AHCAL 2014 test beam and new tiles

- AHCAL goals
- new Uni HH tiles
- DESY testbeam 2013/2014
  - calibration data
  - EM showers
- further testbeam plans
- conclusions & outlook

Katja Krüger

CALICE Collaboration meeting
Argonne, 19 March 2014

On the way to a full engineering prototype

goals:

> 2013/2014:
production, calibration and test of new hardware

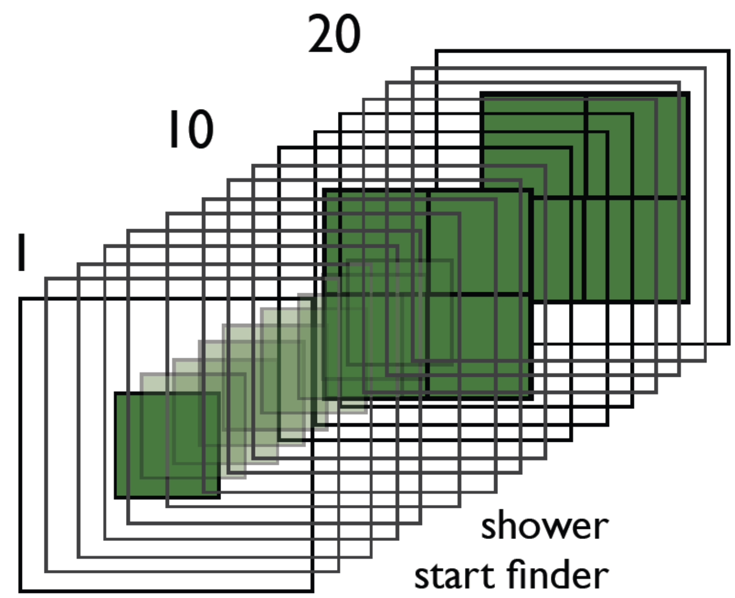
> beginning of 2014:
measurements of EM showers in the small ILD-like stack

> 2014/2015:
first measurements of hadrons with a “shower start finder” and a few 2*2 HBU layers

- ILD stack
- tungsten stack

> longer term: fully equipped $1m^3$

plans from CALICE meeting in September 2013



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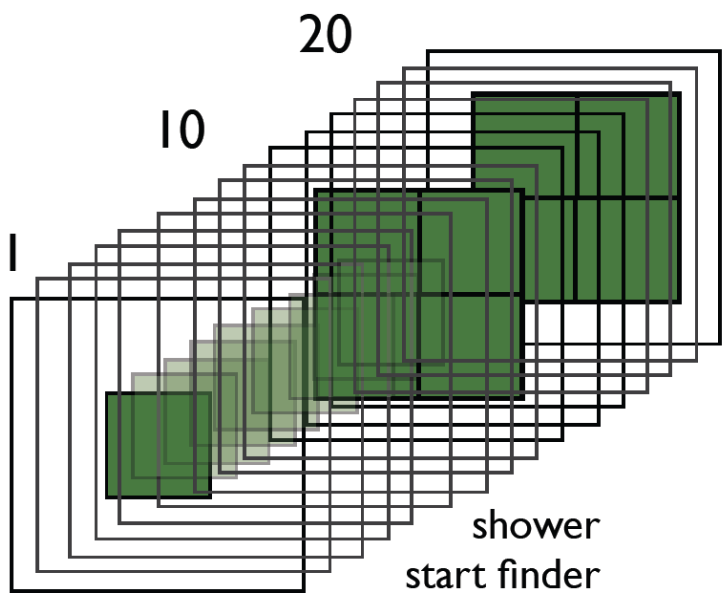
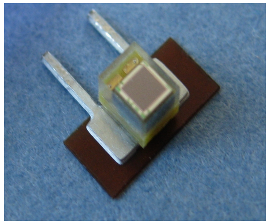


New Tiles produced by Uni HH

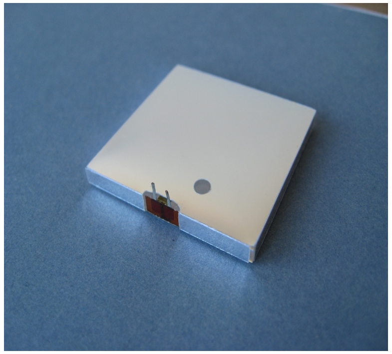
Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

SiPM:



	Gain [e-]	DCR	Cross talk	dV_{BD}/dT	N of pixels
KETEK PM1125	0.7×10^6	0.2 Mcps	~ 5%	~15 mV/K	2300
CPTA	$(0.7\text{-}2) \times 10^6$	1 Mcps	~ 1%	20 mV/K	798

Tile (except first 288 tiles):



- Bicron BC-400 Polyvinyltoluene, peak emission: **λ= 423 nm**
- **machined** instead of moulded: improve accuracy on dimensions (~ 10 µm)
- **no WLS fiber**:
  - Machined coupling to match SiPM
  - SiPM Kapton support glued to plastic tile
  - “cathedral” drill in front of the SiPM to improve uniformity (adaptation of MPI Munich design)

Wrapping:

- tiles are individually wrapped with 3M Vikuiti reflector foil
- foil cut with laser cutter
  - hole for SiPM monitoring via LED on the HBU
  - cut for two different hole positions (75% of HBU LED positions matched)
- **mechanically wrapped** around the tile;
- fixed with sticker with QR code for unique identification

DESY

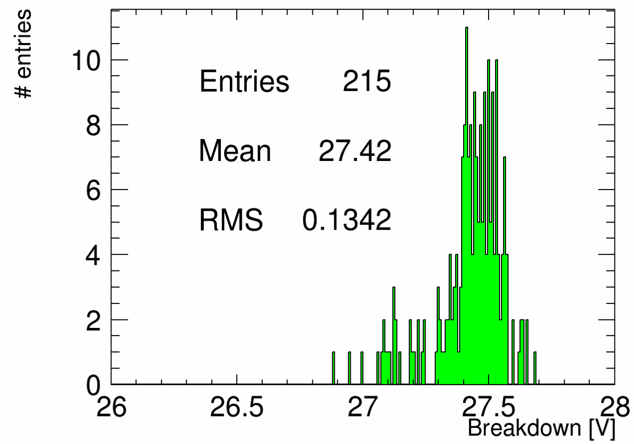
Tile characterization

<u>four HBUs equipped (i.e. 576 tiles)</u>

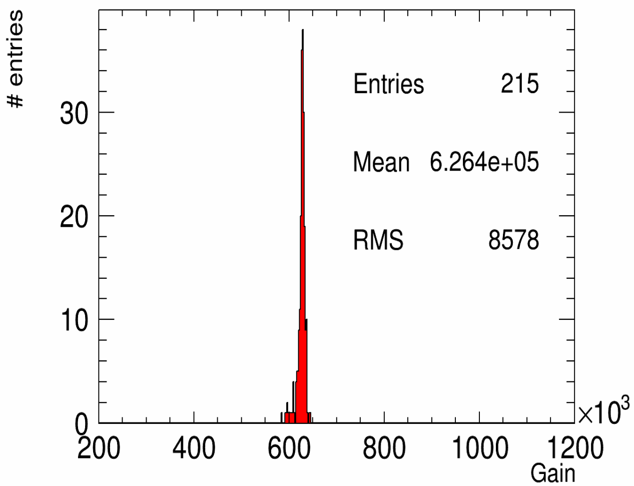
- 357 tiles characterized at UHH (215 of them with BC-400)
  - SiPM performances
    - Breakdown voltage
    - Gain
    - Dark Count Rate
  - Response to MIP with ^{90}Sr
- 285 characterized at Heidelberg KIP (many overlaps)

performance at fixed excess bias (+2.5 V): very good tile-to-tile uniformity, low noise

