HCAL Calibration with Track Segments in Hadronic Showers: CALICE & ILD

On behalf of the CALICE collaboration

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Calorimeter for ILC

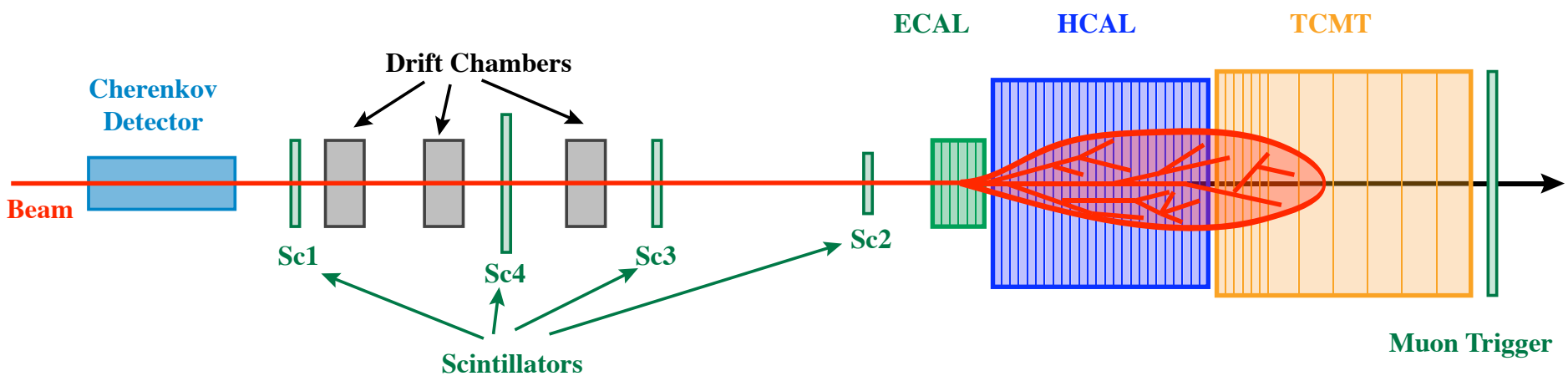
Excellence Cluster
Universe

Outline

- Track segments in hadronic showers in the CALICE AHCAL
- Simulations for the full ILD barrel and endcap HCAL
- Luminosity needs for calibration: rough estimates
- Summary

The CALICE Experiment

- The CALICE test beam setup



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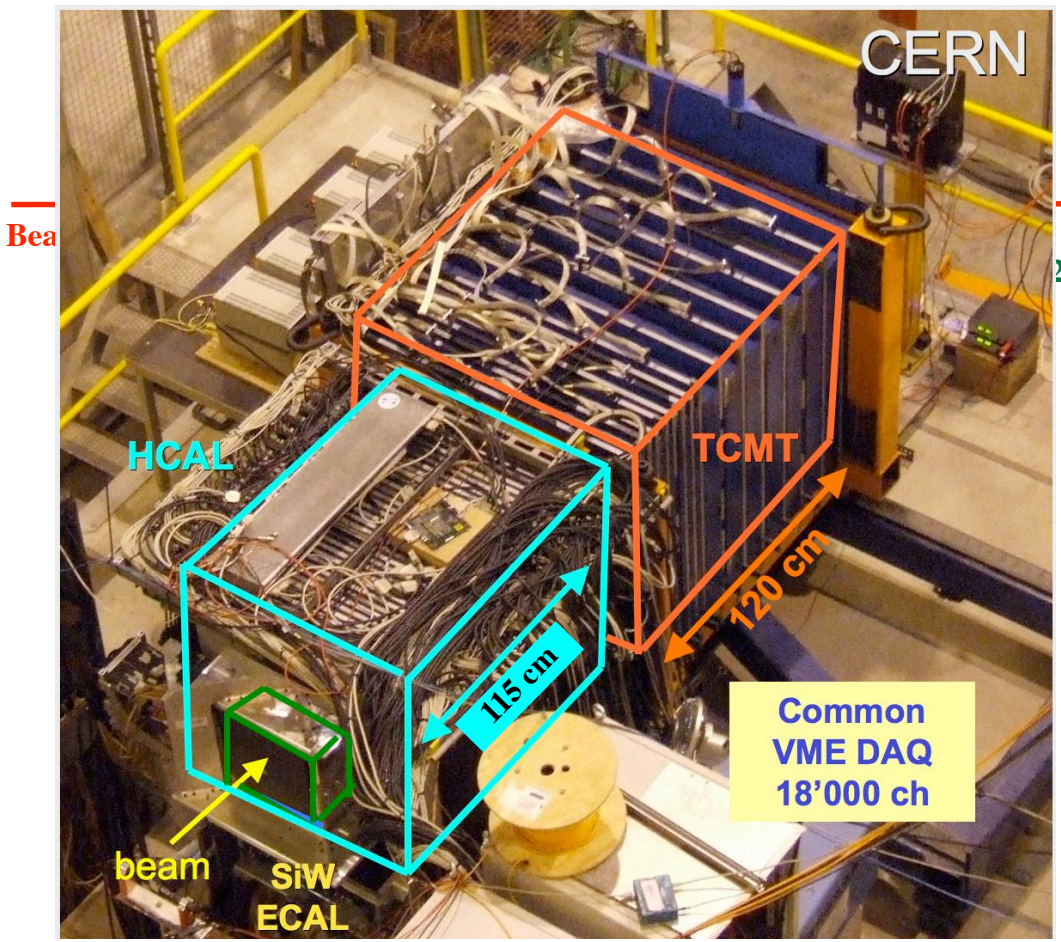
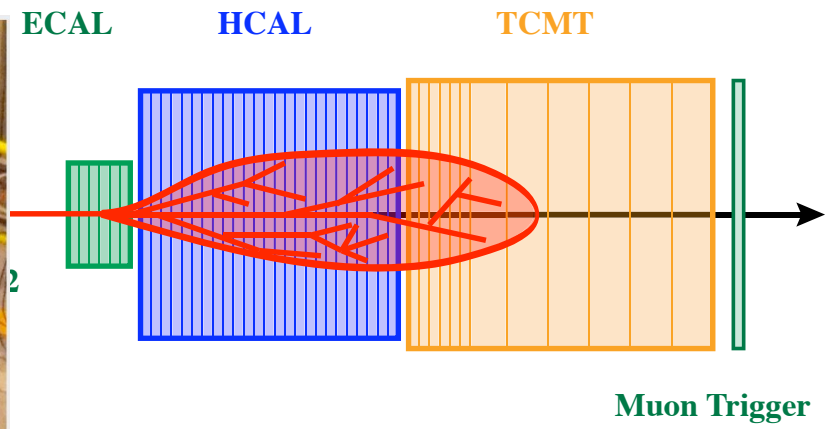
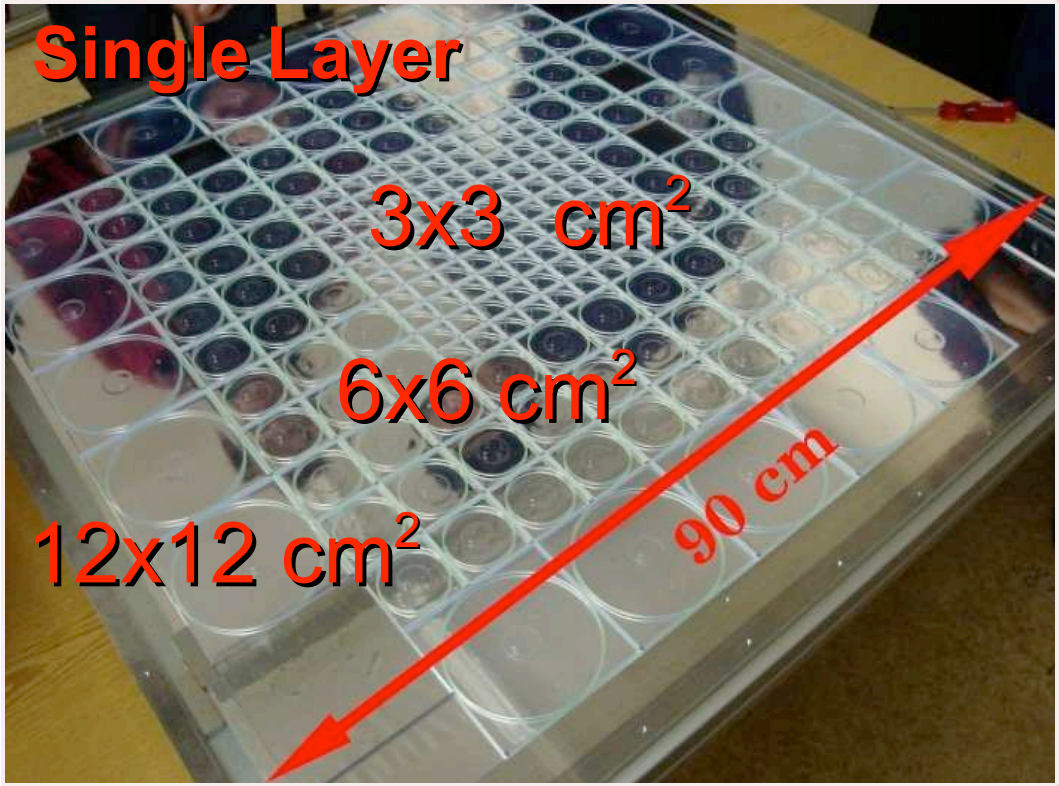
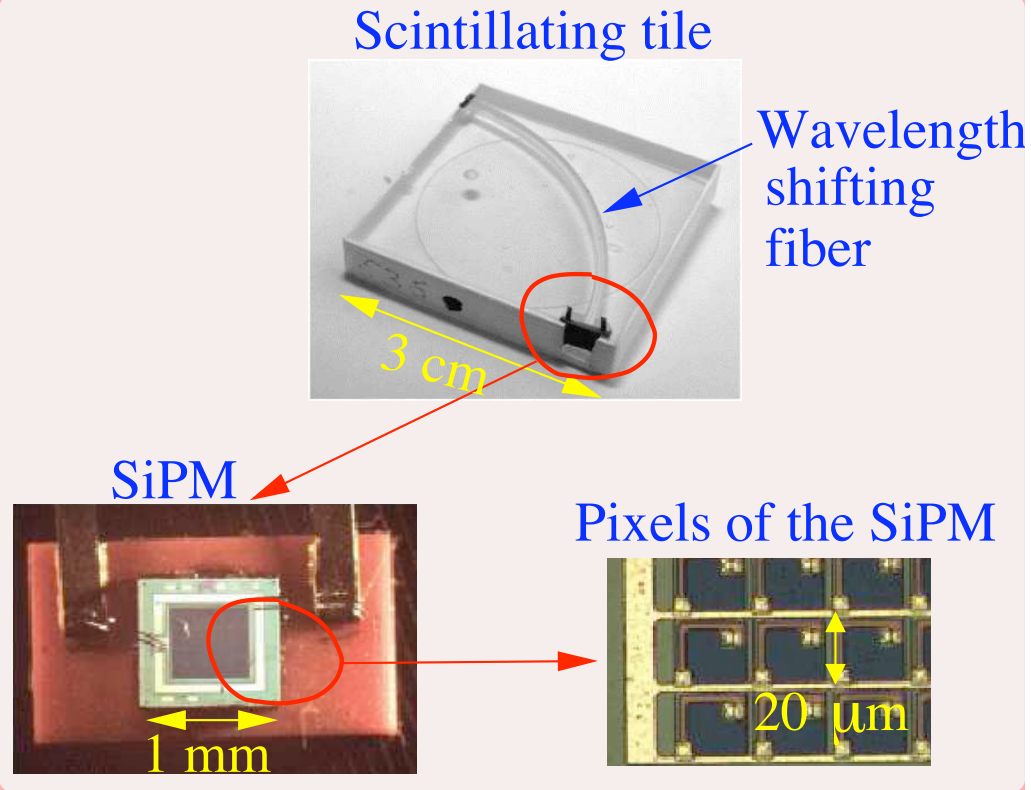




