Jet shapes, dijets and jet axes in CMS

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Motivation

Studying charged particle distributions around the jet axis gives information about jet quenching. In dijet events looking at both leading and subleading jets gives an additional handle on the path length dependence within the medium. When correlating jets and tracks, how one defines the jet axis becomes an important question. We argue that choosing a winner-take-all recombination scheme over the standard E-scheme leads to less biased correlation distribution. This winner-take-all scheme is also used in a new b-jet study exploring parton flavor dependence of the jet shapes.

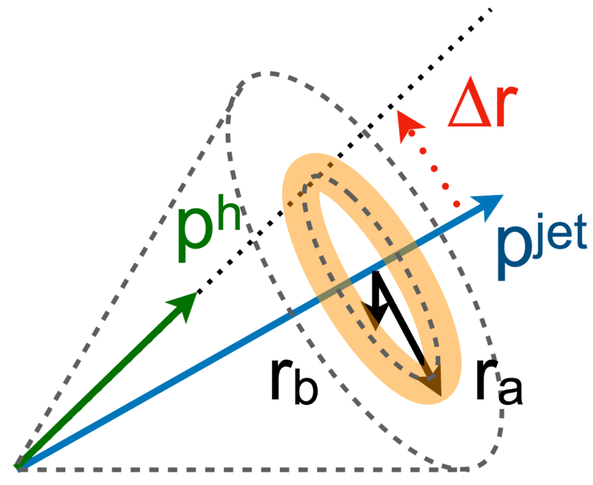
Observables

The radial momentum distribution of tracks around the jet axis is called the jet shape

$$\rho(\Delta r) = \frac{1}{\delta r}\frac{1}{N_{\text{jets}}}\sum_{\text{jets}}\frac{\sum_{\text{track}\in(r_a,r_b)} p_{\text{T}}^{\text{track}}}{p_{\text{T}}^{\text{jets}}}$$

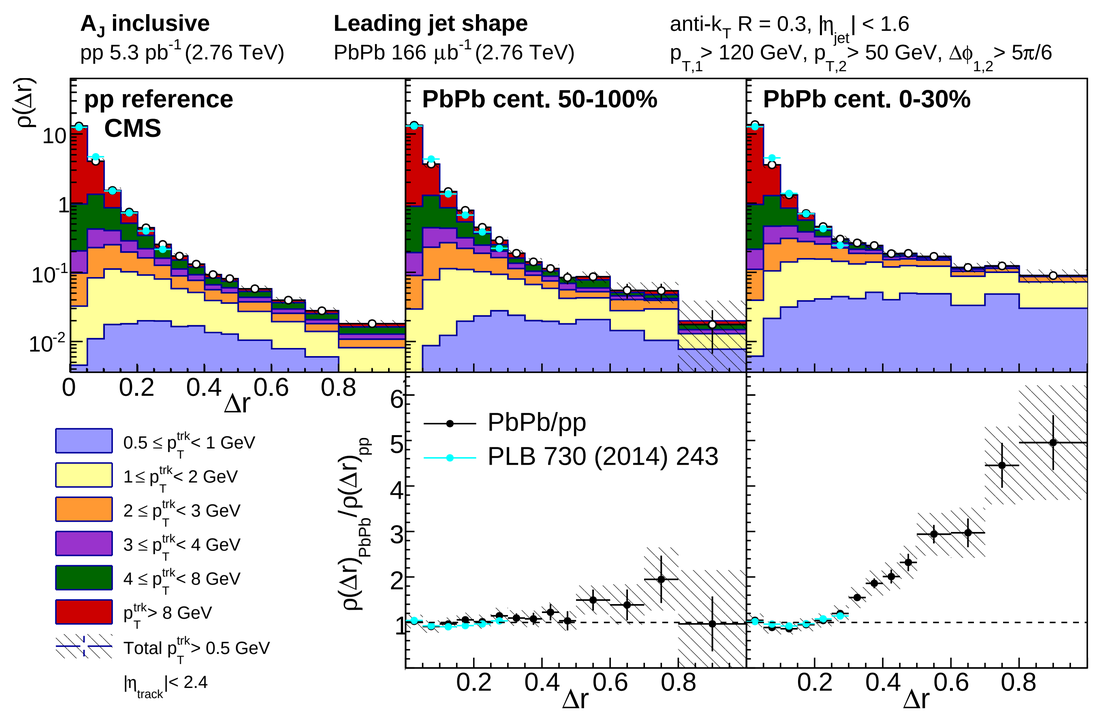
Dijet events can be categorized into balanced and unbalanced events based on the transverse momenta of leading and subleading jets. The variables used for this are x_j and A_j:

