Elementary Particles.

Enrico Fermi and Luisa Bonolis

Citation: Am. J. Phys. **81**, 397 (2013); doi: 10.1119/1.4790806
View online: http://dx.doi.org/10.1119/1.4790806
View Table of Contents: http://ajp.aapt.org/resource/1/AJPIAS/v81/i5
Published by the American Association of Physics Teachers

BOOK REVIEWS

The downloaded PDF for any Review in this section contains all the Reviews in this section.

Craig F. Bohren, *Editor*

Pennsylvania State University, University Park, Pennsylvania 16802; mailing address: P.O. Box 887, Boalsburg, PA 16827; bohren@meteo.psu.edu

Elementary Particles. Enrico Fermi. 132 pp. Yale U.P., New Haven, CT, 2012. Price: $16 (paper) ISBN 978-0-300-18318-4. (Luisa Bonolis, Reviewer.)

The best way to learn physics is to learn from the best physicists. In earlier times, it was part of the intellectual activity of scientists to study the works of their predecessors. Einstein himself mentions in his autobiography his interest in many leading figures of 19th century physics, and his constructive criticism was rooted in a deep knowledge of the scientific literature of the past—notably the works of Galileo, Newton, Maxwell, Lorentz—as well as, for example, in his reflections on Ernst Mach's writings. Yet this habit gradually disappeared, partly owing to increased pressure caused by the acceleration and growing specialization of physics driven by a new strong competitive spirit especially characteristic of post-war research. All this has left less time for curiosity about other branches of physics and generally resulted in a lack of interest in reflection on the development of concepts and ideas of the past.

Enrico Fermi, who was in his time among the guiding spirits of the most active fields of physics (nuclear physics and elementary particle physics), is certainly a figure whose work is still deserving of special attention in this sense. His achievements included the theory of the perfect monatomic gas as a quantized mechanical system, a masterpiece like his theory of beta-decay, as well as well as the experimental discovery of radioactivity produced by neutrons and the realization of the first self-sustained and controlled nuclear chain reaction in 1942. Both a great theorist and a great experimentalist, Fermi was a complete physicist from the very beginning, even being a complete autodidact. His career as a teacher started when he was a student in Pisa between 1918 and 1922 and he taught his own professors the new quantum physics, which in Italy was nearly unknown at the time. When in 1926 he was elected to a professorship of theoretical physics in Rome, the first core of an Italian school of modern physics took shape around him.

Fermi was accustomed to rederiving everything in his own way. For example, during the winter 1928–1929, after the appearance of Dirac's works systematically extended to electromagnetic fields the rules for quantizing mechanical systems, Fermi recast Dirac's theory in a form mathematically more familiar to him. In this early stage, he did not study Pauli's and Heisenberg's papers on quantum electrodynamics (QED) nor was he very familiar with the formalism of second quantization. While doing this work, Fermi taught his results to several of his pupils and friends in Rome, especially in lectures delivered at the Institut Henri Poincaré in Paris and at Ann Arbor during the summer of 1930. His simple, visualizable way of describing the interactions between photons and charged particles was a typical example of his pragmatism and lack of interest in abstract conceptual questions, which he conveyed in his famous 1932 *Reviews of Modern Physics* article, "On the Quantum Theory of Radiation," an exposition of unsurpassable clarity. It came after a number of quite complicated papers and was followed by another set of complicated papers on the subject, so that it was from Fermi's formulation of QED that an entire generation learned how to think about quantum-electrodynamical effects in atomic phenomena. These studies were an important prelude to his 1933 theory of beta-decay, which he formulated in analogy with QED: electrons observed in beta-decay acquire their existence at the very moment they are emitted and cannot be considered as preexisting in the atom prior to emission by radioactive elements. The same happens in the case of a quantum of light, which can in no way be considered as preexisting in the atom prior to emission caused by a quantum jump. It was typical of Fermi that when he discovered a new method, he often applied it later to problems that looked quite different from the one that had originated the method itself.

As many of his contemporaries often remarked, Fermi made little, if any, distinction between teaching and research. His famous power of finding a simple and clear physical model for understanding a seemingly complicated idea can be seen in his papers as well as in his lectures. From him a whole generation learned his pragmatic outlook about theoretical physics, his concrete approach to things, and his capacity for reducing the most complex problems to their essentials and solving them, for the most part, using original approximate mathematical methods which were exactly those most suited to finding the solution to the problem. He had considerable mathematical skill but disregarded the use of unnecessary elaborate mathematics. Since his early contributions, Fermi broke with the traditional mathematical physics, practiced at the highest level by some Italian mathematicians, and followed a typical phenomenological approach characterized by his extraordinary capacity of building concrete and effective models of phenomena, which later became a traditional characteristic feature of Italian theoretical physics. According to Hans Bethe, who visited Rome in 1931–1932, his contact with Fermi changed his whole style of doing physics, weaning him from the formal structure of most European universities. He actually considered Arnold Sommerfeld—notably the unsurpassed master of a whole generation of German physicists—and Fermi, as equal mentors.