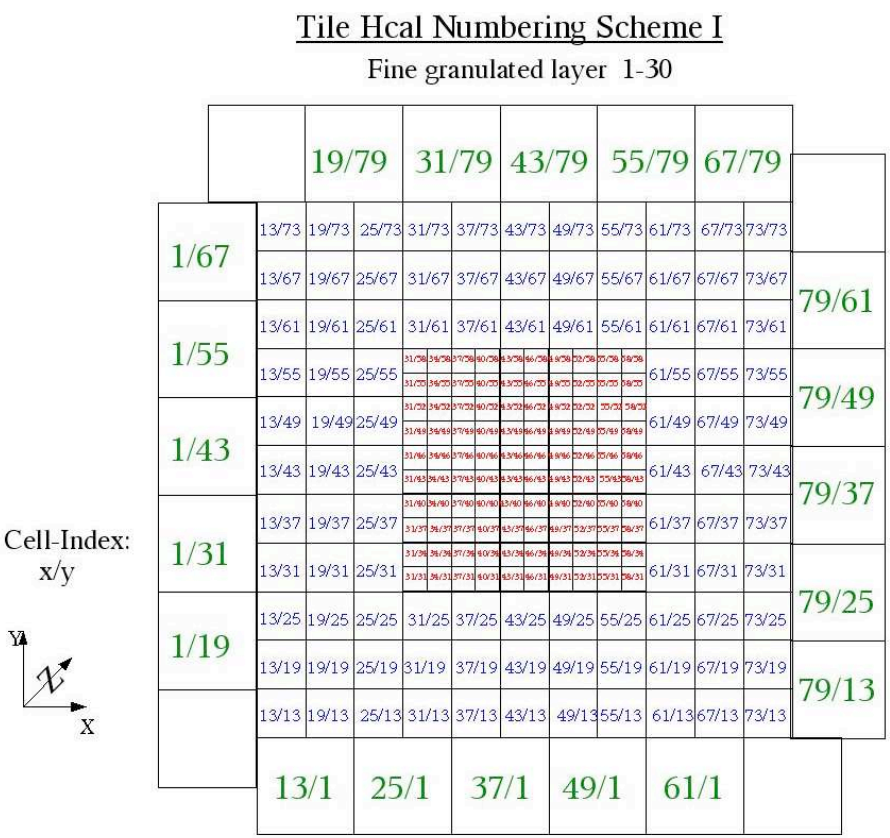
- test beam
  - CERN: 2006 2007
  - FNAL: 2008 ...
  - 2 to 80 GeV
  - muons, $e^{\pm}, \pi^{\pm}$

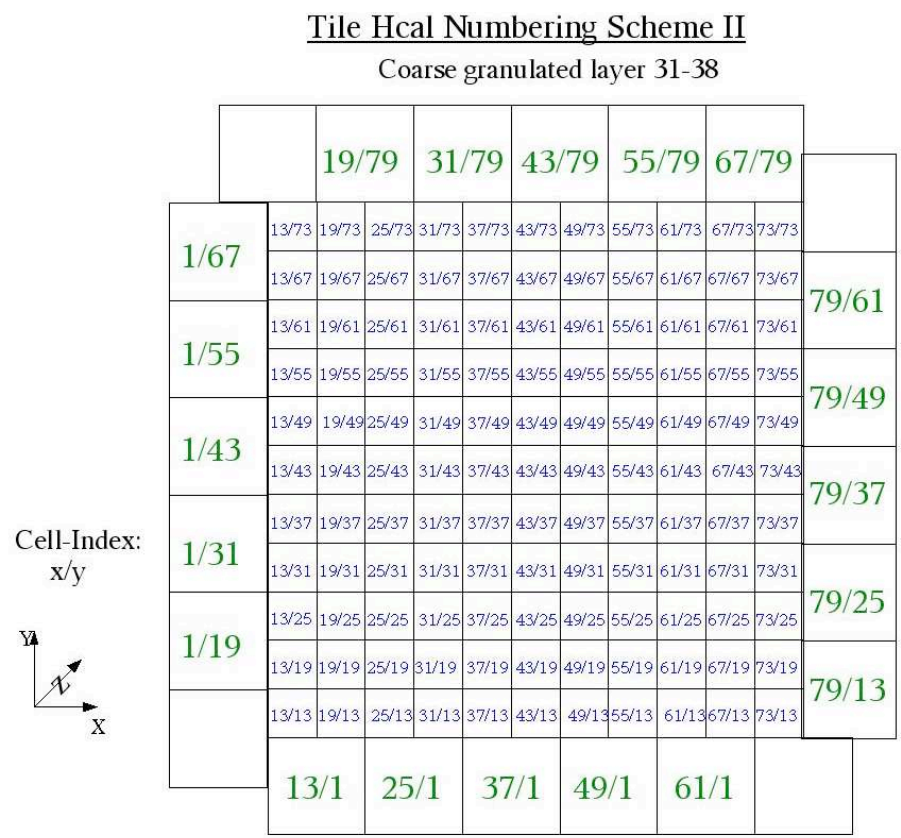
A Prototype of a Tile Hadron Calorimeter





The Definition of Isolated Tiles and Track Like cluster





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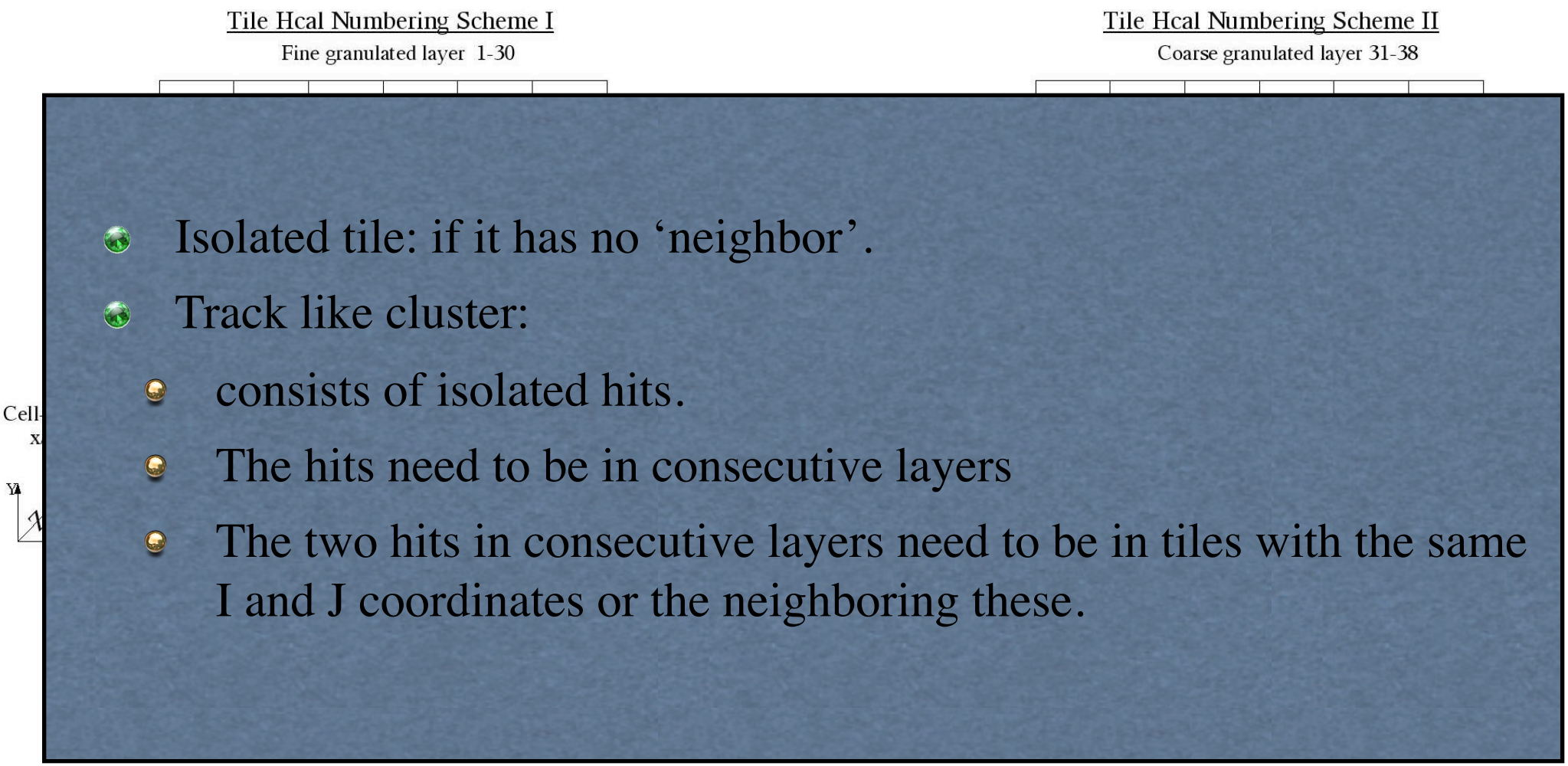

