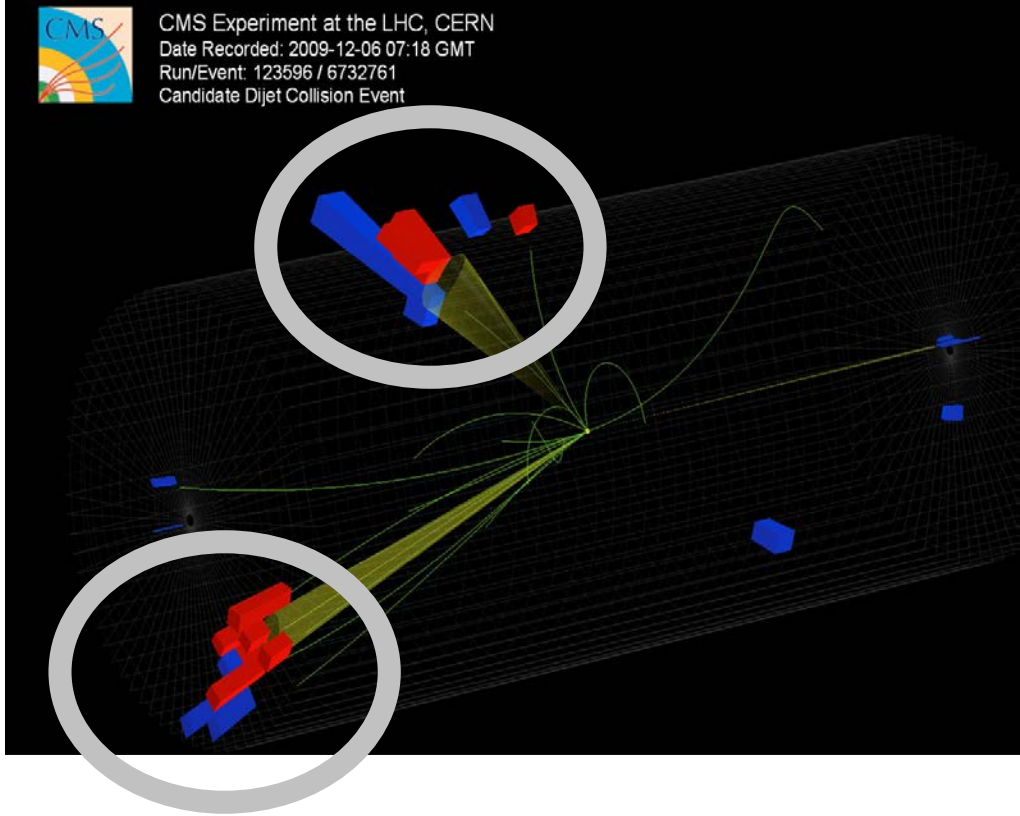
FCC@LPNHE
Detector R&D for Si-W calorimetry (CALICE)

