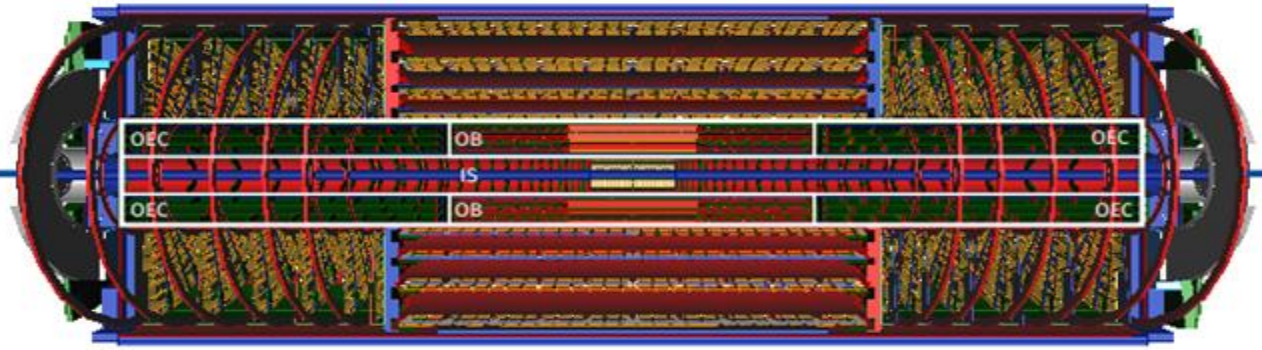
ATLAS Inner Tracker Outer Barrel Demonstrator Project

A new Inner Tracker for the ATLAS detector



at the High-Luminosity Large Hadron Collider

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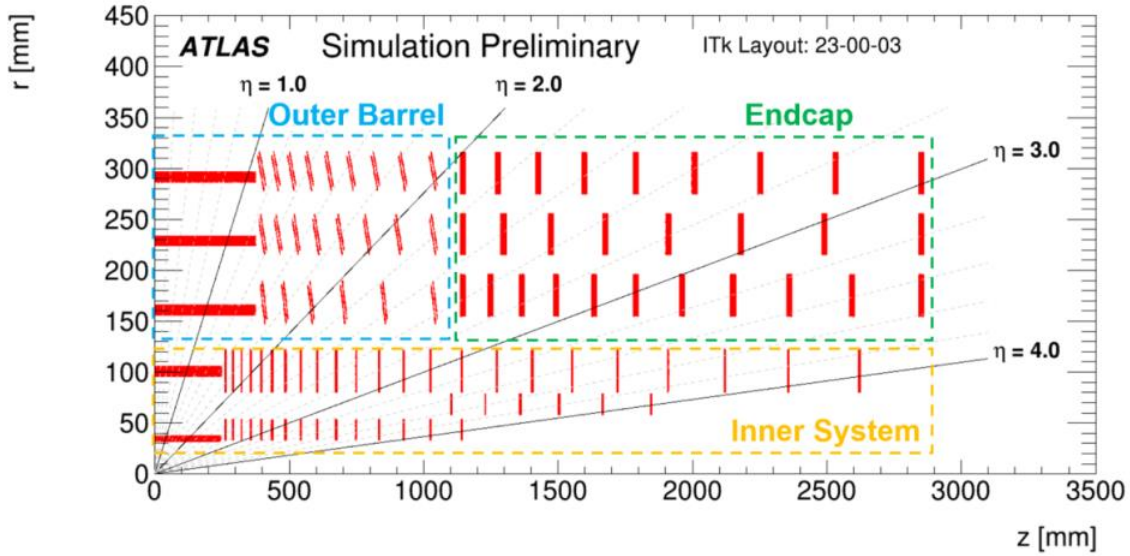
Outline

- Introduction to the Inner Tracker (ITk) Outer Barrel (OB) upgrade for HL-LHC.
- ITk OB demonstrator project
  - Proof of concept of ITK detector services and cooling.
  - Modules production for the OB project.
  - Performance studies and inspection in different stages.
- Quality control assessment for the ITk project.
  - QC study motivation with a novel tool for Pixel examination.
- Stacking 32 quad modules.
  - Investigate various Pixel defects trends.
- Conclusion.



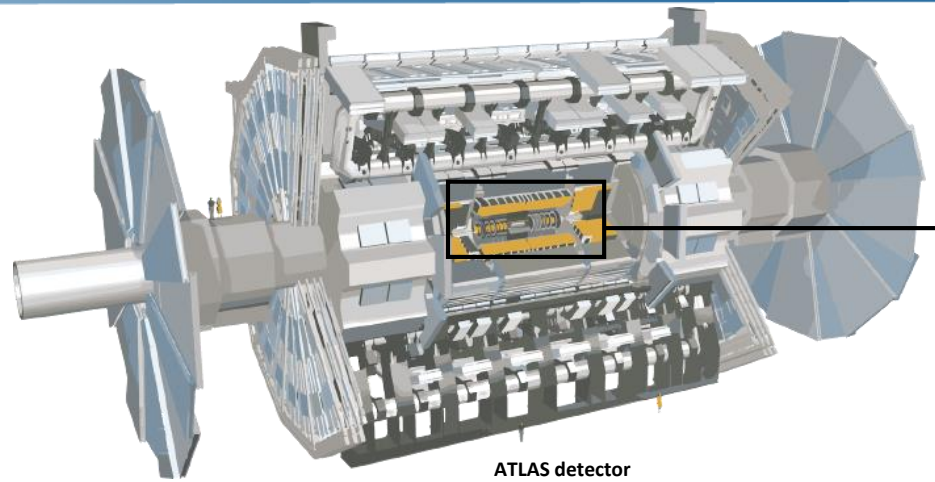
Introduction to Itk OB project:

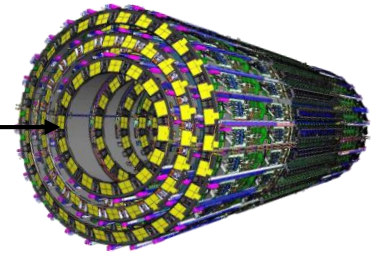
- For the HL-LHC phase the ATLAS Inner Tracker (ITk) will undergo several detector upgrades and new Local-Loaded supports (LLS) designs are presented as follows:

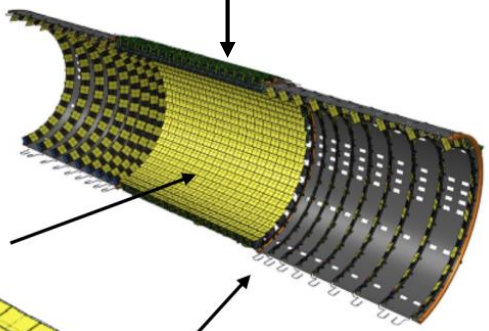
Layer	OB Flat Section			OB Inclined Section		
	# of Longerons	# of Modules in Longeron	# of Modules in the Layer	# of IHR	# of Modules in IHR	# of Modules in the Layer
2	16	36	576	24	16	384
3	22	36	792	32	22	704
4	28	36	1008	36	28	1008
Total	66		2376	92		2096

