TIPP2023

TECHNOLOGY IN INSTRUMENTATION & PARTICLE PHYSICS CONFERENCE

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science & innovation
Department:
Science and Innovation
REPUBLIC OF SOUTH AFRICA

NRF National Research Foundation | iThemba LABS Laboratory for Accelerator Based Sciences

IUPAP International Union of Pure and Applied Physics

Loading of ATLAS ITk pixel module on multi flavour local supports

Gabriele Chiodini - INFN LECCE

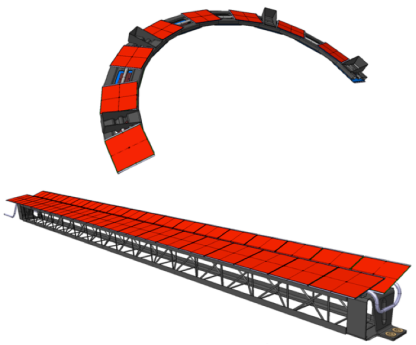
On behalf of ATLAS ITk Collaboration

Overview

- ATLAS ITk Pixel detector layout
- Loaded Local Support specifications
- Local Support module loading techniques
  - Pixel Outer Barrel
  - Pixel Inner Barrel and Inner EndCap
  - Pixel Outer Endcap
- Conclusions

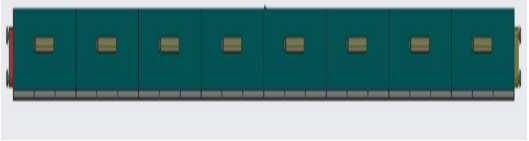
ATLAS ITk Pixel detector

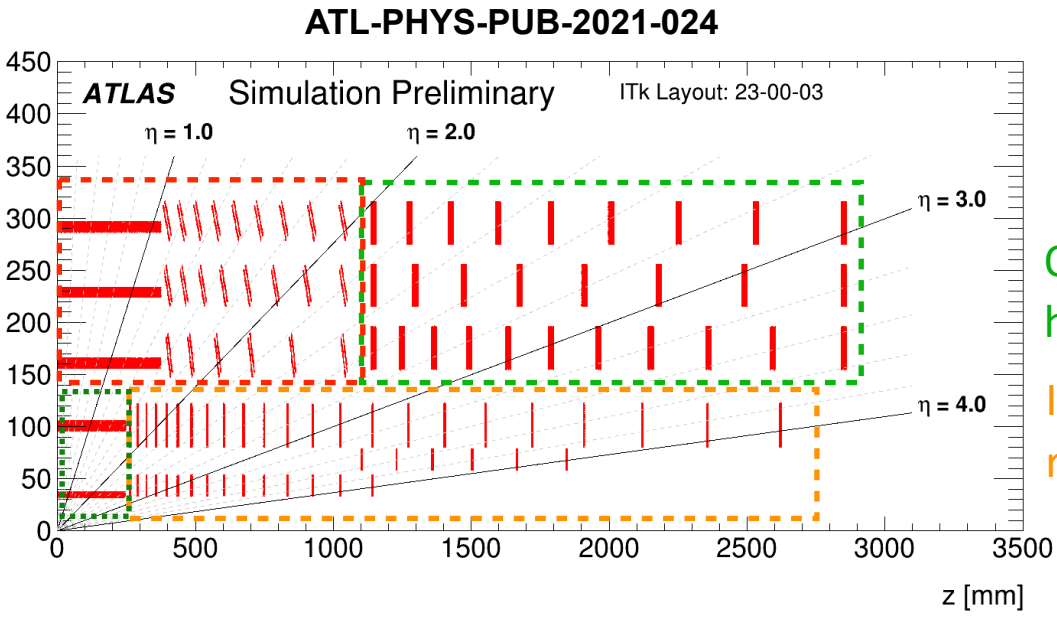
High precision and tracking efficiency in presence of thousands of pile-up tracks keeping the material budget at acceptable level → many sub detector configurations.

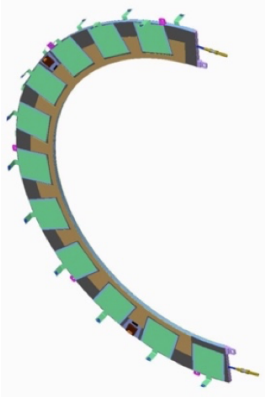


Outer barrel:
longerons + inclined rings

Inner barrel: flat staves

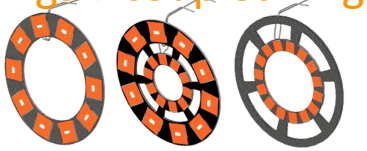






Outer endcap:
half rings

Inner endcap:
rings + coupled rings



Loading Local Supports with pixel modules

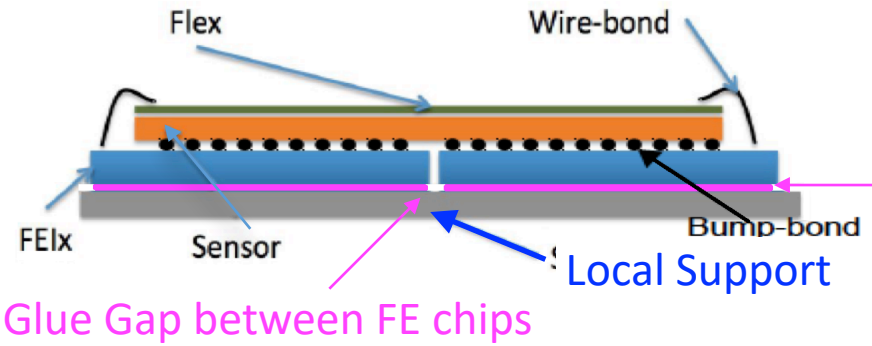
"System tests of the ATLAS ITk planar and 3D pixel modules" D. Vazquez

A Loaded Local Support is a fully functional detector unit

1. Local Support
2. Cooling pipes
3. Flex circuits for biasing
4. Flex circuits for control and data
5. Detector modules
6. Handling frame

Loading

This talk

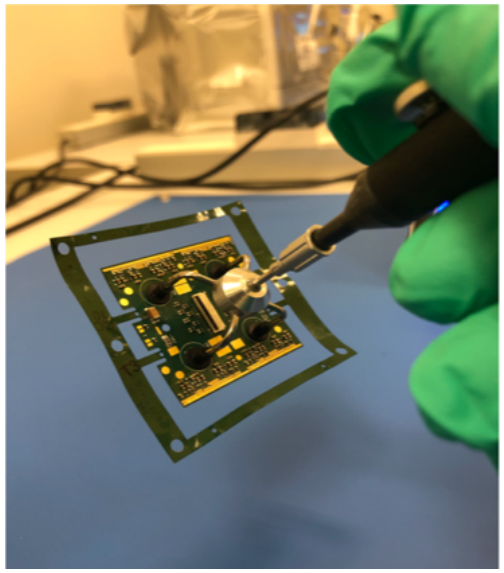


Loading a Local Support with detector modules is a crucial step

1. Detector module integrity
2. Mechanical requirements
3. Thermal requirements
4. Ground&Shield requirements

Detector Module integrity

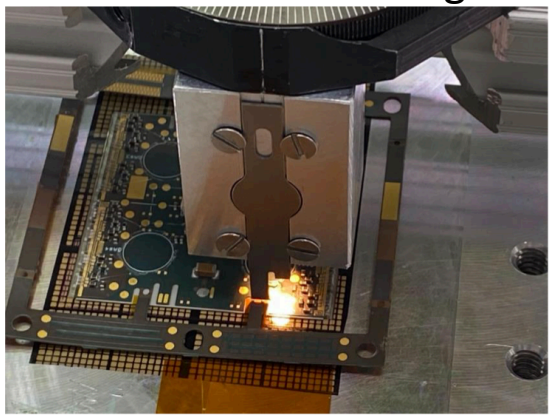
Module handling



Quad Modules are picked up by vacuum tools having 4 suction cups.
Pick-up force in the range of 250-500 g (<< bumps strength) .

Wire-bonding must be protected from dust and bad handling
(for example during Power and Data connection insertion)

Module flex tab cuttings

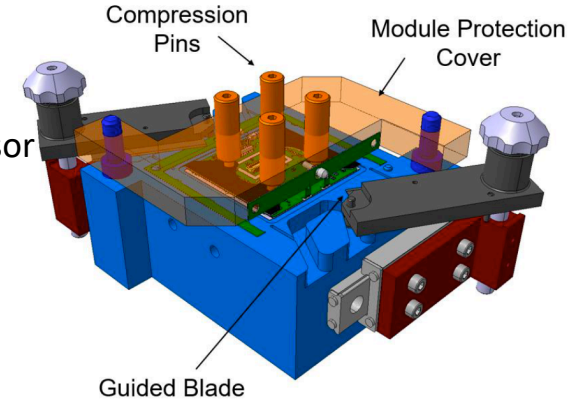


Module removed from carrier and paced on vacuum plate

Kapton strip inserted between flex and sensor to protect sensor

Binocular microscope used to ensure a proper alignment

Tabs cutted with hand-actuated razor blade (3 kg force)



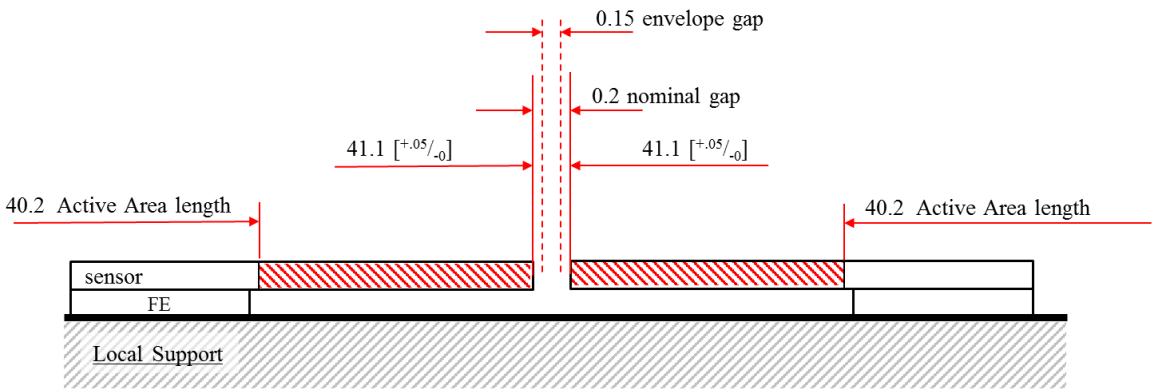
Loaded Local Support specifications

Region	Accuracy (mm)			Error distribution Standart deviation		
	X	Y	Z	X	Y	Z
Flat section of the Outer Barrel (0.3 mm gap)	±0.125	±0.125	(-0.05,+0.1)	0.041	0.041	0.05
Flat section ot the Inner Barrel (0.2mm gap)	±0.075	±0.075	(-0.05,+0.1)	0.025	0.025	0.05
Inclined region, Disks and Rings	±0.15	±0.15	(-0.05,+0.1)	0.05	0.05	0.05

