



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. 261-266
ISSN 0392-4130 • ISBN 978-88-98075-63-8

Ugo Amaldi and Fisica delle Radiazioni¹

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Abstract – *Fisica delle Radiazioni*, authored by Ugo Amaldi, is more than a textbook, it is a meeting point for physics, medicine, and biology. Conceived in the early ‘70s from lecture notes intended for medical students, the book quickly transcended its original audience. Its rigorous yet accessible treatment of the physical principles of radiation made it valuable to a more extended audience encompassing medical physicists, radiation biologists, and engineers intended to become radiation protection officers. By integrating theoretical foundations, experimental methods, and biomedical context, it created a shared conceptual language across disciplines that, at the time, was rare in radiation science education. This contribution, presented on the occasion of Amaldi’s 90th birthday symposium at CERN, revisits the genesis of *Fisica delle Radiazioni*, outlines its structure and pedagogical approach, and reflects on its lasting impact as a model of interdisciplinary scientific communication.

Keywords: Radiation Physics, Ugo Amaldi, Physics Education, Medical Physics, Interdisciplinary Science

Riassunto – *Fisica delle Radiazioni*, scritto da Ugo Amaldi, è più di un semplice libro di testo: è un punto d’incontro tra fisica, medicina e biologia. Concepito all’inizio degli anni Settanta a partire dagli appunti delle lezioni destinate agli studenti di medicina, le sue pagine hanno rapidamente superato il pubblico originario. Il trattamento rigoroso ma accessibile dei principi fisici della radiazione ne ha fatto un riferimento per un pubblico più ampio, comprendente fisici medici, biologi delle radiazioni e ingegneri destinati a diventare esperti di radioprotezione. Integrando basi teoriche, metodi sperimentali e contesto biomedico, il volume ha contribuito a creare un linguaggio concettuale condiviso tra discipline che, all’epoca, era raro nell’insegnamento della fisica delle radiazioni.

Questo contributo, presentato in occasione del simposio per il 90° compleanno di Ugo Amaldi al CERN, ripercorre la genesi di *Fisica delle Radiazioni*, ne illustra la struttura e l’approccio didattico e riflette sul suo impatto duraturo come modello di comunicazione scientifica interdisciplinare.

Parole chiave: Fisica delle radiazioni, Ugo Amaldi, Didattica della fisica, Fisica medica, Scienza interdisciplinare

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

The celebration of Ugo Amaldi's 90th birthday provides an occasion not only to honour a distinguished physicist and educator, but also to revisit one of his most influential works in Italy in the context of physics applied to medicine: the textbook *Fisica delle Radiazioni* [1]. Written at a time when the dialogue between physics, biology, and medicine was far less structured than it is today, the book was conceived to bridge a gap in the education of medical doctors specializing in radiology, providing them with a rigorous understanding of the physical principles underlying the diagnostic and therapeutic use of radiation.

The genesis of the book can be traced back to Amaldi's lectures at the School of Medical Radiology of the La Sapienza University in Rome, in the 70s. These courses were aimed primarily at medical students, but Amaldi's characteristic rigor and clarity meant that the material appealed equally to biologist with interest in radiobiology and even those with a more technical background, namely physics students. His original course hand notes evolved into a comprehensive text that combined fundamental physical principles, such as interaction mechanisms, dosimetric quantities, and detection methods, with detailed discussions of radiation protection. This dual focus gave the book an enduring interdisciplinary significance. While its original audience was the medical profession, its level of detail and precision in the description of radiation interactions made it an indispensable reference for medical physicists engaged in dosimetry, treatment planning, and quality assurance. Similarly, its concise but accurate treatment of radiation effects at the cellular and molecular levels provided radiation biologists with a physical framework to interpret experimental data and design studies.

In retrospect, the book also encapsulates the defining features of Ugo Amaldi's professional life: a constant dialogue between particle physics and the medical applications of physics, a balance that has characterized his scientific vision and continues to inspire generations of researchers.

