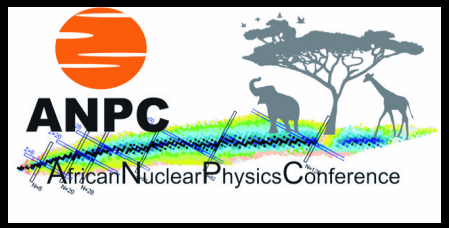


The FOOT experiment

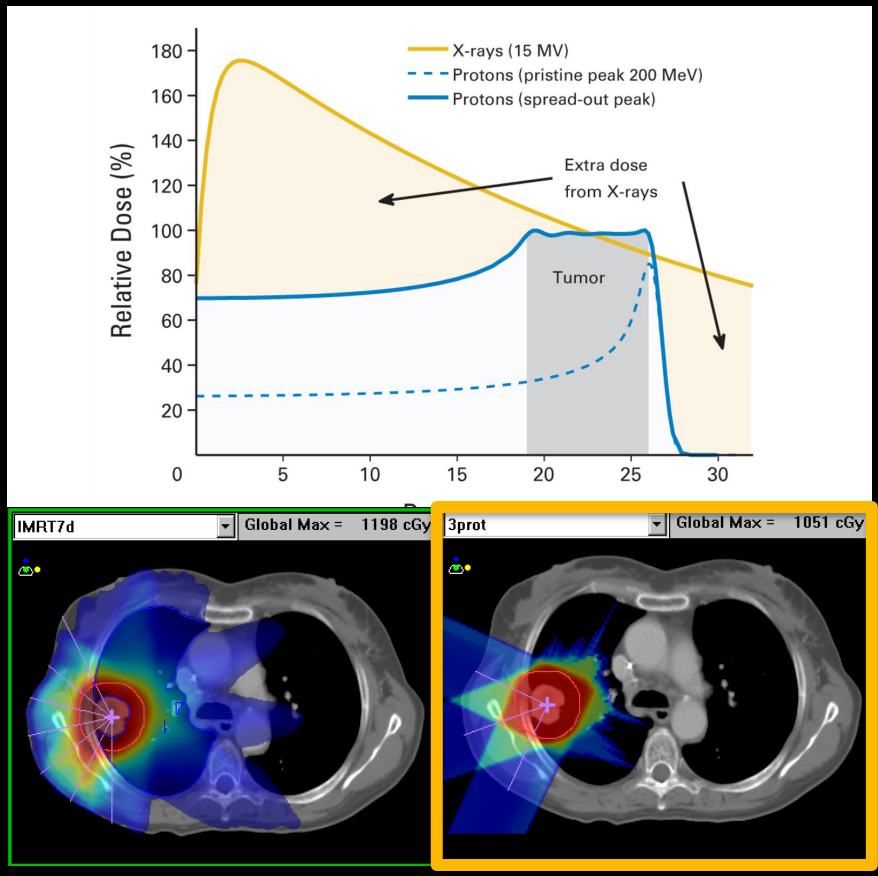
Measuring light nuclei fragmentation cross sections up to 700 MeV/A

