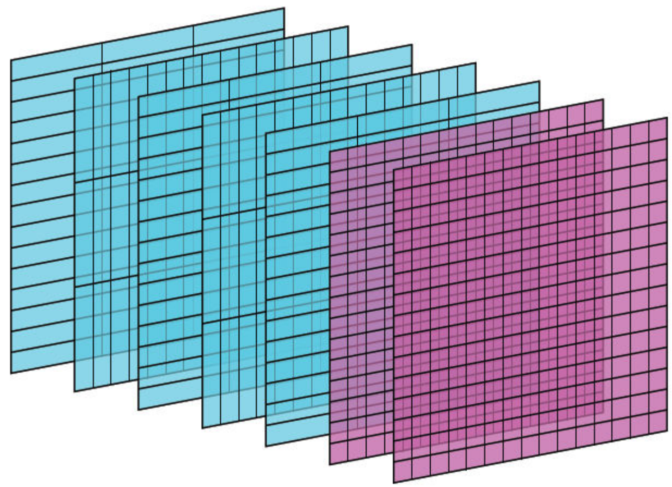
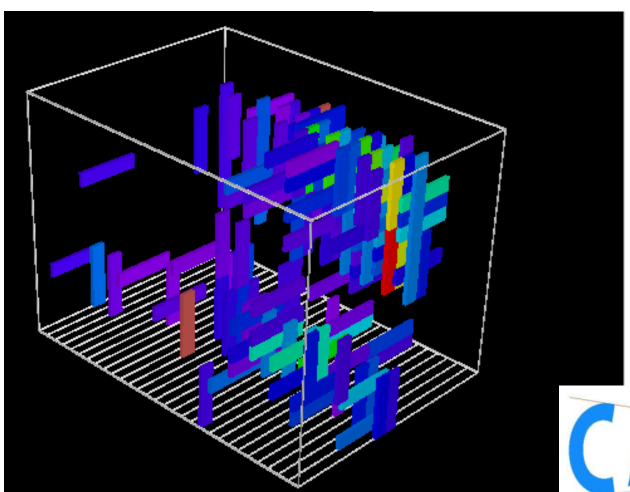
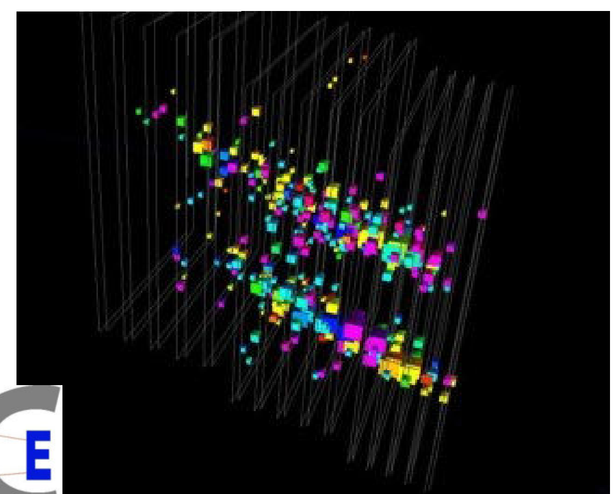
The ILD ECAL

