Imaging dosimetrico per adroterapia

Project Coordinator:

Vincenzo Patera (associate professor)

Research participants (only associate to CF):

Adalberto Sciubba (full professor)

Alessio Sarti (researcher)

Work Institution:

Universita' di Roma "Sapienza", SBAI Department

Collaborations:

- ✓ INFN (Istituto Nazionale di Fisica Nucleare), LNF, Mi, Rm1, To
- ✓ CNAO (Centro Nazionale di Adroterapia Oncologica) , Pavia
- ✓ Universita' di Pisa, Politecnico di Bari
- ✓ GSI Helmholtzzentrum Fur Schwerionenforschung GmbH (Darmstadt)

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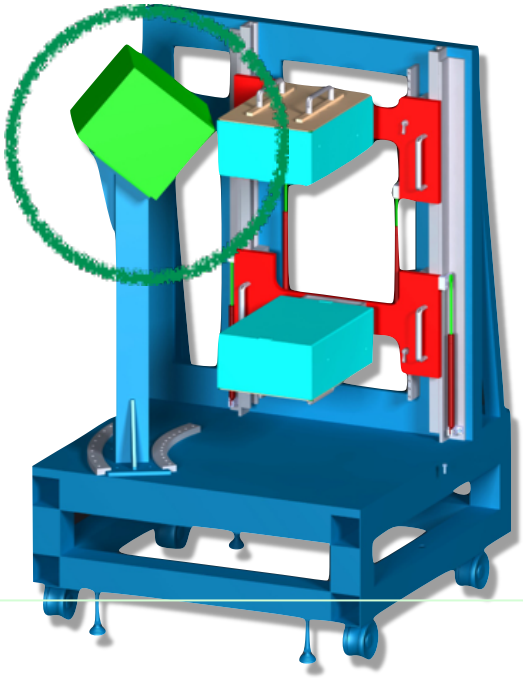
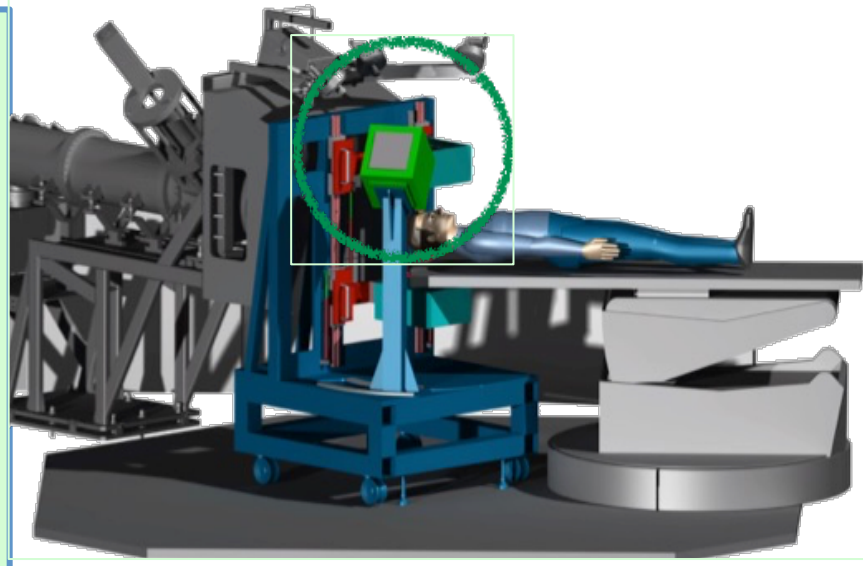
aim of the project

- Developing a range monitor capable of an on-line feedback to the beam control during Charge Particle Therapy treatments.
- The device exploit the PET γ emitted by proton beams or charged particles emitted by ^{12}C, ^{16}O, ^{4}He ion beams.

