CALICE
Calorimeter for ILC

ILD

Technological prototype of the SiW ECAL

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LABORATOIRE
DE L'ACCÉLÉRATEUR
LINÉAIRE

LPNHE
PARIS

LPSC
Grenoble

3rd AIDA annual meeting
Vienna
26/03/2014

AGENCE NATIONALE DE LA RECHERCHE
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東京大学
THE UNIVERSITY OF TOKYO

AIDA

ECAL in AIDA

LLR FZÚ	FE & Silicon sensors (51 kEuro+18 kEuro)
LPSC Grenoble	Mechanical aspects – Cooling (27 kEuro)
LAL Omega	Ecal Front End Electronics (31 kEuro)
LPNHE Paris	Formerly on SiTr & DAQ … now gluing
UNIVERSITY OF CAMBRIDGE Royal Holloway University of London UCL MANCHESTER 1824	Former EUDET partners

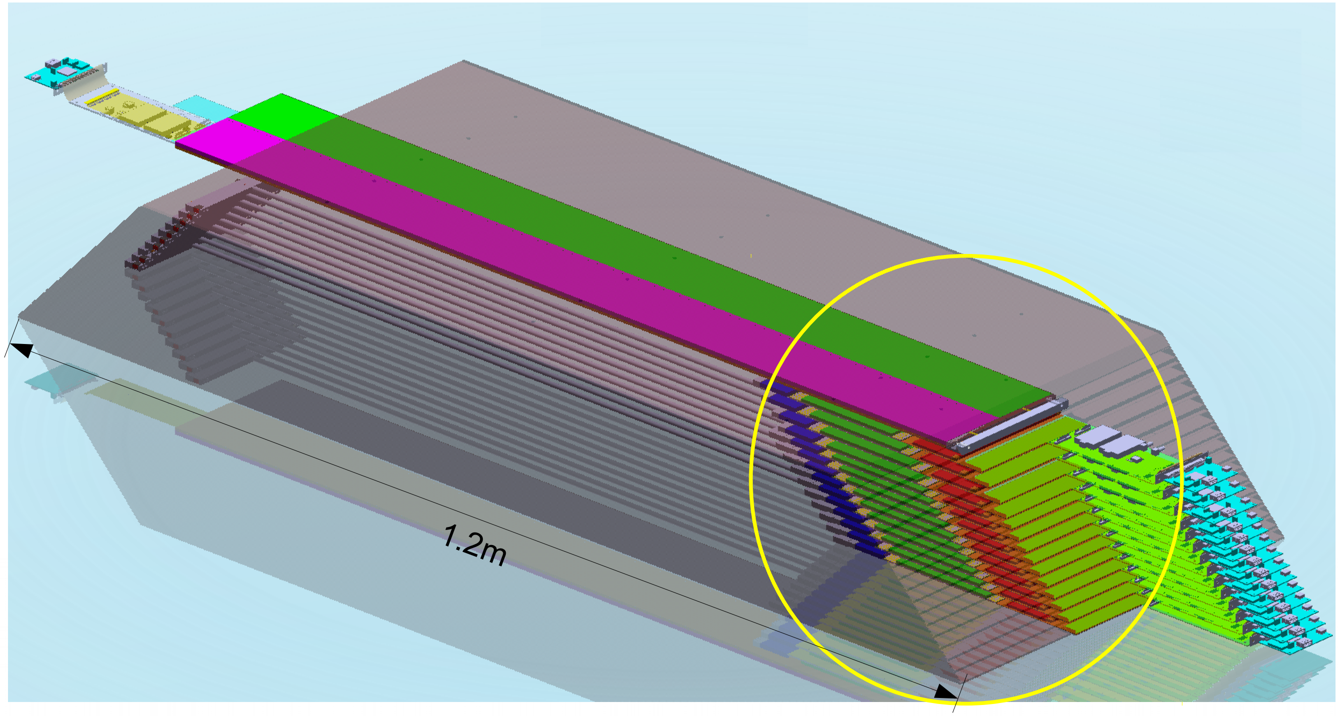
Project description: ECAL extension of the EUDET Module

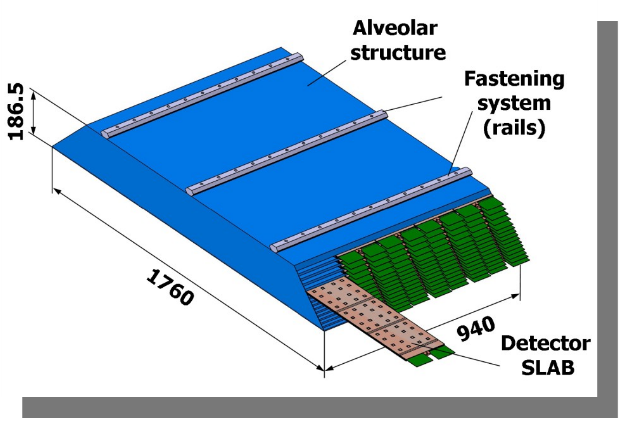
Project task: Electromagnetic calorimeter of at least 18x18 cm^2 area

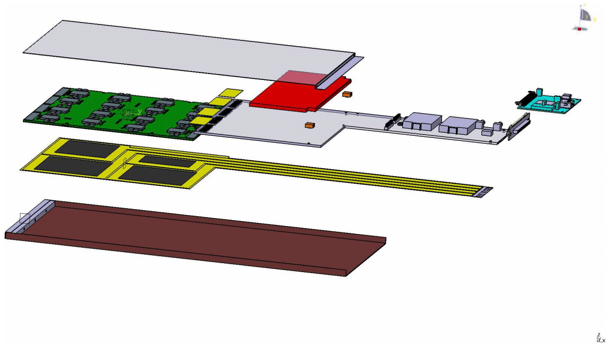
i.e. several short ASUs assembled in vertical direction

MS 46 to be delivered in month 36 → delay expected.

Technological prototype







Additional work not mentionned here:
ILD studies (optimisation,mechanical integration, performances, ...)

Acquisition

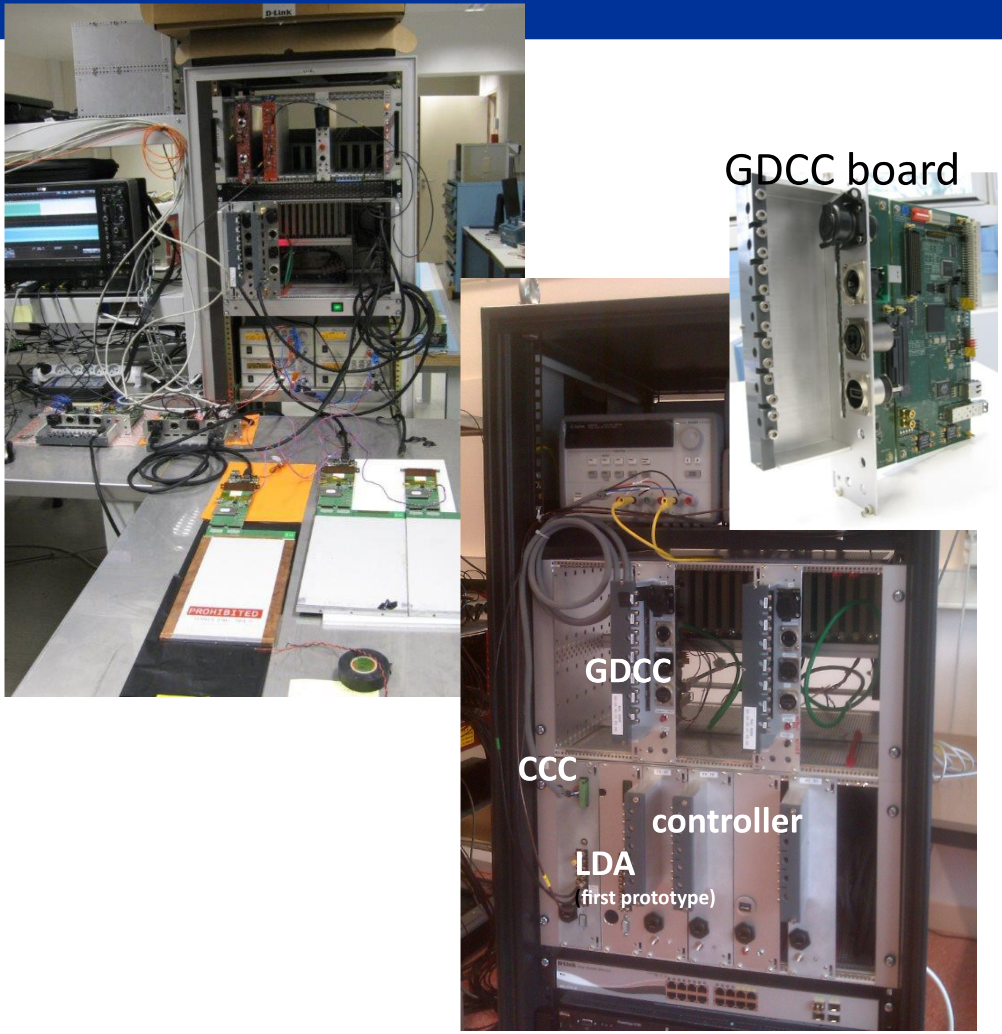
HW:

- (EUDET) LDA is substituted by GDCC
- bug fixes in DIF/LDA–GDCC firmware.
  - Lost packets rate « 1%
- ready for larger production (→ fall)

SW:

- new "distributed" DAQ software (CALICOES)
- quasi-online monitor GUI,
- SKIROC configuration GUI,
  - "automatic" channel masking