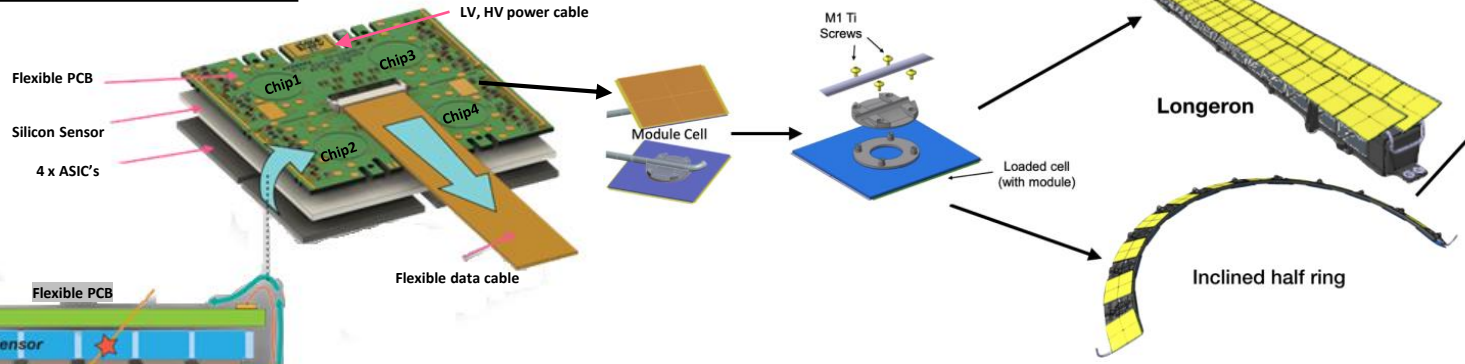
- **Outer Barrel in the ITk will consist of:**
  - 66 Longerons.
  - 92 IHRs.

  ≈ 4500 modules needed for the ITk







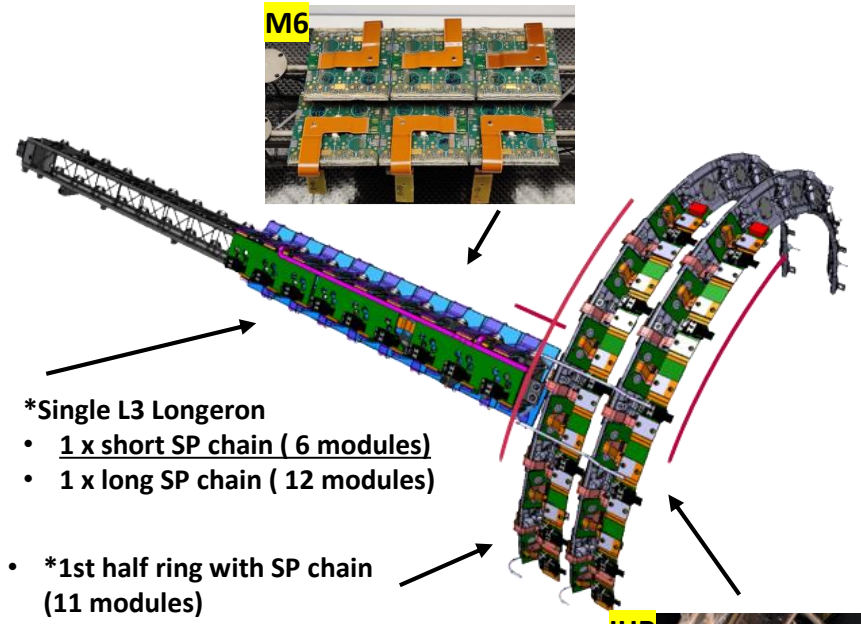


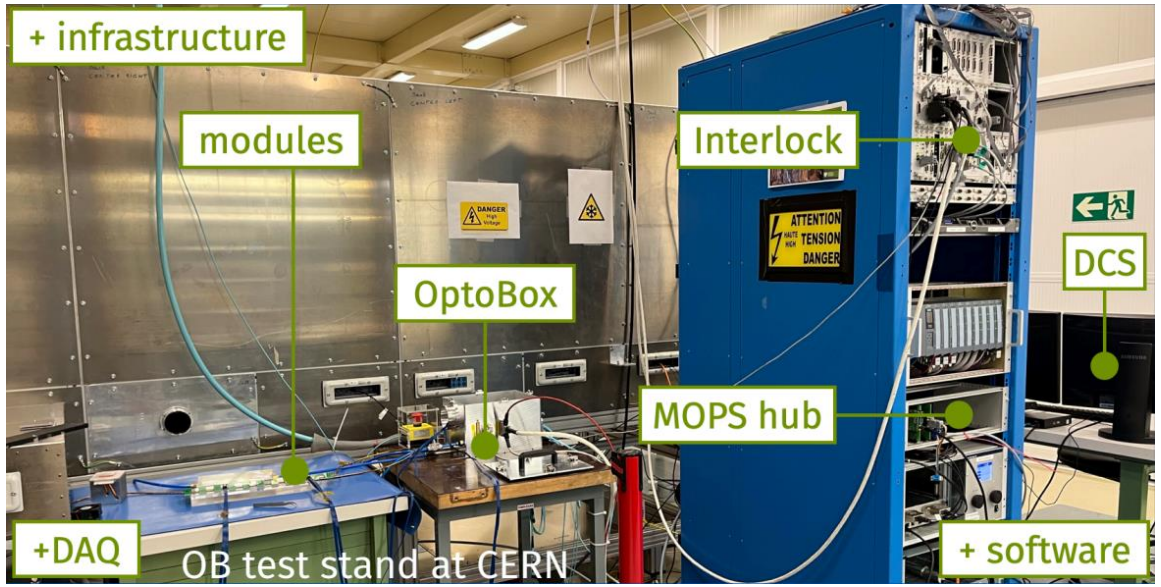
Proof of concept of ITK detector services

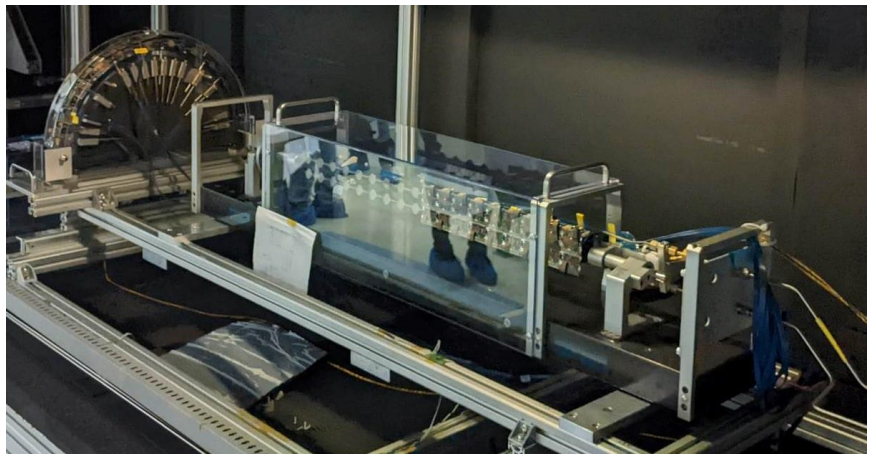
- **Motivation**: Construct a prototype which aims to mimic the real detector ⇒
  1. Study system aspects (services, DCS, cables, interlocks, CO2 cooling . .).
  2. Validate the loading concept needed for LLS (Local loaded supports).

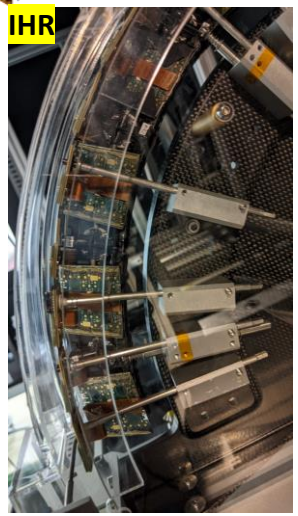
- **Up to 32 RD53A quad modules** connected in 3-4 serial powered (SP) chains.
- Both types of Loaded Local Support (LLS): Two full SP chains on longeron (6+12 modules) and at least one full SP chain on half-ring (11 modules).
- Module performance will be tracked in each production stage.

A demonstrator to proof: That modules perform the same as before loading.

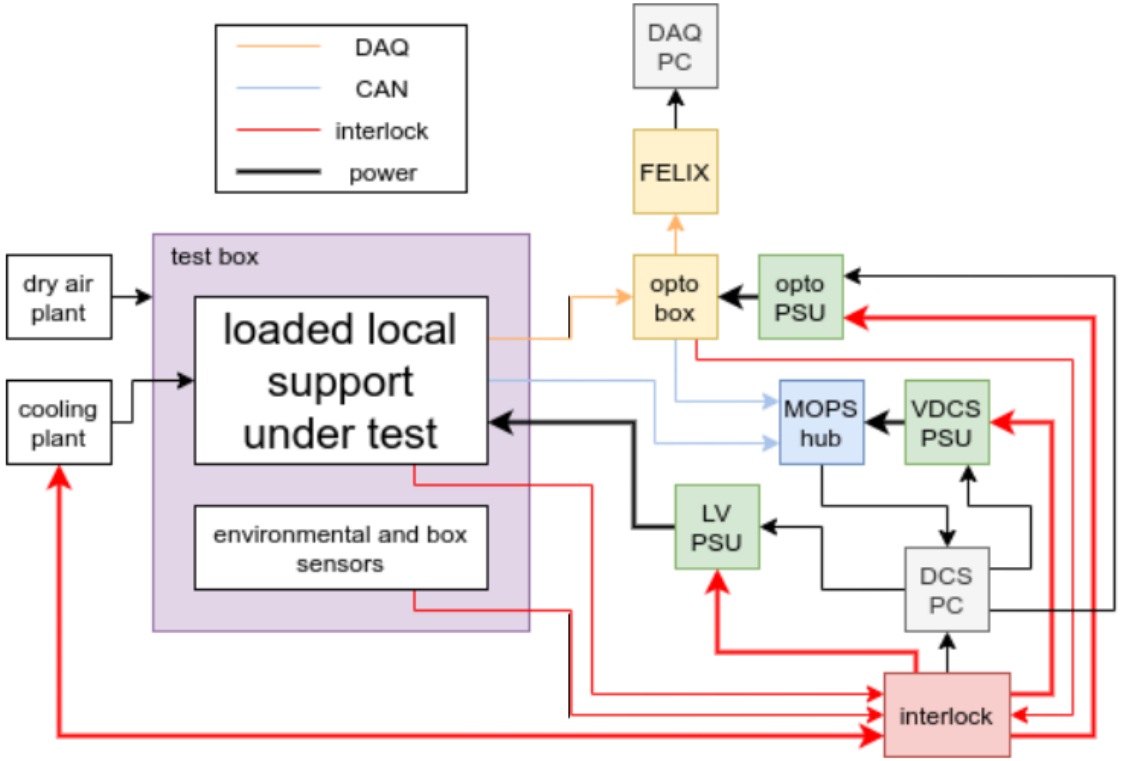


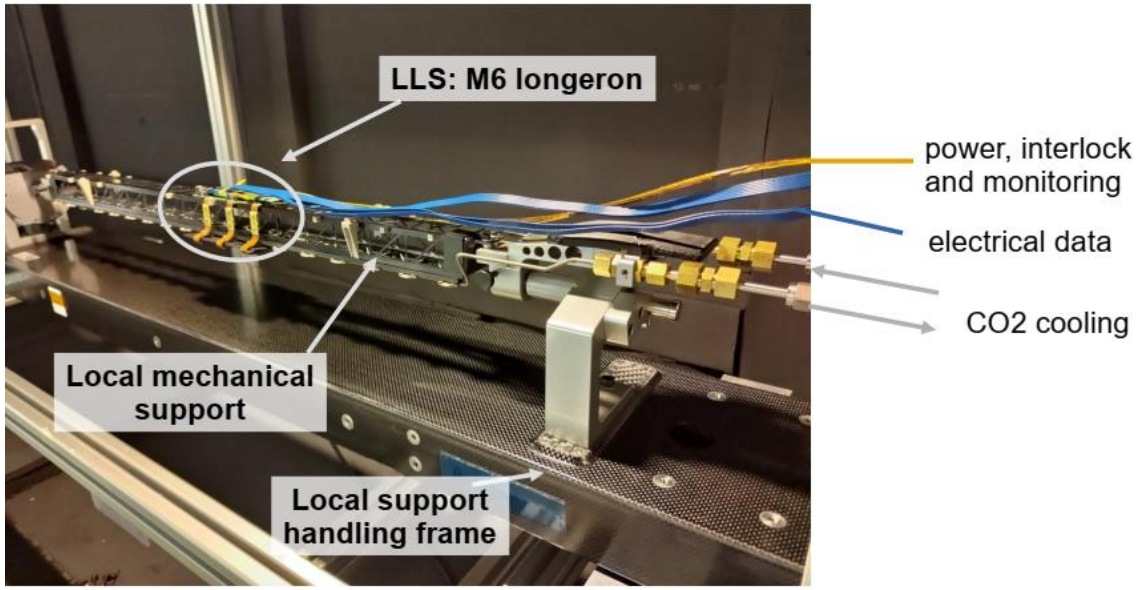


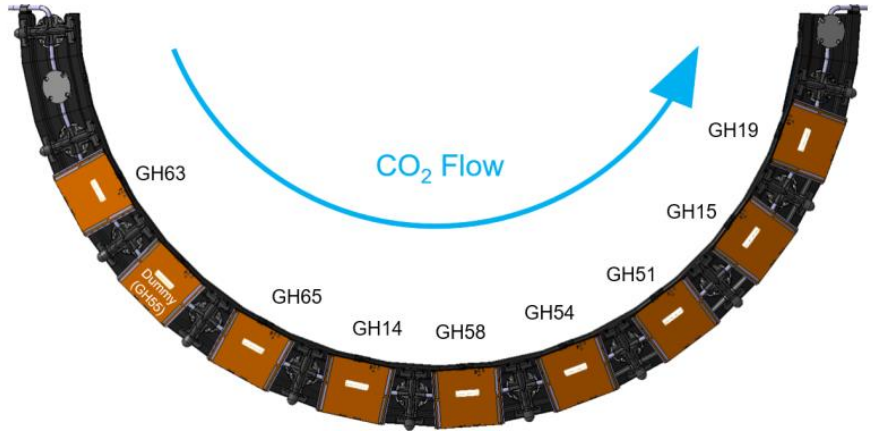




Proof of concept of ITK detector services





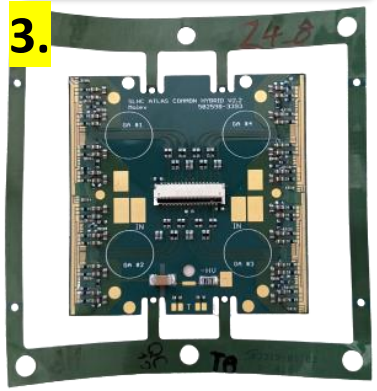


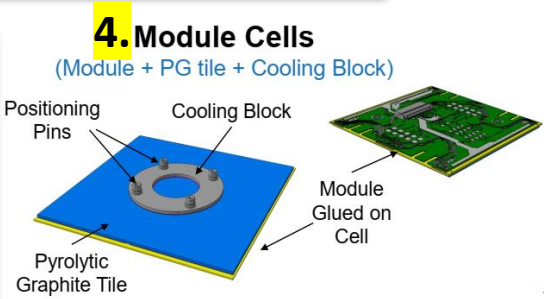
Modules production for OB demonstrator project

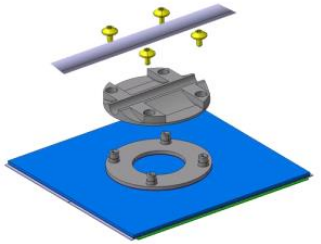
- **Idea:** comparison of module performance at various different stages during assembly **by executing the same tests between each stage** and showing potential differences in the test.

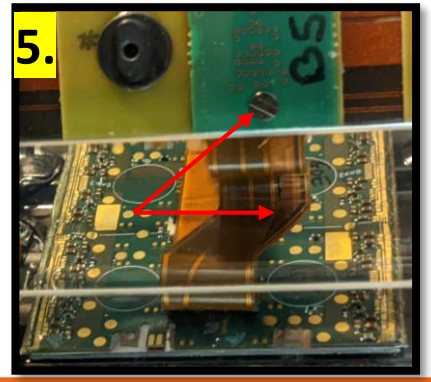
- **Module production stages at CERN :**
  1. **At reception/Before Potting** (module is first received at CERN).
  2. **After Potting** (module wirebonds coated for protection).
  3. **After Tab Cutting** (module is removed from carrier case and got the tabs cutted)
  4. **After Cell loading** (module has received a graphite loading cell).
  5. **PigTail Assembly** (module old pig-tail is removed and replaced with a new connector to PP0).
  6. **Demonstrator System Test** (modules integrated on LLS of the OB demonstrator).

  - Up to 32 RD53A quad modules received at CERN Pixel group.









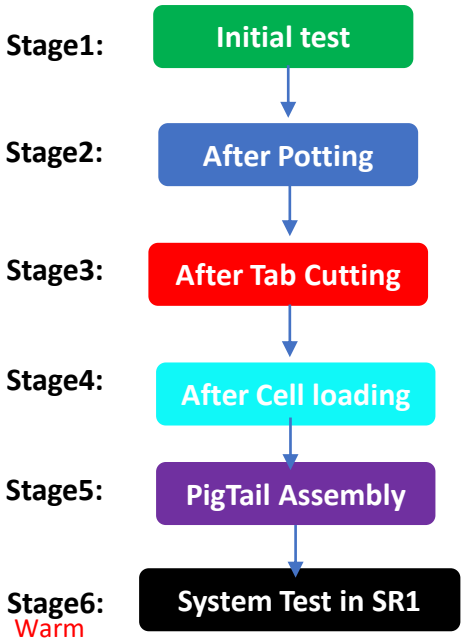
Performance inspection in different stages

- **Testing program:** At previously mentioned stages, full list of electrical scans are performed.
- **On demo-system**: Additional temperature tests at 10°C & -10°C are performed.

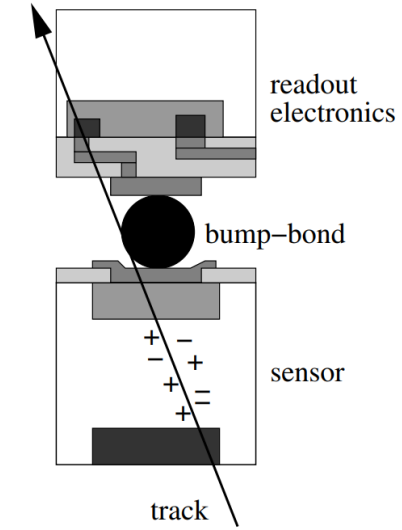
- Warm test with Co2 plant at 10°C

Module ID	Module NTC T°
KEKQ22	20.3
KEKQ24	21.8
KEKQ25	20.1
Liv8	24.2
KEKQ19	23.3
Paris6	22.4
Goe5	22
Paris16	23.3
Paris11	22.2
Goe7	21.1
Paris8	21.5

