Rodeo on Friday night at the historic stockyards in Ft. Worth

- So far on my list:
  - Katja
  - Mathias
  - Frank
  - Yasmine
- Yonathan
- Christophe
- Stéphane
- Lucia
- Phi
- Who else?
  - 25 any currency
  - 8-10 pm

Towards a new AHCAL prototype

- AHCAL Prototypes
- Testbeams in 2015 and 2016
- Next steps

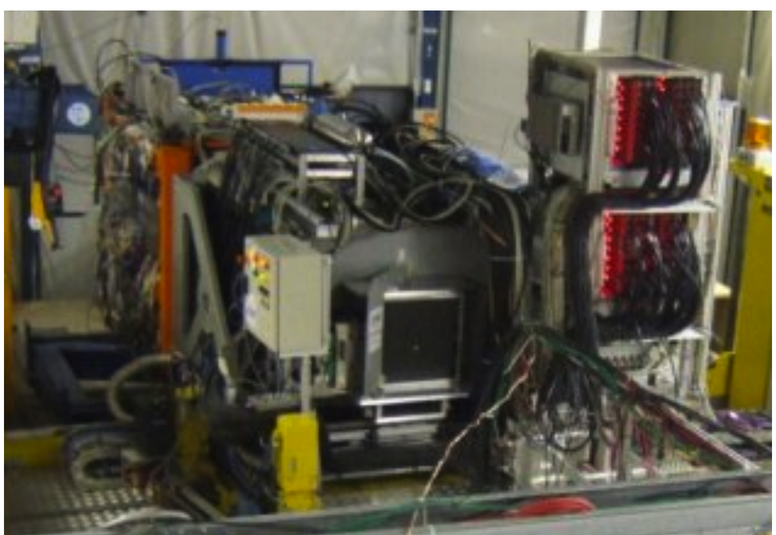
Katja Krüger, Felix Sefkow (DESY)

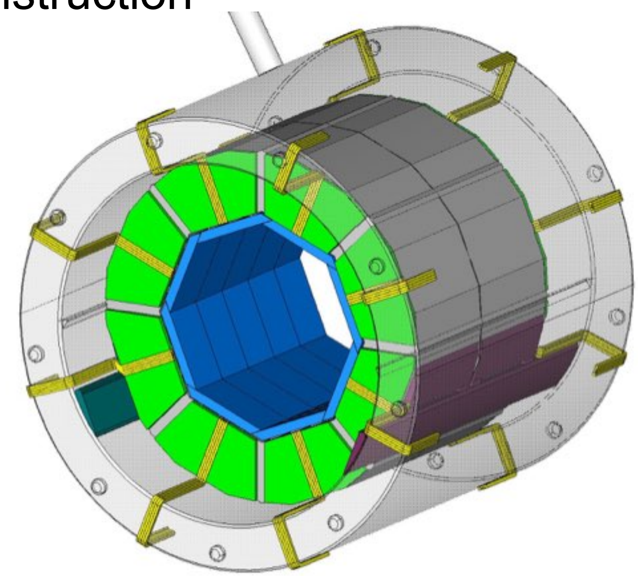
CALICE collaboration Meeting
Arlington, TX
September 15, 2016

AHCAL Prototypes

- capabilities of a highly granular scintillator-steel (or tungsten) calorimeter successfully demonstrated with the first “physics" prototype”:
  - validation of Geant4 simulation
  - validation of PFA performance
  - 12 journal publications + additional 8 Calice Analysis Notes
- fully propagated into large detector simulations

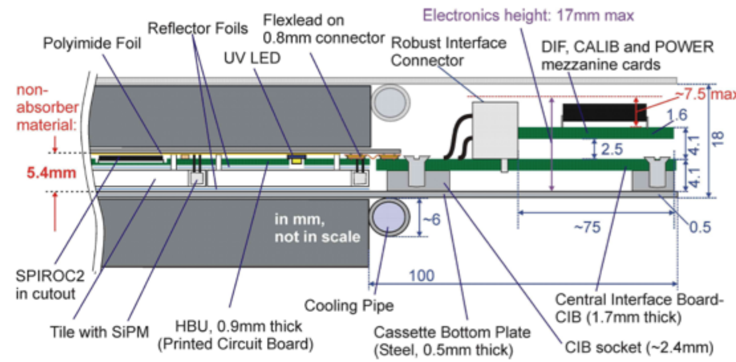
- goals for the 2nd “technological"prototype:
- develop, build and test a prototype scalable to the full collider detector layout
  - integration of electronics into layers
  - realistic infrastructure
  - easy mass assembly
  - detector optimisation and costing
- explore time evolution of showers and possibilities to use timing for PFLOW reconstruction

