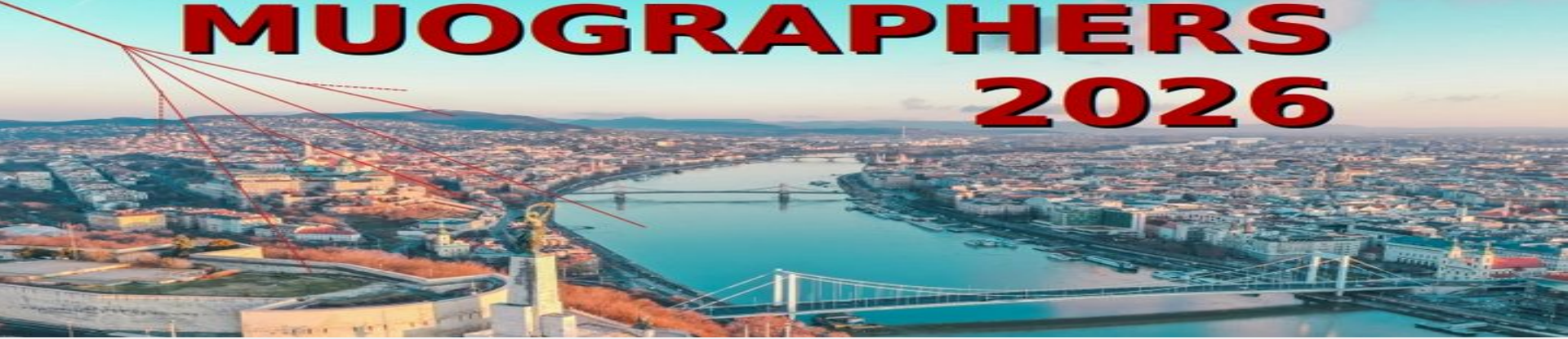



# Portable Glass-RPC Telescope for Muography and Future Applications at Laser Wakefield Accelerators

**Sumaira Ikram**[1], A. Giammanco[1], M. Lagrange[1], E. Cortina Gil[1], P. Demin[1], R. Versaci[3], A. Cimmino[3], G.M. Grittani [3] , M. Nevrkla [3] , D. Ahmadi[2], M. Tytgat[2]

1. Centre for Cosmology, Particle Physics and Phenomenology, UCLouvain, Louvain-la-Neuve, Belgium
2. Inter-University Institute for High Energies (IIHE), Vrije Universiteit Brussel, Brussels, Belgium
3. ELI Beamlines Facility, The Extreme Light Infrastructure ERIC, Dolni Brezany, Czechia

# Portable Particle Detector

Portable muon telescopes are mainly used for experiments conducted in confined or restricted environments.

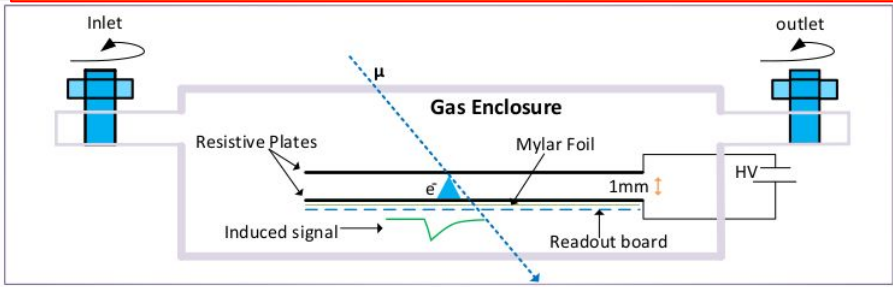
The design goal of the detector includes:

- Portability
- Autonomous Operation
- Gas Tightness (In gaseous Detectors)
- Robustness
- Modular Geometry
- Safe and Cheap

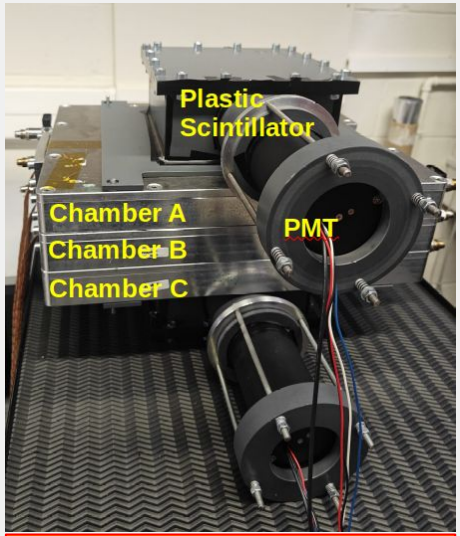
- **Glass electrodes with an active area of 16 × 16 cm²**
- **Detectors have been in operation for ~2 years with good efficiency.**

For more details regarding the detector setup, presentation by Donya Ahmadi, *A Sealed, Light-weight GRPC-Based Muon Telescope for Muography Applications*

**Schematic representation of the glass-electrode resistive plate chamber**



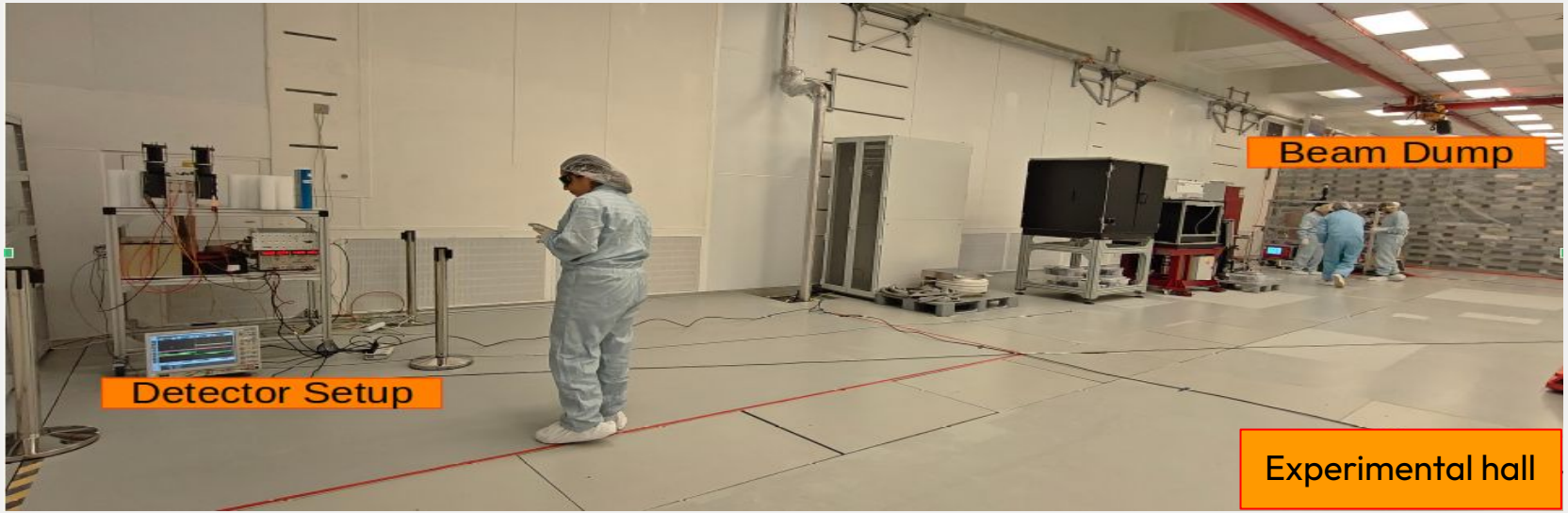

S. Ikram *et al*., "Development and performance analysis of glass-based gas-tight RPCs for muography applications, *J. Appl. Phys.*, vol. 138, no. 17, p. 174502, Nov. 2025.




**Experimental setup for efficiency measurement**

# Portable System Validated

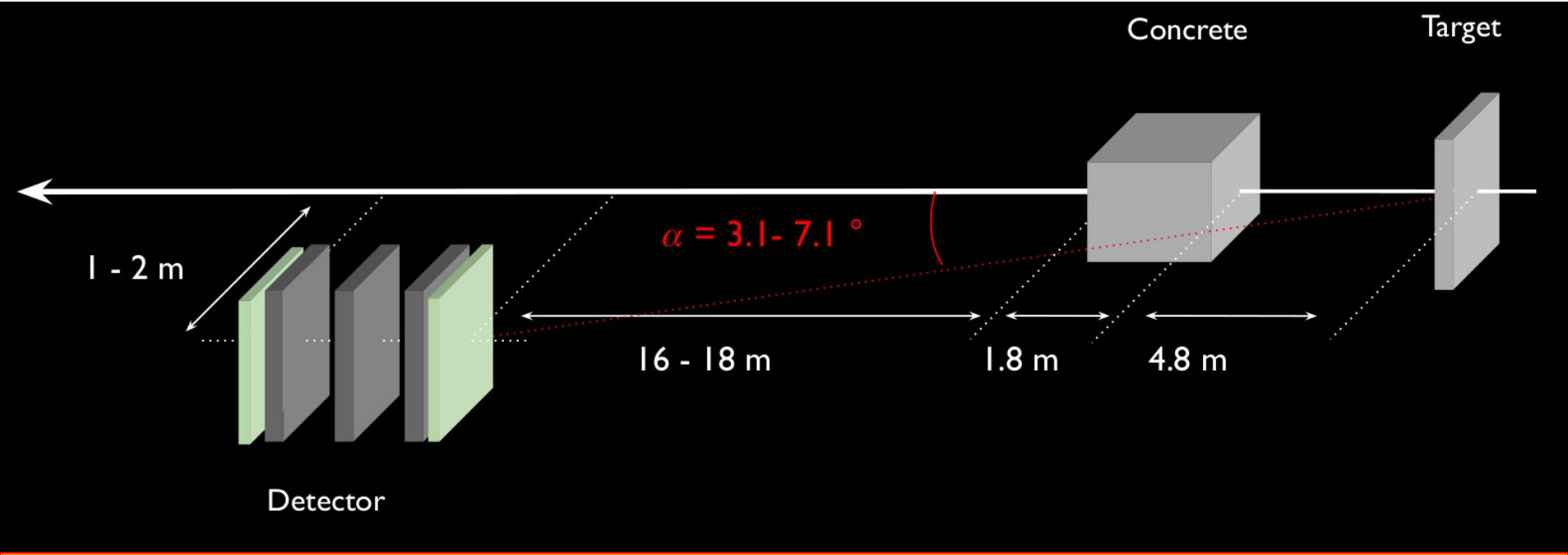
- **ELI (The Extreme light infrastructure )** → One of the world's largest and most advanced high-power laser infrastructure and a global technology.
- **ELBA (Electron Beamline for Fundamental Science)** → a laser–electron collider and powered by the high-repetition-rate L3-HAPLS laser system.




- We successfully transported and operated our detector to the test site (Prague) in April/May (two weeks )and then in August (12 days)/September (10 days).

