



Università
di Genova

Qualification of the bump-bonding process in the ATLAS ITk pixel modules

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Towards the construction of the ATLAS ITk Pixel Detector

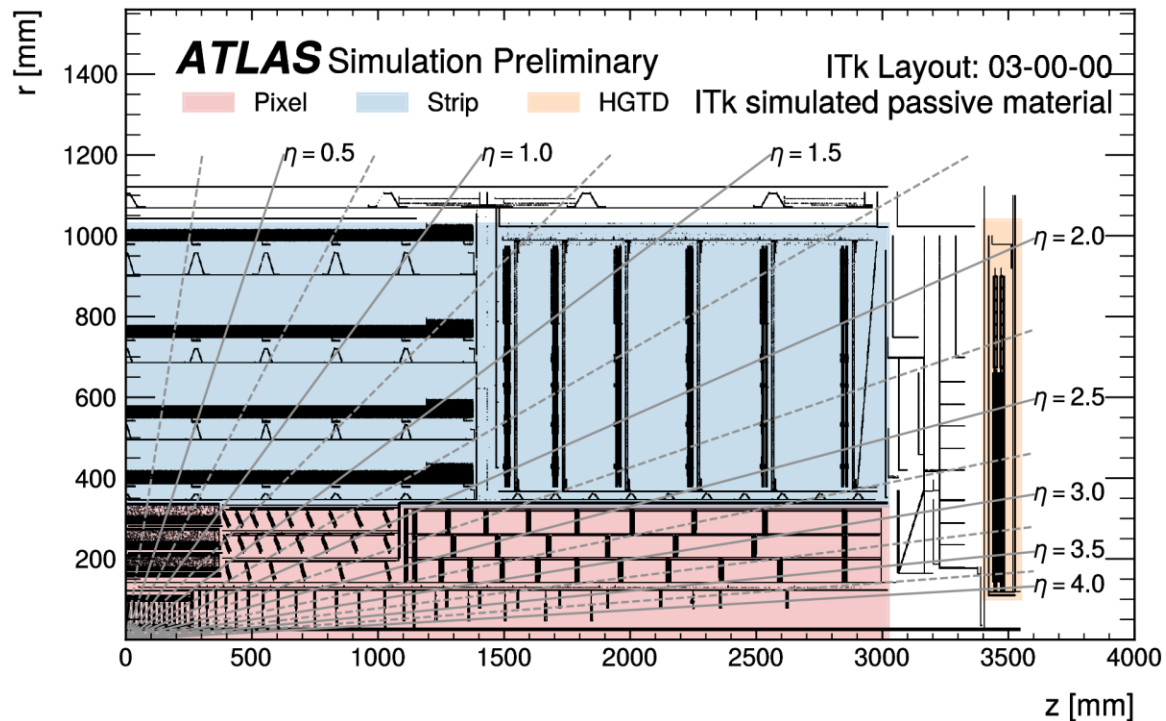


The **High-Luminosity program of the LHC**, starting in the early 2030s, will increase the instantaneous luminosity by a factor up to 7.

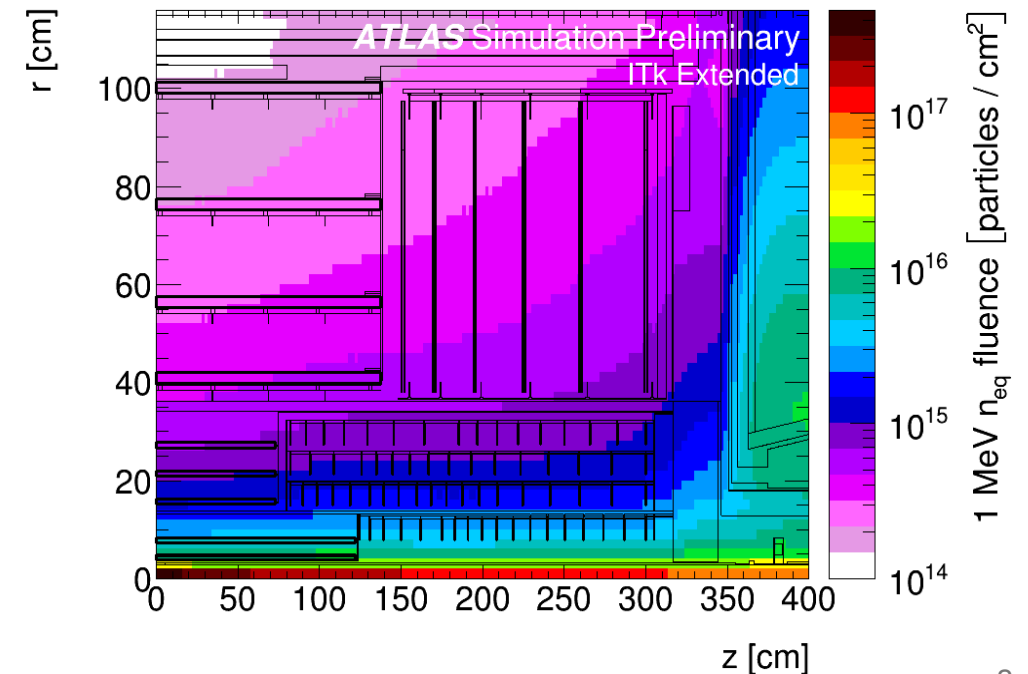
A massive upgrade of the ATLAS tracking system is then schedule to cope with the increase capabilities of the LHC.

