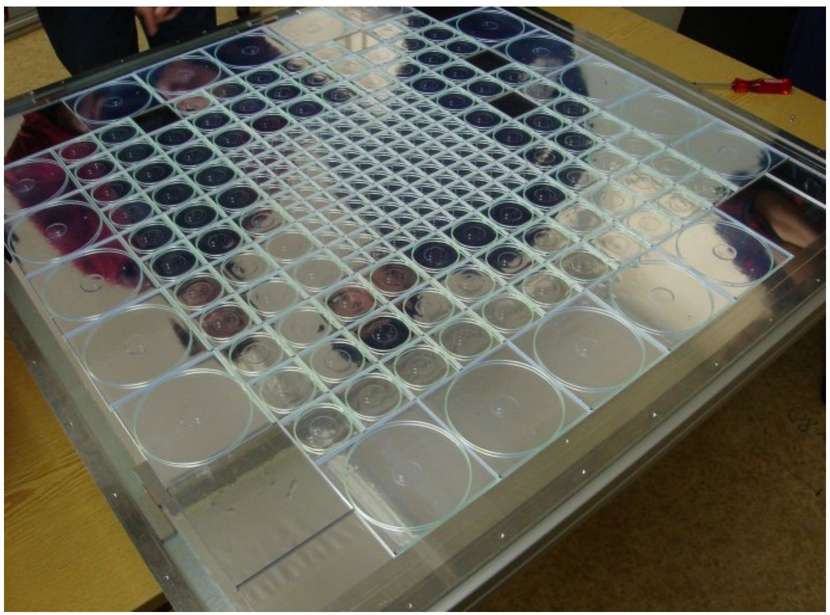
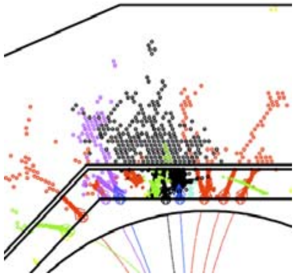
Scintillator HCAL overview



Felix Sefkow

TILC09

Tsukuba, Japan, April 19, 2009



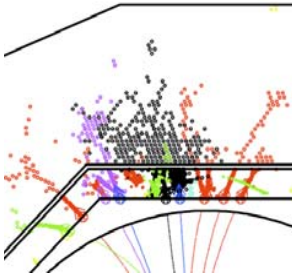
Outline

The physics prototype

- Detector understanding and performance
- New results on energy resolution and shower shapes

The technical prototype

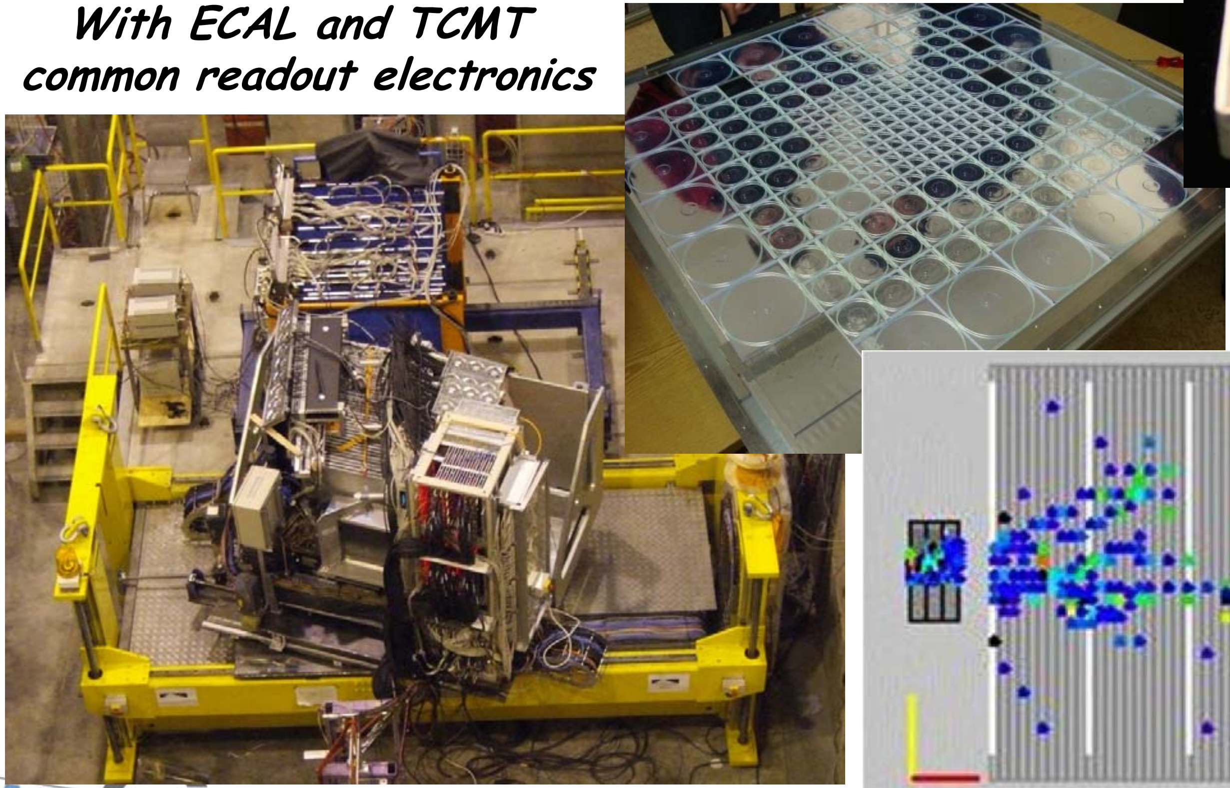
- Status, options and challenges

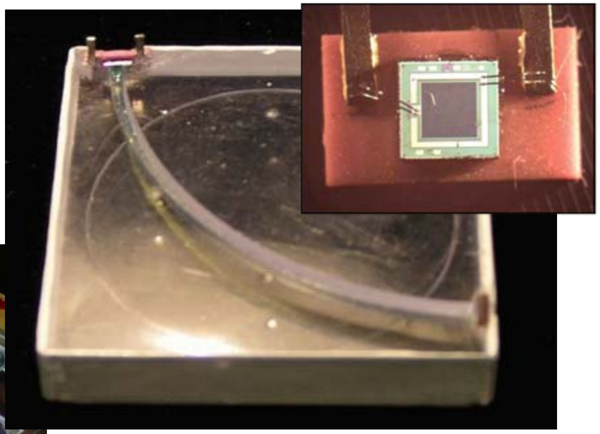


Test beam prototype

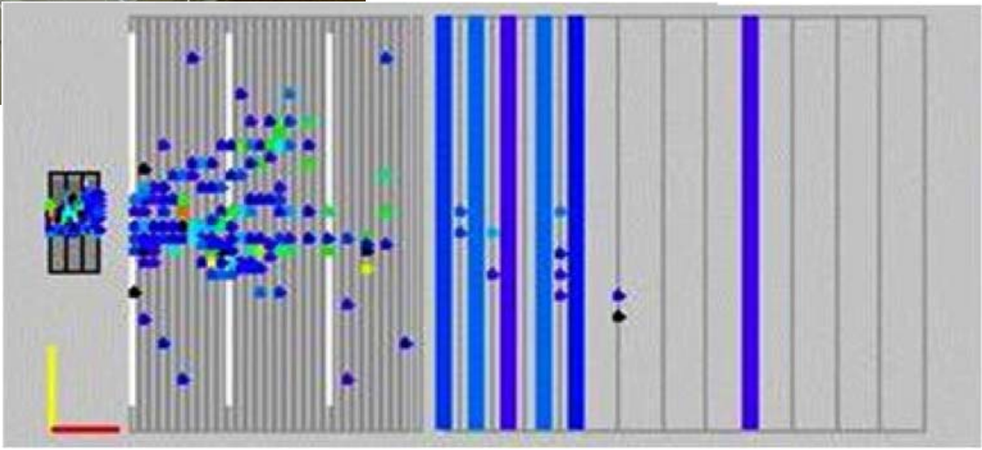
- 38 steel layers a 2cm, 4.5λ
- 7608 tiles with SiPMs
- Tests at CERN 2006-07, FNAL 2008-09

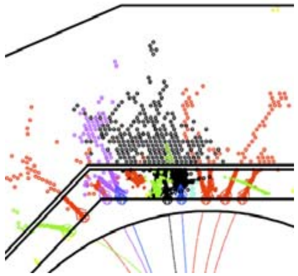
With ECAL and TCMT
common readout electronics





