Status and plans of the AHCAL technical prototype

AHCAL Testbeams in 2015

Ongoing Developments

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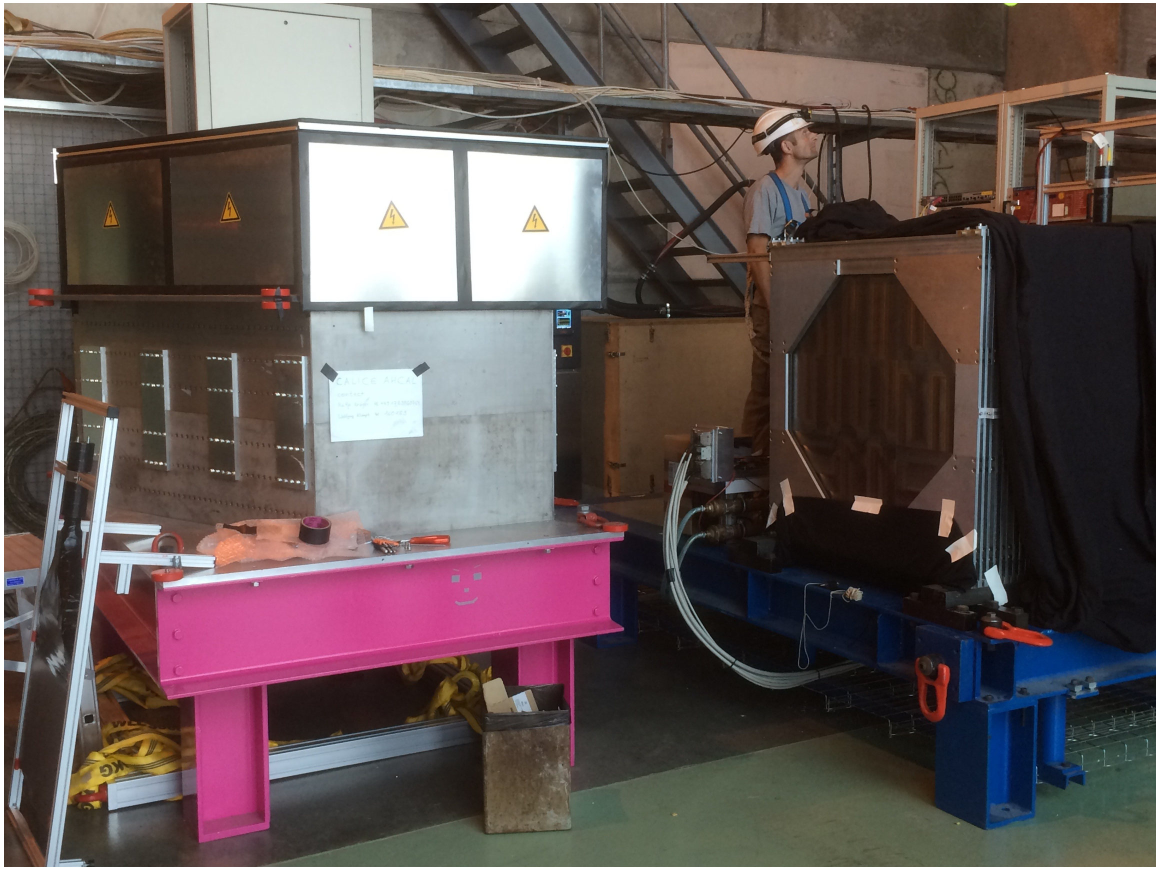
AHCAL Testbeams at SPS in 2015

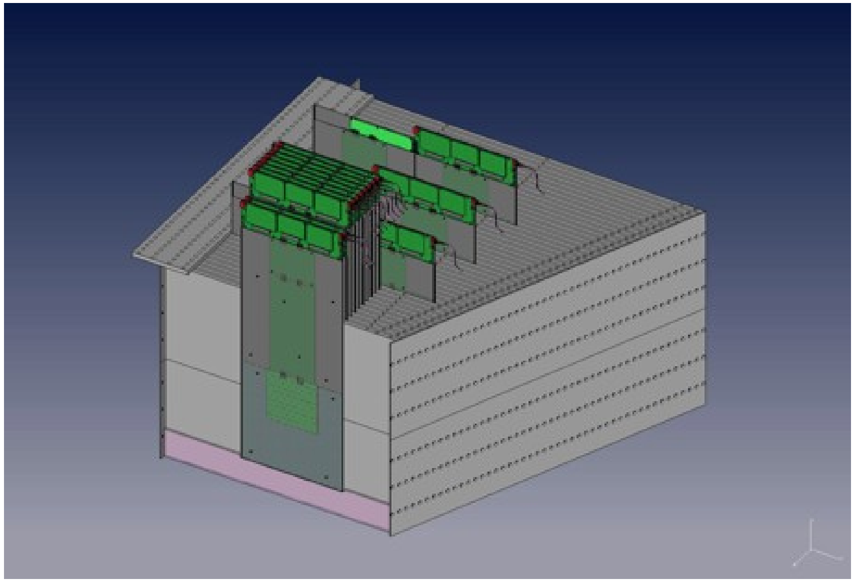


Goals and Preparation

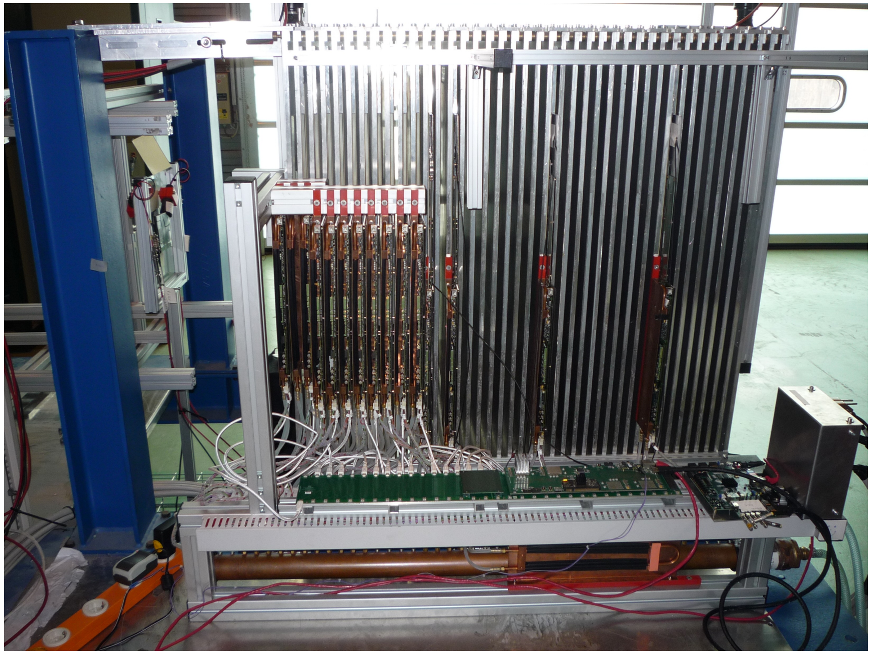
- first SPS test beam with 2nd generation electronics and DAQ
- extensive preparation
  - testbeams at PS in October and November 2014
  - testbeams at DESY in February, April and June 2015
  - tested long term stability of complete setup without beam at DESY
- system test: scalable DAQ, power distribution 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 in hadron showers in tungsten than in iron)
  - study impact of timing cuts on shower shapes and particle flow reconstruction

