3rd I.FAST Annual Meeting

Luca Garolfi (CERN & TERA Foundation, WP4, Task Leader 4.1 & 4.2)

The I.FAST Academia-Industry Exchange Programme

The EU-supported project I.FAST announces the possibility to apply for a grant to finance a programme of exchange of knowledge, expertise, and working practices of new accelerator and magnet component technologies between an I.FAST European Accelerator Development Laboratory* (here called the I.FAST Laboratory) and a European Industrial Company (here called the Company).

The programme offers the opportunity for a Company to send an engineer or technician for one or several visits to one of the I.FAST Laboratories and for a I.FAST Laboratory to send a scientist, engineer or technician to a Company for one or several visits. A grant of up to 7000 € can be requested for financing such a technical exchange programme which should put emphasis on transfer between the two parties of knowledge, expertise, and working practices of design, fabrication and testing of new advanced technological components for frontline accelerator and magnet research and/or technology infrastructures.

The partners

SEE ST South East European International Institute for Sustainable Technologies

2 months
July – August
2023

The South East European International Institute for Sustainable Technologies (SEEIIST)

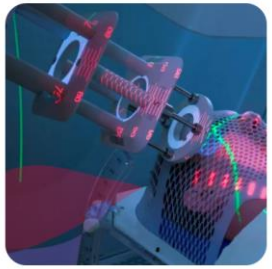
proposed in late 2016 by Prof. Herwig Schopper, a former Director General of CERN and initiator of the international SESAME project in Jordan, received first official political support by the Government of Montenegro in March 2017.

The project will be implemented around the idea of the **real international cooperation in the SEE region**, gathering scientists, engineers, medical doctors, young people and technicians within the joint research infrastructure with the mission "**Science for Peace**". The Institute will be a **regional Centre of Excellence** based on the state-of-art sustainable technology which will assure high competitiveness to the rest of Europe. It will promote the regional collaboration in the fields of science, technology and industry and will represent a **knowledge-based economy project**. Particular component of the project is a **platform for education and training** for young scientists, researchers, technicians, medical doctors, biologists, biomedicine engineers and others who will contribute to the improvement of the whole Region in terms of technological advances, medical innovations, scientific achievements, industrial empowerment and economic benefits.

COSYLAB

Advancing humanity. Engineering remarkable.

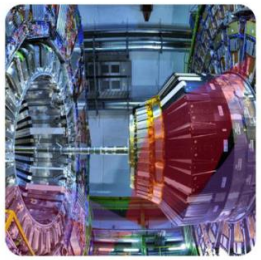
Our leading-edge expertise, software, and electronics enable organisations to make scientific breakthroughs, deliver state-of-the-art cancer treatments, develop healthcare innovations and bring clean fusion energy to the world.



Pushing the boundaries of cancer treatment

Medical

Our technology and experience in system engineering and integration; regulatory practice, patient safety and device usability, will guide you through the entire development process to get your products to patients faster.



Making scientific breakthroughs possible

Science

Our scientists and engineers can help you launch your software systems faster and with less risk, so you can concentrate on exploration.

Powering the world's most complex machines

Industrial

Based on our experience in designing industrial systems for a wide range of industries, we will work with you from the initial concept to the site acceptance test, to make sure your machine is delivered on time, within budget and according to the highest quality and regulatory standards.

iFAST

The collaboration project context

Proton Therapy technology

One-room design

PAUL SCHERRER INSTITUT

Cyclotron

250 MeV Proton cyclotron

Quadrupoles

230-70 MeV Treatment energy range

Degrader

Scanning magnets

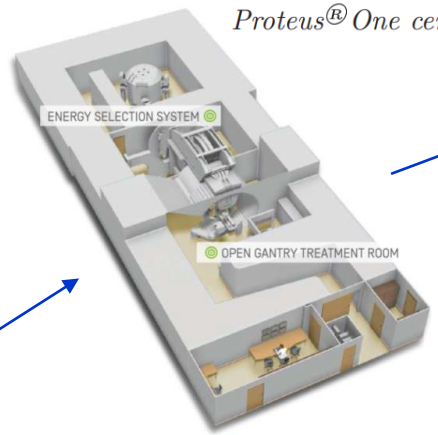
isocenter

Slits

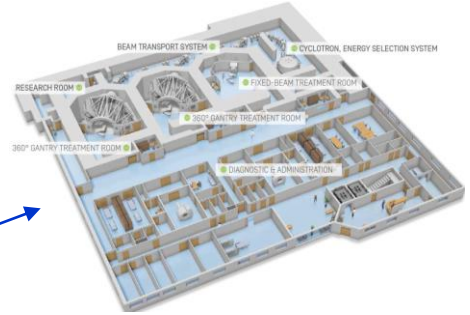
Energy selection system
Momentum acceptance ± 0.7%

Treatment room

IBA
Proteus® One center.

