

Cosmic Ray Tagger for *ARTIC @ GE* (... and full-scale prototype *@ LNL*)

Antonio Surdo

for the Lecce group

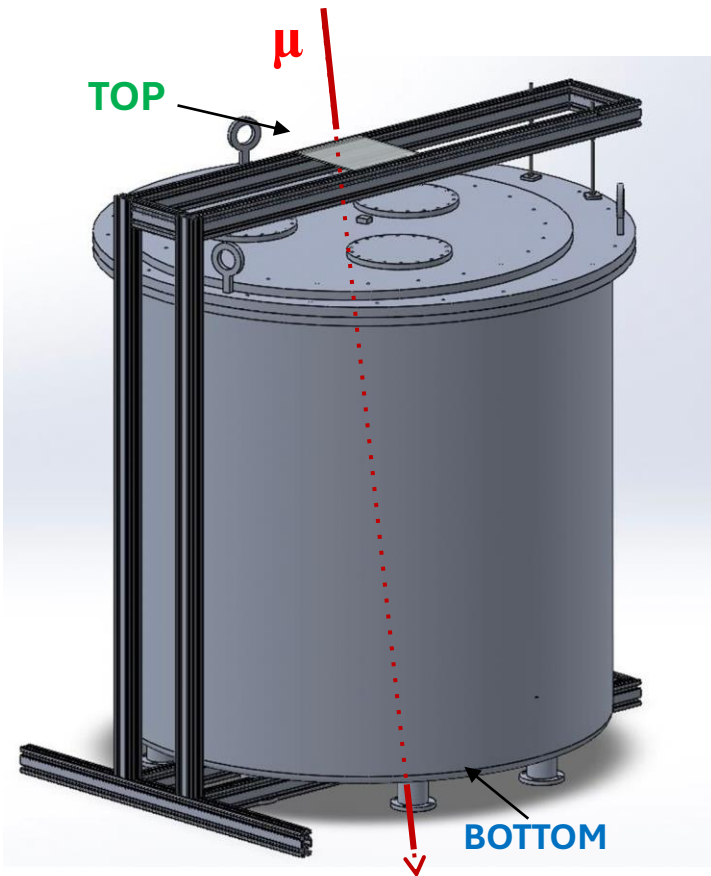
DUNE Italian General Meeting
Ferrara, 28-30 October 2024

Cosmic Ray Tagger (CRT) for *ARTIC @ Genova*



CRT GOALS:

- Trigger for the LAr acquisition (fourfold coincidence)
- Two-view tracking to help the LAr event reconstruction



CRT DESIGN:

TOP (50 cm x 50 cm active surface)

16 bars x 2 orthogonal planes:

- 8 bars (50 x 4 x 1) cm³
- 8 bars (50 x 2 x 1) cm³

BOTTOM (34 cm x 34 cm)

12 bars x 2 orthogonal planes:

- 4 bars (37 x 4 x 1) cm³
- 8 bars (37 x 2 x 1) cm³



SCINTILLATORS:

Saint Gobain BC-408

READ OUT:

6x6 mm² SiPMs

Hamamatsu S14160-6050HS

14331 pixels and 50 μm pitch

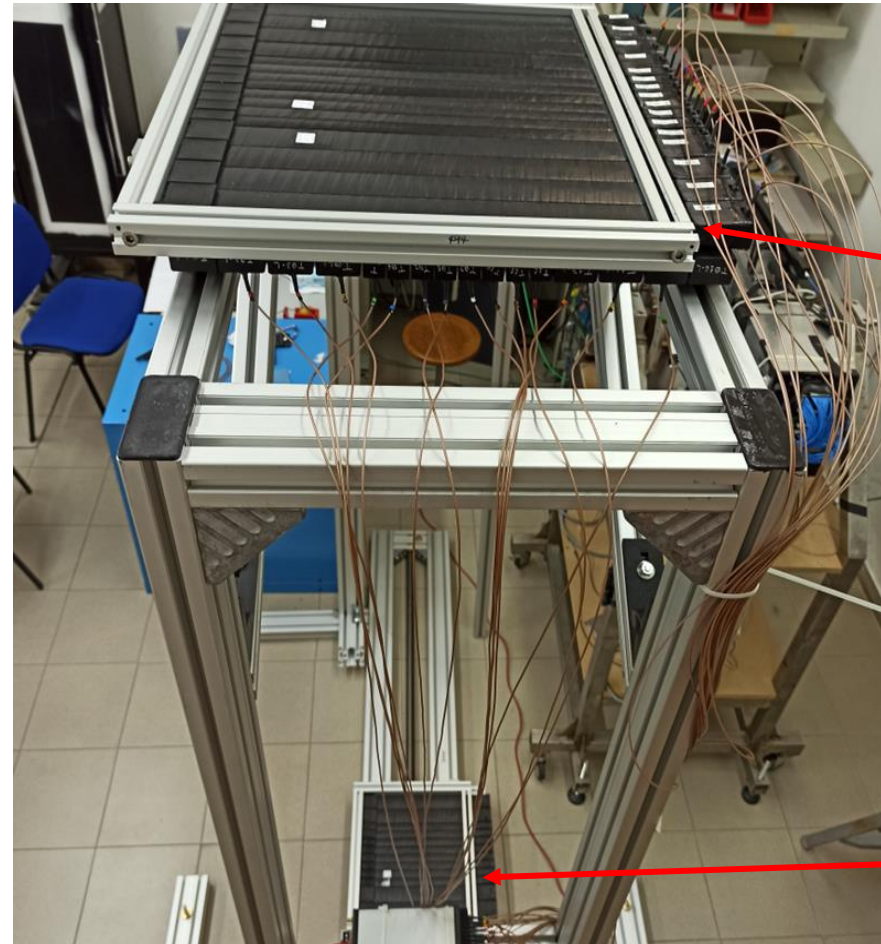


DAQ BOARD

CAEN FERS - DT5202



CRT setup mounted and tested in Lecce



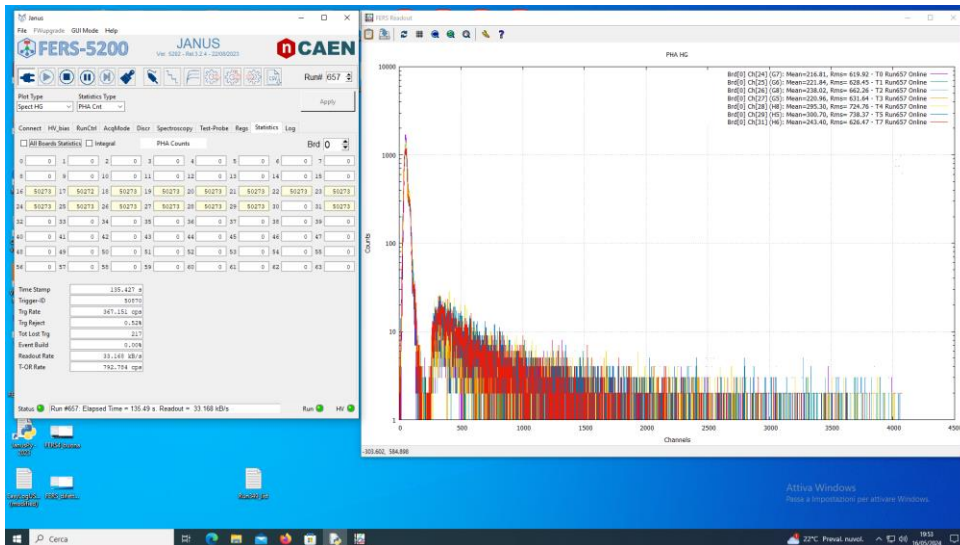
TOP tray



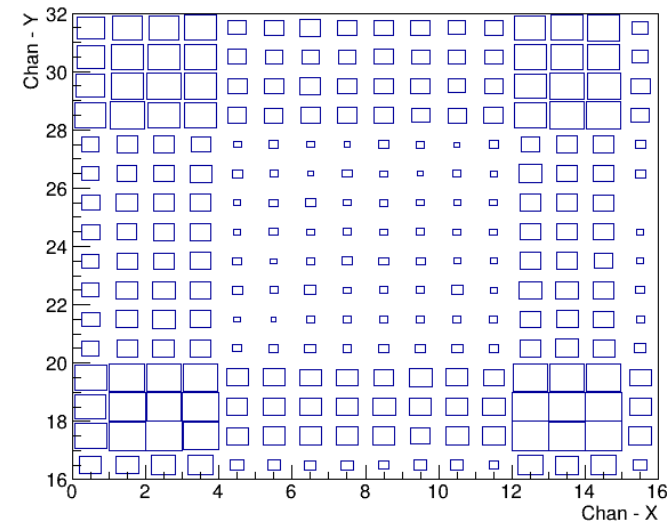
BOTTOM tray

DAQ tests: single plane rate measurement and TOP-BOTTOM fourfold coincidences

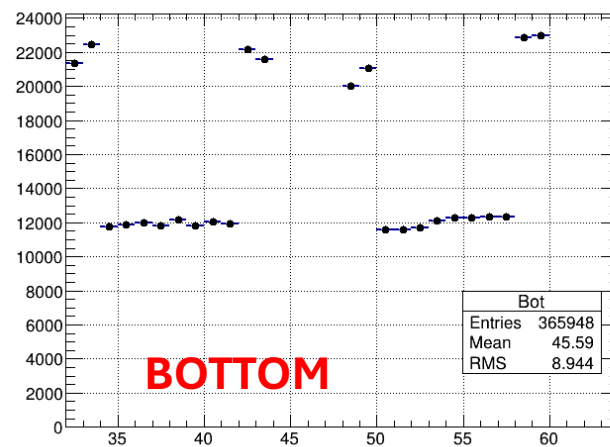
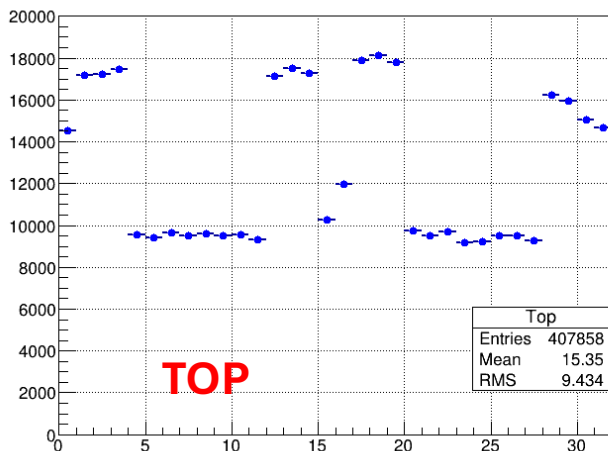
CRT: DAQ-test and debug in Lecce



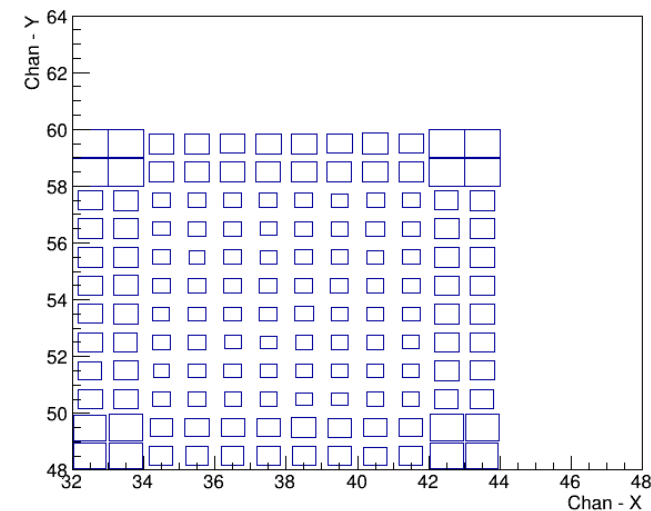
Occupancy: Top_Y vs Top_X



TOP-BOTTOM fourfold coincidence: Bar occupancy



Occupancy: Bot_Y vs Bot_X





ARTIC cryostat was previously lifted up to allow the placement of the CRT bottom arm



