The ATLAS LAr Calorimeter Commissioning for the LHC Run 3

BTTB10

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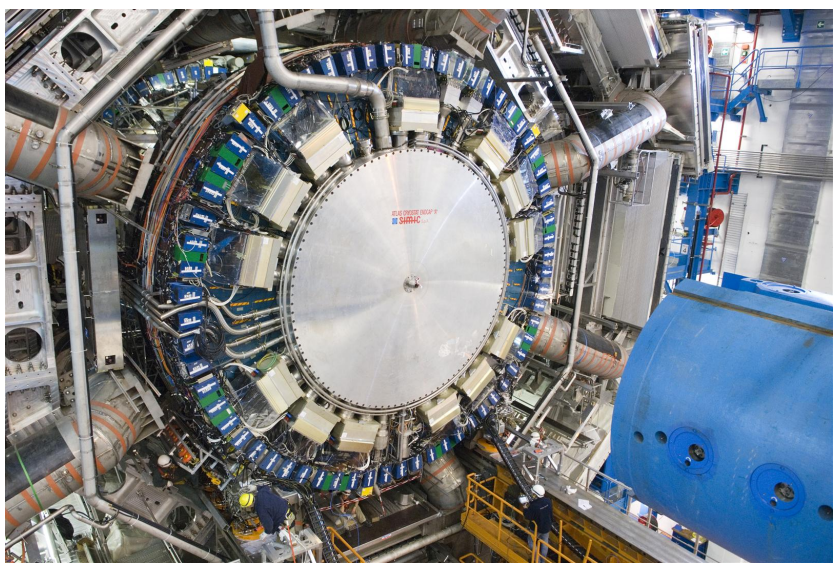
June 23 2021

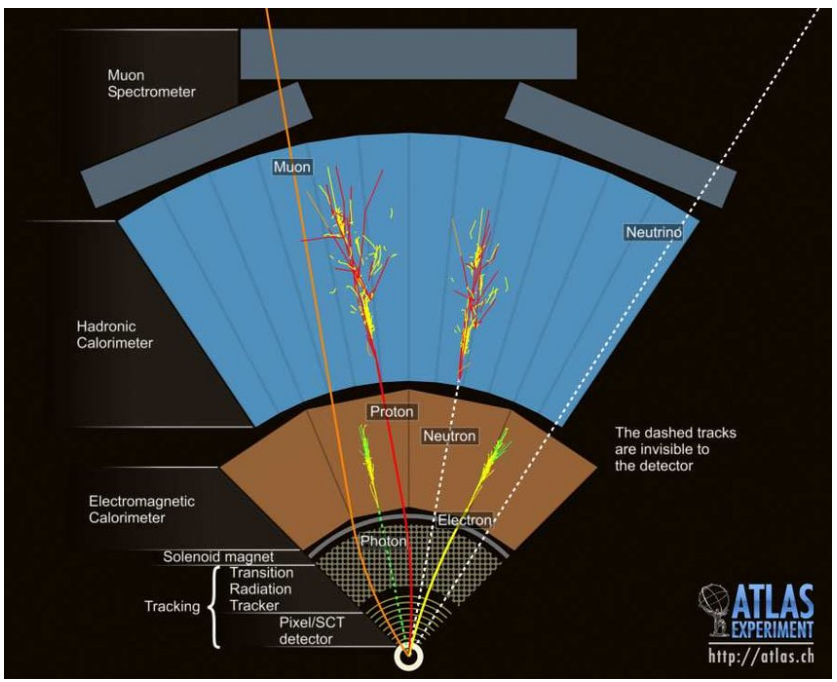
Outline

1. Introduction
2. LAr Phase-1 Upgrade
3. Commissioning
4. Run 3 and the Future

The ATLAS Detector

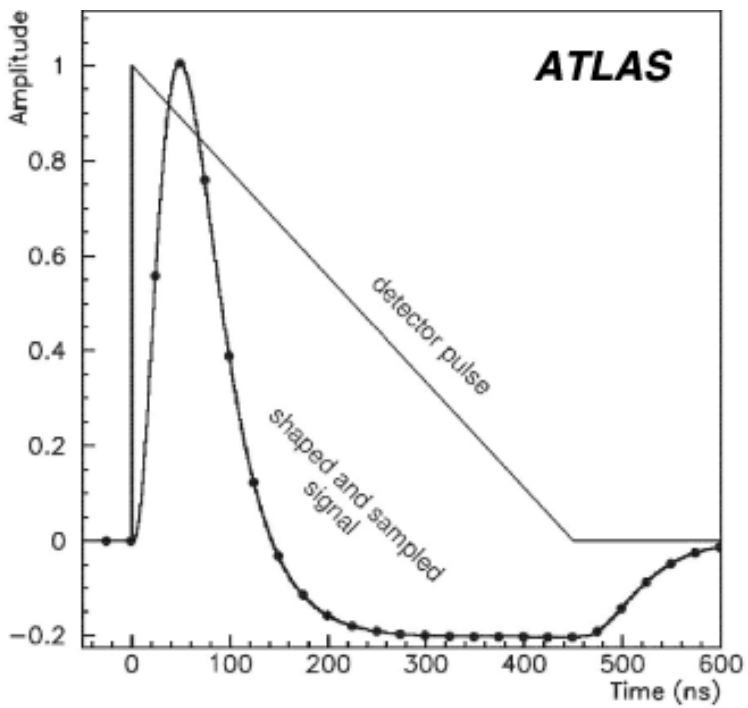
- The ATLAS experiment is one of the 4 main experiments at the LHC
- General purpose detector used to probe SM and BSM physics
  - Liquid Argon (LAr) calorimeter used to measure the energies of electrons, photons, and hadrons