INFN Piergiorgio Cerello
on behalf of the FOOT Collaboration

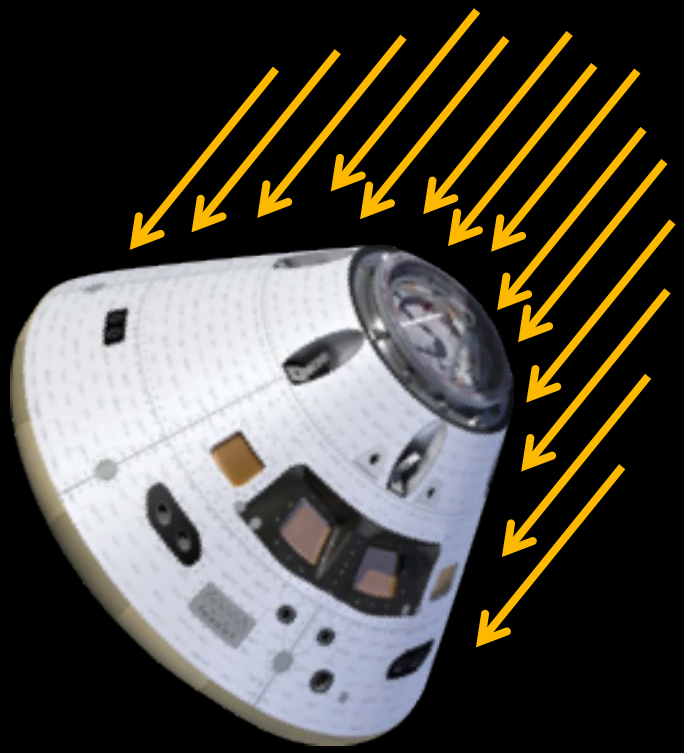
INFN

Why FOOT?*

Particle therapy



Spacecraft shielding

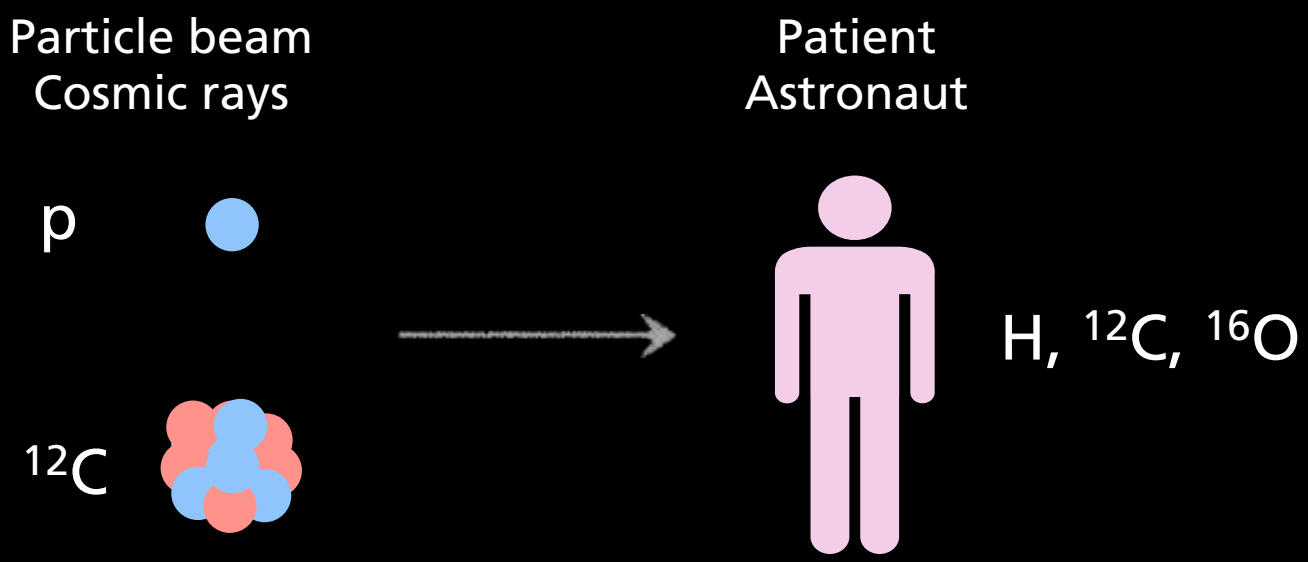


*addressed in Chiara La Tessa's talk, tomorrow morning

Fragmentation

Particle therapy

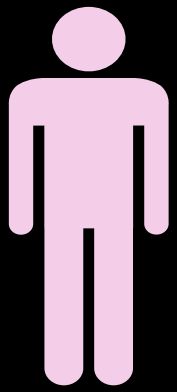
Spacecraft shielding



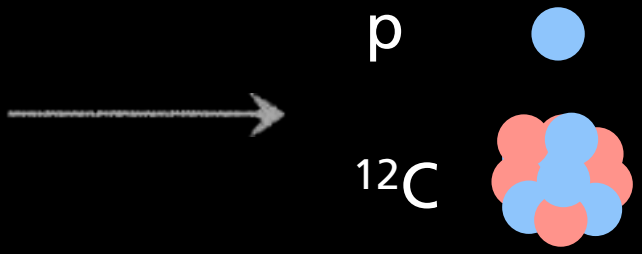
target* (& beam) fragmentation

*about 8% in particle therapy, definitely not negligible

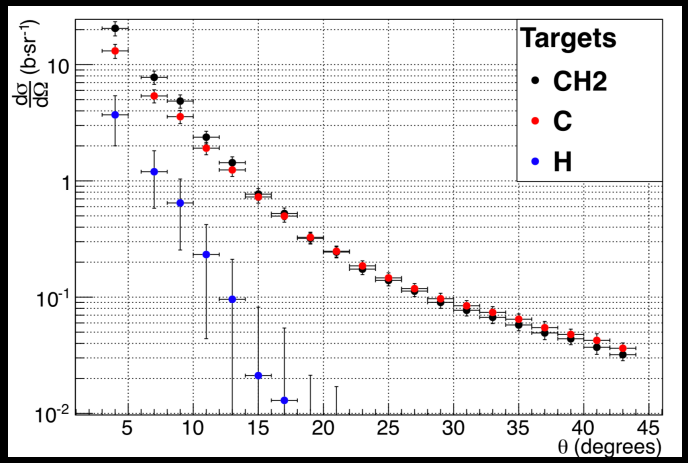
Inverse Kinematics



^{12}C, ^{16}O



C / C_2H_4 target



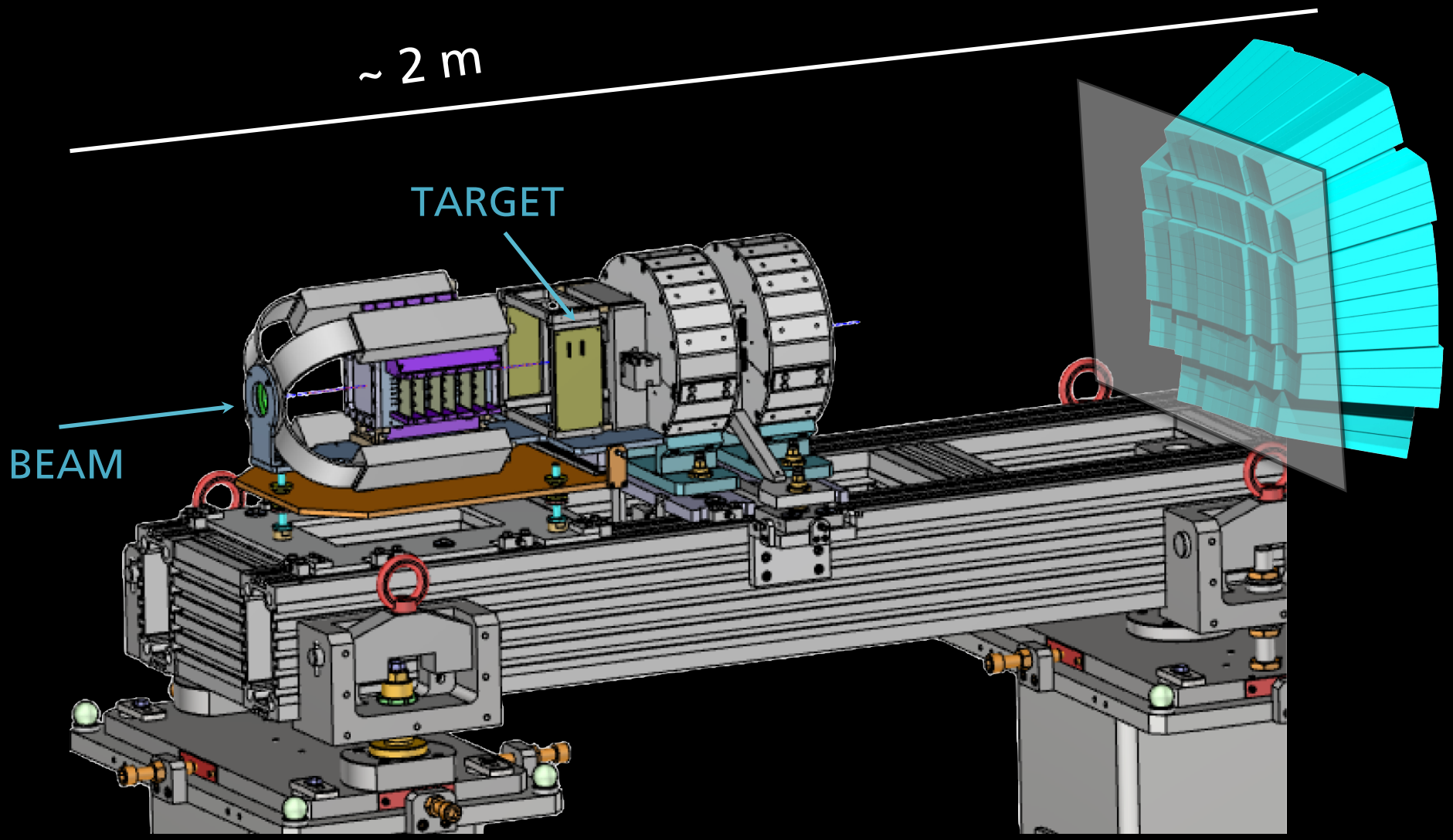
$\delta E_k/E_k < 2\%$

$\delta p/p < 5\%$

δ TOF < 100 ps

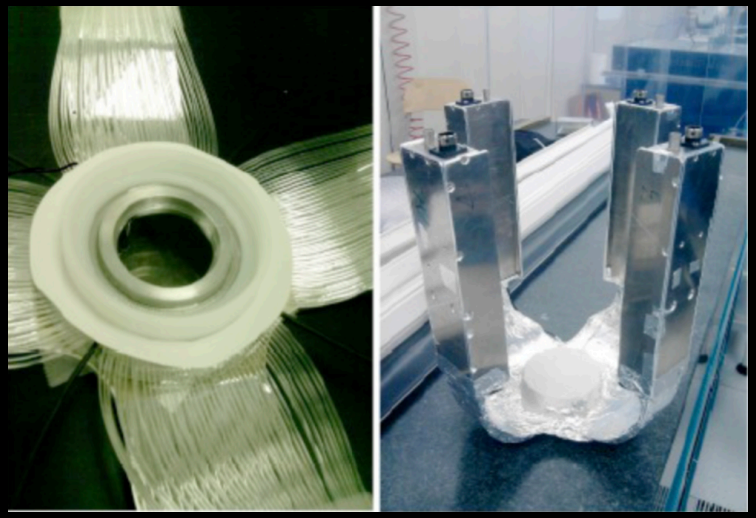
→ $5\% < \delta A/A < 10\%$ → $\delta (d\sigma/dE_k)/d\sigma/dE_k < 5\%$

