ATLAS Trigger Rates and Physics Menu

Sarah Demers, Yale University
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ECFA Meeting
Outline

• Reminder of the physics motivation and establishing TDAQ goals
• Discussion of architecture choices, latency requirements and data flow through the system
• Target menu and rates
• Comments regarding rate predictions

The two previous talks by Masaya Ishino (calorimeters and muons) and Giudo Volpi (tracks) have described the main detector inputs to the trigger. In this talk we’ll focus on the overall TDAQ system.
Physics Motivation: impact of muon threshold requirement

![Graph showing acceptance vs. true muon p_T [GeV] for different processes with Run 1 threshold and No Upgrade threshold.]
VBF $h\rightarrow\tau_1\tau_1$
Mulijet Triggers

**ATLAS Simulation Preliminary**

- $hh \rightarrow b\bar{b}b\bar{b}$
- $G \rightarrow hh \rightarrow b\bar{b}b\bar{b}$

### Graph

- **Acceptance**
- **Fourth jet $p_T$ [GeV]**
- **Run 1 Threshold**
- **No Upgrade Threshold**
- **HL-LHC upgrade**
General Strategy

1) loosen current 100 kHz L1 rate
2) access tracking information early
Possible architectures

Introduced Monday morning, by Brian Petersen

https://indico.cern.ch/event/524795/contributions/2235126/attachments/1346960/2031430/StatusAndPlans.pdf
Possible architectures

Rates and Latencies

Level 0: 1 MHz, 10 μs
Level 1: 400 kHz, 60 μs
EF output: 10 kHz

Level 0: 1 MHz, 10 μs
EF output: 10 kHz
Possible architectures

Track Information

Level 1: regional tracking w/ ITK
EF: Full event tracking w/ FTK++

EF: regional tracking w/ EFTrack, full event tracking w/ FTK++

(See previous presentation by Guido Volpi)
single hardware level architecture
two hardware level architecture
• Can perform jet finding on entire calorimeter with full granularity
• Receives L1 tracks in regions of interest and L0Muon objects
• Excellent pile-up rejection can be achieved with tracking information
Latency Budget: L0/L1

Level 0
- L1Track:
  - R3 mapping and transmission to ITk
  - R3 readout from ITk
  - Data transmission to L1Track
  - L1Track finding

Level 1
- Results to L1Global

L1Global:
- Preprocessing on Calorimeter sources
- Build event on Aggregators, merging data from Calorimeter sources
- Transmit event from Aggregators to Event Processor
- Linear data processing on Event Processor
- Iterative Calorimeter-only algorithms
- Track matching, global and topological triggers
- Transmit decisions to L1CTP
- L1A decision to detector
# HL-LHC ATLAS Target Menu: Lepton triggers

Assumes Instantaneous Luminosities up to $7.5 \times 10^{34}$

**Analysis Thresholds in GeV, Rates in kHz**

<table>
<thead>
<tr>
<th>Description</th>
<th>Run 1 Threshold</th>
<th>HL-LHC Threshold</th>
<th>L0 Rate</th>
<th>EF Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>isolated e</td>
<td>20-25</td>
<td>22</td>
<td>200</td>
<td>2.20</td>
</tr>
<tr>
<td>di-electron</td>
<td>17, 17</td>
<td>15, 15</td>
<td>90</td>
<td>0.08</td>
</tr>
<tr>
<td>forward e</td>
<td>–</td>
<td>35</td>
<td>40</td>
<td>0.23</td>
</tr>
<tr>
<td>single $\gamma$</td>
<td>40–60</td>
<td>120</td>
<td>66</td>
<td>0.27</td>
</tr>
<tr>
<td>di-photon</td>
<td>25, 25</td>
<td>25, 25</td>
<td>8</td>
<td>0.18</td>
</tr>
<tr>
<td>single $\mu$</td>
<td>25</td>
<td>20</td>
<td>40</td>
<td>2.20</td>
</tr>
<tr>
<td>di-muon</td>
<td>12, 12</td>
<td>11, 11</td>
<td>20</td>
<td>0.25</td>
</tr>
<tr>
<td>e-$\mu$</td>
<td>17, 6</td>
<td>15, 15</td>
<td>65</td>
<td>0.08</td>
</tr>
<tr>
<td>$\tau$</td>
<td>100</td>
<td>150</td>
<td>20</td>
<td>0.13</td>
</tr>
<tr>
<td>di-tau</td>
<td>40,30</td>
<td>40, 30</td>
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Total non-hadronic L0 rate: $\sim$750 kHz, EF rate: 5.7 kHz
# HL-LHC ATLAS Target Menu: Hadronic triggers