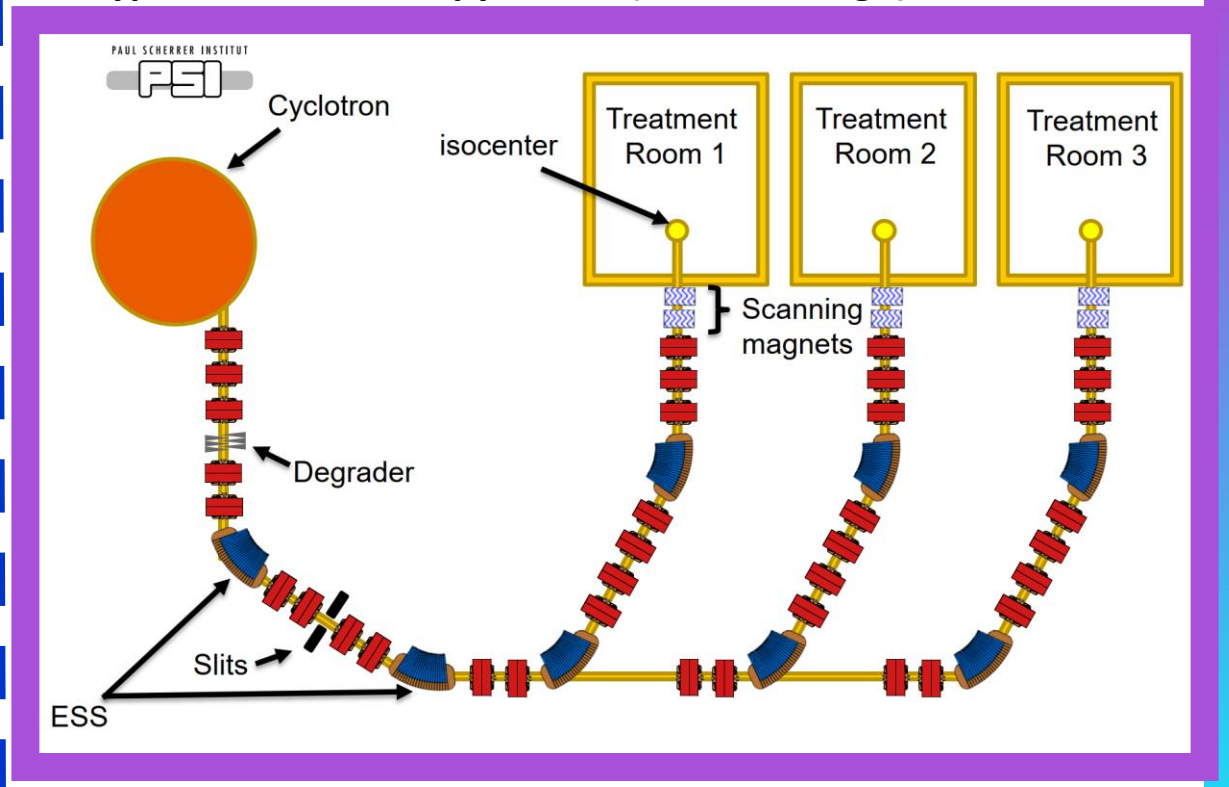


3x



IBA Proteus®PLUS

Typical Proton Therapy centre (3-room design)



