Performance of missing transverse momentum (MET) reconstruction with the ATLAS detector

LHCC poster session, 22 February 2017, CERN

Introduction

The 13 TeV center-of-mass energy and the high luminosity provided by the Large Hadron Collider (LHC) in the last years opens the door to the discovery of a large possible set of particle physics models. In many of the these predictive models, the missing transverse momentum (MET) is a fundamental observable and its reconstruction with the maximal precision corresponds to a crucial task for many of the ATLAS searches for new physics.

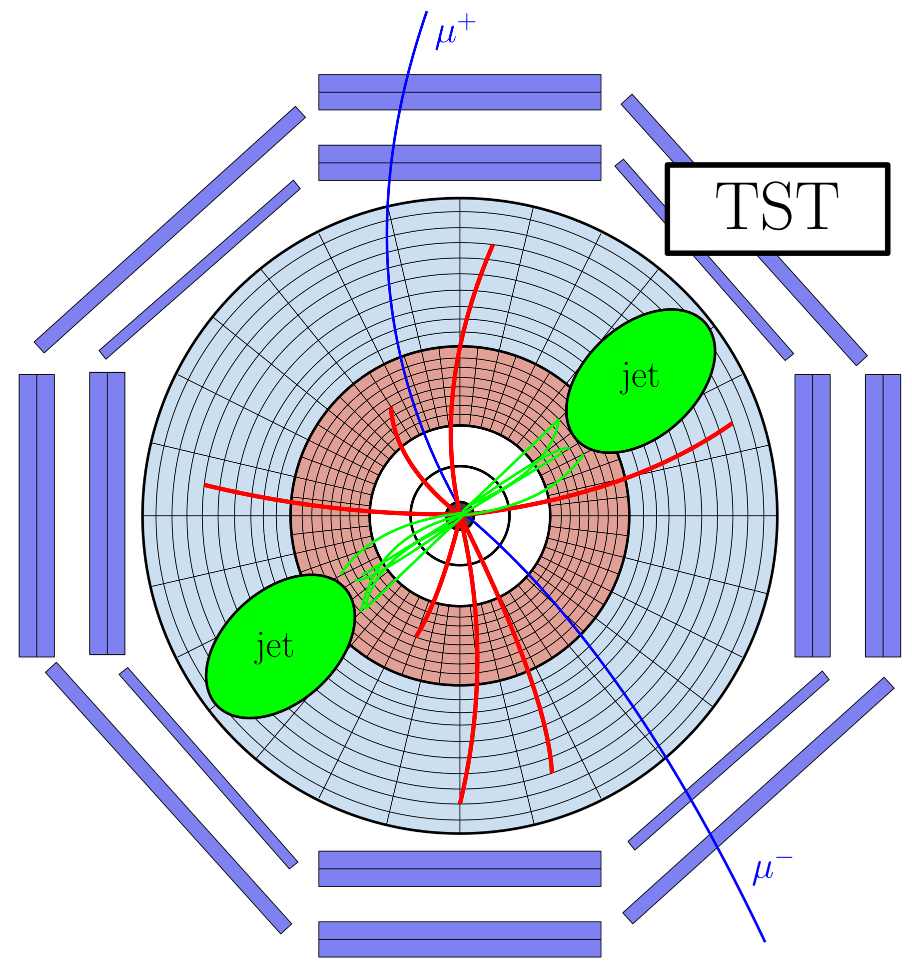
MET definition and reconstruction

The reconstruction of MET in ATLAS is broken into the hard component from objects which can be well identified/calibrated and the soft component reconstructed from signals which are not associated to a well identified object:

$$\mathbf{E}_T^{\text{miss}} = \overbrace{-\sum_{\substack{\text{selected}\\\text{electrons}}} \mathbf{p}_T^e - \sum_{\substack{\text{selected}\\\text{photons}}} \mathbf{p}_T^\gamma - \sum_{\substack{\text{selected}\\\tau-\text{leptons}}} \mathbf{p}_T^\tau - \sum_{\substack{\text{selected}\\\text{muons}}} \mathbf{p}_T^\mu - \sum_{\substack{\text{selected}\\\text{jet}}} \mathbf{p}_T^{\text{jet}}}^{\text{hard term}} \overbrace{- \sum_{\substack{\text{tracks or}\\\text{clusters}}} \mathbf{p}_T^{\text{soft object}}}^{\text{soft term}}.$$

