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AIDA-2020

Advanced European Infrastructures for Detectors at Accelerators

Presentation

A highly granular scintillator-based hadron calorimeter prototype with integrated readout

Hartbrich, Oskar (DESY) *et al*

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A highly granular scintillator-based hadron calorimeter prototype with integrated readout

- AHCAL concept
- physics prototype
- technological prototype
  - integration
  - further testbeam plans
- conclusions & outlook

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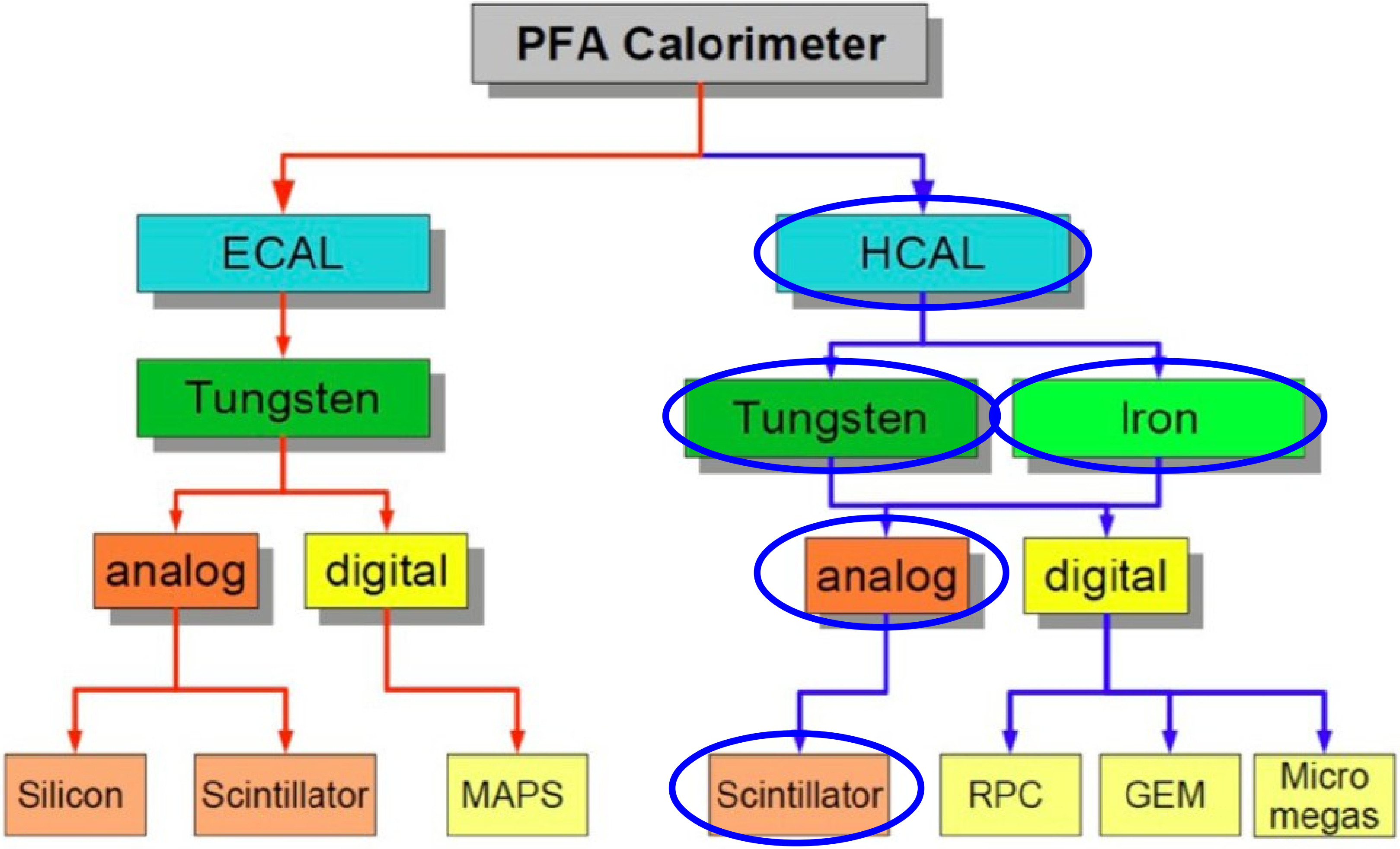
for the CALICE collaboration