More details about ELI beams were presented in Roberto Versaci's talk: Overview of Laser-Driven Multi-GeV Muon Sources and the ELI Beamlines Plan.

arXiv:2605.13118 [physics.ins-det]



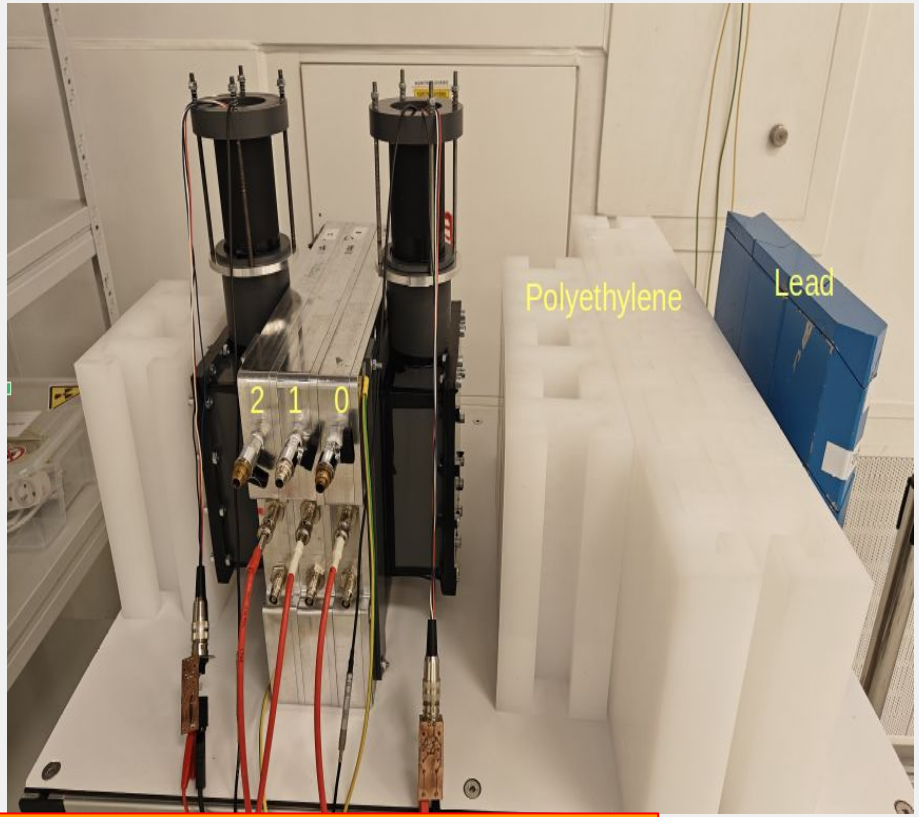

Schematic of the experimental configuration and geometry used to define the detector system in the experimental hall.

# Overview of Data-Taking

- **Cosmic Data (D1, D2, D3)** – baseline reference for detector performance
- **High-Energy Beam (D1, D2)** – ELBA-validation under intense particle flux
  - Multi-GeV electron beams
- **Low-Energy Beam (D3)** – GAMMATRON-study of detector response at
  - Energy ~ 1 GeV.
  - Beam was present  but muon production is negligible,
  - Characterizing the beam-induced background.

## Shielding Configuration

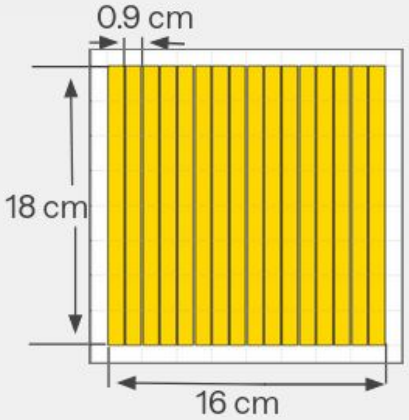
- No Shielding
- Lead
- Polyethylene
- Lead + polyethylene

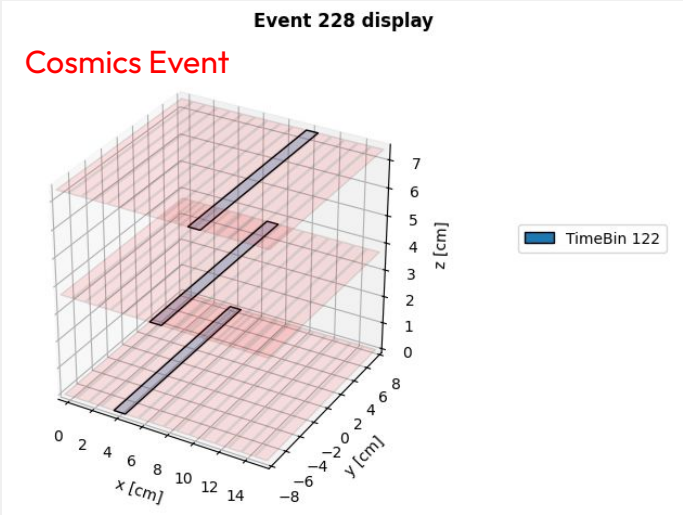




**Detector setup during April–May (left) and August–September 2025 (right) Beam test**

# Event Display Across Datasets

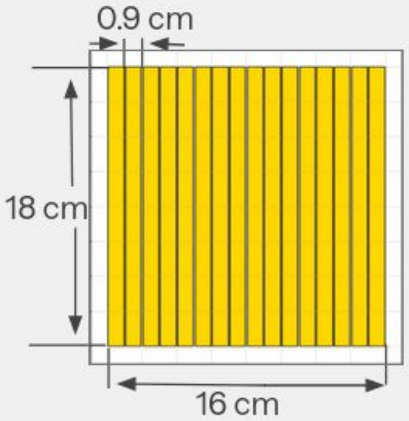
- Cosmic run: ~1 fired strip per layer per event

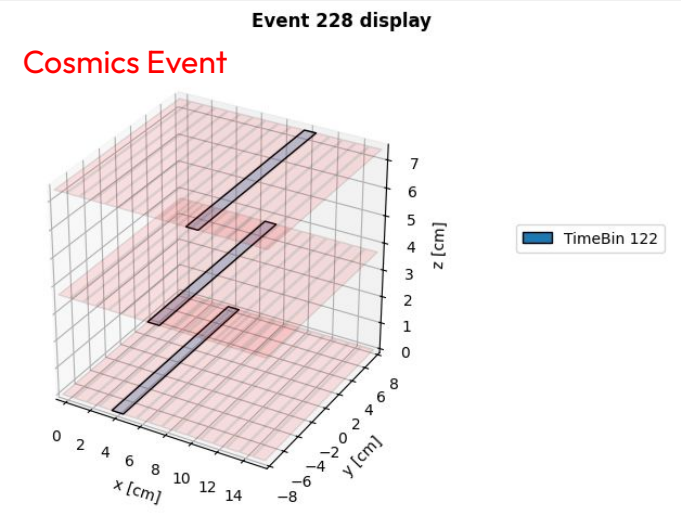


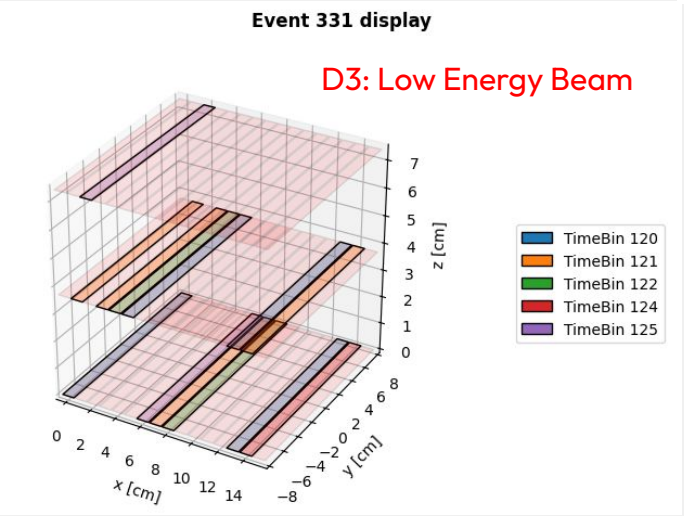



# Event Display Across Datasets

- Cosmic run: ~1 fired strip per layer per event
- D3 low energy beam data: Higher strip multiplicity

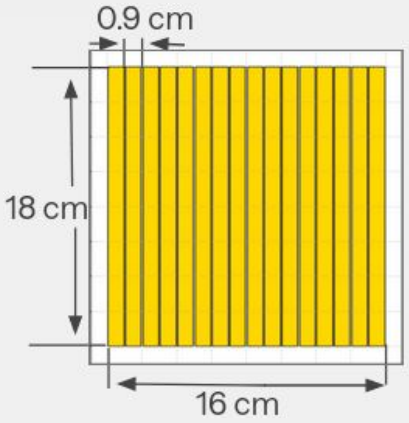


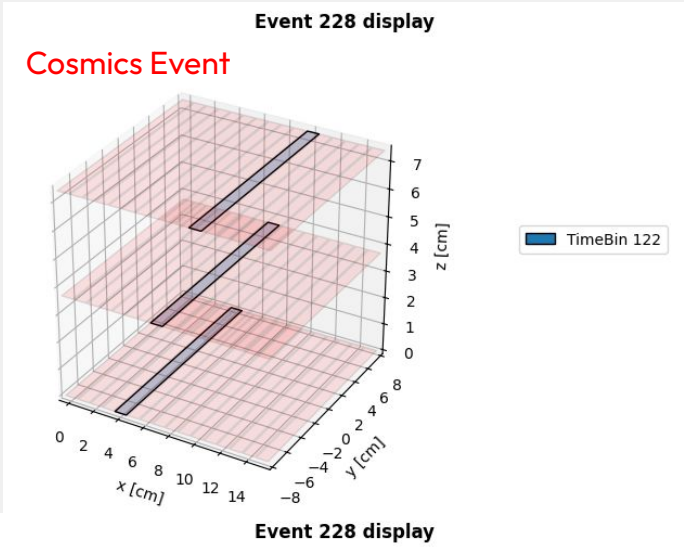



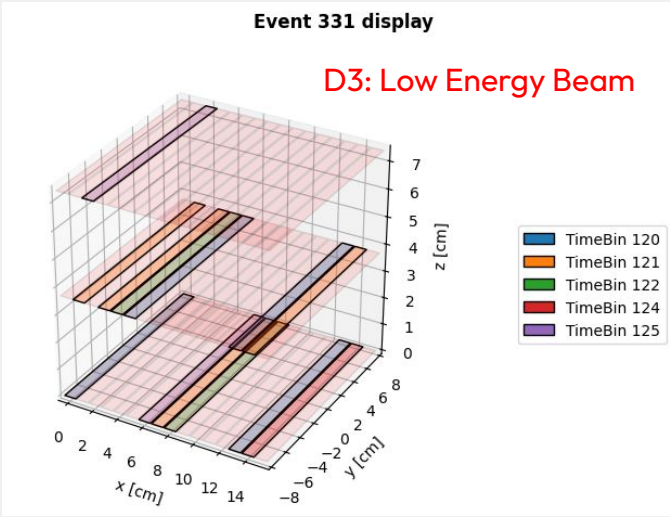



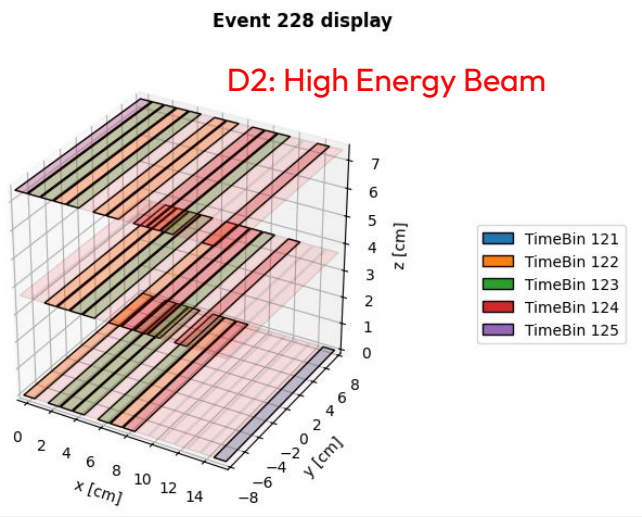
# Event Display Across Datasets

- Cosmic run: ~1 fired strip per layer per event.
- D3 low energy beam data: Higher strip multiplicity.
- High Energy Beam : Up to 9 fired strips observed in the first detector layer.



