The ATLAS Trigger: High-Level Trigger
Commissioning and Operation During Early Data Taking

Ricardo Gonçalo,
Royal Holloway University of London

On behalf of the ATLAS TDAQ High-Level Trigger group

Outline

- The ATLAS High-Level Trigger
  - Overall system design
  - Selection algorithms and steering

- Trigger strategy for initial running
  - Trigger algorithm organisation
  - Trigger strategy for initial running
  - Status

- High-Level Trigger Commissioning
  - Technical runs
  - Cosmic-ray runs

- Summary and outlook
The ATLAS High-Level Trigger
Three trigger levels:

- **Level 1:**
  - Hardware based
  - Calorimeter and muons only
  - Latency 2.5 μs
  - Output rate ~75 kHz

- **Level 2:** ~500 farm nodes(*)
  - Only detector "Regions of Interest" (RoI) processed - Seeded by level 1
  - Fast reconstruction
  - Average execution time ~40 ms(*)
  - Output rate up to ~2 kHz

- **Event Builder:** ~100 farm nodes(*)

- **Event Filter (EF):** ~1600 farm nodes(*)
  - Seeded by level 2
  - Potential full event access
  - Offline algorithms
  - Average execution time ~4 s(*)
  - Output rate up to ~200 Hz

(*) 8CPU (four-core dual-socket farm nodes at ~2GHz

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Selection method

Event rejection possible at each step

Level 1 Region of Interest is found and position in EM calorimeter is passed to Level 2

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ATLAS HLT Operation in Early Running

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Steering

- Algorithm execution managed by Steering
  - Based on static trigger configuration
  - And dynamic event data (RoIs, thresholds)

- Step-wise processing and early rejection
  - Chains stopped as soon as a step fails
  - Reconstruction step done only if earlier step successful
  - Event passes if at least one chain is successful

- Prescale (1 in N successful events allowed to pass) applied at end of each level

- Specialized algorithm classes for all situations
  - Topological: e.g. 2 μ with $m_{\mu\mu} \sim m_Z$
  - Multi-objects: e.g. 4-jet trigger, etc......

ATLAS HLT Operation in Early Running

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Trigger Strategy for Initial Running
Trigger algorithms

- High-Level Trigger algorithms organised in groups (“slices”):
  - Minimum bias, e/γ, τ, μ, jets, B physics, B tagging, \( E_T^{\text{miss}} \), cosmics, plus combined-slice algorithms

- For commissioning
  - Cosmics slice used to exercise trigger – already started!

- For initial running:
  - Crucial to have minimum bias, e/γ, τ, μ, jets
  - B physics will take advantage of initial low-lumi conditions (not bandwidth-critical)
    - Lower event rate allow low transverse momentum thresholds needed for B physics
  - \( E_T^{\text{miss}} \) and B-jet tagging will require significant understanding of the detector

- Will need to understand trigger efficiencies and rates using real data
  - Zero bias triggers (passthrough)
  - Minimum bias:
    - Coincidence in scintillators placed in front of calo.
    - Counting inner-detector hits
  - Prescaled loose triggers
  - “Tag-and-probe” method, etc

1. Select good offline \( Z \rightarrow \mu\mu/ee \)
2. Randomly select “tag” lepton; if triggered, use second lepton as “probe”
3. \( \varepsilon = \#(\text{triggered probes})/\#(\text{all}) \)
Trigger strategy for initial running

- Major effort ongoing to design a complete trigger list (“menu”) for initial running
  - Commissioning of detector and trigger; early physics
  - Start with $\mathcal{L}=10^{31}$ cm$^{-2}$s$^{-1}$ benchmark and scale accordingly

- Many sources of uncertainty:
  - Background rate (dijet cross section uncertainty up to factor $\sim 2$)
  - Beam-related backgrounds
  - New detector: alignment, calibration, noise, Level 1 performance (calo isolation?), etc
  - Event occupancy

- Must be conservative and be prepared to face much higher rates than expected

- Need many “handles” to understand the trigger:
  - Many low-threshold, prescaled triggers, several High Level triggers will run in “pass-through” mode (take the event even if trigger rejects it)
  - Monitoring framework (embedded in algorithms, flexible and with small overheads)
  - Redundant triggers
    - e.g. minimum bias selection with inner detector and with min.bias scintillators

- Expect the menu to evolve rapidly, especially once it faces real data
Status

- Trigger information routinely available in simulated data
  - Trigger decision and reconstructed objects easily accessible in simulated data
  - Generated much work and feedback from physics groups

