AHCAL in the ILD DBD

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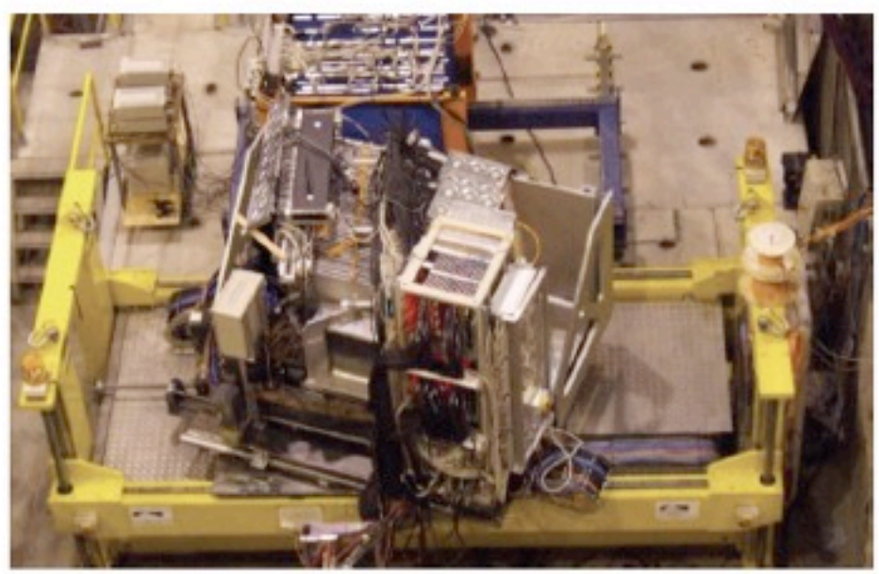
Calorimeter for ILC

Excellence Cluster
Universe

General Structure

- HCAL Section in ILD DBD common for AHCAL and SDHCAL
  - Both options presented side by side
- Embedded in calorimeter section with a general intro on requirements by PFA, roles of each of the subsystems, challenges arising from high granularity, ...
- Common intro to CALICE Testbeams - Highlight of combined analysis: Two-particle separation



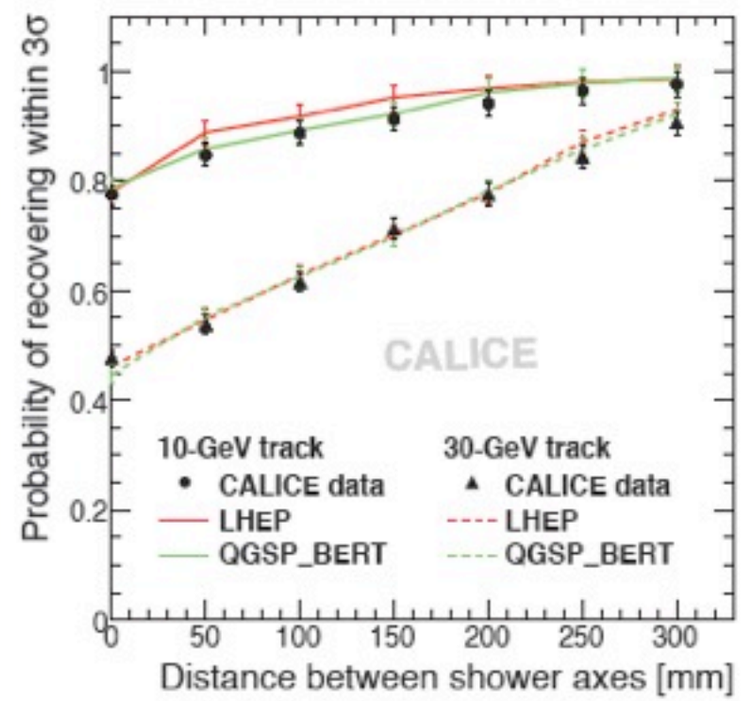


Figure 2.3.1: *Left: CALICE test beam set-up at CERN. Right: Probability to recover the energy of a 10 GeV neutral hadron within three sigma of the detector resolution as a function of the distance from a 10GeV and 30GeV (charged hadron, respectively, using the Pandora PFA for test beam showers mapped into the ILD detector.*

Overview

- AHCAL Design Optimization
- AHCAL Mechanical Design
- AHCAL Module Details
- Performance Validation, Operational Experience & Test Beam Highlights
- Technical Validation
- Future R&D Steps