The FOOT detector

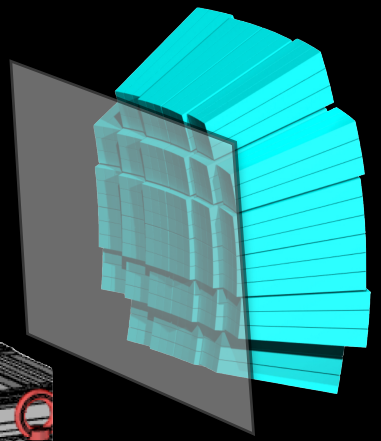


The FOOT start counter

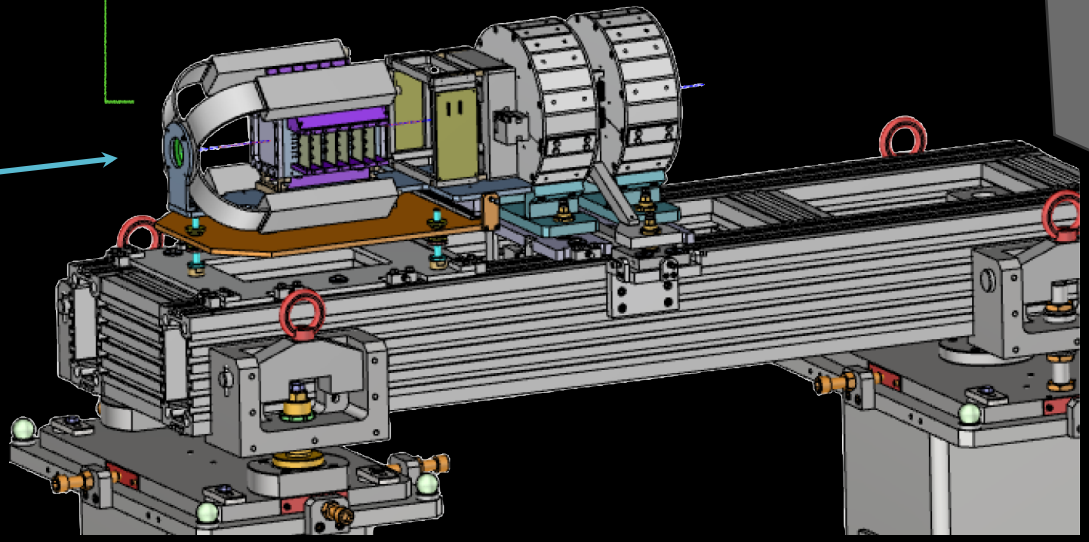
- Plastic Scintillator
- 50 mm radius
- 250 μm thicness
- Readout: 4 PMTs w/ 400 optical fibers



- Trigger
- TOF Start



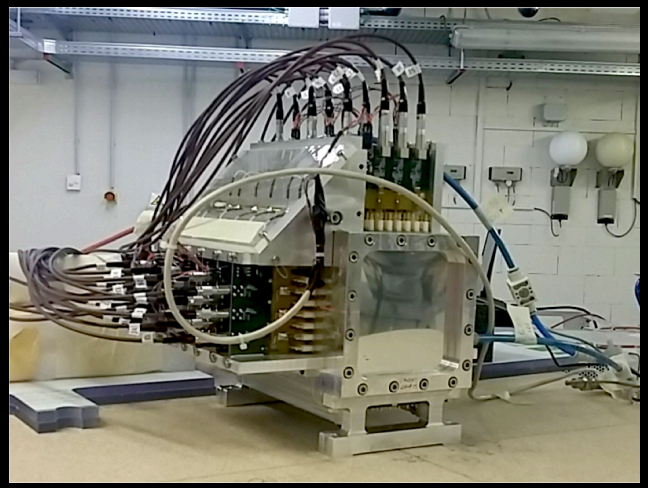
BEAM

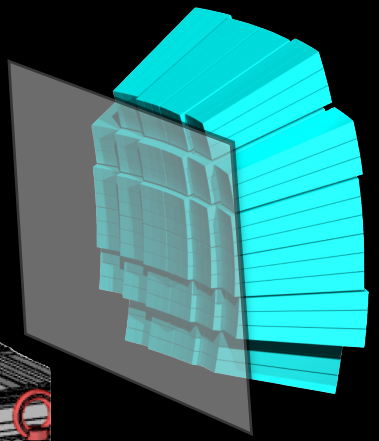


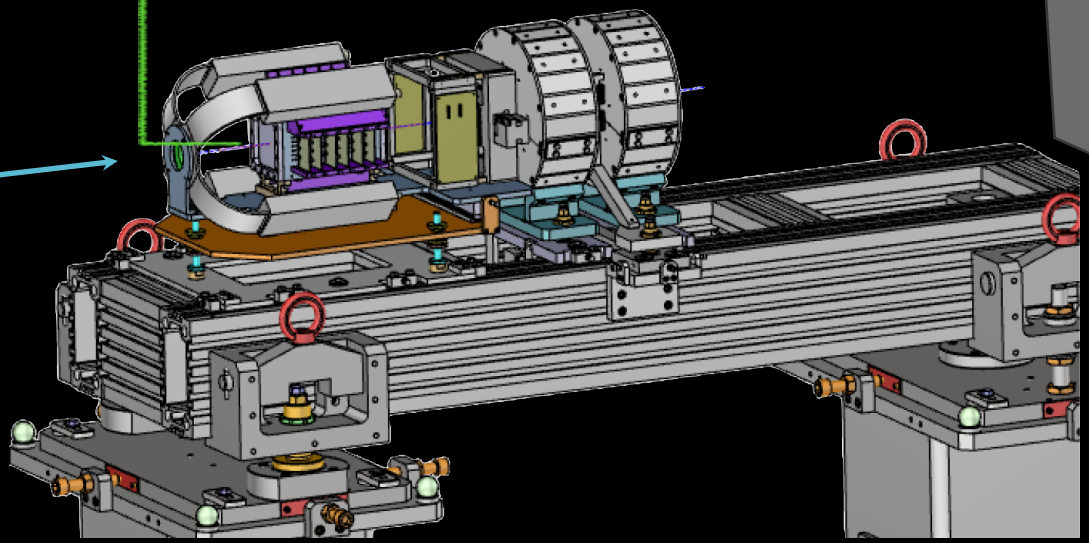
The FOOT beam monitor

- Beam direction

- Drift chamber
- Ar/CO_2 (80/20)

