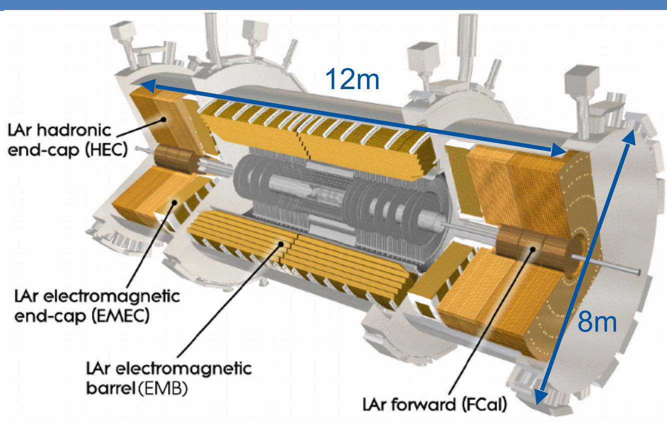
2021 Large Hadron Collider Physics (LHCP) Conference

ATLAS Liquid Argon Calorimeter Commissioning for LHC Run-3

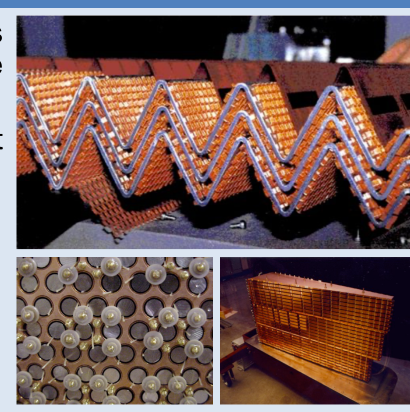
Run-1 (2010-12) 27 fb^{-1}, 7-8 TeV → **Run-2** (2015-18) 150 fb^{-1}, 13 TeV → **LS2** (2019-22) Phase-I Upgrade → **Run-3** (2022-24) 350 fb^{-1}, 13-14 TeV

As part of the **ATLAS Phase-I Upgrade,** the trigger and readout electronics of the Liquid-Argon Calorimeter are being upgraded [1]. Installation began at the start of the LHC shut down in 2019 and is expected to be completed in 2021. A commissioning campaign is underway to realize the capabilities of the new, higher granularity and precision Level-1 Trigger hardware in Run-3 data taking, as well as the recommissioning of the main readout and the legacy analog Level-1 Trigger electronics which had to be dismounted for the installation of the new components. This contribution gives an overview of the new trigger readout commissioning, as well as the preparations for Run-3 detector operation and changes in the monitoring and data quality procedures to cope with the increased pile-up.

1) ATLAS Liquid Argon Calorimeter



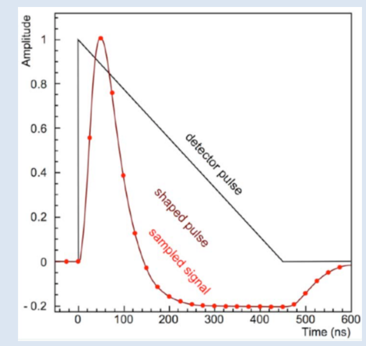
- **Main purpose**: Identify electrons, photons and jets and measure their transverse energy E_T, timing τ, and position
- Sampling calorimeter using liquid argon (at 88K) as active medium
- ~180k calorimeter cells
- Lead, copper and tungsten absorbers
- EMB/EMEC calorimeters with accordion-like geometry
- ~3k Trigger Towers: group of cells of size $\Delta\eta \times \Delta\Phi = 0.1 \times 0.1$
- 4000 tons



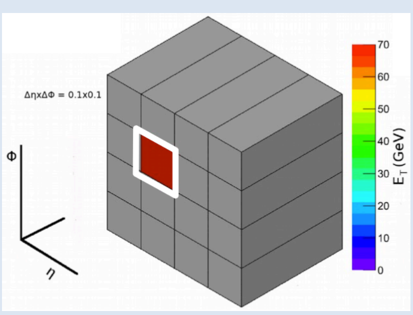
Detector pulse and energy reconstruction

