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ORIGINAL PAPER

ENLIGHT (European Network for Light Ion Hadron Therapy) and its role in Hadron therapy

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Abstract

Purpose This study provides a comprehensive overview of the progress in hadron therapy within Europe, particularly highlighting the critical roles of the Proton Ion Medical Machine Study (PIMMS) and the European Network for Light Ion Hadron Therapy (ENLIGHT).

Methods Our approach includes a retrospective analysis of the advances in hadron therapy facilities, facilitated by a synthesis of interdisciplinary collaboration data gathered from ENLIGHT's annual meetings since 2002, and an assessment of European-funded projects and networks' contributions to the field.

Results The results showcase significant advancements in cancer treatment due to collective efforts in hadron therapy, underscored by ENLIGHT's pivotal role in fostering interdisciplinary cooperation and the harmonization of treatment protocols across Europe.

Conclusion The evolution of hadron therapy, from its inception to its current impact on patient care, demonstrates the successful realization of complex medical technologies through sustained collaboration and standardized practices across European institutions and projects.

Keywords Hadron therapy · ENLIGHT network · Cancer treatment · Radiotherapy innovation · European collaboration

1 Introduction

Hadron therapy, a state-of-the-art radiation therapy using mainly proton and ion beams, with cutting-edge technologies represents a significant advance in oncological treatments. This therapy, notably more precise than conventional radiation, minimizes damage to surrounding healthy tissues while targeting tumours and is particularly effective against those close to critical organs and the radio-resistant ones. The inception of the Proton Ion Medical Machine Study (PIMMS) in the late 1990s marked a turning point in hadron therapy in Europe [1, 2]. PIMMS not only pioneered the conceptual framework for advanced hadron therapy facilities but also set the stage for a broader multidisciplinary European collaboration in this field.

The launch of the European Network for Light Ion Hadron Therapy (ENLIGHT) in 2002 further catalyzed the development of hadron therapy [3]. As a multidisciplinary initiative, ENLIGHT united experts from various fields, including physics, biology, and medicine, fostering a collaborative environment essential for innovation. This network has played a crucial role in addressing the challenges of hadron therapy, such as cost, technical complexity, and the need for specialized medical and technical expertise [4].

Over the years, hadron therapy has evolved from an experimental treatment to a more widely accessible option for cancer patients. This progression can be attributed to the collaborative efforts of various European projects and networks, which have worked tirelessly to improve the technology, increase treatment efficacy, and expand patient access. These collaborations have not only led to the establishment of new treatment centers across Europe but have also been instrumental in driving research, standardizing treatment protocols, and enhancing training and education in the field.

The introduction of hadron therapy marked a new era in cancer treatment, offering hope and improved outcomes for patients with certain types of cancer. The journey from PIMMS to ENLIGHT and beyond highlights the power of

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collaboration and innovation in advancing medical technology. As hadron therapy continues to evolve, it remains a testament to the ongoing efforts of the scientific and medical communities to improve cancer care.

This introduction provides an overview of the evolution and significance of hadron therapy in Europe, setting the stage for the detailed discussions in the main content of the document.

2 Development of Hadron therapy facilities

- Historical overview

The inception of hadron therapy, utilizing protons and heavier ions for cancer treatment, marked a revolutionary step in medical science. The very first patient was treated with protons in September 1954 in Berkeley [5–7] and the first patient in the Gustaf Werner Institute, Uppsala, Sweden [8]. Europe has been at the forefront of hadron therapy innovation, with the early establishment of pioneering facilities dedicated to research and treatment. The first European hadron therapy center began operations in the mid-20th century, laying the groundwork for a new era in oncological care. These initial ventures set a global precedent, spurring the development of advanced treatment protocols and technologies that have significantly improved patient outcomes. Subsequent facilities built upon this foundation, incorporating cutting-edge research and clinical applications to expand the reach and efficacy of hadron therapy.

- Technological advances

Technological innovations have propelled the expansion of hadron therapy, particularly through accelerator development, enhanced beam delivery systems which allow for more precise tumor targeting and reduced impact on surrounding tissues. Simultaneously, imaging techniques have seen significant improvements, integrating tools such as CT, PET, CT-PET and MRI into treatment plans, facilitating accurate real-time tracking and adjustments during therapy.