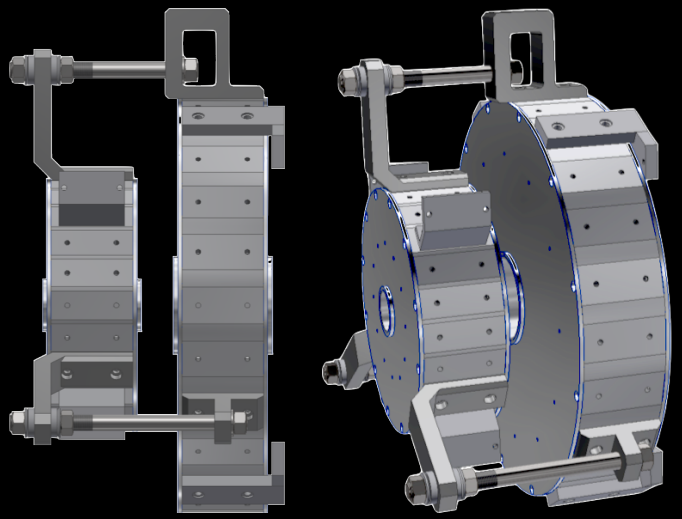




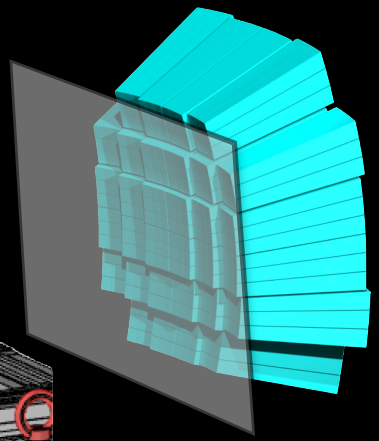


BEAM

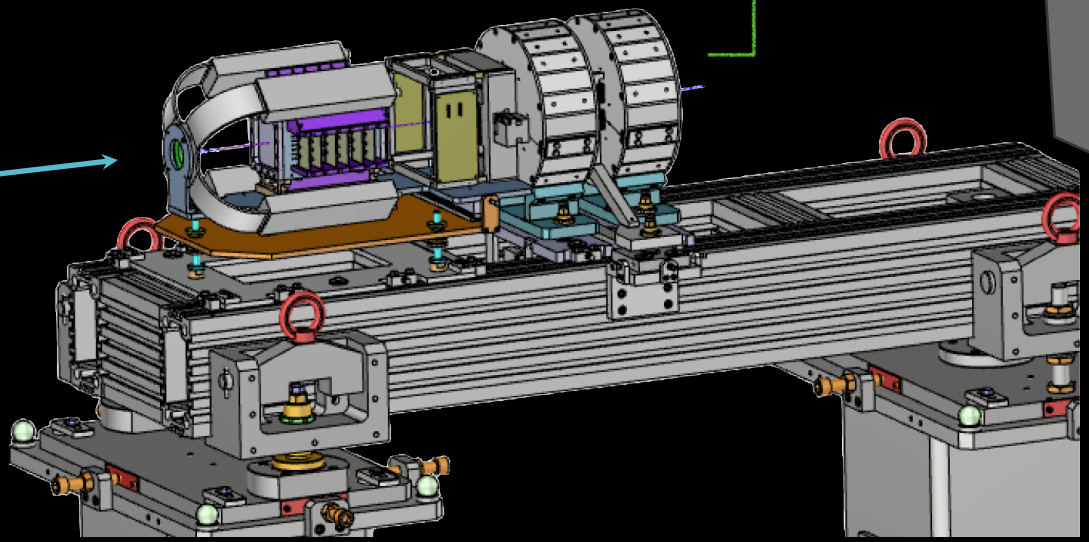
The FOOT magnets



- Permanent Halbach magnets
- B = 1.1 T



BEAM



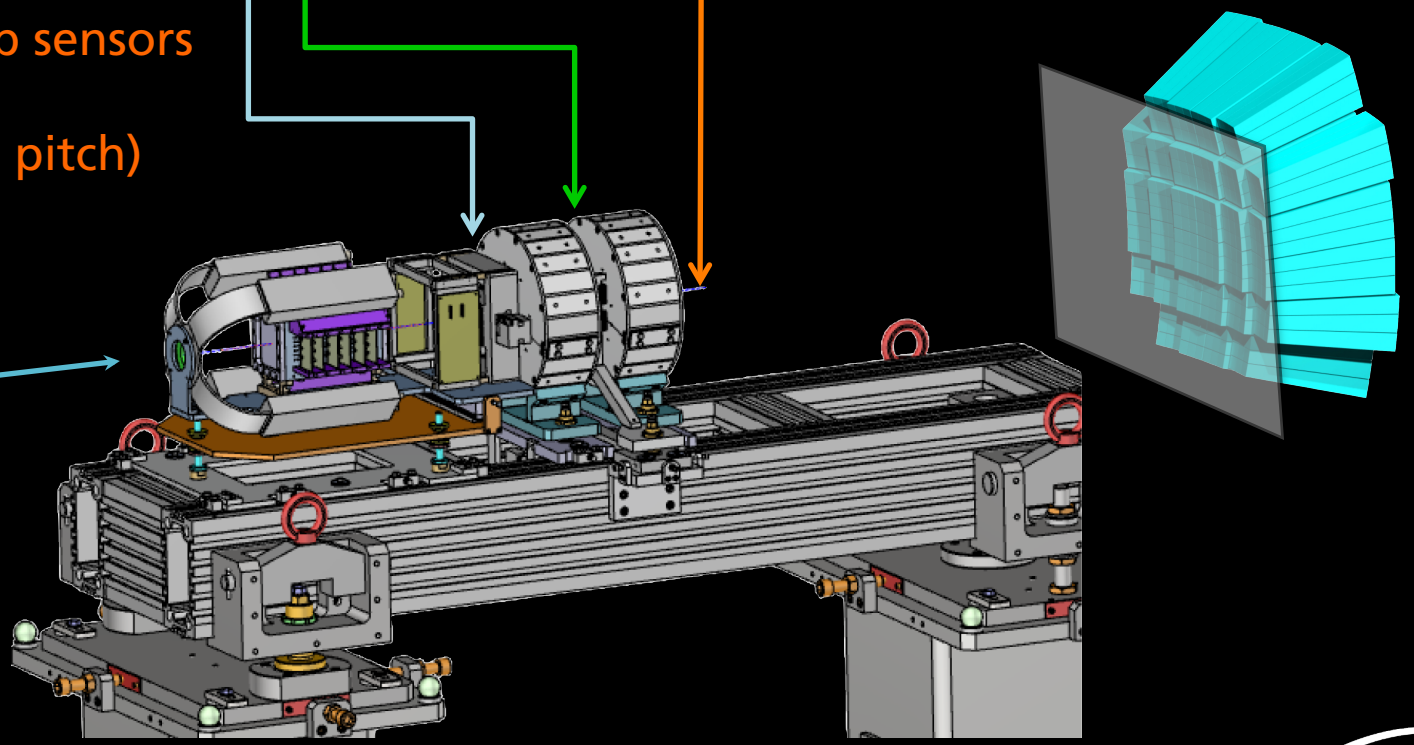
The FOOT silicon tracker

4 layers of Si pixel sensors before magnets
(20x20 μm pitch)

2 layers of Si pixel sensors between magnets
(20x20 μm pitch)

3 layers of Si strip sensors after magnets
(120 μm pitch)

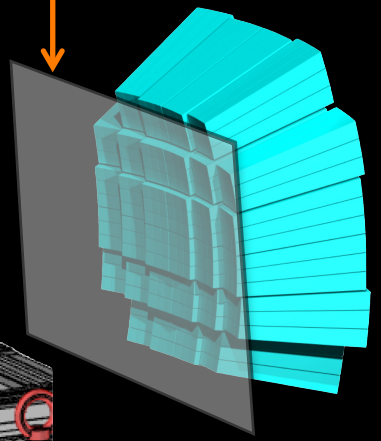
- charge
- momentum



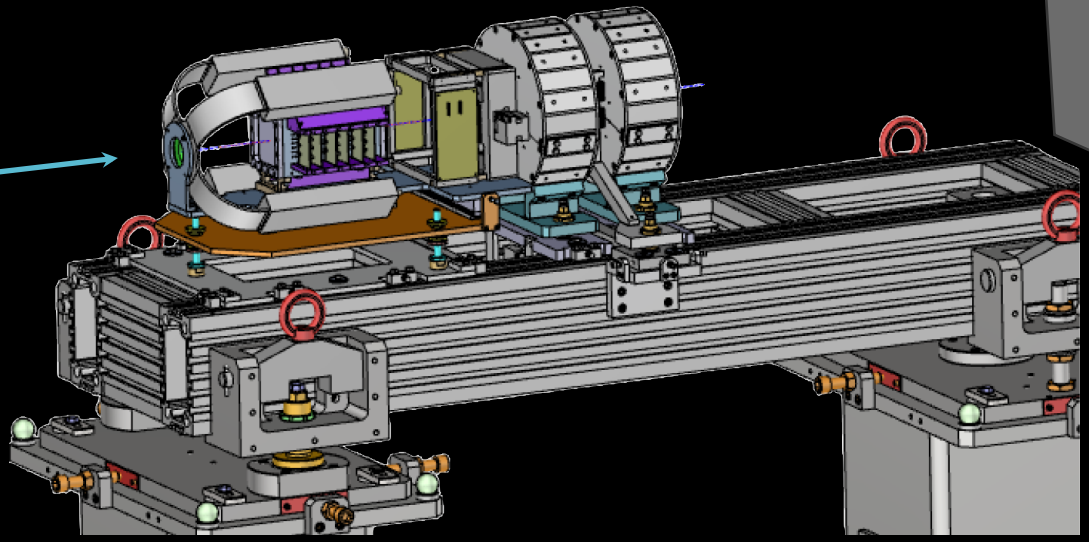
The FOOT TOF wall

- 2 layers x 20 bars of plastic scintillator
- 2 x 40 cm^2, 2-3 mm thickness
- readout w/ SiPMs

