DIGITAL CALORIMETRY

Performance Analysis of the CALICE-Digital Hadronic Calorimeter (DHCAL) for pion measurements

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CALICE – PARTICLE FLOW CALORIMETRY

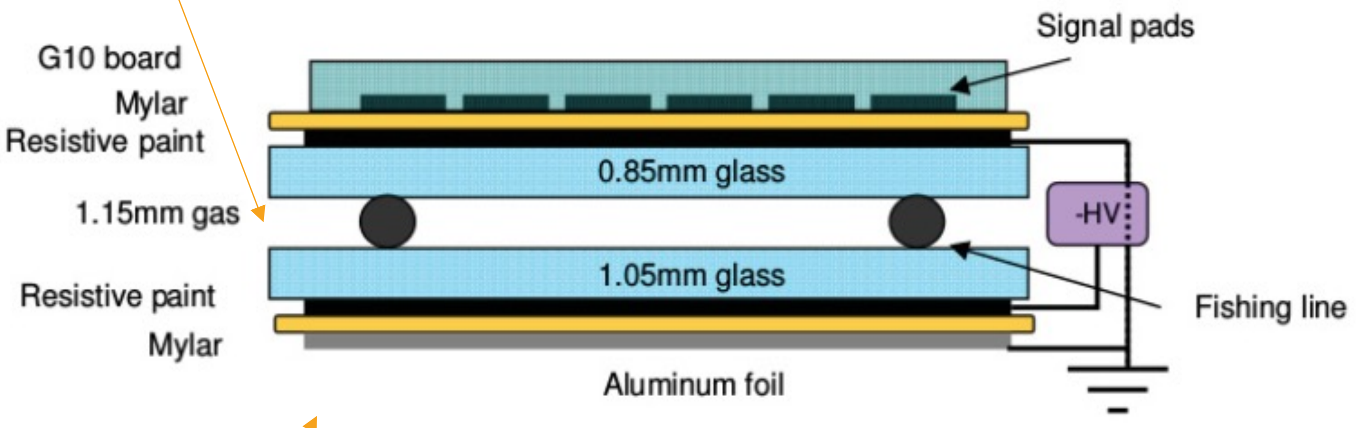
- Need precision measurement of Standard Model
- Particle Flow Algorithm (PFA):
  - Identify individual particles in a jet
  - Improve the jet energy resolution
  - By using high granularity detectors
- CALICE detectors: Energy measurements, Tracking abilities and Timing
- Electromagnetic and Hadronic calorimeters (both analogue and digital)

DHCAL, MIN-DHCAL

- Digital Hadronic CALorimeter (DHCAL): A steel or tungsten absorber between every layer
- DHCAL with minimal absorber: only absorber is from the cassettes
- Resistive Plate Chambers (RPCs)

