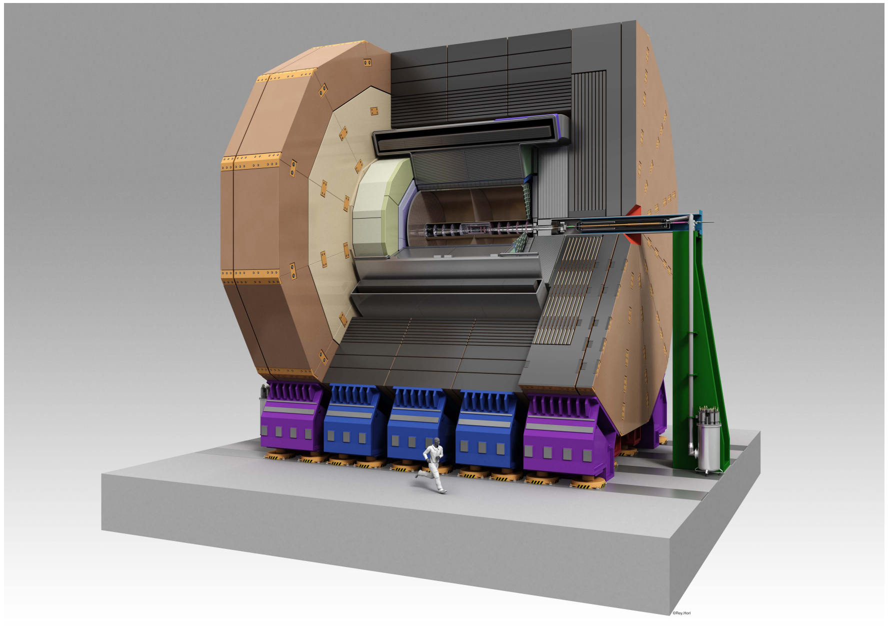
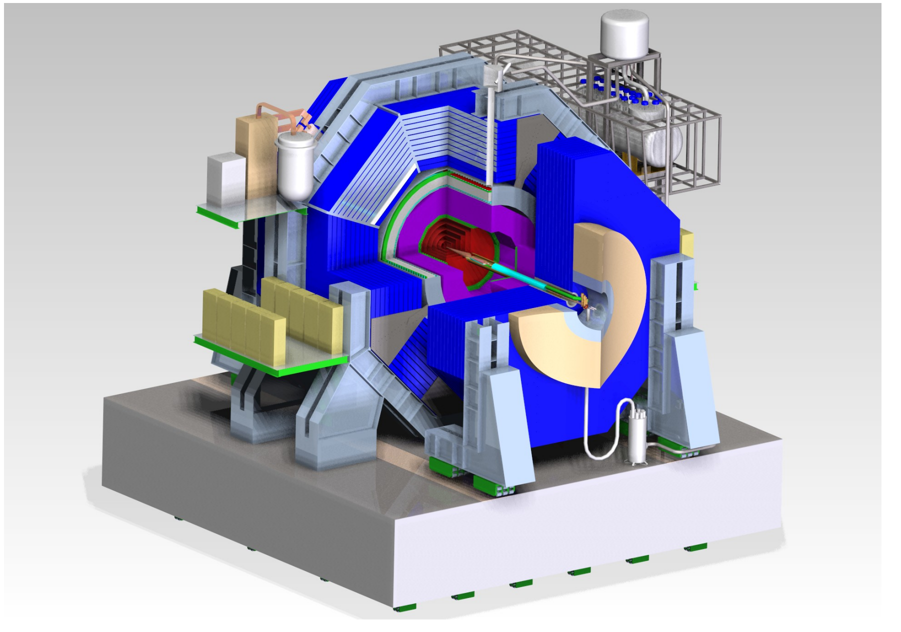
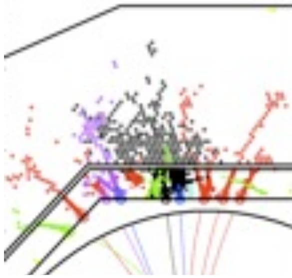
The Scintillator Analogue HCAL for ILD and SiD - an update

Felix Sefkow





SiD workshop, SLAC, 13. Januar 2015



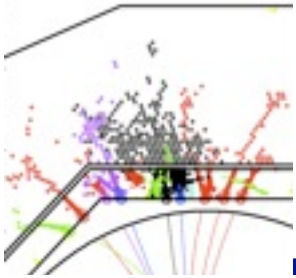
Charge

- Update: latest developments

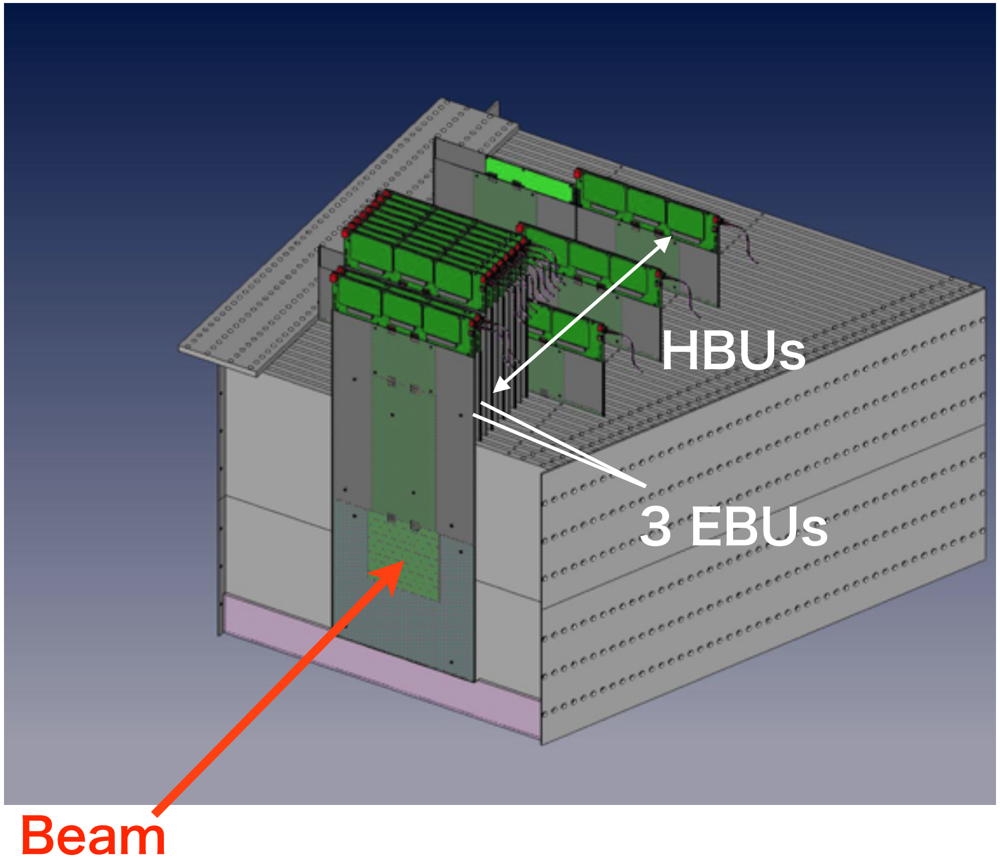
- Specific questions:

a) Remaining R&D which needs to be done if any ?
b) What are the open systems and engineering issues
c) Calibration, Stability, etc
d) Cost estimates
e) Future improvements which are on the horizon ...
f) Simulation/software Status & Issues
g) Services, Power