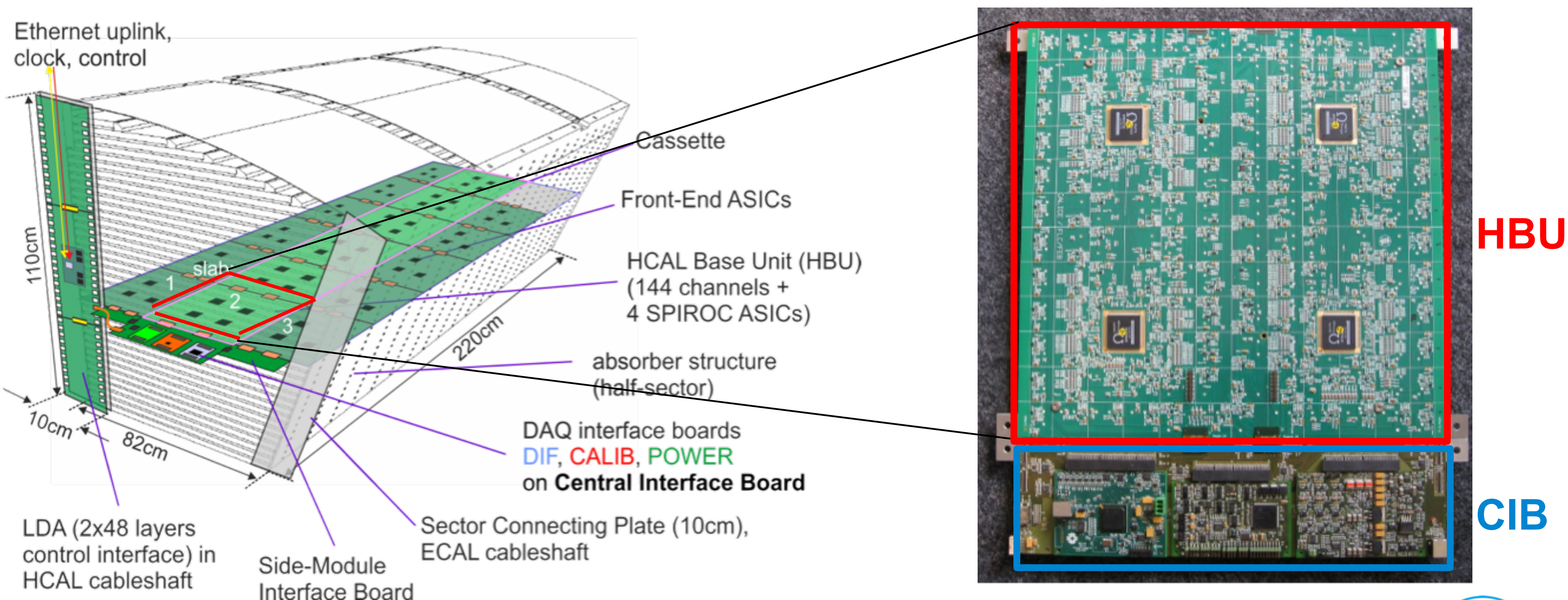




AHCAL: Electronics integration

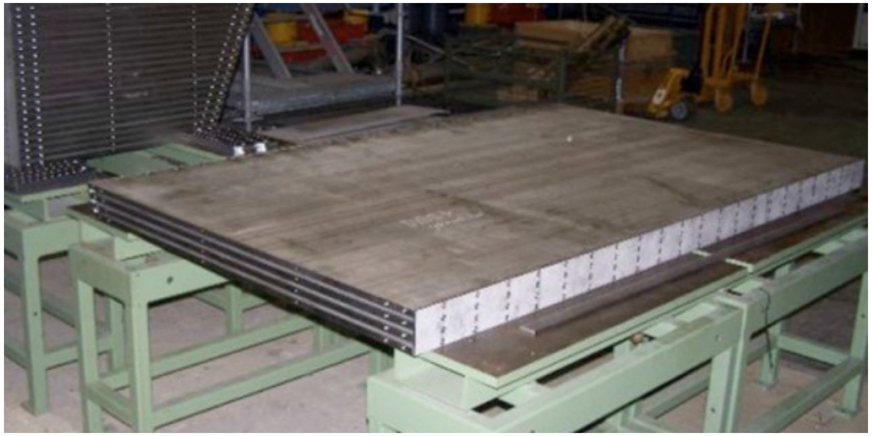
- HCAL Base Unit: 36*36 cm^2, 144 tiles, 4 SPIROC2 readout ASICs
- Central Interface Board: DIF, Calibration, Power for 1 layer
- 5.4 mm active layer thickness
- 1 layer has up to 3*6 HBUs

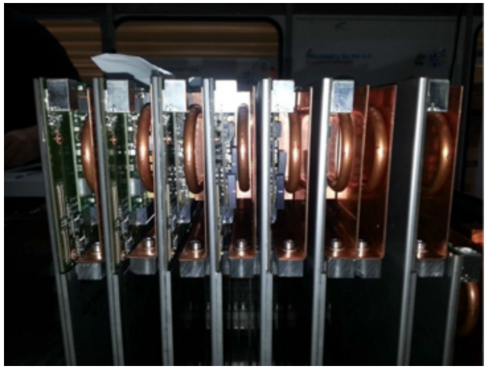




System integration: mechanics, power, cooling

- 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

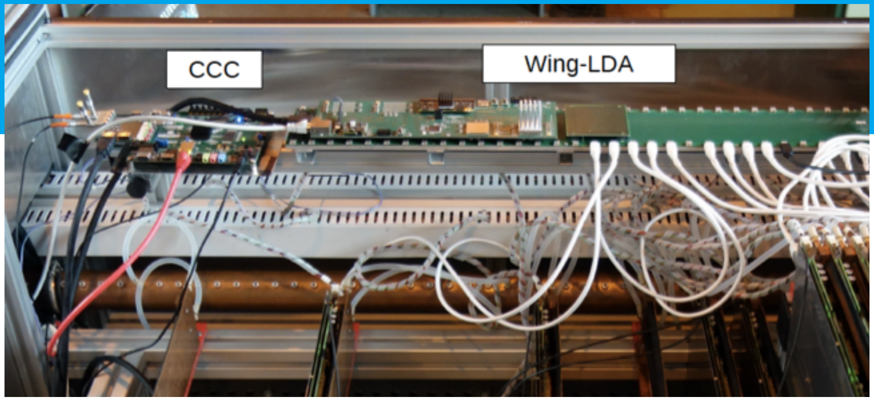


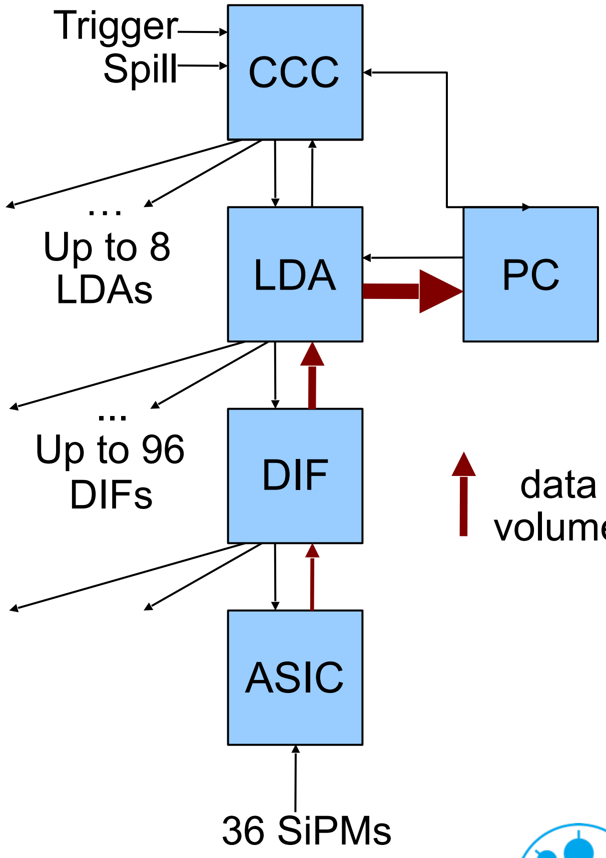


System integration: DAQ

- modular hierarchical DAQ system
- HDMI based
- 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)

