# Analog HCAL and Scintillator Tile R&D

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for the CALICE collaboration

LC Forum Bonn,
29.4.2014

# Overview

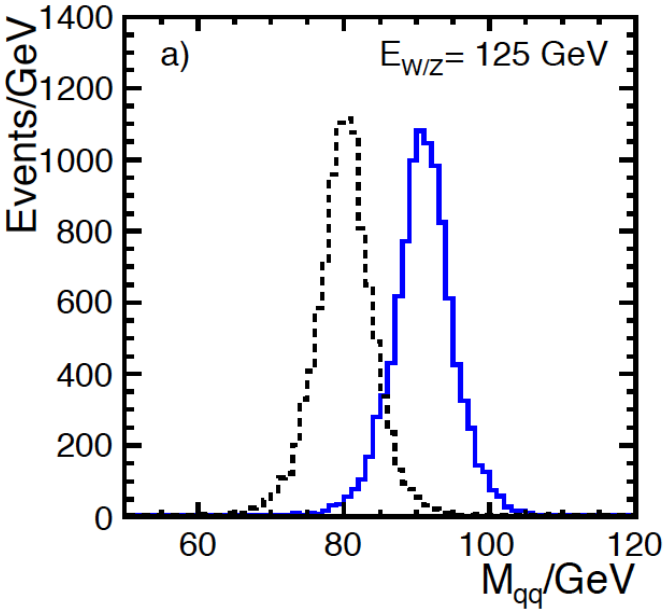
- Calorimetry at a future linear collider
- CALICE AHCAL
  - Physics prototype
  - Technical prototype
- R&D on small fractions – Tile development and automation
- Testbeam status

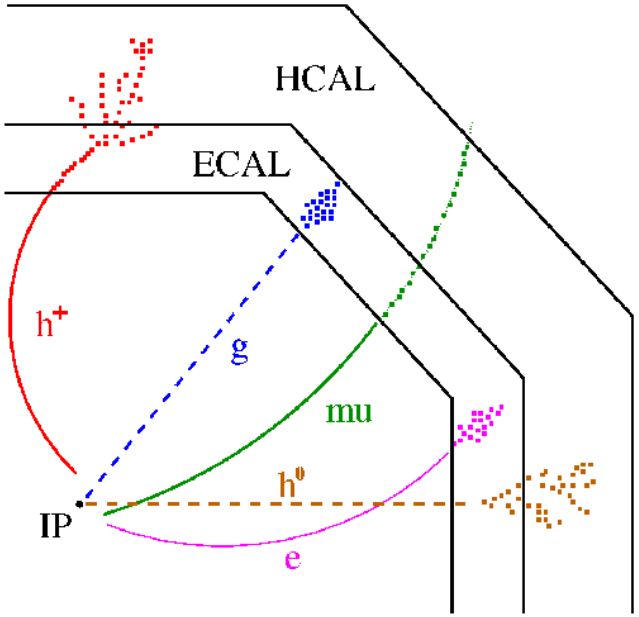
# Calorimetry at a future linear collider

- Goal: Differentiate between hadronic decays of W,Z
- Seeking energy resolution:

  $\sigma(E_{jet})/E_{jet} \approx$ 3-4% for $E_{jet}$= 40 – 500 GeV
- Classical hadronic Calorimeters:

  $\sigma(E_{jet})/E_{jet} \approx 60\%/\sqrt{E[GeV]}$
  $\rightarrow$ 10% for $E_{jet}$ = 50GeV
- ILD approach: Particle flow algorithms



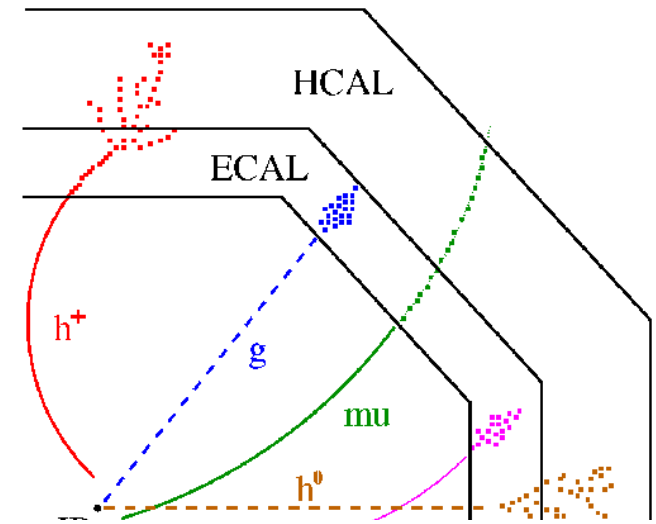
# Calorimeters for Particle Flow

Use subdetector with highest resolution:

charged particles → Tracking

e, γ → ECAL

n, K → HCAL

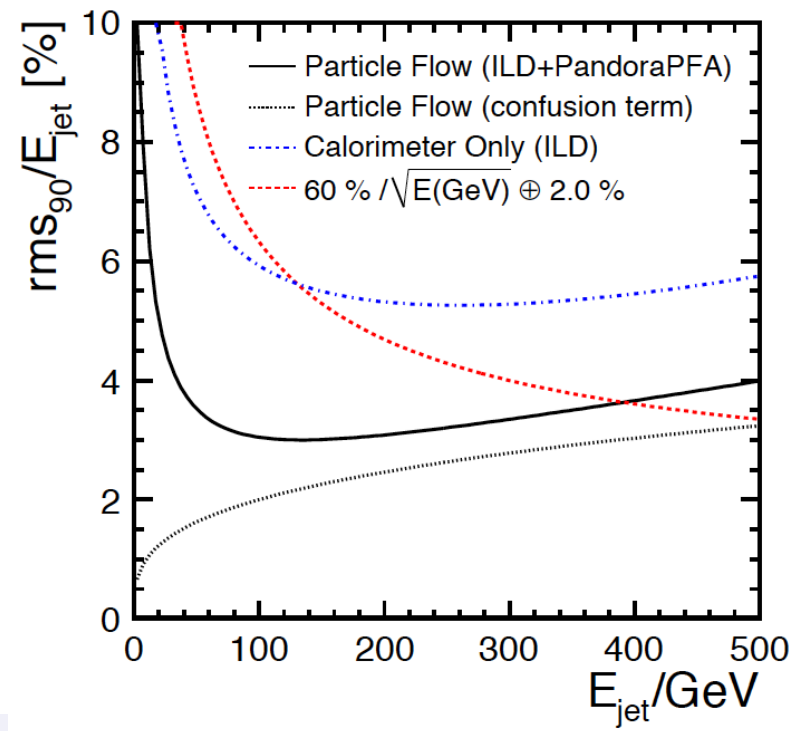



Ideally: Only measure energy of neutral hadrons in HCAL

10 % neutrals in typical jet

→ 16%/√E contribution

Dominant term at higher energies: Confusion




$$\sigma^2_{jet} = \sigma^2_X + \sigma^2_\gamma + \sigma^2_{had} + \sigma^2_{conf}$$

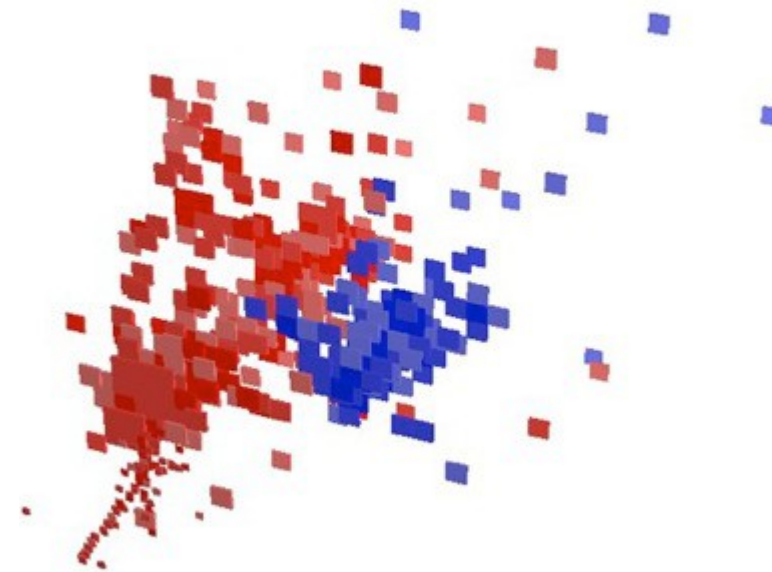
# Calorimeters for Particle Flow

Dominant at higher energies: Confusion

→ shower separation

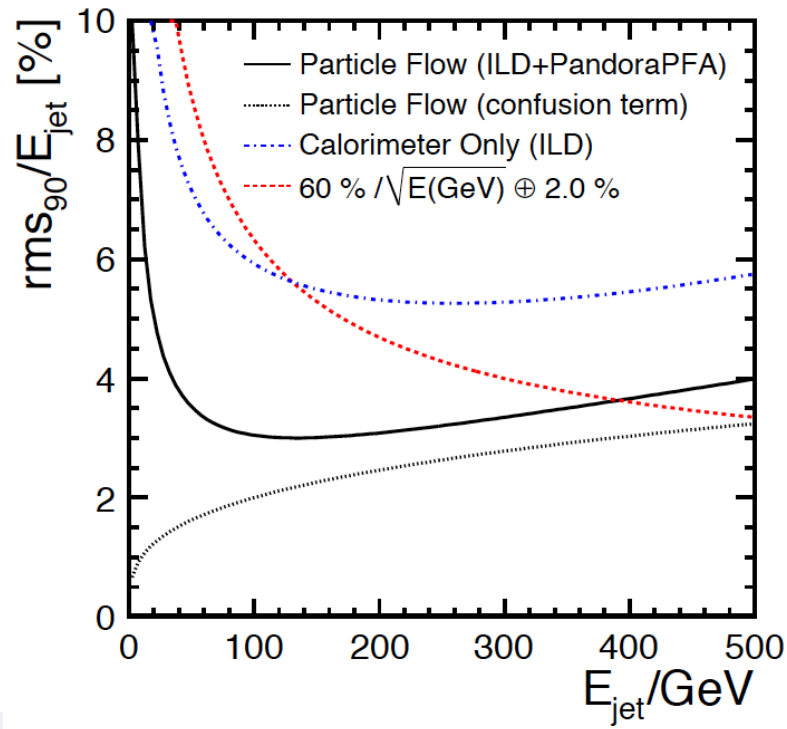
→ electromagnetic performance

→ hadronic performance



Understanding of shower structure

→ MC validation



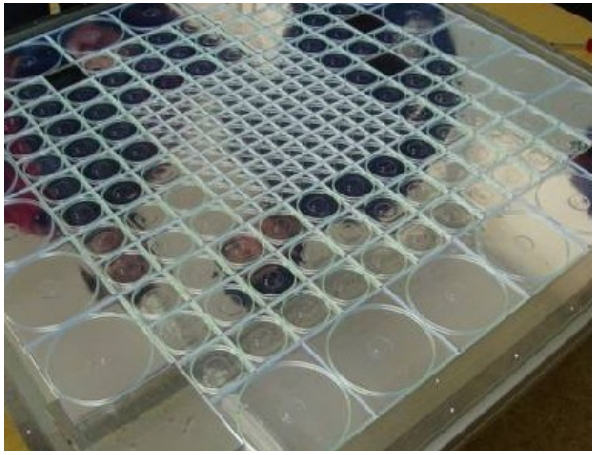

$$\sigma^2_{jet} = \sigma^2_X + \sigma^2_Y + \sigma^2_{had} + \sigma^2_{conf}$$

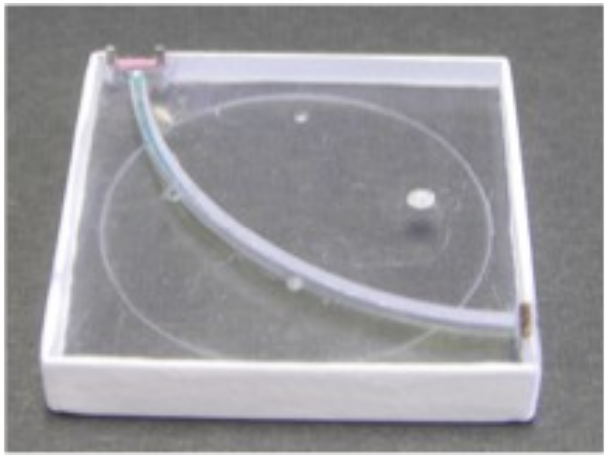
# CALICE AHCAL

- **A**nalog **H**adronic **Cal**orimeter concept
- Scintillator based sampling calorimeter,

  tiles of 3x3cm²
- Individual SiPM readout per cell
- 1m³ physics prototype operated 2006 – 2012
- Intensive Performance studies:

