Track Segments in Hadronic Showers: Calibration Possibilities for a Highly Granular HCAL

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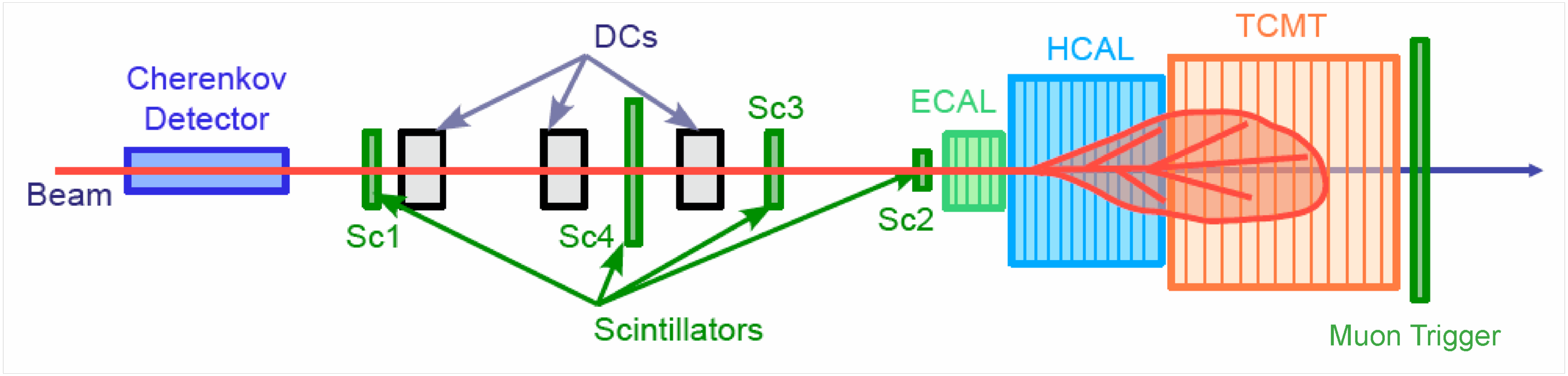
Calorimeter for ILC

Excellence Cluster Universe

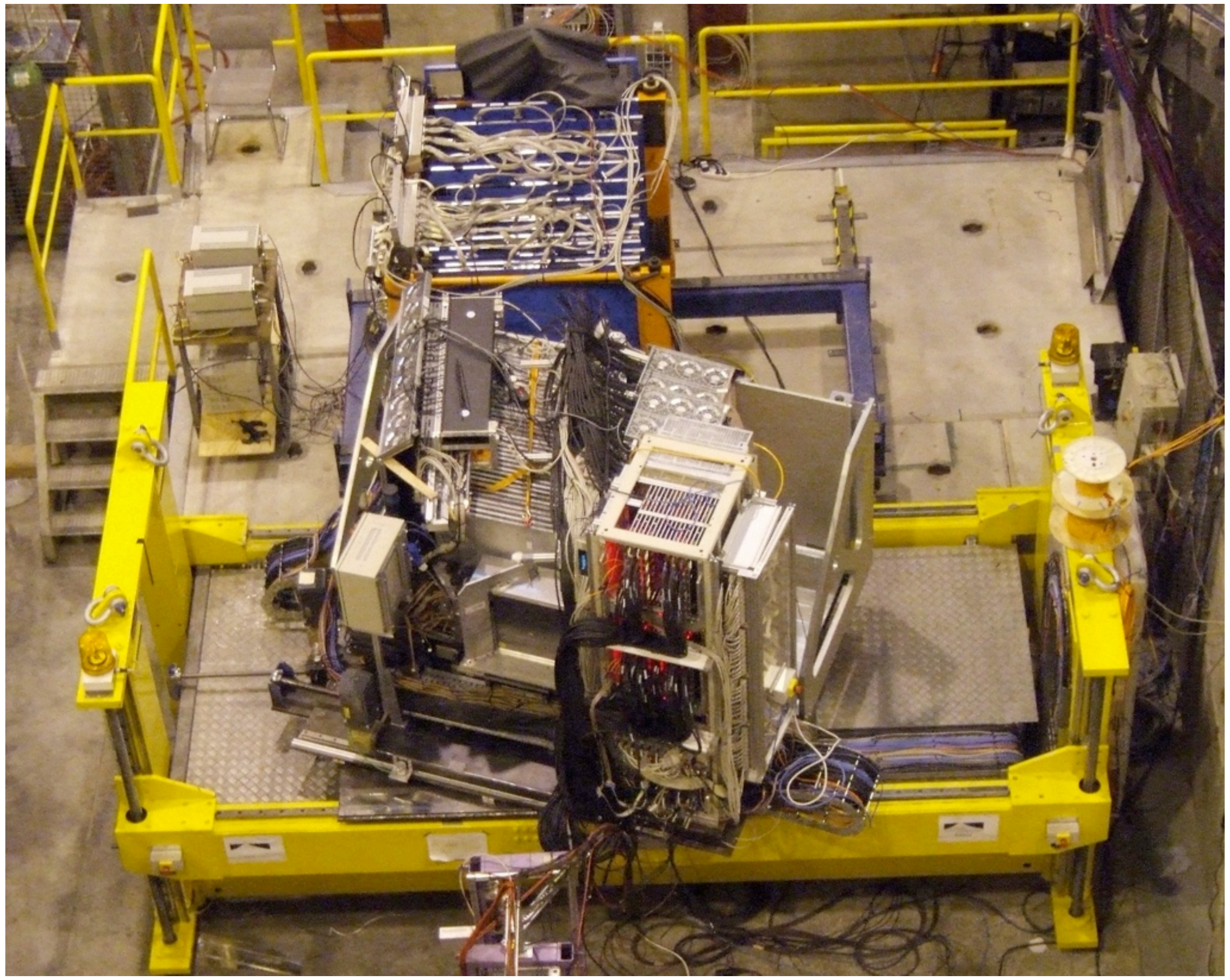
Outline

- The CALICE test beam setup
- Track segments in hadronic showers
- First simulation studies for an ILC Detector (ILD)
- Summary

