ATLAS LAr Calorimeter

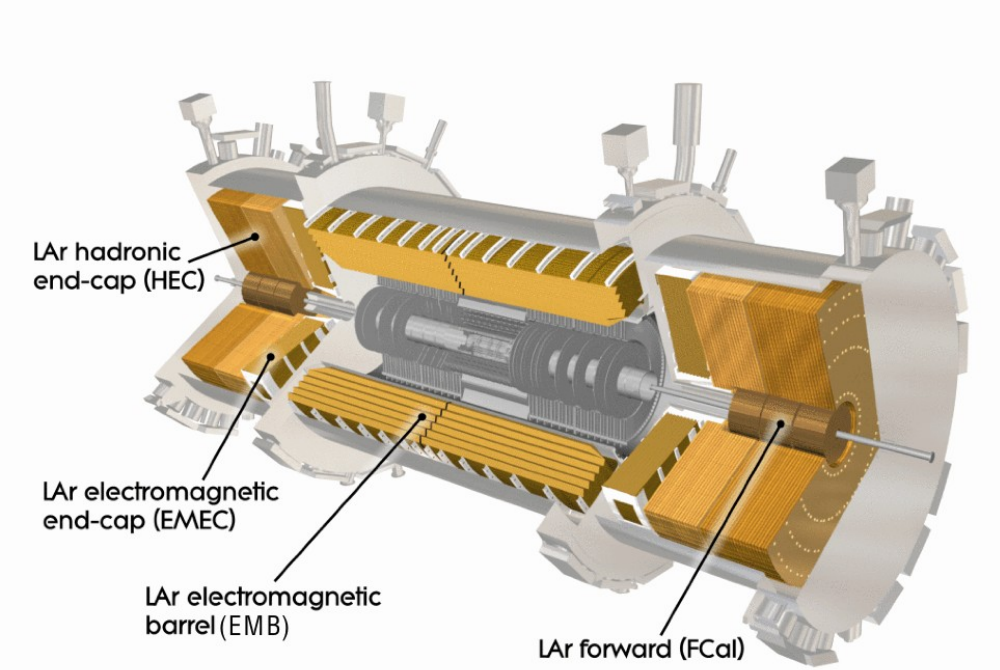
Commissioning for LHC Run-3

Alexander Gavrilyuk (NRC KI)
On behalf of the ATLAS Liquid Argon Calorimeter group

XII ICNFP 2023 (Kolymbari, Crete, Greece) 10-23 July

ATLAS liquid argon calorimeter

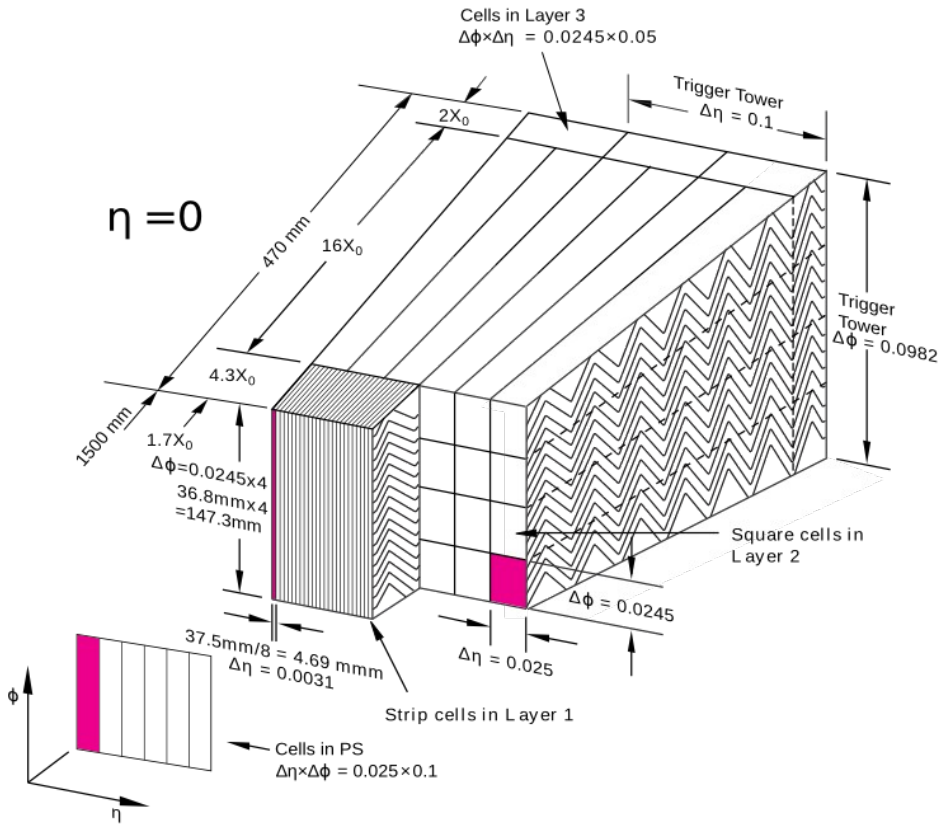
- **Sampling calorimeter:**
  - Absorber material: lead, copper and tungsten.
  - Active material: liquid Argon (LAr).
- **Four major components:**
  - **EMB** $|\eta| < 1.5$
    EMEC $1.4 < |\eta| < 3.2$
    HEC $1.5 < |\eta| < 3.2$
    FCAL $3.1 < |\eta| < 4.9$.
  - Separated by A ($\eta > 0$) and C side ($\eta < 0$).



