

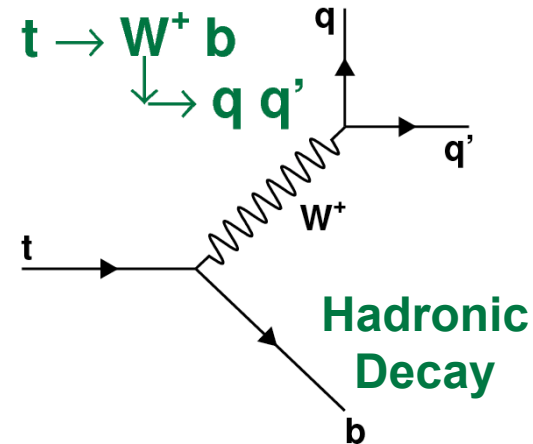
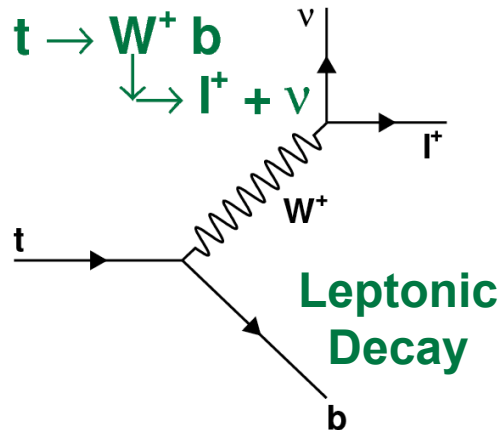
# Top Trigger Strategy in ATLAS

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**Workshop on Top Physics  
Grenoble**

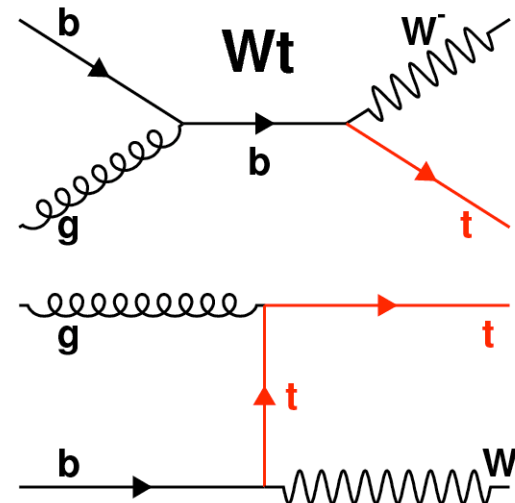
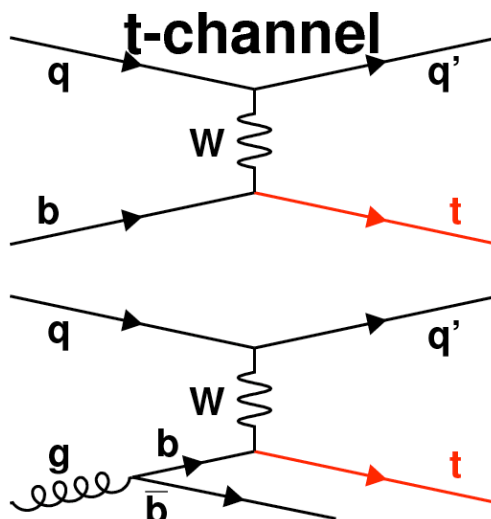
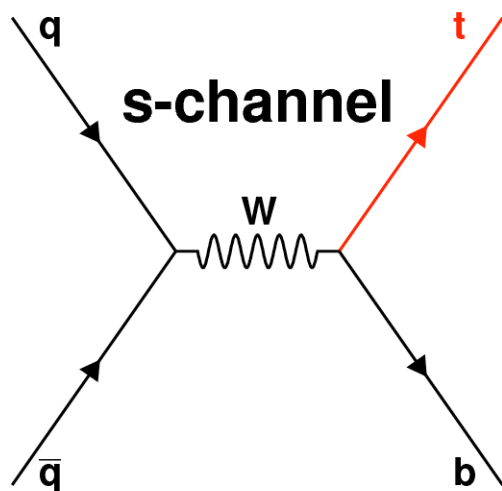
**18 Oct 2007**