AT2-IP-ES-006

OSS.: ±150 um is standard assembly accuracy

1



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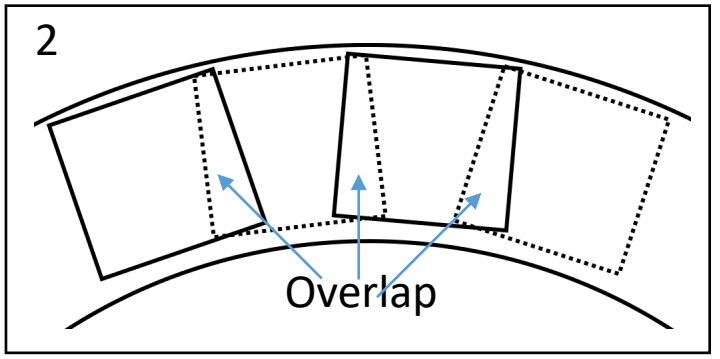
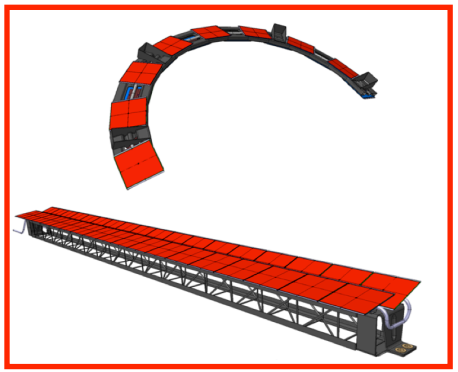
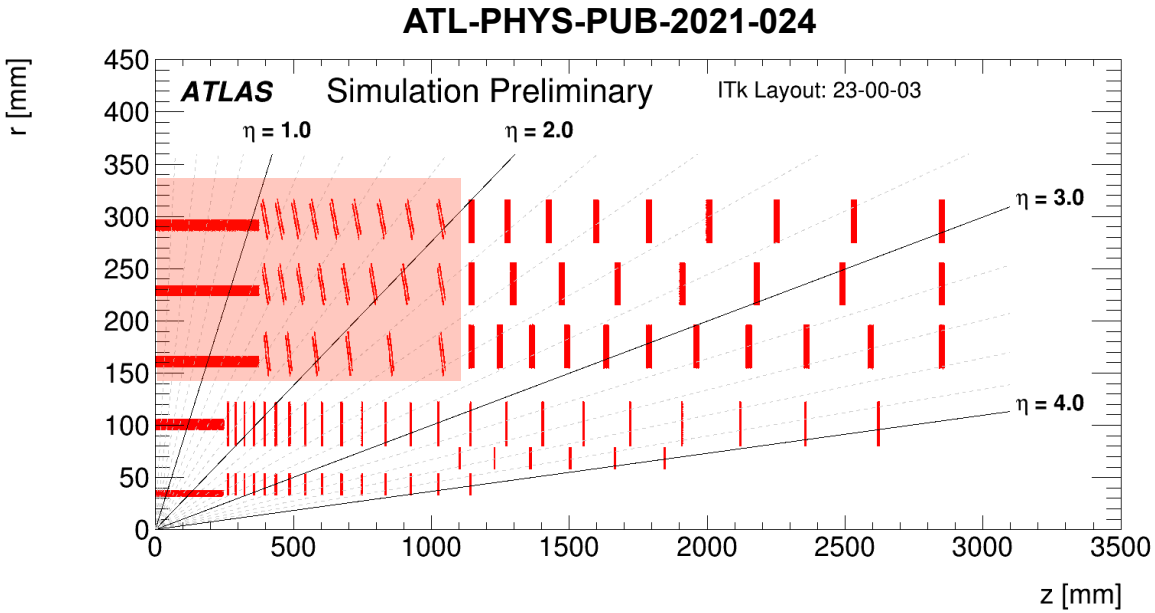


1. Module gap in flat section driven by hermeticity.
2. Rings not constrained by mechanical clash but by modules overlap (> 4 pixels for track alignment) and service connections.
3. Glue thickness is 100 um but a 50-200 um range is acceptable. Driven by thermal performance and G&S.

ATLAS ITk Pixel Outer Barrel



Outer barrel:
longerons + inclined rings

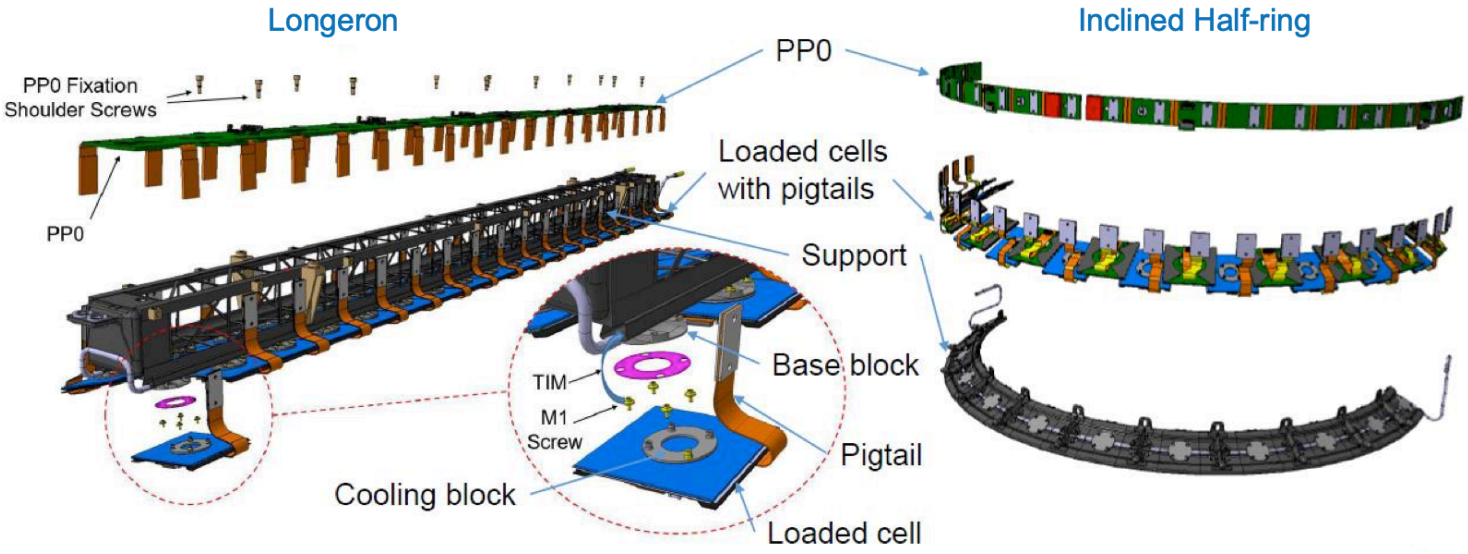


ITK Pixel Barrel: Longerons and Inclined Rings

Longerons and **Inclined Half Rings** are populated by many **Quad Module Loaded Cells** and 2 PP0 interconnections (power and data).

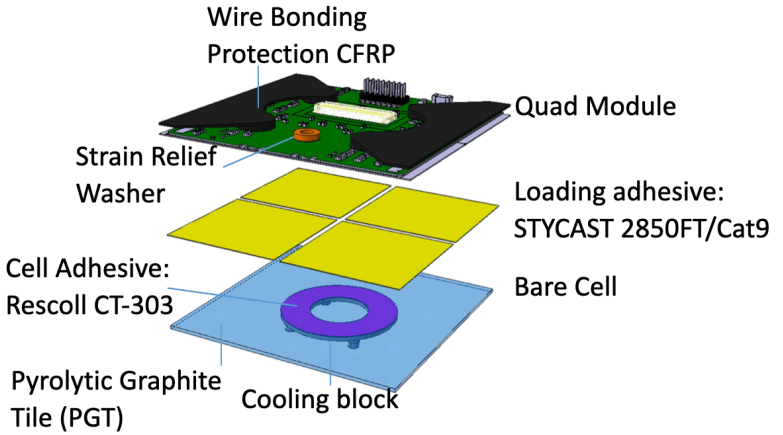
Loaded Cells are integrated at **Base Blocks** with precision pin-holes, M1 screws, TIM (Thermal Interface Material).

Due to the complexity of the geometry the integration is made manually by two operators.



Building block:

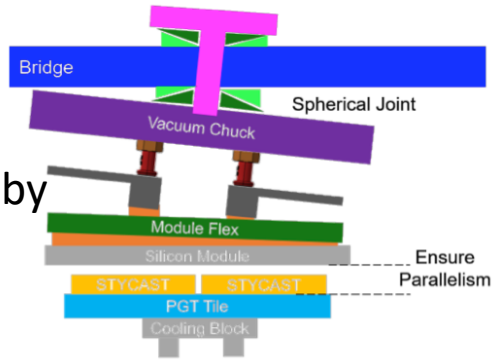
Quad Module Loaded Cell



ITK Pixel Barrel: Loading Cell Methods

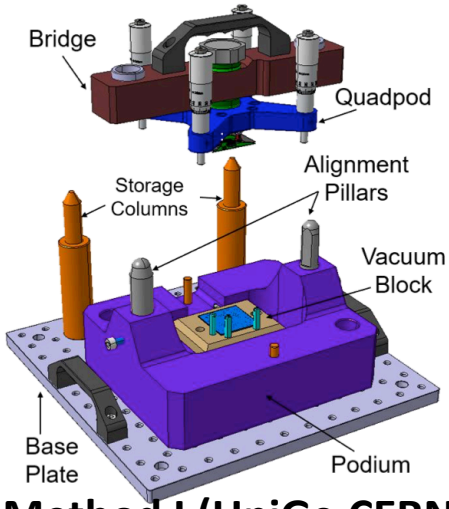
Manual Quadpod/Bridge to pick and place modules.

Module parallelism adjusted by **lockable spherical joint**.