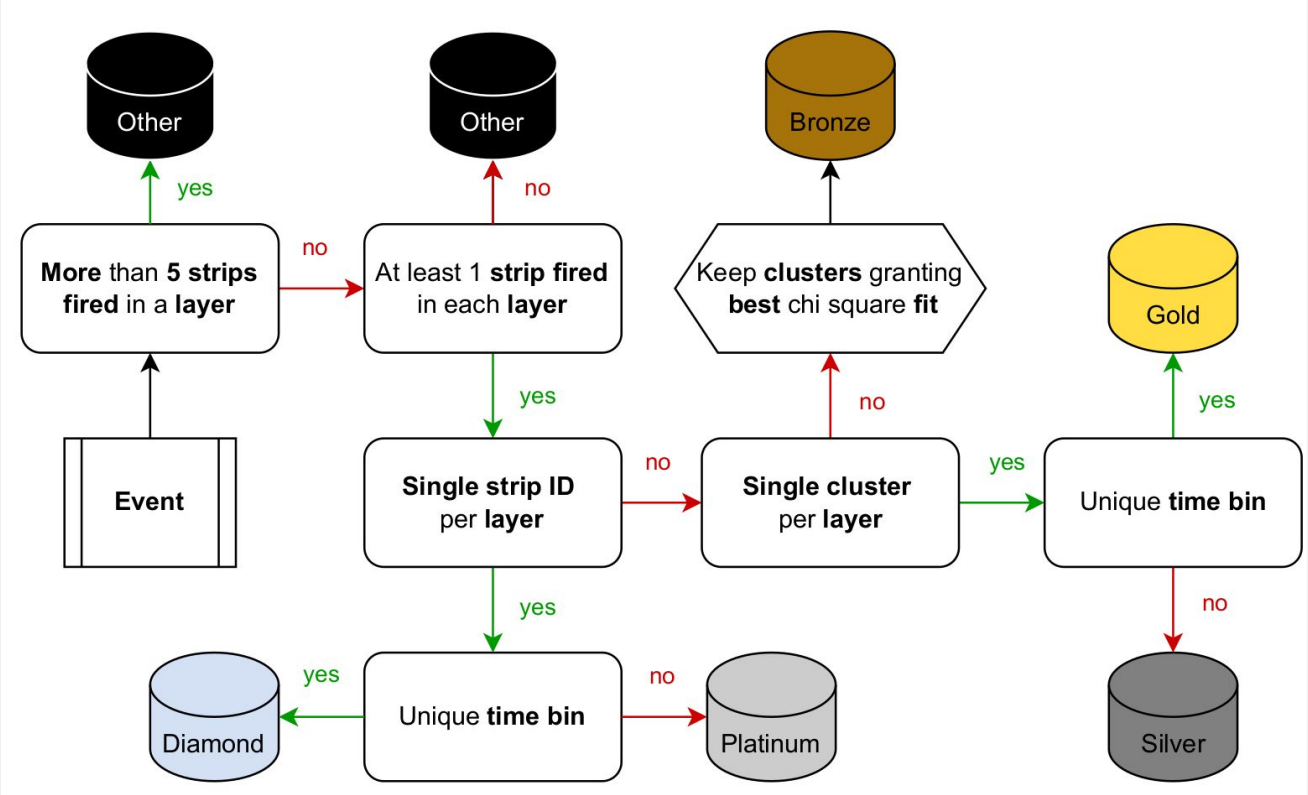



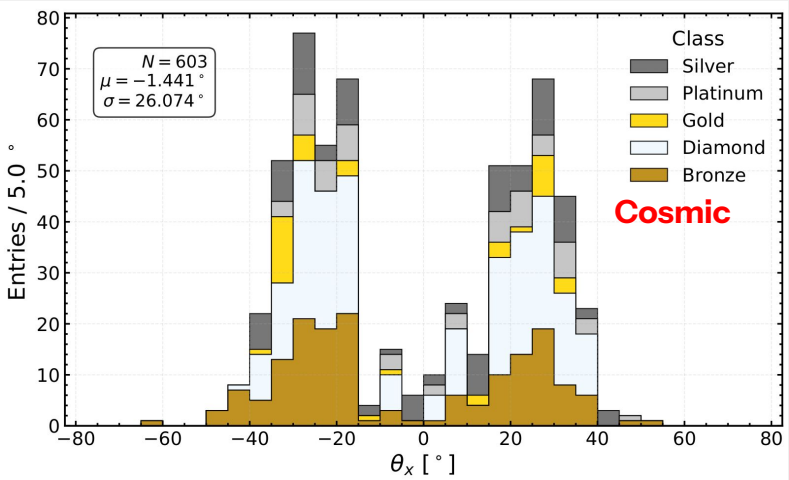
# Event Selection

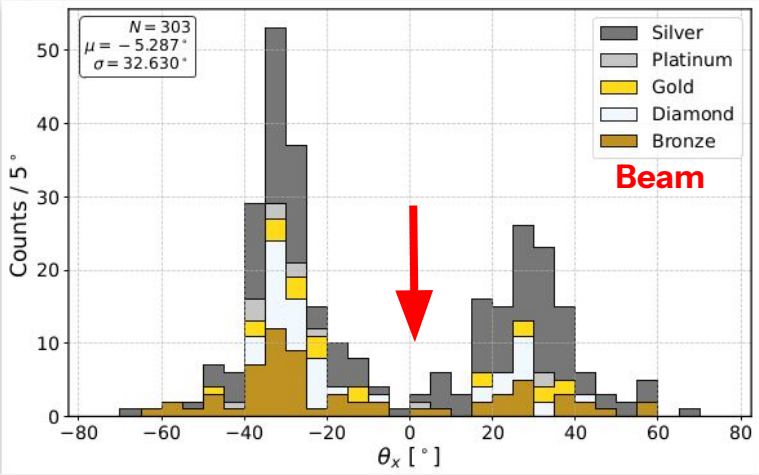
- Events are classified into five categories based on the
  - Number of fired strips and/or clusters per layer
  - Temporal distribution, as well as a final exclusion class.

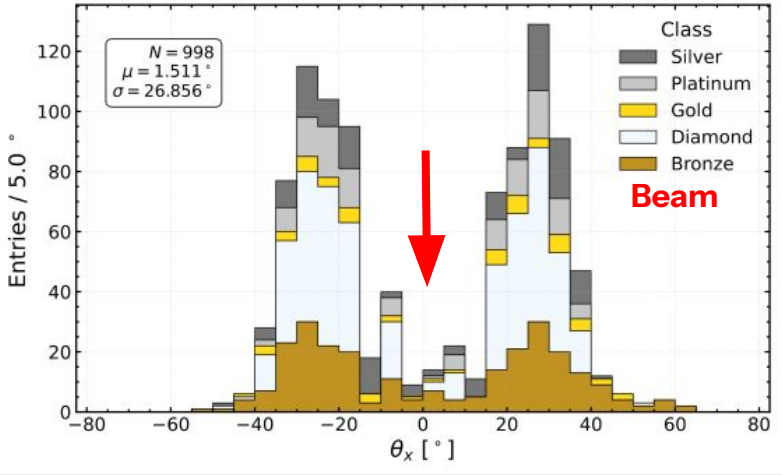


# Angular Distribution

- Angular distribution consistent with cosmic muon behavior.
- Beam-induced muons are expected to show predominantly horizontal trajectories
  Expected angular range: θx ∈ [−5°, 5°].



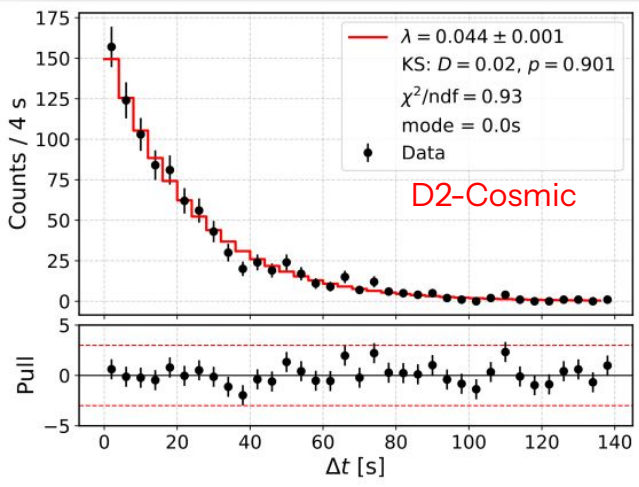



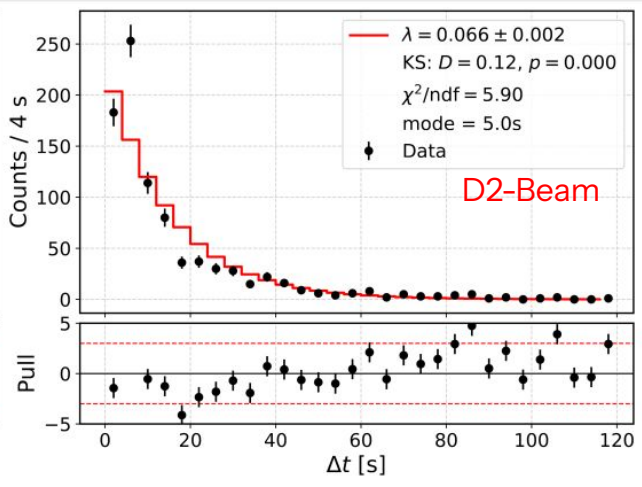

- **Overall tracking results do not conclusively confirm beam-induced muons**

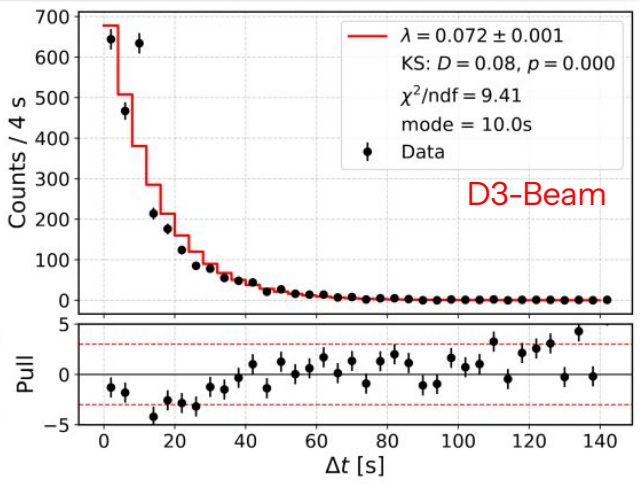
# Inter- arrival time

Exponential fit applied to Δt distributions

- D2 cosmic → consistent with random arrival time (Poisson)
- D2 beam → >5σ deviation
- D3 beam → >5σ deviation