Recent highlights

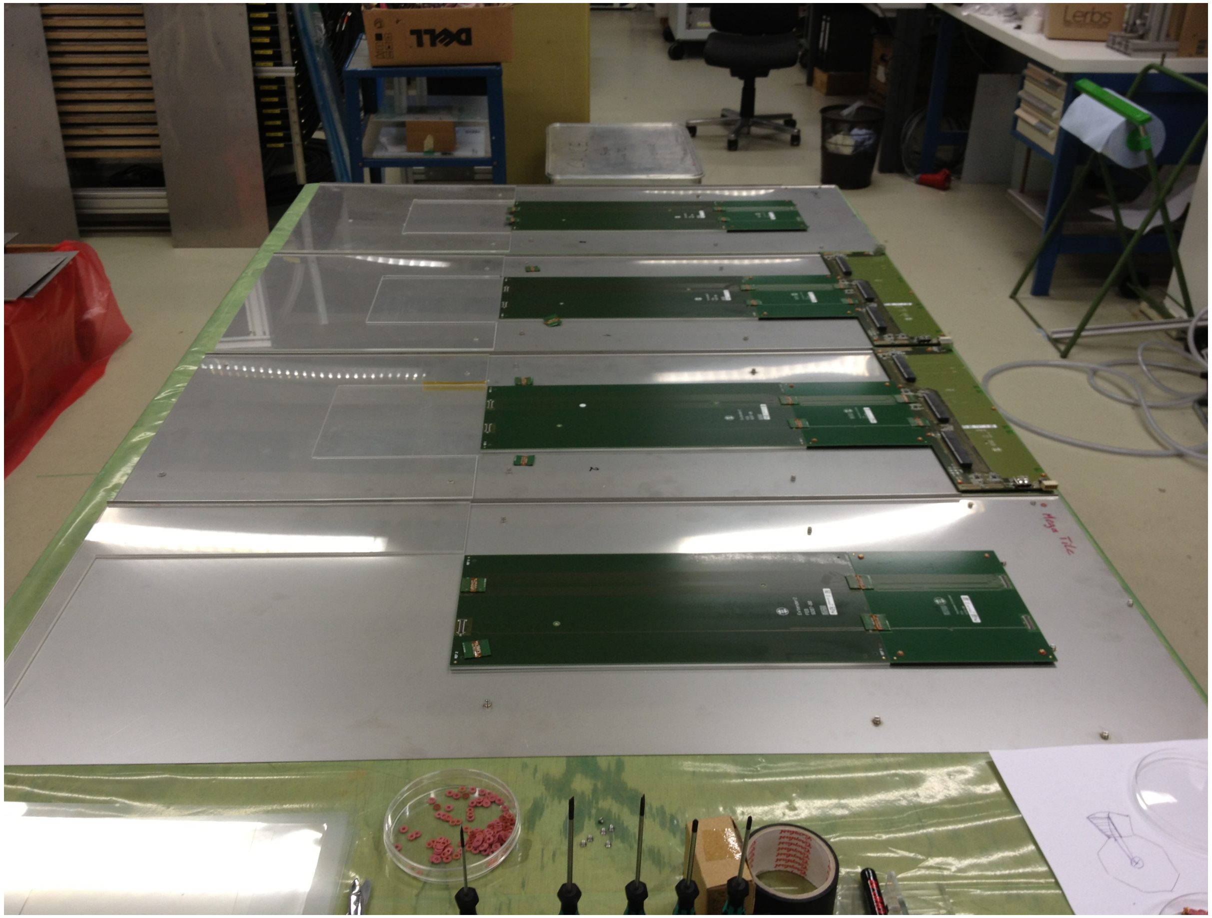


Getting real



- Test beam at CERN PS in Oct and Nov/Dec 2014

Getting real



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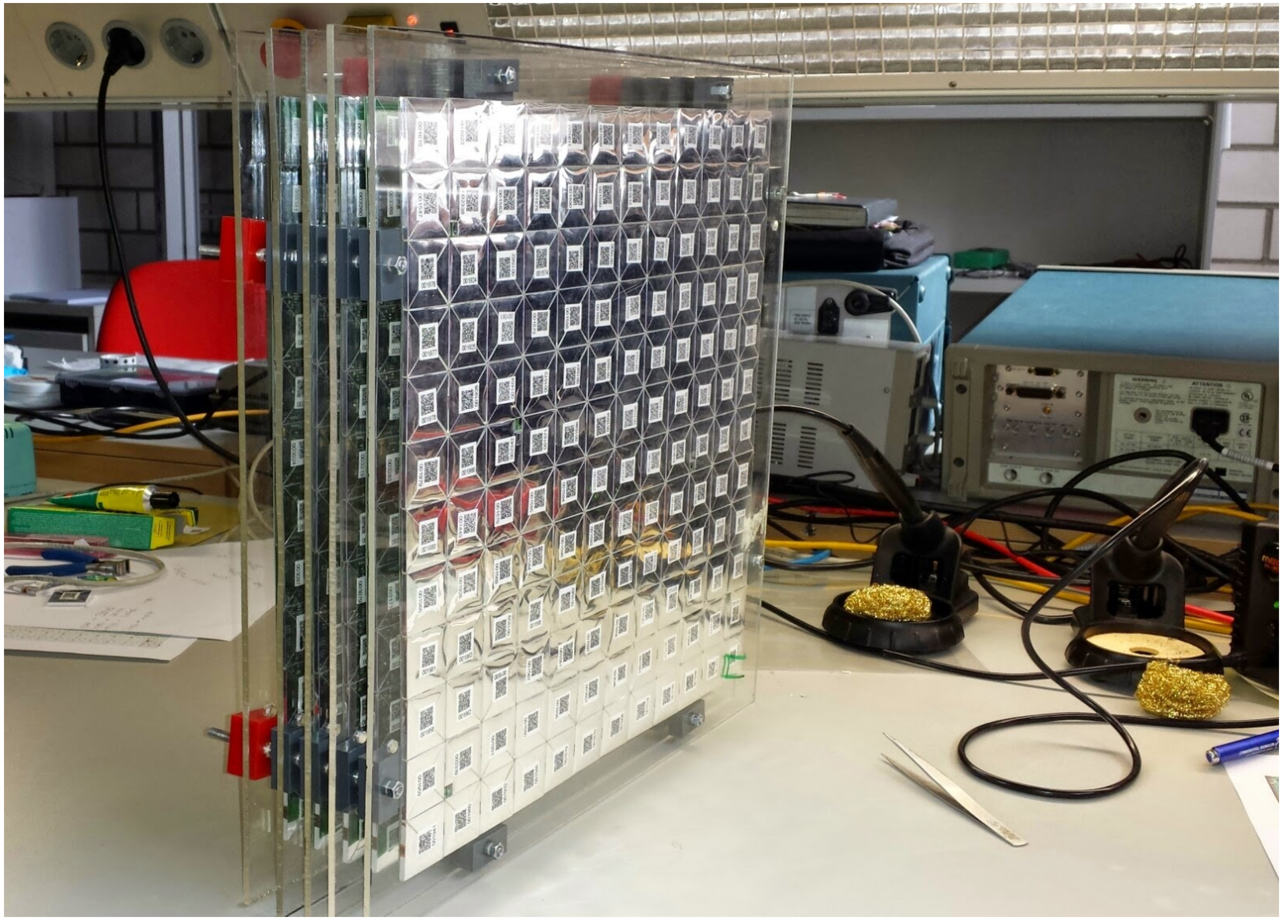

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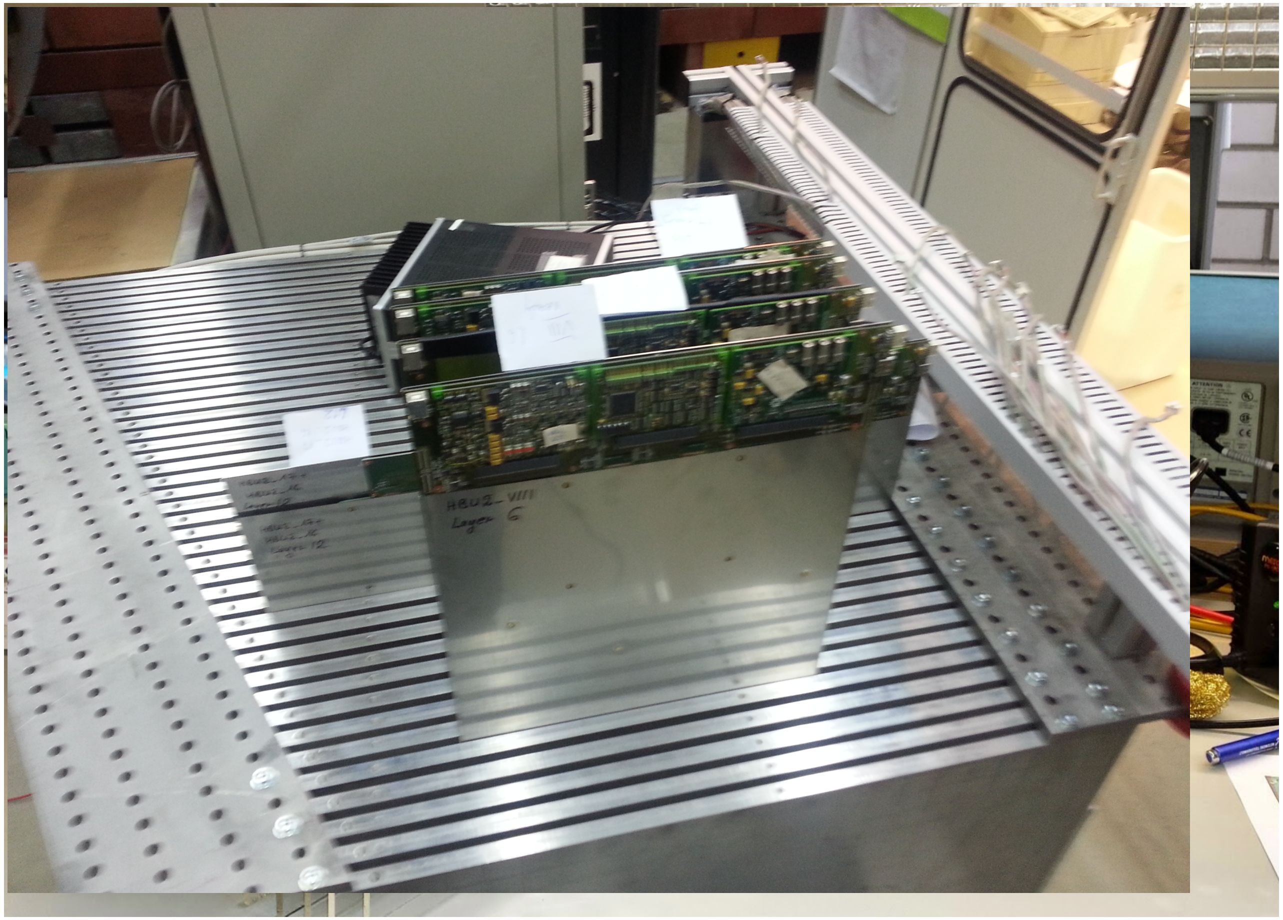

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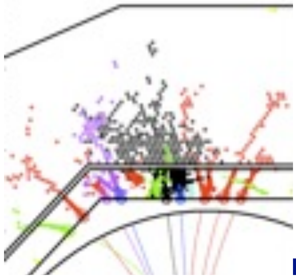

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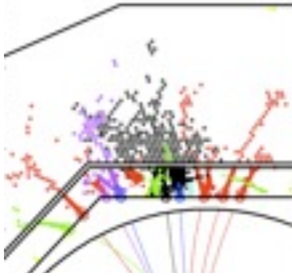
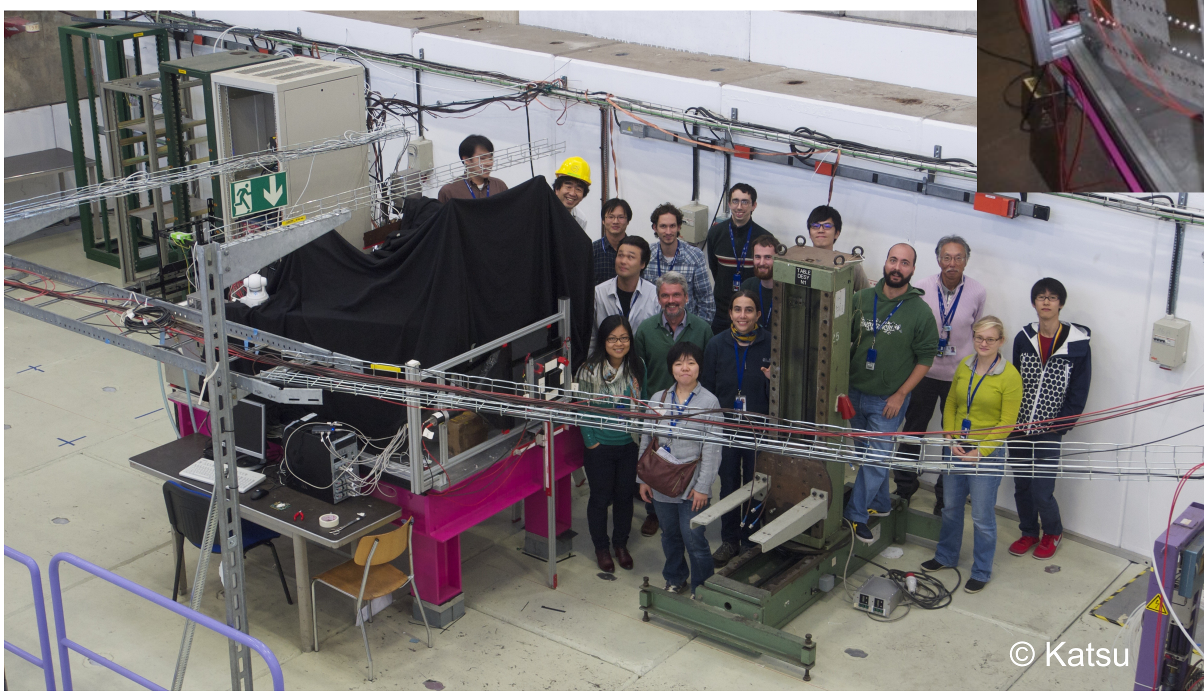
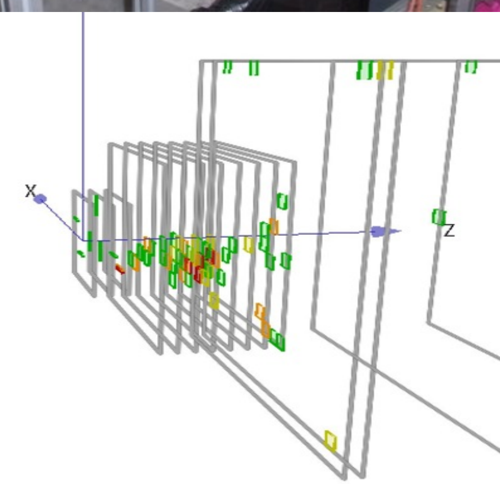
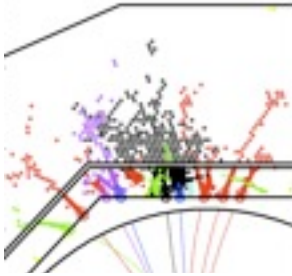


2nd gen AHCAL to test beam

- EUDET stainless steel prototype stack
- 4 large, 8 small HCAL layers, 3 strip-ECAL
- New fully HDMI-based DAQ
- Different types of tiles and SiPMS
- Germany, Russia, Czech, US, Japan