AHCAL Optimization

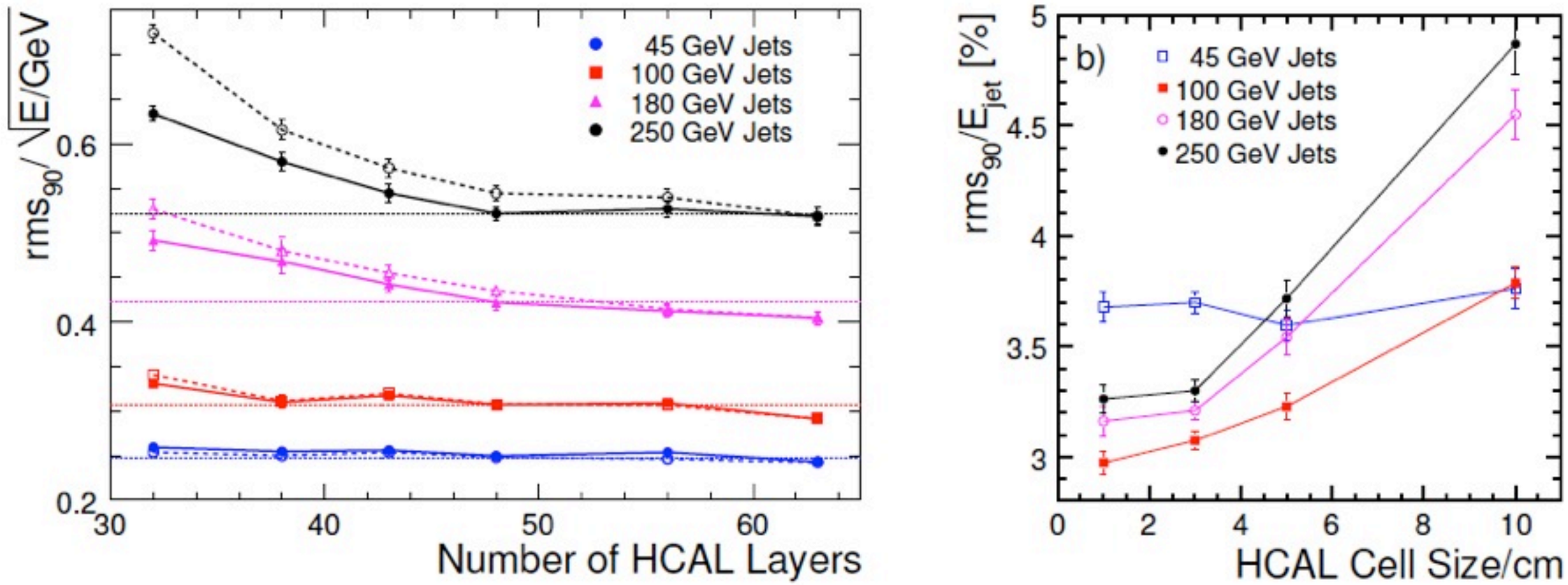


Figure 2.3.11: Particle flow jet energy resolution as a function of AHCAL thickness, given by the number of layers (left) and as a function of AHCAL cell size (right) for different jet energies.

- Studies performed for LOI, still valid:
  - 48 layers, 3 x 3 cm^2 cell size

AHCAL Mechanical Design

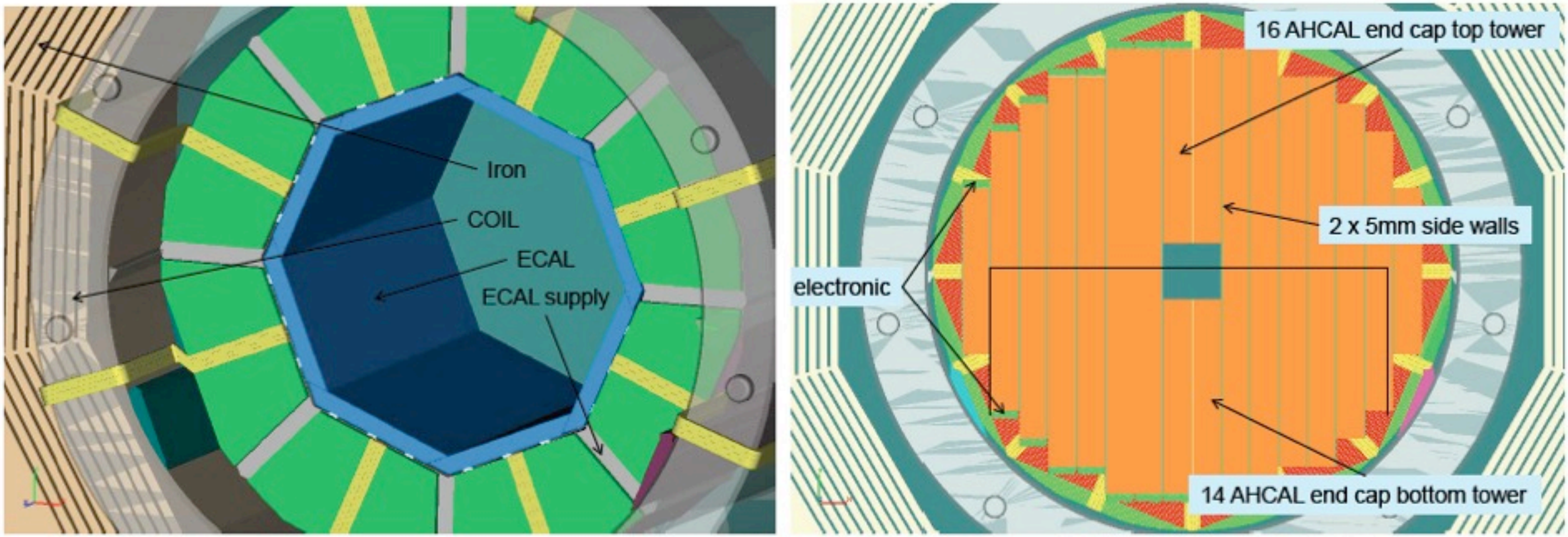


Figure 2.3.13: The AHCAL mechanical design.

