Status of SiW ECAL

Daniel Jeans *for the ILD SiW ECAL group*

ILD meeting, Seoul, 17 February 2009

- Introduction
- Mechanical
- Integration of DAQ
- Thermal issues
- Reconstruction studies
- LoI section

In2p3

Advertisement from Roman Poeschl:

A school on calorimetry at the International Linear Collider (ILC) will take place between the 22/4/09 and 26/4/09 at the CCAST in Beijing China. The course of the lectures will cover all aspects of the calorimeters which are currently under design for the detectors to be operated at the ILC. The lectures will be given by international experts who are working actively in the field. The school is intended for students at the master level and is an ideal starting point to get familiar with experimentation at the ILC. Although mainly addressed to students from Mainland China, participants from other countries of the ACFA study are also very welcome and up to 15 students from abroad can be invited

For more information please consult the webpage of the school

http://www.hep.tsinghua.edu.cn/CalSchool2009

Introduction

Particle Flow requires E-M calorimeter with

- excellent particle separation: small Moliere radius, high granularity
- good energy resolution

Choose to design sampling calorimeter with

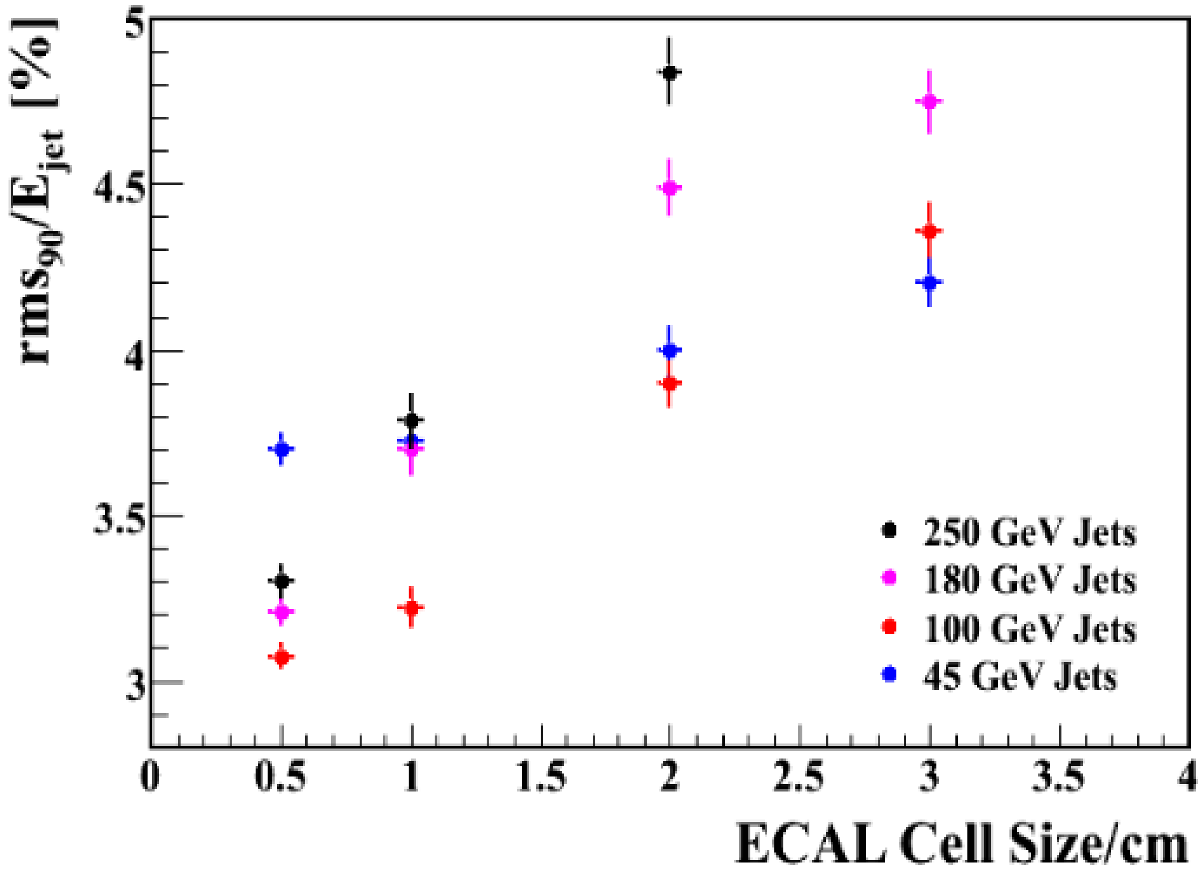
- 30 longitudinal samplings ~ 24 X_0
  - 20 layers @ 0.6 X_0, 9 layers @ 1.2 X_0
  - Detailed information about longitudinal shower development
- Tungsten passive material
  - Small Moliere radius – 2 photon separation
  - Small X_0 - compact size to fit inside coil
- Silicon active layer, segmented into 5x5mm^2 cells
  - Thin – keep Moliere radius small
  - ~10^8 channels

R&D within CALICE collaboration

Why 5x5mm^2?

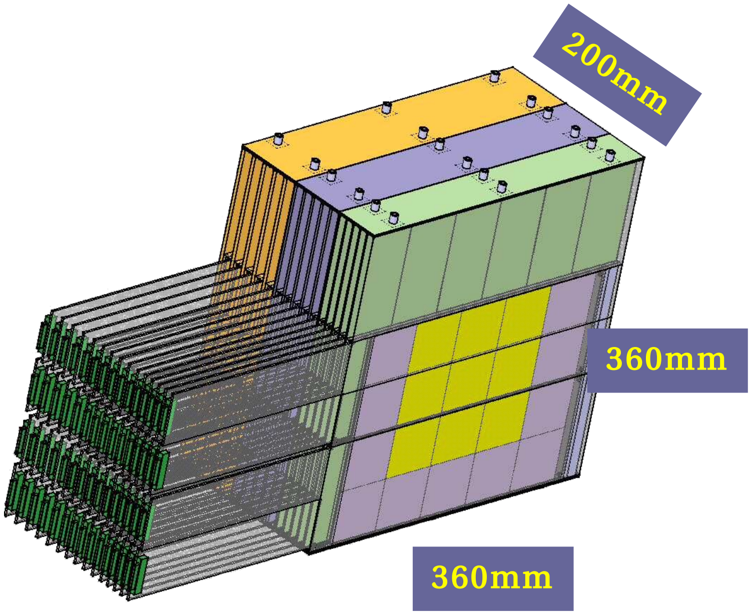
From M. Thomson

- ★ Start from LDCPrime with 5×5 mm^2 SiW ECAL pixel size
- ★ Investigate 10×10mm^2, 20×20mm^2 and 30×30mm^2
  - Note: required changes in PandoraPFA clustering parameters



- ★ Performance is a strong function of pixel size
- ★ Probably rules out segmentation of >10×10mm^2 !!!!