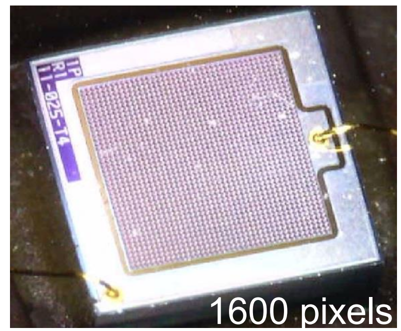


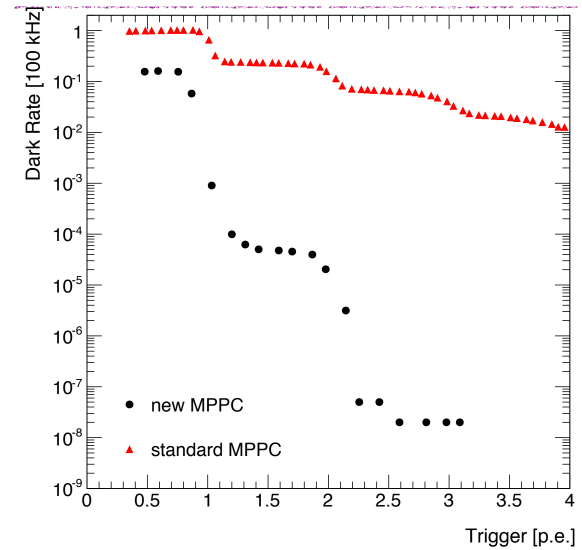


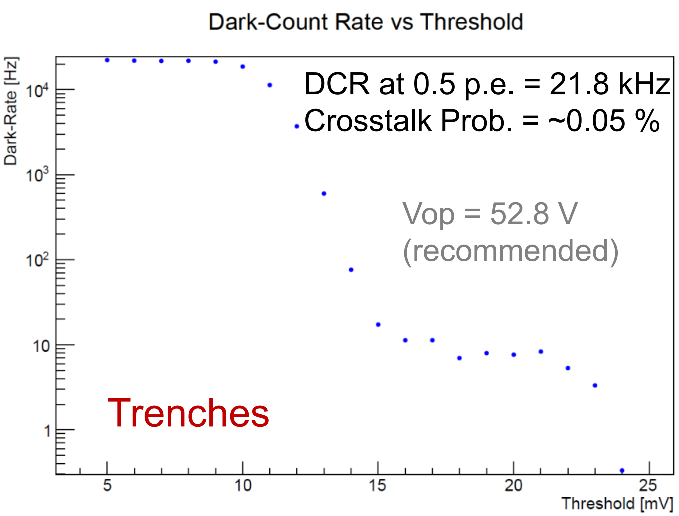


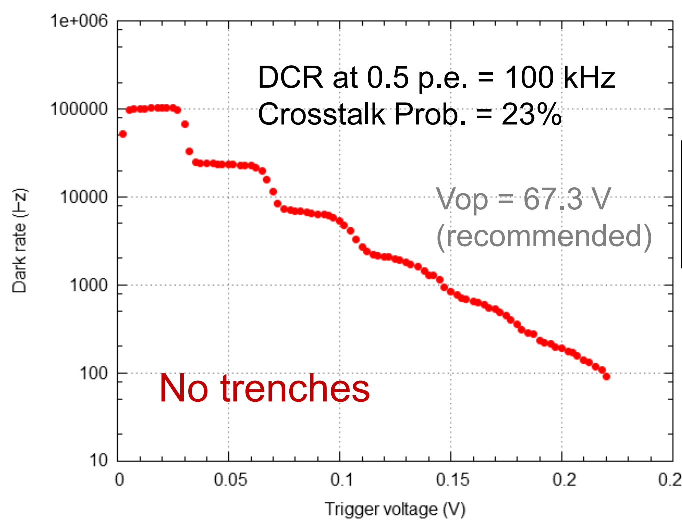
New MPPCs

- Prototype from Hamamatsu
- Tested at Mainz and Munich
- Low inter-pixel cross-talk
- Very low noise above threshold





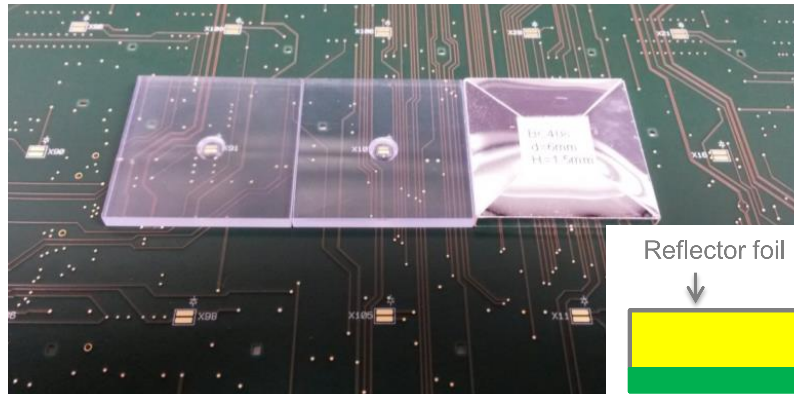


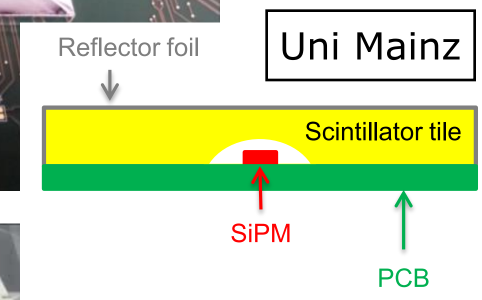


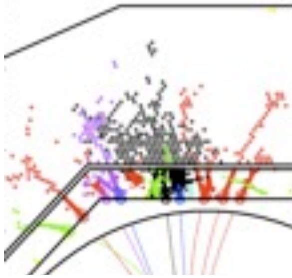
Physics prototype:
DCR 2 MHz, XT 30%

Surface-mounted SiPMs

- Originally proposed by NIU, now followed by different groups
- Vishnu Zutshi coordinating role
- First board assembled - tiles mounted by machine
  - important step towards mass production
- Board works on test bench, will be included in 2015 SPS run

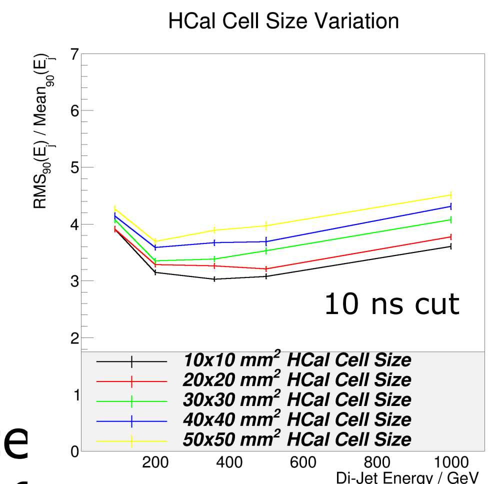


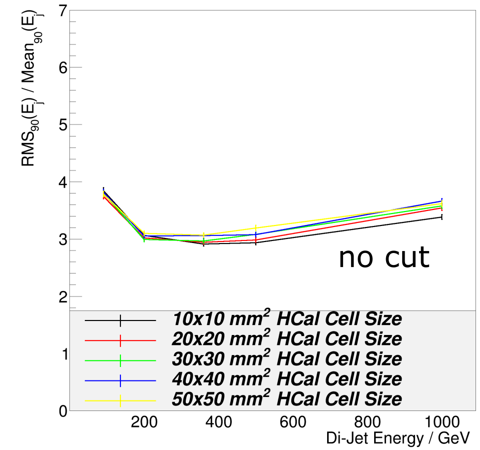


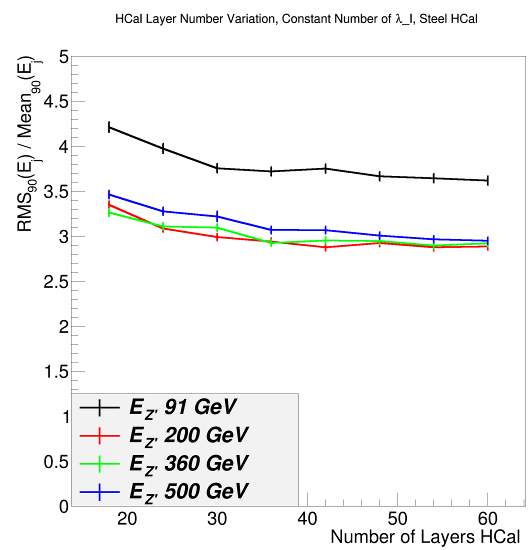


Optimisation studies

- Effort in Cambridge, in CLICdp framework
  - software support by DESY
- Study absorber material, thickness, tile size and longitudinal segmentation
- On-going work, dependence on timing and energy cut-offs still under study
- NB: number of layers has strong cost impact

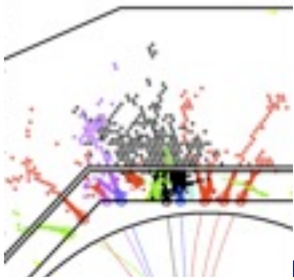






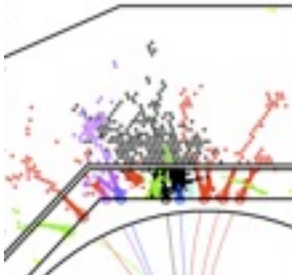
Steven Green

Specific questions



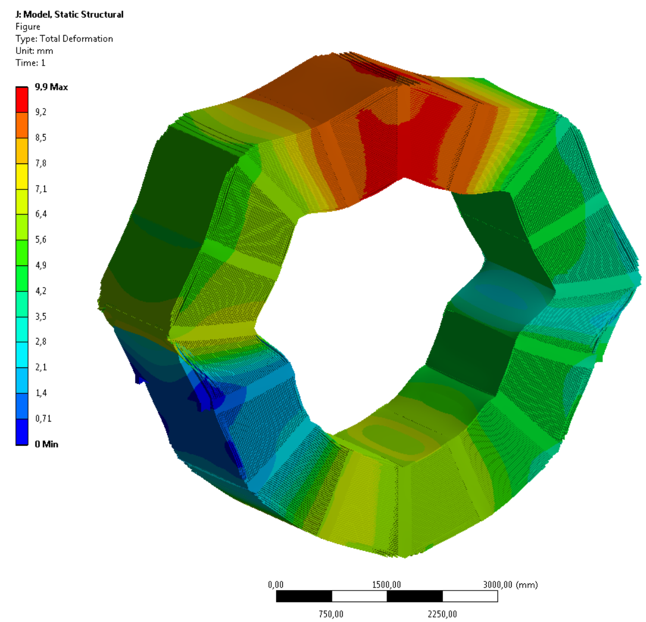
Remaining R&D

- - if any? Oh, yes!
- Finalise and establish SiPM-tile-electronics integration design amenable at mass-production
- Develop automated production and quality assurance procedures
- Re-establish performance with integrated electronics:
  - ultimately need full hadronic prototype (20-40’000 ch.)
  - do not repeat Geant4 study
- Power pulsing
  - e.m. performance is sufficient - and harder anyway

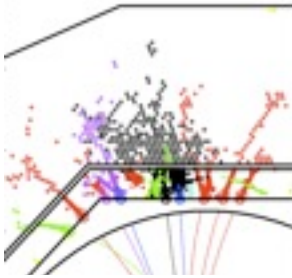


Open systems & engineering issues

- Not many (for ILD), and on the way
- Dynamical seismic stability of absorber structure
  - simulations
  - validation?
- Leak-less under-pressure cooling system
- In-situ compensation of temperature variations (optional)

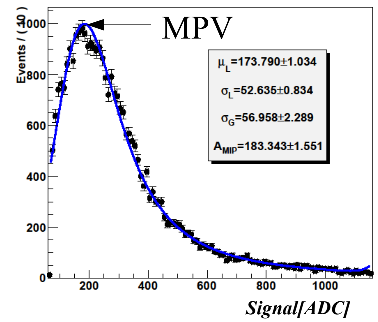


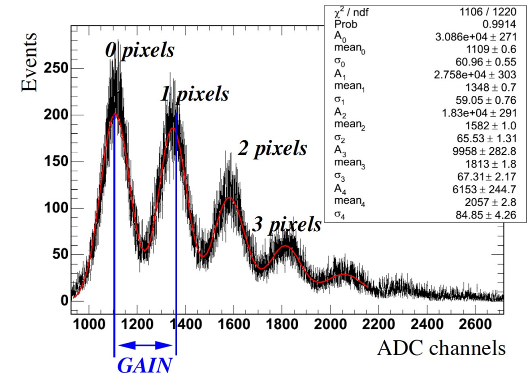
- For SiD, in addition:
- Active layer integration into absorber structure
- Space for interfaces, routing of services



Calibration and stability

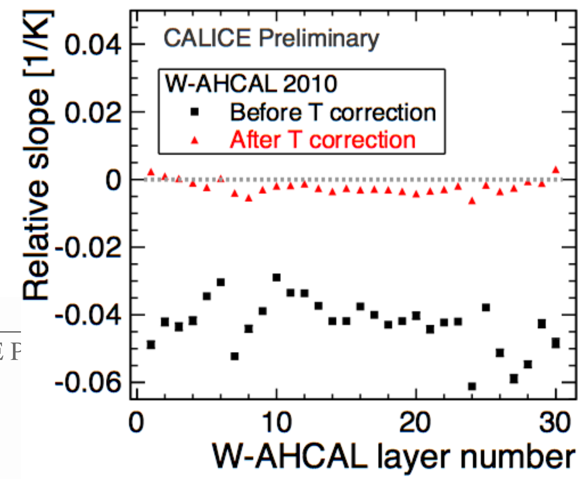
- Cell-wise equalisation: MIP
- Saturation correction: gain
- All SiPM properties depend on one parameter
  - $\Delta V = V - V_{break\text{-}down}(T)$

