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Ugo Amaldi at 90: From his life dedicated to physics to his role in ENLIGHT and STELLA¹

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Abstract – The symposium celebrating Ugo Amaldi’s 90th birthday provided a unique opportunity to reflect on his scientific achievements, his institutional leadership, and his lifelong commitment to bringing the benefits of particle physics to society and illustrating one of his favourite phrases that “physics is not only beautiful but also useful”. This paper highlights the role he played in the creation of the ENLIGHT network (European Network for Light Ion Hadron Therapy) and the birth of the STELLA (Smart Technologies to Extend Lives with Linear Accelerators) initiative to expand access to radiotherapy globally. The symposium underscored Amaldi’s pivotal role in advancing hadron therapy technologies, training a new generation of researchers, and addressing inequalities in cancer treatment.

Keywords: cancer, radiation therapy, hadrontherapy, medical applications, accelerators, collaboration, networks, ENLIGHT, multidisciplinary, societal applications of science, education and training

Riassunto – Il simposio organizzato per celebrare il novantesimo compleanno di Ugo Amaldi ha offerto a tutti i partecipanti un’opportunità unica per riflettere sui successi scientifici, la leadership istituzionale e l’impegno costante portato avanti per tutta la sua carriera. Una delle sue frasi preferite – «la fisica non è solo bella, ma anche utile» – illustra chiaramente il suo pensiero e il suo modo di vedere la Fisica delle particelle come qualcosa di molto utile alla società. Questo articolo evidenzia il ruolo da lui svolto nella creazione della rete ENLIGHT (European Network for Light Ion Hadron Therapy) e nella nascita dell’iniziativa STELLA (Smart Technologies to Extend Lives with Linear Accelerators) per ampliare l’accesso alla radioterapia a livello globale. Il simposio ha sottolineato il ruolo fondamentale di Amaldi nel progresso delle tecnologie di adroterapia, nella formazione di una nuova generazione di ricercatori e nella lotta alle disuguaglianze nel trattamento del cancro.

Parole chiave: cancro, radioterapia, adronoterapia, applicazioni mediche, acceleratori, collaborazione, reti, ENLIGHT, multidisciplinarietà, applicazioni sociali della scienza, istruzione e formazione

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

Cancer is the second leading cause of death globally among noncommunicable diseases (NCDs) with the number of new cancer cases projected to rise to 27.5 million with 16.3 million deaths worldwide in 2040. Currently one in every five people will develop cancer globally [1, 2].

Radiation therapy (RT) is critical for the curative treatment [3,4]. The roots of RT date back to the discoveries of X-rays and radium. While kilovoltage sources were already used from the beginning, it was around the 1950s that X-rays of energy greater than 5 MeV were produced and electron linear accelerators (linacs) became the instrument of choice. Today, around 18,000 linacs are installed in hospitals all over the world and are critical for around half of the patients diagnosed with cancer which would benefit from RT. The main goal of radiotherapy treatment is to maximize the damage by ionizing radiation to the tumour cells while minimizing the exposure of the surrounding normal tissue and critical organs. Research and innovation efforts are being carried out worldwide to improve the effectiveness of RT.

Improving RT is the area towards which Ugo Amaldi, after more than three decades of physics at the highest level, redirected his energy becoming a pioneer of “hadrontherapy” (HT), a new word he coined. HT can offer superior tumour-dose conformality (“conformality” stands for the energy dose shaped to the tumour size and volume) compared to conventional X-ray radiation, mainly because of the favourable depth-dose deposition of ions in tissue, due to the so called “Bragg peak” [5].

From TERA to PIMMS: Laying the Technical Foundations

Amaldi’s entry into medical physics began with the establishment of the TERA Foundation more than 30 years ago [6]. TERA was dedicated to designing accelerators for cancer treatment, particularly synchrotrons and gantries optimized for hadron therapy.

This initiative led to the Proton-Ion Medical Machine Study (PIMMS), a collaborative effort between TERA, CERN, and MedAustron lead by Bryant [7]. PIMMS addressed the technical requirements for delivering both proton and carbon-ion beams in clinical environments, including compact synchrotron designs, radio-frequency cavities, and chromaticity control. The conceptual and engineering work carried out during PIMMS directly influenced the establishment of facilities such as CNAO in Pavia, Italy, and MedAustron in Wiener Neustadt, Austria.

The very first translation of the PIMMS study to a clinical facility, for which Amaldi was the key driving force, is what resulted in the CNAO centre at Pavia, Italy [8].