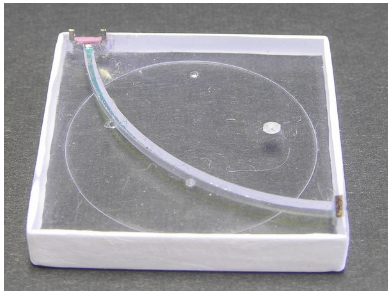
CALOR 2016

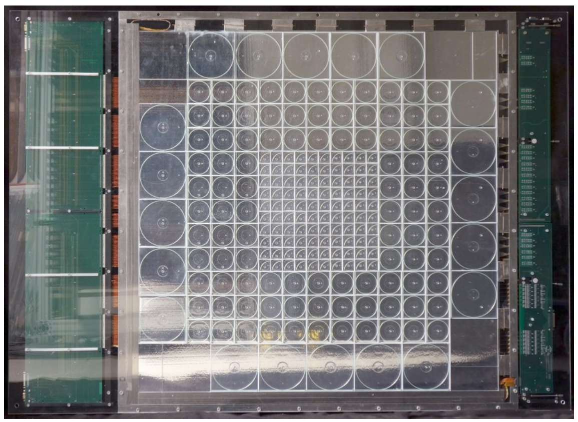
Daegu, 15-20 May 2016

Calorimeter Technologies for Linear Collider detectors

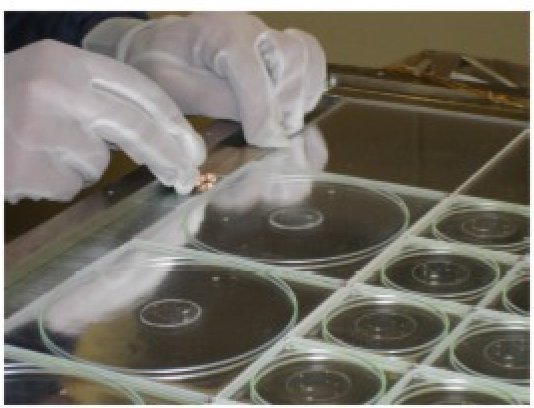


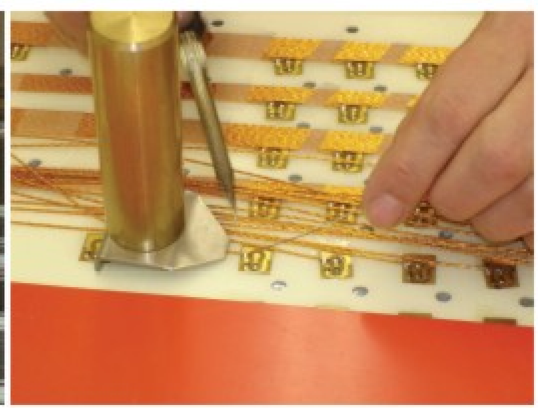
Analogue HCAL: physics prototype

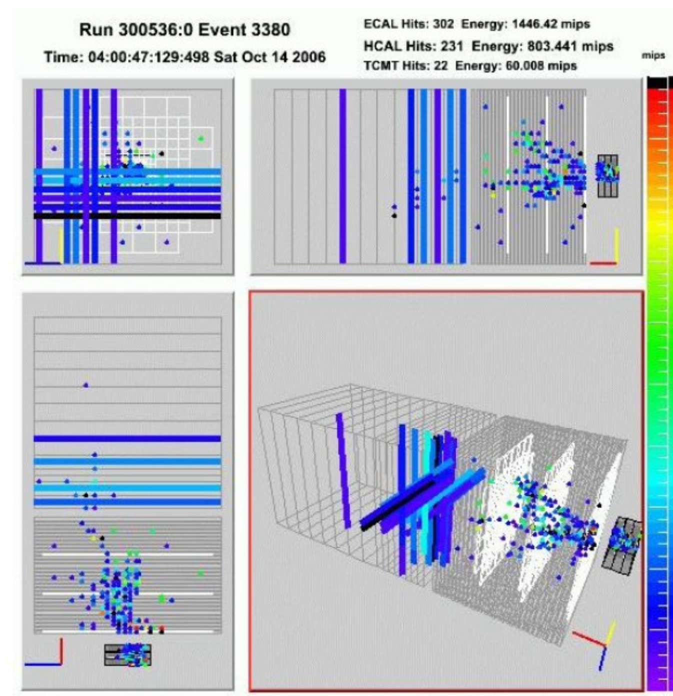




- based on scintillator tiles with WLS fibers, read out by SiPMs
  - 3*3 cm^2 - 12*12 cm^2 tiles, 7608 channels
  - analogue readout: 12 bit
- 1m^3 prototype in beam tests 2006-2012
  - first device using SiPMs at large scale

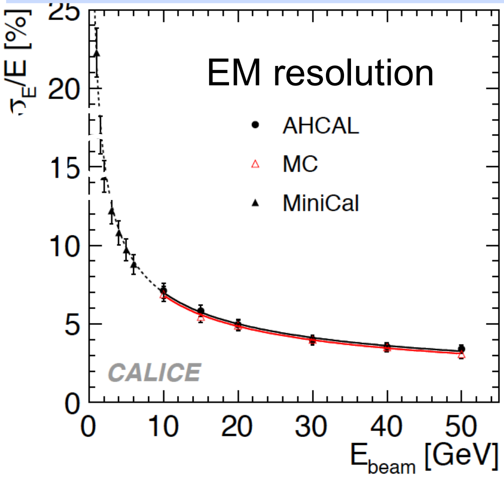






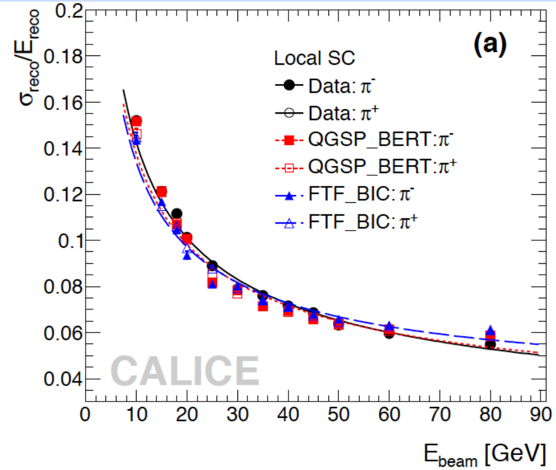
AHCAL physics prototype: results

Detector validation



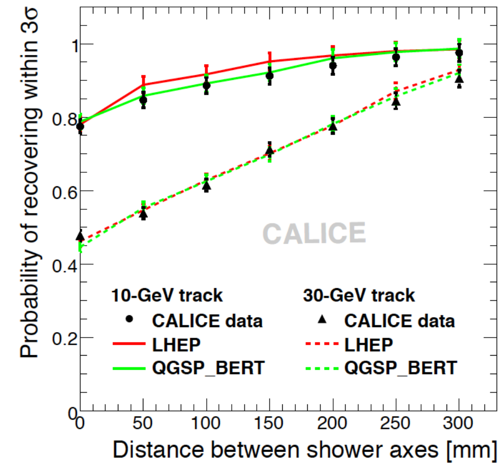
JINST 6, P04003 (2011)

Performance validation



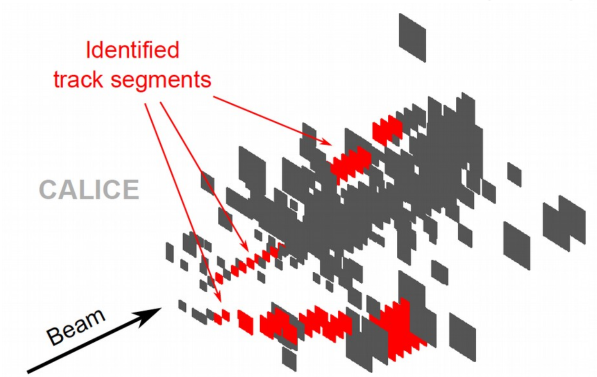
JINST 7, P00917 (2012)

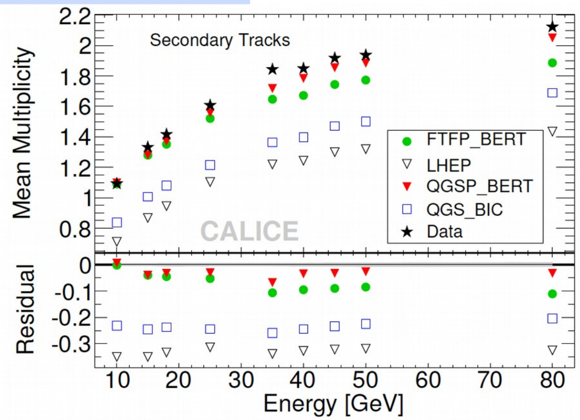
Particle Flow validation



JINST 6, P07005 (2011)