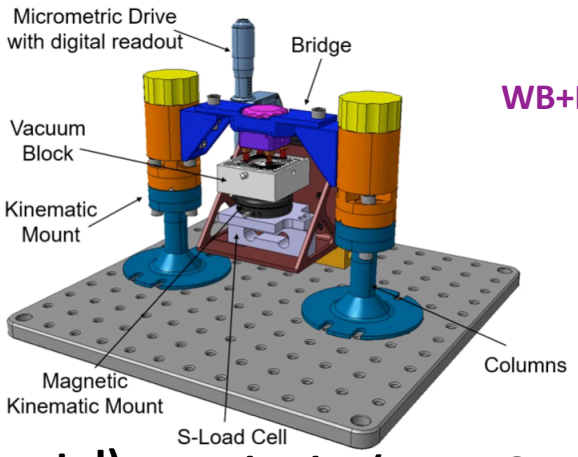


Precise Vacuum block to align Module few times forth and back: alone, above Cell, above Cell+Glue.

Glue thickness from um-metric stoppers or gauge (5 N).



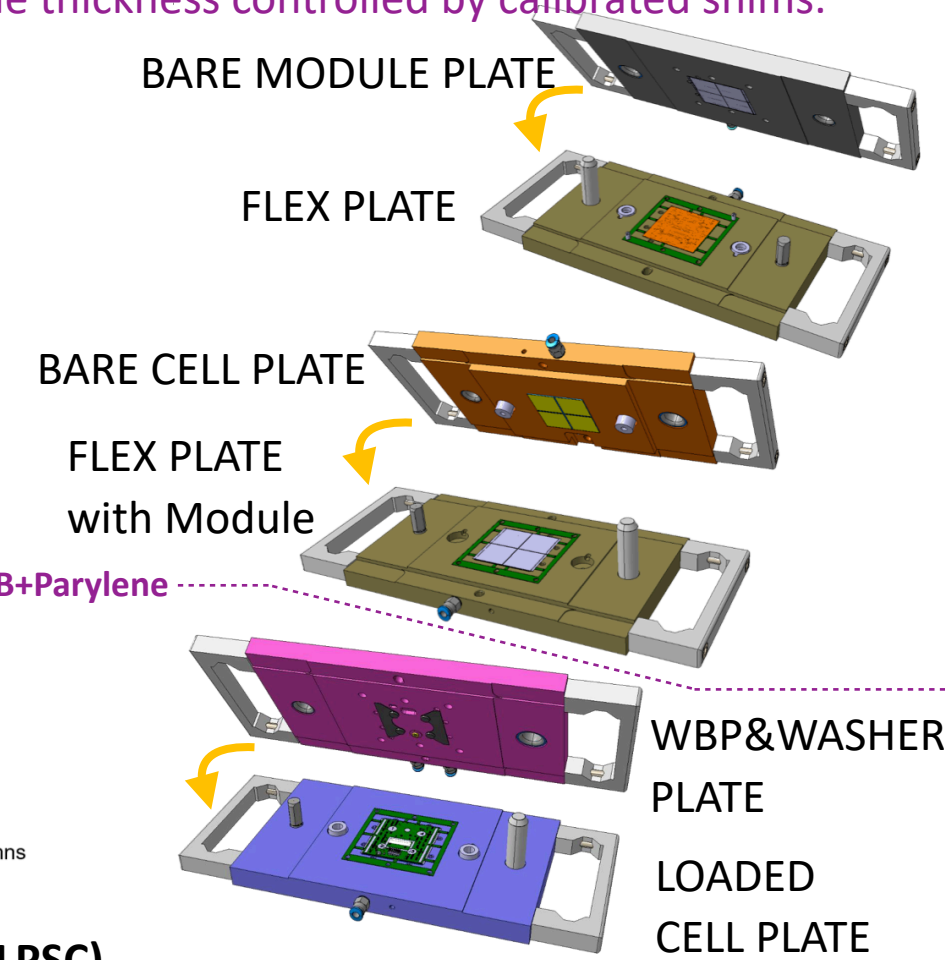
Method I (UniGe,CERN, Wuppertal)



Method II (CPPM&LPSC)

Method III(Japan) **Combine module assembly and cell loading** using a Assembly Plate for each step.

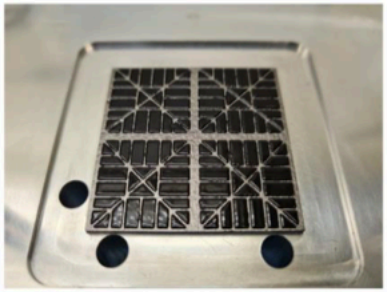
Glue thickness controlled by calibrated shims.

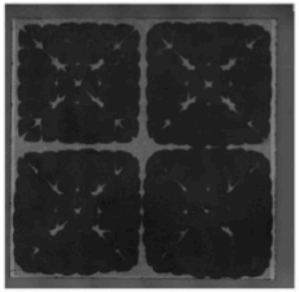


ITK Pixel Barrel: Loading adhesive patterns

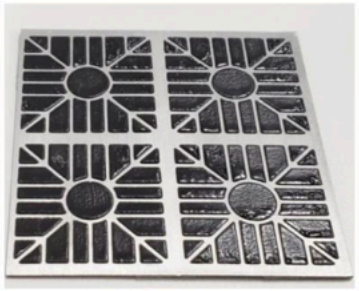
Stencil (method I and III)

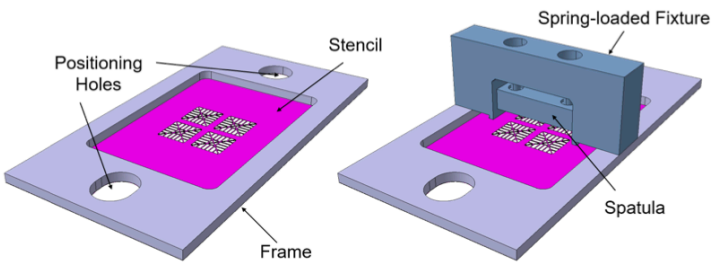
UniGe Test Pattern





Japan Test Pattern

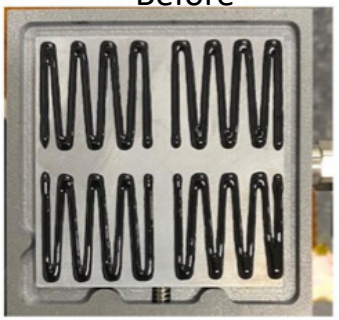




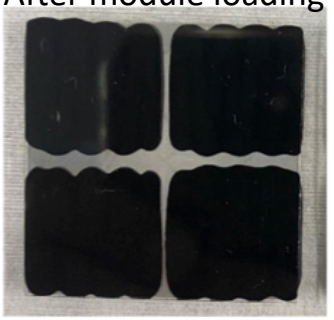
Spring-loaded Spatula

Automatic Dispenser (work with method II)

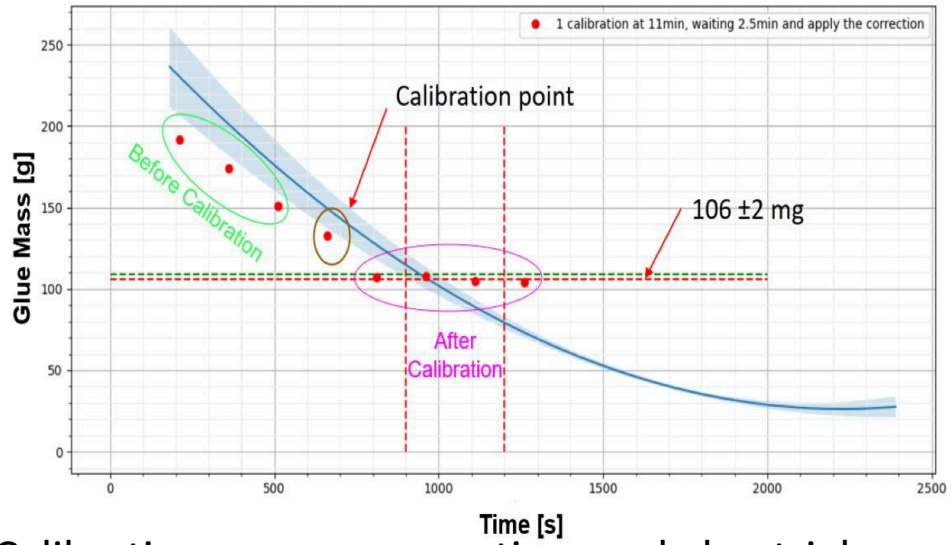
Before



After module loading

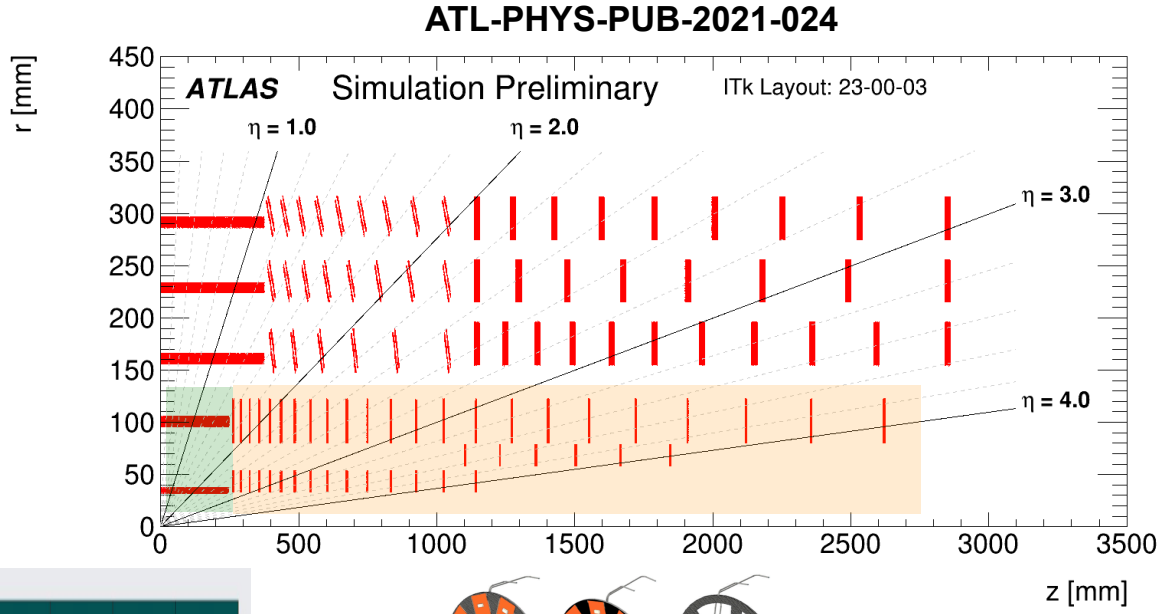


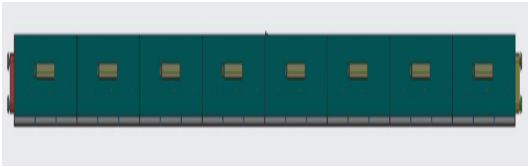
Zig-zag pattern



Calibration curve mass vs time and glue trials needed.

