ECAL and HCAL EUDET Prototypes

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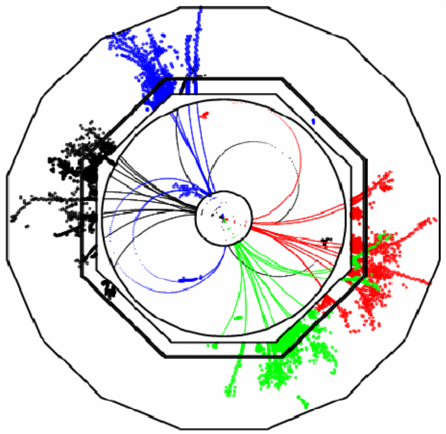
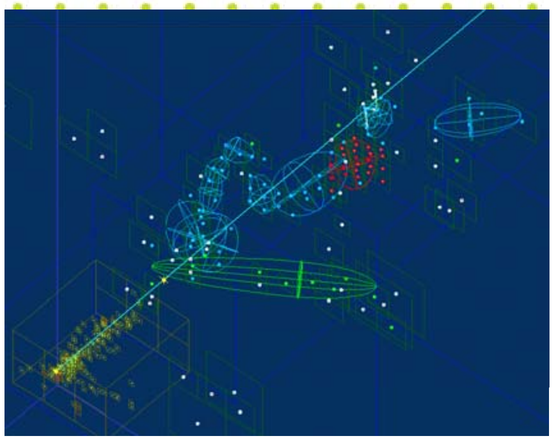
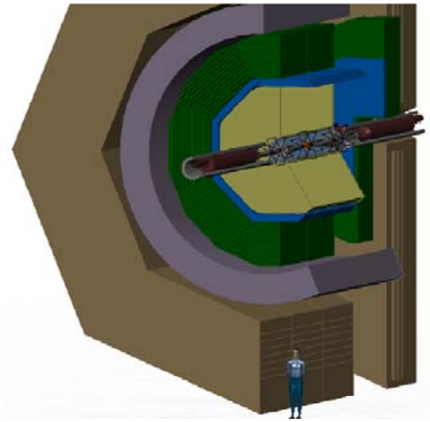
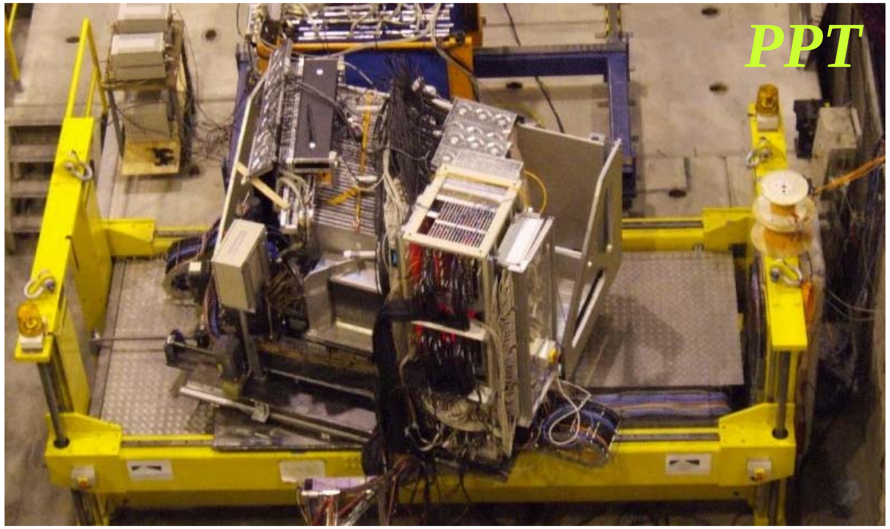
Proof of Principle → Reality

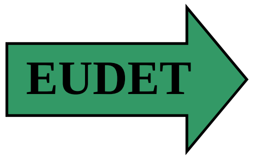




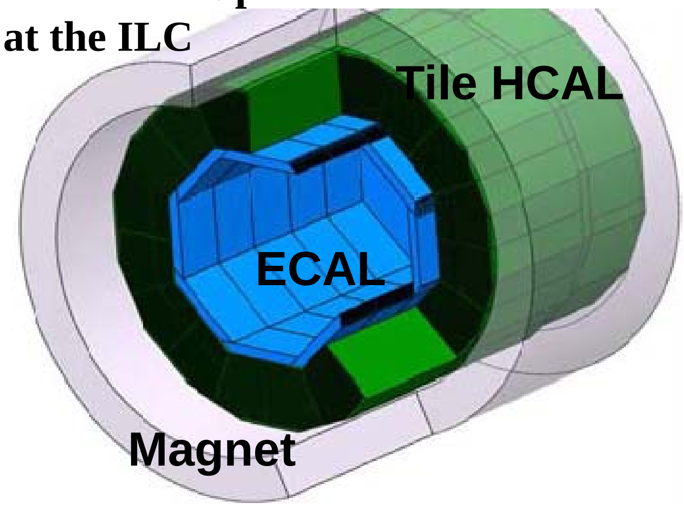


- Anticipated physics at ILC: unprecedented jets energy resolution
- Promising candidate to achieve this goal is PFA ← based on high granularity of EM and Hadronic calorimeters
  (possibility of detection particle tracks and energies in jets)





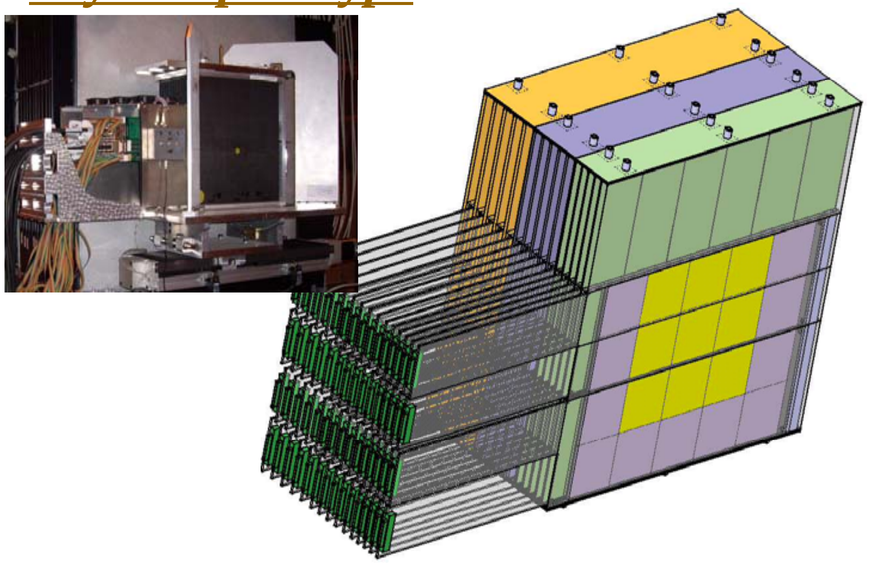
Possible setup for the calorimeters at the ILC



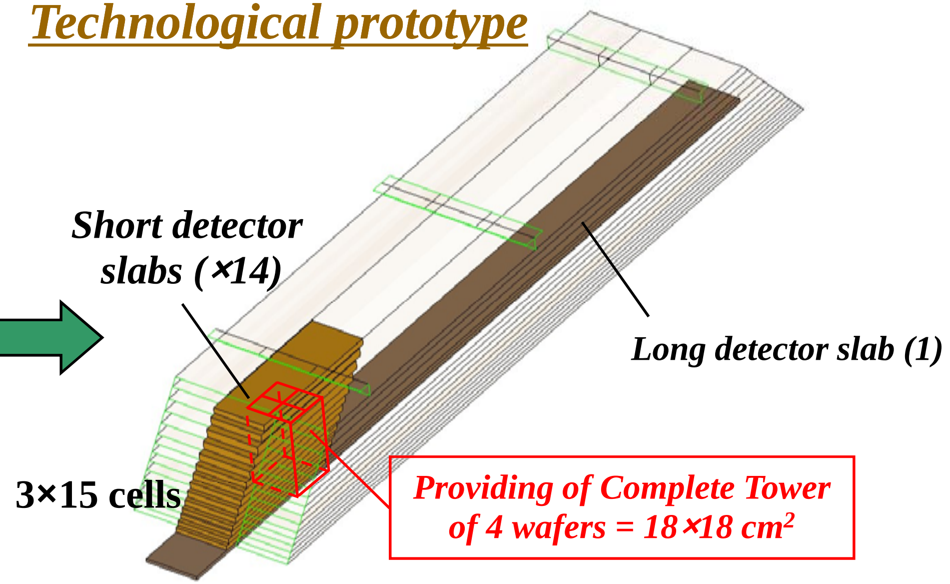
ECAL EUDET Prototype

- Logical continuation to PPT ➔ validated the main concepts: alveolar structure, slabs, gluing of wafers, integration
- Tech Prototype: study and validation of most of technological solutions for final detector (moulding process, cooling system, wide size structures,…)

