Tom Kreße, Arno Straessner
Institut für Kern- und Teilchenphysik, TU Dresden

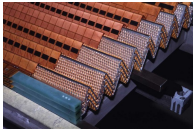
ATLAS Liquid Argon Calorimeter Readiness for LHC Run 3

Session T 41: Calorimeters 1

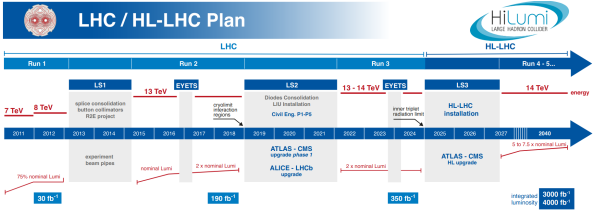
DPG Spring Meeting Heidelberg, 22nd of March, 2022

The ATLAS liquid argon calorimeters

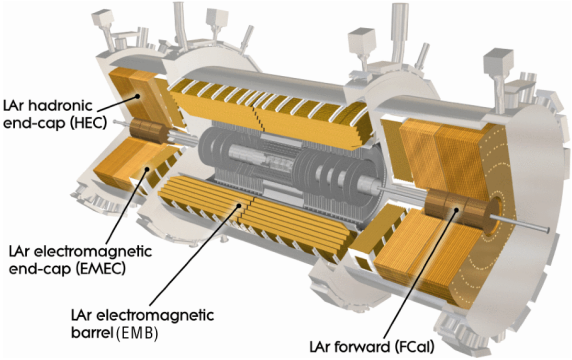
- sampling calorimeters, active medium = liquid argon
- EMB & EMEC: accordion-like lead structures
- HEC absorbers: parallel copper plates
- FCal: copper/tungsten matrix
- signal inputs to level-1 trigger (L1Calo)



Moustapha Thioye: CERN-THESIS-2008-063



https://project-hl-lhc-industry.web.cern.ch/content/project-schedule



ATLAS Collaboration, The ATLAS experiment at the CERN Large Hadron Collider, JINST 3 (2008) S08003.

LAr activities during LS2

- Phase-I LAr upgrade project

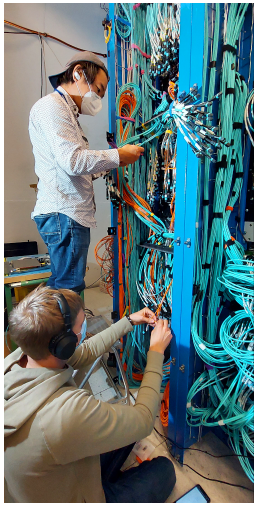
  → installation of the new **D**igital **T**rigger (DT) readout electronics

  → refurbishment of **F**ront-**E**nd (FE) crates

- **T**rigger **T**ime and **C**ontrol (TTC) system upgrade
- validation of main readout and Digital Trigger:

  → cosmics data taking

  → October 2021 test collisions



https://atlas.cern/updates/briefing/upgrading-LAr-calorimeter

Digital Trigger - Motivation

- analog trigger: ~ 6000 "Trigger Towers"

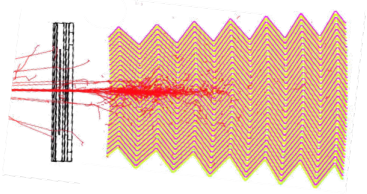
  → sum energy deposit across calorimeter layers

- Digital Trigger:

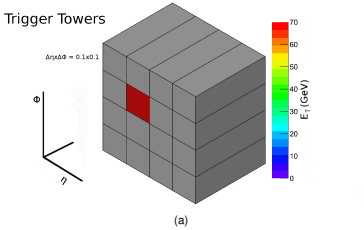
  → usage of digitized samples

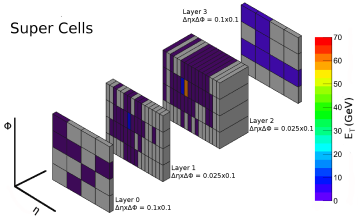
  → "Super Cells" with factor ~ 10 increased granularity