ITK Pixel Inner





Inner barrel: flat staves

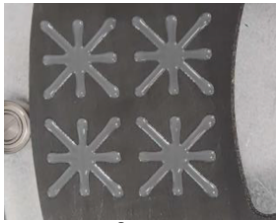
Inner endcap:
rings + coupled rings

ITK Pixel Inner: flat stave and rings

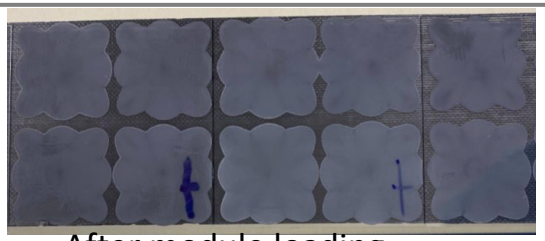
(SLAC&LBL)

Glue deposited with automatic dispenser on 3 axis robot:

1. **Star pattern** to have large coverage and avoid trapped air
2. Bond line controlled by **106 um spheres** (0.25% mass)

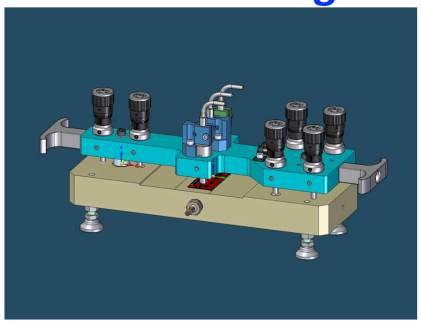


Before

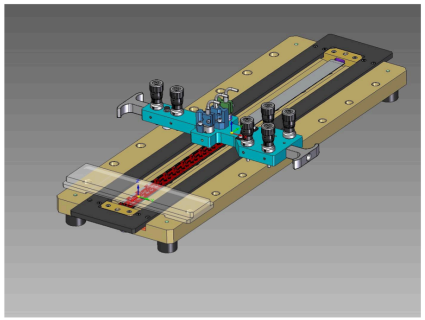


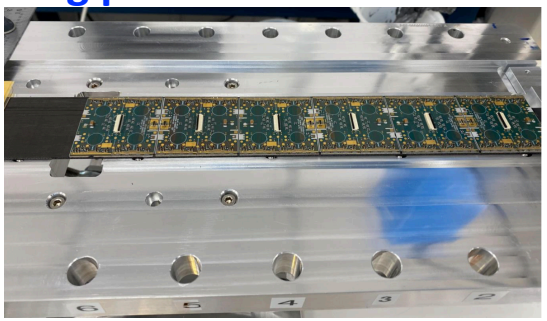
After module loading

Manual Bridge



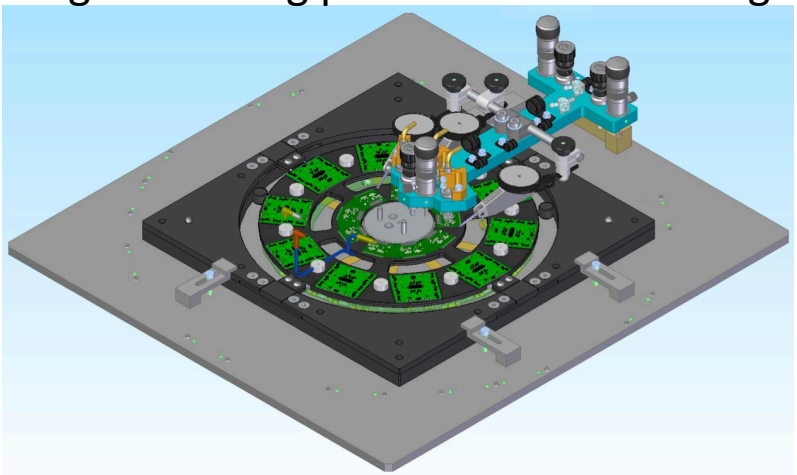
Stave **Mounting plate**

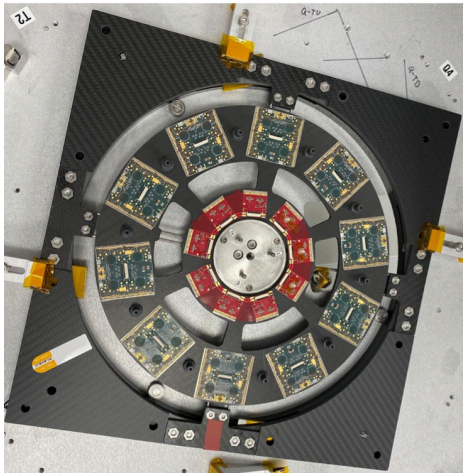




-Center long axis with pin-in-slot
-Longitudinal position indexed with pins
-Support planarity checks

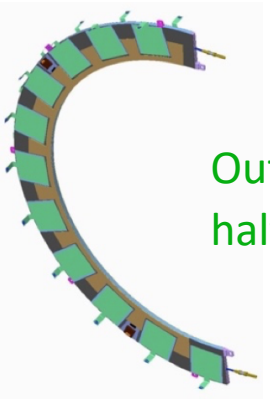
Rings mounting plate and manual bridge



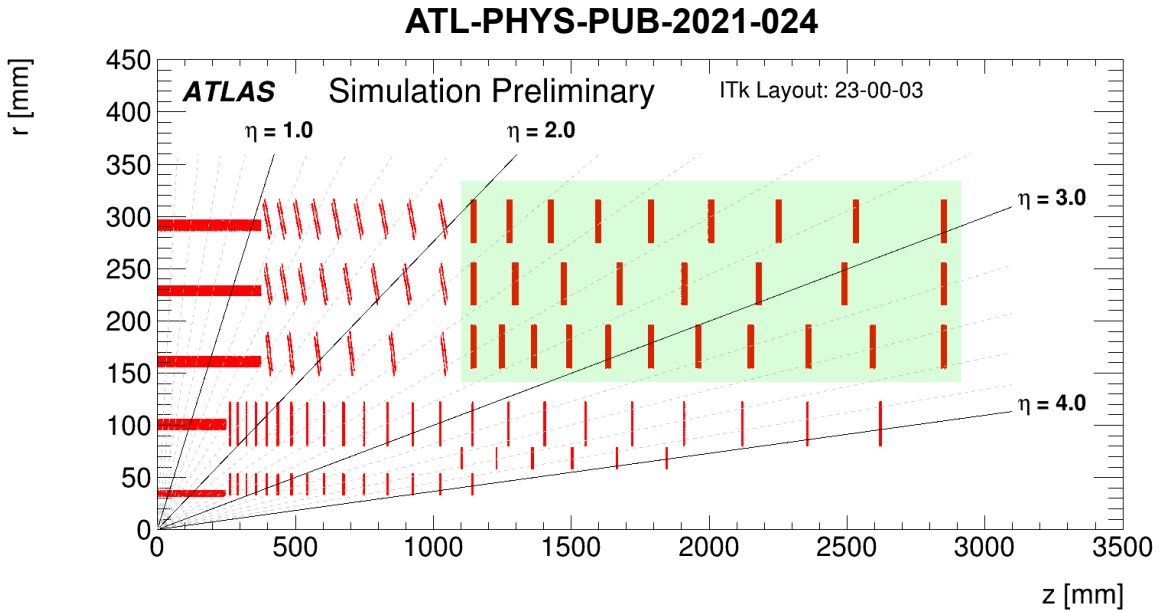


-Ring handling frame centred with rolling bearing
-Theta position indexed with stops

Pixel Outer Endcap

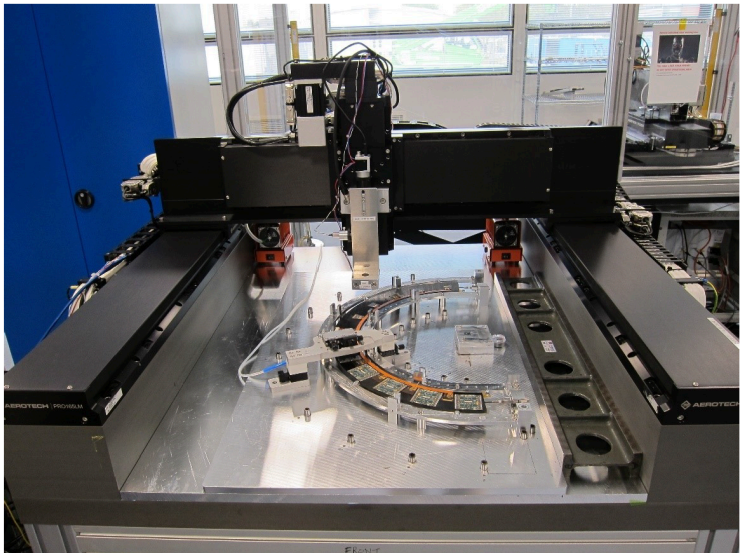


Outer endcap:
half rings

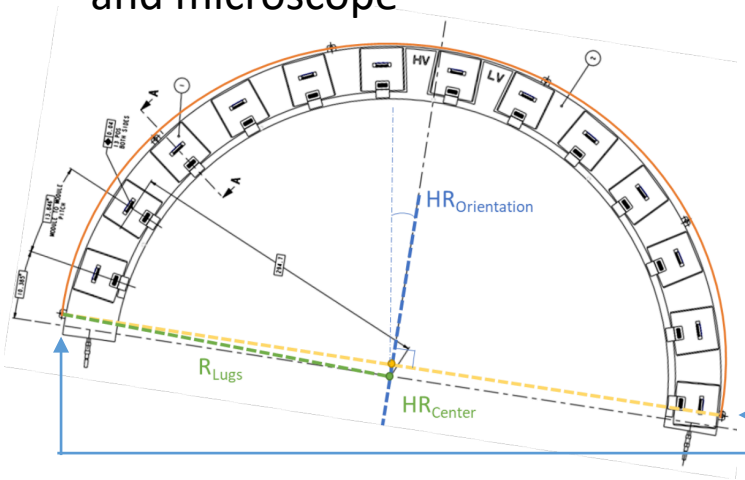


ITK Pixel Outer Endcap: gantries and metrology

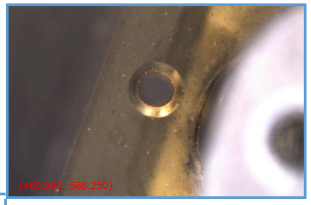
Half Rings loaded on XYZθ Gantries in 4 sites