Public Liquid-Argon Calorimeter Plots

ATLAS liquid argon calorimeter — layers

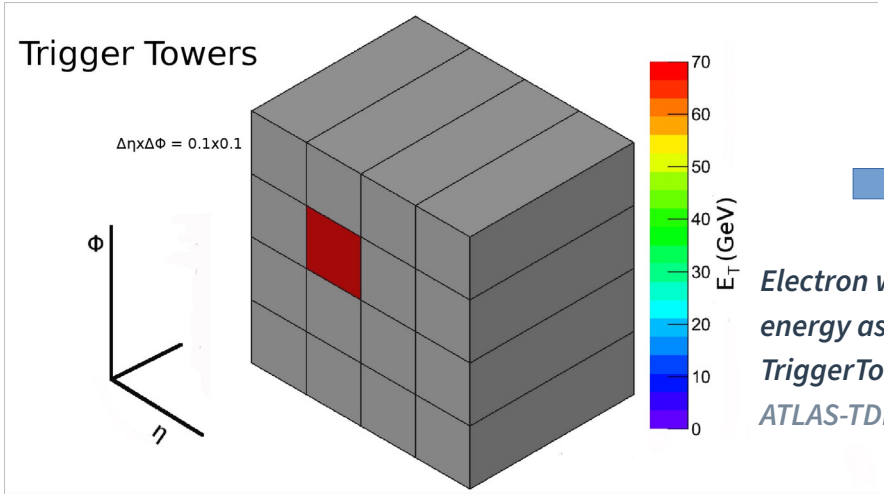
- **LAr detector comprises four layers in the barrel and most of the endcap. For example, EM barrel has:**
  - **Presampler**: measure energy loss before the calorimeter.
  - **Front layer**: fine segmentation, used to distinguish π^0 from γ.
  - **Middle layer**: deepest layer, most of the EM shower deposits energy here
  - **Back layer**: catch the tail of EM shower.



