Unfolding methods in studying nuclear modification factor of high transverse momentum jets in PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV

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Definition of Jet R_{AA}

The jet nuclear modification factor (R_{AA}) is defined as the ratio of inclusive jet yields per event in PbPb collisions over those in pp. It is formulated as follows, where T_{AA} is the ratio of number of binary nucleon-nucleon collisions and the inelastic cross section of pp.

$$R_{AA} = \frac{dN^{AA}_{jets} / dp_T}{< T_{AA} > d\sigma^{pp}_{jets} / dp_T}$$

Unfolding methods

- Unfolding uses the input Monte Carlo (MC) truth and reconstruction information to create a correlation matrix. The matrices are normalized so that the integral of the bins within the same generator level jets bins is one. The physical quantity of both pp and PbPb jet p_T spectra are unfolded from the detector effects that modify it. Besides the provided implementation of the RooUnfold package, the standard Richardson--Lucy method was implemented by ourselves. Correlated error is propagated by taking (numerical) partial derivatives with respect to the input spectrum with 4 iterations.
- For the Bayesian unfolding, the systematic uncertainty is studied by varying the number of unfolding iterations, as shown in Figure 1. The difference between the results from alternative number of iterations to 4 iterations is quoted as systematic uncertainty. The typical size of this uncertainty for the Bayesian unfolding method is 10-17% on the final jet R_{AA}.

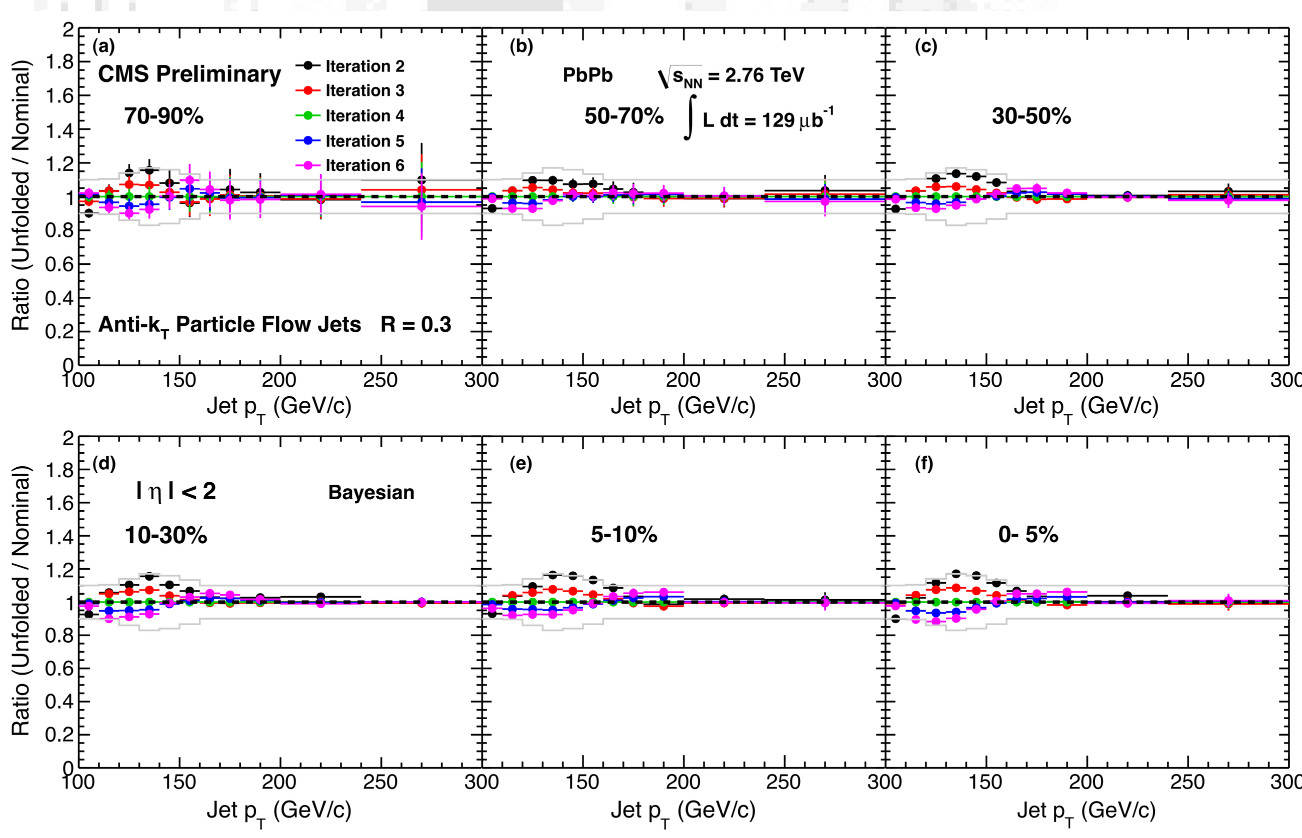

Figure 1. Iteration systematics for various iterations for PbPb with the nominal being four iterations

