Isolation Energy Study in $t\bar{t}$ and $Z \rightarrow e^+e^-$ in the ATLAS detector

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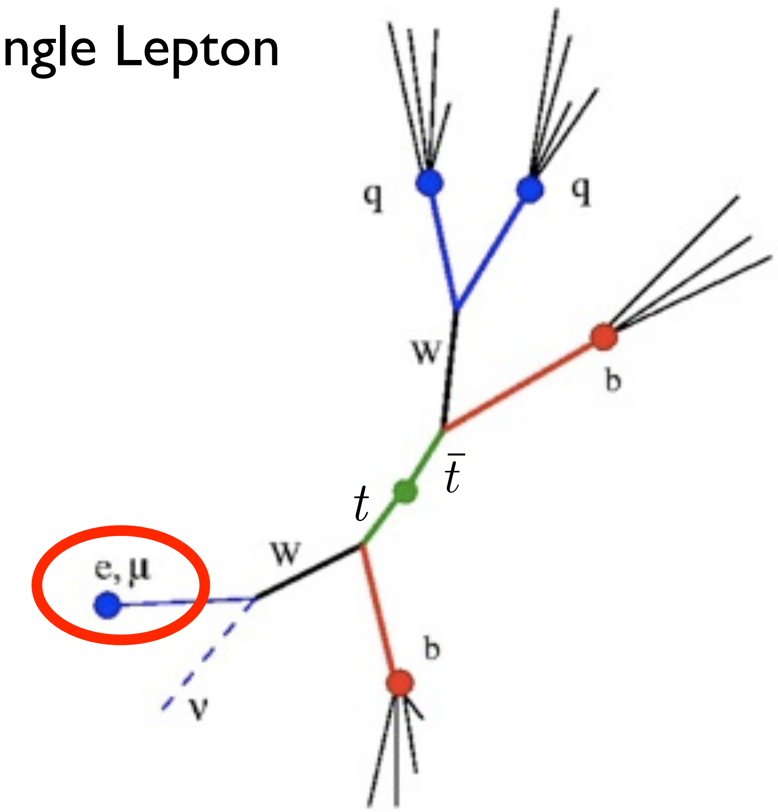
On behalf of the ATLAS collaboration

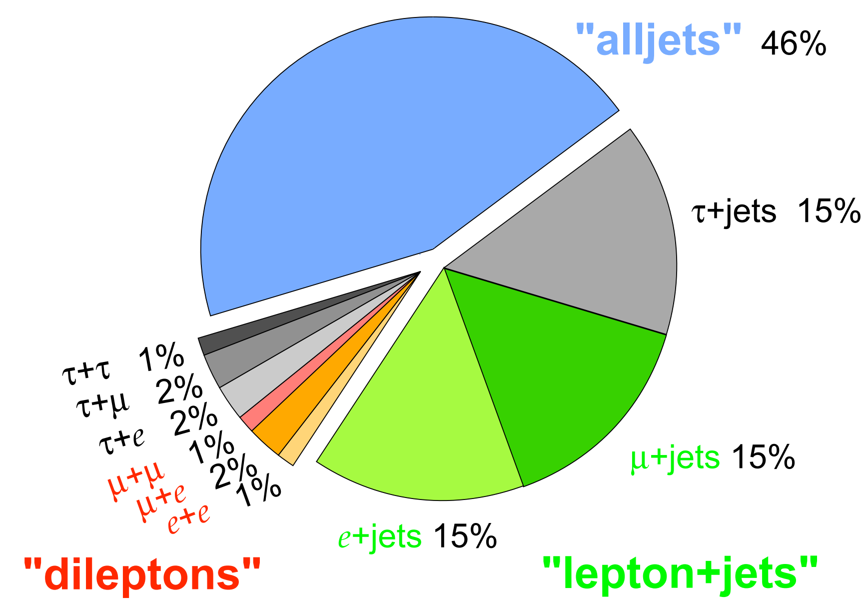
Motivation

- The Top quark is the heaviest elementary particle known and its mass along with that of the W constrain the mass of the Higgs.
- The single lepton channel (“*Golden Channel*”) strikes a balance between high statistics and good signal to background.
- $t\bar{t}$ events will contain one and only one electron from the decay of the W 15% of the time.
- It’s important to ensure the tagging of “true” electrons from the W and not fakes caused by Jets or other sources.
- An isolation requirement on the electron is a very effective method of distinguishing between electrons and fakes in not only the signal event, but also in backgrounds such as QCD.
- We thought we could improve on what the Top group within ATLAS recommended.

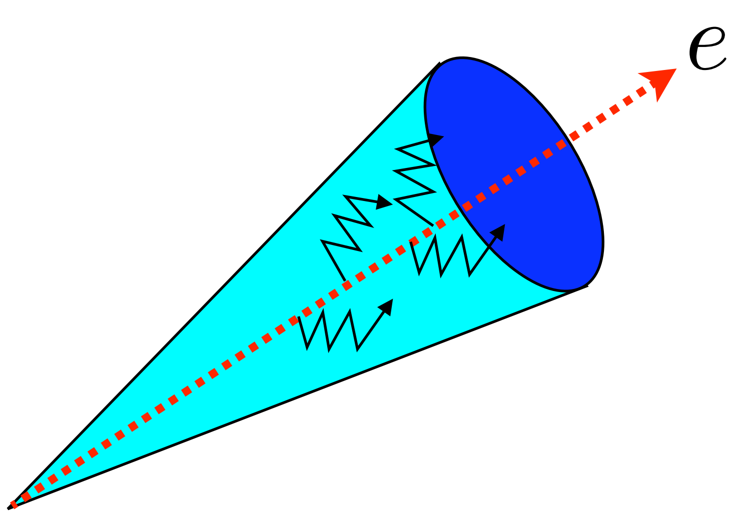
Single Lepton



Top Pair Branching Fractions



Isolation Energy



- E_{T_cone} = Total E_T in 0.2 cone around centroid - EM Cluster E_T (i.e. 5x5 of EM layers only around centroid).
- Top Group recommendation was to use E_{T_cone} < 6 GeV.

We investigated the use of the following rejections:

$$I_R = \frac{E_{T\_cone}}{E_T} \quad \& \quad E_{T\_cone} < C_1 + C_2 \cdot E_T$$