Noise occupancy 10^{-3}

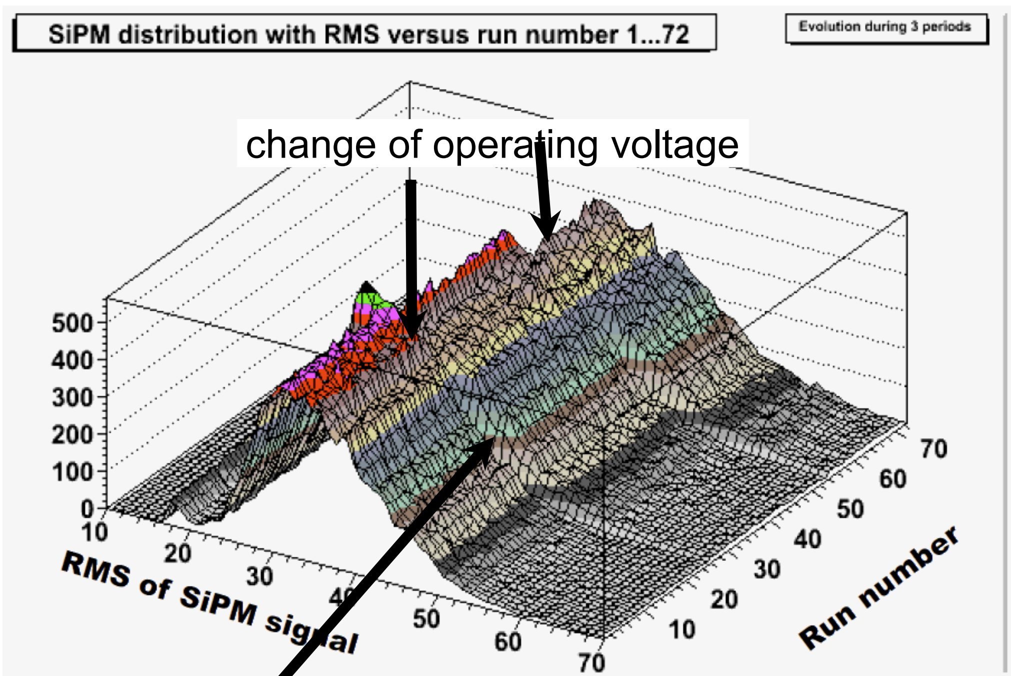


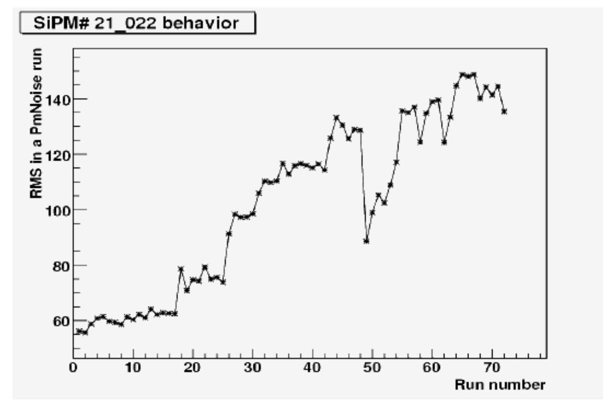


Long-Term Stability

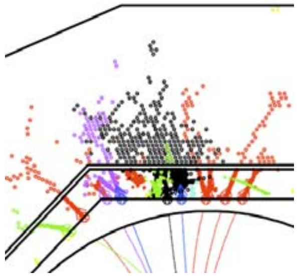
- Monitoring of pedestal distribution to detect changes in status and potential aging

stable performance over long period CERN – FNAL 2007-08
small increase of dead channels (total < 3 %, bad solder)



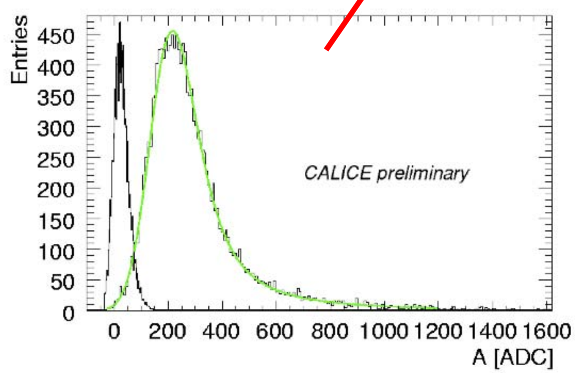


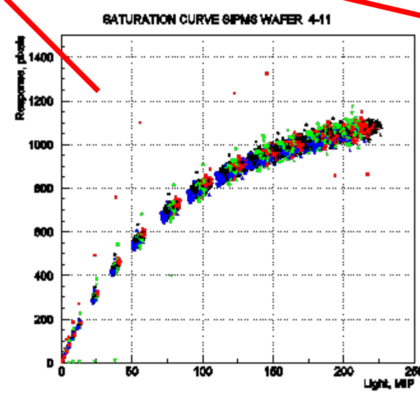
only 8 out of 7608 SiPMs show increasing noise levels with time

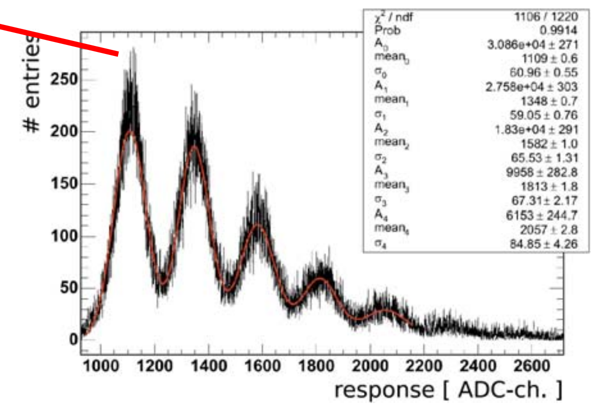


Calibration

- $E(MIP) = A / A_{MIP} * f(A/A_{pixel})$ A = signal in ADC counts





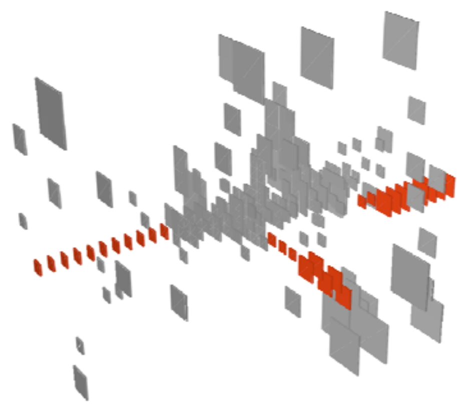


MIP calibration:
1.5 days in test beam

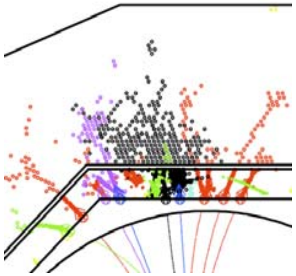
SiPM response function
From test bench

Gain auto-calibration:
Low intensity LED light
Single photo-electrons

At LC: use tracks in hadron showers
See talk by S.Lu tomorrow

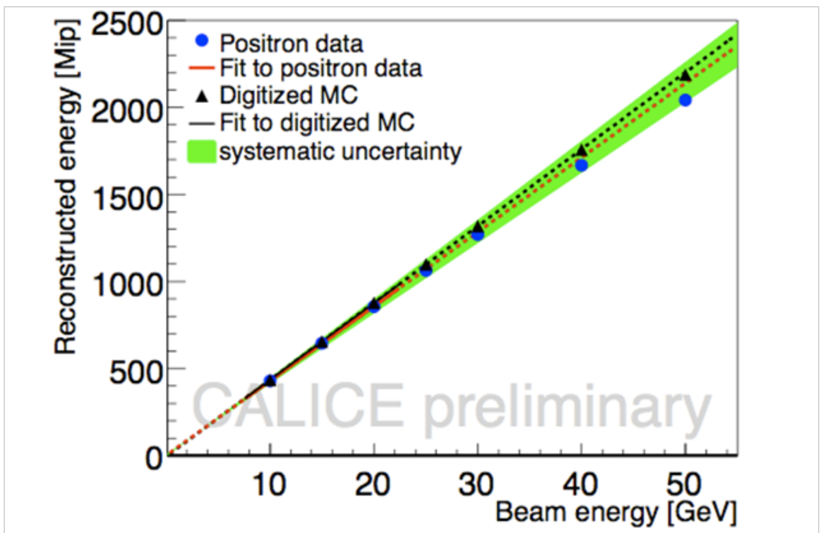


Temperature monitoring:
Correct MIP and gain
Future: compensate by HV adjustment

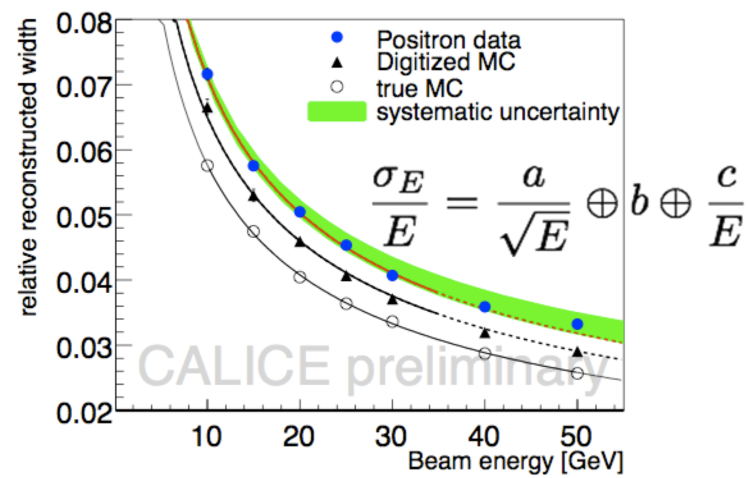


Verification: e.m. showers

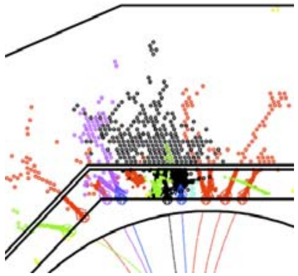
- Use electron data (no ECAL in front) to validate detector understanding and calibration
- Simulation includes p.e. statistics, SiPM non-linearity, electronic noise, light cross talk between tiles, and overlaid hits from random trigger events; tile non-uniformity underway