  EM&Hadronic showers, Imaging capabilities

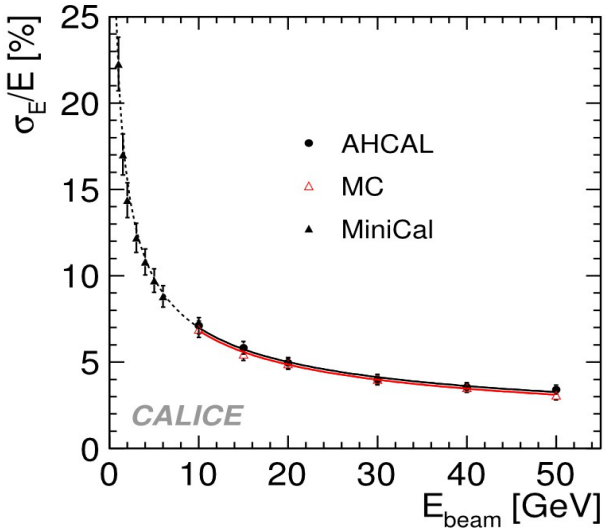




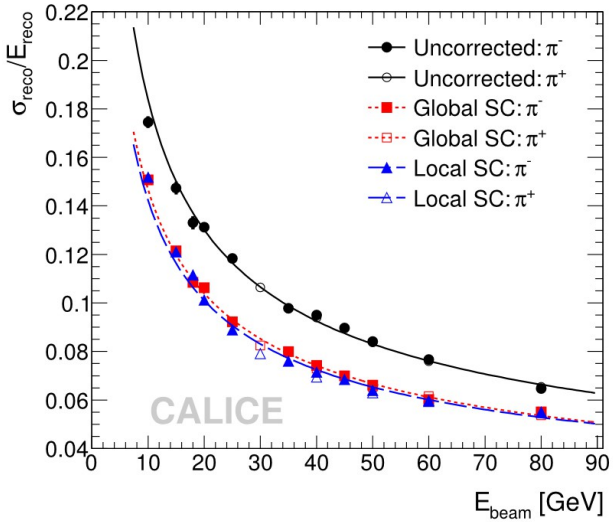
# Performance of the physics prototype

- Energy resolution
  - Electromagnetic showers
  - Hadrons
  - Response in tungsten Absorber

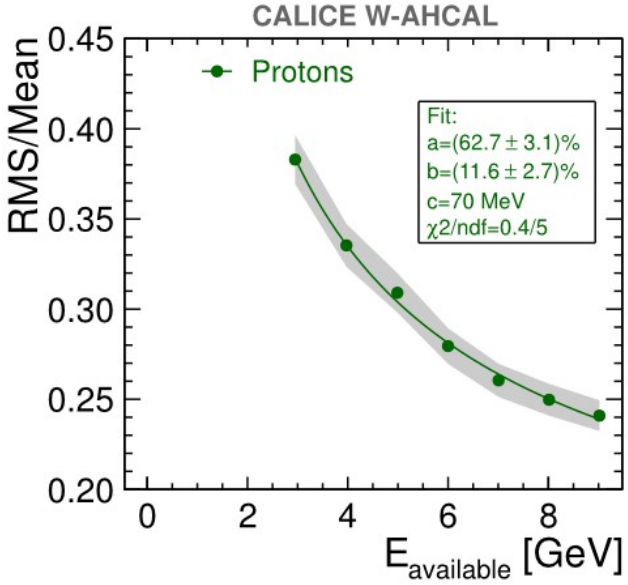
Electromagnetic response
JINST 6 P04003 (2011)




Response to hadrons
JINST 7 P09017 (2012)




Protons in tungsten
JINST 9 P01004 (2014)



