Status and News from the HCAL

- AHCAL
- SDHCAL
- Conclusions

Katja Krüger

ILD meeting

Whistler, 4 November 2015

HELMHOLTZ | ASSOCIATION

CALICE

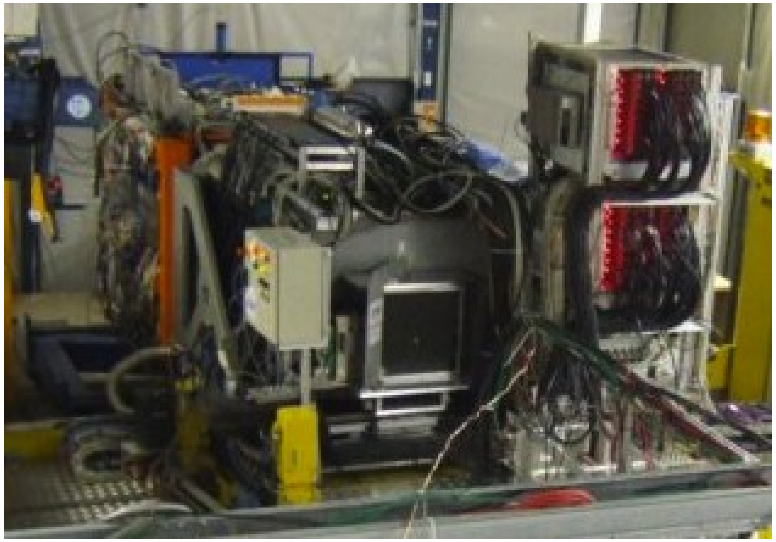
Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

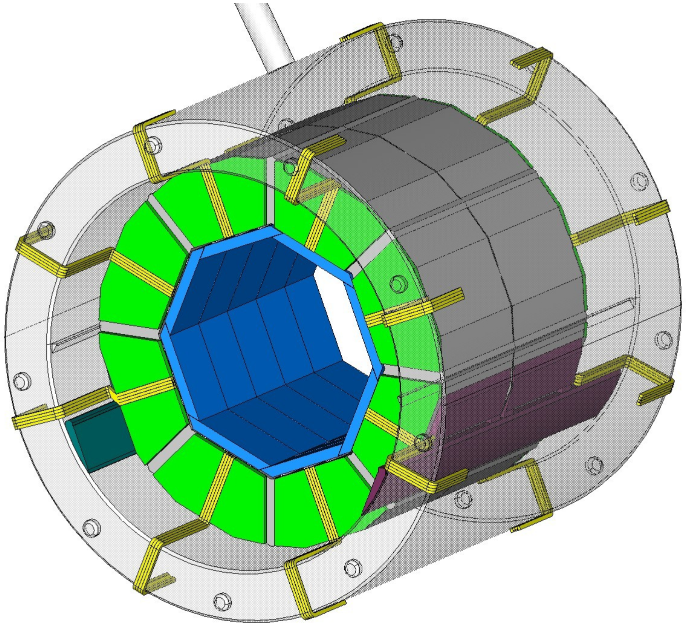
DESY

AHCAL Status

- capabilities of a highly granular scintillator-steel (or tungsten) calorimeter successfully demonstrated with the "physics prototype":
  - validation of Geant4 simulation
  - validation of PFA performance
  - 11 journal publications + additional 9 Calice Analysis Notes

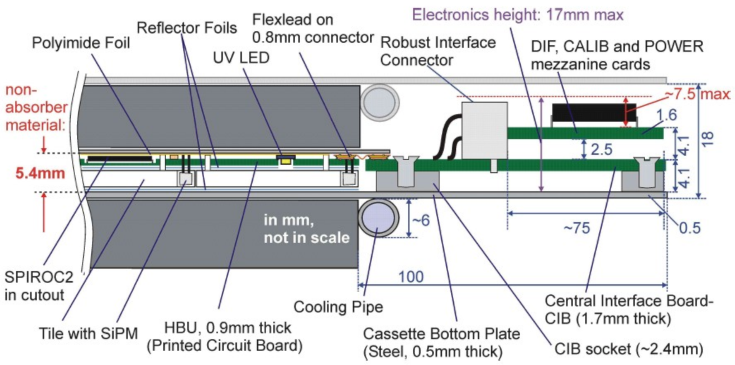
- goal for the "engineering prototype": develop, build and test a prototype scalable to the full ILD layout
  - integration of electronics into layers
  - realistic infrastructure
  - easy mass assembly
  - detector optimisation (Lan's talk)

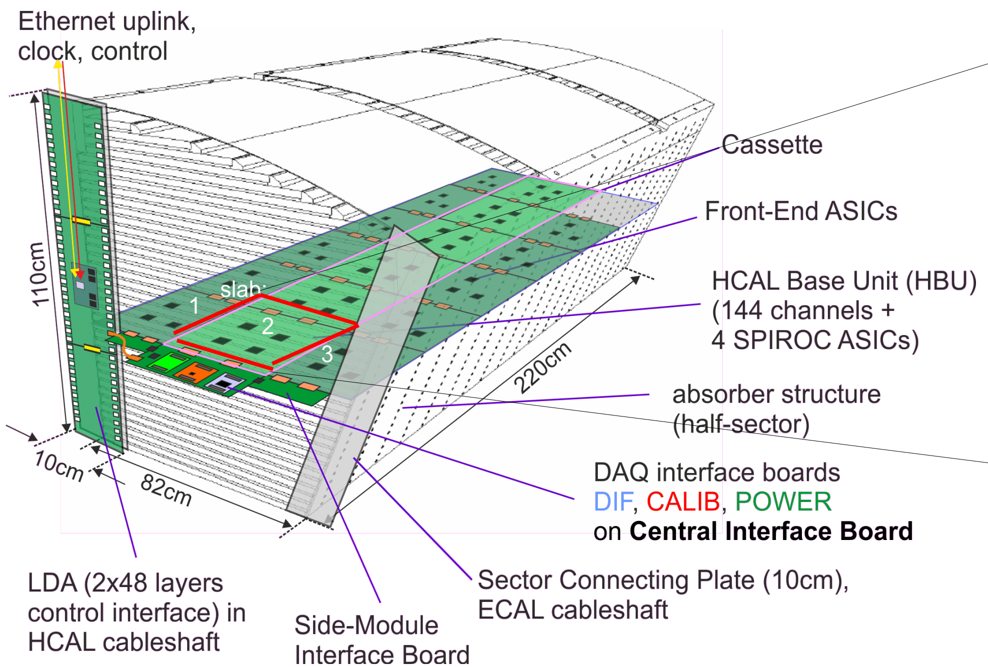


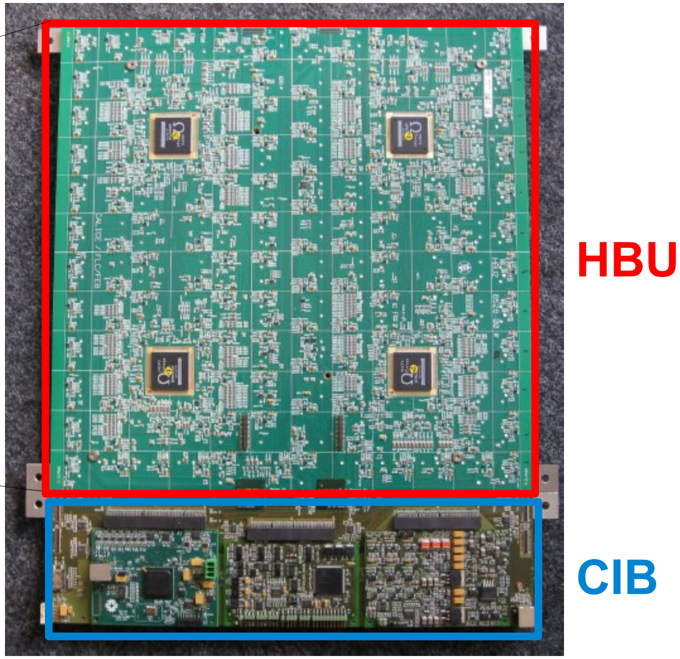


AHCAL engineering prototype: Integrated Electronics

- **H**CAL **B**ase **U**nit: 36*36 cm^2, 144 tiles, 4 SPIROC2 readout ASICs
- **C**entral **I**nterface **B**oard: DIF, Calibration, Power for 1 layer
- 5.4 mm active layer thickness
- 1 layer has up to 3*6 HBUs

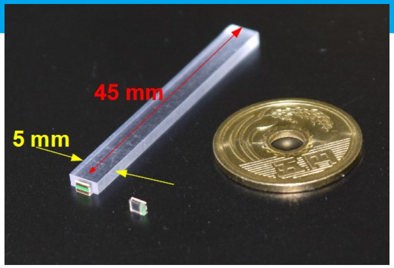


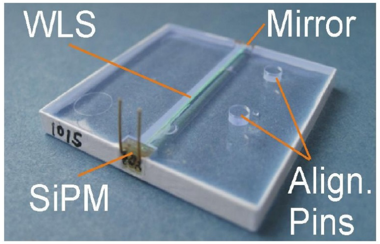


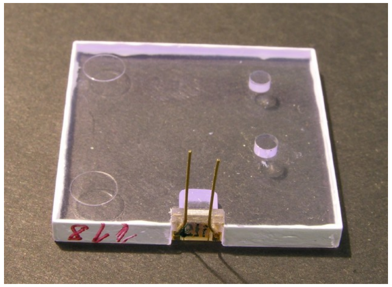


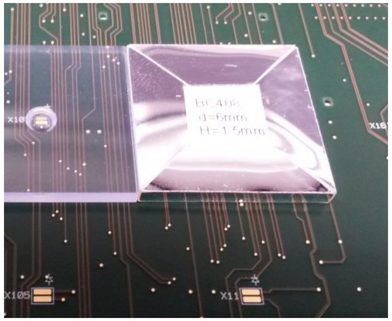
Tiles/Strips and SiPMs

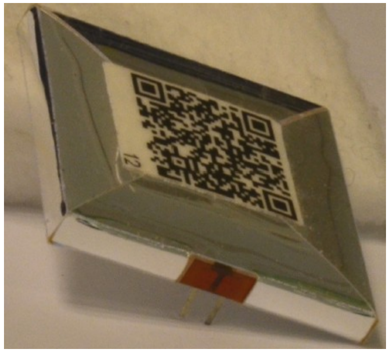
- 2 (ECAL) layers with strips
  - Hamamatsu MPPCs with 1600 pixels
  - Hamamatsu MPPCs with 10000 pixels
- 5 layers with tiles with wavelength shifting fibre
  - CPTA SiPMs with 800 pixels
- 2 layers with tiles without WLS
  - Ketek SiPMs with 12000 pixels
- 1 layer with surface mount SiPMs with individually wrapped tiles
  - Hamamatsu MPPCs with 1600 pixels
- 4 big layers with individually wrapped tiles
  - Ketek SiPMs with 2300 pixels
  - sensl SiPMs with 1300 pixels