  → can keep p_T thresholds in busier luminosity environment



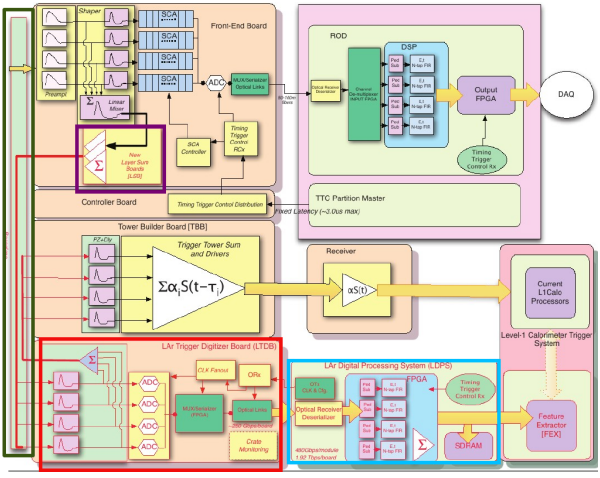
https://lapp.in2p3.fr/spip.php?article1918&lang=en



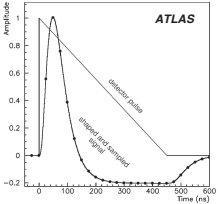


ATLAS Collaboration, ATLAS Liquid Argon Calorimeter Phase-I Upgrade Technical Design Report, ATLAS-TDR-022.

Digital Trigger - Readout electronics upgrades



ATLAS Collaboration, ATLAS Liquid Argon Calorimeter Phase-I Upgrade Technical Design Report, ATLAS-TDR-022.



ATLAS Collaboration, ATLAS liquid-argon calorimeter : Technical Design Report, ATLAS-TDR-2.

new Layer Sum Boards:

→ produce finer cell signal sums

LAr Trigger Digitizer Board (LTDB):

→ digitize signals

→ form layer sums for legacy readout

LAr Digital Processing Blade (LDPB):

→ energy reconstruction

new baseplanes:

→ new slots + handle increase of signal

Triger Timing and Control (TTC) system upgrade

- new ALTI (ATLAS Local Trigger Interface) boards replaced LTPIs

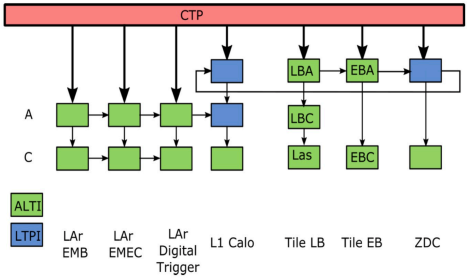
  → combine functionalities of four modules

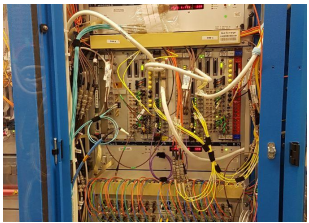
  → fewer cables, prevent aging effects

  → allow modular running of LAr

    → important for commissioning, testing and validation

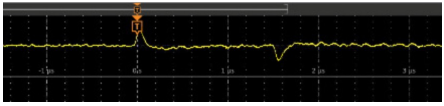
- timing aligned for legacy and digital system
- now back to stable TTC system





Work on trigger interface integration (ALTI boards)

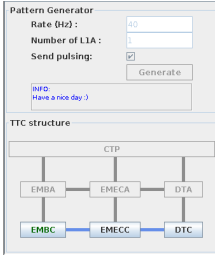
```
#-----------------------
# Rate = 400Hz
# Number L1A = 1
# Pulsing = yes
#-----------------------
#                      M
#                      u
#                      l
#                      t
#                      i
#                      p
#                      l
#   CCC                i
#  BRRR    T BBBB TTT  c
#O UEEE    T GGGG TTTL i
#R SQQQ    Y OOOO RRR1 t
#B Y210    P 3210 321A y
-----------------------
 1 0000 0x00 0000 0000 40
 0 0000 0x00 0000 0000 60
 0 0000 0x00 0100 0000 1
 0 0000 0x00 0000 0000 147
 0 0000 0x00 0000 0001 1
 0 0000 0x00 0000 0000 3315
 1 0000 0x00 0000 0000 40
 0 0000 0x00 0000 0000 3524
 1 0000 0x00 0000 0000 40
 0 0000 0x00 0000 0000 3524
 1 0000 0x00 0000 0000 40
```



- set up LAr detectors with new boards
- development of script to generate signal sequences

  → pulses, level-1 trigger accept, orbit, etc.
- work on online panel for board monitoring
- upgrade Standalone Pulsing to pulse with ALTI

