Monitoring con particelle cariche: stato del dose profiler e prospettive

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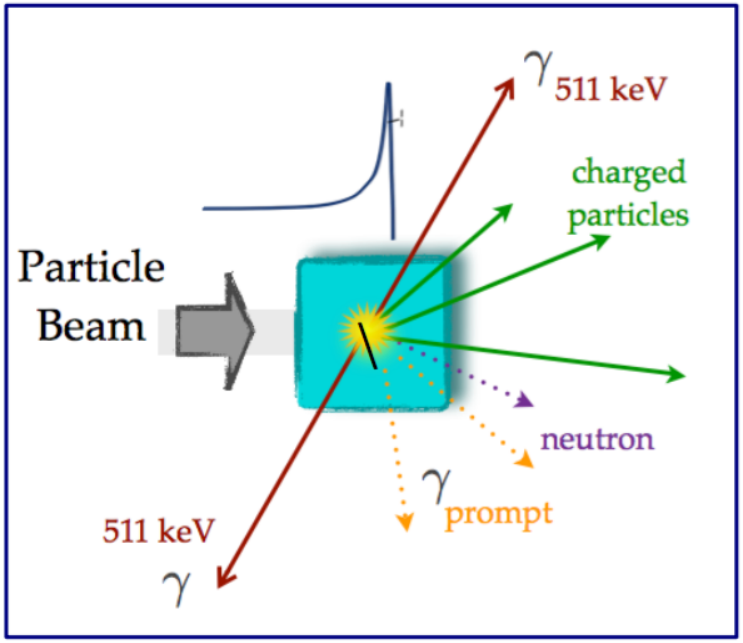
Secondary particles

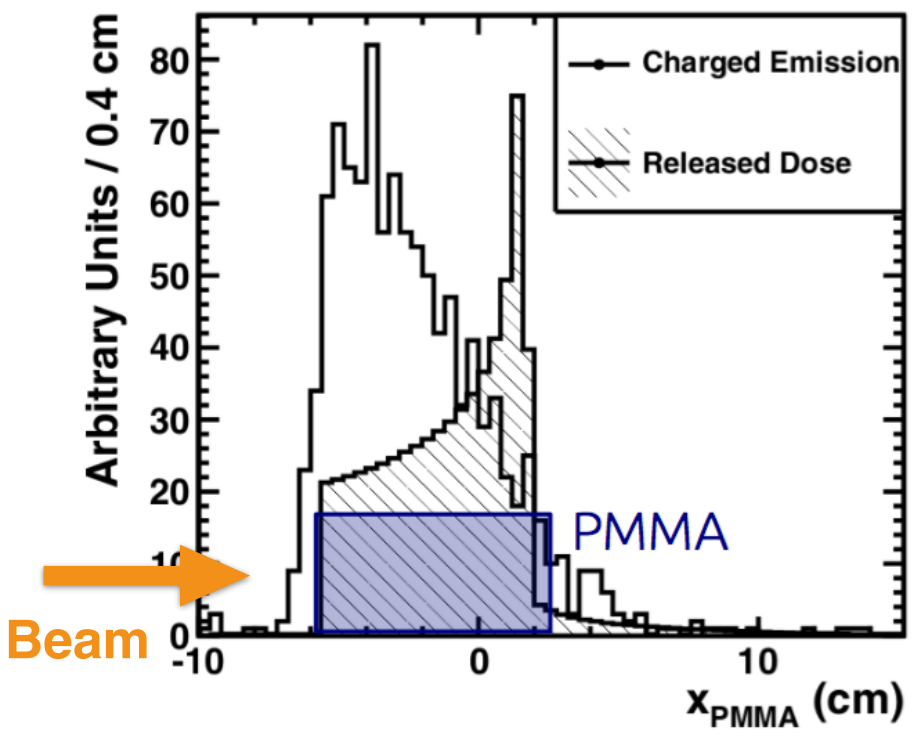


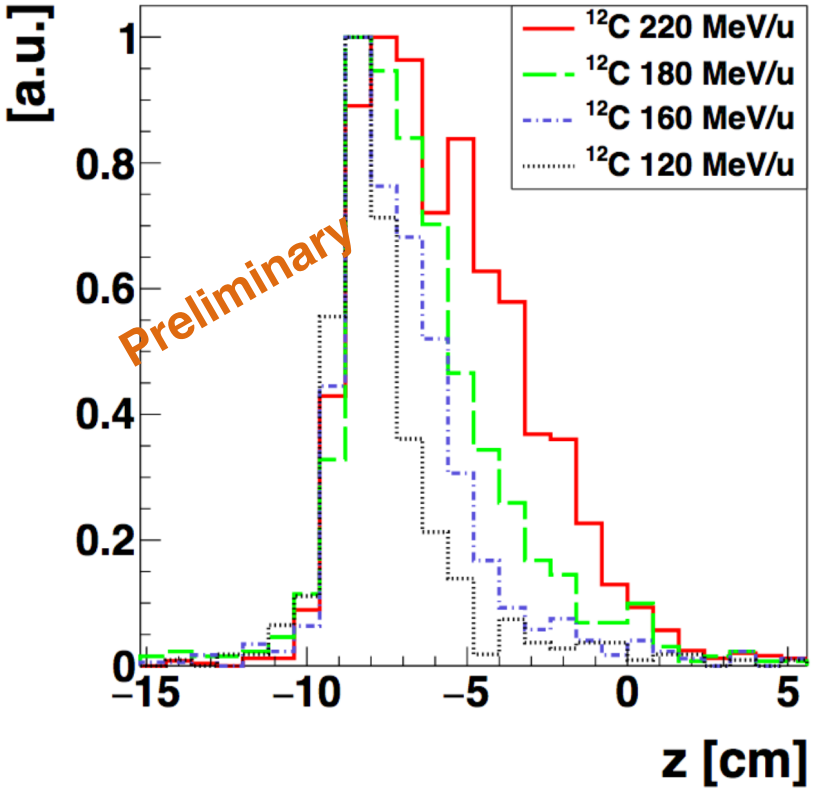
- **Problem**: the primary particles don't escape from the patient!
- **Approach**: use **secondary particles** produced by the nuclear interactions with the tissues

- **Charged particles**: produced by projectiles or target fragmentation (**mostly protons**) end emitted at **large angles (60°-90°)**

Monitoring with charged fragments

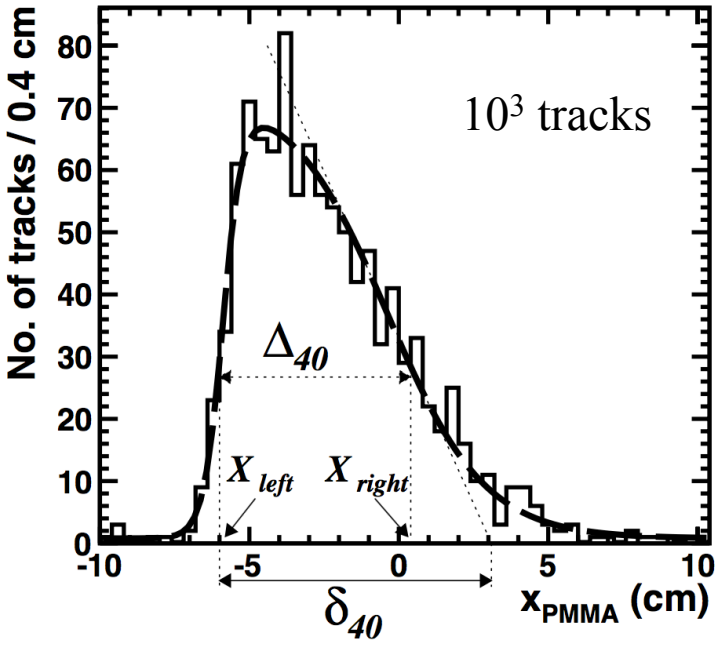
L. Piersanti et al., Phys. Med. Biol. 59 (2014) 185

