Missing ET significance (XS) triggers in ATLAS

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Introduction and overview

- What is the missing $E_{\mathrm{T}}^{\mathrm{miss}}$ significance?
  - Fake $E_{\mathrm{T}}^{\mathrm{miss}}$: theory
  - Operational definition of XS triggers
  - Statistical interpretation
- What are the advantages of XS triggers?
  - Pile-up invariance
  - High signal to background ratio
- How are XS triggers implemented in ATLAS?
  - L1Calo
  - High-Level Trigger
- Can we improve L1Calo further?
  - SumE vs. SumET

What is the missing $E_{\mathrm{T}}^{\mathrm{miss}}$ significance?

- Fake $E_{\mathrm{T}}^{\mathrm{miss}}$: theory
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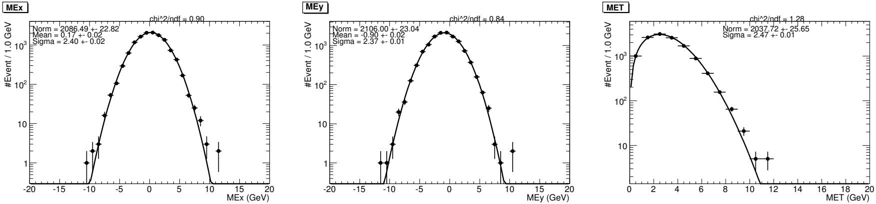
Fake $E_{\mathrm{T}}^{\mathrm{miss}}$: theory

- Events without real $E_{\mathrm{T}}^{\mathrm{miss}}$ still have some calorimetric activity
- Stochastic fluctuations induce a non null $E_{\mathrm{T}}^{\mathrm{miss}}$
- This fake $E_{\mathrm{T}}^{\mathrm{miss}}$ distribution depends on the total energy
  - We model it as a function of the scalar sum SumET (ΣE_{T})

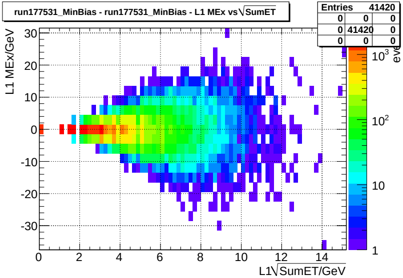
$$\mathcal{M}(x;\sigma(\Sigma E_{\mathrm{T}})) = \frac{x}{\sigma^2}\exp\left(-\frac{x^2}{2\sigma^2}\right) \quad \Rightarrow \quad P(E_{\mathrm{T}}^{\mathrm{miss}} \geq t|\Sigma E_{\mathrm{T}}) = \exp\left(-\frac{t^2}{2\sigma^2}\right)$$

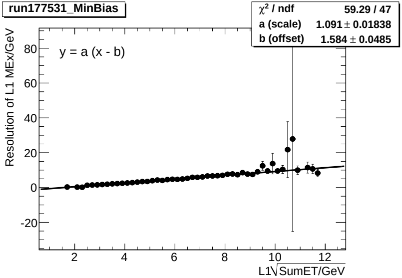


The value of the standard deviation of the Gaussian fits to $\not{E}_x$ (left) and $\not{E}_y$ (center) is also the single parameter $\sigma = \sigma(\Sigma E_{\mathrm{T}})$ which describes the $E_{\mathrm{T}}^{\mathrm{miss}}$ distribution (right).

Operational definition of XS triggers

- Fit the $\not{E}_x$ resolution σ as function of ΣE_T with pure background events
  - It comes out that σ is a linear function of $\sqrt{\Sigma E_T}$
- Set a minimum threshold for the value of XS $= E_T^{miss}/\sigma$
  - It combines two measurements: E_T^{miss} and ΣE_T





$$\text{L1\_MET\_sig} = \frac{\text{L1\_MET/GeV}}{1.09\left(\sqrt{\text{L1\_SumET/GeV}} - 1.58\right)}$$

