Sensor Module Studies

Large Hadron Collider, ATLAS experiment, silicon strips tracker

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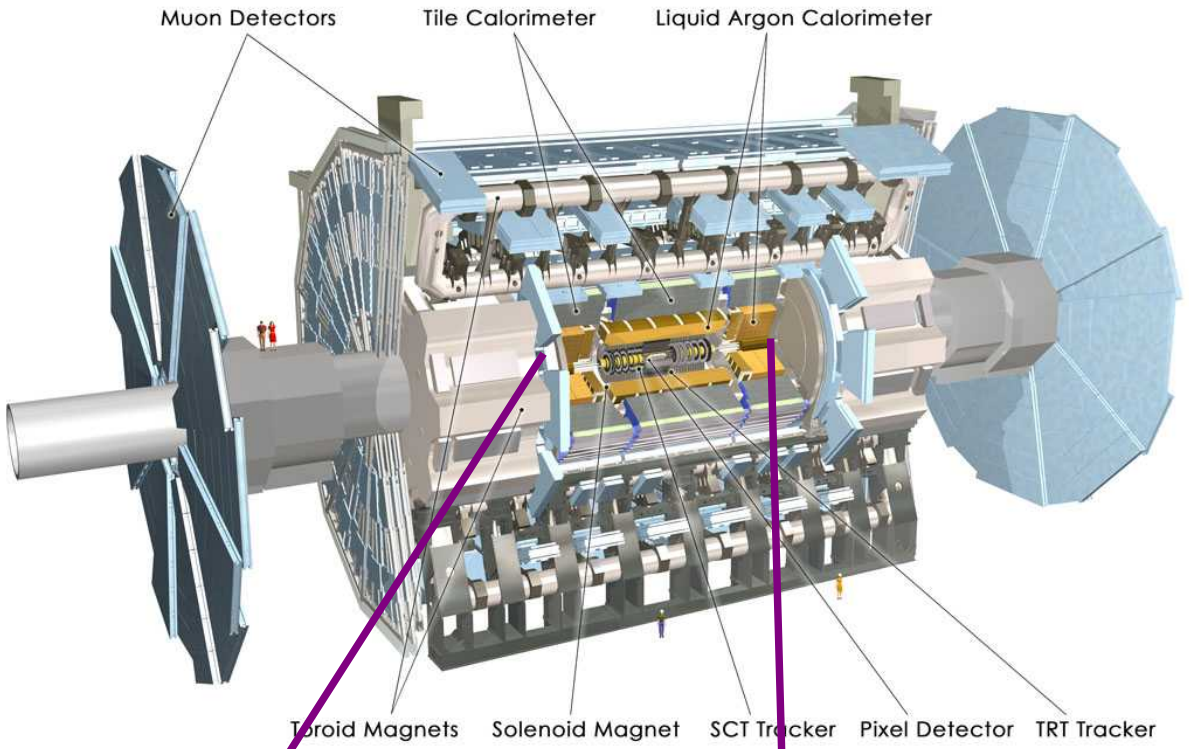
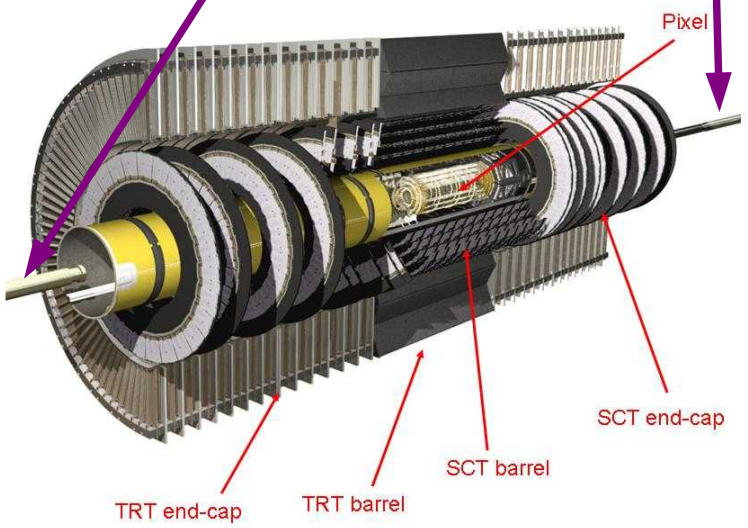
Summary

- Introduction
  - ATLAS upgrade
  - Stavelet : Core & Modules
  - Powering schemes
- Noise studies
  - Extraction method
  - Modules characterization
- SCT HV controllers
- Stavelet assembling
  - Mounting tools
  - Gluing
  - Results & status
- Stavelet testing
- Conclusion

ATLAS upgrade



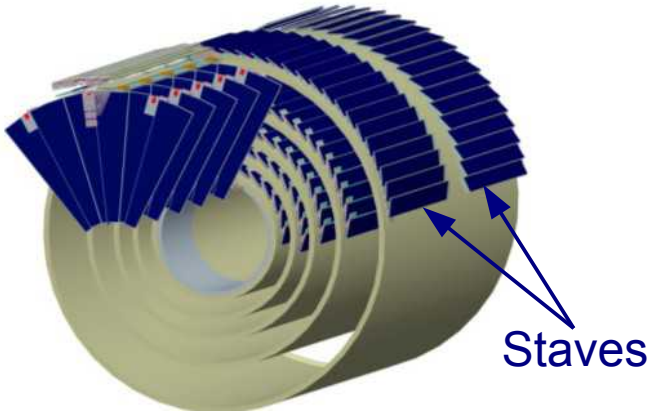


Upgrade goal : increase luminosity

Engineering challenges :
- Speed up readout electronics
- Increase granularity
- Enhance radiation tolerance

All-silicon tracker replaces current pixel, SCT and TRT by :
- Pixel
- **Short strips (2.4 cm)**
- Long strips (10 cm)

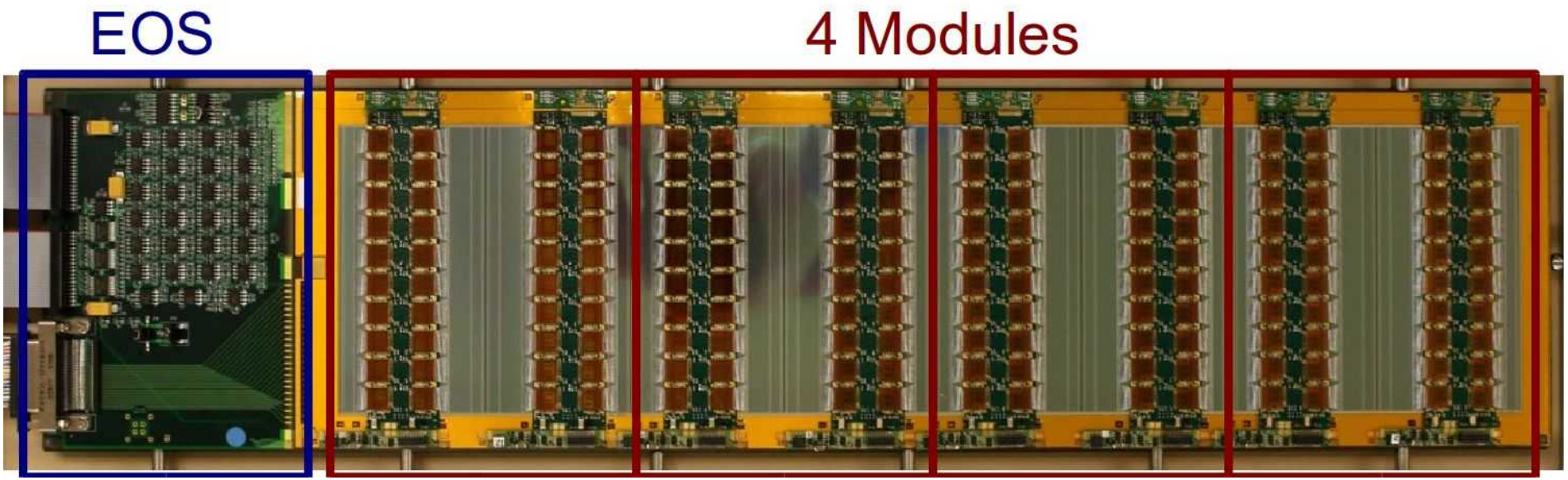
Upgrade 2022



Short strips barrels Stavelet

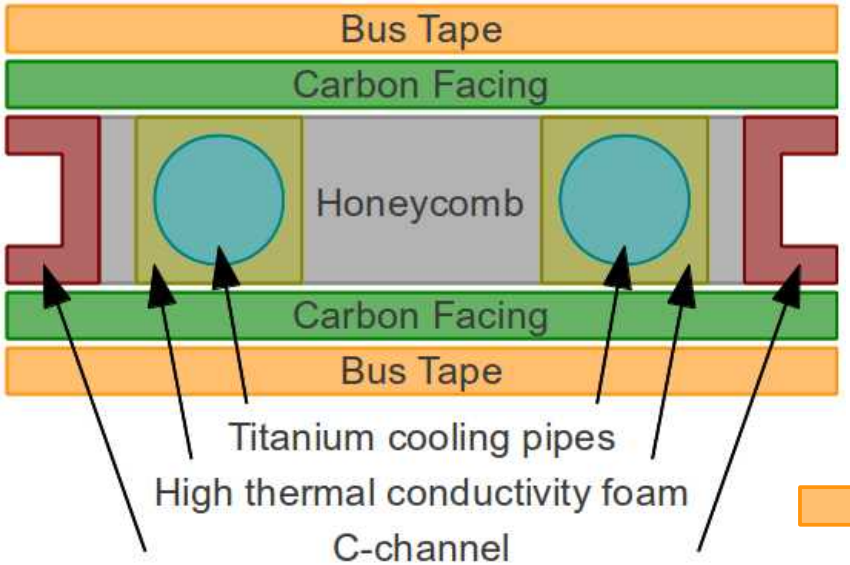
Stave : assembly of silicon strip sensors with integrated control electronics, so called the Modules, on a thermo-mechanical assembly, the Core.

Stavelet : shortened Stave prototype with four Modules per side.



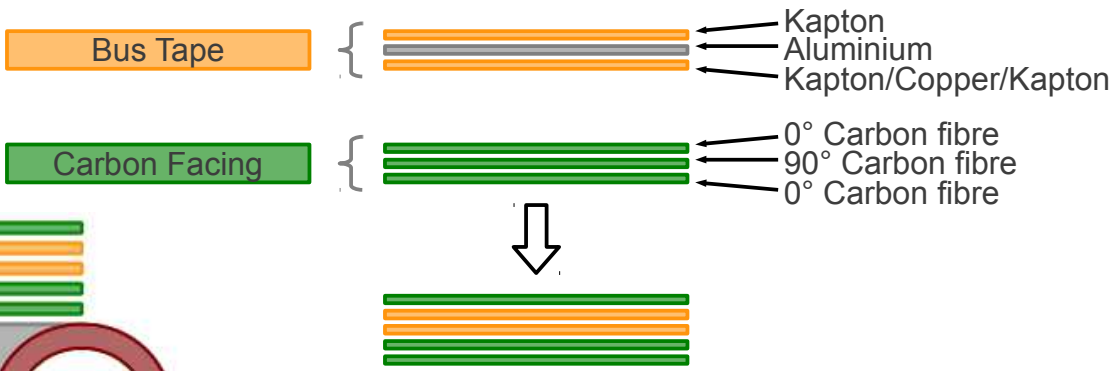
End Of Stave (EOS) : essentially a buffer board driving the Low Voltage Differential Signaling (LVDS) data lines.

