Recent progress in Si-W ECAL for ILD

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on behalf of SiW group from LLR, LAL, LPNHE and LPSC (France).

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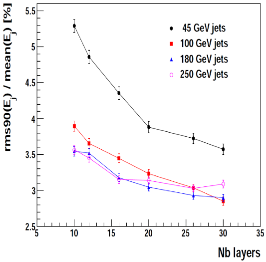
Why only silicon ECAL in France?

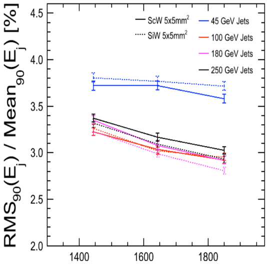
- ILC potential depends on both accelerator and detector. The latter should be considered as part of overall project. Cost savings with fully scintillator ECAL ($\sim$ 50 MILCU depending on ILD radius, cost of SiPM calibration etc.) are <1% of total ILC cost ($\sim$7-8 GILCU). Only one ILC detector is needed from physical (not political) point of view.
- Silicon advantages:
  - better granularity,
  - perfect linearity, easy calibration, time stability, robustness, $\rightarrow$ therefore, low systematics.
- No convincing argument on scintillator performance from simulation, as scintillator systematics (SiPM saturation, scintillator response non-uniformity, temperature dependence etc.) was not included in MC up to now.
- Concerning hybrid ECAL option, with both silicon and scintillator layers: complexity increases by >2, as commissioning of scintillator detectors will be more difficult than silicon. Also higher risks.
- Requirements on systematic errors in ECAL are more stringent than in HCAL. Eg. with 25% and 10% of electromagnetic and hadronic jet energy in average: $\sigma_E = 2\% \cdot 0.25E$ of ECAL systematics translates to 2% $\cdot$ 0.25 / 0.1 = 5% of equivalent HCAL systematics. Note: there may be more π^0 energy in jet due to large fluctuations.
- Synergy with CMS endcap Phase 2 upgrade project HGCAL also with silicon technology (alternative: shashlyk option, final choice in spring 2015).

Optimization studies

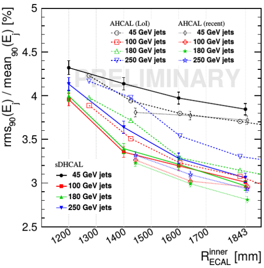
Possible scenario: reduce inner ECAL radius from 1.843 to ∼1.5 m, number of layers 29→∼25, ECAL cost by ∼40% with corresponding reductions of TPC, HCAL, muon and magnet yoke costs.



DBD (H.Tran, SiW+AHCAL)



J.S.Marshall (Si/Sc+AHCAL)

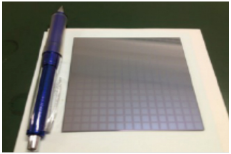


H.Tran (Si+AHCAL/SDHCAL)

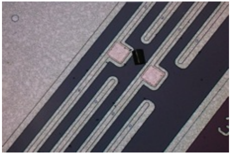
Plan: work on engineering design.

Si producers

- HPK Hamamatsu offer: 2.54 EUR/cm2 if they produce all Si ECAL. Same price as in DBD, $\sim$ 45% of full ECAL cost. Sensors from 6' wafers, 500 μm thick



"no guard ring", GR with 1, 2 or 4 segments:

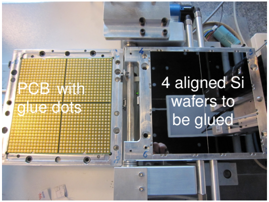


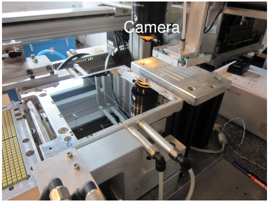
- LFoundry in Europe: agreement with CNRS+Institutes has been signed, first sensors ordered. 8' wafers, 700 μm thick ($\approx$ 6% better EM resolution).

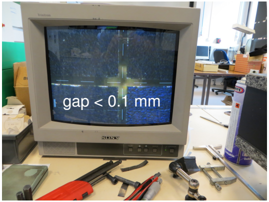
Sensor gluing

9 sensors have been successfully glued to 9 PCB by robot.
Preparation to glue 4 sensors to new PCB with x4 more channels:

- semi-automated process to position, align and glue 4 sensors to PCB has been developed
- 4 glass plates and 4 unprocessed wafers have been successfully glued







New DAQ electronics

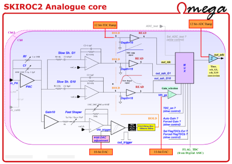
New SKIROC 2B front-end chip production with bug fixes in fall 2014.

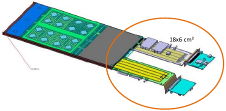
3 iterations of new front-end PCB serving 4 sensors: designed, produced and partially tested (without sensors). x4 higher density of channels due to BGA chip packaging. 2.8 mm thickness.

New low voltage/clock board serving one detector element ("slab") with several front-end PCBs has been designed, produced and tested.

Test production of thinner (1.2–1.5 mm) "chip-on-board" with naked die SKIROC 2 is ongoing in Korean EOS company.