Physical prototype



Technological prototype

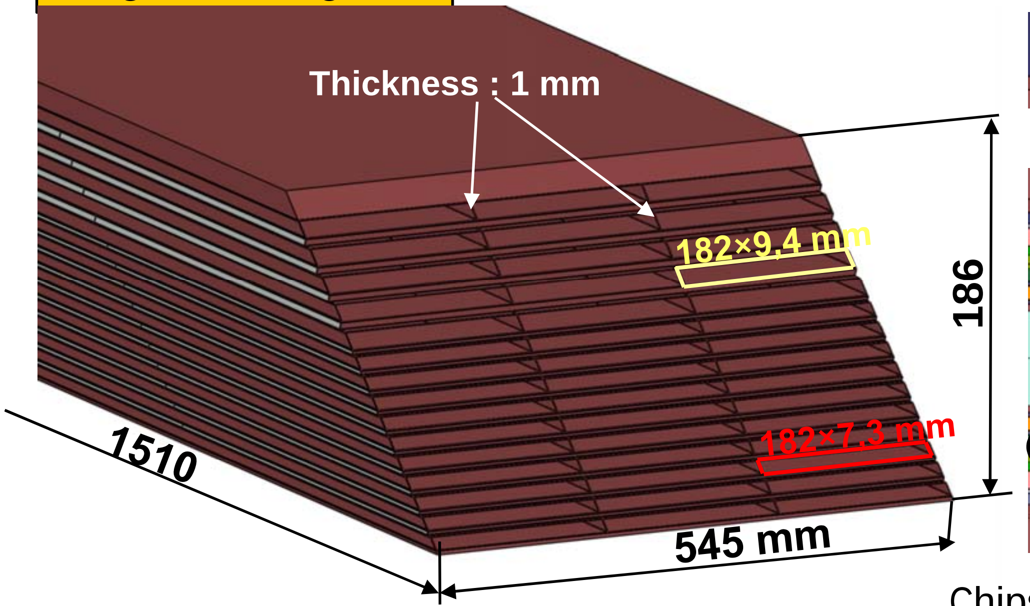


• 3 structures : 24 X_0
(10×1,4mm + 10×2,8mm + 10×4,2mm)
• sizes : 380×380×200 mm^3
• Thickness of slabs : 8.3 mm (W=1,4mm)
• VFE outside detector
• Number of channels : 9720 (10×10 mm^2)
• Weight : ~ 200 Kg

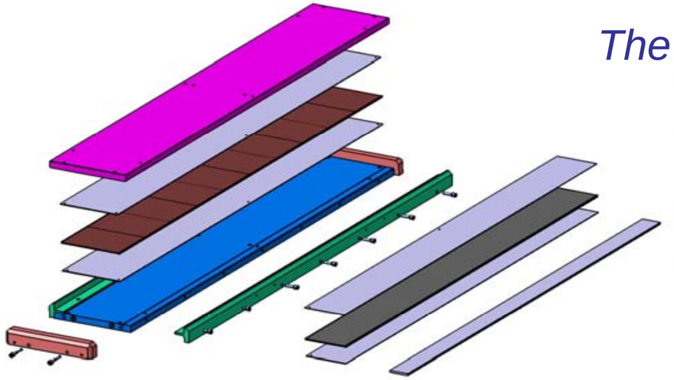
• 1 structure : ~ 23 X_0
(20×2,1mm + 9×4,2mm)
• sizes : 1560×545×186 mm^3
• Thickness of slabs : 6 mm (W=2,1mm)
• VFE inside detector
• Number of channels : 45360 (5×5 mm^2)
• Weight : ~ 700 Kg

Alveolar Structure & Slabs

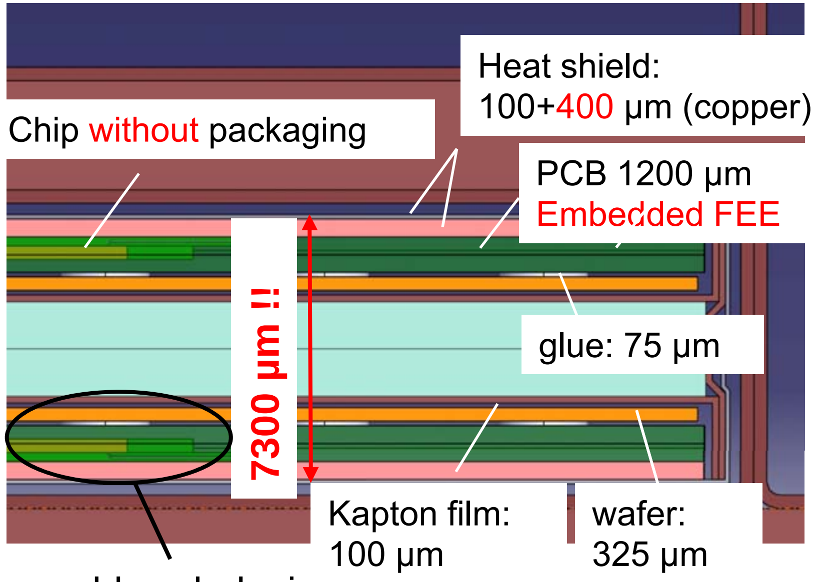
Weight ~ 700 Kg



Composite H Structure (validated)



Design EUDET Slab



Chips and bonded wires inside the PCB

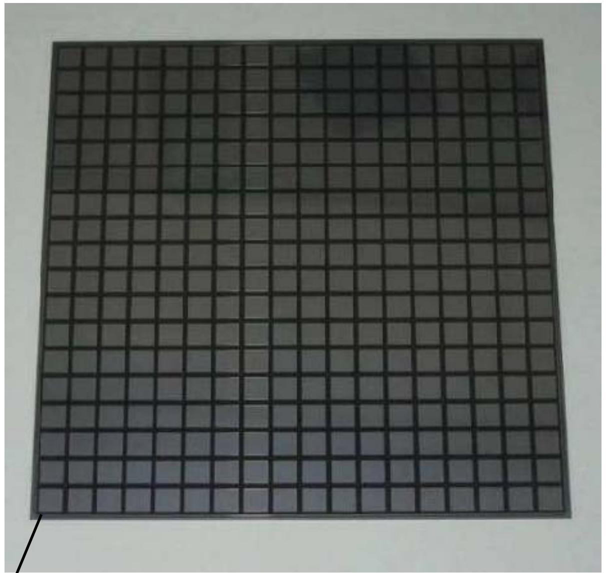
The expected alveolar thicknesses are 7.3 mm and 9.4 mm

- Design of Layout fixed during summer 2008
- Compactness limited by PCB Thickness
- Dimensions are results of dedicated studies

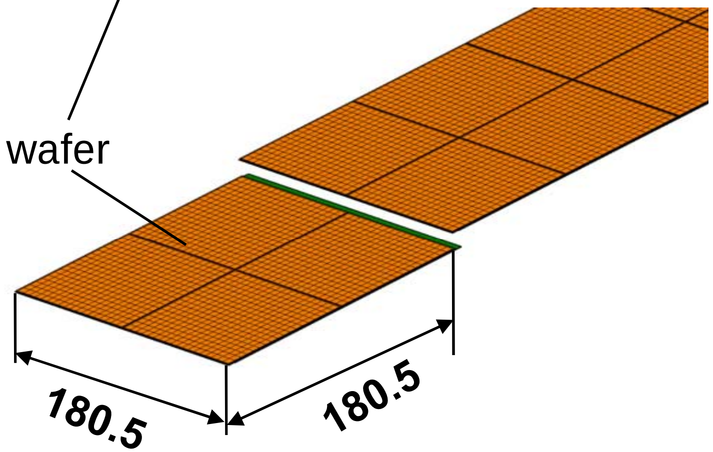
← first small demonstrator build to validate all process before the EUDET module (3alv & 2W layers in 3 columns, trapezoidal shape of 1.3 m length)