24/04/2020

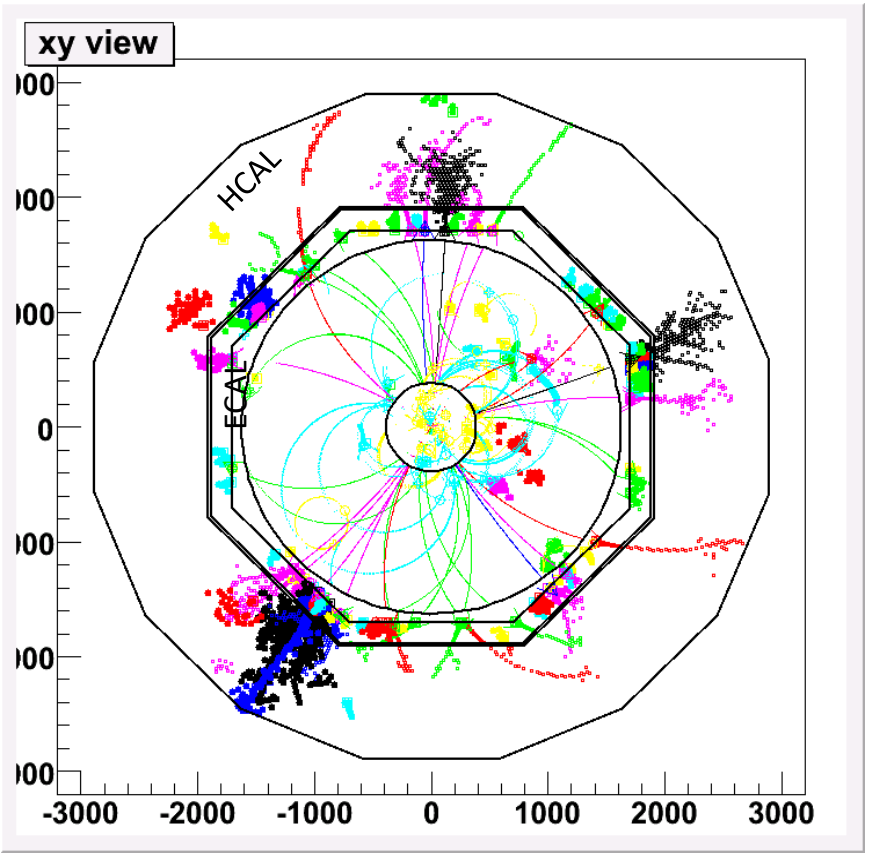
Rémi Cornat

Highly granular calorimetry

From this...



to this :



A mix of technologies qualified with prototypes achieving

5000< "calorimeter grade" channels/dm^3 ,

ie. 16b dynamic, 10 to 12b resolution

Initially planed for ILC/ILD

Improved & Implemented for HGCAL@CMS

Inspiration for HGTD@ATLAS

CALICE Si-W ECAL prototypes : time line

2008 — Physics prototype

2014 — Technological prototype

upgrades@LHC
WAGASCI@T2K

ILD@ILC; x@FCC ; x@CPEC

Proof of concept

- Linearity
- Resolution
- Sensors
- Very front-end

1500 channels/dm^3

Achievability of design options

- Compactness
- Granularity
- Front-end
- Power pulsing
- 2m Long SLAB

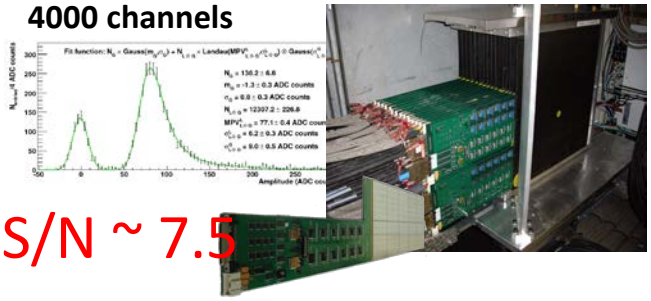
V1 : 4000 channels/dm^3
V2 : 5000 channels/dm^3

Construction

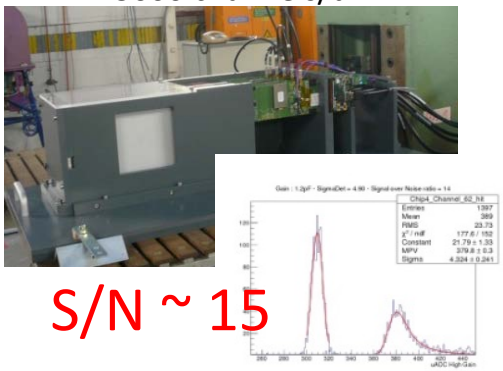
- Integration
- Environement
- Services
- Industrialization
- Tooling
- Project org.

