SAC: Analisi dati Test Beam

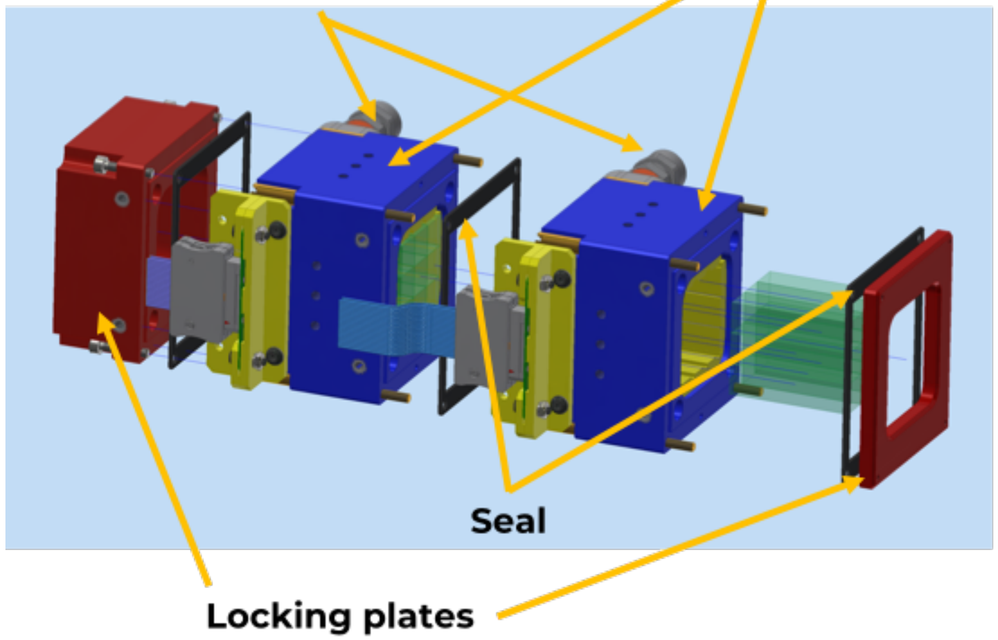
Riunione referees NA62

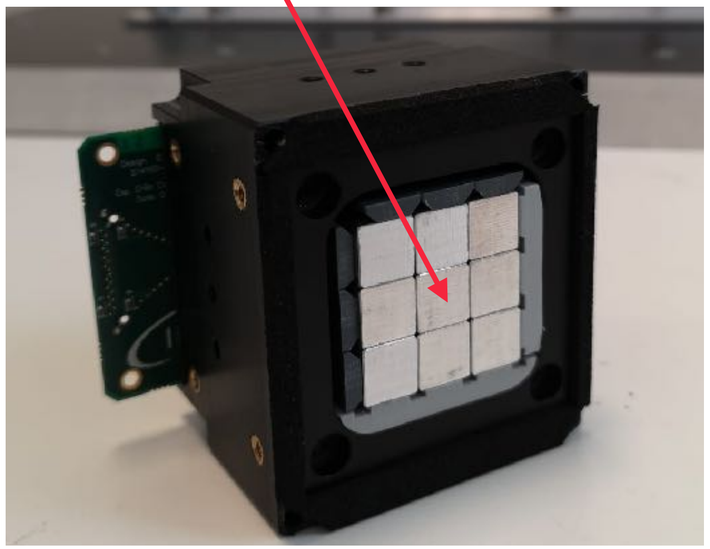
Silvia Martellotti

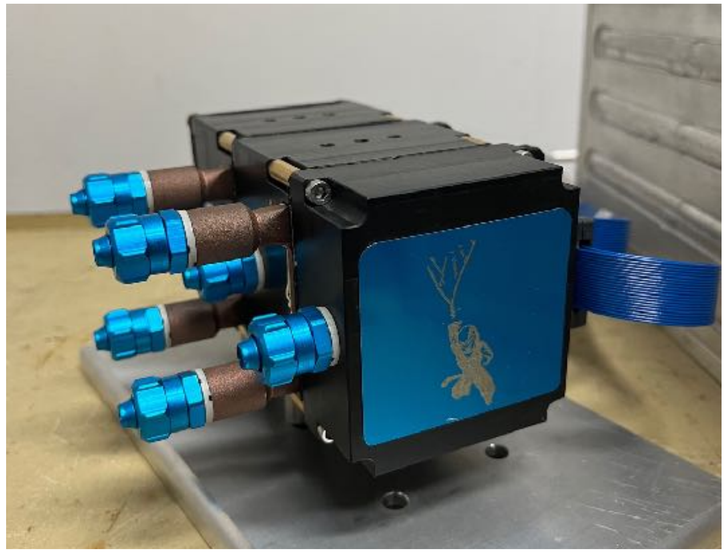
18 Luglio 2025

CRILIN Prototype-1: crystals

3x3 matrices for good transverse shower containment



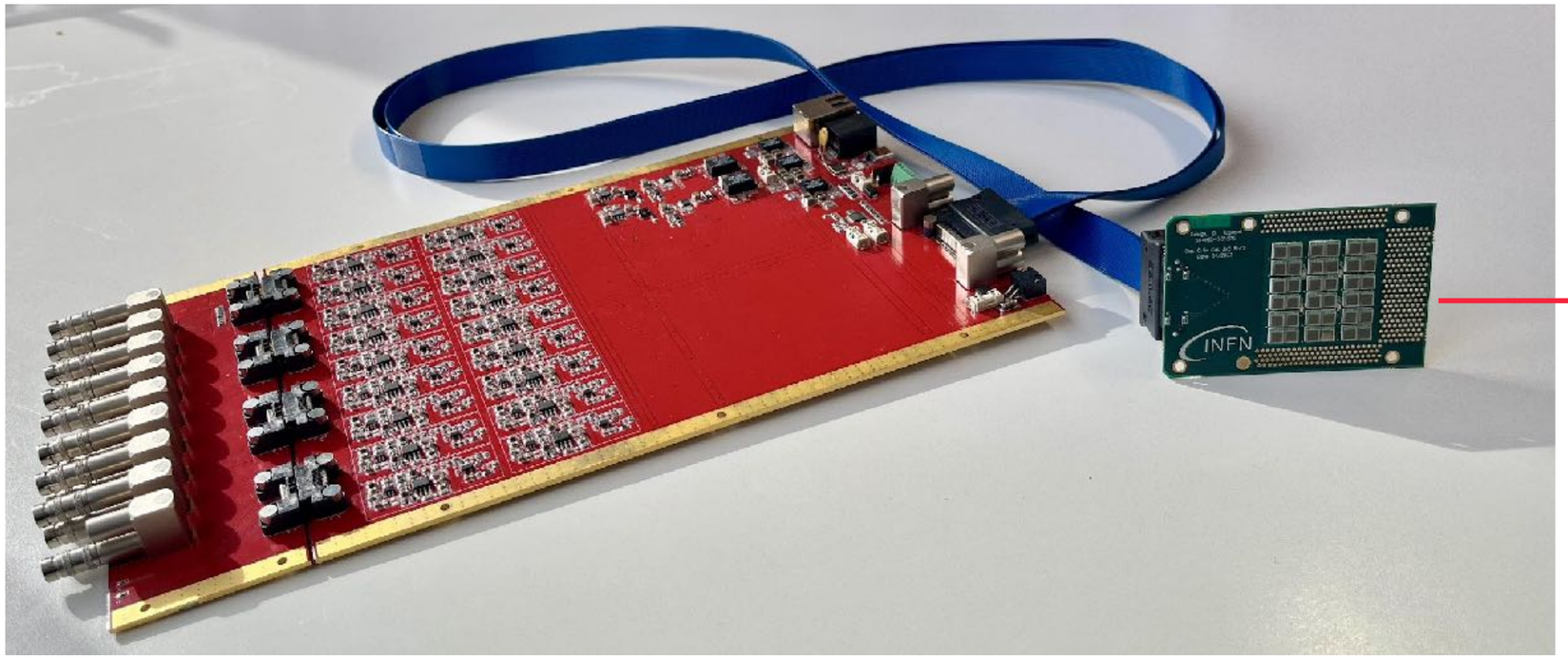


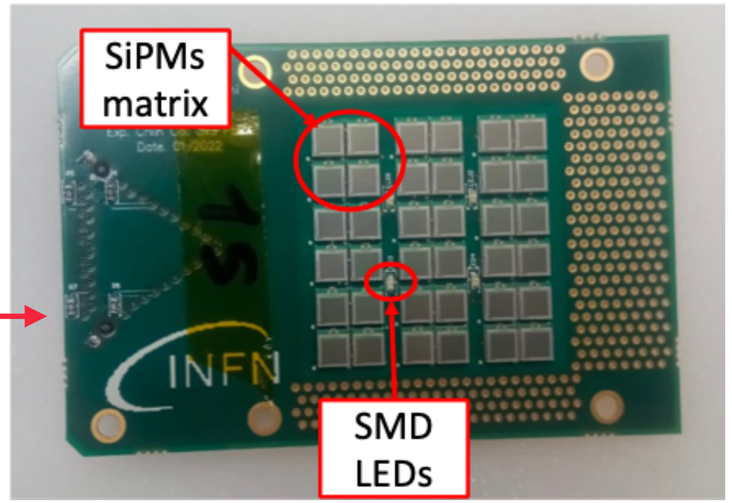


- **2 layers**: 18 crystals in total. Two stackable and interchangeable submodules assembled by bolting
- Light-tight case with integrated SiPM matrix cooling system which embeds the front-end electronic boards
- Each crystal is readout by 4 SiPMs for 2 independent channels: total of 36 electronic channels