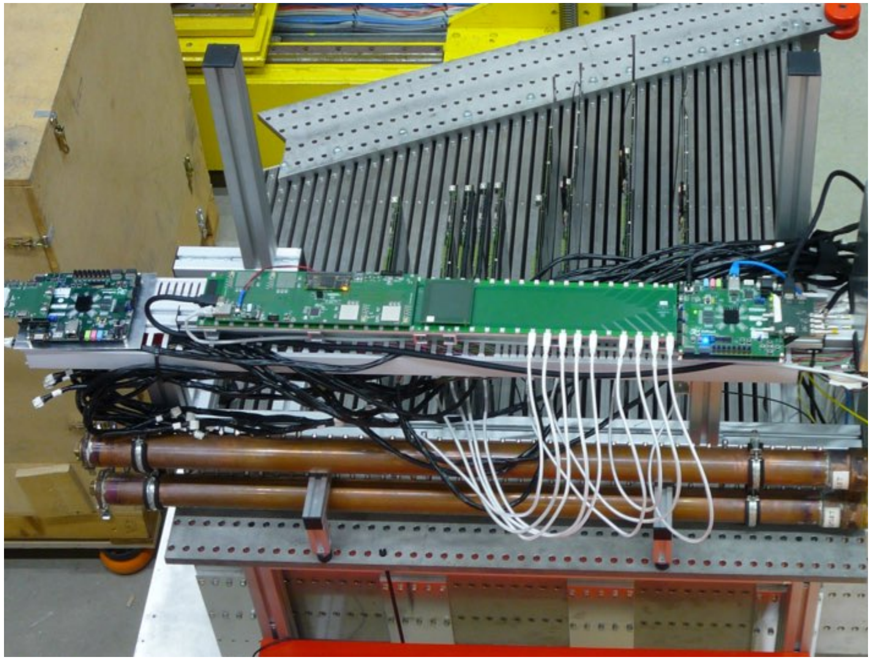
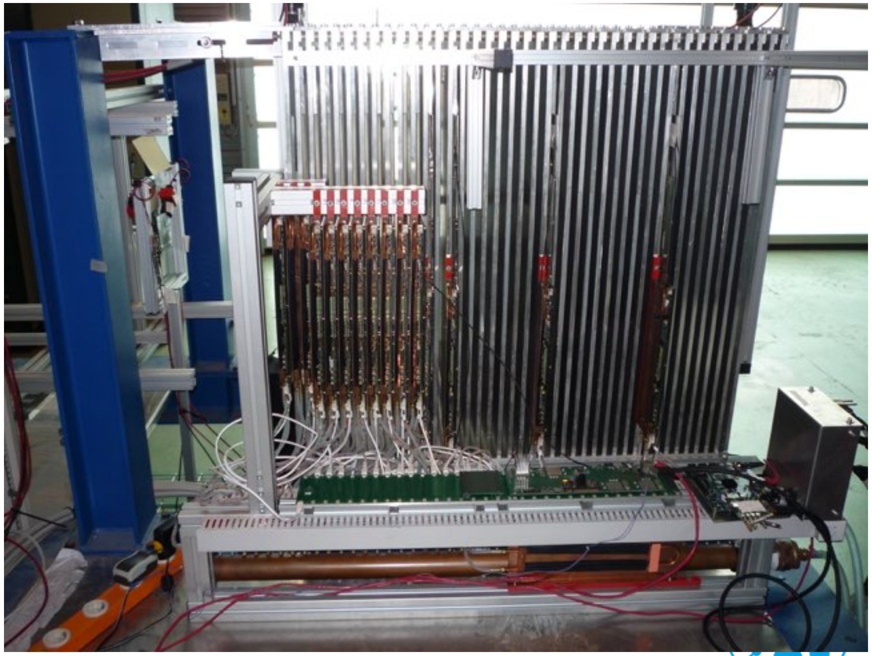
  → >450 Hz sustained event rate
- tested also common running with other calorimeter prototypes





AHCAL testbeams in 2015

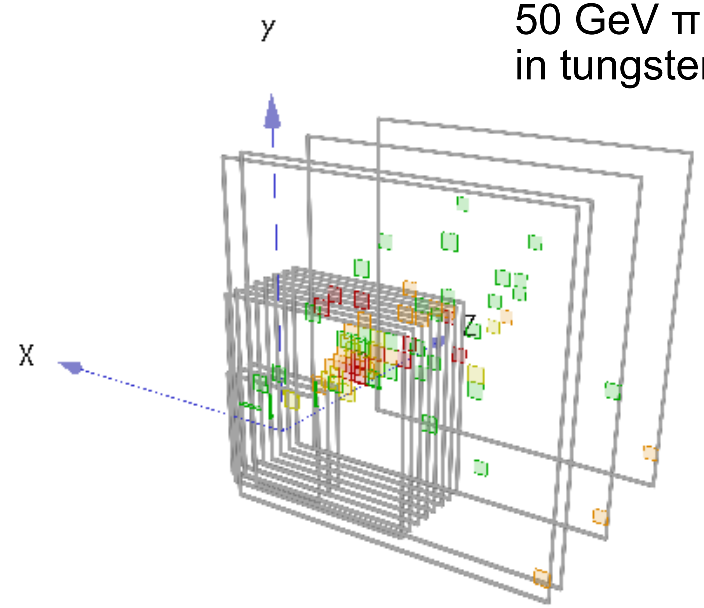
- first testbeam at SPS with 2nd generation electronics and DAQ
  - 2 weeks (8. – 22. July 2015) in EUDAQ steel stack
  - 2 weeks (12.–26. August 2015) in tungsten stack
- Partially instrumented:
  - older versions of tiles and SiPMs to build shower start finding tower
  - include 2-3 EBUs, too
  - 2 different more recent versions for 4 big layers (2x2 HBUs)

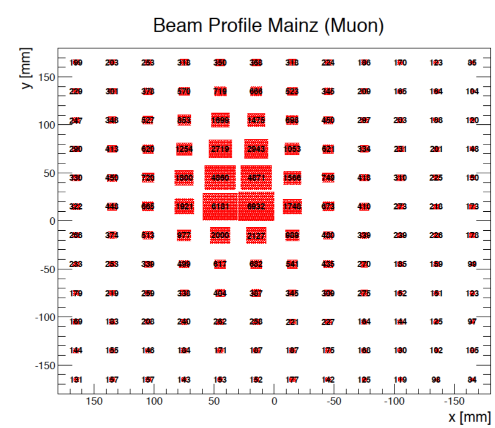



AHCAL Testbeams 2015

- 2 times 2 weeks of testbeam at SPS in 2015
  - steel and tungsten absorber
  - 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

