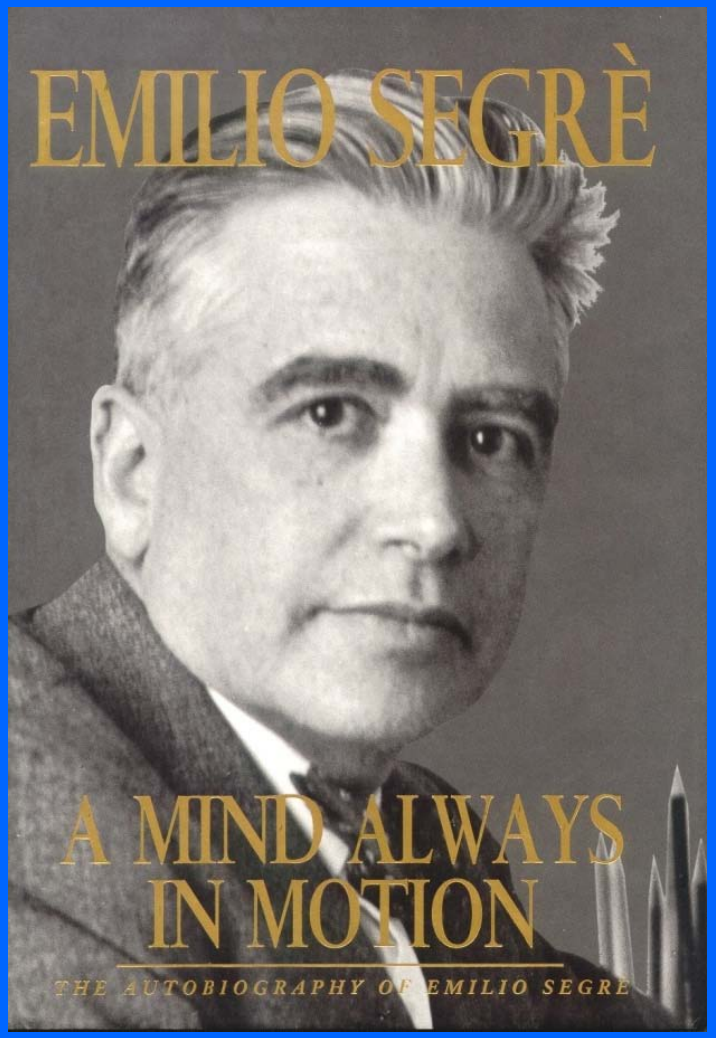
after Fermi left Italy in 1938

Mario Ageno

1947: First test of the optical theorem for neutrons by Bohr et al.

Applications in medical physics

Radioactivity in diagnostics: SPECT = Single Photon Emission Computer Tomography



Emilio Segrè

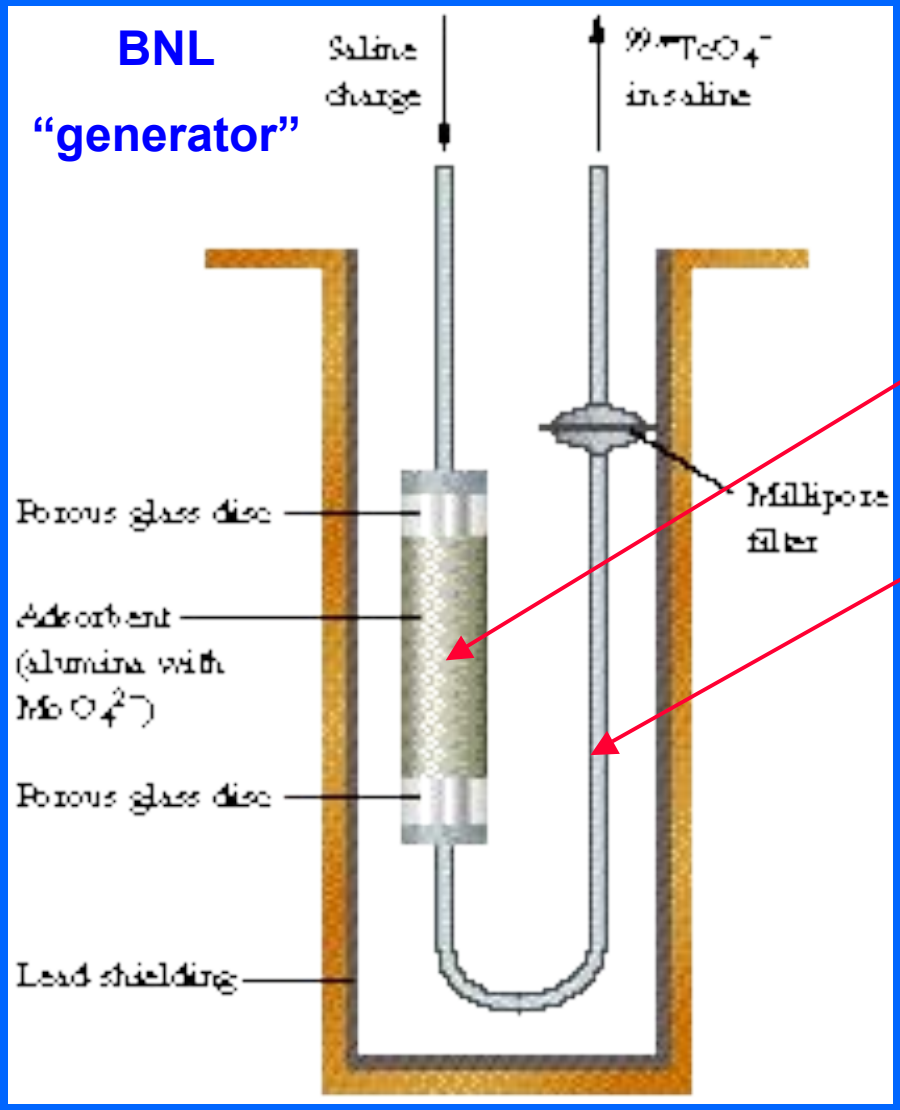
1936: Discovery of technetium with Perrier