CRILIN Prototype-1: electronics

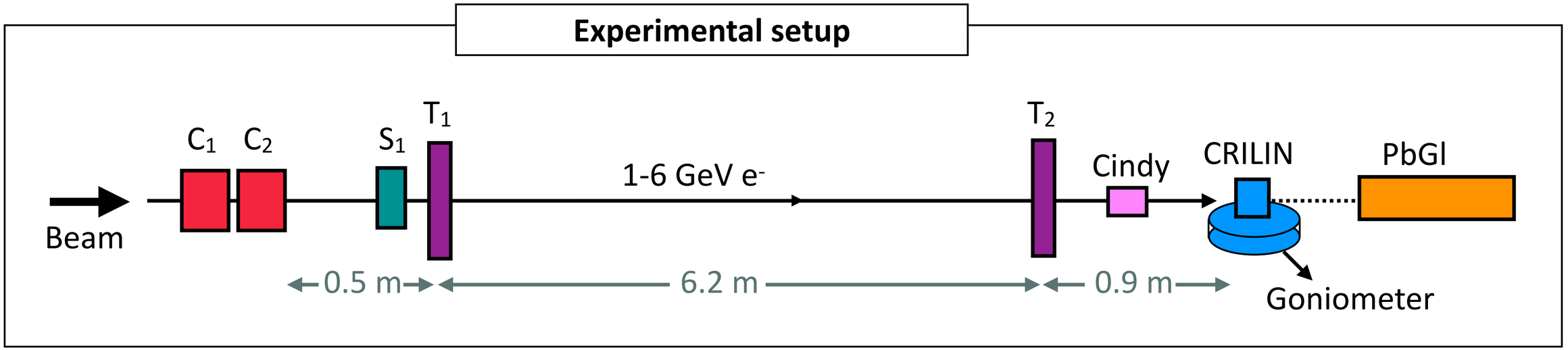
- **Mezzanine board**: 18x readout channels amplification, shaping and individual bias regulation, slow control routines
- **1 layer with pair of SiPMs connected in series**: for a better high-speed response (halves the photosensor equivalent capacitance), short pulse width
- **1 layer with pair of SiPMs connected in parallel**: to study the case in which only one SiPM receives signal





- **SiPMs board**: custom array board 36x10 µm Hamamatsu SMD SiPM

September 2024 test beam @ T9 (CERN)



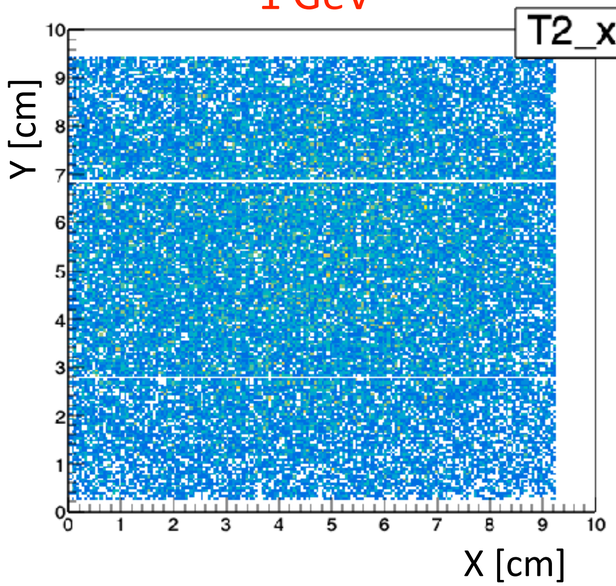
Beam line: 1-6 GeV e^- and MIPs (10 GeV π/μ)

- **2 threshold Cherenkov detectors (C_1, C_2)** to identify electrons
- **Tracking system (T_1, T_2)** made of 2 silicon strip telescopes (σ_X, $\sigma_Y \backsim 30$ μm)
- **Scintillator paddle (S_1)** used as **trigger**
- **Cindy**: custom ultra fast detector used as **trigger** and time reference
- **CRILIN** Prototype-1 with **PWO-UF crystals** wrapped in teflon
- **Lead Glass block calorimeter (PbGl)** for the final energy measurement

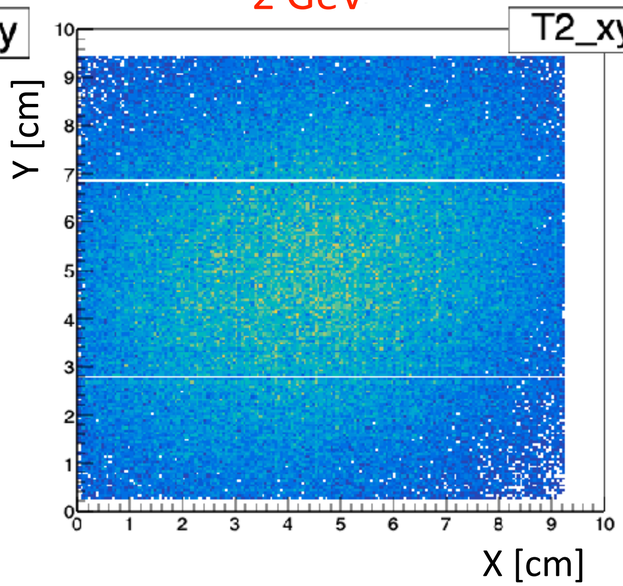
CRILIN is mounted on a goniometer and the central crystal can be aligned with the beam (OREO technology)