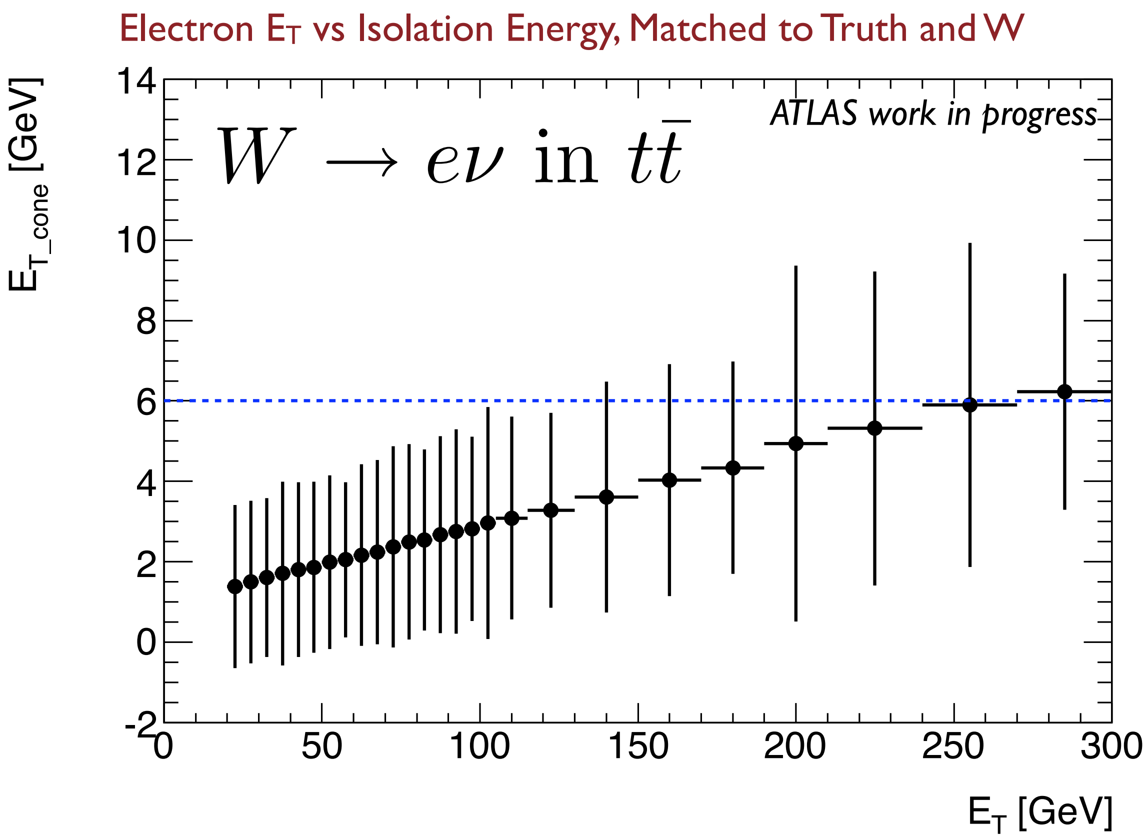
Electron Object

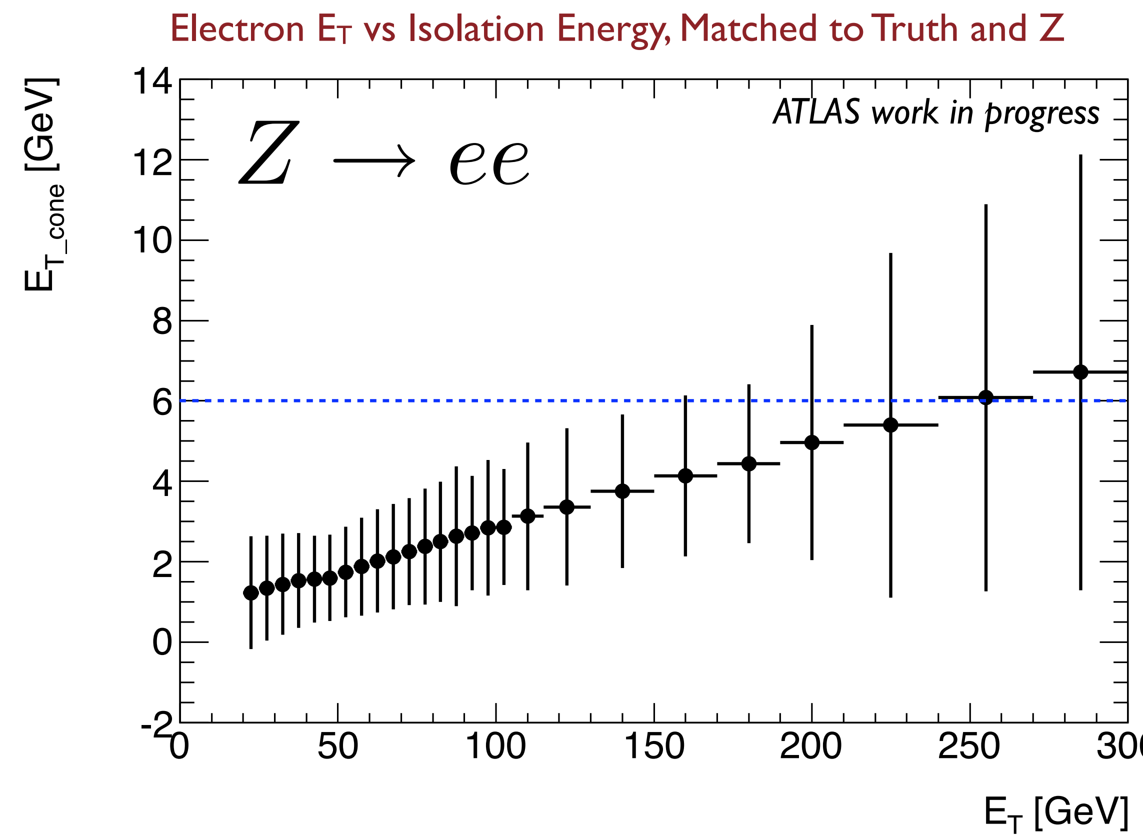
- Medium Electron - Shower shape cuts in calorimeter and inner detecter track matching.
- Electron E_T > 20 GeV.
- |eta| < 2.5 and fiducial crack region (1.37< |eta| < 1.52) objects vetoed.

Datasets

- 10 TeV McAtNlo $t\bar{t}$ Monte Carlo with one forced $t \rightarrow W \rightarrow \ell\nu$ — 2 Million events (~6800 pb^{-1})
- 10 TeV Pythia Monte Carlo $Z \rightarrow e^+e^-$ — 2 Million events (~1820 pb^{-1})