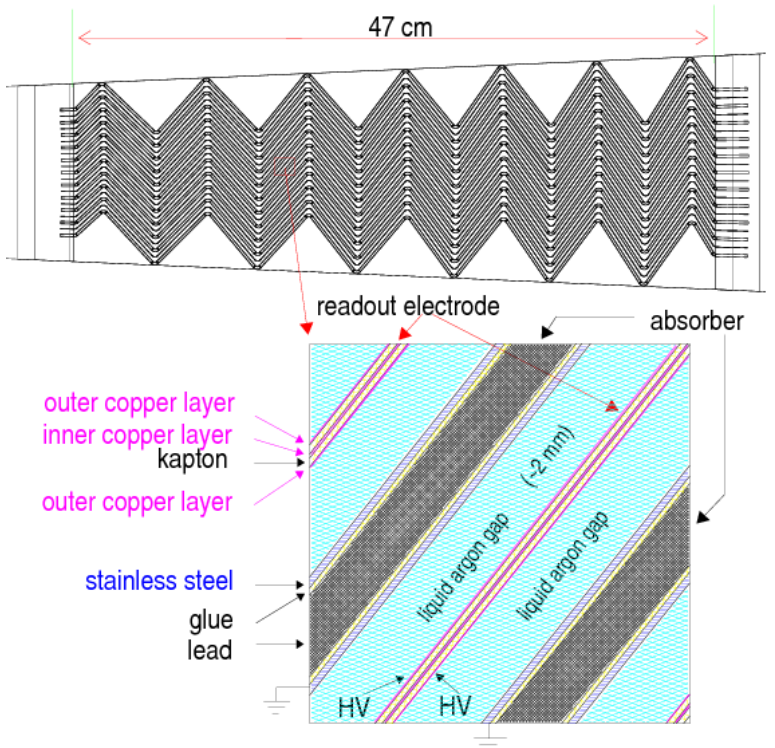




The LAr Calorimeter

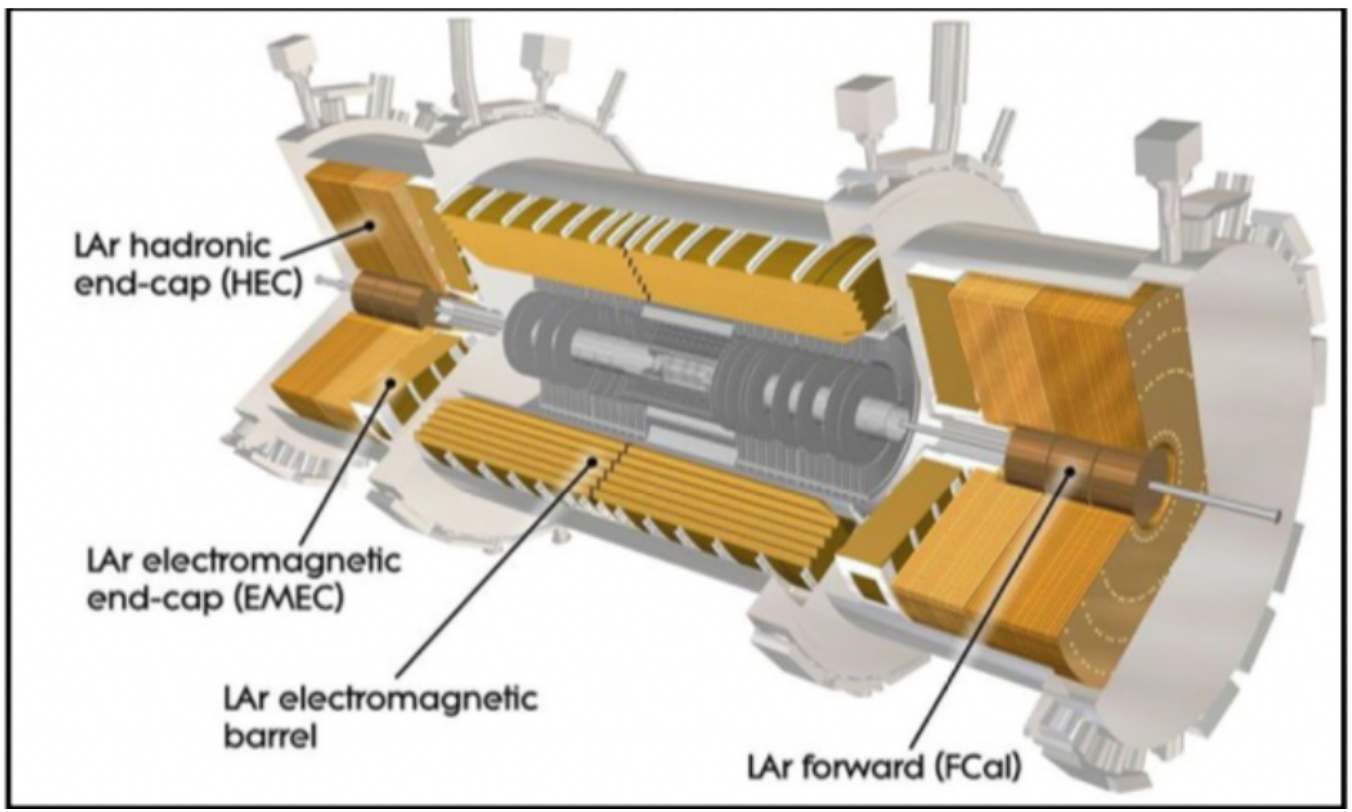
- Sampling calorimeter using LAr as the active material and an absorber in an accordion geometry
  - Absorber changes depending on location in ATLAS
- Absorber causes a particle shower that ionizes the LAr
- Electric current is read out and a triangular pulse is amplified and shaped into a bipolar pulse digitized at 40 MHz



