The ATLAS Liquid Argon (LAr) Calorimeter Level 1 Trigger Signal pre-Processing System: Installation, Commissioning and Calibration Results

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➤ Outline

- ❑ ATLAS detector
 1. LAr Calorimeter (I will concentrate on the ElectroMagnetic calorimeter (EM))
 2. Brief overview of the LAr-L1 trigger System.
- ❑ A description of the:
 - ❑ Commissioning/Calibration of the L1Calo signals
 - ❑ Performance studies using beam data.
- ❑ Summary

ATLAS Detector

ATLAS LAr Calorimeters

➤ High granularity ~180k of readout channels in total (85% is EM calorimeter)

➤ LAr Calorimeters:

- ✓ EM Barrel: $|\eta| < 1.475$ [Pb-LAr]
- ✓ EM End-caps : $1.375 < |\eta| < 3.2$ [Pb-LAr]
- ✓ Hadronic End-caps: $1.5 < |\eta| < 3.2$ [Cu-LAr]
- ✓ Forward: $3.2 < |\eta| < 4.9$ [Cu, W-LAr]

ATLAS EM Calorimeter

- The detection principle: incident particles and their secondary decays produce a current collected at the electrode.
- Read-out electrode:
 - Centered in between two Pb-absorbers by light honeycomb spacers → two LAr gaps of 2.1 mm.
 - Has three distinct conductive layers: HV applied to its outer layers → electric field in the gaps.
- currents induced by electrons drifting in the gaps are read from the central layer.
- EM design properties:
 - ✓ Accordion shape in EM barrel and endcap calorimeters: ϕ uniformity (no cracks).
 - ✓ LAr as active material inherently linear and radiation hard.
 - ✓ High granularity (Cu etching)
 - ✓ Segmented longitudinally in four layers (total of ~ 22 -32 XO).

A view of the Calorimeters

➤ A view of the Barrel

➤ A view of one of the endcaps

GOLDEN TRIGGER

Calibration/Trigger Path

Timing shifts

Gains

Twisted pair Cable

RECEIVER

OUT TOWER

ADC

Tower Builder Board (TBB)

➤ ~150k EM channels

➤ ~3500 channels

Receivers: counting room end of the trigger cables

- ❖ Installation of the Receiver system...
- ❖ Cabling the LAr-Receiver...
- ❖ 8 receiver crates: 6 for LAr and 2 for Tile Calorimeters.
- ❖ Each crate has one controller board, 2 monitoring boards and 16 receiver boards.

Receiver Control And Monitoring (1): Signal Path

Signals out of receiver carried by short trigger cables to L1.

Receiver

Transition Module

Monitoring board

Signals out of Calorimeter carried by long trigger cables

Receiver Control And Monitoring (2): Noise...

- A real GOLDMINE
- System runs remotely and can look at any part of the calorimeter with real time monitoring

Multiplexer (MUX)

Spectrum Analyzer

Receiver Control And Monitoring (3): Analog-to-Digital Converters (ADCs)

- ❖ On each side, there is a VME crate which includes:
 1. VMIC-cpu with USB ports
 2. Two 12bit, 8 channel ADCs.
 3. One VME V976B logic module.
- ❖ This system was used to commission the L1 output of the LAr calorimeters.

● MUX

L1 commissioning Of the LAr Calorimeter: Data Taken...

- ❖ The L1 trigger output of the LAr calorimeter is commissioned in two steps:
 - Step 1: check the connectivity.
 - Step 2: Generate a set of gain values for the receiver and timing shifts for the TBB.
 1. Take data for 4 different energies and 5 delay settings per trigger channel per layer.
 2. For each energy and delay setting we take 100 triggers.
 3. 27 samples for the L1 and 12 samples for the main readout.

L1 commissioning Of the LAr Calorimeter: Procedure to Extract the results (1)

1. Make an average of the 100 triggers $\rightarrow$ minimize the noise.
2. Combine the 5 delay settings $\rightarrow$ 5ns spacing.
3. The 4 different energy curves are used to generate the master waveform (MWF) $\rightarrow$ slopes at a given time $\rightarrow$ energy- and ADC pedestal- independent.
4. A cubic spline interpolation of the 5ns curves, to obtain points at 1 ns spacing for use in convolutions (see next slide).

L1 commissioning Of the LAr Calorimeter: Procedure to Extract the results (2)

5. Master wave forms are convoluted with a known function that contains the circuit parameters and drift time to produce the expected ionization pulse.
→ "transformation function" takes care of current shape difference and the injection point.