- dE/dx
- TOF Stop
- Z



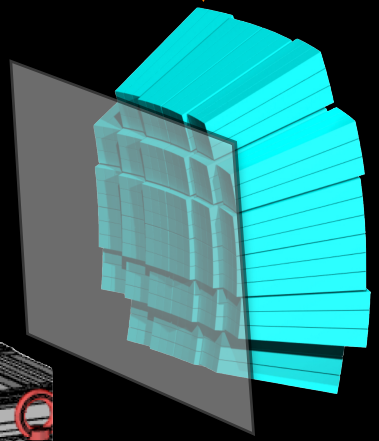
BEAM



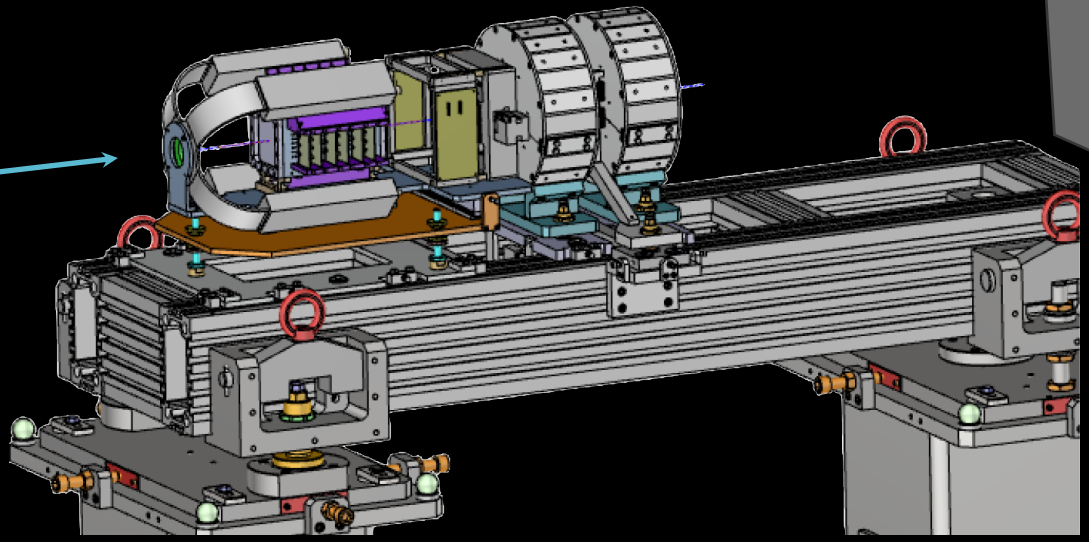
The FOOT calorimeter

- 330 BGO ($Bi_4Ge_3O_{12}$) crystals
- readout w/ SiPM arrays (1 ch/crystal)
- total weight ~ 400 Kg