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



- **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

# Single Top Decay



- **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

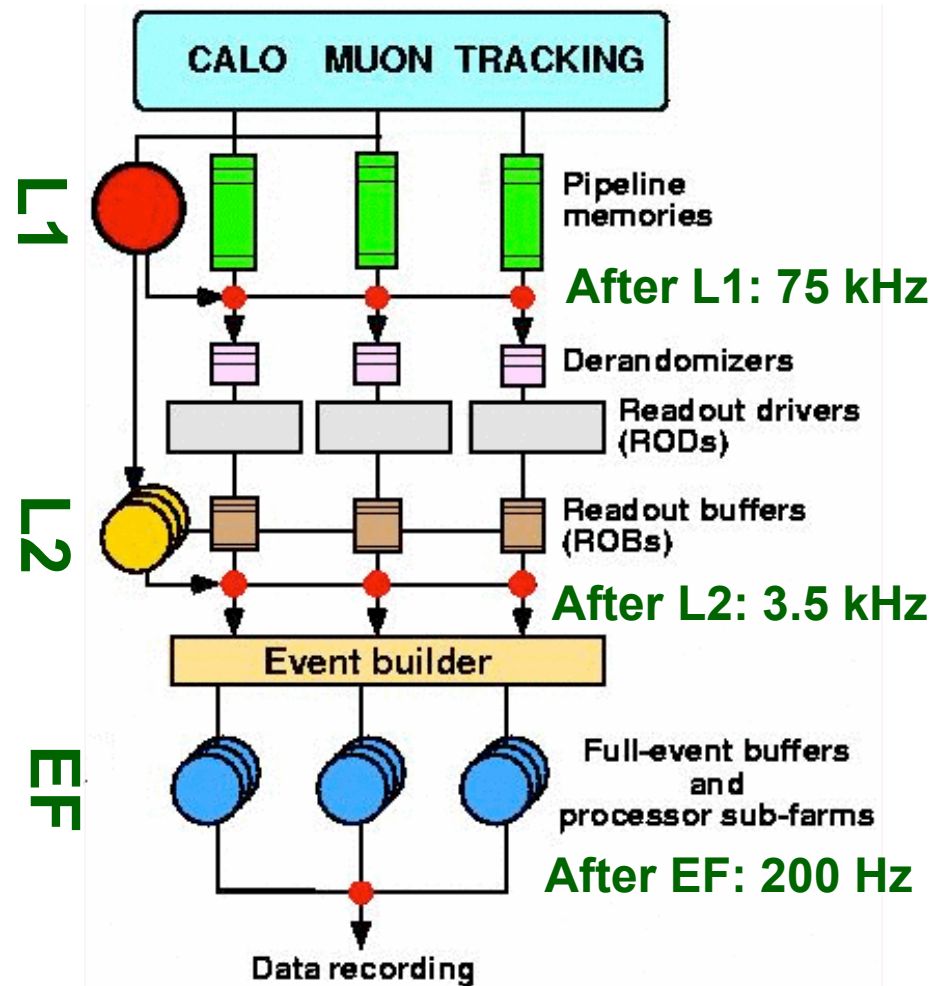
- **Hadronic Single Top**

- Hadronic W decay or hadronic  $\tau$  decay
- Difficult to distinguish from backgrounds
- Not studied yet

- **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  $t\bar{t}$** 
  - May be useful to study fully hadronic single top events

- **Level 1 (2.5  $\mu$ s)**
  - 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



- **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>
- **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





# Trigger Items Important to Top Physics

# 5

Trigger Item	Level 1	Level 2	Event Filter
<b>mu20</b>	<b>L1_MU20</b>	<b>L2_mu20i</b>	<b>EF_mu20i</b>
<b>e25i</b>	<b>L1_EM25</b>	<b>L2_e25i</b>	<b>EF_e25i</b>
<b>e60</b>	<b>L1_EM60</b>	<b>L2_e60</b>	<b>EF_e60</b>
<b>jet160</b>	<b>L1_J45</b>	<b>L2_jet160</b>	<b>EF_jet160</b>
<b>2jet120</b>	<b>L1_2J45</b>	<b>L2_jet120L2jet120</b>	<b>EF_jet120EF_jet120</b>
<b>3jet65</b>	<b>L1_3J45</b>	<b>L2_jet65L2_jet65L2_jet65</b>	<b>EF_jet65EF_jet65EF_jet65</b>
<b>4jet50</b>	<b>L1_4J45</b>	<b>L2_jet50L2_jet50L2_jet50L2_jet50</b>	<b>EF_jet50EF_jet50EF_jet50EF_jet50</b>