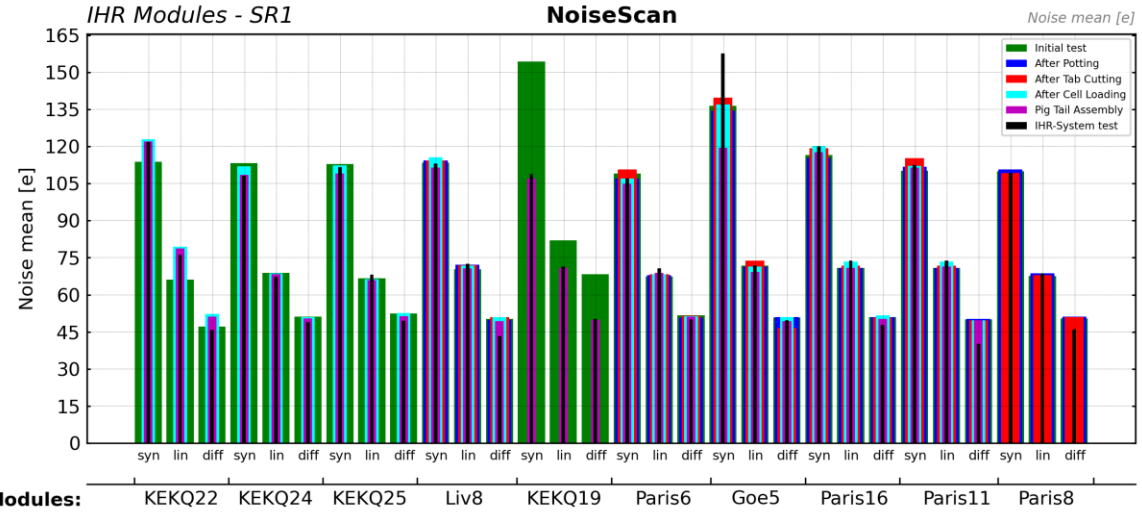
At LV value: I= 4.6A, V = 20.9V

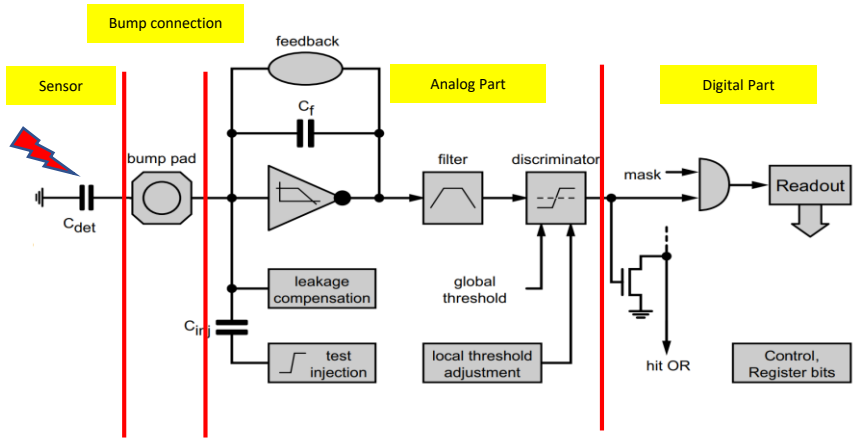


Test
Visual inspection
Basic reception test
→ Sensor IV
Chip configuration
Read_MUX
→ Digital scan
→ Analog scan
→ Noise scan
→ Threshold scan
→ ToT scan
→ Disconnected bump scan
Final threshold scan with +1V forward bias
→ Noise occupancy scan
→ Source/x-ray scan
ADC calibration
Thermal calibration *



Corss section sketch of hybrid pixel detector.



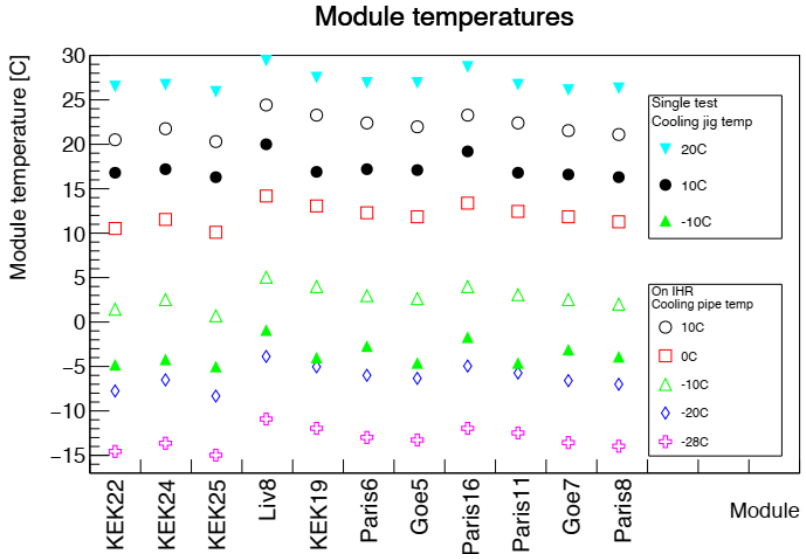


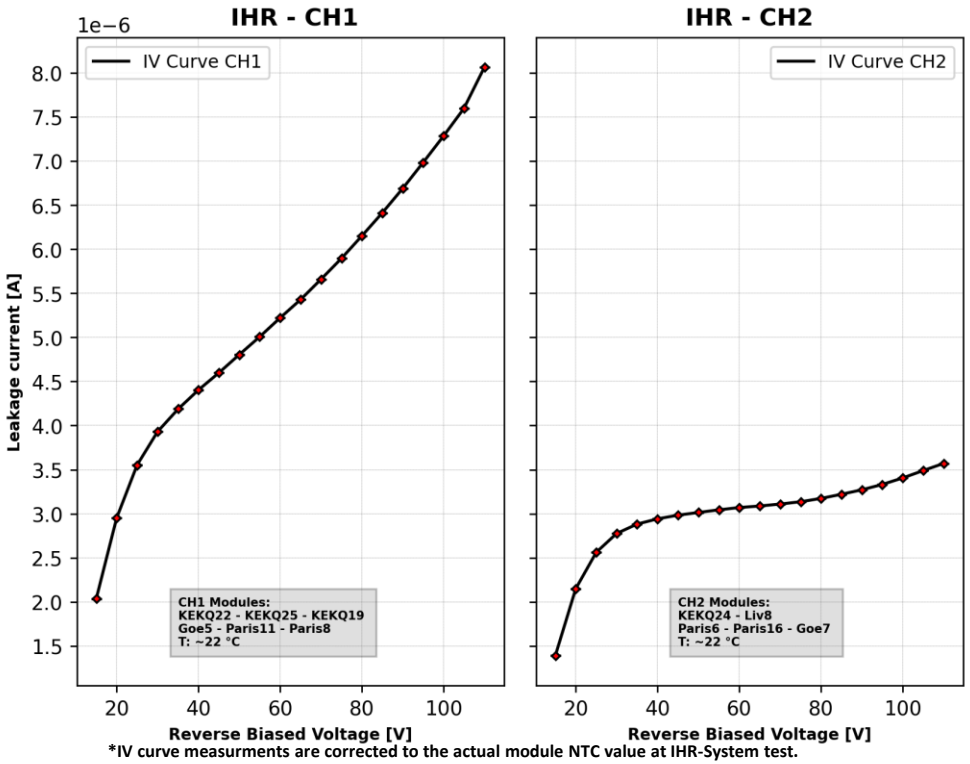
Conventionnel Pixel detector with AFE circuit

Performance inspection in different stages

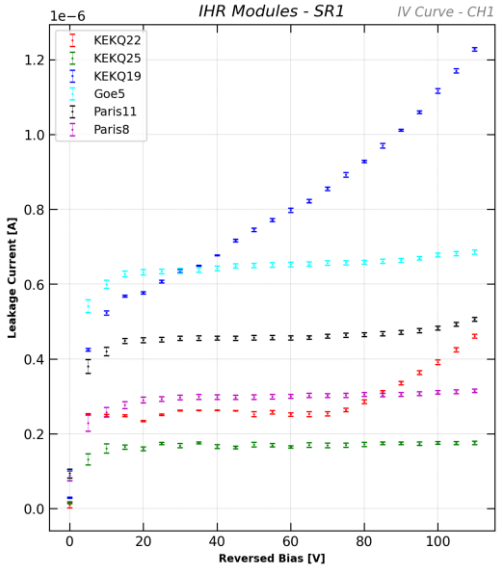
- **Channel 1 have an early breakdown voltage and no clear plateau region for operation.**
- **Early break down is due to KEKQ19 module.**
- **However, Channel 2 behaves good.**

- **Modules temperatures have variations on the local support.**

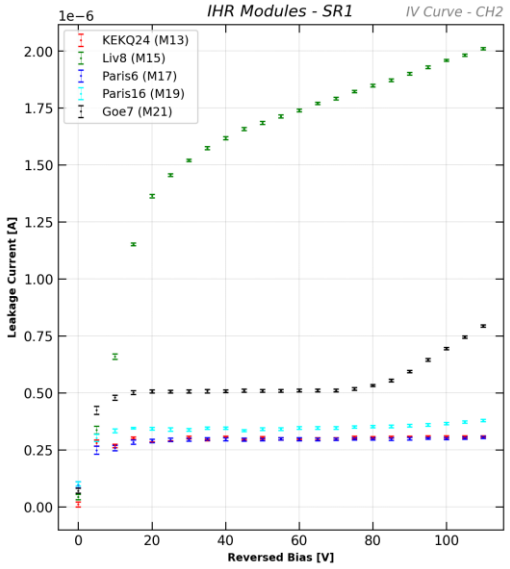




*IV curve measurments are corrected to the actual module NTC value at IHR-System test.