...10000 channels/dm^3

2004-2008
30 layers
4000 channels

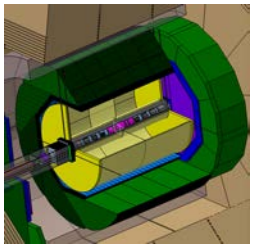


S/N ~ 7.5



S/N ~ 15

~24 X0, 20 cm thick
~2500 m^2 active detectors
~100M readout channels



Prototyping

Carbon – W composite

ASIC (SKIROC)

Cooling system

Simulation Analysis

PIN diodes

Sensor Gluing

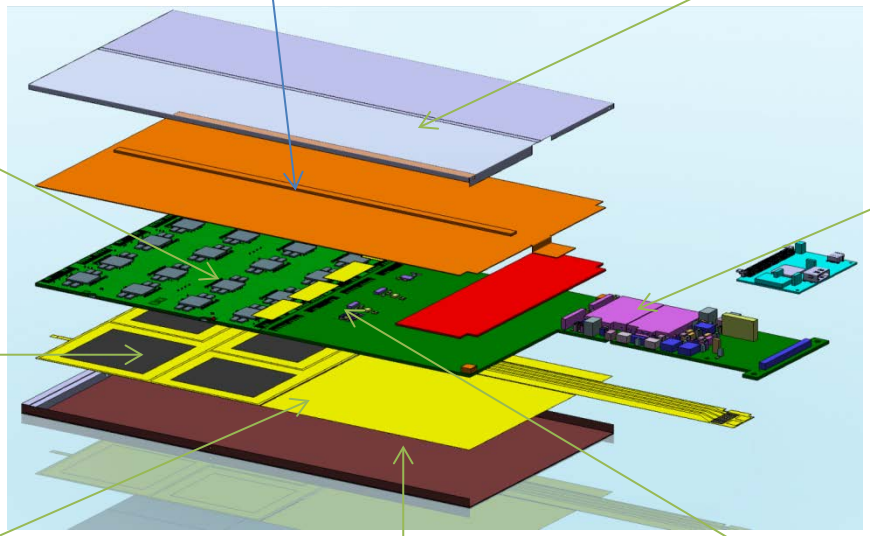
Power pulsing

interconnects integration

DAQ

Front-end board

A detector module



Coper sheet for cooling

Cover (EMI shielding)

PCB 1024 chn. 16x skiroc2

Power pulsing circuitry (400 mF)

Si PIN diodes

Front-end, DAQ, TFC Not shown

HV kapton

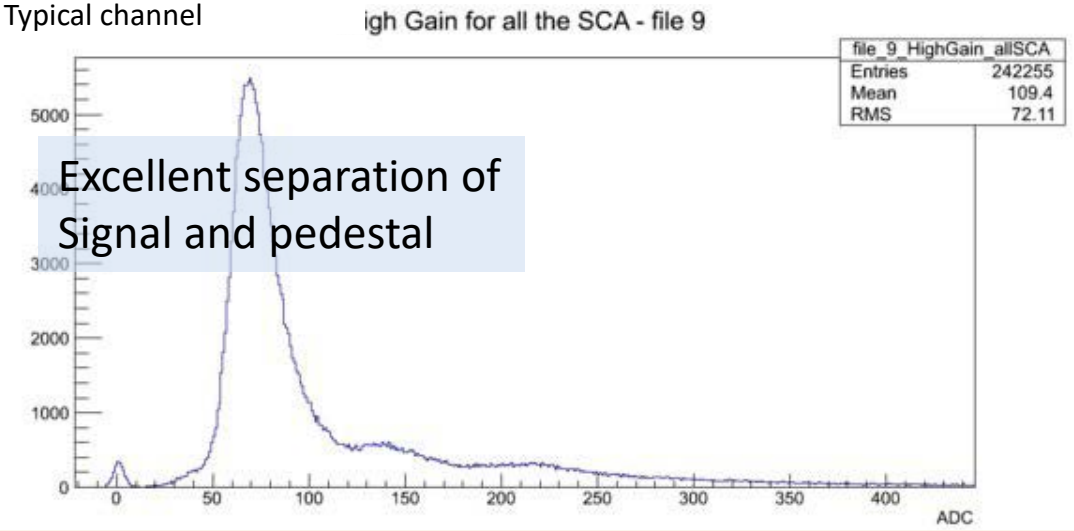
A “short SLAB”