Detector prototypes



Physics prototype exposed to test-beams in last 3 years

~10^4 channels, 10x10mm^2 cells

Electrons in range 6-45 GeV:

Energy resolution $\sigma_E/E = (16.6 \pm 0.1)/\sqrt{E} \oplus (1.1 \pm 0.1)$

Non-linearity <~1%

Several issues identified:

Guard rings at edge of wafers: xtalk wth pixels

Inter-wafer gaps: lost energy

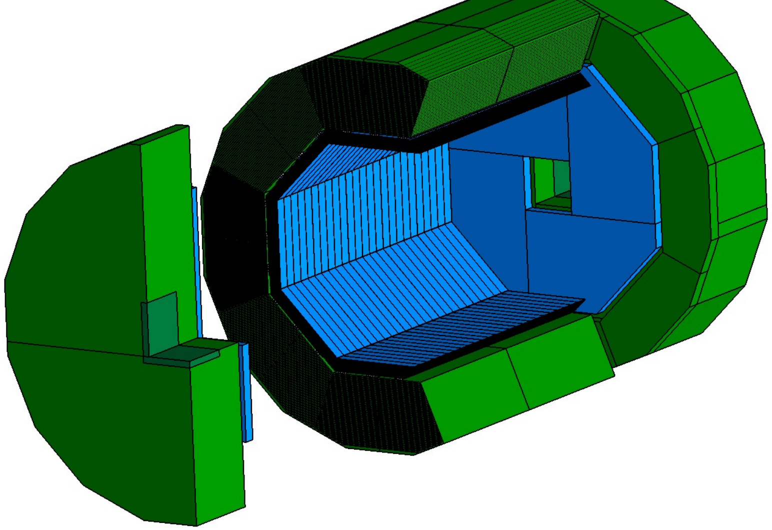
Strategies to improve:

- New Si sensor design to minimise coupling between guard rings & pixels
- Smaller pixels
- Larger wafer to minimise effect of gap effects
- reduction of gaps

Technological prototype planned for future ~ 1 year

- close to ILD ECAL module
- FE electronics inside detector

ILD ECAL



Octagonal barrel + 2 endcaps

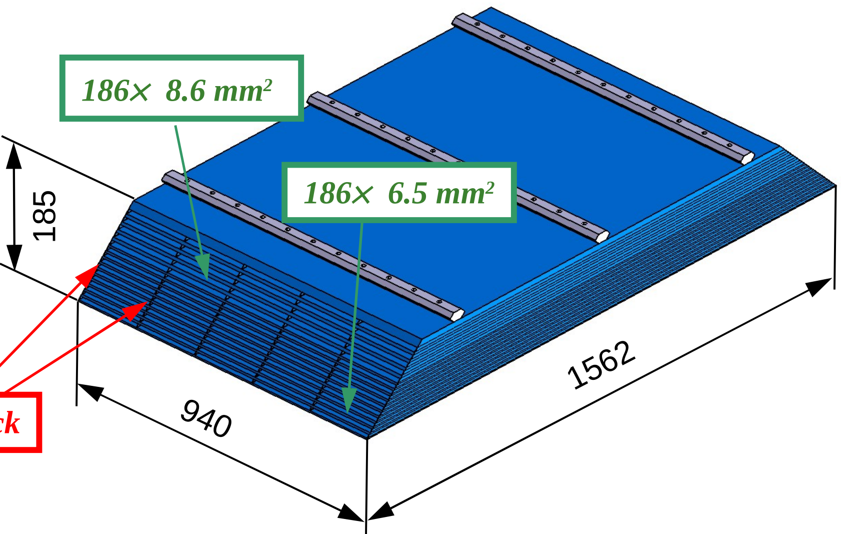
Barrel: 8 (phi) x 5 (z) identical modules

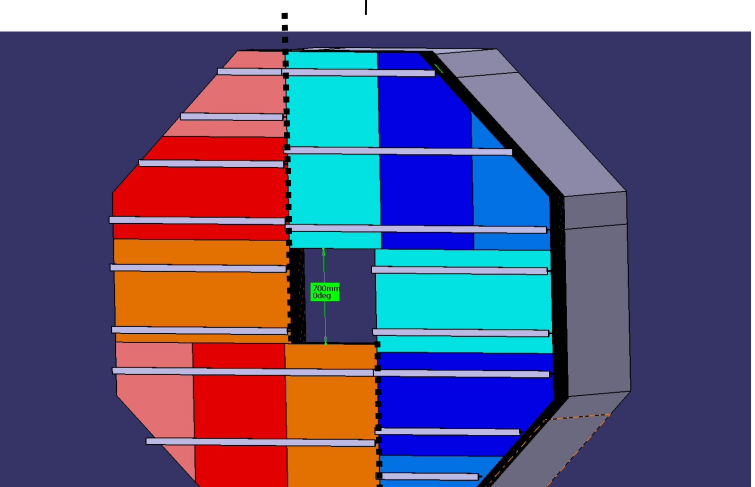
Endcap: 12 modules; 3 types

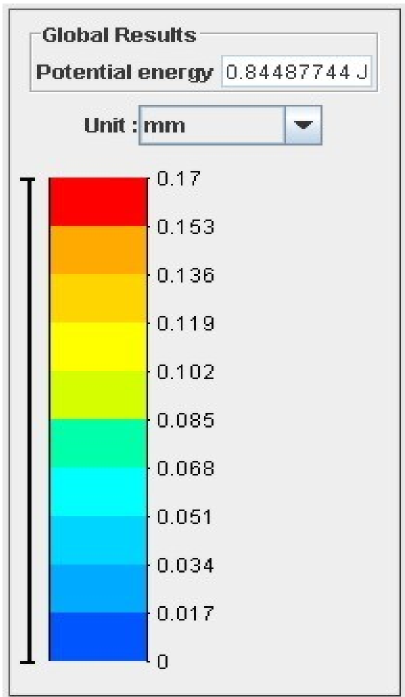
Gaps between modules non-projective

Total mass ~ 80 T (barrel), 32 T (endcaps)
Each module ~ 2-3 T

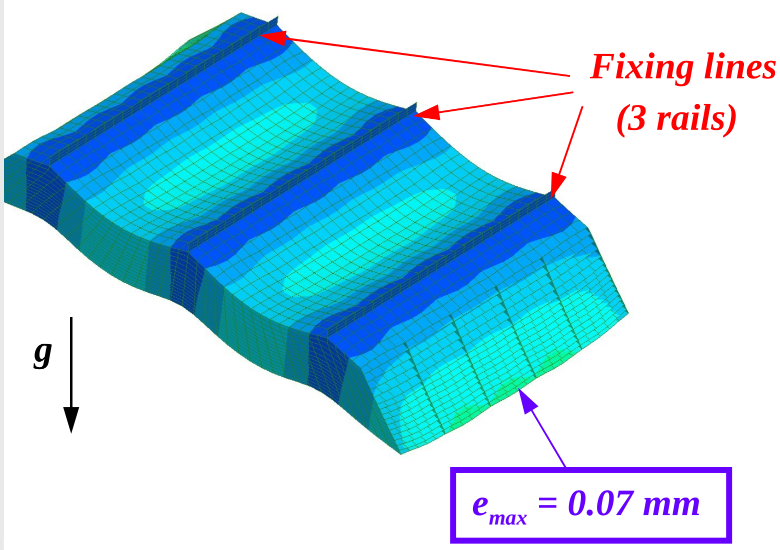
Modules are attached to inner HCAL face with rails