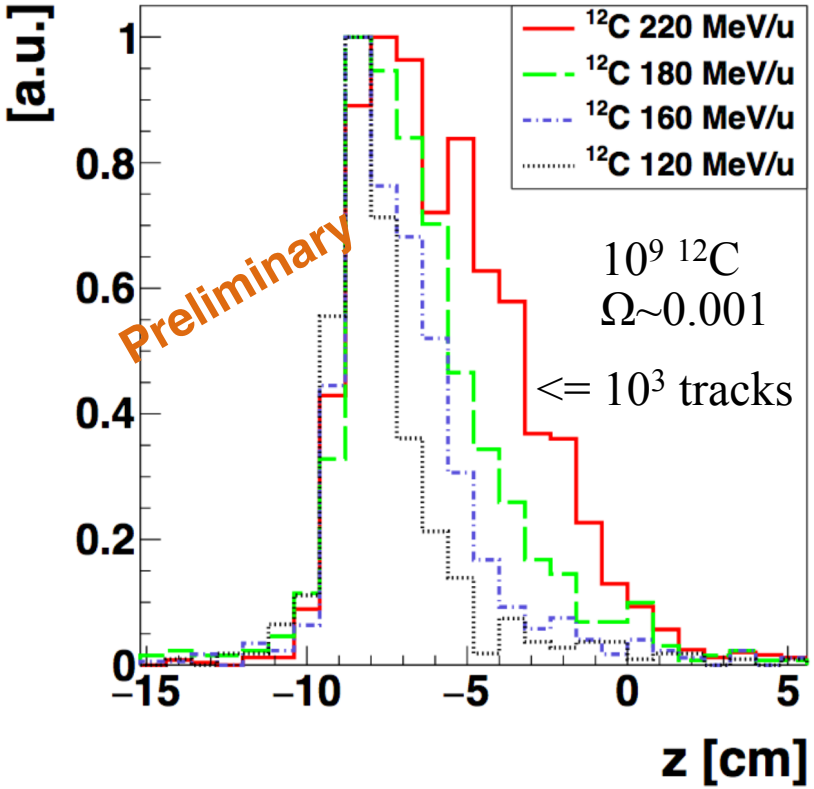




- It is possible to exploit the correlation between the dose distribution and the charged secondary particles emission profile, parametrising the measured distribution with a data-driven mathematical model

The expected resolution





- **Expected resolution on the Bragg Peak position ~ 3mm, totally due to the multiple scattering inside the patient**

Heavily depends on real treatment conditions!!!

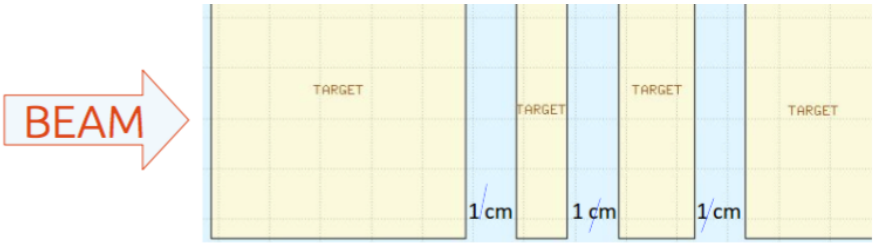
θ	Ion	Energy (MeV/u)	R (cm)	δ_{40} (cm)	R-δ_{40} (cm)
90°	^{12}C	120	2.9	3.8±0.5	0.9±0.5
		160	4.8	5.6±0.8	0.8±0.8
		180	6.0	6.8±0.6	0.8±0.6
		220	8.3	9.3±0.4	1.0±0.4

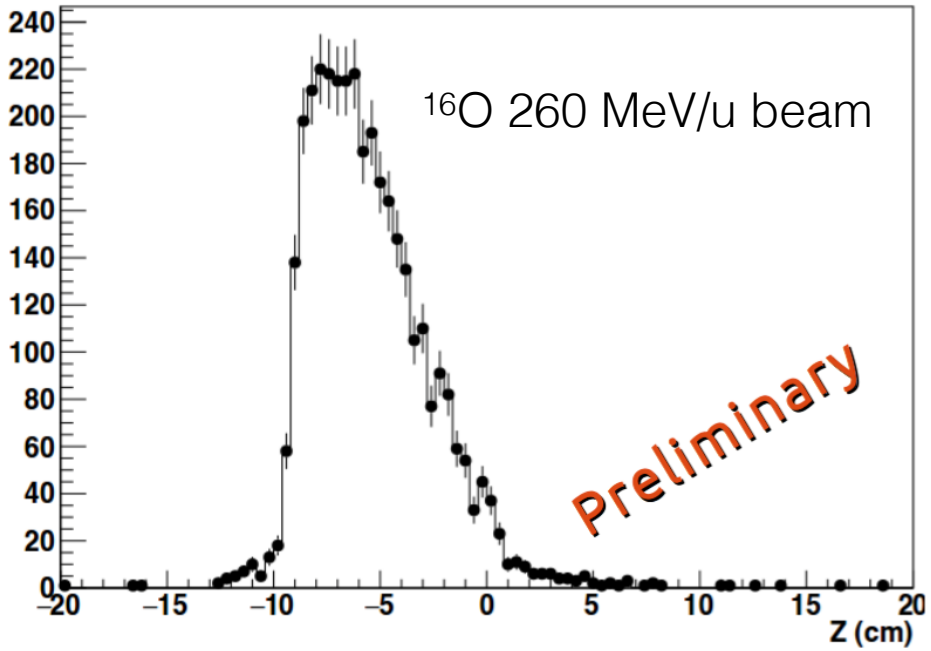
Inhomogeneities detection

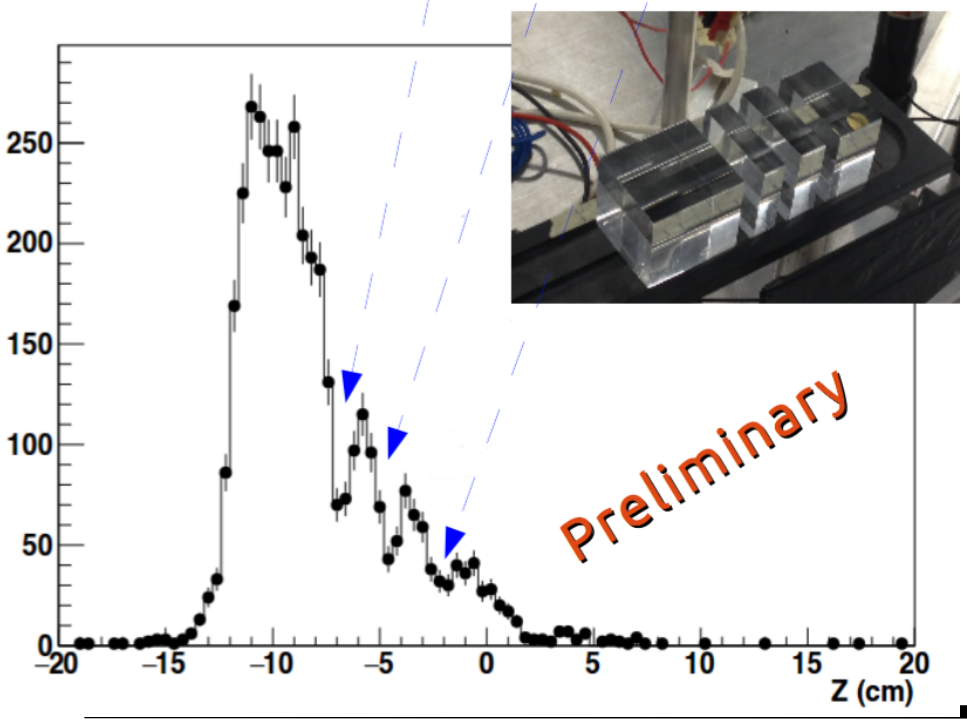
The sensitivity of the charged emission profile to possible inhomogeneities has been tested acquiring data with a non homogeneous target

