ILD Calorimetry Concept

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ILD Philosophy

1) Particle Flow **calorimetry**

- “basic requirement”: sep of $H \rightarrow WW/ZZ \rightarrow 4j$
  - $\sigma_Z/M_Z \sim= \sigma_W/M_W \sim= 2.7\% \oplus 2.75\sigma$ sep $\Rightarrow \sigma_E/E$ (jets) $< 3.8\%$
  - $60\%/\sqrt{E} \rightarrow 30\%/\sqrt{E} \Leftrightarrow +\sim 40\%\ \mathcal{L}$

2) Large TPC

- Precision and low X_0 budget
- pattern recognition

3) Precision by Silicon detectors: vertex & Calo SET

- flavour tagging

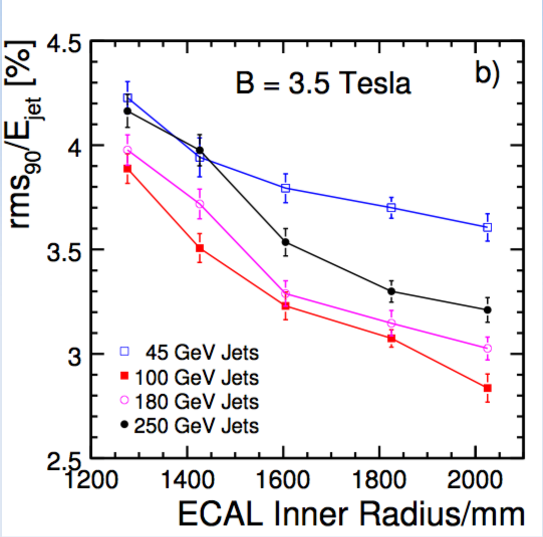
4) Large acceptance

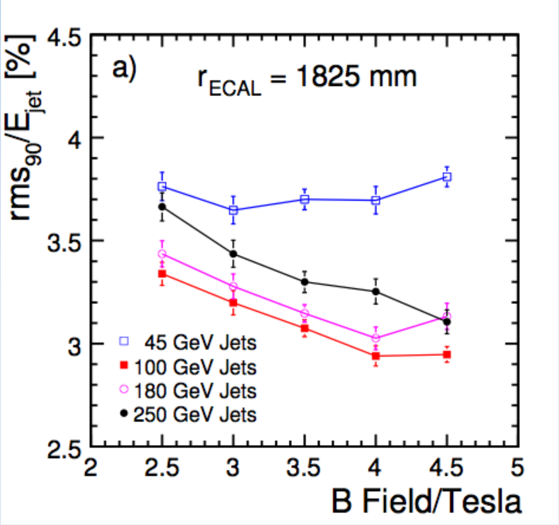
- Fwd Calorimetry:
  lumi, veto, beam monitoring

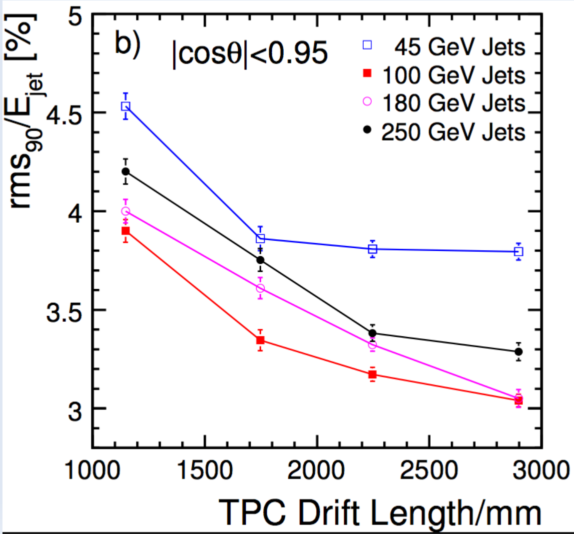
- Merging of LDC & GLD → ILD
  - “best dimension”
  - Optimisation studies

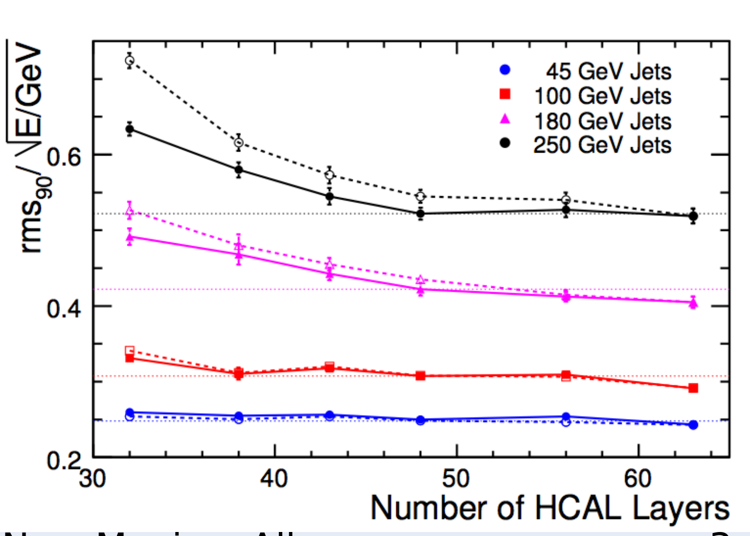
Geometry: dimensions at large

- Mix of LDC & GLD parameters
  + optimisation studies based on PandoraPFA
- Basic measuring rod
  - σ_{Ej}/ Ej (& Bgd) vs
    - TPC dimensions
    - Radius Magnet (HCAL thickness)
    - B field
- Other perfs:
  - τ reconstruction
  - ...
- Done for the baseline (Si-W ECAL + Scint HCAL)



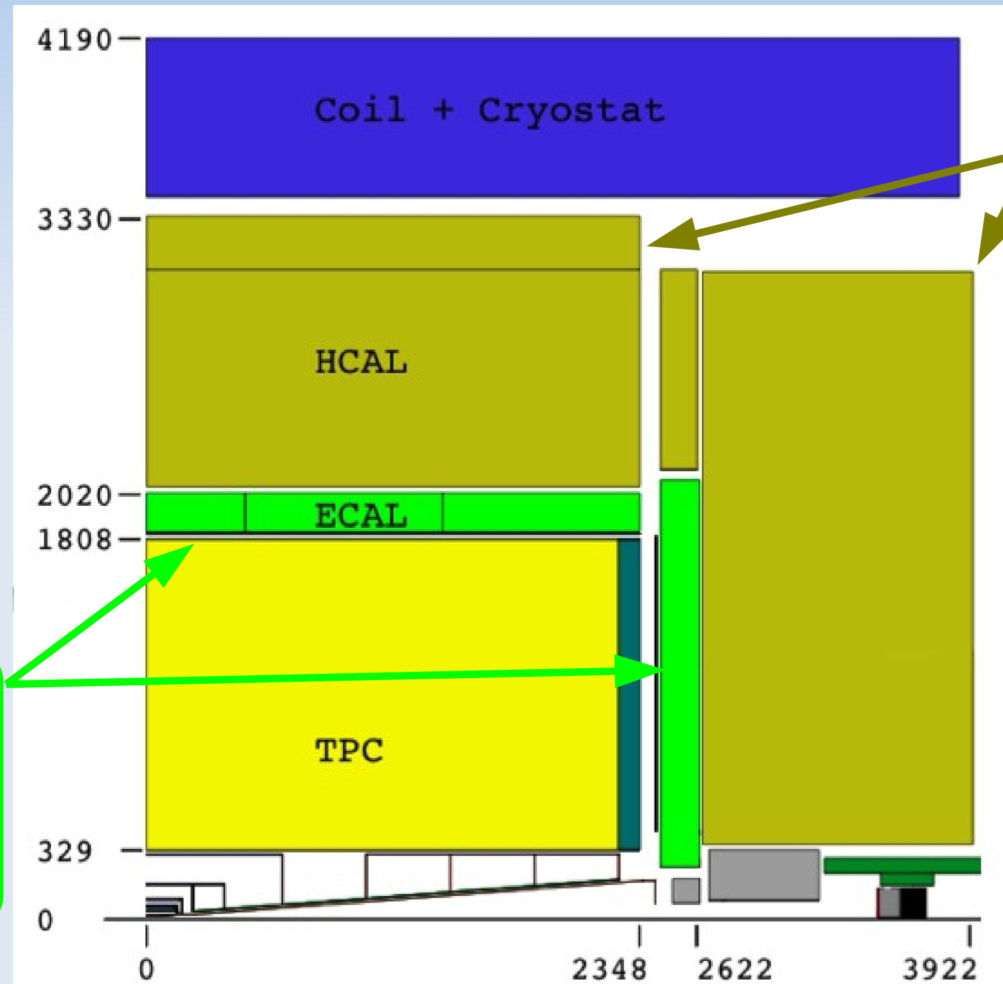






Dimensions & options

- B = 3.5 T

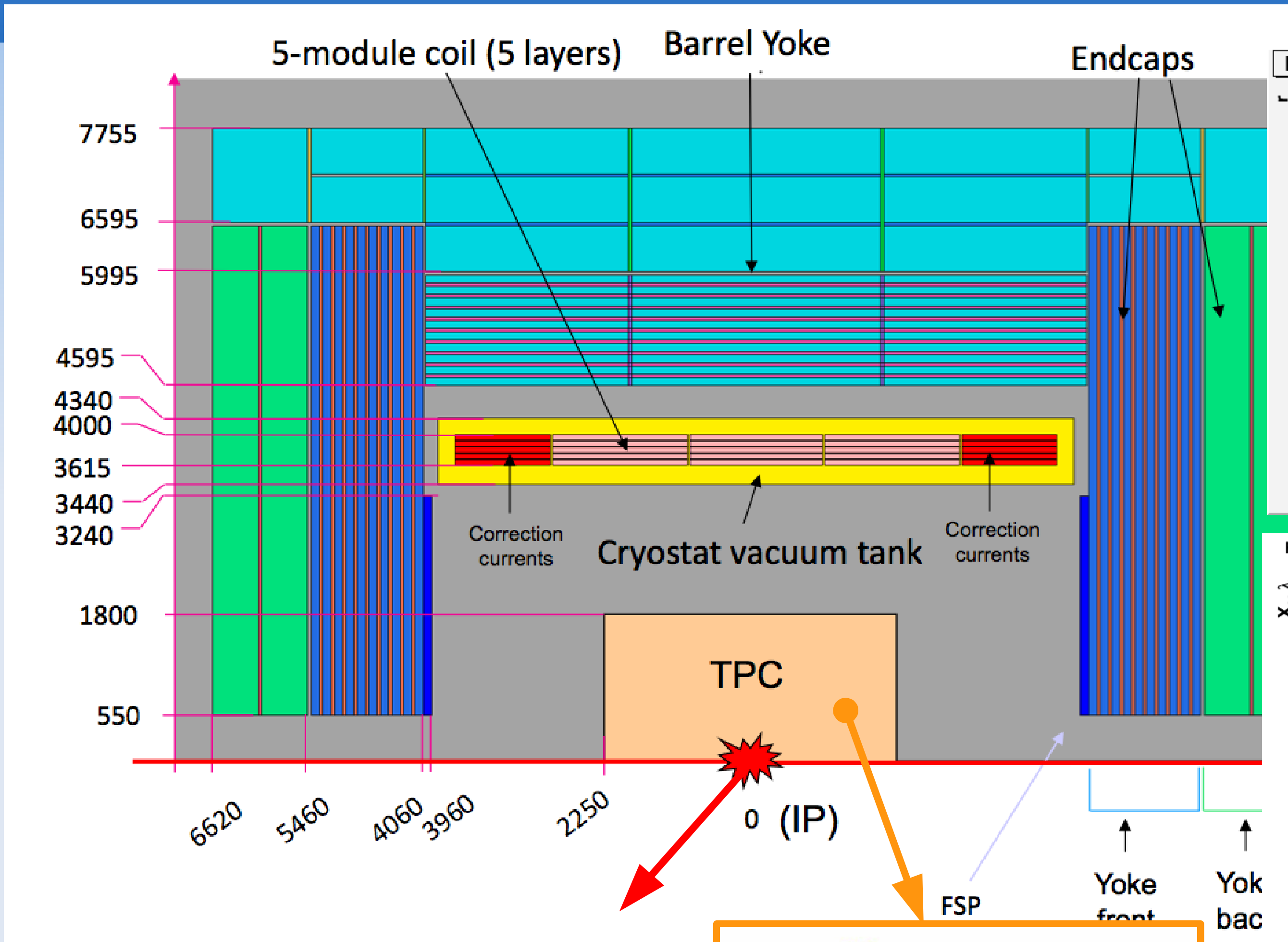


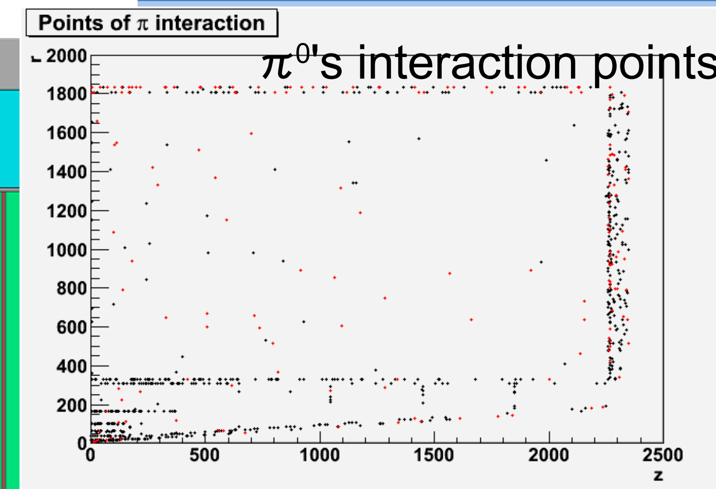
HCAL
- Analog: Scint/Fe
- Digital: Rpc/Fe