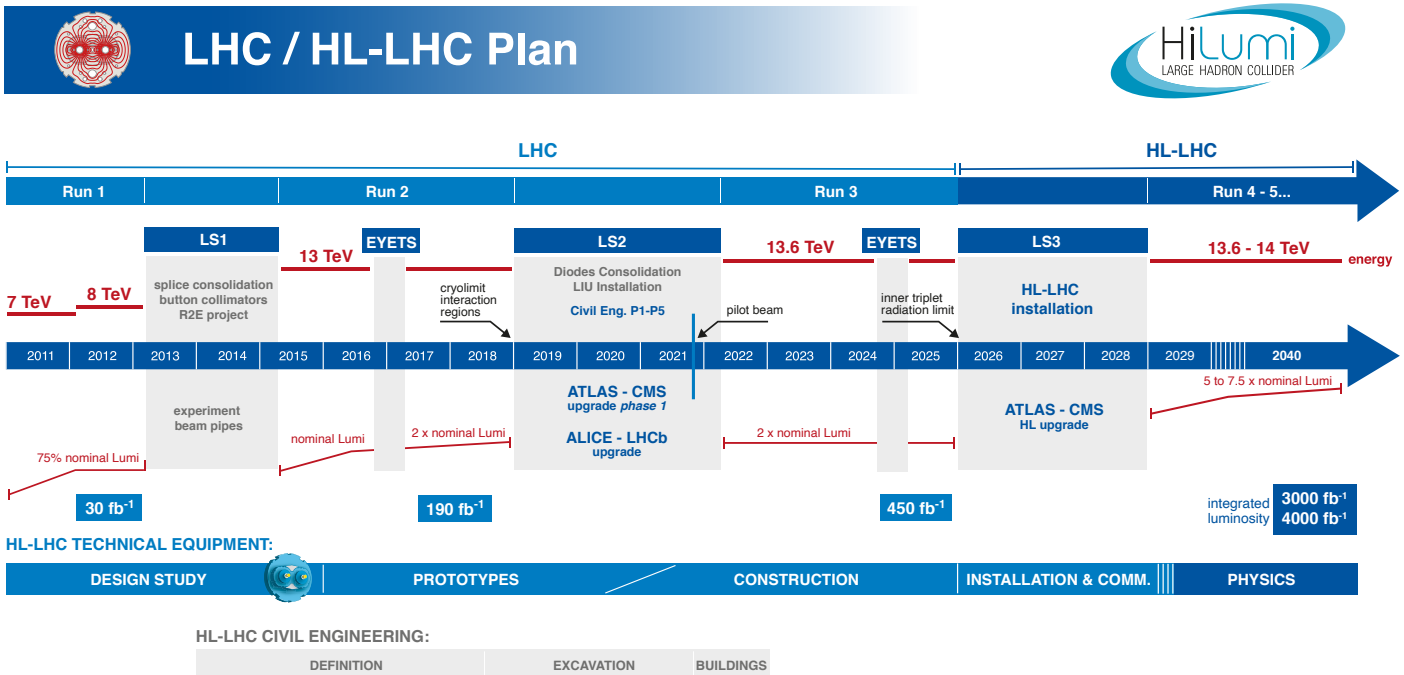


LAr Geometry

- Electromagnetic calorimeter in barrel ($|\eta| < 1.5$) and endcap ($1.375 < |\eta| < 3.2$) use Pb as an absorber
- Hadronic endcap calorimeter ($1.5 < |\eta| < 3.2$) and forward calorimeter ($3.0 < |\eta| < 4.9$) use a Cu and W absorber



LS2 and Run 3

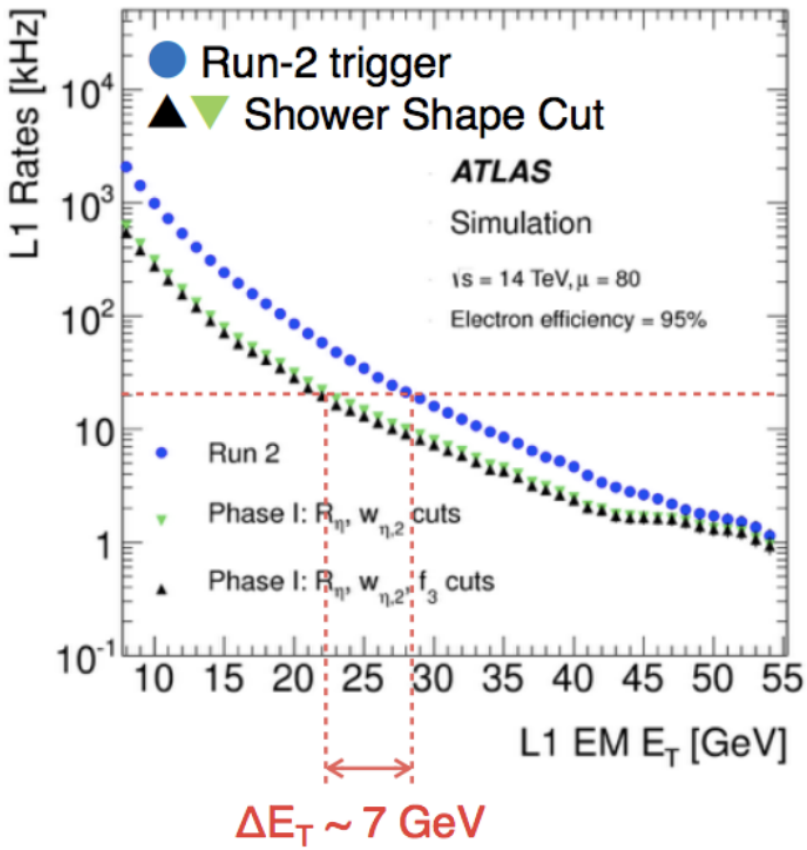


- Run 2 ended in 2018 and lead to Long Shutdown 2 (LS2)
- Preparation for the start of Run 3 ongoing, first 13.6 TeV p-p collisions in early July!
- Twice the peak instantaneous luminosity ($\mathcal{L}$) in Run 3 wrt. Run 2
  - $\mathcal{L} \sim 2.2 \cdot 10^{-34} \mathrm{cm}^{-2}\mathrm{s}^{-1}$ and $< \mu > \sim 80$

LAr Phase-1 Upgrade Motivations

- Upgrades to the LAr calorimeter and trigger path in LS2
- Double the pileup expected in Run 3 but the ATLAS L1 trigger will be kept at 100 kHz
- Increased granularity in the calorimeter to allow for better discrimination of physics objects
  - L1 rate can be maintained without increasing trigger thresholds