Homogeneous PMMA target

Non-homogeneous, three air gaps

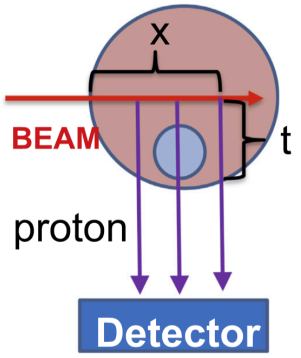


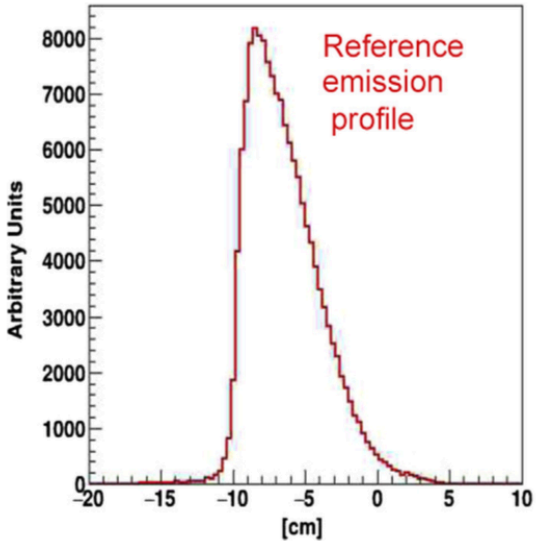


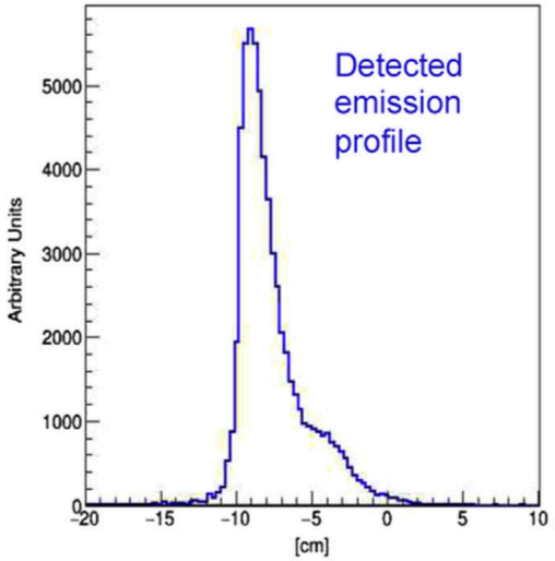


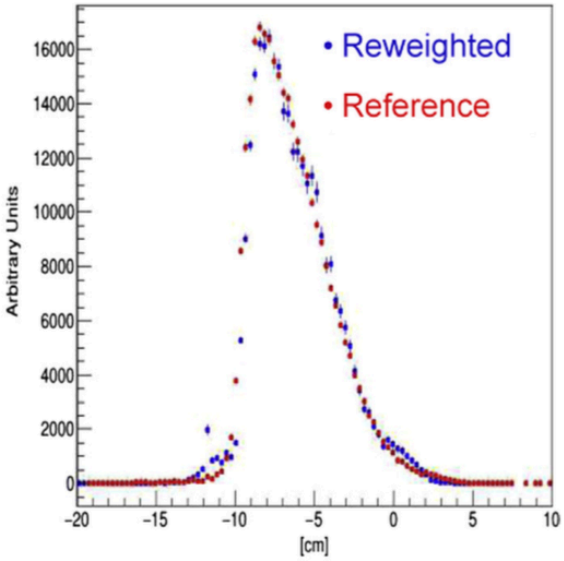
Real case scenarios

- From the simplified case in which a single beam is shot against an homogenous target and the profile is correlated to the BP position, we need to make a big step and move towards realistic case scenarios in which the target inhomogeneities are properly accounted for and the different charged fragments production in different tissues is properly considered.
  - Calibration/Simulation work is needed: G. Battistoni will cover this issue!

