



Rendiconti
Accademia Nazionale delle Scienze detta dei XL
*Memorie e Rendiconti di Chimica, Fisica,
Matematica e Scienze Naturali*
142° (2024), Vol. V, fasc. 3, pp. 245-250
ISSN 0392-4130 • ISBN 978-88-98075-63-8

Particle Physics Courses in Florence and Milan: A Tribute to an extraordinary Professor¹

SAVERIO BRACCINI

Albert Einstein Center for Fundamental Physics (AEC), Laboratory for High Energy Physics (LHEP), University of Bern, Switzerland
E.mail: saverio.braccini@unibe.ch • ORCID:0000-0002-6212-897X

Abstract – This paper summarizes the talk I delivered at the “Symposium to celebrate Ugo Amaldi’s 90th birthday”, held at CERN in April 2025 [1]. I was deeply honoured to speak on this occasion, and I approached this task as a representative of the many students who had the good fortune to attend Ugo’s lectures in Florence and Milan. Most of them immediately recognised in him not only an extraordinary professor, but also a mentor and a guide. I was one of his students in the only particle physics course he taught at the University of Florence in the academic year 1991-1992. This experience was unforgettable, and I will focus mainly on it as an example of his remarkable ability to inspire young generations with the beauty of physics and the value of its applications.

Keywords: Ugo Amaldi, Particle physics education, University of Florence, University of Milan

Riassunto – Questo articolo riassume l’intervento che ho tenuto al “Simposio per celebrare il novantesimo compleanno di Ugo Amaldi”, svoltosi al CERN nell’aprile 2025. È stato per me un grande onore parlare in questa occasione, e ho interpretato questo compito come rappresentante dei molti studenti che hanno avuto la fortuna di seguire le lezioni di Ugo a Firenze e a Milano. La maggior parte di loro ha riconosciuto immediatamente in lui non solo un professore straordinario, ma anche un mentore e una guida. Sono stato uno dei suoi studenti nell’unico corso di fisica delle particelle che tenne all’Università di Firenze nell’anno accademico 1991-1992. Questa esperienza fu indimenticabile, e mi concentrerò soprattutto su di essa come esempio della sua straordinaria capacità di ispirare le giovani generazioni alla bellezza della fisica e al valore delle sue applicazioni.

Parole chiave: Ugo Amaldi, didattica della fisica delle particelle, Università di Firenze, Università di Milano

¹ This peer reviewed article originates from contributions to the “Symposium for Ugo’s 90 years” held at CERN (Geneva) on the 4th of April 2025 to celebrate the 90th birthday of Ugo Amaldi, member of the Accademia dei XL since 1992.

Introduction

In November 1991, I was an undergraduate physics student at the University of Florence. During the previous academic year, I had taken a course in experimental particle physics taught by Professor Annamaria Cartacci, and I had become fascinated by the subject. One year later, Professor Cartacci approached me and another student from her course as we were climbing the steep stairs leading to the Physics Institute in Arcetri (Fig. 1, left). She told us that an exceptionally talented and renowned new professor had just joined the physics department. She strongly encouraged us to attend his course in experimental particle physics, even if we would not receive a grade for it. She said: he is more than a professor; he is a master! (*“È più che un professore, è un maestro!”*, in Italian) We were not particularly enthusiastic at first, but we accepted her proposal. From the very first lecture given by Ugo Amaldi, it became clear that Professor Cartacci had been absolutely right: we were immediately captivated by his teaching style and by his attitude toward students.

Professors in those days had quite a detached attitude, but this professor was different and special. Sometimes when we had questions, he often answered by saying: “let me study this in more detail and next week we can have a sandwich together!” (*“Ci facciamo un panino insieme!”*, in Italian). The physics institute in Arcetri had a nice cloister (Fig. 1, right) where we had unforgettable discussions not only about physics. Professor Amaldi was traveling from CERN to Florence and back every week but, in spite of his very busy life and schedule as a spokesman of the Delphi Collaboration at CERN for the Large Electron-Positron Collider (LEP),

he was always punctual in providing to the students precise printed notes ahead of his lectures (Fig. 2) [2].