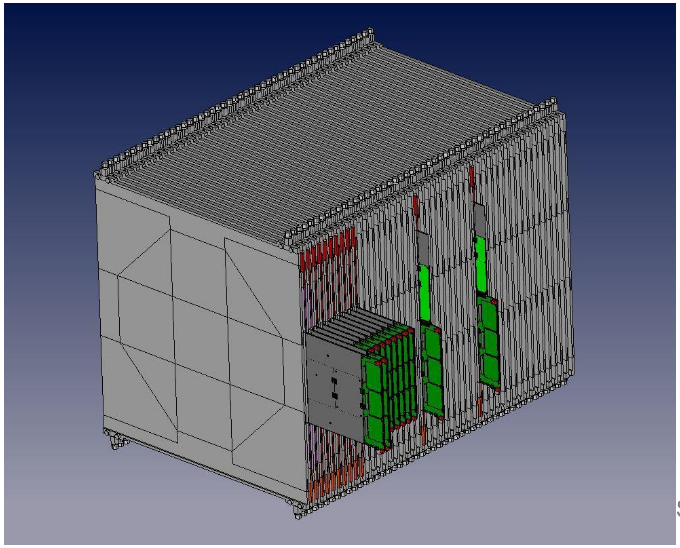
Setup of steel AHCAL technological prototype

- 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



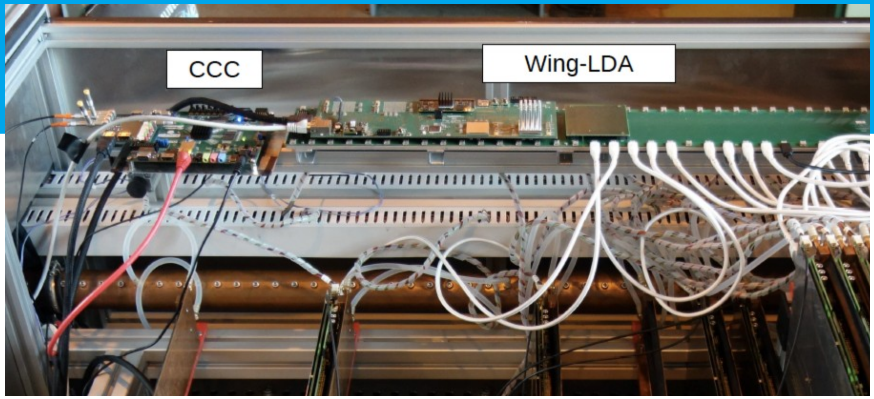
Setup of tungsten AHCAL technological prototype



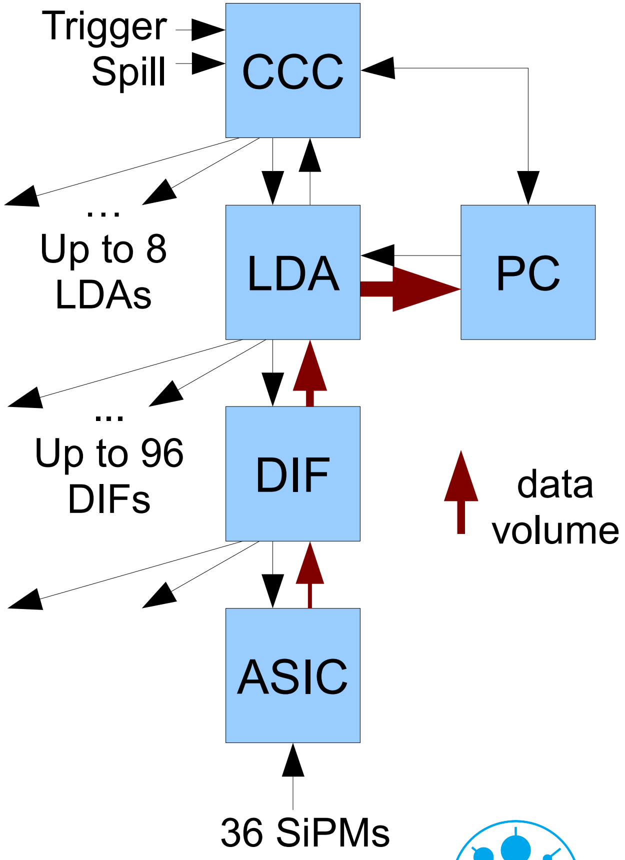


- (nearly) identical layer configuration
  - 11 small layers (18*18 or 36*36 cm^2): shower start finder
  - 4 big layers (72*72 cm^2): shower profile, correlation of hit times
- tungsten absorber structure
  - as already used in physics prototype
  - tested for 2 weeks in August in H6@SPS
- both stacks: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

Scintillator DAQ

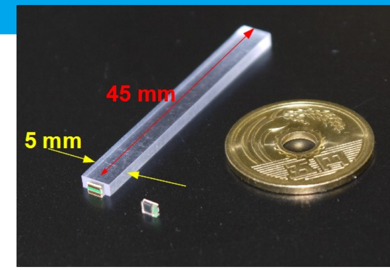


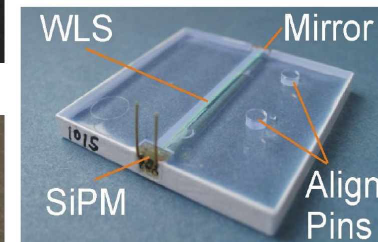
- successfully operated in beam tests
  - stable running
  - reached ~17 readout cycles / s (requirement for ILC: 5)
    → >250 Hz sustained event rate
  - further options for speed-up of factor of ~2
- will need adaptation to 3rd generation ASICs
- scalable to full ILD
- seamless integration of AHCAL and SciECAL
- common running with SiECAL demonstrated
- CALICE DAQ taskforce: work towards common running of all CALICE calorimeters
- planned: **B**eam **I**nter**F**ace for easy integration of external information (trigger, cerenkov)