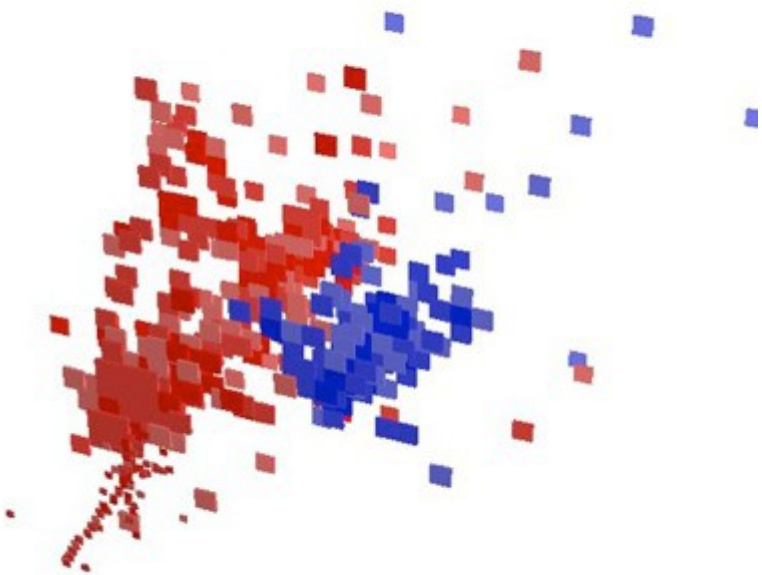
# Performance of the physics prototype

Validation of PFA capabilities and monte carlo shower models

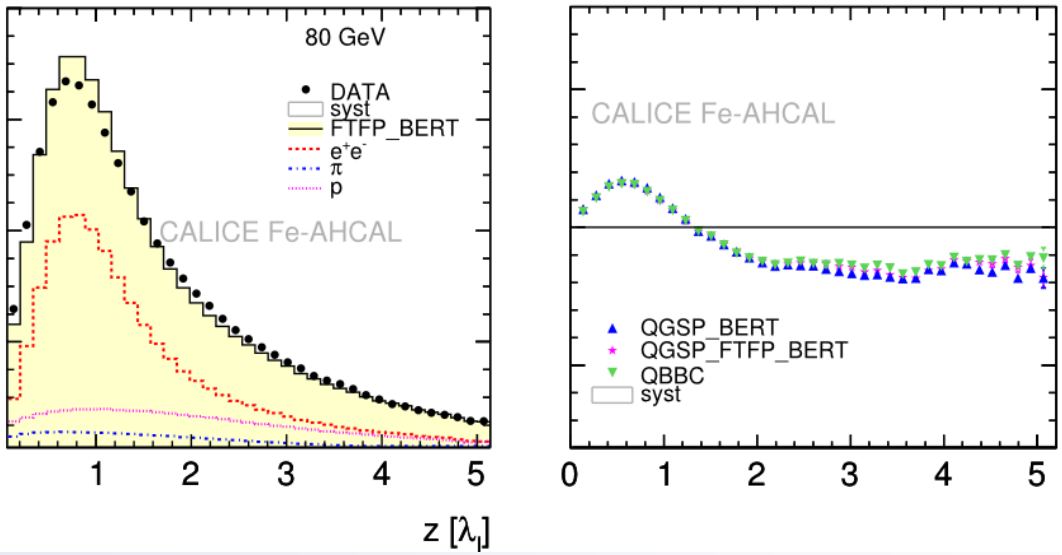
- Shower separation
- GEANT4 shower model validation

Ongoing analysis

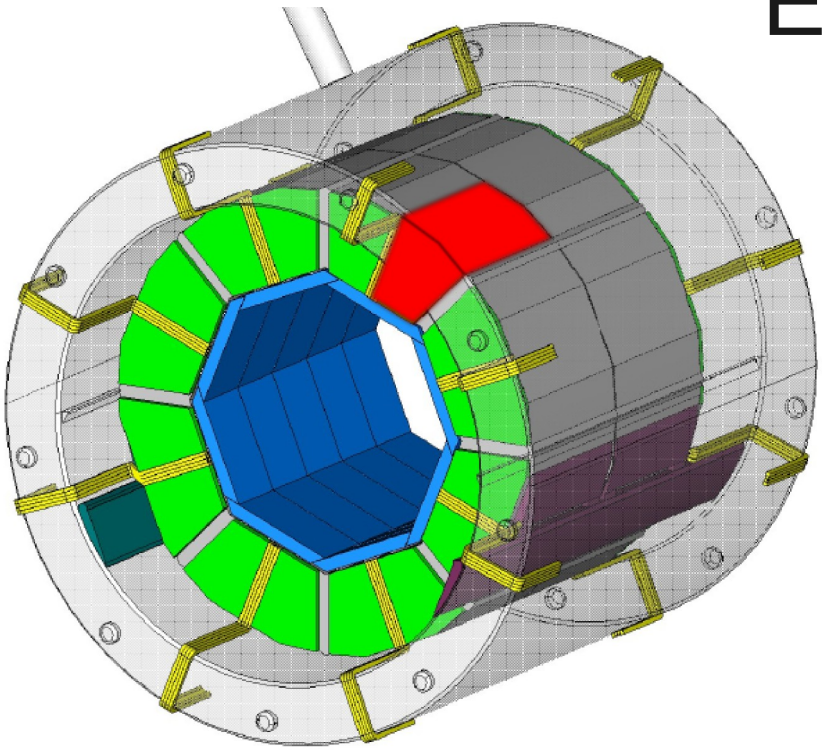
Imaging validation & performance
JINST 6 P07005 (2011)

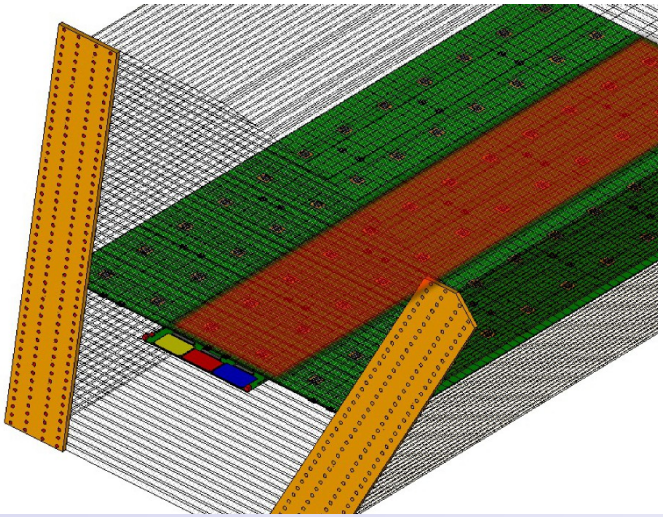


Validation of GEANT4 shower models
JINST 8 P07005 (2013)



# Heading to a scalable system
# Engineering prototype





**Challenges**

Scalability:

10 000 channels in physics prototype

8 000 000 channels in ILD detector

→ *Tile R&D for scalability*

Compactness:

High integration level

→ *Destinct readout electronics, DAQ and calibration system*

# Active elements – Tiles & SiPM

Possibility to detect single MIPs at low thresholds

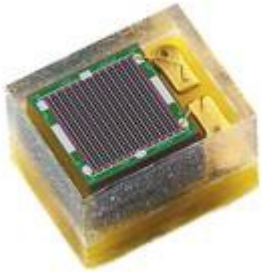
- Electronics running in autotriggered mode
- SiPM Noise rates at threshold level
- (few Photoelectrons)

Dynamic range

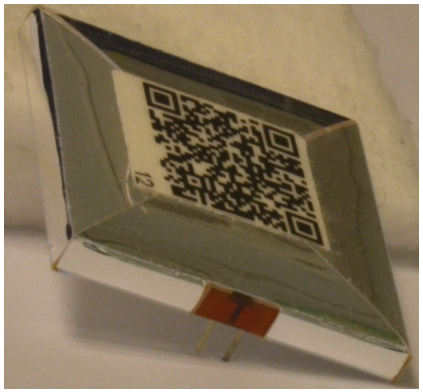
- Detect 10s of MIP without extreme saturation
- Impact on choice of SiPM: pixel count

Millions of channels

- Cost
- Time per tile: Production, Testing, Mounting, … 1s / Tile !



