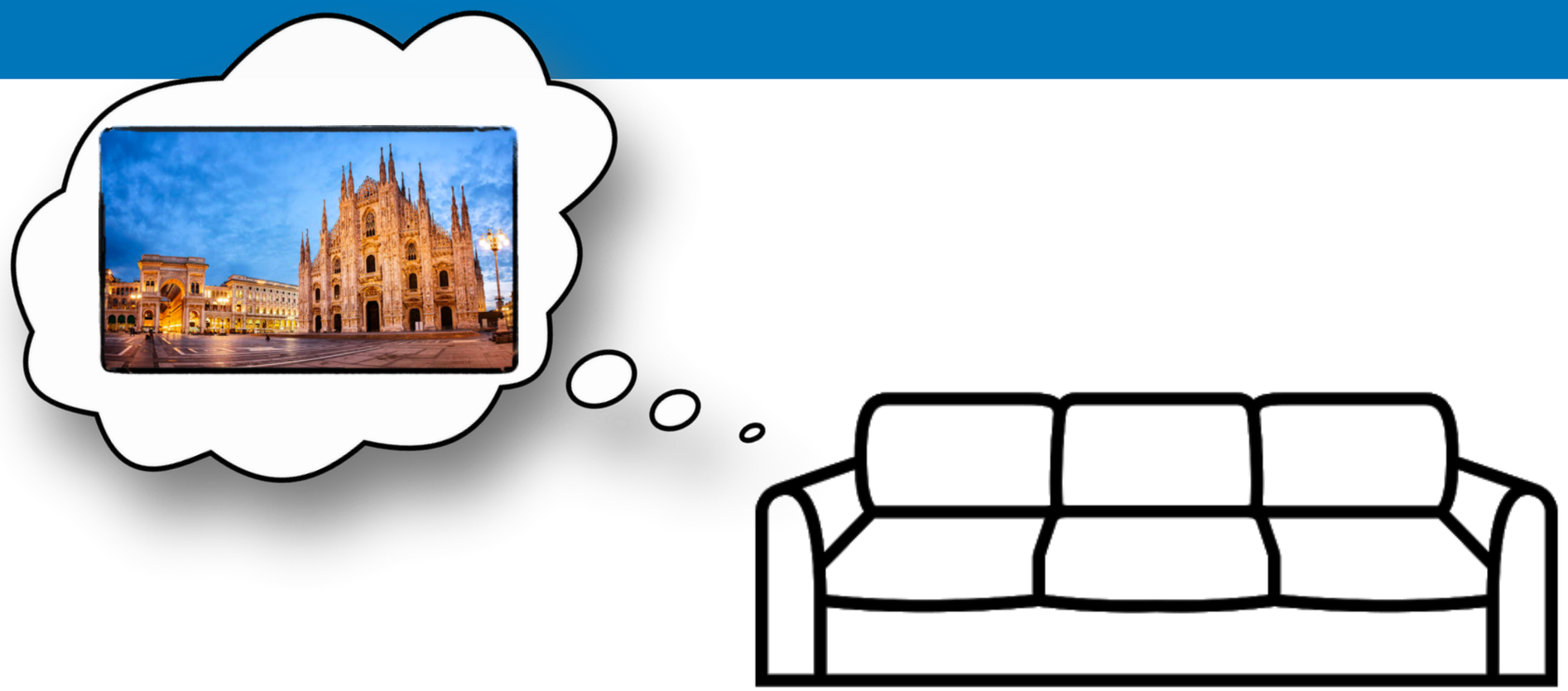
14.09.2020 Milan, Italy

Design and performance of the Calorimeter for the FOOT experiment



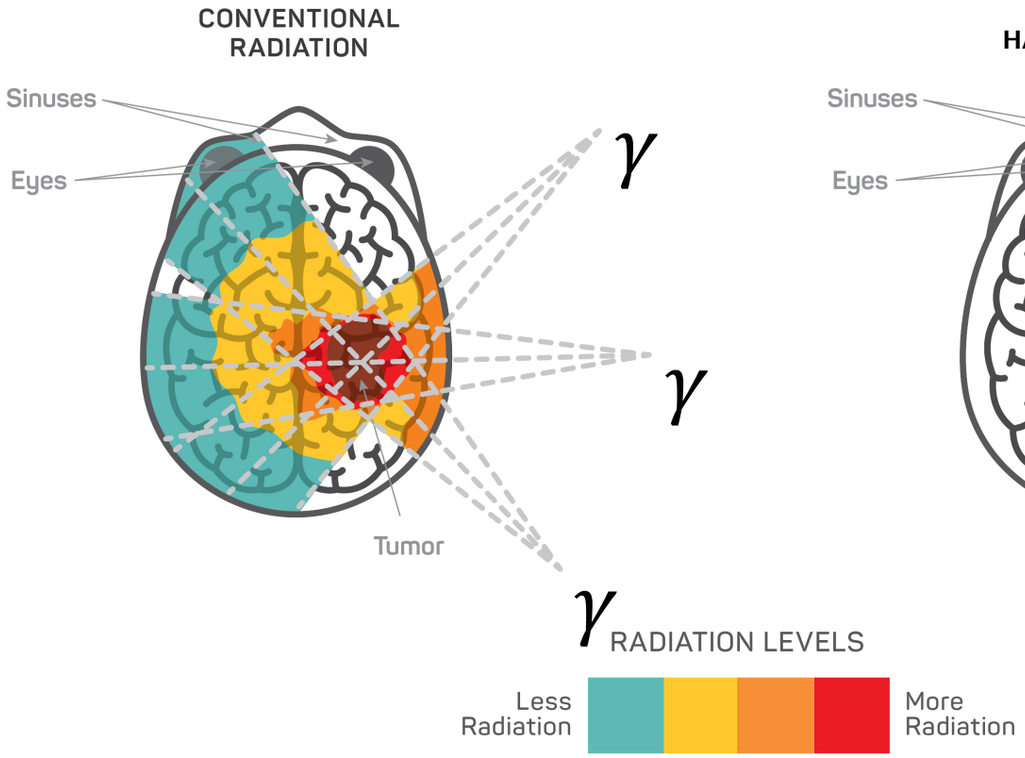
Lorenzo Scavarda

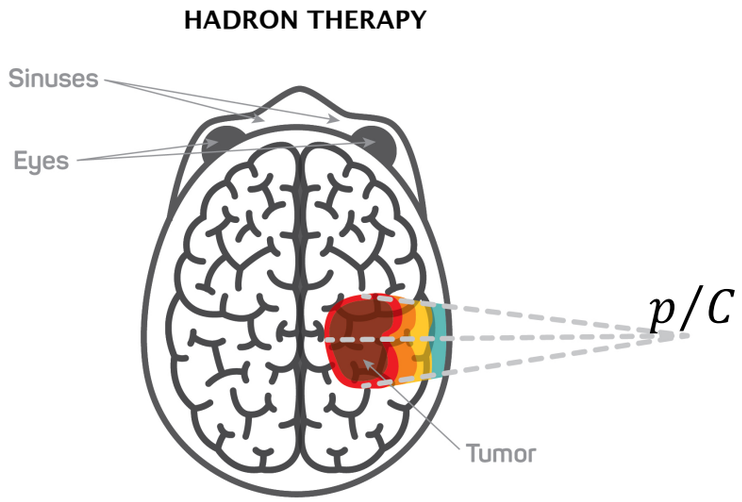
(INFN Torino, Italy)