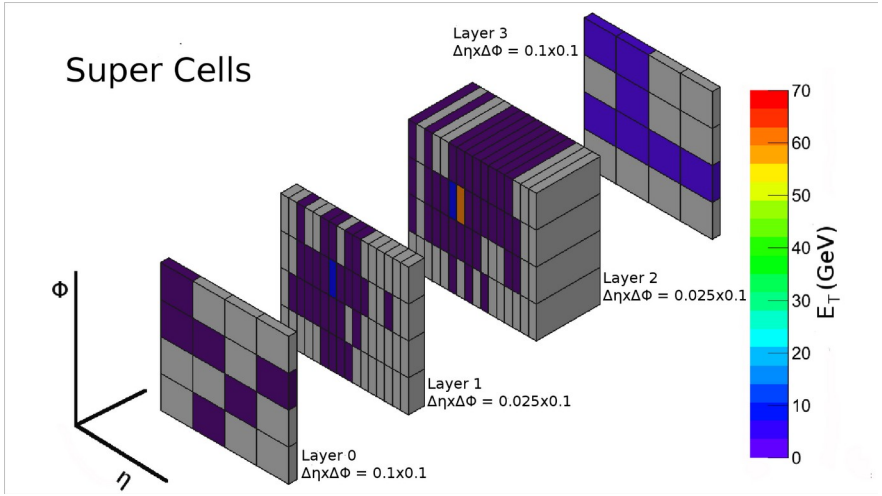
Public Liquid-Argon Calorimeter Plots

Phase-I Upgrade Motivation

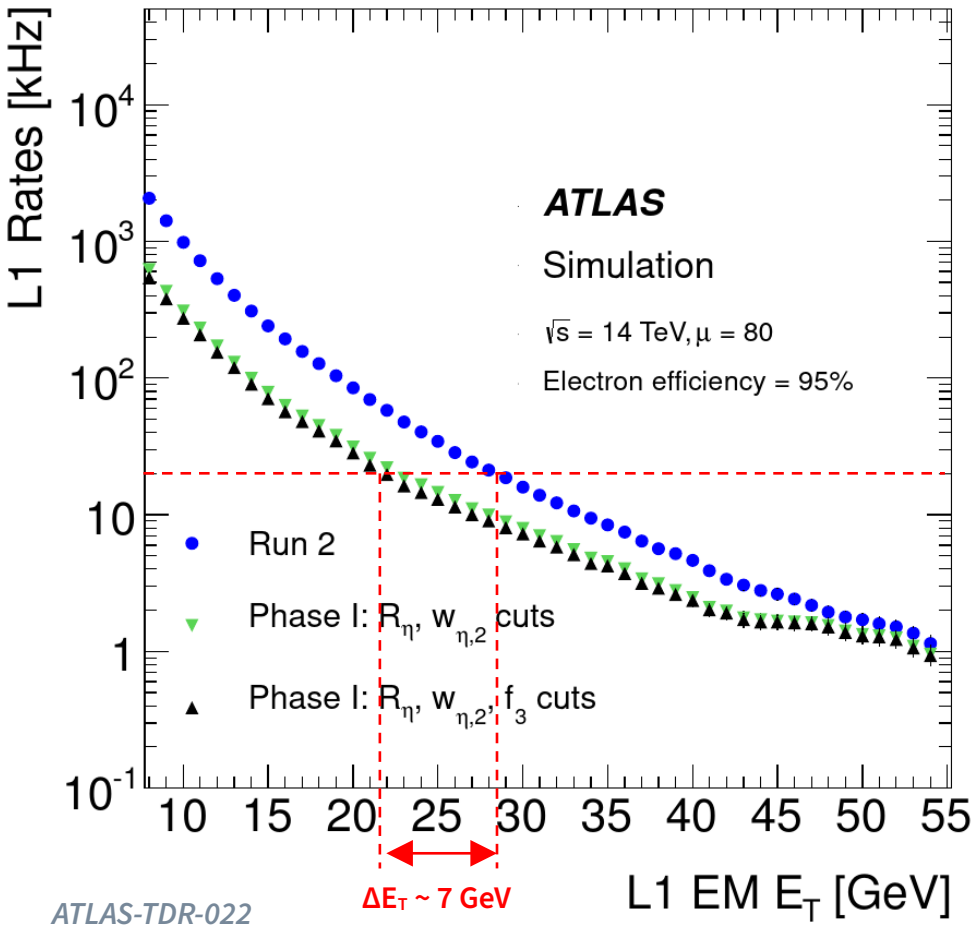
- Enhance the trigger efficiency for Run 3 to prepare for higher pile-up conditions.
- Better detector granularity in longitudinal and η direction allows for improved trigger algorithms and better definition of energy showers.
- Previously Δη × ΔΦ = 0.1 × 0.1 TriggerTower with no longitudinal segmentation → Currently 4 longitudinal layers with varying Δη × ΔΦ, forming SuperCells.
- SuperCells in the pre-sampler and back layers keep the Δη × ΔΦ = 0.1 × 0.1 granularity. SuperCells in layers 1 and 2 cover an area as small as Δη × ΔΦ = 0.025 × 0.1.



Electron with 70 GeV of energy as seen by both the TriggerTower and SuperCells.
ATLAS-TDR-022



Phase-I Upgrade Motivation — L1 Rate

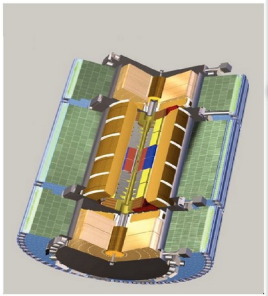


ATLAS-TDR-022

- With Run 3 instantaneous luminosity and pile-up are higher, but the sustainable ATLAS L1 trigger will remain the same as in Run 2.
- 100kHz total, 20kHz for electrons and photons.
- Using shower shape variables L1 rate can be maintained without increasing trigger thresholds