1938: discovery of ^{99m}Tc with McMillan

At BNL the « cow » was made productive

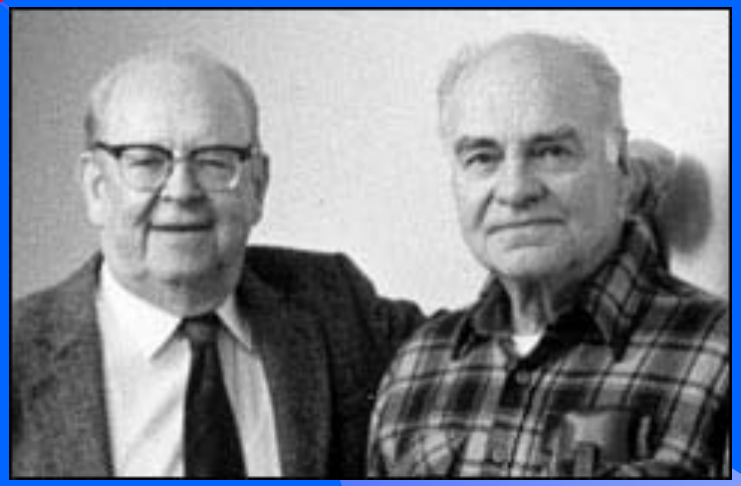
BNL

"generator"



In reactors <u>slow neutrons</u> produce

^{99}Mo (66 h) = ^{99m}Tc (6 h) + e^- + ν



Walter Tucker and Powell Richards

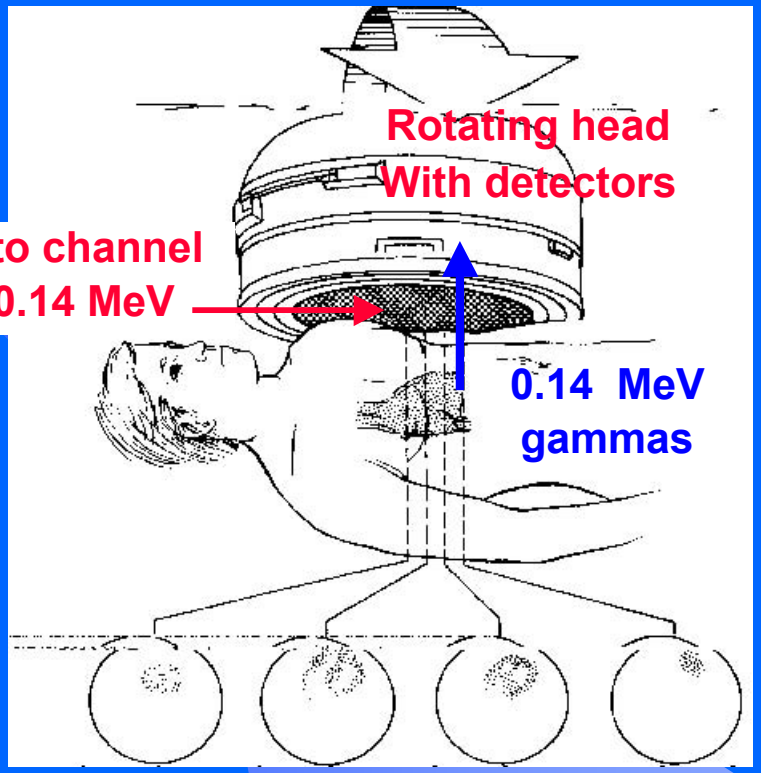
SPECT scanner

85% of all nuclear medicine examinations use technetium produced by slow neutrons in reactors

