LHCC Poster Session - CERN, 22 February, 2017

# Development and Performance of the Combined Jet Mass in ATLAS


## Abstract

The jet mass is a crucial discriminating variable in studies involving jet substructure.The calorimeter mass has been the canonical mass definition during the first run of ATLAS. This poster describes how the calorimeter mass can be combined with the track-assisted jet mass (which is obtained by associating inner detector tracks with calorimeter jets), to yield a new jet mass definition, the combined jet mass.


## What is a Combined Jet Mass ?

Combined mass: a weighted linear combination of **calorimeter mass** [1] (mass from topo-clusters), ***m<sup>calo</sup>***, and the **track-assisted (TA) mass** [1] (associate [2] ID tracks to jets), ***m<sup>TA</sup>***

$$\boxed{m^{comb} = w_{calo} \times m^{calo} + w_{TA} \times m^{TA}}$$

Central idea [3, 4]: determine the weights which minimise the variance of the combined jet mass response, $\boldsymbol{\mathcal{R}^{comb} = m^{comb}/m^{truth}}$, hence produce a minimal **fractional mass resolution** *

~ 0, neglecting correlations

$$var(\mathcal{R}^{comb}) = w_{calo}^2 \times var(\mathcal{R}^{calo}) + w_{TA}^2 \times var(\mathcal{R}^{TA}) + 2w_{calo}w_{TA} \times cov(\mathcal{R}^{calo}, \mathcal{R}^{TA})$$

$$\mathcal{R}^{comb} = w_{calo} \times \mathcal{R}^{calo} + w_{TA} \times \mathcal{R}^{TA}$$

$$\sigma_{comb}^2 = w_{calo}^2 \times \sigma_{calo}^2 + (1 - w_{calo})^2 \times \sigma_{TA}^2$$

Minimise

$$w_{calo} = \frac{\sigma_{calo}^{-2}}{\sigma_{calo}^{-2} + \sigma_{TA}^{-2}}$$

$$w_{TA} = \frac{\sigma_{TA}^{-2}}{\sigma_{calo}^{-2} + \sigma_{TA}^{-2}}$$

*

$$\sigma_{calo,TA} = \frac{IQnR_{calo,TA}}{2 \times \mathcal{M}(\mathcal{R}^{calo,TA})}$$

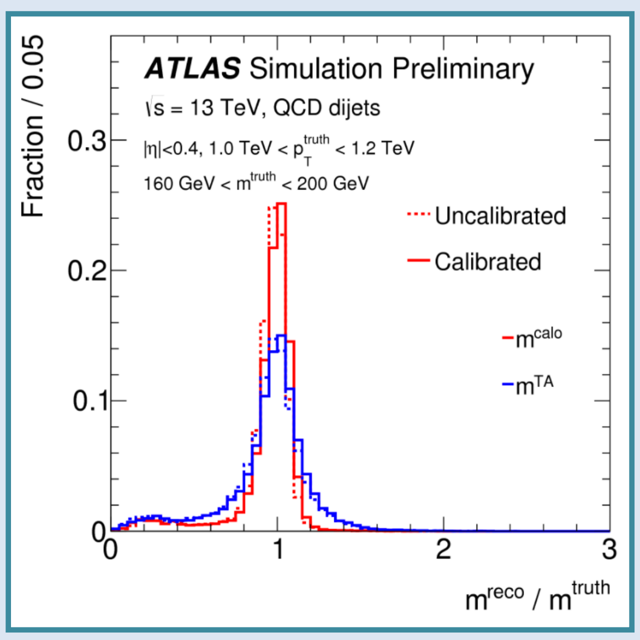



Figure 1: A calorimeter mass response distribution. The fractional mass resolution is calculated from the **median ($\mathcal{M}$)** and 68 % **interquantile range (*IQnR*)** of the mass response.

## Development of the Combined Jet Mass

The calorimeter and TA weights are calculated from fractional resolution maps, where the fractional resolution is plotted in bins of the calorimeter jet transverse momentum, $\boldsymbol{p_T^{calo}}$, and $\boldsymbol{m^{calo(TA)}/p_T^{calo}}$, which measures the Lorentz boost of a jet, for the calorimeter (TA) resolution. The jets have pseudo-rapidity in the range -2.0 to +2.0.

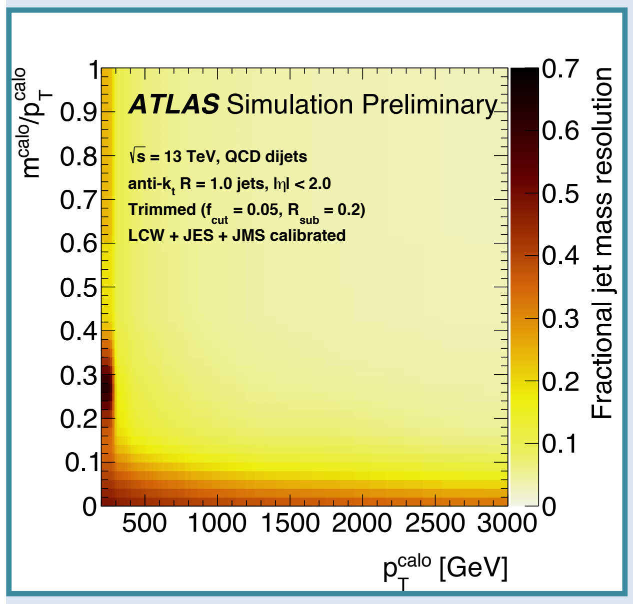



Figure 2 (above): the calorimeter fractional mass resolution map, after (Gaussian kernel) smoothing [6].

