7th International Particle Accelerator Conference

May 8-13, 2016, BEXCO, Busan Korea

The ELIMED beamline at ELI-Beamline (Prague, Cz)

status, plans and potential applications

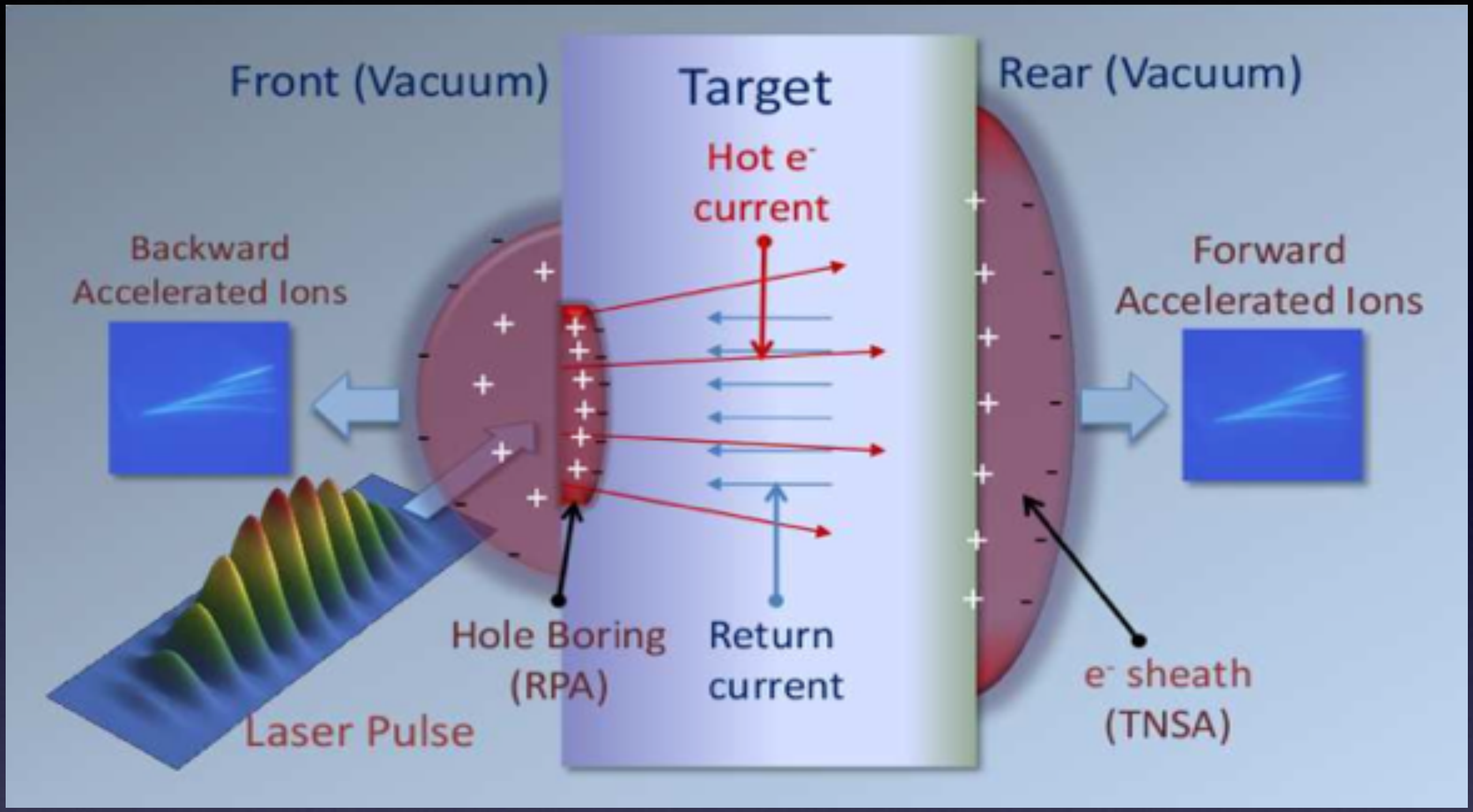
G A P Cirrone, MP, PhD*

Italian Institute for Nuclear Physics

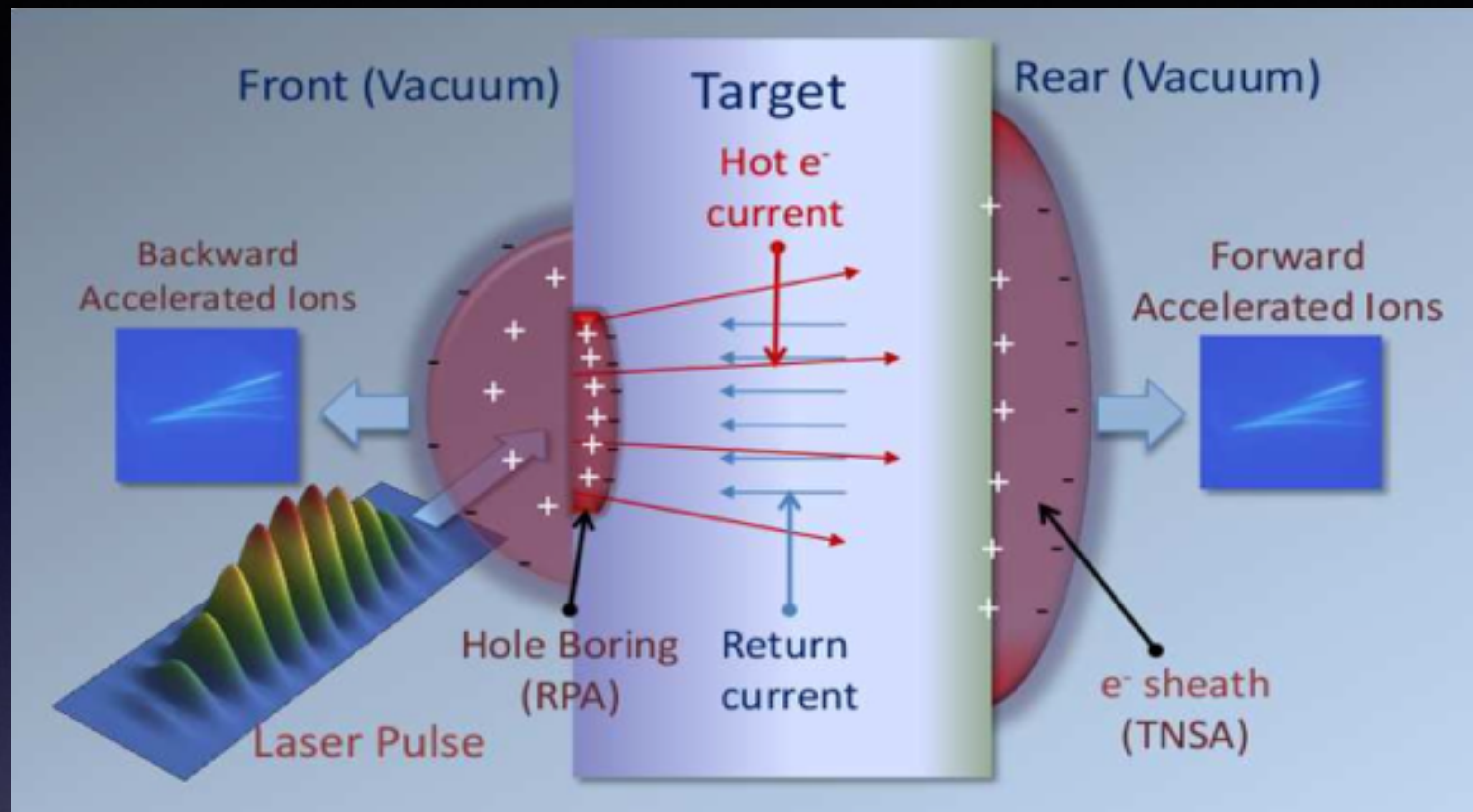
**on behalf of the LNS ELIMED Collaboration*

We are dealing with
high power laser - matter interaction for particle acceleration

We are dealing with high power laser - matter interaction for particle acceleration



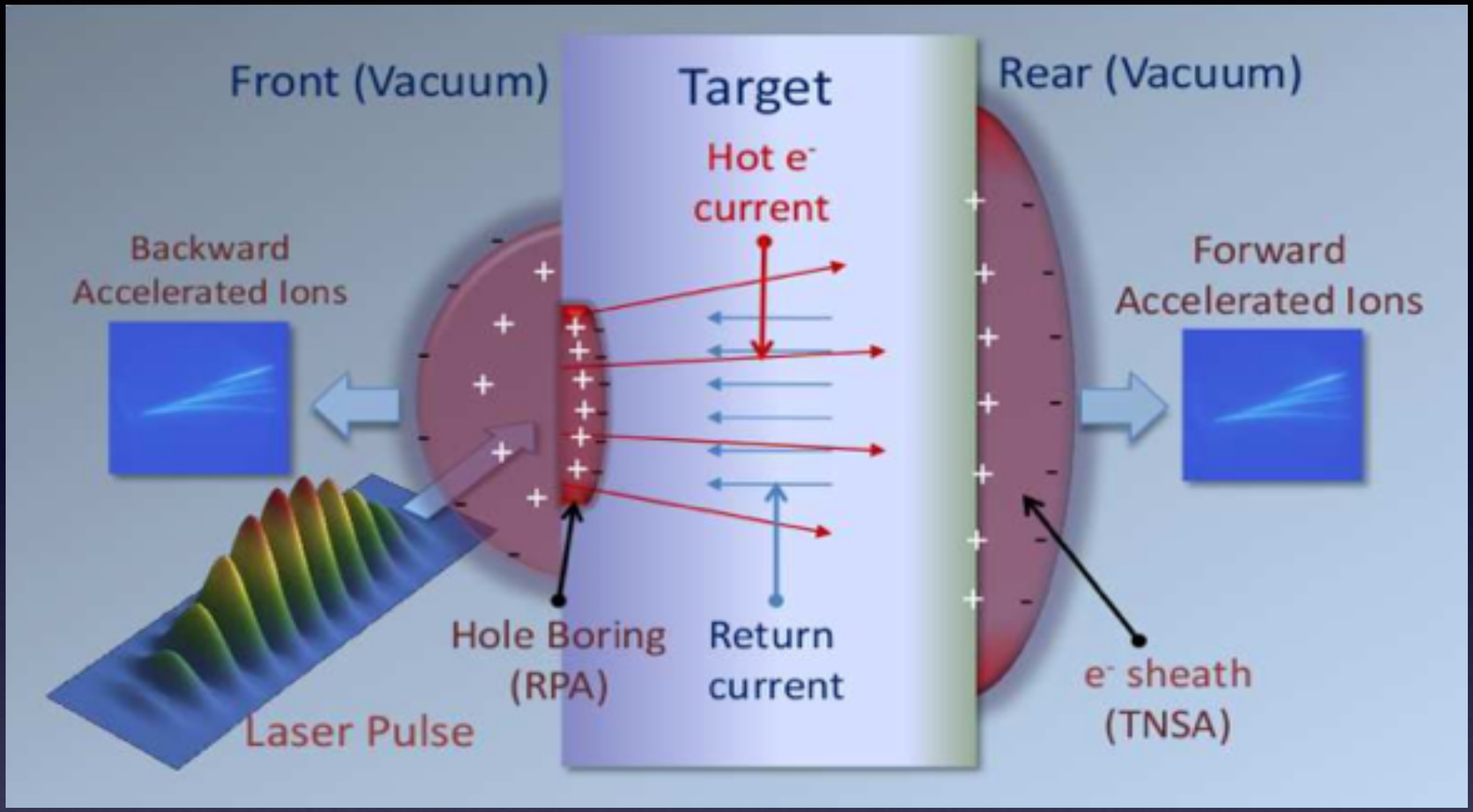
We are dealing with high power laser - matter interaction for particle acceleration

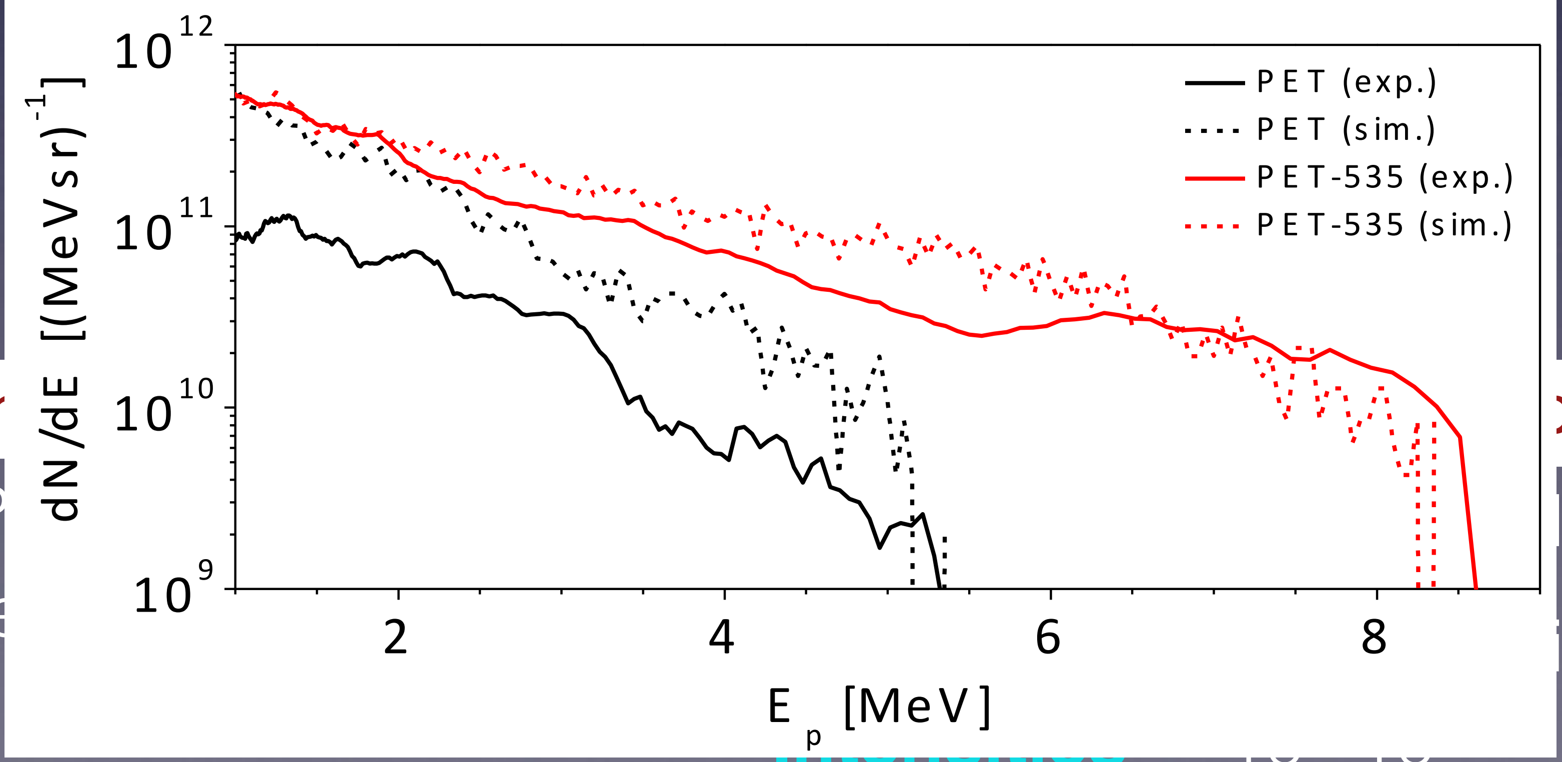


Laser characteristics	
Power	PW order (10^{15} W)
Duration	fews femto seconds
Intensity	10^{21}-10^{23} W/cm^2

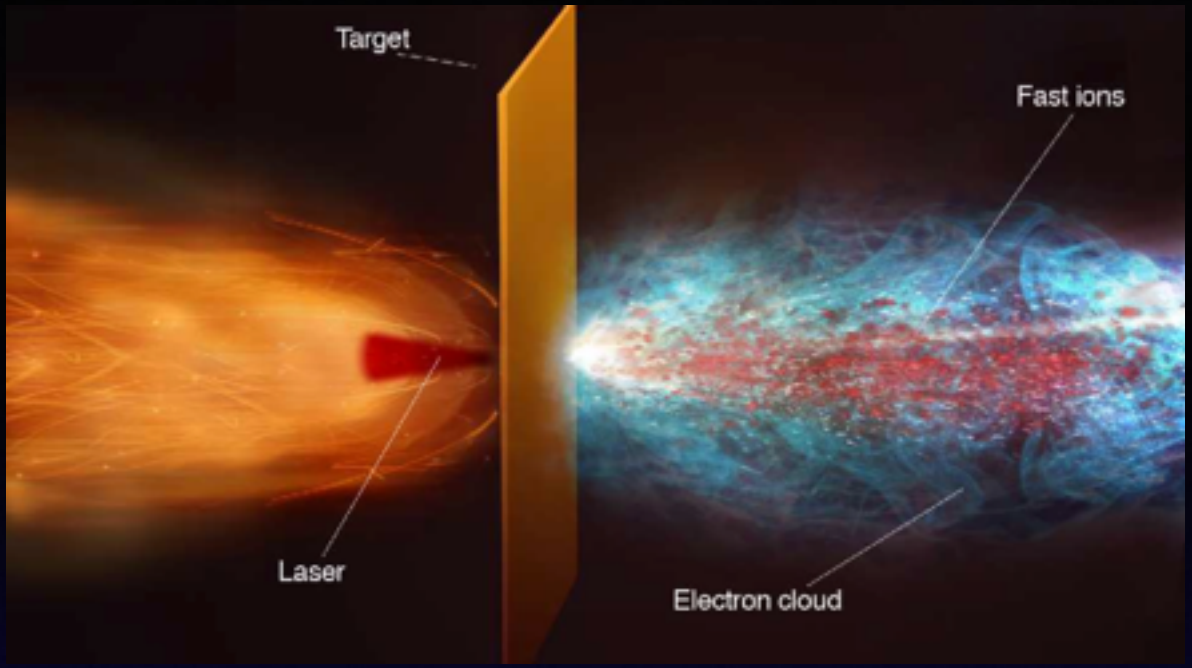
Accelerated beams	
Beams	gamma, electrons, ions,
Energies	MeV/GeV in broad spectra
Intensities	10^{9}-10^{12}

We are dealing with high power laser - matter interaction for particle acceleration





Laser ch		beams
Power	P	lectrons, ions,
Duration	fe	in broad spectra
Intensity	1	



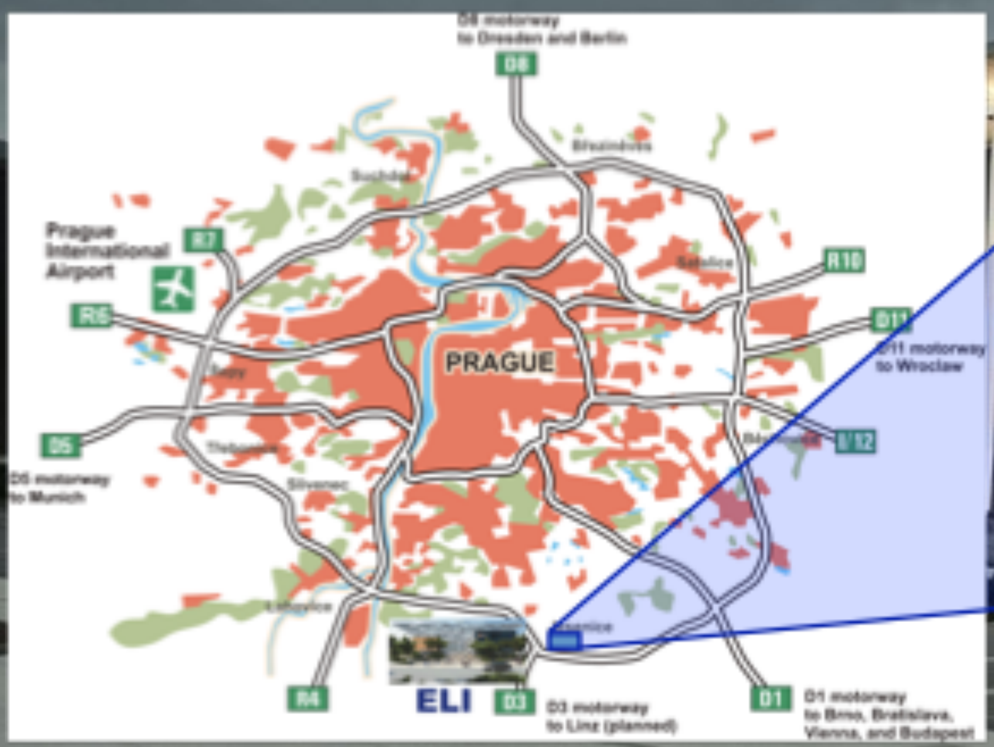
ELI (Extreme Light Infrastructure)

An European distributed infrastructure where laser-power will be exploited

ELI-Beamlines (CZ) ELI-NP (R) ELI-ALPS (H)

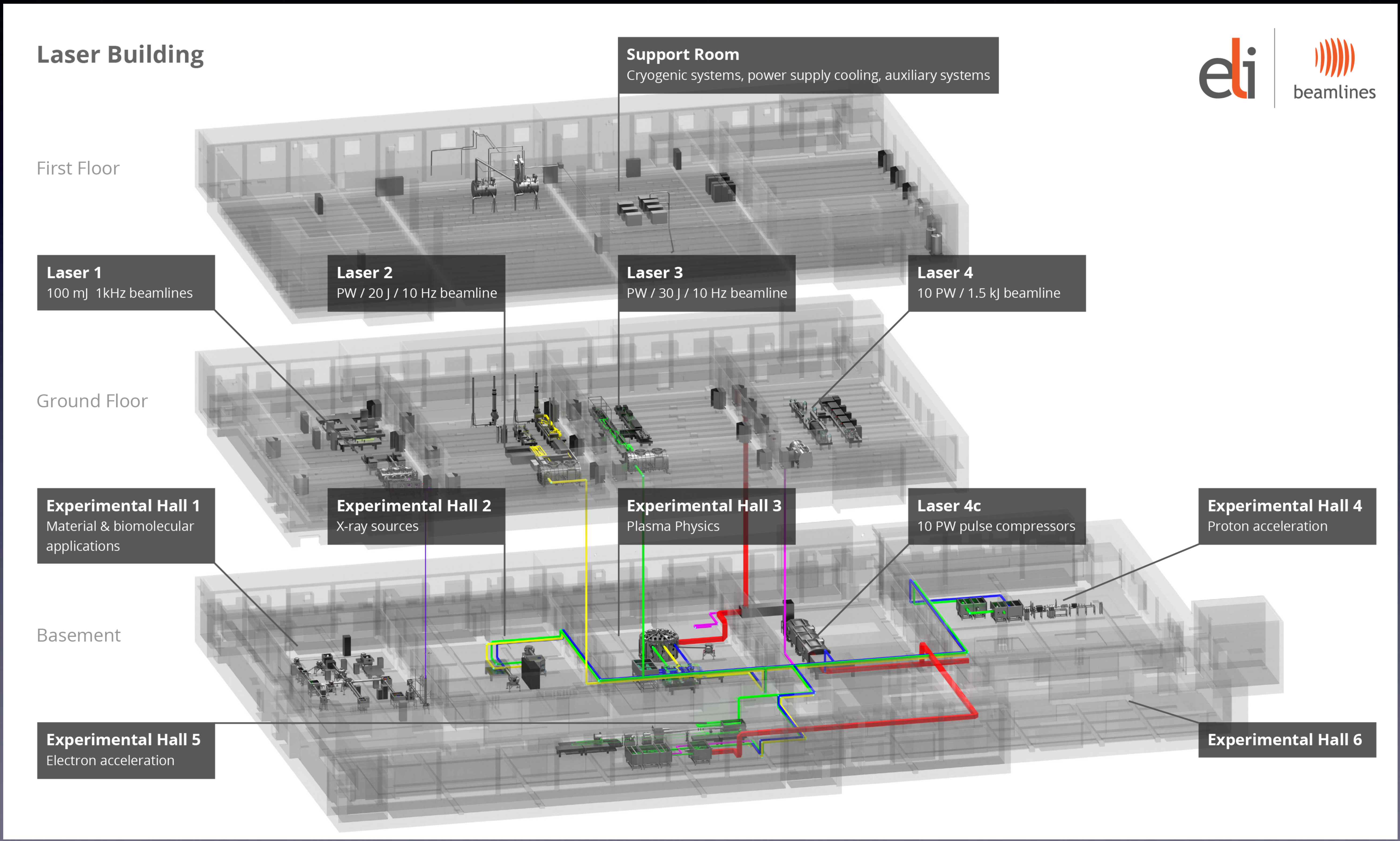
ELI-Beamlines, Prague (CZ)