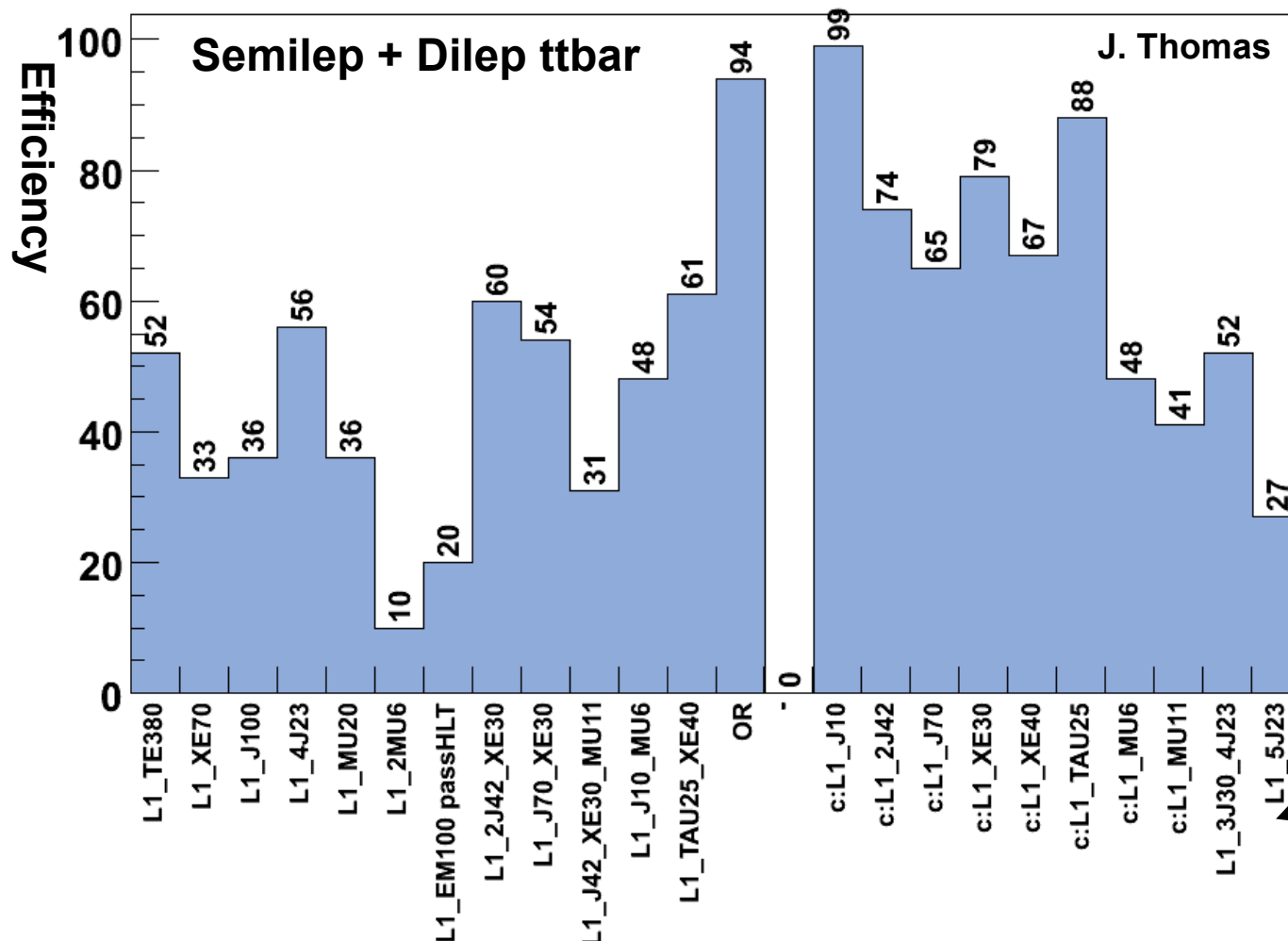


# L1 ttbar triggers at $10^{31}$ pb $^{-1}$ Introduction

- **$10^{31}$  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<sup>-1</sup>