- Ionization pulse shape: triangular
- Pulse amplified and shaped
- Bipolar shape sampled at 40 MHz
- Digitize 4 samples and compute E_T and τ using the optimum filter method at the Level-1 rate

$$E_T = \sum a_i A_i \qquad a_i,\ b_i\text{: Coefficients}$$
$$E_T \cdot \tau = \sum b_i A_i \qquad A_i\text{: Digitized samples}$$



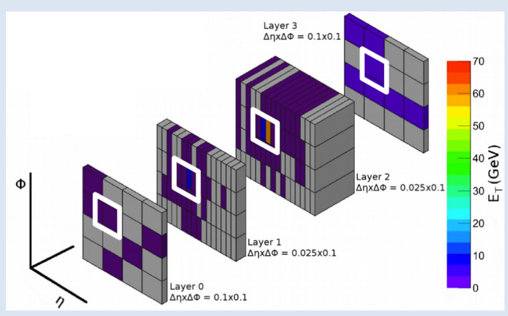
2) LAr Phase-I Upgrade Motivation



Trigger Towers (TT)

LAr Phase-I Upgrade

Granularity x10

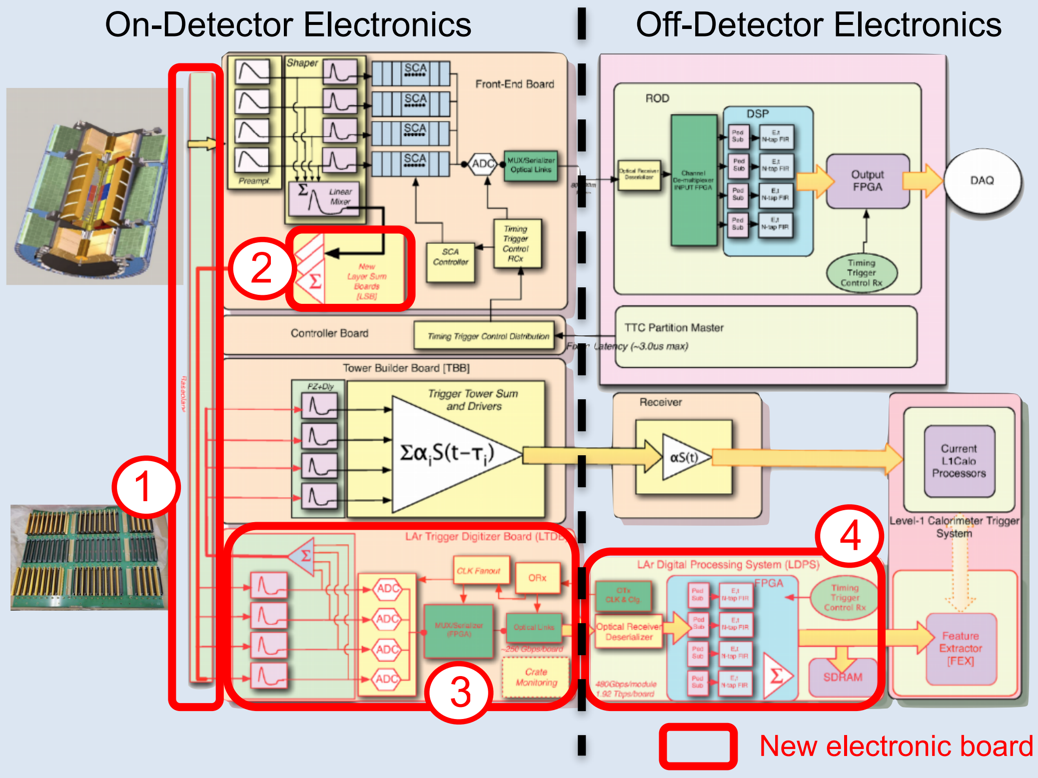


Super Cells (SC)

- **Why**? Pile-up degrades trigger performance
- **How?** Trigger Tower → Super Cells (lateral + longitudinal segmentation)
- **Result:** Better hadron vs electron identification thanks to up to 10 times finer granularity for Level-1 trigger → keeping E_T threshold low for the same maximum throughput (100 kHz)

3) Readout Electronics Upgrade

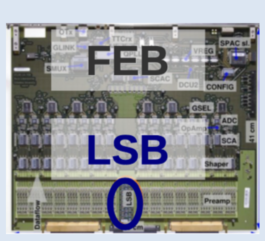
On-Detector Electronics | Off-Detector Electronics