- Isolated tile: if it has no ‘neighbor’.
- Track like cluster:
  - consists of isolated hits.
  - The hits need to be in consecutive layers
  - The two hits in consecutive layers need to be in tiles with the same I and J coordinates or the neighboring these.

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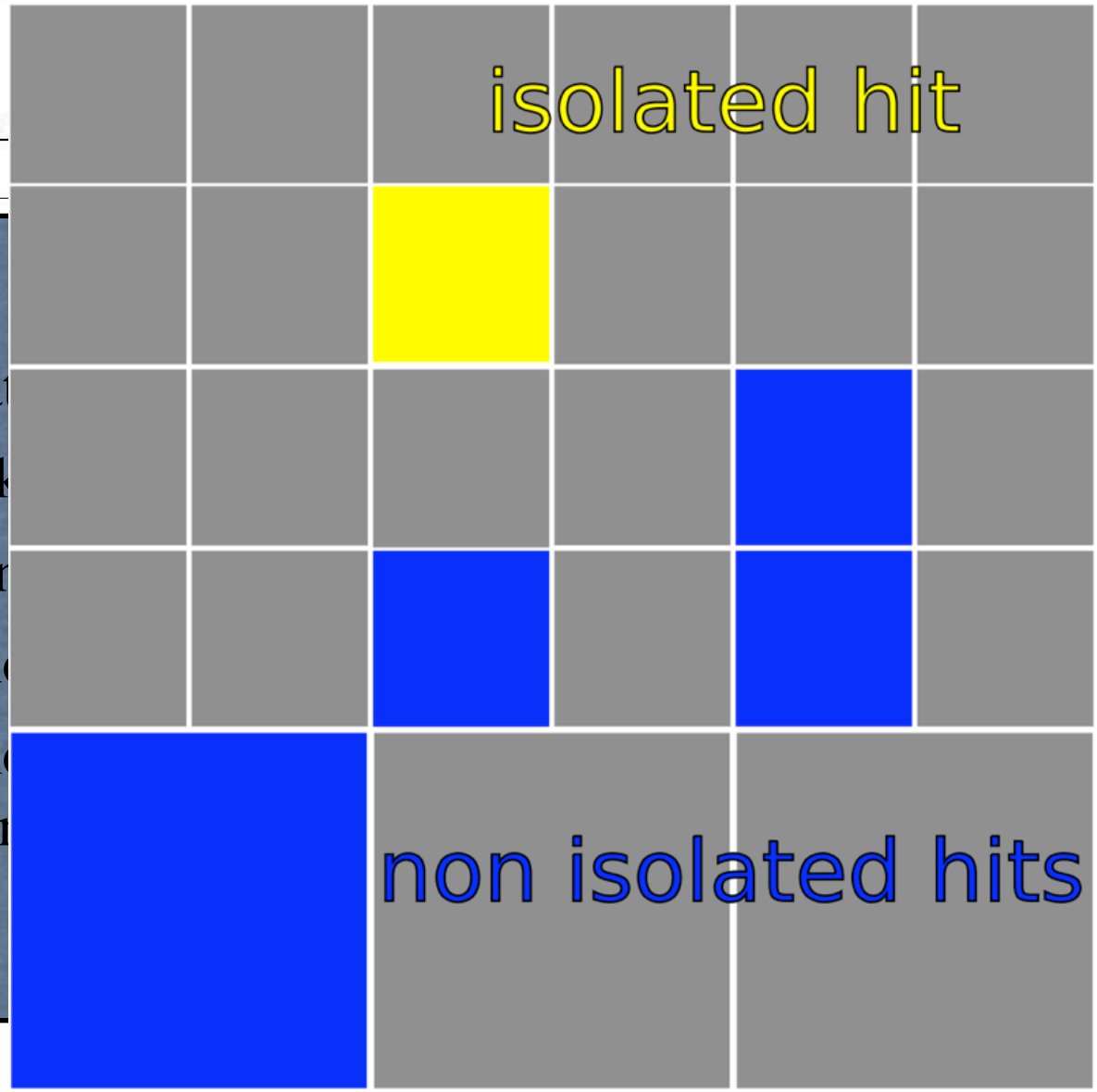


