

07.10.2020



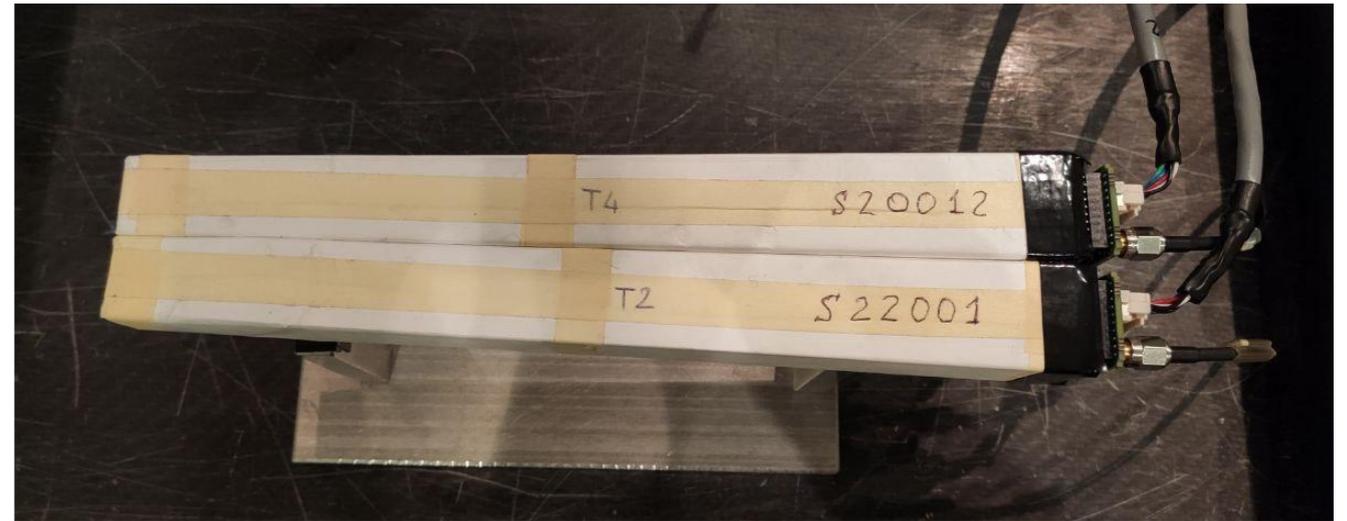
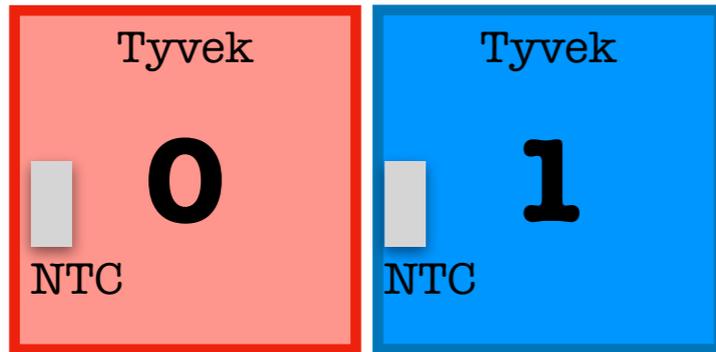
# Calorimeter Test Beam @CNAO

## 30.08.2020

## Physics meeting

S. Argirò, N. Bartosik, F. Cavanna, P. Cerello,  
M. Mignone, M. Pullia, L. Ramello, L.  
Scavarda

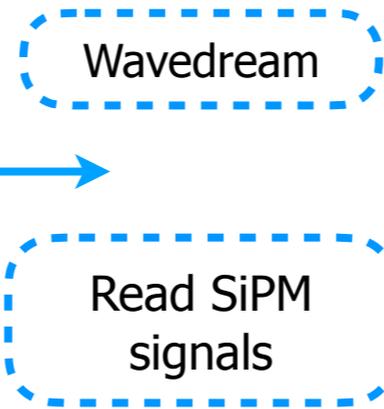
# TEST BEAM SETUP



## SETUP

1. Temperature monitoring of both crystals
2. One scan (70-220 MeV proton, 115-400 MeV/A C) with BGO+**WaveDream** setup
3. Scan along the crystal length with 70, 170 MeV proton beam and 115, 260 MeV/A carbon beam