ECAL: Si Wafers

- Active sensors – PIN diodes matrix Si (5kΩ.cm) wafers
  - compromise between granularity and integration capability (and overall cost)
- 30 wafers from Hamamatsu
  - 90x90 mm^2 wafer size
  - 5x5 mm^2 cell size => 324 cells/wafer
  - 330 µm thickness (x PPT: 500 µm, 1x1 cm^2)
- Start to study guarding effects (X-talk coupling)
  - TB measured data: show some sq. pattern (particle in guarding)
  - Idea: cut g.r. into small segments (avoiding along propagation)



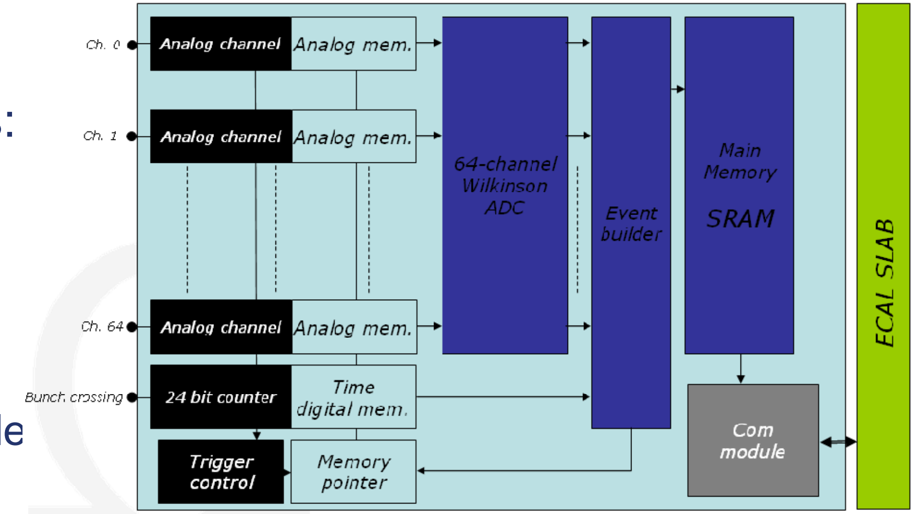
- Gluing simply to PCB (A.S.U. ← 16 r/o chips for 4 wafers)
  - Checking of current leakage w.r.t. electronics after gluing
  - glue dots matrix (min. glue thickness ~100 µm) to integrate
  - Bias voltage distribution (~200 V, each wafer individually)
    - flag shaped film (Kapton, 100 µm space)



Type of Wafers can be used for EUDET Prototype

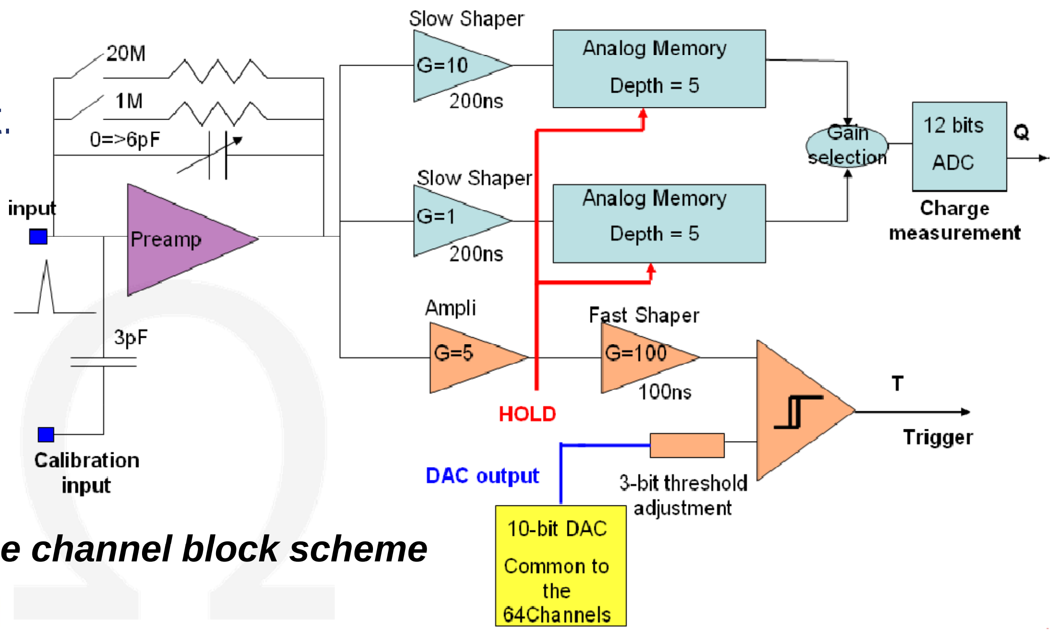
However, continue to study proposals by other manufacturers

SPIROC – ASIC r/o chips



- Front-end electronics requirements:
  - 64 channels for 5x5 mm2 pads…
  - Auto-trigger (MIP/Noise),
  - 2-gains / 12-bit ADC → 2000 MIP
  - Power pulsing
  - DAC for trig threshold
  - Output/Control daisy-chain compatible

- 3 main modes required by beam struct.
  - Acquisition
    - – charge stored in analogue memory
  - A/D conversation
    - – multi channel digitalization
  - DAQ
    - – allows DAQ to output data
    - – serial r/o daisy chain



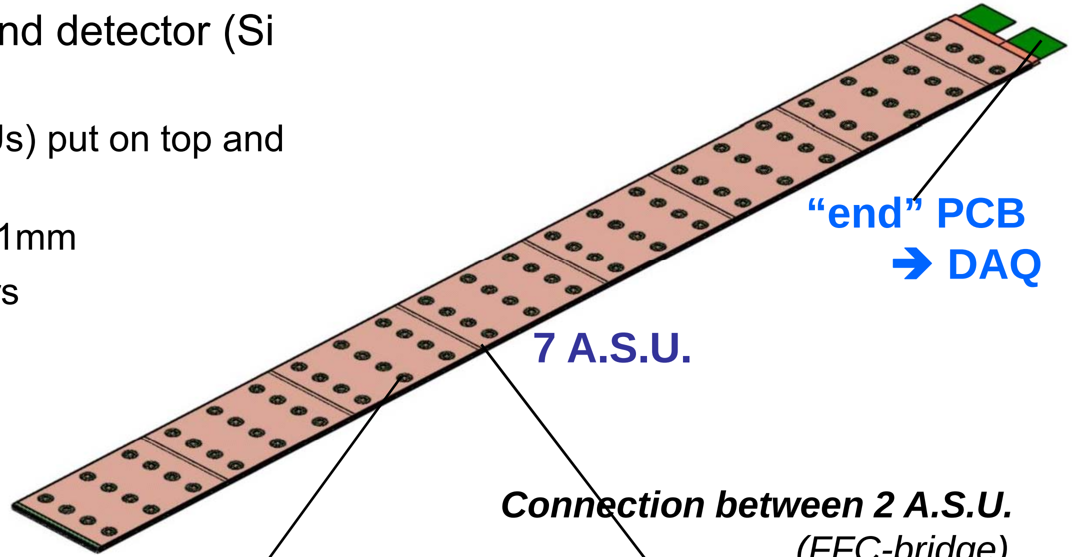
One channel block scheme

A.S.U. and Readout

Long slab is made by several short PCBs:

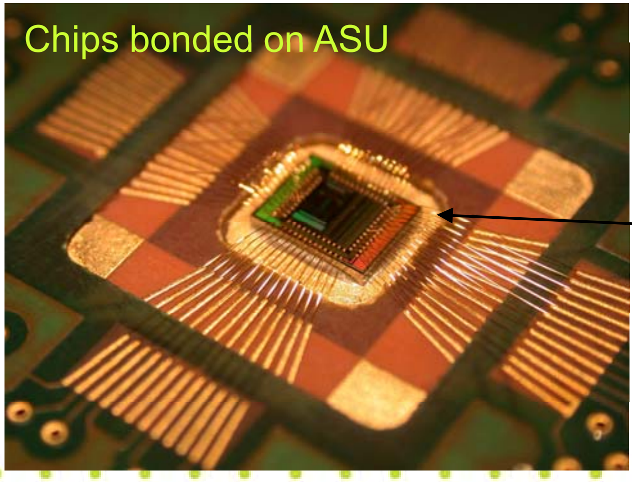
A.S.U.: Active Sensors Unit – FE PCB – interface between FEE (embedded chips with bonded wires) and detector (Si Wafers)

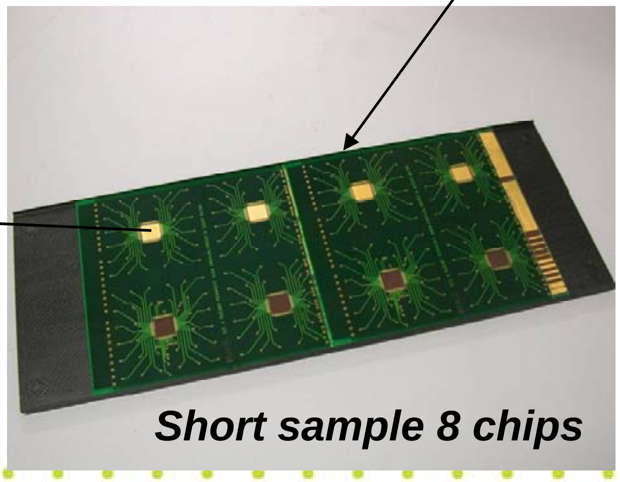
- 2 active readout layers (7 interconnected ASUs) put on top and bottom side of H-structure of the slab)
- Designed of interconnection **"inside"** PCB < 1mm
  ➔ capable to rework w/o damaging of sensors
- realize electrical paths along slabs:
  LV, clocks & fast control, slow control,
  r/o data, monitoring

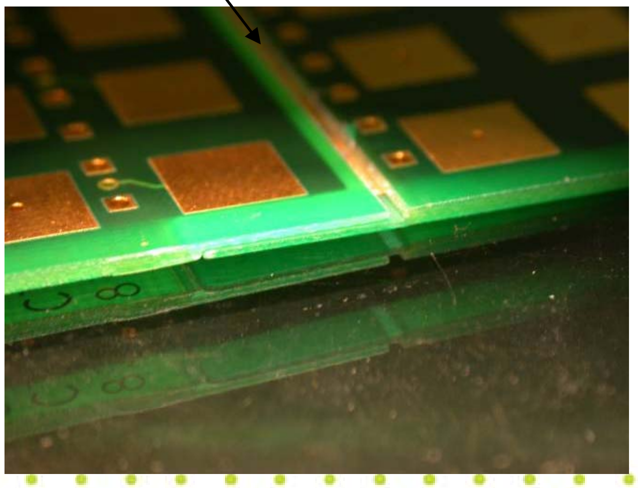


Connection between 2 A.S.U.
(FFC-bridge)

Unity of Chips, PCB and Si Wafers







HCAL EUDET Task

- Calorimeter proposal follow PFA – detection particle track and energy in jets

➔ High energy resolution and granularity

➔ HCAL: cylindrical sandwich structure w/ 38 layers (radius 2.0 m and 3.1 m)

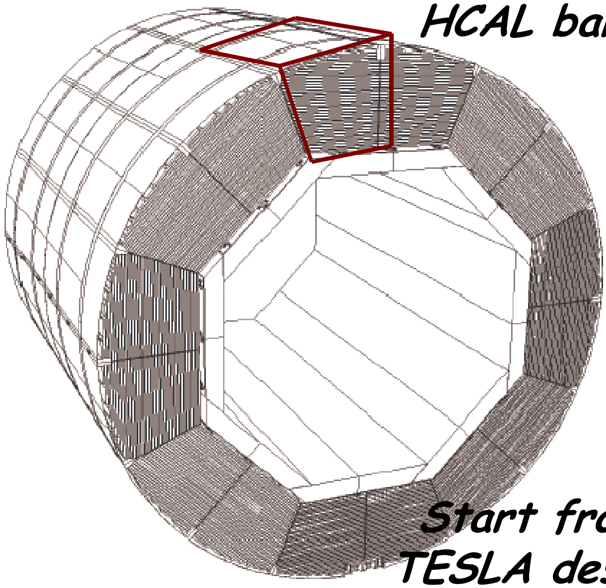
- EUDET Goal: a realistic absorber structure for tests of novel readout techniques
- Realistic: compact and scalable
  - **Compact: minimum dead space and minimum active layer thickness**

  ➔ **Small scintillating tiles w/ embedded r/o (MGPD)**

  ➔ **FEE to be highly integrated inside layers**

- Height / length of barrel: 6.4 m / 4.6 m
- Weight of one module: ≈ 19 t
- Weight of HCAL: ≈ 600 t
- Weight of HCAL + cassettes + ECAL : ≈ 900 t

HCAL barrel



Start from TESLA design

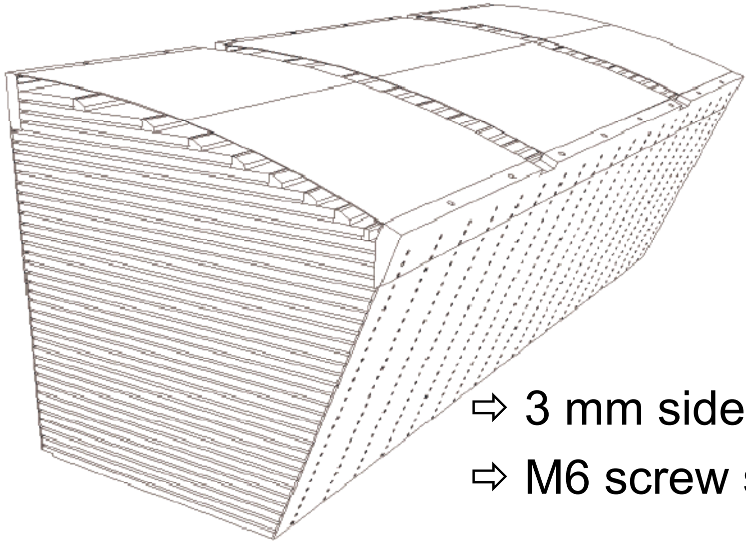
Mechanical Integration

Mechanical design of absorber structure: minimize dead material

➔ Slim support structure

<u>Disadvantages</u>

- Uncertainties regarding stability
- High tolerance requirements (for active layers)