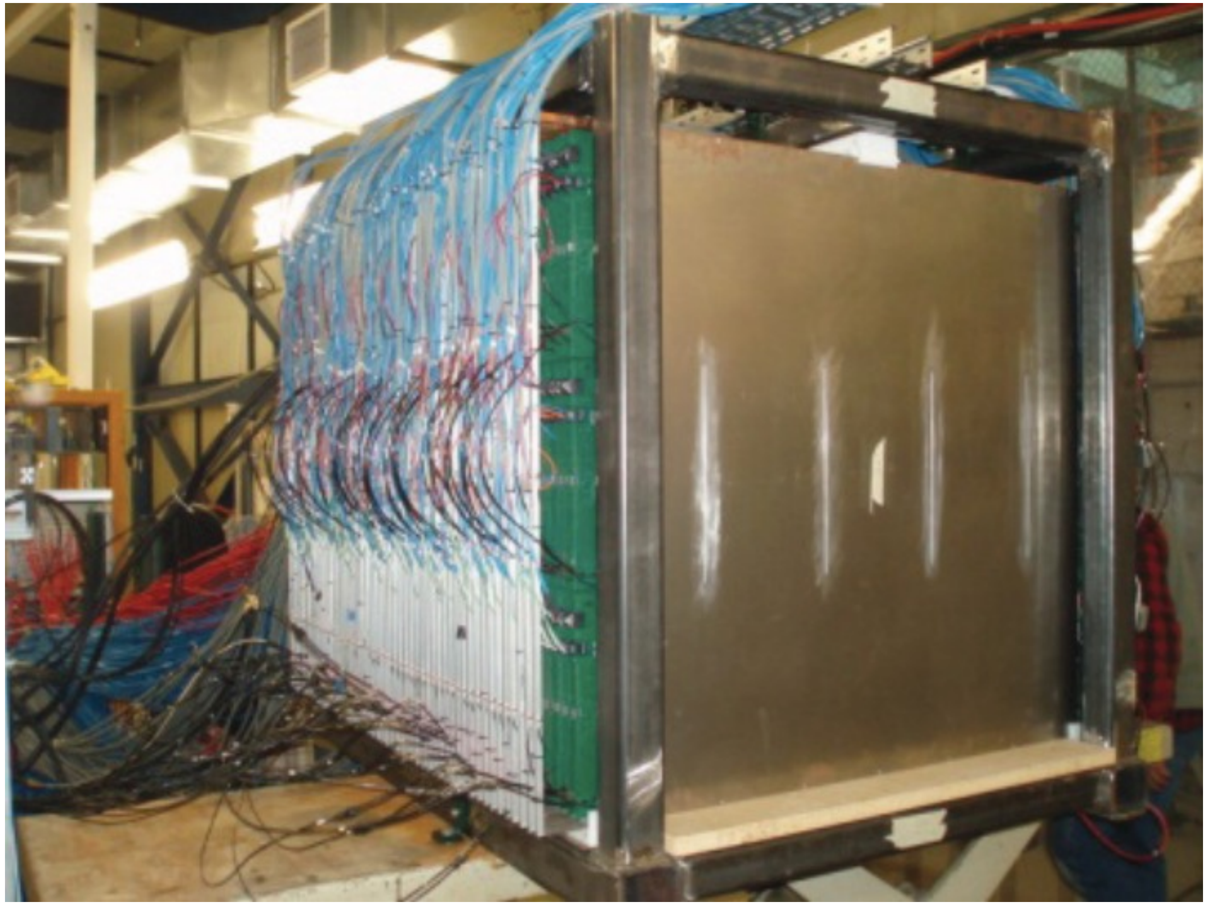
- Tetrafluoroethane (94.5%)
- Isobutane (5.0%)
- Sulfur hexafluoride (0.5%)

- Large avalanche signal
- Quick replenish time



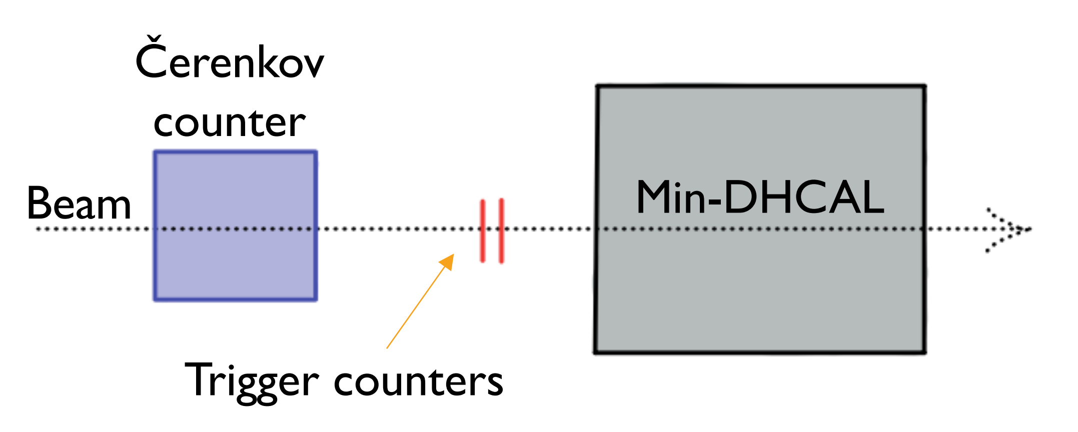
MIN-DHCAL

- Three vertically located 32 x 96 cm^2 RPCs → 96 x 96 cm^2 active area per layer
- 9216 1 x 1 cm^2 readout pads
- Min-DHCAL: 50 cassettes spaced 2.54 cm apart
- 460,800 readout channels
- Recorded hit data: t, x, y, z



DATA SELECTION

- Data taken at Fermilab: Beams provide a mixture of positrons, pions and muons



Momentum (GeV)	#Events
1	107000
2	107000
3	62000
4	84000
6	109000
8	109000
10	226000

