AHCAL status and plans

- AHCAL Prototypes
- Testbeams in 2015
- Towards mass production
- Next steps

Katja Krüger (DESY)
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CERN
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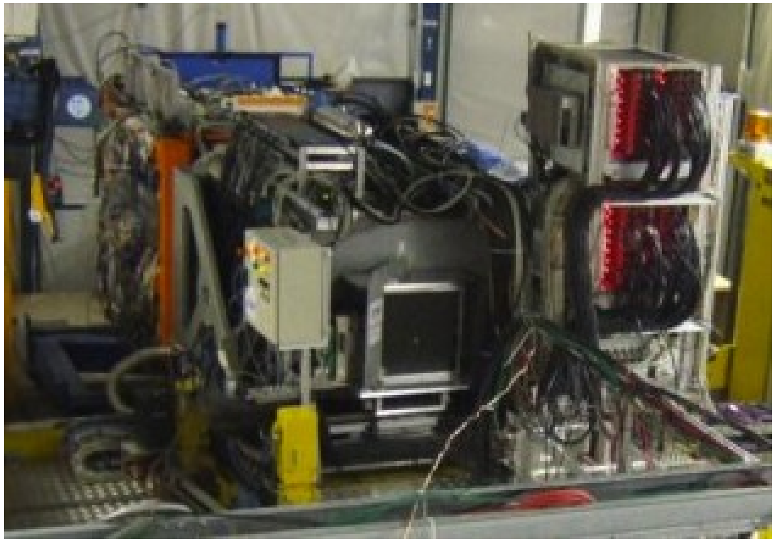
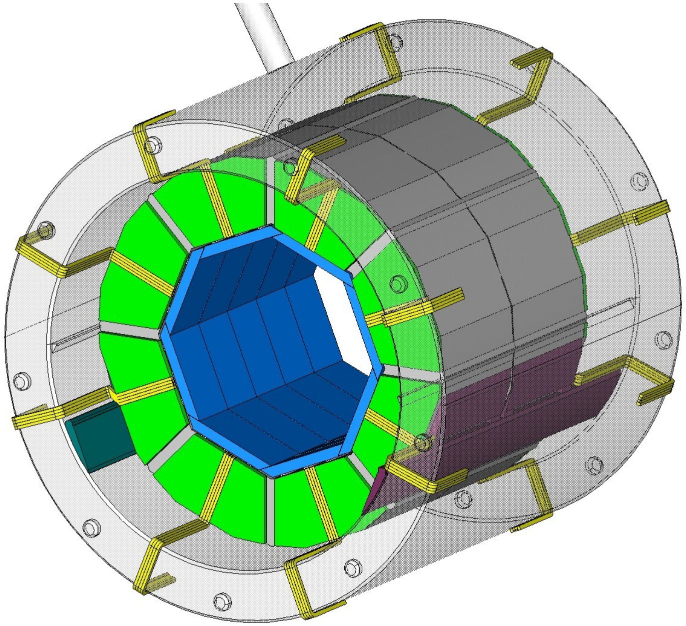
AHCAL Prototypes

- 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

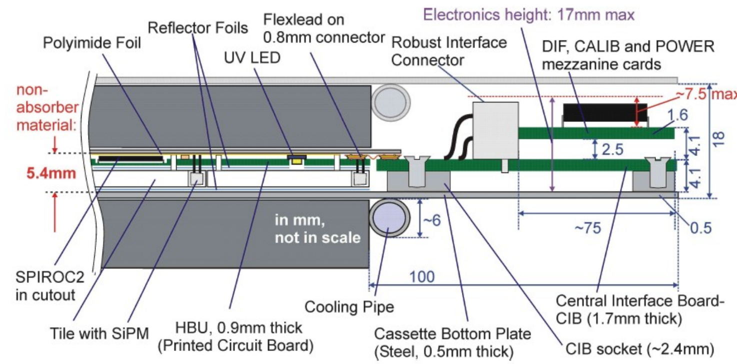


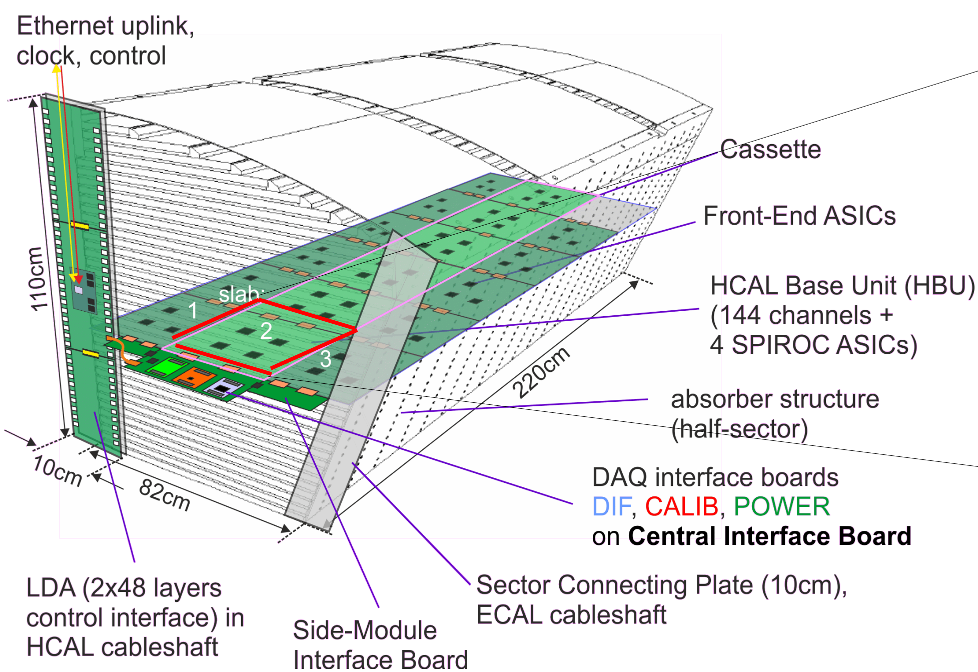
- goal for the "technological prototype": develop, build and test a prototype scalable to the full collider detector layout
  - integration of electronics into layers
  - realistic infrastructure
  - easy mass assembly
  - detector optimisation

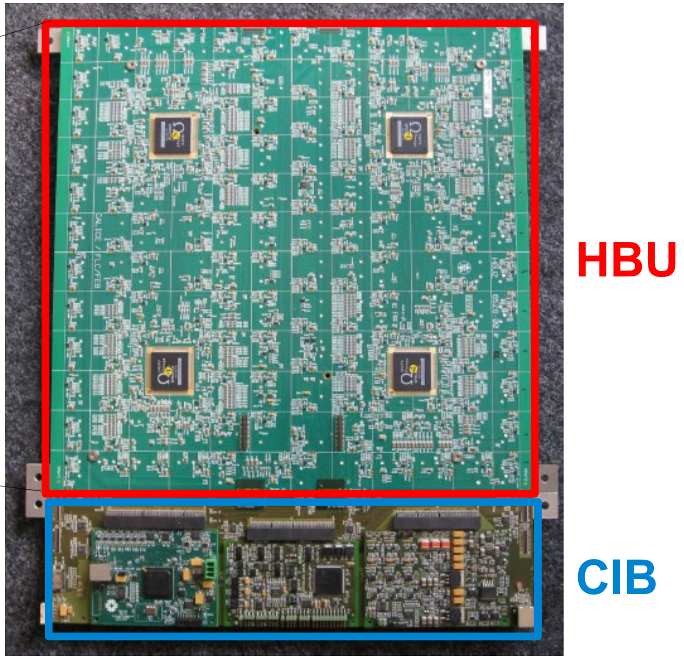


AHCAL engineering prototype: Integrated Electronics

- **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





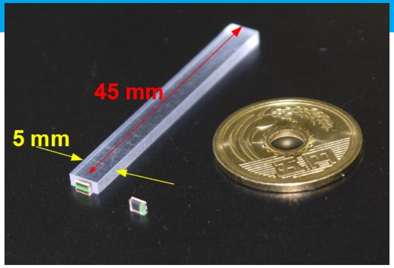


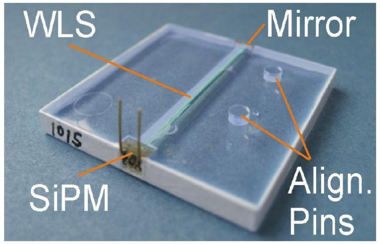
AHCAL testbeams in 2015: Goals and Preparation

