

ATLAS Liquid Argon Calorimeter Commissioning for LHC Run-3

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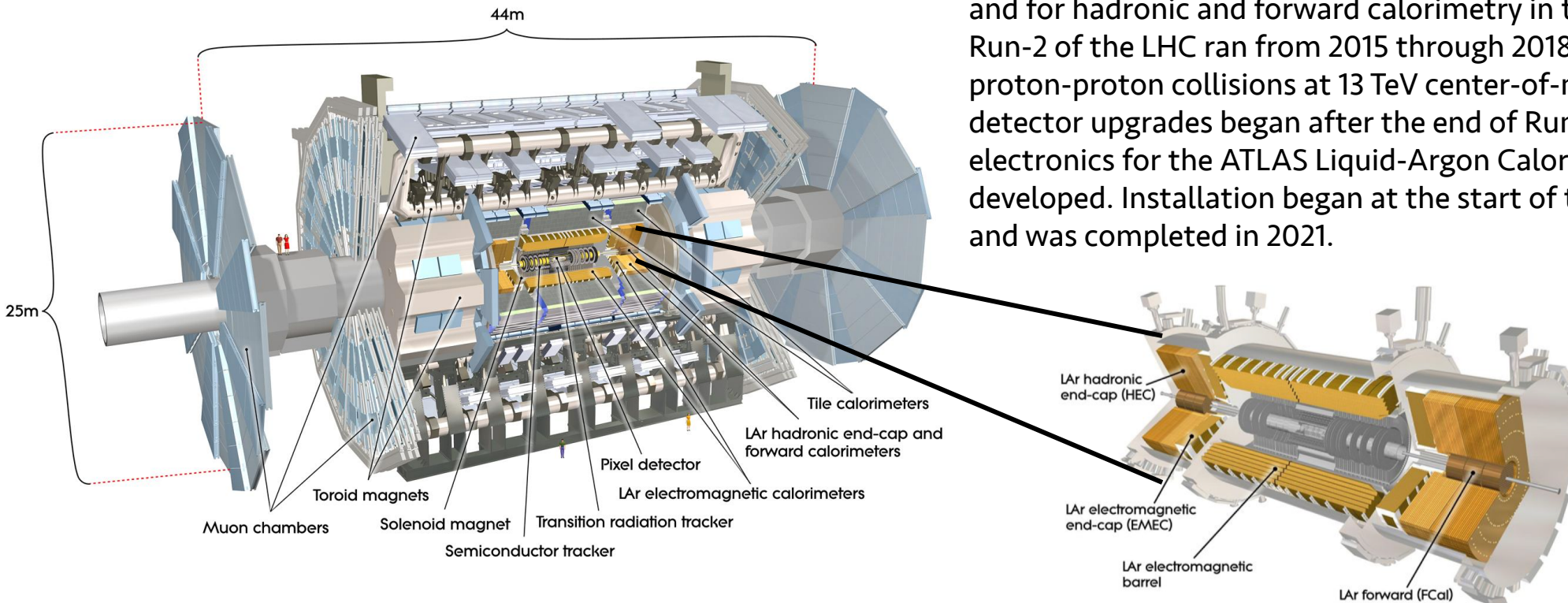


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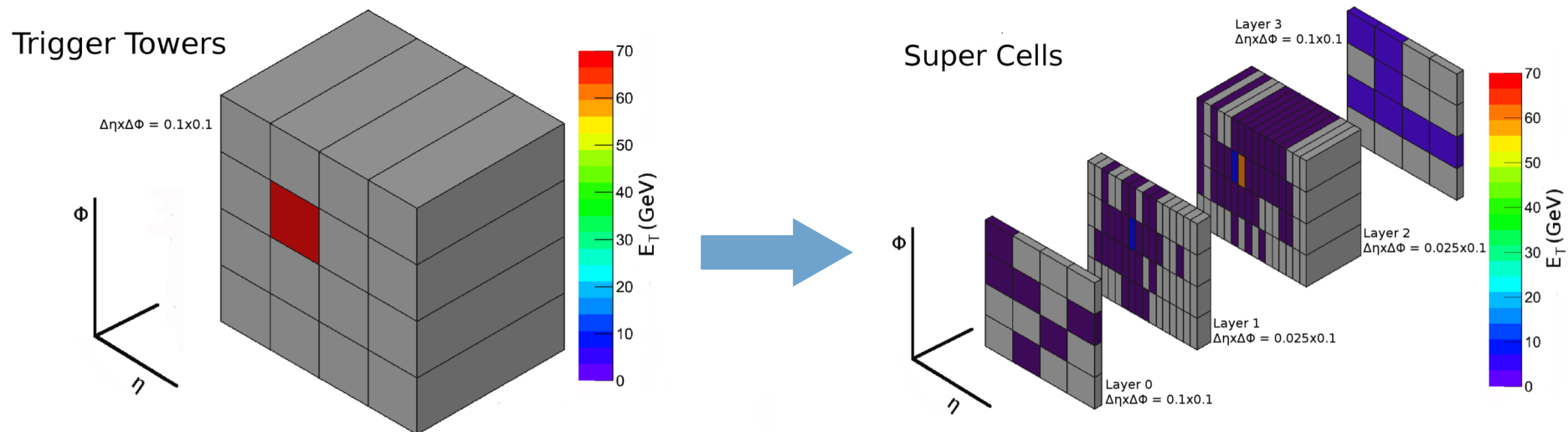
ATLAS and the Liquid Argon (LAr) Calorimeter

