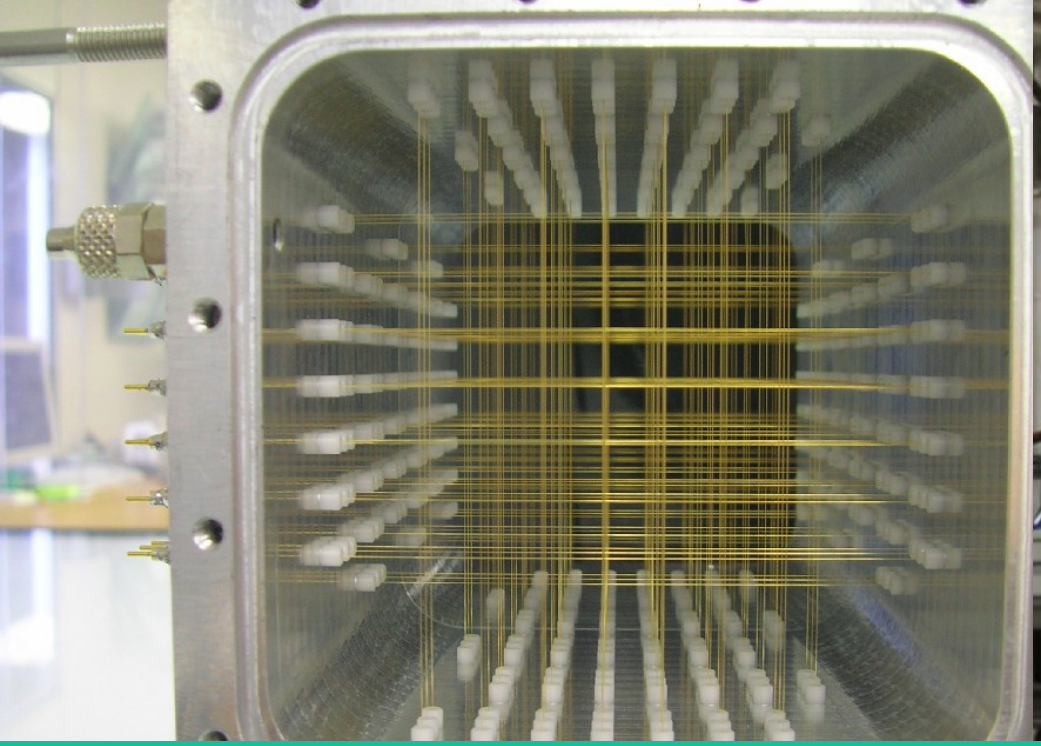
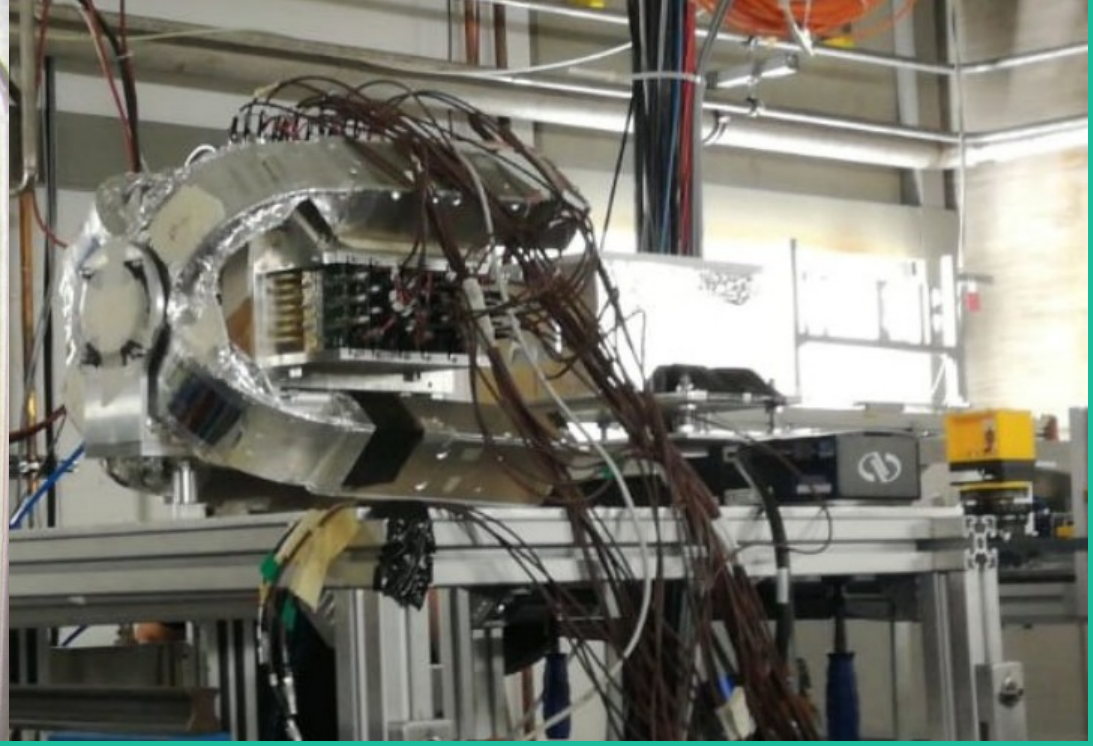