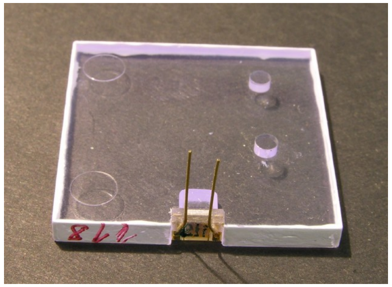
- first SPS test beam with 2nd generation electronics and DAQ
  - 2 weeks (8. – 22. July 2015) in EUDAQ steel stack
  - 2 weeks (12.–26. August 2015) in tungsten stack (already used for physics prototype)
- extensive preparation
  - testbeams at PS in October and November 2014
  - testbeams at DESY in 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

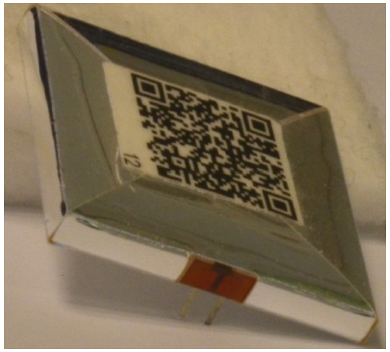
Tiles/Strips and SiPMs

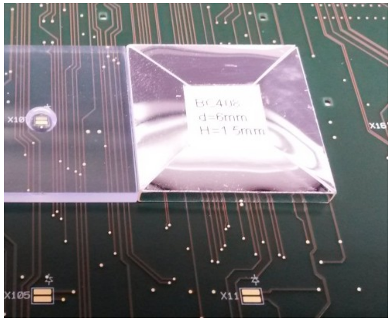
- 2 or 3 (ECAL) layers with strips
  - Hamamatsu MPPCs with 1600 pixels
  - Hamamatsu MPPCs with 10000 pixels
- 5 layers with tiles with wavelength shifting fibre
  - CPTA SiPMs with 800 pixels
- 2 layers with tiles without WLS
  - Ketek SiPMs with 12000 pixels
- 1 layer with surface mount SiPMs with 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







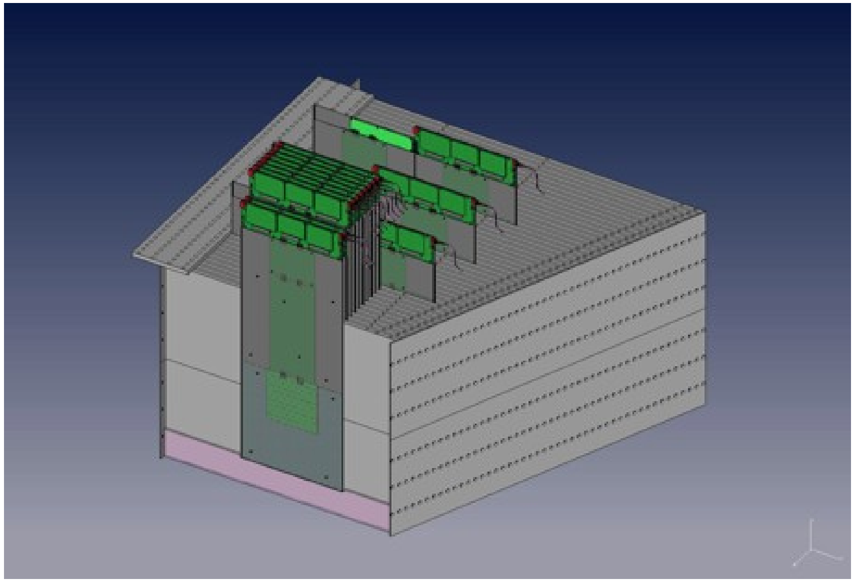




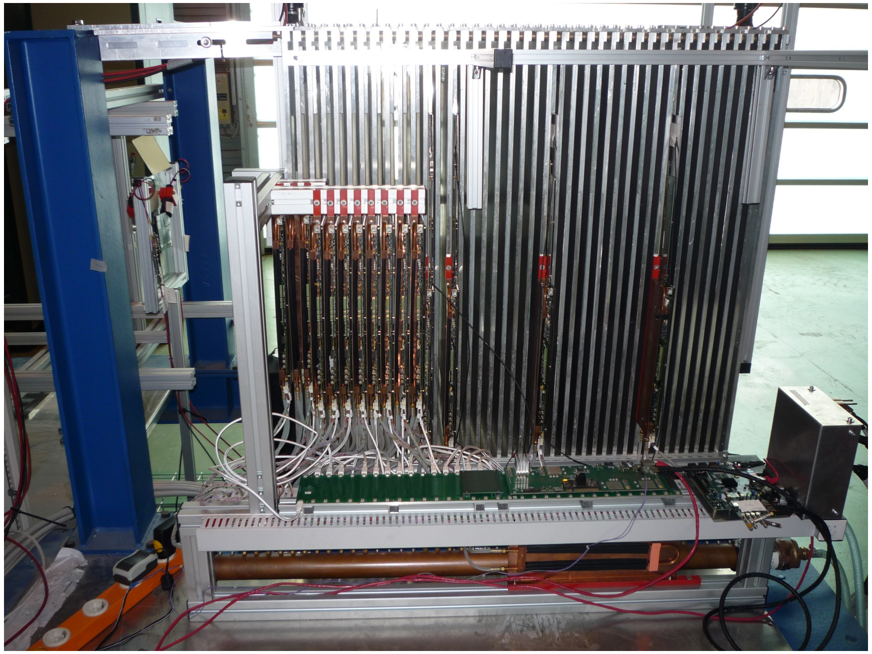
- we want to build a fully equipped prototype in the coming years
- experience from testbeams is important input to chose one option

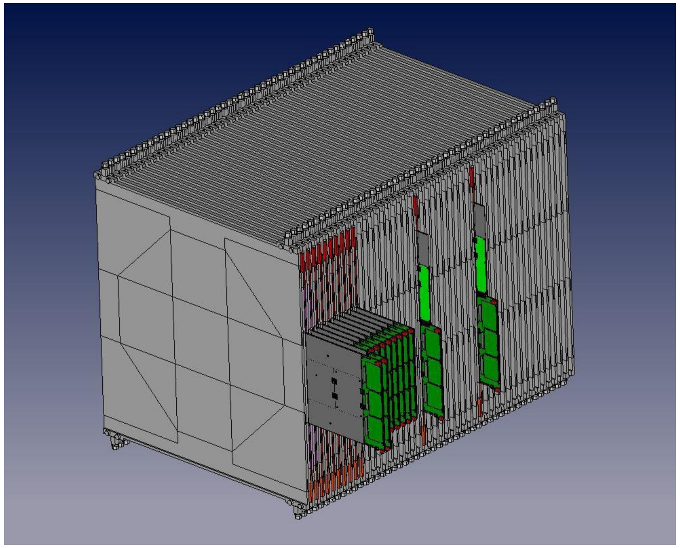
Setup of steel AHCAL technological prototype