A **new all-silicon tracker**, the Inner Tracker (**ITk**) will be installed at the heart of the ATLAS detector.

The **ITk Pixel Innermost layer (Layer 0)**, placed at 33.5 mm from the interaction point, will play a **crucial** role in **tracking and vertexing**



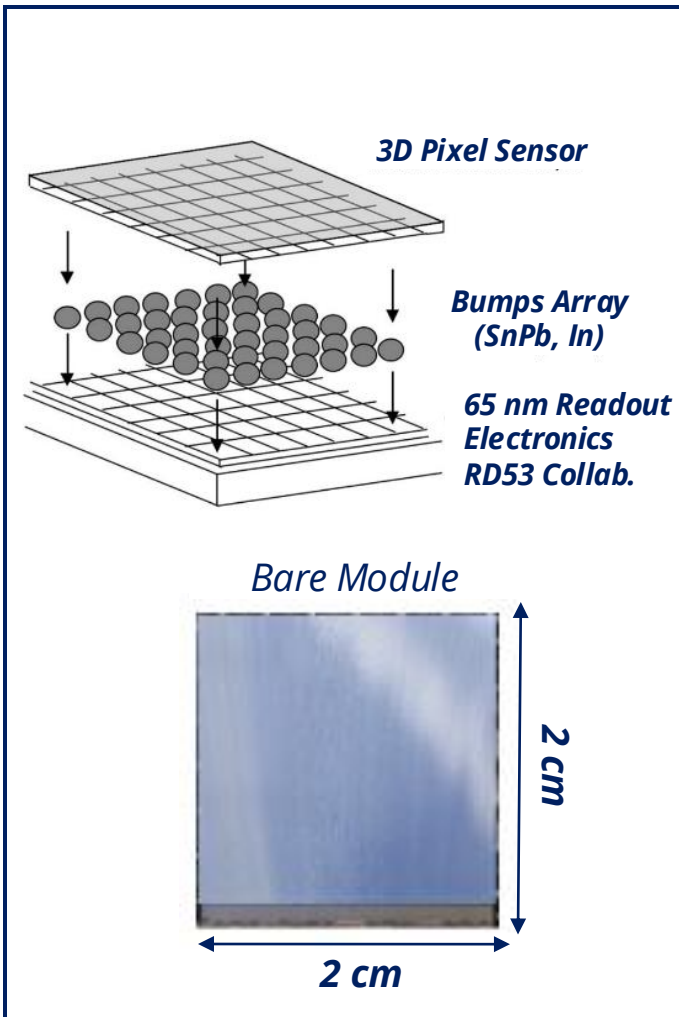
Fluence in ITk volume after LHC deliver 3000 fb⁻¹



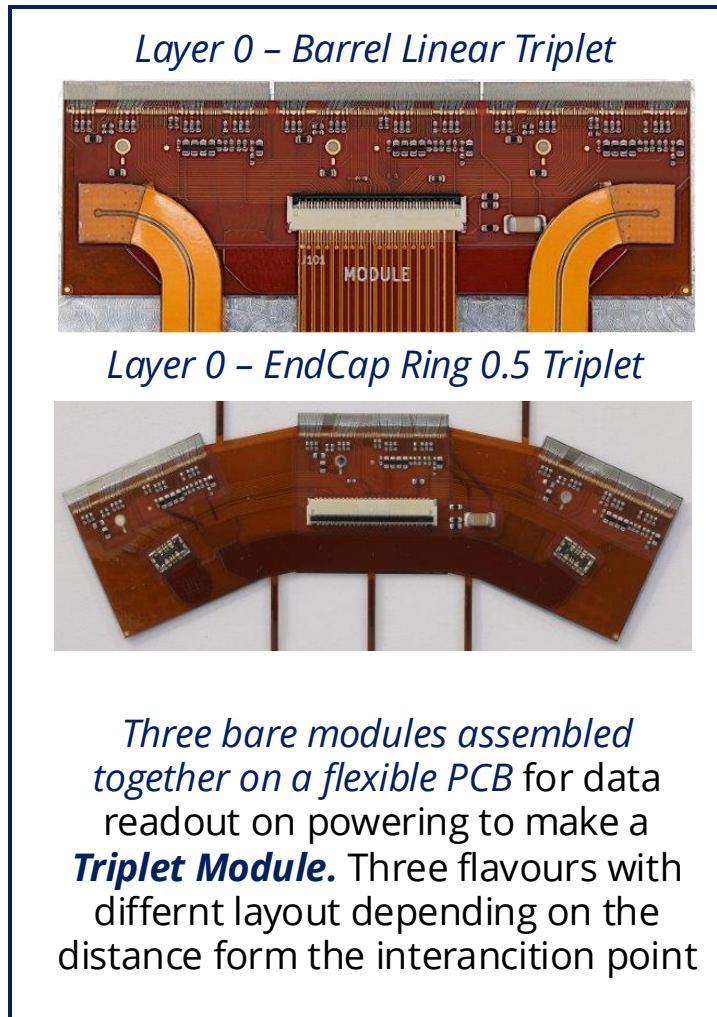
Hybrid pixels modules for the ITK Pixel Innermost layer