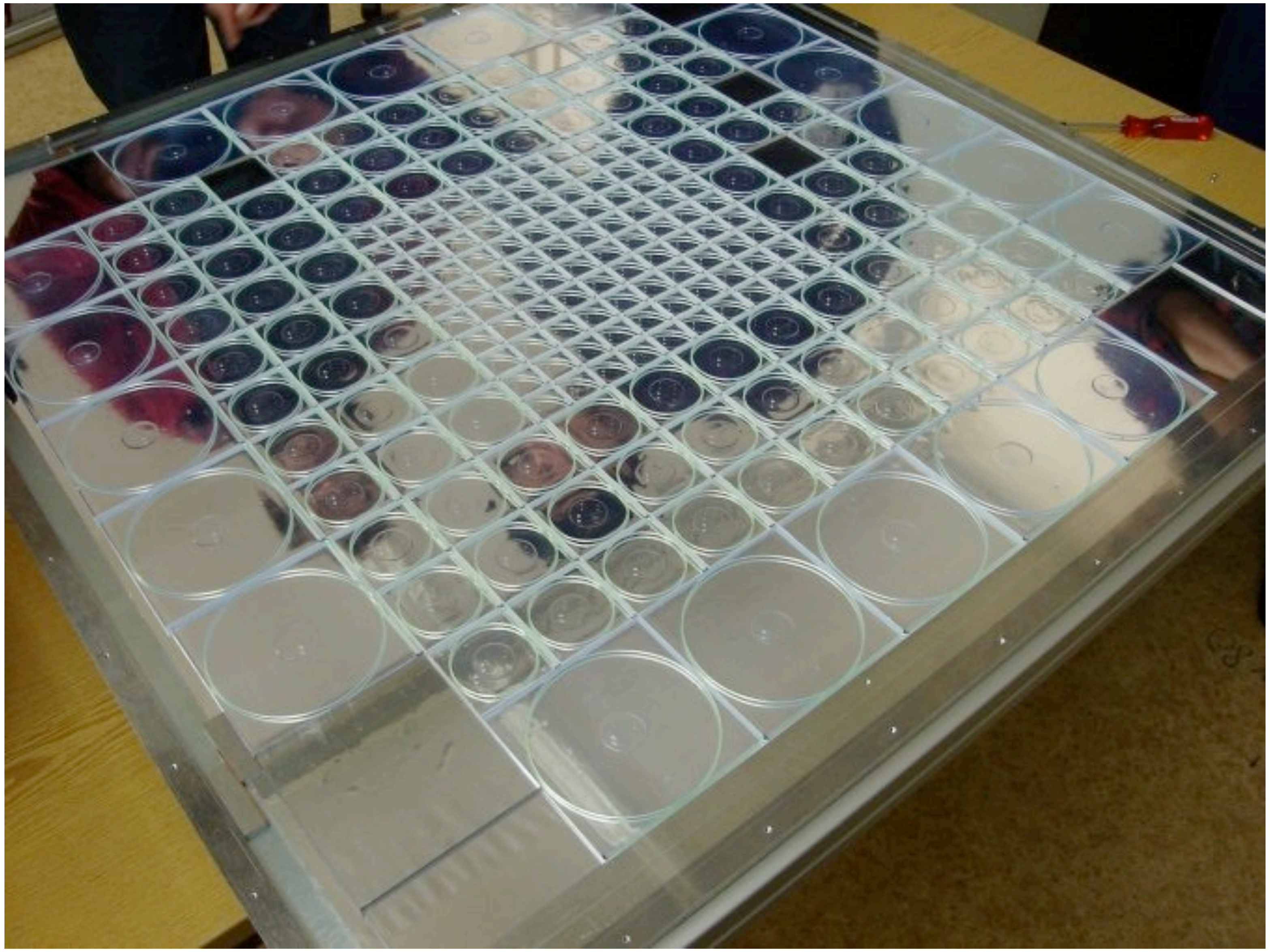
The CALICE Program



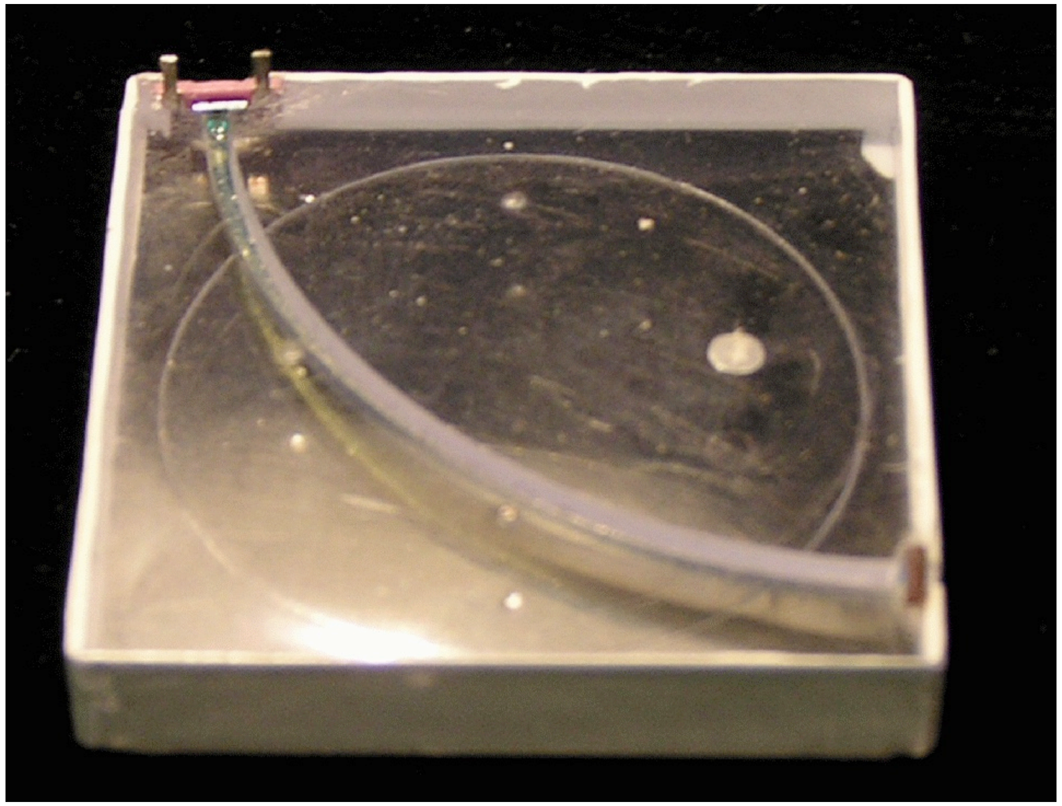
- Extensive test beam campaign
  - DESY: 2006
  - CERN: 2006, 2007
  - FNAL: 2008, ...
- Wide variety of beam energies and particle species
  - 2 GeV to 80 GeV
  - muons, $e^{\pm}$, $\pi^{\pm}$, unseparated hadrons



The CALICE Analog HCAL



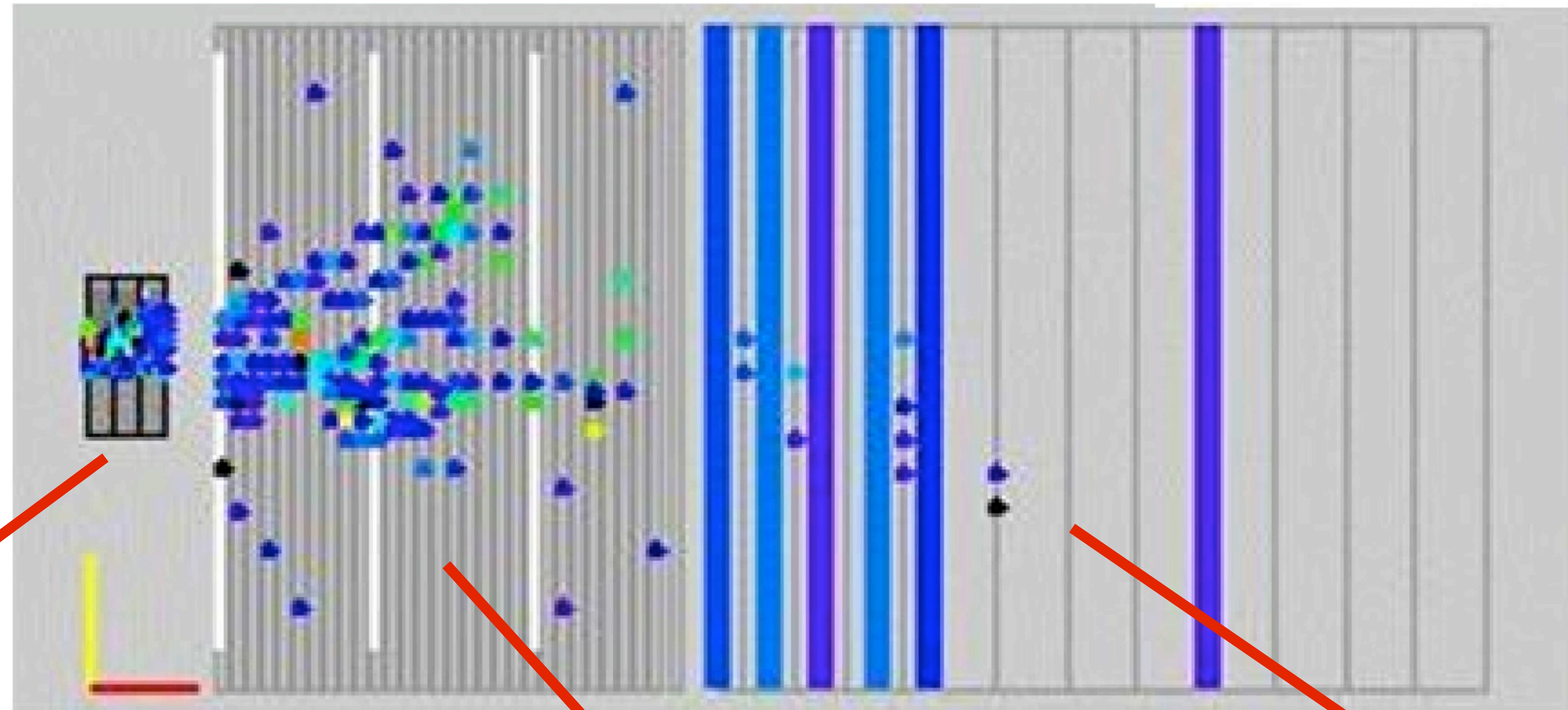
- Steel absorber structure:
  - 38 layers
  - 2 cm total absorber thickness per layer ($1.1\ X_0$, $0.12\ \lambda$)
  - total ~ $4.5\ \lambda$

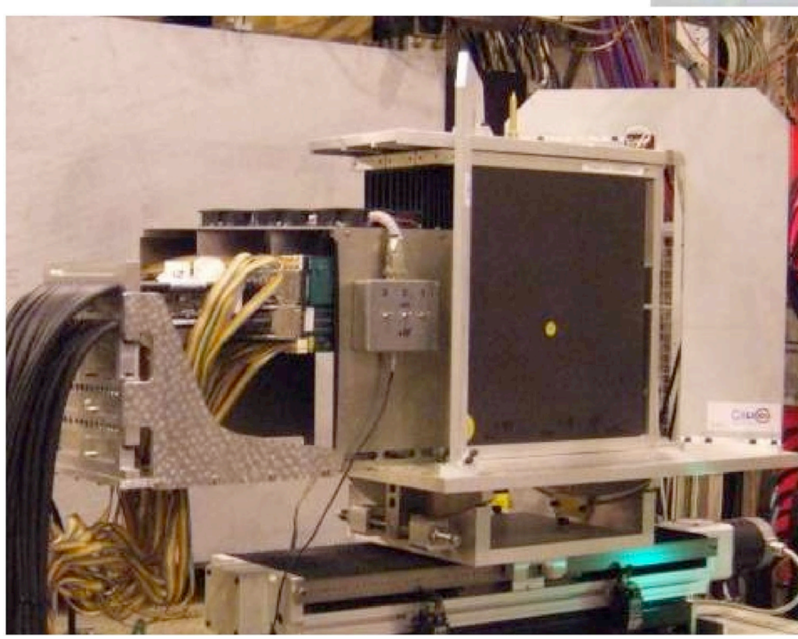


- Active layers: Scintillator tiles
  - high granularity in the layer center: 100 3x3 cm^2 tiles, then 6x6 cm^2 and 12 x12 cm^2
  - light collection via wls fiber, read out with SiPM

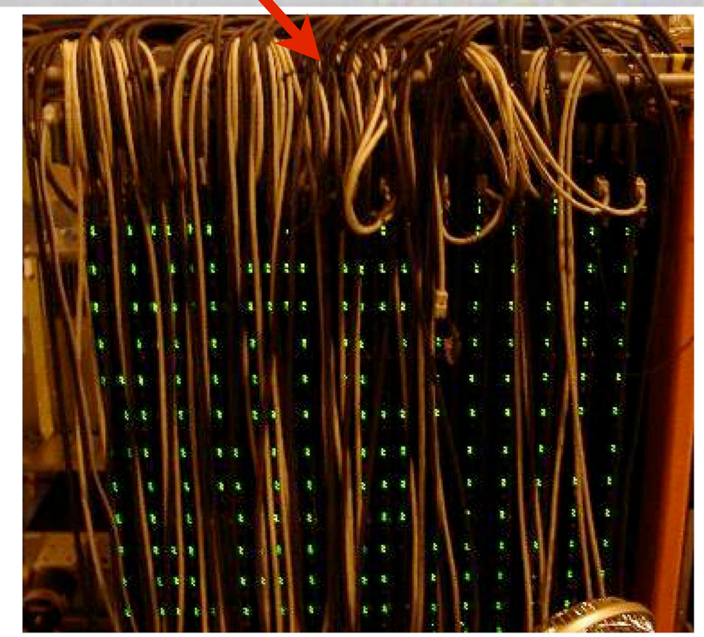
CALICE Calorimeter Setup

- 40 GeV negative pions

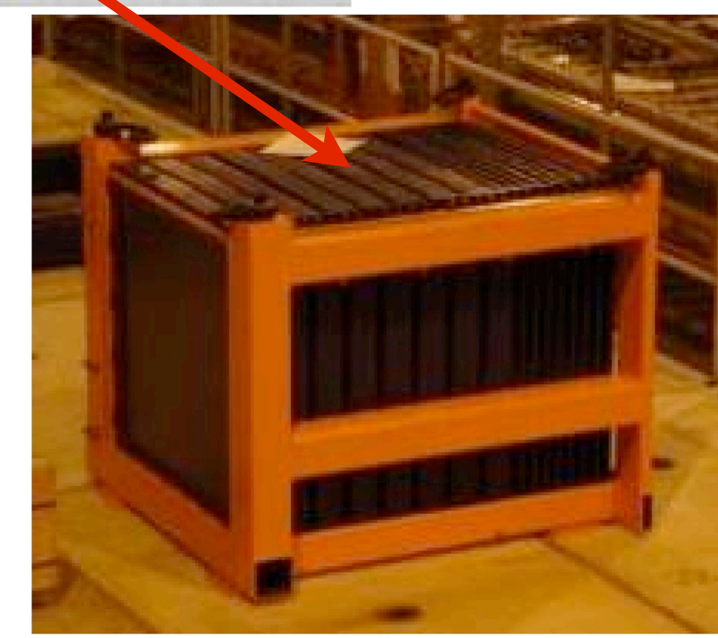




Si-W ECAL
1x1 cm^2 lateral segmentation
30 layers, ~ 0.9 λ, 30 X_0
~ 10 k channels



Analog HCAL
3x3 - 12x12 cm^2 lateral segmentation
38 layers, ~ 4.5 λ
~ 8 k channels



Tail Catcher / Muon Tracker
5 x 100 cm^2 Scintillator Strips
16 layers
~ 300 channels