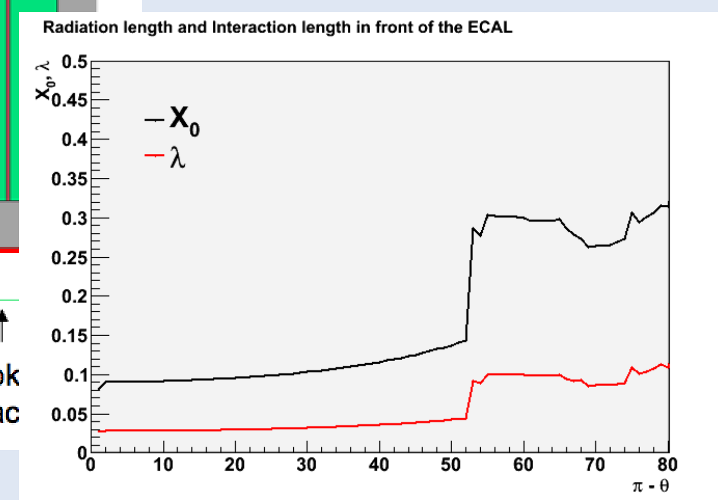
ECAL
- Si/W
- Scint/W
- Maps: Digital

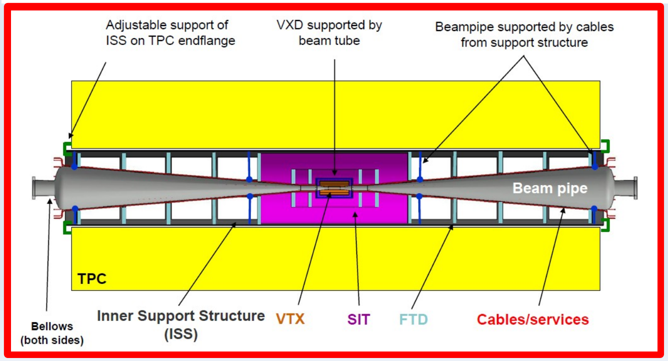
4

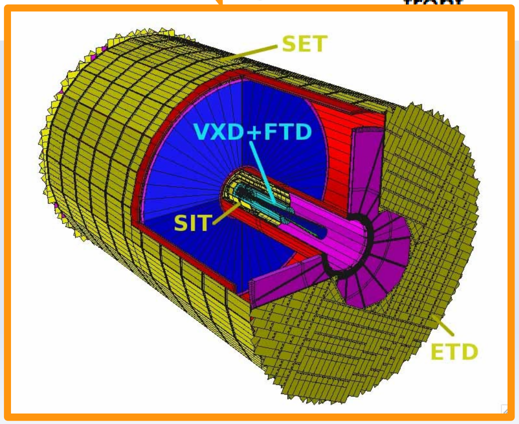
Surroundings







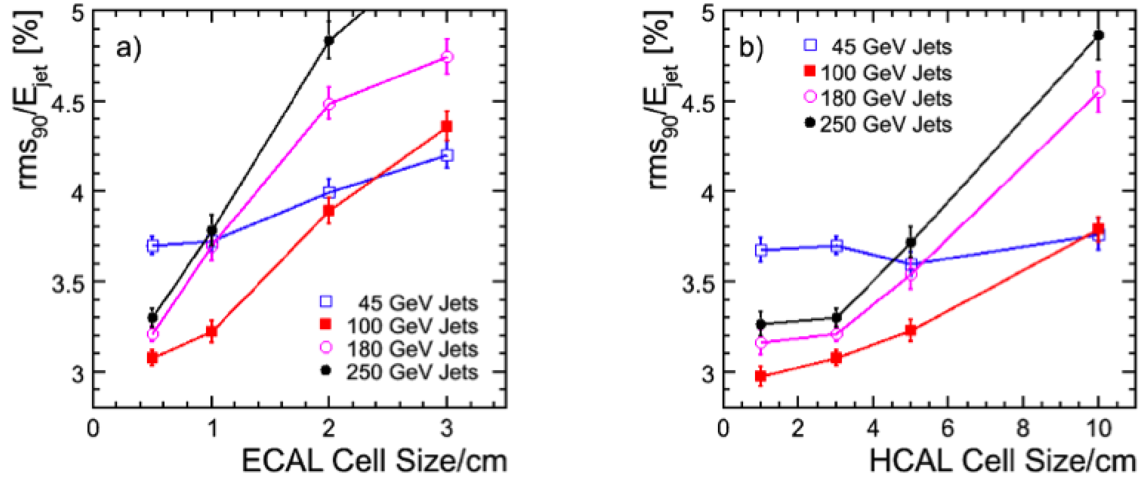


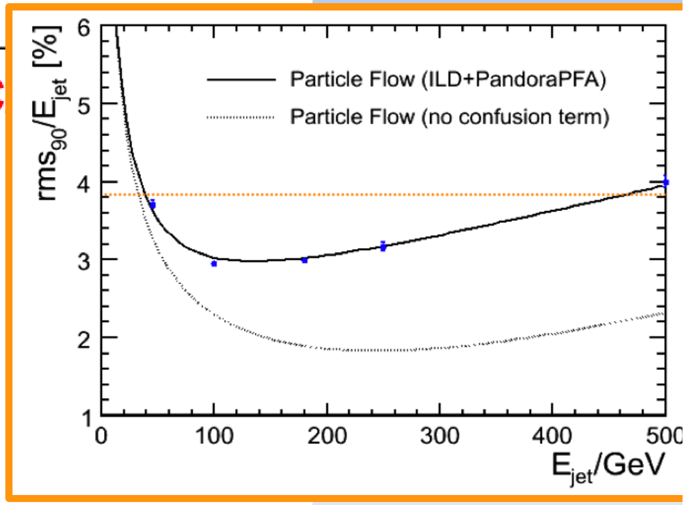


Optimisation

PFA Optimisation: Calorimeter Segmentation

★ Starting from LDCPrime vary ECAL Si pixel size and HC





★ **ECAL Conclusions:**

- Ability to resolve photons in current PandoraPFA algorithm strongly dependent on transverse cell size
- Require at least as fine as 10x10 mm² to achieve 4.0 % jet E resolution
- Significant advantages in going to 5x5 mm²
- For 45 GeV jets resolution dominates (confusion relatively small)

★ **HCAL Conclusions:**

- For current PandoraPFA algorithm and for Scintillator HCAL, a tile size of 3×3 cm² looks optimal
- May be different for a digital/semi-digital RPC based HCAL

Not yet complete

Calorimetry organisations

- Different central Calorimeter types envisaged
  - All in CALICE collaboration
- Common feature
  - High granularity & compact design
  - aim at embedded readout, digitisation and storage electronics
  - Inter-spill readout
  - power pulsing
  - common DAQ
- Fwd calorimetry in FCAL collaboration

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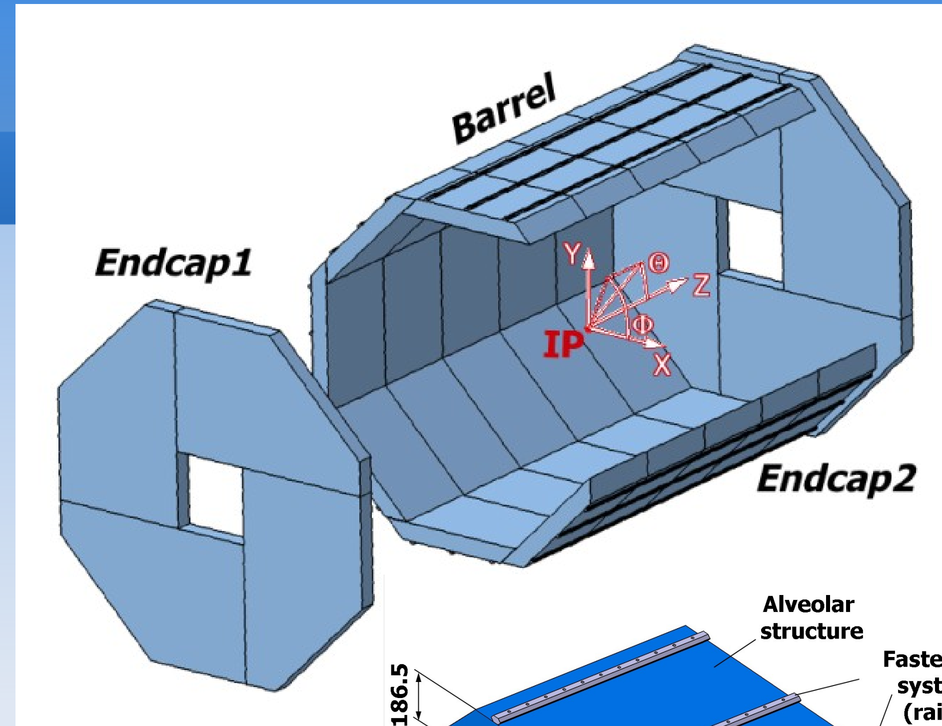
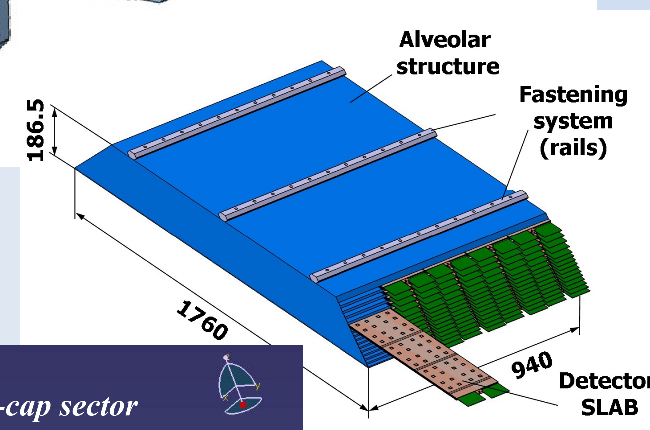
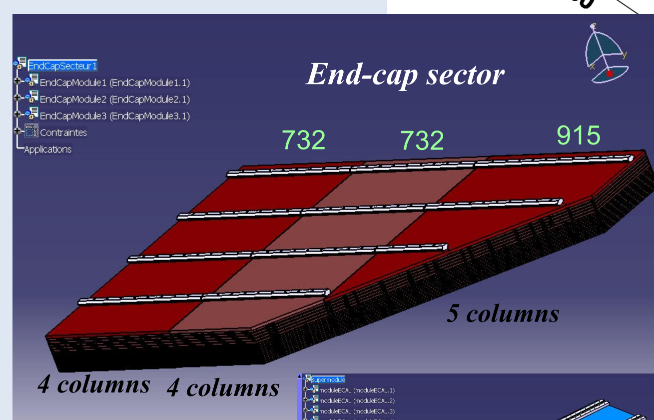
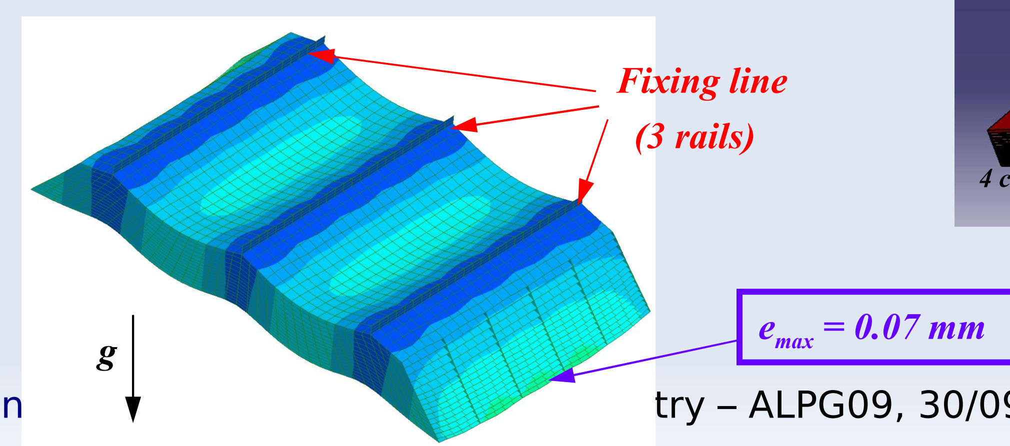
ECAL structure

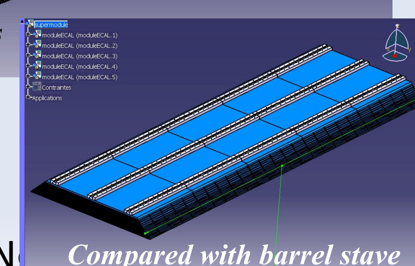


- Barrel: 5 octogonal wheels
  - R_{min} = 1808 mm; R_{max} = 2220
  - Width = 940mm
- End-caps: 4 quarters
  - $\varnothing_{min}$ = 800 mm
- Carbone / Tunsgten structure
  - filled with Si or scintillators (option MAPS/DECAL)
- Extensive mechanical simulation & tests



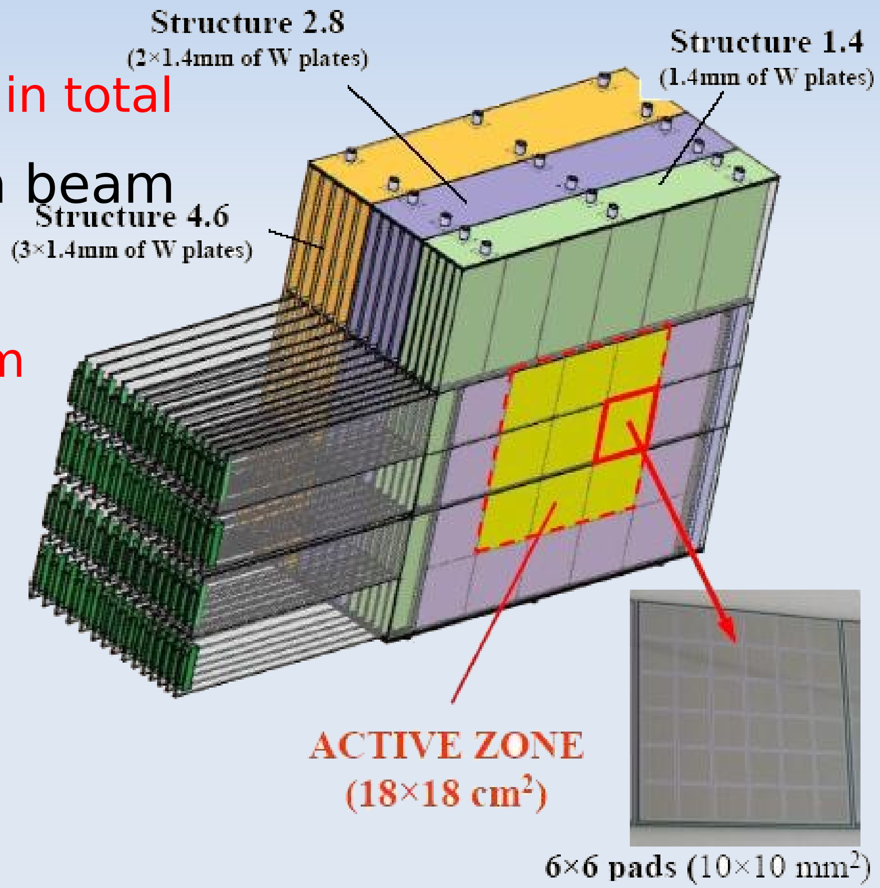






Si/W ECAL (1)