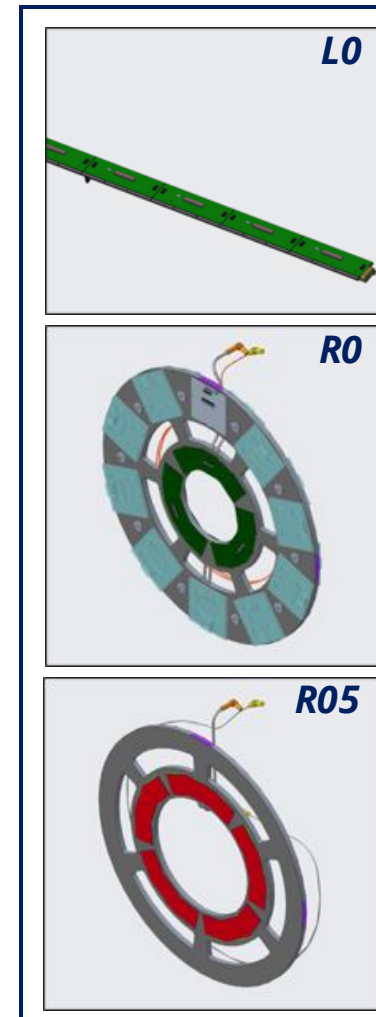
Hybridization



Module Assembly & Test



Integration



Commitments

3D Pixel Sensors

- **Fondazione Bruno Kessler (FBK - Italy)**
- **Stiftelsen for industriell og teknisk forskning (SINTEF - Norway)**

Hybridization

- **Leonardo (Italy)**
- **Das Fraunhofer-Institut für Zuverlässigkeit und Mikrointegration (IZM - Germany)**

Module Assembly & Test

- **Barcelona (L0), Norway (R0)**
- **INFN BO, GE, MI, TN (R05)**

Integration

- **SLAC National Accelerator (USA)**

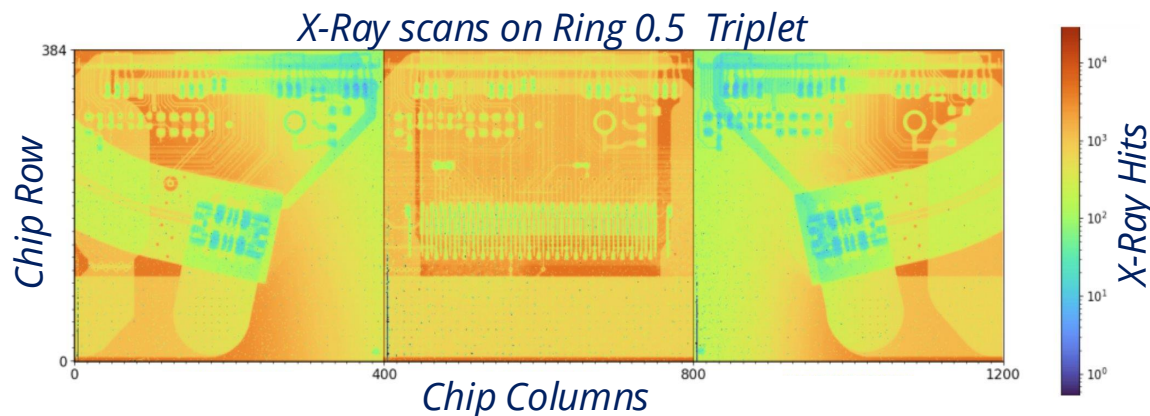


Hybridization QC/QA on ITk Pixel Triplet Modules

Quality Control

Tests to be performed on each module before detector installation

- **Thermal cycles** to test the bumps connectivity
- Two main strategies to check the bumps connection
 - **X-Ray scan**: disconnected pixel will record zero hits
 - **Disconnected bumps scan**: based on the assumption that *disconnected pixels are not subject to crosstalk*. Uses chip injection circuit to simulate hit and measure crosstalk in pixels adjacent to injected pixel