Status: non-linearity <4% @ 50GeV, and improving…

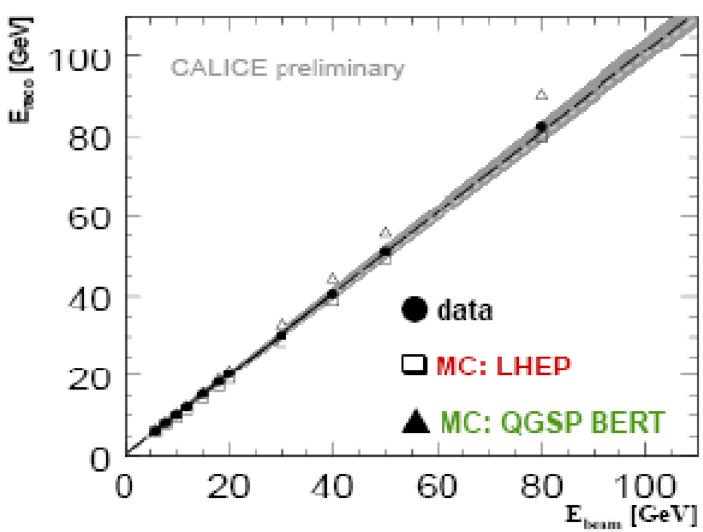


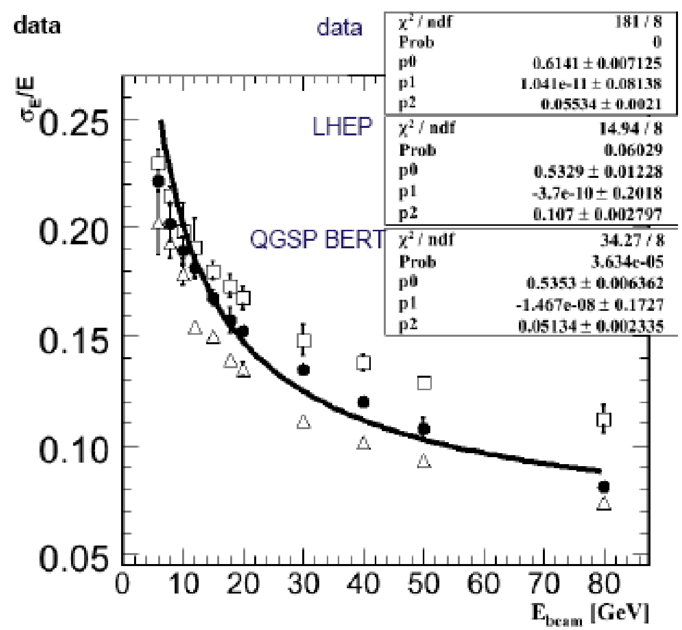
a = 22.5 ± 0.1(stat) ± 0.4(syst) %
b = 0 ± 0.1(stat) ± 0.1(syst) %
c fixed to~ 60 MeV (pedestal events)



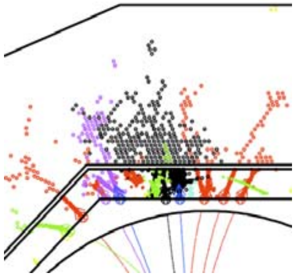
Hadron energy: first look

- 2006 data: 23 layers, reduced sampling in rear part
- Compare with different Geant 4 models
  - LHEP
  - QGSP-Bertini (detailed neutron tranport)
    - LHC production version
- Reasonable agreement



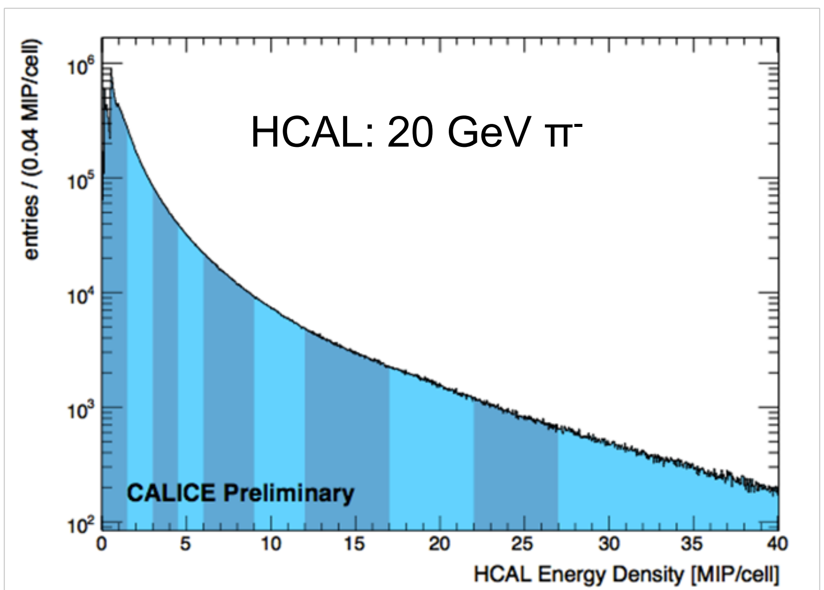


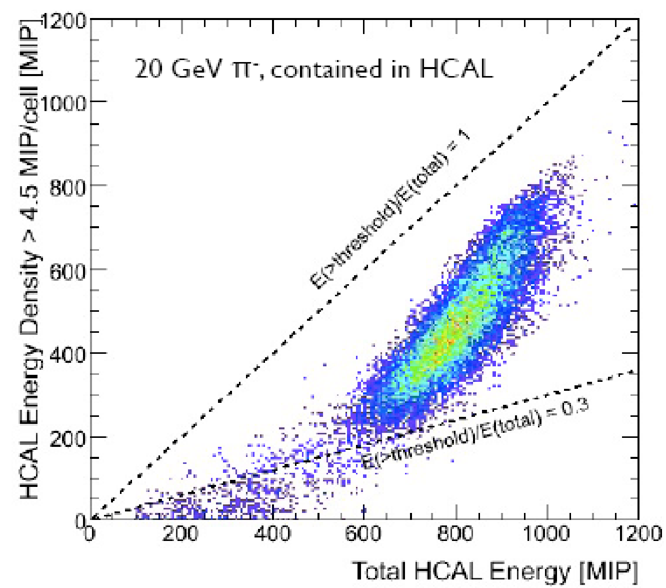
with Birks Law

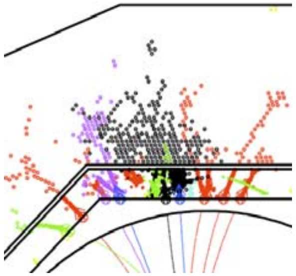


Software compensation

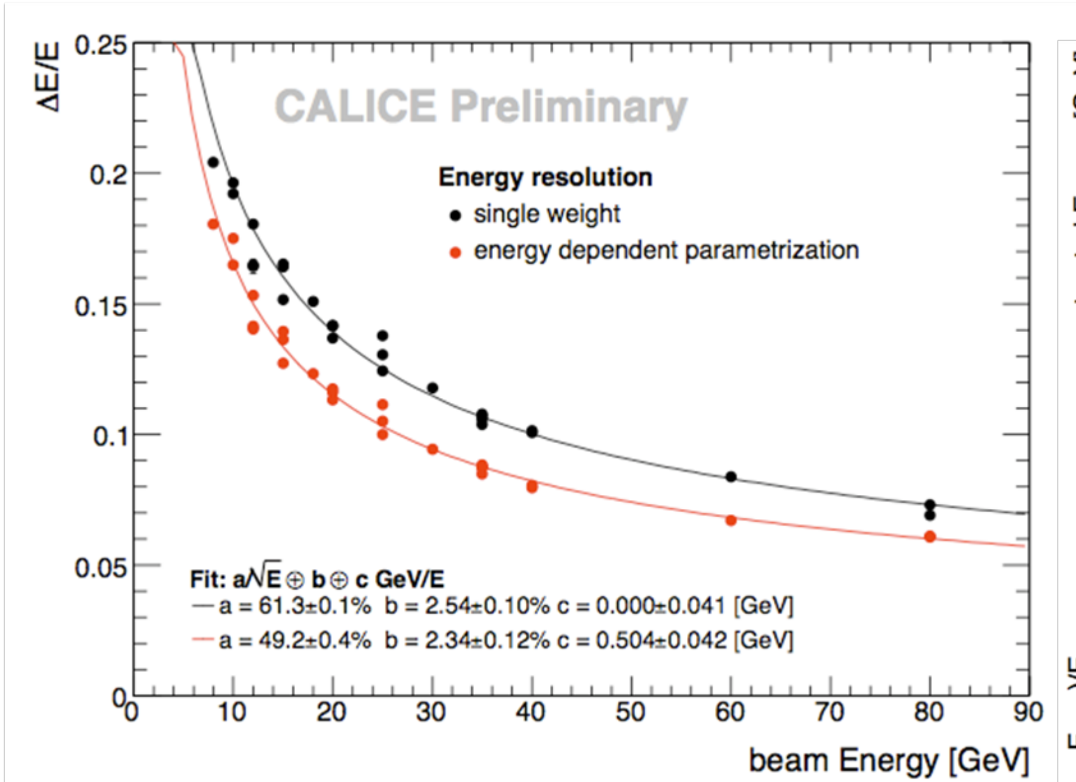
- The AHCAL is (slightly) non-compensating, e/π ~ 1.16
- Hadronic energy resolution can be improved by applying different weights to a.m type and hadron-type energy depositions
- Simplest approach: cell energy density (E/area)
- Apply energy-dependent weights, (E from unweighted measurement)