SiPM from KETEK



Tile, Hamburg University

# Active Elements - Tiles

Compact design

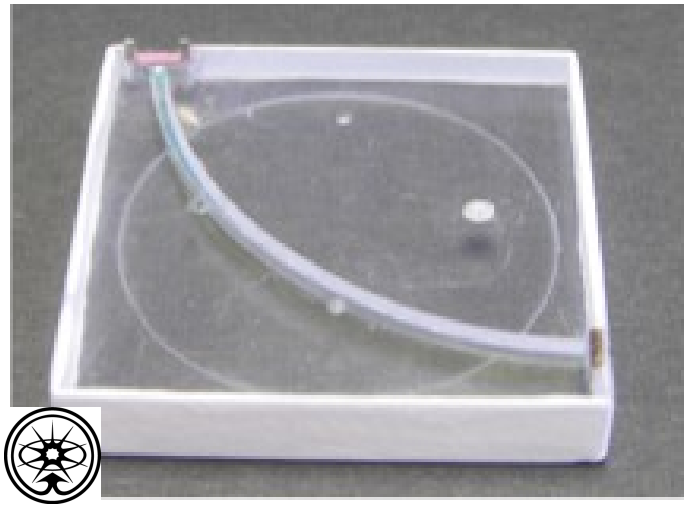
→ tight constraints, small tolerances

Mass production possibility & testing becomes important

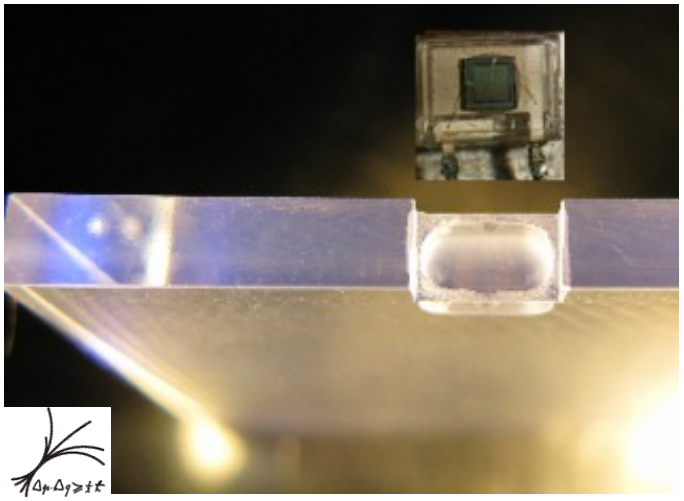
Simplifictation of tile production:

Availability of Blue & UV sensitive SiPMs → Fiberless coupling

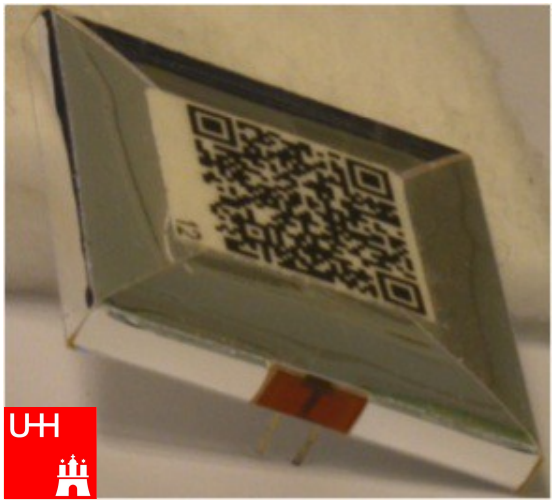
**Physics prototype**



**Concepts for fiberless coupling**



**Design for fast production**



# Active Elements - Tiles

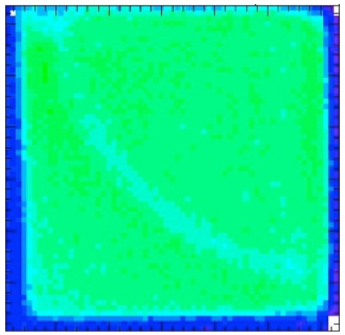
## Parameters for tile R&D

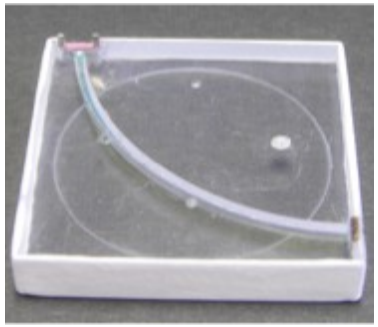
- Light yield & Noise above threshold
- Response uniformity
- Cell to cell crosstalk

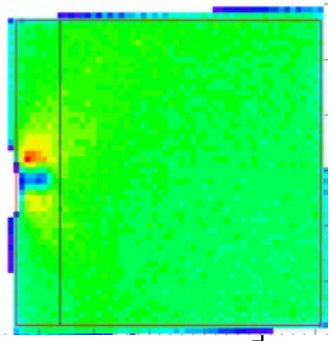
## Choice of SiPM

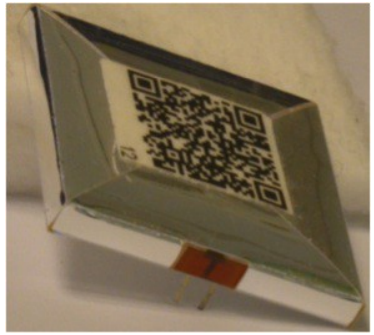
- Emission spectrum of scintillator
  → Detection efficiency of sensor
- Size of sensor
- Electronic's capabilities …

