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On the occasion of the symposium celebrating Ugo Amaldi's 90th birthdate¹

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Abstract – It is the pleasure of the journal to introduce this collection of papers to celebrate the remarkable contributions of Ugo Amaldi to the advancement of fundamental research, medical physics, and scientific outreach. Through his pioneering work, Ugo Amaldi has left an indelible mark on the scientific community, inspiring generations of researchers and scientists.

Keywords: Ugo Amaldi, Physics, Istituto Superiore di Sanità, Università, La Sapienza, CERN, Frascati, Particle accelerators, (e, e'⁺p) Experiment, (e, 2e) Experiment, Charm Quark, Nuclear Reactors, Hadrontherapy, CNAO (National Center for Oncological Hadrontherapy), LEP (Large Electron-Positron Collider)

Riassunto – È un piacere per la rivista presentare questa raccolta di articoli per celebrare i notevoli contributi di Ugo Amaldi all'avanzamento della ricerca fondamentale, della fisica medica e della divulgazione scientifica. Attraverso il suo lavoro pionieristico, Ugo Amaldi ha lasciato un'impronta indelebile nella comunità scientifica, ispirando generazioni di ricercatori e scienziati

Parole chiave: Ugo Amaldi, Fisica, Istituto Superiore di Sanità, Università, La Sapienza, CERN, Frascati, Acceleratori di particelle, Esperimento (e, e'⁺p), Esperimento (e, 2e), Quark charm, Reattori nucleari, Adroterapia, CNAO (Centro Nazionale di Adroterapia Oncologica), LEP (Large Electron-Positron Collider).

Introduction

This symposium has been organised to celebrate the long scientific career of Ugo Amaldi (Fig. 1), from his early years at the *Istituto Superiore di Sanità* (ISS, the Italian National Institute of Health), to his contributions to particle physics, to the creation of the TERA Foundation in the early '90s to introduce hadrontherapy in Italy, the design of novel particle accelerators for medicine,

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.



Fig. 1. Photo of the attendees at the ‘Symposium for Ugo’s 90 years’ held at CERN (Geneva) on April 4, 2025 (CERN Photo).

and his role in setting up an international network for cancer treatment with proton and ion beams.

This collection of papers is introduced by three letters from distinguished scientists, each offering a unique perspective on Ugo Amaldi’s multifaceted legacy. Their contributions not only highlight his groundbreaking research and its impact on our understanding of the world but also pay tribute to his exceptional qualities as a scientist, mentor, and communicator. We are grateful for the opportunity to honor Ugo Amaldi’s achievements and legacy through this collection, which we hope will inspire future generations of scientists and researchers.

1. Luciano Maiani: For Ugo Amaldi’s 90 years

I met Ugo in 1963. I was then starting my physics thesis in the Physics Laboratory of Istituto Superiore di Sanità, located next to Università La Sapienza, where I had followed my course in Physics. Edoardo Amaldi had been one of my professors and Ugo (six years older than me) was then the young leader of an experiment made at Frascati’s Electrosynchrotron (electron scattering off nuclei, the reaction $(e \rightarrow e', p)$, if I remember well). We liked each other since the very beginning. A long friendship started, continued with our families, wives (Clelia and Pucci) and children. Still in Sanità, Ugo was the first in Italy I shared with, in 1970, the GIM mechanism, discussing in a long afternoon how one could discover the newly proposed charmed quark. And Ugo introduced me to the intricacies of nuclear reactors, when he was leaving the CNEN Committee for Nuclear Protection and Security to join CERN in the early seventies (it’s now your time to take care of our institutional work,

his comment). A photo made by Ugo catches me in 1985 while entering in the Amaldi house (Rue du Cock d’Or) proudly carrying my daughter Camilla, a few months old. I was in the CERN conference to greet Ugo, when he retired from CERN at 65, in 2000 (Fig. 2).

Ugo never gives up. This is the dominant aspect of his character. After leading with success one of the four large LEP detectors, he has been able to pick up a mostly unnoticed remark by Bob Wilson about the finite range of protons in human tissues and create a Center for Hadron Cancer Therapy, Centro Nazionale di Adroterapia in Pavia, the largest in Italy and one of the best in Europe. In his recent visit to CNAO, the President of the Italian Republic, Sergio Mattarella, defined the action carried on at CNAO: a message about what humanity requires...to meet the needs of women and men of the present world. Thanks Ugo!!!

