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

Ugo Amaldi

Università Milano Bicocca and TERA Foundation
Photo of a photo

Enrico Fermi at 36

1936

New York, Agosto 1936

Enrico Fermi

Edoardo Amaldi at 80

1988
The discovery of neutron induced radioactivity
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
1934: Fermi discovery was made with a Be-Rn source. Radon extracted at Laboratorio Fisico della Sanità Pubblica.

 Giulio Cesare TRABACCHI

The “Divine Providence”
RADIOATTIVITÀ « BETA » PROVOCATA DA BOMBARDAMENTO DI NEUTRONI. — III.

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

Sono state proseguite ed estese le esperienze di cui alle Note precedenti (1) con risultati che ricordiamo appresso.

Idrogeno — Carbonio — Azoto — Ossigeno. — Non danno 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 Iodio.

Prasodimio. — 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.

The efficacy of slow neutrons
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.”
<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discovery</td>
<td>Saturday</td>
</tr>
<tr>
<td>First paper</td>
<td>Monday</td>
</tr>
<tr>
<td>Patent</td>
<td>Friday</td>
</tr>
</tbody>
</table>

October 1934: discovery of artificial radioactivity induced by slow neutrons

(*) 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
The American patent was deposited on October 3, 1935

“To obtain radioactive substances in quantities of practical importance”

Uranium is explicitly quoted
“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”

Arthur Compton to James Conant:

“The Italian navigator has landed in the New World.”
<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Patent:</td>
<td>3 October 35</td>
<td>Gabriello Giannini &amp; Co. granted</td>
</tr>
<tr>
<td></td>
<td>2 July 40</td>
<td></td>
</tr>
<tr>
<td>Request to the military</td>
<td>14 June 46</td>
<td>Giannini and L. Bernard 0.45 M$</td>
</tr>
<tr>
<td>patent office of ORSD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Request to the civil</td>
<td>13 October 48</td>
<td>Giannini and L. Bernard 1,9 M$</td>
</tr>
<tr>
<td>patent office of USAEC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Event</td>
<td>Date</td>
<td>Inventors</td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>-------------</td>
<td>----------------------------</td>
</tr>
<tr>
<td></td>
<td>2 July 40</td>
<td></td>
</tr>
<tr>
<td>Request to the military</td>
<td>14 June 46</td>
<td>Giannini and L. Bernard</td>
</tr>
<tr>
<td>patent office of ORSD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Request to the civil</td>
<td>13 October 48</td>
<td>Giannini and L. Bernard</td>
</tr>
<tr>
<td>patent office of USAEC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial against USA Government</td>
<td>15 August 50</td>
<td>Giannini and L. Bernard</td>
</tr>
<tr>
<td>Pontecorvo disappears</td>
<td>1 September 50</td>
<td></td>
</tr>
<tr>
<td>November 52: each inventor receives</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Nuclear physics
1935: E. Fermi and E. Amaldi in the Rome Institute

UA:
Nuclear physics from the nineteen thirties to the present day

Springer 2004
1935: E. Fermi and E. Amaldi in the Rome Institute

Amaldi and Fermi worked with enormous energy and concentration for many months \(\ldots\) 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.

UA:

Nuclear physics from the nineteen thirties to the present day
In 1935, E. Fermi and E. Amaldi worked at the Rome Institute. They 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.

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
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 Laboratorio 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 Sanità (1936) and the Queen Maria José 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

Rome - 9.5.11 - U. Amaldi
The “tube” was built on the last floor of Istituto di Sanità
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
The 1 MeV Cockcroft-Walton

Built by
Ageno, Amaldi,
Bocciarelli, Trabacchi
after Fermi left Italy in 1938

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

Mario Ageno
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

In reactors slow neutrons produce

$$^{99}\text{Mo (66 h)} = ^{99m}\text{Tc (6 h)} + e^- + \nu$$

Walter Tucker and Powell Richards
85% of all nuclear medicine examinations use technetium produced by slow neutrons in reactors

... liver
lungs
bones ......

Lead collimators to channel the gammas of 0.14 MeV

Rotating head
With detectors

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

... liver
lungs
bones ......

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 Physics – Como lake

Lectures on pions and nucleons