50 GeV π
in tungsten

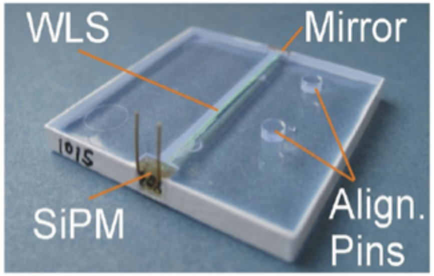


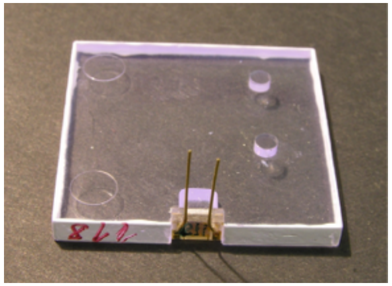
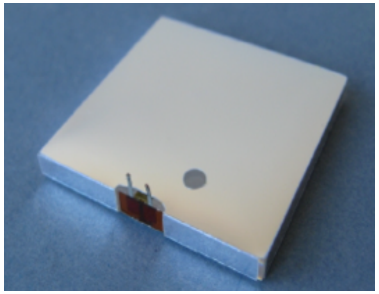
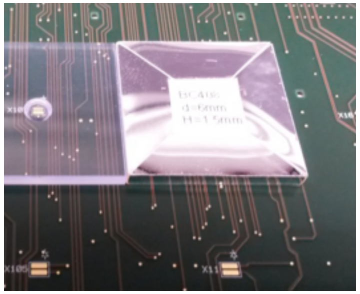


AHCAL testbeams in 2015

- new physics possibilities due to timing capabilities of new electronics
  - study shower evolution with time
  - compare steel and tungsten (expect more late hits for in tungsten than in iron)
  - study impact of timing cuts on shower shapes and particle flow reconstruction
- system test: scalable DAQ, power distribution and cooling
- gain experience with variety of tiles and SiPMs

- analysis on-going, see later talk by Katja

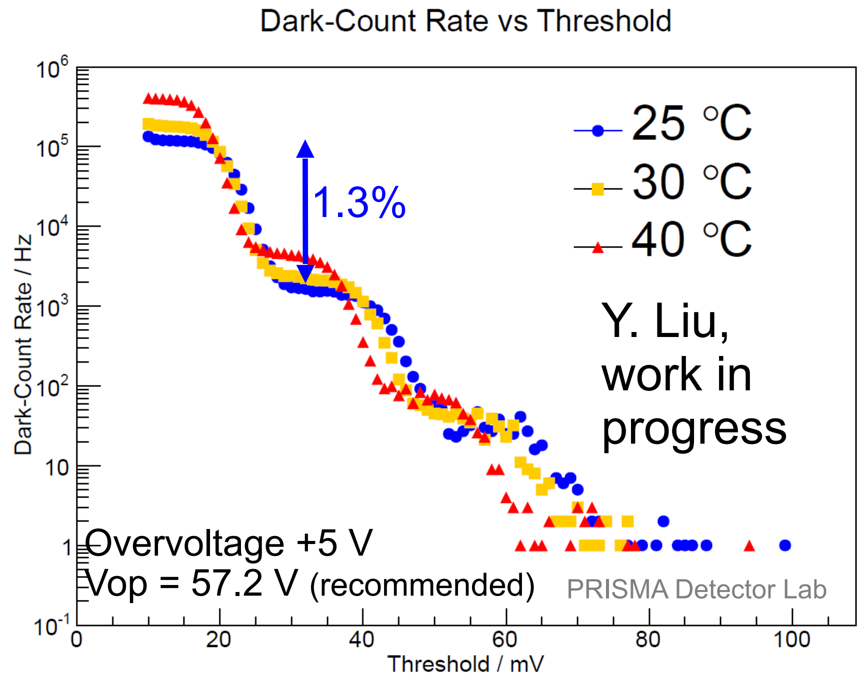


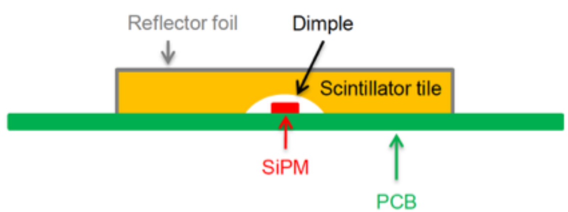




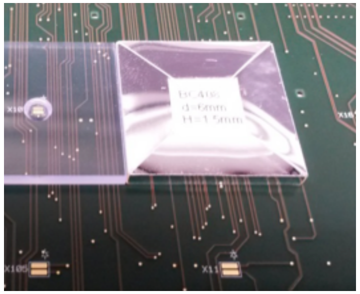
Towards mass production

decided which option to follow:

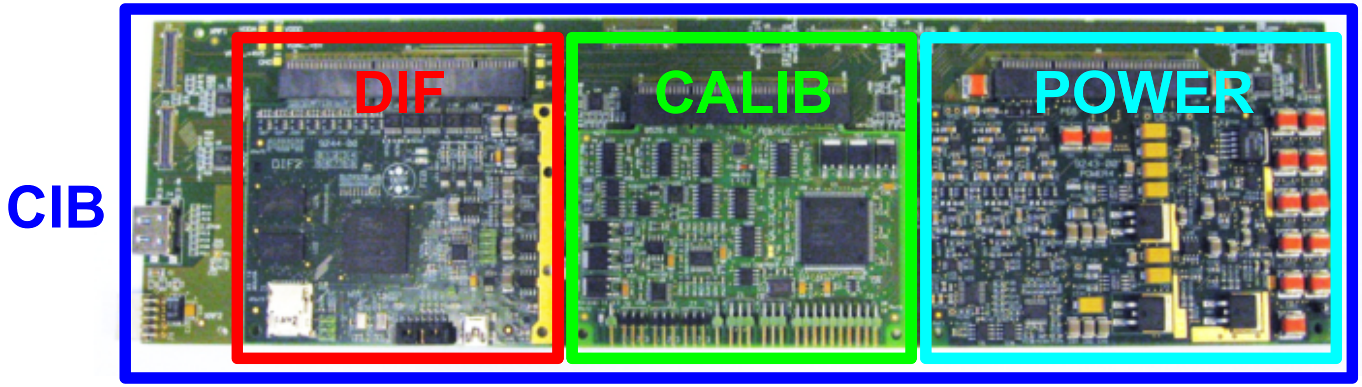
- recent improvements in SiPM technology:
  - improved sample uniformity
  - dramatically reduced dark rate and pixel-to-pixel cross talk
  - in AHCAL conditions **noise-free**
- new tile design with surface-mount SiPMs
- mass assembly with pick-and-place machine done
- pre-series of 1000 MPPCs ordered
- for the pre-series: use BC408 scintillator, cut and polished