Tile

cal Numbering Scheme II

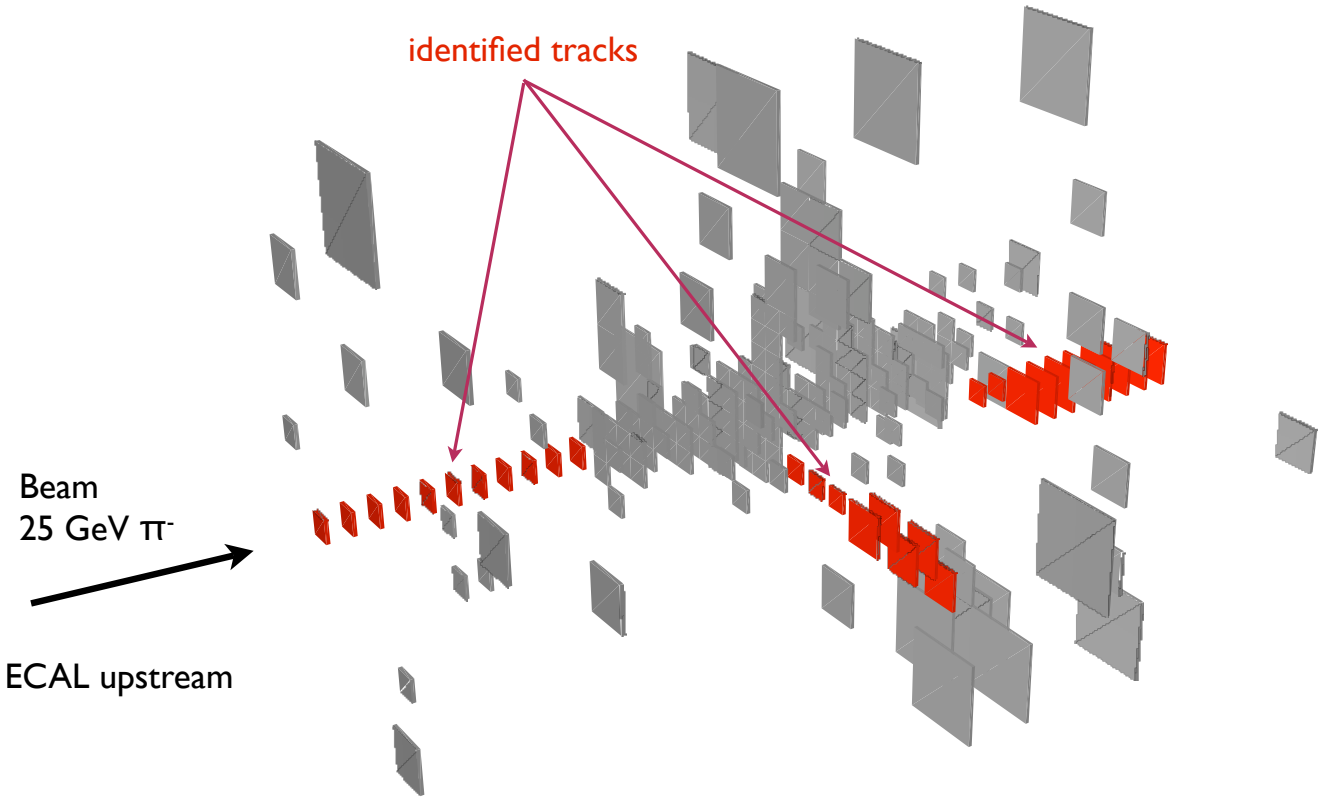
parse granulated layer 31-38

- Isolat
- Track
  - cor
  - The
  - The

iles with the same

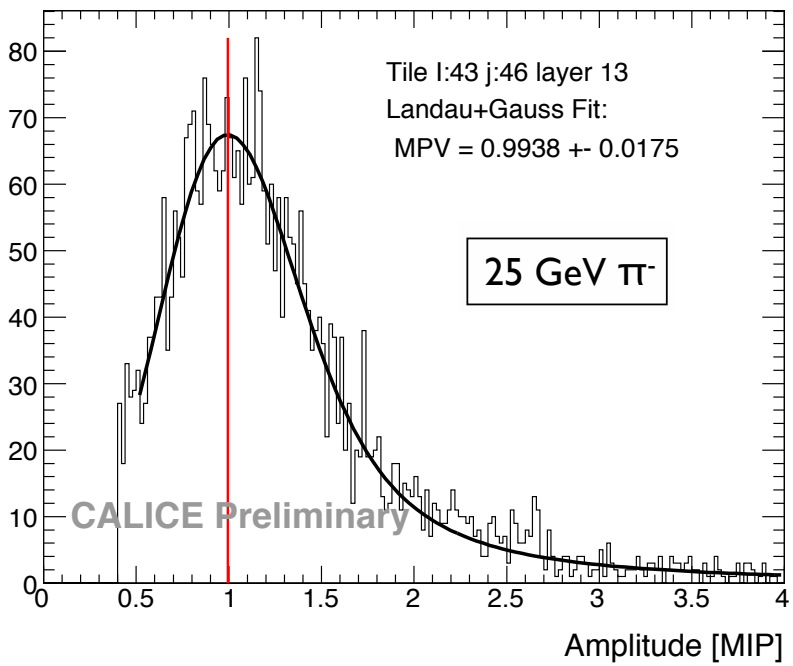
I ar

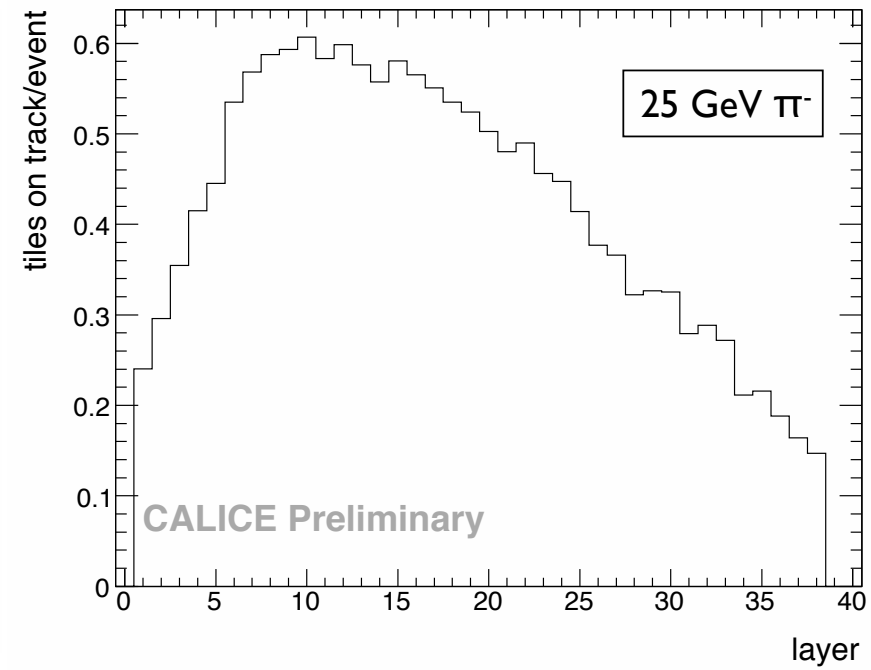
Tracking in Hadronic Showers in Test Beam Data



- Tracking in Hadronic Showers from test beam data.
- Tracking only in HCAL for current study (ECAL upstream not used).

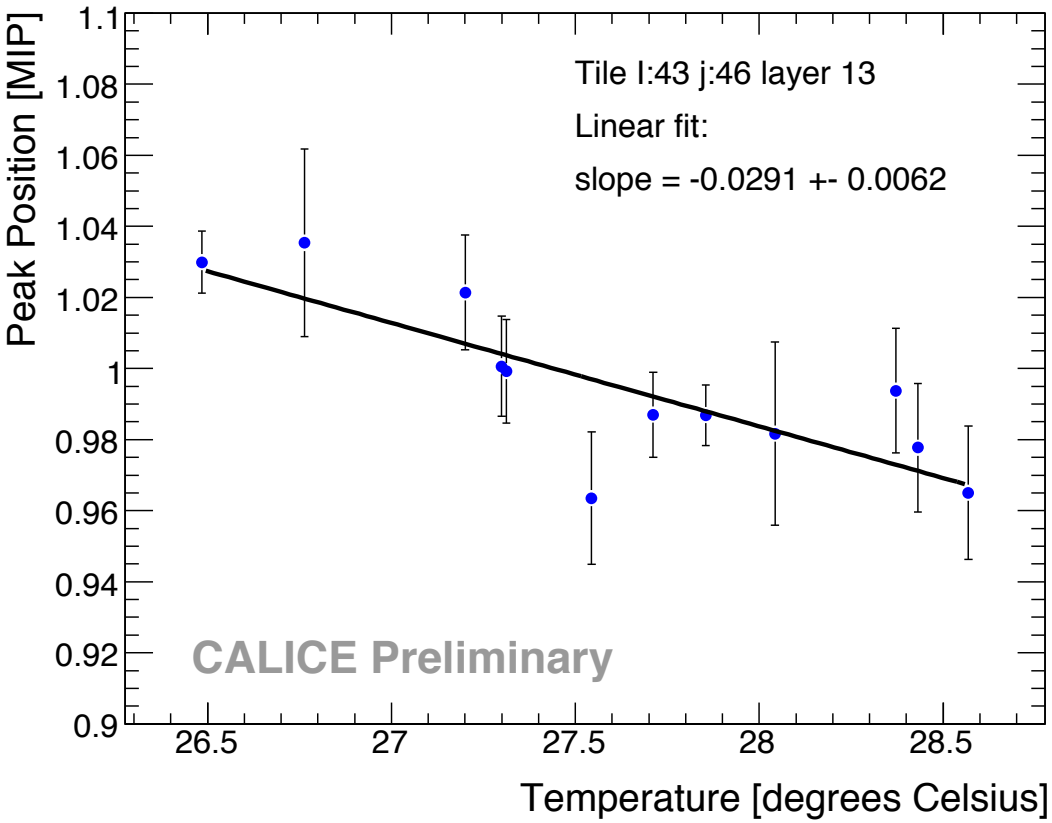
Tracking in Hadronic Showers in Test Beam Data





- 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
  - typically around 2 tracks per incoming hadron (energy dependent)
  - After 4.5 λ still more than 0.1 cells per incoming hadron crossed by tracks

Tracks as Tools: Temperature Study



- Use hadron runs taken at different ambient and detector temperatures to investigate the temperature dependence of the SiPM response

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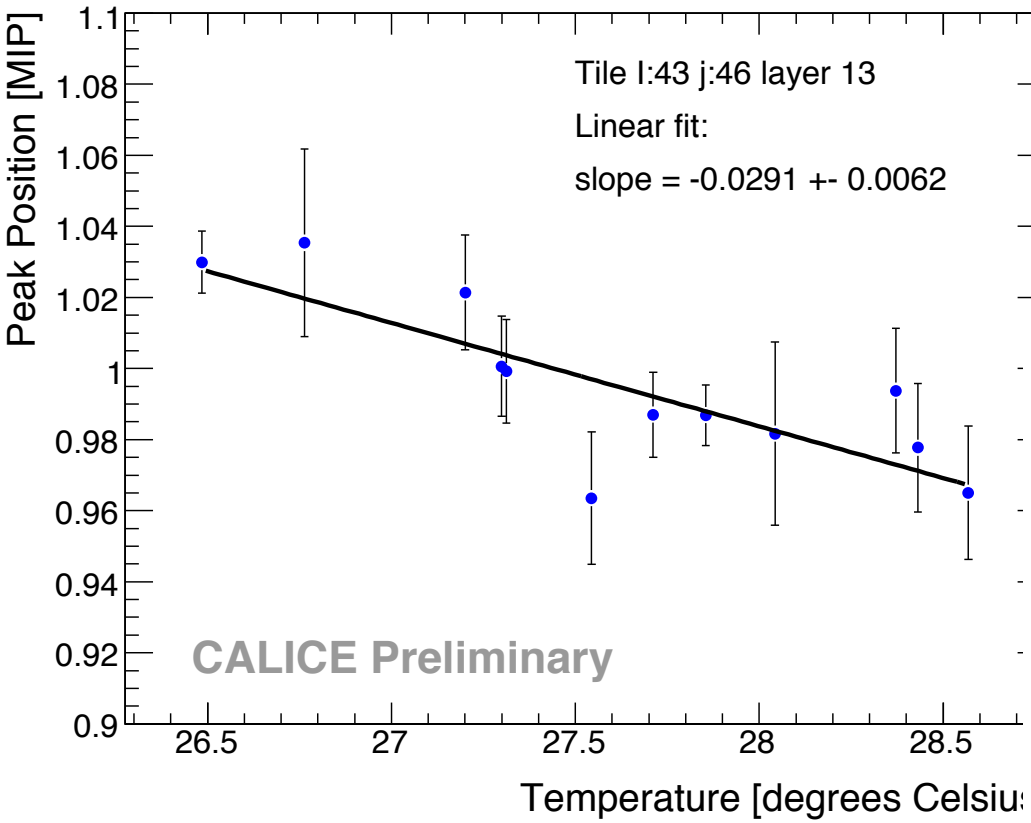