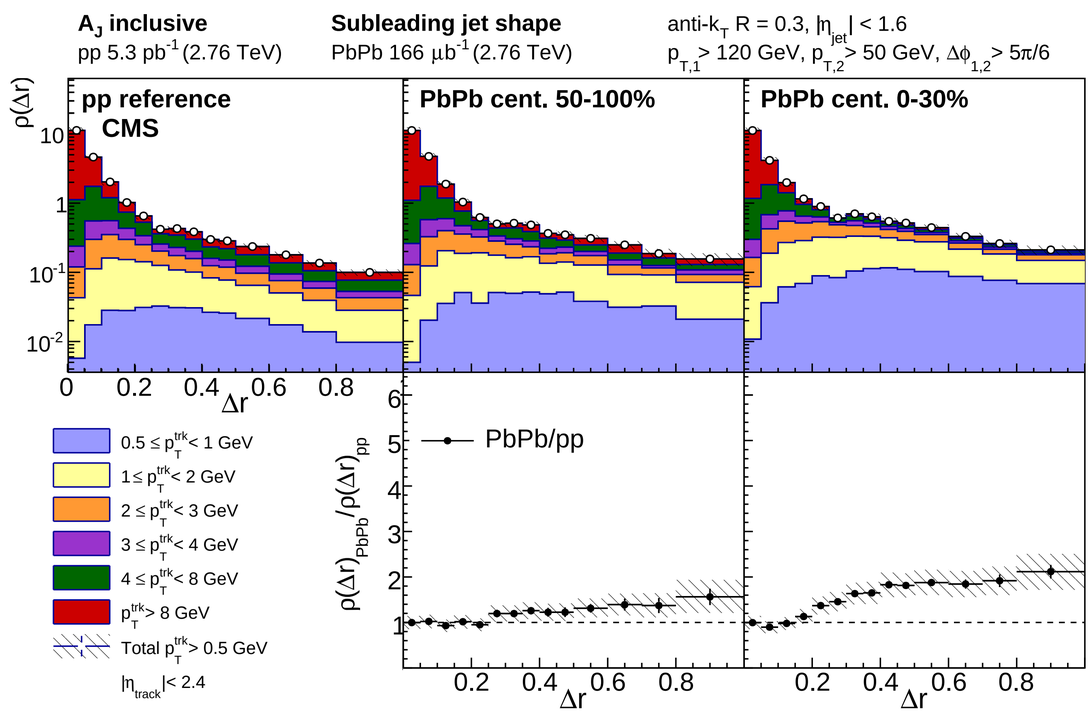
$$x_j = \frac{p_{\text{T,subleading}}}{p_{\text{T,leading}}} \quad A_j = \frac{p_{\text{T,leading}} - p_{\text{T,subleading}}}{p_{\text{T,leading}} + p_{\text{T,subleading}}}$$



Jet shapes from dijet events at $\sqrt{s_{\text{NN}}} = 2.76$ TeV

The CMS collabation has previously measured jet shapes in dijet events for $\sqrt{s_{\text{NN}}} = 2.76$ TeV PbPb collisions [1]. Broadening is seen for both leading and subleading sides. Even though the subleading side is broader overall, the PbPb to pp ratio has less excess there as also the pp reference is wider.





CMS is currently finalizing results to study the path length dependence by doing a jet shape measurement differentially in x_j bins and flavor dependence by constructing jet shapes from b-tagged jets. For these new measurements the jet axis definition is revised as discussed below to get smoother corrections.

Jet axis definitions and b-jet shapes

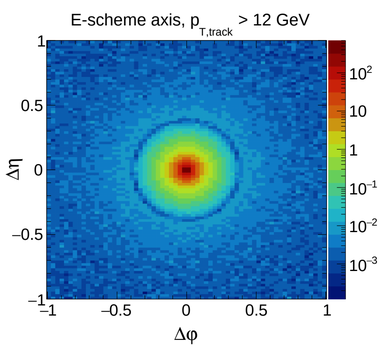
There are two popular methods to determine the jet axis.

i) E-scheme This is the default method in the FASTJET package. The pseudo-jets are merged by adding sub-jet 4-momenta together [2].

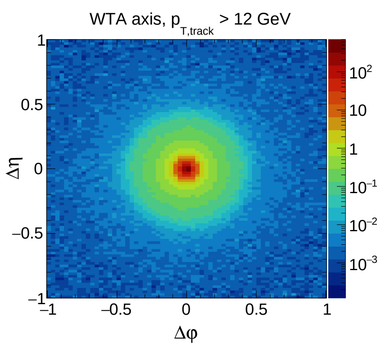
ii) Winner-take-all (WTA) In this method the momentum of the jet is obtained by summing the pseudo-jets, but the direction is given by the hardest pseudo-jet [3].