Selected electrons+ Truth Matched

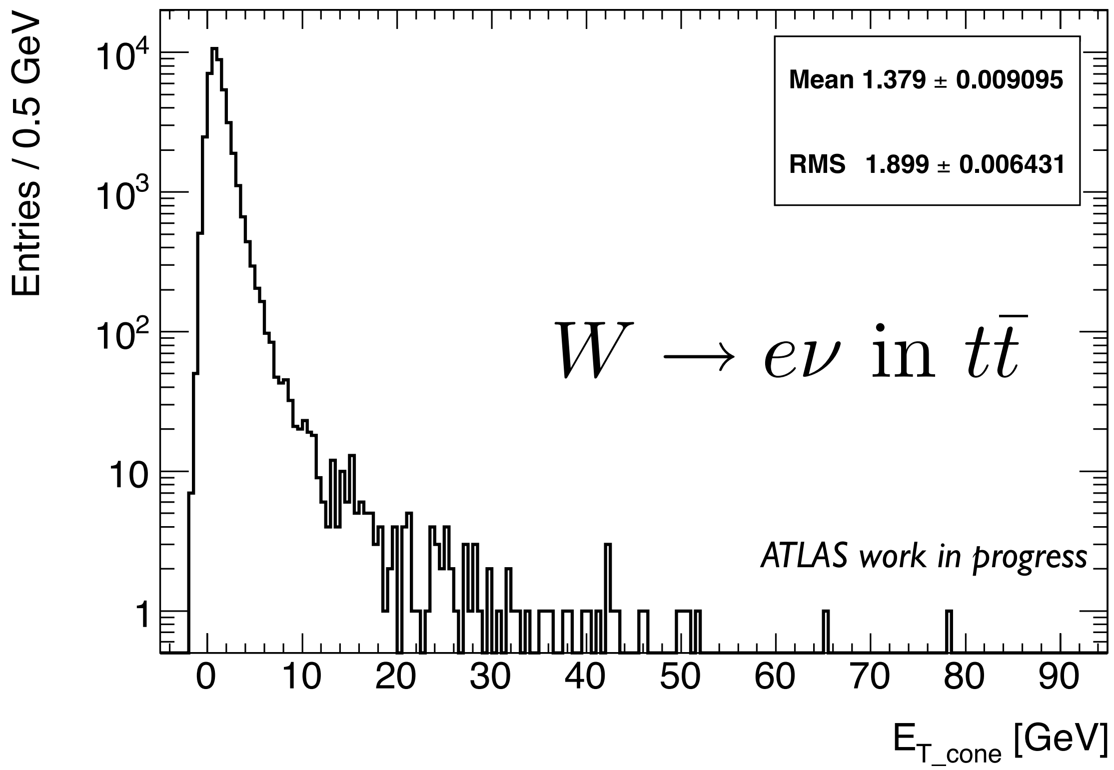




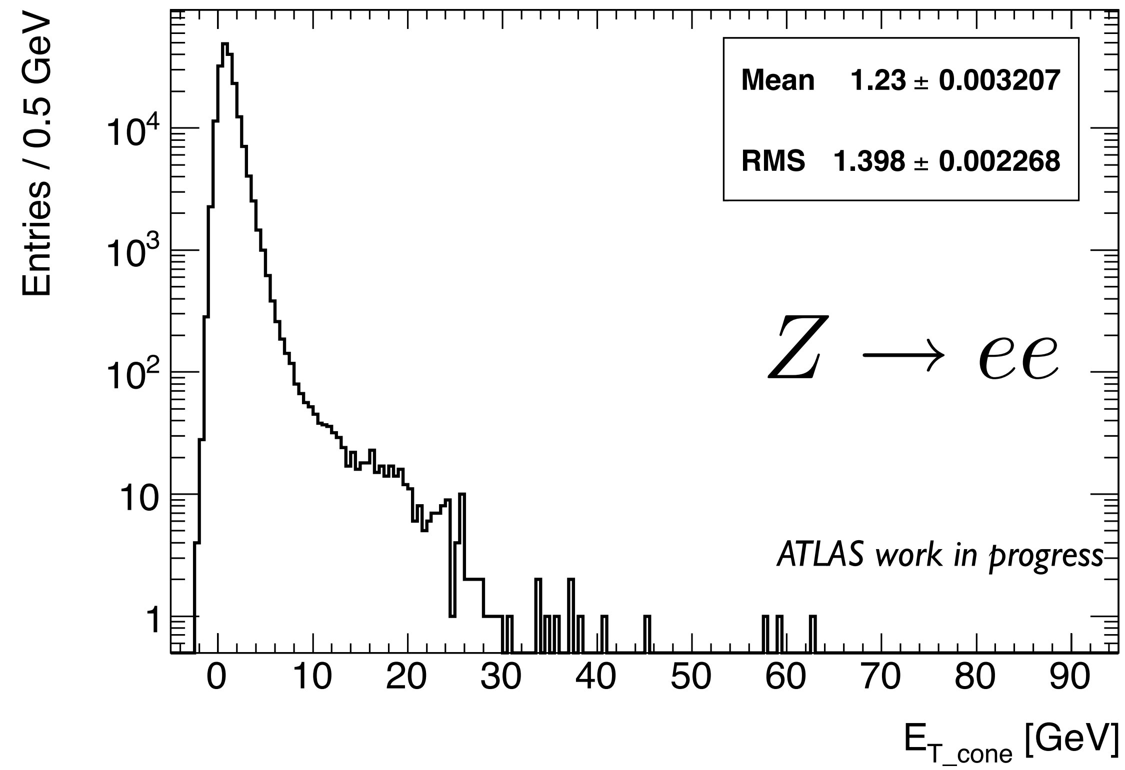
- The average E_{T_cone} increases with E_T , likely as a result of bremsstrahlung.
- For $E_T \rightarrow 0$ the E_{T_cone} tends to ~1 GeV This may be caused by either calorimeter noise, or incorrect energy subtraction in E_{T_cone} .
- The E_{T_cone} <6 GeV requirement will severely impact the efficiency at high E_T values.

*Error bars are the RMS

Electron E_{T_Cone}, 20-25GeV, Matched to Truth and W

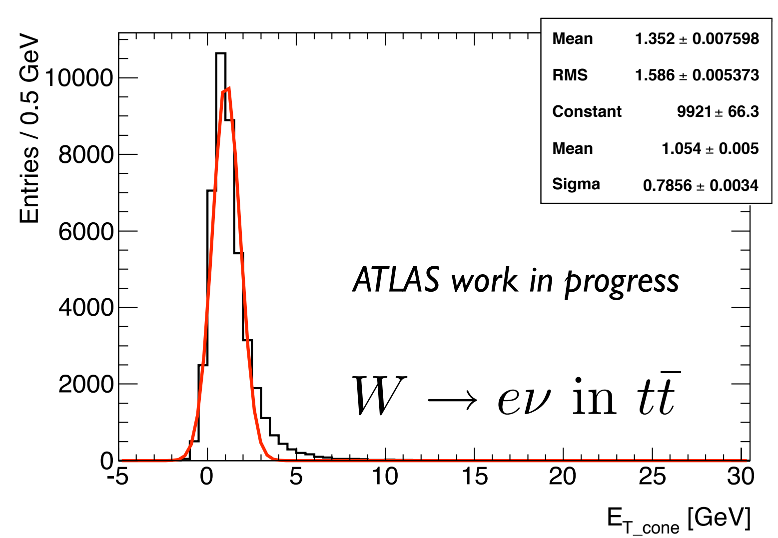


Electron E_{T_Cone}, 20-25GeV, Matched to Truth and Z

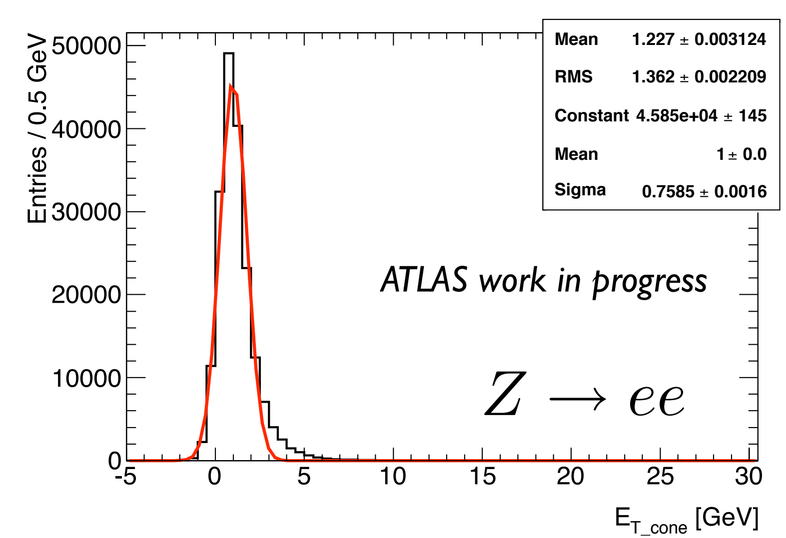


- The body of the E_{T_cone} distribution is the same for W→electrons in top and electrons from the decay of the Z.
- The electrons in $t\bar{t}$ have a longer tail due to nearby jets. These tails cause a larger RMS in the profile plots.

