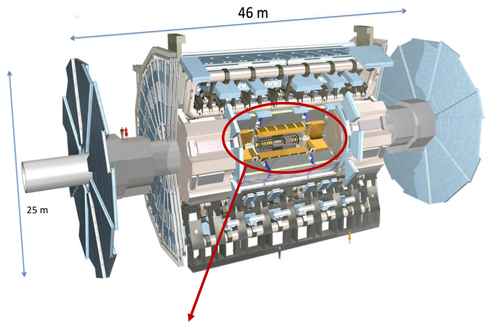
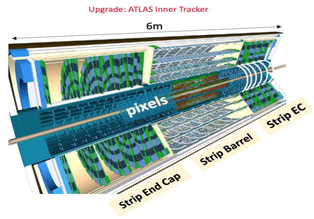
Solving the Sensor Cracking in ITK Strips

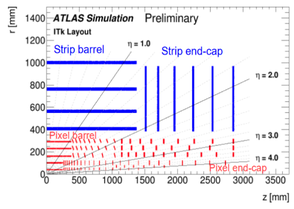
Andrew Blue, on behalf of the ATLAS ITK collaboration

Introduction

- **The Inner Tracker (ITk) is the new all-silicon tracking detector that will be installed in the ATLAS detector [1] in preparation for the High-Luminosity LHC (expected 2030)**
- **The ITk Strip detector is the outer layers, which are tiled with silicon microstrip sensors**

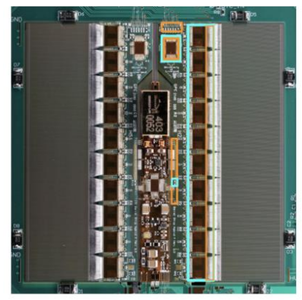






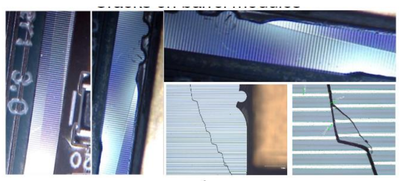
Modules

- **Hybrid** PCB with Binary readout chips (ABCstar) and hybrid controller chips (HCCstar)
- **Powerboard** PCB
- Both glued to a Silicon Microstrip Sensor



Cracking

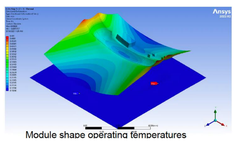
- Pre-production modules were assembled and underwent full Quality Control (QC) tests
- As part of the QC programme, all assembled modules had I-V characteristics recorded (to 500V) and were thermally cycled (-35°C -> +20°C) with no issues seen
- However, a fraction of modules after mounting on support structures (staves) had "**early breakdown**" below the 500V specification
- Investigations found that some of these modules had <100V breakdowns arising from sensors **fracturing** when staves cycled to cold temperatures



HV Taskforce

- Taskforce was formed to study causes and possible mitigation strategies

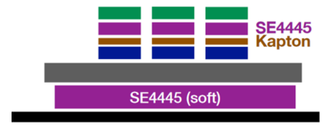
- Intense program of simulations, material studies and irradiations took place.
- Identified that the issue was related to a mismatch in the coefficients of thermal expansion (CTE) of materials



Interposers

Solution found to add a stress-relieving '**interposer**' layer under every PCB [2].

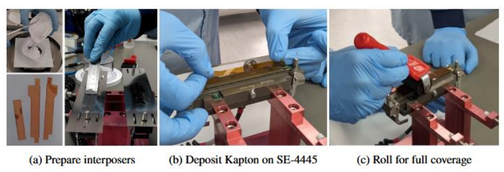
- Use of **Kapton** (50μm) & **SE445** (100μm)
- The soft glue (SE445) mechanically decouples the hybrid/powerboard PCBs and the sensor, to reduce the thermal stress on the sensor.
- The Kapton layer separates SE445 from the stiff glue (**Ecobond F112**) on the sensor, decreasing the CTE mismatch.