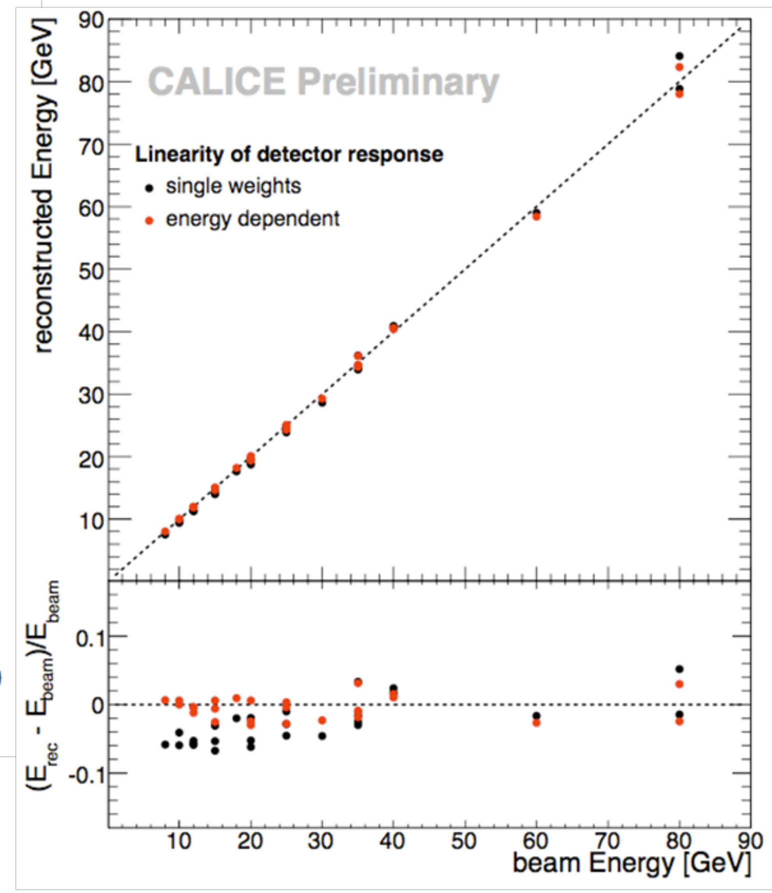




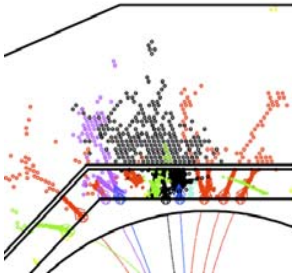


Weighted energy resolution



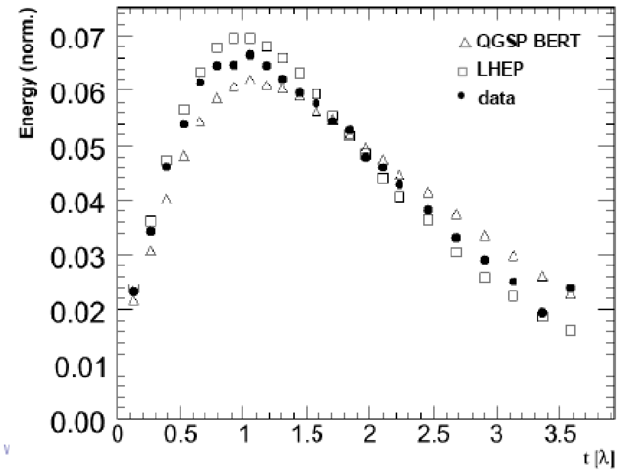


- Stochastic term down from 61 to 49%
- And linearity *improved*

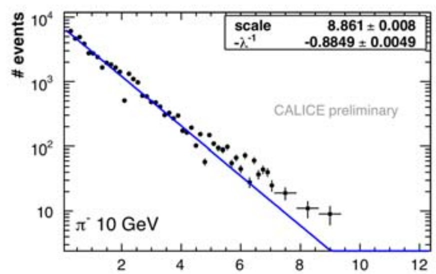


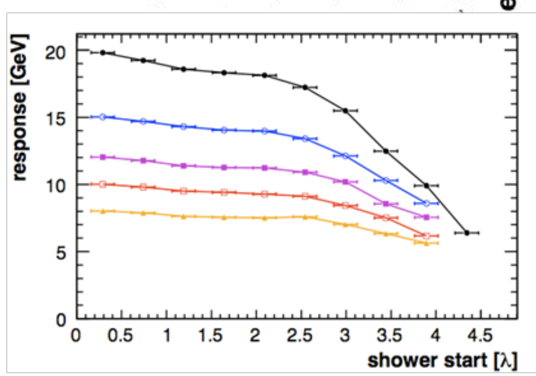
Longitudinal shower profile

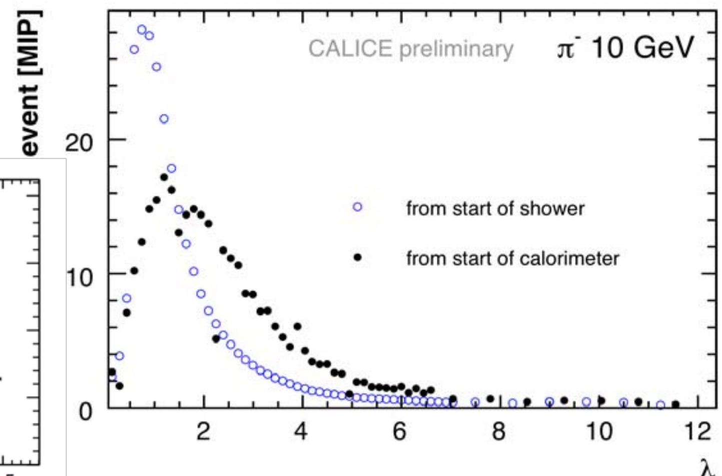
- Integral
  - 2006 data, corrected to MC truth
  - Birks' law included
  - Time cut not yet
    - Further suppression of tails

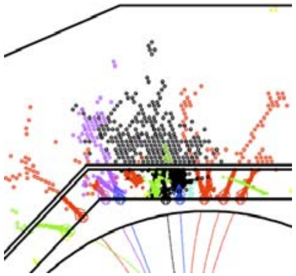


- From starting point
  - Unconvoluted
  - More detailed comparison with models
  - Leakage estimation





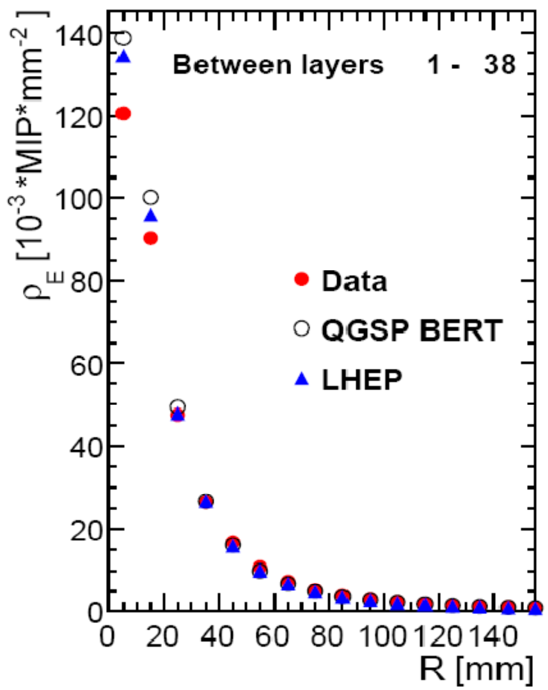


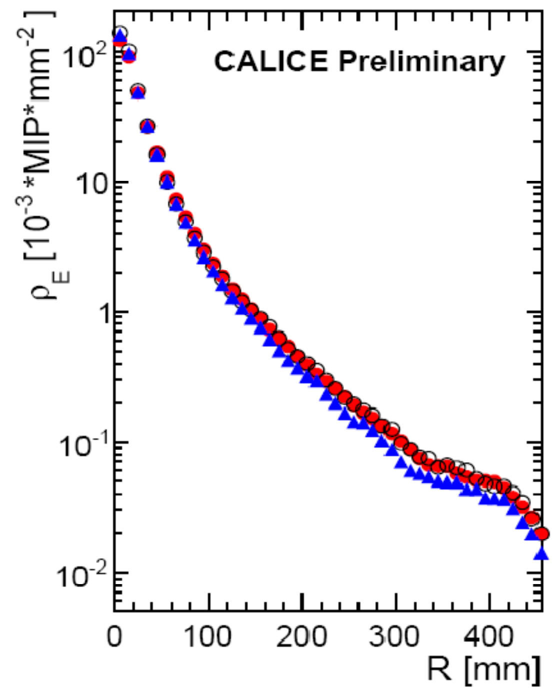


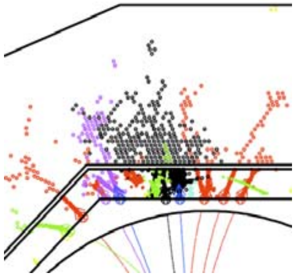
Transverse shower profile

- Important shower property for particle flow performance
- New results, 2007 data
- 18 GeV pions, shower start in HCAL

- Extrapolated DC track as reference axis
- Divide HCAL into rings of 10mm witdth
- Energy density: E(MIP) per ring area, summed in depth