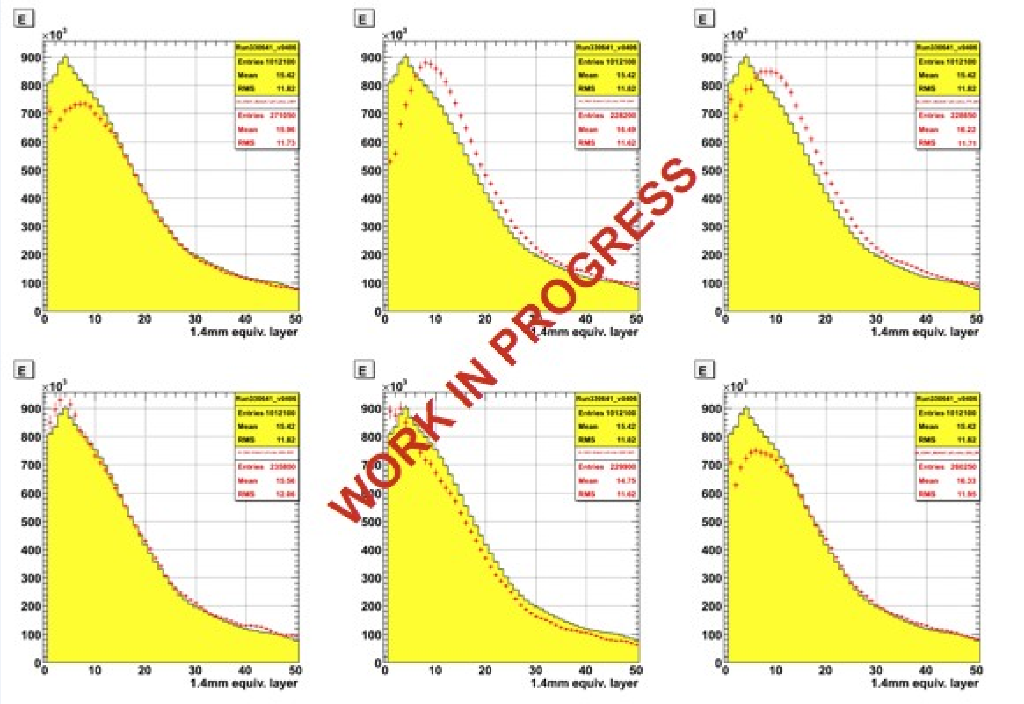
- Structure
  - 20 layers of 2.1 mm (0.6X_0) W + 9 layers of 4.2mm (1.2X_0) W
  - 5x5 mm² granularity of Si ~ 108 M cells in total
- 10×10 mm² physics prototype tested in beam
  - FLC_PHY4=3 chips with analog readout
  - Energy resolution measured in test beam ~ 16.6%/√E(GeV) ⊕ 1.1% with S/N ratio of 7.5 for a mip signal
  - CERN 2006, 2007 FNAL 2008, 2009
- Critical points
  - power pulsing
  - Si sensors price (3000 m²)



SiW ECAL results

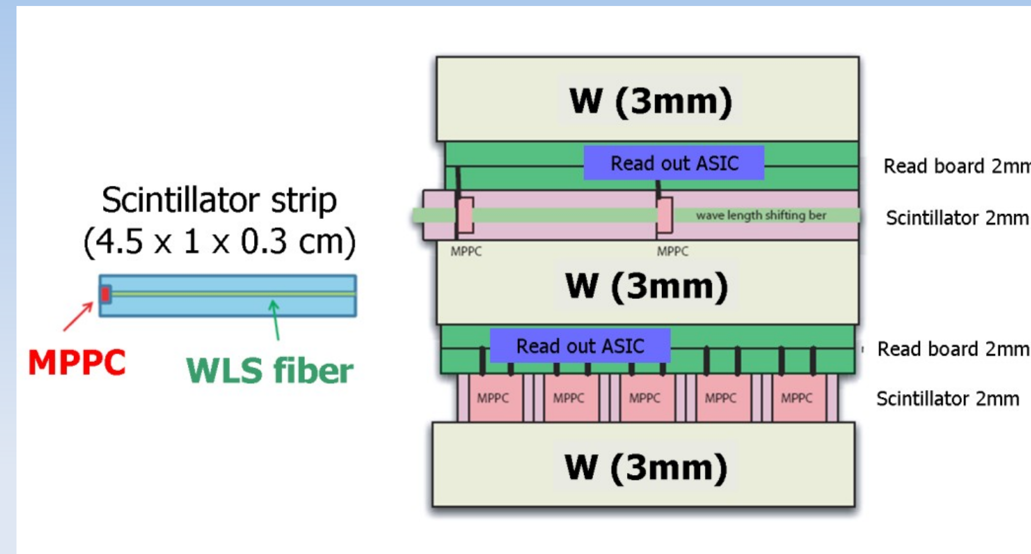
Too many to be fair... Check R. Poeschl Talk for more details

- Square events at high E (Guard Ring X-talk)
- Excellent long term stability (σ_{mip}/mip ~ 1/50 on 2 yrs)
- Good agreement EM Sim/Data (⇔ understanding of detector)
- Optimization of E reconstruction
  - Correction of dead regions
  - pixel counting & weighting
    - layer optimisation
- Data analysis on going:
  - Reconstruction of shower shapes
    - improved position & direction rec.
  - Hadrons in ECAL
    - Geant testing with Tungsten

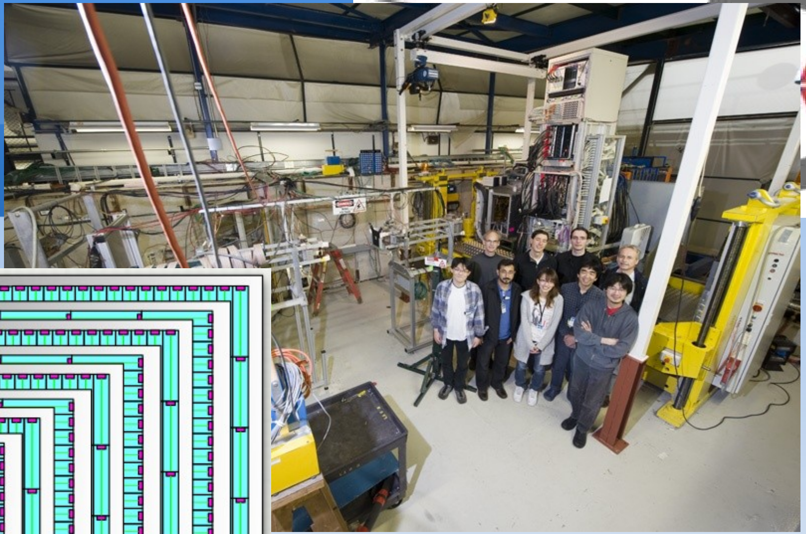


Scint/W ECAL (1)

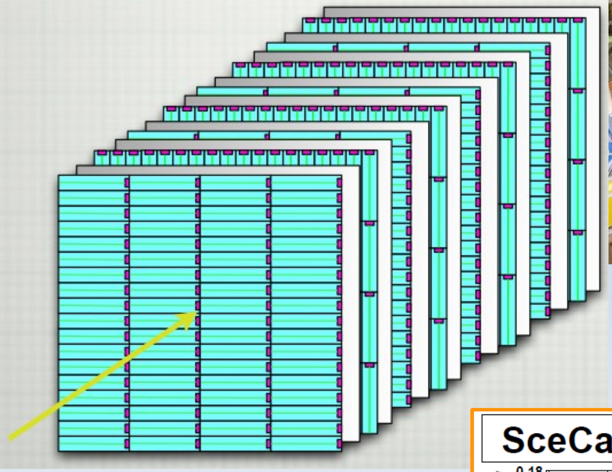
- ILD Structure
  - 24 layers of 3 mm W
    2 mm scintillator + 2 mm r.o.
    - $21X_0$ in total
  - 10×45 mm² scintillator strips to reduce # of ch
  - Wavelength shifter fiber and multi-pixel photon counter (MPPC) readout
  - Energy resolution ~ 14%/√E(GeV) ⊕ 2%

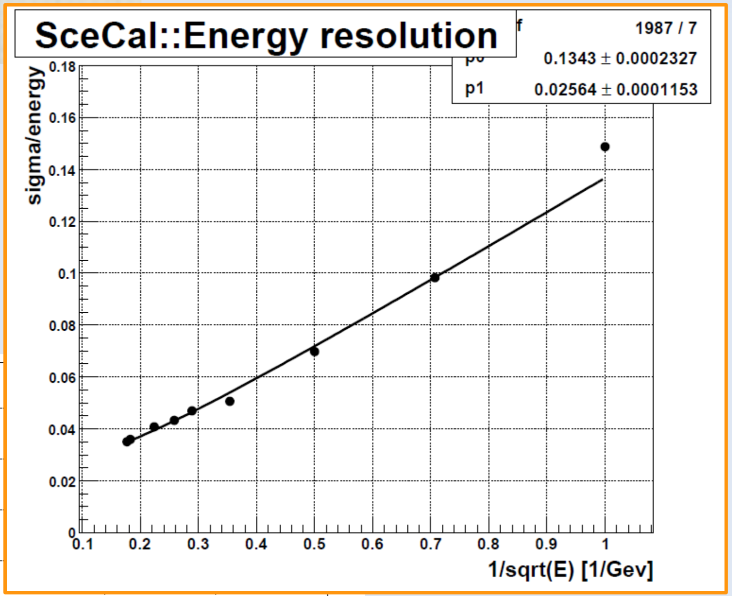


Scint/W ECAL (2)

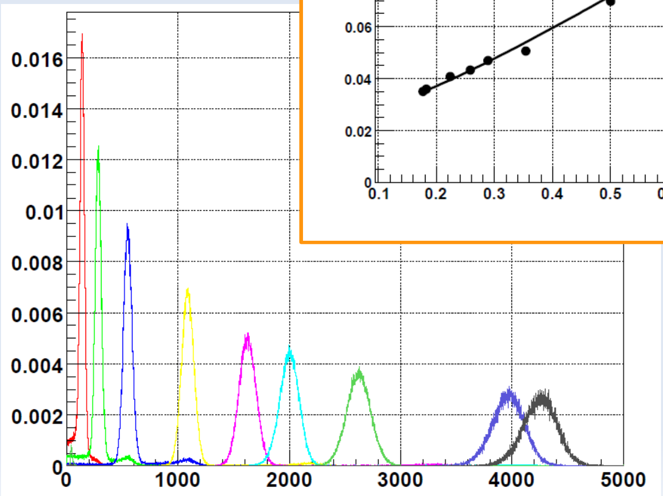


- Physics prototype
  - tested in summer 2009 at FNAL
    - 30 layers of 72 strips
    - 3.5mm W
  - MPPC Correction
    - temperature
    - saturation
    - Slightly Improved resolution
  - Reconstruction code





- MPPC Developments
  - Irradiation tests
    - ~OK < 60 Gy in γ, 10^8 n/cm^2
  - Stability
  - Simulations



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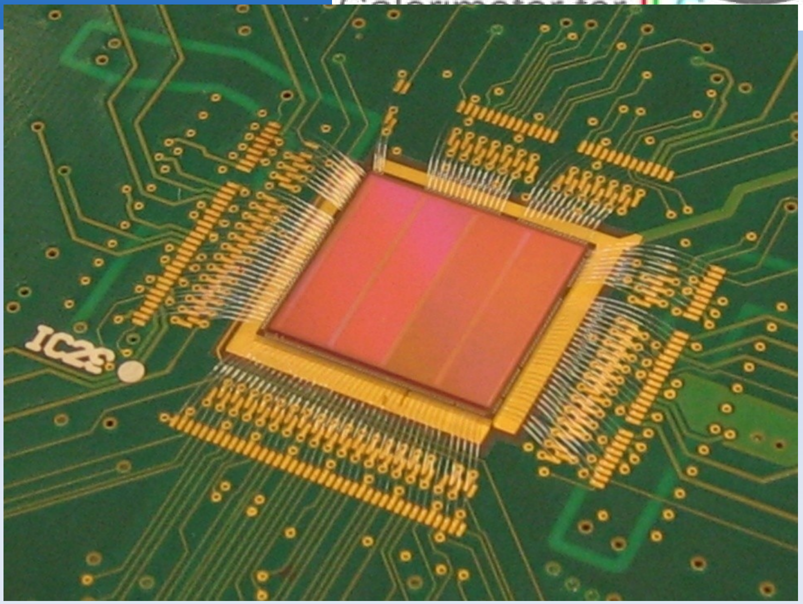
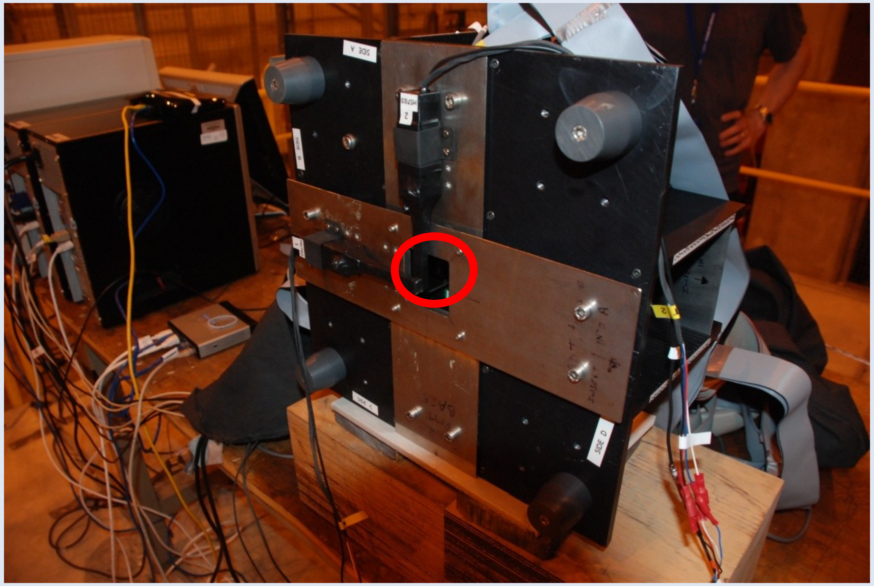
DECAL (MAPS) option

- Ultimate Spatial resolution
  - 50×50 μm² pixels
    - TERA Pixel detector
  - TPAC readout chip
    v1 = 168x168 pixels;
    79.4 mm²
- Expected resolution (pixel counting)
  - $13\%/\sqrt{E(GeV)} \oplus 1\%$
- Status:
  - successful CERN TB of 6 sensors summer 2009
  - New SPiDeR collaboration
  - Physics prototype planned for 2012
- Critical points
  - integration, Power consumption, services, price, ...