In the final lecture of the course, he told us that he wanted to teach us something very important. Physics not only enables us to understand the detailed mechanisms that govern nature, such as the fundamental interactions, but it can also be used for very practical and significant purposes, including the treatment of cancer. In this fascinating lecture, he introduced us to hadron therapy and emphasized that “physics is beautiful and useful”, as he still says today. I did not know at the time that Ugo was in the process of creating the Foundation for Oncological Hadrontherapy (TERA) in those very months, but that last lecture remained engraved in my mind, along with my profound interest in the medical applications of particle physics. His course given in Florence in the academic year 1991-1992 changed my life!

1. The particle physics course at the University of Florence (1991-1992)

The particle physics course that Ugo taught in Florence was titled “Phenomenology of Fundamental Interactions” (*“Fenomenologia delle interazioni fondamentali”* in Italian). It had an original structure and relied on a distinctive teaching methodology that has continually inspired my own courses: the “wall-painting” technique, reported on the first page of the lecture notes (Fig. 2, left). Just as one paints a black wall white by applying multiple layers (*“mani”*, in Italian), knowledge too can be built through successive layers. Building knowledge is a continuous process, Ugo always remarked. Indeed,



Fig. 1. The long, steep stairway (left) and the cloister (right) of the Physics Institute in Arcetri, on the hills surrounding Florence. This building now hosts the Galileo Galilei Institute for Theoretical Physics.