Statistical interpretation

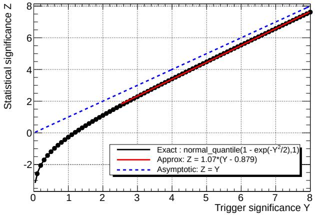
- The *statistical significance Z* is the number of standard deviations at the right of the Gaussian mean which gives the desired right-tail probability p under the null (= no signal) hypothesis

$$Z = \Phi^{-1}(1 - p)$$

- In our case, p is the probability of $E_T^{miss} > t$ given ΣE_T

$$Z = \Phi^{-1}\left(1 - e^{-\frac{t^2}{2\sigma^2}}\right) = \Phi^{-1}\left(1 - e^{-Y^2/2}\right)$$

where Y is the threshold on the significance $XS = E_T^{miss}/\sigma$



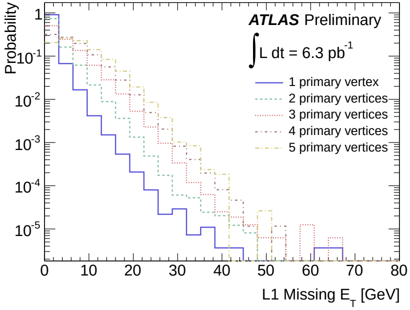
Straight lines:

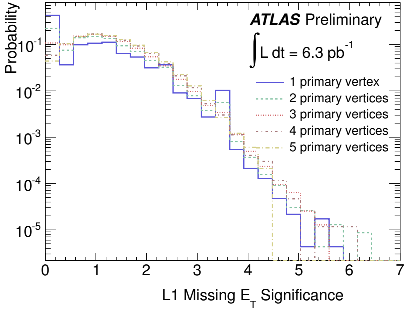
- $Z \approx Y$ (asymptotic)
- $Z \approx 1.07\,(Y - 0.88)$ (fit in the useful range)

What are the advantages of XS triggers?

- Pile-up invariance
- High signal to background (i.e. rate) ratio

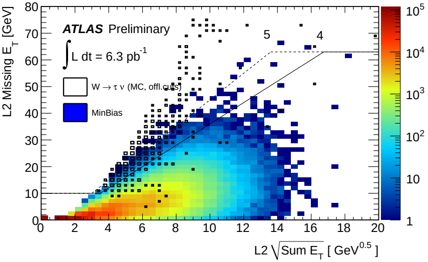
Pile-up invariance

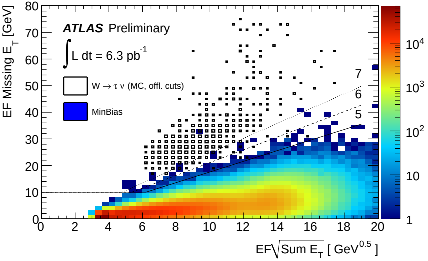




- XE rates largely depend on the pile-up
- XS rates are stable
- Convention: "XS37" means $E_{\mathrm{T}}^{\mathrm{miss}}/\sigma > 3.7$

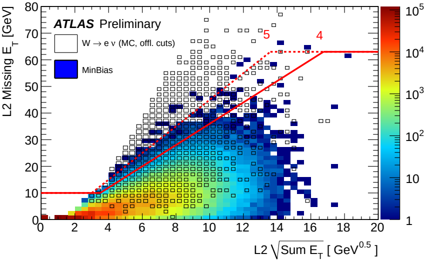
Signal to background ratio: Wtaunu

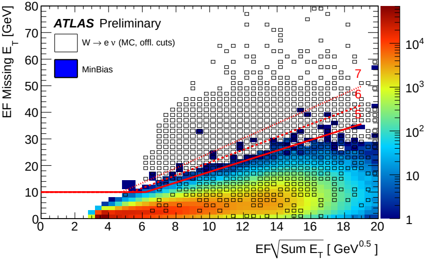




- W decays greatly benefit from XS triggers
- $W \to \tau\nu$ is impossible without XS
- Main trigger for $W \to \tau\nu$ is tau + XS
  - $W \to \tau\nu$ is shown here after offline cuts