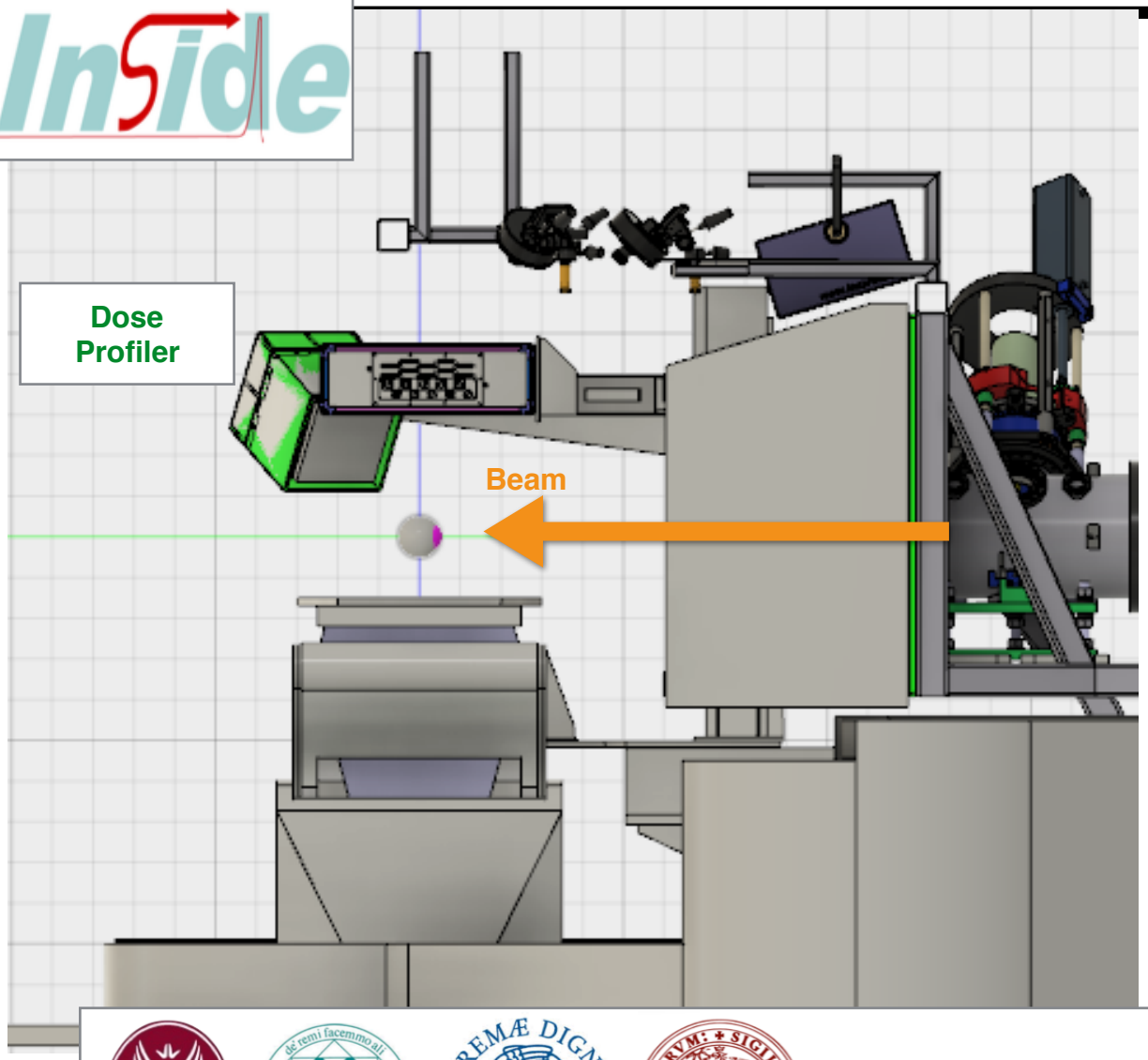








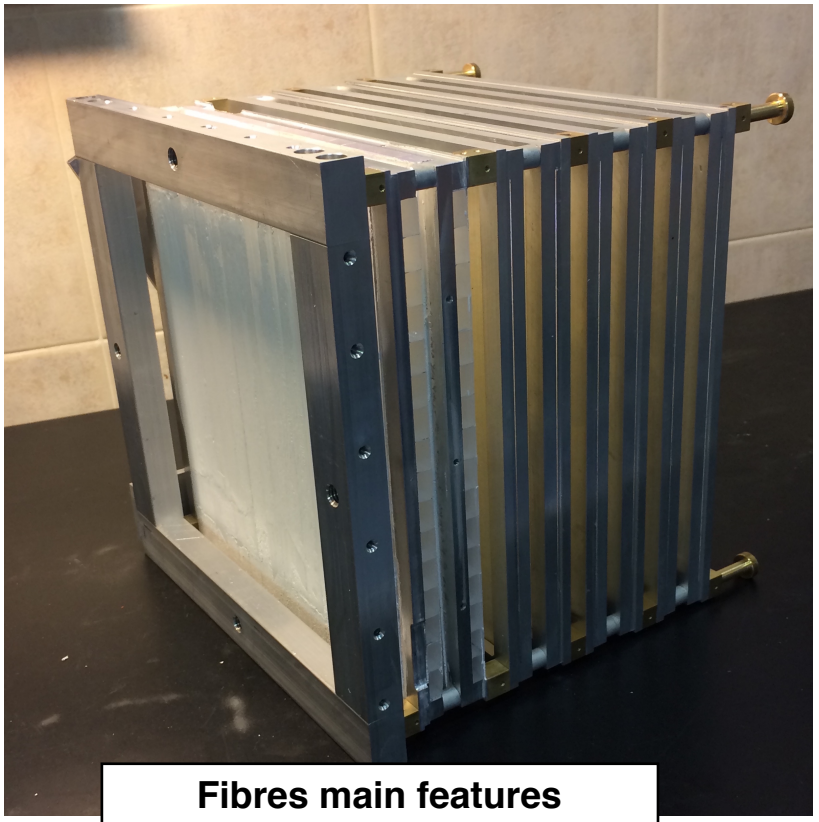
Dose Profiler



- **Dose Profiler**: designed to monitor the beam range by means of the on-line reconstruction of the charged secondary particles tracks
- It is designed to be integrated in the CNAO treatment room, in the framework of the **INSIDE** (INnovative Solution for In-beam DosimEtry in hadrontherapy) project.

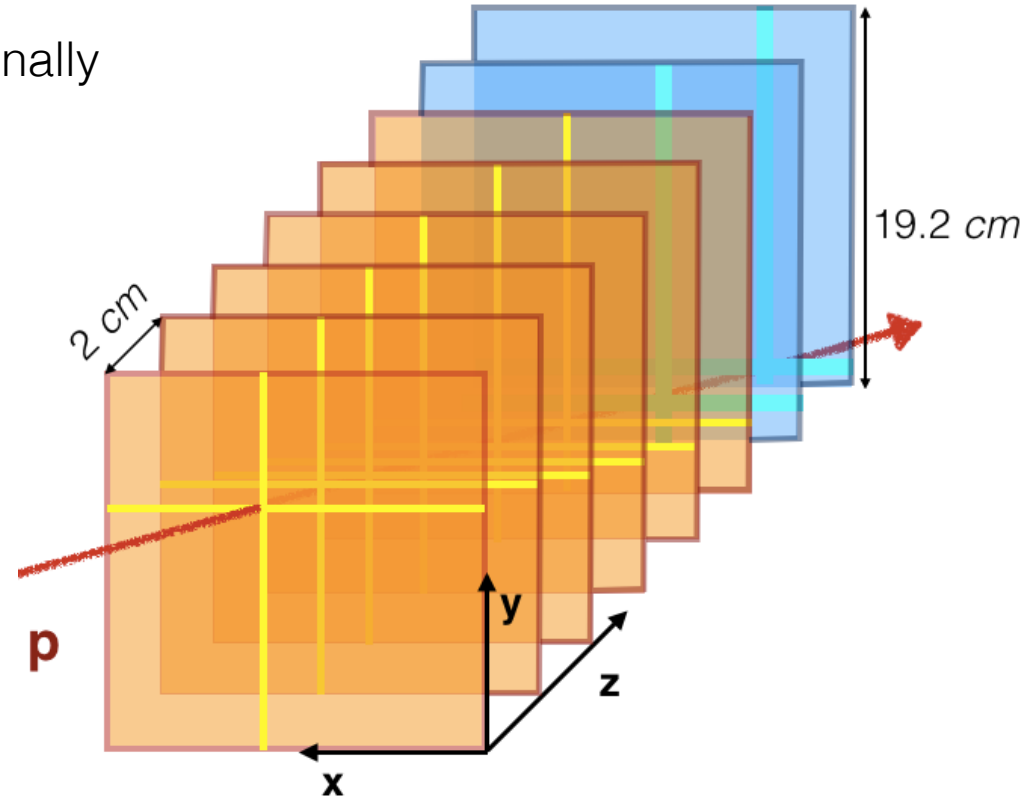
Dose Profiler layout

- **6 planes,** each one composed of 2 orthogonally oriented **scintillating fibres** layers



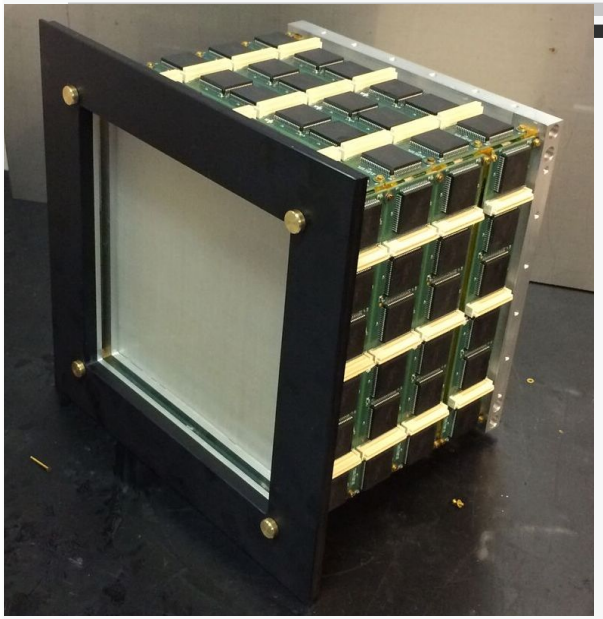
Fibres main features

- Saint Gobain BCF-12
- Squared, 500 μm^2
- Double cladding layer (4%)
- Trapping efficiency 7.2%

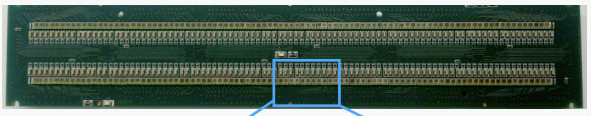


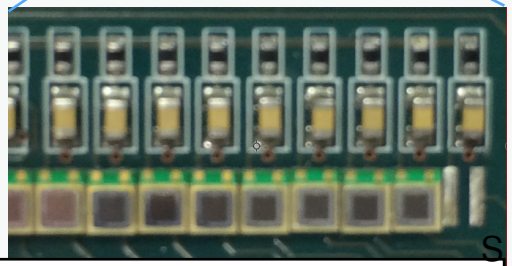
- **2 planes**, each one composed of 2 segmented thicker **plastic scintillators (6 mm),** to perform the energy measurement with a better resolution