Fisica delle Radiazioni, subtitled: *for radiologists, radiobiologists, and radiation protection specialists*, was written in Italian, never translated into other languages and has not been republished since 1978. Nevertheless, it remains a milestone in Ugo's scientific and educational journey. Its clarity of exposition and rigorous style made it an essential reference for generations of professionals. The longevity and widespread adoption of the book

within Italian universities and hospitals stand as enduring proof of its cultural value, as well as of the vision from which it was born. This persistence, despite its limited linguistic reach and lack of recent editions, is a testament to the quality of its content and pedagogical approach.

In what follows, I will retrace the genesis of *Fisica delle Radiazioni*, outline its structure and thematic scope, and highlight the ways in which its integrative approach continues to serve as a model for interdisciplinary education in radiation science.

1. Genesis of *Fisica delle Radiazioni*

While still a student, Ugo Amaldi met Mario Ageno, a prominent physicist from the Enrico Fermi group, he had worked with the "Ragazzi di via Panisperna", and a close friend of his father Edoardo. Ageno, trained as a nuclear physicist, was deeply fascinated by the physical foundations of biological processes, by biology itself and indeed can be considered the founder of biophysics in Italy. With his background in nuclear physics and his subsequent shift to biophysics, Ageno provided the institutional and intellectual context in which Amaldi saw that radiation physics could serve not only the "pure" side of physics but also the medical side, *i.e.* diagnostics, therapy, biological effects. In other words, the meeting with Ageno did not merely introduce Amaldi to "medicine" *per sé*, but showed him the terrain where physics, biology, and clinical applications converge.

In fact, in 1958, shortly after graduating, Amaldi accepted a fellowship offered by Ageno at the Laboratory of Physics of the Istituto Superiore di Sanità (ISS), the national public-health research institute under the Ministry of Health. There, he entered an environment that was intellectually unique, where a physicist with a passion for biology, Mario Ageno, was collaborating with a medical doctor who understood the centrality of physics, Professor Luigi Turano. In fact, Turano, as director of the School of Medical Radiology, was among the first who had introduced in a public hospital in Italy the cobalt bomb and later the betatron for cancer therapy, pioneering steps in the integration of nuclear technology and clinical medicine.

In this context, Ugo Amaldi also assisted Ageno in teaching Radiation Physics to medical doctors training as radiologists. This collaboration continued until 1962, when he assumed responsibility for the course himself, teaching it until 1973. By that time, Ugo was then lecturing on radiation physics to medical students who had

limited prior exposure to advanced physics. His challenge was to convey the subject with full scientific rigor while keeping it accessible and meaningful for future clinicians. Over time, his carefully prepared lecture notes evolved into a coherent and comprehensive manuscript. The intellectual environment of those years, shaped by Ageno's vision of biophysics and by Turano's conviction that radiology must be grounded in physical understanding, was crucial to Ugo's scientific development. It provided the living model of interdisciplinarity that would later inspire *Fisica delle radiazioni*: a book conceived precisely at the crossroads where physics, biology, and medicine meet. Ugo, in his typically meticulous way, transformed his lectures into clear, illustrated course handouts for radiology students, with very illustrative figures, hand-drawn by an excellent technician from the ISS.

Around 1968-'69, Mario Ageno encouraged Ugo to turn those lecture notes, already so well organised and written, into a proper textbook. After accepting the advice and although the notes were already precise, Ugo completely rewrote them, aiming to present physics with full rigor yet in a form accessible to medical doctors, limiting the abstract formalism typical of physicists. He worked tirelessly, often during family holidays, while his

wife Clelia, with her characteristic warmth and patience, managed their four lively children.

Eventually, the book (Fig. 1) was published in 1971, with the dedication: *A mia madre* (To my mother). This choice was deeply meaningful. Ugo, son of the great Edoardo, was also the son of Ginestra Giovane Amaldi, a remarkable physicist and pioneer of science communication in Italy. Though *Fisica delle radiazioni* was not written for the general public but for doctors, biologists, and radiation protectionists, it continued that same family tradition of making science both accurate and accessible to non-specialists in the field, a legacy that surely would have made his mother very proud.