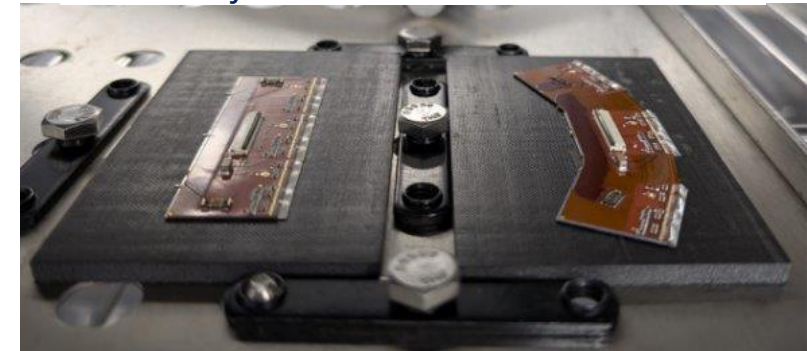
Quality Assurance

Tests to be performed on a sub-sample of the modules

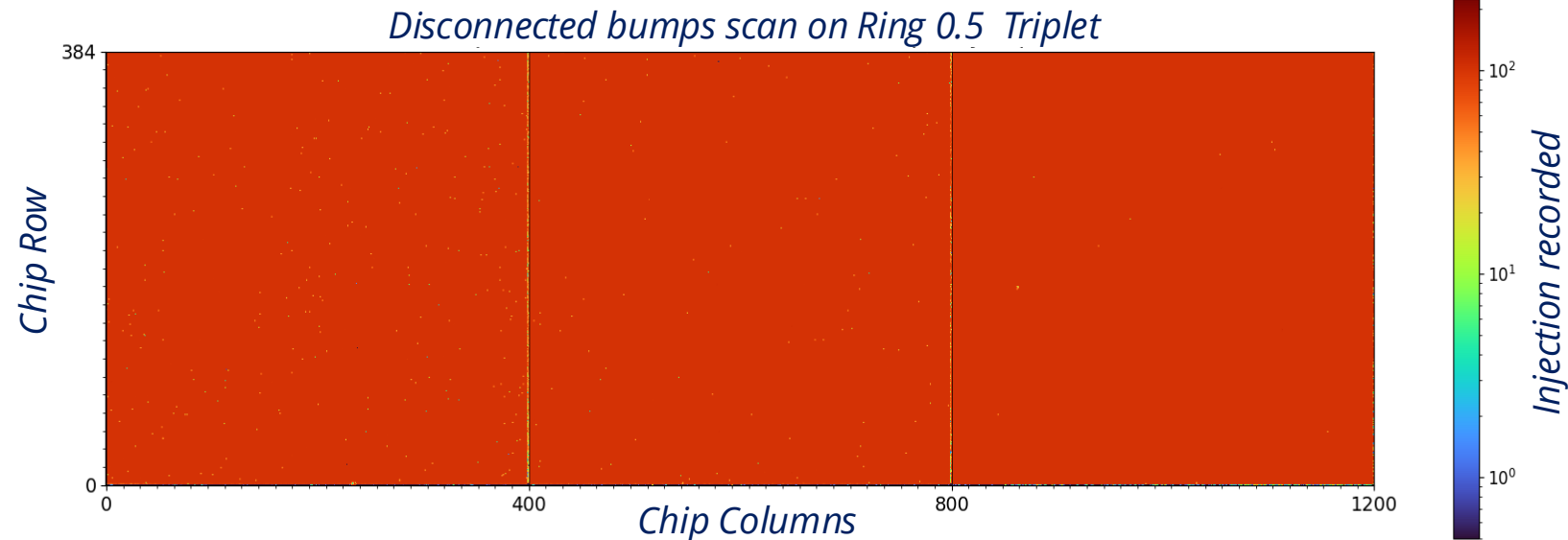
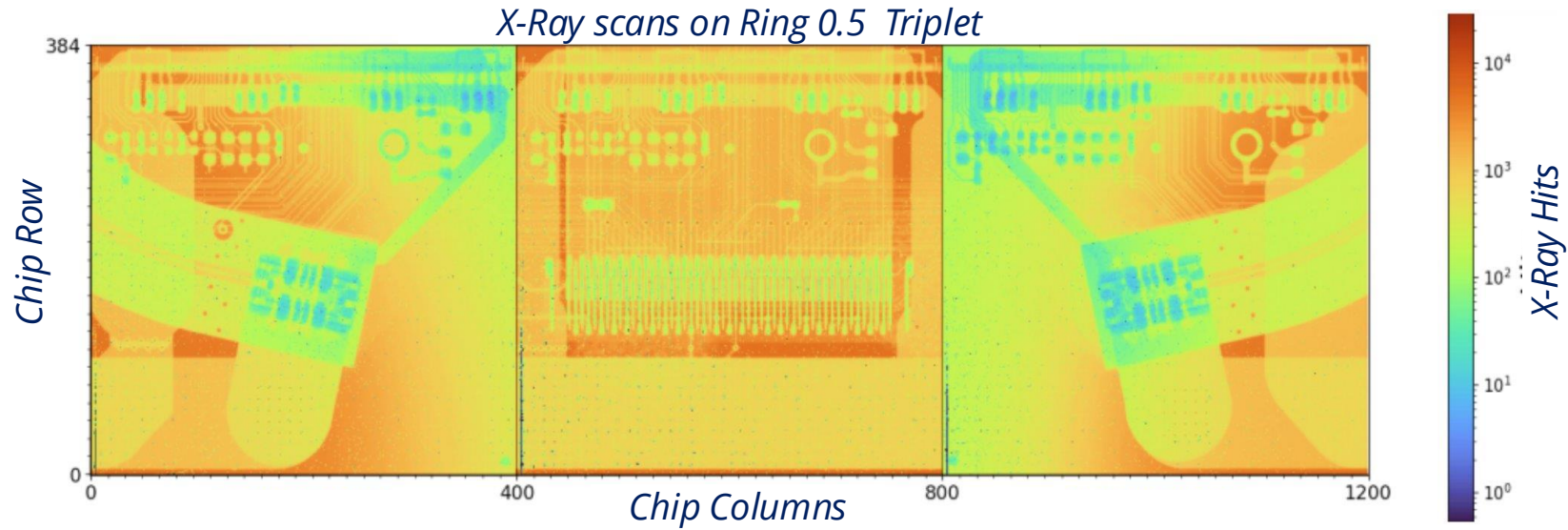
- Aimed to test the tightness of the components
- May be destructive for the parts
- Parts subjected to QA will not be installed in the ITk