For a specific event free of particles creating true MET (*i.e.* neutrinos), a perfect hard and soft term reconstruction would imply $E_T^{\text{miss}} = 0$. The soft component represents then a fundamental quantity in the reconstruction of MET and it can be estimated with two main techniques:

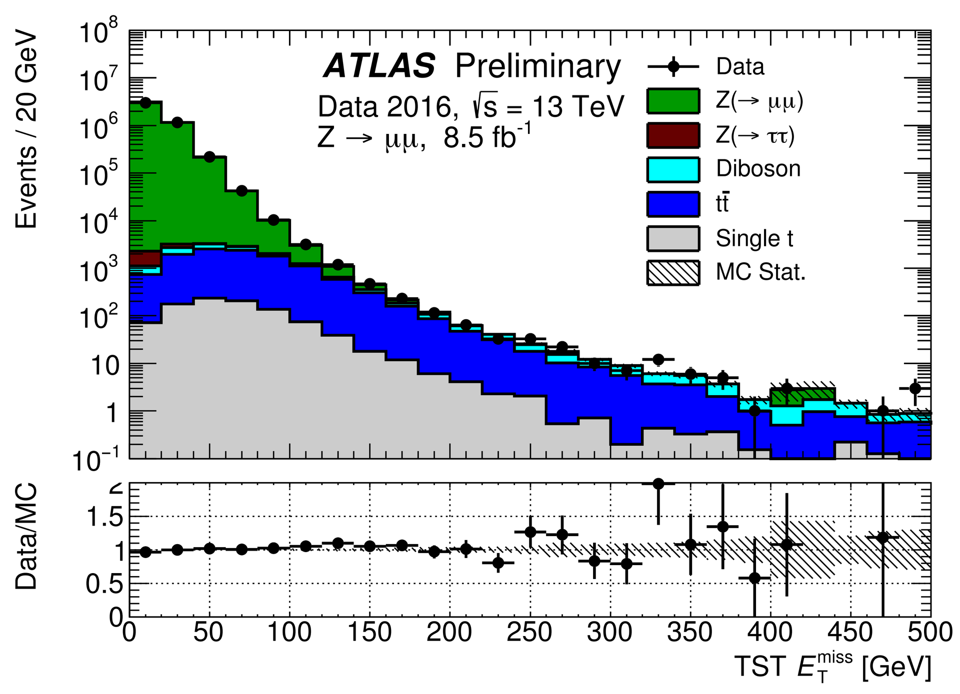
- **Calorimeter based Soft Term (CST),** accounting for both neutral and charged particle energies but strongly pileup dependent.
- **Track based Soft Term (TST),** incorporating pileup suppression by selecting PV tracks only but unable to incorporate neutral particles p_T.



MET contributions

The performance of MET can be evaluated starting from events containing a Z boson decaying to a pair of leptons ($Z \to ee$ or $Z \to \mu\mu$). For such events, we can distinguish two contributions to the total MET:

- The **fake MET component** (0-150 GeV), corresponding to the mismeasurement induced by detector effects (dead regions, object mismeasurement, etc.)
- The **true MET component** (above 150 GeV), associated to particles escaping the event reconstruction (*e.g.* $ZZ \to l\nu l\nu$).



