CALICE vs. Geant4

Calice Data for Optimizing Hadron Shower Simulations

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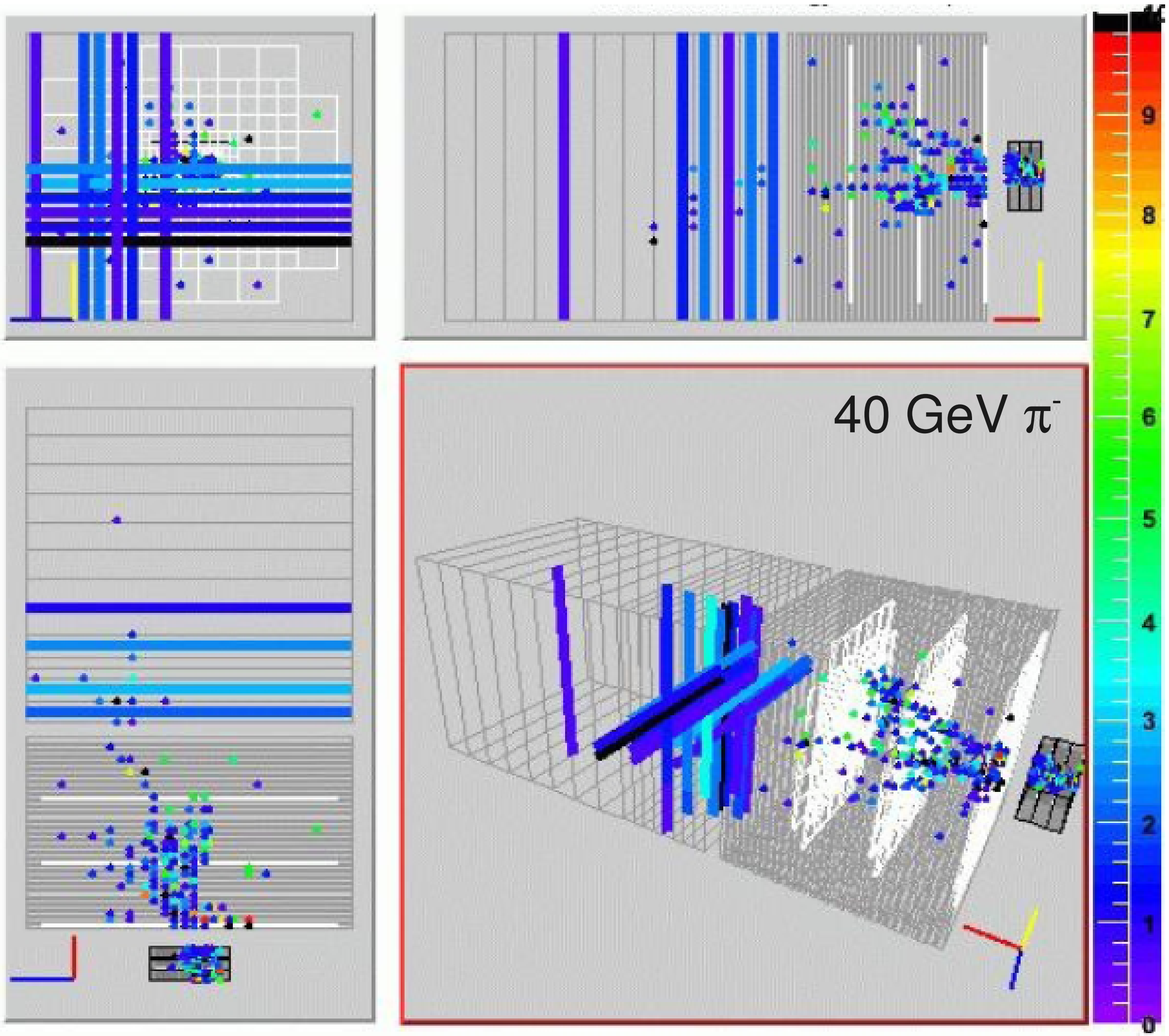
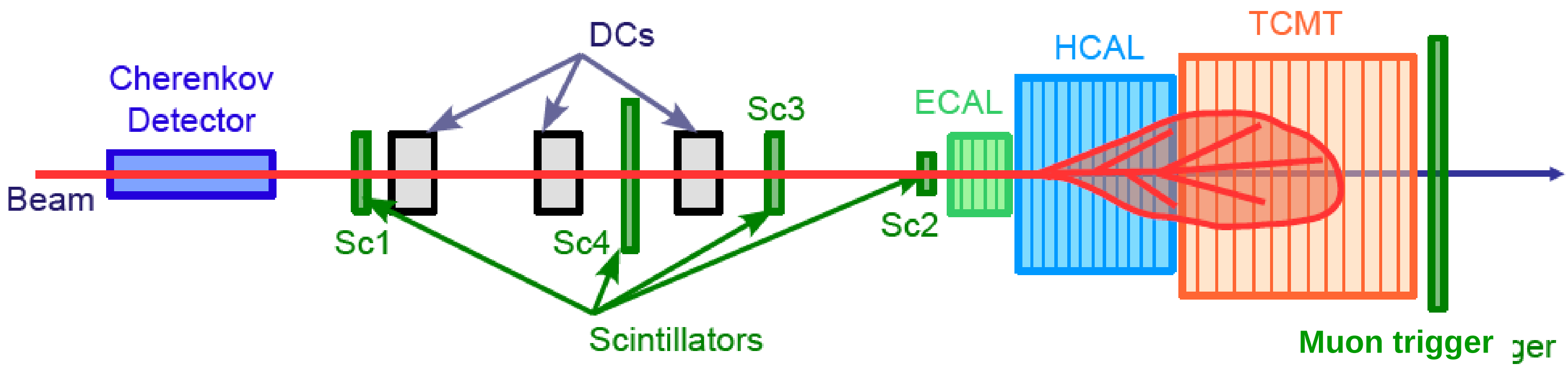
Particle Flow Calorimetry