⇨ 3 mm side panel

⇨ M6 screw size

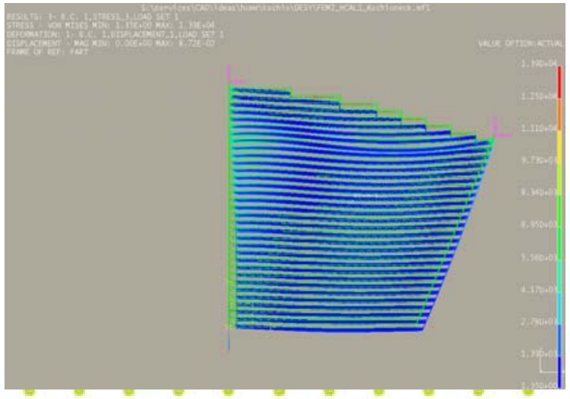
FEM calculations

- first analysis of mechanical stability

Bending of absorber plates for different fixing schemes

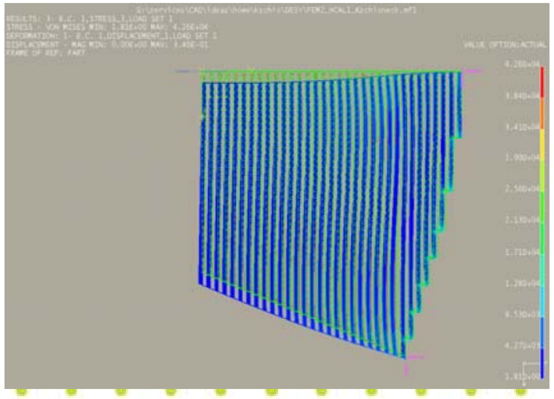
<u>Horizontal hanging</u>

Maximum deformation: 0.09 mm



<u>Vertical hanging</u>

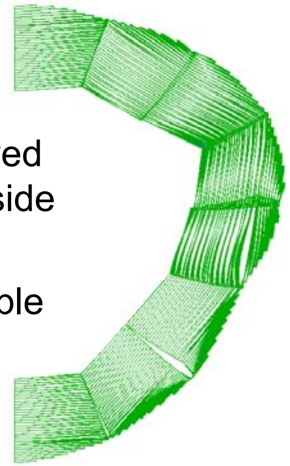
Maximum deformation: 0.35 mm



<u>Calculation of Connections Between Modules</u>

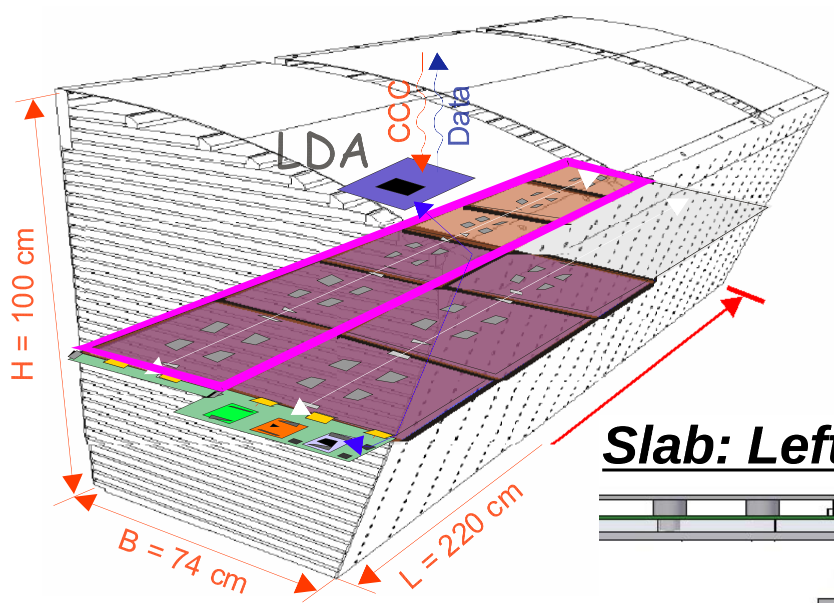
Welded or screwed connections for side panels

➔Proof of principle



Electronics integration

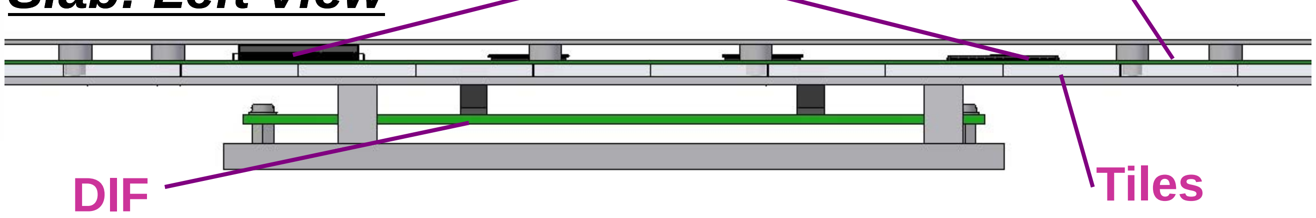
- Goal: fully exploit the potential of
  - Embedded photo-sensors ➔ embedded front end electronics
  - Similarities between highly granular ECAL and highly granular HCAL options; channel densities not so different
  - State-of-the art micro-electronics integration and power pulsing
- Common architecture for ECAL and HCAL (different FEE, same downstream, DAQ)



AHCAL basic structure:

- Slab - divided to 6 units (HBU), 2 or 3 → layer
- HBU - Hcal Base Unit: typically 4 r/o chips
- SPIROC - ASIC chips for 36 detector channels
- HEB - Endcap Board hosts DIF, CALIB, POWER
- HLD - layer distributor (electrical interconnection)