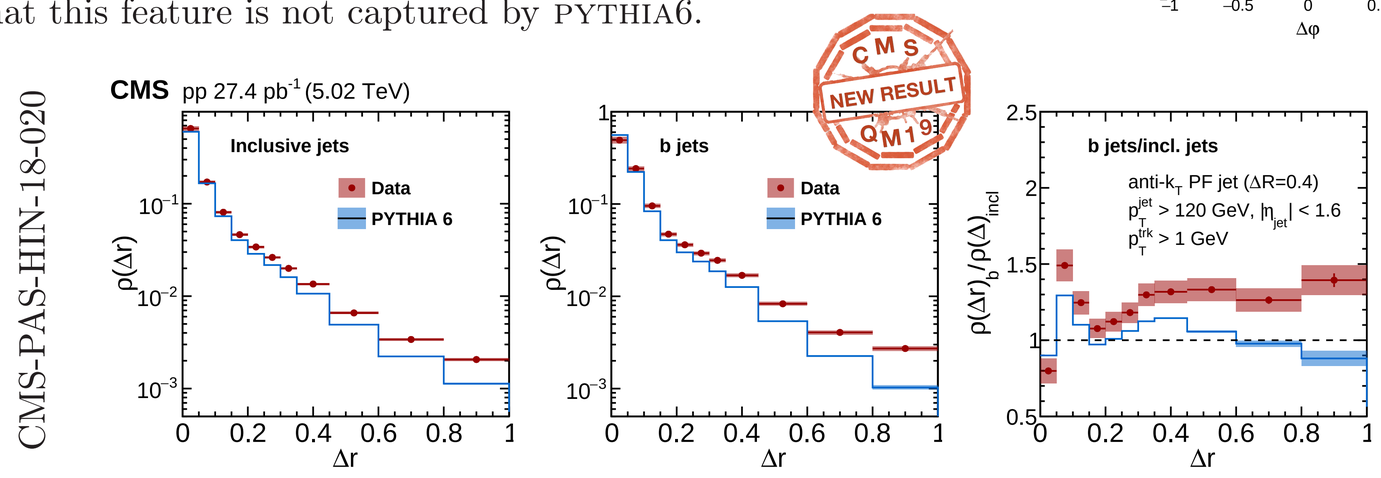
To see difference in correlations between the two axis definitions, we run a PYTHIA8 simulation with tune CP5 [4]. The jets are reconstructed from the generator level simulation using anti-k_{T} algorithm [5]. For E-scheme axis an artificial depletion develops at the jet radius parameter $R = 0.4$. This is not present for the WTA axis. A sharp structure like this makes corrections less stable, which is why WTA axis is better suited for correlation analyses.

The WTA axis is used in the new CMS b-jet measurement, which is the first b-jet shape measurement extending to large Δr. For b-jets at least one b-quark identified by combined secondary vertex discriminator [6] is required in the hadronization products. We see from the figure below that for pp data the b-jets are wider than inclusive jets and that this feature is not captured by PYTHIA6.



PYTHIA 8
Generator level





References

[1] CMS Collaboration, "Decomposing transverse momentum balance contributions for quenched jets in PbPb collisions at $\sqrt{s_{\text{NN}}} = 2.76$ TeV", JHEP 11 (2016) 055

[2] M. Cacciari, G. P. Salam, and G. Soyez, "FastJet User Manual", Eur. Phys. J. C72 (2012) 1896

[3] D. Bertolini, T. Chan, and J. Thaler, "Jet Observables Without Jet Algorithms", JHEP 04 (2014) 013

[4] CMS Collaboration, "Extraction and validation of a new set of CMS PYTHIA8 tunes from underlying-event measurements", arXiv:1903.12179

[5] M. Cacciari, G. P. Salam, and G. Soyez, "The anti-k_{T} jet clustering algorithm", JHEP 04 (2008) 063

[6] CMS Collaboration, "Identification of b-quark jets with the CMS experiment", JINST 8 (2013) P04013

Acknowledgements

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Disclaimer

New high precision jet shape results from dijet events using $\sqrt{s_{\text{NN}}} = 5.02$ TeV PbPb data collected in 2018 by the CMS experiment will soon be released! These new results explore path length dependence using x_j binning of the jet shapes. Also new results featuring b-tagged jet shapes in pp collisions will be released shortly.