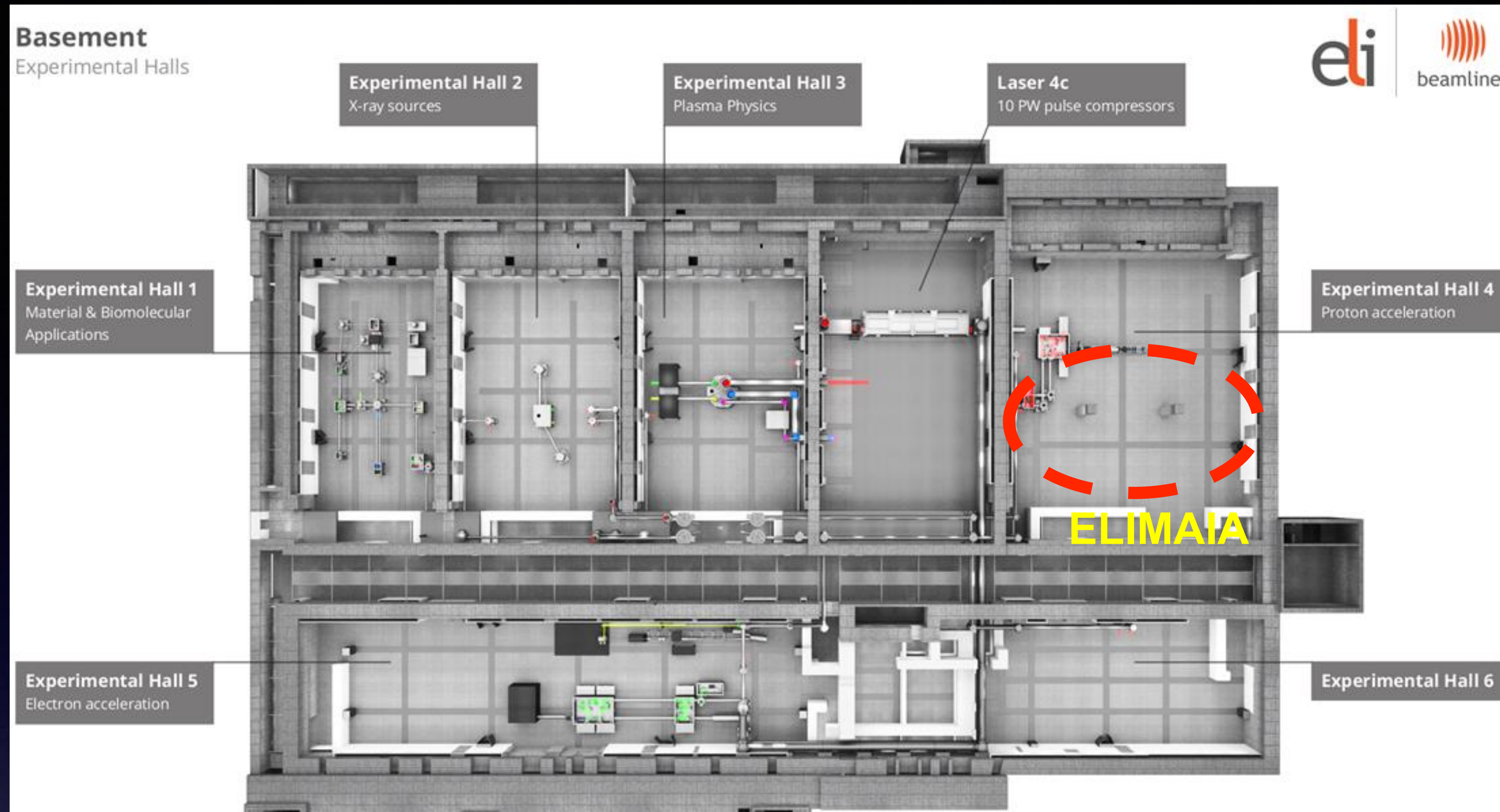
ELI-Beamlines, Prague (CZ)



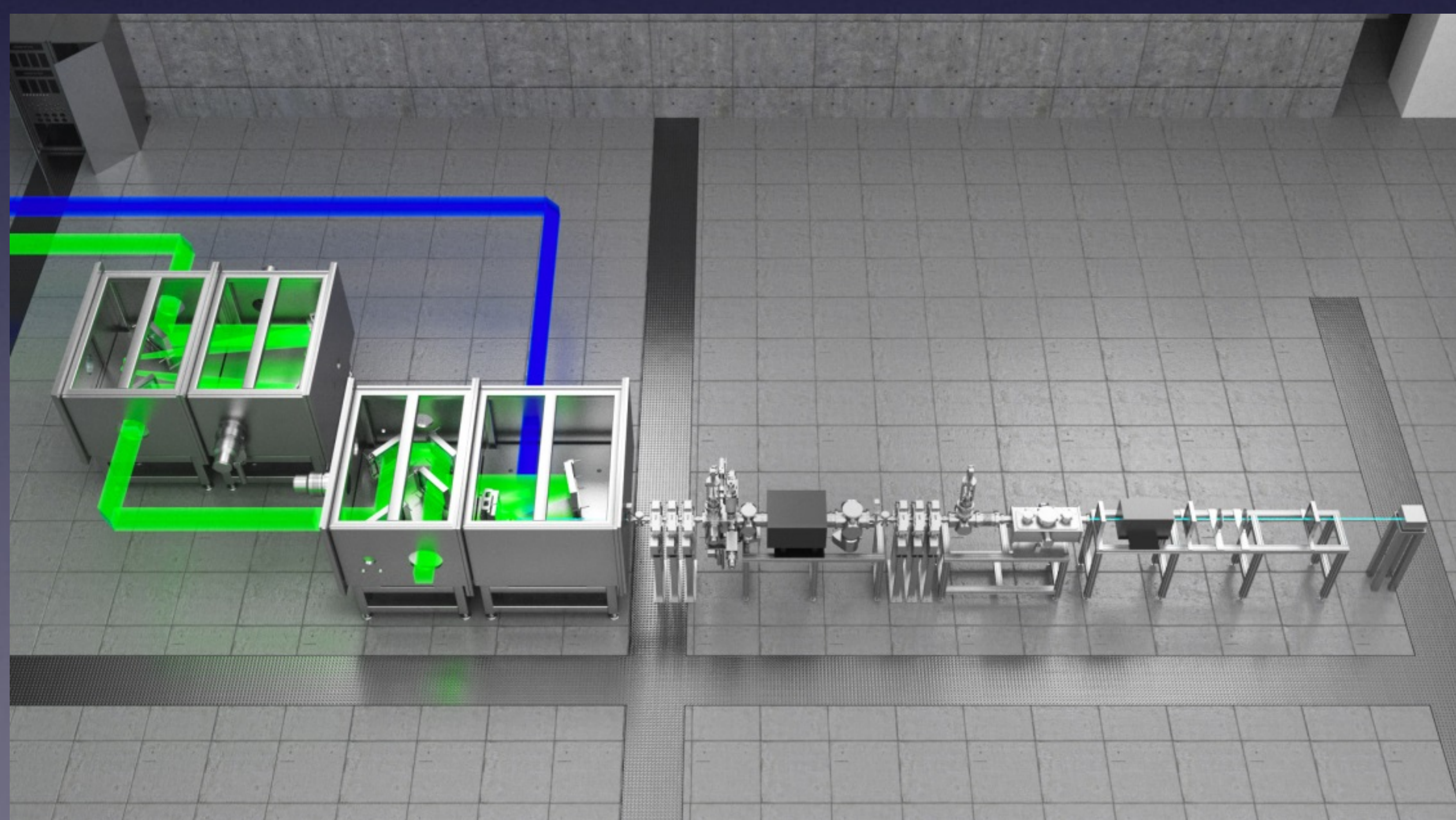
ELI-Beamlines, Prague (CZ)

ELI-Beamlines, Prague (CZ)





ELI Multidisciplinary Applications of laser-Ion Acceleration



Talk mainstream

Hadrontherapy: advantages, its limitations

The ELIMED initiative:
a ion beamline for laser-driven beams

Status of the realisation of the ELIMED beamline

Hadrontherapy

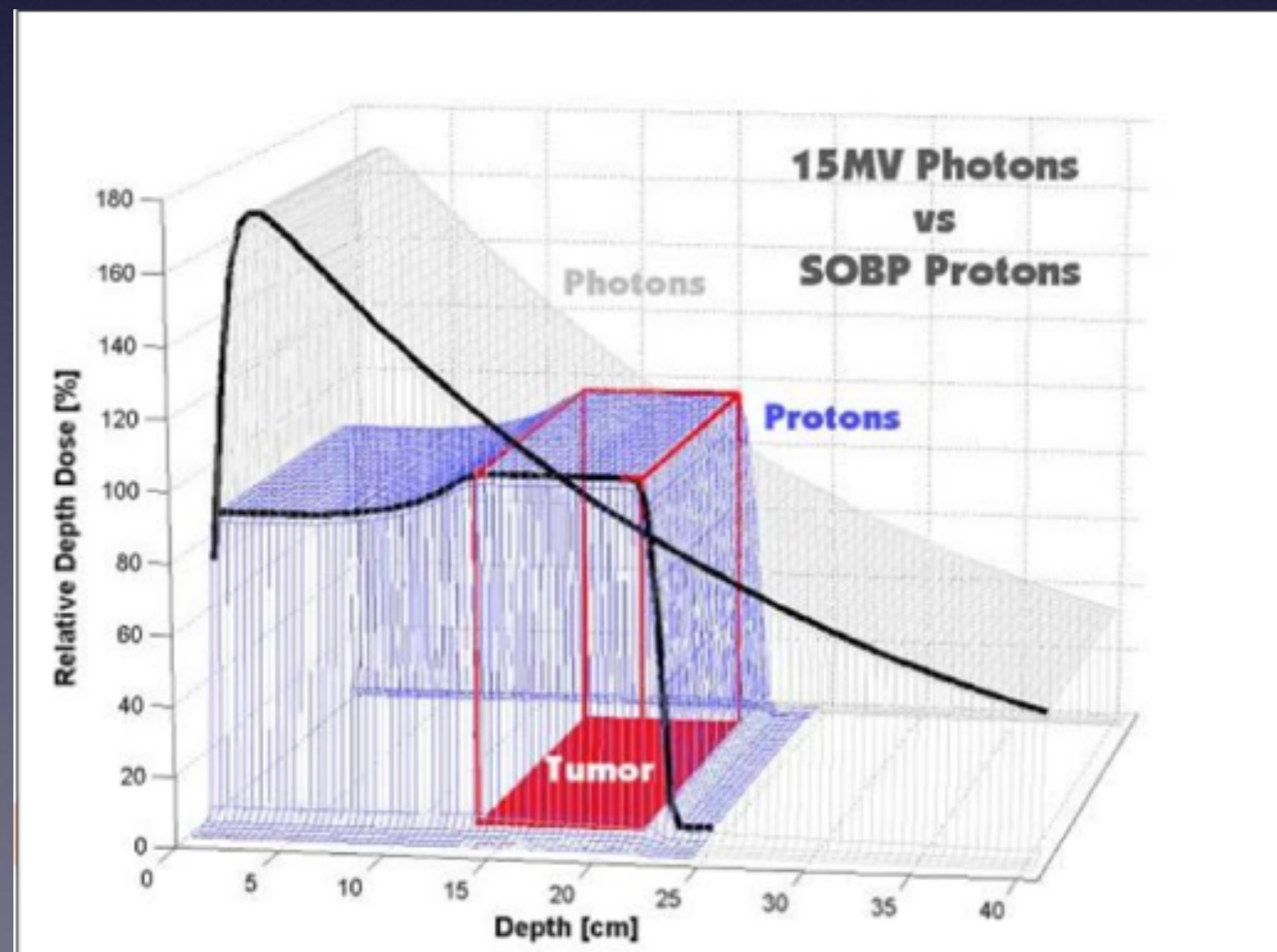
Its advantages, its limitations

External radiation treatment

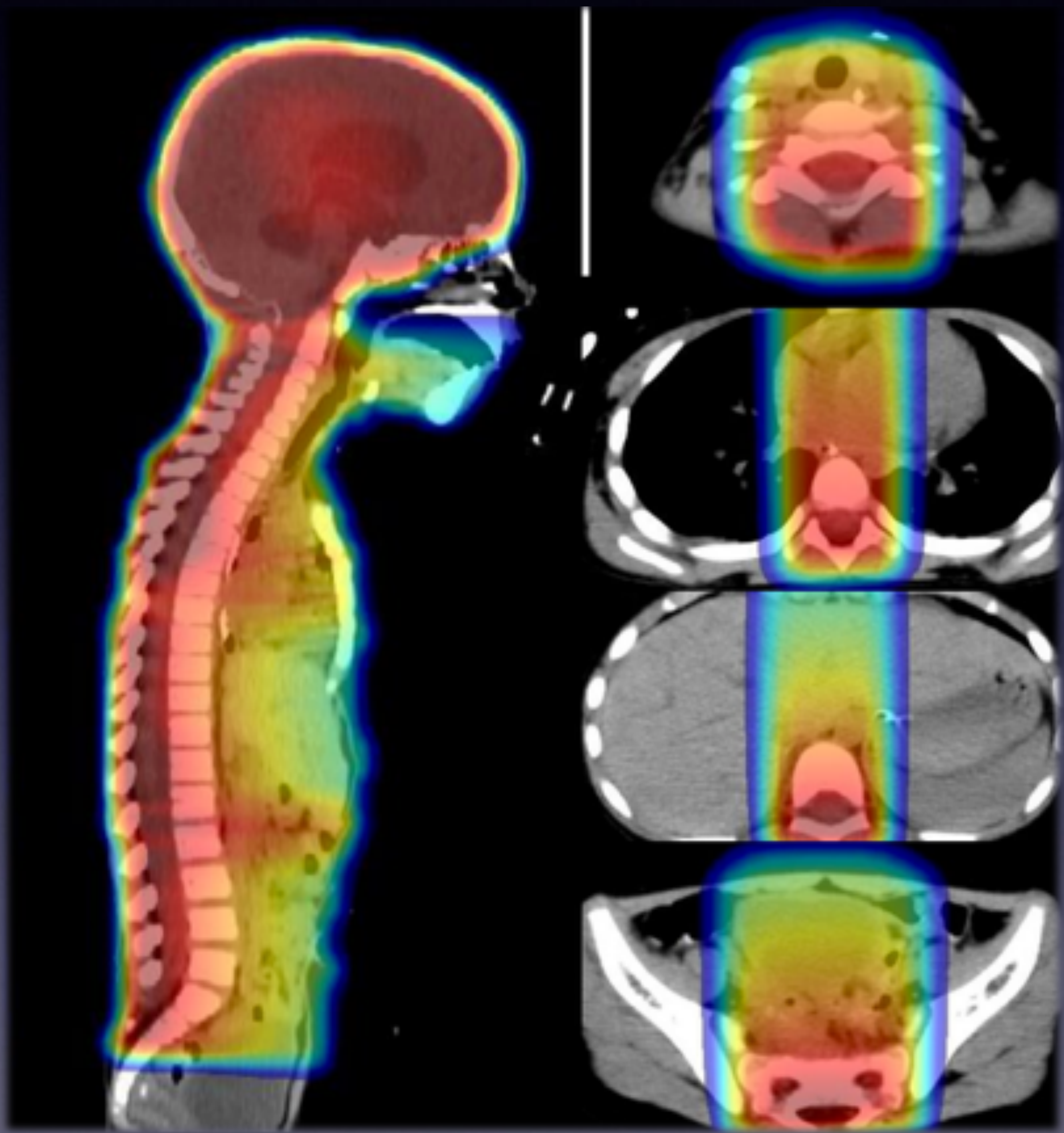
The most common approach in cancer treatment together with surgery

Anatomy does not allow surgery
Radio-resistant tumours close to organ at risk

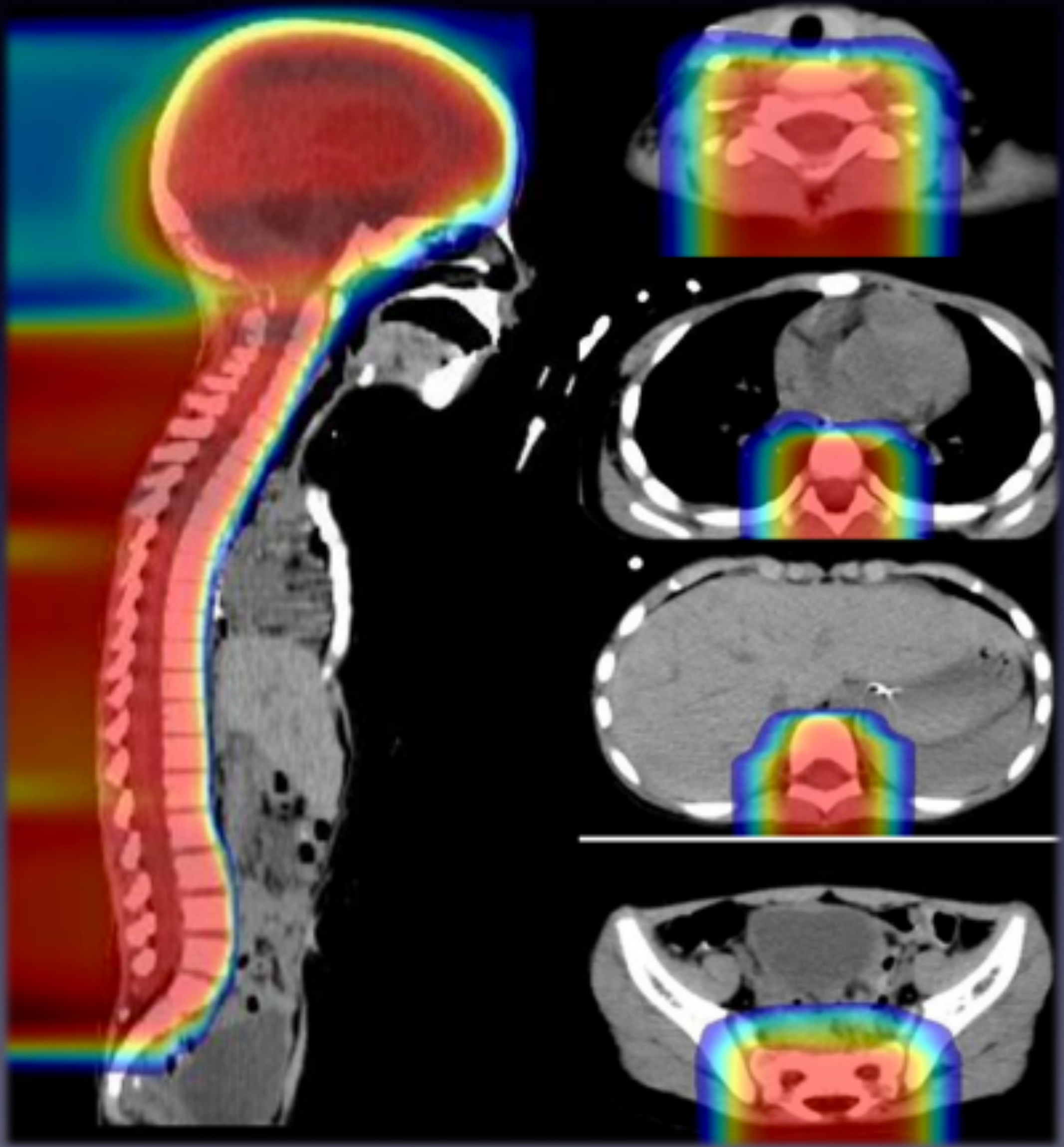
HADRONTHERAPY
and the debate
in the medical community



The medulloblastoma case



x-Ray therapy



Protontherapy

The medulloblastoma case

Reduction of secondary tumour risk

Pediatric Medulloblastoma: The yearly risk of getting a secondary tumor was estimated to be 8 times greater with X-rays than with proton therapy [2]

Tumor Site	Proton Therapy	X-rays/IMRT
Stomach and esophagus	0%	11%
Colon	0%	7%
Breast	0%	0%
Lung	1%	7%
Thyroid	0%	6%
Bone and connective tissue	1%	2%
Leukemia	3%	5%
All Secondary Cancers	**5%**	**43%**

This chart compares the rates of secondary tumors for a pediatric patient treated for medulloblastoma.

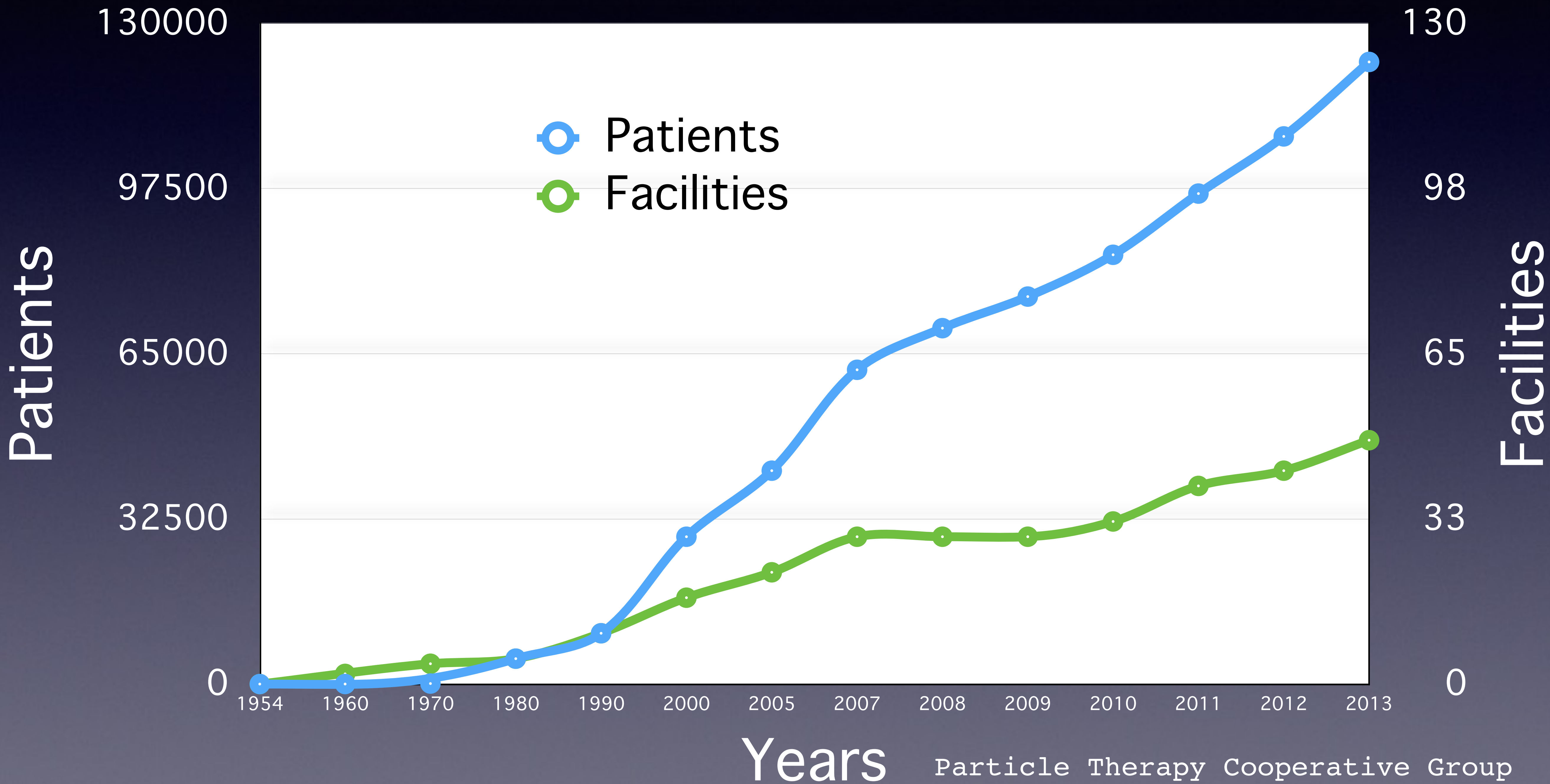
Data shown are from a study that compared treatment plans.

IMRT= intensity modulated radiation therapy (a type of X-ray therapy)

Mirabell RA et al.
Potential reduction of the incidence of radiation-induced second cancers by using proton beams in the treatment of pediatric tumor,
Int. Jour. Rad. Onc. Phys. 2002, 54 (3) 824

Hadrontherapy faces a fast growing demand

Facilities in operation 40 Under realisation 36



Particle Therapy Cooperative Group (PTCOG)
http://www.ptcog.ch

INFN LNS

REVIEWS

Charged particle therapy—optimization, challenges and future directions

Jay S. Loeffler and Marco Durante

Abstract | The use of charged particle therapy to control tumours non-invasively offers advantages over conventional radiotherapy. Protons and heavy ions deposit energy far more selectively than X-rays, allowing a higher local control of the tumour, a lower probability of damage to healthy tissue, low risk of complications and the chance for a rapid recovery after therapy. Charged particles are also useful for treating tumours located in areas that surround tissues that are radiosensitive and in anatomical sites where surgical access is limited. Current trial outcomes indicate that accelerated ions can potentially replace surgery for radical cancer treatments, which might be beneficial as the success of surgical cancer treatments are largely dependent on the expertise and experience of the surgeon and the location of the tumour. However, to date, only a small number of controlled randomized clinical trials have made comparisons between particle therapy and X-rays. Therefore, although the potential advantages are clear and supported by data, the cost:benefit ratio remains controversial. Research in medical physics and radiobiology is focusing on reducing the costs and increasing the benefits of this treatment.

Loeffler, J. S. & D

NATURE REV ... NE PUBLICATION | 1

Research and development in the field of accelerators should be towards a reduction of costs, while maintaining or improving the performances of the current machines. Possible new accelerators for CPT[122] include synchrocyclotrons, rapid cycling synchrotrons, fixed-field alternating gradient rings, cyclotron–linac combinations, dielectric wall accelerators, and laser-driven plasma accelerators.[123] These options are at very different

REVIEWS

Charged particle therapy—optimization, challenges and future directions

Jay S. Loeffler and Marco Durante

Abstract | The use of charged particle therapy to control tumours non-invasively offers advantages over conventional radiotherapy. Protons and heavy ions deposit energy far more selectively than X-rays, allowing a higher local control of the tumour, a lower probability of damage to healthy tissue, low risk of complications and the chance for a rapid recovery after therapy. Charged particles are also useful for treating tumours located in areas that surround tissues that are radiosensitive and in anatomical sites where surgical access is limited. Current trial outcomes indicate that accelerated ions can potentially replace surgery for radical cancer treatments, which might be beneficial as the success of surgical cancer treatments are largely dependent on the expertise and experience of the surgeon and the location of the tumour. However, to date, only a small number of controlled randomized clinical trials have made comparisons between particle therapy and X-rays. Therefore, although the potential advantages are clear and supported by data, the cost:benefit ratio remains controversial. Research in medical physics and radiobiology is focusing on reducing the costs and increasing the benefits of this treatment.