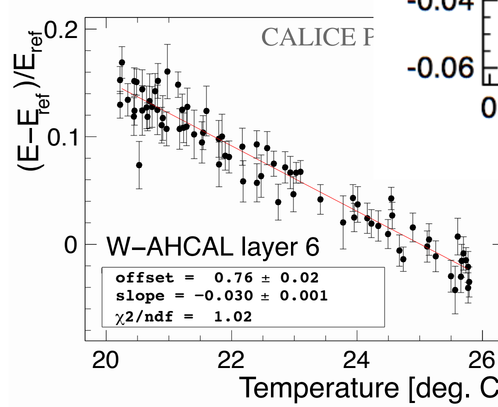




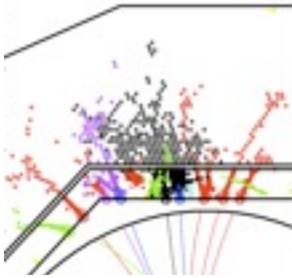
- Needed time to find right procedures
  - some limitations from test bench data
  - large spread of SiPM parameters
- Guidance for future developments
  - e.g. gain stabilisation

no climate control

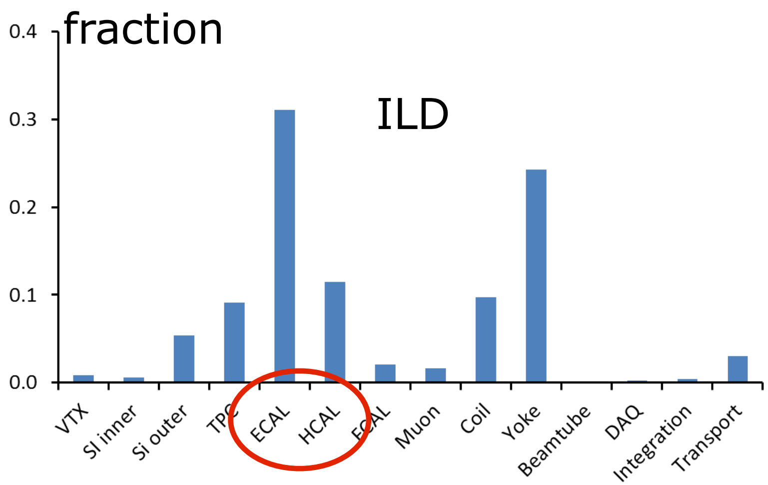




After layer-wise correction stable to better than 0.2%/K



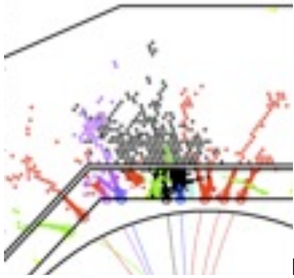
AHCAL cost drivers and scaling



- ILD scint HCAL total: 45M
- 10M fix, rest ~ volume
- 10M absorber, rest ~ area (n_{Layer})
- 16M PCB, scint, rest ~ channels
- 10M SiPMs and ASICs

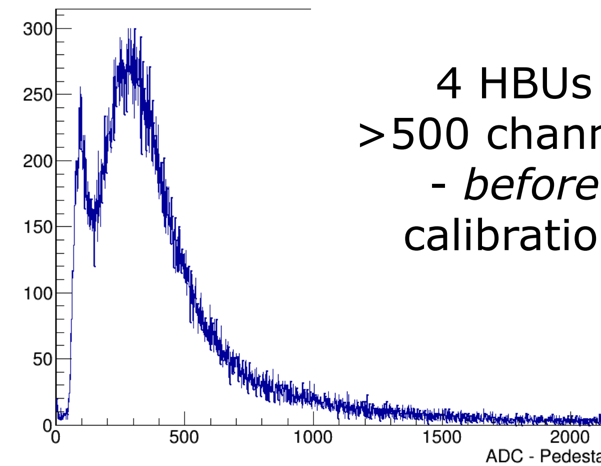
- DBD costing is far from final, but much better than anything before
- Yet, many lessons learnt from 2nd generation prototypes
- What are the real cost drivers at present?
- What are the scaling laws?

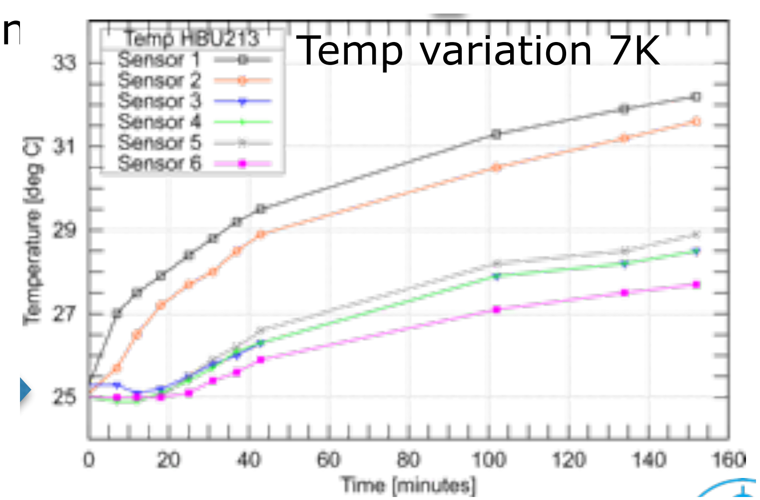
- Not cost drivers:
- Scintillator 1.5M
- ASICs 1.8M
- Interfaces 1.4M
- …

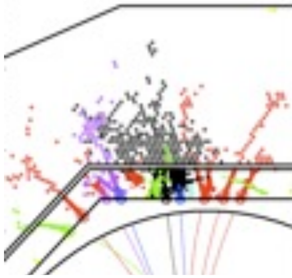


Improvements on the horizon

- Benefits of SiPM progress
- Device uniformity: dramatic simplification of commissioning procedures
- Many degrees of freedom become obsolete
  - no need anymore for bias adjustment to equalise light yield
  - no need anymore for pre-amp compensation of SiPM gain variation
  - no need anymore for channel-wise trigger thresholds
- Low noise: auto-trigger works
- Higher over-voltage possible - reduce temperature dependence







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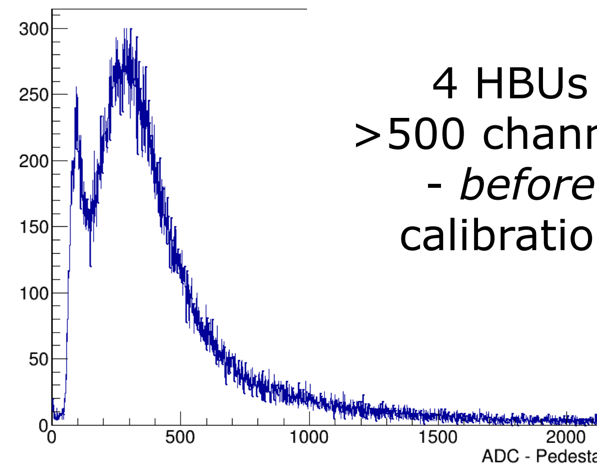
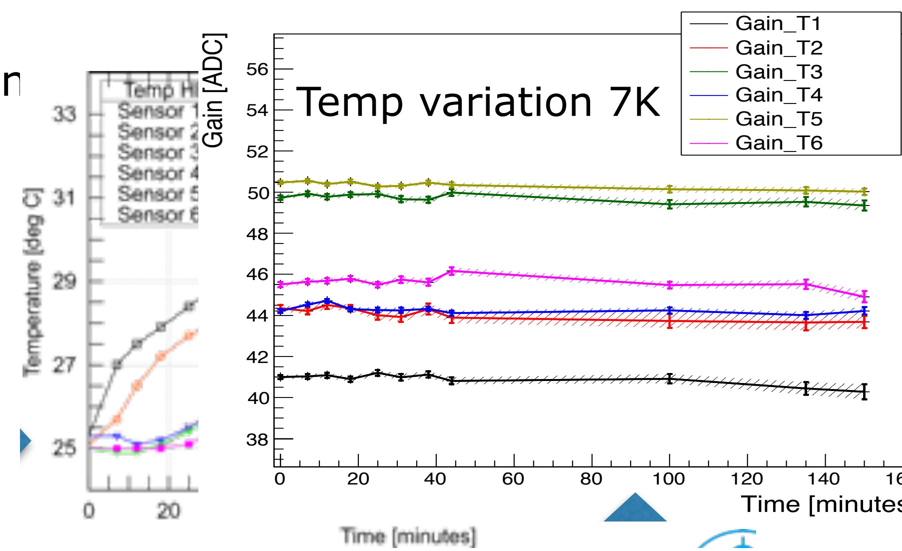
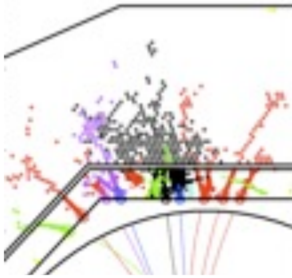
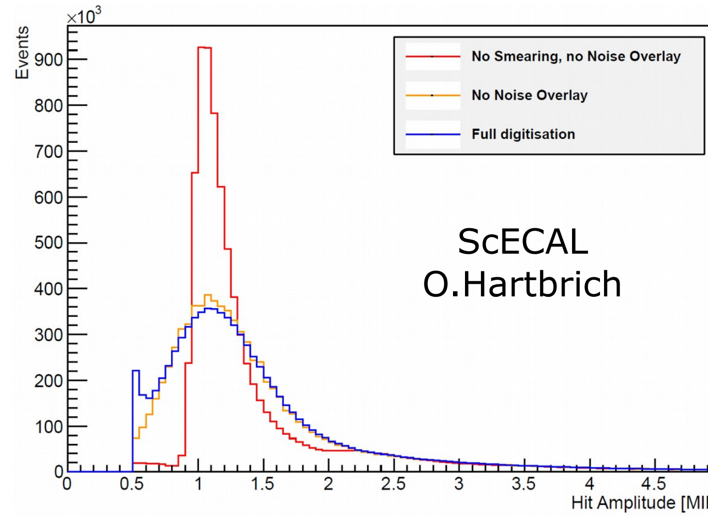


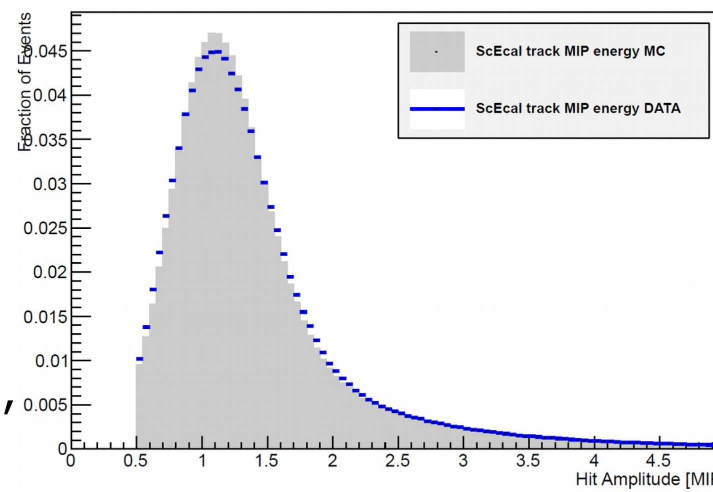


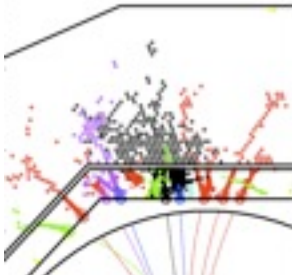


Simulation software status & issues

- AHCAL test beam simulations include
  - variation of light yield (and calibration)
  - saturation (and correction)
  - finite photo-electron statistics
  - noise from data
  - 0.5 MIP threshold
- Scintillator non-uniformities had been implemented, not run routinely
  - negligible effect, CPU intensive
- Temperature variation and correction not included
- Constant terms of 1-2% measured and simulated
- ILD simulation includes threshold only
- The other effects are currently being implemented
- Effects visible for muons, small for electrons, negligible for hadrons