Track Segments in the CALICE AHCAL

Motivation

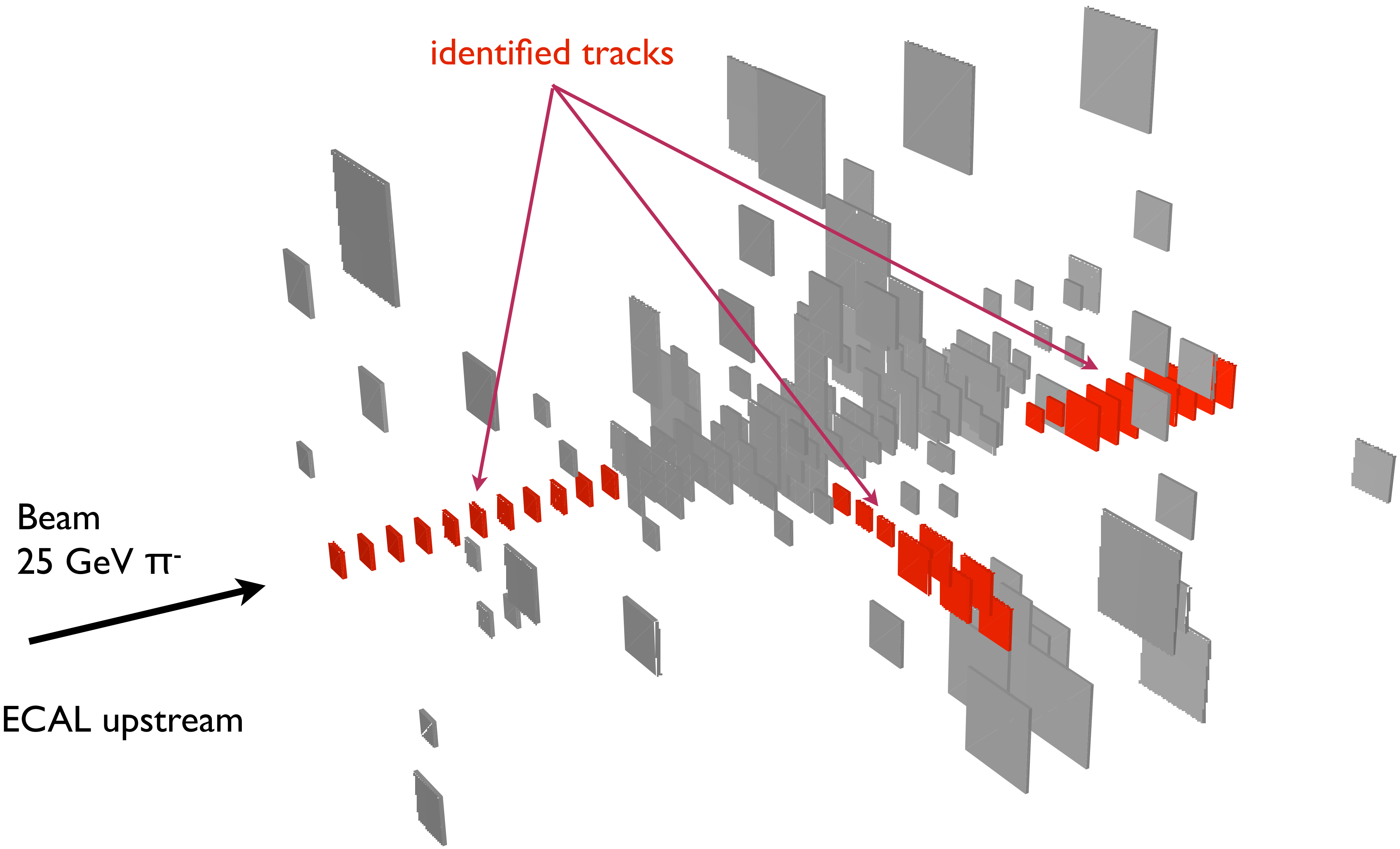
- Muons are usually used for cell-by-cell calibrations of the detector
  - used to for calibrations at CERN and FNAL

- A full ILC HCAL will have ~ 5 M channels, and Muons might not be readily available
  - Investigate the possibility to calibrate using normal data events

- Charged hadrons can be used just as well as Muons
  - Identify minimum-ionizing track segments within hadronic showers

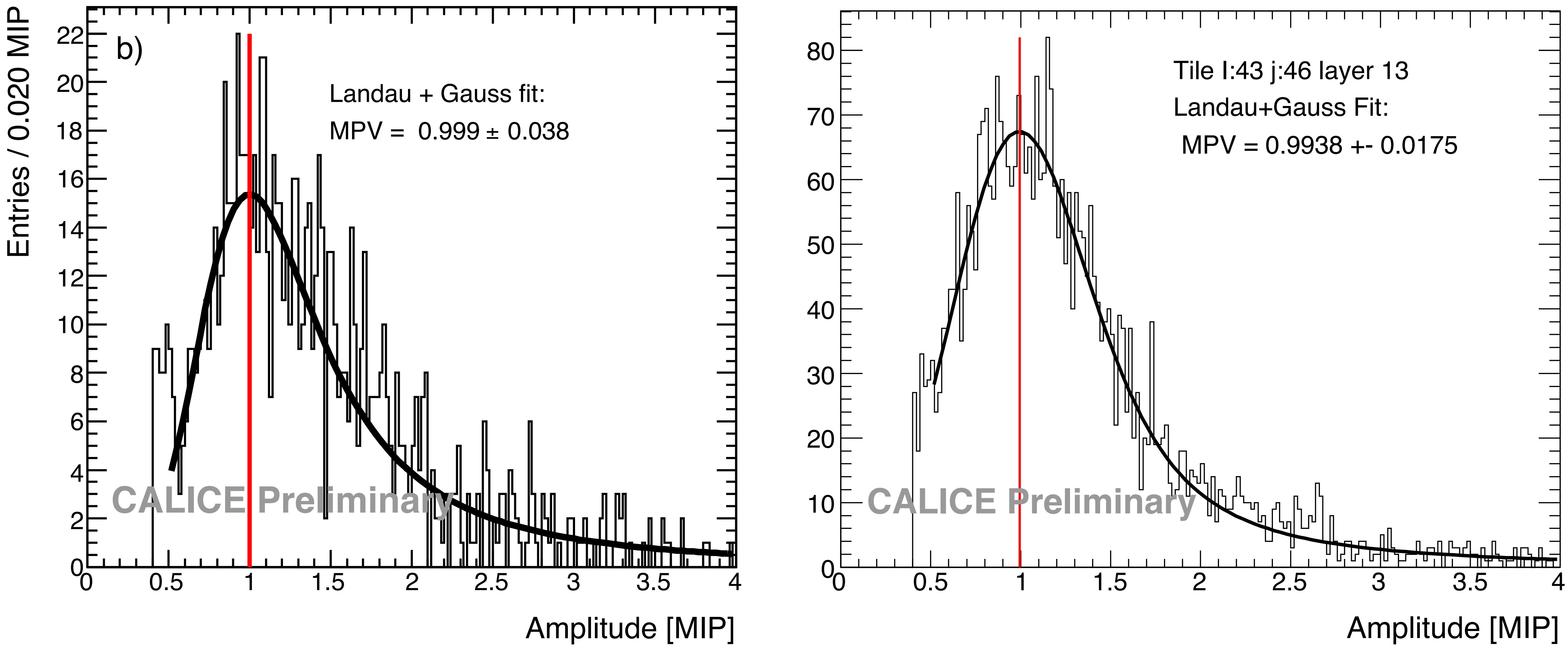
- Such tracks can also be used to investigate the detector in detail: Study the temperature dependence of the SiPM response

Tracking in Hadronic Showers



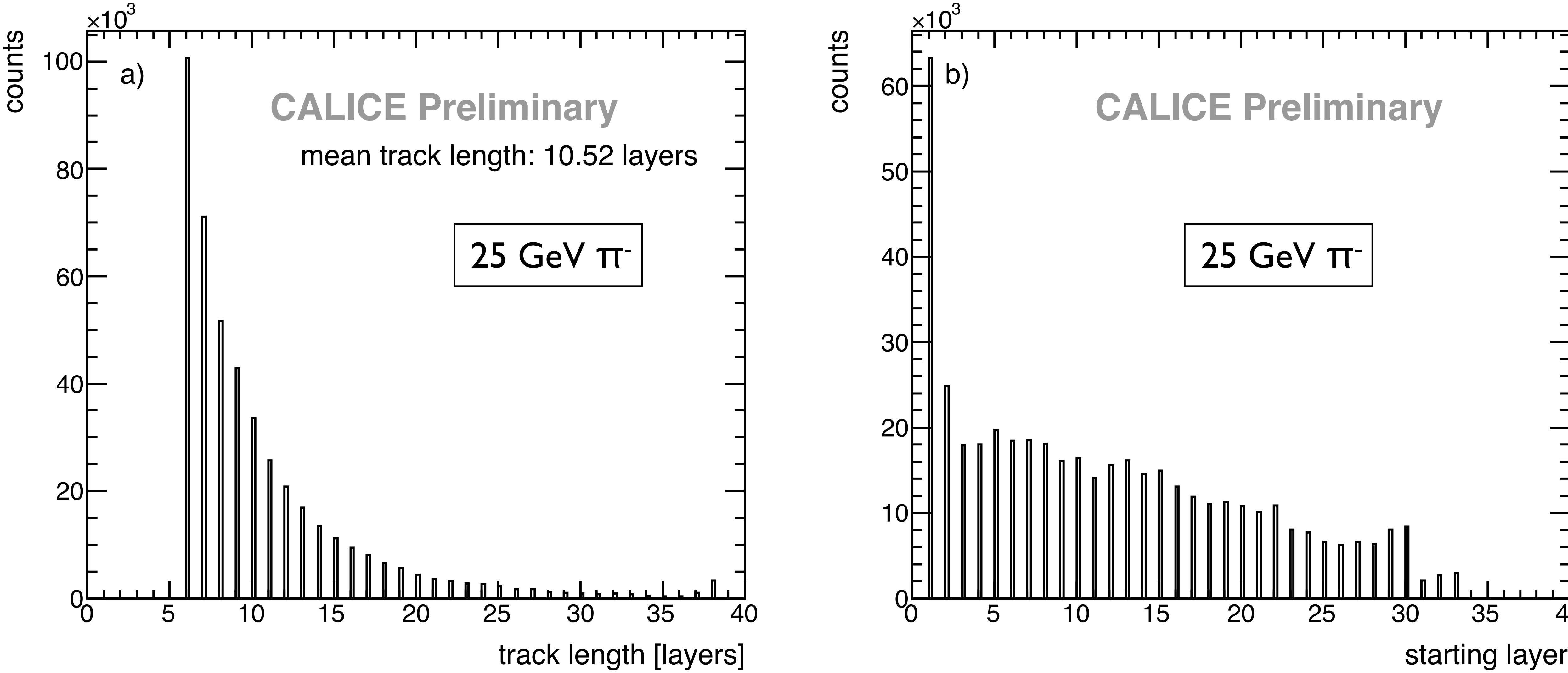
- Find tracks from isolated hits (tiles that don't have energy deposits in their next neighbors on the same layer)

Cells on Tracks: Amplitudes (Muons & Hadrons)



