Performance of missing transverse momentum (MET) reconstruction at the ATLAS experiment

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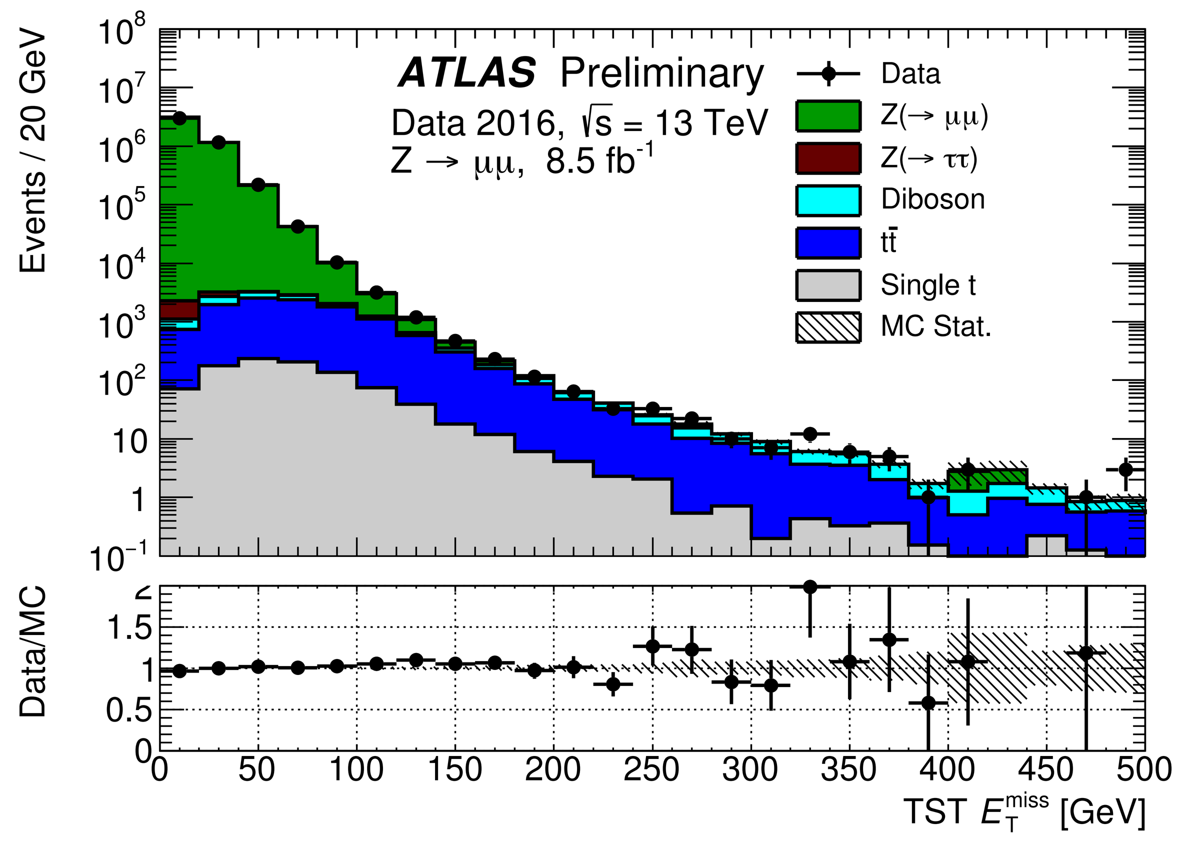
ATLAS EXPERIMENT

Introduction

The 13 TeV center-of-mass energy and the high luminosity provided by the Large Hadron Collider (LHC) in the last years opened the door to a various set of possible discoveries in particle physics. In many of these predictive models, the missing transverse momentum (MET) represents a fundamental piece in the detection of new physics and the studies of MET performance corresponds to a fundamental task in the identification of such processes.