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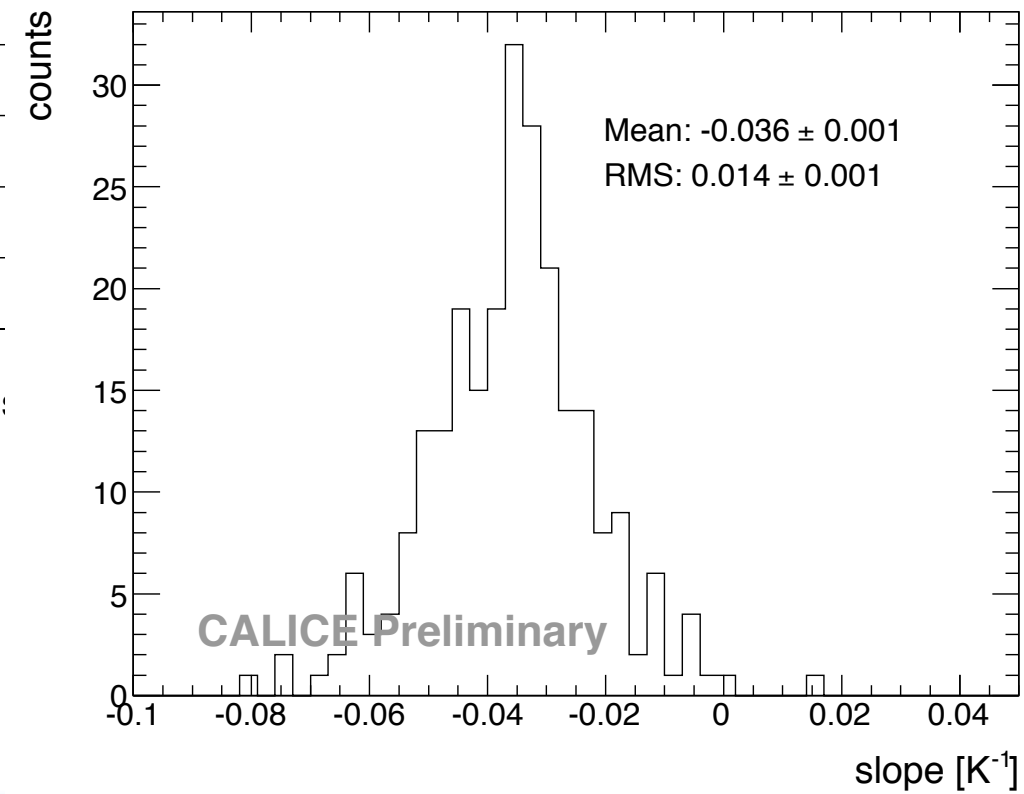

- Average change: -3.6%/K
- Consistent with observations made with muons, more temperature points available in hadron analysis

Full Detector Calibration: Motivation

- The classical way: Use cosmic muons: they come for free, are everywhere, ... But:
  - low rate, in particular in underground locations
    - combined with the extreme channel count in the HCAL, this is a serious problem
  - very hard to get statistics on the detector sides
  - power pulsing of electronics: duty cycle only ~0.5%

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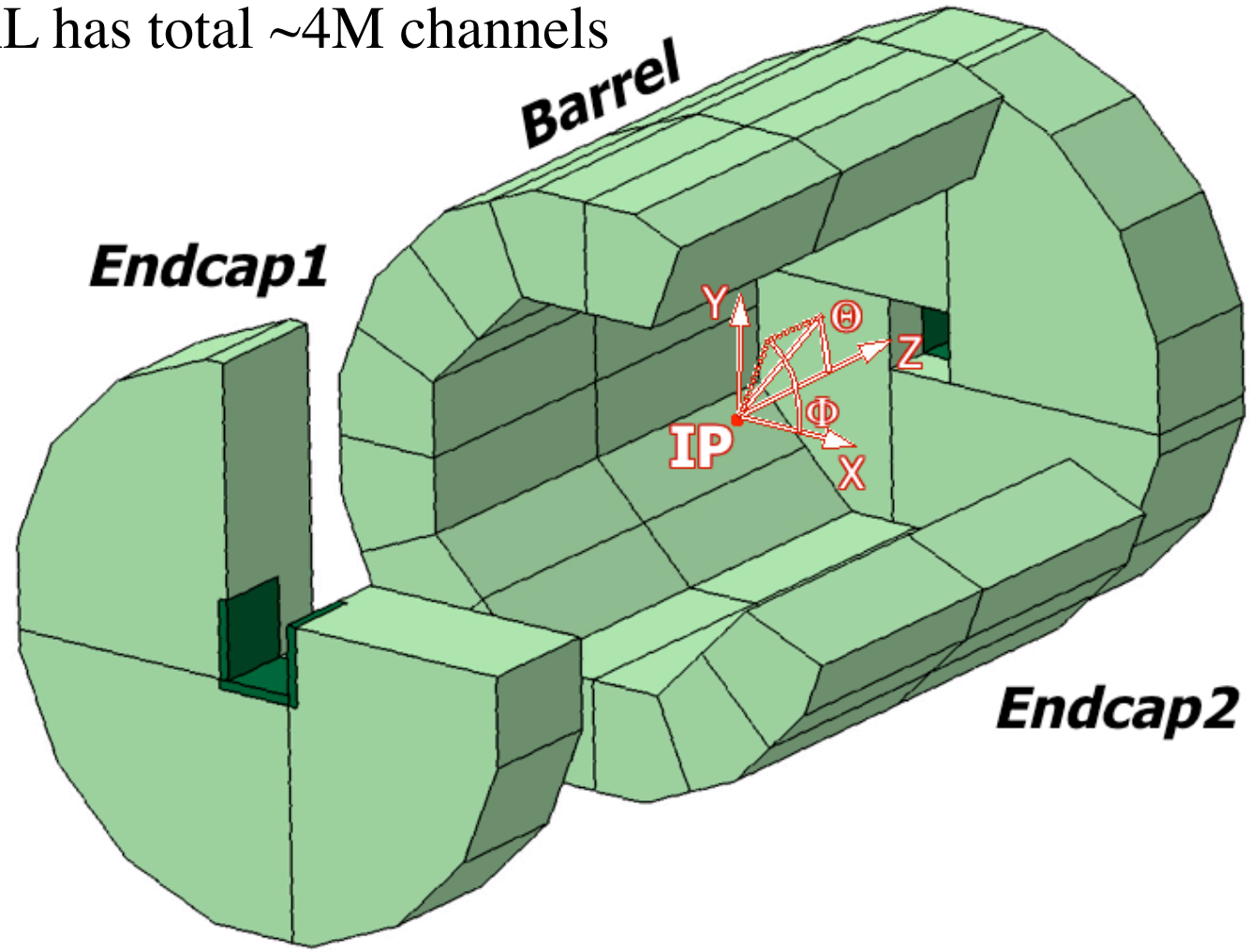
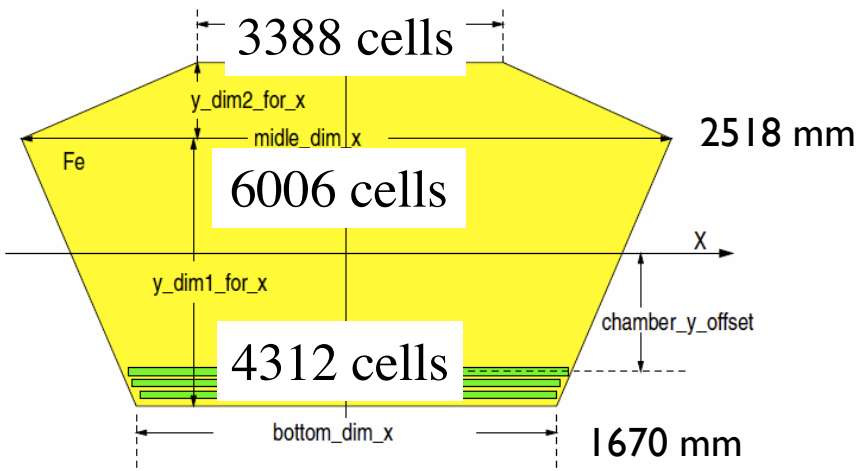
⇨ Monitoring of coherent effects in the detector over time (for example potential aging of the scintillator, ...)

Simulation for the Full ILD Barrel and Endcap HCAL

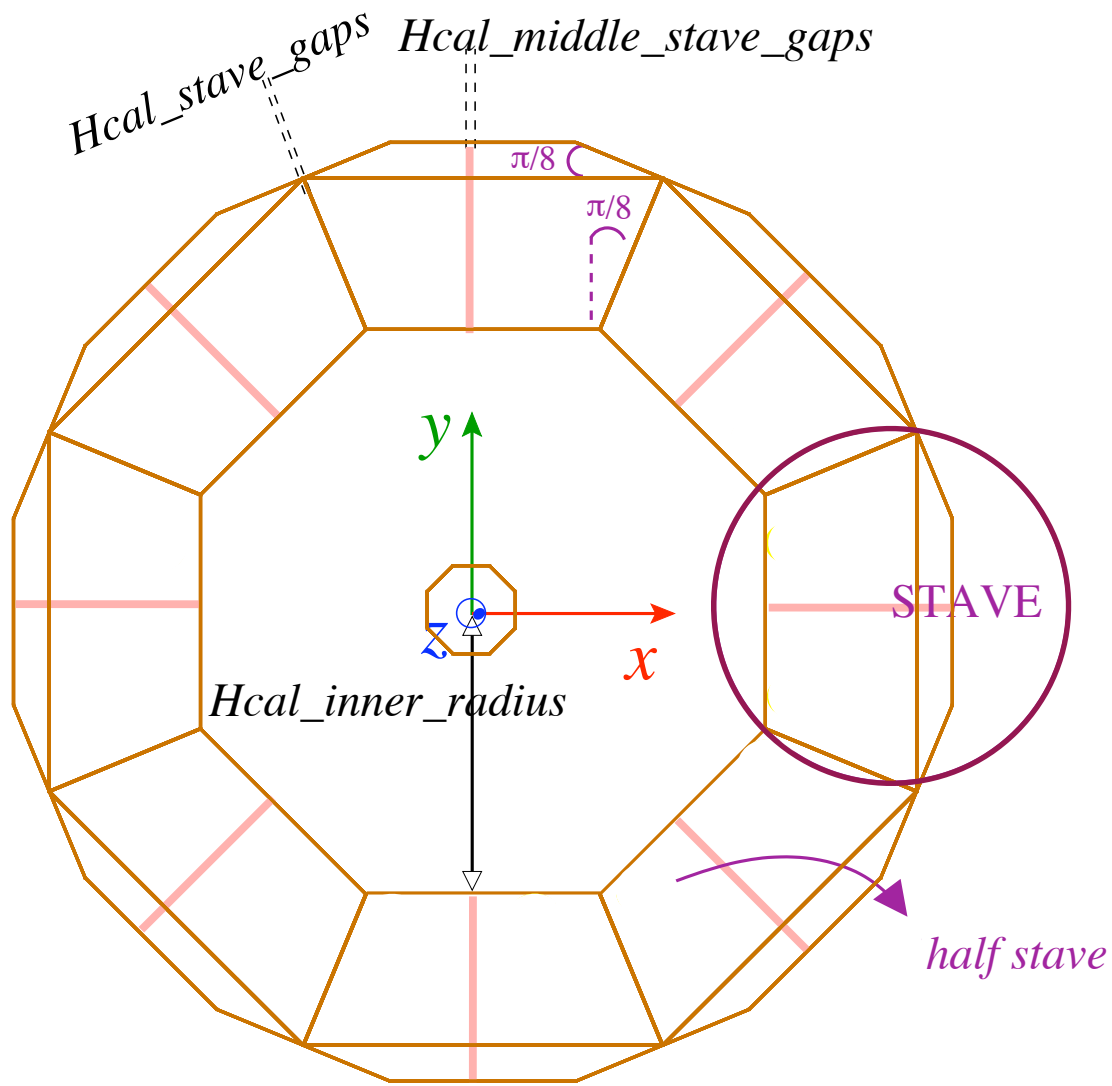
- detector model: ILD_00
  - barrel HCAL has total ~4M channels
  - endcap HCAL has total ~4M channels