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<tr>
<td>single jet</td>
<td>200</td>
<td>180</td>
<td>60</td>
<td>0.6</td>
</tr>
<tr>
<td>large-R jet</td>
<td>-</td>
<td>375</td>
<td>35</td>
<td>0.35</td>
</tr>
<tr>
<td>four jet</td>
<td>55</td>
<td>4 x 75</td>
<td>50</td>
<td>0.50</td>
</tr>
<tr>
<td>forward jets</td>
<td>-</td>
<td>180</td>
<td>30</td>
<td>0.30</td>
</tr>
<tr>
<td>HT</td>
<td>-</td>
<td>500</td>
<td>60</td>
<td>0.60</td>
</tr>
<tr>
<td>MET</td>
<td>120</td>
<td>200</td>
<td>50</td>
<td>0.50</td>
</tr>
<tr>
<td>JET + MET</td>
<td>150, 120</td>
<td>140, 125</td>
<td>60</td>
<td>0.30</td>
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Total hadronic L0 Rate: ~250 kHz, EF Rate: 3.15 kHz

750 kHz (leptonic) + 250 kHz (hadronic) = 1000 kHz
### HL-LHC ATLAS Target Menu: Hadronic triggers

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Total hadronic L0 Rate: \(~250\) kHz, EF Rate: \(3.15\) kHz

\(750\) kHz (leptonic) + \(250\) kHz (hadronic) = \(1000\) kHz
Additional selection power from hardware topology trigger (1)

A factor of four rate reduction is gained with mass and opening angle requirements.
Additional selection power from hardware topology trigger (2)

In the di-tau signature, the (20, 12) GeV tau pair with $\Delta R < 2.9$ gives lower rate than with a 25 GeV jet requirement.

Two taus (20, 12) GeV + a 25 GeV L1 Jet

Two taus (20, 12) GeV with opening angle $\Delta R < 2.9$

Two taus (20, 12) GeV with opening angle $\Delta R < 2.9$ + a 25 GeV L1 Jet
Rate Predictions

• Standard method
  o Use enhanced bias data and extrapolate to higher luminosity

• Challenge of pile-up
  o extrapolation misses possible saturation of high cross-section items at high pile-up
  o neglects combinatorics

• Alternatives
  o high-pileup MC Simulation (requires excellent modeling of low p_T jets)
  o emulate trigger using trigger objects from enhanced bias events

• Currently have large uncertainties related to rates of jet triggers, but are gaining understanding of relationships between rates and thresholds
  o for example, for our multijet trigger, a ten GeV threshold difference on the 4th jet results in a factor of ten difference in rate
Conclusions

• The general strategy for HL-LHC triggering at ATLAS is to increase the rates allowed in earliest levels of triggering while bringing tracking information into the system at an earlier stage.

• The TDAQ System can deliver lepton thresholds for the HL-LHC that meet or beat thresholds seen in Run 1.

• Hadronic triggers are extremely challenging in the high-pileup environment, but are strongly motivated (hh->4b, for example).

• Multiple architectures are currently under consideration, each supporting the HL-LHC physics program with low lepton thresholds and pile-up suppression from early tracking.