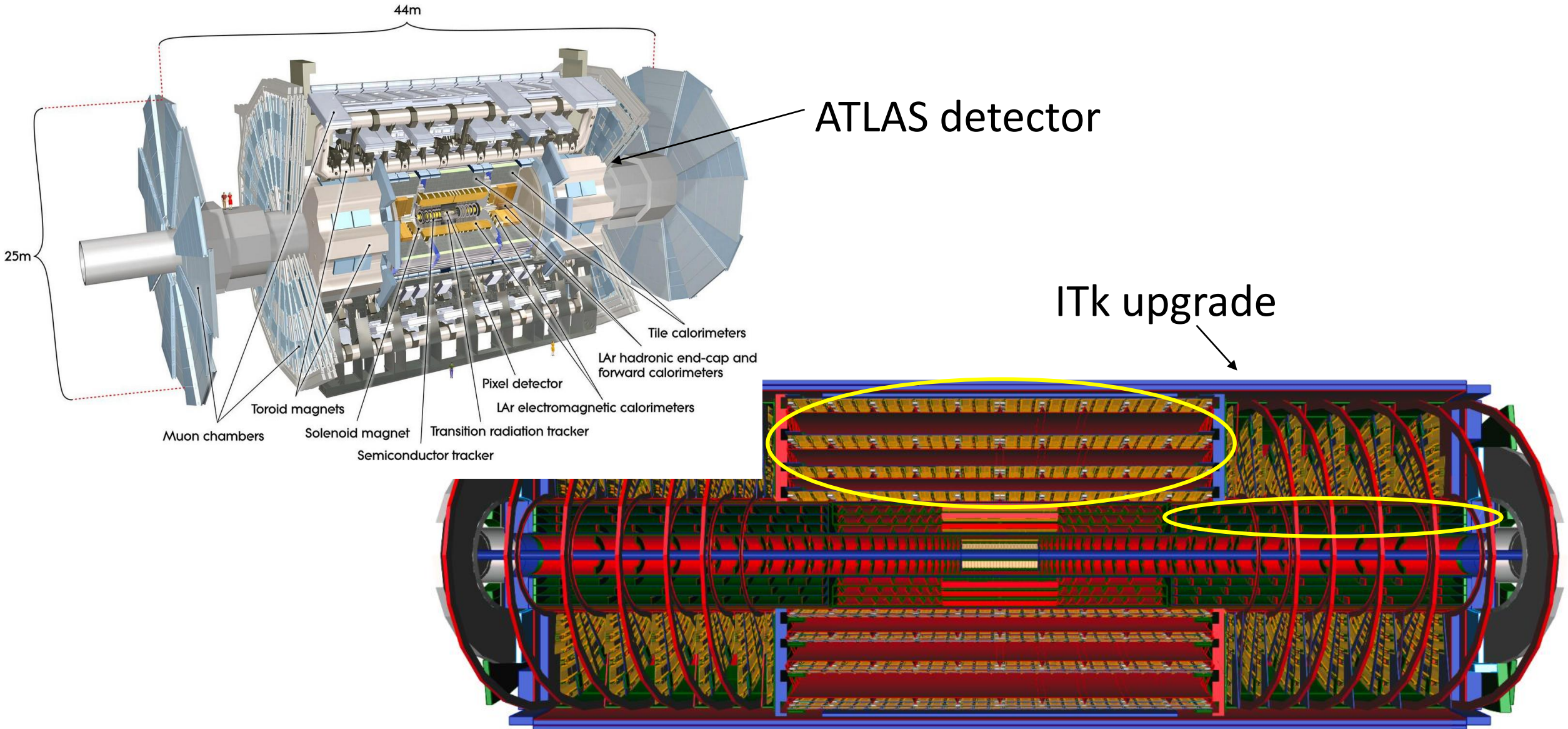


ATLAS Upgrade

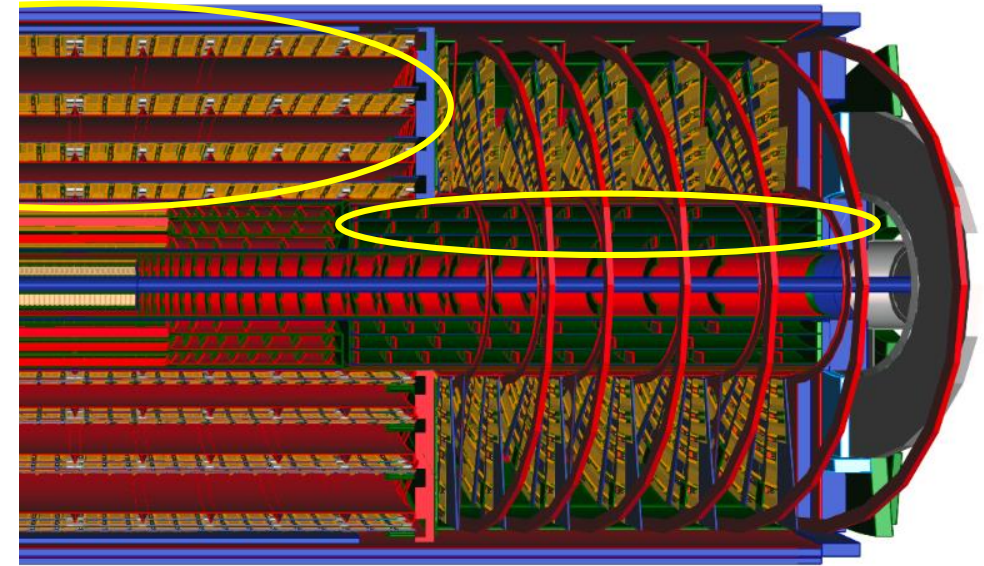
Particle Physics Annual Meeting 2023

What are we doing at Liverpool?