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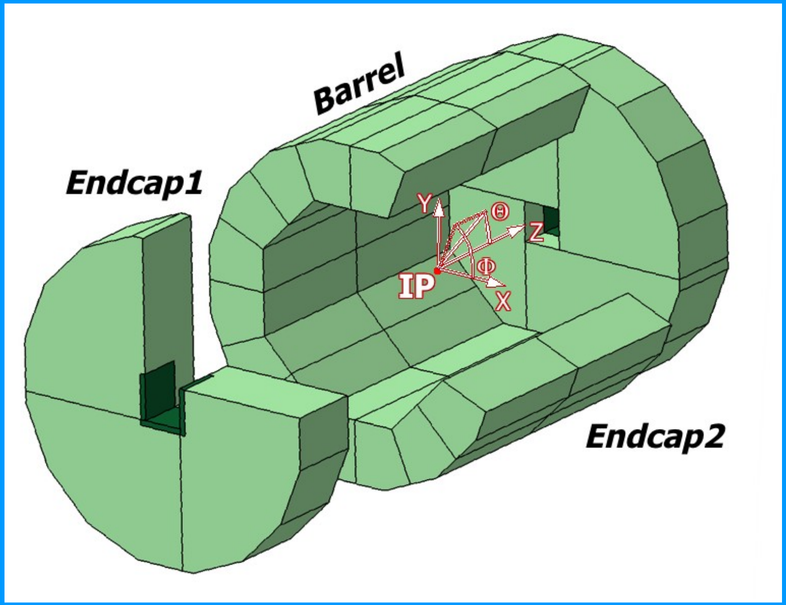
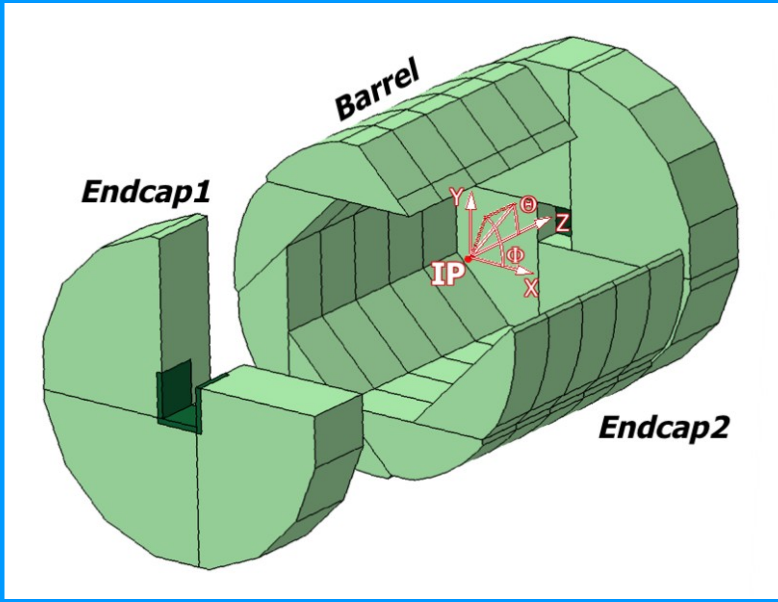
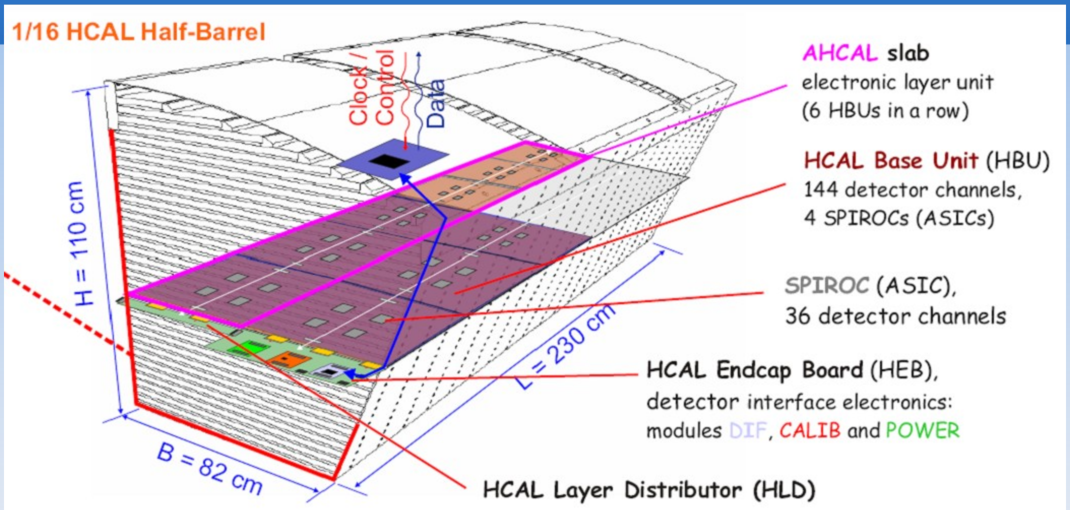
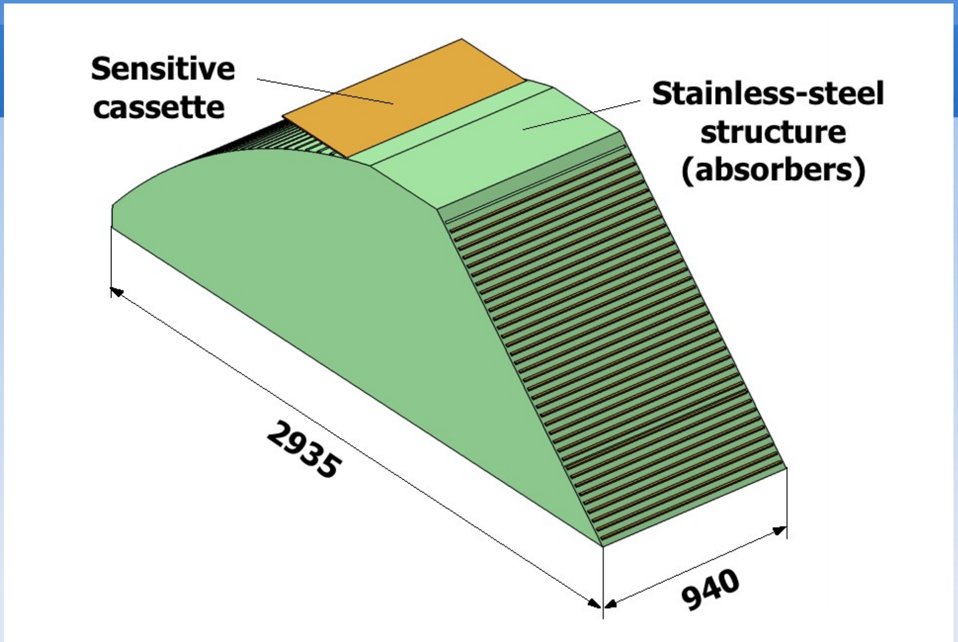
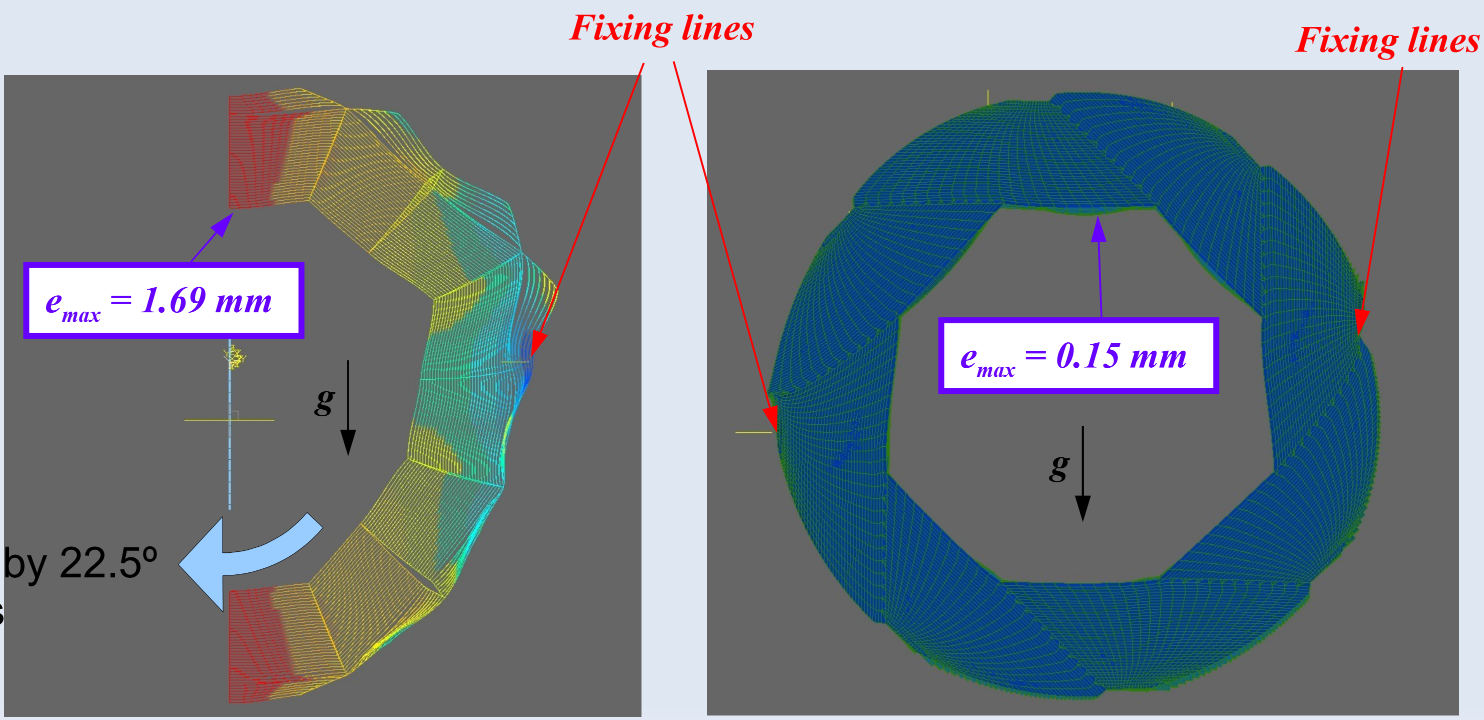
Geometries for the HCALs

- Sensor agnostic ▸ 48 layers of 20mm SS → 5.7 λ_I (6.6 with ECAL)

DESIGN 1 (TESLA)	DESIGN 2 ("a la Videau")
	
Better access to electronics	better hermiticity
Larger radius	
	mechanical rigidity

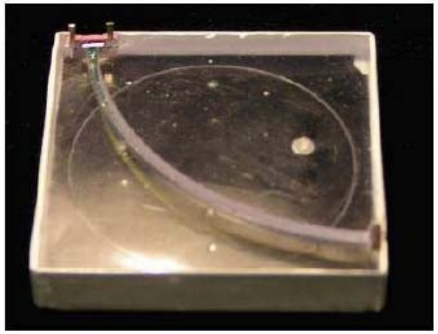


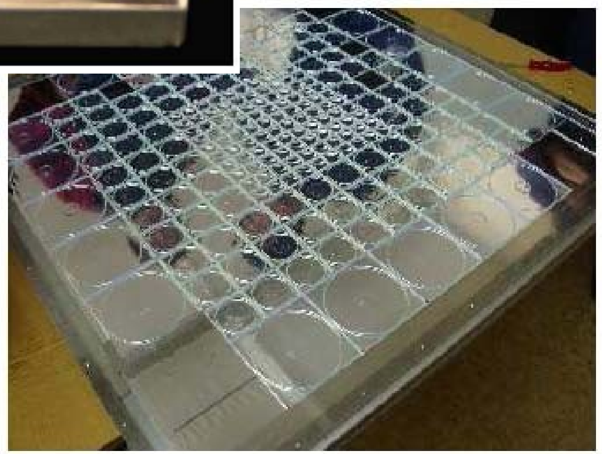




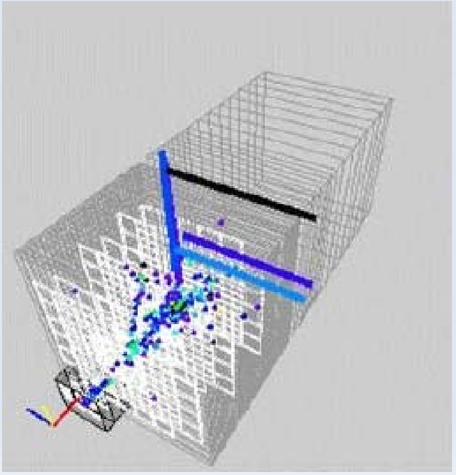
Rotation by 22.5º improves

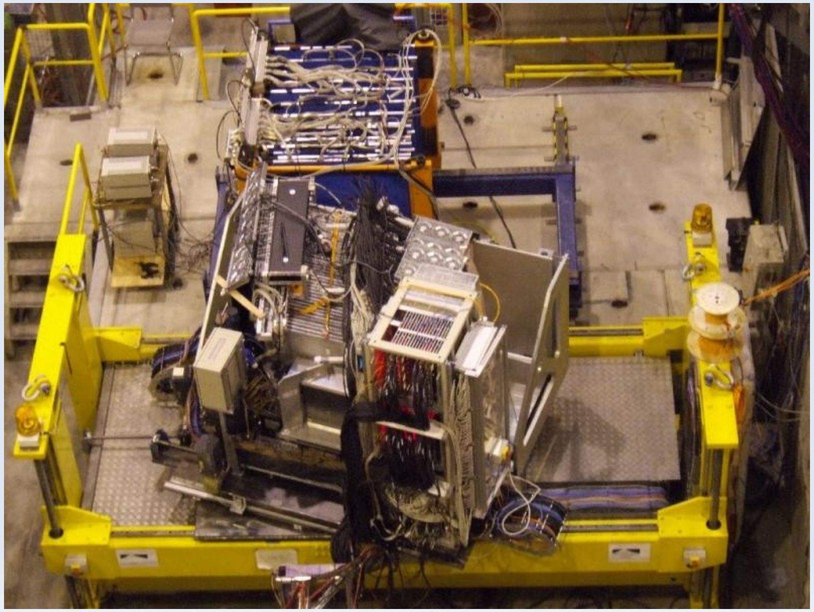
AHCAL: Scint/Fe with SiPM





- 3×3 cm^3 × 3mm scintillator tiles
  - WLS fiber readout by SiPM (studies without)
  - Energy resolution~ 49.2%/√E(GeV)⊕2.3%
- Physics prototype
  - 38 layers Scint + 2cm SS → 5 λ_{had}
  - extensively tested with ECAL + TCMT
    - 2006 → 2008
- Critical element
  - calibration, stability

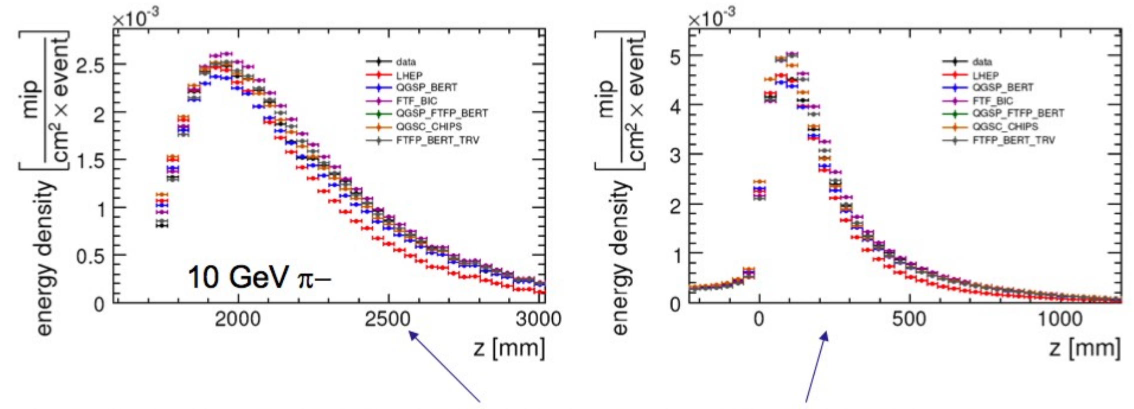




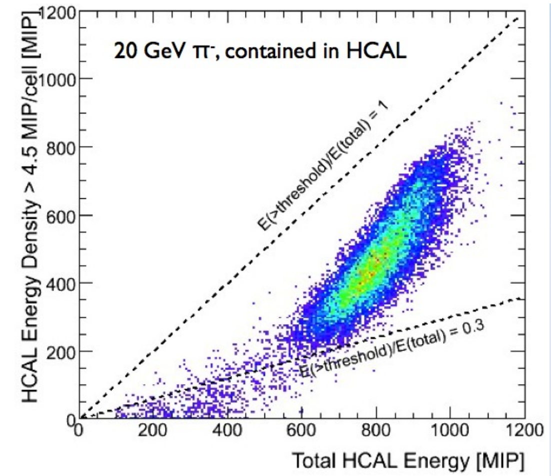
AHCAL results

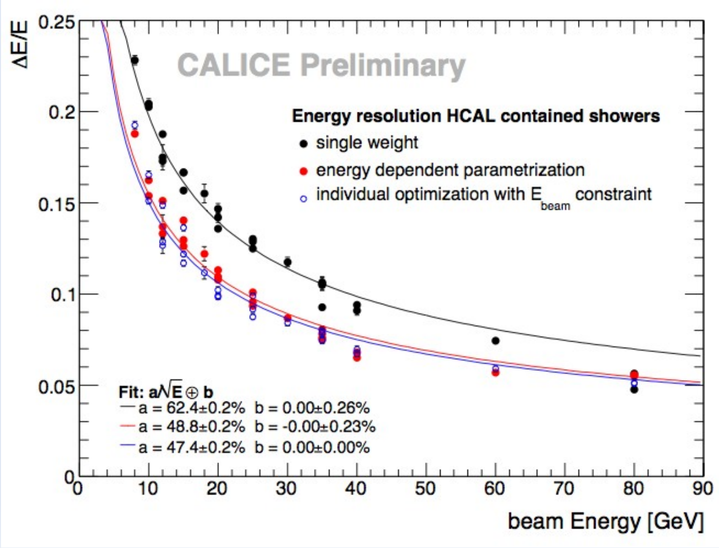
Many many results…
See Angela Lucaci-Timoce talk