- **>** layer configuration
  - 10 small layers (18*18 or 36 * 36 cm^2): shower start finder
  - 4 big layers (72 * 72 cm^2): shower profile, correlation of hit times
- **>** steel absorber structure
  - as planned for ILC detector barrel
  - tested for 2 weeks in July in H2@SPS



Setup of tungsten AHCAL technological prototype





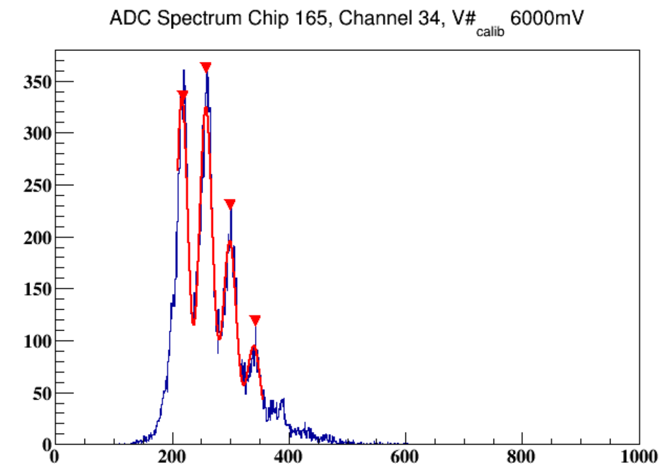
- (nearly) identical layer configuration
  - 11 small layers (18*18 or 36*36 cm^2): shower start finder
  - 4 big layers (72*72 cm^2): shower profile, correlation of hit times
- tungsten absorber structure
  - as already used in physics prototype
  - tested for 2 weeks in August in H6@SPS
- both stacks: infrastructure for 48 layers:
  - complete DAQ setup
  - water cooling
  - power distribution

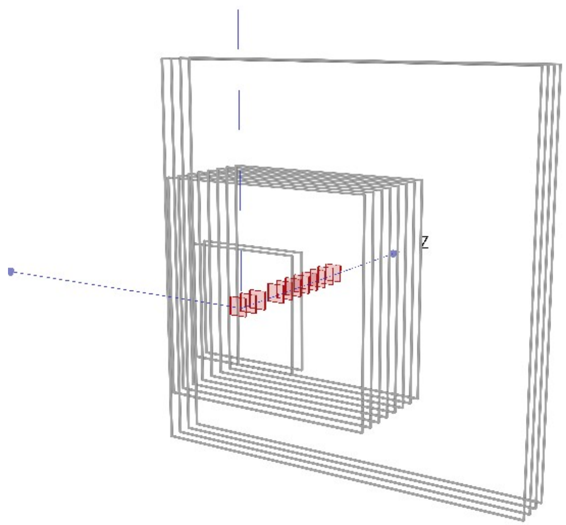
AHCAL Testbeams in 2015

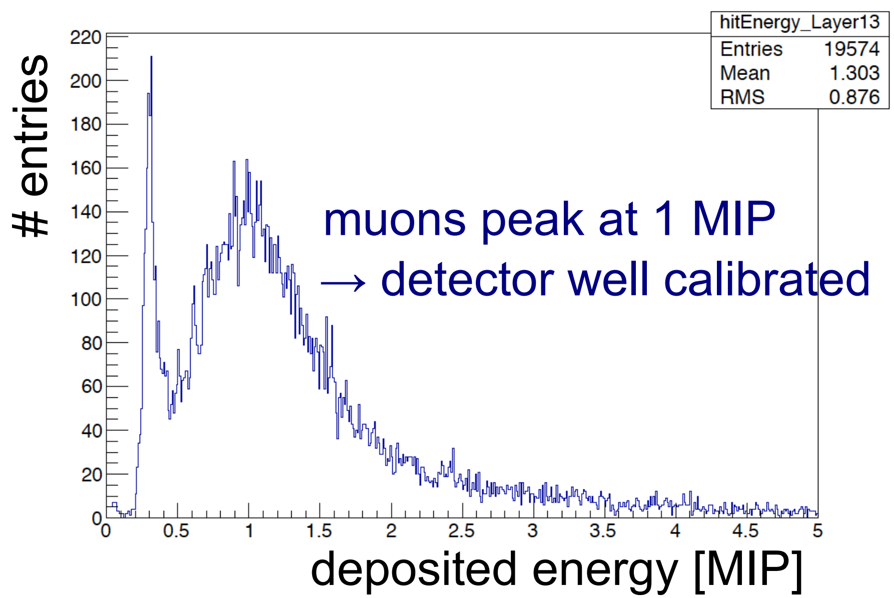
- very stable running of the detector
  - no instabilities in electronics and DAQ observed
  - 5 days without beam from SPS during tungsten data taking
- integration concept for full module successfully tested
- would have been impossible without support from CERN LCD group!

AHCAL Testbeams: data quality and calibration

- online data quality monitoring
  - event display
  - (quasi-)online histograms of reconstructed quantities
- gain monitoring with regular LED runs
  - some layers with old SiPMs developed inefficiencies
- MIP calibration cross check

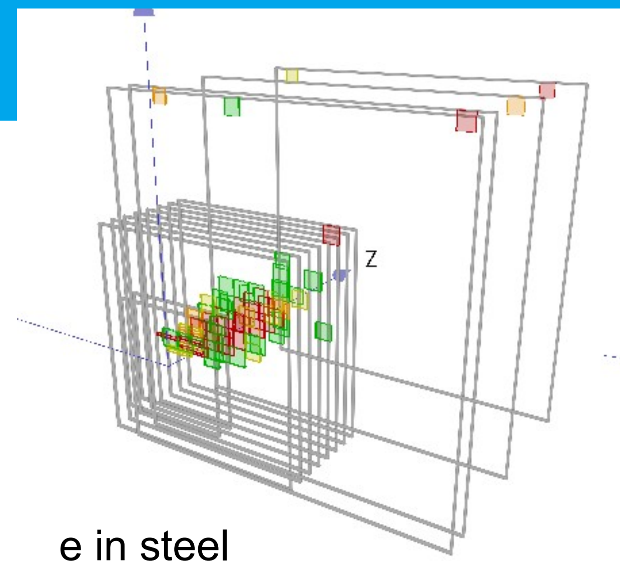




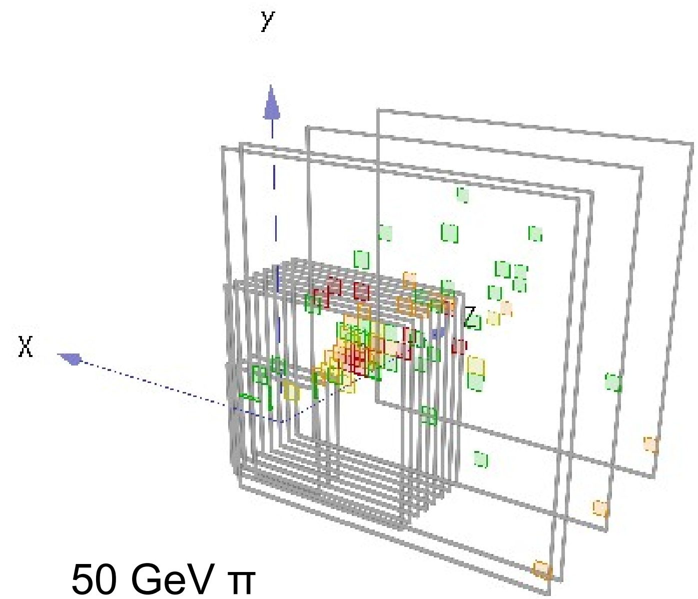


AHCAL Testbeams

- 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
- distributed data analysis started
  - adapted software framework from physics prototype
  - database with geometry description and preliminary calibration constants
  - very first simulation model
  - contributions welcome!