- Based on 'Tesla' Geometry - Insertion of readout modules possible in-situ or pre-installation
  - Manageable modules - Barrel module weight ~ 20 t
  - AHCAL modules can also be designed for 'Videau' Geometry

AHCAL Mechanical Design

Figure 2.3.14: The AHCAL mechanical prototypes.

- Mechanical prototypes available: Tolerances & stability demonstrated with real steel
  - Cost-effective construction: Roller-leveling of plates instead of machining is sufficient to reach required flatness

AHCAL Module Design & Active Layers

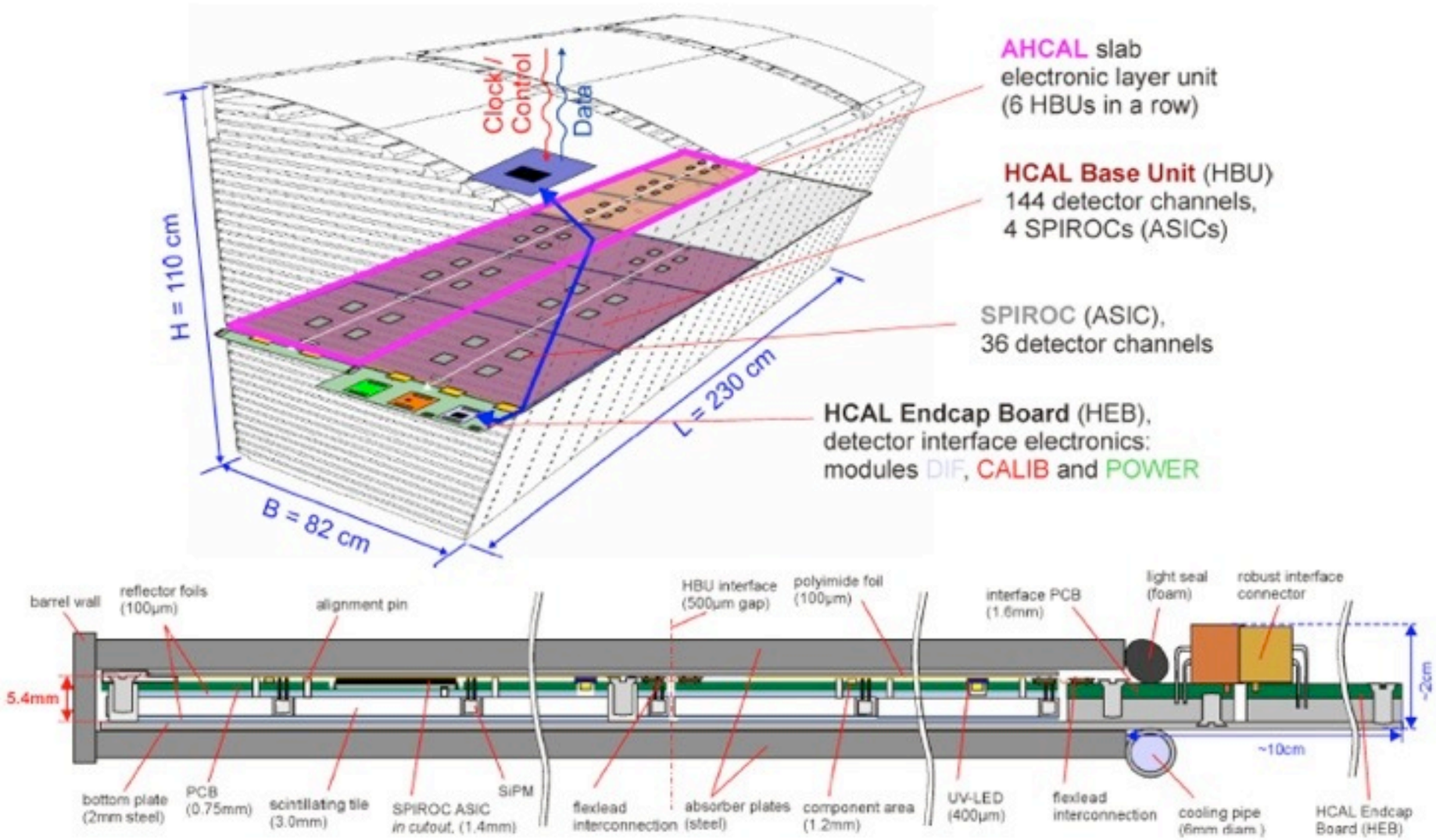


Figure 2.3.15: Arrangement of AHCAL layers with electronic components (top), cross section of an active layer (bottom).