The ATLAS detector is a multi-purpose spectrometer designed to study proton-proton collisions produced at the Large Hadron Collider (LHC) at CERN. The Liquid Argon (LAr) sampling calorimeter is responsible for all electromagnetic (EM) calorimetry in the pseudo-rapidity region $|\eta| < 3.2$ and for hadronic and forward calorimetry in the region $1.5 < |\eta| < 4.9$. Run-2 of the LHC ran from 2015 through 2018 and delivered 156 fb^{-1} of proton-proton collisions at 13 TeV center-of-mass energy. Phase-I detector upgrades began after the end of Run-2. New trigger readout electronics for the ATLAS Liquid-Argon Calorimeter have been developed. Installation began at the start of the LHC shut down in 2019 and was completed in 2021.

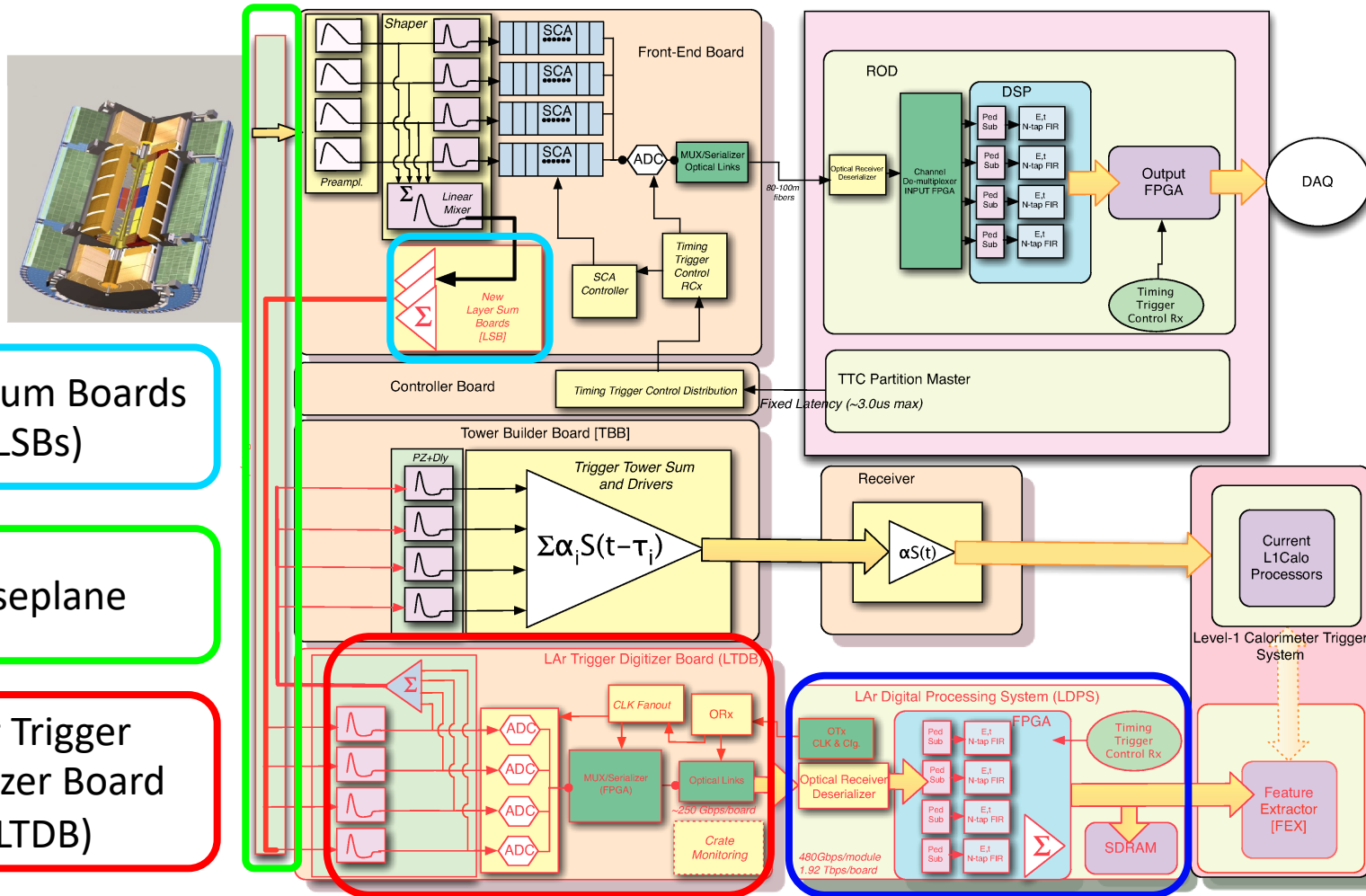


Phase-I Upgrade Overview

The Level-1 trigger readout system was upgraded to replace old *trigger towers* with *super cells*. The super cells improve granularity by up to a factor of 10 in order to improve object discrimination at the trigger level. This allows the transverse