3. Structure and Contents

What makes *Fisica delle Radiazioni* remarkable is its extraordinary completeness. It is not a mere handbook of applied physics, nor a simplified text for non-physicists, but a fully developed physics treatise encompassing all the topics required to understand the interaction between radiation and matter, and their medical implications. It moves with exceptional clarity from the fundamentals of classical physics to the physics of atoms, nuclei, and radiation, before addressing dosimetry and



Fig. 1. The book cover and the dedication to his mother.

radiation protection. In fact, the book is divided into three main parts, followed by several technical appendices and an analytical index. The first part, *Fisica Classica*, introduces the basic methods and concepts of physics, mechanics, waves, and electromagnetism, forming the groundwork for the rest of the text. The second part, *Atomi e Nuclei*, covers atomic and nuclear physics, including radioactivity and the principles of nuclear transformations, thus bridging classical physics and radiation phenomena. The third part, *Radiazioni*, which forms the core of the book, deals with radiation sources, interactions with matter, dosimetry, and protection, providing a direct link between physical principles and medical practice.

The structure and contents of *Fisica delle radiazioni*, clearly illustrates its pedagogical balance. It is, in every respect, a real physics textbook rigorous, complete, and conceived to connect basic physics with its medical and biological applications. This coherent structure makes it a self-contained and enduring reference, one that can guide both students and professionals across disciplines.

3. Scientific Impact and Educational Legacy

At the time of its publication, *Fisica delle Radiazioni* was the suggested textbook and surely studied by radiologists in training, those for whom it was conceived, although direct testimonies from that generation of radiologists are lacking. But there are testimonies of a wider student audience including biologists, radiation protectionists and physicists themselves. As an example, Mauro Belli, former Director of the Radiation Biophysics Unit and later of the Physics Laboratory at the Istituto Superiore di Sanità, recently recalled: “I remember that *Fisica delle Radiazioni* was also one of the main texts studied by candidates preparing for researcher competitions at my Laboratory, since the time in which Ageno was director and for many years thereafter. The first written test in such exams was in physics. Moreover, as the competitions for positions in Biophysics and Medical Physics were open to graduates in both physics and biology, the result was that the biologists who passed the exam had an excellent understanding of radiation physics, practically equivalent to that of their physicist colleagues, with whom they were able to establish genuine multidisciplinary collaboration”. This observation captures the spirit of the book, showing that was used not only by medical doctors but also by biologists, physicists and radiation protection officers. Among the latter, *Fisica delle Radiazioni* became a standard reference for topics such

as radiation shielding, famously treated in Appendix E (Fig. 2). Physicists and engineers preparing for the qualification examination as radiation-protection specialists frequently relied on that section, and a thorough knowledge of it was regarded as essential for success.

As the book has not been reprinted since 1978, printed copies of the book have been very difficult to obtain. Many university libraries hold heavily used issues, often worn from repeated photocopying by successive generations of students. Nevertheless, the book continues to appear in Italian university *syllabi* and recommended reading lists showing that its impact still reaches our time, even though the book ceased publication so long ago and then never updated. Just to give a couple of examples, today at the University of Genoa, it is still cited in current courses on Medical Physics, while at the University of Milan it remains recommended for students of biology and medicine. These examples illustrate the remarkable longevity of *Fisica delle Radiazioni* and its continued relevance across disciplines.

The book's interdisciplinary reach has been one of its most significant contributions. In hospitals, it has supported dialogue between oncologists, radiologists, medical physicists, and radiation biologists. In academia, it has informed curricula that prepare students for collaborative research and clinical work. It also anticipated today's multidisciplinary cancer treatment research teams, where professionals from diverse backgrounds must share a common understanding of radiation science. The fact that it continues to be used in teaching and reference work today underscores its lasting relevance and the absence of a truly equivalent text in any language.

