Enrico Fermi and the Atomic Bomb

By

Maria J. Falco, Ph.D.

Enrico Fermi, born in Rome in 1901, is widely known as one of the "Fathers of the Atomic Bomb" although that was not his primary interest. Surprisingly talented in both experimental and theoretical physics, he frequently arrived at conclusions to very complicated problems in split seconds, sometimes on the backs of envelopes, leaving the proofs to be developed later, if ever. In fact, one of his early Professors at the Scuole Normale Superiore in Pisa, Luigi Puccianti, asked him to organize seminars on quantum physics so that he might learn from Fermi instead of vice versa.

Thus, largely self taught in quantum mechanics, general relativity and atomic physics, Fermi was only seventeen when he was admitted to the Sapienza University in Rome, nineteen when he went to Pisa and twenty when he published his first paper explaining how the mass of an object changes with velocity. His thesis on possible applications of probability theory (sometimes referred to as X-Ray diffraction images) allowed him to graduate (with a Laurea or equivalent of our Doctorate degree) at the surprisingly young age of 21. He followed this up with an

explanation of how hidden inside Einstein's theory of relativity (E=mc2) was such an enormous amount of energy, that, if released, "would smash into smithereens the physicist who had the misfortune to find a way to do it."

In 1924 Fermi studied with Max Born at the University of Goettingen where he met Werner Heisenberg (best known for his formulation of the "uncertainty principle"), then to Leiden where he met Albert Einstein himself. From January 1925 to late 1926 Fermi taught mathematical physics at the University of Florence and applied Wolfgang Pauli's "exclusion principle" to "ideal gas" in a manner similar to that developed by the British Physicist, Paul Dirac, currently known as "the Fermi-Dirac statistics."

In 1926 he applied for and won a professorship at Sapienza University in Rome—a new chair in Theoretical Physics created at the urging of Orso Mario Corbino, the Professor of Experimental Physics there. Eventually Fermi was able to collect a group of students for the Institute of Physics called the "Via Panisperma boys" after the street where the Institute was located.

In 1928 he married Laura Capon and in March of 1929 he was appointed a member of the Royal Academy of Italy by Benito Mussolini and joined the Fascist Party, a move he was later to regret when Mussolini promulgated racial laws in 1938 to approximate those of Nazi Germany. These laws placed Laura, who was Jewish, in great danger and caused

many of Fermi's assistants to be put out of work.

Nevertheless, during his time in Rome, Fermi and his group made many important contributions to both practical and theoretical physics. In 1928 he published his "Introduction to Atomic Physics," a text which provided Italian students with an up-to-date assessment of the topic. He also conducted public lectures and wrote popular articles for students and teachers to spread the knowledge to as wide an audience as possible. Soon foreign students came pouring into Italy to attend his lectures, including Hans Bethe from Germany with whom he collaborated in writing a paper on "The interaction between two electrons" published in 1932.

It was at this time that physicists were searching for an explanation for the phenomenon known as "Beta decay" in which an electron was emitted from an atomic nucleus. In 1933 Fermi postulated that an invisible particle with little or no mass, which he called a "neutrino," was the cause of the difference in mass, a theory which was later called "Fermi's Interaction" and served as one of the "four fundamental forces of nature": the weak force (radioactivity or degrading atomic nuclei), gravity, electromagnetism, and the strong force (binding atomic nuclei together).

That same year the French couple, Frederic and Irene Joliot-Curie, discovered artificial radioactivity caused by projecting alpha particles into helium nuclei. Fermi immediately speculated that the neutron would be a better

projectile and began bombarding more than 60 elements in order to create more radioactive isotopes. He soon realized that slower neutrons were better at creating radioactivity and for what later came to be known as "splitting atoms" (or atomic fission). He also developed a "diffusion equation" to describe this process, which quickly became known as the "Fermi age equation."

In March of 1934 he reported this discovery of "neutron induced radioactivity" in an article in the Italian Journal "La Ricerca Scientifica." And in 1938, at the age of 37, he was awarded the Nobel Prize "for his demonstrations of the existence of new radioactive elements produced by neutron irradiation, and for his related discovery of nuclear reactions brought about by slow neutrons." (The first part of this statement was not entirely accurate, as Fermi pointed out in his acceptance of the Prize.)

It was at this point that Fermi decided to leave Italy in order to prevent the anti-racial laws from affecting the lives of his wife Laura and their two children. Upon leaving Stockholm with the Nobel Prize, he went directly to the United States where he was immediately offered positions at five different universities. He accepted a post at Columbia University in New York where he had already given several summer lectures in 1936. In 1939 he received word through Niels Bohr who was at Princeton at the time, that Otto Hahn and Fritz Strassman had detected the element barium after

bombarding uranium with neutrons, thereby actually producing nuclear fission for the first time and proving Fermi correct in his prediction.