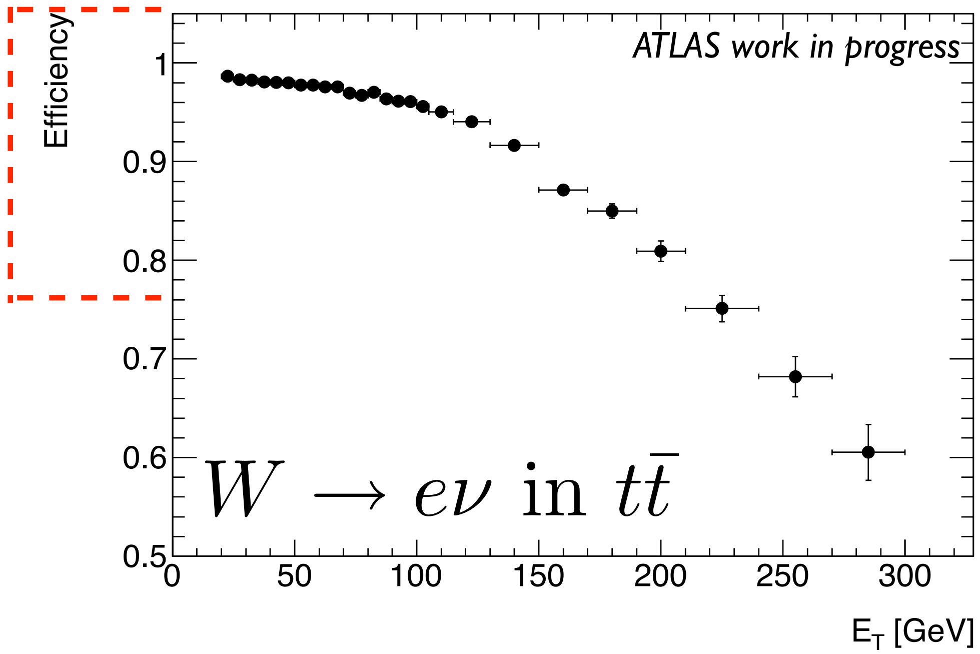
Electron E_{T_Cone}, 20-25GeV, Matched to Truth and W

