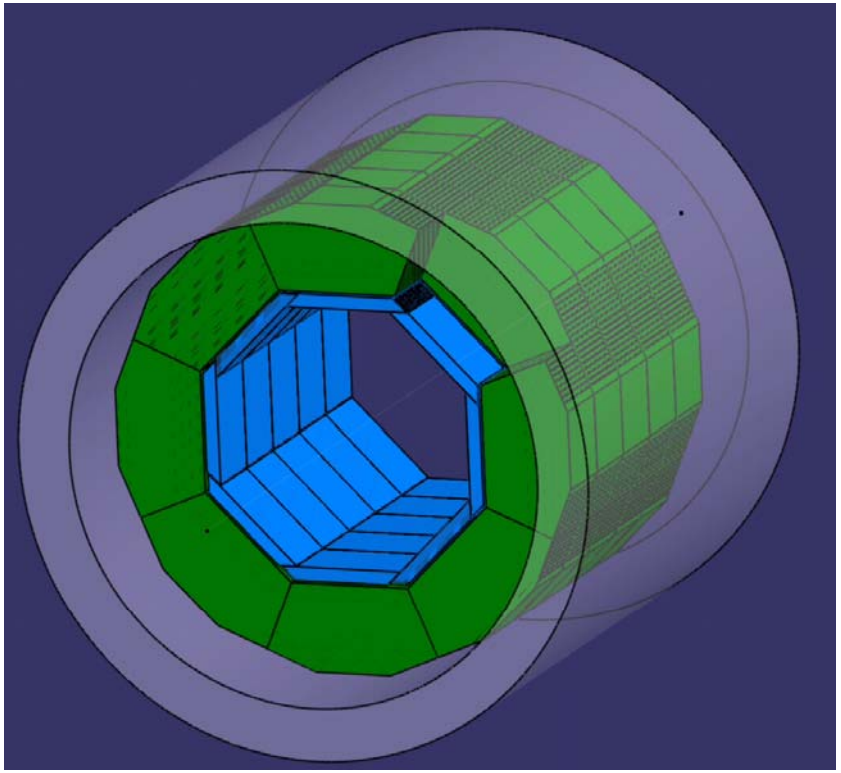
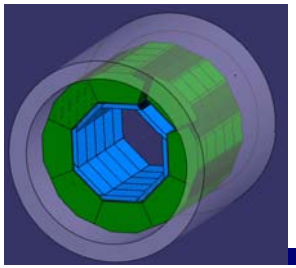


Scintillator HCAL Optimization

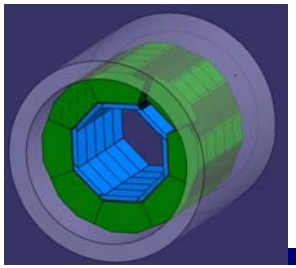
Felix Sefkow

ILD Meeting at DESY, Zeuthen
January 15, 2008

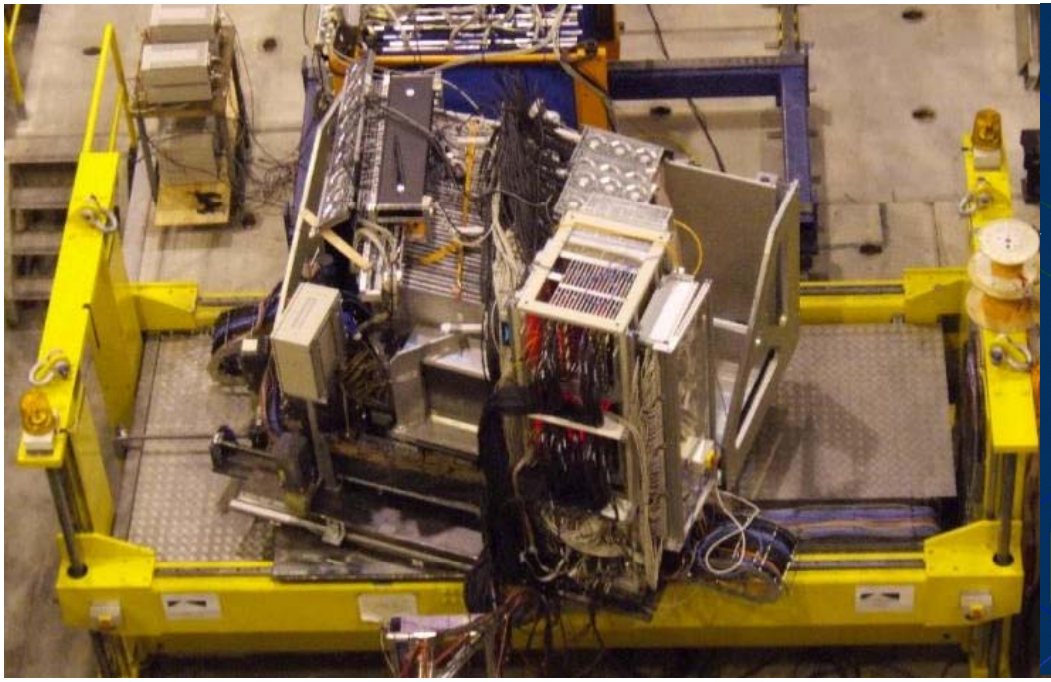


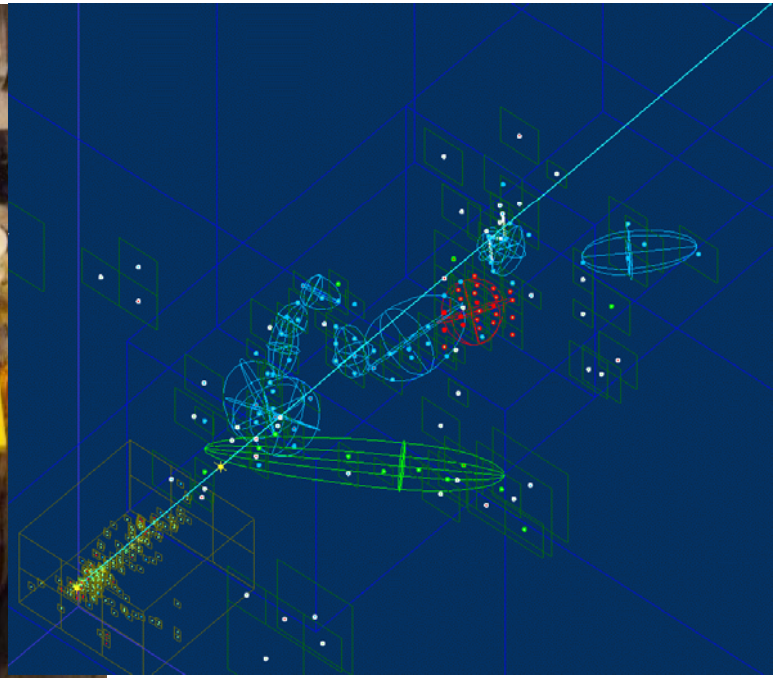
Outline

- Status of R&D
- Open R&D and technological issues
- Open questions for optimization