- Unlike Bayesian unfolding, which allows for the migration of events between bins, the bin-by-bin method assumes no migration, and thus corrects for detector effects only in the height of each jet p_T bin. Bin-by-bin unfolding can be a valid technique in the case where resolution is much smaller than the bin size. However, this technique is only shown as a cross-check.
- In addition, the standard method to perform Phillips--Tikhonov regularization, generalized singular value decomposition (GSVD) is used as another cross check.
- Monte Carlo closure has been done to verify the validity of various unfolding methods. The procedure is that half of the MC sample was used to build the correlation matrix while the other half were treated as "data" with their reconstructed and true jet values extracted. Figure 1 shows the closure test for the Bayesian and bin-by-bin unfolding methods. The jet spectra for unfolded, reconstructed MC jets from the "data" are compared to the generator level jets.

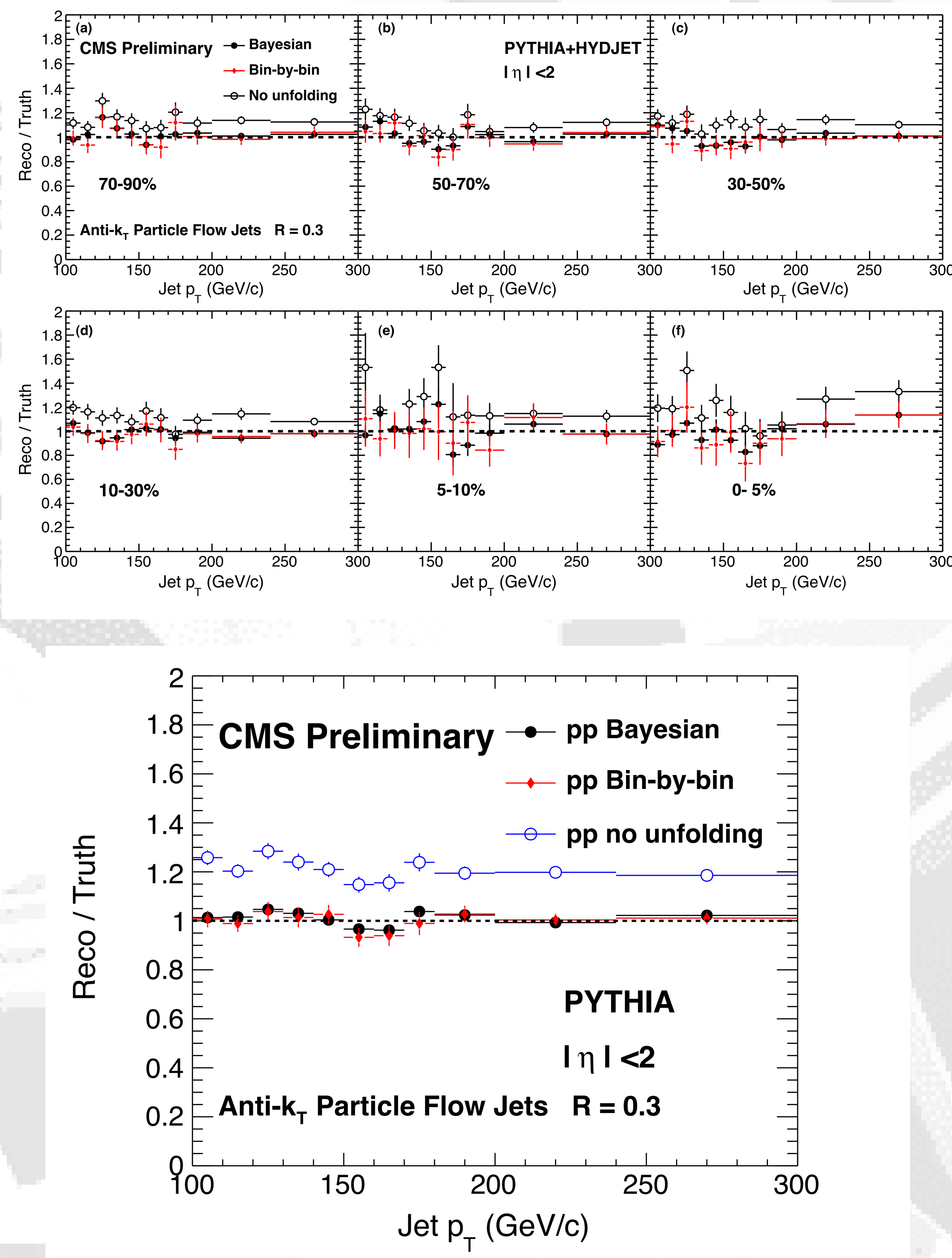

Figure 2. Monte Carlo closure test for PbPb (top panel) and pp (bottom panel)