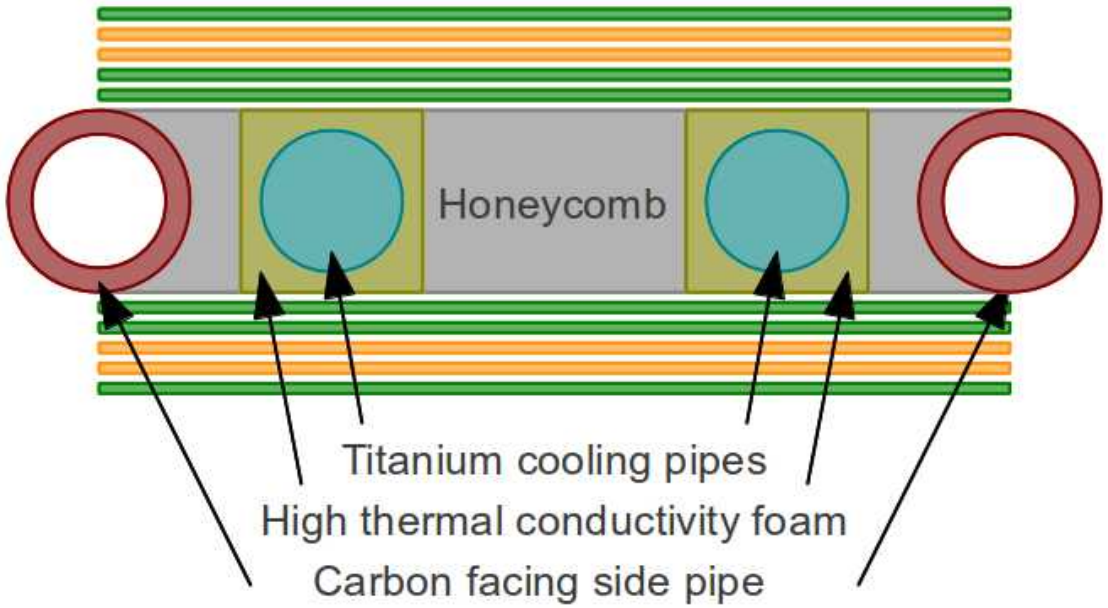
Why another Stavelet prototype ?



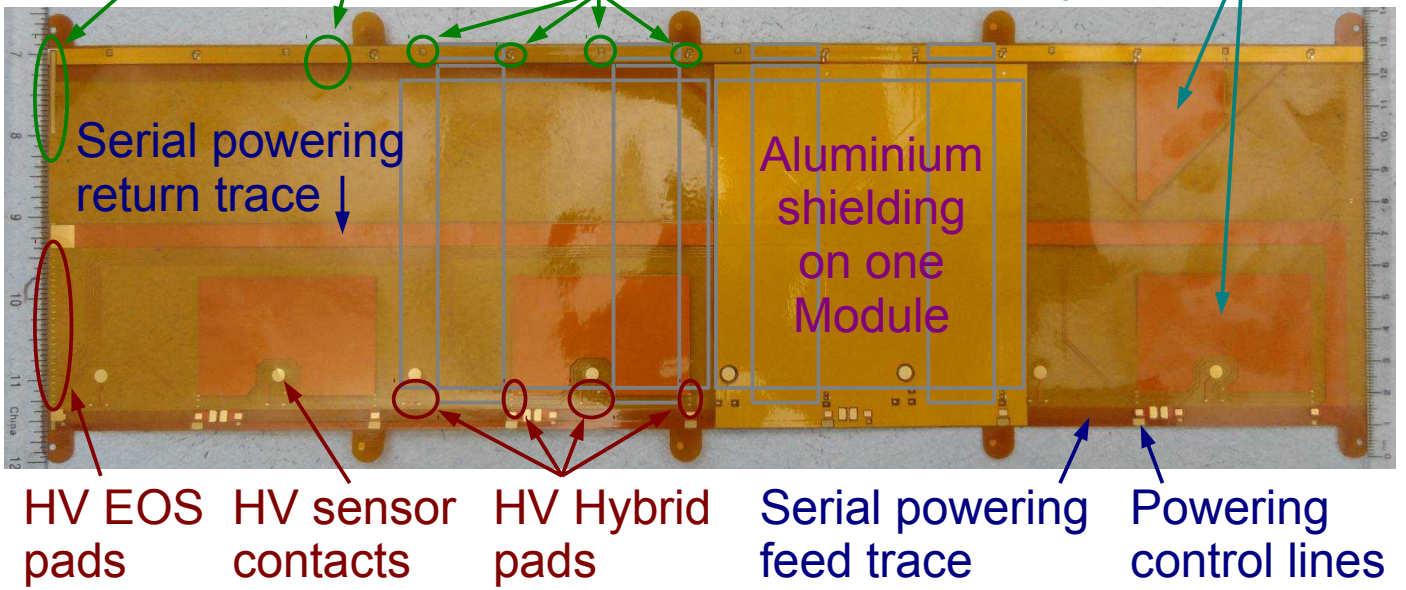
Key differences :

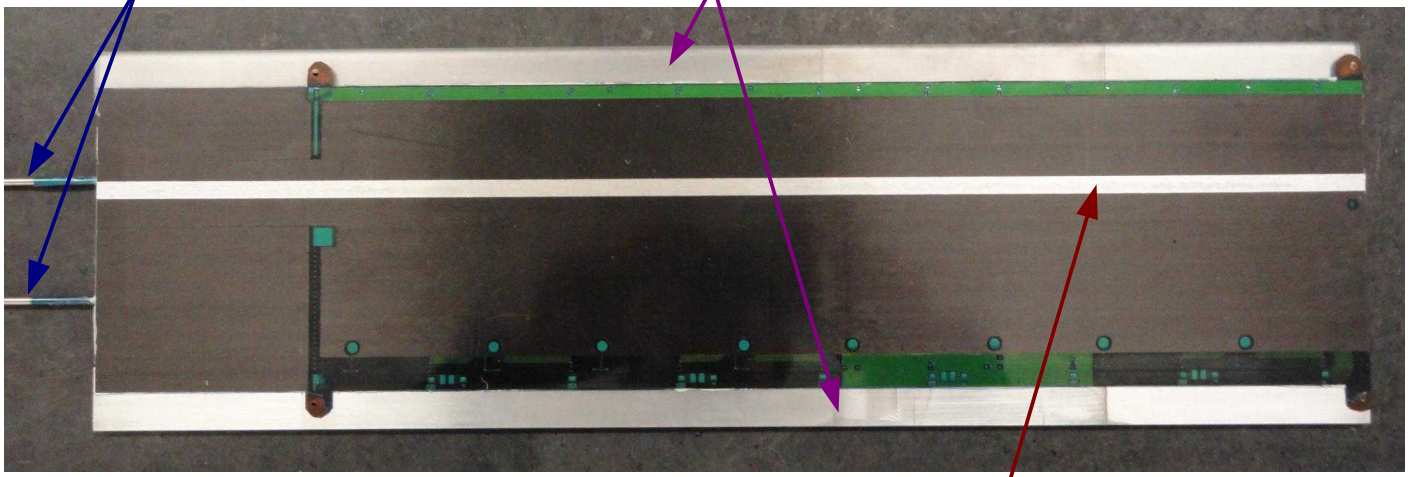
- Double-sided : noise influence study, powering schemes comparison
- Shieldless tape, use carbon fibre as shielding instead : reduce the material cost by 10%



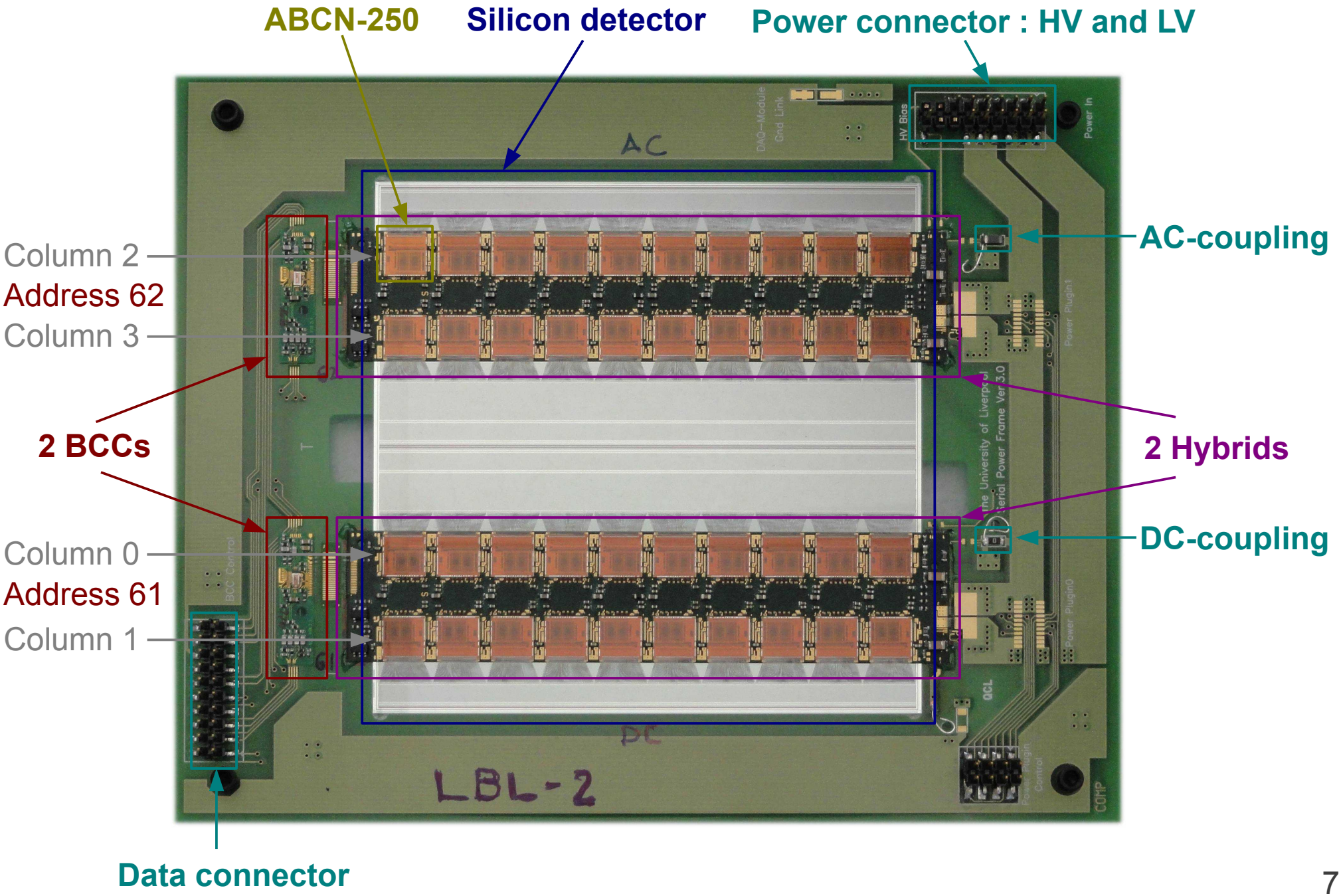


Stavelet bus tape & Core



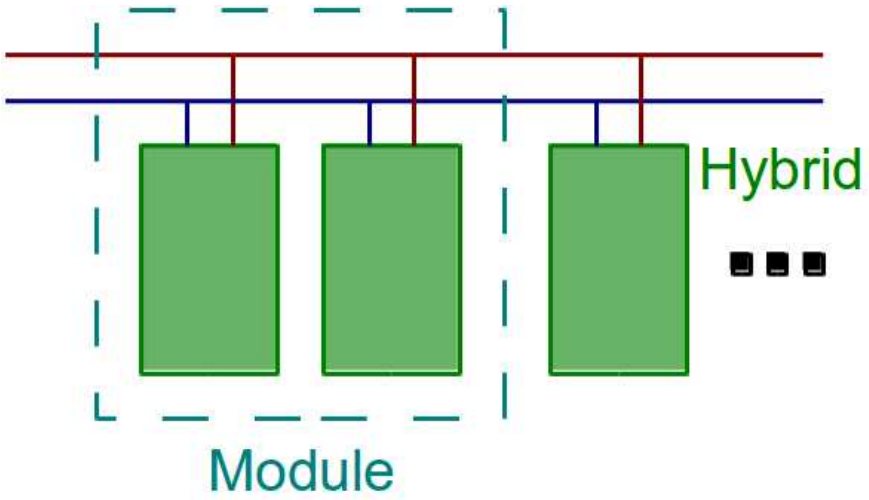


Module


ABCN-250
Silicon detector
Power connector : HV and LV
AC-coupling
Column 2
Address 62
Column 3
2 BCCs
2 Hybrids
Column 0
Address 61
Column 1
DC-coupling
Data connector
AC
DC
LBL-2