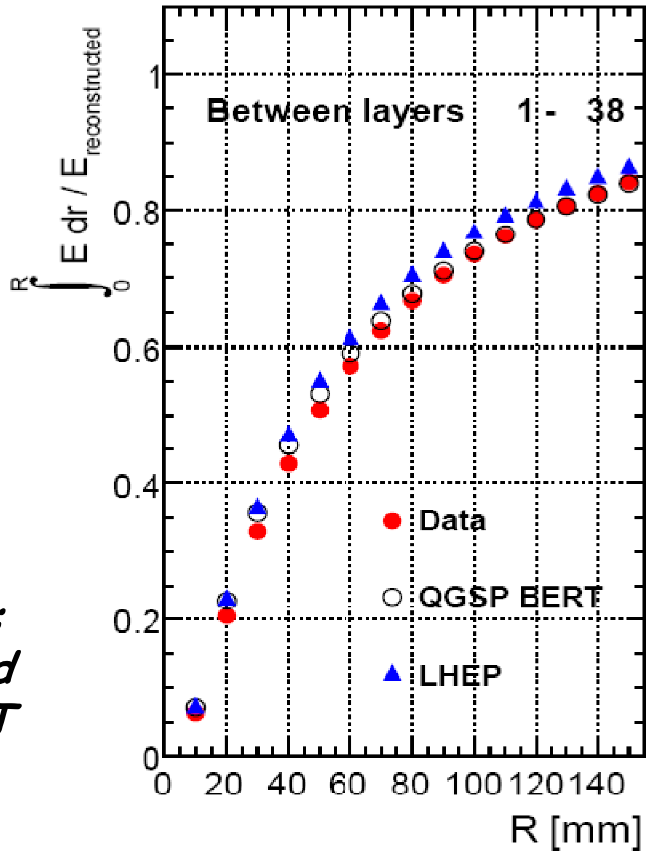


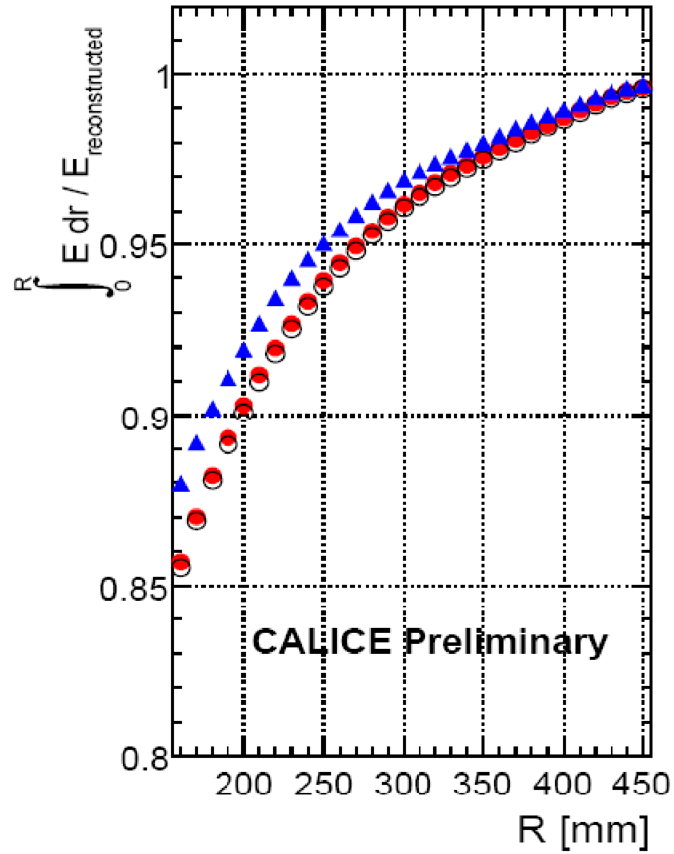




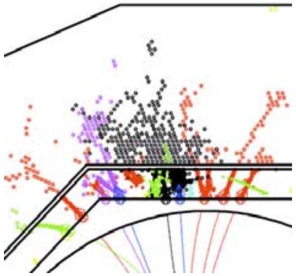
Lateral shower containment

- Integrated lateral energy fraction



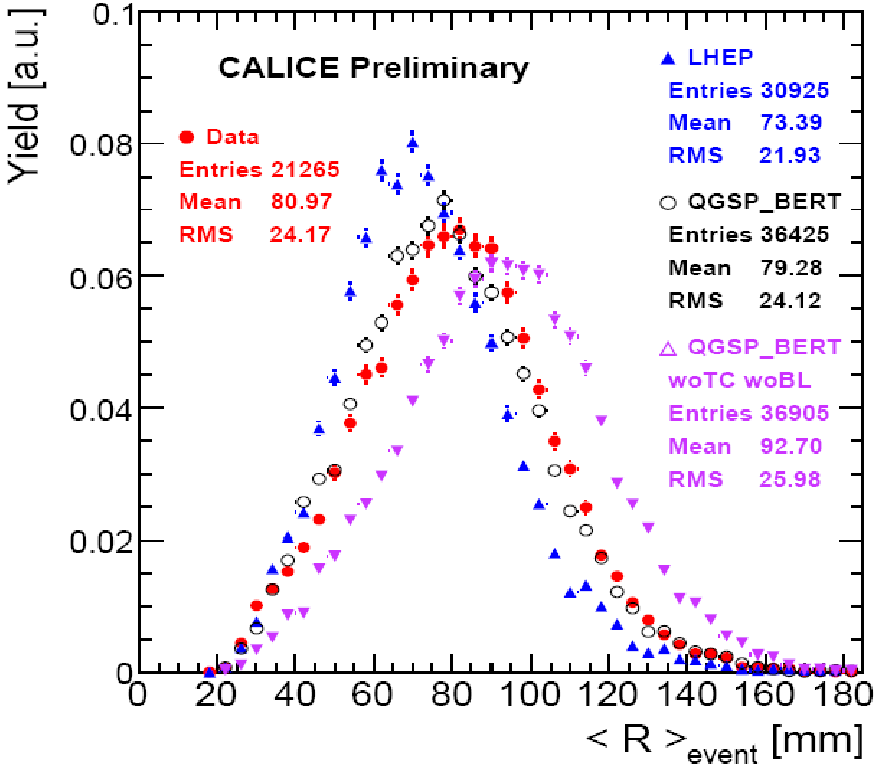


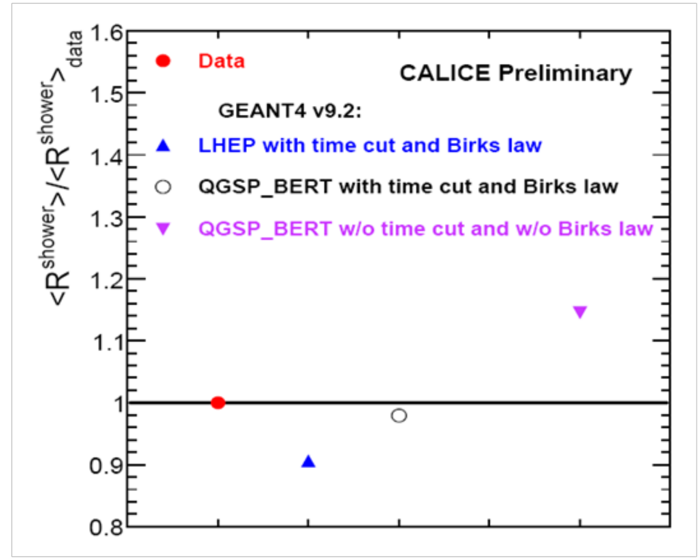
Core and tails: well reproduced by QGSP-BERT



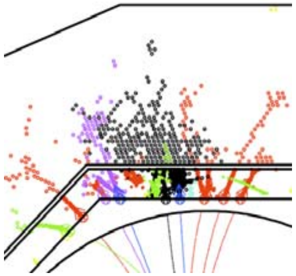
Mean shower radius

$$\langle R \rangle_{event} = \frac{\sum_i E_i \cdot R_i}{\sum_i E_i}$$





- Mean value and event-to-event fluctuations well described
- Proper treatment of neutrons in shower evolution **and** detector response critical



Physics prototype summary:

Detector understanding:

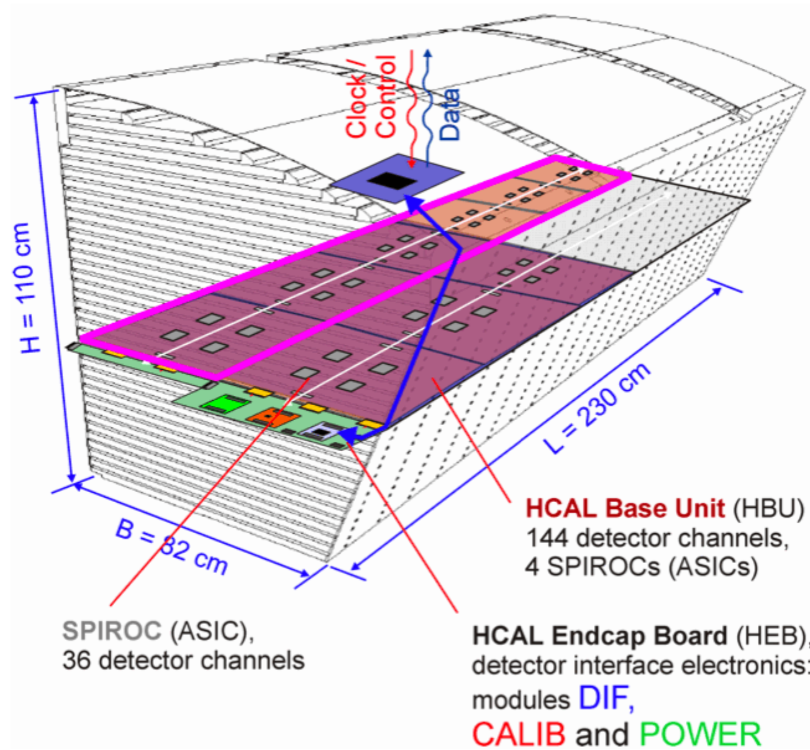
- The SiPM technology has proven to be robust and stable
- The calibration is well under control
- The performance is as expected and understood
- ➔ strong support for predicted PFLOW performance

