A brief presentation of The TERA Foundation

David Watts

on behalf of Prof. Ugo Amaldi and all my colleagues at TERA

TERA Overview

Direction: Prof. Ugo Amaldi

<u>AQUA</u>
(Advanced QUAlity Assurance)

- supervised by Prof. F. Sauli
- 3 students
- 1 post-doc

- involved in several European projects PARTNER, ENVISION, and INTERVISION

<u>Cyclinac Group</u>

- 4 students
- 2 engineers

- Main projects are Caboto, TULIP, Idra...
- Also involved in European projects... PARTNER

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TERA's administration is in Novara, Italy, while both groups carry out their research on the CERN Meyrin site (building 182).

Cyclinac Group

The hadrontherapy community requires accelerating structures that are compact, have a high reliabilty, and appropriate beam parameters:

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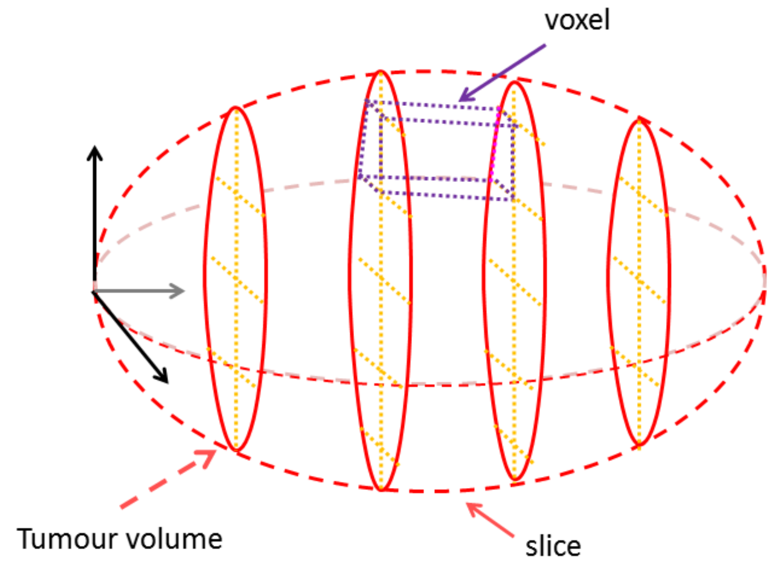
The hadrontherapy community requires accelerating structures that are compact, have a high reliabilty, and appropriate beam parameters:

- active energy modulation

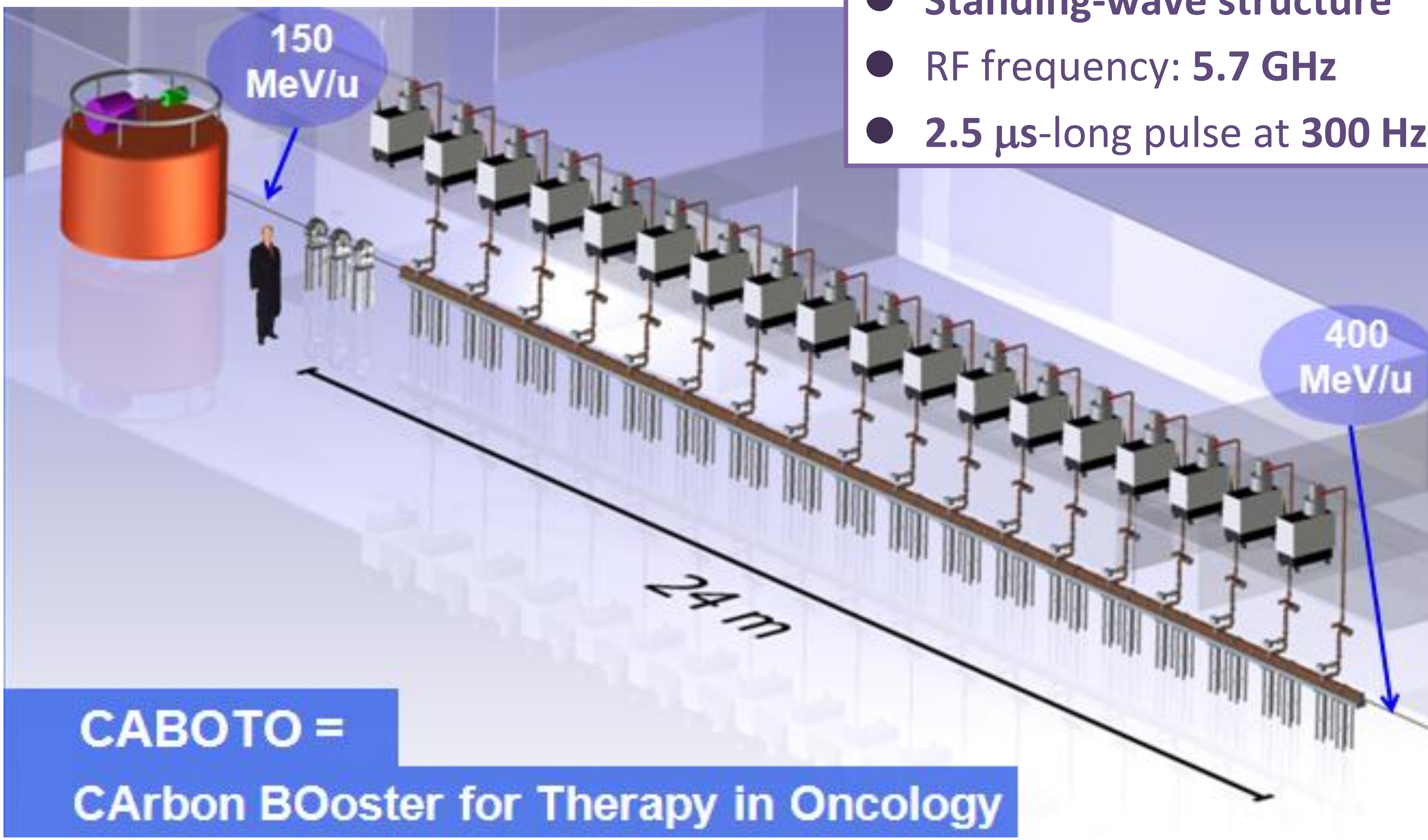
- high repetition rate



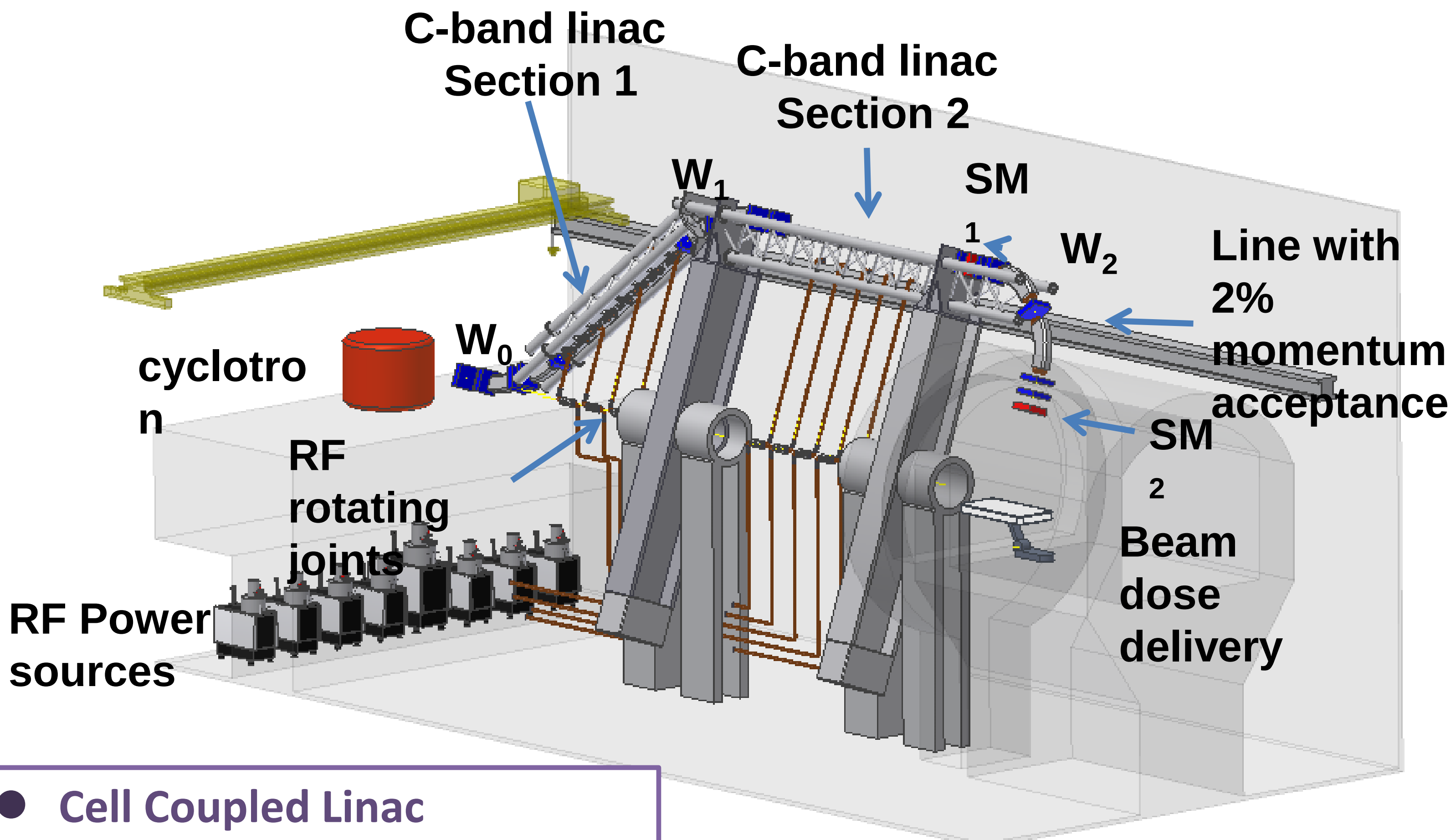
3D spot scanning beam delivery with multipainting

