Toward understanding relativistic heavy-ion collisions with the STAR detector at RHIC

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High-energy heavy-ion collisions produced at RHIC produce a dense partonic matter called quark gluon plasma (QPG). The goal of this project is to study the properties of this material by comparing per-trigger yields of recoil jets produced in Au+Au and p+p collisions. Two papers were recently submitted to Physical Review Letters and Physical Review C [1,2], respectively. A third paper on medium-induced acoplanarity of recoil jets in central Au+Au collisions is in preparation to be submitted to Physical Review Letters. In these papers, the recoil jets were reconstructed with charged particles only and are referred to as “charged jets”. Current efforts are ongoing to reconstruct the “full jets”, which include the neutral energy as well.

In a γ-jet event, the trigger provides a calibrated baseline for the total energy of the jet particles on the recoil side of the trigger (opposite azimuth). The inclusion of the Barrel Electromagnetic Calorimeter (BEMC) provides a more accurate measurement of the total energy of jet particles on the recoil side of the event. The BEMC covers an area of $|\eta| < 1$ and full azimuth. It uses lead-scintillator towers to capture electromagnetic showers of up to 60 GeV [3]. The inclusion of an additional detector in the jet reconstruction requires additional quality assurance work, checking for hot towers and additional bad runs. In this analysis, a tower is considered hot if it registers a hit frequency greater than 5 standard deviations away from the average in set energy ranges for a given dataset. After the hot-tower check, 97% of the detector had valid towers in the dataset we intend to analyze.

The Run-9 dataset in p+p collisions and its corresponding embedding was used as a test of our method of unfolding jet spectra. Full-jet reconstruction was performed using the anti-k_T algorithm from the Fastjet package [4]. In this analysis, charged tracks with transverse momentum p_T between 0.2 and 30 GeV/c, as well as BEMC towers with transverse energy E_T above 0.2 GeV are considered as constituents. A fiducial cut is made on the pseudorapidity of the jet axis, $|\eta_{jet}| < (1 - R_{jet})$, where R_{jet} is the jet resolution parameter associated with the radial size of the jet. Two values of jet resolution parameter are considered, R_{jet} =0.2 and R_{jet} =0.5. Fig. 1 shows a comparison of the (raw) charged vs. full jet p_T spectrum on the recoil side of a p^0 trigger with E_T=9-11 GeV, before unfolding.

The Run-9 embedding sample is composed of PYTHIA di-jet events embedded into zero-bias p+p data. Jets were reconstructed as in data, for both simulated (PYTHIA) and detector-level (where the detector response is from a full GEANT simulation) events. Jets at the PYTHIA level are matched to jets at the detector level by requiring their centroids be within a certain distance in $\eta - \varphi$ space. This distance is 0.1 for a jet radius of 0.2 and 0.2 for a jet radius of 0.5. The response matrix for full jets with a π^0 trigger with E_T= 9-11 GeV, with a match closest in $\eta - \varphi$ space are shown in Fig. 2. PYTHIA jets which did not have a corresponding match at the detector level were considered an inefficiency, a correction applied after unfolding the jet p_T spectrum.

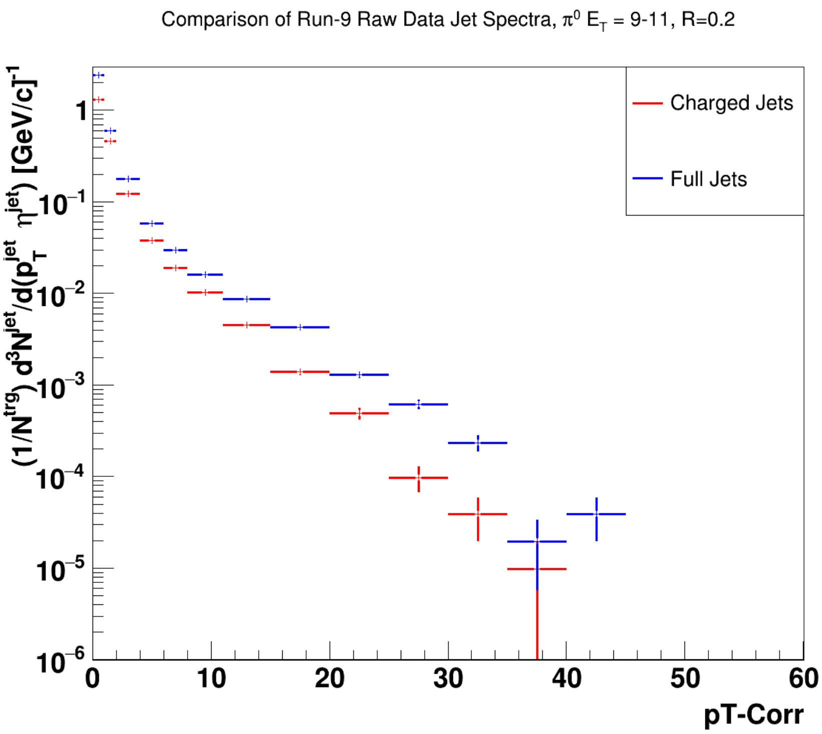

FIG.1. The semi inclusive jet p_T spectrum, on the recoil side of a π^0 trigger with E_T between 9 and 11 GeV, for full vs. charged jets. The jet resolution parameter is 0.2.