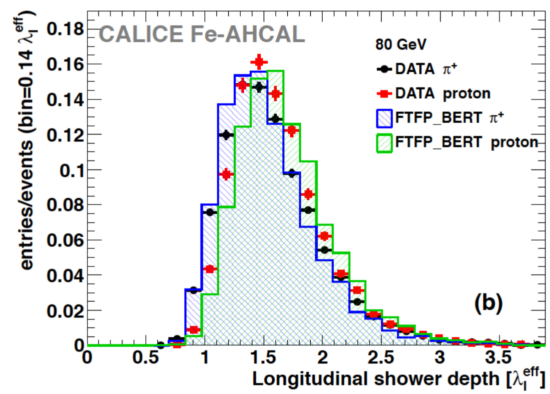
Imaging validation





JINST 8, P09001 (2013)

π/p separation

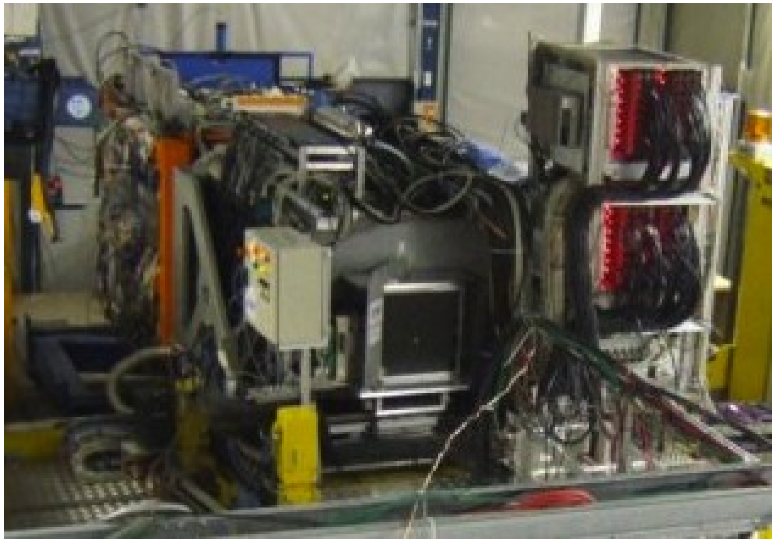


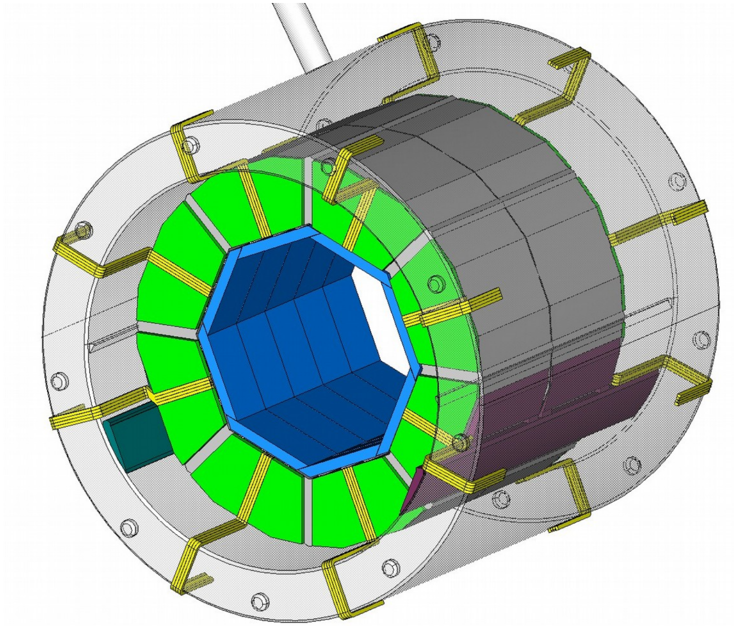
JINST 10, P04014 (2015)

From physics prototype to technological prototype

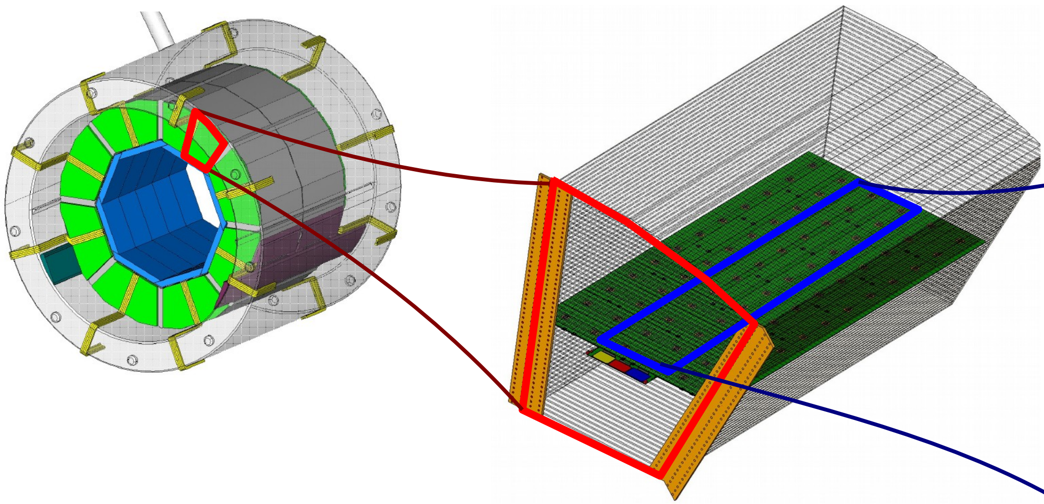
- capabilities of a highly granular scintillator-steel (or tungsten) calorimeter successfully demonstrated with the "physics prototype"
- not scalable to a collider detector:
  - external electronics
  - external LED calibration system
  - labour intensive assembly

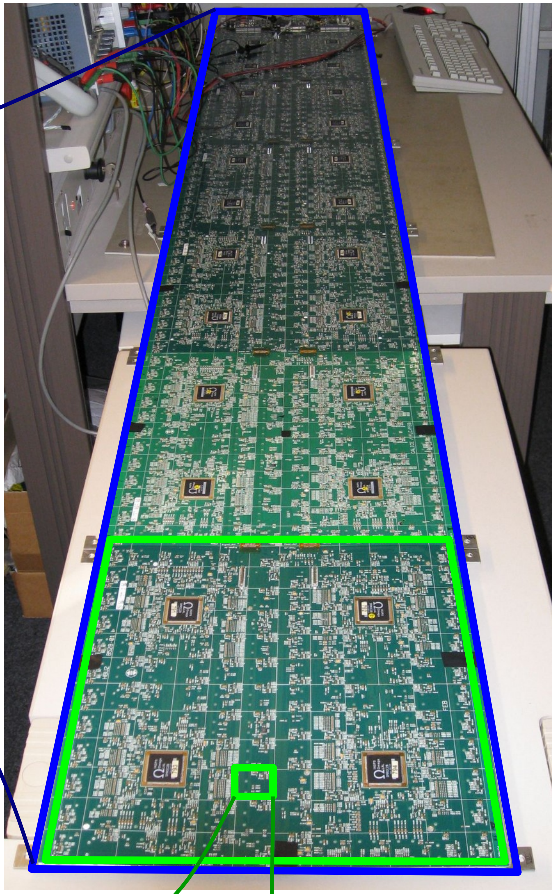
- goal for the "technological prototype": develop, build and test a prototype scalable to the full ILC detector layout
  - integration of electronics into layers
  - realistic infrastructure
  - easy mass assembly