This discovery immediately incited scientists at Columbia to attempt to do the same, and in January of 1939, in the basement of Pupin Hall, an experimental team, including Fermi, conducted the first nuclear fission experiment in the United States. This came to be known as the "Manhattam Project." Soon, similar experiments were conducted all over Europe and elsewhere.

Eventually Fermi and Leo Szilard, using 200 kilograms (440 pounds) of uranium oxide, attempted to produce a self sustaining controlled nuclear reaction with slowed neutrons, realizing that the same neutrons at high speed could produce an uncontrolled chain reaction resulting in the production of enormous amounts of energy (E=mc2) within a fraction of a second: an atomic bomb! So they began by experimenting with various arrangements of neutron sources and pieces of uranium with control rods of varying materials to slow or stop the reaction.

Fermi tried to get the Navy interested in these experiments but his restrained explanations got him only a tiny grant. It took a letter from Einstein himself to President Franklin D. Roosevelt in the summer of 1939 about the importance of an atomic bomb, for the project to eventually get substantial funding. Slowly, Fermi built a series of "piles" of uranium

interspersed with different slowing materials to see which worked best to achieve a sustained chain reaction or permanent "nuclear reactor."

When Japan bombed Pearl Harbor in December of 1941 drawing the United States into World War II, the importance of the development of a possible Atomic Bomb became ever more obvious. At the urging of Arthur Compton, head of the S-1 Committee to oversee the project, Fermi moved to the University of Chicago where he continued to build his "piles" in a squash court beneath Chicago stadium, or football field.

The final structure was a "flattened sphere" about 7.5 meters (25 feet) in diameter containing 350 tons of graphite blocks to slow or stop the speed of neutrons in six tons of uranium metal and 40 tons of uranium oxide as the fuel, in a carefully devised pattern. Finally, on December 2, 1942, the pile went "critical" thereby showing that a nuclear reaction could be created, controlled and/or stopped, as necessary. This was called "Chicago Pile-1," the first self-sustaining nuclear reactor ever built.

On hearing of the results, Compton made a coded phone call to James B. Conant, the Chairman of the National Defense Research Committee, saying: "Jim…you'll be interested to know that the Italian navigator has just landed in the new world…The earth was not as large as he had estimated, and he arrived at the new world sooner than he had expected

(about a week ahead of time)." Conant replied: "Is that so? Were the natives friendly?" to which Compton responded, "Everyone landed safe and happy."

To eliminate the possibility that this project might become a health hazard to the people of Chicago, the reactor was carefully disassembled and moved to Argonne Woods, not far from Fermi's home. Initially part of the University of Chicago, it became a separate entity with Fermi as its Director in 1944.

Another reactor, air-cooled, went critical at Oak Ridge, Tennessee in November of 1943, with Fermi present to ensure that nothing went wrong. It produced the first small quantities of reactor-bred plutonium to make even more effective the process of nuclear fission.

Fermi became a citizen of the United States in 1944, and a month later was invited to insert the first uranium "fuel slug" into the B Reactor at Hanford, Washington, designed by Fermi's team and built by DuPont, to breed plutonium in large quantities. Shortly afterwards, J. Robert Oppenheimer persuaded him to join him in his "Project Y" as Associate Director of the "F Division" (named for him) at Los Alamos, New Mexico. This division had four components: F-1 to investigate Super and General Theory to lead to a "Super" thermonuclear bomb; F-2 which investigated the "water boiler" research reactor; F-3, "Super Experimentation"; and F-4"Fission Studies."

In July of 1945 Fermi became a Professor at the University of Chicago and observed the "Trinity" test of the first Atomic Bomb at White Sands New Mexico. He became part of the scientific panel that advised the interim committee for target selection. The panel as a whole agreed that such bombs should be used without warning on industrial targets. In August Fermi heard of the bombings of Hiroshima and Nagasaki over a public address system. But since Fermi did not believe that atomic bombs would prevent nations from going to war, nor that the time for world government had come, he did not join the Association of Los Alamos Scientists.

In 1946 Fermi's Metallurgical Laboratory became the Argonne National Laboratory, the first to be established by the Manhattan Project. Since Chicago and Argonne were just a short distance apart, Fermi was able to teach at the university and continue his work on experimental physics at the same time. When the Manhattan Project was replaced by the Atomic Energy Commission in 1947, Fermi served on the General Advisory Committee chaired by Oppenheimer.