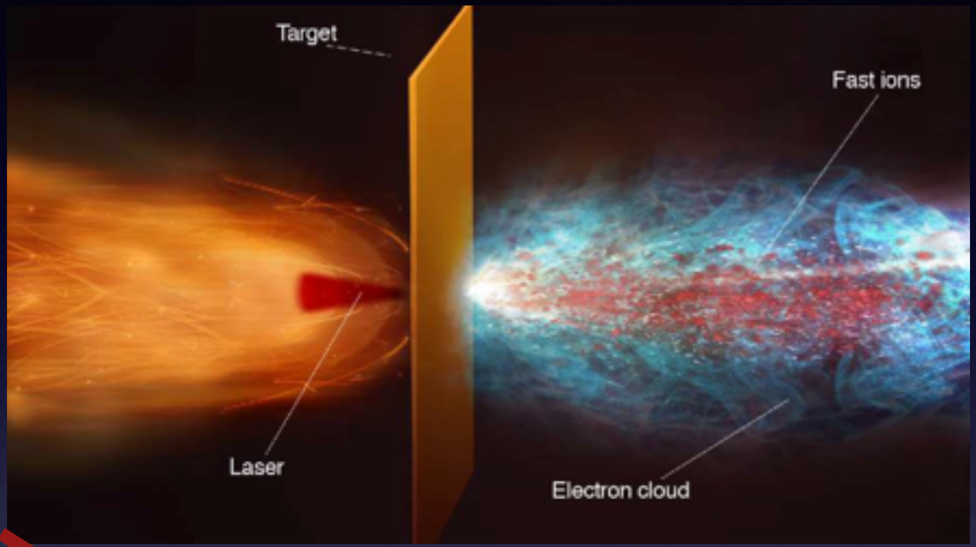
Loeffler, J. S. & D

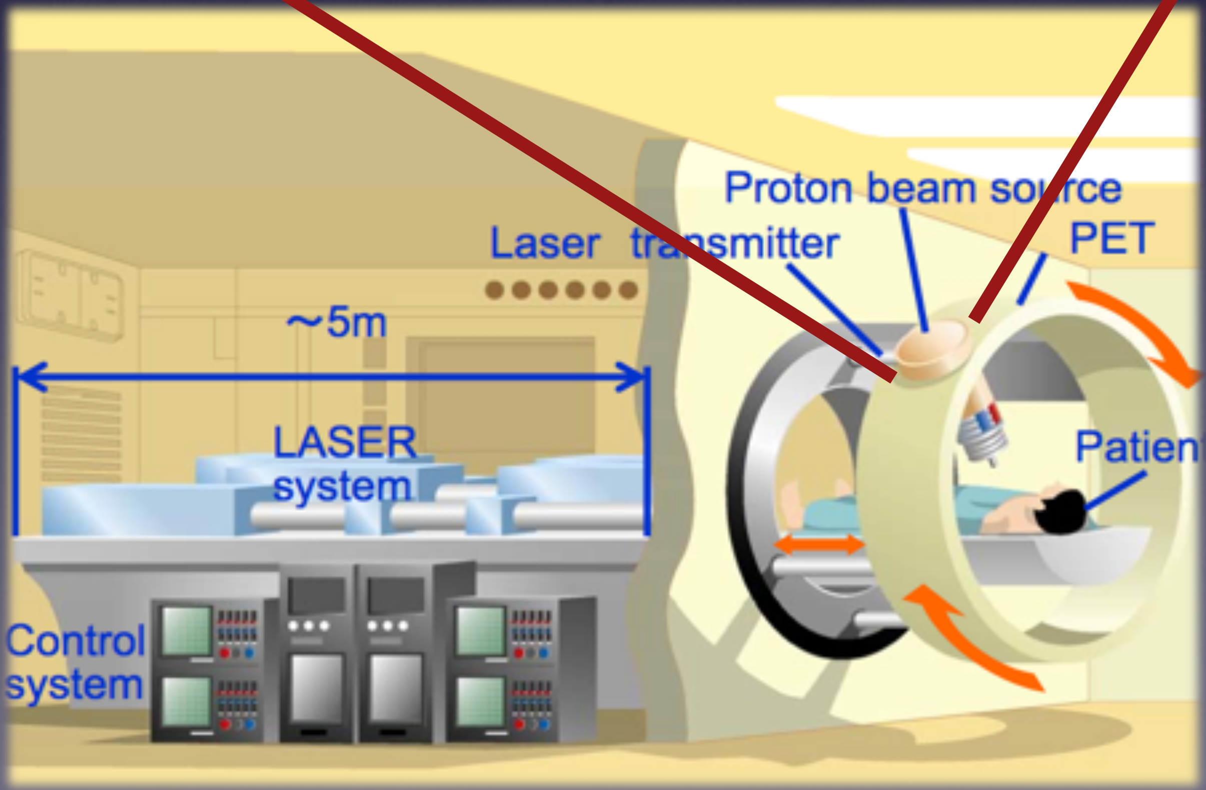
Research and development in the field of accelerators should be towards a reduction of costs, while maintaining or improving the performances of the current machines. Possible new accelerators for CPT[122] include synchrocyclotrons, rapid cycling synchrotrons, fixed-field alternating gradient rings, cyclotron–linac combinations, dielectric wall accelerators, and laser-driven plasma accelerators.[123] These options are at very different

Are new acceleration solution available, reducing cost and size still maintaining quality?

Research for a ‚dream' solution

can we reduce size, complexity and cost without loosing the quality ?





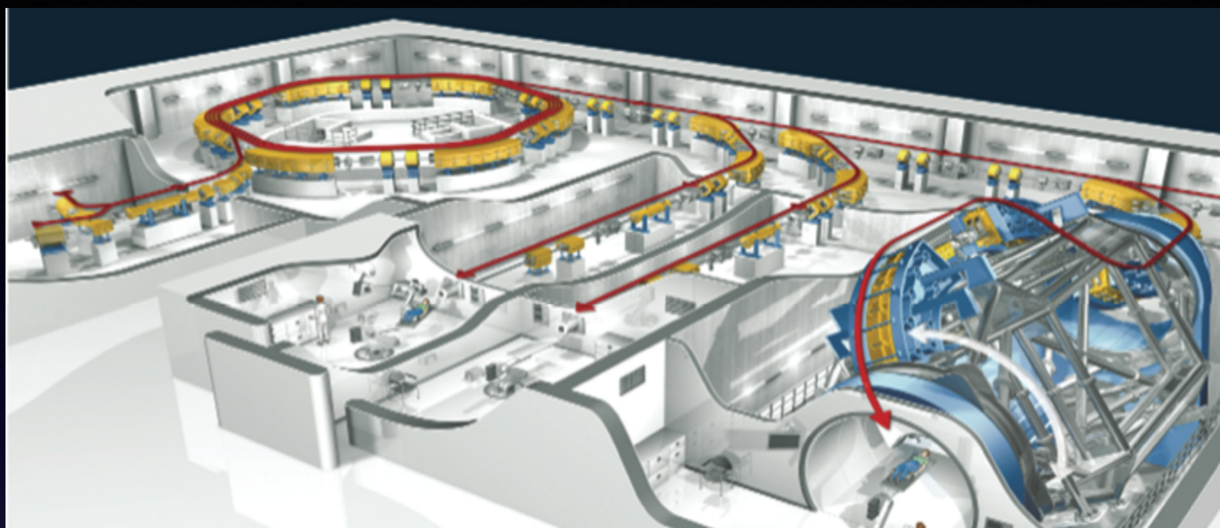
Simple

Small

Cheap (order of 10 M€)

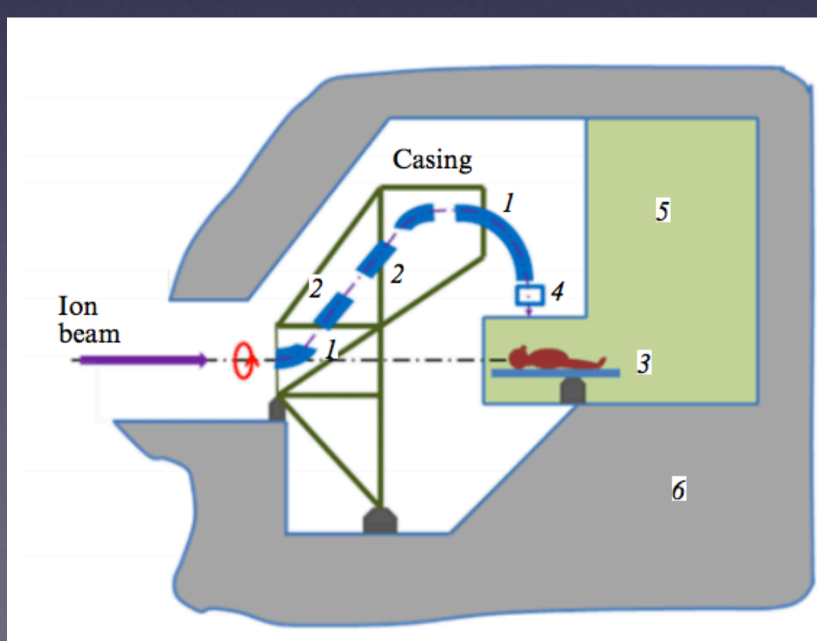
Widespread

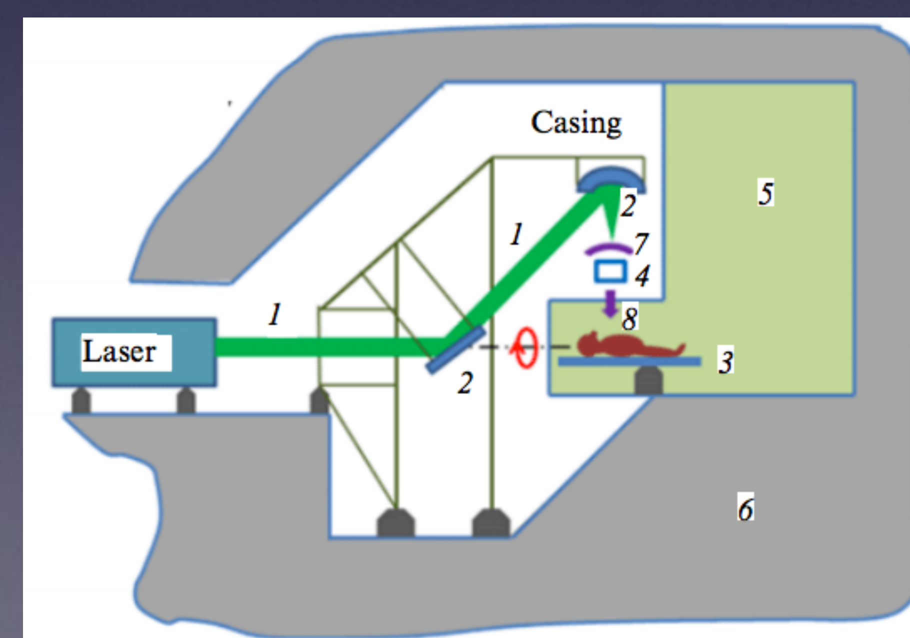
Multi-beam and modalities



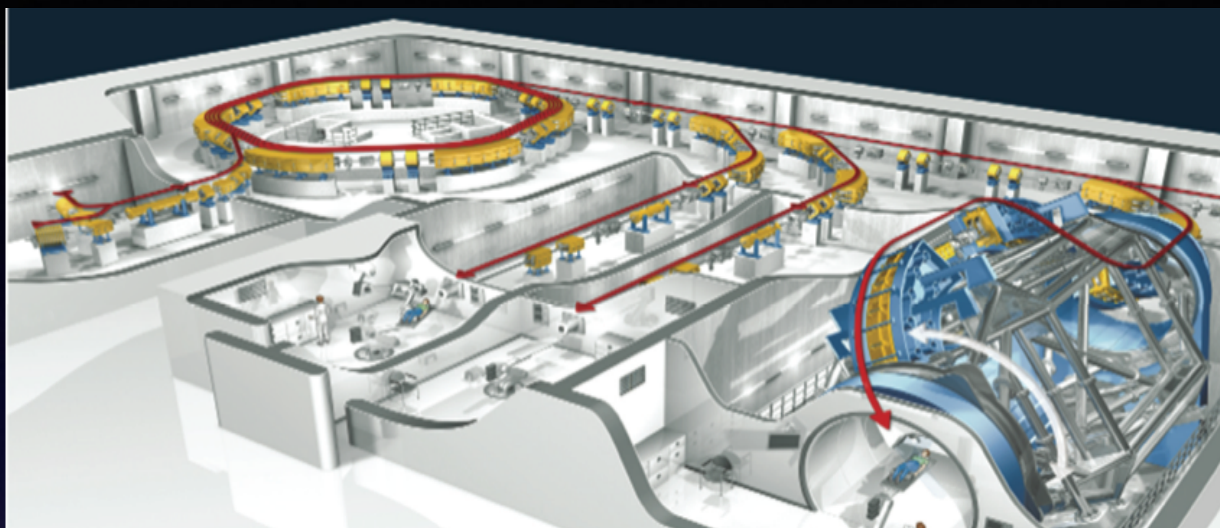
Quite large accelerators
Sophisticated beam transport (gantry)
High costs
Limited number of hadrontherapy centres
Alternative solutions

"If 200 MeV proton accelerators would be as cheap and small as the 10 MeV electron linacs used in conventional radiotherapy, at least 90% of the patients would be treated with proton beams"
U. Amaldi et al., NIM A 2010.



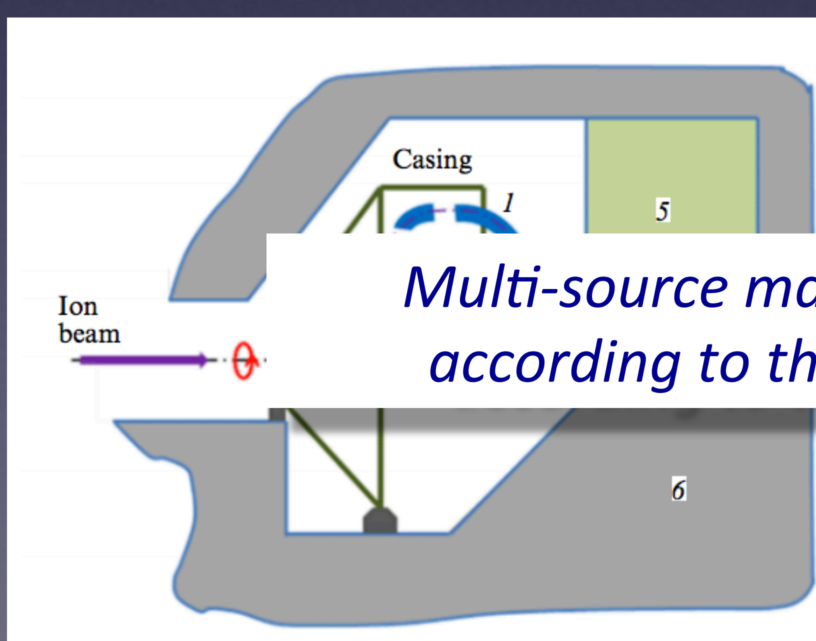


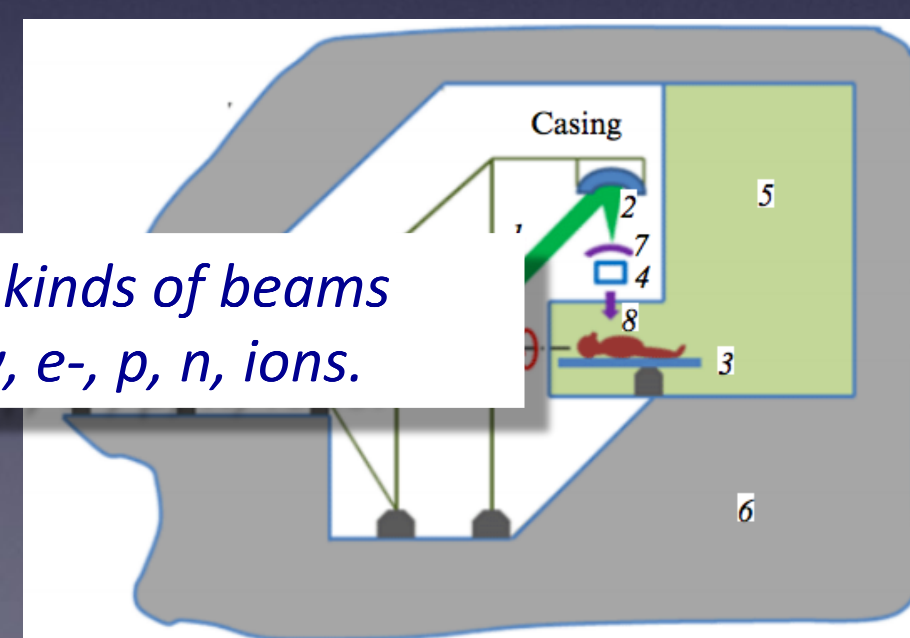
Bulanov et al. REVIEWS OF TOPICAL PROBLEMS (2014)



Quite large accelerators
Sophisticated beam transport (gantry)
High costs
Limited number of hadrontherapy centres
Alternative solutions

"If 200 MeV proton accelerators would be as cheap and small as the 10 MeV electron linacs used in conventional radiotherapy, at least 90% of the patients would be treated with proton beams"
U. Amaldi et al., NIM A 2010.





Multi-source machine to deliver different kinds of beams according to the specific requirements: γ, e-, p, n, ions.

Bulanov et al. REVIEWS OF TOPICAL PROBLEMS (2014)

The ELIMED initiative

ELI-Beamlines MEDical and multidisciplinary applications

ELIMED goals

Beam control

Answer to the question

can we use laser-ions for medical/multidisciplinary applications?

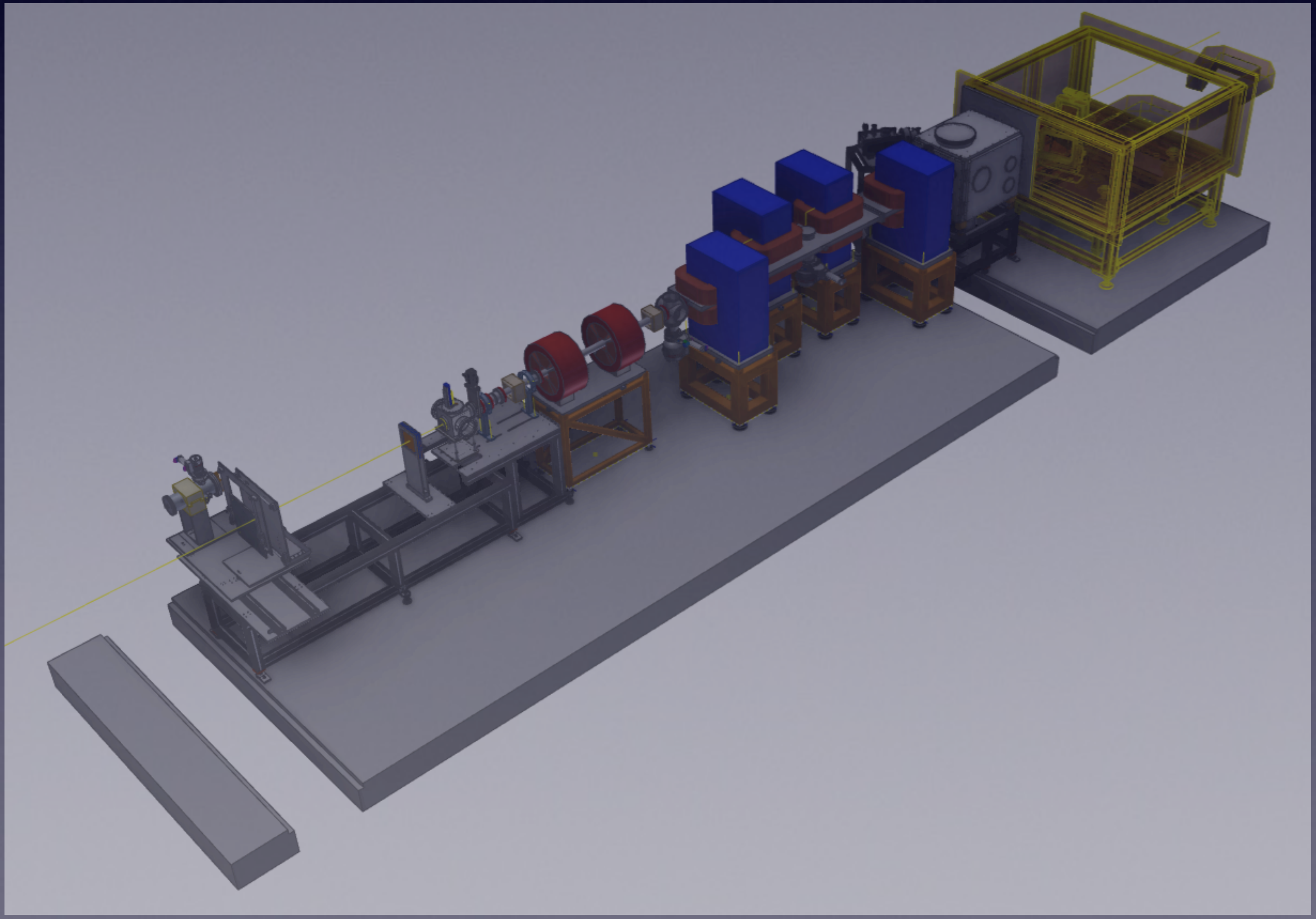
Try to fill this table

	Conventional beams	Laser-driven beams
Maximum energy	250 MeV 400 AMeV	?
Current	order of nA	?
Monochromaticity	$\Delta E/E \lesssim 10^{-2}$	?
Stability, reproducibility, control, absolute dosimetry	Less that 3%	?
Radiobiology	Almost known	?

ELIMAIA final goal: Users' beamline realisation

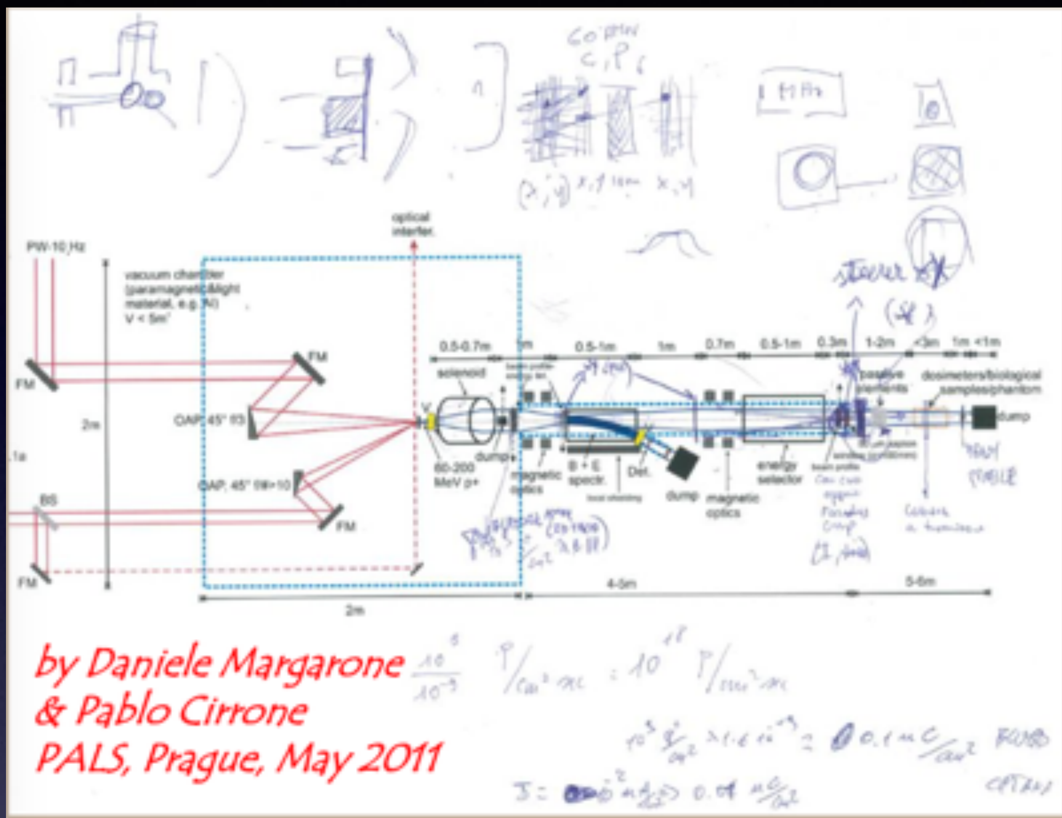
ELI-Beamlines (Prague, CZ) within 2017

Flexible, modular, Users' addressed



ELIMED history

2011



2012

Fyzikální ústav
Akademie věd ČR, v. v. i.

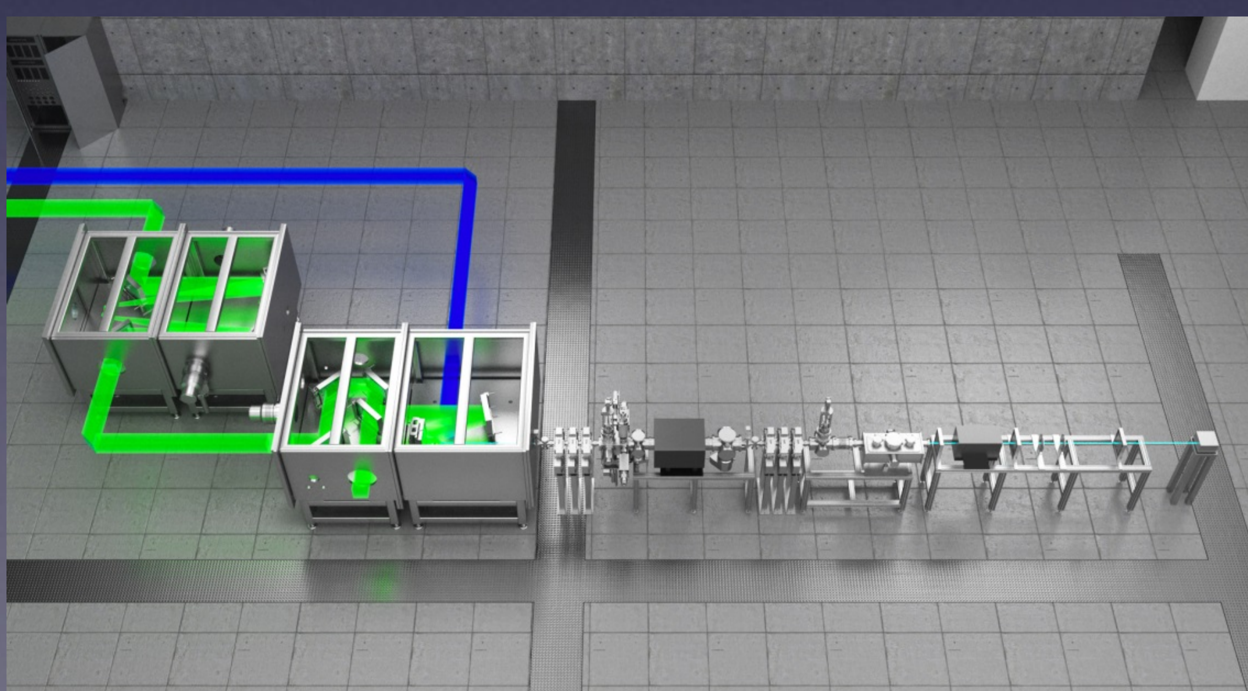
Memorandum of Understanding for a scienti[...]
collaboration towards medical applications[...]