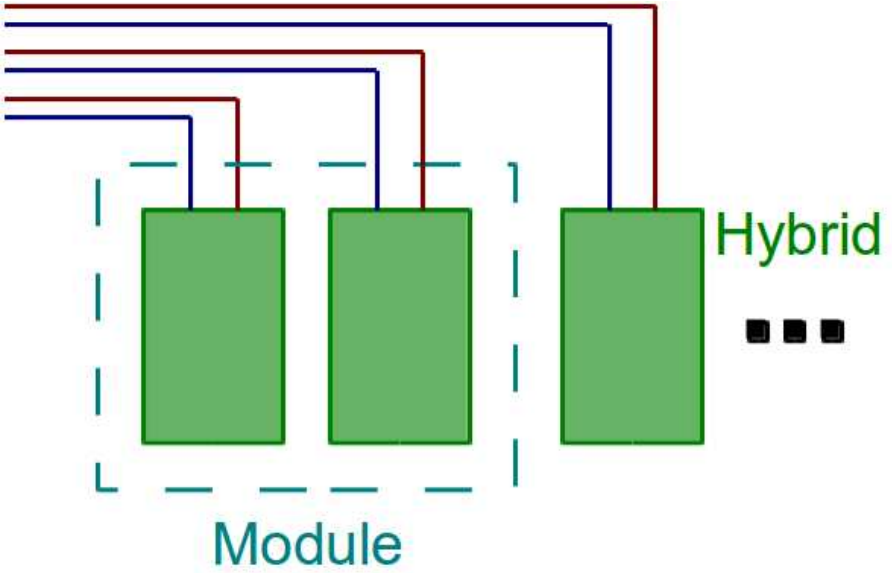
Powering schemes (1)

Parallel



- Reduced number of cables = low material cost
- All Modules have the same ground.
- High current in the cables = power loss

Independent

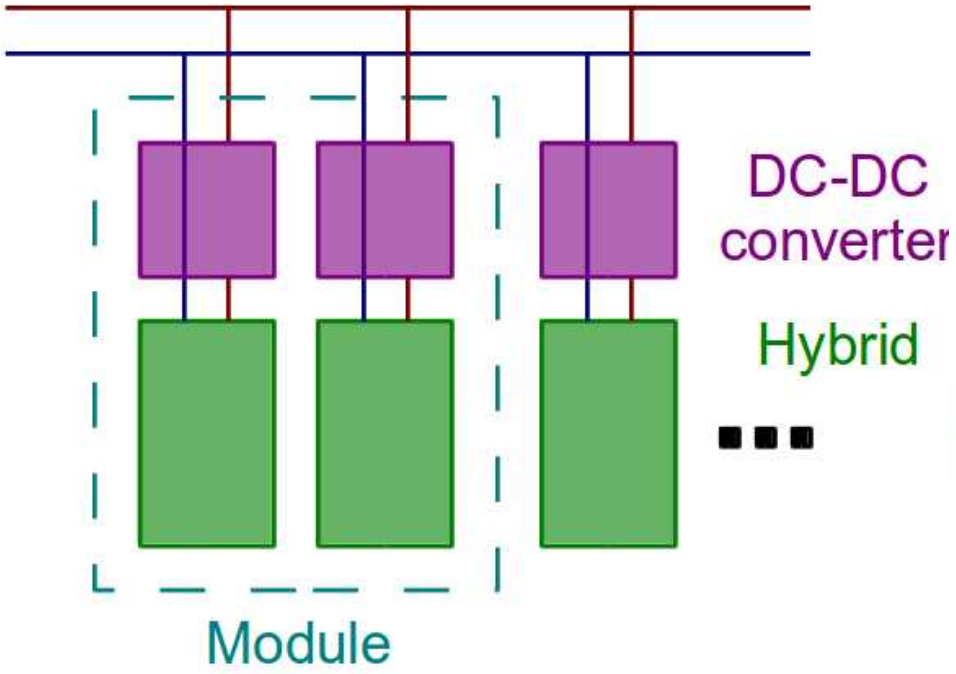


- High number of cables = high material cost.
- All Modules can have the same ground.
- Low current in the cables = efficiency
- Hybrid can be turned ON / OFF from outside without integrated control electronics.

Powering schemes (2)

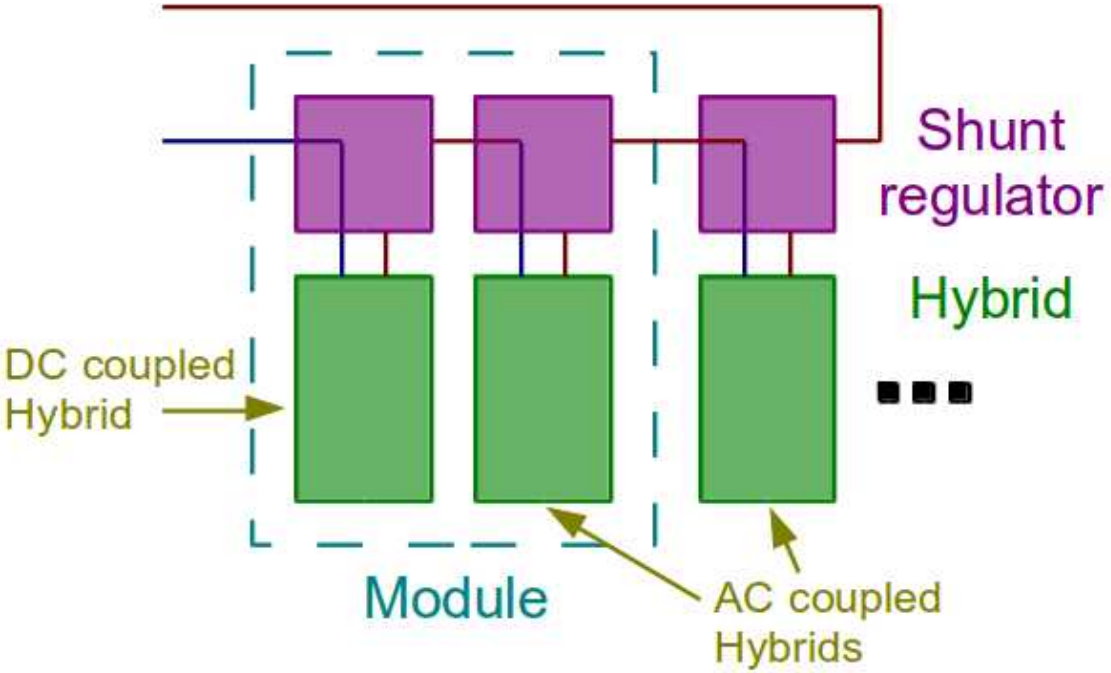
Reduced number of cables & power efficiency : increase distribution voltage

DC-DC



- **DC-DC converters increase the material cost.**
- All Modules have the same ground.

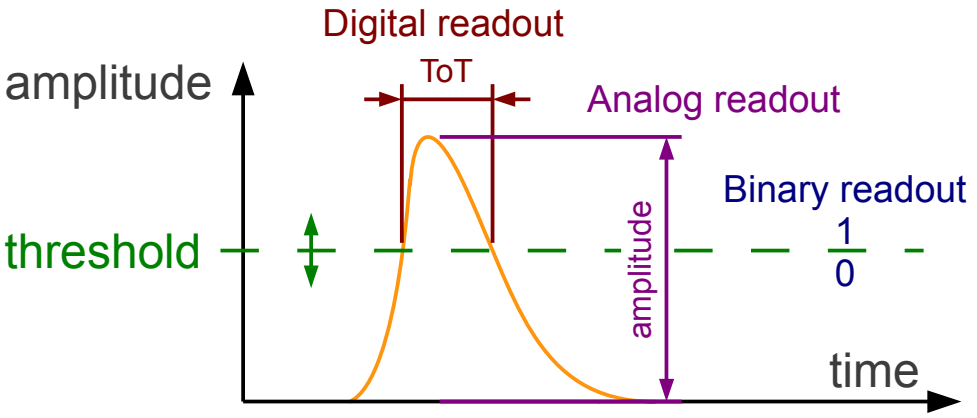
Serial

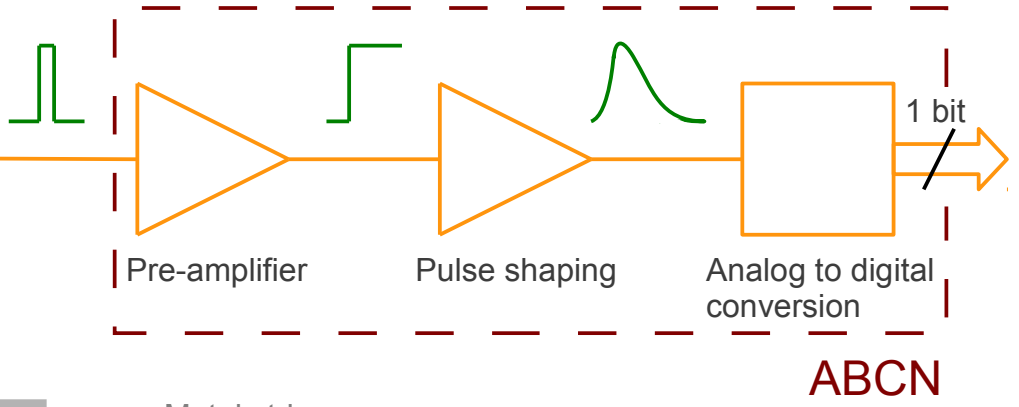


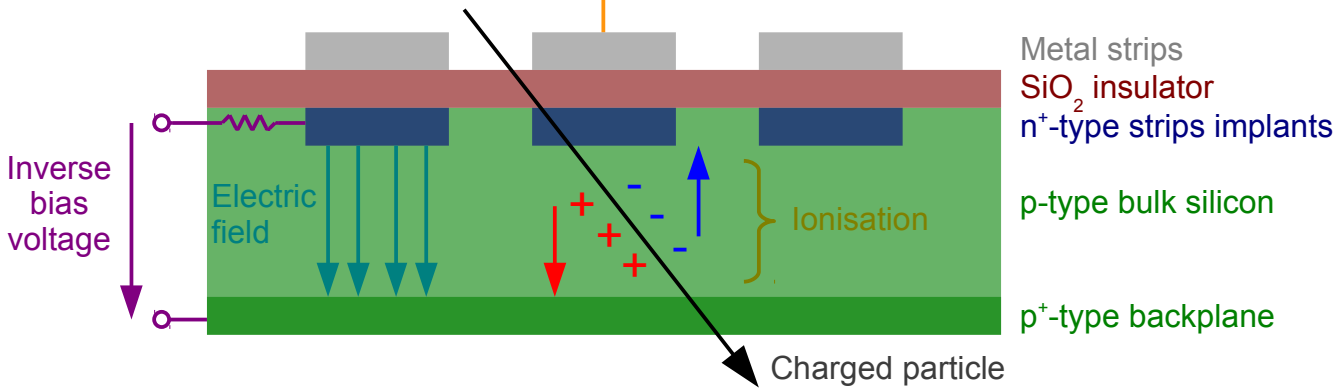
- Small material cost increase.
- Each Module has a different ground. Only one can be DC coupled for data communication. The others must be AC coupled.
- **Higher double trigger noise.**