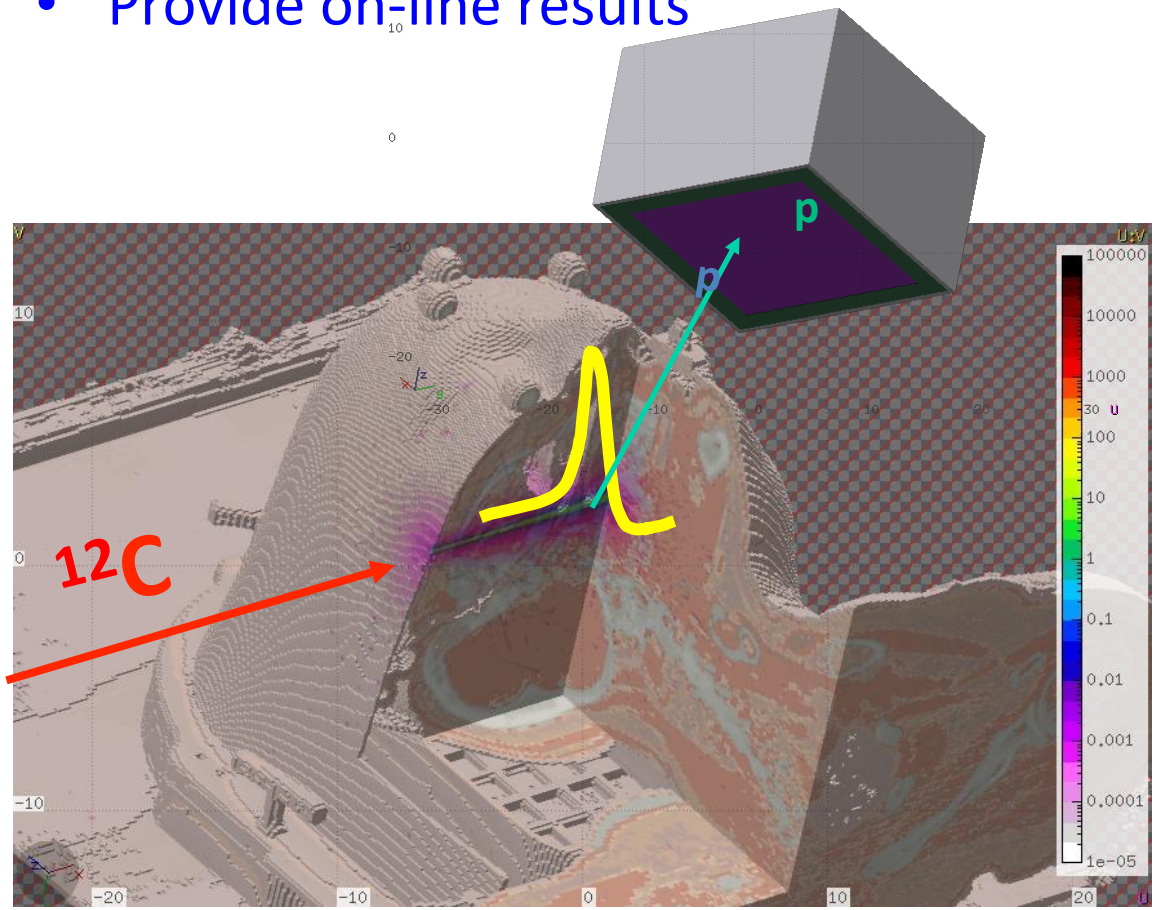


The PET technique is problematic with carbon beam due to reduced signal/noise ratio.
The Centro Fermi is in charge of the development of a dose profiler that exploit the charged secondary produced by the beam interactions in the patient tissue



DP main features

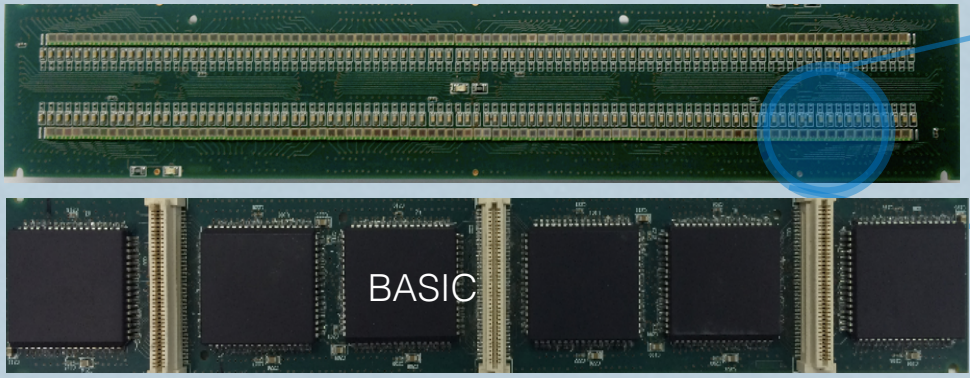
- High tracking efficency and acceptance
- Robustness and reliability (clinical environment!!!)
- Provide on-line results

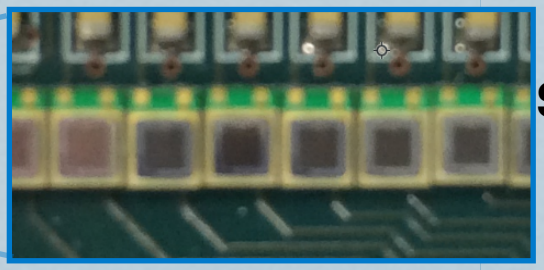


- **Tracker**: 6 xy planes with 2 cm spacing. Each plane is made of 2 stereo layers of 192 0.5x0.5 mm^2 square scintillating fibres.
- The fibers are read-out by Hamamatsu 1mm^2 SiPM S12571-050P
- **Absorber**: 2 planes made of segmented plastic scintillator 6 mm thick for dE/dx measurements and trigger

DP electronics:

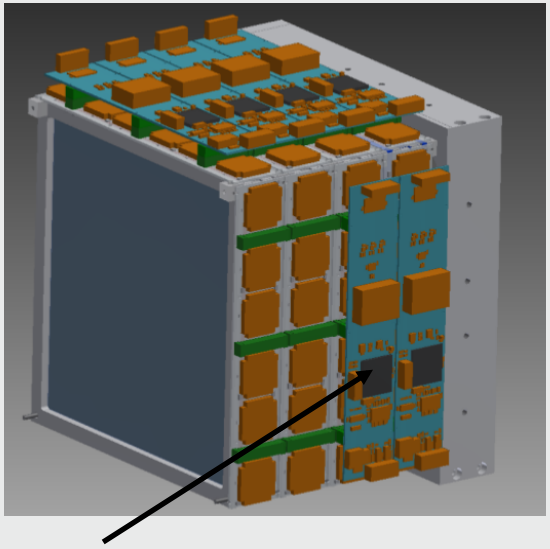
3200 overall electronic channels





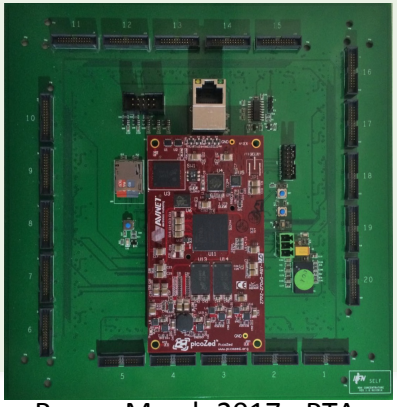
32 SiPM feed a 32-channel ASIC named BASIC32_ADC

The read-out system has been built and tested during 2016 in cooperation with the LNF-INFN electronic workshop



16 FPGA provides the read-out of all ASIC

A Concentrator collects the FPGA data and provides the communication via ethernet with a PC



