ATLAS LAr Calorimeter Commissioning for LHC Run-3

Energy computation in LATOME boards

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on behalf of the ATLAS LAr Calorimeter Group

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LAr Phase 1 upgrade: improving the trigger

**ATLAS Calorimeter**
Divided in subsystems based on Tiles and Liquid Argon (LAr)
- Each LAr subsystem divided in cells computing energy in ($\eta, \phi$) coordinates and 3-4 layers in depth

**Hardware trigger system** (L1 accept)
40 MHz → 100 kHz = decide in few $\mu$s based on computed energy
- Reduced granularity to be faster: **Trigger Towers ~ 60 cells** combined in depth and $\eta, \phi$ ($\Delta \eta \times \Delta \phi = 0.1 \times 0.1$)

**Phase 1 Upgrade**
**Higher pile-up** expected: $<\mu> = 80$ (Run 3) to 200 (HL-LHC)
- Increase granularity to improve discriminating power: **Super Cells**

**From Trigger Tower to SuperCells**
- Granularity: 1 TT = 10 SC = 1+4+4+1 SC
  - From 5248 TT to 34 048 SC
- Digitization (improved precision)
- Pile-up subtraction (baseline correction) maintained though more challenging
Detector pulse lasts around 400 ns, that is **around 20 bunch crossings**!

- Shaping of detector response: cancel out this **out-of-time pile-up**
  - Negative part: need for a pedestal
- Digitization: at 40 MHz (bunch crossing frequency), **encoded on 12 bits**

Input data in LDPB: One ADC count (12 bit integer) per bunch crossing

- **Compute energy? Associate to correct bunch crossing?**
  - **Optimal Filtering Coefficients (OFC)**

\[
E_T(m) = \sum_{i=0}^{N-1} a_i \cdot (ADC_{m+i} - ped_{m+i})
\]
\[
\xi(m) = \tau(m) \cdot E_T(m) = \sum_{i=0}^{N-1} b_i \cdot (ADC_{m+i} - ped_{m+i})
\]
Energy computation, done in **UserCode of LATOME** board (FPGA) in LAr Digital Processing Blades, need coefficients:

- **SuperCell Specific**: to be stored in correct register of correct LATOME
- From calibration run = condition specific (run number, lumi block,...) : stored in Condition database (~ database with Intervals of Validity)

**ADC input to Filtering block**

<table>
<thead>
<tr>
<th>ADC counts</th>
<th>Pedestal</th>
<th>Baseline</th>
<th>Pure ADC</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 bits unsigned integer</td>
<td>14 bits unsigned integer with hardpoint</td>
<td>9 bits integer with hardpoint</td>
<td>16 bits integer with hardpoint</td>
</tr>
</tbody>
</table>

**FIR Filter**

\[
E_T(m) = \sum_{i=0}^{N-1} a_i \cdot (ADC_{m+i} - ped_{m+i})
\]

\[
\xi(m) = \tau(m) \cdot E_T(m) = \sum_{i=0}^{N-1} b_i \cdot (ADC_{m+i} - ped_{m+i})
\]

**Selection Block**

\[-8E_T(m) < \xi(m) < 16E_T(m) \text{ for } 10 \text{ GeV} < E_T(m)\]
\[-8E_T(m) < \xi(m) < 8E_T(m) \text{ for } 0 < E_T(m) \leq 10 \text{ GeV} \]
\[8E_T(m) < \xi(m) < -8E_T(m) \text{ for } -1 \text{ GeV} < E_T(m) \leq 0 \text{ GeV} \]

OFCs, pedestals come from calibration runs as floats
- Multiplied by factors to make least significant bit of computation (DSP) output correspond to 12.5 MeV
- Converted to 13bit + 1 sign bit integers to be stored in registers

Correctly implemented in LATOME? Computation result comparable to full float precision?
1. Create **condition database** with **calibration coefficients** converted to integers
   ➔ Load it in LATOME registers

2. Check **energy** ($E_T$) **computation** by the LATOME is correct with a monitoring run:
   ➔ 1000 events each with 11 ADC (1 per Bunch Crossing) sent to each channels
      (=SuperCell) of LATOME boards (here 2 LATOMEs = 580 channels)
   ➔ Recompute $E_T$ for each 8 first samples : $8 \times 580 = 4640$ $E_T$/event **computed**

3. Check **energy resolution**: LATOME $E_T$ vs $E_T$ computed with **full float precision**

4. Enable **selection block** ($E_T$ set to 0 upon failure) and repeat step 2
   ➔ Check $\xi = \tau \times E_T$ computation AND selection criteria correct in LATOME

**Prospect**: keep validating all blocks of UserCode on all LATOME boards (covering all SuperCells of LAr Calorimeter)

**Energy resolution**: around 50 MeV

**Energy accuracy**: At the 1 % level

1 event: 11 ADC samples (consecutive BCs)

$E_T(m) = \sum_{i=0}^{3} a_i \cdot (ADC_{m+i} - ped_{m+i})$
BACKUP SLIDES
Energy in ADC counts

Recalculation of Energy as in LATOME
Selection Block disabled

Recalculation of Energy as in LATOME
Selection Block enabled

LATOME vs reco full precision Energy
good correlation

Energy resolution: around 5 ADC

Energy accuracy: At the 1% level
Energy in MeV

Recomputation of Energy as in LATOME
Selection Block disabled

Recomputation of Energy as in LATOME
Selection Block enabled

LATOME vs reco full precision Energy
good correlation

Energy resolution: around 50 MeV

Energy accuracy: At the 1‰ level