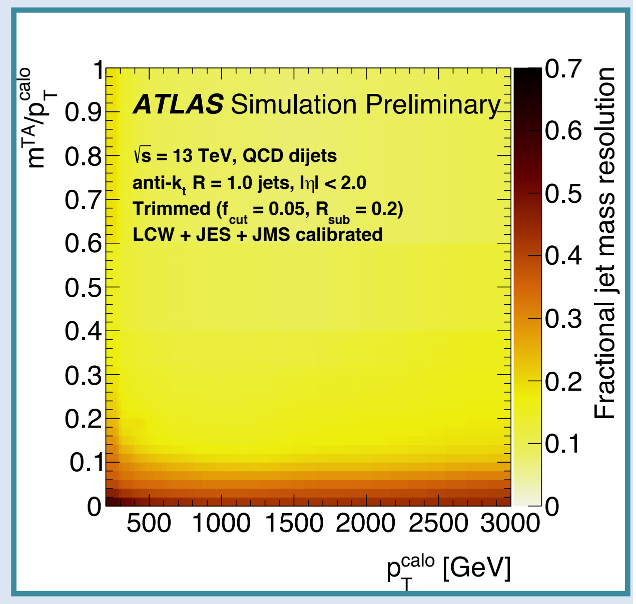



Figure 3 (above): the track-assisted fractional mass resolution map, after (Gaussian kernel) smoothing [6].

It is possible to also derive **combined mass weights with a correlation correction**, where the correlation correction comes from the correlation between the calorimeter and track-assisted mass responses. With correlations it should be possible to further improved the combined jet mass performance. This work is still preliminary and non-negligible correlations do not form part of the current Moriond recommendations. The combined mass recommendations for Moriond, 2017 [5], can be summarised:

- Combined mass weights derived from the calorimeter and track-assisted resolution maps, using jets from Pythia 8 QCD dijets.
- Correlations between mass responses are neglected.
- Correlation-corrected weights are available, but not recommended.

