PROCEEDINGS OF SCIENCE

Measurement of colour flow with the jet pull angle in $t\bar{t}$ events using the ATLAS detector

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The distribution and orientation of energy inside jets is predicted to provide information about colour connections between the quarks and gluons that initiate the jets. If this information can be exploited then it may be a useful additional technique for Standard Model measurements and searches for physics beyond the Standard Model. One variable predicted to contain information about the colour connections between a pair of jets is the jet pull angle. The ATLAS collaboration has measured the jet pull angle using $t\bar{t}$ events, where a sample of dijets from the decay of a W boson can be cleanly identified.

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1. Introduction

The distribution and orientation of energy inside jets are predicted to provide information about colour connections between the hard-scatter quarks and gluons that initiate the jets. If these colour connections as well understood, it may be possible to exploit them to aid Standard Model (SM) measurements and searches for Beyond the Standard Model (BSM) Physics.

Techniques proposed to exploit colour connections can be tested using jets with an expected colour structure. Top anti-top quark ($t\bar{t}$) events in which one of the W bosons from one of the top quark decays hadronically can be used to perform these tests, as the jets from the W are expected to be colour connected.

One observable predicted to contain information about the colour representation of a dijet resonance, such as the W, Z or Higgs boson, is the *jet pull angle* [2].

2. The jet pull angle

The jet pull angle, θ_P, is constructed using the *jet pull vector*. The jet pull vector for a given jet J with transverse momentum p_{T}^{J} is defined as

$$\vec{v}_p^{\,J} = \sum_{i \in J} \frac{p_{\mathrm{T}}^{i} |r_i|}{p_{\mathrm{T}}^{J}} \vec{r}_i \,, \tag{2.1}$$

in which the sum is over the constituents of the jet, p_{T}^{i} is the transverse momentum of the i^{th} constituent and $\vec{r}_i$ is the distance between the jet axis and the constituent in (y, ϕ) space. The jet pull angle is the angle that this vector makes with the vector in the (y, ϕ) plane that connects jet J with a second jet. This is shown in Figure 1. The ATLAS collaboration [1] has measured the jet pull angle using lepton-plus-jets $t\bar{t}$ events [3].

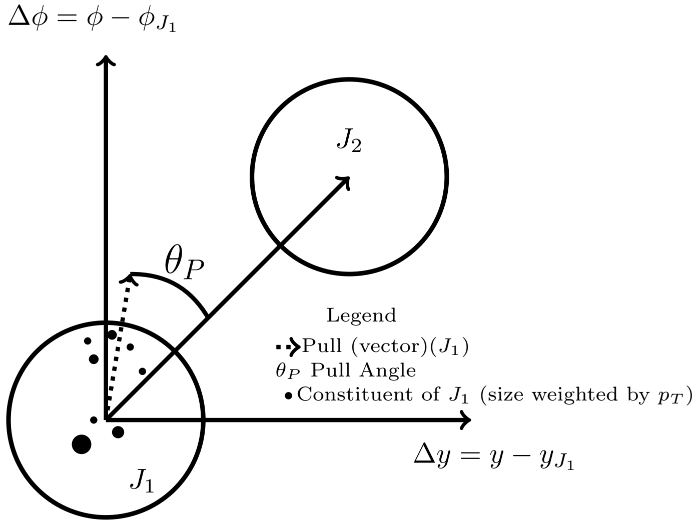

Figure 1: Diagram illustrating how the jet pull angle, θ_P, is constructed using the jet pull vector and the connecting line between two jet axes in the (y, ϕ) plane. Taken from [3]

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3. Event selection

To select a pure sample of $t\bar{t}$ lepton-plus-jets events, events must contain exactly one high-p_{T} lepton and missing transverse momentum. In addition, events must contain at least four jets in total, at least two of which are required to have been identified as originating from a b-quark [4]. The two highest-p_{T} non b-tagged jets are used to construct the jet pull angle, with the constituents of the highest-p_{T} jet used to construct the pull vector. If these jets are colour connected, then the jet pull angle is predicted to peak at zero. The sensitivity to colour flow effects is demonstrated by comparing data to SM $t\bar{t}$ Monte Carlo (MC) and to modified $t\bar{t}$ MC in which the W boson is exchanged for a colour octet. A schematic of the colour flow in these two scenarios is shown in Figure 2. Two pull angles are constructed using different jet constituents; inner detector (ID) tracks and calorimeter clusters. These are both corrected for detector resolution and acceptance effects using an iterative Bayesian unfolding algorithm [5]. While all particles and thus more information is included in the all-particles pull angle, constructed using calorimeter clusters, the better resolution of the ATLAS ID means that more bins can be used for the charged-particles pull angle.

