



Jon Taylor on behalf of the Liverpool ATLAS Upgrade Group



...nigh-er than last year anyway



Who are we and what are we doing at Liverpool?

- Matt Brown
- John Carroll
- James Coleman-Mills
- Paul Dervan
- Ashley Greenall (lead strip hybrid designer)
- Tim Jones (Pixel GM co-Ordinator, UK Pix Integration lead)
- Warren Jones
- Carl Gwilliam
- Helen Hayward (Outer Endcap Coordinator, UK Pix Integration lead)
- David Vazquez
- Paul Sinclair
- Jon Taylor (Pixel module activity co-ordinator, UK pixel module coordinator)
- Sven Wonsak (Strip Database lead)

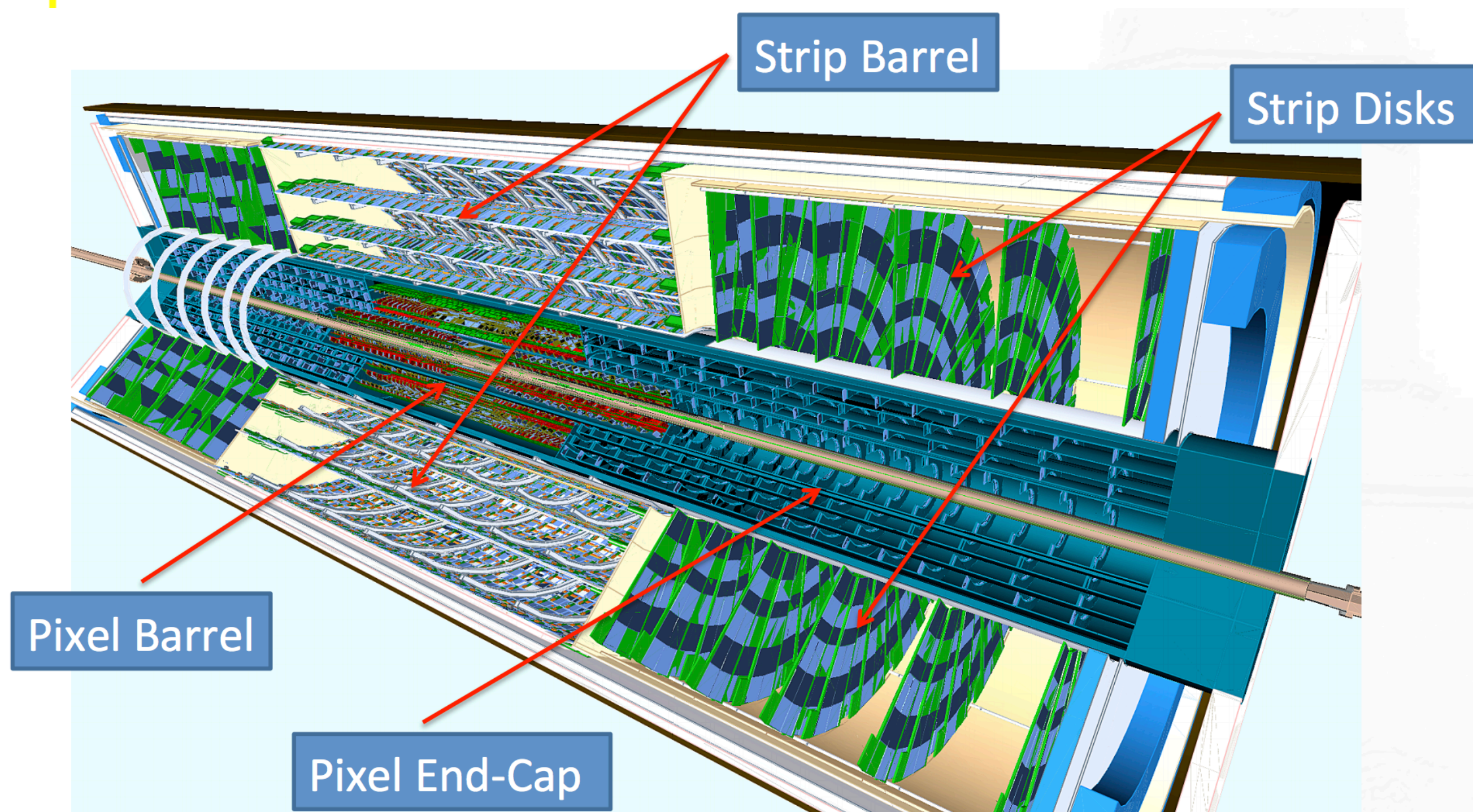
- Welcome:
 - Akhil Kumar
 - Andy Bukowski
 - Tony Watling



Plus continued thanks to : Liam Boynton, Tom Lee, DFF, Julie, Angie, Hannah, and the ATLAS group

Who are we and what are we doing at Liverpool?

- module production for both the ITk barrel strip detector and the endcap pixel tracker;
 - 10,000 strip hybrid reception testing
 - 3000 hybrids ASIC loading and wire bonding
 - ~580 strip modules
 - ~500 pixel modules
- mechanical support structures for both detectors;
 - 100 strip stave cores
 - 6 CF half-cylinders
- the full integration of one of the ITk's pixel endcaps; and

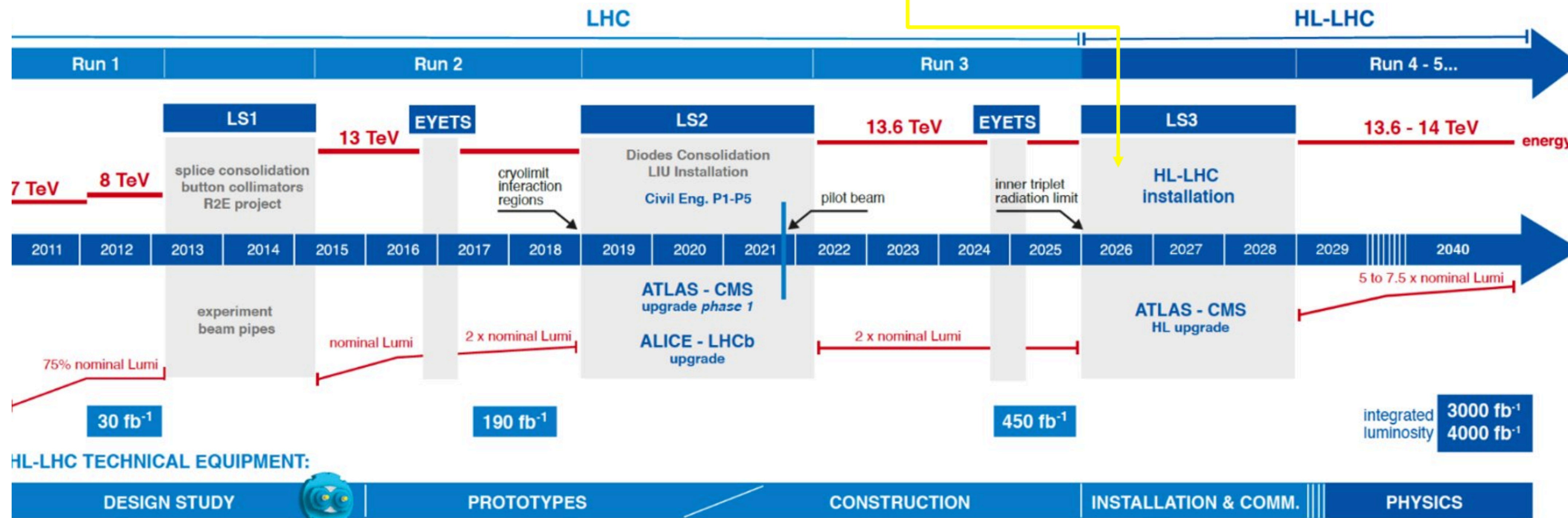
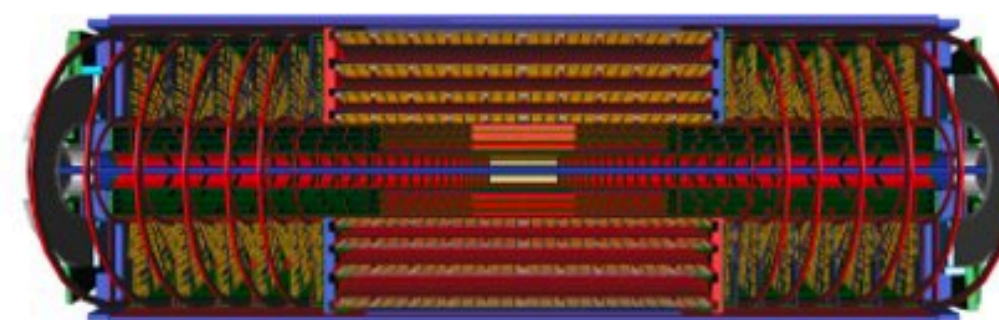




HL-LHC schedule and where ITk fits in...

ATLAS SCT vs ATLAS ITk

Detector	Area [m ²]	# channels	Dose [1MeV neq/]
ID Pixel	2.1	80M	$\leq 1.4 \times 10^{15}$
ID strips	61	6.3M	$\leq 2 \times 10^{14}$
ID TRT	N/A	350k	$\leq 2 \times 10^{13}$
ITk Pixel	>10	>1 x 10 ⁹	$\leq 2 \times 10^{16}$
ITk Strips	165	~50M	$\leq 2 \times 10^{15}$



HL-LHC TECHNICAL EQUIPMENT:

The slide is titled "ATLAS Upgrade" and is from the "Particle Physics Annual Meeting 2023". It features the ATLAS Experiment logo. The main heading is "Strips modules". A red box highlights a bullet point: "Barrel Strip Module PRR happened last week". Below this, a list of bullet points details the situation: preliminary feedback was positive for production hybrid assembly, but UK sites still need to finish pre-production. A 2022 issue of "cold noise" was a showstopper, caused by excess noise from vibrating ceramic capacitors on the powerboard. Endcap modules don't show cold noise. A new glue had to be qualified. Production starts with long-strip modules using Eccobond F112 glue. To the right of the text are two images: a top-down view of a strip module assembly and a photograph of a physical module.

From last years Annual Meeting:

“Preliminary feedback from reviewers was positive to start production hybrid assembly”

- Production of Flex circuits (re)started in May 2023
- Then stopped 4 months later in October
 - And has yet to restart...
- What happened?
- Modules crack when glued to staves at low temperature
 - Required to operate at low T → show-stopper

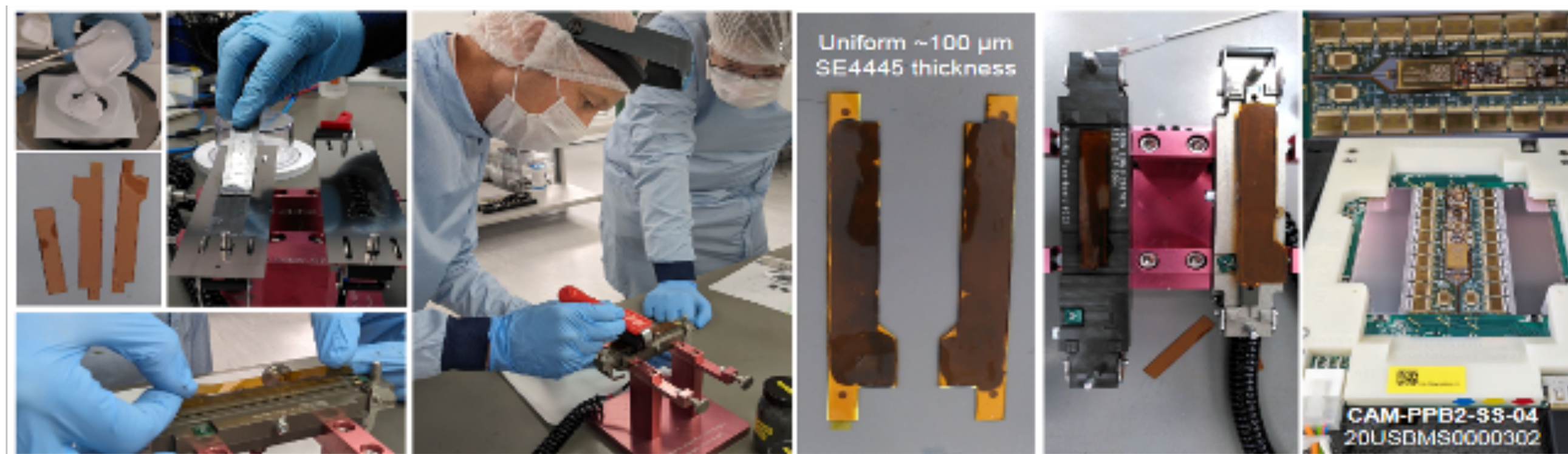
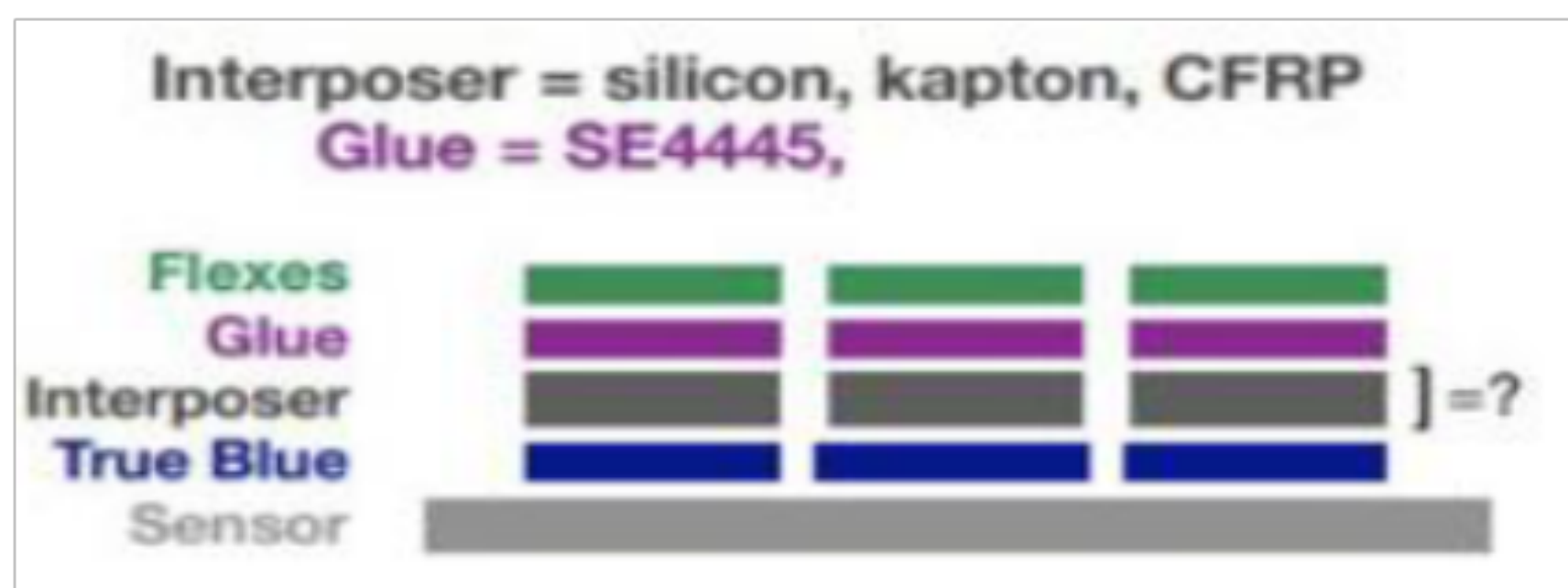
• Task Force set up to address problem

- FEA being used extensively to provide guidance
 - Stress build up on Si sensor due to material CTE mismatch is the problem
 - Reduce Cu in flex circuits (25% reduction), change glue used to attach sensors to stave
- Suggestion of further mitigation is required
- How?