Between the

Eli-Beamlines, Institute of Physics of AS CR, public research institution (FZU),
Prague, Czech Republic

And

Laboratori Nazionali del Sud (LNS), of INFN, public research institution,
Catania, Italy



2013

4. WORK SUBJECT-MATTER; WORK SCOPE

4.1. The Contract concerns the design, assembling, performance optimization, and delivering to the Client at the Client's Place of Business of a complete transport beamline and a number of dosimetric endpoints that will enable the users to apply laser-driven ion beams in multidisciplinary fields in accordance with this Contract (hereinafter the *"System"*). Furthermore, the scope of this Contract mainly encompasses (i) various training services to be provided to the Client's personnel in compliance with Article 13 of this Contract (ii) a royalty free licence, if any according to Article 14, to use the System for the purposes of the use of the ELI-Beamlines Project after completion and (iii) the possible realization of the Additional System, subject to the exercise of the Call Option right by the Client under par. 4.6 (the System and the other parts of the works/services are hereinafter referred to as the *"Works"*).

– 5 DIC. 2014

Signed in Prague on 8/12/2014	Signed in Rome on ________
On behalf of: **Fyzikální ústav AV ČR, v. v. i.**	On behalf of: **INFN, Instituto Nazionale di Fisica Nucleare**
Signature:	Signature:
Name: Prof. Jan Řídký, DrSc.	Name: Prof. Fernando Ferroni
Title: the Director	Title: the President

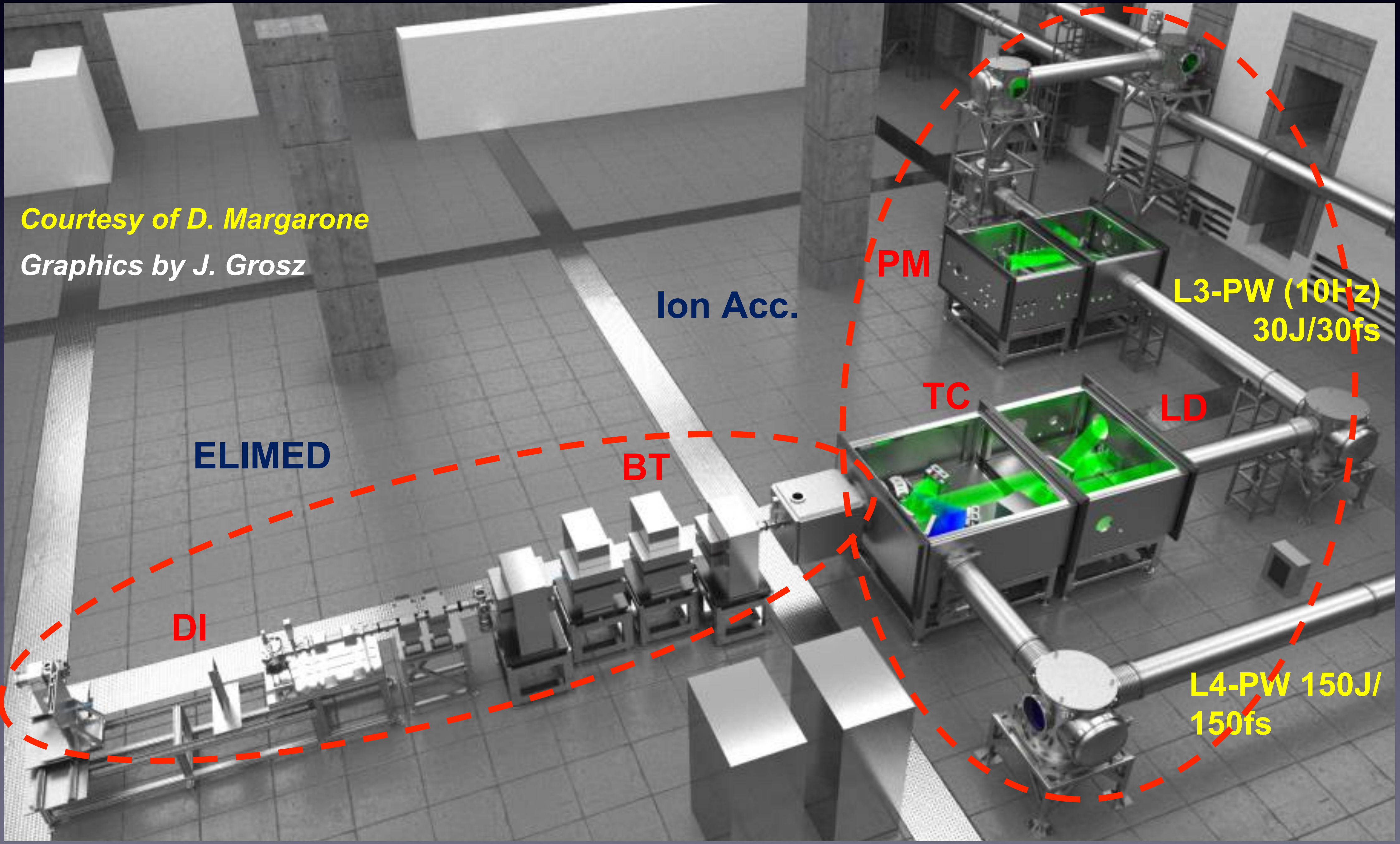
ISTITUTO NAZIONALE DI FISICA NUCLEARE
IL PRESIDENTE
(Prof. Fernando Ferroni)

2014

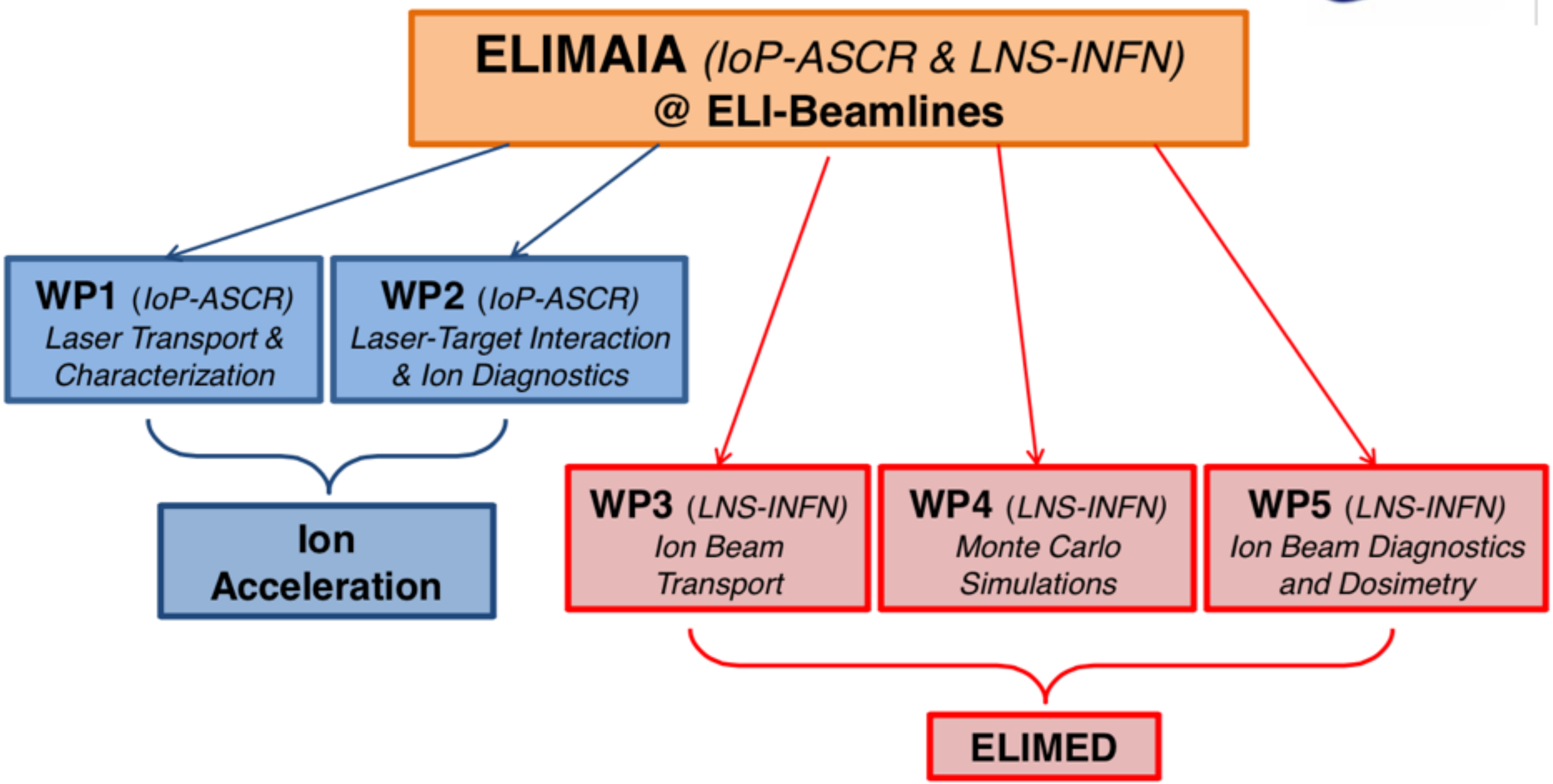
ELIMAIA hall and the ELIMED beamline

ELI Multidisciplinary **A**pplications of laser **I**on **A**cceleration

ELI MEDical and multidisciplinary applications



ELIMAIA WPs


ELIMAIA (IoP-ASCR & LNS-INFN)
@ ELI-Beamlines
WP1 (IoP-ASCR)
Laser Transport & Characterization
WP2 (IoP-ASCR)
Laser-Target Interaction & Ion Diagnostics
Ion Acceleration
WP3 (LNS-INFN)
Ion Beam Transport
WP4 (LNS-INFN)
Monte Carlo Simulations
WP5 (LNS-INFN)
Ion Beam Diagnostics and Dosimetry
ELIMED

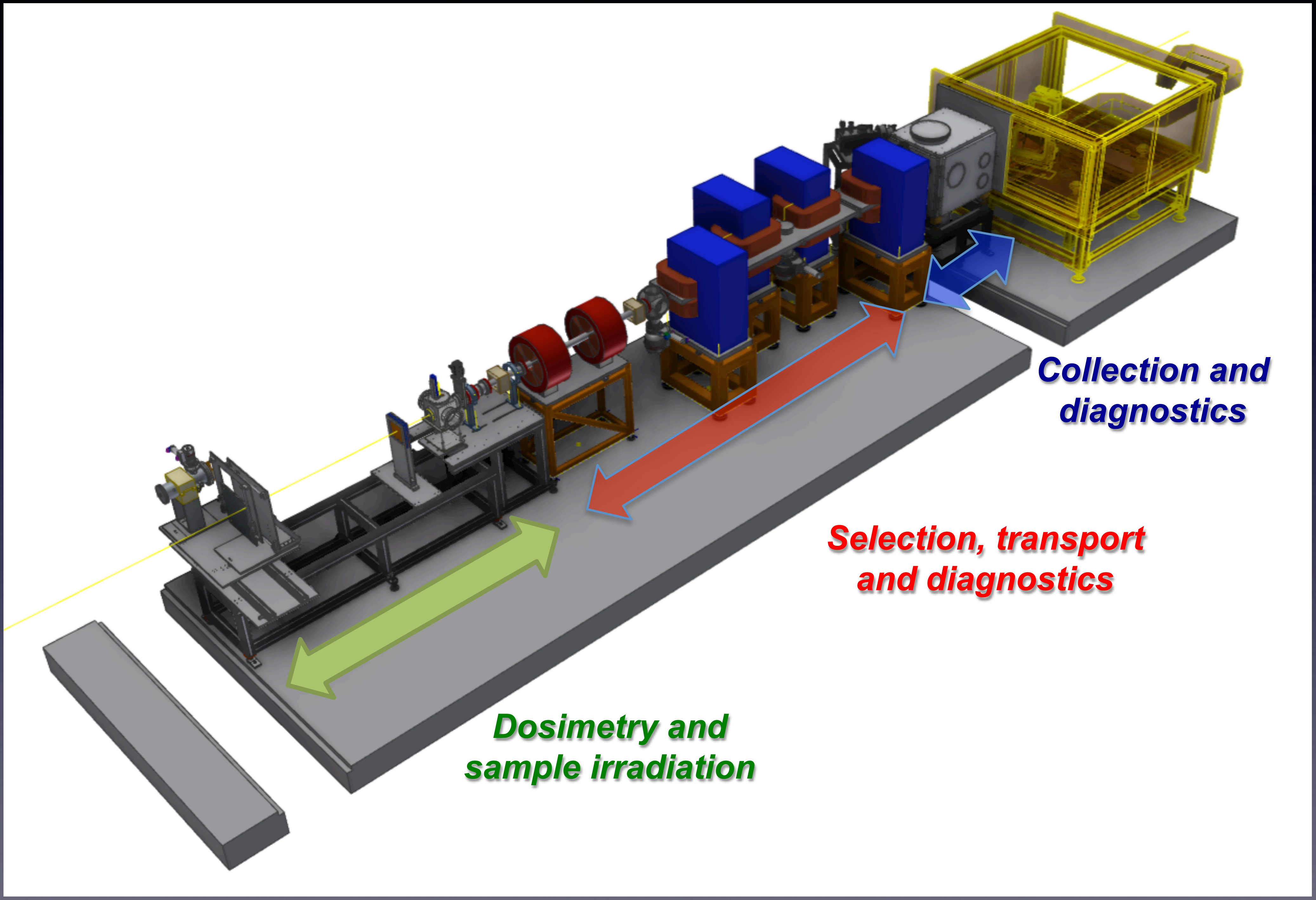
The ELIMED beamline

Implementation status

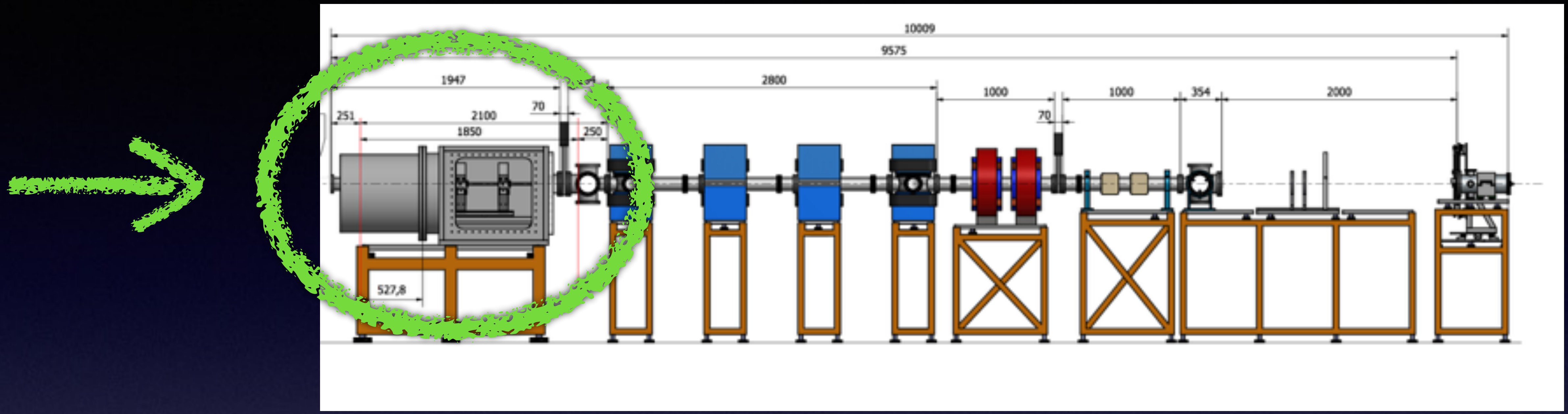
Three ingredients:

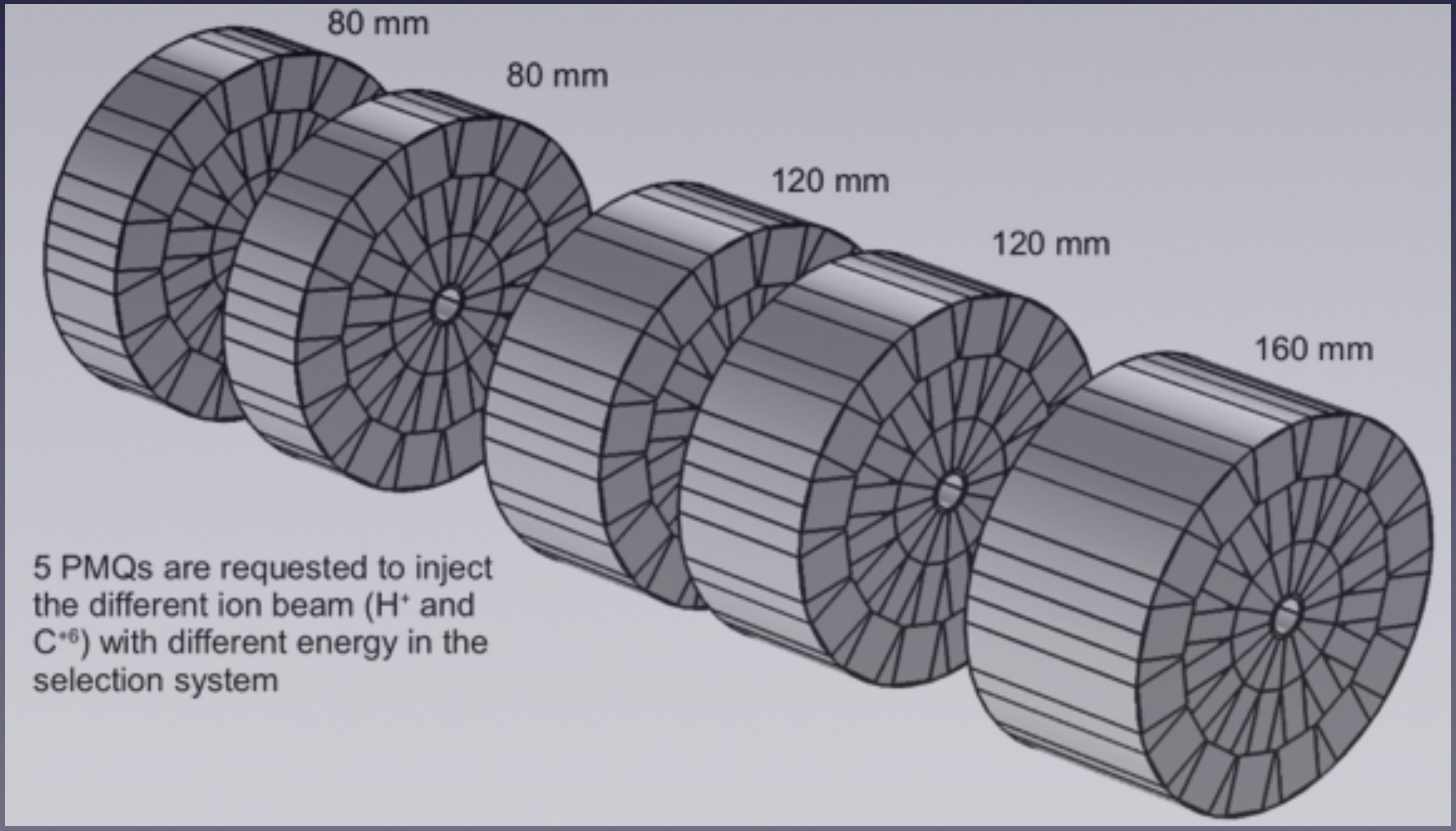
- Beam transport solutions
- Diagnostic and dosimetry
- Monte Carlo simulations

ELIMED beamline



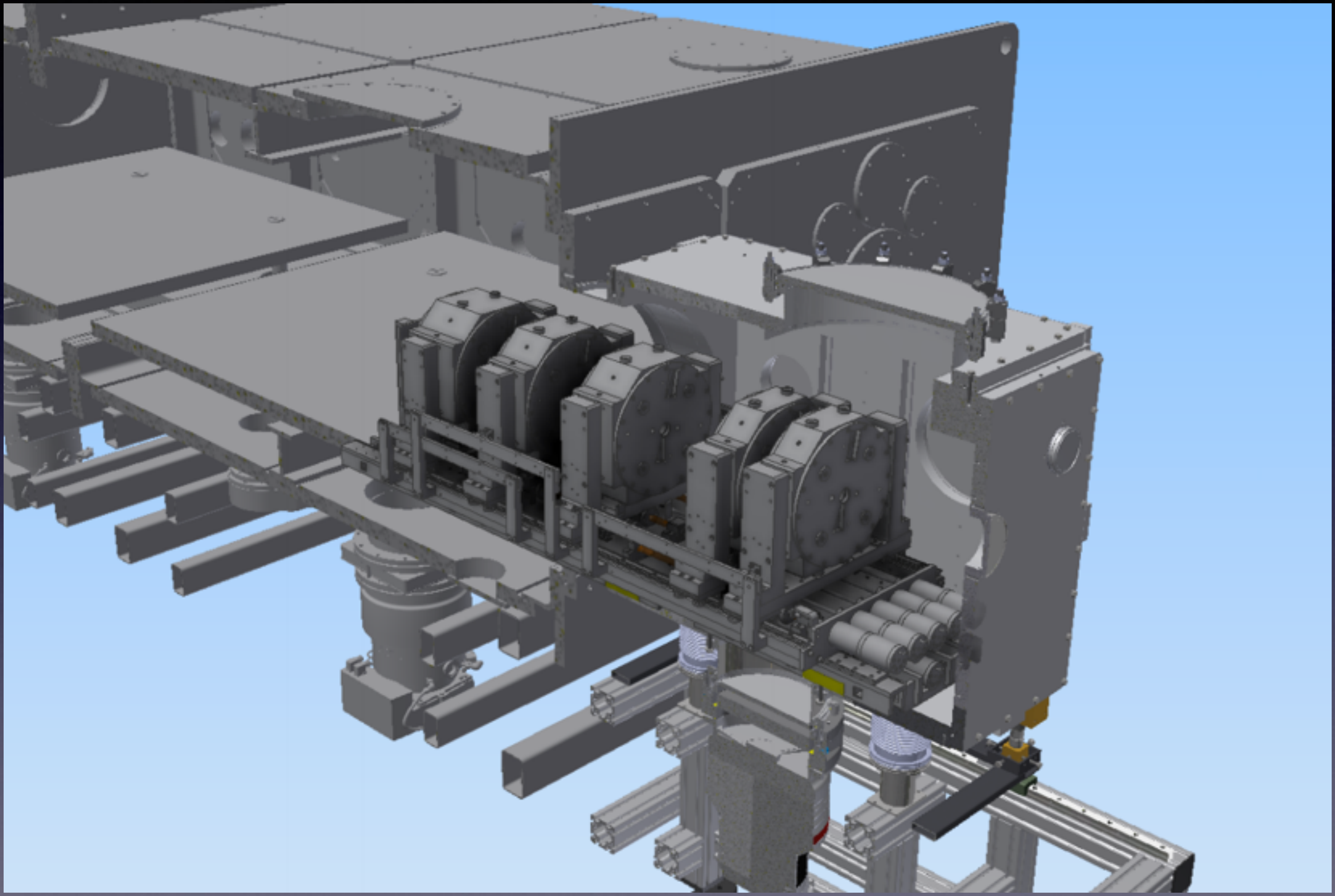
Collecting and focusing: permanent magnetic quadrupoles





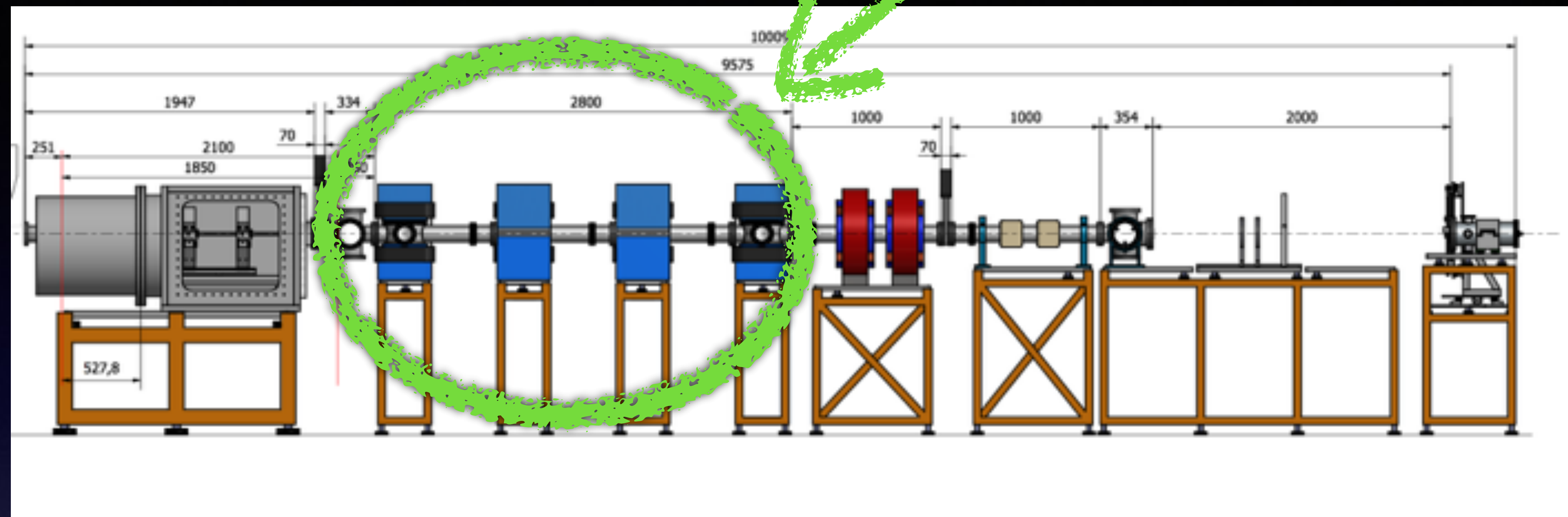
High field uniformity (2% in radial direction) and gradient 100 T/m on 36 mm bore