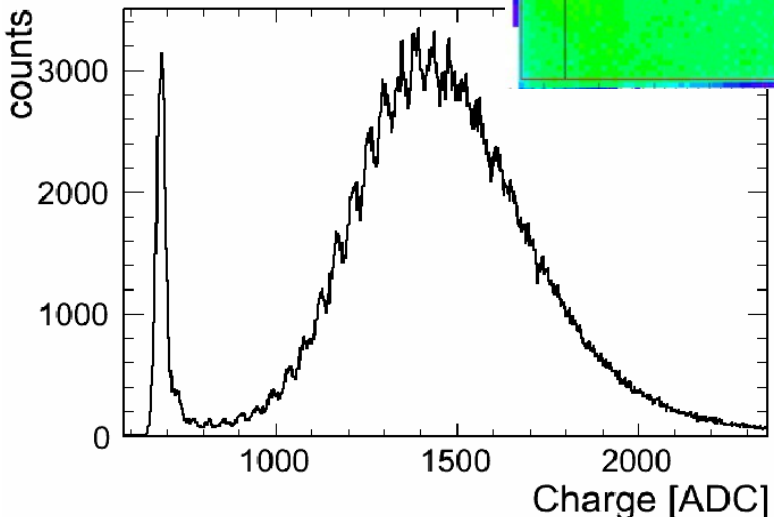
Uniformity scans
using Sr90 source









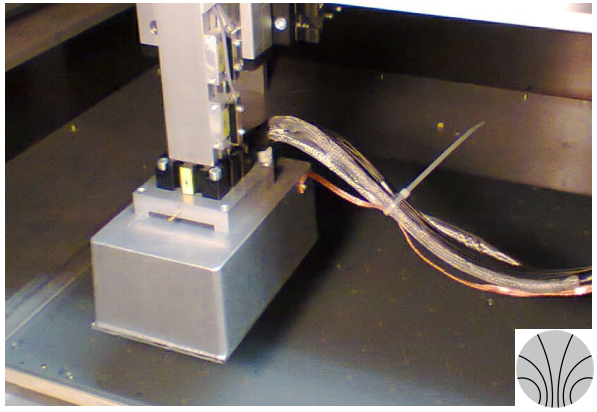


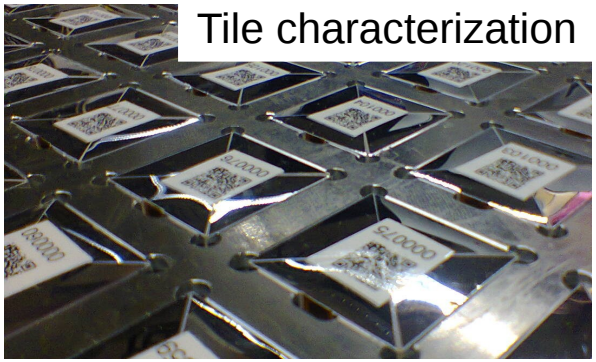

Tile B) response to
β source

# After the tile production...

## Quality assurance

- Basic functionality test
- Uniform detector response
- → LY or SiPM parameter equalization across detector