- SiW Ecal
  $24 X_0$ / 1λ
- Tile Hcal
  4.5λ / $35 X_0$
- Tail catcher

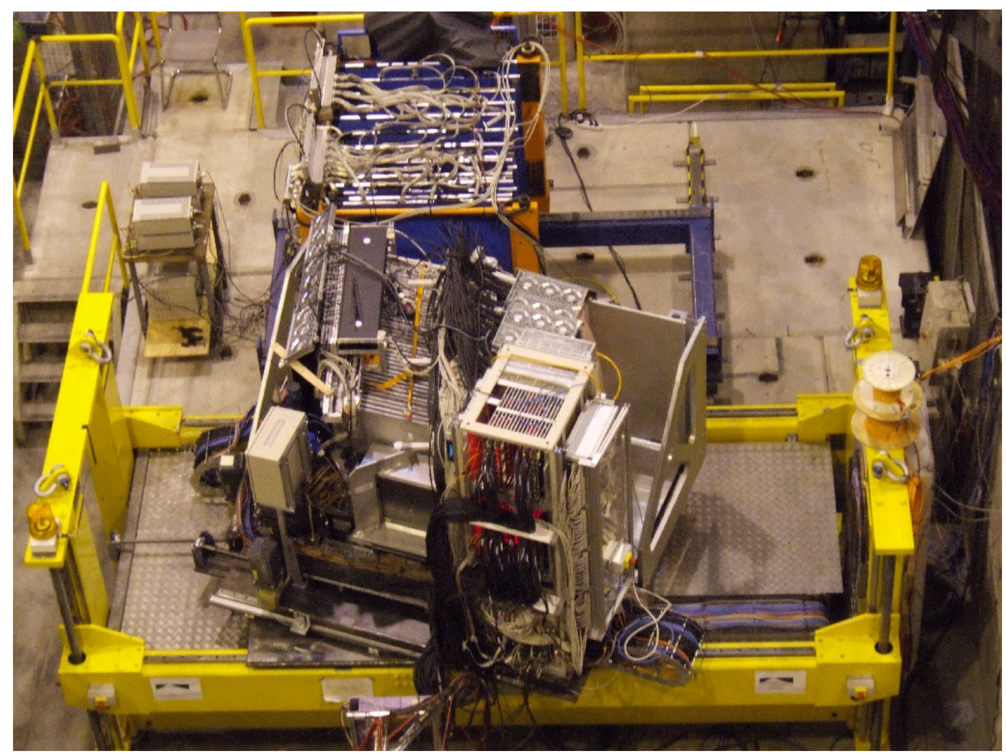


Combined Test Beam



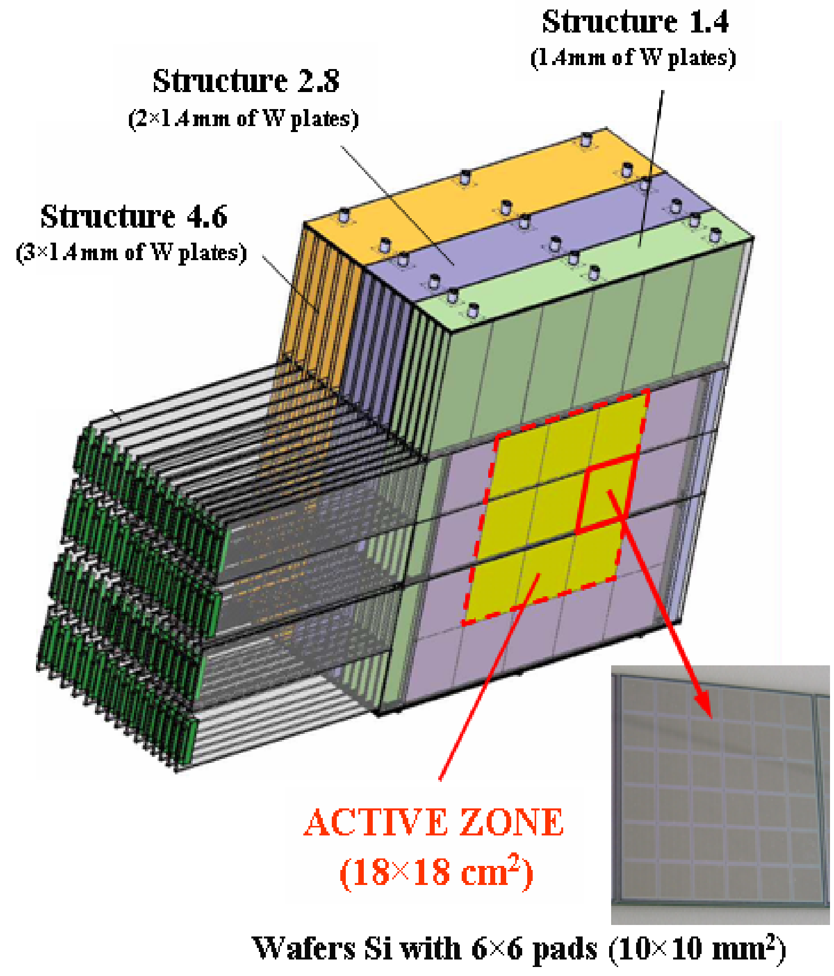
Data recorded:

- 2006 – DESY/CERN
- **2007 - CERN**
- 2008 – Fermilab MTBF
- Si-W ECAL, HCAL, TCMT
- $e^{\pm}$ 1-50 GeV
- $\mu^{\pm}$ (mainly for calibration)
- $\pi^{\pm}$ 2-180 GeV
- Various impact points
- Angles of incidence:
  $0^{\pm}$, $20^{\pm}$, $30^{\pm}$, $45^{\pm}$
- Typically ~200K events per configuration.

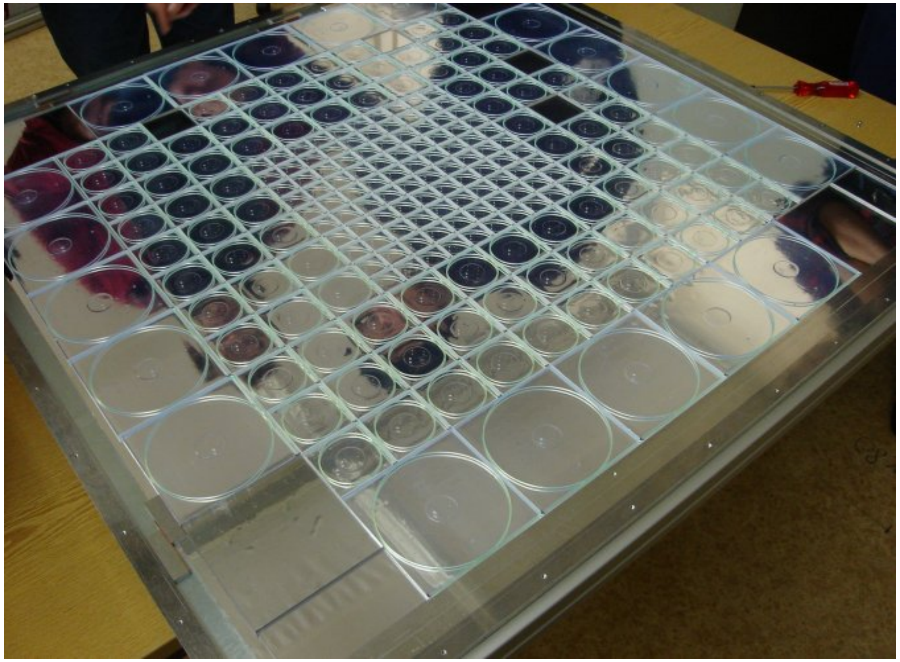


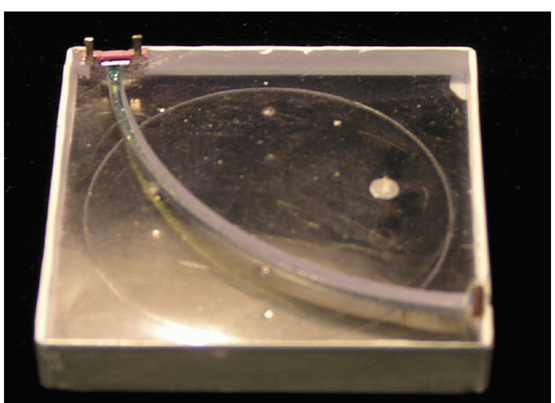
SiW EM Calorimeter

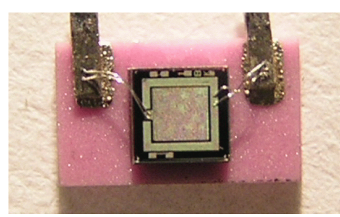
- 3x10 layers with 0.4, 0.8, and 1.2 X_0 tungsten
- 9 wavers/layer with 36 pads of $1x1cm^2$ each
- Challenge:
  - Correlation and leakage effects from guard ring around wavers



SciFe Had Calorimeter

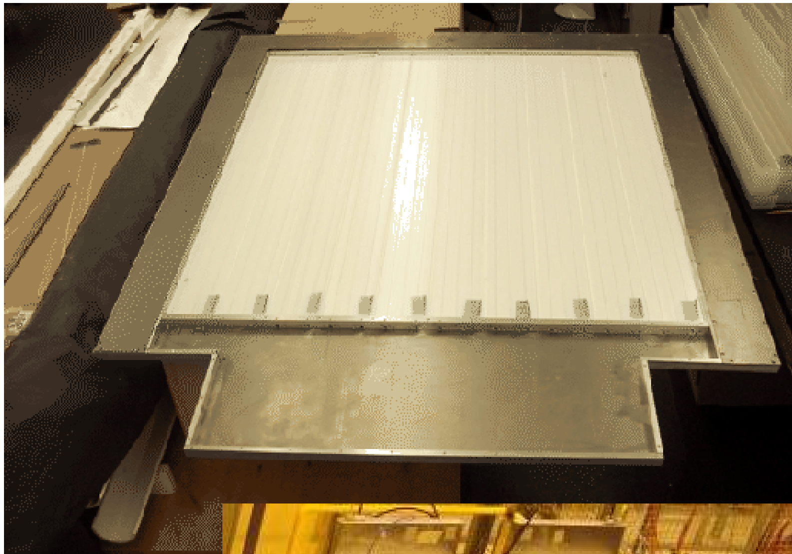






- 38 layers, 2cm steel
- 216 or 141 cells/layer
  $3x3cm^2$ to $12x12cm^2$
- Readout via SiPM
- Challenge:
  - T-dependence of gain and amplitude
  - SiPM non-linearity