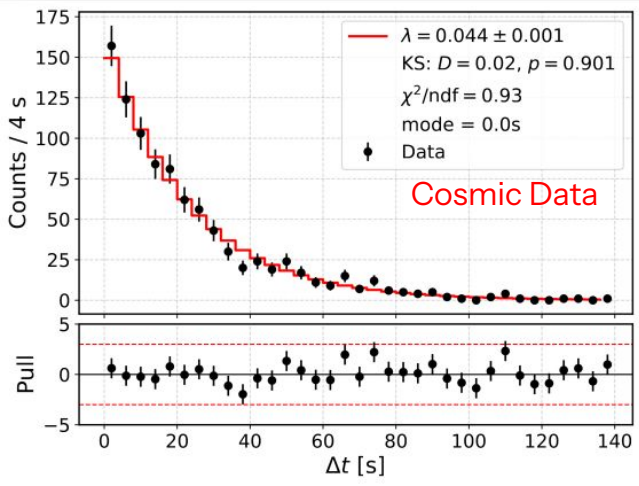



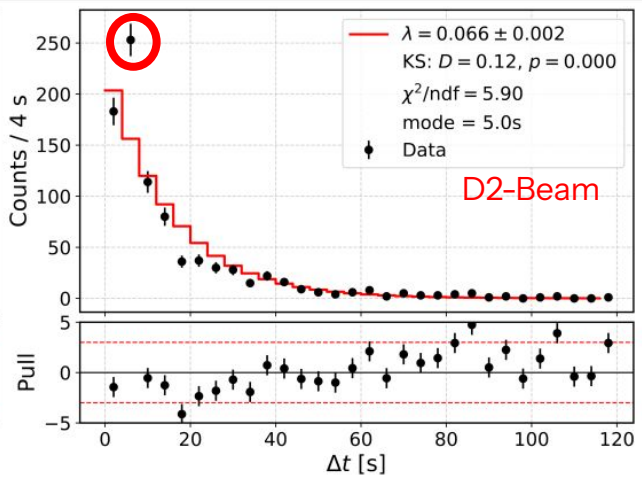



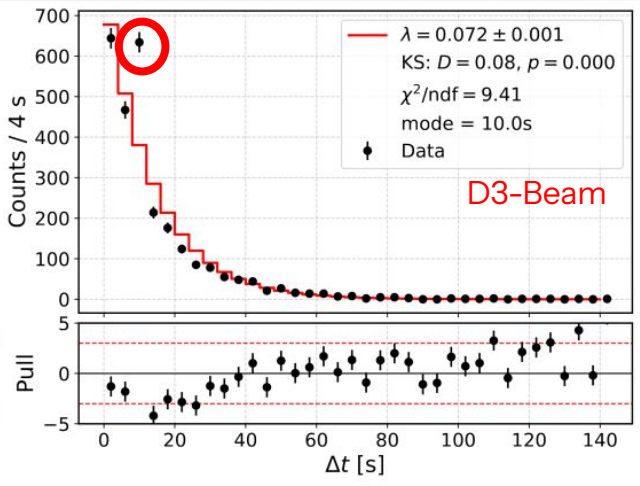
# Inter- arrival time

Exponential fit applied to Δt distributions

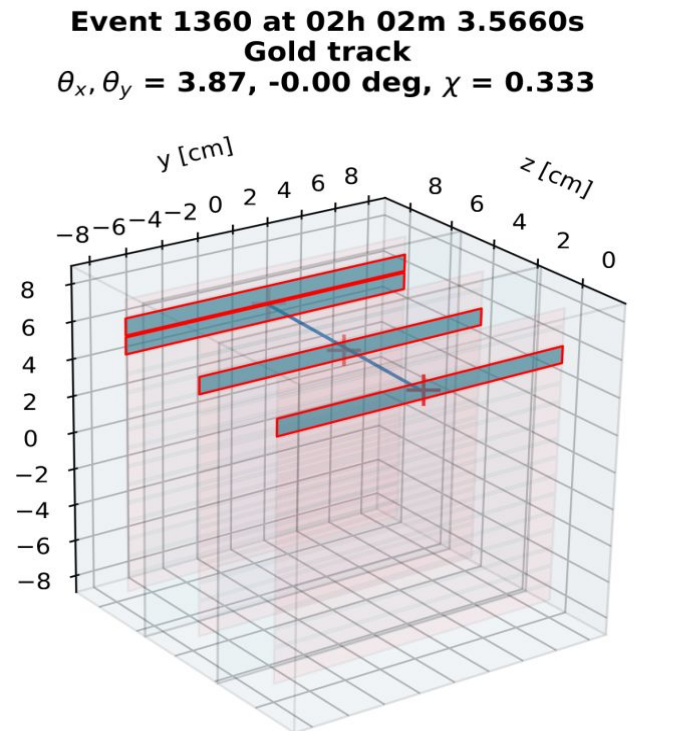
- D2 cosmic → consistent with random arrival time (Poisson)
- D2 beam → >5σ deviation
- D3 beam → >5σ deviation
- Both spikes correspond exactly to the repetition rates of the lasers in those runs → cause-effect relationship



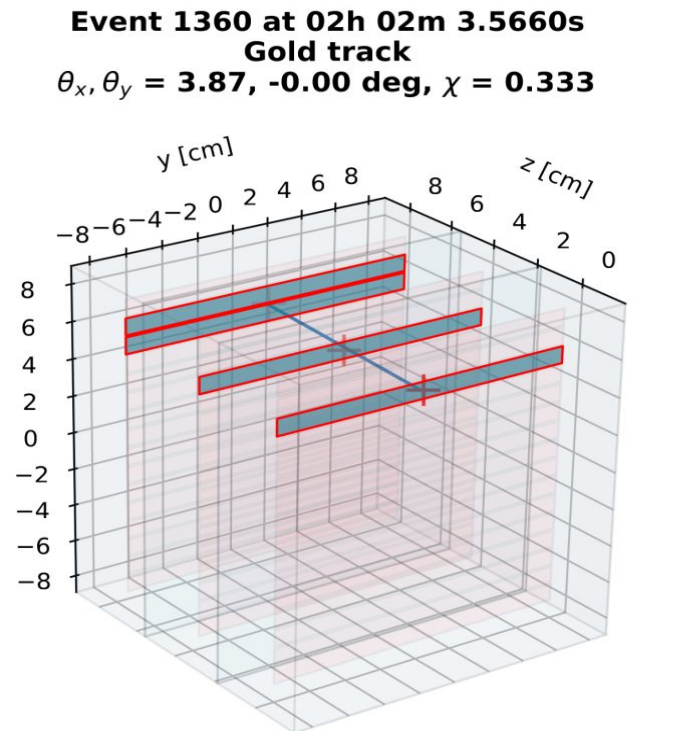



# Beam muon candidates

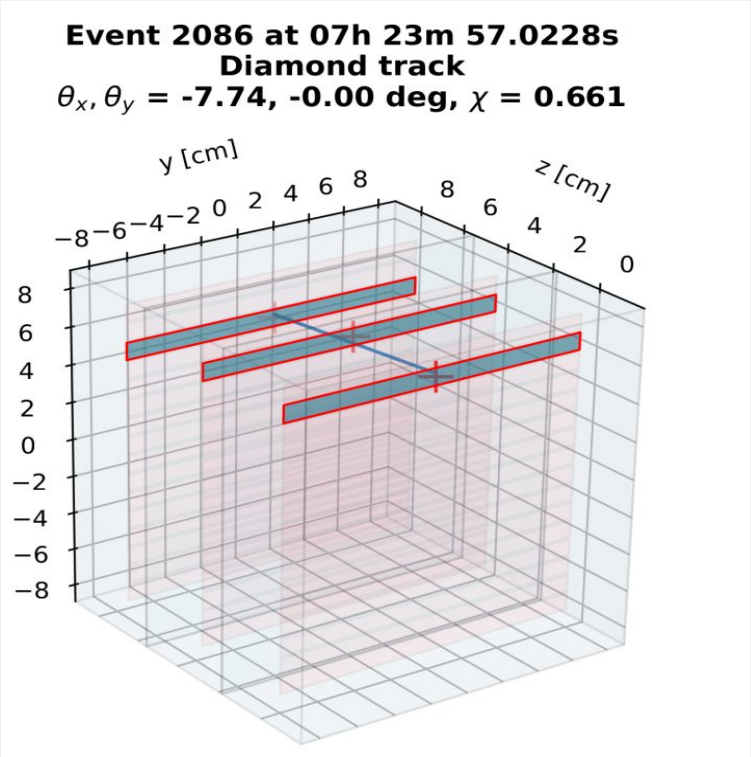



- Beam induced muon candidate from the D2 beam data-taking.

# Beam muon candidates



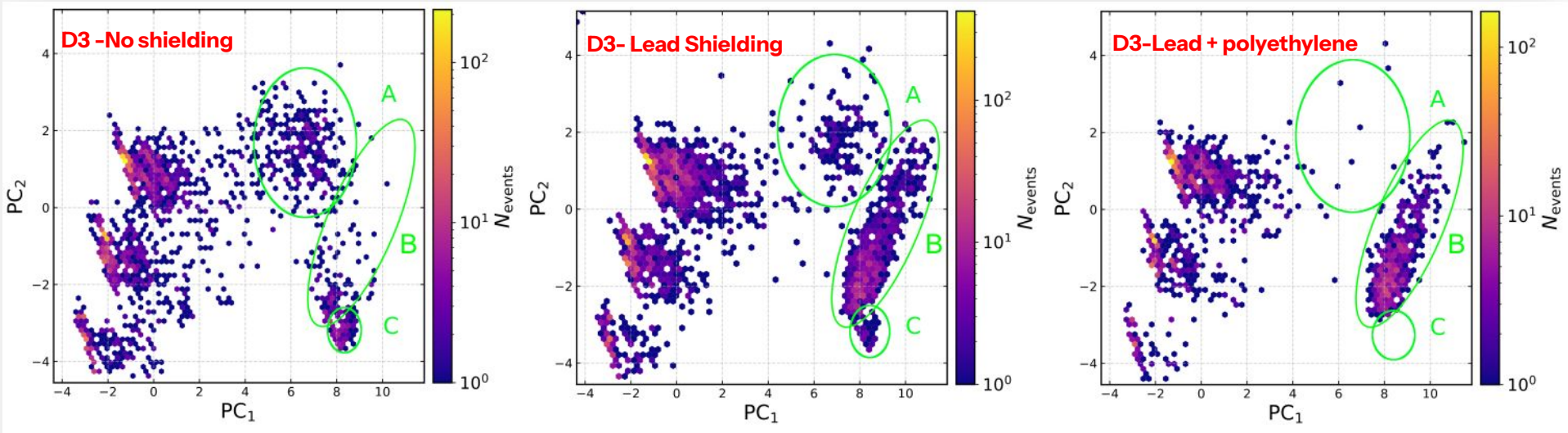

- Beam induced muon candidate from the D2 beam data-taking.




- Beam-induced candidate observed in the D3 beam dataset, potentially corresponding to either a cosmic muon or an electron.