- E_{kin}



BEAM

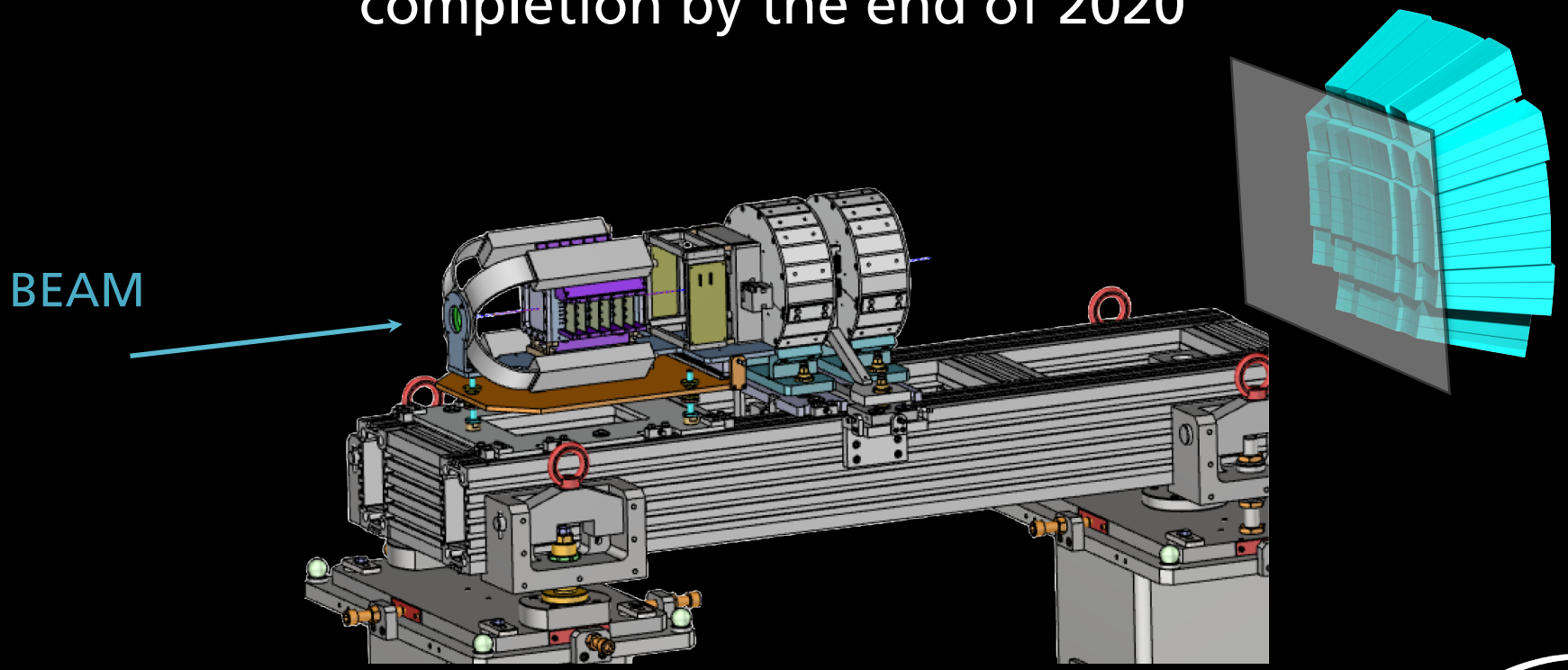


FOOT status

Magnets
Silicon tracker
Calorimeter

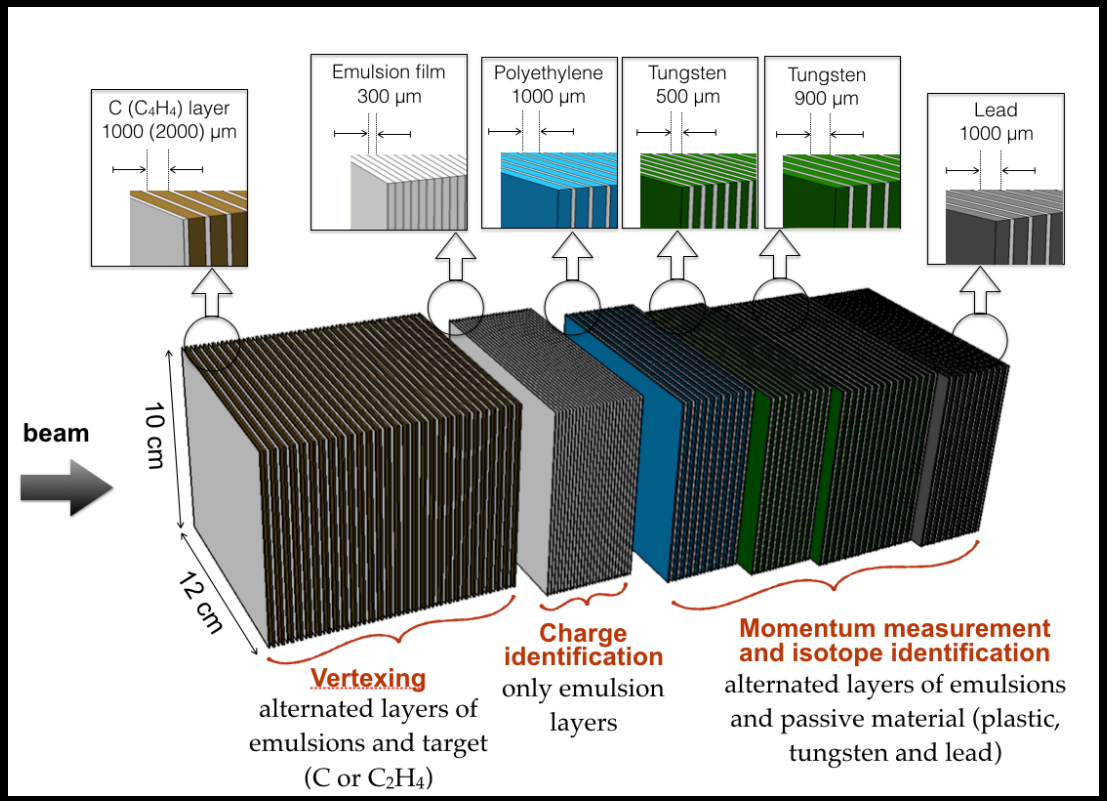
} under construction

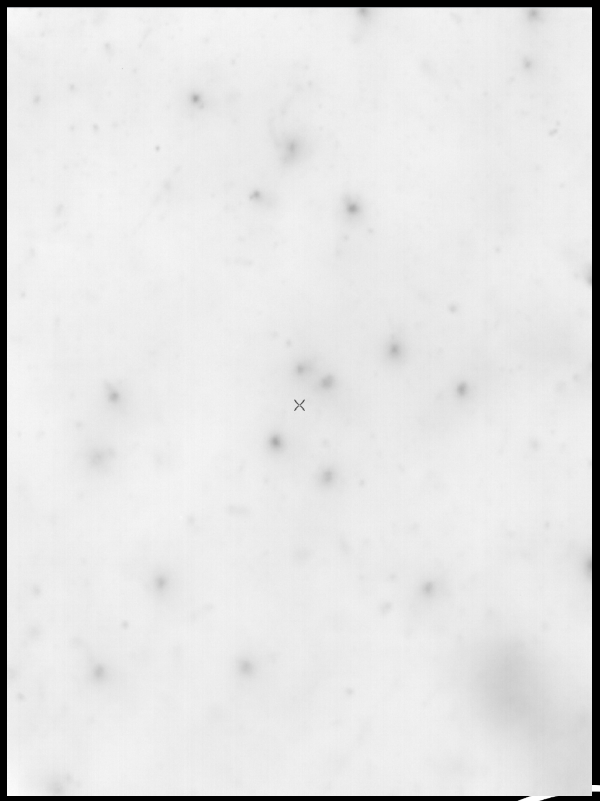
completion by the end of 2020



FOOT: the emulsion setup

Target	Beam
Carbon	Oxygen 200 MeV/A
Polyethylene	Oxygen 400 MeV/A

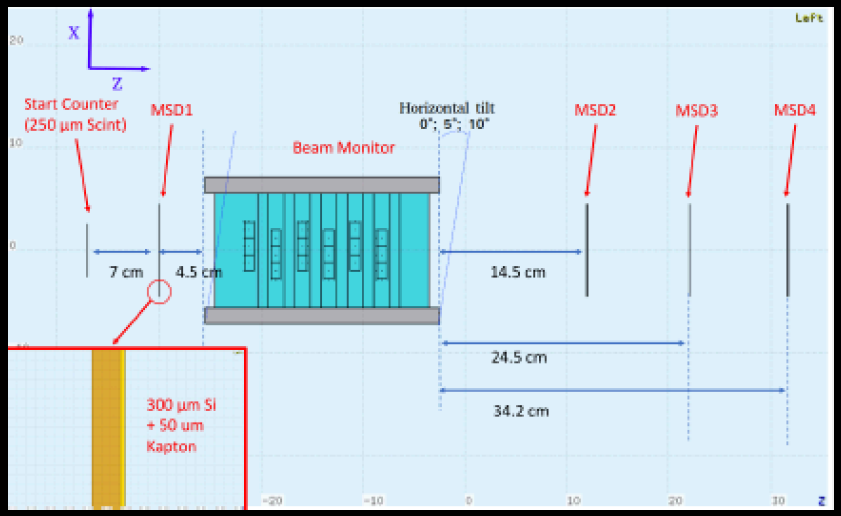


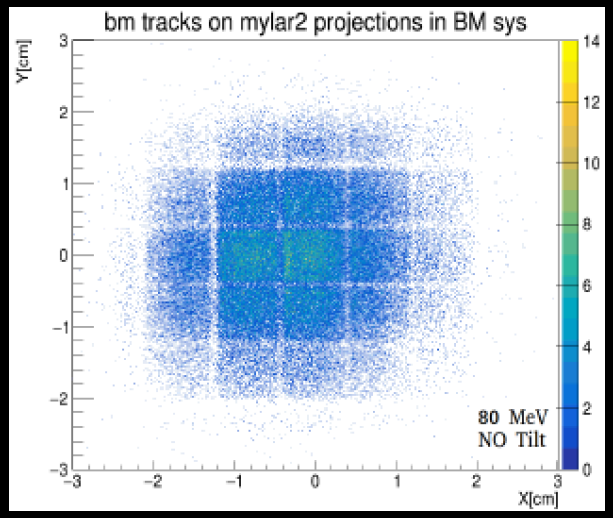


FOOT: beam monitor status

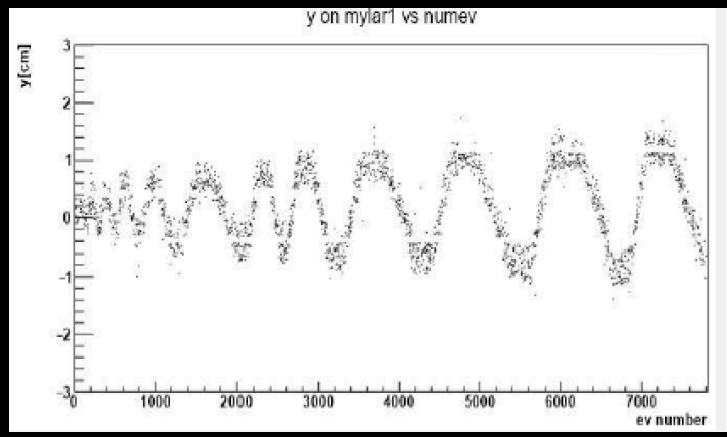
2019 GSI data taking

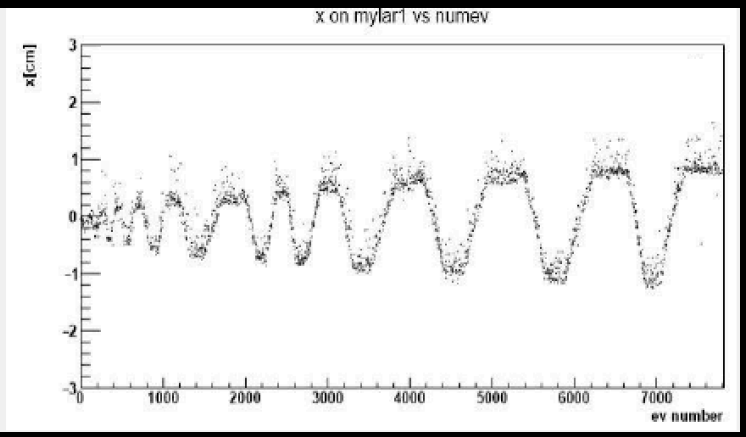
electronic layout





emulsions layout

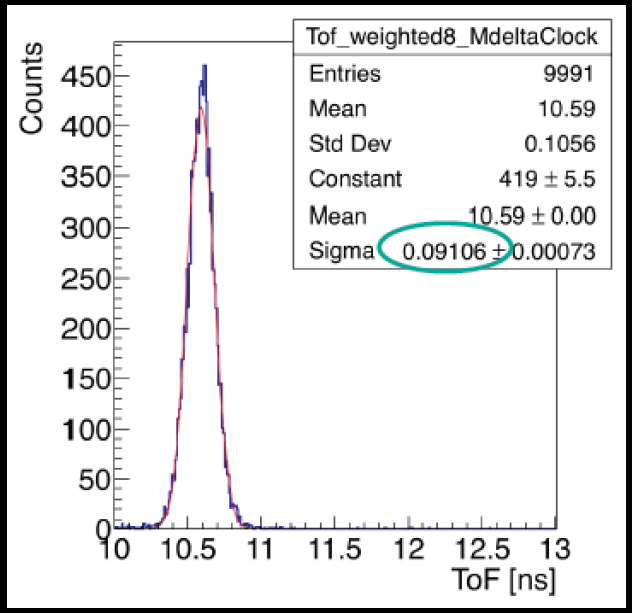




FOOT status: ToF resolution

Carbon beams: 115 – 280 MeV/A