T9 beam line

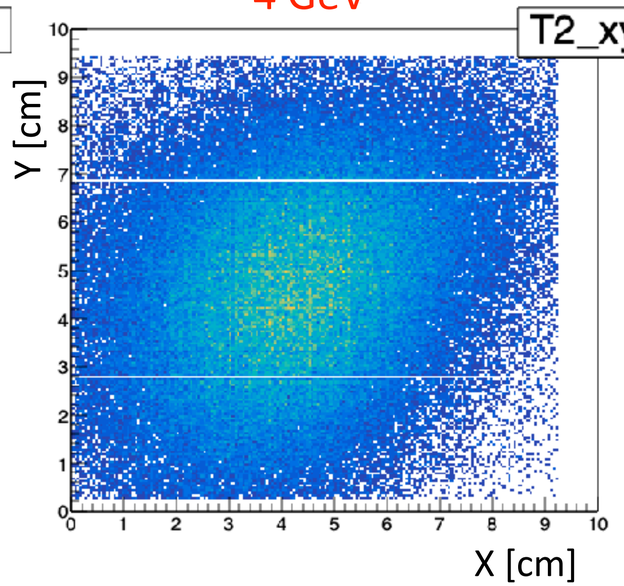
1 GeV



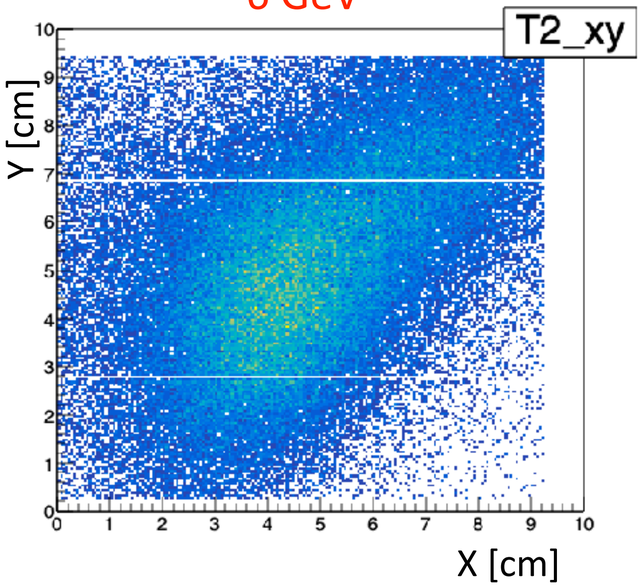
2 GeV

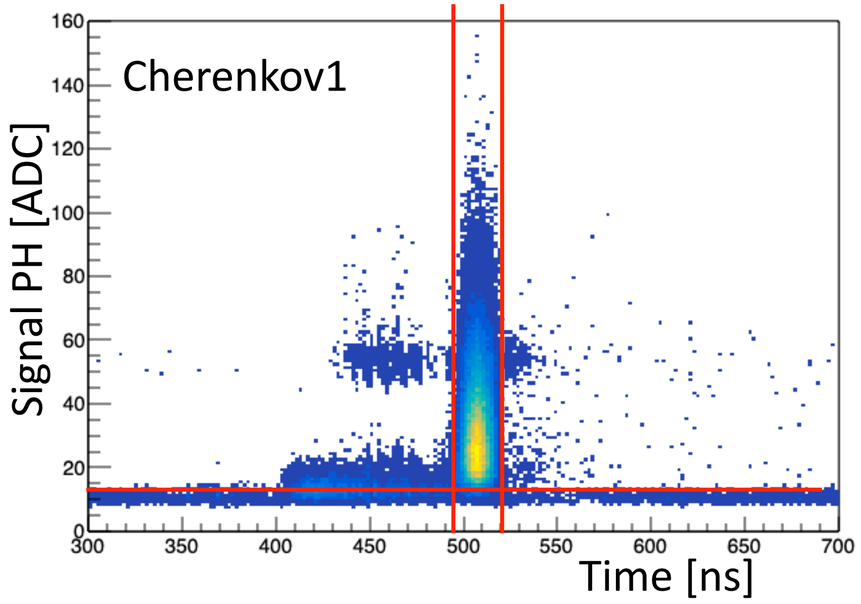


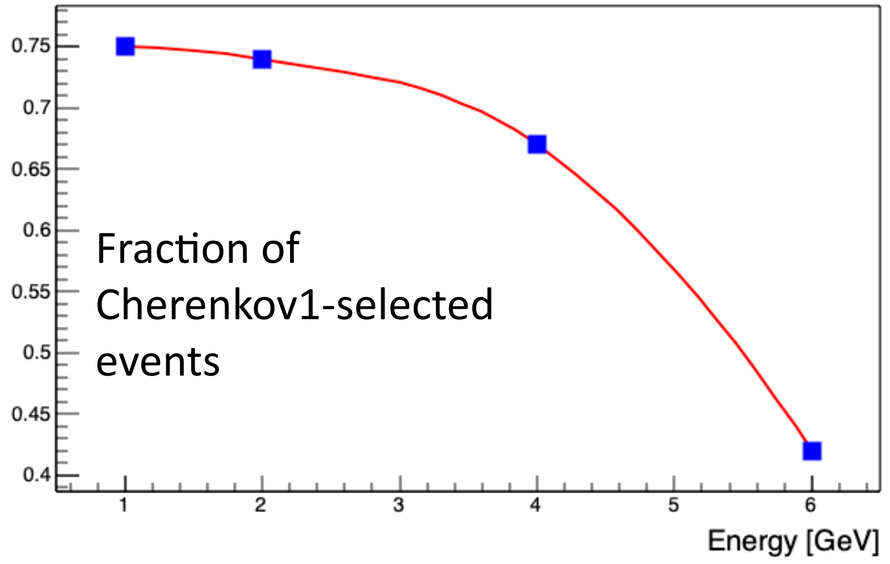
4 GeV



6 GeV







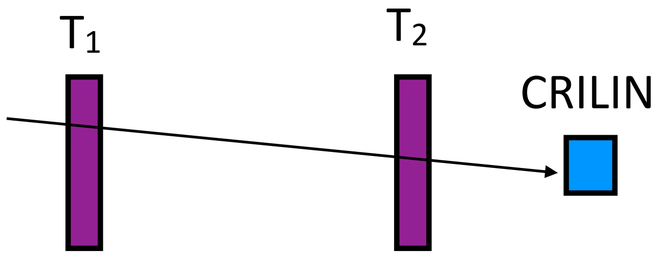
Electrons selection:

- OR between the 2 Cherenkovs

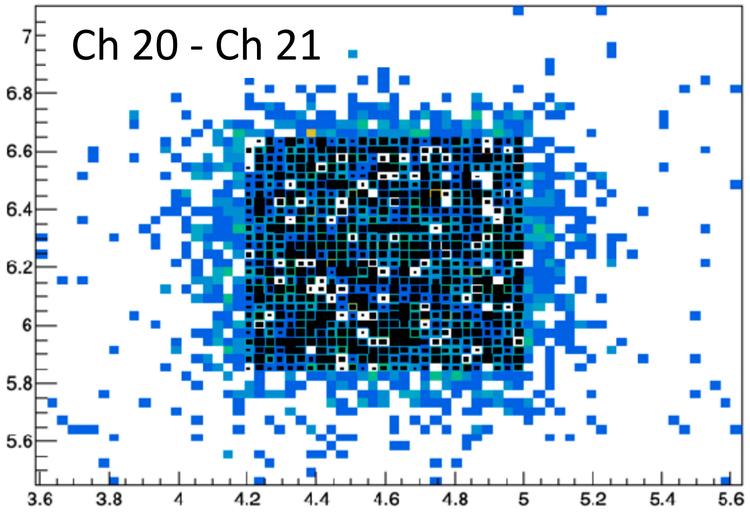
MIPs selection:

- NOT of both Cherenkovs

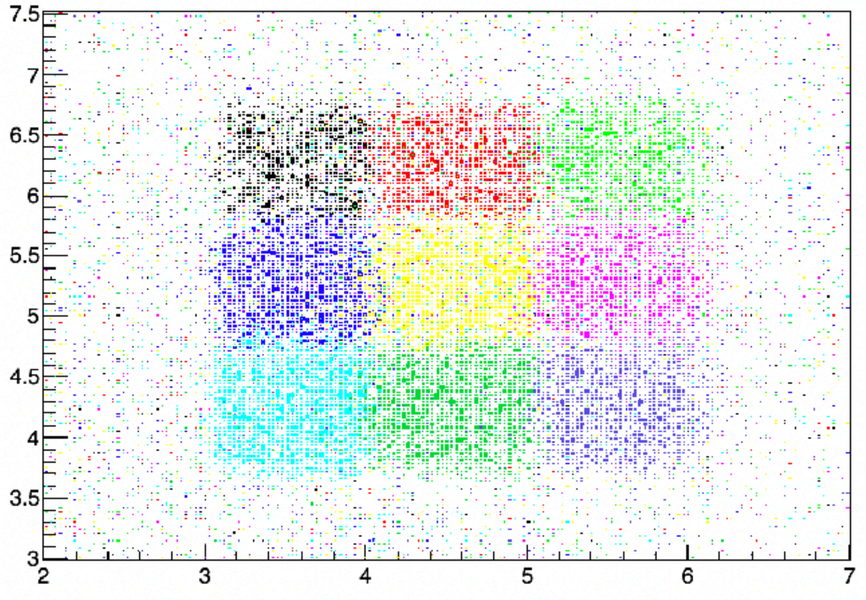
Analysis: crystals fiducial volume



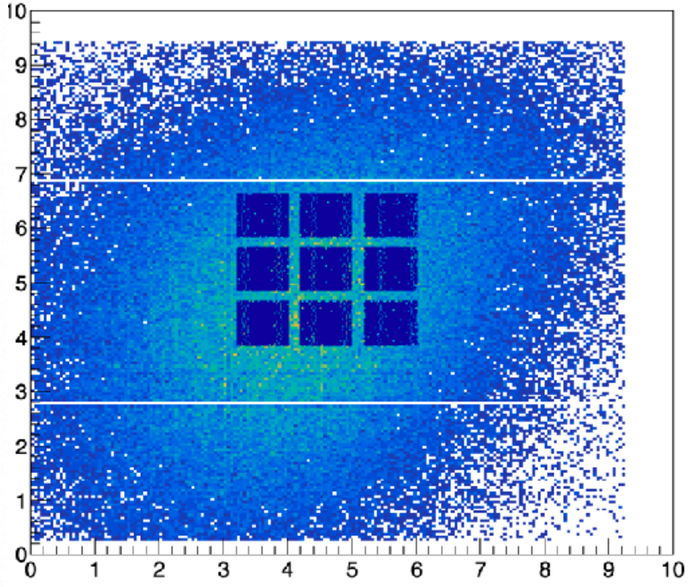
- From the 2 hit points in T1 and T2 we can extract the expected (x,y) of the particles at the CRILIN's surface
- If we require a high pulse height in specific SIPMs we can extract the fiducial volume of each crystal



Plots corresponding to single SiPMs PH cut are here superimposed:



Single crystal FVs are shown superimposed with whole stat:

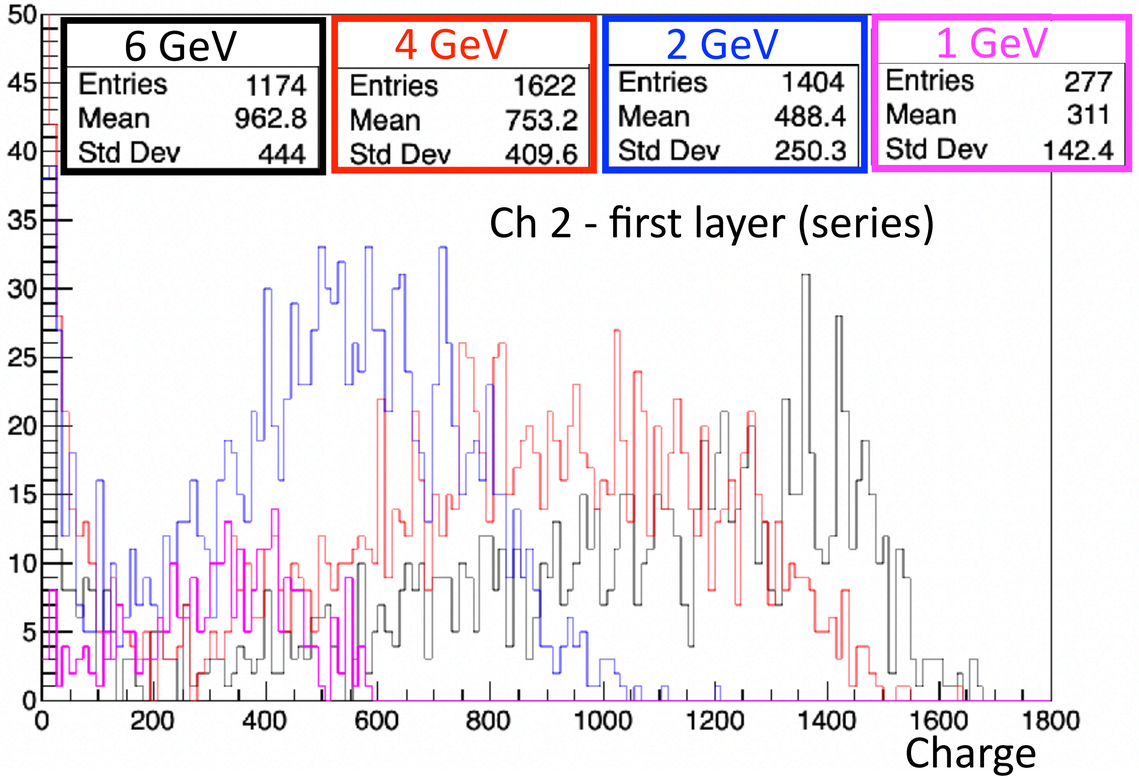


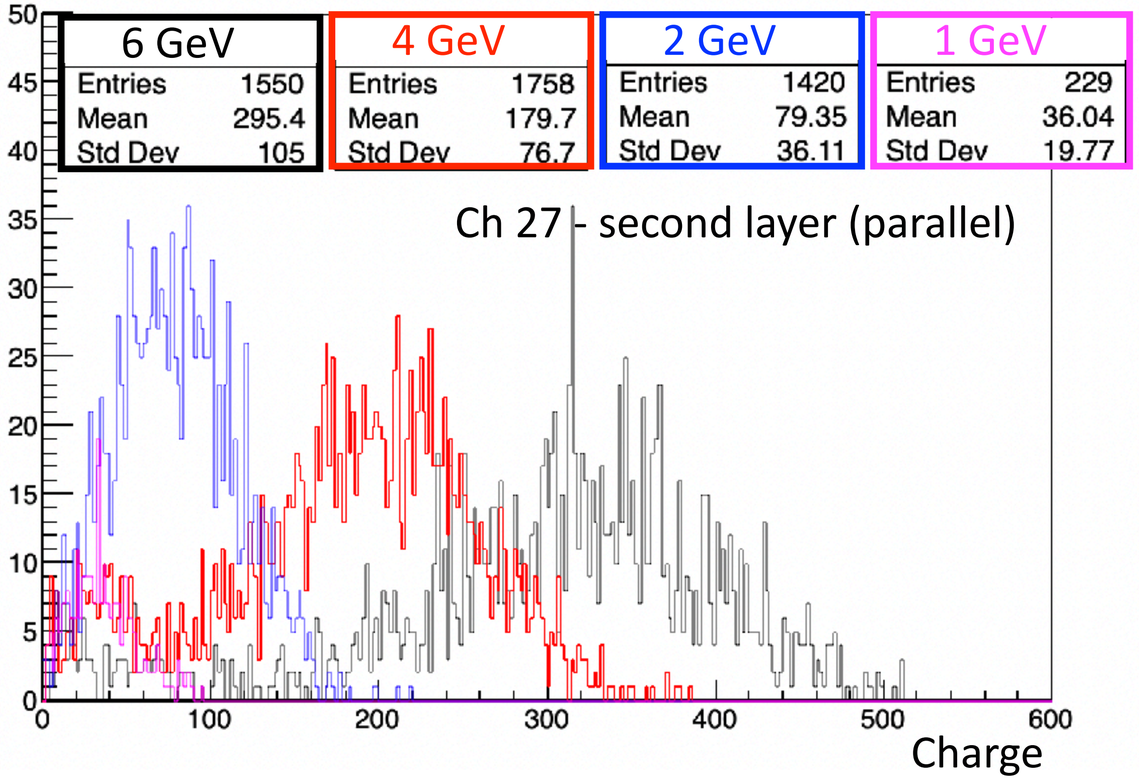
Analysis: channels equalization in charge

e- selection (4 runs at different energies: 1 GeV, 2 GeV, 4 GeV, 6 GeV)

- OR of the 2 Cherenkovs
- FV cut for each crystal

Single-channel charge distributions for e- incident on crystal, with FV cut:

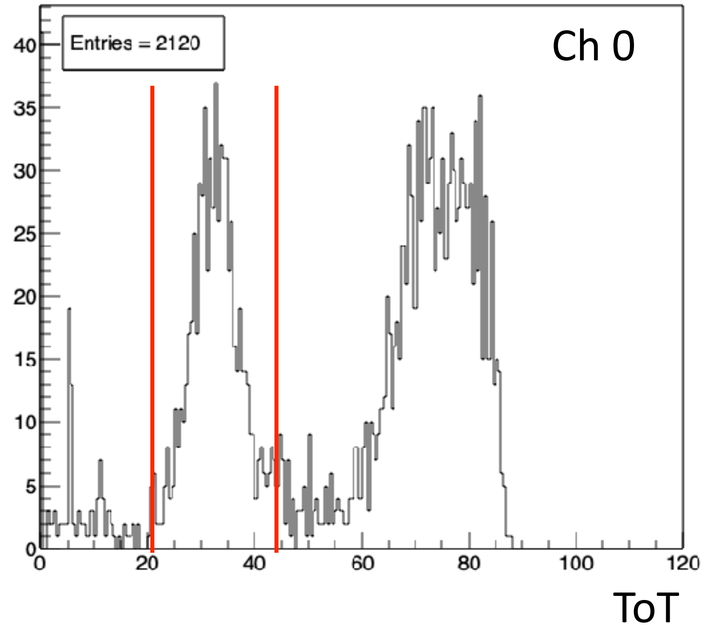




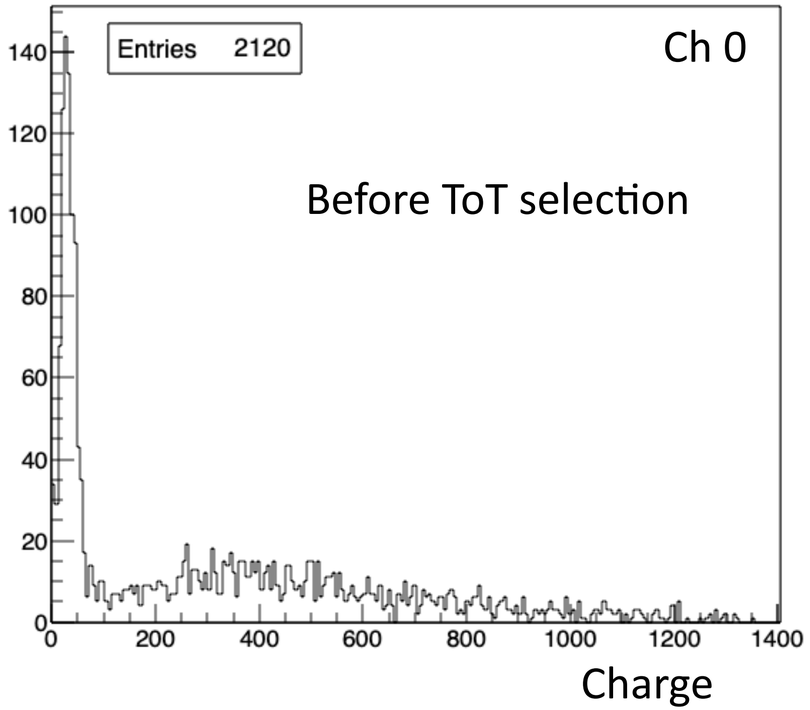
Analysis: channels equalization in charge

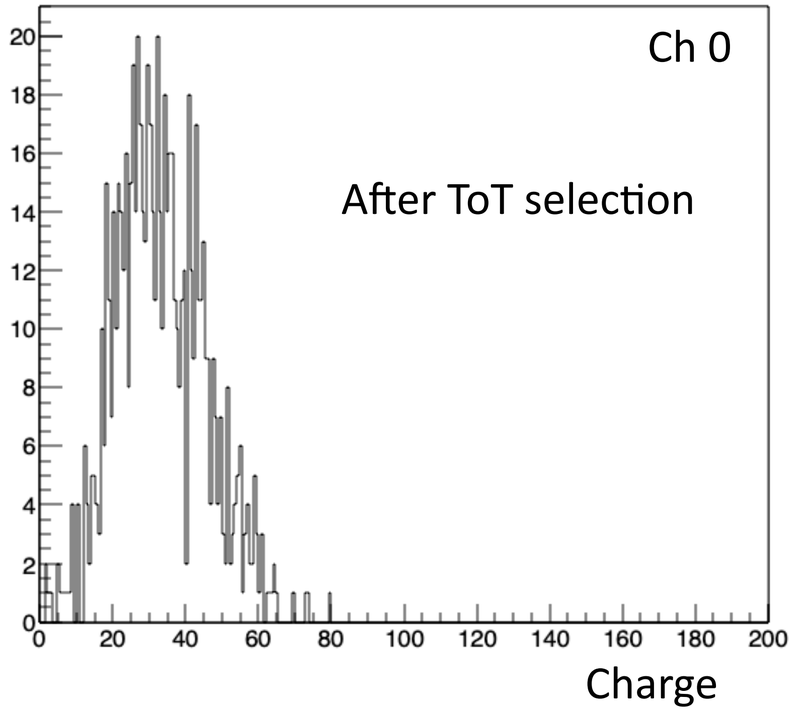
MIPs selection (all statistics: 1 GeV + 2 GeV + 4 GeV + 6 GeV)

- Cherenkovs in NOT
- FV cut for each crystal
- Additional cut in the Time Over Threshold to isolate MIP peak