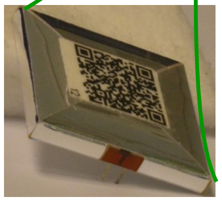




AHCAL: Technological Prototype



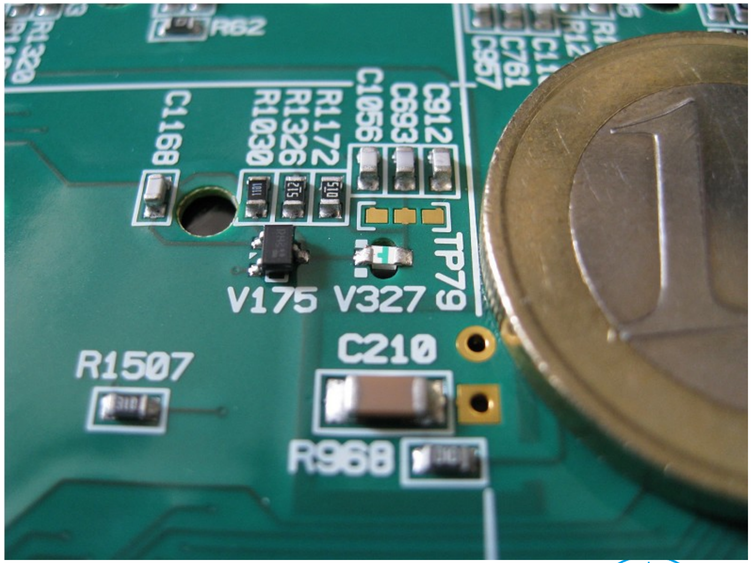




- fully integrated design
  - front-end electronics, readout
  - voltage supply, LED system for calibration
  - no cooling within active layers
- scalable to full detector (~8 million channels)
  - mechanics, electronics, sensors
  - production, commissioning

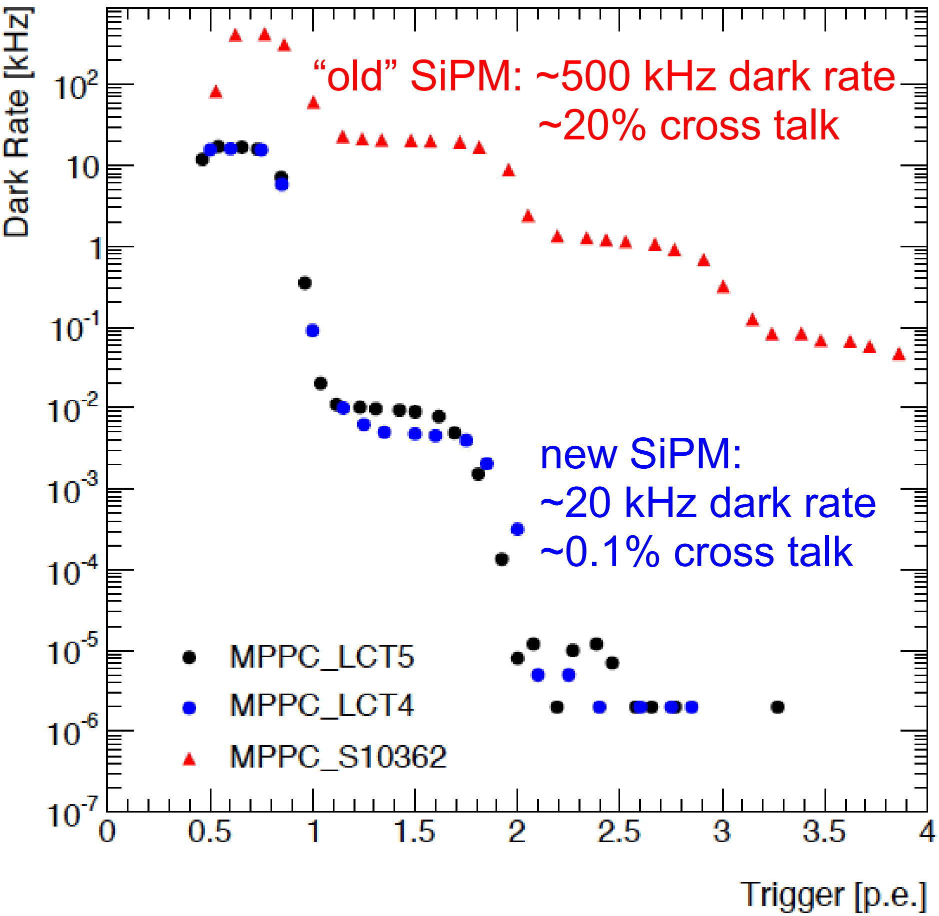
Electronics: HBU

- HCAL Base Unit (HBU)
  - extra-thin PCB, cutout for ASICs
  - $36*36cm^2$, 144 channels
- readout ASIC: SPIROC2b
  - designed by OMEGA, France
  - alternative: KlauS2, Heidelberg
- integration
  - readout (DAQ), voltage supply
  - LED system for SiPM calibration
- flexible technology
  - can be used for different SiPMs
  - adapted versions for several scintillator geometries
  - plan to go to BGA-mounted ASICs for easier assembly



New generation of SiPMs

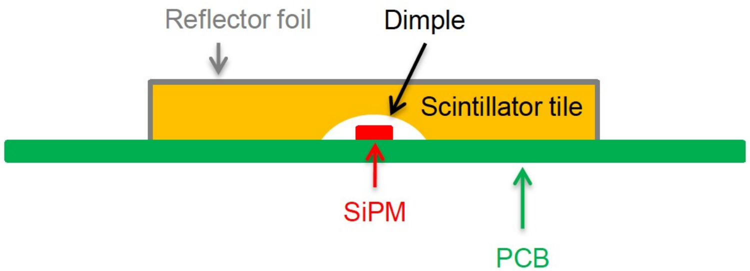
- recent SiPMs show very much improved sample uniformity
  - operating voltage
  - gain
  - → no need for equalisation
- very recently, SiPMs with trenches between pixels became available
  - dramatically reduced dark rate and pixel-to-pixel cross talk
  - for typical trigger threshold of AHCAL (~7 p.e) **noise-free**
  - → allows auto-trigger operation
- SiPMs are a rapidly evolving field
  - new generation fulfills our requirements