When the Soviet Union detonated its first fission bomb in 1949, Fermi joined with others in opposing the development of a pure fusion bomb on moral as well as technical grounds. Even if possible to develop, the General Advisory Committee argued, its use would amount to the "practical effect of genocide." Nevertheless, the United States went forward

with the development of the Hydrogen or "H-Bomb" designed by Edward Teller and Stanislaw Ulam, in 1951.

Fermi continued teaching at Chicago, and eventually wrote a paper "On the Origin of Cosmic Radiation," in which he proposed that cosmic rays were produced by "material being accelerated by magnetic fields in interstellar space." He also wondered about the contradiction between the "presumed probability of the existence of extraterritorial life and the fact that no contact has been made," now referred to as the "Fermi Paradox:" "Where is everybody?" he asked. At one point he speculated that the answer might be the result of nuclear annihilation.

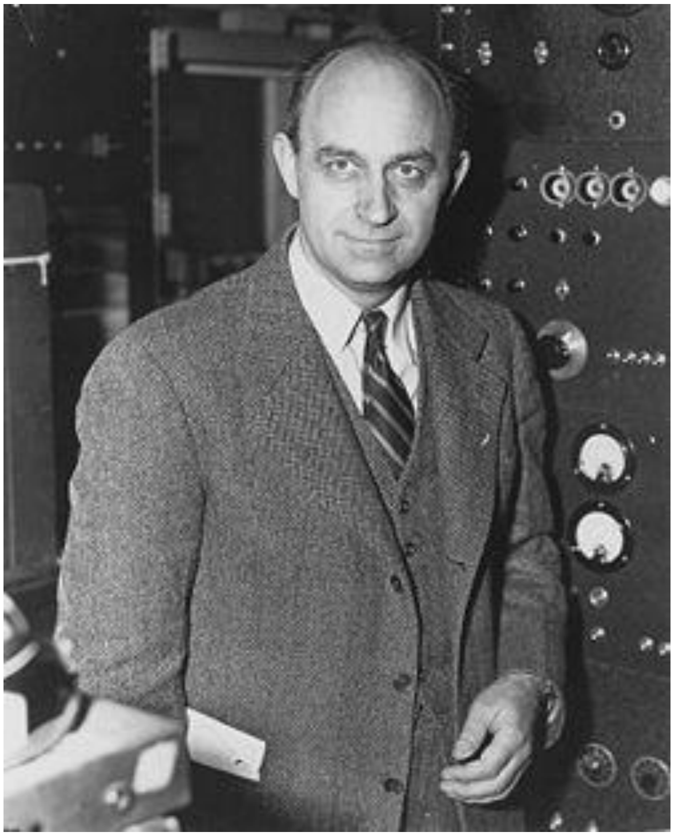
Toward the end of his life he questioned whether society in the future might be able to make wise choices concerning nuclear technology. The history of science and technology, he said, "have taught us that scientific advances in basic understanding have sooner or later led to technical and industrial applications that have revolutionized our way of life. It seems to me improbable that the effort to get at the structure of matter should be an exception to this rule. What is less certain, and what we all fervently hope, is that man will soon grow sufficiently adult to make good use of the powers that he acquires over nature."

Fermi died at the age of 53 of stomach cancer at his home in Chicago and was buried at Oak Woods Cemetery. His life has nevertheless been commemorated for all time at the

Basilica of Santa Croce in Florence, Italy, by the erection of monument in his honor, and the city of Rome has named a street after him. In 1974 the "Fermilab particle accelerator" and physics lab in Batavia, Illinois were re-named in his honor. In 2008 the "Fermi Gamma-ray Space Telescope was named for him in recognition of his work on cosmic radiation. In addition, three nuclear reactor power plants have been named for him: Fermi 1 and 2 in Newport Michigan, the Enrico Fermi Nuclear Power Plant at Trino Vercellese in Italy, and the RA-1 Enrico Fermi research reactor in Argentina. Two synthetic elements isolated in 1952 from the Ivy Mike nuclear test were created and named the "fermium," and the "einsteinium."

And in 1956 the United States Atomic Energy Commission named its highest honor the "Fermi Award," with early recipients being J. Robert Oppenheimer, Otto Hahn, Edward Teller, and Hans Bethe.

August 6th and 9th of 2015 marked the seventieth anniversaries of the dropping of the Atomic Bomb on Hiroshima and Nagasaki in Japan.



Enrico Fermi

Trinity, the First Atomic Bomb