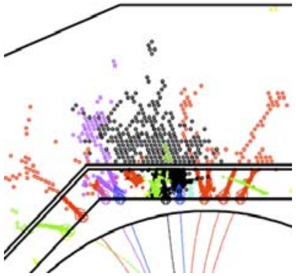
There is still a huge potential for further analysis:

- Shower substructure (e.g. track multiplicity, e.m fraction)
  - "almost a thin target experiment" for model developers
- Compensation techniques
- Particle flow reconstruction with overlay events
- New ideas

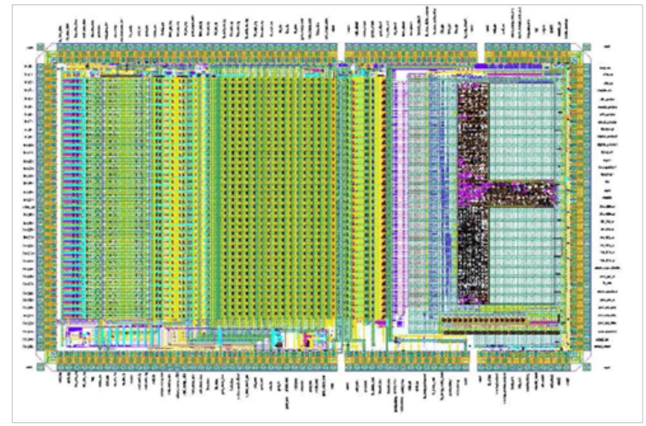
Technical prototype

- Towards a scalable and compact detector
- Embedded front end ASICS
- Mechanical structure with minimum dead space
- Options for scintillator and photo-sensor integration





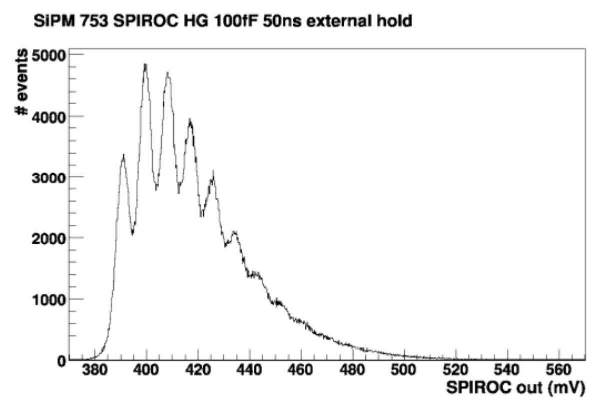
New ASICs: SPIROC

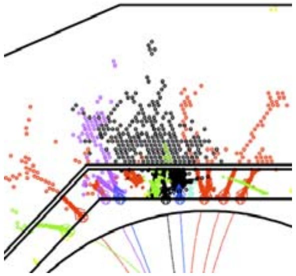


- Electronics is the key
- See R.Poeschl's talk on 2nd generation ASIC family
- Power pulsing: 40 μW / channel
- Auto-trigger
- Analogue pipeline
- ADC and TDC integrated
- Shown to work with SiPM
- Digital part tested with DHCAL

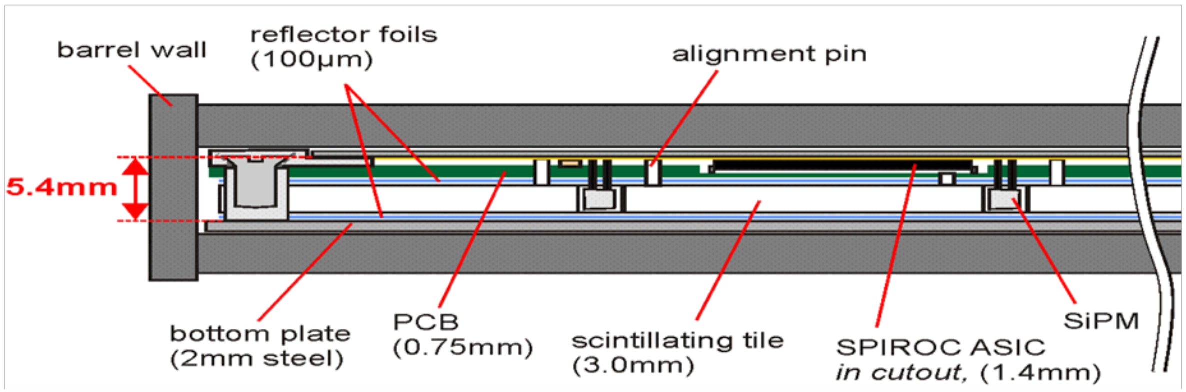
➔ Major challenges

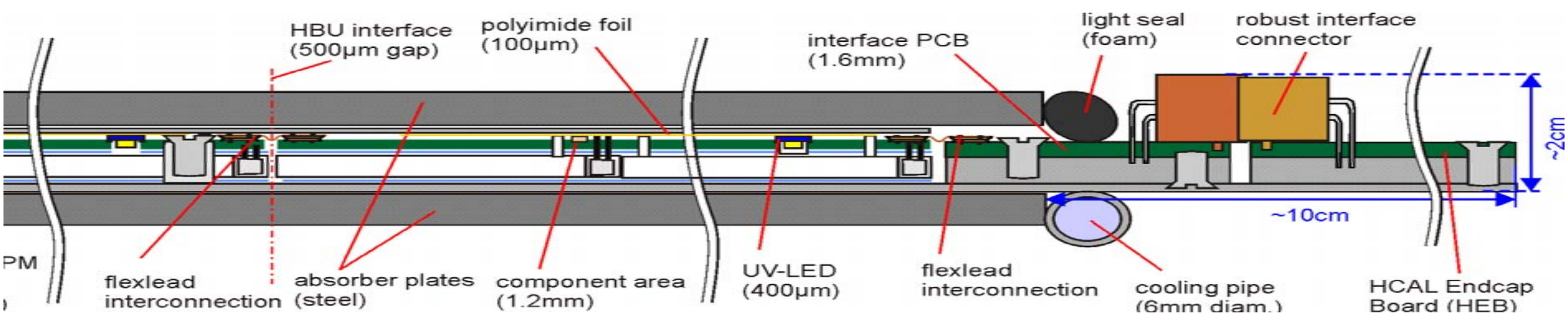
- Establish full readout and calibration chain
- On-detector zero suppression requires on-line control of thresholds

