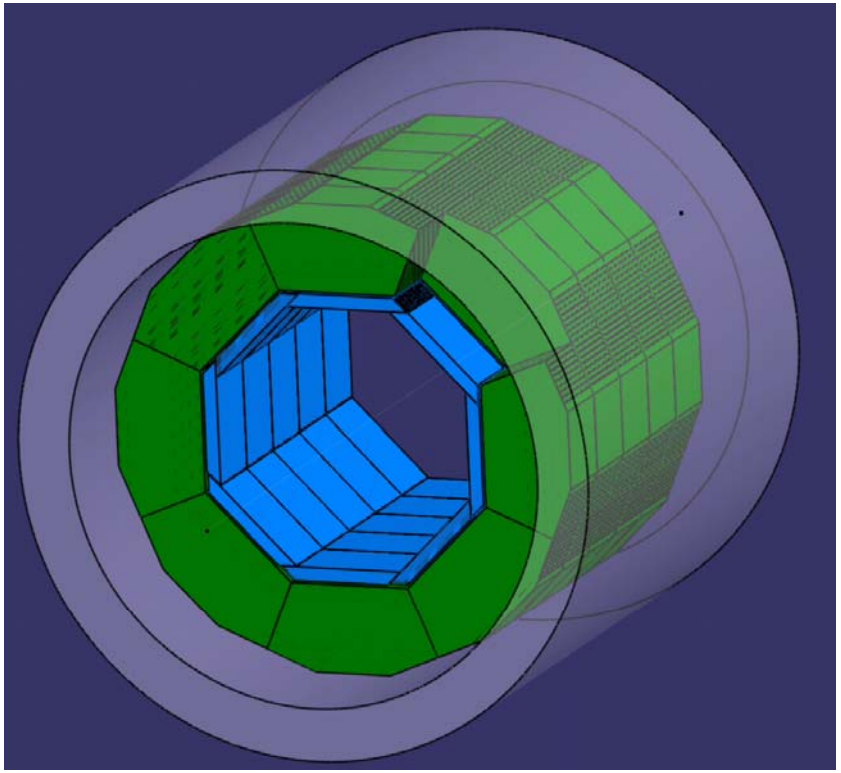
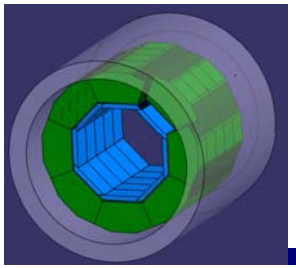


HCAL future: 2nd generation module and testbeam plans

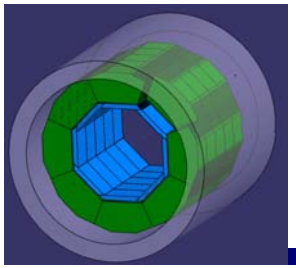
Felix Sefkow

CALICE collaboration meeting
Kobe, May 10-12, 2007



Outlooks

- EUDET module prototyping
- Test beam plans 2007 and beyond
- Detector optimization



Next generation

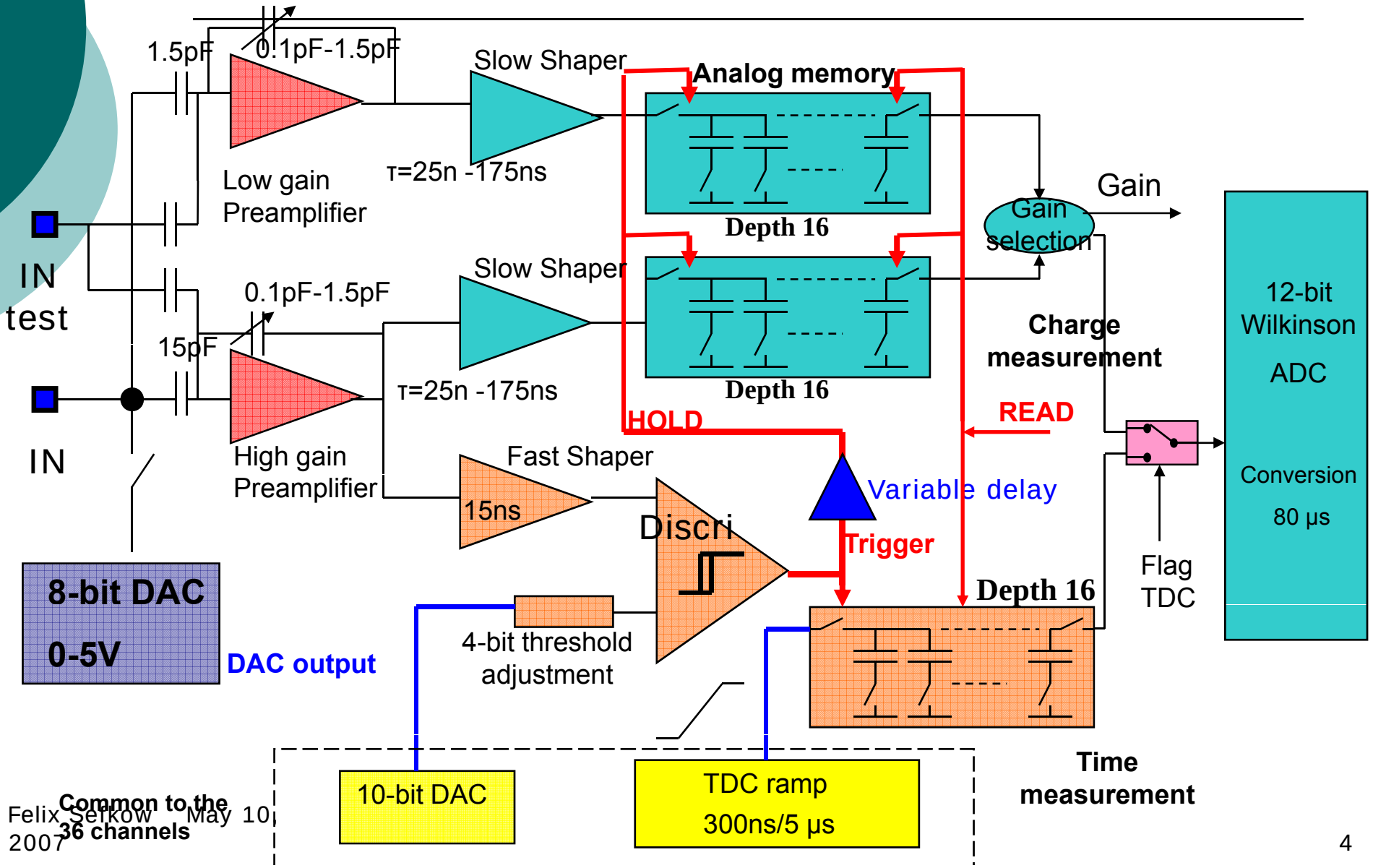
- February 15: EUDET milestone 1: calorimetry conceptual report submitted

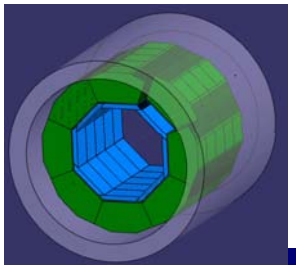
- June 2007: first AHCAL front end ASIC prototype submission
  - See Christophe's talk on SPIROC

- September 2008: DAQ first prototype (including C3 and s/w)
- June 2009: DAQ full system
  - See Valeria's and Paul's DAQ talks tomorrow

- End of 2007: HCAL mechanical design concept
  - Start prototyping now
- Calibration system single channel prototype
  - Learn from CMB experience

SPIROC : One channel schematic

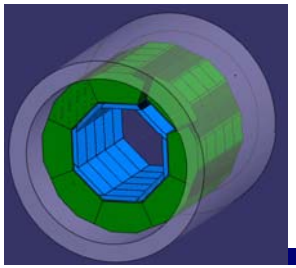




SPIROC

- First CALICE ASIC with full analogue and digital functionality integrated
  - ~ 8 times larger than present ILC_SPM