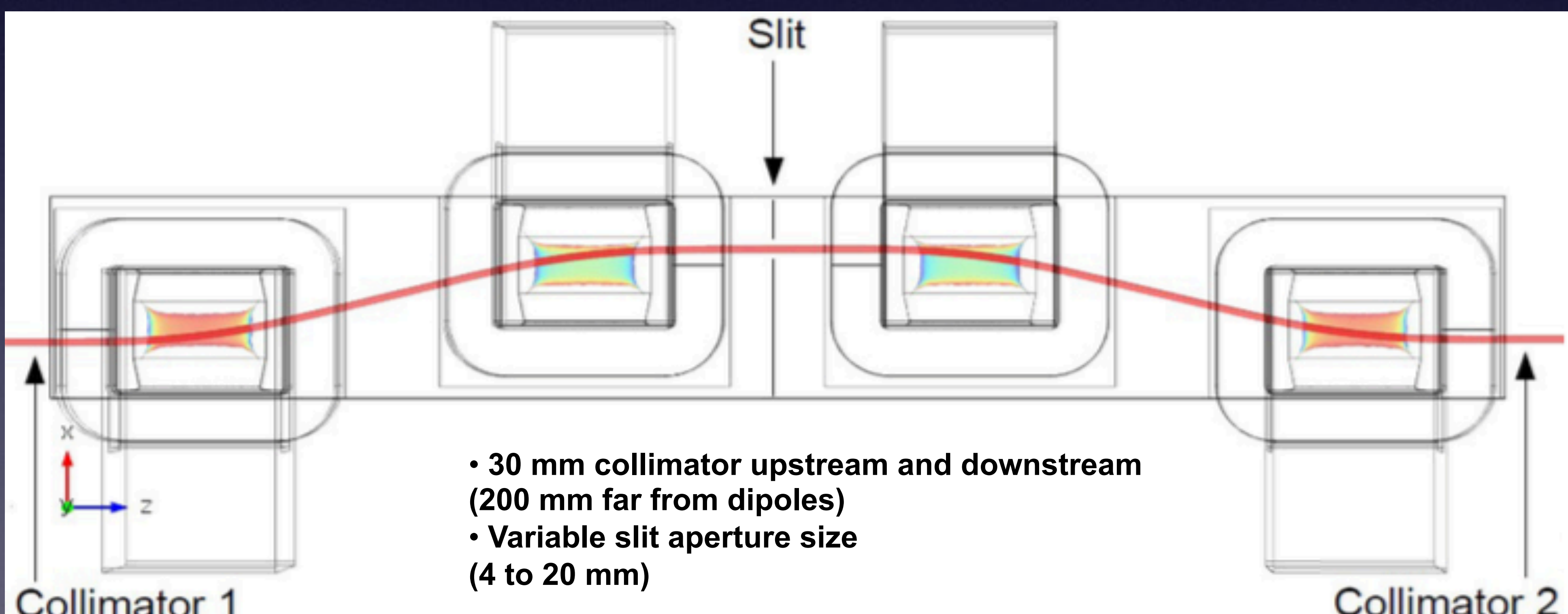
Collecting and focusing: permanent magnetic quadrupoles



Quadrupoles delivering expected within September 2016

Energy selection



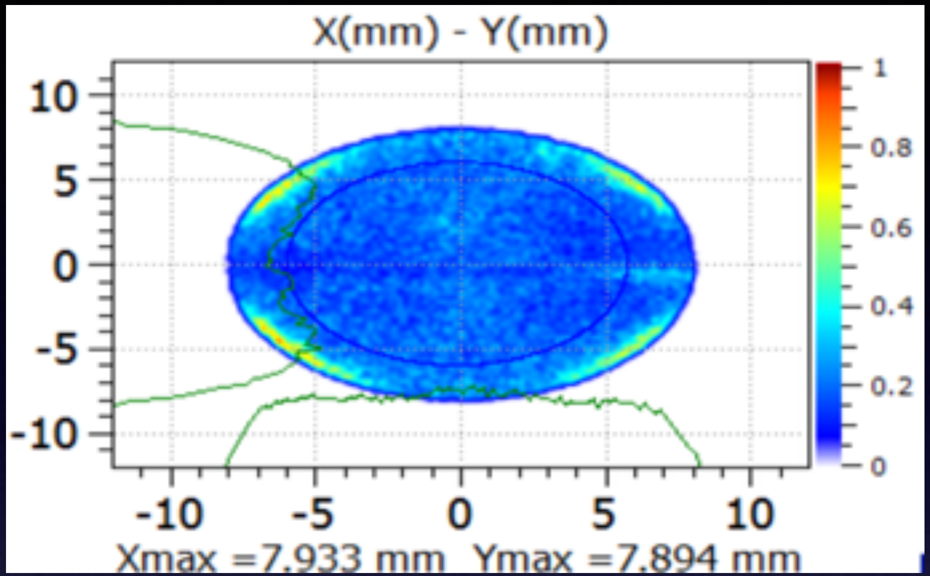


Public tender will be launched this month

n° of Dipoles	B field	Geometric length	Effective length	Gap
4	0,085 – 1,2 T	400 mm	450 mm	59 mm
Good Field region (GFR)	**Field uniformity**	**Curvature radius**	**Bending angle**	**Drift between dipoles**
100 mm	< 0,5 %	2,5293 m	10,10° (176,3 mrad)	500 mm

Angular divergence: 5° (FWHM)

Angular divergence: 12% (9.2 $*10^7$ H+/bunch)



60 MeV case

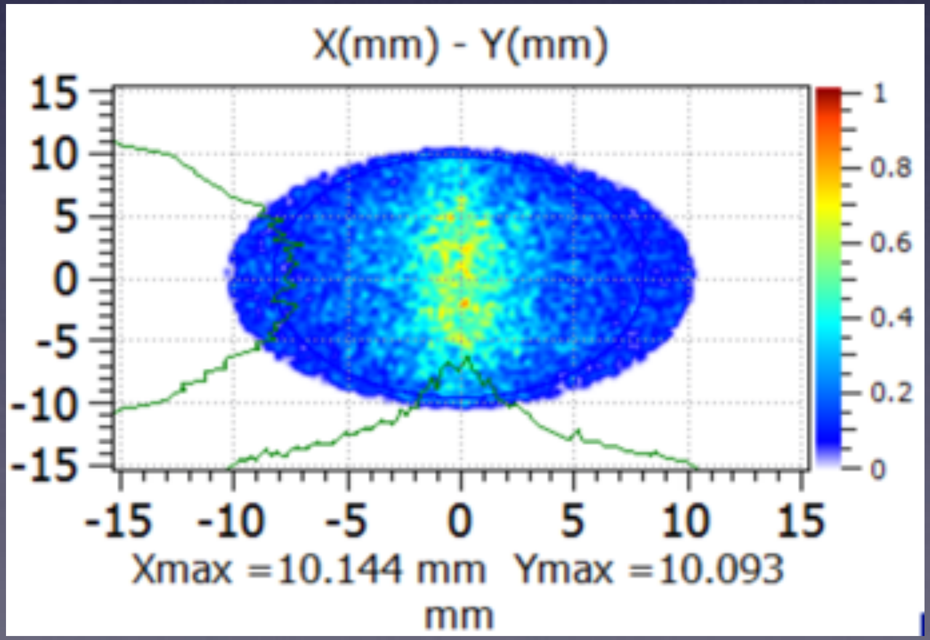
Dose: 0.05 Gy/bunch

Fluence: $3*10^7$ H^+/cm^2

Dose rate: 3 Gy/min

Angular divergence: 5° (FWHM)

Angular divergence: 14% (3.2 $*10^9$ H+/bunch)



30 MeV case

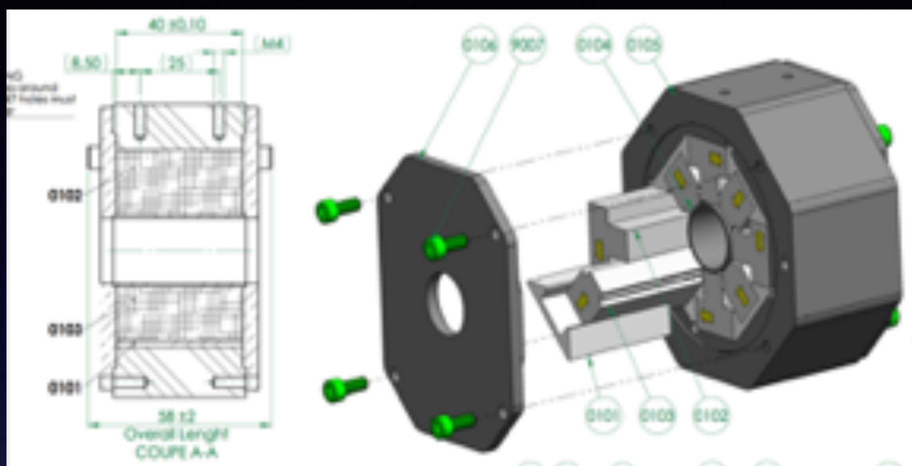
Dose: 0.35 Gy/bunch

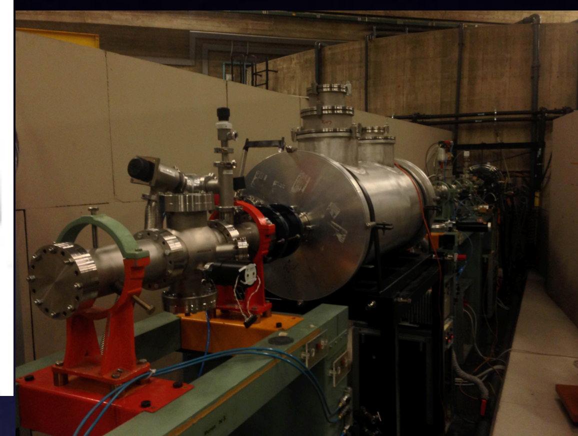
Fluence: $3.4*10^8$ H^+/cm^2

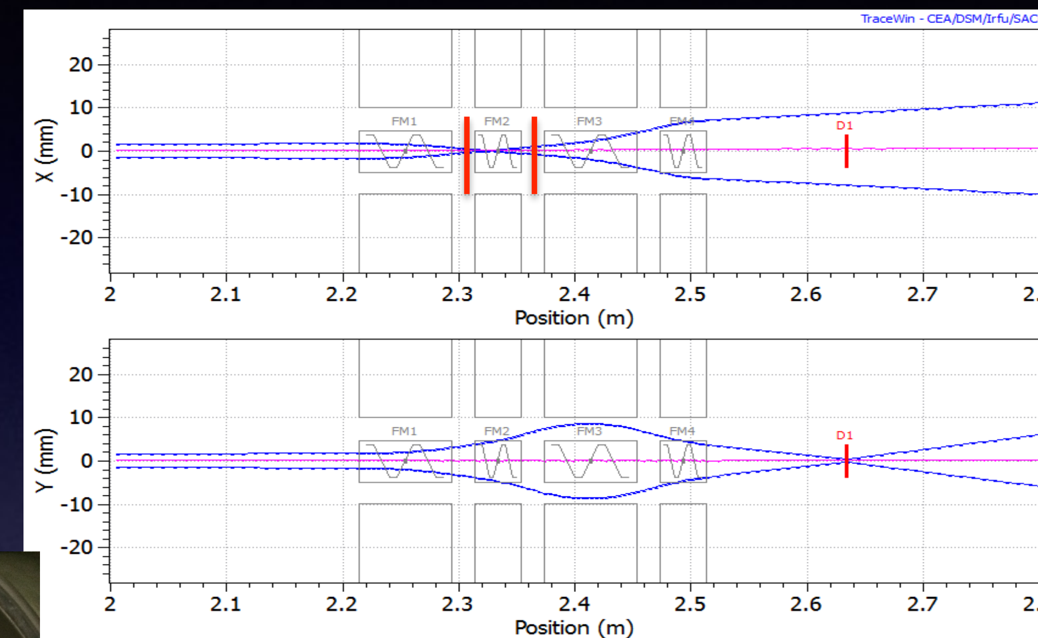
Dose rate: 21 Gy/min

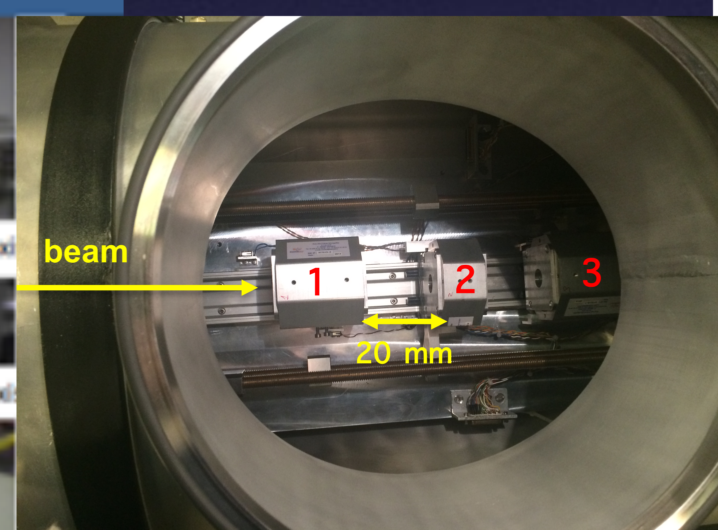
Beam-transport prototypes completed (up to 30 MeV)

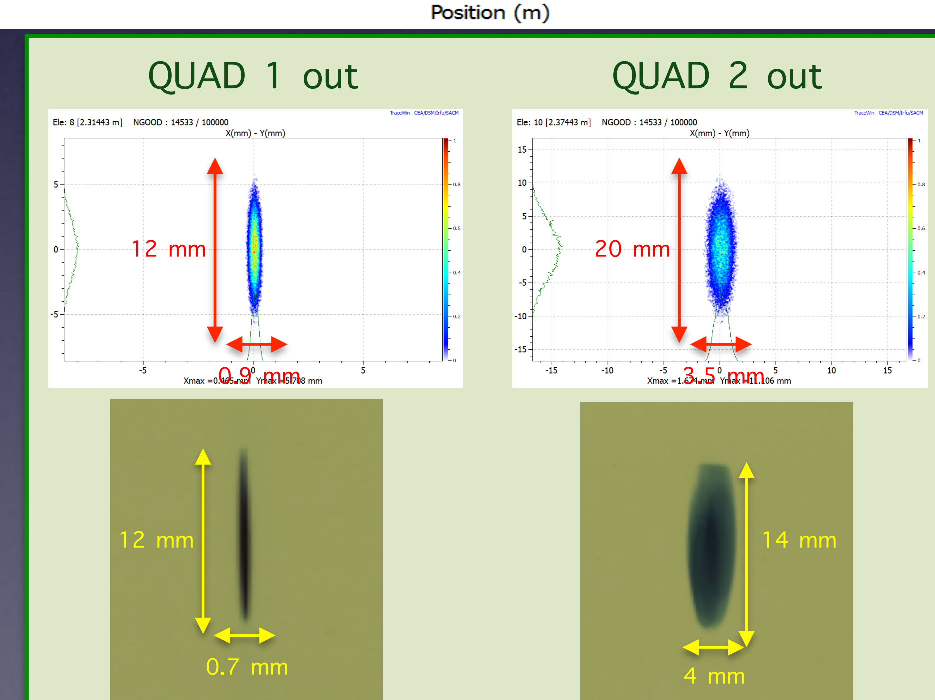
INFN-LNS conventional 30 beams





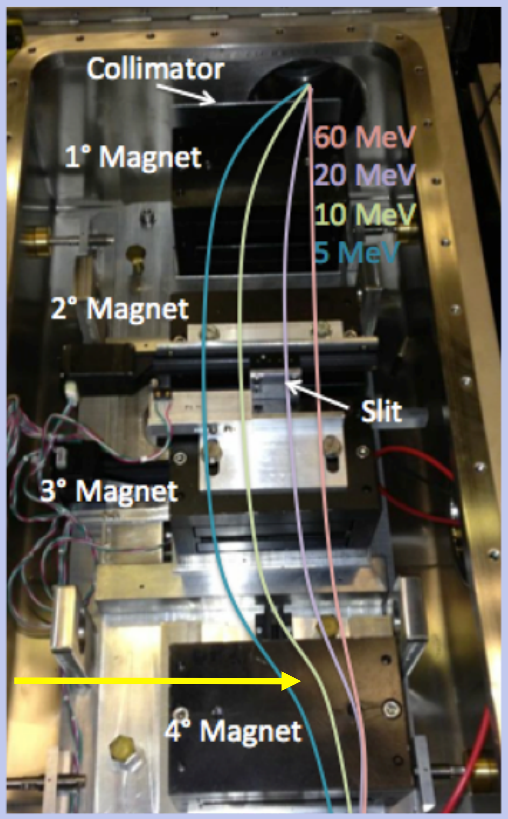






ELIMED R&D: beam transport and selection prototypes

ESS test experiment @ TARANIS
(Queen's University of Belfast)

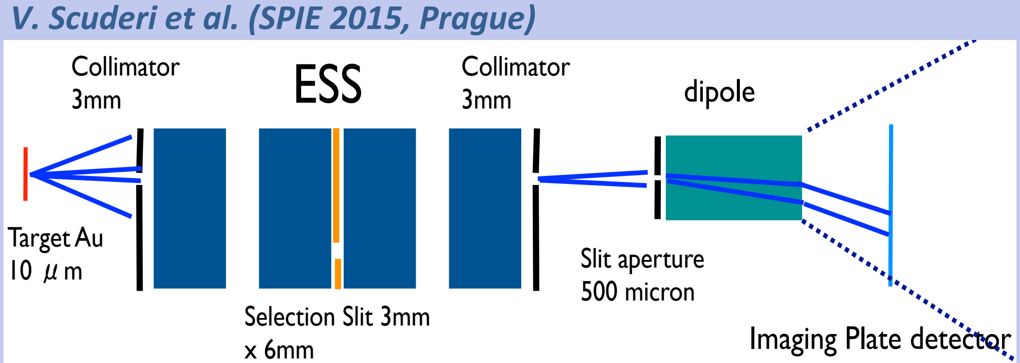


INPUT BEAM
Ep: 1-10 MeV (ΔE/E=100%)

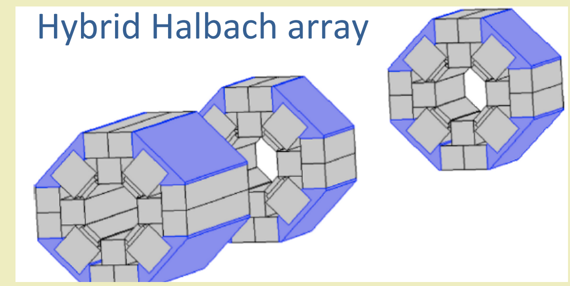
SELECTED BEAM
Ep : 4.5 ± 0.3 MeV
(ΔE/E = 13%)

Ep : 7.4 ± 0.6 MeV
(ΔE/E = 16%)

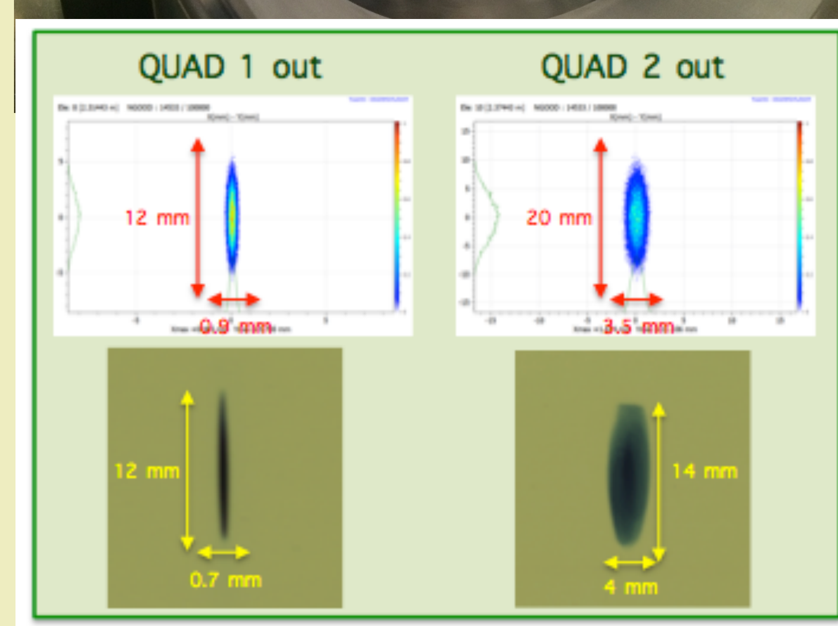
V. Scuderi et al. (SPIE 2015, Prague)



Permanent Magnet Quadrupoles (PMQs) prototype characterization at LNS-INFN



4 MQs
Net bore 20 mm
Lengths: 2x80mm; 2x40mm
Gradients: 103 T/m; 100 T/m



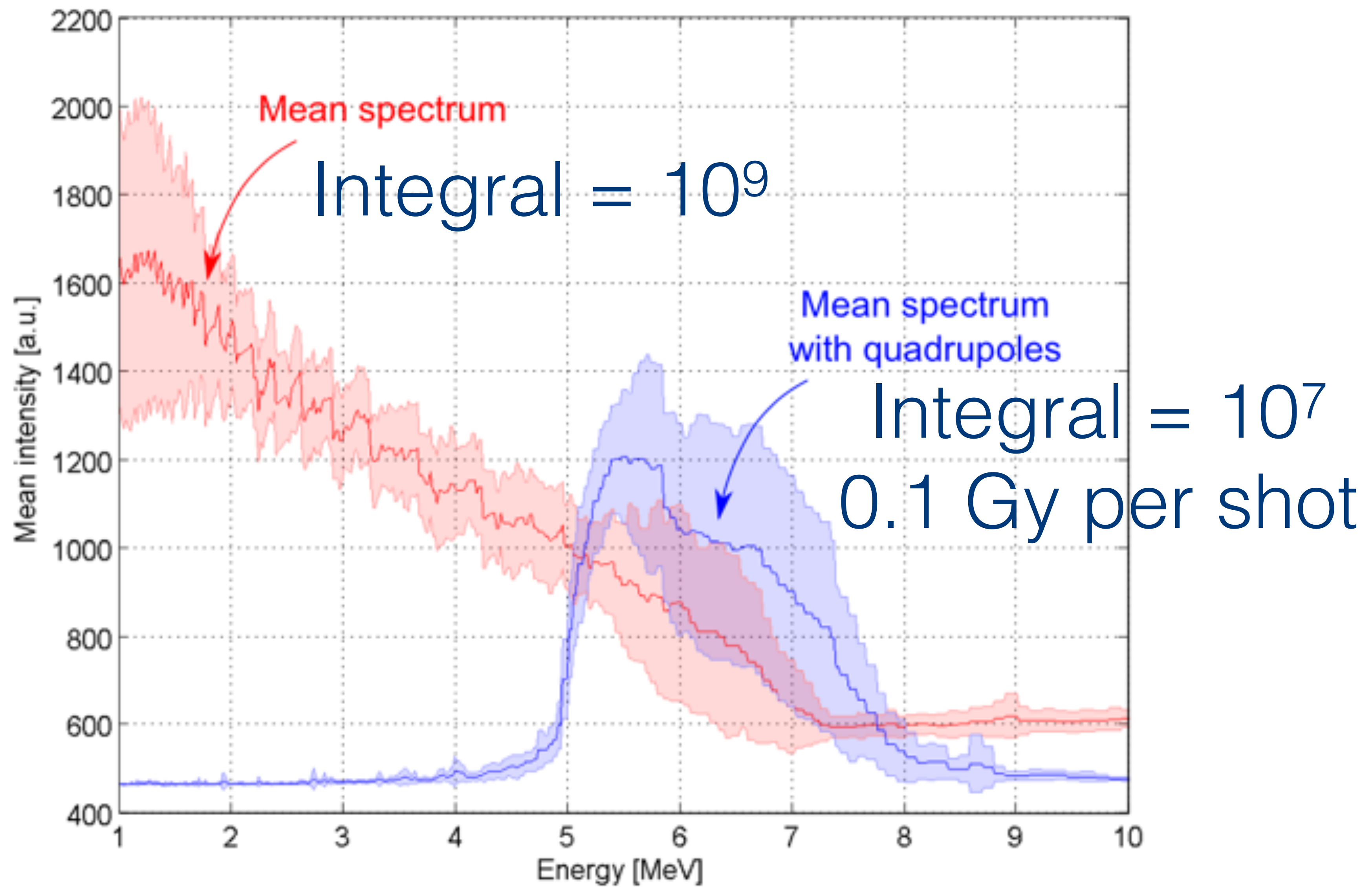


FIGURE 4 – Average proton beam spectrum extracted from the traces recorded by the forward Thomson Parabola, without (in red) and with (in blue) the quadrupole system.