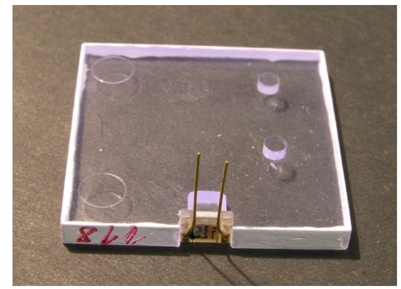


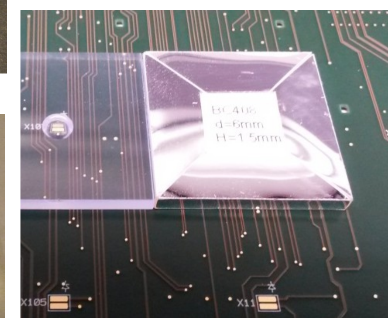
Tiles/Strips and SiPMs

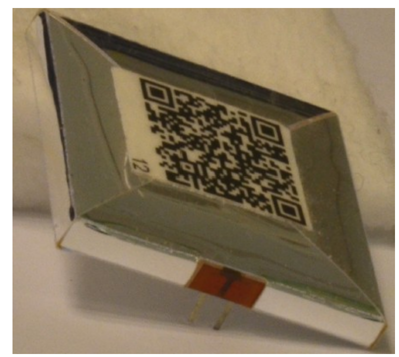
- 2 (3) layers with strips
  - Hamamatsu MPPCs with 1600 pixels
  - Hamamatsu MPPCs with 10000 pixels
- 5 layers with tiles with wavelength shifting fibre
  - CPTA SiPMs with 800 pixels
- 2 layers with tiles without WLS
  - Ketek SiPMs with 12000 pixels
- 1 layer with surface mount SiPMs with individually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







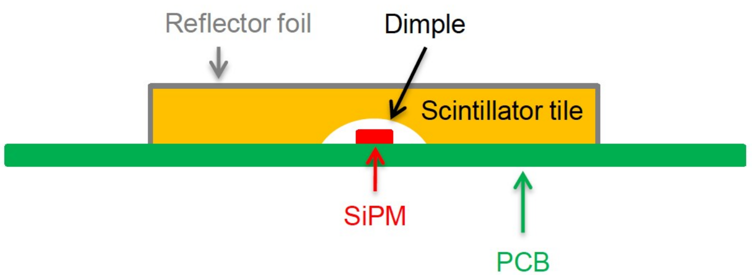




- we want to build a fully equipped prototype (40 layers) in the coming years
- experience from testbeams is important input to chose one option

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



Towards mass production: simplifi

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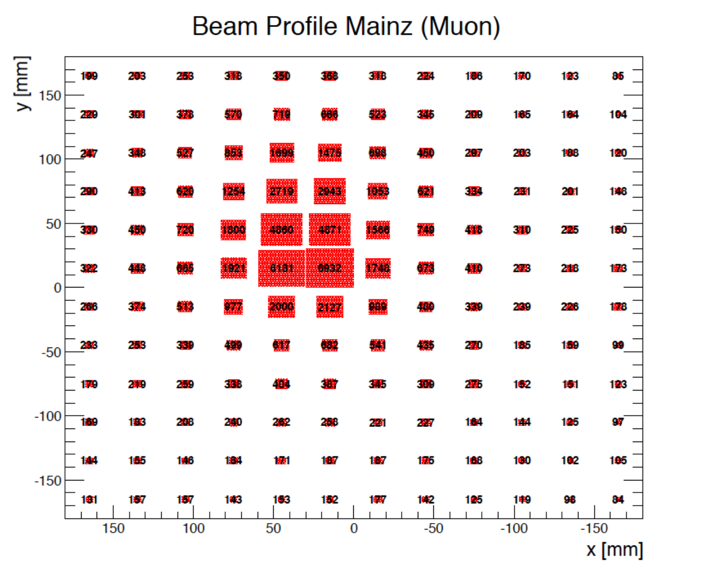
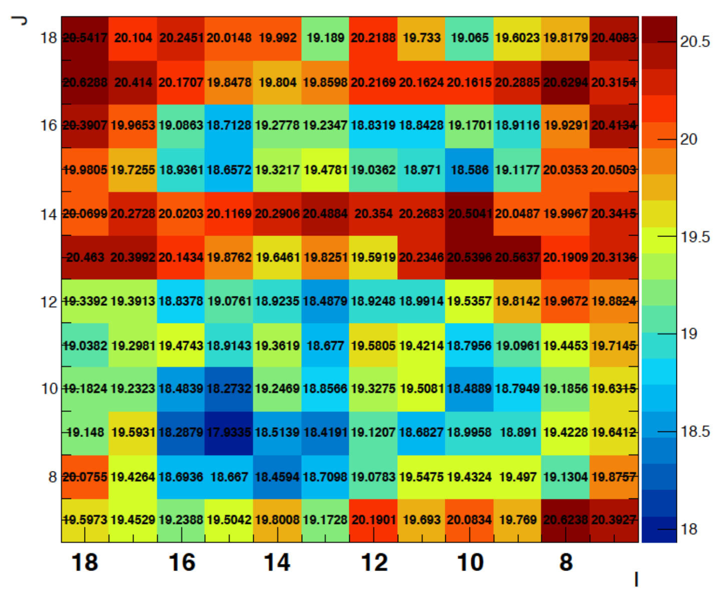
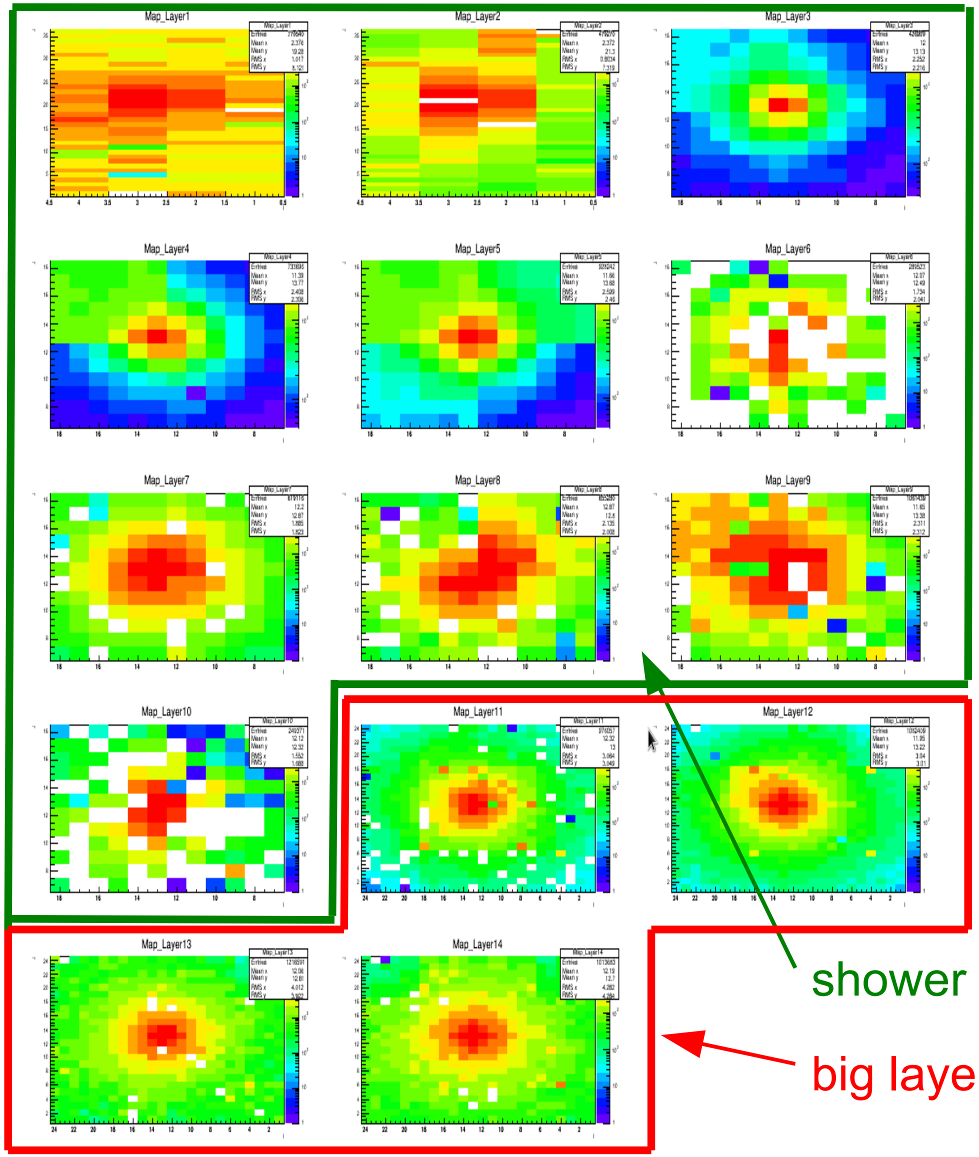
  - ➔mass assembly with pick-and-place machine possible
  - further possible improvements identified, to be tested
- very positive experience
  - all channels working
  - very homogeneous gain