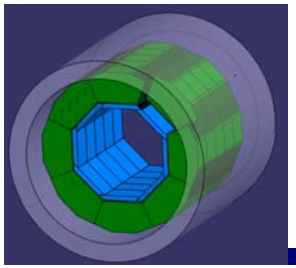
- Huge effort at LAL – not undisturbed as recent experience and new ideas are incorporated while design is being finalized
  - Accommodate SiPM and MPPC characteristics, experience from March '07 DESY testbeam
  - Still a lot of flexibility required to accommodate large range of SiPM parameters
    - Noise, dynamic range, gain, light yield variation
  - Testbeam usage, trigger issues



Scint – SiPM – PCB integration

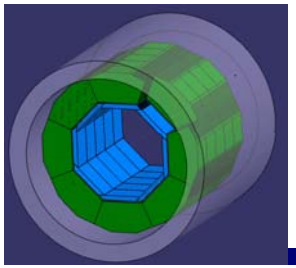
- Two possibilities:
  1. Photo-sensor scintillator unit + PCB with VFE
  2. Scintillator + PCB with photo-sensor and VFE

- We follow option 1, based on the good experience with TB prototype
  - Stable optical connection
  - Early and easy single channel quality control
  - independent of final electronics (schedule)
- Option 2 is followed by NIU and FNAL
  - Advantage: automated SMD technology for photo-sensor mounting



Tile PCB positioning

- The first "LEGO tile" with positioning pins has been produced at ITEP
  - Individual tie positioning to match PCB precision for SiPM connection
- Discussions with scintillator producer have started
  - Mass production with injection molding seems feasible
- Mega-tiles / mega-strips can use same or different positioning method
  - PCB design largely unaffected

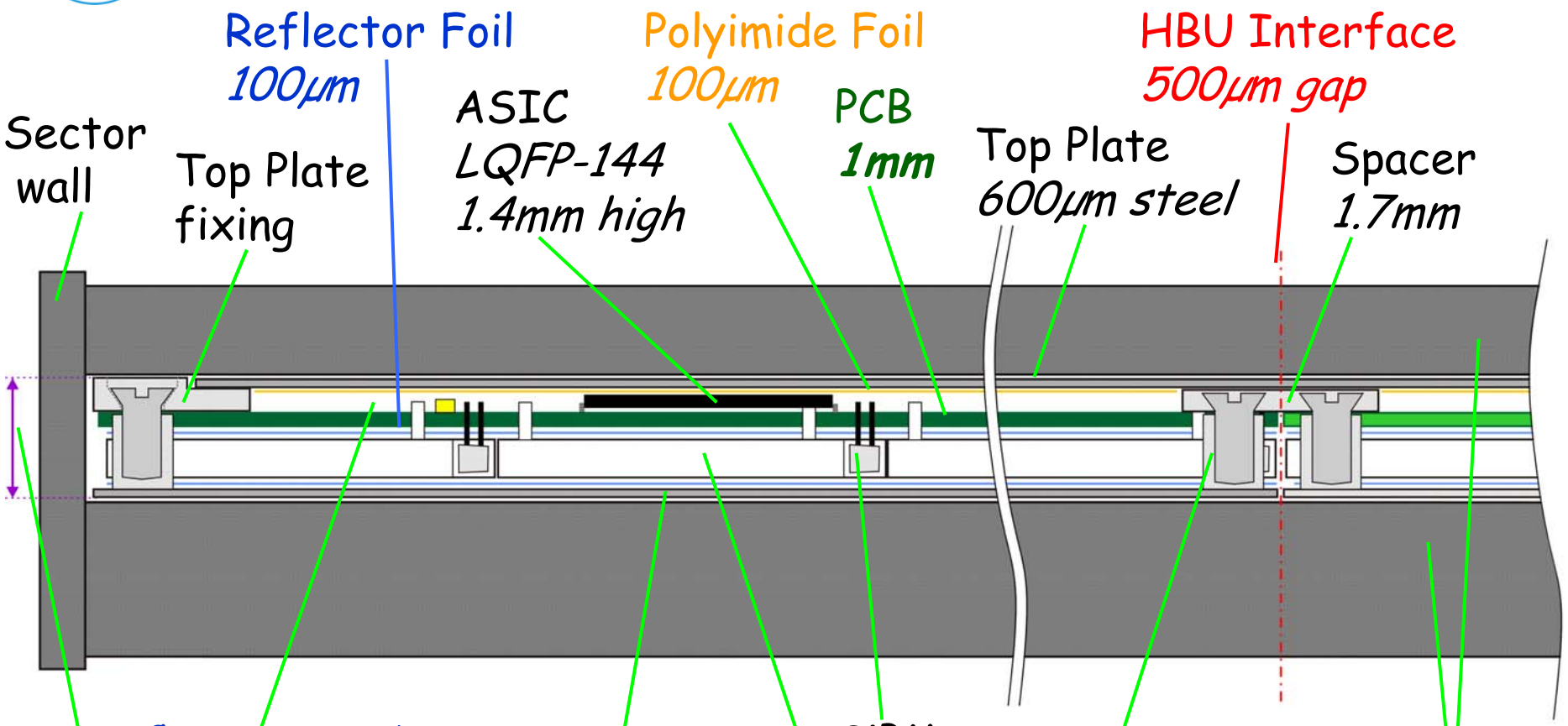


LED options

- Present system very versatile – and complicated:
  - Low intensity for gain, PIN readout for reference, high gain for saturation
  - We assume gain monitoring is enough
    - Still to be demonstrated
- Light distribution (low intensity)
  - One LED for many channels
    - Required uniformity difficult to achieve
    - Complicated sub-division of HCAL layers
  - One LED per channel
    - Often proposed, never tried

HCAL Base Unit (HBU) – first idea

FEB



HBU – Constraints

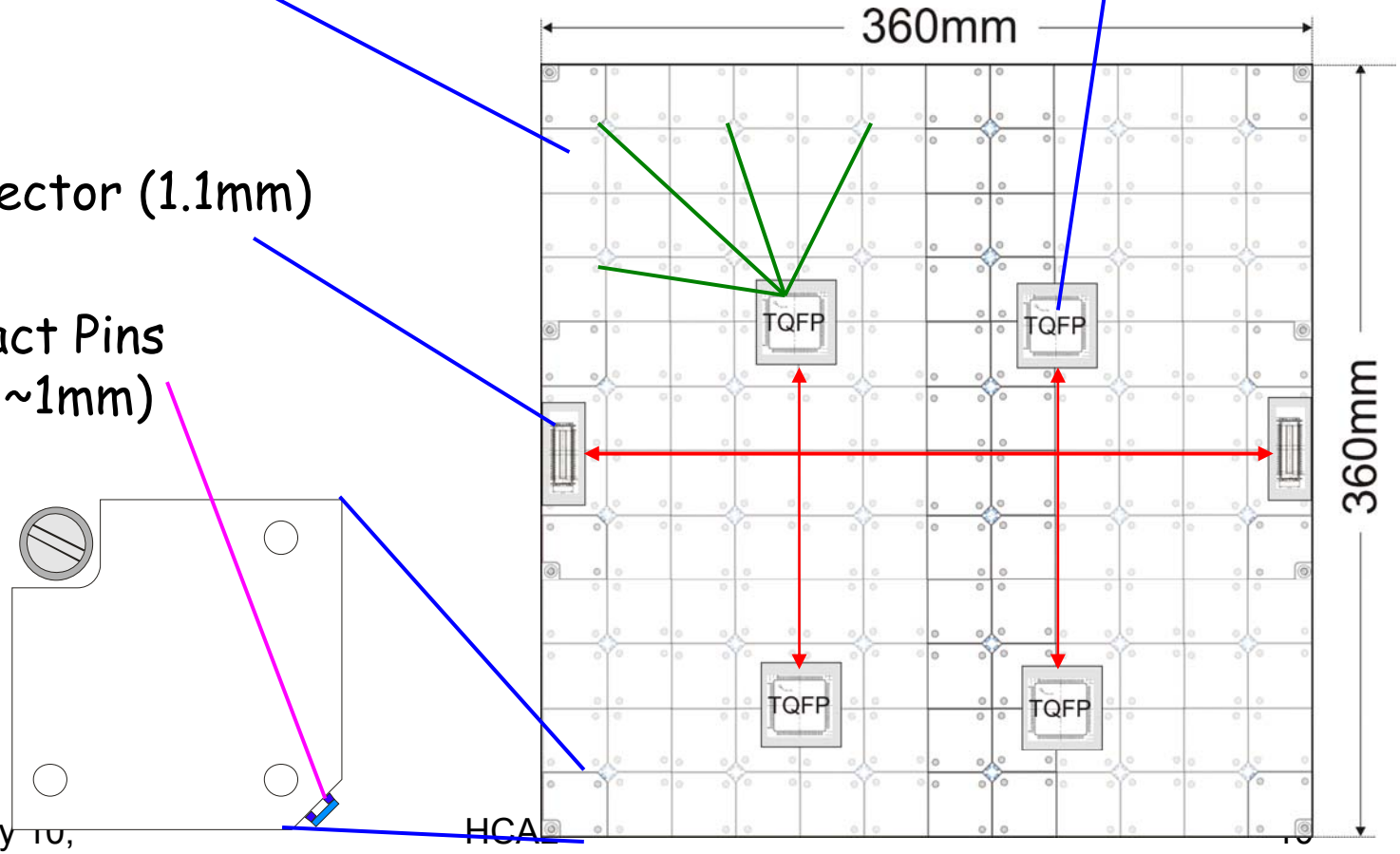
FEB

PCB (*shown transparent*):
Two signal layers (50Ω):
- CLK, Control, Data, LED
- SiPM Readout, HV