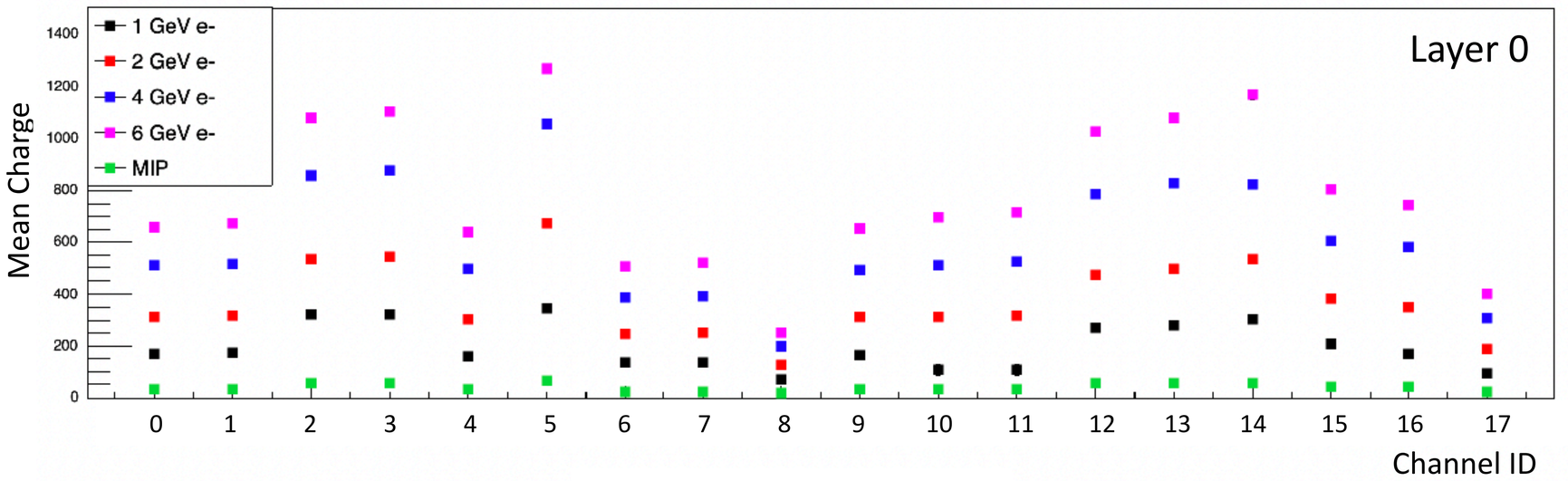


Single-channel charge distributions with FV cut:

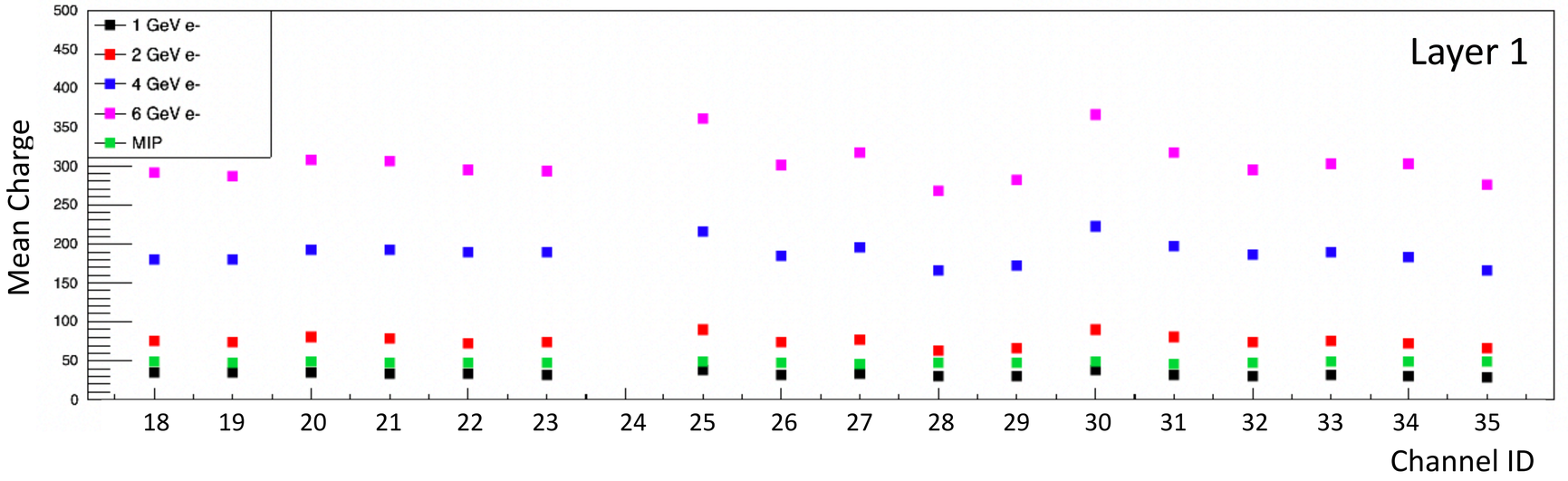




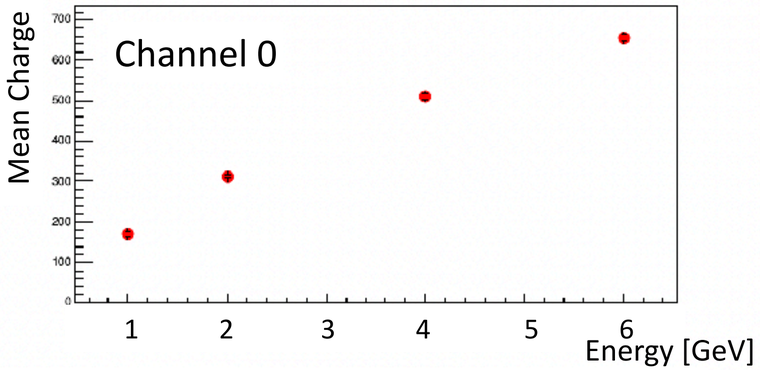
Analysis: channels equalization in charge



Mean of the Gaussian fits to the charge peak distributions for the 36 channels

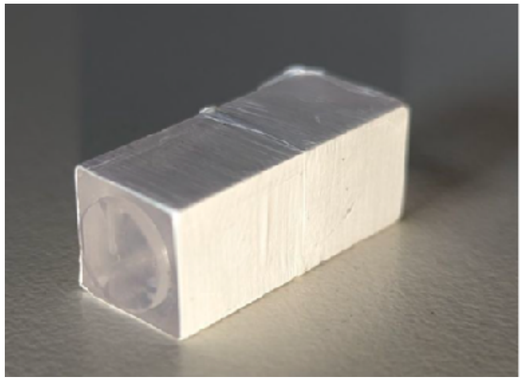


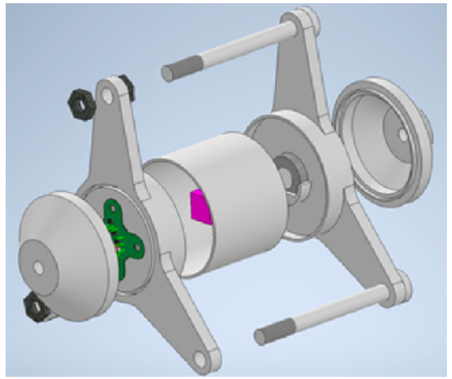
Saturation effect observed:

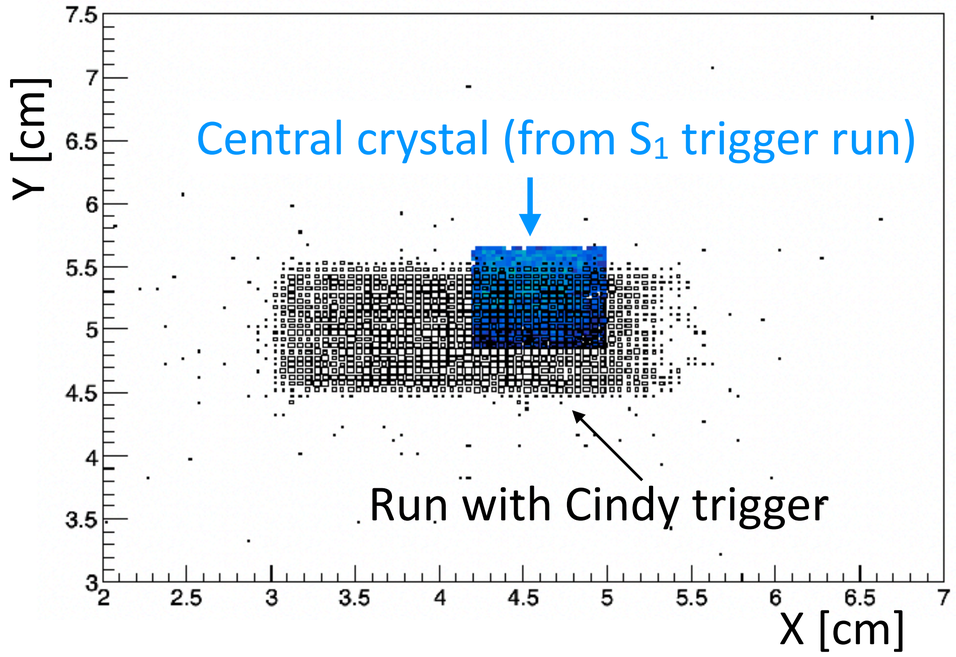


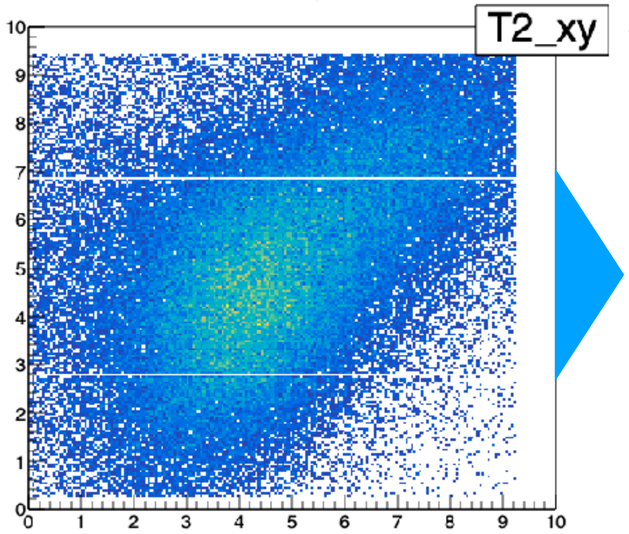
Data taking for the shower studies

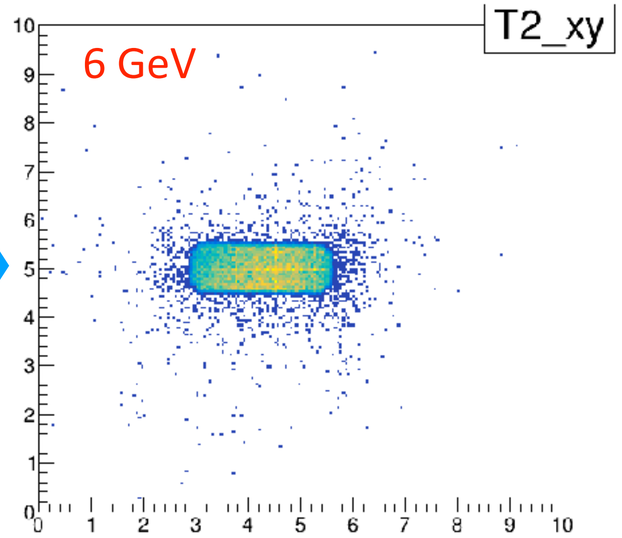
Cindy: Trigger and T_0. Plastic fast scintillator read out on both sides by fast PMTs (Hamamatsu R14755U-100)