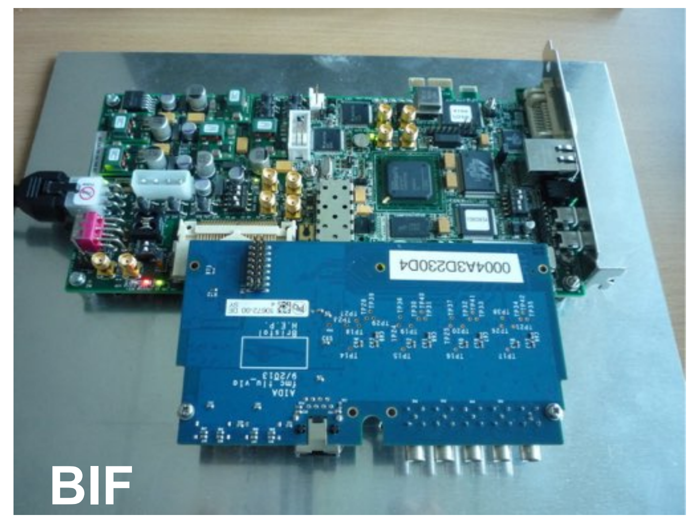


New Electronics 2016: Interface boards & BIF



new interface boards:

- DIF:
  - more modern FPGA
- POWER:
  - reduced LV (6 → 4 V) for reduced heat
  - capacitor bank for **power pulsing**
  - **software adjustment of SiPM bias voltage**
- CIB:
  - additional capacitors and protection resistors for power pulsing
- new Beam Interface (BIF)
  - time-stamp external signals (trigger, cherenkov...)

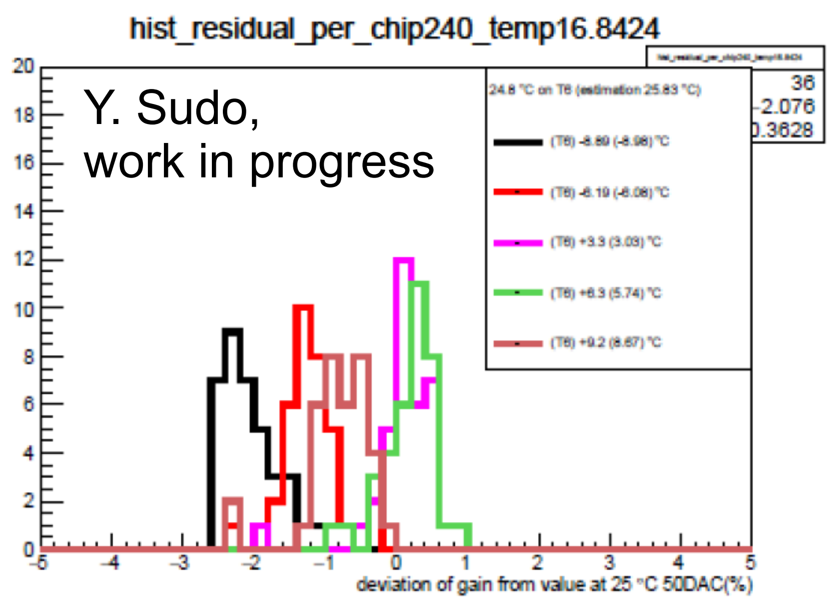


AIDA 2020

DESY

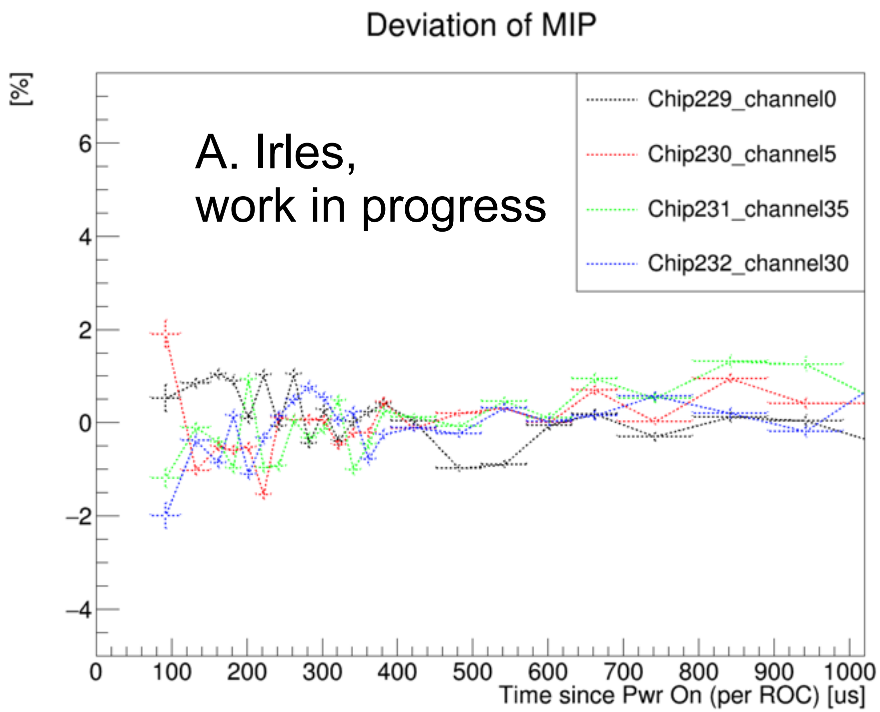
Active temperature compensation

- SiPM gain changes caused by temperature variation can be compensated by HV adjustment (Uni Bergen, Prague: single SiPMs)
- new power board: software adjustment of SiPM bias voltage
  - reasonable linearity verified
- in climate chamber
  - measure dependence of gain on temperature
  - measure dependence of gain on HV
  - derive (linear) correction of HV as function of temperature (1 correction per HBU!)
- discovered hardware feature which caused non-linearity in temperature measurement on HBUs; fixed.
- gain stable within ~2% for temperatures 16-34º C (before fixing the linearity)
- next steps:
  - repeat with correct temperature measurement
  - optimise procedure (threshold, frequency)
  - try in testbeam



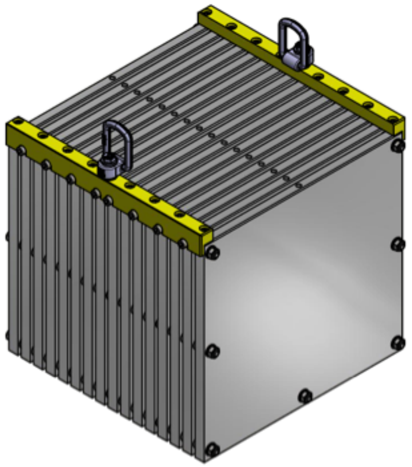
AHCAL testbeams in 2016 (1): power pulsing