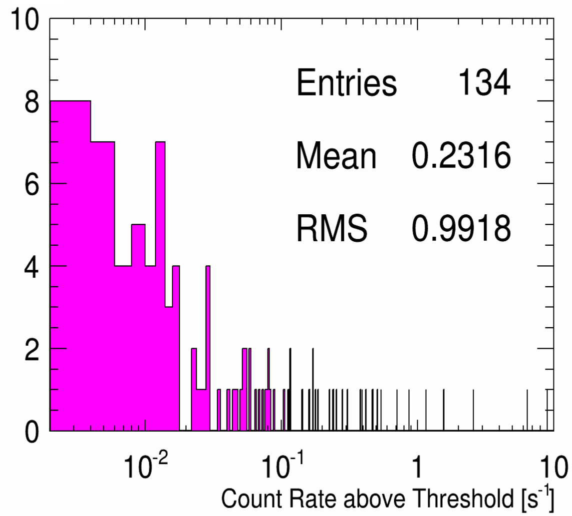
Min-to-max: 0.8 V



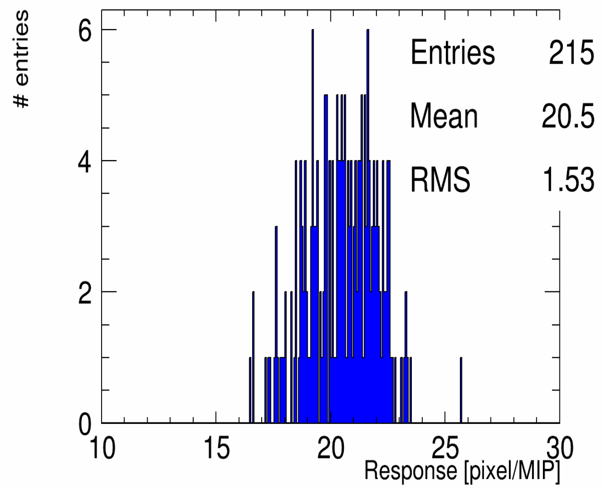
Gain spread: 1.4%



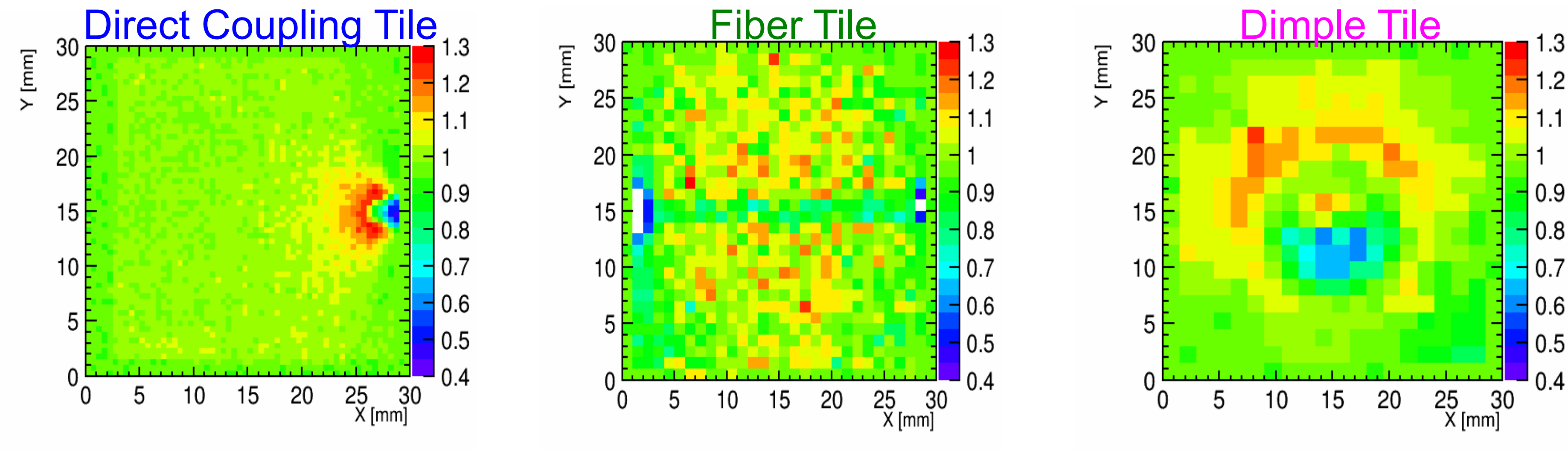
DCR above 0.2 MIP:



Response spread: 7.5%



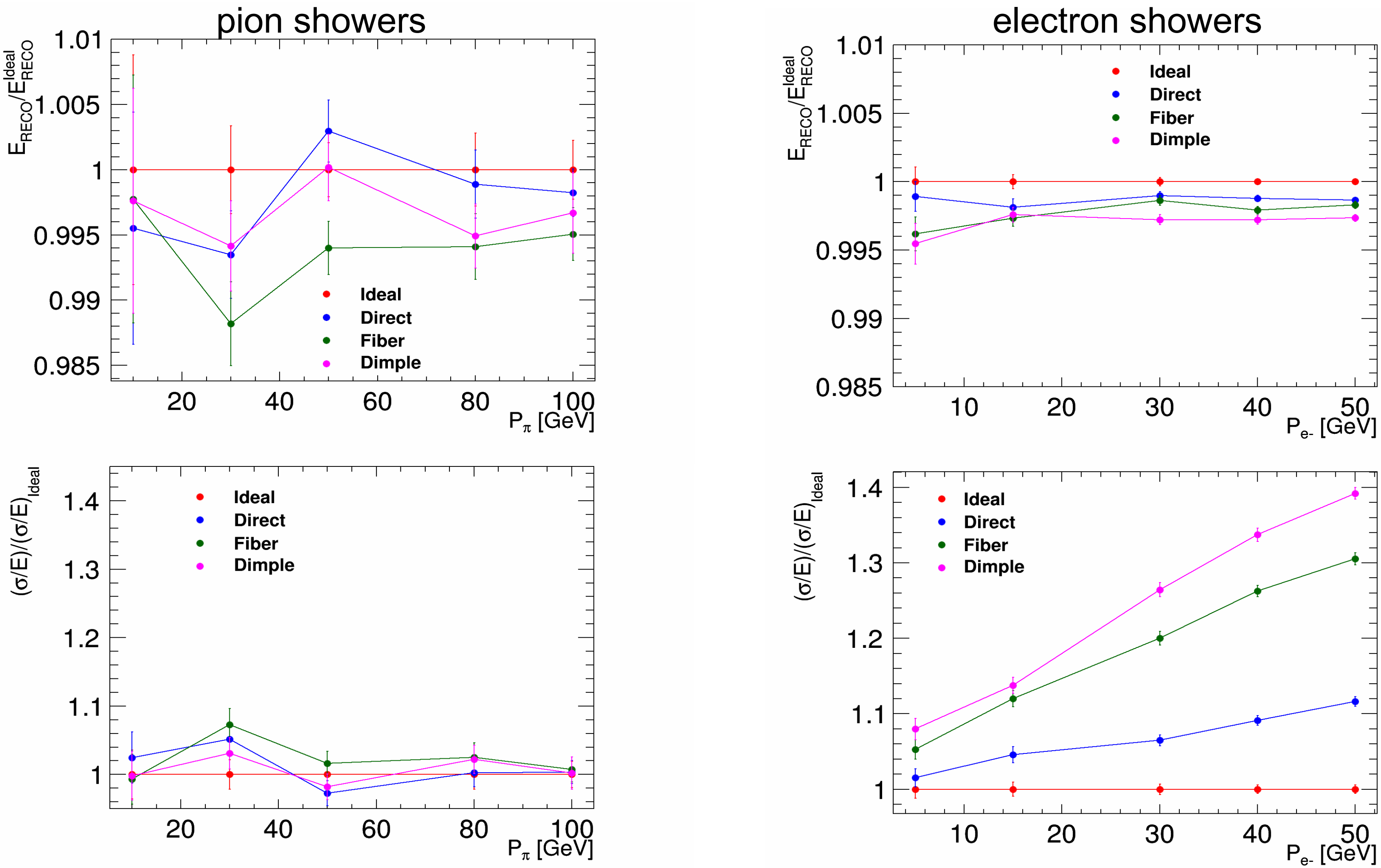
Impact of tile non-uniformities on physics



Evaluate the impact of tile non-uniformity on single shower reconstruction:
^{90}Sr tile scans used to weight the Monte Carlo energy depositions

	10 GeV π-			100 GeV π-			50 GeV e-		
	E_{reco} [MIP]	σ/E [%]	Hits	E_{reco} [MIP]	σ/E [%]	Hits	E_{reco} [MIP]	σ/E [%]	Hits
Ideal	361 ± 2	17.4± 0.4	99 ± 1	3873 ± 6	7.9± 0.1	632 ± 2	2299	2.83± 0.08	184
Direct/Ideal	0.996	1.02±0.04	0.99±0.01	0.998	1.00±0.02	0.997±0.003	0.9967	1.12	1.000±0.001
Fiber/Ideal	0.998	0.99±0.04	1.00±0.01	0.995	1.00±0.02	0.995±0.003	0.9983	1.31	1.000±0.001
Dimple/Ideal	0.998	1.00±0.04	1.00±0.01	0.997	1.00±0.02	1.005±0.003	0.9974	1.39	1.000±0.001

Impact of tile non-uniformities: Energy dependence



Influence of tile non-uniformity on reconstructed energy below 1%, on energy resolution negligible for hadrons