What are we doing at Liverpool?

- Module production for both the ITk barrel strip detector and the endcap pixel tracker
 - 10000 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
- Coordination of the development of the overall core ITk software



Who are we?

- Paul Dervan
- Ashley Greenall (lead strip hybrid designer)
- Helen Hayward (PI, Strip SW Co-ordinator, UK pixel WP20 lead, pixel sys test co-ordinator)
- Tim Jones (UK pixel WP20 lead)
- Jon Taylor (UK pixel WP13 lead, international pixel module activity co-ordinator)
- Sven Wonsak (International Strip Module Co-ordinator)
- John Carroll
- Warren Jones
- Manex Ormazabal
- Phil Timko
- Carl Gwilliam
- Sergey Burdin

Welcome:

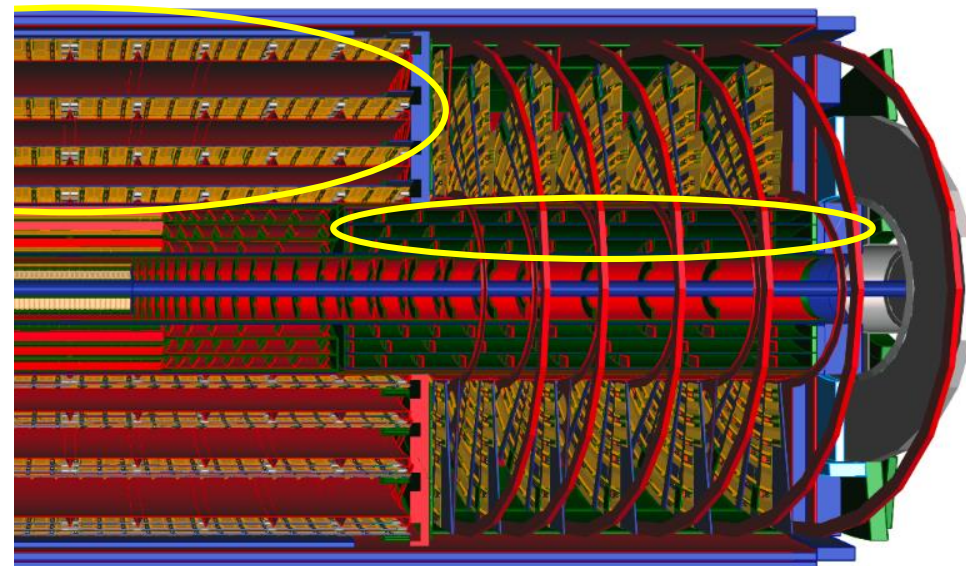
- David Vazquez Furelos
- Matt Brown
- James Coleman-Mills

Continued thanks to:

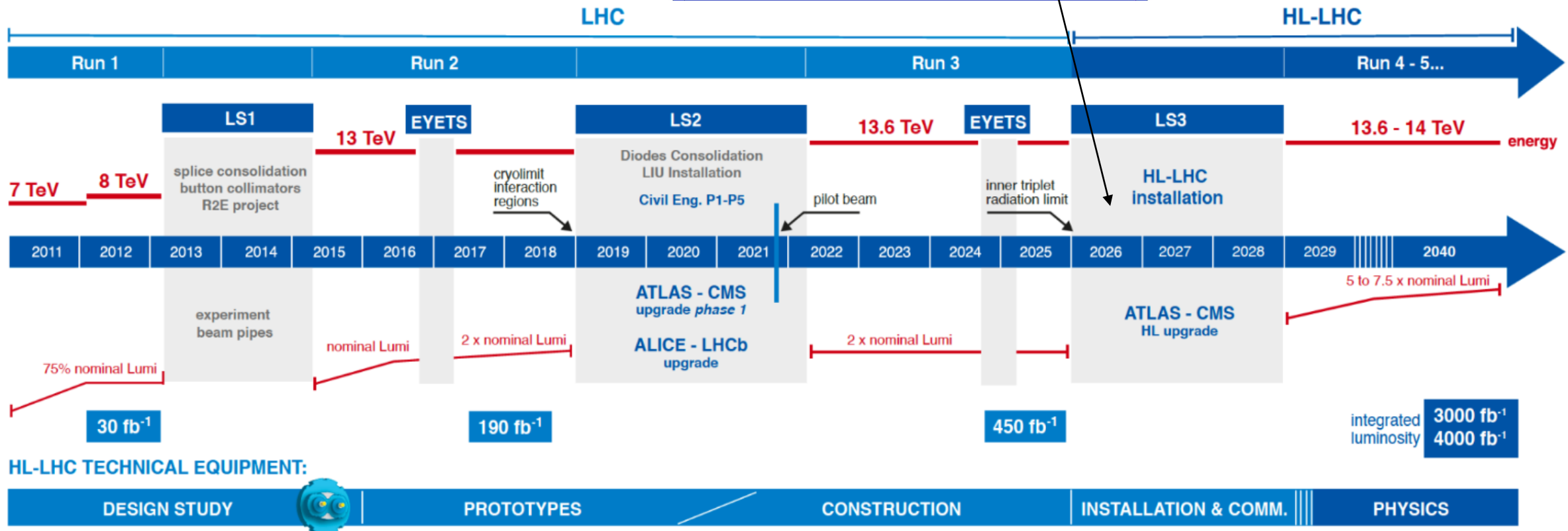
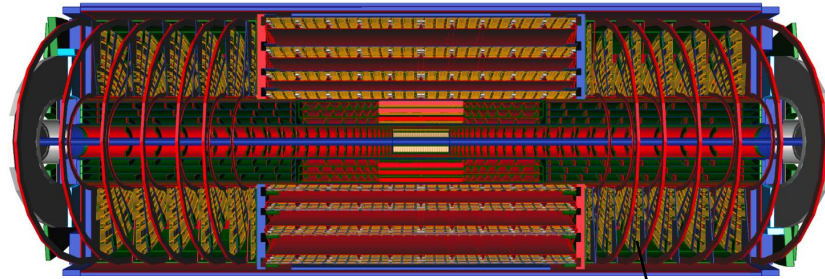
- Liam Boynton, Dave Sim, Tom Lee, AML / DFF / LSDC, Mike Lockwood...