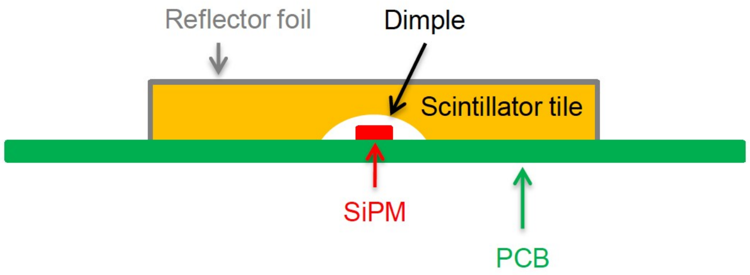
e in steel



50 GeV π
in tungsten

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



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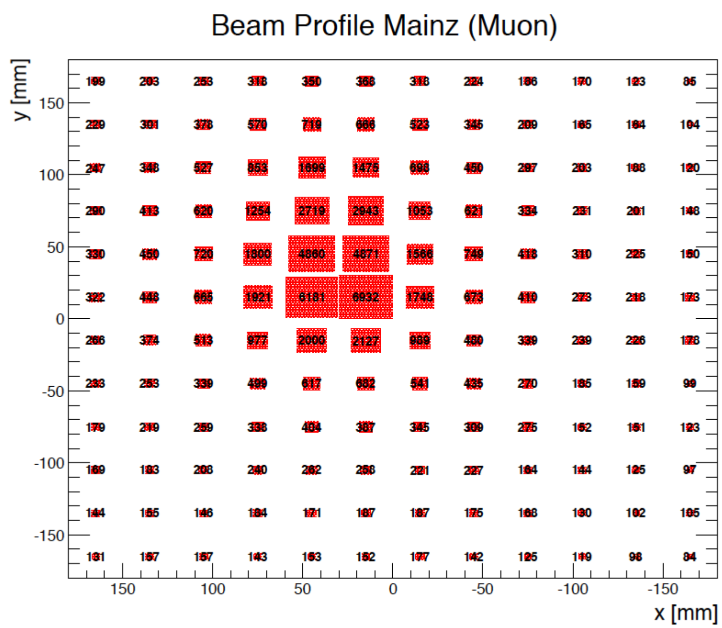
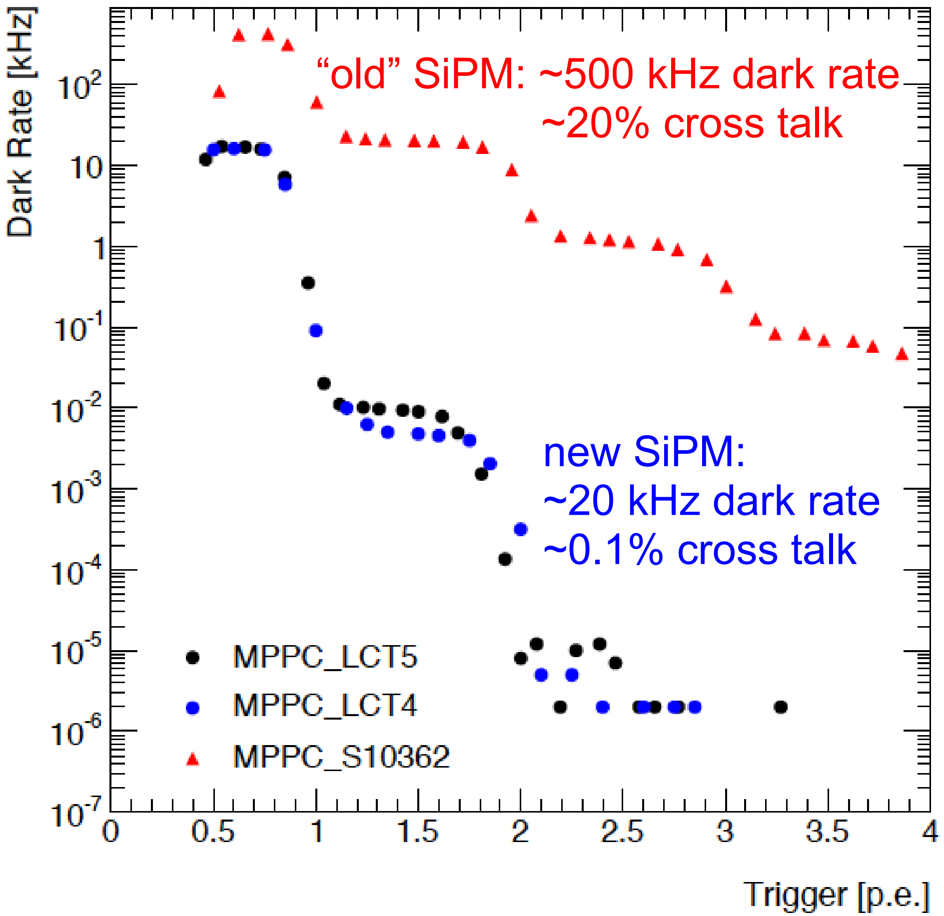
- new HBU design for surface-mount SiPMs:
  - SiPMs mounted directly on PCB
  - individually wrapped tiles
  - → mass assembly with pick-and-place machine possible
  - further possible improvements identified, to be tested
- very positive experience
  - all channels working
  - very homogeneous gain



New generation of SiPMs

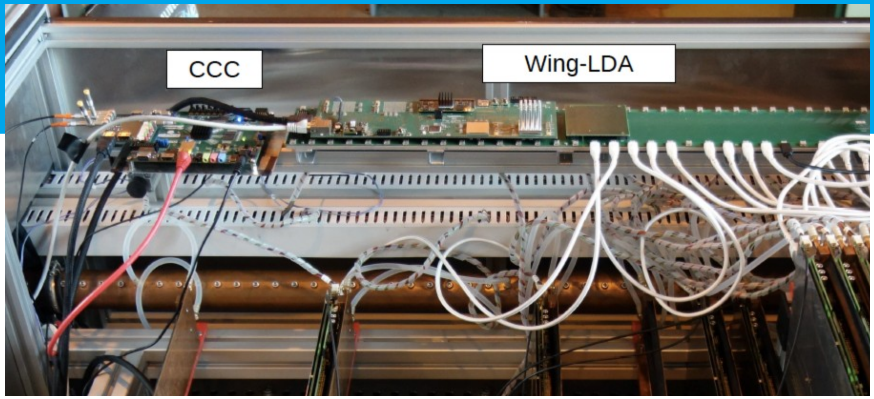
- recent SiPMs show very much improved sample uniformity
  - operating voltage
  - gain
- very recently, SiPMs with trenches between pixels became available
  - slightly reduced geometrical fill factor
  - dramatically reduced dark rate and pixel-to-pixel cross talk
  - for typical trigger threshold of AHCAL (~7 p.e) **noise-free**
- SiPMs are a rapidly evolving field
  - new generation fulfills our requirements
  - further developments expected