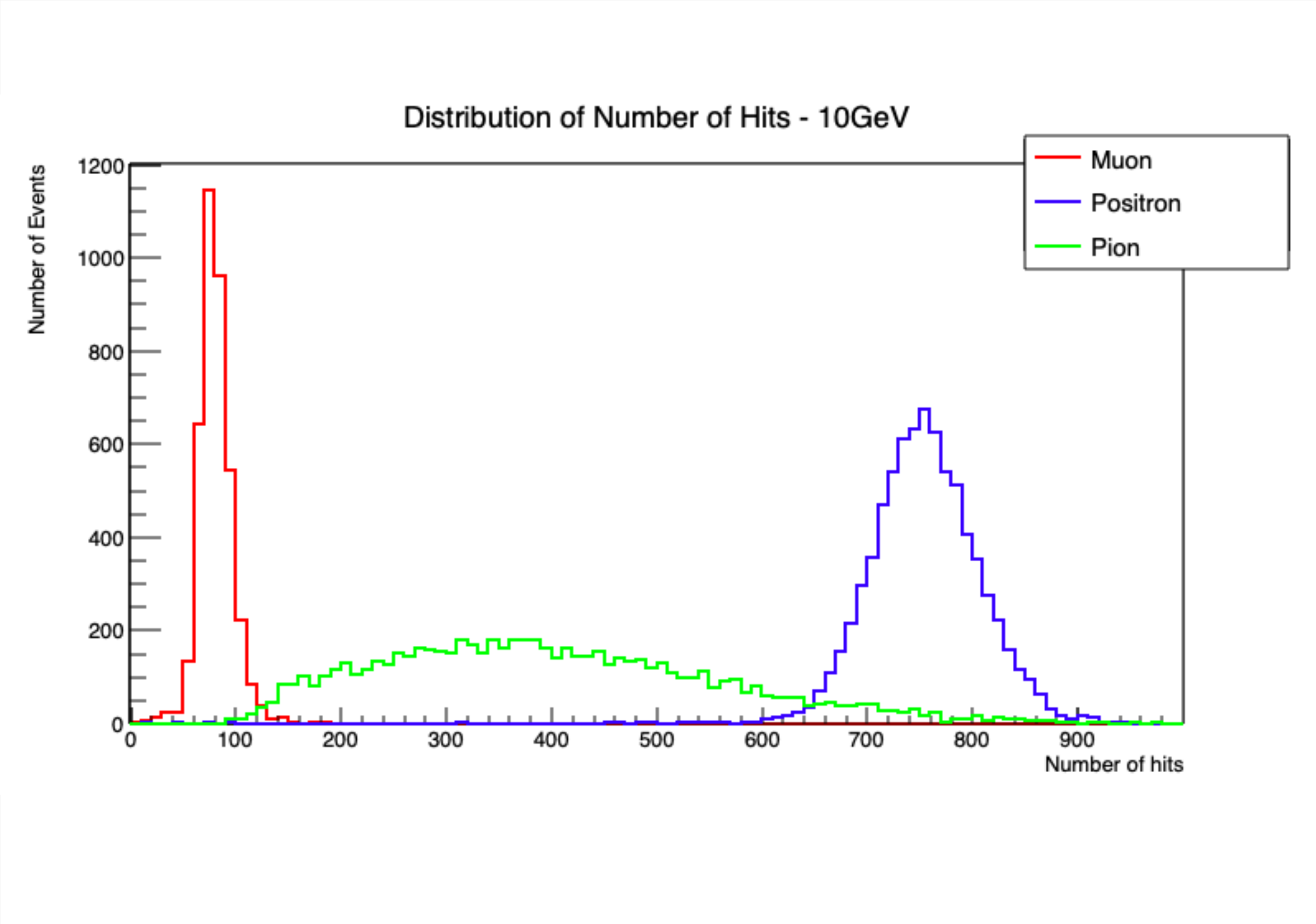
SELECTION CUTS

Event Selection Cuts
Timing
Only one cluster in the 1st layer
>5 active layers

Particle Selection Cuts		
Particles	cuts	
μ	$\check{C} = 0$	No interaction layer
π^+	$\check{C} = 0$	Interaction layer
e^+	$\check{C} \neq 0$	-