Cyclinac: cyclotron + high freq linac

- **Cell Coupled Linac**
- **Standing-wave structure**
- RF frequency: **5.7 GHz**
- **2.5 μs**-long pulse at **300 Hz**



TULIP: TUrning LInac for Protontherapy



- **Cell Coupled Linac**
- **Standing-wave structure**
- RF frequency: **5.7 GHz**
- **2.5 μs**-long pulse at **100 Hz**

Test Cavities

These structures operate at high-gradient and have similar high requirements on reliability as CLIC.

Such structures must be tested...

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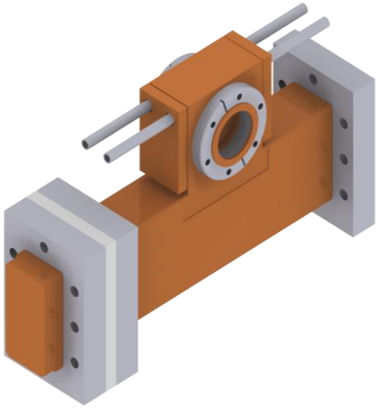
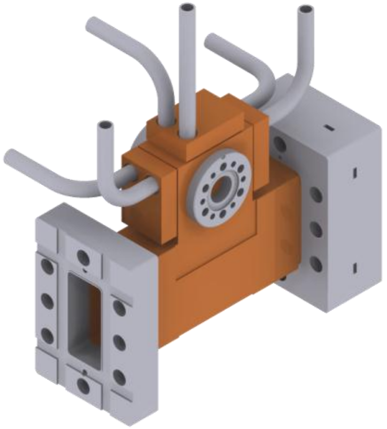


S-band: 3 GHz

- One 3 GHz TERA Single-Cell Cavity → **already** high-power **tested**



C-band: 5.7 GHz

- Three 5.7 GHz TERA Single-Cell Cavities
  - 2 conventional maching and 1 diamond machining

Why do we need Quality Assurance?

The use of protons or ions as a radiotheraputic beam *requires* a higher precision in the correct delivery of the prescibed treatment plan.

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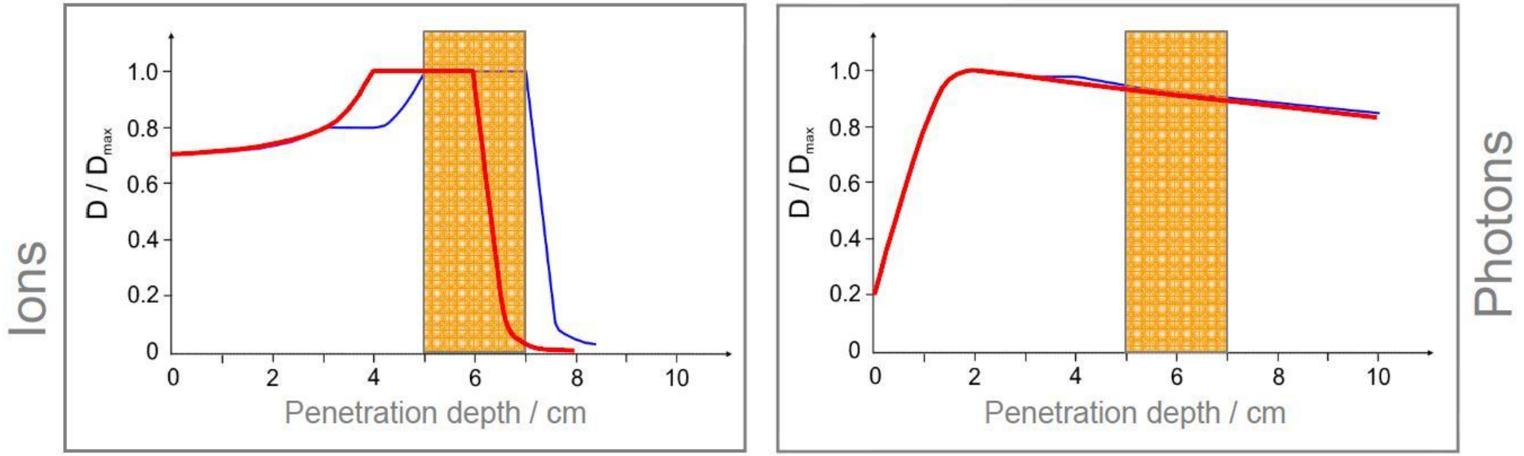

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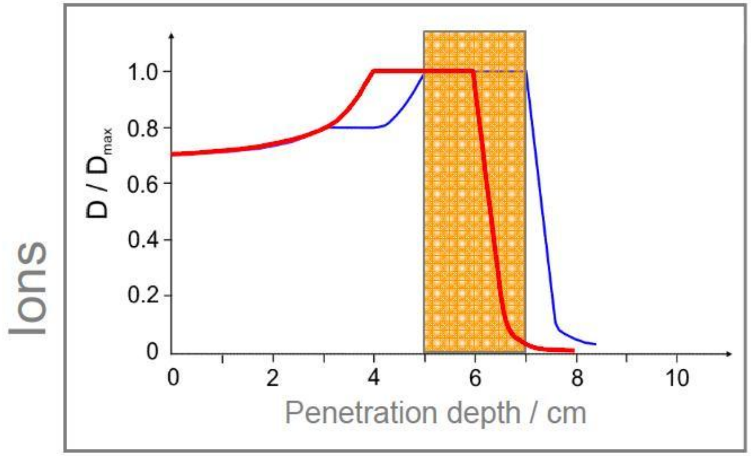
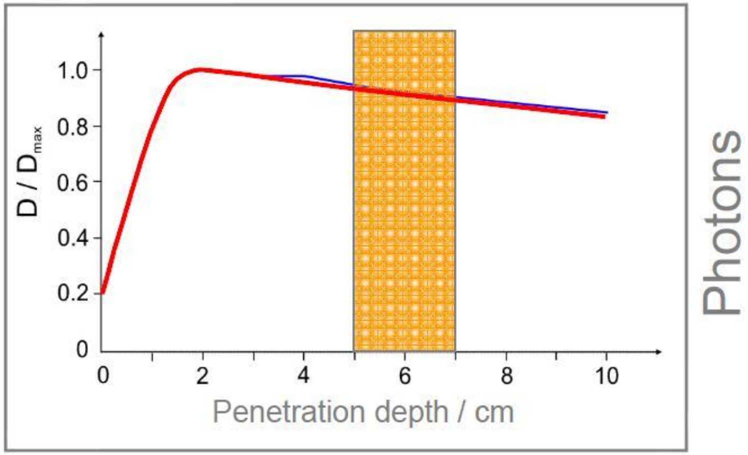