Fully stable → started sharing



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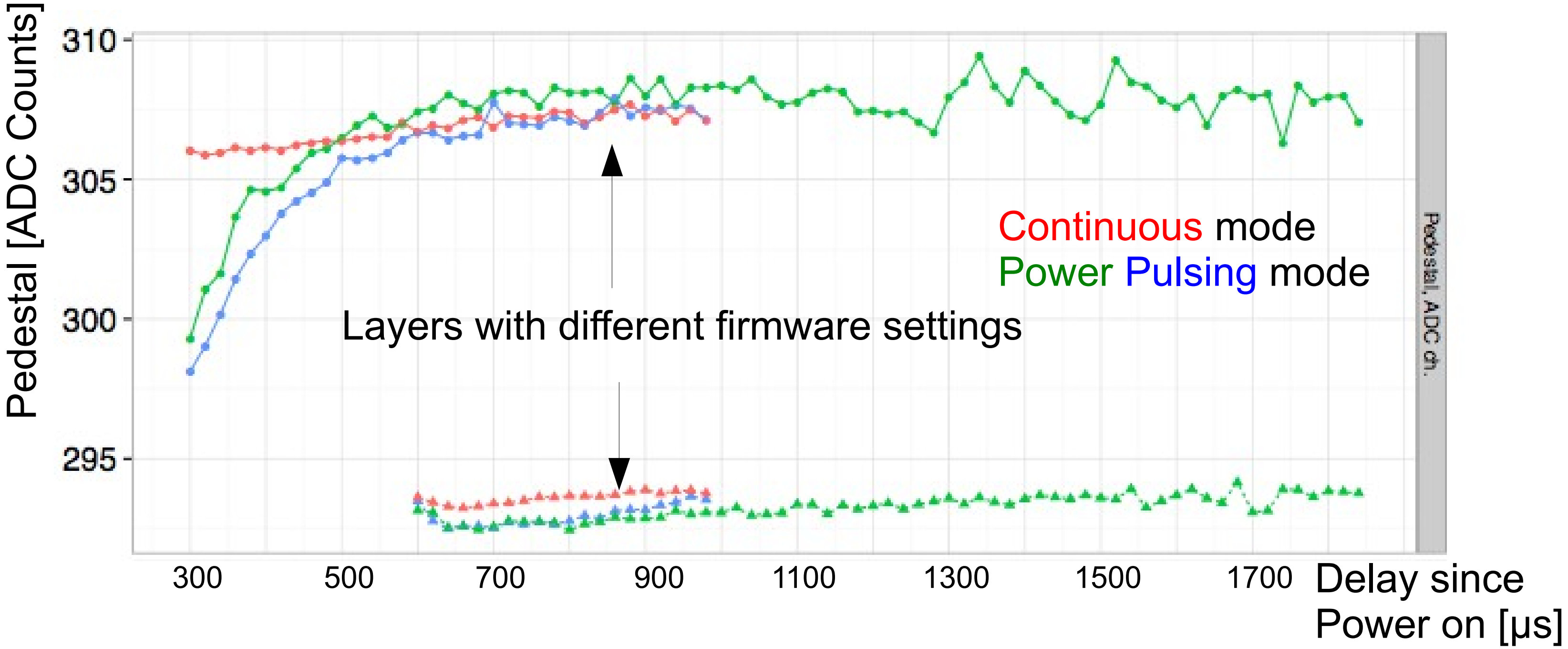
2013 TB activities:

- 2 beam tests in 2013 in DESY with 1–5 GeV electrons

  … debugging

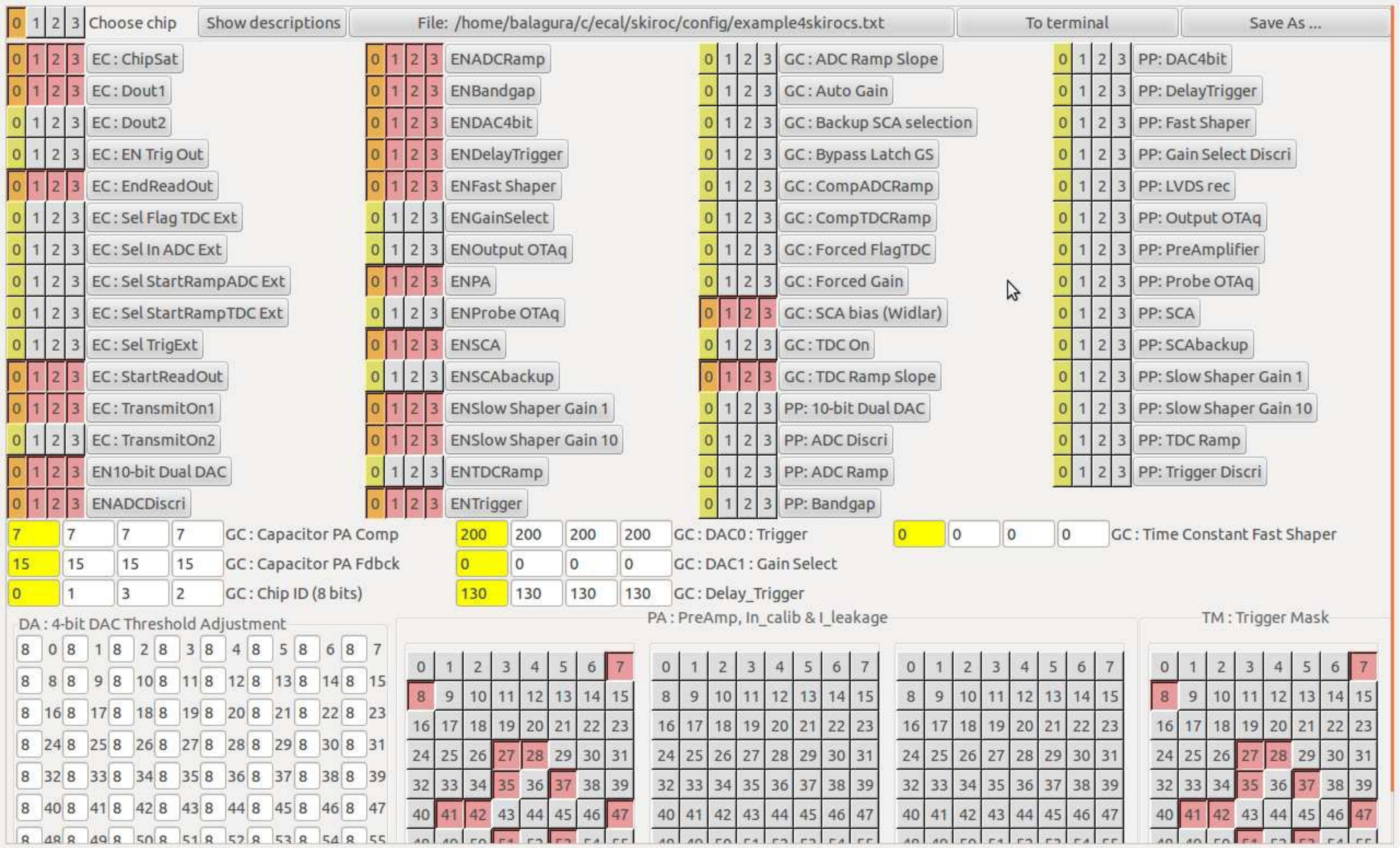
- Power pulsing works, pedestal stabilizes during 600 µs,
  S/N is worse for first few msec. S/N improves for higher SKIROC gains
  - Performance paper submitted [JINST]



SKIROC configuration tool

Full control of 4 SKIROCs in one ASU. Plan to extend to many ASUs.

- (labview) → Currently in Ruby (→? Python) + GTK



File: /home/balagura/c/ecal/skiroc/config/example4skirocs.txt

0 1 2 3 EC : ChipSat
0 1 2 3 EC : Dout1
0 1 2 3 EC : Dout2
0 1 2 3 EC : EN Trig Out
0 1 2 3 EC : EndReadOut
0 1 2 3 EC : Sel Flag TDC Ext
0 1 2 3 EC : Sel In ADC Ext
0 1 2 3 EC : Sel StartRampADC Ext
0 1 2 3 EC : Sel StartRampTDC Ext
0 1 2 3 EC : Sel TrigExt
0 1 2 3 EC : StartReadOut
0 1 2 3 EC : TransmitOn1
0 1 2 3 EC : TransmitOn2
0 1 2 3 EN10-bit Dual DAC
0 1 2 3 ENADCDiscri

0 1 2 3 ENADCRamp
0 1 2 3 ENBandgap
0 1 2 3 ENDAC4bit
0 1 2 3 ENDelayTrigger
0 1 2 3 ENFast Shaper
0 1 2 3 ENGainSelect
0 1 2 3 ENOutput OTAq
0 1 2 3 ENPA
0 1 2 3 ENProbe OTAq
0 1 2 3 ENSCA
0 1 2 3 ENSCAbackup
0 1 2 3 ENSlow Shaper Gain 1
0 1 2 3 ENSlow Shaper Gain 10
0 1 2 3 ENTDCRamp
0 1 2 3 ENTrigger

0 1 2 3 GC : ADC Ramp Slope
0 1 2 3 GC : Auto Gain
0 1 2 3 GC : Backup SCA selection
0 1 2 3 GC : Bypass Latch GS
0 1 2 3 GC : CompADCRamp
0 1 2 3 GC : CompTDCRamp
0 1 2 3 GC : Forced FlagTDC
0 1 2 3 GC : Forced Gain
0 1 2 3 GC : SCA bias (Widlar)
0 1 2 3 GC : TDC On
0 1 2 3 GC : TDC Ramp Slope
0 1 2 3 PP: 10-bit Dual DAC
0 1 2 3 PP: ADC Discri
0 1 2 3 PP: ADC Ramp
0 1 2 3 PP: Bandgap

0 1 2 3 PP: DAC4bit
0 1 2 3 PP: DelayTrigger
0 1 2 3 PP: Fast Shaper
0 1 2 3 PP: Gain Select Discri
0 1 2 3 PP: LVDS rec
0 1 2 3 PP: Output OTAq
0 1 2 3 PP: PreAmplifier
0 1 2 3 PP: Probe OTAq
0 1 2 3 PP: SCA
0 1 2 3 PP: SCAbackup
0 1 2 3 PP: Slow Shaper Gain 1
0 1 2 3 PP: Slow Shaper Gain 10
0 1 2 3 PP: TDC Ramp
0 1 2 3 PP: Trigger Discri

7 7 7 7 GC : Capacitor PA Comp
15 15 15 15 GC : Capacitor PA Fdbck
0 1 3 2 GC : Chip ID (8 bits)

200 200 200 200 GC : DAC0 : Trigger
0 0 0 0 GC : DAC1 : Gain Select
130 130 130 130 GC : Delay_Trigger

0 0 0 0 GC : Time Constant Fast Shaper

DA : 4-bit DAC Threshold Adjustment

8 0 8 1 8 2 8 3 8 4 8 5 8 6 8 7
8 8 8 9 8 10 8 11 8 12 8 13 8 14 8 15
8 16 8 17 8 18 8 19 8 20 8 21 8 22 8 23
8 24 8 25 8 26 8 27 8 28 8 29 8 30 8 31
8 32 8 33 8 34 8 35 8 36 8 37 8 38 8 39
8 40 8 41 8 42 8 43 8 44 8 45 8 46 8 47
8 48 8 49 8 50 8 51 8 52 8 53 8 54 8 55