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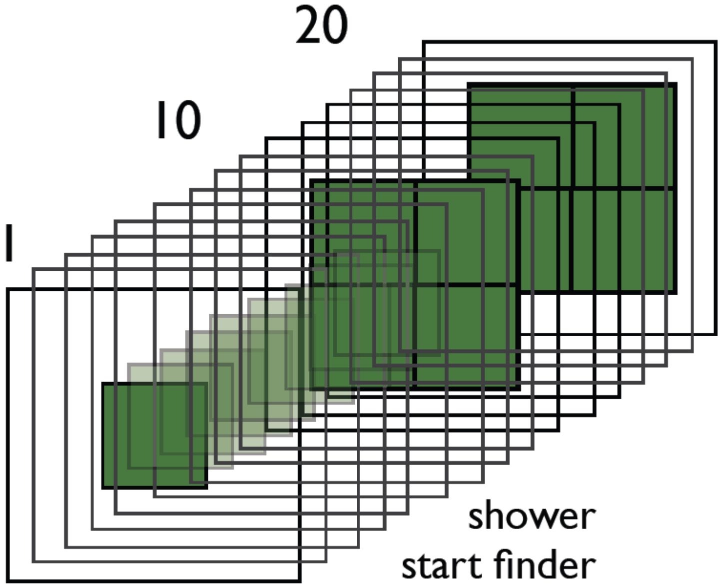
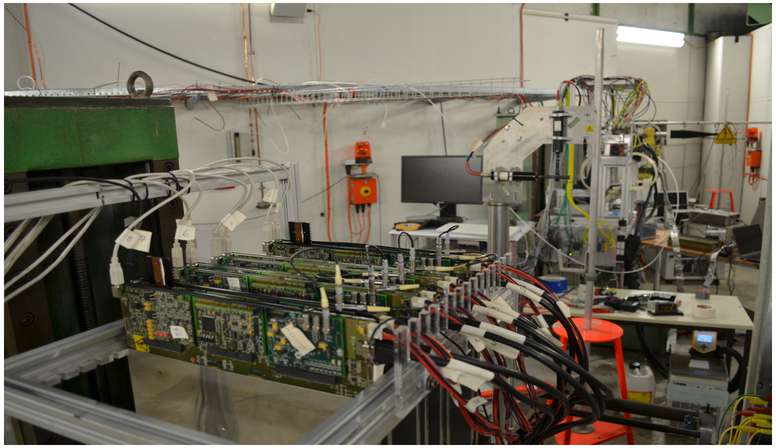
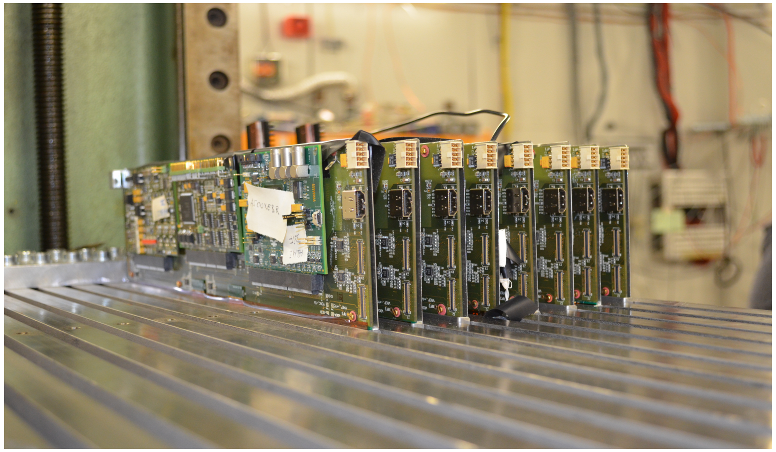


DESY electron testbeam 2013/2014

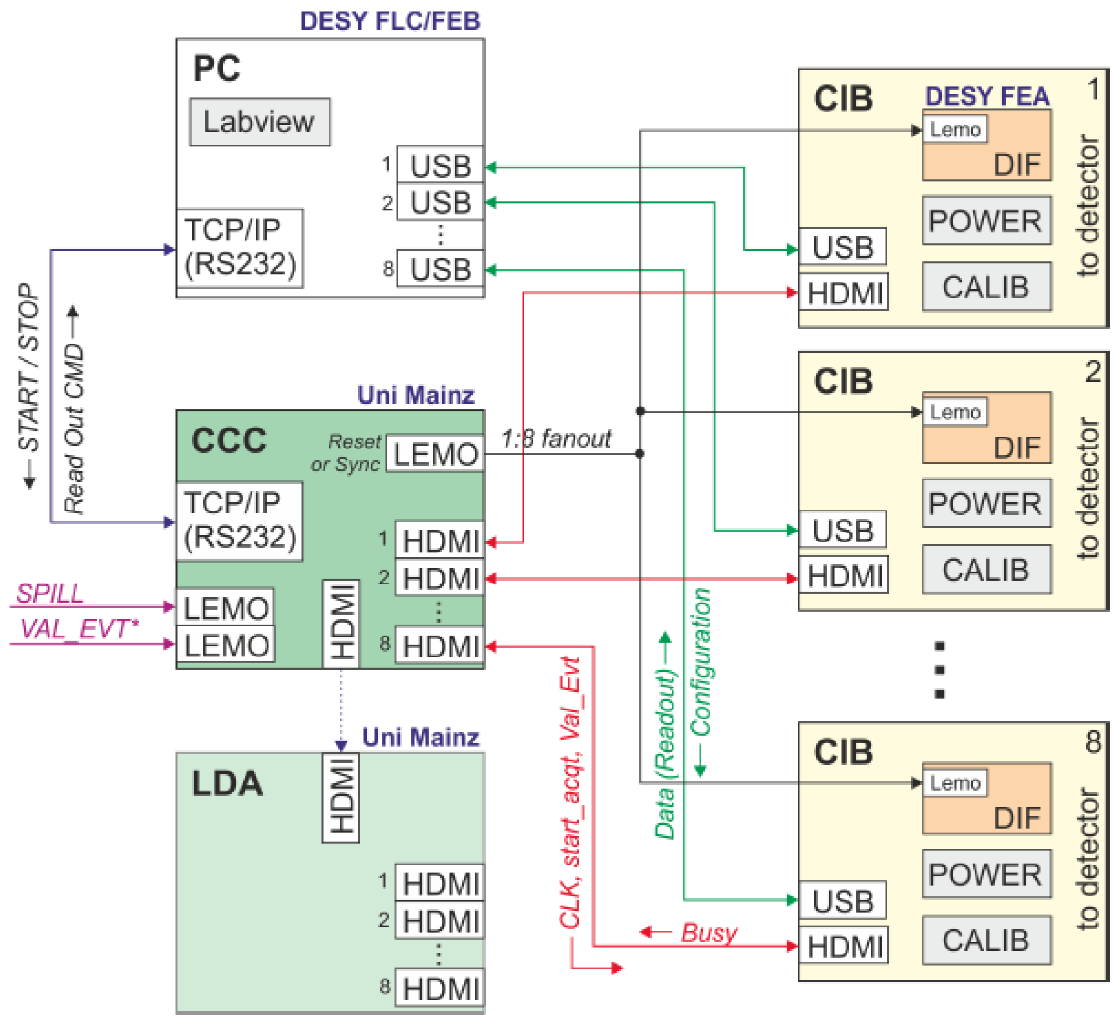
- three weeks of beam time Dec.13-Jan.14
  - personpower from DESY, UniHH, UniHD, UniW
  - probably last DESY beam for this year
- MIP calibration
  - calibration through eight layers
  - four new UHH layers, first time in beam
- EM showers
  - all eight layers in ILD absorber stack
  - data for EM energy resolution analysis
- Electronics
  - next iteration on DAQ hard-/software
  - temperature readout
  - heat dissipation studies