A. Greenall, S. Wonsak, T. Lee, A. Kumar, A. Bukowski

Strip hybrids & modules

- **Interposers** (*cf* interpose: “To place between”)
 - Add 50µm Kapton to the back of hybrid using a soft glue then use hard glue to attach hybrid to sensor
 - FEA predicts 10 ->15 reduction in stress compared to current build – **most promising proposal**



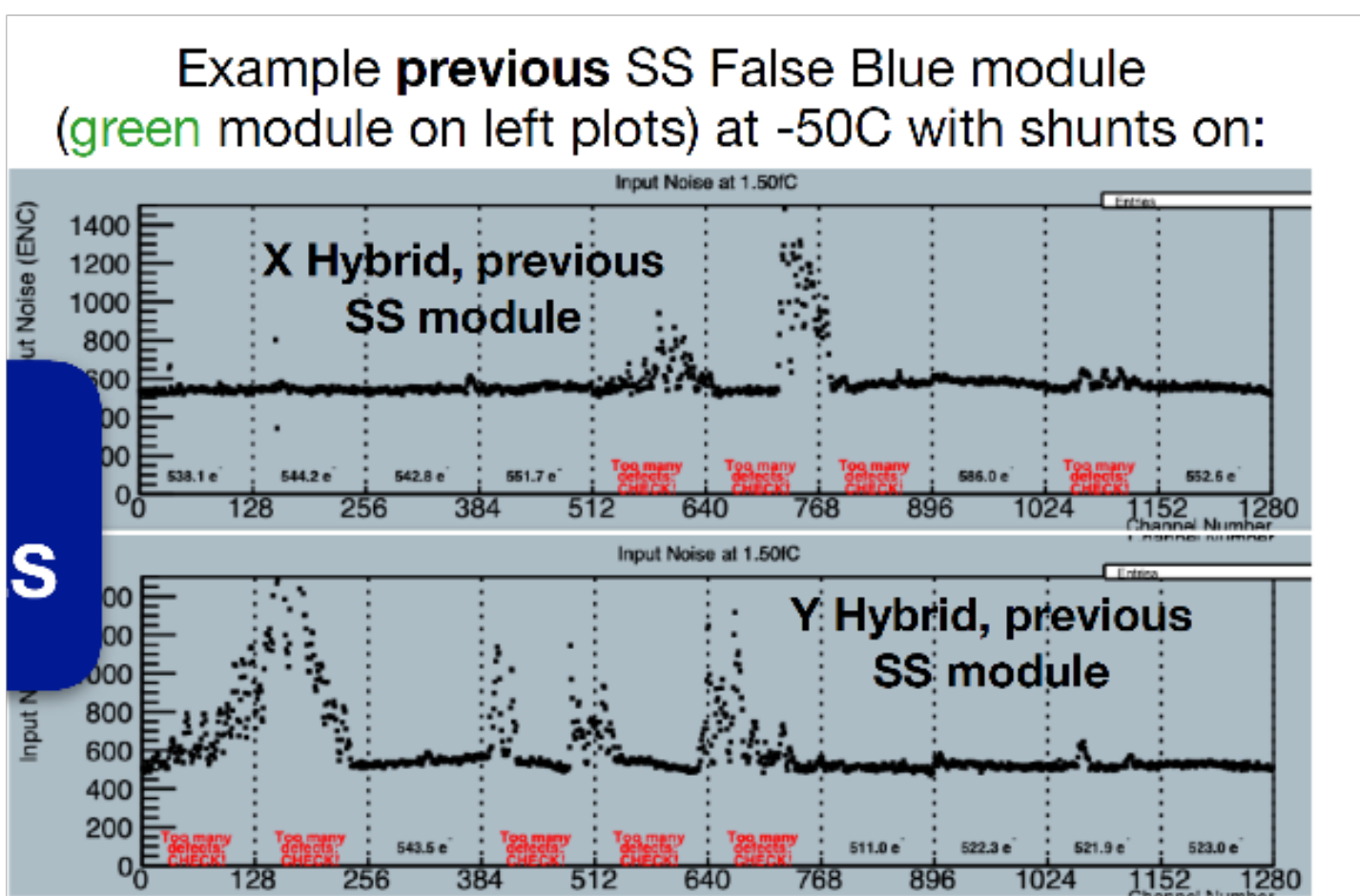
The reality is not easy – BUT first test results look promising

- **Liverpool looking at industrialising the process – 20k circuits to be done**
 - Cannot be done by flex manufacturer – they use sheet adhesives and not soft glues
 - Interposer must be added after SMD solder reflow → compliant glue cannot survive high T
- **7 circuits at a time, aligned to circuit array**
- **Early days, 3+ months R&D program**
- **If interposer works expect restart of production Q4 2024.**

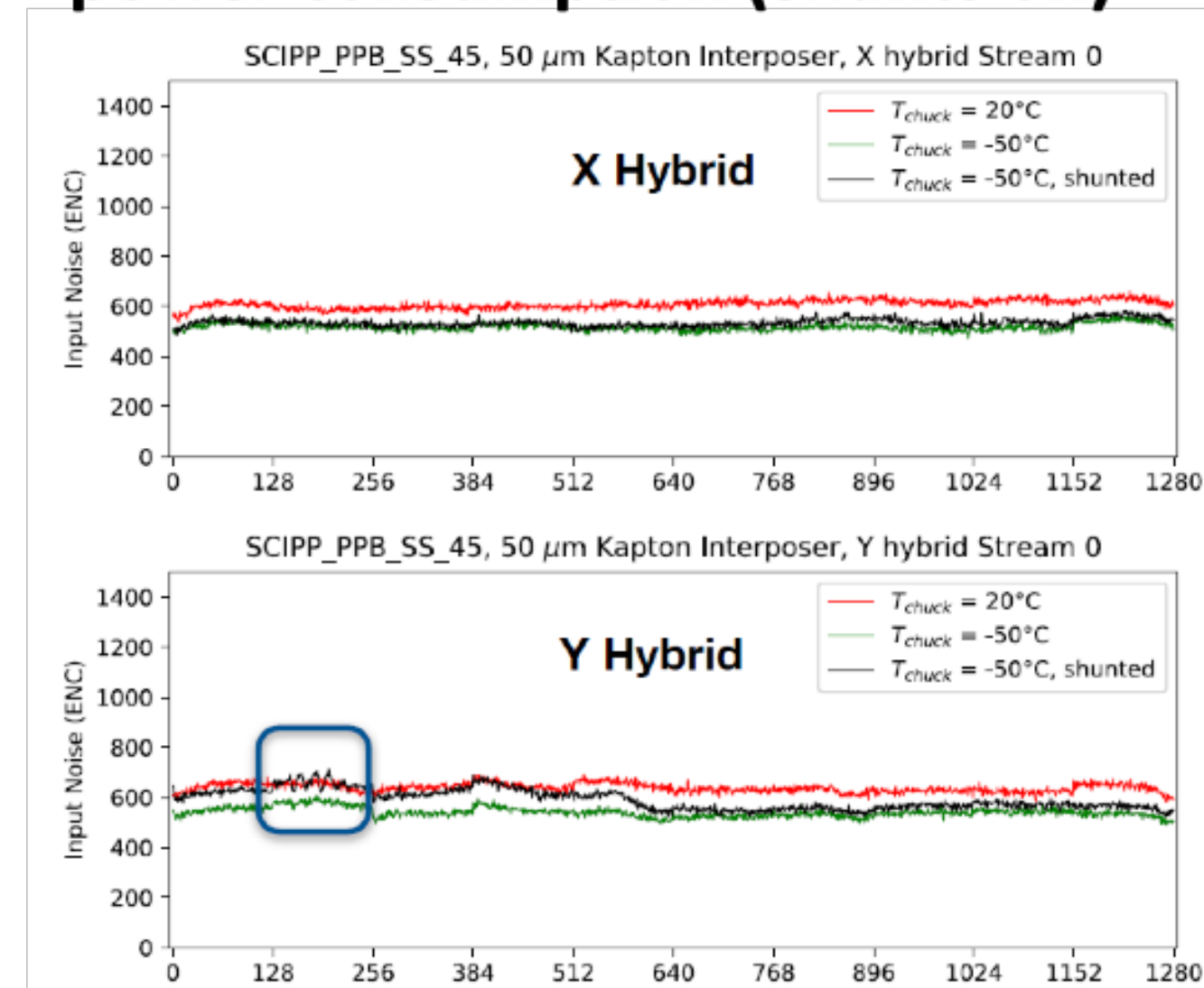
Strip hybrids & modules

- Last year had issue with module cold noise
 - Noise increase when cooling down modules
 - Under control for long-strip modules by switching glue, but not for short-strip modules
- New results with interposer modules:
 - No cold noise seen in standard assembly method
 - Minimum cold noise when using glue that enhances cold noise and when increasing power consumption at temperatures below normal range (tested at -50C, expected operation temperature -35C)
- Interposers also help with cold-noise issue

Old module, -50C, increased power consumption (shunts on)



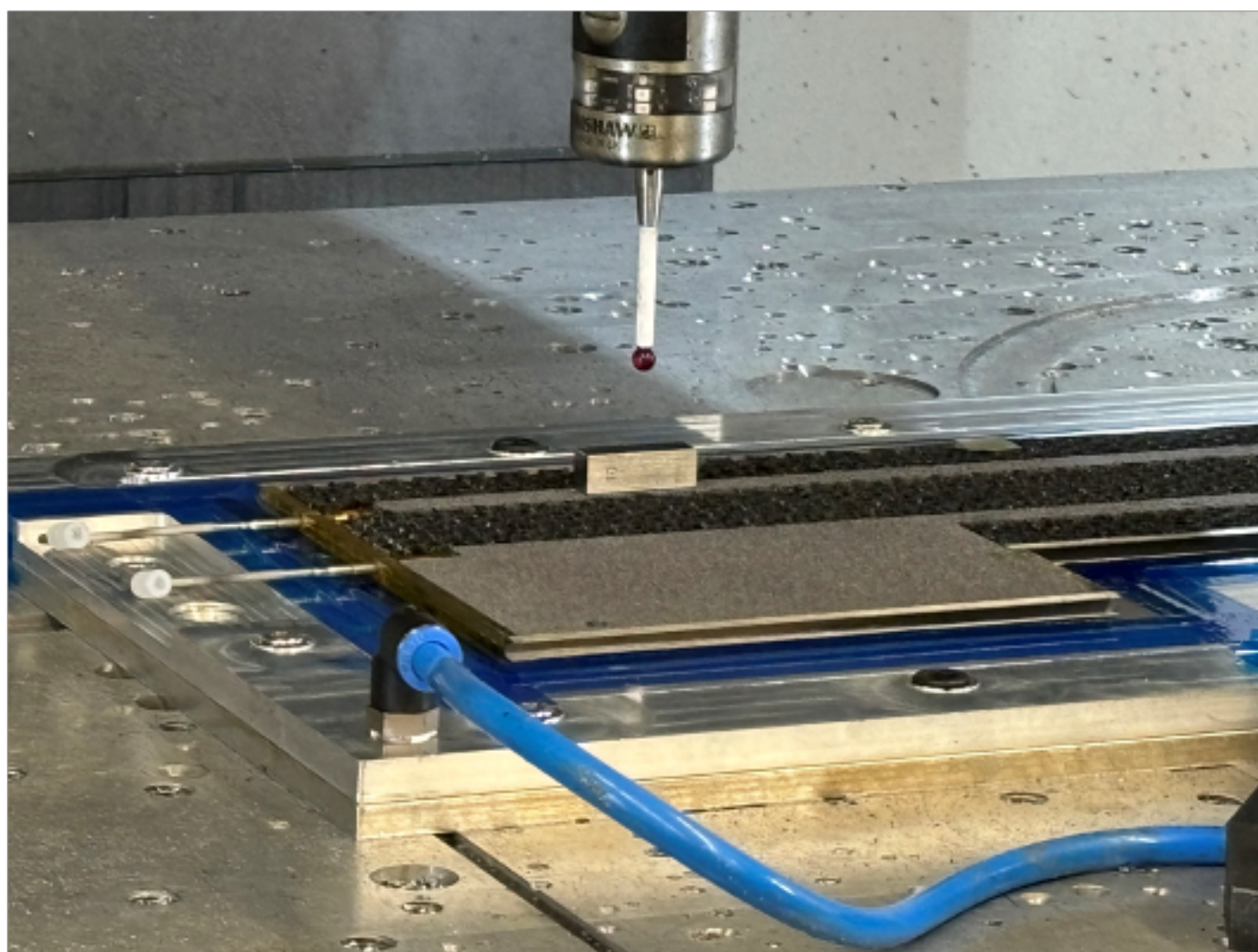
Interposed module, -50C, increased power consumption (shunts on)





This Year...

- Many many trips to Oxford, these visits were necessary to help iron out the last of the Engineering and Technical problems facing UK stave cores. The main issue being the local flatness of UK cores as excessive undulation could cause problems with module mounting. After some time, it was accepted that the “Protective tape” used on stave cores was the culprit and therefore removed.
- Final QC of updated core tooling, after receiving tooling back from the workshop we are in the process of re-checking our tooling and generating measurement reports to qualify and document the physical changes to the tooling. This will bring Liverpool’s tools UpToDate with the rest of the UK collaboration.
- Starting to receive production quantity and “quality” numbers of items, Liverpool is being loaded with parts to be used in making our x100 stave cores.



Machining of a core undertaken at Oxford without “protective tape” to help us better understand local flatness.

