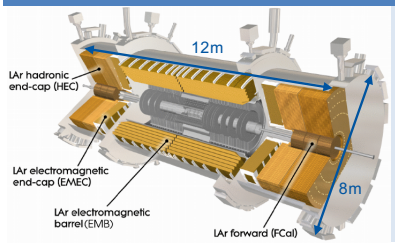
2020 IEEE Nuclear Science Symposium & Medical Imaging Conference

ATLAS Liquid Argon Calorimeter Commissioning for LHC Run-3

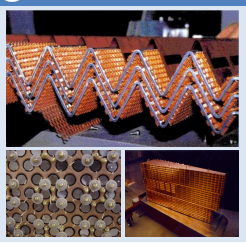
Run-1 (2010-12) 27 fb^{-1}, 7.8 TeV → **Run-2** (2015-18) 150 fb^{-1}, 13 TeV → **LS2** (2019-21) Phase-I Upgrade → **Run-3** (2021-24) 350 fb^{-1}, 13-14 TeV

As part of the **Phase-I Upgrade**, new trigger readout electronics of the ATLAS Liquid-Argon Calorimeter have been developed. 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.

ATLAS Liquid Argon Calorimeters



- **Main purpose**: measure energy, time and position of electrons, photons and jets
- Sampling calorimeter using cryogenically cooled liquid argon 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 Δη x ΔΦ = 0.1 x 0.1
- 4000 tons

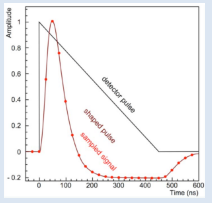


Detector pulse and energy reconstruction

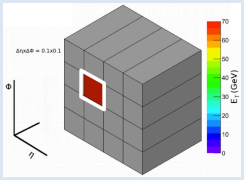
- Ionization pulse shape: triangular
- Pulse amplified and shaped
- Bipolar shape sampled at 40 MHz
- FIR filter: compute energy E-tau and collision timing t-tau for each bunch crossing (p-p collision)

$$E_T = \sum a_i A_i \qquad \tau_T = \sum b_i A_i$$

a_i, b_i: Coefficients
A_i: Digitized samples



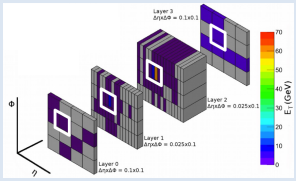
LAr Phase-I Upgrade Motivation



Trigger Towers (TT)

LAr Phase-I Upgrade

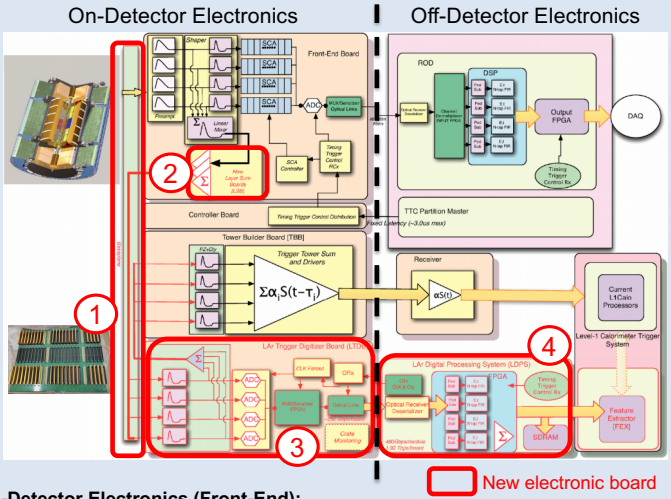
Granularity x10



Super Cells (SC)

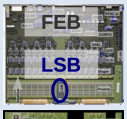
- **Why**? Old (or "legacy") trigger electronics not designed for higher luminosity (pile-up)
- **Improvement:** Trigger Tower → Super Cells (lateral + longitudinal segmentation)
- 10 times finer granularity for trigger → Enhanced rejection algorithms → Higher quality data + avoid trigger rate going above maximum throughput (120 kHz)