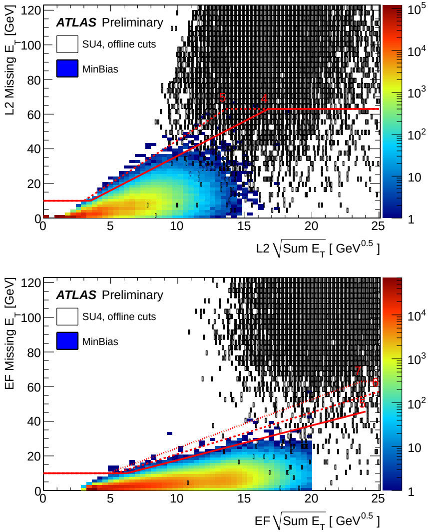
Signal to background ratio: Wenu





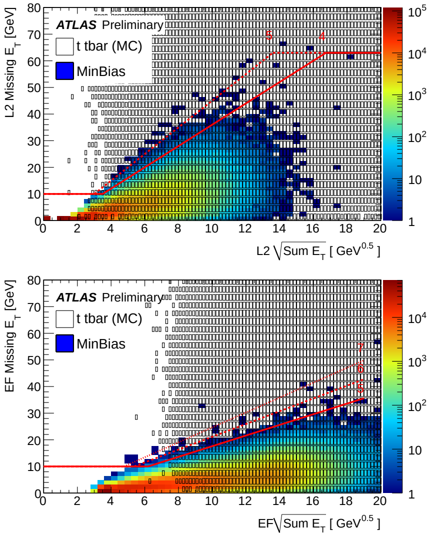
- $W \to e\nu$ is also easier with XS triggers
- XS triggers are used to study the electron efficiency
  - $W \to e\nu$ is shown here after quite loose offline cuts

Signal to background ratio: SU4



- The SUSY group is concerned about XS, but there is no reason
- The built-in L1 E_T^{miss} upper limit saves most of the phase space
  - The lowest unprescaled XE chain might help
  - At present, L1_XE50 and L1_XE60 are the primary items
  - METmax is 63 GeV for all L1_XS items
- What is the optimal value for this limit at EF? 80 GeV?

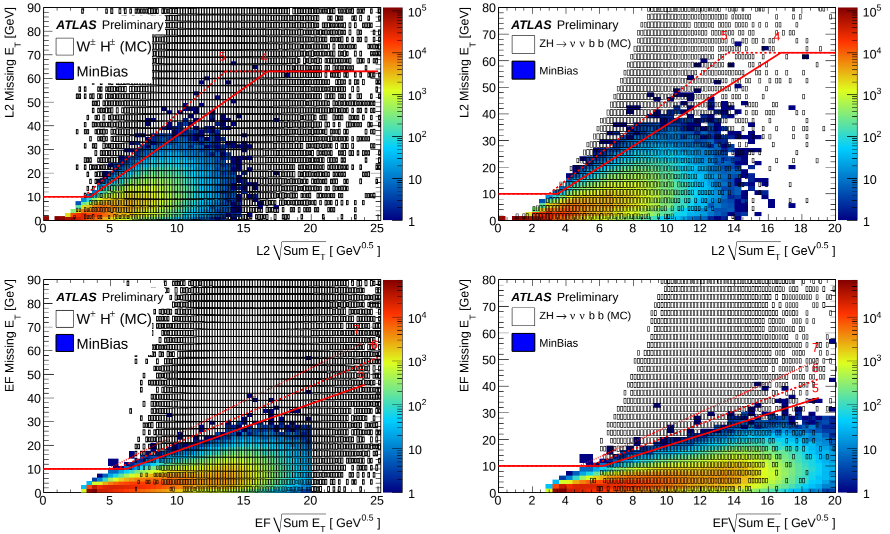
Signal to background ratio: ttbar



- Here, t tbar with at least one electron in the final state is considered
  - Background for Higgs searches
- Due to the high calorimeter activity, lots of events are discarded

(All plots show L2_xs40, L2_xs50 and EF_xs50, EF_xs60, EF_xs70)

Signal to background ratio: Charged Higgs (no offline cut)



How are XS triggers implemented in ATLAS?

- L1Calo
- High-Level Trigger

L1Calo

- Moved from the single LUT to a two-steps approach
  - Just 25 ns slower (total time is 1 μs)
- Configuration (from CTP onward) also changed