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

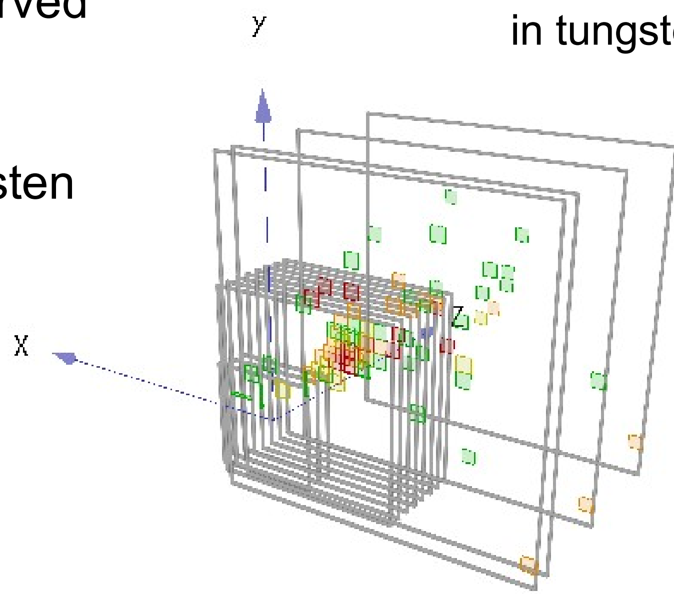
AHCAL testbeams: Goals and Preparation

- first SPS test beam 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 (already used for physics prototype)
- extensive preparation
  - testbeams at PS in October and November 2014
  - testbeams at DESY in February, April and June 2015
  - tested long term stability of complete setup without beam at DESY
- system test: scalable DAQ, power distribution and cooling
- gain experience with variety of tiles and SiPMs
- 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

AHCAL Testbeams

- integration concept for full module successfully tested
- very stable running of the detector
  - no instabilities in electronics and DAQ observed
  - some layers with old SiPMs developed inefficiencies
  - 5 days without beam from SPS during tungsten data taking
- collected data sets
  - muons for MIP calibration check
  - energy scan for electrons
    - 10 – 50 GeV for steel
    - only 20 GeV for tungsten
  - energy scans for pions
    - 10 – 90 GeV for both steel and tungsten
- online data quality monitoring
- distributed data analysis started

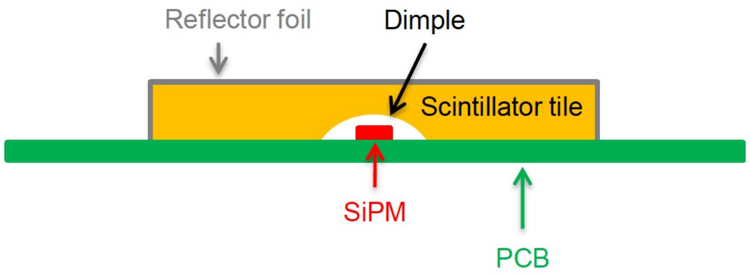
50 GeV π
in tungsten



DESY

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 fulfil 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
  - further possible improvements identified, to be tested
- very positive experience in SPS testbeam



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- new HBU design for surface-mount SiPMs:
  - SiPMs mounted directly on PCB
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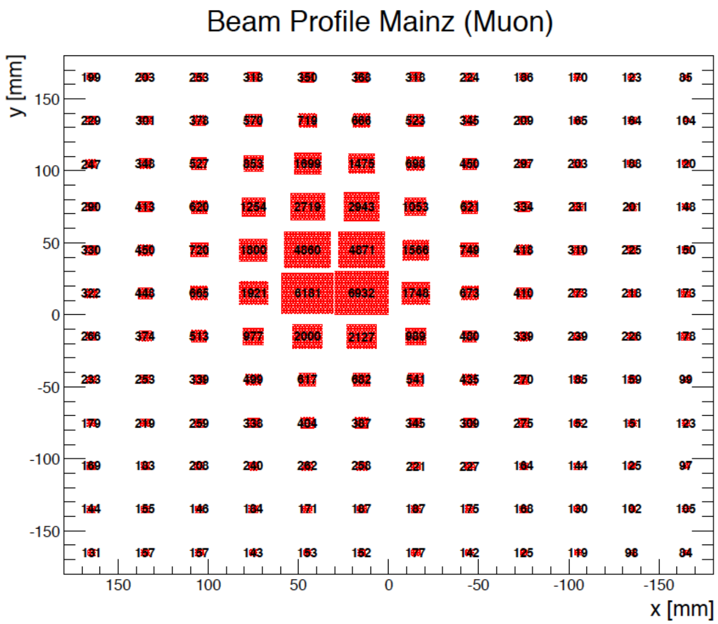
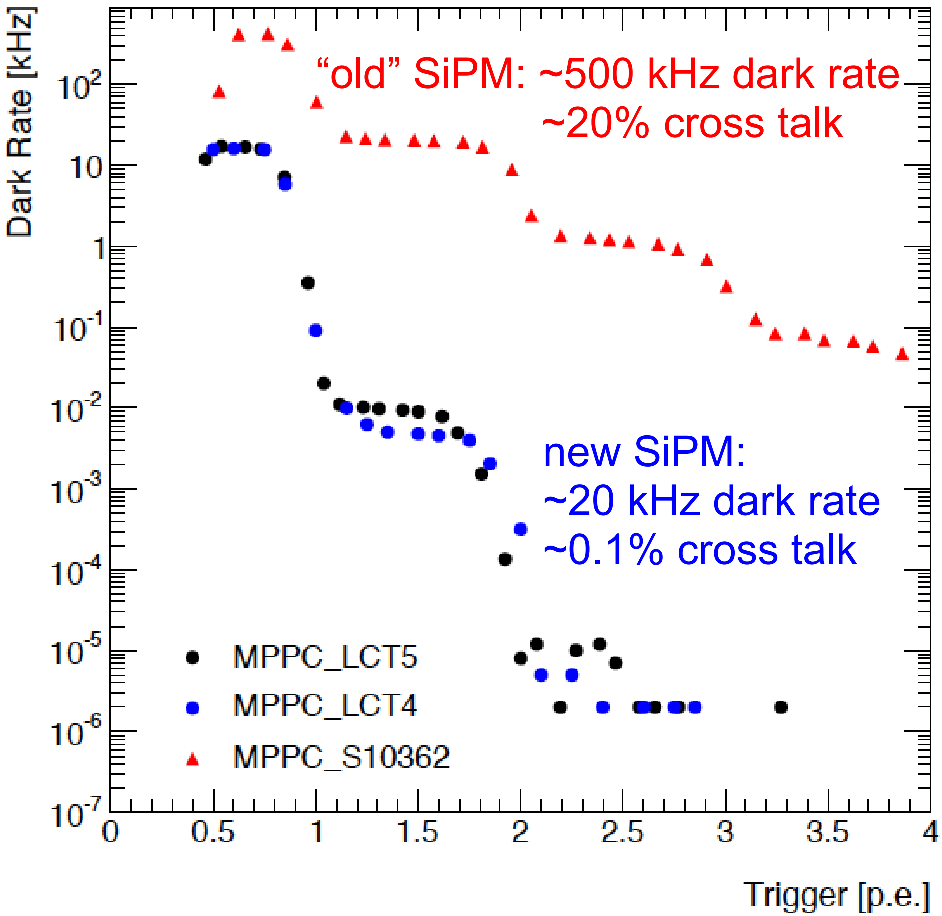
  - → mass assembly with pick-and-place machine possible
  - further possible improvements identified, to be tested
- very positive experience
  - all channels working
  - very homogeneous gain



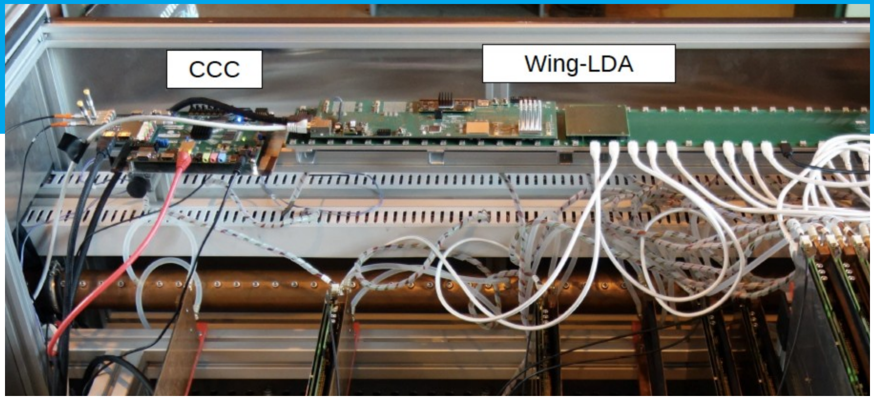
New generation of SiPMs

- recent SiPMs show very much improved sample uniformity
  - operating voltage
  - gain
- very recently, SiPMs with trenches between pixels became available
  - slightly reduced geometrical fill factor
  - dramatically reduced dark rate and pixel-to-pixel cross talk
  - for typical trigger threshold of AHCAL (~7 p.e) **noise-free**