- 2 weeks in May 2016 at DESY:
  - many tests of new electronics, BIF, DAQ, data quality monitoring
  - first beam for first new pre-series surface-mount HBU4_SMD (+2 older HBUs): MIP calibration
- tested several power pulsing configurations
  - restart data acquisition as soon as readout is finished
  - with "ILC" spill signal (1 ms beam, 199 ms off)



- no problems, smooth running, reduced power consumption
- analysis shows stable MIP signal 100-150 μs after switch on (consistent with lab results)

New small prototype



Stack: MPP Munich

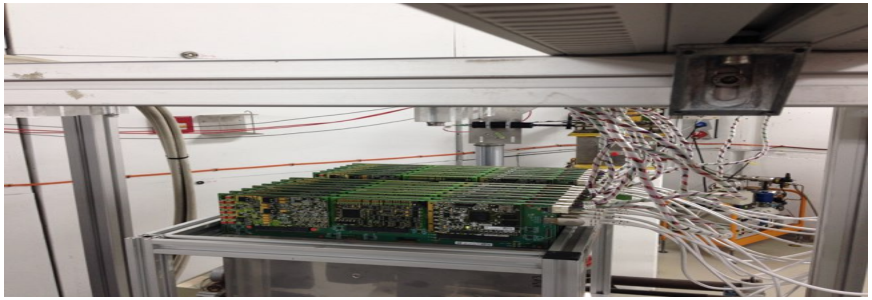
- 6 new HBUs with surface-mount tiles and new generation SiPMs produced
  - expect very homogenous, high-quality layers
- together with already existing good HBUs, have built small prototype for electromagnetic showers with high-quality photo-sensors in all channels
  - demonstrate the precision we can reach for e.m. shower response and resolution
  - demonstrate power pulsing behaviour for a (small) calorimeter system
- easy to put in a magnet or on a plane

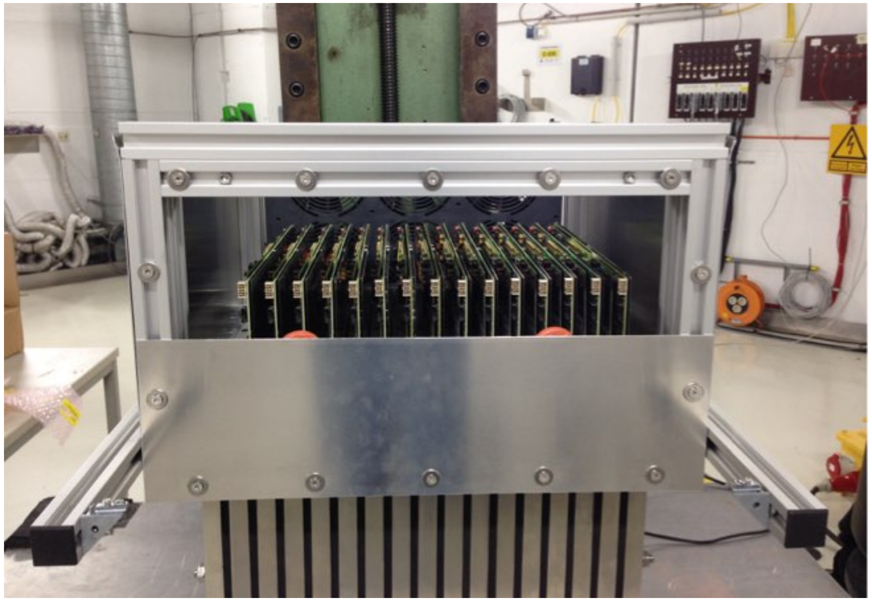
AHCAL testbeams in 2016 (2): small stack with pre-series

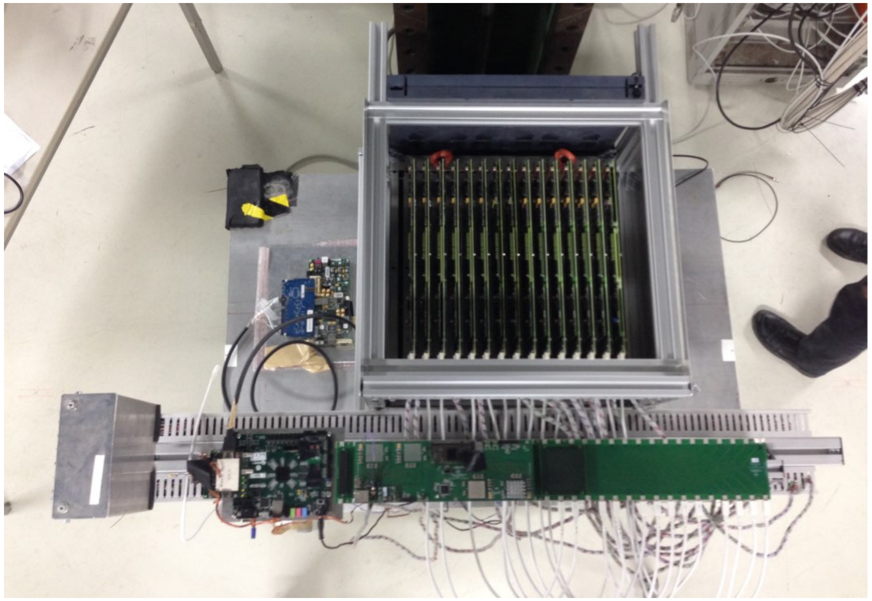
- 2 weeks in July and August 2016 at DESY
- setup: 15 layers of 1 HBU
  - **6 new HBU4_SMD** + 9 older HBUs
  - **new interfaces for all layers**
- commissioning simplified due to excellent uniformity of MPPCs
  - no cell-by-cell settings anymore for bias, gain or trigger
- first week: MIPs
  - integration of new HBUs and interfaces
  - MIP calibration for all HBUs
- second week: EM showers
  - new absorber stack
  - energy scans 1 – 5 GeV
  - reference measurement: no power pulsing, no temperature compensation
  - tests with power pulsing (and temperature compensation)

Impressions from July/August 2016 DESY testbeam

- after fixing a few small problems, very smooth and stable running
- all layers working well in nominal conditions