4. Personal Reflections

My own encounter with *Fisica delle Radiazioni* occurred during the third year of my physics degree. But it was not my first encounter with the name Amaldi. Like many Italian students, not just those in physics, my life has been marked since the age of fourteen by the constant presence of a book with “Amaldi” on its cover, a name that soon became legendary to me. I first met the name Amaldi on my geometry textbook in high school. This was a book by Ugo's grandfather, also named Ugo Amaldi, a prominent Italian mathematician, active in the first half of the 20th century. Then again that surname on my physics book from the third year of high school, *Corso di Fisica*, but for us Italians simply “*l'Amaldi*”, that was first published in the 1950s. This was authored by Edoardo Amaldi and his wife Ginestra, Ugo's parents.

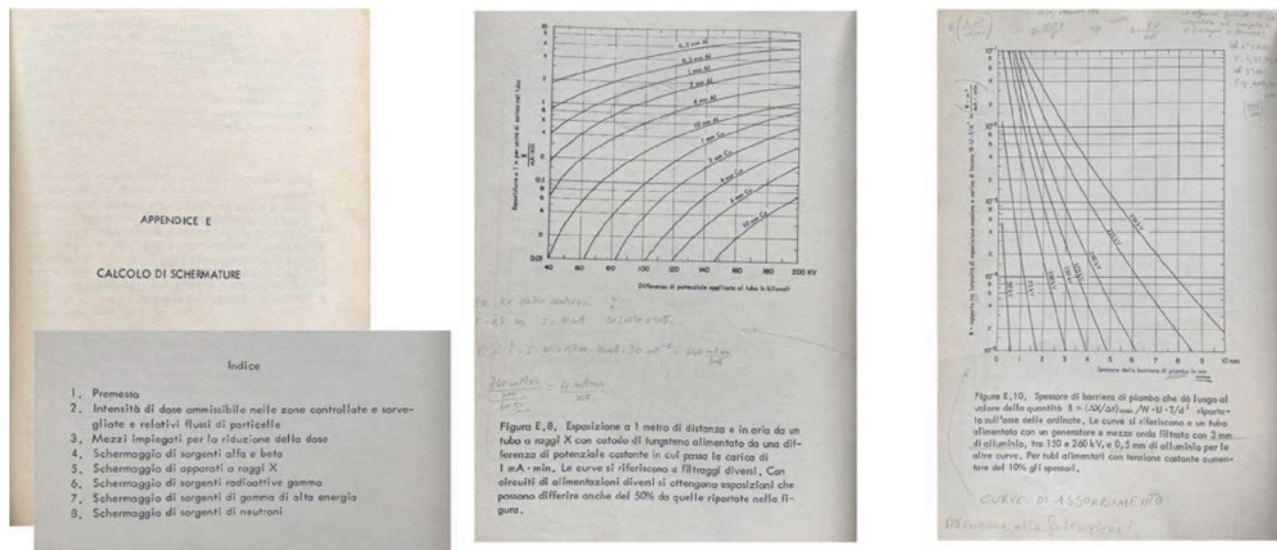


Fig. 2. The Appendix E of the book: shielding calculations, which was legendary among those who had to pass the exam to qualify as radiation-protection officers. This figure, taken from a rare second-hand copy of the book, suggests that it had probably belonged to one of those exam candidates.

Indeed, the original high-school physics textbook was first written by Enrico Fermi. Once they took it over from Fermi, Edoardo and Ginestra Amaldi expanded and modernized it. Their goal was to preserve Fermi's clarity and logical rigor while adapting the material to the structure and needs of post-war education in Italy. The resulting textbook became the foundation of physics instruction in Italian *licei* for decades, appreciated for its balance between conceptual depth and pedagogical accessibility, a distinctive trademark of the Amaldi family, that we can recognize also in *Fisica delle Radiazioni*. That physics textbook was later taken over by Ugo, who made it entirely his own. In later years, Ugo renewed the series for contemporary curricula, thus extending across three generations a unique tradition of scientific clarity and pedagogical excellence that has shaped Italian physics education for nearly a century.