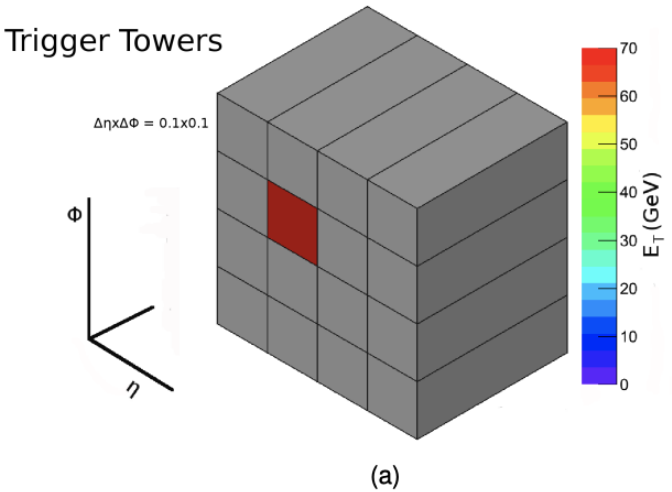
ATLAS-TDR-022



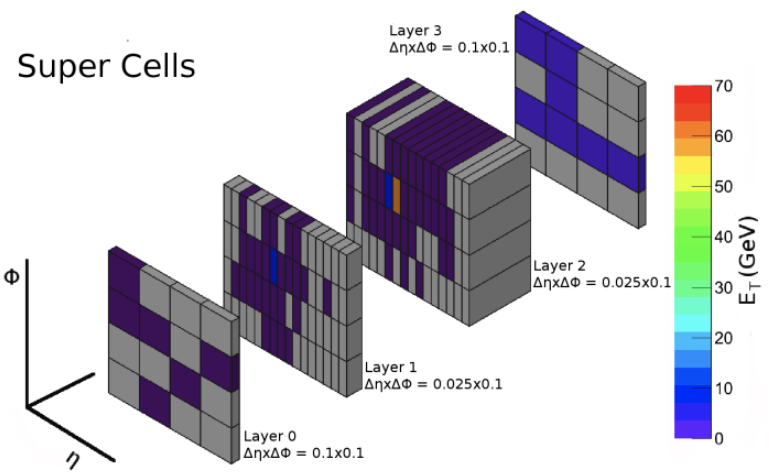
LAr Phase-1 Upgrade Overview

- Trigger towers were used in Run 2
- Super cells to be used for Run 3
  - 4 layers: presampler, front, middle, and back
  - Front and middle layers are 0.025×0.01 in$\Delta\phi \times \Delta\eta$
  - Better granularity
- Addition of a new phase-1 digital trigger readout
  - Super cells computed with new digital trigger readout

ATLAS-TDR-022



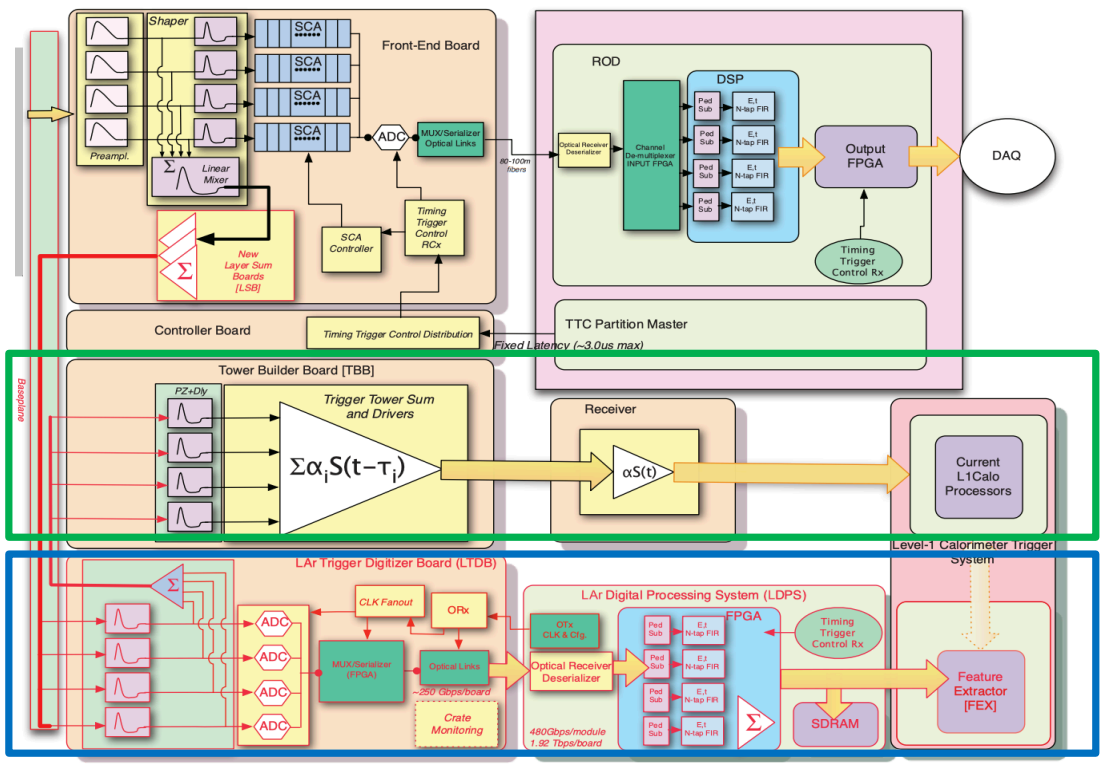
(a)



(b)

LAr Phase-1 Upgrade Overview

- Both legacy and digital trigger readouts to be kept operational during commissioning
- Eventually plan to move to digital trigger readout only

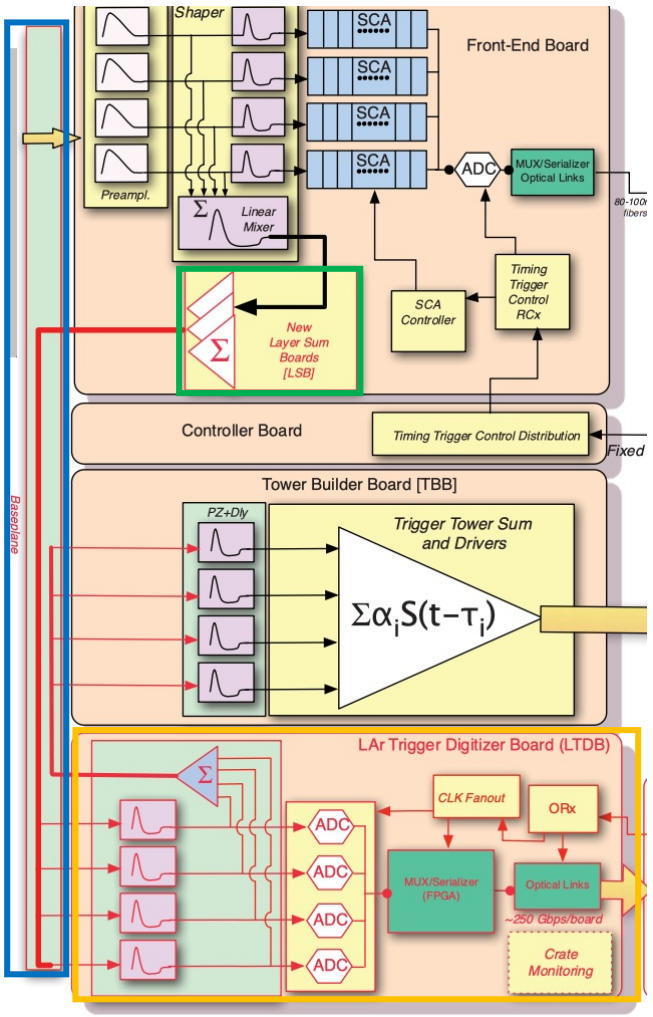


ATLAS-TDR-022

LAr Phase-1 Upgrade - Front-end

- 2328 Layer Sum Boards (LSBs) replaced on Front end Boards (FEBs)
  - Sums signals of cells within one layer into super cells
- 124 LAr Trigger Digitzer Boards (LTDB) added as part of the digital trigger front-end
  - Digitzes 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