Delamination test is an example of QA

FBK-IZM Triplets loaded on carbon fiber for delamination tests



FBK – IZM Ring Modules - Hybridization status



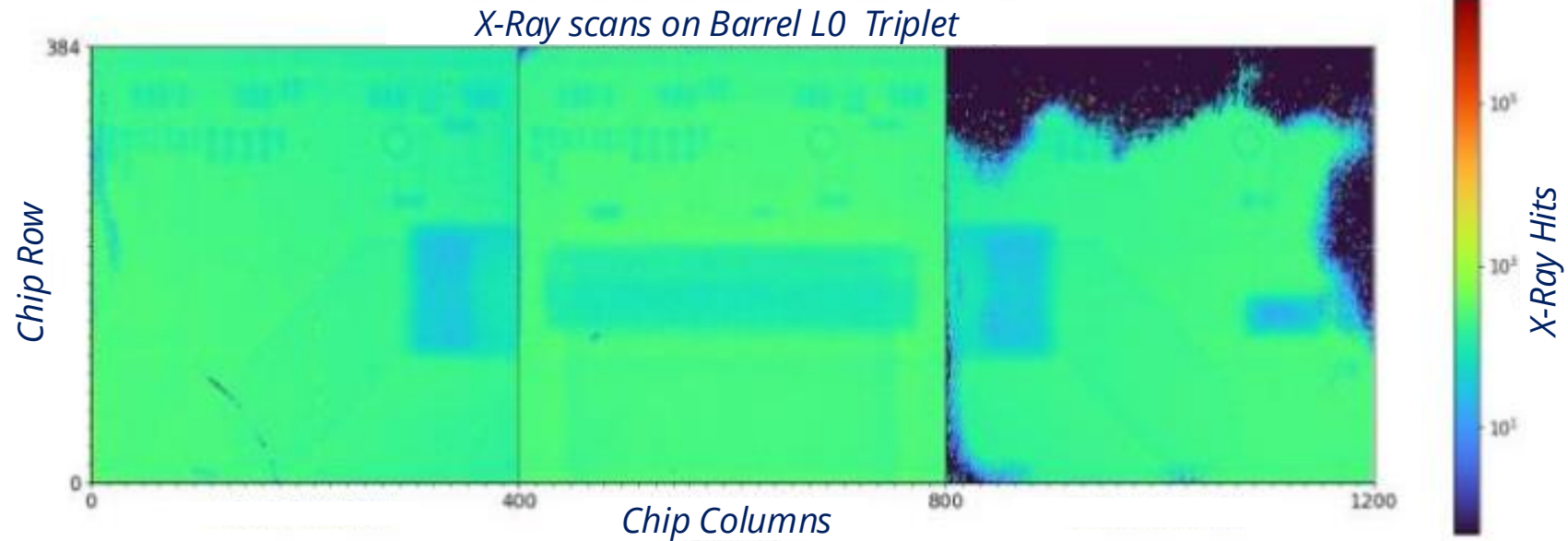
FBK – IZM modules shows **high quality bump bonding connections.**

This combination is qualified and production parts will come very soon, in the next months where we will start building modules that will instrument the ITk