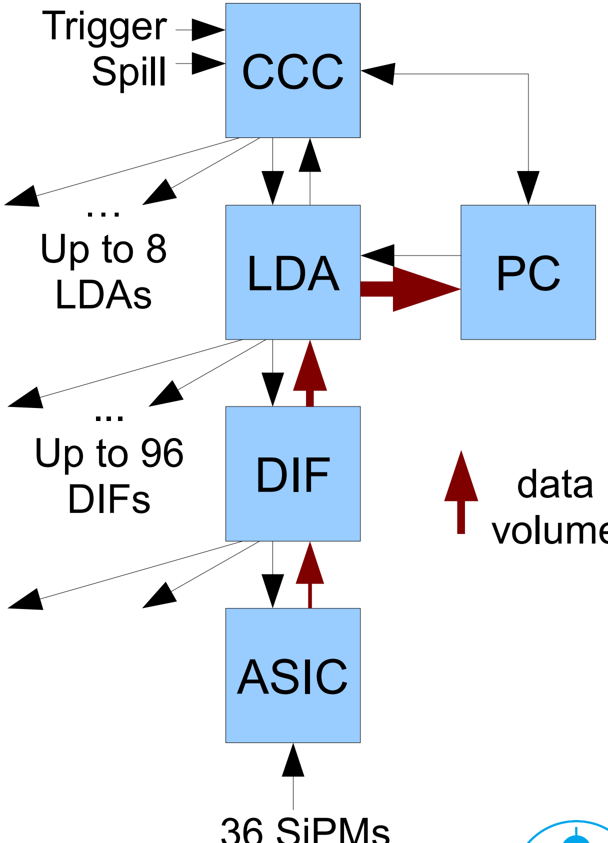


for comparison: SiPMs in physics prototype
2 MHz dark rate, 30% cross talk

Scintillator DAQ

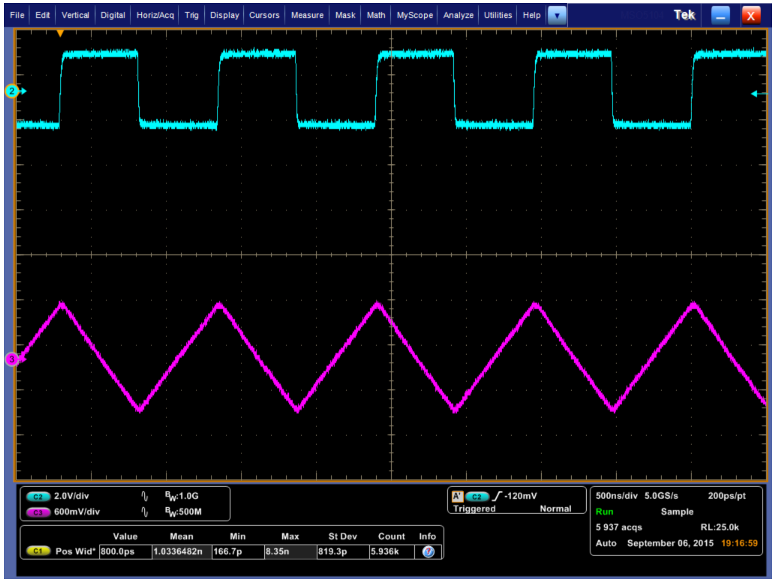


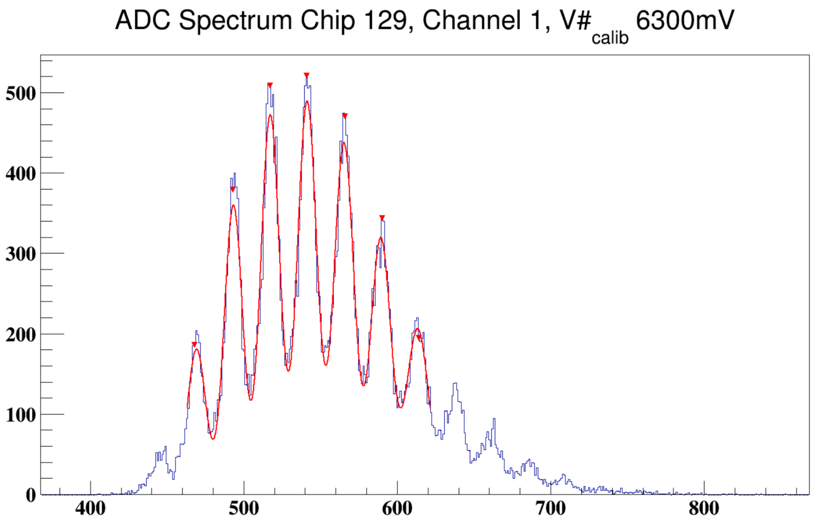
- successfully operated in beam tests
  - stable running
  - reached ~17 readout cycles / s (requirement for ILC: 5)
    → >250 Hz sustained event rate
  - identified further options for speed-up of factor of ~2
- will need adaptation to 3rd generation ASICs
- scalable to full ILD
- common running with SiECAL demonstrated
- CALICE DAQ taskforce: work towards common running of all CALICE calorimeters



Tests of Spiroc2D

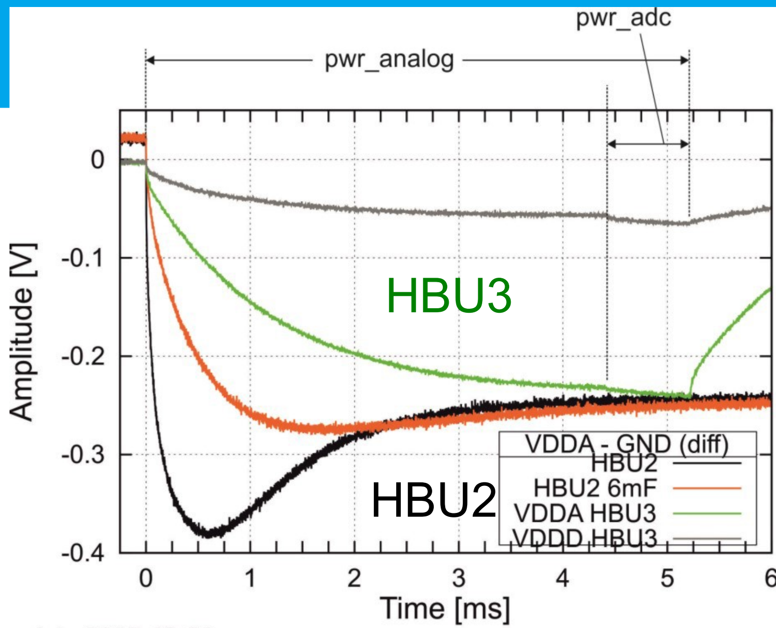
- test modifications before switching to 3rd generation ASIC
- several improvements compared to “working horse” Spiroc2B
  - better pedestal stability
  - improved channel-to-channel uniformity for inDACs (HV settings for SiPMs)
  - new scheme for TDC ramps (improved hit time measurement)
  - different pin-out and slow controls than Spiroc2B → need to gain experience
- first measurements look encouraging

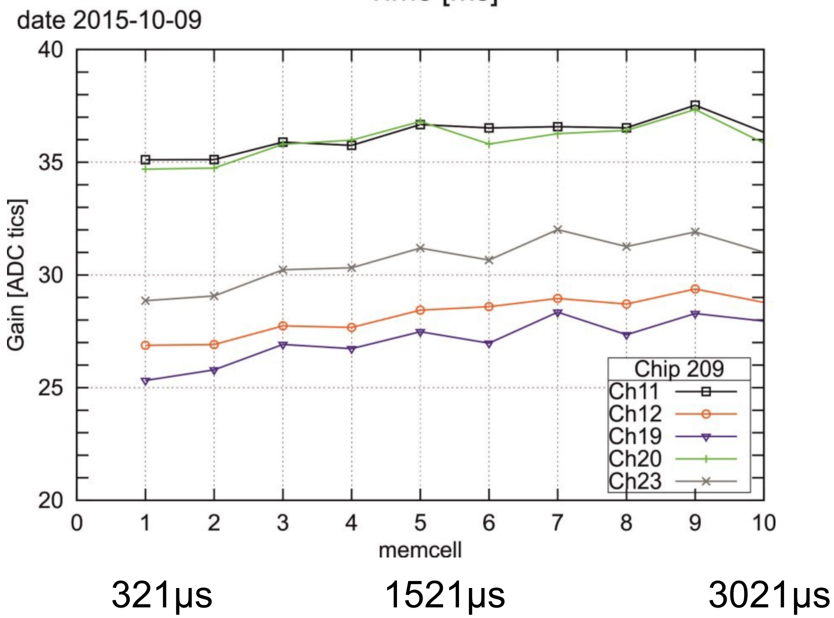




Power pulsing tests with HBU3

- HBU3: revised version of HBU to improve power pulsing behaviour
- under test with full-length slab (6 HBUs) in lab now
- very first results:
  - power consumption looks encouraging (currents on VDDA and VDDD factor of 100 and 10 lower when ASICs are off)
  - single pixel spectra look good for all switch-on times
  - gain seems to still change slightly after switch-on times of 2-3 ms
- measurement setup and analysis chain established, more results expected soon





AHCAL Plans

several important steps towards ILD-ready detector taken:

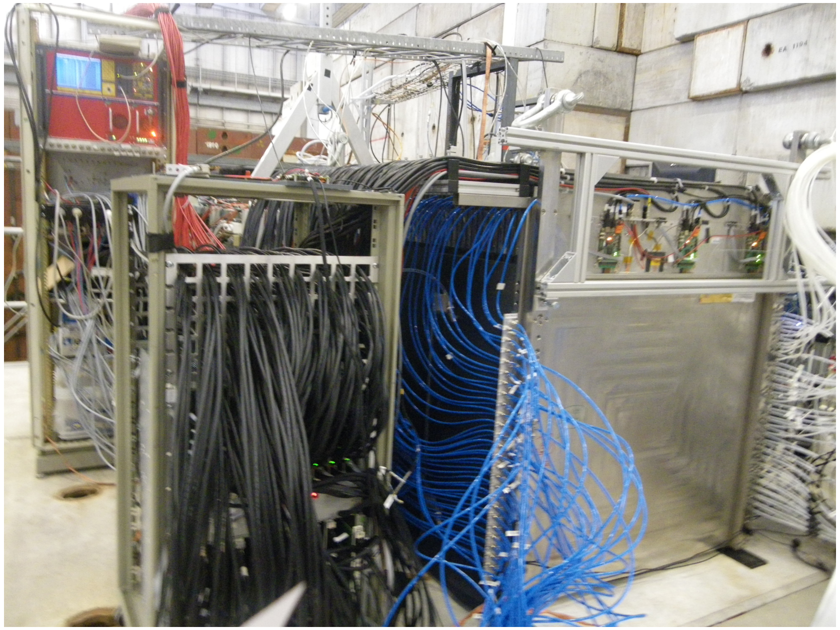
- successful demonstration of the system integration (DAQ, power etc)
- established electronics design with surface mounted SiPM and automated assembly
- latest generation SiPMs are very uniform and practically noise-free