Students:

- Bhupesh Dixit, Conor McPartland, Ting Lee, James Smith



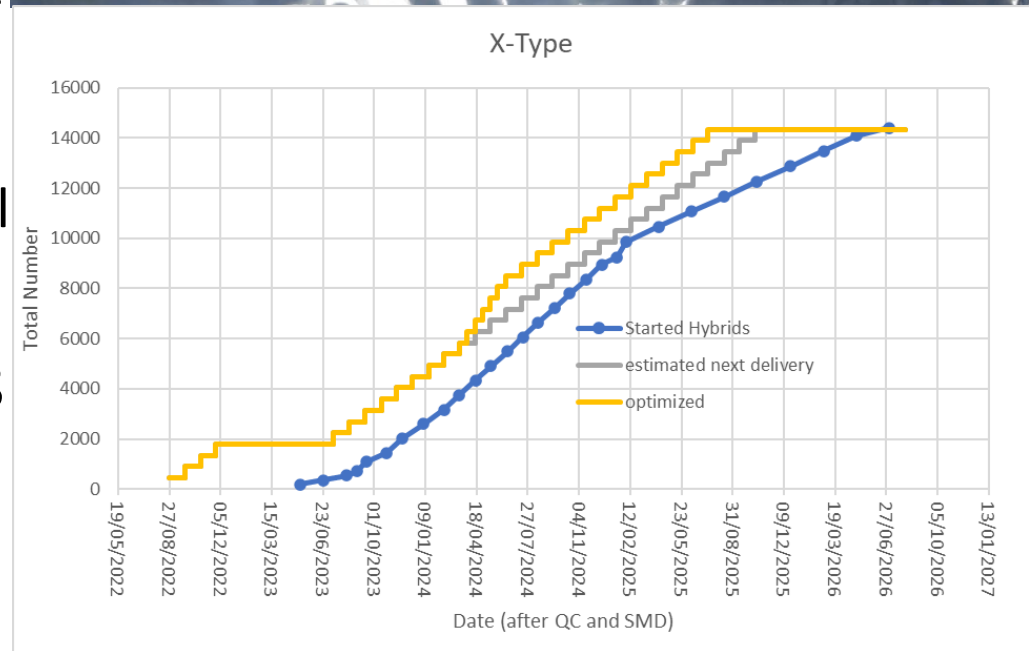
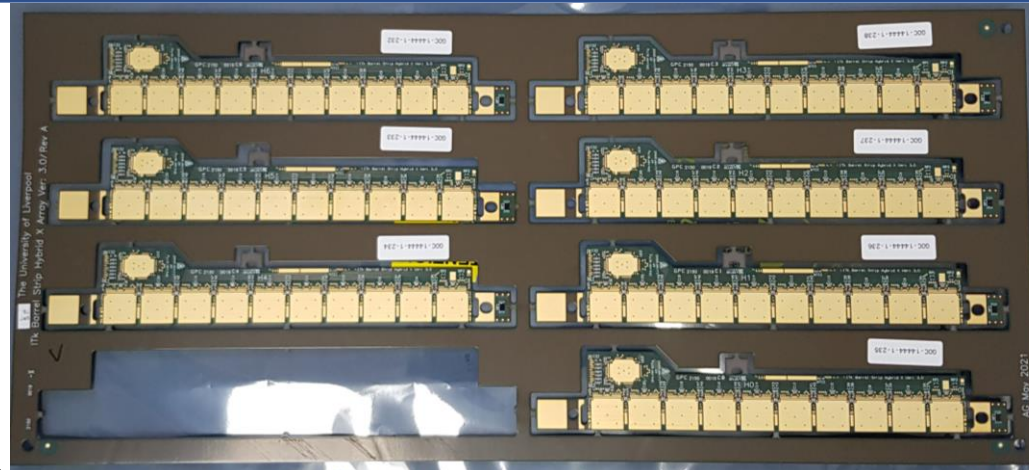
HL-LHC schedule



Strip modules

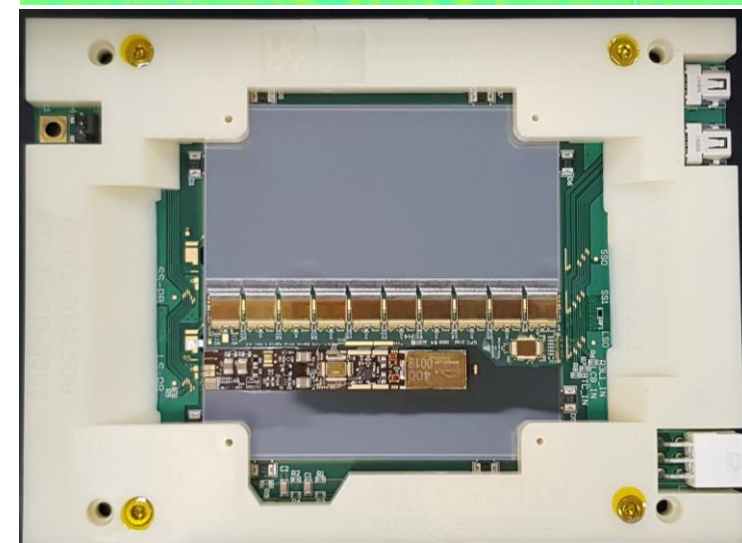
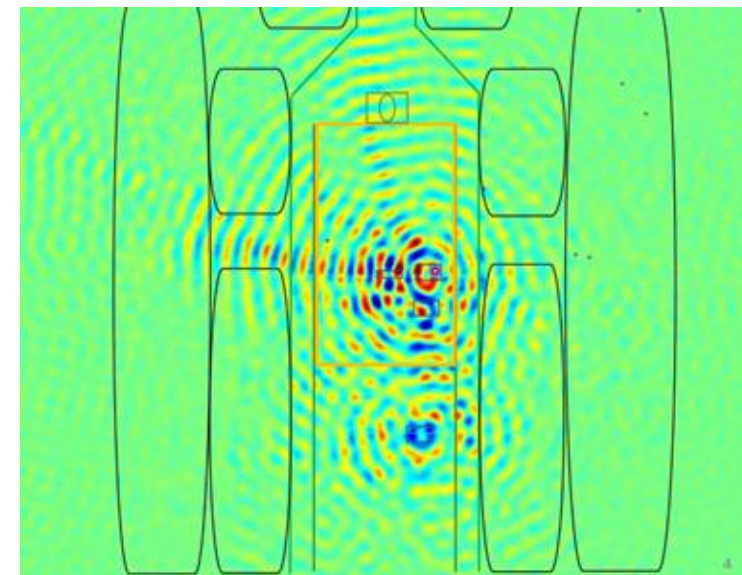
Strips modules