MET distributions



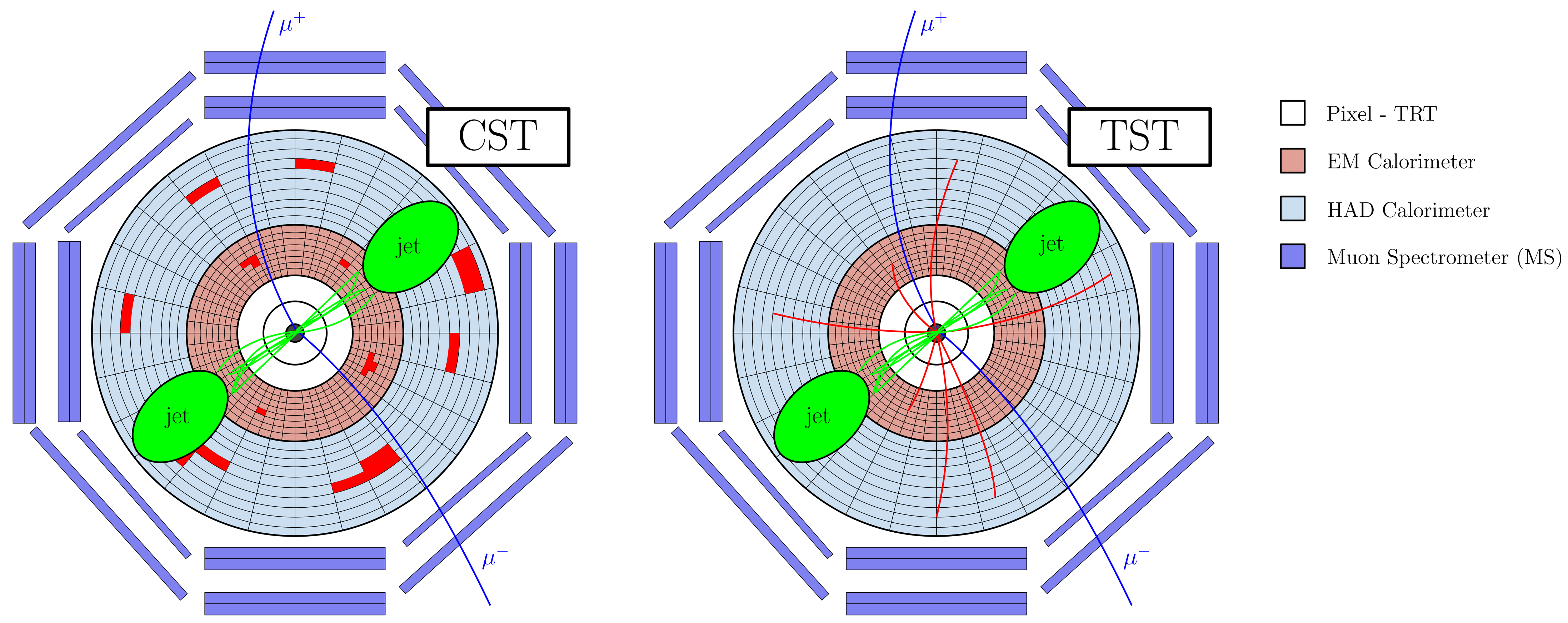
MET definition and reconstruction

The reconstruction of MET at the ATLAS detector is studied from two main contributions: the **hard component** issued from objects which can be well identified/calibrated and the **soft component** reconstructed from signals which are not associated to a hard object:

$$\mathbf{E}_T^{\rm miss} = -\left(\mathbf{p}_T^{\rm hard} + \mathbf{p}_T^{\rm soft}\right) = \overbrace{-\sum_{\substack{\rm selected\\ \rm electrons}} \mathbf{p}_T^{e} - \sum_{\substack{\rm accepted\\ \rm photons}} \mathbf{p}_T^{\gamma} - \sum_{\substack{\rm accepted\\ \tau-\rm leptons}} \mathbf{p}_T^{\tau} - \sum_{\substack{\rm selected\\ \rm muons}} \mathbf{p}_T^{\mu} - \sum_{\substack{\rm accepted\\ \rm jet}} \mathbf{p}_T^{\rm jet}}^{\text{hard term}} \overbrace{- \sum_{\substack{\rm tracks\ or\\ \rm clusters}} \mathbf{p}_T^{\rm soft\ terms}}^{\text{soft term}}.$$