Silicon sensor & readout electronics

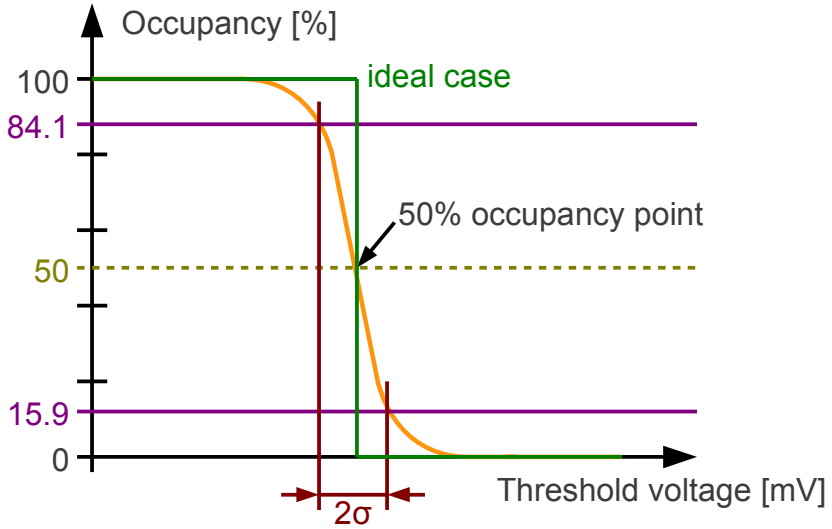
- Simple detection principle
- Three readout techniques