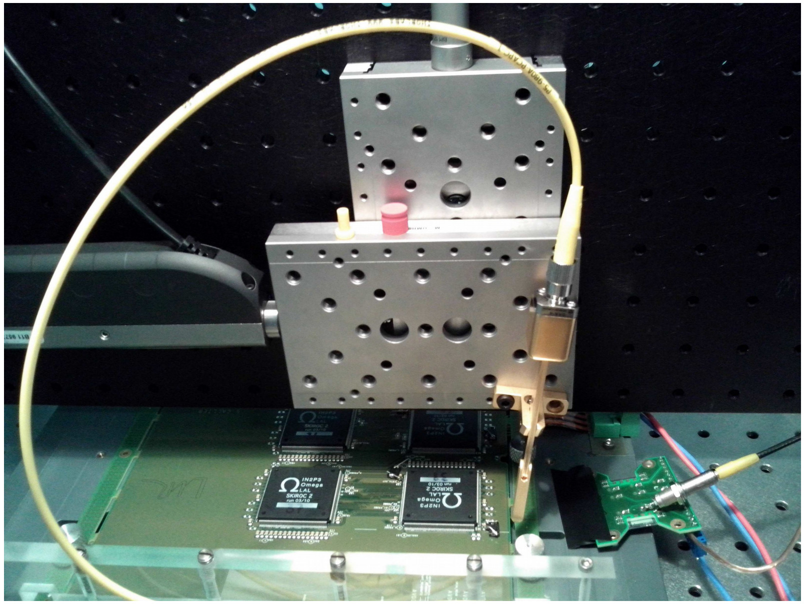
PA : PreAmp, In_calib & I_leakage

TM : Trigger Mask

Si Wafers studies : test benches

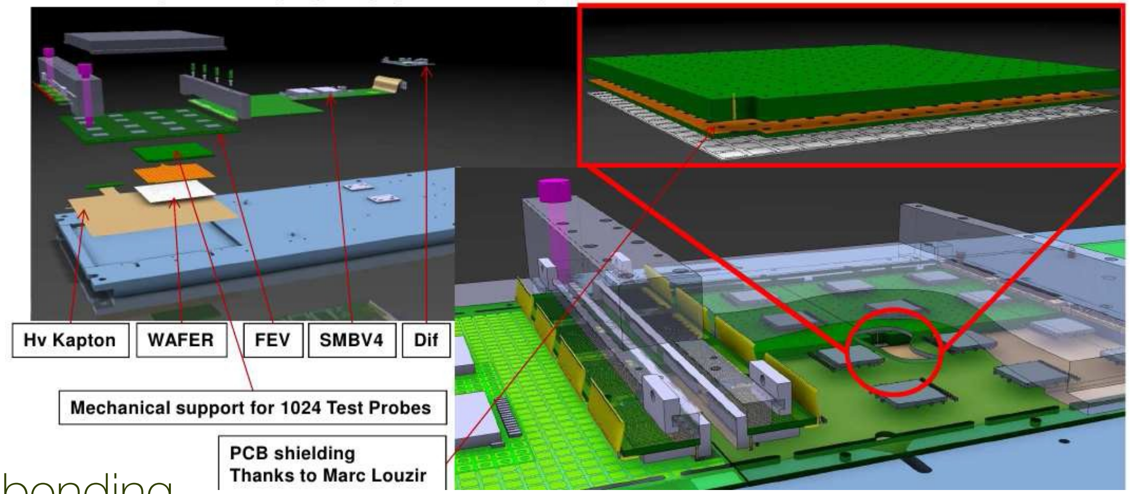
New laser TB ⇒ X-talks studies

- Laser characteristics: = 1056 ± 5 nm, 200 kHz, < 1 nsec pulse generates
    - ~ 700 MIP signal. Intrinsic silicon absorption length at 300 K: ≈ 0.8 mm.
    - Reproduction of “square events”...



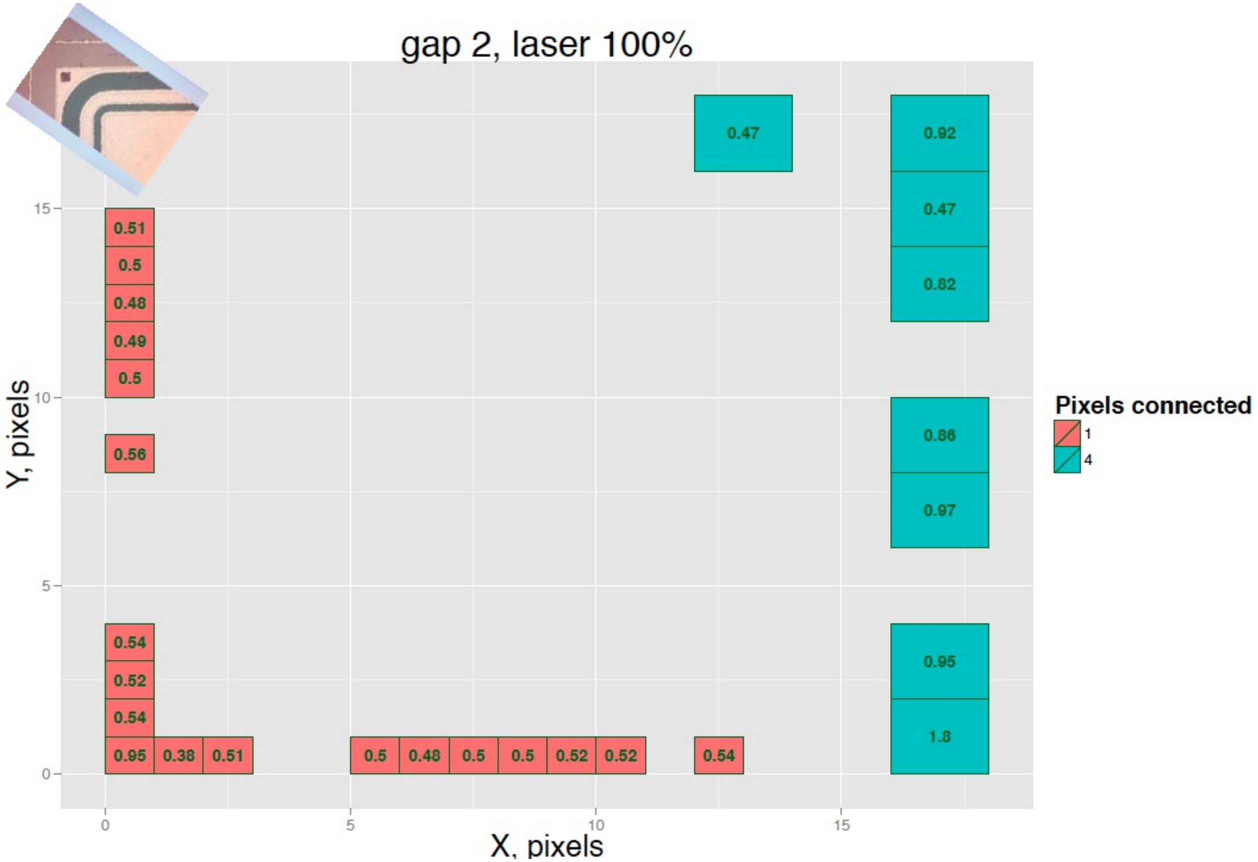
Hamamatsu Silicon sensors:
16x16 pixels of 5.5 x 5.5 mm^2, thickness 330 μm.

- In technological prototype Si pixels are glued to PCB with conductive epoxy.
- New mechanical setup was designed ⇒ sensors may be easily changed.
    - ≤1024 spring contacts of 5 mm length between pixels and PCB pads.
    - To be improved: high noises, PCB bending.

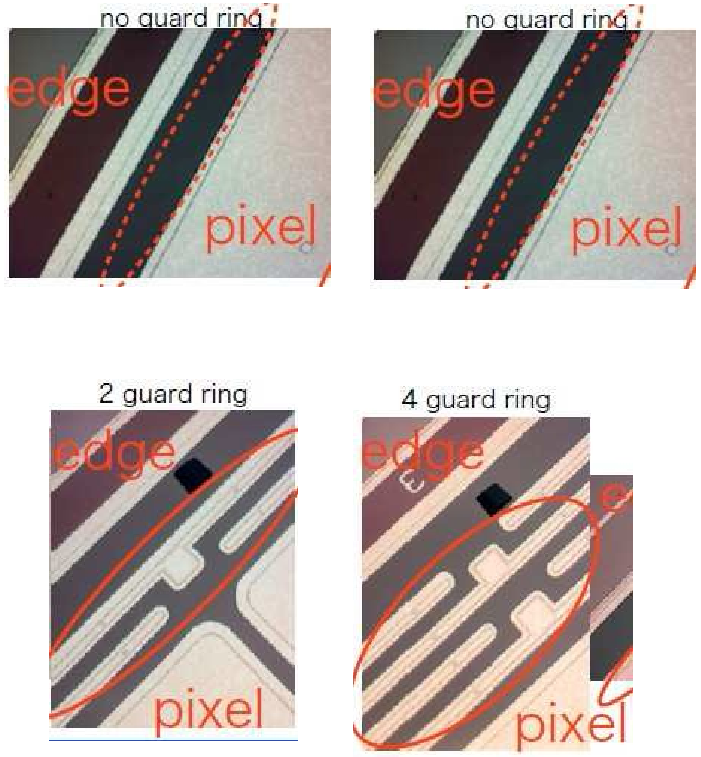


X-talks measurements

- Preliminary:
  - Not all springs installed and not all have contacts ⇒ ~50% operational.
- Clear signals in connected pixels.
  - A typical induced signal is ~ 0.4...0.5% per outer pixel side (x2 for corner, x2 in case of 4 connected pixels).



« baby wafers »
(Hamamatsu)



New PCB: FEV8 → 9 → 10

4 → 16 chips per ASU with BGA packaging.