-29/10/2024

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CRT commissioning

- Installed on ARTIC @ Genova in July
- Preliminary stand-alone test: OK
- Ready for ARTIC operations on next months

CRT: DAQ Runs with Cosmic Rays in Lecce

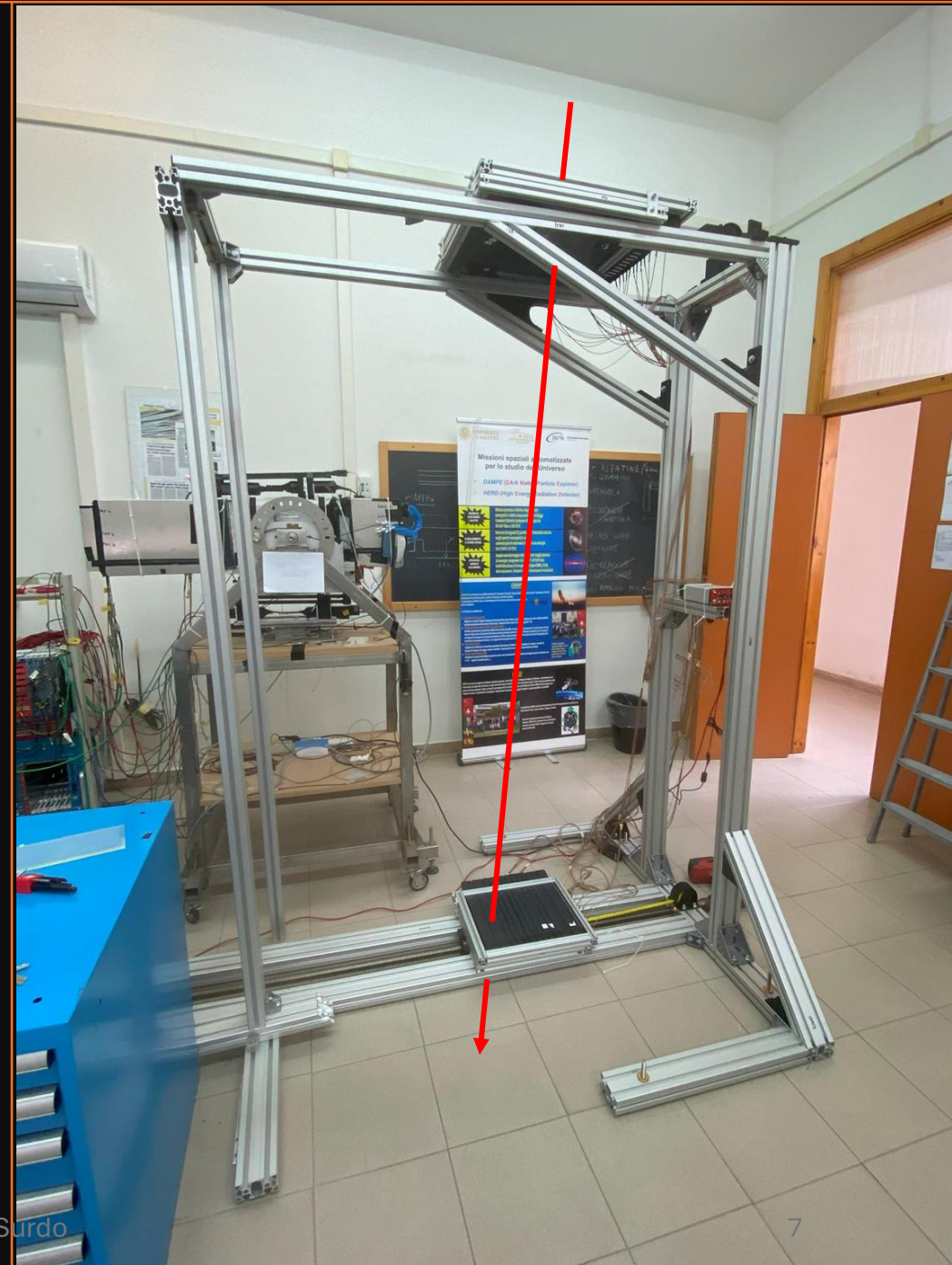
- Implementation of the **four-fold coincidence** trigger (**2 on TOP .and. 2 on BOTTOM**) for different configurations of the setup
- DAQ by the **CAEN FERS** Board and **decoding of data** by means of a proper program, called ***DecodeFERSAndTrigger*** (developed by F.Alemanno)
- On the **sub-sample of the «1 bar for each plane» events: track reconstruction** (same code) according to the nominal telescope layout geometry
- Comparison of **zenith angle distribution** (shape and rate) with the prediction of a simplified **Monte Carlo** implementing just dimensions and geometry of the layout

$$\mathbf{Flux} = \mathbf{I_0 \cos^2\theta} \quad \mathbf{I_0 \approx 72 /m^2 /s /sr}$$

- Overall muon flux on a horizontal surface: $\sim 113 \mu /m^2/s$
- Expected Rate on TOP ($A=0.25 \text{ m}^2$): $\sim 28 \mu /s$