energy trigger thresholds to remain at the same level, even with future increases in luminosity. Additionally, the super cells allow access to the longitudinal shower shape, enabling shower shape parameter calculations at the Level-1 trigger stage.



Phase-I Upgrade – Electronics Readout



Layer Sum Boards (LSBs)

Baseplane

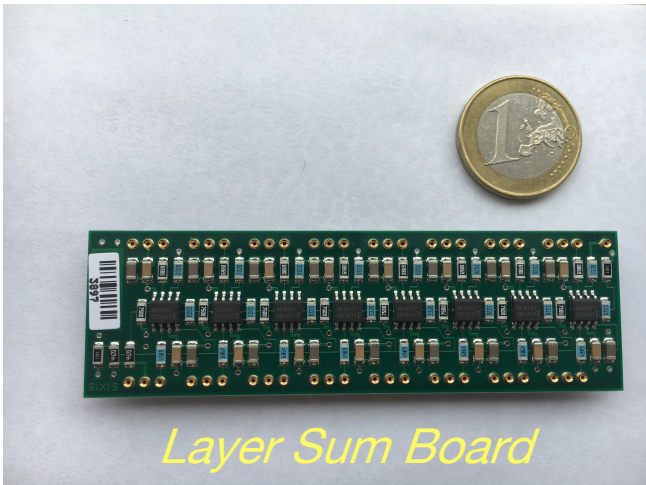
LAr Trigger Digitizer Board (LTDB)

- The highlighted systems have been upgraded as part of the LAr Phase-I upgrade.
- The new trigger readout path is illustrated with solid red arrows.
- The current analog trigger readout (*legacy* system) is also kept functional and will remain operational during the initial phase of LHC Run 3.

LAr Digital Processing Blade (LDPB)

Phase-I Upgrade – New LSBs and Baseplanes

The **Layer Sum Board (LSB)** is a plug in card for the Front End Board (FEB) which provides summing of signals from the new super cells. For the Phase-I upgrade, the new LSBs send finer sums to the LTDBS, while also retaining the signals needed for the legacy trigger path.