ENLIGHT: Building a European Community

Recognizing that scientific progress in hadron therapy required coordinated European collaboration, Amaldi co-founded the European Network for Light Ion Hadron Therapy (ENLIGHT) in 2002 with Hans Hoffmann and Manjit Dosanjh. Supported by the European Commission, ENLIGHT aimed to create a multidisci-

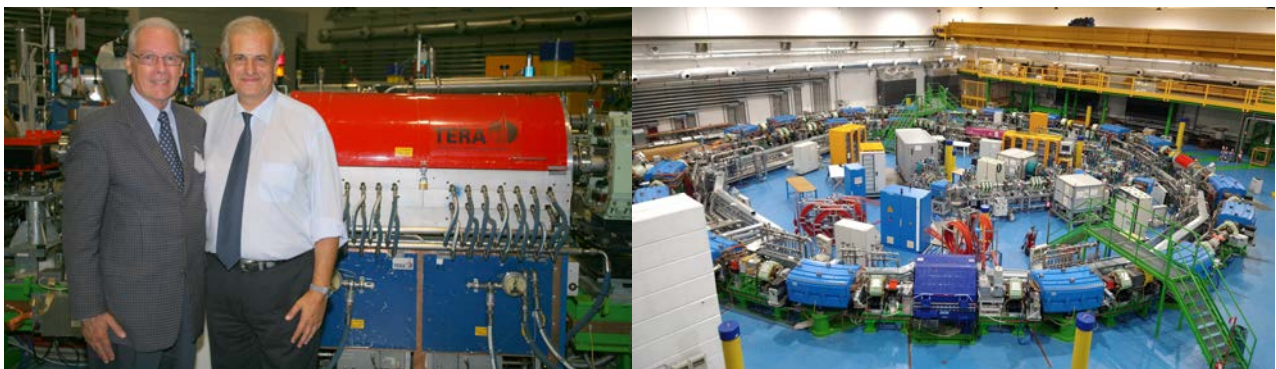


Fig. 1. Ugo Amaldi and Roberto Orecchia, the first medical director of CNAO facility in the TERA Hall. CNAO was the very first facility in Pavia based on PIMMS design that started treating patients in 2011. It is an example of one of the first-generation hadron therapy centres and Amaldi’s brainchild (@ CERN).



Fig. 2. Launching of ENLIGHT (European Network for Light Ion Therapy) in February 2002 at CERN, Ugo Amaldi is first on the left: <https://enlight.web.cern.ch/enlight> (@ CERN).

plinary forum uniting physicists, oncologists, radiobiologists, and engineers [8].

Its objectives included harmonizing treatment protocols, sharing best practices, building research capacity,

and advocating for sustainable funding. Over two decades, ENLIGHT has matured into Europe's primary coordination platform for particle therapy, linking research centres and clinical facilities across the continent.



Fig. 3. Signing of the partnership between CERN and ADAM at CERN in December 2007. From right to left: Maximilian Metzger, Robert Aymar, Erminio Borloni, Giorgio Brianti, Alberto Colussi, Roberto Petronzio, Manjit Dosanjh, Ugo Amaldi, Carlo Lamprecht, Sandro Rossi, Domenico Campi (@ CERN).

The Creation of ADAM (Applications of Detectors and Accelerators to Medicine)

On December 2007, a fundamental change took place for TERA when Alberto Colussi helped to create the company ADAM, Applications of Detectors and Accelerators to Medicine. The company, founded as CERN spin-off, had the goal of developing a linear protons accelerator for cancer therapy based on the cyclinac studies.

Training and Education: Investing in People

Amaldi emphasized that new technologies would only achieve their potential if a trained workforce could operate and develop them. Programs such as Marie Curie Initial Training Networks such as the PARTNER initiative (Particle Training Network for European Hadrontherapy) were launched within ENLIGHT, involving universities, hospitals, and companies across Europe [9].

The EU funded programs PARTNER, ENVISION, ENTERVISION and ULICE, trained dozens of young researchers who now occupy leadership roles in hadrontherapy worldwide [10]. Their success demonstrates the

foresight of coupling research, infrastructure development with capacity building.

Importance of multidisciplinary collaboration. Translating Physics to Health in Europe and beyond

The ENLIGHT community gave rise to “Physics for Health in Europe” (PHE). The first PHE workshop was organized at CERN in February 2010. It successfully showed the big potential that particle accelerators and detectors have in serving as instruments for early diagnosis and effective treatment of tumours [11].

Launching of ICTR-PHE 2012 conference: alliance between the physics and medical communities with a vision of a global strategy for better healthcare

The ICTR-PHE 2012 Conference resulted from the merging of two, formerly independent, successful gatherings: The International Conference in Translational Research in Radio-Oncology, which had been held every two years since 2000, and CERN’s Physics for Health, whose first edition took place in 2010. This was an initia-



Fig. 4. Celebrating 10 years of ENLIGHT at CNAO, Pavia which also coincided with the launch of ENLIGHT Highlights and the successful conclusion of the PARTNER Project (Left to Right: Richard Poetter, Michael Holzscheiter., Manjit Dosanjh, Ugo Amaldi, Juergen Debus, Bledwyn Jones, Roberto Orrechia, Marco Durante) (@ ENLIGHT).