max. spread in gain: 13%
without gain equalisation



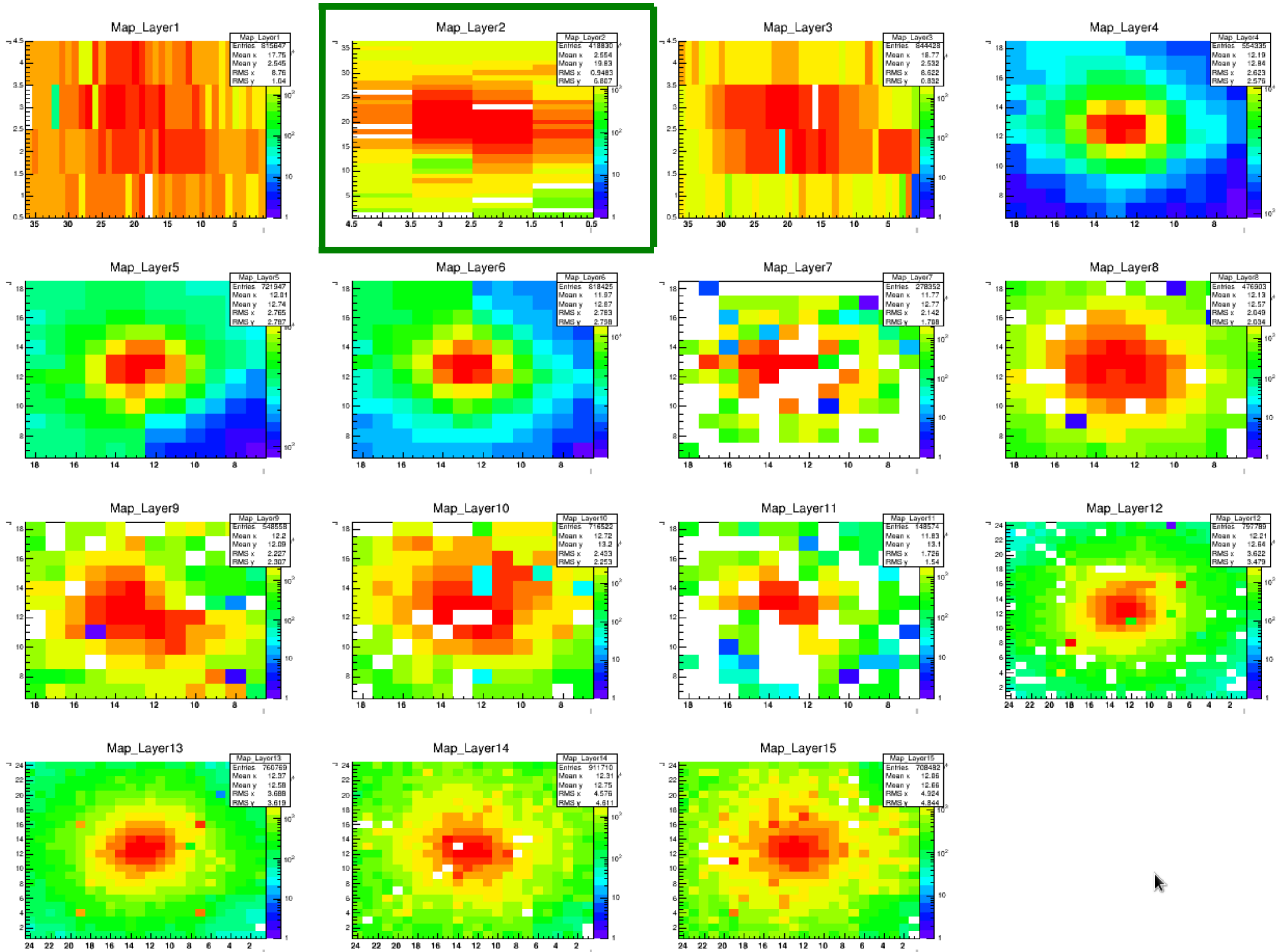
Hit map: steel



- 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

Hit map: tungsten

additional EBU with opposite strip orientation



Summary of Data Taking

first beamtime: 8. – 22. July 2015

- 2 very successful weeks, running continuously and smoothly
- data taking:
  - muons for calibration (scanning of different positions with stage)
  - negative pions: energy scan 10 – 90 GeV
  - electrons: energy scan 10 – 50 GeV
  - high statistics pion sample at 50 GeV
  - second muon position scan
- we got all the data samples we hoped for!

second beam time: 12.–26. August 2015

- detector running fine, but 5 days no beam from SPS! (many thanks to CLICpix for letting us stay one day longer!)
- data taking:
  - muons for calibration
  - positive pions/protons: energy scan 10 – 90 GeV
  - positrons: skipped except for 20 GeV
  - high statistics pion/proton sample at 50 GeV
  - second muon calibration run
- we got what we need, would have hoped for more positron energies