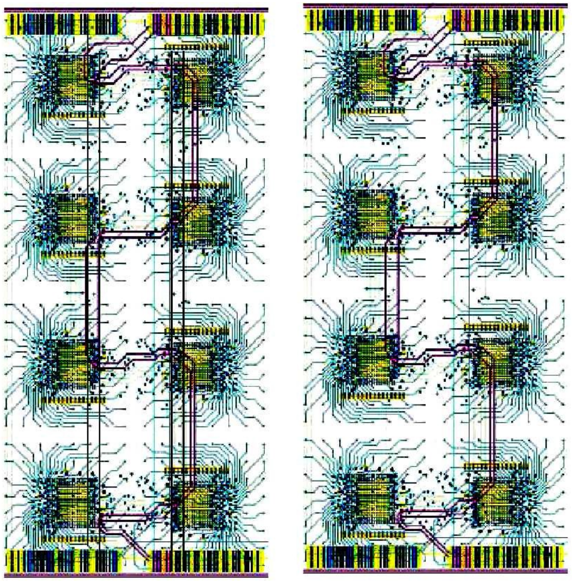
- 10 FEV9 received
- good flatness <0.5 mm: OK to glue flat Si sensor.

Many improvements:

- x4 channel density
- 2–3 times shorter signal traces
  - less input C and pick up noises
- power decoupling capacitors to reduce noises, corrected SKIROC “grounding”
- signal transmission (esp. clock) over long distances ~ 1.5m, two options in FEV9:
  - snake or straight lines (x2 interconnections),

FEV10 will have straight lines.; BGA thickness 1.6↘1.2mm

FEV9 with all components installed (⊃ 16 tested SKIROCs) ordered, expected this week



Straight and snake lines

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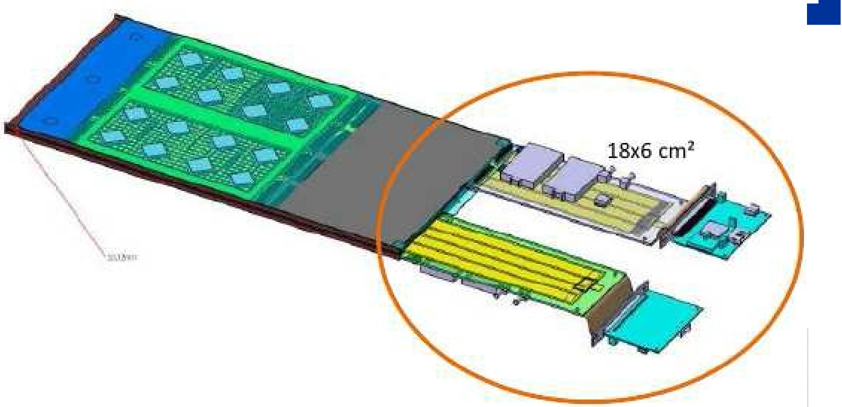
Next steps



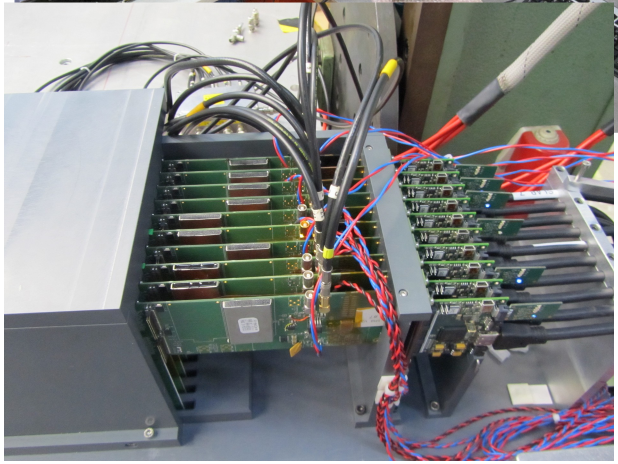
SMB4 design (between ASUs and DIF) has started: with power distribution for many ASUs and with special drivers for signal propagation along long lines.

- U-type short slab production
- Physics tests (cosmics, laser, PHIL?)
- Long slab production
- Goal: produce ≥ 1 long(6-7 ASUs) and short slabs to fill one tower in full scale mechanical prototype.
  - Possibly reuse existing 1/4 ASU short slabs.

With GEANT4 simulation, find their affordable fraction in the tower ⇒ “ECAL” of 18×18 cm^2

Test at CERN in 2015.

In parallel, look at boards integration in ILD.



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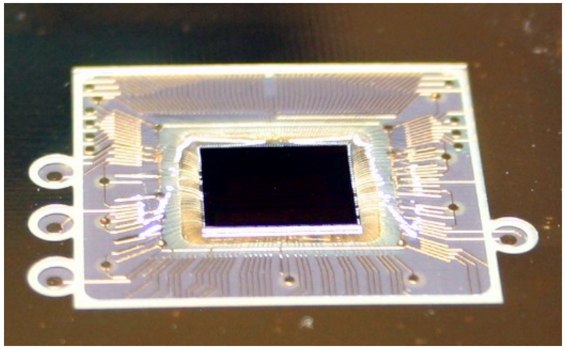
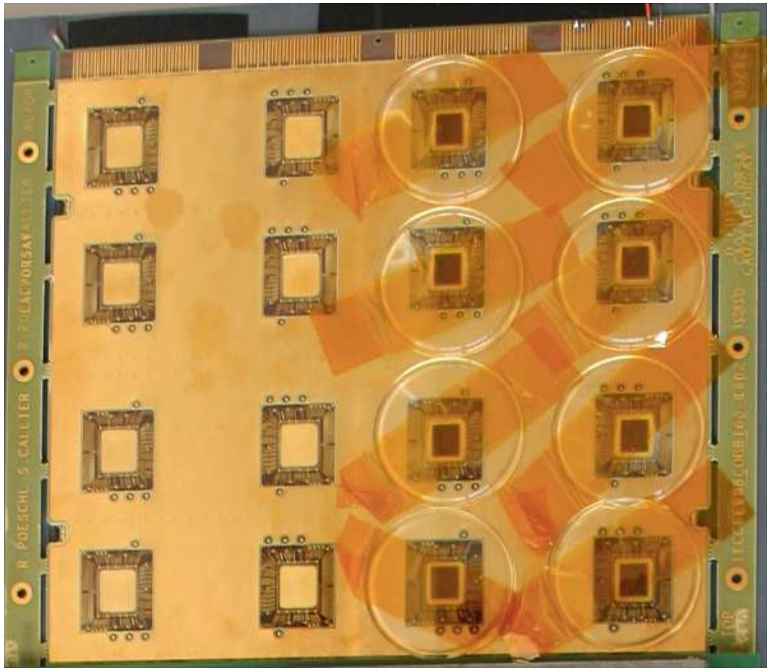
Chip-On-Board PCB

Only 1.2 mm thick,
8 naked die chips wire bonded





Status: two productions,

- ≥ 1.2 mm bending prevents gluing Si.
  - Production under supervision of SKKU@Suwon (Mechanically) promising board from EOS (Incheon)
  - Visit to SKKU to arrange FEV_COB production with SKKU
  - Contact with two manufacturers (EOS and HSDGT)

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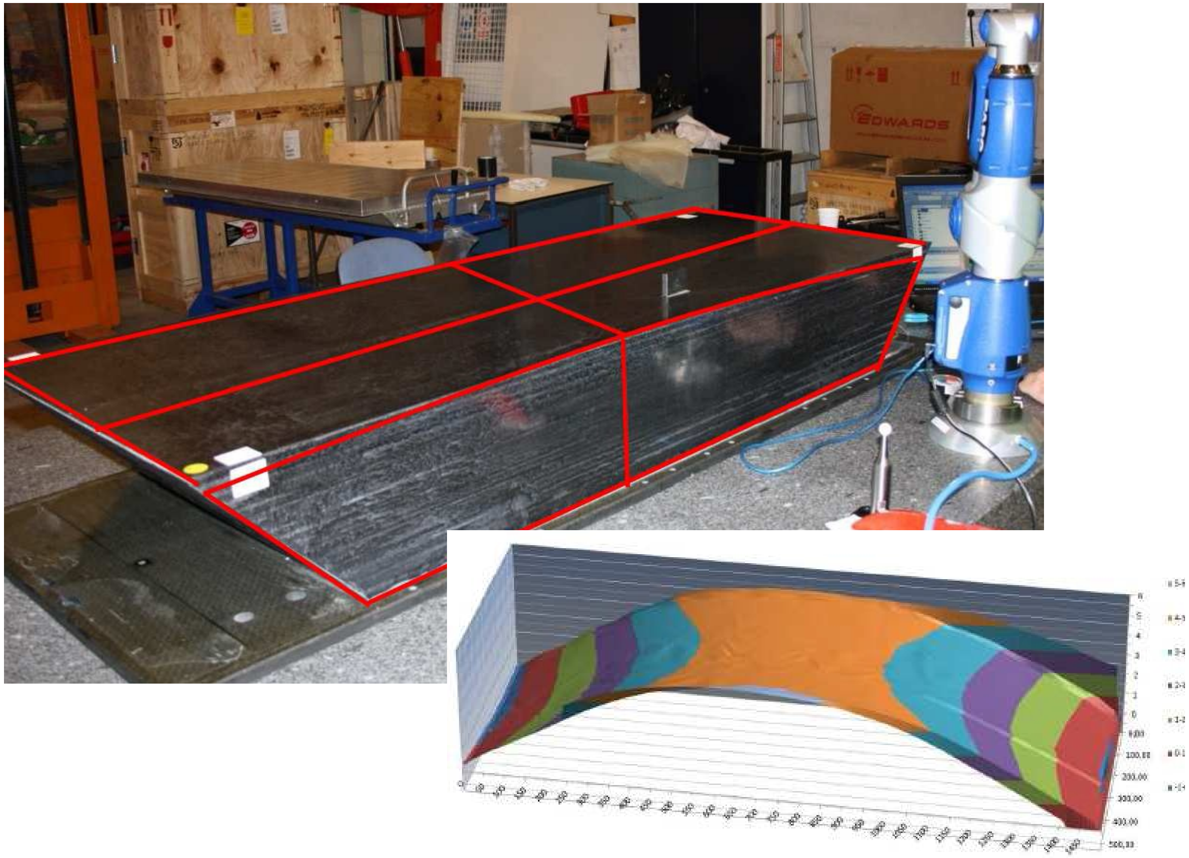
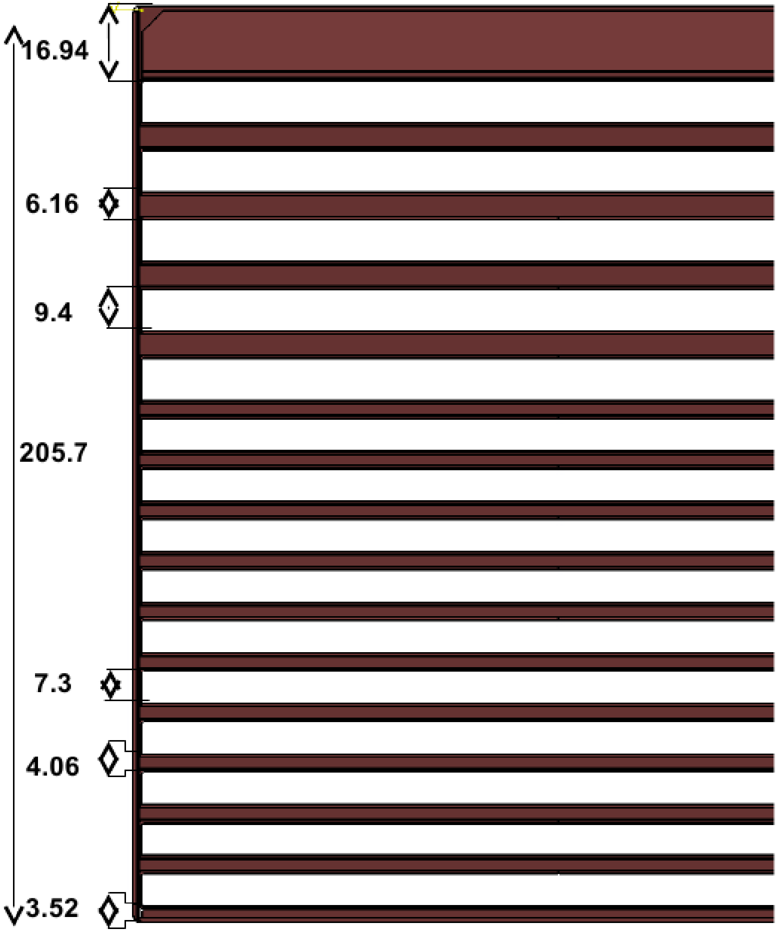
Carbon-Fiber Tunsten structure