## Efficiencies



4000 Events with no offline selection

OR: Only items from trigger menu

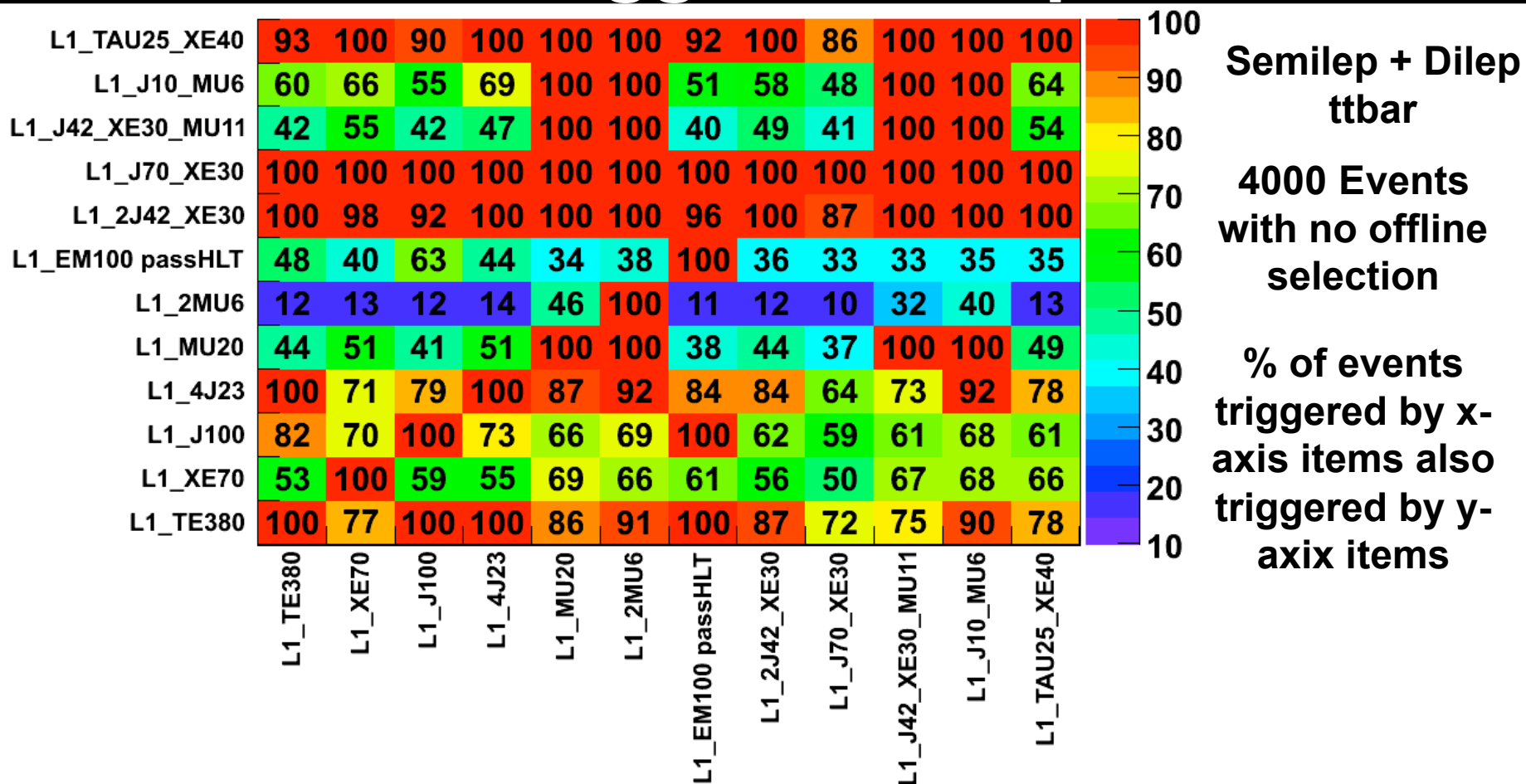
C: items used in combined triggers

L1\_3J30\_4J23 and L1\_5J23 may be substituted for L1\_4J23 if rate is too high

- 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

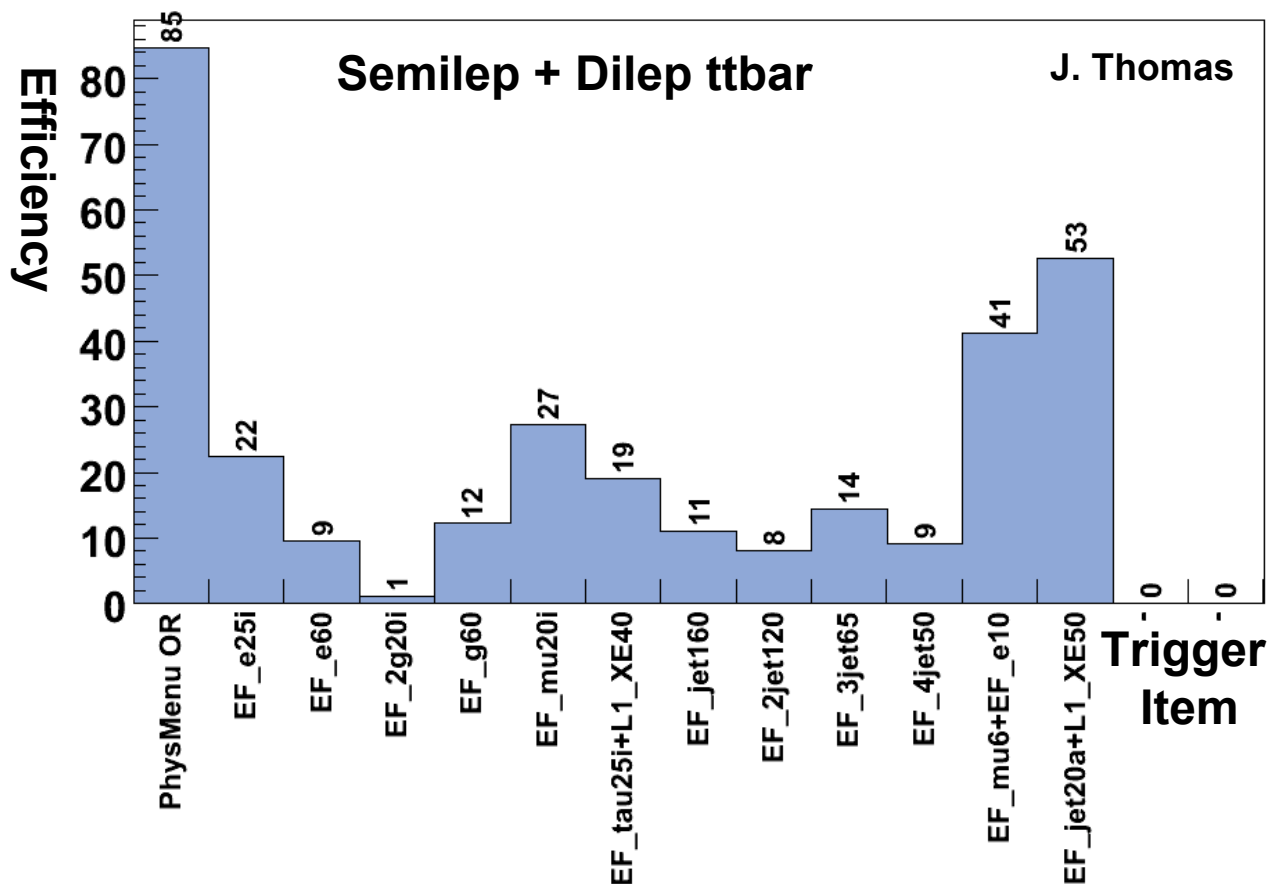
# L1 ttbar triggers at $10^{31}$ pb<sup>-1</sup>