ASIC - TQFP100
36 inputs (1mm)

Connector (1.1mm)

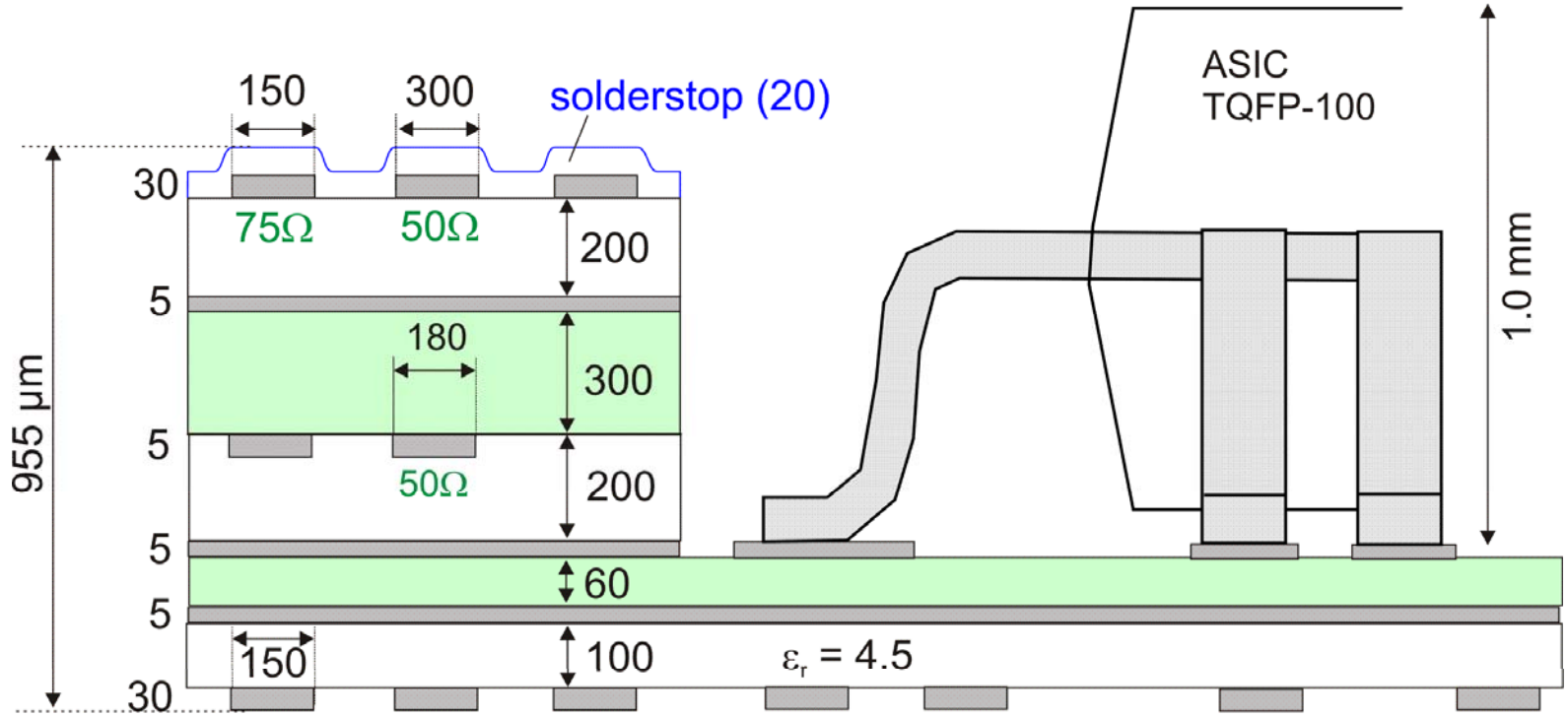
SiPM Contact Pins
(soldering, ~1mm)



HBU - PCB layer structure I

FEB

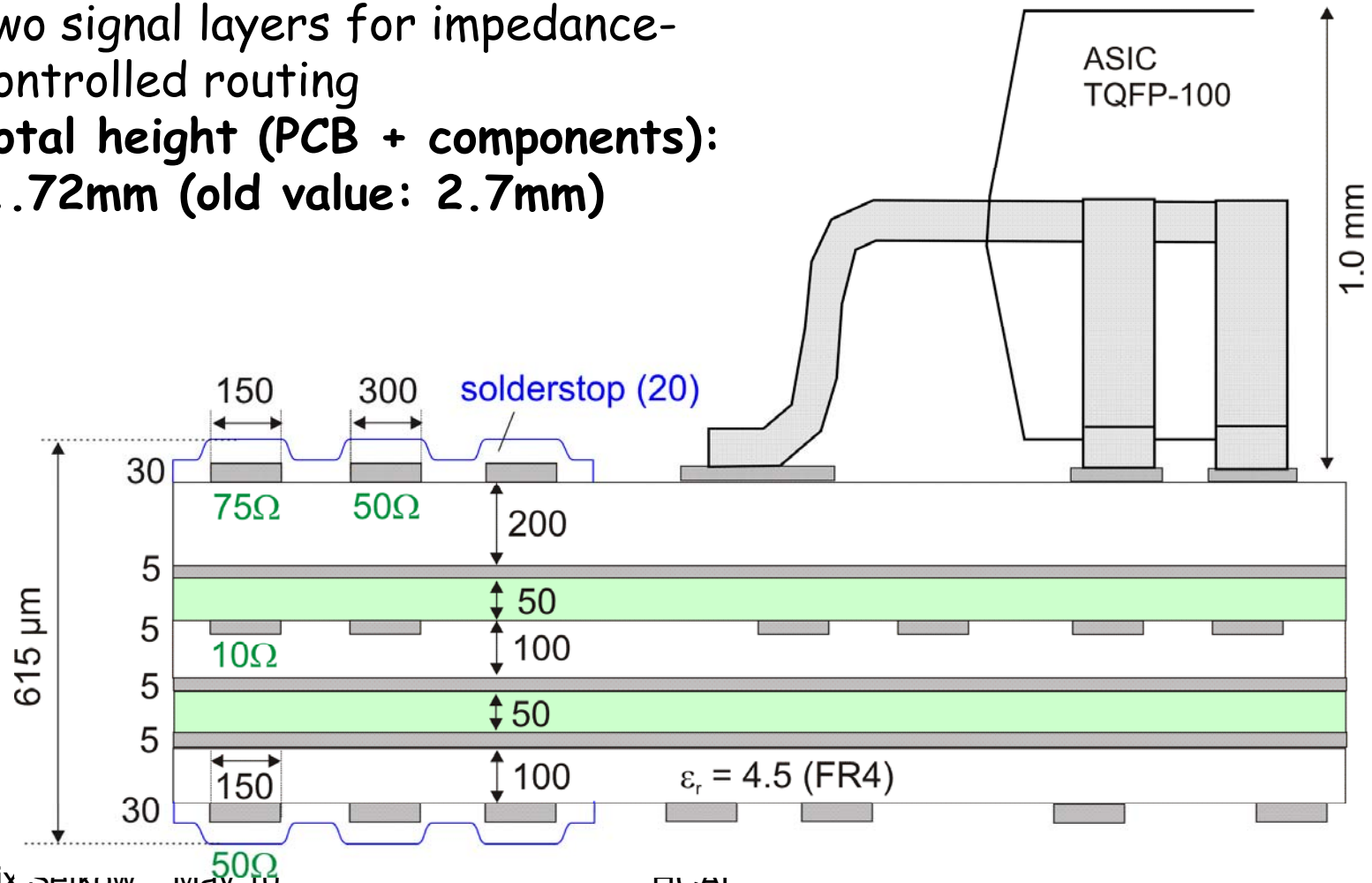
-6 layer design with cut-outs for ASICS and connectors
-75Ω Lines for high-gain SiPM setup
-Three signal layers for impedance-controlled routing
-**Total height (PCB + components): 1.32mm**
- Feasibility / Cost-factor under investigation