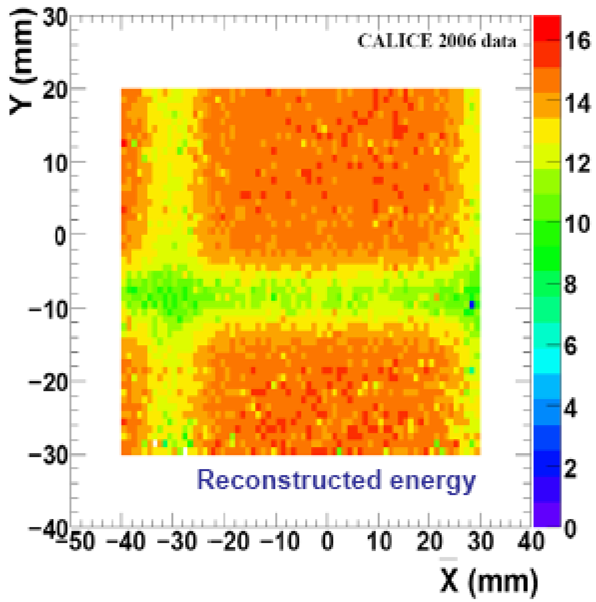
SciFe Tail Catcher

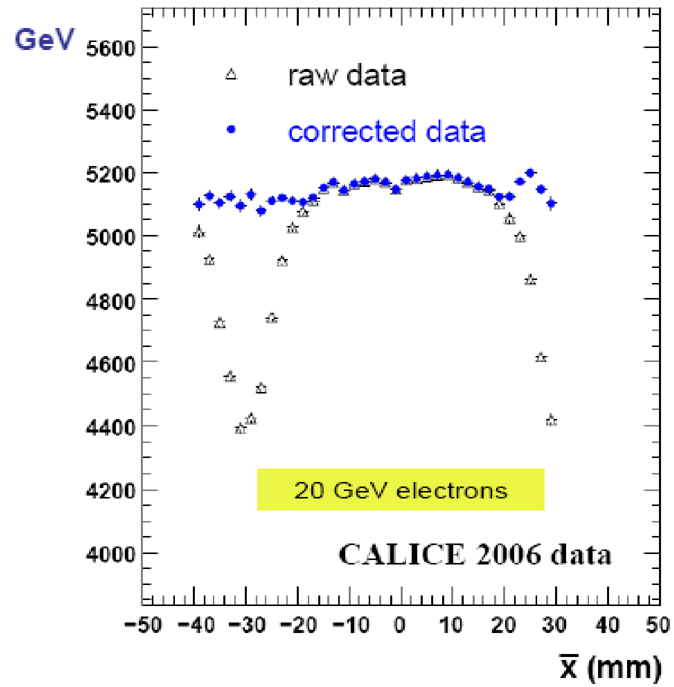


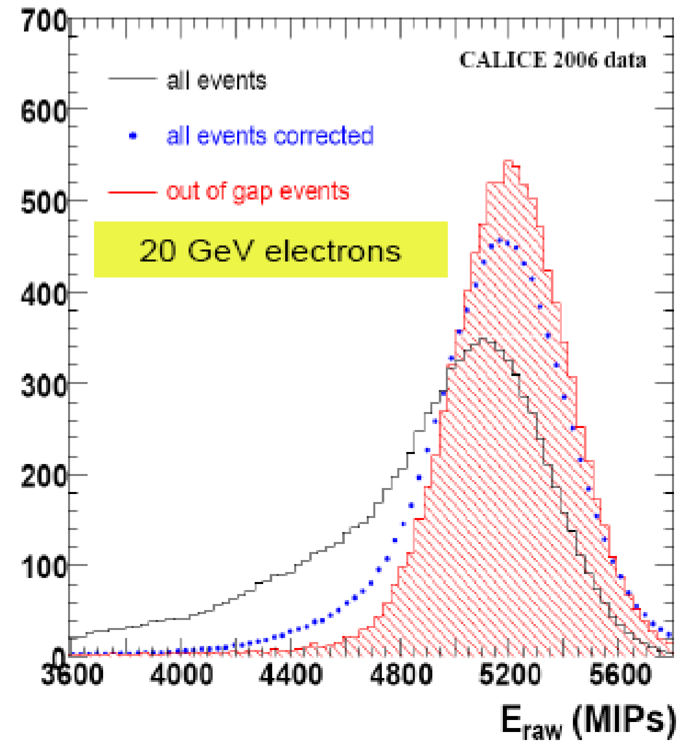
- 20 strips 5x100 cm^2
- Readout via SiPM (same as Hcal)
- 16 layers, alternating orientation
- Two samplings: 1xHcal and 3xHcal

Electrons/Positrons

SiW ECal: Gap Effects

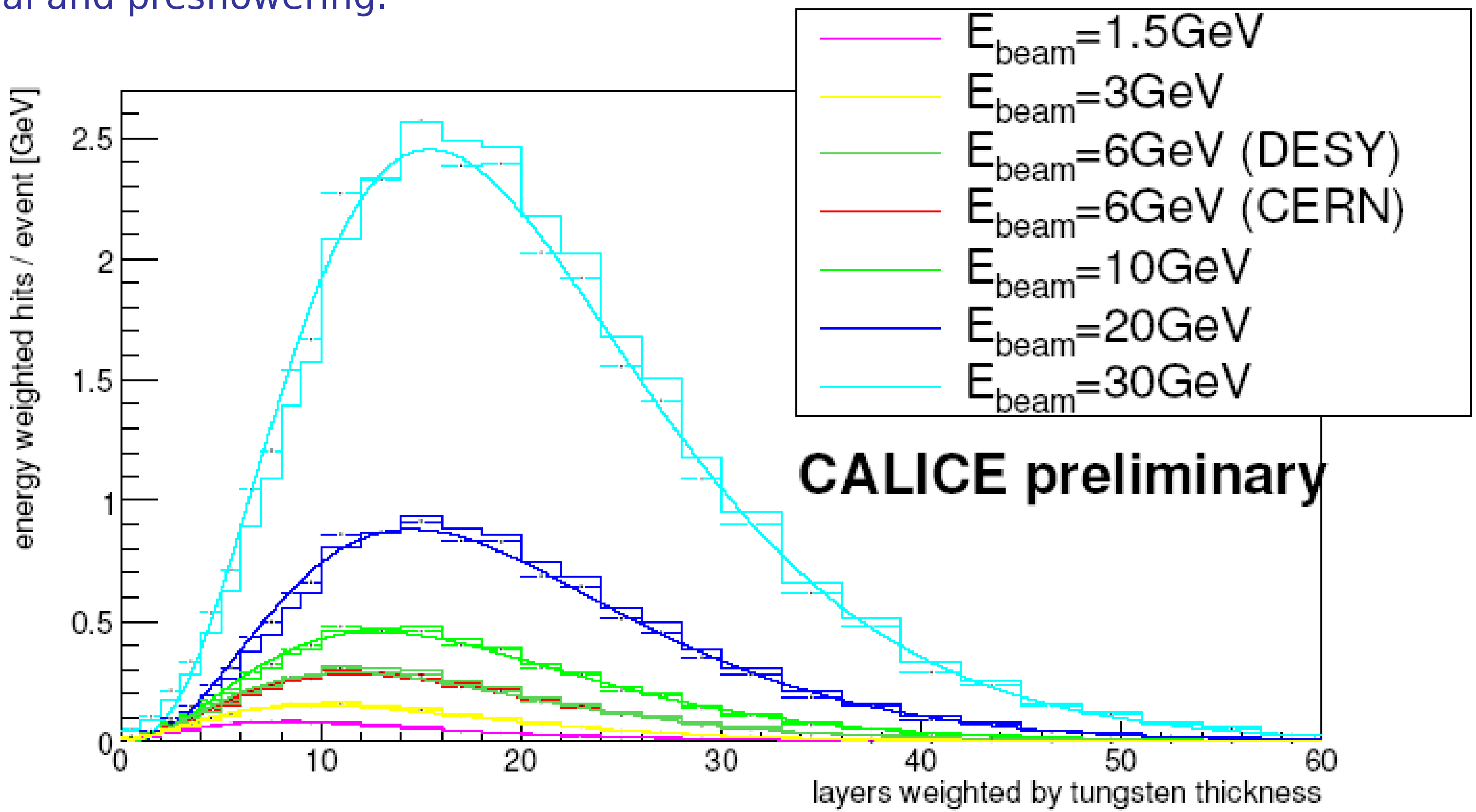




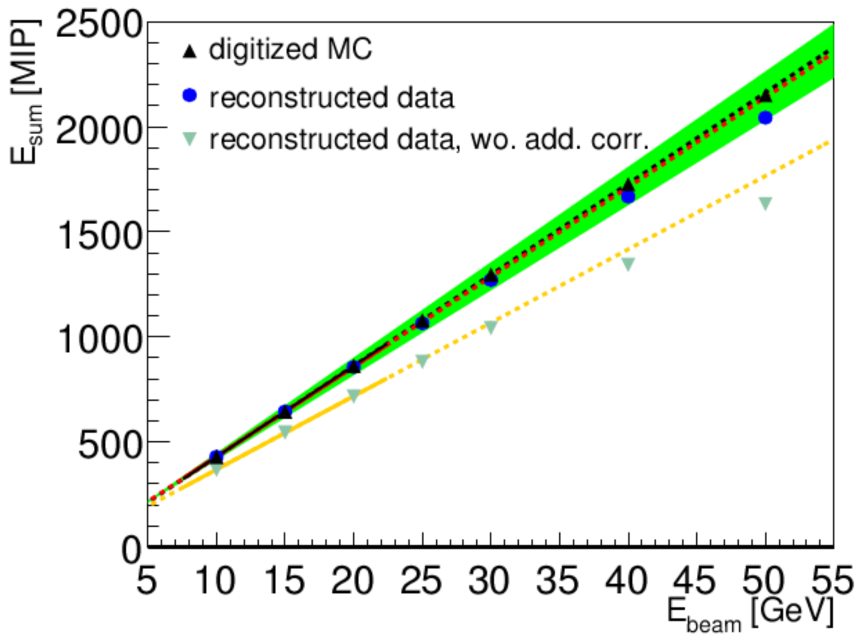


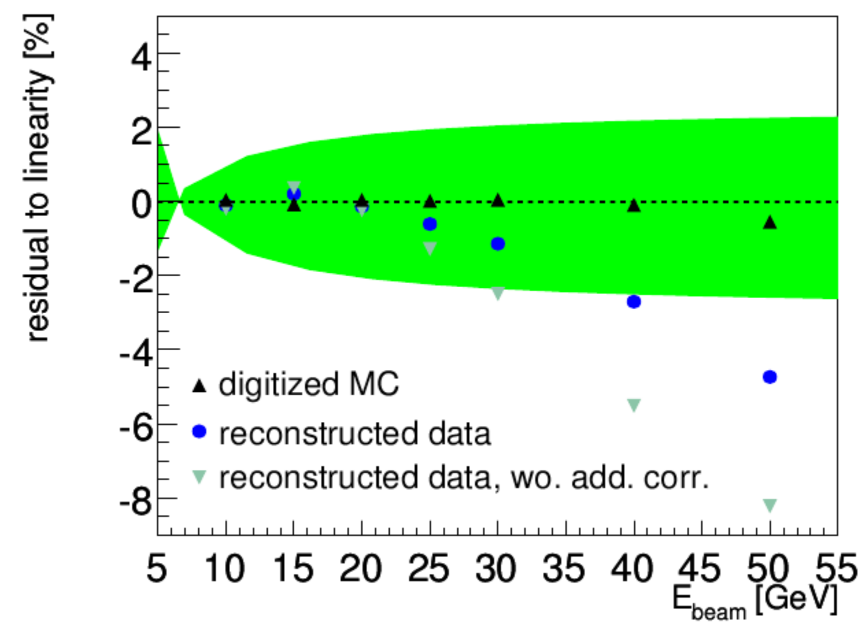
- Gaussian parametrisation of energy loss
- Permits a reasonable uniformity vs (x,y)
- Reduces low tail in measured energy
- But inevitable penalty in resolution.