Uncertainties may arise from:

Dose delivery uncertainties

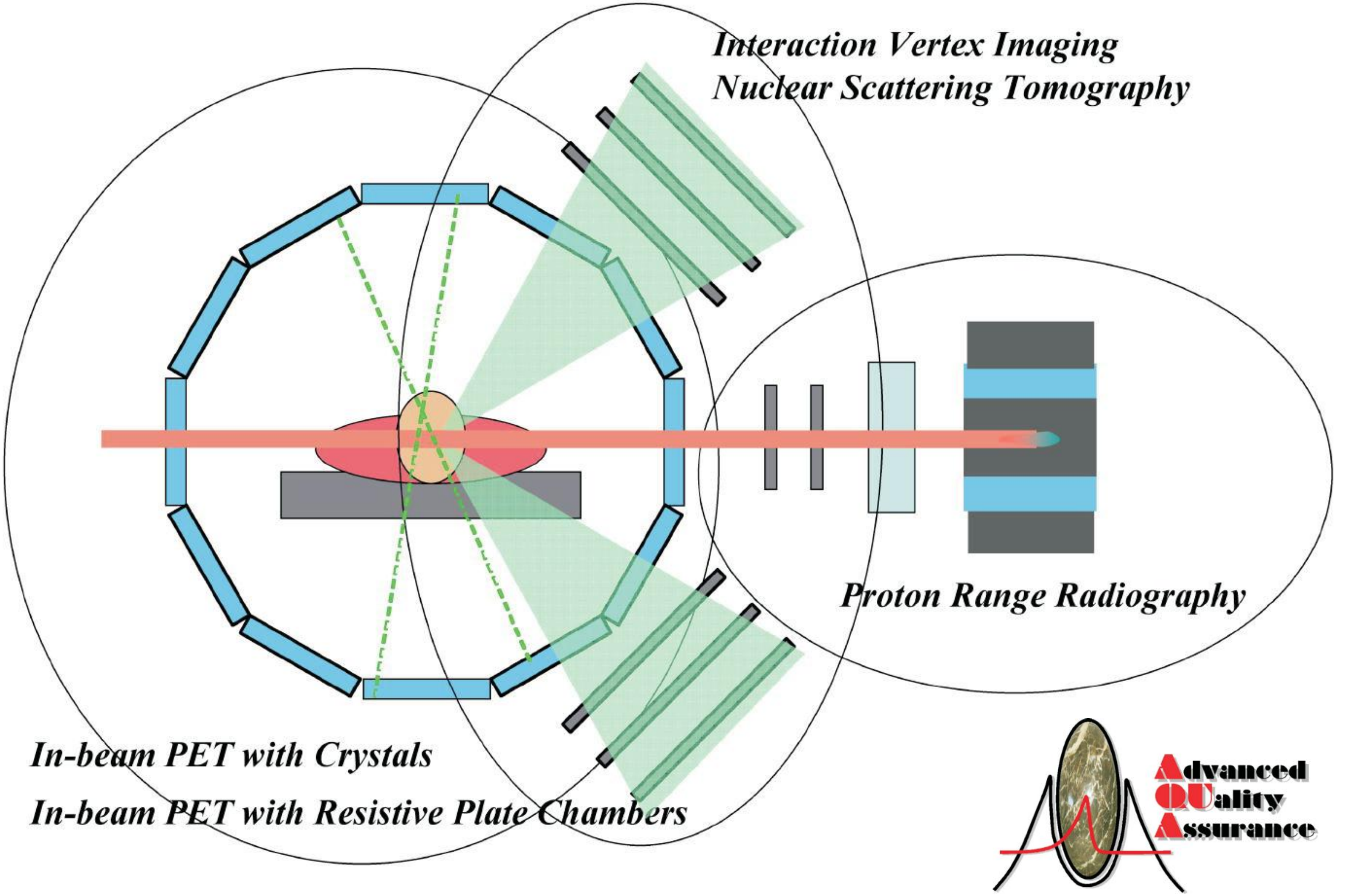
- Delivery system
- Beam modelling
- CT units and range

Spatial uncertainties

- Patient positioning
- Target delineation
- Organ motion
- Patient anatomy, motion, repositioning

The AQUA Overview

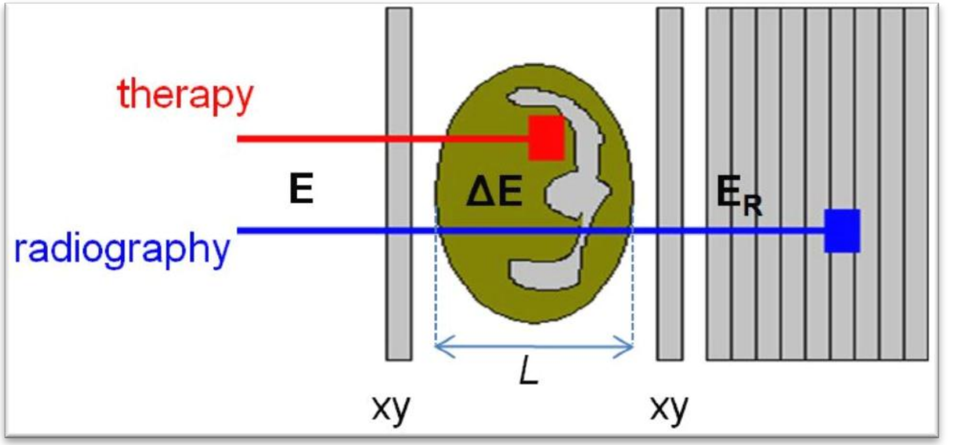
AQUA
ADVANCED QUALITY ASSURANCE



Proton Range Radiography

Principle

- Energy loss of each proton is proportional to the integrated relative electron density of the target



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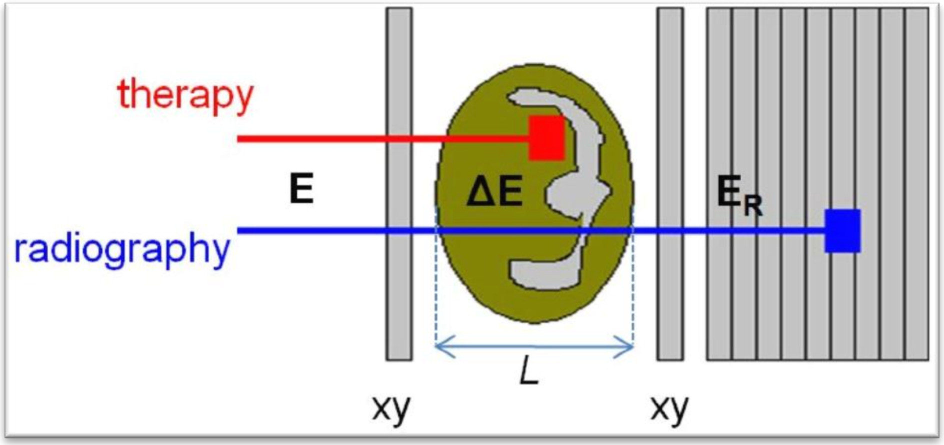
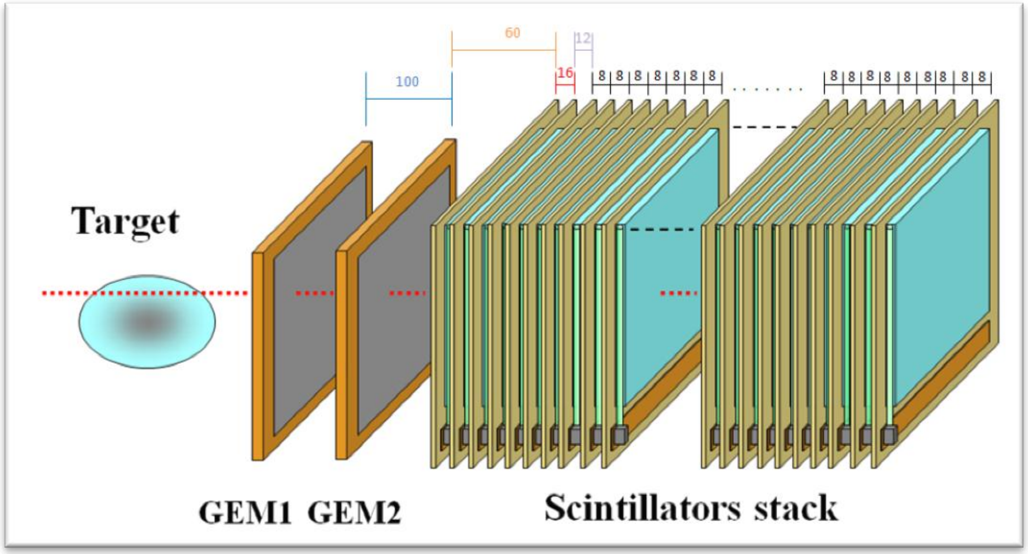