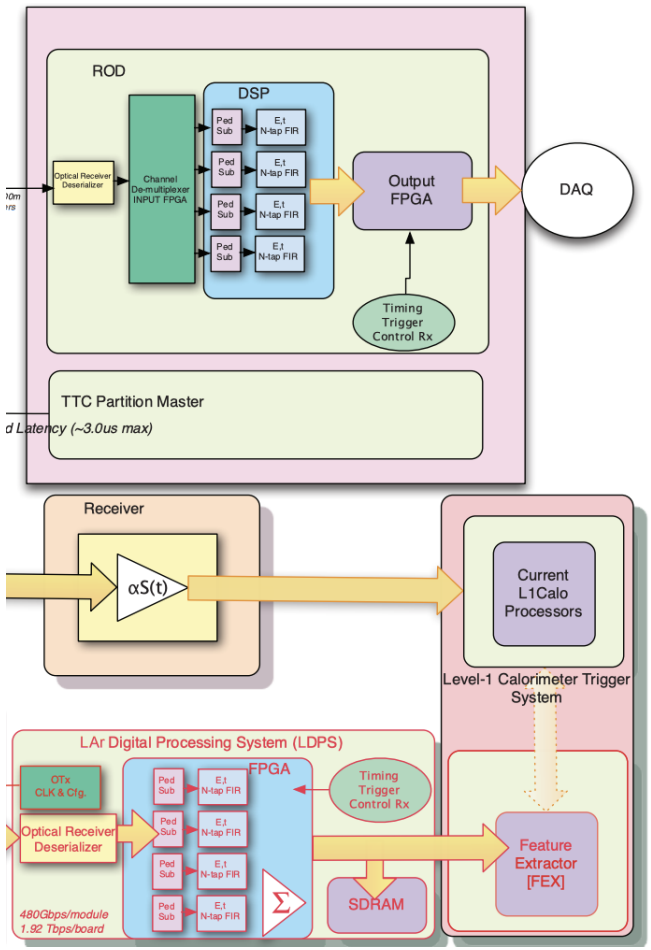
ATLAS-TDR-022



LAr Phase-1 Upgrade - Back-end

- 30 LAr Digital Processing Blade (LDPB) used to compute energies and send them to the level 1 system at 40 MHz
  - Four LAr Trigger prOcessing Mezzanines (LATOMEs)
  - One LAr Carrier (LArC) board
  - One Intelligent Platform Management Controller (IPMC) in ATCA crate
- 116 LATOMEs receive inputs from LTDBs, compute energies, and send them to the level 1 system
- LArCs provide Trigger, Timing, and Control (TTC) signals to LATOMEs and readout to TDAQ path
- IPMCs provide management for the various boards on the ATCA crates

ATLAS-TDR-022



LAr Phase-1 Upgrade - Hardware

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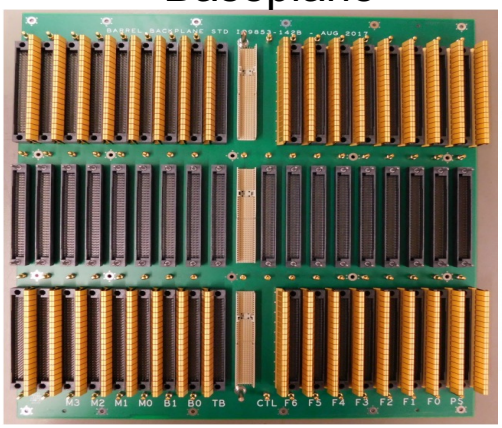
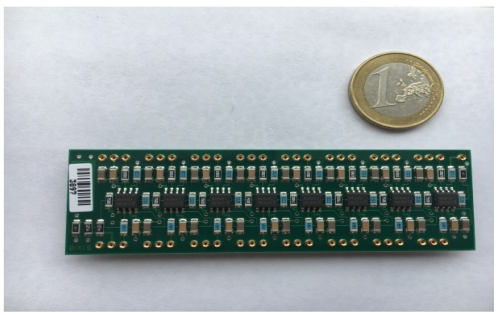
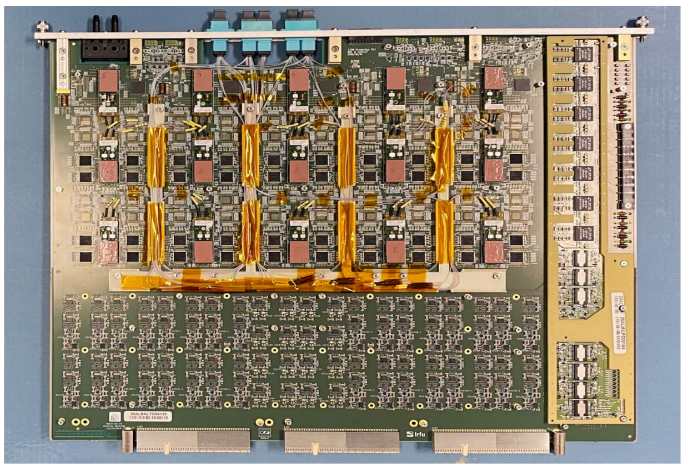
Baseplane