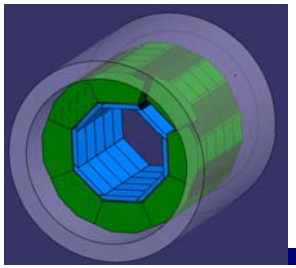


Test beam experience



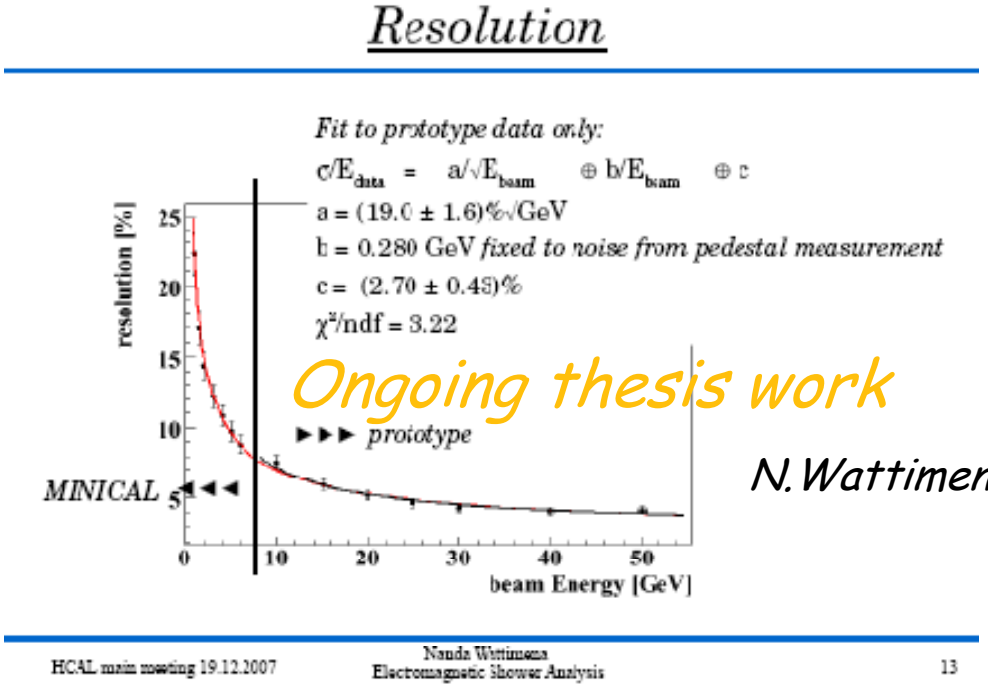


- Established the scintillator SiPM technology on large scale (7608 SiPMs)
  - Robust and stable operation, 95% up-time, 1.6% dead channels (mostly solder)
  - Noise occupancy 10^{-3} as expected, 0.8 MIP = 25 MeV / hit
  - Imaging capability nicely demonstrated, millions of events collected

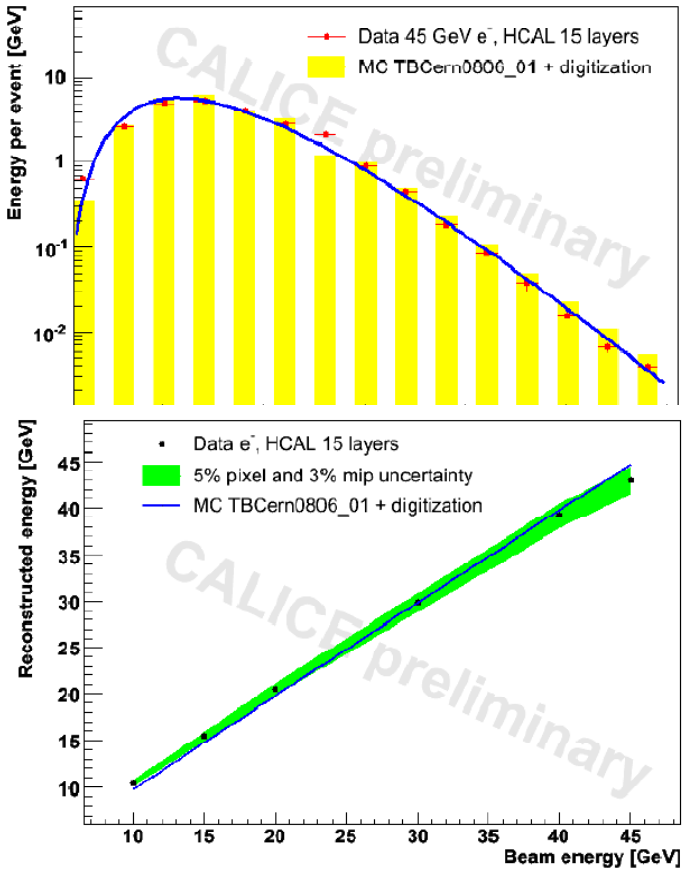


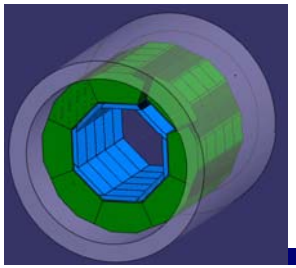
Analysis potential: electrons

- Electromagnetic showers:
- Verify detector model and calibration procedures
- Muons: see N. D'Ascnezo's talk