Jan 28-30th 2010 ILDWS @ Paris

Satoru Uozumi (Kyungpook Natl. Univ.) *for the ILD ECAL group*





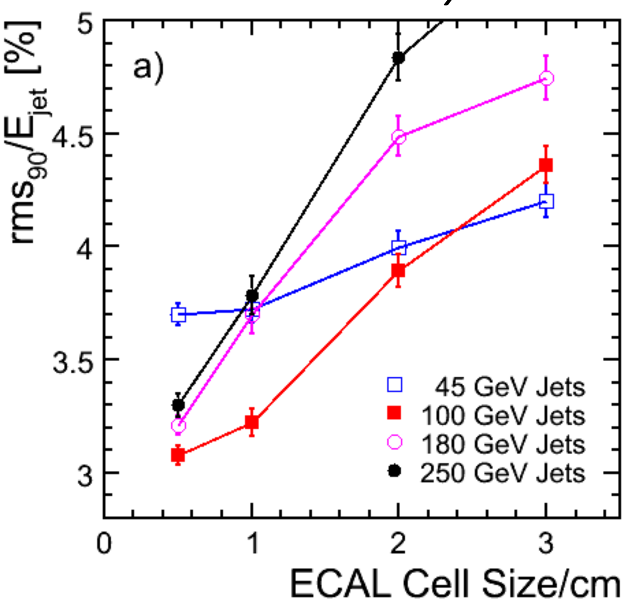


CALICE
Calorimeter for ILC

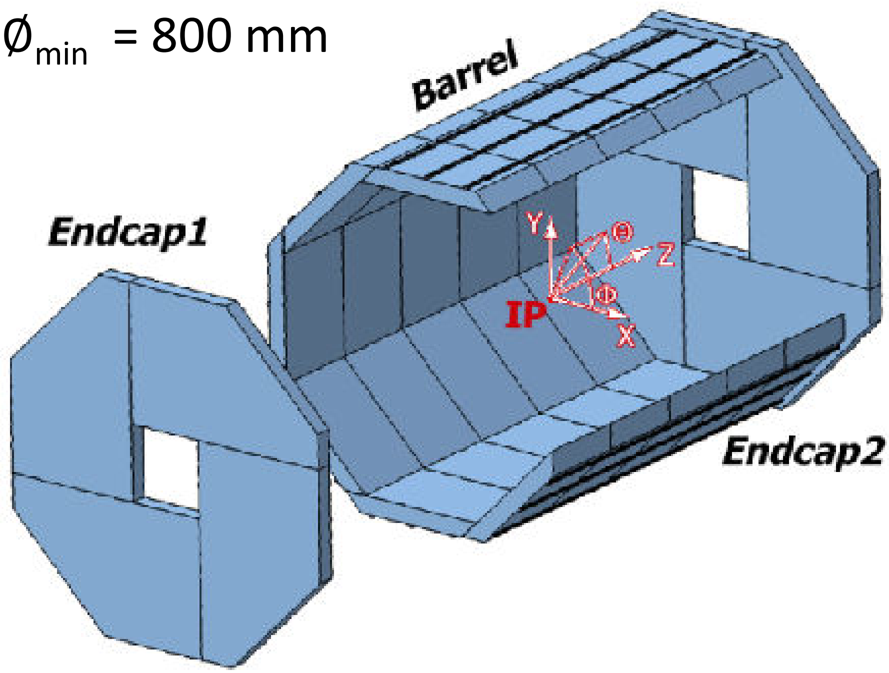
The ILD ECAL

- Finely granular PFA calorimeter with tungsten absorber
- Cell-size in baseline design ~ 5 x 5 mm^2, num. of cells ~100M in total
- Necessary to achieve less dead space, low production cost

Jet Energy Resolution by M. Thomson



Barrel: 5 octogonal wheels
R_{min} = 1808 mm; R_{max} = 2220 mm
Width = 940 mm
End-caps: 4 quarters
$\emptyset_{min}$ = 800 mm