FOOT: Purpose

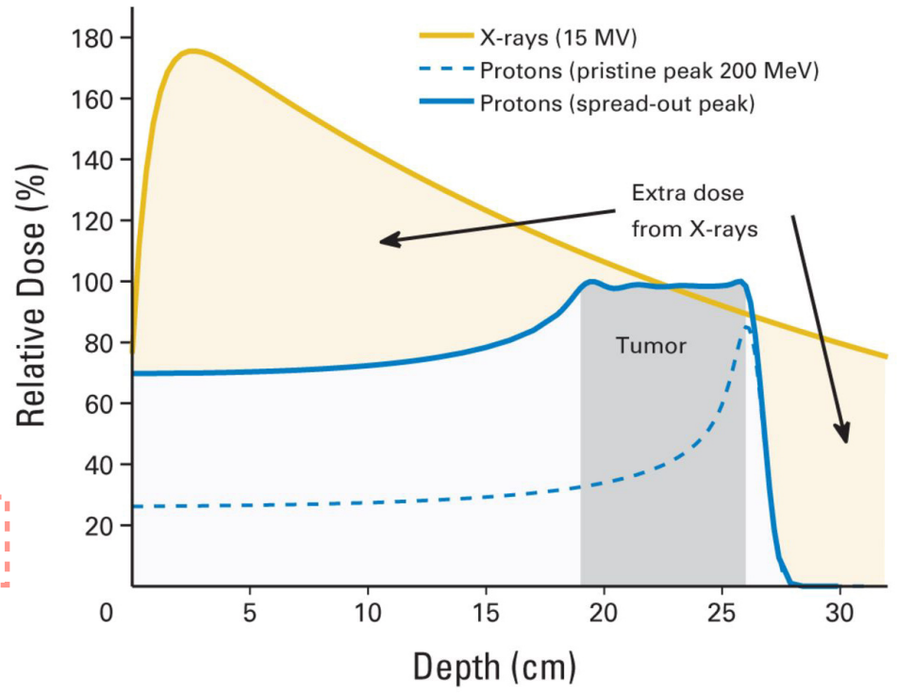
Measurement of the cross section of secondary fragments relevant for

1 Hadron therapy treatments:





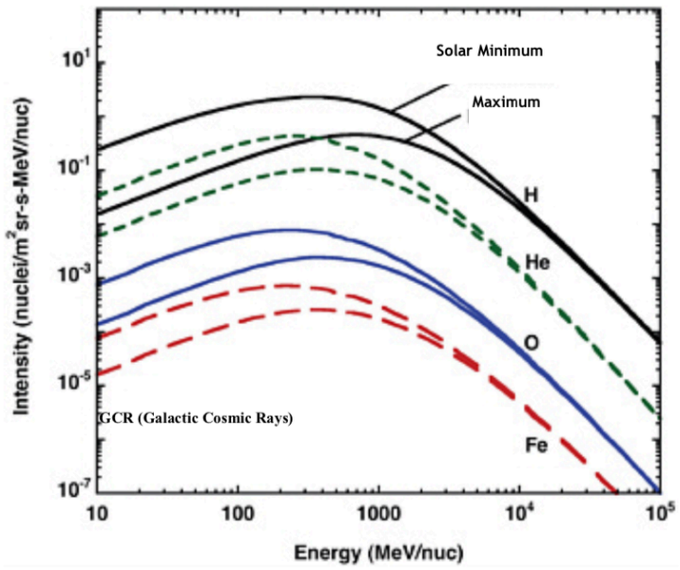
E < 400 MeV/A



2 Space Missions:

Particles in space (protons) when interacting with walls/shielding of spacecraft produce secondary fragments

E < 800 MeV/A



FOOT: Design & Detectors

REQUIREMENTS:

Cross sections

$$\frac{\delta(d\sigma/dE_k)}{d\sigma/dE_k} < 5\%$$

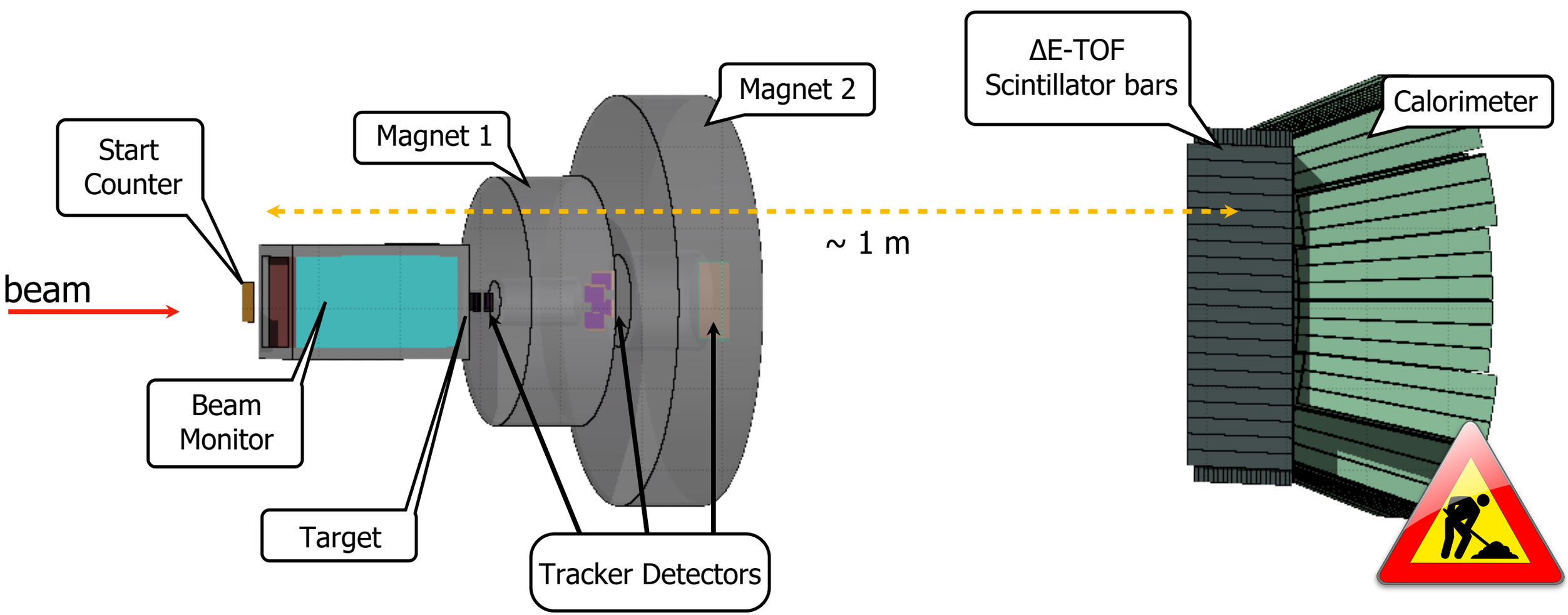
Fragment mass

$$5\% < \frac{\delta A}{A} < 10\%$$

$$\frac{\delta E_k}{E_k} < 2\%$$ Kinetic Energy

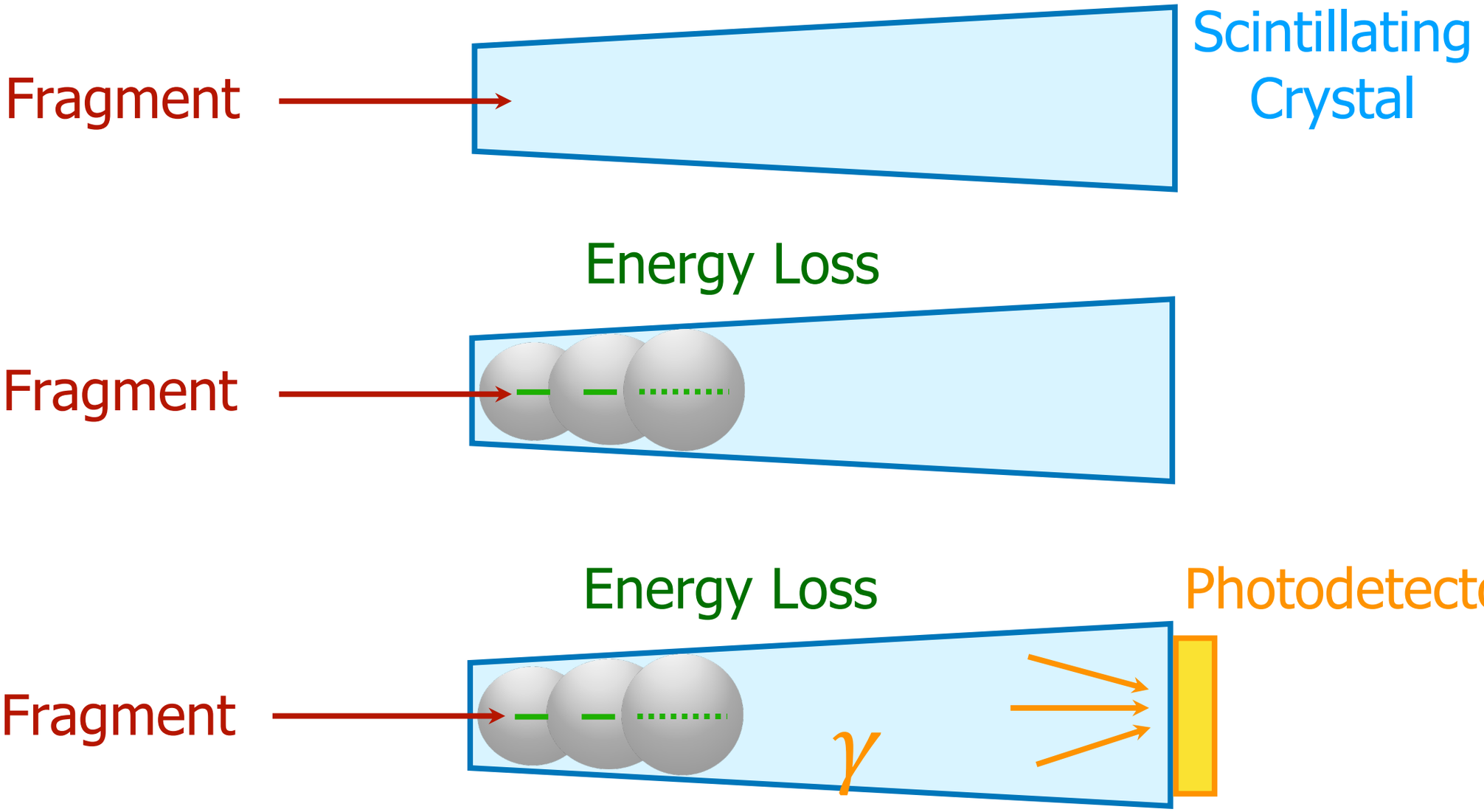
$$\frac{\delta p}{p} < 5\%$$ Momentum

$$TOF < 100ps$$ Time of Flight



Principle of the FOOT Calorimeter

What is a scintillating calorimeter?