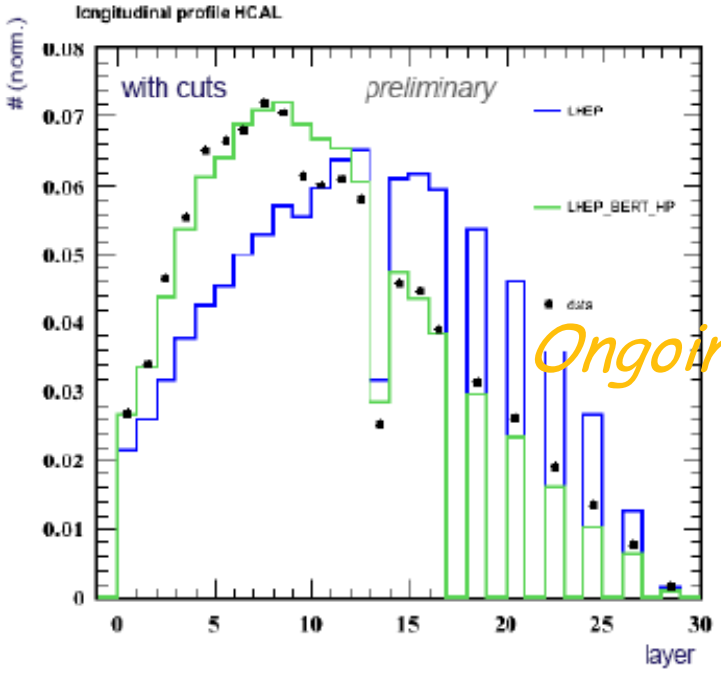
N. Wattimena





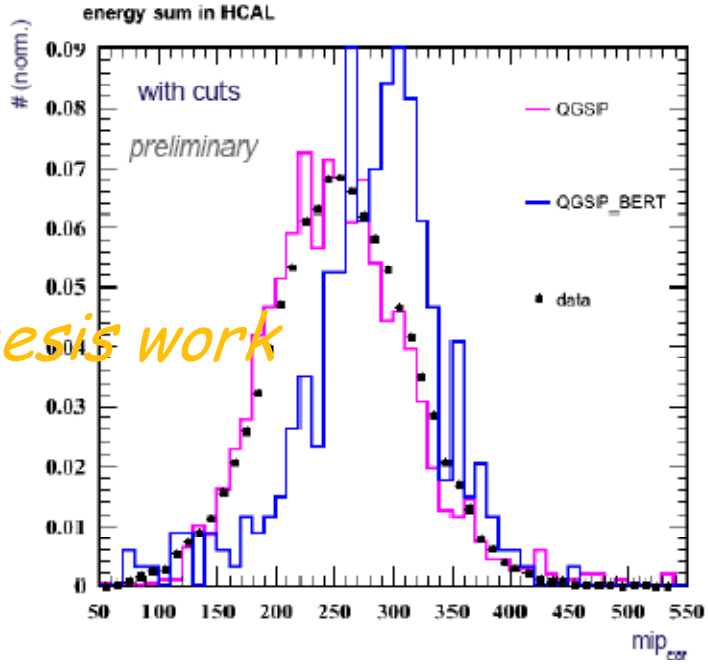
Analysis potential: hadrons

- Verify shower simulation models



profile

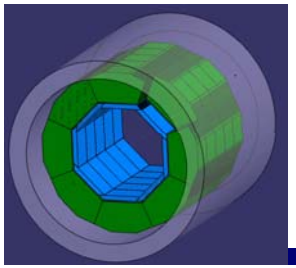
Ongoing thesis work



Energy sum

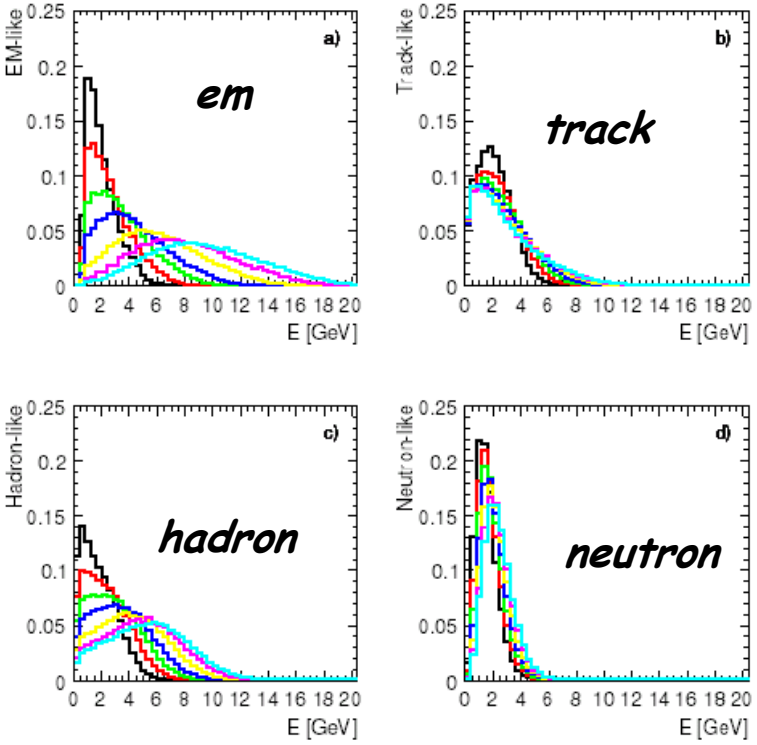
O. Wendt

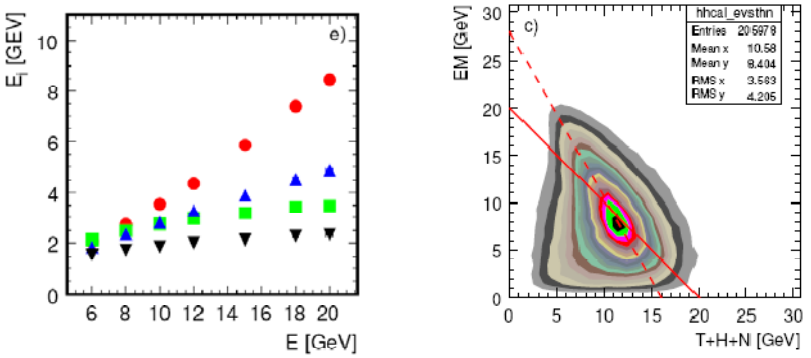
Also on tape: tagged protons



Analysis potential: correlations

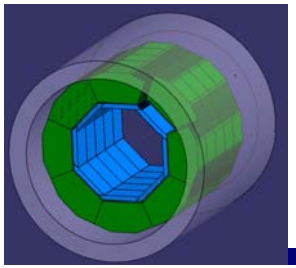
- Ideas V.Morgunov, first steps M. Groll (PhD thesis)
- Shower decomposition, using energy and topology





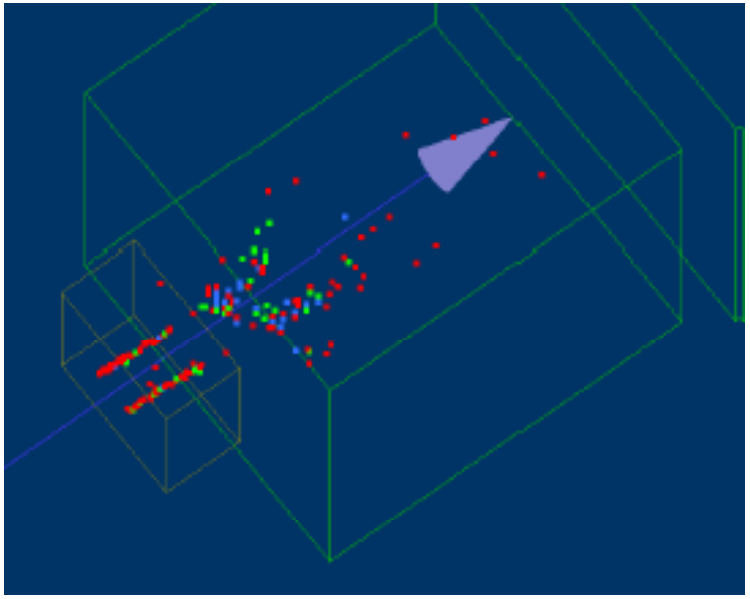
Energy dependence, correlation
Starting point for weighting techniques

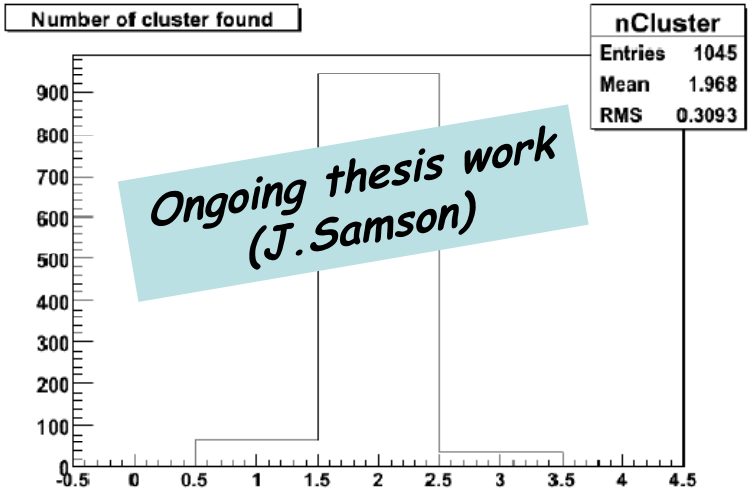
Novel quality of input to shower model development



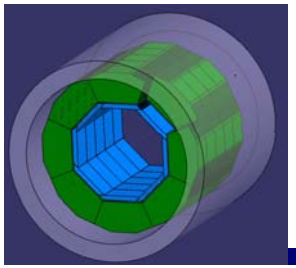
Analysis potential: two hadrons

- Thanks to low occupancy, can use "event mixing" techniques
- Measure the confusion term
  - Non-associated fragments ➔ double counting
  - Wrong assignments ➔ losses
- As a function of particle separation - in data and MC



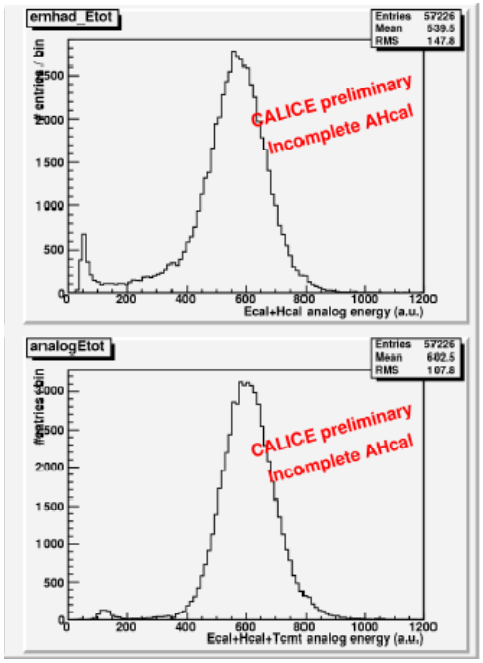


Towards benchmarking the PFLOW performance

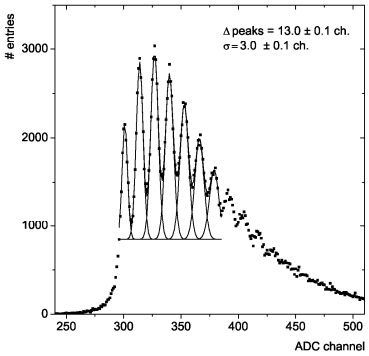


And more:

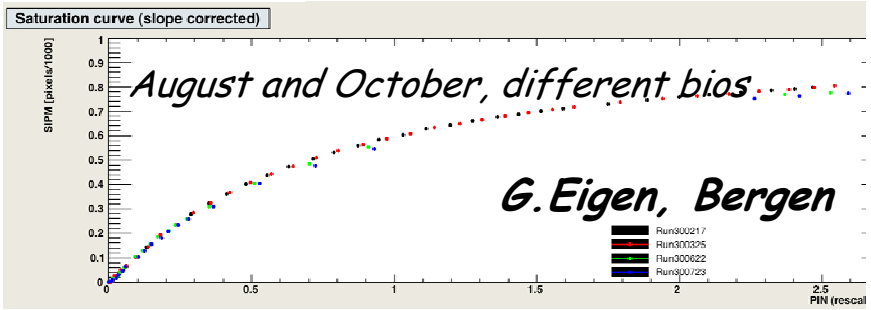
- ECAL, HCAL and TCMT combined

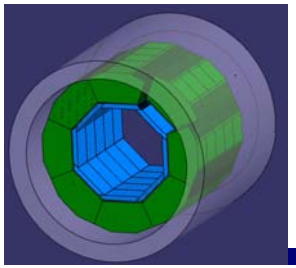


- Semi-digital approach
  - 2 bits, 3 thresholds



- Calibration strategies
  - Auto-calibration concept
  - SiPM response stability



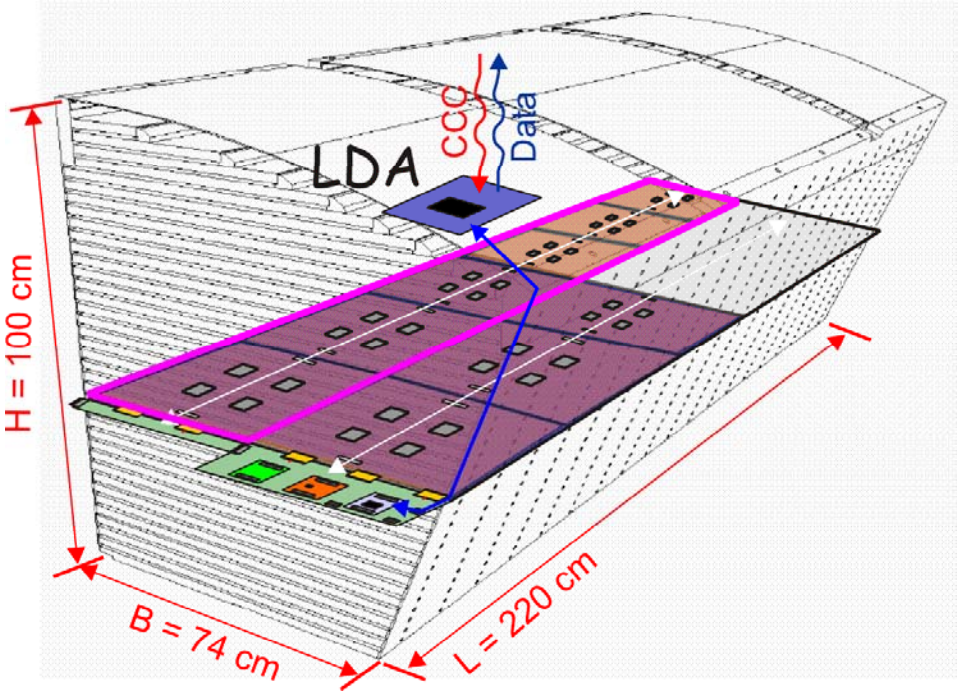


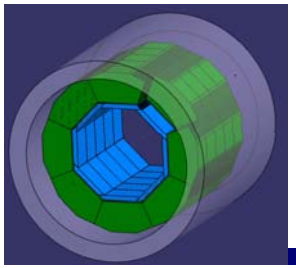
Next: technical prototype

- Goal: A compact and realistic (i.e. scaleable) scintillator HCAL structure with embedded electronics

- Integration issues
  - Readout architecture
  - Ultra-low power ASICs
  - Calibration system
  - Tile and SiPM integration
  - Absorber mechanics with minimal cracks

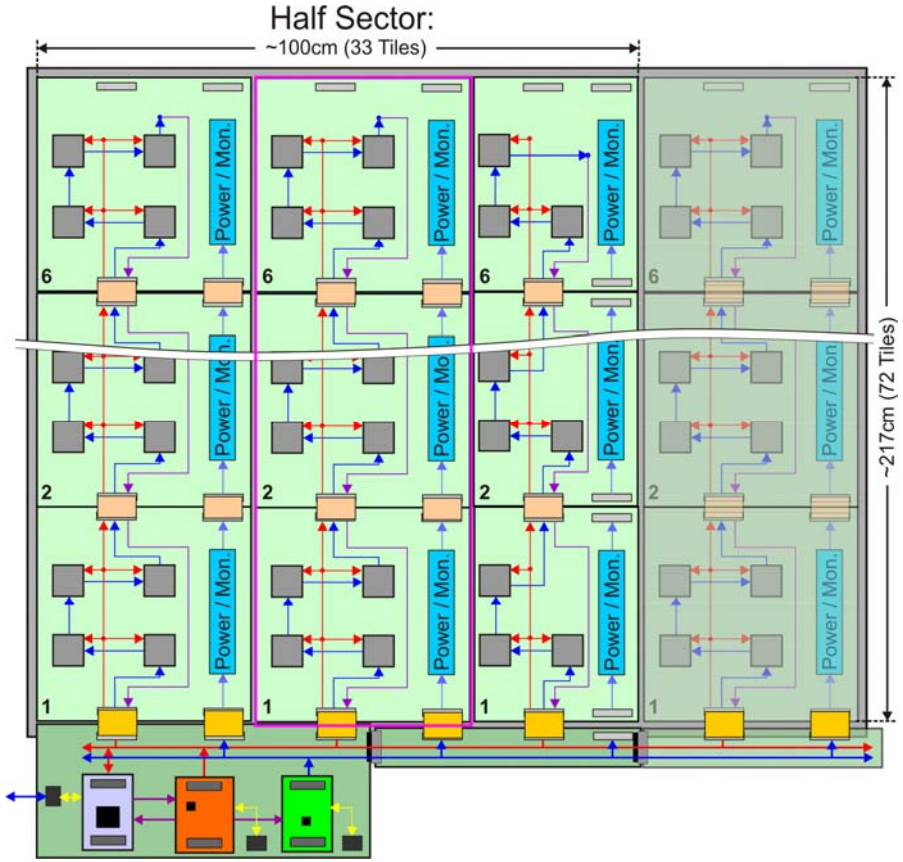
- Feed-back from test beam essential
  - Calibration concept
  - Overall detector optimization



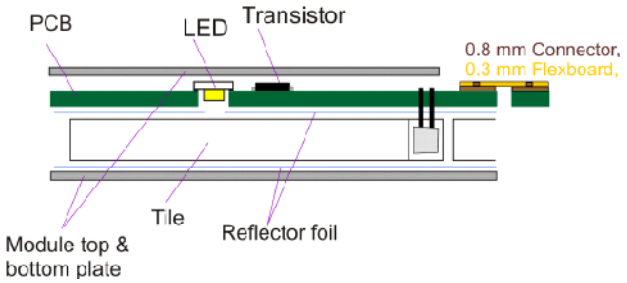


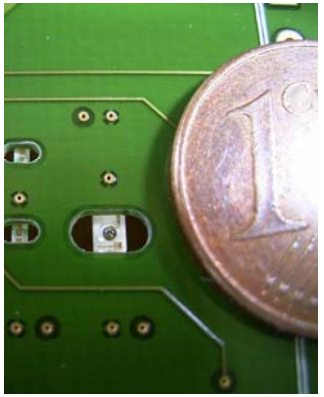
R/o layer design progress

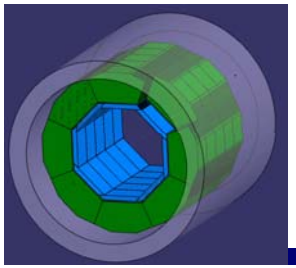
- Modular design, thin gap (scint + 1.6mm), embedded LEDs