# Principal Component Analysis (PCA) for data categorization

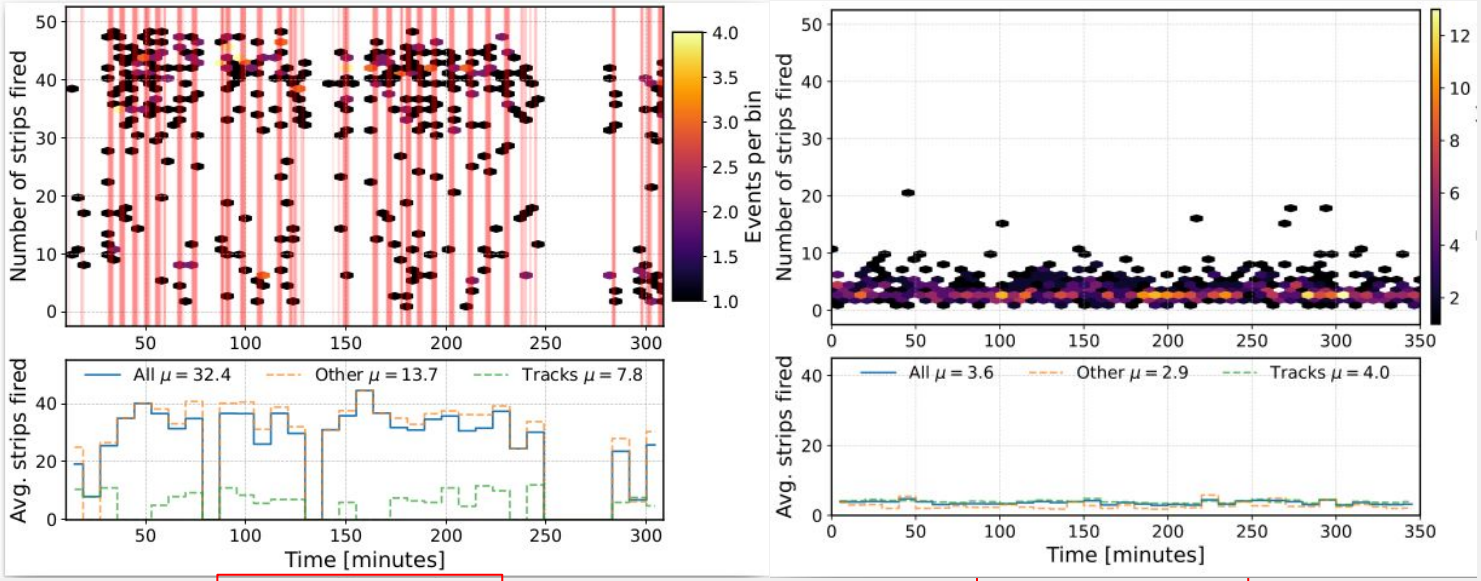
- Identifies dominant patterns and correlations while reducing data complexity for easier visualization and interpretation.
- Inputs: multiplicity, position and time information at strip and cluster levels.




- **Region A** → moderate cluster multiplicity and relatively low strip counts,
- **Region B** → large strip multiplicity with fewer clusters
- **Region C** → very high strip multiplicity.

# Laser Tag-D2 Beam Data

- 5.5 h additional D2 beam run with recorded laser trigger
- Laser tag directly indicates beam status
- Laser ON: muon beam present
- No laser tag: beam absent




**Laser Tagged**

**Non tagged**

# Summary

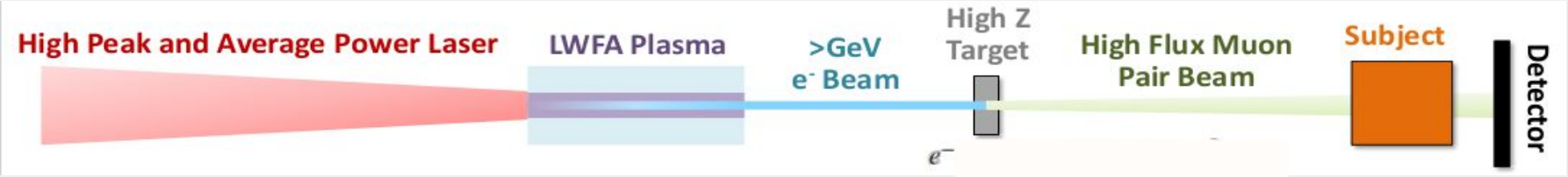
- **Successful Beam Test at ELI in 2025**
  - BeamTest at ELI validated the **portability and robustness** of the prototype in real operational conditions.
- **Data Analysis**
  - Beam events are **high-multiplicity events**, making tracking difficult.
  - **No statistically significant** excess of muons with horizontal direction was found.
  - **Muons candidates were identified** in each data set.
- **Beam Test at ELI in 2026**
  - Aiming at first observation of muon production at ELI, for long beam time as **main users.**

## Thank you..

# Backup slides

# Muon Production via Laser Accelerated Electrons

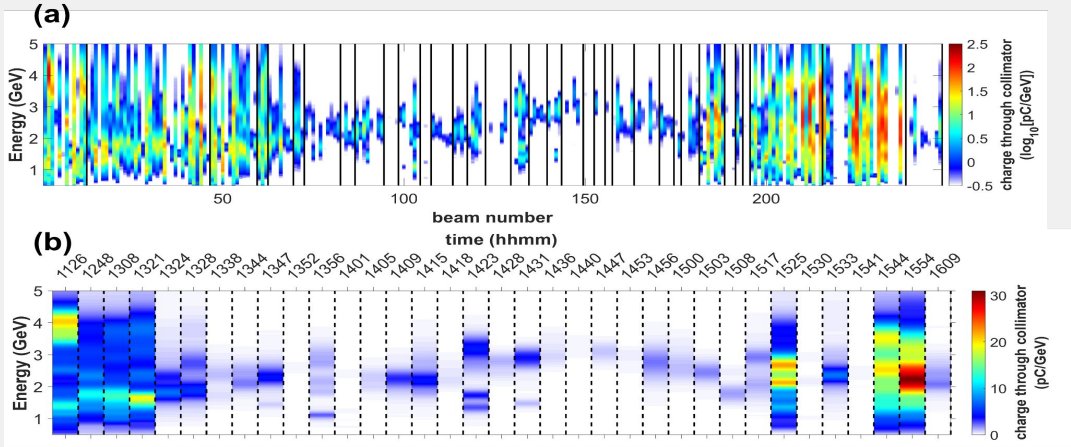
- Muons could be a game changing technology if there were a compact active source of muons available.
- Muons produced via photo-production or electro-production are characterized by their short pulse duration and high flux.




Conceptual layout of the muon source.

Image Source: "Reagan ELI-BL Muon Source Workshop".

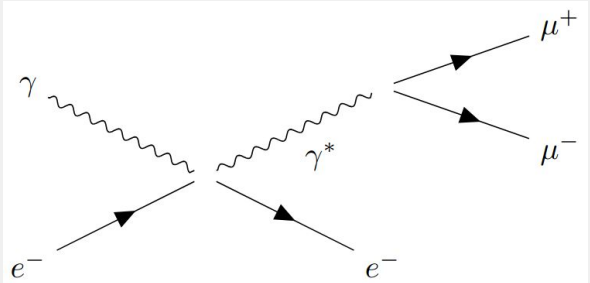
Example of beams produced during a typical day of parasitc operation. (a) All angle-integrated spectra collected during a day of operation at 0.2 Hz repetition rate. The solid lines denote periods of operation when the operating conditions were fixed. (b) Mean angle-integrated collected for fixed operating conditions noted in panel (a). The top axis labels show the time each data set was collected at a 0.2 Hz repetition rate.



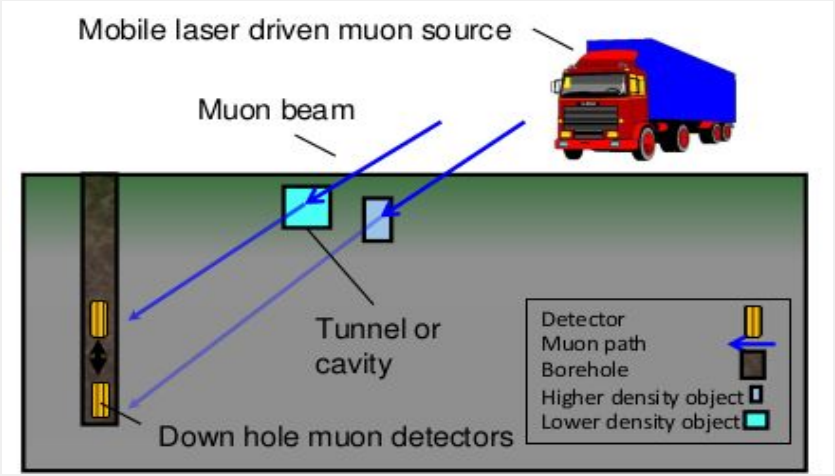
# Potential Benefits of Artificial Muons

- **Higher Particle Flux:** The flux is significantly higher than that of cosmic muons.
- **Controllable Energy**: Unlike cosmic muons, whose energies vary unpredictably, beamline allows for control over the energy of the beam.
- **Known Directionality:**The beam direction is well defined, unlike cosmic muons which arrive from random directions.

- Muons are not hazardous to life forms or the environment, provided the flux is not extremely high.
- Muons can be used to detect many different materials




Feynman Diagram for Muon pair production




Source: Todd Ditmire “Laser Induced Muon Production for Detecting Special Nuclear Materials and WMD”