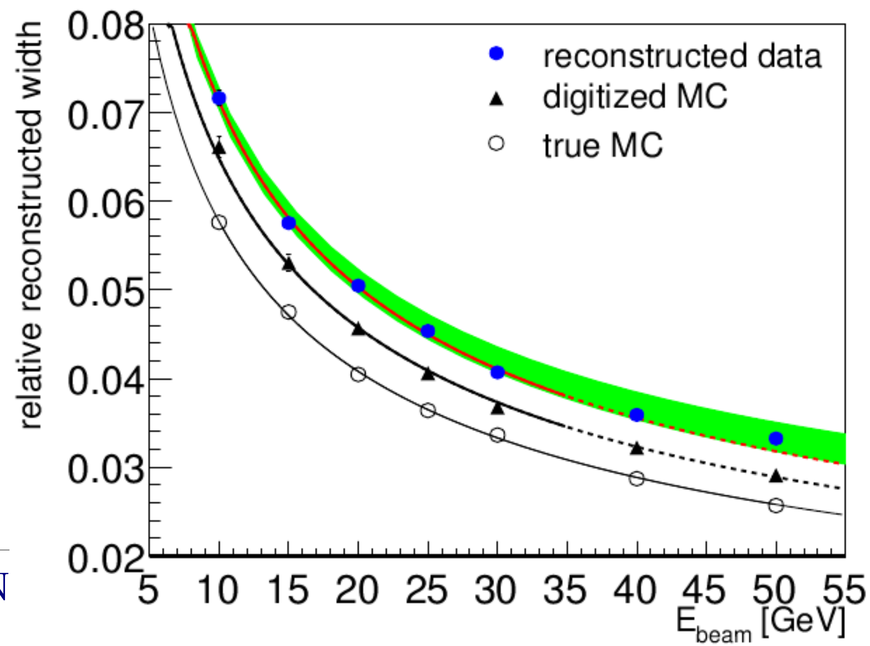
•Data (dashed) agree quite well with Monte Carlo expectation (solid).
•Some shift – likely associated with upstream material and preshowering.



EM Showers in Hcal





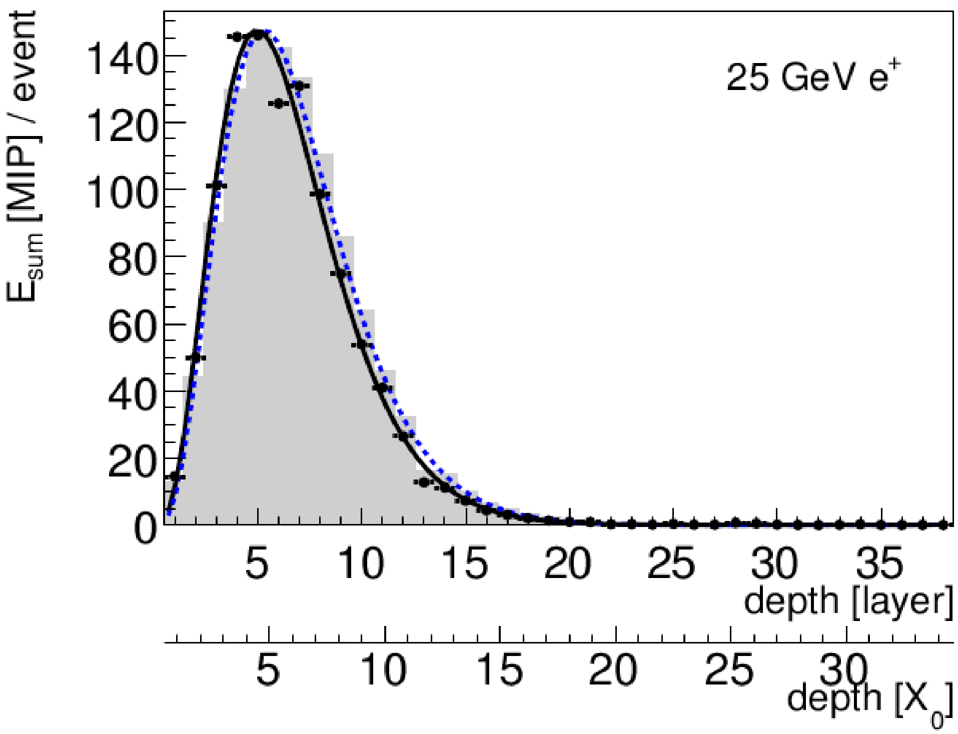


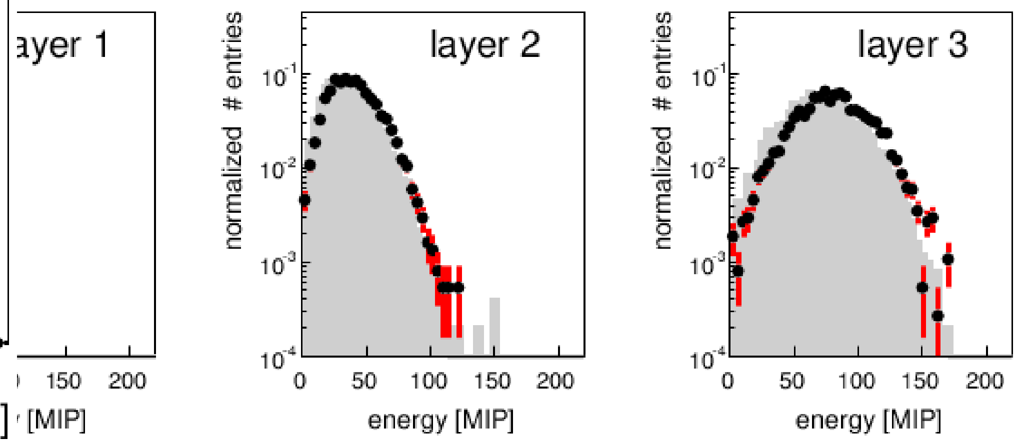
Average corrections for temperature and saturation effects necessary to reproduce simulation

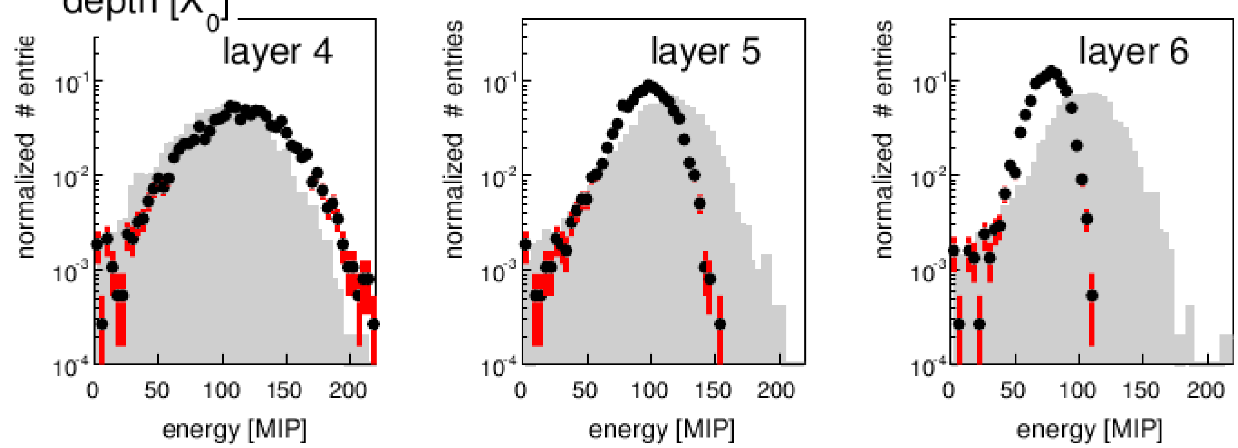
<5% non-linearity at highest energy density