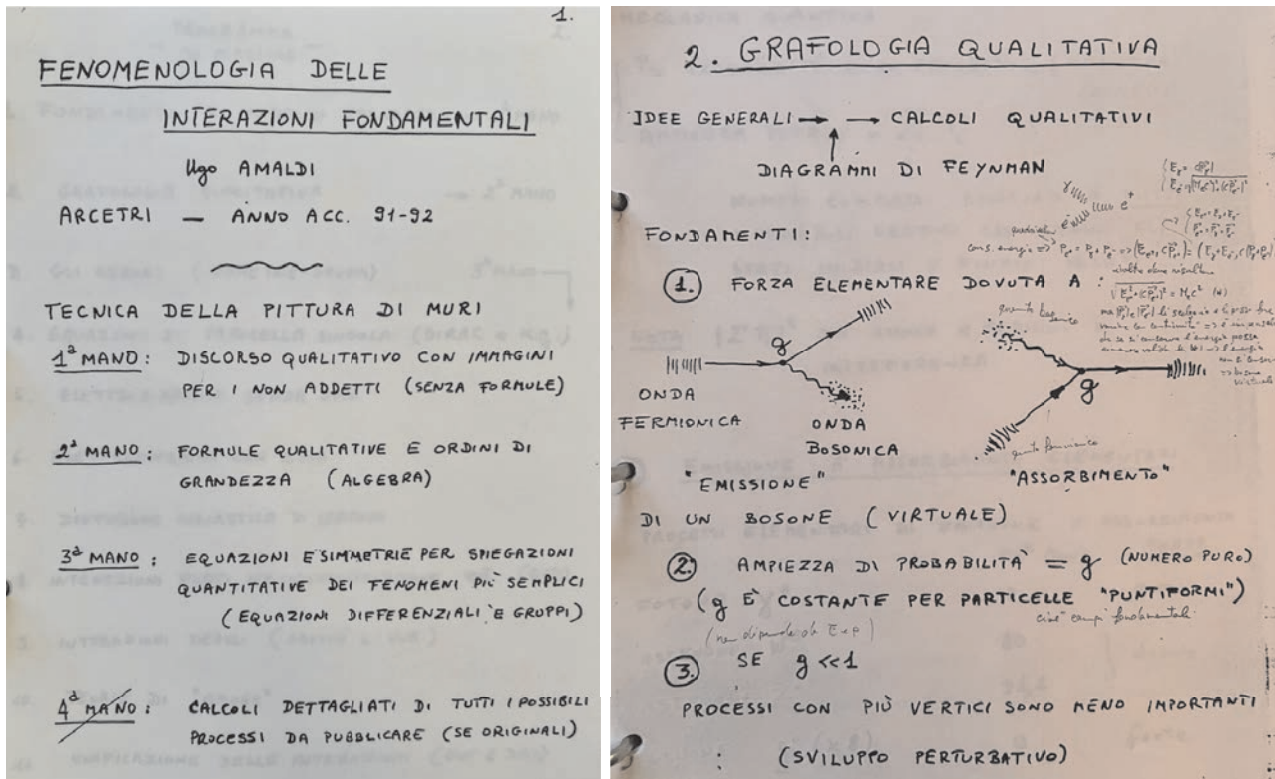


Fig. 2. The first slide of the particle physics course entitled “Phenomenology of Fundamental Interactions” (“*Fenomenologia delle interazioni fondamentali*”, in Italian) (left) and the first page of the section on “Qualitative graphology” (“*Grafologia qualitativa*”, in Italian).

he managed to achieve this goal with remarkable clarity, effectively “painting” physics into our minds.

The first layer consisted of a qualitative overview of all the subjects in the course, presented mainly through images and graphs. It served as an introduction that could have been understood even by the general public. This was a very effective way to capture students’ interest and convey Ugo’s contagious enthusiasm. The main goals were outlined simply and directly, enabling students to grasp the purpose of the course and to keep it in mind even when complex equations and calculations arose later on.

The second layer was perhaps the most original and, in my view, the most important. Using simple calculations based on dimensional analysis and only a few fundamental constants, one could derive the correct orders of magnitude for phenomena such as muon decay or electron-positron interactions directly from Feynman diagrams. This is what Ugo called “Qualitative Graphology” (“*Grafologia qualitativa*”, in Italian) (Fig. 2, right). This method is remarkably powerful and helps guiding students to the very essence of particle-physics phenomena.

The third layer consisted of a more traditional parti-

cle physics course, involving equations and quantitative calculations. Hadron physics, electrodynamics, deep inelastic scattering, strong and weak interactions, and gauge theories formed the core of this part devoted to the Standard Model.

Although not formally part of the course, Ugo warned us that there is a fourth layer, consisting of far more detailed and advanced calculations. This level of understanding is the realm of active research. This is another important hallmark of Ugo’s teaching: bringing the most recent developments in scientific research to his students, who – as we all know, but sometimes forget – will be the ones driving science forward in the future. Moreover, Ugo always emphasized that publishing original results is essential for the progress of both science and society.

The complete set of lecture notes comprised about 300 handwritten slides, which I still keep in my office and often consult. In preparing this talk, I even found my university “*Libretto*”, the small booklet in which all courses, grades, and professors’ signatures were recorded. Interestingly, for bureaucratic reasons, Ugo’s course was officially titled “Nuclear Measurements” (“*Misure*

nucleari", in Italian). This was the only particle-physics course Ugo taught in Florence, as he moved to the University of Milan the following academic year.

2. Particle physics courses at the University of Milan (1993-1996)

Before being appointed full professor in Florence, Ugo had taught at the School of Medical Physics in Milan from 1982 to 1991. It was there, during breaks spent discussing with Giampiero Tosi, that the idea of building a hadron-therapy centre in Italy first emerged. Together, they wrote the seminal paper "*For a centre for teletherapy with hadrons*" [3], which marked the beginning of a long journey that ultimately led to the establishment of the Italian National Centre for Cancer Hadrontherapy (CNAO), now operating in Pavia.

The particle-physics course at the University of Milan was an expanded version of the one he had taught in

Florence and was offered over three consecutive academic years. It was titled "*Fisica superiore*" (Fig. 3, left). Additional chapters covered particle accelerators, interactions of particles with matter, and particle detectors. The complete set of lecture notes comprised more than 500 handwritten slides [4].