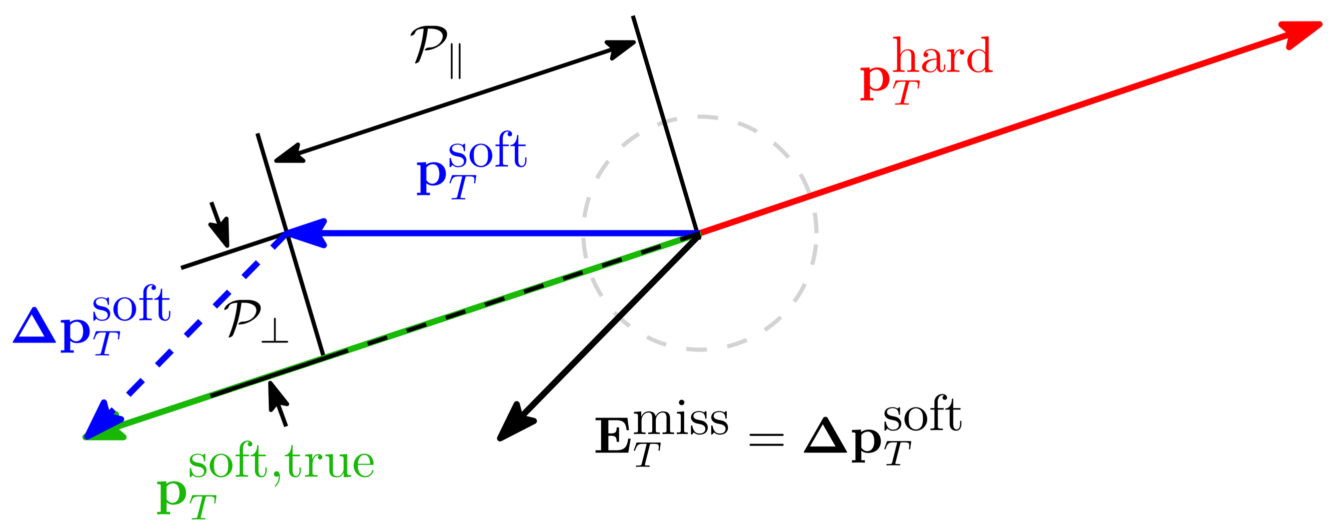
TST systematic uncertainties

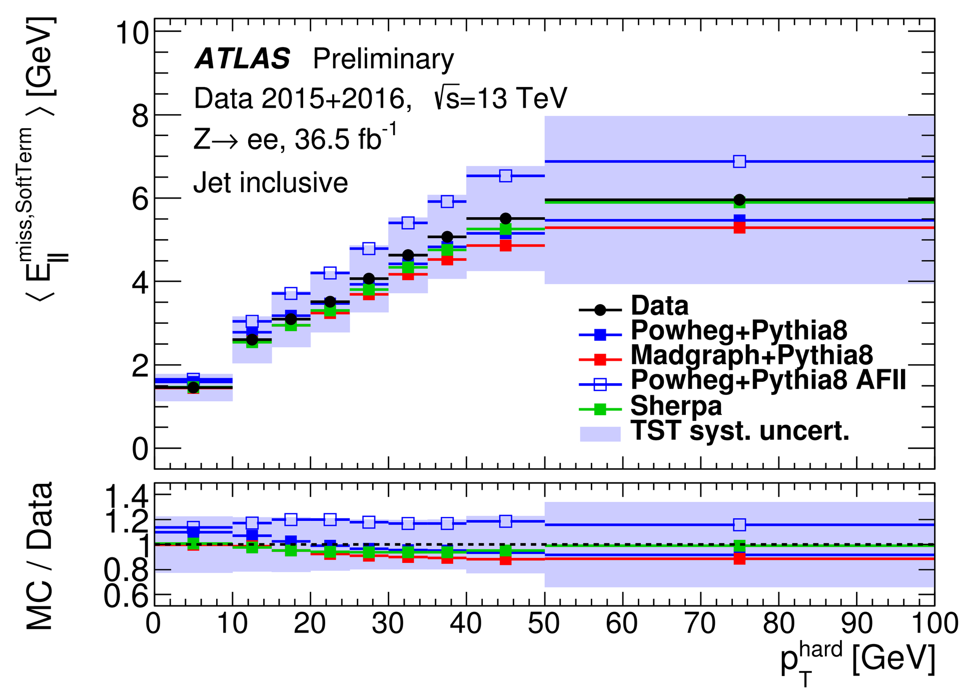
The systematics associated to the soft MET reconstruction play an important role in the full set of uncertainties associated to the ATLAS experiment. Considering the ideal balance between hard and soft components (*i.e.* $\mathbf{p}_T^{\text{hard}} = -\mathbf{p}_T^{\text{soft,true}}$), it is possible to study the features of the $\mathbf{p}_T^{\text{soft}}$ distributions after projection along $\mathbf{p}_T^{\text{hard}}$:

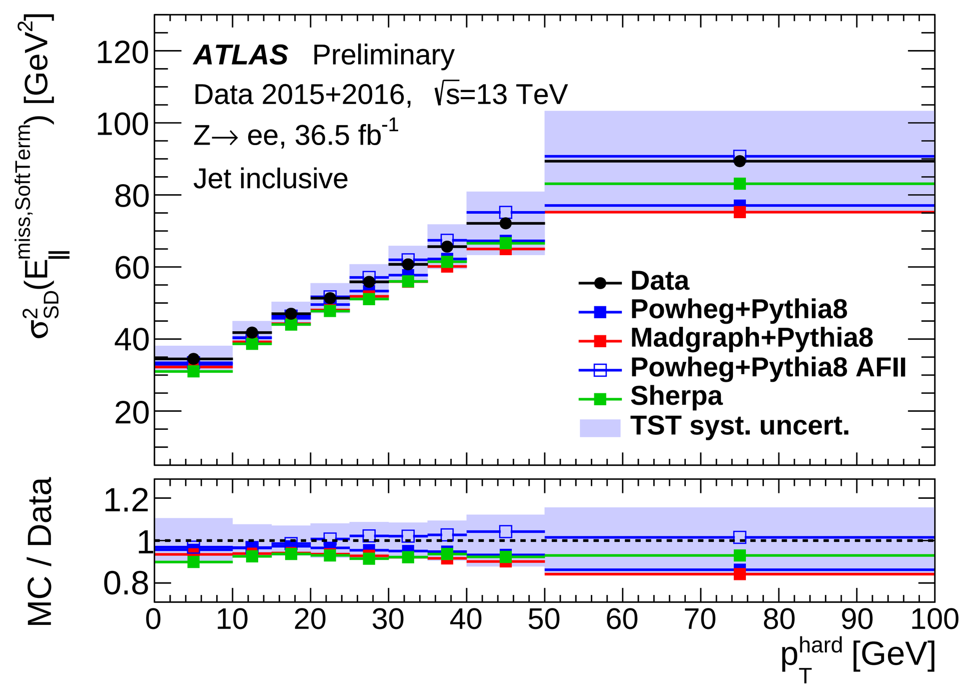
$$\mathbf{p}_T^{\text{hard}} = \sum_{\substack{\text{selected}\\\text{electrons}}} \mathbf{p}_T^e + \sum_{\substack{\text{selected}\\\text{photons}}} \mathbf{p}_T^\gamma + \sum_{\substack{\text{selected}\\\tau-\text{leptons}}} \mathbf{p}_T^\tau + \sum_{\substack{\text{selected}\\\text{muons}}} \mathbf{p}_T^\mu + \sum_{\substack{\text{selected}\\\text{jet}}} \mathbf{p}_T^{\text{jet}}.$$

The systematics are then studied by computing the **maximal Data to Monte Carlo discrepancies** in the following projected quantities:

- **Parallel mean value**: $\left\langle E_\parallel^{\text{miss,soft term}} \right\rangle$
- **Parallel resolution**: $\sigma^2\left(E_\parallel^{\text{miss,soft term}}\right)$
- **Perpendicular resolution**: $\sigma^2\left(E_\perp^{\text{miss,soft term}}\right)$