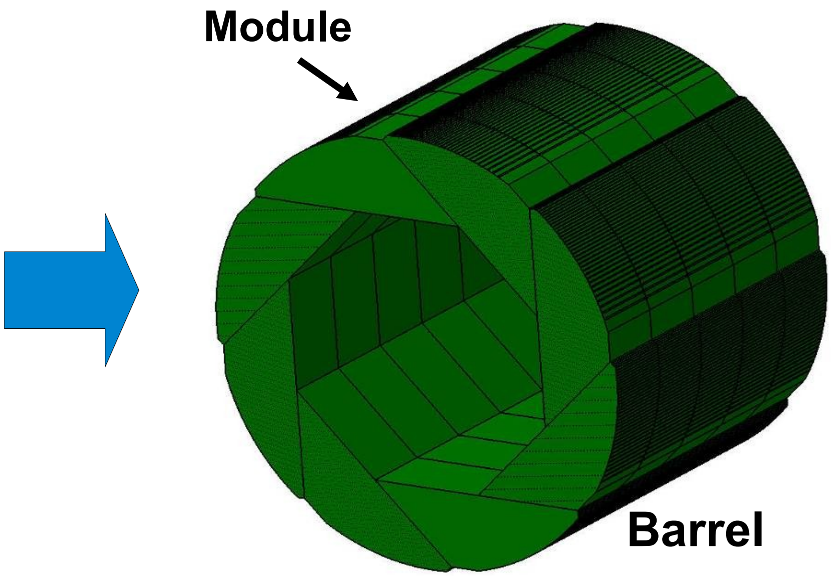
next steps

- 2016: test of a 15 layer e.m. stack with high quality photo-sensors at DESY and possibly SLAC: test power pulsing!
- 2017: construction of a big hadronic prototype
- 2018: test with hadrons at CERN

SDHCAL Status

- 1m³ prototype with 48 GRPC layers realised as technological demonstrator:
  - electronics integrated in active layers
  - power-pulsed
  - data analysis ongoing, first results very satisfactory
- needed to demonstrate scalability to full ILD layout:
  - large GRPC detectors
  - mechanical structure for Videau geometry
  - optimised PFA



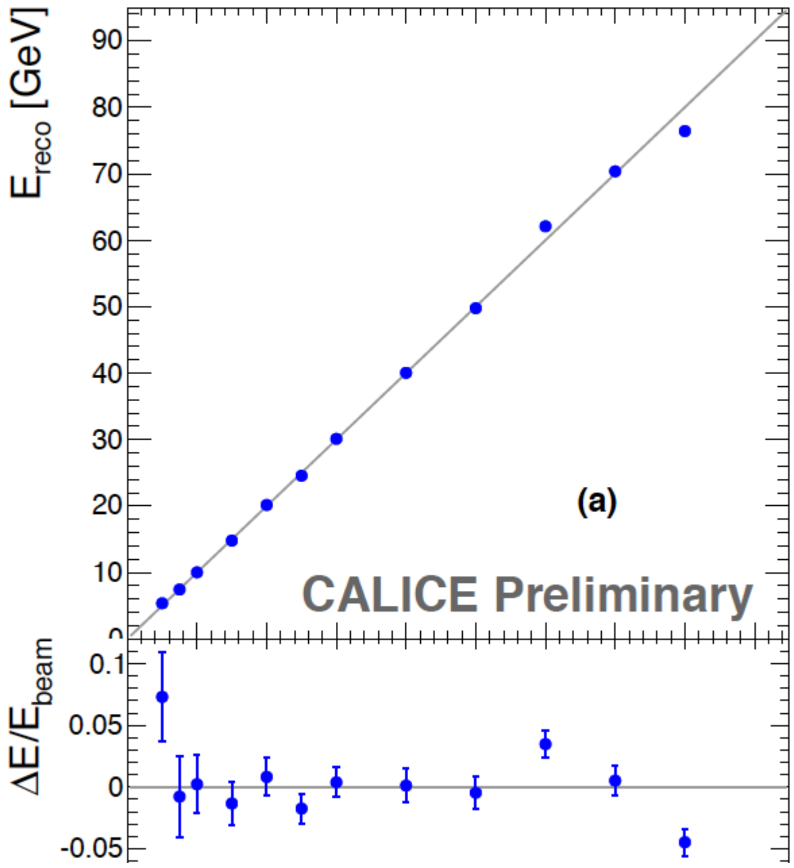


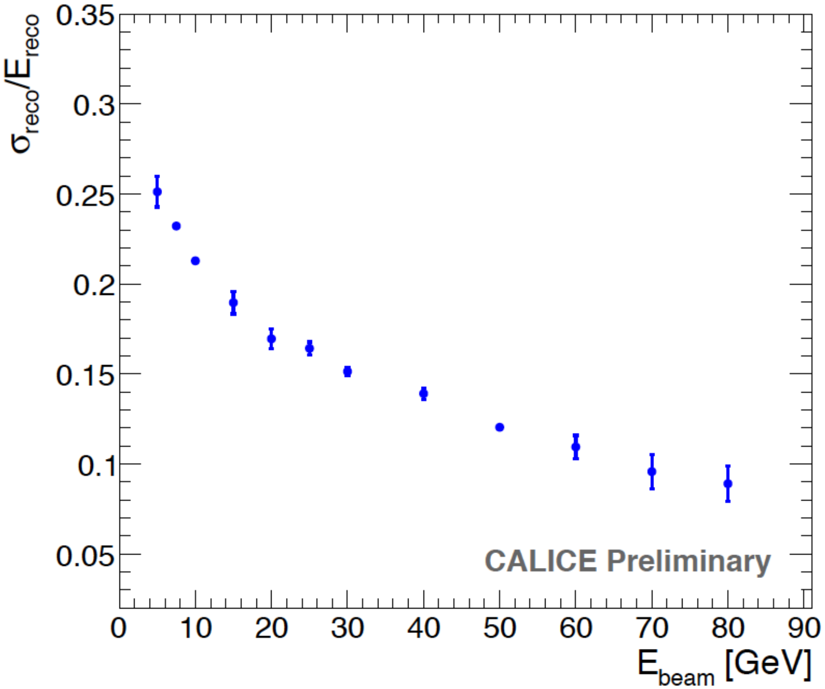
SDHCAL testbeams

- three periods of TB in 2015
  - SPS 27 April – 13 May 10 – 80 GeV
  - PS 25 May – 3 June 2 – 12 GeV
  - SPS 21 Oct. – 3 Nov.
- hadron energy scans with different conditions:
  - use temperature-pressure correction → compare with data without this correction
  - apply electronic gain correction (using noise maps) to have more homogenous response and to reduce the DAQ dead time (factor of 2)
  - three angles (0, 10, 20 degrees) of exposition
- for Neural Network tests: scan of 1 GeV step between 40 and 50 GeV
- tests of two different values of the first threshold (114 and 142 fC)
- very efficient testbeam. quick analyses were made during the testbeam but detailed analyses to come in the future.

SDHCAL publications

- "Construction and commissioning of a technological prototype of a high-granularity semi-digital hadronic calorimeter" now published in JINST
- energy resolution from 2012 SPS testbeam data
  - analysis note available
  - paper draft well advanced in CALICE publication procedure

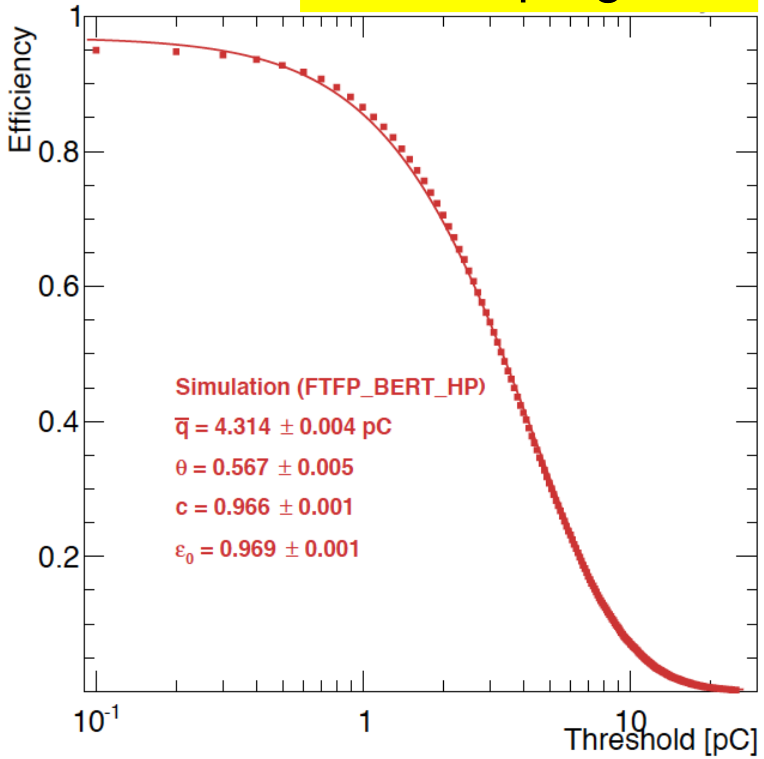




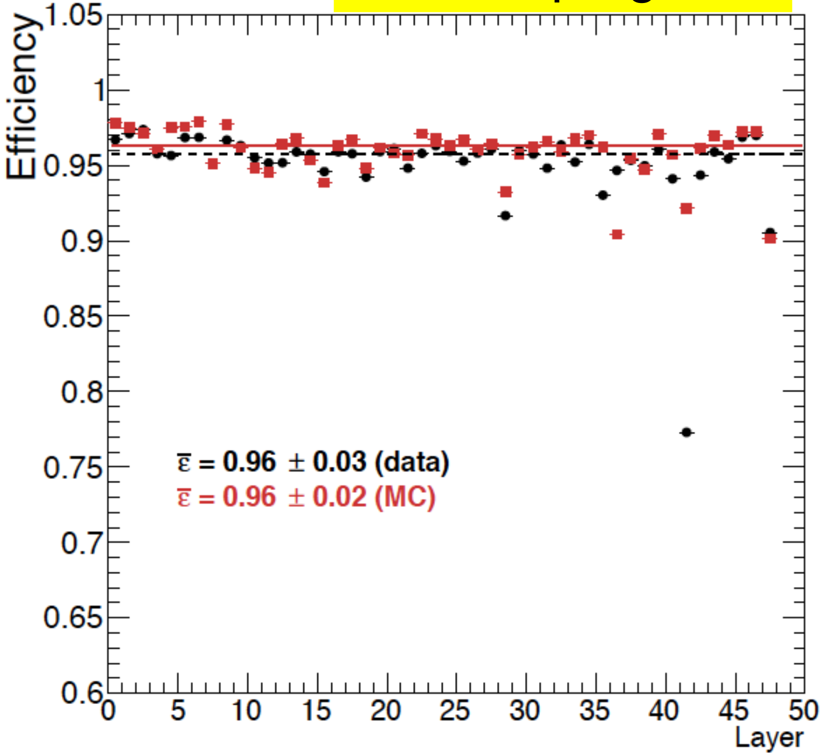
SDHCAL simulation

- digitizer is finalized
  - parameters tuned using muons and electrons
  - detector inefficiencies (dead channels) included