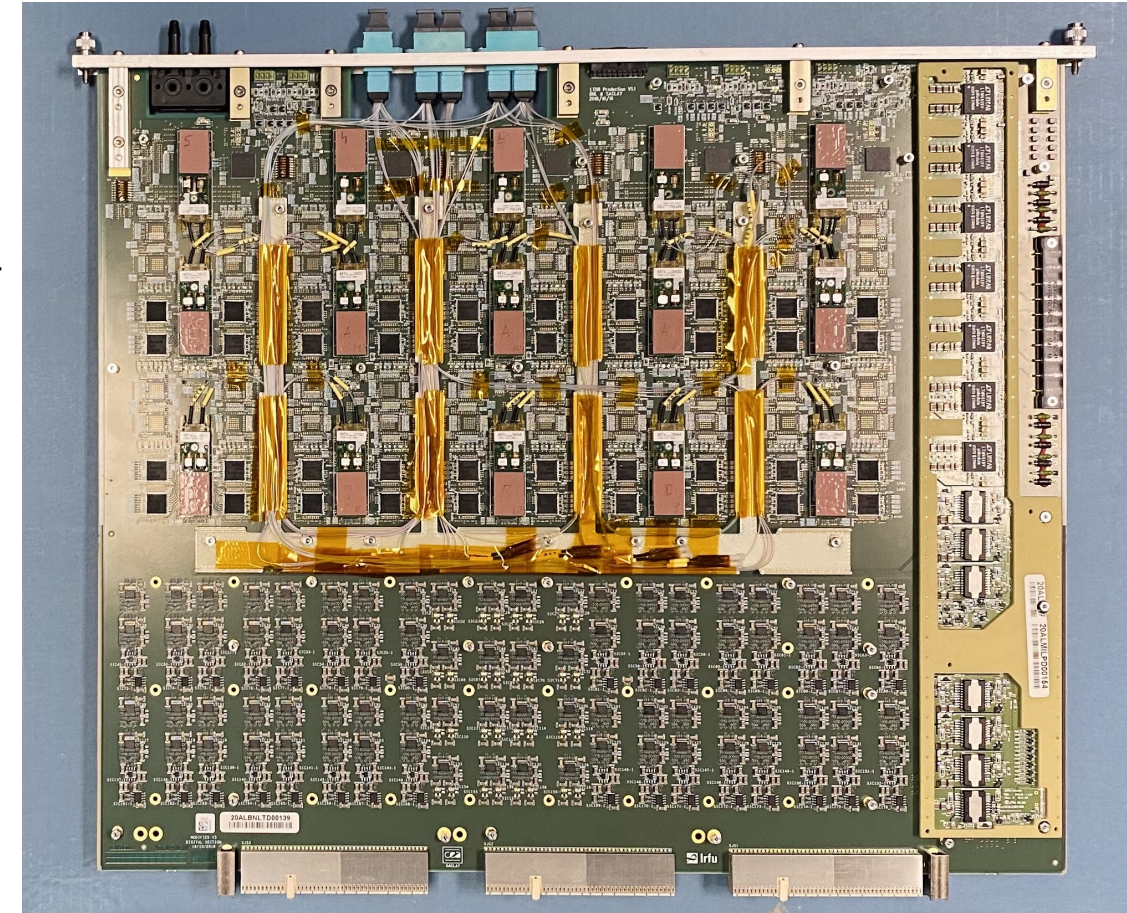
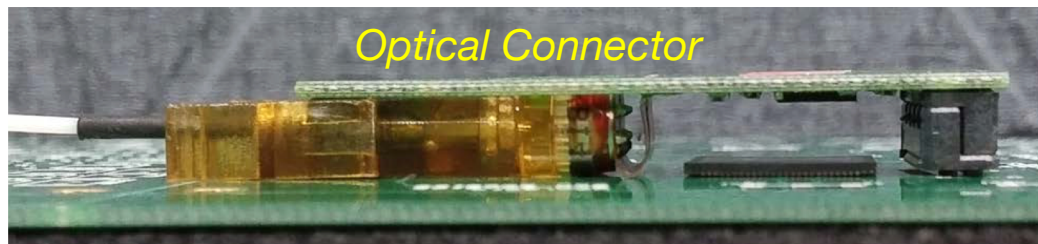
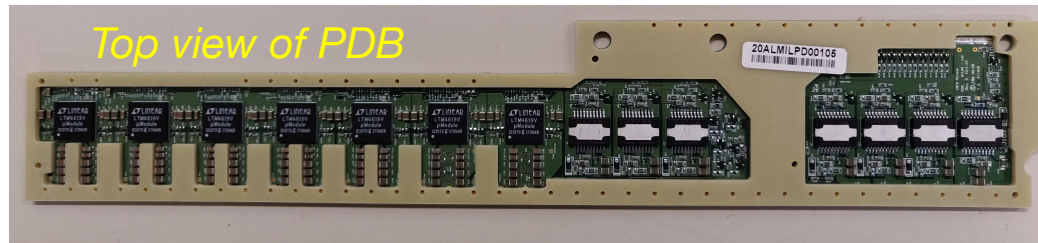


The **baseplanes** are connected to the front end crates and enable signal feedthrough. The new baseplanes (1) accommodate finer trigger segmentation, (2) allow connection of the LTDBs, and (3) maintain the legacy Level-1 trigger system.



Phase-I Upgrade – Trigger Digitizer Boards

The **LAr Trigger Digitizer Board (LTDB)** digitizes up to 320 Super Cell signals (“channels”) and transmits them at 40MHz via optical links to the back-end electronics for trigger processing. The LTDBs also provide summed analog signals for the legacy trigger system via the new baseplanes. The LTDBs depend on custom radiation hard analog to digital converter (ADC) ASICs, specialized optical transmitters, a motherboard for digitizing signals, and a power distribution board (PDB)



Assembled LTDB with PDB installed

Phase-I Upgrade – Digital Processing Blades

LAr Digital Processing Blades (LDPBs) reconstruct the transverse energy E_T , and transmit it to the L1Calo system

$$1 \text{ LDPB} = 1 \text{ LArC} + \text{LATOMEs} + \text{IPMC}$$

LAr Carrier (LArC):

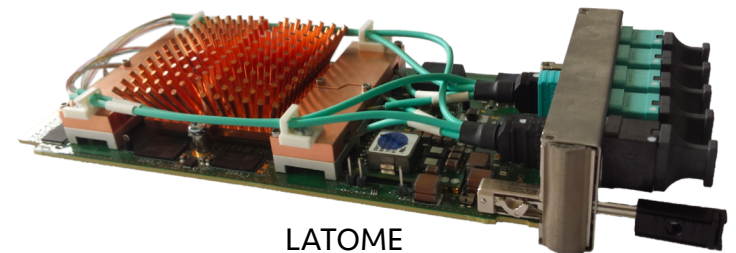
- Global & local readout
- Provides trigger, timing and control signals to the LATOMEs