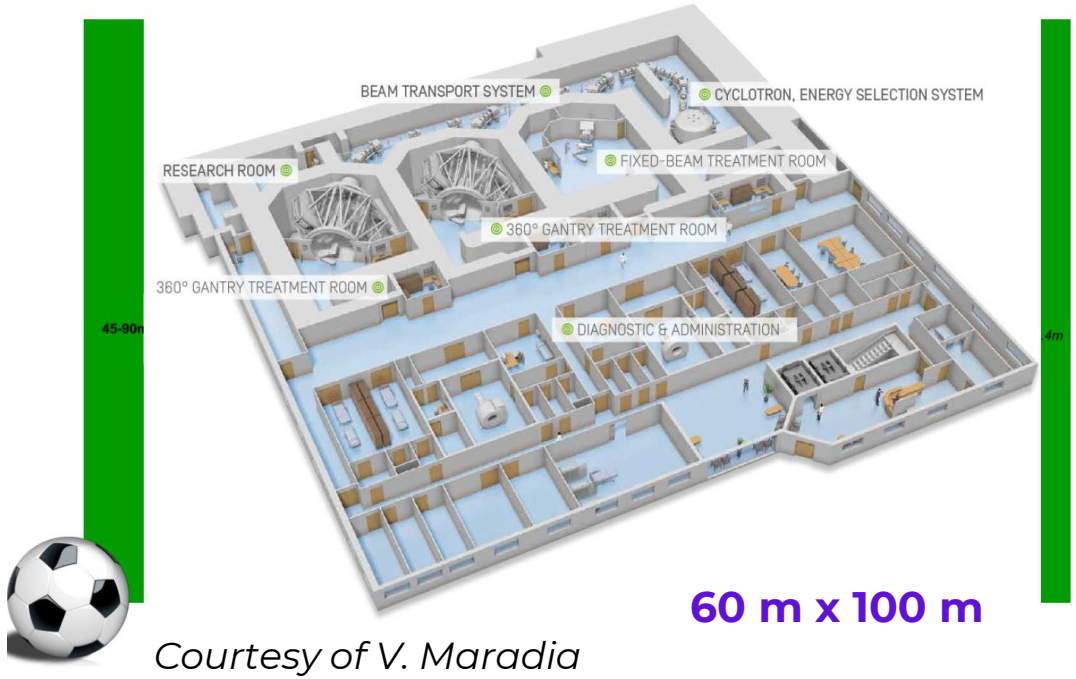
Courtesy of V. Maradia

“The race toward compactness”

A new **Proton Therapy facility** is only attractive if it is **compact**, **cost-effective**, and **efficient**