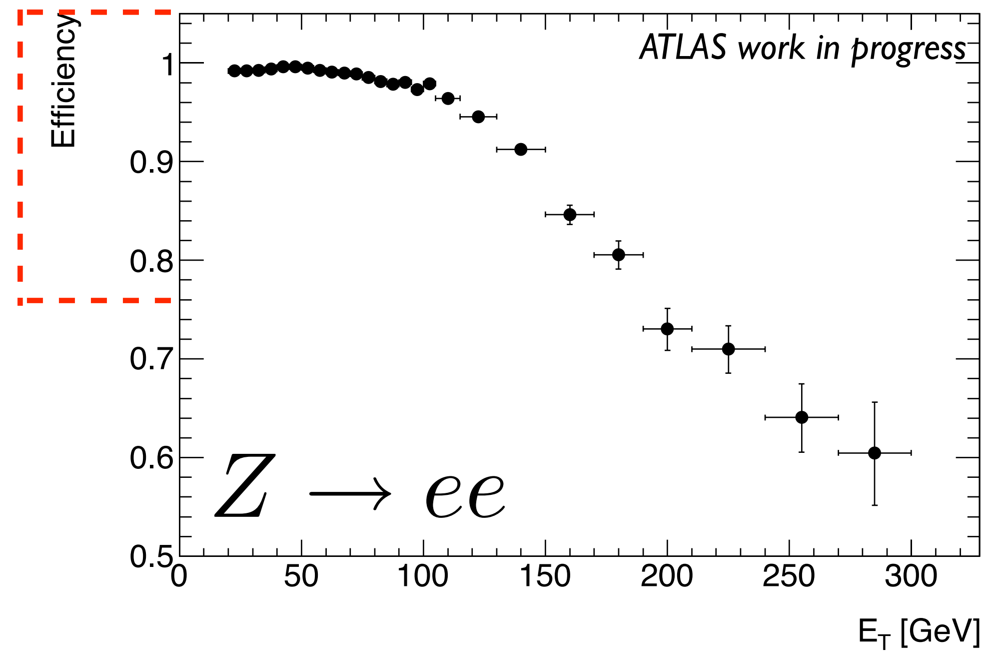


Electron E_{T_Cone}, 20-25GeV, Matched to Truth and Z

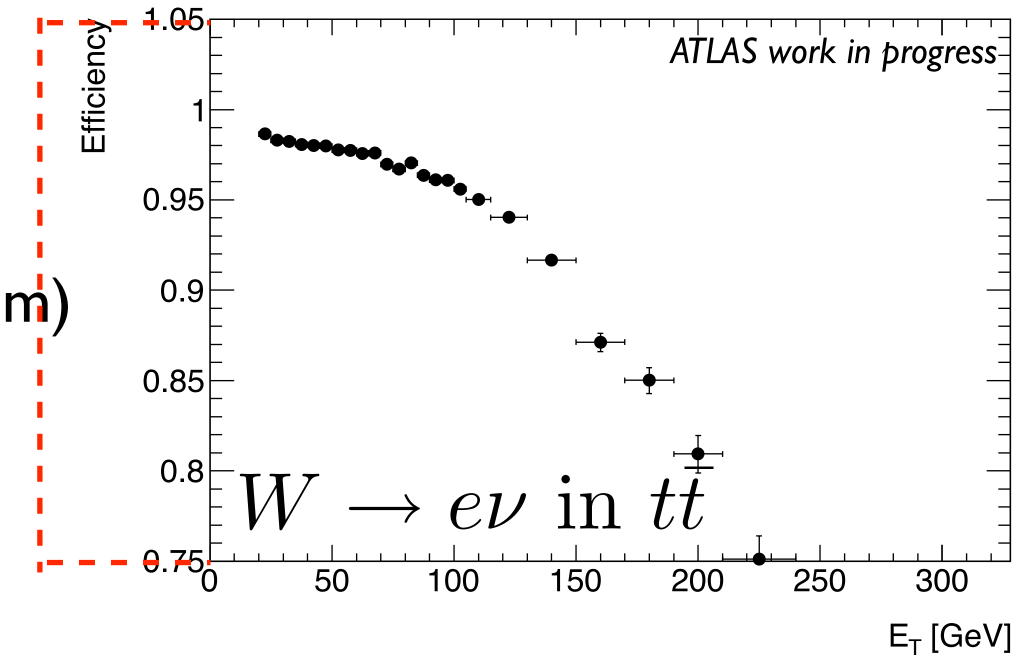


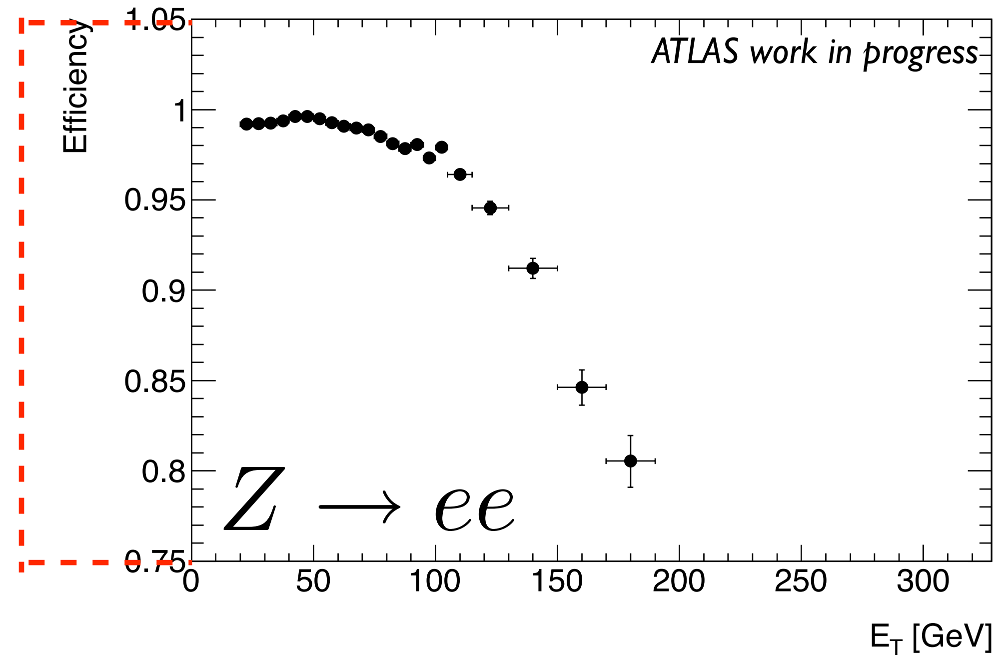
E_{T_cone}<6 GeV Efficiency





(zoom)





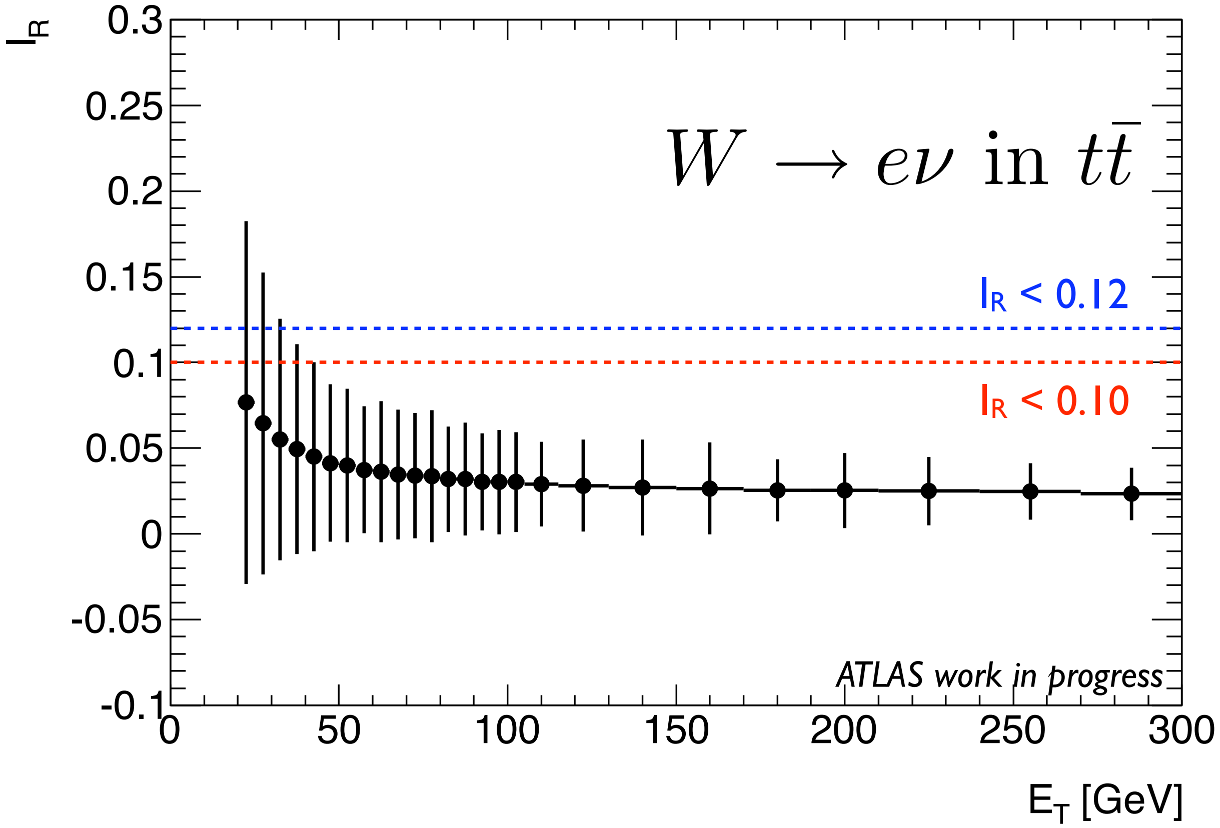
$$Efficiency = \frac{\text{Number of Electrons that Pass}}{\text{Total Number of Electrons}}$$

Efficiency at E_T ~250 GeV is ~ 60%.

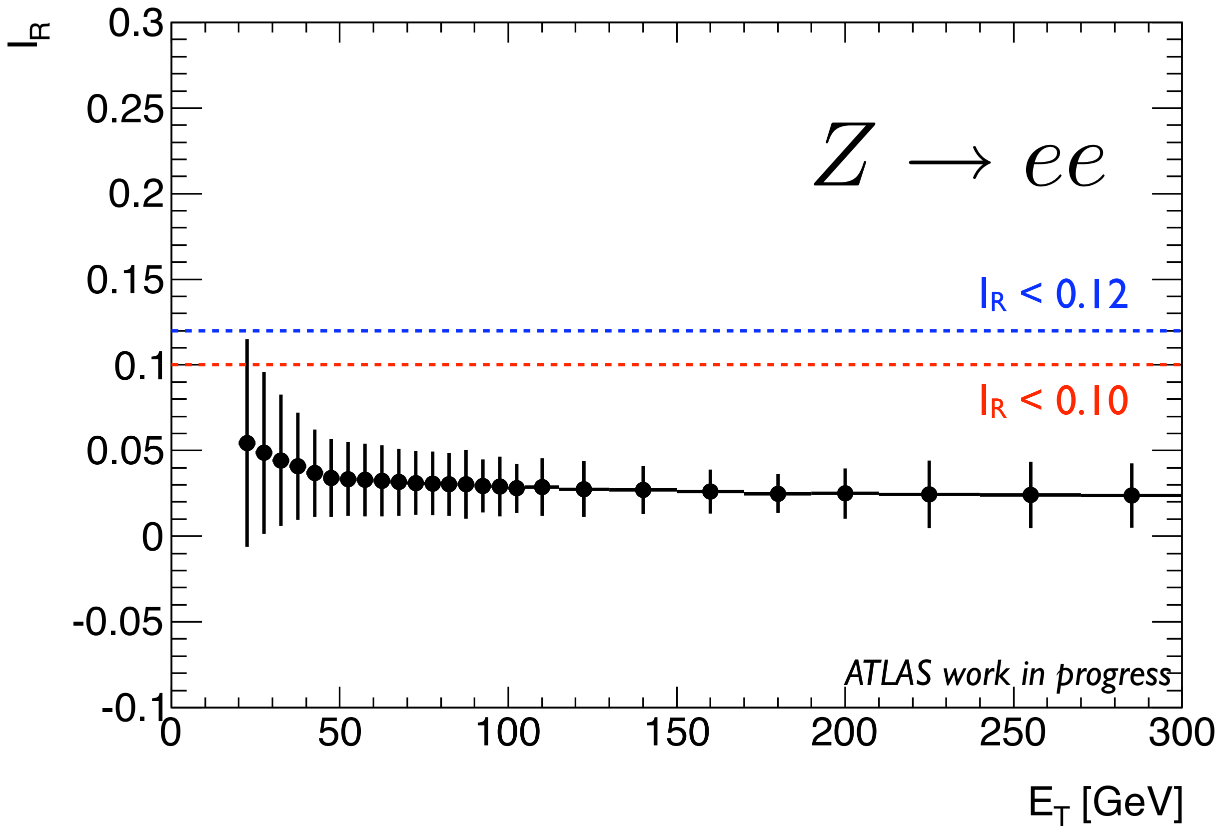
An alternative method to recover efficiency at high E_T is to use the isolation ratio:

$$I_R = \frac{E_{T\_cone}}{E_T}$$

Electron E_T vs Isolation Energy Ratio, Matched to Truth and W



Electron E_T vs Isolation Energy Ratio, Matched to Truth and Z



*Error bars are the RMS

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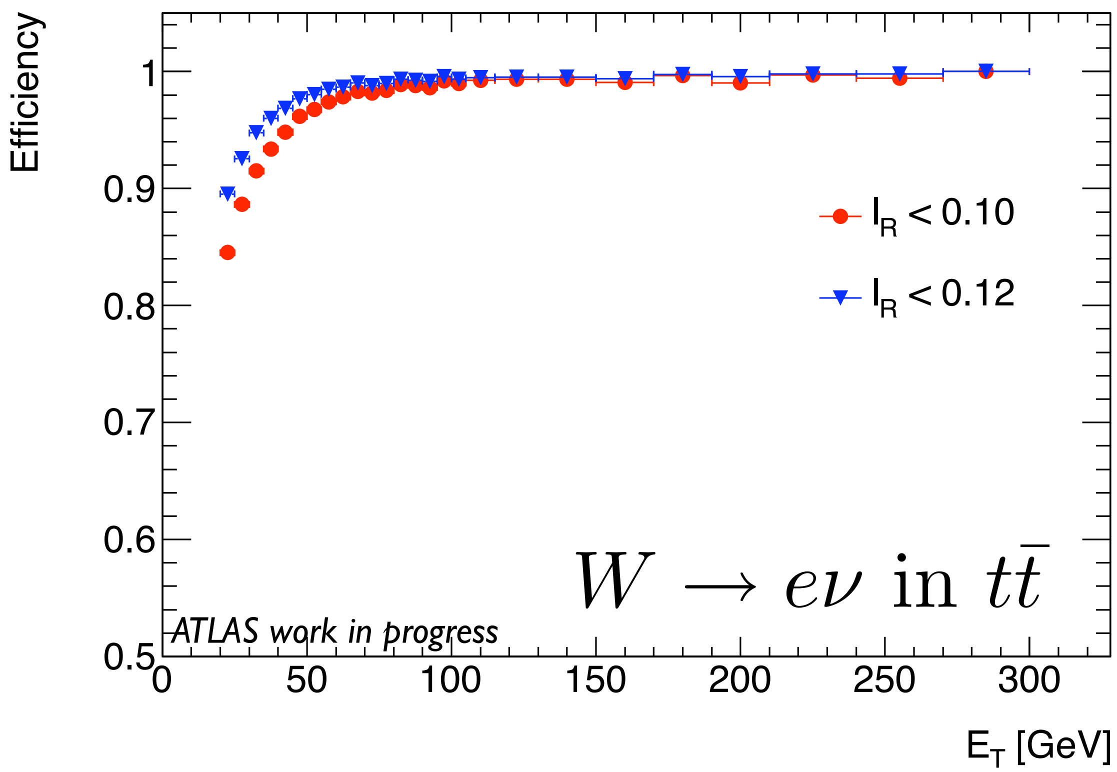
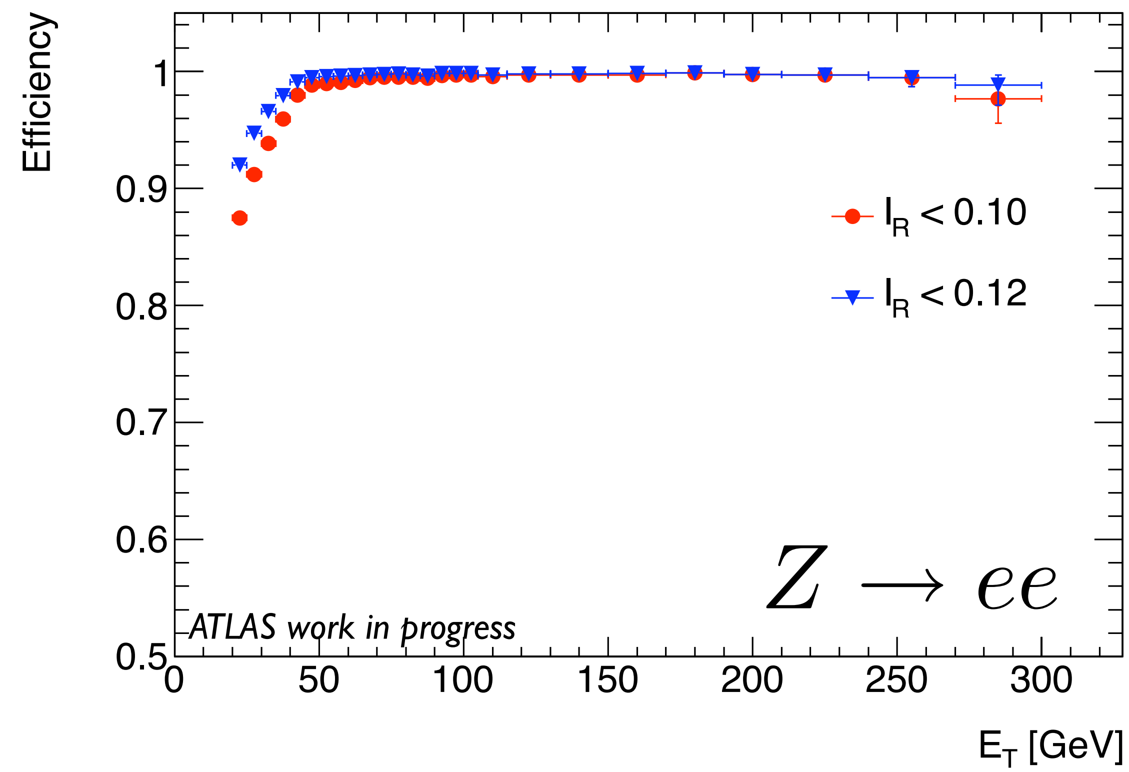
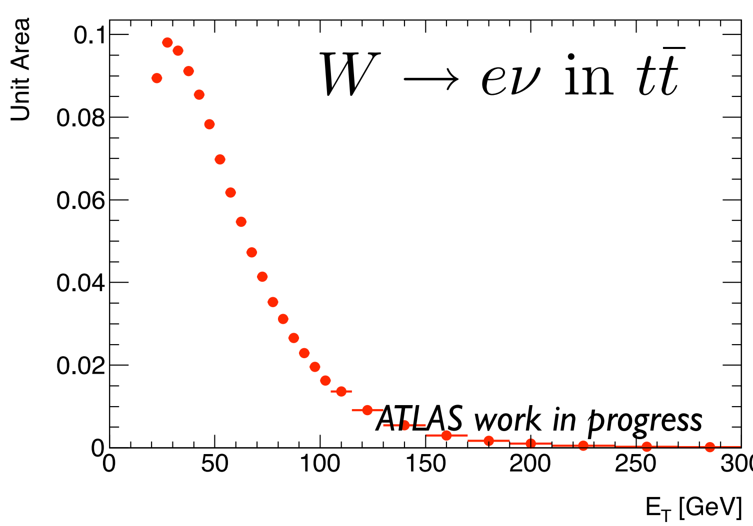
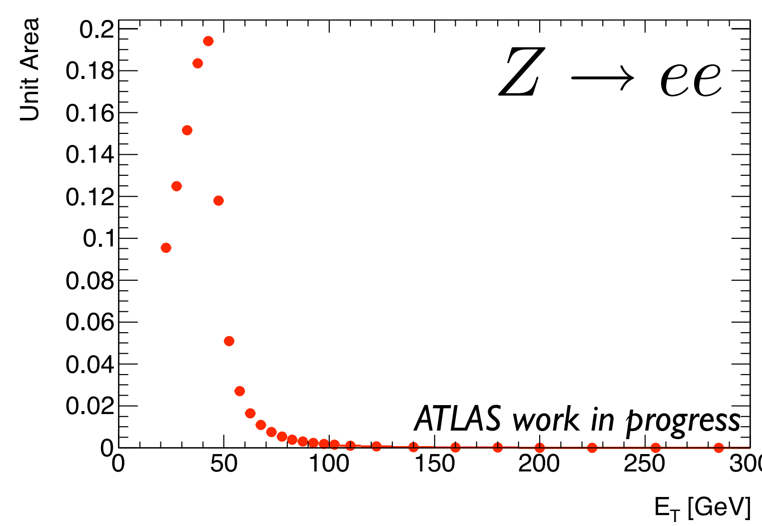