Stiffener, Absorber Carbon fiber + W

FCC Interconnects

Low energy (<6GeV e-) test beams @DESY 2012-2015

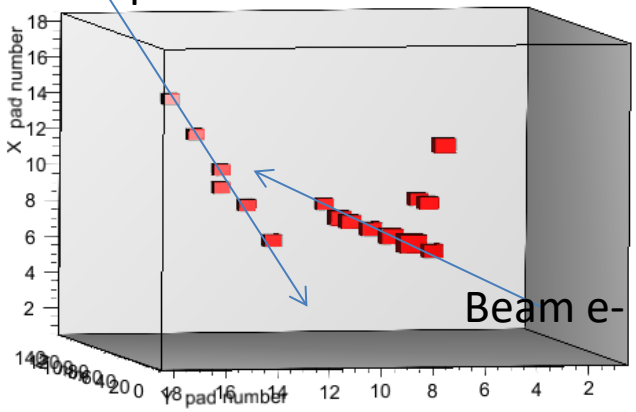
Typical channel



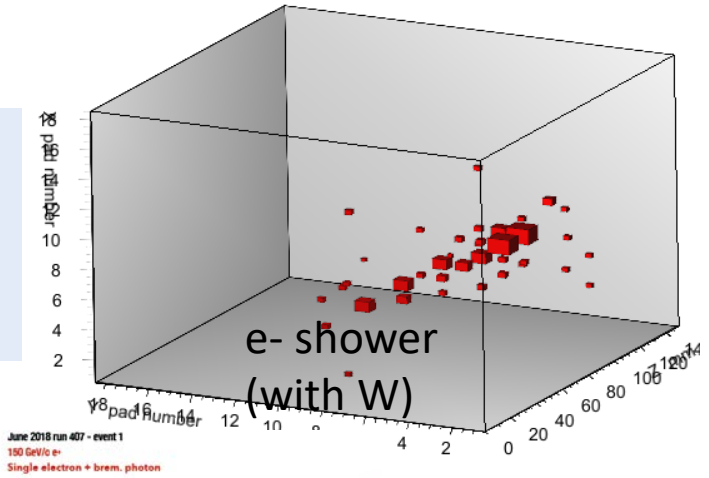
Excellent separation of Signal and pedestal

S/N = >15 better than the target (10), non uniformity understood (pixel-pcb capacitance)
Updated versions of DAQ, PCB & integration methods in 2019

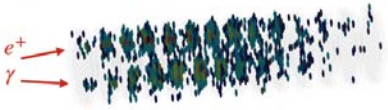
Cosmic μ



6 detector SLABS
1278 channels
10% off due to out-of-range calib.



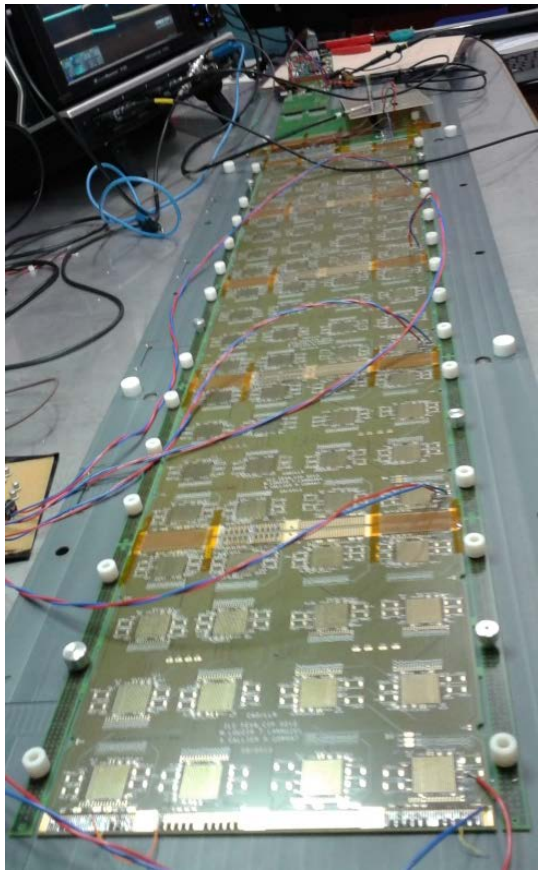
HGCAL 2020 : https://indico.in2p3.fr/event/20042/