HBU – PCB Layer Structure II

FEB

-6 layer design with standard setup
-75Ω Lines for high-gain SiPM setup
-Two signal layers for impedance-controlled routing
-**Total height (PCB + components): 1.72mm (old value: 2.7mm)**



Testboard I : LED

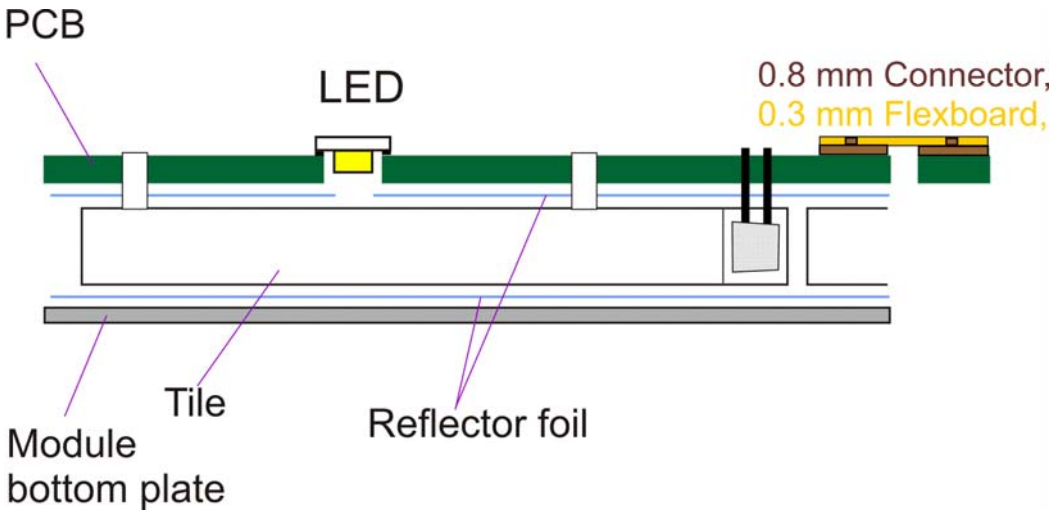
FEB

Test LED integration into HBU (LCS):
Proof of principle together with our colleagues from Prague

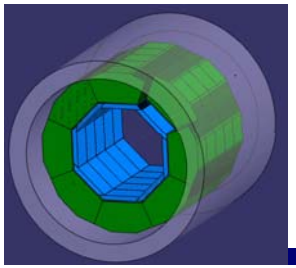
-Crosstalk of driving circuit to SiPM?

-Integration to PCB / coupling to tile?

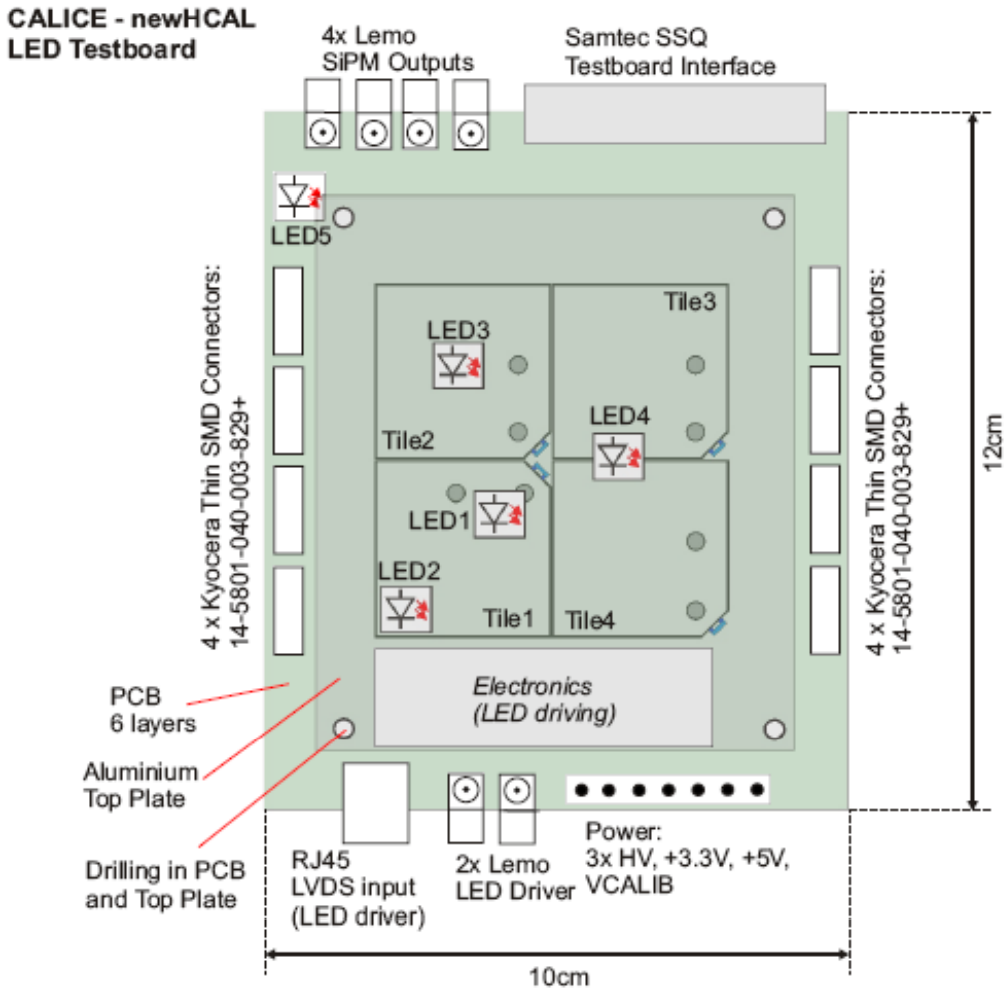
-Connector test: stability, number of connection-cycles?



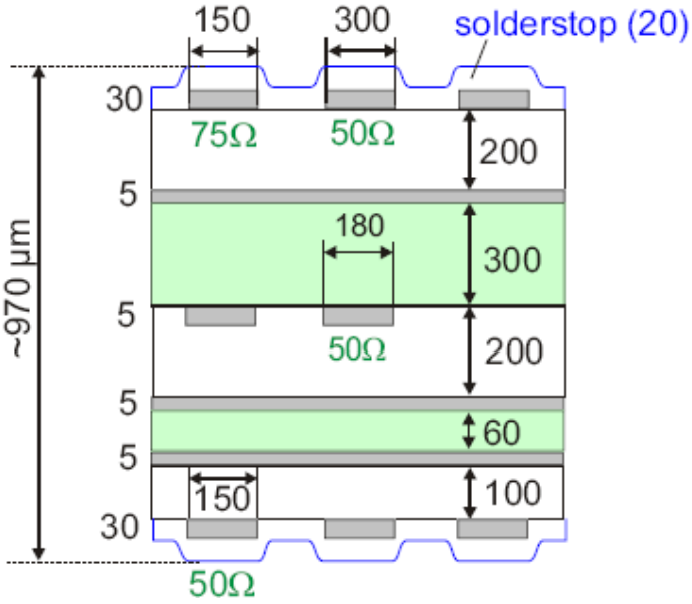
Features:
- SMD LEDs (two types)
  LED size 1.6 x 0.8 x 0.6 mm³
- Several LED driving circuits
- >2 Tiles with analog output
- proposed HBU Connector
- Multilayer PCB needed!!
  (crosstalk test)
- No ASIC…



LED testboard



- Verify cross talk limits with realistic PCB structure



Testboard II : SPIROC

FEB

SPIROC (ASIC) Testboard **IS** HBU prototype!

