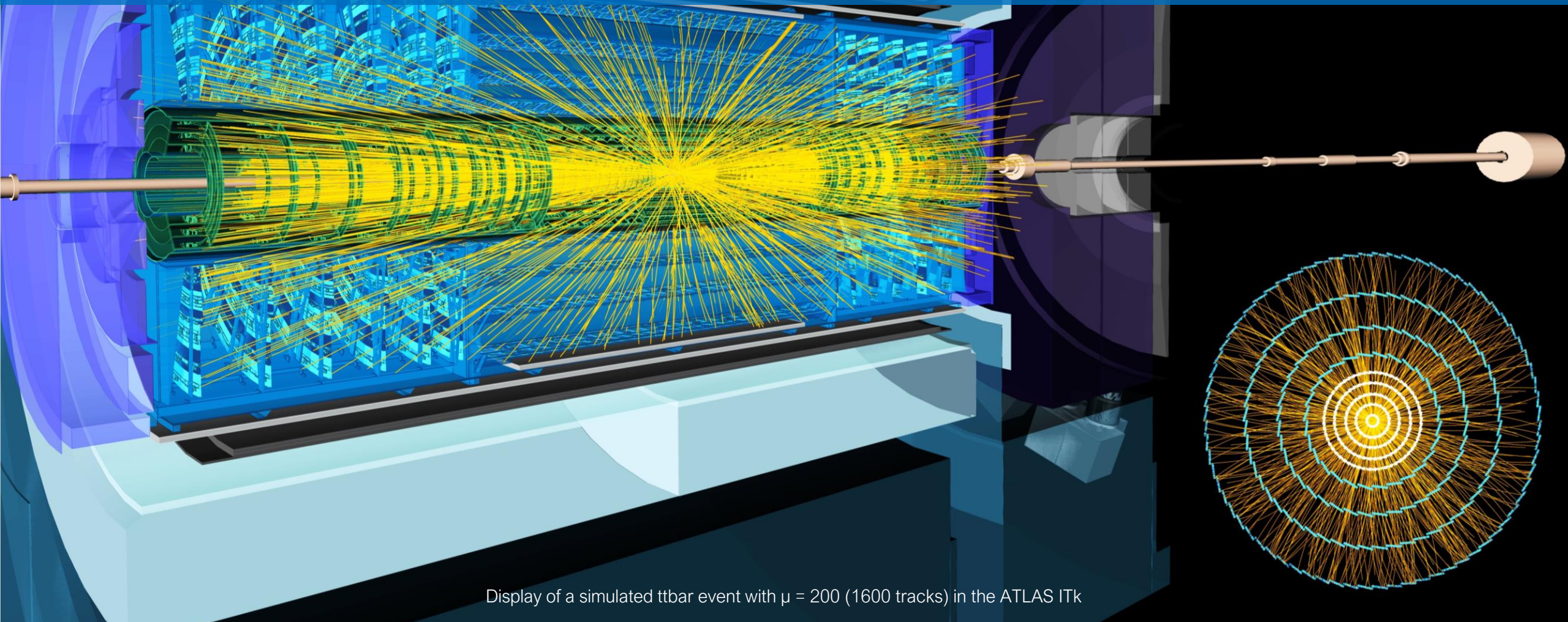
ATLAS Upgrades and Plans

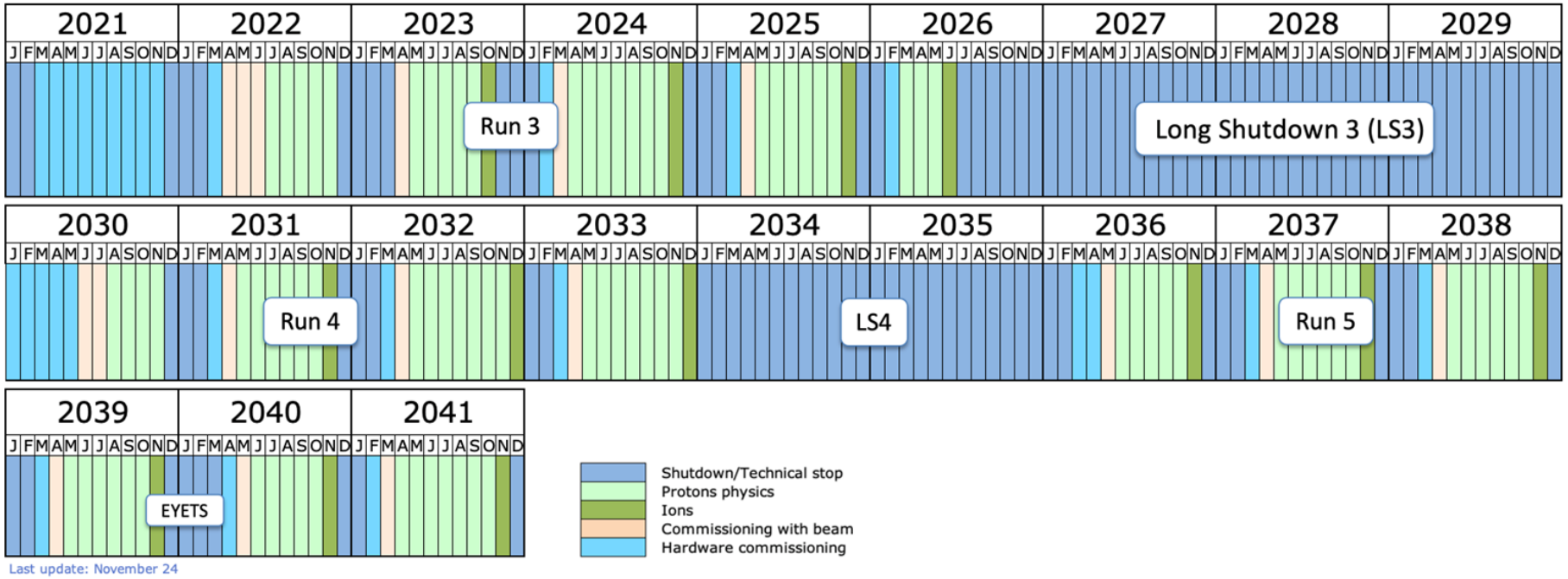
Craig Sawyer (STFC, Rutherford Appleton Laboratory) on behalf of the ATLAS Collaboration