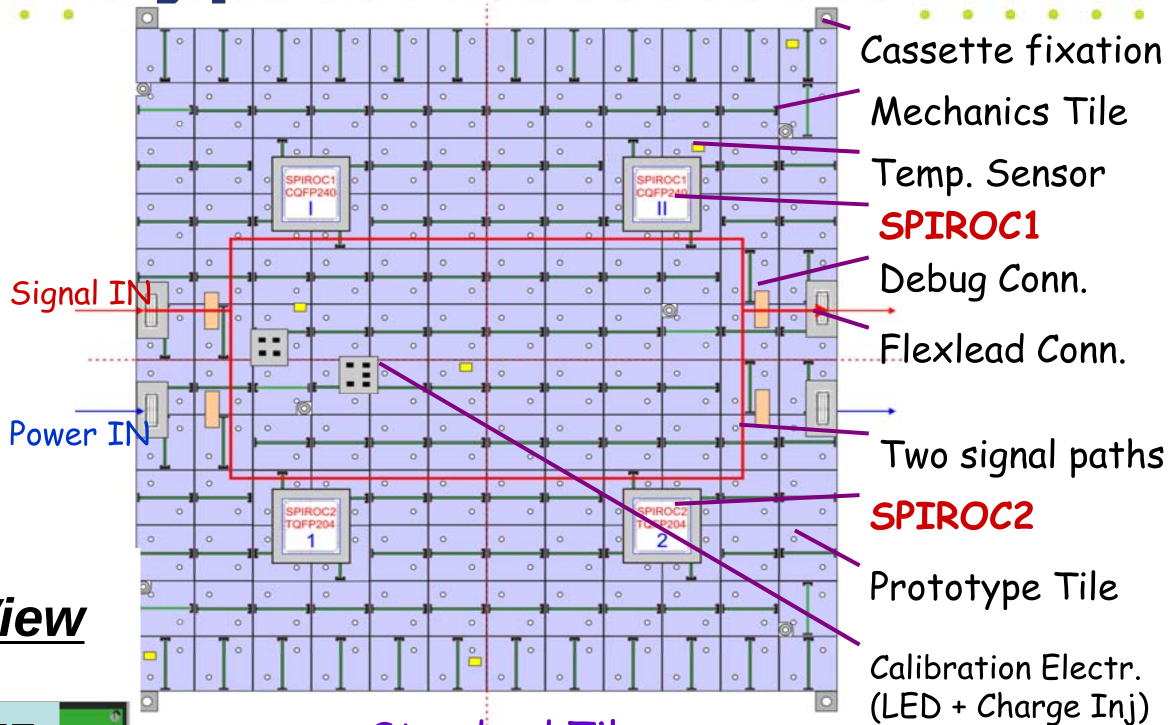
Slab: Left View

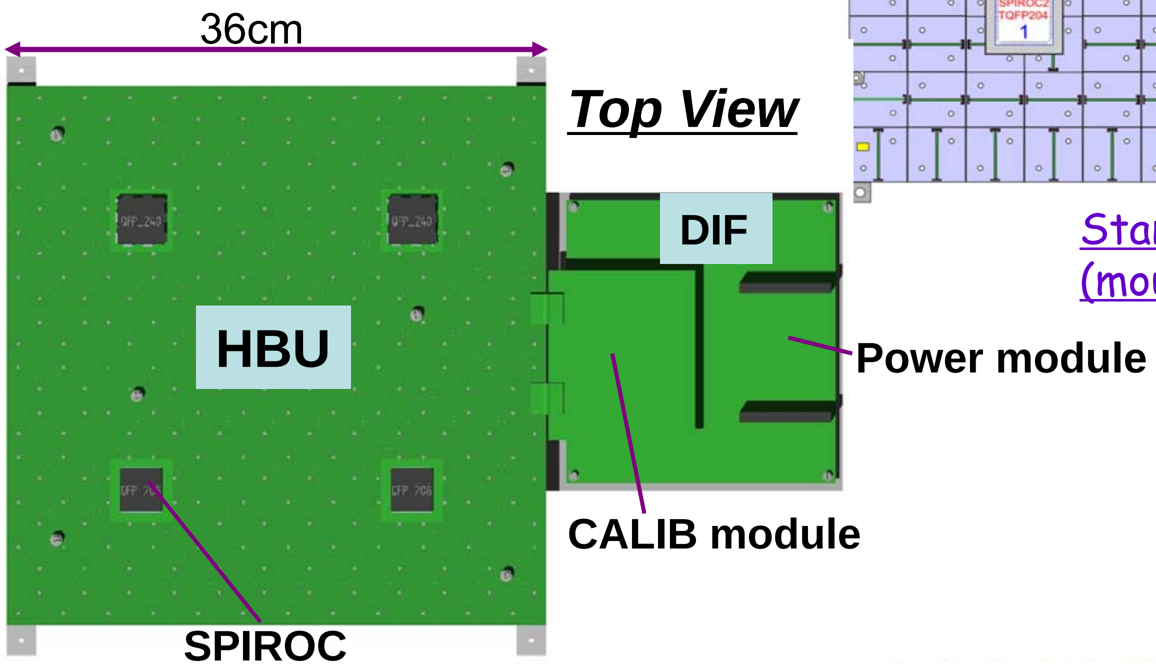


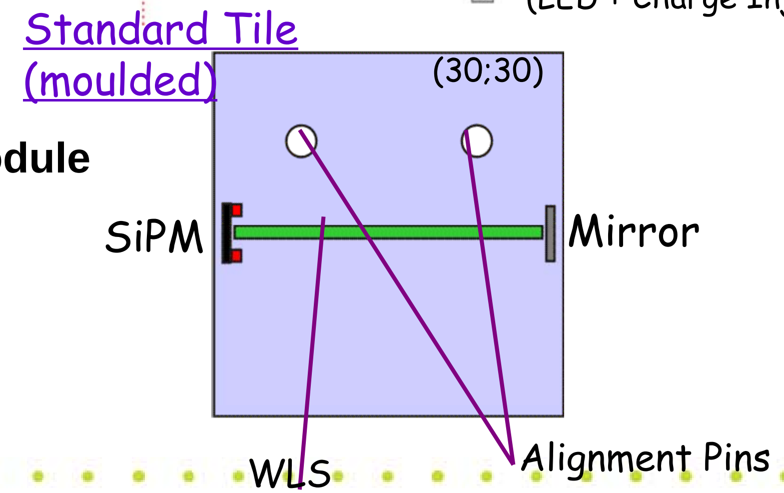
Next prototype: Architecture

HCAL Base Unit (HBU0)

- Integration concept fixed
- Critical parts (connectors) ordered.
- Schematic finished.
- Next:
  - •Layout starts now.
  - •PCB manufacturing and assembly





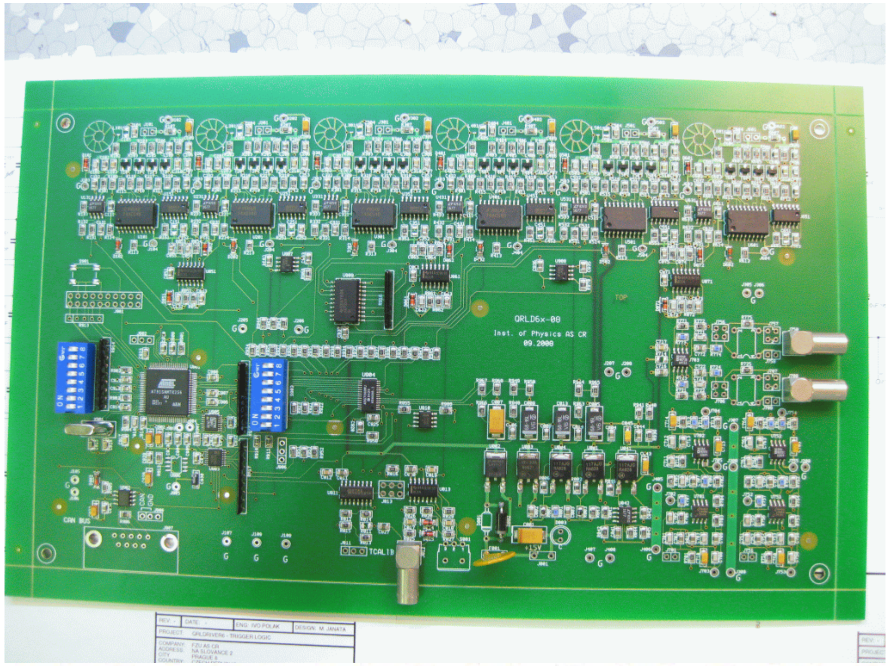


Calibration system

- Non-linearity correction, MIP calibration, Correction temperature variations
- Use gain monitoring, adjust voltage → see G. Eigen's talk
- Many procedures developed during last year's analysis, but not finally proven yet
- Stability of saturation still an issue -> need dynamic range
- Two appr.: electrical or optical signal distribution - One LED / one tile or central driver plus fibres
- Differences inside the active gap, but same external interfaces

Option 2: LED driver

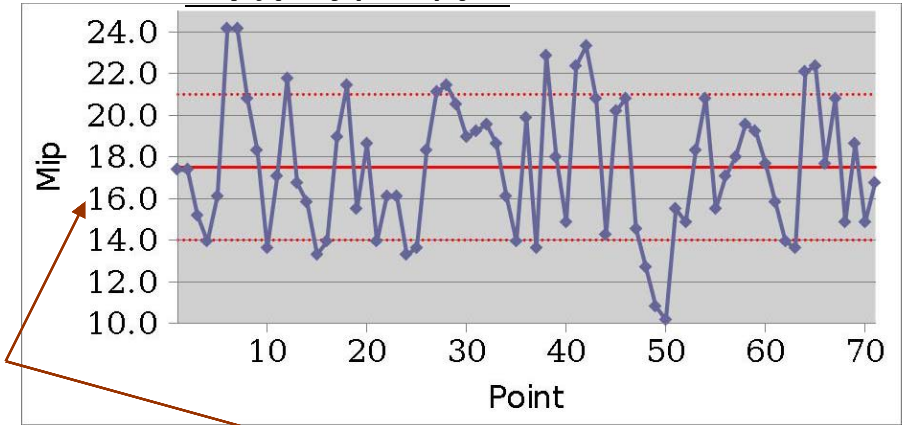
- Electronics: multi-channel prototype complete
- Optical system: uniformity again competitive
  - Integration into active layer still an open issue
- Multichannel LED driver
  - 1 PCB with the communication module µC, power regulator, 6 channels of QRLed driver
  - Communication module to PC via CAN bus or I2C
  - Controlling the amplitude and monitoring temperature and voltages
  - LED pulse width ~ 5 ns fixed, tunable amplitude up to 50-100 MIPs is controlled by the V-calib signal
  - 2 LEDs can be monitored by a PIN photodiode

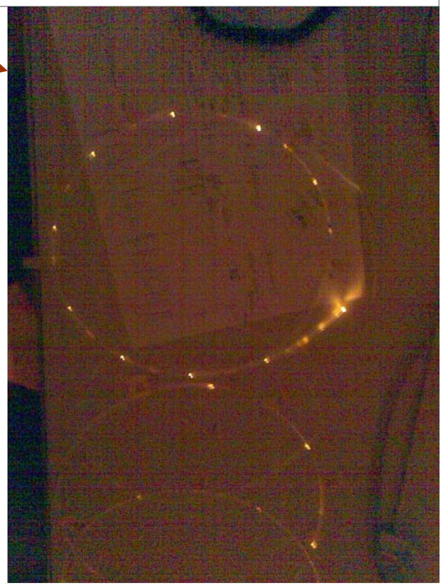


Option 2: Optical system

- Idea: use one fiber for one row of tiles (72)
- Problems:
  - uniformity of distributed light
  - enough intensity of distributed light
  - concentration of LED light into one fiber
- Two fibres:
  - Side-emitting - exponential fall of intensity
  - Notched fibre - better uniformity of distributed light - need to mechanize production - R&D