Read-out electronics and trigger



SiPM boards

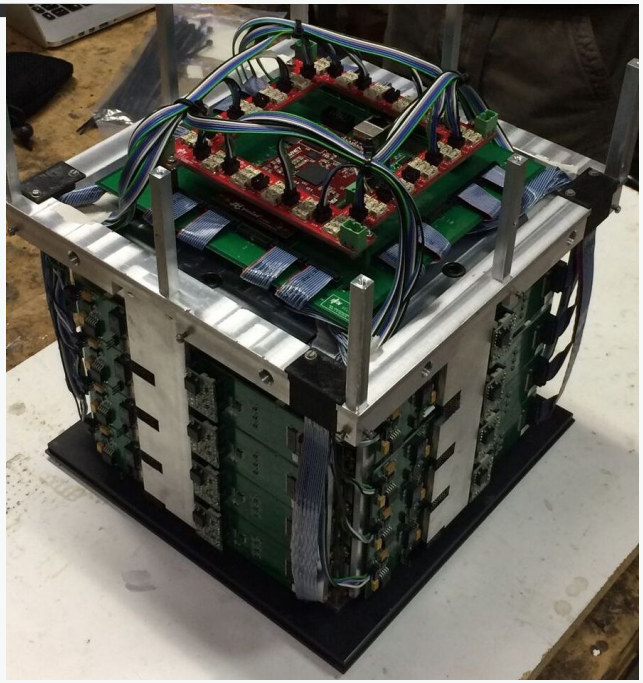




Hamamatsu SiPM 1 mm²

FPGAs boards

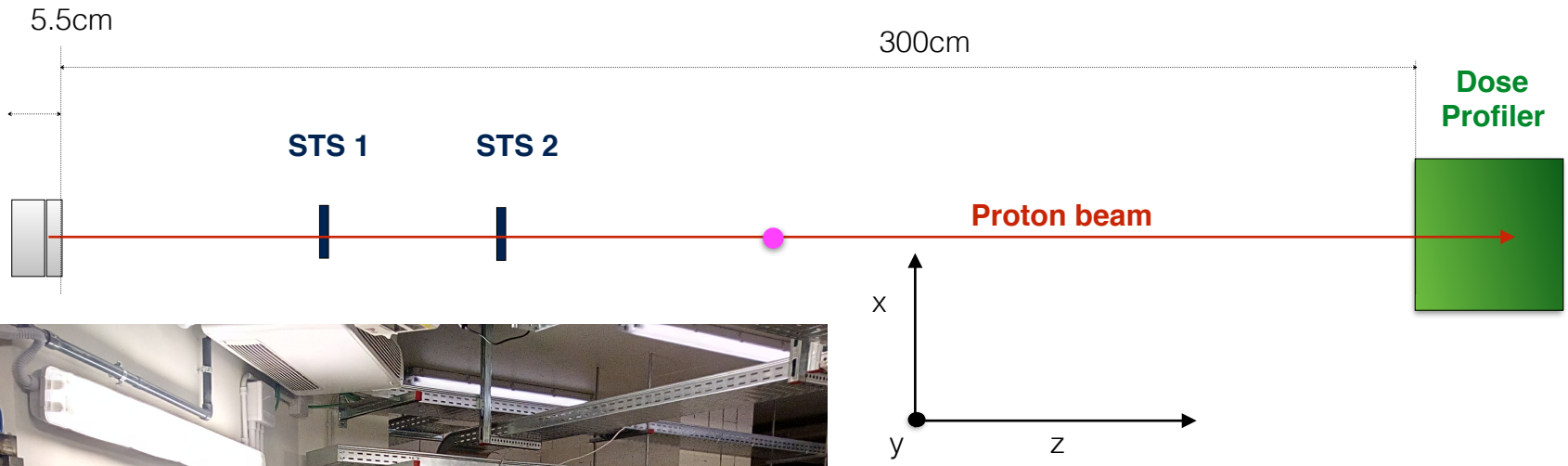
- FPGAs provide ASICs configuration and read-out
- Temperature sensor
- Module for SiPM Bias Voltage

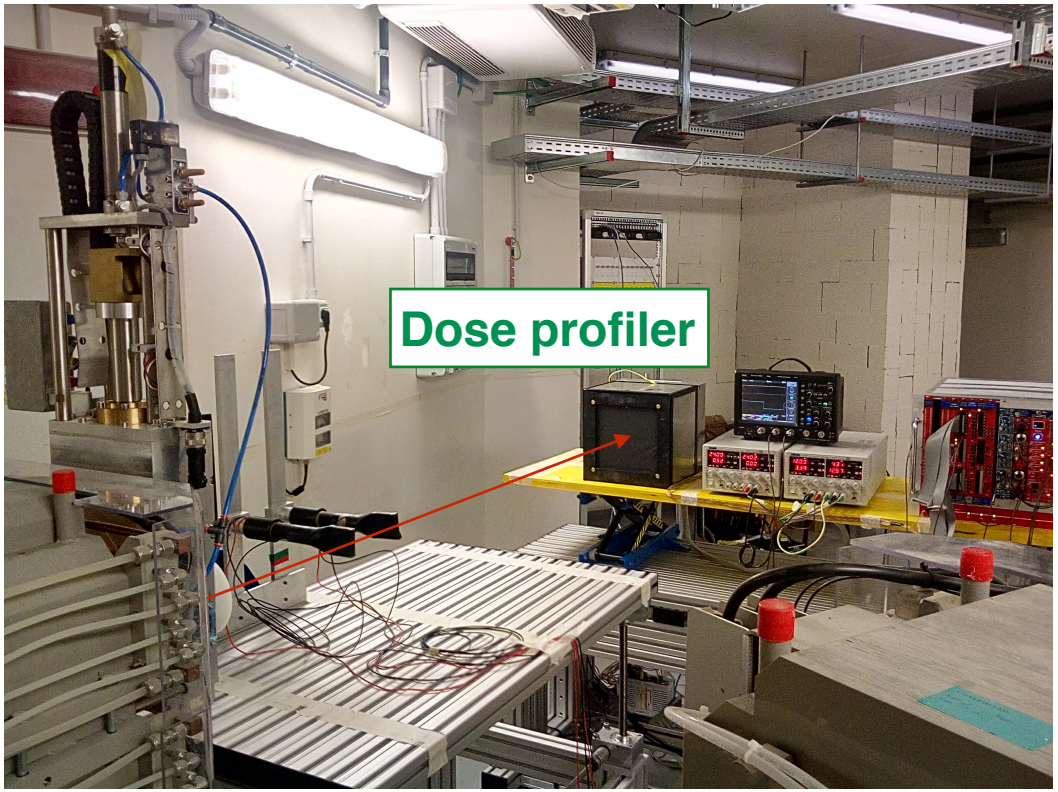


Concentrator board

- FPGAs data collection
- Trigger (10kHz), with external or internal logic
- DAQ PC connected with ethernet

Test-beam @Trento Proton Center



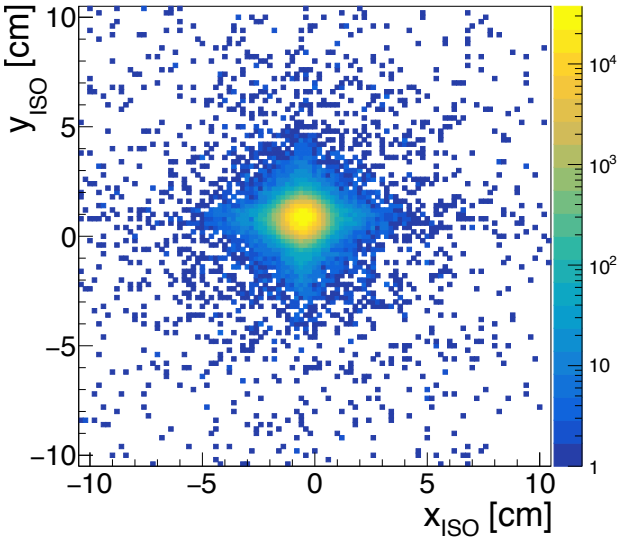


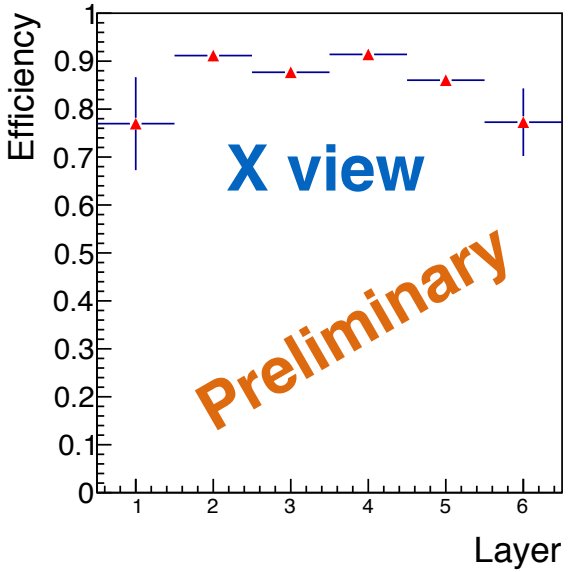
- Proton energy range (40-220 MeV)
- Beam size @ Isocenter: (3mm - 7mm)
- STS1, STS2 plastic scintillators (1 cm) for external trigger