- Barrel Hybrid Production Readiness Review (PRR) passed (January 2023)
 - Allowed restart of barrel hybrid flex production
 - 20k circuits to be procured over the next 3yrs
- Liverpool responsible for the initial QC of all barrel hybrid flex circuits
 - Involves many QC steps, checking suitability for wire-bonding, PTH/VIA integrity and inter-layer delamination by exposure to thermal stressing – using dedicated test coupons
 - QC of all hybrid flexes after SMD attachment that will be used in the UK/China cluster, responsibility for QC of 10k circuits
- During production, will receive one batch of 448 bare hybrid flexes (64 arrays) every month
 - Production flexes start arriving May 2023 with a completion date of June 2026
 - With 50% of circuits shipped to the USA



Strips modules

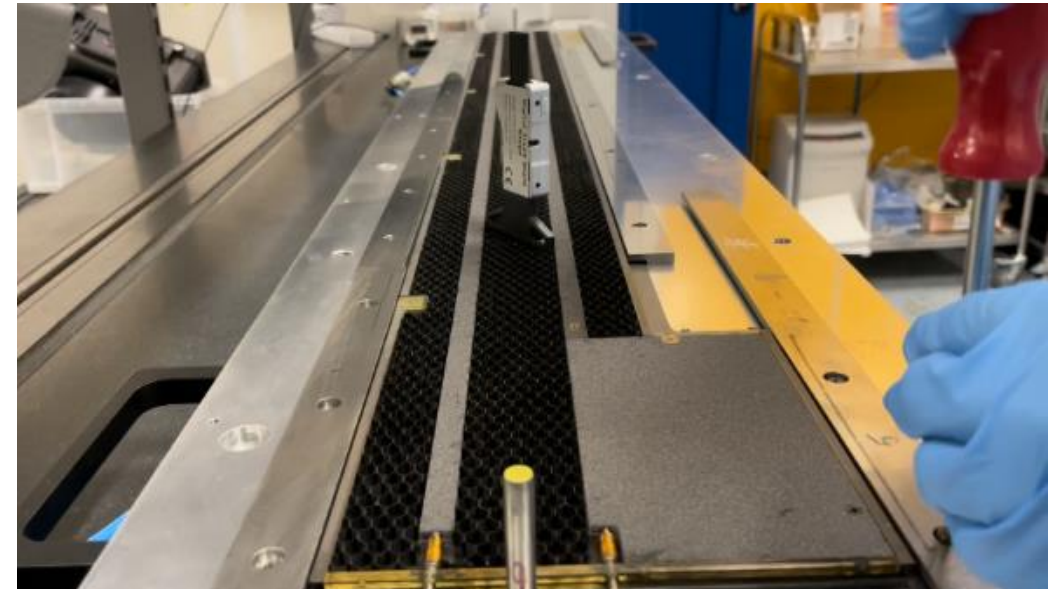
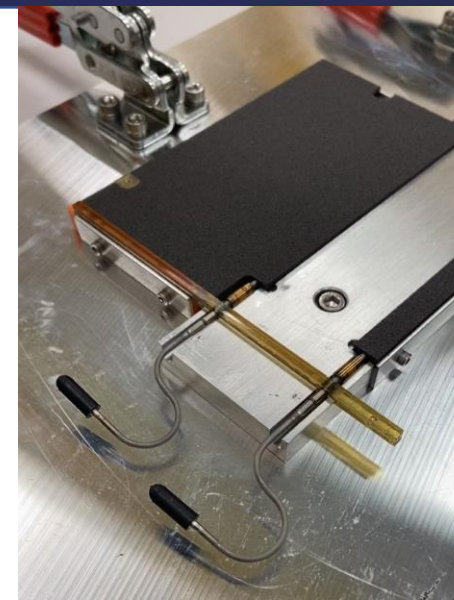
- Barrel Strip Module PRR happened last week
 - Preliminary feedback from reviewers was positive to start production hybrid assembly
 - UK sites still required to finish the pre-production
 - Module production to start at a slow pace after getting more measurements
- In 2022 discovered “cold noise” - showstopper
 - Excess noise across many channels at low temperature
 - Mitigation strategies have been explored
 - Vibrating ceramic capacitors on powerboard most likely cause – circa 2nm movement (cf laser vibrometer)
- Whilst Endcap modules don't show cold noise
 - Further investigations ongoing (including barrel powerboard made by endcap vendor)
- In addition, a new glue had to be qualified because the current baseline glue was discontinued
- Production starts with long-strip modules:
 - Using glue Eccobond F112 (True Blue) and standard glue thickness



