Top Trigger Strategy in ATLAS

Patrick Ryan

Workshop on Top Physics
Grenoble

18 Oct 2007
Outline

• Top Physics w.r.t. triggering
• The ATLAS Trigger
• ATLAS Trigger Menus
• Top Trigger Studies
  • Level 1 ttbar triggers at $10^{31}$ pb$^{-1}$
  • ttbar triggers at $10^{33}$ pb$^{-1}$
  • Single top lepton triggers
• Summary
ttbar Decays

- **Semi-leptonic**
  - One W decays hadronically and one W decays leptonically
  - 1 lepton + 4 jets in final state

- **Fully leptonic**
  - Both Ws decay leptonically
  - 2 leptons + 2 jets in final state

- **Fully hadronic**
  - Both Ws decay hadronically
  - 0 leptons + 6 jets in final state
• **Leptonic Single Top**
  - **s-channel**: 1 lepton + 2 jets
  - **t-channel**: 1 lepton + 2 jets OR 1 lepton + 3 jets
  - **Wt**: 1 lepton + 3 jets OR 2 leptons + 1 jet

• **Hadronic Single Top**
  - Hadronic W decay or hadronic \(\tau\) decay
  - Difficult to distinguish from backgrounds
  - Not studied yet
Triggering on Top Events

• All aspects of trigger important to top physics
• Electron and muon triggers vital for main top decays
  • High-$p_T$ decay products from $W$ allows for high-$p_T$ lepton triggers
  • High efficiency of electron and muon triggers necessary
  • Most important triggers for early running
    • Related to processes visible at lower luminosities
    • Processes with $W$, $Z$, and top can help calibrate detector
• Multi-jet triggers can enhance acceptance
  • Can be used in combination with electron and muon triggers
  • Important for top physics at higher luminosities
• Missing $E_T$ triggers can enhance acceptance
• $b$-jet trigger not crucial for $ttbar$
  • May be useful to study fully hadronic single top events
ATLAS Trigger

- **Level 1 (2.5 µs)**
  - Custom hardware
  - Maximum 1% deadtime
  - Reduced granularity
  - Uses subset of detectors
  - Finds $p_T$, Missing $E_T$, Total $E_T$

- **Level 2 (30 ms)**
  - Commercial computers
  - Seeded by L1 (region of interest)
  - Full granularity and precision
  - All detector components used

- **Event Filter (1 s)**
  - Commercial processing farm
  - Operates on fully built events
  - Standard ATLAS reconstruction
  - Event size after EF: 1.5 MByte

Bunch Crossing: 40 MHz
Interaction: 1 GHz

After L1: 75 kHz
After L2: 3.5 kHz
After EF: 200 Hz
ATLAS Trigger

- Trigger Item is a combination of triggers at each level
- Event must pass L1, L2, and EF associated with trigger item
- Trigger Threshold
  - $p_T$ of an object for which the trigger is about 90% efficient (in most cases)
    - Actual $p_T$ cut is less than the threshold
    - Example: The $p_T$ cut for L2_mu20 is 17.5 GeV
  - L1 threshold represents actual cut for some triggers
- Isolation requirement
  - Help distinguish leptonic and hadronic signals
  - Available at L2 and EF of leptonic triggers
  - May not be applied to muon triggers in early running
- Example: Trigger Item e25i
  - 1 electron with threshold of 25 GeV
  - Isolation requirement
  - Level 1: L1_EM25    Level 2: L2_e25i    Event Filter: EF_e25i
• A Trigger Menu is a collection of trigger items
• Several Trigger Menu configurations and versions
  • Different versions for different software releases
  • Different configurations for startup \((10^{31})\) and full \((10^{33})\) lumi
  • [https://twiki.cern.ch/twiki/bin/view/Atlas/TriggerMenuVersions](https://twiki.cern.ch/twiki/bin/view/Atlas/TriggerMenuVersions)

• Triggers can be prescaled
  • Necessary when a trigger has a high rate
  • Prescale of \(X\) means \(1/X\) events from trigger item are accepted