1 Gigabit Ethernet link

DAQ PC

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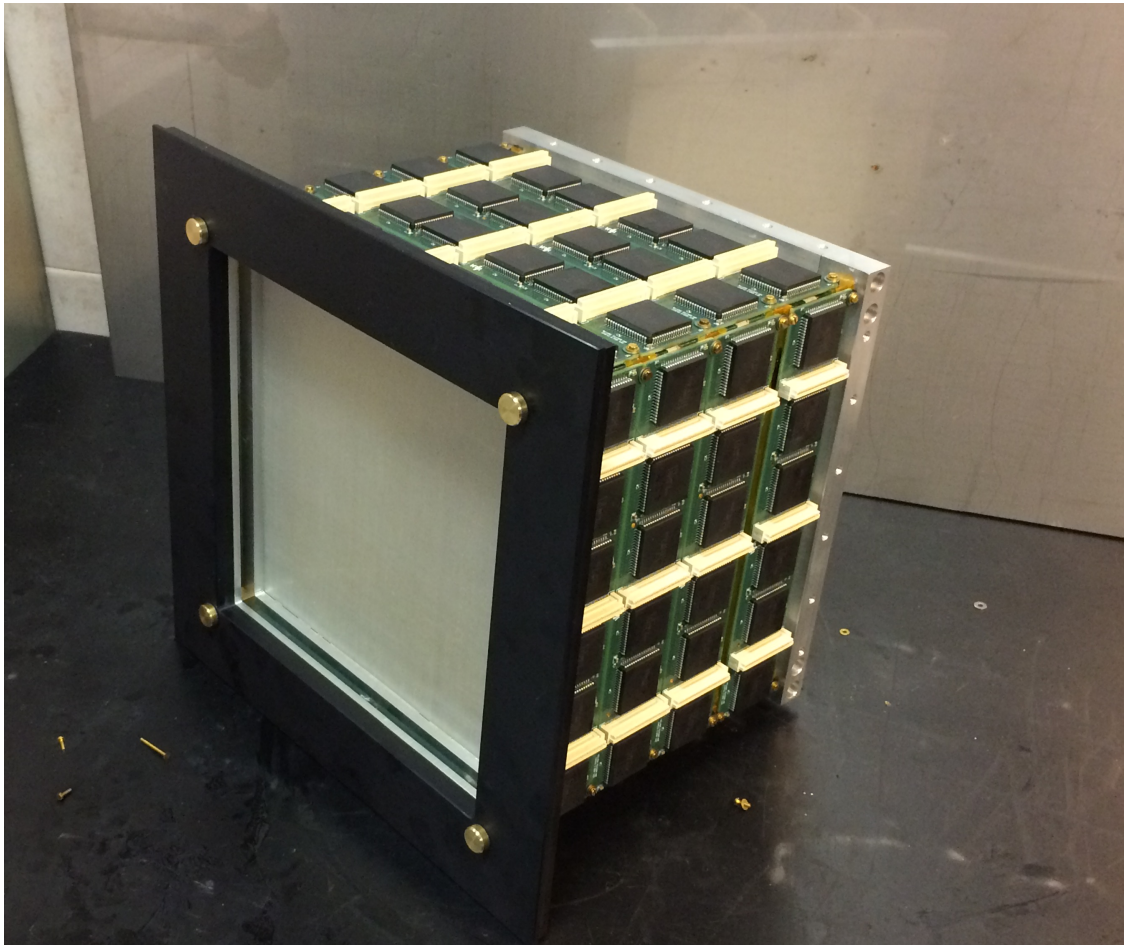
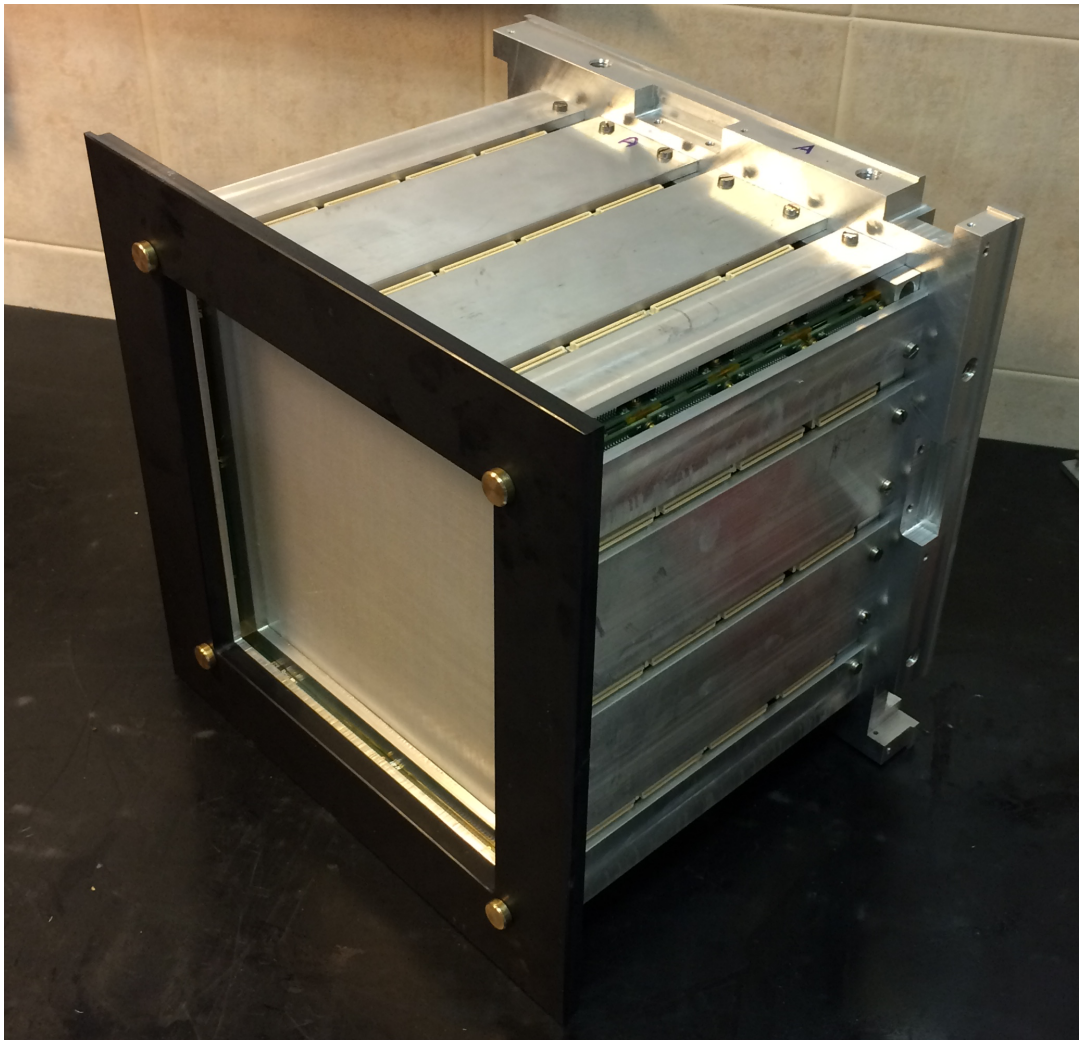
Dose Profiler: hardware assembling