Strip mechanics

Strip Stave Core Production

- Sub-assembly / cooling loop assemblies
 - This is the first component that is constructed during the build of a stave core
 - The assembly consists of two layers of thermally conductive foam that are bonded together using graphite loaded glue to assist in the heat transfer between the two mating layers
 - Also bonded into this sandwich is the titanium cooling loop that provides cooling along the length of the stave core
 - Liverpool is currently updating the assembly tooling to prepare for production
 - Liverpool will manufacture the UK's supply of cooling loop assemblies (about 200)
- Liverpool's sanding procedure
 - Recently Liverpool shared its sanding procedure for sanding the carbon fiber honeycomb that fills the void between the cooling loop and the rest of the stave core structure
 - Previously this honeycomb was machined to the correct depth however this required a lot of time and would require large CNC machines to be tied up to this specific purpose
 - By adopting Liverpool's sanding procedure, the tight surface tolerances were still maintained without having the time commitment of setting up large CNC machines
- Stave Core production
 - Stave core manufacture is scheduled to start in July 2023 and Liverpool have to construct about 200 cooling loop assemblies and 100 stave cores by May 2026

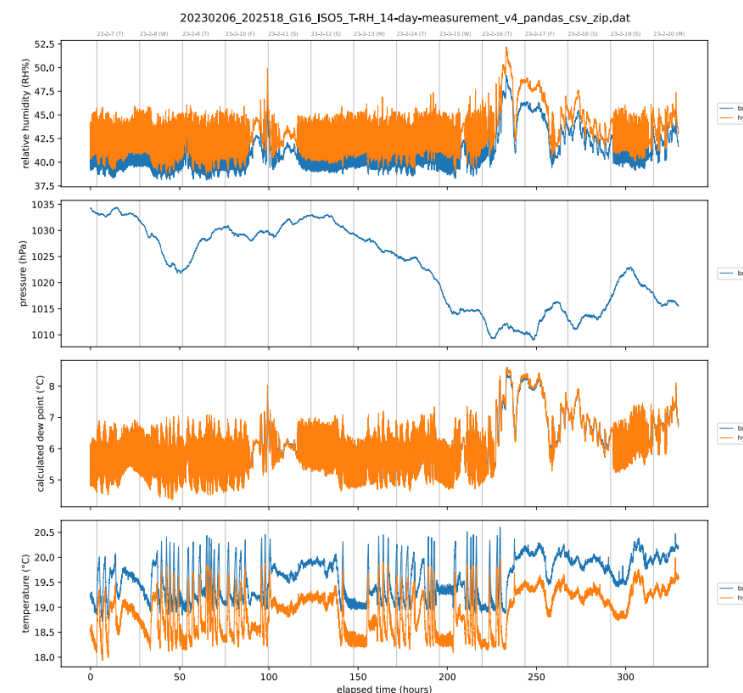
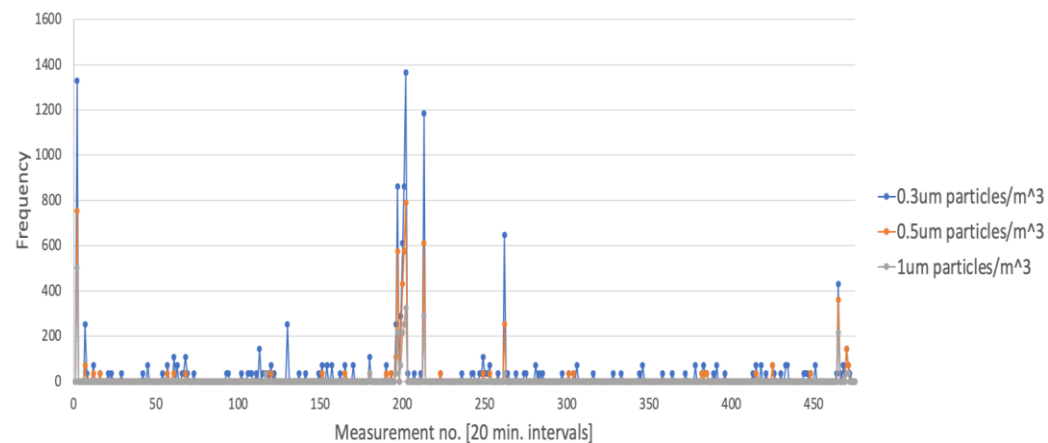


Pixel modules

Organisation

- Pixel modules jointly organised in the UK by Liverpool and Oxford
- UK responsibilities divided
 - 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
- UK required to build enough pixel modules for one endcap ~1500 quad modules over ~2 years
- Additional modules now required due to Russian commitments being re-distributed
 - UK module building (and testing) rate increased from 6.5 to 7 modules/week/site
- All module building sites are now beginning the site qualification process

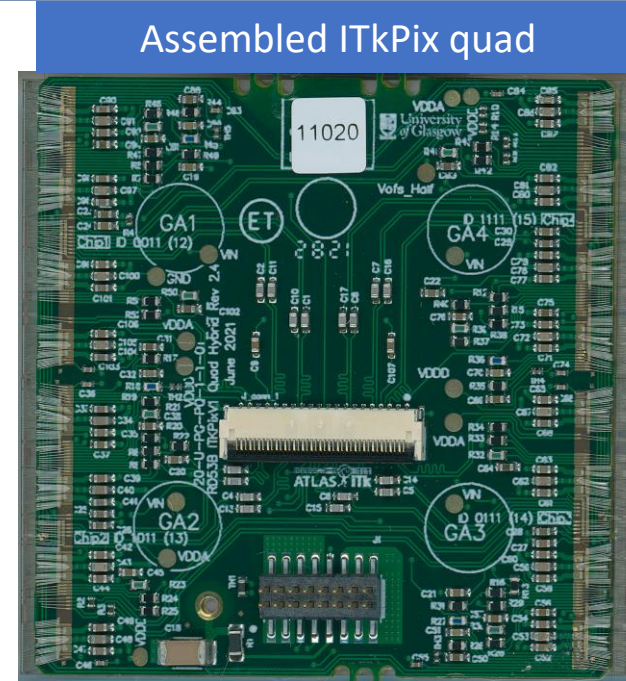
ISO Class 5 Assembly Clean Room (G16) Particle Monitoring Data 06-13th Feb 2023