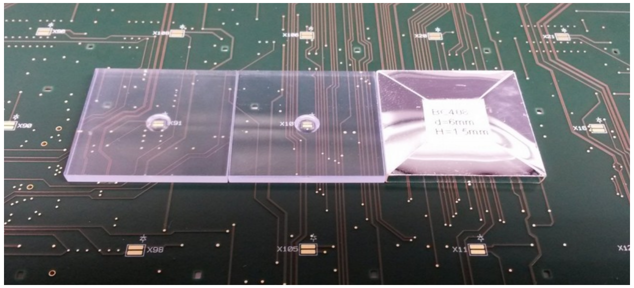


for comparison: SiPMs in physics prototype
2 MHz dark rate, 30% cross talk

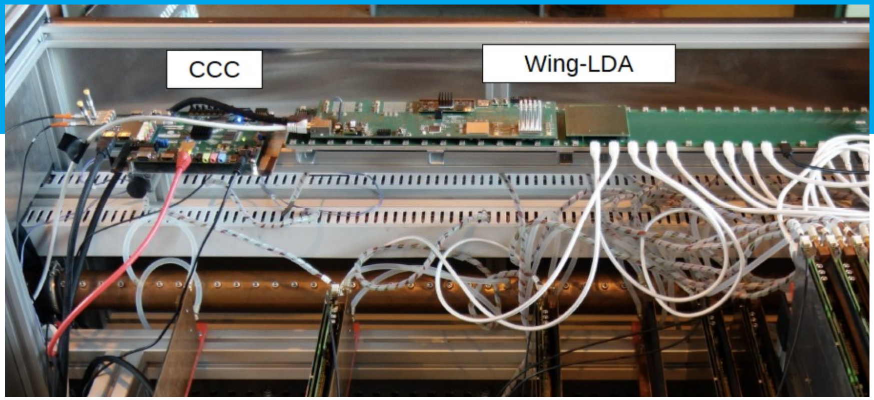
Towards mass production: simplified tile & HBU design

- tile design with SiPMs mounted on the side of the tile not suitable for mass assembly
- tiles with surface-mount SiPMs fulfill HCAL requirements
  - signal size
  - signal uniformity across tile
- new HBU design for surface-mount SiPMs:
  - SiPMs mounted directly on PCB
  - individually wrapped tiles
  - ➔mass assembly with pick-and-place machine possible
- very positive experience in testbeam



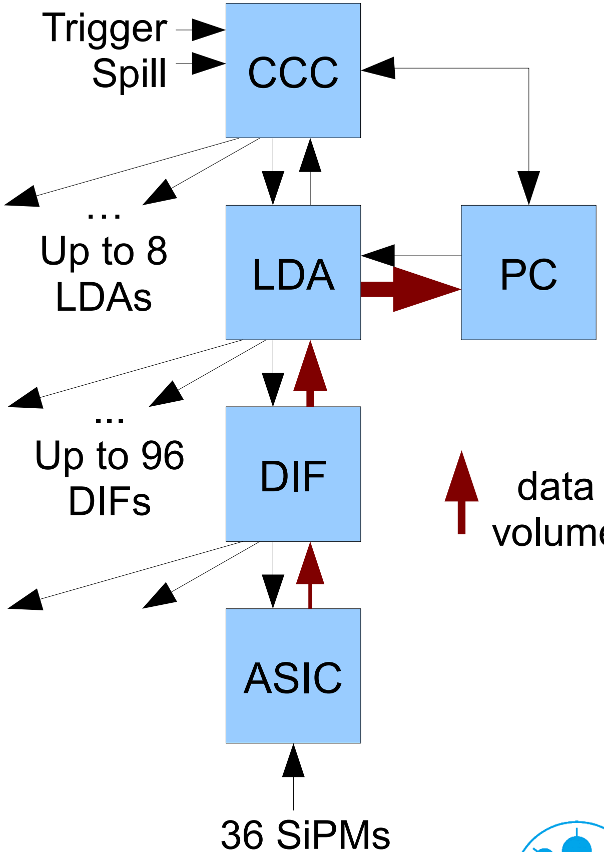


System integration: DAQ



- modular hierarchical DAQ system
- based on HDMI cables
- versatile for use in testbeam and in ILC-like conditions
- scalable to full collider detector
  - setup used in testbeam adapted to LC detector geometry, can read out 2*48 layers
- successfully operated in beam tests
  - stable running
  - power pulsing
  - reached ~30 readout cycles / s (requirement for ILC: 5)

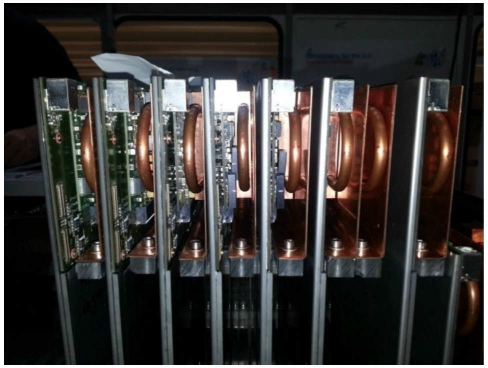
    → >450 Hz sustained event rate
- tested also common running with other calorimeter prototypes



DESY

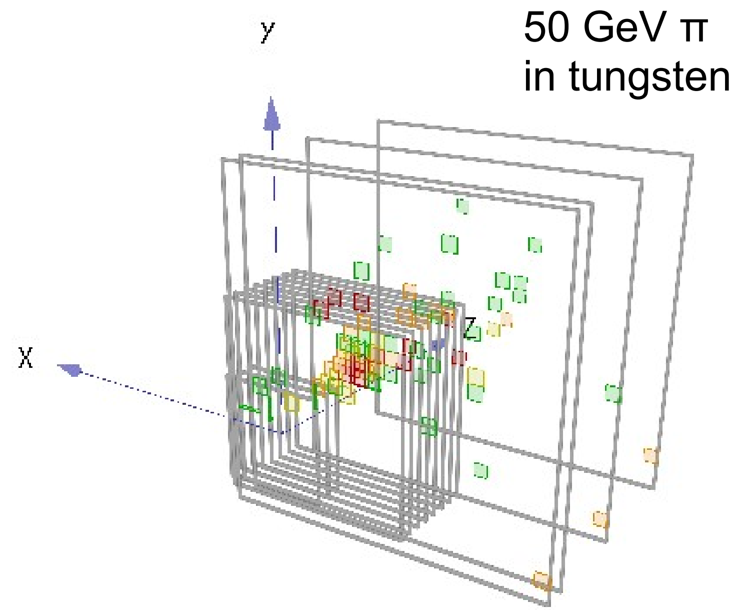
System integration: mechanics, power, cooling