- SiPM board coupled to fibres with optical grease

Dose Profiler: hardware assembling



- SiPM board coupled to fibres with optical grease
- Aluminum strips for heat transferring

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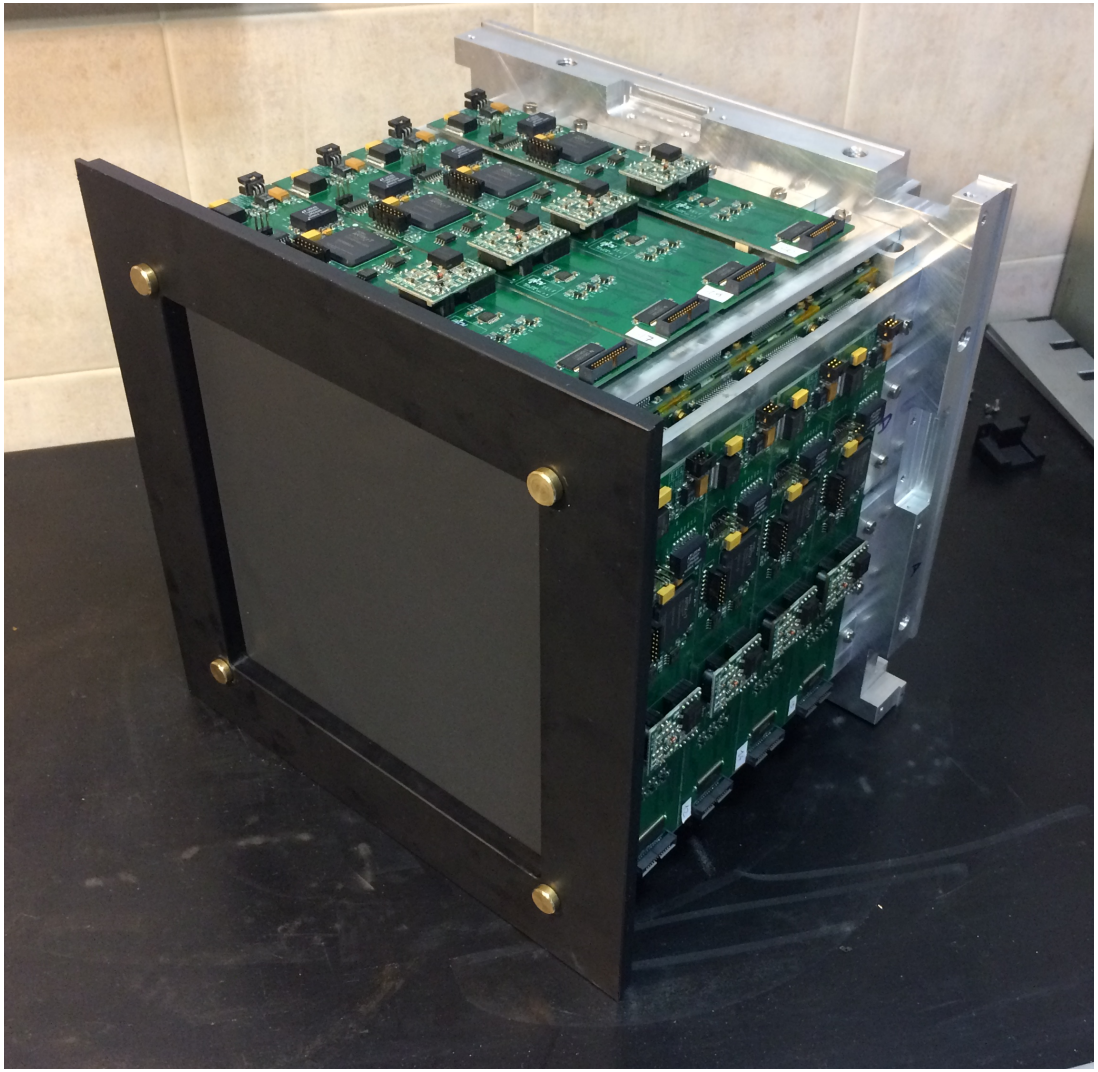
Dose Profiler: hardware assembling



- SiPM board coupled to fibres with optical grease
- Aluminum strips for heat transferring
- FPGA for data acquisition