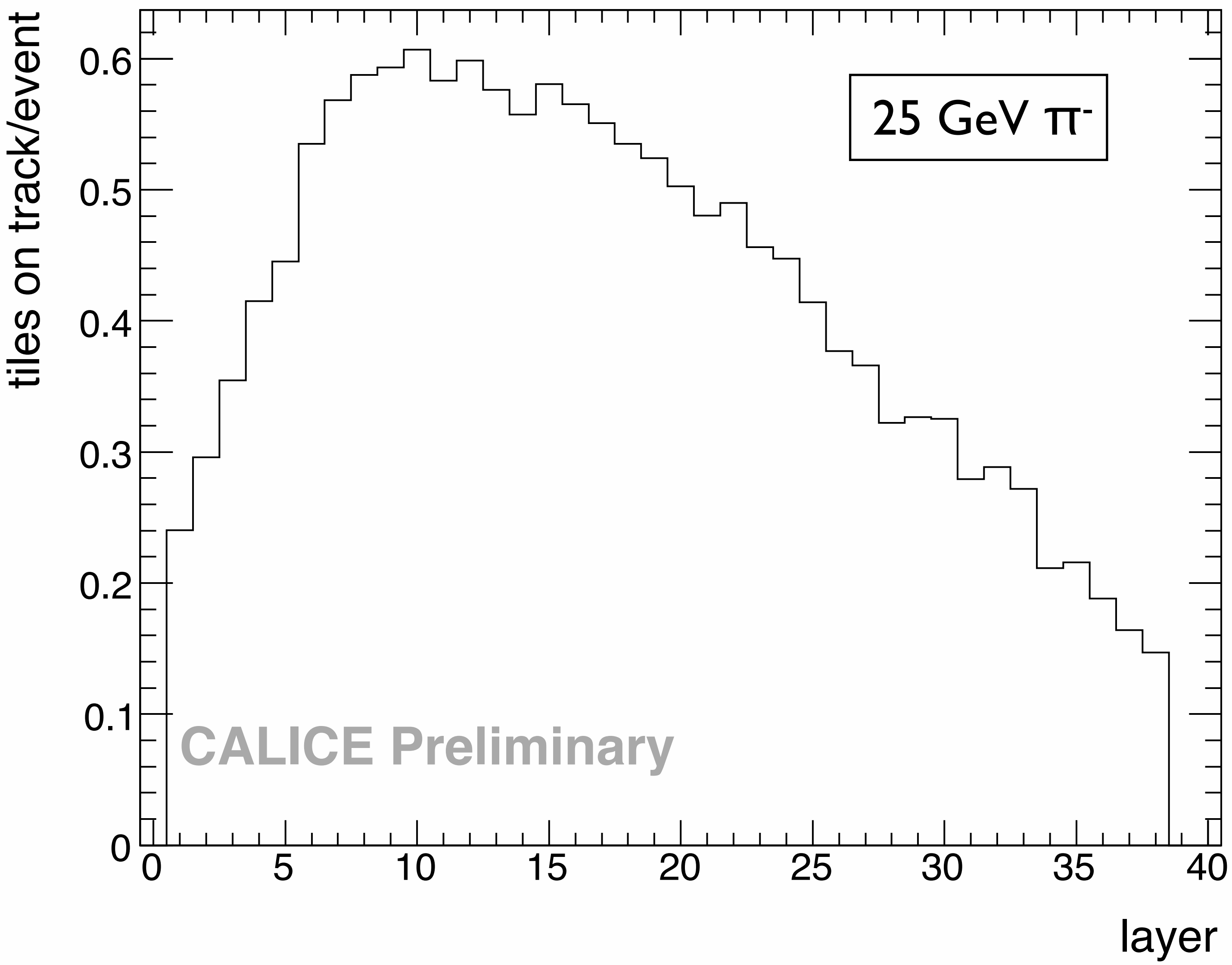
- Track finding applied to Muon runs and Hadron runs:
  - clean spectrum of energy deposit in both cases
  - Most probable value extracted with a Landau+Gauss fit

Hadronic Track Segments: Global Properties I



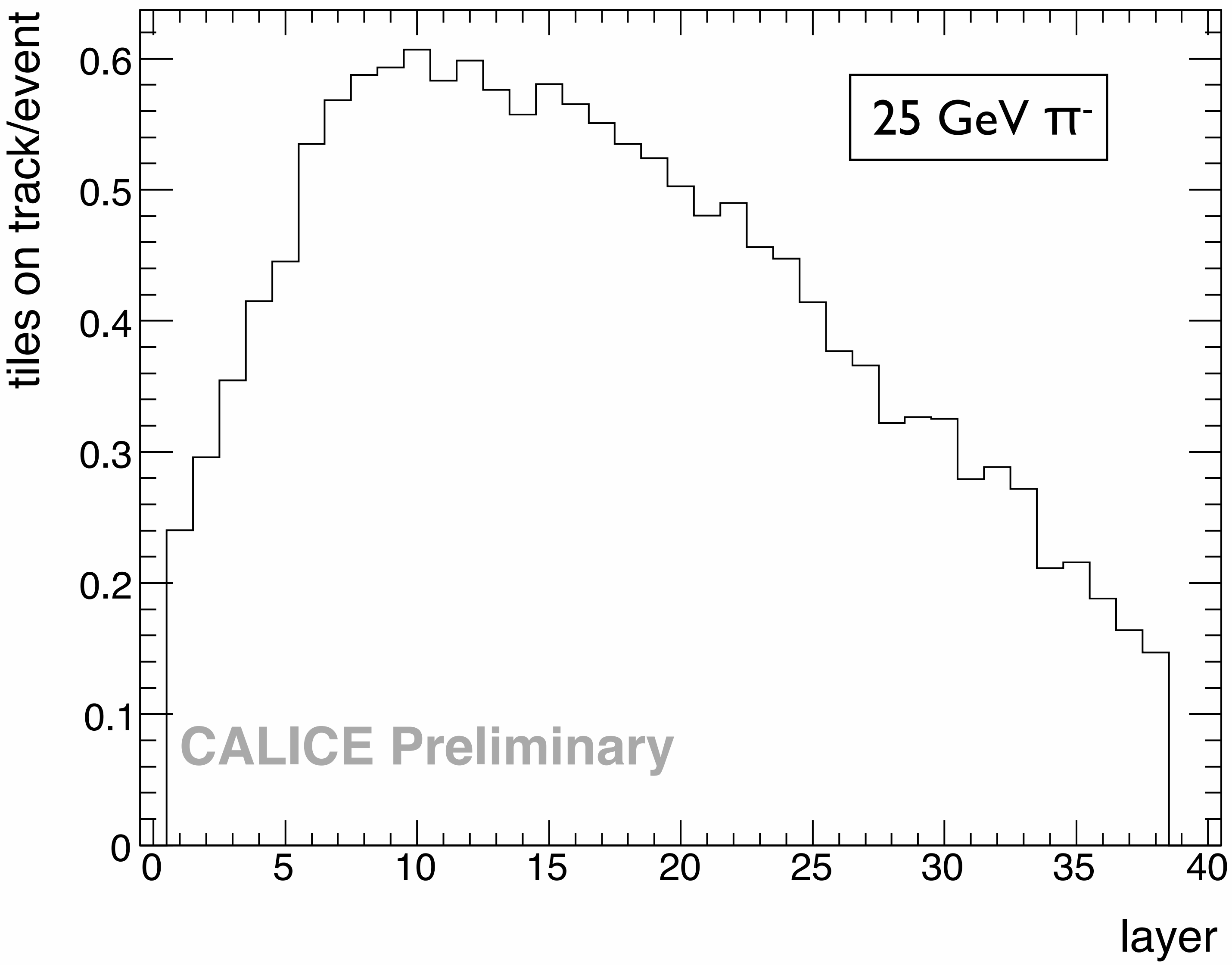
- On average 1.7 identified tracks per hadron
- A significant number of tracks start in the first layers, since the hadrons enter the calorimeter without interacting before (about 1 λ of ECAL upstream)

Hadronic Track Segments: Global Properties II



- At best more than 0.5 cells per layer crossed by tracks per hadron
- after 4.5 λ still more than 0.1 cells per layer per incoming hadron crossed by tracks