2. Domenico Campi: Ugo Amaldi, a master of science and of life

I first met Ugo in the early 1990s. I was a young engineer, a little over five years into my time at CERN, working on the cooling systems for particle accelerators and on the general infrastructure of those great machines that, even today, continue to astonish the world.

Every Saturday, I would guide visitors through the laboratory, and I was often asked: “What you do here is wonderful, but what is it really for, right now, for society?” It was a question we were all used to hearing, yet for me it sparked the desire to focus on the practical applications of accelerators, particularly in the industrial field.

It was thus that my small initiative reached the ears of



Fig. 2. Ugo's 65 years celebration, CERN, September 2000. Photo CERN.

Giorgio Brianti, then CERN's Technical Director, who said to me: "Why don't you talk to Professor Ugo Amaldi? He's putting together a group to propose the construction, in Italy, of a clinical center that would use a synchrotron for radiotherapy with hadrons and heavy ions." And so, thanks to him, I met Ugo Amaldi for the first time, one of CERN's great physicists, of whom I had heard so much. That meeting marked the beginning of a long human and scientific collaboration, which would later become a profound friendship.

I was immediately struck by his simplicity and by the clarity with which he could describe such complex projects. At that time, Ugo was working on the creation of the TERA Foundation, together with Giampiero Tosi and a group of young researchers. It was a project as ambitious as it was inspiring: the construction of a clinical center using particle accelerators for cancer treatment.

For me, it was the first opportunity to be involved in a major project as a whole, and to realize how physics could be both "beautiful and useful", as our mentor often reminded us.

Those were exhilarating years. We were young, full of enthusiasm, and with very limited resources we had to build an organization inspired by the CERN model but with clinical and therapeutic purposes.

The spirit that animated us, as we were told by our more senior colleagues, was the same as that of the pioneers who had founded CERN forty years earlier: dedication, lively discussions, joy, disappointment, and perseverance. During those intense days, a deep friendship grew among us, a bond that still endures today.

With Ugo and other colleagues, I learned to navigate uncharted territory, where each day we took one step forward and two steps back, yet always with the conviction

and determination to build something meaningful. In that laboratory of ideas and hopes, a sense of mutual esteem was born, one that remains intact after nearly forty years.

Some of us stayed in the field of hadron therapy; others, like myself, carried the skills we had learned into different domains.

I remember Ugo not only as a scientist, but as a true mentor and friend. During our journeys between Geneva and Novara, he would often speak of his ancestors and of the extraordinary people he had met.

He told the story of science, as lived by himself and his forebears, as a great human adventure, and he did so with the modesty and simplicity that still define him today. It is a memory I will carry with me for the rest of my life.

Another figure I would like to remember from those years is Gaudenzio Vanolo, another quiet yet essential protagonist in the history of TERA. From him I learned the courage to engage with everyone, and the determination to build something real, never giving up, even when finding the necessary resources for the project proved difficult. Thanks to his relationships, and to the respect that Ugo inspired around us, we were even able to invite President Scalfaro to visit CERN, and later remained in contact with his family, united by shared goals and faith.

We are no longer young, and perhaps Ugo is still the youngest in spirit among us all. He has never stopped thinking, proposing, and creating new initiatives. Each time we meet, we feel the same energy and passion return to him as in those early days. Perhaps this is Ugo's greatest legacy: his ability to transform a scientific dream into a deeply human project, one that unites people and continues to inspire generations of researchers and students.

TERA and CNAO stand today as tangible proof of that vision. But they are also, and above all, the first chapter of a journey that will continue to grow, guided by the same enthusiasm and spirit of service that Ugo has passed on to us.

Dear Ugo, thank you, from the heart, for showing us that science can also be an act of love toward humanity.

3. Marco Silari: A brief overview of Ugo Amaldi's careers and achievements

In this introduction to the proceedings of the symposium, I will briefly go through the main steps of Ugo's career, with some insight into the period I worked with him. You will find detailed descriptions of his many achievements in the following articles.

I first met, very briefly, Ugo in 1983, when he gave a

lecture at the *Scuola di Perfezionamento in Fisica Sanitaria e Ospedaliera* (the post-university diploma school in medical physics) at the University of Milano, that I was attending after obtaining my university degree in physics in June 1982. I remember that we, the seven or eight students, had been fascinated by both the scientist and the man (in particular the female components of the class, as I well remember), and by the clarity of his lecture. Those two hours spent listening to him strengthened my intention to pursue a career in medical physics; but it was only several years later that I got to know him professionally, as I will explain below.