If gain calibration sufficientsmall intensities

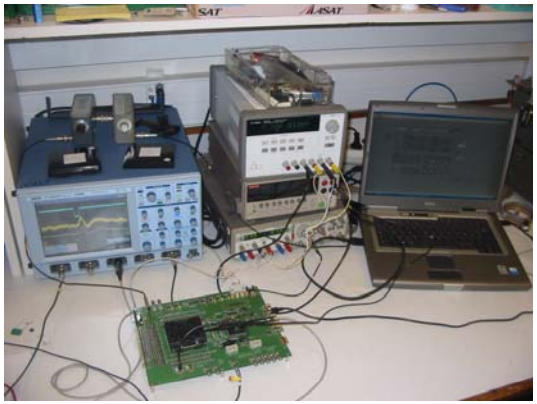


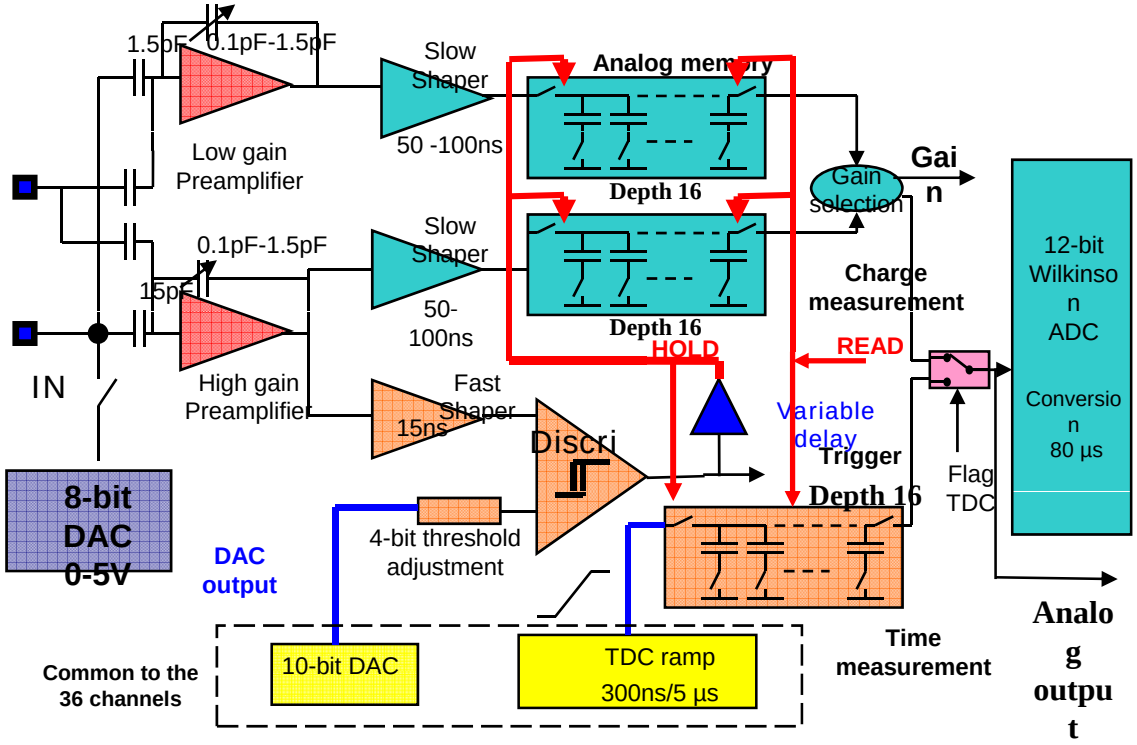


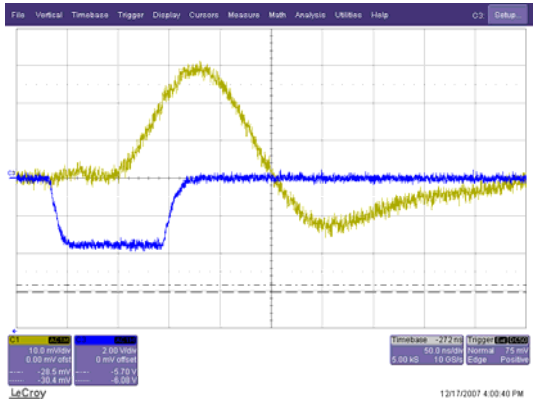


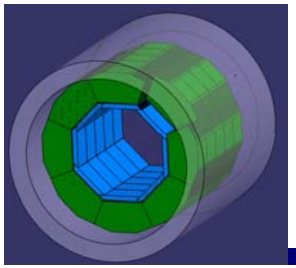
New ASIC on the test benches

- Auto-triggering and time measurements
- ADC and TDC integrated
- Power pulsing, low (continuous) power DAC



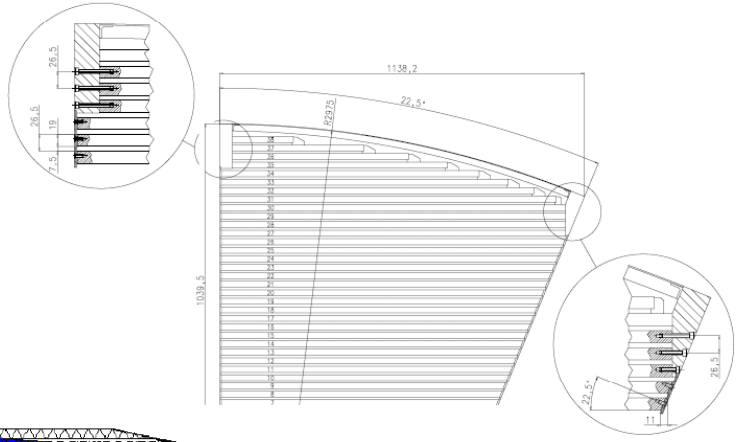


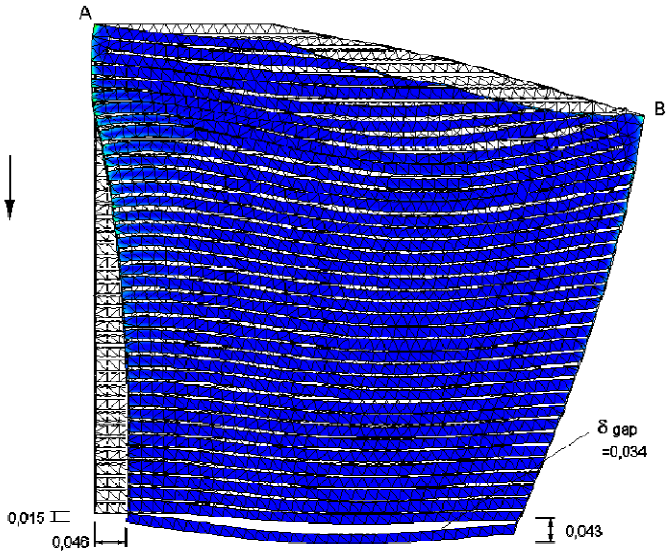


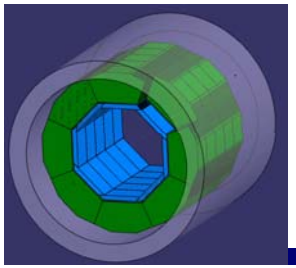


Mechanical design: to start

- TESLA TDR: rather detailed design with "no" cracks
- Questions raised on stability with realistic tolerances, assembly sequence
- Started to re-evaluate
- No alternative designs yet
- No mechanical design for Pb or W structures







R&D issues

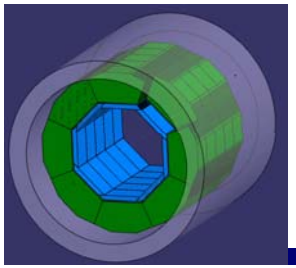
Musts

- Operation with on-line zero suppression
  - e.g. threshold setting and monitoring for auto-trigger FEE
- Calibration and monitoring
  - monitoring with auto-(gain-) calibration alone (or not)
  - mip calibration with hadronic showers (or r/a souces)