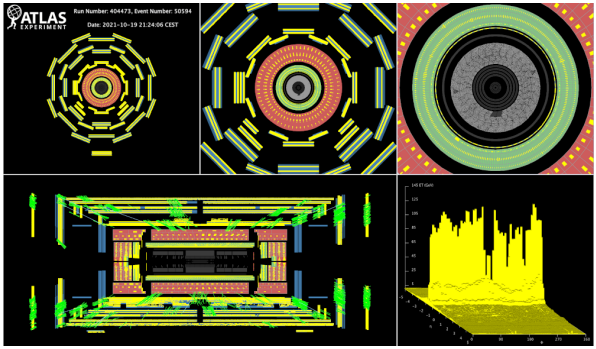
  → used for connectivity scans and beam splash emulation



Legacy analog trigger validation

- find dead channels after installation work
- connectivity scans to check trigger tower mapping
- timing refined with L1Calo
- successfully used in October 2021 beam splashes

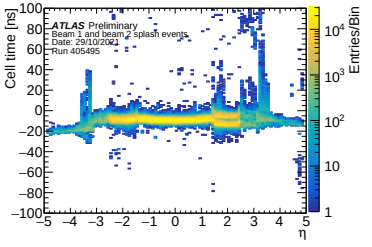
→ analog legacy trigger is fully functional!

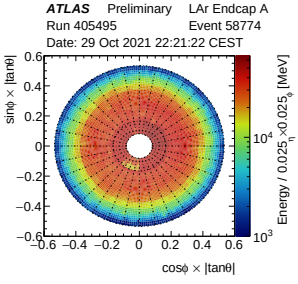


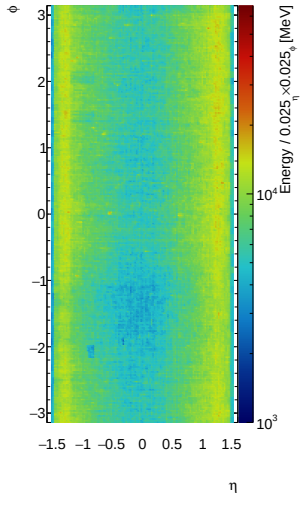
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/EventDisplayRun3Collisions

Main readout validation

- successfully ramped HV for cosmics
- smooth operation during 2021 beam splashes and test collisions
- exercised and validated FEB timing
- full detector coverage confirmed with splashes



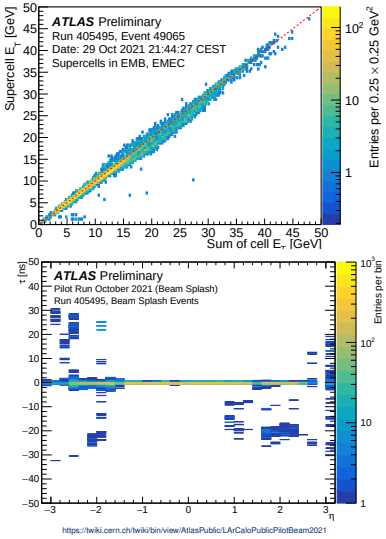




https://twiki.cern.ch/twiki/bin/view/AtlasPublic/LArCaloPublicPlotBeam2021

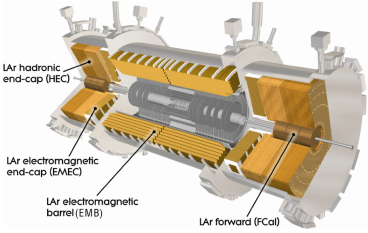
Digital trigger validation

- pulsing scans to verify channel mapping
- calibrations for energy and timing of Super Cells
- stability monitored with long runs
- validation with cosmics and test collisions
- tuned Super Cell timing with splash events
- good agreement with main readout energies data



Summary and Readiness for Run 3

- hardware installation completed
- main readout ready for operation during Run 3
- analog trigger system fully recovered
- new Digital Trigger system operational
- successfully taken cosmics and test collision data



ATLAS Collaboration, The ATLAS experiment at the CERN Large Hadron Collider, JINST 3 (2008) S08003.

→ ATLAS LAr calorimeters are ready for Run 3!

Thank you for your attention!

Questions?

Backup

Backup - General overview

- What is ATLAS?

  → multi-purpose particle detector at the **L**arge **H**adron **C**ollider (LHC) at CERN

- What is LAr?