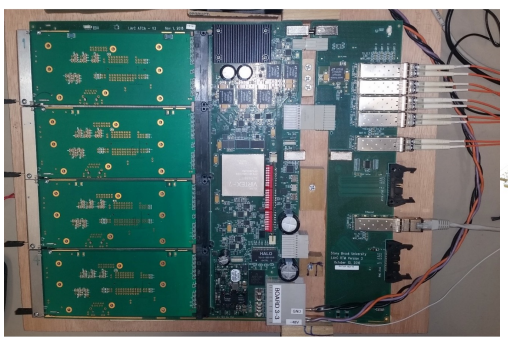
LSB



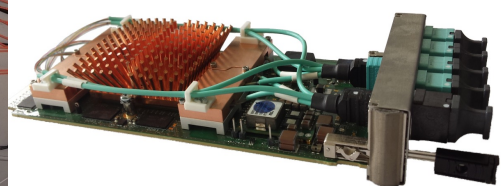
LTDB



LArC



LATOME

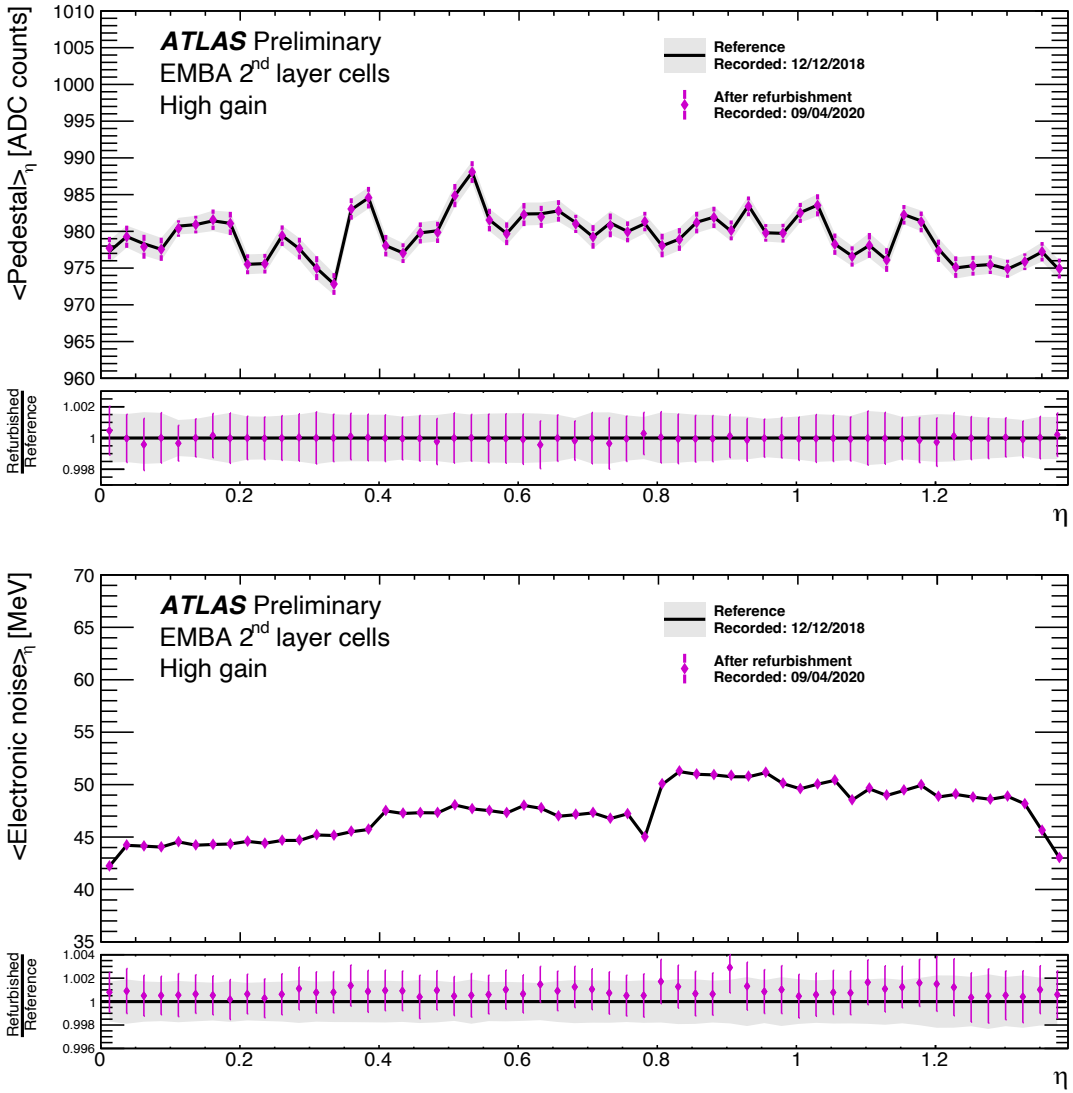


IPMC

Front-end Commissioning

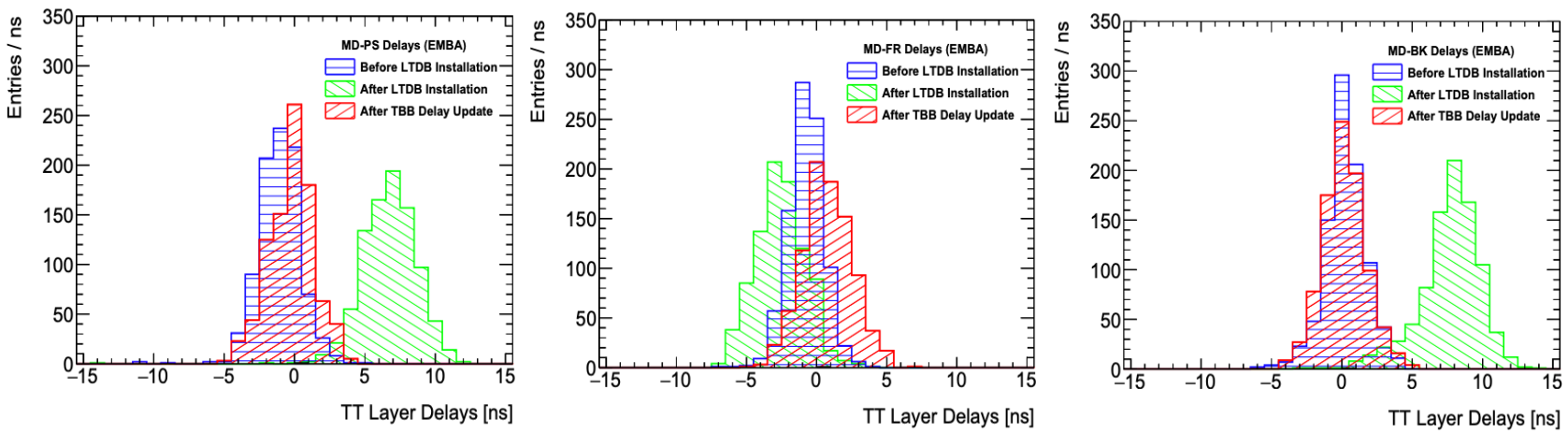
- FEBs expected to have similar performance wrt. Run 2
- Can compare Run 2 values and post-installation values
- Pedestal ADC counts and electronic noise compared
  - Averaged over all cells in η-slice
- No significant change seen after phase-1 upgrade