LAr Trigger prOcessing MEzzanine (LATOME):

- Receive up to 48 high speed input links from LTDB at 40MHz
- Reconstruct super cell E_T and identify the bunch crossing ID (BCID)
- Transmit results to the L1Calo system

Intelligent Platform Management Controller (IPMC):

- An intelligent hardware management system for ATCA boards and ATCA carrier boards
- Control, monitor, and generate alarms



LATOME

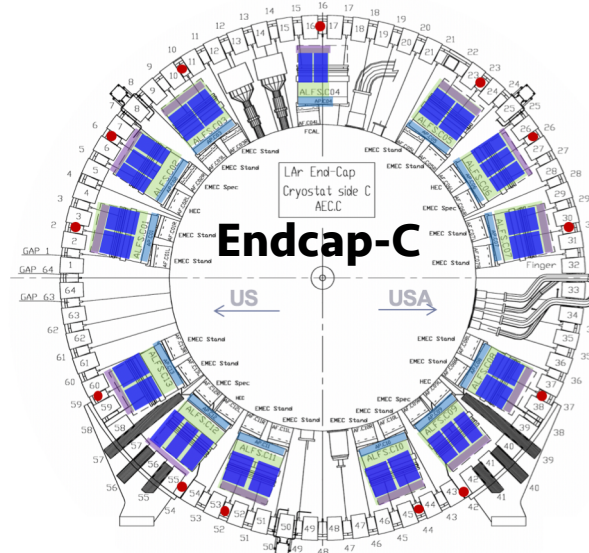
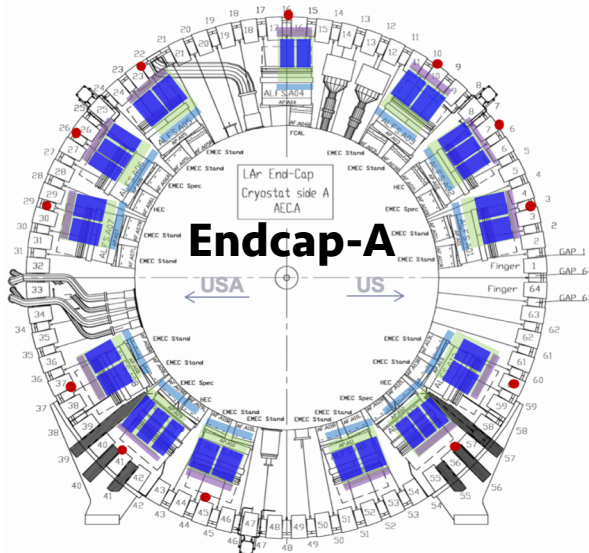
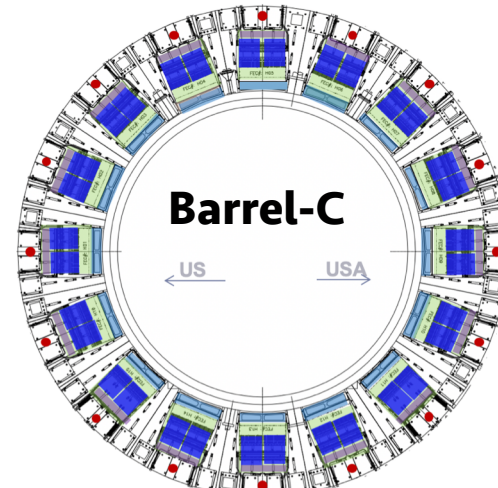
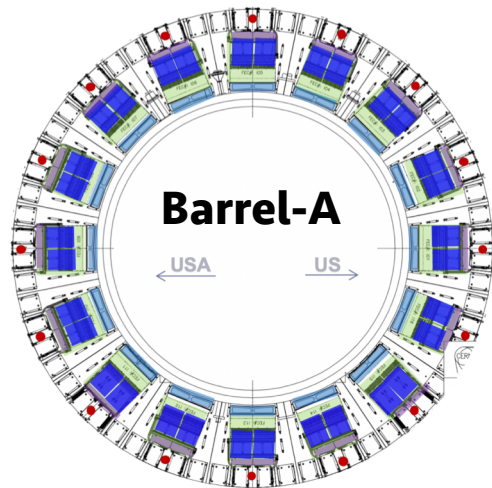


