Performance of the Missing Transverse Energy Reconstruction in the first ATLAS Data at 7 TeV

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In April 2010, the ATLAS experiment collected over 43M collision events at a center-of-mass energy of 7 TeV. These data are used to test the performance of the missing transverse energy reconstruction with up to 250 GeV total transverse energy accumulated per event. The resolution and tails of the missing transverse energy distributions are in good agreement with the simulation.

1 Data and Monte Carlo Simulation Samples and Event Selection

The performance of the missing transverse energy ($E_{\mathrm{T}}^{\mathrm{miss}}$) reconstruction was studied [1] using 43M proton-proton collision candidate events recorded by the ATLAS detector at a center-of-mass energy of 7 TeV under nominal magnetic field conditions.

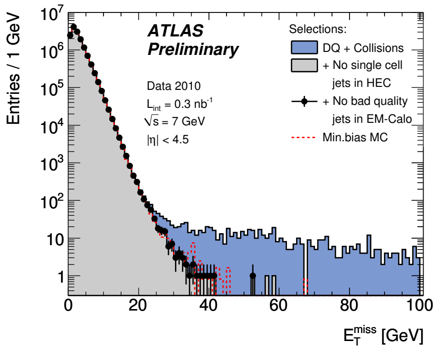

Figure 1: $E_{\mathrm{T}}^{\mathrm{miss}}$ distribution for collision events from 7 TeV data, after successive selections. The corresponding distribution from Monte Carlo simulation is overlaid.

Only those luminosity blocks (periods corresponding to about two minutes of data-taking) satisfying data quality (DQ) criteria for inner detector, calorimeters and jet and missing transverse energy reconstruction were analyzed [2]. The integrated luminosity of the sample after all data quality criteria applied was about 0.3 nb^{-1}.

Selected "minimum bias" events, triggered by the Minimum Bias Trigger Scintillators (MBTS) located on the Liquid Argon (LAr) calorimeter cryostat walls covering the pseudorapidity range $2.1 < |\eta| < 3.8$ [3], and passing additional timing criteria constitute a final data sample of about 14.4 million collision events.

About 18 million minimum bias events were generated using the PYTHIA Monte Carlo program [4], tuned with data from previous hadron colliders [5]. These events were passed through a full Geant4 [6] detector simulation with a detailed description of geometry and material.

Jets are reconstructed with the anti-k_T algorithm [7] with a distance parameter $R = 0.4$ and full four-momentum recombination. For this study, events were rejected if any jet in the event with transverse momentum $p_T > 10$ GeV at the electromagnetic scale fell into any of the following three categories:

- Fake jet caused by sporadic noise bursts in the Hadronic Endcap (HEC) calorimeters.
- Fake jet caused by noise bursts in the electromagnetic calorimeter causing large coherent noise in neighboring cells
- Jet reconstructed from large out-of-time energy deposits in the calorimeter

This requirement removed only a fraction of about 1.0×10^{-4} of all selected collision events. The E_T^{miss} distribution before and after cleaning cuts, is shown in Figure 1. The data are well described by the Monte Carlo simulation and no significant tails are observed after cleaning cuts are applied.

2 Reconstruction of E_T^{miss}

E_x^{miss}, E_y^{miss}, E_T^{miss}, and the total transverse energy ($\sum E_T$) are defined as:

$$E_x^{miss} = -\sum_{i=1}^{N_{cell}} E_i \sin\theta_i \cos\phi_i \quad , \quad E_y^{miss} = -\sum_{i=1}^{N_{cell}} E_i \sin\theta_i \sin\phi_i$$
$$E_T^{miss} = \sqrt{(E_x^{miss})^2 + (E_y^{miss})^2} \quad , \qquad \sum E_T = \sum_{i=1}^{N_{cell}} E_i \sin\theta_i$$

where E_i, θ_i and ϕ_i are the cell energy, polar angle and azimuthal angle, respectively, and E_T^{miss} is reconstructed over the range $|\eta| < 4.5$ using only calorimeter information.

All cell energies are calibrated at the electromagnetic scale. The electromagnetic scale gives the correct energy scale for the energy deposited in electromagnetic showers, while it does not correct for the lower hadron response in non-compensating calorimeters.

Only cells belonging to three-dimensional topological clusters (topoclusters) [8] are used. These topoclusters are seeded by cells with $|E_i| > 4\sigma_{noise}$ (σ_{noise} is the Gaussian width of the cell energy distribution measured in randomly triggered events), and are built by iteratively adding neighboring cells with $|E_i| > 2\sigma_{noise}$ and, finally, by adding all direct neighbors of the accumulated secondary cells.

3 E_T^{miss} Performance

Figure 2 shows the E_x^{miss} and E_y^{miss} distributions for collision events from 7 TeV data, after data quality selections with the corresponding distributions from Monte Carlo simulation overlaid. The shift of 0.35 GeV of the average E_T^{miss} in the data with respect to the simulation is caused by a displacement of the actual beam spot with respect to the calorimeter center, together with a small misalignment of the LAr forward calorimeters (FCal), neither of which is perfectly modeled in the Monte Carlo simulation.

A more quantitative evaluation of the E_T^{miss} performance can be obtained from a study of the E_x^{miss} and E_y^{miss} resolutions as a function of $\sum E_T$. The resolutions are expected to increase

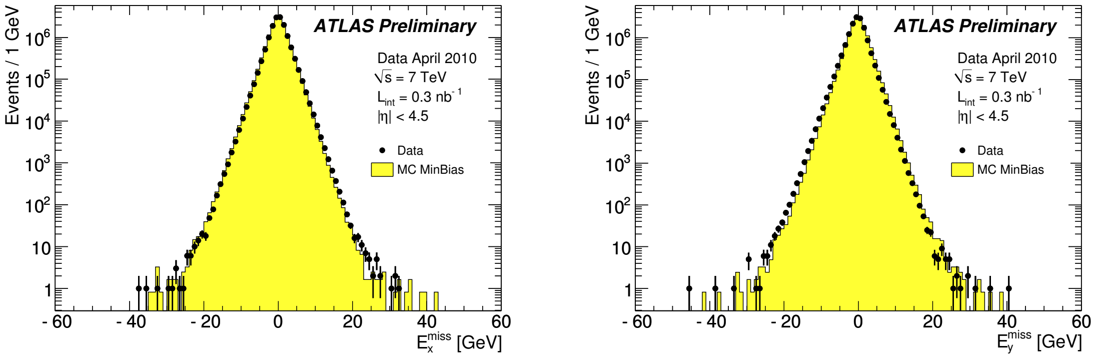

Figure 2: $E_{\mathrm{x}}^{\mathrm{miss}}$ and $E_{\mathrm{y}}^{\mathrm{miss}}$ distributions for data and Monte Carlo simulation.

proportionally with $\sqrt{\sum E_{\mathrm{T}}}$, as can be seen for ATLAS data and Monte Carlo in Figure 3. A good fit to the resolution as a function of $\sum E_{\mathrm{T}}$ is obtained with σ ($E_{\mathrm{x}}^{\mathrm{miss}}$, $E_{\mathrm{y}}^{\mathrm{miss}}$)=0.41 $\times$ $\sqrt{\sum E_{\mathrm{T}}/[\mathrm{GeV}]}$ for the data and with σ ($E_{\mathrm{x}}^{\mathrm{miss}}$, $E_{\mathrm{y}}^{\mathrm{miss}}$)=0.43 $\times$ $\sqrt{\sum E_{\mathrm{T}}/[\mathrm{GeV}]}$ for Monte Carlo simulation.

4 $E_{\mathrm{T}}^{\mathrm{miss}}$ Refined Calibration

A more refined calculation of $E_{\mathrm{T}}^{\mathrm{miss}}$ is being commissioned in which the calorimeter cells associated with each of the different types of reconstructed 'physics' objects (electrons/photons, τ-lepton, jets, muons) will be separately and independently calibrated. Also, cells belonging to topoclusters not associated with any such objects [9] are added as a last step of the refined calculation. For minimum bias events only two terms contribute significantly to the calculation of $E_{\mathrm{T}}^{\mathrm{miss}}$: the main contribution is from cells in topoclusters not associated to any reconstructed object (CellOut) and a lesser contribution comes from cells belonging to jets (RefJet). Such jets are reconstructed at the electromagnetic energy scale using the same anti-k$_T$ algorithm with the same configuration mentioned earlier, but with a lower p_{T} threshold of 7 GeV to test the ability of the Monte Carlo simulation to describe the detector response.

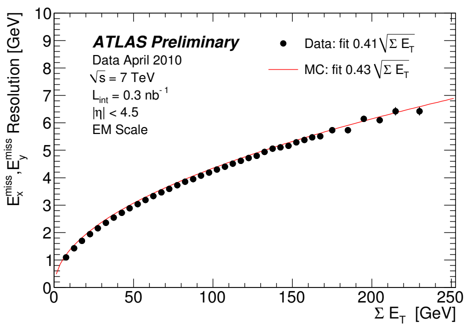

Figure 3: The $E_{\mathrm{x}}^{\mathrm{miss}}$, $E_{\mathrm{y}}^{\mathrm{miss}}$ resolutions as a function of the $\sum E_{\mathrm{T}}$ for data and Monte Carlo simulation.

The contributions to $E_{\mathrm{T}}^{\mathrm{miss}}$ given by these two terms is shown in Figure 4. The RefJet term is non-zero for only a small percentage of events, at 4% and 5% in data and MC respectively. The RefJet contribution tends to be small because the most frequent occurrence is di-jet events, which are nearly back-to-back in ϕ and closely matched in p_{T}.

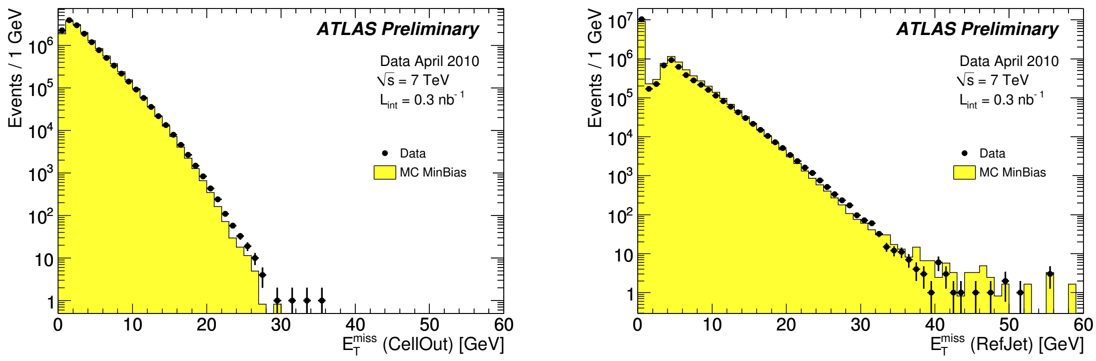

Figure 4: Distribution of $E_{\mathrm{T}}^{\mathrm{miss}}$ computed with cells from topological clusters not in reconstructed objects (CellOut) (left) and distribution of $E_{\mathrm{T}}^{\mathrm{miss}}$ computed with cells from topological clusters in Jets (RefJet) (right) for data (dots) and Monte Carlo simulation (histograms). The number of events in Monte Carlo simulation are normalized to the number of events in data.

5 Conclusions

The missing transverse energy reconstruction has been studied in the first minimum bias collisions at a center-of-mass energy of 7 TeV. No large tails are observed in the $E_{\mathrm{T}}^{\mathrm{miss}}$ distributions after cleaning cuts are applied, and the measured $E_{\mathrm{T}}^{\mathrm{miss}}$ resolution is in reasonable agreement with the Monte Carlo simulation.

A more refined calculation of $E_{\mathrm{T}}^{\mathrm{miss}}$ is being commissioned that will allow the full exploitation of the detector capability.

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