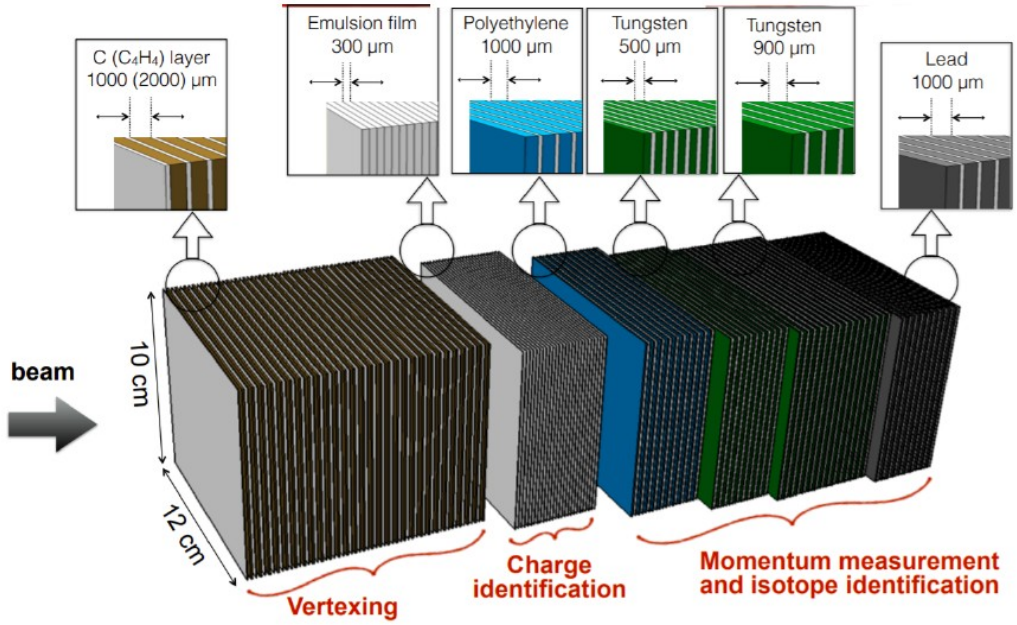
Calibration of the drift chamber within the FOOT experiment

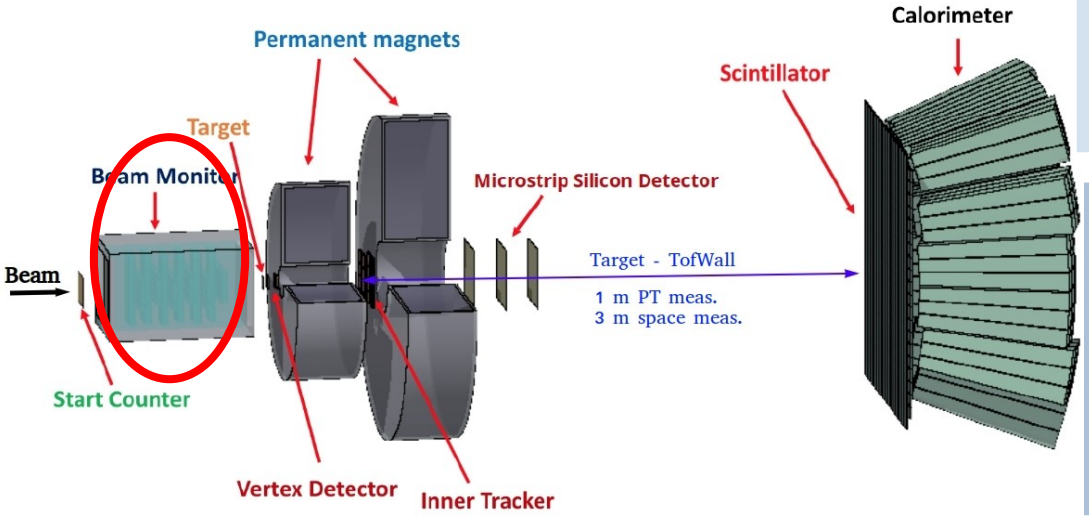
1st Workshop – Trento proton beam line facility

Yunsheng Dong

Università degli studi di Milano, INFN sezione di Milano

The FOOT (FragmentatiOn Of Target) experiment





FOOT aims to measure the nuclear fragmentation cross sections relevant in PT and space radioprotection.

The data will be adopted:
- **as benchmark for the MC tools**
- **to improve the current TPS**
- **to develop new shielding materials**