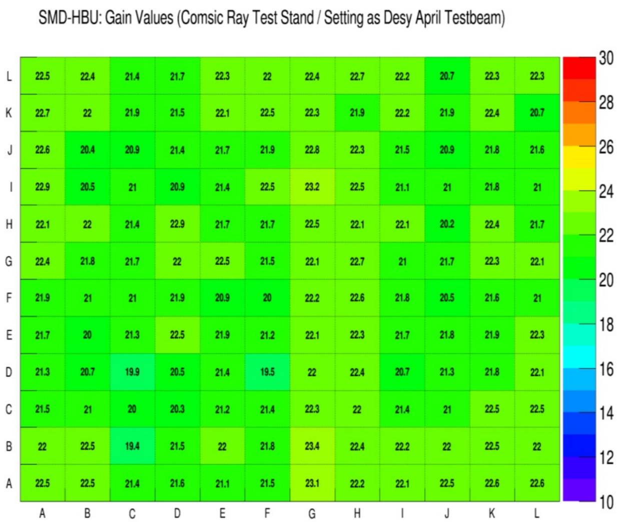
- steel absorber structure for beam tests
  - realistic sizes and tolerances
  - corresponds to ~1% of ILC detector barrel
- horizontal steel structure for thermal tests
  - size of a full layer
- cooling for interface electronics
- power supply and distribution for full barrel sector



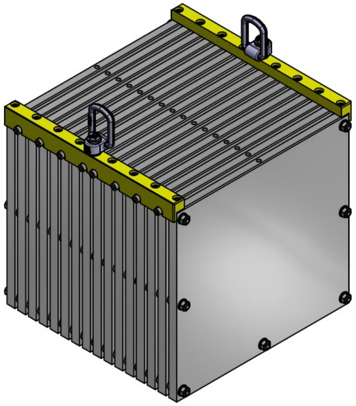
AHCAL Testbeams

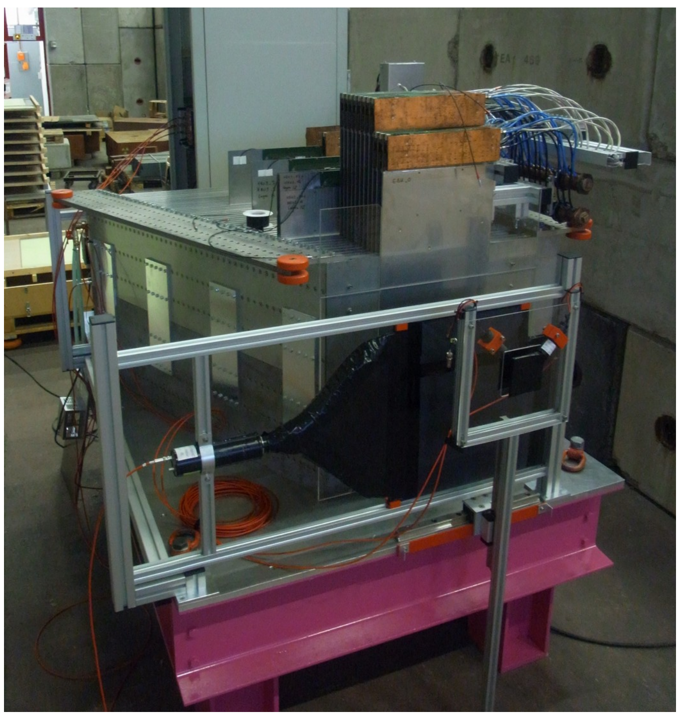
- 2 times 2 weeks of testbeam at SPS in 2015
  - steel and tungsten absorber
  - partly equipped active layers
  - muons and electrons for calibration
  - energy scans 10 – 90 GeV for pions to study shower shapes and hit timing
- one small layer with recent SiPMs and new tile design
  - very positive experience
- successful test of system aspects
  - DAQ, mechanics, power, cooling
  - online monitoring
  - distributed data analysis
  - simulation





Next steps





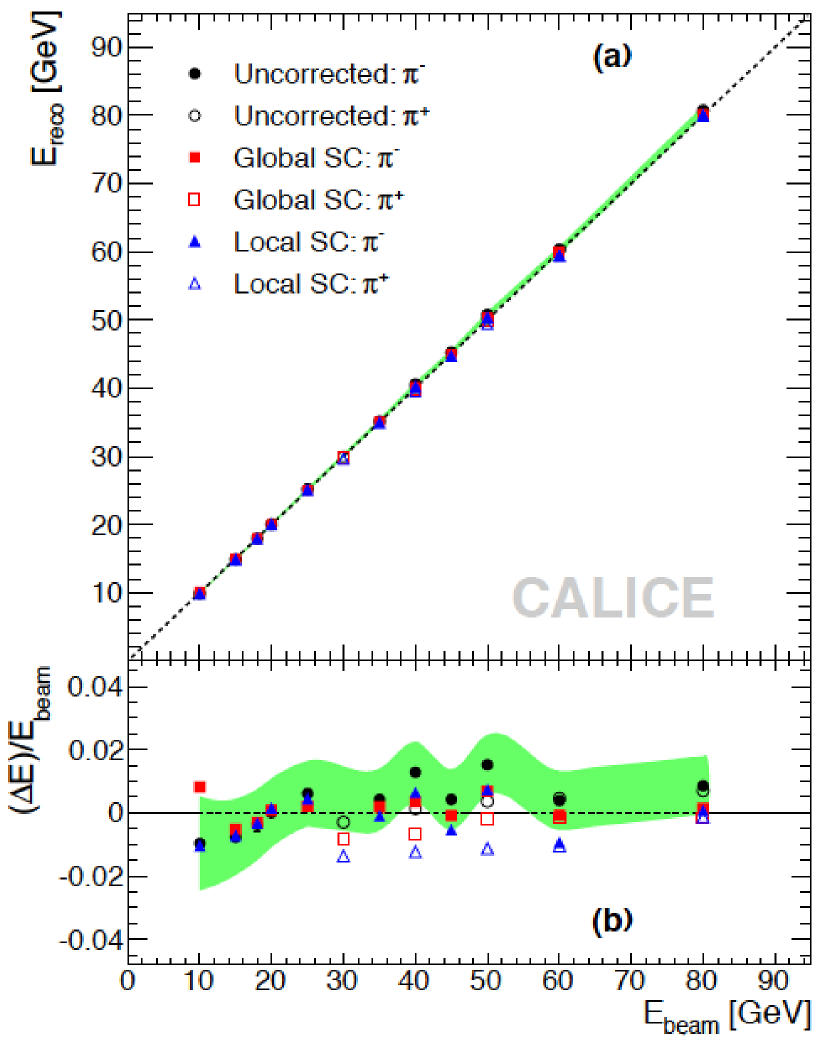
- short term: small prototype for electromagnetic showers with high-quality photo-sensors in all channels
  - demonstrate power pulsing
  - measure e.m. shower response and resolution
  - production started, first calibration measurements successful
- medium term: ~1m^3 prototype
  - big step towards mass production
  - scalable to full linear collider detector
  - barrel sector geometry
  - infrastructure as for linear collider detector