Fig. 5. Launch of Physics for Health (PHE) conference at CERN with Ugo Amaldi being a major driving force, members of the PHE2010 committee left to right: Jean-Francois Chatal, Ulli Köster, Bleddyn Jones, Marco Durante, Purificacion Tejedor del Real, Alberto del Guerra, Wolfgang Enghardt, Manjit Dosanjh, Ugo Amaldi (@ CERN).

tive made possible by the collaboration between Jacques Bernier, Genolier Clinic, Ugo Amaldi, TERA and Manjit Dosanjh, CERN and provided a much-needed venue to present the state of the art of the research in various domains and identify the best way forward. A broad community of experts involved in diagnosis, treatment, and cure gathered to share and discuss their latest results in 2012 and repeated every two years. (<https://www.youtube.com/watch?v=d5zGpqk140s>). These global multidisciplinary meetings encouraged dialogue between high-energy physics and medical physics, highlighting the contributions of particle accelerators to both fundamental science and societal needs (<https://cerncourier.com/a/ictr-phe-uniting-physics-medicine-and-biology>).

Amaldi's keynote lecture in ICTR-PHE 2014, coinciding with CERN's 60th anniversary, articulated his long-standing belief that "physics is not only beautiful but also useful", underscoring his commitment to bridging basic and applied research.

Addressing Global Inequalities in Cancer Care

Global inequities in radiotherapy access remain one of the most pressing challenges in oncology. According to the IAEA [12], the majority of the world's 18,000 radiotherapy machines were concentrated in high-income countries, leaving many low- and middle-income countries (LMICs) without adequate facilities. In Africa,

there is approximately one radiotherapy unit per 3.5 million people, compared to one per 86,000 in the United States [13, 14]. Projections suggest that by 2030, cancer incidence in Africa will exceed 1.4 million new cases annually, amplifying the urgency of addressing these disparities, Lancet Oncology Commission [15].

The STELLA Initiative: Smart Technologies for Global Health

In response, Amaldi helped to catalyze the STELLA initiative, launched in 2016 at CERN with partners including IAEA, ICEC, and NASA [16]. STELLA's vision is to design robust, modular, and cost-effective linear accelerators suitable for deployment in LMICs.

The project's objectives for democratising RT globally (<https://cerncourier.com/a/how-to-democratise-radiation-therapy/>) include reducing capital and maintenance costs, simplifying operations, and integrating imaging technologies. Equally important is its training component, ensuring that local clinicians and technicians can sustainably operate and maintain the equipment.

Tera-Care Foundation and Future Projects

In 2023, Amaldi announced the creation of the Tera-Care Foundation in Geneva, which builds upon his legacy by advancing three programmatic strands:



Fig. 6. Ugo Amaldi giving the public seminar “*Physics is not only beautiful but also useful*” at ICTR-PHE 2014 in celebration of his 80th birthday and 60th Anniversary of CERN (@ CERN).

1. Hadron Therapy Programme – Developing compact synchrotrons and gantries, particularly for helium ions, in collaboration with CERN’s NIMMS activities.

2. Nuclear Medicine Programme – Producing novel isotopes such as Astatine-211 for theragnostics.

3. Low-Income Countries Programme – Training professionals and designing radiotherapy systems tailored to resource-constrained settings, in synergy with STELLA.

The proposed CHeFS (Clinical Helium Facility for Switzerland) exemplify this vision, combining isotope production with compact helium and proton therapy capabilities.

2024 marked the 70th anniversary of CERN. By a singular coincidence, in the same year and month of the foundation of CERN, the very first patient was treated with hadrons in Berkeley by a collaboration of the two Lawrence brothers one being an accelerator physicist and the other being a medical doctor. 2024 also marked the 90th birthday of Ugo Amaldi which was the reason for celebrating together. One of CERN’s 70th anniversary celebration was the event “From particle physics to

medicine” and I had the huge privilege of sharing the stage with Ugo Amaldi.

Conclusion

The symposium marked Ugo Amaldi’s 90th birthday celebrated a career that seamlessly bridged the worlds of fundamental physics and clinical medicine. From the pioneering work of TERA and PIMMS to the establishment of ENLIGHT, and from the global aspirations of STELLA to the launch of the Tera-Care Foundation, Amaldi has been a driving force in transforming particle physics into a force for human health.

As the global community looks ahead to 2034, Amaldi’s centenary, his legacy will be measured not only in scientific papers or facilities built but, in the lives, improved and extended by the technologies and networks he helped to create and number of future leaders he has mentored and continues to mentor.

Amaldi’s enduring message, that physics must be both beautiful and useful, continues to inspire the pursuit of scientific excellence aligned with social responsibility with his latest initiative of (<https://tera-care.ch/>).



Fig. 7. CERN's 70th anniversary event "*From particle physics to medicine*" sharing the stage with Ugo Amaldi. (<https://www.youtube.com/watch?v=WhgDZKr9GQQ>) (@ CERN).

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