IPMC with coin for scale



LArC

Phase-I Upgrade – Installation Completed

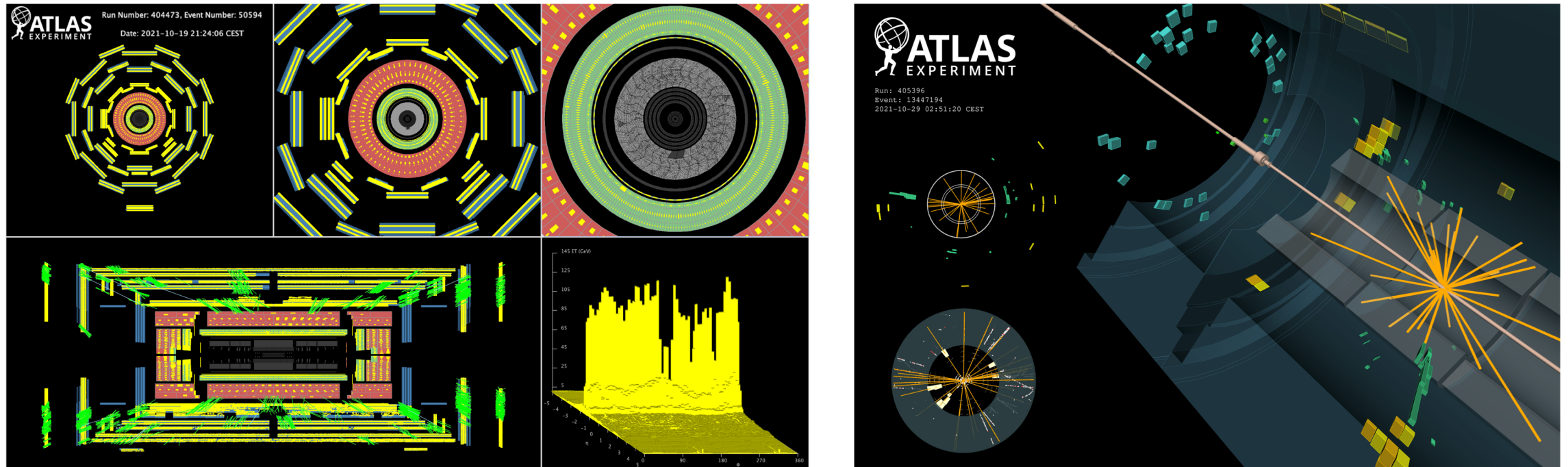


- Baseplane exchanged ✓ All baseplanes and front-end boards (FEBs) have been refurbished and reinserted – in total 114 new baseplanes
- Re-cabled for commissioning
- Boards reinserted ✓ All LTDBs are installed and connected – in total 124 LTDBs
- LTDB installed, In commissioning ✓ All LTDBs are undergoing validation and commissioning
- LVPS cooling hose replaced ✓ All 30 LDPBs are have been installed and connected

Following installation, a number of validation tests for legacy trigger and new digital trigger were performed. These included connectivity and mapping scans, calibration tests, and joint tests with the L1 Calo system. Both legacy and digital trigger systems were confirmed to be working well.

Pilot Run

In October 2021, the LHC “Pilot Run” took place over a two week period. During this time, all ATLAS detector subsystems worked together to record the first splash events and stable beam “frictions” since the end of Run 2. The LAr system operated successfully – the legacy trigger was used for triggering, and the new digital trigger chain was tested and observed to be working. The pilot beam period provided a comprehensive test of the LAr Phase-I upgrade and LAr’s preparedness for data taking in Run 3.