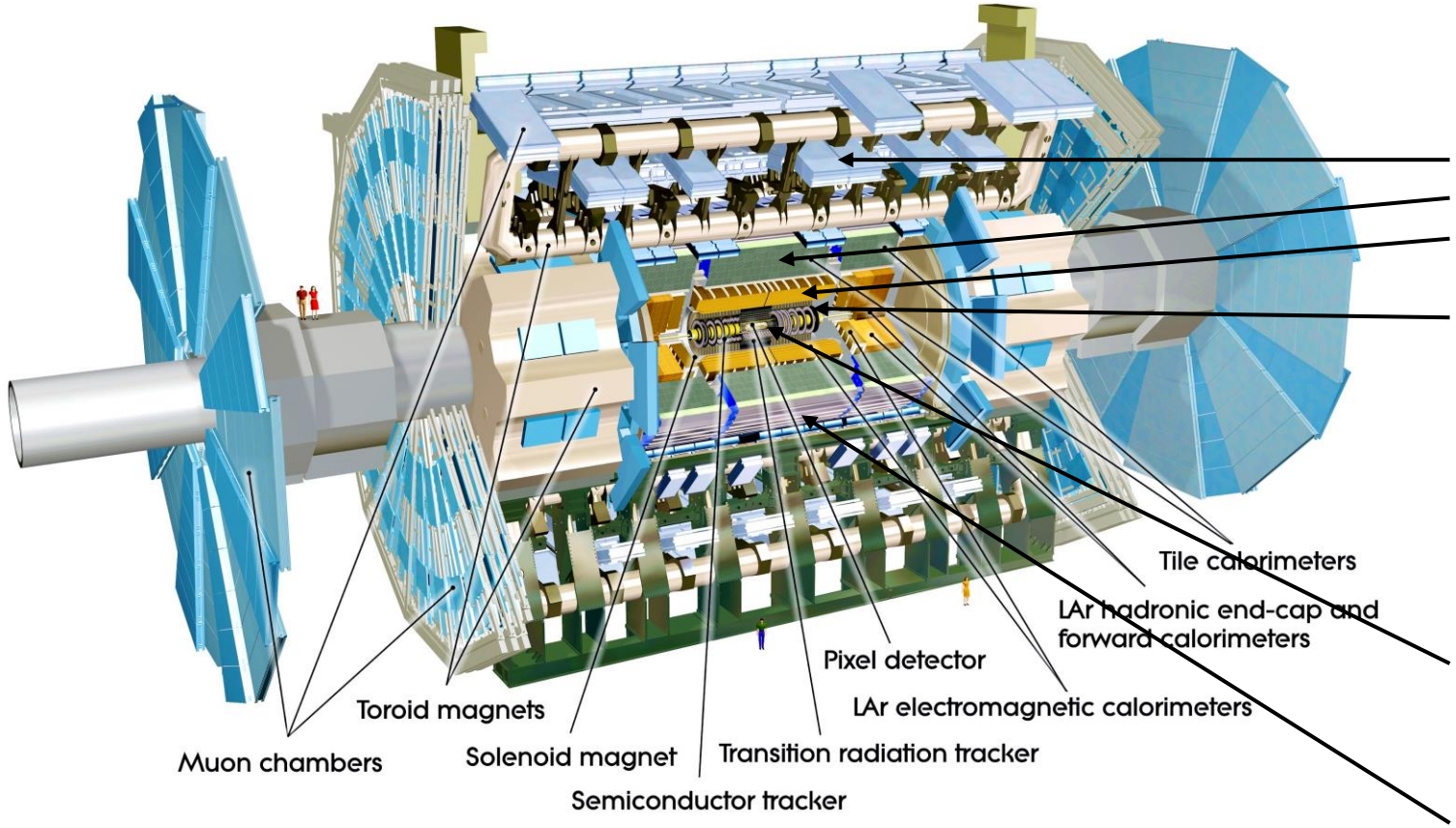
Display of a simulated ttbar event with μ = 200 (1600 tracks) in the ATLAS ITk

High Luminosity LHC

- Higgs factory (350M Higgs bosons produced) for precise Higgs coupling measurements, access to Higgs self-interaction and longitudinal vector boson scattering, and increased overall rare & new physics sensitivity
- Unique physics opportunities for many decades, in many ways complementary to an FCC-ee HET Factory
- The HL-LHC's luminosity requires unprecedented detector and computing technologies and thus significant experiment upgrades



ATLAS Phase-II Upgrade



Upgraded Trigger and Data Acquisition System
Level-0 Trigger at 1 MHz
Improved High-Level Trigger
150 kHz full-scan tracking

Electronics Upgrades
Muon System
Tile Calorimeter
LAr Calorimeter

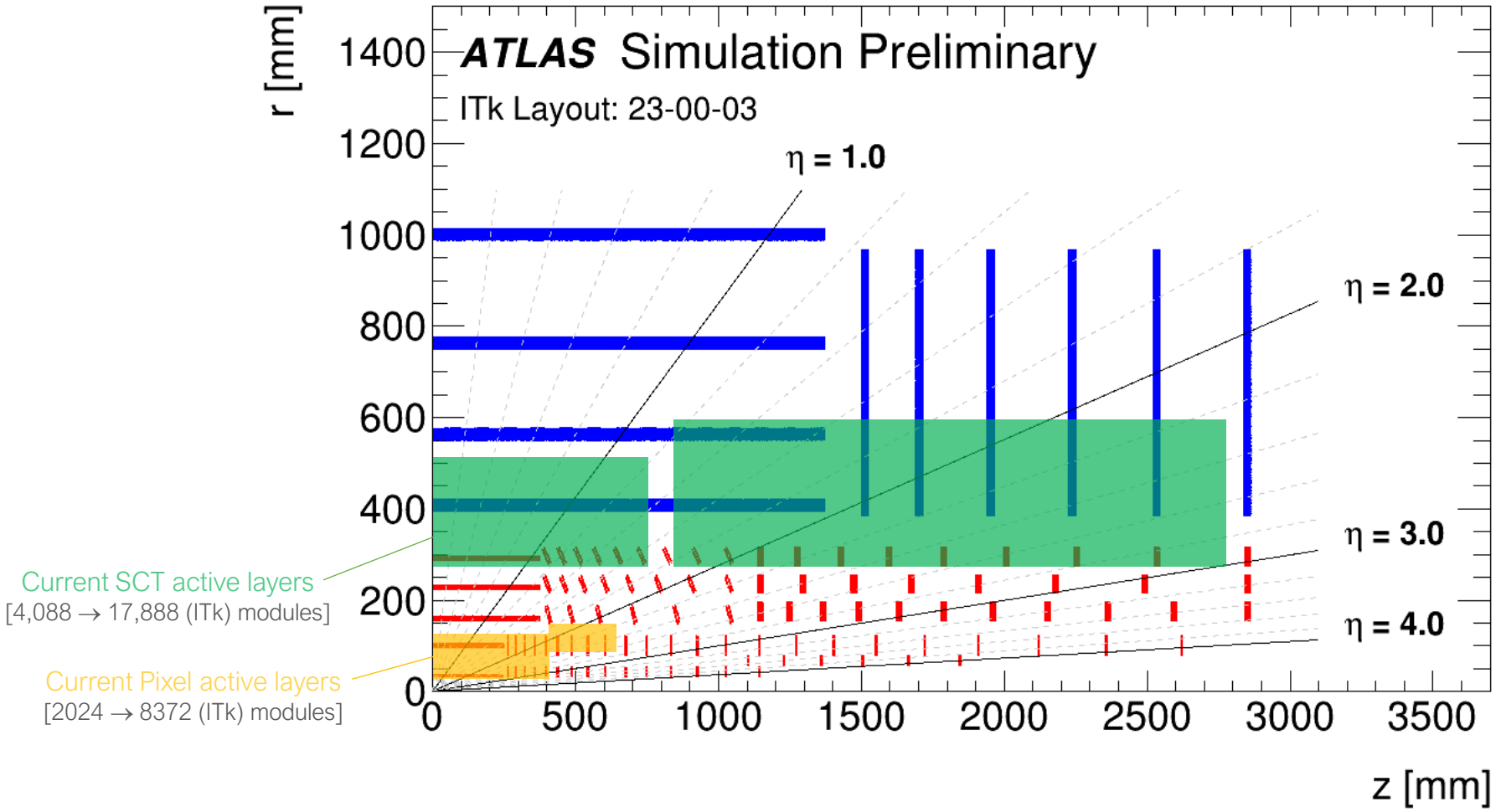
High Granularity Timing Detector (HGTD)
Forward region ($2.4 < |\eta| < 4.0$)
Low-Gain Avalanche Detectors (LGADs) with 30 ps track resolution