LAr LS2 public results



Legacy Readout Timing Differences

- Timing on Tower Builder Boards (TBB) used in legacy readout changed after LTDB installation
  - Signals now pass through the LTDB where supercell signals are added for each layer and used as inputs to TBB
- Correction to TBB delays needed to ensure correct timing
  - Timing difference between middle layer used as metric



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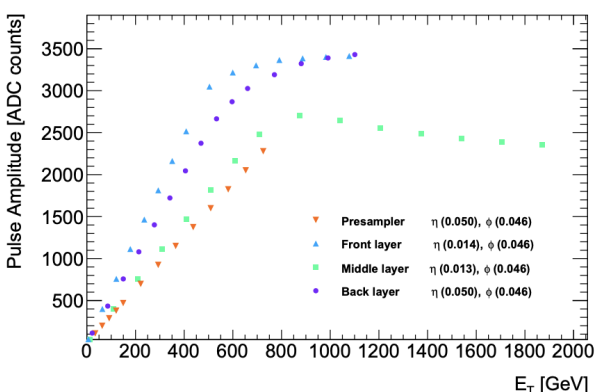
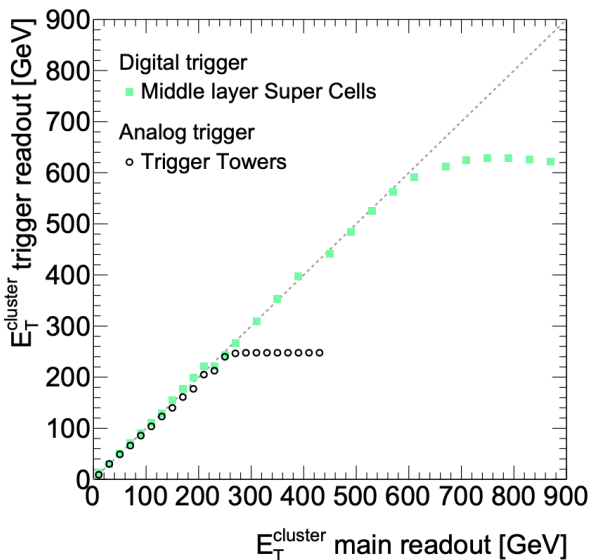
Digital Trigger Commissioning

- Energy calculated by the digital trigger is proportional to ADC counts given by LTDBs
- Peak ADC value computed as a function of injected E_T for select supercells
  - Saturation at $\sim$ 800 GeV due to limitations of analog electronics
  - Good linearity is seen!
- The calculated energies from digital trigger readout can be compared with the values seen by the main readout
  - Good agreement and higher saturation point for digital trigger!





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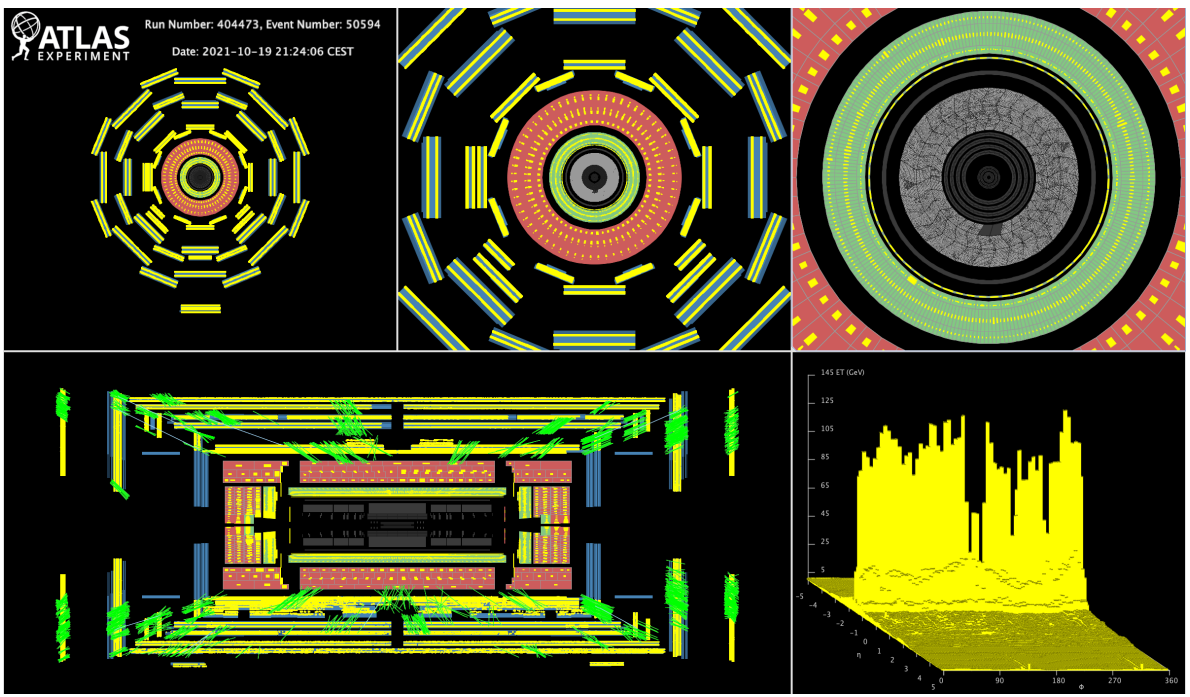
2021 Pilot Beam Run

- First time beams were seen after Run 2 at the LHC in October 2021
- The LAr calorimeter was fully operational with the phase-1 upgrades
- Beam splashes used to further validate the phase-1 upgrades
  - Protons accelerated and focused on a collimator magnet