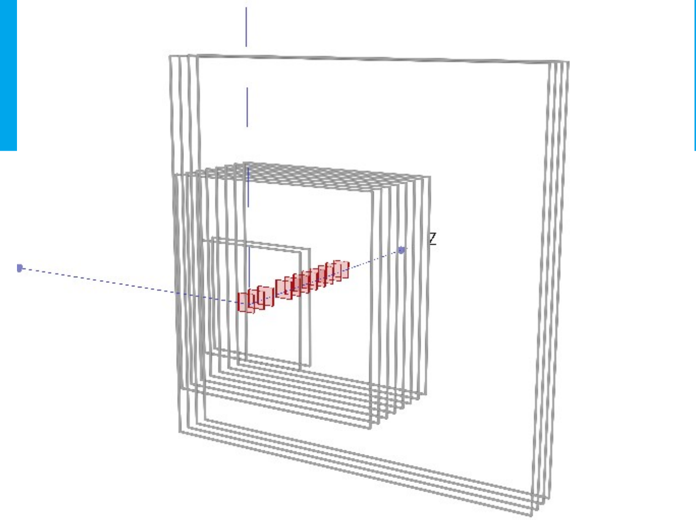
Data quality & Monitoring

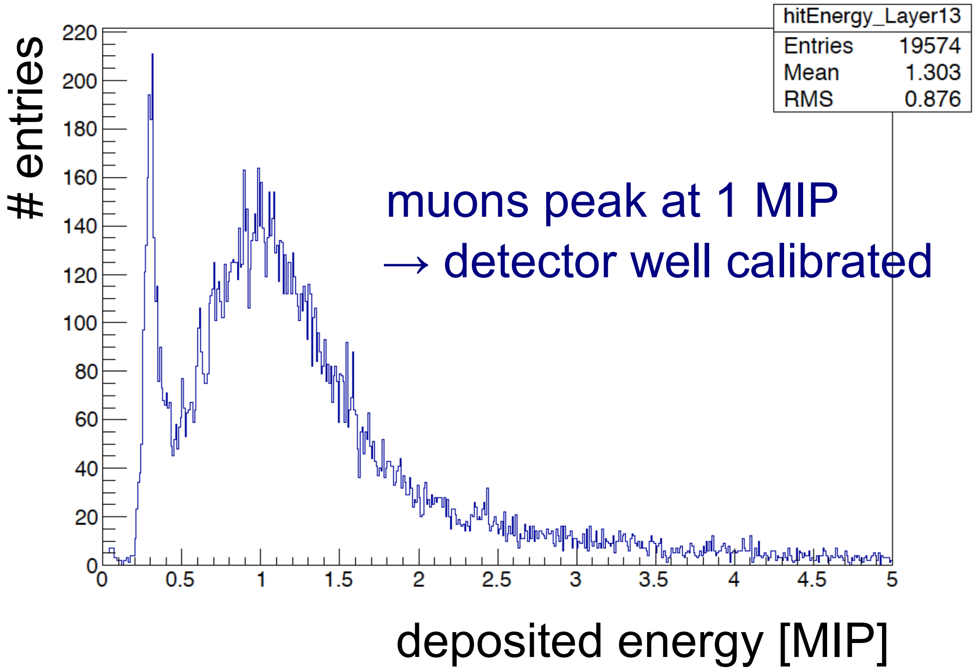
- constant monitoring of data during runs
  - raw data per channel
  - reconstructed quantities (with initial calibration): hit maps, shower quantities, ...
  - event display

  → important feed-back for beam tuning
- regular LED runs
  - long run before beam
  - short daily runs
- data immediately copied to dcache & analysed at DESY
- little startup problems
  - noise on t0 channels (→ in future: Beam InterFace)
  - some problems with EUDAQ in the beginning, traced back to an automatic update of the OS (CentOS) → fixed
- no stuck TDCs, no other indication of instabilities we had observed in previous testbeams!

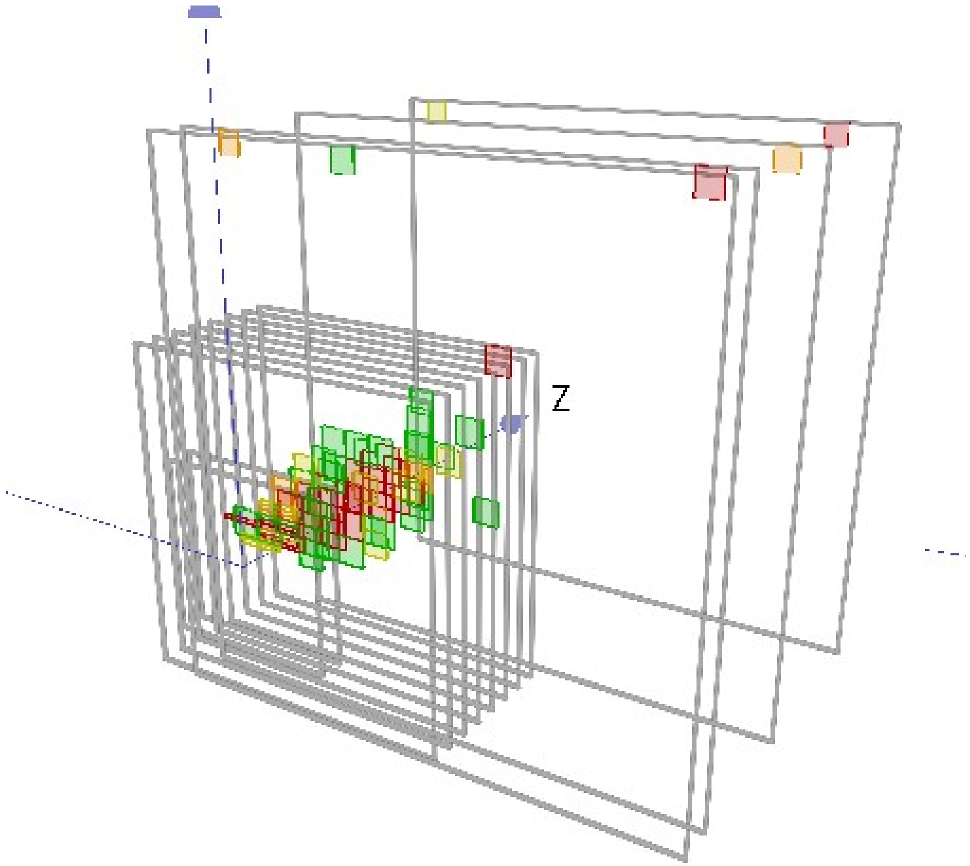
Data samples: muons

- 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!