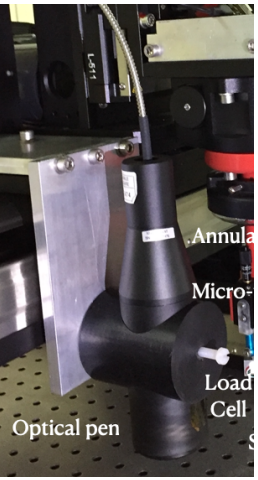


Global coordinates given by XYZθ gantry motor encoders and microscope



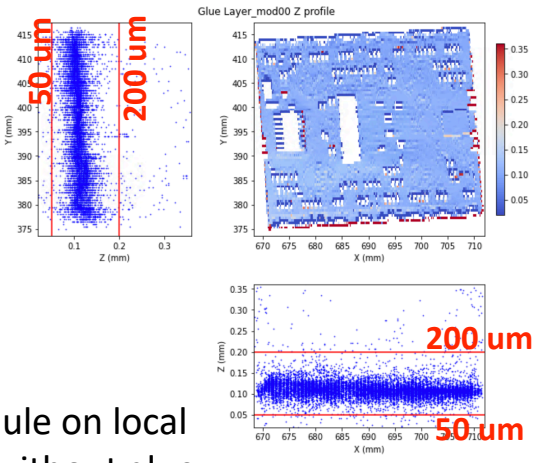
Reference system given by two fiducial holes on support and nominal radius



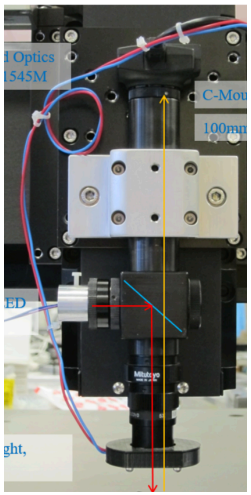


Z metrology:

1 um resolution Chromatic conformal profilometer

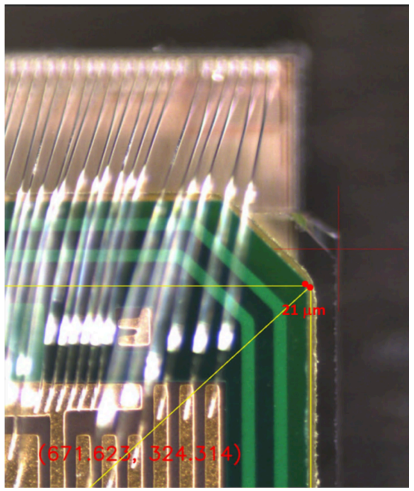


z-map diff. of Module on local support with and without glue



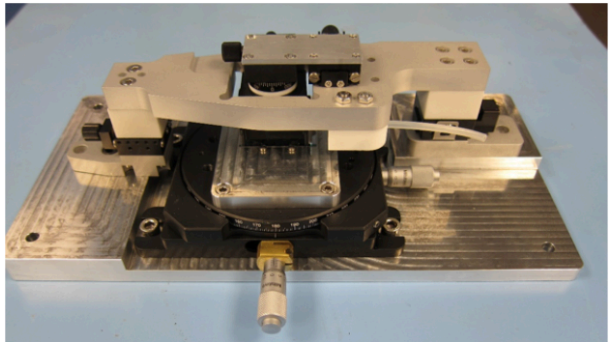
XY metrology:

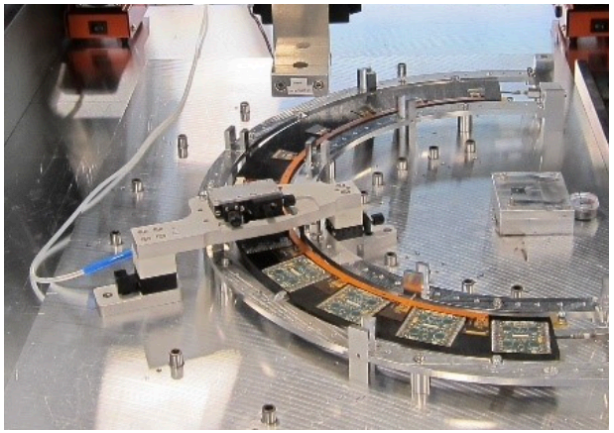
Tele-centric microscope (FoV 3x2 mm²)



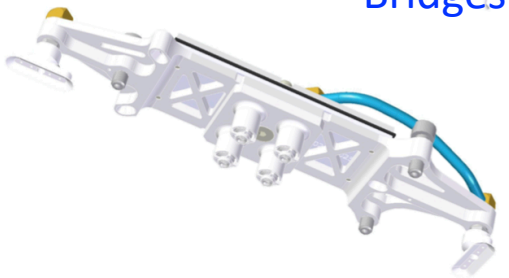
ITK Pixel Outer Endcap: Loading techniques

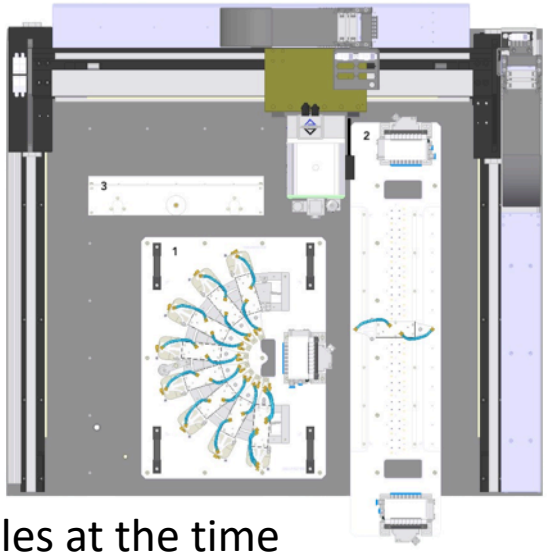
Method I (RAL): Manual Bridges with XYZθ micro-metric adjustments





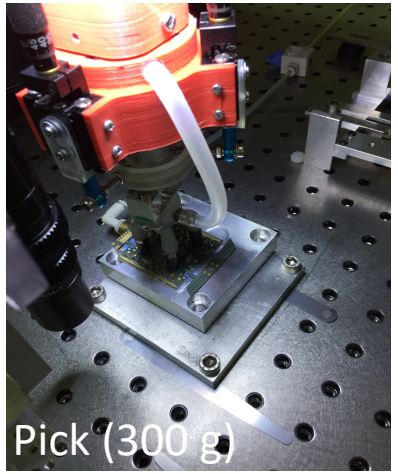
Method II (Oxford): Pick&Place Bridges



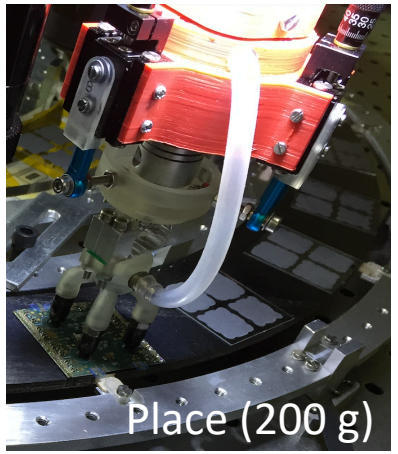


Loading of many modules at the time

Method III (Ge, Le): Pick&Place head with strain gauge



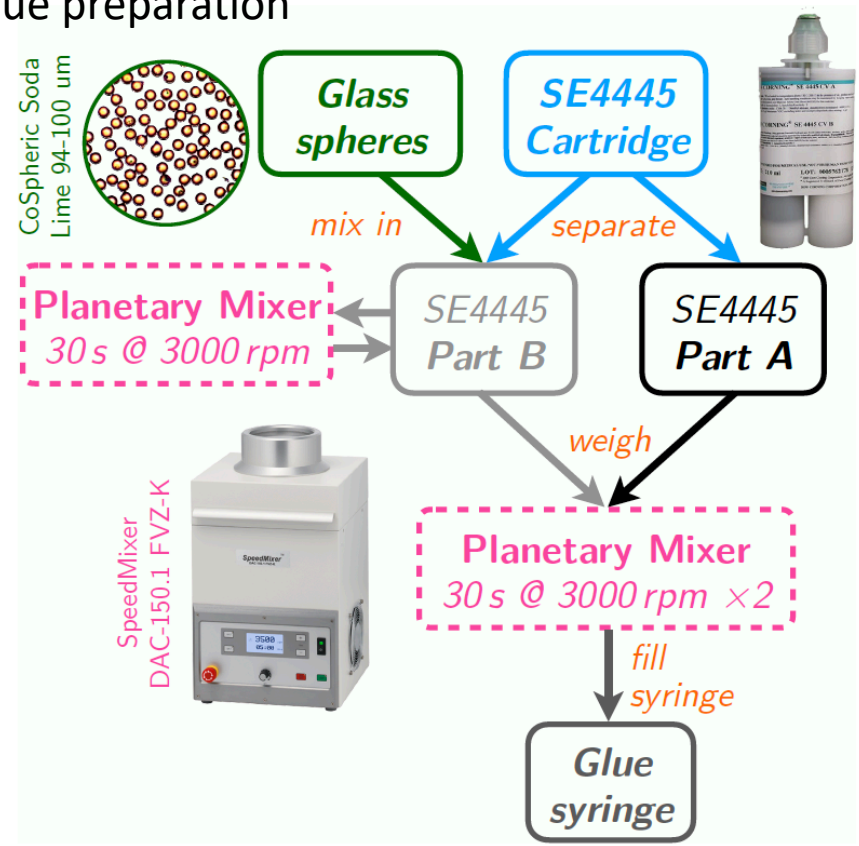
Semi-Automatised

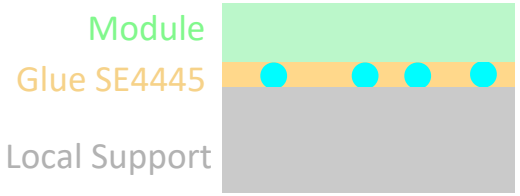


Huge flexibility

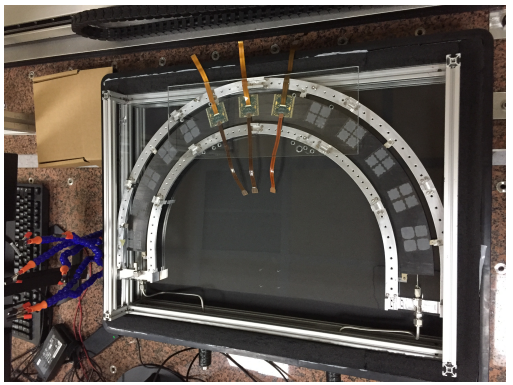
ITK Pixel Outer Endcap: Automatic Glue Deposition and spheres