LAr Phase-I upgrade: electronics readout

ATLAS-TDR-022

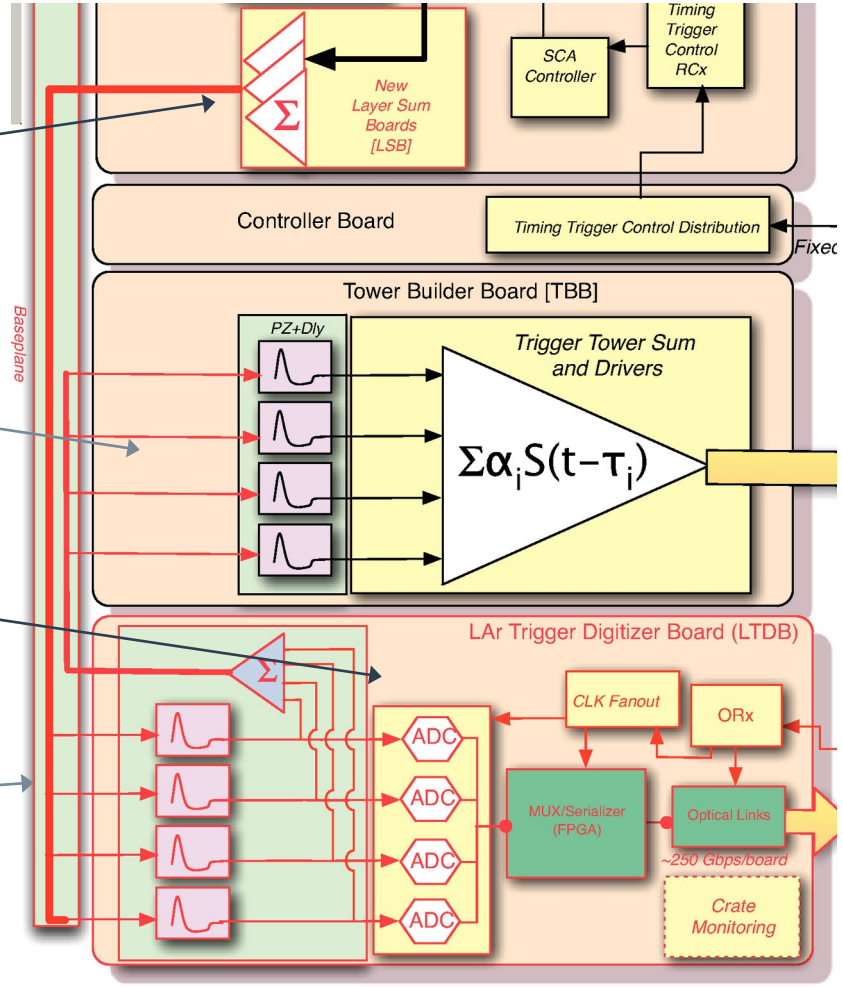


- To ensure smooth transition legacy system runs concurrently with digital trigger

Front-end electronics upgrade, on-detector

ATLAS-TDR-022

- 2328 **Layer Sum Boards** (LSBs) replaced on Front end Boards (FEBs)
  - Sums signals of cells within one layer into super cells
- Analog data sent to legacy Tower Builder Board (TBBs)
- 124 **LAr Trigger Digitizer Board** (LTDB)
  - Digitizes signals from super cells and send information to TBB and digital trigger back-end
- Baseplane replaced due to a higher number of signals transmitted. New slots were also needed for LTDBs

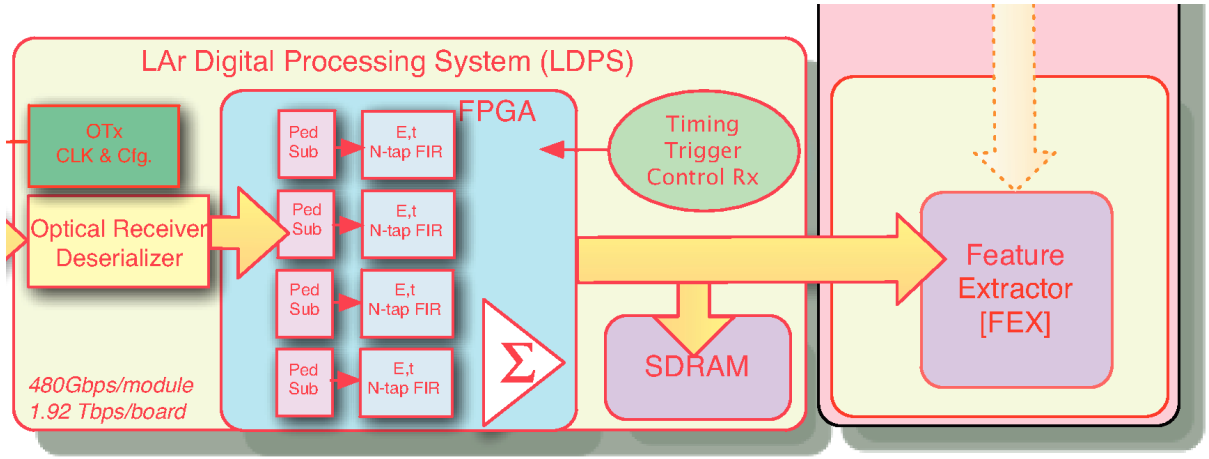


Back-end electronics upgrade, off-detector

- 30 LAr Digital Processing Boards (LDPB)
- LAr Carrier boards (LArCs) provide Trigger, Timing, and Control (TTC) signals to LATOMEs and readout to TDAQ path
- 116 LAr Trigger prOcessing Mezzanine (LATOMEs) receive inputs from LTDBs, compute energies, and send them to the L1Calo trigger system (FEX)