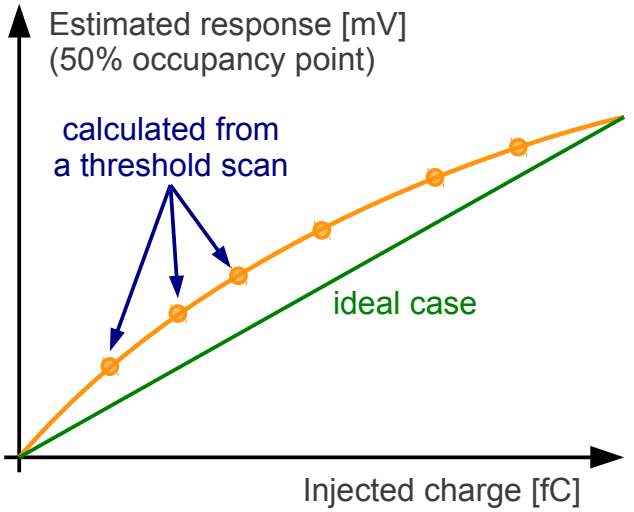




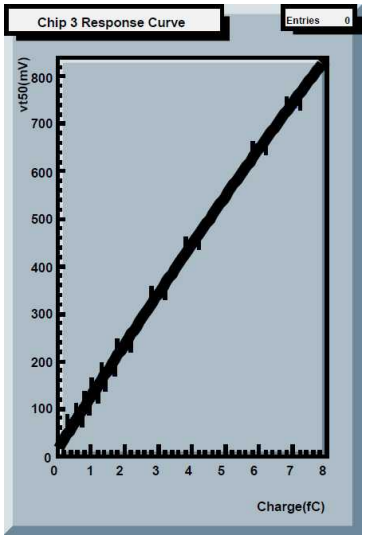
Noise extraction method



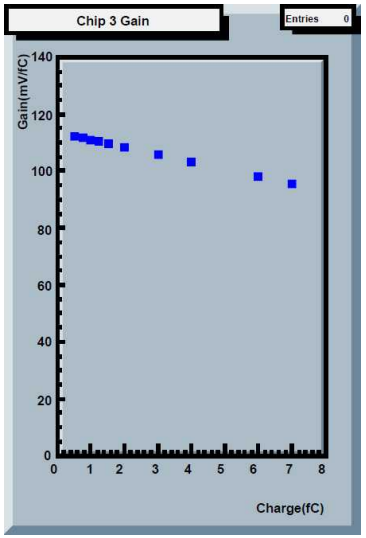
S-curve



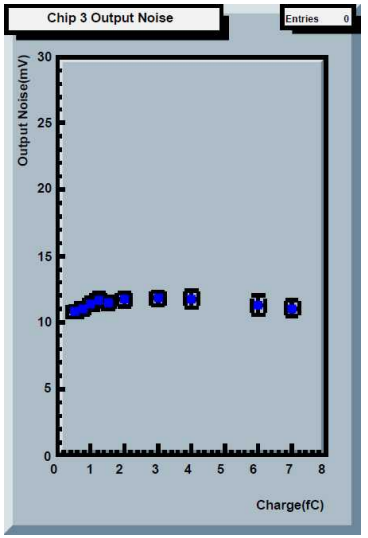
Response curve



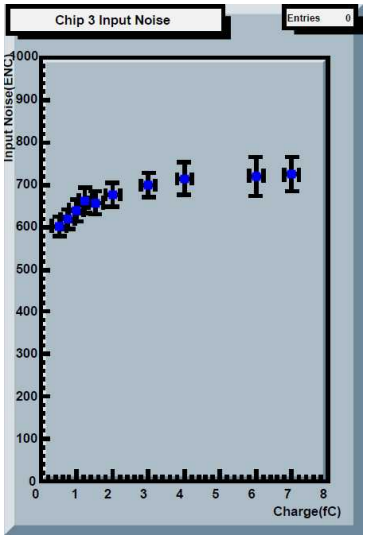
Response curve



Small signal gain

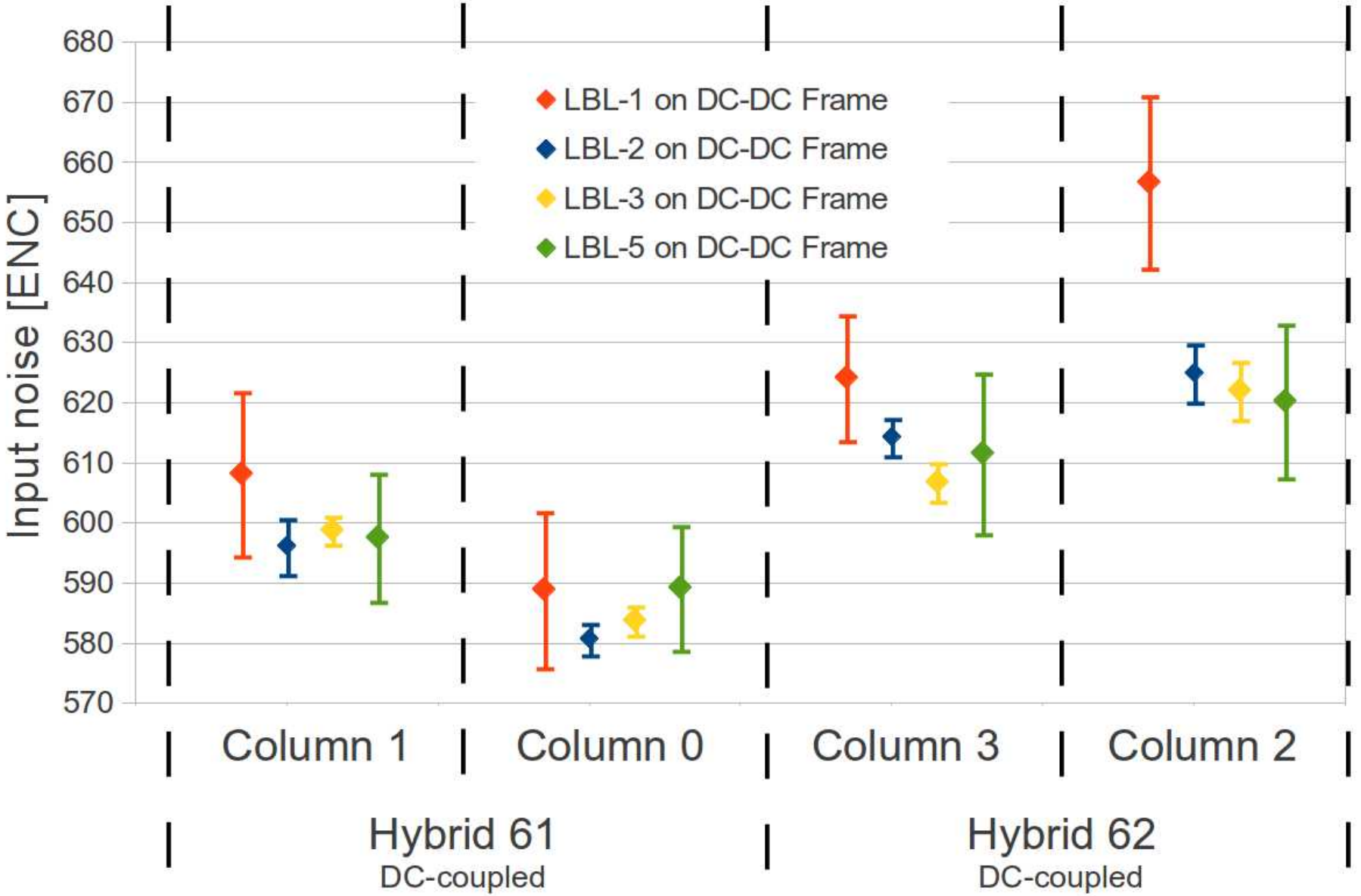


Output noise



Input noise

Modules characterization



Modules baseline noise

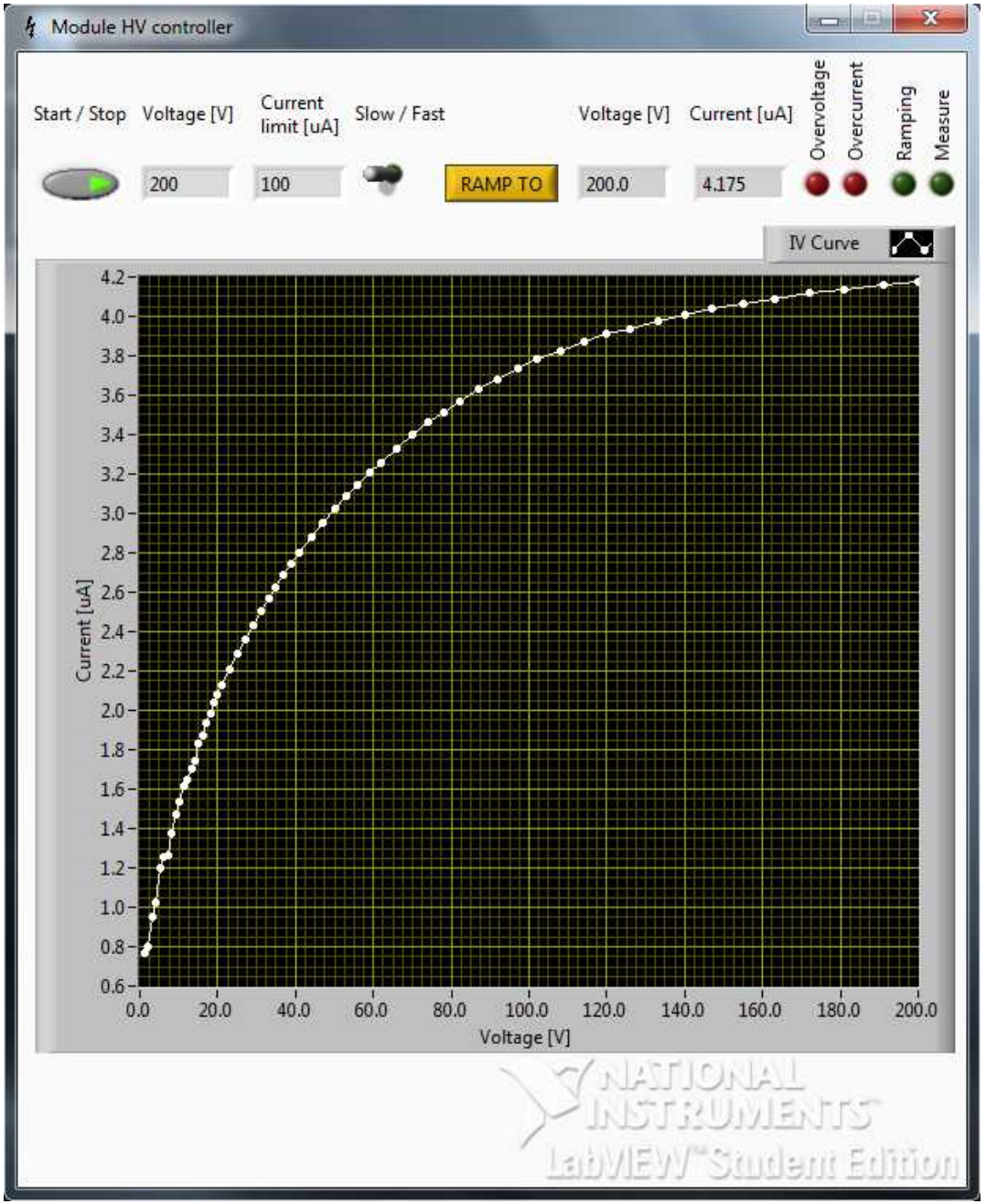
The baseline noise is the noise of an individual Module before its installation on a Stavelet.

Module	Powering	Hybrid 61 Column 0	Hybrid 61 Column 1	Hybrid 61 Columns 0&1	Hybrid 62 Column 2	Hybrid 62 Column 3	Hybrid 62 Columns 2&3
LBL-1	serial	607	658	**621**	644	597	**632**
LBL-1	DC-DC	589	608	**599**	657	624	**641**
LBL-2	serial	605	620	**612**	633	603	**618**
LBL-2	DC-DC	581	596	**589**	625	614	**620**
LBL-3	serial	608	624	**616**	618	599	**608**
LBL-3	DC-DC	584	599	**591**	622	607	**615**
LBL-5	serial	-	-	**-**	-	-	**-**
LBL-5	DC-DC	589	598	**594**	620	612	**616**

the values are the mean noise over all channels of a column or an Hybrid
all values are given as ENC (elementary charge e^-)

- Outer columns are noisier.
- Lower noise in DC-coupled Hybrids when using DC-DC Frame.

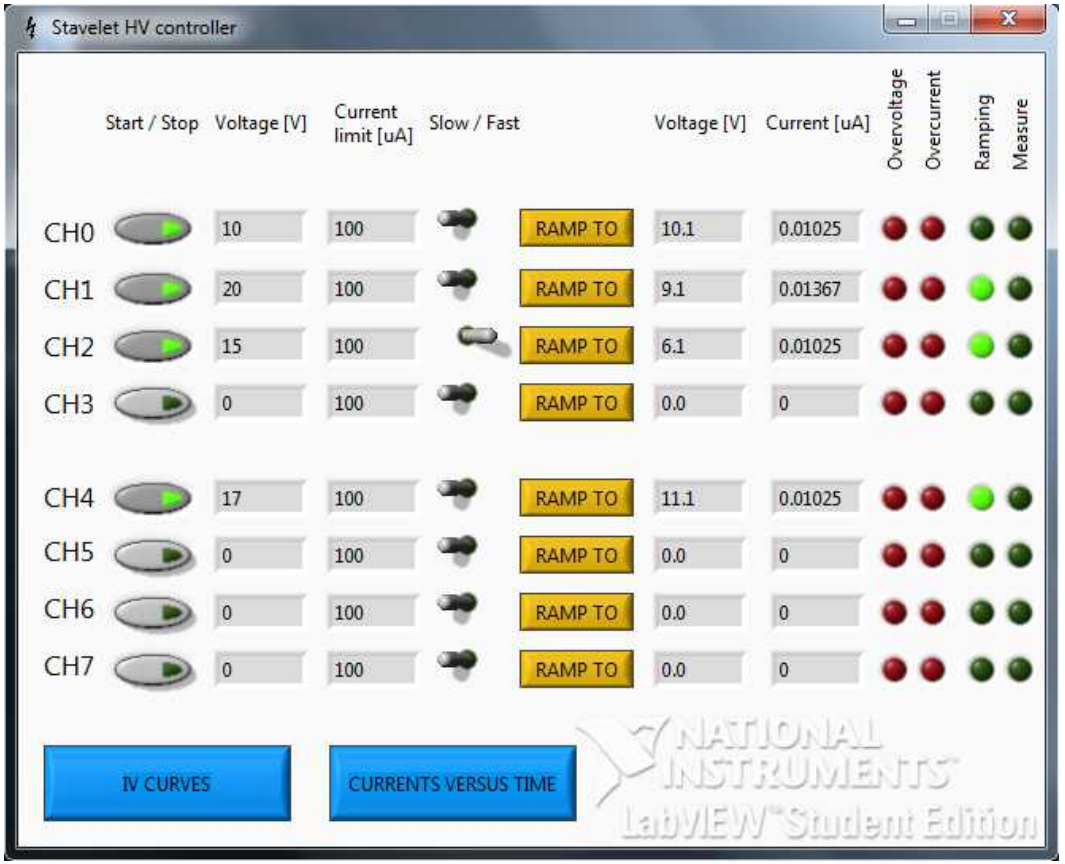
Module HV controller

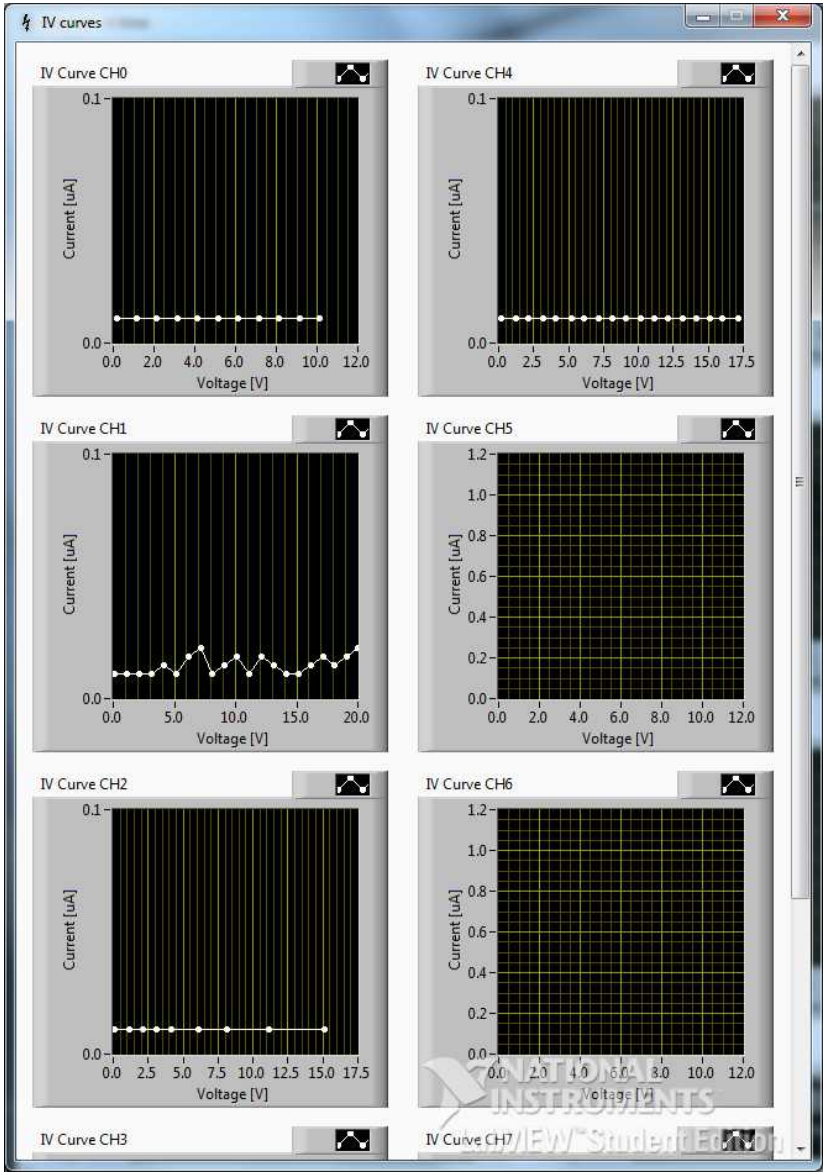


- LabVIEW based application
- Final voltage and current limit adjustable
- Actual voltage and current printout
- Overvoltage and overcurrent protection (hardware)
- Measure and print IV curve during powering up / down
- Slow (4 minutes) and fast (1.30 minutes) mode : influence the number of points measured and ramping speed