Readout Electronics Upgrade



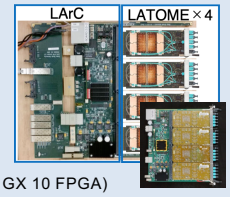
On-Detector Electronics (Front-End):

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 (LDPS):** Latency < 375 ns. 48 input fibers at 5.12 Gb/s. 48 output fibers at 11.2 Gb/s. Receive super cell ADC counts from LTDB at 40 MHz. Assign bunch crossing ID of the SC signal. Buffer ADC data. Compute super cell E_T. Send data to L1 Trigger (41 Tb/s) + local monitoring

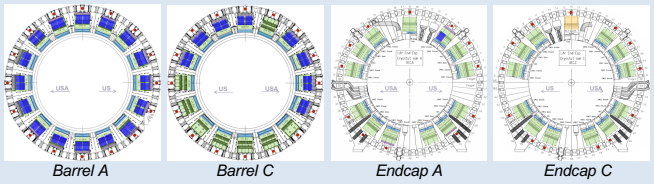


Main board: LAr digital processing blade (LDPB)
1 LAr Carrier (Xilinx Virtex-7 FPGA) + 4 LATOME (Intel® Arria® GX 10 FPGA)

Installation & Commissioning Status

Installation & commissioning status as of 30th October 2020

On-Detector (Front-End) Installation



- Installation started in winter 2019
- Expected end: January 2021
- Access depending on the detector opening

- All baseplanes but one installed (114)
- All FEBs reinserted (1524) with new LSBs
- 49 LTDBs installed, cooling system refurbished

Off-Detector (Back-End) Installation

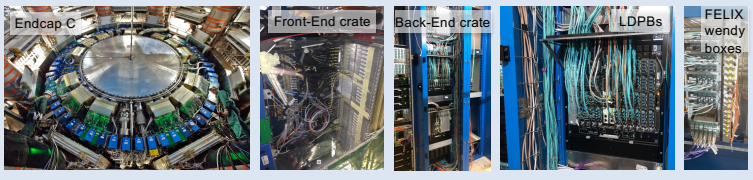
- Despite COVID-19 lockdown system running, firmware/software development not interrupted
- 34 LAr Carrier boards produced (4 spares) as well as 150 LATOME boards (34 spares)
- New boards already installed, many fibers (742 fibers in 58 cables) to route from experimental cavern to counting room
- New detector control system machines installed (monitoring temperatures and fan speed)
- FELIX (control/monitoring/DAQ) servers installed and operational
- Integration tests and commissioning on the real system well underway
- Data-taking and recording from the full digital trigger system chain progressing

Commissioning (3 steps)

1) **Main readout:** check refurbished FEBs with new LSBs are OK
2) **Legacy Trigger readout:** check LTDBs provide correct analog sums to legacy system
3) **New Trigger readout:** check new digital sums → tools to automatized procedures being developed

Preparation for LHC run 3 ongoing

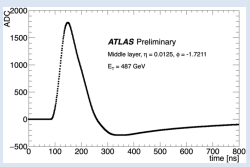
- Offline software, data quality and detector control systems (monitoring/control parameters)



Results and Conclusion

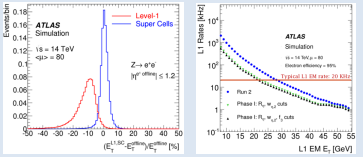
Results

- Pulse signal recorded with Phase-I boards
- Preliminary data taking using LAr local monitoring and L1 trigger path showed consistent results



Conclusion

- No major issues found; despite the lockdown on schedule to be ready for LHC restart
- The calorimeters are not changed, only the electronics:
  - Keep providing excellent performance during Run-3
  - True also for HL-LHC (scheduled for 2027)
- Expected L1A trigger performance:
  - Better energy resolution at trigger level
  - Better signal/background separation



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ATLAS EXPERIMENT