- Understanding of calibration
  - LED system
  - Scint + SiPM tº & saturation correction
- Good overall agreement Data/MC
  - EM response 10-50 GeV
  - HAD response
    - Test bench for Geant4
    - Shower start & profile
    - Shower spatial separation
    - Leakage corrections
- Resolution improvement by weighting technique
- Calibration from track segments



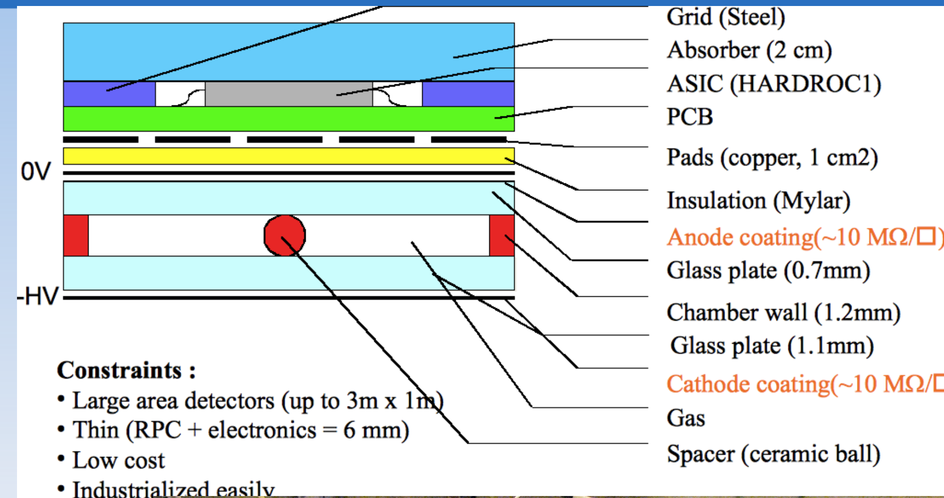
Presents longitudinal profiles from detector start and from shower start for various energies and MC models

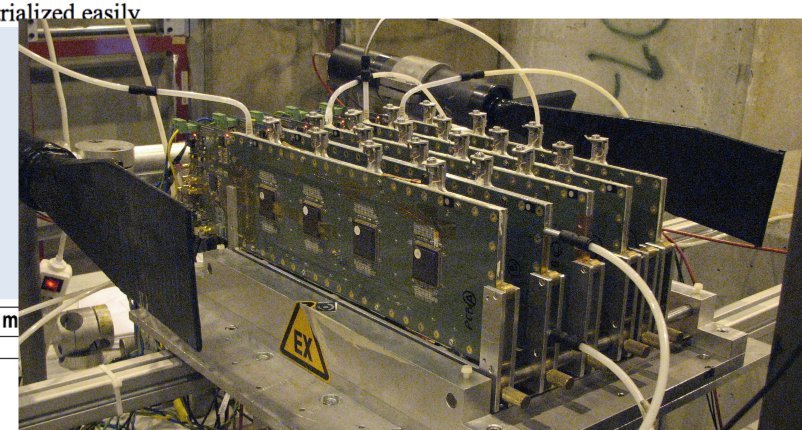


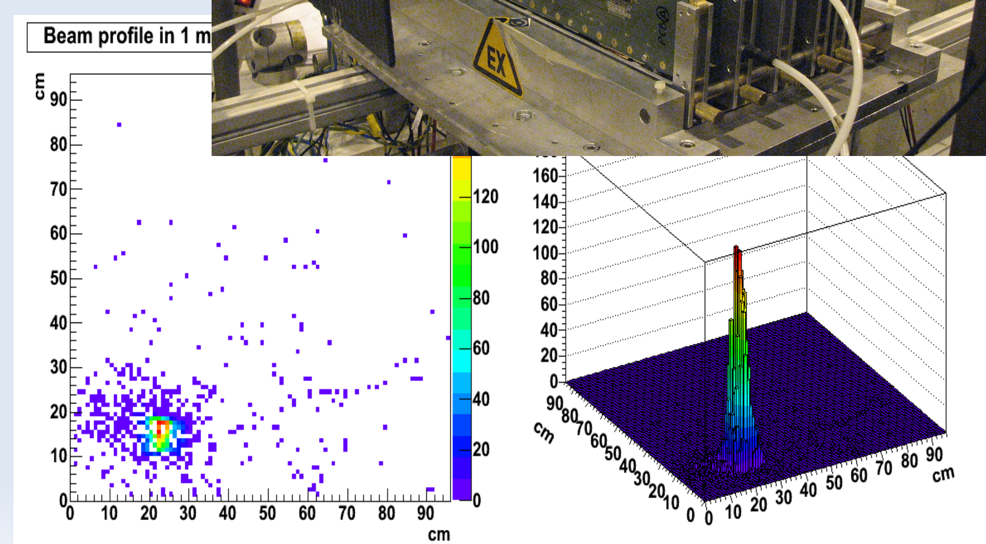


DHCAL : semi-digital gaseous

- Glass Resistive Plate Chamber (GRPC) with 1×1cm² readout pads
  - Semi-digital (2bits) readout
  - Expected raw σ_{Ej}/Ej ~ analogue one
- Prototypes chambers
  - small (8×32 cm² and large 1m²) RPC tested
  - with embedded electronics (HARDROC1)
- R&D
  - on semi-conductive paints
    - stability & industrial painting
  - On (fast) semi-conductive glass
  - Gas distribution
    - and replacement for Isobutane

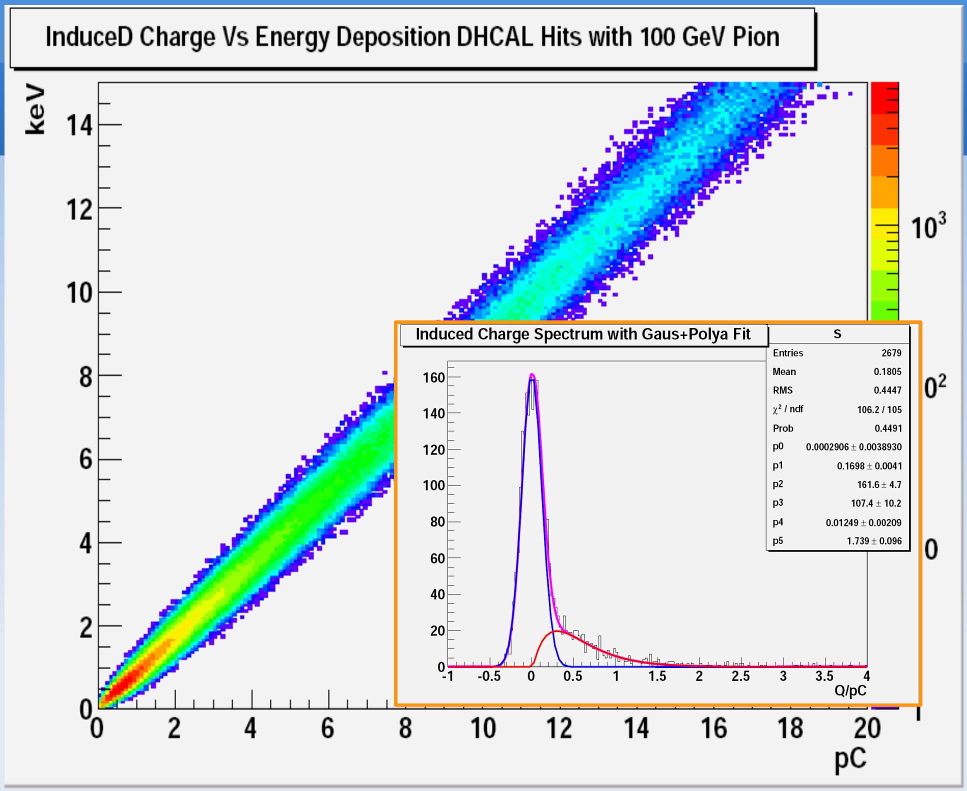


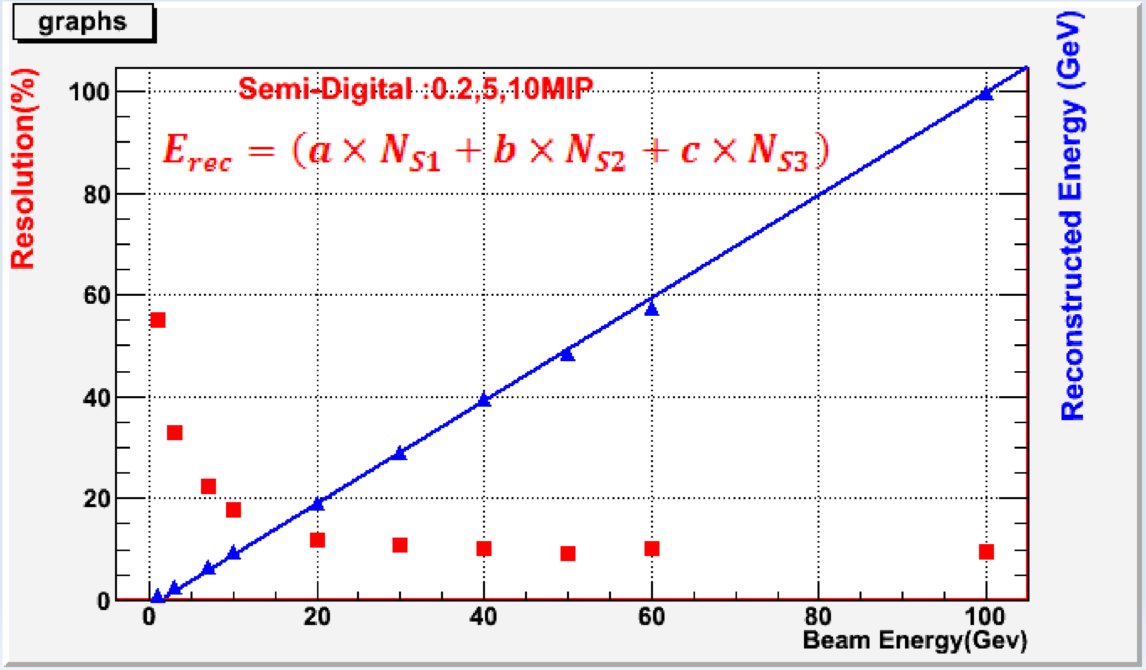




SDHCAL (2)

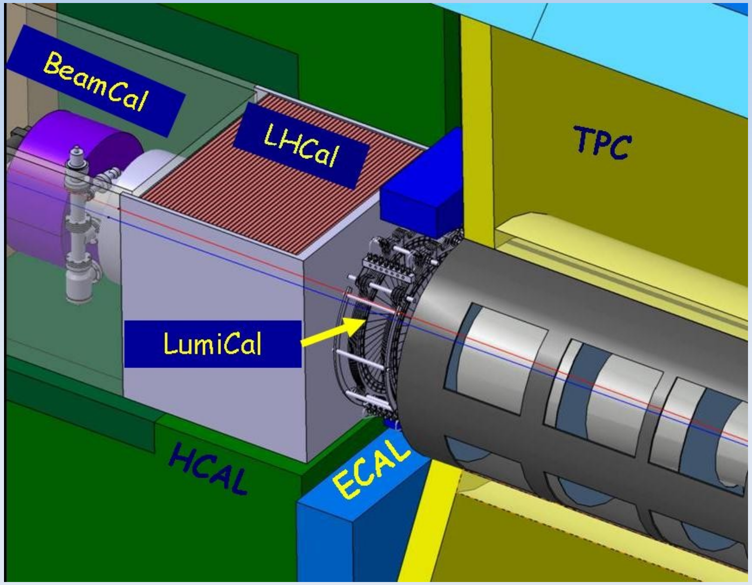
- Simulation
  - Digitisation : response from RPC
- Reconstruction
  - Efficiency & multiplicity
  - Energy from hits
    - ∑ Wi×Ni ; Neural network
  - Simulated hadronic response

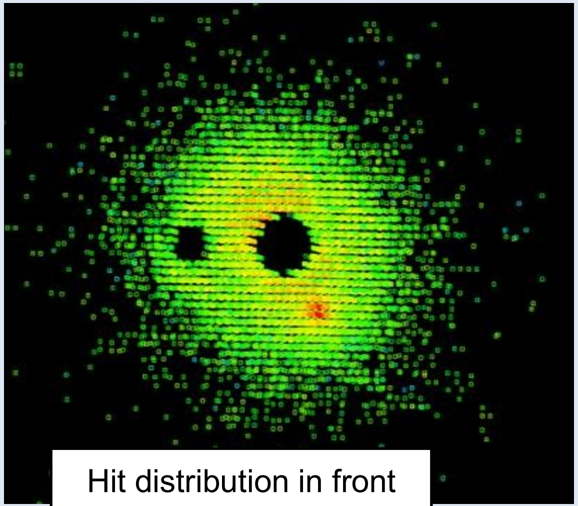




Forward Detectors

- LumiCAL
  - Si/W
  - 32 – 74 mrad
  - Luminosity measurement accuracy of < 10^{-3}
- BeamCAL
  - 5 – 40 mrad
  - Hit by e+e- pair-background caused by beam-beam interaction
  - Si, GaAs, or diamond – W sandwich
- Pair-monitor
  - Placed in front of BeamCAL
  - Measure beam shape from the distribution of Pair-background
  - Si pixel detector
- LHCAL
  - Locates after LumiCAL
  - Si/W sandwich, $4\lambda_I$