Hadronic Track Segments: Global Properties II



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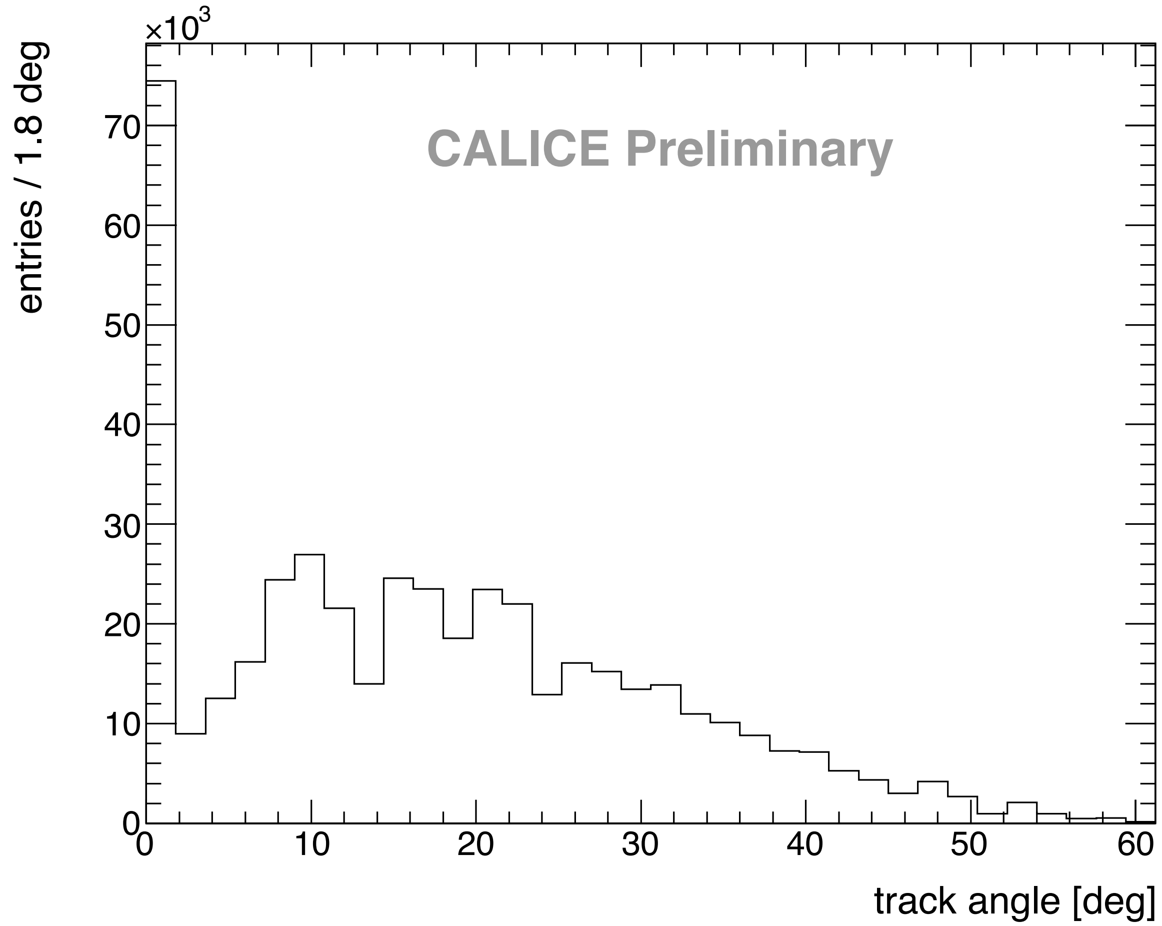
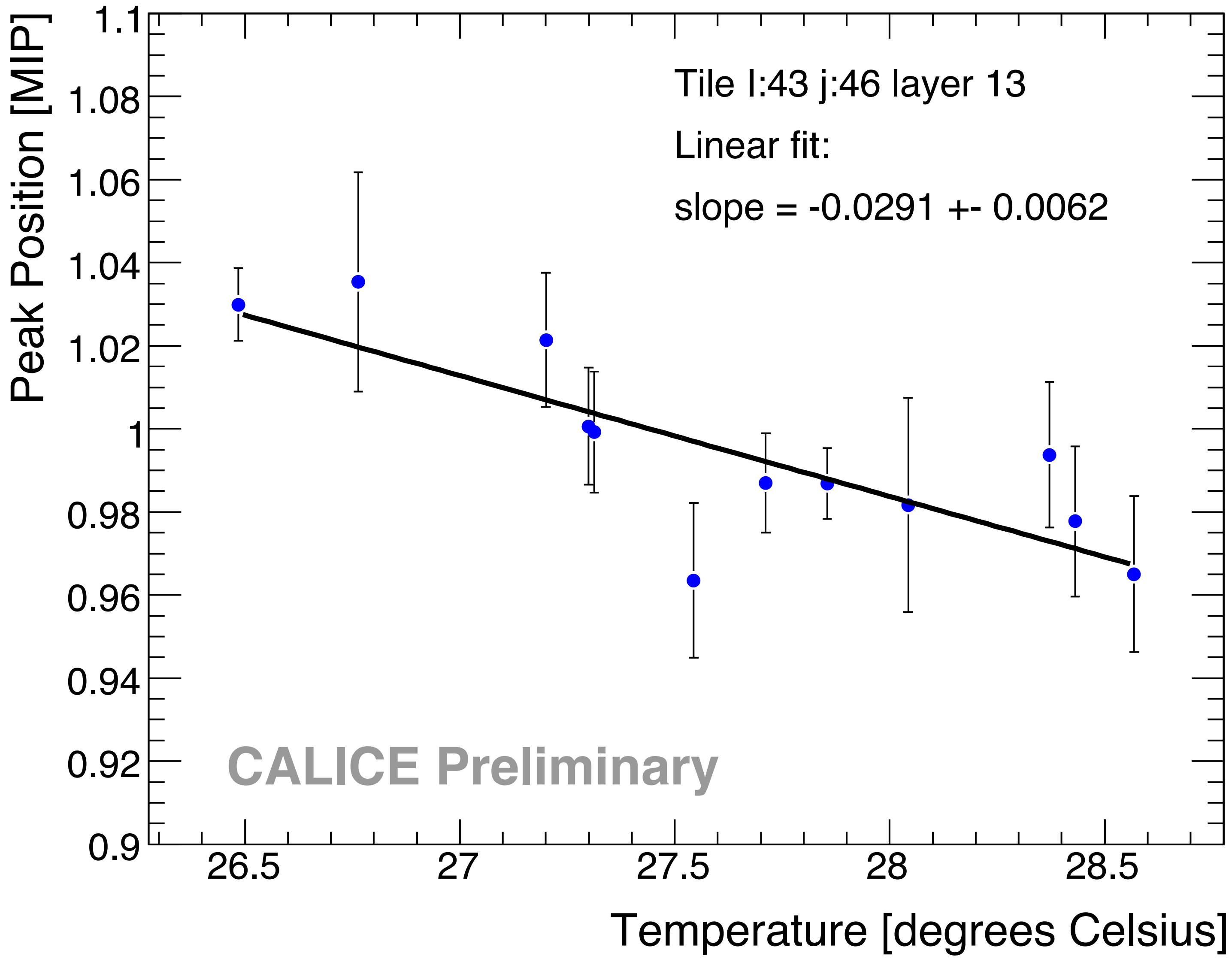


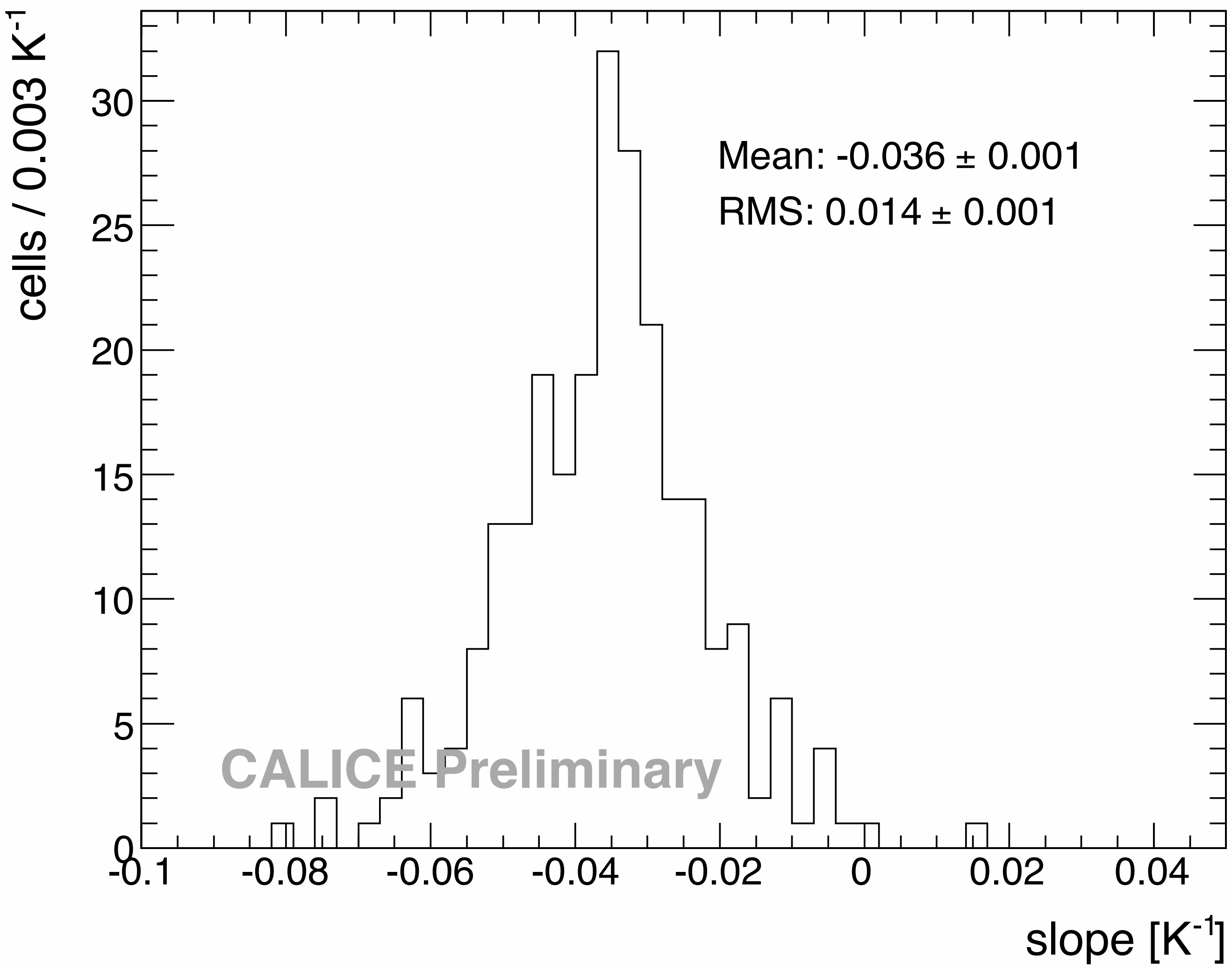
- wide distribution of track angles from secondary particles, currently not corrected for in subsequent analysis

Temperature Dependence of SiPM Response: I



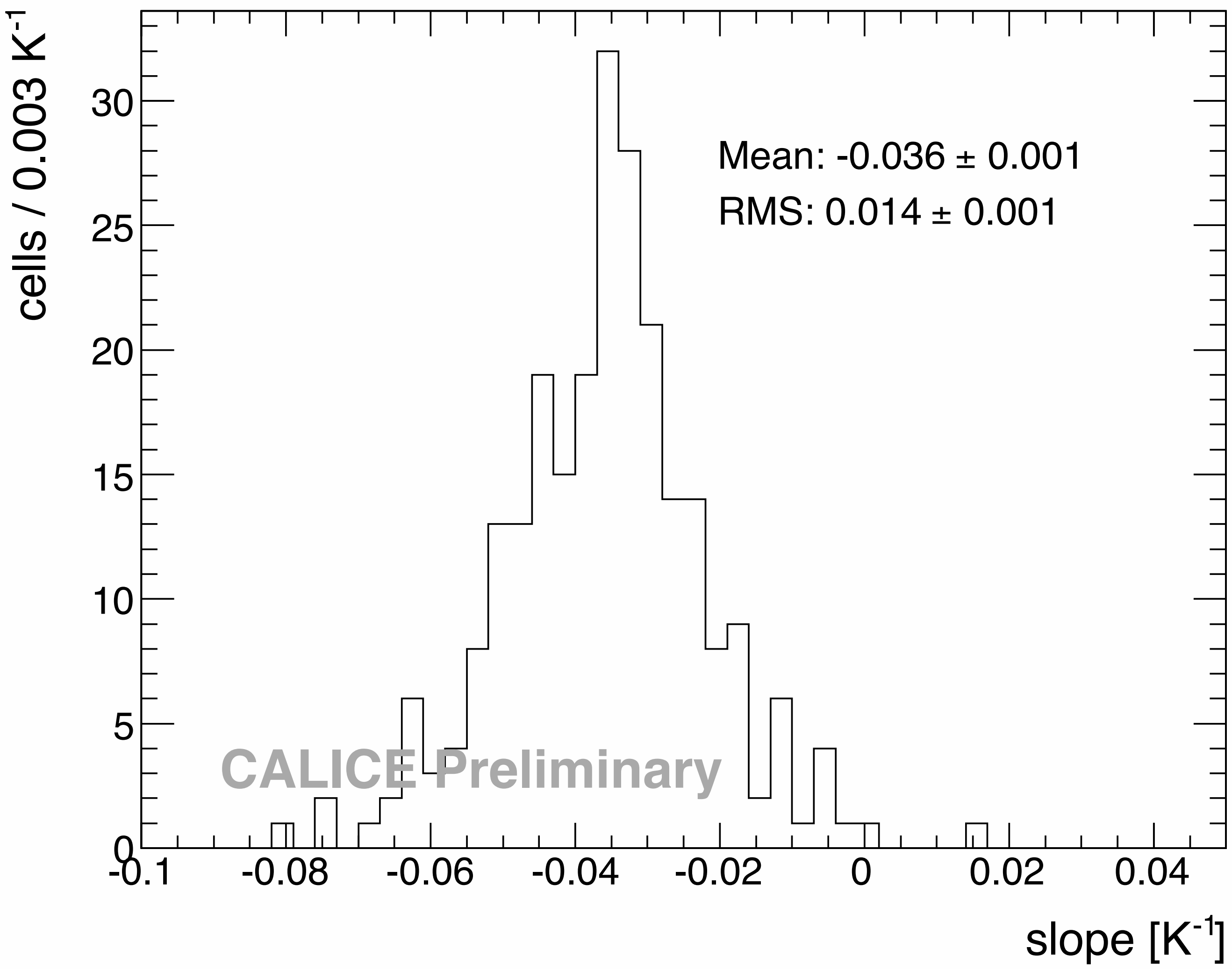
- study of reconstructed MPV of the energy loss as a function of cell temperature
  - no correction for temperature effects in reconstruction
- Temperature dependence of cell response extracted from the reconstructed MPV
  - requirement: at least 2000 tracks in cell under study at a given temperature