Additional small upgrades
Luminosity detectors (1% precision goal)
HL-ZDC

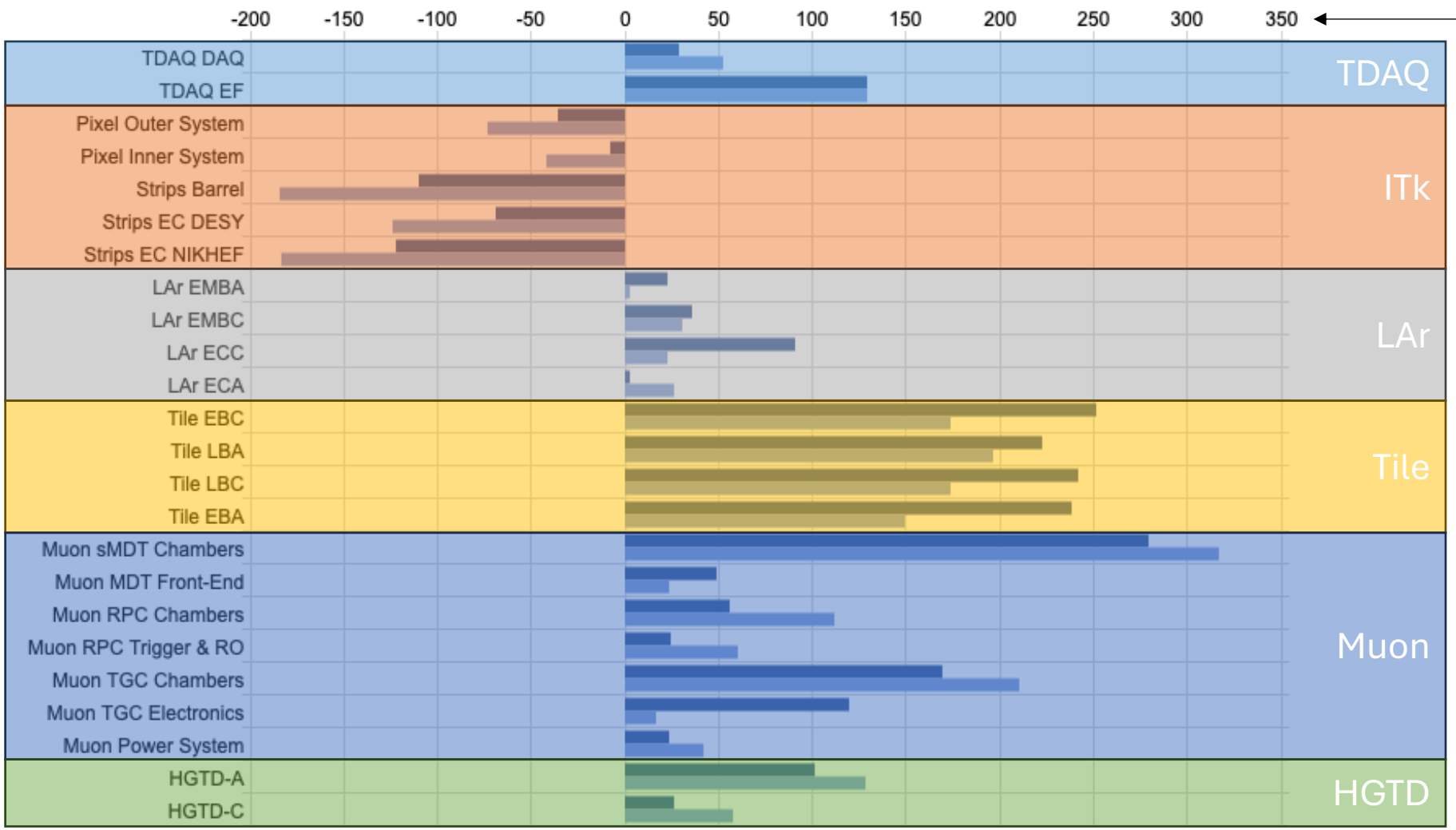
New Inner Tracking Detector (ITk)
All silicon
Coverage up to $|\eta| = 4$

New Muon Chambers
Inner barrel region with new RPC and sMDT detectors

ATLAS Phase-II Upgrade – Inner Tracker



Schedule Contingency Summary



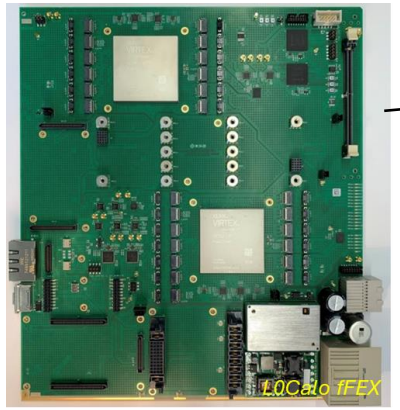
Schedule contingencies shown **not including** extra time from latest LHC schedule

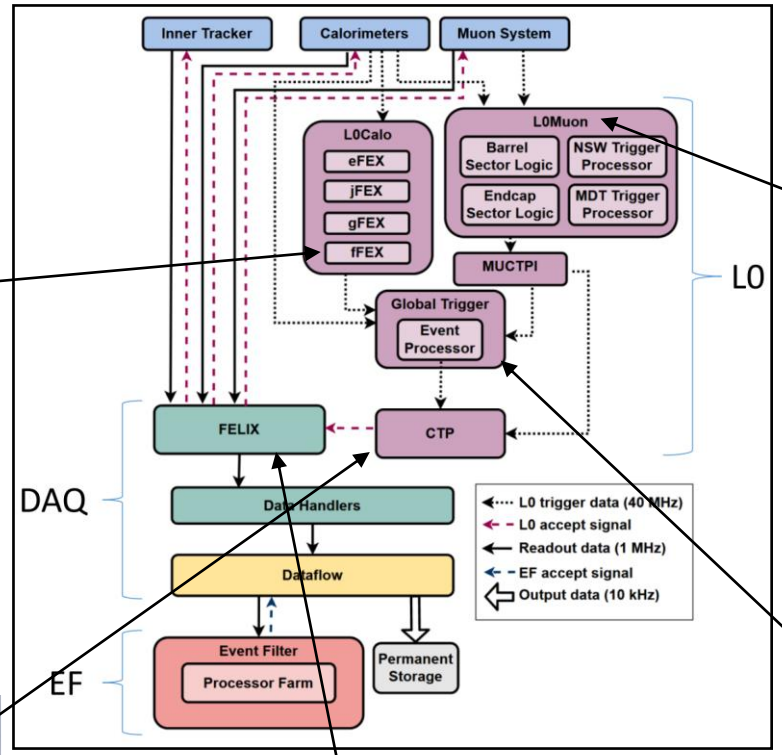
Work is ongoing to update LS3 schedule for latest LHC schedule

Once latest LHC schedule included expect smallest schedule contingency to be **+6.3 months (ITk)**

TDAQ

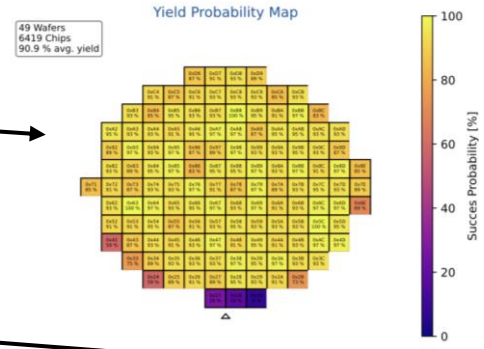
- Three major project areas
  - L0 Trigger
    - Low latency FPGA-based global trigger enabling complex event selections
  - DAQ
    - Readout, data handling, dataflow
  - Event filter (EF)
    - High level event selection
- Excellent progress in many areas
  - LTI, fFEX and GCM prototypes all received recently
  - Prototype DAQ boards received at CERN (FLX-182), first sample of production candidate card (FLX-155) tested
  - Proceeding towards EF technology choice through 2025

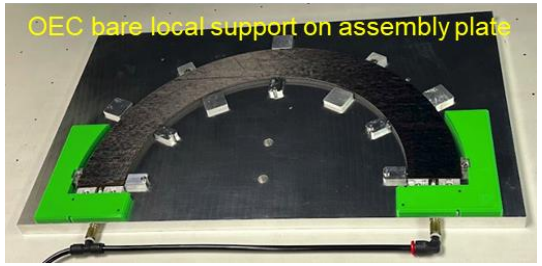


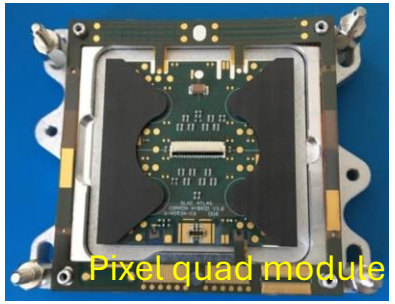


ITk Pixel

- Pixel production starting
  - Sensors and ASIC production progressing well
  - Production hybridisation started with 2/4 vendors
  - Two stage Production Readiness Review (PRR) for module assembly
    - First stage completed in July, second stage scheduled in November
  - Outer system local supports ongoing
- Tooling for integration etc. coming together nicely