Technolgy driven
Guidance helpful

Wishes

- SiPMs with lower noise, larger efficiency and dynamic range
- Scintillator tile systems, thin and with direct coupling
  - light yield, uniformity
- Optimization of electronics analogue performance
  - better s/n for low gain SiPM and gain calib robustness
- Timing: synchronization and stability



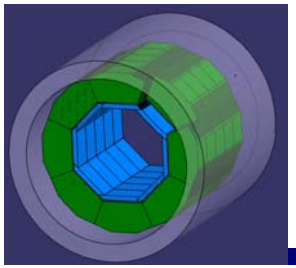
Technological issues

- Finalize technological prototype design
  - mechanics, electronics interfaces
  - FEE digital data handling (indiv. channel triggering and addressing)
- Mass production QC and characterization sequence
- Electro-mechanical system integration

Guidance helpful

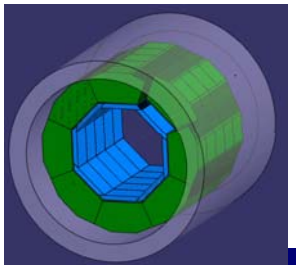
- Absorber mechanical structure with thin cracks
- Service integration
- End cap layout
- Mechanical design for other absorber materials (Pb, W)

Waiting for input from optimization studies



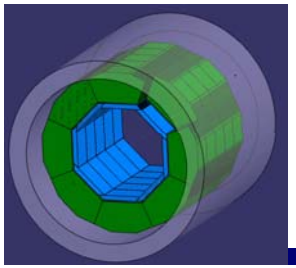
Optimization

- All this needs to be done, independent on the exact parameters of the detector we want to build
- We thought we know these to good approximation thanks to
  - Studies done for the TESLA TDR
  - Intuition of the experienced
  - The granularity studies performed by A.Raspereza and M.Thompson
    - And V.Zutshi for the semi-digital approach
- Our GLD friends thought so, too
- Similar, but also new and different ideas
  - Lead absorber, compensation
  - Scintillator strips
  - Timing for particle flow
- ILD optimization: time for re-assessment



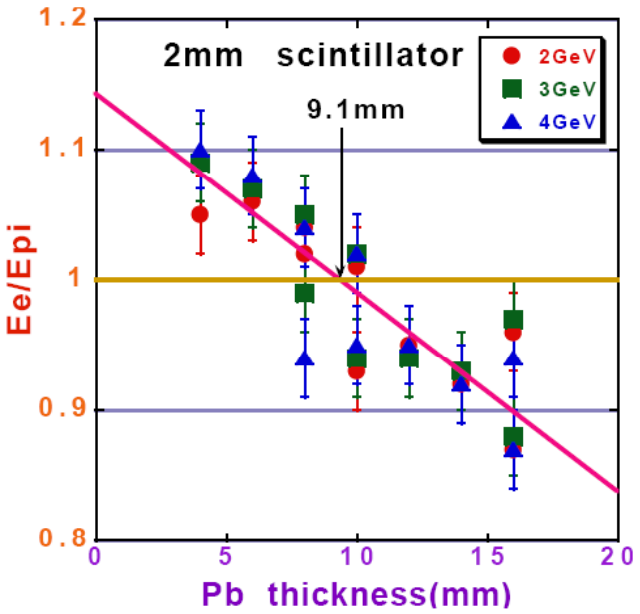
General

- Basic understanding of energy resolution
  - Studies on "ideal PFLOW" were extremely instructive
  - Need the same for the high energy limit (classical calorimetry)
  - Would like to further break down the hadronic energy measurement
    - role of sampling statistics, e/pi fluctuations
    - mip efficiency, (thresholds)
    - Leakage and dead materi
- Radiation exposure - revisited
  - Occupancy (electronic bandwidth)
  - Rates and damage
  - Possible impact on technology choice close beam line



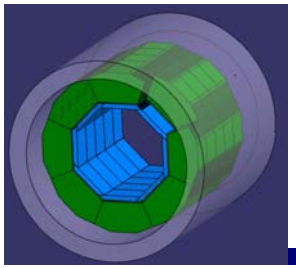
Absorber material

- Iron preferred for mechanical reasons
  - Additional support structure increases dead material
- Lead offers compensation and more compact shower core



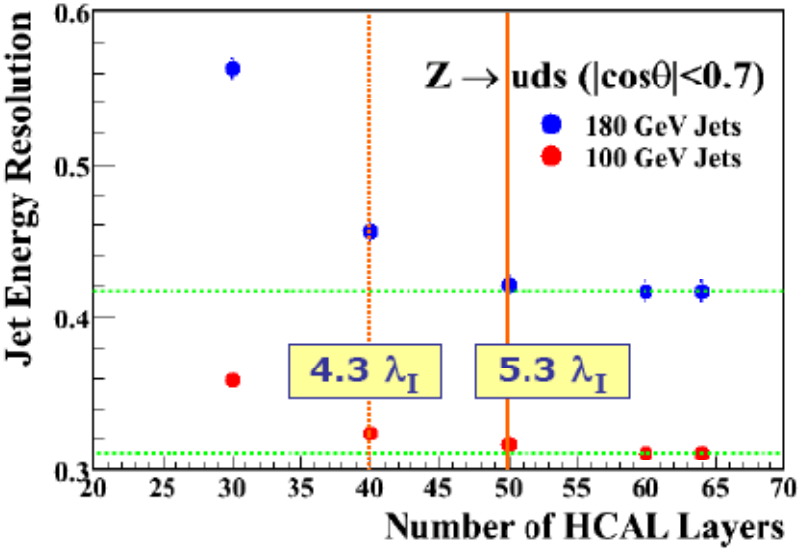
- Need to adapt segmentation (?)
  - Scale long./ transv, both, none with X0
- Muon cut-off will be significantly higher
  - Physics impact

- Tungsten gives more hadronic interaction depth
  - also Gold, Platinum,..
- Does anyone remember why we do not consider Uranium?

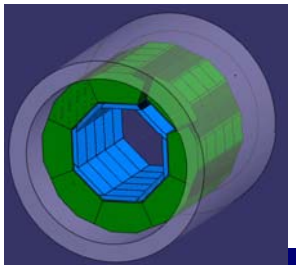


Geometry

- Depth
  - Earlier pointed out by V.Morgunov
  - Recently affirmed by M.Thomson
  - May be not the final word
- Understand and control leakage
  - No use of tail catcher in reco yet
    - TB data!
  - PFLOW approach: Estimate leakage fr shower shape, starting point (Thesis B.
- Cracks
  - Motivate engineering effort
  - Effect of phi cracks, edge tiles
  - Benefits from non-pointing geometry
- Barrel end-cap transition, endcap (!) ring
- Angular coverage:
  - interplay with FCAL, FHCAL
- Is enough attention paid to missing energy performance?