Football pitch

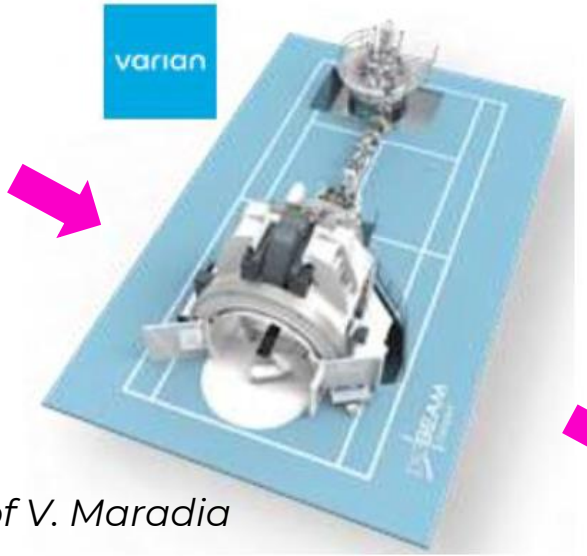
IBA Proteus®PLUS



60 m x 100 m

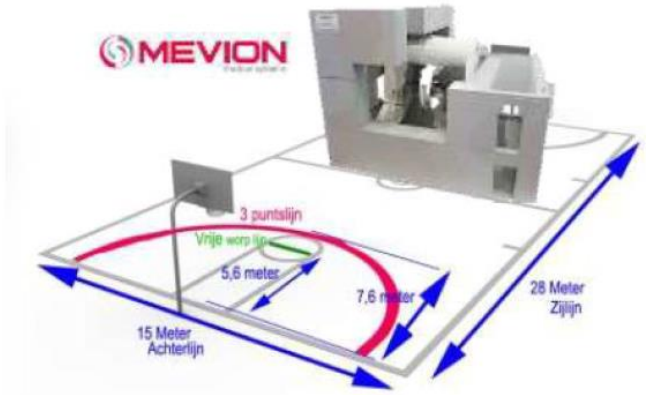
Courtesy of V. Maradia

Tennis court



Courtesy of V. Maradia

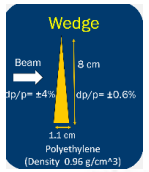
Basketball court



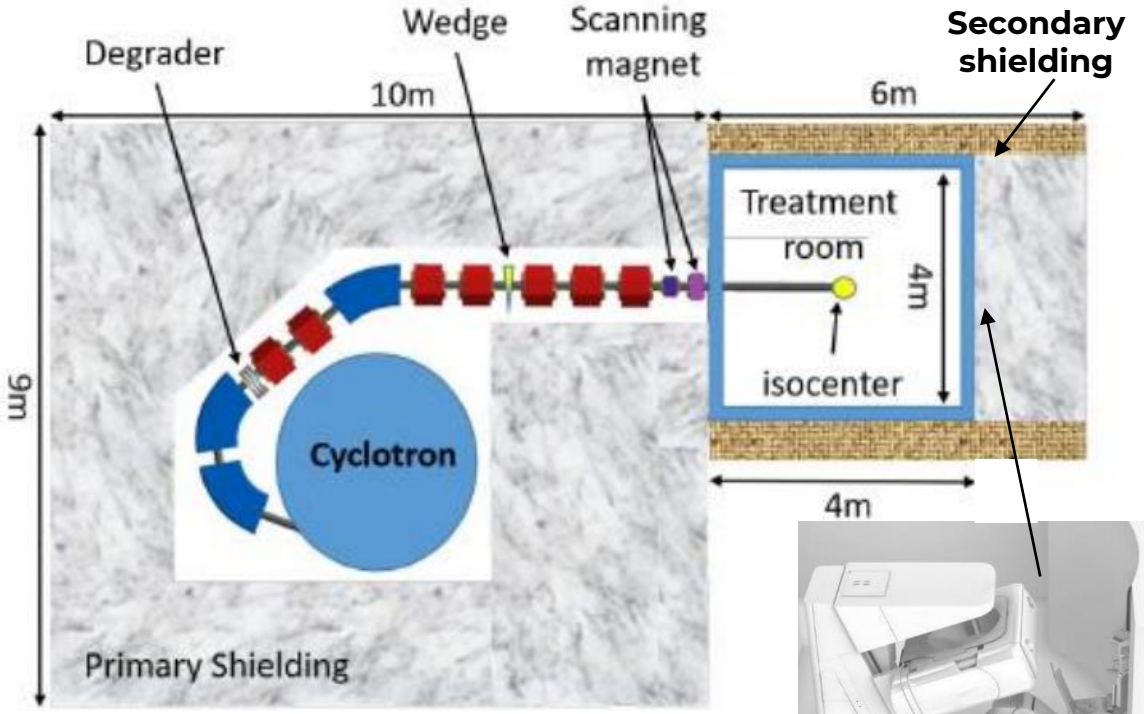
Courtesy of V. Maradia

“The project”

- COSYLAB GmbH - Paul Scherrer Institute (PSI) collaboration
  - **Commercialise** a **Proton Therapy technology**
- <u>Peculiar characteristics:</u>
- **Compact foot-print** (16 x 9 m2):
  - Infrastructure + shielding
  - cyclotron vault + beam transfer line + beam delivery + treatment room
- **Gantry-less fixed beam transfer line**
- Replacement of **Energy Selection System (ESS) with a “beam momentum cooling wedge”**
- **Pencil Beam Scanning System (PBS)**
- **“Chair-based” patient positioning (e.g., P-cure type)**



Use of momentum cooling to achieve high FLASH dose-rates even for low-energy beams in cyclotrons-based proton therapy facilities, V. Maradia et all.



Courtesy of V. Maradia

Business case:
Does beam momentum cooling reduce costs?

Objective #1: Engineering Requirements

Treatment Room	1-3
Footprint of the facility	~140 m^2 (1-room) and ~250 m^2 (3-room)
Transmission (cyclotron to isocenter)	~15% (70 MeV beam)
Max beam current	~ 120 nA (70 MeV beam) assuming 800 nA from cyclotron
Beam Size at isocenter	Similar to commercial facilities (i.e. IBA facilities)
Momentum spread of the beam	±0.5%
Scanning	Downstream scanning
Scanning area	40*40 cm^2
Field delivery time	<10 sec for any size tumor (including hypofractionation)
Dose rate at isocneter	~1520 Gy/s (70 MeV beam) at Bragg peak on central axis

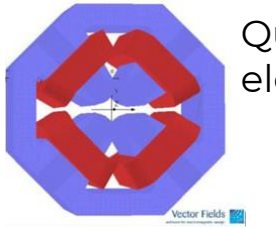
Courtesy of V. Maradia

- **Superconducting (SC) proton cyclotron** (1x):
  - Max beam energy: 250 MeV;
  - Max beam current extracted: 800 nA;
- **Fast-switch kicker electromagnet** (1x):
  - < 100 us;
- **57-deg sector bend electromagnet** (3x):
  - Bending radius: 1.5 m;
  - Pole gap: 60 mm;
  - Operating field range: 0.8 – 1.62 T;
- **In-line or rotating degrader wedge** (1x);
- **Quadrupole electromagnet** (7x):
  - Effective length: 368 mm;
  - Aperture (radius): 50 mm;
  - Operating field range: 5.7 – 10.6 T/m;
- **Polyethylene, Plexiglas wedge** (beam momentum cooling)
- **Coupled scanning magnets system (beam delivery)**

Objective #2: Product Design Specification

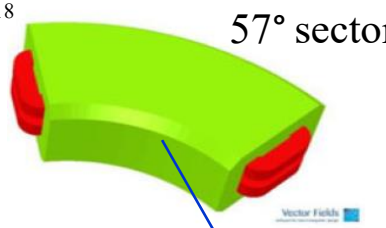
capability of the nowadays most advanced Pencil Beam Scanning (PBS) cancer treatment