The ILD Barrel HCAL

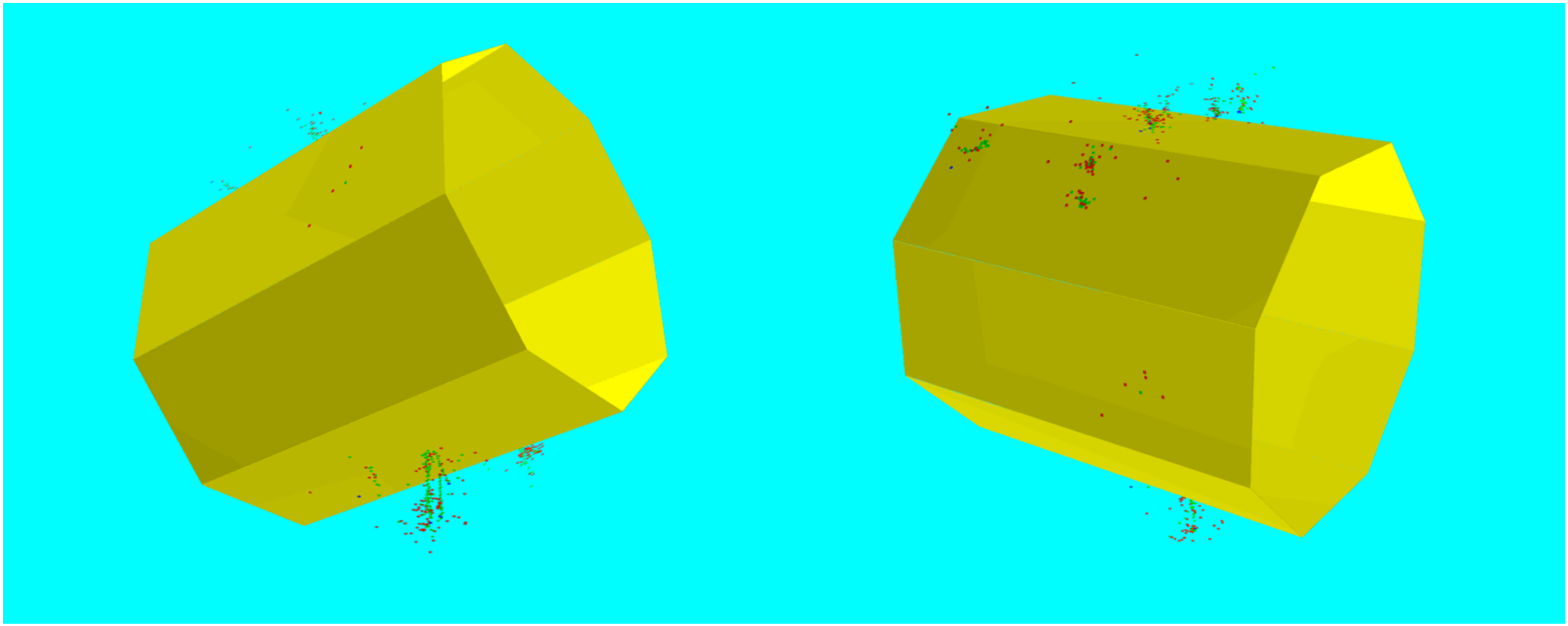


- 5236 cells on layer 18, with16 modules (2 rings a 8 modules): ~90k cells
- To get 1000 tracks per cell on average: ~90M tracks



One Event for the Barrel HCAL from the Mokka Data

$e^+e^- \rightarrow Z^0 \rightarrow q\bar{q}$ @ 91GeV



- one event for the Barrel HCAL in the Monte Carlo data out of Mokka with ILD_00. (The yellow shows the boundary of the inner radius of Barrel HCAL)

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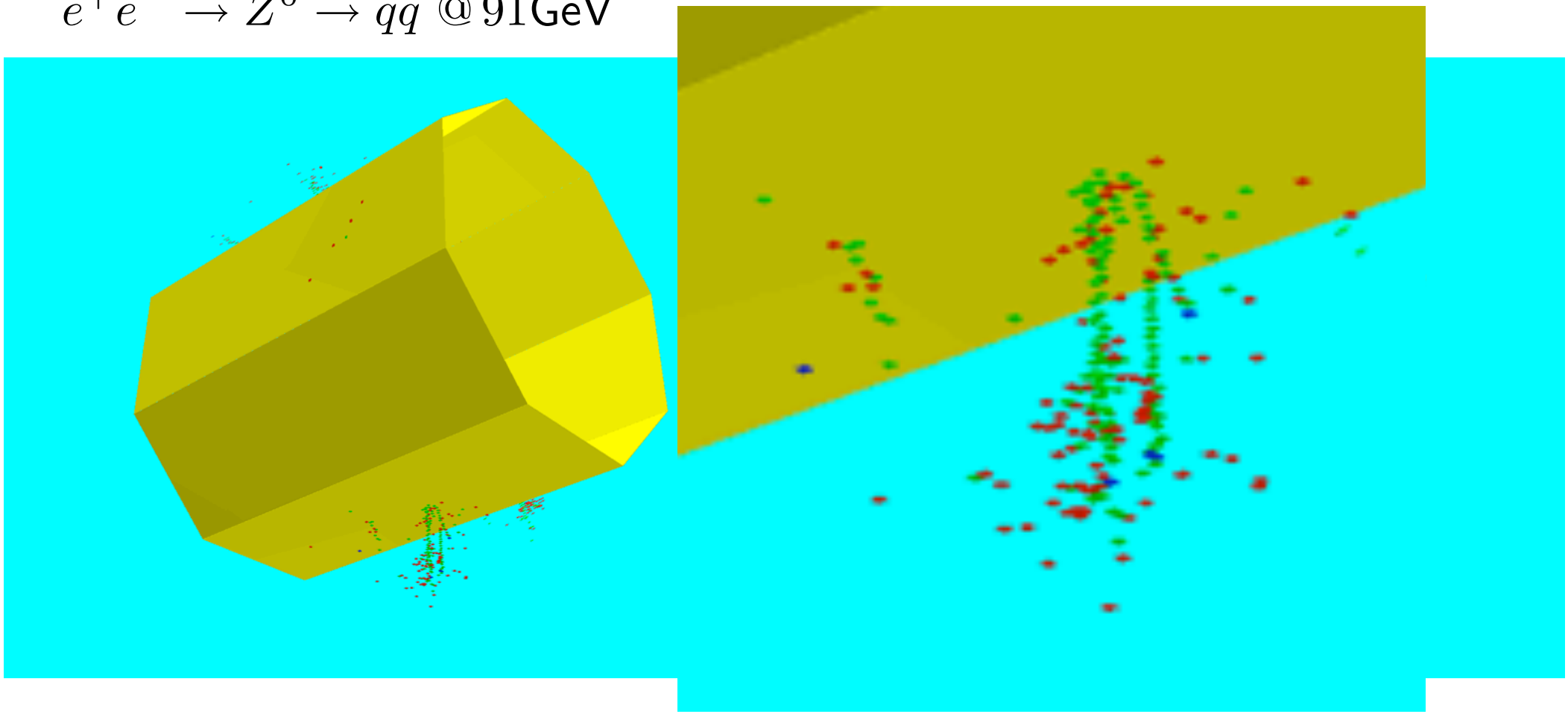