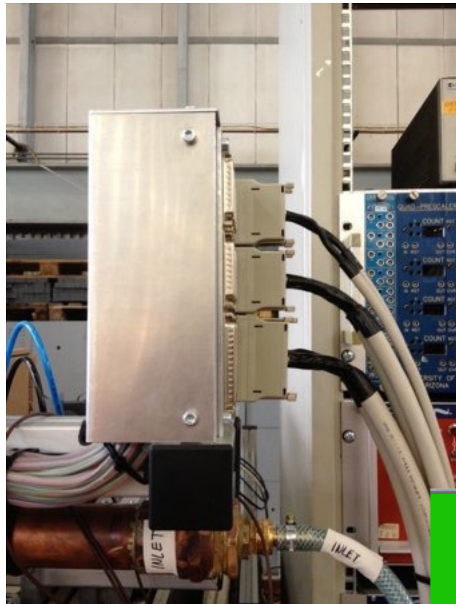


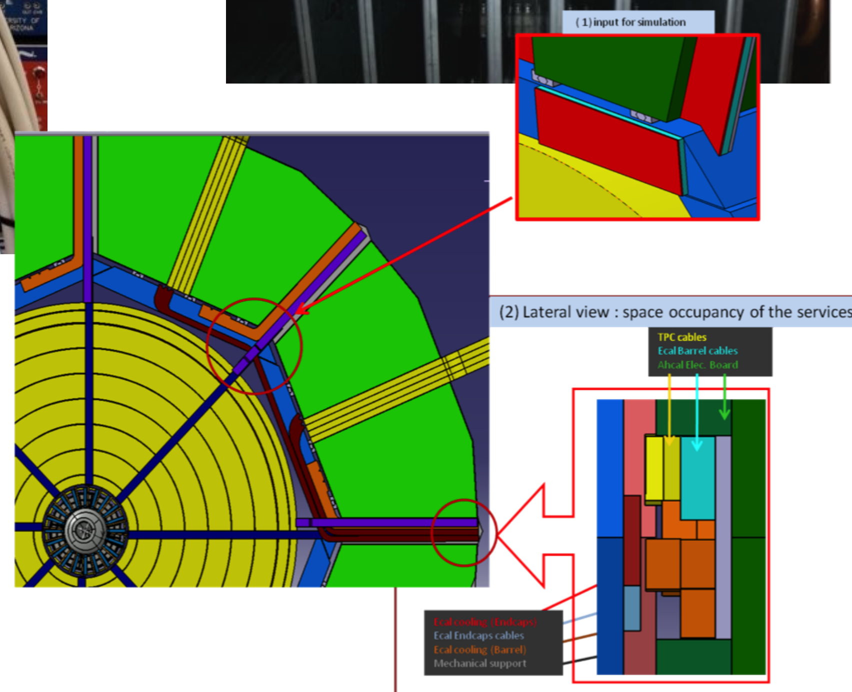




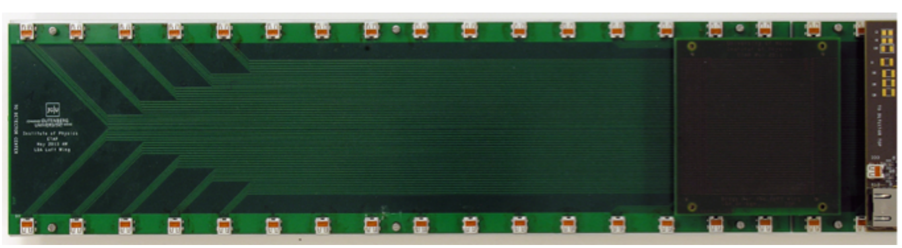
Services, Power

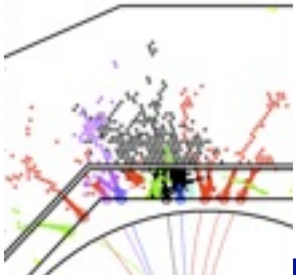
- Detailed implementation in ILD engineering model and simulation
- Being realised with upcoming 2nd generation prototype





data concentrator

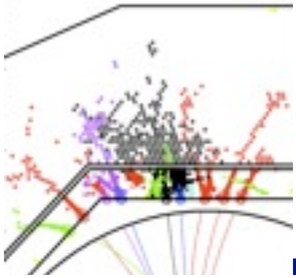




Conclusion

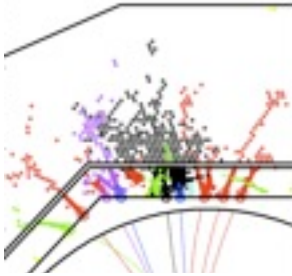
- Very nice and important progress recently
- Few remaining open issues being addressed
- Looking forward to the next steps

Back-up



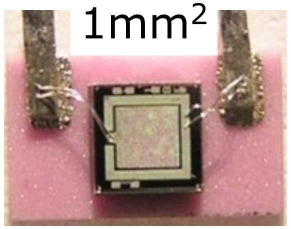
AHCAL groups in CALICE

thanks, Katja!

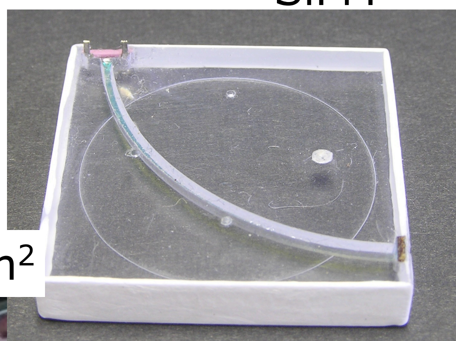


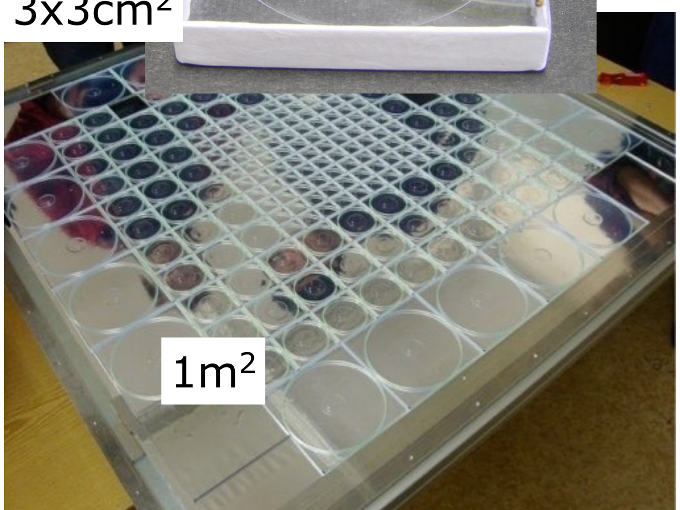
AHCAL physics prototype

7608 channels
38 layers
Fe & W



SiPM



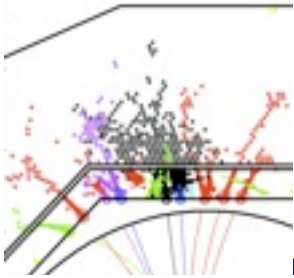


- Constructed in 2005-06: first device using SiPMs at large scale
- Now many followers: T2K, Belle2, CMS, medical applications,...
- Extremely robust: 6 years of data taking
  - 2006-7 CERN: Fe with SiW ECAL
  - 2008-9 FNAL: Fe with Si/Sci ECAL
  - 2010-11 CERN: Tungsten

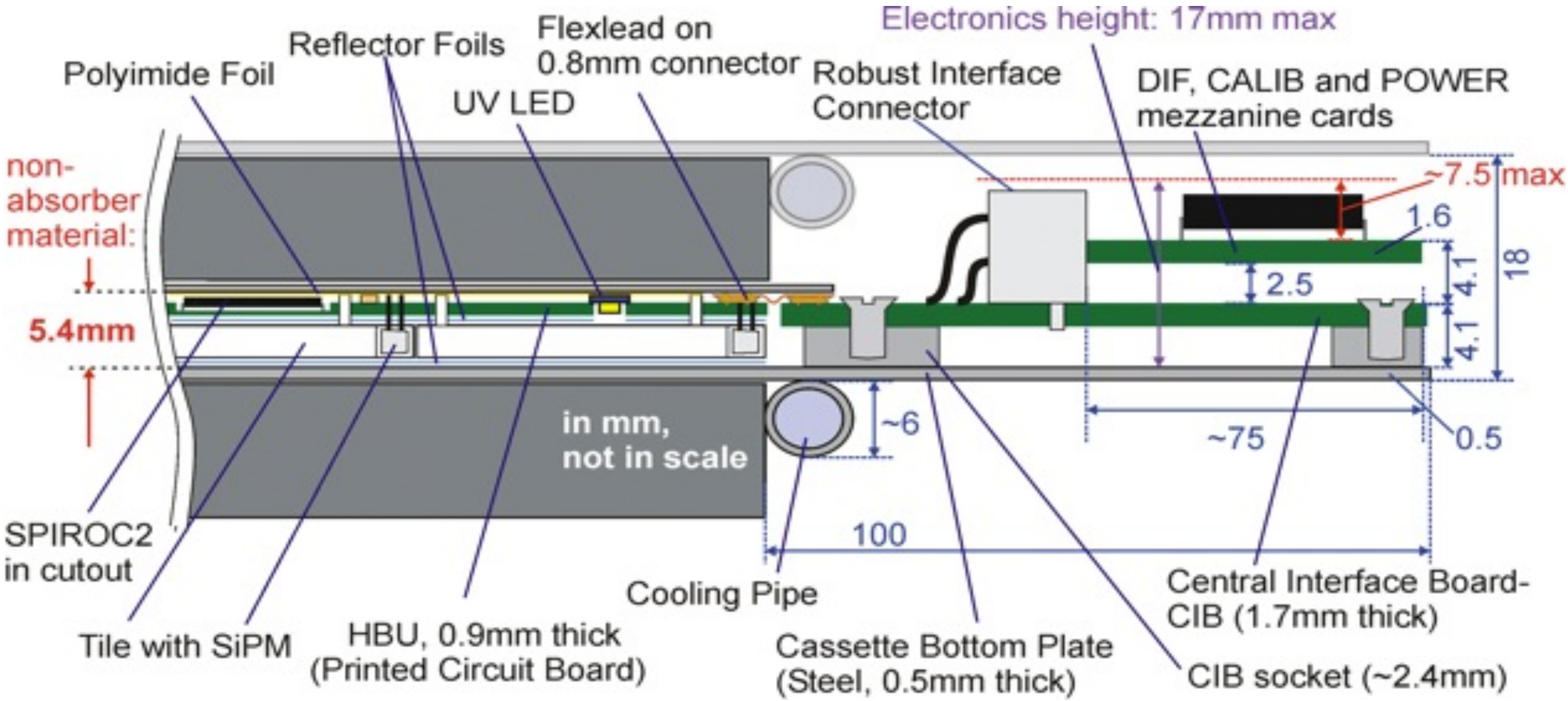
Many trips with disassembly & reassembly of the calorimeter:

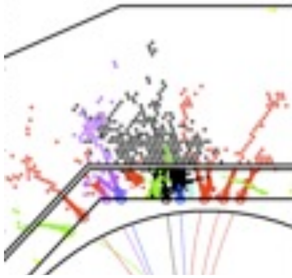
DESY - CERN - DESY - FNAL - DESY - CERN PS - CERN SPS

... and the SiPMs survived without problems!