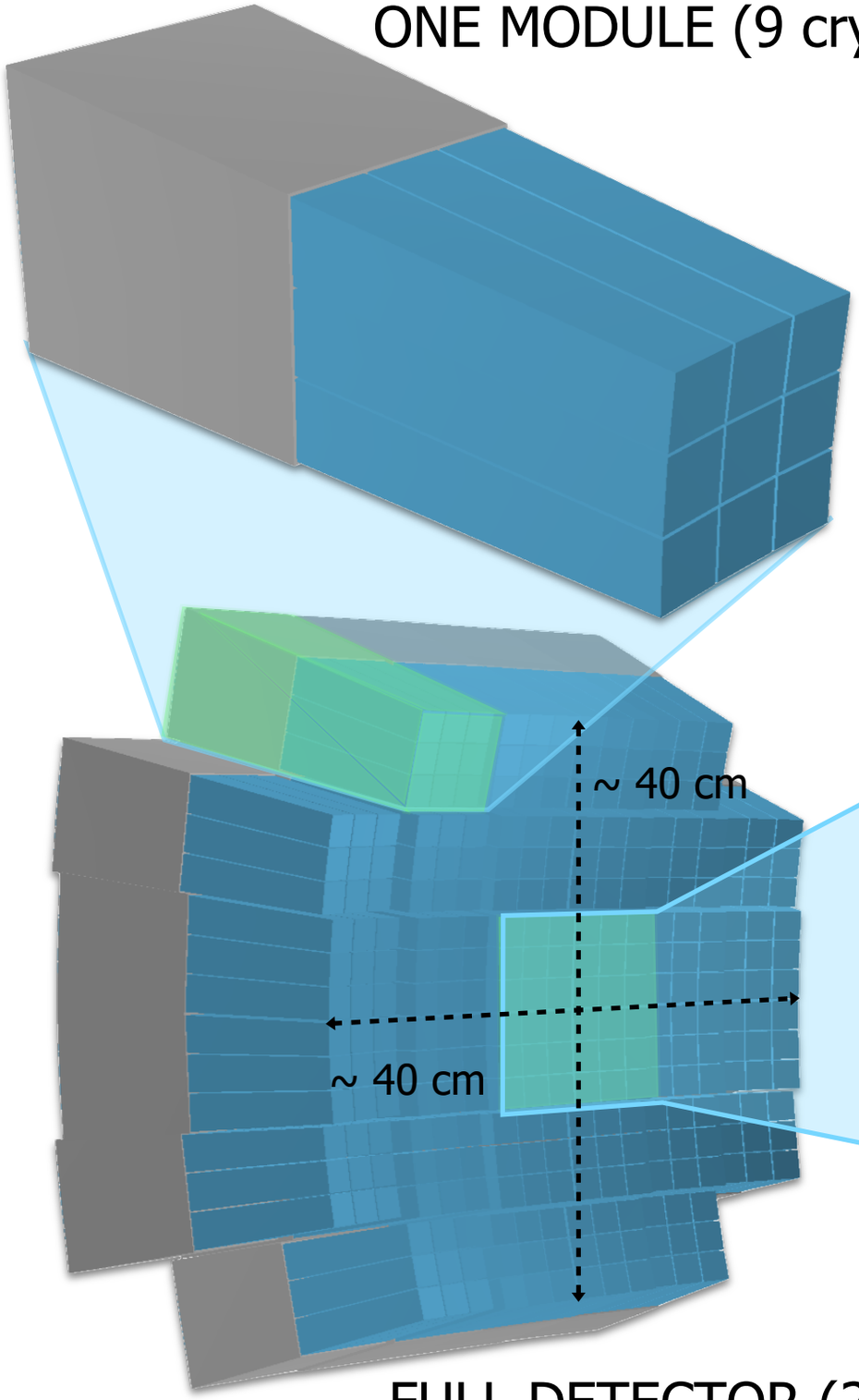


N. optical photons $\propto$ Initial fragment energy

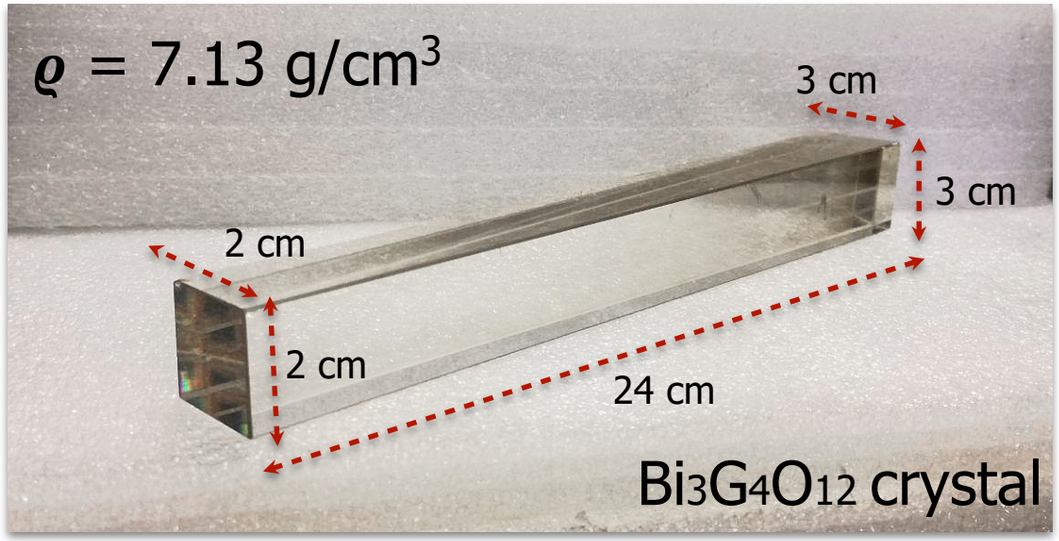
Light yield:
8-10 photons/KeV

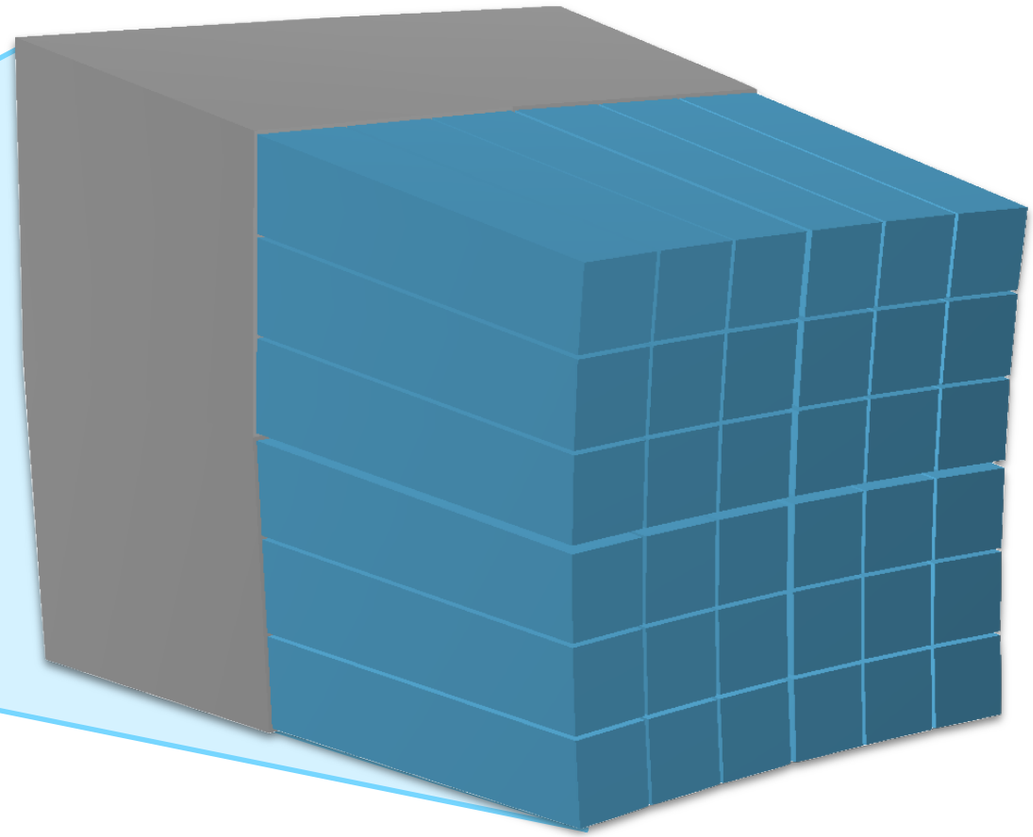
Calorimeter Arrangment

ONE MODULE (9 crystals)



FULL DETECTOR (290-320 crystals)

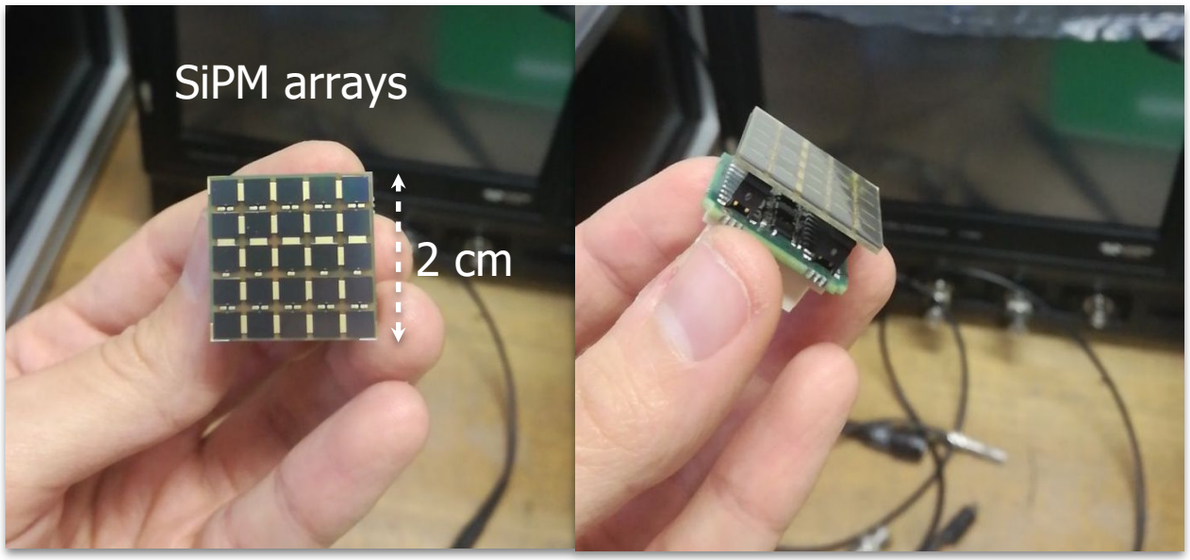




CENTRAL PART

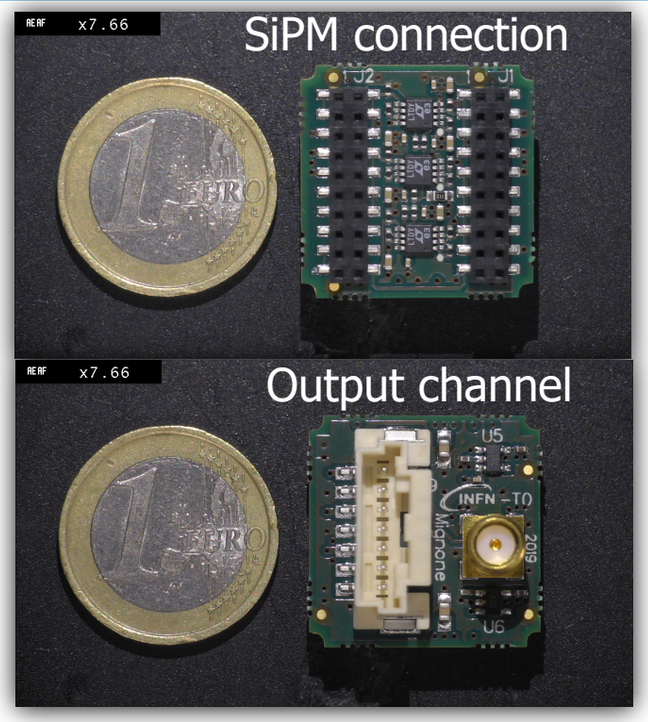
Calorimeter Design

PHOTODETECTOR & READOUT BOARD



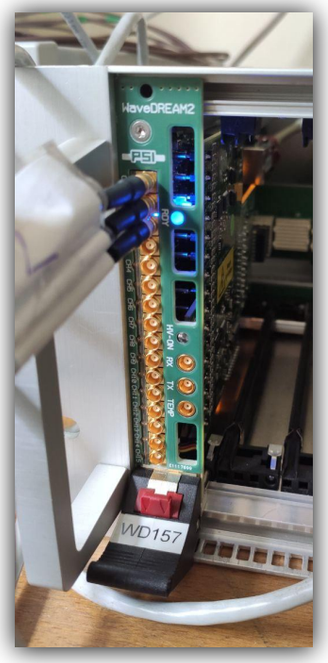
SiPM arrays with 15μm size of microcells