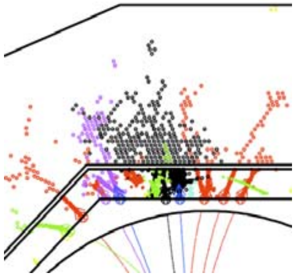




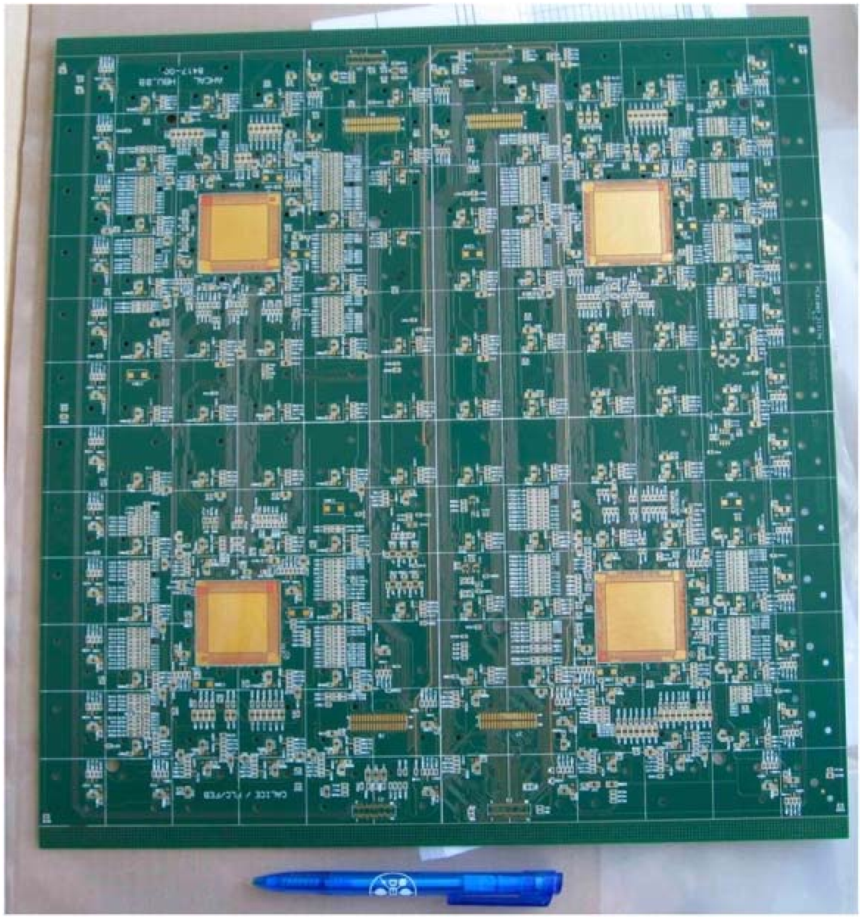
Readout layer

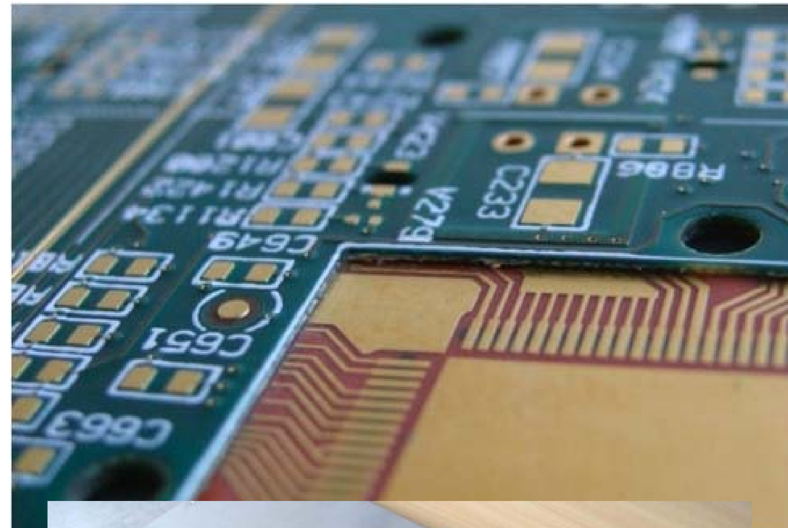


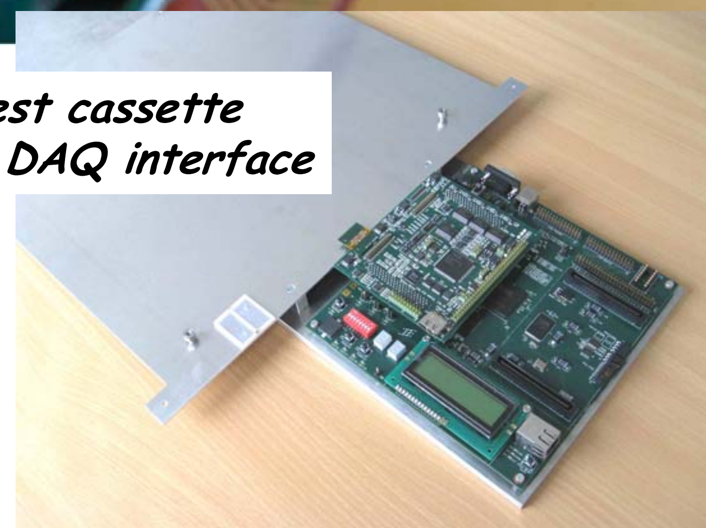




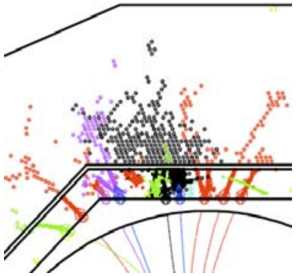
Readout board







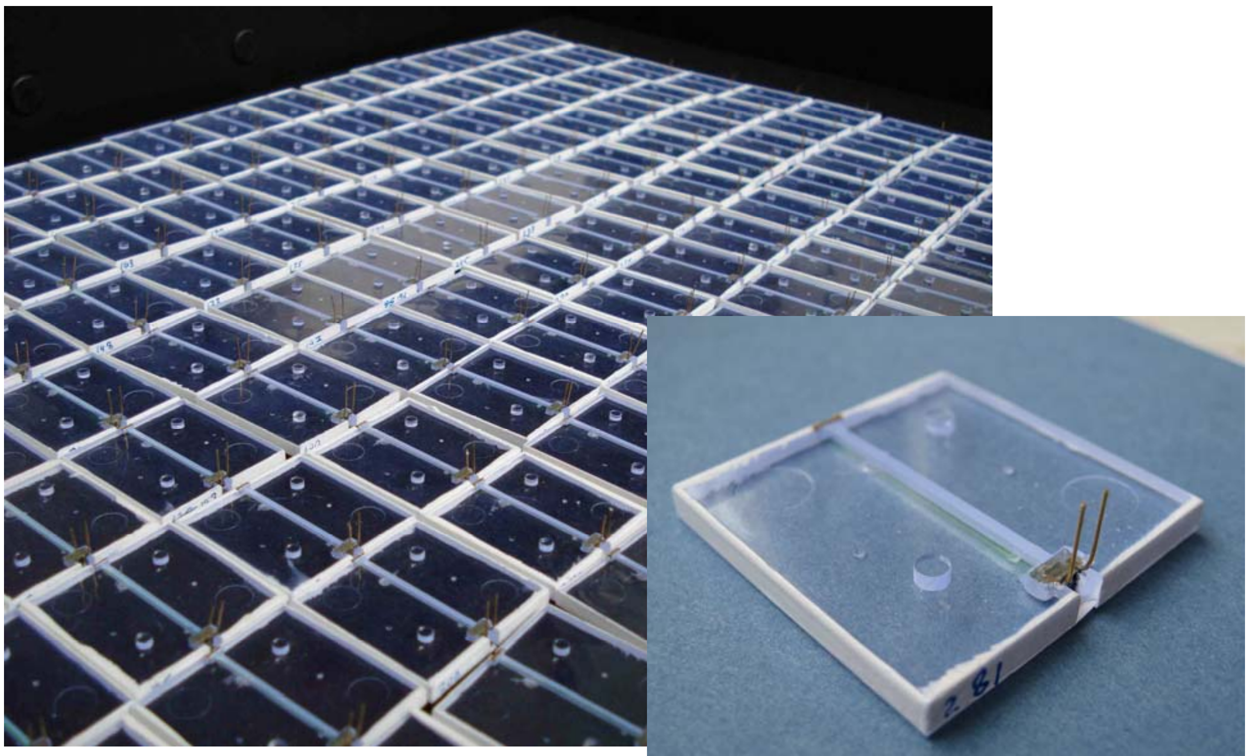
Test cassette with DAQ interface

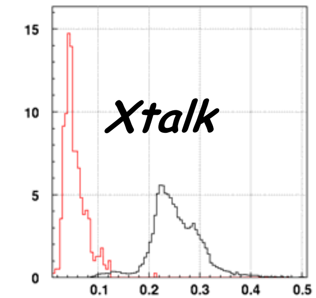


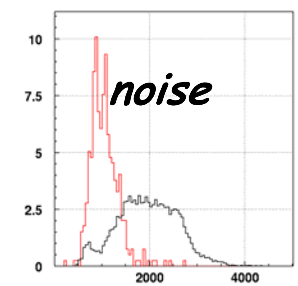
New tiles and SiPMs

- First 144 tiles from ITEP
  - Larger set underway for 2m layer
- SiPMs (MRS-APDs) from CPTA