- frequency: 1GS/s (1024 samplings in 1 $\mu$ s)
- gain: 0.5
- HV SiPM: 34.5V



## GOAL

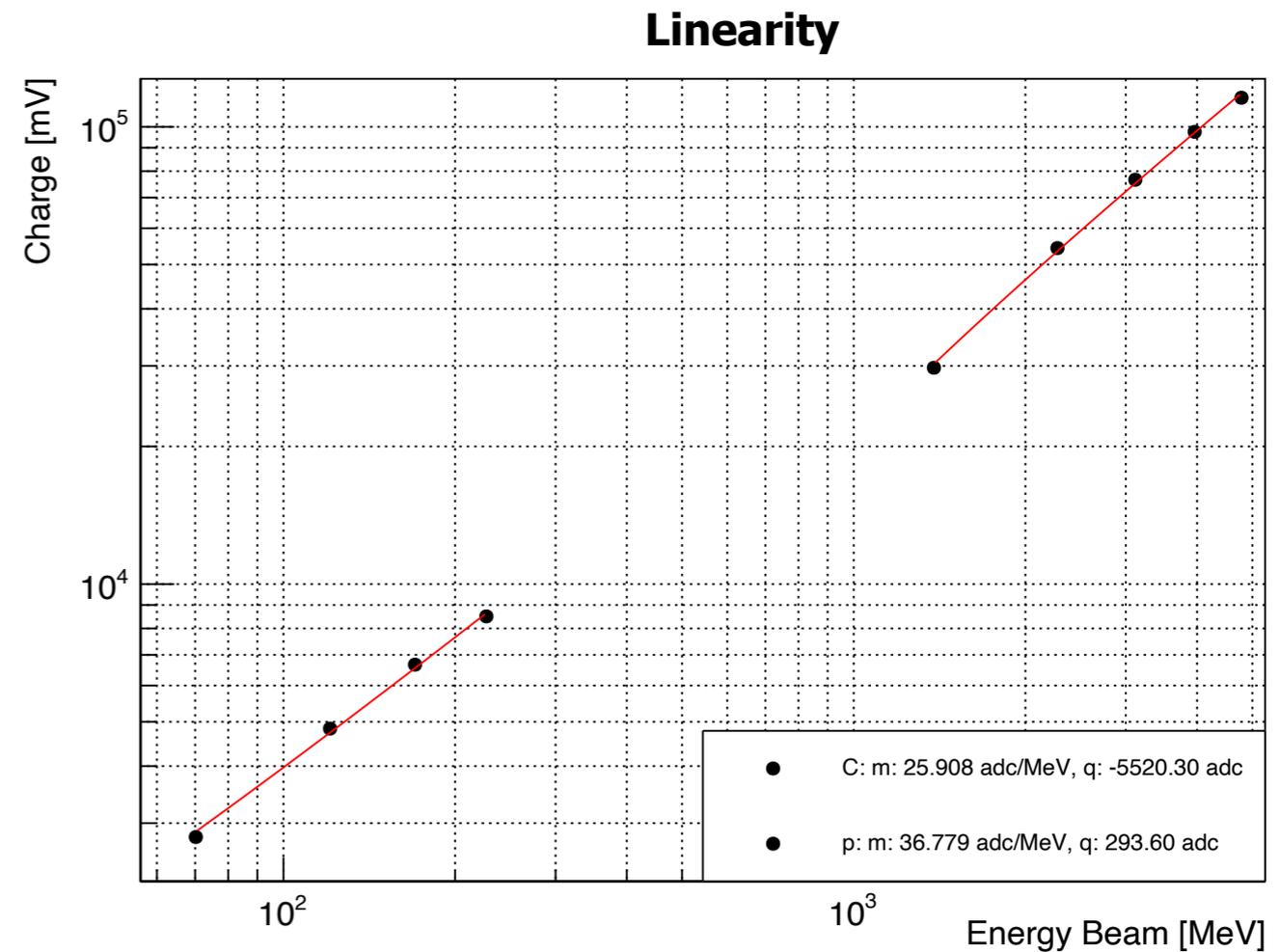
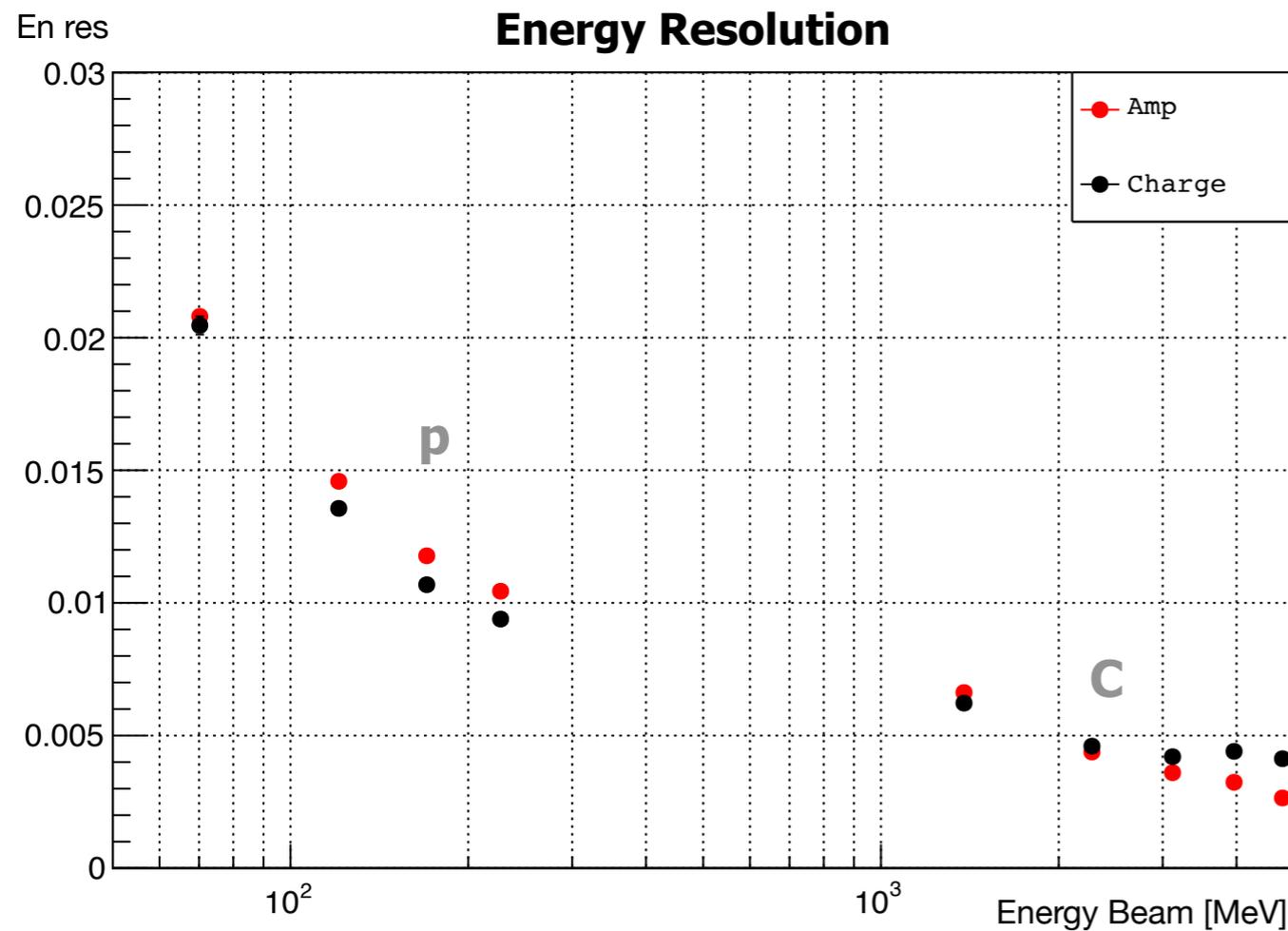
- 1. Understand better the temperature fluctuations
- 2. Study the performance (energy resolution) of BGO+WaveDream
- 3. Study the optical light absorption along the crystal



v1740 (10V)

Read temperature sensor

# CALORIMETER PERFORMANCES



Performances achieved:

- Energy resolution  $< 2\%$  (both for amplitude and charge analysis)
- No optical saturation

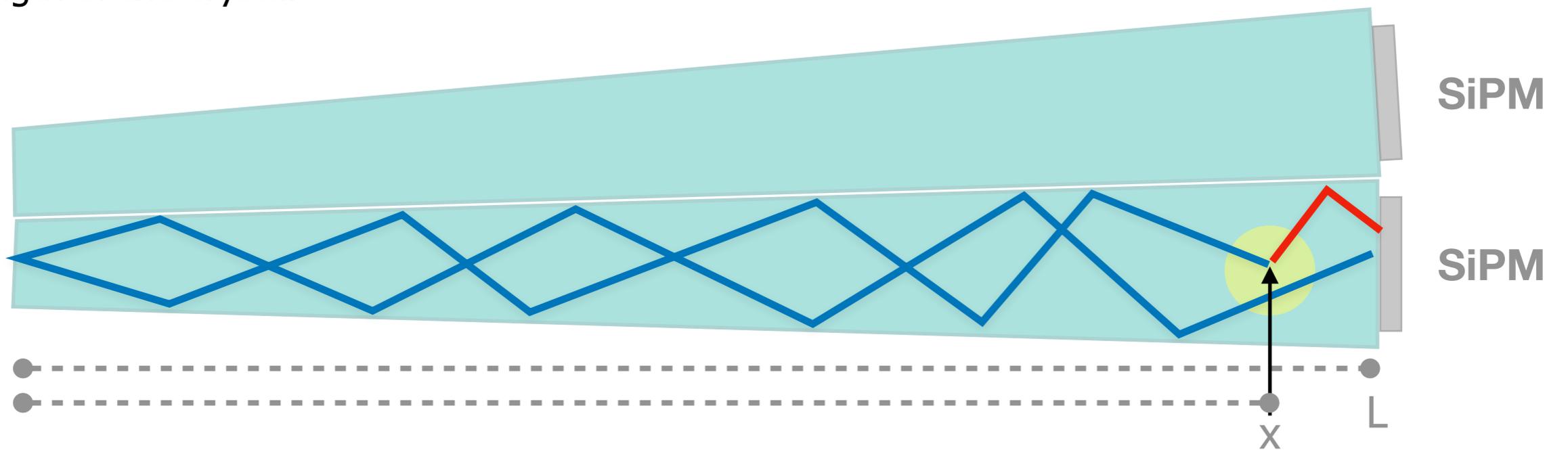
# LIGHT ABSORPTION



$$f(x) = A \cdot [R \cdot e^{-\alpha \cdot (L-x)} + (1 - R) \cdot e^{-\alpha \cdot (L+x)}]$$

- A: normalisation factor
- R: relative weight of the "direct" component of the light to the SiPM
- $\alpha$ : attenuator factor
- L: length of the crystal

C @115 MeV/A  
p @70 MeV



C @260 MeV/A  
p @170 MeV

Bragg Peak

the 2 contributions  
have to be summed

SiPM

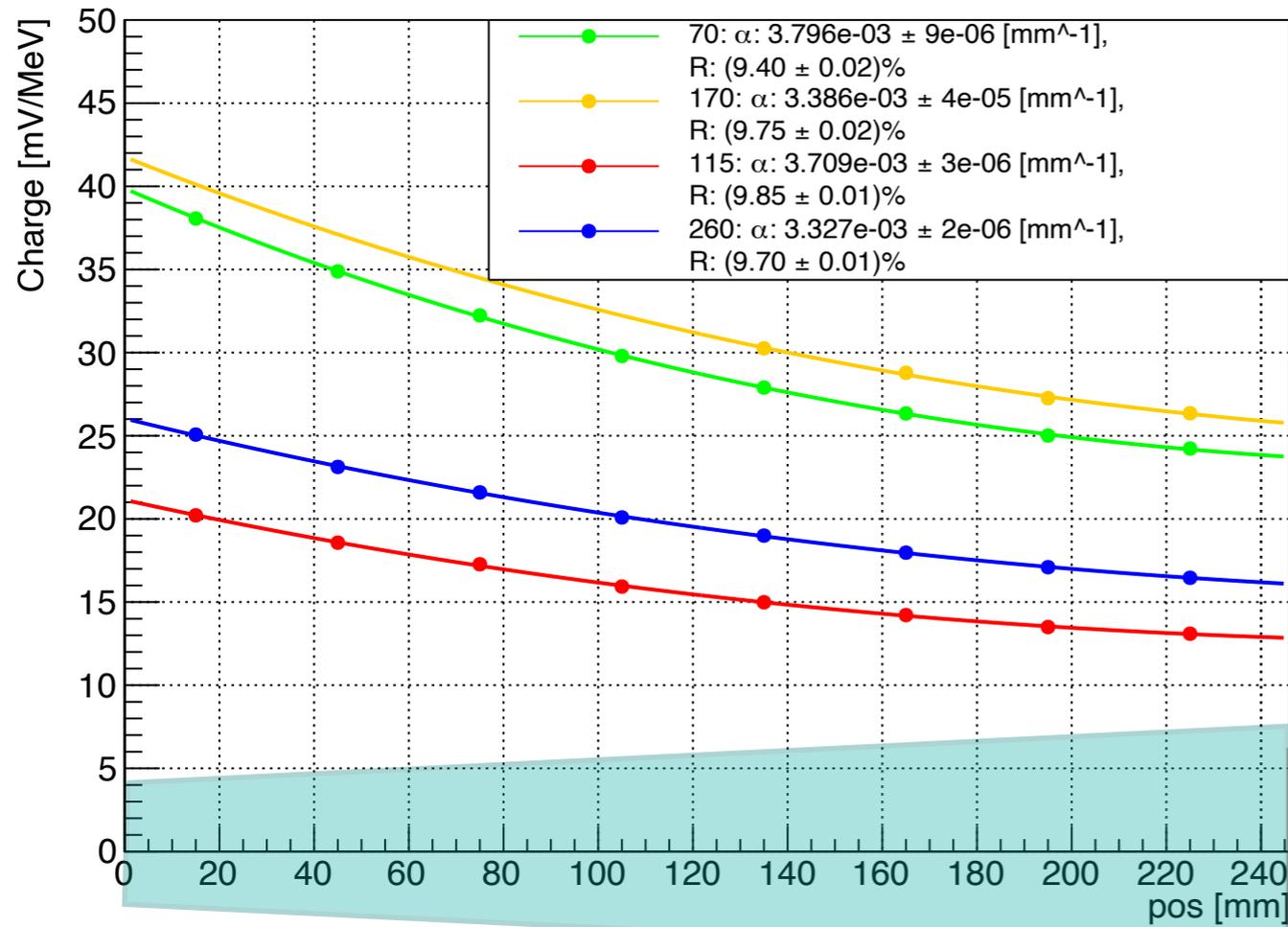
SiPM

# LIGHT ABSORPTION



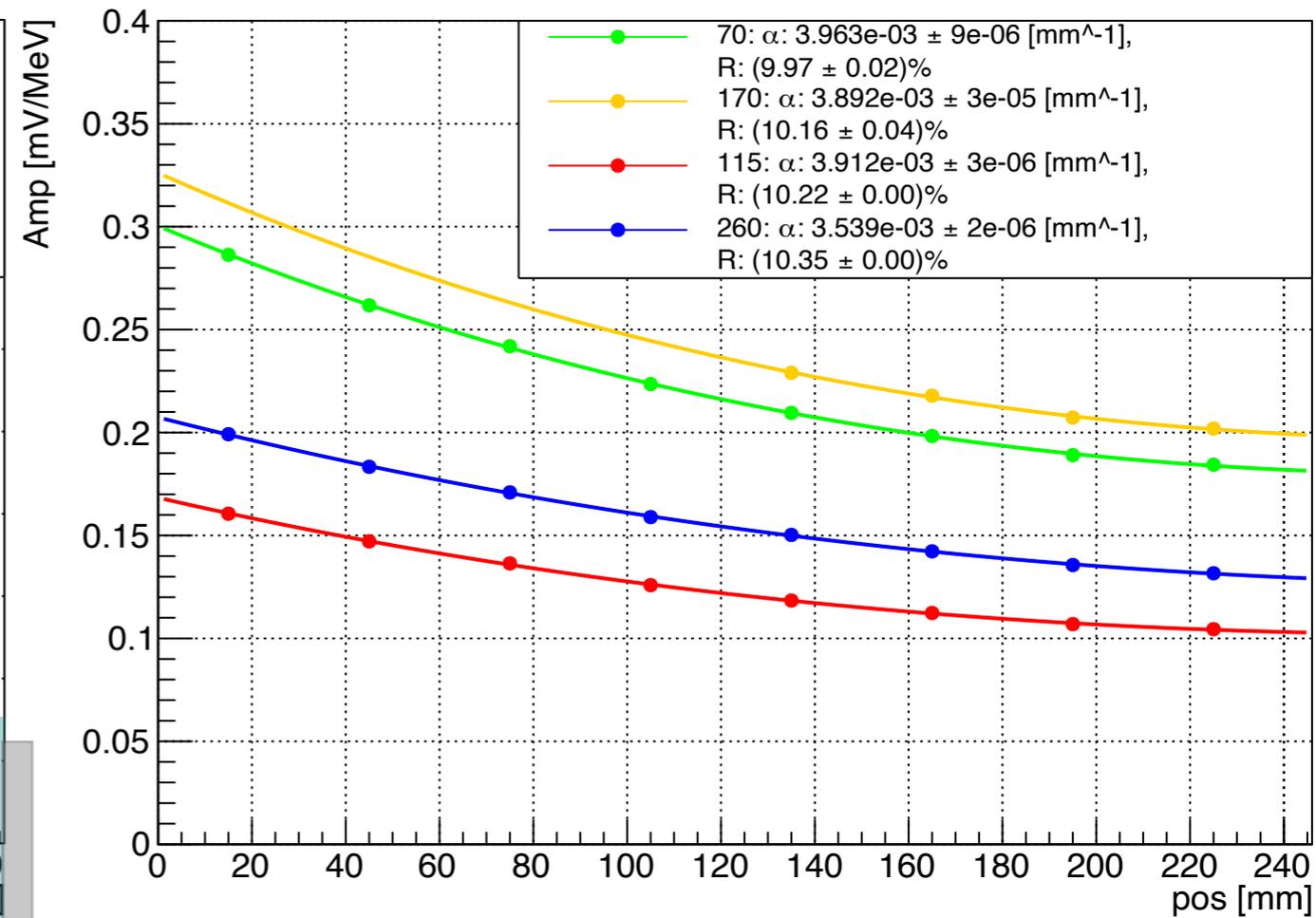
$$f(x) = A \cdot [R \cdot e^{-\alpha \cdot (L-x)} + (1 - R) \cdot e^{-\alpha \cdot (L+x)}]$$

