Tera-Care Foundation


CNAO 25-metre synchrotron – www.cnao.it

WHY AND HOW

In collaboration with national and international players active in **radiation medicine**, Tera-Care aims **at improving the technologies to diagnose and fight cancer and at saving lives** via

A. the Hadron Therapy Programme

that is focused on the design and the construction, in **Middle- and High-Income Countries,** of **novel synchrotrons** for treating tumours with hadrons: in particular, with beam of **helium ions**;

B. the Nuclear Medicine Programme

that aims to produce novel **medical radioisotopes**, in particular **Astatine-211,** for '*theragnostics'*, which combines diagnostic imaging and therapy through the injection of labelled molecules;

C. the Low-Income Countries Radiotherapy Programme

that trains radiation oncologists and technicians of **Low-Income Countries** and participates in the design and realisation of a **robust X-ray radiation system** adapted to challenging environments.

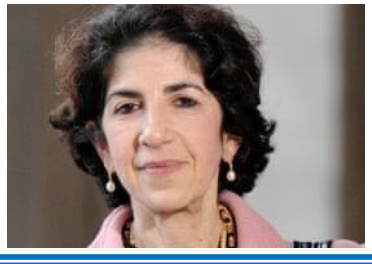
RADIOTHERAPY WITH X-RAYS AND HADRON BEAMS

In High Income Countries (HICs) there is more than one X-ray radiotherapy unit every 250,000 people and **50-60% of all cancer patients are irradiated with X-rays (**3000 per million inhabitants). The about 20,000 X-ray units are accompanied by a similarly large numbers of diagnostic instruments (CT, PET, MRI...). In Africa there are only 400 systems instead than the needed 5000-6000 units (see the figure at the bottom of page 2). Diagnostics instruments are also missing.

In the last 30 years a different type of radiotherapy - called '**hadron therapy**' or 'particle therapy' - has been introduced by utilizing narrow beams of either protons (of 70-250 MeV with 1 positive charge) or carbon ions (of 1500-5000 MeV with 6 positive charges). **Protons**, available world-wide in more than 100 centres, have the same effect on cells as X-rays but deposit the radiation dose more precisely much better sparing close-by organs. **Carbon ions** (available in about 20 centres) are different radiation, because of the large charge, and can kill '**radioresistant'** cells, insensitive to both X-rays and protons. In HICs, about 1% of the patients treated with X-rays have a radioresistant tumour. **Helium ions** (of 300-1000 MeV with 2 charges) are twice more precise than protons.

TERA FOUNDATION

Since 1992, the development of hadron therapy has been the main purpose of the Italian **TERA FOUNDATION** that, working with CERN, designed the protons and carbon ions synchrotron of the Italian *National Centre for Oncological Hadron Therapy* CNAO, built in Pavia with Government funds and INFN important contributions. In its projects TERA has profited from the collaboration with highly-competent CERN staff members and retirees. The **CNAO has treated 5400 patients** with protons and Carbon ions in the framework of the Italian National Health Service. One can estimate that **1000-1500 lives** have been saved with respect to what would have happened if the same patients had been treated with X-rays. Seven centres with protons and carbon are active in Japan, China and Europe. The first American centre of this type is being built in Florida by Mayo Clinic.