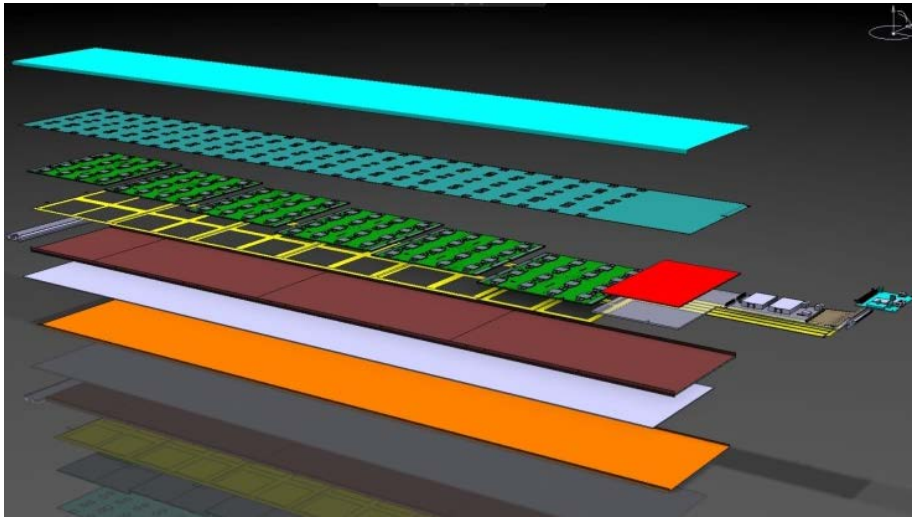


Toward a full length module

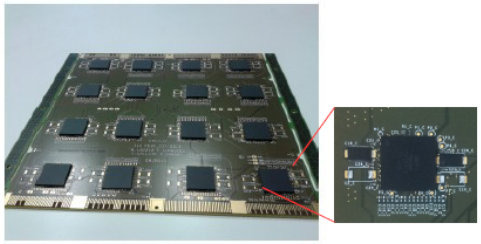
In principle, front-end boards will be chained forming up to 2m long detector SLAB, most of signals in bus

large C-W structure exists





Latest developments



- BGA packaged chips
  - Space for external decoupling capacitors
  - Symmetric stacking will improve flatness,
  - good for wafer gluing
  - Optimal shielding of signal traces