- Expansion of facilities

The expansion of hadron therapy centers across Europe has been substantial, reflecting the region's commitment to advancing cancer treatment. As of June 2023, Europe is home to 35 such centers, with four offering both proton and carbon ion therapies, signifying a versatile approach to oncological care (Figs. 1 and 2). These facilities are at the forefront of medical innovation, offering hope and advanced treatment options to patients. Notable among these is the very first dual-ion center with the very first carbon gantry

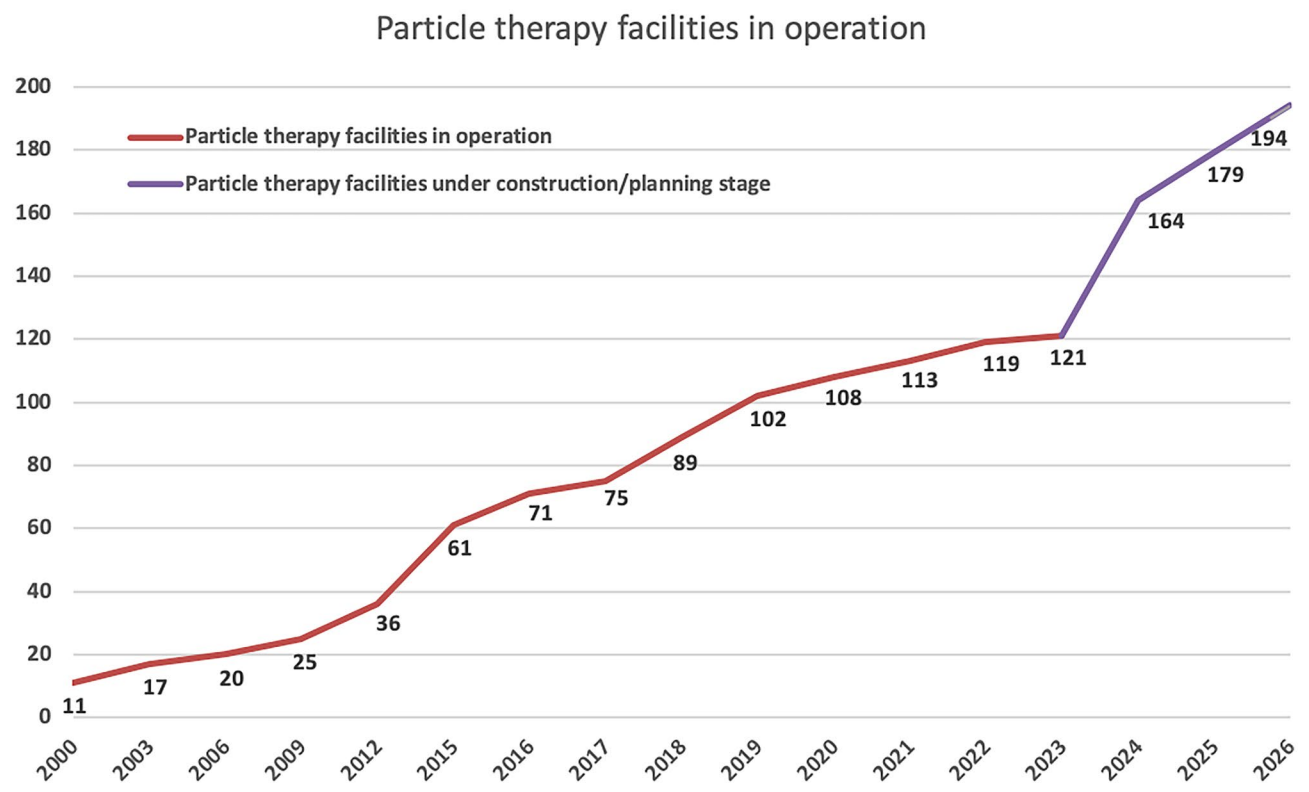

Fig. 1 Hadron therapy facilities in operation worldwide, under construction and in the planning stage in June 2023 (www.ptcog.com)

Fig. 2 European hadron therapy facilities in operation in 2023

in Heidelberg, Germany, which stands as a beacon of comprehensive cancer therapy in Europe [9].

- Patient access and impact

The expansion of hadron therapy centers has significantly improved patient access across Europe (Fig. 3). Enhanced availability has led to more patients benefiting from targeted treatments, showing promising outcomes, especially in complex cancer cases. This increased accessibility is a leap forward in-patient care, reflecting a shift towards more personalized and effective oncological treatments [10, 11].