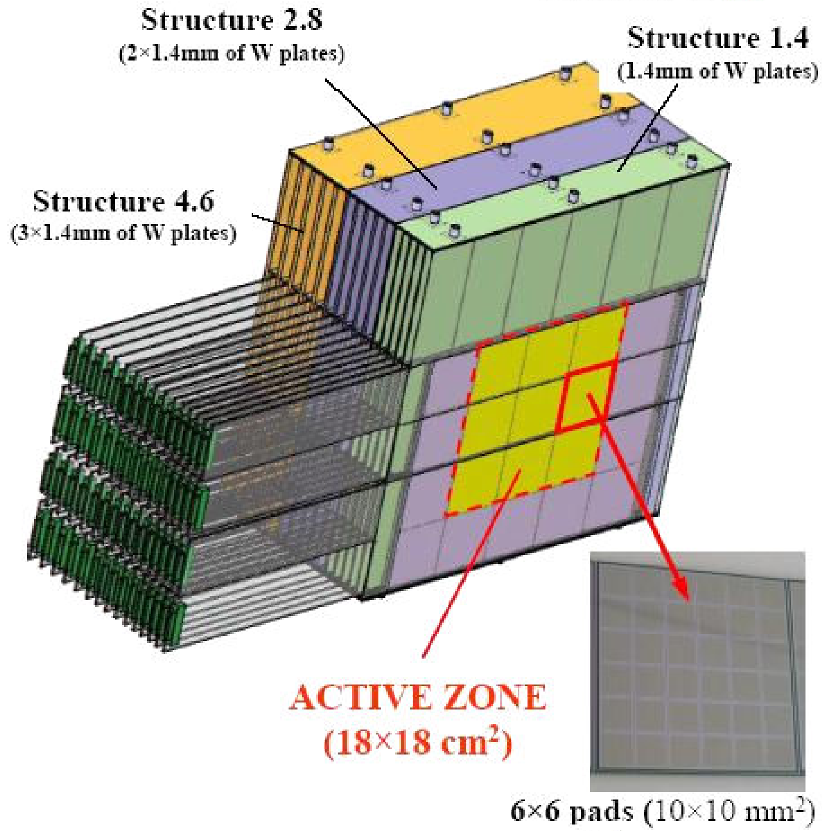


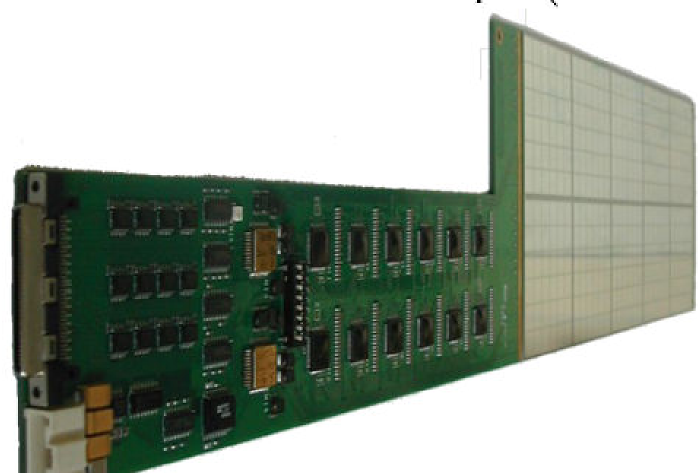
Candidate technologies :

- **Silicon-tungsten**
- **Scintillator-tungsten**
- **MAPS/DECAL**

Silicon-tungsten ECAL

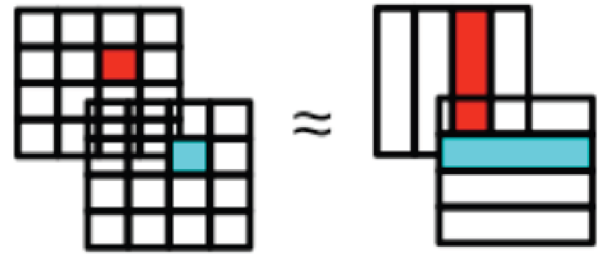
- **ILD Structure**
  - 20 layers of 2.1 mm ($0.6X_0$) W
    + 9 layers of 4.2mm ($1.2X_0$)W
  - 5x5 mm^2 granularity of Si
    ~ 108 M cells in total
- **10x10 mm^2 physics prototype tested in beam**
  - Energy resolution measured in test beam ~ $16.6\%/\sqrt{E(\mathrm{GeV})} \oplus 1.1\%$ with S/N ratio of 7.5 for a mip signal
  - CERN (2006, 2007), FNAL (2008)
- **Remaining hardware R&D issues**
  - Power pulsing of FE electronics (common issue also for Sci ECAL)
  - Si sensor cost reduction … need 2400 m^2, current price 10 euro/cm^2