PARTICLE IDENTIFICATION

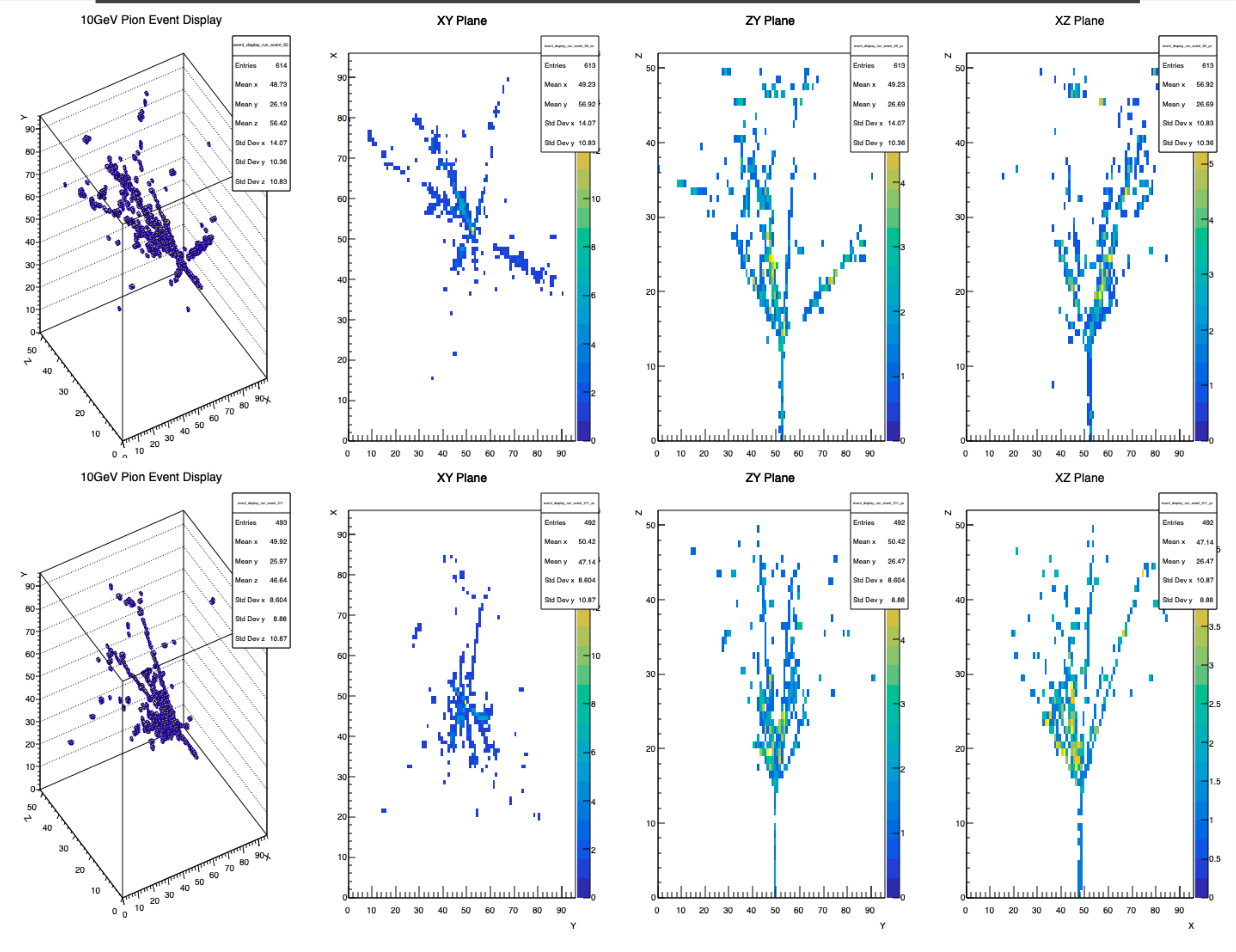
- Muons: least hits
- Positrons: higher hit density due to dense electromagnetic showers
- Pions: large distribution (interact electromagnetically and hadronically, fluctuations in deposited energy)