No calibration uncertainties in digitization, yet

Lower Scale Comparison



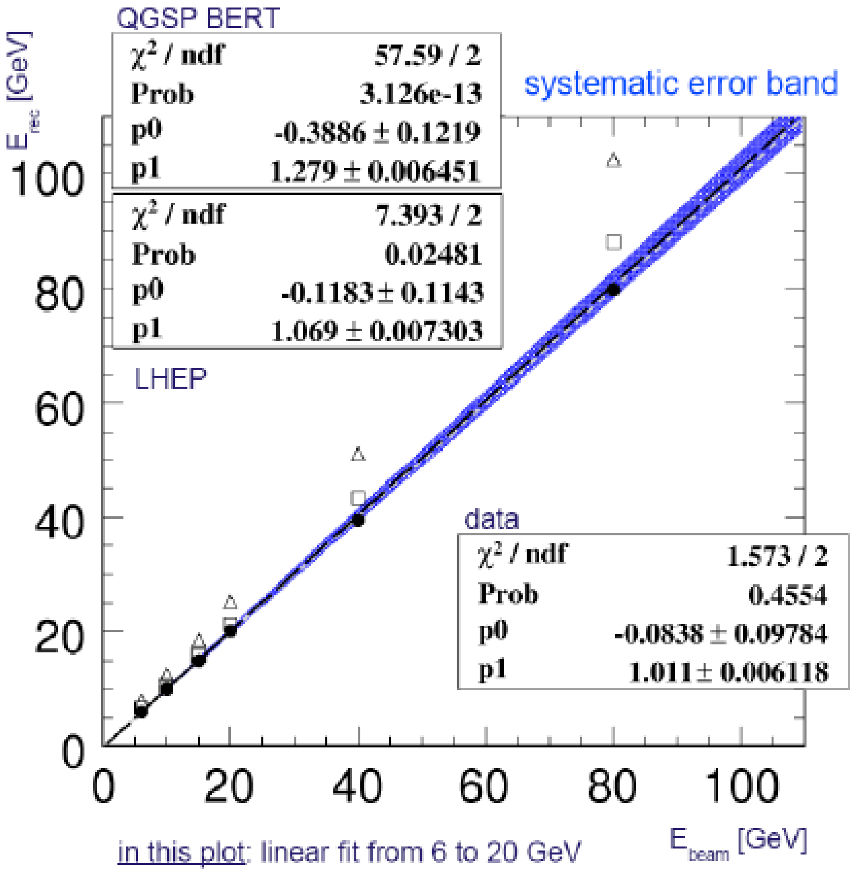


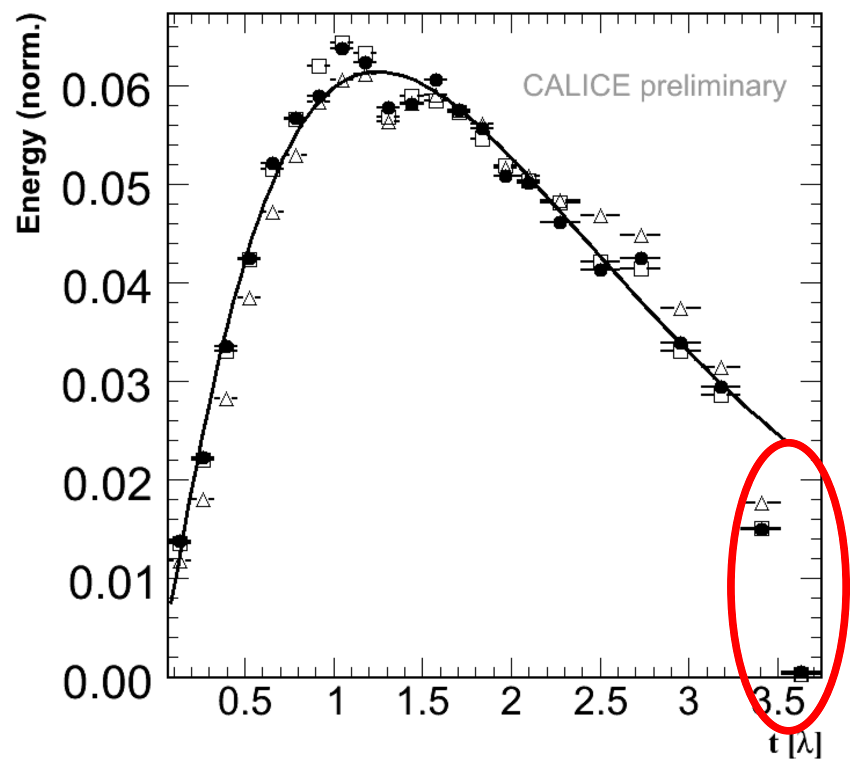


Average corrections insufficient on level of individual cells - more complex, but possible