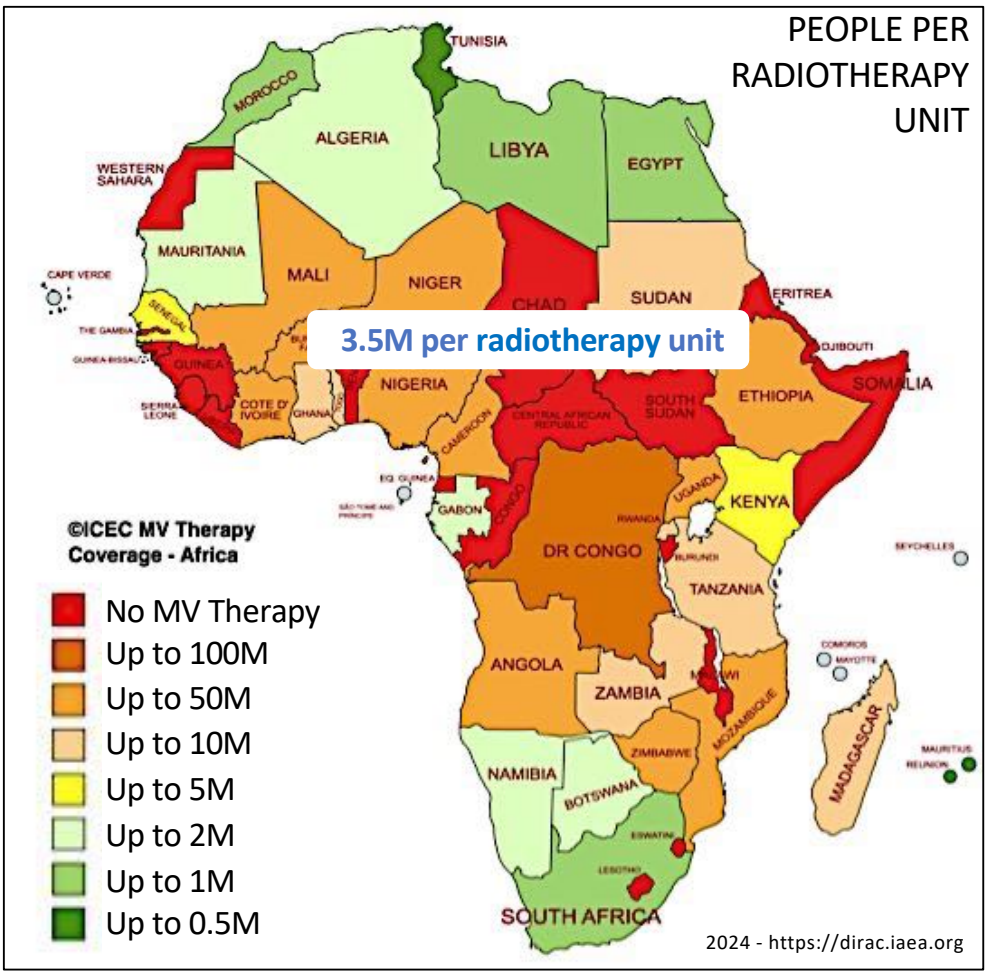


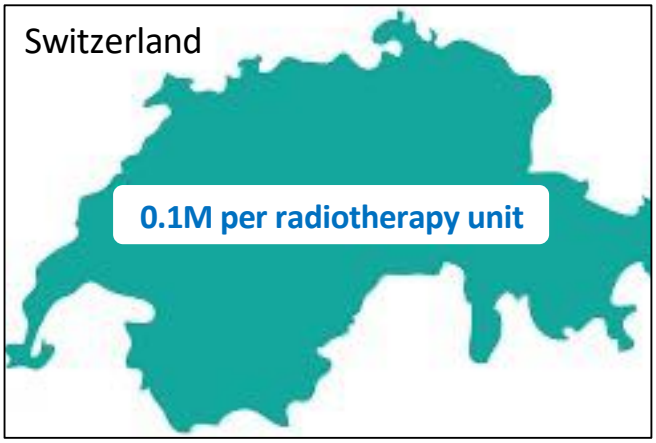
On September 15, 2022, the 30-years of TERA were reviewed in a Symposium held at CERN. **Fabiola Gianotti** – Director General of the world's largest particle-physics laboratory – said "*TERA has been extremely useful to CERN for two reasons: it gave the opportunity to advance and apply our technology and helped CERN to become more aware of the importance of the societal impact of our work. In the early '90s, this was not as evident at CERN as it is today*".