CRT: DAQ-Runs on Cosmic Ray muons - 1

→ Near-vertical tracks

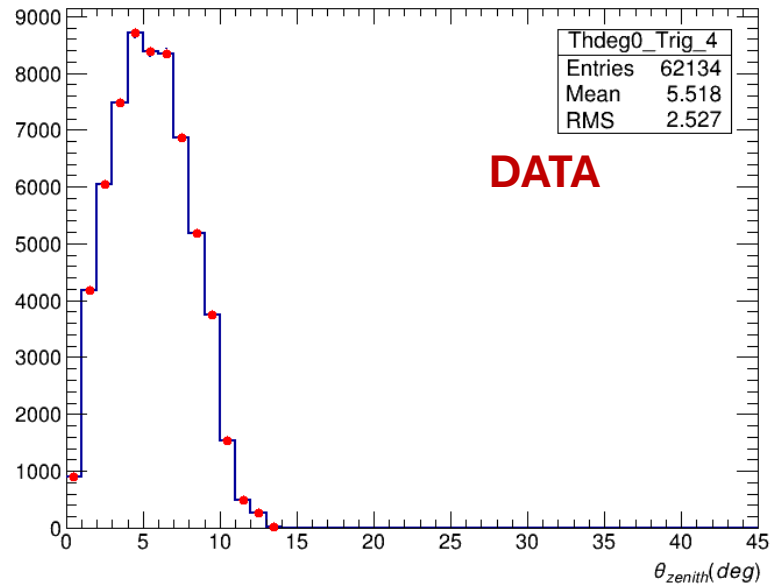


Vertical CR muons

DATA

- Global sample: 80,705 events (DT \approx 95,000 s)
- ‘Muons’ (≥ 1 bar on each plane): 97 %
Rate $_{\mu}$ \approx 0.53 Hz
- Tracks (1 bar on each plane): 79 %