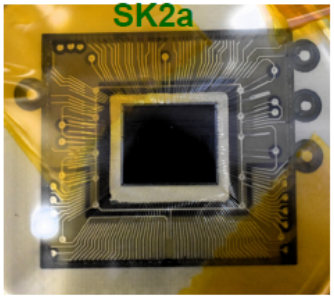
DAQ@IJClab

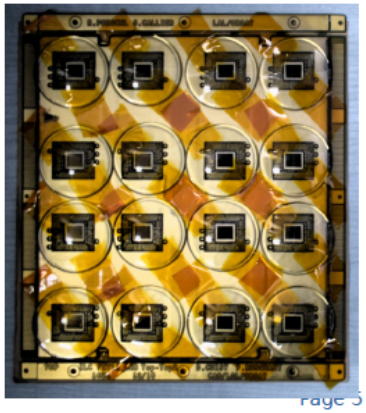
The CORE mother

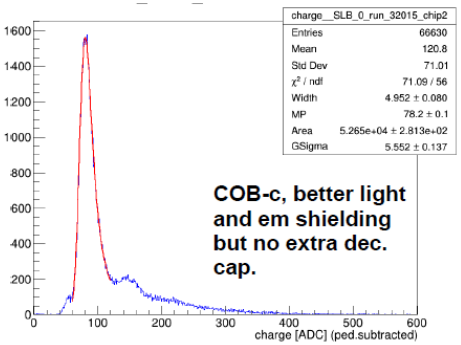
The CORE daughter

Ultra thin PCB: Chip On Board

- **ILD tight spatial constrains:** Total space for ASICs and PCB 1.8mm (was 1.2mm since ~2007)
- **Chip-On-Board proposal:**
  - Naked ASICs wirebonded.
  - Cavities (~250um) for the ASICs
- **LAL & OMEGA** collaboration with **ITAEC/SKKU** (Sungkyunkwan University, Suwon – Korea) and **EOS company** for the PCB production.
- 10 FEV11_COB produced.
  - **1.2mm thickness** → 9 layers PCB !
  - **Good Planarity** (metrology made in LAL) and electrical response.
  - **No extra components** (i.e. decoupling capacitances, etc)
- **4 boards wirebonded** at **CERN** bonding lab. Also In contact with CAPTINNOV Platform.
  - Extensively tested at LAL before gluing a full size sensor to them



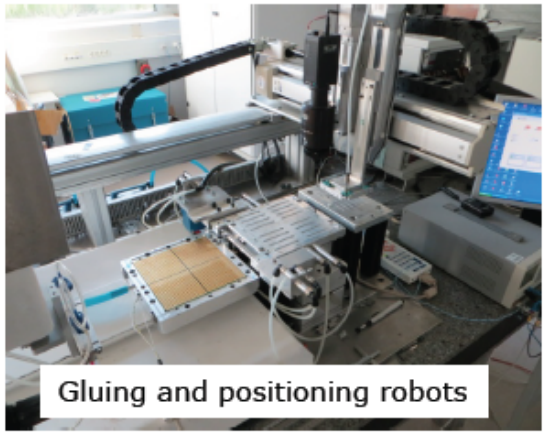


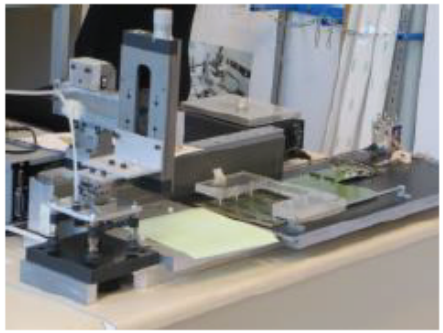


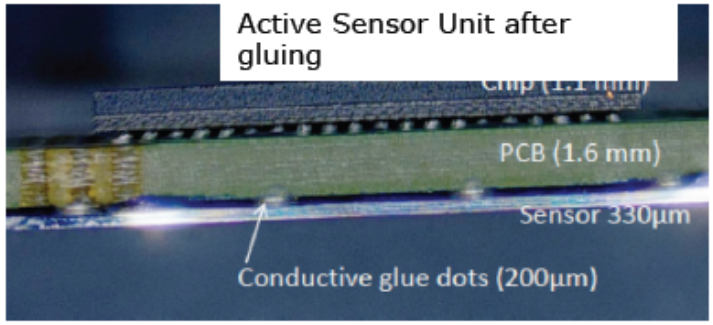
Courtesy R. Poeschl, A. Irles, J. Malmi

Contribution of LPNHE

- Assembly done with gluing and positioning robots: automated system developed in the framework of the Calice R&D program for ILD SiW EM calorimeter
- Assembly of the ultra flat active sensor unit (Chip On Board design) in 2019
- Electrical test to control the sensors before gluing, to check the short cuts immediately after gluing, to measure the I(V) curves
- PCB Metrology using a coordinate measuring machine (tri-dim machine)