Test of:

-Cassette (=HBU) assembly (tiles, electronics, cover)

-Performance of SPIROC in the dense HBU setup
(noise, crosstalk, power, gain, …)

-LCS with LEDs on board

-Signal Integrity (see Testboard III),
Communication with DAQ

-Analog AND digital outputs / interfaces (next slide)

Testboard II : Integration

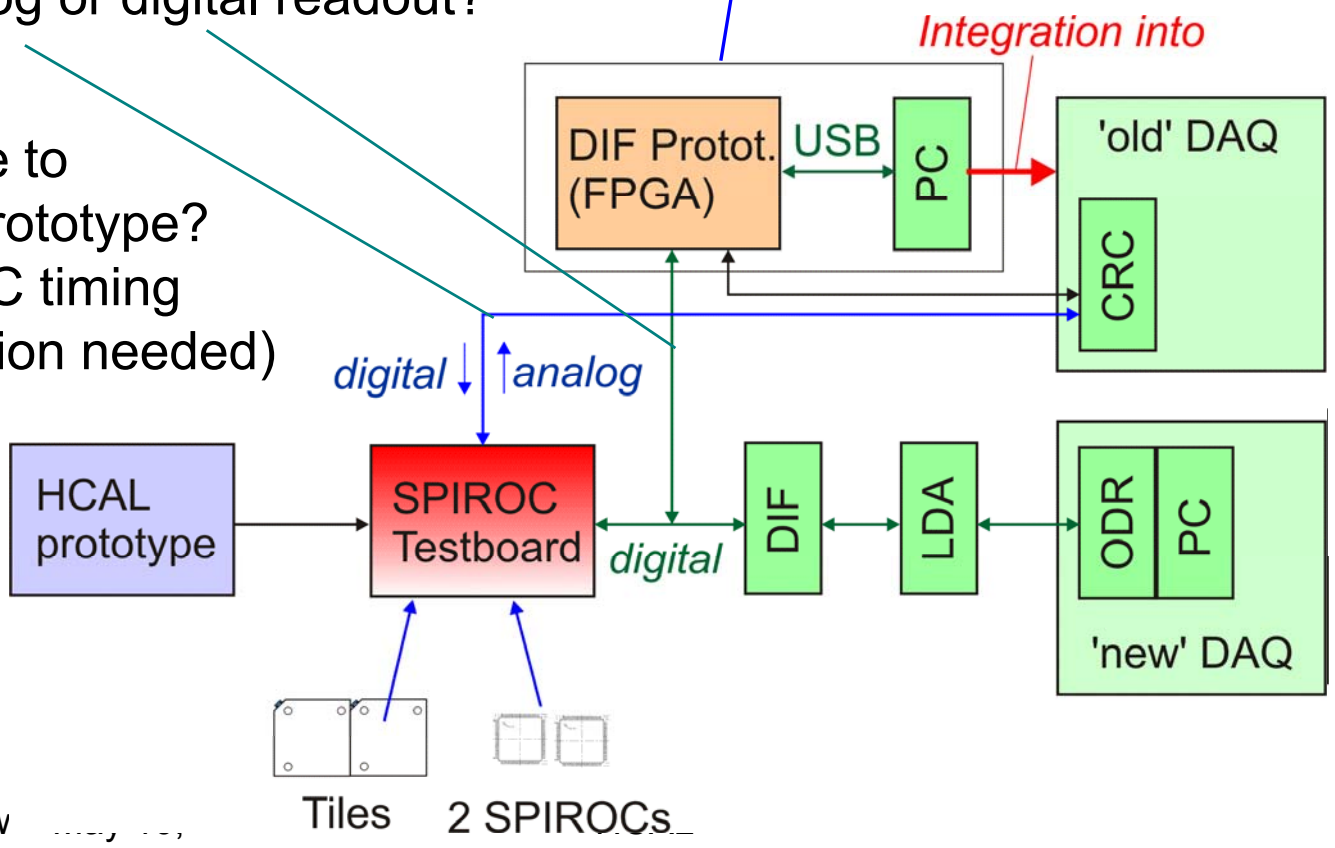
FEB

Environment of the SPIROC Testboard:

Stand-alone, or Integration into old DAQ?
(Menpower problem …)

When using CRC:
Analog or digital readout?

Interface to
HCAL prototype?
(SPIROC timing
information needed)



Testboard III : Power-System

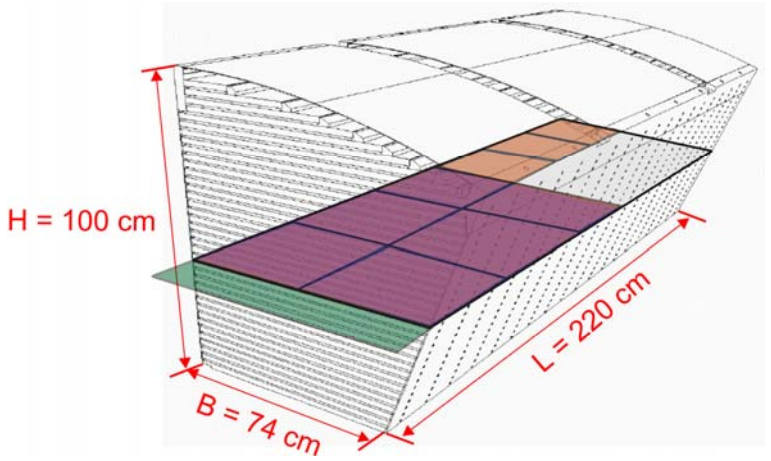
FEB

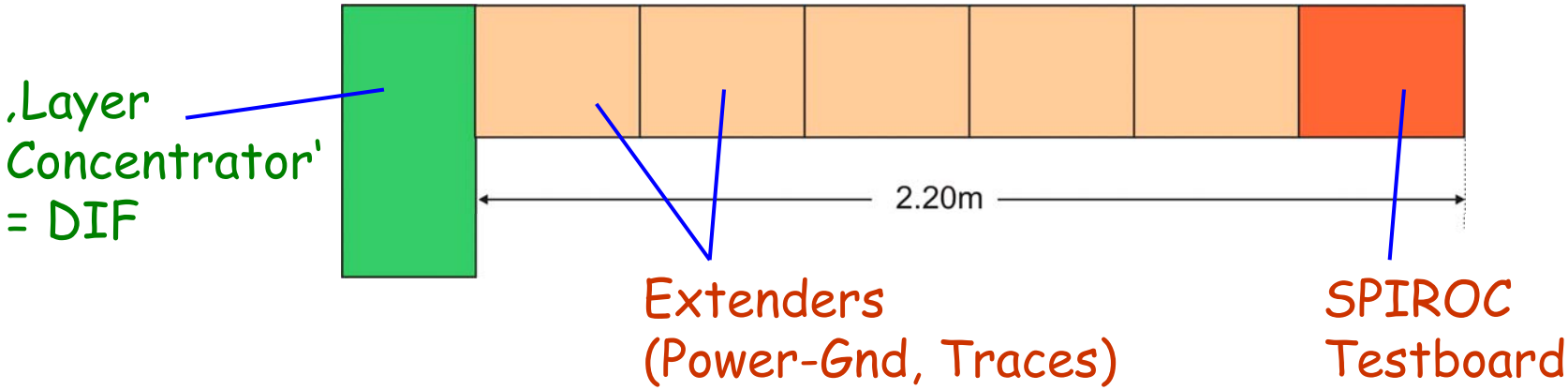
Test Power-Ground System (2.20m):

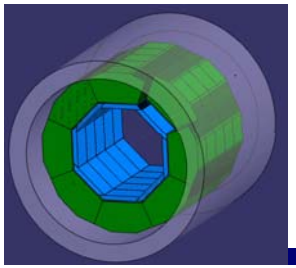
-Oscillations when switching?

-Voltage drop, signal integrity (traces, connectors)?

-SPIROC performance @ far end (blocking caps sufficient)?



