Commissioning of ATLAS Electron and Photon Trigger selection

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Outline

- ATLAS detector and trigger
- Electron and Photon trigger strategy
- Results from first 7 TeV proton-proton collision data
- Commissioning steps and near future plans
**Physics motivations/requirements**

- **Electrons and photons** are typical signatures of many key physics process:
  - J/ψ, B physics → low $p_T$ electrons [5 – 20 GeV]
  - Z, W, Higgs, SUSY, top, prompt γ → medium $p_T$ electrons and photons [20 – 100 GeV]
  - exotics, G, Z’ → high $p_T$ electrons and photons [>100 GeV]

- At nominal LHC conditions:
  - bunch crossing *every 25 ns* (40 MHz rate)
  - cross section dominated by soft pp interactions
  - on average 20 interactions per bunch crossing (pile up) $10^{34}$ cm$^{-2}$s$^{-1}$

- Data saving rate limited by offline processing time and storage capability to ~200 Hz

- **Trigger ‘requirement’: reducing rate by factor of 200000 while retaining events with interesting physics objects**
The ATLAS detector

- Muon chambers
- Toroid magnets
- Solenoid magnet
- Semiconductor tracker
- Transition radiation tracker
- Pixel detector
- LAr electromagnetic calorimeters
- LAr hadronic end-cap and forward calorimeters
- Tile calorimeters

44 m
25 m
sub-detectors for egamma triggers

3 technologies Tracker

- 3 Si pixel layer
- 8 Si strips layer (4 space point)
- straw TRT detector (~36 hits per track)
  electron PID capability

LAr EM calorimeter: more on this in H. Zhang talk

- coverage $|\eta|<3.2$ (precision meas. $|\eta|<2.5$)
- total thickness: 24 $X_0$ (3 longitudinal layers)
- different granularity in each layer
A 3 level trigger system:

- **Level 1 (L1):**
  - hardware based
  - only muon and calo information
  - reduced granularity

- **Level 2 (L2):**
  - software based
  - all detectors available (RoI approach)
  - dedicated algorithms and calibration

- **Event Filter (EF):**
  - software based
  - full event information available
  - ‘quasi’ offline algorithms

- **Region of Interest (RoI) concept:**
  - only detector information contained in an angular region around directions triggered by L1 (em objects, jets and muons) are processed by next level (increase speed and reduce network load)
**Only calorimetric information available**

- **Granularity** *(Trigger Tower)*: summing up EM cells energy in region $\Delta \eta \Delta \phi = 0.1 \times 0.1$

- **Sliding window** clustering algorithm (4x4 Trigger Tower)

- $E_T$ calculation with ADC conversions:
  - at output *1 count ~ 1 GeV*
  - linear up to ~ 250 GeV

- $E_T$ threshold applied to highest energy 1x2 or 2x1 T.T. combination inside the window

**Naming convention example:**

```
L1_(2)EM3
```

- $E_T$ threshold (on ADC counts) >3 counts $\rightarrow E_T \geq \sim 4$ GeV
- minimal number of objects passing the selection
- EM object: no distinction between electrons and photons

Dao Valerio

**XIV CALOR Conference  IHEP, Beijing**
**Egamma trigger: HLT**

- HLT selection consists of a *series of steps*:
  - performed in parallel on each RoI at L2
  - aim for the *earliest possible rejection*

  - **Feature EXtraction (“FEX”) algorithm** builds the object (track, cluster, ....)

  - ‘HYPothesis’ algorithm applies identification cuts and (eventually) rejects the event

  - **clustering**: hottest cell approach for cluster finding, fixed cluster size
  - **tracking**: 3 fast pattern recognition algorithms (2 based on silicon hits, one on TRT standalone)

  - **clustering**: sliding window for cluster finding, variable cluster size (*barrel/endcap*)
  - **tracking**: optimized tuning of offline algorithms
  - “as close to offline as trigger timing constraints allow”: no *conversion finding, no brems recovery* ....

**Example:** *(2)e5_loose

**Electron**

- $E_T \geq 5$ GeV

**Photon**

- Set of selection criteria
Electron and photon identification exploits the difference in calo shower shapes between signal and background. 

HLT and offline use the same variables for signal identification.

Simple cut based identification criteria on ‘well understood’ variables:

- calorimeter: lateral shapes in 2nd EM layer, leakage in hadronic calorimeter, 1st EM layer variables (high granularity in η direction)
- tracking (electron specific): track \( p_T \), number of hits in silicon detectors, calo cluster-track angular match

Trigger cut values comes from a compromise between:

- having sufficient rate reduction
- being as efficient as possible with respect to events selected by offline

A good trigger-offline resolution is an important requirement.

more on this in talk from D. Banfi

Example from MC photons

\[ R_\eta \]
**2009: collisions at 900 GeV c.m.e.**
- peak luminosity $\sim 7 \times 10^{26}$ cm$^{-2}$s$^{-1}$
- $\sim 500$ M collision event with stable beam

**2010: collisions at 7 TeV c.m.e.**
- first collisions on 30-03-2010
- peak luminosity $\sim 2 \times 10^{28}$ cm$^{-2}$s$^{-1}$
- so far $\sim 1$ nb$^{-1}$ of stable beam data

- **Electron/photon trigger operational mode:**
  - $L1$: active and used for event streaming (relying on Minimum Bias triggers to check its performance)
  - $HLT$: running online in pass-through mode (producing objects and decisions but NOT rejecting events) during stable beam operation

- **Assessing trigger performance through:**
  - comparison of trigger quantities with Monte Carlo at each level
  - evaluation of trigger resolution w.r.t. offline identification variables