SiPM arrays + board



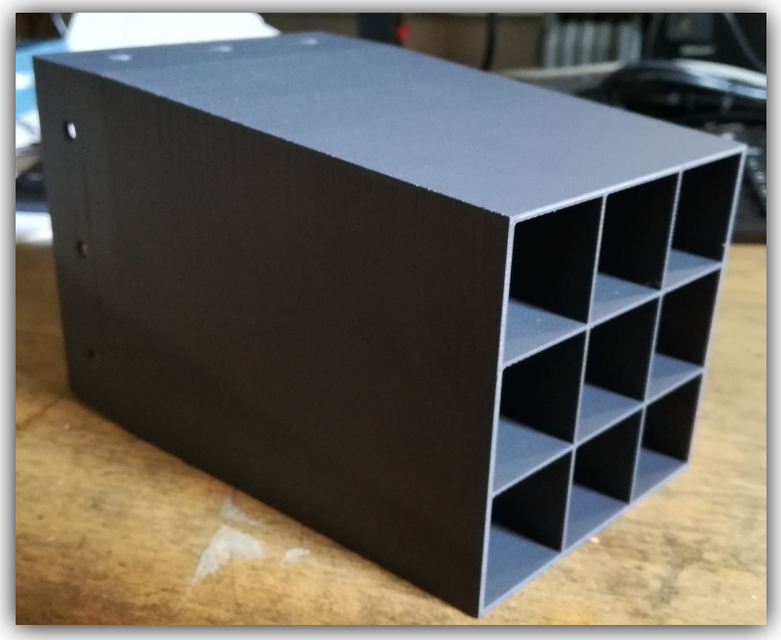
WRAPPING

DIGITIZER

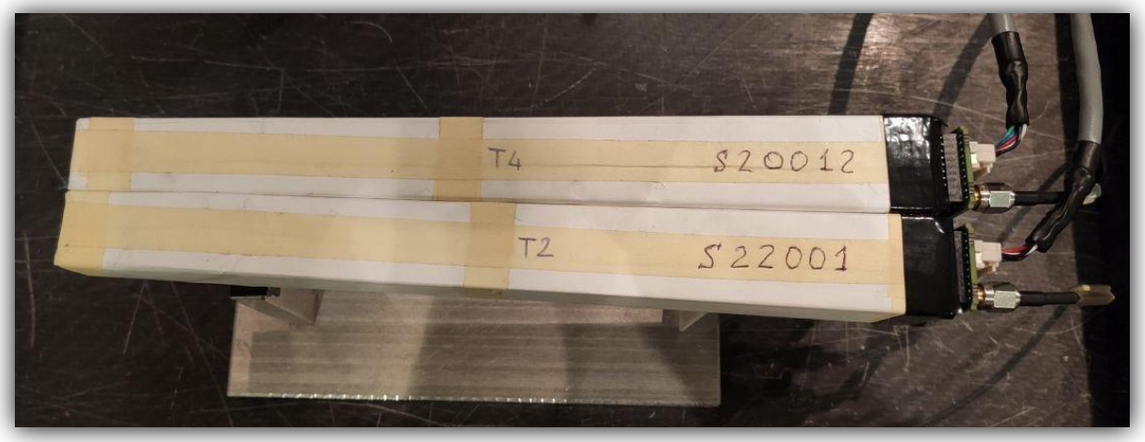


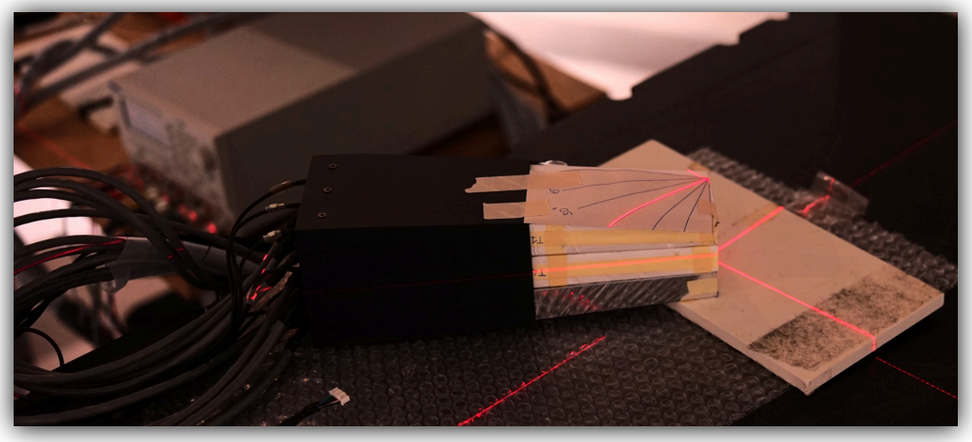
dynamic range: 1V
frequency: 1 GS/s

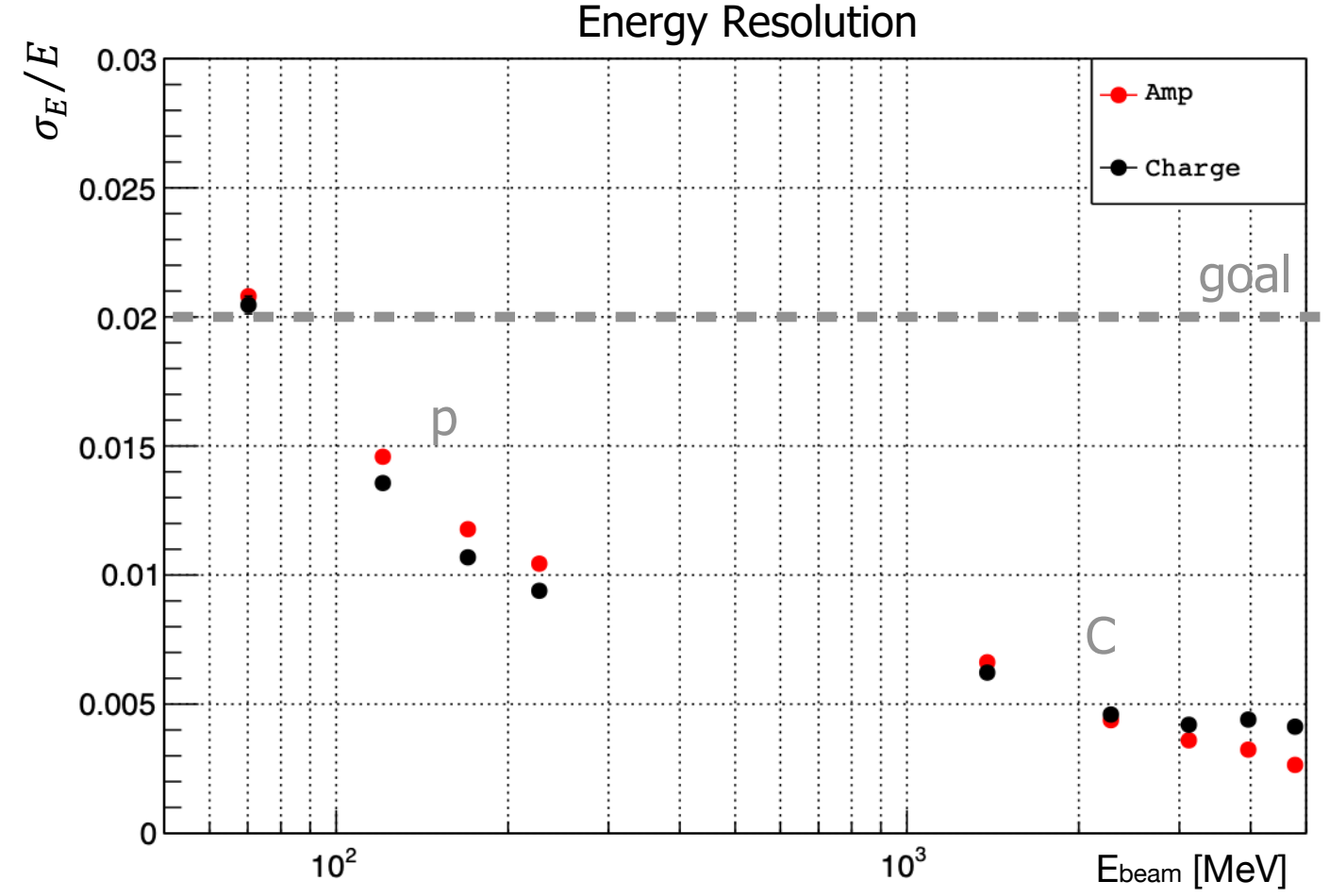
MODULE MECHANICS