LOA run (Paris, F) is running — PRELIMINARY

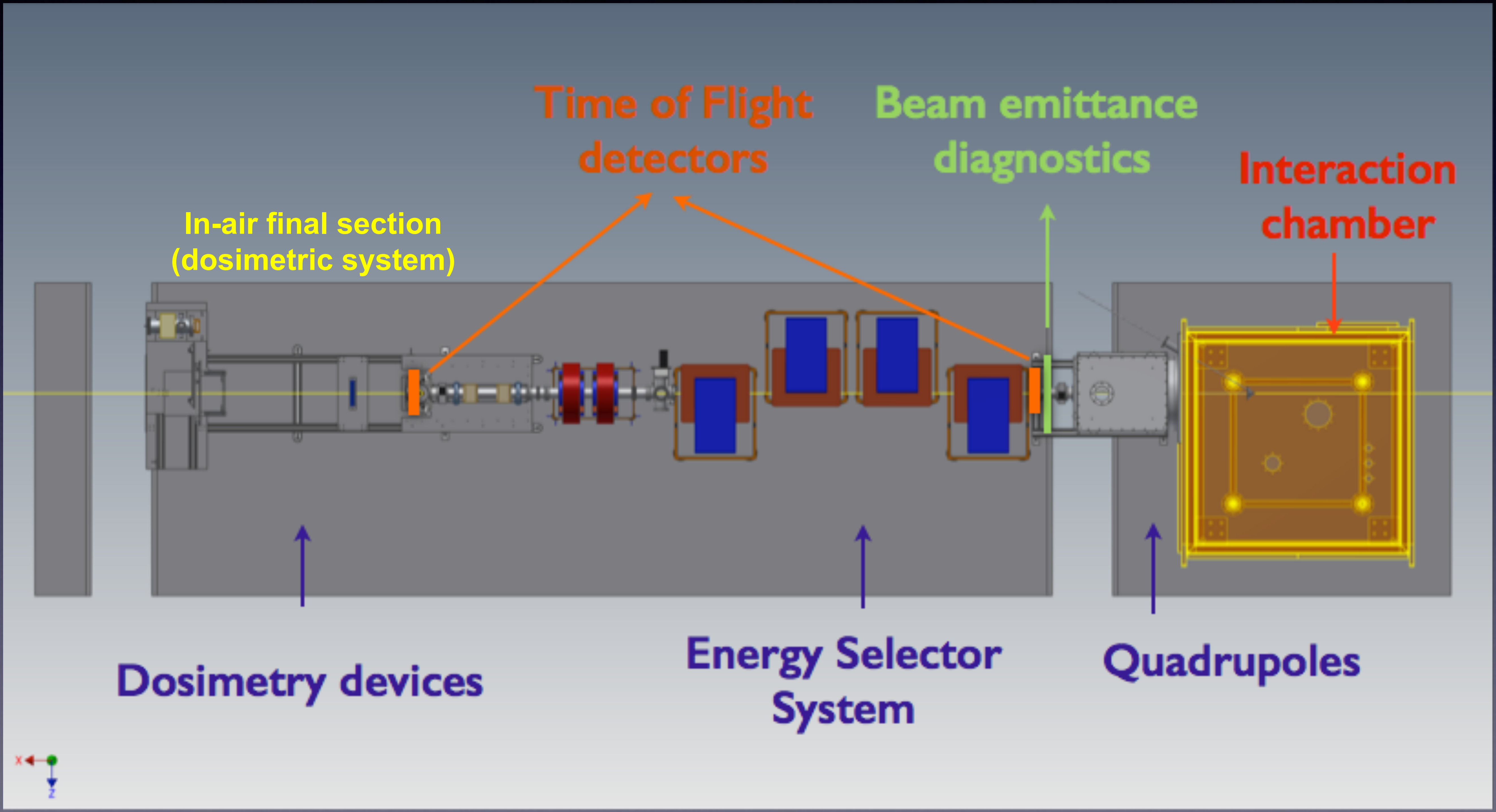
laboratoire d'optique appliquée

Diagnostics and Absolute dosimetry

Beam characteristics:

- Energy spread
- High intensities (10^9 Gy/min)
- Shot to shot low reproducibility
- Electromagnetic noise

Diagnostics and dosimetry



Diagnostics and dosimetry

Time of Flight approach

- On-line energy distribution and flux for p up to 60 MeV

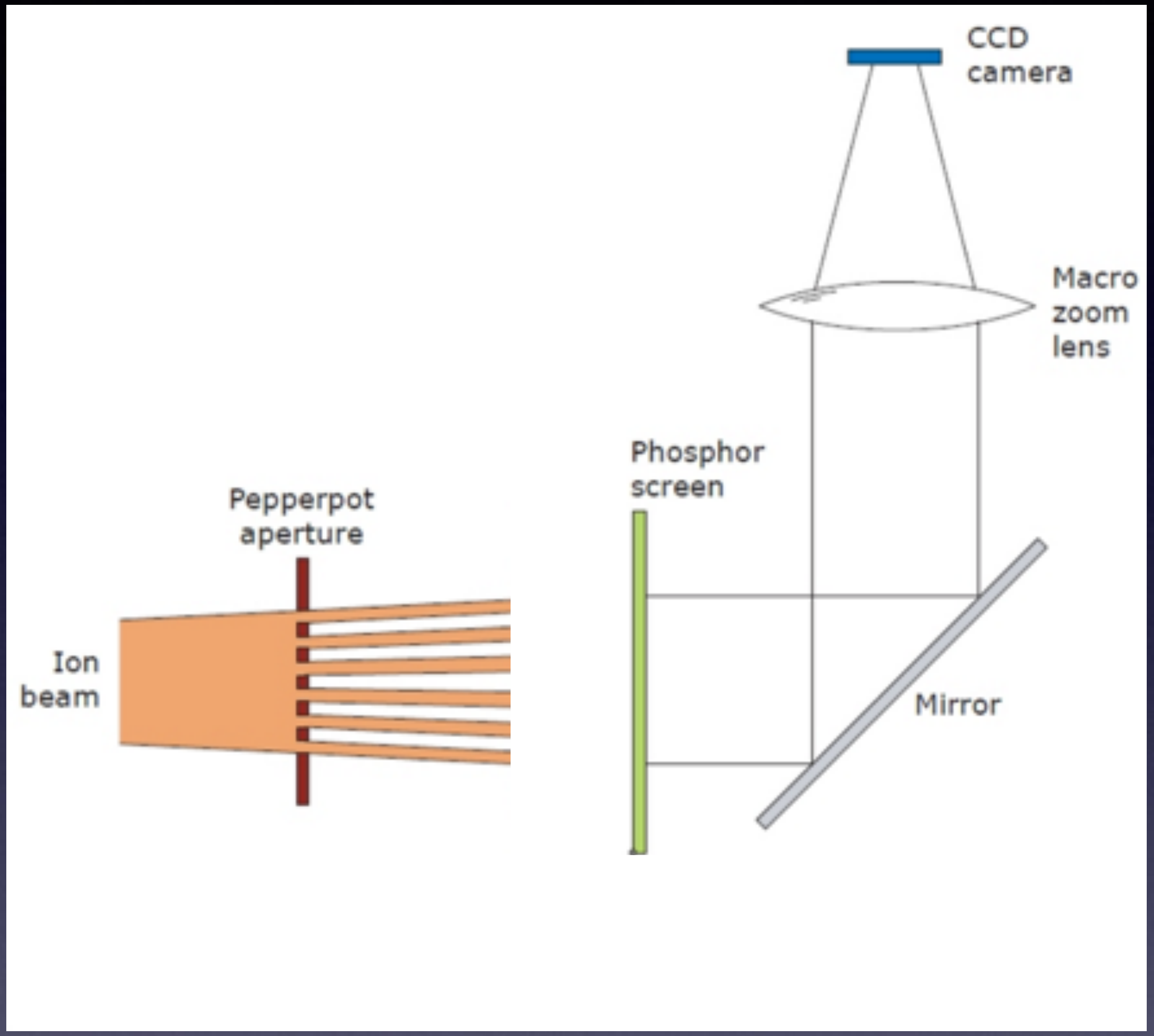
Detector requirements

- Radiation hardness
- Time resolution

- Diagnostics along the beamline

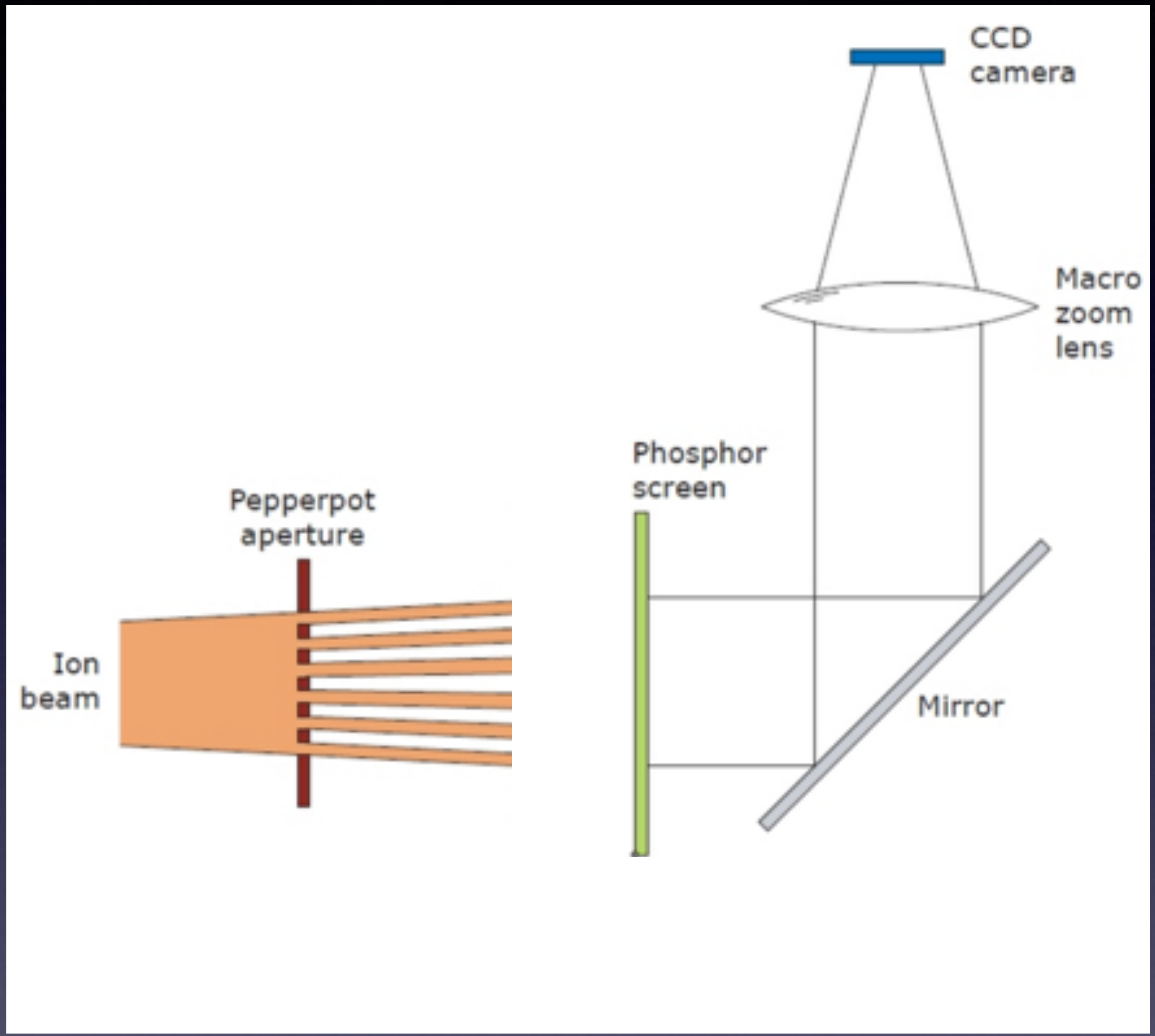
On-line beam emittance measures

‘pepper-pot’ approach



On-line beam emittance measures

‘pepper-pot’ approach

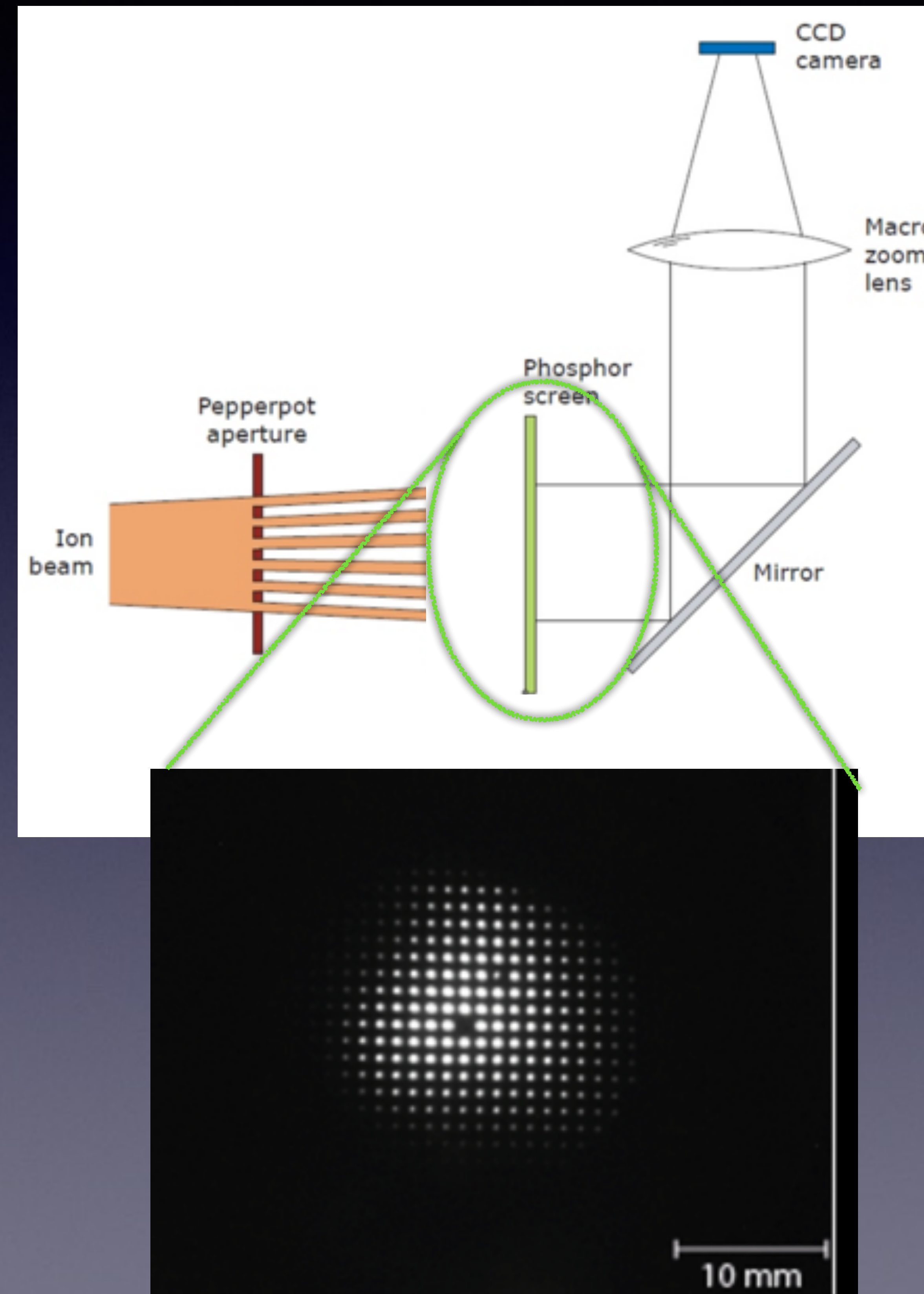


Grid characteristics
Tantalum
13 mm in thickness
4 mm pitch
1 mm hole diameter

On-line beam emittance measures

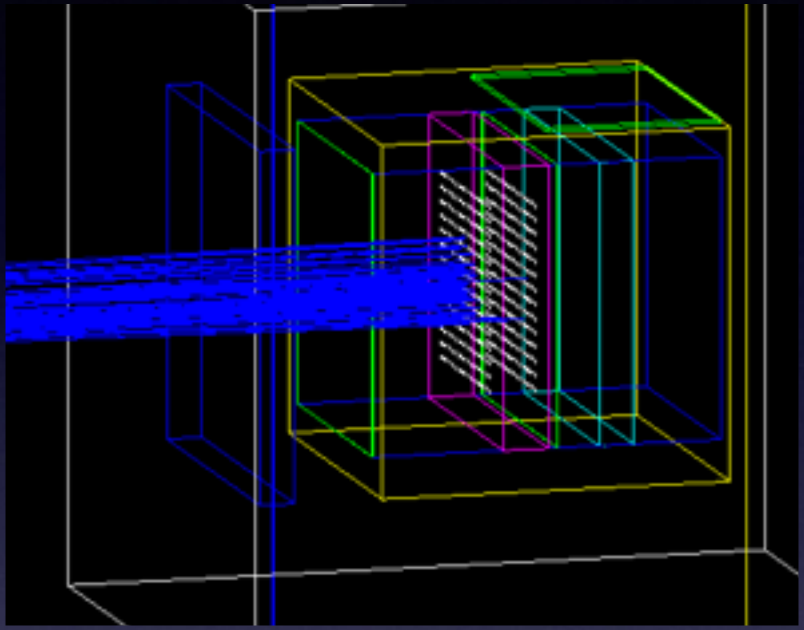
‘pepper-pot’ approach

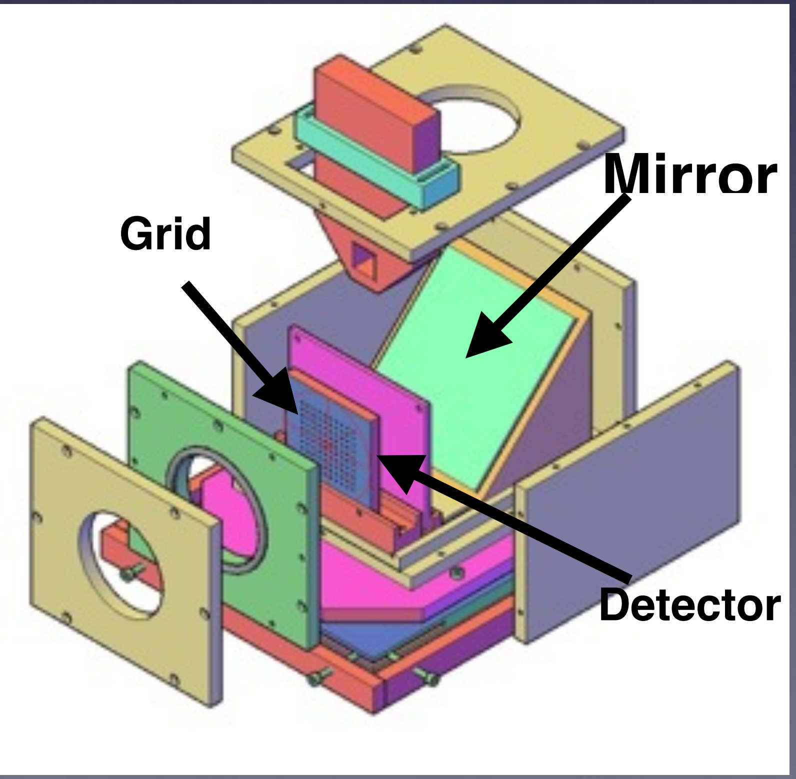
Grid characteristics
Tantalum
13 mm in thickness
4 mm pitch
1 mm hole diameter