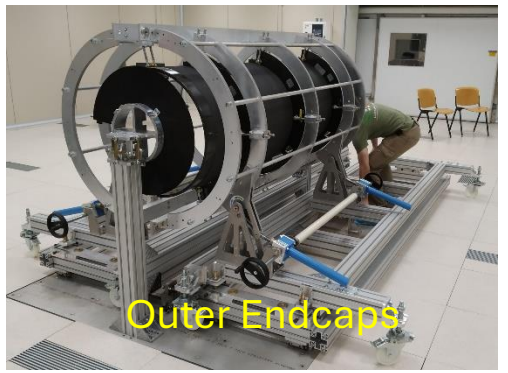


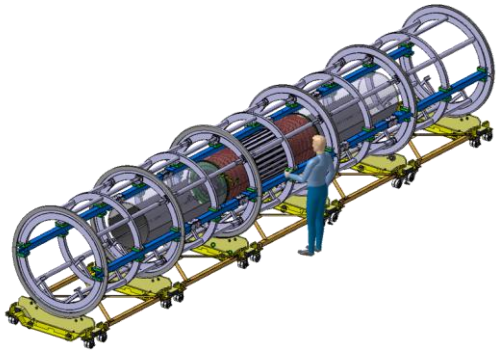




Area	PDR	Prototyping	FDR	Preproduction	PRR	Production
Planar Si sensors						
3D Si Sensors						
FE-ASIC						
Hybridization						
Module Assembly						
On-detector Services						
Off-detector Services						
Data Transmission						
Bare Local Supports						
Loaded Local Supports						
Global Mechanics						
Integration						
Power Supplies						

Complete Ongoing Upcoming



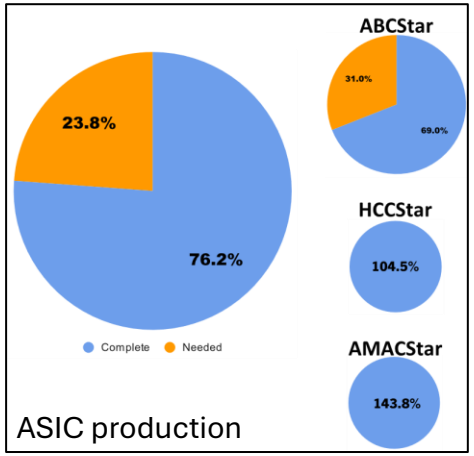


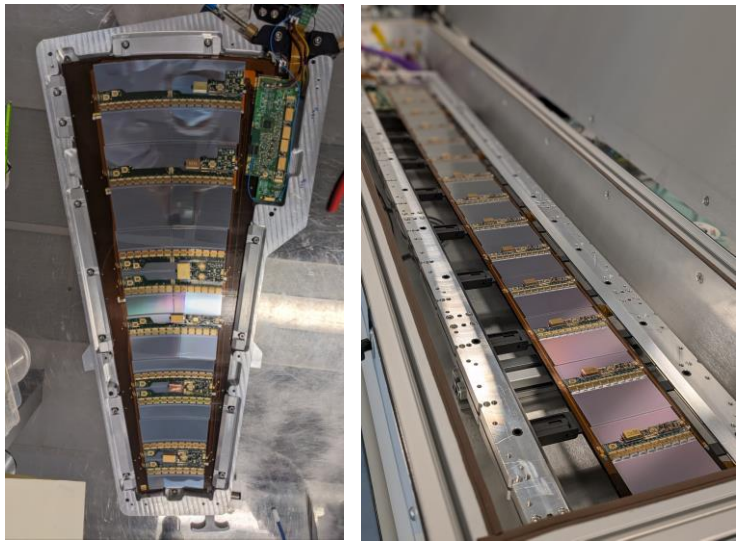
ITk Strip

- Many areas well into production
  - Sensors, ASICs, EoS, EoS-DCDC, bus-tapes, cores, common mechanics, service modules
- Module production on hold since May 2022 due to two major technical issues
- Currently building final prototypes validating solutions
  - Expect to start module production in early 2025
- Global mechanics being produced
  - 2 ECs, L3 and L2 all assembled

Area	PDR	Prototyping	FDR	Preproduction	PRR	Production
Sensors						
ASICs						
Modules						
EoS						
EoS-DCDC						
Cores (B)						
Cores (EC)						
Module mounting						
Global Mechanics						
Services (on-detector)						
Services (off-detector)						
Power Supplies						

Complete Ongoing Upcoming





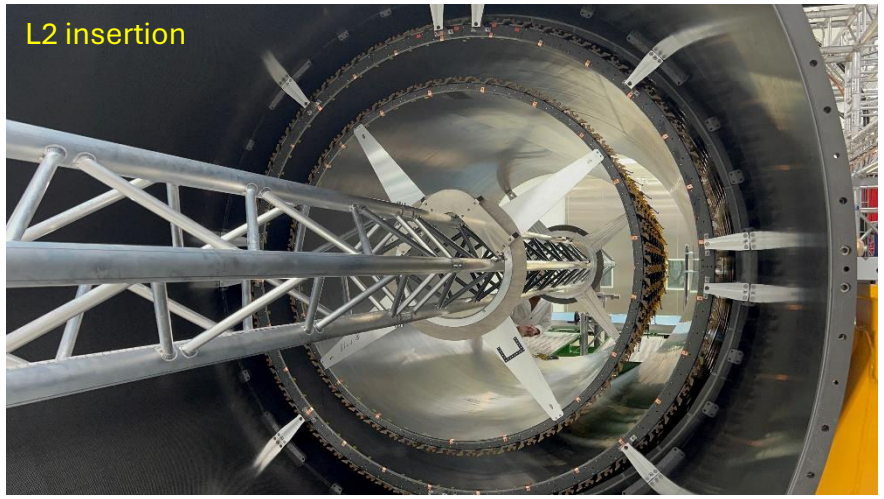
Recent prototype stave/petal

ITk Common

- Outer Cylinder (OC) has been delivered and assembled at CERN
  - Polymoderator and first two barrels inserted
- Surface integration facility at CERN coming together


Outer cylinder and access platforms


OC assembly (B180)