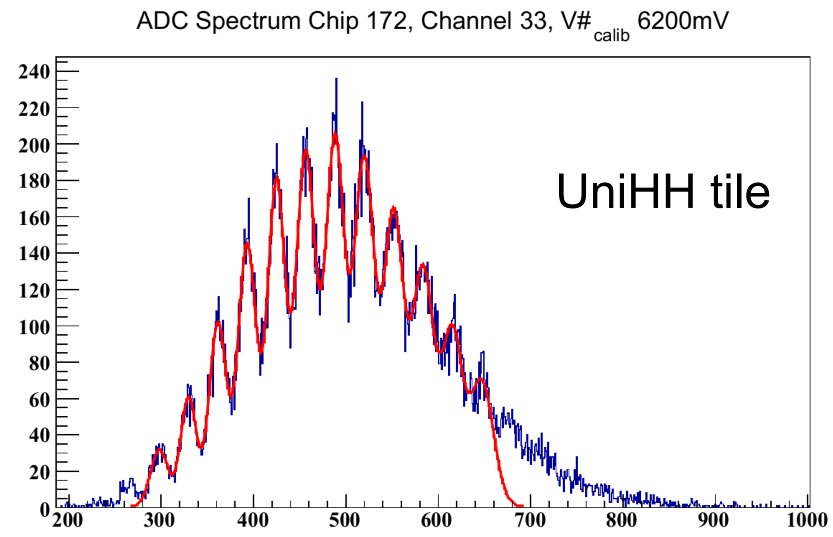
DAQ setup and development

- progressing towards scalable scintillator DAQ
- status: CCC and LDA (working as fanout) included, fast signals via HDMI, operated successfully in testbeam with up to 8 layers
- full LDA integration and switch to data transfer via HDMI on-going
- intensive discussion with T. Suehara to ensure compatibility of Silicon and Scintillator DAQ
- more details in talk by J. Caudron



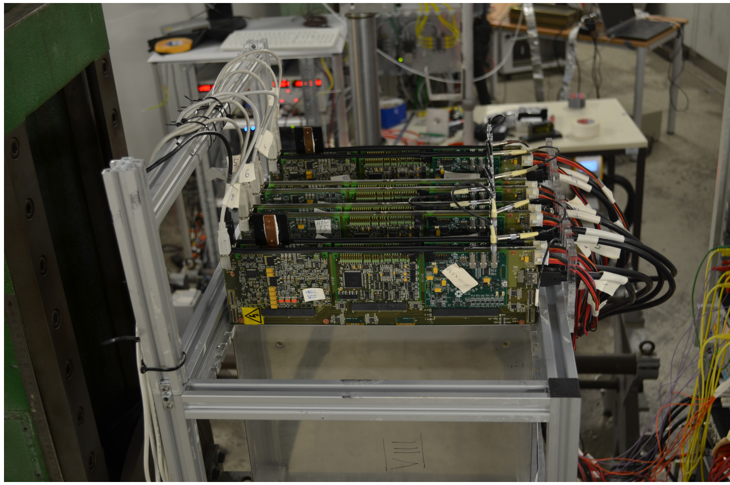
Hardware Setup

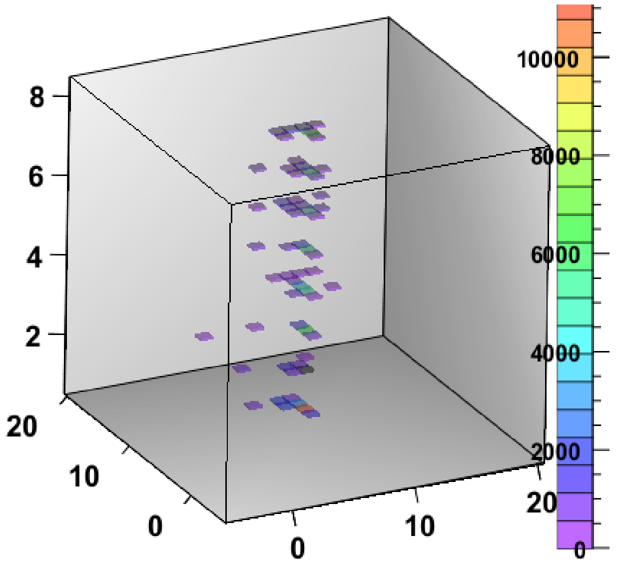
- eight HBU layers
  - four layers UniHH tiles
  - three layers “new batch” ITEP tiles
  - one layer “old batch” ITEP tiles
  - ~1200 channels total
- commissioning
  - full commissioning for UniHH boards
  - old boards partly recommissioned (IDAC calibration, exchanged chips)
  - all hold times revisited and checked



MIP Scan

- mount all layers in airstack
  - no absorbers between layers
  - airstack mounted on stage, target 3 GeV beam at each tile position
- electrons are not real MIPs
  - EM showers induced by upstream material → move telescope/DUTs out of beam
  - HBUs and cassettes are significant material e.g.: 1mm steel/layer → 0,5 X_0 total
  - increasing beam energy reduces showers, but also reduces rate





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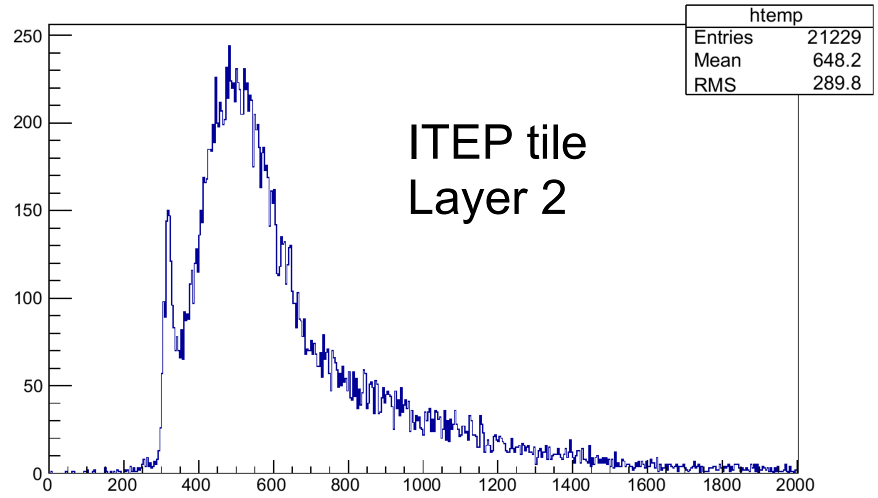
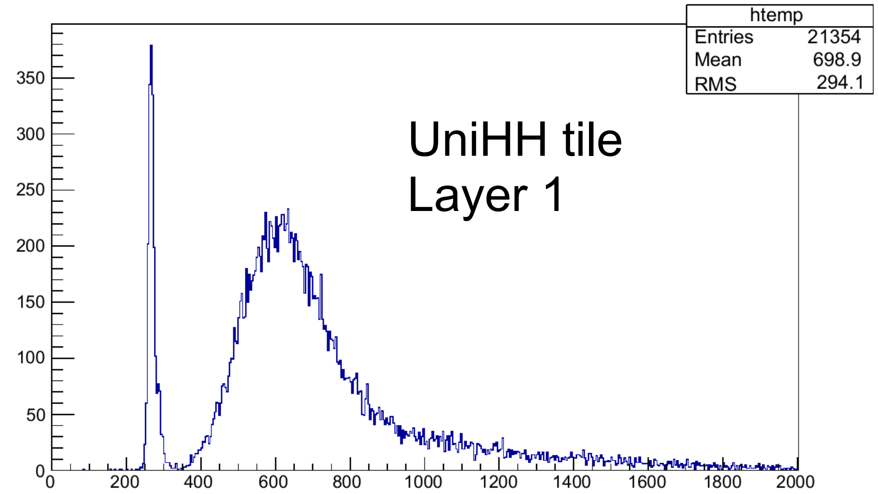
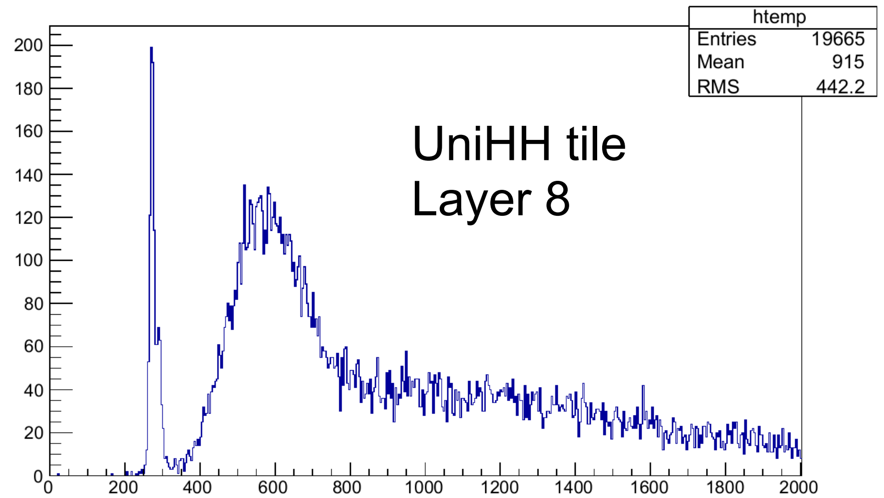


- very low thresholds (<0.2 MIP) for most channels
  - no threshold retuning during scan
  - trade threshold position for r/o efficiency
  - ~4 beam hits per r/o cycle
- ~5 min/position → ~20 h in total
  - 5000 r/o cycles, ~20000 events/channel
- calibration of eight HBUs at the same time succeeded!