Ugo Amaldi started his career in 1957 at the *Laboratorio di Fisica* of the ISS, first with a scholarship, then as researcher and later as *Dirigente di ricerca* (Research director). He worked at ISS for fifteen years under the guidance of Mario Ageno, the founder of biophysics in Italy. Ugo's institutional tasks were the verification of the shielding barriers of the novel betatrons that were being installed in hospitals, radiation protection of the population, participation in the national committee for licensing nuclear reactors and establishing evacuation plans in case of accidents. In 1964 Ugo took up from Ageno the course of radiation physics at the Specialisation school in radiology, which ten years later brought to the publication of "*Fisica delle radiazioni*", a fundamental textbook discussed later in these proceedings.

In this period, Ugo's research interests developed along four lines: accelerator physics, under the guidance of Enrico Persico and Ageno; nuclear and sub-nuclear physics, conducting experiments at the Frascati electron synchrotron and at CERN proton synchrotron; atomic physics, introducing, with Guido Pizzella, electron momentum spectroscopy; and the theory of strong interactions, developing with Franco Selleri a novel method to account for pion production in proton-proton interactions. Later Ugo passed his research activities in atomic physics on to Anna Giardini, a classmate of him, and two younger colleagues, and in the following decades he pursued his three other lines of research, together with medical physics.

At the end of the sixties, together with Giorgio Matthiae of the ISS, Amaldi proposed a proton-proton scattering experiment at small angle to be carried out at CERN Intersecting Storage Rings (ISR). For this purpose, he contributed to the design and construction of a novel device, which is now universally known as "Roman pot", as discussed later in these proceedings. The experiment, conducted in collaboration with a CERN group led by Giuseppe Cocconi, unveiled that the proton-pro-

ton interaction probability is not constant but raises with energy, against the theoretical predictions. Following this discovery, Amaldi, who was analyzing the data and first saw the new phenomenon, moved to CERN with a position of senior scientist, and for the following twenty years he devoted himself to fundamental research in experimental and theoretical particle physics.

Later Ugo moved from the study of strong interactions to research on electroweak interactions founding, together with Klaus Winter and Guido Barbiellini, the CHARM collaboration (CERN-Hamburg-Amsterdam-Roma-Moscou). Between 1975 and 1980 CHARM investigated the interactions with electrons and nucleus of the neutrinos produced at the super proton synchrotron that had just started operation. Between 1980 and 1993 Amaldi first created and then chaired the DELPHI collaboration, a consortium of about 500 physicists from 40 institutions in 20 countries. The collaboration built the 3000-ton particle detector "DELPHI", which from 1989 until 2000 collected 5 million events at LEP. His article "Comparison of grand unified theories with electroweak and strong coupling constants measured at LEP", published in 1991 with Wim de Boer and Hermann Fürstenau, created at the time, in the particle physics community, a great excitement about Supersymmetry and has now more than 2500 citations [1].

In 1991, while still at CERN, Ugo obtained a professorship at the University of Florence. One year later he moved to the Second Sciences Faculty of Milano University, that was seated in Como. He taught both particle physics and accelerator physics. In 1996 he moved to the University of Milano Bicocca, to teach medical physics.

In May 1991 I received a phone call from Giampiero Tosi [2], the director of the Health Physics department of the *Ospedale Niguarda* in Milano. At that time, I was researcher with the *Istituto Tecnologie Biomediche Avanzate* (ITBA, Institute for Advanced Biomedical Technologies) of the *Consiglio Nazionale delle Ricerche* (CNR, the Italian National Research Council), and I was collaborating with Giampiero since my years at the *Scuola di Perfezionamento*.

Giampiero told me that Ugo Amaldi was looking for people to set-up a project team to introduce proton and ion therapy in Italy. I was immediately triggered by the idea as I knew that proton therapy was a novel radiation therapy modality that was being slowly introduced in various countries. I thus had no hesitation to accept Ugo's invitation to meet him at CERN a few days later, to better understand what he had in mind. It was the first of my many trips to CERN in the years to come and

the beginning of daily work with Ugo for the following five years, during which I deeply appreciated his scientific, human and managerial qualities. This period was one of the most fruitful in my career, and I learnt a lot from him [3].