Prototype: 3/5 of one ILD module, ~ 600 kg.

Separately built layers “cooked” together.

Simulated mechanically & thermally.

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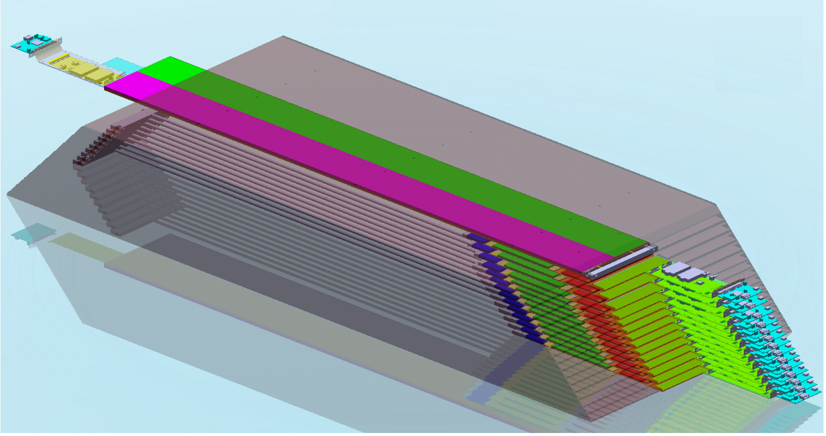
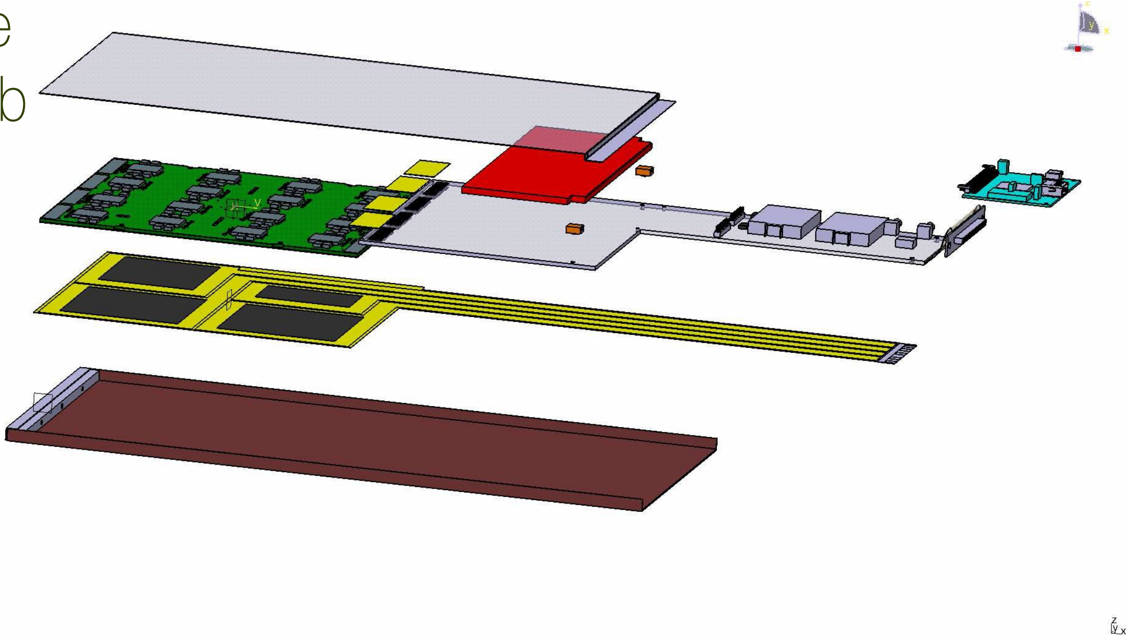
U- and H-shape slabs: plans



Fill alveolas with

- 14 “U”–shape short slabs
- 1 “H”– or
  1 “U”– shape
  long slab without or with W.
  - If without: possibility to glue (and then detach) W to slab from Si side and insert to alveola.



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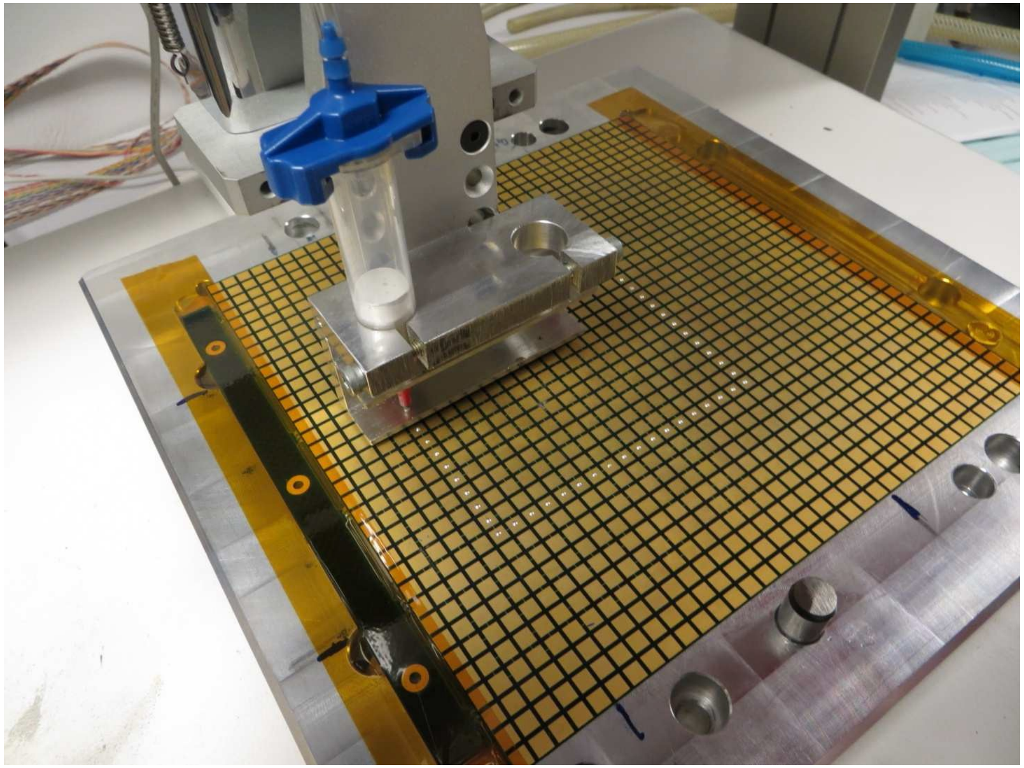
Wafer Gluing

9 sensors were glued by robot



Next steps:

- second robot for positioning and aligning
- glue 4 sensors on PCB with 100 µm gaps
  - ⇒ for summer…
- prepare technology for mass production

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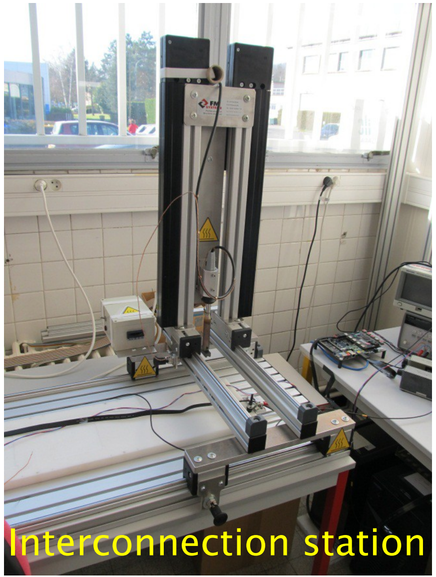
Assembly bench

Development of a set of specifications to assure proper assembly of four wafer ASUs

- Tolerances of PCB, H or U board
- Example : Mechanical stress on wafers during interconnections
  - First set end spring 2014

Revision/Scrutinisation of assembly tools

- Development and validation of assembly bench, “easy” reproducibilty
- Combination of ASU positioning and interconnection
  - Continous revision of process with aim to propose a procedure for LC Ecal in ~ 1 year (first version exists however)