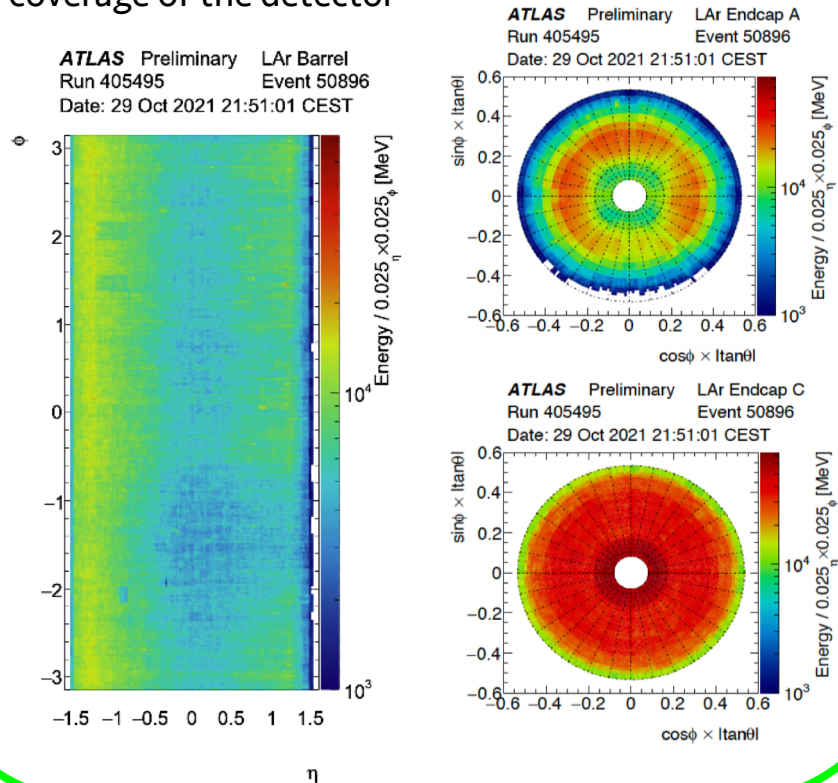


ATLAS Event Displays from the 2021 Pilot Run

Pilot Beam Results

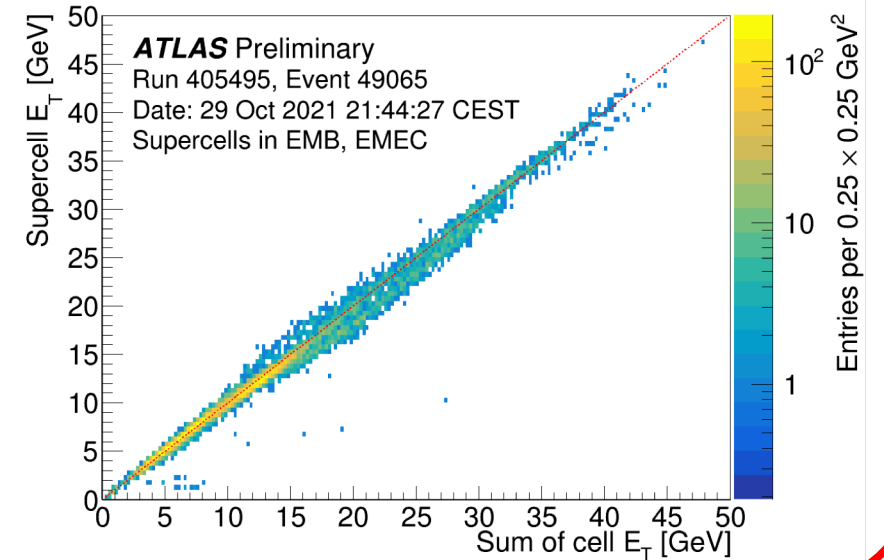
LAr Cell Coverage

With splash data, the plots show readout of all the calorimeter cells, which is a confirmation of the good coverage of the detector



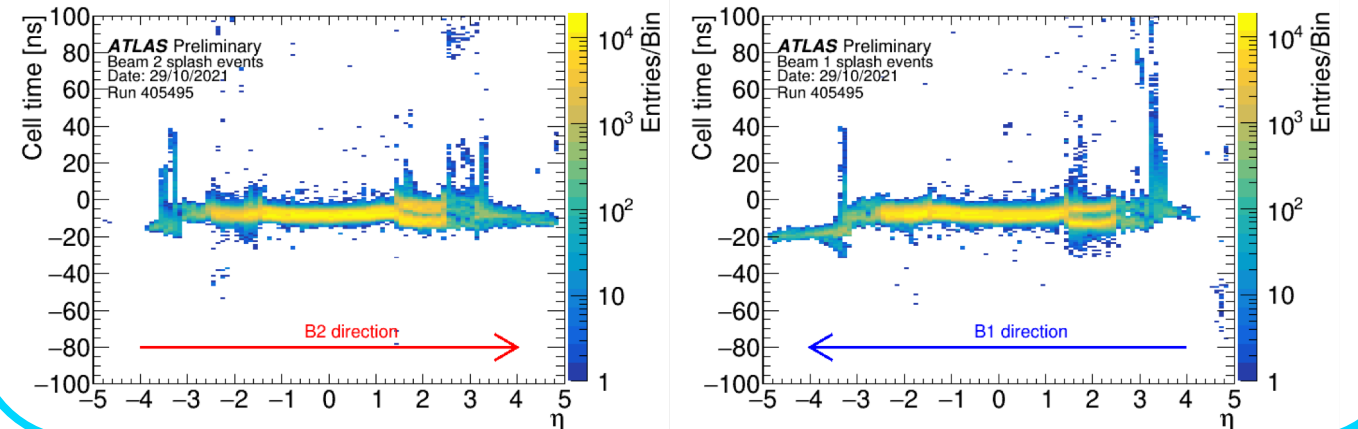
Digital Trigger Energy Reconstruction

The E_T computed for the main readout and the E_T computed with the digital trigger show very good agreement