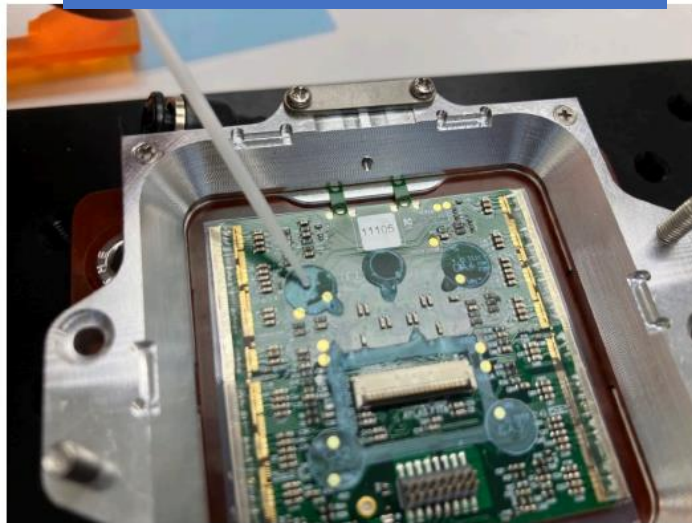
- Particle count, temperature and relative humidity are stable over a 14 day period in class 5 and class 7 labs

Module assembly and testing

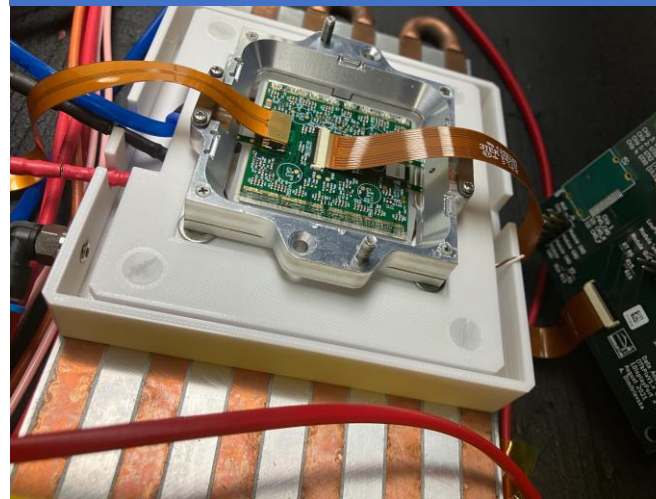
- Pre-production tooling has arrived in the UK (designed and manufactured in Germany)
- First assemblies on glass and mechanical silicon for glue distribution and wire bonding trials currently underway
- Radiation hard polymer layer deposited to prevent HV discharge and bump bond delamination
- First digital modules under test