3 ENLIGHT's aims and activities

- Mission and goals

ENLIGHT, the European Network for Light Ion Hadron Therapy, plays a pivotal role in harmonizing and advancing hadron therapy across Europe. Its mission is to foster collaboration and knowledge exchange among leading institutions, with the overarching goal of optimizing patient care through cutting-edge treatments. ENLIGHT's objectives encompass promoting interdisciplinary research, establishing standardized treatment protocols, and nurturing educational initiatives. The network acts as a catalyst for innovation, bringing together experts from various fields to enhance the precision and efficacy of hadron therapy. By facilitating cooperation and resource-sharing among its members, ENLIGHT embodies a commitment to ensuring equitable access to state-of-the-art cancer treatment options for all patients.

- Interdisciplinary approach

ENLIGHT's core strength lies in its unwavering commitment to fostering interdisciplinary collaboration within the field of hadron therapy. By seamlessly bridging the expertise of professionals from diverse fields, ENLIGHT has pioneered a holistic approach to advancing cancer treatment. The network serves as a dynamic platform where physicists, medical experts, radiobiologists, and engineers converge to synergize their knowledge and talents. This interdisciplinary synergy is at the heart of ENLIGHT's

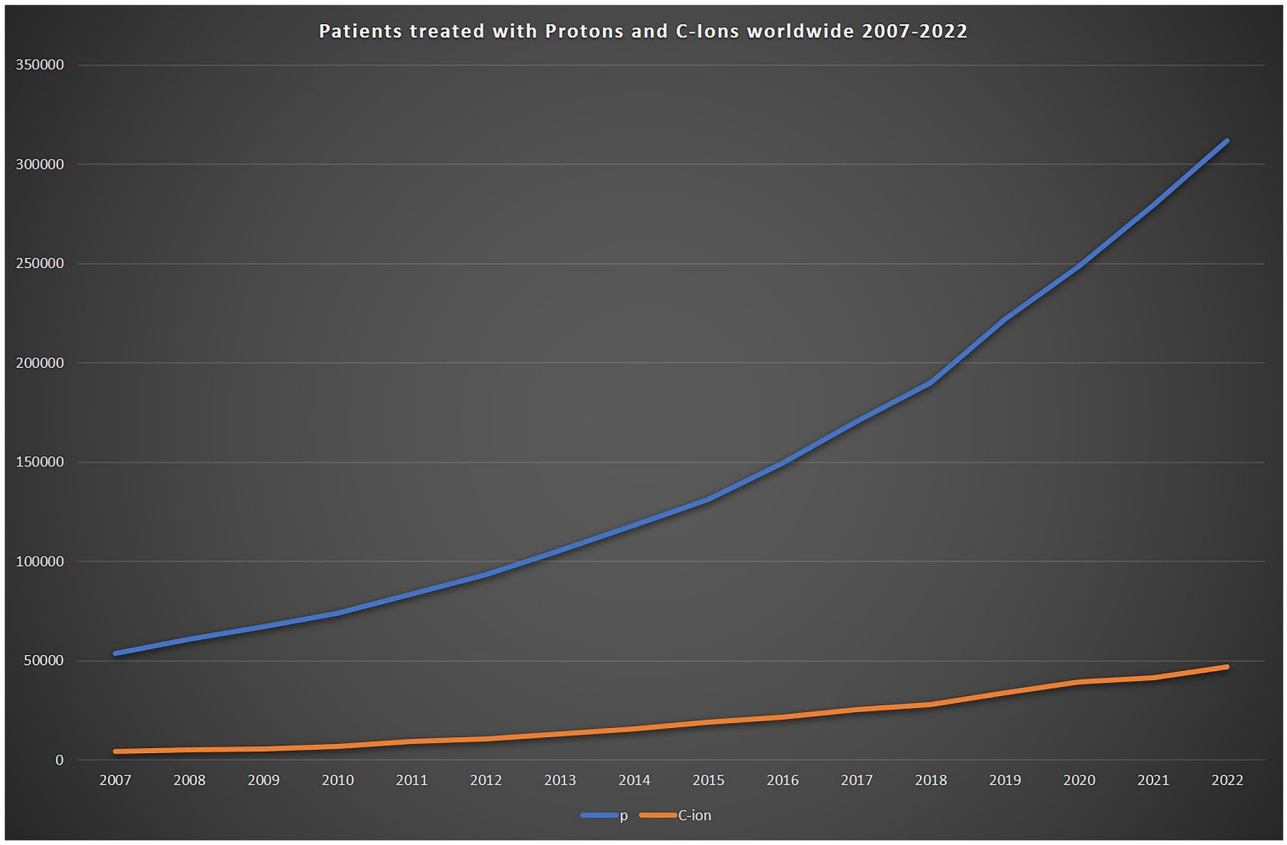

Fig. 3 Patients treated with proton and carbon ion beams worldwide by the end of 2022

success, driving innovations that transcend traditional boundaries and propel the field forward. The network's emphasis on knowledge exchange and sharing of ideas has resulted in ground-breaking developments, ultimately benefiting patients by enhancing the precision, safety, and accessibility of hadron therapy across Europe.