ORIGIN OF Tera-Care

In August 2023, Tera-Care was created in Geneva with funds donated by a Sponsor who, 20 years before, had financed TERA for the design of CNAO. The Sponsor, having participated in the Symposium held on September 2022 at CERN for the 30th Anniversary of TERA, was struck by the many achievements and the more than 200 young physicists and engineers who have been trained, most of them at CERN where the TERA scientific team has its offices and laboratories.

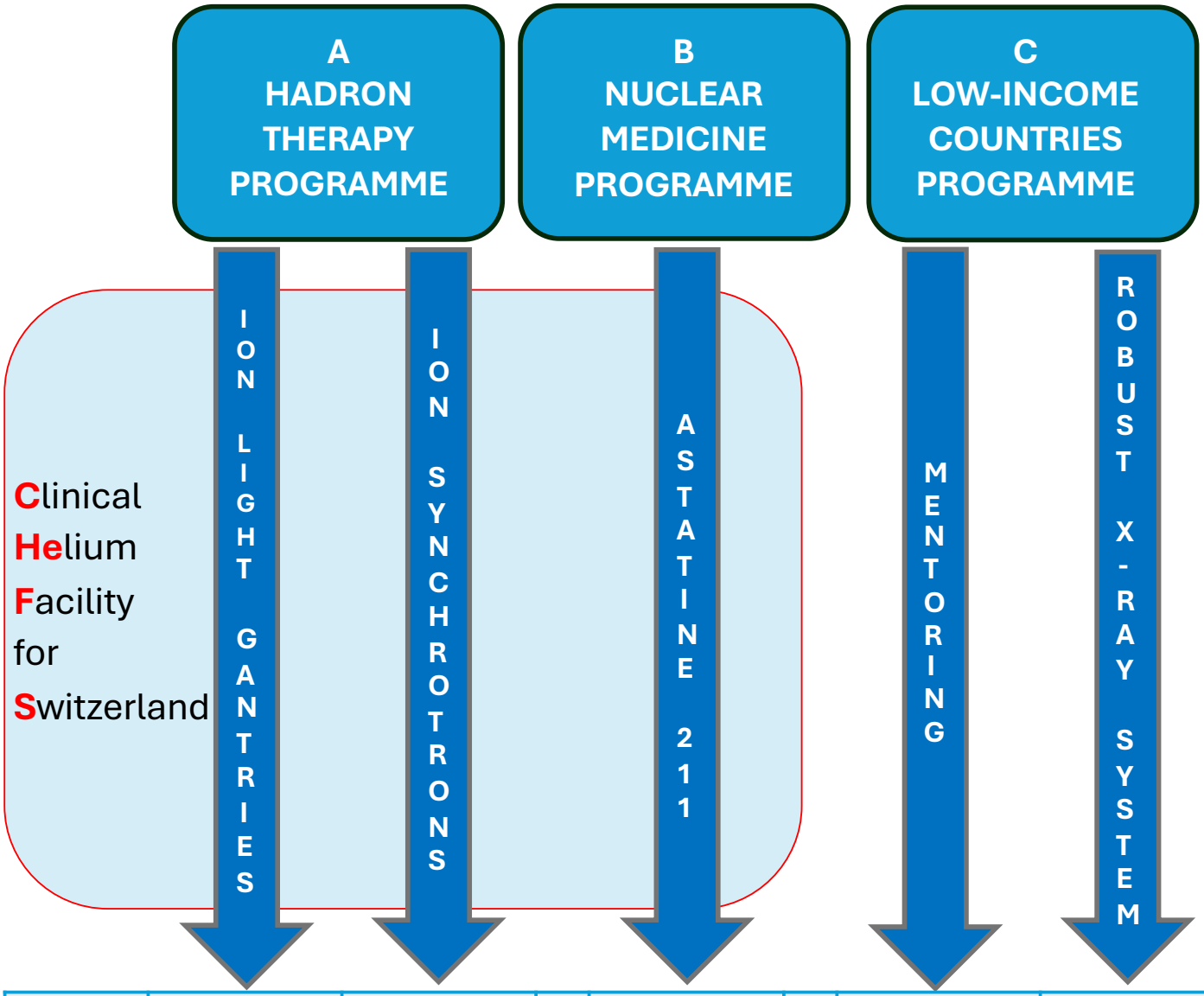
X-RAY RADIOTHERAPY






X-ray unit based on an electron linac-Courtesy of Elekta

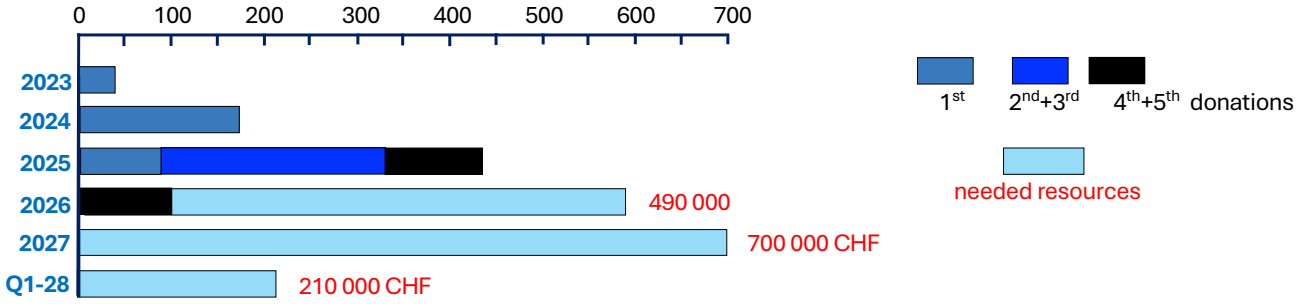
Tera-Care Foundation in Geneva



	Project 1	Project 2		Project 3		Project 4	Project 5
2023	-	35 000		-		-	-
2024	20 000	125 000		-		-	25 000
2025	10 000	90 000		270 000		10 000	50 000
2026	-	90 000		390 000		20 000	90 000
2027	-	80 000		470 000		30 000	120 000
Q1-28		20 000		150 000		10 000	30 000
Total	**30 000**	**440 000**		**1 280 000**		**70 000**	**315 000**

On average 10% of each amount is spent in overheads

FINANCIAL NEEDS



HADRON THERAPY AND THERAGNOSTICS PROJECT

1. Ion light gantries

A gantry, rotating around the patient's bed, can irradiate a tumour with beams coming from the directions that minimize the damages to normal tissues. The lightest **gantry for carbon ions**, built in Japan, weights 300 tons. TERA has proposed a novel superconducting design called SIGRUM. Its performances will be further improved using novel high-temperature superconducting magnets.

EXPECTED OUTCOMES: *Tera-Care will reassess the initial design of SIGRUM, already improved in collaboration with CERN (Project 1). The advantages are the weight (4-5 time less than the existing gantries) and the simplifications in transporting and mounting it. The final Report will be ready by the end of 2025. Probably a patent will be deposited. Then the project will be left in standby till the beginning of 2028 when the use of novel superconducting magnets will be resumed.*

2. Ion synchrotrons

The **Next Ions Medical Machine Study**, initiated in 2018 by CERN, focuses on novel technologies for cancer therapy with ion beams. An important part of NIMMS is the design of two compact synchrotrons: the first for **helium ions** and the second, based on superconducting magnets of the last generations, for carbon ions. On behalf of the Collaboration, **Technical Director Elena Benedetto leads these designs** so that Tera-Care contribution is essential for NIMMS success.