## Trigger Overlaps



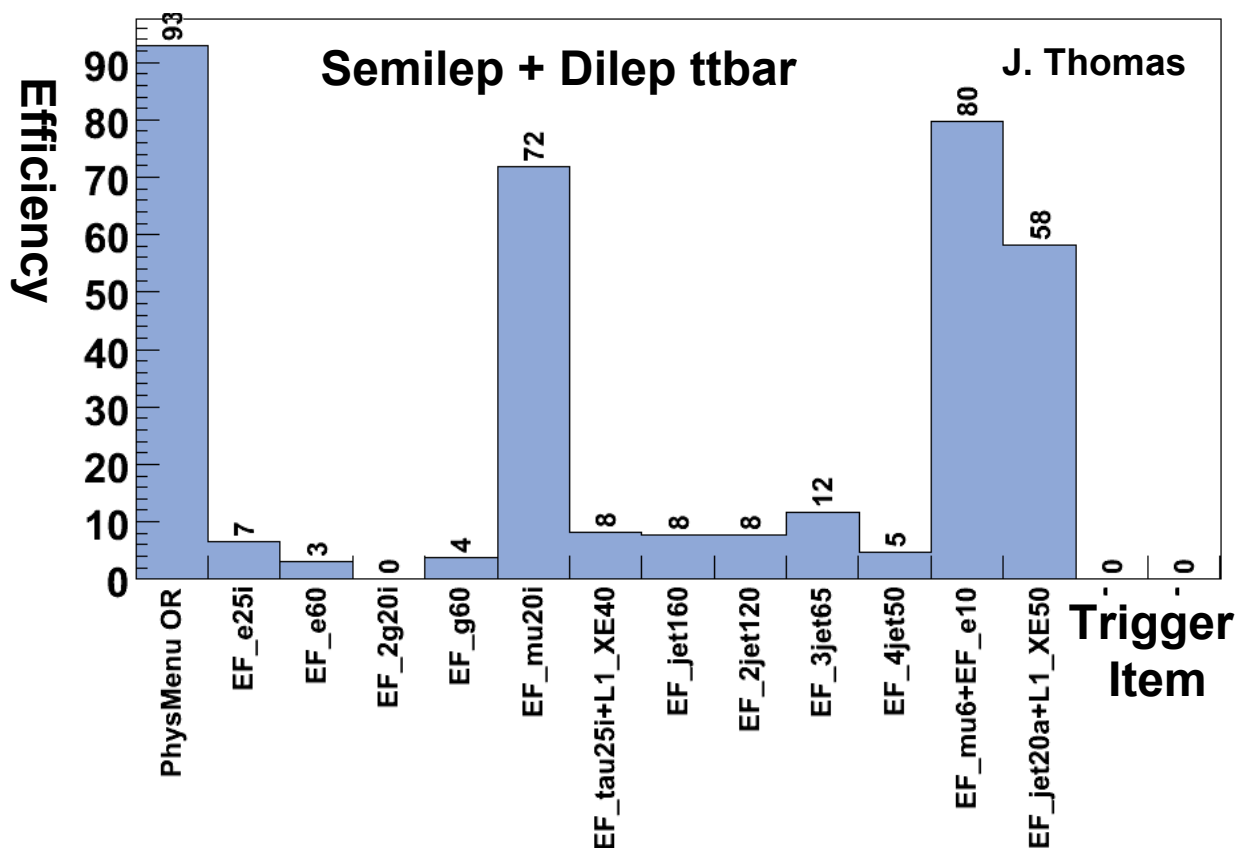
- **Low percentage: useful combination (if one item has a high acceptance)**
  - **Most useful combinations include lepton triggers**
- **High percentage: redundancy**

# ttbar triggers at $10^{33} \text{ pb}^{-1}$ No Event Selection



No Event Selection

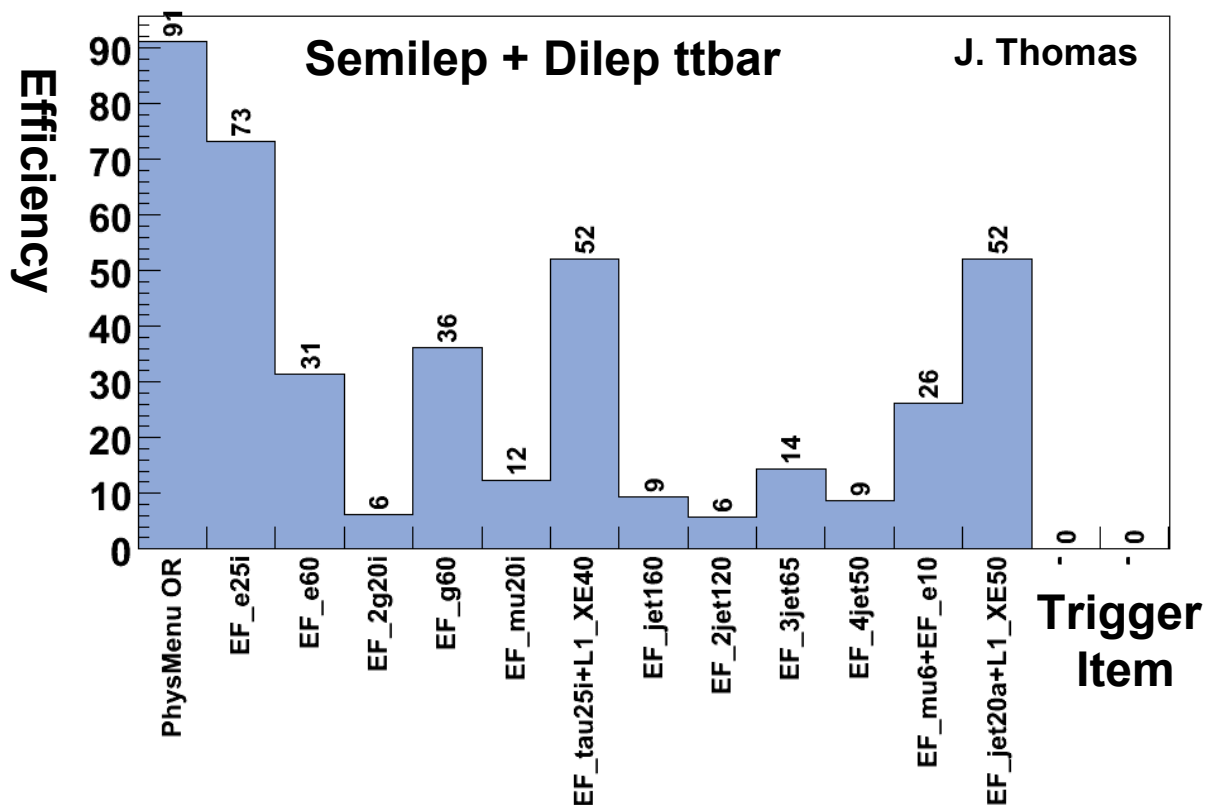
- Lepton triggers have low efficiencies (mu20i: 27% and e25i: 22%)
- Jet triggers have low efficiencies
  - Between 9 and 14% depending the number and  $p_T$  of jets