FBK – LEONARDO Barrel Modules - Hybridization status



R&D
Started in
Summer
2023

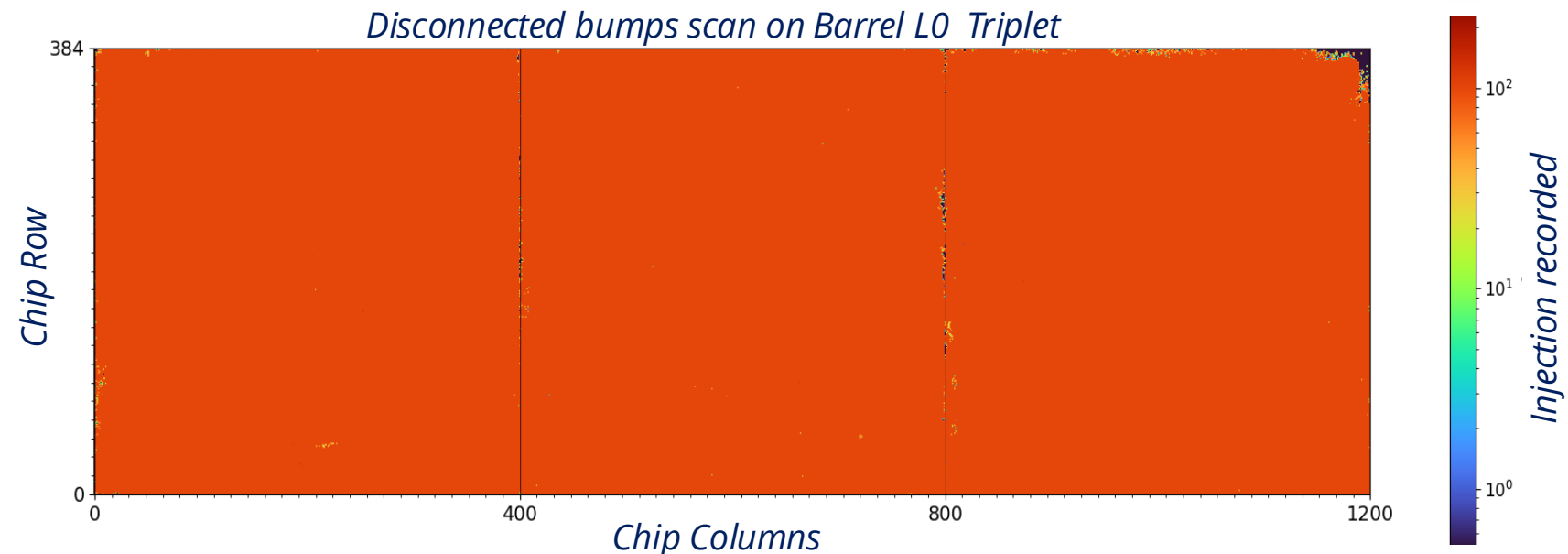


Leonardo is still not qualified for the ITk pixel modules production

Still some **corners / edges disconnected**

Last pre-prod batch to come in the next month

Pre-prod
January
2025

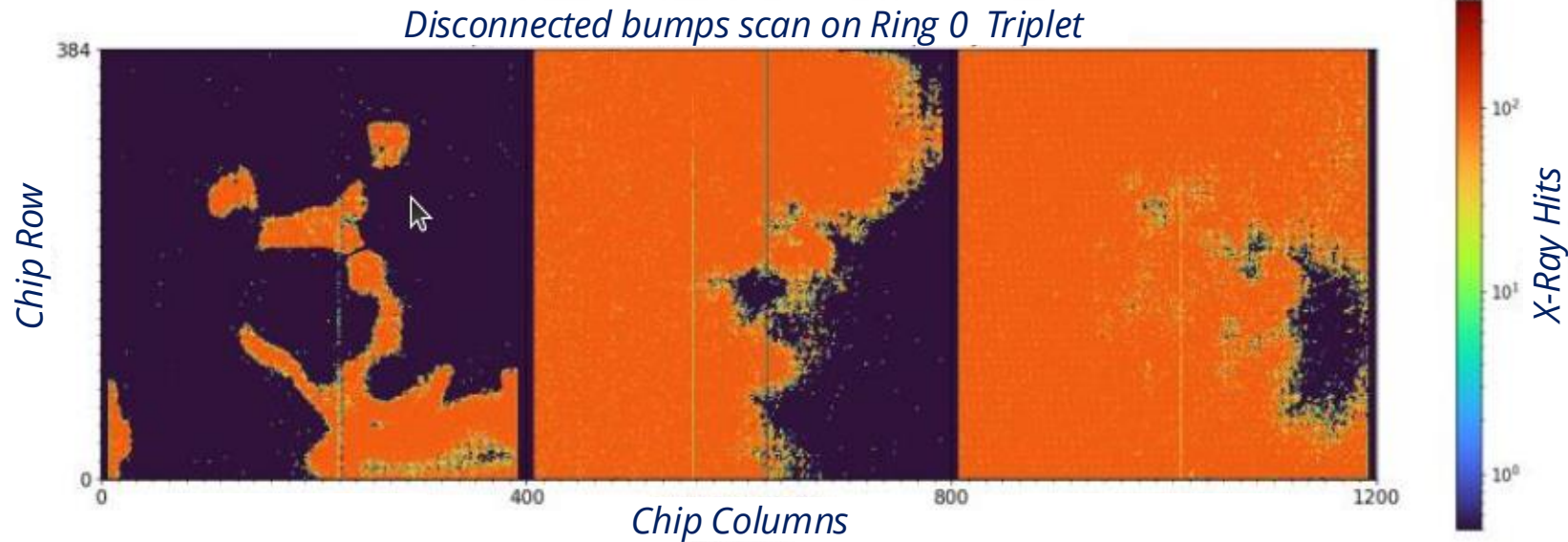


If the quality is still low **we may consider other vendors (ADVAFAB)** already qualified for ITk outer layers modules