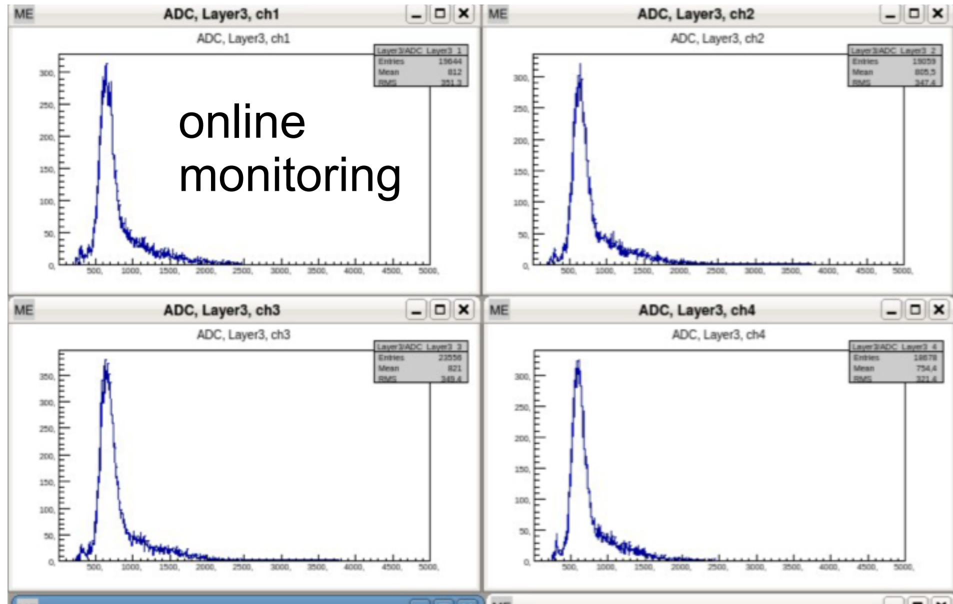


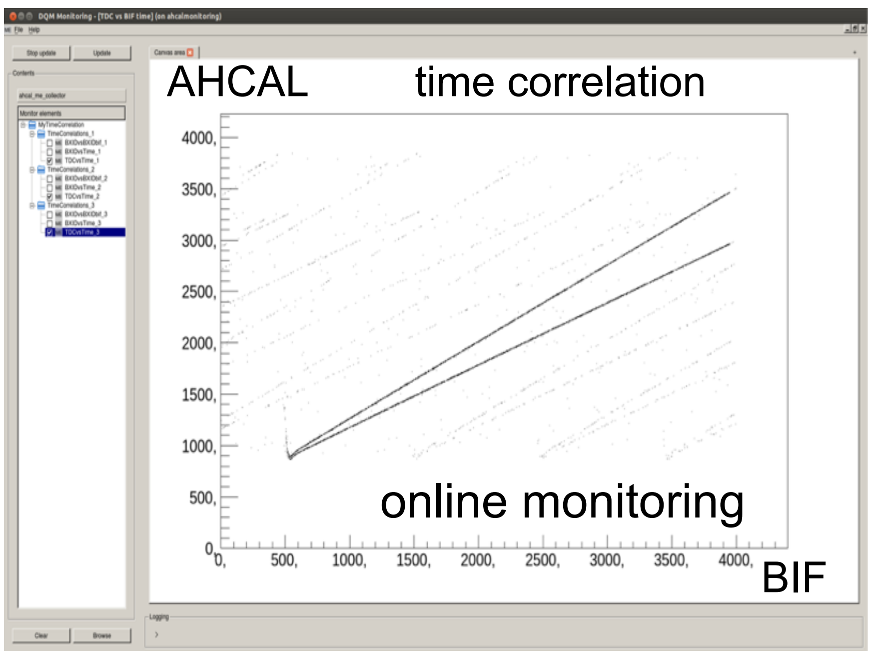


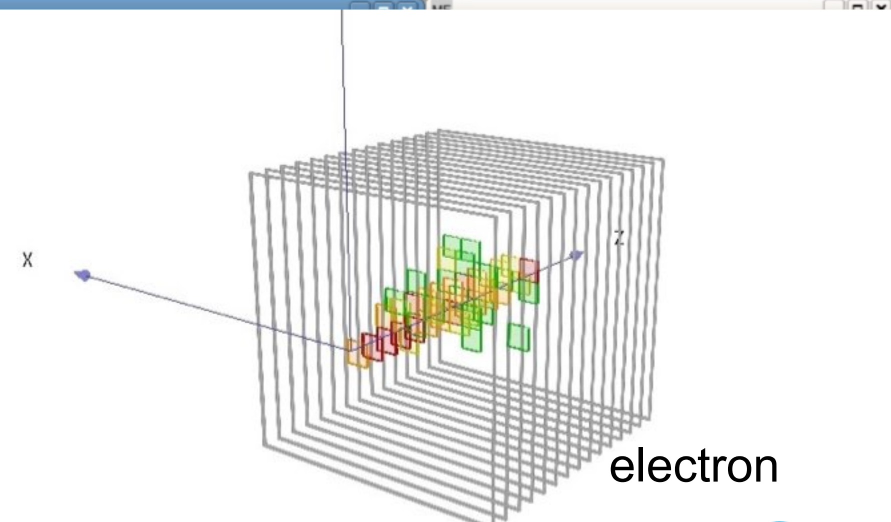


Impressions from July/August 2016 DESY testbeam

- after fixing a few small problems, very smooth and stable running
- all layers working well in nominal conditions
- quality of new HBUs very good
  - all 864 channels operational, 863 show nice MIP spectrum

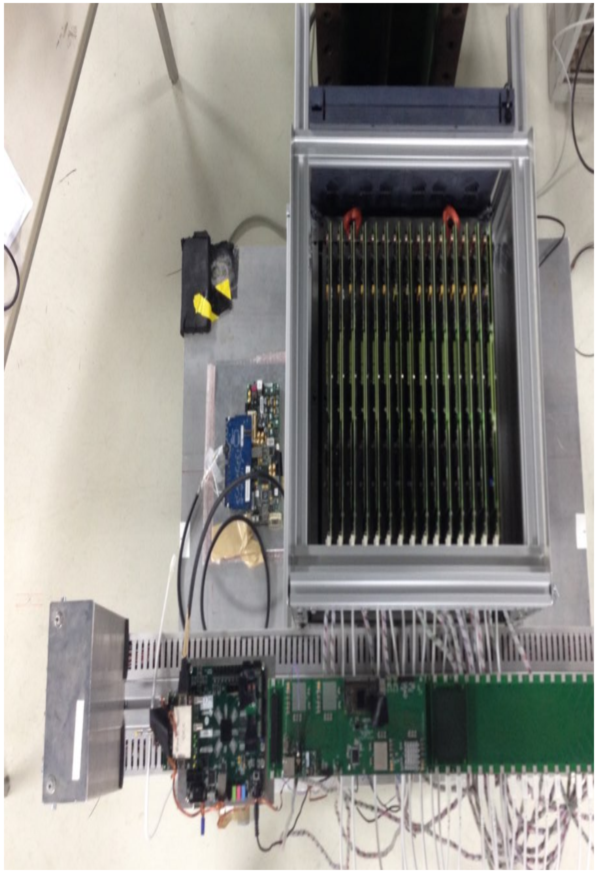






DQ4HEP framework integrated into EUDAQ

Next steps, small stack



- short term: additional measurements with small prototype
- test temperature compensation
- common running with other detectors:
  - beam telescope: 1 week at DESY in October 2016
- power pulsing in magnetic field
  - first with a single layer
  - then with complete prototype, either at DESY or at CERN
- further options under investigation