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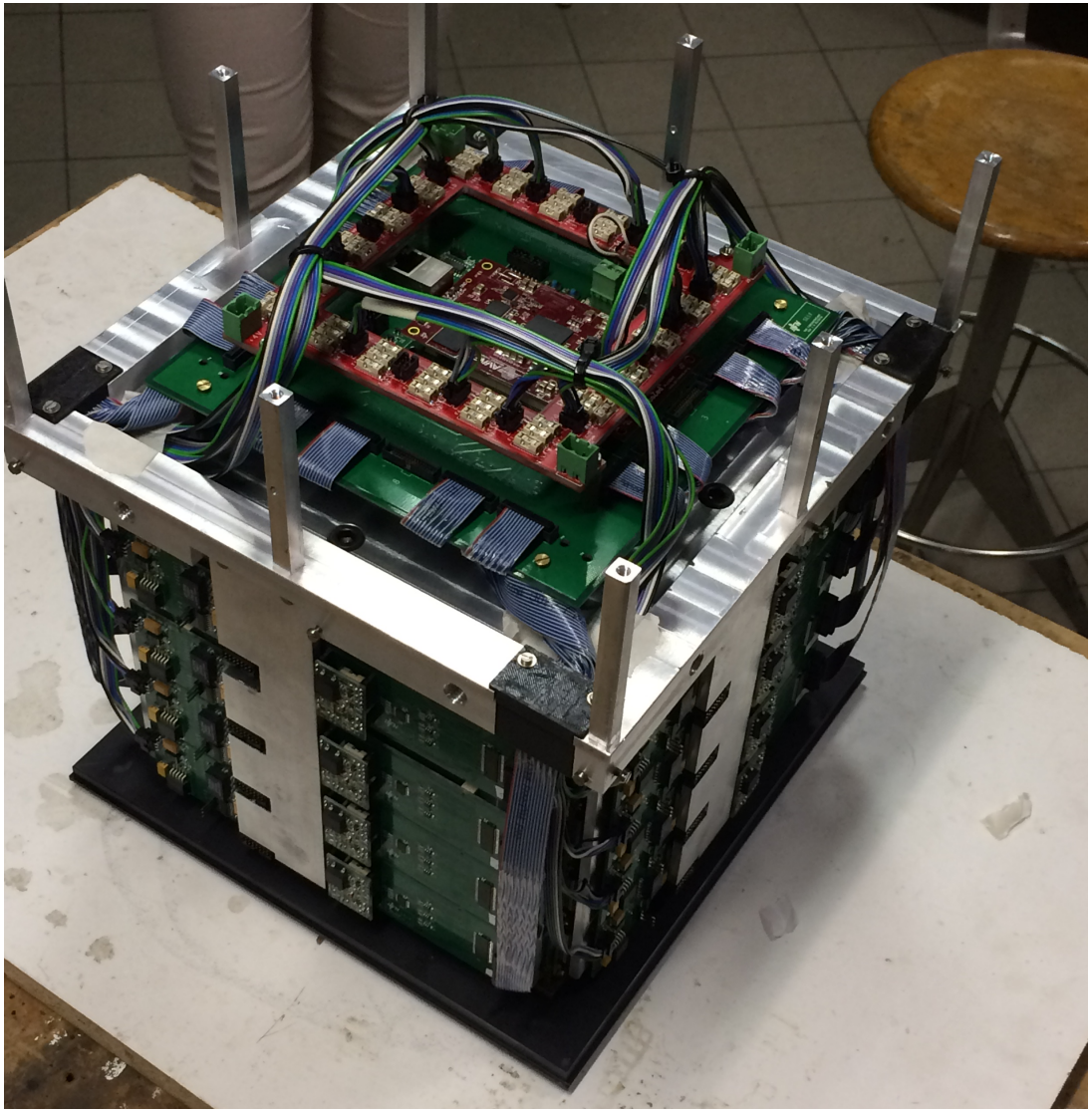
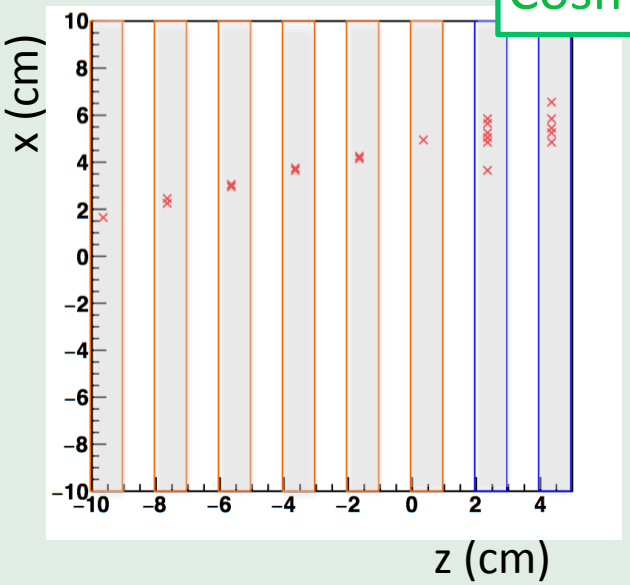
Dose Profiler: hardware assembling

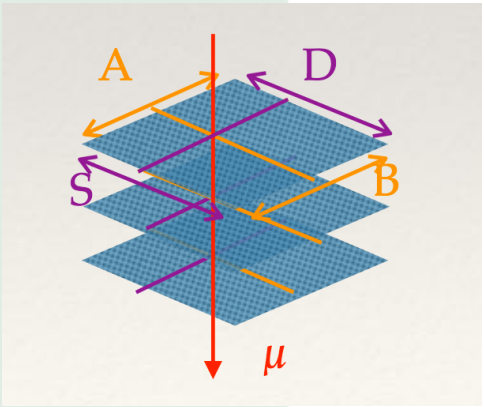


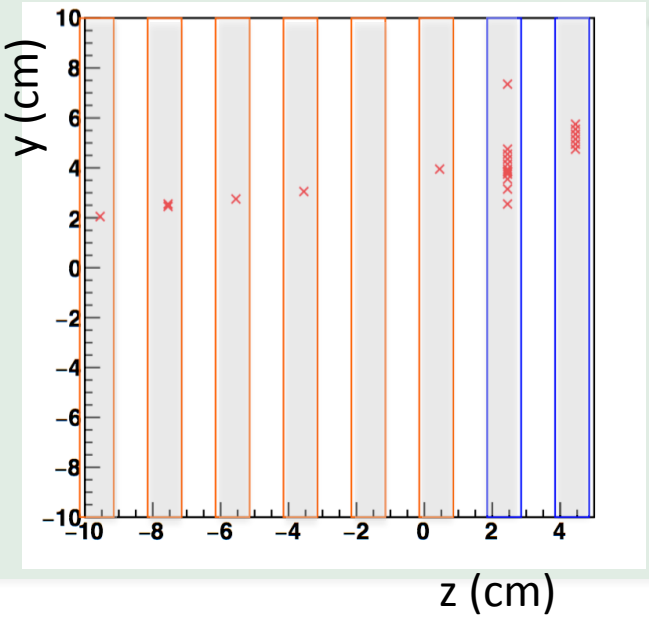
- SiPM board coupled to fibres with optical grease
- Aluminum strips for heat transferring
- FPGA for data acquisition
- Cabling