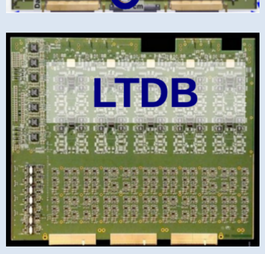


New electronic board

On-Detector Electronics (Front-End):

1) **Baseplane:** Transmission of signals from the front end board (FEB) to the LAr trigger digitizer board (10x more channels). Legacy path is kept operational
2) **Layer sum board (LSB):** Summing calorimeter cells into units of SCs
3) **LAr trigger digitizer board (LTDB):** Custom radiation-hard ASICs and high-performance ADC (40 MHz). Processing and digitization of 320 SC signals per board and transmission to LAr digital processing system using optical fiber links (8 SCs per fiber at 5.12 Gb/s, ASIC serializer and VCSEL driver). Also, feeding back summed signals to tower builder board for compatibility with legacy readout

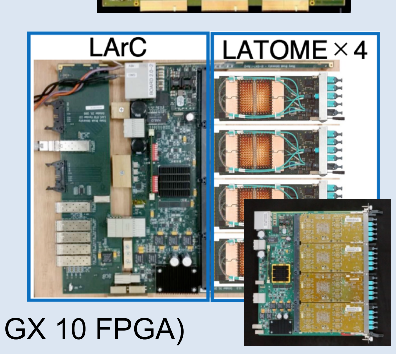




Off-Detector Electronics (Back-End):

4) **LAr digital processing system:** computing the energy deposited after aligning all inputs to the same bunch crossing, and then send it to the FEXes [2]. Buffer ADC data and energy information to Readout system at L1A. Level-1 latency < 375 ns. 48 input fibers at 5.12 Gb/s. 48 output fibers at 11.2 Gb/s.

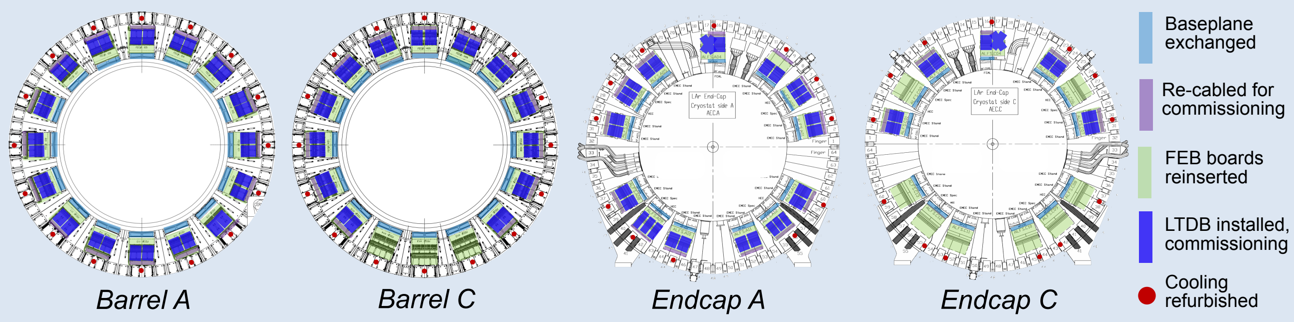
Main board: LAr digital processing blade (LDPB)
1 LAr Carrier (Xilinx Virtex-7 FPGA) + 4 LATOME (Intel® Arria® GX 10 FPGA)