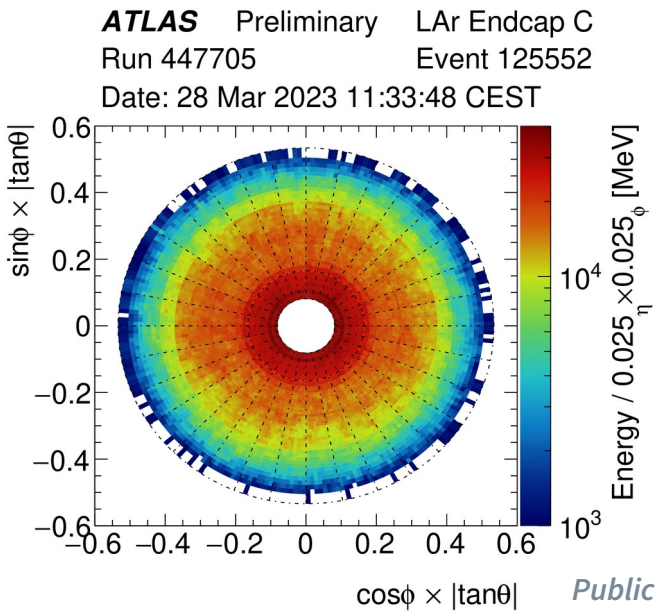
ATLAS-TDR-022

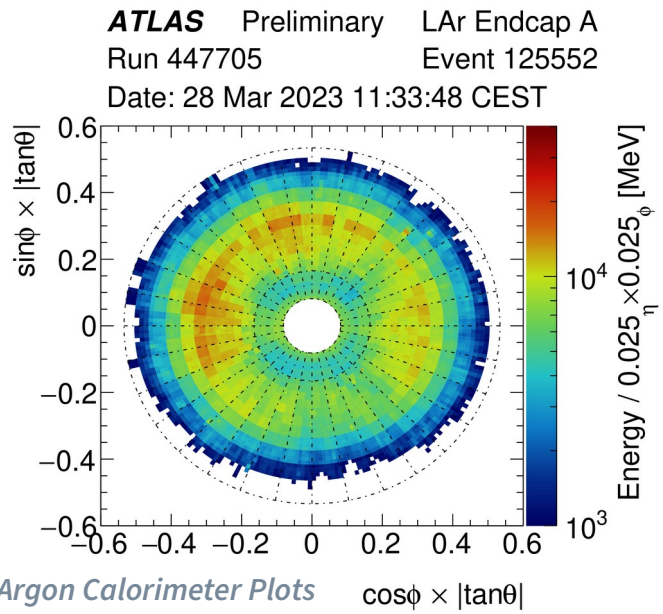
- IPMCs provide management for the various boards on the ATCA crates
- LDPB = LArC + LATOMEs + IPMC

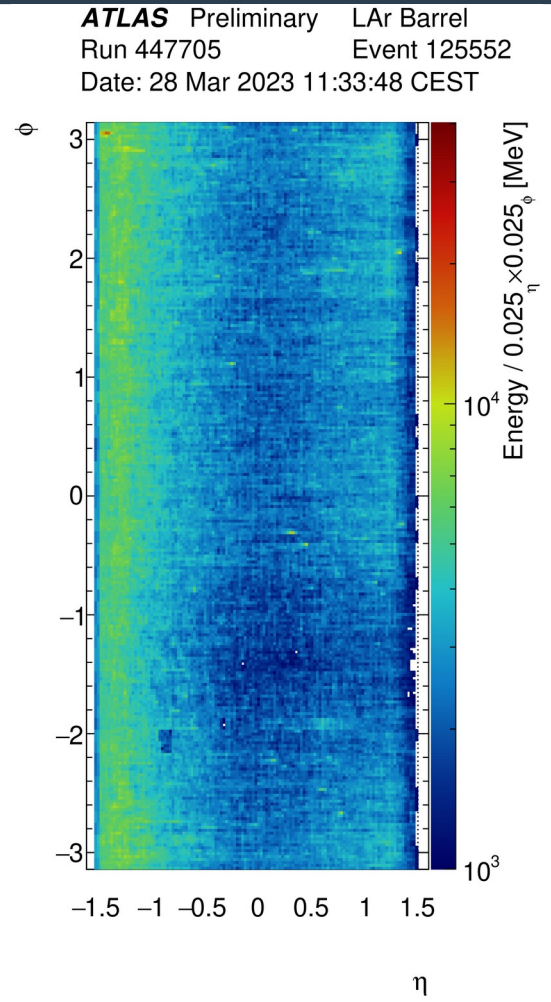


LAr Performance

- LAr cell energy sums (without FCal) distributed in a hypothetical tower grid with $\Delta\eta \times \Delta\phi = 0.025 \times 0.025$ for a beam splash event from March 2023. Particles were delivered by Beam 2 (B2) and entered from negative η (C) side.