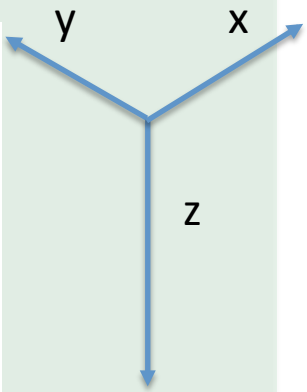
Dose Profiler: first measurements

Cosmic rays



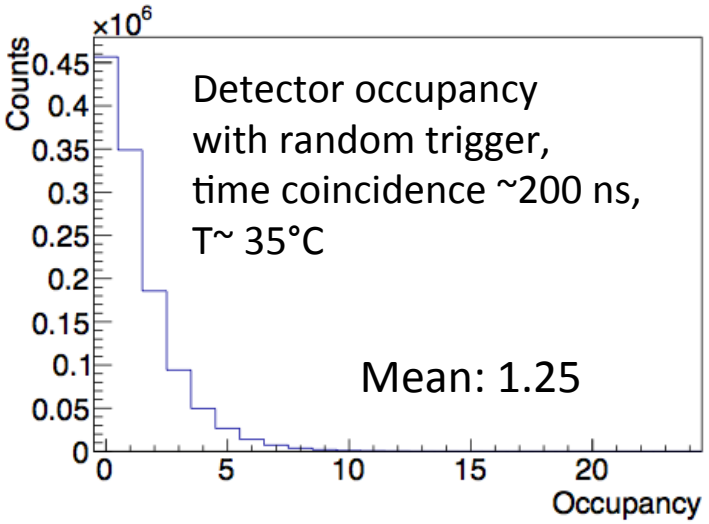




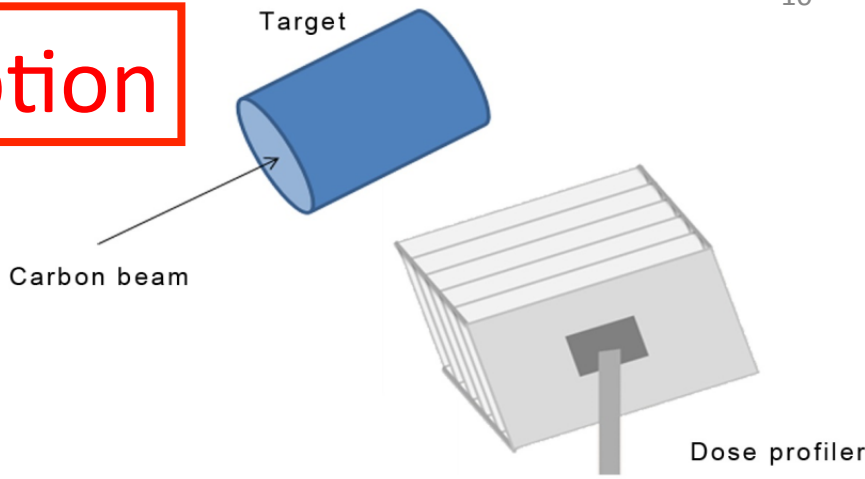


- Detection and tracking efficiency with cosmic rays is under evaluation
- Calibration measurements with led are in progress
- A serious study of temperature impact have to be done

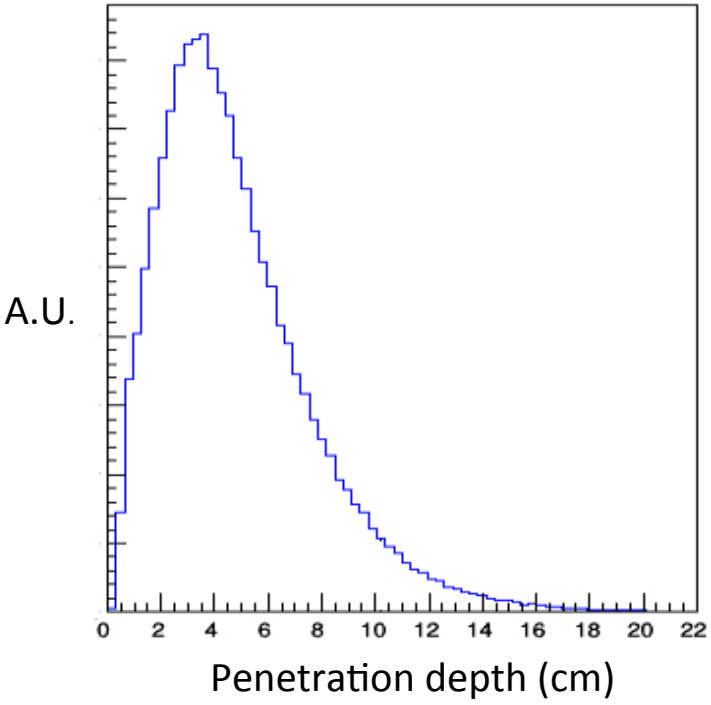
Noise evaluation

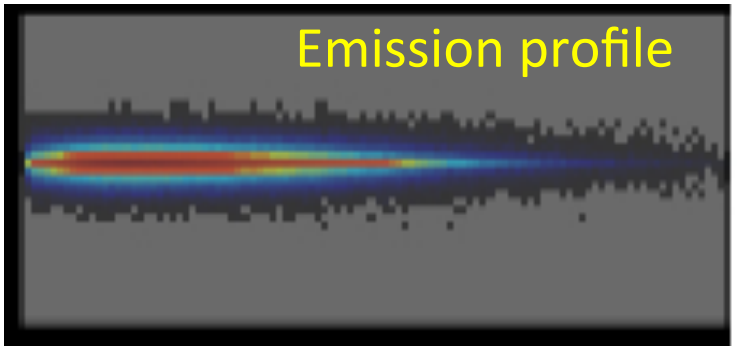


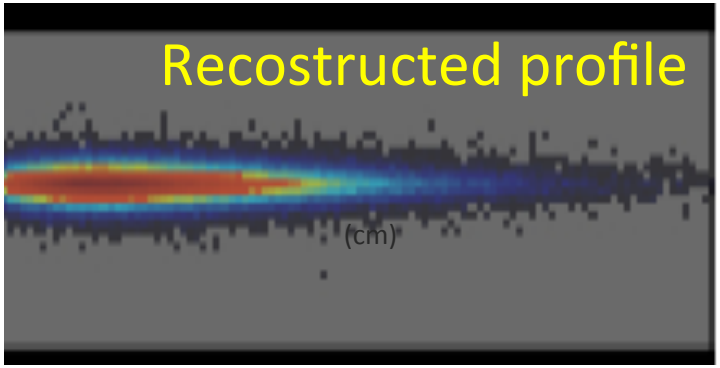
DP & patient auto-absoption



Reconstructed emission profile of secondary protons produced by a ^{12}C a 220 MeV/u beam on a water cylinder