Pions

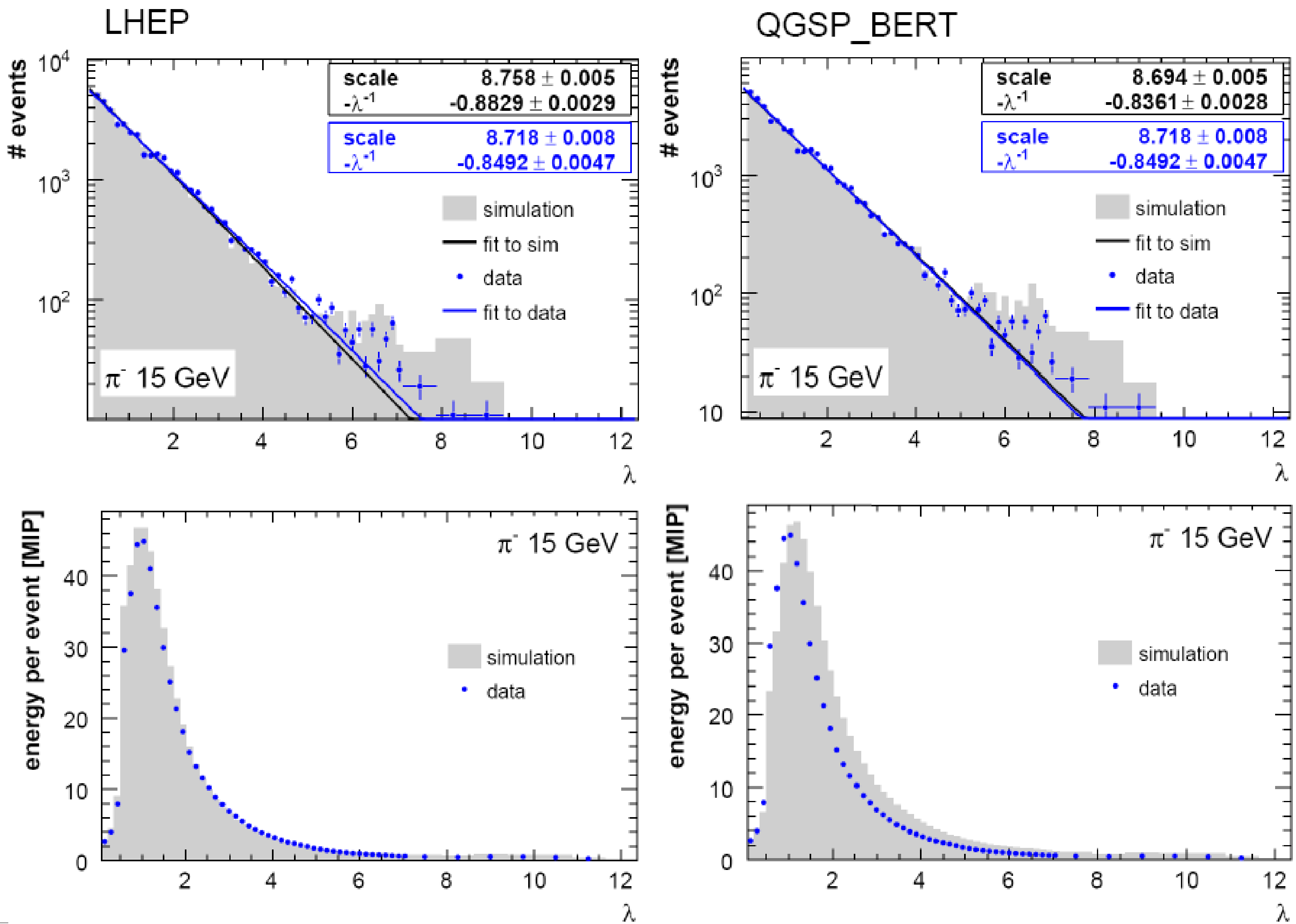
Pion Showers in Hcal



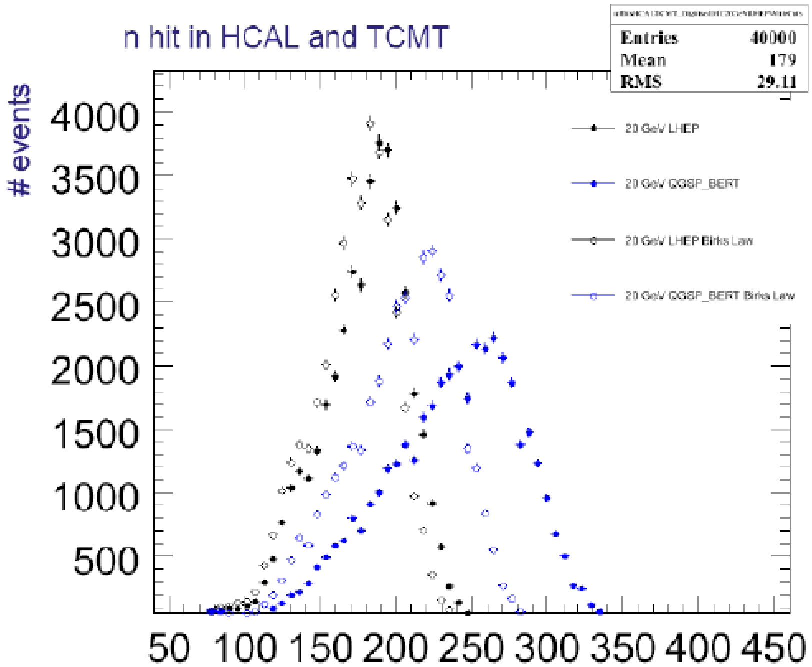


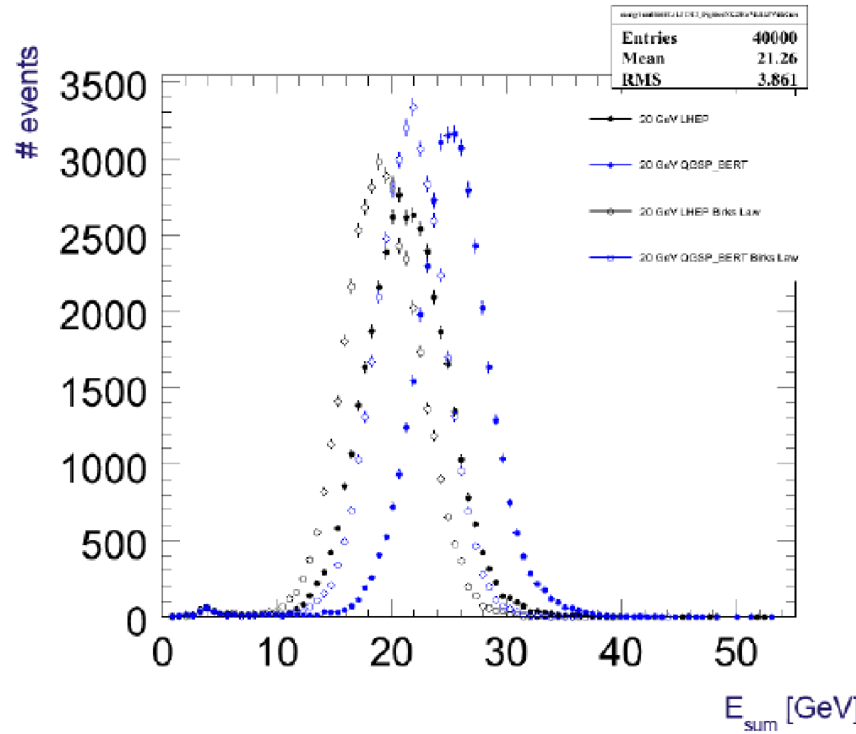
Initial study using QGSP_BERT and LHEP, largest deviation in energy sum
A word of caution: More illustrative than conclusive: incomplete instrumentation; most recent calibration not included

Topological Studies



Birks Law



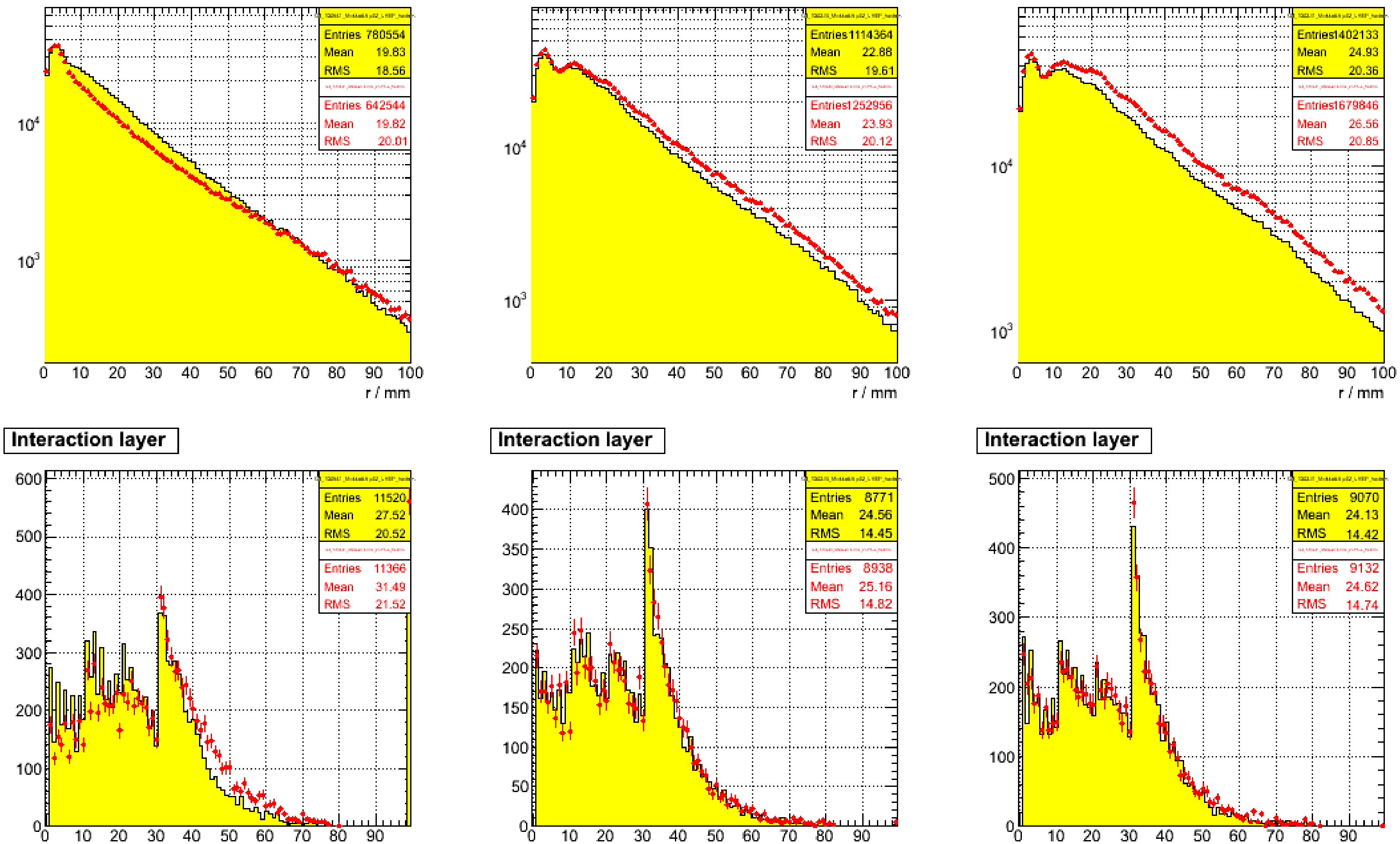


Saturation effect in scintillator at high ionization densities, reduces significantly number of neutron hits. Also total energy deposition reduced, reduces difference between QGSP_BERT and LHEP

Clearly interested in 'released' Geant4 with Birks Law

Where to Look?