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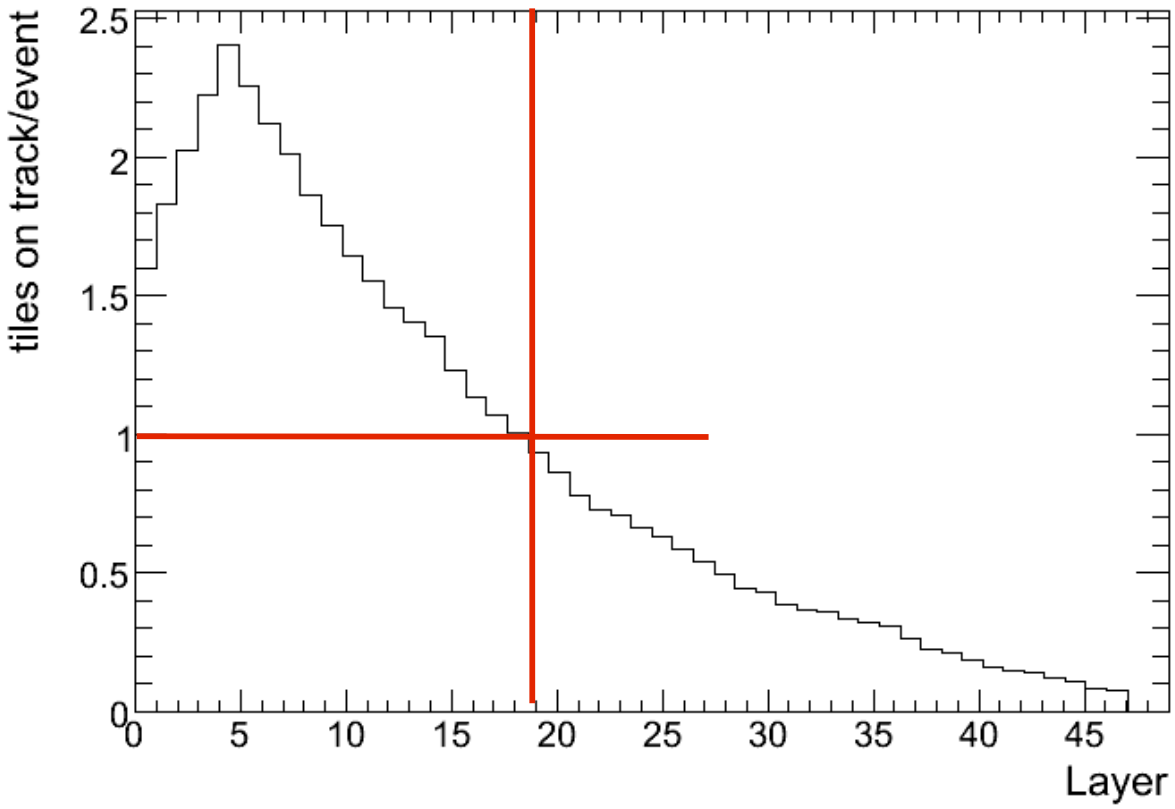
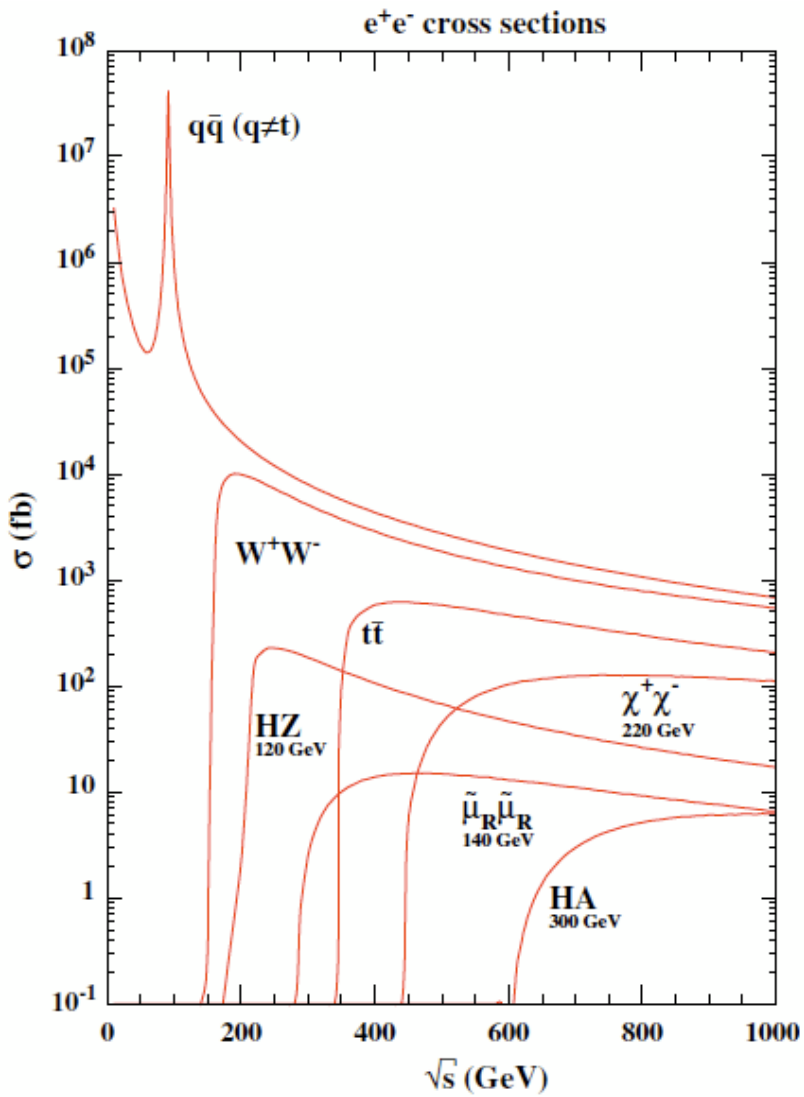
Prospects for Calibration with Full Energy Data

$e^+e^- \rightarrow q\bar{q}$@500GeV



- >1 track / Layer out to 18 layer (counting from 0)
- Average over all events, no requirement that the jets actually go into barrel HCAL
- High statistics in the first few layers, then a fast drop to late layers: Made worse by the presence of the strong magnetic field.

Full Energy: Rough Luminosity Estimate

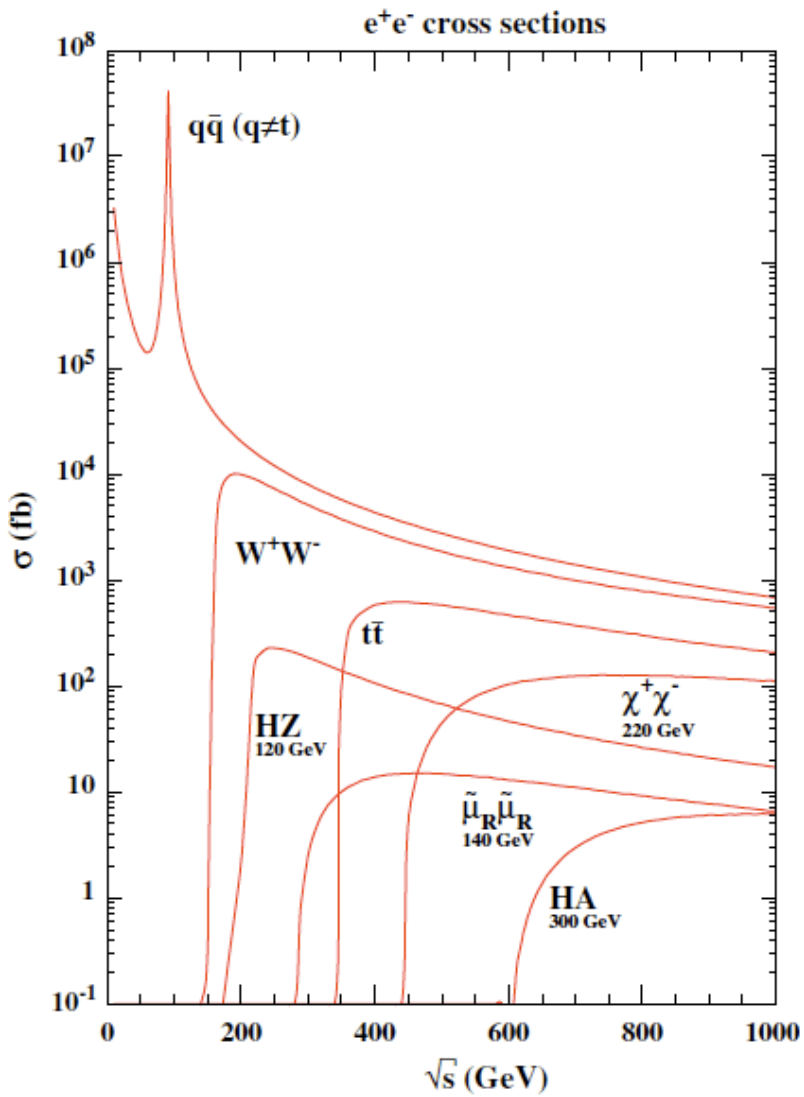


Reference:
G. Weiglein et al. Physics Reports 426, 47 (2006)

- cross section is 3000 fb
- at Luminosity $2 \times 10^{34} \mathrm{cm}^{-2} \mathrm{s}^{-1}$:

  $\sim 1.7 \mathrm{fb}^{-1}/\mathrm{day}$
- 5000 identified tracks per day in layer 18, only ~ 0.06 tracks per cell! ⇨ no hope of getting 1000 hits per cell at full energy
- The good news: Grouping of cells possible for most (if not all) studies!