## Event Selection

- 1 isolated muon
  - $p_T > 20 \text{ GeV}$
  - $|\eta| < 2.5$
- 4 Jets with
  - $E_T > 20 \text{ GeV}$
  - Jet  $|\eta| < 2.5$
- Missing  $E_T > 20 \text{ GeV}$
- 1 or more b jets
- No Electron in gap

- 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



## Event Selection

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

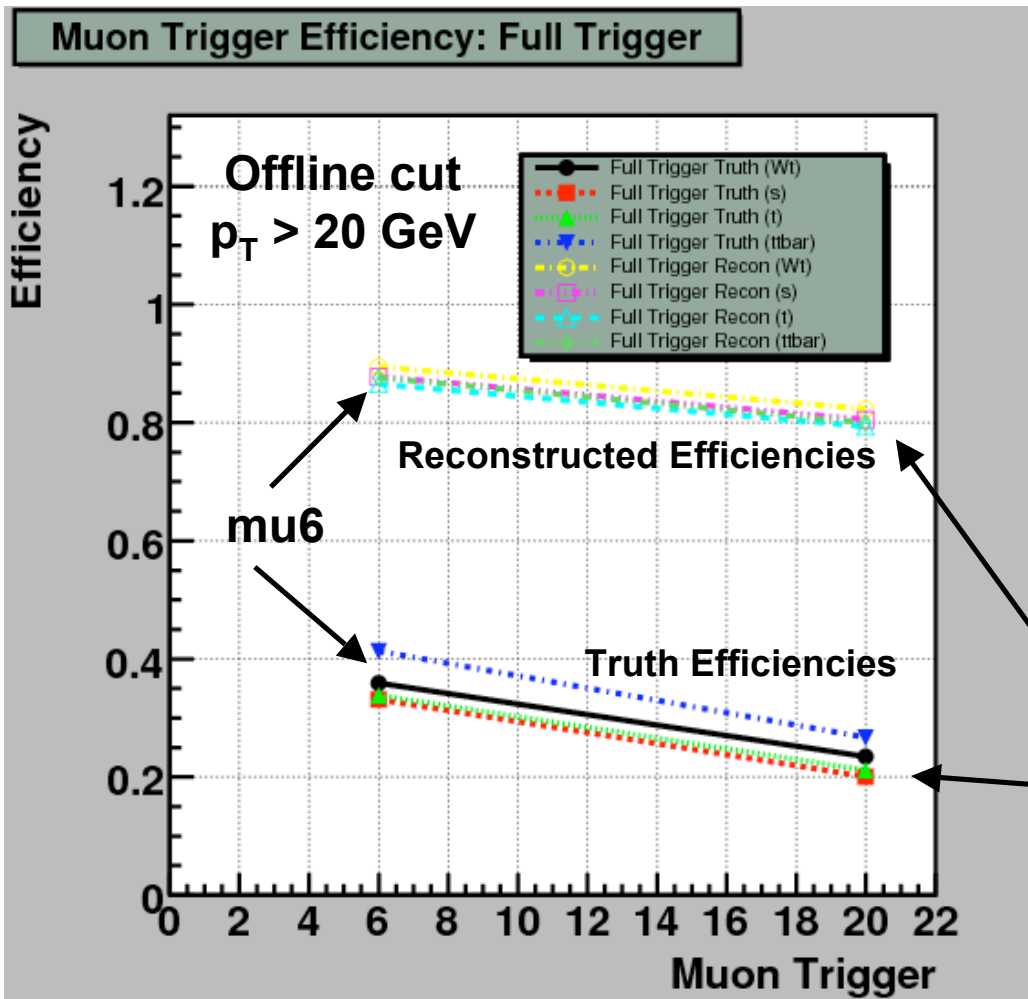
- e25i has high eff (73%) while e60 has reasonably low eff (31%)
- Jet triggers have low efficiencies (between 6% and 14%)
- OR of all triggers has 91% efficiency
  - Jet, Missing  $E_T$ , and tau triggers can help raise efficiency