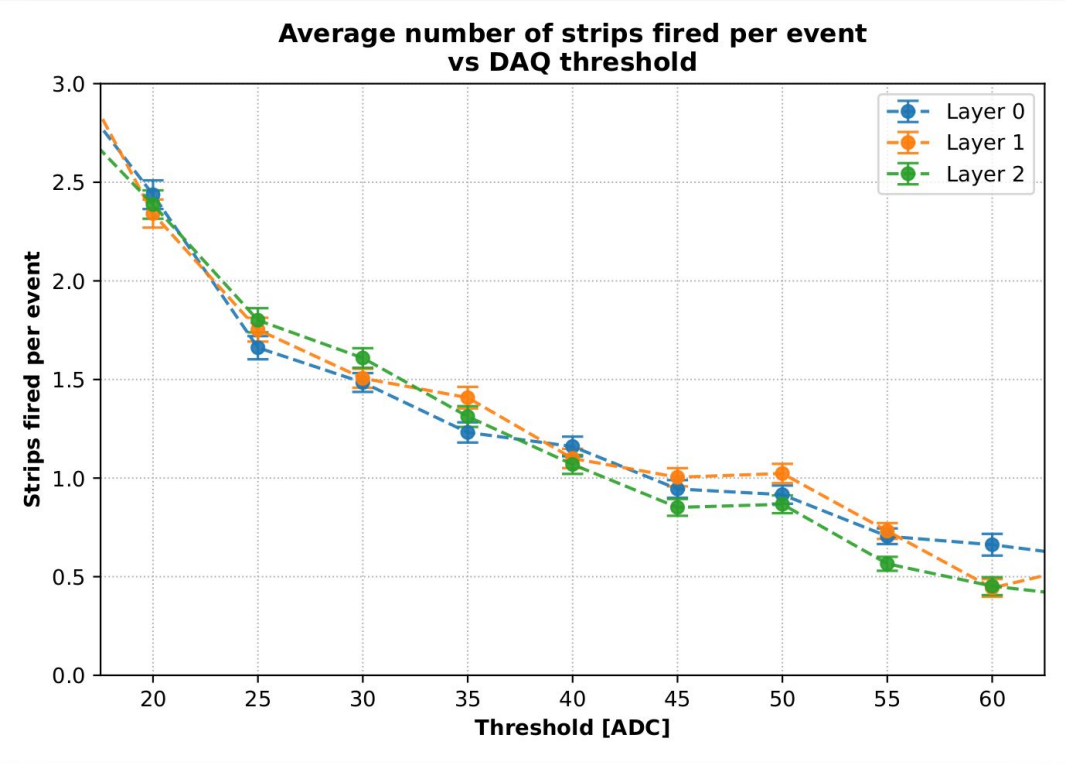
# Overview of Data-Taking

## Shielding Configurations and Durations

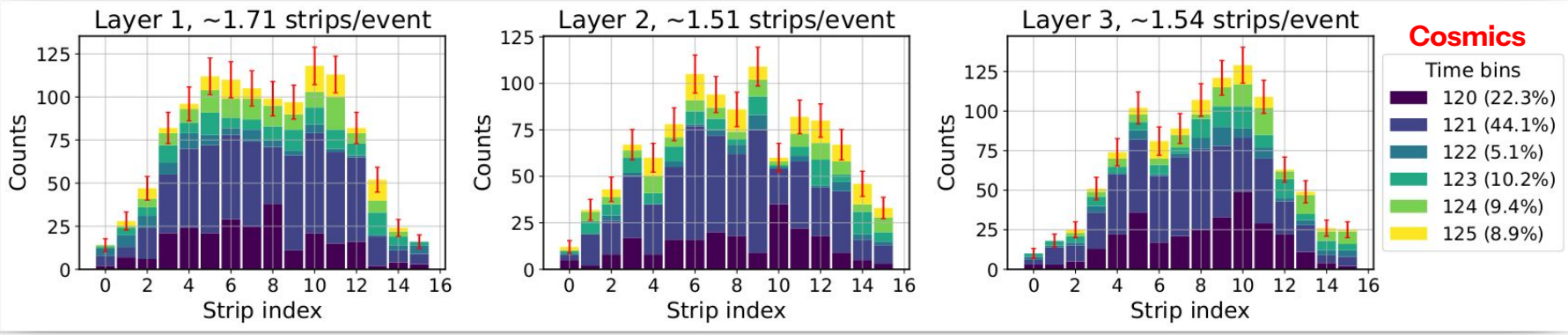
| Configuration | Shielding | Duration |
|---|---|---|
| D1 Cosmic | Polyethylene | 4 h |
| D1 Beam | Polyethylene | 28 h |
| D2 Cosmic | None | 6 h |
| D2 Beam | None | 3 h 45 min |
| D2 Beam | Lead + Polyethylene | 5 h 30 min |
| D3 Beam | None | 10 h 30 min |
| D3 Beam | Lead | 15 h |
| D3 Beam | Lead + Polyethylene | 7 h 30 min |

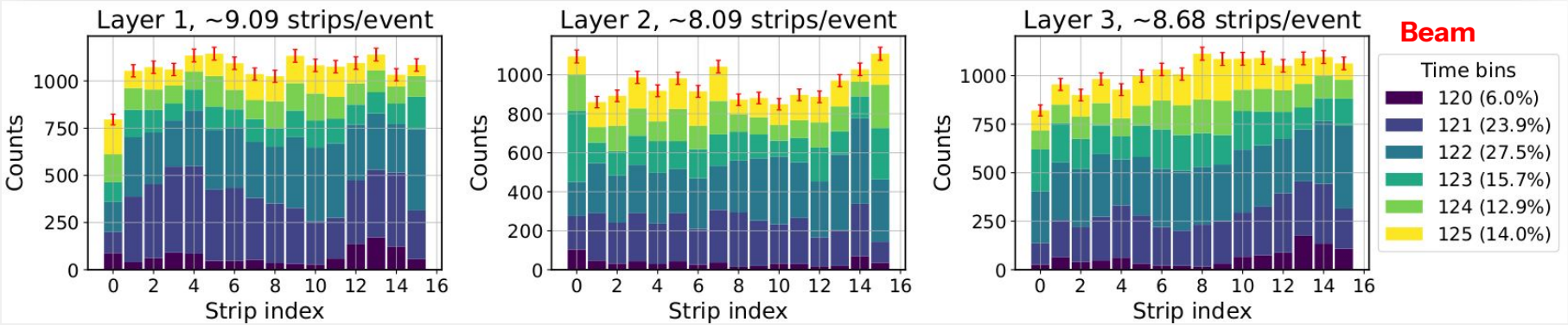
# Threshold Scan

- Mean strip multiplicity > 1 for all chambers
- Matches expectations for cosmic muons
- Validates selected threshold values [35,40].