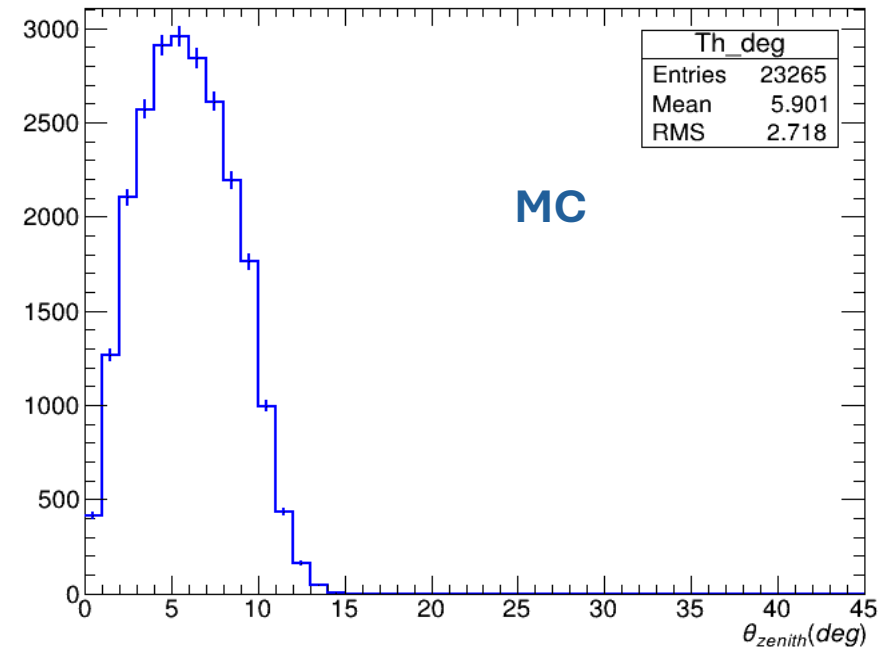
Zenith-angle distribution



Monte Carlo

Geometrical acceptance (T+B): 0.023
Expected T/B Muon Rate: 0.65 Hz

Zenith-angle

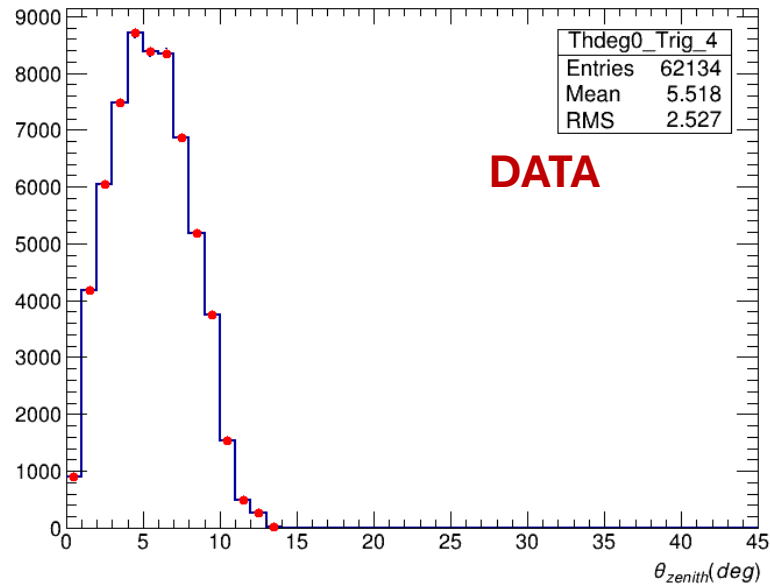


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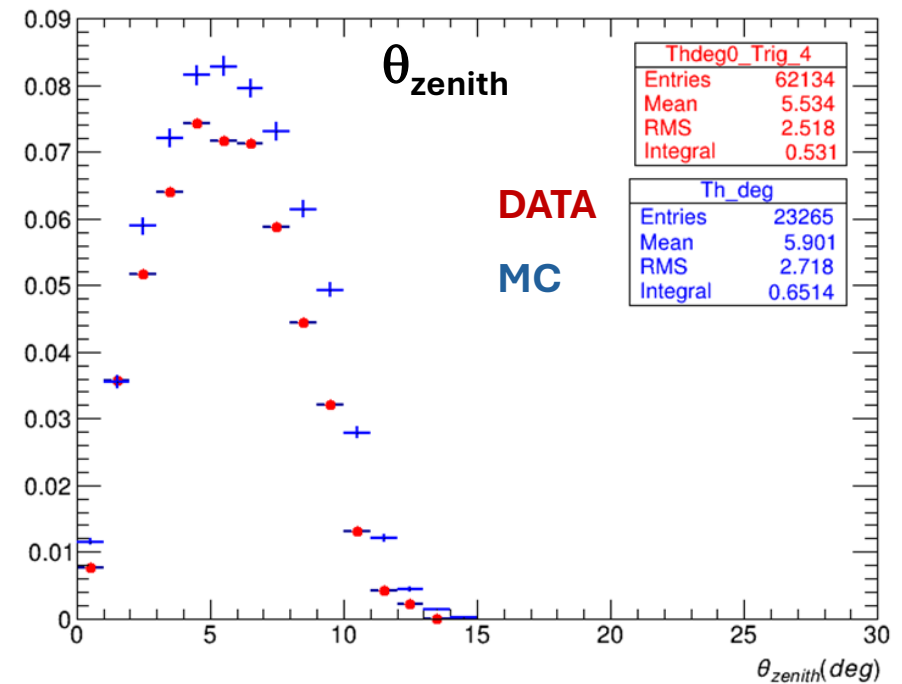
Zenith-angle distribution



Monte Carlo

Geometrical acceptance (T+B): 0.023
Expected T/B Muon Rate: 0.65 Hz

DATA-MC comparison



**CRT:
DAQ-Runs on
Cosmic Ray muons - 2**

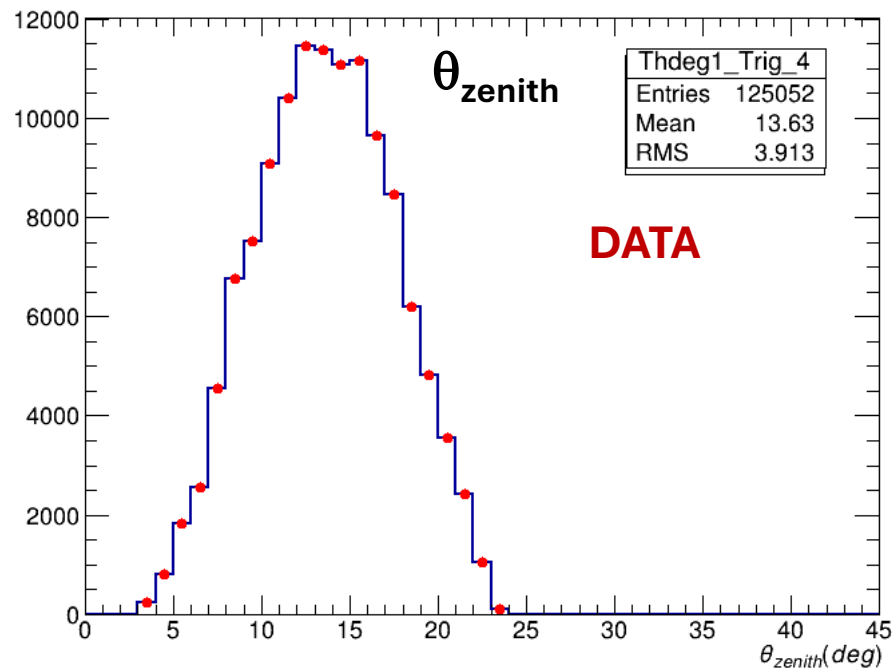
→ **Slanted tracks**



Inclined CR muons (Dist. B-C ~50 cm)

DATA

- Global sample: 167,911 events (DT \approx 336,700 s)
- ‘Muons’ (≥ 1 bar on each plane): 96 %
Rate $_{\mu} \approx 0.48$ Hz
- Tracks (1 bar on each plane): 77 %