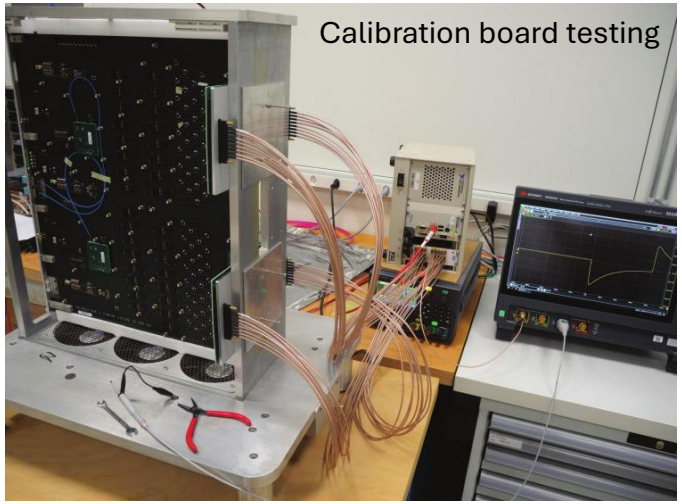

L2 insertion

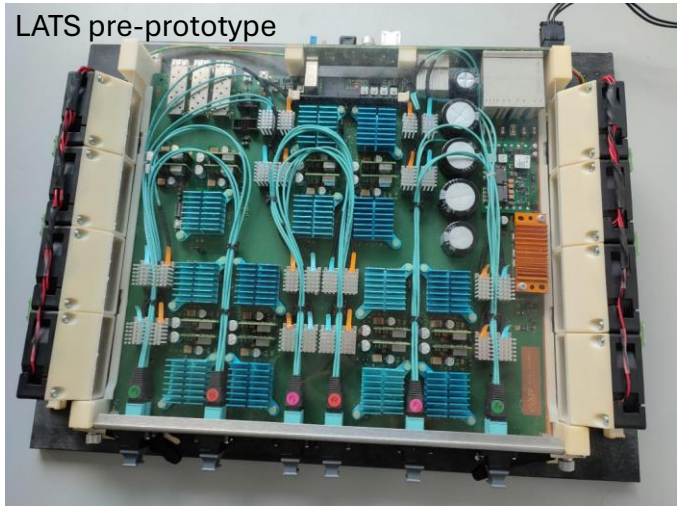

Polymoderator insertion

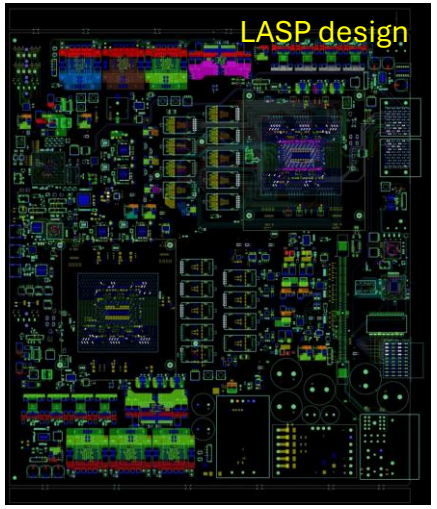

L3 insertion

LAr Calorimeter

- Upgrade of readout electronics
- On detector
  - Front end ASICs in production with excellent test results
  - Final prototype (v2.5) of FEB2 board in hand
    - Initial tests show excellent analogue performance
    - Mini-series being produced now for important half-crate test (by end of year)
  - Calibration board prototypes also in hand and being tested
- Off detector
  - Finalising routing of signal processor board (LASP)
    - First prototypes in March 2025
  - Timing system pre-prototypes (LATS) full assembled and being tested

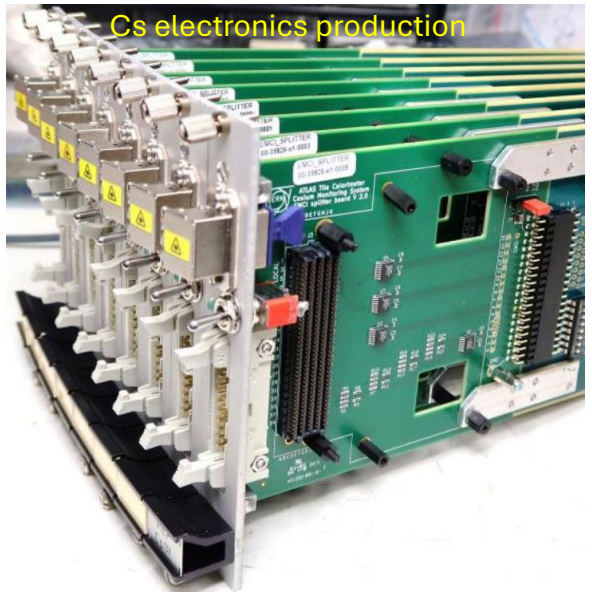




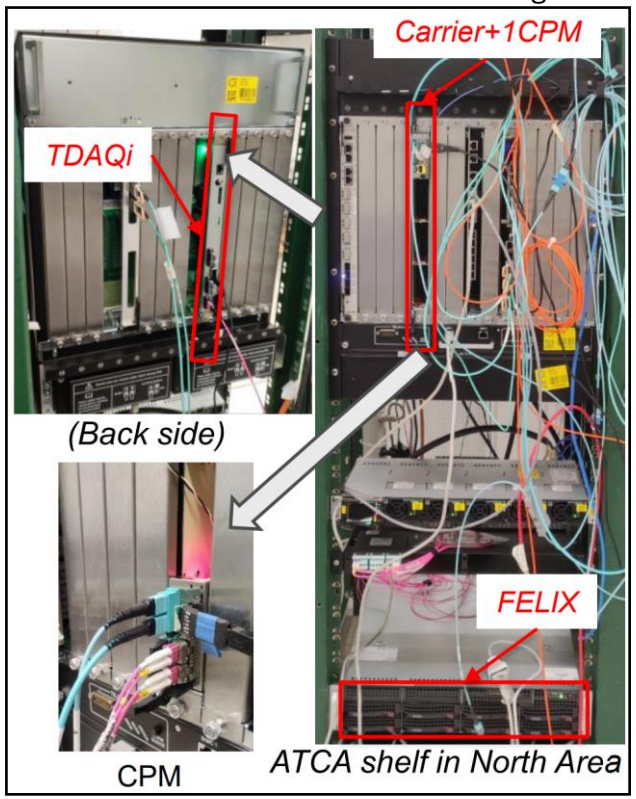


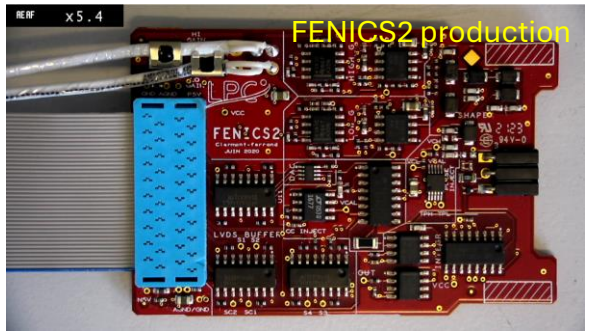
Tile Calorimeter

- Upgrade of readout electronics
- On detector
  - Production and testing of replacement PMTs proceeding well
  - FE board (FENICS2) production running well
  - Daughter board prototypes under test and preproduction starting
- Off detector
  - Compact processing module (CPM) v2 fully validated
  - Successful integration of readout slice during last testbeam
- Calibration
  - All electronics parts have entered production