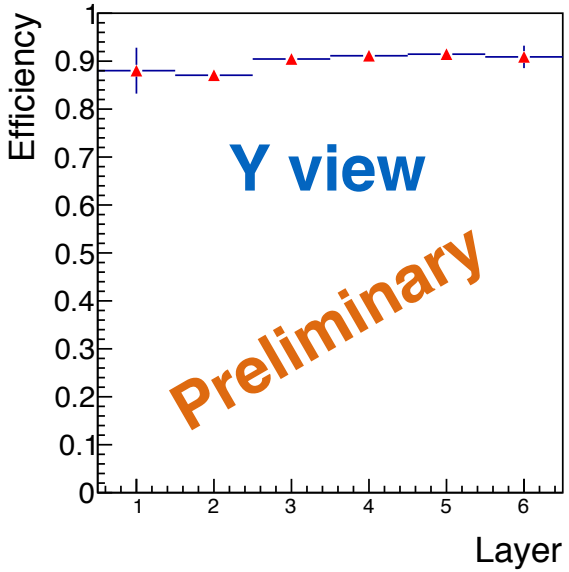
DP tests @ Trento

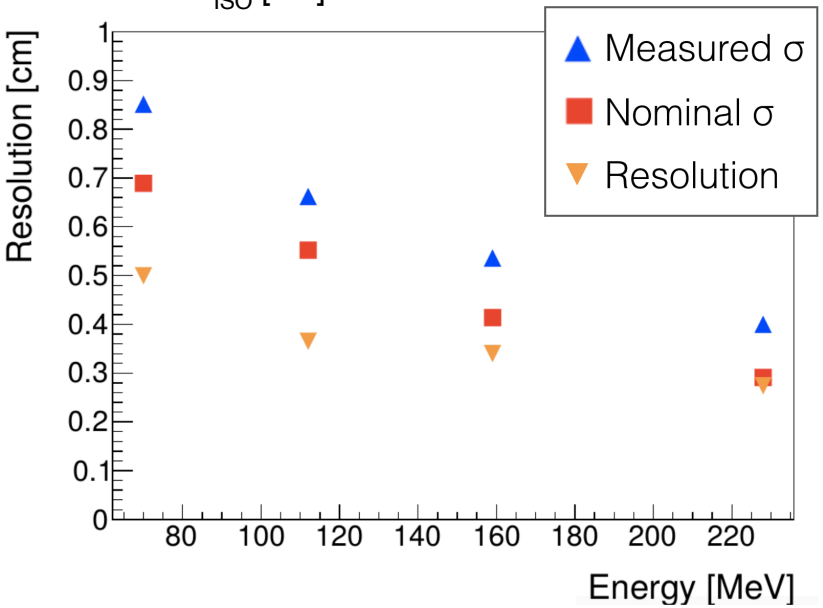
- Used protons from Trento to measure the detector performance.

Proton beam as seen from dose profiler





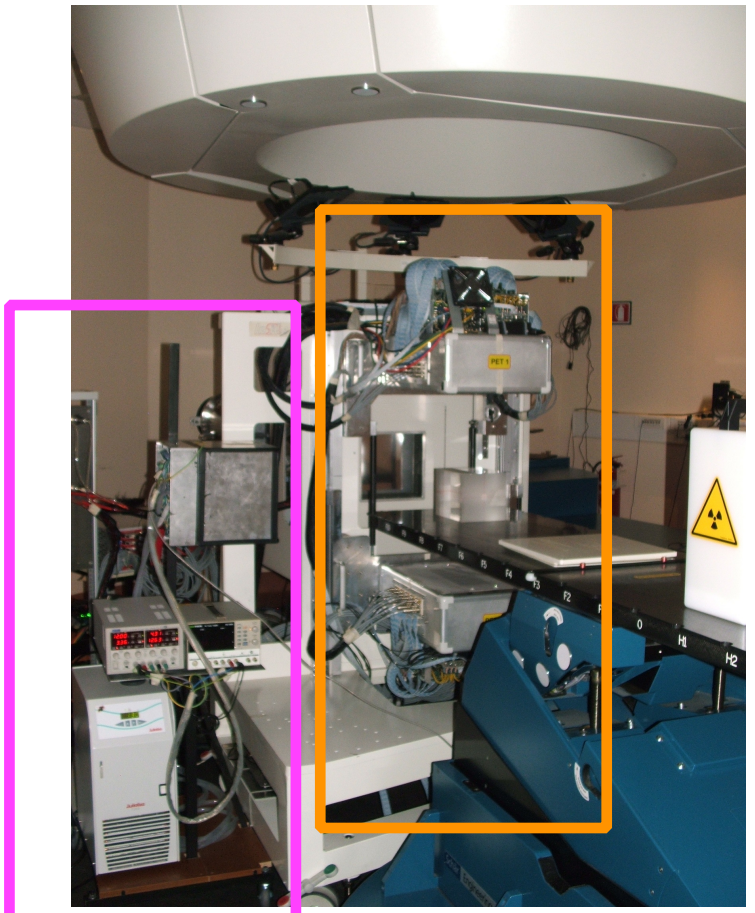




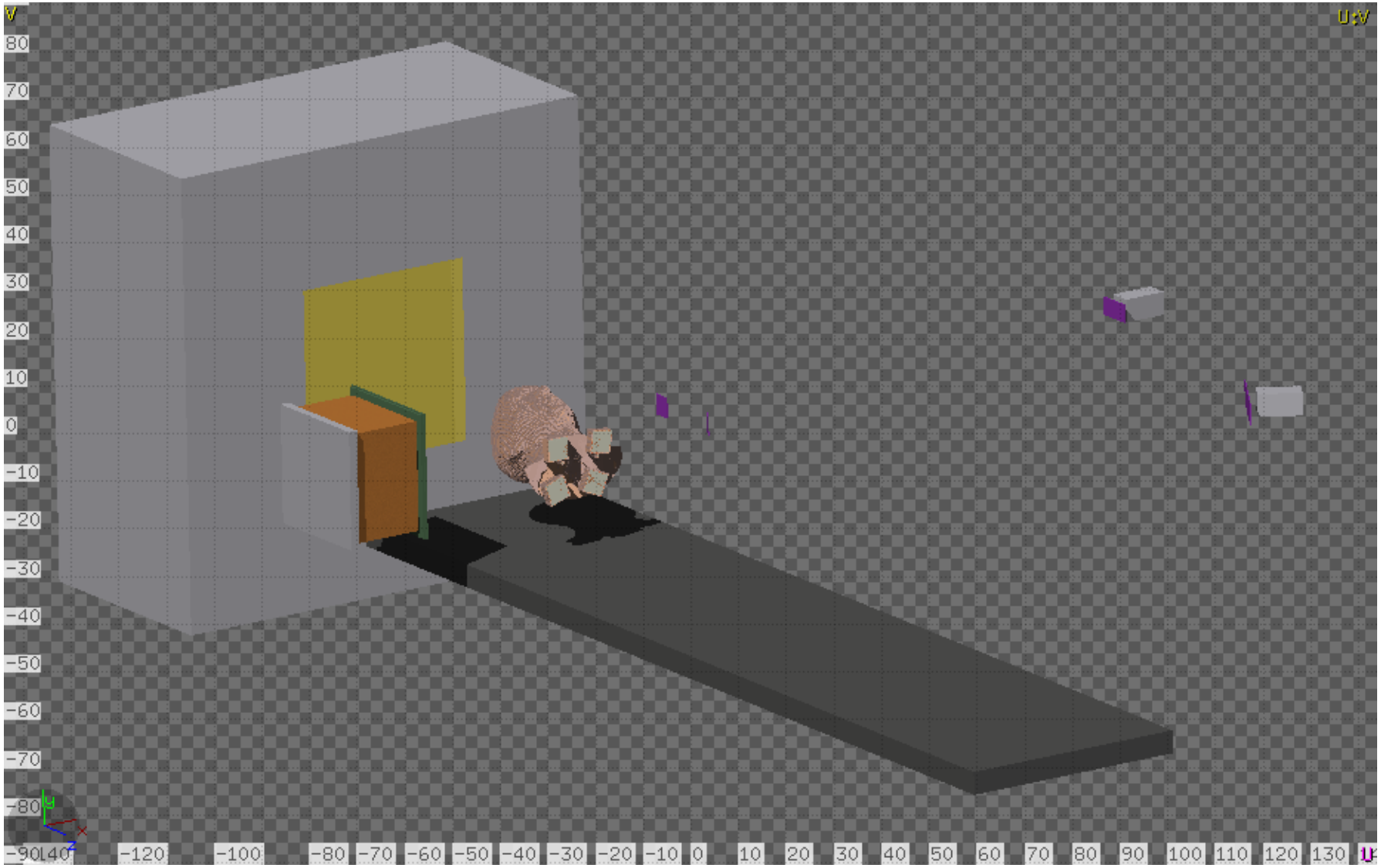
Test performed @ CNAO

- @ end of july both the PET and the DoseProfiler systems have acquired data @ CNAO….
- Dose profiler portable setup included:
  - Detector, power supply, chiller.
- Data taken on:
  - thin targets
  - RANDO
  - Thick PMMA target (comp. with PET)