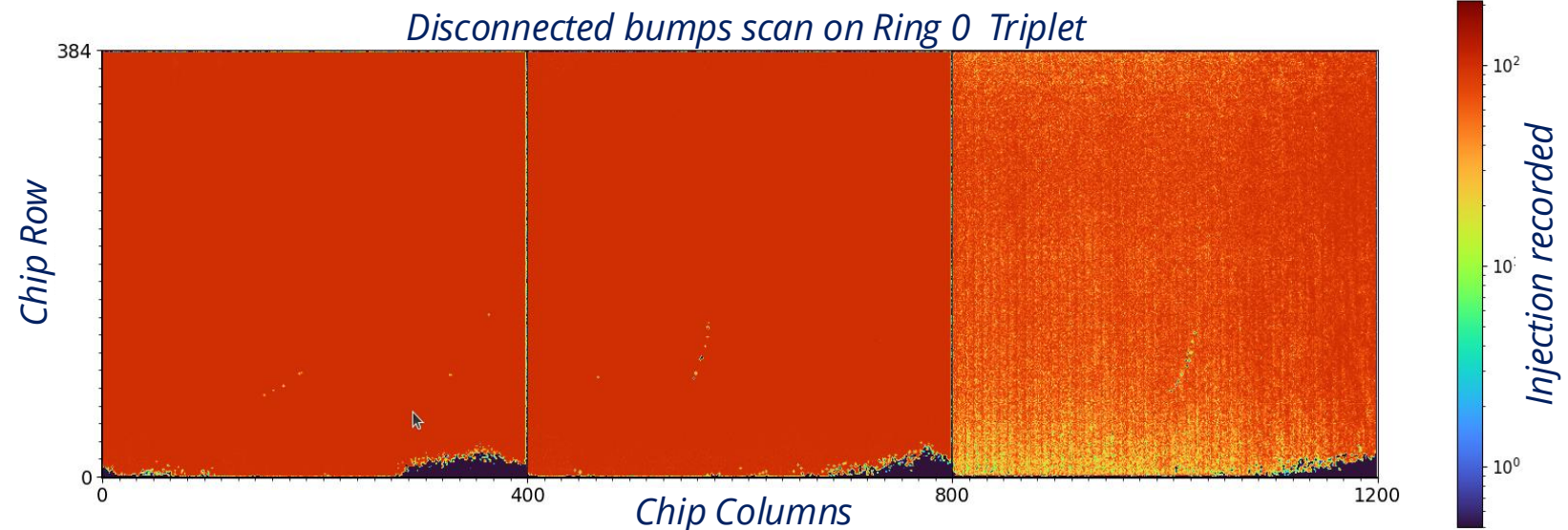
SINTEF – IZM Ring Modules - Hybridization status



**Old
passivation
2023**



**New
passivation
2024**



The SINTEF – IZM hybridization was initially very hard due to a **significant bow of the sensor**

In 2024 SINTEF re-processed several wafers with a **new passivation, that reduced the bow, improving the bump bonding quality**

The modules still have some disconnected corners, that may not be critical for the tracking performance due to the overlap of the modules in the rings.