Gluing and positioning robots



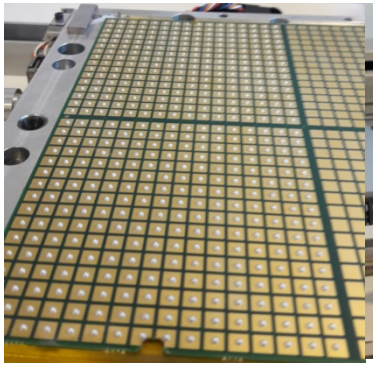


- Industrialization of the process considered – preliminary contacts with Eolane company
- Measurements are compliant with HPK data - Monthly survey has started – Wafers kept in a dry cabinet
- Metrology: Latest FEV12 batch (24 boards) is 100% within tolerances
- Software permanently updated with **Python**

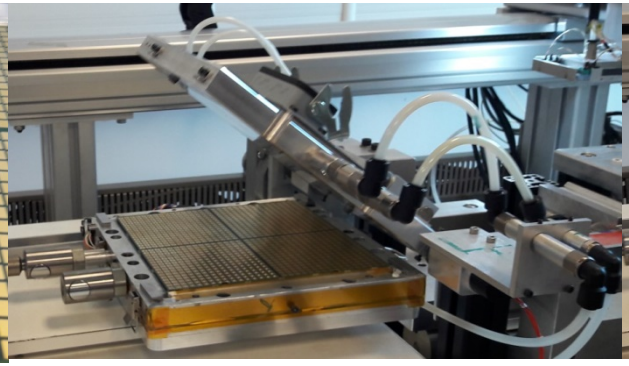
Courtesy D. Lacour

Technical skills at LPNHE

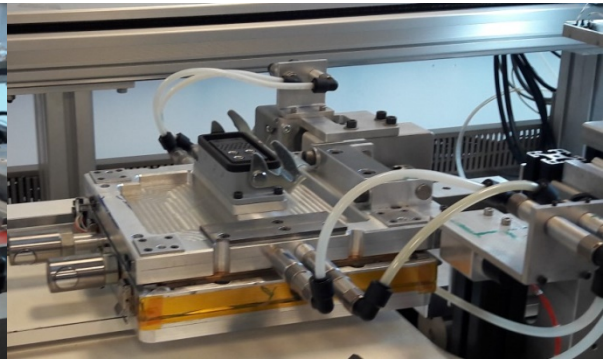
Glue dispensing



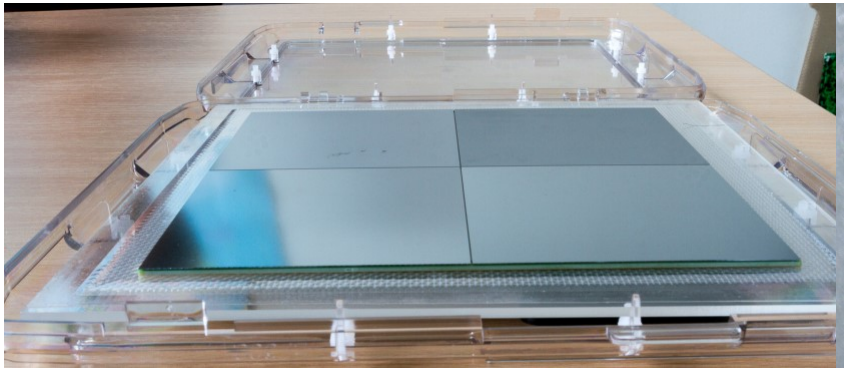
PCB-Sensors alignement



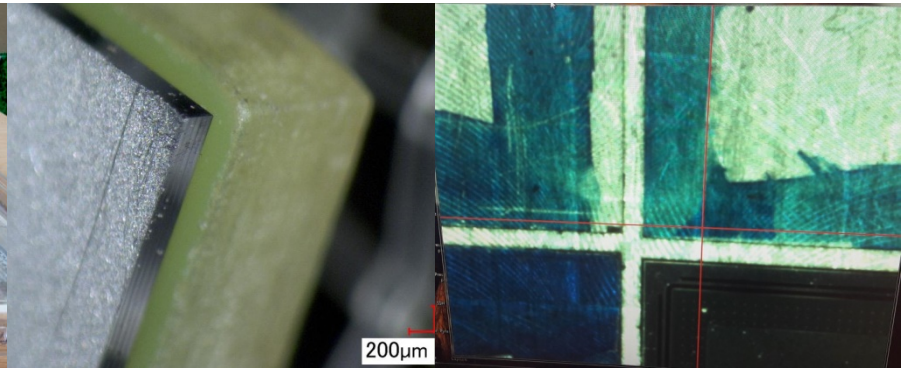
Sensors gluing



Active module sensors + PCB + VFE



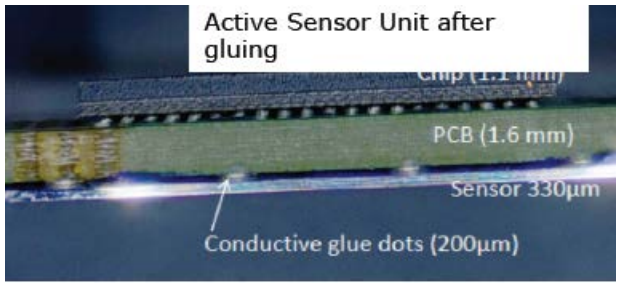
Reproducible positionning @ σ<25µm



Developing dedicated robots, with reproducible movements σ<25µm : glue dispensing, Si detector hybridation & metrology