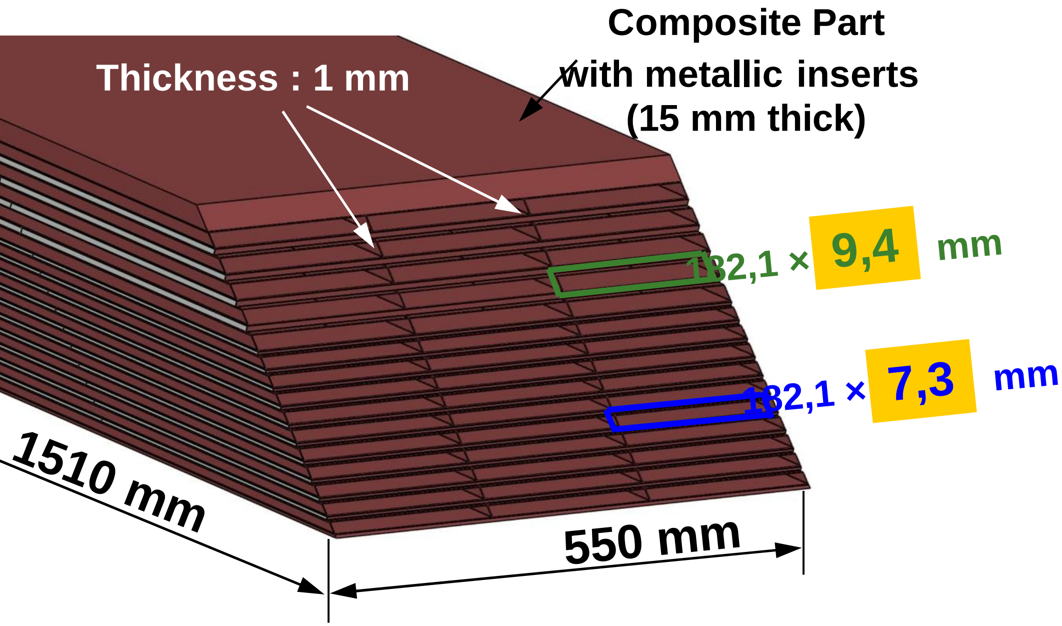






octagonal design: distortions





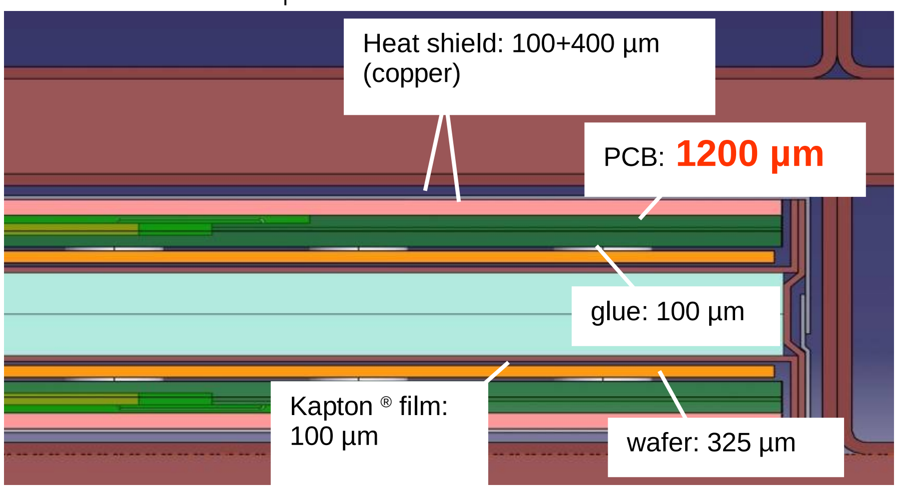
Alveolar structure

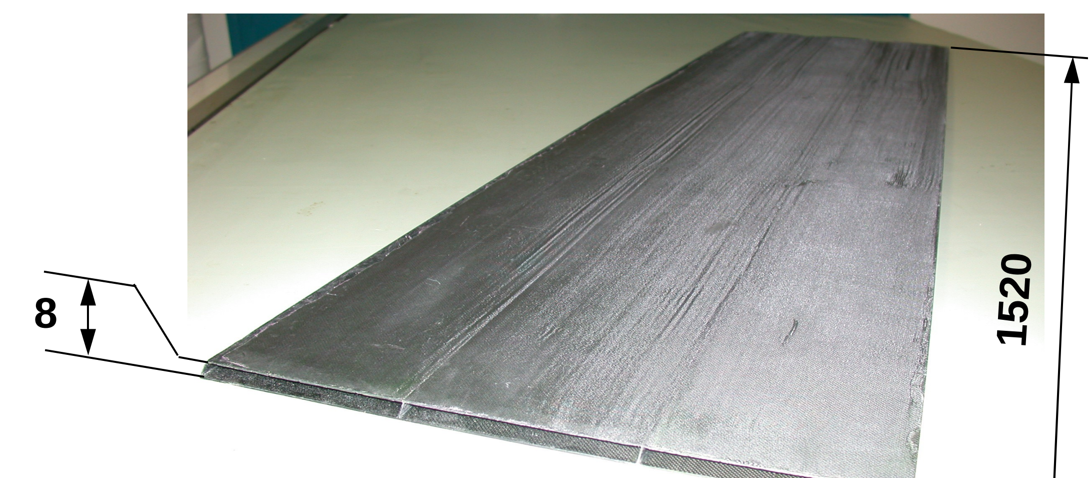
Carbon Fibre impregnated with Epoxy
- Layer made in mould
- Layers combined in 2nd step
- Helps quality control for manufacture

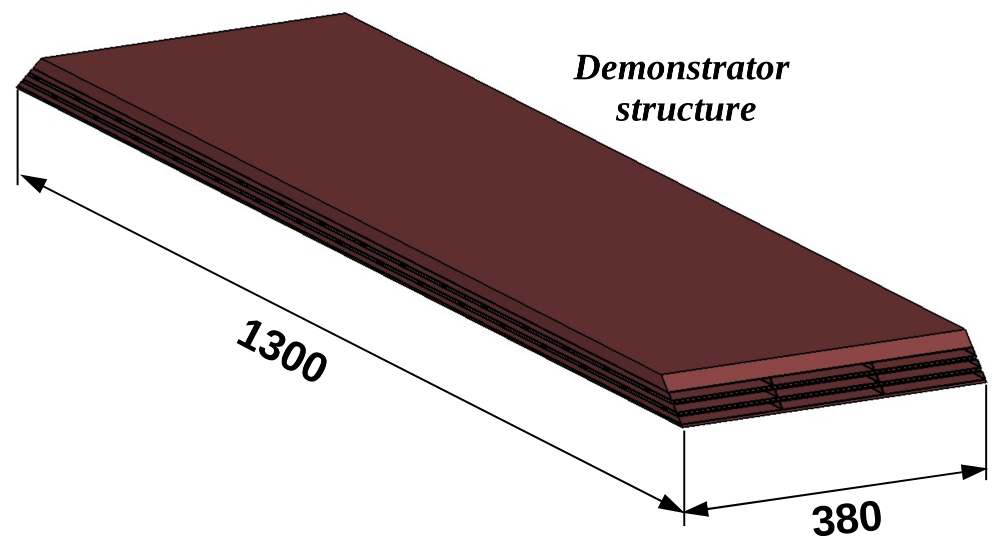
½ of tungsten layers integrated in structure

Active detector slabs slide into structure
- Carbon Fibre “H” structure
- Tungsten
- PCB+Silicon sensors+heat shield

3-layer, 1.3m-long demonstrator module
- Now ~ ready
- Mechanical & thermal tests







Active layers

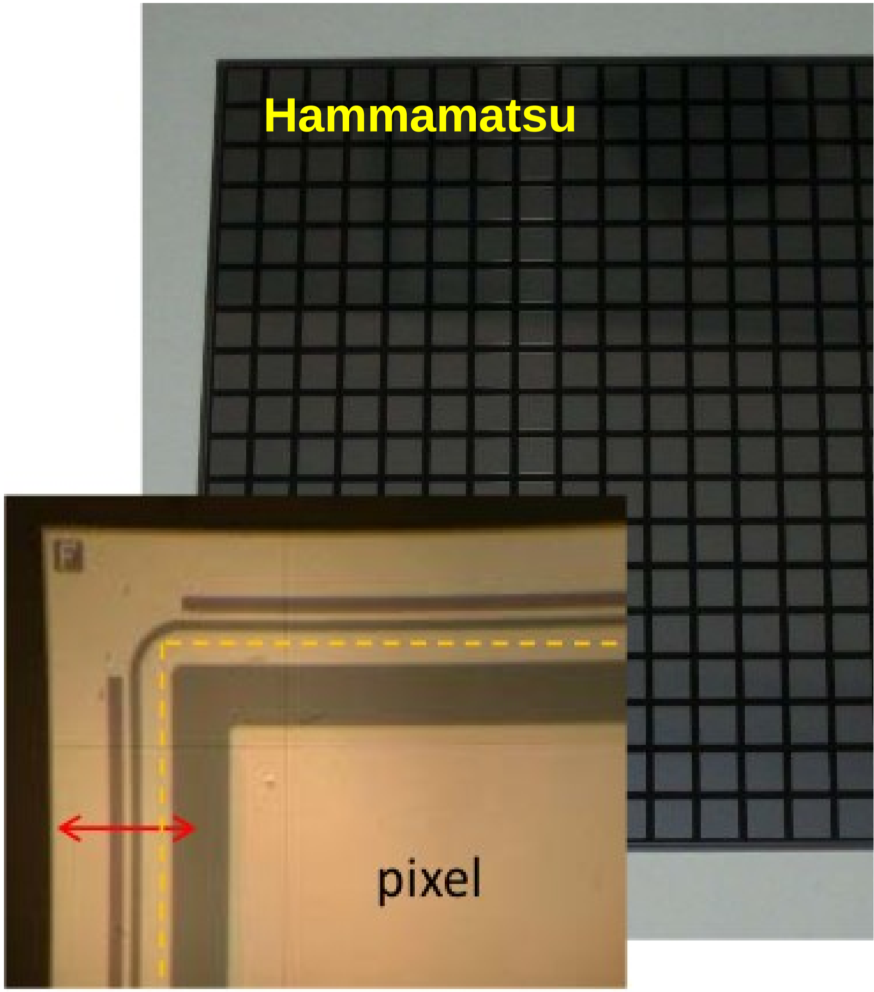
Silicon wafers, segmented into square PIN diodes
- total area in ILD ~3000m^2
- well-known industrial Si technologies