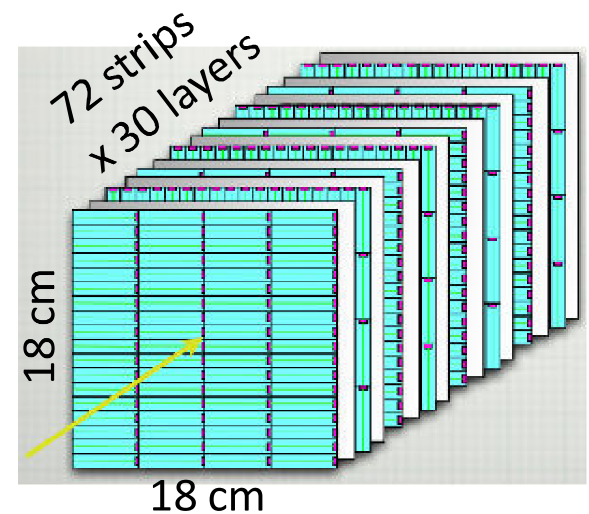


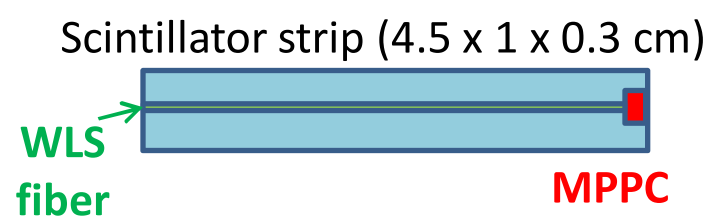


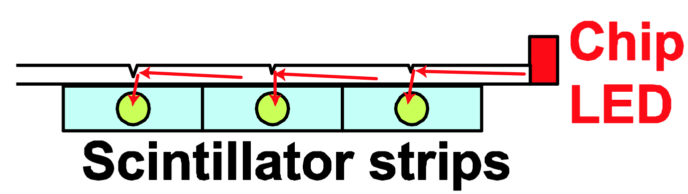
Scintillator-tungsten ECAL

- Cost-effective scintillator strip calorimeter aiming to have virtual cells by x-y strips crossing.
- Beam tests of the physics prototype have been performed to prove feasibility.
  - DESY 2007 (small prototype)
  - FNAL 2008, 2009 (test with AHCAL)
- ILD structure
  - Scintillator strips with 5 mm width
    2 mm thick without WLS fiber
  - 3 mm tungsten, ~21 X_0 in total
- Study of "strip-clustering" underway with realistic simulation
- Remaining Hardware R&D issues :
  - Study of 5 mm width scintillator-strip without WLS fiber
  - Dynamic range of photo-sensor
  - Establish design of the photo-sensor gain calibration system