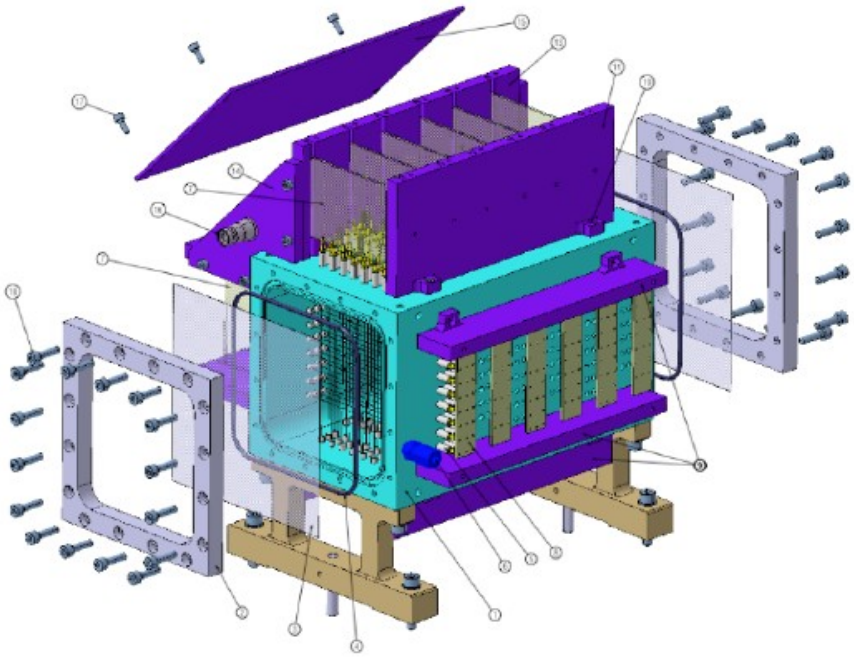
Emulsion spectrometer:

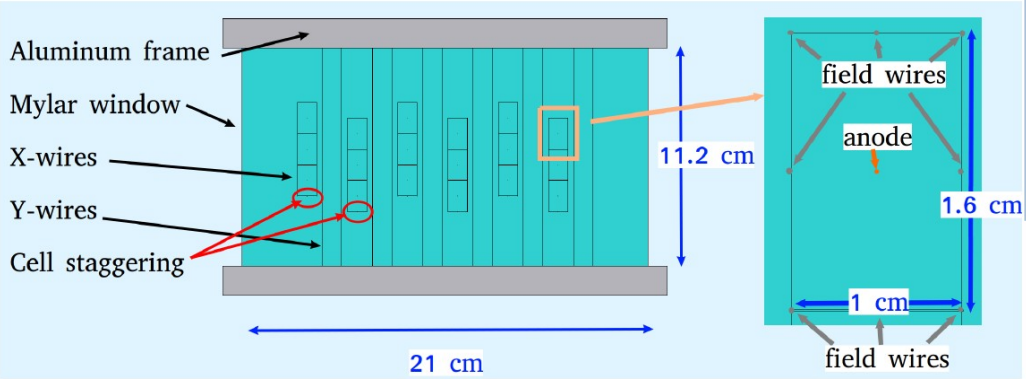
- $Z \leq 3$ and $\theta < 70°$
- Emulsion technology from the OPERA exp.
- A compact detector composed of emulsion, target and absorber material layers.

Electronic spectrometer:

- $Z \geq 3$ and $\theta < 10°$
- Composed of different sub-detectors
- To measure the fragments TOF, momentum, dE/dx and kinetic energy

The Beam Monitor detector



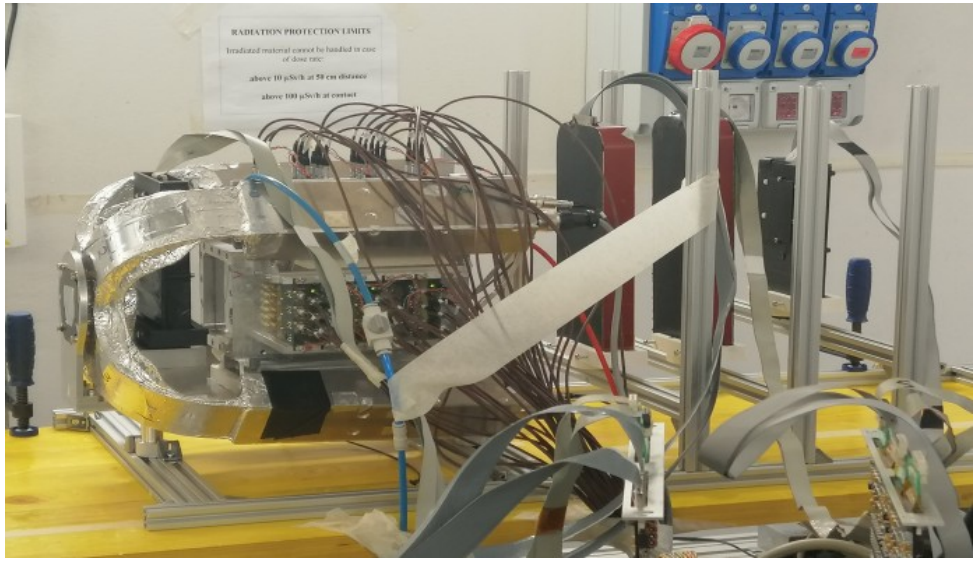


The detector goal is to measure the beam direction and position

Detector specs:

- Dimensions: 11.2 cm x 11.2 cm x 21 cm
- 6 staggered layers of cells on X and Y view
- Each layer composed of 3 rectangular cell (16 mm x 10 mm)
- 2 mylar windows at beam entrance and exit
- Filled with Ar/CO_2 at 80/20%
- 0.9 atm overpressure