MC only, compare LHEP with LCPhys



Radial distribution of hits in Ecal

First interaction layer

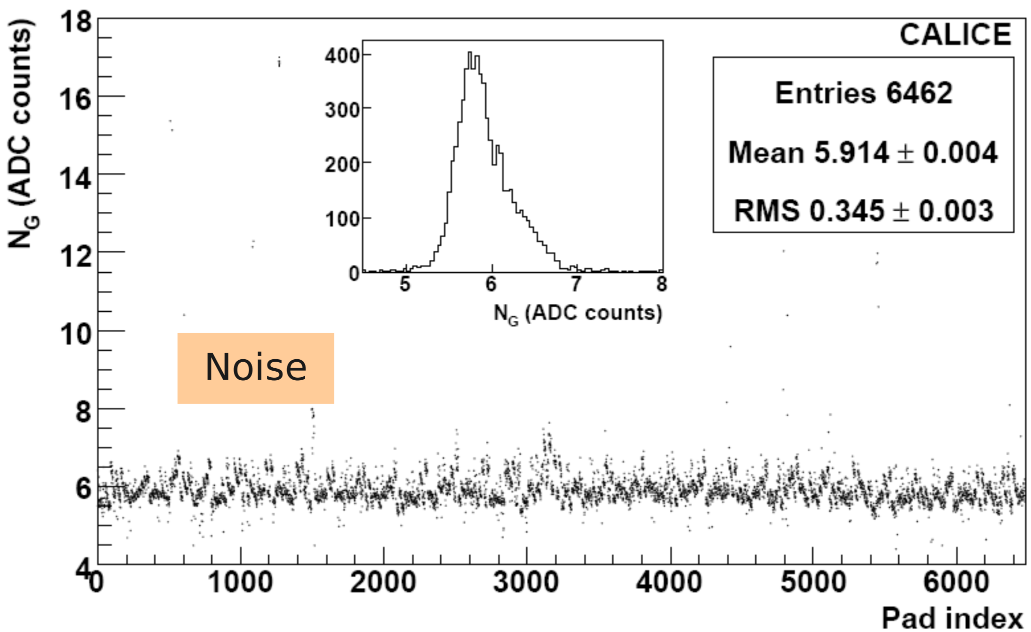
Conclusions

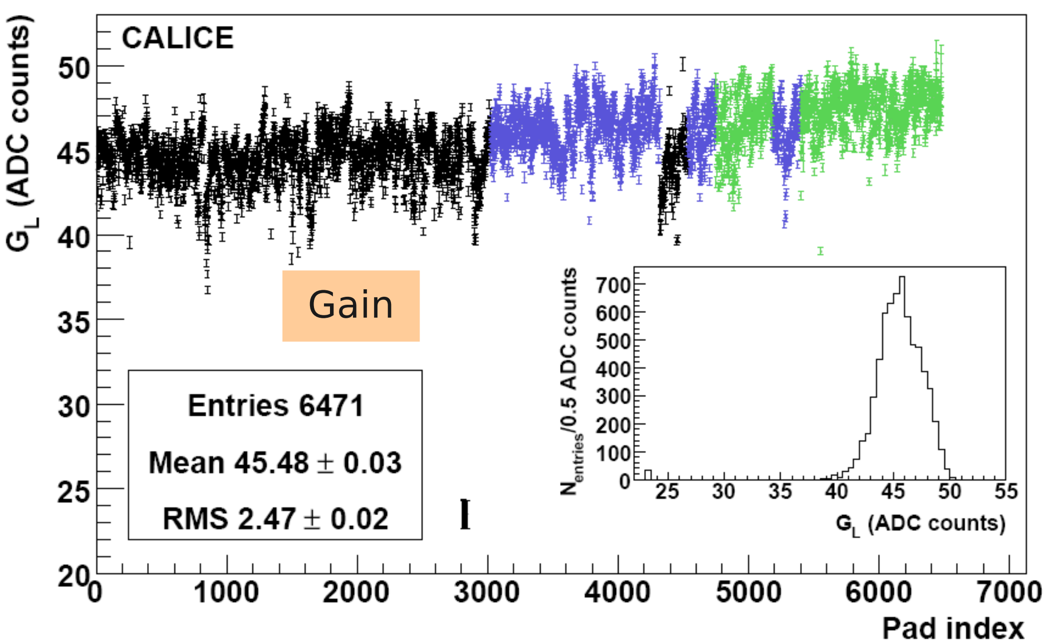
- CALICE has recorded millions of single particle showers in combined setup of ECal, HCal and TCMT prototypes with unprecedented granularity
- Detector understanding approaches per-cent level, becoming ready for conclusive data/MC comparisons and validation of hadronic shower simulation
- Set of promising/sensitive variables to distinguish different shower models would be very helpful

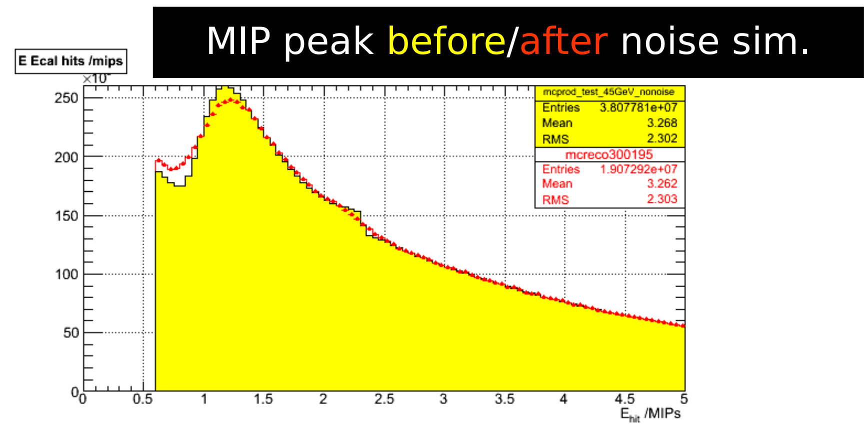
Backup

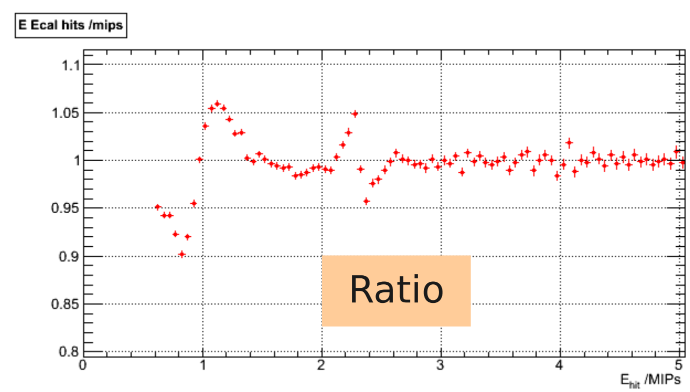
ECAL – noise and gain

•Gain calibrated with muons. Rather uniform channel to channel.
•Average noise ~6 MIPs. Signal/Noise ~8.
•With a typical threshold cut for analysis of ~0.6 MIP, the effect of noise on the MIP peak is small. We include in simulation, but the effect is minimal for most purposes.





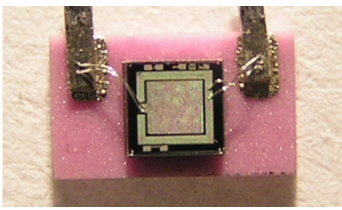


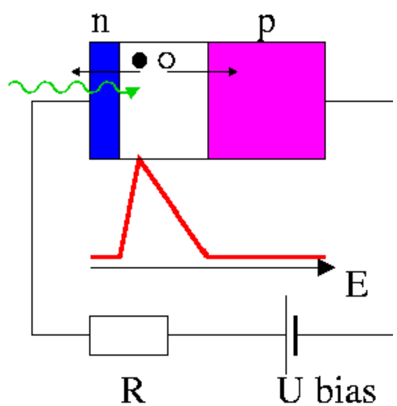


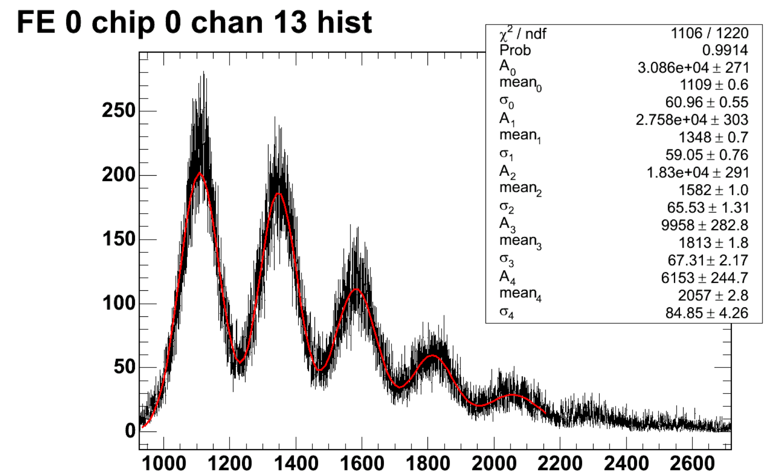
D. Ward, ILD Meeting, Cambridge

HCal Calibration

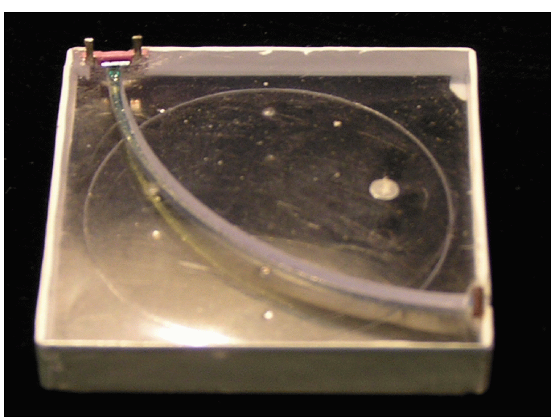
SiPM scale: single-pixel amplitude (gain)