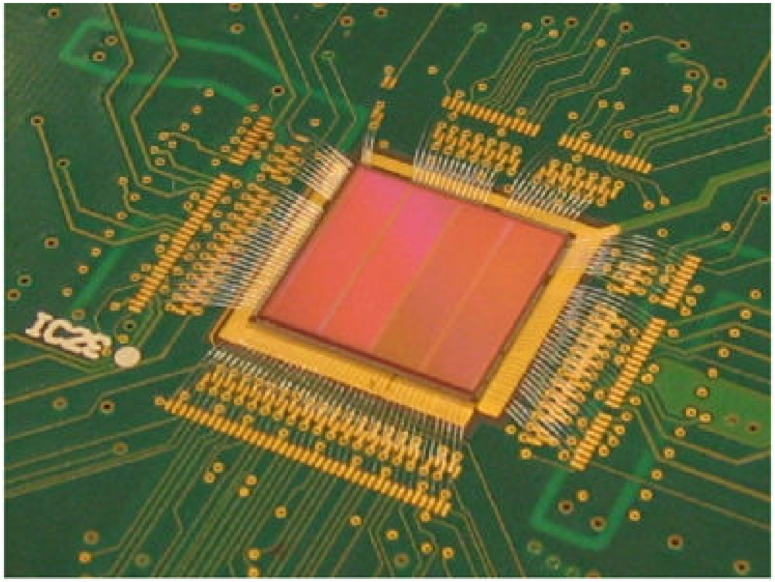


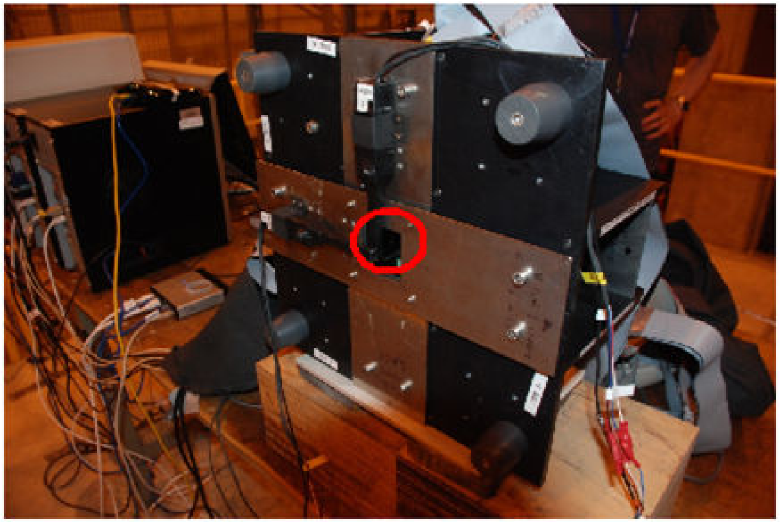


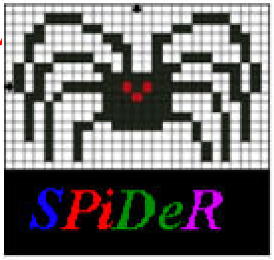


MAPS (DECAL) option

- Potential large cost reductions
  - Standard CMOS sensor
  - No proprietary processes
  - Electronics all on sensor, reduced fabrication/assembly costs
- Ultimate spatial resolution
  - $50x50\ \mu m^2$ pixels
  - “TERA Pixel” detector
- TPAC readout chip
  v1.0-v1.2 = 168 x 168 pixels; $79.4\ mm^2$
  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
  - Funding issue for further R&D







Question from IDAG

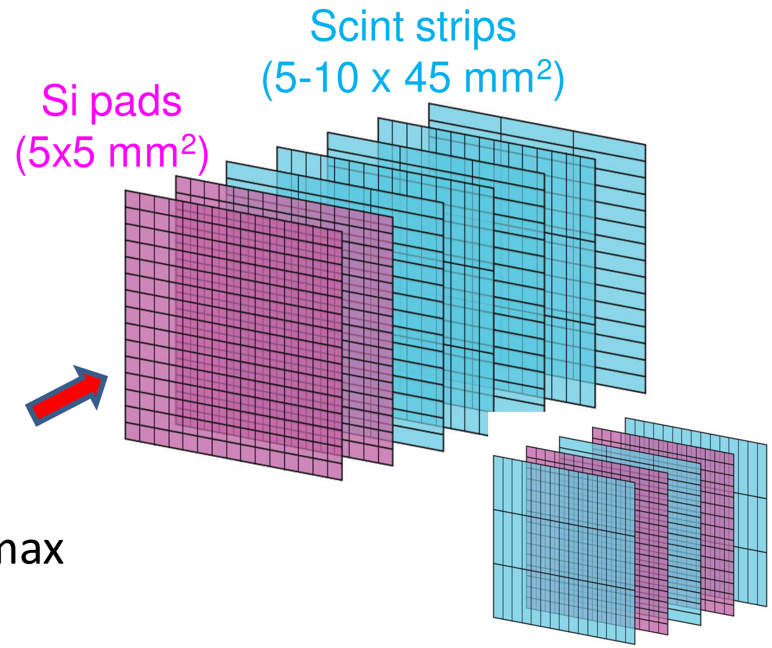
- **Each validated detector group will produce a detailed baseline design by 2012. To this end the following steps are planned.**