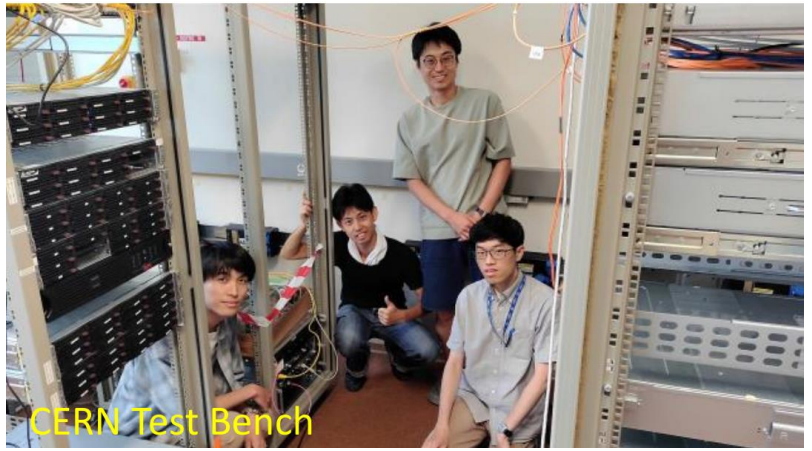
Readout slice integration

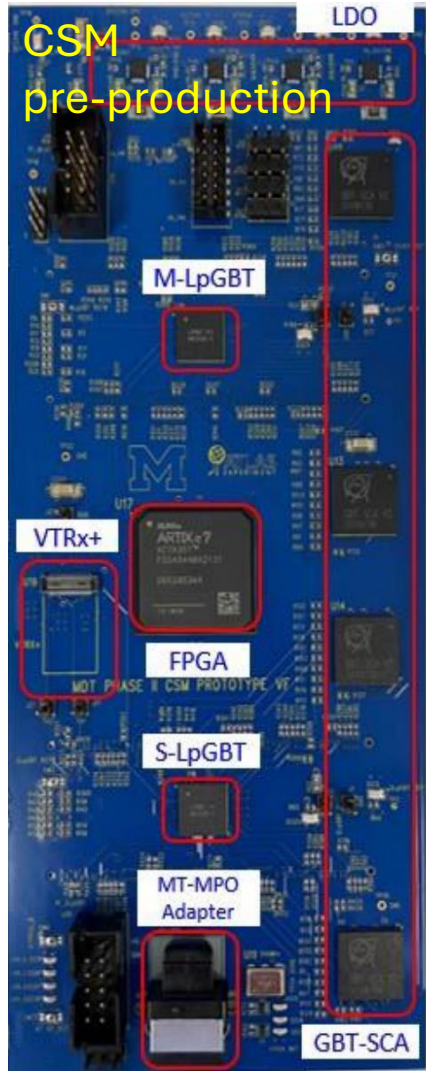




Muons

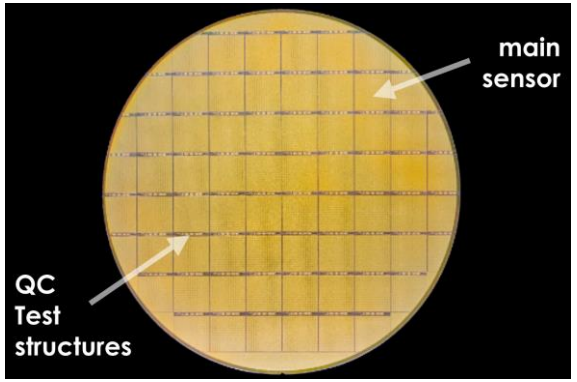
- Electronics upgrades of MDT, RPC & TGC to cope with Phase-II trigger and readout requirements
  - MDT electronics all in final design, heading towards production
  - Full RPC readout chain tests progressing
  - TGC electronics ASIC production complete, board production in progress
- New RPC and sMDT in inner barrel layer
  - RPC gas leak found during production has been extensively studied an alternative solution developed, tested and validated
  - sMDT production is complete

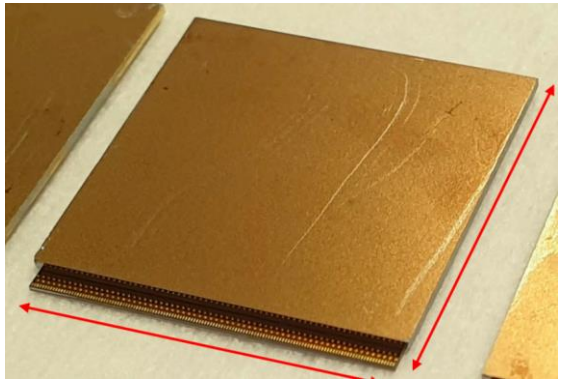


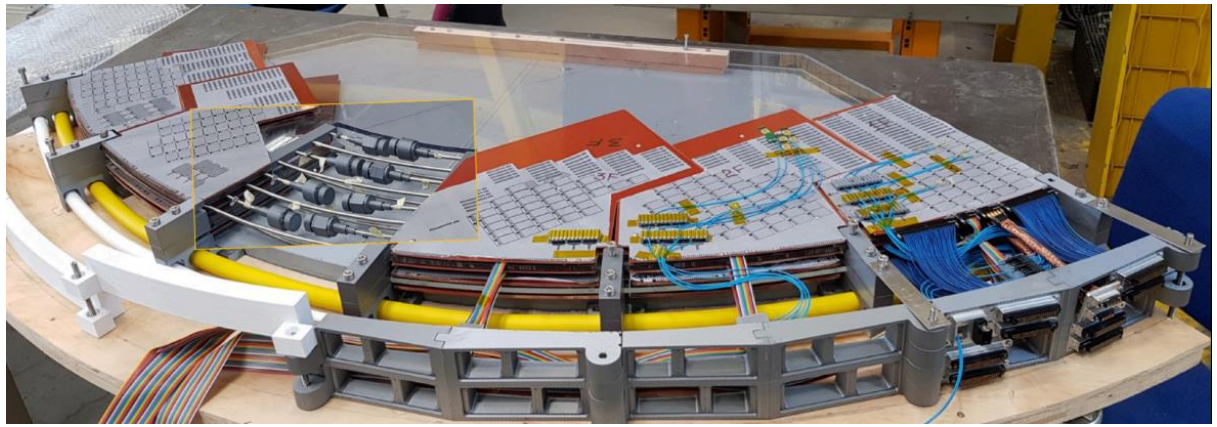


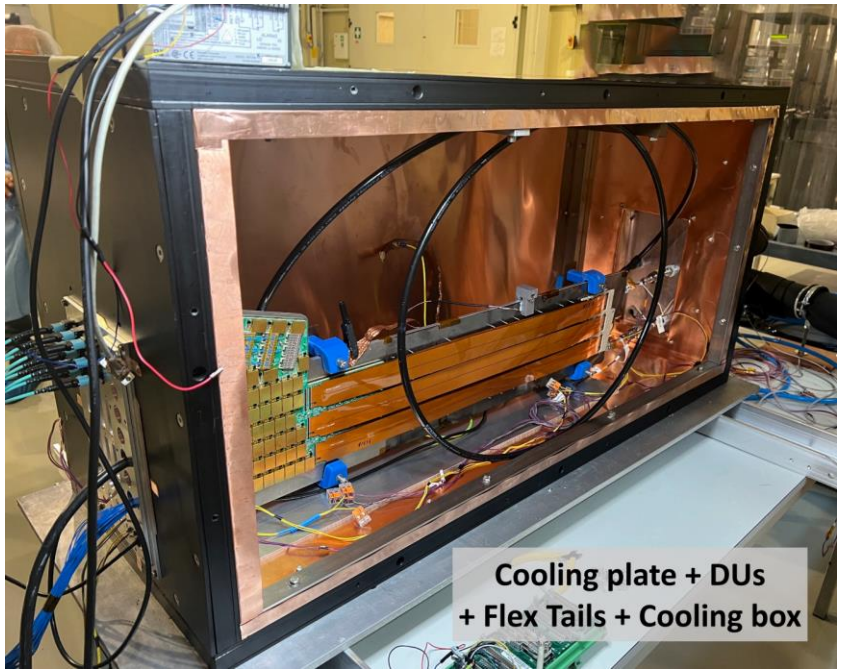
HGTD

- Pixel detector with coarse spatial resolution but precision timing
- LGAD sensor & readout ASICs tested extensively
  - Sensor and ASIC production imminent
- Extensive testing and simulation performed on hybridised modules
  - Expect to start pre-production soon with unthinned sensors following hybridisation studies
- Excellent progress on services and fibre mock-ups
- Demonstrator tests ongoing