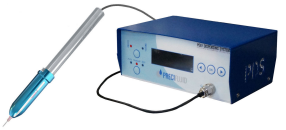
Glue preparation



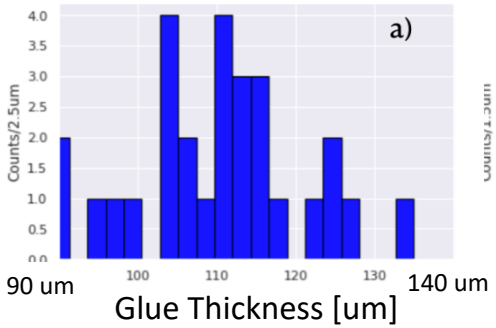


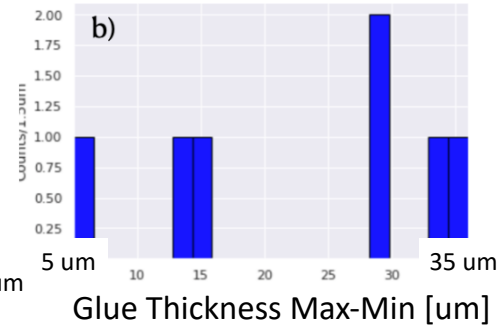
Volumetric dispenser: No need calibration or glue trials