Selected Electron E_T Spectrum



Selected Electron E_T Spectrum



Overall integrated efficiency

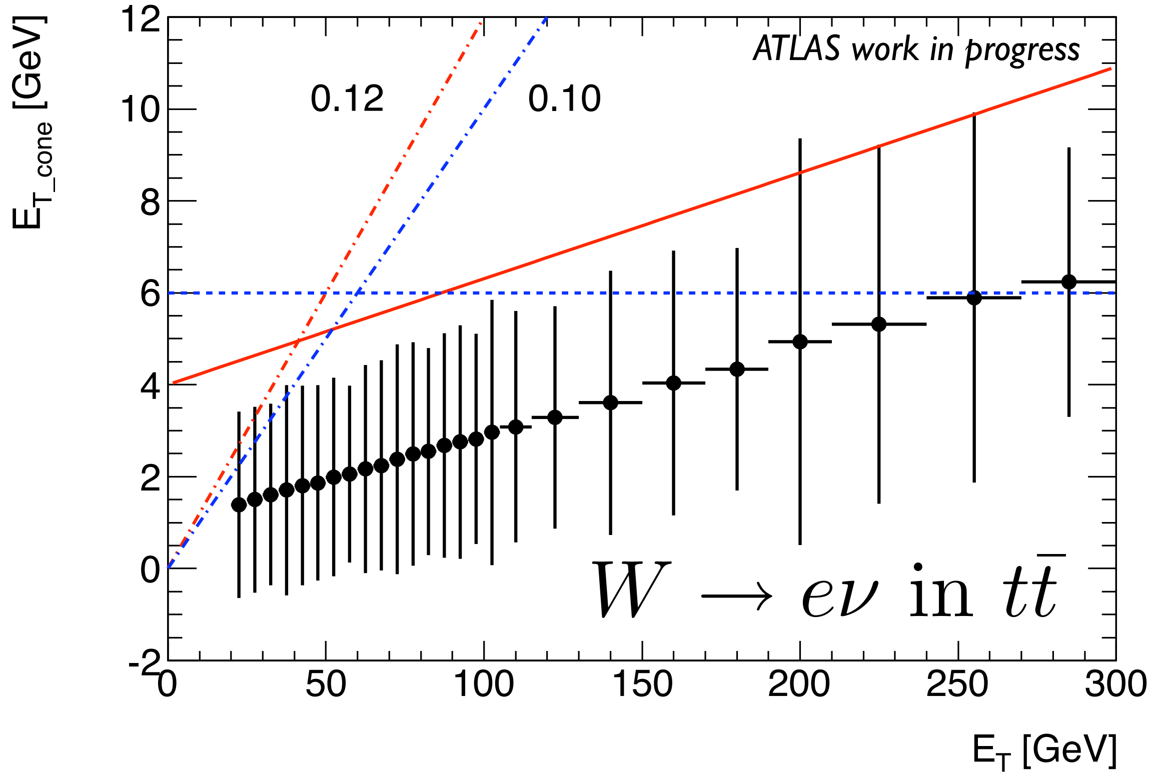
Efficiency of different isolation ratio cuts [%]

	$t\bar{t}$	$Z \to e^+e^-$
E_{T_cone} < 6 GeV	97.06 ± 0.03	99.30 ± 0.01
I_R < 0.1 GeV	94.79 ± 0.04	95.41 ± 0.01
I_R < 0.12 GeV	96.70 ± 0.03	97.42 ± 0.01

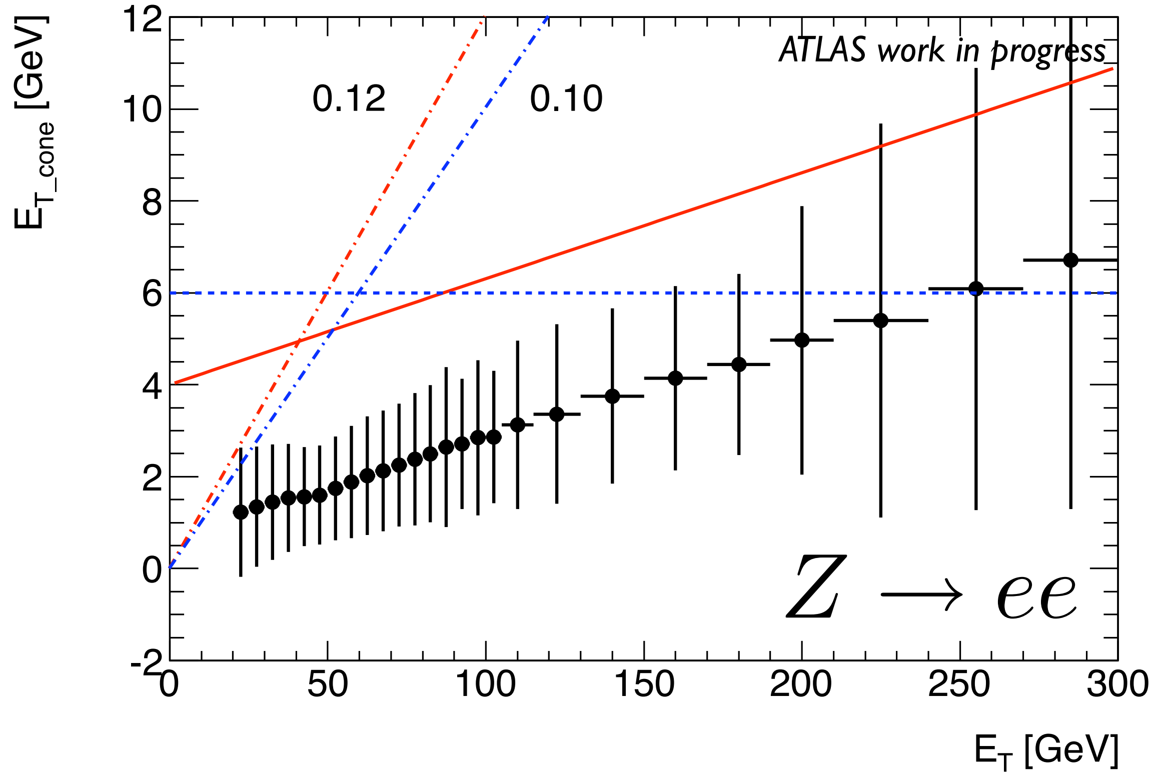
The ratio cut has very good efficiency at high E_T but cuts off a lot of lower E_T electrons.