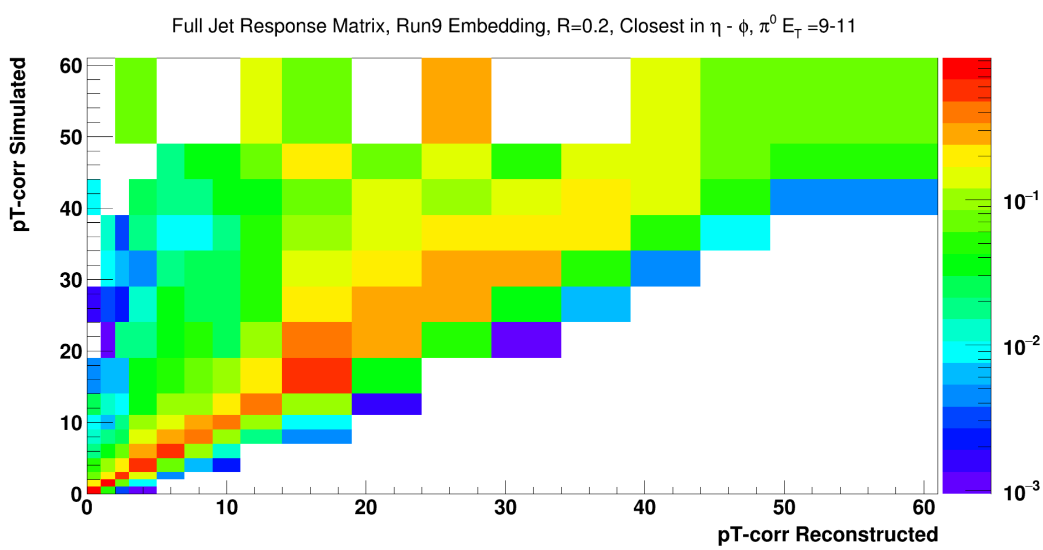

FIG. 2. The Run-9 embedding response matrix for full jets, on the recoil side of a π^0 trigger with E_T between 9 and 11 GeV. The jet resolution parameter 0.2. The matches closest in $\eta - \varphi$ space are selected.

The unfolding was handled by RooUnfold, a framework for deconvoluting particle physics data [5]. The iterative "bayesian" unfolding method was utilized. To test the closure of this method, the embedding was separated into two subsamples. The response matrix and efficiency were generated from the first subsample as described above. The reconstructed spectrum was generated from the second subsample and was then unfolded using the first subsample's response matrix and efficiency. Fig. 3 shows a comparison of the reconstructed spectrum, simulated spectrum, and unfolded spectrum in this so-called "closure test". The closure test indicates that this method provides closure for a range of $6 < p_{T,jet} < 35$ GeV/c. Closure means that the corrected detector-level spectrum agrees with the original PYTHIA-level spectrum, which validates the unfolding procedure.

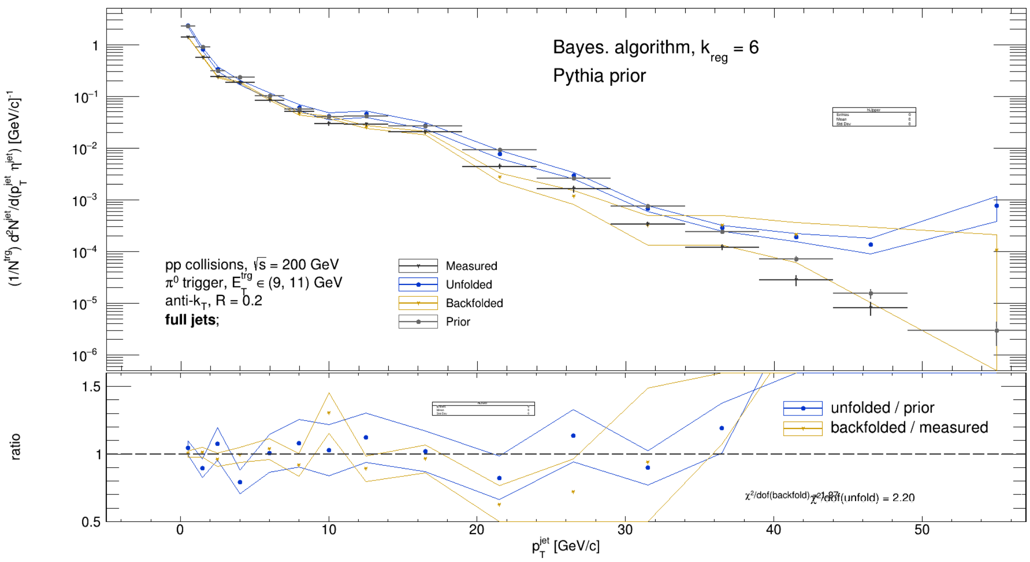

FIG. 3. "Closure Test", as described in the text. The denominator shows the ratio of the corrected spectrum (labeled as "unfolded") to the original PYTHIA spectrum (labeled as "prior"). The ratio being consistent with 1 shows that closure is achieved.

[1] STAR Collaboration. (2023). arXiv:2309.00156

[2] STAR Collaboration. (2023). arXiv:2309.00145.

[3] STAR Collaboration (2003). Nucl. Instrum. Methods Phys. Res. **A499(2-3)**, 725 (2003).

[4] M. Cacciari and G. Salam, Phys. Lett. B **641**, 57 (2006); M. Cacciari, G. Salam and G. Soyez, J. High Energy Phys. **0804** 005 (2008), http://fastjet.fr.

[5] T. Adye, arXiv:1105.1160 (2011).