3. Medical applications of physics courses at Milano-Bicocca University (1996-2006)

In the following years, and up until 2006, Ugo taught – together with Sandro Rossi – a course on medical applications of physics at the Milano-Bicocca University. In some years, the course was accompanied by a laboratory component, for which I once served as an assistant. We would travel from Geneva to Milan and back on the same day. I will never forget the lively discussions about physics and society that we had on the train in the early morning and in the late evening.

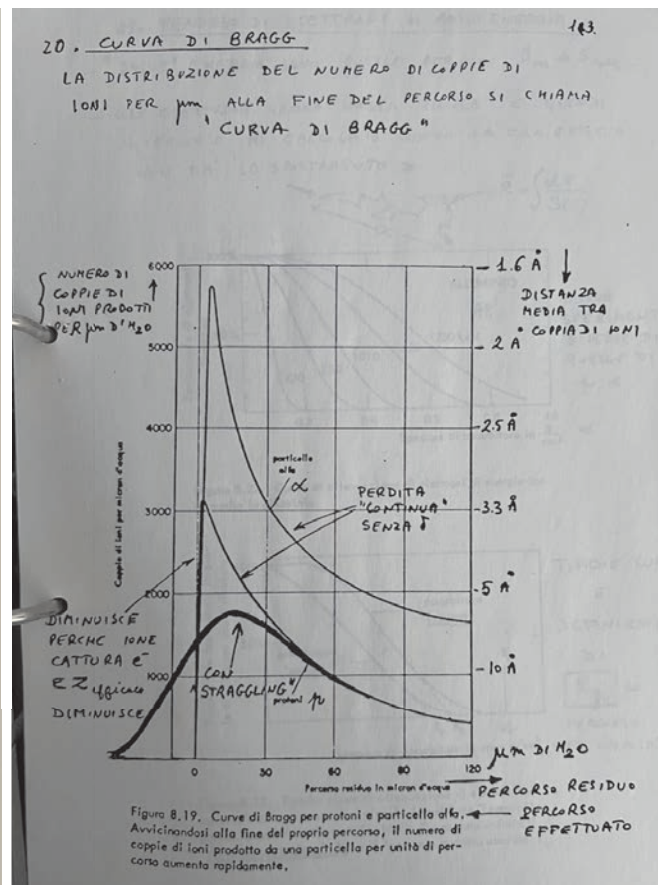
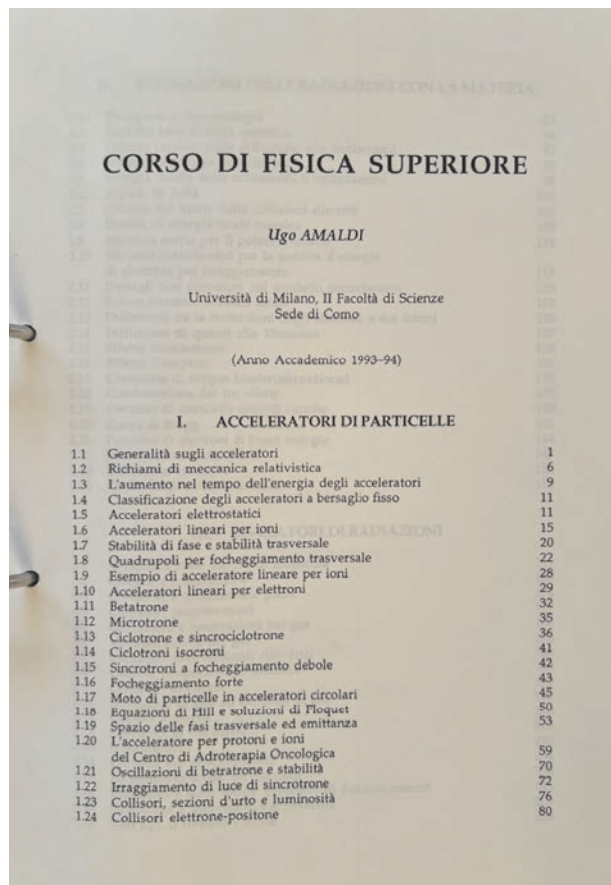


Fig. 3. The first slide of the course on particle physics given at the University of Milan in the academic year 1993-1994 (left). The Bragg curve taken from the lecture notes of the course on medical applications of physics given at Milano-Bicocca University (right). The plot is taken from Ref. [5].