work in progress

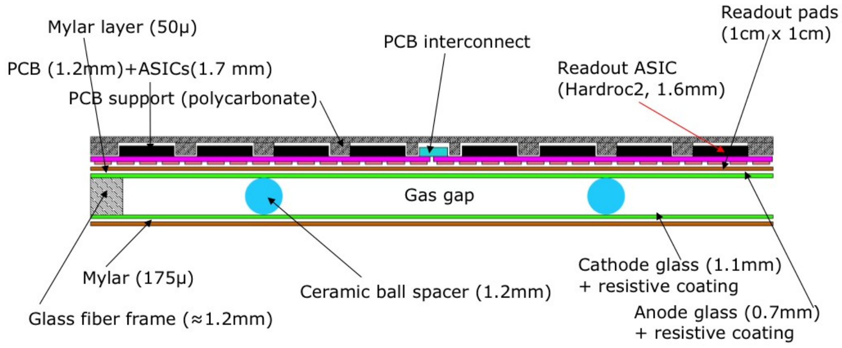


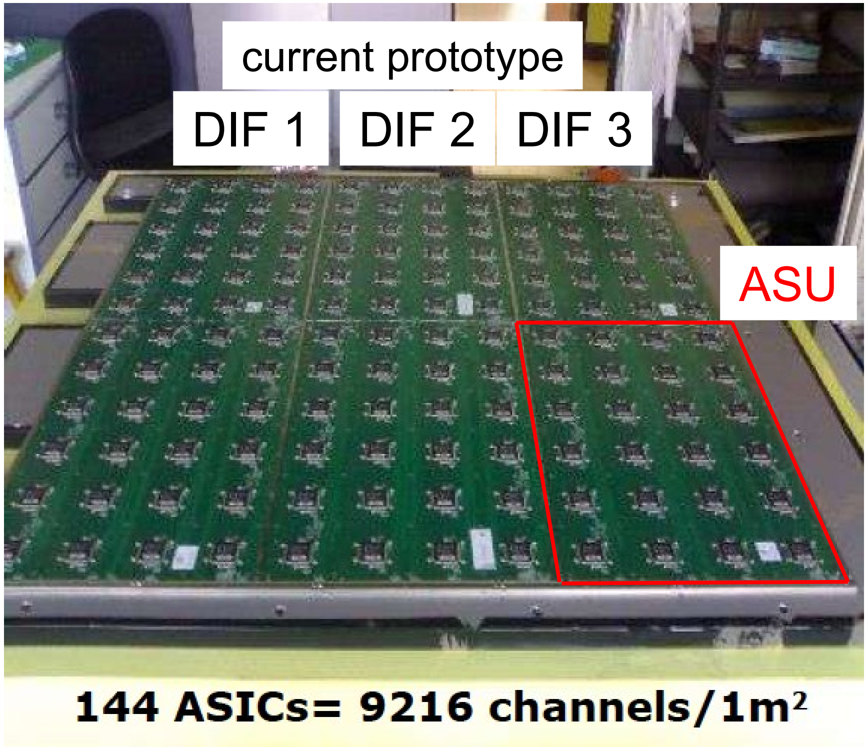
work in progress



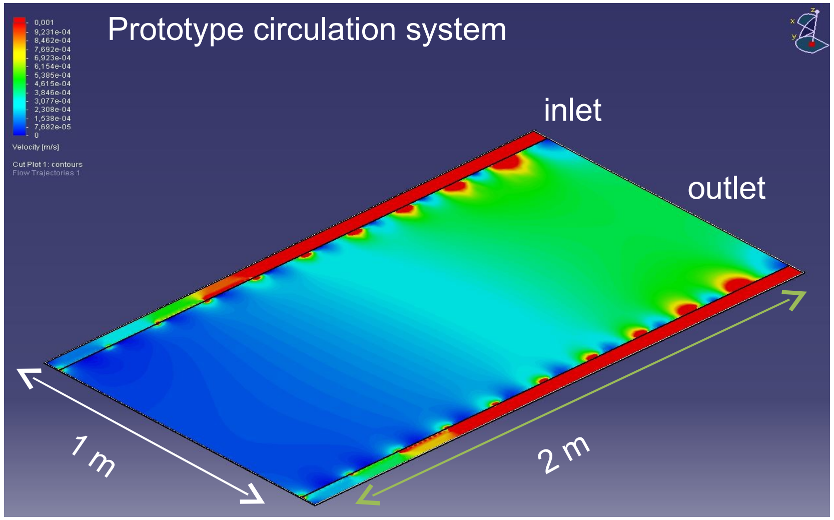
SDHCAL: Current Layer Layout and Plans

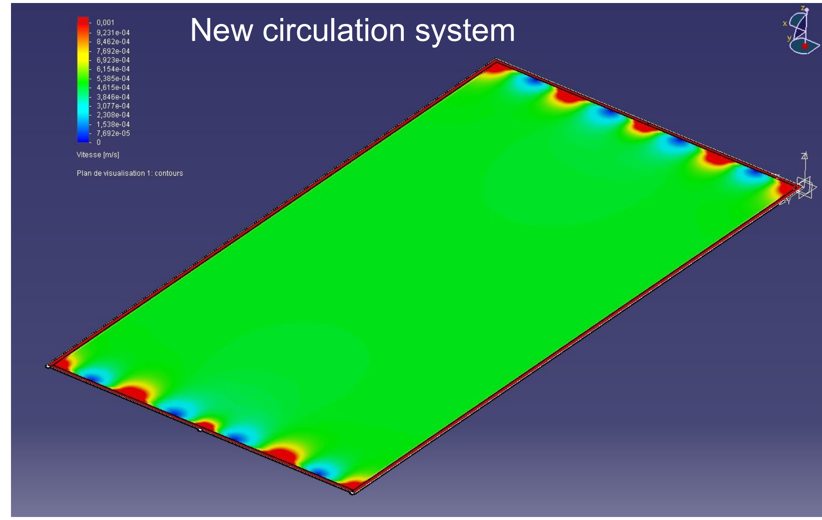
- have demonstrated layers with integrated electronics of 1 m^2
- next steps:
  - build few very large GRPC detectors (2-3 m^2): gas circulation system, thickness…
  - build a small mechanical prototype to host the few large chambers
  - improve on the readout electronics (3^{rd} generation ASICs)
  - design a new ASU capable to read the large GRPC
  - develop a new DIF (low power consumption, reduced size, new functionalities)





Hardware R&D for next generation of SDHCAL: Gas distribution

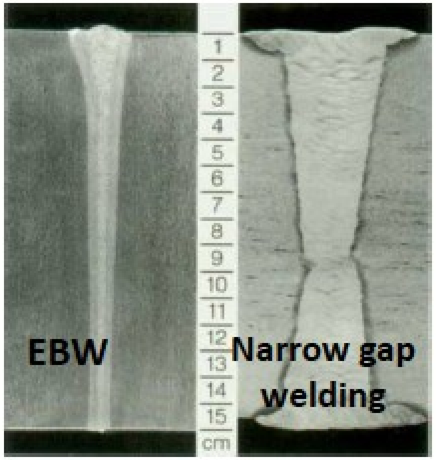


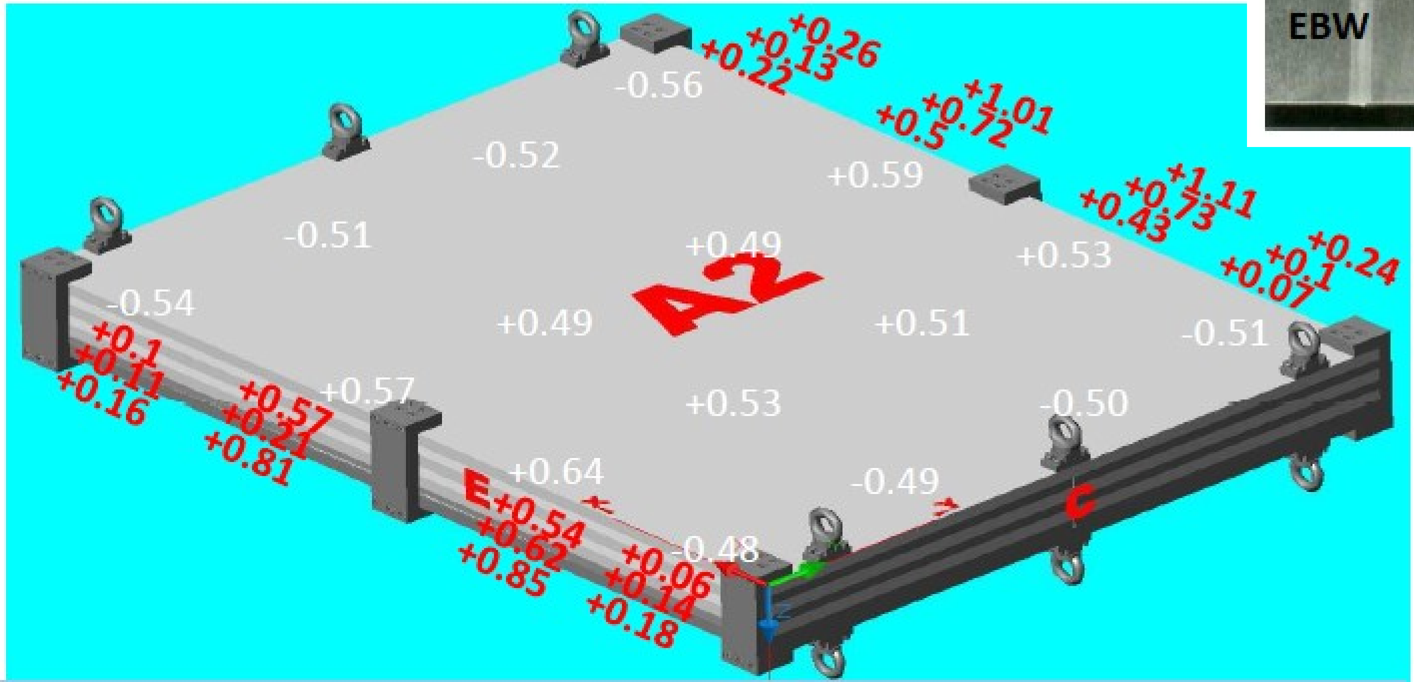


- new circulation system → homogenous gas flow

Hardware R&D for next generation of SDHCAL: Mechanics

- electron beam welding allows very narrow welding which should lead to only small deformations
- first test with 1m² plates showed deformations bigger than expected (up to ~1mm)
- working on improving the welding sequence