- Trigger decision can be re-played with different thresholds on already reconstructed data: important for optimisation of selection

- Tools being developed for trigger optimisation
  - Estimate efficiency, rate and overlaps
  - Need to be able to react quickly to changing luminosity conditions

- A draft menu exists with some 90 triggers
  - Much work is under way to optimise it and test it against the expected conditions

- Rates, efficiencies and overlap between selections being studied for the menu
  - Including misaligned detector in simulation
  - Including overlapped events per bunch crossing
  - Including natural cavern radiation (for muons)
High-Level Trigger Commissioning
Technical runs

- A subset of the final High-Level Trigger CPU farm and DAQ system were exercised in “technical runs”

- Simulated (Level 1 triggered) Monte Carlo events in raw data format preloaded into DAQ readout buffers and distributed to farm nodes

- Realistic trigger list used (e/\gamma, jets, \tau, B physics, E_T^{\text{miss}}, cosmics)
  - HLT algorithms, steering, monitoring infrastructure, configuration database

- Measure/exercise:
  - Event latencies
  - Algorithm execution time
  - Monitoring framework
  - Configuration database
  - Network configuration
  - Run-control

ATLAS HLT Operation in Early Running
Cosmics runs

- A section of the detector was used in cosmics runs (see previous talk) including:
  - Muon spectrometer
  - Tile (hadronic) calorimeter
  - LAr (electromagnetic) calorimeter
  - Inner detector

- The High-level was exercised successfully on real data in test cosmic runs.
Conclusions and outlook
Conclusions and outlook

- The ATLAS High-Level Trigger is getting ready to face LHC data

- The final High-Level Trigger system was successfully exercised in technical runs on simulated data and was shown to be stable

- High-Level Trigger algorithms and machines took part in cosmosics test runs

- Trigger information now routinely available in simulated data
  - Used for trigger optimisation

- Looking forward to triggering on LHC data next year!
Backup slides
Event data **pulled:** partial events @ ≤ 100 kHz, full events @ ~ 3 kHz

Event data **pushed** @ ≤ 100 kHz, 1600 fragments of ~ 1 kByte each
Configuration

- Trigger configuration:
  - Active triggers
  - Their parameters
  - Prescale factors
  - Passthrough fractions
  - Consistent over three trigger levels

- Needed for:
  - Online running
  - Event simulation
  - Offline analysis

- Relational Database (TriggerDB) for online running
  - User interface (TriggerTool)
  - Browse trigger list (menu) through key
  - Read and write menu into XML format
  - Menu consistency checks

- After run, configuration becomes conditions data (Conditions Database)
  - For use in simulation & analysis
Single-e Tr. Eff. (from $Z \rightarrow e^+e^-$) as a function of $\eta$, $\phi$ and $E_T$

Misaligned Geometry

Wrt. offline:
- Loose electron
- Tight electron

ATLAS HLT Operation in Early Running
Trigger efficiency from data

- Electron trigger efficiency from real $Z \to e^+e^-$ data:
  1. Tag $Z$ events with single electron trigger (e.g. e25i)
  2. Count events with a second electron (2e25i) and $m_{ee} \approx m_Z$

- No dependence found on background level (5%, 20%, 50% tried)