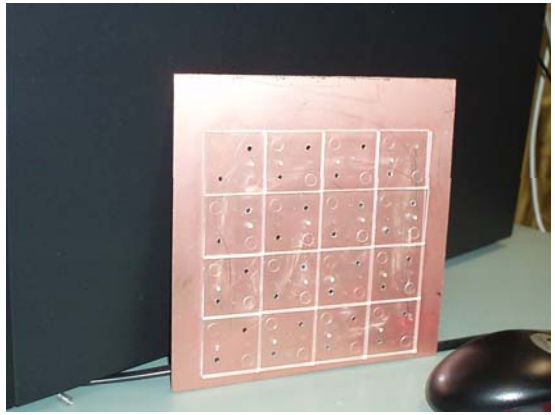


Suggestion: compare aggressive and conservative design options
Needs engineer input to start the loop

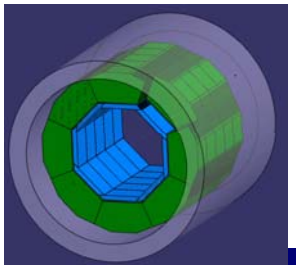


Longitudinal sampling

- 2 cm steel absorber plates: does not sound like a natural unit
  - Vary up and down
- Scintillator thickness
  - Under pressure from coil volume and hadronic interaction depth
  - Compromises in light yield (s/n)
- Lose in sampling statistics
- Proposal: compare 3mm and 5mm
  - Invest thicknees budget into
    - More layers, same sampling
    - Thicker absorber plates

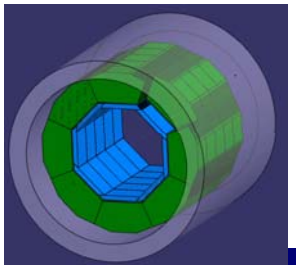


New 3 cm ties from ITEP



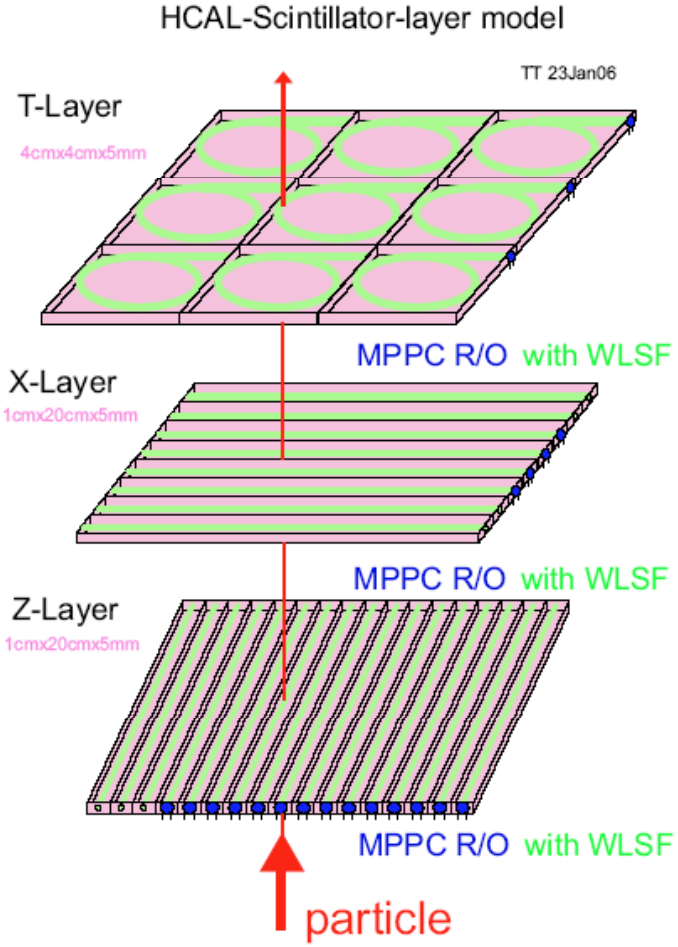
ECAL HCAL transition

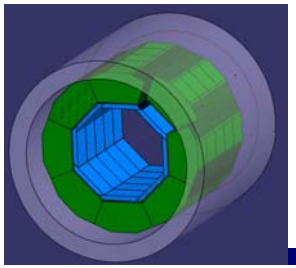
- Given good em resolution of scintillator HCAL
- And possibility to refine granularity further:
- How much Si tungsten is needed?
  - impact on em resolution
  - em shower separation
  - had shower separation
- Proposal: try a thinner ECAL and finer segmentation in first 10 HCAL layers



Transverse segmentation

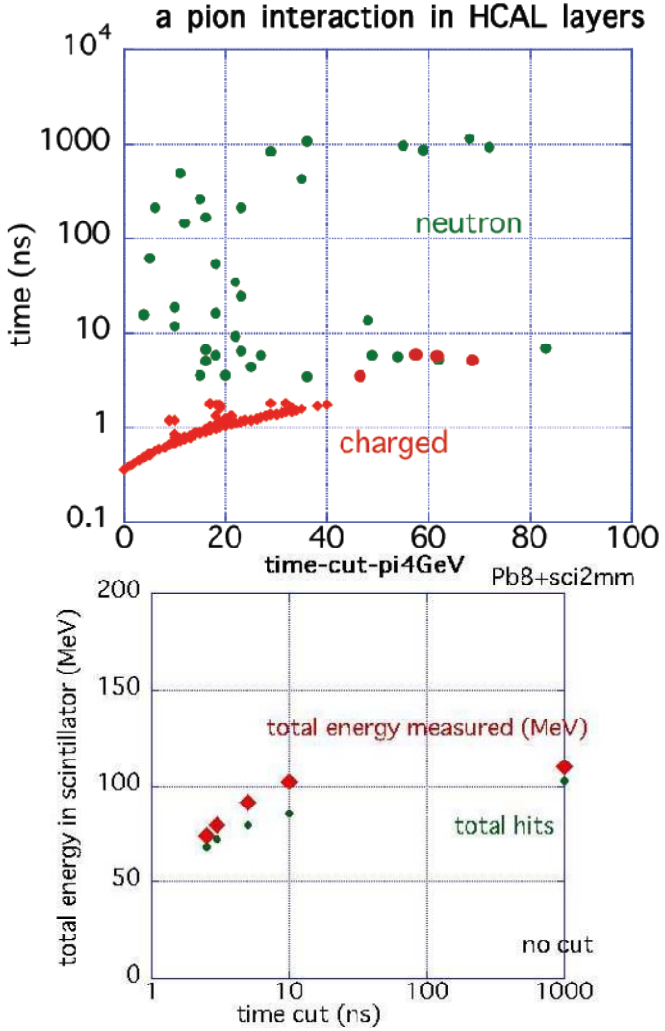
- Reduction with depth
  - Still on the agenda
  - Proposal: 6x6 from last 10 or 20 layers
- Strips
  - Better position resolution for same channel count
  - Potential degradation of pattern recognition due to ghost hits
  - Results from GLD at this work-shop
  - Possibility to adapt Pandora?