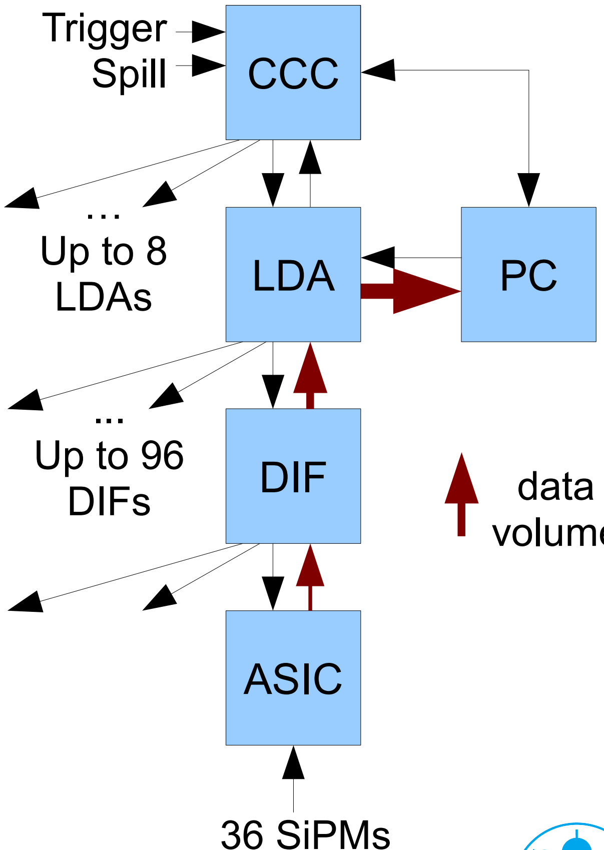


for comparison: SiPMs in physics prototype
2 MHz dark rate, 30% cross talk

Scintillator DAQ

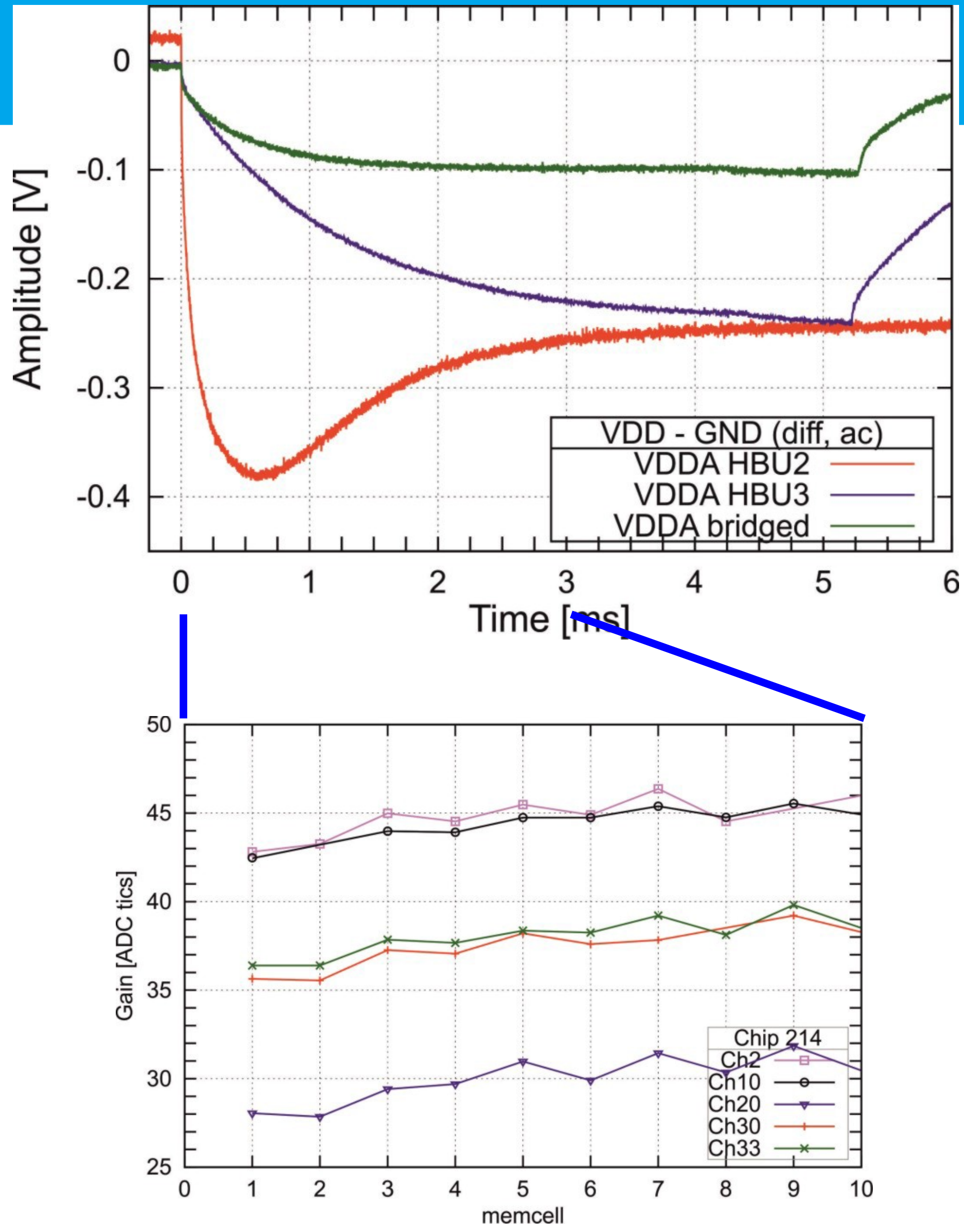
- successfully operated in beam tests
  - stable running
  - reached ~17 readout cycles / s (requirement for ILC: 5)
    → >250 Hz sustained event rate
  - speed-up of factor of ~2 possible
- scalable to full collider detector
- new Beam InterFace under development: include beam signals (trigger scintillators, ...) into DAQ
- common running with SiECAL demonstrated
- ongoing effort towards common DAQ
  - CALICE DAQ taskforce: common running of all CALICE calorimeters
  - within AIDA-2020: common running with silicon detectors and possibly TPC prototype





Power pulsing tests

- HBU3: revised version of HBU to improve power pulsing behaviour
- tested with full-length slab (6 HBUs) in lab
- first results:
  - power consumption looks encouraging
  - single pixel spectra look good for all switch-on times
  - gain lower by ~5-10% for short switch-on times
- to be done: demonstrate power pulsing operation with beam



Next steps

- 6 new HBUs with surface-mount tiles and new generation SiPMs in production
  - gain further experience towards mass production
  - expect very homogenous, high-quality layers
- together with already existing good HBUs, can build small prototype for electromagnetic showers with high-quality photo-sensors in all channels
  - e.m. shower response and resolution
  - power pulsing
- 2 weeks of testbeam at DESY in May and June 2016 (second half of 2016 not yet decided)
  - characterize new HBUs
  - test power pulsing in beam
  - test new BIF
  - common running with beam telescopes later this year

Summary

several important steps towards full-scale detector taken:

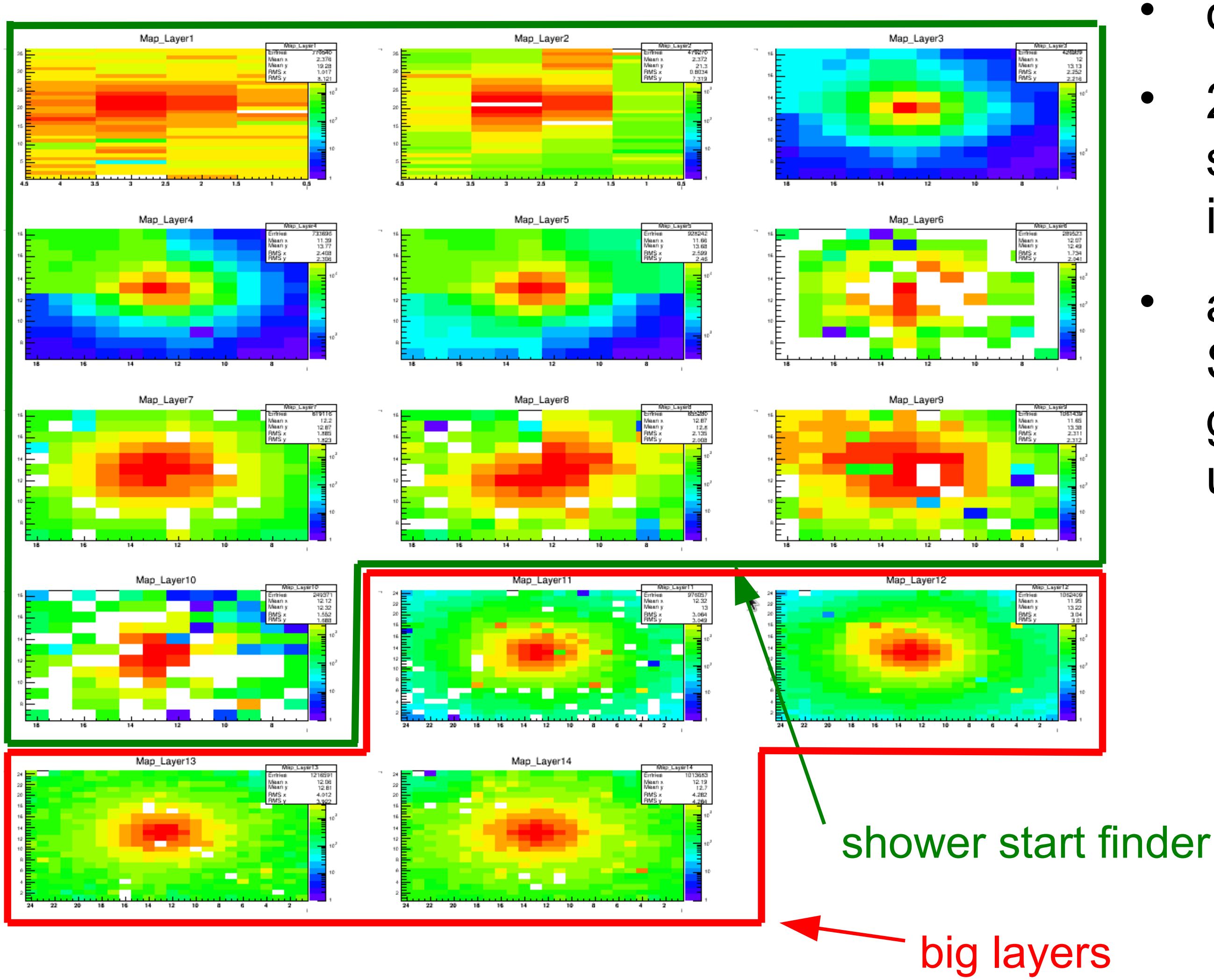
> successful demonstration of the system integration (DAQ, power etc)
> established electronics design with surface mounted SiPM and automated assembly
> latest generation SiPMs are very uniform and practically noise-free

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
> in parallel: continue studies on SiPMs and tiles (e.g. megatiles)

Backup

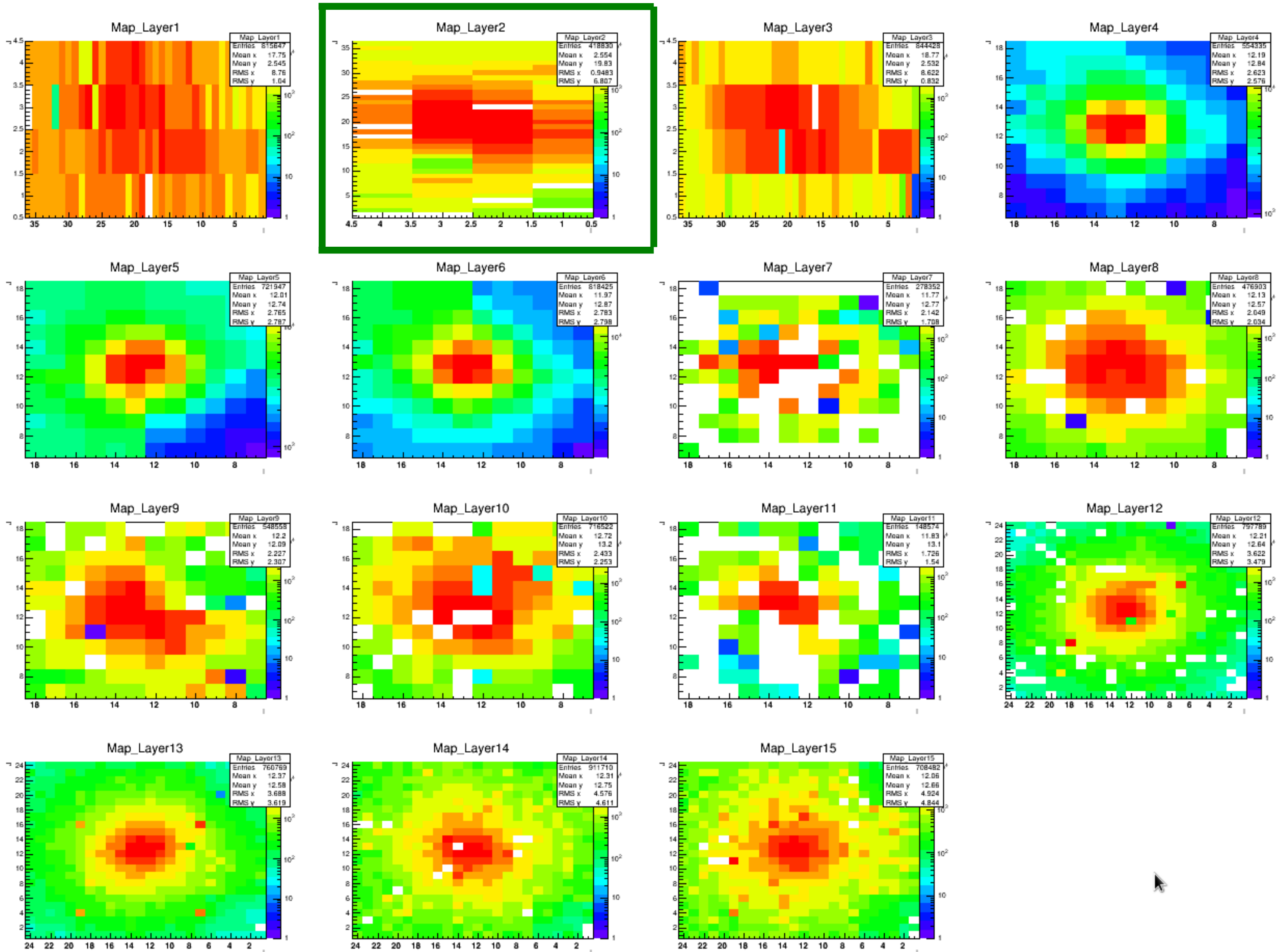
Hit map: steel



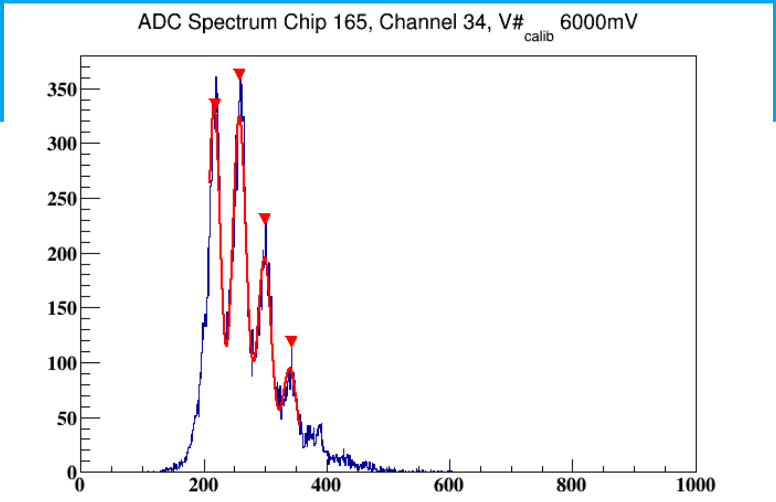
- one pion run
- 2 layers in shower start finder rather inefficient
- all layers with new SiPMs and tiles show good efficiency and uniformity
  - strips
  - tiles without WLS
  - surface-mount SiPMs
  - 4 big layers