# Single Top Lepton Triggers Introduction

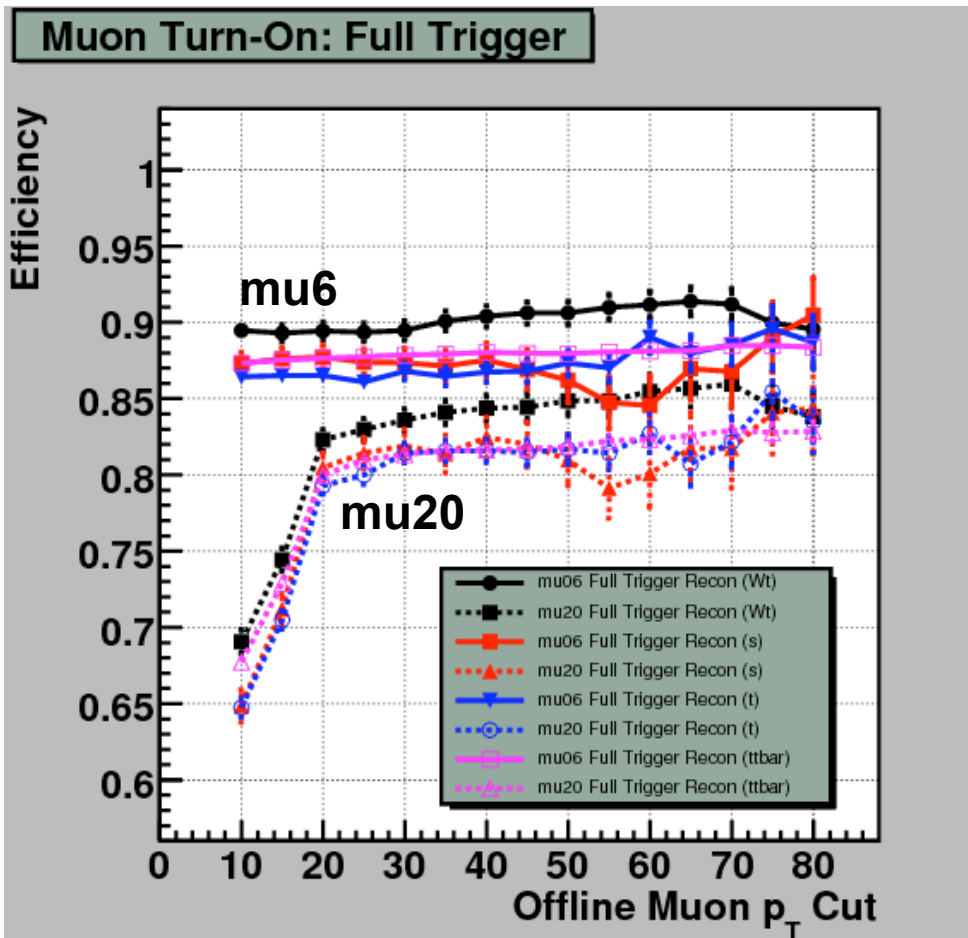
- **Samples studied**
  - **Wt channel**
  - **s-channel**
  - **t-channel**
  - **ttbar (background for single top)**
- **Electron and Muon Triggers studied**
- **Single Top Event Selection**
  - **Lepton**
    - At least 1 isolated  $\mu$  with  $p_T > 20$  GeV OR 1 e with  $p_T > 25$  GeV
    - $-2.5 < \eta < 2.5$
    - 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

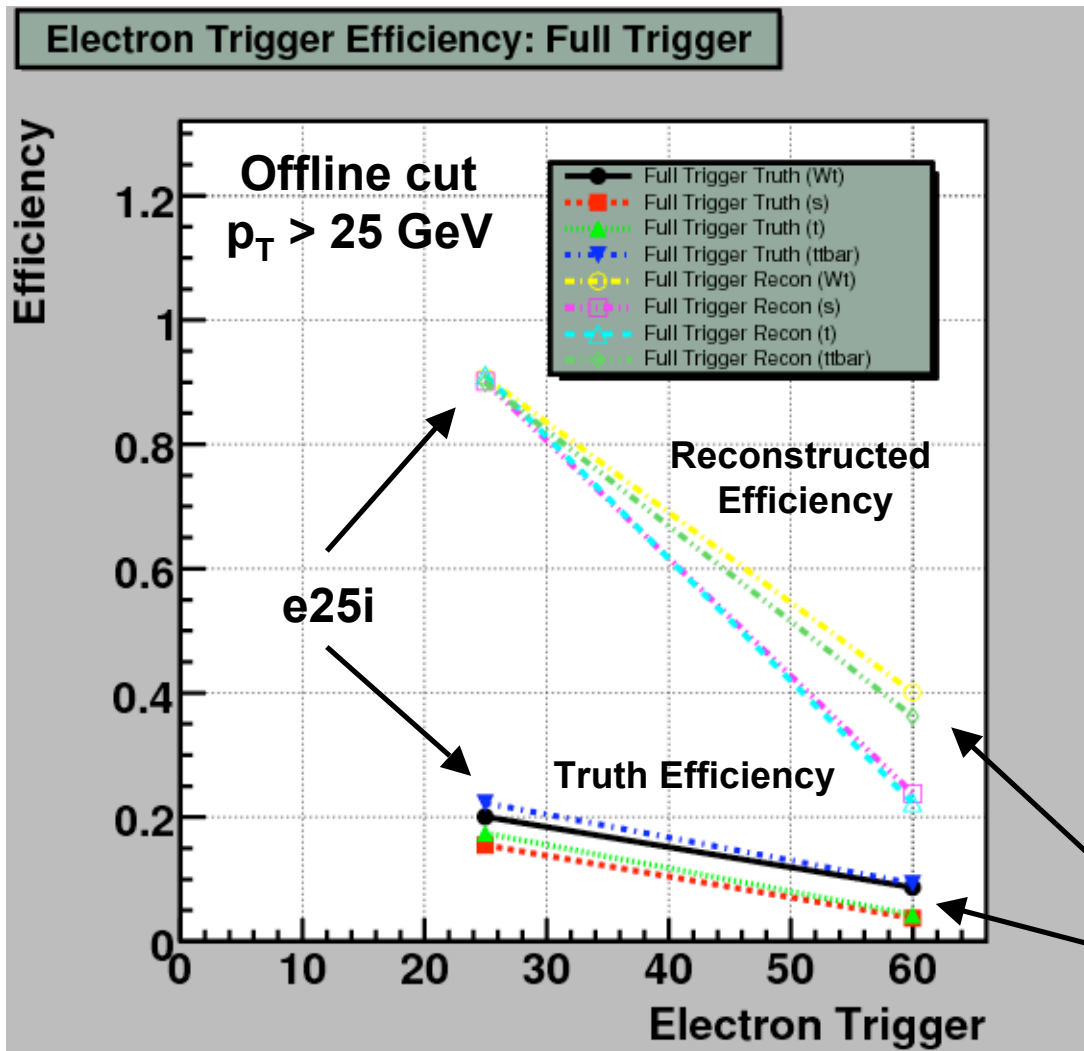
**Muon Triggers  
greater than 80%  
efficient**