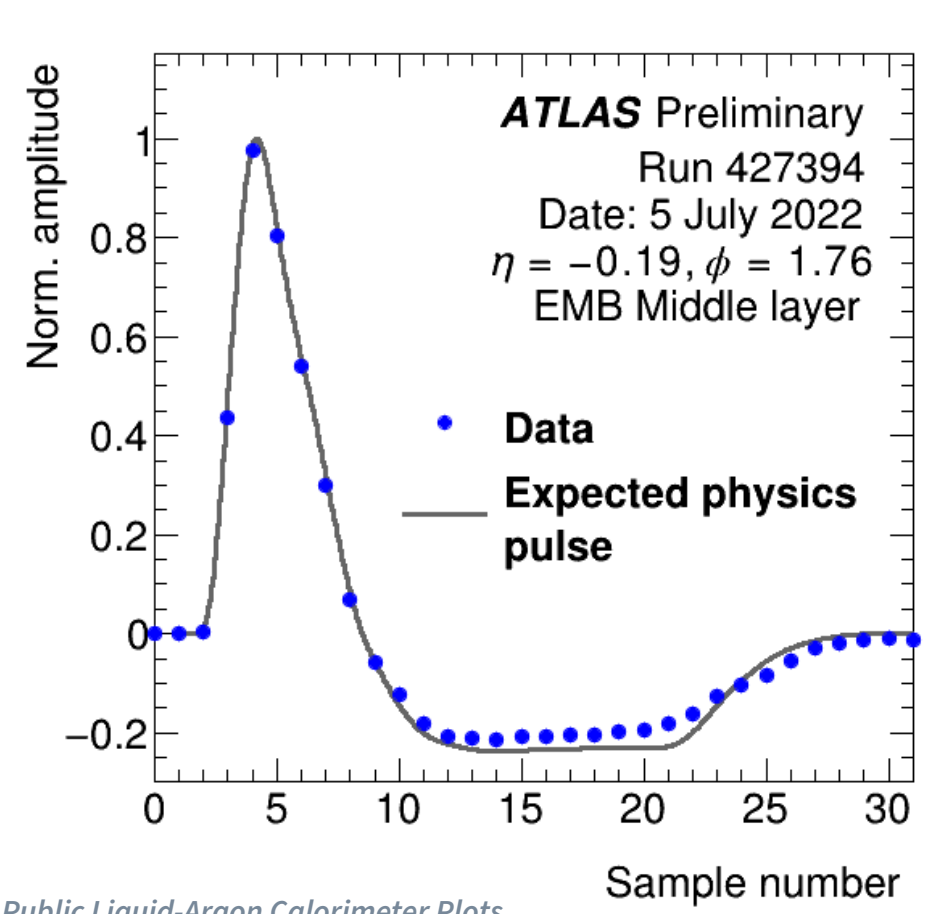






Public Liquid-Argon Calorimeter Plots

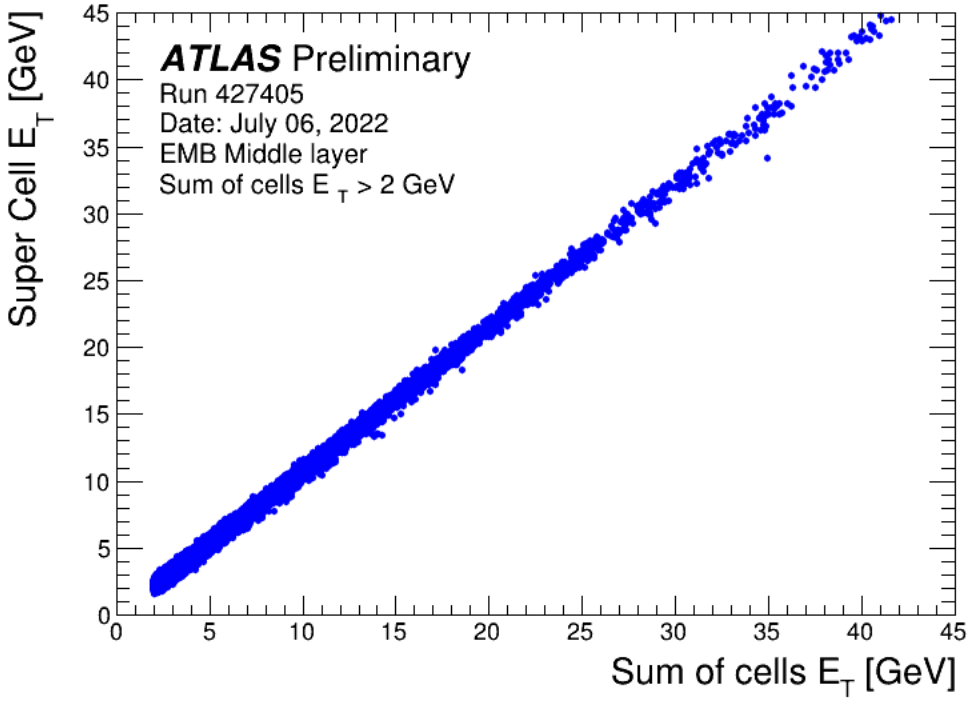
LAr Super Cells Pulse Shapes



Public Liquid-Argon Calorimeter Plots

- Measured pulse shape of a Super Cell in the LAr Electromagnetic Barrel from the digital trigger readout.
- The expected physics pulse shape is extracted using preliminary conversion parameters from a calibration pulse obtained with an injected calibration charge.