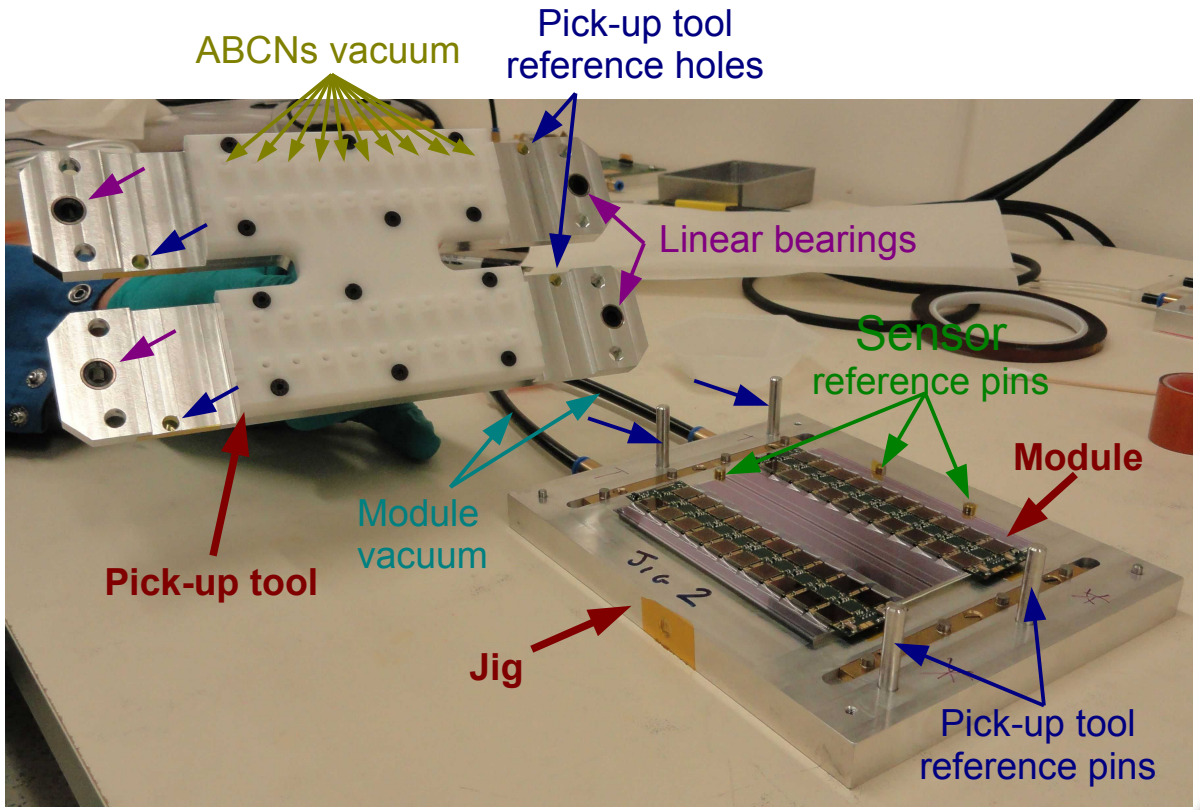
Stavelet HV controller

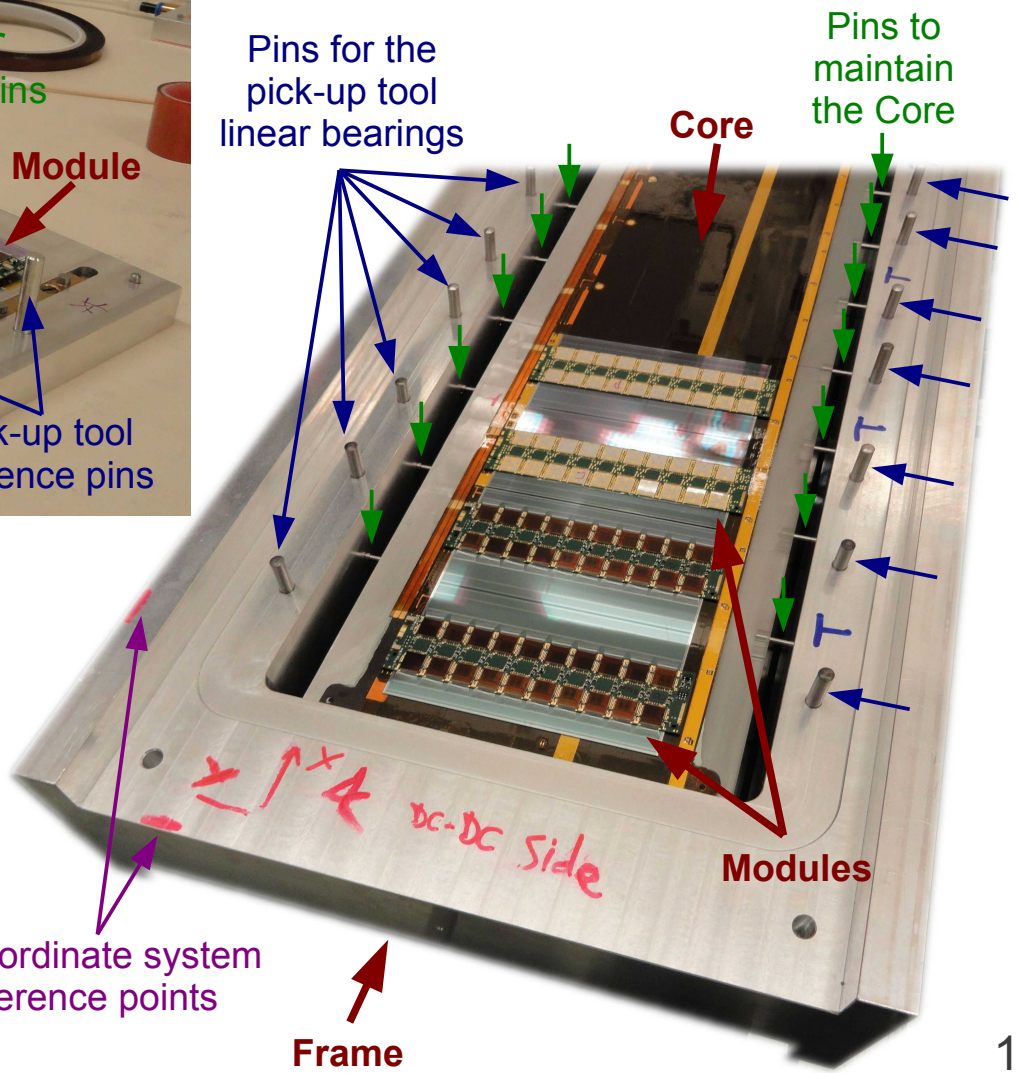
- 8 channels independently and simultaneously controlled.
- IV curves and currents versus time for each channel in a separate window.





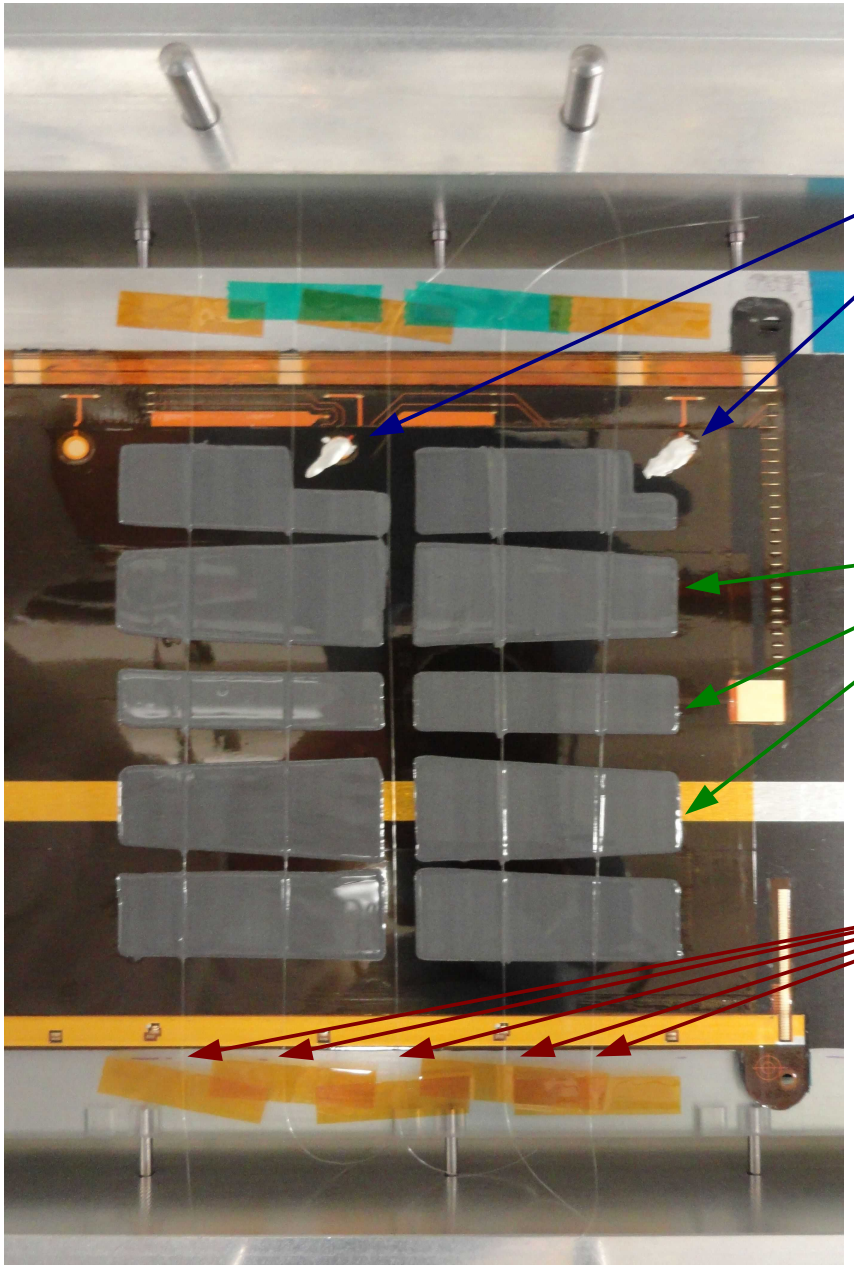
Mounting tools





- Pick the Modules by vacuum on top of the ABCNs, leaving enough clearance for the wirebonds.
- Place them precisely on the Core : ~ 500 µm between the silicon sensors, pads for wire bonding.

Gluing



Silver epoxy :

- Electrically conductive
- HV contacts to sensor backplane
- Two contacts for redundancy

SE4445 :

- Electrically insulator
- Thermally conductive
- Resistive to radiation
- Pattern by “blue tape” mask

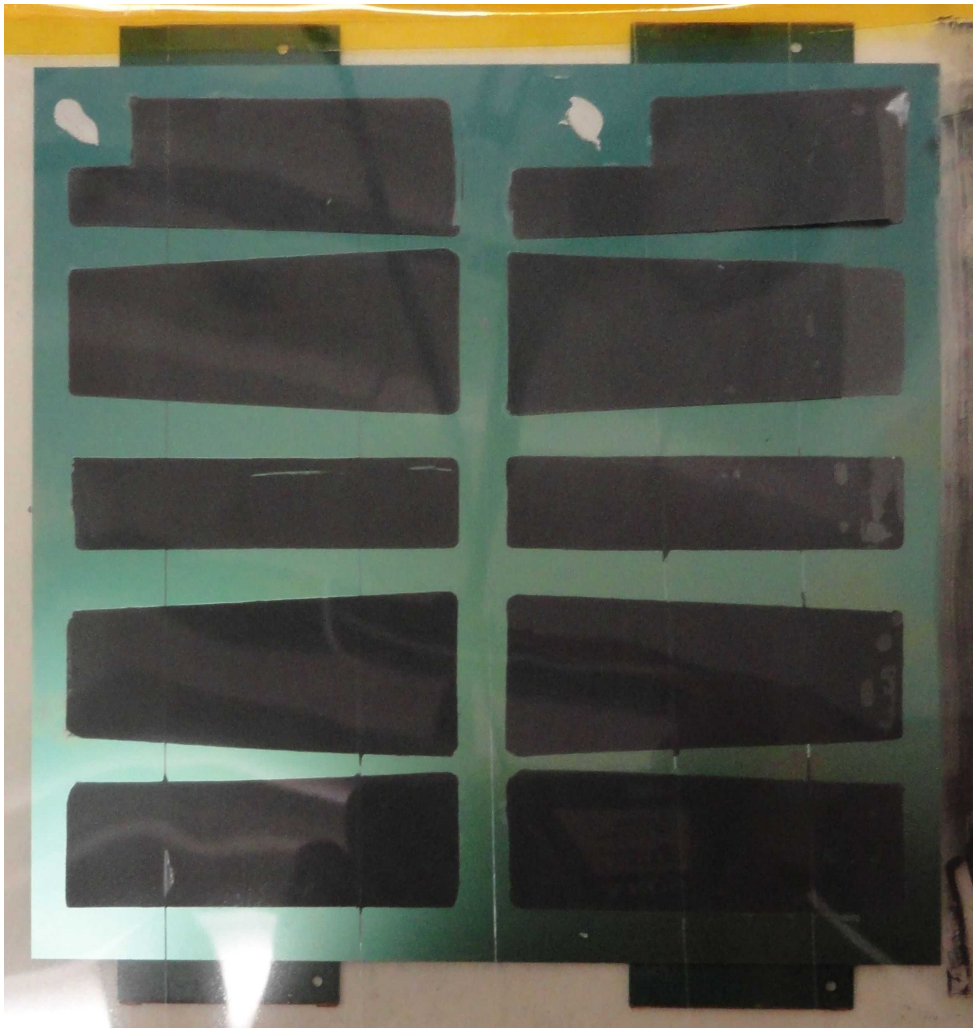
Fishing lines :

- 125 µm diameter
- Height control
- Allow Module removing by cutting the glue.

