ATLAS High-Level Trigger Algorithms for Run-2 Data Taking

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Short overview of infrastructural HLT changes:
- unified High-Level Trigger processing
- use of offline reconstruction tools and data structures

Improvements in trigger selections:
- examples of improvements in trigger detector software
- a few selected highlights from different trigger signatures

Not only HLT:
- many general improvements in the overall trigger strategy
- see talk by Yu Nakahama
The HLT processing is now unified into just one farm:

- **reduces the complexity** of the system
- **provides efficient coupling** between subsequent selection steps, reducing duplication of CPU usage and network transfer
- **allows flexible combination** of fast and detailed processing

The Run-1 HLT selection ran in two separate farms: Level2 and Event Filter

A few of the consequences:
- separate rate boundaries;
- data transfer from L2 to EF;
- some processing duplication
Harmonization with Offline Reconstruction

Feedback from Run-1 analyses: important to improve the correlation between online and offline object identification.

For Run-2 all trigger signatures focused on adopting offline techniques wherever possible:

- data preparation
- detector software
- reconstruction
- selection cuts

Aim: increased acceptance after analysis cuts and higher rejection.

In addition: allows specific trigger tuning for particular analyses.

Technical aspects:

- adoption of xAOD data structures, mostly in common with offline: allows easier reuse of offline code
- large reduction of coding and commissioning duplications
- easier calibration of triggers along with offline selections
- pile-up corrections: possible access to average collision number
New HLT ID tracking exploits running on a single CPU node:

- **common data preparation** performed just once
- first **Fast Track Finder step** provides fast tracking info
- this is **reused as a seed for Precision Tracking** instead of restarting from scratch, as in the L2/EF scheme
- **common data structures for both steps**: easy switching
- ready to receive seeds from additional sources, as **FTK**
- see poster by **Stewart Martin-Haugh**
The new unified HLT approach also performs much better in terms of CPU consumption, after offline and online code optimization:

- example: approximate average total electron chain execution time is now 90 ms to be compared with 260 ms for Run-1
- faster execution obtained without affecting efficiency
- similar improvements measured for the muon slice
Trigger Signatures: EGamma and Taus

Both signatures profit from L1 improvements and disambiguation

EGamma:
- aim to have HLT as close as possible to offline, using MVA energy calibration and conversion reconstruction
- for electrons, will commission in parallel two alternative selections, one cut-based and one likelihood-based
- exploit L1Topo for ultimate precision tag-and-probe calibrations

Taus:
- implemented two-step tracking approach, granting faster processing enhancing early rejection: process core region first, looking for signal tracks, then process isolation ring
- following offline, introduced new variables sensitive to $\pi^0$
- also pile-up corrections harmonized with offline
Trigger Signatures: EGamma and Taus

**Taus:**

- implemented **two-step tracking approach**, granting faster processing enhancing early rejection: process core region first, looking for signal tracks, then process isolation ring
- following offline, introduced **new variables sensitive to π^0**
- also **pile-up corrections harmonized with offline**
Muon identification proceeds in two steps:

- major rewrite of the standalone reconstruction for the first selection
- news: $p_T$ calculation enhanced using hits from new EE MDT chambers (approx. factor 2 resolution improvement)
- final selection using offline strategies for muon reconstruction

Completely redesigned muon full scan search: used to improve search for di-muon events, starting from single muon at L1

- in Run-1, full scan done in both Muon Spectrometer and ID
- now, full scan MS reconstruction is followed by ID tracking is run in small projections of each muon
- more than a factor 3 faster with no efficiency loss!
Trigger Signatures: Jets

Major infrastructural rewrite allows broad use of offline tools:
- implemented jet area pileup suppression and jet energy scale
- working on further steps based on tracking result

Implemented new partial scan option for data access and reconstruction: runs a single-pass scan on calorimeter data from merged regions around L1 jets
Trigger Signatures: b-Jets

Many performance improvements from infrastructural work:

- tracking / vertexing can be executed in the geometrical union of jet RoIs (SuperRoI): flexible multi-step tracking approaches
- provides significant computing speed up, even processing larger cone sizes around each jet
- big effort to reuse offline code and move to the use of advanced tools and multivariate taggers online (JetFitter, MV1, MV2, …)
- larger rejection power allows looser working point definitions

CHEP2015, April 13-17
ATLAS HLT Algorithms for Run-2
Trigger Signatures: MET and B-physics

For both, large improvements from new L1 topological capabilities:
MET using KF jet corrections, invariant mass cuts for B-physics

**MET:**
- use of cell-level info immediately after L1 (L2 sums in 2012)
- offline-like algorithms being examined, e.g. jets for hard activity plus topoclusters for soft activity
- pileup suppression, rejecting events where the minimum energy per object is below threshold
- additional corrections constraining MET from pileup to zero
- use of final trigger muons for MET (L2 muons in 2012)

**B-physics:**
- preparing HLT selections with cut on di-muon lifetime
- could be adopted for studies of rare and semileptonic decays
- requires care for onia and lifetime/angular measurements
Conclusions

Many news since Run-1: HLT merging into a single processing node, new data structures written in collaboration with offline, in general a larger harmonization effort aiming at a better online/offline correlation and larger acceptance after analysis cuts, while enhancing rejection power against uninteresting events.