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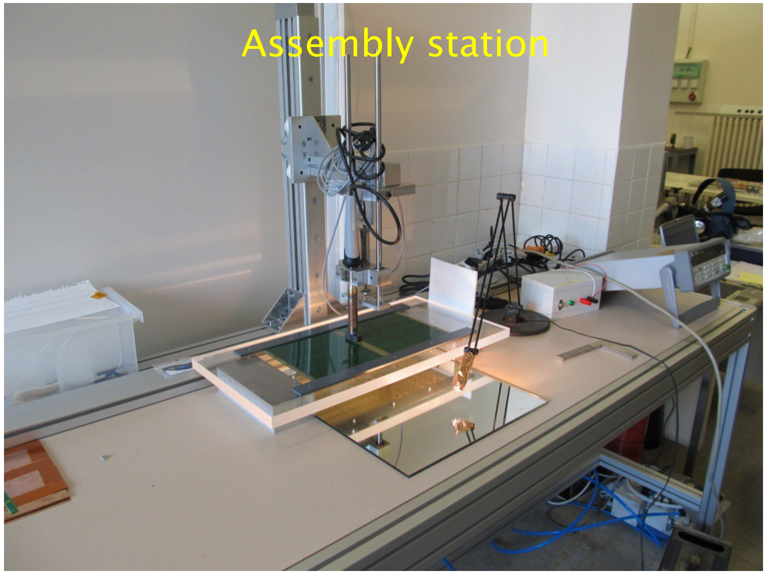

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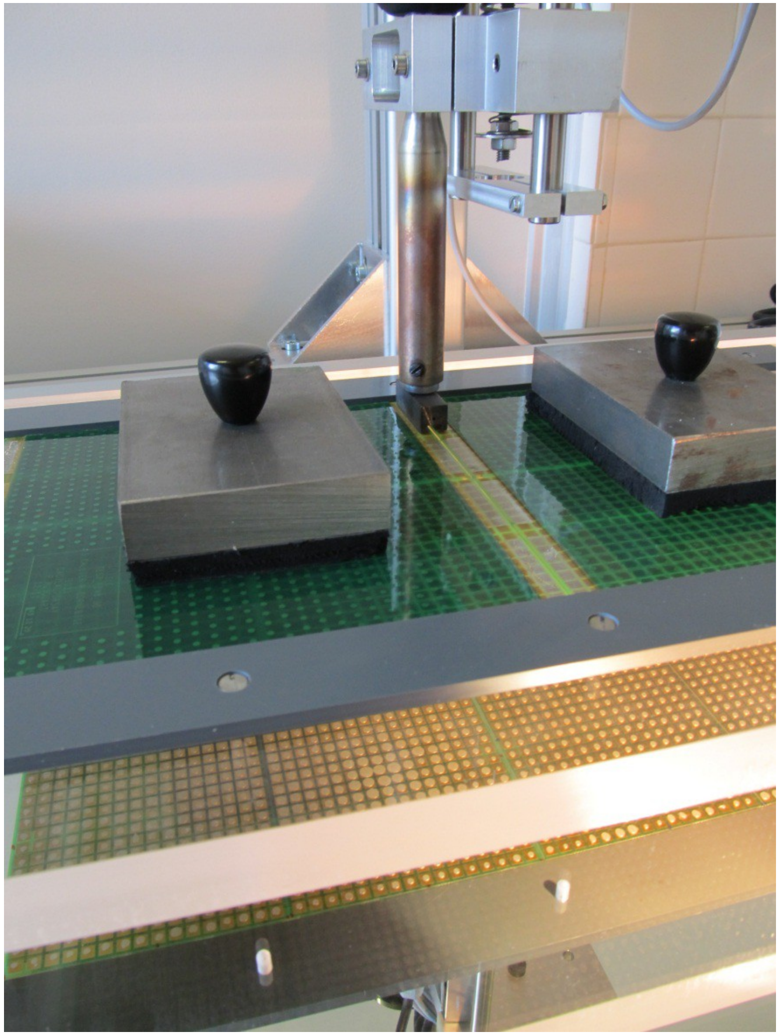
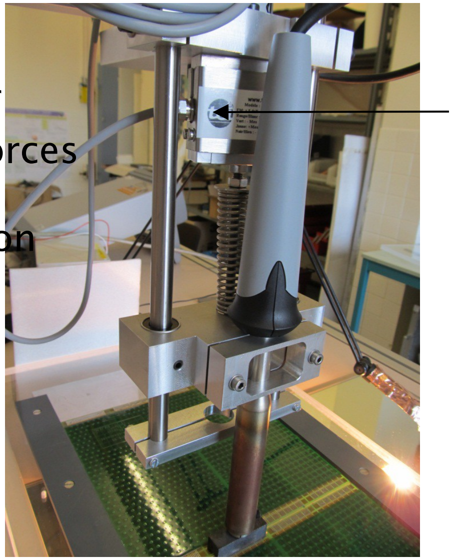
Assembly bench (details)

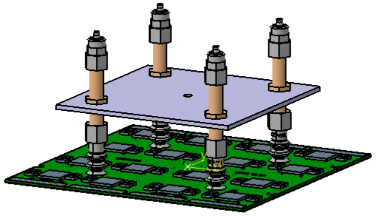


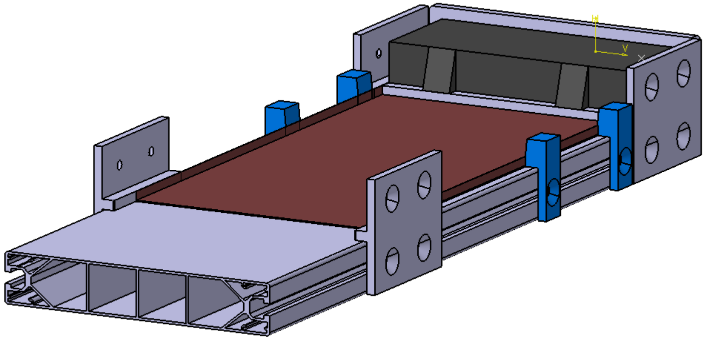


Monitoring of mechanical forces during interconnection

Pressure probe

Proposal for an assembly tool for four wafer ASUs





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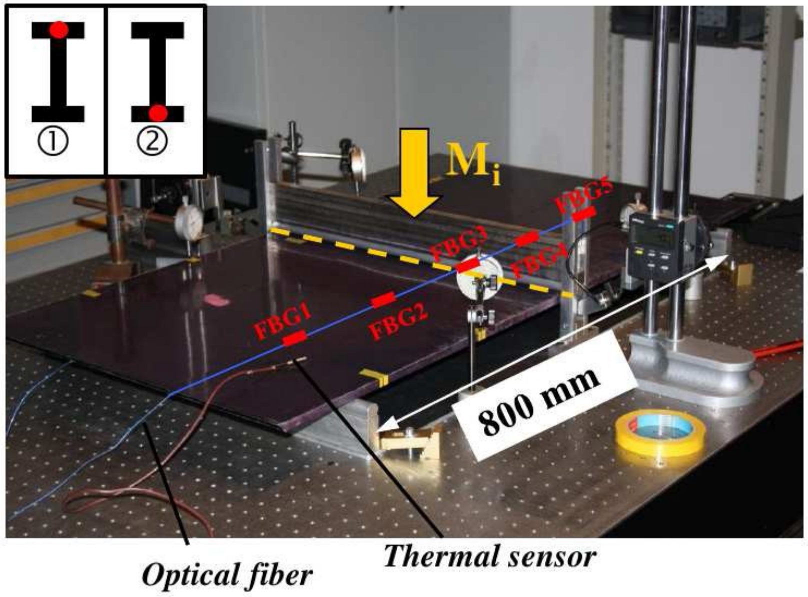
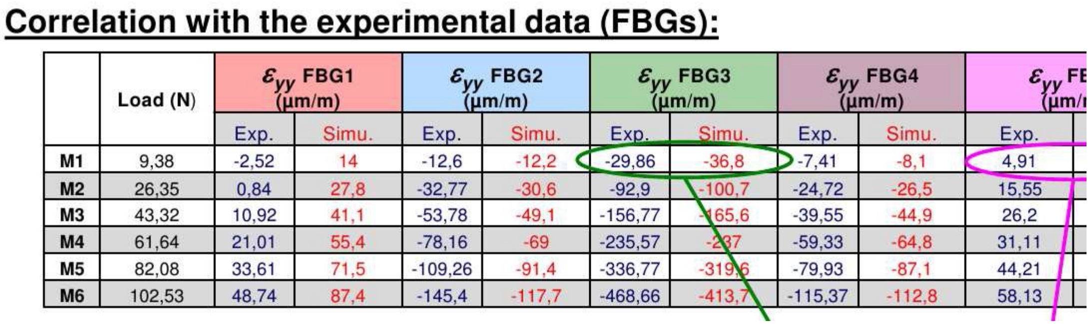
Prototype with molded Bragg grating fibers

Detailed verification of simulated elongations under loads (by monitoring frequency shift of light reflected by fiber).

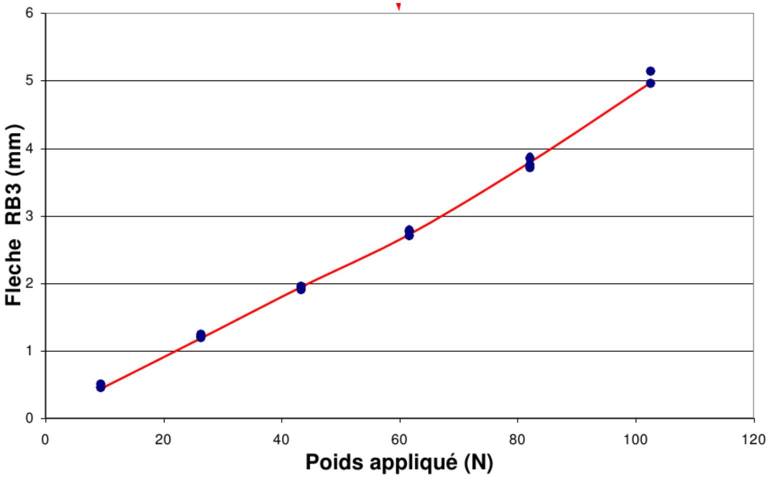
- Details on first measurements: http://indico.cern.ch/event/274076/, French IRFU Linear Collider Days, Nov'13.
- Done on single alveola
  - to be repeated on structure