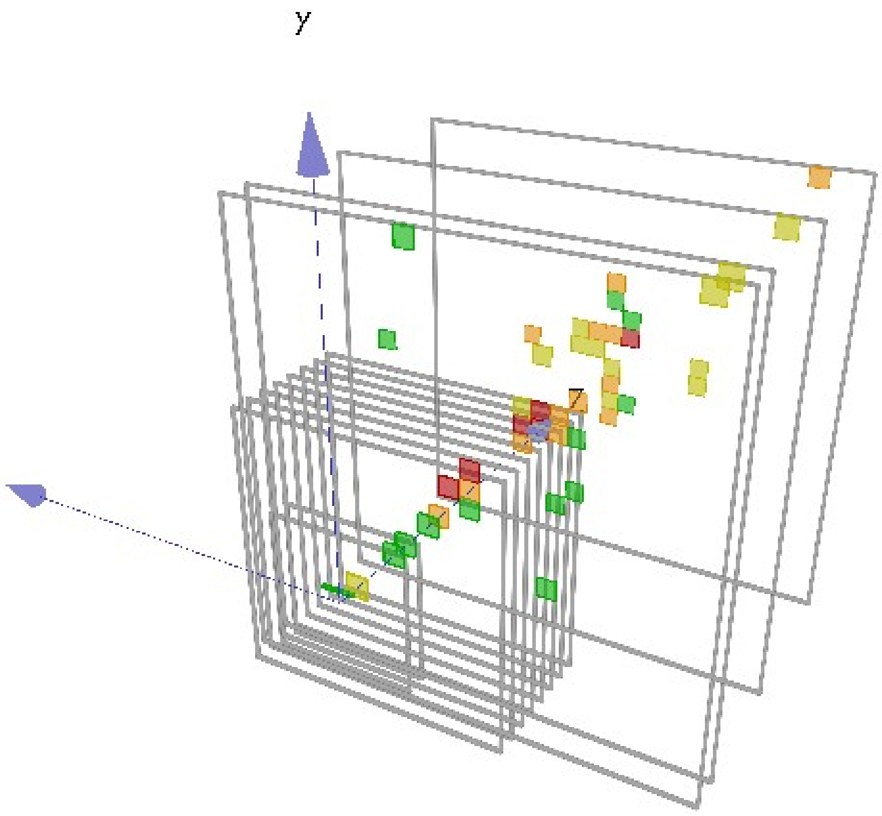


Data samples: electrons



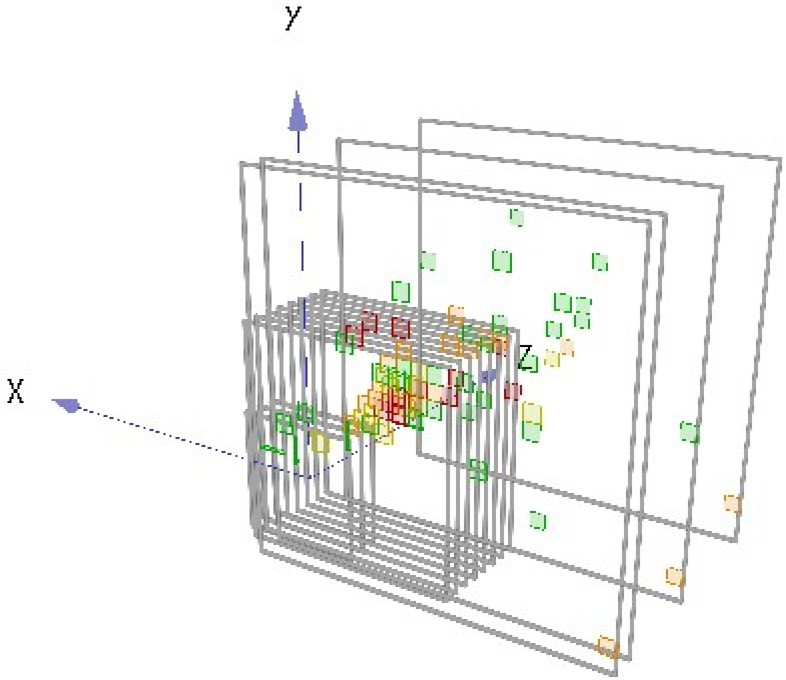
- check of calibration at high cell energies
  - saturation corrections
- demonstrate understanding of detector in simulation
- steel: energy scan: 10, 15, 20, 30, 40, 50 GeV
  - clean electron beam
  - >300k events with cerenkov ID per energy (but cerenkov inefficient)
  - typically ~500k events with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

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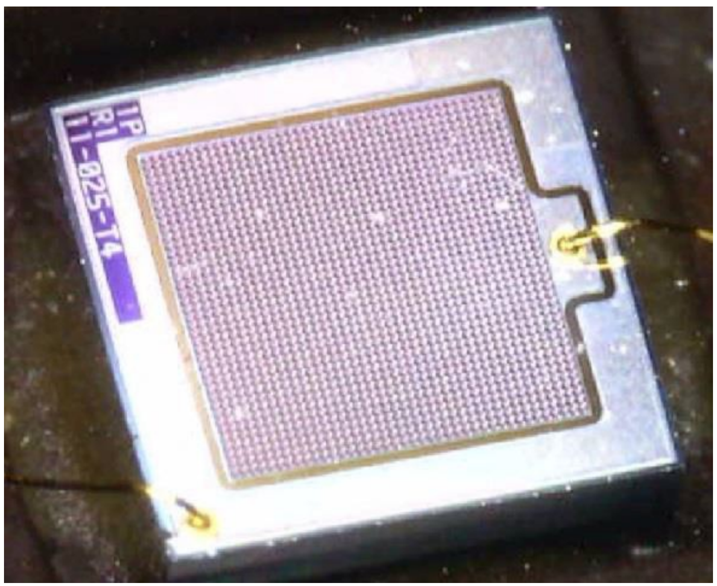
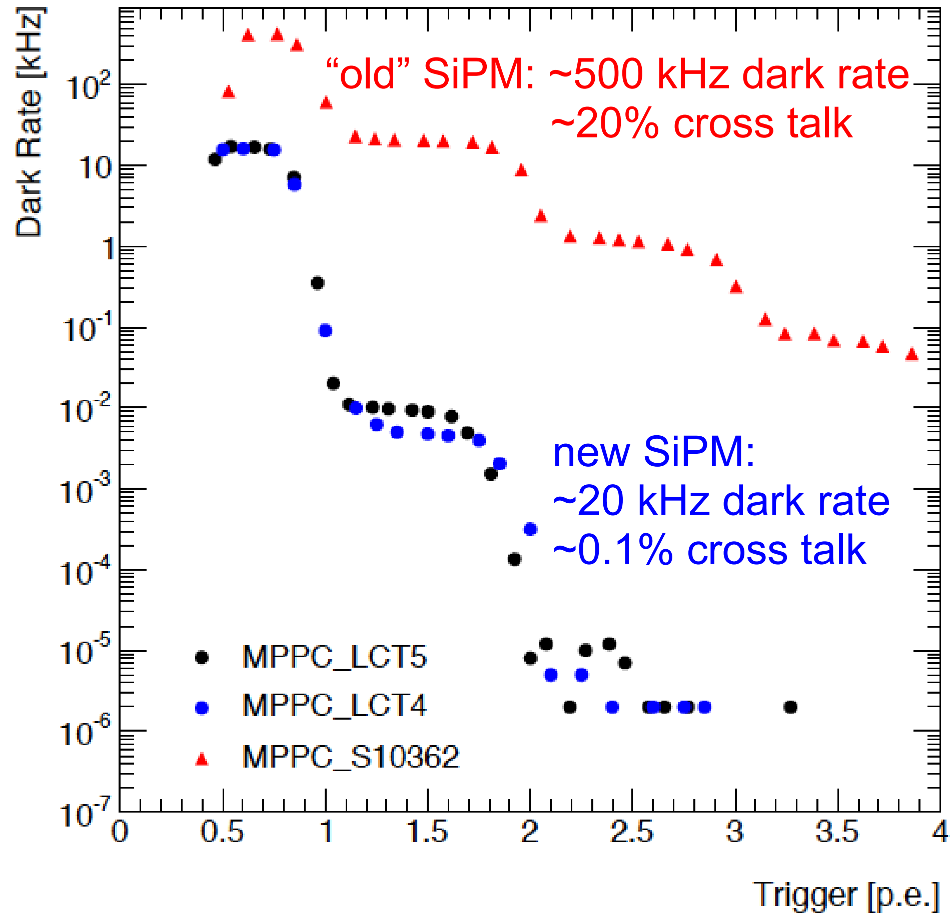
Ongoing Developments