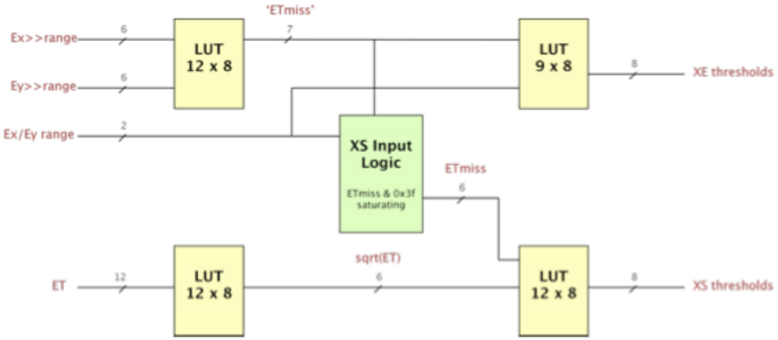


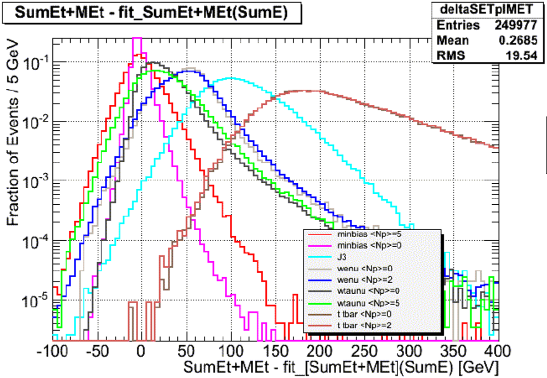
Figure 2: Illustration of the XE/XS logic performed in four LUTs

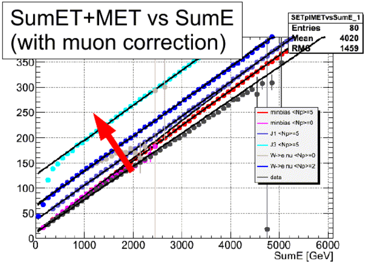
HLT

- At L2 and EF we can perform a quadratic fit of the $\not\!\!E_x$ resolution
- However, there is no need: we are setting the quadratic term to zero
- Menu definition under refinement

Can we improve L1Calo further?

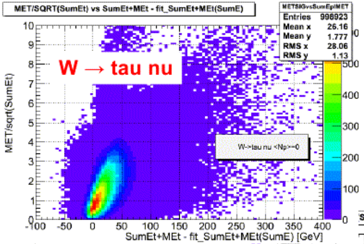
If we can get both SumE and SumET from each trigger tower, we can provide a trigger on the scalar sum of the transverse energies which is almost pile-up independent

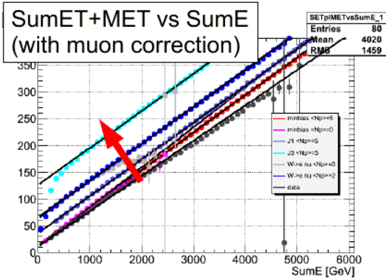




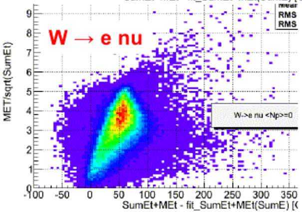
- It appears that there is a linear relation between SumE and SumET for all similar events
- This correlation is almost independent from the pile-up
- This is a new quantity which measures the scalar sum of all transverse momenta (inclusing invisible particles) and is independent from the pile-up
- At present, it can only be defined at EF

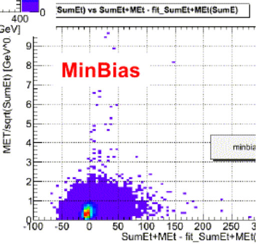
- MET significance and SumTE (length of the red arrow →) can be combined

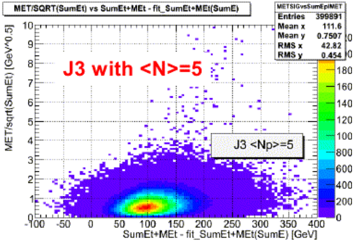




Plots by Allen Mincer







A new challenge for the L1Calo group? :-)

Summary

- The missing $E_{\mathrm{T}}^{\mathrm{miss}}$ significance is an estimate of $E_{\mathrm{T}}^{\mathrm{miss}}$ in units of fake RMS
  - Higher XS thresholds decrease the background efficiency
- XS triggers are almost pile-up independent
  - Much easier to operate
- XS triggers can be used to select W decays
- XS triggers have good sensitivity to new physics
- XS triggers required changes at L1Calo, HLT, configuration
  - They are working :-)
- A possible improvement for L1Calo would allow to operate also with the scalar sum of transverse momenta