Coming from classical studies, I used the more advanced edition intended for scientific high schools: it helped me bridge the gap to university-level physics. So, even in my early university years, I was still studying from *l'Amaldi*. That alone says much about Ugo's long-lasting legacy as a textbook author.

In my third year course in Health Physics at Perugia University, I came across with *Fisica delle Radiazioni* for the first time. The course was taught by Professor Gloria Campos Venuti, a leading figure in Italian radiation protection, whose own research on indoor radon and ambient radioactivity brought the physics of radiation direct-

ly into the context of public-health and environmental protection. Naturally, she recommended that book, which was quite surprising for us students in physics, as the book cover clearly stated that it was intended for radiologists, biologists, and radiation protection officers, while physicist were not mentioned in that cover. But, in fact, many of us studied it thoroughly. It offered a rare and precious balance, rigorous yet accessible, making it ideal not only for doctors and biologists seeking a deeper, more authentic understanding of the subject but also for students of applied physics. This personal thread, woven through decades of study and teaching, has continued to shape my perspective on both physics and education, and has been an invaluable reference throughout my professional career devoted to the medical applications of particle physics. In this context, it is easy to recognize how *Fisica delle Radiazioni* anticipated a transdisciplinary, much more effective than interdisciplinary, way of thinking, one that remains essential today for anyone wishing to navigate the complex intersections of physics, biology, and medicine, and the consequent creation of new disciplines.

My final remark concerns what I have always found truly unique about this textbook. Many books are excellent, and some are truly outstanding. One cannot fail to mention The Feynman Lectures on Physics, for instance. Yet, in my experience, when studying even the best of them, new questions often arise, not because the exposition lacks clarity, but since certain steps are left



Fig. 3. The Geometry textbook for Italian high schools authored by Ugo's grandfather (left), and the Amaldi, the physics textbook that has shaped generations of Italian students since 1947 and remains in use today.

implicit or taken for granted. This is not the case with *Fisica delle Radiazioni*. Whenever a question originates while reading, the answer almost invariably appears a few lines later, or perhaps on the following page. This may be partly because the book was originally written for physicians and biologists, but it also reflects Ugo's remarkable meticulousness. I believe this is the key reason the book has retained its value over time, even for physicists, indeed, perhaps especially for physicists, working in the field of ionizing radiation, whether in research or in technical applications.

Conclusions

Fisica delle Radiazioni exemplifies how a textbook can transcend its original scope to become a shared intellectual space across and beyond disciplines. Its legacy not only lies in the knowledge it conveys, but also in the model it offers for communicating complex science beyond disciplinary boundaries.

In fact, the spirit of *Fisica delle Radiazioni* perfectly reflects the scientist Ugo Amaldi. He is a true Master of Physics, endowed with a profound and far-reaching scientific vision; a passionate disseminator and bridge-builder across disciplines, which uneventfully had a formidable impact for the common good, transforming scientific knowledge into lasting public benefit. Indeed,

his civic commitment found one of its finest expressions in the establishment of proton and carbon-ion therapy in Italy, and in his tireless work to promote hadron therapy across Europe.

These qualities, deeply woven into his teaching and research, continue to inspire those who study and apply physics in the service of medicine and society. In celebrating Ugo Amaldi's 90th birthday, we also celebrate the long-lasting relevance of his vision: that rigorous science, expressed with clarity, is the cornerstone of education, collaboration, and societal progress. Thank you Ugo for having shown us that Physics is beautiful and useful!

Acknowledgments

I wish to thank the Accademia Nazionale delle Scienze detta dei XL for the opportunity to contribute to this commemorative volume, and the organisers of the symposium for creating such an inspiring occasion to honour Ugo Amaldi. I am also deeply grateful to my colleagues – in particular Mauro Belli – whose discussions have greatly enriched my reflections on *Fisica delle Radiazioni*.

REFERENCES

Amaldi, U. *Fisica delle Radiazioni*. Bologna: Boringhieri, 1971.