T. Jones, W. Jones, T. Watling

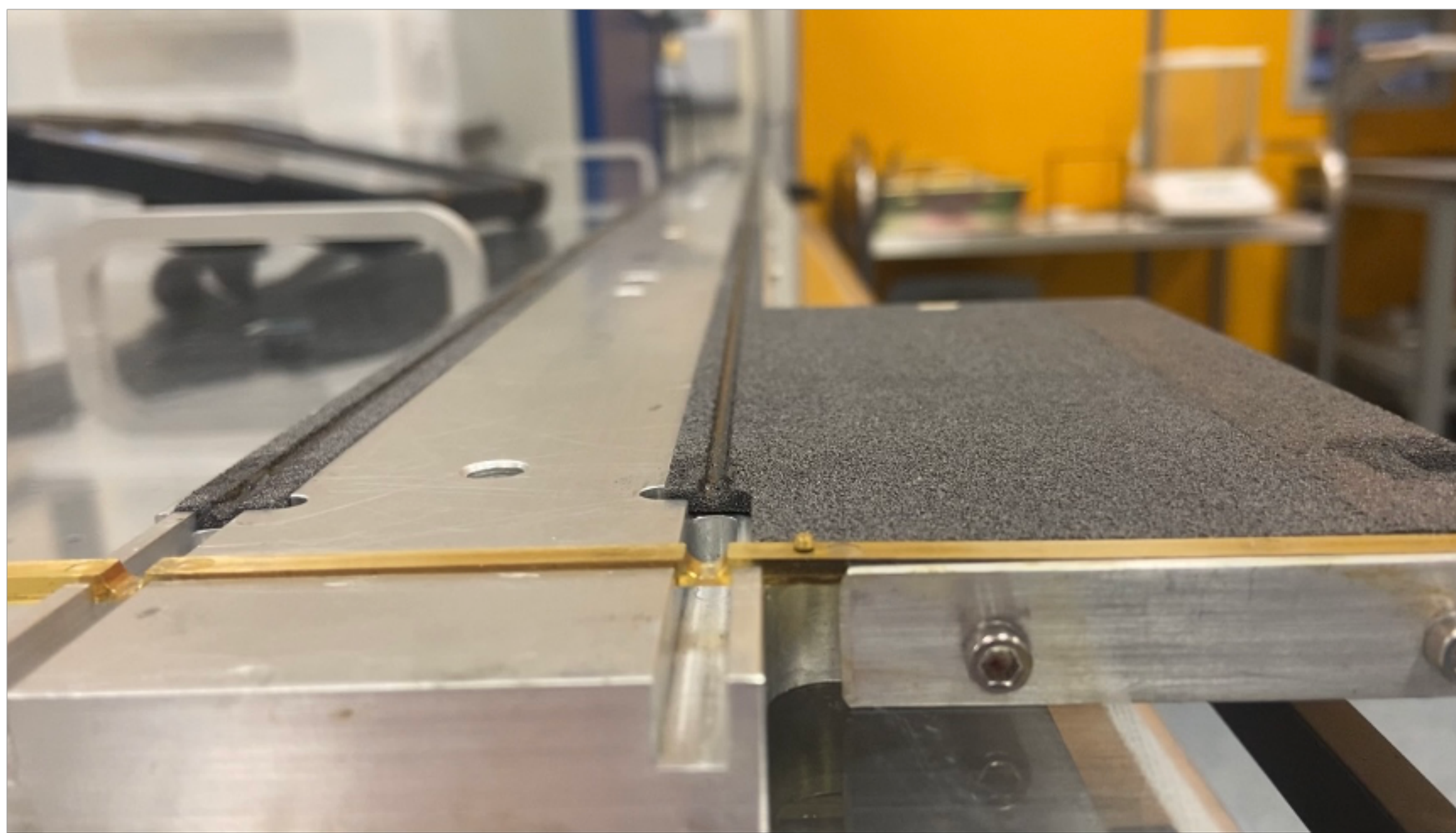
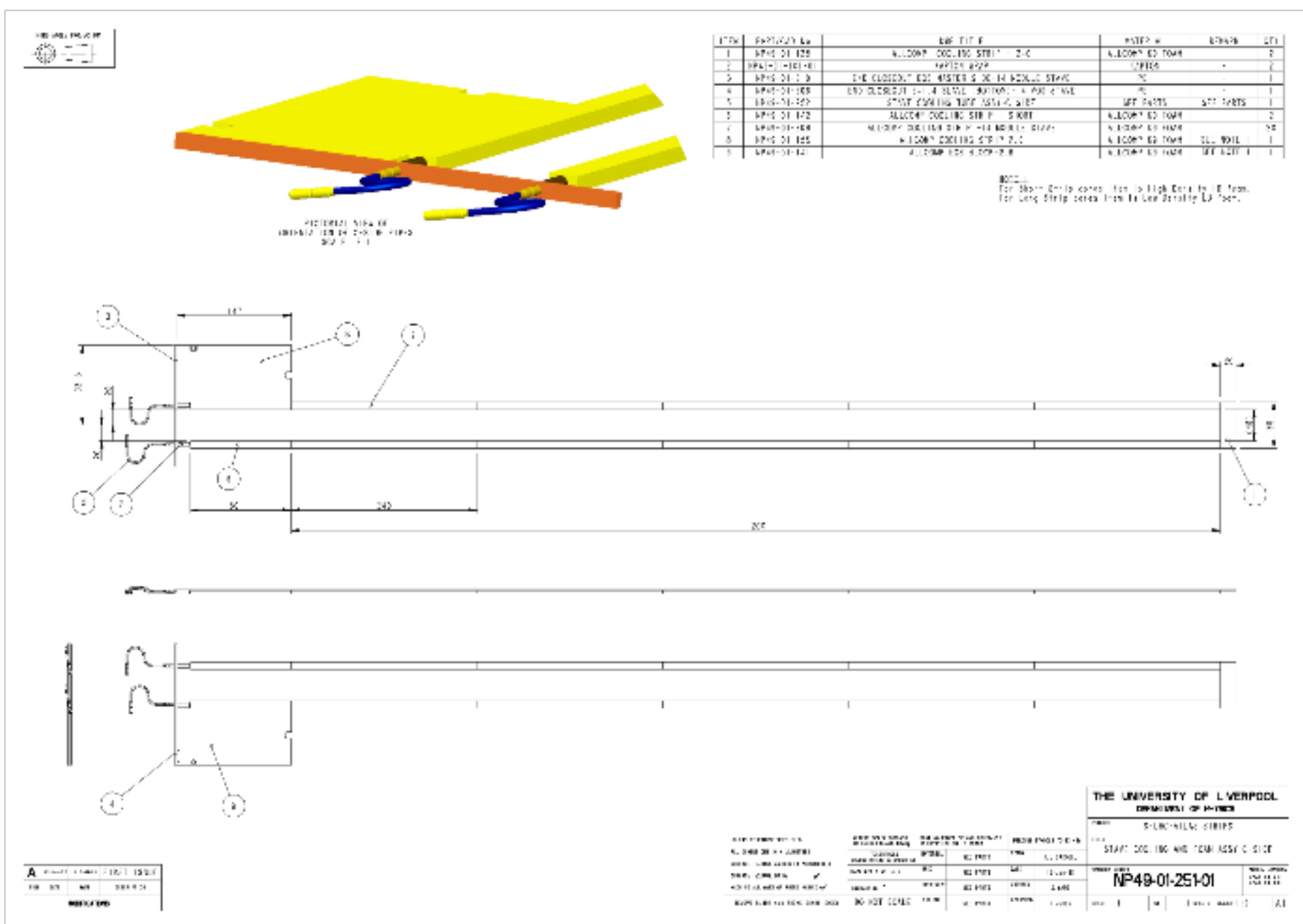




Strip stave core assembly in the LSDC

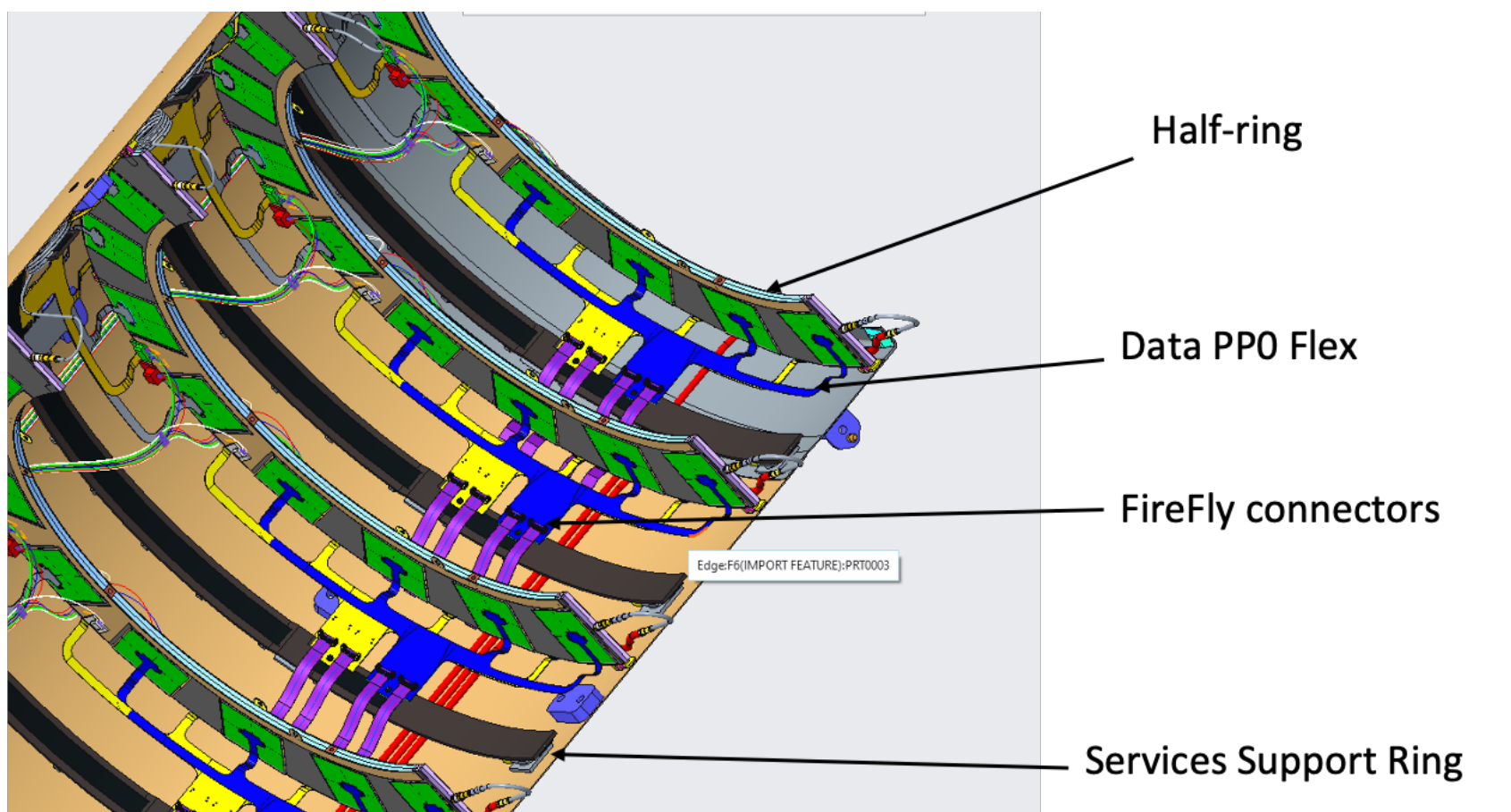
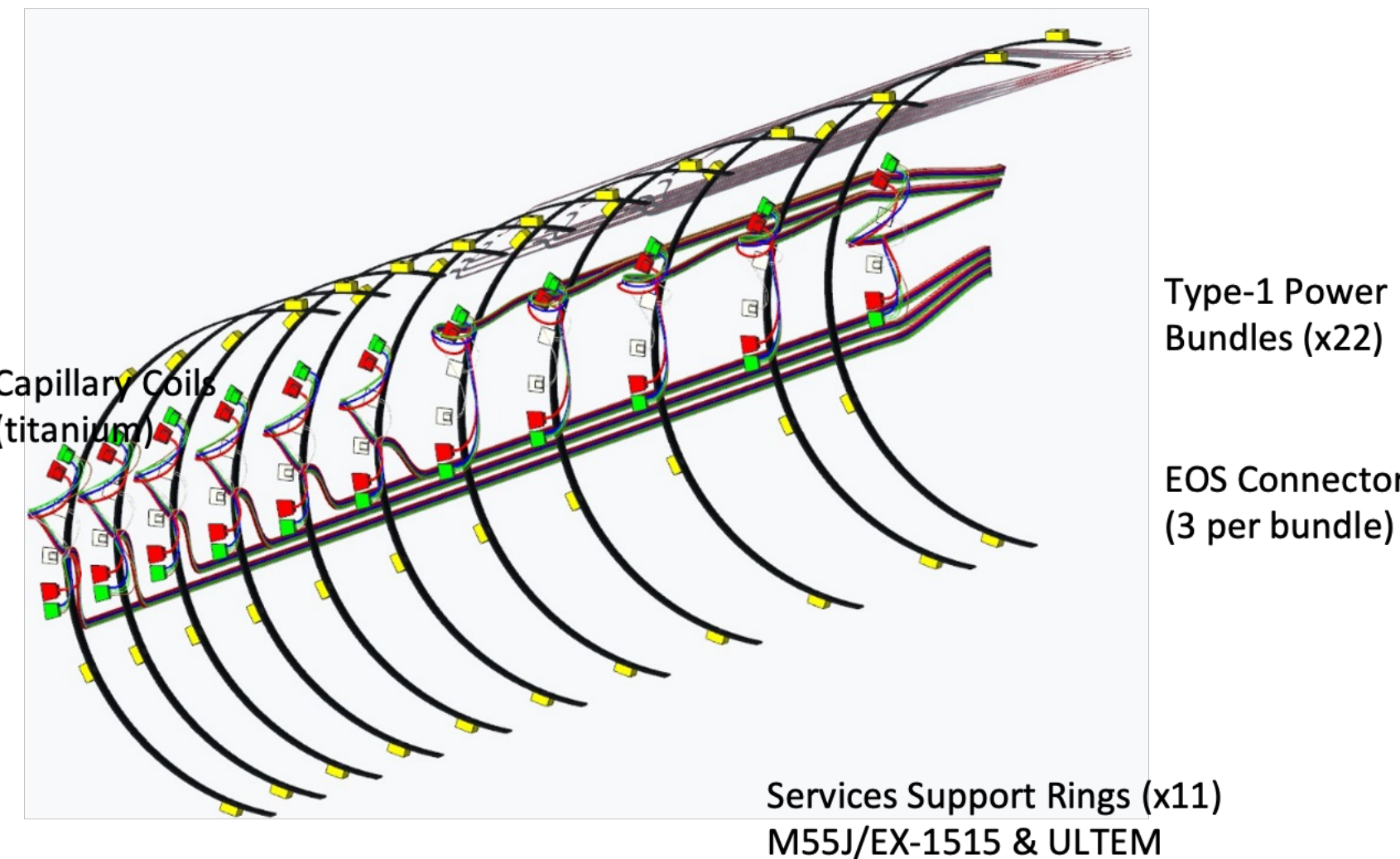
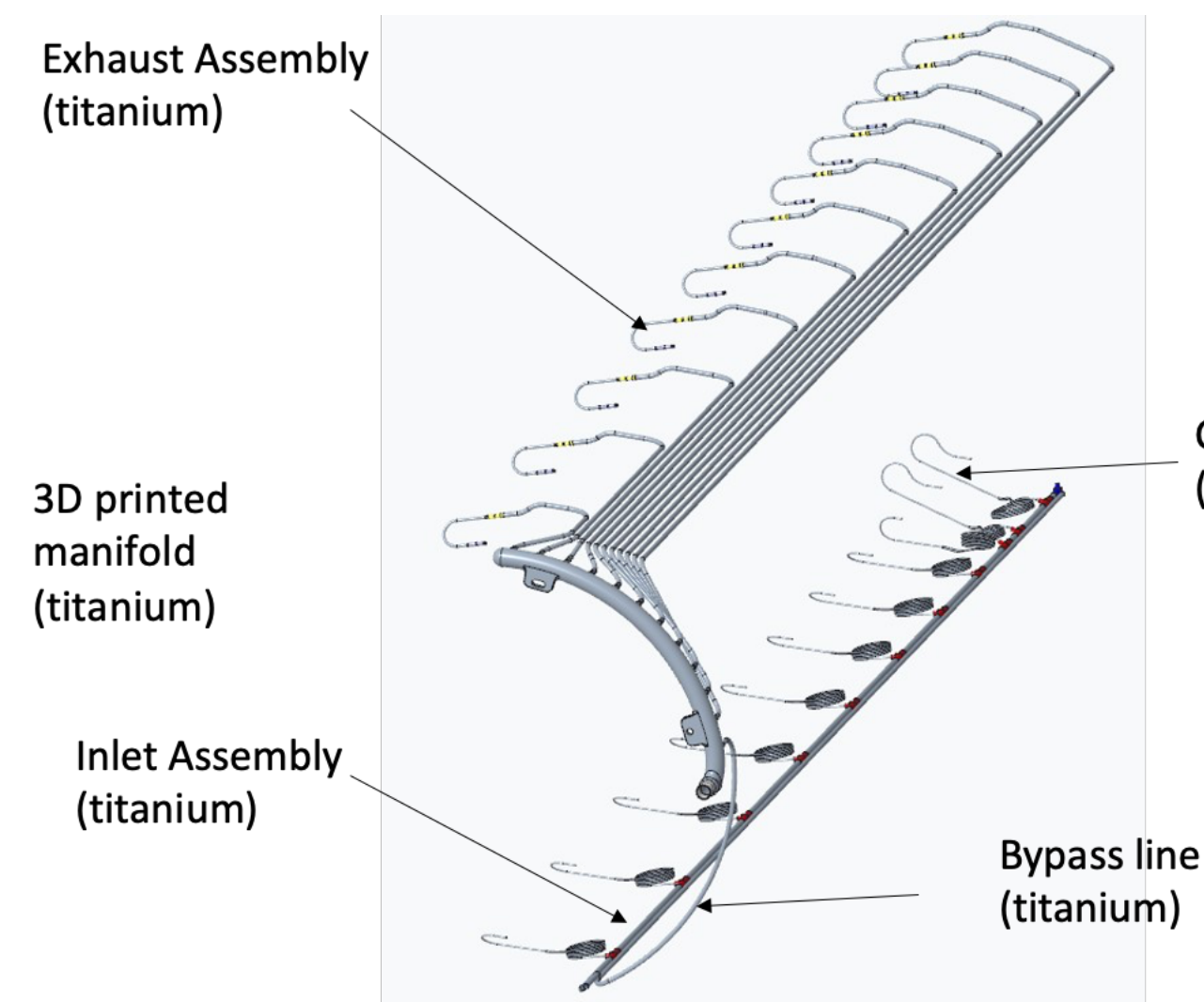
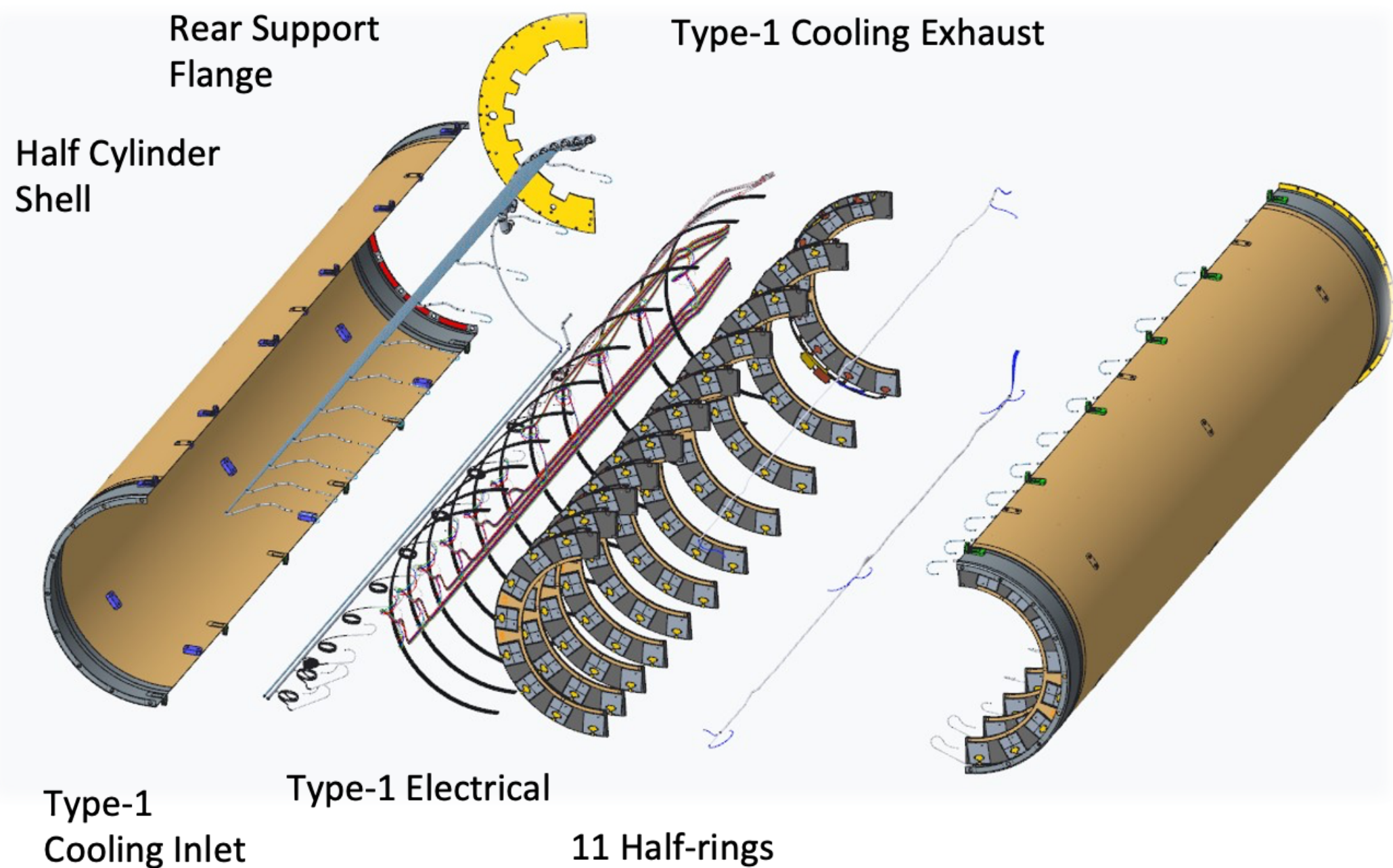
Next year...

- By next year we are hoping to be in full production of cooling loop assemblies. This means Liverpool can produce two cooling loop assemblies a day. Hopefully, in the very near future we will begin the initial ramp of towards full production. This initial ramp will provide enough of a stockpile of cooling loop assemblies that we can deliver large quantities to our UK collaborators and give ourselves a jump start in stave core production. Once all subassemblies are built, we can transition to building full stave cores with the option of building both cores and cooling loop assemblies if the need arises.



Pixel mechanics CAD design and FEA input

John Carrol & James Coleman-Mills



- Full 3-D model of Layer 2 including the services routing and their interfaces between the half-rings.
- Work presented at three Endcap workshops and at the Final Design Review (May 15th)
- The model has been used to ...
- Generate input for FEA and drawings for a full-scale prototype at Milan.
- Work is currently focussed on ...
- Completing the design of the Front and rear Supports, extending the services routing to Layers 3 and 4 and the design of the mechanical interfaces between the Outer Endcap and other Pixel sub-systems.

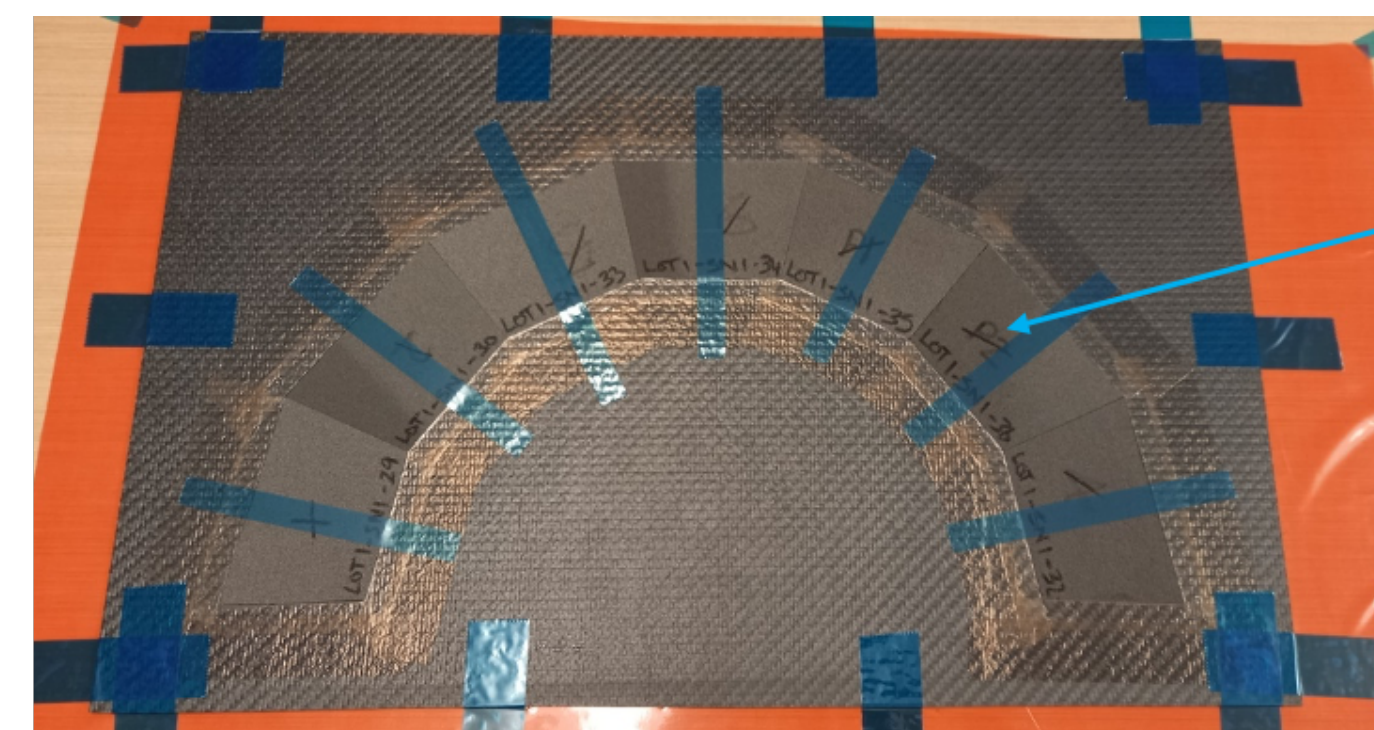
Pixel mechanics assembly in the LSDC and AML

J. Coleman-Mills, T. Jones, W. Jones, P.Sinclair, T. Watling

- **L4 Prototype programme**
- Completed the assembly of a full-length prototype of the Layer 4 half cylinder.
- The primary aim of the programme was to complete the manufacture of the half-cylinder assembly tooling, commission it and evaluate its suitability.
- A core part of the programme was the manufacture of a prototype which will be used for integration studies at Frascati.

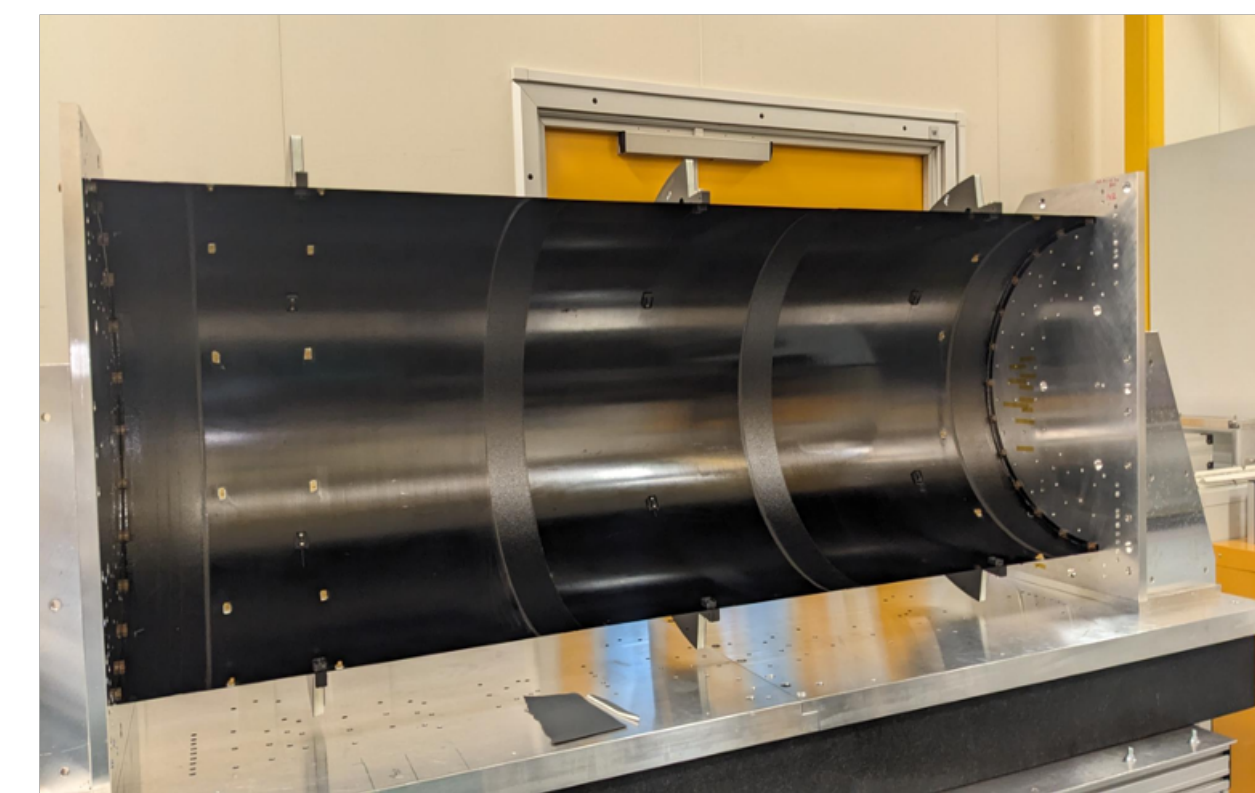
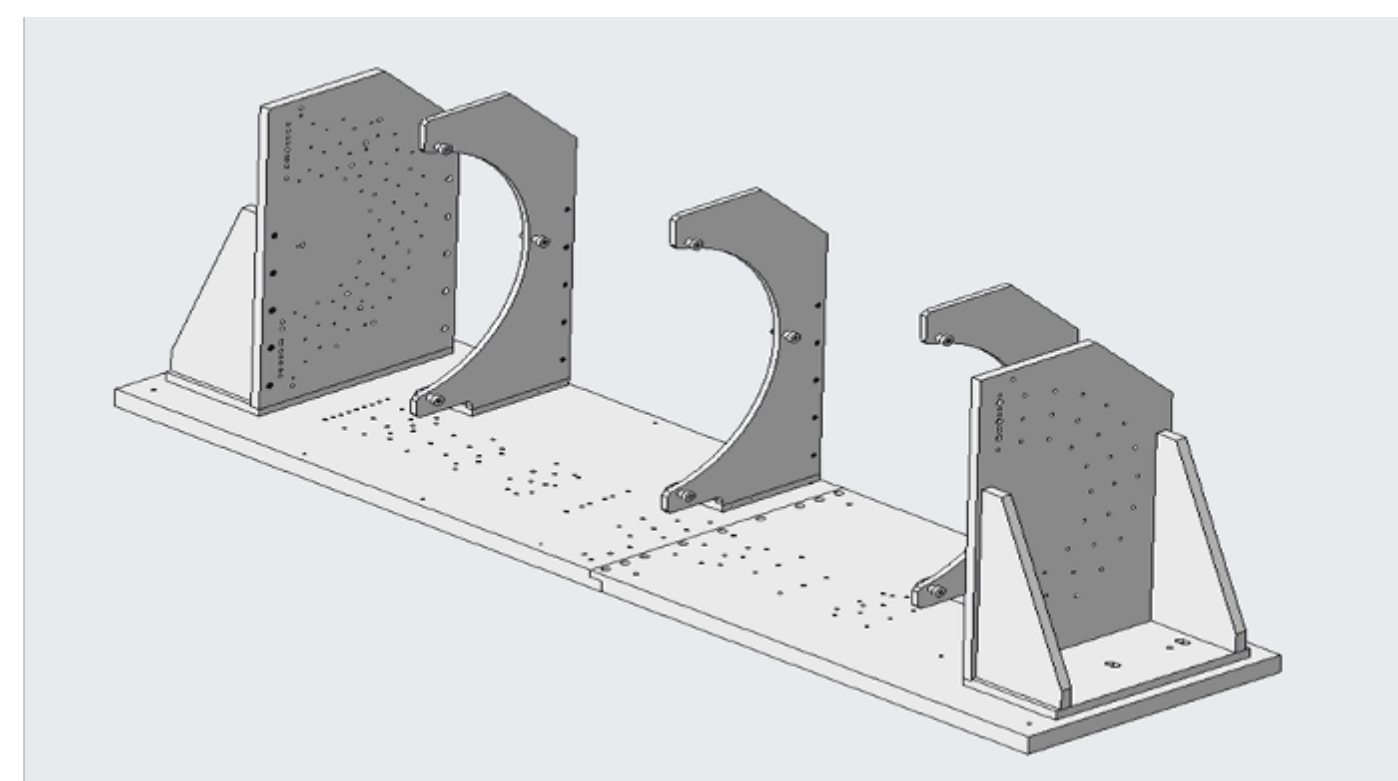
- **Work is currently focussed on ...**
- Fixing some of the short-comings in the tooling to improve dimensional accuracy and stability and fully documenting the precision of the

Pixel Half-ring Co-curing in the AML



Thermally-conducting foam

Carbon-fibre frame (waterjet cut in Mech E)



Layer 4 Half-cylinder Prototype design, manufacture and assembly

- All parts manufactured by DFF to tight tolerances
- Issue has been in assembling end-towers and positioning jigs to equal precision – making extensive use of 3D metrology



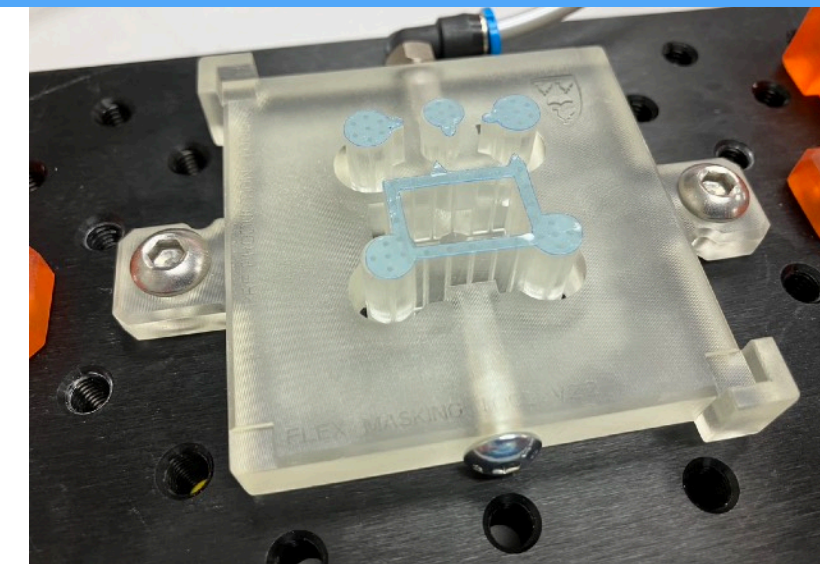
Pixel modules - assembly

- Pixel modules jointly organised in the UK by Liverpool (J.Taylor) and Oxford (D.Bortoletto)
- Parts and assembled modules passed around the UK as follows:
 - Edinburgh: Hybrid QC
 - Lancaster: Sensor QC
 - Glasgow: Module building and testing, hybridisation (flip-chip)
 - Oxford: Module building and testing, module loading
 - RAL: Module loading and hybridisation (flip-chip)
 - Liverpool: Module building and testing, parylene coating

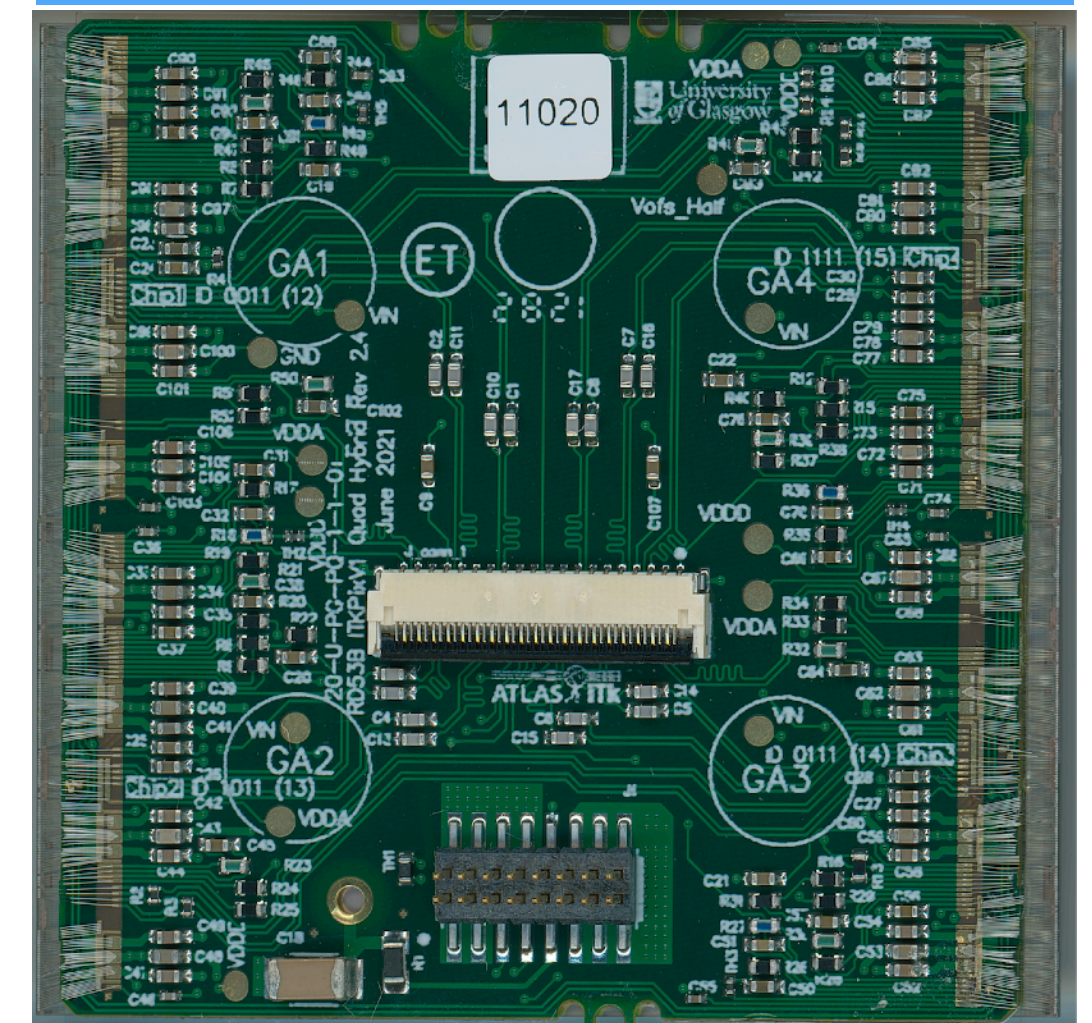
New resin printer



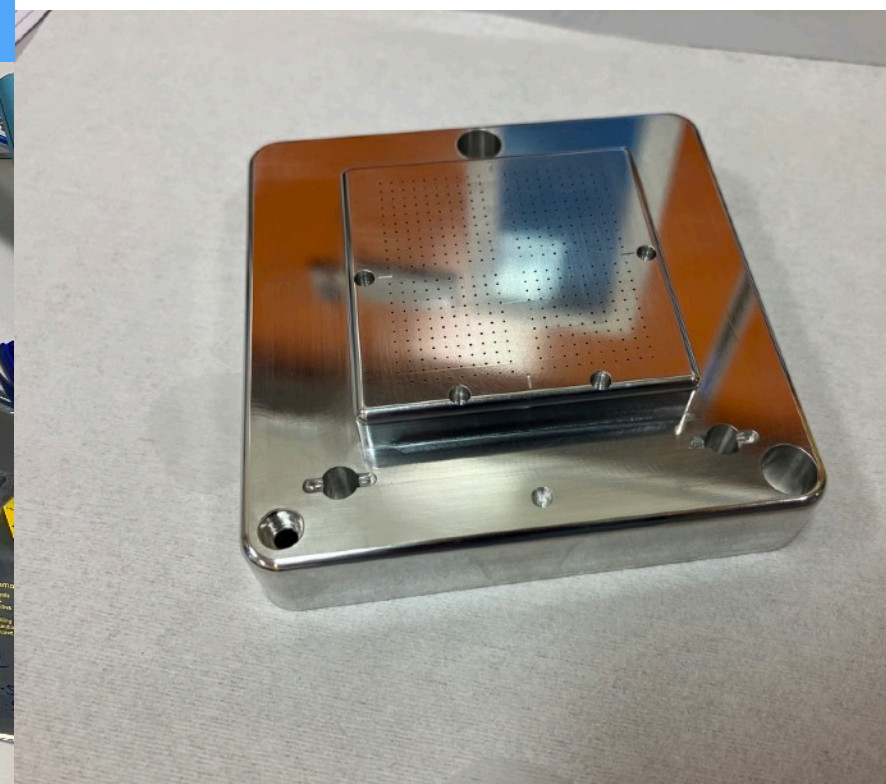
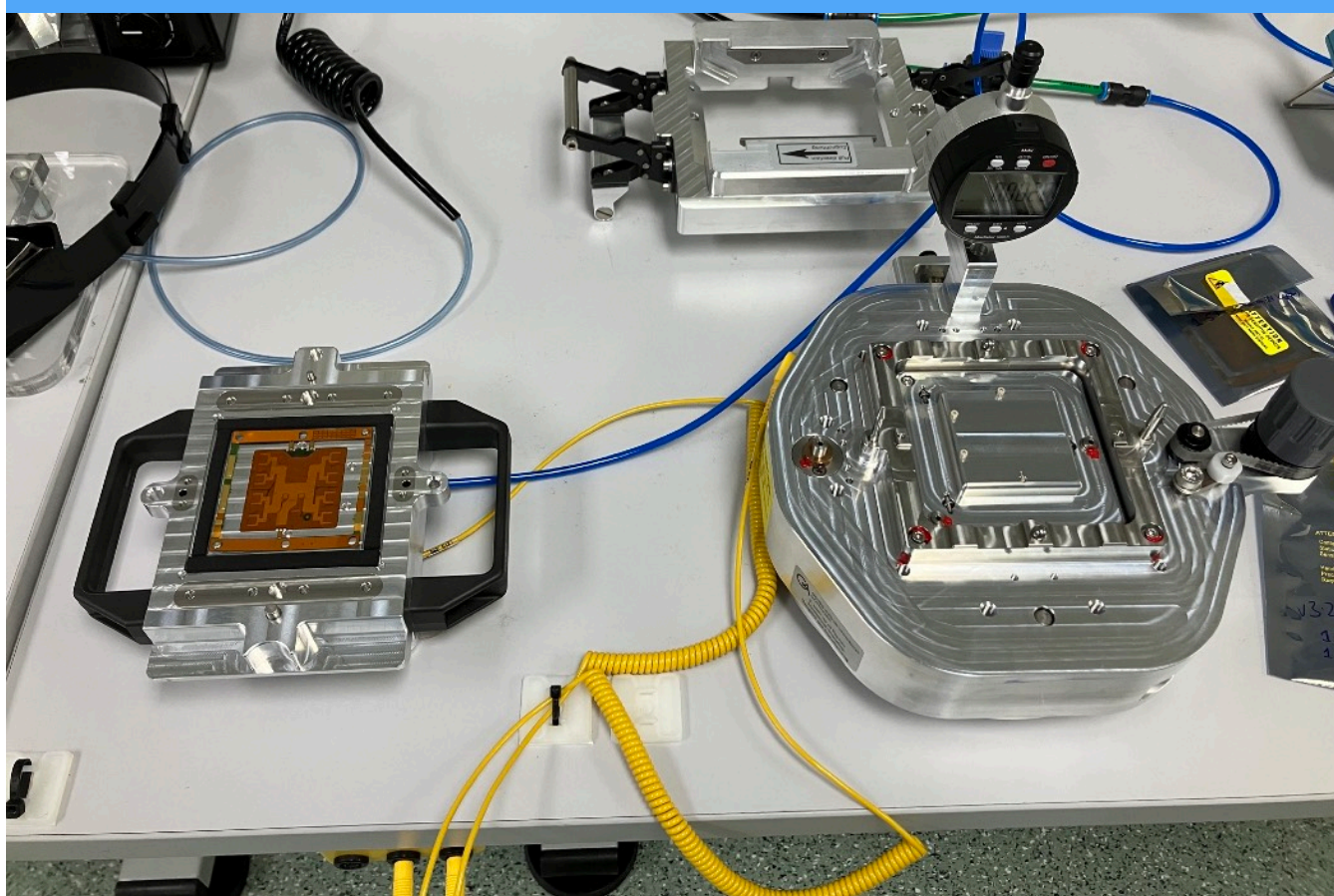
Resin vacuum tooling
~25um resolution



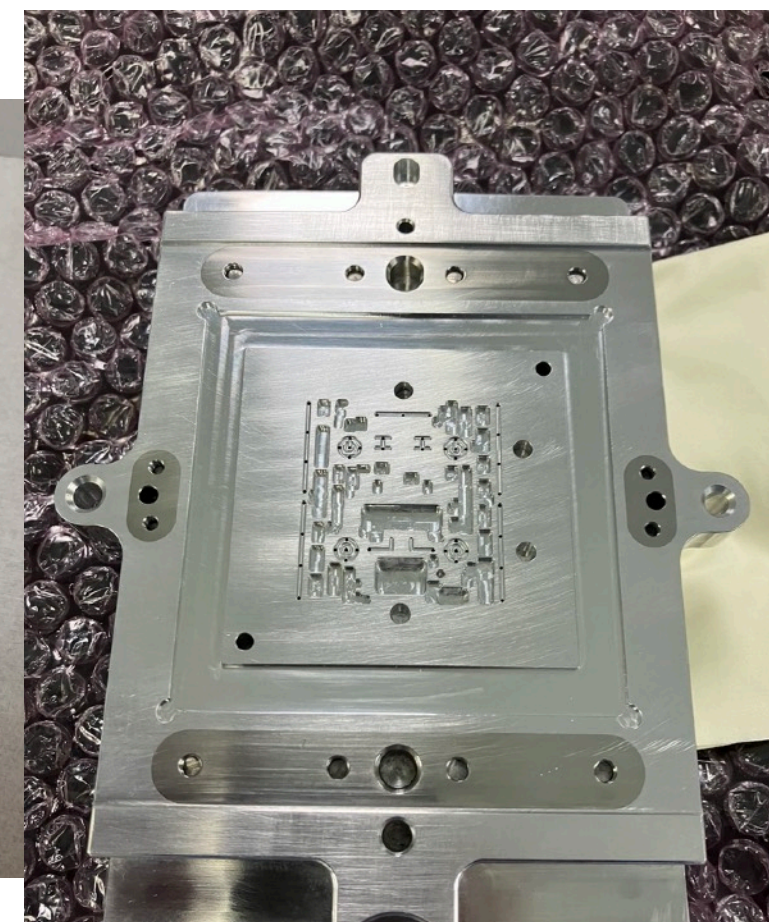
Assembled ITkPix quad - we need to make 500!



ITkPix tooling for Pre-production x4

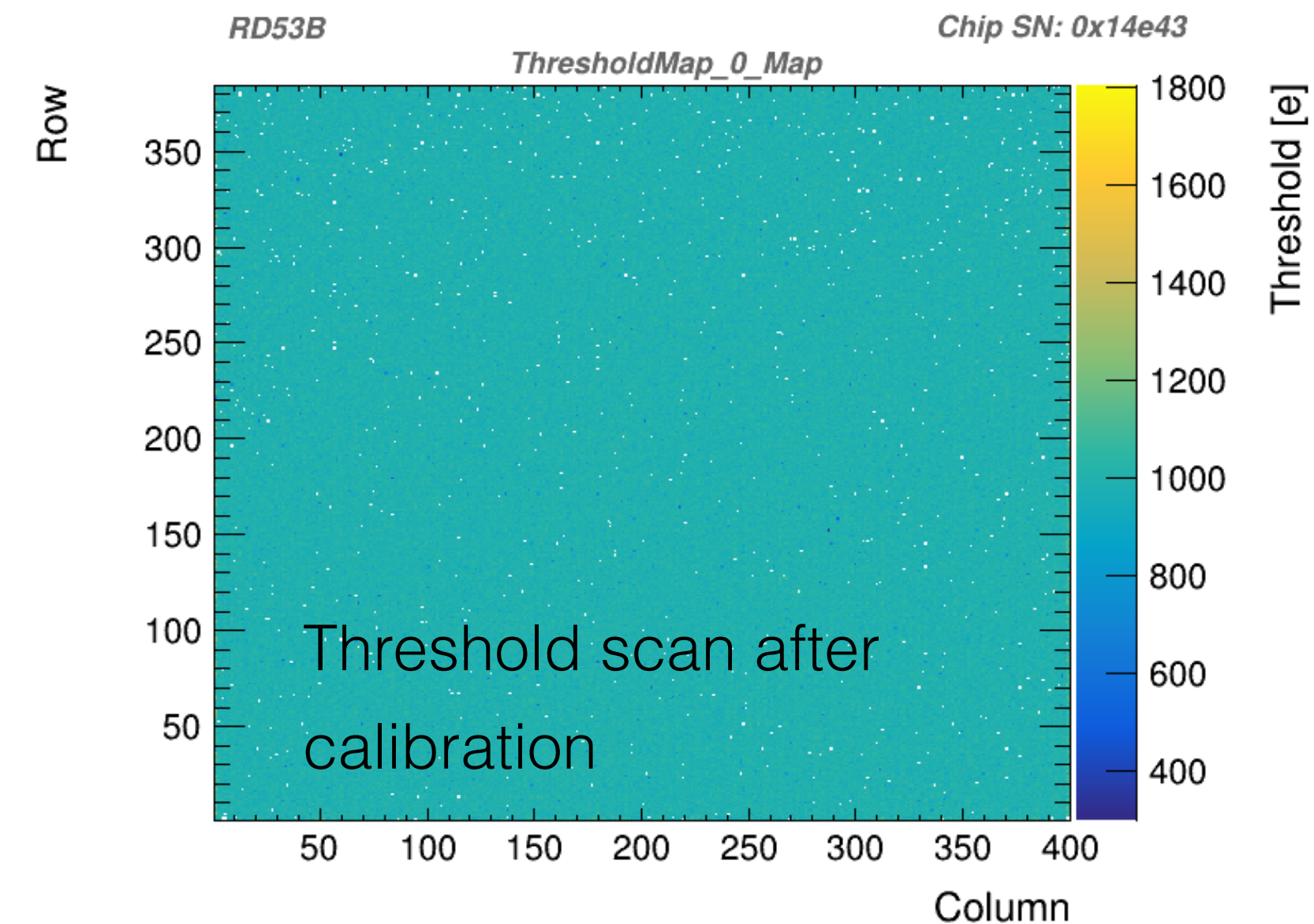
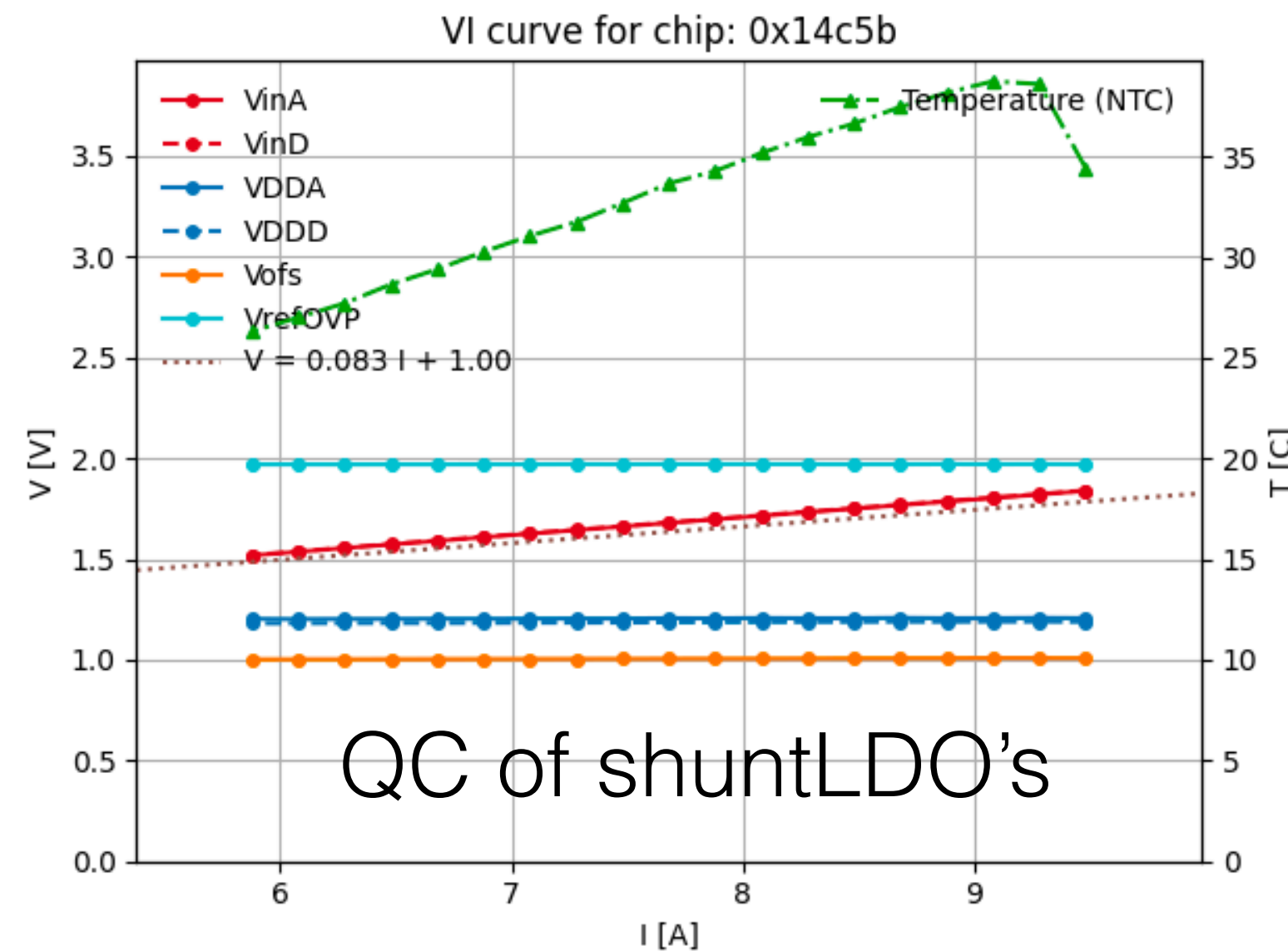


Metrology tooling (DFF) < 10um precision!

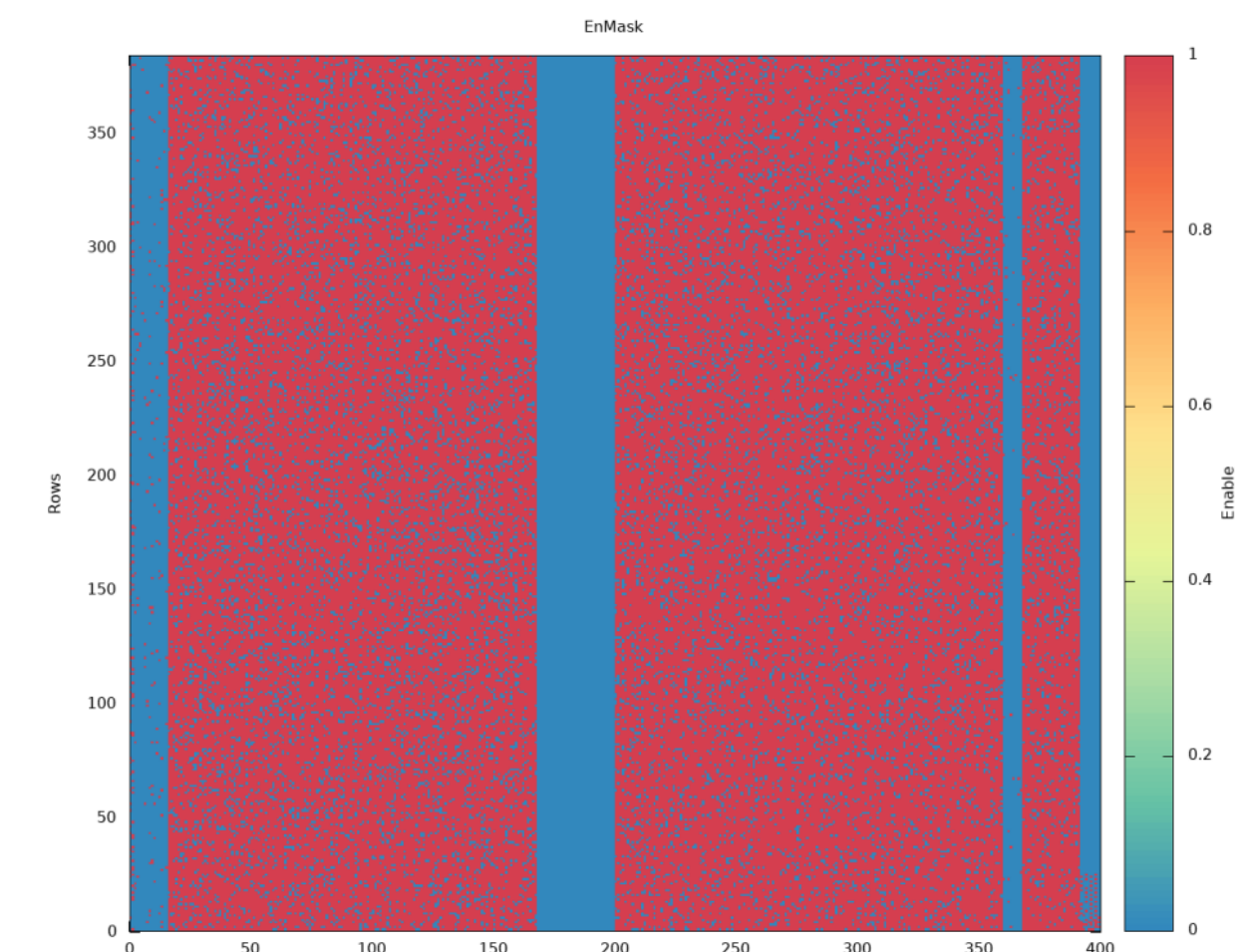


A. Bukowski,
D. Hollywood,
A. Kumar,
J. Taylor,
M. Whitley

C.Gwilliam, .P. Dervan, A.Taylor, J.Taylor, A.Bukowski, D.Vazquez



- Pixel modules planned to be tested in batches of four (need to test ~8 / week)
- Custom thermal cycling setup (MMCB) developed for thermal cycling in the range -55deg. to +60deg. (modules unpowered) to check for bump bond de-lamination
- Electrical testing of modules carried out close to the nominal operating temperature of -15deg.
- Current version of the chip (used by ATLAS & CMS) shows a problem with roughly ~10% of chips dubbed 'the core column issue' where columns of pixels have to be turned off for chip to work
- Problem only seen after wafer probing -> large yield loss for module production if not understood
- Taskforce to investigate is ongoing, results from the v2 ASIC still being collected

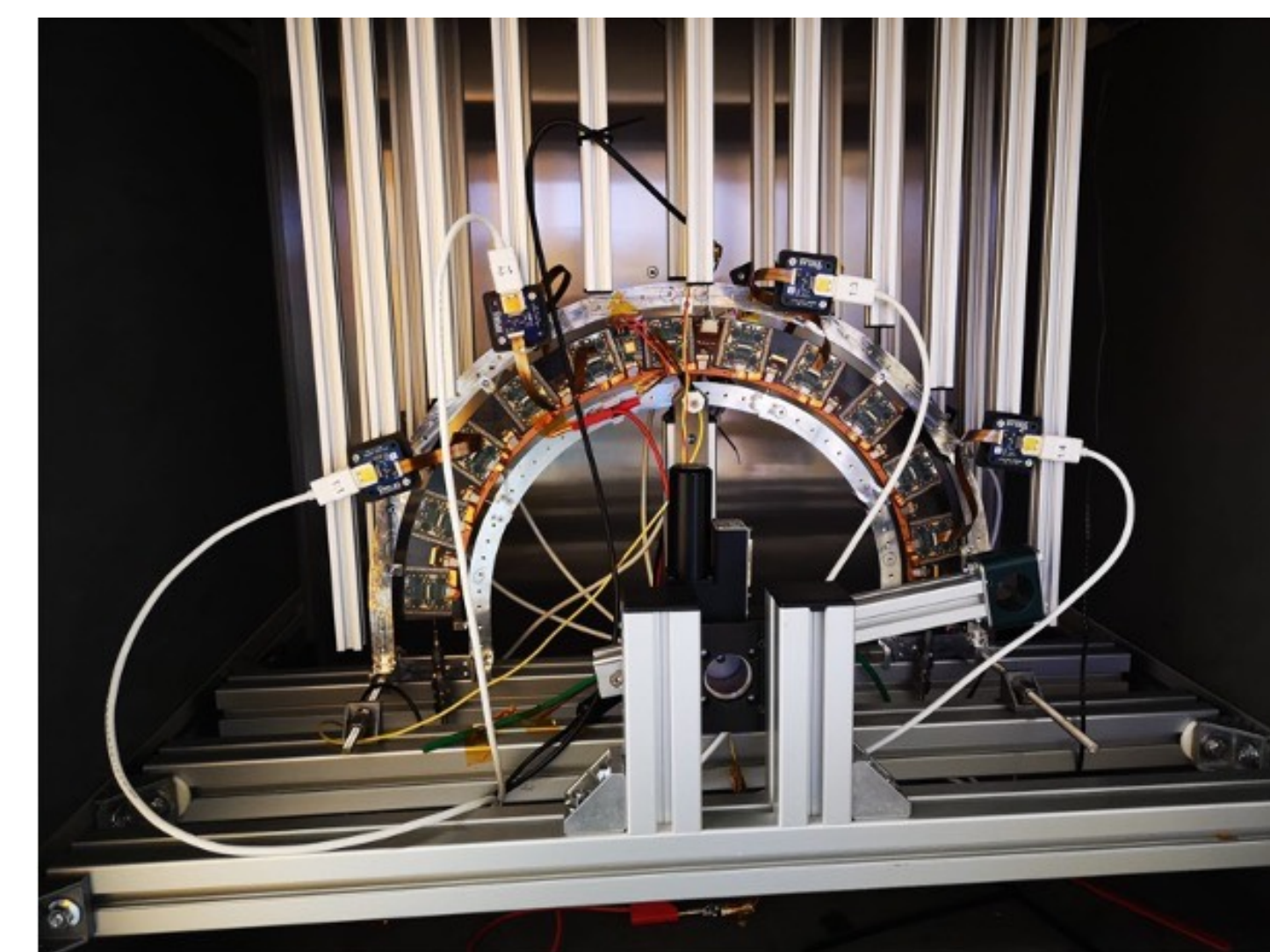
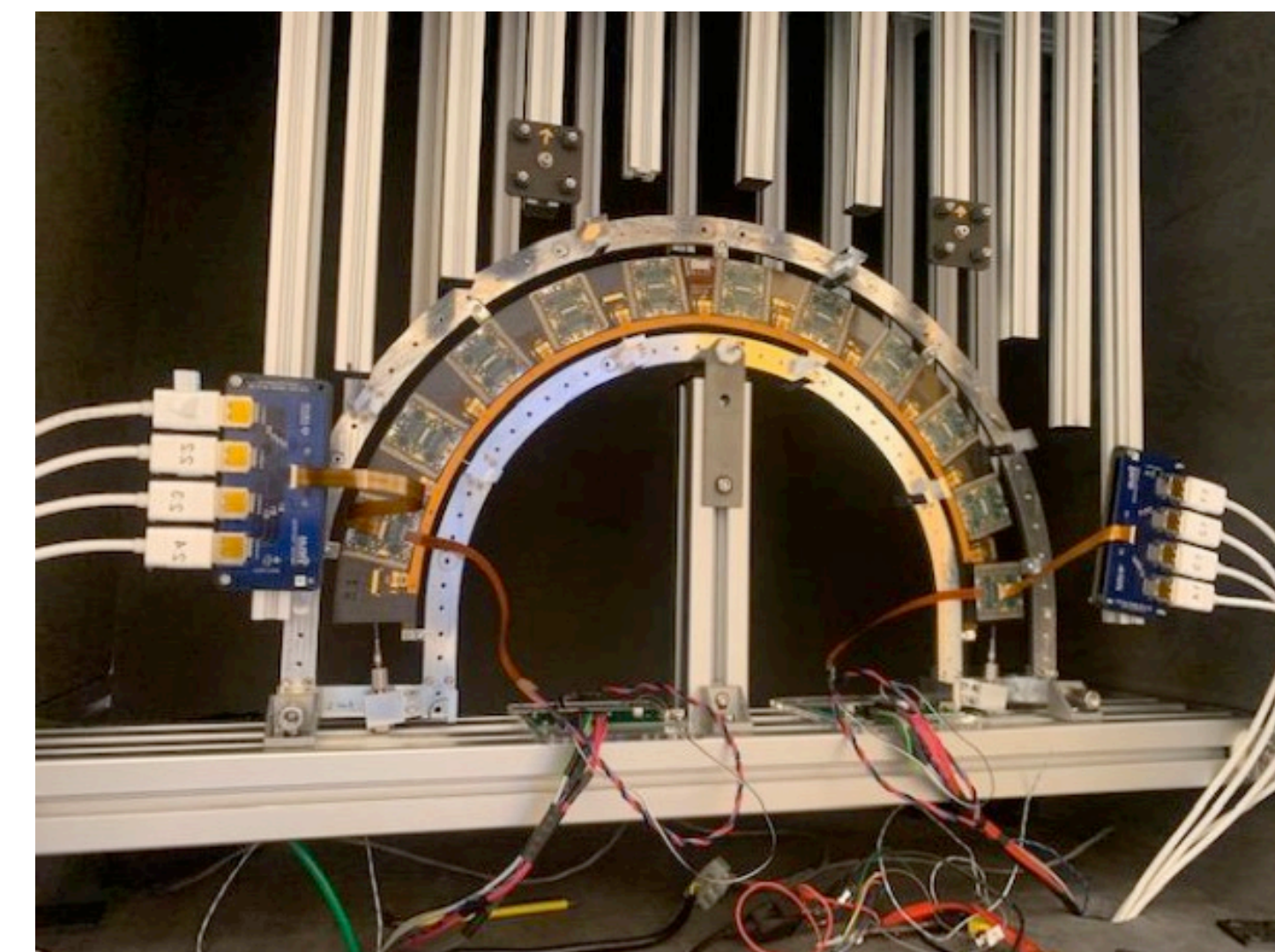


ITkPix v1.1 showing 'Core-column' behaviour

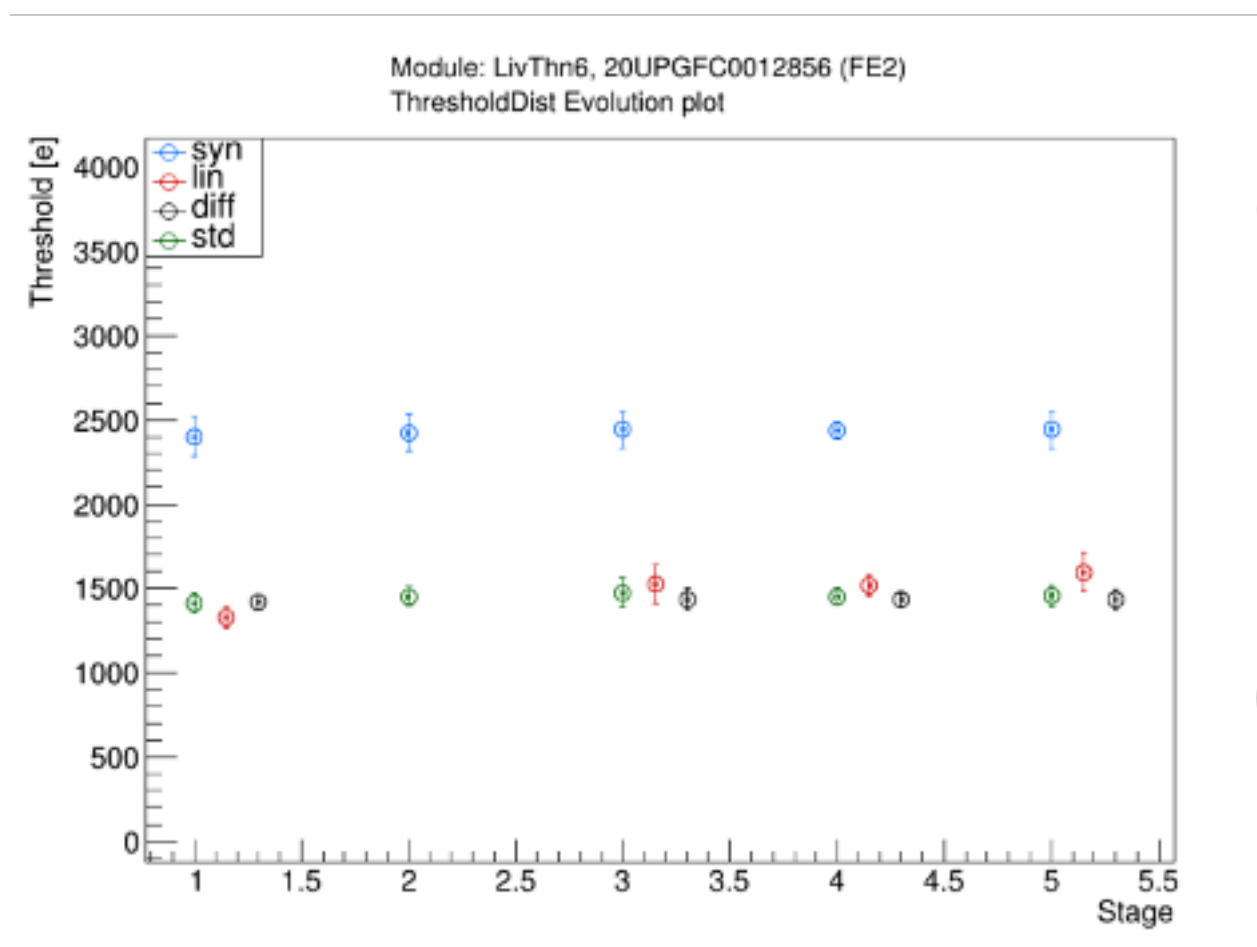


- Since last year Annual Meeting:
- Ring 1 in a Serial Power Chain (SPC): single module readout → multiple module (up to 8 modules)
- Ring 1 testing program was prepared: electrical characterization, source scans, MOPS investigation, thermal camera, noise injection, thermal cycling
- All these tests need cooling to be performed → cooling system was down for some months
- The problem was fixed ~September and the program restarted

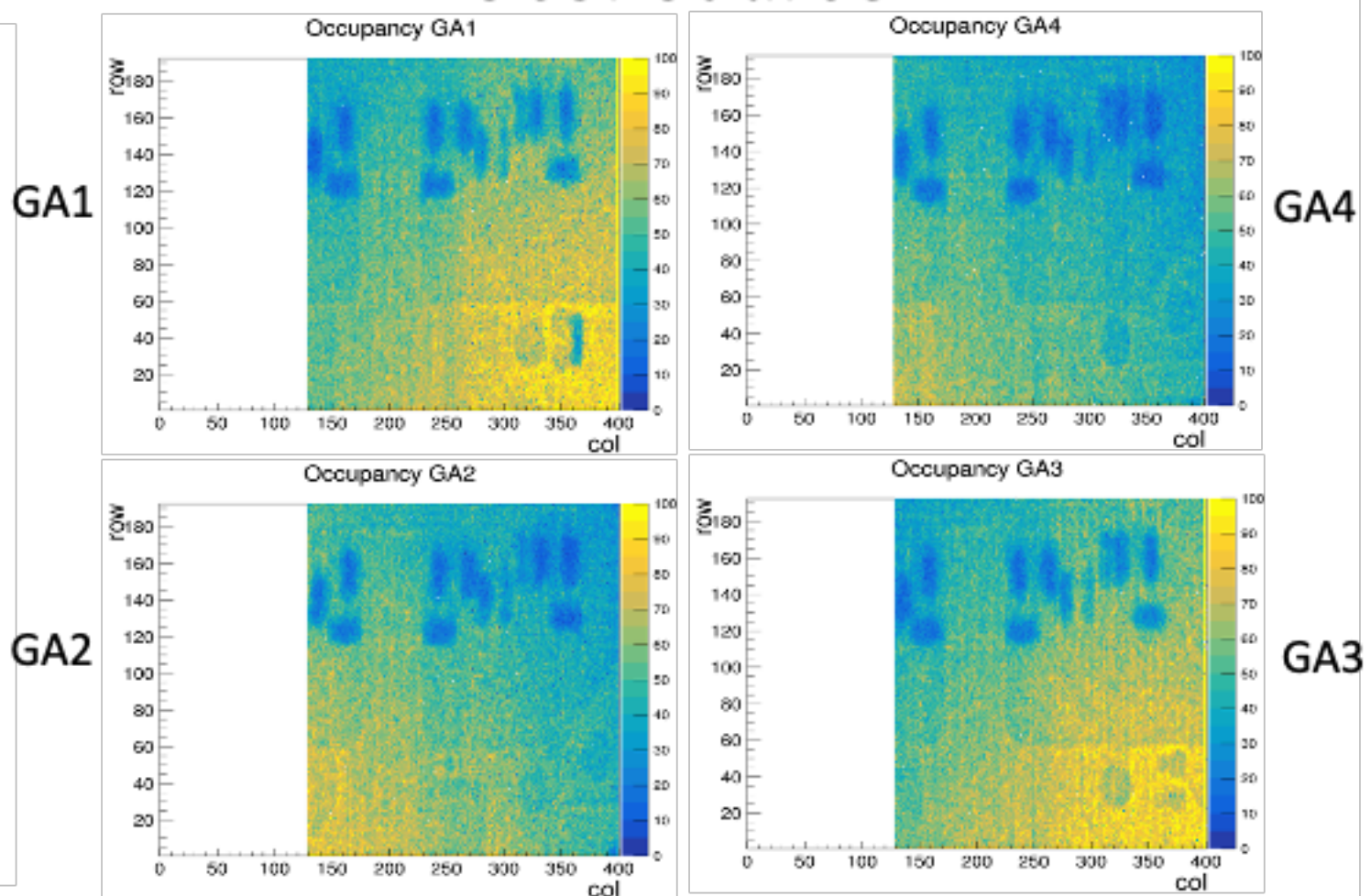
P. Dervan, D.Vazquez, G.Miller (Manchester)



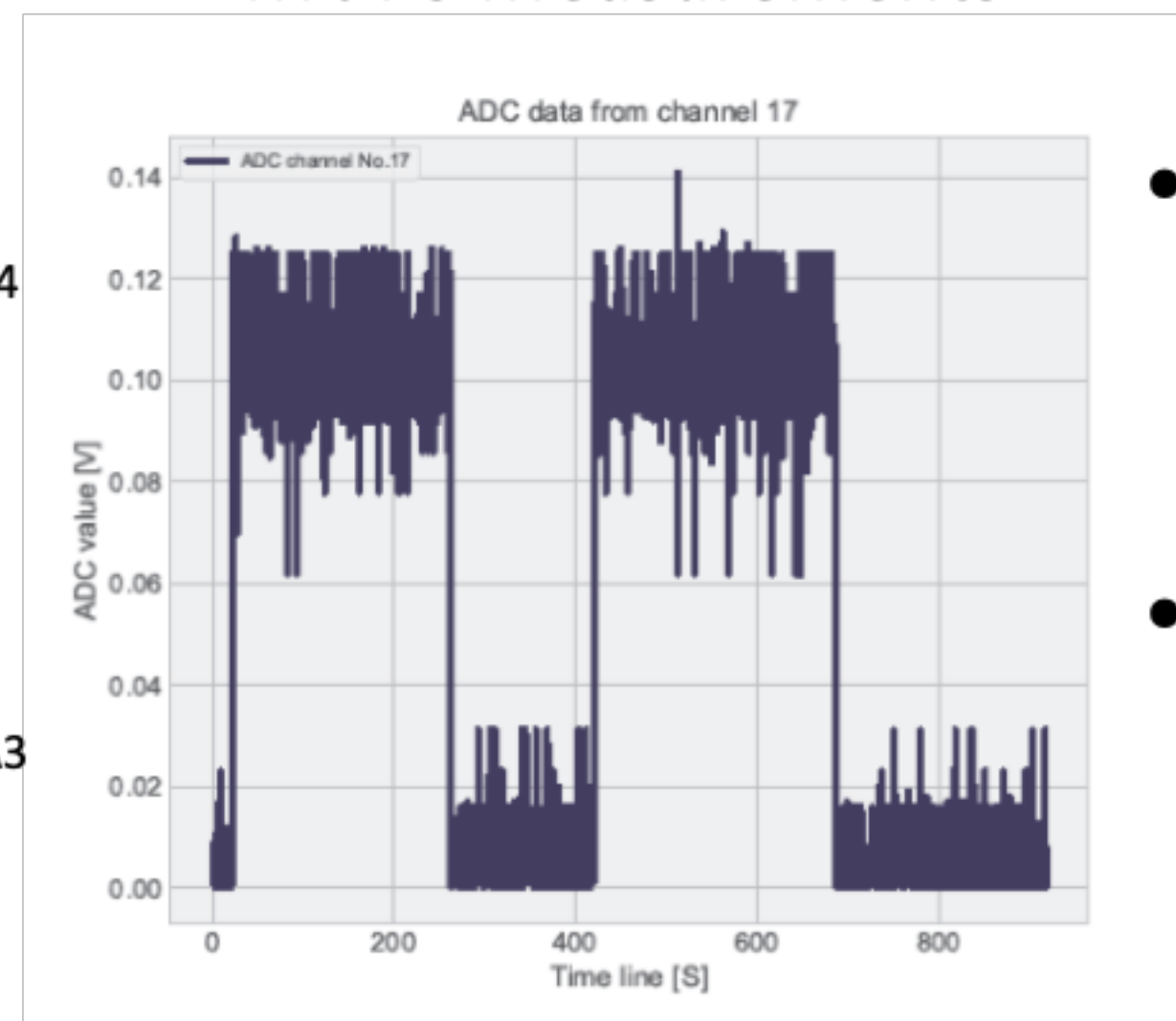
Threshold at different integration stages



Measurements with a 90Sr source

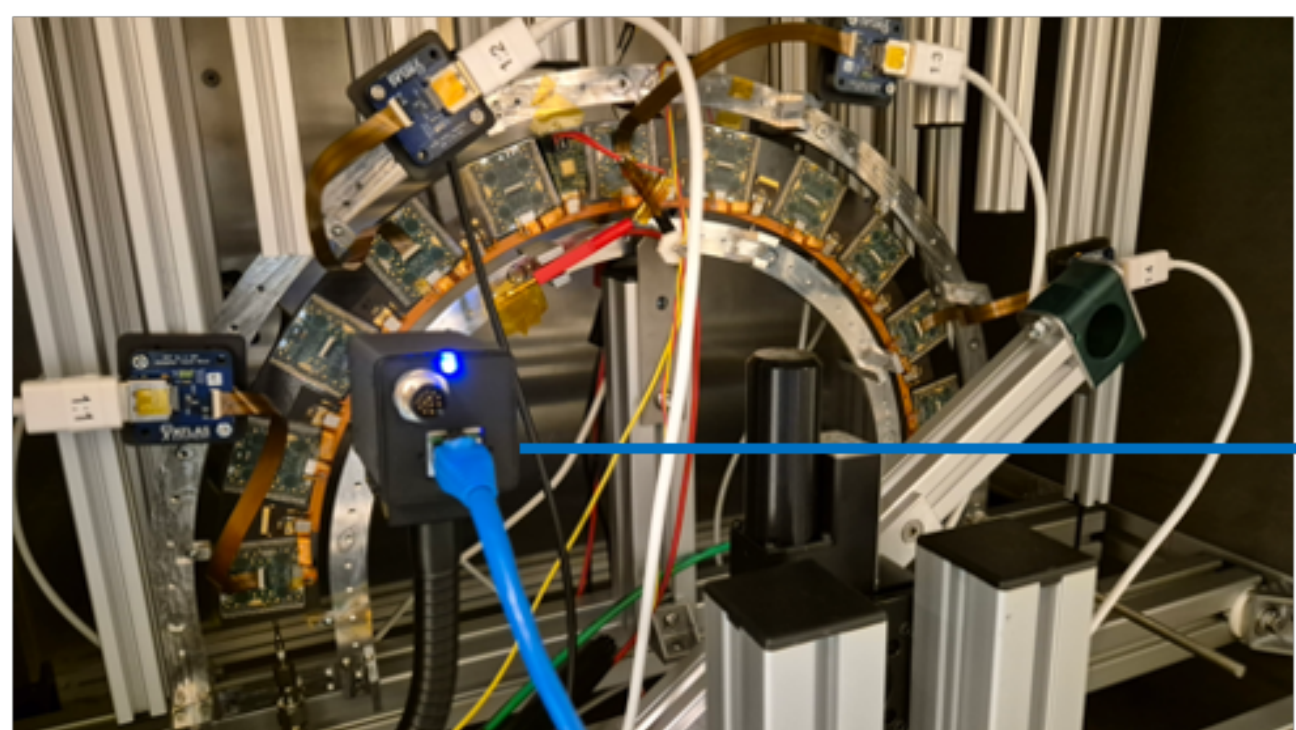


MOPS measurements

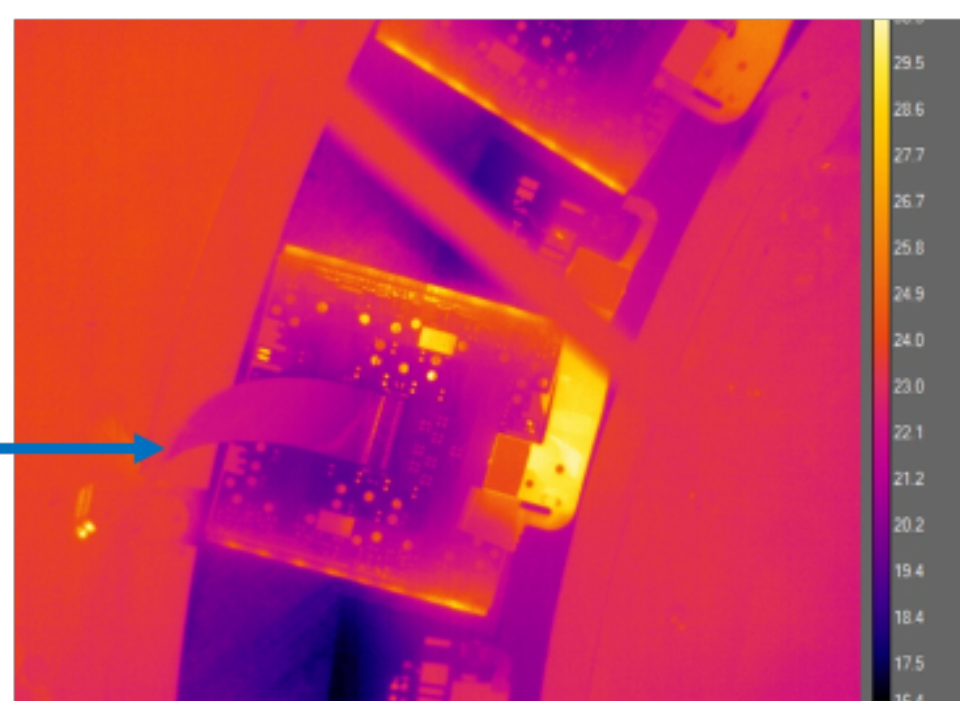


- MOPS measures voltage and NTC across modules in the SPC
- Shows a high level of noise → under investigation

Thermal camera setup



Preliminary results

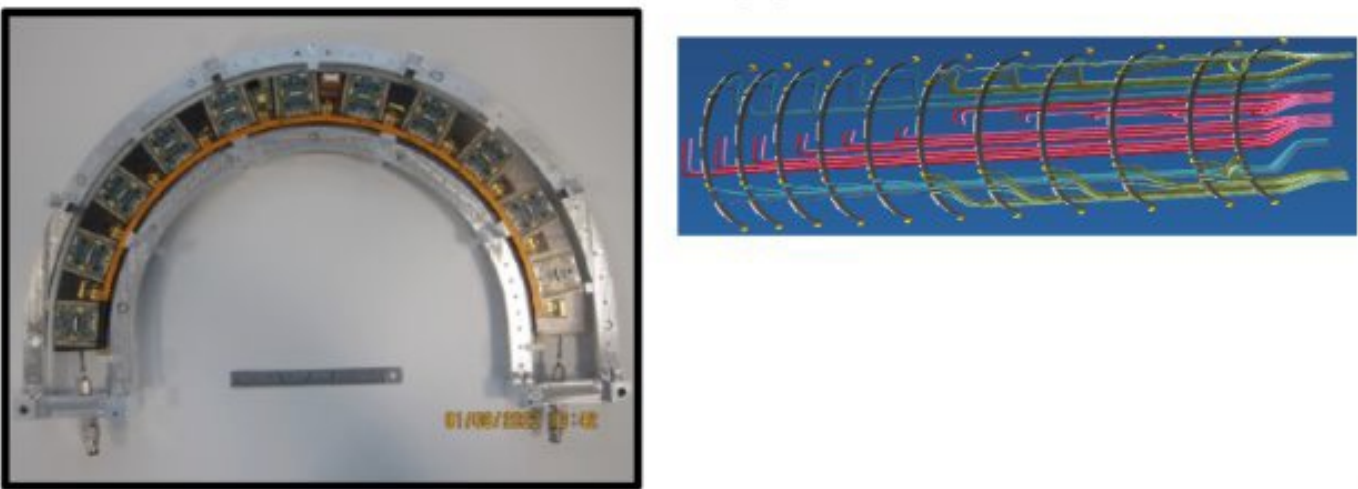


- To be done:
 - Noise injection
 - Thermal cycling

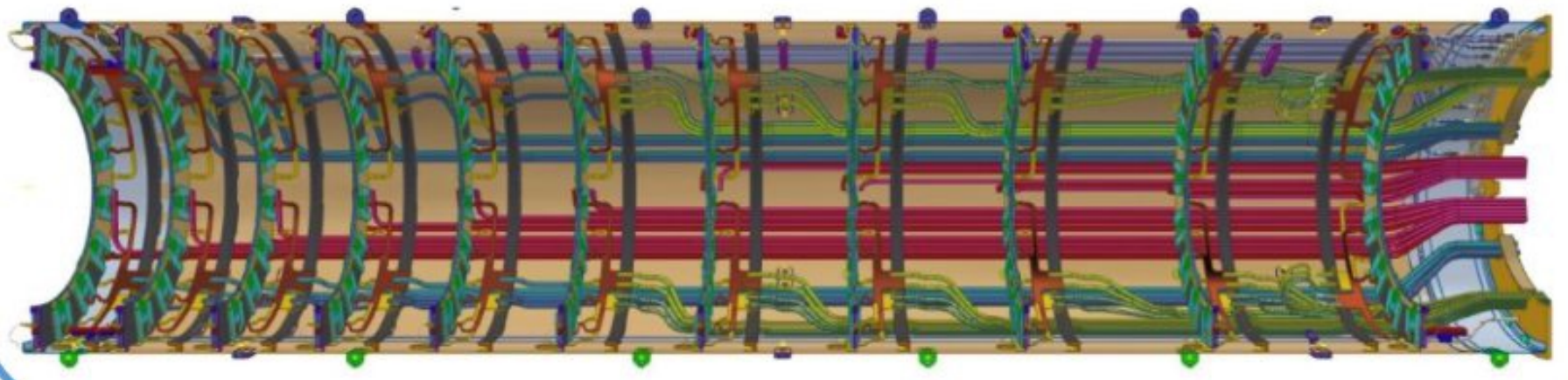
Pixel integration... how it started

OEC Integration process requires mechanical assembly and testing

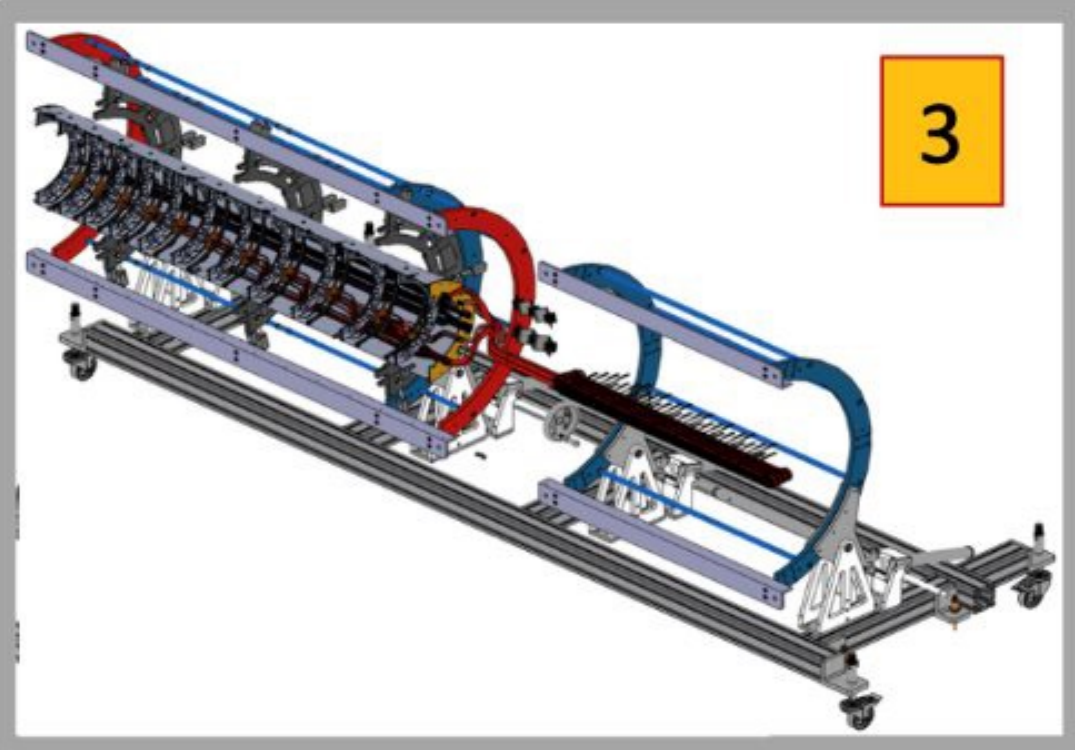
Reception tests of **1**
Half-rings type 1-services



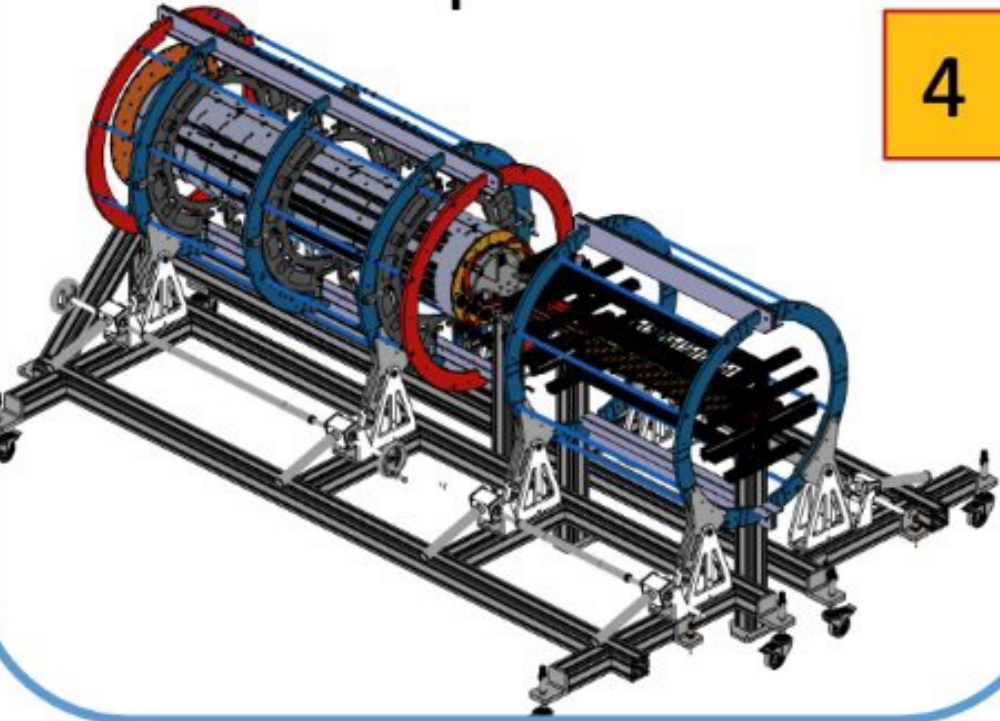
Insertion type-1 services and Half-rings on Half-Shells **2**



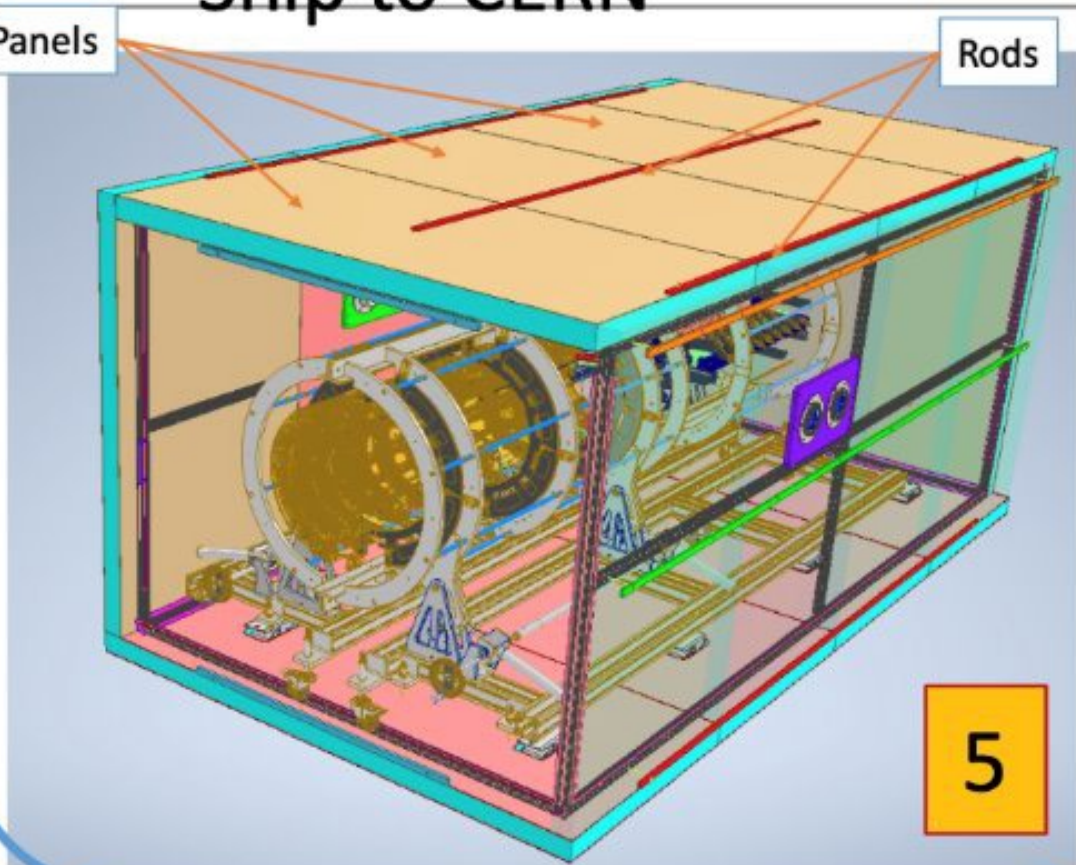
HS test – thermal cycle -- test **3**



Test on Complete Layer/ Full Endcap **4**



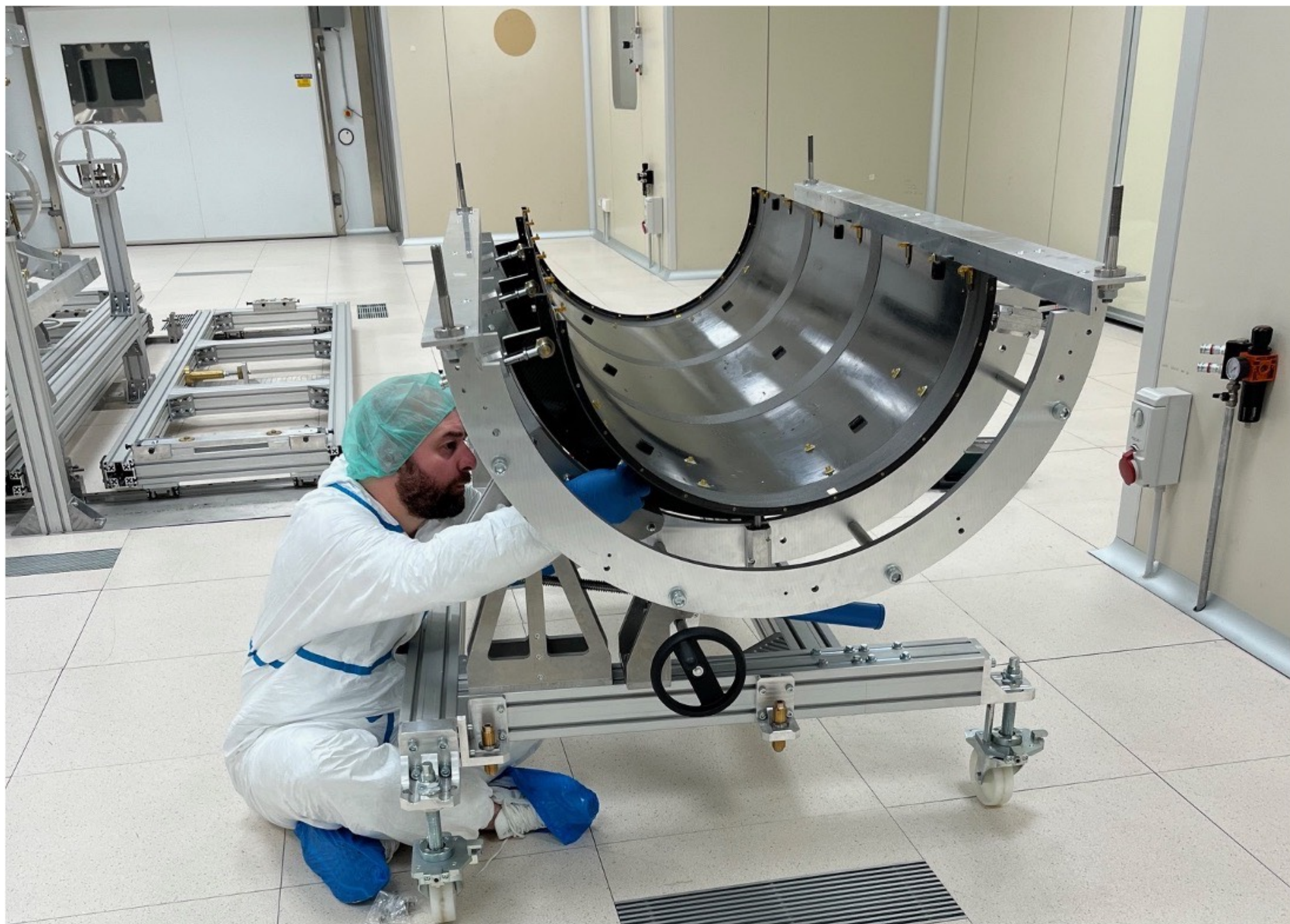
Ship to CERN **5**



H.Hayward, T. Jones, M. Brown



Pixel integration... how it's going



Half-cylinder in Frascati



Liverpool ITkWeek@Spine 9th-13th Sep



ITk Week at Liverpool

- Liverpool hosting ITkWeek at Spine in September
 - Approx 250 people expected



- ITk muddles on!
- Lots of the Final Design Reviews (FDRs) are now complete and several Production Readiness Reviews (PRR's) are also complete or scheduled as the project transitions from pre-production to production
- It's encouraging to see *'myth become fact'* as parts transform from the realm of drawings and models to become tangible objects in the lab
- (Pre-)Production has thrown up some *interesting* new problems:
 - Cold-noise
 - Cracking of modules
 - Core-column issues
 - To be expected that some subtleties will emerge as statistics are gathered in production and system level effects emerge
- It's exciting to see Global Mechanics structures for strips and pixels are now being assembled and measured in the LSDC and AML
- At some point we will crawl over the finish line and surprise everyone including ourselves!