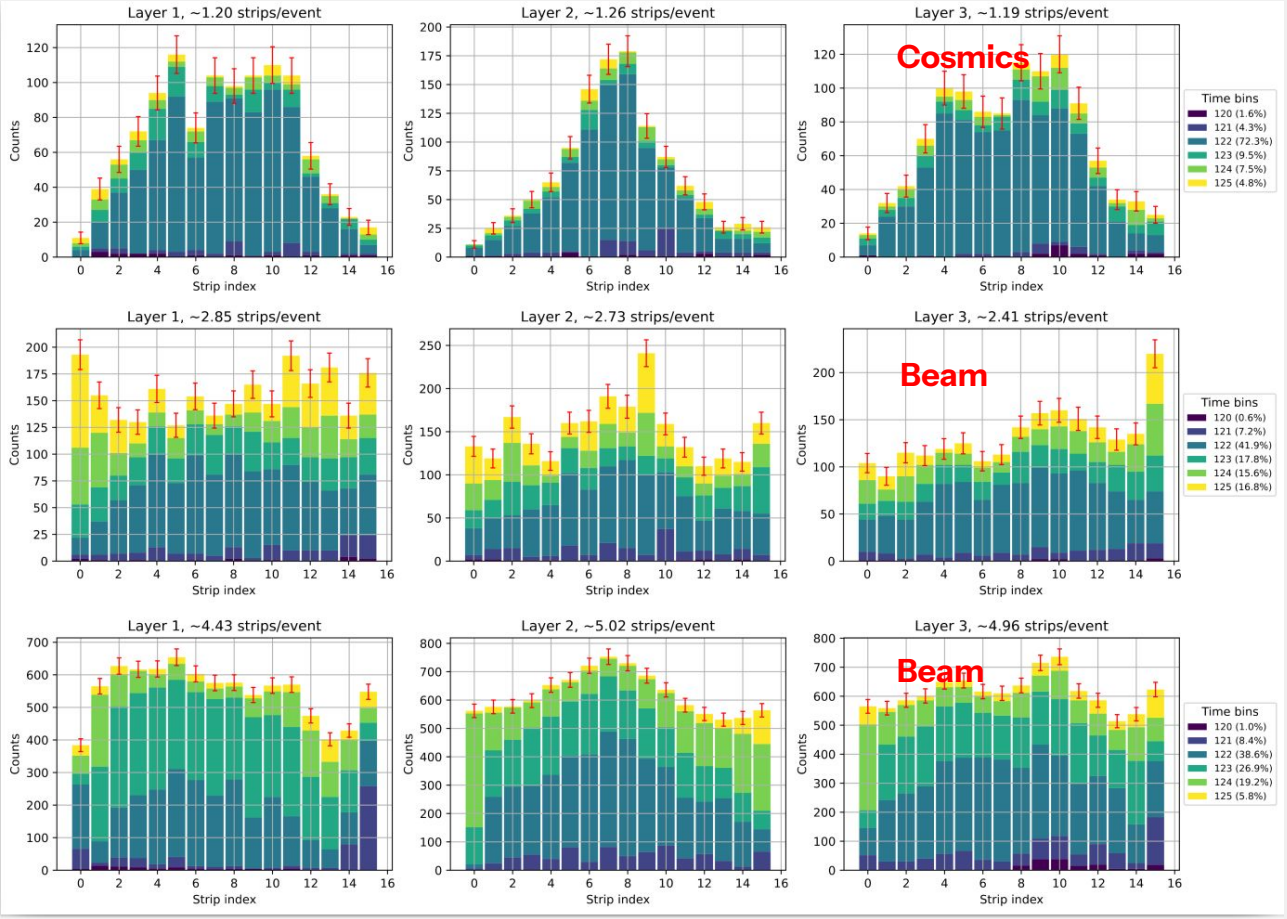


# Occupancy D1

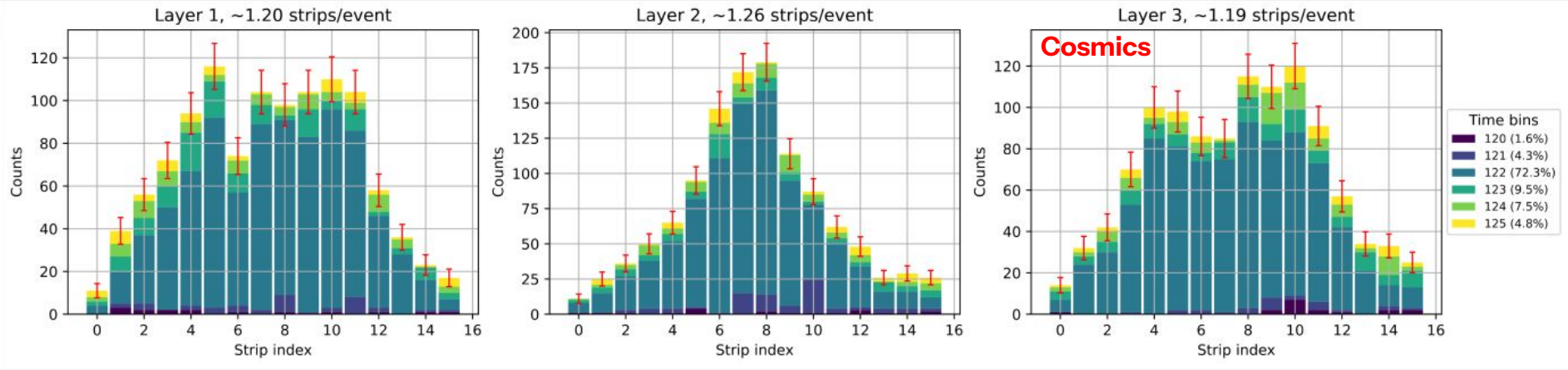


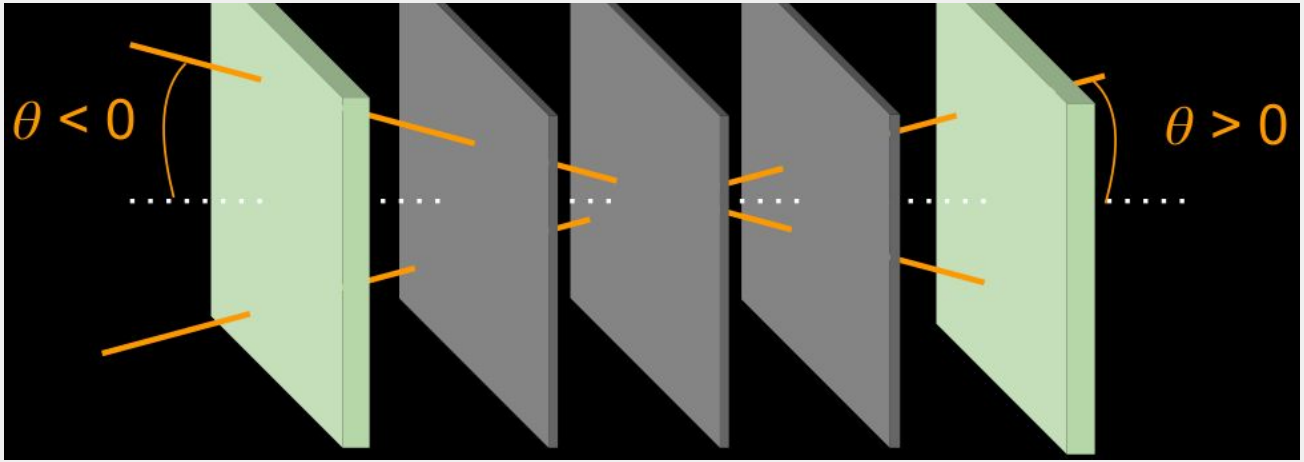



# Occupancy D2 and D3

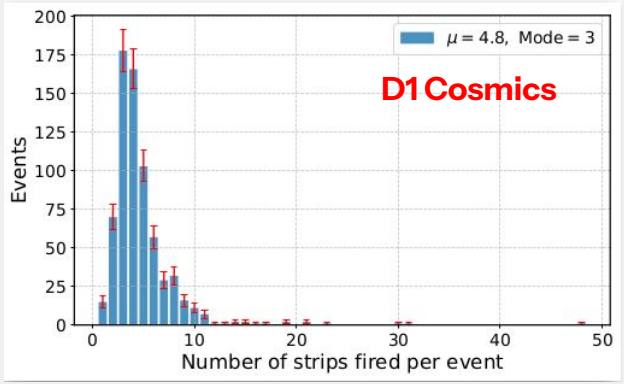


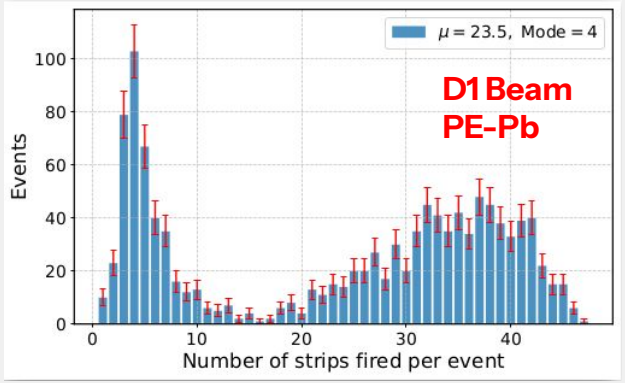
# Occupancy

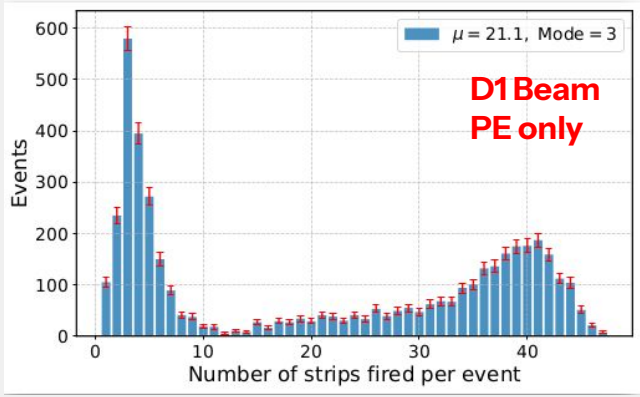

Layer 1, ~1.20 strips/event
Layer 2, ~1.26 strips/event
Layer 3, ~1.19 strips/event
Cosmics
Counts
Strip index
Time bins
120 (1.6%)
121 (4.3%)
122 (72.3%)
123 (9.5%)
124 (7.5%)
125 (4.8%)

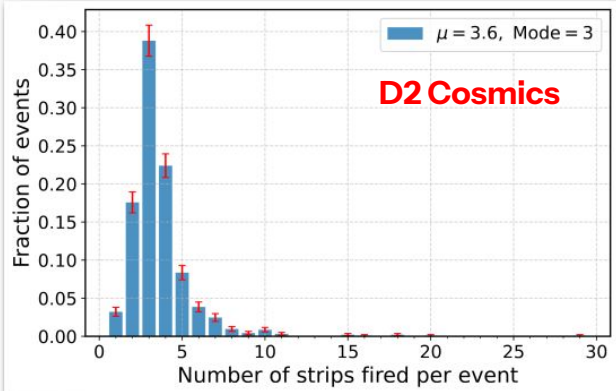

θ < 0
θ > 0

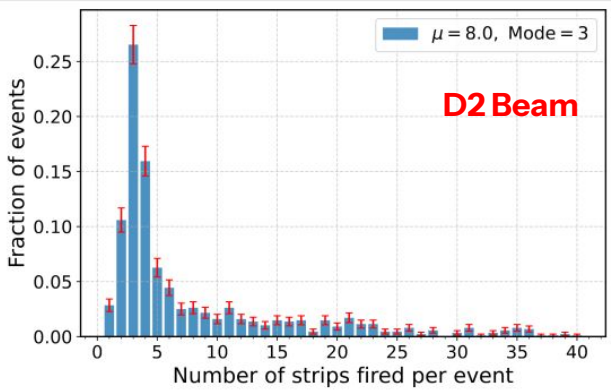
# Strip Multiplicity

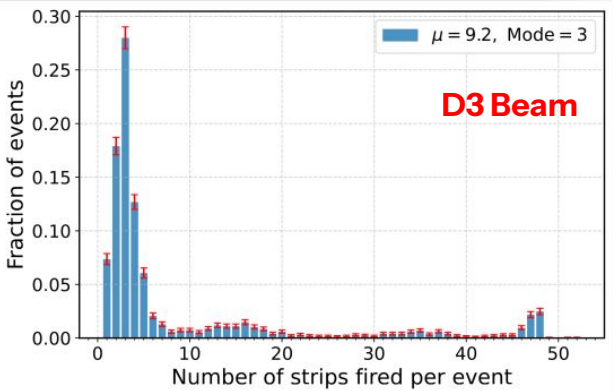


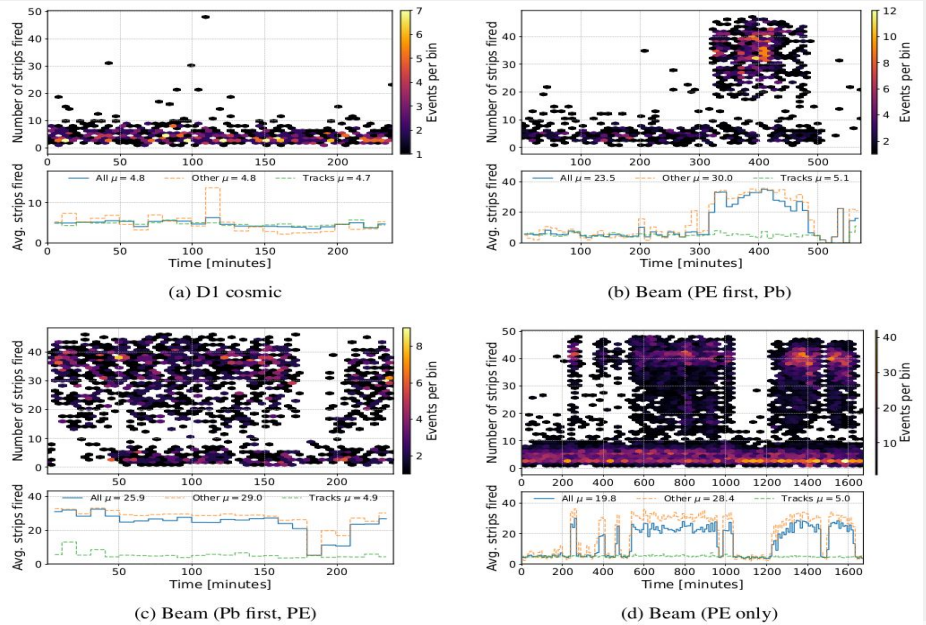



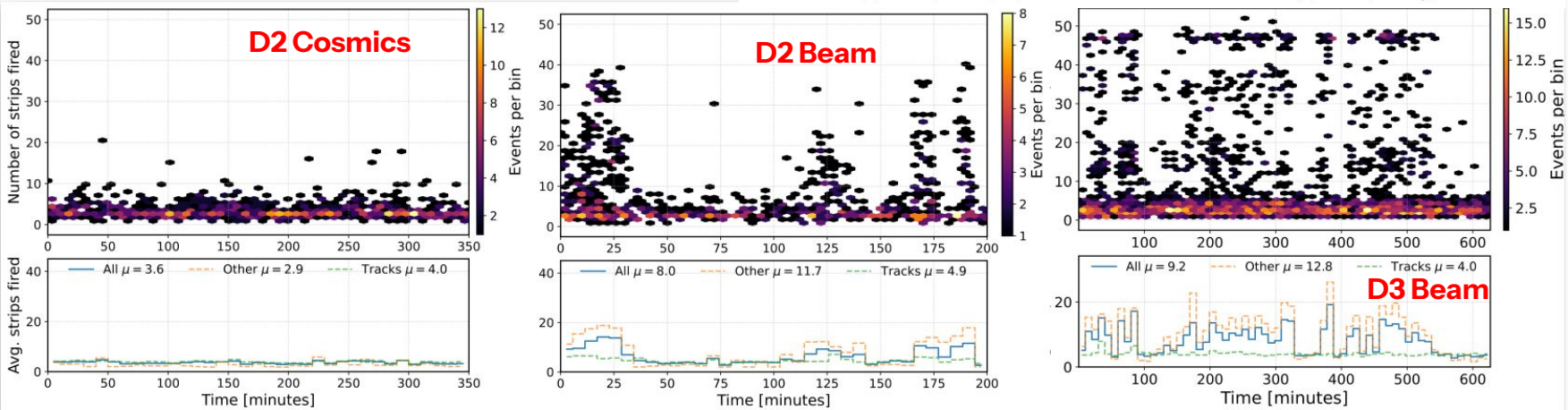



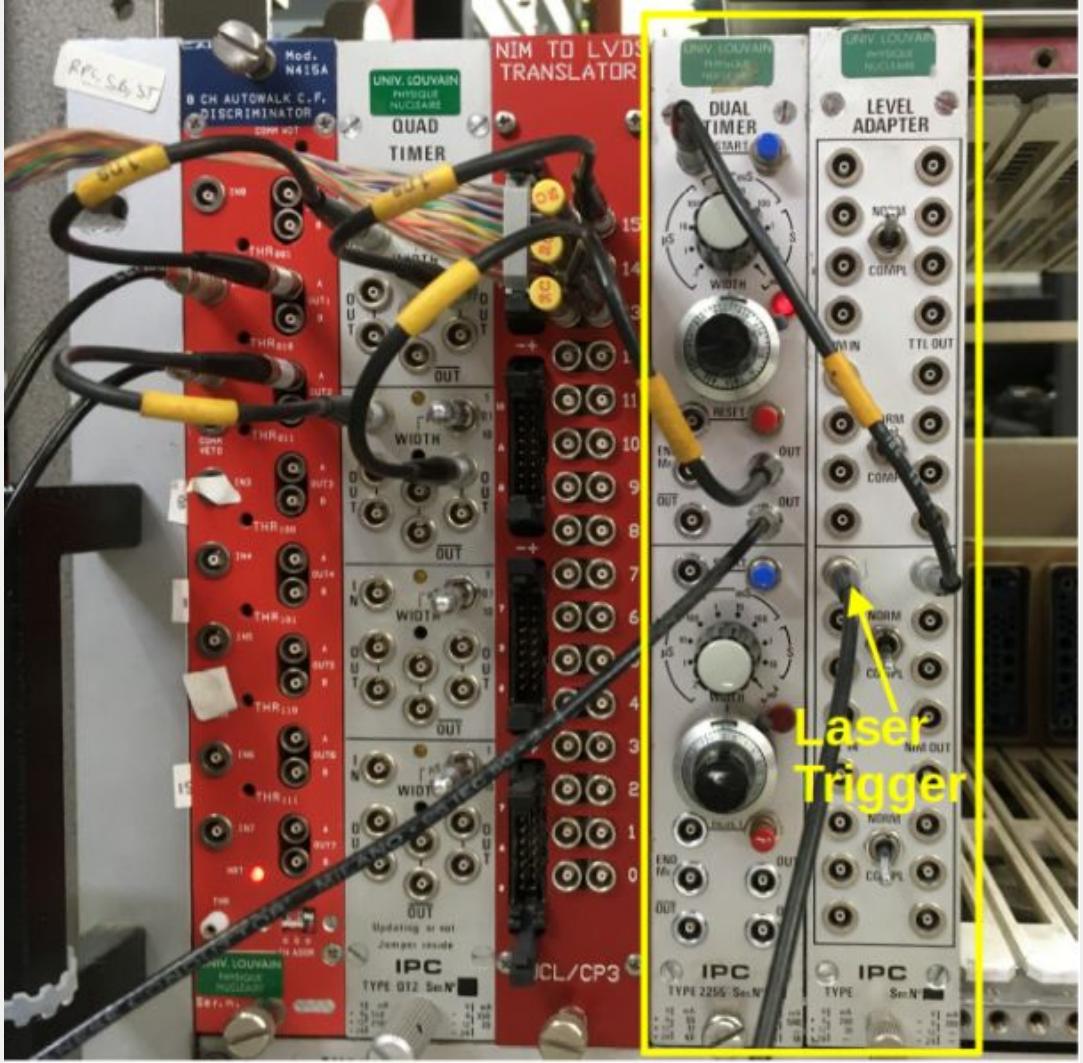



# Strip Multiplicity VS time

- External scintillator trigger timestamps recorded for all configurations Allows study of temporal structure of detected events
- cosmic run shows stable behavior over time

