Determining the ATLAS electron trigger efficiency in BSM channels from Data

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Overview

The LHC and ATLAS

The ATLAS trigger system
  • Overview
  • Electron trigger

Trigger Efficiency
  • Measurement from data

Monte Carlo studies of efficiency

Application of data driven methods
  • SUSY
  • Dielectron resonances at high mass

Conclusions
## ATLAS and the Large Hadron Collider

<table>
<thead>
<tr>
<th>LHC</th>
<th>Design Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CoM energy</strong></td>
<td>14 TeV</td>
</tr>
<tr>
<td><strong>Luminosity (cm(^{-2})s(^{-1}))</strong></td>
<td>Low: 2x10(^{33})</td>
</tr>
<tr>
<td></td>
<td>High: 10(^{34})</td>
</tr>
<tr>
<td><strong>Bunch crossing</strong></td>
<td>25 ns</td>
</tr>
<tr>
<td><strong>Overlaid events</strong></td>
<td>23 @ 10(^{34})cm(^{-2})s(^{-1})</td>
</tr>
<tr>
<td><strong>Stored energy</strong></td>
<td>362 MJ/beam</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ATLAS</th>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>Magnetic field</strong></td>
<td>2T solenoid + toroid</td>
</tr>
<tr>
<td></td>
<td>(0.5 T barrel 1 T endcap)</td>
</tr>
<tr>
<td><strong>Tracker</strong></td>
<td>Si pixels, strips + TRT</td>
</tr>
<tr>
<td></td>
<td>(\sigma_{p_T}/p_T \approx 5 \times 10^{-4} p_T + 0.01)</td>
</tr>
<tr>
<td><strong>EM calorimeter</strong></td>
<td>Pb + Lar</td>
</tr>
<tr>
<td></td>
<td>(\sigma_{E}/E \approx 10%/\sqrt{E} + 0.007)</td>
</tr>
<tr>
<td><strong>Hadronic calorimeter</strong></td>
<td>Fe + scint, Cu + Lar (10(\lambda))</td>
</tr>
<tr>
<td></td>
<td>(\sigma_{E}/E \approx 50%/\sqrt{E} + 0.03) GeV</td>
</tr>
<tr>
<td><strong>Muon System</strong></td>
<td>(\sigma_{p_T}/p_T \approx 2% @ 50\text{GeV}) to 10 % @ 1 TeV (ID+MS)</td>
</tr>
<tr>
<td><strong>Trigger</strong></td>
<td>Hardware Level 1 + Region of Interest-based HLT</td>
</tr>
</tbody>
</table>
Maximum raw **event rate** seen in ATLAS at design luminosity ~ **40 MHz** (from the 25 ns bunch crossing).

Trigger system needs to reduce this to the **100-200Hz rate** able to be written to tape.

Rejection factor to be achieved at maximum luminosity ~ **$10^7$**.

Interesting cross sections often at least ~$10^6$ times smaller than total cross section.

Trigger must remain efficient for rare signal processes.

In one second at design luminosity:
- 40,000,000 bunch crossings
- ~1,000 W events
- ~500 Z events
- ~10 top events
- ~9 SUSY events?
- ~0.1 Higgs events?
- 200 events written out

**Must ensure the correct 200 events are recorded.**
Seeded and stepwise three tier trigger system.

- Custom hardware Level 1 (L1).
  - 40 MHz → 100 kHz.
- Software High Level Trigger (L2+EF).
  - L2: 100 kHz → 1 kHz.
  - EF: 1 kHz → 100-200 Hz.

Region of Interest mechanism means only 1→4% of detector information is needed.

ATLAS trigger
ATLAS electron trigger

L1 electron trigger applies simple **hardware** cuts in electromagnetic and hadronic calorimeters.

Uses analog sum of **calorimeter** towers with coarse granularity. $\Delta \eta \times \Delta \phi = 0.1 \times 0.1$

L2 seeded by L1, fast reconstruction algorithms within RoIs. **Full detector granularity including tracking.**

EF seeded by L2. Offline reconstruction algorithms, **refined calibration and alignments.**

Jet backgrounds are rejected by transverse energy thresholds, isolation cuts and electron hypothesis algorithms

Trigger naming conventions:

- **EF_e25i_tight**
- EF – Event Filter stage
- e – electron hypothesis algorithm
- 25 – transverse energy threshold in GeV
- i – isolation required at L1
- tight – 'tight' identification cuts applied at EF
Title: Trigger efficiency measurement from data

The Tag and Probe method.