New generation of SiPMs

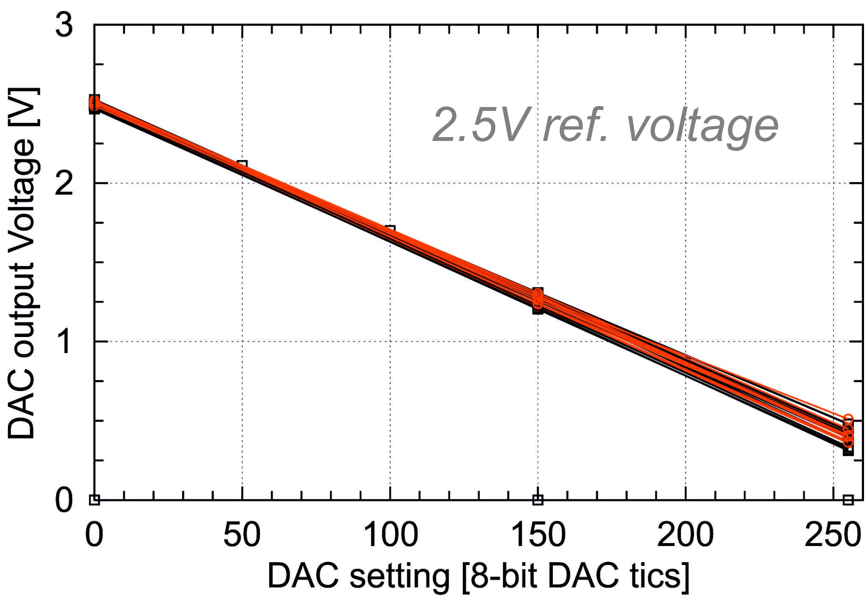
- recent SiPMs show very much improved sample uniformity
  - operating voltage
  - gain
- very recently, SiPMs with trenches between pixels became available
  - slightly reduced geometrical fill factor
  - dramatically reduced dark rate and pixel-to-pixel cross talk
  - for typical trigger threshold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

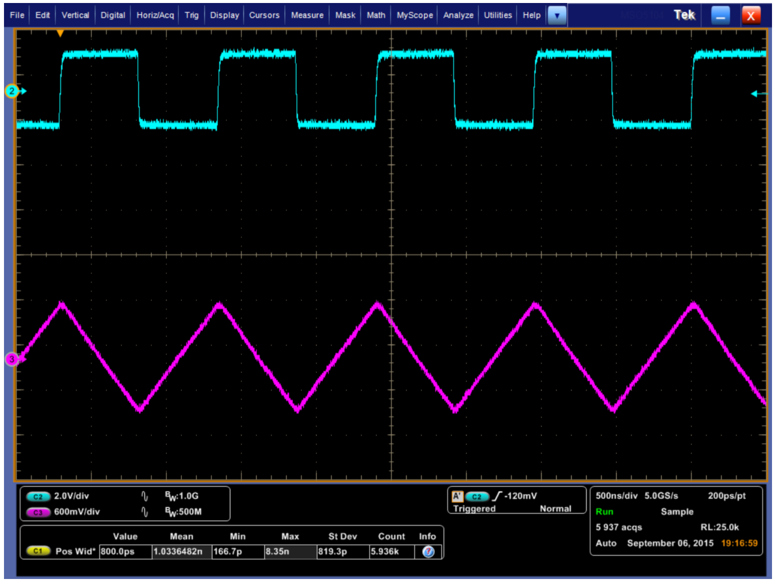


for comparison: SiPMs in physics prototype 2 MHz dark rate, 30% cross talk

Tests of Spiroc2D

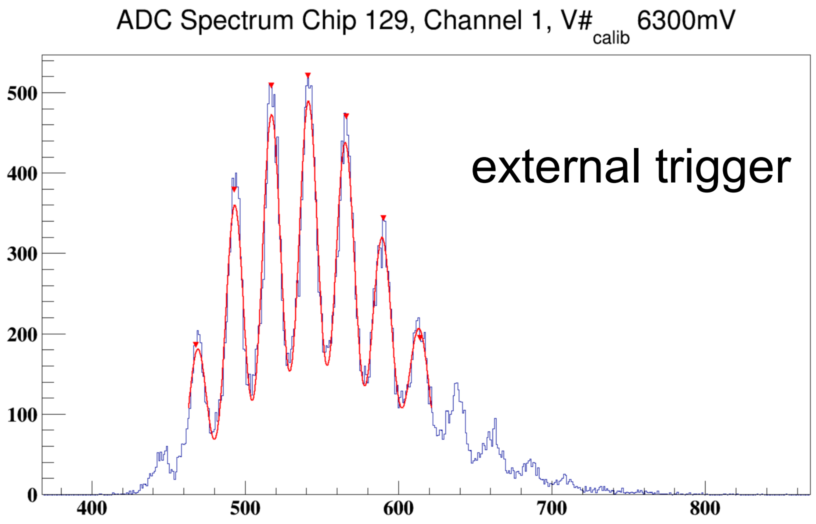
- test modifications before switching to 3rd generation ASIC
- several improvements compared to “working horse” Spiroc2B
  - better pedestal stability
  - improved channel-to-channel uniformity for inDACs (HV settings for SiPMs): factor of ~2 less spread than Spiroc2B
  - new scheme for TDC ramps (improved hit time measurement)
  - different pin-out and slow controls than Spiroc2B → need to gain experience