### Charge Analysis



BGO

### Amplitude Analysis



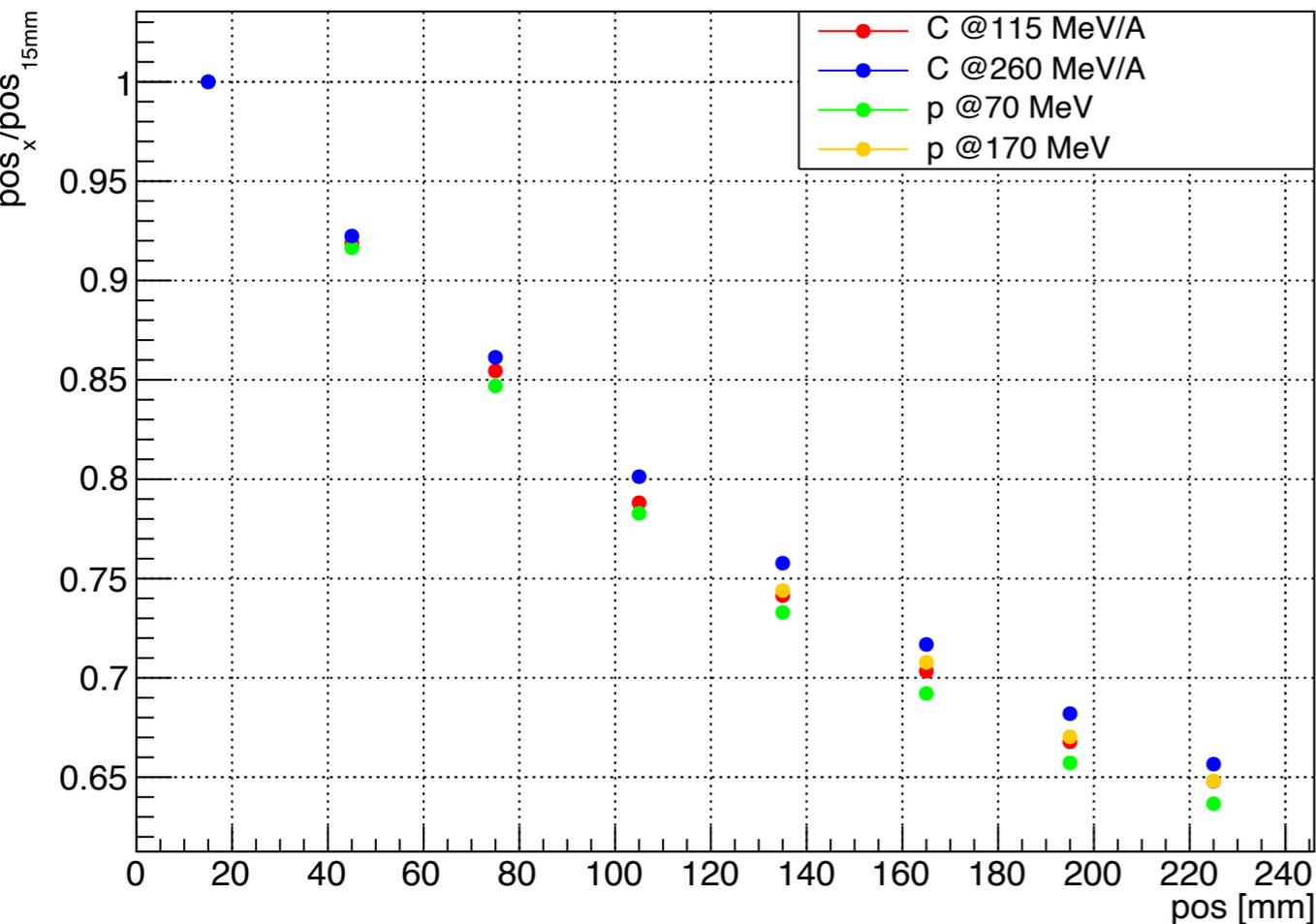
SiPM

# LIGHT ABSORPTION

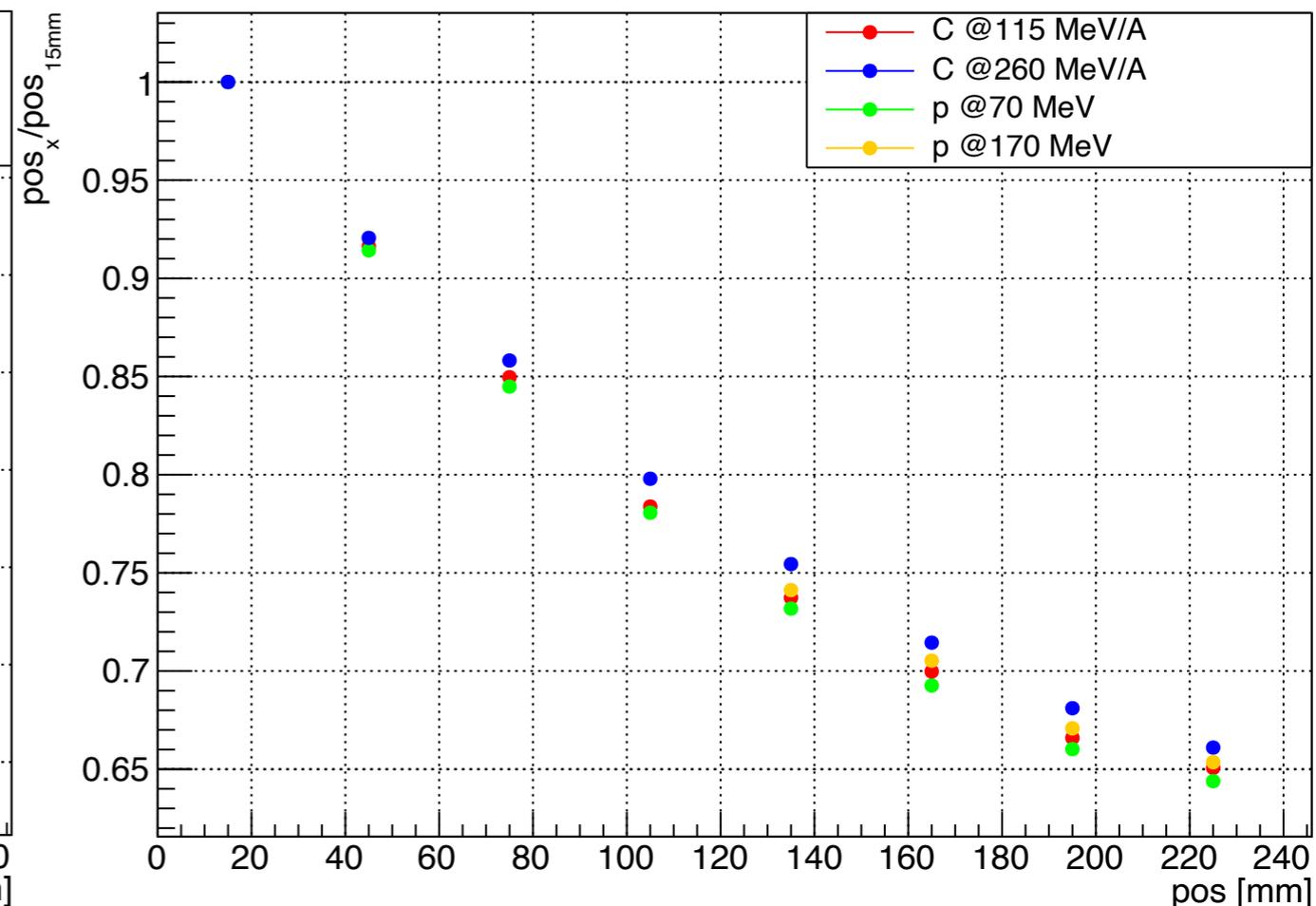


In order to compare better the different particles the ratio between the light collected in the different positions and light collected at 15 mm is showed:

### Charge Analysis

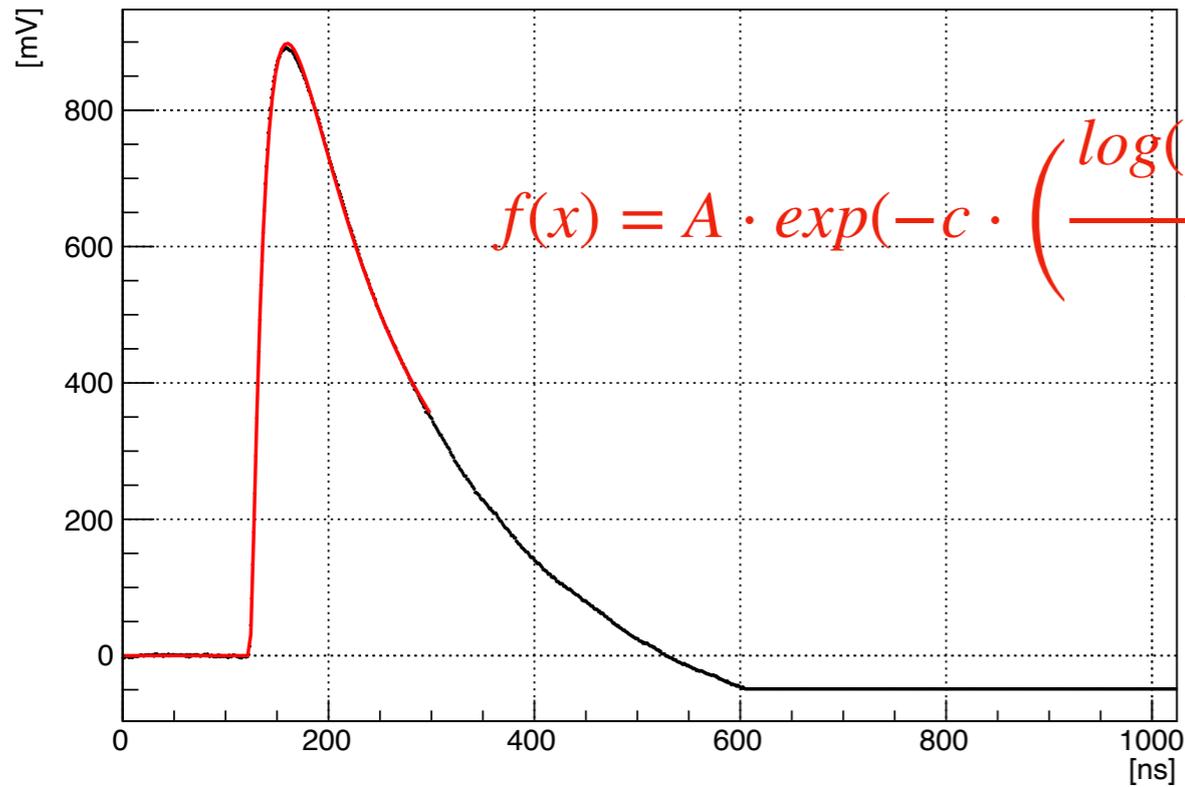


### Amplitude Analysis



This contribution is not negligible even if it seems constant between different particles/energies

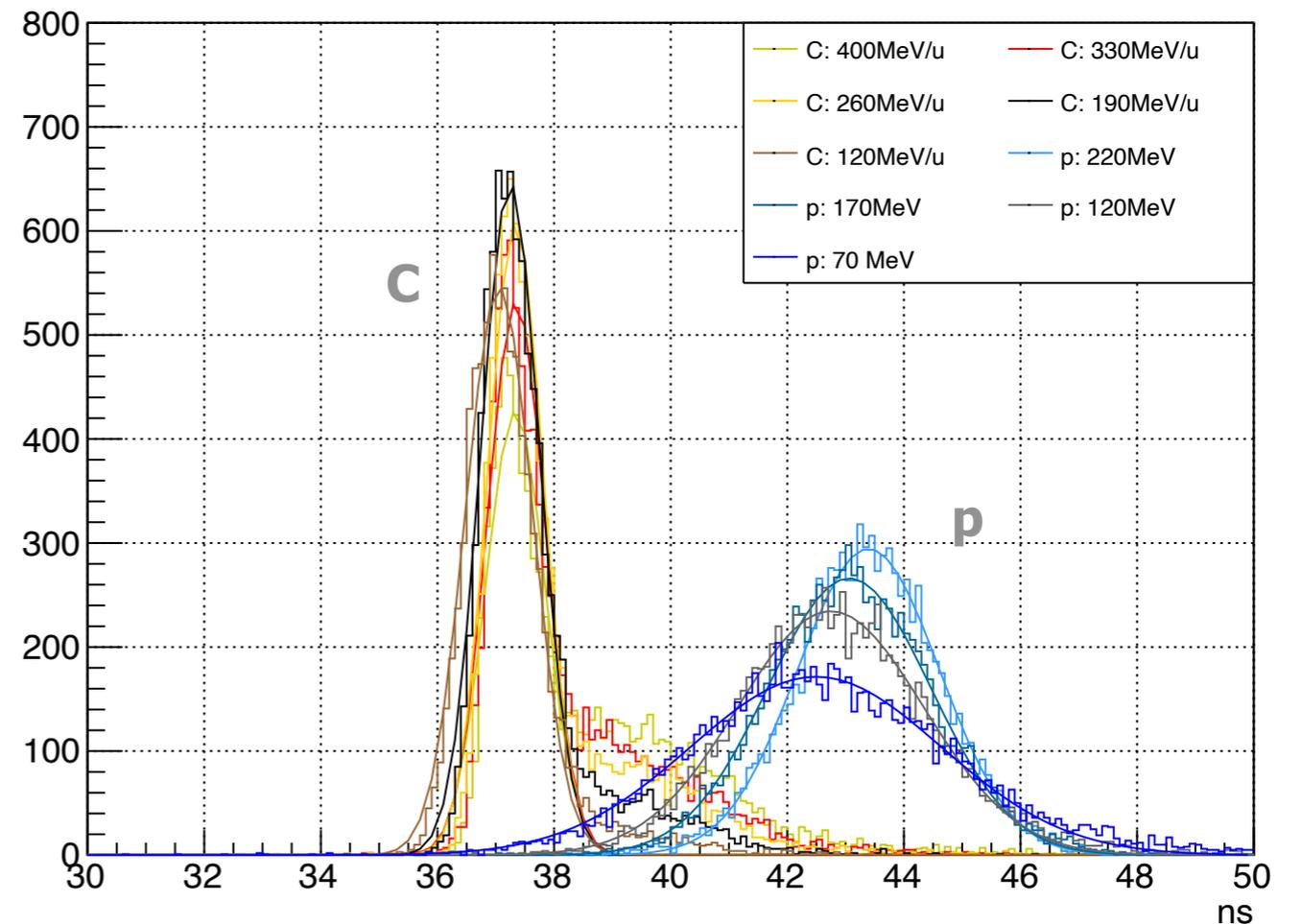
# PULSE SHAPE ANALYSIS



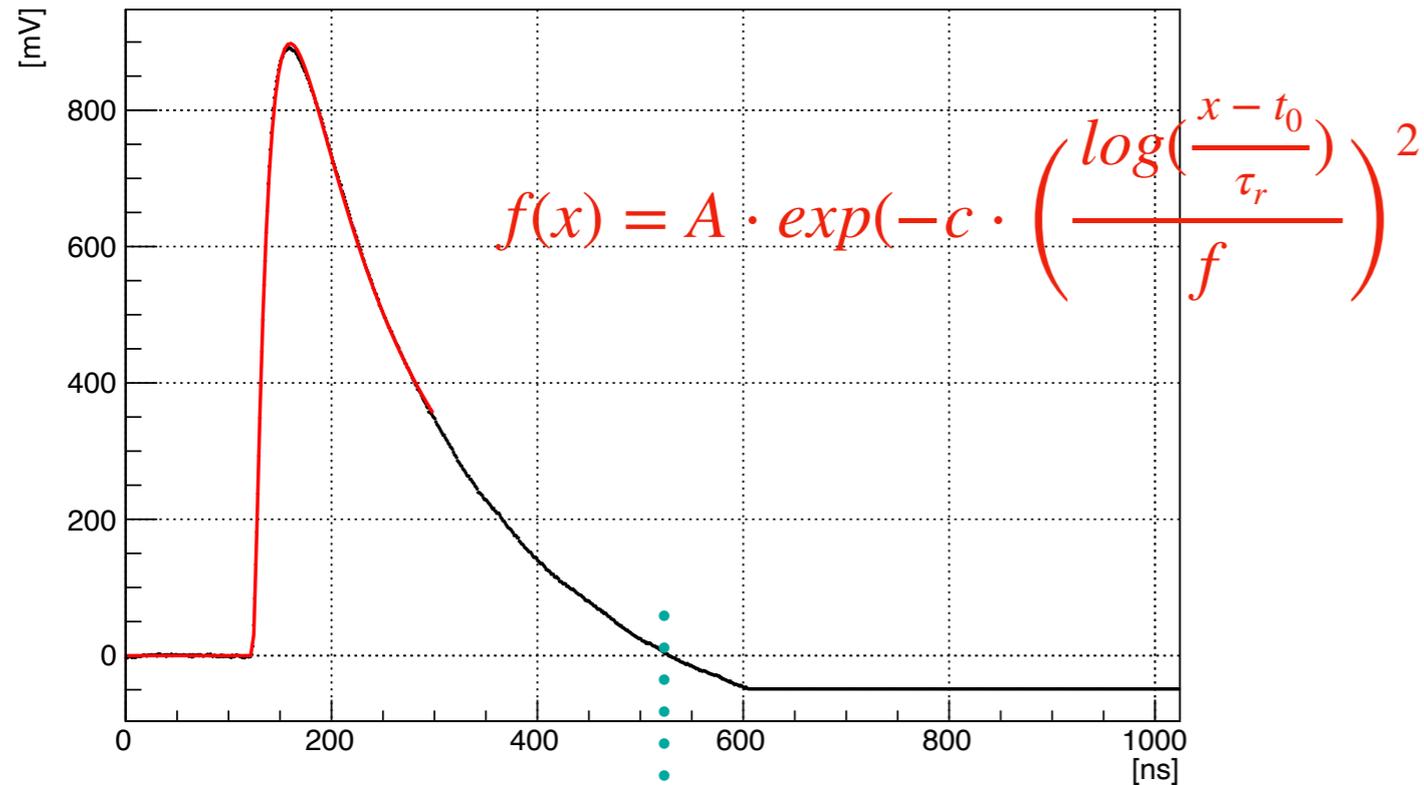
$$f(x) = A \cdot \exp(-c \cdot \left(\frac{\log\left(\frac{x-t_0}{\tau_r}\right)}{f}\right)^2)$$