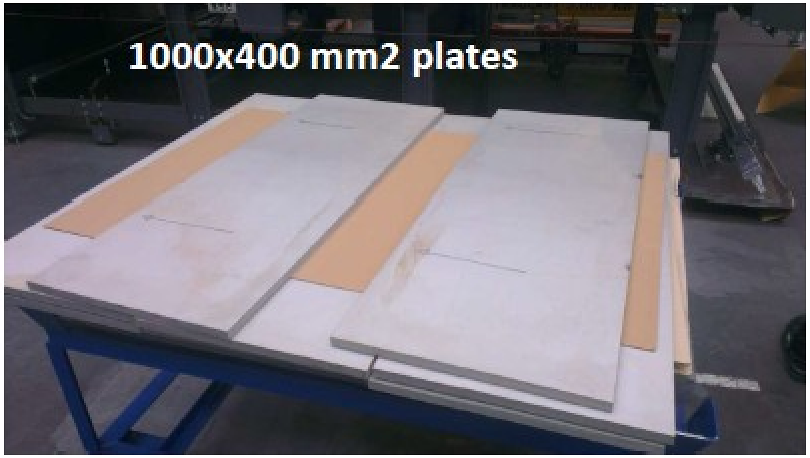


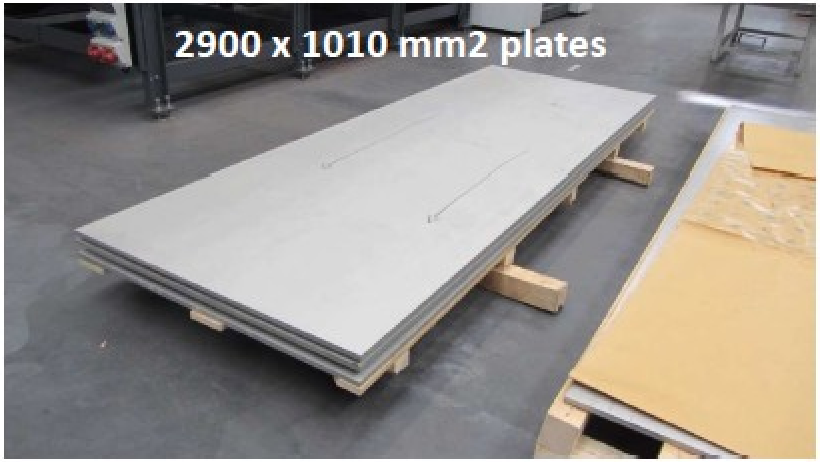
Differences with respect to the initial status of the plate in Z.
Differences with respect to the initial status of the distance between plates

Hardware R&D for next generation of SDHCAL: Mechanics

- up to now plates have been obtained by machining
  → time consuming and expensive
- possible solution: roller levelling (already used for AHCAL for ~2m long structures)
- first test with small and big plates in September 2015 at company ARKU

ARKU



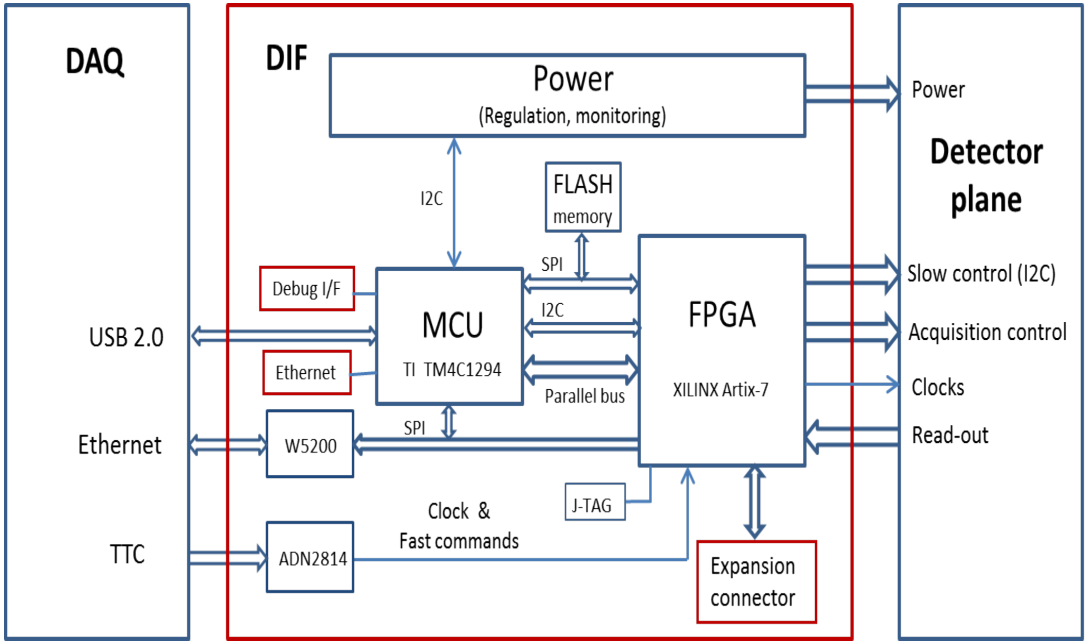


Hardware R&D for next generation of SDHCAL: Mechanics

- results of first measurement done at the company (more precise ones will follow)
- very good flatness (better than the required 1mm)

Hardware R&D for next generation of SDHCAL: Electronics

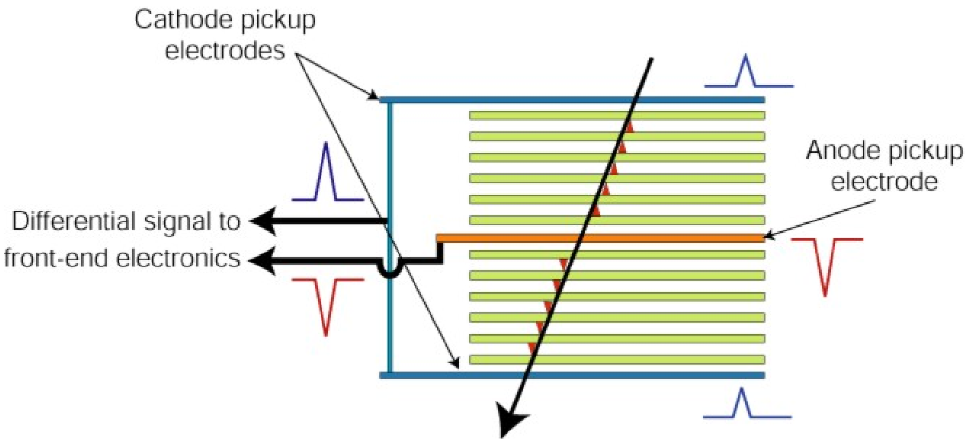
- **HARDROC3:** preliminary results confirm that all functionalities are ok. test of 600 HARDROC3 is in preparation
- **DIF:** design is in an advanced stage

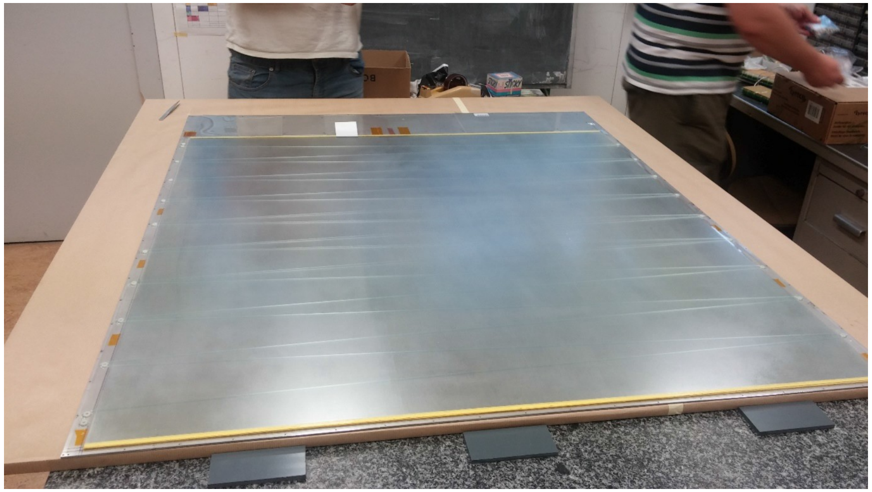


- **ASU:** routing is being finalized
  - baseline is 50x33 cm² PCB (24 ASICs)
  - large PCB of 1m width seems achievable