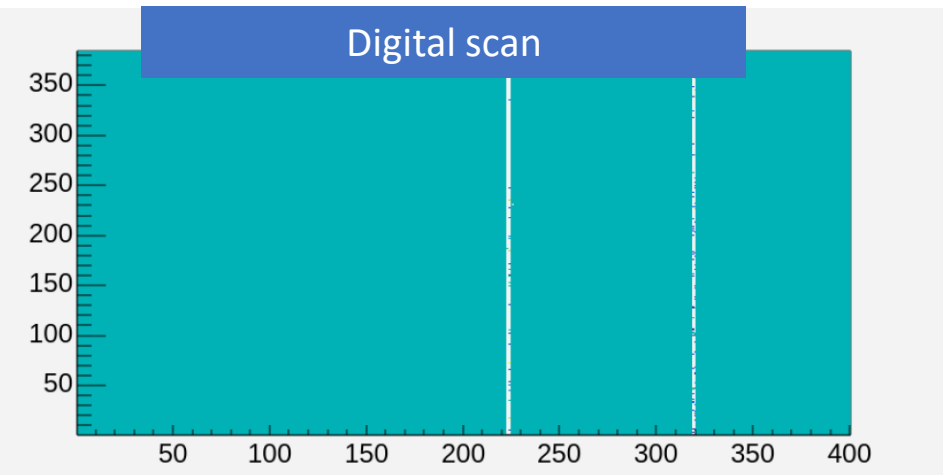
Masking applied to ITk module



ITk quad module ready for testing



Digital scan

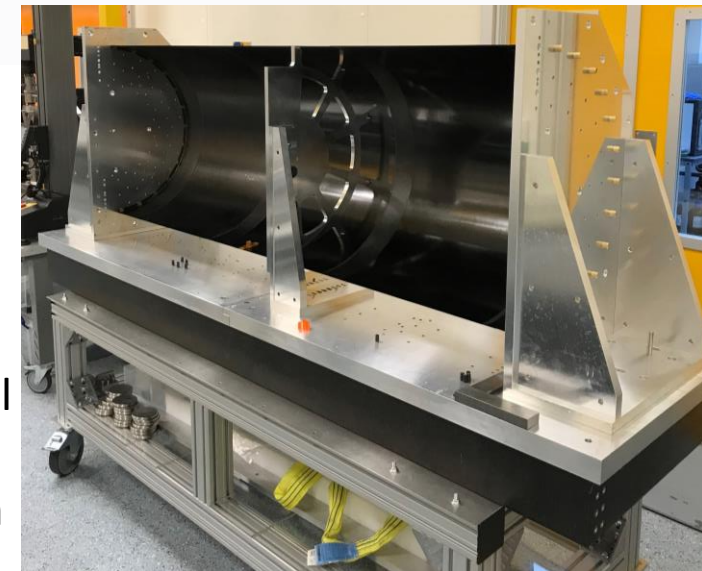
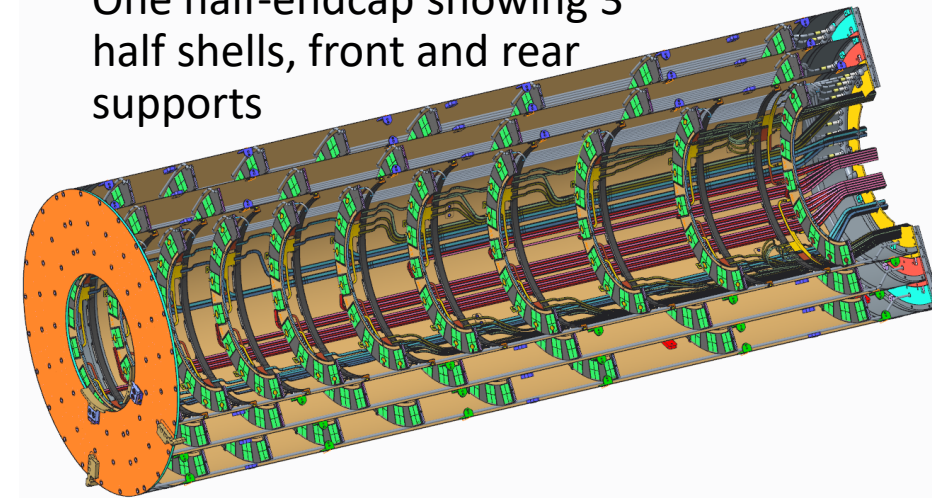


Pixel mechanics

Endcap Pixel mechanics

- Liverpool is responsible for overall 3D CAD modelling of Outer Pixel Endcap for ITk upgrade
 - This work has to be complete for the Final Design Review in September 2023
 - In addition to the 3D geometry Liverpool will have to play a leading role in qualifying the mechanical design of the global support structures (e.g. assessing loads, checking stability, assembly tolerances, safety-factors against structural failure)
- Liverpool also has to design and manufacture the 12 half-cylinders (6 for UK and 6 for IT)
 - We are currently manufacturing a Layer 4 prototype which will be used at Frascati to qualify the integration tooling

One half-endcap showing 3 half shells, front and rear supports

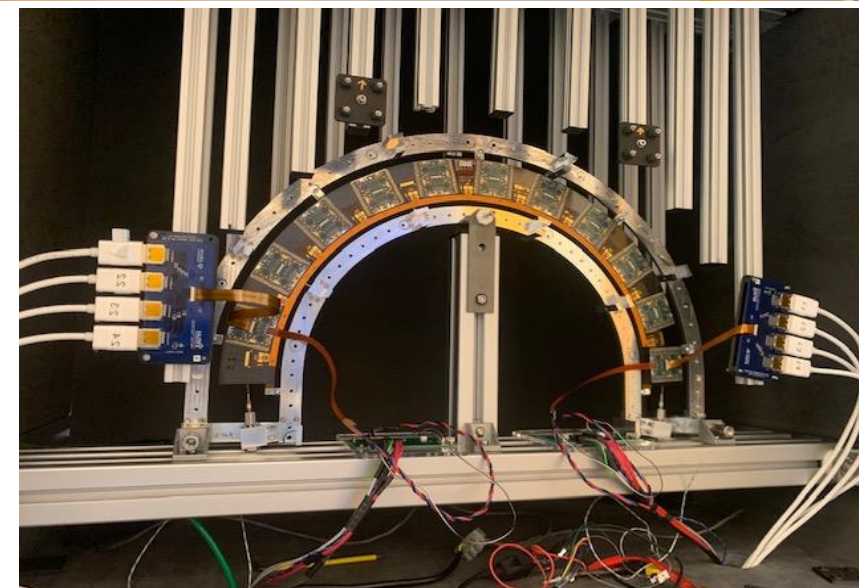
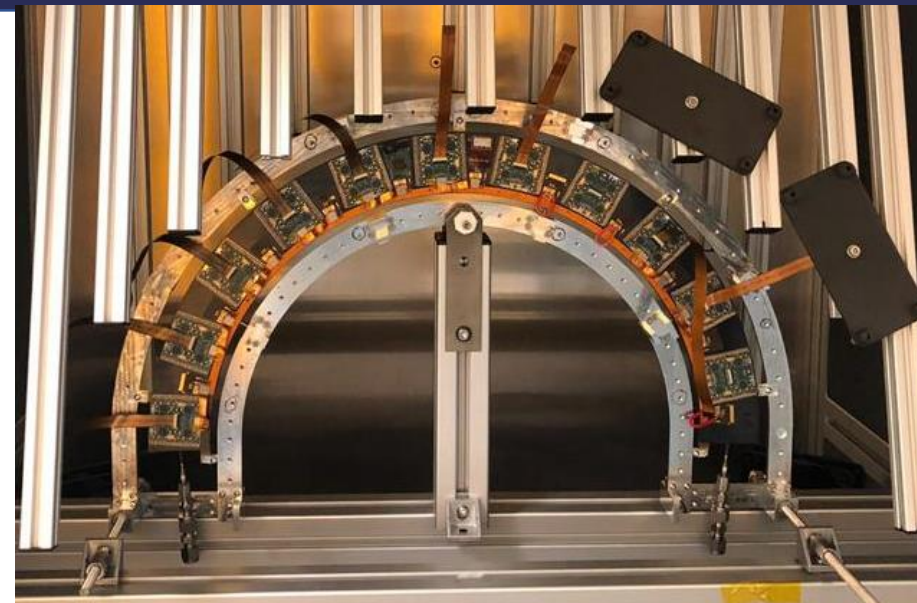