- A: amplitude
- c: curvature of rising time
- $\tau_r$ : rising time
- $t_0$ : start time
- f: falling shape

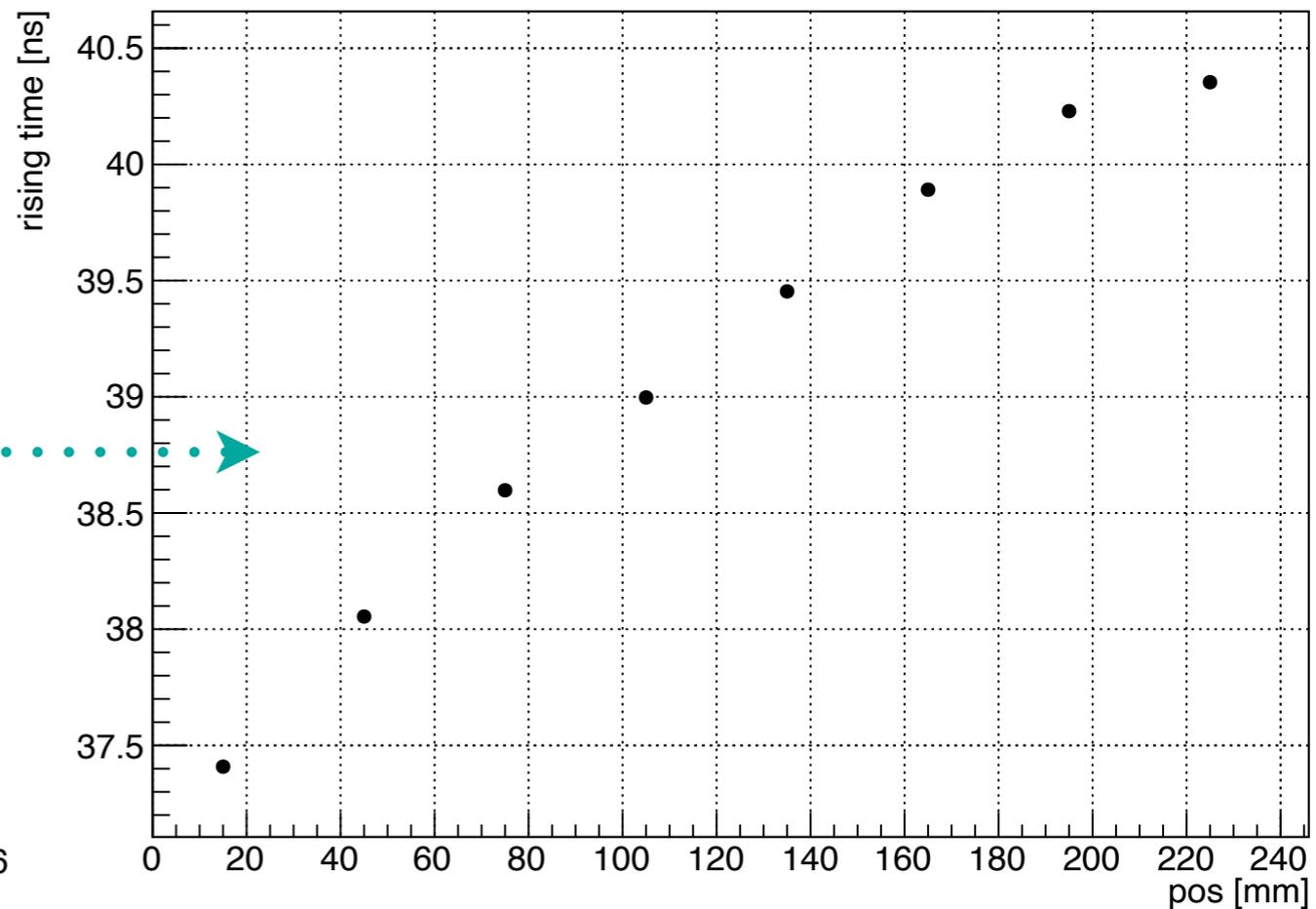
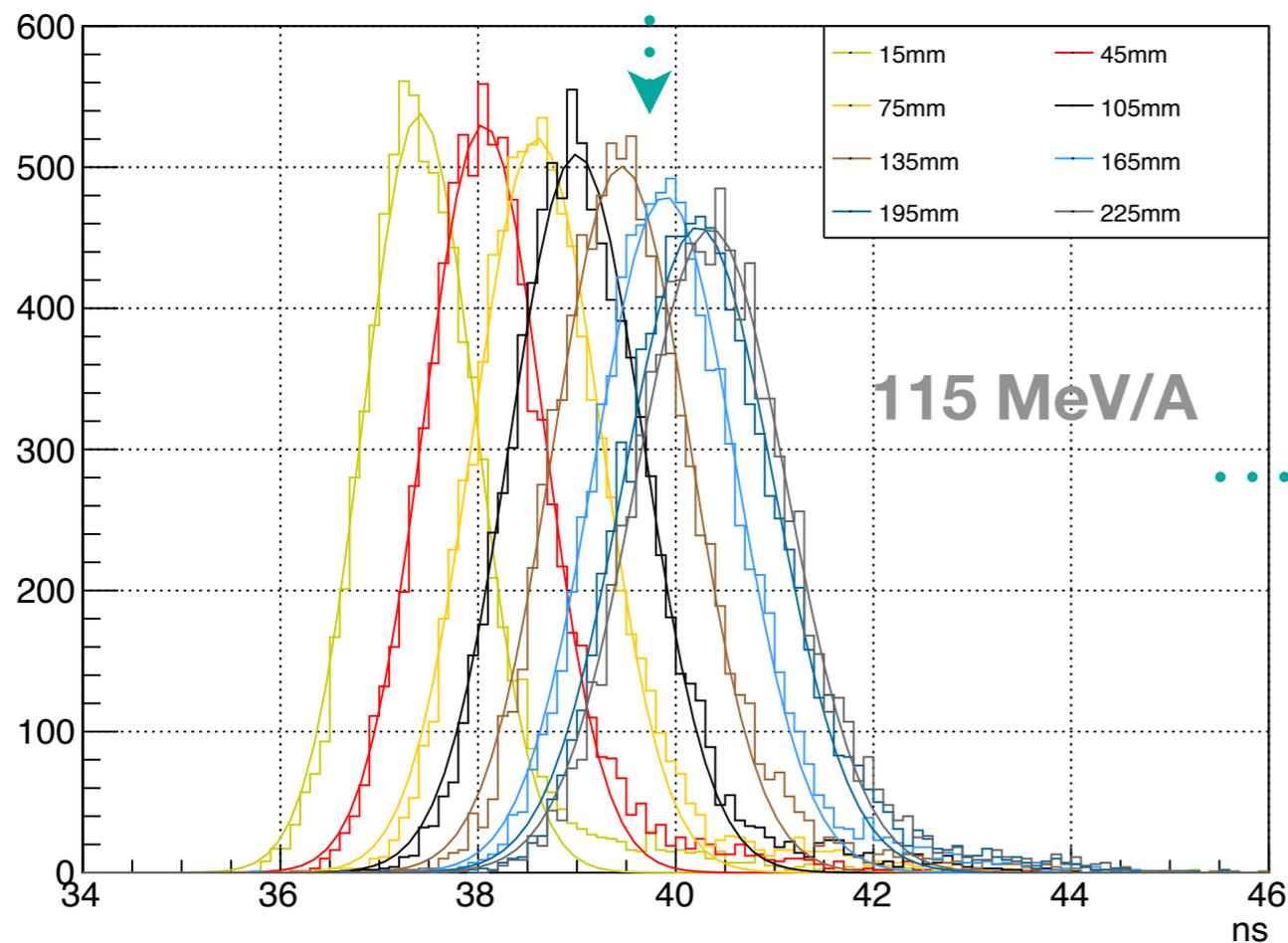
Clearly visible two different rising time populations