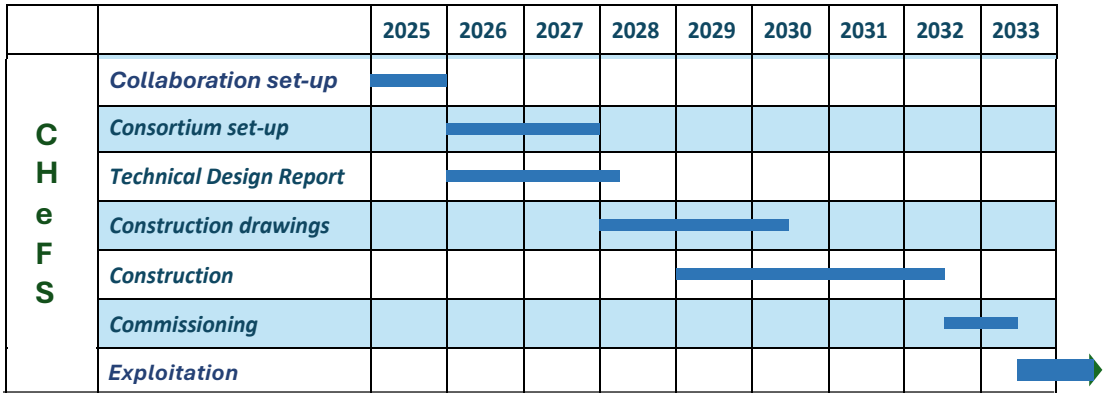
EXPECTED OUTCOMES: *Using **t**he helium synchrotron of NIMMS, Tera-Care has proposed to collaborate with CERN and other partners and design **CHeFS**, a* Clinical Helium Facility for Switzerland. *The linear accelerator (linac), which injects helium ions in the synchrotron, will be also used to produce Astatine-211 (Project 3). The synchrotron will treat patients with high energy helium beams (Project 2). The* **Technical Design Report** *of CHeFs will be ready by March 2028.*

3. Astatine-211

Theragnostics is a rapidly-growing clinical modality that combines diagnostic imaging (PET and SPECT) and therapy through the injection of the same molecule, labelled with one or two radioisotopes. TERA-Care - in collaboration with CERN, the University of Bern and other partners - will desig the linac and the radio-pharmacy of CHeFS (Project 3) to produce **Astatine-211**, a promising isotope for the cure of **disseminated tumours** and **micro-metastases**.

EXPECTED OUTCOMES: *The linac, which injects helium in the* Clinical Helium Facility for Switzerland *(CHeFS), will accelerate a very intense beam of helium ions up to 29 MeV to produce Astatine-211. In the years 2025-2027 Tera-Care will contribute – with CERN and other partners among which CNAO – to the **design of CHeFS** and to the organization of a **private-public Consortium**, which will take the responsibility to build In Switzerland the first Facility.*

In the years 2025-2028 Tera-Care will invest CHF370,000, CHF480,000 and CHF540,000 for the **Technical Design Report of CHeFS**, which - in the present plan - will be completed by March 2028. If the CHeFS Consortium will be fully organized by the end of 2027, and initial construction money will be available for this date, the production of construction drawings could start in January 2028.



LOW-INCOME COUNTRIES PROJECTS

4. Mentoring in Low-Income Countries

By setting-up of collaborations with international organizations, Tera-Care aims at contributing to the training in LMICs of the much-needed radiation oncologists and technicians. Collaborations with AORTIC (African Organisation for Research and Training in Cancer) and with AROME (Association de Radiothérapie et d'Oncologie de la Méditerranée) have been initiated.

EXPECTED OUTCOMES: *With the support of collaborating organizations, mentoring schemes and education programs will be strengthened in Low-Income Countries to train the local staff to become well-qualified radiation oncologists and technicians. They will then be in a stronger position to deploy the benefits of the (few) existing radiation therapy machines and of the (hopefully many) future robust X-ray radiotherapy systems to be built by the STELLA collaboration presented in the next subsection.*

5. Robust X-rays system for Low-Income Countries

Tera-Care is a member of the **STELLA Project** (Smart Technology to Extend Lives with Linear Accelerators: *https://www.iceccancer.org/innovative-radiotherapy-technologies/*) that has as main aim the design and the construction of a **novel robust X-ray linac** system, which is conceived for the challenging conditions often found in LICs, requires less maintenance and is cost effective without compromising the quality of the radiation treatments.