Implementation

- Use a "diagnostic" mono-energetic beam of higher energy and lower intensity
- Measure each proton's position and residual range
- Build the 2D integrated density image: a proton radiograph



Proton Range Radiography

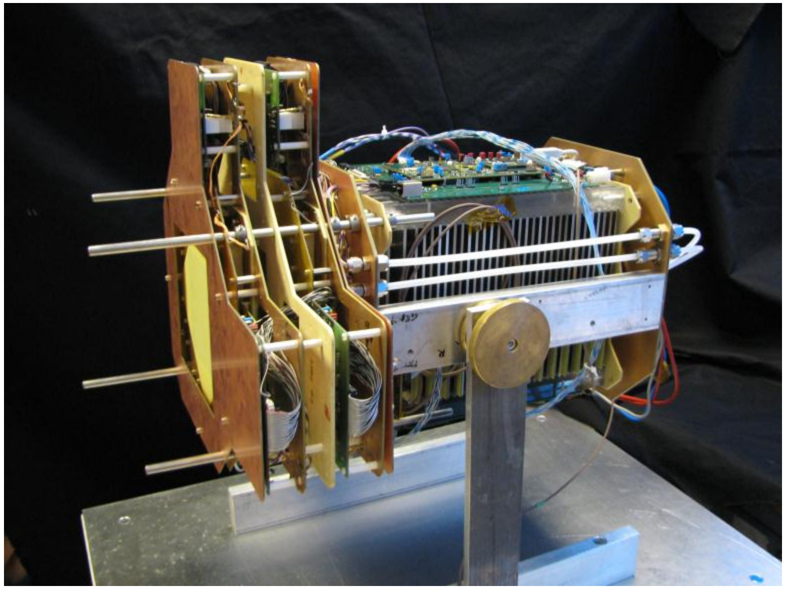
Purposes of 2D PRR

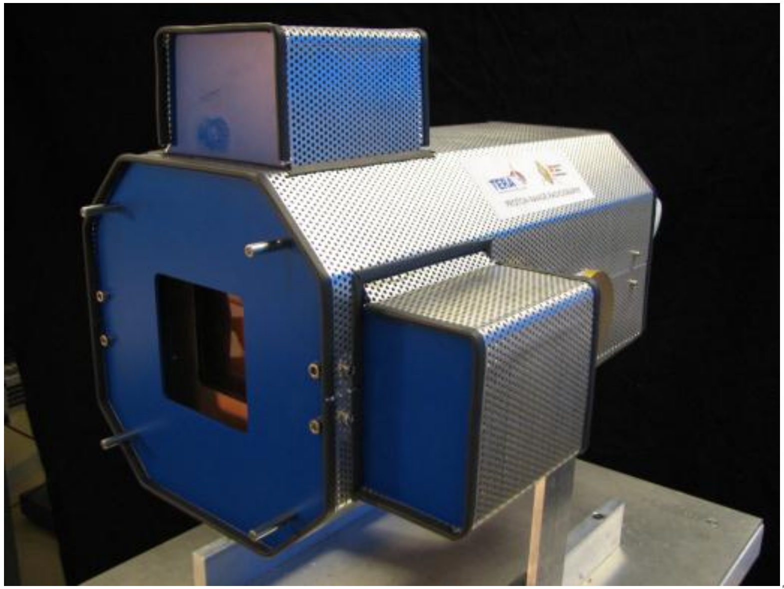
- Optimal patient positioning (low dose radiography)
- Treatment planning verification
- First step towards Proton CT

N. Depauw and J. Seco, Phys. Med. Biol. 56 (2011) 2407-2421

Realization

- First Proton Range Radiography prototype – PRR10 (2010)

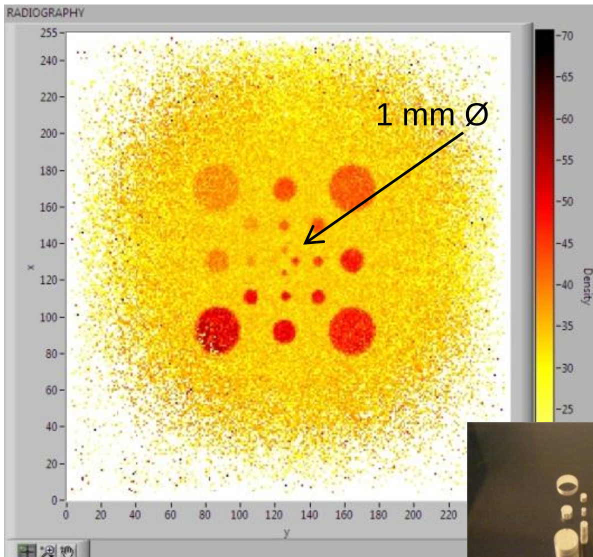




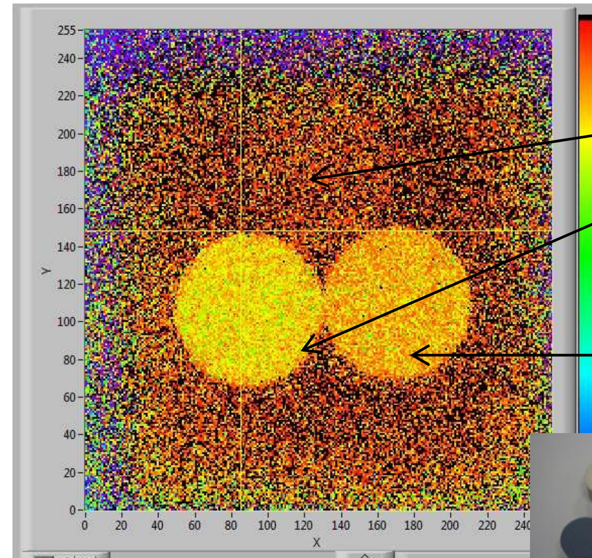
PRR10 Beam Tests

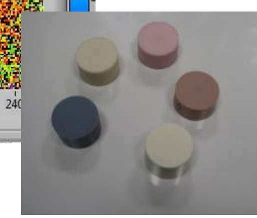
PSI

U. Amaldi et al, Nucl. Instr. and Meth. A629(2011)337



CNAO





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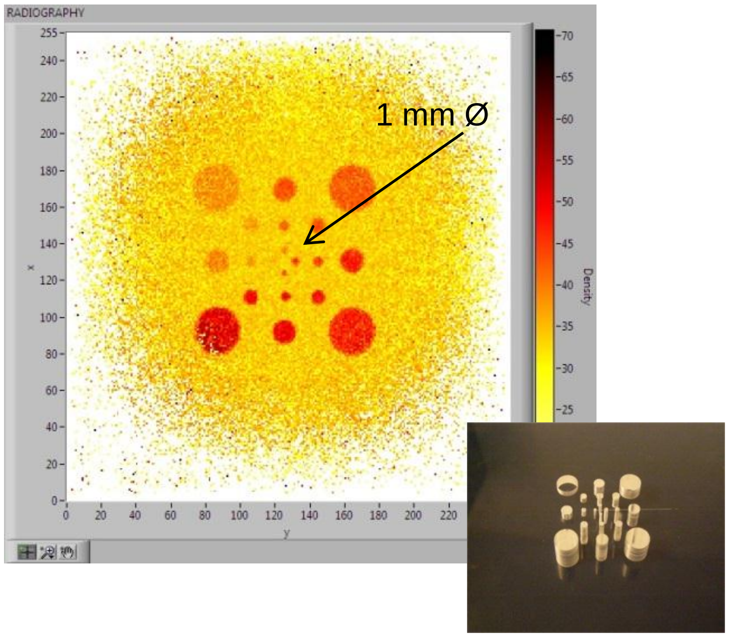