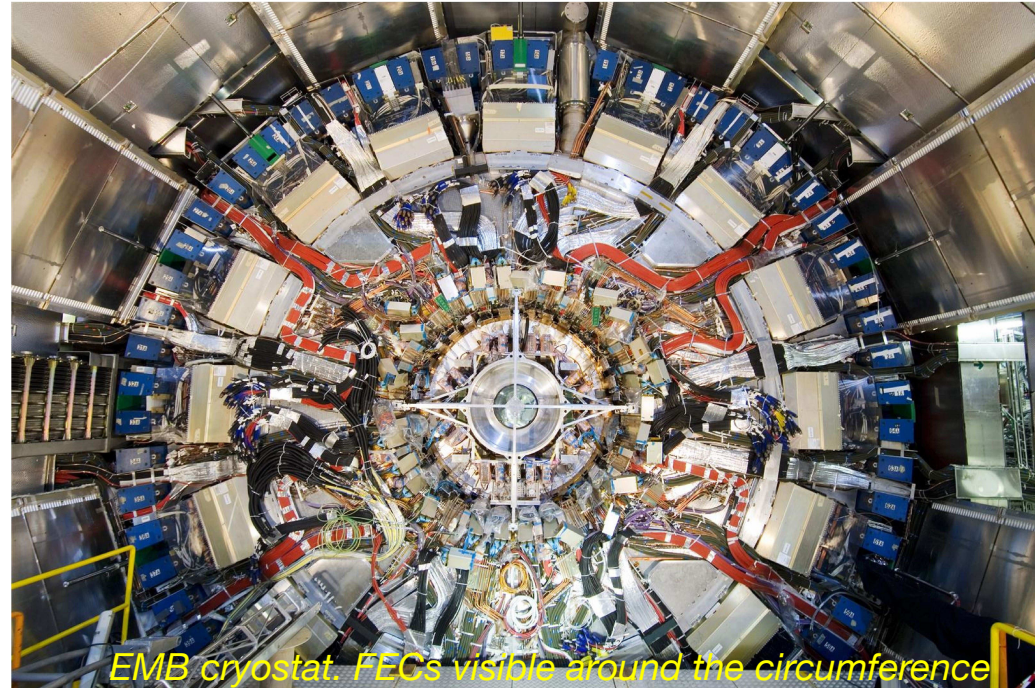
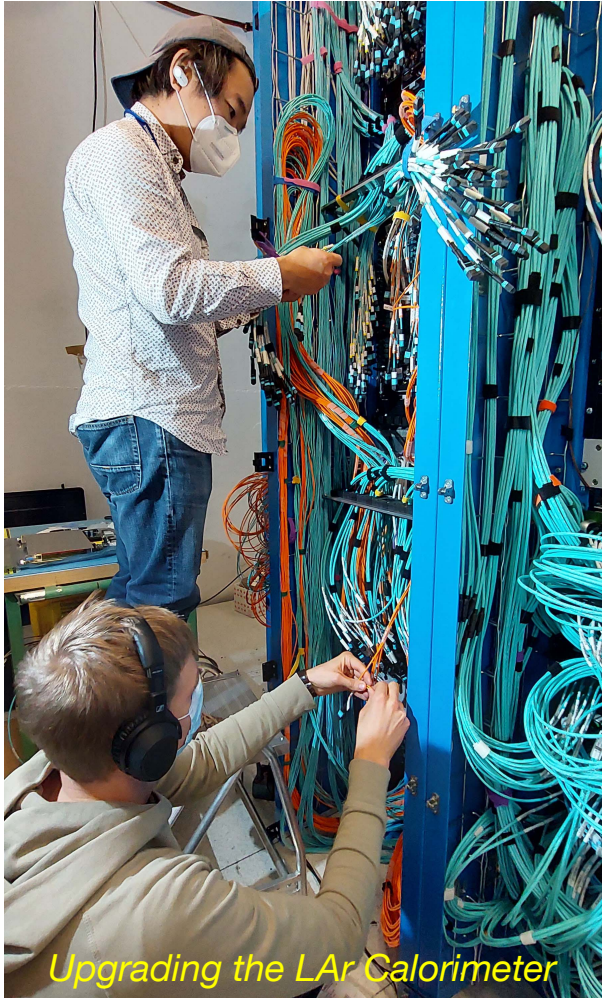


Cell-by-Cell Readout Timing

The full granularity readout time re-alignment was done using splash events, and verified with additional splash events. The cell timing shows good uniformity across the detector



Conclusions



- ✓ Installation of new phase-I front-end and back-end electronics is fully completed
 - ✓ The new Super Cells and accompanying upgraded readout electronics will provide increased trigger performance during Run 3
- ✓ Data from Pilot Run shows good performance of the new digital trigger system and continued performance of the legacy trigger system, following the Phase-I upgrades
- ✓ The LAr calorimeter is prepared for LHC Run 3, which will start in 2022