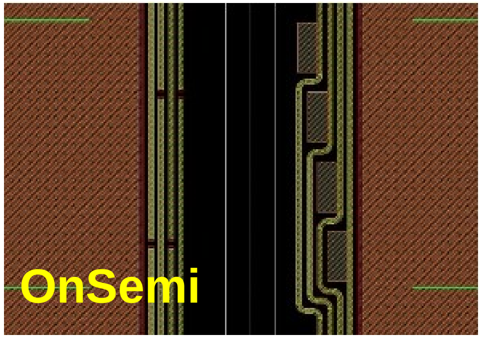
1st generation (2 manufacturers)
6X6cm^2 wafers, 10X10mm^2 cells
Stable operation during 3 years beam tests
Cross-talk between guard ring and cells

Next generation
Hammamatsu
9x9cm^2 wafers, 5X5mm^2 cells
- smaller effect of edges
OnSemi
Collaboration to study different designs
e.g. several small test wafers with different guard ring designs

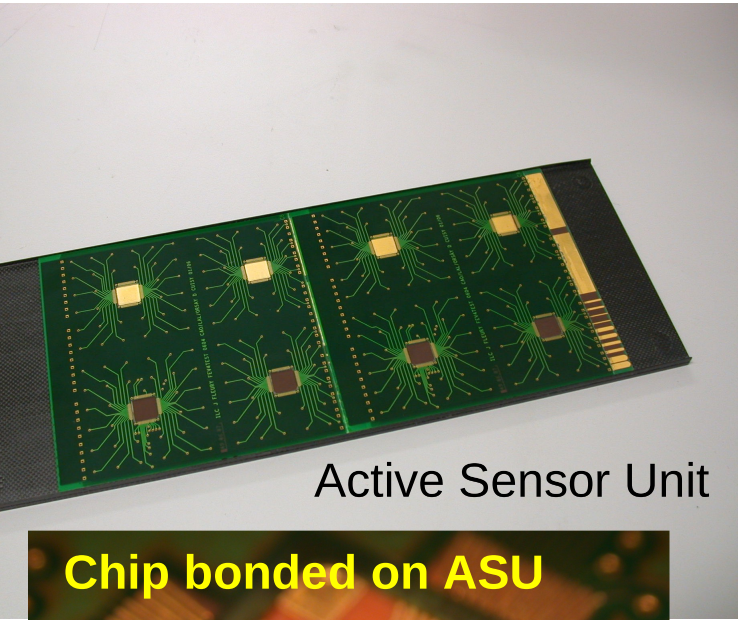
Links with other manufacturers:
Competition is good for us!

Aim for final cost of ~2.5$ per cm^2.



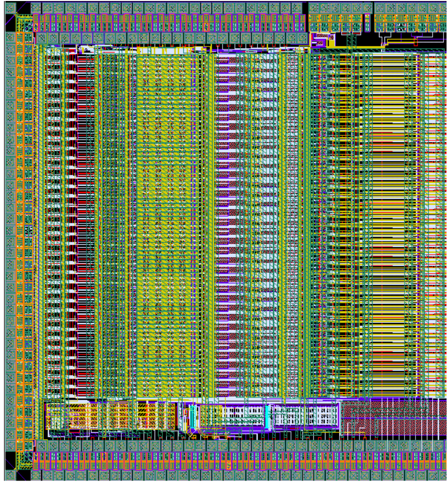


Front-end electronics/DAQ integration

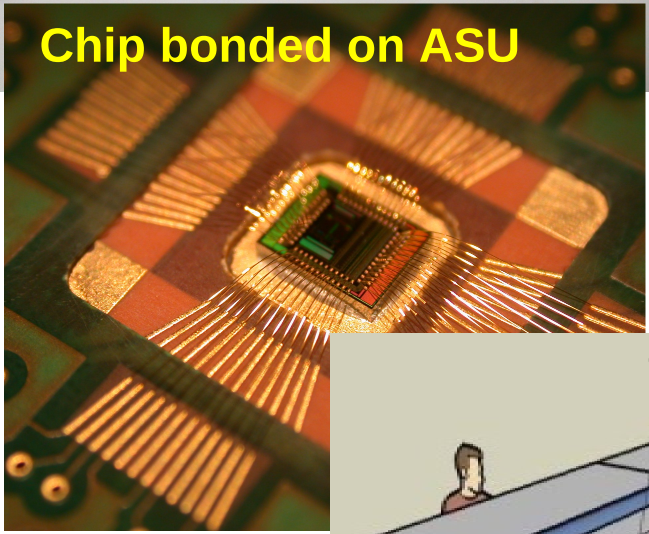


Si sensors mounted on PCB with front-end electronics (SKIROC chip), electrical services, sensors

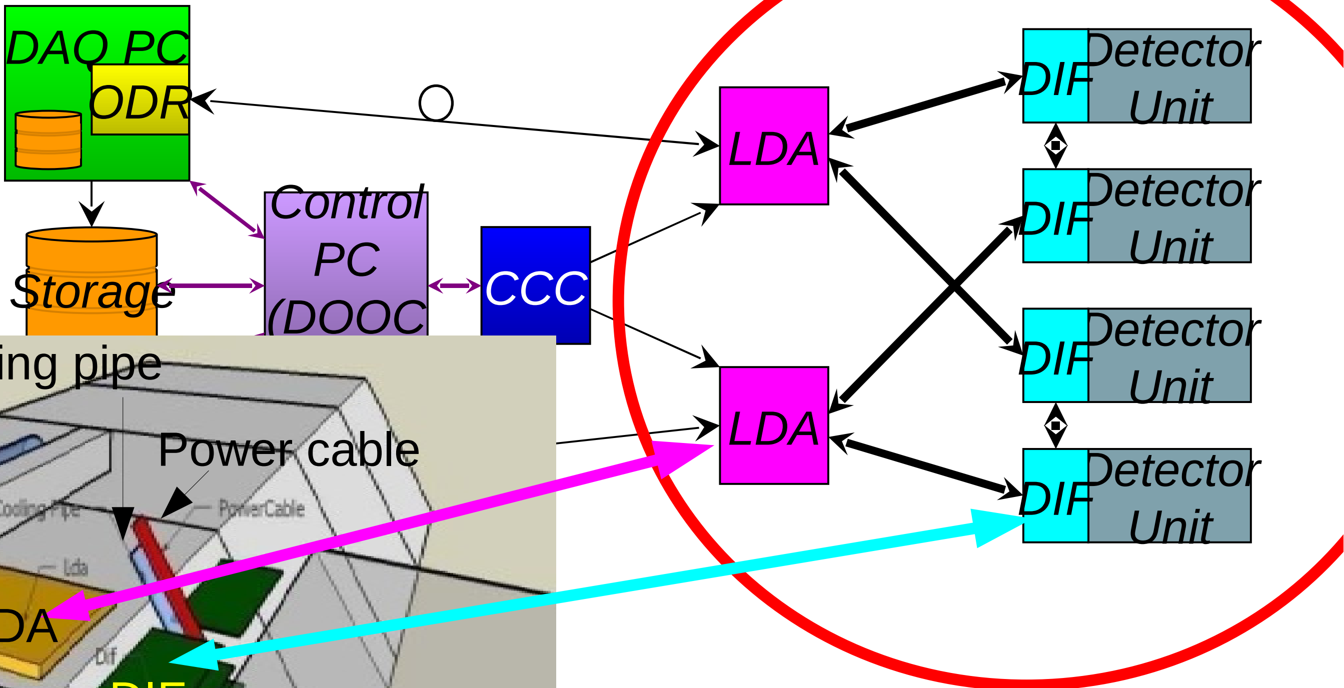
Several ASU connected into one slab, read out by a single DIF card