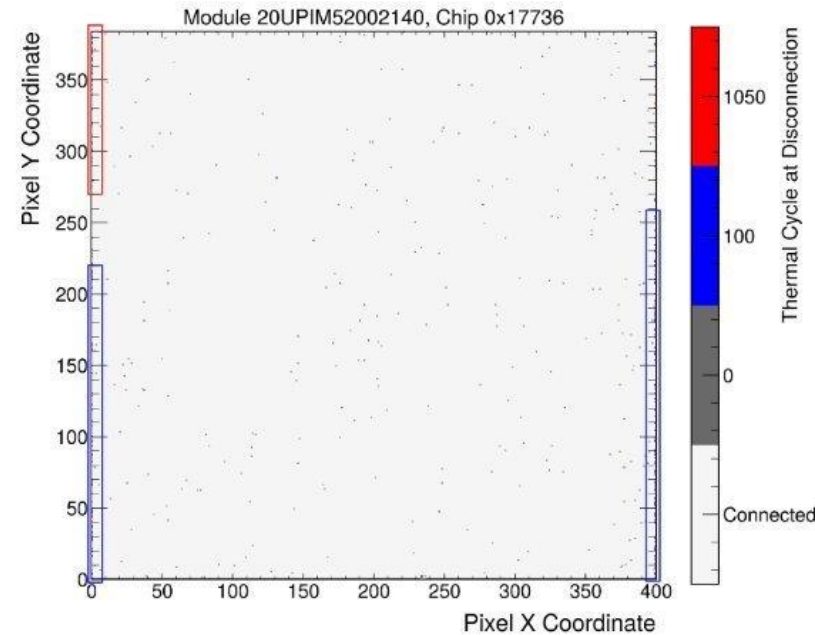
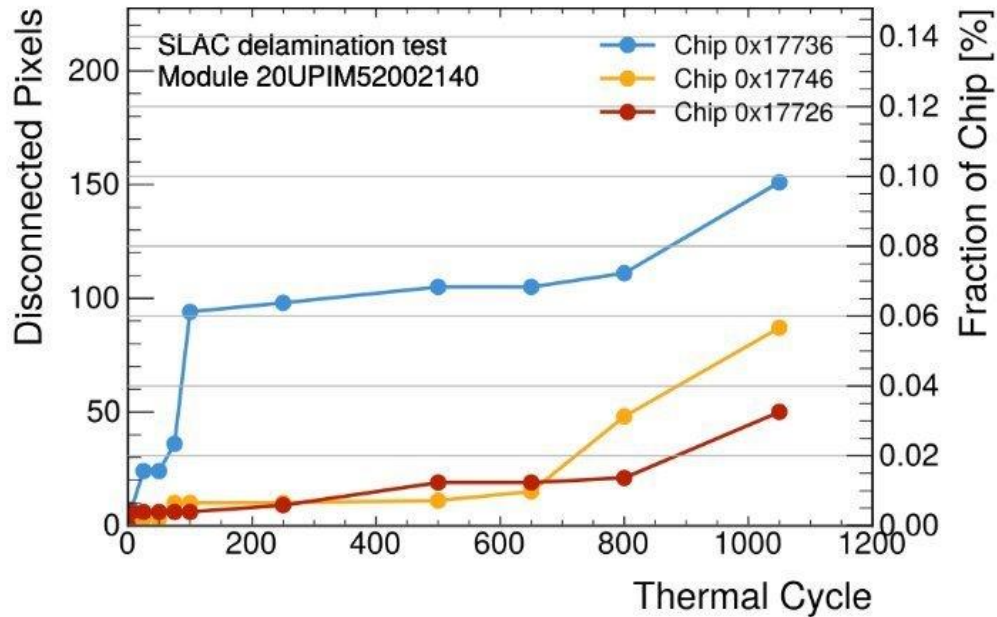
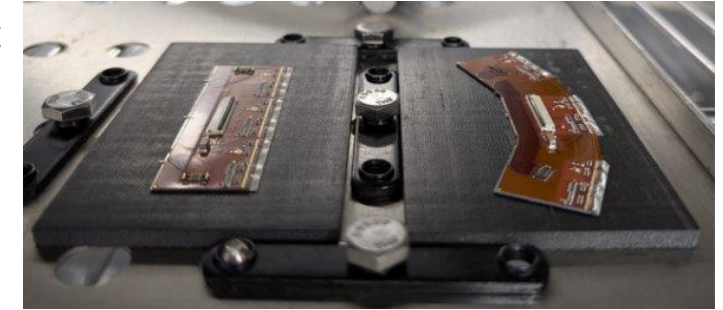
Bumps delamination studies – FBK + IZM Triplets

Bumps are the most delicate interface within a pixel module: the different **thermal expansion coefficients (CTE)** between the module components and the carbon local support cause considerable stress on the bumps, which **could lead to their disconnection**.

Special samples with Triplets loaded on carbon fiber realized at SLAC

Each sample has undergone about *1000 thermal cycles* (-55° C / +60° C), and possible bumps delamination has been checked every 100 cycles with the crosstalk technique

FBK-IZM Triplets loaded on carbon fiber for delamination tests



Outcome: The *number of disconnected pixels is stable within 0.1% after the delamination test.*

FBK-IZM modules are ready for the ITk. The same tests will be performed on Leonardo & SINTEF-IZM Triplets in the next months



Thank you!

Quick summary of the activities



Triplets mini-workshop in Genova – 7th / 9th May 2024

- Tuesday - Clean room visit and L0/R05 electrical tests
- Wednesday – Assembly & metrology discussions
- Thursday – Electrical tests and Q/A session with Emily/Elisabetta/Timon

Bergen

Thomas, Sohaib, Simon, Simen

Oslo

Aleksei, Havard

Barcelona – IFAE

Niraj, Krishnan

Milano

Riccardo

Genova

Claudia, Alessandro, Simone



INFN Genova

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Bumps delamination studies – SINTEF 50x50 + IZM



SINTEF bumps seems to be mechanically connected but shows electrical misbehaviour. However they can sustain delamination studies: the increase in the number of disconnected pixels is limited in the originally disconnected area (corner)

Cross section of SINTEF – IZM bumps, some contamination between the bumps