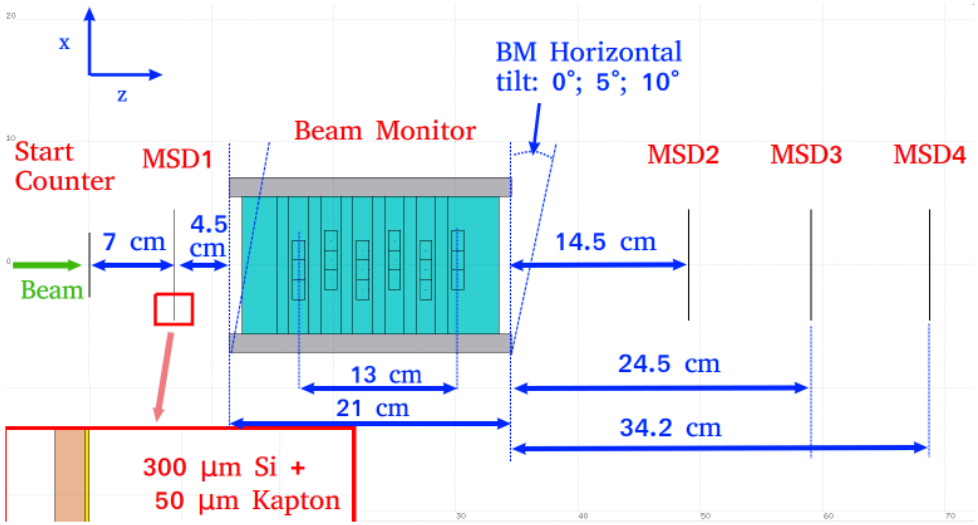
BM characterization @ Trento



The BM has been characterized by means of an external independent tracking detector

Goals:

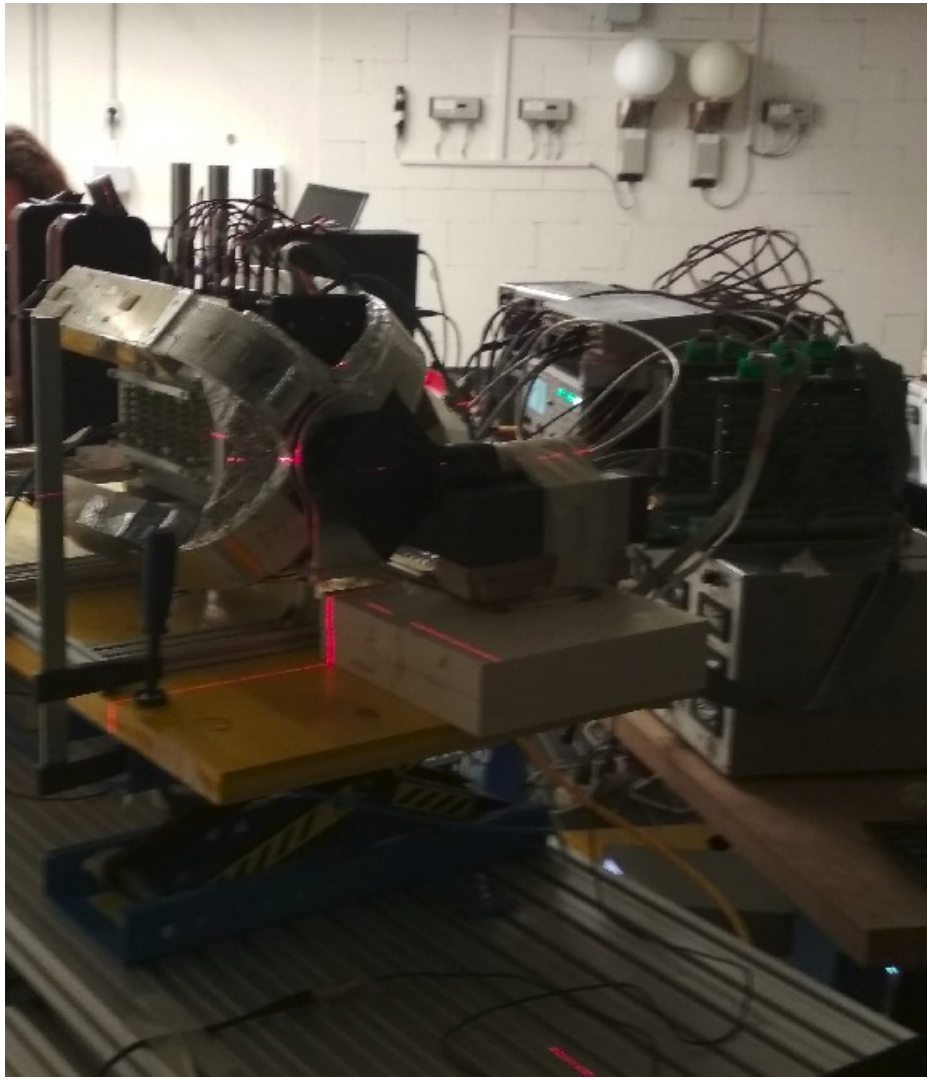
- Calibration of the BM space-time relations
- Efficiency
- Resolution



Experimental setup:

- Plastic scintillator for trigger and BM time ref.
- BM tilted horizontally at 0°, 5° and 10°
- 4 layers of micro-strip silicon detectors with a mean resolution of 45 µm
- Proton beams at 228 and 80 MeV

Space and beam time availability



Materials inside the experimental rooms:

- Detectors (BM, Start Counter and MSD)
- 3 Crates with different modules
- 1 delay box
- 2 laptop and 2 desktop pc
- Ar/CO2 80-20% gas bottle

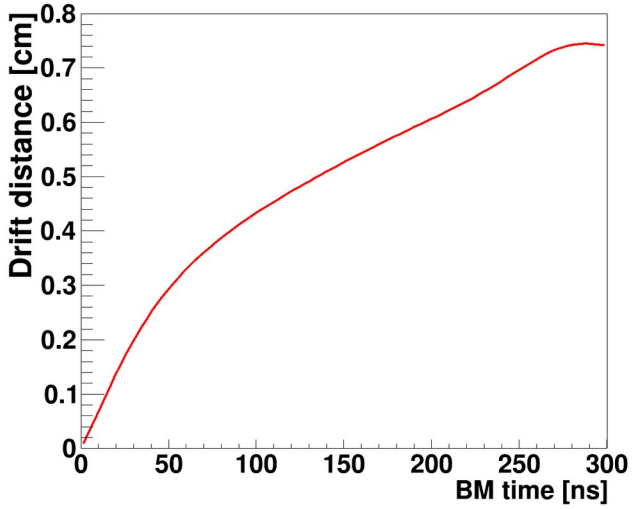
The space availability was sufficient to place all the required materials

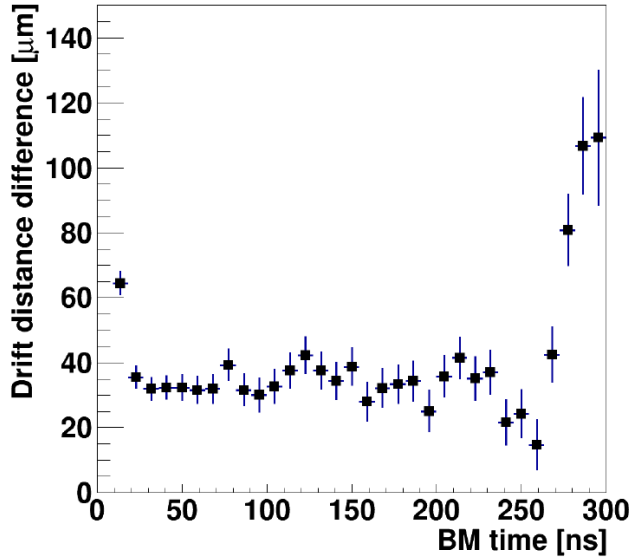
Beam time:

- 3 days of data taking ~ 9 hours
- Acquisition rate 300 Hz
- Total number of collected events ~ $2 \cdot 10^6$

The beam time was just sufficient to perform the calibration. Maybe the possibility of a longer shift after 22.30 would be helpful

Space-time relations calibration





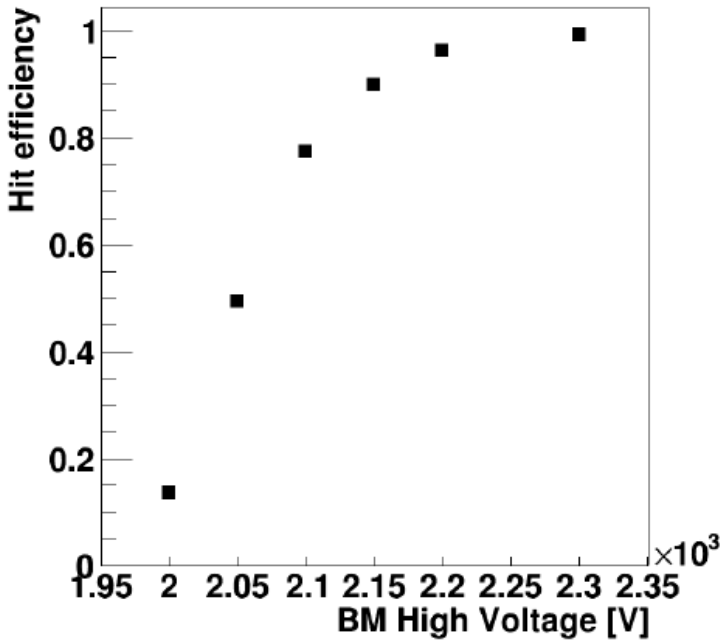
Calibration method:

- Exploits the 228 MeV proton to minimize the Multiple Coulomb Scattering (MCS)
- Uses a previous set of space-time relations to reconstruct the BM tracks and align the detectors
- Combines the BM time measurements with the MSD projected distances

New space-time relations evaluated

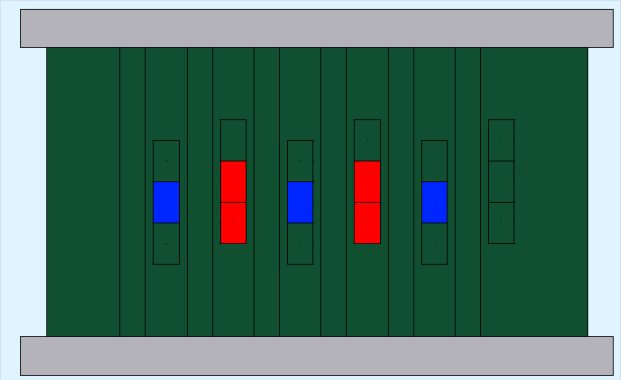
No relevant changes btw 228 and 80 MeV results