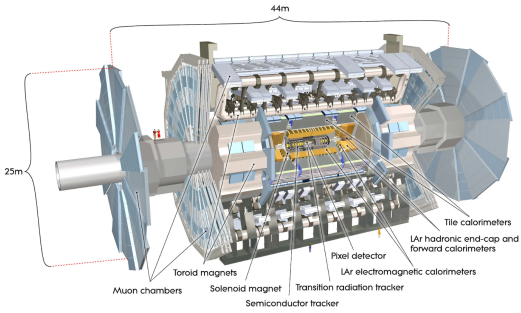
  → **L**iquid **Ar**gon calorimeter as subdetector of ATLAS

  → used for electromagnetic calorimetry and in hadronic calorimeter end-caps

- What is the LHC schedule?

  → currently in second long shutdown (LS2) since 2018

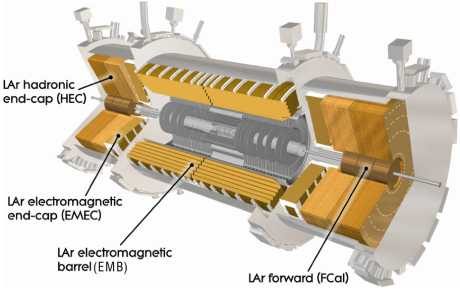
  → Run 3 planned to start in July this year



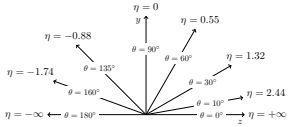
ATLAS Collaboration, The ATLAS experiment at the CERN Large Hadron Collider, JINST 3 (2008) S08003.

Backup - Details on LAr calorimeters

- sampling calorimeters using liquid argon as active medium
- electromagnetic barrel (EMB) and end-caps (EMEC) with accordion-like structures of lead absorbers
  → allows fast readout and full azimuthal coverage
- hadronic end-caps (HEC) use conventional design with parallel copper plates as absorbers
- forward calorimeters (FCal) consist of a copper/tungsten matrix with liquid argon tiny gaps
- pseudorapidity regions covered are:
  - EMB: $|\eta| < 1.475$
  - EMEC: $1.375 < |\eta| < 3.2$
  - HEC: $1.5 < |\eta| < 3.2$
  - FCal: $3.1 < |\eta| < 4.9$
- LAr calorimeter signals serve as inputs to level-1 trigger (L1Calo)

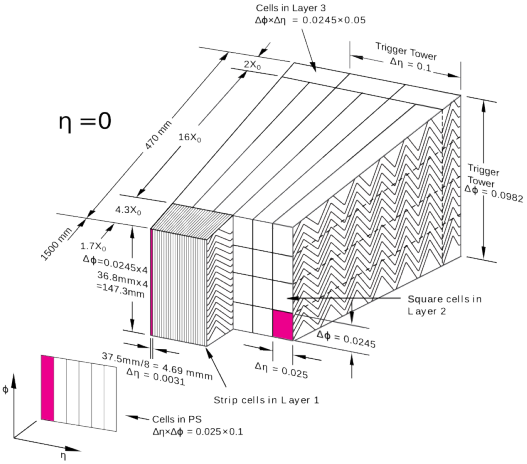


ATLAS Collaboration, The ATLAS experiment at the CERN Large Hadron Collider, JINST 3 (2008) S08003.



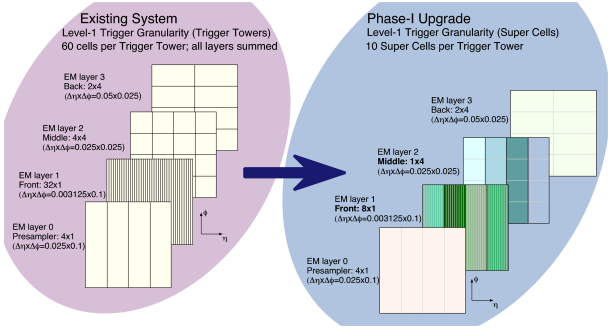
https://project-hl-lhc-industry.web.cern.ch/content/project-schedule

Backup - Accordion shaped barrel calorimeter



ATLAS Collaboration, ATLAS liquid-argon calorimeter : Technical Design Report, ATLAS-TDR-2.