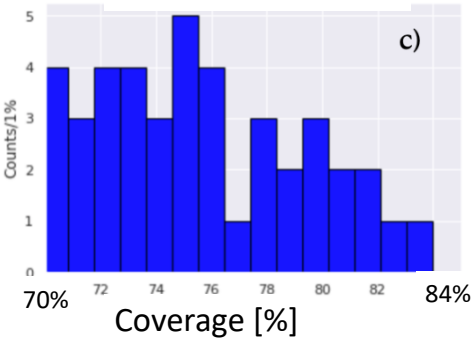


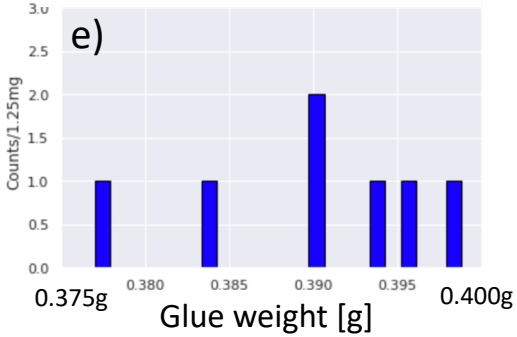


Half Ring prototype loaded with 10 glass tiles and 3 RD53a quad modules



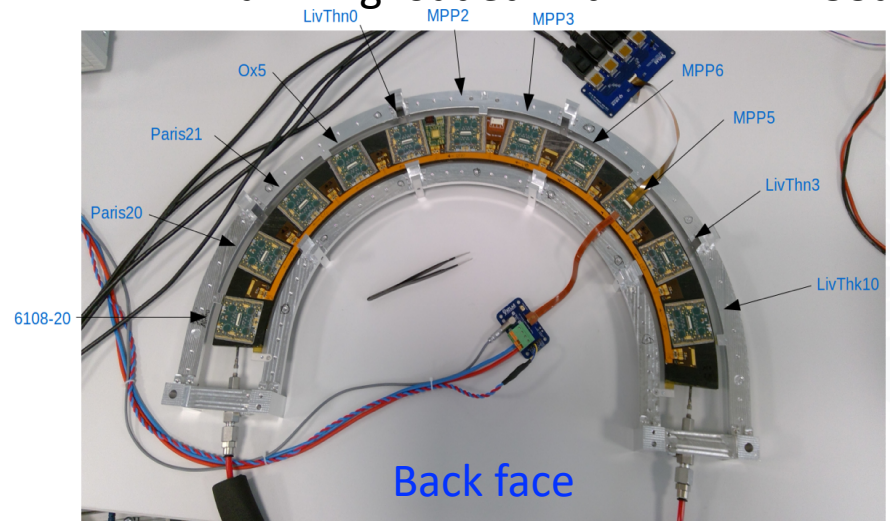


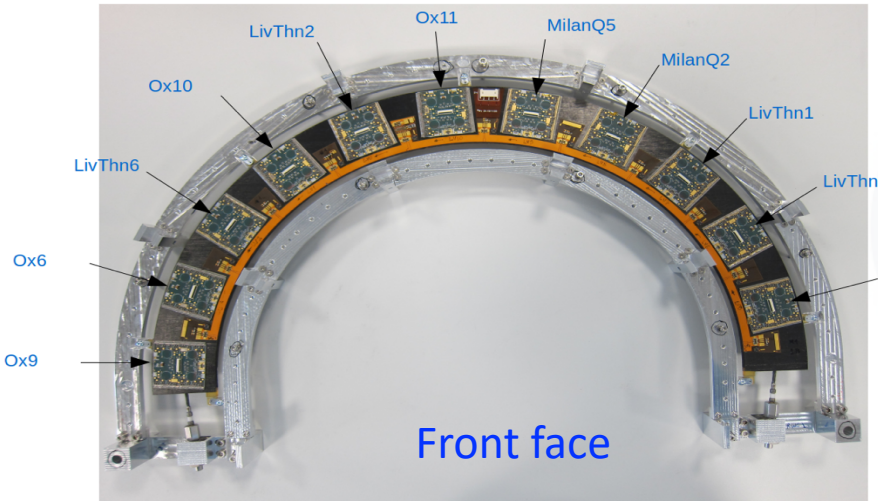


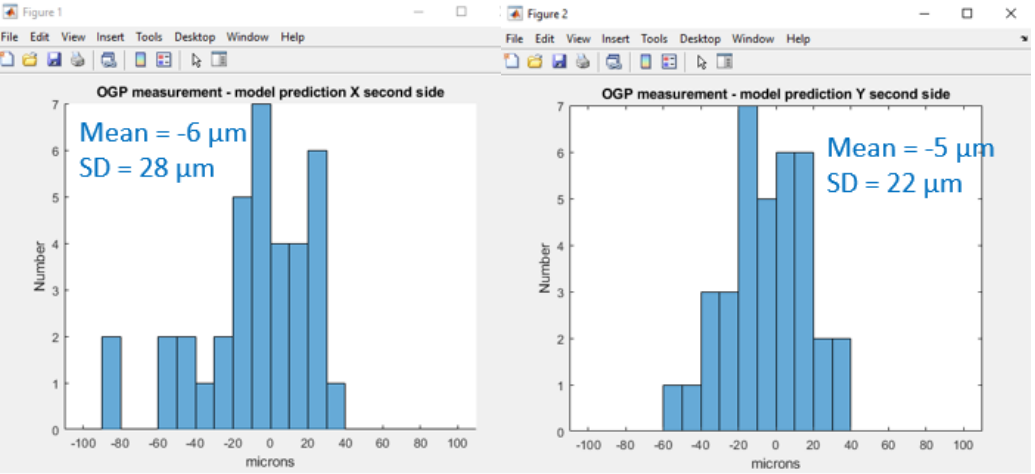


ITK Pixel Outer Endcap: Placing Accuracy

Half Ring loaded with 11+11 RD53a quad modules interconnected to old bus tape

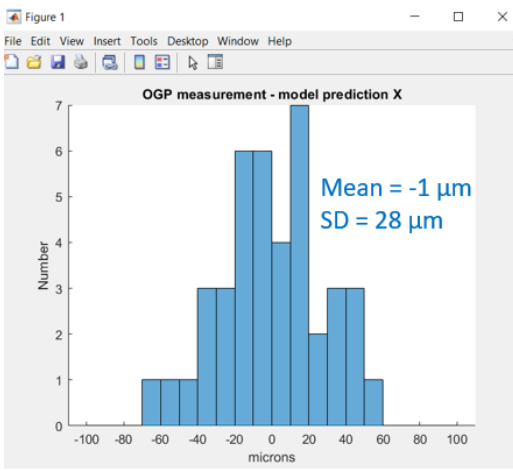




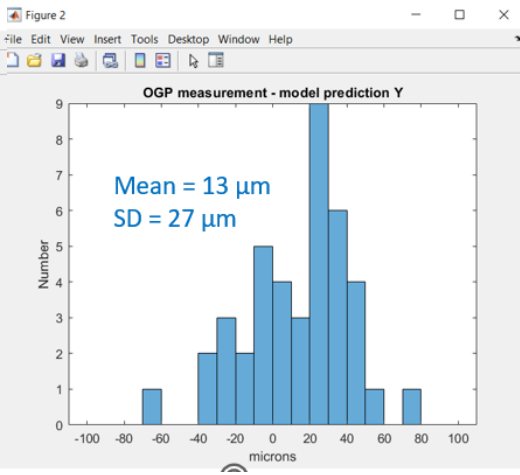


X residuals

Y residuals



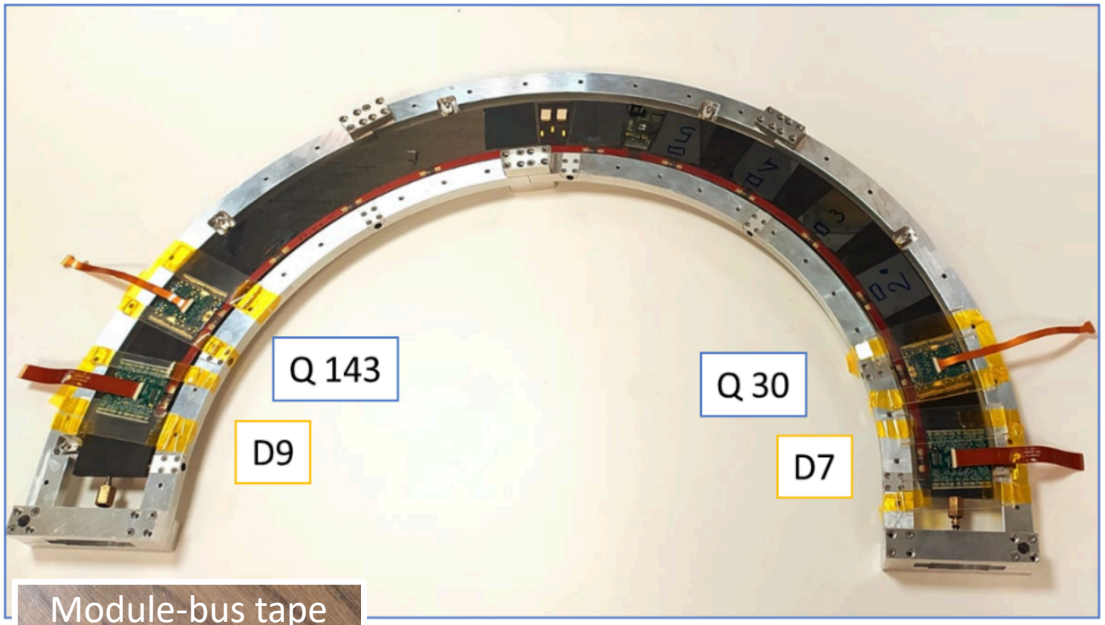
X residuals

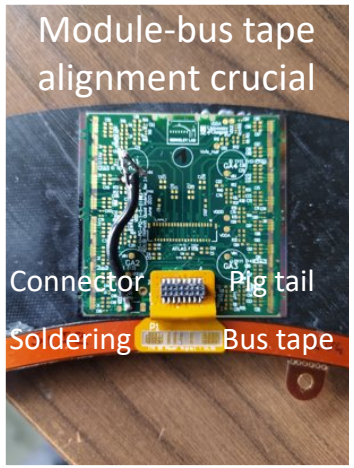


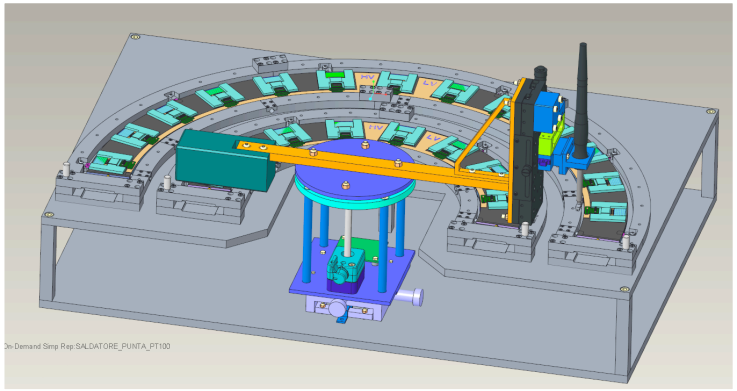
Y residuals

ITK Pixel Outer Endcap: Power Pig Tail Soldering

Half Ring loaded with ITKpix quad modules interconnected to final bus tape

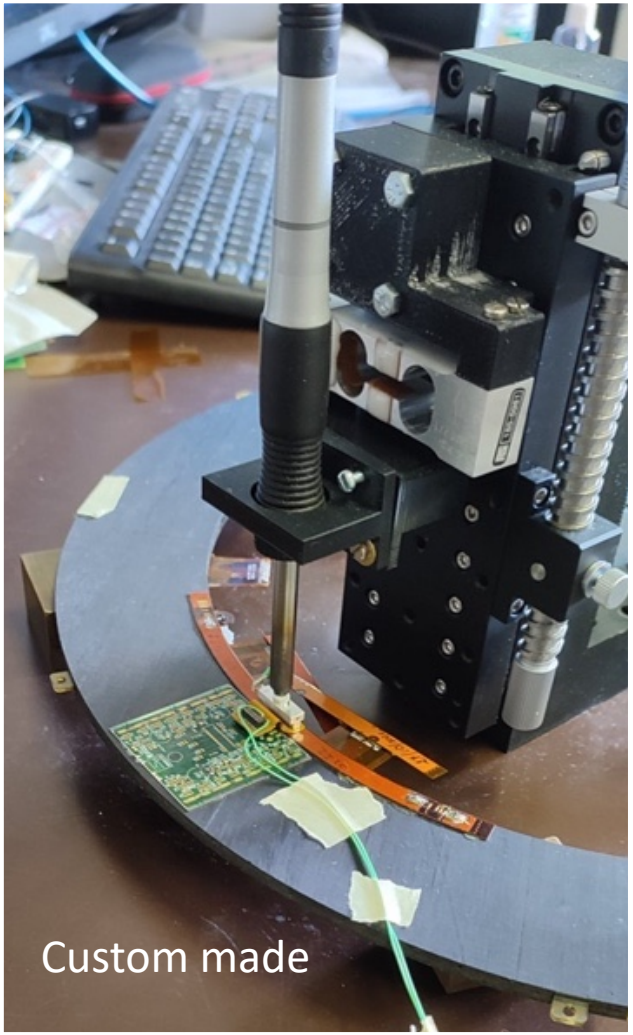






Power pig tail soldering tool final setup

Power pig tail soldering tool



Conclusions

1. ATLAS ITK pixel loading based on two general approaches:
    1. Inner Pixel, Outer Barrel Pixel: Custom tools
    2. Outer EndCap Pixel: XYZθ Gantries

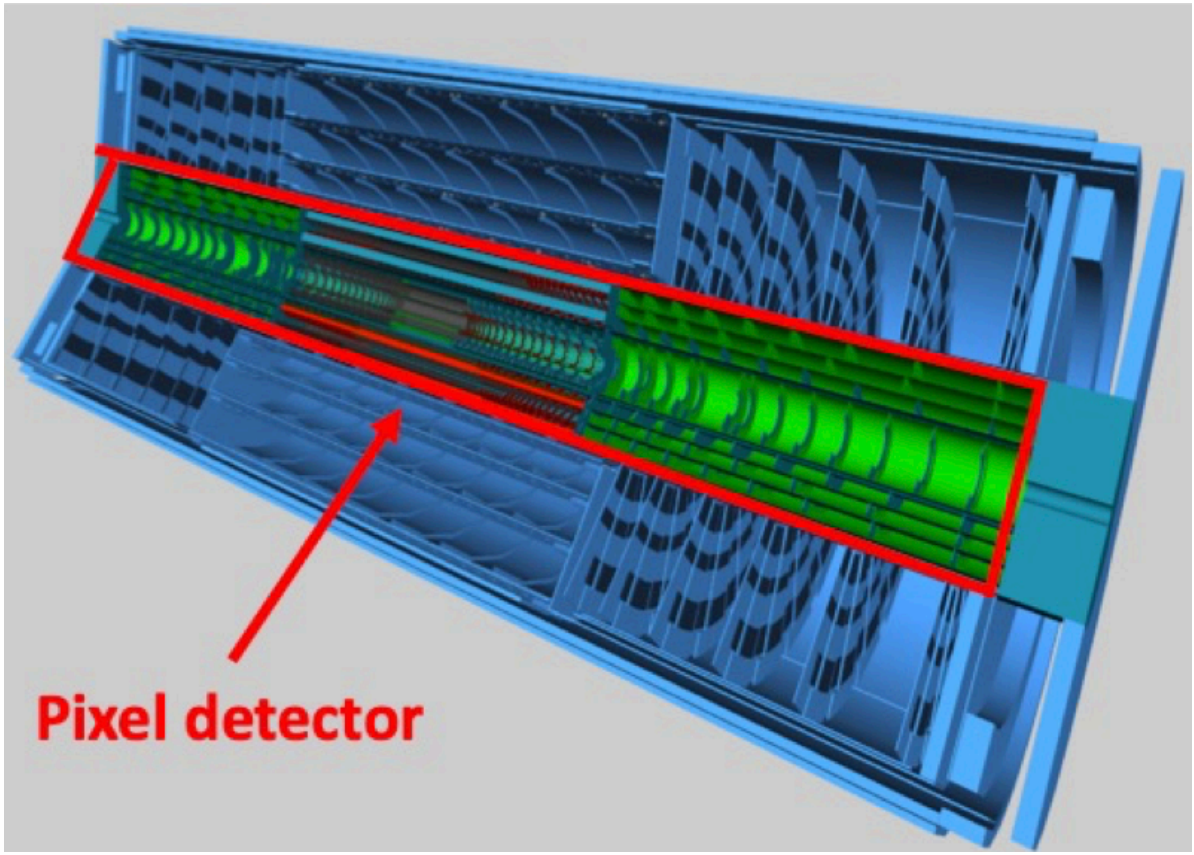
2. Large area requires many loading sites to stay in schedule → many methods and setups to load local support also of the same kind (correlated to group previous experiences).

3. All 10 ATLAS ITK PIXEL loading sites pass the final design review and are basically ready for pre-production.

4. The comparison between such variety of loading techniques is very valuable.

5. The loading sites should deliver the same detector → Metrology and QC Tests must be comparable and not site dependent.

Back-up



Other ITK pixel talks

84. ATLAS ITk Pixel Detector Overview
Dr Koji Nakamura (CERN)
06/09/2023, 12:00

137. System tests of the ATLAS ITk planar and 3D pixel modules
Dr David Vazquez
06/09/2023, 16:00

155. Module development for the ATLAS ITk Pixel Detector
Dr Matthias Saimpert (CEA Saclay IRFU/DPhP)
06/09/2023, 16:40

133. Loading of ATLAS ITk pixel module on multi flavour local supports
Dr Gabriele Chiodini (CERN)
06/09/2023, 17:40

136. Design and prototyping of large-scale flex circuits for the ATLAS ITk Pixel detector
Dr Steven Welch (CERN)
06/09/2023, 18:00

146. Novel pixel sensors for the Inner Tracker upgrade of the ATLAS experiment
Stefano Terzo (IFAE, Bracelona)
07/09/2023, 12:40