L4 half-shell mock-up mounted in assembly tooling in LSDC

System test

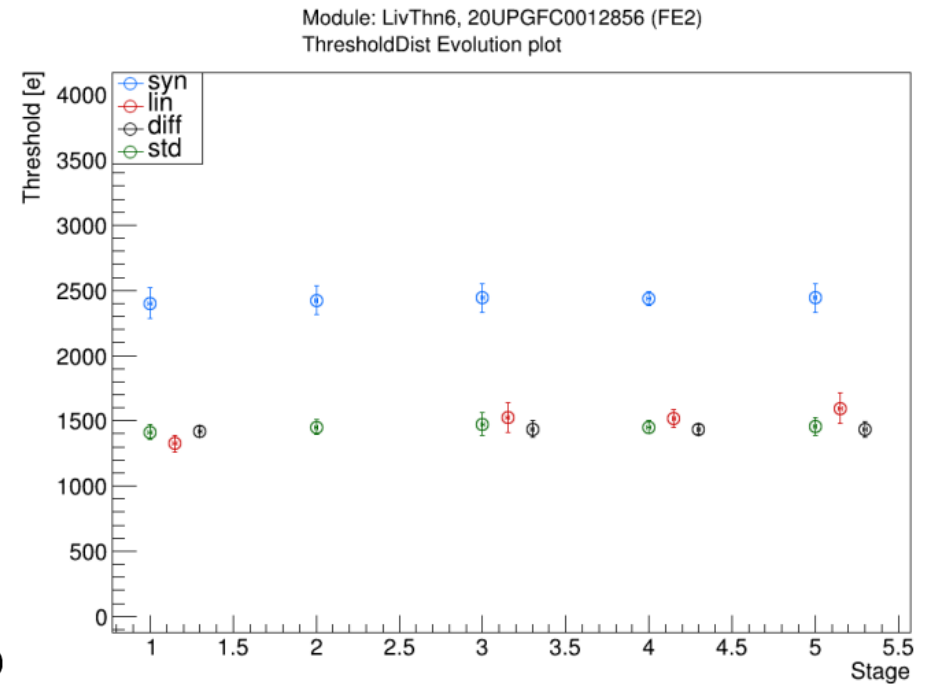
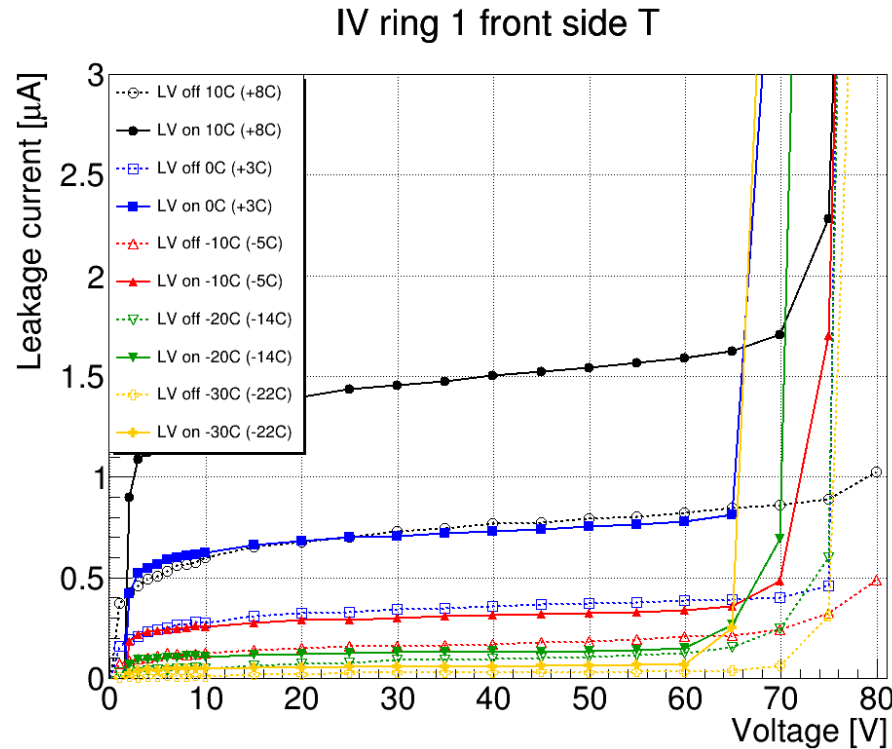
System test

- Liverpool is currently testing a prototype of half ring for the middle half endcap
- Pixel modules mounted in a half ring and connected together through a Serial Power Chain (SPC)
- The LV and HV connections checked in side A
- Readout of the modules were successfully tested individually
 - Currently testing multiple module readout



System test

# of devices	LV (V)
1	2.375
2	3.992
3	5.613
4	7.249
5	8.888
6	10.503
7	12.069
8	13.685
11	18.4



- LV applied to an increasing number of sensors in the SPC to reach 4.6 A on operation

- Leakage current of all the modules in the SPC at different temperatures

- Threshold distribution for a module at different stages of production

Summary

- Many activities for the ATLAS phase II upgrade at Liverpool
 - Strip modules
 - Strip mechanics
 - Pixel modules
 - Pixel mechanics
 - System test
- All moving forward!
- In addition to hardware, Liverpool also heavily involved in production database and ITk simulation activities
- Many thanks to Qualification Task students including Bhupesh Dixit who is currently working on "Implementing Masking of ITk Pixel and Strip Modules and Studying Noise Modelling"