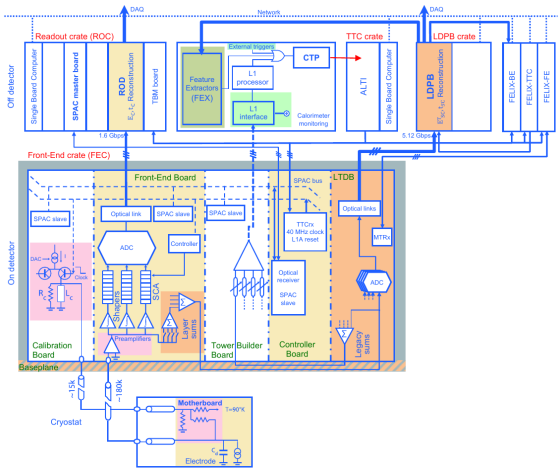
Backup - Granularity comparison



ATLAS Collaboration, ATLAS Liquid Argon Calorimeter Phase-I Upgrade Technical Design Report, ATLAS-TDR-022.

Geometrical representation in η,ϕ space of an EM TT in the current system, where the transverse energy in all four layers are summed (left) and of the SCs proposed for the Phase-I upgrade, where the transverse energy in each layer is retained in addition to the finer granularity in the front and middle layers (right). Each square represents an area of size $\Delta\eta \times \Delta\phi = 0.1 \times 0.1$.

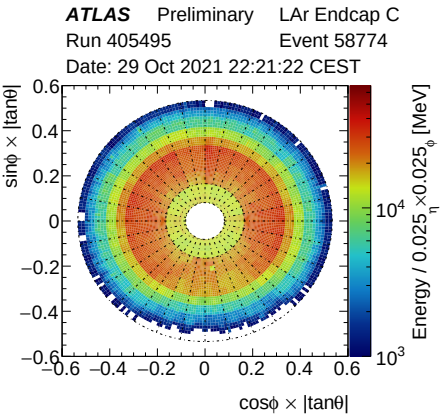
Backup - Readout electronics



The Phase-I Trigger Readout Electronics Upgrade of the ATLAS Liquid Argon Calorimeters

The ATLAS LAr calorimeter electronic architecture as of LHC Run 3. The new LAr boards are highlighted in orange. This diagram depicts the EM calorimeters; HEC and FCal electronics are slightly different.

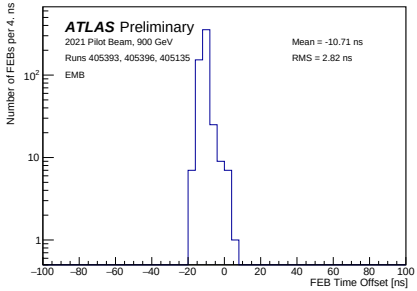
Backup - Coverage LAr Endcap C



https://twiki.cern.ch/twiki/bin/view/AtlasPublic/LArCaloPublicPilotBeam2021

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 October 2021. The particles were delivered by Beam 2 (B2) and entered from the negative η (C) side. From left to right the plots show the summed energies in the endcap C, in the barrel and in the endcap A. In total the displayed LAr layers recorded $1.187\,\mathrm{PeV}$ in this event.

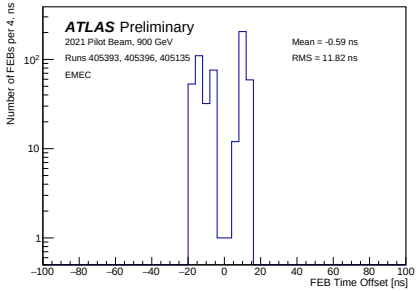
Backup - FEB timing EMB



https://twiki.cern.ch/twiki/bin/view/AtlasPublic/LArCaloPublicPilotBeam2021

Average time per front end board (FEB) in the LAr electromagnetic barrel (EMB) with collision data at $s_{1/2} = 900\,\mathrm{GeV}$ collected during LHC pilot beam of October 2021. 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. The system was aligned with respect to the barrel side A using beam splash events. This preliminary time alignment will be further tuned to improve the uniformity and the observed residual bias.

Backup - FEB timing EMEC



https://twiki.cern.ch/twiki/bin/view/AtlasPublic/LArCaloPublicPilotBeam2021

Average time per front end board (FEB) in the LAr electromagnetic end-cap (EMEC) with collision data at $s_{1/2} = 900\,\mathrm{GeV}$ collected during LHC pilot beam of October 2021. 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. The system was aligned using beam splash events from beam 2 (from side C to side A) and not accounting for the shift of 3.1 m of the side C, causing a misalignment between side A and side C. This preliminary time alignment will be further tuned to improve the uniformity and the observed residual bias.