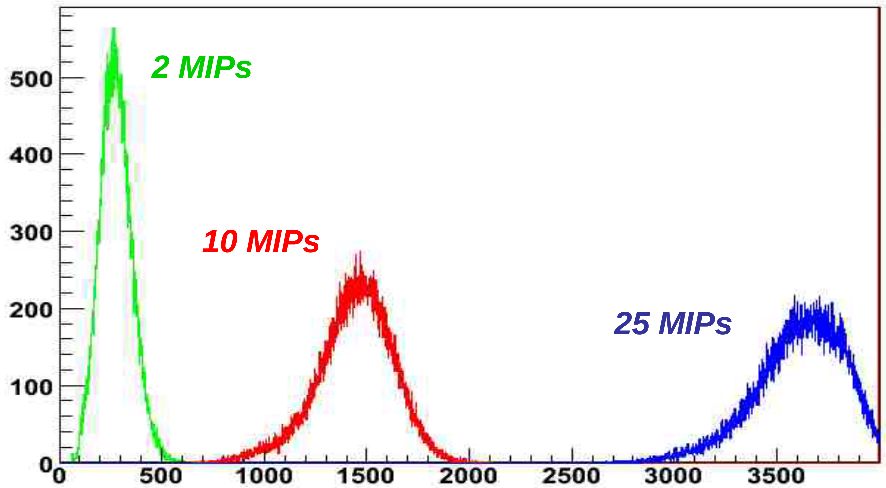
Notched fiber:





- No optical cross talk seen (< 1-2 %)

  @ different amplitudes



FEE and DAQ

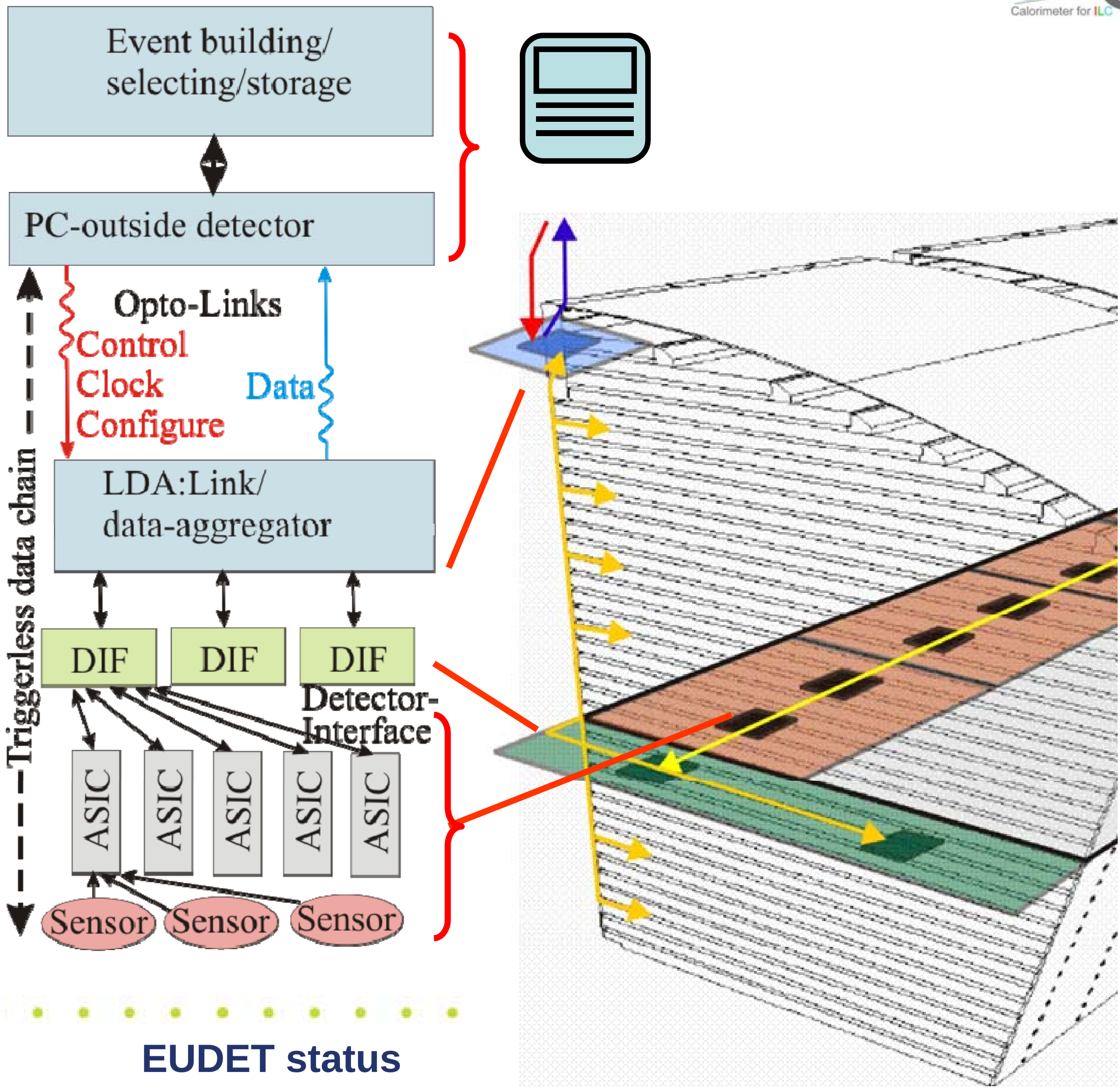
DAQ software

Off Detector Receiver (ODR)

Link Data Aggregator (LDA)

Detector Interface (DIF)