- 5.4 mm non-absorbing material (scintillators & PCB)
- 2 x 0.5 mm cassette cover, 1 mm additional tolerance per layer

Active Elements

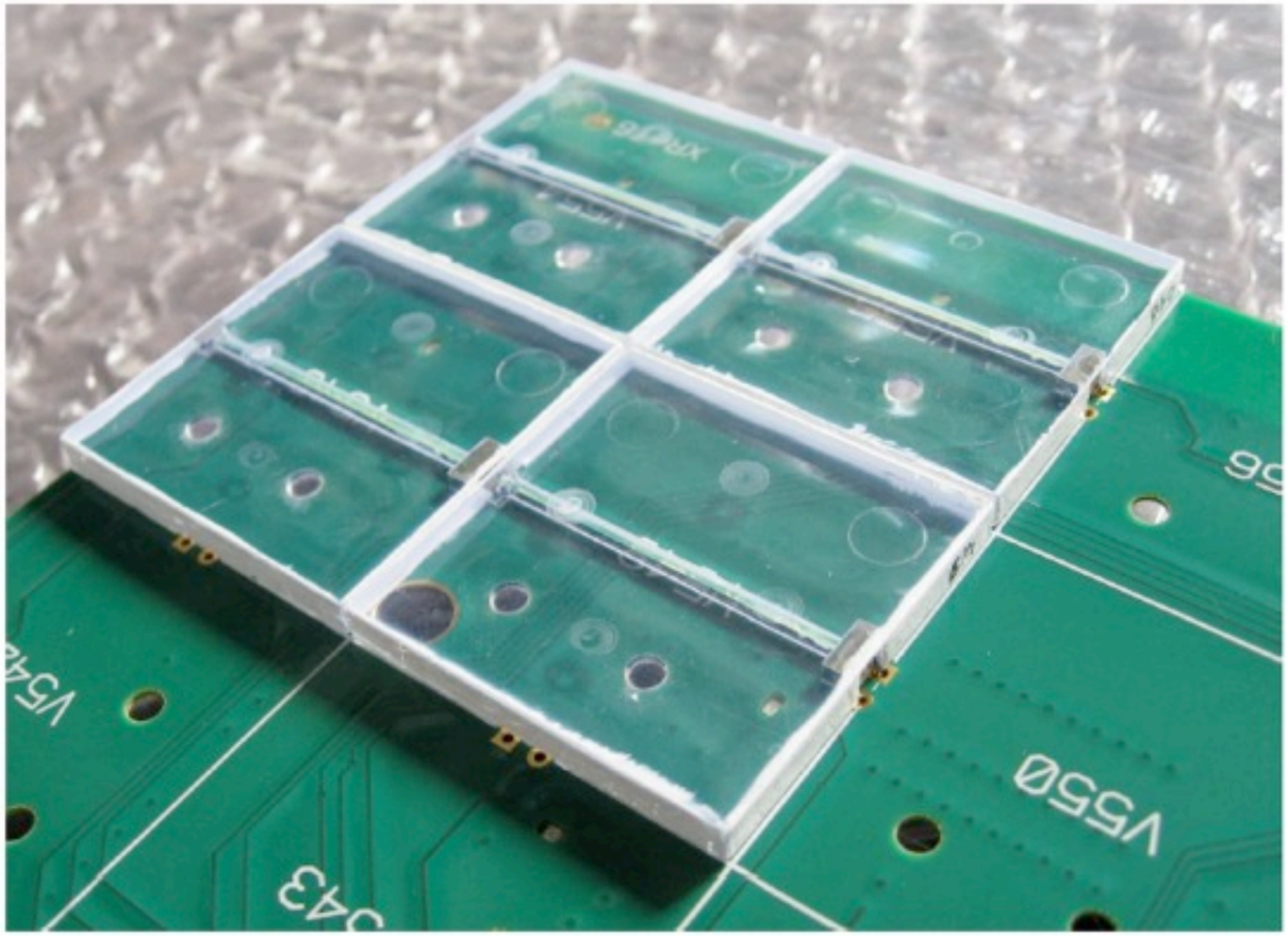
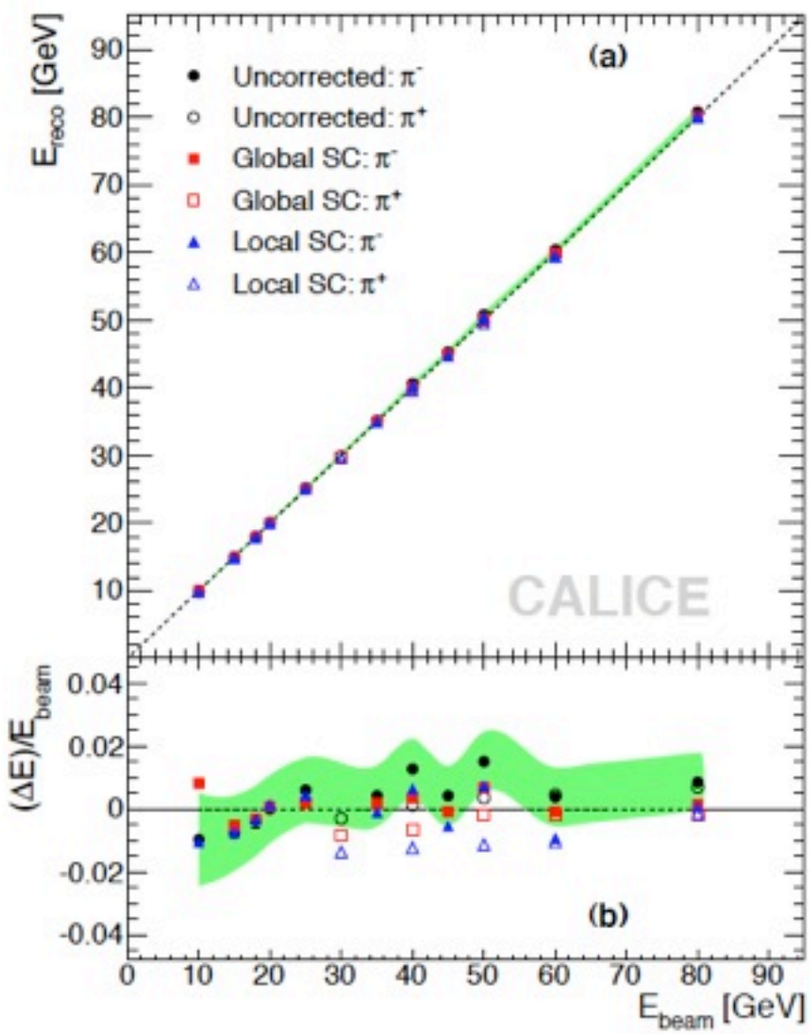
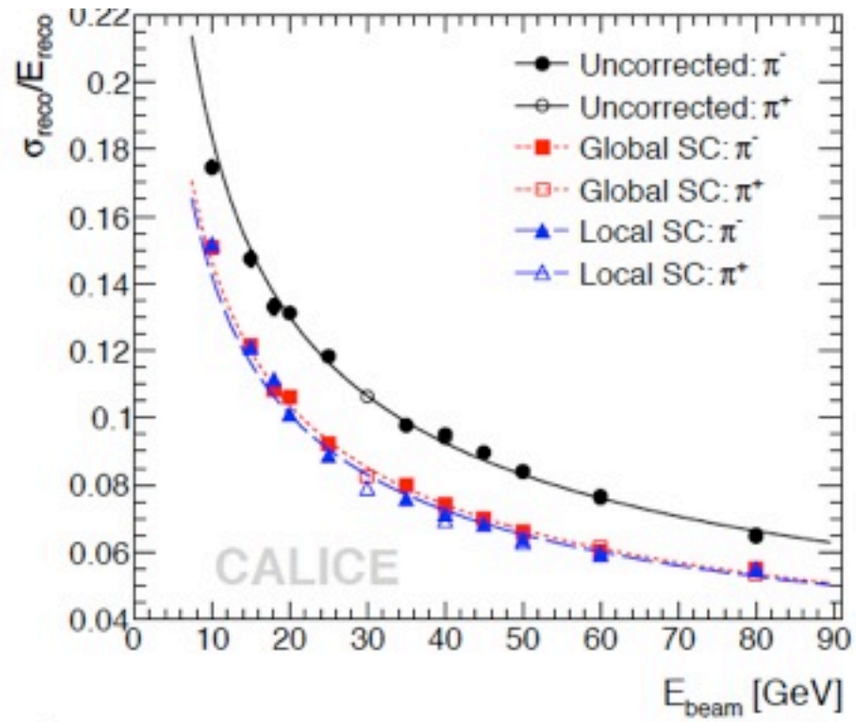


