THE DESIGN AND PERFORMANCE OF THE ATLAS INNER DETECTOR TRIGGER FOR RUN 2 LHC COLLISIONS AT 13 TeV

LHC Run 2

- Step up from Run 1 to Run 2 requires faster data processing, and increases amount of data to process per collision

<table>
<thead>
<tr>
<th>LHC parameter</th>
<th>Run 1</th>
<th>Run 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_{\text{cm}}$</td>
<td>7 TeV</td>
<td>13 TeV</td>
</tr>
<tr>
<td>Peak luminosity</td>
<td>$7 \times 10^{23}$ cm$^{-2}$ s$^{-1}$</td>
<td>$2 \times 10^{24}$ cm$^{-2}$ s$^{-1}$</td>
</tr>
<tr>
<td>Bunch separation</td>
<td>50 ns</td>
<td>25 ns</td>
</tr>
<tr>
<td>Interactions per crossing</td>
<td>~ 21</td>
<td>~ 55</td>
</tr>
<tr>
<td>Detector input rate</td>
<td>20 MHz</td>
<td>40 MHz</td>
</tr>
</tbody>
</table>

ATLAS Inner Detector (ID) and ID Trigger

- ID uses a number of layers of silicon detectors (Pixels and SCT) and gas filled straw tubes (TRT) to detect charged track hits, with spatial resolution ranging from 10 µm to 130 µm. A new Insertable B-Layer (IBL) innermost pixel layer added for Run 2 significantly improves tracking and vertexing. [1]
- Trigger systems must reduce rate from input ~MHz to output ~1 kHz, without rejecting interesting events
- ID trigger rapidly reconstructs tracks for further processing in the trigger systems, and for use in the overall trigger decision to keep an event

New Approaches for Run 2, and Optimisations

2-step Trigger Approach [2]:
Using new architecture, introduce 2-step method for some triggers (e.g. tau triggers)
- Run FastTrackFinder within long but narrow first-step Region of Interest (RoI)
- Select track of interest, seed second-step RoI with shorter length, increased width
- Precision tracking then run in significantly less volume compared to original 1-step RoI approach (see below)

Run 1 general trig. architecture:
- Level 1 (L1)
  - Hardware based
  - No ID
  - < 2.5 µs decision
  - 70 kHz output
  - Low detector granularity
- Level 2 (L2)
  - Software based
  - Fast tracking with ID
  - ~75 ms decision
  - 5-8 kHz output
  - Full detector granularity

Run 2 general trig. architecture:
- Level 1 (L1)
  - Upgraded hardware
  - < 2.5 µs decision
  - 100 kHz output
  - New topological trigger (L1Topo) for angular and event-level quantities
- Level 2 (L2)
  - Merger L2 and EF, no repeating data
  - ~200 ms decision
  - Full detector granularity
- Event Filter (EF)
  - L2 style FastTrackFinder algorithms
  - EF style Precision Tracking algorithms
  - Single PC farm, single node per event

Optimisations:
- General optimisation of code hot spots using Valgrind
- Faster linear algebra library (Eigen)
- Compiler upgrade from GCC 4.3 to GCC 4.8, 64-bit CPU architecture

Improvements from New Approaches, and Results from Run 2 Data

Summary

- ID trigger upgraded for Run 2
- Architecture and algorithms updated
- Excellent performance improvement