Glue trials

160 µm of glue

Fail : no glue spreading

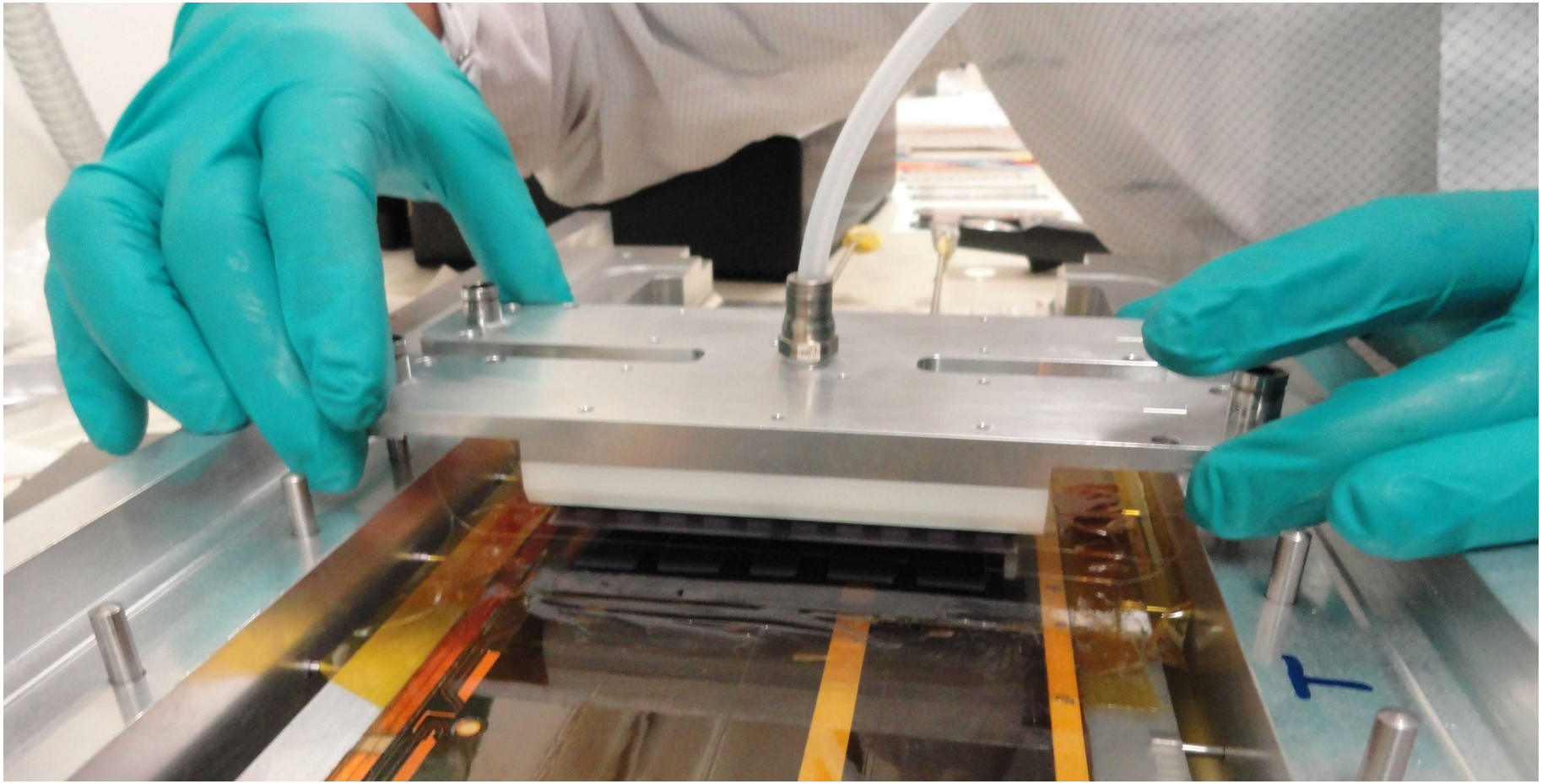


240 µm of glue

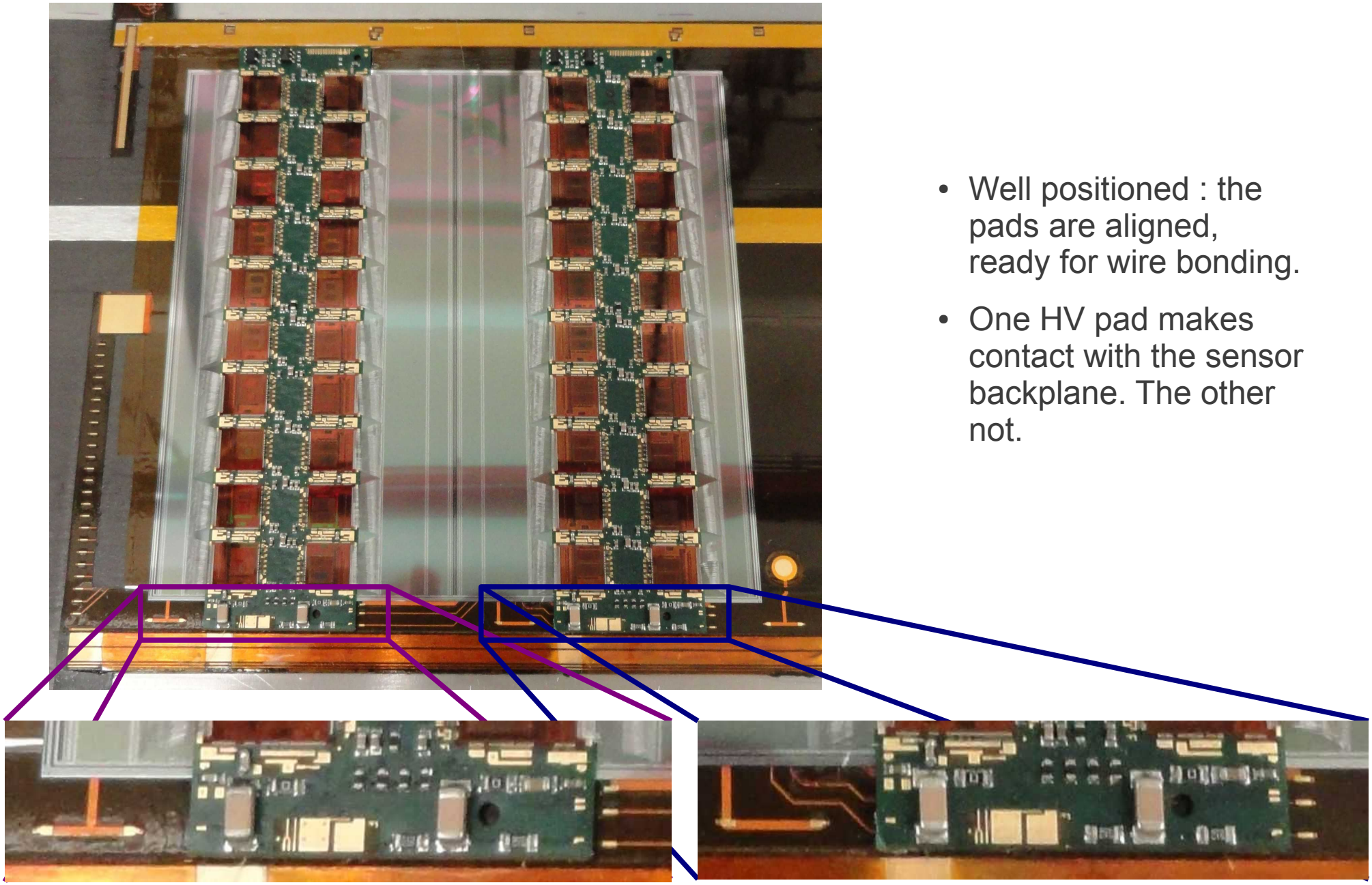
Pass : glue spreading

Module placement

- Linear bearings allow the pick-up tool to move vertically but not horizontally.
- Module position controlled by the dowel pins.
- Manual procedure, automatic pick-and-place for mass production.