- **No identification cuts applied on offline reference $\Rightarrow$ all distributions dominated by fakes**
◆ Reliable operation of L1 calorimeter system

◆ Rate is stable within 10 %

◆ Timing calibration improved after few runs (see talk from J.T. Childers)

◆ For energy resolution studies see talk from H. Zhang

◆ L1 efficiency w.r.t offline:
  ◆ excluded barrel/endcap transition region
  ◆ general agreement in shape with MC but turn-on in data starts slightly earlier
  ◆ reaching plateau within 1-2 GeV above L1 threshold
\[ R_\eta = \frac{\text{energy deposition in } 3 \times 7 \text{ cells}}{\text{energy deposition in } 7 \times 7 \text{ calo cells}} \]
(lateral shower shape variable using 2\textsuperscript{nd} sampling layer information)

- L2 clusters matched to offline electrons
- Slight shift with respect to MC also observed at L2 and offline (*); related to description of crosstalk between cells in second layer
- Good agreement between offline and HLT: EF resolution is \( \sim \) factor 2 smaller than L2

(*) plot from 900 GeV data in D. Banfi’s talk
◆ A few more examples ....

◆ General agreement with MC also for shapes variables in other layers of the EM calorimeter

◆ No visible bias and reasonable trigger-offline resolution

◆ “the faster and simpler L2 algorithms perform adequately with respect to the more complex EF/offline reconstruction ones”
Next steps in commissioning

- egamma trigger bandwidth is \( \sim 30\text{-}50 \text{ Hz} \)
  
  \[ L1_{\text{EM2}} \text{ rate will reach this limit starting from a luminosity of few } 10^{28} \text{ cm}^{-2}\text{s}^{-1} \]

- deploying HLT in rejection mode needs many validation steps:
  - check the correct functionality on the trigger in offline reprocessing ✔️
  - deploy the HLT online without active rejection ✔️
  - detailed verification of HLT results w.r.t. offline
  - measure performance on signal enriched sample
    (Tag&Probe on \( Z \rightarrow ee \) and \( J/\psi \rightarrow ee \), MET trigger for \( W \rightarrow e\nu \)) in progress
  - at higher luminosity need to prescale(*) the lowest \( E_T \) chains.
    (*) randomly accepting 1 in N triggers

- …. looking just ahead:
  
  \[ \text{the electron/photon trigger menu for } 10^{31} \text{ cm}^{-2}\text{s}^{-1} \] (MC rate estimates)

<table>
<thead>
<tr>
<th>primary trigger</th>
<th>rate (Hz)</th>
<th>motivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2e5_medium</td>
<td>1.3</td>
<td>( J/\psi \rightarrow ee, \ Y \rightarrow ee, \ Drell-Yan )</td>
</tr>
<tr>
<td>e10_medium</td>
<td>18.4</td>
<td>( e^\pm ) from ( b,c ) decays, ( E/p ) studies</td>
</tr>
<tr>
<td>e20_loose</td>
<td>2.9</td>
<td>( Z \rightarrow ee, \ W \rightarrow e\nu, \ high \ p_T ) phys</td>
</tr>
<tr>
<td>g20_loose</td>
<td>10.5</td>
<td>( \text{direct photon, } \gamma\text{-jet calibration} )</td>
</tr>
</tbody>
</table>

\[ \text{Primary trigger: lowest unprescaled chain for a given set of identification cuts} \]
\[ + \text{ many other signatures for monitoring, calibration, performance measurement} \]
The analysis of the first 7 TeV LHC collisions represented a further step in the commissioning of the electron and photon trigger in ATLAS:

- *L1 calo trigger* system shows good performance and stability
- *HLT electron and photon chains* (currently in pass-through mode) are working properly online

Comparison of trigger quantities with offline references shows good agreement

The distributions measured online are well reproduced by MonteCarlo simulation

- we increased our confidence in the correctness of the MC-based trigger studies and trigger optimizations (rates, efficiencies, etc..)

*Electron and photon triggers will play a major role in physics analysis with increasing LHC instantaneous luminosity*
first W candidate ‘seen’ by offline ...

... same W candidate ‘seen’ also by trigger

L2 clusters and tracks

L1 energy deposition
backup
** events passing L1_EM3

** L2 EM clusters $E_T$ spectrum:
- well reproduced by MC simulation
- the same holds for angular variables distributions at both levels
- spectrum is harder than at 900 GeV

** EF-offline energy resolution:
- resolution at few % level
- in the initial running phase EF relies on real time energy calculation in DSP while offline recompute the energy with a more precise algorithm since timing calibration is not yet optimal.
- For startup condition mainly relying on silicon hits based algorithms (both for L2 and EF).
- *Offline benchmark* (#Pixel hits>0 and #SCT hits>5)
- L2 plateau (\( p_T > 2 \text{GeV} \)) losses due located at high \(|\eta|\) region.
- EF plateau efficiency \( \sim 100\% \)

**Trigger resolution on offline track parameters:**
- *dominated by low \( P_T \) tracks*
- \( d0 \) resolution: EF \( \sim 25 \mu \text{m} \), L2 \( \sim 90 \mu \text{m} \)
- \( 1/p_T \) resolution: EF \( \sim 3.5\% \), L2 \( \sim 23\% \)
- good agreement with MC
- L2 approaches EF values at higher \( p_T \)
Electron identification variable: $\Delta \eta$ between cluster and extrapolated track

- L2 distribution well described by MC (same observed at EF)
- Good EF resolution w.r.t. offline
- Larger L2 resolution due to the less sophisticated tracking algorithms