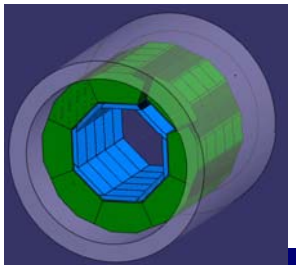




Testbeam 2007 and beyond

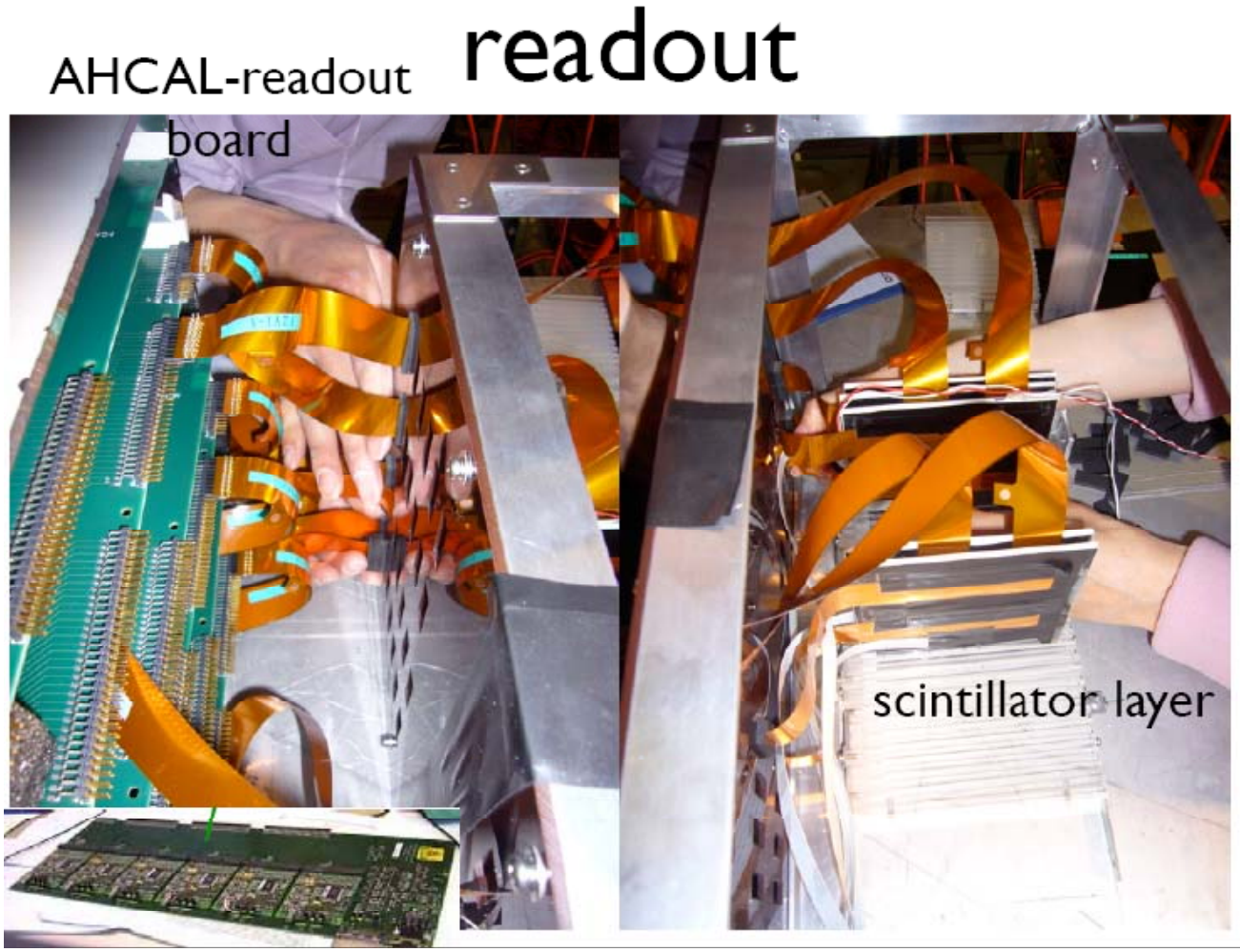
- CERN 2007: 2 periods of 2 weeks: 4.-18.7., 8.-22.8.
  - Latest news: might get 1 or 2 weeks more (between periods)
  - You are kindly urged to help Erika and Fabrizio to fill the shift plan!

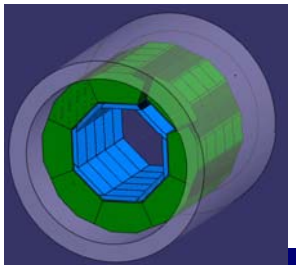
- Move to FNAL:
  - Currently assume de-installation end September (earliest)
    - after CERF muon run
  - Move to FNAL via DESY: 6 weeks
  - ➔ Arrive end November, say, before Xmas
- Goals at FNAL:
  - Low energy (2 GeV), particle ID
  - CERN FNAL connection
  - Gas scintillator comparison reference points
  - Common "all scintillator" run with GLD ECAL



Scintillator ECAL

- 500 channel prototype test at DESY March 2007



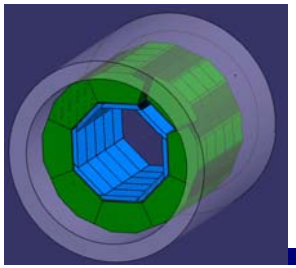


Scint ECAL upgrade

- Plan to upgrade to 2000 channels
- Cannot run anymore simultaneously with AHCAL
  - Enough CRCs, but too few front end boards

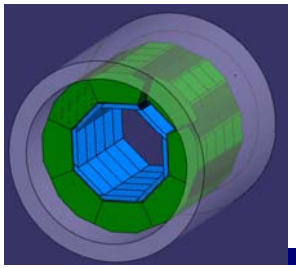
- Plan to produce additional 20 baseboards / 120 piggy backs at DESY
  - There are still 200 - 300 ILC_SiPM ASICs from LAL left
  - Does not interfere with next generation R&D
  - Cost sharing being discussed

- Aim at combined scintillator ECAL + HCAL run at FNAL
  - In 2008, following SiW ECAL + ScintHCAL run



Further beam tests

- There is more physics for the physics prototype:
  - Neutron hit timing for energy and space reconstruction
    - Use new SPIROC ASIC and (most likely) new DAQ
    - Build new front end boards for existing tile HCAL modules
    - Should become possible ~ 2009
  - GLD HCAL Lead Scintillator option
    - Replace steel absorber on movable stage
    - total stack weight limited to 7t
    - Thickness ratio 4:1 not (quite) possible with 5mm scintillator
  - Strip HCAL
    - PFLOW pattern recognition performance to be demonstrated in MC first
    - ***If*** promising: must be tested with beam (short-range correlations)
    - Physics prototype stack or EUDET structure: to be decided later



(Test beam) analysis

- Test the models, measure shower shapes, e/h
- Test weighting schemes and FLOW algorithms

- Ultimate goal: detector design and optimization
  - Calibration and correction strategies
  - Simulations to define requirements (uncertainties, MIP supply)

- Depth,
- granularity
- and one vs the other

- ➔A few slides from Mark Thomson's talk at the Orsay workshop

Current performance

rms90

E_{JET}	$\sigma_E/E = \alpha\sqrt{(E/GeV)}$ $\lvert\cos\theta\rvert<0.7$
45 GeV	0.295
100 GeV	0.305
180 GeV	0.418
250 GeV	0.534

For jet energies < 100 GeV
ILC goal reached !!!

For jet energies ~ 200 GeV
close to 40 %/√E(GeV) !!