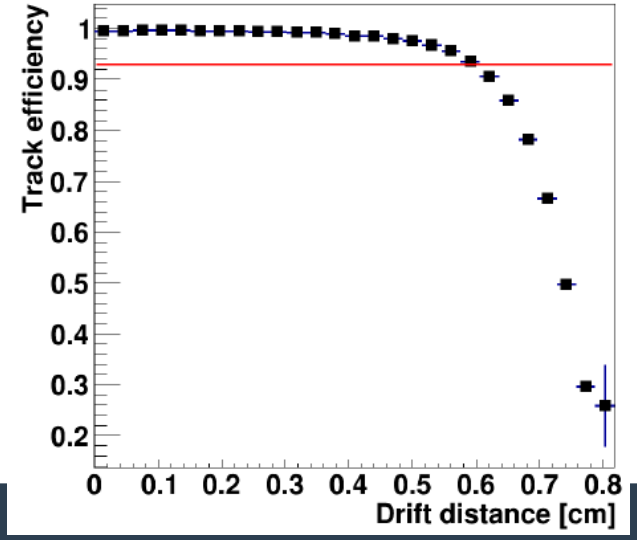
Efficiency



Hit efficiency = 0.929 ± 0.008 (HV=2200 V)

Fraction of events with one or two hits detected on even (odd) planes, when three single hits on odd (even) planes have been scored



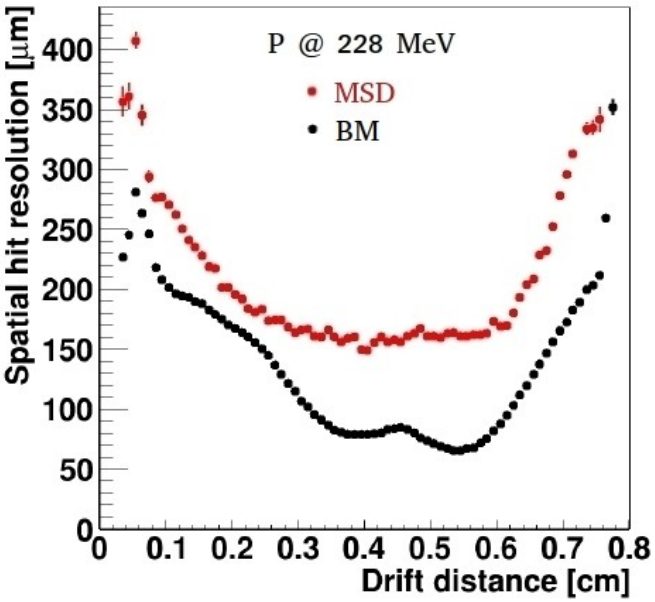


Efficiency as a function of the drift distance:
Propagate the MSD tracks into the BM cells to check the presence of a BM hit

The BM is inefficient at the cell border

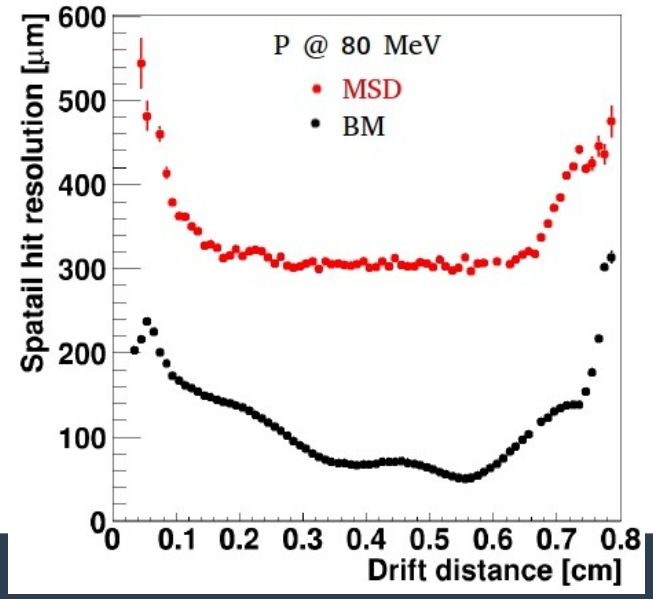
Inefficiency partially compensated by the cell staggering

Spatial resolution



BM track method:
Residual between the BM tracks and the BM hits.