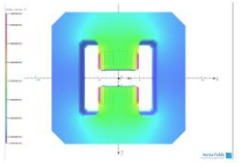
IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY, VOL. 28, NO. 3, APRIL 2018

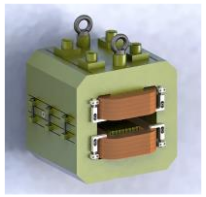


Quadrupole electromagnets

57° sector bend electromagnets



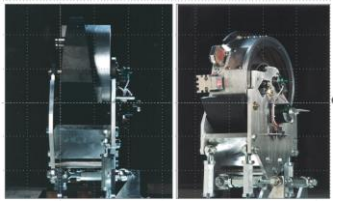




Proceedings of Cyclotrons2016, Zurich, Switzerland MOP12

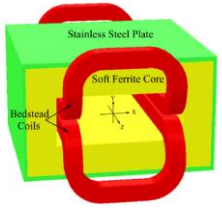
Degrader system

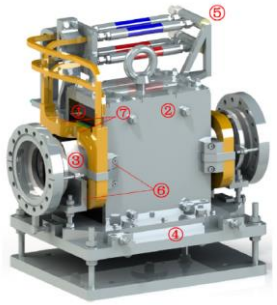
2.5 graphite wedge

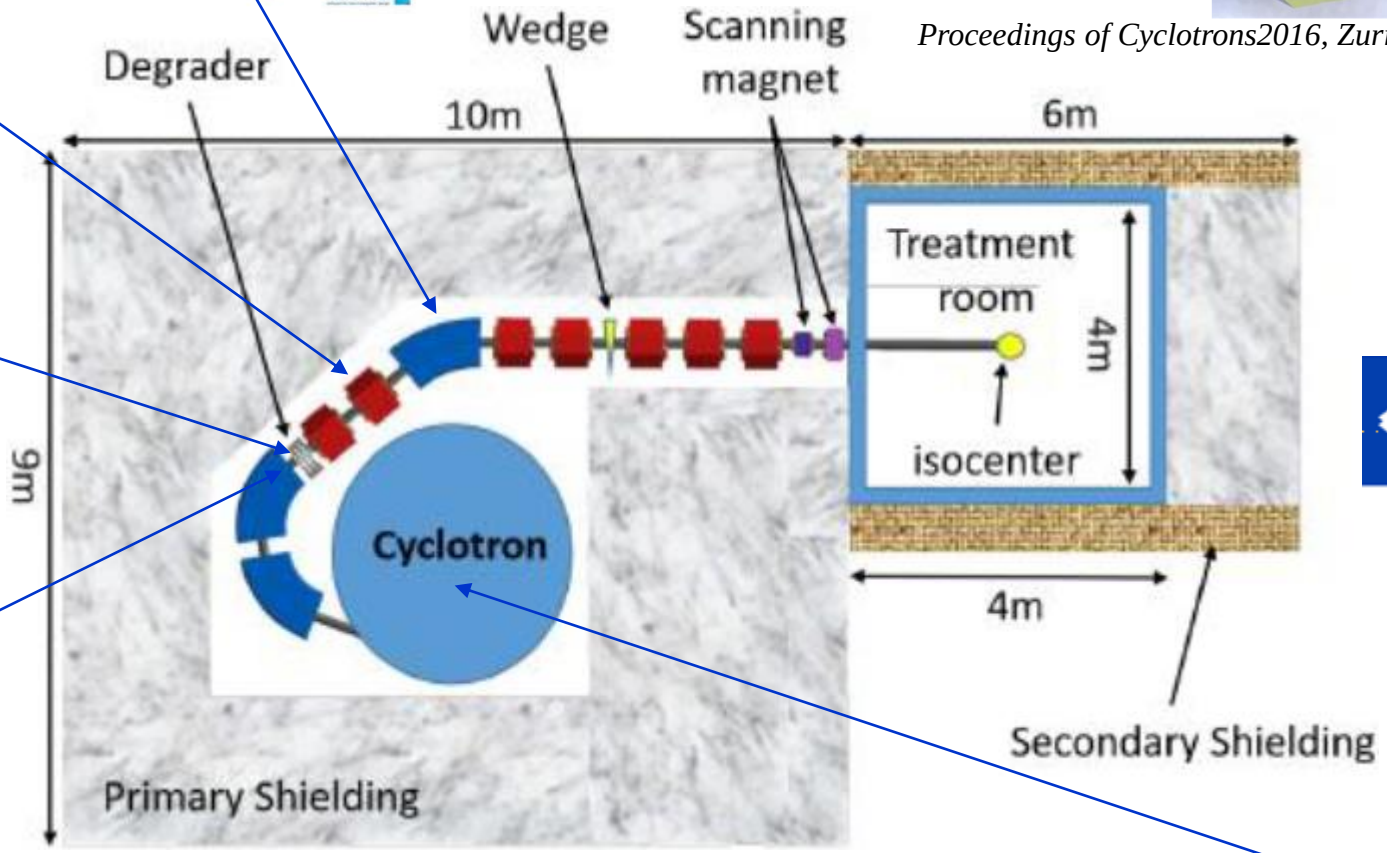


rotating wedge
IBA design

kicker

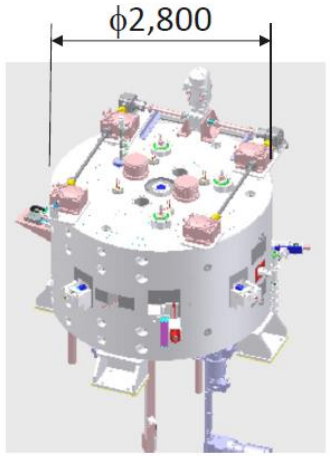






+ detailed design of the beam Instrumentation

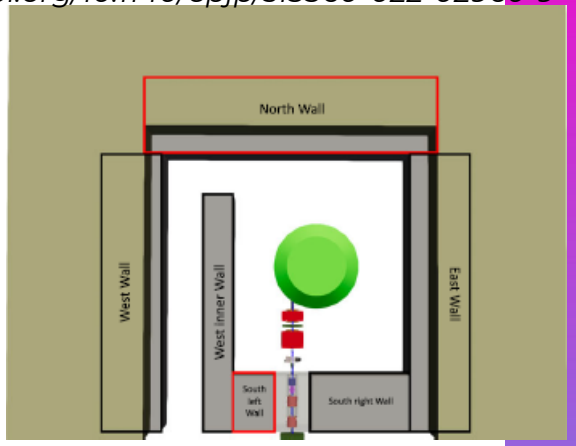
Sumitomo Heavy Industries, Ltd.



Nuclear Inst. and Methods in Physics Research, A 940 (2019) 199–205

Objective #3: Business case

Eur. Phys. J. Plus (2022) 137:889
https://doi.org/10.1140/epjp/s13360-022-02960-9

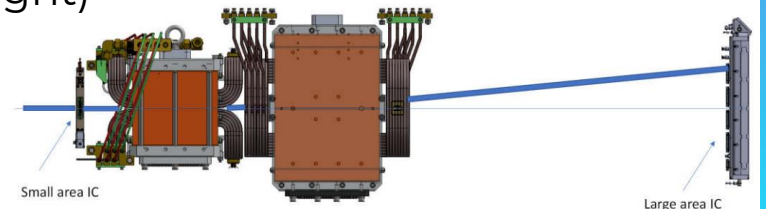


- **SC cyclotron cost:**
  - max extracted **beam energy**: 250 MeV → size, RF system capacity
  - max extracted **beam current**: 800 nA → 50 nA → only particle source adjustment
- **Shielding requirements:** Monte Carlo simulation for materials activation
  - scaling at 50 nA
- **Transfer line cost:**
  - **Vacuum system:** off-the-shelf components (pipes, valves, pumps)
  - **Diagnostics:** replace Ionisation Chambers (IC) and MultiLayer Faraday Cups (MLFC) with Scintillation Screens (HUT facility) or “Beam Monitors”

detector-group.com

Nuclear Inst. and Methods in Physics Research, A 998 (2021) 165208

- **Beam delivery system cost:**
  - Coupled scanning magnets + QA diagnostics basis solution (Pyramid)
- **Patient positioning system cost:** commercial P-cure (chair) / LeoCancer (upright)
- **Capital single-room facility cost breakdown (“Top-down approach”)**



PYRAMID

Pyramid Note, TN0019.pdf

Achievements

- **SEEIIST**
  - **relation** with the **scientific stakeholder** of the PT facility design
  - **knowledge** of PT **key systems** and **cancer treatment techniques**
  - **detailed project documentation:**
    - product design specification
    - Bill of Materials (BOMs)
  - **Business case analysis:**
    - structured cost breakdown and comparison