Conclusions and Outlook

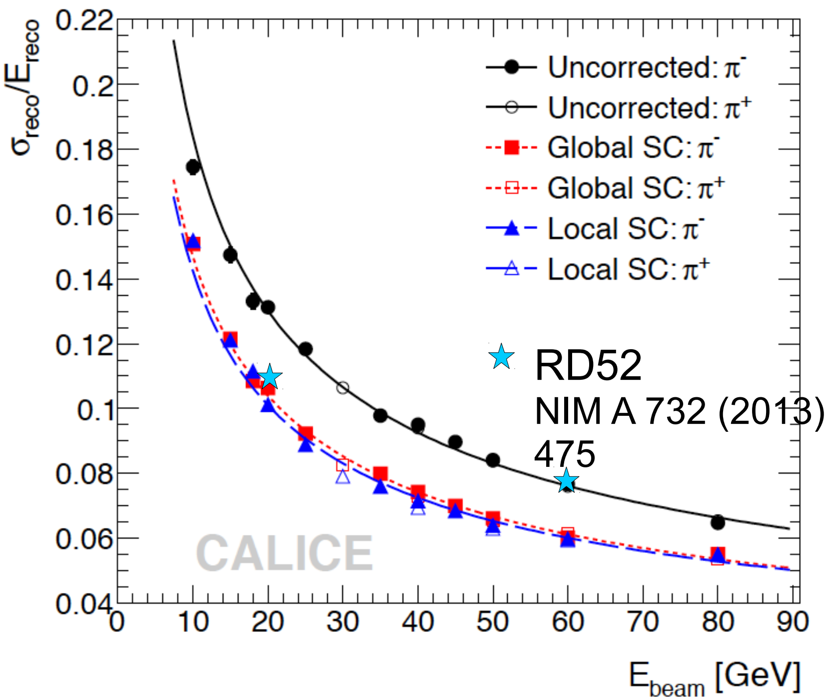
- CALICE AHCAL: hadronic calorimeter based on scintillator tiles read out by SiPMs
- physics prototype: validated detector performance and particle flow capabilities
- technological prototype: demonstrate scalability and study time development of hadronic showers
  - new generation of SiPMs: low noise and much improved sample uniformity
  - allows for simplified design, construction, commissioning and operation
  - many system aspects already tested in beam tests
  - in the process of building a large prototype to demonstrate all aspects needed for a linear collider detector

Backup

Energy resolution

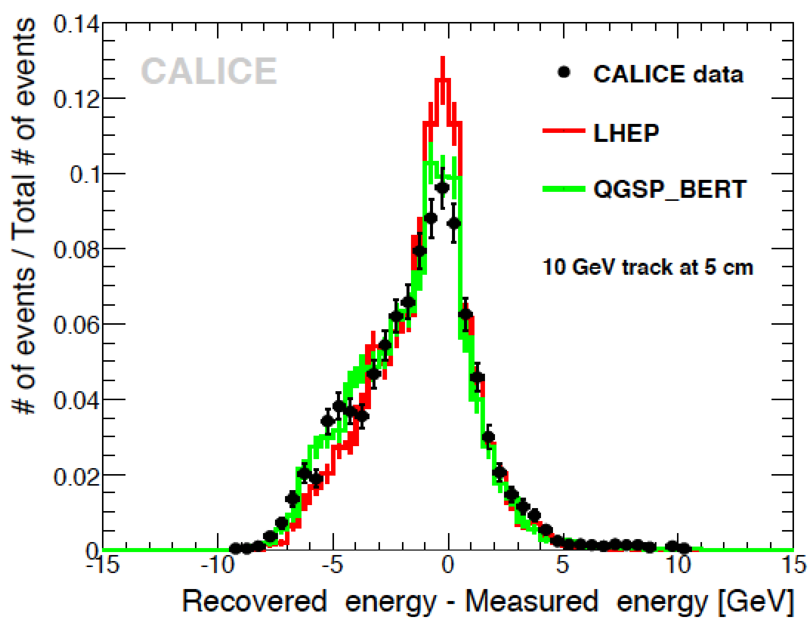


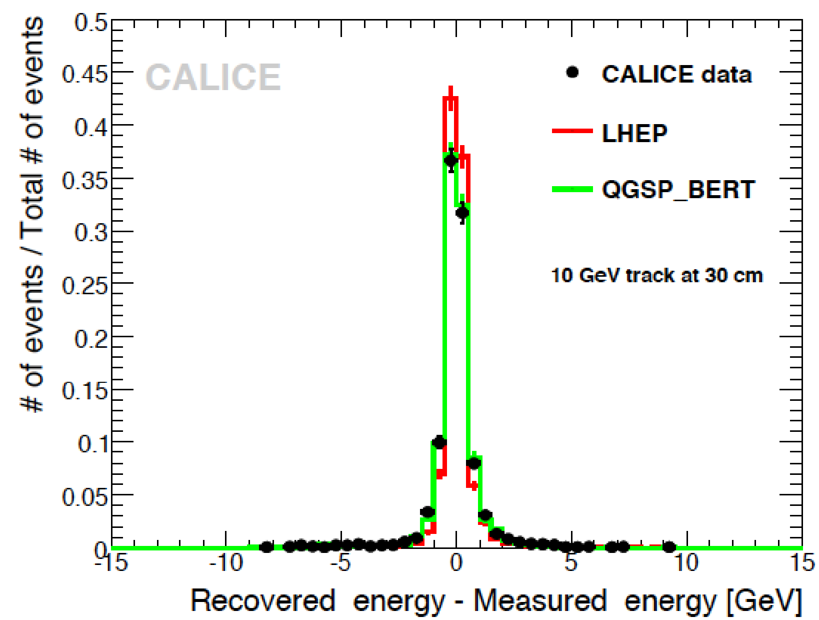
- AHCAL mainly designed for particle flow
- nevertheless, AHCAL is a quite good hadron calorimeter