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

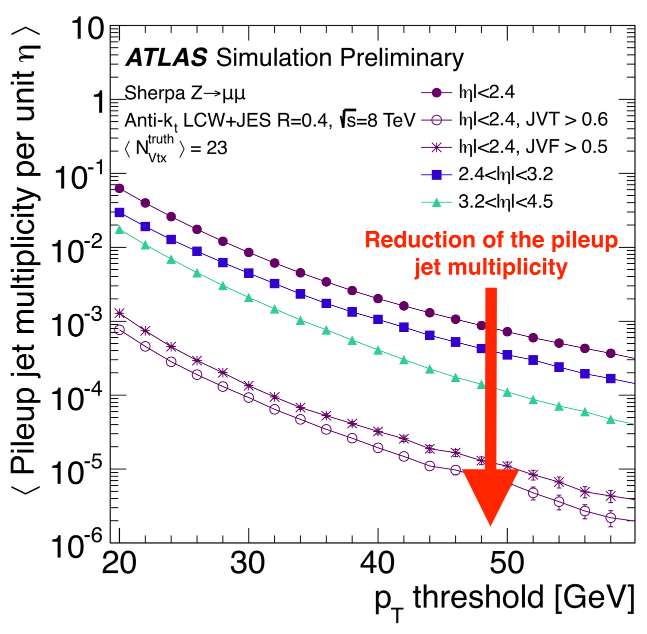
- **Calorimeter based Soft Term (CST),** accounting for both neutral and charged particle energies.
- **Track based Soft Term (TST),** incorporating a natural pileup suppression by selecting only PV tracks.



Pileup jet suppression

The pileup suppression of a TST based reconstruction is provided by applying a cut over the output of a **multivariate algorithm**, also referred as Jet-Vertex-Tagger (JVT). The input of JVT is represented by the following quantities:

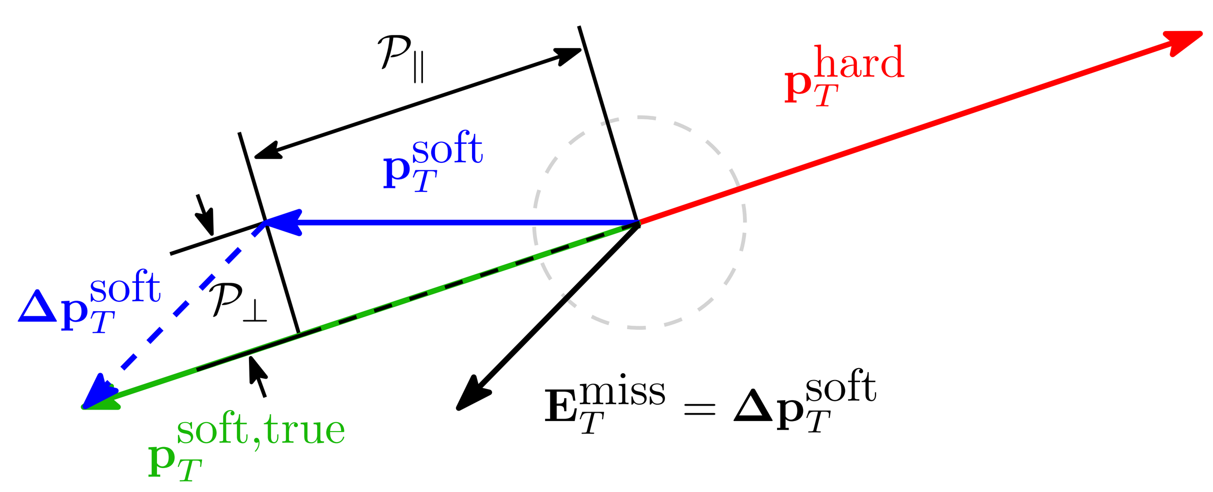
$$\mathrm{corrJVF} = \frac{\sum_k p_T^{\mathrm{trk}_k}(PV_0)}{\sum_l p_T^{\mathrm{trk}_l}(PV_0) + \frac{\sum_{n\geq1}\sum_l p_T^{\mathrm{trk}_l}(PV_n)}{k \cdot n_{\mathrm{trk}}^{\mathrm{PU}}}}, \quad R_{pT} = \frac{\sum_k p_T^{\mathrm{trk}_k}(PV_0)}{p_T^{\mathrm{jet}}}.$$