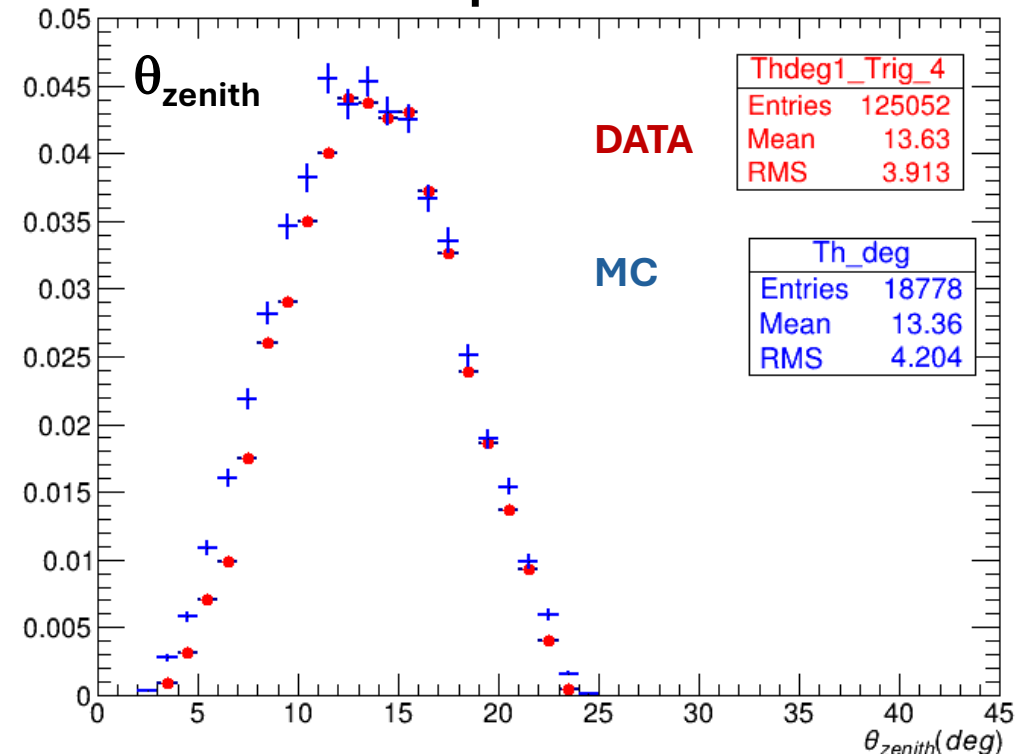


Monte Carlo

Geometrical acceptance (T+B): 0.019

Expected T/B Muon Rate: 0.53 Hz

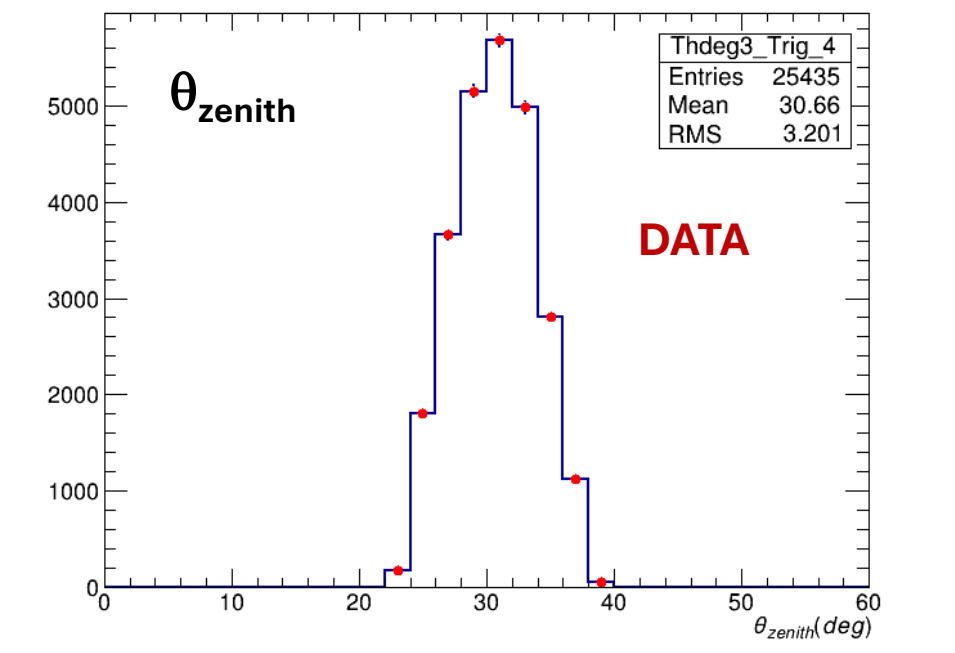
DATA-MC comparison



Inclined CR muons (Dist. B-C ~130 cm)

DATA

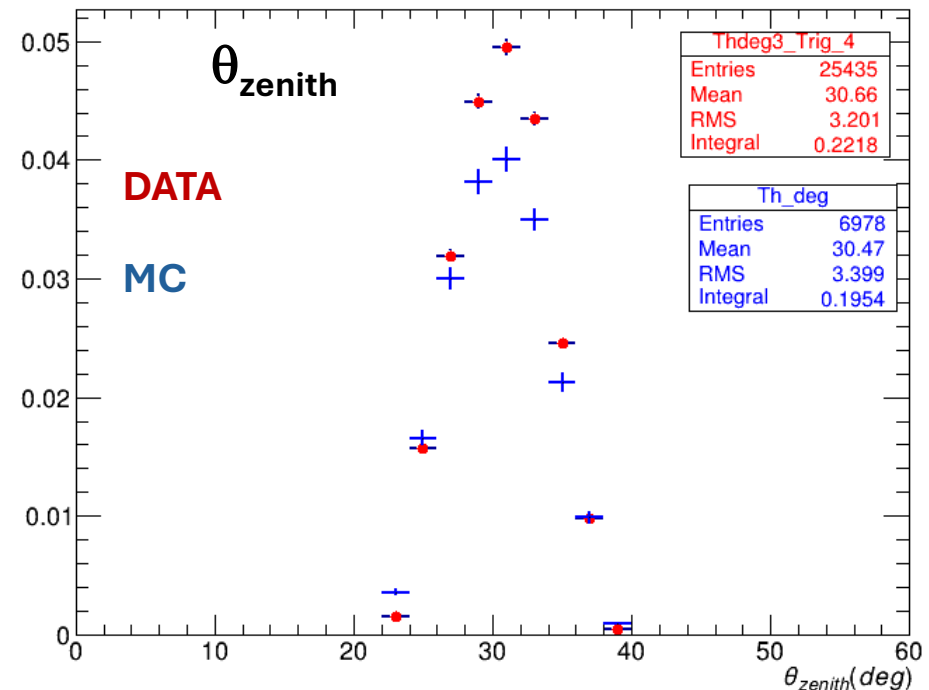
- Global sample: 44,490 events (DT \approx 190,100 s)
- 'Muons' (≥ 1 bar on each plane): 95 %
Rate $_{\mu}$ \approx 0.22 Hz
- Tracks (1 bar on each plane): 60 %