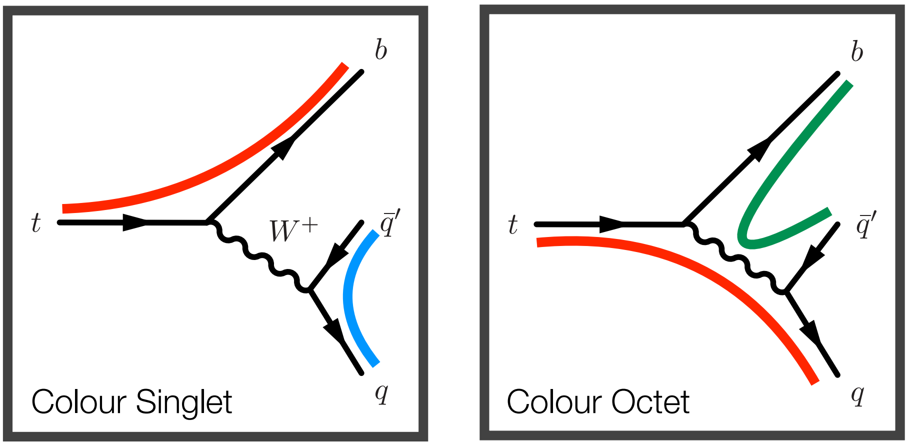
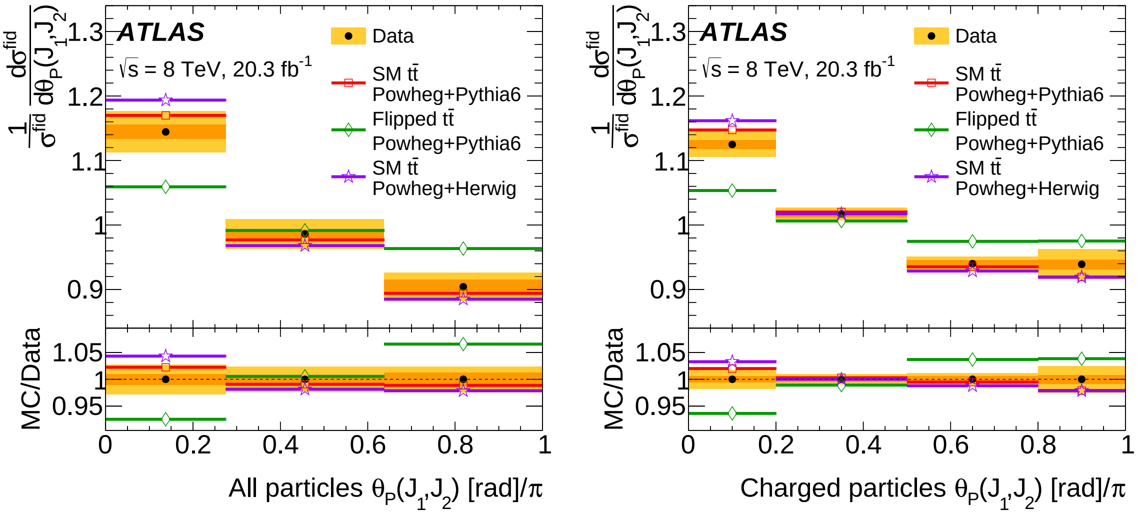


Figure 2: Schematic of the colour structures used in [3] to evaluate the sensitivity of the jet pull angle to colour flow. Taken from [3].

4. Results

The unfolded distributions are shown in Figure 3 for (a) calorimeter clusters unfolded to all stable particles inside the jet and (b) ID tracks unfolded to only charged particles inside the jet. The data are compared with three predictions, two SM predictions using different MC modelling, and one prediction in which the W-boson is replaced with a colour octet. The data are found to agree with the SM prediction and disfavour the colour octet model at 2.9σ (3.7σ) for the all-particles (charged-particles) pull angle. While it is found that there is little correlation between the statistical uncertainty of the two pull angles, the same is not true for the systematic uncertainty and thus a combination of the two pull angles does not significantly improve the sensitivity. The ability to distinguish between the two colour models considered in this analysis illustrates the potential to use the jet pull angle in future SM measurements and searches for BSM physics. Furthermore, the measurement is presented as a normalised fiducial differential cross-section, allowing the results to be used in the future to test models of colour connection.



(a) (b)

Figure 3: Comparison of data to $t\bar{t}$ predictions for the (a) all-particles and (b) charged-particles pull angle. The “Flipped” label in the legend refers to the colour-octet model described in the text. Taken from [3].

5. Acknowledgements

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References

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