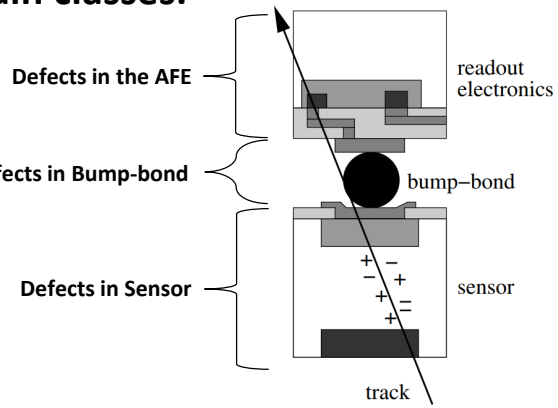
CH1 Modules IV Curves stacked from PigTail Assembly stage*



CH2 Modules IV Curves stacked from PigTail Assembly stage*

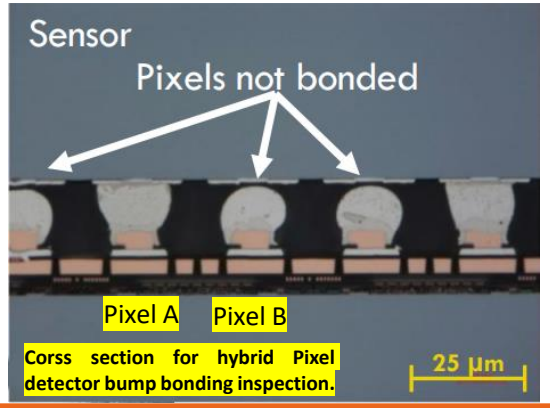
Quality control - Pixel failures categories

- **Pixel defects can be categorized into three main classes:**
  1. Defects in the **readout electronics**:
     - Digital Dead or bad response.
     - Analog dead or bad response.
     - Failling to tune or bad tuning Pixel.
     - High AFE noise detected.
  2. Defects in **Bump-bond**:
     - Merged bump.
     - Open Bump.



Corss section sketch of hybrid pixel detector.

- A combined analysis of Pixel electrical scans would reveal the major defects in the Pixel cricut. Keeping in mind that the failure classification is exclusive, **which means that only one category of Pixel defects** would be assigned per Pixel.



Corss section for hybrid Pixel detector bump bonding inspection.

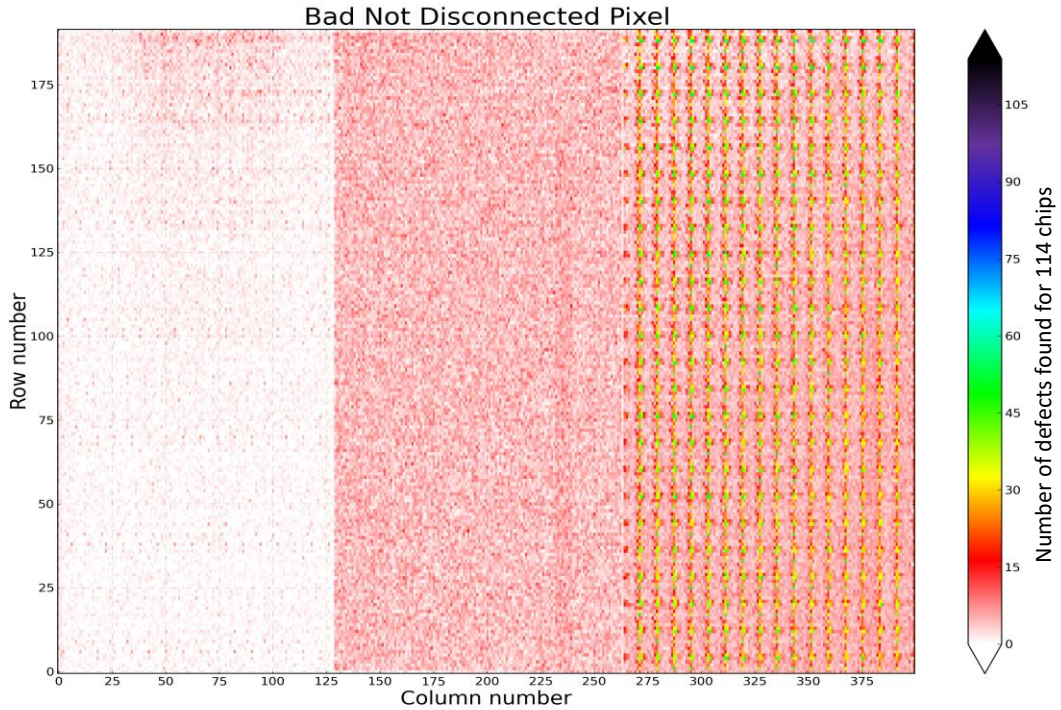
*Test injections in digital & analog scans are fixed to 100^e.
**Total number of injection is 25Ke for syn, 40Ke for lin,diff