When I met Ugo, he and Giampiero had just issued a document titled “*Per un centro di teleterapia con adroni*”, illustrating their proposal for a clinical hadron facility for Italy. The first public occasion in which Ugo introduced the now universally-known term “hadrontherapy” – to indicate radiation therapy with protons, neutrons and light ions – was on 10 April 1992 at a symposium of the *Associazione Italiana di Fisica Biomedica* (AIFB, the Italian Association of Biomedical Physics) in Ferrara.

In 1992 Ugo together with Giampiero Tosi, Elio Borbonovi and Gaudenzio Vanolo created the TERA Foundation [4], of which he is still president, a non-profit organisation with the scope of promoting hadrontherapy-related studies in Italy and the design of a major clinical facility to treat around 1000 patients per year. During those first years the Foundation raised the funds required to finance the growing team of young physicists and engineers working on the design of the facility and related projects. The TERA Foundation was recognised by the Italian government with a decree of the Ministry of Health dated 5 November 1994.

With his innate capacity to cluster people around him, in a short time Ugo set up a collaboration of several Italian national institutes and universities, involving tens of physicists, engineers, radiobiologists and medical doctors, and a network of international collaborations worldwide. The *Progetto Adroterapia* grew rapidly to consist of several activities, which can be divided into three lines, with the overall scope of developing hadrontherapy in Italy: 1) the above-mentioned project of an Hadrontherapy Centre, later named by Ugo CNAO (*Centro Nazionale di Adroterapia Oncologica*, National Centre for Oncological Hadrontherapy) [5]; 2) the project for a compact accelerator, for which three main solutions were investigated over the years: a synchrotron using high-field pulsed magnets, a linear accelerator and a superconducting cyclotron. Ugo's vision was that, on a longer time scale, compact accelerators would equip several single-room proton therapy centres throughout the country treating 200-300 patients per year, something that only relatively recently became reality with the

single-room units now commercialised by several manufacturers [6]; 3) an Italian Network for hadrontherapy (RITA, *Rete Italiana Trattamenti Adroterapici*), that would include CNAO, the smaller proton therapy centres and various associated centres employing conventional radiation therapy all over the Italian territory [7].

It took Ugo several years to convince the Ministry of Health to approve the CNAO project, decide a suitable site (finally in Pavia, adjacent to the S. Matteo hospital) and secure the necessary funds. Eventually, in 2000 the CNAO Foundation was created by Umberto Veronesi, recently nominated Health Minister by Premier Giuliano Amato, and at the end of 2003, upon completion of the design and before starting construction of the facility [8], 25 members of the TERA Foundation moved to the CNAO Foundation to form the core team of the new *Centro Nazionale di Adroterapia Oncologica*, that started patient treatments in 2011. The construction and current operation of CNAO are illustrated in another contribution to these proceedings.

Since then, Amaldi kept pursuing his activities in medical physics along several lines, contributing to the design of novel accelerators like the “cyclinac”, TULIP (a single-room proton therapy unit using a linac), CABOTO (a linac for carbon ion therapy) and PERLA (Protontherapy and Exotic Radioisotopes from Linked Accelerators), promoting the creation of the ENLIGHT (European Network for Light Ion Hadron Therapy) and STELLA (Smart Technologies to Extend Lives with Linear Accelerators) collaborations, the foundation of Tera-Care in Geneva, and CHeFS (A Clinical Helium Facility for Switzerland), his latest initiative to promote in Switzerland a centre for the production of novel theragnostics radioisotopes and hadron therapy with proton and helium ion beams.

All these activities are discussed in some of the contributions to these proceedings, along with his parallel activity, started in the early years of his career following the steps of his parents Edoardo and Ginestra, of science dissemination, writing many scientific books for both students and the public.

Thank you, Ugo, for all what you have given to physics, to your many colleagues and collaborators, to society, and to me personally, all along your brilliant career. I am so happy that we can continue working together on the latest of your projects.

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- [2] Giampiero Tosi had agreed to lecture at this symposium, but sadly he left us, unexpectedly, a few months before the event, just two weeks after I had invited him.
- [3] A full account of the first five years of the CNAO project is in the first chapter of the “Silver Book” to be published soon.
- [4] The 30th anniversary of the TERA Foundation was celebrated with a symposium at CERN on 15 September 2022, <https://indico.cern.ch/event/1184432/>
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