A look at the Z^0 Resonance



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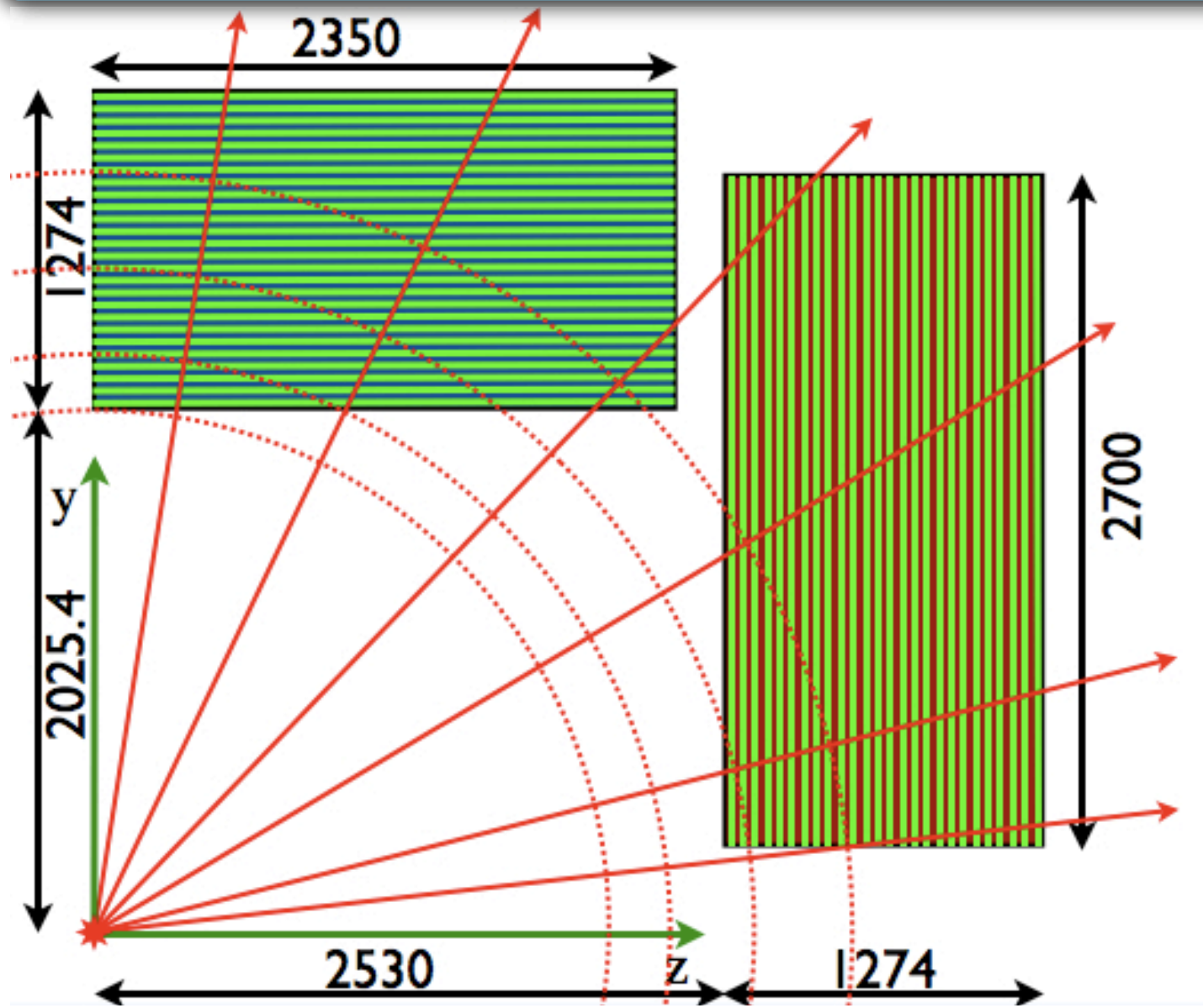
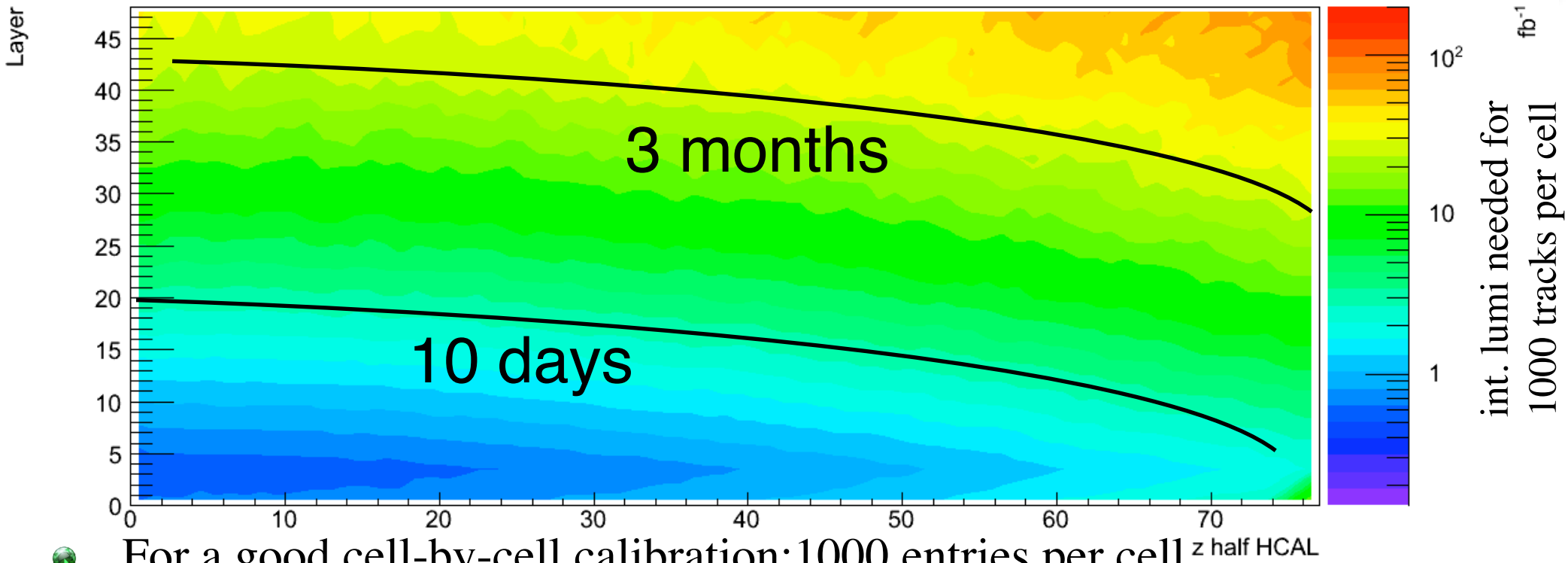
- $\sigma(e^+e^- \to Z^0 \to q\bar{q})$@91GeV
- cross section is 30 nb, about 10^4 times higher than at 500 GeV
- Luminosity for 91GeV is lower than 500GeV:
- $4 \times 10^{33} cm^{-2} s^{-1} \sim 0.33 \text{fb}^{-1}/\text{day}$ (This luminosity is for GigaZ option)
- 10 Million events per day!

Study the Calibration for Barrel and Endcap HCAL



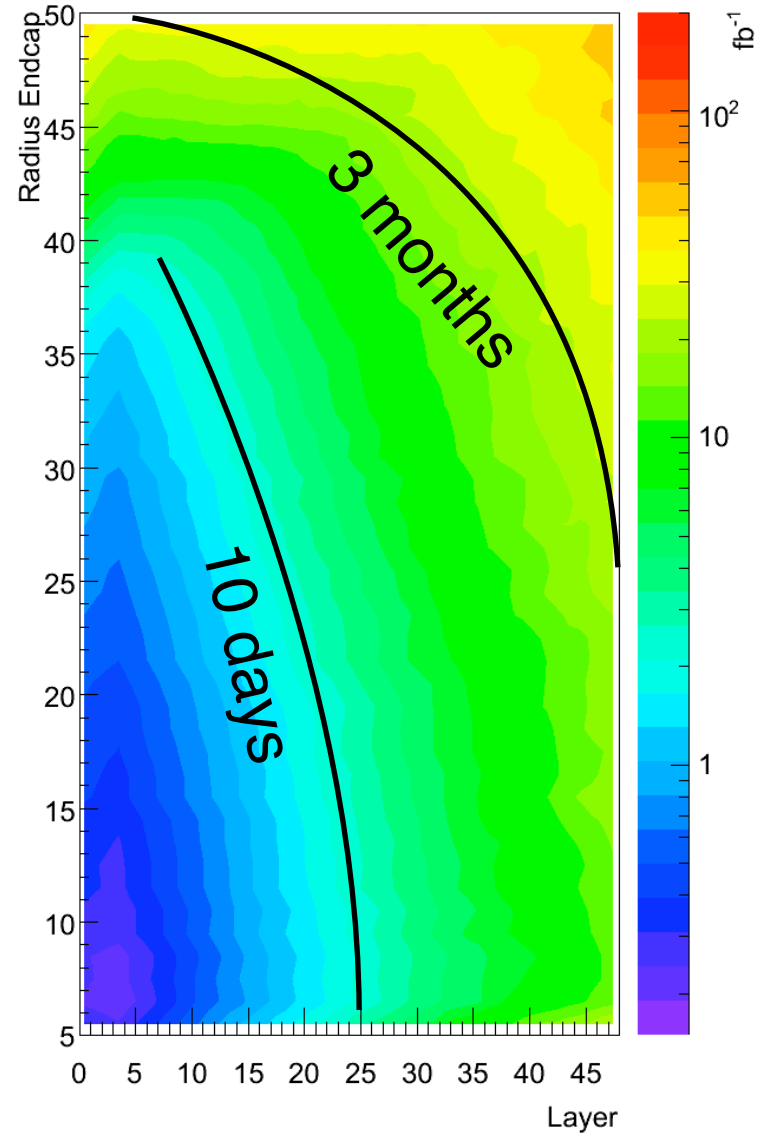
Rough Estimate for the Barrel HCAL



- For a good cell-by-cell calibration: 1000 entries per cell
- combining several cells will significantly reduce luminosity needs, does not compromise the calibration studies
  - Natural unit: One electronics board (HBU) with 144 scintillator tiles
  - already get somewhere with a few 10 pb^{-1}!

Rough Estimate for the Endcap HCAL

- For a good calibration:1000 entries per cell
- combining several cells will significantly reduce luminosity needs does not compromise the calibration studies: same as for the Barrel: group ~150 cells together
- Only HCAL is used for tracking
- The time estimates are based on a very optimistic luminosity



int. lumi needed for 1000 tracks per cell

Summary

- Track segments in hadronic showers can be found both in real CALICE test beam data and in ILD Monte Carlo data.
- the tracks are of high quality, can be used for calibration.
- the ILD MC study suggest that several 10M events are needed to get sufficient statistics in most cells of the HCAL to provide a precise cell-by-cell intercalibration; only possible at the Z resonance
- Grouping several cells together, for example one HBU with 144 cells, reduces luminosity requirements, w/o compromising the power of this method: get somewhere with a few 10 pb^{-1}
  - Would require good intercalibration of the cells within one HBU before installation, and stability of this over time
- Data / MC comparisons for CALICE data ongoing, first studies indicate reasonable agreement: This will be a powerful test of the hadronic shower models