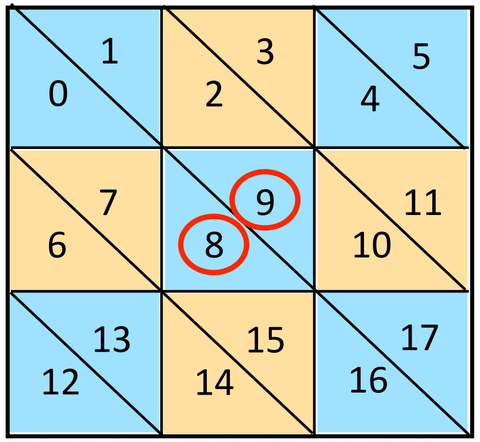
Test beam goals:

- Measure of the **time resolution**
- Measure of the **Molière radius**

In the 2 different configurations:

1. **Random**
2. With crystal axis **aligned** with the beam

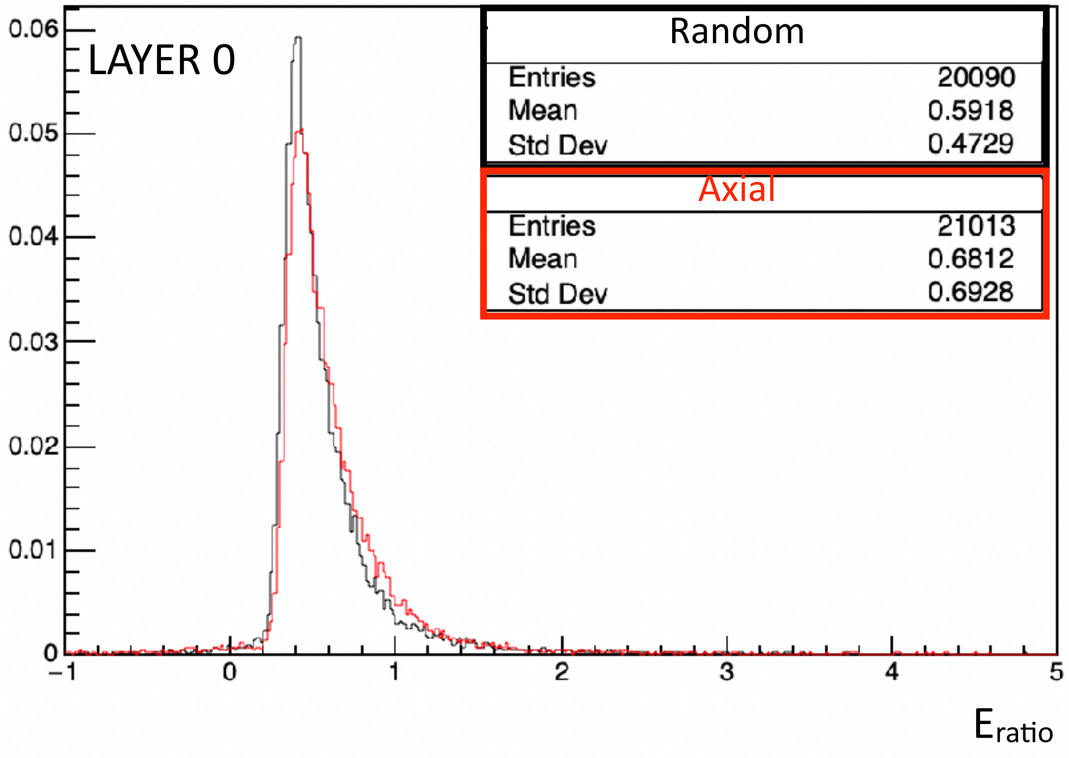
Shower energy ratio

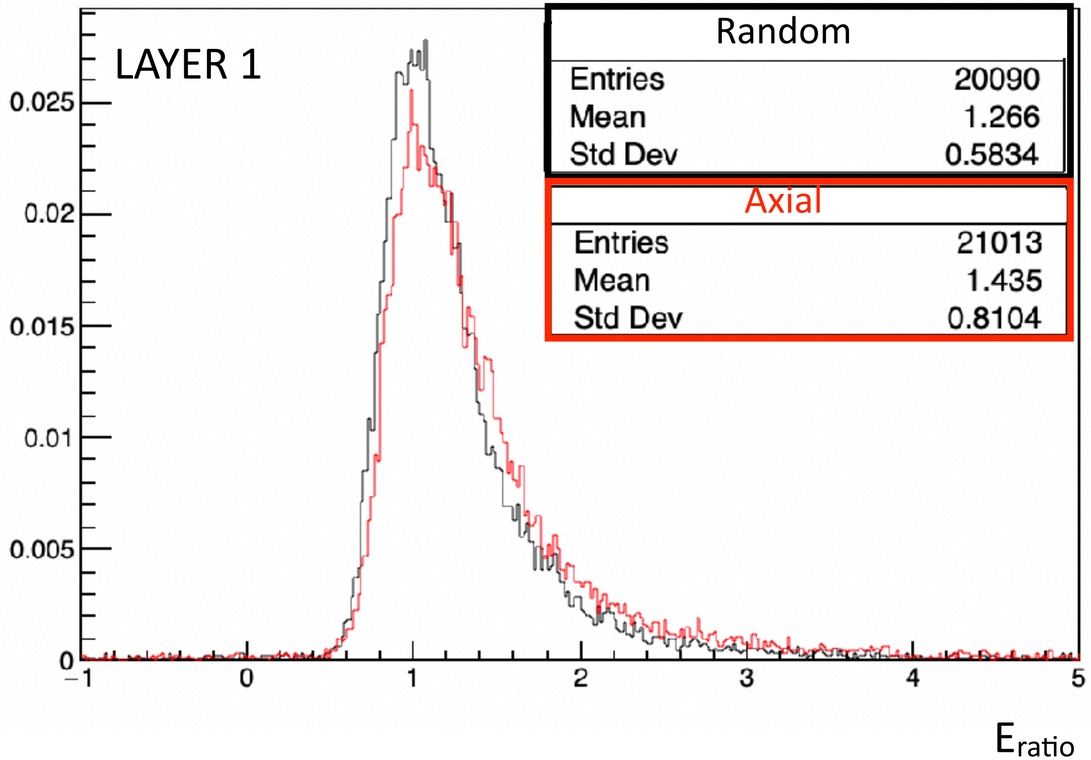


- Selection of particles hitting the central crystal (FV cut of central crystal)
- Ratio between the energy deposit in all external crystal over energy deposit in center

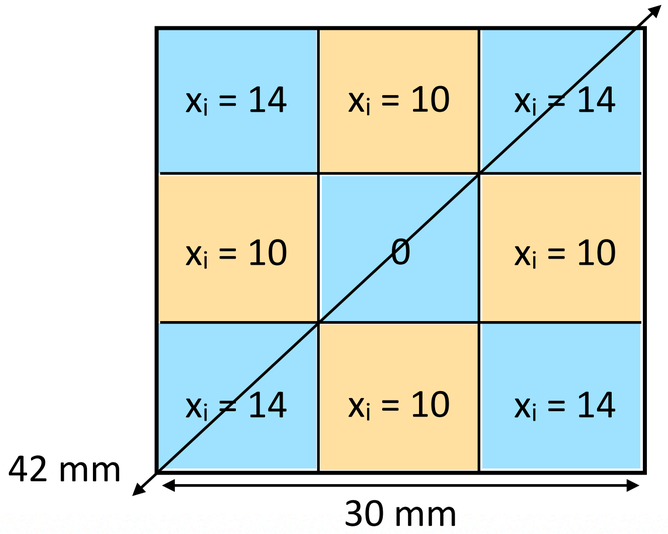
$$E_{ratio} = \frac{E_{external}}{E_{central}}$$

Preliminary! (To be compared with MC)