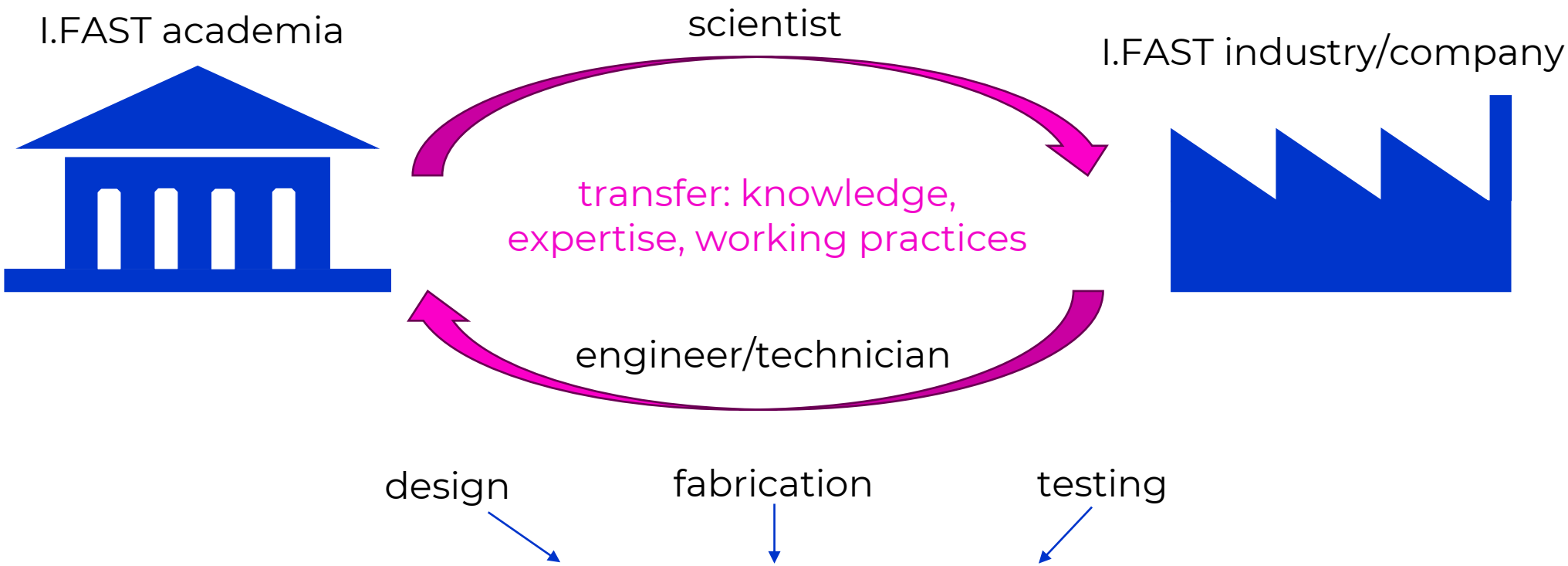
V. Maradia, L. Garolfi

- **COSYLAB GmbH:**
  - **successful collaboration** with **PSI PT researchers**, and **scientists**
  - **business analysis to enhance its services and market position:**
    - technical design documentation, and cost-effective insights
    - technical insights on the compact facility's systems integration

C. Slater, L. Garolfi

Apply for the programme!

4 → I.FAST Academia-Industry exchange applications granted till February 2024



Subject: advanced technological ***components*** for ***accelerators*** and ***magnets*** and/or technology ***infrastructures***

A grant of **up to 15 k€** can be used to finance: salary, travel, subsistence

Total budget = 60 k€ → 4 project = ~ 37 k€ → ~ 23 k€ → 3 new projects

iFAST

Application process:

- contact your industrial collaborator
- formulate an exchange proposal
- submit a fund request