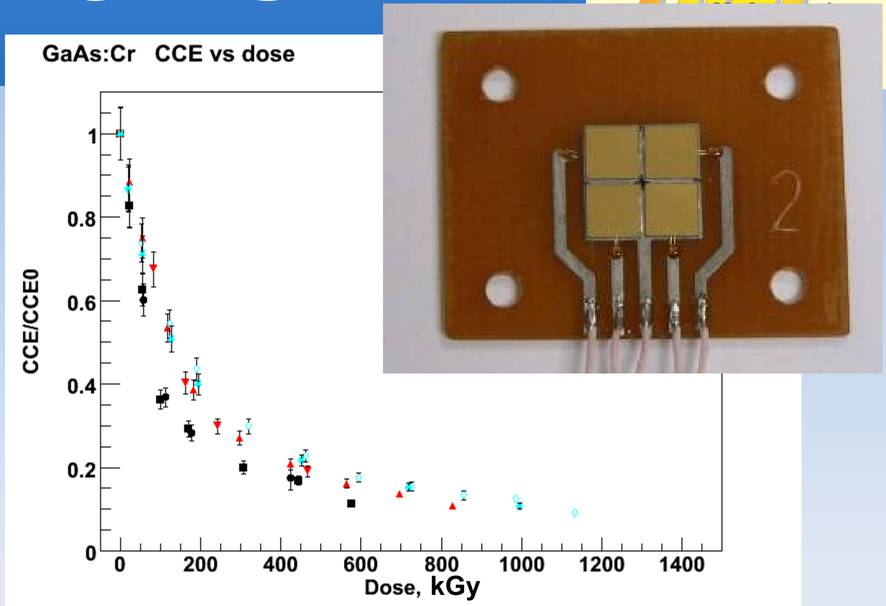


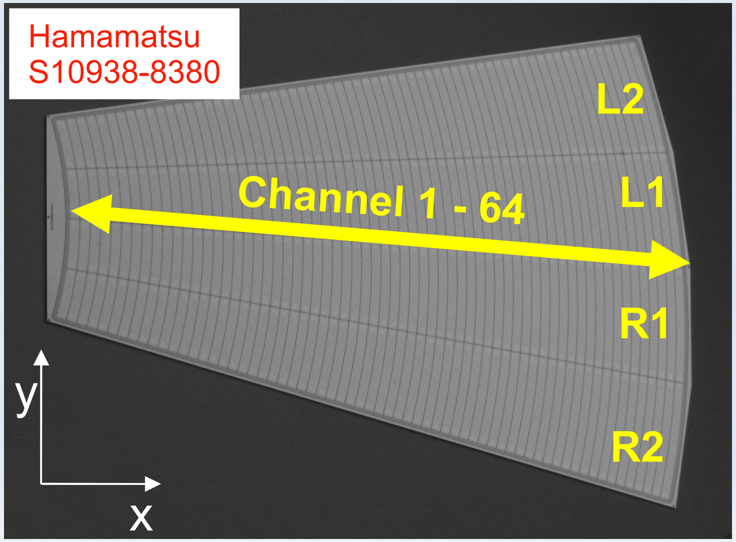
Hit distribution in front of BeamCAL

20

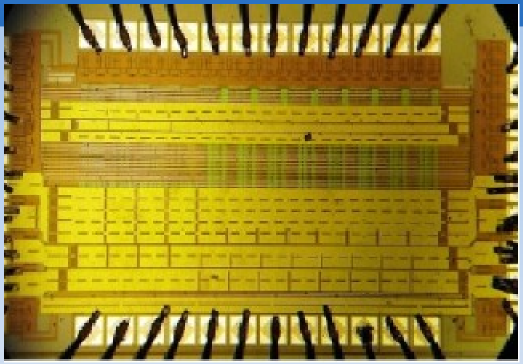
FCAL recent developments

- BeamCal Sensor Prototyping
  - n-type GaAs(Te,Sn)+Cr
    - made by SIPT (Tomsk)
    - OK ≤ 500 kGy (10 MeV e^-)
  - sCVD diamond (E6), 5×5×0.3 mm^3
    - ≤ 10 MGy (^{90}Sr)
  - Sapphire: Single crystal, 1x1 cm^2
    - ~ 30 % of the initial charge collection eff. after 12 MGy
  - No choice done so far
- LumiCal
  - High resistivity n-type Si
    - 10,8× 4…12 cm^2 (6 Inch Wafers)
    - I(V) & C(V) meas. → successful

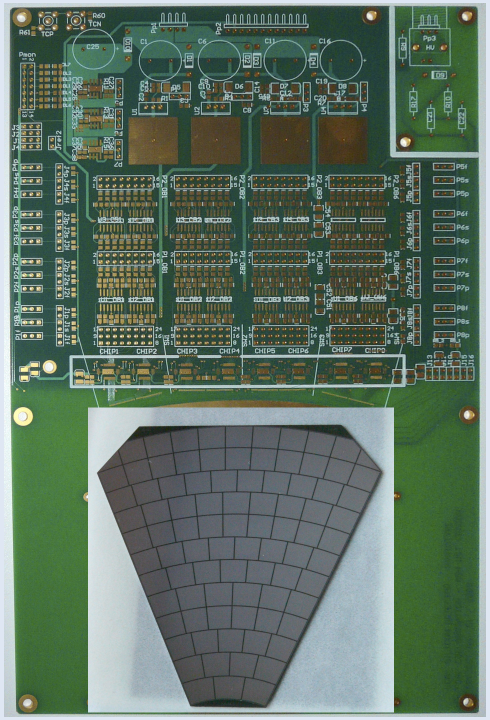




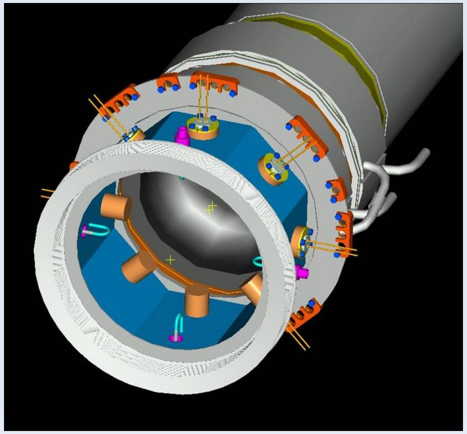
FCAL recent developments(2)



- ASIC Development and Test
  - BeamCal
  - LumiCal
    - 8 channel preamplifier,
      lab tests, matches the requirements (power consumption, noise, lin.)
    - 1 ch. 10 bit ADC, 35 MHz on test → multichannel



- Test beams
  - with various sensors: scheduled for 2010
  - diamond sensor tested in bunched e- beam
    - beam profile, no EMI
- Applications as beam monitors:
  - 4 diamond & 4 sapphire sensors for FLASH
  - CMS : BCMF1



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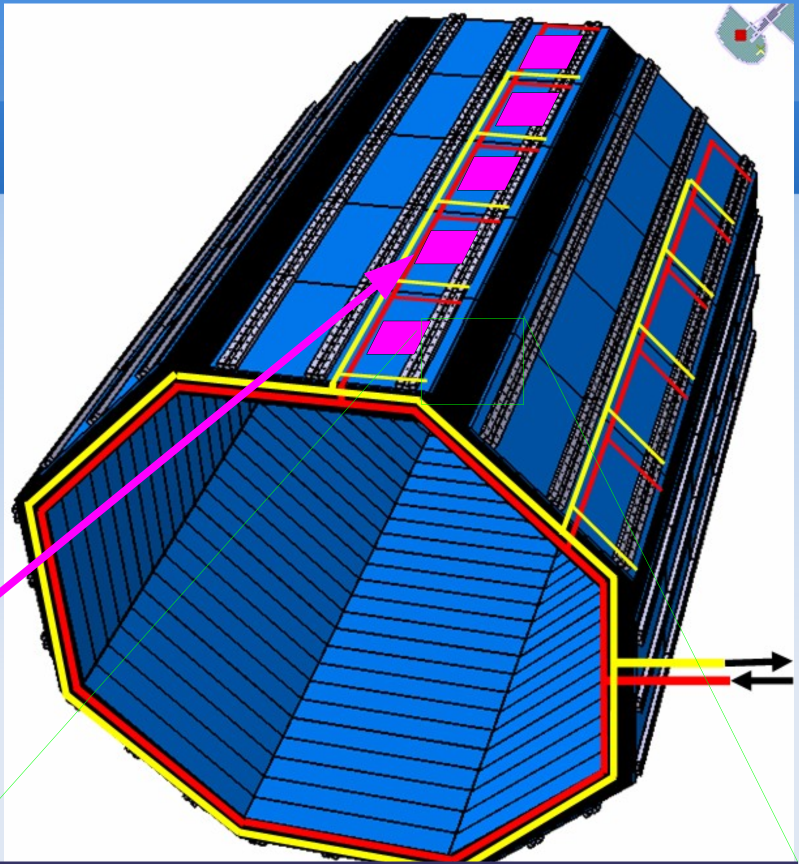
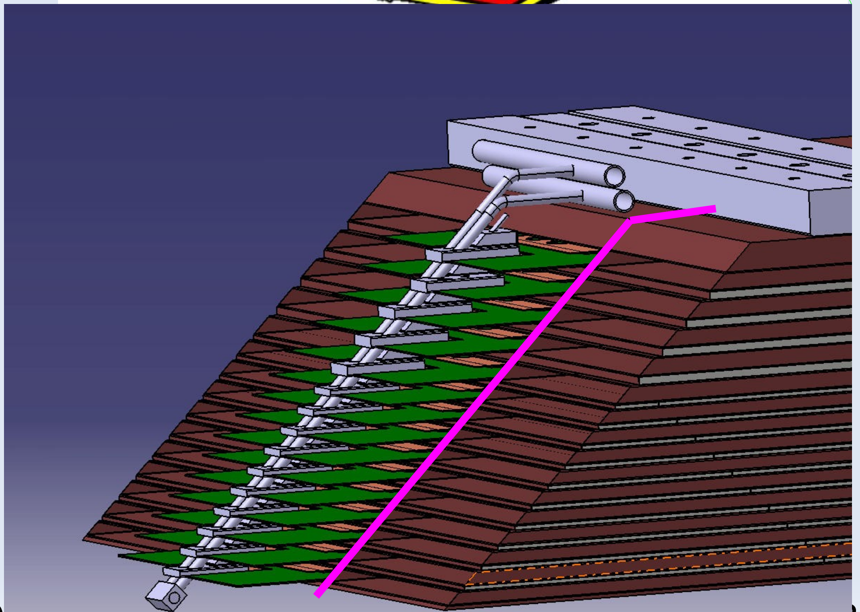
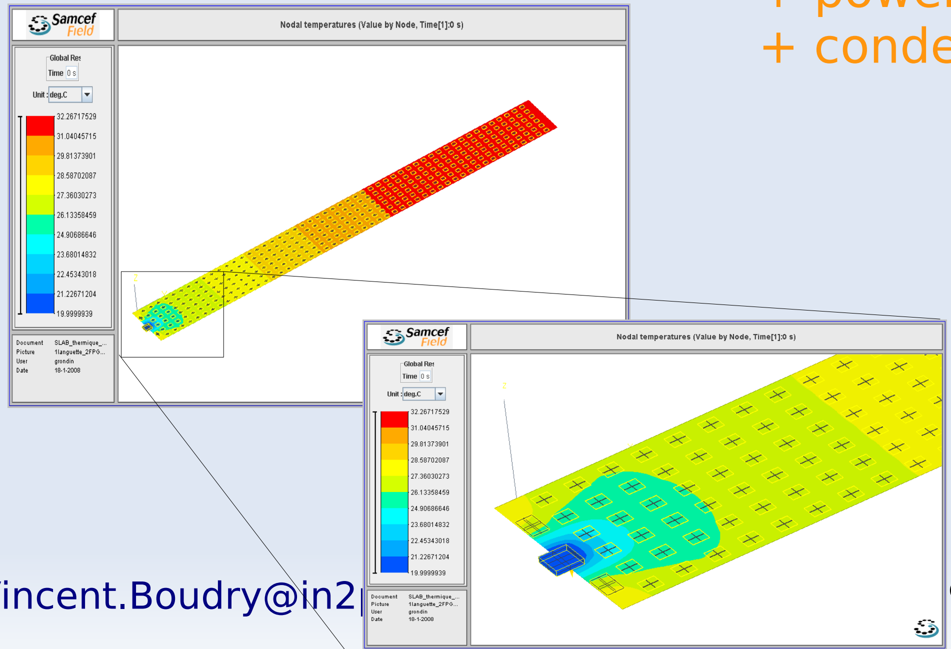
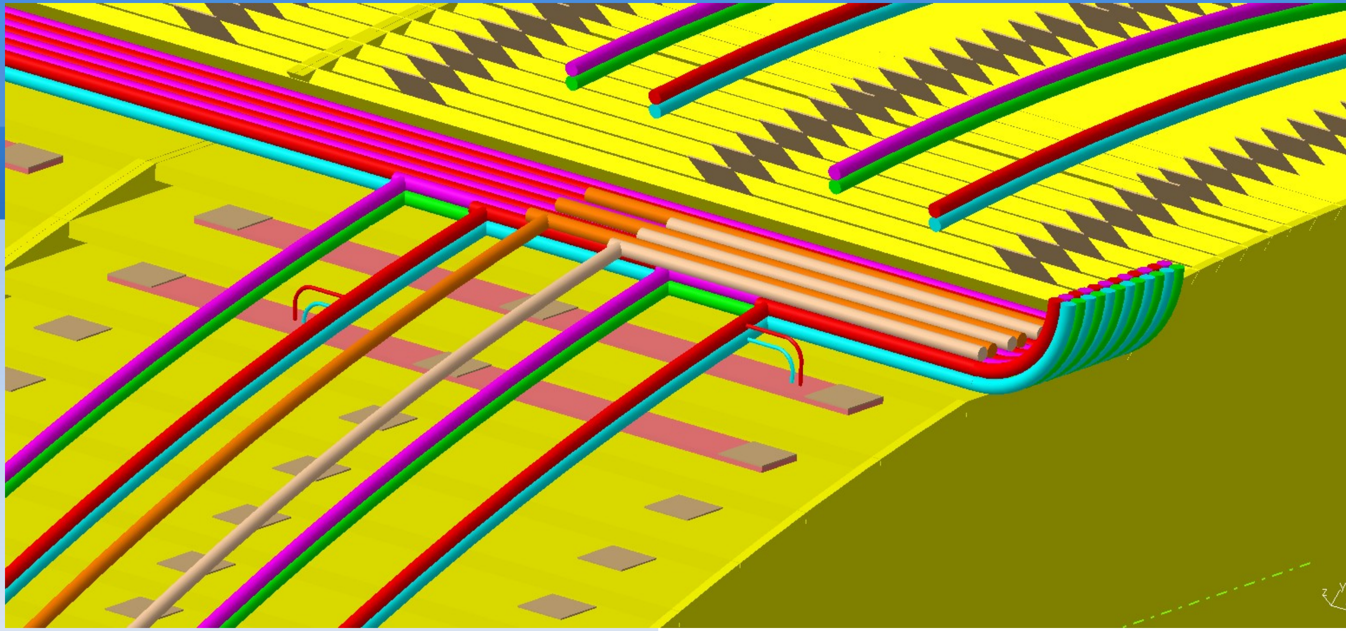
Integration & services