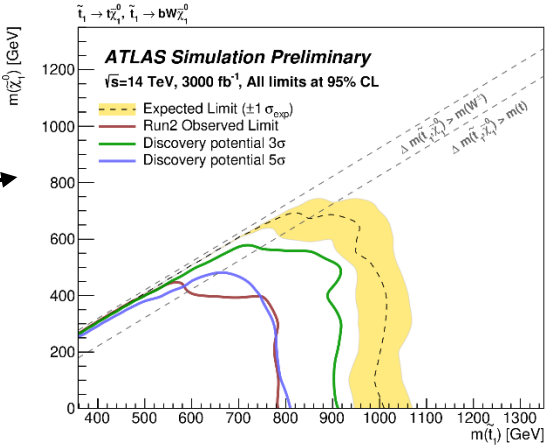


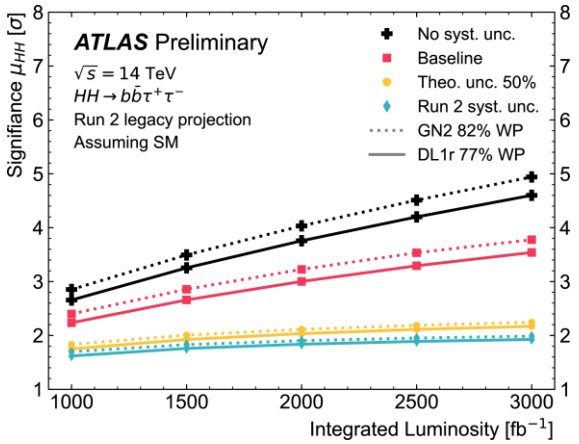


Upgrade Physics

- Many physics studies for HL-LHC are in the process of being updated for European Strategy Update
- Huge range of physics goals for ATLAS @ HL-LHC
  - Di-Higgs, Higgs couplings, rare Higgs decays, VBS, BSM …

ATL-PHYS-PUB-2024-001





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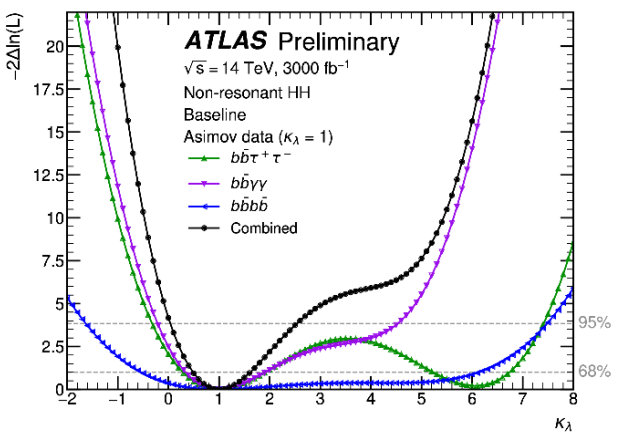
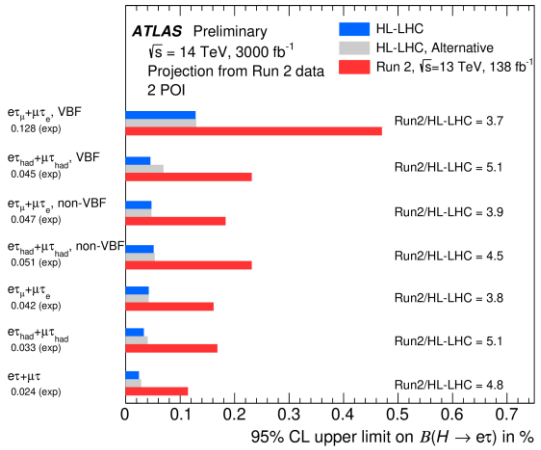


ATL-PHYS-PUB-2022-053



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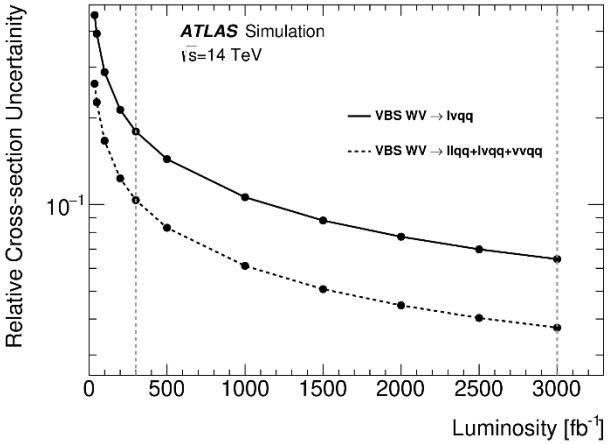


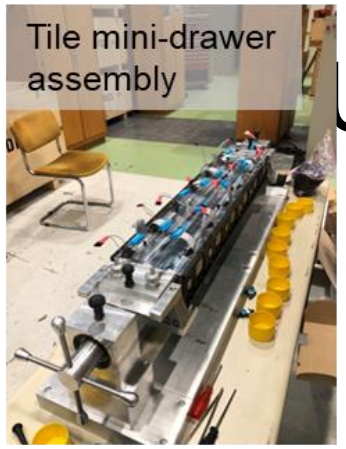
ATL-PHYS-PUB-2022-018

Conclusions

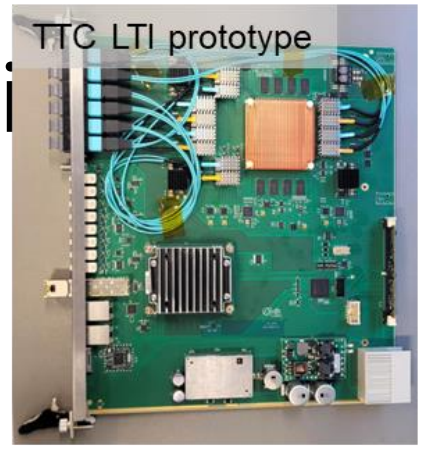
- Huge amount of activity ongoing to upgrade the detector for HL-LHC
  - All new Inner Tracker, fully upgraded calorimeter readout, new muon chambers, new high precision timing layer, new trigger and DAQ systems
- Facing, and traversing, a number of challenging technical problems that have led to delays in our schedule
- Currently schedule has at least 6 months of float for all upgrade projects
- Delivering the upgrade on time for the HL-LHC start is the highest priority for the collaboration

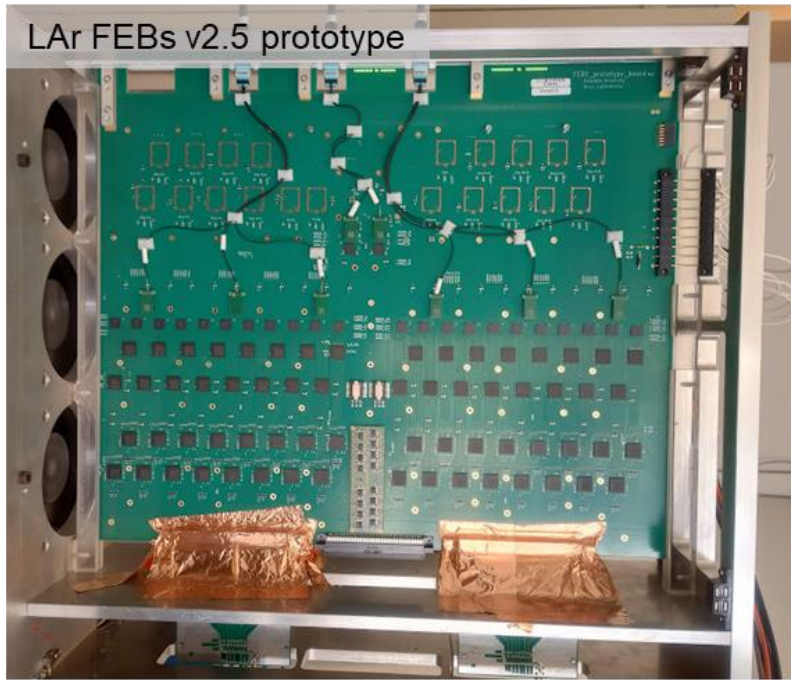
During October ATLAS Week we organised visits to various upgrade sites at CERN (150 participants)