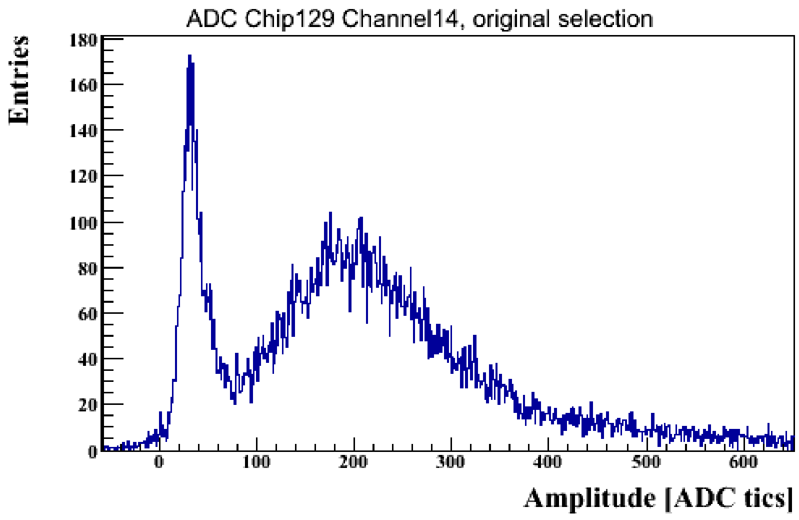


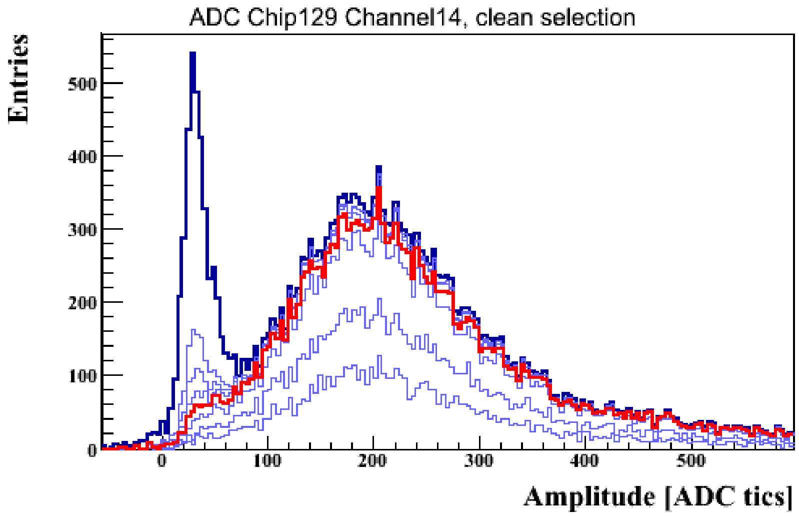


MIP analysis with TDC cuts

- MIP data taken on purpose with very low thresholds
  → need cleaning of data
- Idea: use TDC measurement and clustering in time of MIP hits in several layers in time to select hits from MIPs
- Example shown: testbeam data with 4 layers, works better with more layers
  - very simplistic TDC 'calibration' to correct for different TDC ranges on different ASICs
  - variation of width of sliding time window: 400ns, 200ns, 100ns, 50ns, 20ns, 10ns, 5ns

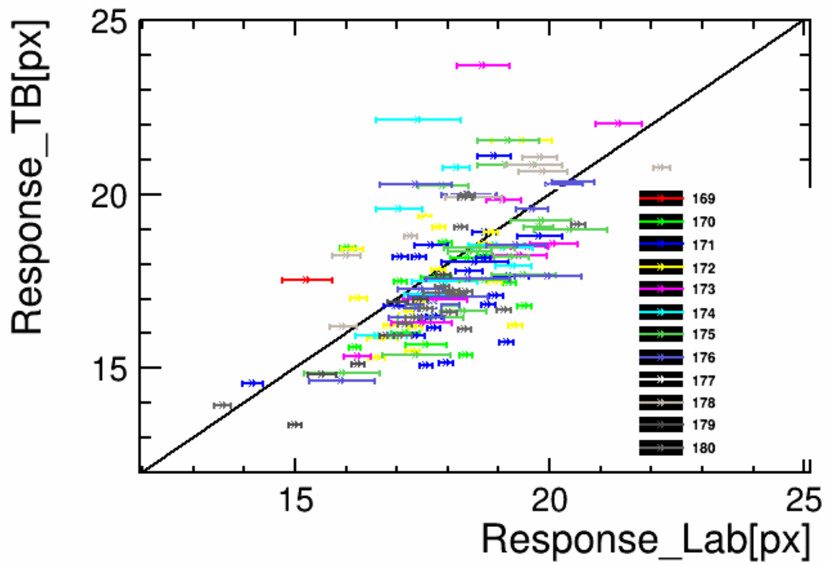
  → nearly noise-free MIPs with 50 ns
- Optimisation ongoing (UniW bachelor)

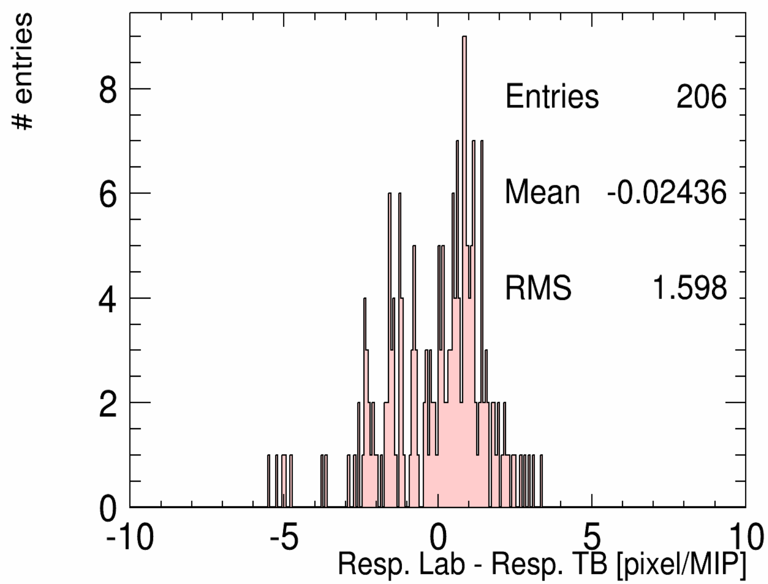




First look into MIP correlation lab ↔ testbeam

- MIP calibration data for UniHH tiles taken for individual tiles with ^{90}Sr source in lab (with dependence on overvoltage) and in DESY testbeam
- analysis ongoing, very preliminary comparison





- difference is centred around zero
- spread of ~ 1.6 pixel/MIP
- one source of large spread identified: HV applied in testbeam up to 200 mV different from the expected value (reason needs to be clarified)

→ re-measure applied HV, correct lab value

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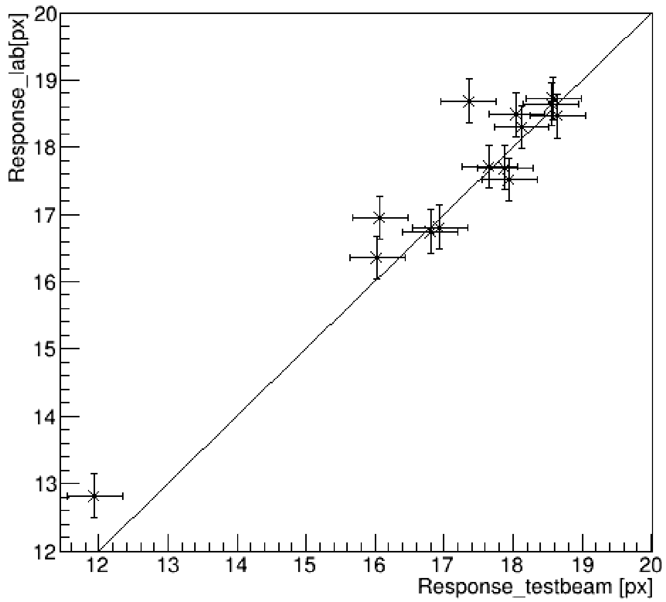