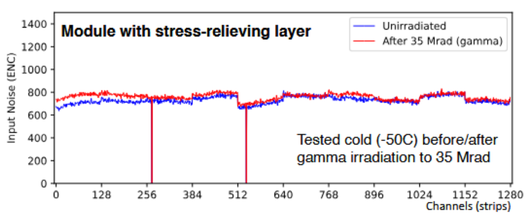
- Stress simulations predicted up to a **factor of 10 reduction** in stress

Interposed Modules

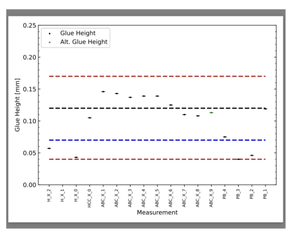
- First trials of interposed Hybrids and Powerboards made in institutes [3]



- Design verification program took place for potential changes in mechanical properties with temperature & irradiation

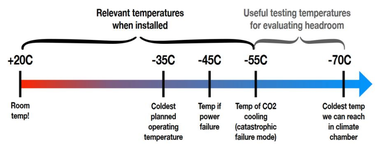


- Additional Quality Control procedures established (interposer thickness, shear tests), as well as modified metrology & visual inspection

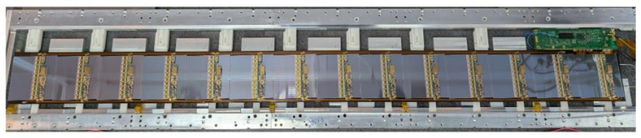


Interposed Modules on Local Supports

- Evaluated cracking problem by building loaded objects (**interposed modules** mounted onto **staves**) and testing at progressively lower temperatures



- Six barrel staves were built in the UK/China and US with interposer modules



A barrel support structure loaded with modules built with the stress-relieving layer.

- **Zero interposer modules** showed signs of cracking at operational temperature of -35C
- All staves taken to -70C with no signs of any cracking apart from one module that cracked on the 4th cycle at -70C (**1 out of 154 modules**)

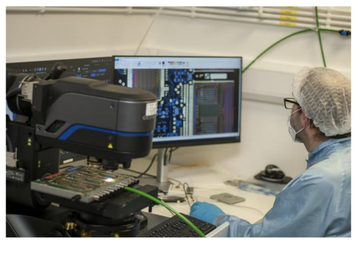
Stave	5 cycles -35C	5 cycles -45C	5 cycles -55C	5 cycles -63C	5 cycles -70C
UK LS Stave 43 (single side)					
UK LS Stave 47					
UK LS Stave 50					
US LS Stave 14					Crack for one module on 4th cycle at -70C
US LS Stave 16		Received 100 cycles (Rogue HV power supply killed 4 modules)			
US Stave 17	One module damaged during EoS replacement	Received 100 cycles (Accidentally exposed to +60C)			
UK/US SS Stave 28					

No evidence of sensor cracking

Evidence of a cracked sensor

Going Forward

- Interposers now fully adopted for production of modules
- The last technical review (Production Readiness Review) passed in Sep 2025
- The taskforce studies showed no detrimental effect of interposers on mechanical or thermal properties of the modules, pre and post irradiation.
- **Strip Barrel modules and loading now in production!**
  - Endcap review to follow in Late November 2025
- Interposing processes now fully developed by industrial partners
- All barrel module sites (US, UK, China) now assembling and testing Production barrel modules
- As of Nov, **460** modules have been assembled, with an additional **308** mounted on to staves with **no cracking**



[1] ATLAS Collaboration, The ATLAS Experiment at the CERN Large Hadron Collider, JINST 3 (2008) S08003
[2] A.W. Fortman et al, A New Stress-Relieving Layer in ATLAS ITk Strip Modules, ATL-ITK-PROC-2025-009 (2025)
[3] Nikolai Fomin et al, Extended thermal cycling of ATLAS ITk strip modules with and without stress mitigating interposers JINST 20 (2025) P09036