# PULSE SHAPE ANALYSIS

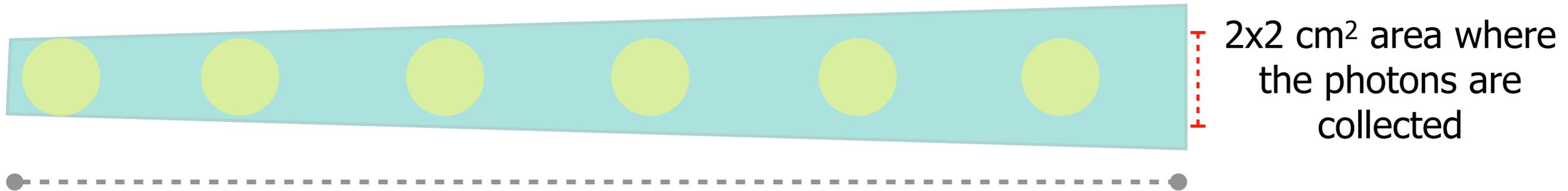


When the beam is shot closer to the SiPM more time is needed to collect all photons since there are more reflections





Photon sources have been simulated at different distance from the collecting area (the same used at CNAO during the test beam)

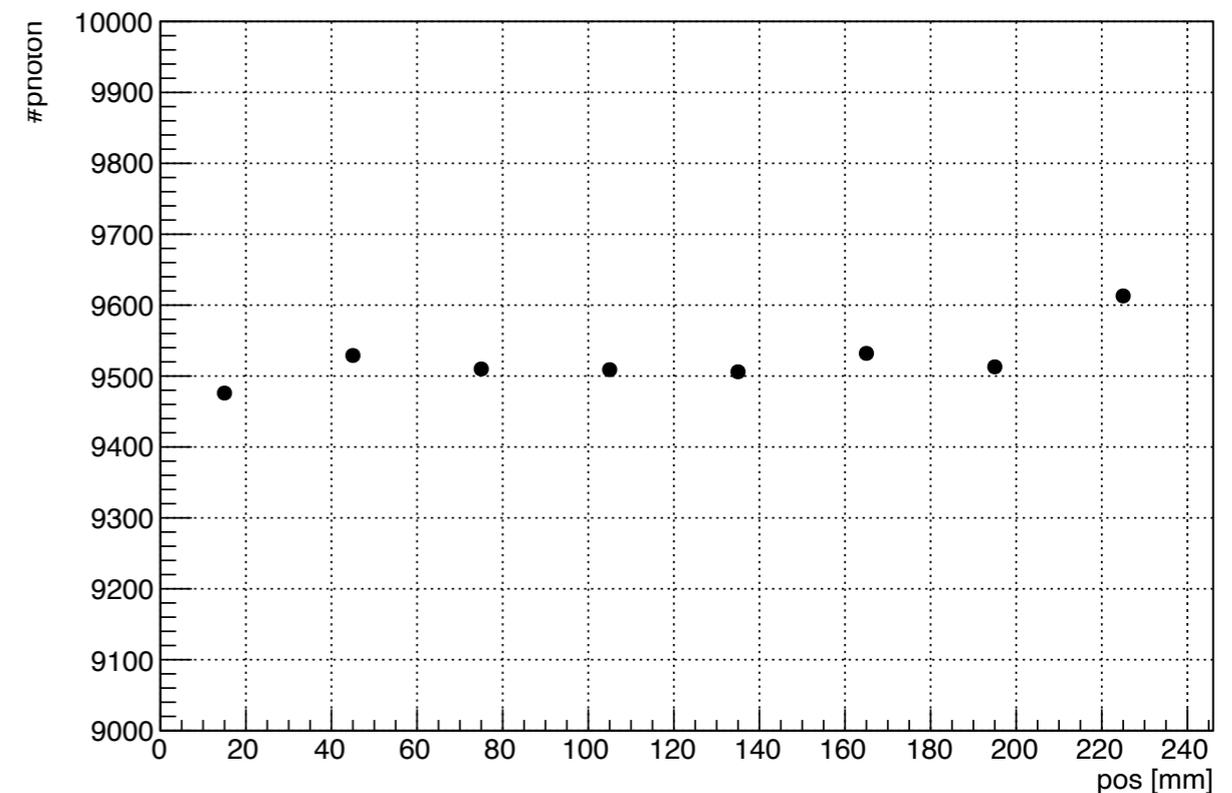


#Photon collected

## Parameters of GEANT simulation

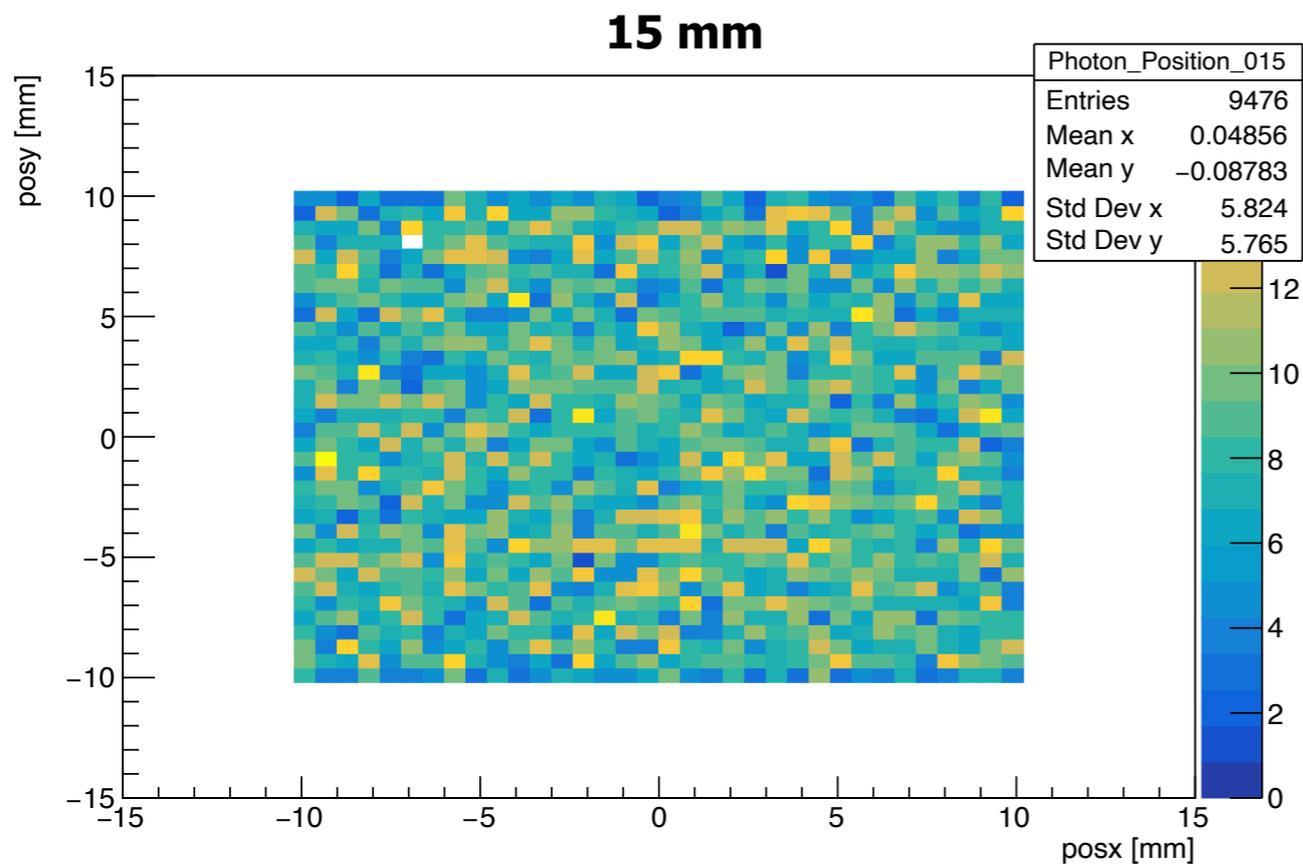
- Crystal dimension:
  - 2x2 cm<sup>2</sup> front face
  - 3x3 cm<sup>2</sup> back face
  - 24 cm length
- Collecting area: 2x2 cm<sup>2</sup> (as our SiPM)
- Refraction index of BGO: 2.15
- Wrapping: Tyvek
  - R: 97% (LUTs)

Thanks Esther!