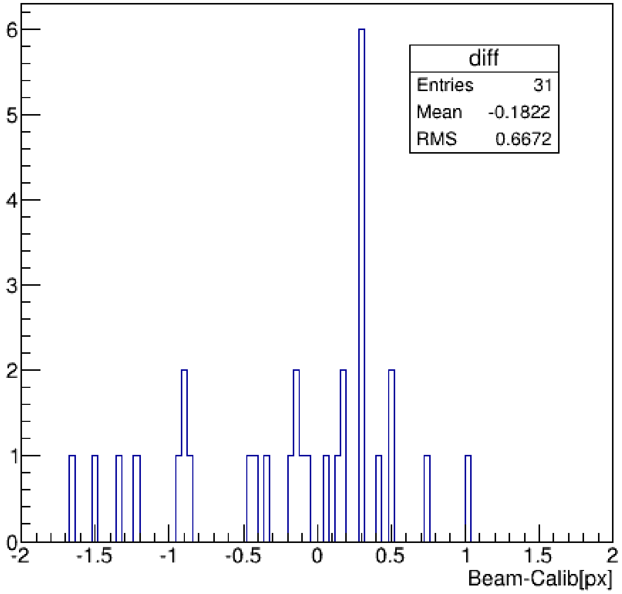

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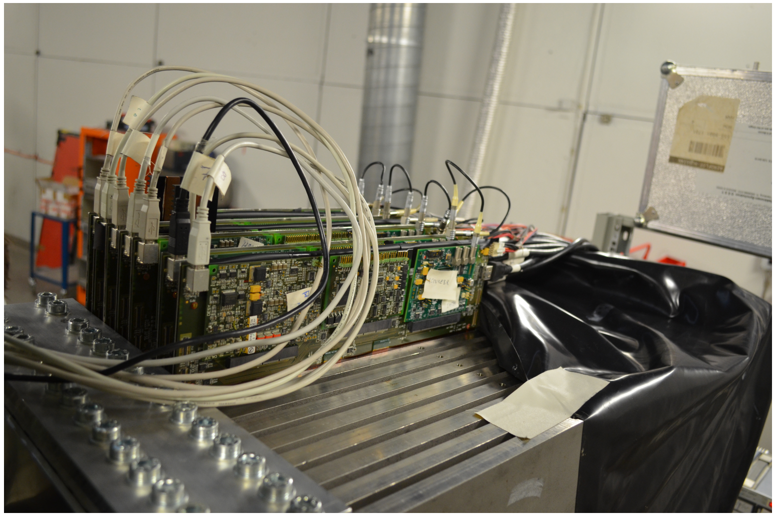
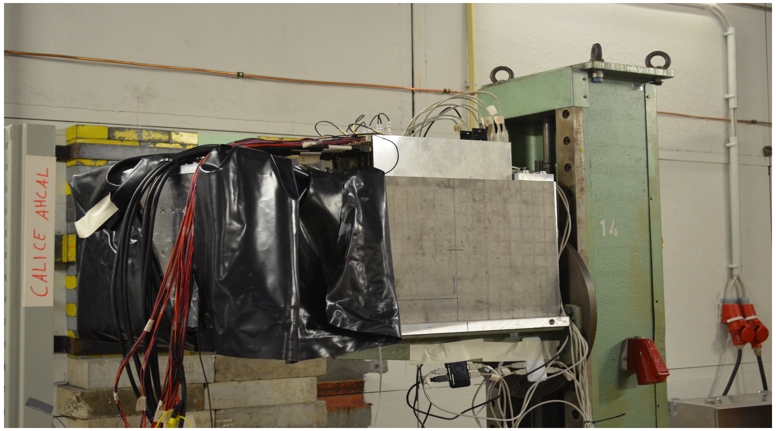
→ re-measure applied HV, correct lab value

→ **reduces spread to ~0.7 pixel/MIP**

EM Showers in ILD Absorber

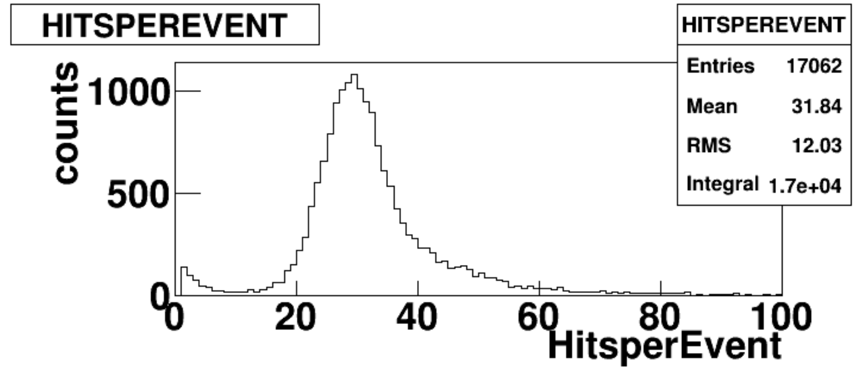
- after MIP calibrations: move layers to ILD stack
  - steel absorber in true ILD HCAL geometry
  - no chips broken during transfer
- measure EM energy resolution
  - fixed trigger setup <0.5 MIP for comparability
- energy scan 1 – 5 GeV in 0.5 GeV steps
  - rates at >5 GeV too low to keep trigger threshold setup fixed