- Research and development

ENLIGHT has made significant contributions to research in the field of hadron therapy, driving innovations that have a profound impact on cancer treatment. The network actively supports and initiates a multitude of research projects, with a focus on advancing the understanding of radiation biology, treatment planning, and patient-specific dosimetry. Notable projects include investigations into the radiobiological effects of different ion beams, the development of novel treatment protocols, and the exploration of advanced imaging techniques for treatment monitoring. ENLIGHT's commitment to research excellence extends to collaborative studies that explore the clinical efficacy of hadron therapy for various cancer types. These efforts collectively position ENLIGHT as a catalyst for ground-breaking discoveries that continue to shape the future of cancer treatment across Europe [12–16].

- Education and training

ENLIGHT's commitment to education in hadron therapy features a comprehensive spectrum of initiatives designed to empower the next generation of experts. Through the PARTNER and ENTERVISION programs, ENLIGHT has cultivated a vibrant research exchange, encouraging mobility and collaborative learning. The cornerstone of their educational structure includes annual European meetings and specialized training days, which are complemented by competitive poster sessions that spotlight emerging scientific talent. These gatherings not only serve as knowledge hubs but also as arenas for recognizing and nurturing future leaders. Towards the culmination of these efforts, ENLIGHT Highlights (Fig. 4) and HITRIplus Monthly seminars stand out as platforms for extensive global information sharing, reflecting ENLIGHT's dedication to a universally informed and interconnected scientific community.