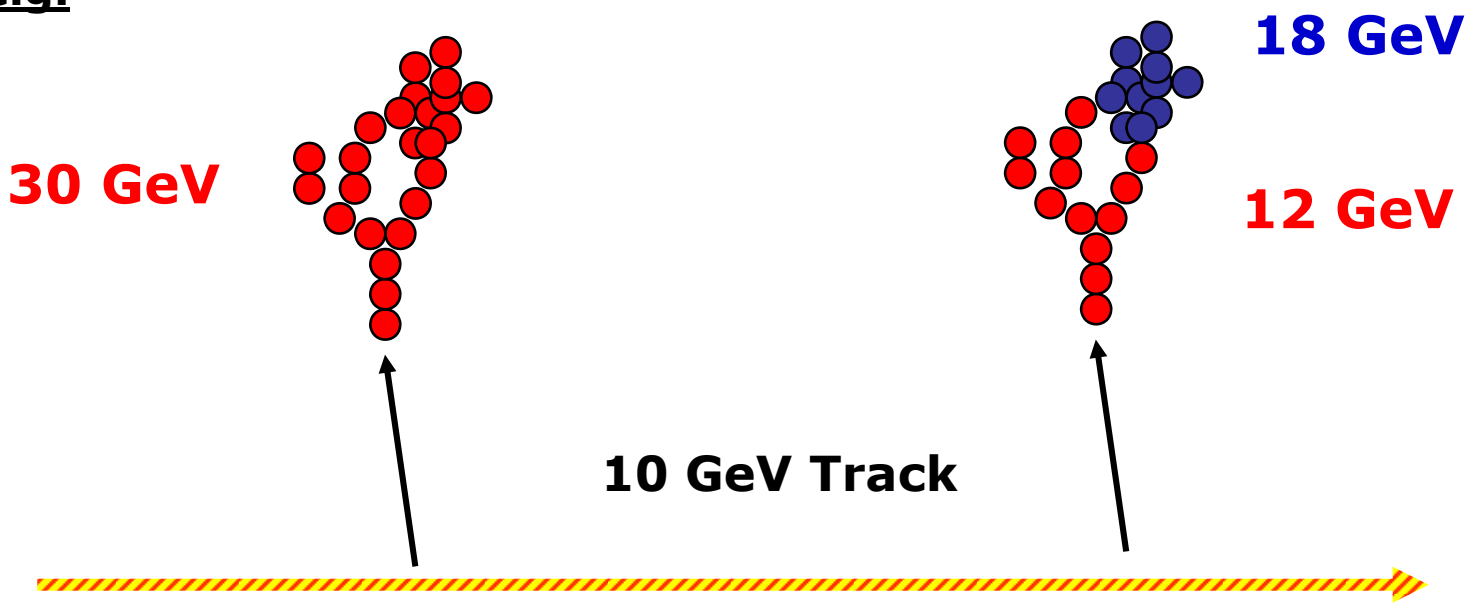
Opinion:

★There is no doubt in my mind that PFA can deliver the required ILC jet energy performance*.
★ It is already there for 100 GeV jets - QED
★ The current code is not perfect (see later), things will get better

*this is not a statement have made before - please feel free to quote me on this

★ If track momentum and cluster energy inconsistent : RECLUSTER

e.g.



Change clustering parameters until cluster splits and get sensible track-cluster match

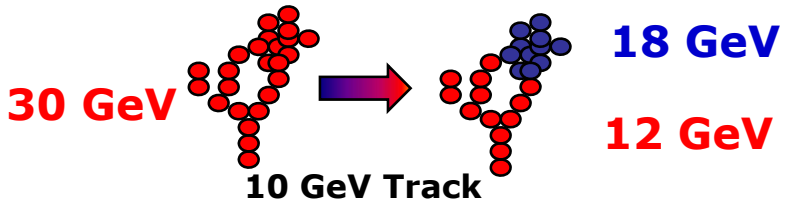
NOTE: NOT FULL PFA as clustering driven by track momentum

This is very important for higher energy jets

Iterative Reclustering Strategies

① Cluster splitting

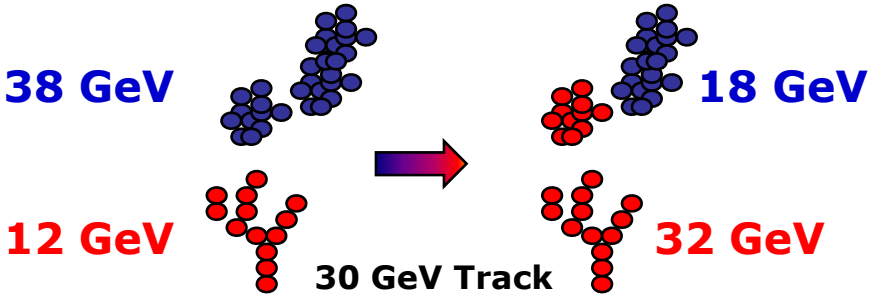
Reapply entire clustering algorithm to hits in "dubious" cluster. Iteratively reduce cone angle until cluster splits to give acceptable energy match to track



★ Could plug in alternative clustering (to some extent this is now done)

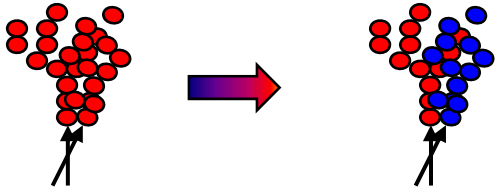
② Cluster merging with splitting

Look for clusters to add to a track to get sensible energy association. If necessary iteratively split up clusters to get good match.



③ Track association ambiguities

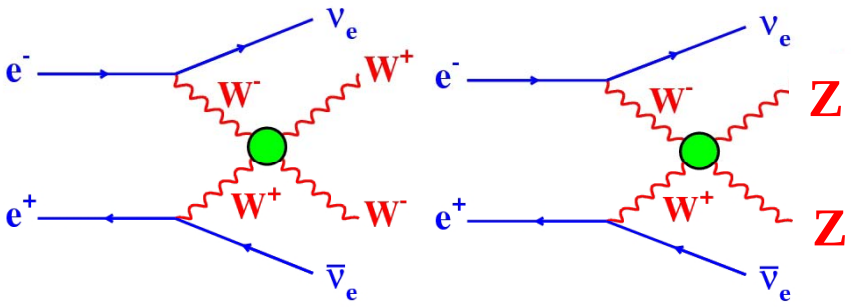
In dense environment may have multiple tracks matched to same cluster. Apply above techniques to get ok energy match.

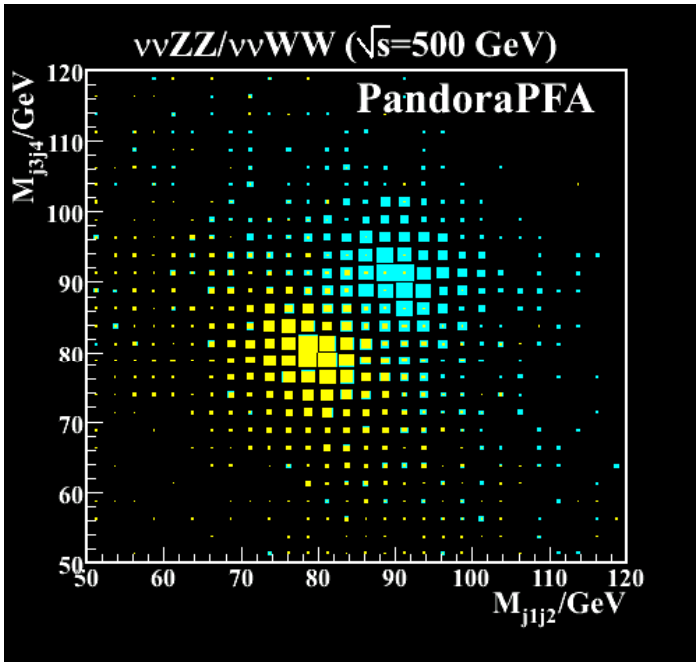


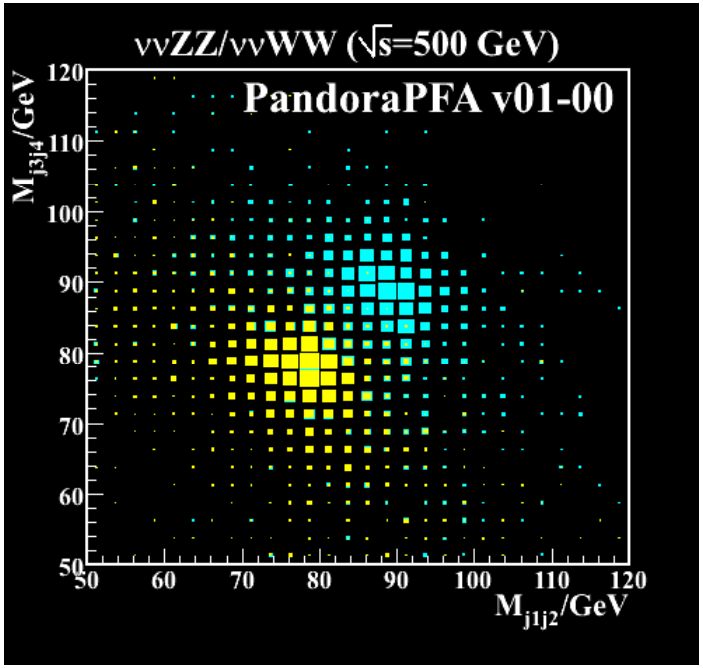
④ "Nuclear Option"