References

[1] J. D. Bjorken, "Energy loss of energetic partons in QGP:possible extinction of high pT jets in hadron-hadron collisions",. FERMILAB-PUB-82-059-THY.
[2] J. Casalderrey-Solana and C. A. Salgado, "Introductory lectures on jet quenching in heavy ion collisions", Acta Phys. Polon. B38 (2007) 3731–3794, arXiv:0712.3443.
[3] D. d'Enterria, "Jet quenching", Landolt-Boernstein, Springer-Verlag Vol. 1-23A (2010) 99, arXiv:0902.2011.
[4] http://hepunx.rl.ac.uk/~adye/software/unfold/RooUnfold.html

Results

Figures 3 illustrates the Bayesian unfolded R_{AA} results as a function jet p_T for anti-k_T particle flow jets in R=0.3. Figure 4 shows the R_{AA} results as a function of jet p_T with all methods, including Bayesian unfolding, bin-by-bin unfolding, GSVD unfolding, and an alternative method using the smearing of pp data. All methods give consistent values of R_{AA} within the given uncertainties. For both figures, the statistical uncertainty is shown with the separation of uncorrelated and total (including correlated uncertainty). Jet R_{AA} without unfolding in comparison to the unfolded R_{AA} shows the amount of correction applied.

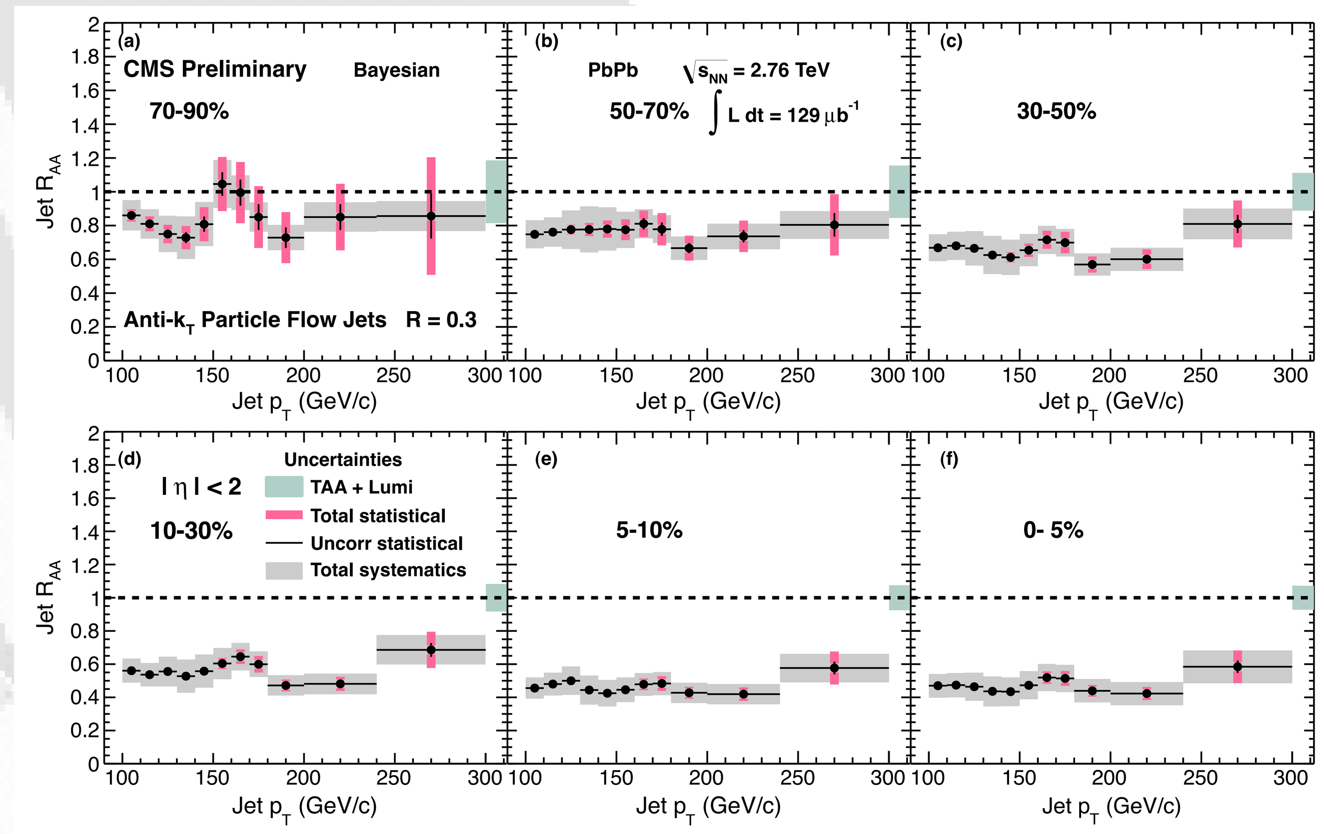

Figure 3. R_{AA} vs. Jet p_T with Bayesian unfolding

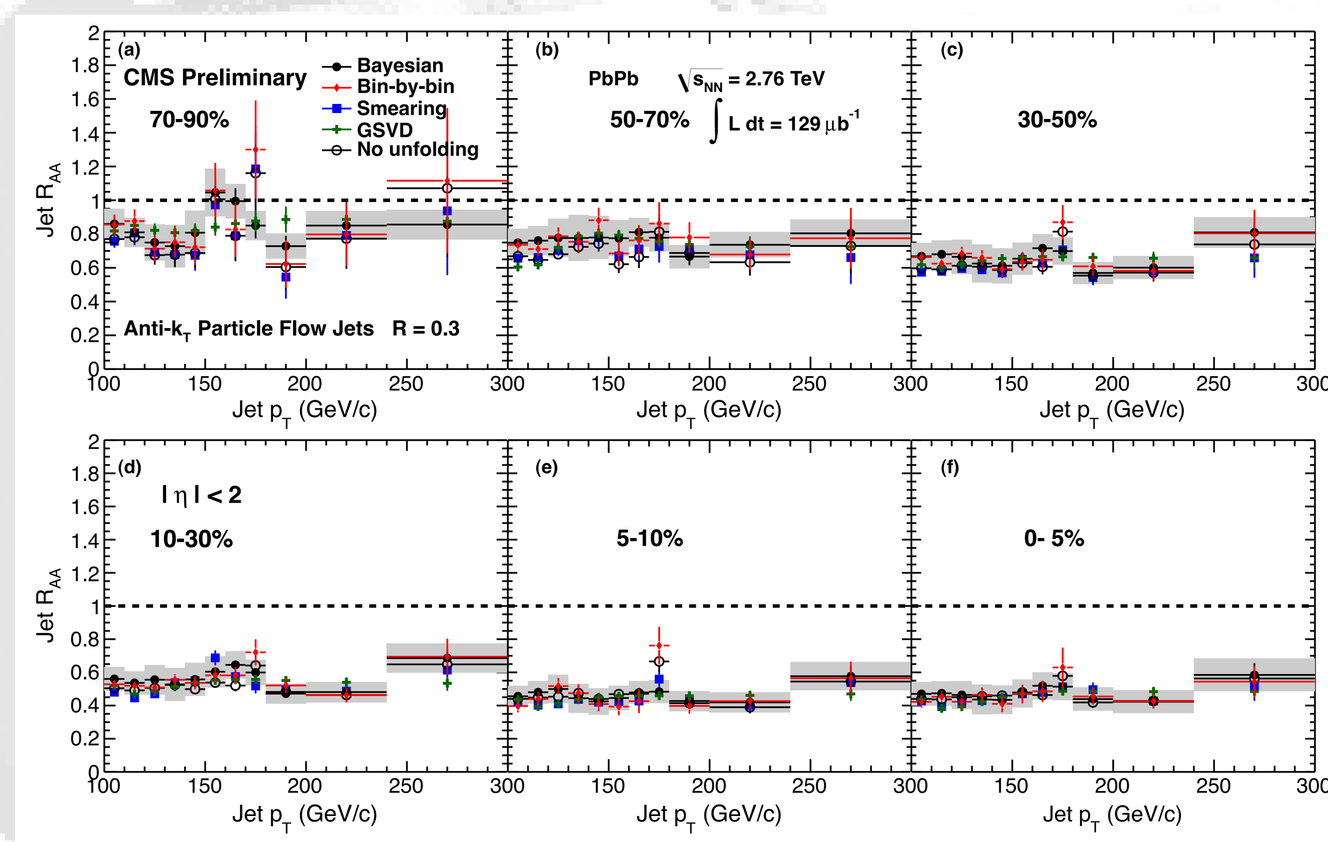

Figure 4. R_{AA} vs. Jet p_T with all correcting techniques

Conclusion

A suppression of high p_T jets is observed in central PbPb collisions in comparison to peripheral collisions at $\sqrt{s_{NN}}$=2.76 TeV with the implementation of various unfolding methods. Jet R_{AA} as a function of jet p_T results are consistent within systematic and statistical uncertainty for four different methods.