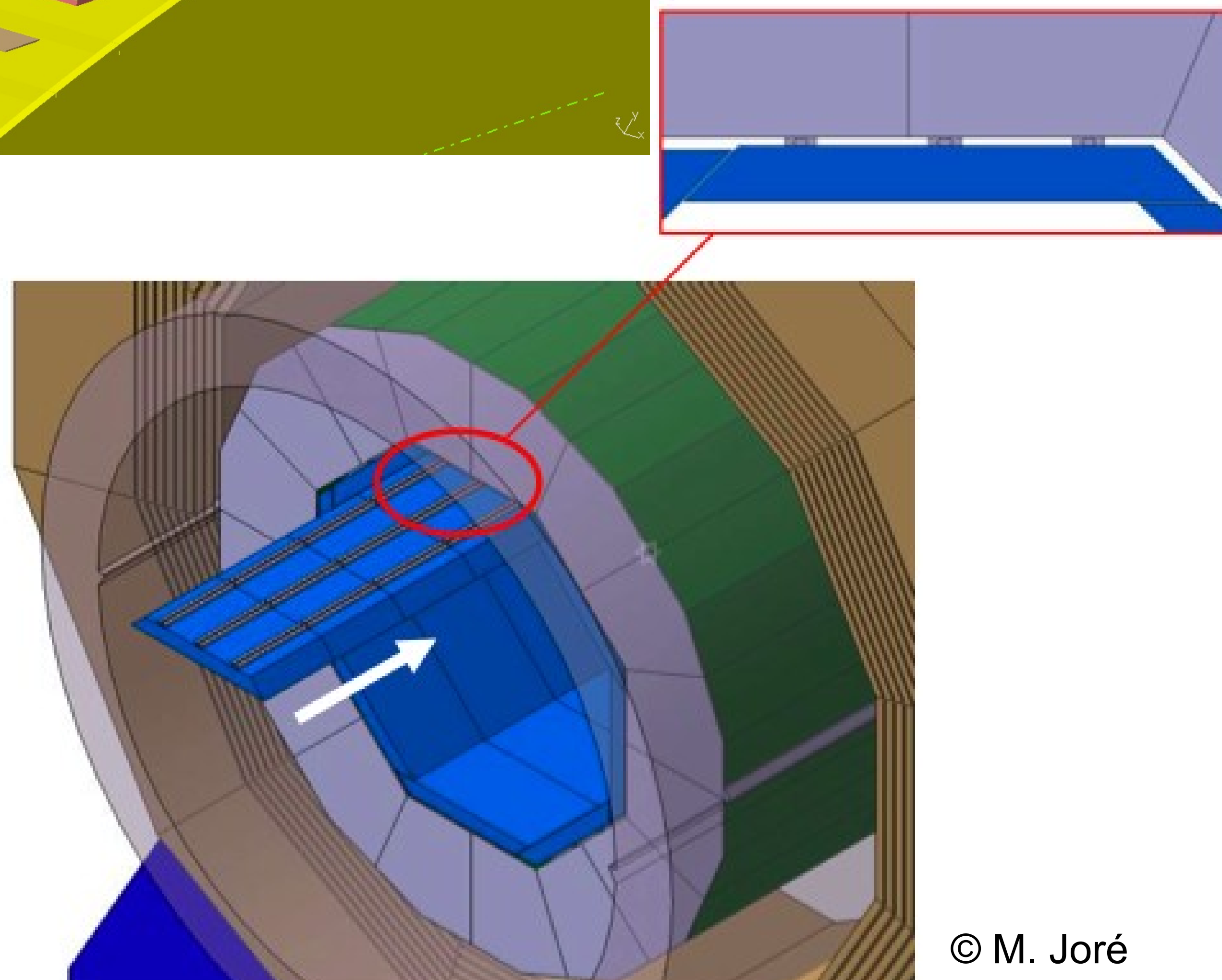
- Services & cabling
  - cooling philosophy
    - Each detector should remove its own heat
    - ECAL 120 Mch ×25µW ⇒ 3 kW
      - with 200 gain from Power Pulsing
  - DAQ
    - 1 Concentrator board per Module
      + power
      + condensators











Main critical points

- Calibration
  - Answered to IDAG: muon from beam halo, tracks in showers
- All: Power pulsing
- SiW: cost of Si, heating → indust.
- ScW: reconstruction → coding / manpower
- MAPS: power & integration → physics prototype on the way
- AHCAL: price of SiPM, operational stability with zero suppr.
  → indus. + TB analysis
- DHCAL: reconstruction & operational stability
  → to be validated in Simulation & TB

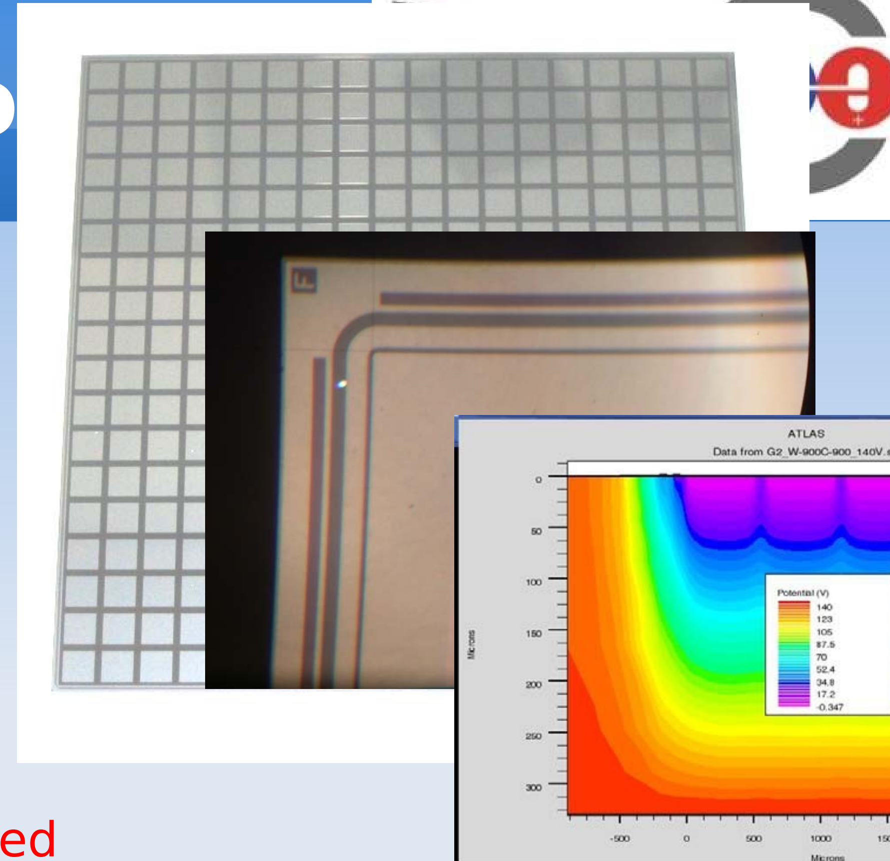
→ Construction of complete or partial **technological prototypes**

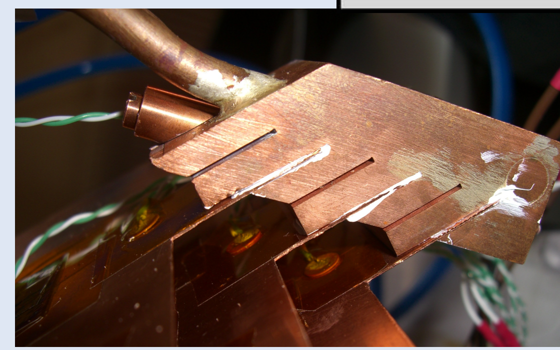
- embedded ASICS
  - daisy chain readout
  - cooling
  - power pulsing testing
- (Now) For ECAL, AHCAL & DHCAL

Not yet addressed:
Power pulsing in B field

Si/W ECAL Tech. Proto

- 5×5 mm² technological prototype (see R. Poeschl talk @ ILD sess.)
  - 9” wafers with improved guard rings and reduced dead zone
    - R&D on GR
  - embedded on board SKYROC2 chips [64 channels; power pulsing; ADC + 8-deep pipeline on chip]
  - 1 layer of mechanical structure completed
    - other by mid-2010
  - Cooling & thermal test ongoing
  - TB scheduled for mid for 2011
- Most critical problem:
  - Si sensors prices: now per wafer **10-20€ → 2€ for ILD**
    - industrialisation (scale) / partnership / competition / self production under investigation during the next 2 years