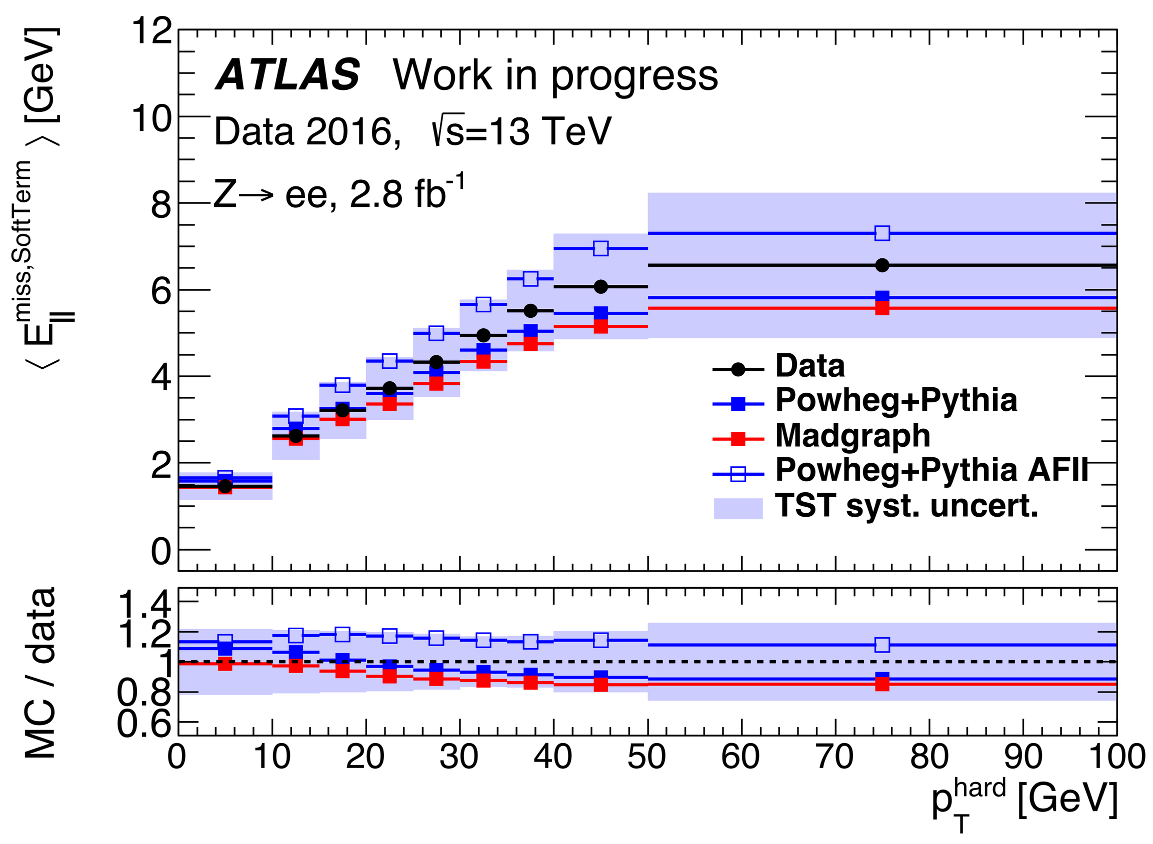


TST systematic uncertainties

The systematics associated to the soft MET reconstruction play an important role in the ATLAS experiment uncertainties. Considering the ideal balance between hard and soft components (*i.e.* $\mathbf{p}_T^{\rm hard} = -\mathbf{p}_T^{\rm soft,true}$), it is possible to study the features of the $\mathbf{p}_T^{\rm soft}$ distributions after projection along $\mathbf{p}_T^{\rm hard}$. The systematics are then studied by computing the **maximal data/mc discrepancies** in the following projected quantities:

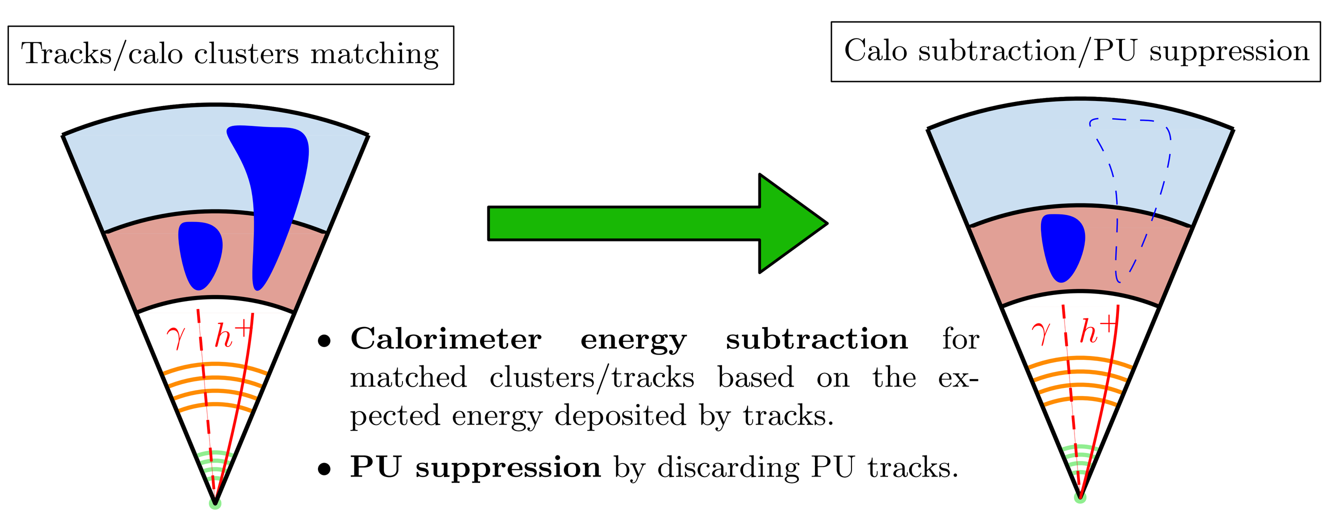
- **Parallel mean value**: $\left\langle E_{\parallel}^{\rm miss,soft\ term}\right\rangle$
- **Parallel resolution**: $\sigma^2\left(E_{\parallel}^{\rm miss,soft\ term}\right)$
- **Perpendicular resolution**: $\sigma^2\left(E_{\perp}^{\rm miss,soft\ term}\right)$