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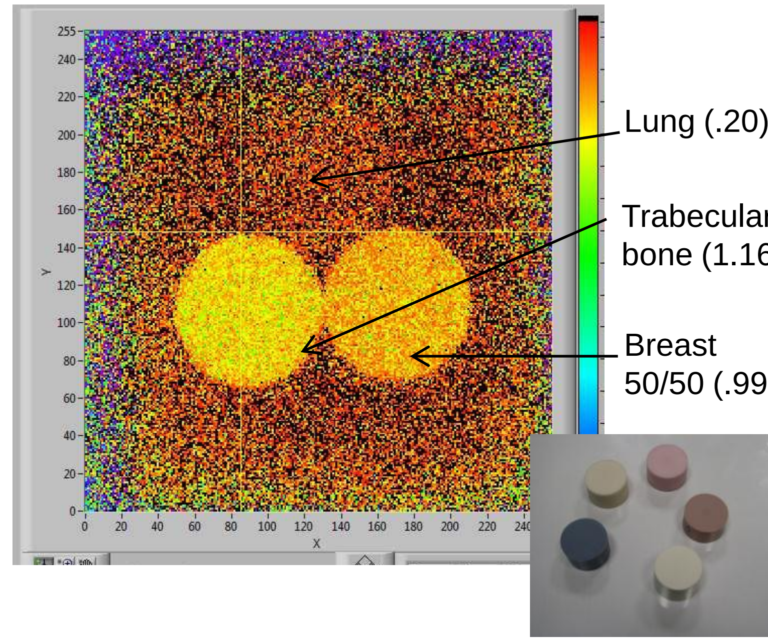

For 1x1 mm^2 pixels and an image size of 30x30 cm^2 (10^5pixels) ~10^7 proton tracks to be recorded (possible in 10 seconds with 1 MHz readout rate)

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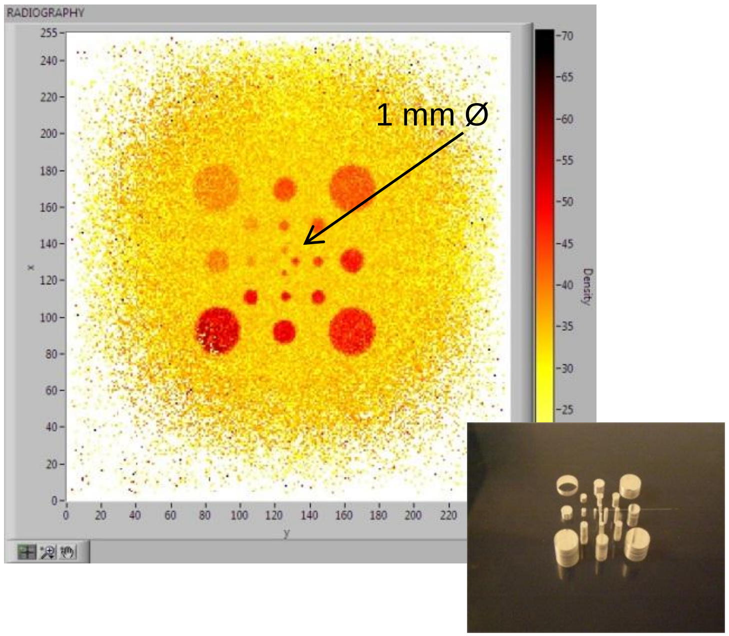

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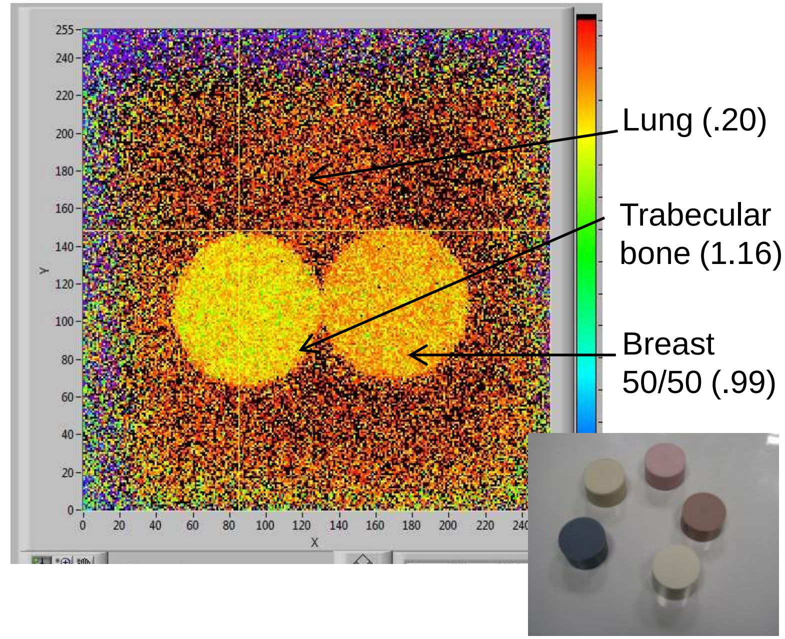

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- Larger area (30x30 cm^2)
- 48 scintillators (~ 15 cm tissue equivalent)
- Faster readout electronics ~ **1 MHz**

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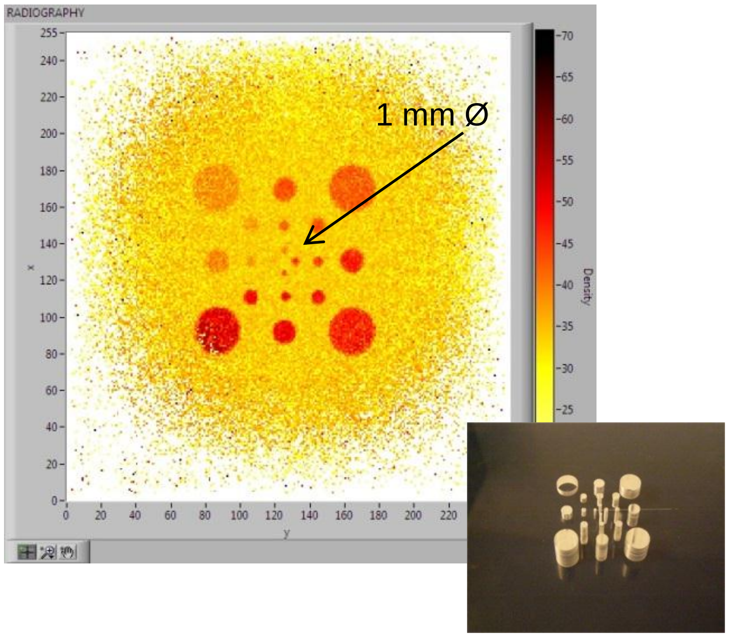