Hitmap: tungsten

additional EBU with opposite strip orientation

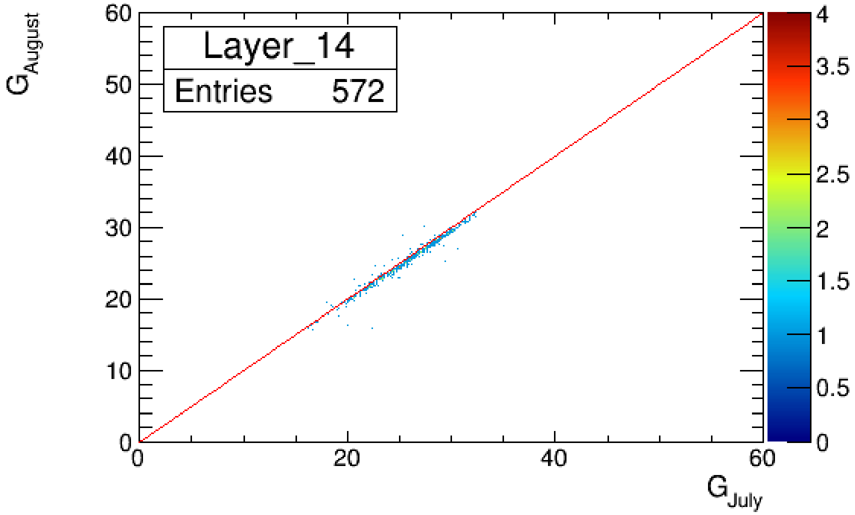


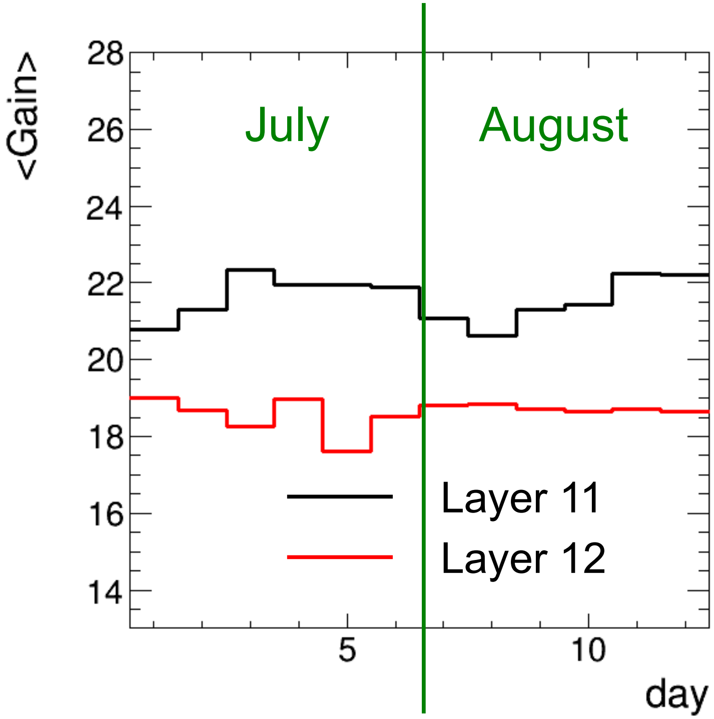
LED data quality monitoring



- most layers look fine
- few smaller problems
  - 2 HBUs with old tiles developped inefficiencies
  - single pixel peaks disappearing for 2 HBUs
  - jump of gain between July and August for 1 HBU