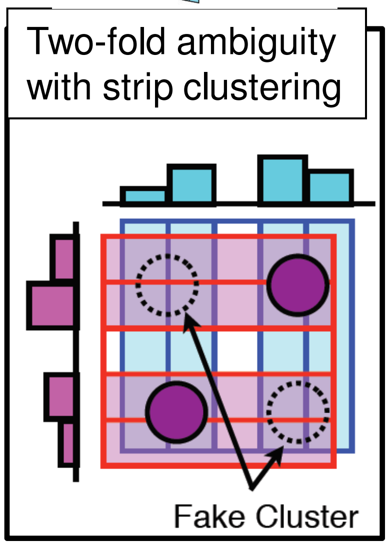
1. Demonstrate proof principle on critical components.
   - When there are options, at least one option for each subsystem will reach a level of maturity which verifies feasibility.
2. **Define a feasible baseline design.**
   - **While a baseline will be specified, options may also be considered**
3. Complete basic mechanical integration of the baseline design accounting for insensitive zones such as the beam holes, support structure, cables, gaps or inner detector material.
4. Develop a realistic simulation model of the baseline design, including the identified faults and limitations.

Possible Idea for baseline design of the ILD ECAL

- A lot of discussion has been done to form the “Unified ILD ECAL” in this month.

- One possible idea is a “hybrid-type ECAL” with silicon pads and Scintillator-strips.
  - The silicon pads in pre-shower and shower-max region
  - The scintillator layers cover after the shower maximum
  - Another idea : Si layers interleaved in scintillator layers
  - Cost-effective
  - No two-fold ambiguity for the strip clustering with silicon sensors
  - Can use established the silicon and Scintillator ECAL technologies.
  - Need extensive simulation study to determine configuration of Silicon / Scintillator layers
  - Specific cell & strip combined clustering must be developed.





- Mokka simulation of the hybrid-type ECAL is under preparation.

Question from IDAG

- **Each validated detector group will produce a detailed baseline design by 2012. To this end the following steps are planned.**

1. Demonstrate proof principle on critical components.
   - When there are options, at least one option for each subsystem will reach a level of maturity which verifies feasibility.
2. **Define a feasible baseline design.**
   - **While a baseline will be specified, options may also be considered**

→ **The Silicon-Scintillator hybrid ECAL could be the possible candidate in case of problem with silicon cost or reconstruction problem of scintillator. This possibility is subject to study in next 2 years. MAPS pixels for digital ECAL under investigation as an option beyond the baseline.**

3. Complete basic mechanical integration of the baseline design accounting for insensitive zones such as the beam holes, support structure, cables, gaps or inner detector material.
4. Develop a realistic simulation model of the baseline design, including the identified faults and limitations.

Question from IDAG

- **Each validated detector group will produce a detailed baseline design by 2012. To this end the following steps are planned.**

1. **Demonstrate proof principle on critical components.**
   - **When there are options, at least one option for each subsystem will reach a level of maturity which verifies feasibility.**
2. Define a feasible baseline design.
   - While a baseline will be specified, options may also be considered
3. **Complete basic mechanical integration of the baseline design accounting for insensitive zones such as the beam holes, support structure, cables, gaps or inner detector material.**
4. **Develop a realistic simulation model of the baseline design, including the identified faults and limitations.**