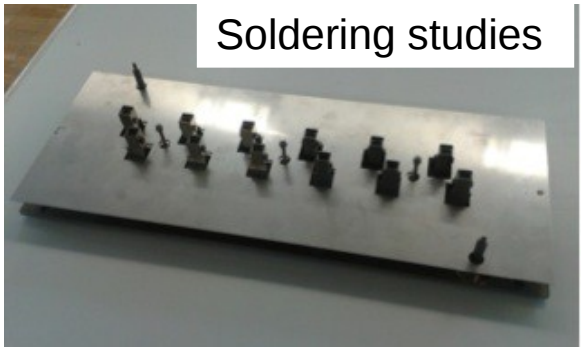
Tile characterization

## Assembly in larger modules:

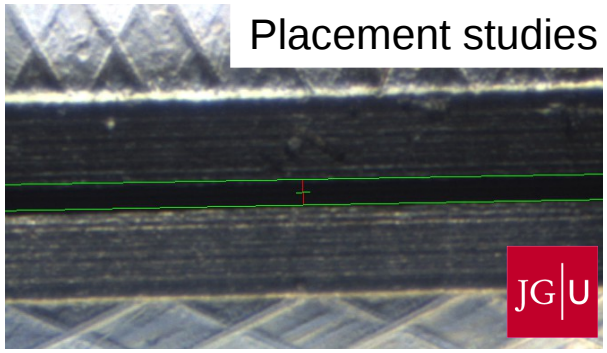
- Precise placement
- Soldering

**Challenges**

- Precise placement
- Heat sensitive components

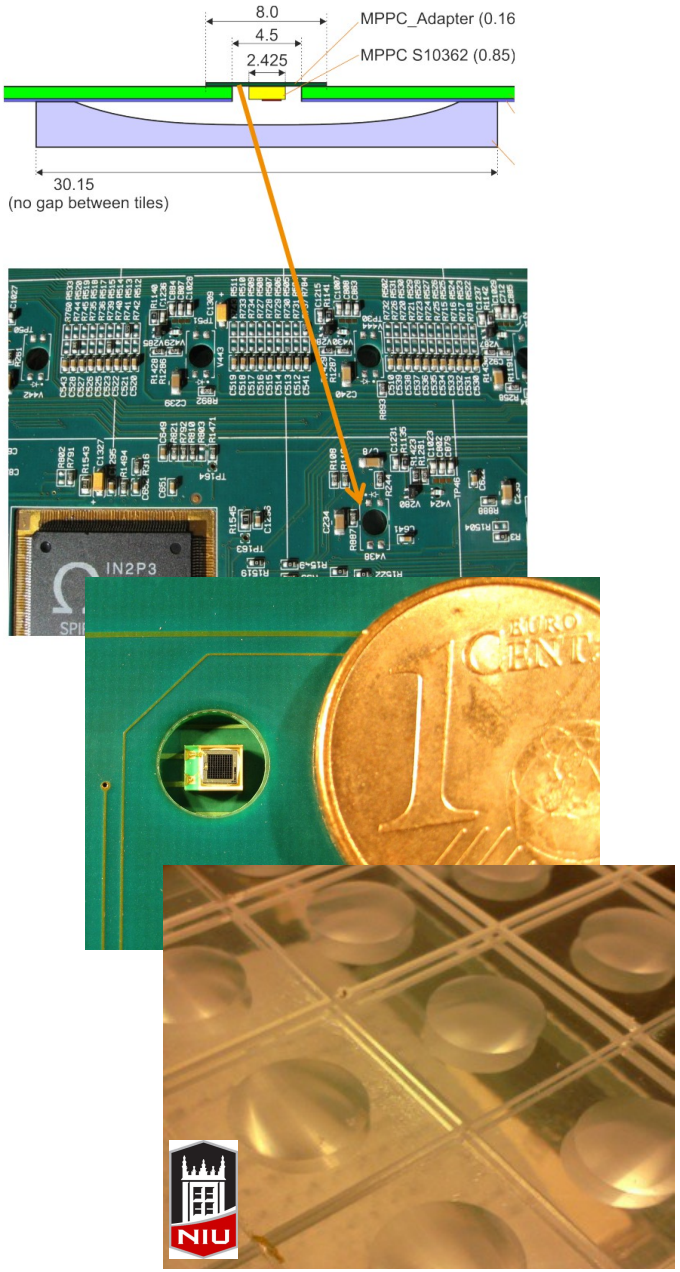


Soldering studies



Placement studies

# Reevaluating the tile designs




Tile production is still challenging

- complex production
- placement & soldering

Differing Concept:

- SiPM mounted on board directly
- Dimple in tile for uniform light response

Scintillator in one piece:

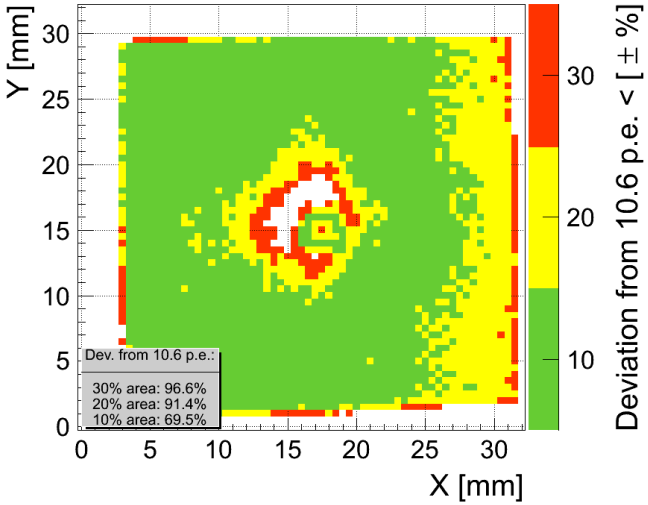
**Megatiles**

- Reducing the number of individual components by ≈ 100

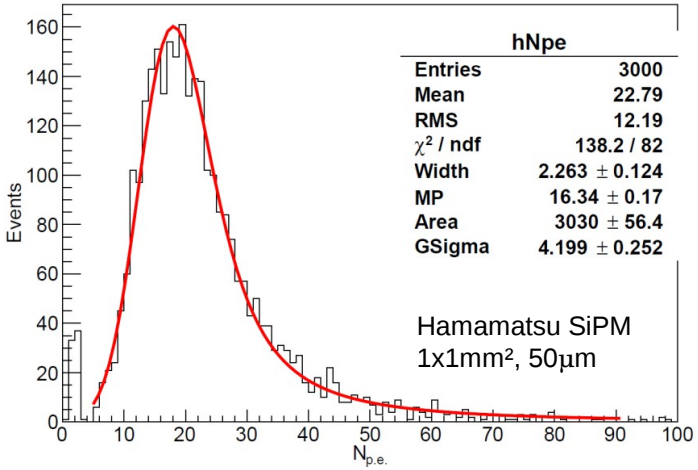
# Reevaluating the tile designs

Similar studies:

- Single tile designs
  - Light yield & uniformity comparable to tiles w. side readout
- Requiring different approaches for QA




Light yield from cosmics



# Readout electronics

## Lots of requirements

Precise charge measurements

→ SiPM gain calibration, cleanly detect single pixel peaks

Large dynamic range

→ Minimal nonlinear contributions from electronics

Timing

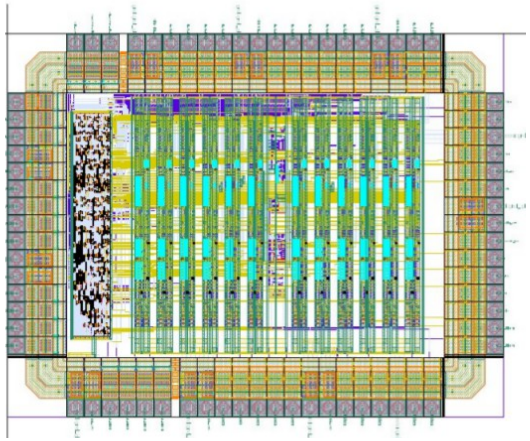
Autotriggering capability

Low Power consumption (→ Power pulsing)

Stabilization of Temperature & SiPM parameter fluctuations

(SiPM bias voltage adjustment)

SPIROC2b, Omega, Fr



Alternative input stage:
KLauS2, Hd (analog only)