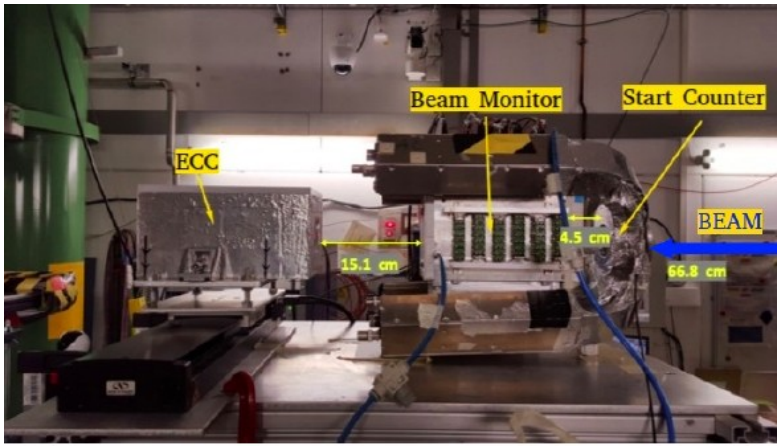
- Uses only BM hits and tracks
- Depends on the BM reconstruction algorithm
- **Multiple Coulomb Scattering negligible**
- **Measures the detector upper limit**
- **Resolution: 60 – 100 μm**
  (in the central part of the cell)



MSD track method**:**
Residual between the MSD tracks and the BM hits

- External independent detector
- Independent from the BM reconstruction algorithm
- **Multiple Coulomb scattering included**
- **Resolution: 150 μm (228 MeV) and 300 μm (80 MeV)**
  (in the central part of the cell)

Conclusions and future perspectives



The calibration and performance assessment of the BM has been successfully conducted at the Trento proton beam line facility
https://doi.org/10.1016/j.nima.2020.164756

FOOT 2019-2020 data takings

- Emulsion data taking @ GSI
  with C @ 700 MeV/u and O @ 200 and 400 MeV/u
- Electronic setup test @ GSI with O @ 400 MeV/u

Next step: new data taking at CNAO with C ions

- Electronic spectrometer: almost full geometry data taking with: SC, BM, VTX, Tof-Wall and a 3x3 module of the Calorimeter

  -Independent test of the MSD detector
- Emulsion spectrometer: data taking at CNAO with C ion beams

CNAO
Centro Nazionale di Adroterapia Oncologica

Back up

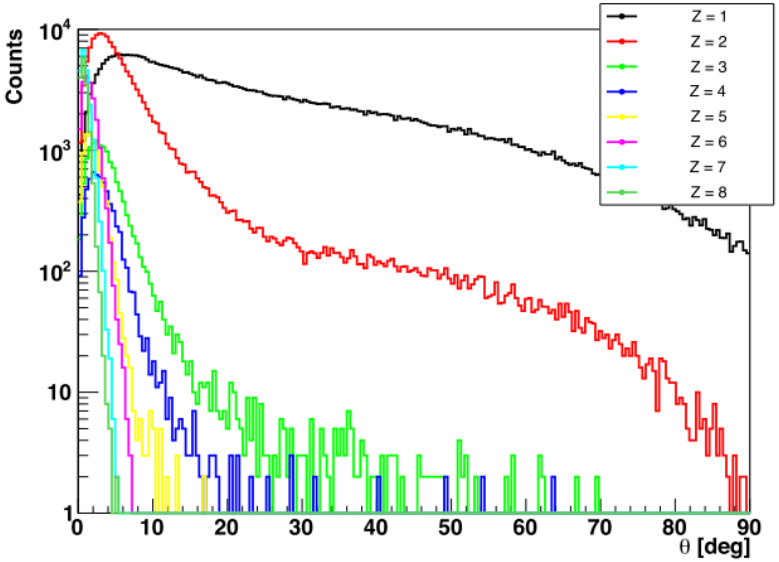
The FOOT (FragmentatiOn Of Target) experiment

FOOT aims to measure the nuclear fragmentation cross sections relevant in PT and space radioprotection

Radiobiological desiderata (from PT):

- dσ/dE for target fragm. in PT ~ 10%
- $d^2\sigma/d\Omega dE$ for projectile fragm. in PT ~ 5%
- Z ~ 2-3% ; A ~ 5%

Physics	Beam	Target	Energy (MeV/u)	Kinematic approach
Target fragm. in PT	^{12}C	C, C_2H_4	200	inverse
Target fragm. in PT	^{16}O	C, C_2H_4	200	inverse
Beam fragm. in PT	^{4}He	C, C_2H_4, PMMA	250	direct
Beam fragm. in PT	^{12}C	C, C_2H_4, PMMA	350	direct
Beam fragm. in PT	^{16}O	C, C_2H_4, PMMA	400	direct
Space Radioprotection	^{4}He	C, C_2H_4, PMMA	700	direct
Space Radioprotection	^{12}C	C, C_2H_4, PMMA	700	direct
Space Radioprotection	^{16}O	C, C_2H_4, PMMA	700	direct