Major Milestones to prove Si-Sci-W ECAL feasibility by end 2012

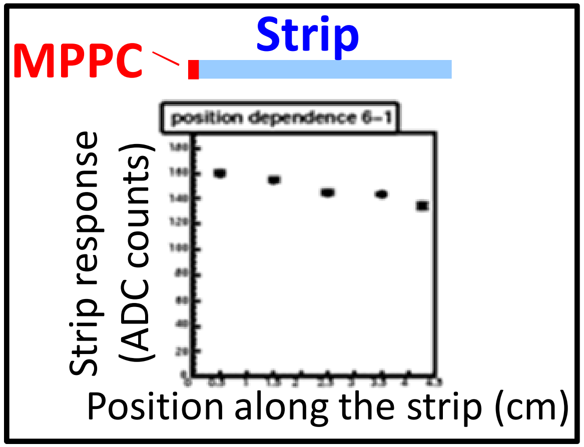
- **Technical points**

  - Produce short detector slab for both Silicon and Scintillator layers (by mid 2011)
    test it with cosmics and beams
  - Produce long Silicon detector slab (over ~1.5m) to test signal integrity etc.
    (by end 2011)
  - Demonstrate power pulsing of FE chips
    - First with single chip, short slabs of Si / Sci layers (by mid 2011)
    - Then with long slab (by end 2011)
    - Test in the magnetic field (by mid 2012)

  - Analysis of past test beam data, comparison with simulation (ongoing, ASAP)
  - Establish 5 mm width scintillator strip (by ~ 2010/2011)
  - Design and produce thin PCB for scintillator/MPPC layers (by mid 2011)

Major Milestones to prove Si-Sci-W ECAL feasibility by end 2012 (cont'd)

- **Simulation (all by mid 2010)**
  - Implement dead zones of scintillator (photo-sensor, covering films)
  - Implement non-uniformity of strip response
  - Update ILD Si simulation to same level as CALICE SiW testbeam simulation
  - Implementation of service inside gap between barrel and end-cap



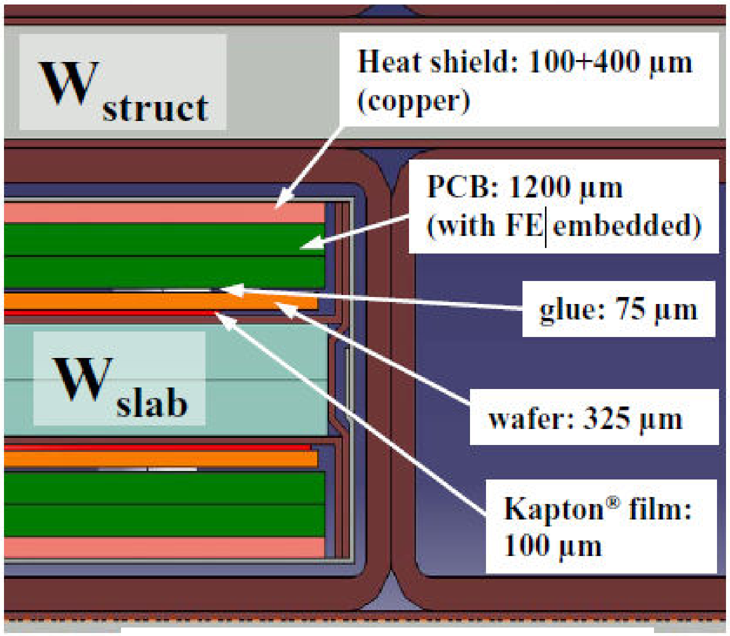
- **Reconstruction**
  - Realistic digitization (end-of-slab instrumentation, MPPC saturation) (by end 2010)
  - Clustering with strip and hybrid geometries (by mid 2011)
  - Study of PFA performance in different configurations of Si-Sci hybrid ECAL (by end 2011)
- **Detector calibration**
  - Define ILD ECAL calibration procedure (by end 2011)