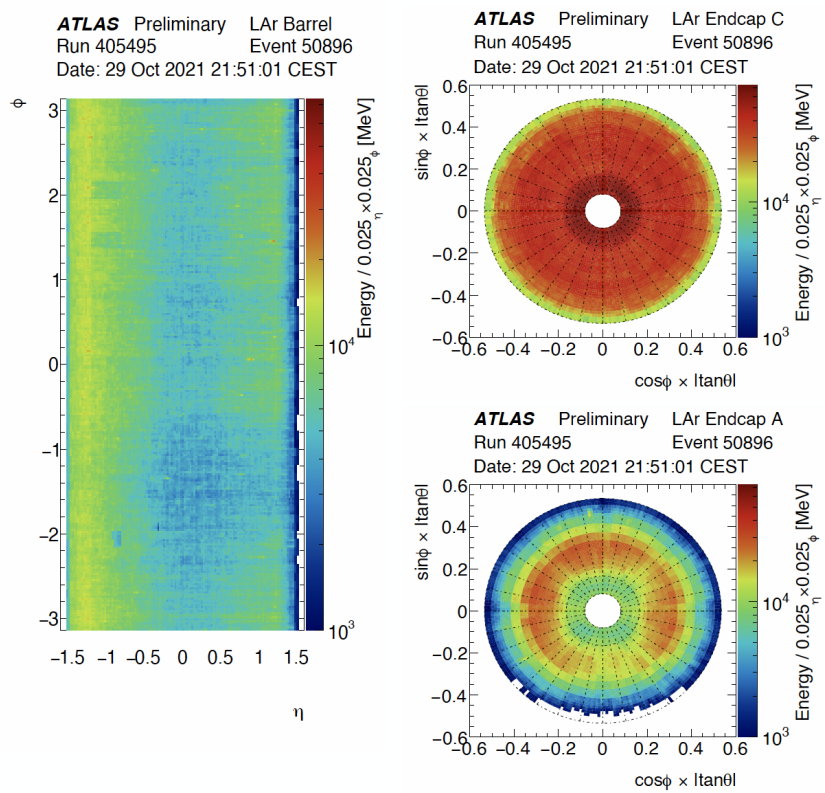


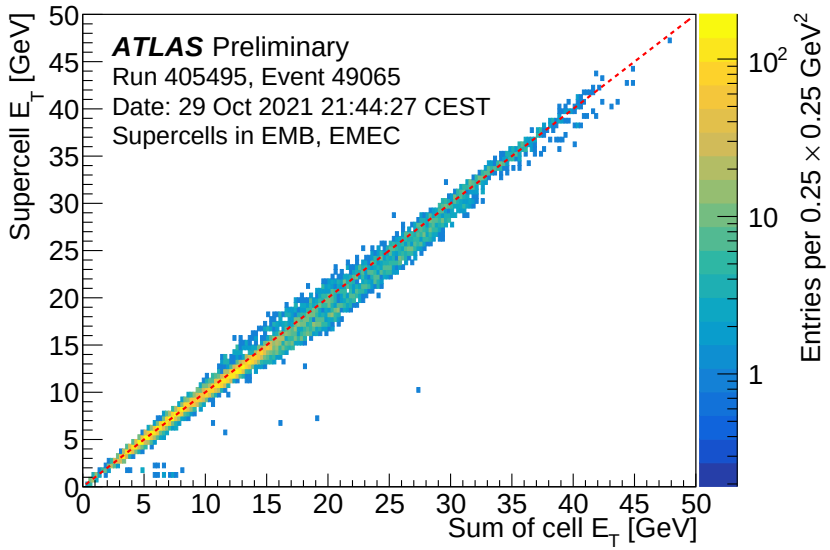
Run 3 public event displays

2021 Pilot Beam Results

LAr 2021 pilot beam public results

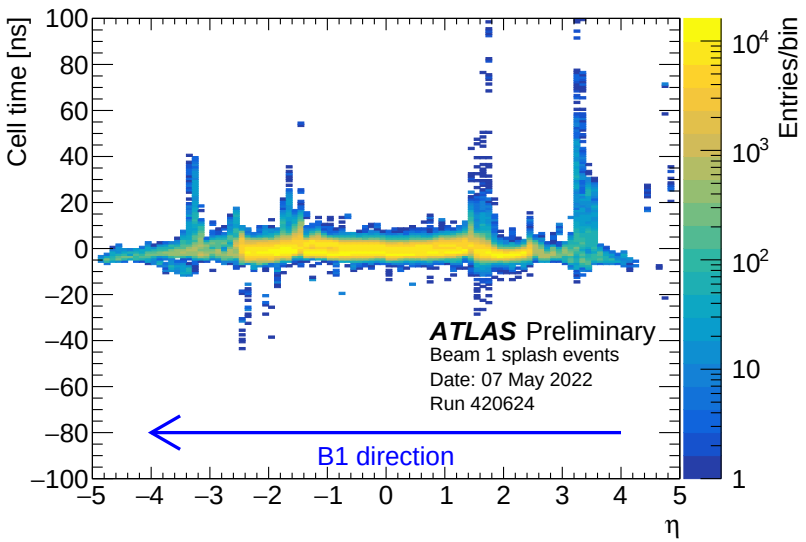
- Energies computed using the main readout for for barrel and endcap
  - 1.3 PeV measured by LAr
- Main readout energies compared with energies from digital trigger readout and good agreement can be seen!

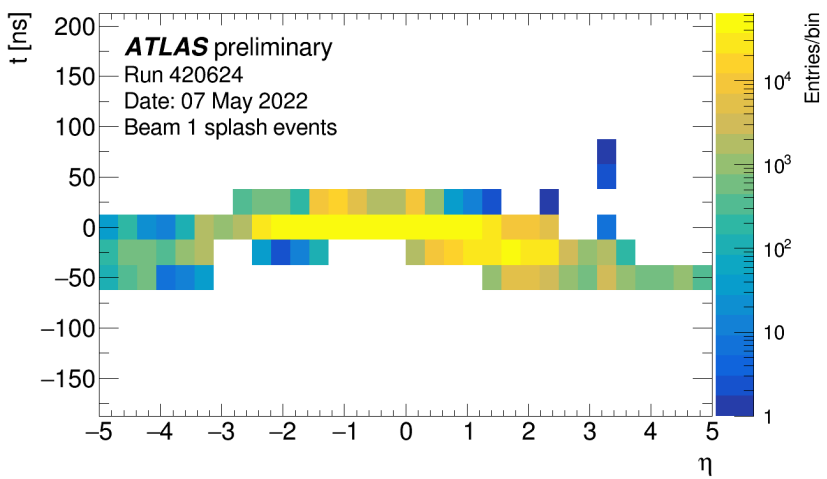




Run 3 Beam Splashes - Timing Analysis

- Beam splashes used to align timing of main readout to ns level
- Timing in digital trigger currently aligned at BCID level (25 ns)
  - To be aligned at the ns level in the future





LAr May 2022 beam splash public results

The Start of Run 3

Run 3 public event displays

- The phase-1 upgrade of the ATLAS LAr calorimeter was successfully completed!
- The 2021 pilot beam was used to validate and help commission the new digital trigger system
- Run 3 has already started with beam splashes, and p-p collisions at $\sqrt{s} = 900$ GeV
- Commissioning period is still ongoing but LAr will be ready to collect data during Run 3!