Figure 2.3.16: The AHCAL scintillator tiles with embedded SiPMs, mounted on the readout PCB.

- 3 mm thick scintillator tiles with new SiPMs on HBUs

Test Beam Highlights



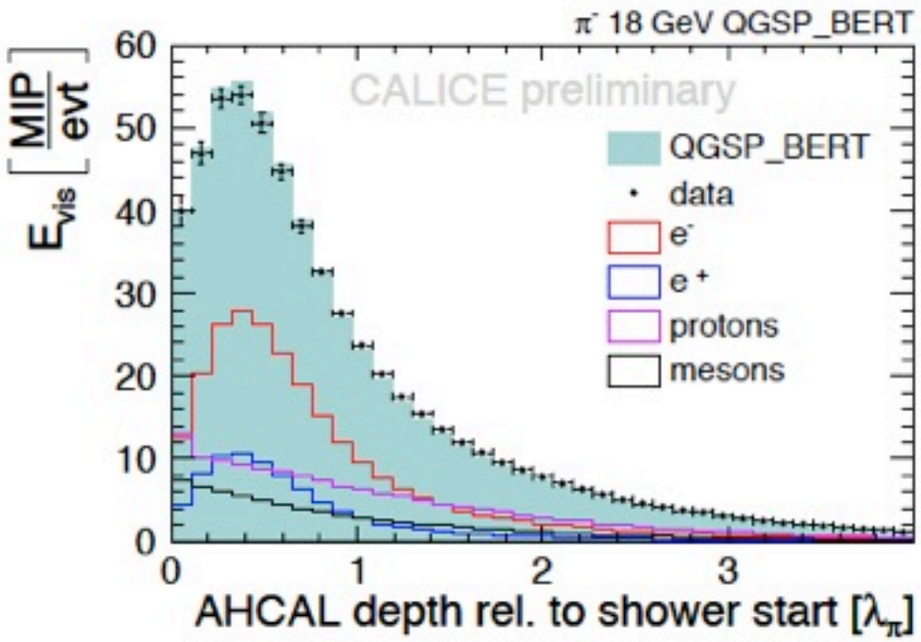


fit results		
	stochastic	constant
initial	57.6%	1.6%
global SC	45.8%	1.6%
local SC	44.3%	1.8%

- Energy resolution: Exceeds PFA requirements

Figure 2.3.19: *Reconstructed energy (left) and energy resolution (right) of the AHCAL for pion showers starting in the first five calorimeter layers. Shown are results obtained with a simple energy sum and with a local and a global software compensation technique, respectively. The green band indicates the systematic error of the detector calibration, and is shown around the results with with initial energy reconstruction. Figure taken from [38].*