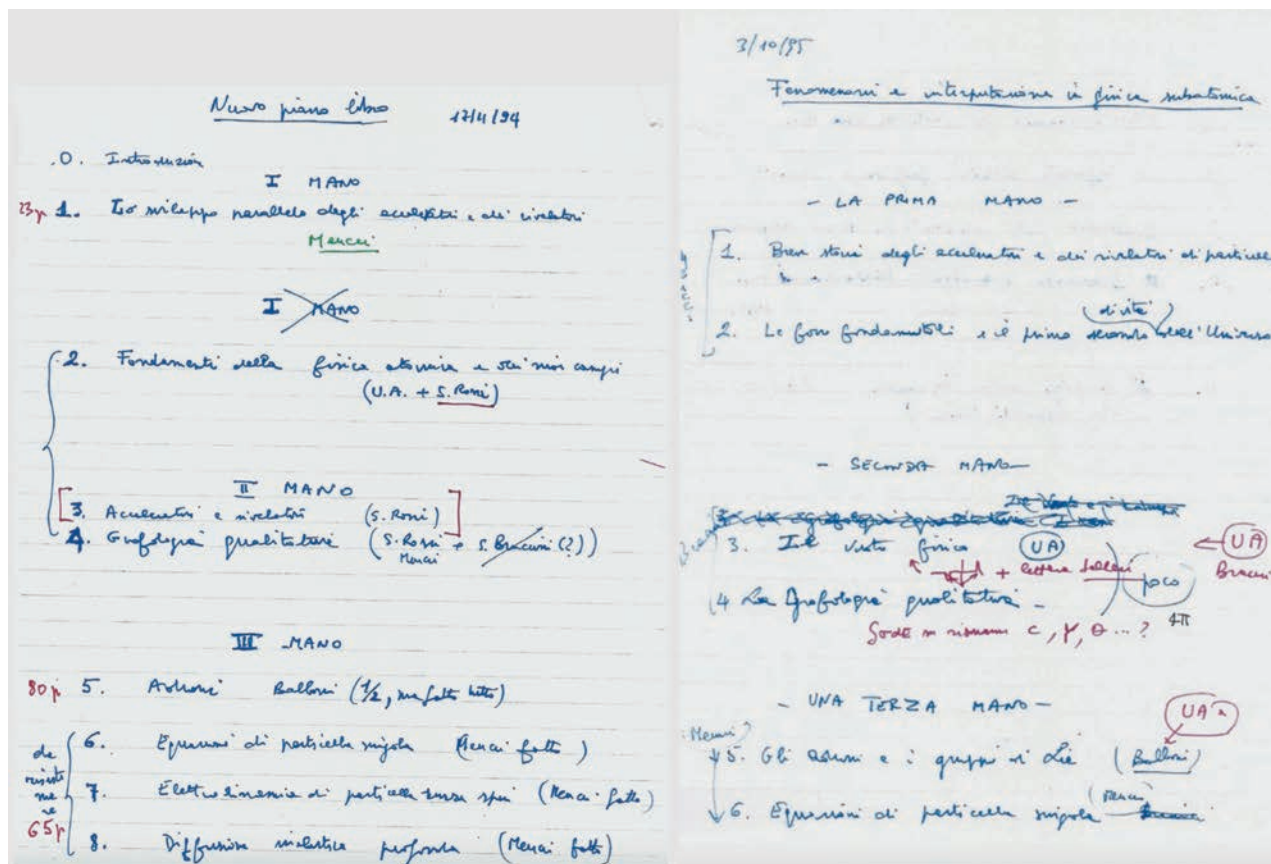


Fig. 4. Initial outline of the book, drafted together with students from Florence and Milan in 1994 (left); revised outline prepared during the Italian Physical Society Congress in Perugia, October 1995 (right).