EXPECTED OUTCOMES: *Within the STELLA Project (an initiative of the* International Cancer Expert Corps – ICEC in USA*) Tera-Care has the responsibility of designing the mechanical support which rotates around the patient bed. The active parts of the electron linac system attached to this 2.5-meter gantry will be easily accessible and replaceable. A first scheme will be ready by the end of 2025 and, if accepted, the* Technical Design Report *will be presented to the STELLA collaboration by the middle of 2026. The construction of a prototype is foreseen in the years 2026-2027.*

HIGH-LEVEL EXPERTS

In its three decades of activity the TERA Foundation - having a collaboration agreement, and offices and laboratories on CERN premises - has greatly benefited from the collaboration with **CERN physicists and engineers** and the contributions of a dozen **retired CERN staff members** who, not wanting to stop working, have made their time and competences available free of charge. Tera-Care will benefit from the same two sources of invaluable know-how.

AGREEMENTS AND LOCATION

Tera-Care has signed Collaboration Agreements with **CERN** (so that its staff will share with TERA staff five offices and a meeting room in building 182 of the Meyrin site), with **TERA Foundation** and with the **University of Malta**, home institution of the first PhD student supported by Tera-Care.

EUROPEAN PROJECTS

In the framework of the Hadron Therapy Programme, Tera-Care has joined two Collaborations, approved and partially financed by the EU:

- **HITRIplus** (*Heavy Ion Therapy Research Integration*)
  https://www.hitriplus.eu
- **I.FAST** (*Innovation Fostering in Accelerator Science and Technology)*
  https://ifast-project.eu

TEN-YEAR PLAN

In the next years, Tera-Care will invest about **80% of the budget** in the Hadron Therapy and the Nuclear Medicine Programmes, i.e. in the design, promotion and follow up of the *Clinical Helium Facility for Switzerland* (**CHeFS**), which will be **mainly** dedicated to the production of novel radioisotopes, like **Astatine-211,** and to hadron therapy with proton and **helium beams**. The construction funds will be collected by the *CHeFS Consortium* and do not appear in the table.

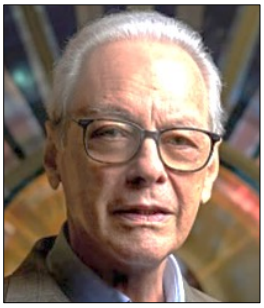
In parallel, **about 20% of the budget** will be devoted to **Low- and Medium-Income Countries for** both **mentoring** and contributing to designing, prototyping and following the construction of **the gantry of** the STELLA robust X-ray system.

	Hadron Therapy	Nuclear Medicine	Low-Income Countries	Total
2024	145 000	-	25 000	170 000
	85%	-	15%	100%
2027	80 000	470 000	150 000	700 000
	12%	67%	21%	100%
2030	140 000	630 000	190 000	960 000
	14%	66%	20%	100%
2033	190 000	790 000	220 000	1 200 000
	16%	66%	18%	100%

BOARD MEMBERS

Matti Aapro – President – is member of the Board of Directors of the Genolier Cancer Center in Switzerland and President of Sharing Progress in Cancer Care (SPCC) and All.Can. He was formerly President of the European Cancer Organization (2020-2021), Past Chair of the Medical and Radiation Therapy Department at the European Institute of Oncology in Milan and Past Executive Board member of the European School of Oncology (ESO).

Saverio Braccini – Secretary General – has been Technical Director of TERA and at present is Professor of experimental physics at the University of Bern and Chief of the Medical Applications of Particle Physics research group at the Bern medical cyclotron of Inselspital, an innovative facility for radioisotope production and multidisciplinary research.