Oxygen beam: 400 MeV/A

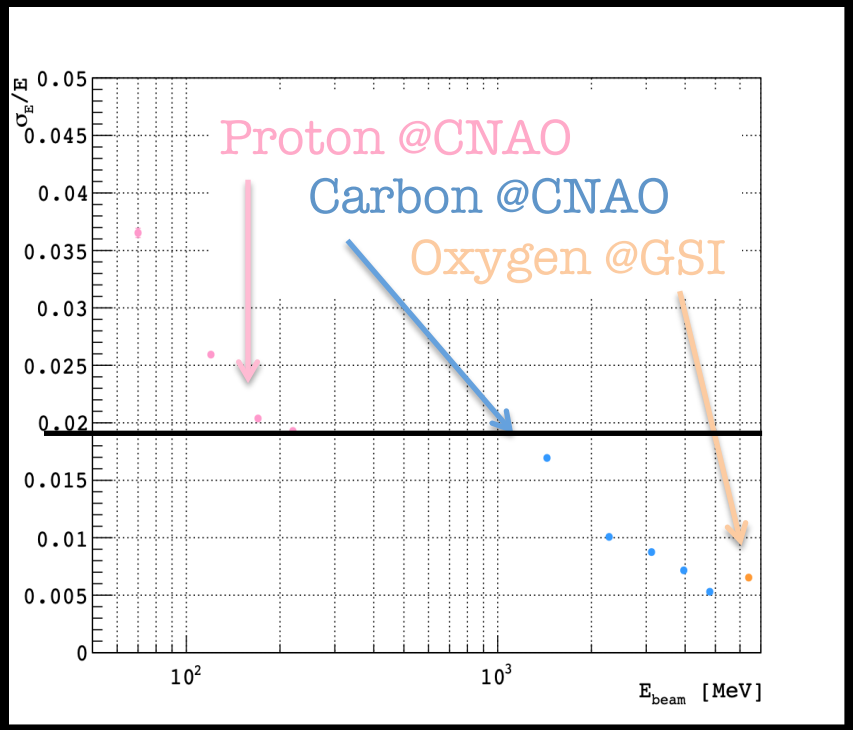


Ion	Energy [MeV/n]	σ(ToF) [ns]
^{12}C	115 MeV/n	0.091 ns
	151 MeV/n	0.095 ns
	221 MeV/n	0.103 ns
	280 MeV/n	0.108 ns
^{16}O	400 MeV/n	0.085 ns

FOOT: calorimeter status

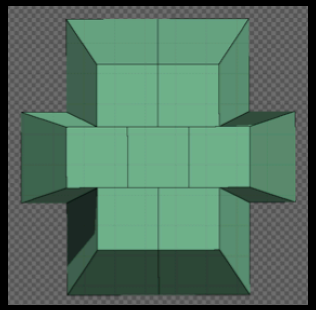
Energy resolution in a Calorimeter BGO crystal
p and ^{12}C at CNAO (Pavia, Italy) and ^{16}O GSI

Resolution ≤ 2% with
reflective paint and
15μm pitch of SiPM



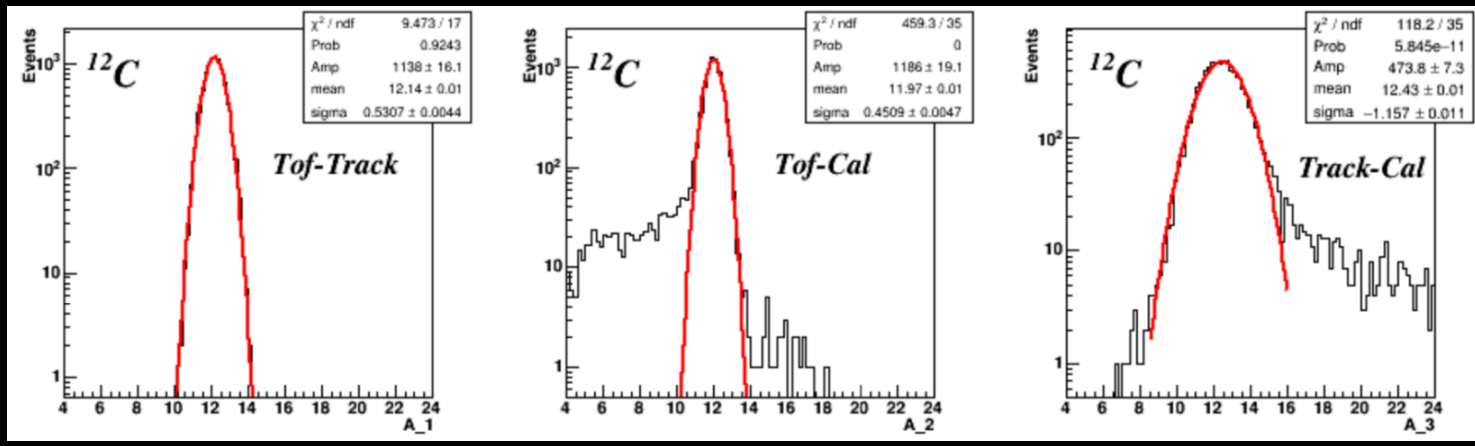
First module under construction

- Mechanics
- Front-end / readout
- DAQ



FOOT: mass reconstruction

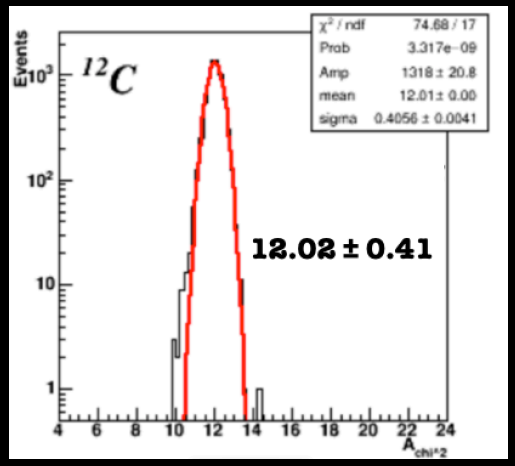
Δ E/E ~ 1.5%
Δ p/p ~ 4%
Δ TOF ~ 70-140 ps
Δ dE/dE ~ 3-10%