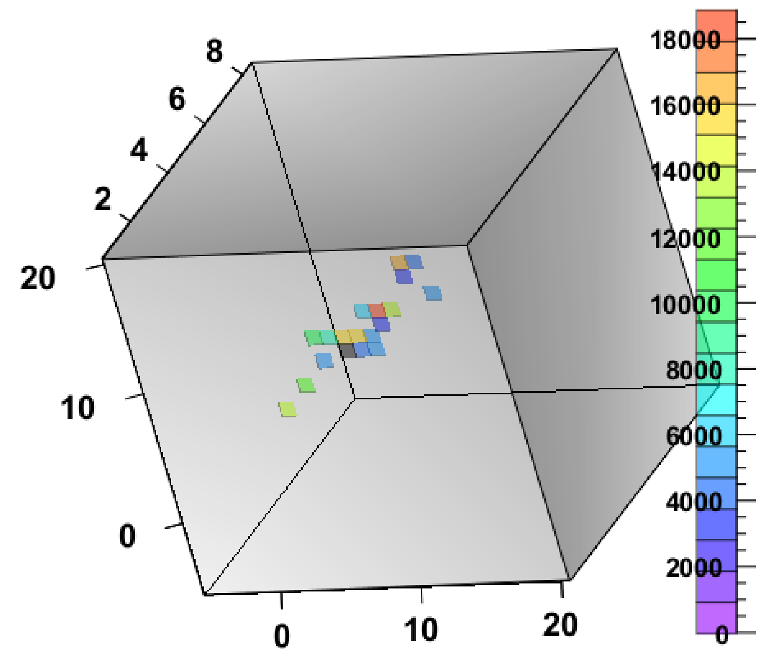




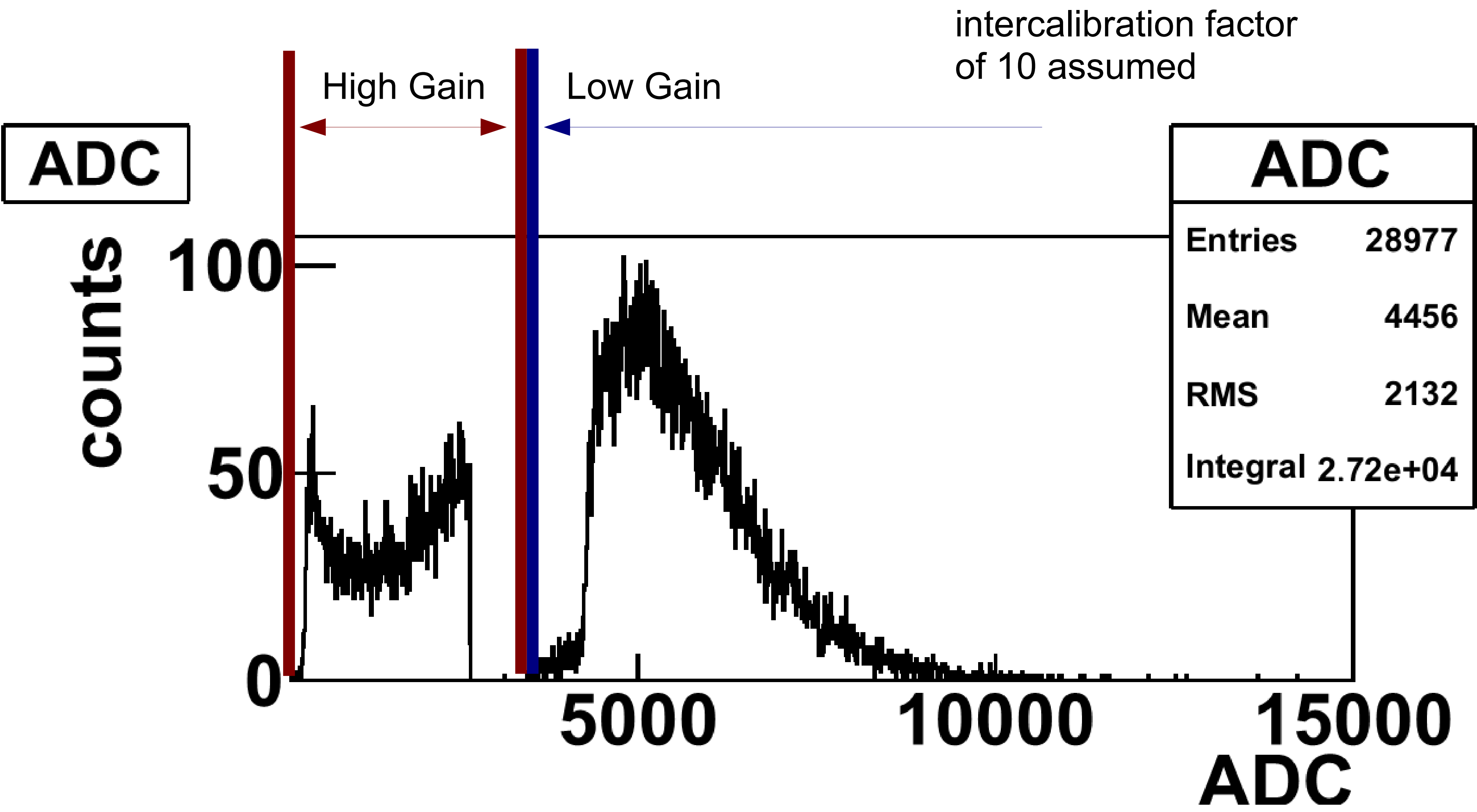
First Look into EM Showers

- first shower characteristics in online monitor tool
  - based on simplified event building, not to be taken as final values
- mean hits per event scales with beam energy
  - very dependent on noise contributions
- mean ADC sum scales with beam energy
  - uncalibrated, but good sign
- Shower dynamic range
  - auto-gain feature of ASIC is used
  - EM showers exceed dynamic range of high gain, chip switches to low gain when necessary
  - intercalibration data with simultaneous readout of high gain and low gain taken

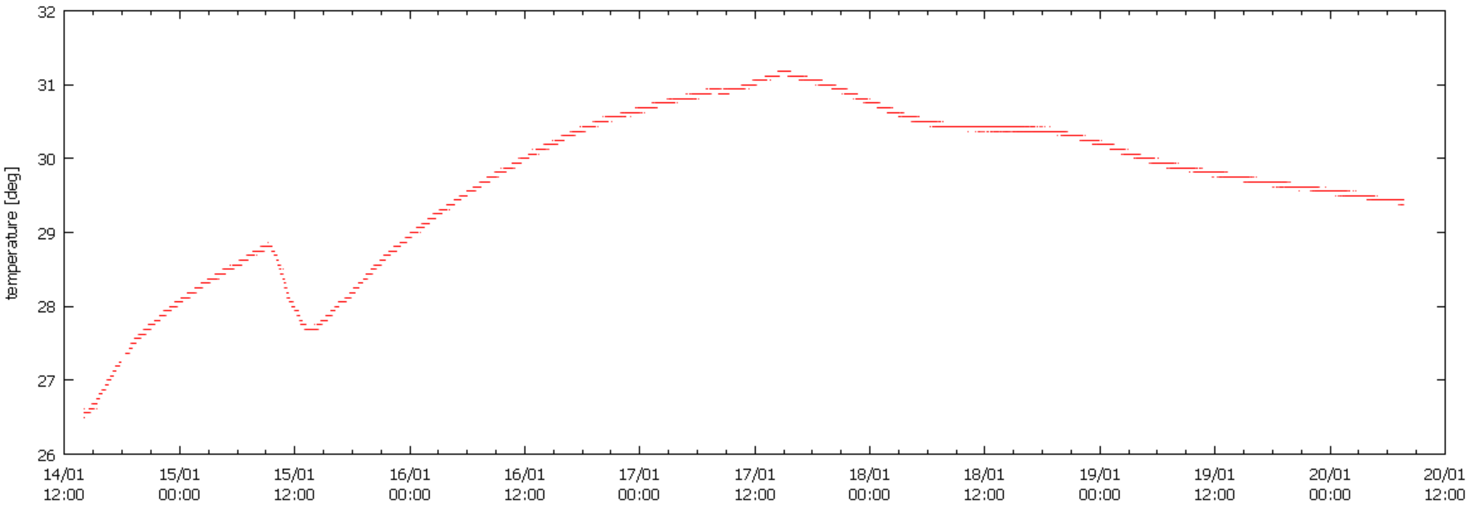




EM shower deposition (Layer 4)