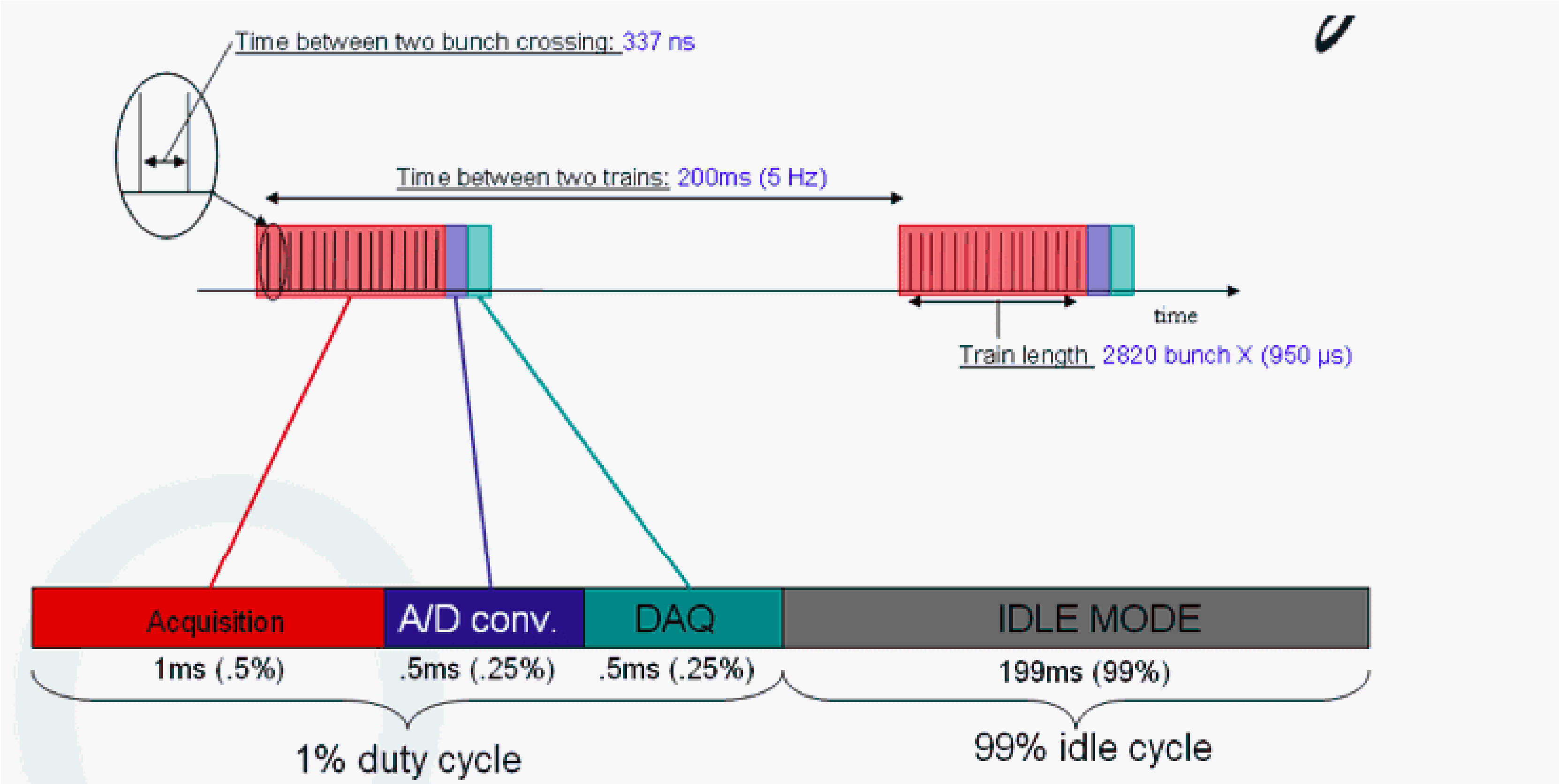
Detector Unit



Power pulsing

• No active cooling system for in-electronics in gaps of absorbers (compactness, cost,..)
➔ restriction to the power dissipation of E/HCAL electronics (ASICs,..)
← advantage for power balance: ILC bunch structure
➔ switching-off not needed in-detector electronics ➔ 1% effective switched-on time

ASIC switched-on/off status w.r.t. beam structure



Summary and Conclusion

-EUDET Prototype is logical continuation of
CALICE ECAL and HCAL Prototype

- Next steps towards ILC Detector Module
  - Addresses technological challenges of detector construction
  - Large scale integration
  - Power consumption

- Most of the items of the construction process are under control

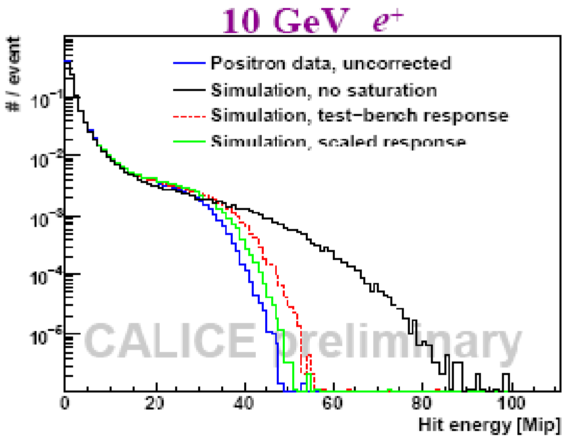
- Electronics is extremely challenging
  - Analog and digital part on one chip
  - Limited space for PCB

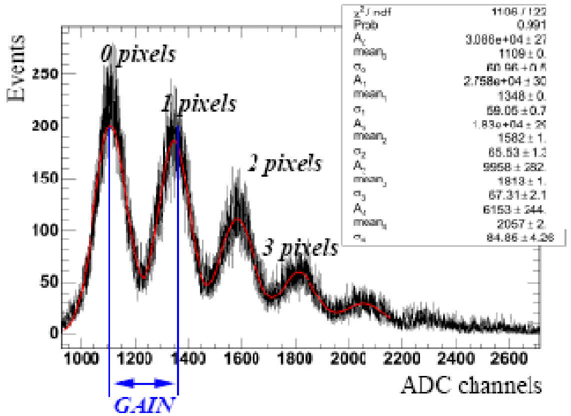
- Start of construction phase

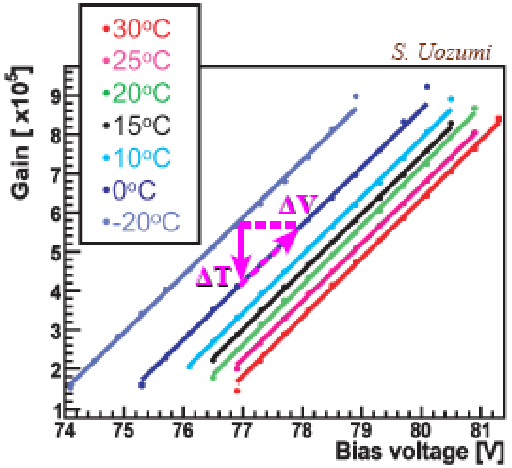
Backup slides

Calibration system

- Non-linearity correction: test with electron data
- MIP calibration: in test beam data, explore use of MIP segments in hadron showers
- Correct for temperature-induced variations
  – Use T-sensors and dependences
- Use gain monitoring, adjust voltage







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- Stability of saturation still an issue -> need dynamic range
- Two approaches: electrical or optical signal distribution
  – One LED / one tile or central driver plus fibres
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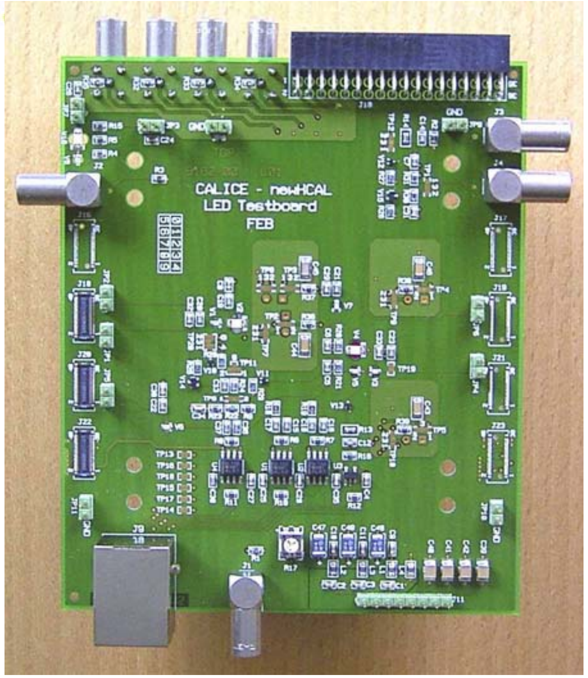
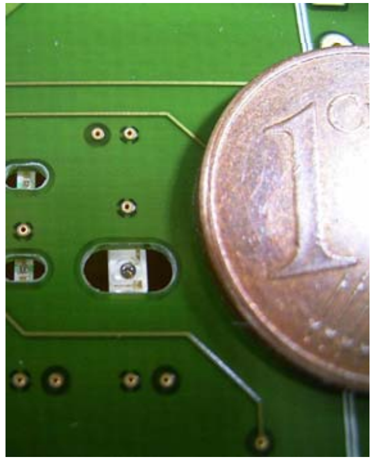
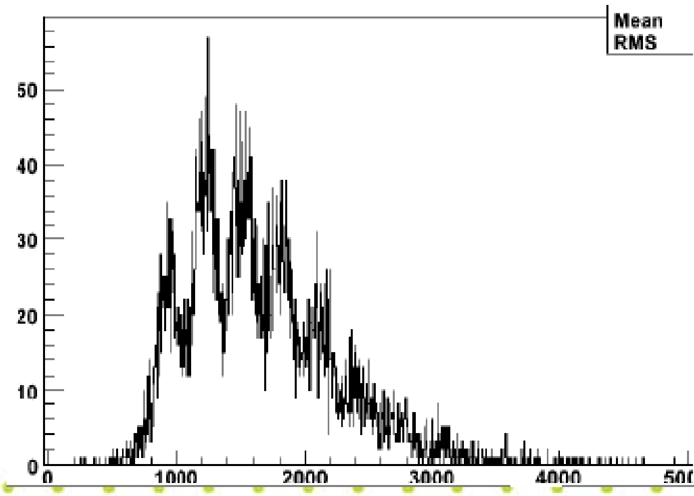
Option 1: embedded LEDs

- Electronic signal distribution
- Setup of LED Test system has started:
  - Optimization of LED position
  - Control of homogeneity of response
  - Test of different LED types foreseen
  - System will be suitable to compare light calibration with “real” particle response from radioactive source
  - System will be temperature controlled
- Tested, no cross-talk to sensors seen
- To be optimized: dynamic range, LED uniformity







Option 2: LED driver

- Option with optical distribution
- Electronics: multi-channel prototype complete
- Optical system: uniformity again competitive
  - Integration into active layer still an open issue

- Multichannel LED driver
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