Multi-gap RPCs

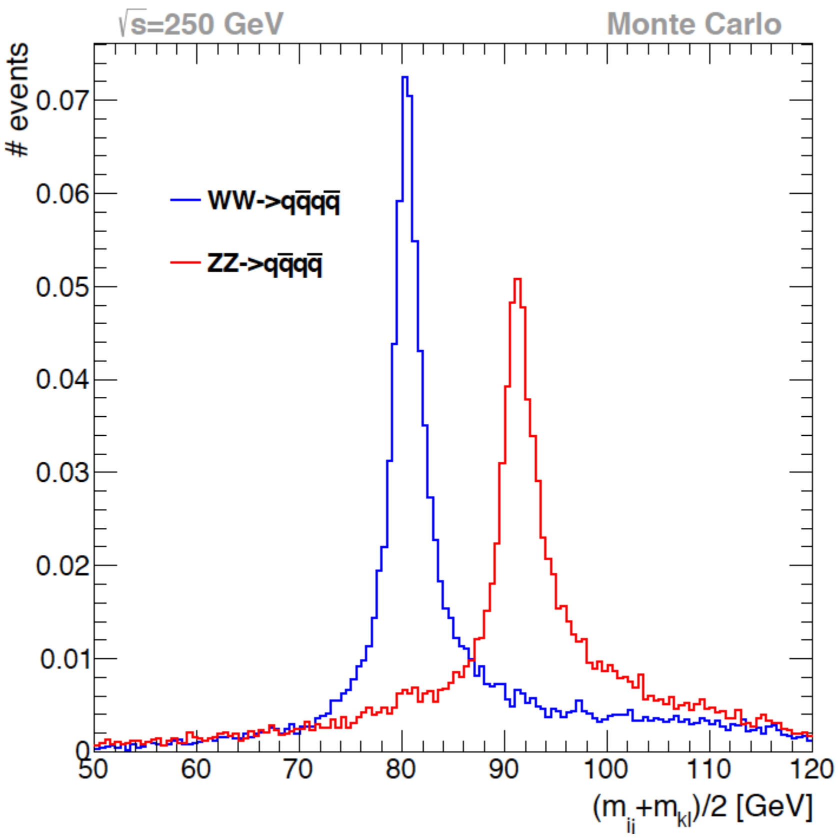
- MRPCs offer
  - good rate capabilities: better than 1000 Hz/cm²
  - large efficiency plateau with no streamers
  - very good time resolution: better than 100 ps
  - large areas at a reasonable cost
- used for example in ALICE TOF (160000 channels, built in 2004)
- prototype layer for SDHCAL built
  - 1m² in size
  - 5 glass layers, 4 gaps
  - in testbeam at PS in October 2015: good efficiency (>90%)

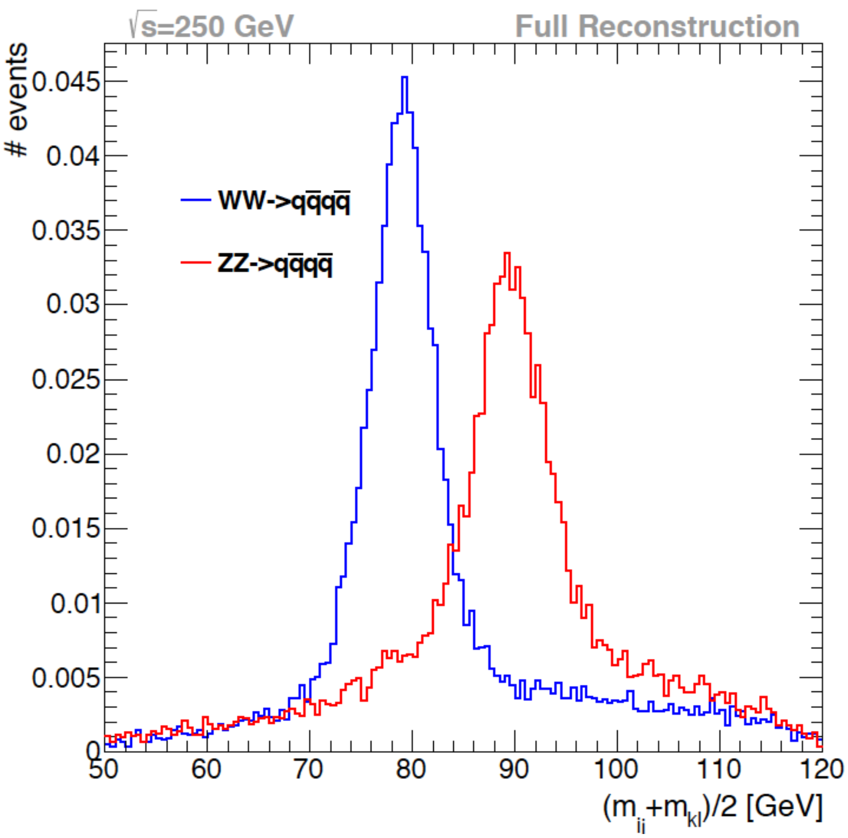




SDHCAL performance in ILD simulation

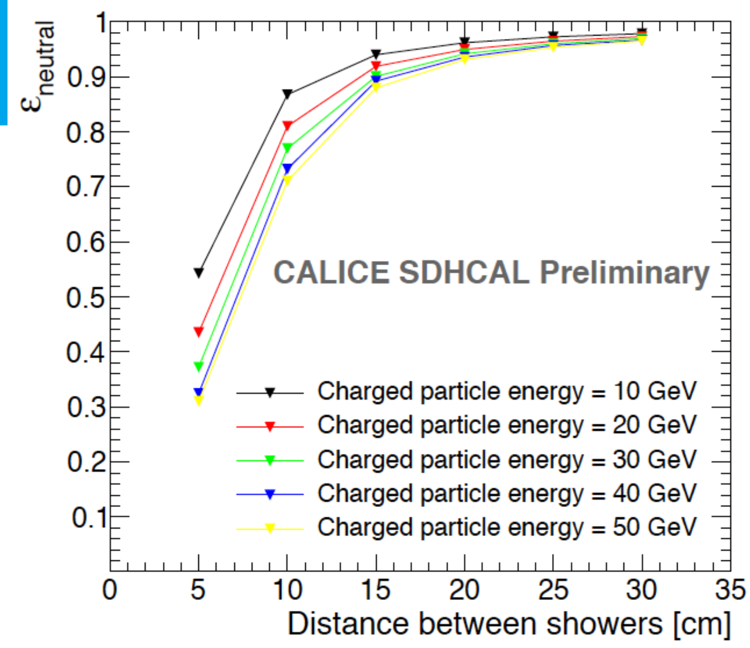
- simulation of 4-jet events from WW or ZZ production at 250 GeV
  - full ILD simulation with SDHCAL, Pandora PFA
  - FastJet run on MC particles or reconstructed particles

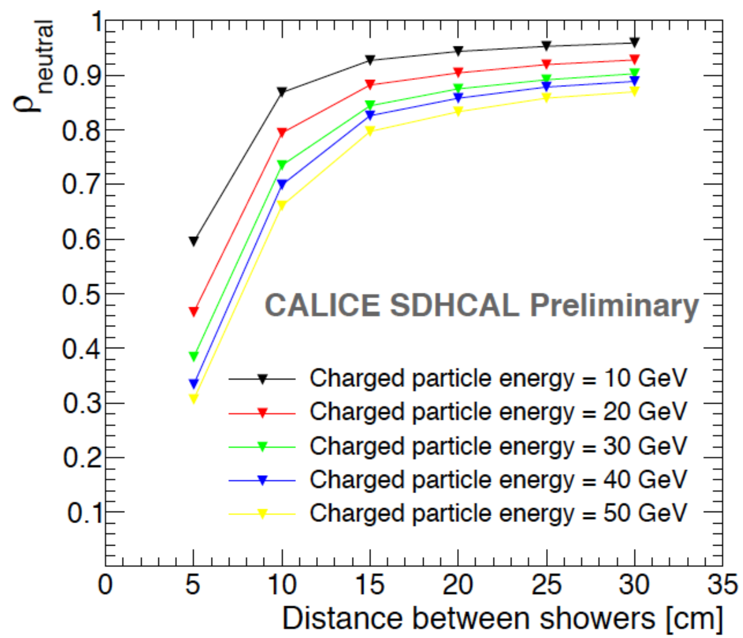




ARBOR

- ArborPFA:
  - particle flow algorithm using the tree-like structure of showers
  - energy information used in finalising clustering and track association
  - modular architecture: uses PandoraSDK toolkit and Marlin framework, available at https://github.com/SDHCAL/ArborPFA
- test of cluster separation with SDHCAL pion shower data
  - overlay of 2 pion events: 10 GeV "neutral" particle (initial track segment removed) and charged hadron with 10 – 50 GeV at 5 – 30 cm distance
  - good efficiency and purity to assign hits to the neutral cluster for distances of 10 cm or more





SDHCAL plans

successful operation of prototype with integrated electronics & power pulsing

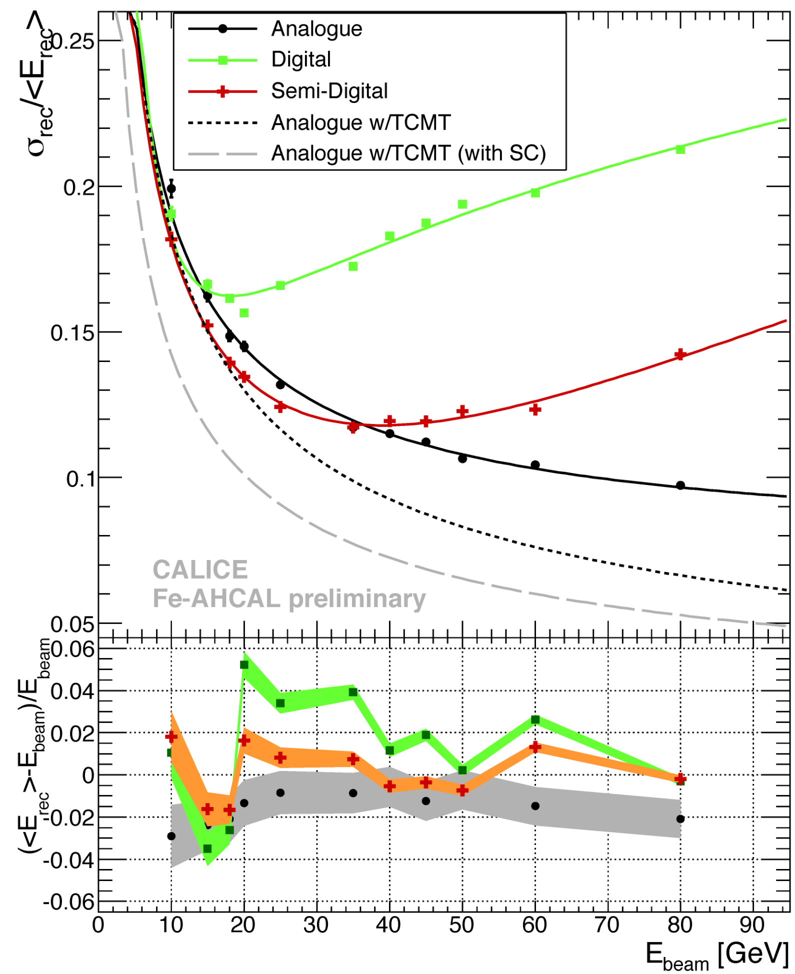
- preliminary results documented in analysis notes, papers in preparation
  - energy resolution
  - simulation validation
  - advanced energy reconstruction algorithms (Hough transform, Neural Net)
- ArborPFA: alternative particle flow algorithm

next steps

- build large chambers
- demonstrate mechanics: welding and flatness
- build electronics for 3rd generation readout chips