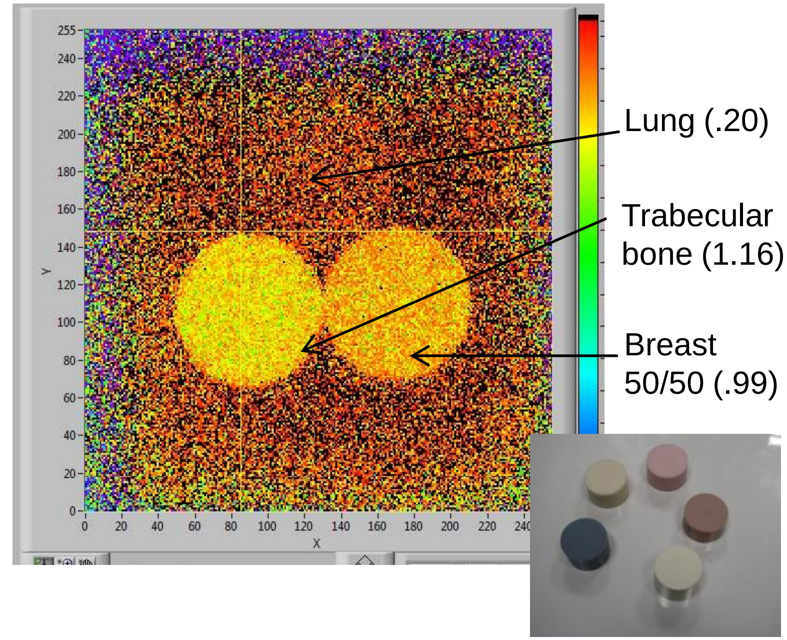

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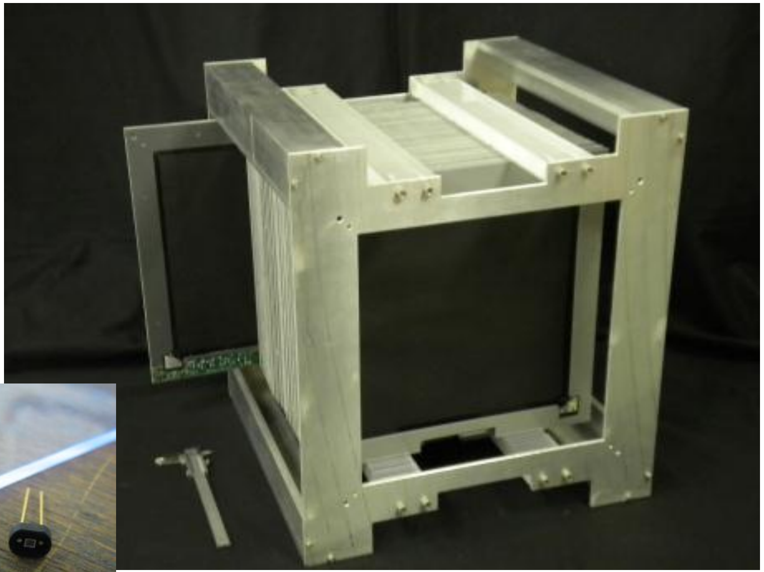
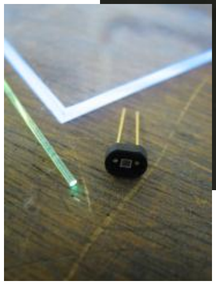
➡ **PRR30** in construction

Under construction: PRR30

Range Finder

- 48 Plastic scintillators 3mm each (15cm water equ)
- WLS fiber to SiPM
- ADC readout triggered by 2 scintillators in coincidence





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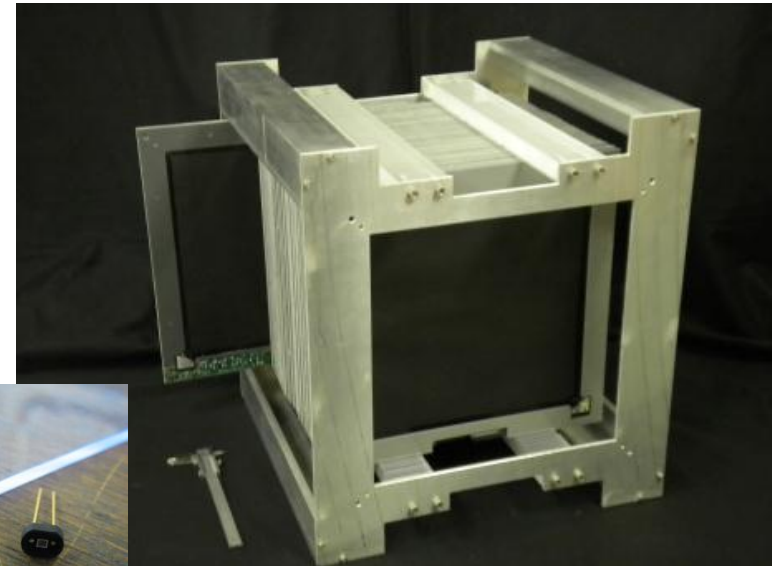
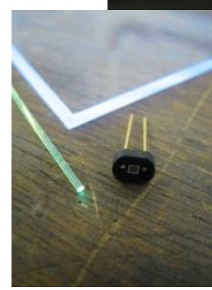
30MeV to 190MeV Residual Energy





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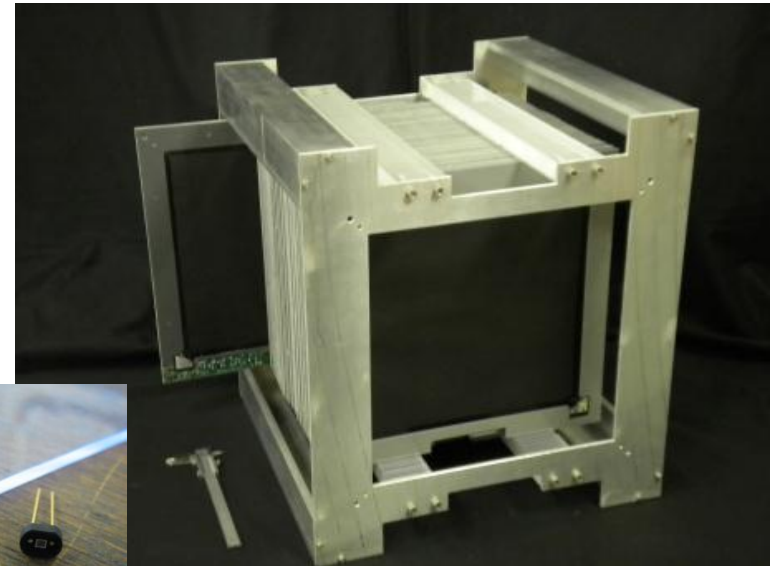
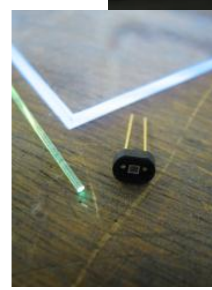
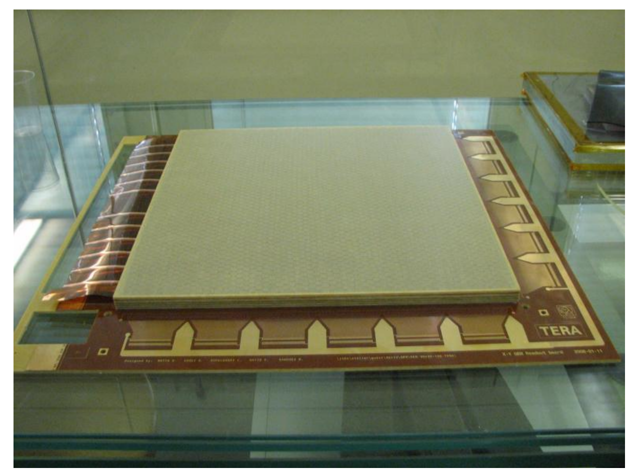




30MeV to 190MeV Residual Energy

Tracker

- Two 30x30cm triple-GEM detectors
- 2D XY strip readout (400um pitch)
- Readout electronics capable of 1M events/sec



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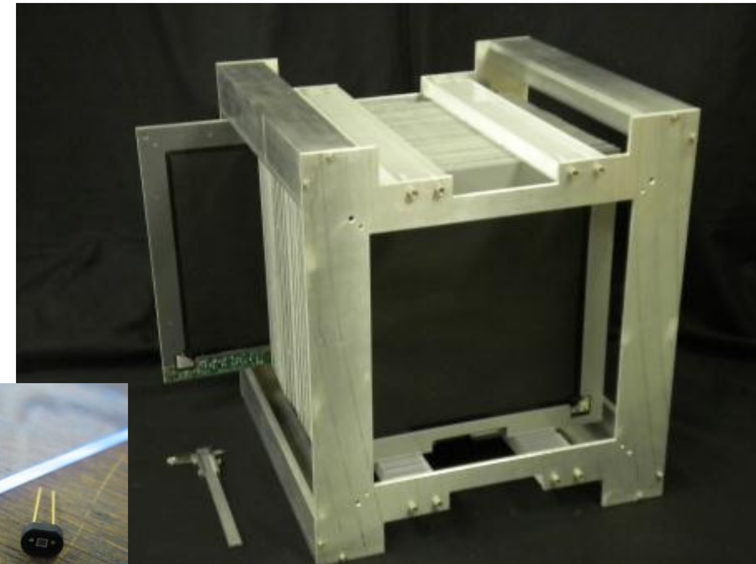