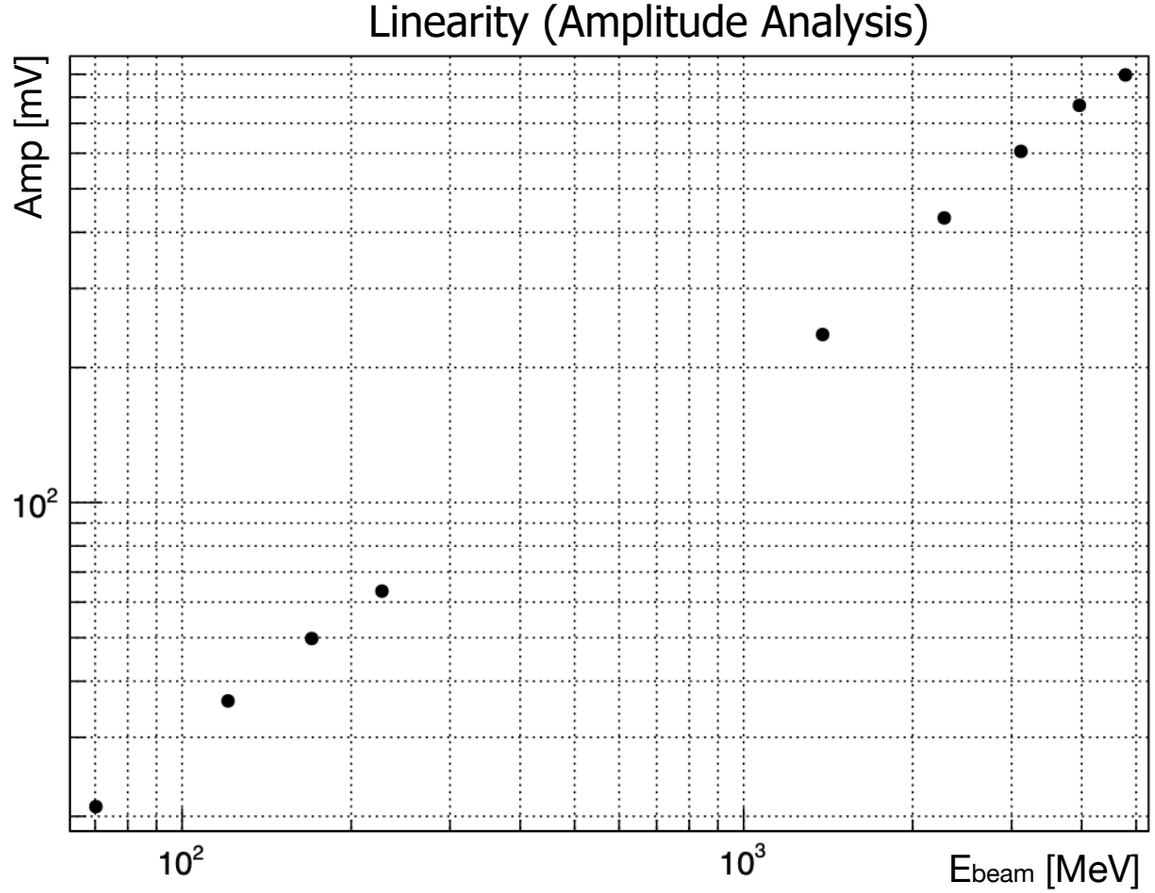


Calorimeter Performances



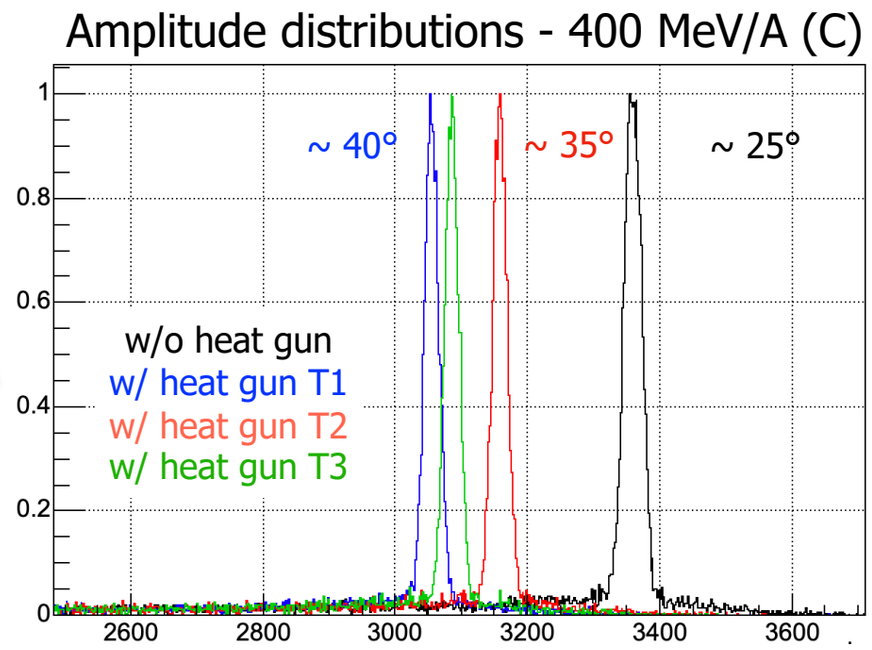




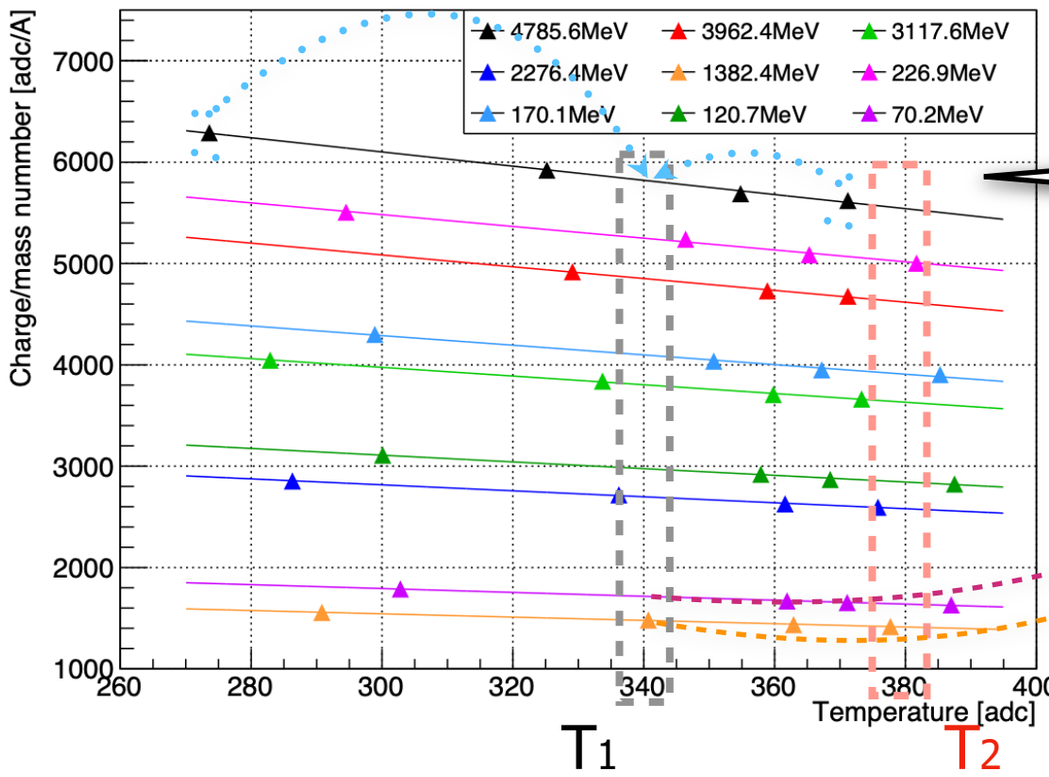


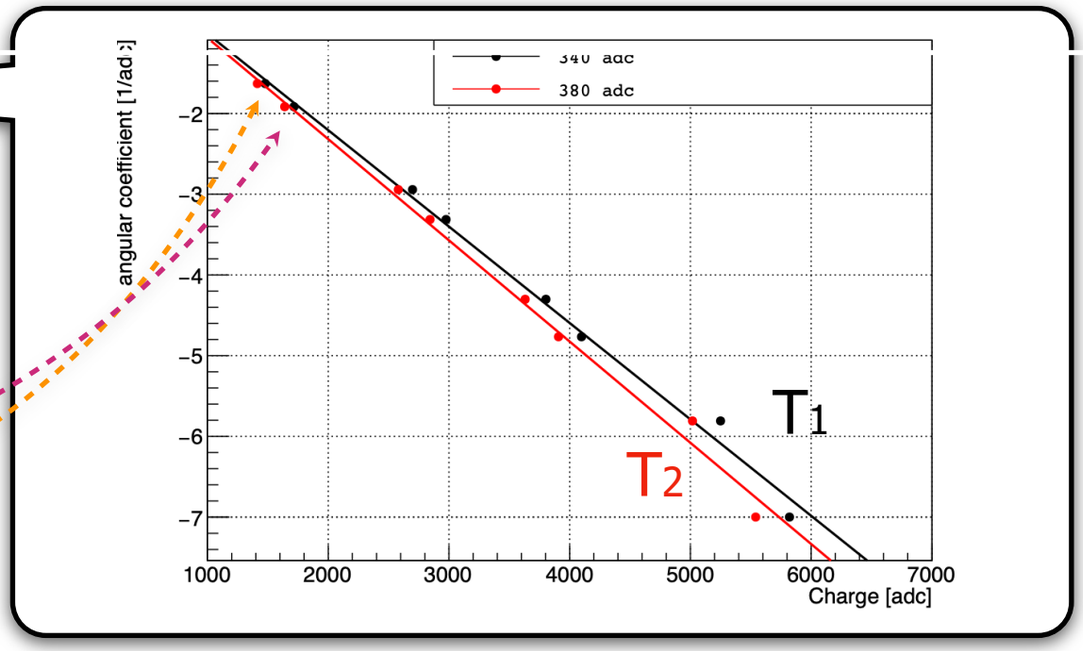
Temperature monitoring

SiPMs are temperature fluctuations sensitive → Is a cooling system necessary?