PION EVENT DISPLAY

Min-DHCAL data

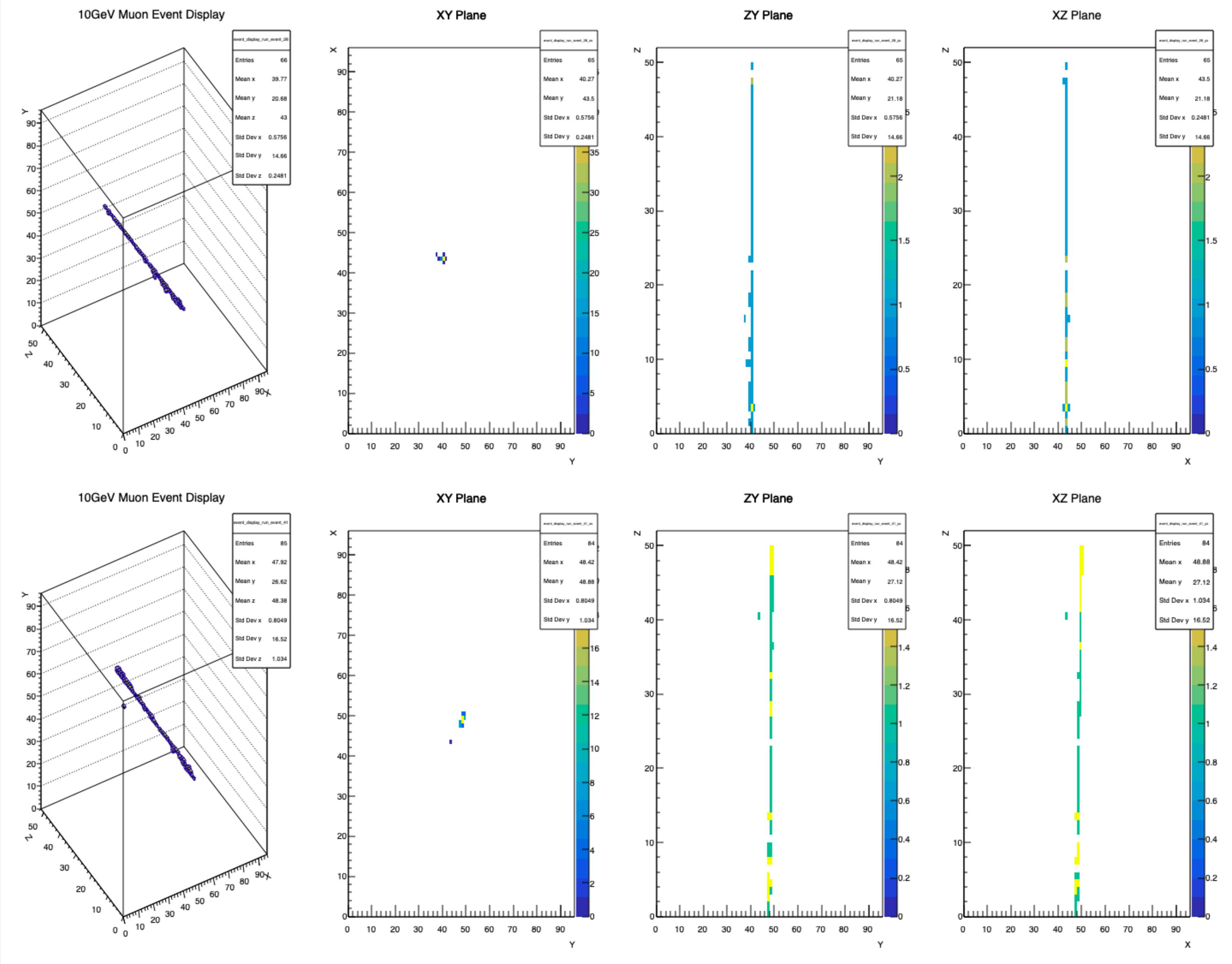
Monte Carlo data



MUON EVENT DISPLAY

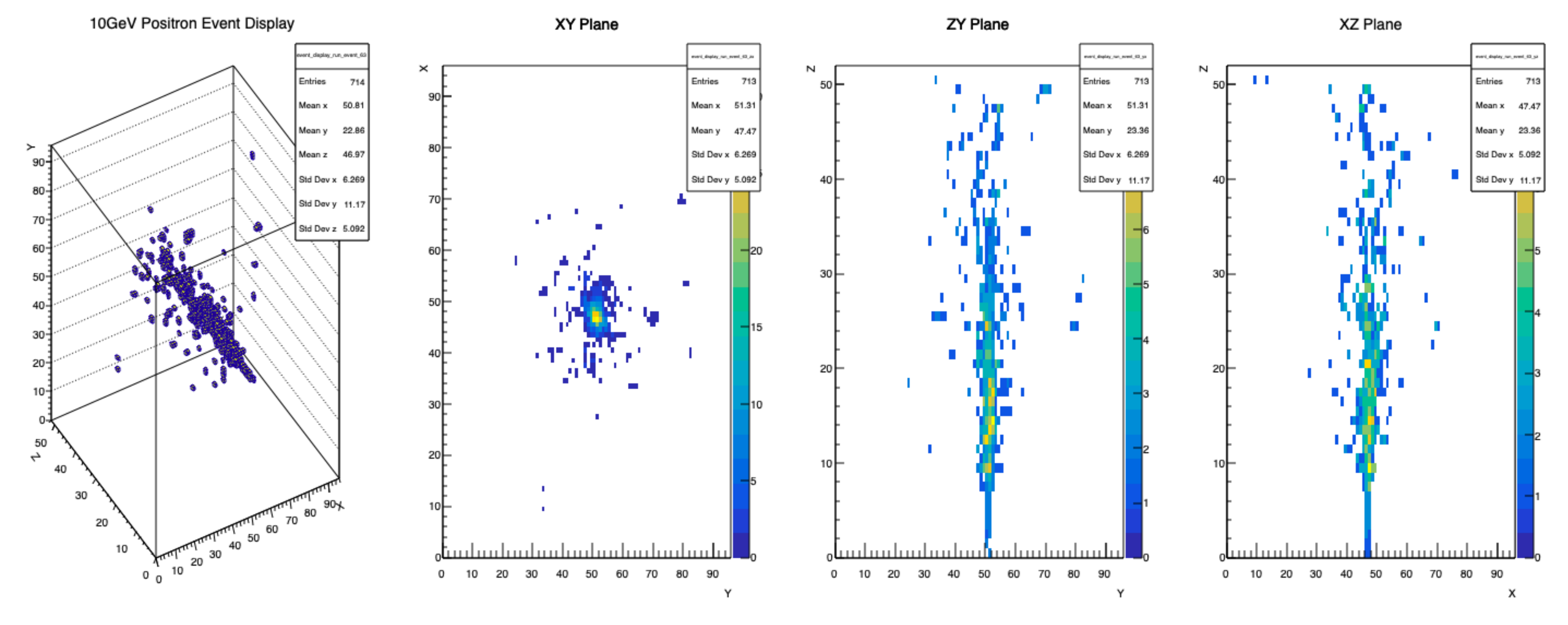
Min-DHCAL data

Monte Carlo data



POSITRON EVENT DISPLAY

Min-DHCAL data



In progress: Monte Carlo data

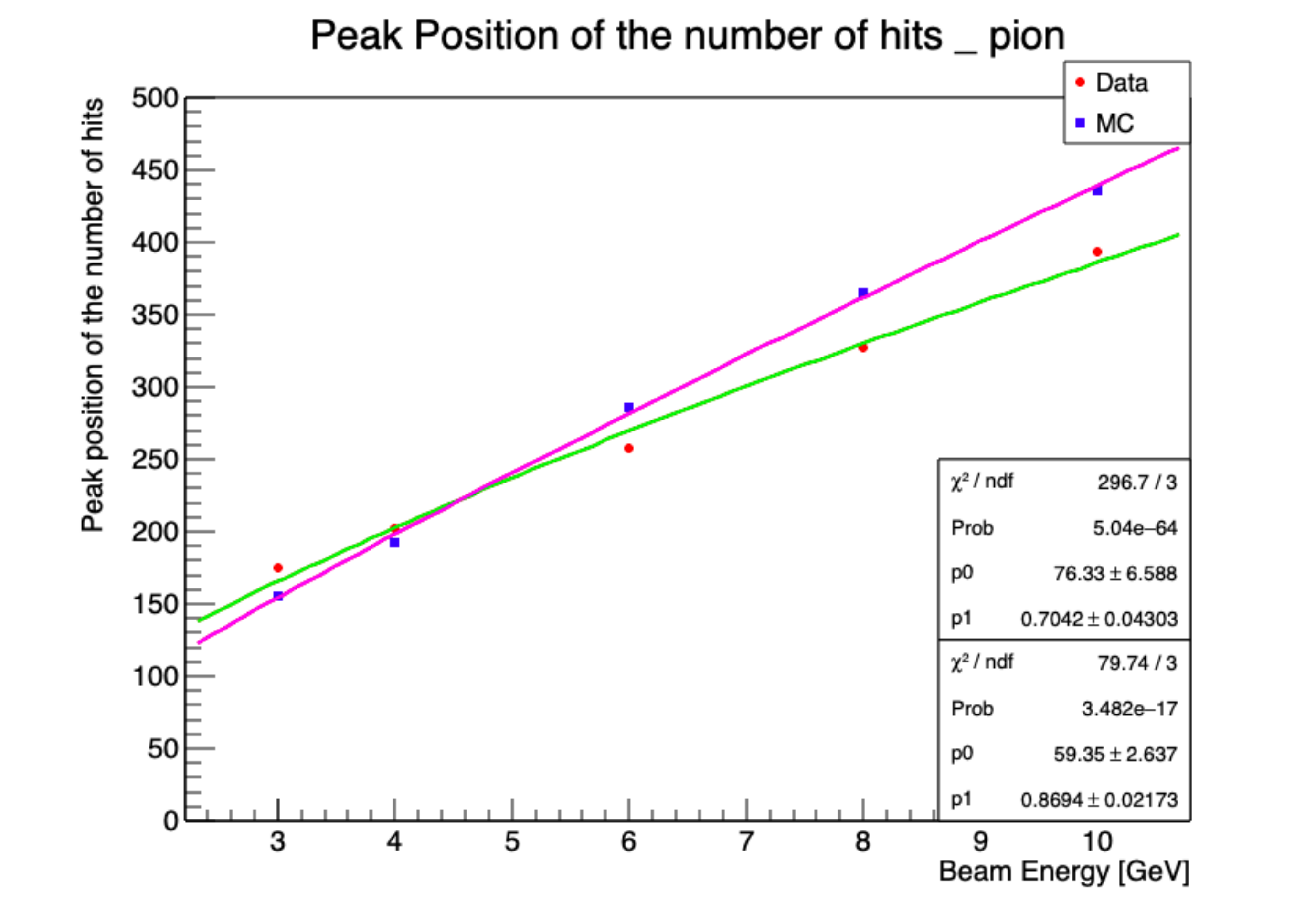
PION MEAN RESPONSE

- Power law fit:

$$N_{hit} = p_0 E_{beam}^{p_1}$$

- Linear response: p_1=1
- Limited granularity, only one hit is recorded ⟹ saturation of the response p_1<1
- p_1=0.87 uncalibrated pion data

**preliminary MC data



CONCLUSION

- Min-DHCAL data can be used to validate current hadronic shower models