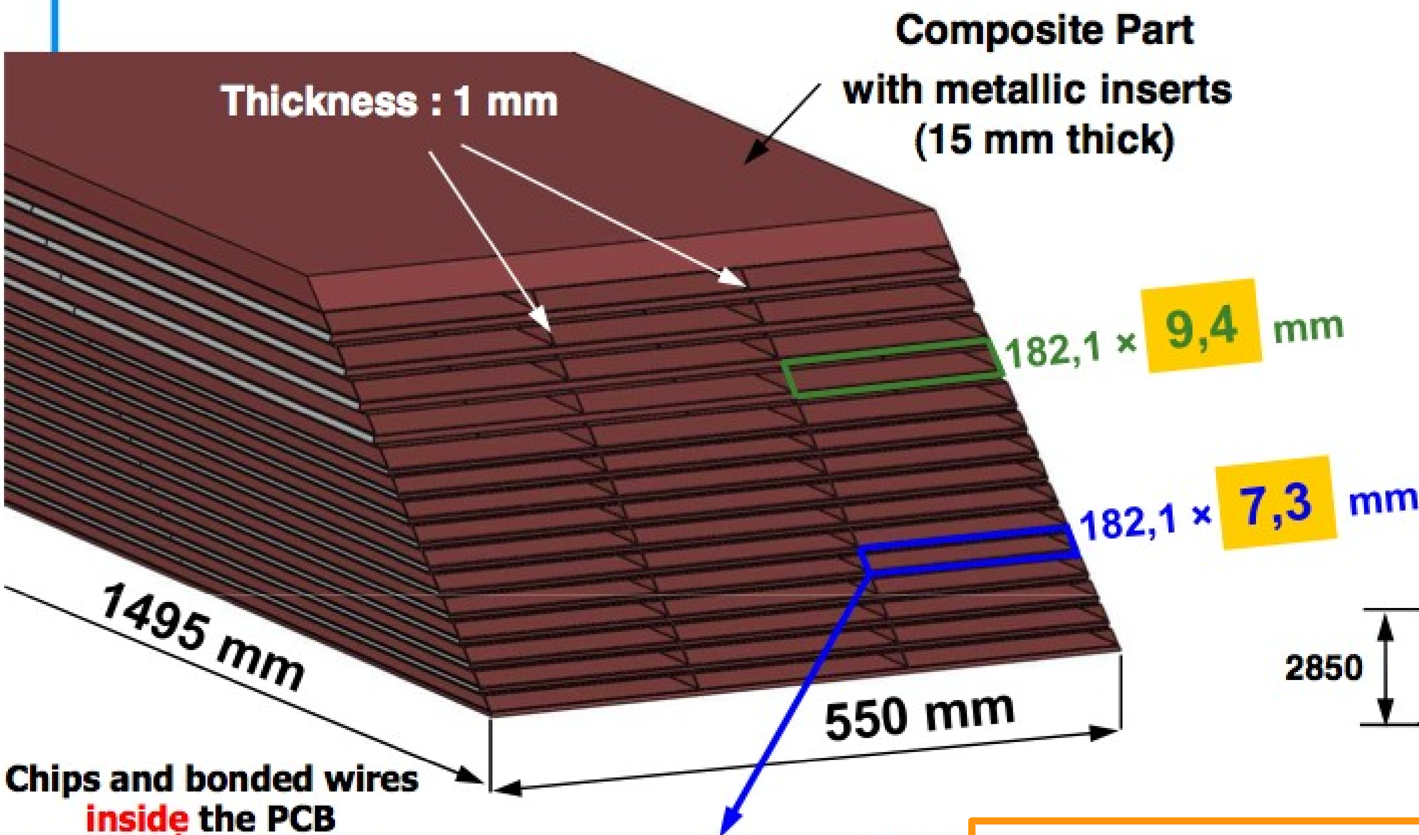




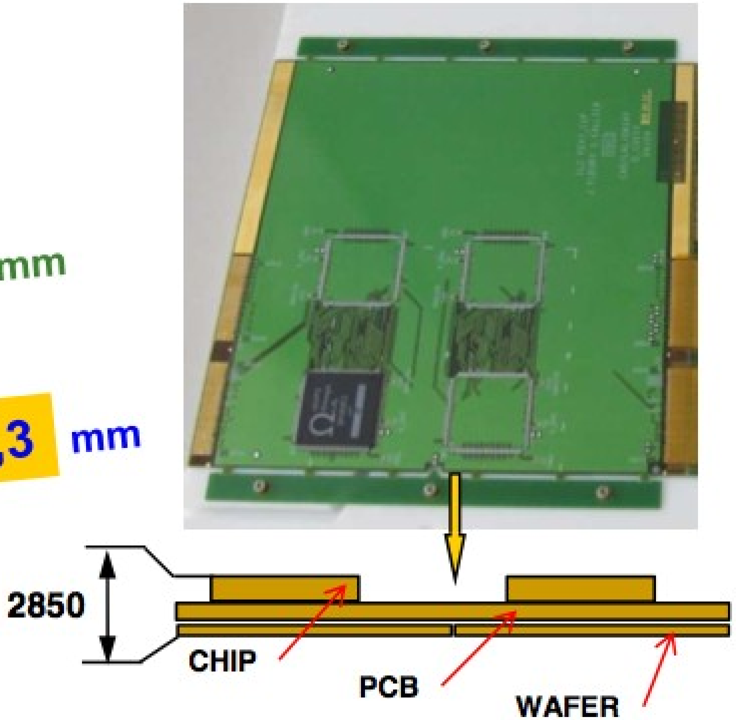
Vincent.Boudry@in2p3.fr

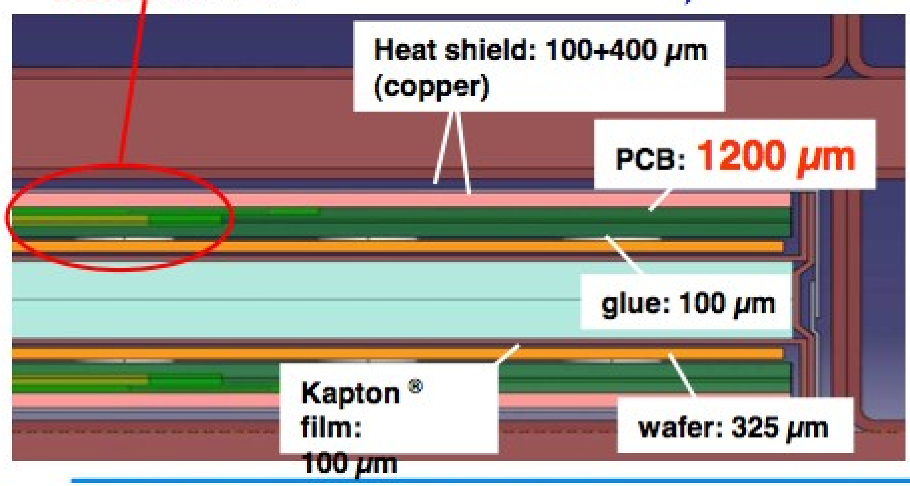
See R. Cornat talk's at CALICE meeting

EUDET design



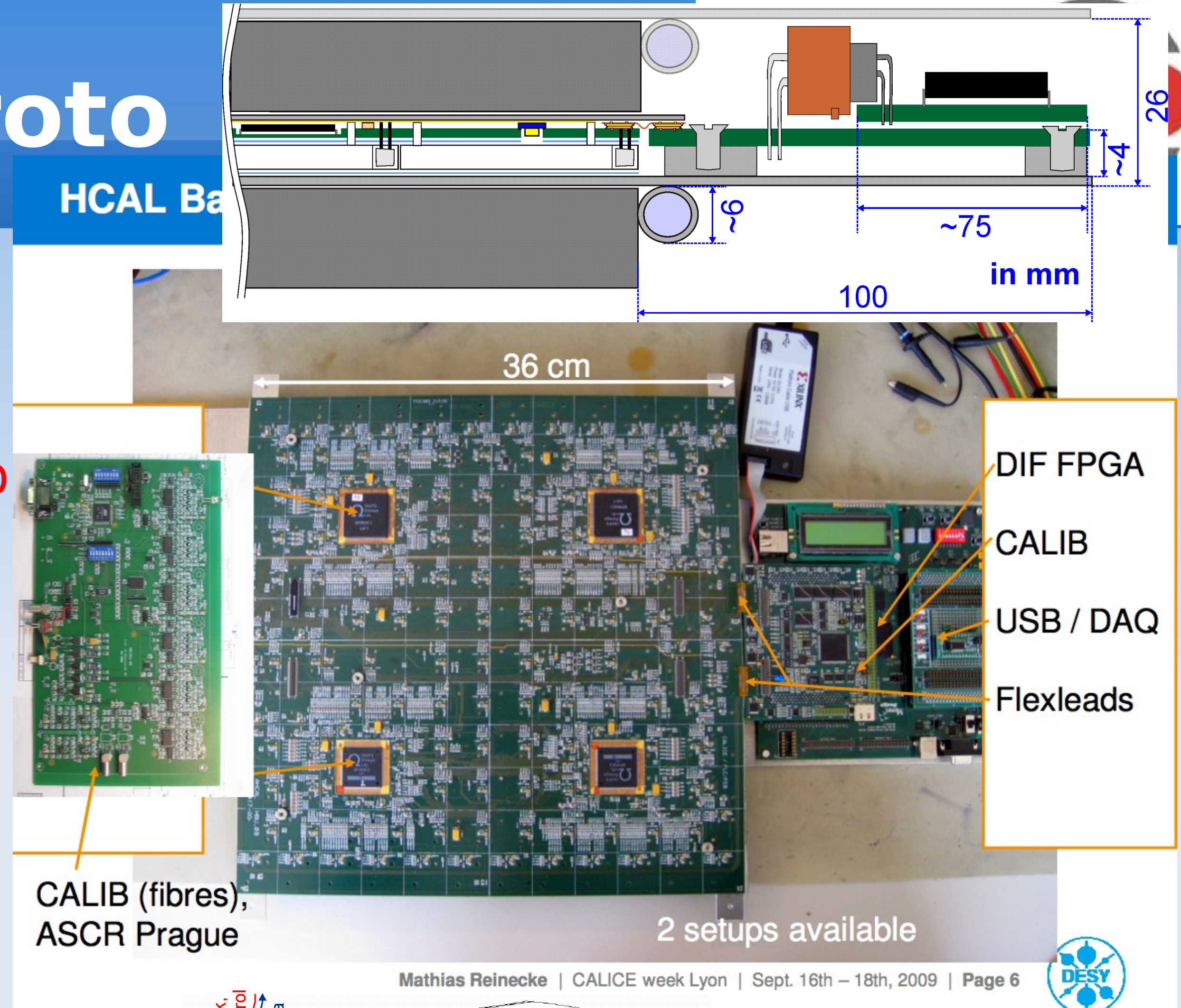
FEV7 CIP at the present time

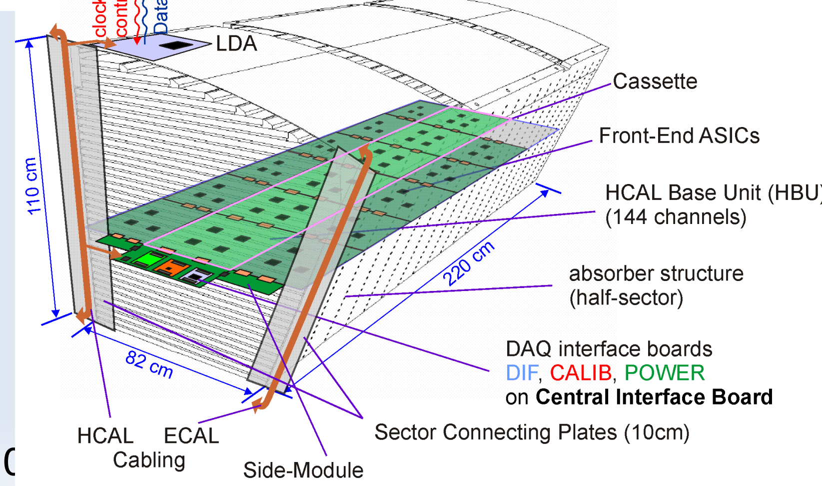




AHCAL tech. proto

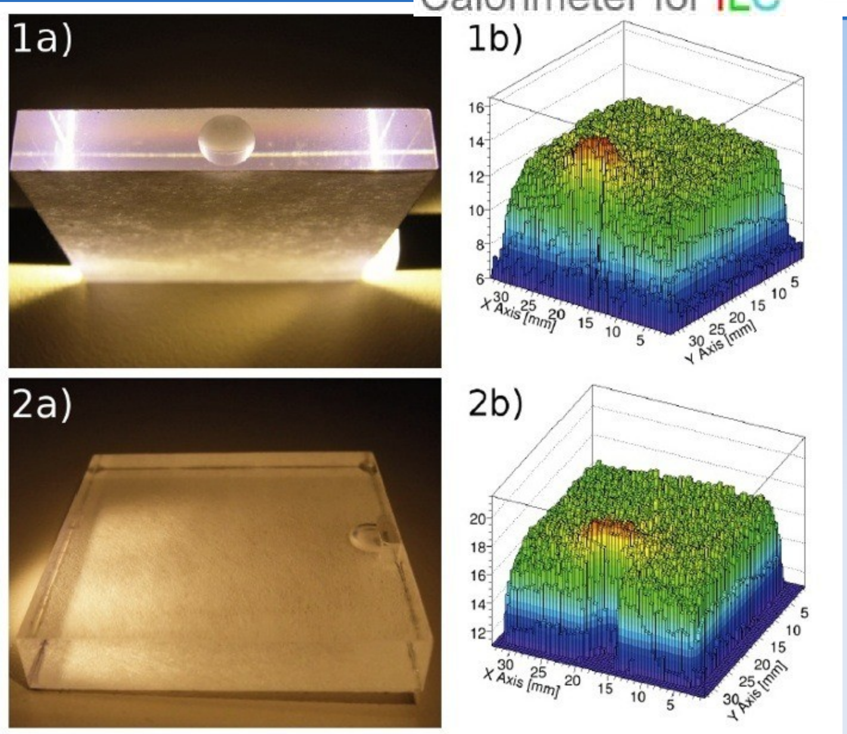
- 1 layer funded
- Electronics integration
  - SPIROC, daisy chain, LED
- Mechanical integration & test
  - SS plates mecanical and magnetic properties, price being investigated



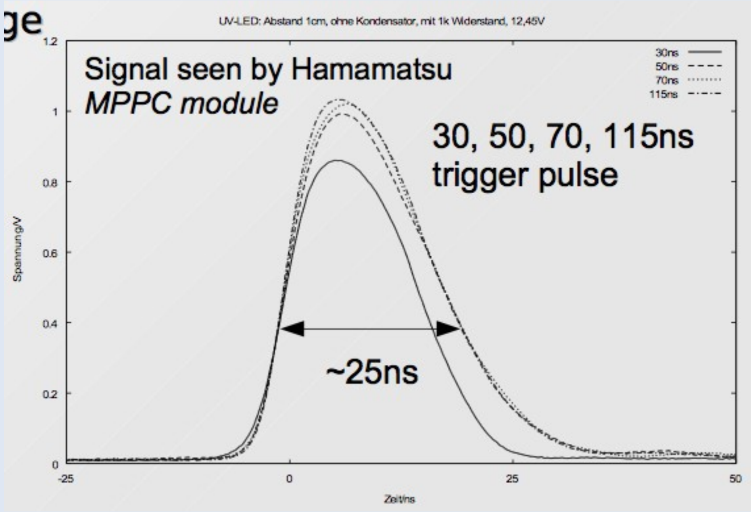


AHCAL techn. prototype

- Tile optimisation
  - without WLS
    - with or w/o direct coupling
  - optimise for uniformity

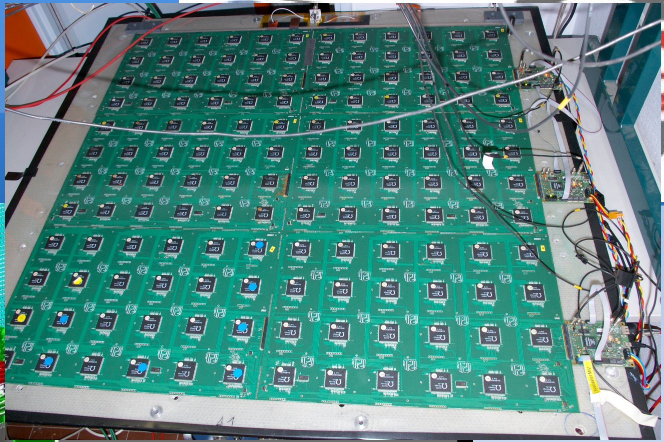


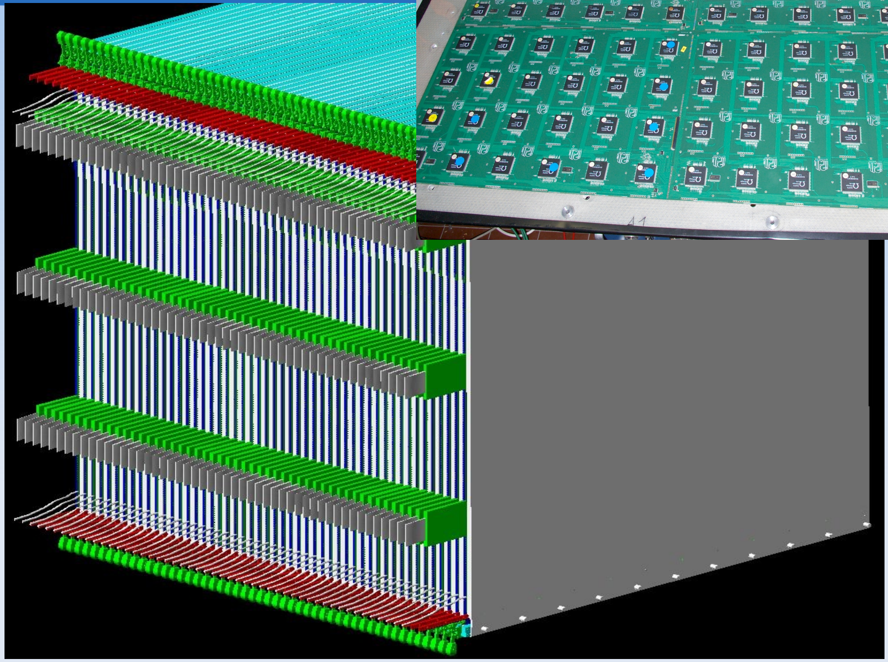
- Embedded LED calibration system
  - 1 blue LED / tile
  - Studies for position & tº behaviour

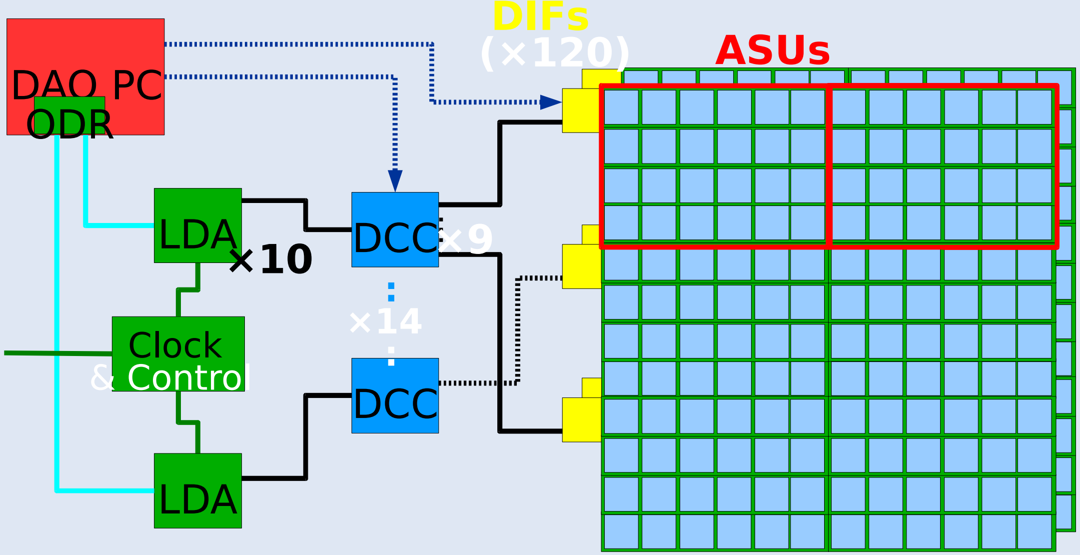


SDHCAL

- 1 m³ technological prototype planned
  - 40 layers with 20 mm SS
  - Rpc and/or MicroMegas
  - Hardroc2 (3 thresholds)
- testbeam scheduled for 2010-11
  - Validation of semi-digital calorimetry
  - Test of CALICE DAQ2 on 400000 channels







Overview

- Lot of engineering work in the conception of the ILD calorimetry since the LOI
- Still a lot to do to get the price reduction and establish the perf.
  - industrialisation studies are starting
    - mechanics of SS
    - Si sensors for the Si-W ECAL
  - performance program well advanced
    - techn. prototypes of (AHCAL), SDHCAL, SiW ECAL
    - Physics prototype of MAPS, Scint W, FCALs
  - Many test beam in the next 2 years
- Main points addressed by IDAG have been / will be responded
  - power pulsing in B field
    - Needs special tests
      Under investigation...
- Find a logo for ILD....

Muon system

- ILD muon system
  - 10 layers of 10cm Fe yoke + few layers of thick Fe yoke interleaved with muon detectors
  - Scintillator strip, resistive plate chambers (RPC), or plastic streamer tubes (PST) as the detector
  - Muon system as “tail catcher” of HCAL: still controversial