The light absorption is not present in the simulation. Why?

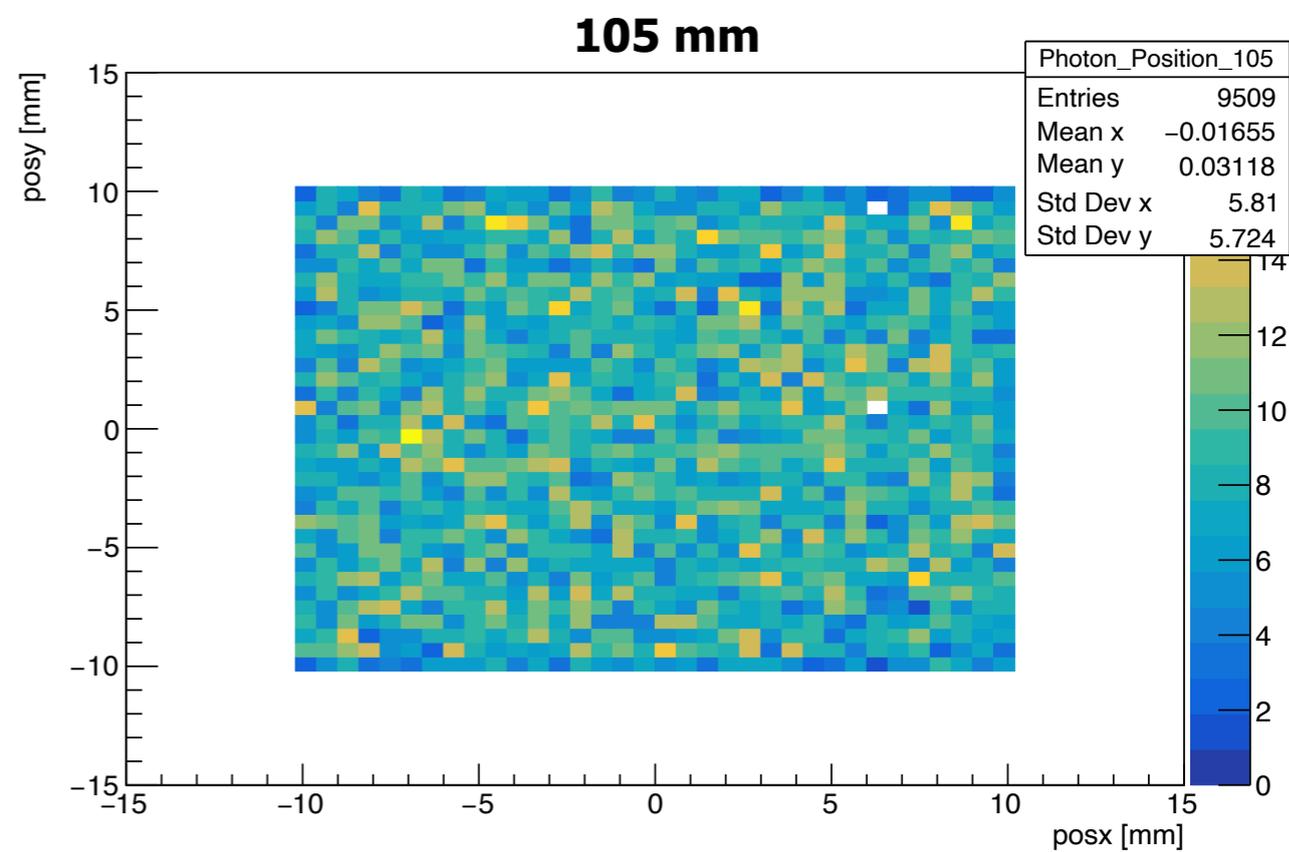
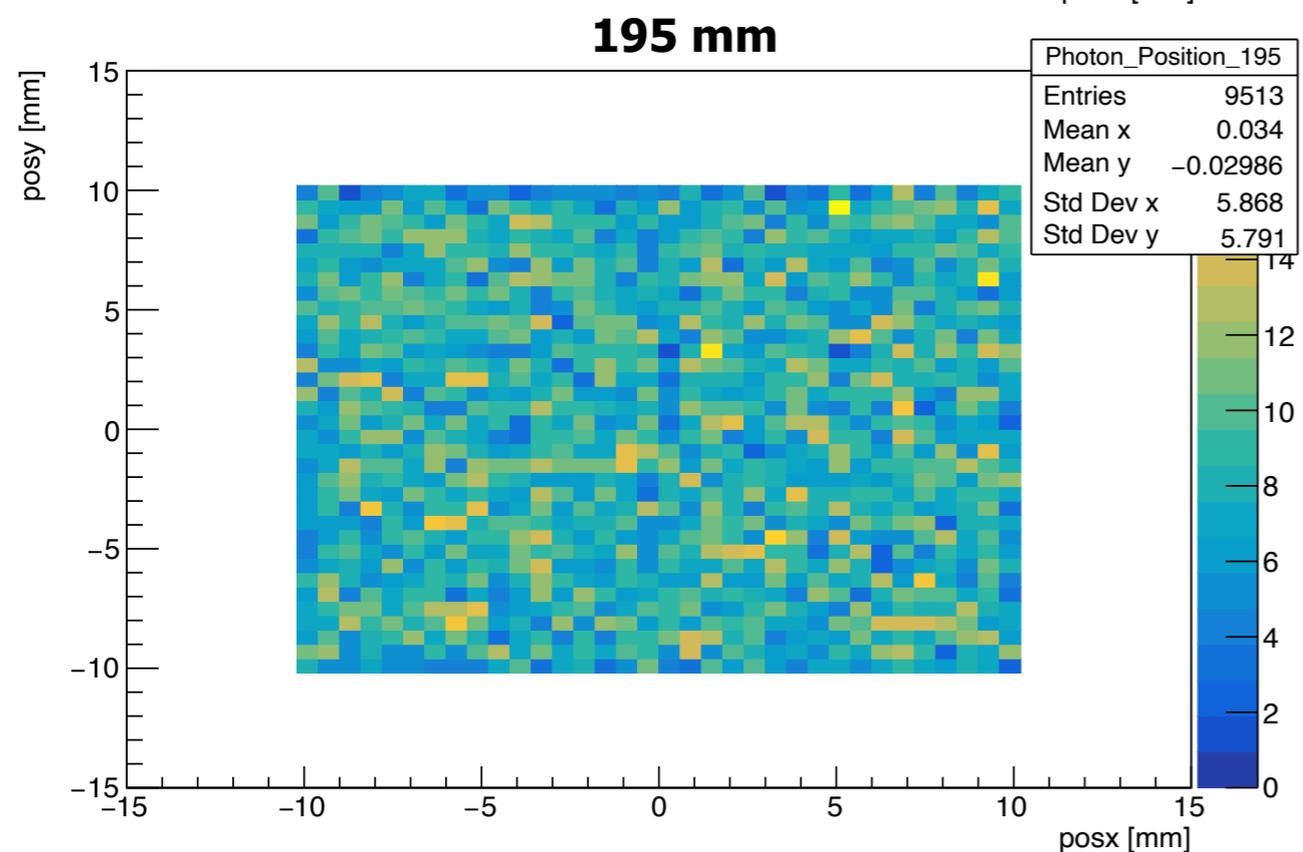
# GEANT SIMULATION



✗ SiPM saturation due to more concentration of photons in specific area of the tile

? Problems with the wrapping reflections?

? Shifting of the photons wavelength?





- The design requirements of Calorimeter performance achieved with the Wavedream board
- The study of the absorbed light along the crystal showed that the effect is not negligible but it is constant between different particles and energies.
- GEANT simulation with all parameters of crystal and tyvek coating not showed this effect, why?

## **Test Beam at CNAO in December:**

- Calibration of the 9 crystals with proton beam (70 and 227 MeV) and carbon beam (115, 260 and 400 MeV/A)
- No particular requests concerning the physics