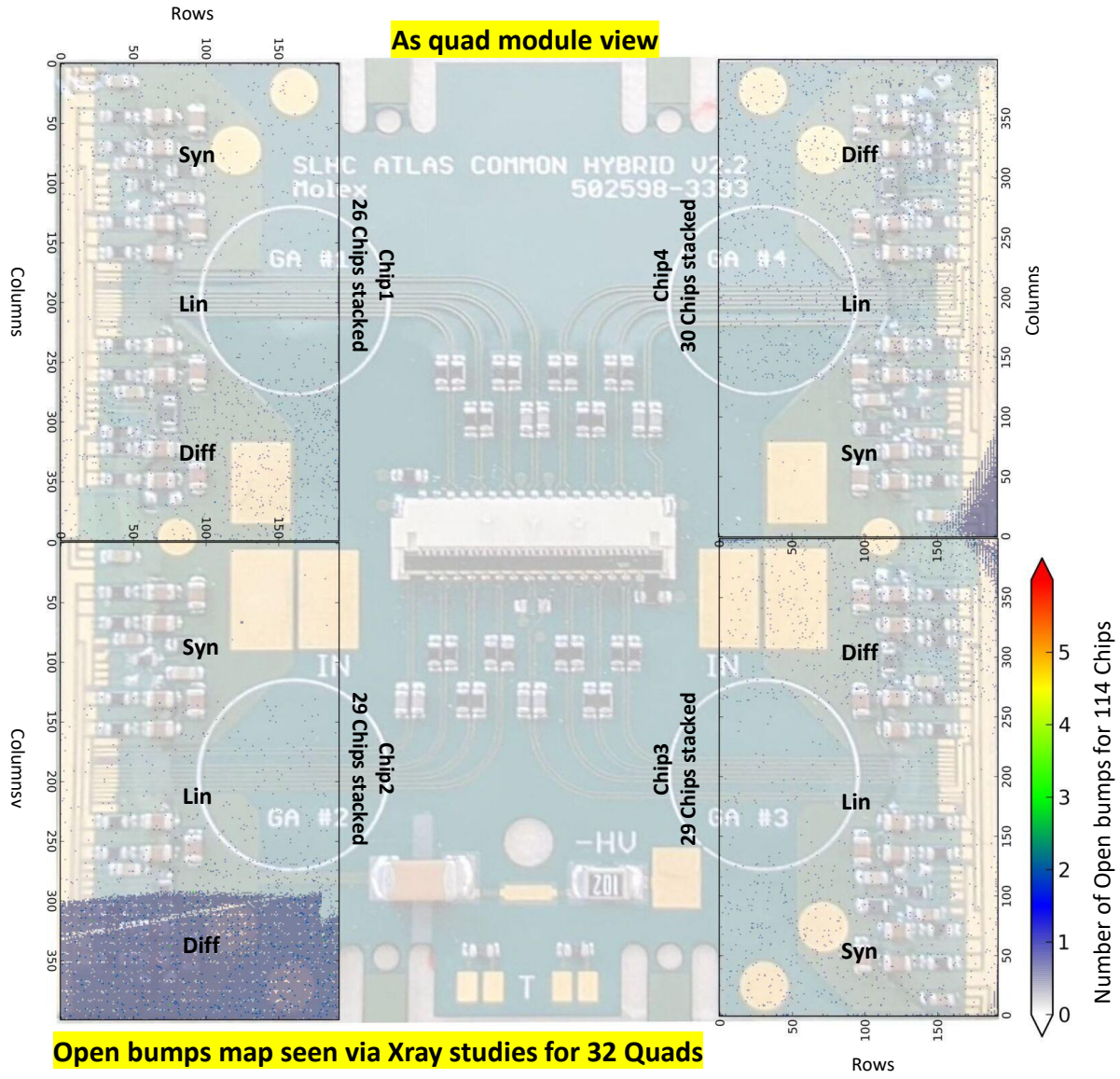
Failure ID	Scan Type	Criteria conditions
Digital Dead	Digital Scan	Occu= 0
Digital Bad	Digital Scan*	Occu < 98 or > 102
Analog Dead	Analog Scan*	Occu= 0
Analog Bad	Analog Scan	Occu < 98 or > 102
Merged Bump	CrossTalk & Analog Scan	Analog Scan: Occu < 98 or > 102, and not Analog Dead And CrossTalk Scan: Threshold Occu < 10% of total Injections**. And CrossTalk Scan: Threshold Occu ≠ 0
Tuning Failed	Threshold Scan	Threshold Occu = 0 (S-curve Failed)
Tuning Bad	Threshold Scan	| Pixel Threshold – Threshold mean | > 5σ
Noisy Pixel	Noise Scan	| Pixel Noise – Noise mean | > 3σ
Open Bump	Source or X-ray Scan	Occu = 0

Pixel defects order of exclusion for RD53A Quad Modules with Cut_Values

Quality control – Exploring Pixel defects trends

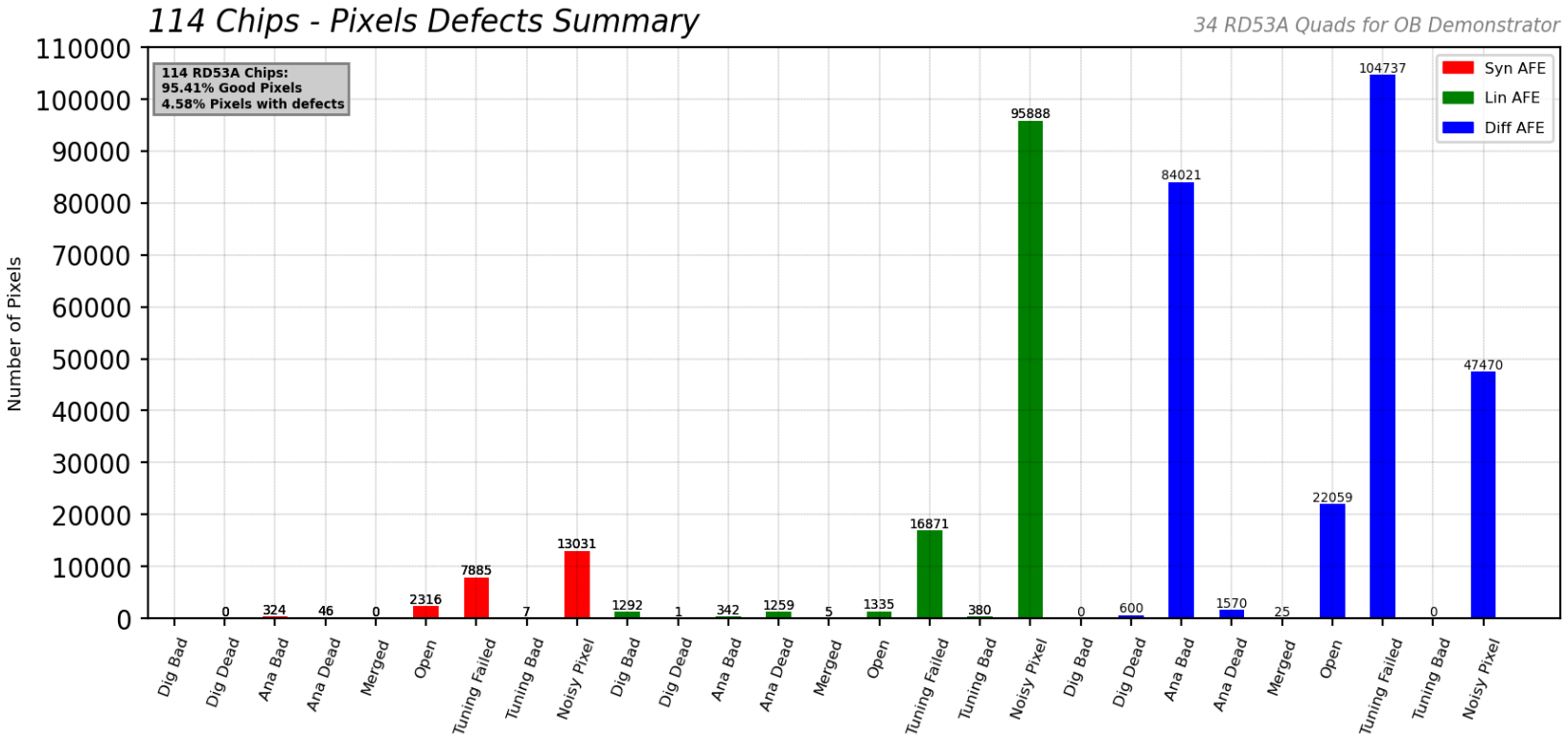
- **32 Modules** for the OB demonstrator were tested:
  - 14 chips not functional.
  - Total of 114 chips working well (8,7M Pixel channels).
- All the chips are stacked based on the position [cols, rows] in order to **see if a particular position have more defects events compared to the total pixel matrix** after applying the analysis method discussed before.

