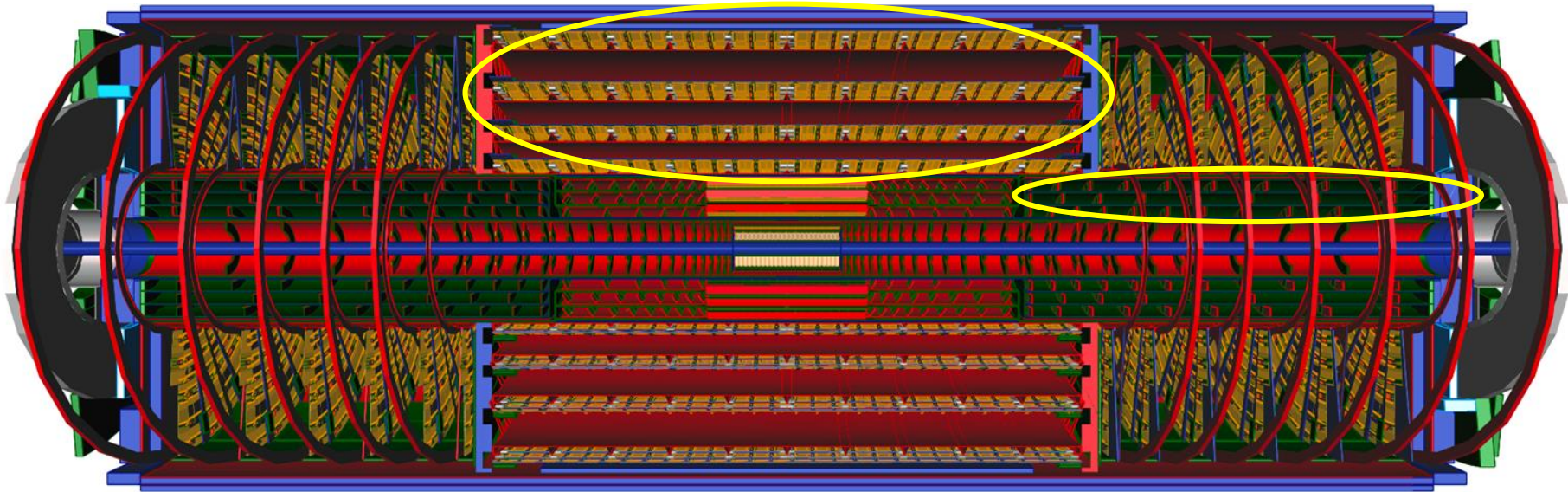


ATLAS Upgrade

Particle Physics Annual Meeting 20/05/2022

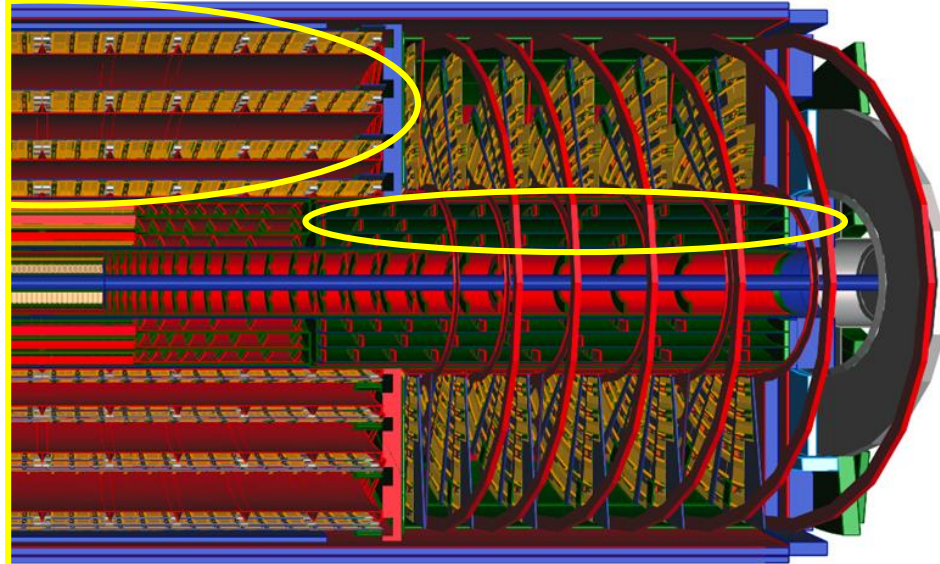


What are Liverpool Doing?



What are Liverpool Doing?

- Module production for both the ITk barrel strip detector and the endcap pixel tracker;
 - 15,000 strip hybrid reception testing
 - 3000 hybrids ASIC loading and wire bonding
 - ~580 strip modules
 - ~400 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
- Coordination of the development of the overall core ITk software.



Who are we?

- Liam Boynton
 - Paul Dervan
 - Ashley Greenall
 - Carl Gwilliam
 - Helen Hayward
 - Tim Jones
 - Dave Sim
 - Paul Sinclair
 - Jon Taylor
 - Sven Wonsak
-
- The team in the DDMF

Welcome:

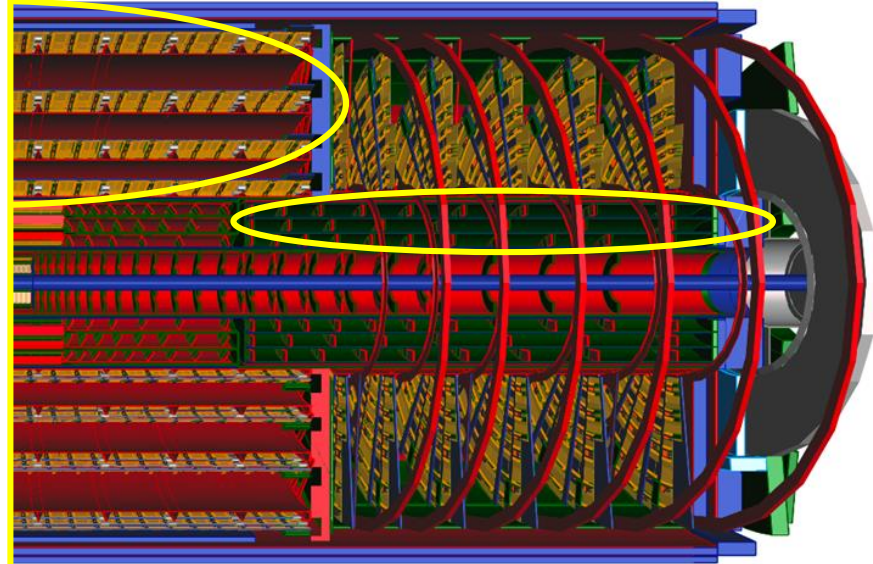
- Phil Timko, Warren Jones, Manex Ormazabal
- John Carroll (pixel engineering)

Thanks to:

- Peter Sutcliffe, Marcin Poblacki,
- Peter Cooke, Ilya Tsurin

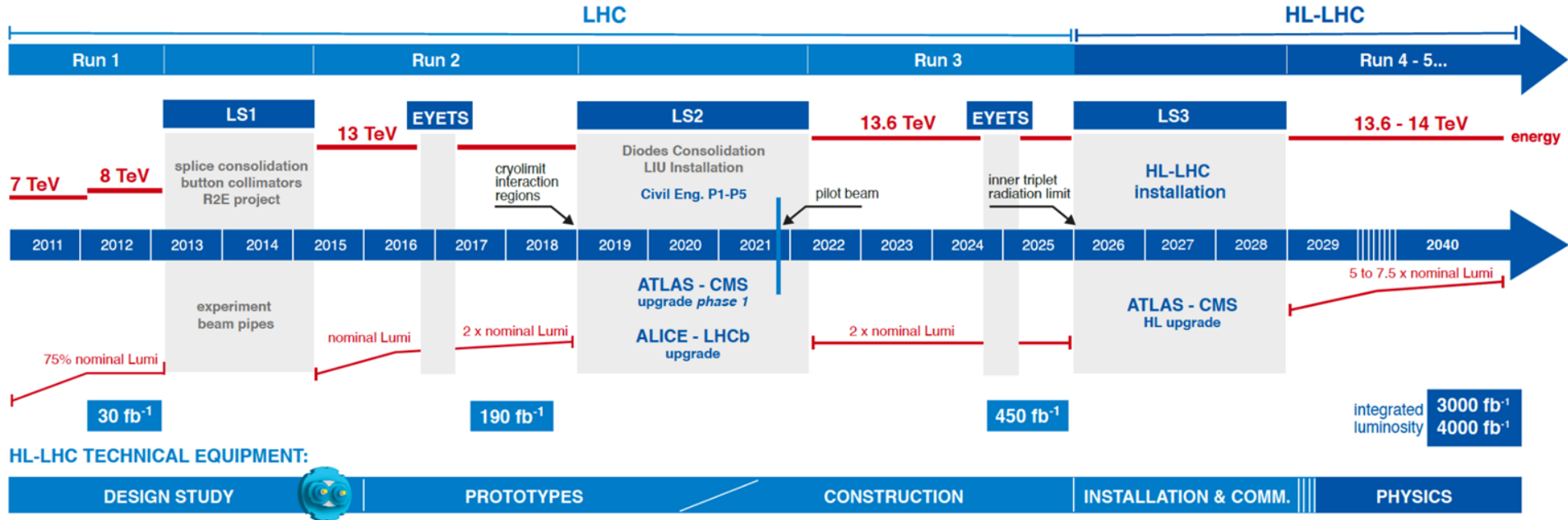
Students:

- Conor, Ting, Adam, Ricardo, Alessandro, Matt, Hamish, Jake
- James



(new) HL-LHC Schedule

we have only 4 years to go before every thing needs to be at CERN



ITk need by date moved to 25/02/2028

Software

Helen Hayward is the strip sw co-ordinator

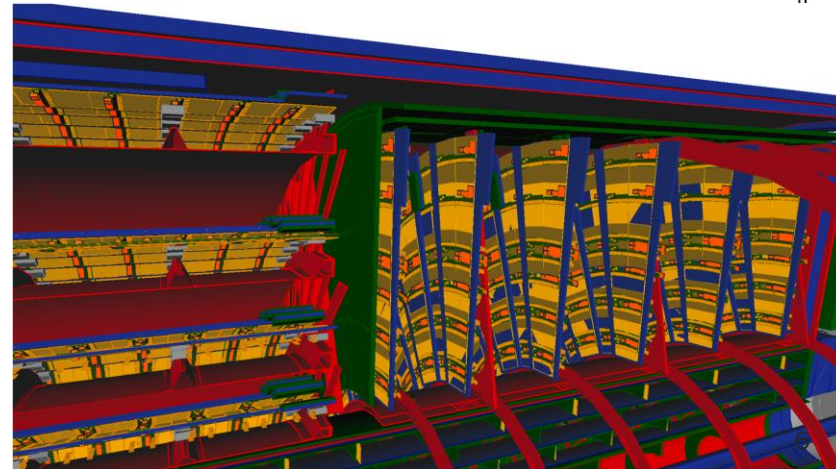
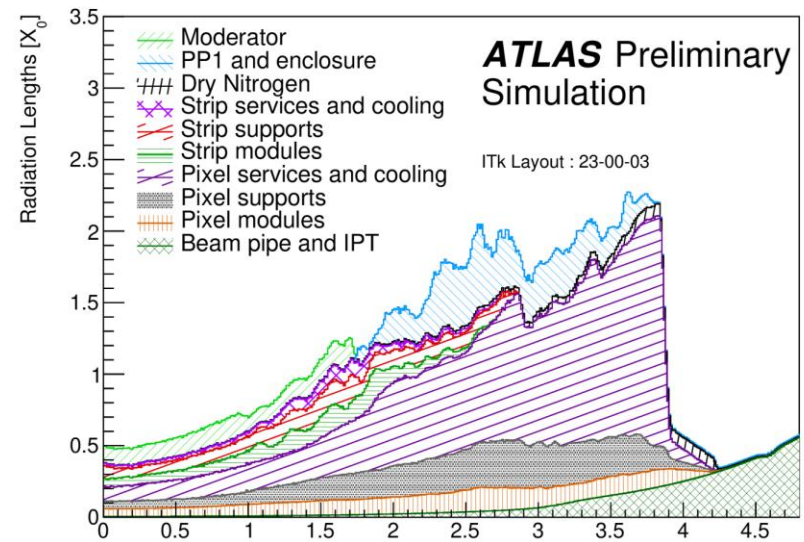
- Currently also acting-ITk-SW co-ordinator

Major program has started to update the entire ITk SW geometry with comparisons the pre-production items

- To be repeated when production starts
- Accurate material simulation is crucial to efficient commissioning and early physics results

Discussions started with production DB experts to get easier access to measurements

James Smith is doing his QT on strip software.



Production Database

- During production, all info on the components must be tracked via the Production Database
 - Components parts, assembly stages, test (metrology, electrical, ...), configuration, shipping etc
- At Liverpool, we have made significant progress towards the end-to-end use of the database (Carl)
 - Successfully registered pixel modules, strip hybrids and recently strip staves, and linked to children
 - Able to format + upload majority of test results
- Have developed scripts to analyse test results, automate registration + upload to the database
 - Several of which are now shared centrally
- Once the information is in the database it is crucial for tracking production + seeing trends
 - Conor produced a web-based pixel reporting app to produce automated tables/plots in various forms
 - Successfully qualified as ATLAS author and now extending to strips + reporting as a function of time

Pixel Module Example

The screenshot displays a web interface for a 'Pixel Module Example'. The main content area is titled 'Component Details' and shows information for component '20UPGM20025052'. The component is identified as 'Module - Outer system quad module'. The 'Basic Info' section lists: ATLAS Serial Number (20UPGM20025052), Alternative Identifier (No alternative identifier), Component Type (Module), Type (Outer system quad module), Current Stage (MODULE LOADED), Current Location (STFC Rutherford Appleton Laboratory), Shipment Destination (No current shipment destination), and Home Institute (University of Liverpool). To the right, the 'Properties' section lists: PCB-Bare Orientation isNormal (true), FE chip version (RD53A), and Thickness (Thin). Below the component details, the 'History' section shows a list of stage events: 'Module loaded' (02/05/2022 09:20), 'Reception at module loading site' (02/05/2022 09:20), 'Module completed' (11/03/2022 19:07), 'Burn-in' (11/03/2022 19:07), and 'Thermal cycling' (11/03/2022 19:07). On the right side, the 'Children' section shows a 'Child Component List' with two entries: 'Bare Module - QUAD_BARE_MODULE' and 'Module PCB - QUAD_PCB', both with dates and the name 'Carl Gwilliam'. At the bottom right, the 'Tests' section shows a 'Test Run List' with three entries: 'Glue Information Module+Flex Attach', 'Mass Measurement', and 'Metrology', all marked as 'PASSED'.

Stage History	History
02/05/2022 09:20	Module loaded
02/05/2022 09:20	Reception at module loading site
11/03/2022 19:07	Module completed
11/03/2022 19:07	Burn-in
11/03/2022 19:07	Thermal cycling

Properties	
PCB-Bare Orientation isNormal	true
FE chip version	RD53A
Thickness	Thin

Child Component List
Module carrier 0 (CARRIER) is missing
✓ Bare Module - QUAD_BARE_MODULE 20UPGB40000040 28/01/2022 Carl Gwilliam
✓ Module PCB - QUAD_PCB 20UPGP0025052 28/01/2022 Carl Gwilliam

Test Run List
✓ PASSED Glue Information Module+Flex Attach
✓ PASSED Mass Measurement
✓ PASSED Metrology

Production Database

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Reporting of pixel module components by country

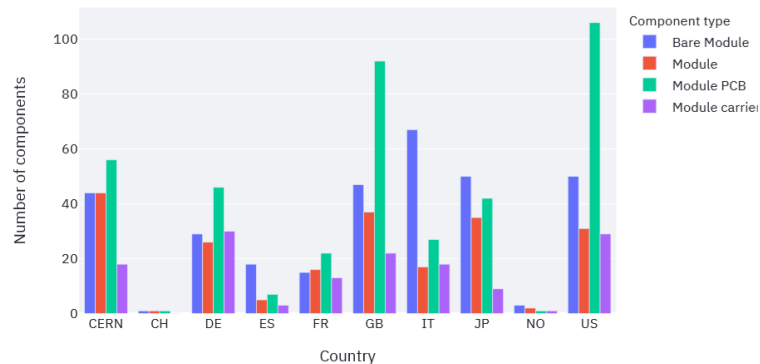
ITK pixel overview plots

Please select a plot type

- All components and countries
- All countries with particular component
- All components for particular country
- Particular component and country

[Download plot data](#)

Number of components per country, subdivided by component type



ITk Pixel Module Status

Jon Taylor is one of the UK endcap pixel module work-package leaders

- 2022 is the 'year of the FDR' (Final Design Review) with many reviews in Q2-Q3
- FDRs release core funds at CERN that allow progression into pre-production and the Production Readiness Reviews (PRRs)
- Sensor pre-production has begun and is progressing well with many deliveries now received, FE chip PRR in Q2 2022
- Production flow for modules optimised with a build of ~100 RD53A quad modules across 12 assembly sites (Liverpool, Oxford & Glasgow in the UK)
- First ITkPix quad module assembled and bonded in Liverpool last week (Phil, Liam, Jon)

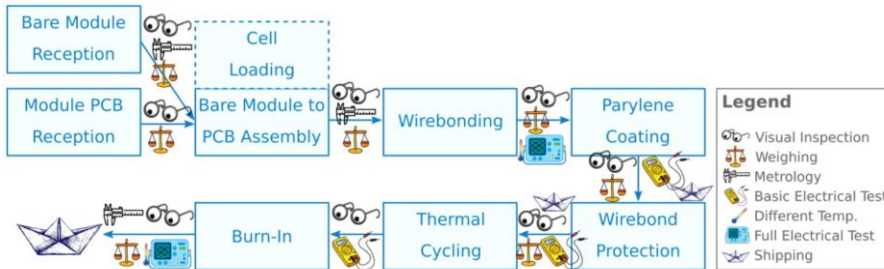


Figure 2: Production flow.

Planar sensors

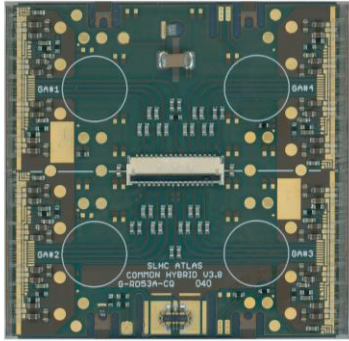
Vendor	Sharing	Pre-production	
		Pieces (Quads)	Expected delivery
FBK 100	40.00%	48	received
Micron 100	60.00%	72	received
HPK in-kind	21.8%	149	received
HPK 150	70.4%	481	June 2022
Micron 150	7.8%	54	received

3D sensors

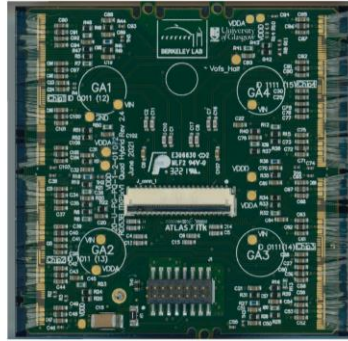
Vendor	Sharing	Pre-production	
		Pieces (singles)	Expected Delivery
CNM 25x100	100.00%	50	Dec 2022
FBK 25x100	100.00%	50	Summer 2022
FBK 3D	50.00%	80	received
SINTEF 3D	50.00%	80	Ready to ship

ITk Pixel Module Assembly and Loading

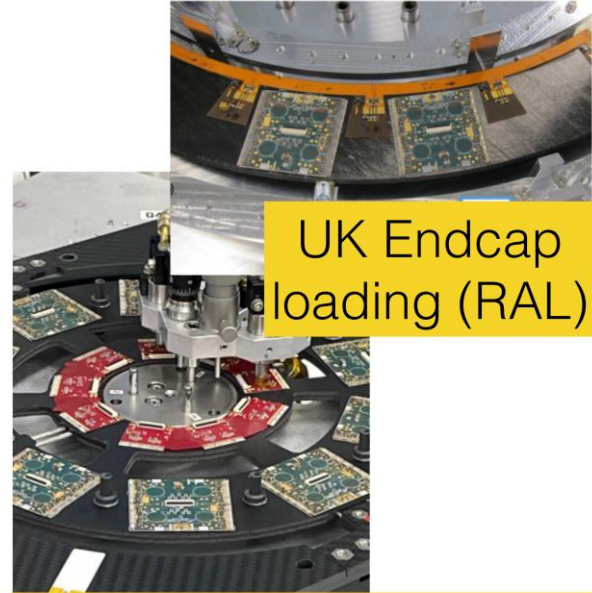
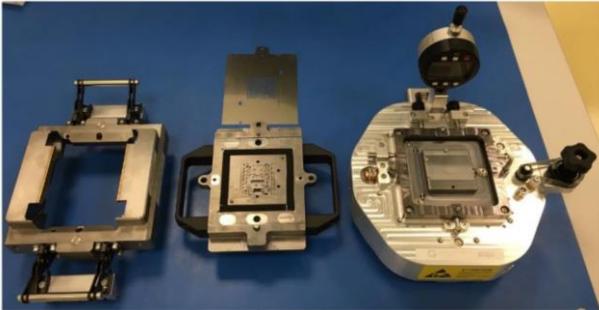
RD53A



ITkPix



New v2 ITkPix tooling (Goettingen)



UK Endcap loading (RAL)

US Inner system loading (SLAC)

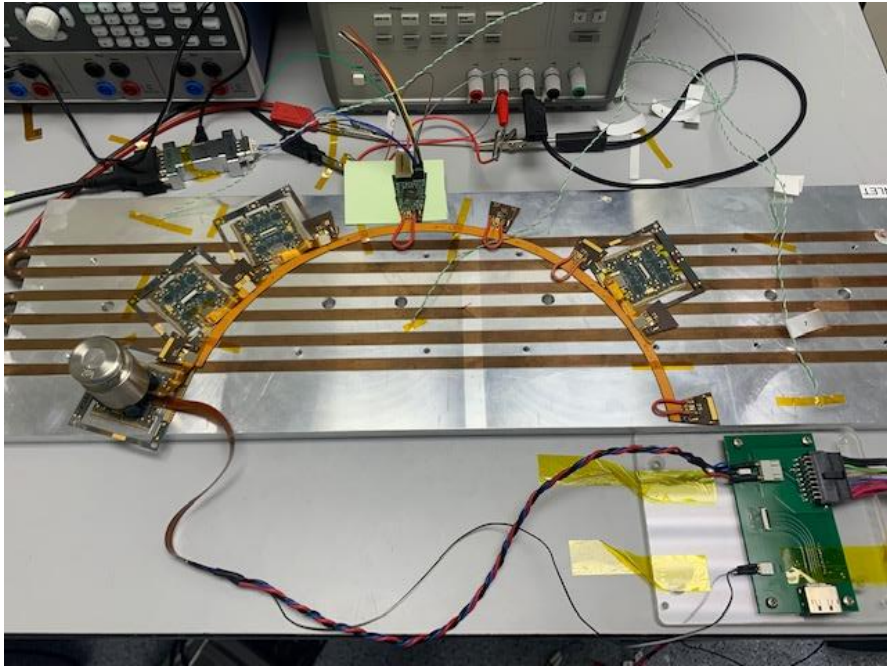
Preparing for Ring 1 (Pixel Test Box)



- The box is in its new location (G17).
- The prototype ring is back in the box.
- With a module attached to it.
- All cables are attached.
- Dry Nitrogen supply has been connected
- The module has been cabled up.
- Powering and a very quick DAQ (YARR) test have been done.
- This will be the test bed for DAQ tests (electrical \rightarrow optical) (Paul)
- The next step is to cool the box down (with LN2) and do more DAQ/DCS tests.
- Then we need to learn how to use the Lukasz CO2 cooling system



Pixel Serial Power Tests and MOPS Chip Testing

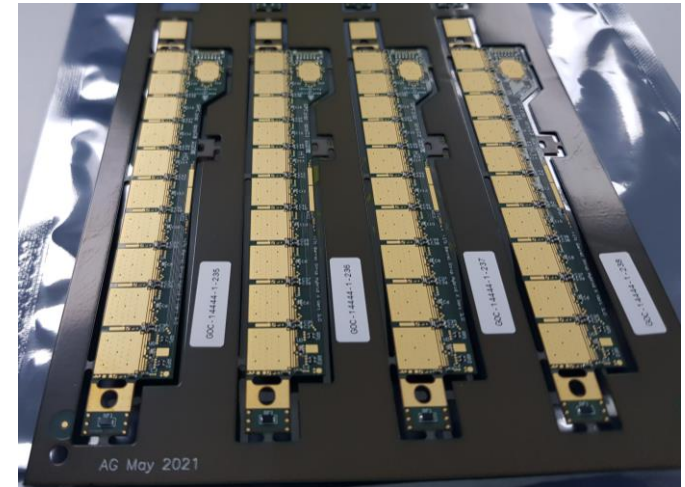
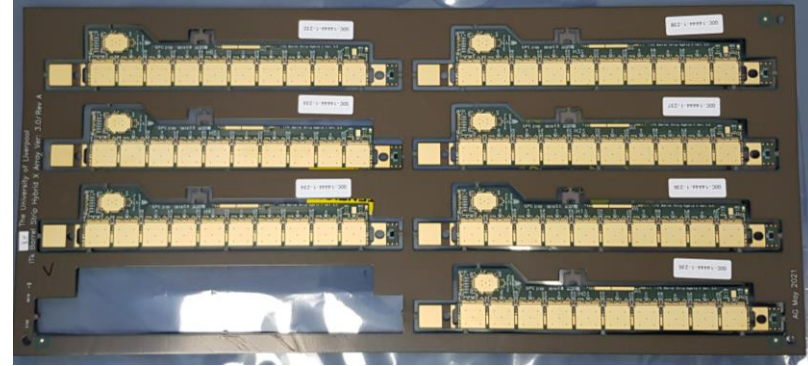


- A tape with up to 7 modules and a MOPS chip
- Serial power tests are being done (Paul)
- Learning how to use the MOPS chip (this monitor the voltages and NTC's on the modules)
- This will be used on Ring 1
- This is work with Manchester University



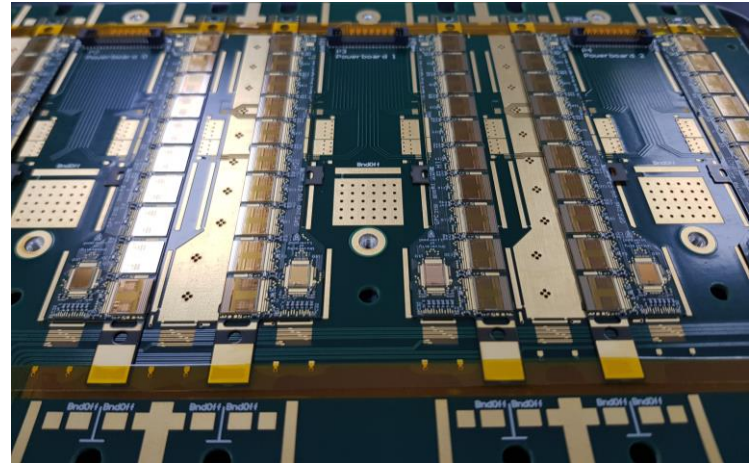
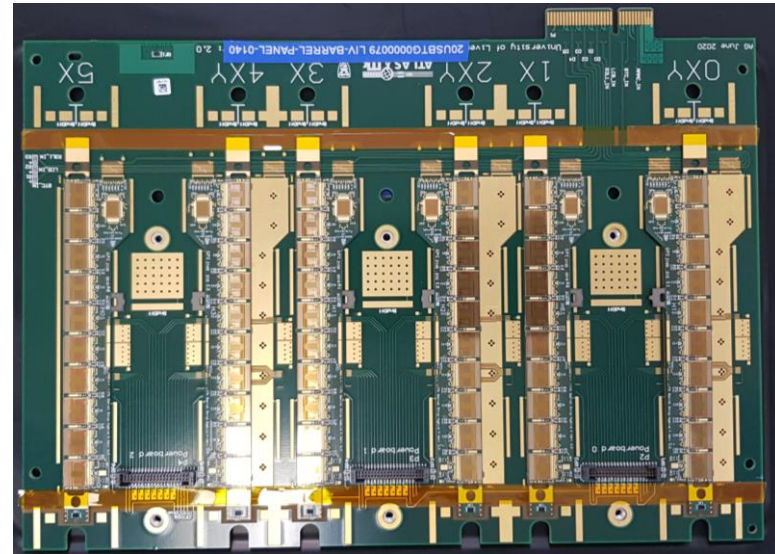
Strip Module – Hybrid Flex QC

- Liverpool is the site responsible for the initial QC of all barrel hybrid flex circuits
 - Several QC steps when the bare hybrid polyamide flexes arrive from the manufacturer, including pull tests and electrical tests on dedicated test coupons
 - QC of all hybrid flexes after SMD attachment that will be used in the UK/China cluster (50% all arrays)
 - Tests done by Manex, Ashley, Liam, Sven
- During production, we will receive one batch of 448 bare hybrid flexes (64 arrays) every month
- In addition, we will receive one other batch of SMD assembled hybrid arrays every month



Strip Module – Hybrid Assembly

- Liverpool will assemble 40% of all strip barrel hybrids that are used in the UK/China cluster for module assembly
- In production, need to assemble 1.2 panels with 6 hybrids per day
 - Assembly and wire-bonding by Manex and Liam
 - Testing by Ashley and Sven



Strip Module – Module Assembly

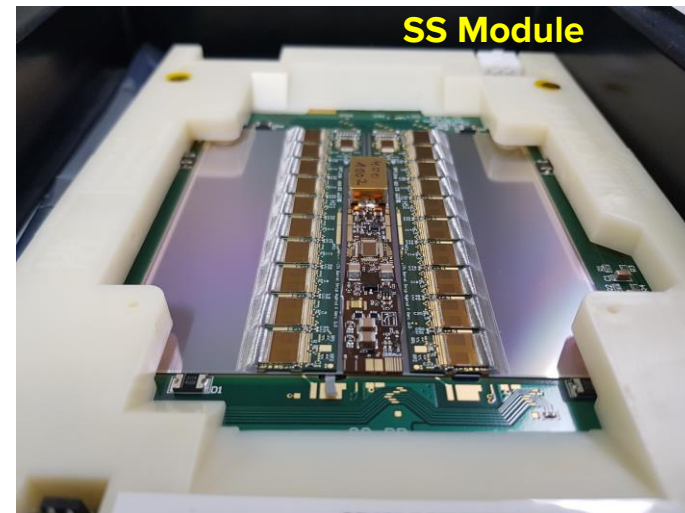
- As one of the 6 UK module assembly sites, the team at Liverpool will build at the peak 2.5 LS modules per day and later 1.25 SS modules per day
 - Assembly and wire-bonding by Manex and Liam
 - Testing by Ashley and Sven

Pre-Production has started

- Two main parts
 - PPA: using prototype chipset (ABCStarV1, HCCStarV0, AMACv2a)
 - We have build all hybrids for this part and are in the process of finishing our share of modules
 - PPB: using production chipset and build parts for final set of reviews (ABCStarV1, HCCStarV0, AMACv2a)
 - Phase 1: UK/China to build 1 SS and 1 LS stave for systems test (in total 4 together with the US)
 - Our team has started assembling our share of hybrids for this last week
 - We will have to build some modules
 - Phase 2: UK/China to build 2 more staves (total 8 with the US) for the strip module PRR
 - Phase 3: gap between pre-production and production start, build more hybrids and modules

Production will start December 2022/January 2023

Sven Wonsak is a ATLAS strip module activity co-ordinator

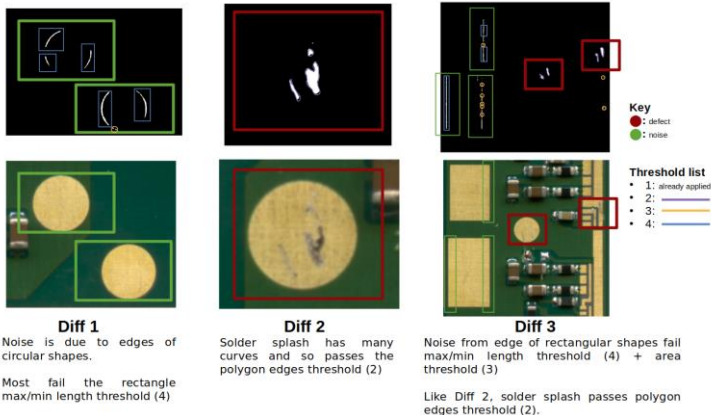


Visual Inspection (Strips and Pixels)

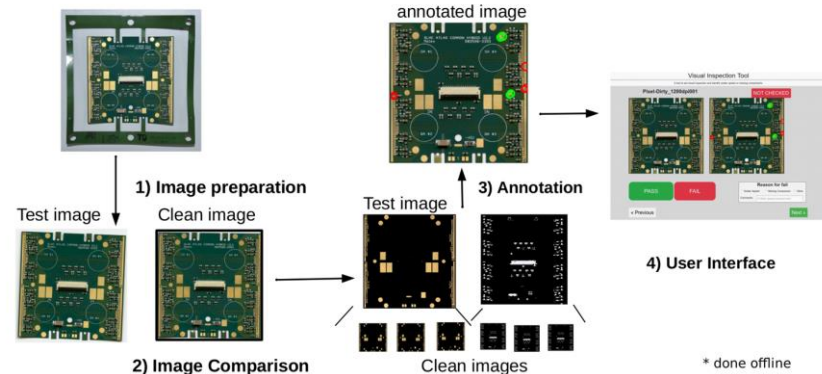
Lots of automated visual inspection software written (and notes) with of input from students Adam, Jake and Ting, supervised by Paul

From the more traditional computer vision methods to machine learning methods:

- Extract the modules from the hybrid panels (crop and snip scripts written)
- Colour correction using histogram matching
- Solder splash/scratch's are discovered using a comparison to “golden images” and thresholds.

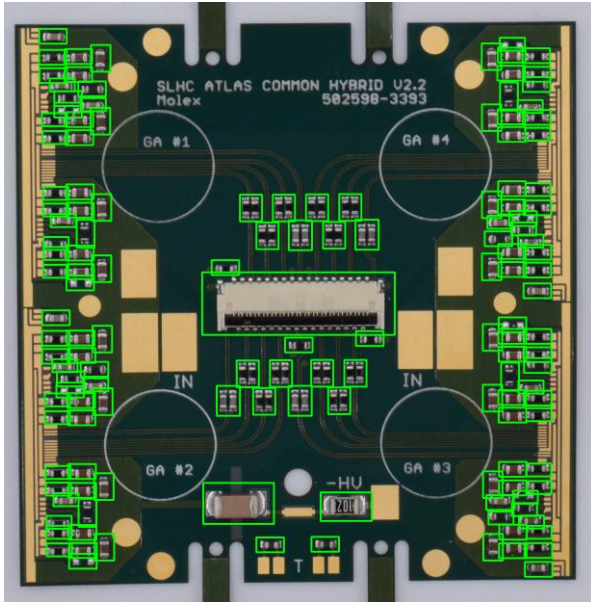


Overview of software workflow

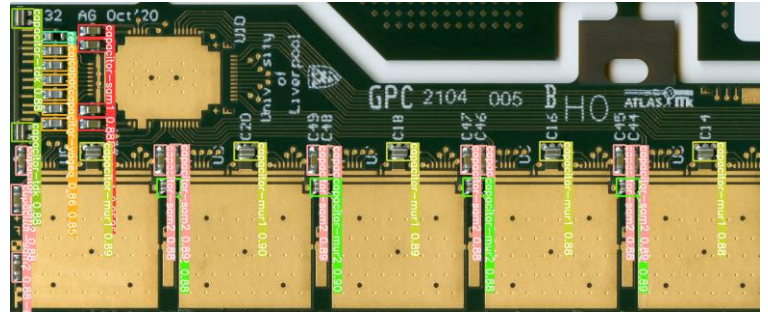
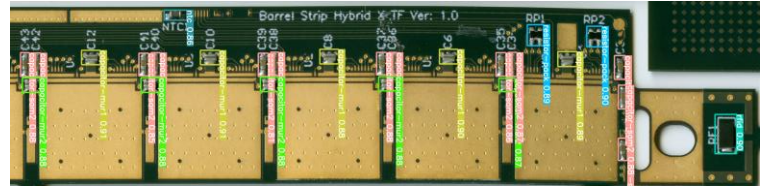


Visual Inspection (Strips and Pixels)

Convolutional neural networks and object detection methods have been used to find SMD components



CNN method used on a pixel module (using a region of interest map).
(Left)



Object Detection (Right)

This work reduces the amount of modules that a human has to check to less than 10%
And the time taken is reduced to seconds.

ATLAS Mechanics Summary

- Pixel Half-rings
 - Co-curing final prototype half-ring half-sandwiches (AML = Tim)
 - Manufacture & QC of precision plastic parts in DDMF – so far best available across UK/Italy collaboration 😊
- Pixel Global Mechanics
 - Manufacture of prototype carbon-fibre half-cylinders (AML = Tim)
 - Manufacture of high-precision half-cylinder assembly tooling in DDMF
 - Grounding & Shielding connections for CFRP (Ash & Tim)
- Strip Barrel Staves
 - Manufacture of PPA staves (Warren, Dave, DDMF)

Pre-production Half-ring Co-curing (Paul Sinclair)

3-ply un-cured laminate cut to shape on ply cutter



Foam positioned on laminate – note silicone edge protector

Vacuum bagging before transfer to Autoclave



Final co-cured half-sandwich

Half-cylinder Prototyping



Full-length mock-up of outer-most half-cylinder constructed in AML (Peter, Paul & Warren)

Metrology in LSDC (Dave & Warren)

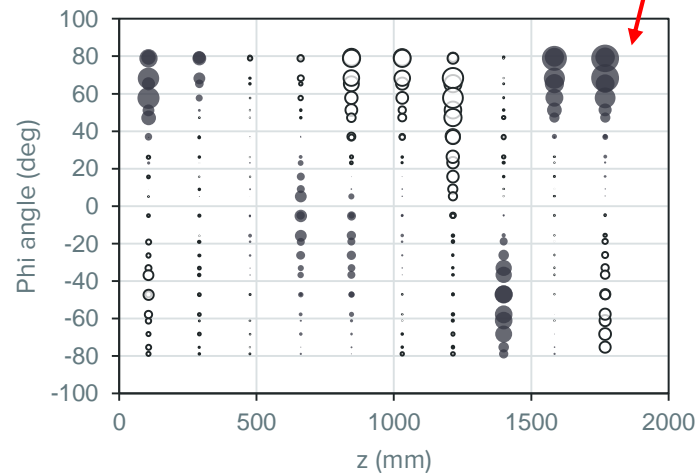
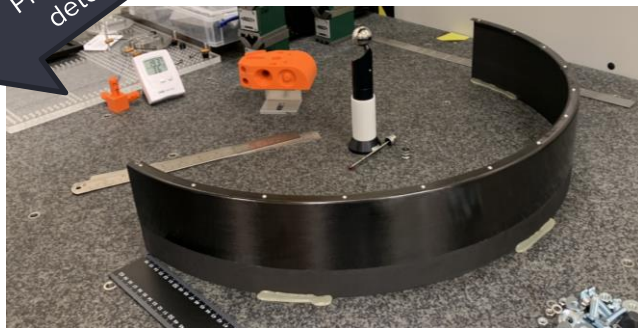
Metrology of full-length half cylinder



Radial deviation

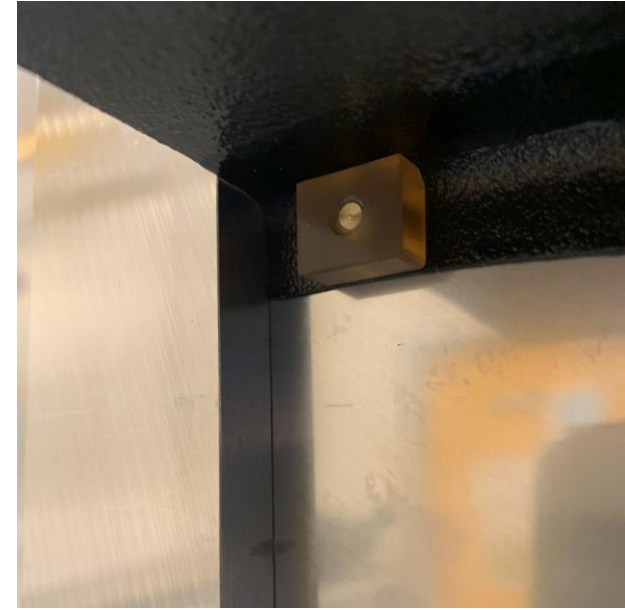
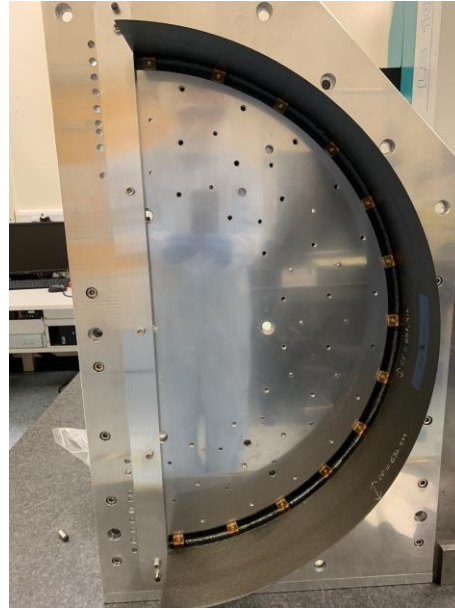
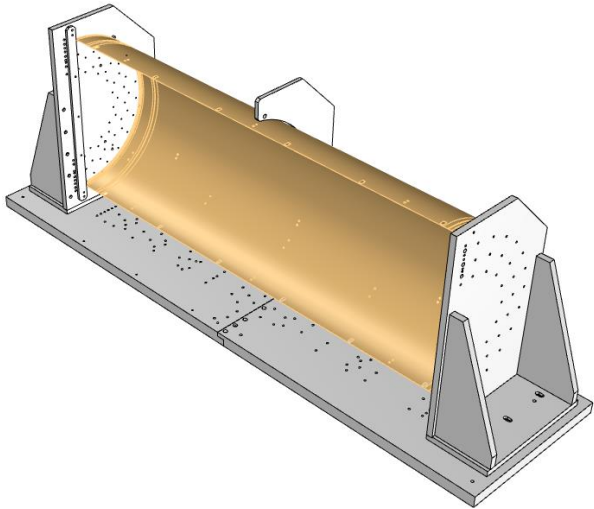
0.3

Probing spheres to determine PCD



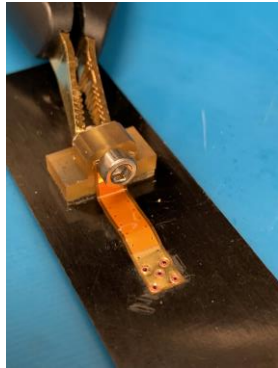
Assembly Tooling

- Partial set of assembly tooling manufactured – accuracy requirements challenging (thanks to DDMF)
- Dry-fit of end-flanges
- Metrology of end-towers in progress (Dave & Warren)



Endcap G&S Connections

- Electrical contacts to CFRP needed for Grounding & Shielding
- Investigating Cu/Kapton flexes (Ashley) connected to laminates using 0.8mm copper rivets
- Typical contact resistance $< 0.1\Omega$



Half cylinder to
Half-ring



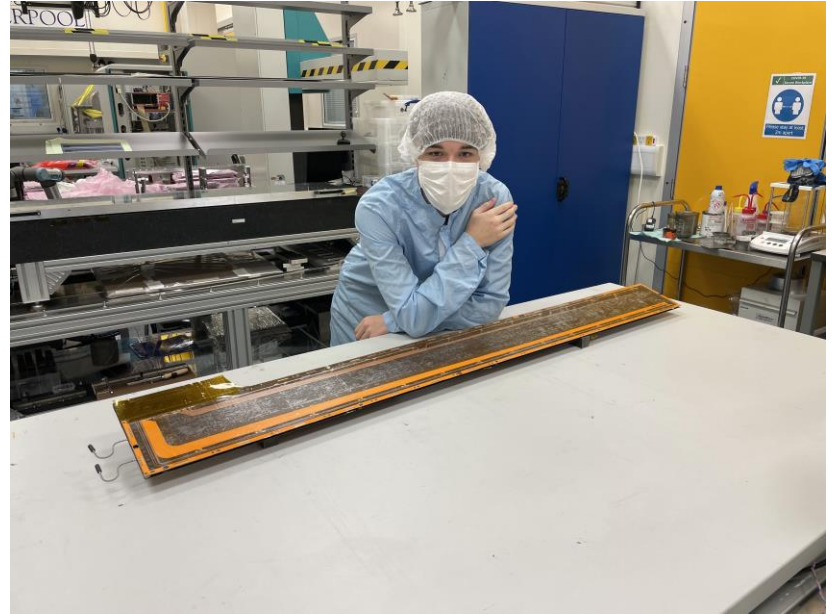
Half-cylinder



20cm test sample

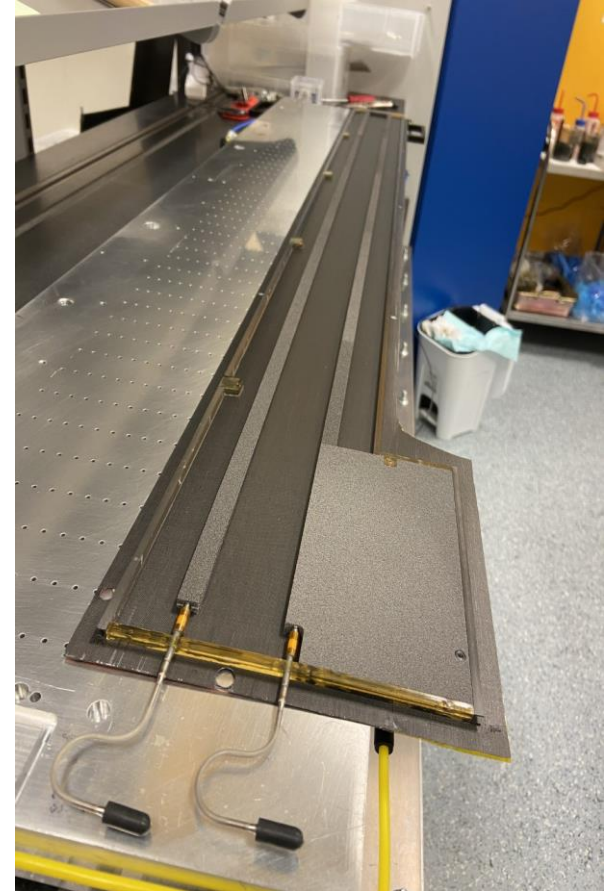
Battel Strip Stave Development

Manufacture of final prototype and pre-production barrel strip stave cores. DDMF manufactured the vacuum jig and all the carbon-foam. Assembly in LSDC by Dave & Warren



Pre-Production Strip Stave Cores

- Face sheets received for first Liverpool PPB stave
- All normal checks to be carried out IE visual and mechanical checks
- Stave core assembly procedure has been revised to include more QC and is to be followed for PPB
- New jig maintenance procedure will be followed for PPB to prolong tool life



What are Liverpool Doing? A lot.

Thank you all here in Liverpool contributing to the ATLAS Upgrade