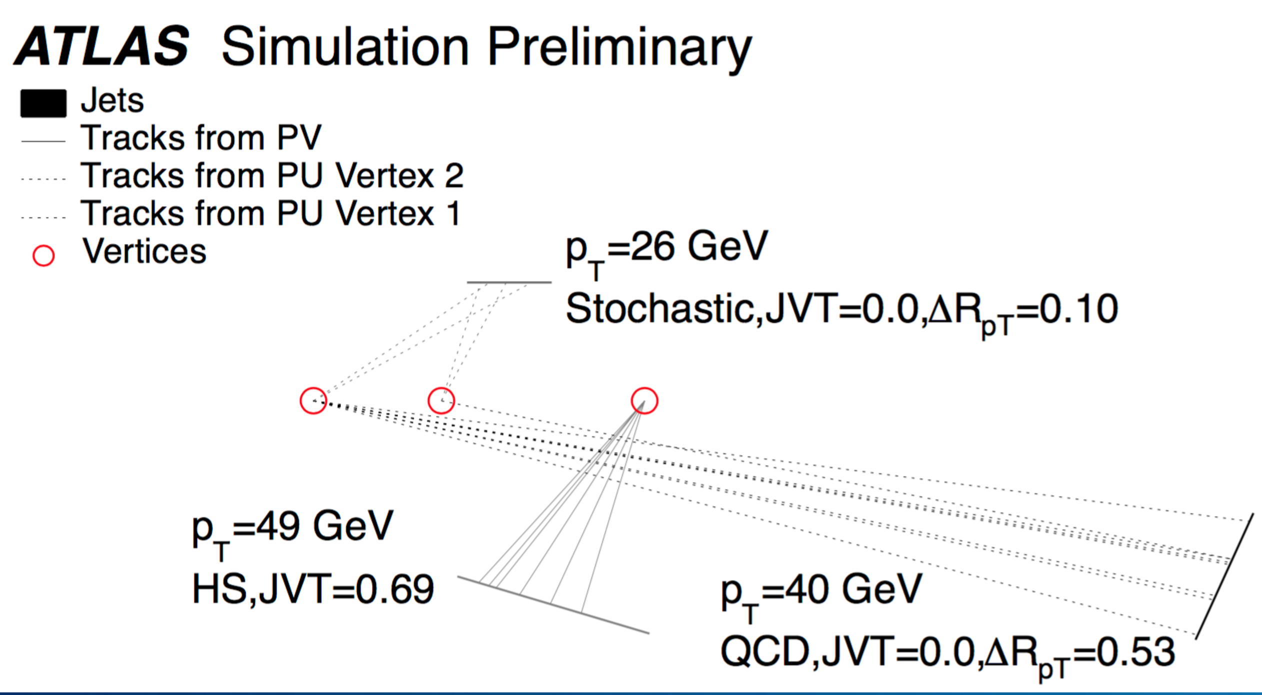


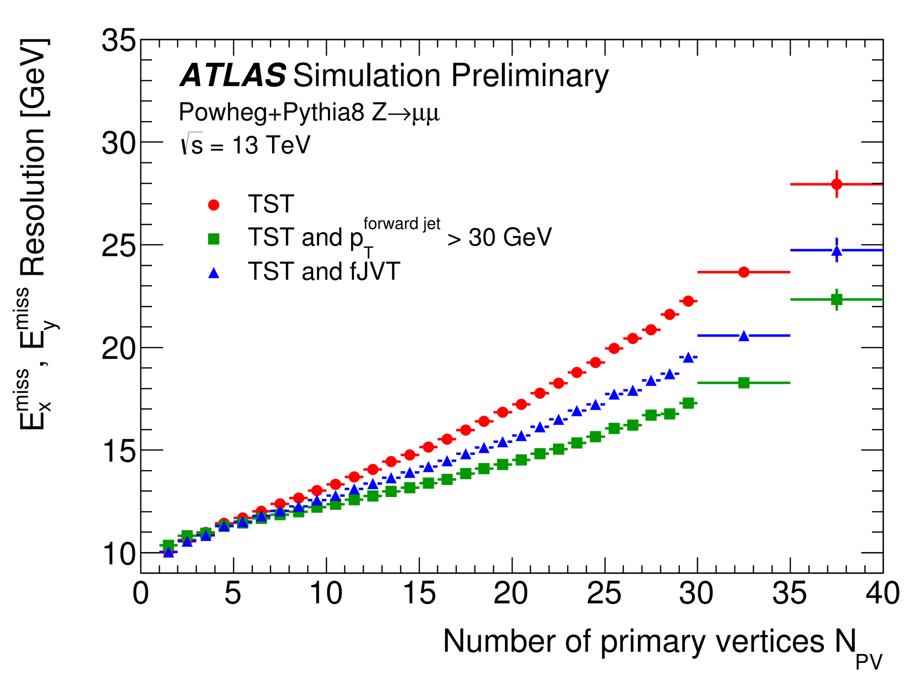


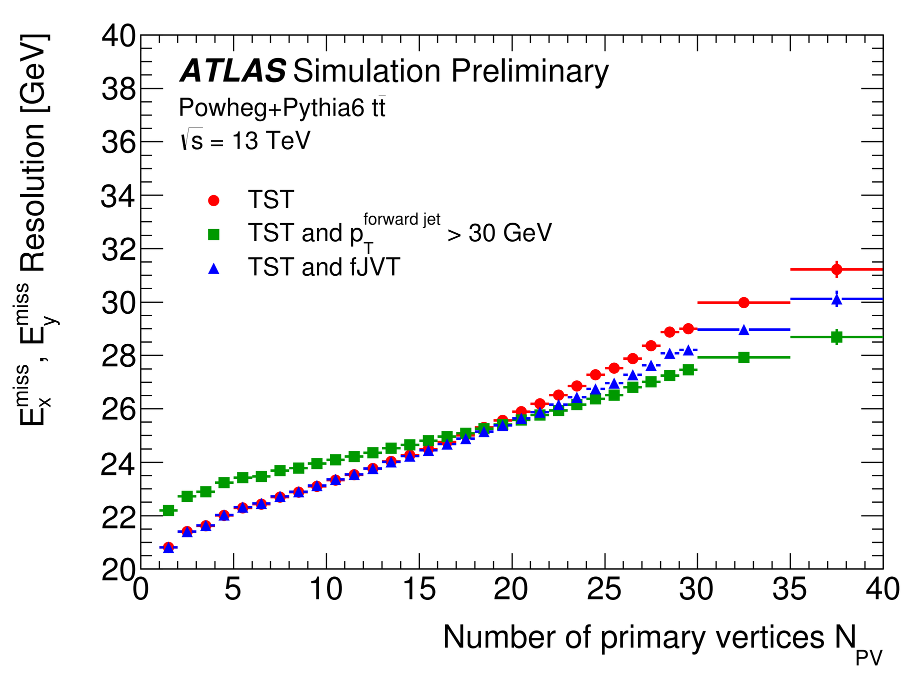


Forward Jet Vertex Tagger (fJVT) and MET

Hard Scatter (HS) pileup jets can be efficiently rejected by the Jet Vertex Tagger (JVT) in the region surrounded by the ATLAS inner tracking system ($|\eta| < 2.5$). However, soft QCD pileup jets produced outside the ATLAS tracker can escape this suppression, resulting in a bad MET resolution. The forward Jet Vertex Tagger (fJVT) exploits the back-to-back jet topology of these pile-up interactions to efficiently suppress pileup from the region uncovered by the ATLAS tracking system ($2.4 < |\eta| < 4.9$). This suppression allows to significantly reduce the tails in the total MET, resulting in an improvement of the MET resolution as function of the number of primary vertices (N_{PV}). The tight forward jet working point (forward jet $p_T > 30$ GeV) also allows to efficiently remove pileup jets in events simulated with a low jet multiplicity ($Z \to \mu\mu$). However, the MET resolution becomes worse than the current TST reconstruction in $t\bar{t}$ events for $N_{\text{PV}} < 20$.







Conclusions

The achievement of the best possible MET reconstruction represents a fundamental task for many of the ATLAS searches for new physics. The current MET recommendations (TST, TST + fJVT, and TST + tight forward jets) have recently improved the ATLAS MET resolutions by values between 0 and 7 GeV. The TST systematic uncertainties have also been developed using the actual statistics collected during the Run II data taking. New MET reconstruction techniques are always under study at the ATLAS experiment, leaving space for further improvements in the near future.

References

[1] Tagging and suppression of pileup jets with the ATLAS detector. Technical Report ATLAS-CONF-2014-018, CERN, Geneva, May 2014.

[2] Forward Jet Vertex Tagging: A new technique for the identification and rejection of forward pileup jets. Technical Report ATL-PHYS-PUB-2015-034, CERN, Geneva, Aug 2015.

[3] The ATLAS collaboration. Expected performance of missing transverse momentum reconstruction for the ATLAS detector at $\sqrt{s}$ = 13 TeV. Technical Report ATL-PHYS-PUB-2015-023, CERN, Geneva, Jul 2015.

Marco Valente (Université de Genève), for the ATLAS collaboration.