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

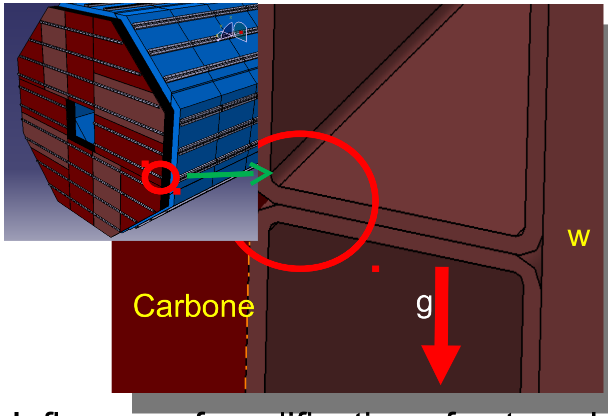


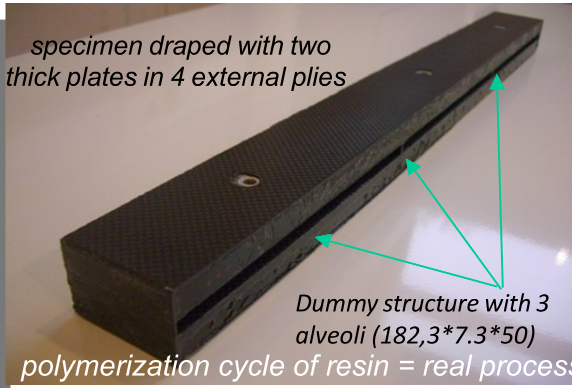
Vérification des paramètres du modèle en comparant la flèche FBG3 mesurée et simulée

Evolution of skin thickness

Correlation of FEA simulations / shearing tests of representative structure

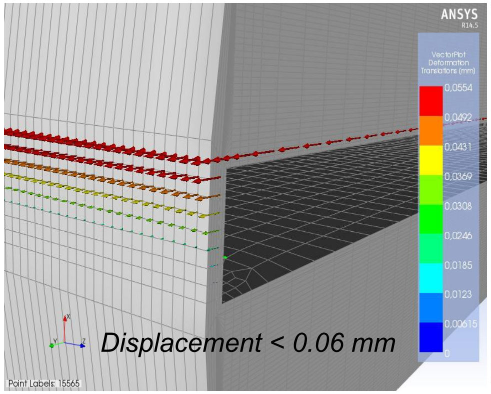
Problem of bending stress of alveoli skins / evolution of external plies




specimen draped with two thick plates in 4 external plies

*Dummy structure with 3 alveoli (182,3*7.3*50)*

polymerization cycle of resin = real process



Displacement < 0.06 mm

Influence of modification of external ply thickness on the first main constraint of external and internal walls

If external plies thickness increases => **Impact** on ECAL dead zone => Optimization of deflection values

Displacements	~0.1 mm vs 0.5mm for fatigue shearing tests ...
Main contraints	< 159 Mpa *both*
Shearing constraint	11.5 Mpa vs **6** (1,8/wall) Mpa for shearing tests ...

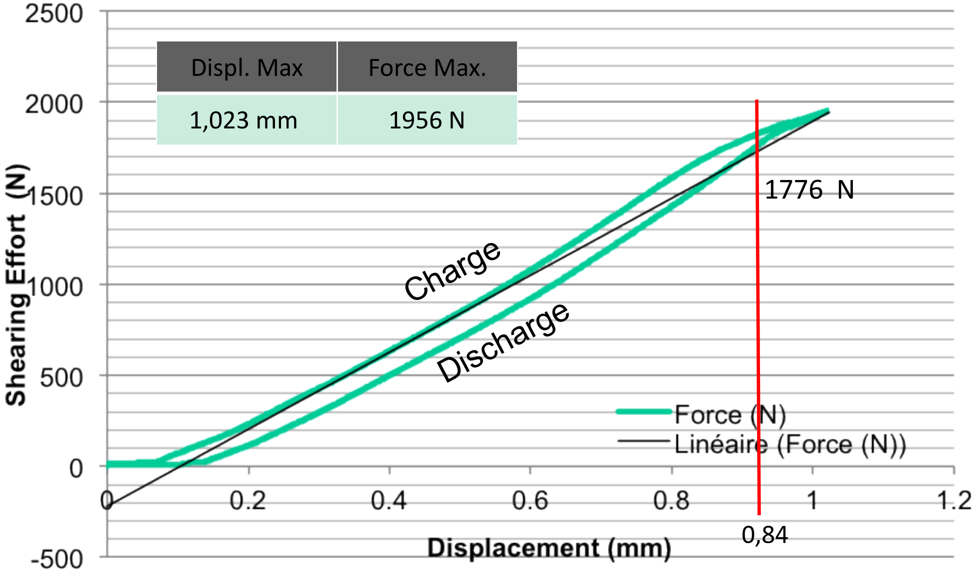
From simulations to shearing tests
(ANSYS APDL / SAMCEF / ANSYS ACP)

Tests & simulations to be performed

- Adapt FEA parameters to simulate the whole structure / shearing results
- Destructive test on a existing structure *(demonstrator -EUDET)* / verification of bonded structures
- Process: increase intercoat adhesion with structural adhesive film
- Process: obtaining reliable thicknesses of walls *(specific long moulds, tooling development)* / Draping optimization
- Reliability tests: good & uniform impregnation of parts, good compacting
- Resistance of End-Caps to earthquake
- "Mass" production conception *(ply book enhancement, tooling, process)*

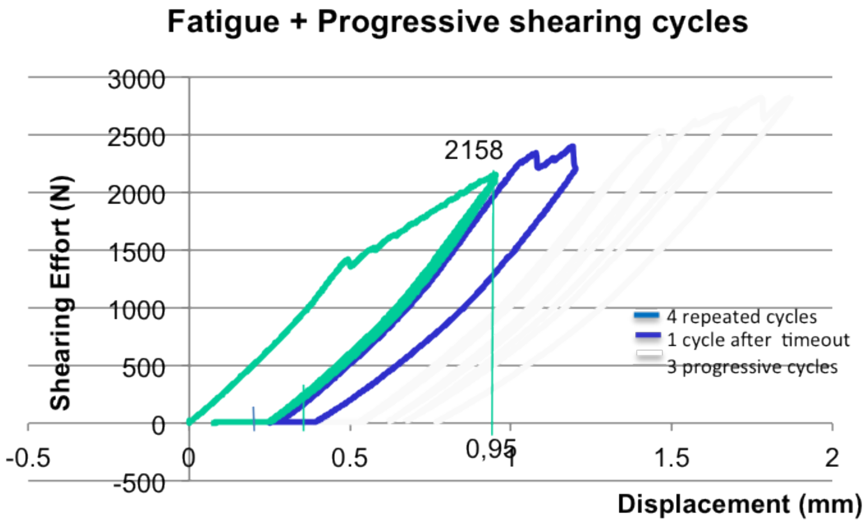
ECAL End-Caps: shearing tests

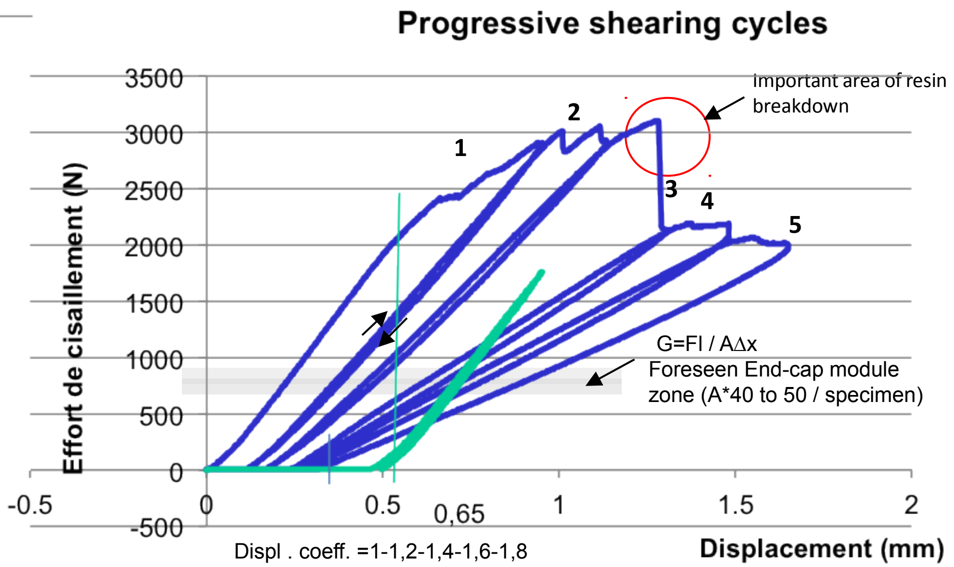
Monotonic shearing test



Displ. Max	Force Max.
1,023 mm	1956 N

Destructive tests with charge & discharge cycles / *hysteresis & weakening of the structures (resin) during repeated stresses*





Reduction in stiffness
predictable during integration
(G# 85 MPa to 74 Mpa)
Stay < Δx = 0.35 mm (mechanical limiters) or
Increase No. of envelope folds (/ seism)
Max. admissible flexion value of slabs to be confirmed

To be continued in 2014

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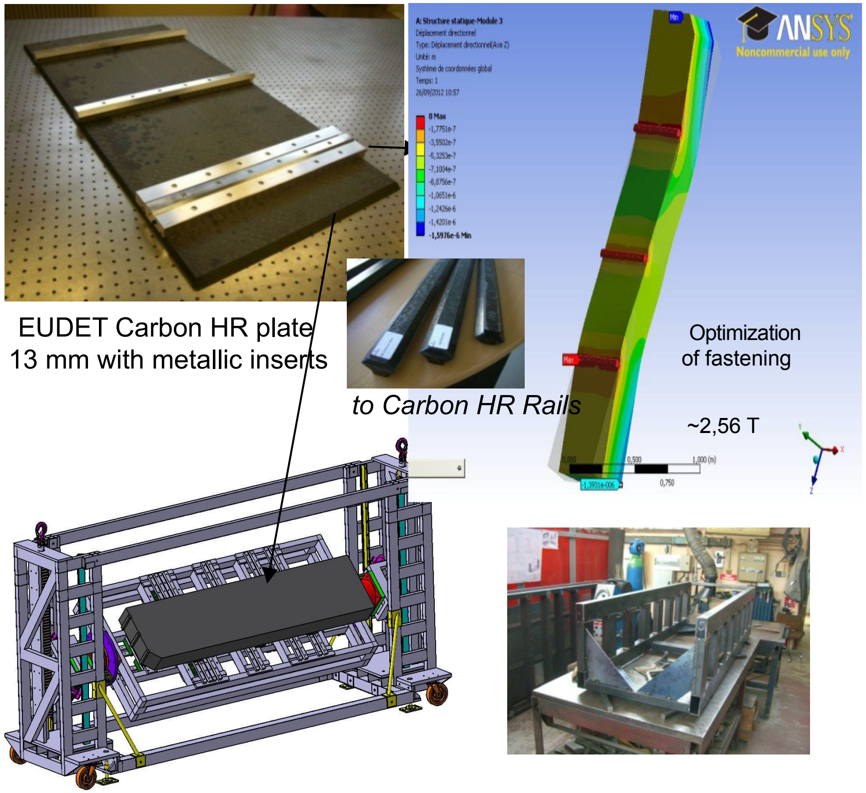
Structure of end caps