Test Beam Highlights



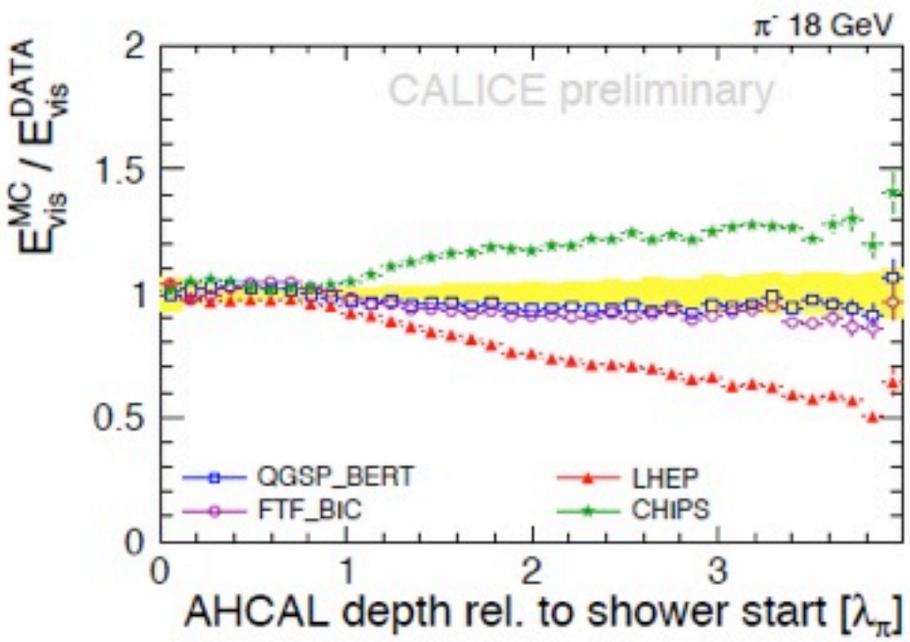
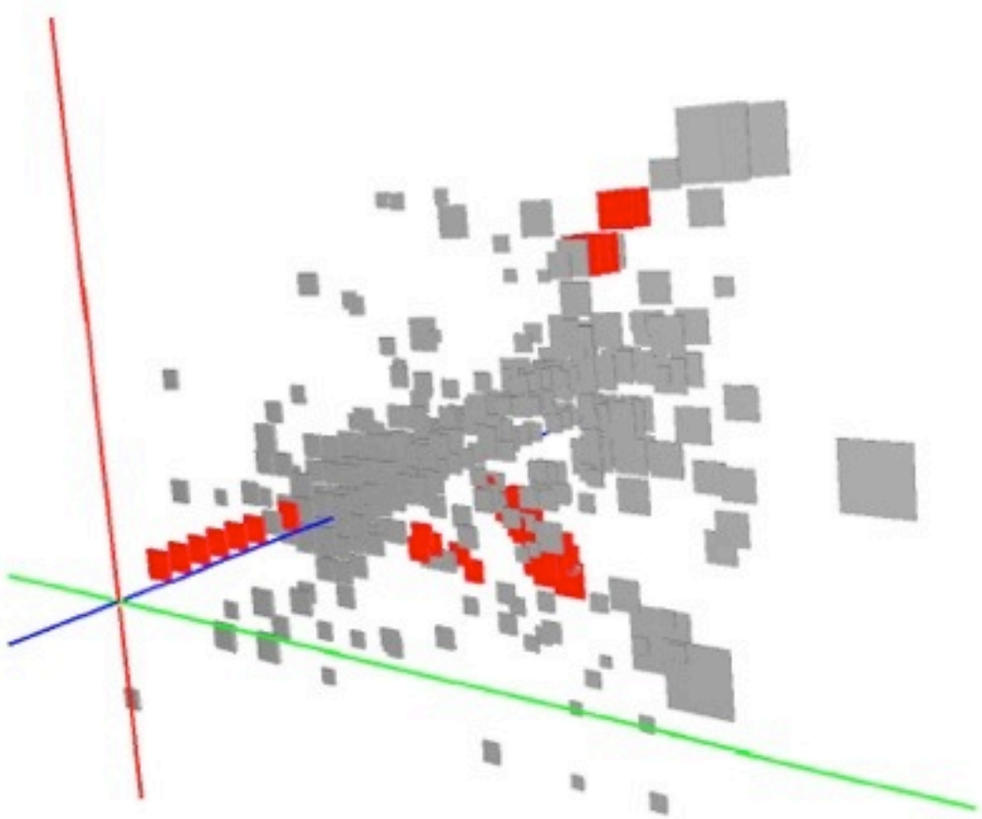


Figure 2.3.20: *Right: Longitudinal profile of 18 GeV pion showers relative to the shower start in the AHCAL. In addition to data, simulation results with the QGSP_BERT physics list are shown, detailing the different sub-components of the hadronic shower. Left: Ratio of data and simulation as a function of longitudinal depth relative to the shower start for a selection of physics lists.*

- Sensitivity to differences of hadronic physics models - Some reproduce data quite well, gives confidence in full detector simulation & physics studies