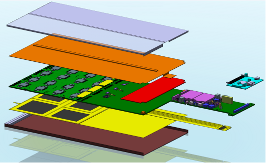
New version of DAQ software (PYRAME + CALICOES) has been written and tested.



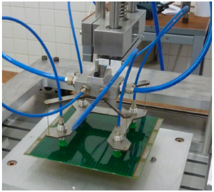


Detector assembly

- short slab with 1 front-end PCB and 4 sensors, production by end of this year

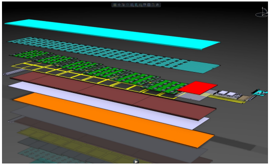


Carbon support + HV Kapton + PCBs with 4 sensors + Cu cooling + cover



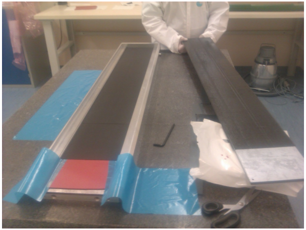
One assembly bench

- long slab, up to 8 front-end PCBs connected together, production next year

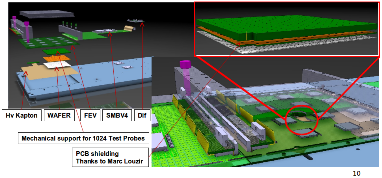


R&D of mechanical design

ILD slab: W absorber in carbon-fiber structure sandwiched between two active layers. Production of full-scale W + carbon-fiber absorber is planned. Same structure fully in carbon has been already built.

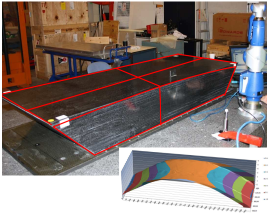


To test sensors without permanent gluing (eg. before detector assembly): setup with 1024 spring contacts (instead of glue) btw PCB and sensors.



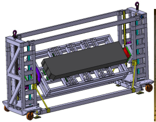
Structure with alveoli

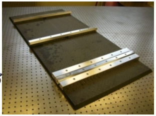
Big prototype (3/5 of ILD barrel module) has been built in 2011, 5 years of R&D, $\sim$600 kg. Separate layers of carbon fiber + W “cooked” together. Simulated mechanically & thermally.



Similar endcap structure is being designed. Long 2.5 m module for endcap with 3 alveoli has been built.

Special transport & handling tools, fastening rails are under development.





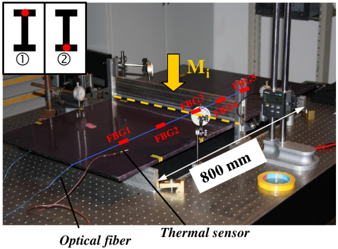
Thermal simulations eg. in endcap alveola:
passive cooling is sufficient.

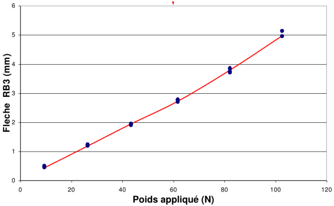
End Cap : (2.5m)

$\Delta T = 6°C$

Measurements with Bragg grating fibers

Another prototype with molded Bragg grating fibers. Detailed verification of simulated elongations under loads (by monitoring frequency shift of light reflected by fiber).





Vérification des paramètres du modèle en comparant la flèche FBG3 mesurée et simulée

Correlation with the experimental data (FBGs):

	Load (N)	ε_{yy} FBG1 (µm/m)		ε_{yy} FBG2 (µm/m)		ε_{yy} FBG3 (µm/m)		ε_{yy} FBG4 (µm/m)		ε_{yy} FBG5 (µm/m)	
		Exp.	Simu.	Exp.	Simu.	Exp.	Simu.	Exp.	Simu.	Exp.	Simu.
M1	9,38	-2,52	14	-12,6	-12,2	-29,86	-36,8	-7,41	-8,1	4,91	29
M2	26,35	0,84	27,8	-32,77	-30,6	-92,9	-100,7	-24,72	-26,5	15,55	42,51
M3	43,32	10,92	41,1	-53,78	-49,1	-156,77	-165,6	-39,55	-44,9	26,2	55,8
M4	61,64	21,01	55,4	-78,16	-69	-235,57	-237	-59,33	-64,8	31,11	70
M5	82,08	33,61	71,5	-109,26	-91,4	-336,77	-319,6	-79,93	-87,1	44,21	86,2
M6	102,53	48,74	87,4	-145,4	-117,7	-468,66	-413,7	-115,37	-112,8	58,13	102,2

Conclusions

- No convincing argument for large ECAL radius.
  Plan: develop engineering design with smaller radius and number of layers.
- potential Si producers:
  - Hamamatsu HPK, 2.5 EUR/cm^2, 6' wafers, 500 μm
  - LFoundry (Europe), 8', 700 μm
  - ...
- FE chip SKIROC 2B production by end of 2014,
  new FE PCB with x4 channels (ILD channel density),
  new LV/clock board,
  gluing of 4 sensors per PCB,
  - assembly of short slab with one FE PCB by end of 2014,
  - long slab with many FE PCBs in 2015
- mechanical design + prototyping is ongoing.