- 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

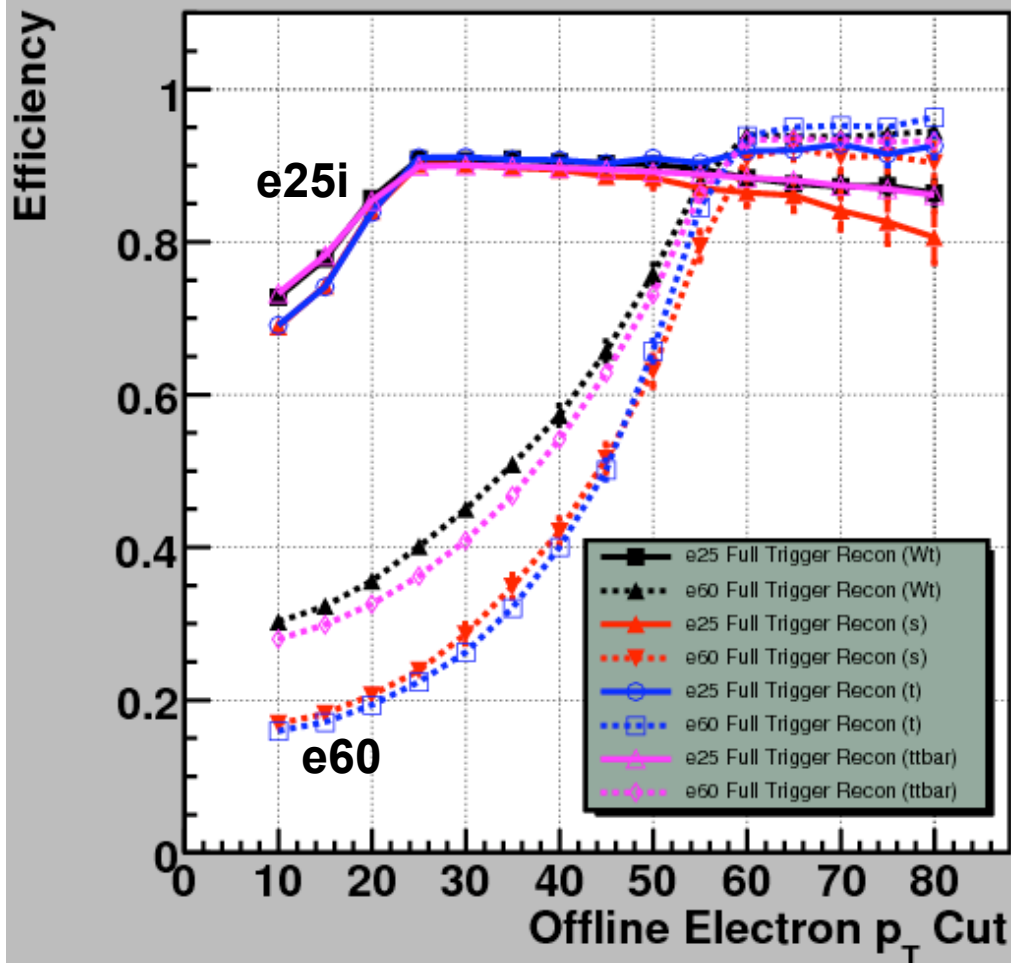
# Single Top Triggers Electron Efficiency



- **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

# Single Top Triggers Electron Turn-on Curve

Electron Turn-On: Full Trigger



- 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

- **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
- **ttbar triggers**
  - mu20i: 72% efficiency
  - e25i: 73% efficiency
- **Single Top triggers**
  - mu20i: 80% efficiency
  - e25i OR e60: 95% efficiency