Milestones to prove MAPS DECAL option feasibility by end 2012

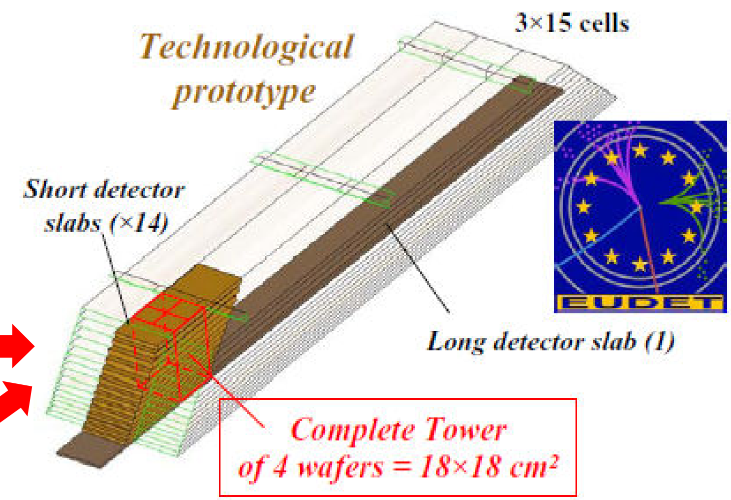
- **Technical – individual sensor characterization**
  - Measure MIP efficiency from 2009/10 test beams for sensor variants – by end 2010
    - Including epitaxial layer dependence: deep P-well; high resistivity; layer thickness
  - Publish essential characterisation data – by end 2010
    - Pedestals; noise; response uniformity; trimming; calibration with ^{55}Fe; diffusion time
  - Comparison of shower densities in data and simulation - DESY testbeam, March 2010
    - Electron response and core shower density
    - Results vs. particle energy and vs. material depth
    - Single most critical result for DECAL – by early 2011
  - Soft photon response downstream of absorber
- **Simulation**
  - Resolution of realistic DECAL to photons – by end 2010
    - Study dependence on pixel size; noise; deep P-well; charge diffusion; dead areas, etc.
  - Maintain compatibility with SiW analogue geometry/mechanics where appropriate, as expected for a high performance/lower cost *option*
- **Reconstruction**
  - Single particle and PFA tuned for DECAL in performance benchmark studies with most complete simulations – by end 2011

The EUDET prototype

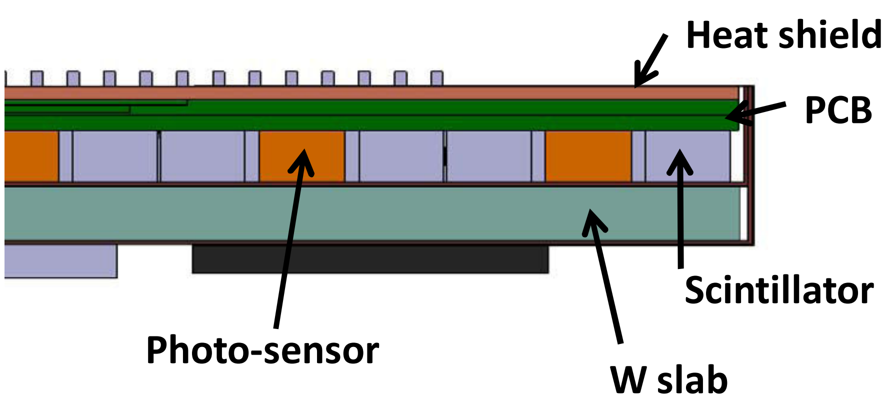
Silicon module



- The EUDET alveolar structure can accommodate both Si / Sci ECAL modules.
- Discussion underway to make the compatible structure.



Scintillator module



- Construction of the mechanical structure by end-2010.
- Implement detector modules ~ mid 2011.
- Future beam tests from ~ 2012
  - Si + Sci module test
  - Validate power pulsing
  - Test simulation with finer granularity

Summary

- Technologies and feasibility for the ILD ECAL is being established (in the CALICE collaboration).
  - Several beam test has been done with SiW and SciW ECAL prototypes during 2006-2009.
  - Realistic simulation study with PandoraPFA is ongoing.
- Now those technologies are being unified to an idea of the hybrid-ECAL with the silicon and scintillator layers.
  - It could be a possible candidate of the ILD ECAL baseline design.
  - Extensive simulation study will be done in next 2 years.
- MAPS pixels for digital ECAL under investigation as an option beyond the baseline design.
- Still a lot of works need be addressed to finish homework given by IDAG.
- EUDET technical prototype will be the next stage of the hardware R&D.
  - Several tests will be running from 2010 until the DBD.