Next steps: towards an HCAL prototype

- medium term: large prototype, instrument EUDET stack
  - corresponds to ~1% of barrel
  - big step towards mass production
  - scalable to full linear collider detector
  - infrastructure as for linear collider detector
- mechanics and cooling need only small adaptations
- tendering for SiPMs in progress
- electronics:
  - SPIROC2E under test at OMEGA and DESY
  - BGA package done
  - HBU5 for BGA package: prototype has been produced
  - test board for BGA and s/w in production (with Wuppertal)
- tiles: less expensive version for large prototype, moulded scintillator in preparation

Summary

several important steps towards full-scale detector taken:

- successful demonstration of the system integration (DAQ, power etc)
- established integrated design with surface mounted SiPM and automated assembly
- successful experience with test stands
  - SiPMs at Heidelberg, HBUs at Mainz
- much simplified commissioning procedures
- very successful test of 6 HBUs in new design with new SiPMs in small 15 layer stack at the electron test beam at DESY

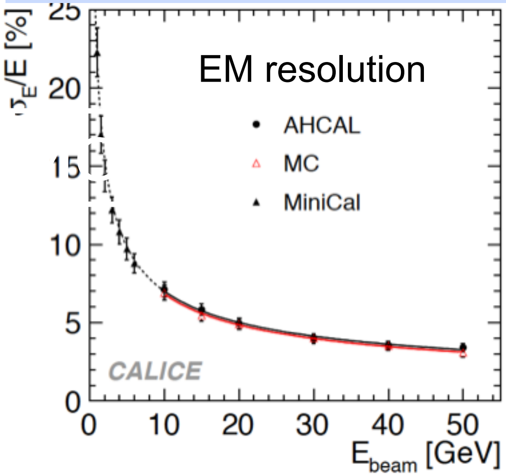
next steps

- small prototype:
  - test temperature compensation
  - test power pulsing in magnetic field
  - DAQ integration with telescope
- big hadronic prototype
  - 2017: construction
  - 2018: test with hadrons at CERN
- in parallel: continue studies on SiPMs and tiles (e.g. megatiles)

Backup

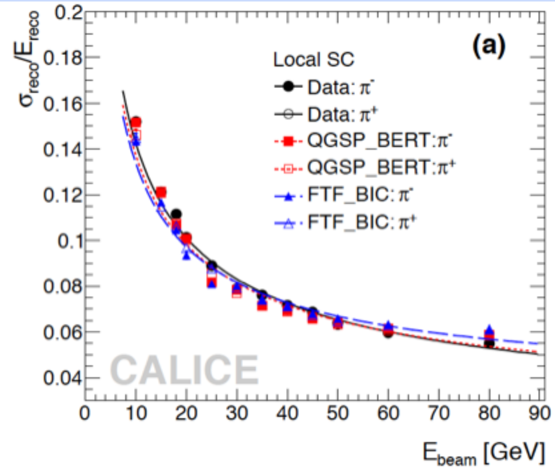
AHCAL physics prototype: results

Detector validation



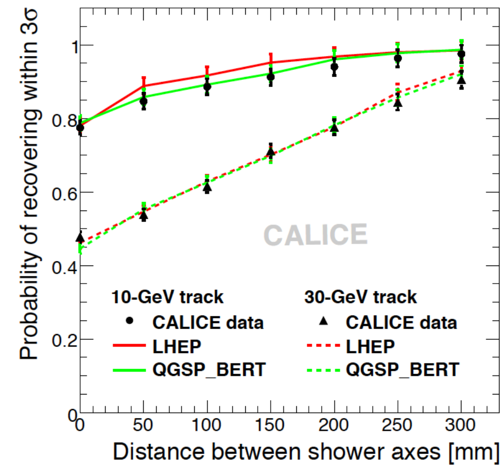
JINST 6, P04003 (2011)

Performance validation



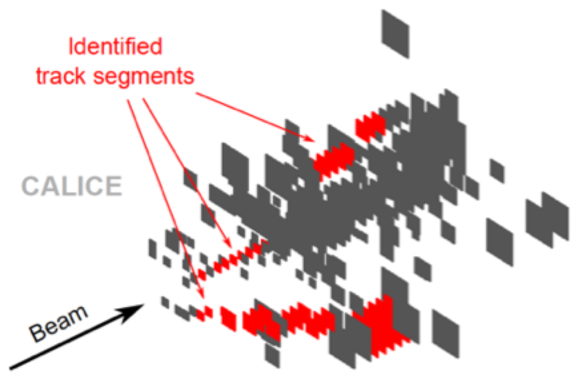
JINST 7, P00917 (2012)

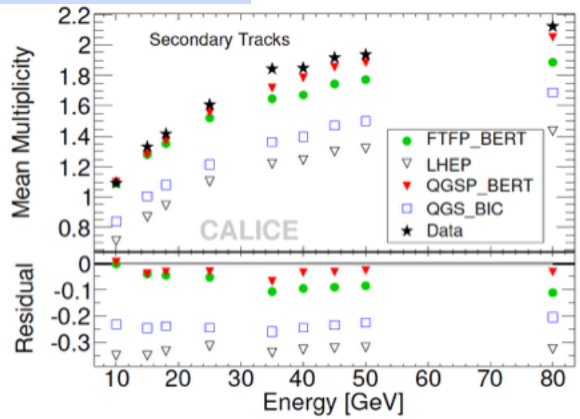
Particle Flow validation



JINST 6, P07005 (2011)

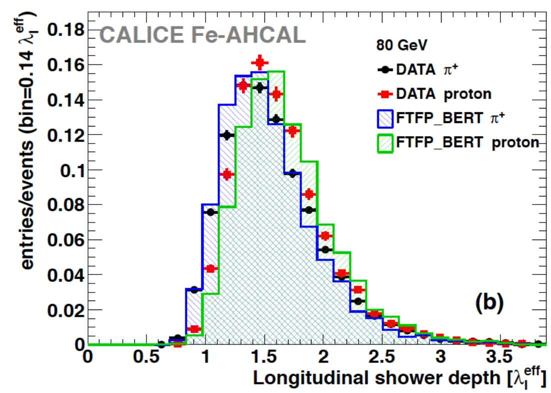
Imaging validation





JINST 8, P09001 (2013)

π/p separation



JINST 10, P04014 (2015)