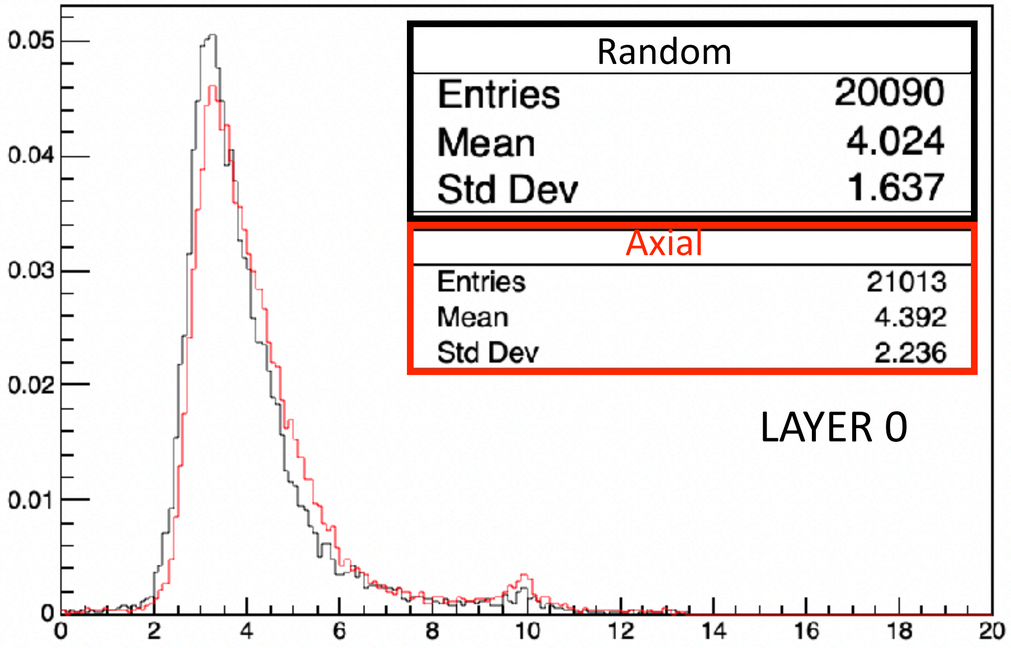
Shower effective radius

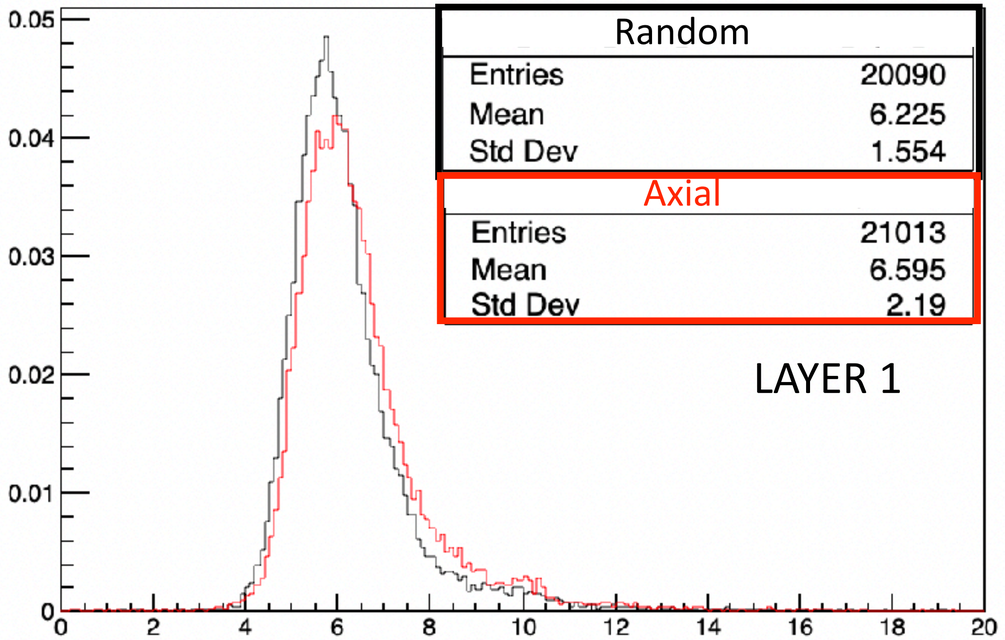


- Selection of particles hitting the central crystal (FV cut of central crystal)
- Effective cluster radius obtained with energy weighting

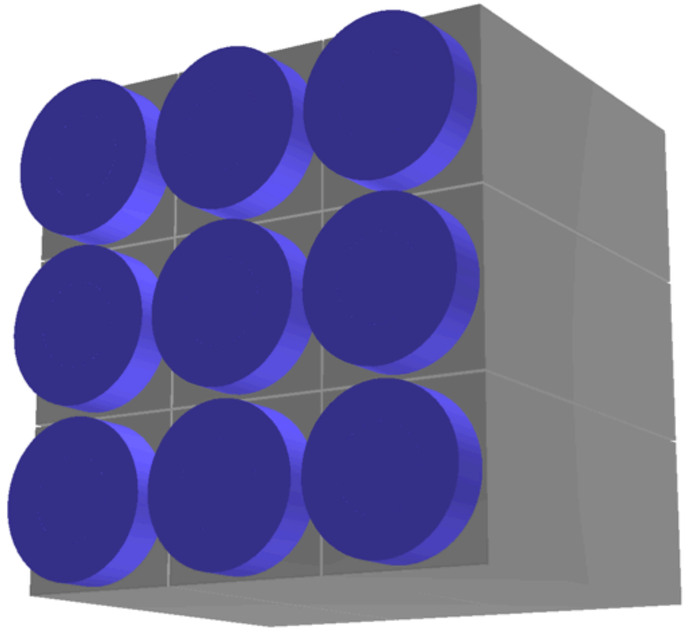
$$R_{eff} = \frac{\sum E_i \cdot x_i}{\sum E_i}$$

Preliminary! (To be compared with MC)





Conclusions



Analysis ongoing to reach new result

- Effect of crystal alignment in Molière radius
- Comparison with GEANT4 simulation with aligned crystal effect

To do

- Time resolution studies

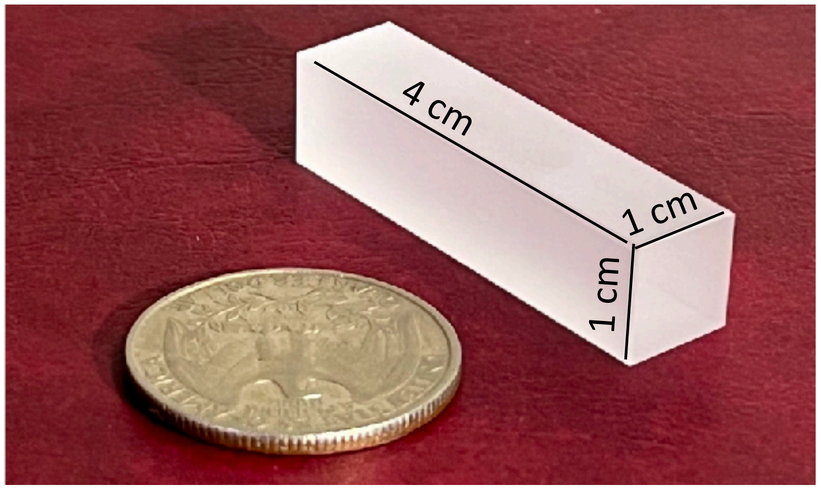
Next step

- Complete construction of new 2-layers prototype: 3x3 alignable bigger crystals (18x18x40 mm^3), with single-board PMTs readout
- Test the SAC prototype in September 2025 at T9
- Publication with test results for an ultra-fast, highly compact, radiation robust, alignable calorimeter for intensity frontier experiments

Backup

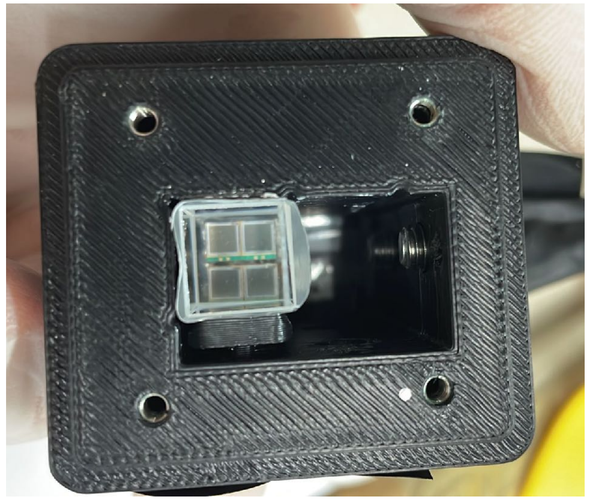
CRILIN Prototype-0

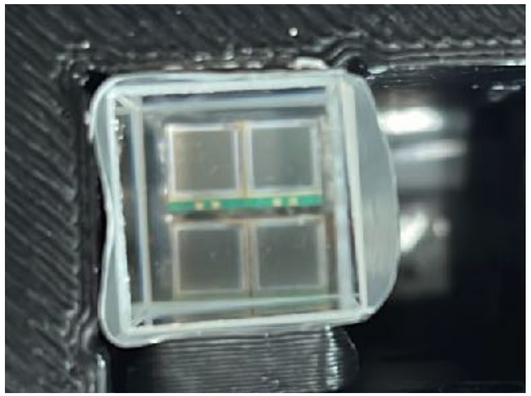
1 single crystal (10 × 10 × 40 mm^3). 2 options: **PbF_2** (4.3 X_0) **PWO-UF** (4.5 X_0)

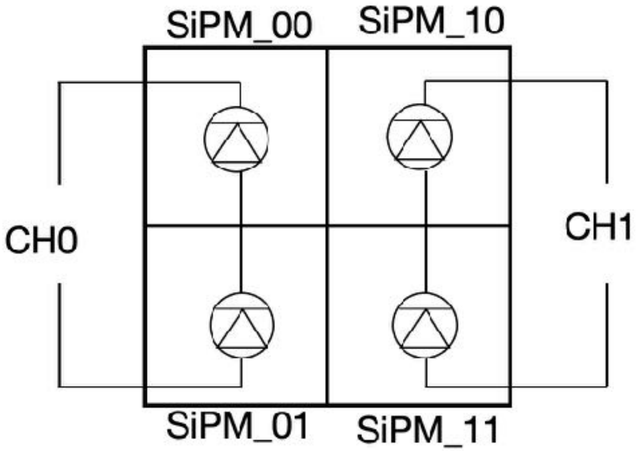


Readout electronics:

- 4x4 mm^2, 10 µm pixel size SiPMs
- 4 SiPMs (2x2-series connection: 2 independent readout channels)
- Electronics gain = 4 (amplifier)
- digitizer with a dynamic range of 1 V
- signals digitized at 5 GS/s (1 ADC = 0.2 ns)



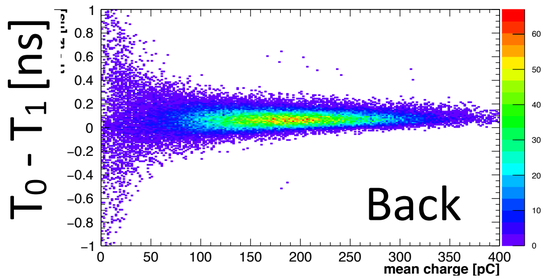


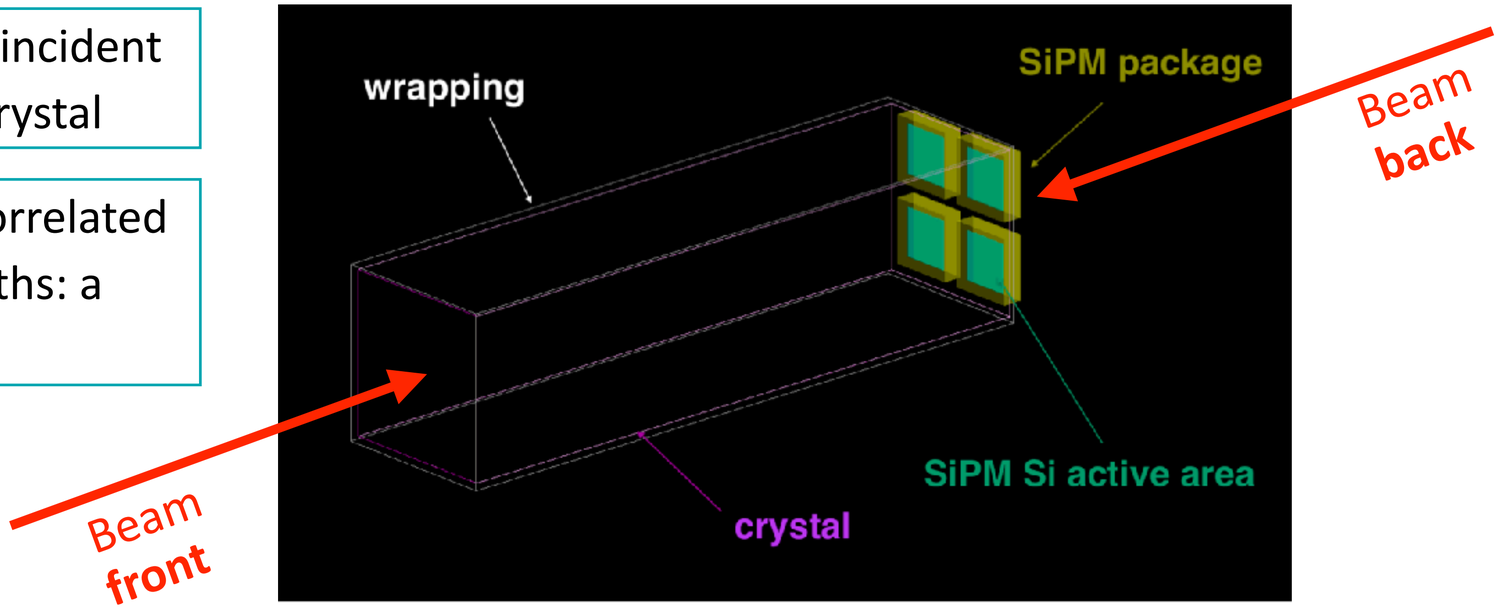


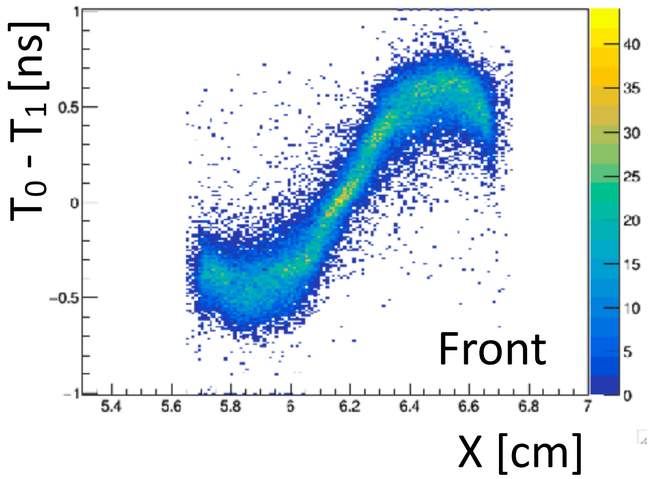
Systematics of light transport

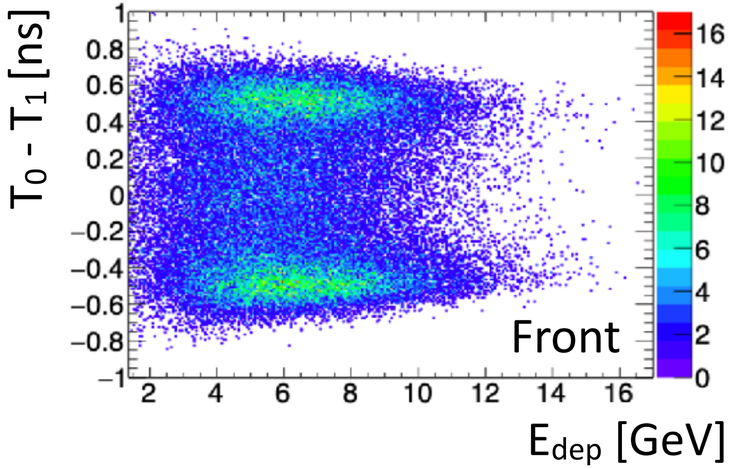
2 different configurations have been tested: incident beam with SiPM upstream or downstream crystal

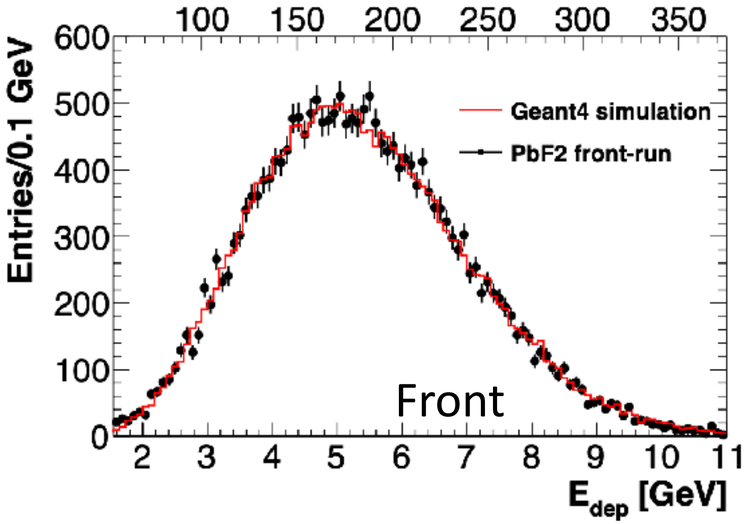
For **FRONT** runs the reconstructed time is correlated to the geometry, there are different light paths: a correction should be applied







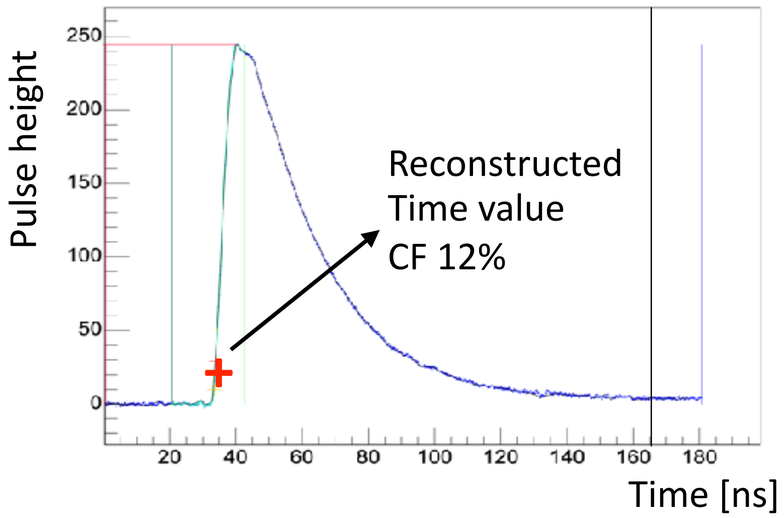




Good MC agreement!

Prototype-0 Results

SiPM waveform study



TSpline multiple fits to interpolate the SiPM waveform shape + Constant Fraction (12%)

Time resolution for single 10×10×40 mm³ calorimeter cell (mean time of two SiPM readout channels) for E_{dep} > 3 GeV:

PbF_2: < 25 ps (20 ps) with beam incident front (back)

PWO-UF: < 45 ps (30 ps) with beam incident front (back)

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