Ugo Amaldi – Founding Member and Scientific Director – as CERN senior research scientist has made important contributions to particle physics and – as promoter of TERA Foundation (Italy), Professor in Medical Physics (Milan) and Distinguished Affiliated Professor at TUM (Munich) – has worked for 30 years on cancer therapy with hadron beams. He is Doctor honoris causa of the Universities of Helsinki, Lyon, Uppsala, and Valencia, TERA President and CNAO President Emeritus.

Frédérick Bordry – Board Member – joined CERN in 1986, where he has held scientific and management positions. From 2014 to 2020 he was Director for Accelerators and Technology. As a long-time advocate for sustainability in energy, science, and medical applications of accelerators, he is at present scientific advisor to several institutions, industries, and start-ups.

Marta Guglielmetti – Board member – has an over 25 years' experience as a senior executive championing sustainability and inclusiveness. She has held various leadership positions in the United Nations, and philanthropic organizations such as the Bill & Melinda Gates Foundation, engaging with large corporations and major global health stakeholders.

Gaudenzio Vanolo – Board Member – is Secretary General of TERA Foundation. In this role he has been working for more than 40 years in the dissemination of scientific culture to the general public, in the organization of activities related to cancer care with particle beams, in fund raising, and in the nutrition of cancer patients, as leader of the Food Bank in Oncology project.

OUR STAFF

Elena Benedetto – Technical Director – has been CERN staff and was TERA Technical Director. With her 20 years' experience in particle accelerators, she designs novel and compact accelerators to improve performances, reduce costs and extend the access to therapy with beams of carbon and other light ions. She is also involved in technology and innovation activities in Switzerland. Elena is also leading the personnel that TERA keeps at CERN to work on hadron therapy.

Eleonora De Cata – Administrative Manager – has a PhD in Economics and, having worked for over 10 years both in Corporate and non-profit organizations linked to public health and research, provides ancillary work of quality for the needs of the Foundation. She is primarily responsible for Finance, Administration, Tax and Accounting.

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Ariana Cassar – PhD Student – is an Electrical Engineer with expertise in electrical systems and process automation. She brings her experience from industry together with her background in particle accelerators to research techniques and solutions for optimization of treatment time and energy efficiency of ion medical accelerators to achieve a more sustainable and economically feasible machine.

Gaia Dellepiane – Postdoctoral Researcher – Ph.D. in Physics with experience in accelerator-based medical applications, including radionuclide production with medical cyclotrons and beam characterization in ultra-high dose rate proton therapy. At Tera Care, she brings her expertise in cross-section measurements and the optimization of production routes for novel medical radionuclides to advance theragnostics applications.

Tânia de Melo Mendonça – Research Engineer - is a materials engineer and physicist with extensive experience in target development for radioisotope production. She led and contributed to key projects in target design, prototyping and validation for medical and nuclear applications in leading research facilities such as ISOLDE at CERN. With over 14 years of experience, she specialized in materials characterization, thermal analysis, and prototype testing. At Tera Care, she contributes to the nuclear medicine program, applying her expertise to enhance isotope production technologies.

OUR STAFF

Ruiliang Lin - Project Engineer - is a robotics engineer with experience in medical devices and space robotics . With extensive expertise in mechatronics design and motor control, he has contributed to research projects in both private and academic settings, including the design of lower-limb rehabilitation exoskeletons, space-rated robotic arms and underwater autonomous probes. He provides specialized knowledge in electronics and mechatronics design.

Mathias Widmer - Project Engineer - is a Mechanical Engineer with expertise in aerospace, railway, and high precision fluid mechanics systems. He focuses on precision with robust yet lightweight design at Tera- Care, is also professor at the Technical School of Geneva (HES) and is working on the new efficient nozzle design of the Geneva fountain.

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Site: www.tera-care.ch