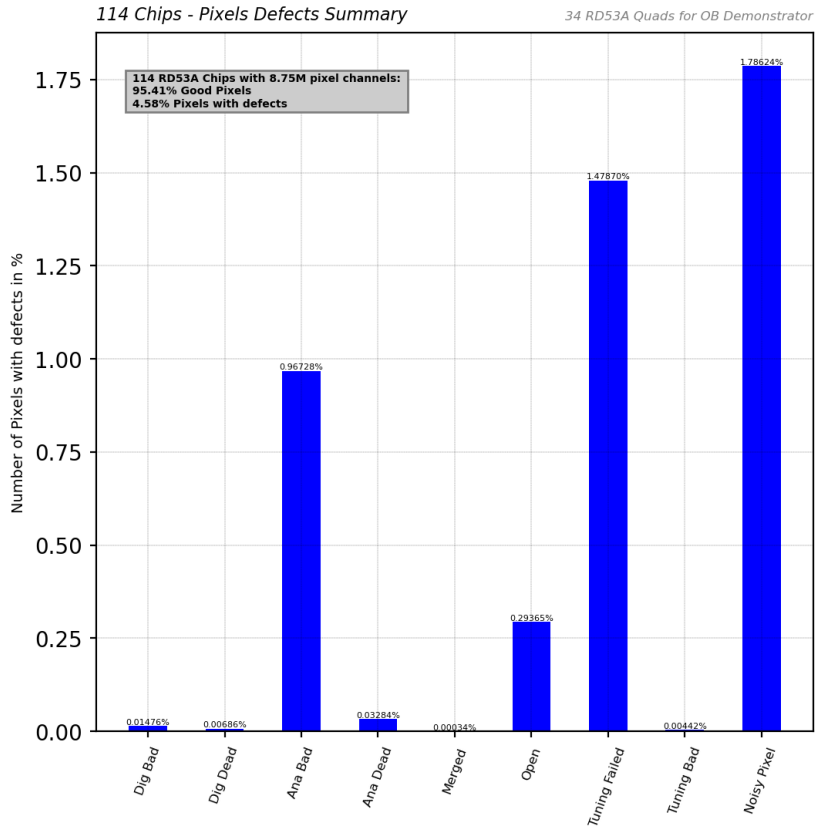




Quality control – Stacking 32 Quad Modules

- 114 chips with Pixel defects at 3 different AFE seen in the plot below.
- Syn AFE records the lowest number of defects for different categories.
- Only 30 merged bumps found for 114 chips (32 modules).
- Open bumps are less than 0.3%



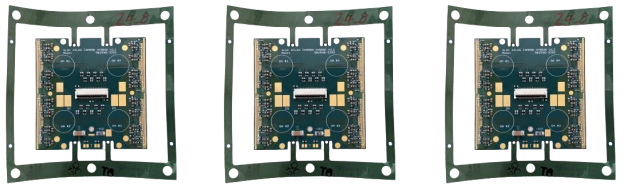


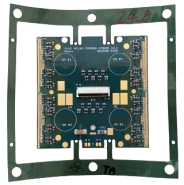
Conclusion

- Clear demonstration of the Pixel quad modules performance in different stages. **No potential degradation is found.**
- OB demonstrator system test with on-detector services (DAQ, interlock, DCS, cooling ..etc) to mimic the real detector **is done successfully.**
- Local loaded supports concepts has been **validated.**
- Some operational difficulties during testing, but in general all went very smoothly with steady progress. (Thanks to pilot tests and early commissionning of SR1 infrastrcuture) **However, a lot of work has been done within a very tight time bears fruit.**
- **QC ellaboration & assesment for the mass-production of OB Pixel modules is explored.**
- **32 modules have shown good performance. In more, some AFE types have more Pixel defects.**

THANK YOU :)

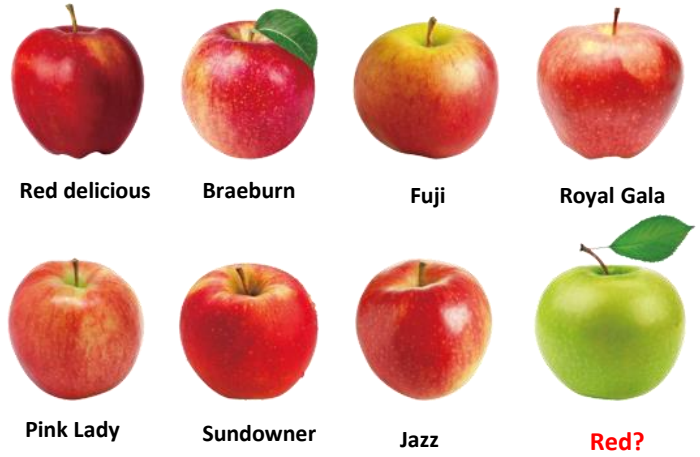
Future Quality control and ranking

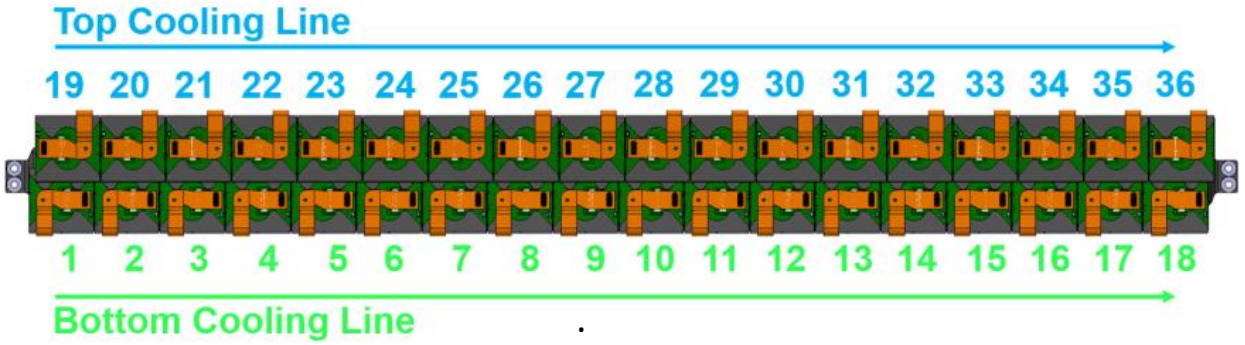




Individual module ranking based on performance:

1. IV Cuvre
2. Pixel performance
3. Temperature dissipation





N staves