M = 12.11 ± 0.67 M = 11.93 ± 0.37 M = 12.4 ± 1.4

17% of fragments produce neutrons
in the calorimeter that escape the detector

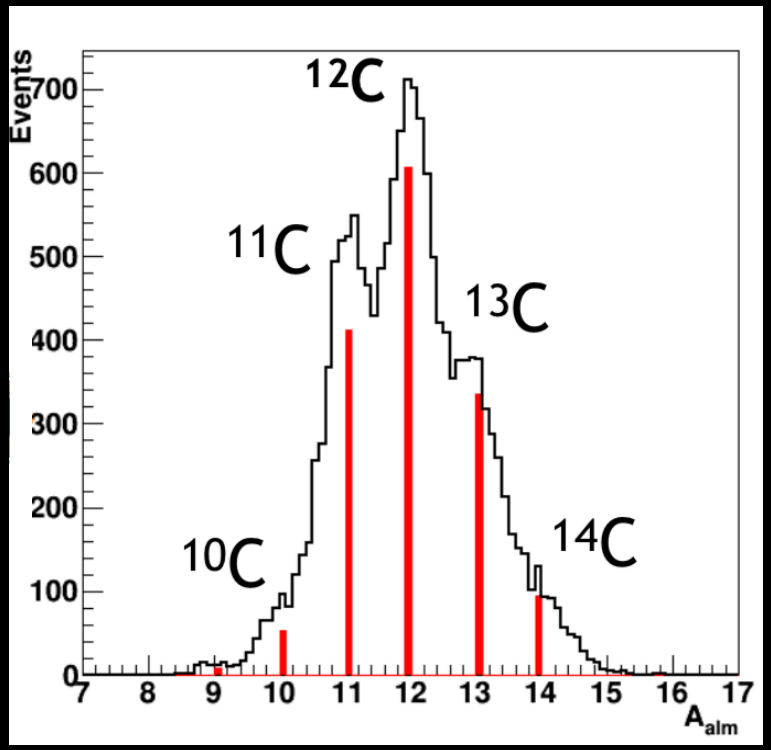
M = 12.02 ± 0.41

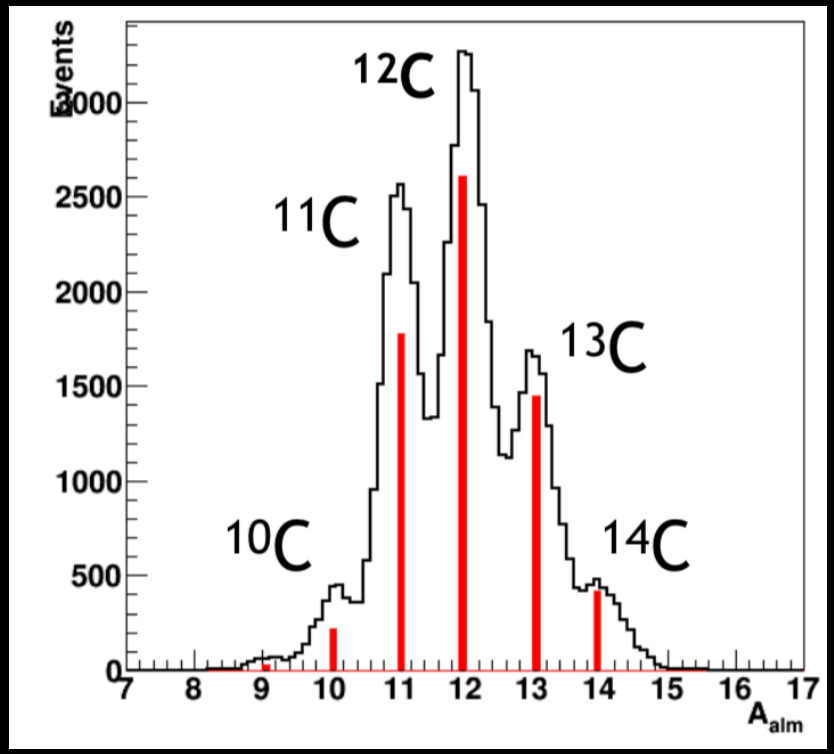


FOOT: mass reconstruction

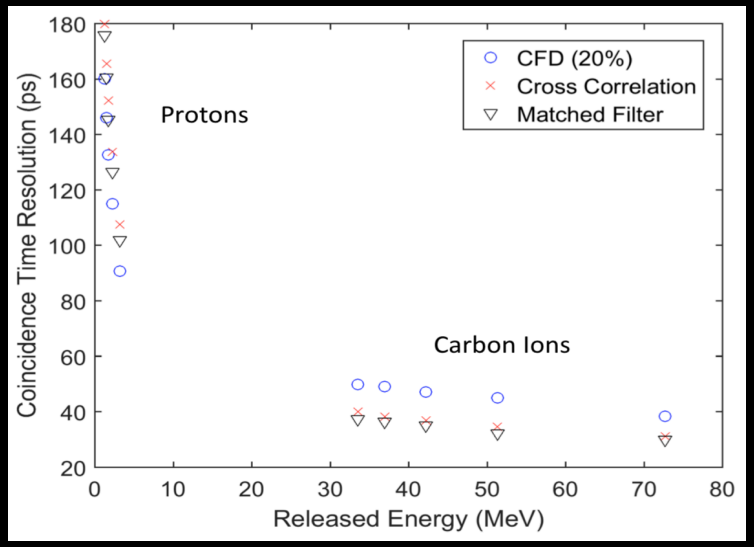
Δ E/E ~ 1.5%
Δ p/p ~ 4%
Δ TOF ~ 140 ps
Δ dE/dE ~ 3-10%

Δ E/E ~ 1%
Δ p/p ~ 4%
Δ TOF ~ 100 ps
Δ dE/dE ~ 3-10%





FOOT: expected performance

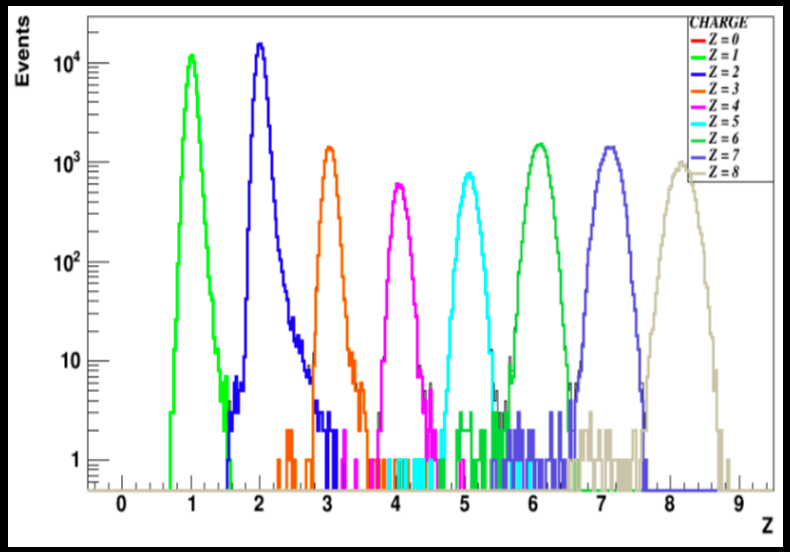


TOF and Start counter test at CNAO

- σ_t ~ 90 - 160 ps
  (50 – 220 MeV protons)
- σ_t ~ 40 - 50 ps
  (120-400 MeV/A carbons)

From FLUKA simulations & σ_t measured at test beam

- 2% < σ_z < 6% for ^{16}O and ^{1}H respectively
- misidentification ≤ 1%



the FOOT program

(as of now)

Beam	Energy (MeV/A)	Targets	Fragmentation	Application
^{12}C, ^{16}O	200	C, C_2H_4	Target	Particle therapy
^{4}He, ^{12}C, ^{16}O	350	C, C_2H_4, PMMA	Projectile	Particle therapy
^{4}He, ^{12}C, ^{16}O	700	C, C_2H_4, PMMA	both	Radio-protection in Space

Timeline: data taking with the full detector from 2021 @ GSI, CNAO

the FOOT Collaboration

FOOT (**F**ragmentati**O**n **O**f **T**arget)

about 100 members:

- 10 INFN units
- 3 laboratories
  CNAO, GSI, IPHC
- 14 universities
  12 Italy + 1 Japan (Nagoya) + 1 Germany (Aachen)