… liver

lungs

bones ……



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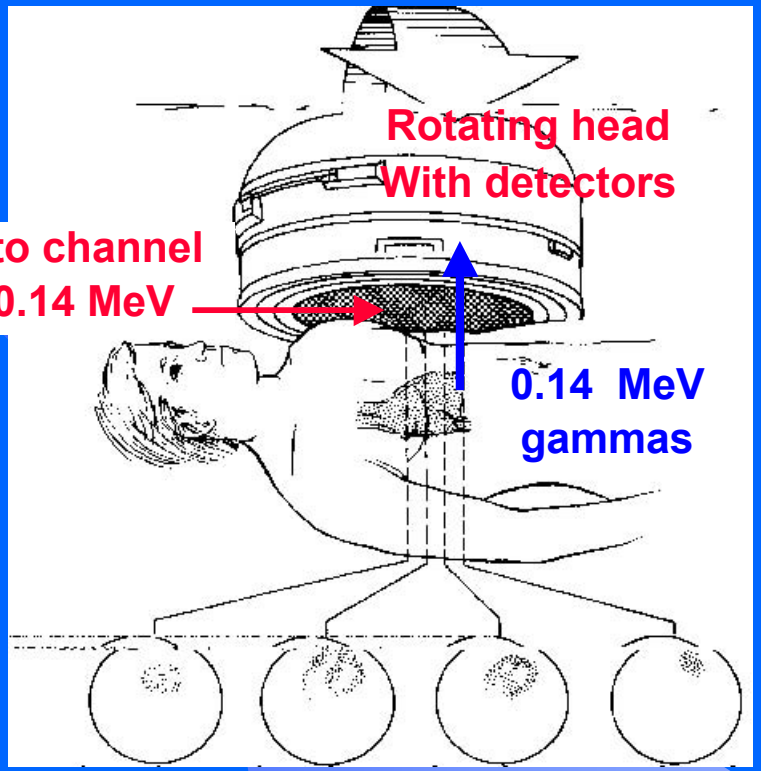


SERIOUS PROBLEM: AGING REACTORS

Radioactivity in therapy: Cobalt-60 gammas spare the skin

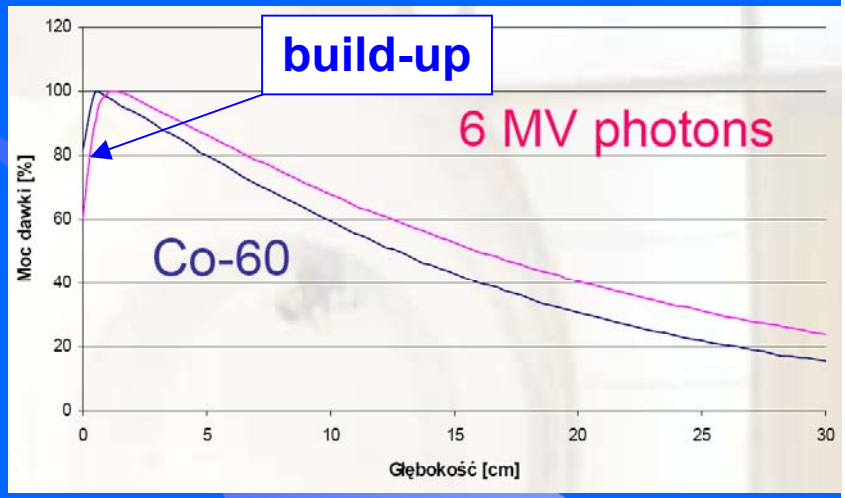
1943 - Bruno Pontecorvo joins the CANDU construction in Canada