A glimpse of the future!!

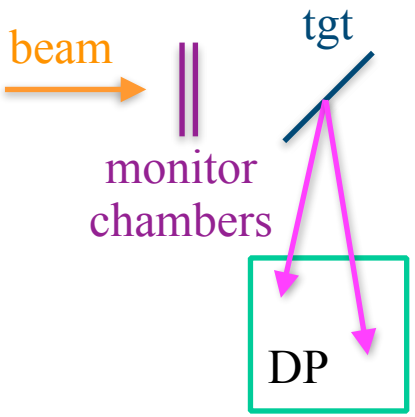


The measurement setup



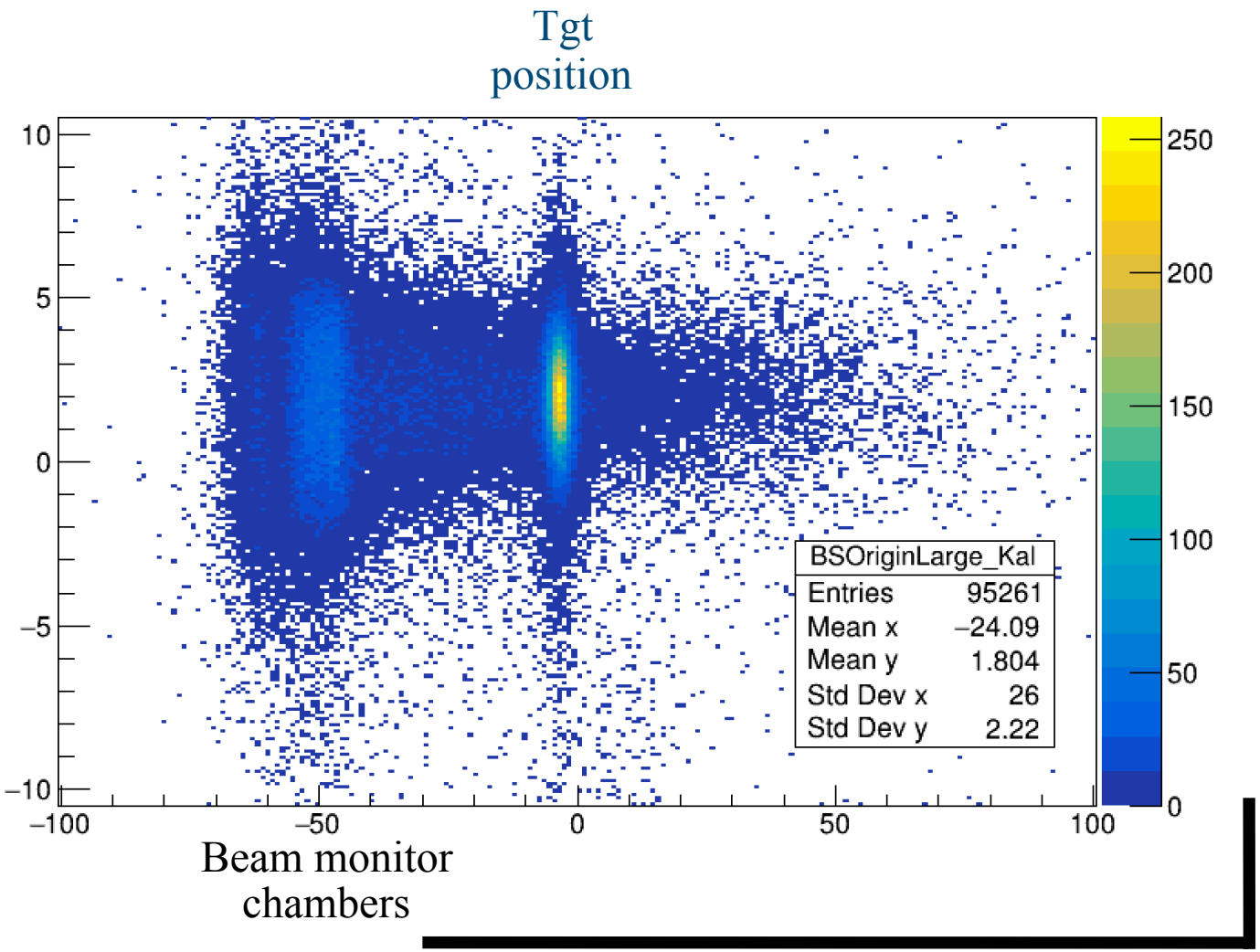
Preliminary results

- Data taken @ end of July. Only quick online checks performed



Graphite thin target (@45° wrt beam incoming direction)

Tracking optimisation and background subtraction is still to be done



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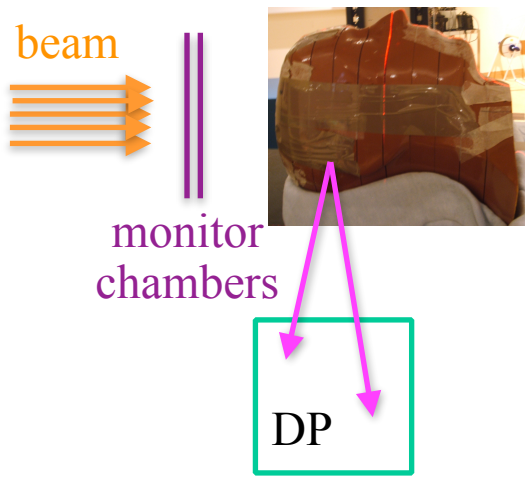
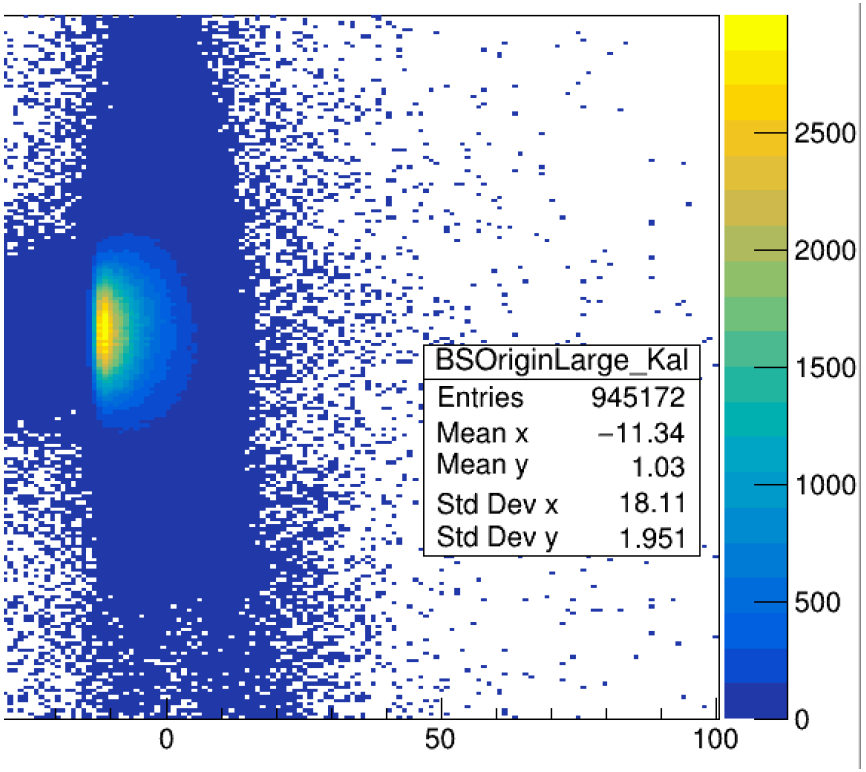