The course focused on medical radiation physics and often drew inspiration from the 1971 textbook on the subject [5]. A substantial portion was devoted to the application of particle accelerators in medicine, particularly hadron therapy. The subjects were always introduced starting from the physics principles, demonstrating that there is no true separation between fundamental and applied science. Ugo often emphasized that “physics is one”. The slide introducing the Bragg curve – on which hadron therapy is based – is shown in Fig. 3 (right). The complete set of lecture notes comprised about 250 handwritten slides [6].

4. An unpublished book

During one of the final lectures of the course Ugo taught in Florence, he proposed to his students a very original, uncommon, and provocative idea: why not write a book about the course together? Several students – including myself – enthusiastically accepted the proposal. Later, a few students from Milan joined those

from Florence. In the first outline drafted in 1994 (Fig. 4, left), one can clearly see the layered structure inspired by the “wall-painting” methodology.

In October 1995, Ugo and I met at the Congress of the Italian Physical Society in Perugia, where we worked on the book for an entire day, making what Ugo used to call a “*lavorata*” (“a good piece of work”, as one might translate it into English). The updated table of contents is shown in Fig. 4 (right).

I was passionate about running at that time, and we came up with an analogy to explain global and local transformations in relation to gauge invariance and the fundamental forces. As an example of the original ideas contained in the manuscript, I would like to share it here [7].

Let us imagine watching a marathon. It is obvious that if the entire course – with its ups and downs – were raised by one meter, the outcome of the race would remain unchanged: this is a global invariance. However, if some eccentric organizers (or a goblin – “folletto” in Italian –, as it was in the original version) were to modify the height of

the course locally in space and time, hills and descents would appear and disappear, and the result of the race would obviously be distorted: the race would not possess a local invariance with respect to this strange kind of operation. But if one were to design a system capable of slowing down or pushing the runners – a special kind of force – so that their effort in space and time exactly matched what they would have exerted on the original course, then the result of the race would once again remain unchanged. In this way, one obtains a local invariance, provided that something new is introduced: a force. This is how every local invariance of matter particles corresponds to a fundamental force of nature.

Although several chapters were completed, such as those on qualitative graphology and gauge theories, the book was unfortunately never published due to the many commitments of Ugo and the students, who in the meantime had begun PhDs, medical physics schools, or other careers.

Conclusions

Thinking back to the course that Ugo Amaldi taught in Florence, in which I was fortunate to be one of his students, many reflections come to my mind. Ugo taught us not only particle physics and its applications, but also

fundamental values such as humbleness (“*bisogna essere umili*”), patience (“*ci vuol pazienza*”), perseverance (“*bisogna sempre insistere*”), and collaboration (“*da soli non si fa niente*”).

On behalf of all your students, thank you very much, Ugo, for everything you have given – and continue to give – to all of us.

REFERENCES

- [1] The slides and the video of the talk are available on-line: <https://indico.cern.ch/event/1513622/contributions/6369170/>
- [2] Ugo Amaldi, *Fenomenologia delle interazioni fondamentali*, lecture notes from the course held at the University of Florence, Academic year 1991-1992, unpublished.
- [3] Ugo Amaldi and Giampiero Tosi, *Per un centro di teleterapia con adroni*, CERN/PPE/UA/eo, May 1991.
- [4] Ugo Amaldi, *Corso di fisica superiore*, lecture notes from the course held at the University of Milan, 1993-1994, unpublished.
- [5] Ugo Amaldi, *Fisica delle radiazioni: ad uso di radiologi, radiobiologi e protezionisti*, Boringhieri, Torino, 1971.
- [6] Ugo Amaldi and Sandro Rossi, *Applicazioni della fisica alla medicina*, lecture notes from the course held at the Milano-Bicocca University, Academic year 2001-2002, unpublished.
- [7] This text is also published in Italian in the article: Saverio Braccini, *Le particelle di luce ad alta energia e la ricerca delle glueball*, Atti e Memorie della Accademia Petrarca di Lettere, Arti e Scienze, p. 379, Arezzo, 1998.