- ~3% statistical uncertainty after 30 mins at initial luminosity

- Small estimated systematic uncertainty

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Method Z→$e^+e^-$ counting

<p>| Level 2 efficiency | 87.0 % | 87.0 % |</p>
<table>
<thead>
<tr>
<th>Trigger</th>
<th>$p_T$ threshold(*)</th>
<th>Obs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electron</td>
<td>5, 10, 15,</td>
<td>Prescale</td>
</tr>
<tr>
<td>Electron</td>
<td>20, 25, 100</td>
<td>No presc</td>
</tr>
<tr>
<td>Di-electron</td>
<td>5, 10</td>
<td>Prescale</td>
</tr>
<tr>
<td>Di-electron</td>
<td>15</td>
<td>No presc</td>
</tr>
<tr>
<td>Photon</td>
<td>10, 15, 20</td>
<td>Prescale</td>
</tr>
<tr>
<td>Photon</td>
<td>20</td>
<td>No presc</td>
</tr>
<tr>
<td>Di-photon</td>
<td>10</td>
<td>Prescale</td>
</tr>
<tr>
<td>Di-photon</td>
<td>20</td>
<td>No presc</td>
</tr>
<tr>
<td>Jets</td>
<td>5, 10, 18, 23, 35, 42, 70</td>
<td>Prescale</td>
</tr>
<tr>
<td>Jets</td>
<td>100</td>
<td>No presc</td>
</tr>
<tr>
<td>3 Jets</td>
<td>10, 18</td>
<td>B-tag</td>
</tr>
<tr>
<td>4 Jets</td>
<td>10, 18</td>
<td>B-tag</td>
</tr>
<tr>
<td>4 Jets</td>
<td>23</td>
<td>Express</td>
</tr>
<tr>
<td>$\tau$</td>
<td>10, 15, 20, 35</td>
<td></td>
</tr>
<tr>
<td>Di-$\tau$</td>
<td>$10+15, 10+20, 10+25$</td>
<td></td>
</tr>
<tr>
<td>Muon</td>
<td>4, 6, 10, 11, 15, 20, 40</td>
<td>Muon spectr.</td>
</tr>
<tr>
<td>Muon</td>
<td>4, 6, 10, 11, 15, 20, 40</td>
<td>ID+Muon</td>
</tr>
<tr>
<td>Di-muon</td>
<td>4, 6, 10, 15, 20</td>
<td>Passthr.</td>
</tr>
<tr>
<td>$\Sigma E_T$</td>
<td>100, 200, 304</td>
<td>prescale</td>
</tr>
<tr>
<td>$\Sigma E_T$</td>
<td>380</td>
<td>No presc</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trigger</th>
<th>$p_T$ threshold(*)</th>
<th>Obs</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Sigma E_T$ (jets)</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>$E_T^{miss}$</td>
<td>12, 20, 24, 32, 36, 44</td>
<td>Prescale</td>
</tr>
<tr>
<td>$E_T^{miss}$</td>
<td>52, 72</td>
<td>No presc</td>
</tr>
<tr>
<td>$J/\Psi\rightarrow\mu\mu$</td>
<td>Topological</td>
<td>B-phys</td>
</tr>
<tr>
<td>$J/\Psi\rightarrow\mu\mu$</td>
<td>Topological</td>
<td>B-phys</td>
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<tr>
<td>BsDsPhiPi</td>
<td>Topological</td>
<td>B-phys</td>
</tr>
<tr>
<td>$B\gamma X$</td>
<td></td>
<td>B-phys</td>
</tr>
<tr>
<td>$e + E_T^{miss}$</td>
<td>18+12</td>
<td>Prescale</td>
</tr>
<tr>
<td>$\mu + E_T^{miss}$</td>
<td>15+12</td>
<td>No presc</td>
</tr>
<tr>
<td>Jet + $E_T^{miss}$</td>
<td>20+30</td>
<td>No presc</td>
</tr>
<tr>
<td>2 Jets + $E_T^{miss}$</td>
<td>42+30</td>
<td>No presc</td>
</tr>
<tr>
<td>Jet + $E_T^{miss}$ + $e$</td>
<td>42+32+15</td>
<td>No presc</td>
</tr>
<tr>
<td>Jet + $E_T^{miss}$ + $\mu$</td>
<td>42+32+15</td>
<td>No presc</td>
</tr>
<tr>
<td>4 Jet + $e$</td>
<td>23+15</td>
<td>No presc</td>
</tr>
<tr>
<td>4 Jet + $\mu$</td>
<td>23+15</td>
<td>No presc</td>
</tr>
<tr>
<td>$\tau + E_T^{miss}$</td>
<td>15+32, 25+32, 35+20, 35+32</td>
<td></td>
</tr>
<tr>
<td>$\tau + e$</td>
<td>10+10</td>
<td>Express</td>
</tr>
<tr>
<td>$\tau + \mu$</td>
<td>10+6</td>
<td>Express</td>
</tr>
<tr>
<td>2 $\tau + e$</td>
<td>10+10</td>
<td>Express</td>
</tr>
</tbody>
</table>
L2PU Timing for Electron Run March

**Level 2PU Accepted Event Total Processing Time**
- Total time for accepted
  - mean 71.5 ms/event

**Level 2PU Rejected Event Total Processing Time**
- Total time for rejected
  - mean 19.7 ms

**Level 2PU Accepted Event Pure Processing Time**
- Processing time for accepted
  - mean 53.0 ms
  - *Two tracking algorithms!*

**Time in Data Collector for Accepted Event**
- Data collection time for accepted
  - mean 25.0 ms