Monte Carlo

Geometrical acceptance (T+B): 0.007
Expected T/B Muon Rate: 0.20 Hz

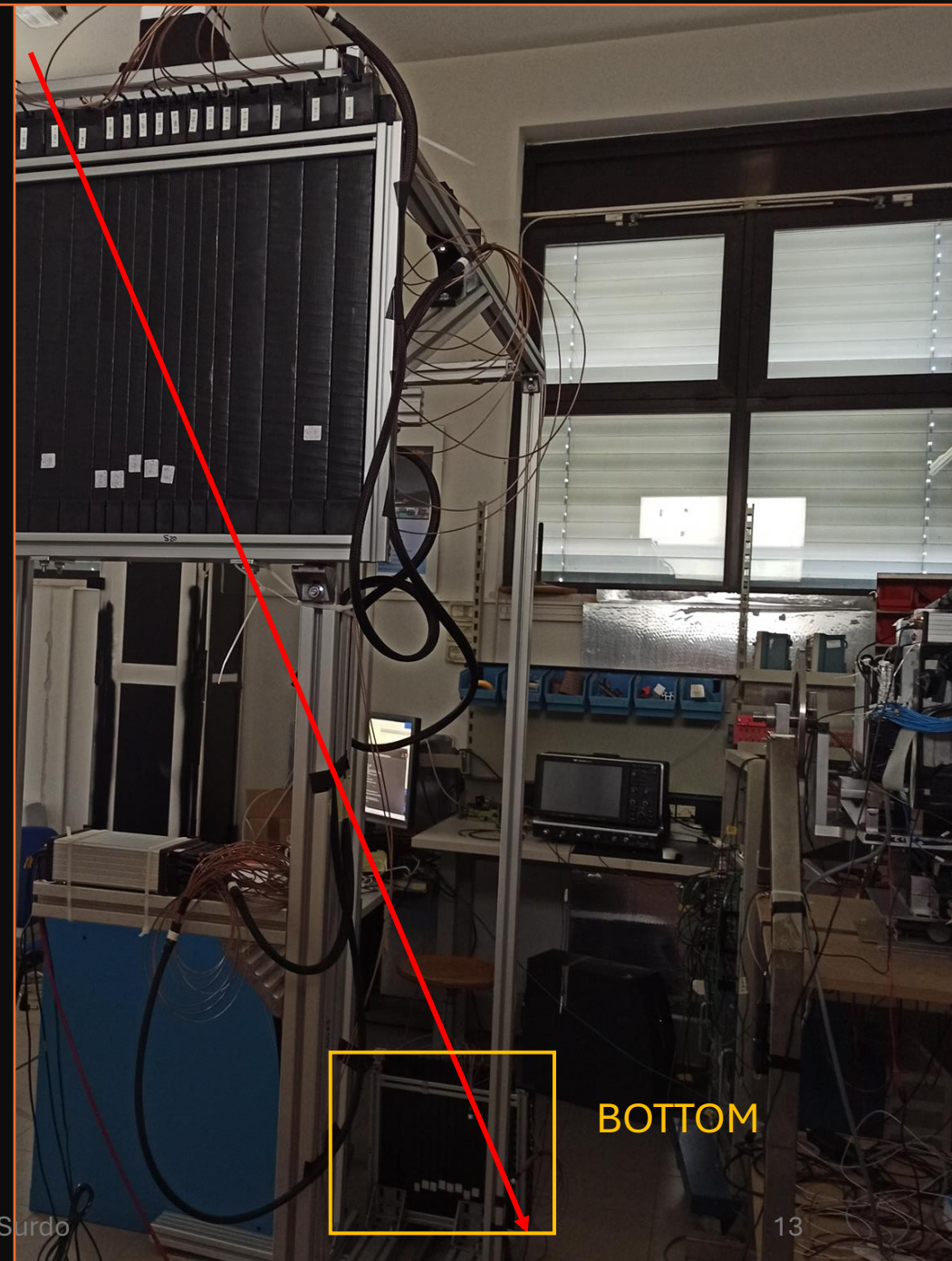
DATA-MC comparison



CRT: DAQ-Runs on Cosmic Ray muons - 3

TOP and BOTTOM arranged vertically
(as foreseen for prototype at LNL)

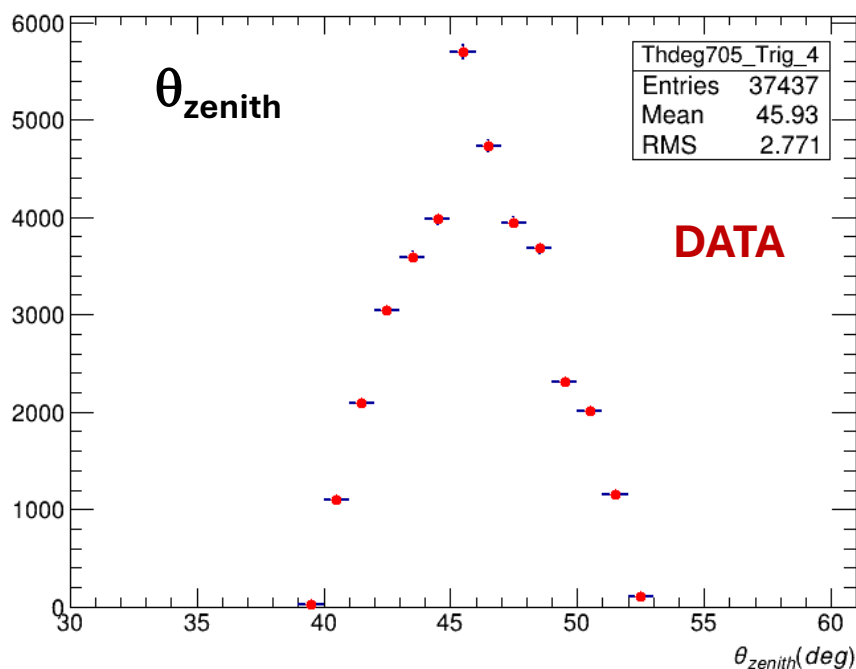
→ **Very slanted tracks**



Very inclined CR muons (Dist. B-C ~170 cm)