https://ifast-project.eu/ifast-traineeship-programme

Thank you for your attention

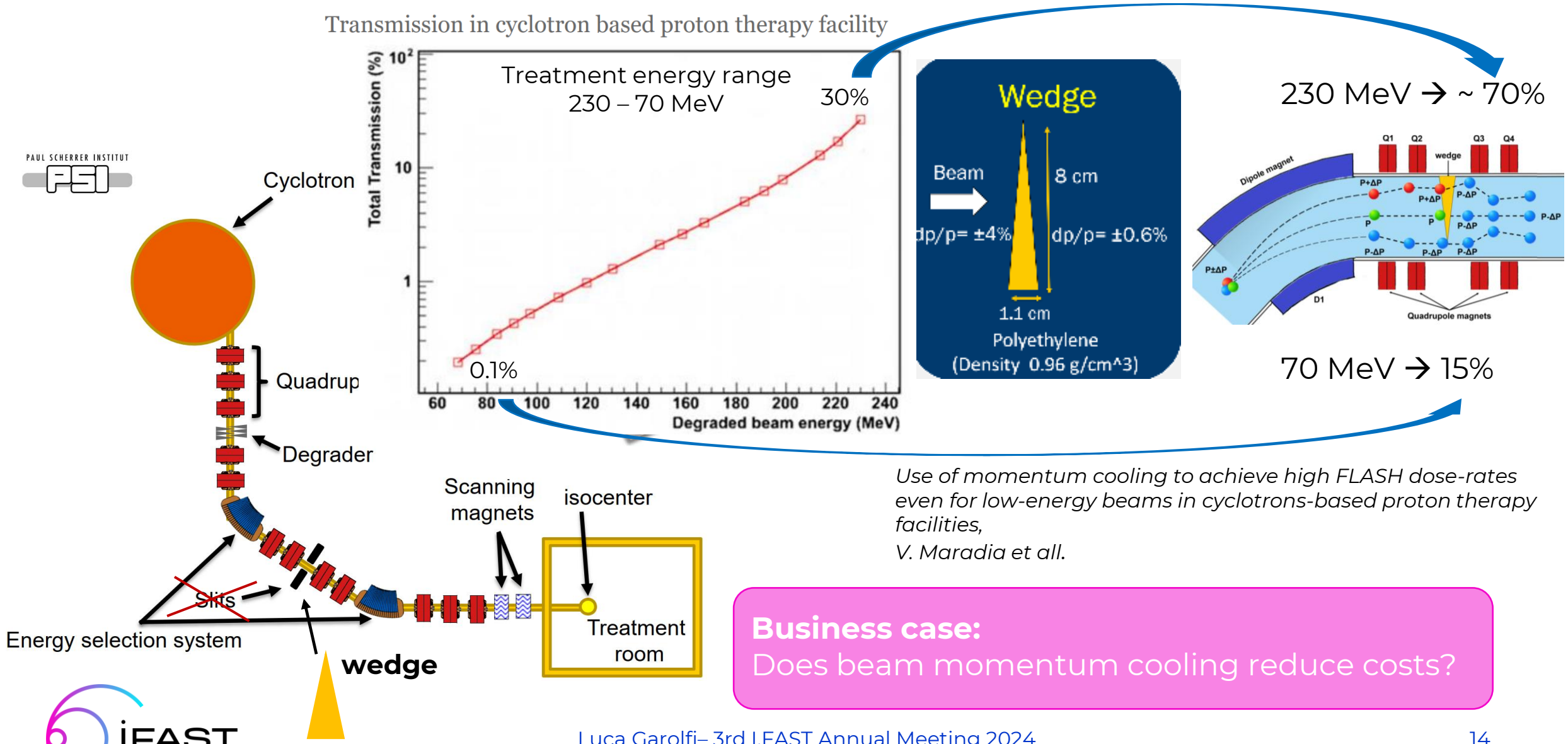
This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under GA No 101004730.

iFAST

Back-up

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under GA No 101004730.

“Beam momentum cooling”



Use of momentum cooling to achieve high FLASH dose-rates even for low-energy beams in cyclotrons-based proton therapy facilities,
V. Maradia et all.

Business case:
Does beam momentum cooling reduce costs?

The objectives

- Prepare a comprehensive **product design specification documentation that** highlights:
  - the capability of the nowadays most advanced cancer treatment (PBS)
  - the reduced physical footprint compared with the most compact one-room PT designs on the market

- Detailed **Bill of Materials (BOMs)** that allows for a “bottom-up” components breakdown cost of cyclotron, beam transfer line, beam delivery system and patient positioning system

Detailed **Engineering Requirements** study

COSYLAB

Account

Document UID	Revision	Status	Link	Date (last change)
Product Design Specification Example	0.1	Draft		2023-09-01

Compact gantry-less PT facility

Product Design Specification

	Name	Role/Company	Signature and Date
Author(s)	Luca Garolfi	Collaborator	

Detailed **Bill of Materials (BOMs) of components**

COSYLAB

SOURCE / SUPPLIER	MANUFACTURER PART NO.	SUPPLIER PART NO.	LINK TO SUPPORTING DOC	COMMENTS	CAD file	CUSTOM MADE	UNIT PRICE	TOT
Sumitomo Heavy Industries (SHI)	n/a	n/a	Excitation_Test_of_Superconducting_Magnet_in_230-MeV_Isochronous_Cyclotron_for_Proton_Therapy.pdf	Output beam energy = 250 MeV, current = 800 nA	n/a	COTS		0
SigmaPhi Accelerator Technologies	n/a	n/a	mopml039.pdf	O-type - Pole gap = 160 mm; Tot length = 170 mm; Integral magnetic field > 1.5e-2 Tm	n/a	Customized		0