Sample defined by: $Z \rightarrow ee$ reconstructed (from offline $e^+e^-$) + 1 $e$ trigger signature satisfied (tag).

Trigger efficiency determined by counting in how many cases the second $e^\pm$ satisfies the trigger requirements (probe).

Number of events $= \sigma \cdot \int L dt \cdot \epsilon$

To know the cross section of any process observed at the LHC we must have a good understanding of efficiency.

Efficiency is a convolution of reconstruction efficiency and trigger efficiency.

ATLAS work in progress
Well motivated extension to SM providing answers to divergent loop corrections to Higgs boson mass, cold dark matter and force unification.

Typical SUSY phenomenology at ATLAS is dominated by pair production of sparticles and cascade decays to the Lightest Supersymmetric Particle (often the $\tilde{\chi}_1^0$).

To evaluate ATLAS performance two benchmark points in mSUGRA parameter space are studied here that are relevant for early physics at ATLAS.

- SU3 – low mass SUSY (in 'bulk region').
- SU4 – low mass SUSY (at the edge of Tevatron limits).

<table>
<thead>
<tr>
<th>mSUGRA parameters of considered points.</th>
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<tbody>
<tr>
<td>SU3</td>
</tr>
<tr>
<td>$m_0$</td>
</tr>
<tr>
<td>$M_{1/2}$</td>
</tr>
<tr>
<td>$A_0$</td>
</tr>
<tr>
<td>$\tan \beta$</td>
</tr>
<tr>
<td>$\text{sign}(\mu)$</td>
</tr>
<tr>
<td>$\sigma_{\text{total}}$ [pb]</td>
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Squark cascade decay to SM particles and LSP Neutralino.

SUSY phenomenology is electron and jet rich.
Main factors that can effect trigger efficiency:

1. Electron kinematics.
   Trigger efficiency differs over the $\eta$ spectrum (for example). If different samples have different $\eta$ distributions then trigger efficiency integrated over this will differ.

   These fake electrons are not electrons so should not be passing trigger cuts.

3. Event topologies, i.e nearby Jets etc.
   If an event is more jets rich, these will interfere with the isolation and identification of electrons.
SUSY and ttbar are much 'busier' environments than $Z \rightarrow ee$.

Proximity of energetic objects leads to a decrease in trigger efficiency.

Efficiency as a function of distance to nearest 'truth jet'.

ATLAS work in progress
An identical electron should have the same efficiency regardless of its physics origin.

For trigger efficiencies it is sufficient to describe 'identical' electrons as having the same $E_T$, $\eta$, and surrounding energy.

$Z \rightarrow ee$ efficiency is computed in 3-D ($E_T$ vs $\eta$ vs etcone40) then applied to other samples and compared to MC.

Agreement to within 1%!

$Z \rightarrow ee$ efficiencies are representative of efficiency in a SUSY/top environment if determined in 3-D.
High mass dielectron resonances are predicted by several extensions to the standard model.

High Mass $\rightarrow$ very high energetic electrons.
- Unsuitied to isolated triggers as energetic electrons have broad showers which cause them to fail isolation cuts.

$Z\rightarrow ee$ T&P suffers from poor statistics at high energies.

Efficiency shows a flat plateau in $E_T \Rightarrow$ fit plateau efficiency from low mass $Z$ resonance and extrapolate results to high $E_T$.
Conclusions

• Every analysis at ATLAS that utilizes electrons must have an understanding of the electron trigger efficiency.
  • Studied extensively using MC.

• The Tag and Probe method of trigger efficiency determination from data has been validated using MC.

• A 3-D efficiency parameterisation produced using T&P has been shown to well reproduce MC efficiencies in other samples.
  • Therefore validated as a sample independent method of trigger efficiency determination from data.

• Efficiency for highly energetic electrons, such as those produced from Z' resonances, can be determined by extrapolation from T&P results providing energy dependence is flat.

Outlook

• Other samples and those including pile-up can be studied, and methods extended to electrons offline and muon trigger/offline efficiencies.