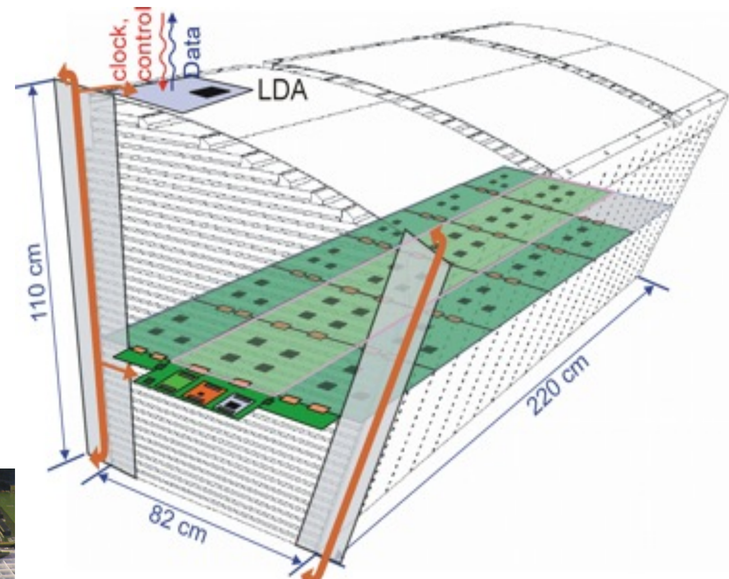
Layer cross section

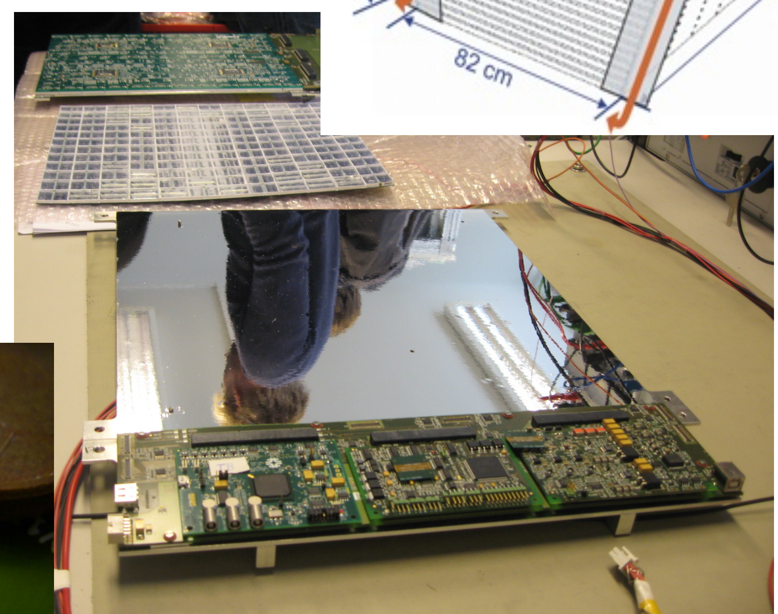


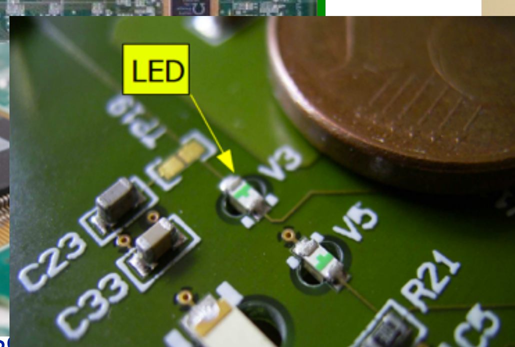


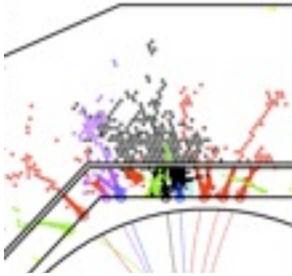
Electronics integration

- Basic unit: 144 tiles, 36x36cm^2
- 36 ch. ASICs, power pulsed
  - self-trigger, 16x memory, ADC
- embedded LED system
- compact design
  - 5.4mm incl 3mm scintillator



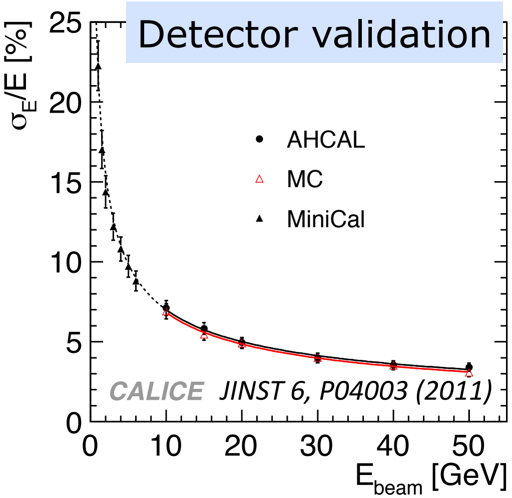




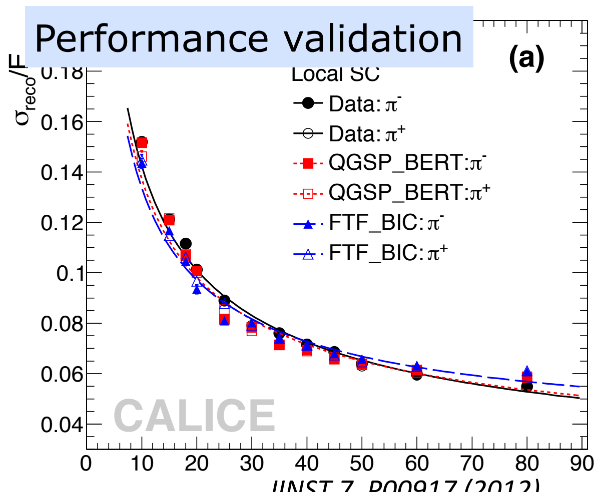


Validation of Simulation

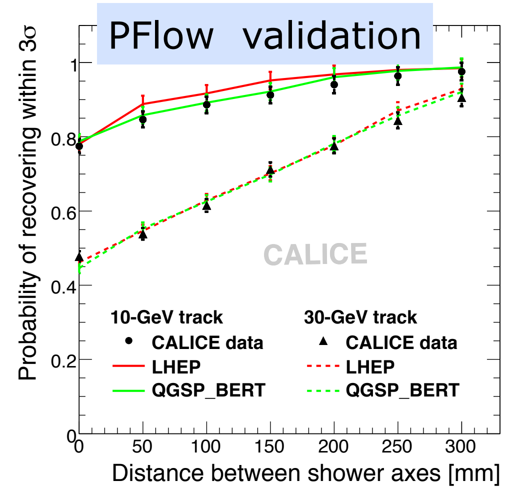
- Validation with first generation prototype
- Published 8 papers



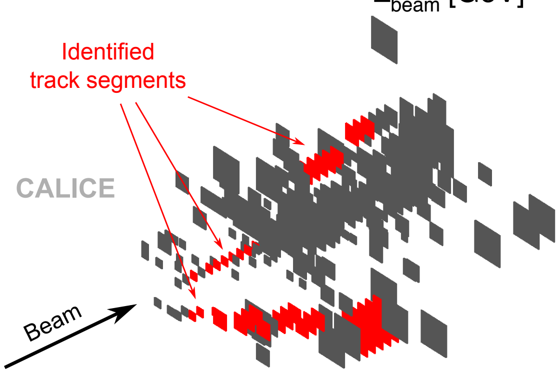
JINST 6, P04003 (2011)



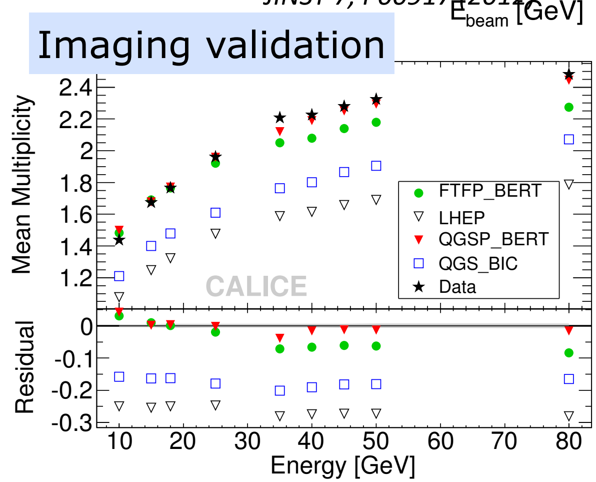
JINST 7, P00917 (2012)

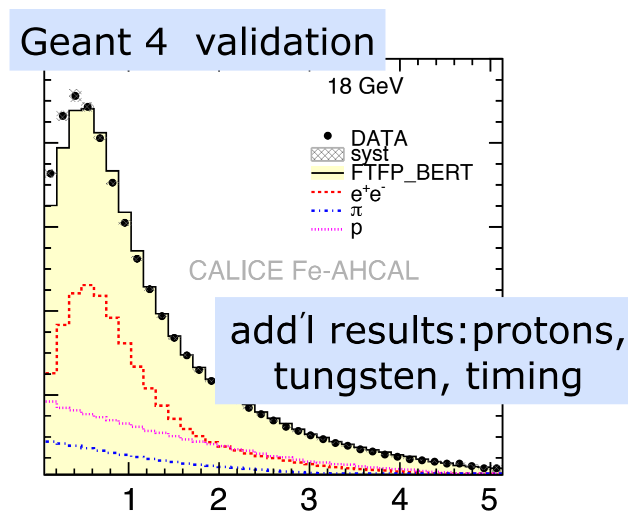


JINST 6, P07005 (2011)



JINST 8, P09001 (2013)





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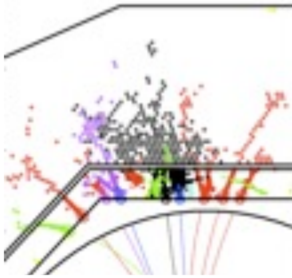
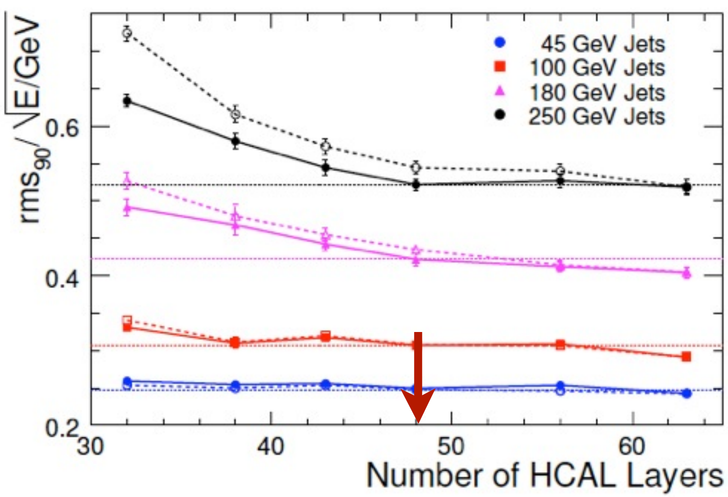


ILD optimisation

- Based on Pandora PFA
- Extensive studies done for the LOI
- AHCAL design parameters in plateau region

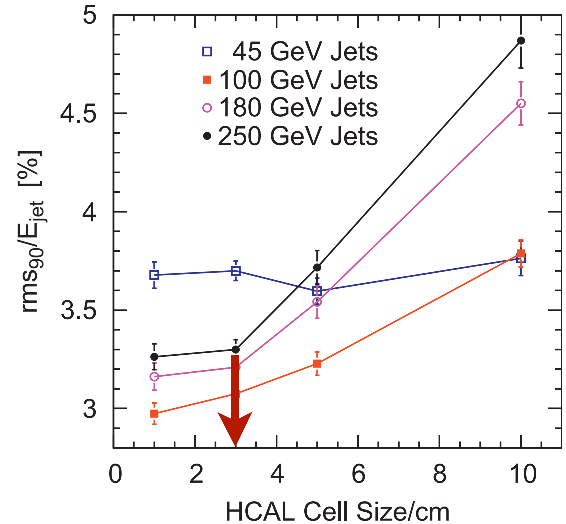
- Cost optimisation postponed

Depth

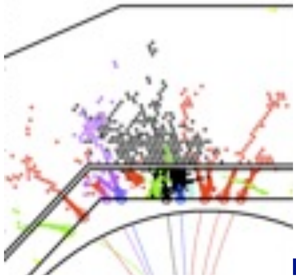


Granularity

b

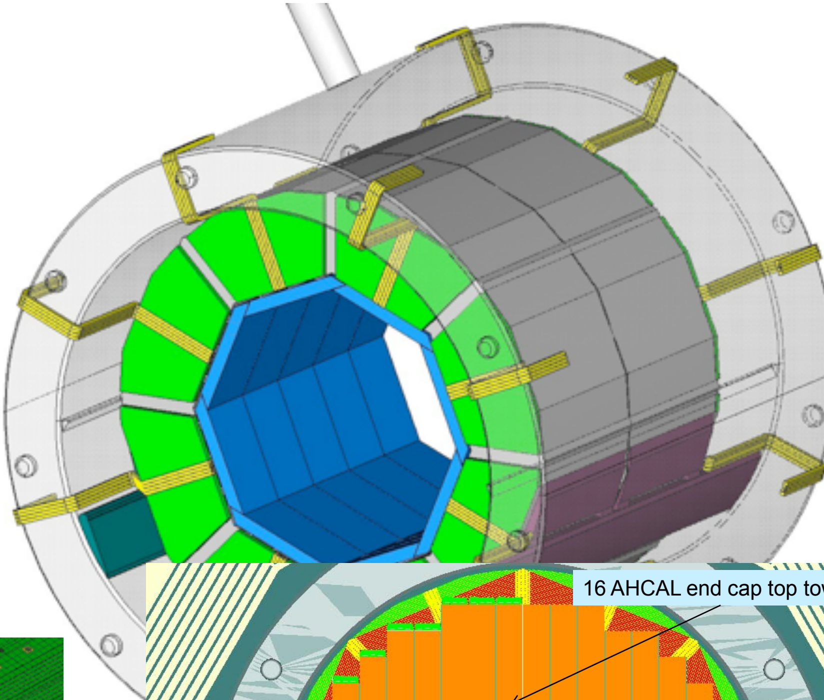


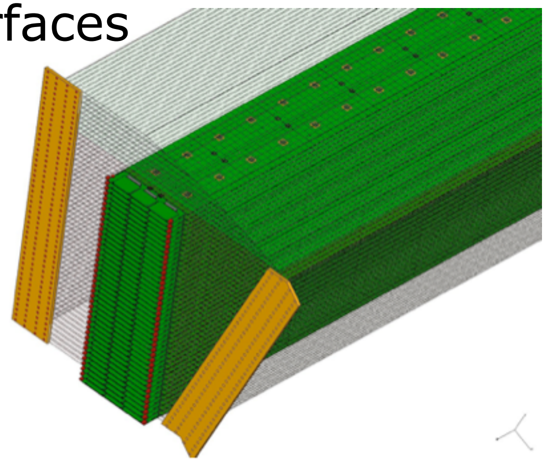
reflects shower feature size rather than particle separation