Visible dependency between charge and angular coefficient





Temperature monitoring

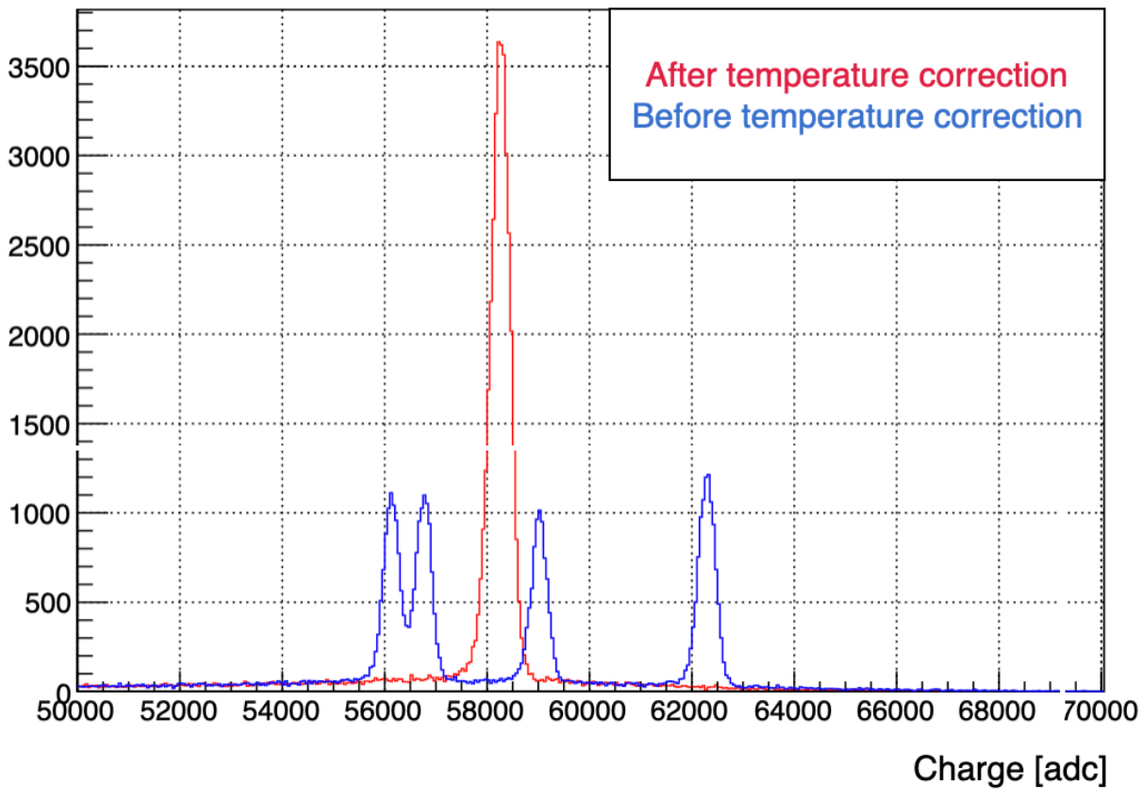
Interpolating the slope at T_1 and T_2:

$$m_0 = m_1 + \left(\frac{m_2 - m_1}{T_2 - T_1}\right) \cdot (T_0 + T_1)$$

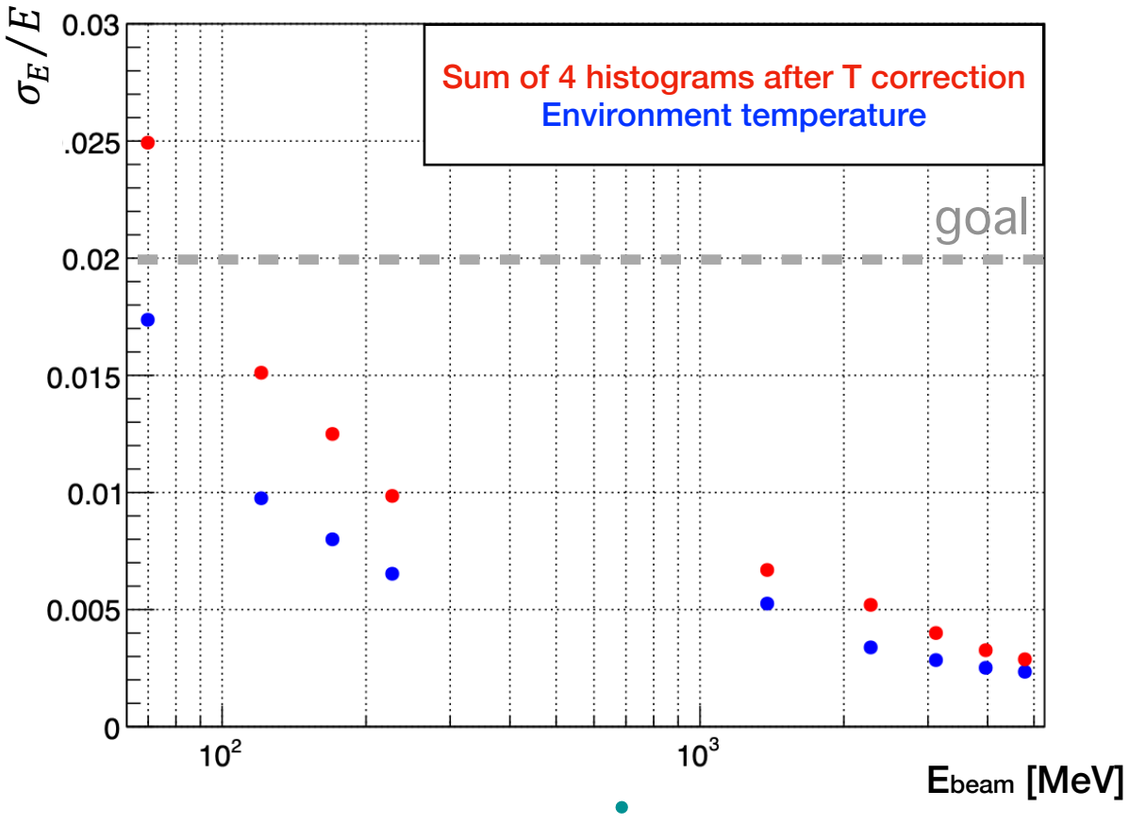
$$Q_0{}' = Q_0 + m_0 \cdot (T_1 - T_0)$$

Where:

- Q_0: charge must be corrected
- T_0: temperature at which Q_0 has been taken
- m_0: actual angular coefficient to correct Q_0
- m_1 and m_2: the angular coefficients respectively at T_1 and T_2



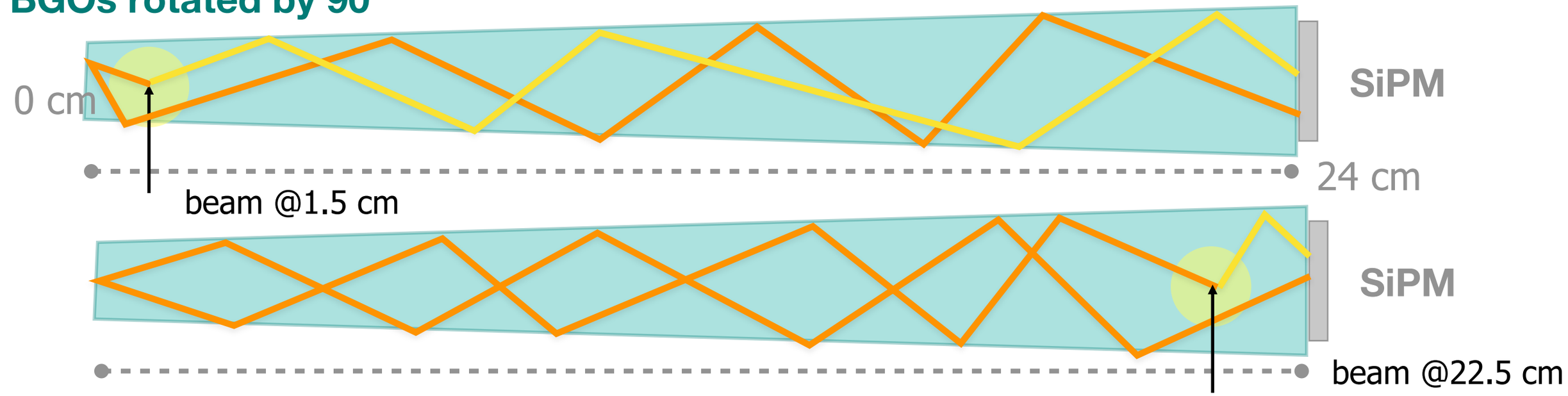
In order to prove the validity of the model: sum of the charge distributions at different temperatures