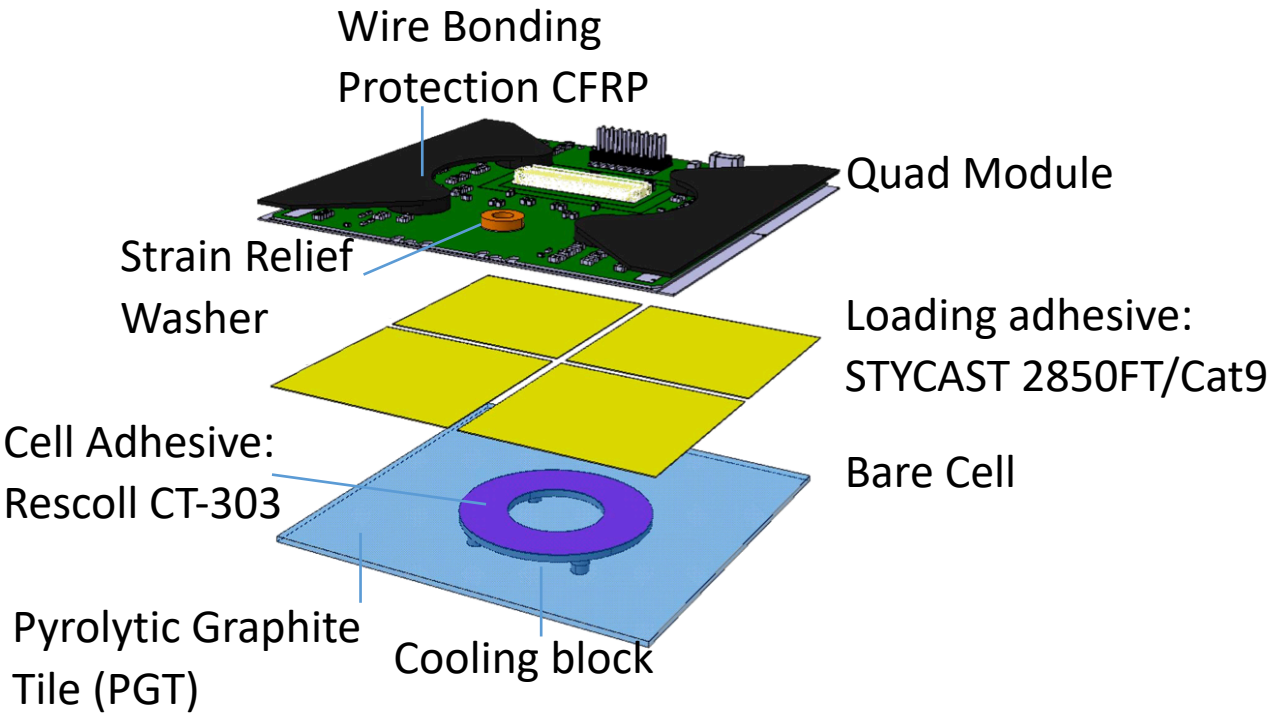
Loading Local Supports with pixel modules

1. Mechanically fix bare local support on loading table by its handling frame
2. Fix pixel module on pick-up plate by vacuum
3. (X,Y) local support and module metrology with respect to loading table

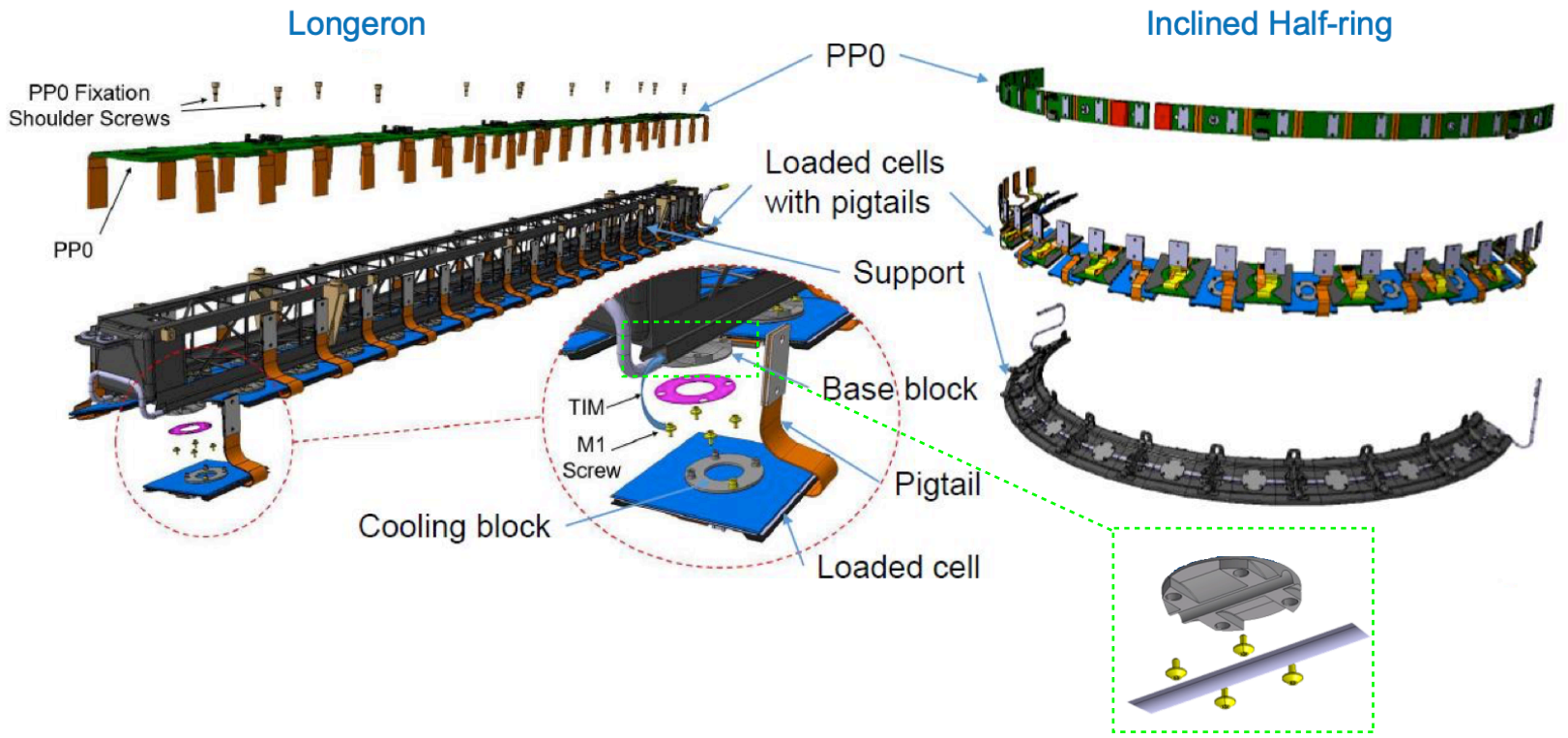
   or

   local support and module aligned with precision-machined edges or holes or pins
4. Z local support and module metrology
5. Deposit glue pattern on local support
6. Pick-up the pixel module with bridge or Pick&Place head vacuum feet
7. Place with bridge or Pick&Place head the pixel module on local support above glue in the nominal XYZ position with respect to the local support

ITK Pixel Barrel building block: Quad Module Cell

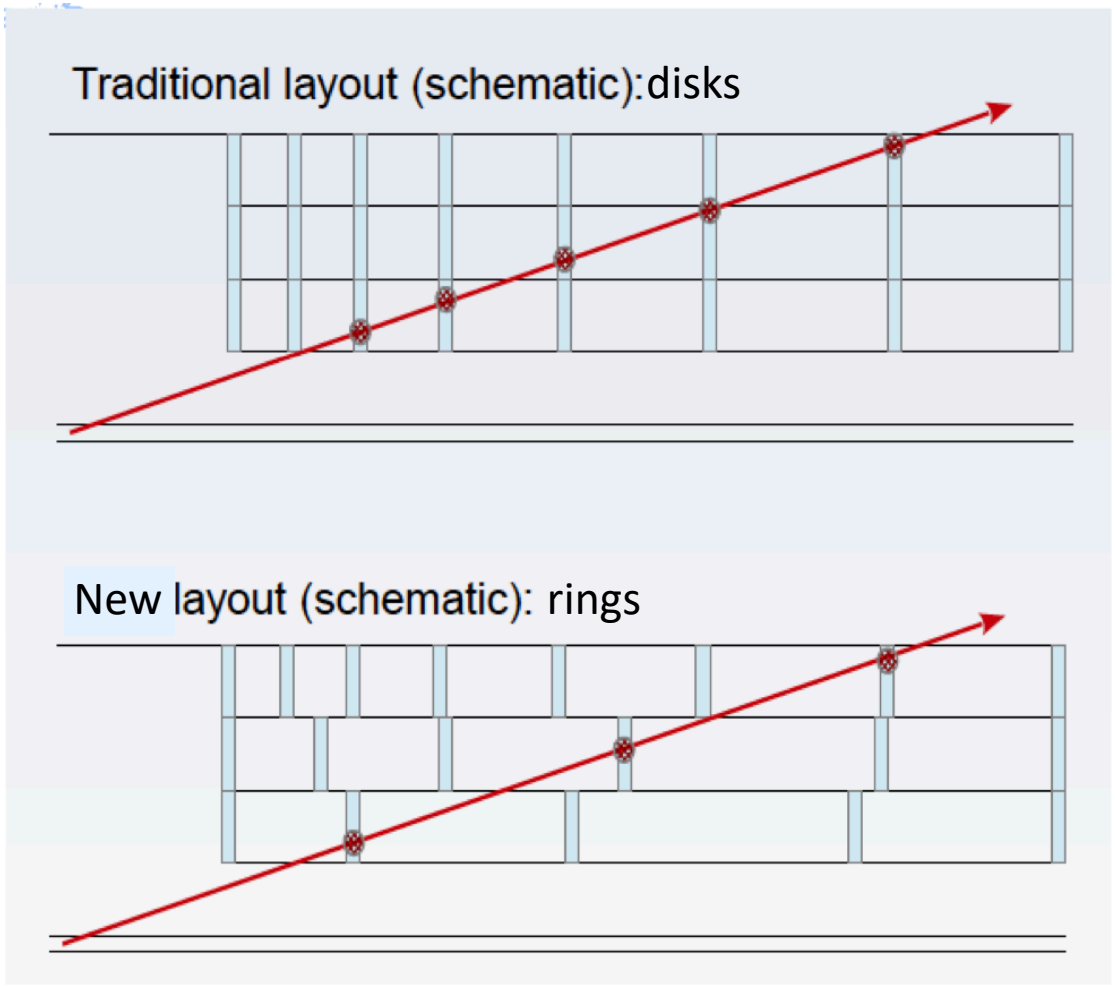


ITK Pixel Barrel: Longerons and Inclined Rings



Functional Longerons and Inclined Half Ring are populated by coupling many **Quad Module Loaded Cells** to **Base Blocks** with M1 screws and TIM (Thermal Interface Material) and to PP0 interconnection cable. Due to the complexity of the geometry the integration is made manually by two operators.

ITK Pixel Endcap: Layout



Endcap cover the high η region

Number of rings and z positions optimised for track hermeticity for each pixel layer, separately.

Rings gives flexibility in location and number without large engineering changes

Services routed on support structures

Designed to minimize mass and to improve tracking at high η

ITK: Material budget

ITk silicon surface area (165m^2) is 2.6 times large than the current ID, but the maximum radiation length reduced from 5.5X_0 to 2X_0

- Lower material budget than ATLAS ID.
  - Evaporative CO2 cooling system with titanium pipes.
  - Carbon structures for local supports.
  - Optimised number of readout cables using link sharing.
  - Innovative Serial Powering (SP) scheme in the pixels.