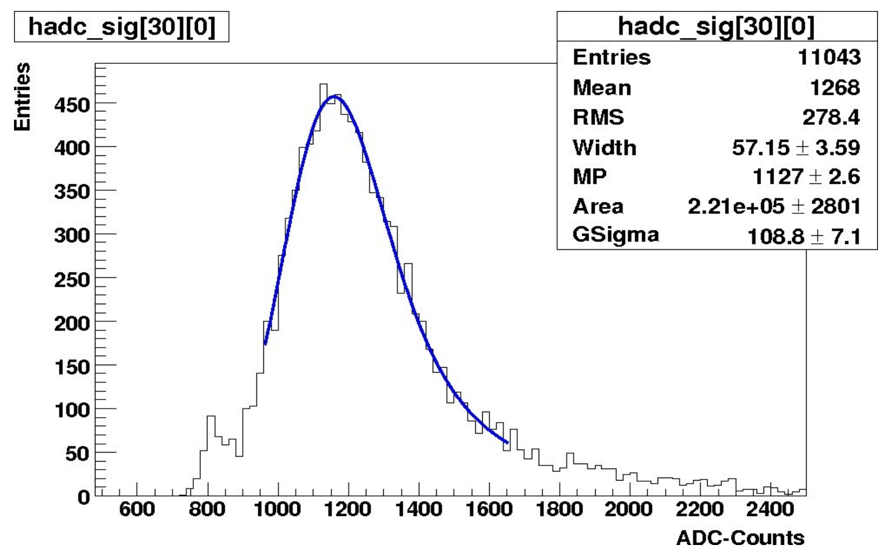






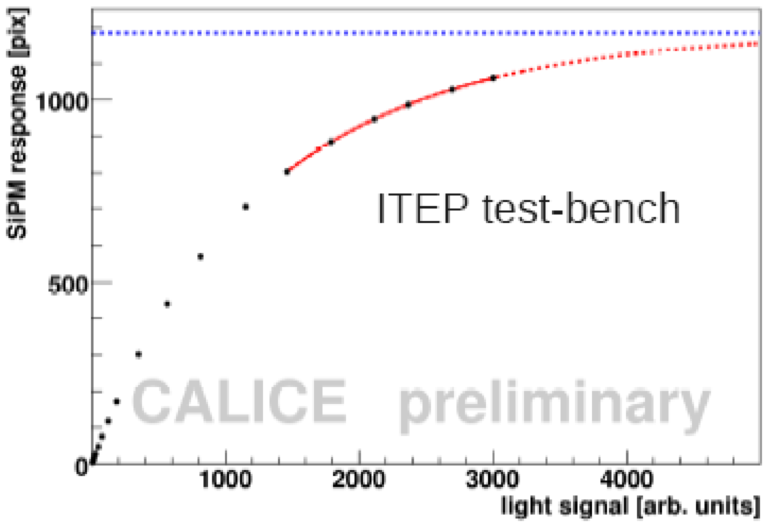
Physics scale: tile response to MIP

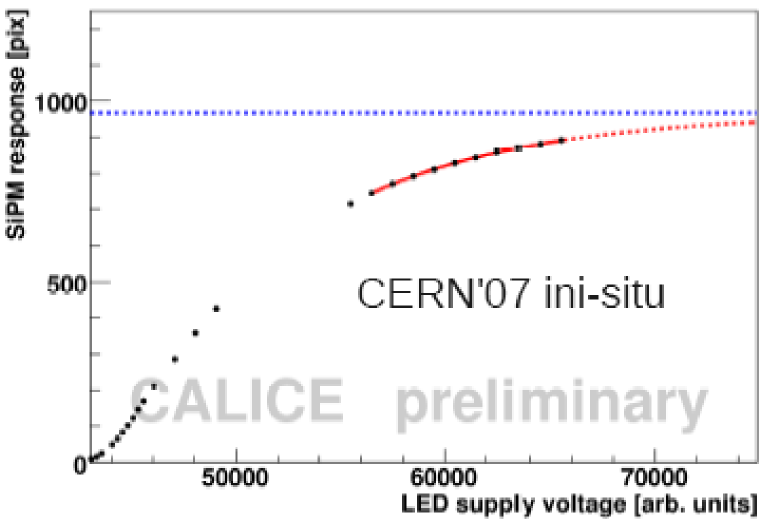




Lightyield: MIP response on the SiPM scale [pixel/MIP]

SiPM Saturation

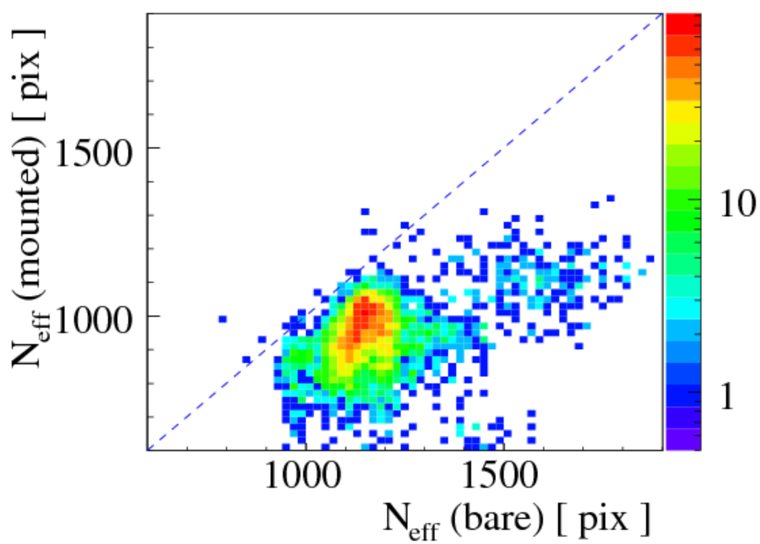




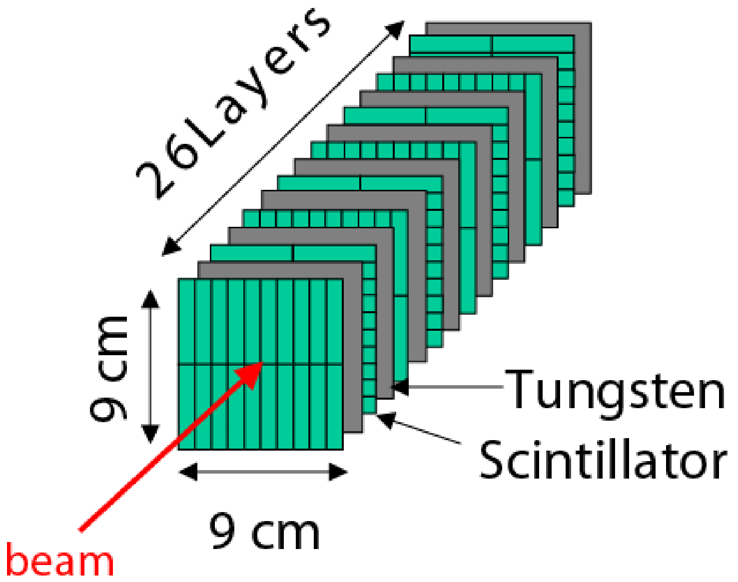
Response curves measured on bare SiPM on test-bench

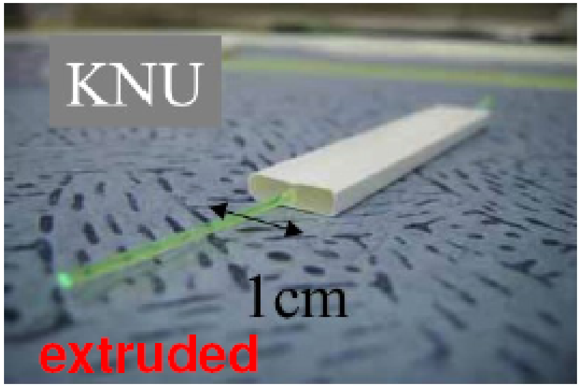
In-situ tests show lower maximum amplitude (SiPM not fully illuminated)

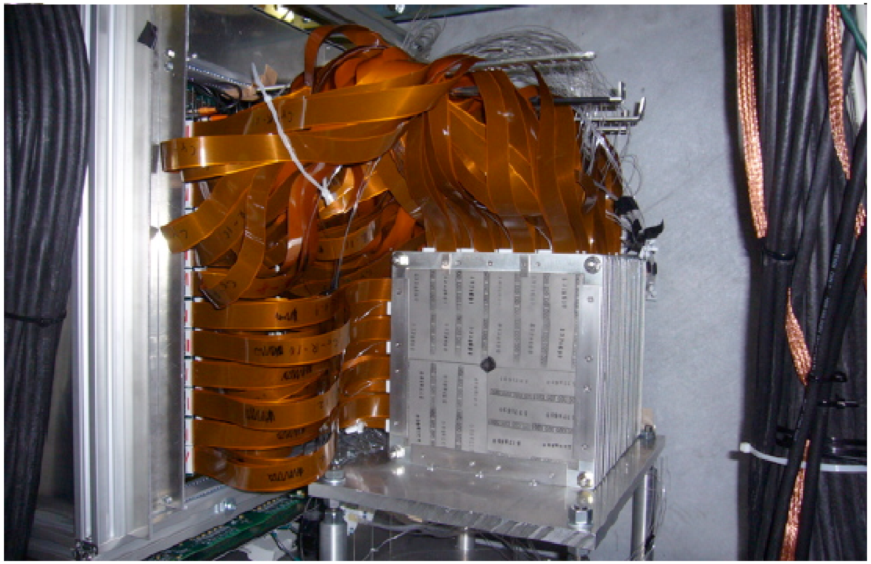
In-situ response not normalizable to photon intensity over full dynamic range
⇒ use test-bench curve and scale by ratio of saturation levels



SciW EM Calorimeter







- Full size prototype (18x18 cm)
- Extruded strip technology
- Just entered MTBT test beam at FNAL in September 2008 (replaces SiW ECal), campaign successfully concluded last week