- Thanks to high granularity calorimeter ⟹ develop better GEANT4 simulations
- Ongoing: complete calibration and get energy resolution responses

BACK UP

- **RPCs avalanche mode**: initialized by a charged particle ionizing the molecules in the gas gap. The free electrons ⟹ accelerated by a high voltage applied across the chamber ⟹ ionize more electrons on their way. Default high voltage is 6.3 kV.
- **Min-DHCAL**: cassette thickness = 12.5 mm ⟹ average of 0.41radiation length (X_0) or 0.037 nuclear interaction lengths (λ_I). Each readout chip: 1.4 mm plastic casing (~ 30 cm X_0 for plastic) ⟹ 1.4 mm plastic = 0.004 X_0 or $\frac{1}{100}$th of one active layer.
- DHCAL thickness ~ 600 $\frac{g}{cm^2}$ with 1 cm steel absorber between every layer, min-DHCAL thickness ~ 210 $\frac{g}{cm^2}$,
- 1 GeV muon stops in 565 $\frac{g}{cm^2}$ ⟹ 1GeV muon won't stop in the min-DHCAL

BACK UP

- **"hit":** a cell recording a particle passing through it
- Threshold of each readout cell = 180 fC (digital readout) ⟹ set to measure only passage of a particle in the gas gap
- Cells do not record any energy deposited measurements
- **Digital calorimetry**: estimated the energy of a full particle shower by counting the total number of hits recorded in an event