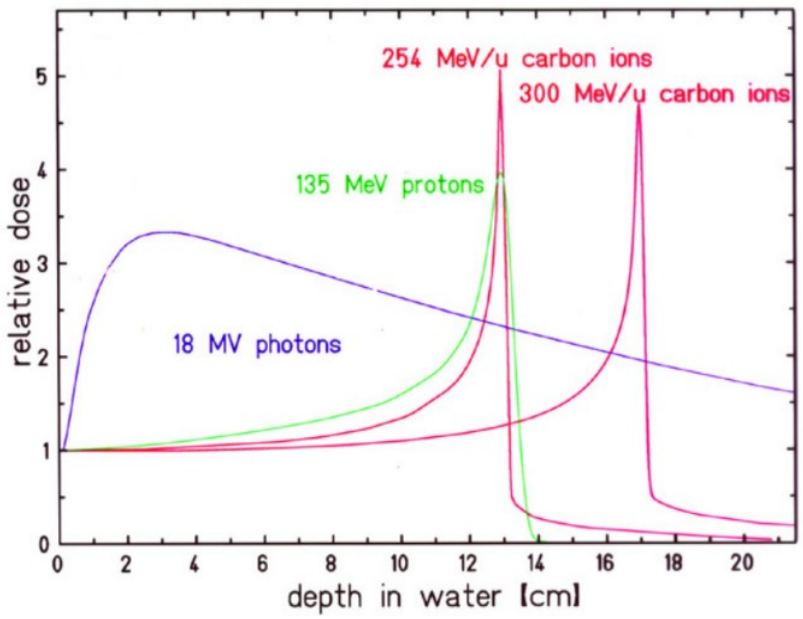


Two experimental setups:

- Emulsion spectrometer: Z≤3 and θ<70°
- Electronic spectrometer: Z≥3 and θ<10°

Particle therapy

A form of radiotherapy that uses hadrons for the treatment of solid tumours



Main properties:

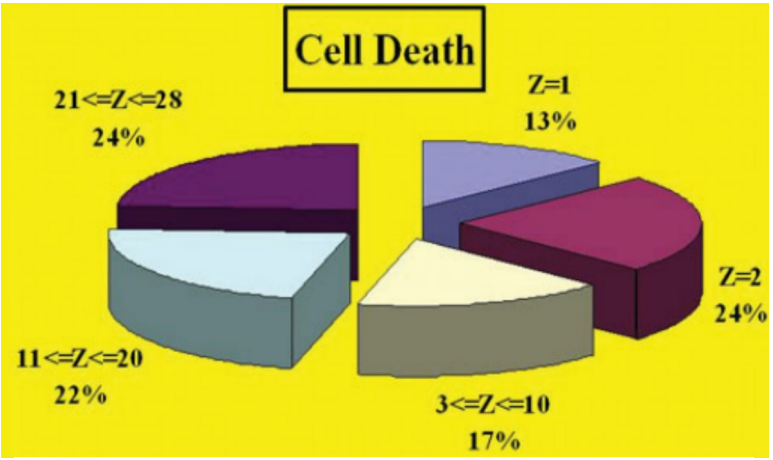
- Proton (50-250 MeV); Carbon ion (50-400 MeV/u)
- Max dose release in the Bragg peak
- Better dose conformation over the tumor volume with respect to conventional radiotherapy
- High biological effectiveness for heavy ion therapy

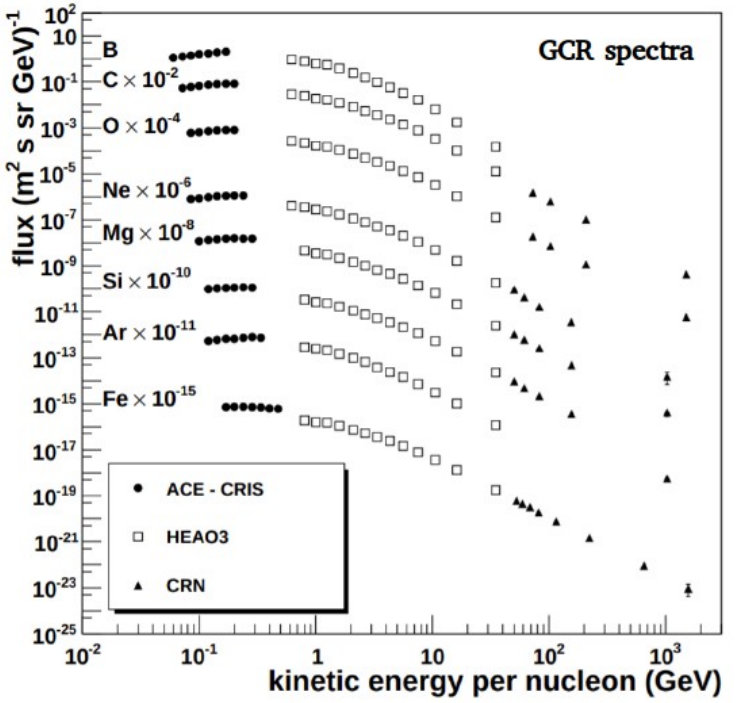
Nuclear interactions in PT:

- Target fragmentation in proton therapy
- Projectile fragmentation in heavy ion therapy

Need of differential cross section data to improve the treatments and study new PT ions

Radioprotection in space missions





Radiation hazard in future long term and far from earth space missions to the Moon and Mars:

- Galactic Cosmic Radiations:
  -Protons: ~85-90%
  -Helium ~10-14%
  -Heavy nuclei with Z>2: ~1%
  -Energies up to 10^{20} eV

- Solar Particles events:
  -Protons: ~90%
  -Helium: ~10%
  -Heavy nuclei with Z>2 ~1%.
  -Energies up to hundreds of MeV/u

The HZE (High Z and Energy) particles are the most dangerous

Need of nuclear interaction differential cross section data to optimize shielding design and strategy for shielding