4) Installation & Commissioning Status

Installation & commissioning status as of 28th May 2021

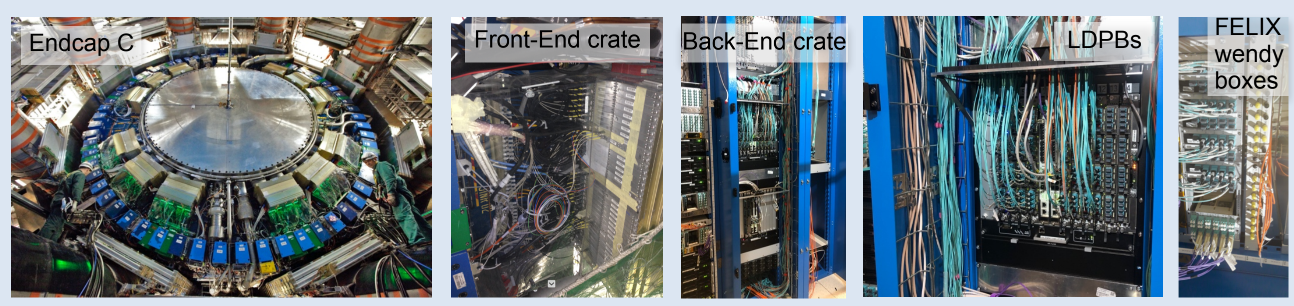
On-Detector (Front-End) Installation



- Installation started in winter 2019
- Expected end: September 2021
- All baseplanes installed (114)
- All FEBs reinserted (1524) with new LSBs
- 98 out of 124 LTDBs installed, cooling system being refurbished

Off-Detector (Back-End) Commissioning

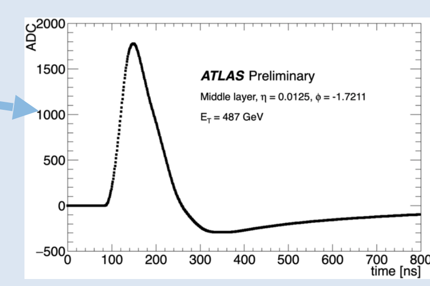
- Installation and firmware/software development not interrupted by COVID-19 lockdown
- 34 LAr Carrier boards produced (4 spares) as well as 150 LATOME boards (34 spares)
- New boards already installed, ~5000 fibers routed from experimental cavern to counting room
- New detector control system being developed (monitoring voltage, temperatures, and etc)
- FELIX (control/monitoring/DAQ) being used for commissioning
- Interface testing and data-transfer latency measurement with FEXes
- Data-taking and recording from the digital trigger system chain progressing

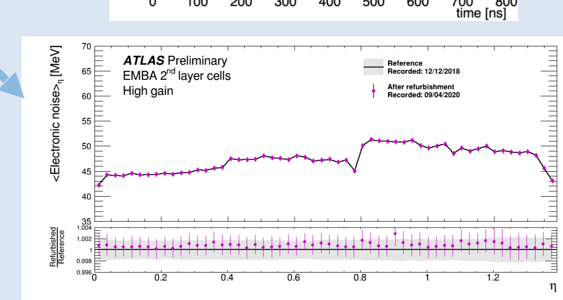


5) Results, Conclusion, and References

Results

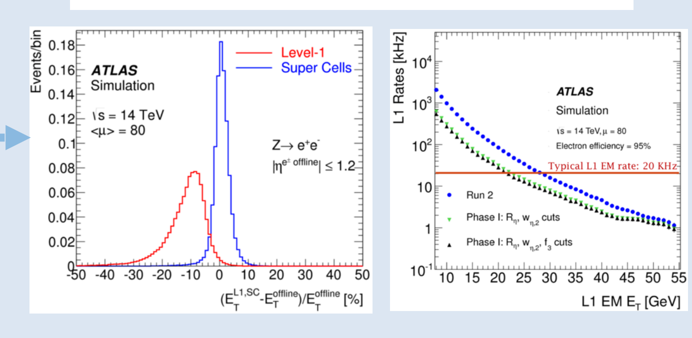
- Pulse signal recorded with Phase-I boards
- Preliminary data taking using LAr local monitoring and L1 trigger path showed consistent results
- Electronic noise unchanged after refurbishment of the FEBs





Conclusion

- No major issues found; despite the lockdown on schedule to be ready for LHC restart
- The calorimeters sensors are not changed. Front-end and back-end electronic cards being added or replaced
- Expect to keep providing excellent performance during Run-3
- Expected L1 trigger performance:
  - Better energy resolution at trigger level
  - Better signal/background separation



[1] M. Aleksa *et al.*, "ATLAS Liquid Argon Calorimeter Phase-I Upgrade Technical Design Report," 2013.
[2] G. Aad *et al.*, "Technical Design Report for the Phase-I Upgrade of the ATLAS TDAQ System," 2013.

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ATLAS EXPERIMENT