A dose **cube** shot inside the anthropomorphic phantom



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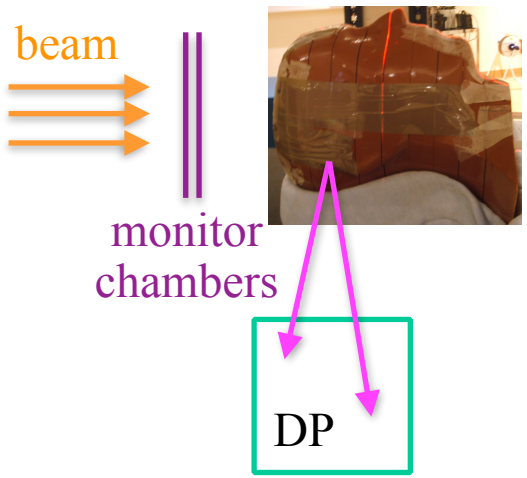
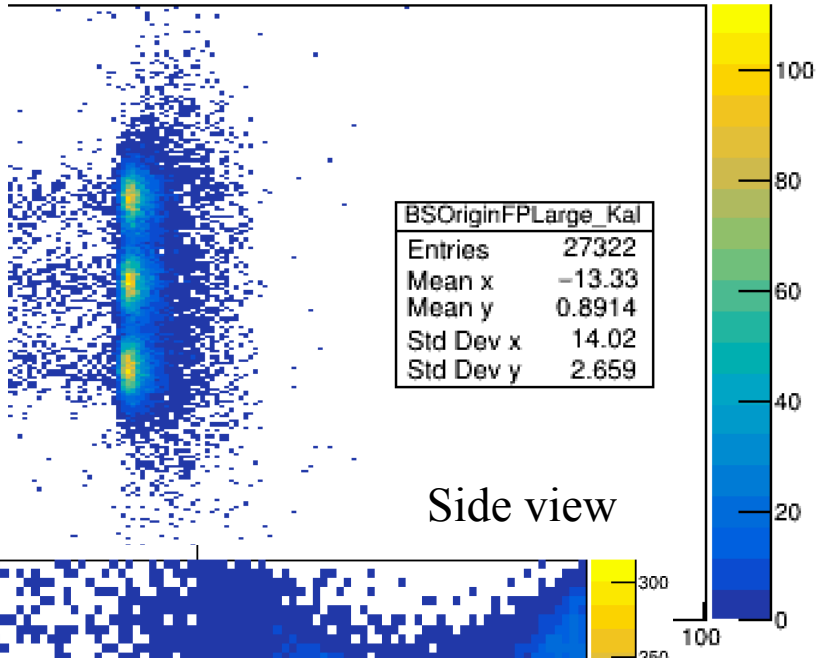
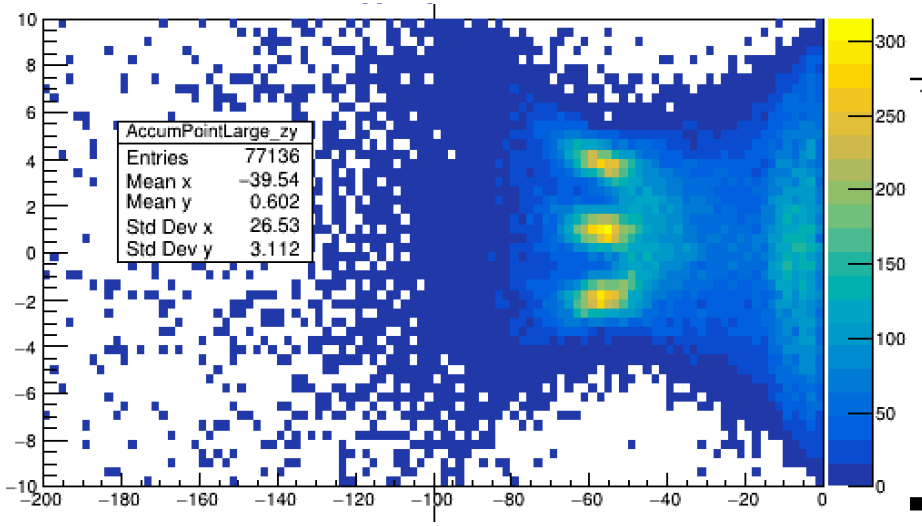


Treatment plan, a grid of 9 points, in x,y @ 220MeV



Side view



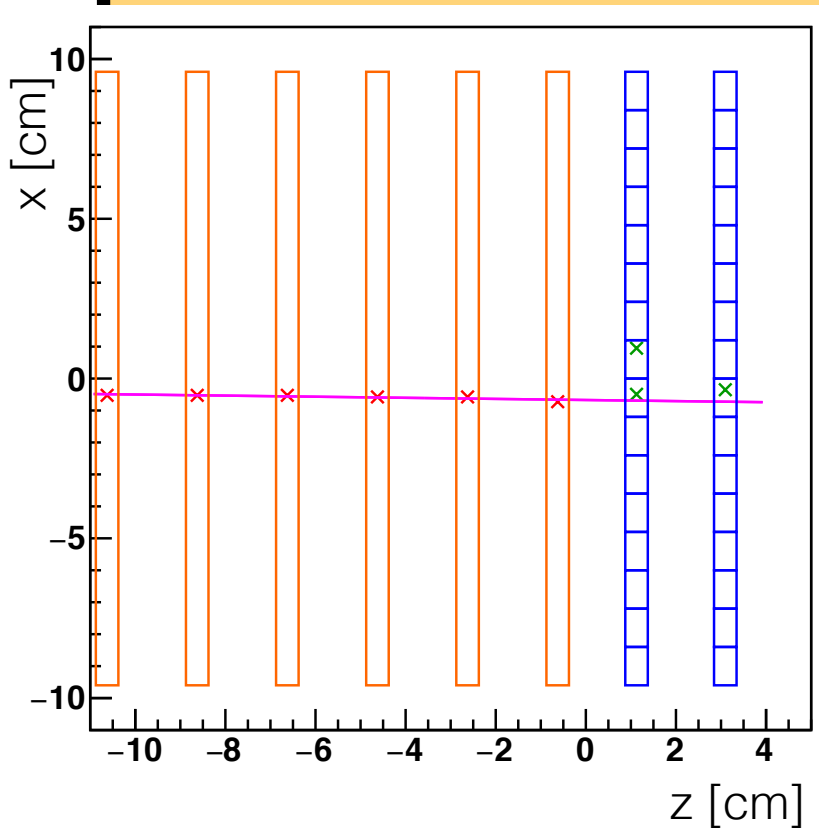
Preliminary (rough) attempt of pencil beam standalone reconstruction using POCA of tracks from consecutive events.

Status - Future steps

- Status
  - Detector is up and running, matching (so far) expected performances. CNAO data will be crucial to assess the performance in real case scenario conditions.
- Future
  - Hardware
    - Study of the detector rate capability have started: after the evaluation of dead time inefficiency the readout strategies will be reviewed.
  - Software
    - The pattern recognition and tracking algorithms are under development. So far only 'offline' reconstruction is provided.
  - MC & Cross Section
    - The fast backtracking implementation, by means of a fast MC, and the matter effect accounting have to be implemented

Spares

Tracks



- **Clustering**: channels over threshold are grouped with proximity criteria
- **Cluster selection**: Hough transform
- **Fitting**: implementation of **Kalman filter** with GenFit tool

Hough Transform