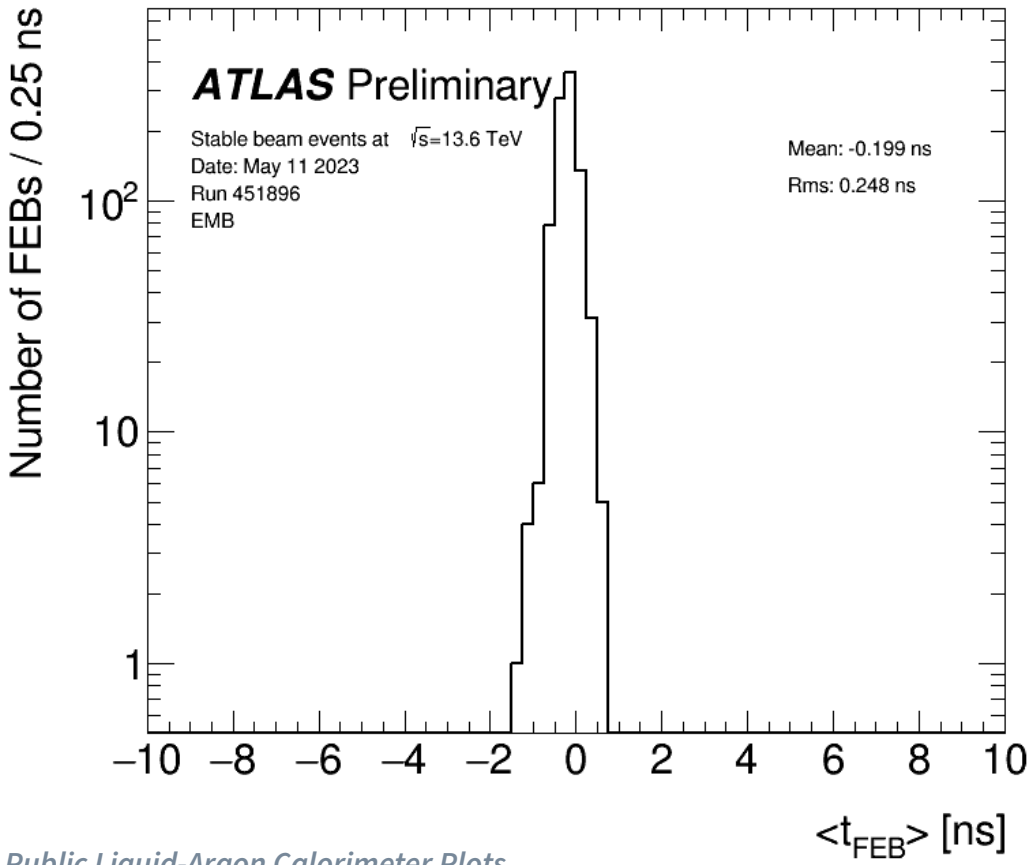
Energy comparison digital trigger and main readouts



Public Liquid-Argon Calorimeter Plots

- The measured **SuperCells** transverse momentum ***E*$_T$**, compared to the **summed *E*$_T$** from the full precision calorimeter cell read out in EMB (using data collected with the first stable beam *pp* collision at 13.6 TeV)

FEB Offset Timing



Public Liquid-Argon Calorimeter Plots

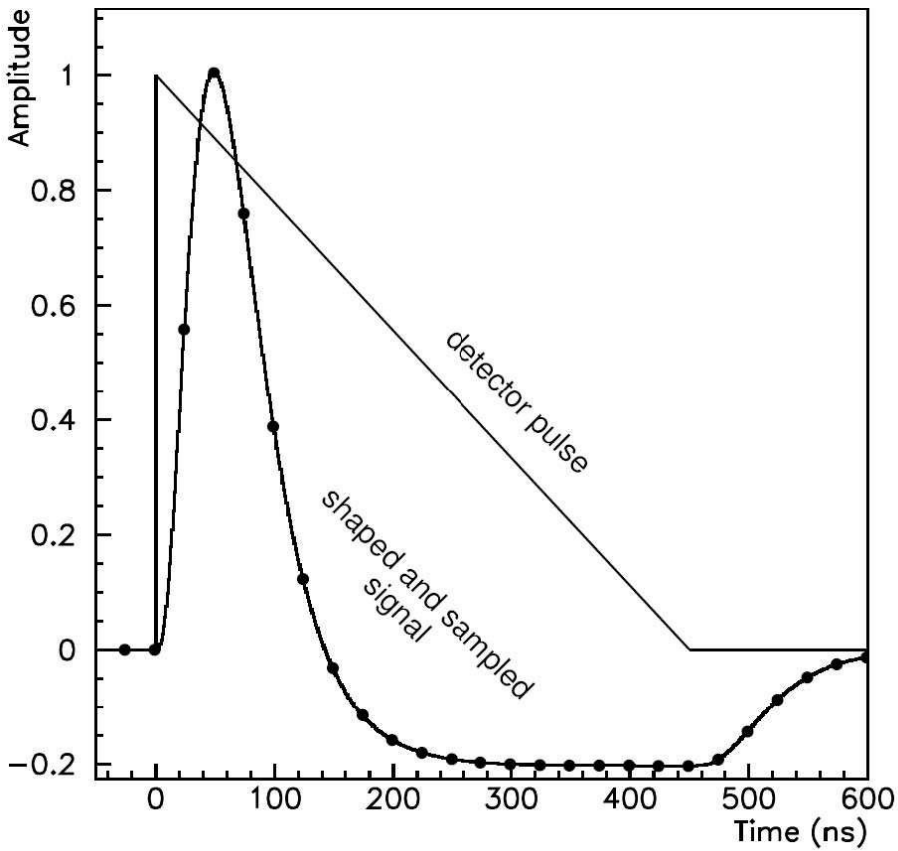
- Average time per FEB in EMB collected with 13.6 TeV stable beam.
- The average time for one FEB is the result of a Gaussian fit on the time distribution from pulses reconstructed from medium and high gain for all channels of this FEB.
- All FEBs are well aligned since the distribution is centered at zero and no significant outliers are observed.