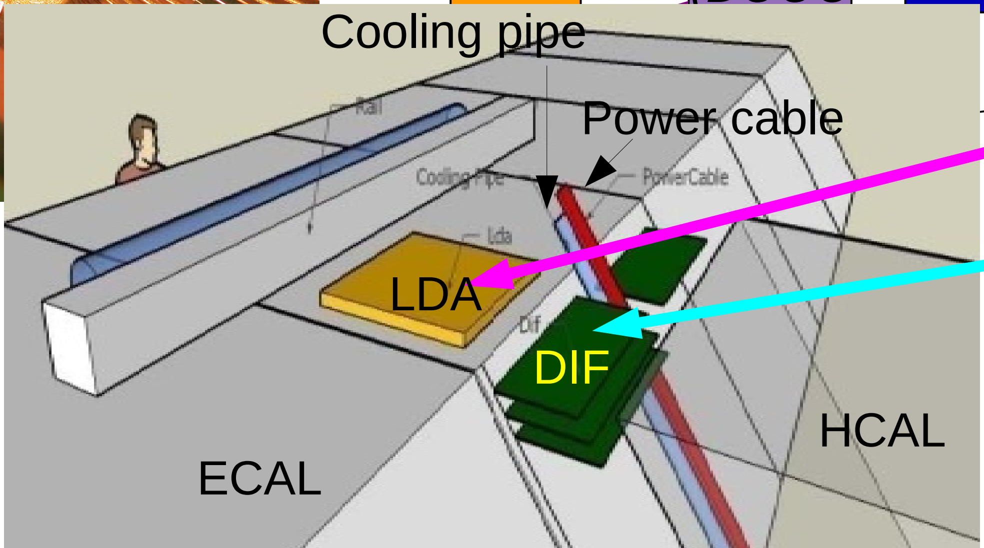


SKIROC



CALICE DAQ architecture





These sit in ECAL/HCAL gap

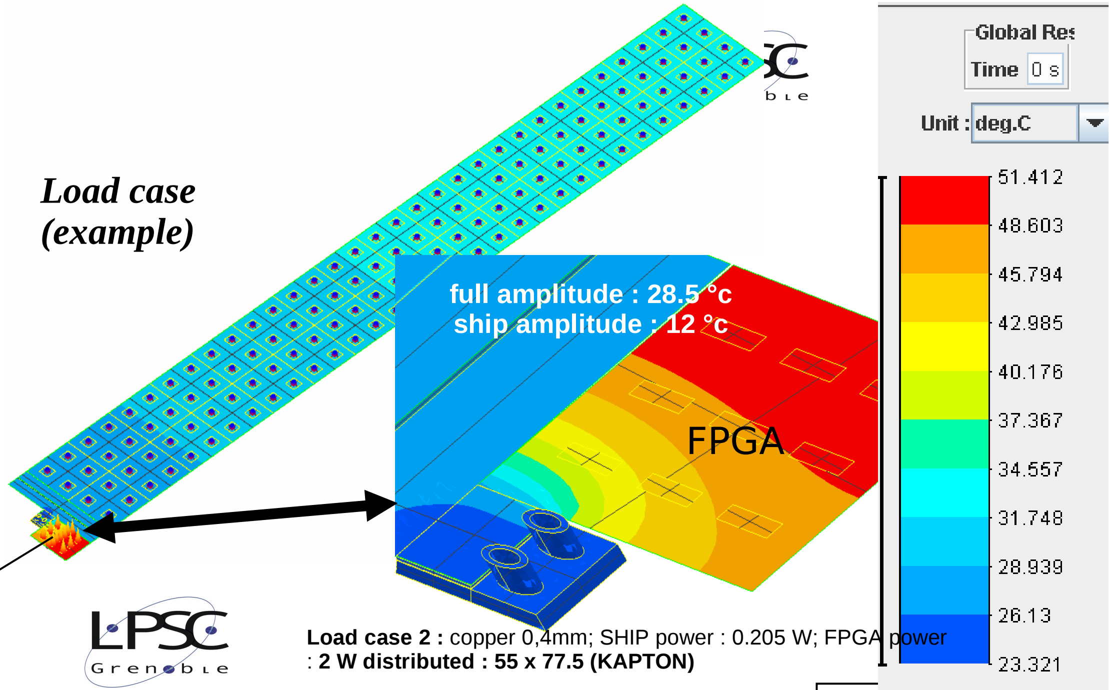
Heat & Cooling

VFE ~ 25 µW/channel (with power pulsing)
Cu layer in slab brings heat to module edge

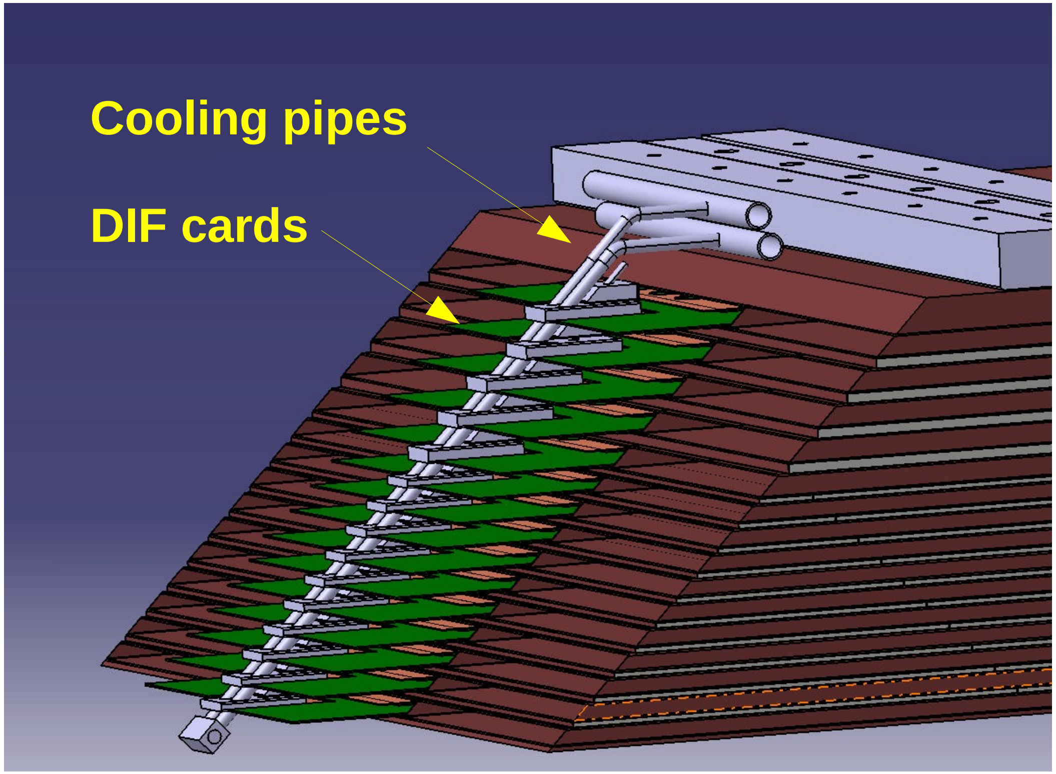
FPGA on DIF card produces additional heat