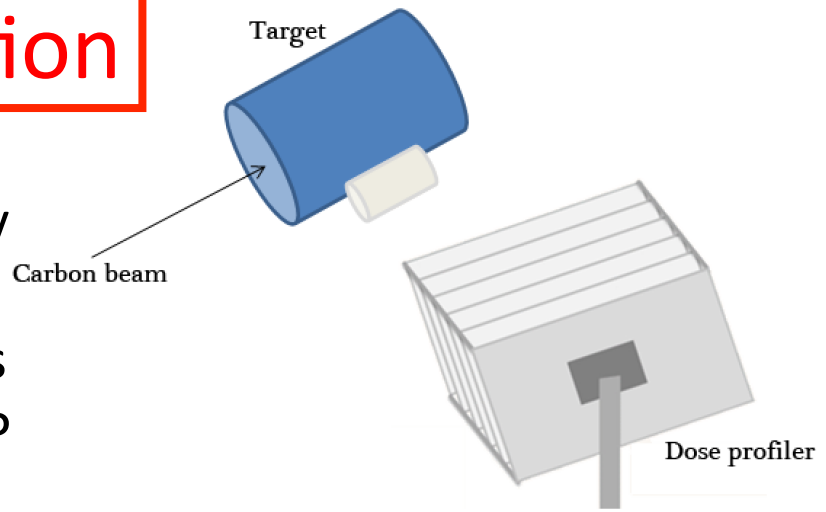




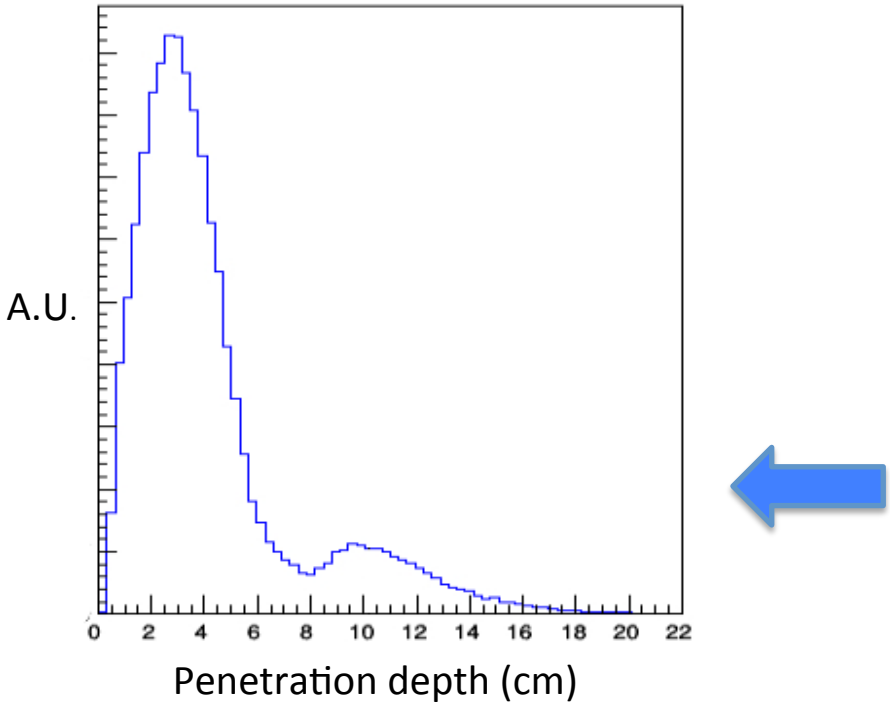


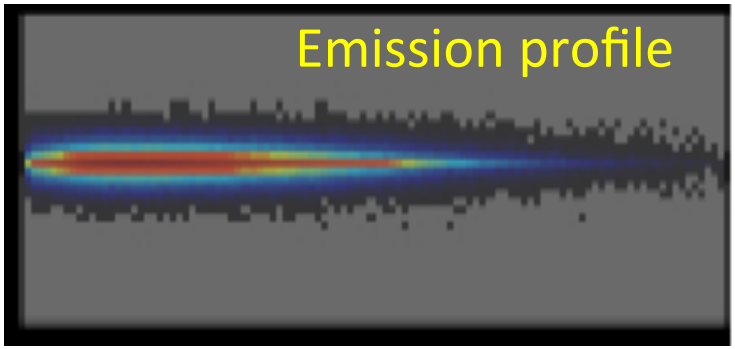
DP & patient auto-absoption

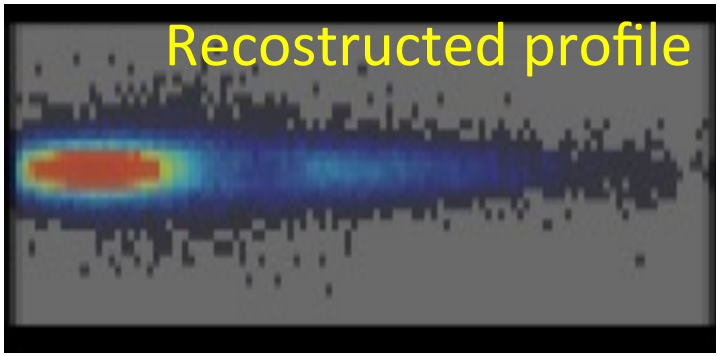
Reconstructed emission profile of secondary protons produced by a ^{12}C a 220 MeV/u beam on a water cylinder. A bone cylinder is on the way between emission region and DP