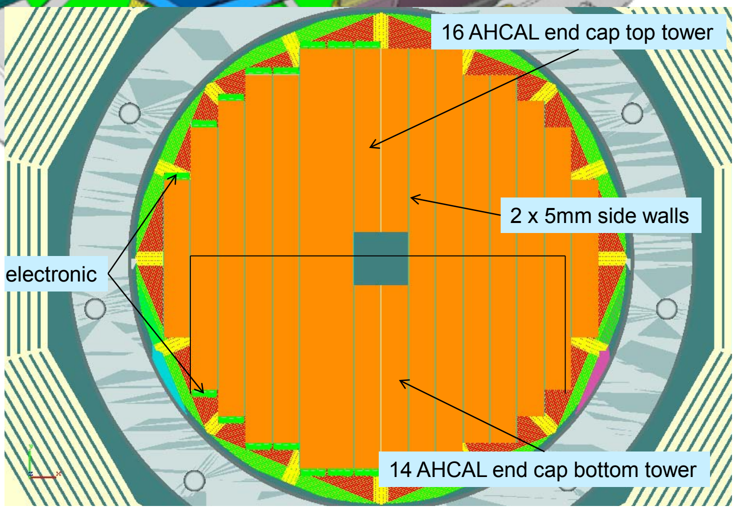


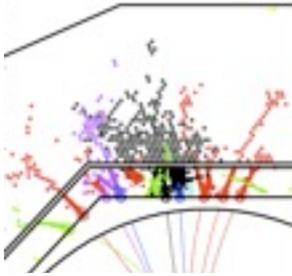
AHCAL implementation

- Short barrel (2x 2350 mm)
  - big endcap R = 3190 mm
- 8-fold symmetry
  - 16 sub-modules
- 6 λ deep, 48 layers x 2 mm
  - R = 2058-3410 mm
  - $8000 m^2$
- Cracks filled with steel
- Embedded front end electronics
- Accessible interfaces





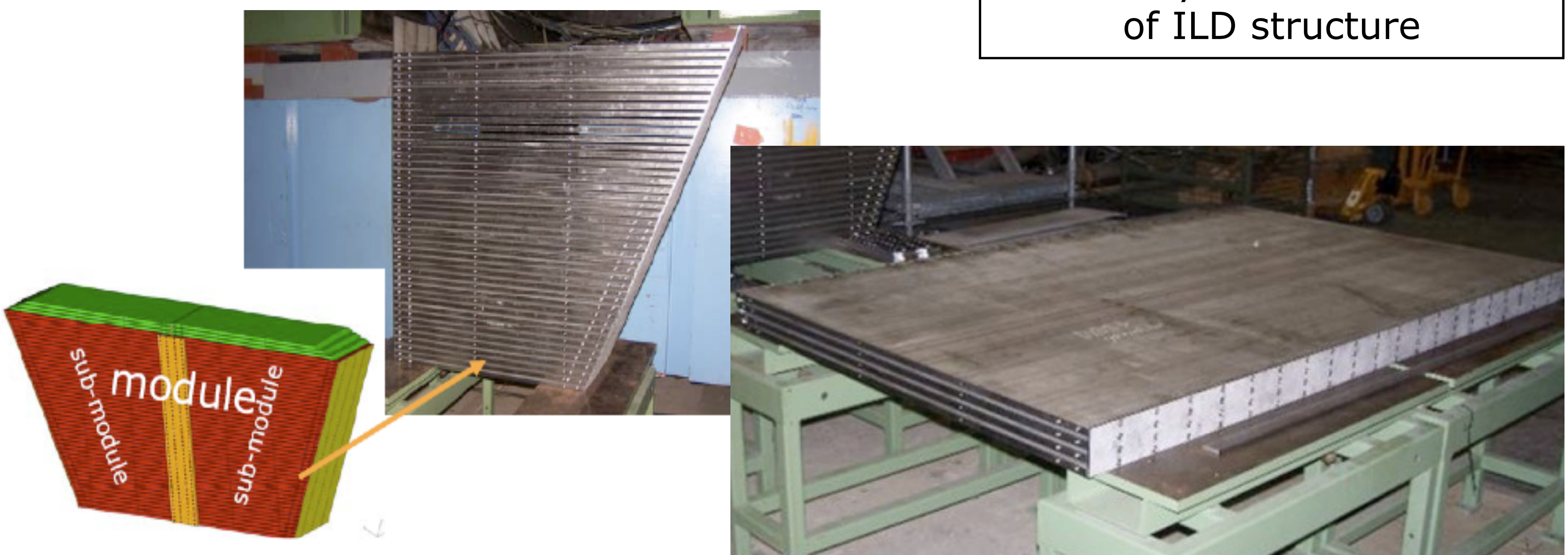


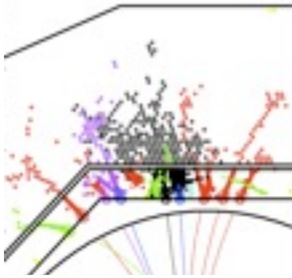


Mechanical prototypes

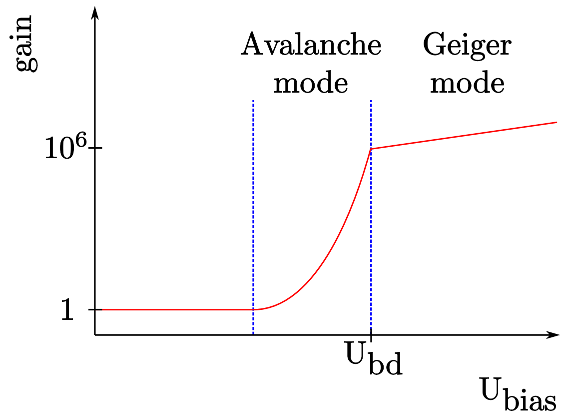
- Horizontal and vertical test structures built
  - used cost-effective roller leveling - no machining
- Tolerances verified: 1mm flatness over full area
- To be used for integration studies, test beams
  - and earthquake stability tests

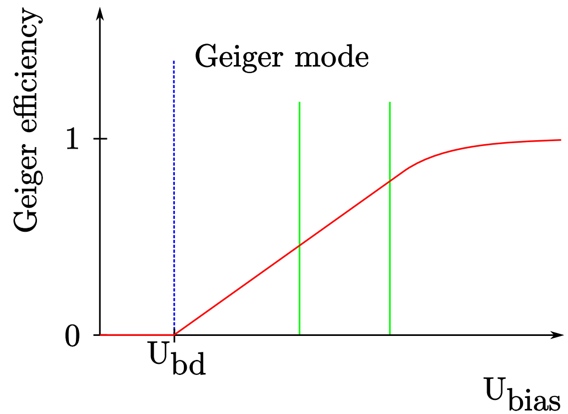
started dynamic simulations of ILD structure

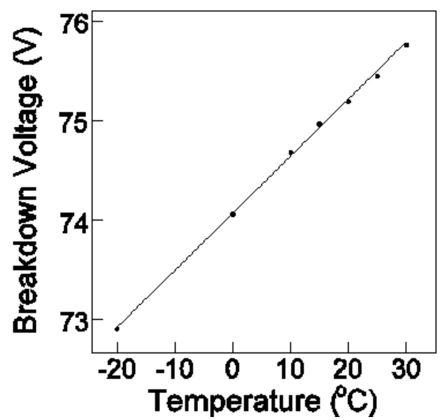


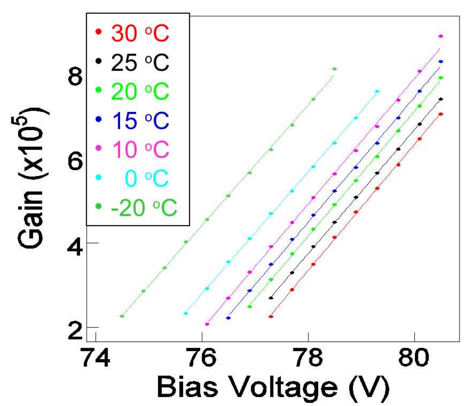


SiPM response

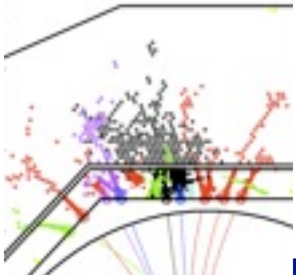






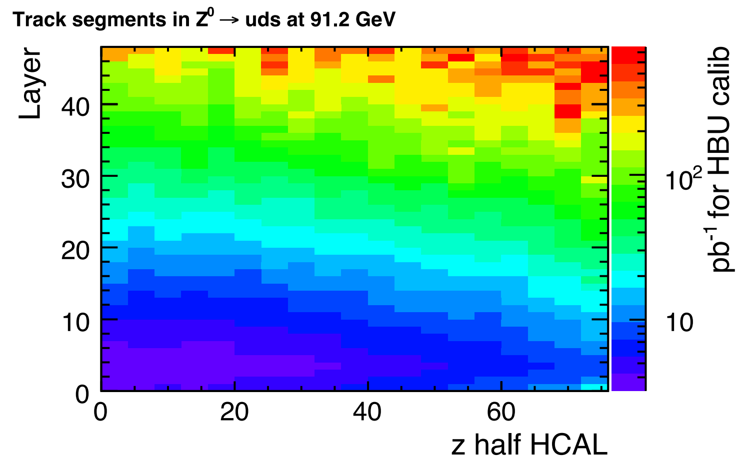


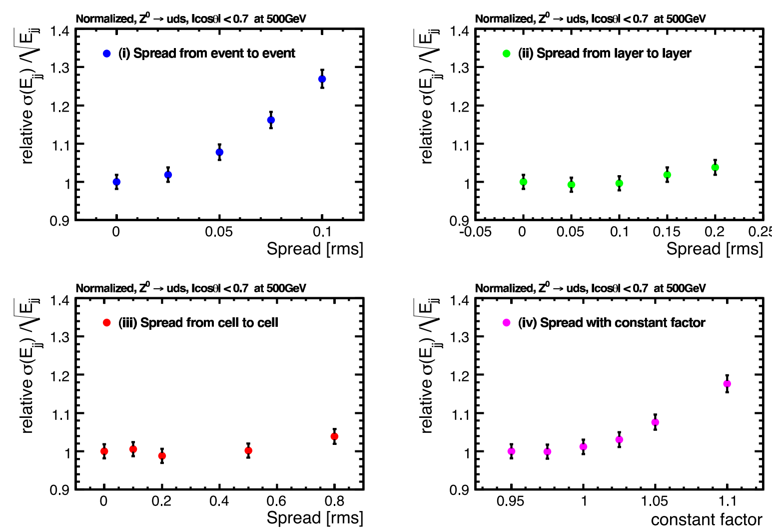
- $X = X(\Delta V)$, $\Delta V(T) = V_{bias} - V_{breakdown}(T)$



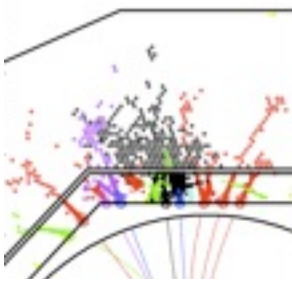
Calibration: look at full chain

- LOI validation: IDAG triggered study of required precision and luminosity for calibration
- Using track segment finding established in test beam showers
- Studied also impact of systematics due to calibration uncertainties on single particle and jet resolution
- Very insensitive to single channel effects
- For averages, statistics is not an issue
- Test benches: "Precision" = measurement accuracy or device-to-device non-uniformity



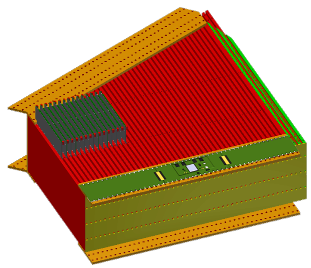


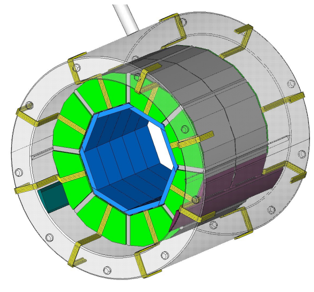
Calice Analysis note 18 and ILD note

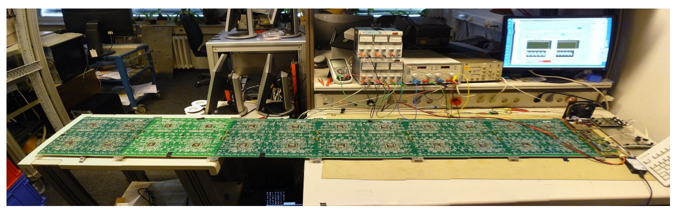


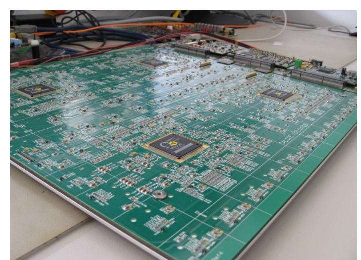
Industrialisation: Numbers!