In a characteristic fashion, for each topic Fermi always started from the beginning, treating simple examples and avoiding as much as possible complicated formalisms, which he jokingly said were for the "high priests." Both students and more mature physicists were fooled by the apparent simplicity of Fermi's reasoning, and only when they abandoned his guide and moved alone following a similar train of thought did they realize that they had been masterfully led through an impervious maze without being aware of the underlying complexity.

His teaching was in fact the fruit of careful preparation and of deliberate weighing of different alternatives of presentation. Like many great masters, Fermi derived pleasure from the very act of teaching and never showed annoyance at student's failure to grasp on the first try what he was trying to explain. His lectures had an almost hypnotic effect even on more experienced physicists, who derived a special pleasure from seeing an accustomed landscape from the viewpoint of a soaring eagle, appreciating all the important points.

As an experimental physicist, Fermi always started off in the right direction. His systematic work leading step-by-step to the opening of the nuclear age at the end of 1942 was done, as usual, by setting aside the irrelevancies, seizing all the essentials, and proceeding to the core of the matter. When he joined the secret Los Alamos Laboratories in 1944, Fermi served mainly as a super-consultant, a sort of oracle to whom any physicist could appeal. There was no limit to the variety of problems that were brought to him and usually solved.

Since the war years, Fermi strongly felt the necessity of shifting to high-energy nuclear physics to keep at the frontiers of research. When he returned to Chicago after the war, a rumor spread that Fermi was about to create a new school of physics, and a group of extraordinary students gathered at the Institute for Nuclear Studies. Among them, Chen Ning Yang, Tsung Dao Lee, Jack Steinberger, Owen Chamberlain, and Jerome I. Friedman would later be awarded Nobel Prizes. It can in fact be safely assumed that the first great contribution Fermi gave to elementary particle physics was the Chicago School of Physics he created.

While he got more and more involved in his activity as a teacher and, as he later said, as a "student" of the new theoretical physics, he was anxiously waiting the beginning of operation of the Chicago synchrocyclotron, which for a few years would be the highest energy accelerator in the world. It was actually built with the idea that Fermi would be its principal user. In the meantime, due to the limitations of the available theoretical knowledge, he made a determined effort to calculate all that was possible on the basis of all that was known. This work was useful as a qualitative guideline in the preliminary planning of experiments. Traces of this activity are in the Silliman Lectures on elementary particles that he gave at Yale University in April 1950, both for physics students and the general public.

By the end of the 1940s and beginning of the 1950s, during many years of work in the field of nuclear physics, Fermi had highly refined his special gift for representing physical reality through the intermingling of empirical data, plausibility arguments, and analogies. The six lessons given to physics students were rewritten and amplified to make them accessible to a larger number of students and, as Fermi hoped, "to a large fraction of experimental physicists." As stressed in Fermi's foreword written in September 1950, the presentation of the most significant results of the field theories of elementary particles could be understood "at least in a semi-quantitative way, without excessive mathematical apparatus."

The appearance of a new edition of his *Elementary Particles*, based on the Silliman Lectures now provides a great opportunity for reading what today can be considered a classic of physics literature, giving a glimpse of Fermi's unique style of making physics, always built from the ground up, brick by brick, leaving abstractions at the end, only after detailed foundation work has been done. The foreword by Yale University physicist Thomas Applequist is a perfect complement in providing a key to put the text in due historical perspective, skillfully tying research in Fermi's time to the extraordinary developments of the field during the following sixty years.

Physics *is* history and history *is* physics, there is no real distinction—good physics of the past has simply become a classic of scientific literature. Physicists should be more aware of having a special privilege: enjoy the pleasure of reading some of the fundamental works of 20th century physics and feel something similar to the emotion evoked by a beautiful poem.

Reading the Silliman Lectures, a great model of transparent and simple organization of the most important concepts of particle physics in Fermi's time, may thus represent still today a valuable guide, a sort of training ground for young researchers and students, and especially an intellectual challenge for more mature physicists and historians who should try to take up the challenge of analyzing Fermi's secret underlying his masterly way of presenting physics facts and ideas.

Luisa Bonolis is a researcher at Max Planck Institute for the History of Science. She is the co-editor (with Carlo Bernardini) of Enrico Fermi: His Work and Legacy. Her research focuses on the history of 20th century physics.

BOOKS RECEIVED

The Long Road to Stockholm: The Story of Magnetic Resonance Imaging (MRI): An Autobiography. Sir Peter Mansfield. 251 pp. Oxford U. P., Oxford, UK, 2013. Price $44.95 (hardcover) ISBN 978-0-19-966454-2.

The Quantum Divide: Why Schrödinger's Cat is Either Dead or Alive: Nature's Algorithms for Learning and Prospering in a Complex World. Christopher C. Gerry and Kimberly M. Bruno. 206 pp. Oxford U. P., Oxford, UK, 2013. Price $44.95 (hardcover) ISBN 978-0-19-966656-0.

INDEX TO ADVERTISERS