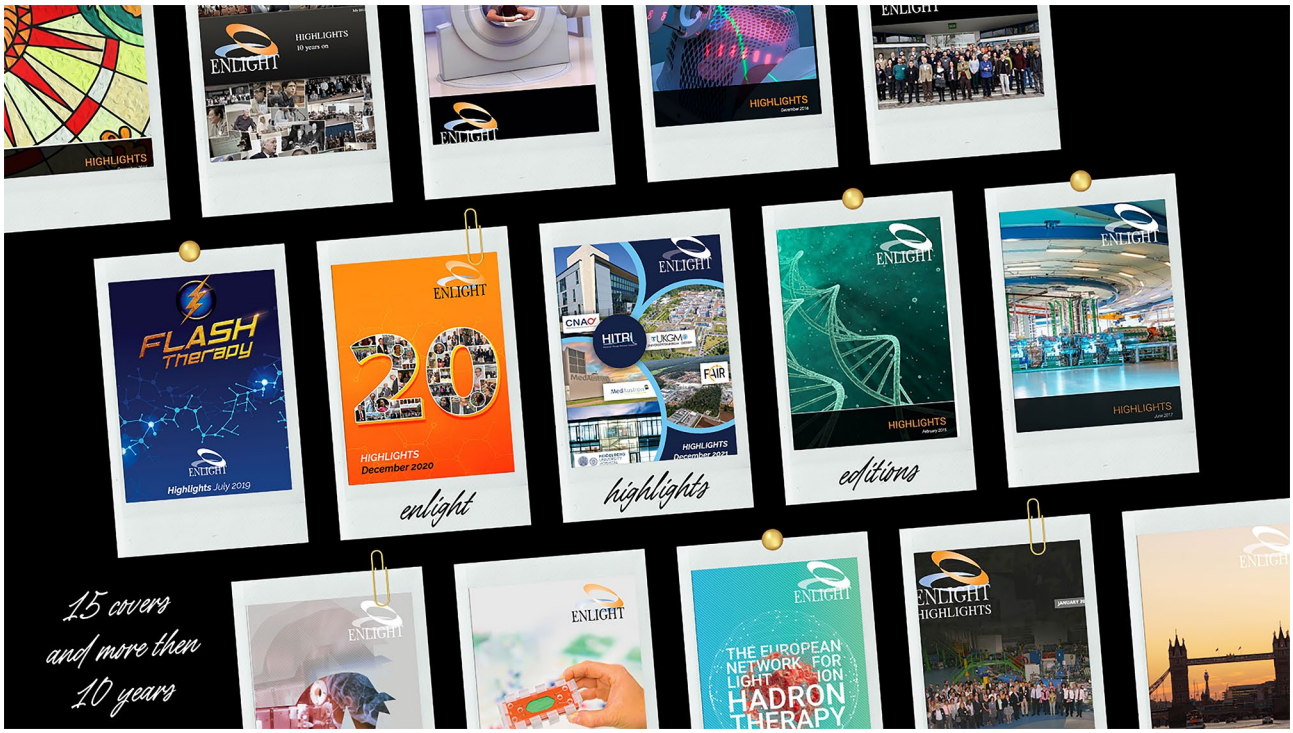

Fig. 4 ENLIGHT Highlights covers from 2012 to now - https://enlight.web.cern.ch/highlights

4 Role of European Projects and Networks

- Collaborative initiatives

European projects and networks are pivotal in propelling hadron therapy to new heights. Collaborative initiatives like ENLIGHT, alongside joint research programs, have established a robust framework for innovation and resource sharing. These collective endeavors facilitate a synchronized approach to scientific challenges, allowing for the pooling of expertise, data, and cutting-edge technology. Such synergies not only accelerate research outcomes but also ensure a cohesive-advances in knowledge and therapeutic techniques. By fostering a community that prioritizes cooperation over individual endeavor, networks like SEEIIST and initiatives in the Baltic countries are instrumental in shaping a future where hadron therapy becomes a standard, accessible treatment option for cancer patients across Europe and beyond, ensuring inclusive healthcare advances.

- Funding and support

The progress in hadron therapy has been significantly enhanced by the backing of European funding. Financial support from organizations such as the European Commission has been instrumental in catalyzing research and development. Through initiatives like the Horizon programs, substantial grants have been allocated to consortia like ENLIGHT, enabling the seamless operation of extensive research networks and top-quality collaborative projects. This funding is critical, not only for the direct scientific endeavors, but also for establishing infrastructure, procuring advanced equipment, and supporting the cross-border movement of researchers. The generosity of these funding bodies underscores the European commitment to pioneering a future where hadron therapy is a cornerstone in the fight against cancer, illustrating a model where financial support is directly correlated with healthcare innovation.

5 Looking forward: Expansion and inclusivity in radiotherapy

As we look to the future, projects such as SEEIIST and the Baltic region initiatives are at the forefront of expanding the reach of radiotherapy. SEEIIST, with its focus on building a state-of-the-art research facility, aims to not only drive forward scientific inquiry but also to become a hub for medical advancements within South East Europe. This project is a testament to the power of transnational collaboration in advancing medical technology [17].

Simultaneously, efforts are being made to integrate countries with lower and middle incomes into the fold of advanced radiotherapy treatments. Through the cultivation

of partnerships and the exchange of knowledge, European networks are actively striving to break down obstacles to access. The aim is to create a global environment where cutting-edge cancer treatment, like hadron therapy, is not a privilege of the few but a universal healthcare standard.

Financial support is critical in this inclusive approach, providing the necessary resources for research, development, and the dissemination of knowledge. With sustained funding and support, the gap in radiotherapy access can be bridged, ensuring that advances in the field benefit not just a select region but contribute to the global fight against cancer. Through projects like SEEIIST and collaborations within the Baltic region and STELLA the path is paved for a more equitable distribution of high-quality cancer care [18].

It is hard to say where the field will go in the next 10-20 years, but at the moment it appears clear that protons in particular are fairly mature as a technology, but still not as a clinical practice. Indeed, in spite of a huge number of treatment centers across the globe, we have not yet treated enough patients with clinical protocols so that hadron therapy has become an automatic part of cancer treatment. Hadron therapy will become part of the radiation therapy practice once there are enough facilities and enough patients for whom that is the right treatment based on sufficient clinical data and experience. ENLIGHT and its powerful network of world specialists will continue to contribute to the growth of the particle therapy field.