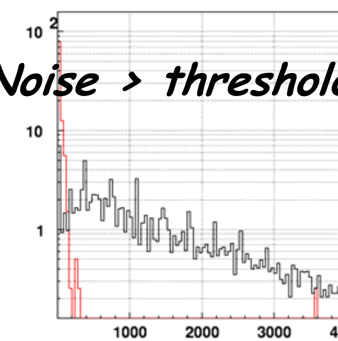
Improved properties w.r.t. PPT SiPMs

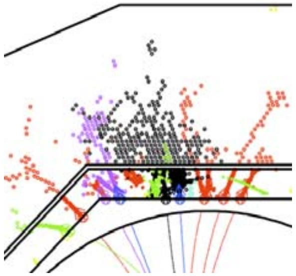






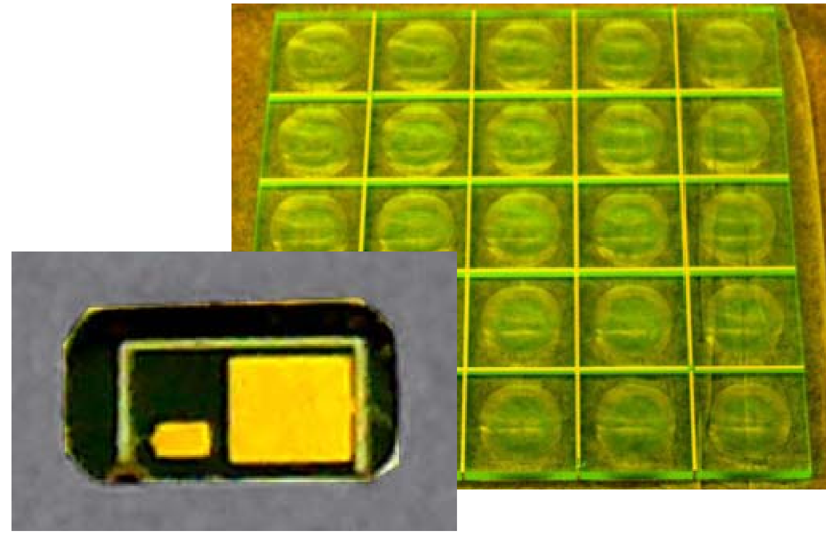
ITEP



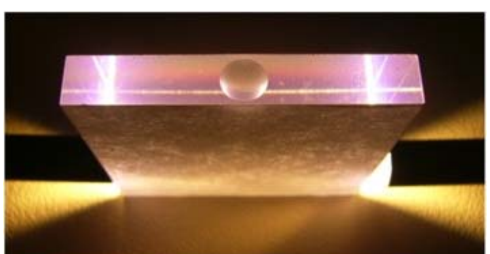


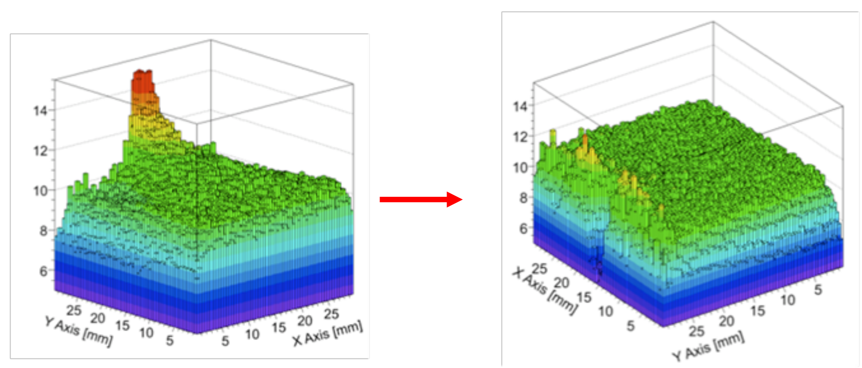
Other coupling schemes

- Surface-mounted MPPCs
- Scintillator cells with dimple to compensate non-uniformity
  - See NIM paper by NIU group



- Strips a la Sci ECAL
- New idea from MPI group
  - Dimple for direct coupling from the side

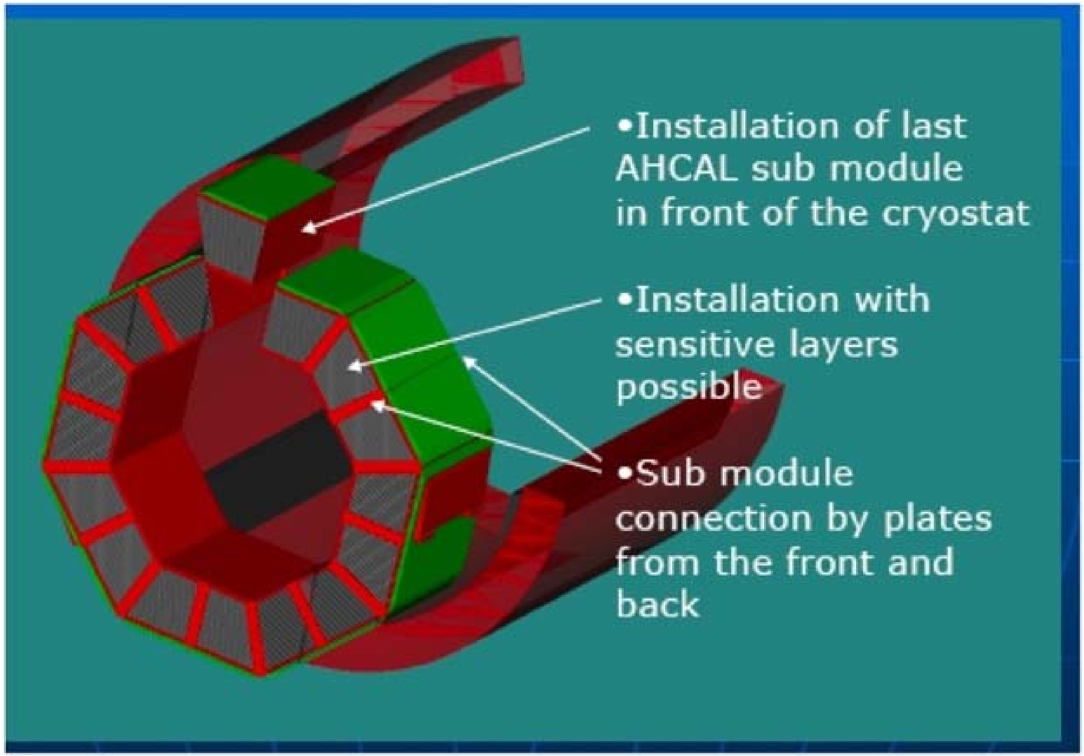


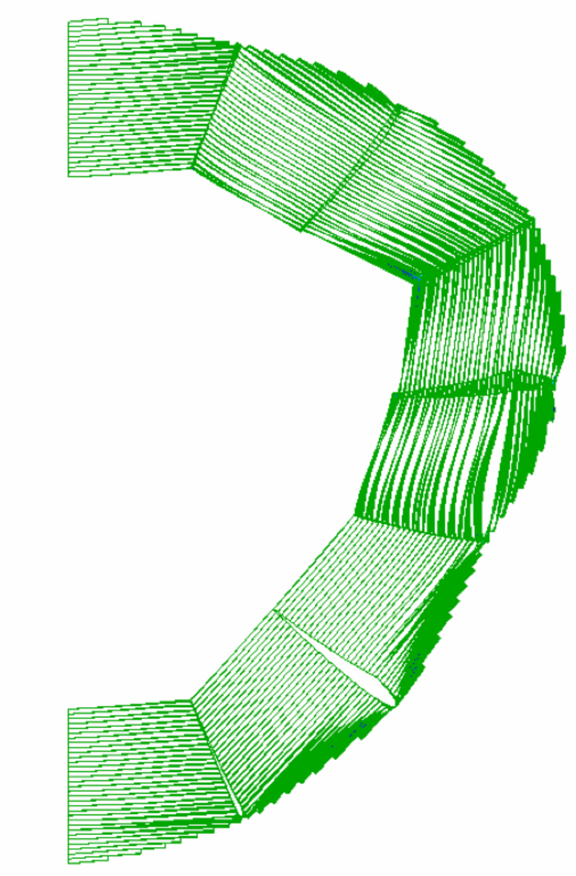


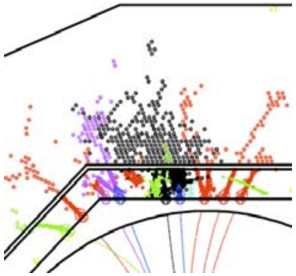
Scintillator HCAL

Mechanical structure

- Motivated by ILD, similar to SiD



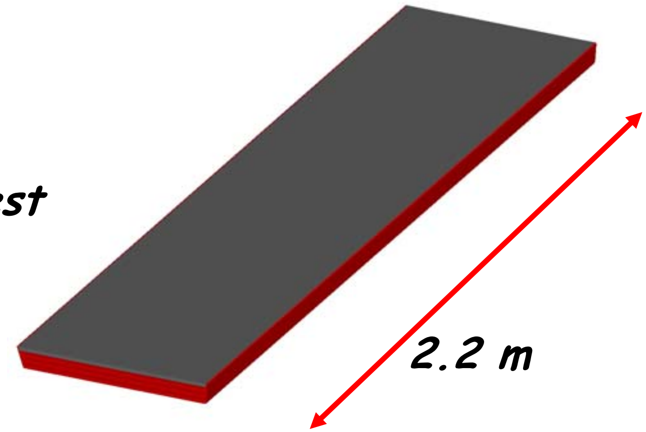


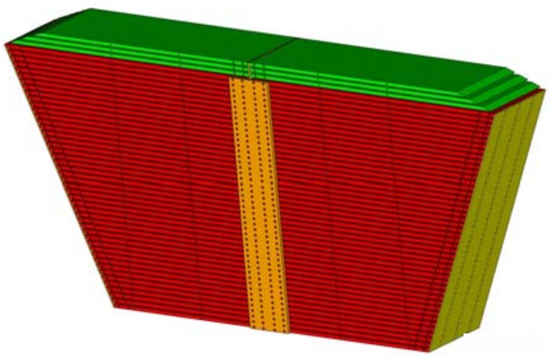


Prototyping

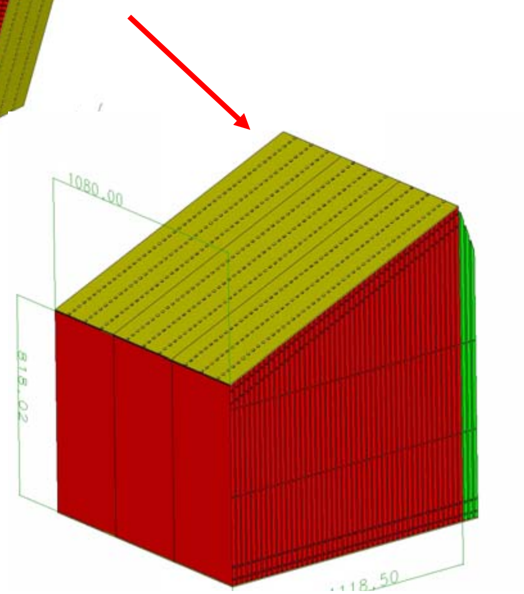
- Horizontal and vertical cross sections
- Scalable structure

Long layer test





Mechanical tests
Depth = 1 HBU
e.m showers



2 units:
Had showers

Technical prototype summary

- This is how the team sees it: