Missing Transverse Momentum and its Significance For Full Run 2 using ATLAS 13 TeV pp data

Introduction

- The momentum imbalance of an event gives physicists the ability to identify non-interacting standard model particles, such as neutrinos, and to search for signatures indicating the presence of physics beyond the Standard Model.
- A new method of normalizing the missing momentum by expected detector resolutions allows for improved discrimination between signals and backgrounds.

Missing Transverse Momentum (E_T^{miss})

- Conservation of momentum implies that for collider experiments the sum of momenta in the x-y plane (perpendicular to beam line) is zero.
- Any imbalance in this sum may indicate the presence of weakly interacting particles.
- This missing transverse momentum is known as E_T^{miss}
- There are two main contributions in ATLAS to E_T^{miss}

$$E_T^{miss} = -\left(\sum_{i\in \text{muons}} p_T{}^i + \sum_{i\in \text{electrons}} p_T{}^i + \sum_{i\in \text{photons}} p_T{}^i + \sum_{i\in \text{hadronic } \tau} p_T{}^i + \sum_{i\in \text{jets}} p_T{}^i + \sum_{i\in \text{Soft Term}} p_T{}^i\right)$$

Hard Objects → Fully reconstructed and calibrated physics objects

Soft Objects → Additional signals not associated with physics objects

Soft Objects determined in two ways

1. Tracks from inner detector (ID) form the track-based soft term (TST) [used in work presented here], or:
2. Topoclusters form the calorimeter-based soft term (CST).

Resolution of E_T^{miss}

- Each of the physics objects previously described has a set of selections and resolutions.
- One parallel to the direction of motion of physics object σ_{p_T}
- And one perpendicular $p_T \cdot \sigma_\phi$

Results

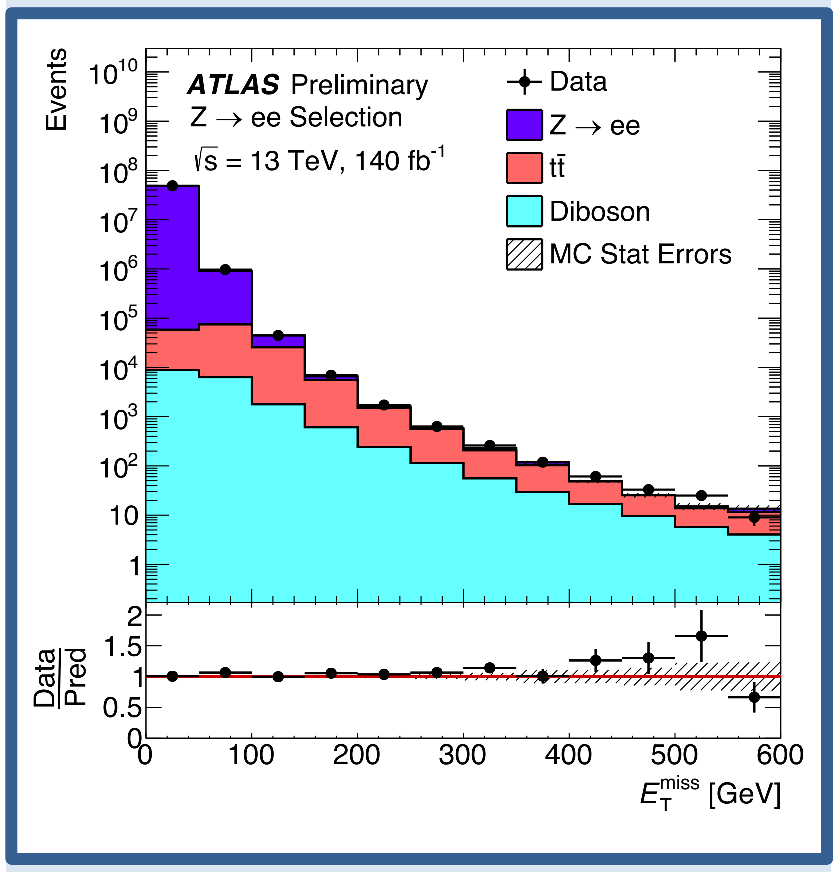

Figure 1. The E_T^{miss} distribution is shown for data and compared to simulation which is broken up in to the contribution from each physics process. The error bars on the data points (black) are statistical and the hashed areas in the main body and ratio plot represent the total statistical uncertainty in the simulated samples.

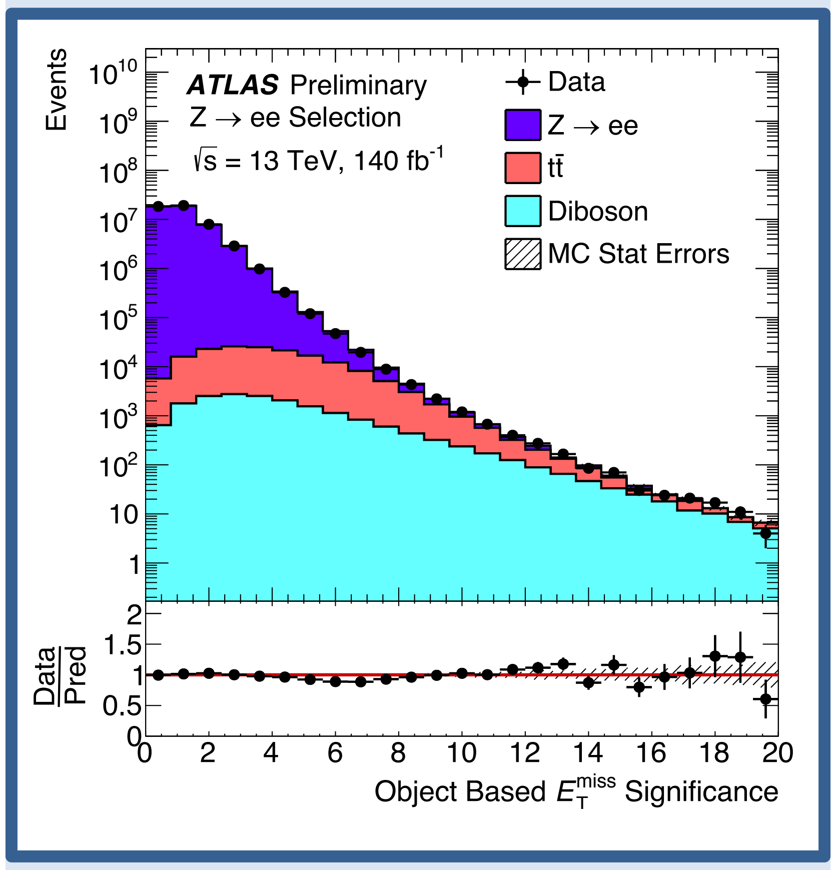

Figure 2. The E_T^{miss} significance distribution is based upon a logarithmic hypothesis test on the compatibility of the observed transverse momentum (p_T^{inv}) to be coming from invisible particles. Low values indicate E_T^{miss} comes from resolution effects and hence not from a real physical source and high values suggest the presence of an invisible particle in the event. The calculated distribution from data shows excellent agreement with that from simulation.

E_T^{miss} Significance (S)

- E_T^{miss} Significance, or S, is a hypothesis test in the form of a logarithmic likelihood.

$$\mathcal{S}^2 = 2\ln\left(\frac{\max_{p_T^{inv}\neq 0}\mathcal{L}(E_T^{miss}|p_T^{inv})}{\max_{p_T^{inv}=0}\mathcal{L}(E_T^{miss}|p_T^{inv})}\right).$$

Likelihood that the MET is consistent with real invisible particles (numerator)

Likelihood that the MET is NOT consistent with real invisible particles (denominator)

- Significance was previously defined as the ratio below.
- $\sqrt{H_T}$ was to approximate the resolution of E_T^{miss}

$$S = \frac{E_T^{miss}}{\sqrt{H_T}}$$

H_T: Sum of p_T of Hard Objects

- New object-based definition encodes the resolution of each physics object in denominator.
- This is a true dimensionless significance

$$\mathcal{S}^2 = \frac{|E_T^{miss}|^2}{\sigma_L^2\left(1-\rho_{LT}^2\right)}.$$

Measured quantity: $|E_T^{miss}|$

σ_L^2: Longitudinal variance in measurement

ρ_{LT}: Correlation factor between longitudinal and transverse projections

References

1. The ATLAS Collaboration, "Object-based missing transverse momentum significance in the ATLAS detector", ATLAS-CONF-2018-038, 09/09/2018.
2. The ATLAS Collaboration. "Missing transverse momentum performance using the full run II pp data set at 13 TeV", ATL-COM-PHYS-2019-109. 19/02/19

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