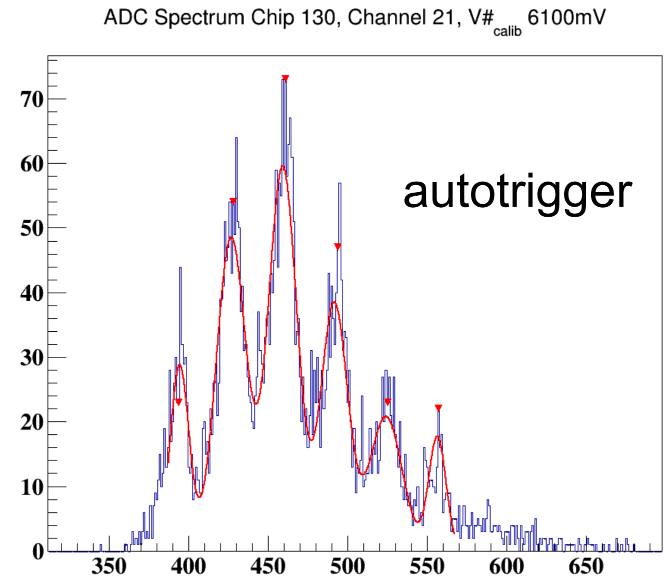




Tests of Spiroc2D

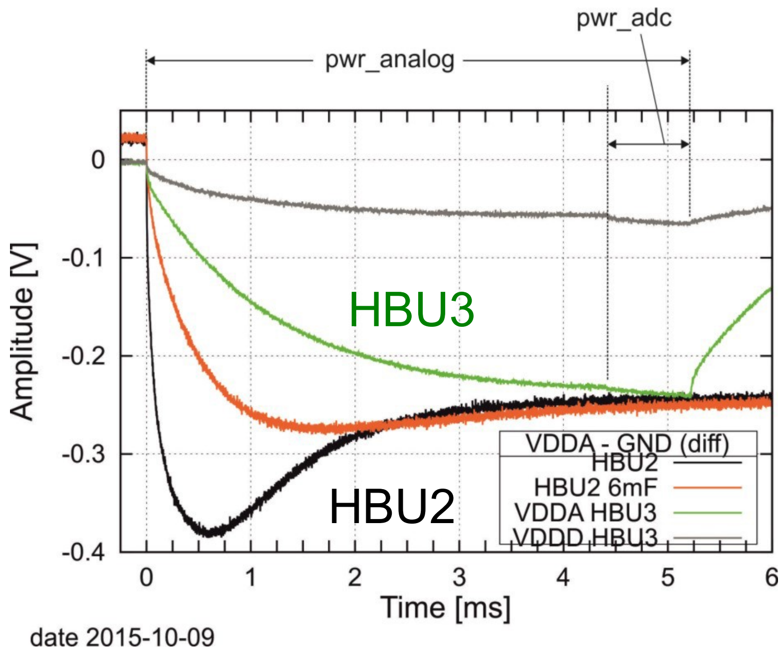
- one HBU equipped with Spiroc2D and a few tiles for tests
- tests in lab started
  - LED spectra in external trigger and autotrigger mode
  - first measurements look encouraging
- known bug in trigger logic, implications to be understood
- test with MIP-like particles in DESY testbeam planned in November 2015





Power pulsing tests with HBU3

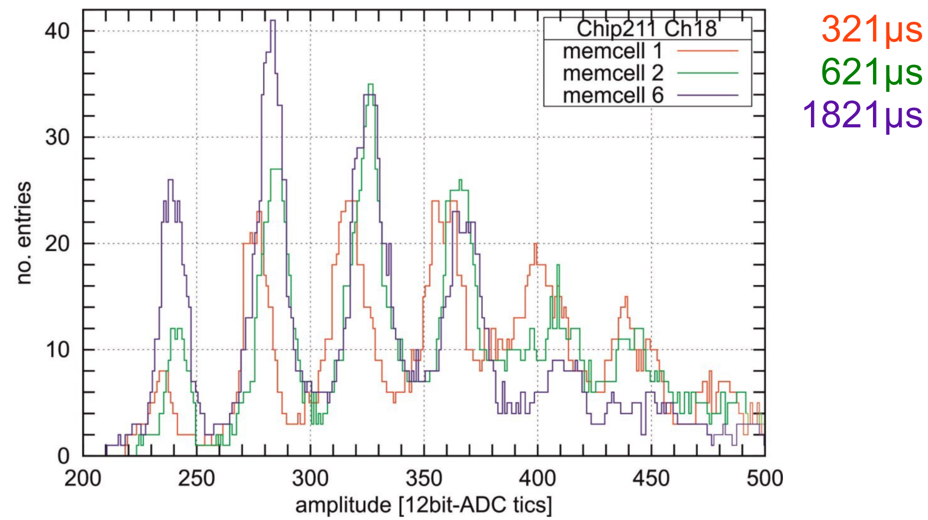
- HBU3: revised version of HBU to improve power pulsing behaviour
  - added large blocking capacitors, maybe too large
- under test with full-length slab (6 HBUs, 2.2 m) in lab now
- power consumption looks encouraging (currents for full slab with 24 ASICs)

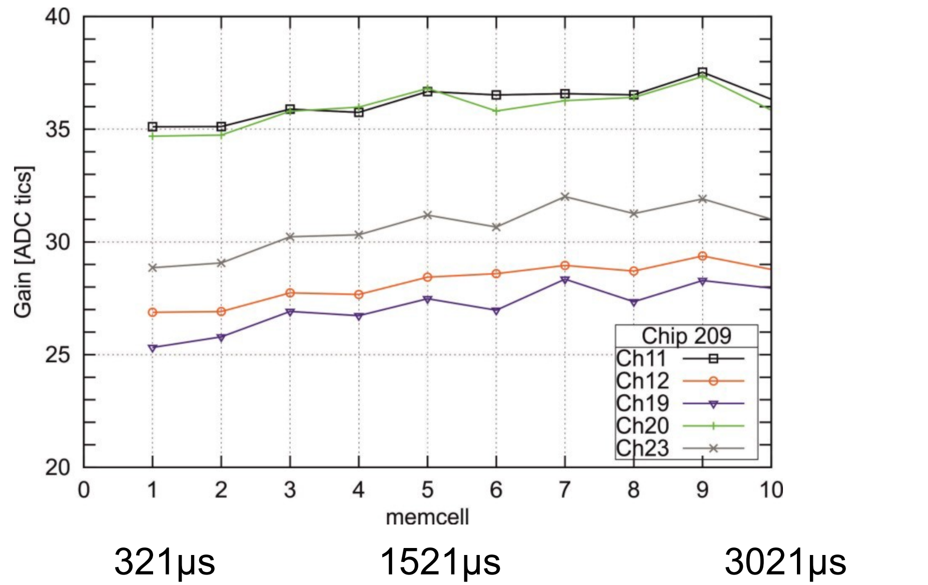


	V - SPIROCs off [V]	V - SPIROCs on [V]	I - SPIROCs on, [mA]	I - SPIROCs off, [mA]
VDDA	3.30	3.10	2000	18
VDDD	3.30	3.26	225	24
VDAC	5.0	5.0	2.06	2.06
VREF	4.68	4.68	0.8	0.8
+6V input	-	-	4360	1220

Power pulsing tests with HBU3

- very first results (measured on HBU on the end of the slab):
  - 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





Summary and Plans

several important steps towards an ILC-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

Backup

Flying Calos :-)

Electronics

- new interface boards
  - DIF2 with updated ZYNQ FPGA
  - POWER4
    - can switch all Spiroc supply voltages individually
    - adjustments for power pulsing
  - CIB adapted, CALIB unchanged
  - all delivered by now
- **B**eam **I**nter**F**ace
  - allow easy integration on external signals (trigger scintillators, Cerenkov detectors, ...) into DAQ
  - based on AIDA miniTLU
  - work started