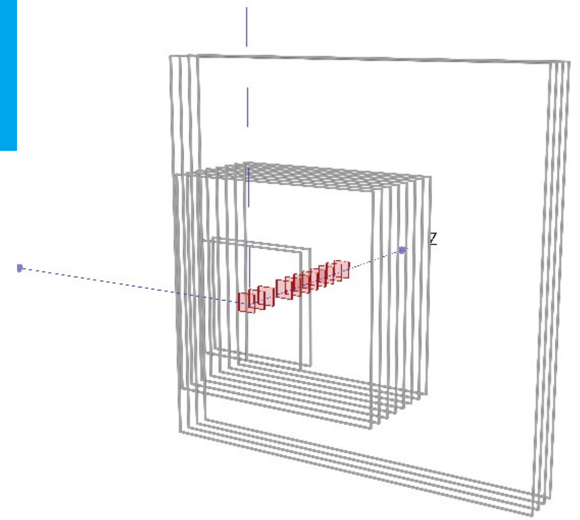
→ to be investigated

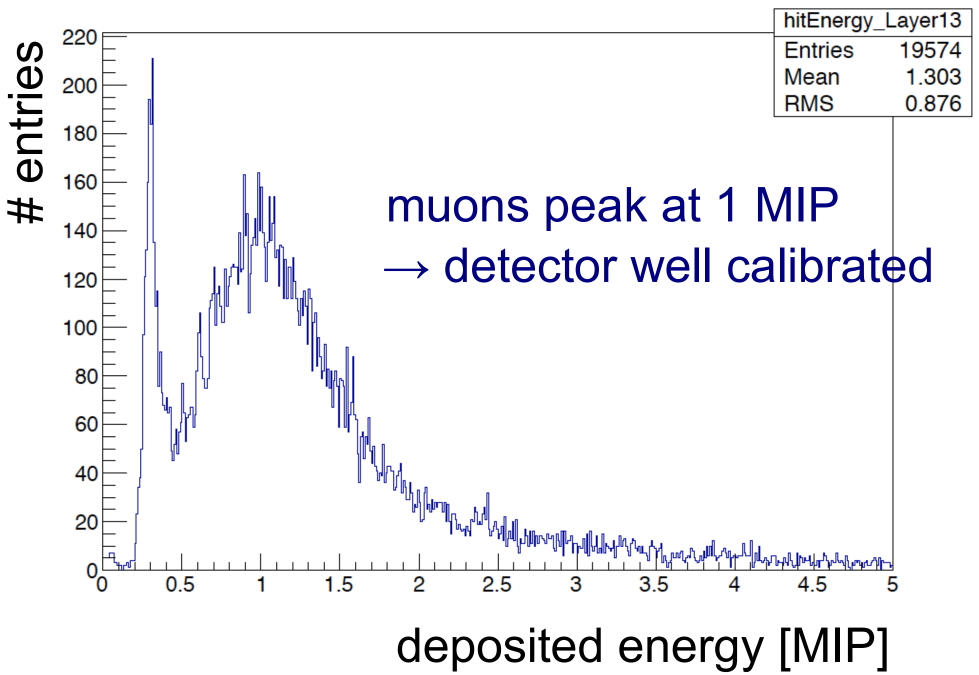




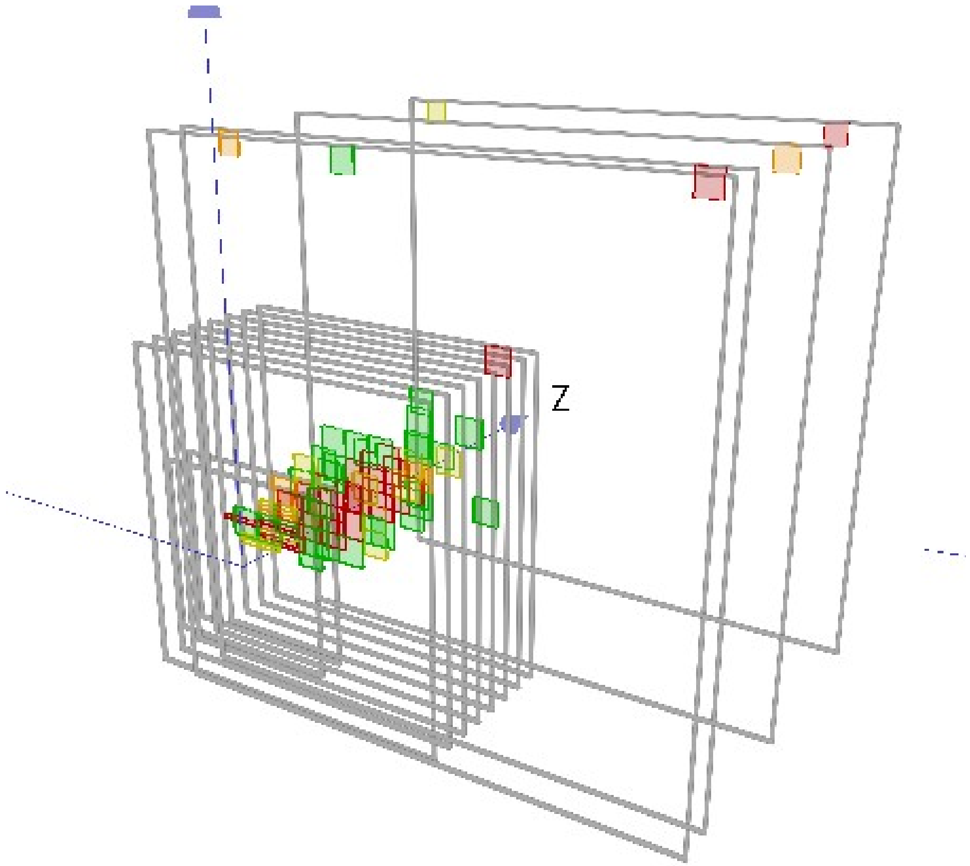
Data samples: muons

- check of calibration at low cell energies
- timing reference
- steel:
  - 2 scans of innermost 36*36 cm²
  - first scan: ~60 positions, ~50k beam events in each (all inner positions with rather high threshold on trigger scintillator)
  - second scan: 36 positions, ~50k beam events in each
- tungsten:
  - ~700k beam events with wide beam
  - should cover innermost 36*36 cm² with enough statistics
- muon calibration within ~3 days!



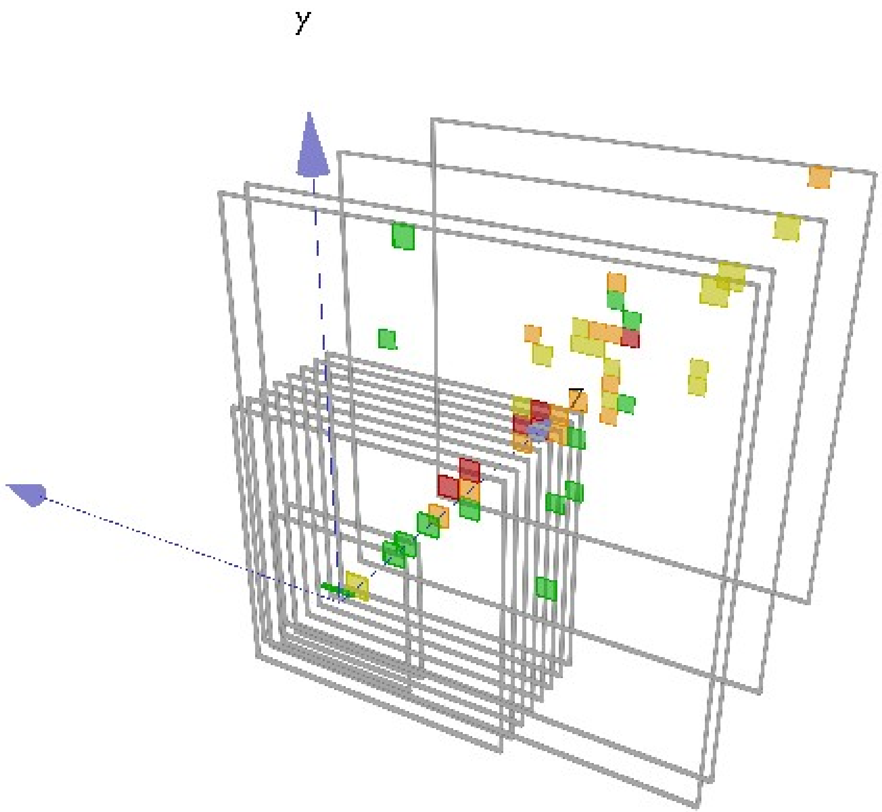


Data samples: electrons



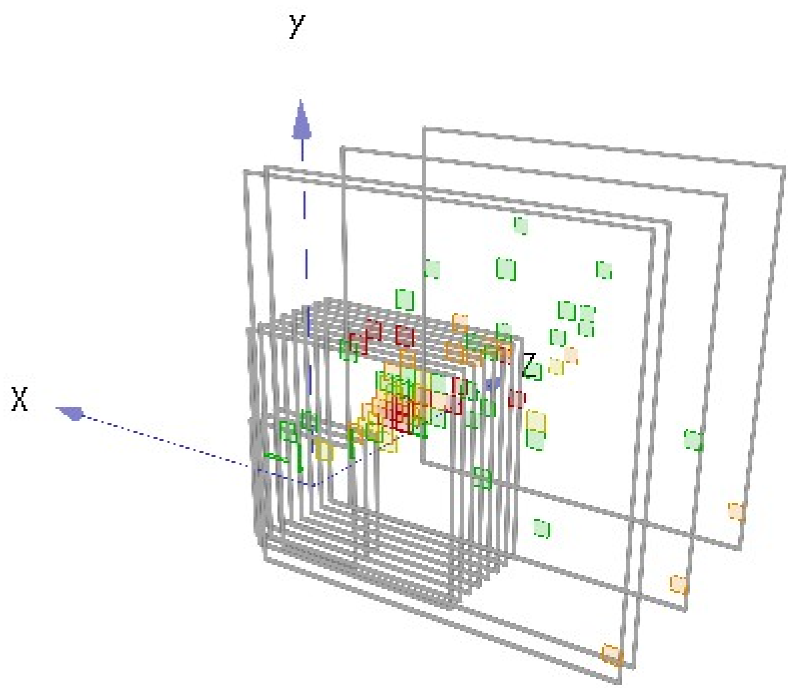
- check of calibration at high cell energies
  - saturation corrections
- demonstrate understanding of detector in simulation
- steel: energy scan: 10, 15, 20, 30, 40, 50 GeV
  - clean electron beam
  - >300k events with cherenkov ID per energy (but cherenkov inefficient)
  - typically ~500k events with trigger scintillator per energy
- tungsten: 20 GeV: ~500k events

Data samples: pions in steel



- shower shapes
- hit times and their correlations
- can hit time information help in particle flow reconstruction?
- negative pions: energy scan 10, 30, 50, 70, 90 GeV
  - at first without absorber: only ~50% hadrons, 600k events with trigger scintillator per energy
  - second scan with absorber: 300k events per energy
- high statistics run at 50 GeV: > 1000k events

Data samples: pions in tungsten



- shower shapes
- hit times and their correlations
- can hit time information help in particle flow reconstruction?
- positive pions/protons: energy scan 10, 30, 50, 70, 90 GeV
  - cerenkov detector to separate pions and protons
  - 500k events identified as pions by cerenkov per energy
- high statistics run at 50 GeV: >1000k events with cerenkov

Testbeam Summary

- ~7 weeks (including preparation, installation and de-installation) successful weeks of AHCAL@SPS

- would be impossible without support from many people!
  - engineers & technicians for installation
  - in total 23 shifters from University of Hamburg, University of Heidelberg, University of Mainz, ITEP Moscow, MEPhI Moscow, MPI Munich, Northern Illinois University, IPASCR Prague, Shinshu University, Tokyo University, University of Wuppertal and DESY
  - local support from CERN LCD group
  - “back office” at DESY looking into the data and providing “immediate” calibration and feedback

- next step:
  - power pulsing tests → testbeam with (small) EM stack