Particle Flow validation

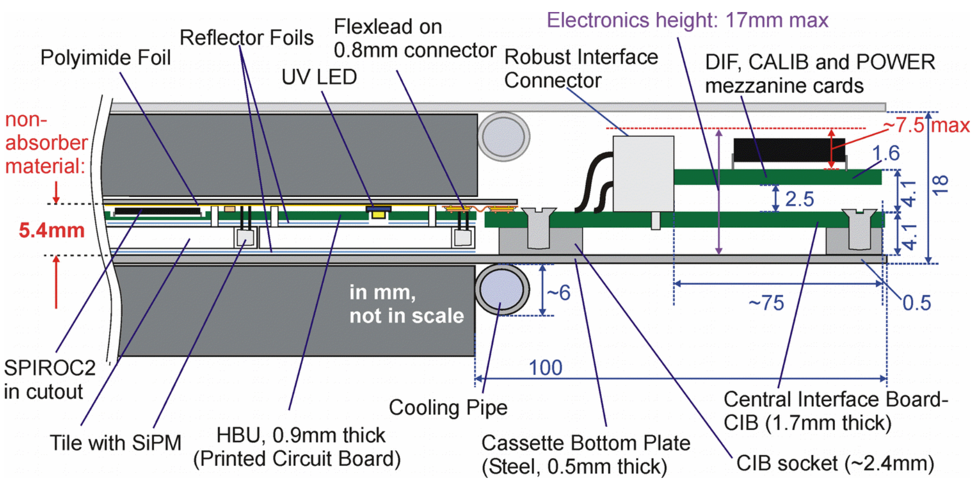
- for a direct test of the Particle Flow Algorithm a jet in a full detector slice (silicon, TPC, ECAL, HCAL, tailcatcher) with B field is needed
- beam test were done with ECAL, HCAL, tailcatcher without B field
- map measured test beam showers onto LC collider detector geometry, test distributions most relevant to PFA: shower separation of a charged hadron of 30 GeV and a “neutral” hadron of 30 or 10 GeV

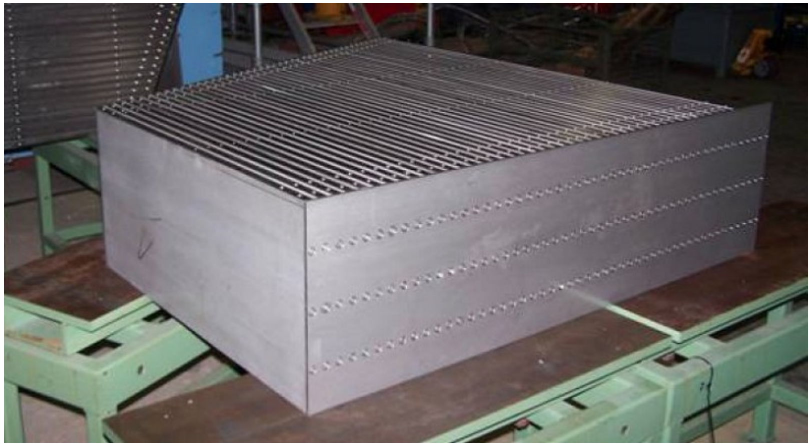


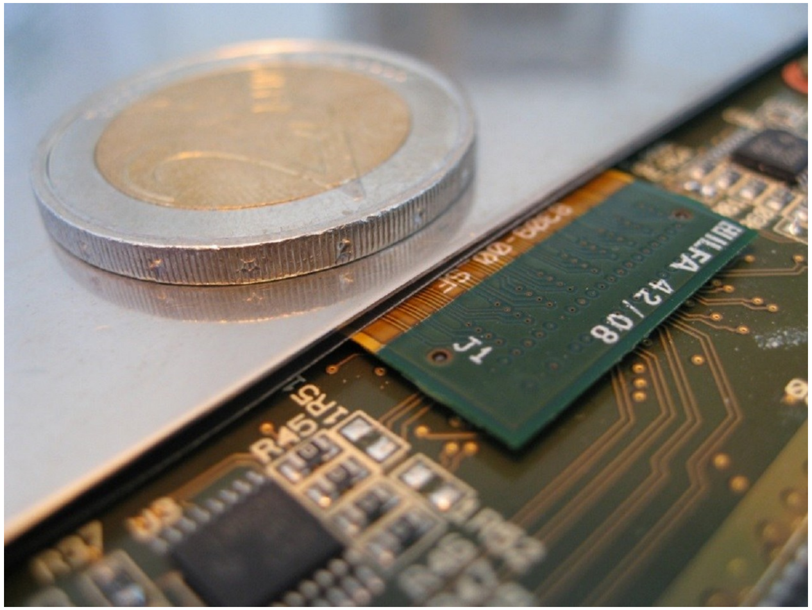


Mechanics

- absorber prototype
  - HCAL geometry for LC detector
  - ~1% of the barrel
  - many thin gaps, tight tolerances
- cassettes
  - 0.5 mm steel
  - adapted to LC detector design



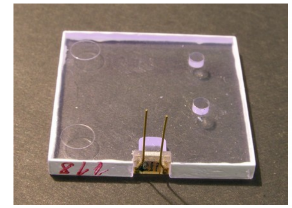


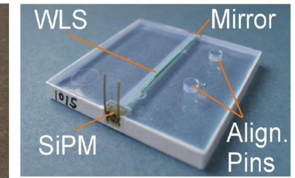


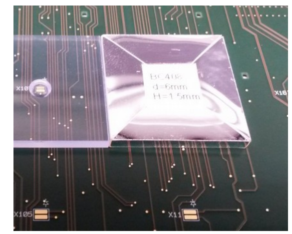
Tiles and SiPMs

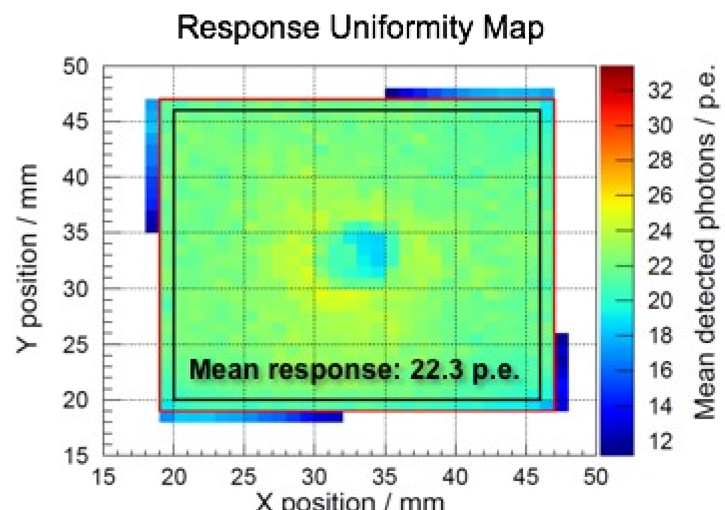
variety of scintillator tile designs and SiPM types tested

- tiles with wavelength shifting fibre
  - CPTA SiPMs with 800 pixels
- tiles without WLS
  - Ketek SiPMs with 12000 pixels
- individually wrapped tiles
  - Ketek SiPMs with 2300 pixels
  - sensl SiPMs with 1300 pixels
- surface mount SiPMs with individually wrapped tiles
  - Hamamatsu MPPCs with 1600 pixels









- we want to build a fully equipped prototype in the coming years
- experience from testbeams is important input to chose one option

Testbeams: data quality monitoring and and calibration

- online data quality monitoring
  - event display
  - (quasi-)online histograms of reconstructed quantities
- gain monitoring with regular LED runs
- MIP calibration cross check