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References

1. Badano L, Benedikt M, Bryant PJ, Crescenti M, Holy P, Maier AT, Pullia M, Rossi S, Knaus P. Proton-Ion Medical Machine Study (PIMMS), 1. CERN-PS-99-010-DI. CERN-TERA Foundation-MedAustron Oncology-2000 Collaboration; 2000. p. 232.
2. Bryant PJ, Badano L, Benedikt M, Crescenti M, Holy P, Maier AT, Pullia M, Reimoser S, Rossi S, Borri G, Knaus P, Gramatica F, Pavlovic M, Weisser L. Proton-Ion Medical Machine Study (PIMMS), 2. CERN-PS-2000-007-DR. Geneva, Switzerland: CERN; 2000, p. 340.
3. Cancer therapy initiative is launched at CERN. CERN Courier, 24 April 2002. [Online]. Available: http://cerncourier.com/cws/article/cern/28632.
4. Dosanjh M, Hoffmann HF, Magrin G. Status of hadron therapy in Europe and the role of ENLIGHT. Nucl Instrum Methods Phys Res Sect A. 2007;571:191–4.
5. Wilson RR. Radiological use of fast protons. Radiology. 1946;47(5):487–91. https://doi.org/10.1148/47.5.487.
6. Lawrence JH. Proton irradiation of the pituitary. Cancer. 1957;10(4):795–8. https://doi.org/10.1002/1097-0142(195707/08)10:4%3c795:AID-CNCR2820100426%3e3.0.CO;2-B.
7. Lawrence JH, et al. Pituitary irradiation with high-energy proton beams: a preliminary report. Cancer Research. 1958;18(2):121–34.
8. Larsson B, et al. The high-energy proton beam as a neurosurgical tool. Nature. 1958;182(4644):1222–3. https://doi.org/10.1038/1821222a0.
9. Combs SE, et al. Particle Therapy at the Heidelberg Ion Therapy Center (HIT) - Integrated Research-Driven University-Hospital-Based Radiation Oncology Service in Heidelberg, Germany. Radiother Oncol. 2010;95(1):41–4.
10. Orlandi E, et al. The Role of Carbon Ion Therapy in the Changing Oncology Landscape—A Narrative Review of the Literature and the Decade of Carbon Ion Experience at the Italian National Center for Oncological Hadrontherapy. Cancers. 2023;15(20):5068. https://doi.org/10.3390/cancers15205068.
11. Enlight, "ENLIGHT Hightlights - Issue 15", Enlight Highlights, no. 15, Dec. 2021. https://doi.org/10.5281/zenodo.6559647.
12. Dosanjh M, Jones B, Mayer R. ENLIGHT and other EU-funded projects in hadron therapy. Br J Radiol. 2010;83:811–3.
13. Dosanjh MK, et al. Introduction to the EC's Marie Curie Initial Training Network (MC-ITN) project: Particle Training Network for European Radiotherapy (PARTNER). J Radiat Res. 2013;54:i1–5.
14. Dosanjh M, Cirilli M, Navin S. Introduction to the EC's Marie Curie initial training network project: the European training network in digital medical imaging for radiotherapy (ENTERVISION). Front. Oncol. 2015;5. https://doi.org/10.3389/fonc.2015.00265.
15. Orecchia R, Pötter R, Debus J, Dosanjh M. SP-0304: The contribution of the ULICE project to the development of hadron therapy in Europe. Radiother Oncol. 2015;115:S152–3. https://doi.org/10.1016/S0167-8140(15)40302-0.

16. Pötter R, et al. Union of Light Ion Therapy Centers in Europe (ULICE EC FP7) – Objectives and achievements of joint research activities. Radiother Oncol. 2018;128(1):1–7. https://doi.org/10.1016/j.radonc.2018.04.027.
17. Amaldi U, et al. "South East European International Institute for Sustainable Technologies (SEEIIST)," Front. Phys. 2021. https://doi.org/10.3389/fphy.2020.567466.
18. Dosanjh M. Collaboration, the force that makes the impossible possible. Adv Radiat Oncol. 2022;7(6). https://doi.org/10.1016/j.adro.2022.100966.