Particle Flow and MET

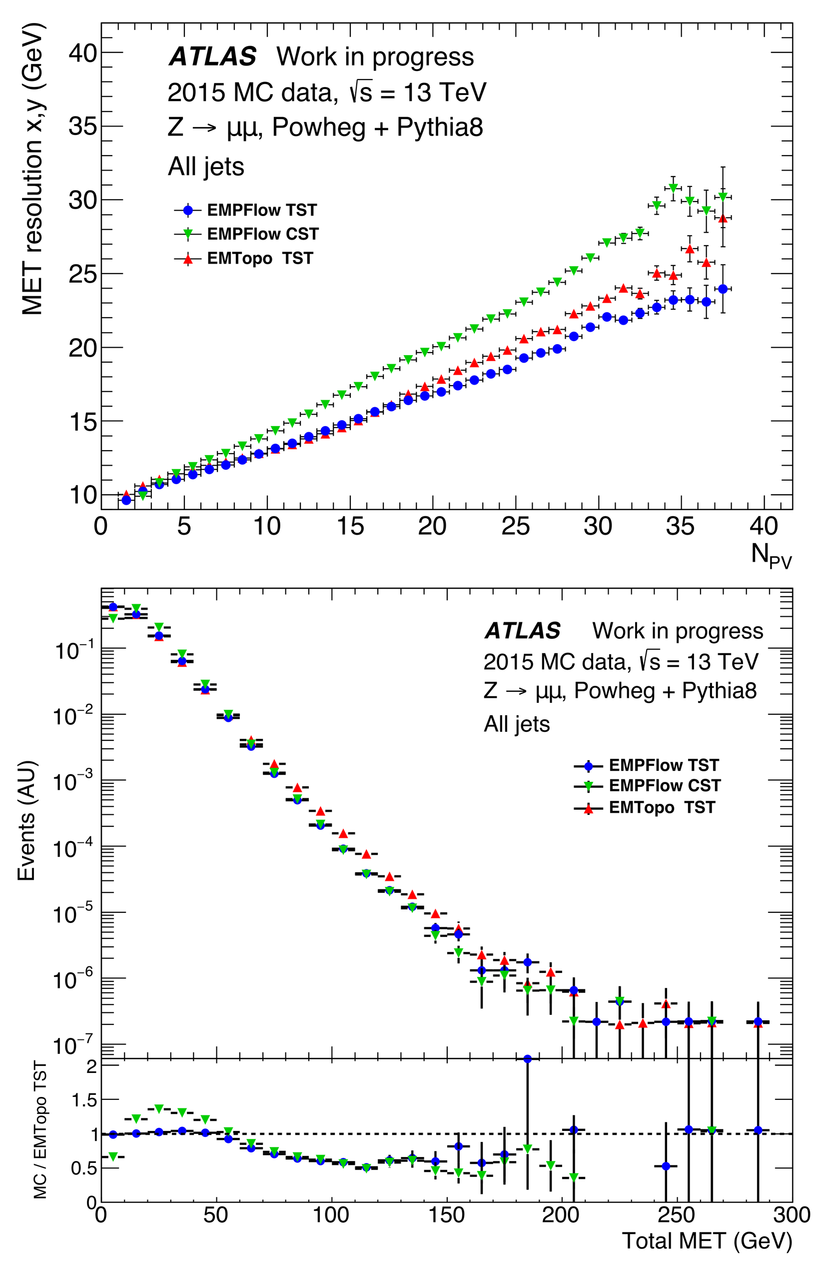
The combination of the large energy resolution associated to low p_T tracks and high p_T calo clusters could greatly improve the performance of the ATLAS MET reconstruction. *Particle Flow* – or *PFlow* – algorithms aim to combine the tracker and calorimeter information in order to improve the event reconstruction performance. These algorithms have already produced successful results in several particle physics experiments and could improve both $\mathbf{p}_T^{\rm hard}$, $\mathbf{p}_T^{\rm soft,true}$ reconstructions.



- **Calorimeter energy subtraction** for matched clusters/tracks based on the expected energy deposited by tracks.
- **PU suppression** by discarding PU tracks.

How does Particle flow work?

1. Tracks are selected and extrapolated up to the calorimeter system.
2. Matched calorimeter energy deposits subtracted based on $E^{\rm calo}/p^{\rm track}$.
3. MET and jets are reconstructed from PV-associated tracks surviving calo energy.



Conclusions

The understanding and improvement of MET represents a key task for a lot of the analysis associated to the ATLAS detector. The current recommendation (TST) allows to reconstruct MET with resolutions values between 10 and 28 GeV. The utilisation of PFlow based techniques could provide in the near future an important improvement to this quantity and to the ATLAS detector performance.

References

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