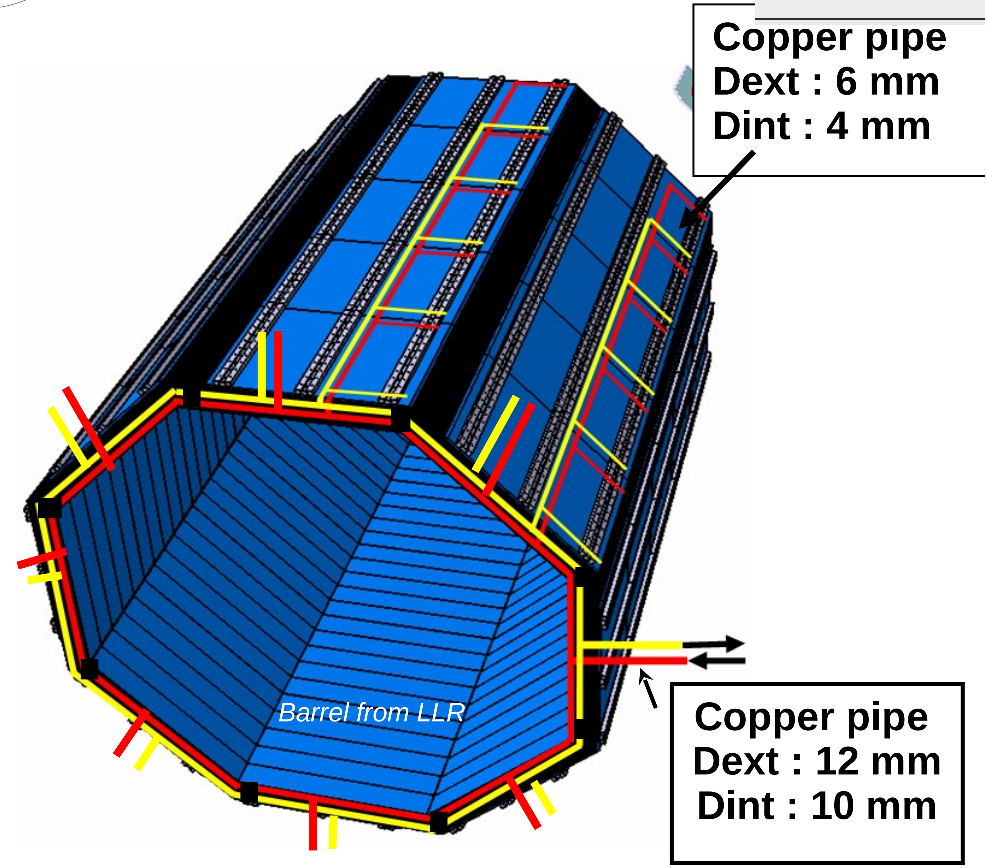
Total: ~ 3000W for barrel
~ 800W per endcap

cooling pipes (in ECAL/HCAL gap) extract
heat from module edge
Go to outside world via barrel/endcap gap

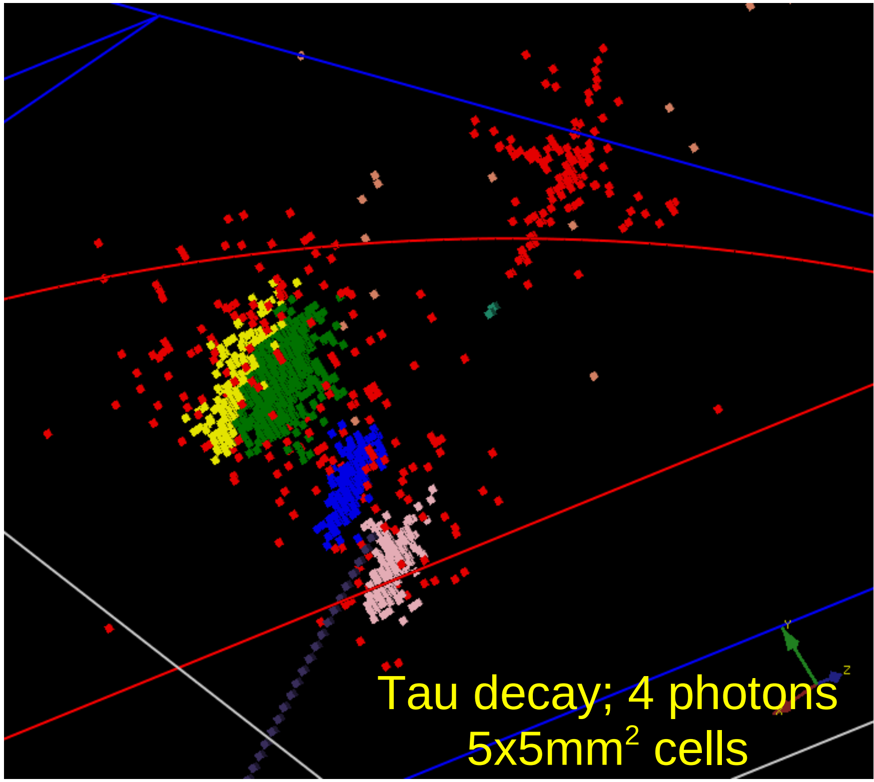


Load case 2 : copper 0,4mm; SHIP power : 0.205 W; FPGA power : **2 W distributed : 55 x 77.5 (KAPTON)**





Photon reconstruction



Dedicated photon identification: GARLIC algorithm
- Identify photons & electrons
- Estimate energy
- Distinguish near-by photons

see Marcel's talk (yesterday)

LoI contents

General Calorimeter section

- Introduction
  - Di-jet mass resolution for W/Z separation
  - dE/E ~ 3%
  - PFA drives design

- general mechanical description
  - Different calorimeter options in EM & Had

SiW Ecal section of LoI

- Introduction
  - PFA requires compact EM cal with high granularity, small Moliere radius
  - Fine longitudinal and transverse segmentation
  - Tungsten absorber, Si measurement layers

- Geometry & mechanical design
  - 20 layers * 0.6 X0, 9 layers @ 1.2 X0
  - 5X5mm2 cells

  - Hermeticity
    - large detector modules to reduce cracks
    - Non-pointing cracks in octagonal geometry

  - Assembly and integration of ECAL modules in ILD.

- Active layers
  - Silicon sensors
    - 3000M2 in total, standard production techniques
  - Silicon producers
    - Long-term (~3 year) tests of 1st generation sensors from 2 manufacturers
    - Collaboration with industry to study sensor design improvements
    - Silicon simulation tools available

Summary

Mechanical structure of ECAL modules well studied,
various prototypes built, under construction

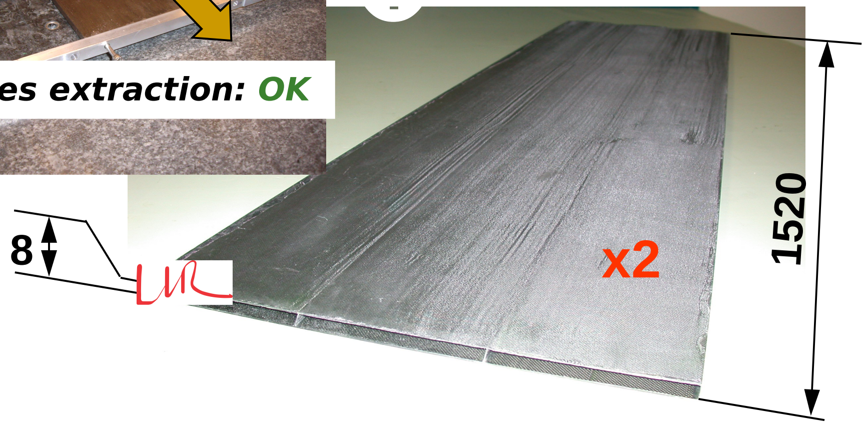
Now have had ~3 years operating 1^{st} generation Si wafers
Si development continuing, with several manufacturers