2.5 m alveoli layer molding

- <u>**The end-cap layer test consisted of**</u>
- **3 long alveoli** (representative of end-cap module longest layers)
- **Width of cell : 182,3 mm** like barrel's one (for electronic uniformity)
- **Thickness of cells : 7.3 mm - wall: 0.5 mm**
- **Length : 2.490 m**

long layer of 3 alveoli demolded nov.2013 with new system woven-resin (C202+ET445) .To be improved

Thick plates & fastening system



EUDET Carbon HR plate
13 mm with metallic inserts

to Carbon HR Rails

Optimization
of fastening

~2,56 T

Building on going of transport and handling tools for integration & tests

Ongoing developments

- Design of specific tools for long draping
- Industrialisation study of process / long alveoli layers (~ 540 cells up to 2,50m)
- Continuing the mounting of the handling tool of modules & design /quarters End-Cap
- Thick composite plate for double low section rails: OK
- Characterization, tests & optimization: positioning / bending of modules
- Towards construction of a long EC module ?

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Conclusion

Much progress:

- acquisition: GDCC, firmware, low level SW (Calicoes) + other software tools
    - to be integrated with EUDAQ for common DAQ
- VFE: BGA solution ready to be tested, small defects form FEV, Power pulsing works, with only slightly higher noises
    - Fixed design for technogical prototype: FEV10 (BGA)
    - Design new adaptor board SMB4 for long slab
- Wafers caracterisation: test benches (flexible & laser), first measurement of capacitive guard ring cross talks
    - Physics tests: charge injection, cosmics, laser, possibly PHIL accelerator

Production of 14 short slabs and ≥1 long slab being prepared

- quality procedure being established;
- 9 sensors glued by LPNHE robot
    - Test gluing 4 sensors to PCB with 100 um gaps, positioning and alignment robot
    - Produce U-type short slabs with FEV10, test them, then produce ≥ 1 long slab (6-7 ASUs)
- First assembly chain running ~ july
    - **Equip with detectors one tower of full scale prototype and test at CERN beams (2015)**
        - **⇒ ~fall 2014**
    - Possibly, test silicon sensors from other producers

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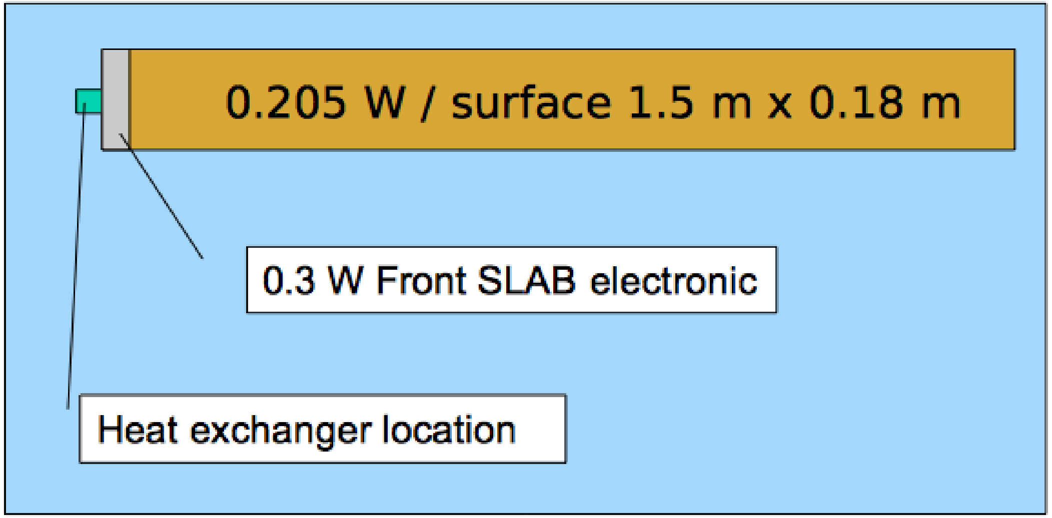
Cooling capacity

Power dissipation : Final goal with power pulsing 1/100 s

For ½ SLAB from barrel
Wafers consumption : 0.205 W
Front SLAB electronic : 0.3 W

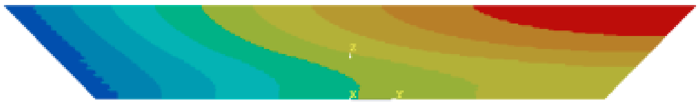
→ Ecal detector : 4.5 kW



Passive cooling : OK

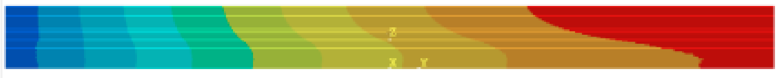
… support up to 10x bigger heat load (for details see backup)

Barrel : (1.5m)



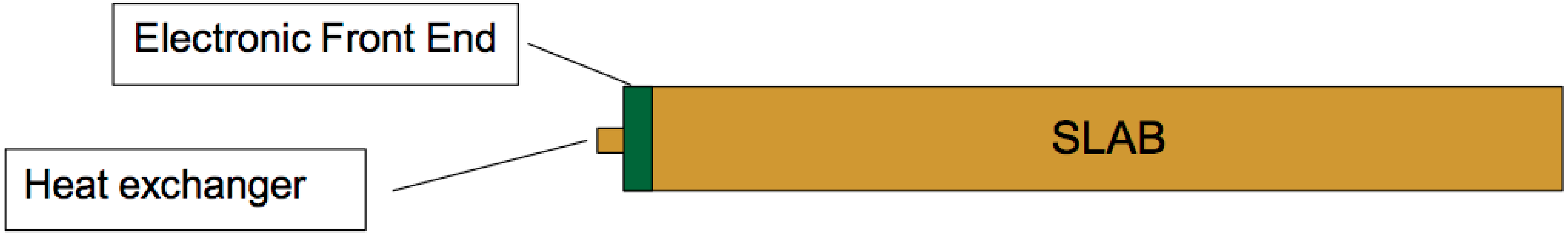
ΔT = 2,2°C

End Cap : (2.5m)



ΔT = 6°C

		1/2 SLAB						
/ Electronic consumption		Front electronic (W)	Wafer (W)	Total ECAL (W)	Temparature variation near the exchanger (°c) (Thermal contact resistance)	Temperature variation along the SLAB (°c)	Température at the end of the SLAB (°c) (water temp : 18°c)	Remark
Configuration 1	ECAL Goal	0.3	0.205	4500	0.5	2.2	20.7	Passive cooling : OK
Configuration 2	Front elec x 10	3	0.205	30 000	3.2	2.2	23.4	Front SLAB electronic close to the heat exchanger => low impact of the SLAB temperature
Configuration 3	Wafer x 10	3	2.05	45 000	5.1	24	47.1	Passive cooling may work
Configuration 4	Wafer x 100	3	20.5	205 000	24	250	292	Passive cooling will not work !! We need to work on active cooling in the SLAB



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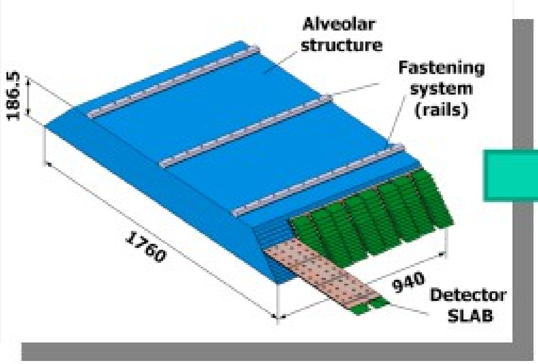
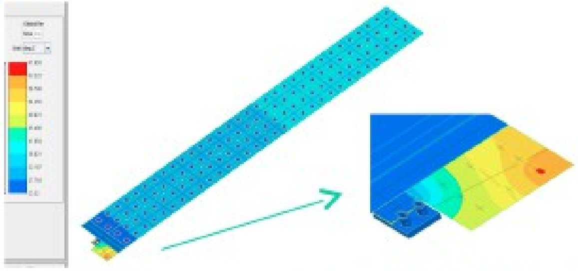
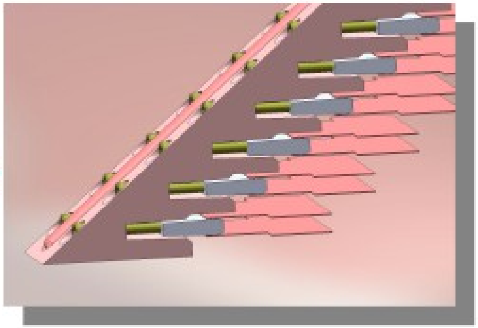
Study from the power source to the global cooling



SLAB

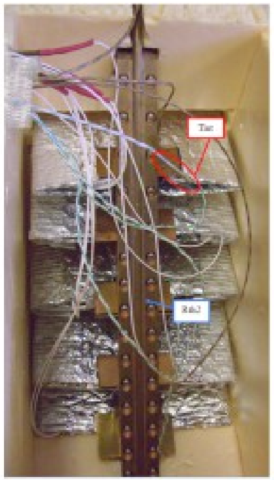
Thermal simulation and test on Slab

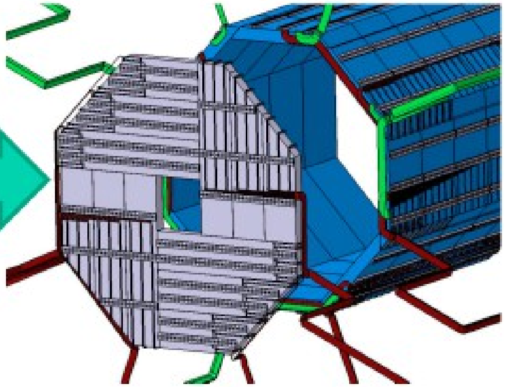




Heat exchanger

Simulation and test on different type of heat exchangers





Global cooling

True scale leak less loop