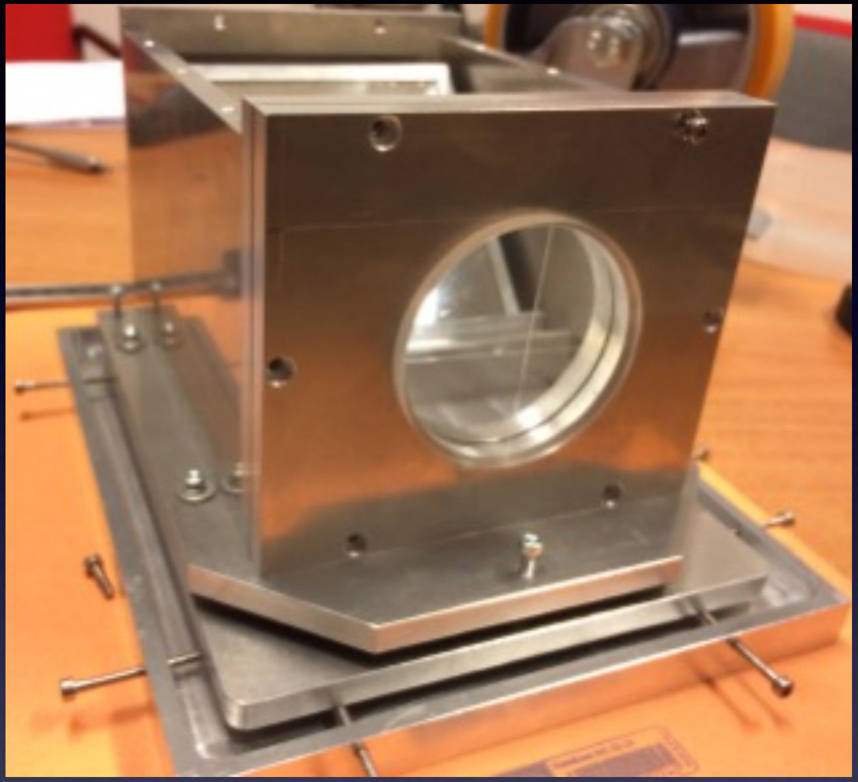


On-line beam emittance measures

Monte Carlo simulation

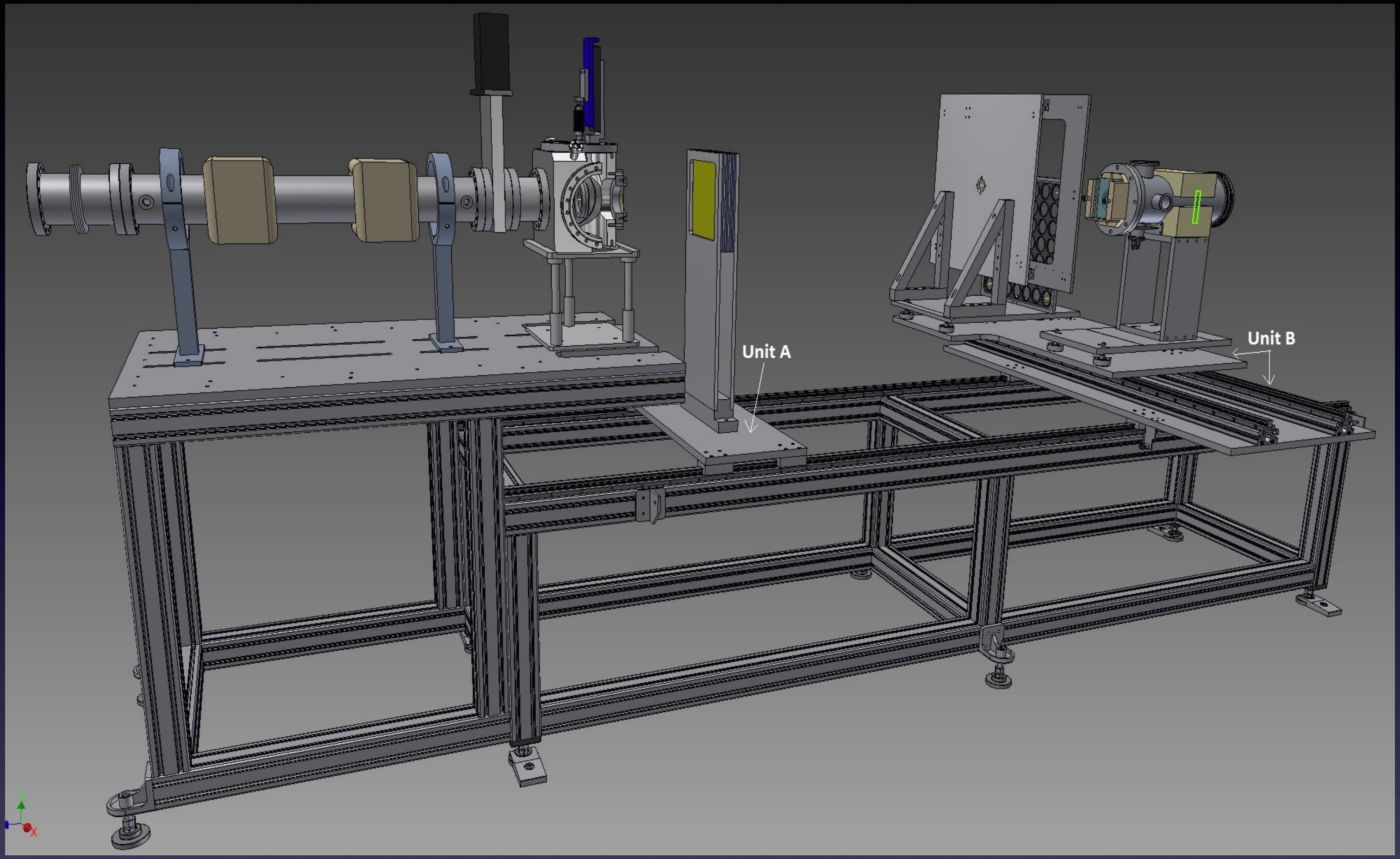




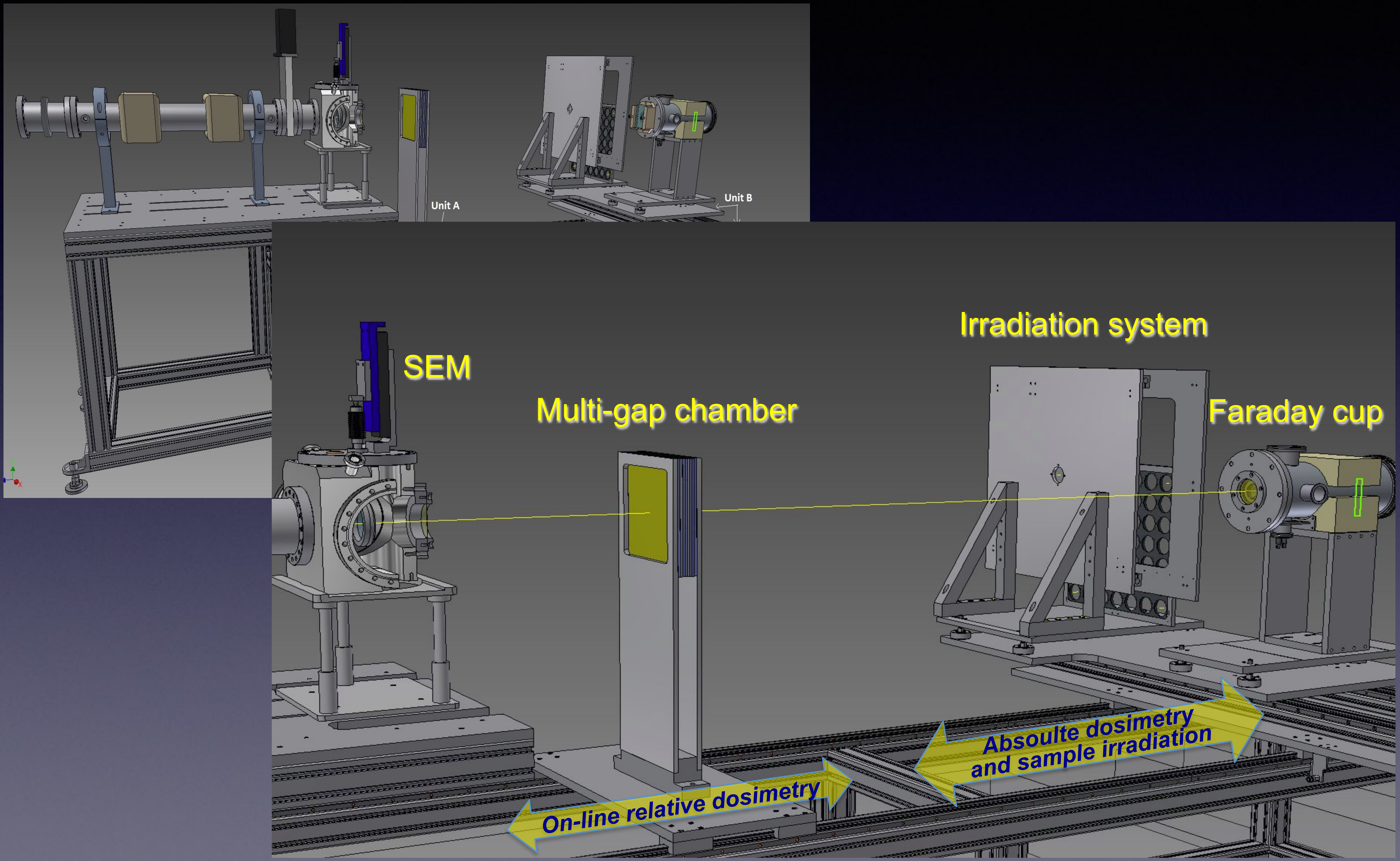


Tests with conventional proton beams ongoing

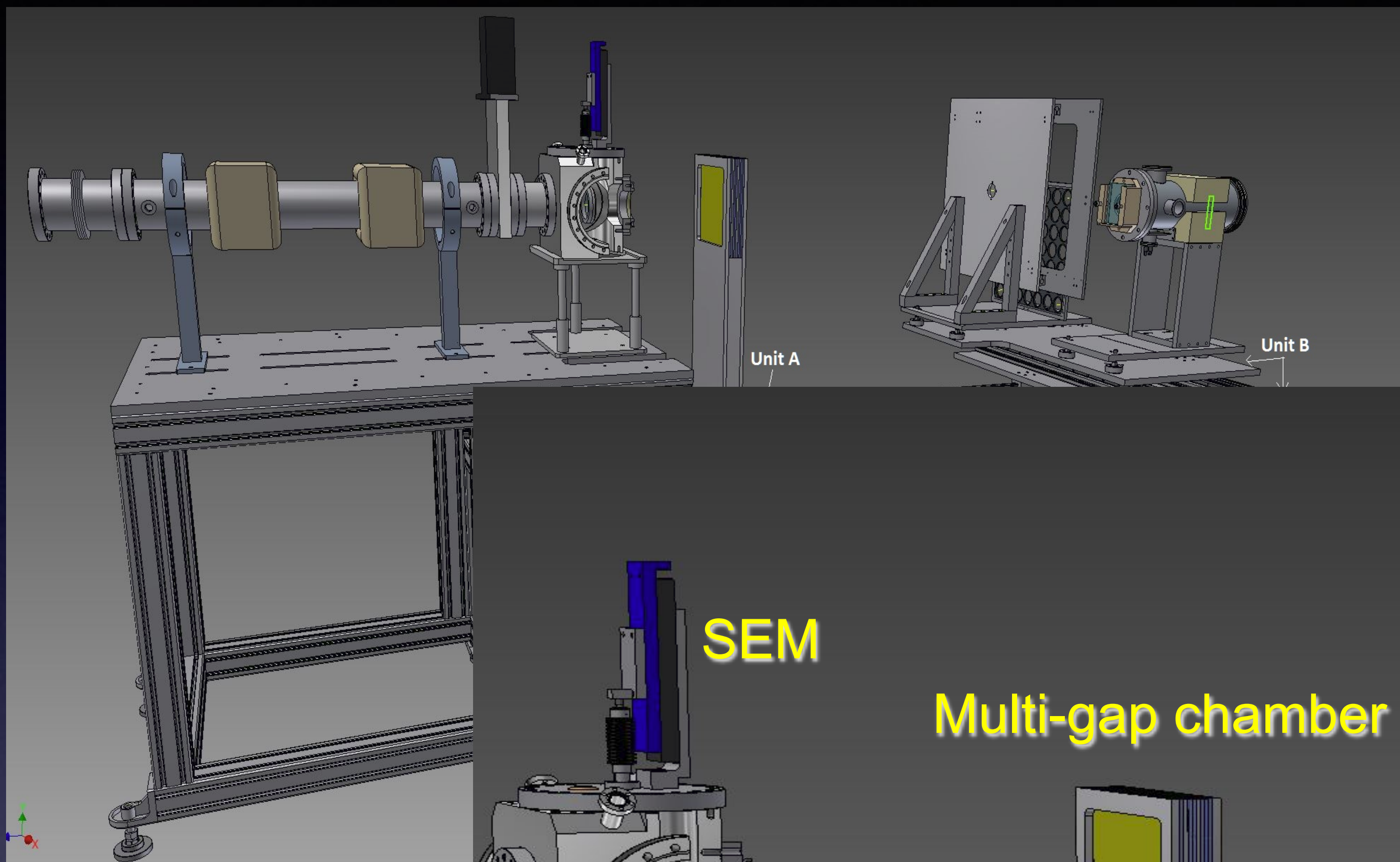
Diagnostics and dosimetry: in-air final section

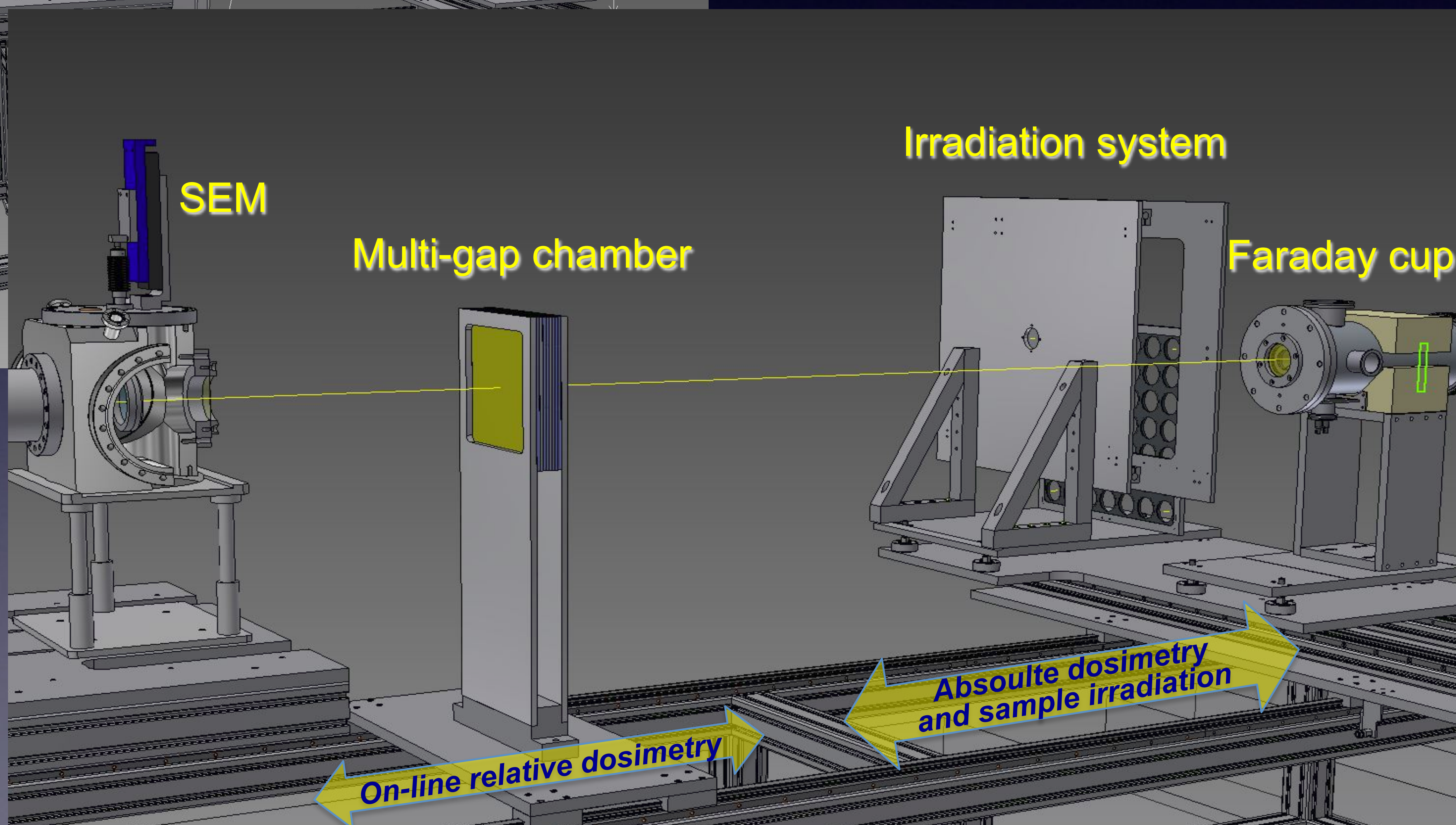


Diagnostics and dosimetry: in-air final section



Diagnostics and dosimetry: in-air final section





Passive detectors:
RCF
TLD
CR39

absorbed dose to water

$$D_{w,Q} = M_Q \, N_{D,w,Q_o} \, k_{Q,Q_o}$$

corrected instrument reading at Q

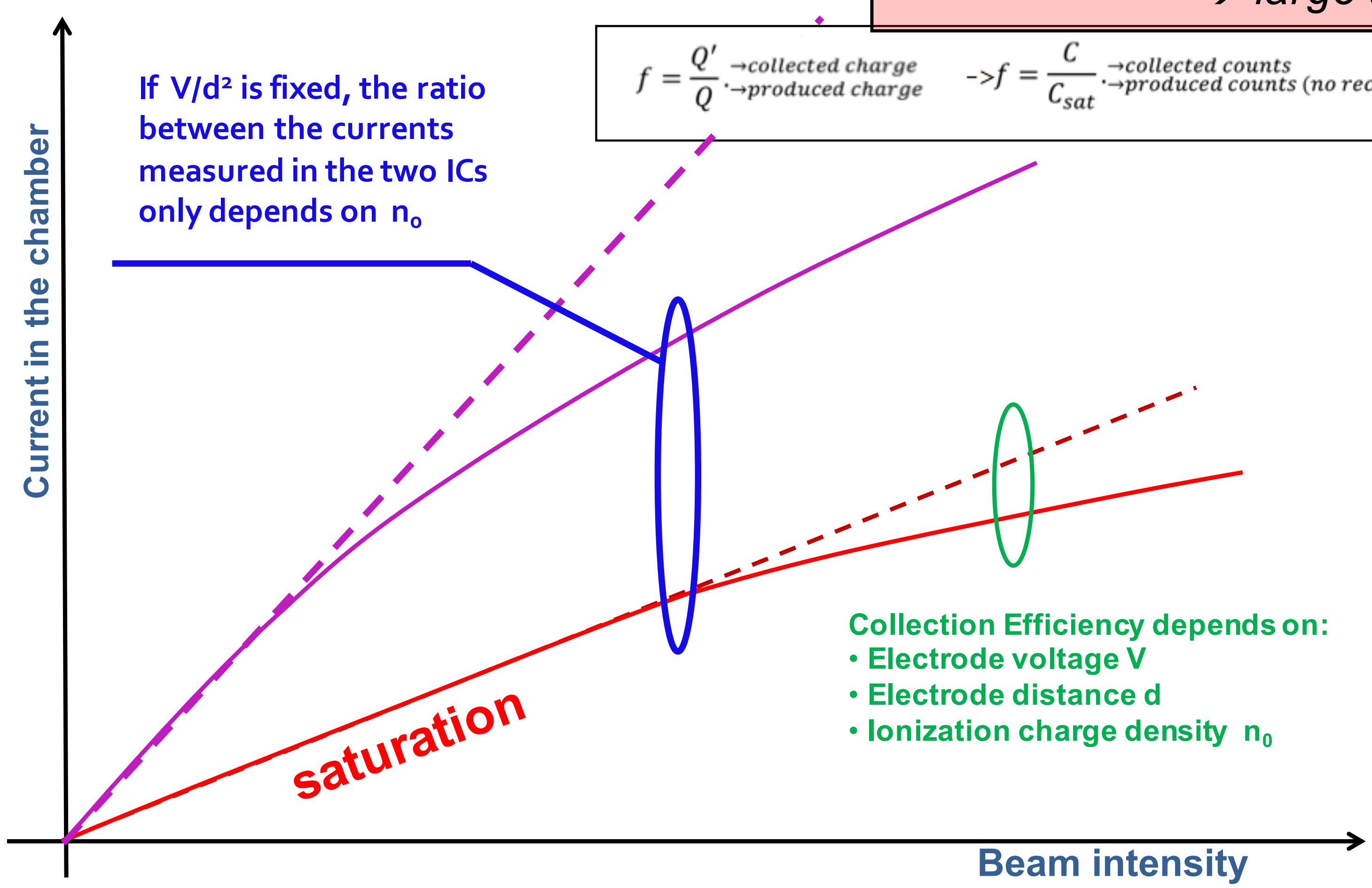
calibration coefficient at Q_o

beam quality factor

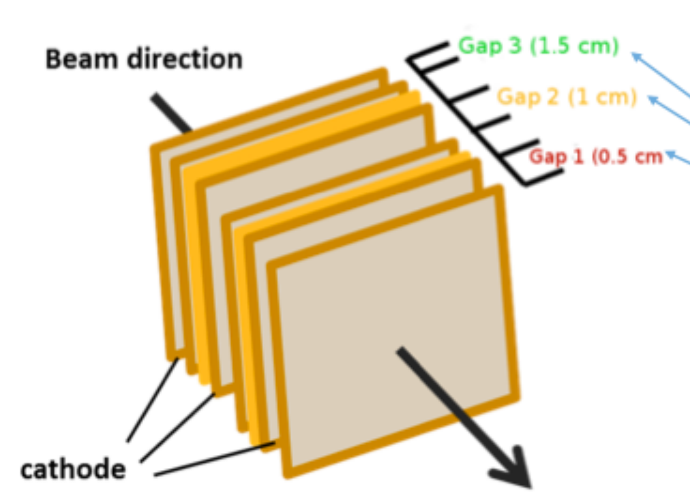
$$M_Q = M_{raw} \, k_{TP} \, k_{elec} \, k_{pol} \, k_s$$

*Volume **recombination** effects due to high ionization density → large **uncertainties** (>> 3%)*

$$f = \frac{Q'}{Q} \; \begin{matrix} \to \textit{collected charge} \\ \to \textit{produced charge} \end{matrix} \qquad \text{->} f = \frac{C}{C_{sat}} \; \begin{matrix} \to \textit{collected counts} \\ \to \textit{produced counts (no recombination)} \end{matrix}$$



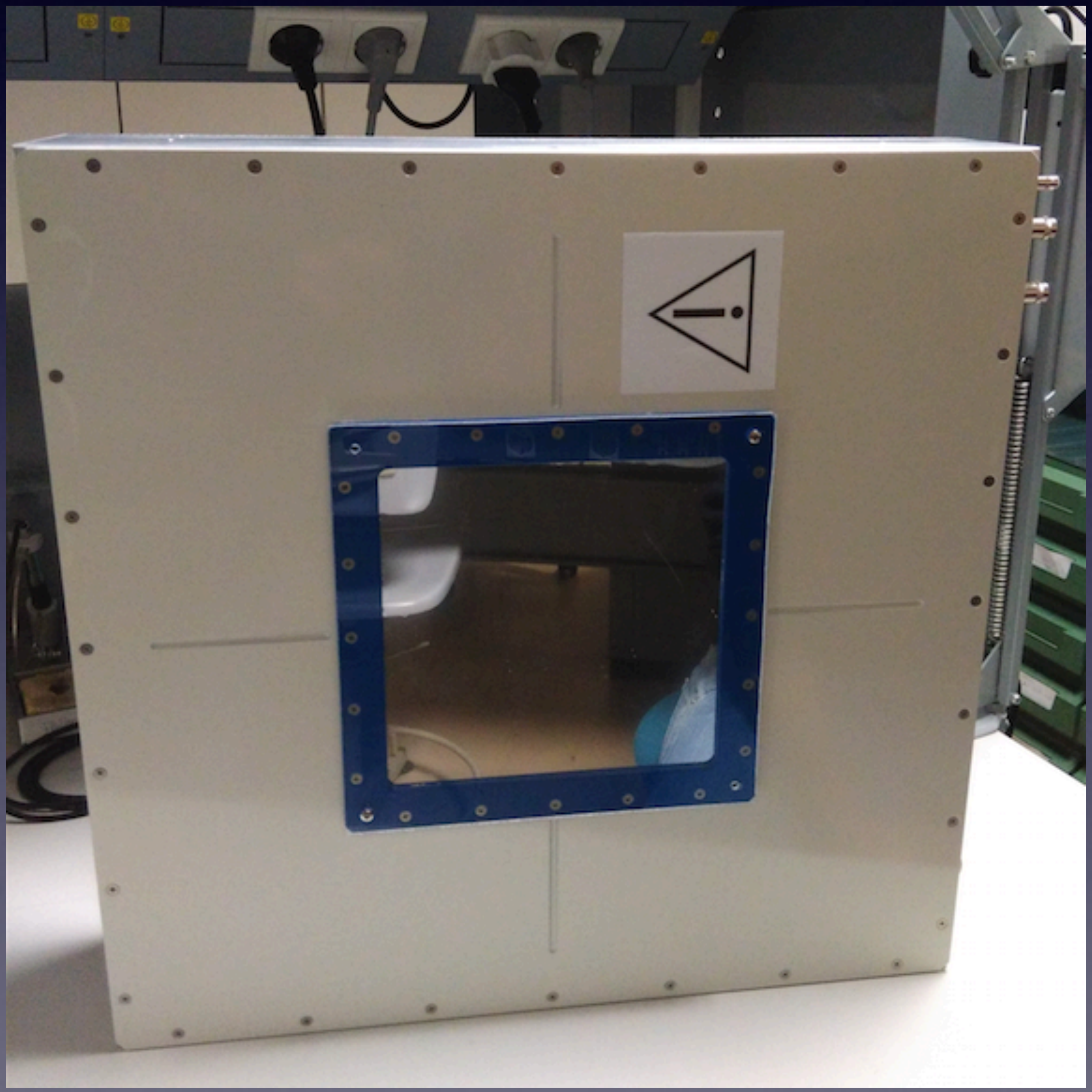
On-line dosimetry: multi-gap ionisation chamber



Material	Thickness (mm)	
Mylar	12,00 E-3	Cathode
Aluminum		
Nitrogen/Air	Gap	Frame
Aluminum	17,00 E-3	Anode
Kapton	25,00 E-3	

Thanks to the the different gaps we can correct for the charge recombination effects at very high beam intensity

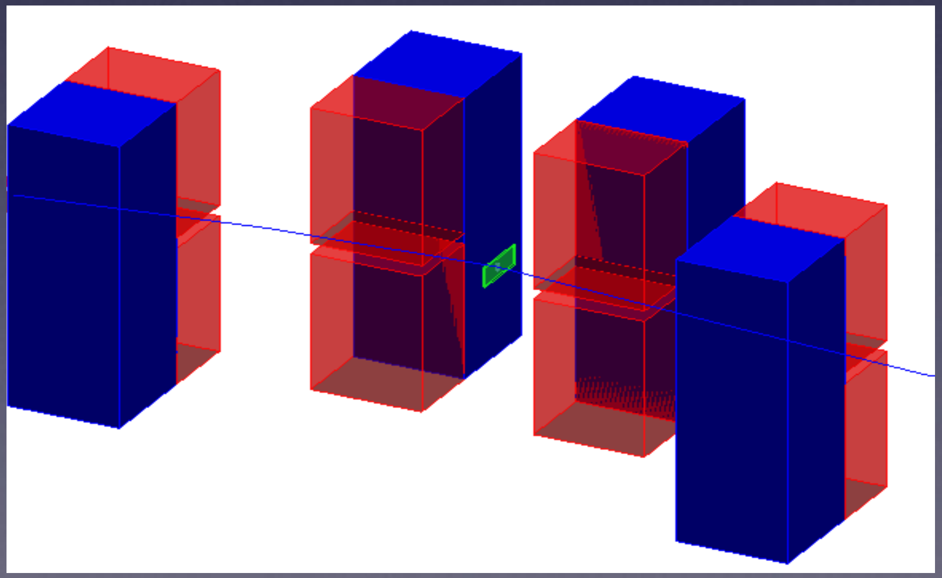
Collaboration with Turin INFN section



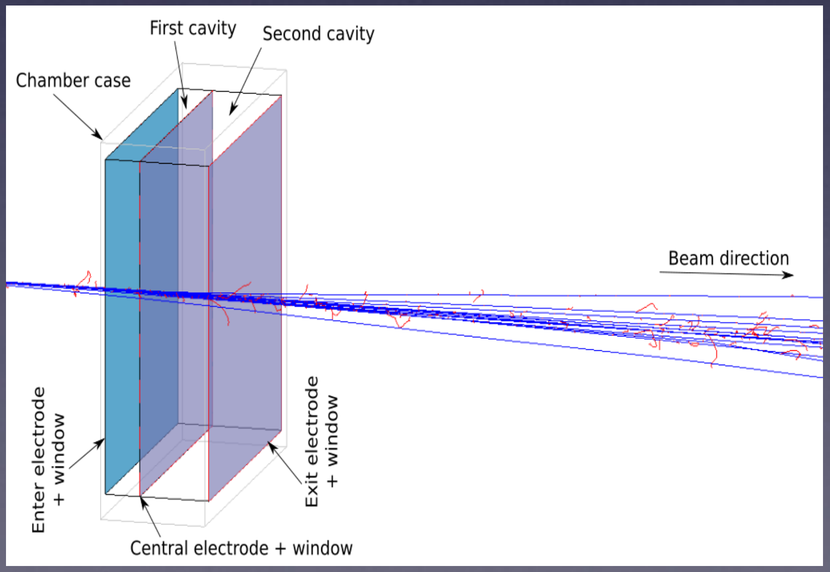
ELIMED Monte Carlo simulations

Main requirements of the application

- Accurately simulate the particle source using PIC
- Implement magnetic and electric fields described by maps
- Provide a graphical user interface to easily modify geometry
- Provide tools to easily retrieve output information on specific virtual planes
  - Energy spectrum, emittance, fluence, dose
  - The secondary radiation produced along the beam line