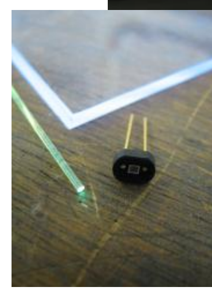

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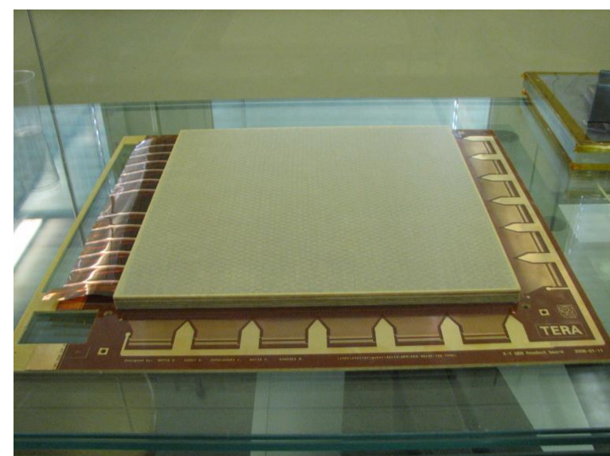
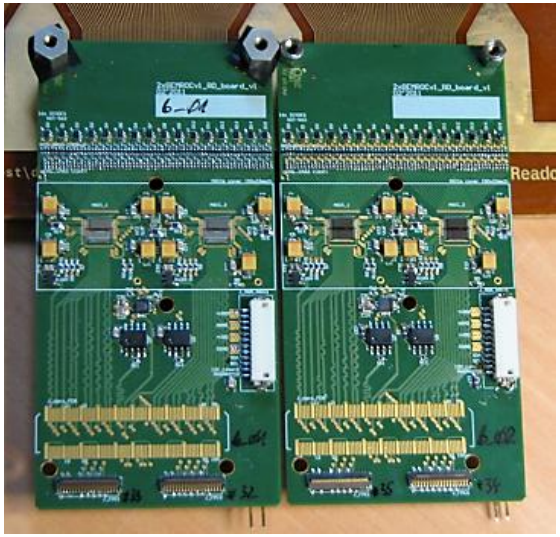


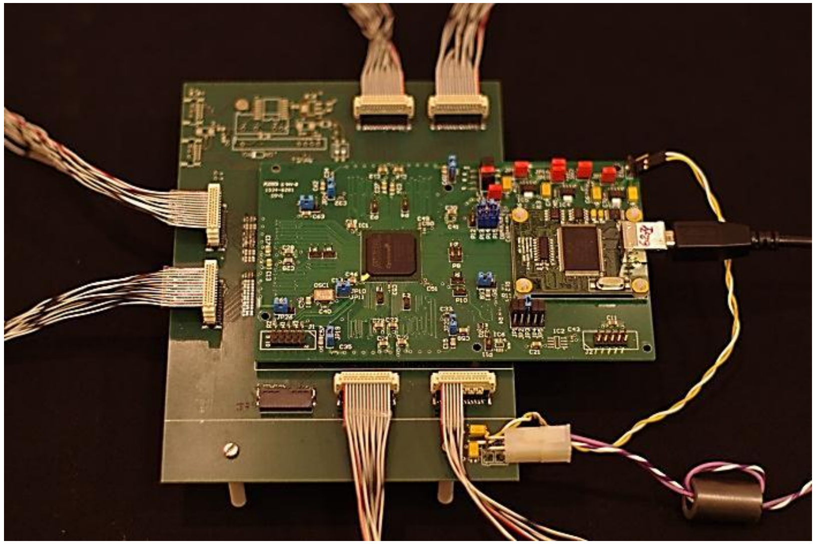
→ New development was needed!

High-speed GEM readout

New developments in GEM readout technology

Main goal: <u>~ 1 MHz DATA THROUGHPUT</u>





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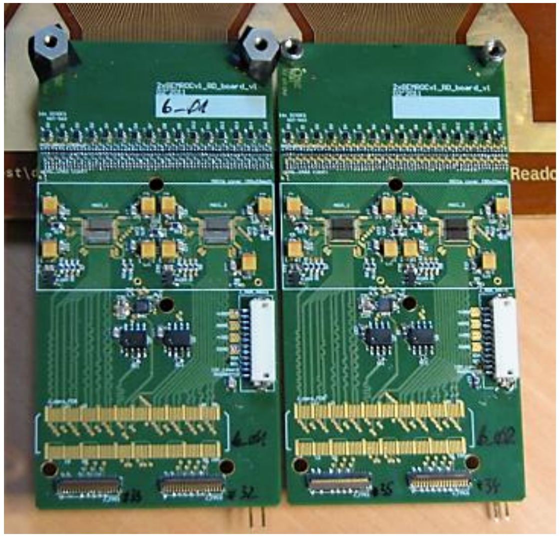