Conclusion

- Triggers based on the new Run 3 digital trigger readout are activated and runs in parallel to the legacy triggers based on the Run 2 readout.
- Triggers for electromagnetic objects are fully relying on the new Run 3 digital trigger readout.
- Full Legacy trigger will be decommissioned this year.

backup

Front End Boards



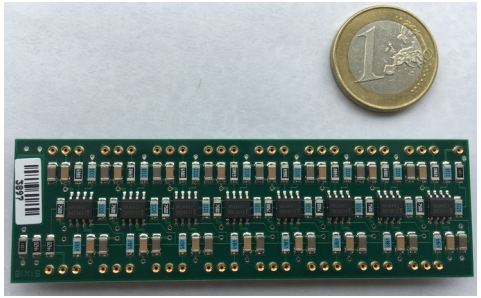
ATLAS-TDR-022

- 1524 FEBs, with up to 128 channels on each FEB.
- Total of ~180 000 channels.
- Split into 3 gain scales (low/medium/high) and shapes.
- Electric current is read out and a triangular pulse is amplified and shaped into a bipolar pulse digitized at 40 MHz (each 25 ns, i.e. equal to time between bunch crossings)

Hardware Upgrade

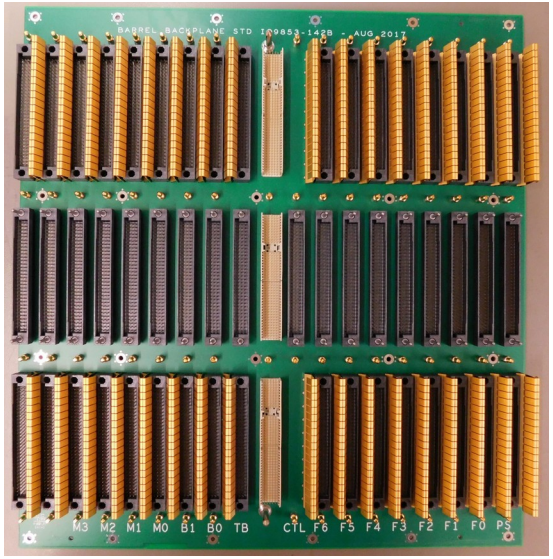
LSB

JINST 17 (2022) P05024

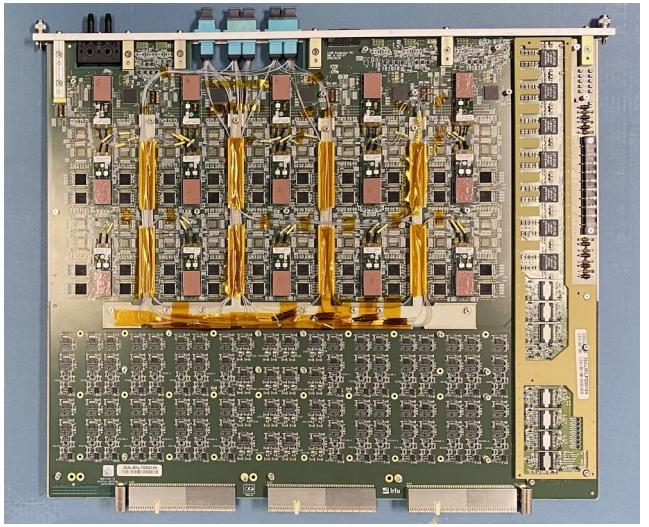


Baseplane

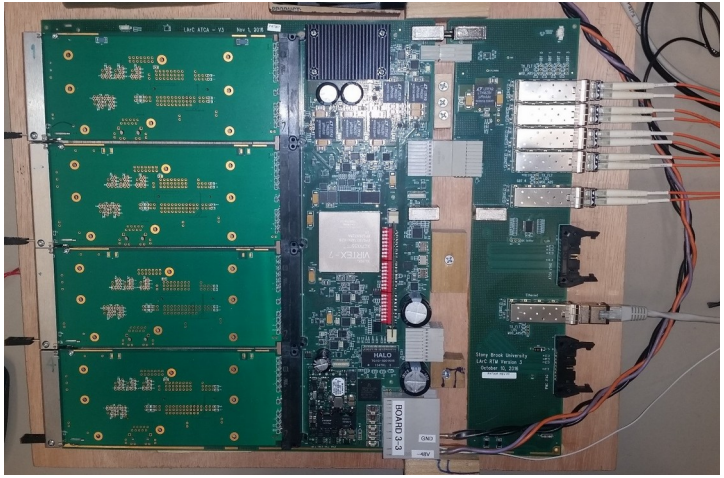
arXiv:2305.16623



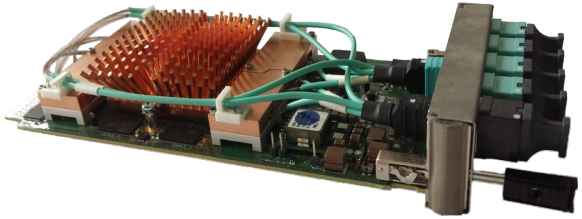
LTDB



LArC



LATOME



IPMC