Good idea of DAQ and thermal integration into ILD

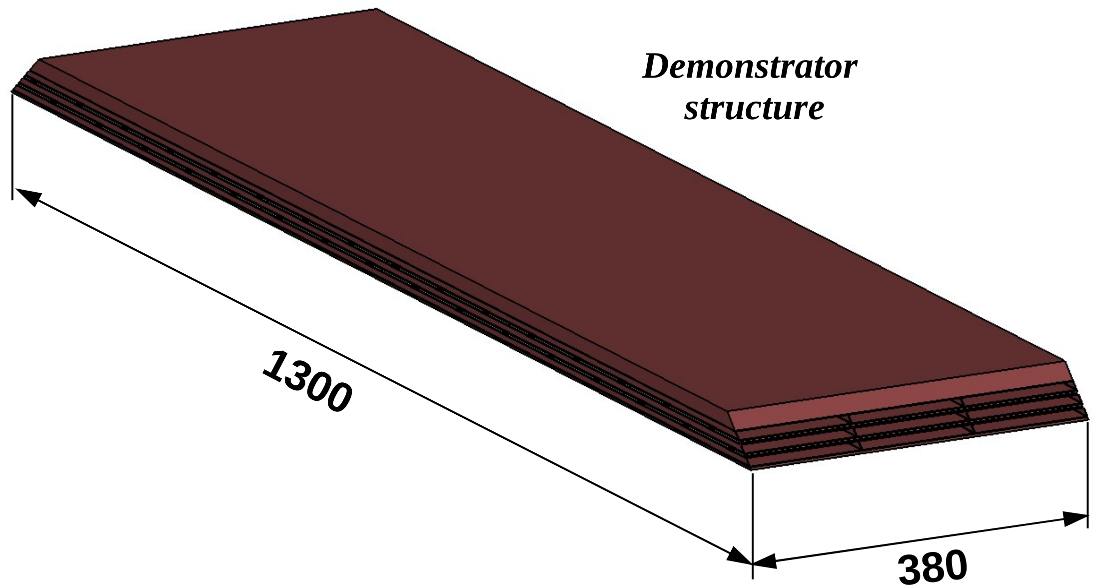
Specialised photon reconstruction agorithms under devlepment