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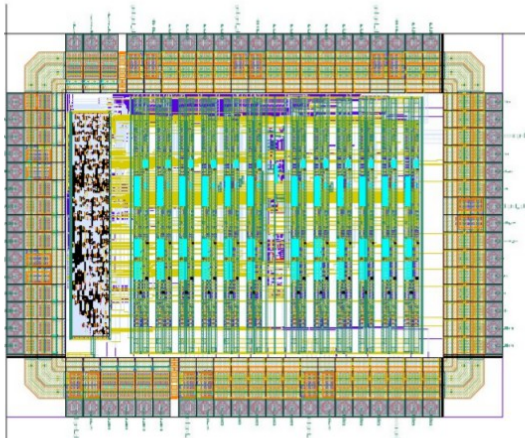
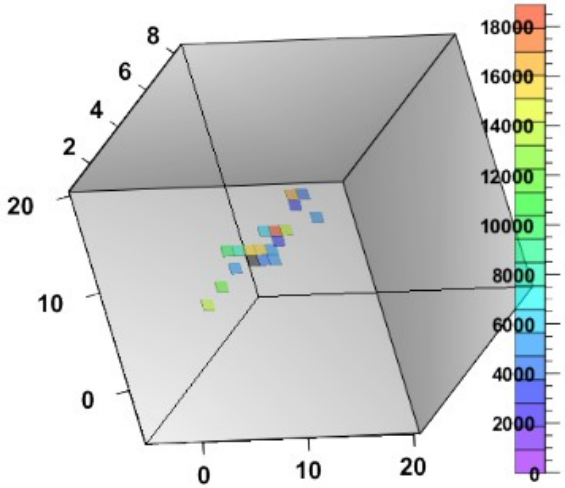


Alternative input stage:
KLauS2, Hd (analog only)

→ Requires a versatile chip that can handle different SiPMs & tiles

# Recent and upcoming testbeams

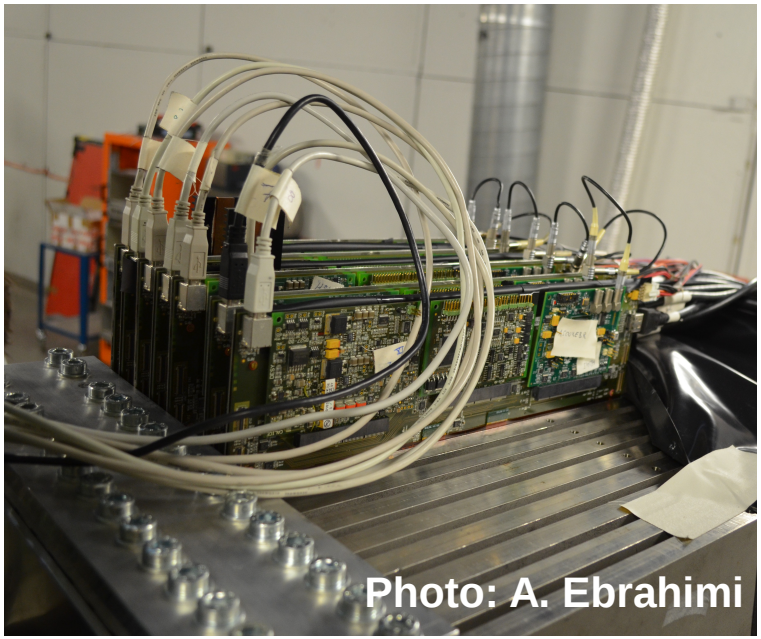



3 Weeks in DESY testbeam: Dec.13 / Jan.14

Multilayer operation extended to 8 layers

Intermediate step forward on the DAQ:

- HDMI interface for layer syncronization, USB for readout




MIP calibration runs in Airstack

EM-Showers at 1-5 GeV for energy resolution analyses

# Hadron Testbeam at CERN

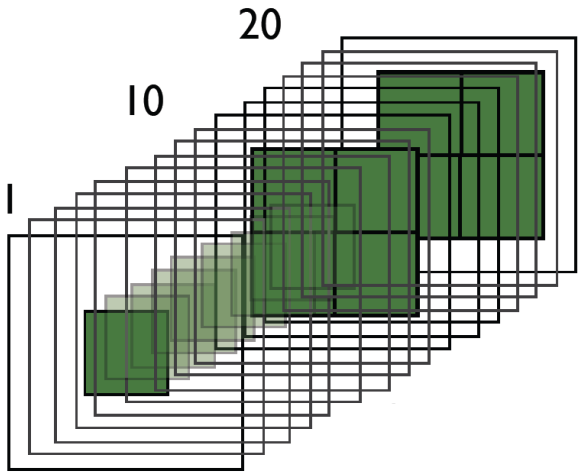
~ 4 Weeks of Beamtime in Nov/Dec 2014

Additional HBUs using fiberless tiles

ECAL layers as shower start finder

Use of full HDMI - Based DAQ:

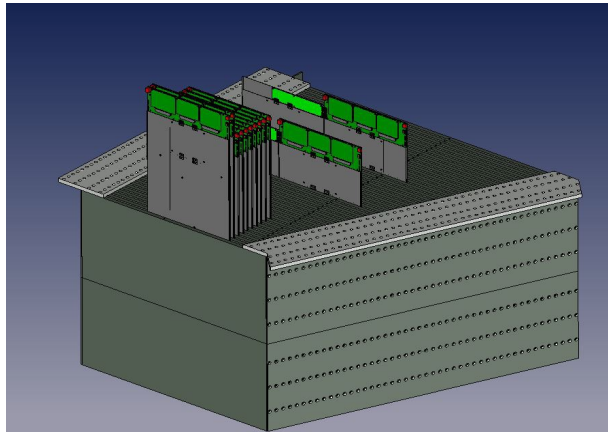
Better scalability




Shower profiles with full timing capability

Steel and Tungsten

Muon calibration data



# Summary

- The CALICE collaboration is developing calorimeters for a future linear collider
  - AHCAL concept: SiPM + Scintillator based hadronic calorimeter
  - Physics prototype:
    - performance shown in various testbeam experiments, analysis ongoing

- Scalable prototype being developed and continuously growing:
  - Increasing number of layers
  - Tile R&D
    - Various options, stronger focus on scalability of production, testing and assembly

# CALICE AHCAL Contributors

- Backup -