Test Beam Highlights



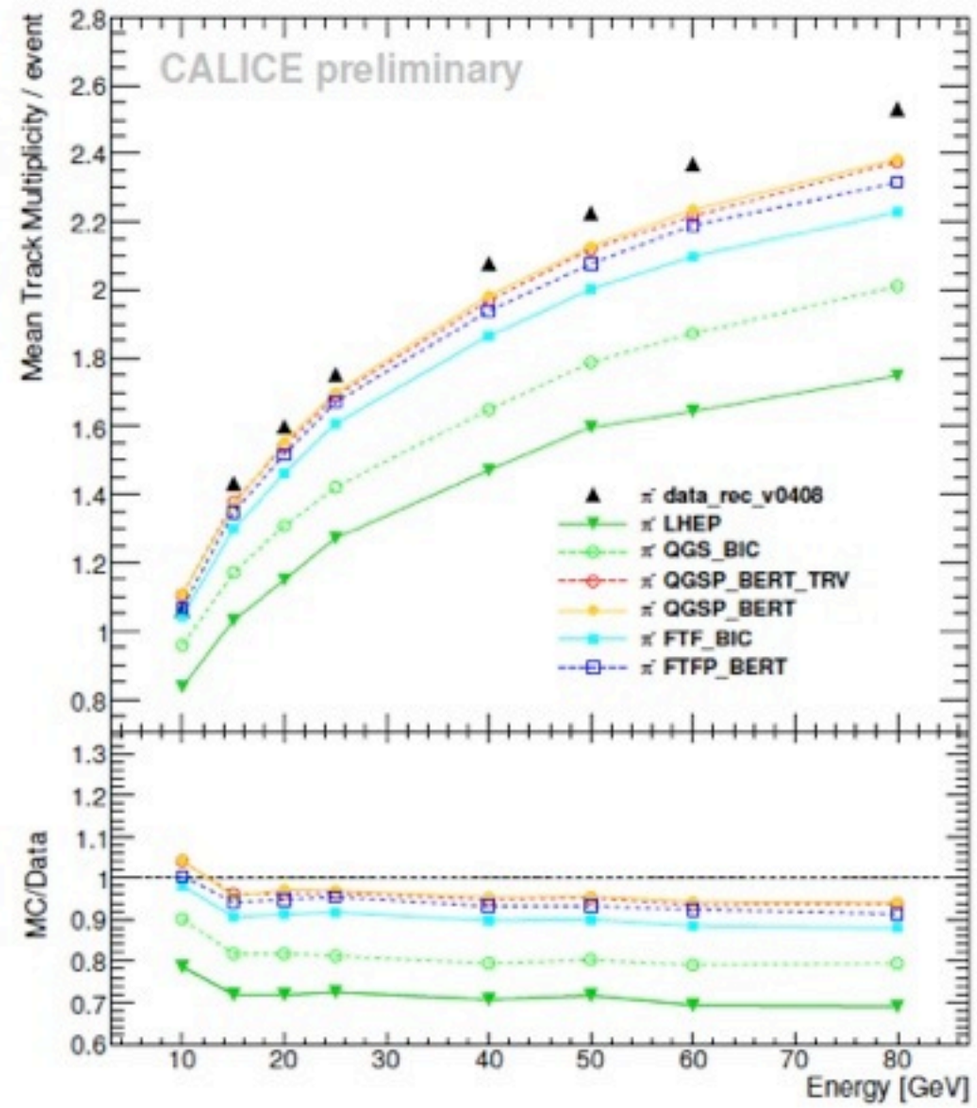
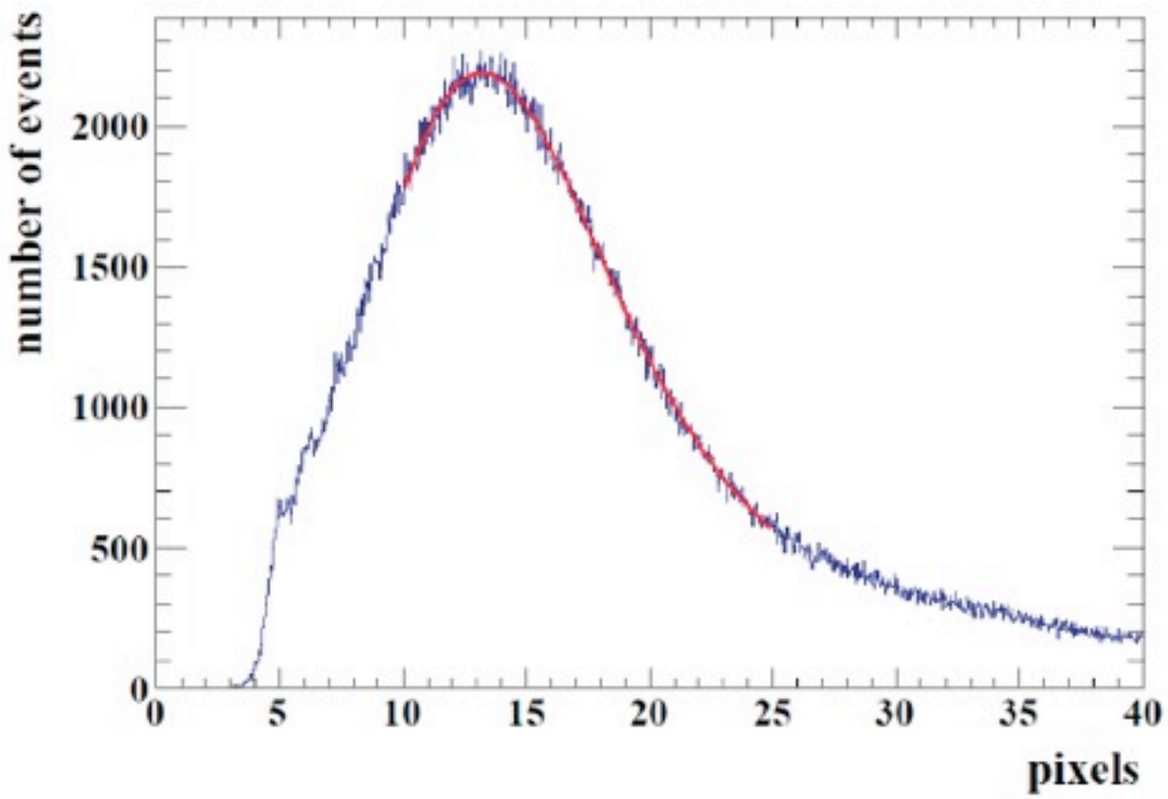