• Express Stream
  • Small subset of the physics data (5\% to 15\%)
  • Reconstructed in less than 24 hours
  • Allows for immediate feedback before full reconstruction starts
  • Not for published physics results
<table>
<thead>
<tr>
<th>Trigger Item</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Event Filter</th>
</tr>
</thead>
<tbody>
<tr>
<td>mu20</td>
<td>L1_MU20</td>
<td>L2_mu20i</td>
<td>EF_mu20i</td>
</tr>
<tr>
<td>e25i</td>
<td>L1_EM25</td>
<td>L2_e25i</td>
<td>EF_e25i</td>
</tr>
<tr>
<td>e60</td>
<td>L1_EM60</td>
<td>L2_e60</td>
<td>EF_e60</td>
</tr>
<tr>
<td>jet160</td>
<td>L1_J45</td>
<td>L2_jet160</td>
<td>EF_jet160</td>
</tr>
<tr>
<td>2jet120</td>
<td>L1_2J45</td>
<td>L2_jet120L2jet120</td>
<td>EF_jet120EF_jet120</td>
</tr>
<tr>
<td>3jet65</td>
<td>L1_3J45</td>
<td>L2_jet65L2_jet65L2_jet65</td>
<td>EF_jet65EF_jet65EF_jet65</td>
</tr>
<tr>
<td>4jet50</td>
<td>L1_4J45</td>
<td>L2_jet50L2_jet50L2_jet50L2_jet50</td>
<td>EF_jet50EF_jet50EF_jet50EF_jet50</td>
</tr>
</tbody>
</table>
L1 ttbar triggers at 10^{31} pb^{-1}

Introduction

- **10^{31} Trigger Menu** designed for commissioning
  - Differs from 10^{33} menu in the prescale values
  - Subject to change

- **Reasons for studying 10^{31} Menu** are to investigate
  - Efficiency
  - Redundancy
  - Overlaps

- **Single Object Triggers at Level 1**
  - Study items which are not prescaled
  - Muon, EM, Jet, Tau, Missing $E_T$ and Total Energy triggers investigated

- **Combined Object Triggers at Level 1**
  - Jet items + Missing $E_T$ and Muon items
  - Tau item + Missing $E_T$ item
  - Combine Jet triggers + other Jet triggers
L1 ttbar triggers at $10^{31}$ pb$^{-1}$

Efficiencies

- **Highest efficiency of combined triggers from Jets + Missing $E_T$**
  - L1_2J42_XE30 (60%) and L1_J70_XE30 (54%) should be used in express stream

4000 Events with no offline selection

OR: Only items from trigger menu

C: items used in combined triggers

J. Thomas

L1_3J30_4J23 and L1_5J23 may be substituted for L1_4J23 if rate is too high

Patrick Ryan, MSU  Top Trigger Strategy in ATLAS  Workshop on Top Physics, 18 Oct 2007 - 11
Top Trigger Strategy in ATLAS

Workshop on Top Physics, 18 Oct 2007 - 12

Patrick Ryan, MSU

L1 ttbar triggers at $10^{31}$ pb$^{-1}$

**Trigger Overlaps**

<table>
<thead>
<tr>
<th>Trigger Combination</th>
<th>Percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1_TAU25_XE40</td>
<td>93, 100, 90, 100, 100, 100, 92, 100, 86, 100, 100, 100</td>
</tr>
<tr>
<td>L1_J10_MU6</td>
<td>60, 66, 55, 69, 100, 100, 51, 58, 48, 100, 100, 64</td>
</tr>
<tr>
<td>L1_J42_XE30_MU11</td>
<td>42, 55, 42, 47, 100, 100, 40, 49, 41, 100, 100, 54</td>
</tr>
<tr>
<td>L1_J70_XE30</td>
<td>100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100</td>
</tr>
<tr>
<td>L1_2J42_XE30</td>
<td>100, 98, 92, 100, 100, 96, 100, 87, 100, 100, 100</td>
</tr>
<tr>
<td>L1_EM100 passHLT</td>
<td>48, 40, 63, 44, 34, 38, 100, 36, 33, 33, 35, 35</td>
</tr>
<tr>
<td>L1_2MU6</td>
<td>12, 13, 12, 14, 46, 100, 11, 12, 10, 32, 40, 13</td>
</tr>
<tr>
<td>L1_MU20</td>
<td>44, 51, 41, 51, 100, 100, 38, 44, 37, 100, 100, 49</td>
</tr>
<tr>
<td>L1_4J23</td>
<td>100, 71, 79, 100, 87, 92, 84, 84, 64, 73, 92, 78</td>
</tr>
<tr>
<td>L1_J100</td>
<td>82, 70, 100, 73, 66, 69, 100, 62, 59, 61, 68, 61</td>
</tr>
<tr>
<td>L1_XE70</td>
<td>53, 100, 59, 55, 69, 66, 61, 56, 50, 67, 68, 66</td>
</tr>
<tr>
<td>L1_TE380</td>
<td>100, 77, 100, 100, 86, 91, 100, 87, 72, 75, 90, 78</td>
</tr>
</tbody>
</table>

- Low percentage: useful combination (if one item has a high acceptance)
  - Most useful combinations include lepton triggers
- High percentage: redundancy

Semilep + Dilep ttbar

4000 Events with no offline selection

% of events triggered by x-axis items also triggered by y-axis items
Lepton triggers have low efficiencies (mu20i: 27% and e25i: 22%)