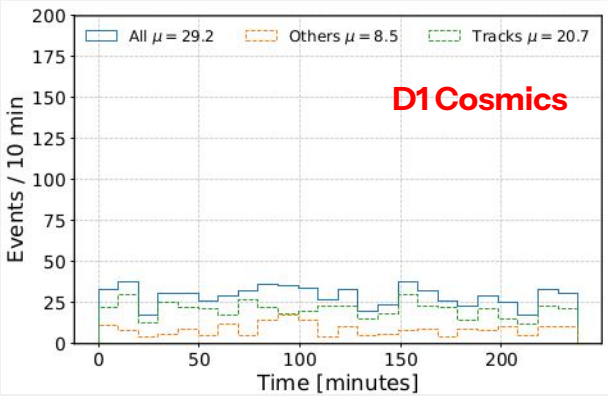


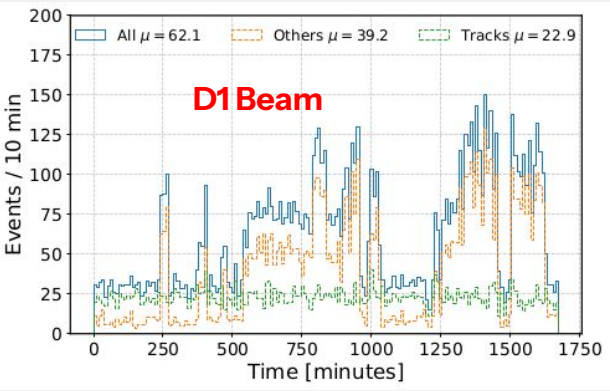



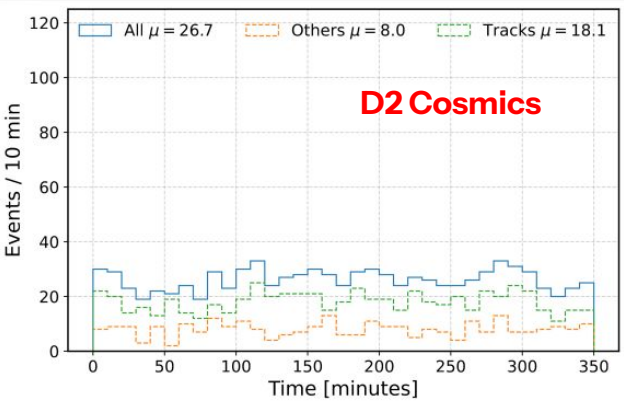

Mod. N415A
8 CH AUTOWALK C.F. DISCRIMINATOR
UNIV. LOUVAIN
QUAD TIMER
NIM TO LVDS TRANSLATOR
DUAL TIMER
LEVEL ADAPTER
WIDTH
OUT
IPC
Laser Trigger

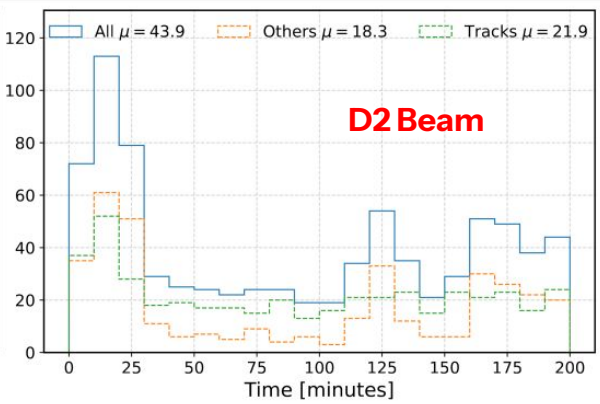
# Event Rate

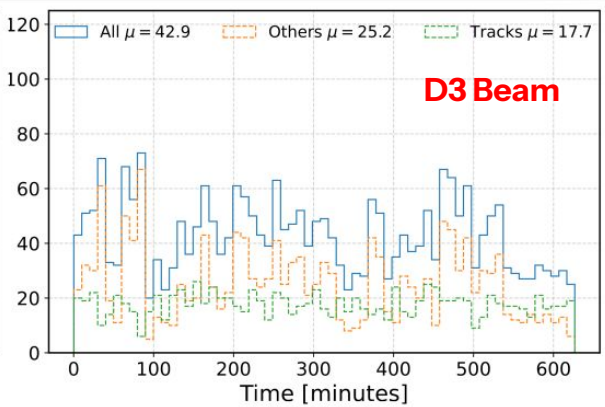
- Cosmic run shows stable behavior over time
- Track rate ≈ 18 events / 10 minutes
- Beam dataset shows strong temporal fluctuations



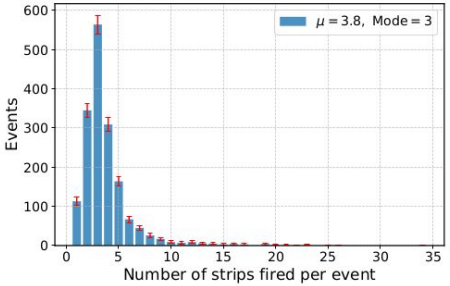



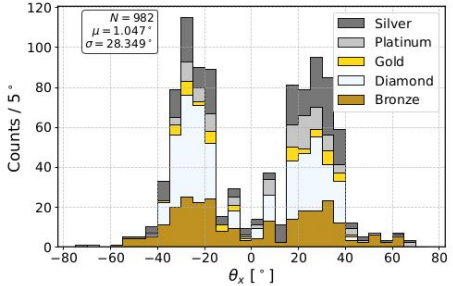



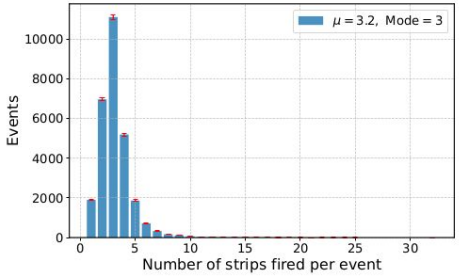
# Validation with cosmics Data at CP3



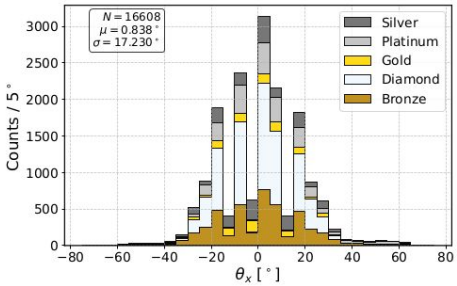

(a) Strip multiplicity for the D1 cosmic-ray dataset.




(b) Zenith-angle distribution for laboratory cosmic rays.



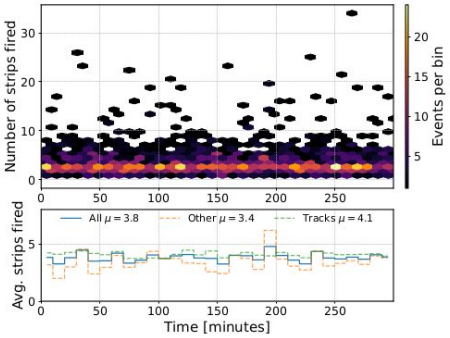

(a) Strip multiplicity for the D1 cosmic-ray dataset.



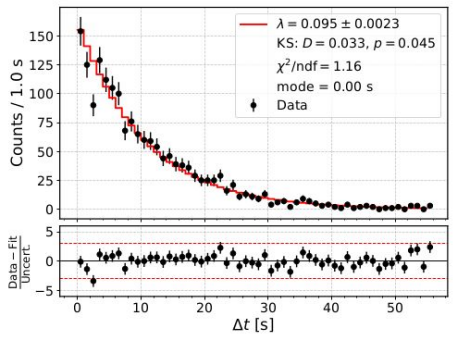

(b) Zenith-angle distribution for laboratory cosmic rays.

**ELI- like Setup Data**

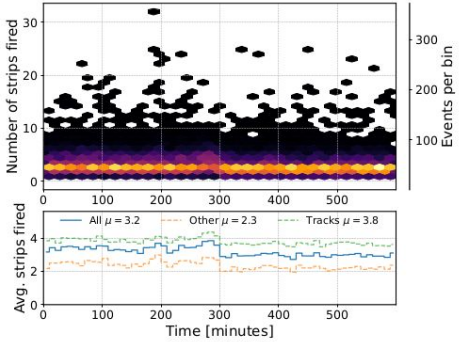
**Vertical Flux Setup data**



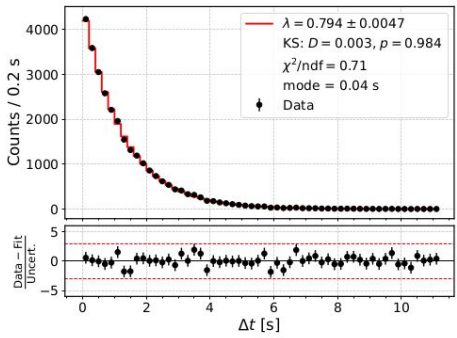

(c) Strip multiplicity as a function of time.




(d) Inter-arrival time distribution.




(c) Strip multiplicity as a function of time.




(d) Inter-arrival time distribution.

# Principal Component Analysis (PCA)

**26 dimensions**

```
['dt_next',
 'dt_prev',
 'hit_l0',
 'hit_l1',
 'hit_l2',
 'n_clusters_l0',
 'n_clusters_l1',
 'n_clusters_l2',
 'n_clusters_total',
 'n_layers_hit',
 'n_strips_l0',
 'n_strips_l1',
 'n_strips_l2',
 'n_strips_total',
 'tb_mean_l0',
 'tb_mean_l1',
 'tb_mean_l2',
 'tb_std_l0',
 'tb_std_l1',
 'tb_std_l2',
 'x_mean_l0',
 'x_mean_l1',
 'x_mean_l2',
 'x_std_l0',
 'x_std_l1',
 'x_std_l2']
```

**2 dimensions** `[PCA1, PCA2]`