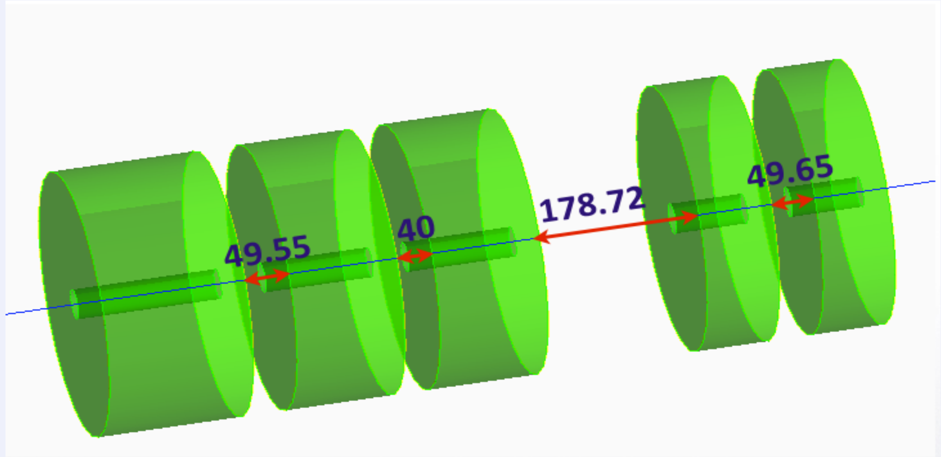
ESS



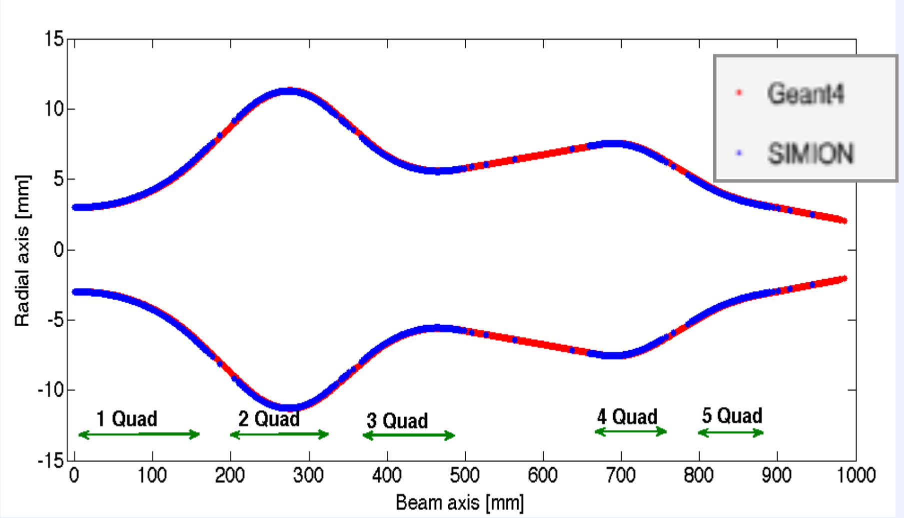
Multigap chambers

ELIMED Monte Carlo simulations

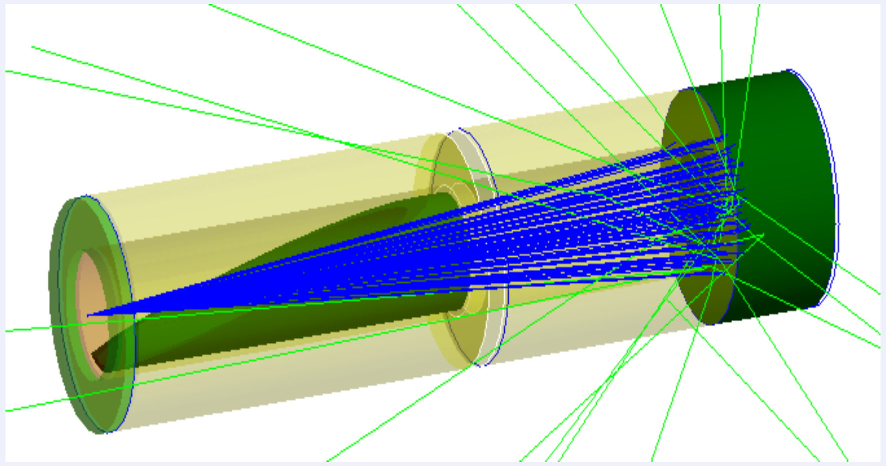
PMQ



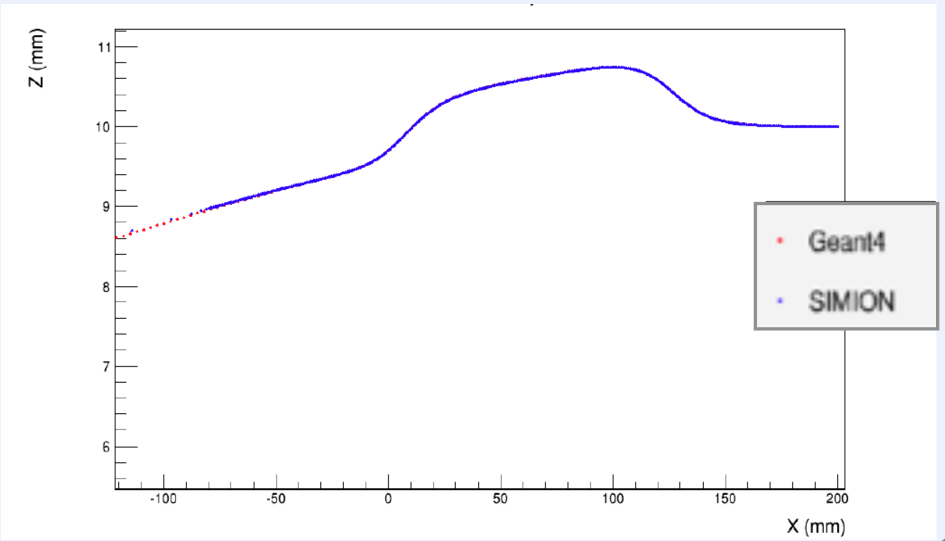
Tracks in ***magnetic fields***



Faraday cup

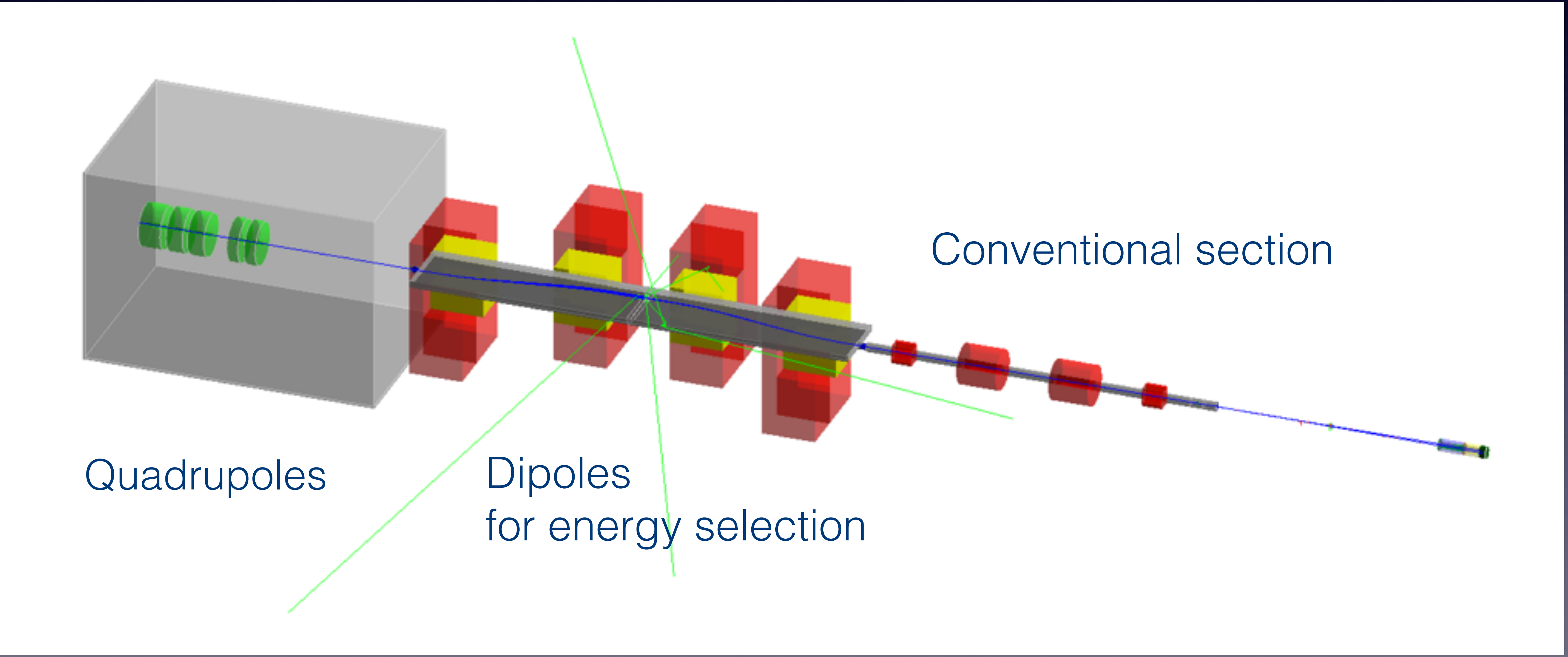


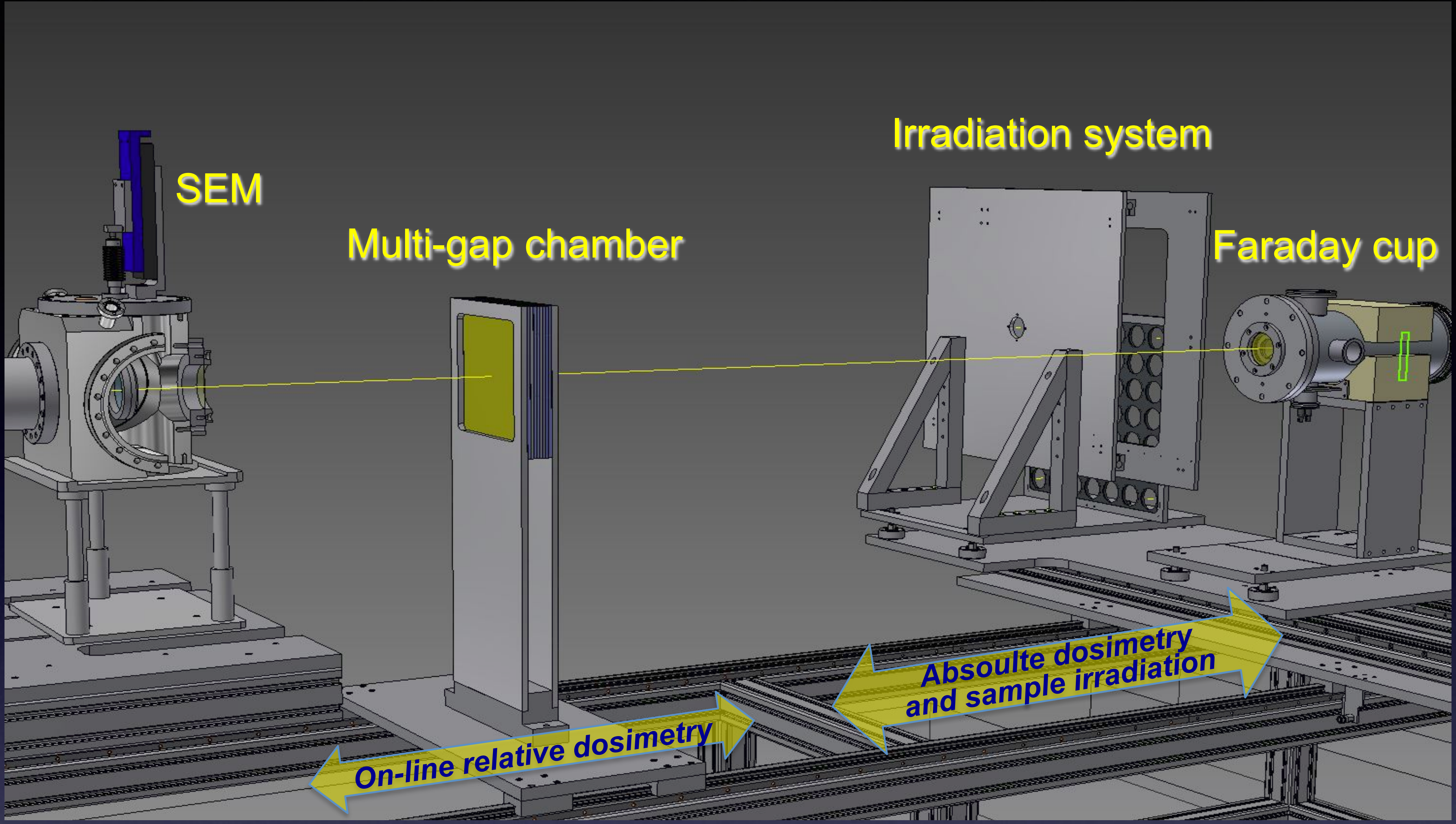
Tracks in ***electric fields***



ELIMED Monte Carlo simulations

The complete simulation with Geant4





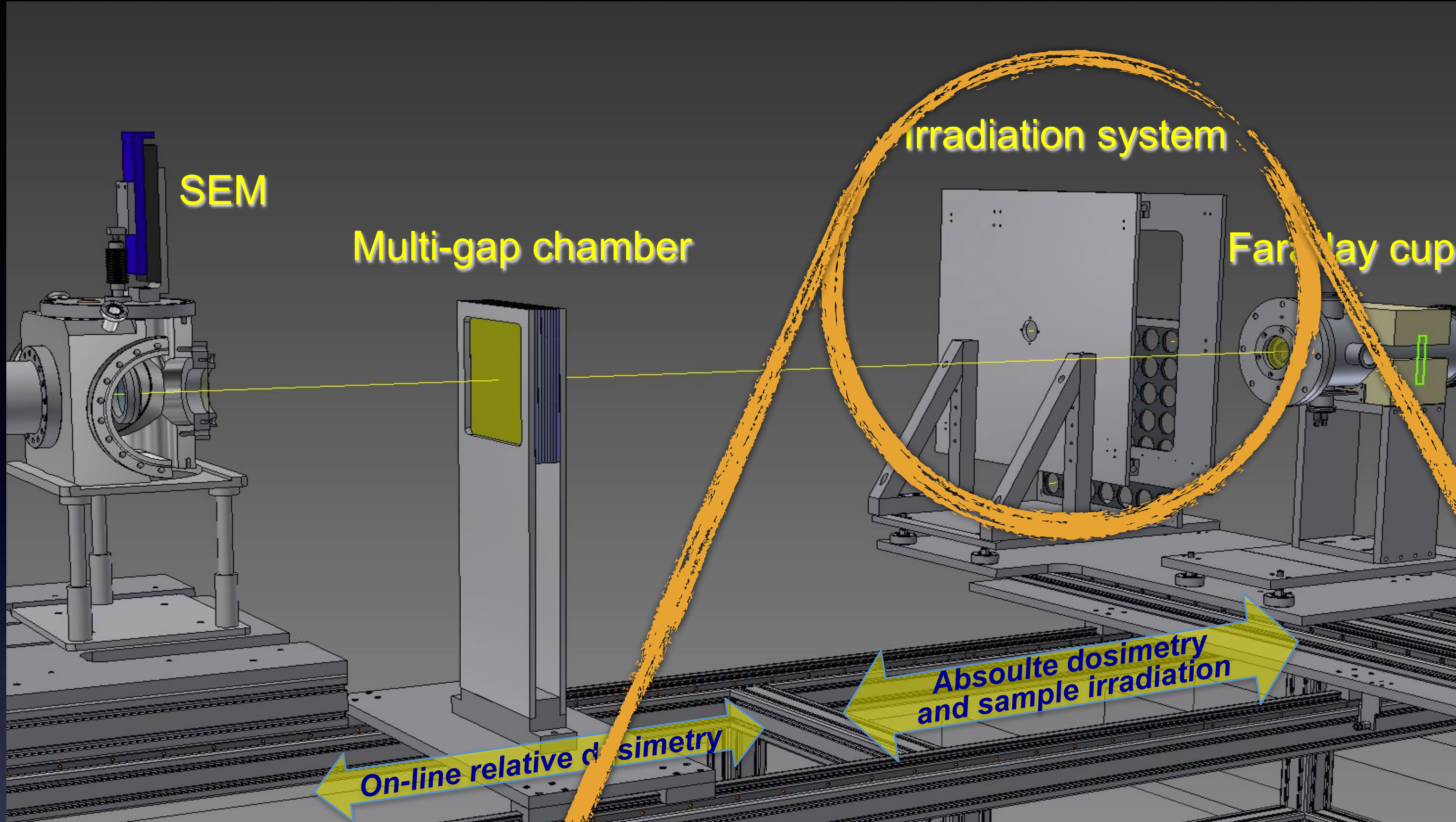
Radiobiology

Cultural heritage

Radiation damage

Proton imaging

Detector and dosimetry tests-bench



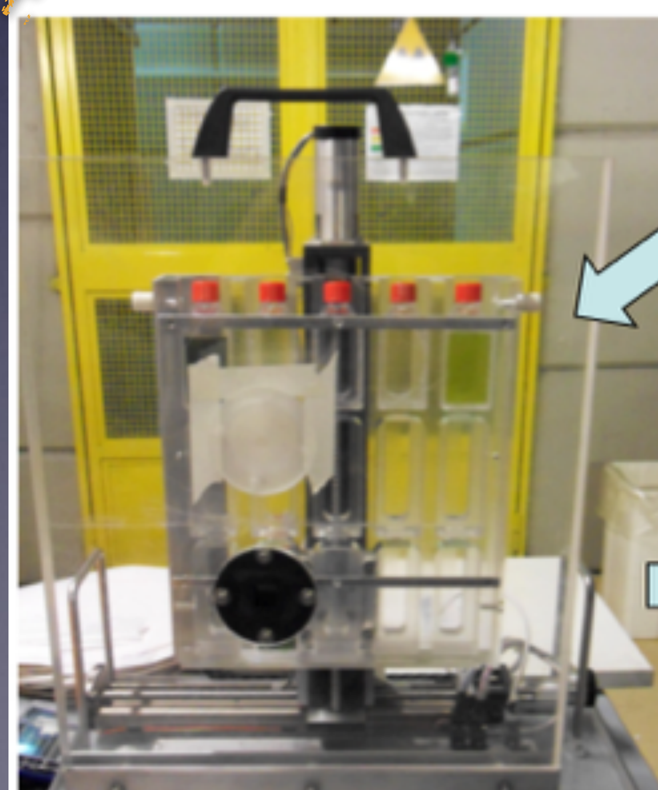
Radiobiology

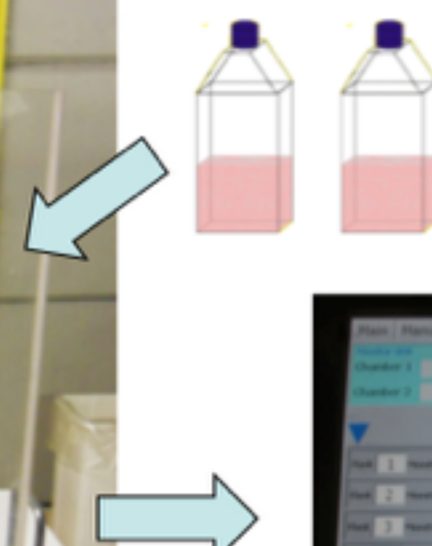
Cultural heritage

Radiation damage

Proton imaging

Detector and dosimetry tests-bench





- Motorized system with 100 um precision
- Remotely controlled
- Interfaced with beam control system
- Real time dose-rate monitoring

GAP Cirrone, pablo.cirrone@lns.infn.it

	Conventional beams	Laser-driven beams
Maximum energy	250 MeV 400 AMeV	😃 (250 😟 ?)
Current	order of nA	😃
Monochromaticity	$\Delta E/E \leq 10^{-2}$	Broad beam: optical solutions, target solutions?, both? 😟
Stability, reproducibility, control, dosimetry	Less that 3%	😱
Radiobiology	Almost known	😟

Conclusions

Hadrontherapy, its advantages, its limited spread

Laser driven ion beams as possible future alternative

ELIMED: a Users' open transport beamline for laser-driven ion beams equipped with dosimetry for multidisciplinary studies will be ready in 2018

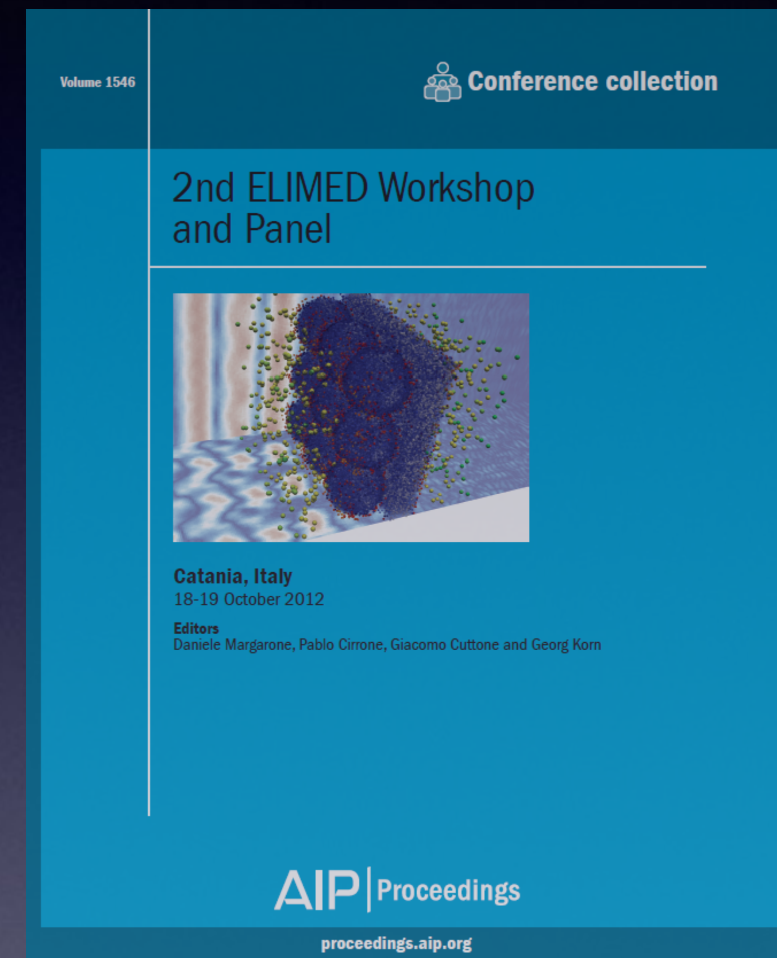
TÉCNICO LISBOA

Queen's University Belfast

SAPIENZA UNIVERSITÀ DI ROMA

Fyzikální ústav AV ČR, v.v.i.

INFN Istituto Nazionale di Fisica Nucleare



THE UNIVERSITY OF CALIFORNIA 1868

HZDR HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

KPSI Kansai Photon Science Institute

AZIENDA OSPEDALIERO-UNIVERSITARIA POLICLINICO-VITTORIO EMANUELE

University of Belgrade
Универзитет у Београду

ITA Istituto Tecnologie Avanzate
Laboratorio Nano Tecnologie

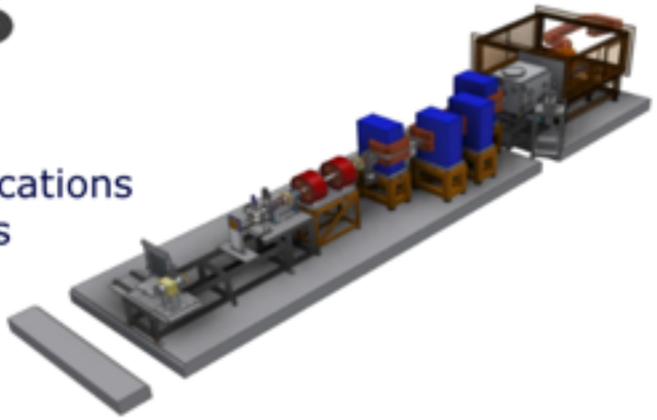
Consiglio Nazionale delle Ricerche
Istituto di Bioimmagini e Fisiologia Molecolare

FONDAZIONE BRUNO KESSLER

ELI MED 2016

The 3rd **ELI MED**ical and Multidisciplinary Applications of Laser-Driven Ion Beams at the ELI Beamlines

7-9 September, 2016
Catania, Italy



SCOPE

The **ELIMED** project aims to demonstrate the validity of new approaches based on laser-driven ion sources for potential future applications in medical and other multidisciplinary fields, including hadrontherapy. In 2018, a User-oriented beam-line, ELIMAIA (ELI Multidisciplinary Applications of laser-Ion Acceleration) equipped with diagnostics and dosimetry end-points will be commissioned at the ELI-Beamlines facility in the Czech Republic with the main goal to perform proof-of-principle experiments, dosimetry measurements and radiation biology investigations at high repetition rate.
The main goal of **the 3rd ELIMED** workshop is to strengthen the collaboration among the international research groups involved in this challenging project and gather new ideas, proposals and additional requirements from a broad community of users coming from different fields (Physics, Biology, Medicine, Chemistry, Material Science, etc.) interested in exploiting the availability of non-conventional (laser-driven) ion beams at the ELI Beamlines.

INTERNATIONAL SCIENTIFIC COMMITTEE

W. Bonvicini, INFN-Trieste (IT)
M. Borghesi, Queen's University (UK)
S.V. Bulanov, JAEA (Japan)
T. Cowan, HZDR (Germany)
G. Cuttone, INFN (IT)
G. Korn, ELI-Beamlines (CZ)
K. Parodi, LMU (Germany)

ORGANIZING COMMITTEE

G.A.P. Cirrone, INFN-LNS (IT)
D. Margarone, ELI-Beamlines (CZ)
F. Nicotra, Consorzio COMETA (IT)
F. Romano, INFN-LNS (IT)
F. Schillaci, INFN-LNS (IT)
V. Scuderi, ELI-Beamlines (CZ)

Fyzikální ústav Akademie věd ČR, v. v. i.
eli beamlines
INFN LNS
COMETA

TOPICS

- Non-conventional Ion Acceleration Techniques
- New generation Ion Acceleration Beam-lines
- Radiation Biology and Medical Applications
- Multidisciplinary Applications
- Targetry, Diagnostics and Dosimetry

IMPORTANT DATES

April 1, 2016
First Announcement
April 18, 2016
Online Registration Opens
June 30, 2016
Early Bird Registration & Abstract Submission

eli med beamlines

LOCATION

Laboratori Nazionali del Sud
Via Santa Sofia 62
95123 CATANIA
ITALY

http://agenda.infn.it/event/3rdElimedWorkshop

III ELI 2016 MED

The 3rd **ELI MED**ical and Multidisciplinary Applications of Laser-Driven Ion Beams at the ELI Beamlines

SCOPE

The **ELIMED** project aims to demonstrate the validity of new approaches based on laser-driven ion sources for potential future applications in medical and other multidisciplinary fields, including hadrontherapy. In 2018, a User-oriented beam-line, ELIMAIA (ELI Multidisciplinary Applications of laser-Ion Acceleration) equipped with diagnostics and dosimetry end-points will be commissioned at the ELI-Beamlines facility in the Czech Republic with the main goal to perform proof-of-principle experiments, dosimetry measurements and radiation biology investigations at high repetition rate. The main goal of **the 3rd ELIMED** workshop is to strengthen the collaboration among the international research groups involved in this challenging project and gather new ideas, proposals

INFN:

Attili Andrea , Calabretta Luciano, Candiano Giacomo, Cirrone Pablo, Cuttone Giacomo, Giordanengo Simona, Gammino Santo, Giove Dario, Larosa Giuseppina, Leanza Renata, Manna Rosanna, Marchese Valentina, Marchetto Flavio, Milluzzo Giuliana, Pandola Luciano, Petringa Giada, Pipek Jan, Romano Francesco, Sacchi Roberto, Schillaci Francesco, Vignati Anna

ELI-Beamlines:

Georg Korn, Daniele Margarone, Andrey Velyhan, Lorenzo Giuffrida, Scuderi Valentina, Jan Kaufman, Filip Grepl

eli beamlines

INFN LNS

COMETA

eli beamlines

LOCATION
Laboratori Nazionali del Sud
Via Santa Sofia 62
95123 CATANIA
ITALY

http://agenda.infn.it/event/3rdElimedWorkshop

III ELI 2016 MED

The 3rd **ELI MED**ical and Multidisciplinary Applications of Laser-Driven Ion Beams at the ELI Beamlines

SCOPE

The **ELIMED** project aims to demonstrate the validity of new approaches based on laser-driven ion sources for potential future applications in medical and other multidisciplinary fields, including hadrontherapy. In 2018, a User-oriented beam-line, ELIMAIA (ELI Multidisciplinary Applications of laser-Ion Acceleration) equipped with diagnostics and dosimetry end-points will be commissioned at the ELI-Beamlines facility in the Czech Republic with the main goal to perform proof-of-principle experiments, dosimetry measurements and radiation biology investigations at high repetition rate. The main goal of **the 3rd ELIMED** workshop is to strengthen the collaboration among the international research groups involved in this challenging project and gather new ideas, proposals

INFN:

Attili Andrea , Calabretta Luciano, Candiano Giacomo, Cirrone Pablo, Cuttone Giacomo, Giordanengo Simona, Gammino Santo, Giove Dario, Larosa Giuseppina, Leanza Renata, Manna Rosanna, Marchese Valentina, Marchetto Flavio, Milluzzo Giuliana, Pandola Luciano, Petringa Giada, Pipek Jan, Romano Francesco, Sacchi Roberto, Schillaci Francesco, Vignati Anna

ELI-Beamlines:

Georg Korn, Daniele Margarone, Andrey Velyhan, Lorenzo Giuffrida, Scuderi Valentina, Jan Kaufman, Filip Grepl

Thank you

LOCATION
Laboratori Nazionali del Sud
Via Santa Sofia 62
95123 CATANIA
ITALY

http://agenda.infn.it/event/3rdElimedWorkshop

Thank you