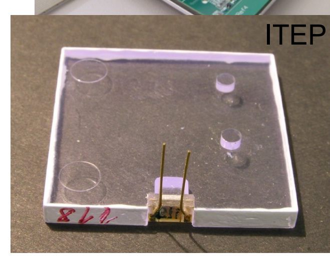
- The AHCAL
- 60 sub-modules
- 3000 layers
- 10,000 slabs
- 60,000 HBUs
- 200’000 ASICs
- 8,000,000 tiles and



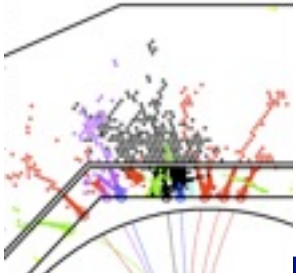




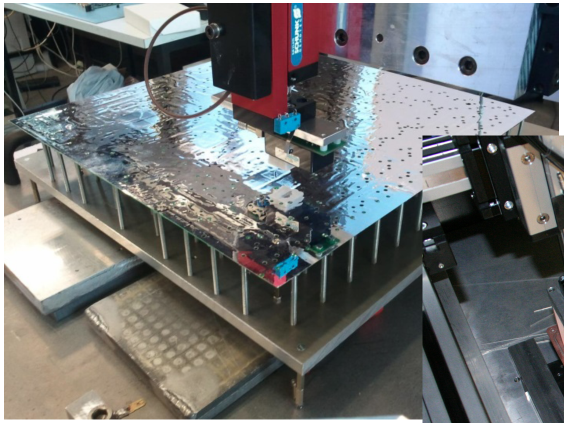


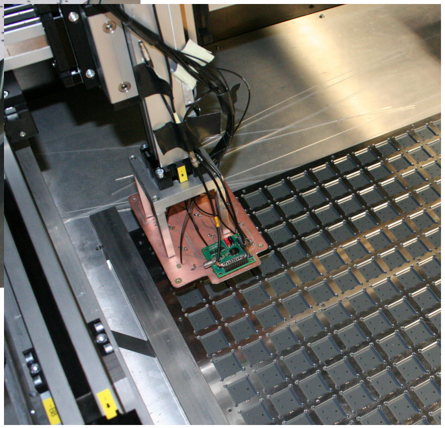


- One year
- 46 weeks
- 230 days
- 2000 hours
- 100,000 minutes
- 7,000,000 seconds



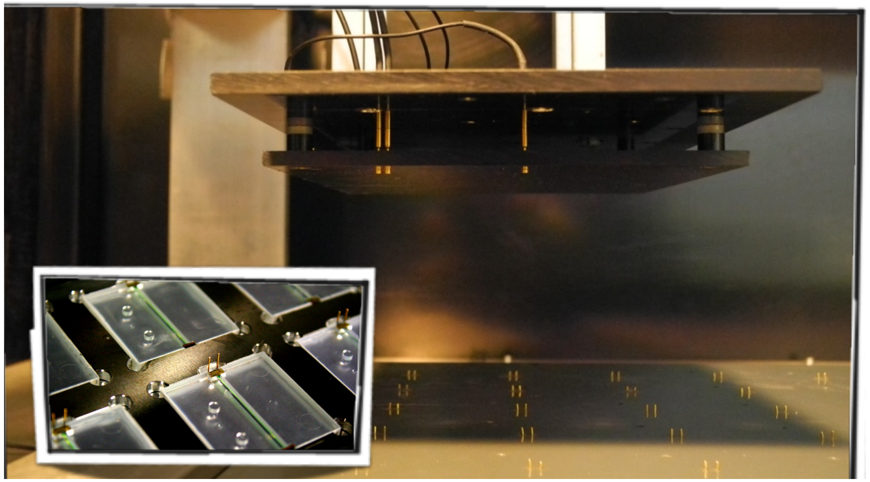
Quality control and production



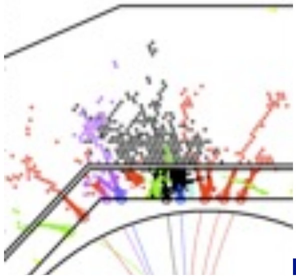


- Can be done: our engineers are looking forward to it
- There are interesting problems to solve
- Some efforts started:

- SiPM and tile QC and characterisation
  - with UV light and beta source
  - fully automatised, fast parallel readout
- LED ad ASIC tests
- HBU assembly
  - place tiles, solder SiPMs
  - close relation to tile design and SiPM coupling
  - impact on QC chain

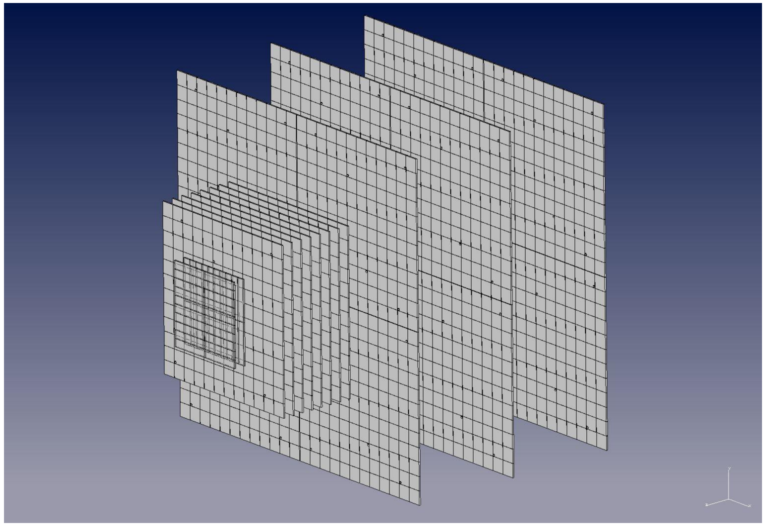


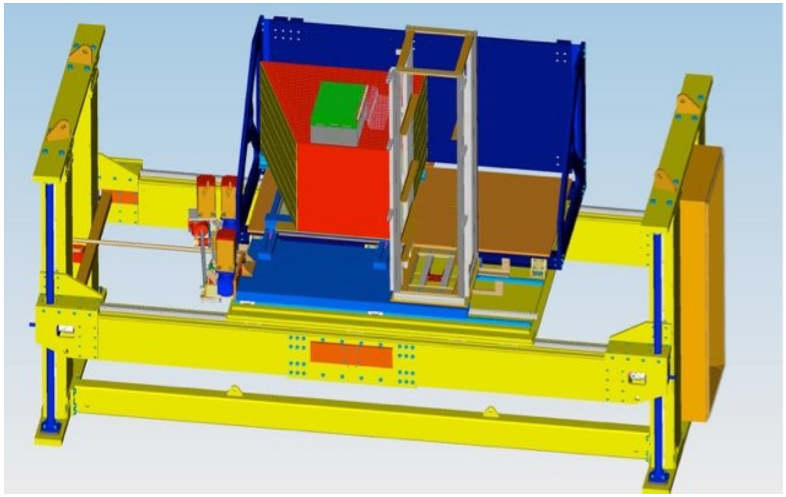
Heidelberg

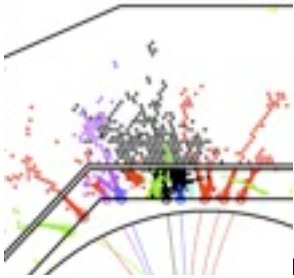


Flexible test beam roadmap

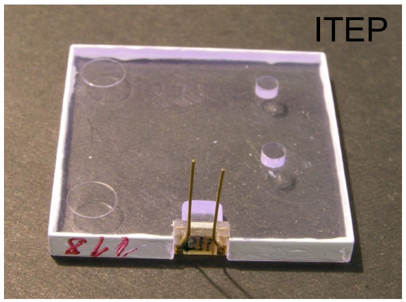
- 2013-14:
  - e.m. stack, 10-15 layers, ~2000 ch
- 2015-16:
  - hadron stack w/ shower start finder
  - 20-30 ECAL and HCAL units, ~ 4000 ch
- 2017-18:
  - hadron prototype, 20-40 layers, 10-20,000 ch
- Gradual SiPM and tile technology down-select
- Exercise mass production and QC procedures





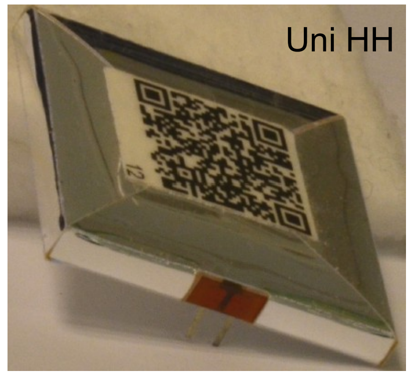


Scintillator tile options

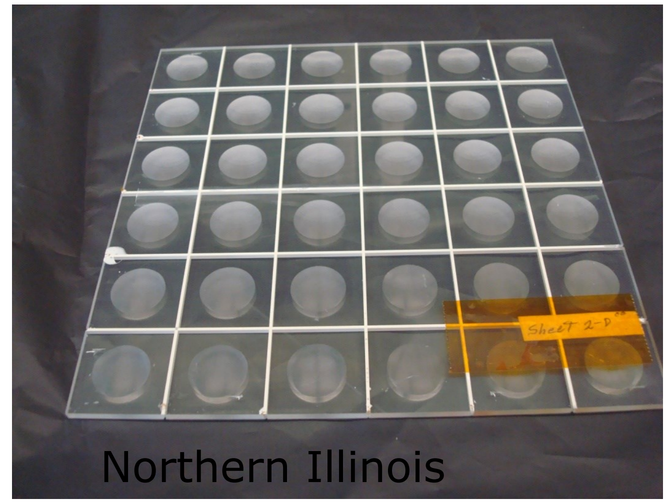


CPTA, KETEK or Hamamatsu sensors

no WLS fibre

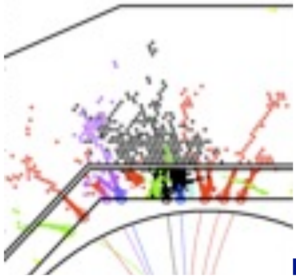


individually wrapped; KETEK sensors



Hamamatsu sensors, on PCB surface

- Simplification, industrialisation
- Blue-sensitive sensors: eliminated WLS fibre and reflector
  - Developed direct coupling - from side or from top
- Megatiles interesting alternative for mass assembly
  - need to optimise design and production together



SiPM improvements

- Dynamic field, driven by medical applications (PET)
  - commercial use requires uniform devices, too, and moves to larger channel counts
  - SensL quotes 0.25V bias spread for several 100,000 devices
- 1€ per piece not unrealistic
  - Hamamatsu, SensL
- Improved performance in today’s prototypes
  - today’s sensors (Russian, German, Irish, Japanese) have 100x less noise than in physics prototype