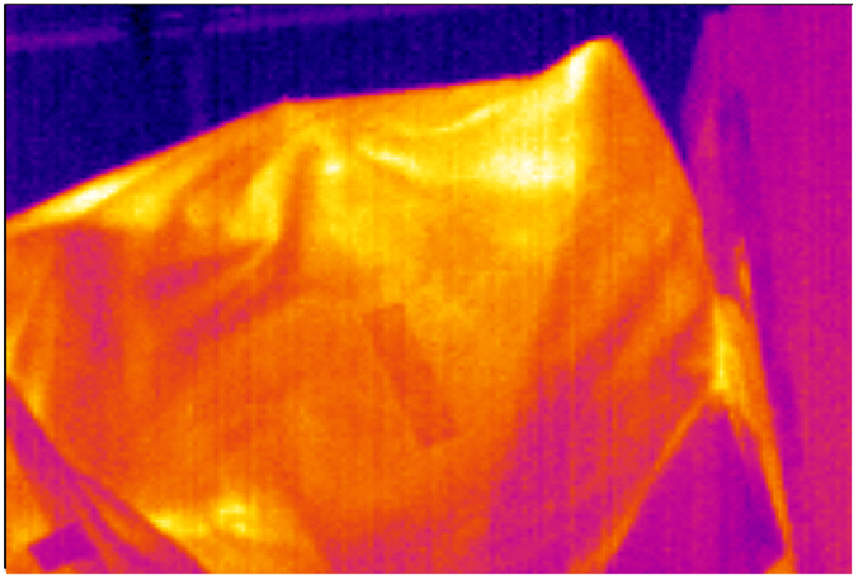


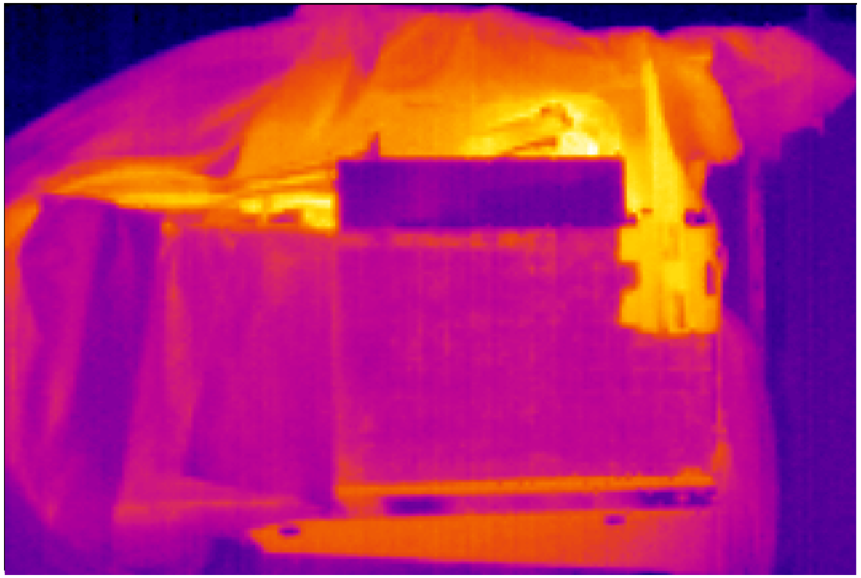
Stack Temperature

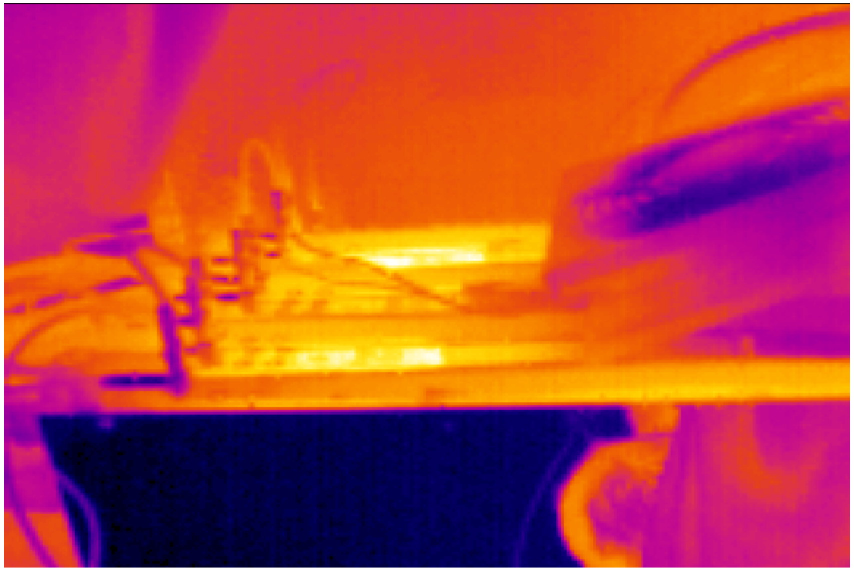


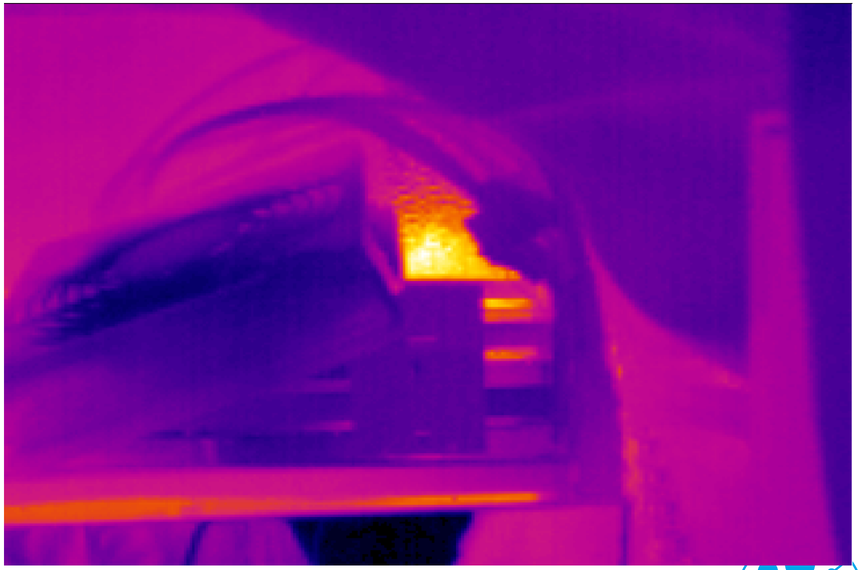
- stack temperature development measured over time
  - external sensor attached to inside of absorber stack next to HBU
  - will be used to calibrate temperature sensors on the HBUs
  - can identify most features in measured temperature
- also took IR (heat) photographs of stack during/after operation
  - need to know hotspots for design of cooling system

Heat Distribution and Sources









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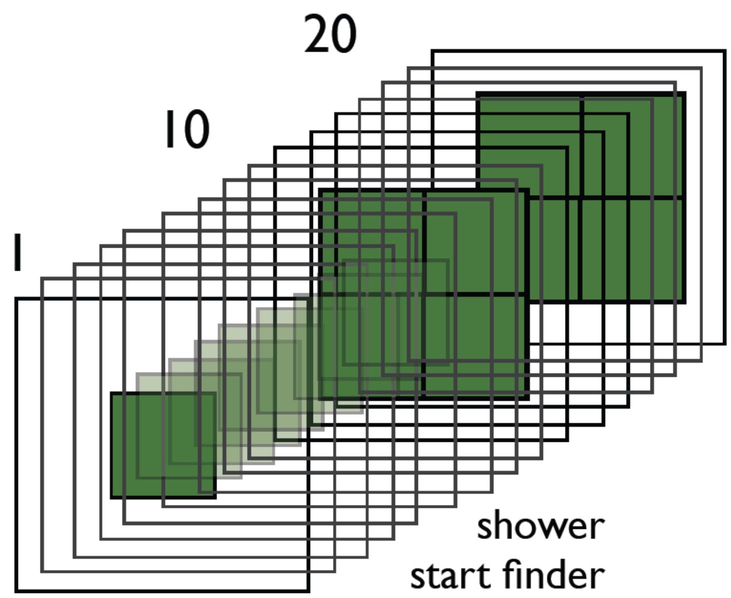


Preparations for hadron testbeam at CERN

- applied for 2 times 2 weeks beam time at PS towards the end of 2014 goals:
  - shower profiles with timing in tungsten and steel
  - test of different photosensors with EM showers
  - muon calibration data
- first very preliminary PS and SPS schedule available
  - AHCAL listed with 14 days in October/November 2014 and 12 days in November/December (3 weeks between the 2 periods)
- Preparations started:
  - DAQ
  - Hardware
    - mechanics, cassettes, tooling: see talk by K. Gadow
    - electronics: see talk by M. Reinecke
    - **Power supplies and distribution**
    - **HBUS + tiles + SiPMs**

Preparations for hadron testbeam at CERN

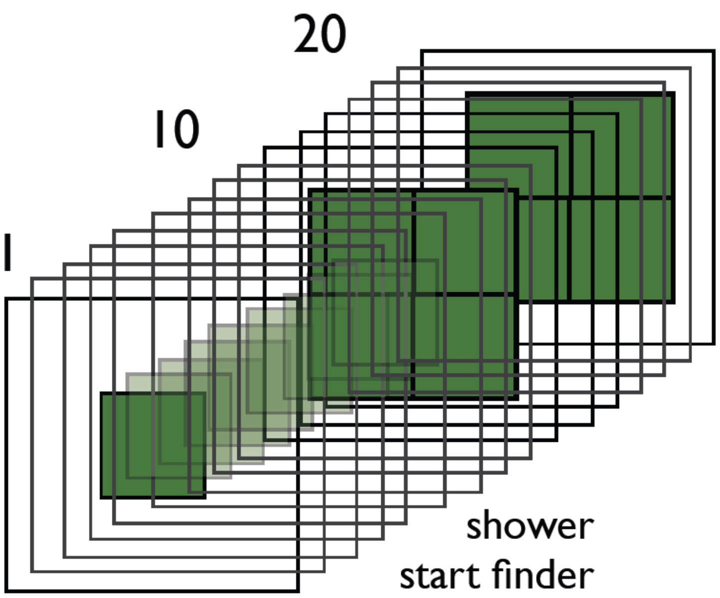
Power supplies and distribution

- Ordered commercial WIENER crate with LV and HV plug-in modules
- Crate and LV modules delivered
- HV modules need modification to limit current, more difficult than expected by supplier, solution exists now for one channel
- Cables and cable distribution box (cable bundle per layer ↔ cable per voltage) exist

Preparations for hadron testbeam at CERN

HBUs + tiles + SiPMs

- Existing: 4 HBUs with 'old' ITEP tiles with WLS fibre + 4 HBUs with UniHH tiles with Ketek SiPMs
- Ketek SiPMs for 4 more HBUs delivered, tiles being produced by UniHH
- ITEP produced direct-readout tiles (+ Ketek SiPMs with 12100 pixels) for 2 HBUs, arrived at DESY, very first tests in lab done
- Unis HH and HD ordered SenSL SiPMs for 8 HBUs, tile production and testing to be clarified between HH and HD
- Plan to use 1-2 EBUs for first layers in shower start finder
- 1 SM-HBU from NIU with top-view SiPMs?



Close progress monitoring and testing & commissioning crucial

Conclusions and Outlook

- New direct-coupling tiles with Ketek SiPMs produced by UniHH
  - characterized by UniHH and UniHD
  - very low noise and very small tile-to-tile spread
- Influence of tile non-uniformity for all designs (WLS fibre, fibre-less, top-view dimple) negligible for hadrons
- Successful DESY testbeam in 2013/2014
  - 4 HBUs with old tiles, 4 HBUs with new UniHH tiles
  - MIP calibration through 8 layers, good correlation lab ↔ testbeam
  - EM showers: energy scan 1 – 5 GeV in 0.5 GeV steps
- Preparation for 4 weeks of CERN PS hadron testbeam at end of 2014
  - more hardware, especially tiles+SiPMs, in production
  - preparing infrastructure & DAQ
  - close progress monitoring necessary

Backup

Timing Selection: Calibration

- TDC range differs from channel to channel
  - Hit timing selection needs TDC calibration
- Simple calibration employed here:
  - Edge detection on TDC spectra
  - Min-max mapping
  - Works directly from data
- Full TDC calibration
  - In progress for hadron shower timing data
  - Not easily transferable