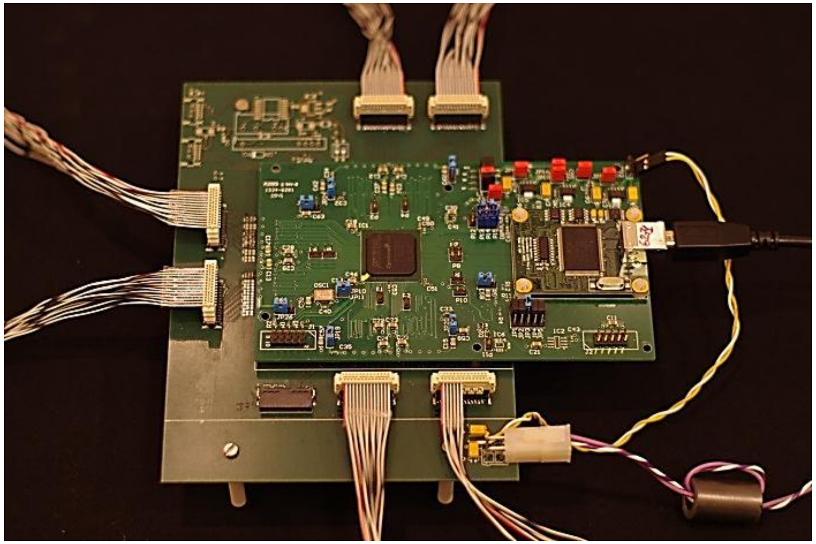

Novel dedicated ASIC for GEM chambers
GEMROC Hybrid Front End board

developed by AGH Cracow University in collaboration with TERA

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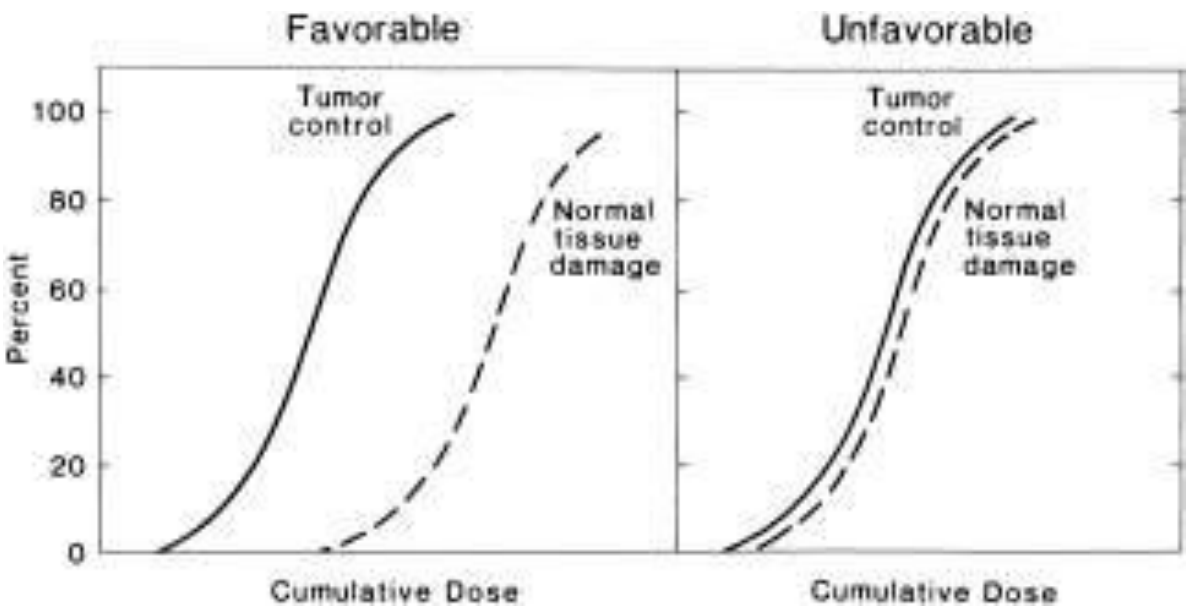
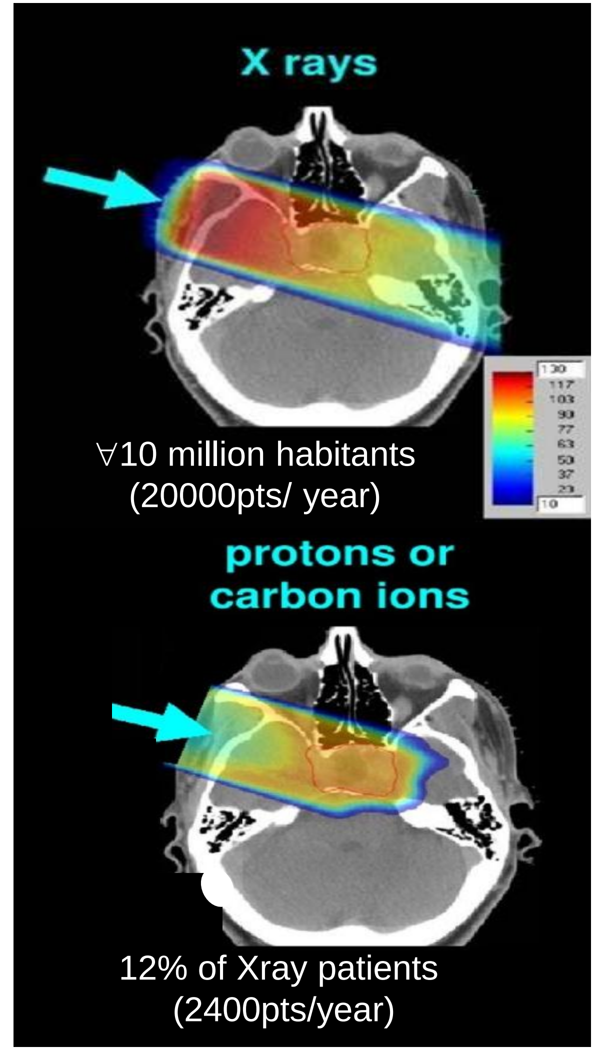
- TERA's main projects are CABOTO, TULIP, PRR10, PRR30, IVI…
- The TERA Foundation would benefit highly from a medical beam facility located at CERN

Backup Slides

Why Hadrontherapy?





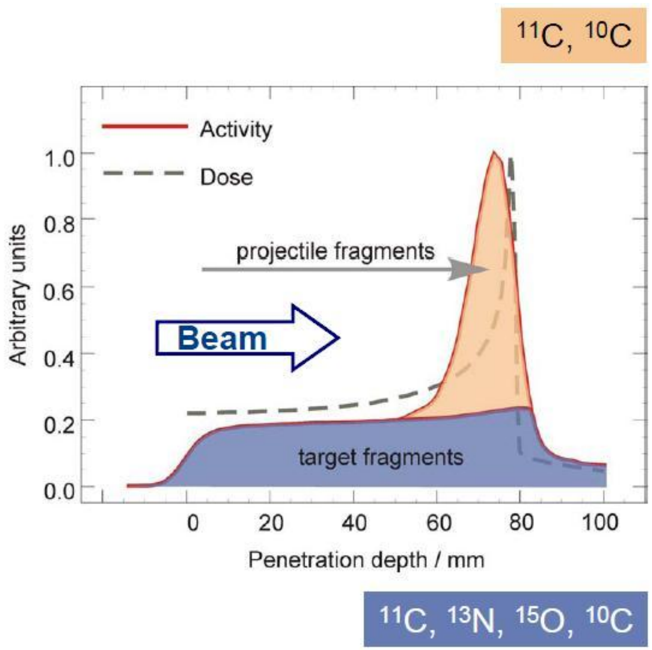
Protons and ions deposit the bulk of their energy at the end of their range in the Bragg peak.

-better conformity of dose distribution
-Higher RBE at tumour site
-lower dose to healthy tissues both on entry and exit channels

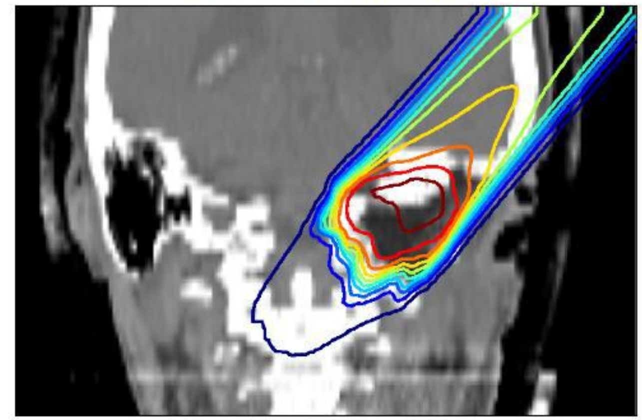
Hoffmann, PPARC 2005

In-beam PET

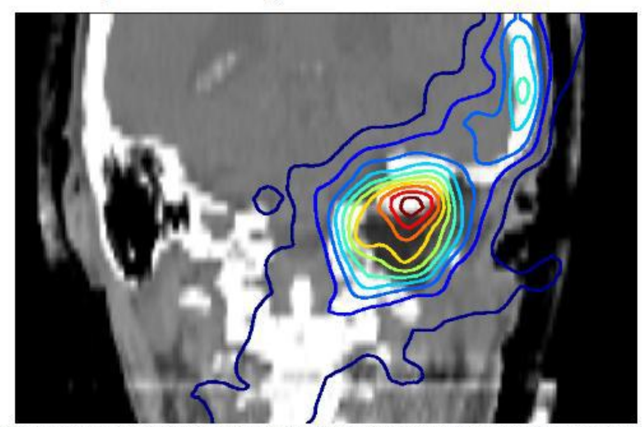
Proton and ion therapy results in B+ activation of tissues which can be measured by a PET detector and used to verify the treatment plan immediately following irradiation



Dose distribution

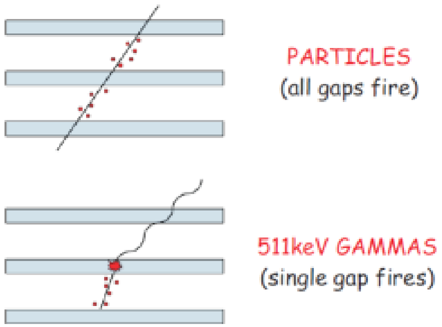


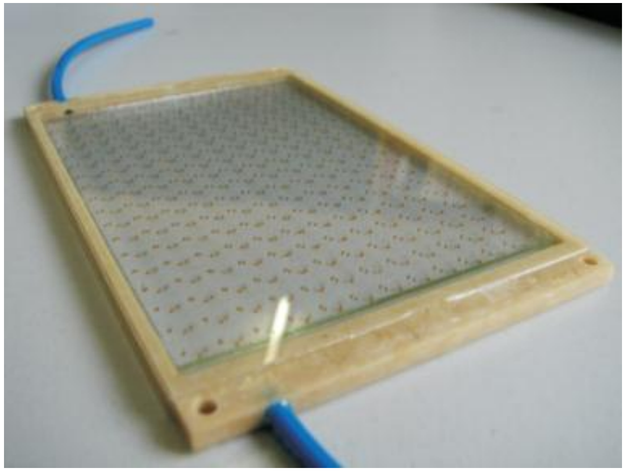
β^+-activity measurement

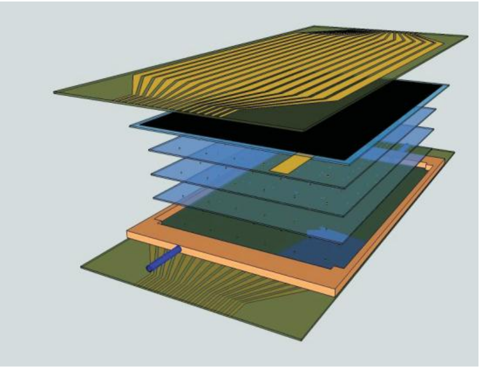


In-beam PET Detectors

In-beam PET using mRPC







In-beam PET using crystals