## Performance of the Combined Jet Mass

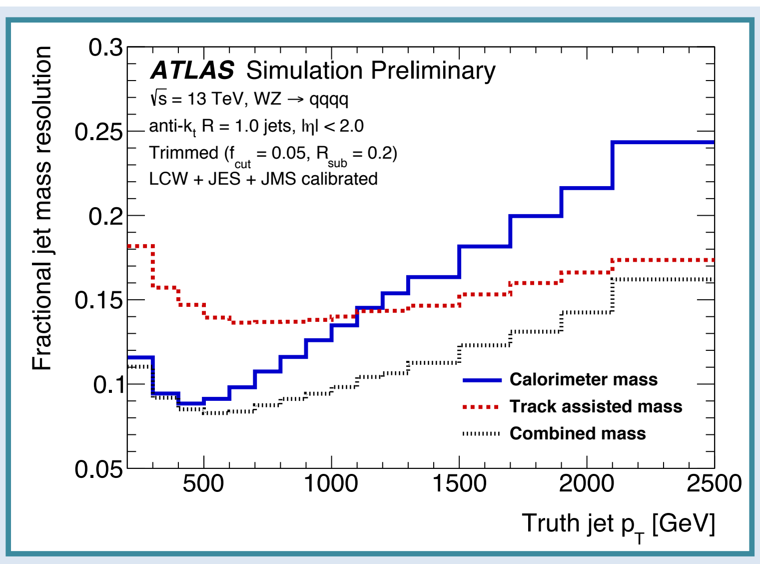


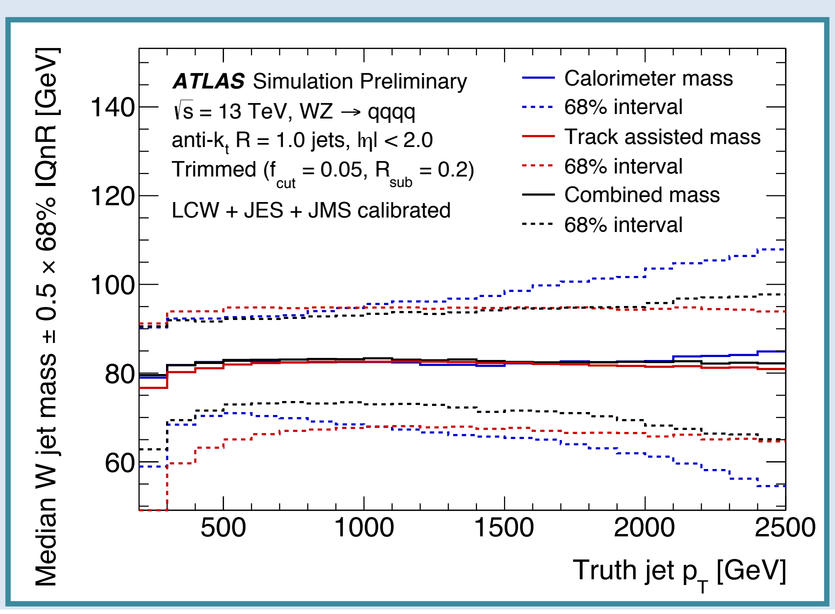

Figure 4 (above): The fractional jet mass resolution against the truth jet transverse momentum. Three mass definitions are considered: the calorimeter mass (blue), TA mass (red), and the combined mass (black).

Figure 4 demonstrates the **significant improvement in resolution achieved by the combined mass definition**, across both the resolved and boosted jet $p_T$ range.

- The combined mass weights were derived using the QCD dijets sample, **without including the effects of correlations**, (the current recommended weights).
- The weights are applied to a *W' —> WZ —> qqqq* jets sample.
- The degradation, at high $p_T$, of the calorimeter resolution is due to the finite granularity of the calorimeter.

Figure 5 compares the performance of the combined jet mass, with the calorimeter and TA masses, in **reconstructing the *W* mass peak**. The central line remains fixed at the *W* mass, indicating little bias between the mass definitions. Comparing the 68 % intervals, it can be seen that **smallest resolution of the *W* peak is given by the combined jet mass approach**.

Figure 5 (below): the median reconstructed *W* mass, against the truth jet $p_T$, for the calorimeter mass (black), TA mass (blue), the recommended combined mass (no correlations, red). The 68 % mass window intervals are also shown.



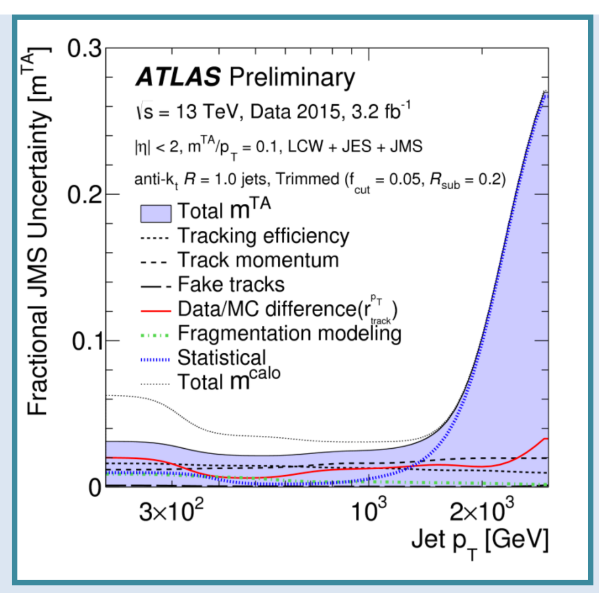




Figure 6 (above): the fractional jet mass uncertainties [7] for the track-assisted mass and calorimeter mass definitions, calculated using Monte-Carlo and 2015 data.

Figure 6 is an plot of the **fractional jet mass scale uncertainty** for the track-assisted and calorimeter jet masses, across a truth-jet $p_T$ range extending up to several TeV, for pseudorapidity ranging from -2.0 to +2.0, and $\boldsymbol{m^{TA}/p_T^{calo}}$. The total combined mass uncertainty lies between the calorimeter (black, dotted) and track-assisted (filled, purple) uncertainties and is therefore significantly lower than the total uncertainty from the standard calorimeter jet mass.

## References


[1] Jet Mass Reconstruction with the ATLAS Detector in Early Run 2, https://cds.cern.ch/record/2148246 ATLAS-COM-CONF-2016-029 (2016) The ATLAS Collaboration; [2] The Catchment Area of Jets, arXiv 0802.1188 (2008), JHEP0804:005 M., Salam G. P., Soyez G. ; [3] The Derivation and Performance of the Combined Jet Mass in the ATLAS Experiment, https://cds.cern.ch/record/2231534 ATL-COM-PHYS-2016-1596 (2016) Nelson M. E. et al. ; [4] The Summary of the Combined Jet Mass in ATLAS, https://cds.cern.ch/record/2231538 ATL-COM-PHYS-2016-1597 (2016) Nelson M. E. et al. ; [5] JetCalibTools, https://twiki.cern.ch/twiki/bin/viewauth/AtlasProtected/JetCalibTools (2016) ; [6] Kernel Smoothing, Chapman & Hall (1994) Jones M. C., Wand M. P. ; [7] Performance of Jet Substructure Techniques using large-R Jets in proton-proton collisions at sqrt(s) = 7 TeV using the ATLAS Detector, J. High Energ. Phys. (2013) 2013: 76



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