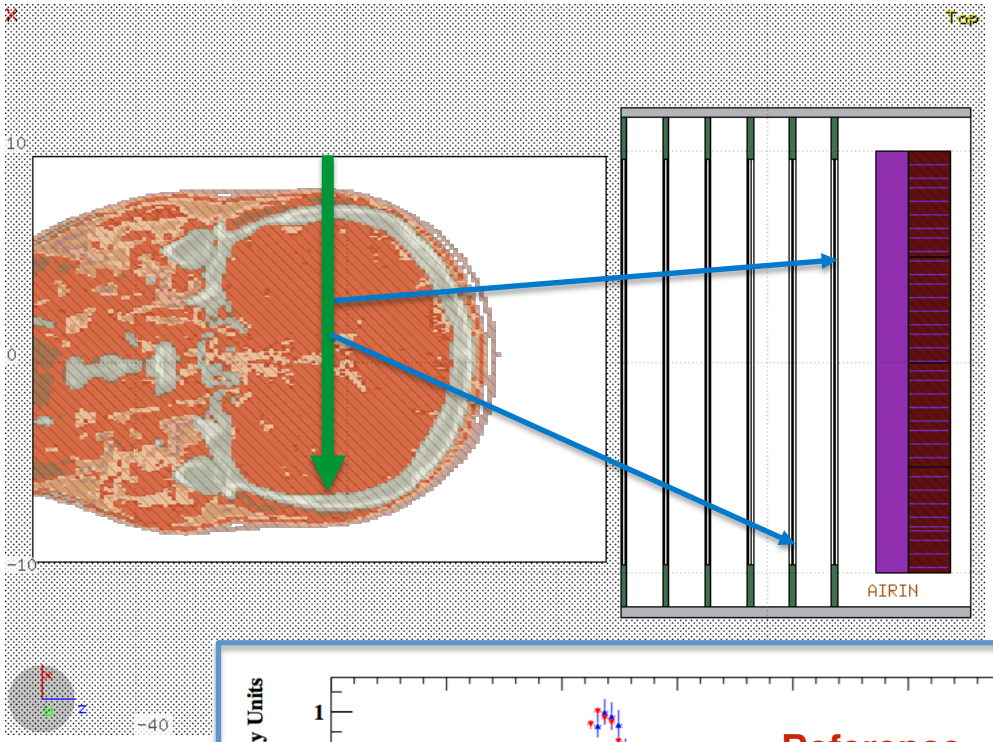
Mater absorption must be filtered!!





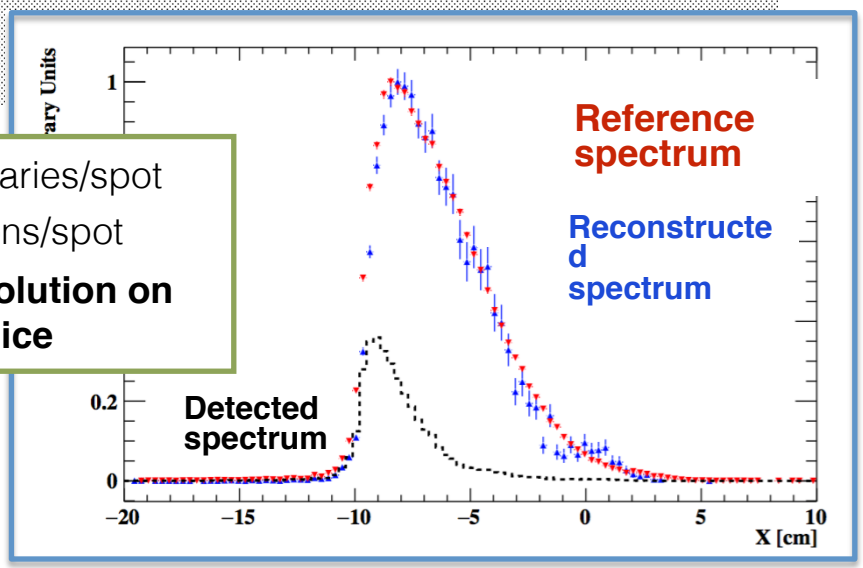


Dose Profiler: use in clinical case



- In order to make use of the measured emission profile, the **absorbing effect due to the different thickness** material MUST be taken into account
- We are able to take into account of this in real time. It can be achieved buy means of a fast GPU-based MC code **back-propagating the reconstructed tracks though a geometry derived from the same CT used for planning.**

- 2.3 10^5 primaries/spot
- ~1000 protons/spot
- **2-3 mm resolution on the distal slice**



Traini et al. , Physica Medica (2017), DOI: http://dx.doi.org/10.1016/j.ejmp.2017.01.004

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Activity planning 2017-2019

2017:

characterization of the DP at the Trento TIFPA proton beam: efficiency & resolutions.

Measurement at the CNAO beam of the proton production X-section on different materials of clinical interests (C,O,H,Ca)

2018-2019

Test of the dose profiling during patient treatment.

Integration of the DP in the CNAO information system

Development of a robotized mechanical system to embed the DP in the CNAO treatment room

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Publication (only article) in 2016. Source : SCOPUS

G. Battistoni et al. " Design of a tracking device for on-line dose monitoring in hadrontherapy" Nuclear Instruments and Methods in Physics Research, Section A: 845, pp. 679-683.

I. Mattei et al. "Secondary radiation measurements for particle therapy applications: Prompt photons produced by 4He, 12C and 16O ion beams in a PMMA target" Physics in Medicine and Biology, 62 (4), pp. 1438-1455

M. Marafini et al. "Secondary radiation measurements for particle therapy applications: Nuclear fragmentation produced by 4He ion beams in a PMMA target" Physics in Medicine and Biology, 62 (4), pp. 1291-1309

S. Muraro et al. "Monitoring of hadrontherapy treatments by means of charged particle detection" Frontiers in Oncology, 6 (AUG), art. no. 177

G. Traini et al. "Design of a new tracking device for on-line beam range monitor in carbon therapy" Physica Medica, . Article in Press

The project produced also several talks at international conferences:

SIRR2016, VERTEX2016, ISIT16, VCI2016, ICTR-PHE2016, AAPM2016

Imaging dosimetrico per adroterapia

Possible links to other Projects (internal or external to Centro Fermi):

- **INSIDE:** PRIN 2010 project "**INnovative Solutions for In-beam DosimEtry in Hadrontherapy**"
- **FOOT** : **FragmentatiOn Of Target** experiment. INFN project funded by CSN3 (nuclear physics) aiming to the measurement of the fragmentation of the beam/patient nuclei during PT
- **MONDO** : **MOnitor for Neutron Dose in hadrOntherapy** CF project (see M.Marafini talk)
- **ENSAR-2:** H2020 project (**European Nucler Science and Application Research 2**). Deliverable D5.1 Specific needs and proposed solutions of nuclear tools for medicine

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Expected funding in the 3-year period:

- **Request of funding by Centro Fermi**

2017 : 25 kEuro (data taking in Trento e CNAO, GPU station for reconstruction)

2018-2019 : 60 kEuro / 2 grants (integration of the DP output in the CNAO information system, mechanical robotized arm for the beam nozzle integration)

- **Co-funding**

2018-2019 : 40 kEuro from CNAO (sub-judice the validation)

- **Potential external funding**

H2020, ERC, SIR, PRIN, Regional funding on LS