A lot of good new ideas in the design of Run-2 HLT triggers, surely promising an enhanced physics reach...

which is soon to be confirmed with fresh new collision data!
BACKUP
**ATLAS** Preliminary Simulation

Muon trigger - ID tracking (built April 2013)

Monte Carlo, 14 TeV $Z \rightarrow \mu^+\mu^-$

- Total EFID processing time
- EFID pattern recognition
- EFID spacepoint ambiguity resolution
ATLAS Preliminary Simulation
Monte Carlo, 14 TeV \( Z \rightarrow e^+e^- \), \( \langle \mu \rangle = 46 \)
EFID Pattern Recognition
- Run 1 strategy (built Aug 2014): \( \langle t \rangle = 100 \text{ ms} \)
- Run 1 strategy (built Apr 2013): \( \langle t \rangle = 297 \text{ ms} \)
ATLAS Preliminary Simulation
Monte Carlo, 14 TeV Z→ e⁺e⁻, 〈μ〉 = 46
EFID Ambiguity Solver

Run 1 strategy (built Aug 2014): 〈t〉 = 13.3 ms
Run 1 strategy (built Apr 2013): 〈t〉 = 129 ms
**ATLAS** Preliminary Simulation

Monte Carlo 14 TeV, $Z \rightarrow e^+e^-$, $\langle \mu \rangle = 46$

24 GeV isolated electron trigger

Run 2 strategy: $\langle t \rangle = 90.2$ ms

Run 1 strategy: $\langle t \rangle = 262$ ms
**ATLAS** Preliminary Simulation

Monte Carlo, 14 TeV $Z \rightarrow e^+e^-$, $\langle \mu \rangle = 46$

EFID Ambiguity Solver

- **Run 2 strategy:** $\langle t \rangle = 3.8$ ms
- **Run 1 strategy:** $\langle t \rangle = 13.3$ ms
ATLAS Preliminary Simulation
14 TeV Monte Carlo, $Z \rightarrow \mu^+\mu^-, \langle \mu \rangle = 40$

$p_T(\mu^\pm) > 3$ GeV

- Precision Tracking
- Fast Track Finder
ATLAS Preliminary Simulation
14 TeV Monte Carlo, $Z \rightarrow \mu^+\mu^-$, $\langle \mu \rangle = 40$

- Precision Tracking
- Fast Track Finder
**ATLAS** Preliminary Simulation

- Full Scan
  - \(<\text{no. cells}> = 187652\)
- Partial Scan ($\eta \times \phi = 1 \times 1$)
  - \(<\text{no. cells}> = 6489\)
- Partial Scan ($\eta \times \phi = 1.5 \times 1.5$)
  - \(<\text{no. cells}> = 13392\)
ATLAS Preliminary Simulation

- Full Scan
  - \(<t_\text{ime}> = 10.1\ ms\)
- Partial Scan (\(\eta \times \phi = 1 \times 1\))
  - \(<t_\text{ime}> = 3.1\ ms\)
- Partial Scan (\(\eta \times \phi = 1.5 \times 1.5\))
  - \(<t_\text{ime}> = 5\ ms\)
Events / 20 ms

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<th>Cell clustering time per event [ms]</th>
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<tr>
<td>400</td>
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<tr>
<td>500</td>
</tr>
</tbody>
</table>

- Full Scan
  \(<time> = 98.1 \text{ ms}\)
- Partial Scan ($\eta \times \phi = 1 \times 1$)
  \(<time> = 6.3 \text{ ms}\)
- Partial Scan ($\eta \times \phi = 1.5 \times 1.5$)
  \(<time> = 9.7 \text{ ms}\)

*ATLAS Preliminary Simulation*
\begin{itemize}
  \item Full Scan \hspace{1cm} <E_T> = 40.6 \text{ GeV}
  \item Partial Scan (\eta \times \phi = 1 \times 1) \hspace{1cm} <E_T> = 39 \text{ GeV}
  \item Partial Scan (\eta \times \phi = 1.5 \times 1.5) \hspace{1cm} <E_T> = 39 \text{ GeV}
\end{itemize}
ATLAS Preliminary Simulation

number of jets ratio (PS/FS)

Partial Scan (\eta \times \phi = 1 \times 1)

Partial Scan (\eta \times \phi = 1.5 \times 1.5)

E_{T}^{FS} [GeV]
ATLAS Preliminary Simulation

- Partial Scan ($\eta \times \phi = 1 \times 1$)
- Partial Scan ($\eta \times \phi = 1.5 \times 1.5$)