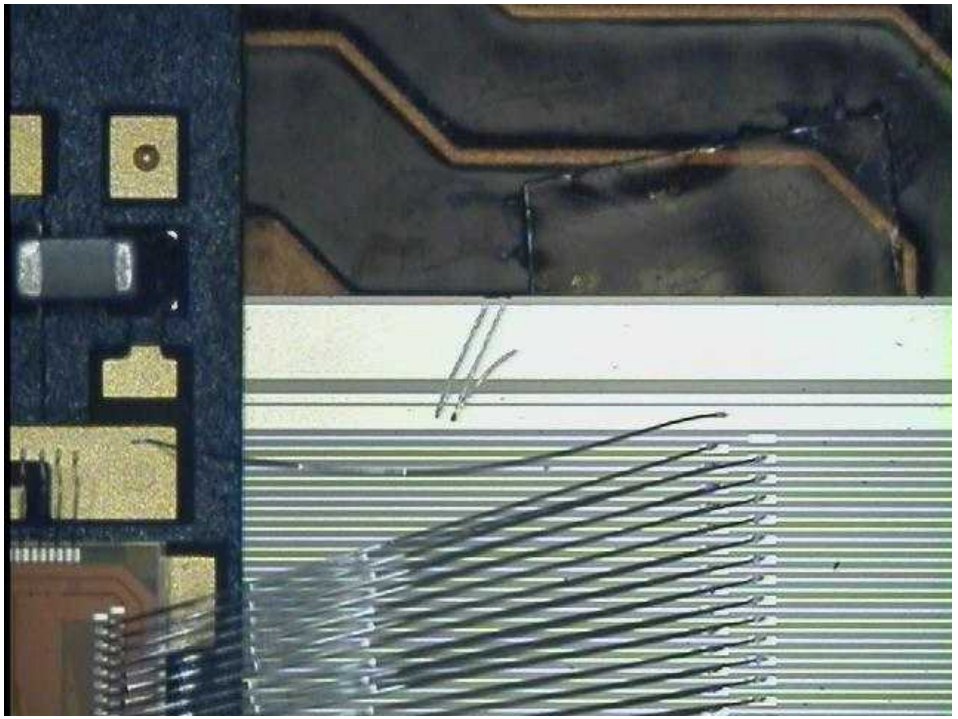


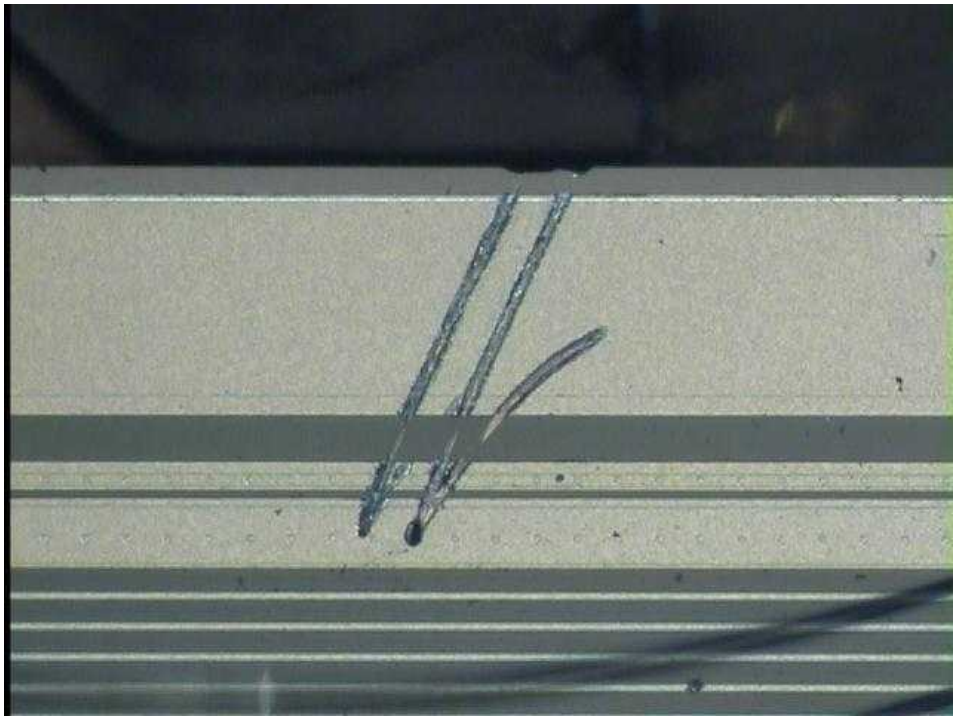
First Module glued...



- Well positioned : the pads are aligned, ready for wire bonding.
- One HV pad makes contact with the sensor backplane. The other not.

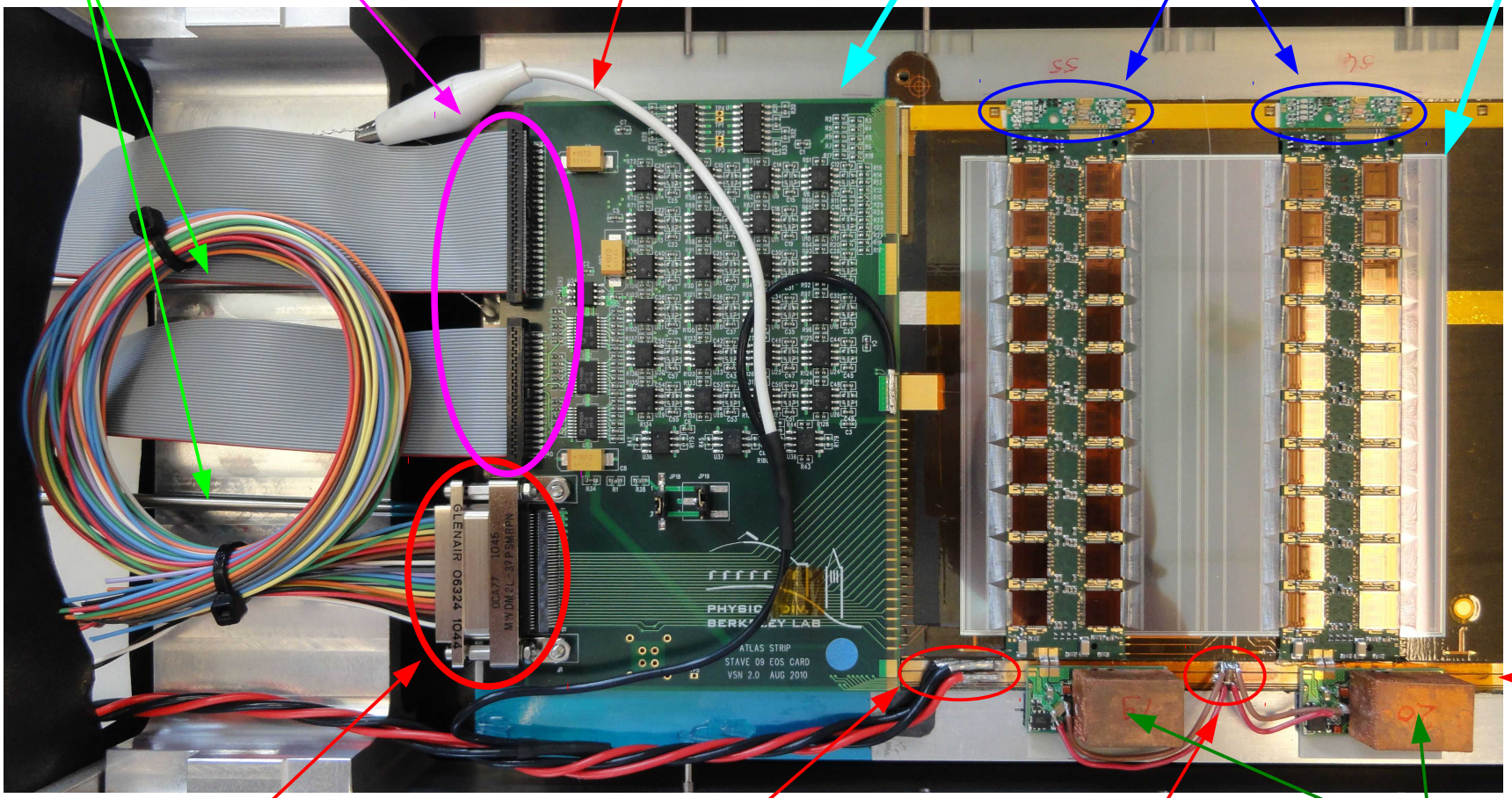
But damaged...



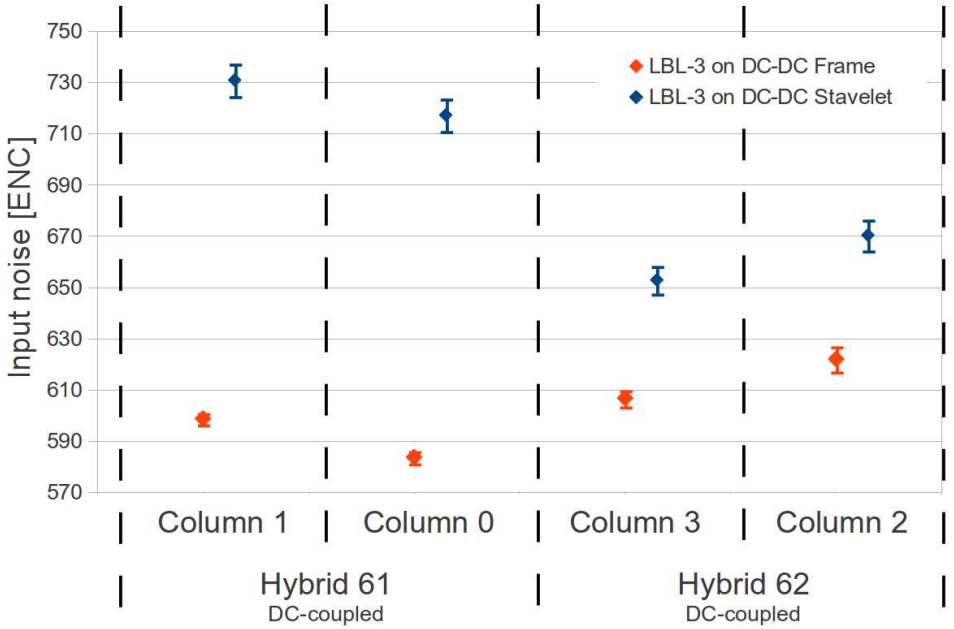


Probably down by tweezers before Module gluing

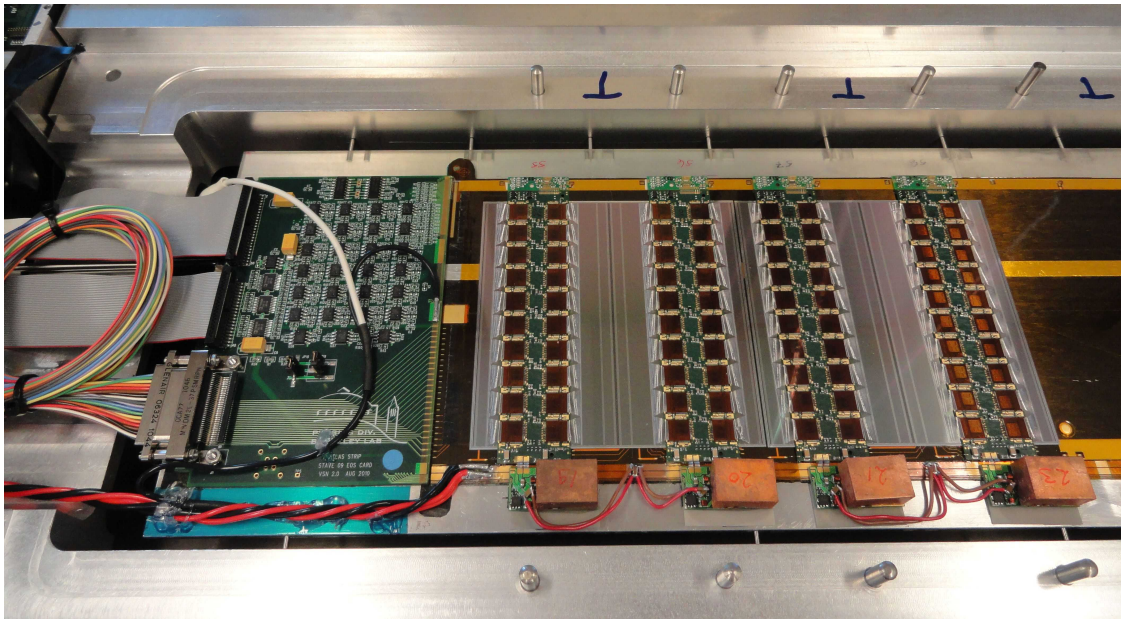
Stavelet additional components



Finally two Modules



- Columns are noisier, especially on Hybrid 61
- Noise level comparable with other groups
- Further investigation needed



Conclusion

- Stavelet test setup installed and tested. Module and Stavelet HV controllers developed to command and control bias voltage and current.
- All Modules characterized.
- All steps for Stavelet mounting completed.
- First Module damaged. Testing of the second Module initiated.

- Full Stavelet was not completely assembled due to delays at the different stages of the project.
- Multi-disciplinary project : development of mechanical tools, mechanical assembling, metrology measurements, software development, noise studies etc.