Figure 2.3.21: *Right: 25 GeV pion shower in the AHCAL with identified minimum-ionizing tack segments. Left: Mean multiplicity of identified track segments as a function of particle energy, comparing data to various Geant4 physics lists.*

- Can investigate complex aspects of shower structure -
- Agreement with some physics lists give confidence in simulations!

Technical Validation



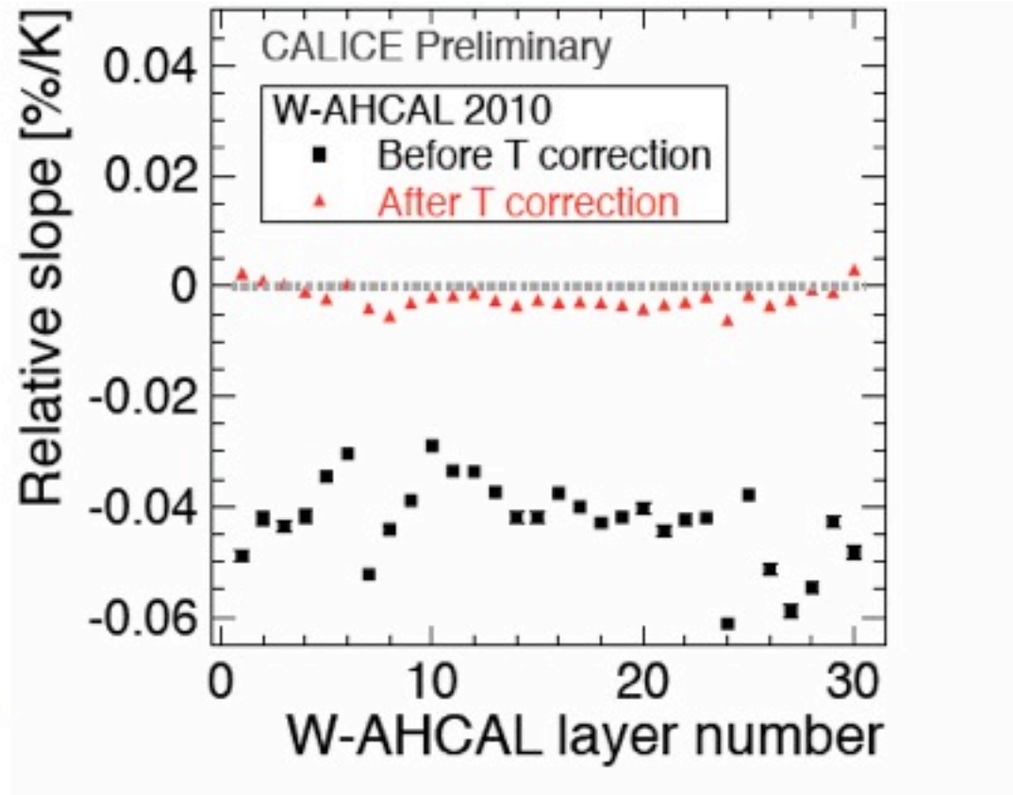


Figure 2.3.24: Left: Response of a HBU of the technical prototype to 2 GeV electrons, showing a light yield of approximately 15 photons per MIP. Right: Layer wise distribution of the relative slopes of the temperature dependence for minimum-ionizing particles with (red) and without (black) temperature correction.

- Good control of response variation due to changing environmental parameters
- First test beam results of technical prototype HBU units

Future R&D Steps

- Coming up: One module with 4 HBUs in TB at CERN
  - Full system validation, measurement of time structure of hadronic showers
    - Performance results will go into DBD
- Laboratory test of one full slab (6 HBUs in a row) in mechanical prototype - Results can also enter final version of DBD
- First board for SMD-SiPM version (for NIU scintillator concept - SiD)

- Construction of an EM stack (ca. 10 HBUs), test at DESY in 2013
  - Expansion to a full hadronic prototype 2014 or beyond
- Longer term: Scintillator tiles without WLS fiber: Tiles + SiPMs under construction, further development ongoing

- Further work on proof of concept: Industrialization, interfaces, services,...