★ If none of above works – kill track and rely on clusters alone (NOT USED)

for completeness…





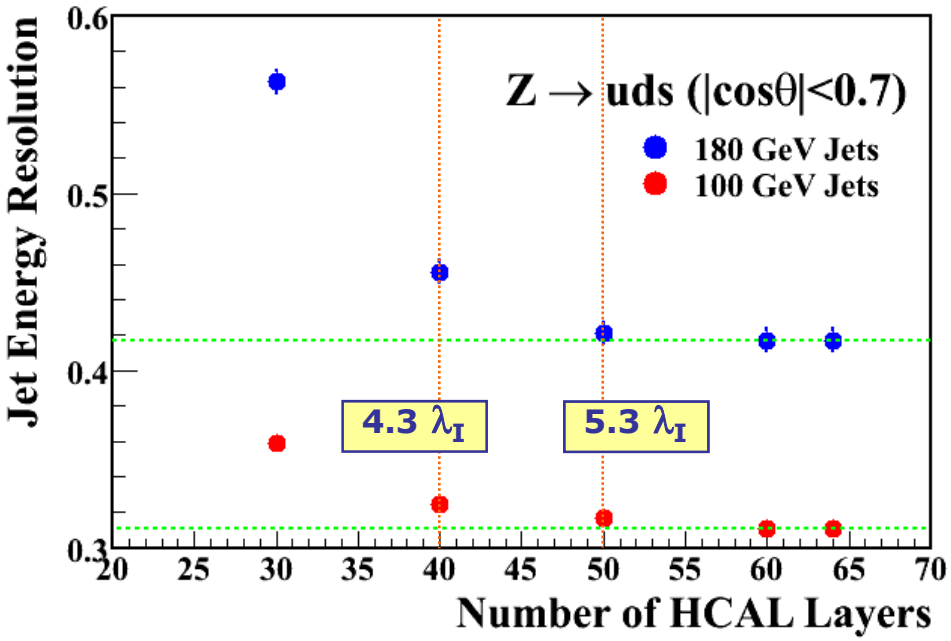


Visible improvement in WW/ZZ separation **(will return to this later)**

HCAL Depth and Transverse segmentation

★ Investigated HCAL Depth (interaction lengths)

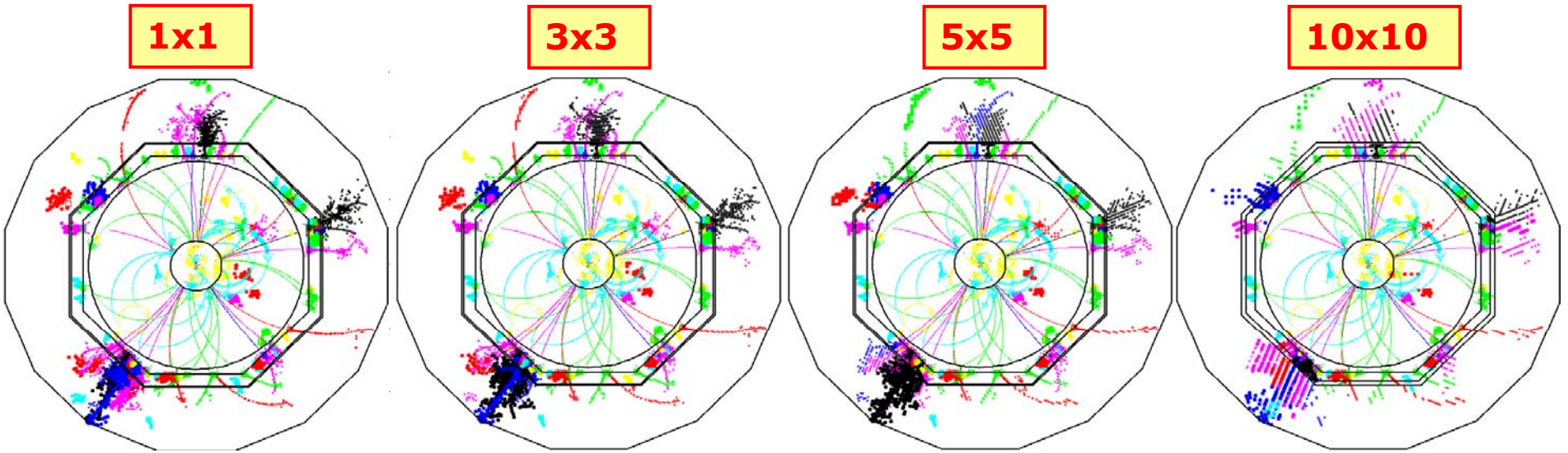
- Generated Z→uds events with a large HCAL (63 layers)
  - approx 7 λ_I
- In PandoraPFA introduced a configuration variable to truncate the HCAL to arbitrary depth
- Takes account of hexadecagonal geometry

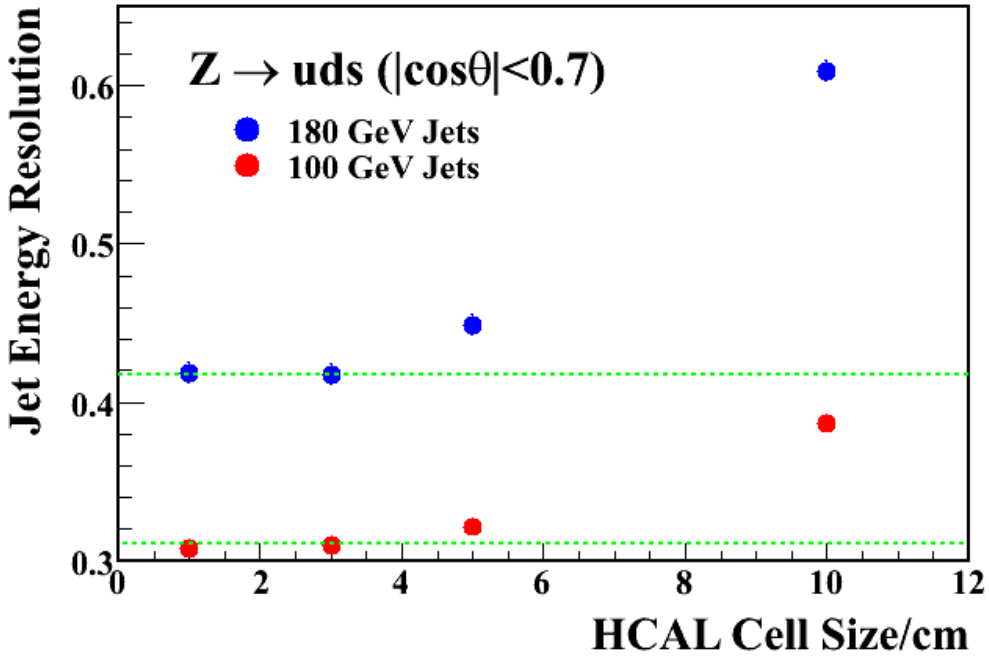


- HCAL leakage is significant for high energy
- Argues for ~ 5 λ_I HCAL

NOTE: no attempt to account for leakage – i.e. using muon hits - this is a worse case

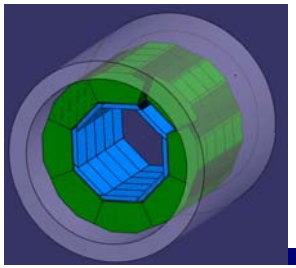
✶ Analogue scintillator tile HCAL : change tile size 1x1 ➞ 10x10 mm²





"Preliminary Conclusions"

- 3x3 cm² cell size
- No advantage ➞ 1x1 cm²
  - physics ?
  - algorithm artefact ?
- 5x5 cm² degrades PFA
  - Does not exclude coarser granularity deep in HCAL



Summary

- 3x3cm confirmed with full PFA
  - But maybe not everywhere – keep in mind for integrated design
- HCAL depth discussion opened
  - TCMT studies are important
  - Pressure on layer thickness and channel count
- Come-back of energy resolution in PFLOW
  - "Energy momentum-assisted clustering" depends on energy estimate