Tile PMT block tests


Tile mini-drawer assembly


RPC Gas Gap production


TTC LTI prototype

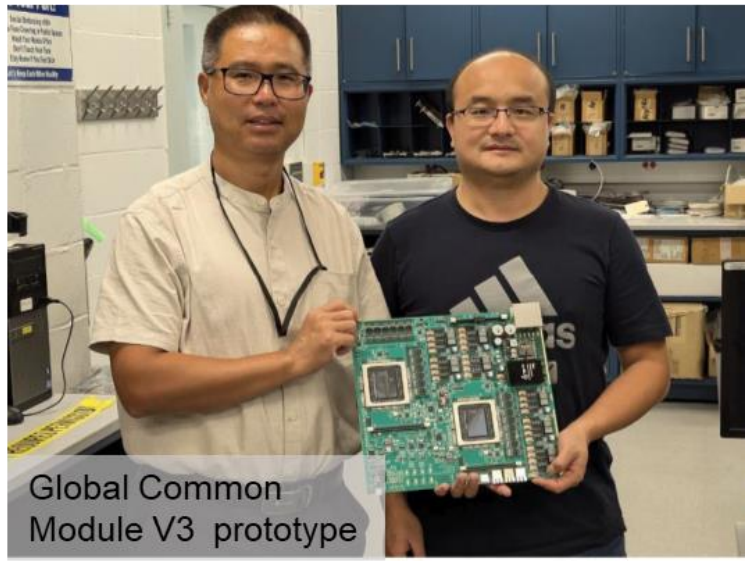

LAr FEBs v2.5 prototype


Alternative RPC gas distribution studies

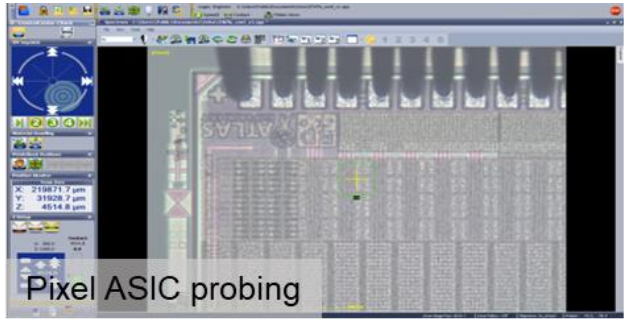

First batch of FELIX FLX-182 boards

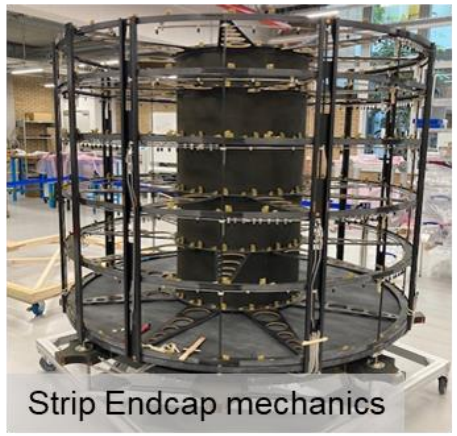

HGTD demonstrator

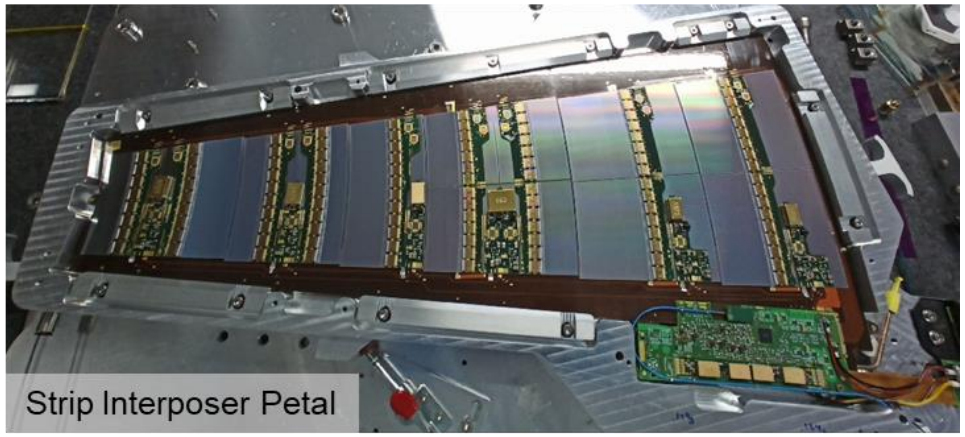

Robotic test setup for LAr ALFE

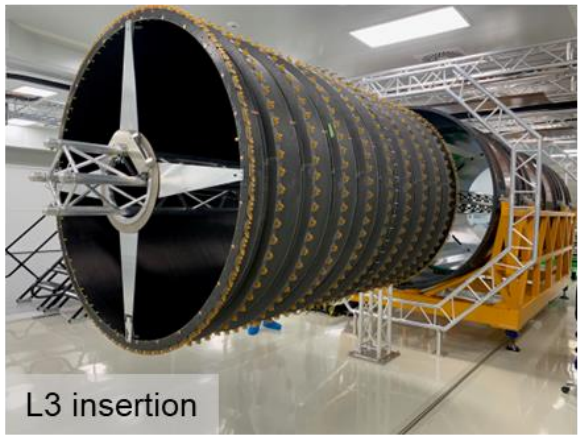

Global Common Module V3 prototype

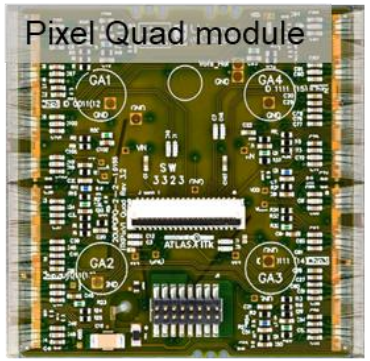
CO2 plant SR1


Pixel ASIC probing


Strip Endcap mechanics

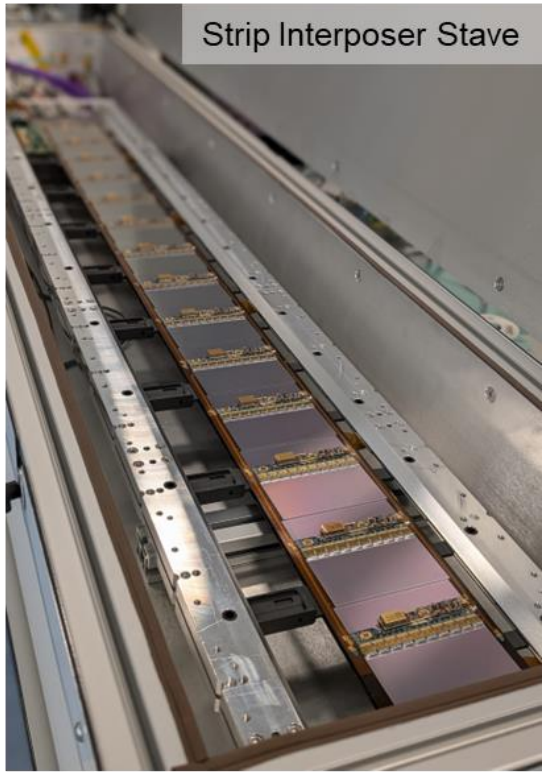

Strip Interposer Petal

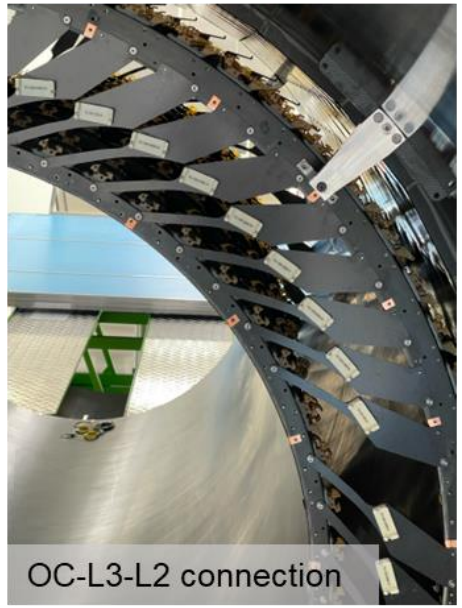

L3 insertion



Pixel Quad module


Pixel Inclined Half-rings


Strip Interposer Stave


OC-L3-L2 connection


Fiber Optic Sensors on L3


Strip Interlock in SR1