DATA

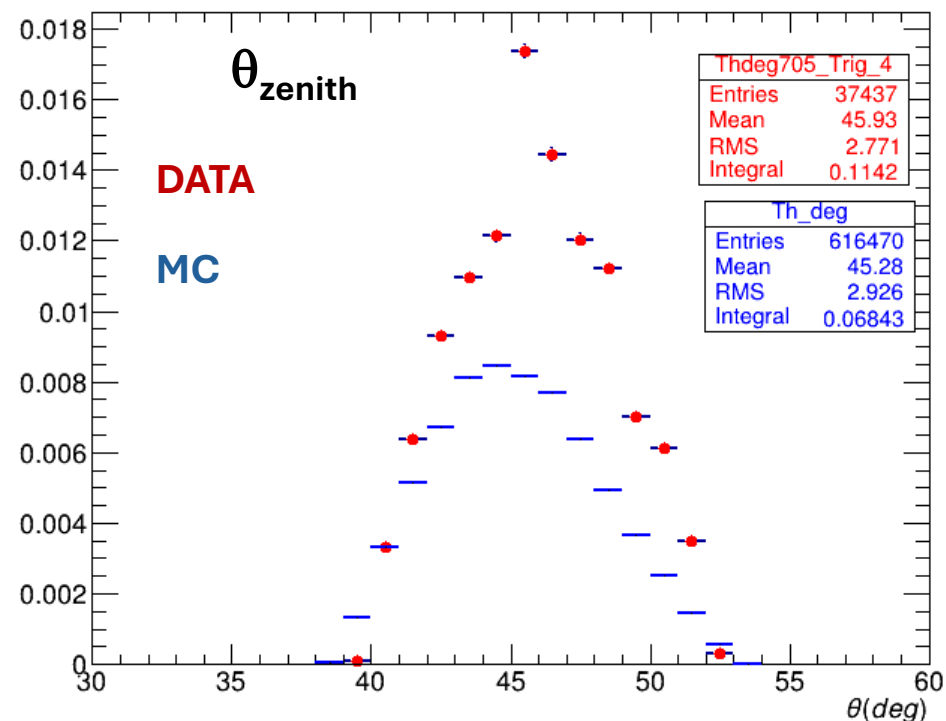
- Global sample: 86,012 events (DT \approx 664,300 s)
- 'Muons' (≥ 1 bar on each plane): 85 %
→ Rate $_{\mu} \approx 0.11$ Hz
- Tracks (1 bar on each plane): 49 %



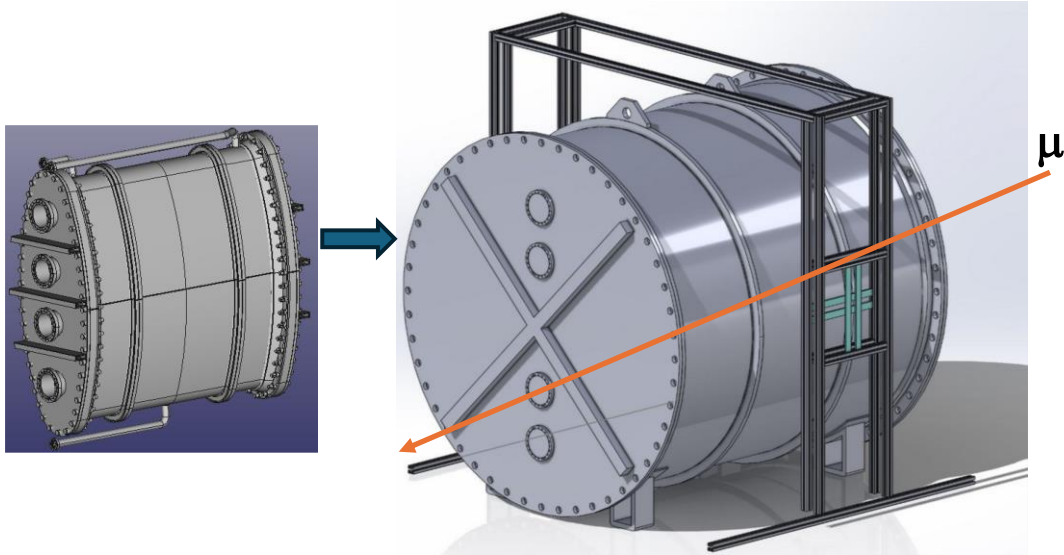
Monte Carlo

Geometrical acceptance (T+B): 0.006
Expected T/B Muon Rate: 0.07 Hz

DATA-MC comparison



CRT for GRAIN full-size prototype @ LNL

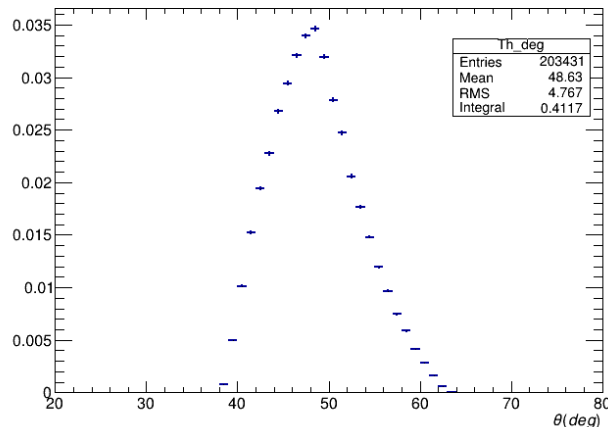


Monte Carlo simulation with

- TOP & BOTTOM size: 68cm x 68cm
- (T-B) Horizontal Distance: 180 cm
- (T-B) Vertical-Distance: 160 cm

Muon rate on a vertical surface A (one side):
Rate $\approx 44 \mu / \text{m}^2/\text{s} * A \rightarrow$ **Rate(TOP) $\sim 20 \mu / \text{s}$**

Znith angle
distribution



From the simulation:

- Geometrical acceptance of (T+B): 0.02
- **Expected Muon Rate: $\sim 0.4 \text{ Hz}$ ($\sim 1500 \mu/\text{h}$)**
 $\rightarrow \sim 10^3 \text{ tracks /h}$ (for inefficiency, track reco, ..)

Conclusions

- ✓ CRT for ARTIC installed in July, ready for operations
- ✓ Several DAQ tests and runs with cosmic rays in Lecce
- ✓ Objective: verify trigger implementation, DAQ performance, rates, reconstruction code, zenith angle distribution, ..
- ✓ Rates and zenith angle distributions of reconstructed tracks are obtained from Data samples
- ✓ Comparisons with predictions by a simplified Monte Carlo simulation show a reasonable agreement, thus allowing to estimate the expectation and properly design the size of the CRT for the GRAIN prototype in LNL