Backup slides

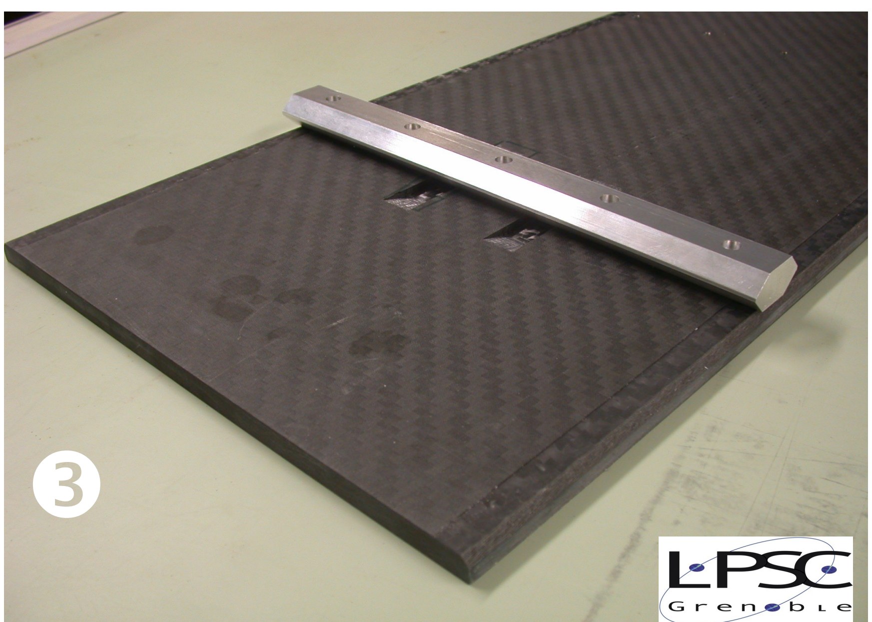
first test of alveolar layer

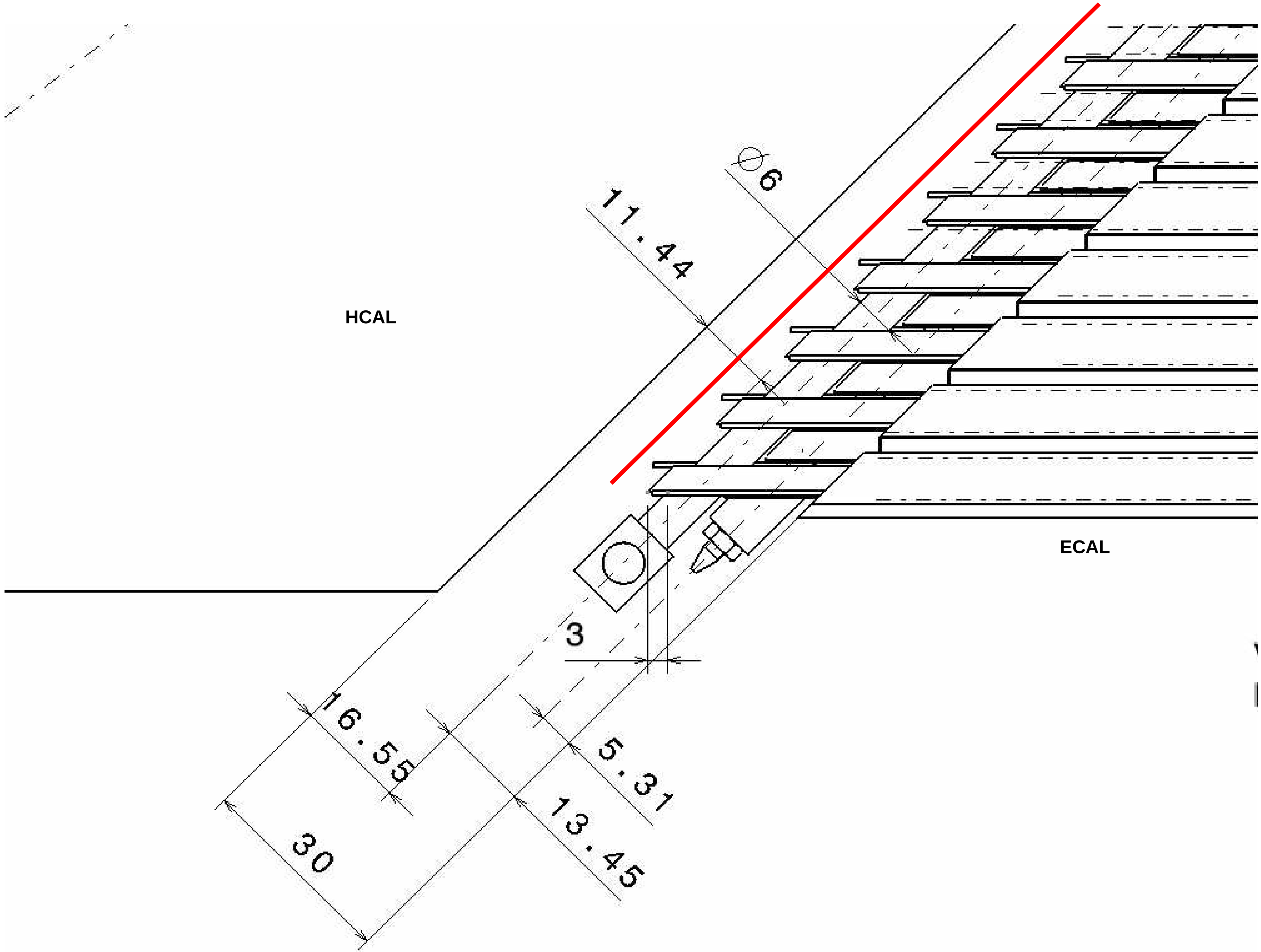


Demonstrator structure

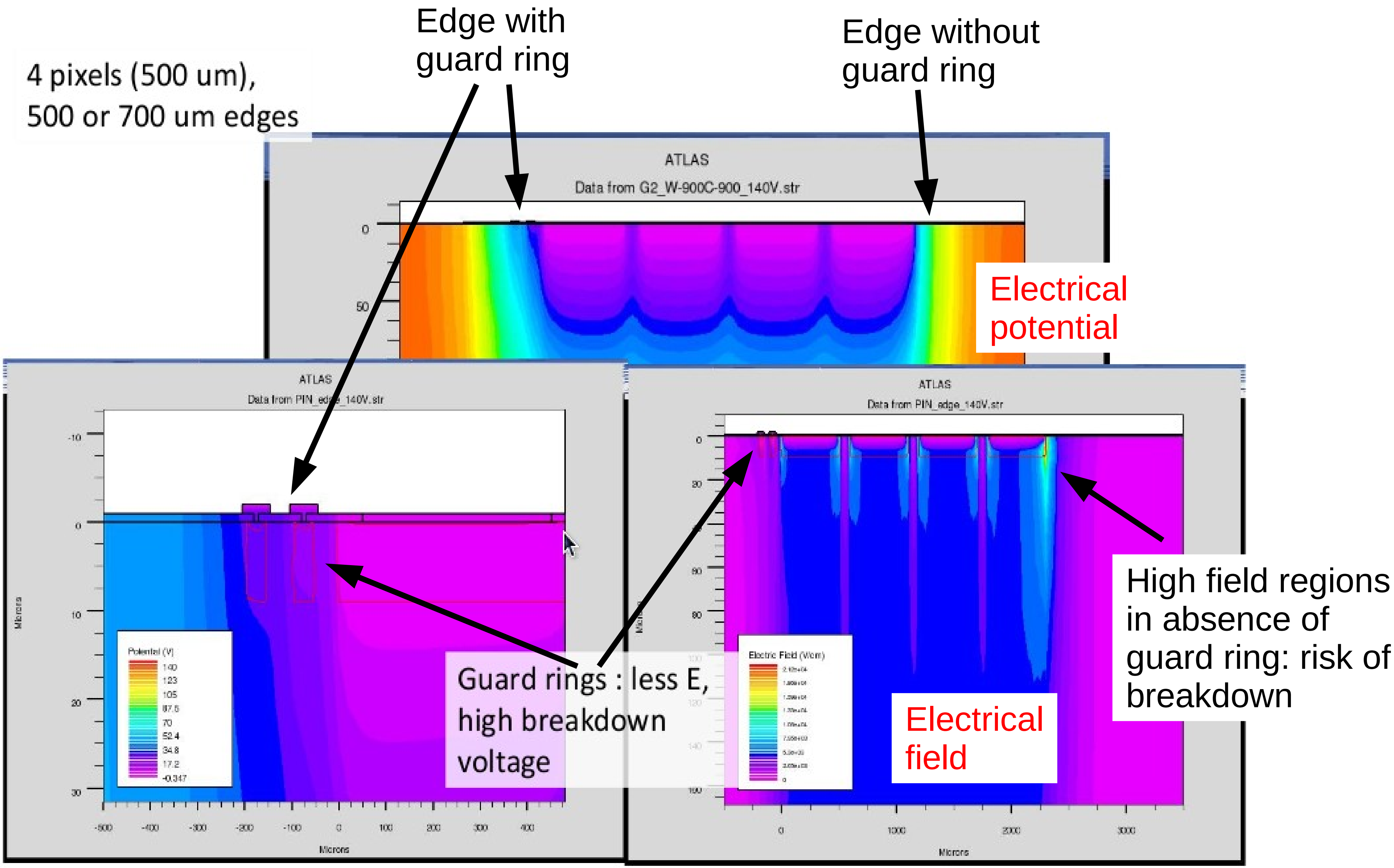


top composite plate (15mm)




HCAL
ECAL
11.44
∅6
3
16.55
5.31
13.45
30

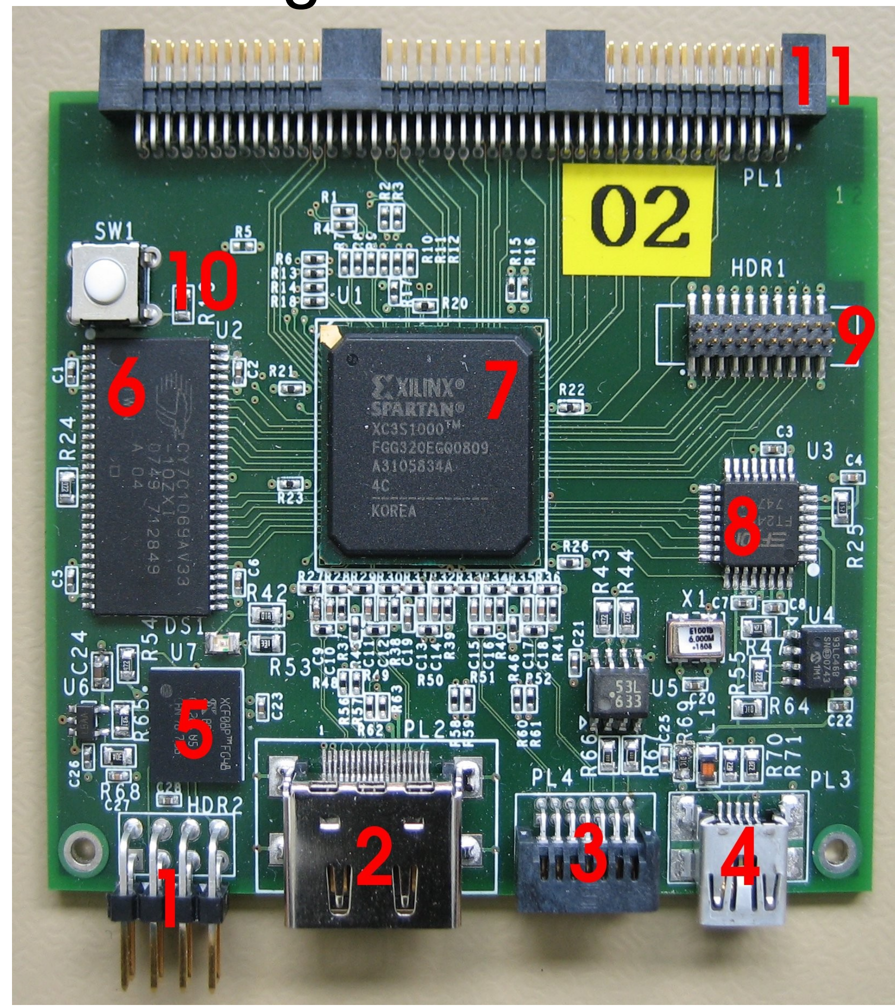
Simulations of guard rings etc.



DIF: Status (generic) and Plans

- Test hardware in place
- Firmware development started
  - LDA Link integration

e.g: ECAL DIF



ECAL DIF prototype:
65x72mm, 8 layers

1. JTAG programming header
2. LDA link HMDI connector
3. DIF link connector
4. mini-USB connector
5. Xilinx PROM
6. Cypress 2MB 10ns SRAM
7. Xilinx Spartan3-1000 FPGA
8. FDTI FT245R USB controller
9. 20p user header connector
10. reset pushbutton
11. 90pin SAMTEC IB connector

- 2 DIFs produced, parts available for 10 more.
- DIF hardware is (at least partly) functional