Choosing a cut

Electron E_T vs Isolation Energy, Matched to Truth and W



Electron E_T vs Isolation Energy, Matched to Truth and Z



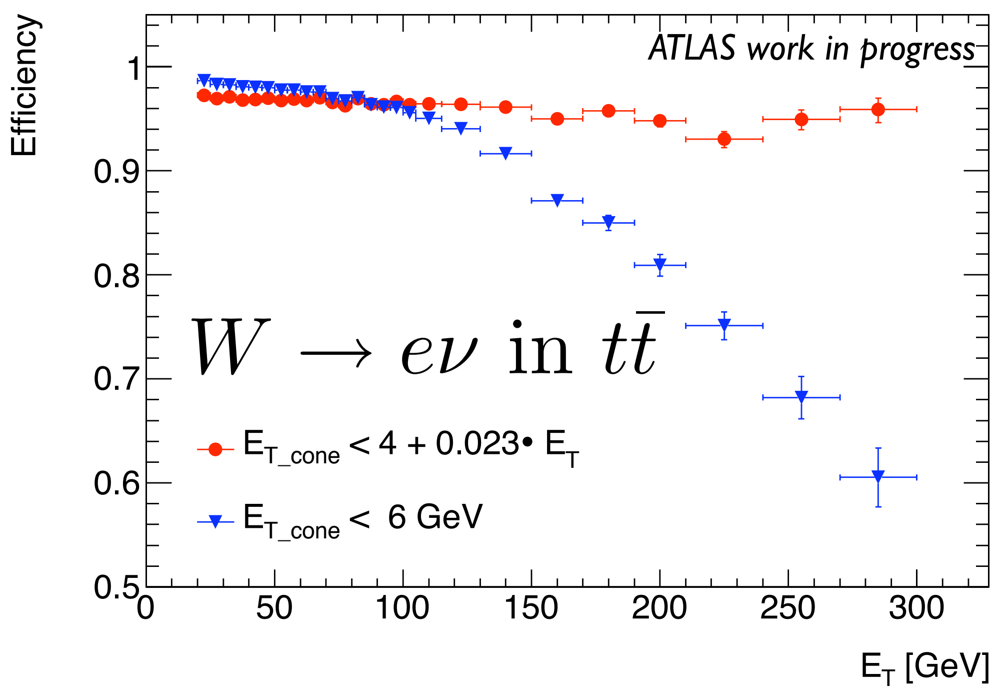
The optimal choice is actually a sliding cut of the form:

$$E_{T\_Cone} < C_1 + C_2 \cdot E_T$$

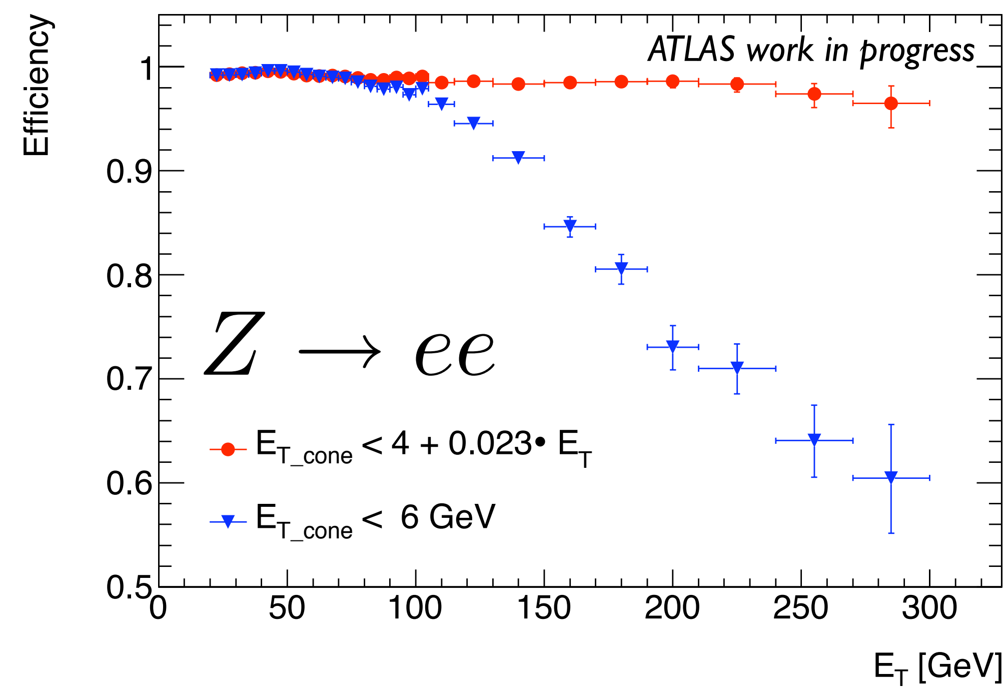
E.g., we take: C_1 = 4 GeV C_2 = 0.023

Sliding Cut Efficiencies

Electron E_T vs Isolation Energy, Matched to Truth and W



Electron E_T vs Isolation Energy, Matched to Truth and Z



Efficiency of different isolation cuts [%]

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E_{T_cone} < 6 GeV	97.06 ± 0.03	99.30 ± 0.01
I_R < 0.1 GeV	94.79 ± 0.04	95.41 ± 0.01
I_R < 0.12 GeV	96.70 ± 0.03	97.42 ± 0.01
E_{T_cone} < 4 + 0.023 • E_T	96.78 ± 0.03	99.39 ± 0.01

A flat efficiency is maintained across the whole E_T region.

Fakes rejection

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- Studies within ATLAS have shown using this cut improves background/fake rejection in the region of 30% over a simple cut on E_{T_cone}, whilst still maintaining the same signal efficiency.

Cut	Single Top	ZZ	WZ	WW	$t\bar{t}$	Wbb +Jets	W+jets	Zbb+jets	Z+jets	QCD
$E_{T\_Cone} < 4 + 0.023 \cdot E_T$	545	2.1	45	163	2065	104	17268	32.2	422	1583
$E_{T\_Cone} < 6$ GeV	546	2.1	45	162	2073	104	17228	31.7	414	2208

Event yields normalised to $10pb^{-1}$ at 10 TeV

Conclusions

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- E_{T_cone} has a linear dependence on the E_T of the electron, for electrons from W or Z decays.
- An isolation cut must take this dependence into account in order to avoid a significant efficiency drop with E_T.
- We proposed a sliding cut as a linear function of E_T at the end of 2009, as of Feb 2010 the sliding cut is an official ATLAS top group recommendation cut on electrons.
- A sliding E_{T_cone} cut has be shown to better at removing fake electrons in QCD background events while at the same time preserving the efficiency in tagging real electrons from W decay.

- Backup

- For atlas people see ATL-COM-PHYS-2009-605 for plots and discussion