Jet triggers have low efficiencies
  - Between 9 and 14% depending the number and \( p_T \) of jets
mu20i has high efficiency (72%)
Jet triggers have low efficiencies (between 5% and 12%)
OR of all triggers has 93% efficiency
  - Jet, Missing E_T, and tau triggers can help raise efficiency
**Top Trigger Strategy in ATLAS**

**Workshop on Top Physics, 18 Oct 2007 - 15**

Patrick Ryan, MSU

---

**Semilep + Dilep ttbar**

- **Event Selection**
  - 1 electron
    - $p_T > 20$ GeV
    - $|\eta| < 2.5$
  - 4 Jets with
    - $E_T > 20$ GeV
    - Jet $|\eta| < 2.5$
  - Missing $E_T > 20$ GeV
  - 1 or more b jets
  - No Electron in gap

- **Trigger Item**
  - 1 electron
  - 4 Jets
  - Missing $E_T$
  - 1 or more b jets
  - No Electron in gap

- **Efficiency**
  - e25i has high eff (73%) while e60 has reasonably low eff (31%)
  - Jet triggers have low efficiencies (between 6% and 14%)
  - OR of all triggers has 91% efficiency
    - Jet, Missing $E_T$, and tau triggers can help raise efficiency
• **Samples studied**
  • Wt channel
  • s-channel
  • t-channel
  • ttbar (background for single top)

• **Electron and Muon Triggers studied**

• **Single Top Event Selection**
  • **Lepton**
    • At least 1 isolated μ with $p_T > 20$ GeV OR 1 e with $p_T > 25$ GeV
    • $-2.5 < \eta < 2.5$
    • No secondary lepton
  • **Jets**
    • $2 \leq N_{\text{jet}} \leq 4$
    • $p_T^{\text{Jet}1} > 30$ GeV, $p_T^{\text{Jet}2} > 30$ GeV, $p_T^{\text{Jet}3} > 15$ GeV, $p_T^{\text{Jet}4} > 15$ GeV
    • At least 1 b-tagged jet with $p_T > 30$ GeV and $|\eta| < 2.5$
  • $E_T^{\text{Miss}} > 20$ GeV
  • No electrons in gap regions (-1.65 < $\eta$ < -1.35 and 1.35 < $\eta$ < 1.65)
• **Truth Efficiency**
  - Truth MC sample
  - No event selection
  - mu6 to mu20: 20% decrease
  - ttbar (blue) slightly higher

• **Reconstructed Efficiency**
  - Reconstructed MC sample
  - Single Top event selection
  - mu6 to mu20: 10% decrease
  - All channels similar
Top Trigger Strategy in ATLAS
Workshop on Top Physics, 18 Oct 2007

Patrick Ryan, MSU

• Reconstructed MC events
• mu6 Turn-on
  • Turn-on behavior below 10 GeV
  • Wt channel has higher efficiency
• mu20 Turn-on
  • Between 10 and 25 GeV
  • Channels similar at low $p_T$
  • Wt higher at high $p_T$

Use mu20 in single top selection
Single Top Triggers
Electron Efficiency

Electron Trigger Efficiency: Full Trigger

- Truth Efficiency
  - Truth MC sample
  - No event selection
  - e25i to e60: 15% decrease
  - All channels similar

- Reconstructed Efficiency
  - Reconstructed MC sample
  - Single Top event selection
  - e25i to e60: 60% decrease
  - Channels differ at e60
    - t and s-channel: 22% eff
    - Wt and ttbar 40% eff

e25i greater than 90% efficient

Patrick Ryan, MSU
Top Trigger Strategy in ATLAS
Workshop on Top Physics, 18 Oct 2007 - 19
Single Top Triggers
Electron Turn-on Curve

- **Reconstructed MC events**
- **e25i Turn-on**
  - Between 10 and 25 GeV
  - Channels similar at low $p_T$
  - Channels differ at high $p_T$
- **e60 Turn-on**
  - Between 10 and 60 GeV
  - Channels differ at low $p_T$
    - Wt (black) & ttbar (purple) differ from s-channel (red) & t-channel (blue)
- Curves cross at 60 GeV
  - e60 has no isolation cut
- **e25i OR e60**
  - About 3% efficiency gain
  - Includes “tails” of top

Use e25i OR e60 in single top selection
Summary

- Lepton triggers most critical for top selection
  - Muon: mu20i
  - Electron: e25i and e60

- Jet and $E_T^{\text{Miss}}$ triggers improve acceptance
  - Use in combination with lepton triggers

- $t\bar{t}$ triggers
  - mu20i: 72% efficiency
  - e25i: 73% efficiency

- Single Top triggers
  - mu20i: 80% efficiency
  - e25i OR e60: 95% efficiency