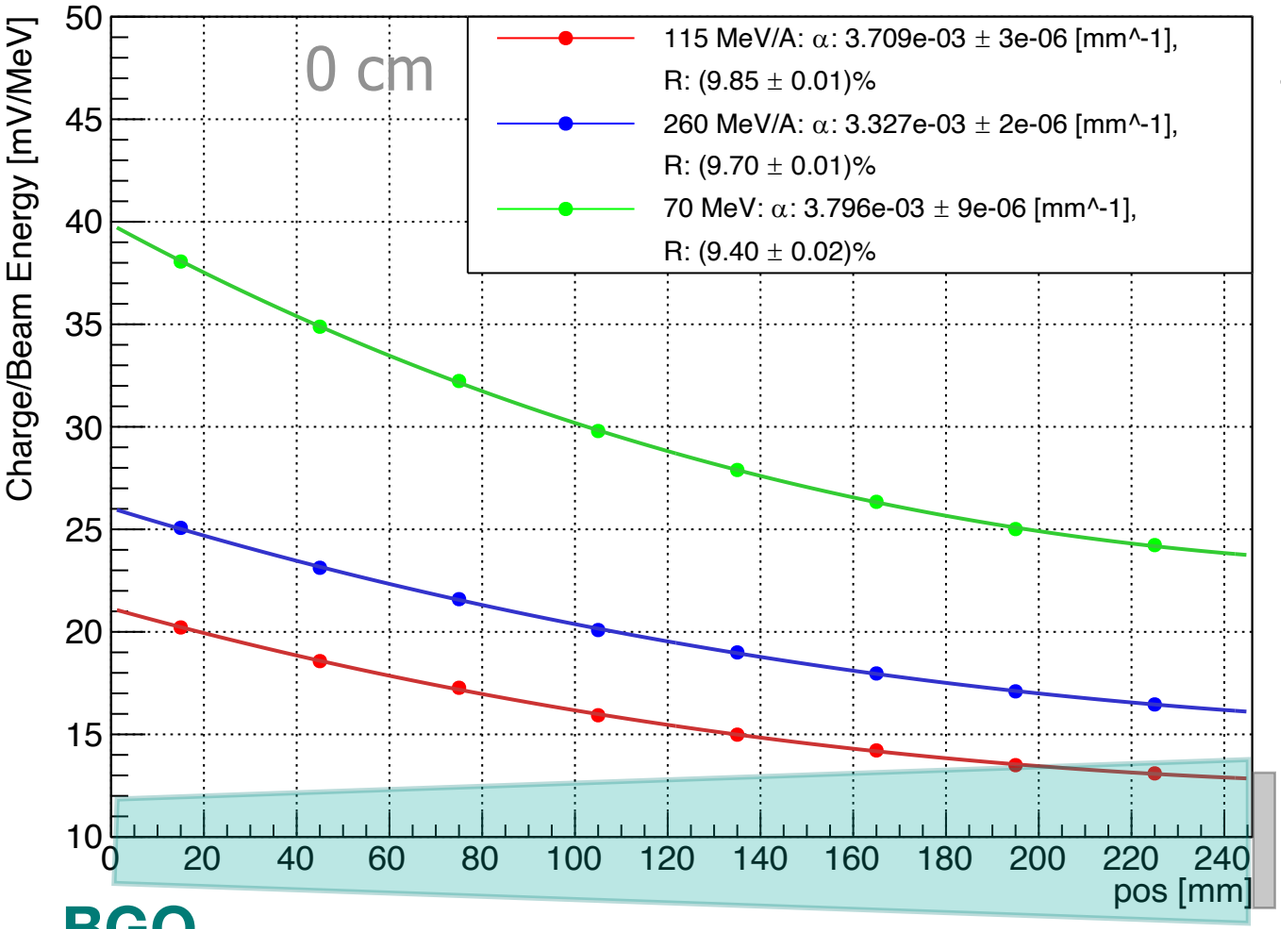


Energy Resolution < 2% after T correction

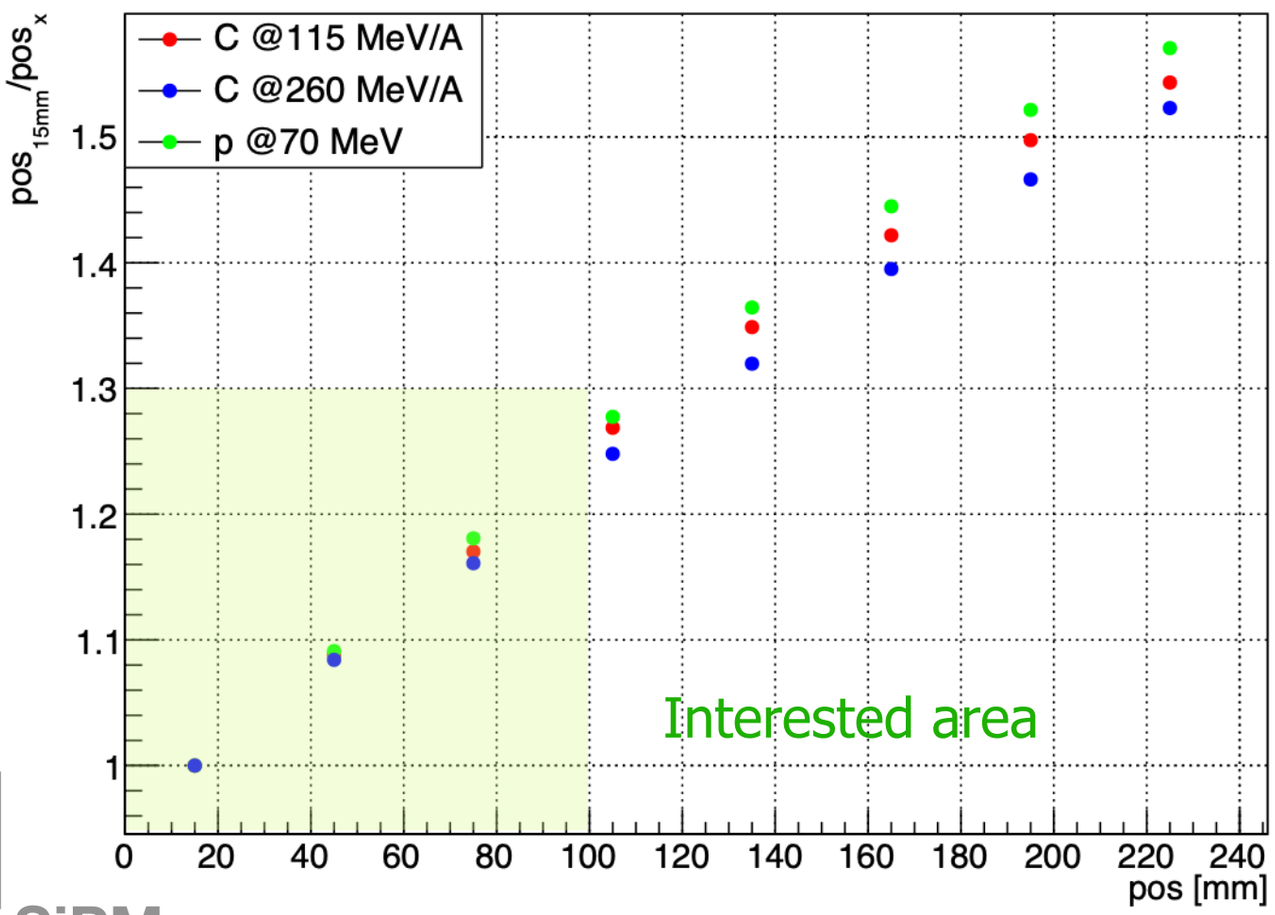
Light collection vs position

BGOs rotated by 90°





BGO



SiPM

Conclusions & Next Steps

Calorimeter design

The results of beam tests at CNAO were crucial in making the calorimeter design choices:

- crystal size
- wrapping
- photodetector type and configuration
- readout parameters
- temperature variation compensation
- DAQ

In the next future:

- test beam at Heidelberg Ion-Beam Therapy Center (HIT) in order to measure the crystal response function with different ions (H, He, C, O)
- Mechanics

Traverse crystals

- Study the light absorption along the path of the crystal
- This contribution is not negligible even if it seems constant between different particles/energies
- It will have to be taken into account for the future data taking and some corrections will have to be applied