Ability to machine and assemble precision mechanics (bearings, gears, guides…)

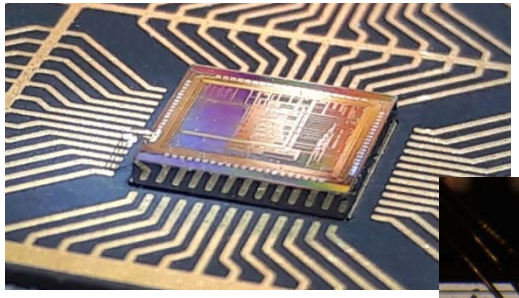
Semiconductor characterization



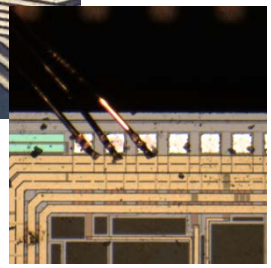
What next ?

Continue module assembly for next **Calice** tesbeams (Q4'20,…)

Developing skills in wirebonding (wedge bonding)

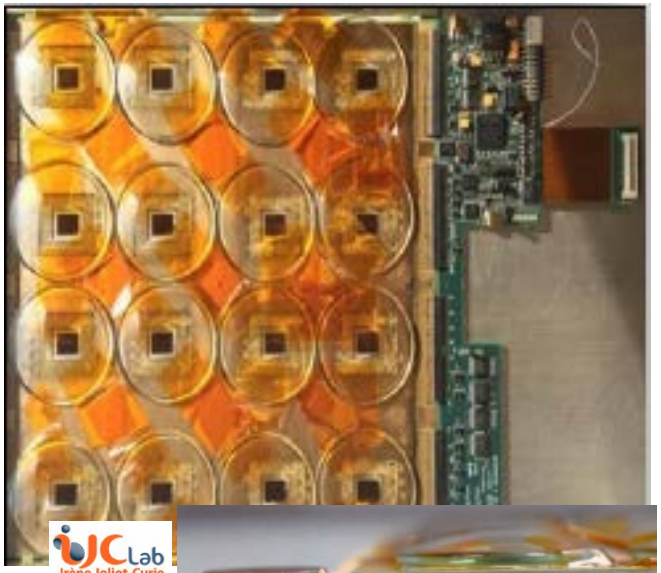


HGTD : gluing process



Calice & **AIDAinnova** :
electronics integration = miniaturization and minimizing power consumption

In the case of an approved R&D :
Industrial transfer of the gluing & hybridation process



Contribution to next generation detectors,
in particular @**FCC**
→ LPNHE can contribute to a wide range of technical fields DAQ, timing, powering, detector integration detector characterization