



ATLAS LAr Calorimeter Commissioning for LHC Run 3

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ATLAS liquid argon calorimeter

Sampling calorimeter:

- > Absorber material: lead, copper and tungsten.
- > Active material: liquid Argon (LAr).

Four major components:

- > Electromagnetic calorimeter barrel (EMB)
- > Electromagnetic calorimeter endcap (EMEC)
- > Hadronic endcap calorimeter (HEC)
- > Forward calorimeter (FCAL).
- Separated by A ($\eta > 0$) and C side ($\eta < 0$).
- LAr detector comprises four layers in the barrel and most of the endcap:
 - > **Presampler:** measure energy loss before the calorimeter.
 - > Front layer: fine segmentation, used to distinguish π^0 from γ .
 - > Middle layer: deepest layer, most of the EM shower deposits energy here
 - **Back layer:** catch the tail of EM shower.



LAr legacy readout system

- Front-end boards (FEBs):
 - > Buffer and digitize the signals
 - > 1524 FEBs, with 128 channels on each FEB.
 - Split into 3 gains scales (low/medium/high) and shapes.
 - The triangular pulse shaped and digitised at 40MHz and stored in a buffer.





- Receives analog signal built by tower builder boards (TBBs) and send L1 accept (L1A) back to FEB.
- FEB select the proper gain, digitise the signal and transmit to read out drivers (RODs), and further to ATLAS DAQ system.



LAr Phase-I upgrade: super cells

Challenge in LHC Run 3:

- Instantaneous luminosity and pile-up will increase, but the sustainable ATLAS L1 trigger will remain the same as Run 2.
 - 100kHz at maximum, 20kHz for electrons and photons.

Super cells (SC) proposed for the Phase-I upgrade

- \succ E_T in each layer is retained \rightarrow Access to the longitudinal shower shapes.
- > Using shower shape variables to better distinguish electrons and jets
 - E_{T} thresholds could be lowered to 21.5 GeV for 20kHz
- > Building ~34k SC from 180k cells \rightarrow Finer granularity for triggering compared with ~7k legacy trigger towers
- \succ Move to digitised signals \rightarrow LAr digital trigger system



L1 EM E_T [GeV]



LAr Phase-I upgrade: electronics readout



New back-end system



✤ 1 LDPB = 1 LArC + LATOMEs + IPMC.

- > 4 LATOMEs on each LArC, except 2 special ones with only 2 LATOMEs.
- > Totally 30 LArCs and 116 LATOMEs for full system.

LAr Carrier (LArC):

- ➢ Global and local readout.
- > Providing trigger, timing and control signals to LATOMEs

LAr Trigger prOcessing MEzzanine (LATOME):

- \succ Receive up to 48 high speed input links from LTDB at 40 MHz.
- > Reconstruct super cell E_{τ} and identify Bunch Crossing ID (BCID).
- > Transmit results to L1Calo feature extractor (FEX)



- Intelligent Platform Management Controller (IPMC):
 - An intelligent hardware management system for ATCA boards and ATCA carrier boards.
 - > Control, monitor, generate alarms.



refurbished and reinserted. \succ In total 114 new baseplanes.

All baseplanes and front-end boards (FEBs)

All LTDBs are installed and connected.

- 124 LTDBs, with 7 "flavours" depending on the \succ location.
- LTDBs operating stably during calibration runs \succ
- LTDB monitoring in good shape and still being \succ improved
- LTDB ADC calibration constants finalized \succ
- During Year-End Technical Stop (YETS): **Replacements/repairs**
 - Three LTDBs with no light on data fiber >replaced.
 - Four LTDBs with Miniature Transceiver (MTRx) \geq replaced.
 - Replaced/refurbished LTDBs recalibrated and \succ revalidated.
- List of noisy supercells is regularly compiled and masked Currently ~0.5% of supercells are masked.

Back-end commissioning

- All 30 LDPBs installed in 3 ATCA crates.
- Connection done.
 - 100% LATOMEs connected to LTDBs.
 - 100% LATOMEs connected to L1Calo Fiber-Optic eXchange (FOX) system.
- All network/TTC/TDAQ readout connections in place.
- IPMC Operating stably
- Monitoring and control system ready.



- Firmwares for LATOME and LArC ready and deployed
 - Added support for DHCP
 - Good timing closure obtained
 - > Baseline correction implemented
 - Corrects for a baseline shift that occurs due to out of time pileup



Calibration procedure

- Both main readout (legacy system) and the digital trigger (Phase-I system) calibrated by daily and weekly calibrations.
 - Validate the readout chain >
 - Provide calibration constants used online and offline for \succ energy reconstruction \rightarrow Optimal Filtering Coefficients (OFCs) extracted from good calibration set
- Three different types of calibration runs are taken: pedestal, ramp and delay:
 - **Pedestal:** without injecting any pulse to the FE electronics. >
 - Also used to study the electronic noise. **1**
 - **Ramp:** the peak ADC wrt the pedestal as a function of E_{τ} >for the pulse.
 - Saturation at ~800 GeV. **1**
 - Delay: fixing amplitude of the pulses but introducing delay >between injection and readout time.
 - Used for reconstructing the pulse shape with high **1** granularity of readout points

The ionization signal in the detector can be mimicked by a precise calibration system



Validation of the main readout

Comparing between:

- Data taken after the FEB refurbishment.
- Data recorded at the end of Run 2.
- In the level of pedestal ADC values, RMS in ADC counts, electronic noise and mean value of gains.
- No significant change observed after the Phase-I upgrade installation.



LArCaloPublicResultsLS2





Legacy system during data-taking 2022

- Legacy system working reliably since the start of Run 3
 - Totally 35.7 fb⁻¹ data recorded by ATLAS
- Data quality assessed for ~168 stable beam and ATLAS ready runs

Lost luminosity due to defects [%]

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Digital trigger during data-taking 2022

- Since September 2021, a few highly prescaled digital trigger items were enabled during data taking
- Last week of 2022 data-taking: LHC luminosity pushed to 2.5 × 10³⁴ cm⁻² s⁻¹
 - > Took the opportunity to enable digital trigger items, triggering at high rate
 - luminosity was too high to record good physics data

- Digital trigger was enabled during last physics runs of 2022.
- Had 3 hours of high luminosity and recorded ~20k events with our private server

Also operated smoothly during heavy ions run



The measured Super Cells (SC) transverse energy E_T computed on LATOME in real time are compared to the summed transverse momentum from their constituent calorimeter cells, obtained through the main readout path.

Goals to be completed

Clear goal for LAr:

- > Continue 13.6 TeV data taking with excellent data quality
- Gradually make digital trigger as default in 2023
 - Current plan is to run with electron feature extractor (eFEX) triggers from the beginning of the 2023 LHC run

eFEX: generates e/γ and τ candidates using 0.025x0.1 (η, ϕ) input granularity with improved isolation variables compared to the 0.1x0.1 e/γ module in Runs 1 & 2

- Later in the year (June-August) we would add more Phase-I items
- Last item to be switched on will probably be MET (~2024)

Conclusion

- Liquid Argon calorimeter system operated very successfully during the 2022 data-taking period
 - Both the legacy and digital trigger systems were included in physics runs
 - > Triggered on the legacy system by default \rightarrow Totally 35.7 fb⁻¹ data recorded by ATLAS
 - > Continued to commission the digital trigger and successfully enabled it in the last week of data-taking \rightarrow ran successfully at high rate
- All repairs planned for YETS have been completed and validation is progressing well
- Very good progress towards the restart of data-taking No major showstoppers!
- Digital trigger will continue to be commissioned and gradually become the default trigger in 2023

Thanks to the remarkable hard work and commitment of the LAr calorimeter team!