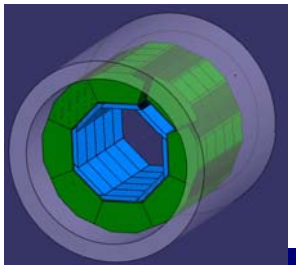




Timing for PFLOW

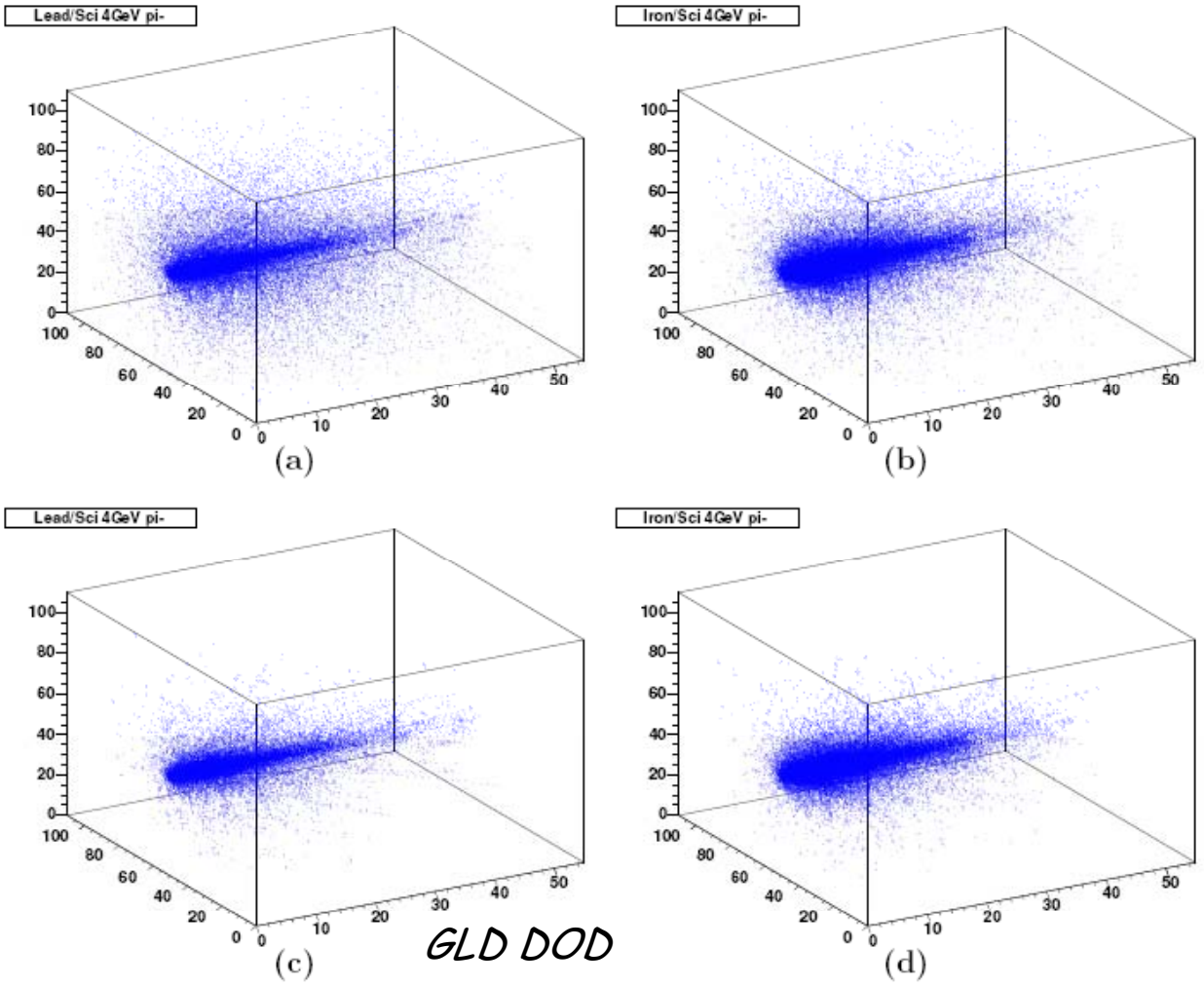
- Use time measurements to tag neutron hits
  - Clean up picture for PFLOW reconstruction ➔ cut at 5 ns
  - Keep late hits for energy resolution ➔ gate open for full bx
- Neutrons: blessing or curse?
- Proposal: study benefits in state-of-the art PFLOW
- Check model dependence
  - Can test beam tell?

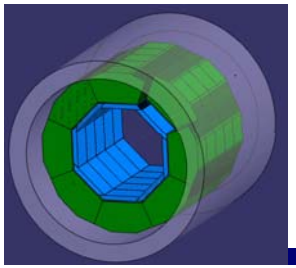




Showers with timing cut

- Effect is stronger for Pb



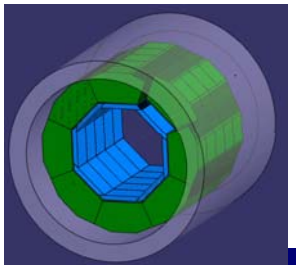


Electronics

- We need robust numbers on Occupancy
  - from physics
  - from beam related background
  - (from noise)
- For band width considerations

- Electronics effects of PFLOW pwrformance
  - Noise impact on energy resolution and pattern recognition
  - MIP efficiency, threshold effects
  - Time resolution

- Dynamic range of SiPMs
  - Proposal: compare two options, different range, same accuracy of corrections

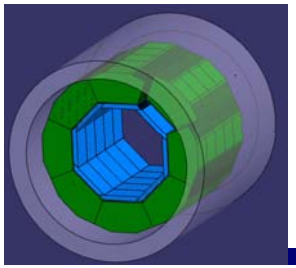


Calibration

- Impact of calibration uncertainties
  - statistical limitations (number of mips will be small)
  - Systematic (temperature effects)
  - dynamic range
  - threshold dispersion
  - timing offsets

- Calibration methods
  - MIPs in showers: to be demonstrated
  - Absolute scale
    - Total energy, single hadrons; systematics?

- Goal: Realistic estimate of stoch/const/noise term

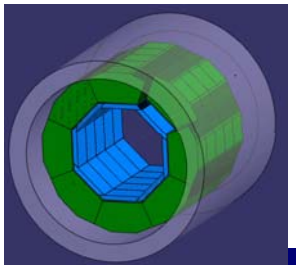


Summary

- A rich program for h/w and s/w studies
- For the ILD LOI, need to prioritize
  - driven by sequence of decisions for engineering desin
- 1st absorber material (Fe, Pb)
- 2nd depth and cracks (l;eakage with PFLOW)
- 3rd longitudinal sampling (3 or 5 mm scintillator/)
- 4th granularity: strips vs tiles on same footing
- 5th impact of timing

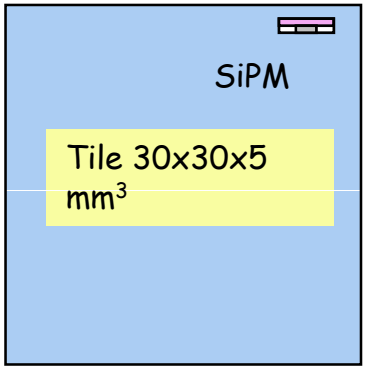
- In parallel: general understanding & calib issues

- Use full detector simulation AND test beam data

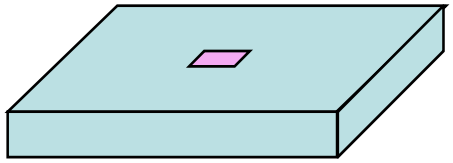


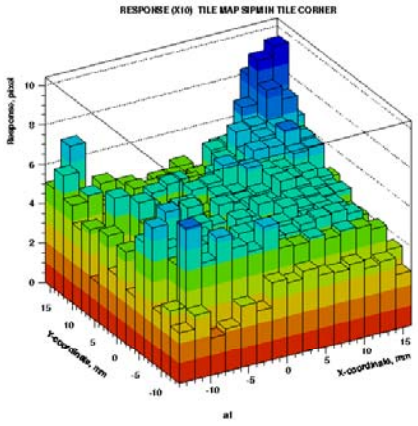
SiPM scintillator coupling

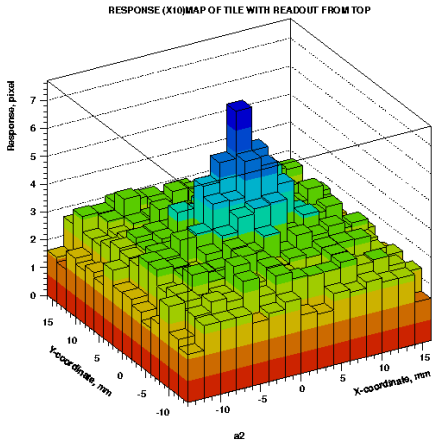
- More efficient SiPMs:
- simpler coupling, thinner tiles



Tile 30x30x5 mm3





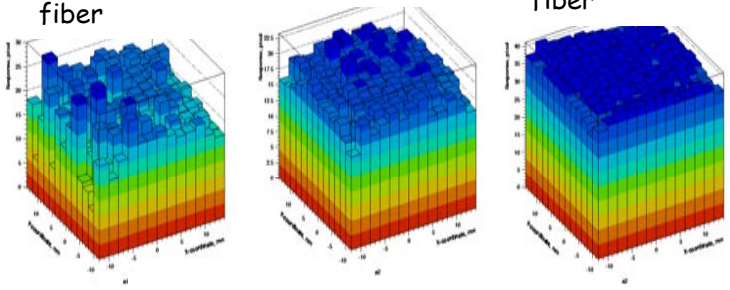


- Uniformity to be re-addressed, not as good as with fibre
- Also studied: 3mm thin tiles

Tile with diagonal fiber

Tile with arch fiber

Standard 5 mm thick tile with arch fiber



E. Tarkovsky

Back-up slides

Integrated layer design