Temperature Dependence of SiPM Response II



- Temperature dependence for 250 cells mostly in the center of the calorimeter, with response measured for at least 6 different temperatures

Temperature Dependence of SiPM Response II



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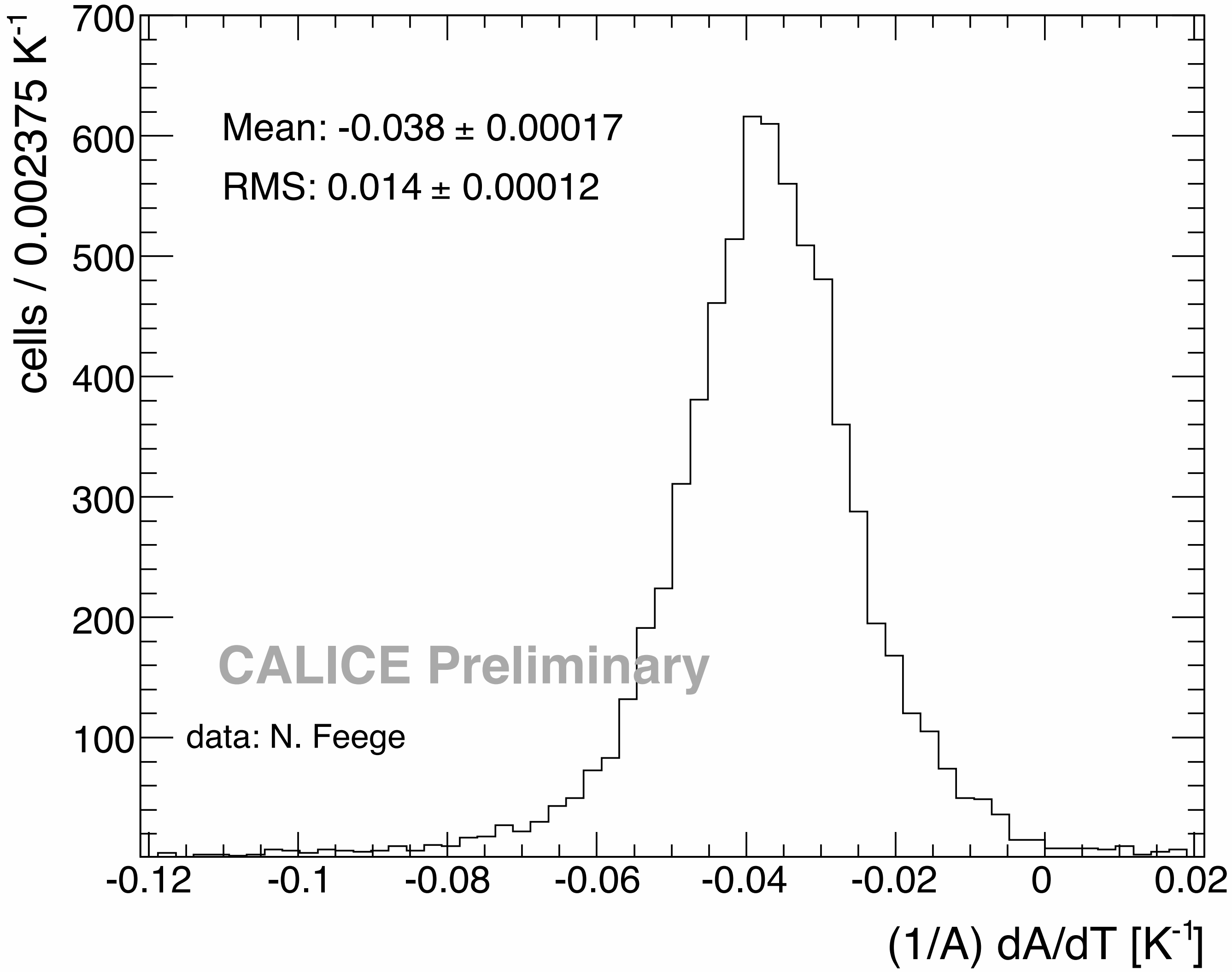
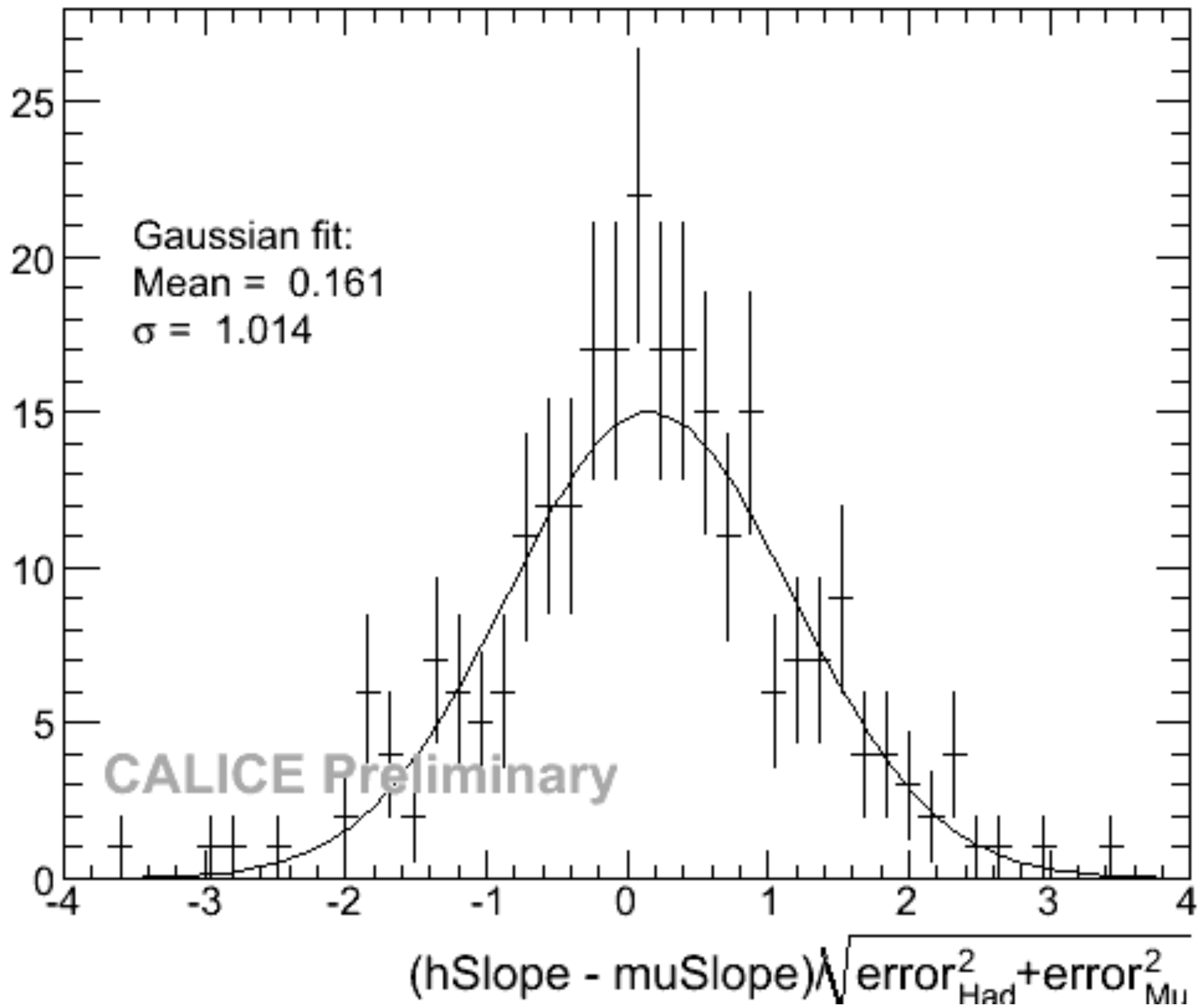


- Consistent with observations with muon data: sufficient statistics in most of the cells (6980 out of 7608), but less temperature points (at most 4)

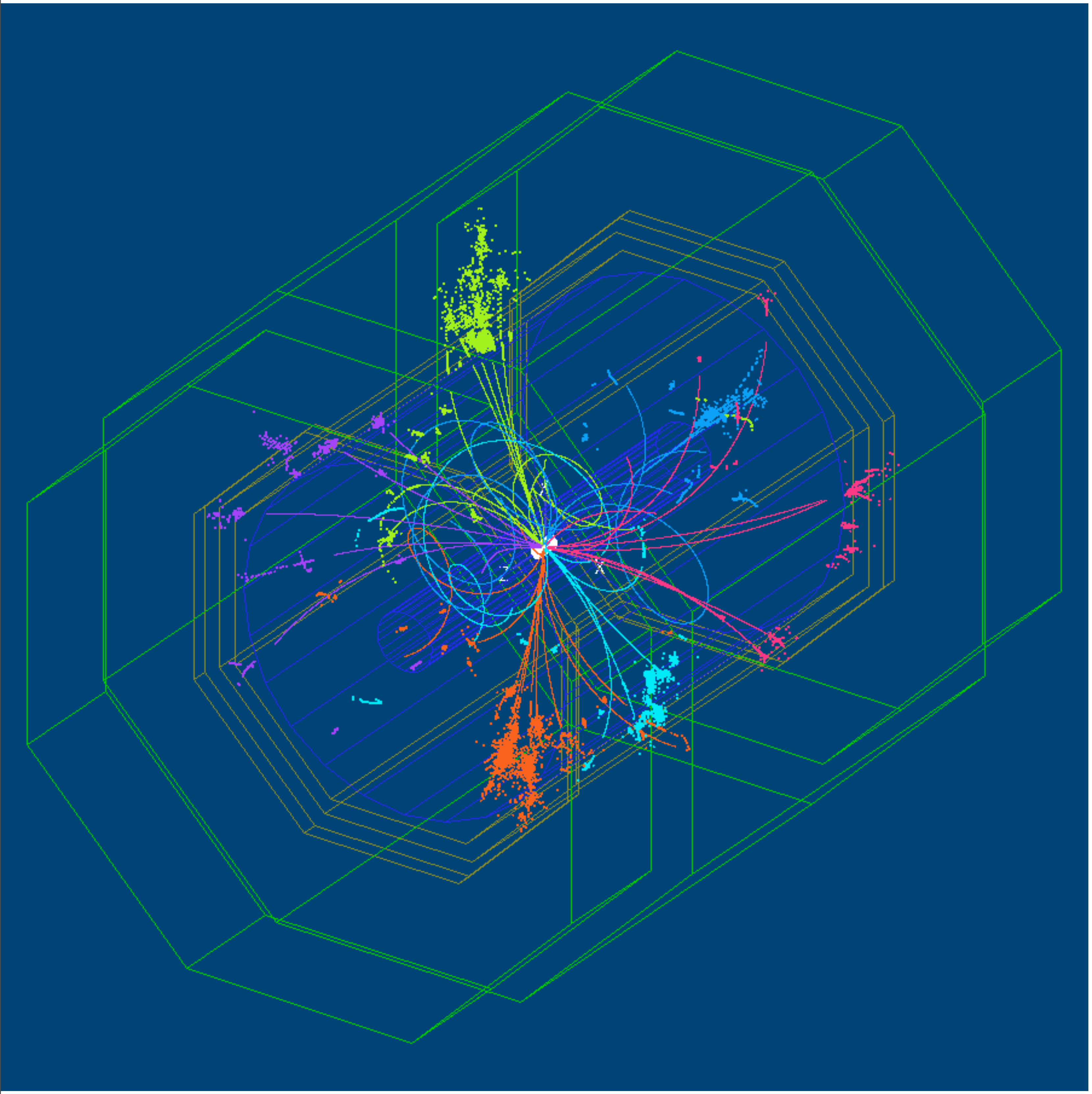
Consistency of Measurements: Checking under the Hood



- Also on a cell by cell basis, the two independent measurements are compatible within errors (typical errors on the slope ~ 25%)
- ‣ Validation of the method of extracting calibration data from hadron runs

Beyond CALICE:
Possible Applications in ILD

Hadronic Events in ILD: ttbar -> 6 Jets



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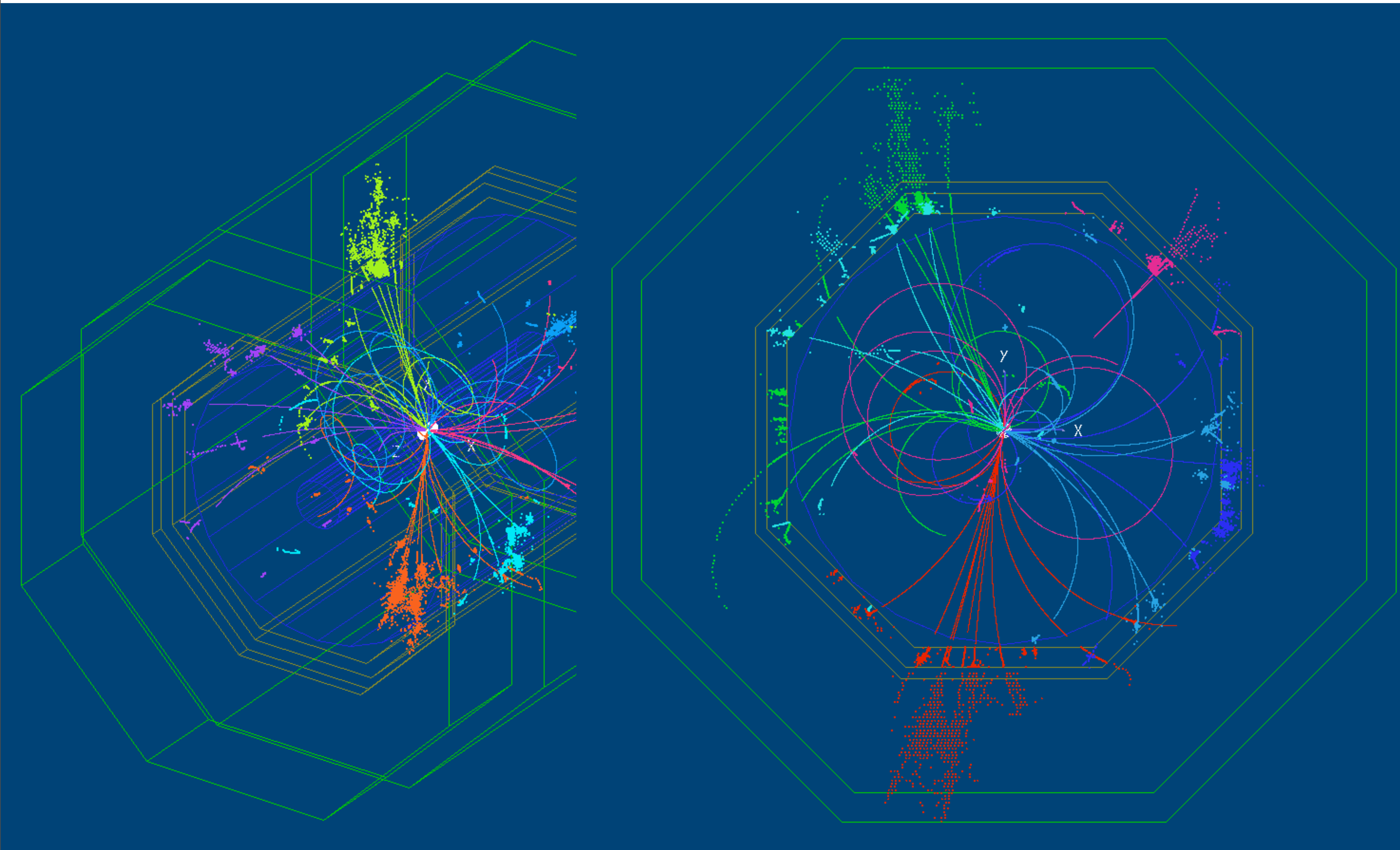
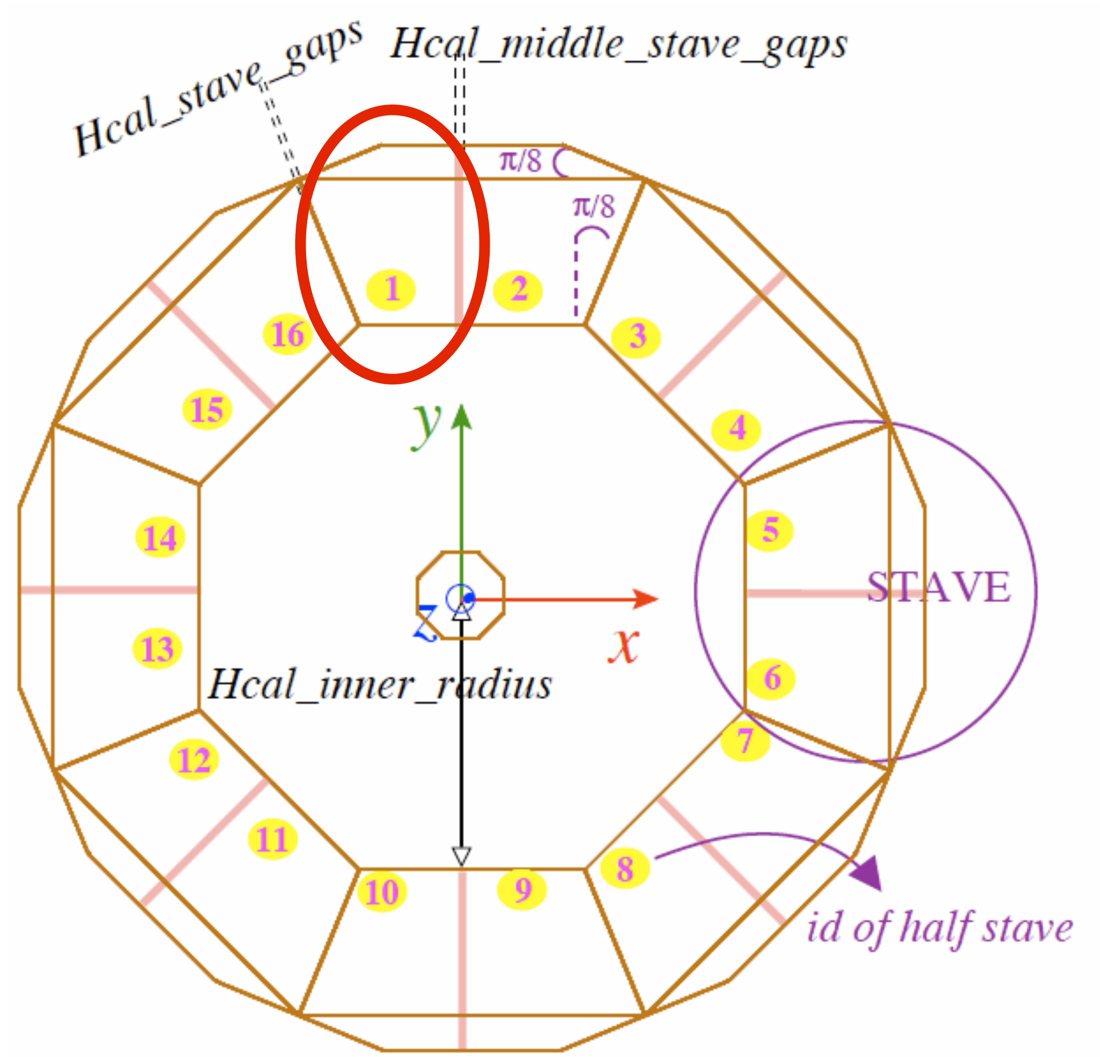
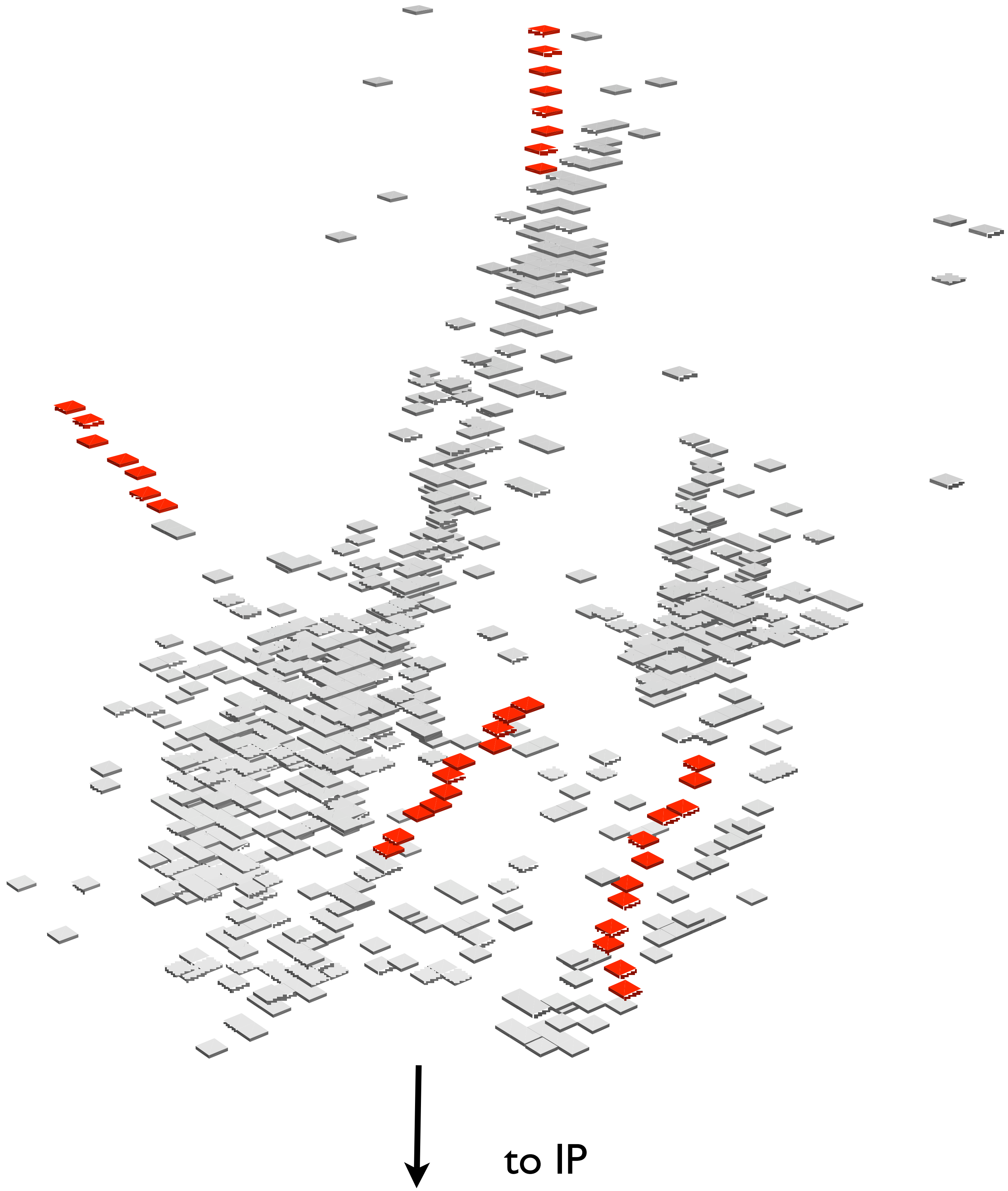


Proof of Principle in full ILC Detector Simulations

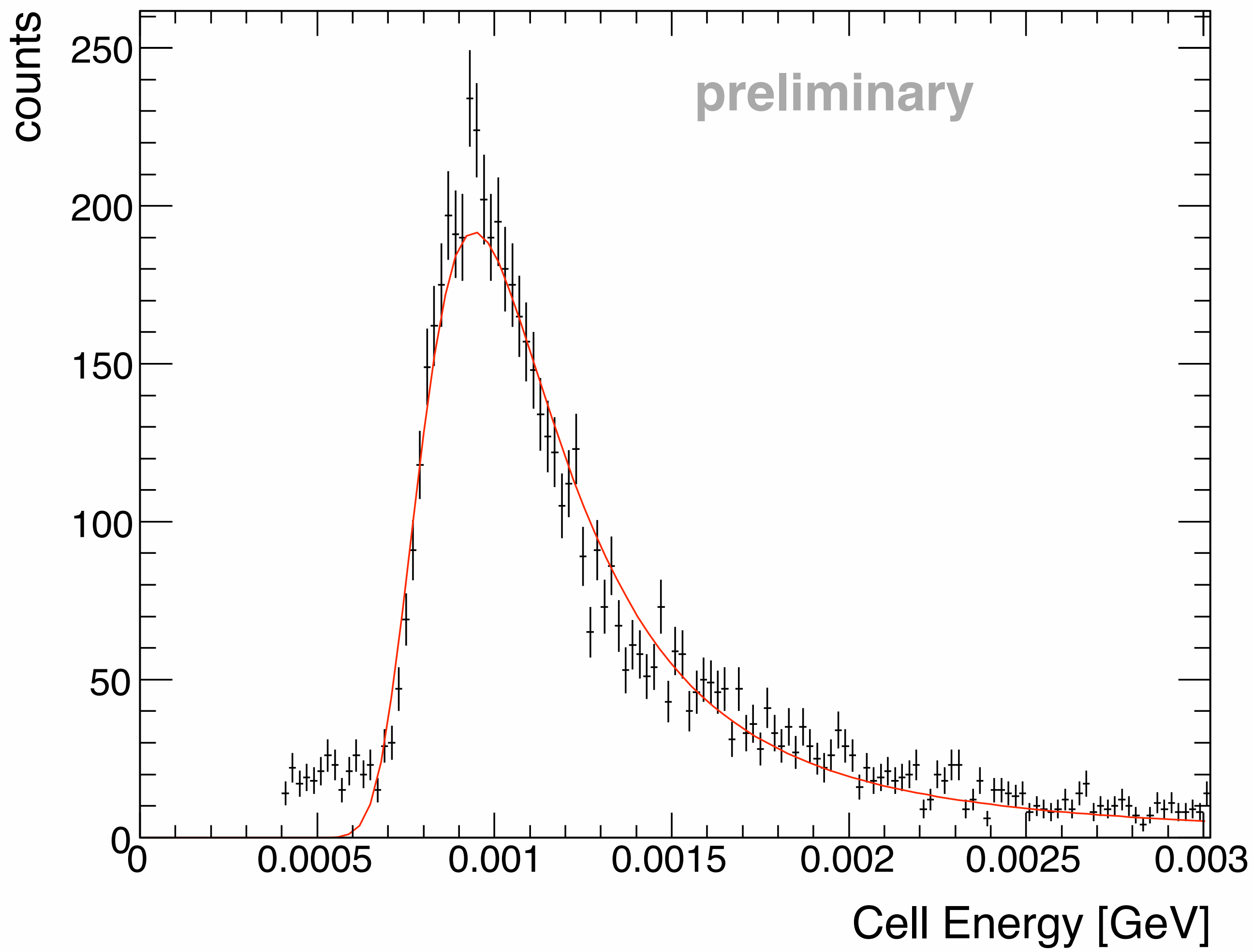
- Tracks in one calorimeter half-stave of the LDCPrime detector model for one t tbar 6-jet event:
  Tracking in hadronic showers and in jet environments is possible

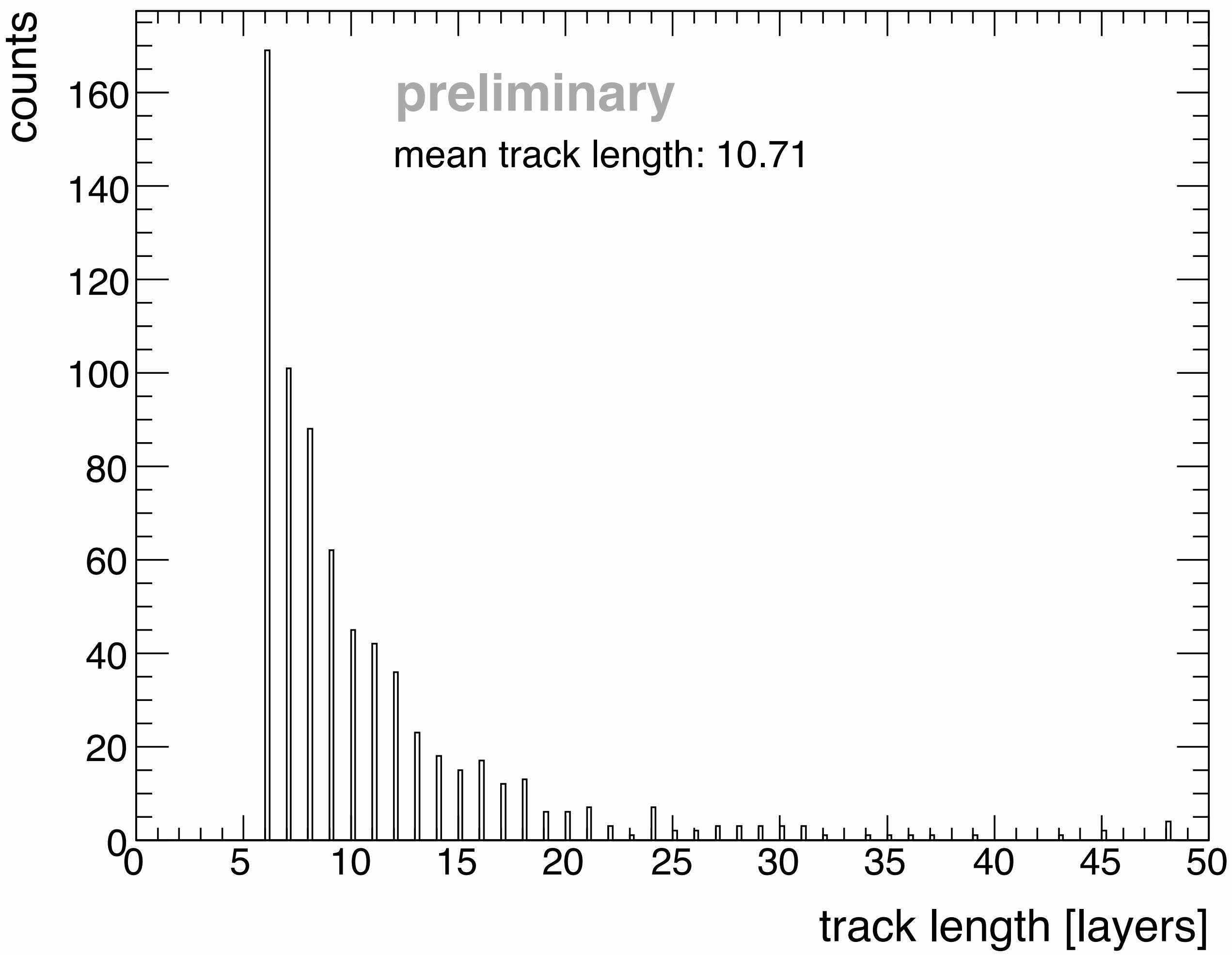




Tracks in ILD / LDCPrime

- First study in one module of the HCAL: using ttbar, WW, ZZ events (created for a top study)





- encouraging results from full detector simulations, track reconstruction in the HCAL seems to allow detailed detector studies and calibration
- track yield still under study, necessary luminosity likely an issue

Summary and Outlook

- The CALICE collaboration has a rich data set recorded with calorimeters of unprecedented granularity

- Finding of track segments within hadronic showers is possible
  - Track segments are of sufficient quality to be used for detailed detector studies and calibration

- Temperature dependence of detector response studied with hadronic track segments: Consistent with previous observations with Muons

- First proof of principle studies with full simulations in ILD: Promising first steps