1951 – first treatment at Victoria Hospital, London, Ontario

Roy Errington

founder of MDS Nordion

Dr. Ivan Smith

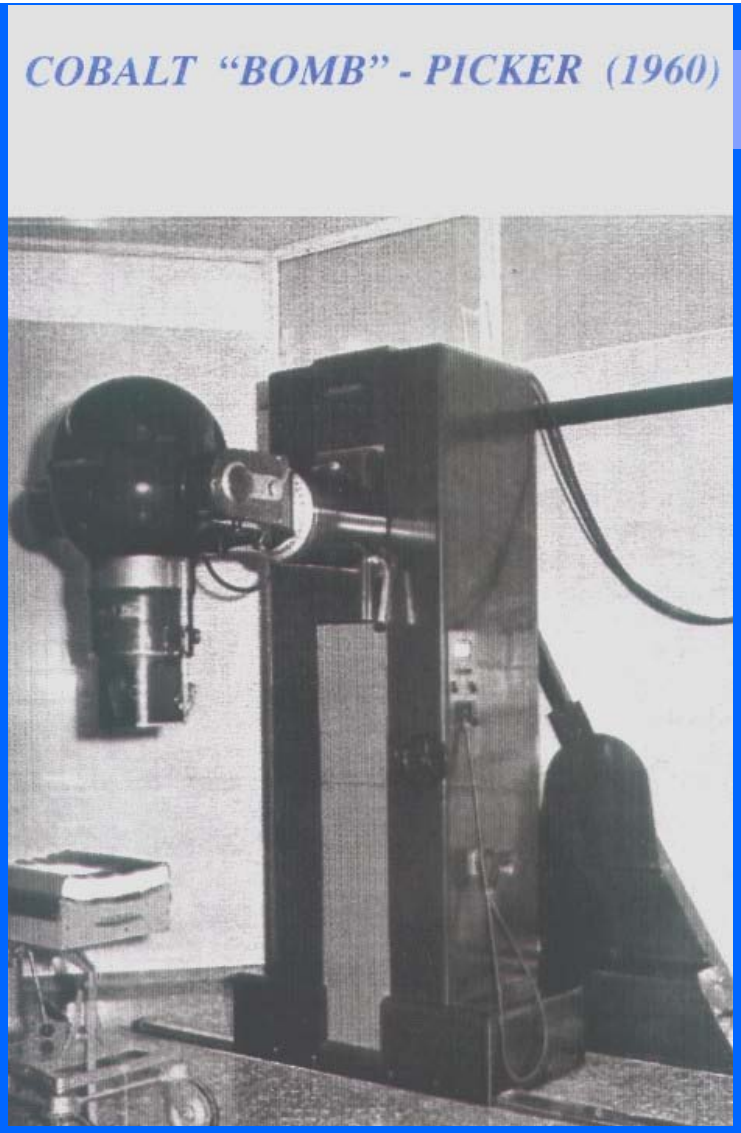


Cobalt-60 (1.1 MeV gammas)

has been produced for 50 years in CANDU reactors

by slow neutrons

Radioactivity in cancer teletherapy



10 million patients treated with cobalt gamma rays

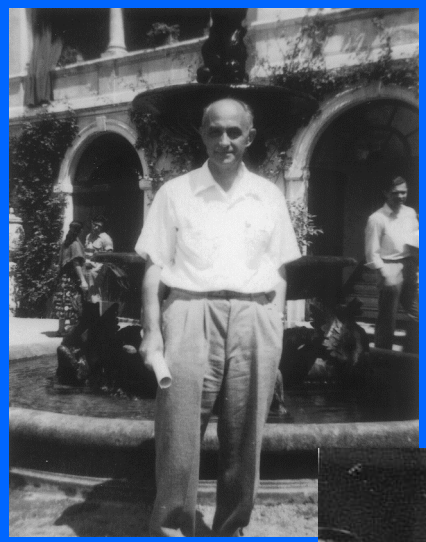
Important for developing countries

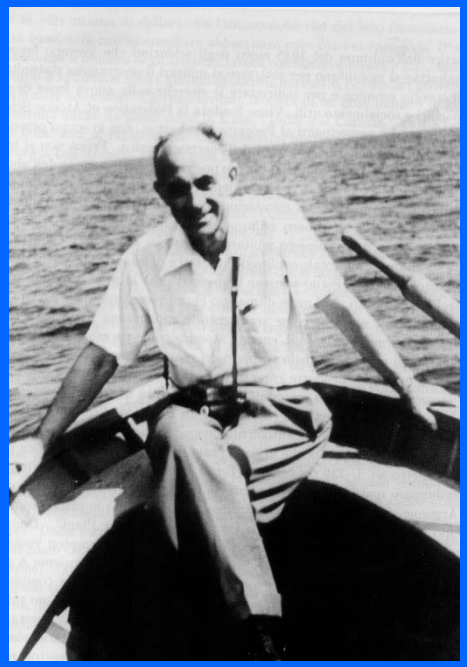
My last recollection of Enrico Fermi

Fermi's last visit to Italy: summer 1954

Varenna School of Phsics – Como lake

Lectures on pions and nucleons





Pera di Fassa - summer 1954