- For the calibration pulses:

$$I_{\text{calib}}^N = I_C \cdot \left(\frac{(1 - f_{\text{step}}) \cdot T_C}{1 + s \cdot T_C} + \frac{f_{\text{step}}}{s} \right)$$

$$V_{\text{calib}} = I_{\text{calib}}^N \cdot R_{\text{calib}}^N$$

f_{step} A measure of the resistive component of the non-ideal inductance
 T_C Exponential decay constant (function of R and L)

$$s = j \cdot \omega$$

- For the signal pulses:

$$I_{\text{ion}}^N = \left[I_s \cdot \left(\frac{1}{s} - \frac{1}{s^2 \cdot T_D} \cdot (1 - e^{-s T_D}) \right) \right] \cdot \frac{1}{s \cdot C \cdot Z^N}$$

$$V_{\text{ion}} = I_{\text{ion}}^N \cdot R_{\text{ion}}^N$$

$$Z^N = \frac{1}{sC} + R + sL$$

Norton equivalent impedance

$$T_D$$
 Drift time
$$R_{\text{calib}}^N = R_{\text{ion}}^N = \frac{1}{\frac{1}{R_L} + \frac{1}{Z^N}}$$

➤ How well we understand our timing → calibration/signal paths?

$$\Delta = \underbrace{Y_{\text{cal}} + Y_{\text{sig}}}_{\text{Time related to all cable lengths in the calibration and signal paths.}} + \underbrace{X_{\text{cal}} + X_{\text{sig}}}_{\text{Transit times for PCBs [calorimeter MBs, traces on the FEBs, and traces on the baseplane (L1 signals only)]}} + \underbrace{T_{\text{calc}}}_{\text{Calculated pulse rise time from 0 to 3\% of the maximum}} + \underbrace{T_{\text{rise}}}_{\text{Measured pulse rise time from 3\% to peak}} - (\underbrace{T_{\text{meas}}}_{\text{Measured time}} - \underbrace{T_0}_{\text{Time offset [per feedthrough]}})$$

Time related to all cable lengths in the calibration and signal paths.

Transit times for PCBs [calorimeter MBs, traces on the FEBs, and traces on the baseplane (L1 signals only)]

Calculated pulse rise time from 0 to 3% of the maximum

Measured pulse rise time from 3% to peak

Measured time

Time offset [per feedthrough]

➤ Correction → narrower distribution for the main readout

L1 commissioning Of the LAr Calorimeter

Procedure to Extract the results (3): Timing (EMB) (Cont.)

6. Extract the time for each layer, then subtract the time needed for the calibration pulse to arrive to the electrode

$$Y_{\text{cal}} + X_{\text{cal}}$$

→ the physics time:

$$T^{\text{phy}} = T^{\text{calib}} - Y_{\text{cal}} - X_{\text{cal}}$$

• We align the pulses from different layers at their peaks.

L1 commissioning Of the LAr Calorimeter Procedure to Extract the results (4): Gains

7. Extract Et for the LVL1 and Main readout → deduce the Et ratio (per layer for EM) → receiver gains.
8. For EM, and sometimes, different layers have slightly different gains → A weighted average: Middle (80%) and the front (20%).

✓ Built-in fixed factor of 2 to compensate for cable delays (based on a 70m long trigger cables).

✓ Mean~0.87 mostly due to shorter trigger cables

✓ Using MonteCarlo simulation: align all 4 layers of each TT and apply the gain correction.

→ Then look at the dispersion.

✓ The minimum of the dispersion is at the peak.

Receiver Gains: Precision of the Variable Gain Amplifiers...

- ❖ How well we can set the gains using the variable gain amplifier?
- ❖ Ratio = $(Et_MainReadout/Et_L1)$, measured out of the calibration system.

Ratio before setting the gains

Ratio after setting the gains (referred to as "new ratios")

Ratios per TT for four different phi intervals.

New Ratios Distribution

Gdistrib	
Entries	56
Mean	1.001
RMS	0.001622

✓ The new ratios are equal to 1 within 0.5%.

Checking the Receiver Gains Using Beam Data: Et Correlation for EM Barrel...

- ❖ L1Calo Trigger Performance: **REAL DATA** → **Ultimate Truth**...
- ❖ Determine the reliability of the measured L1-Gain values.
- ❖ **Studies of the energy correlation from two independent readouts** → **Debug hardware/software problems.**

Summary/Conclusion

- The receiver system for all calorimeters is installed and commissioned.
- An online system, for checking/debugging noise problems and taking standalone calibration data for L1Calo, is operational.
- Calibration of the L1Calo system was done, and the first gains and timing shifts for different layers are ready (in anticipation for the first collisions).
- Variable Gain Amplifiers can set gains to a precision of 0.5%.
- An indication of the accuracy of the gains is given by the dispersion at the peak of the signal, which ranges from 0.2% to 2% in the EM barrel.
- Calibration constants (timing, gains) for LAr-L1, being validated using physics data.