Towards understanding the differences

- AHCAL and SDHCAL differ in several aspects
  - granularity
  - energy reconstruction method
  - active medium
- all of them influence the energy resolution for single particles and jets
- disentangle with data and validated simulation
  - 3*3 cm² AHCAL data with different reconstruction methods



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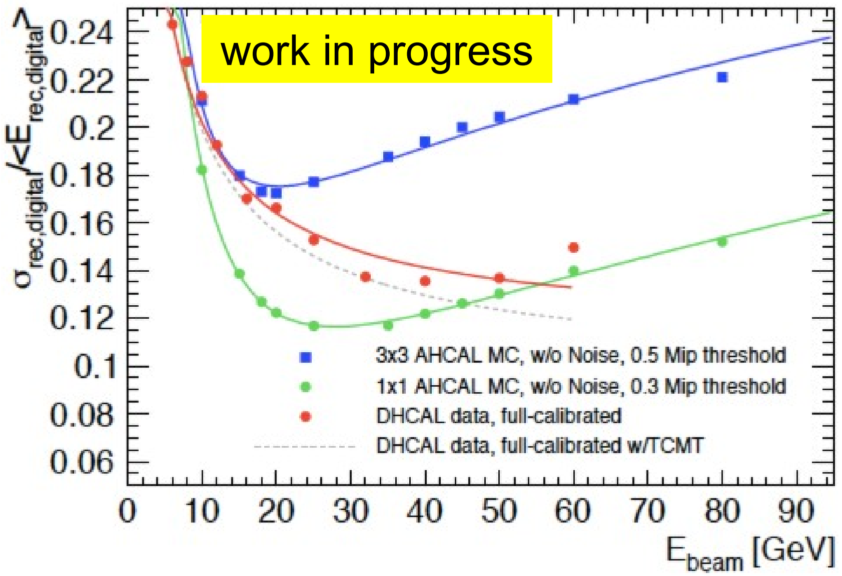
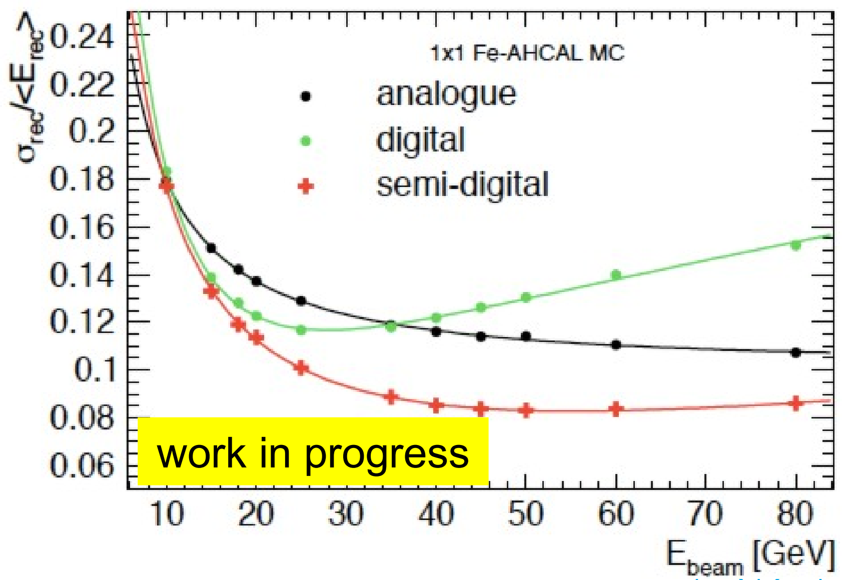
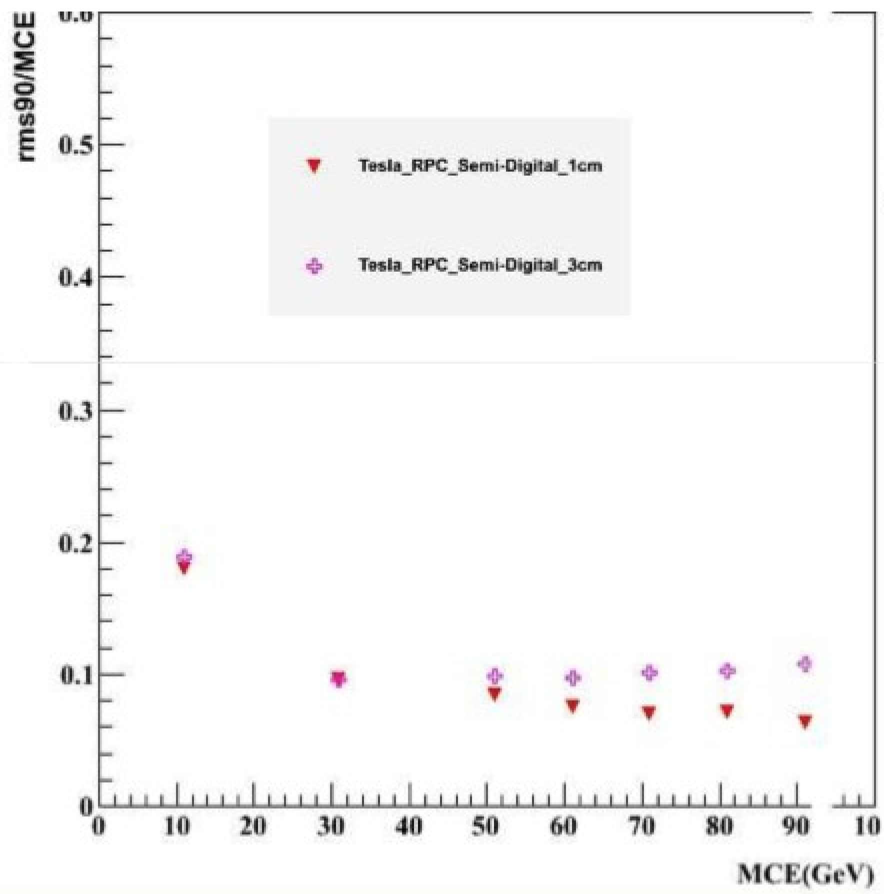
- all of them influence the energy resolution for single particles and jets
- disentangle with data and validated simulation
  - 3*3 cm² AHCAL data with different reconstruction methods
  - 3*3 cm² and 1*1 cm² AHCAL simulation with different reconstruction methods

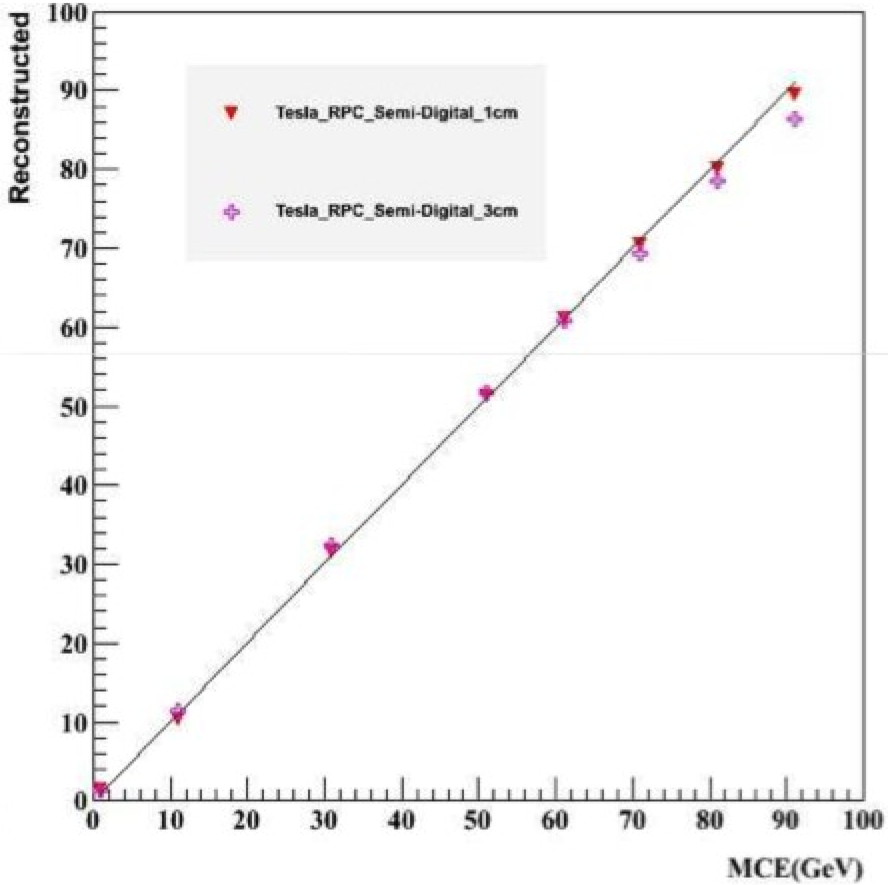




Towards understanding the differences

- for comparison: K0 starting showering in the ILD SDHCAL, simulation with 3*3 cm² and 1*1 cm² granularity





Conclusions

AHCAL

- successful operation of physics prototype, validation of simulation and PFA
- on the way to an ILD-ready detector:
  - demonstrated system with 2nd generation integrated electronics and scalable DAQ in testbeams
  - demonstrated tile design for large scale production and automatic assembly
  - tests of power pulsing with improved electronics started, testbeams to come

SDHCAL

- successful operation of prototype with integrated electronics & power pulsing
  - preliminary results available as analysis notes, papers well under way
- on the way to an ILD-ready detector:
  - development of large GRPCs and mechanics for large chambers ongoing
  - tests of 3rd generation readout chips & corresponding changes in DAQ and electronics started
  - optimisation of PFA

Many thanks to all AHCAL and SDHCAL colleagues providing material and feedback!

More details in talks in muon/calo session:

- SDHCAL prototype status: M. Fouz Iglesias
- ArborPFA: R. Ete
- AHCAL prototype status: K. Krüger
- Particles up to 150 GeV in the W-AHCAL: E. Sicking, F. Sefkow
- SiPM gain studies for adaptive power supply: G. Eigen