Exploring cold nuclear matter effects in d+Au with high-p_T reconstructed jets at PHENIX

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Abstract

Proton-nucleus (p+A) collisions can be used to investigate cold nuclear matter effects on hard-scattered partons and serve as an important baseline for heavy-ion collisions. In particular, p+A collisions at different centrality selections can probe the impact parameter dependence of nuclear *parton* distribution functions, initial state energy loss and final state parton interactions in the cold nucleus. Jet reconstruction can better determine the initial parton kinematics and recent improvements in analysis techniques allow the exploration of these effects over a wide p_T range. We present the latest jet reconstruction measurements performed with the PHENIX detector at RHIC in deuteron-gold (d+Au) collisions at 200 GeV using the Gaussian filter algorithm and discuss the possible implications on descriptions of cold nuclear matter.

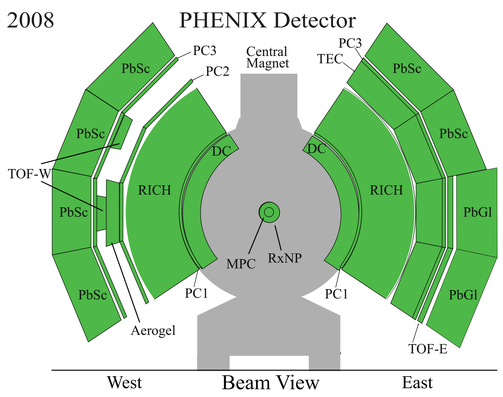

Figure 1: PHENIX detector configuration 2008

PHENIX Detector

- RHIC 2008 data, d+Au (46×10^9 events, $\int\mathscr{L}=23$ nb^{-1}) and p+p (4.7×10^9 events, $\int\mathscr{L}=190$ nb^{-1}) collisions at $\sqrt{s_{NN}}=200$ GeV
- PHENIX central arms at $|\eta|<0.35$, $\Delta\phi=\pi$ (Figure 1):
  - Charged tracks $p_T>400$ MeV/c in the Drift Chamber (DC), Pad Chambers (PC1,3), Ring Imaging Čerenkov Detector (RICH) measure $h^{\pm}$, $e^{\pm}$
  - Neutral clusters $p_T>400$ MeV/c in the Electromagnetic Calorimeter (EMCal) measure π^0, γ, and some h^0 (with lower efficiency)
- High-rate DAQ can take complementary Minimum Bias and triggered datasets
  - Electromagnetic/RICH Trigger (ERT) requires $>2.1(1.6)$ GeV in 4x4 tile in lead-scintillator (lead-glass) calorimeter modules

Jet Reconstruction

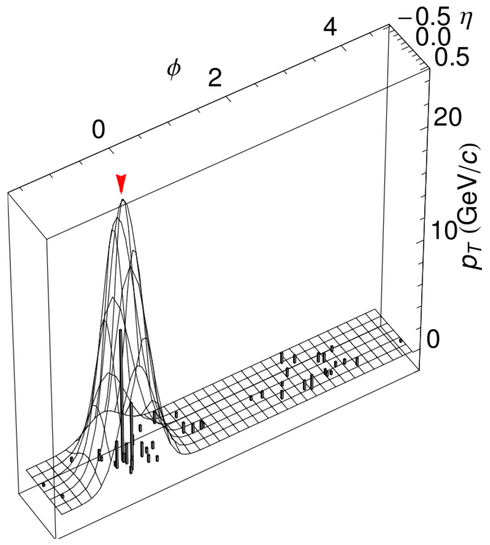

Figure 2: Example of Gaussian filter local maximum finding

- Gaussian filter $\sigma=0.3$ jet reconstruction[1] (Figure 2):
  - Seedless, infrared and collinear safe algorithm with continuous angular weighing
  - Focuses core of the jet, optimizing S/B and increasing stability against background
  - Previously used in p+p and Cu+Cu collisions at PHENIX[2]
- Good jet reconstruction requirements:
  - Fiducial cut $\Delta\eta,\Delta\phi>0.05$ away from acceptance edges
  - Gaussian-weighted constituents >2.5 (three or more hard fragments)
- Corrected for trigger efficiency using data-driven efficiency determination
- Mild underlying event effects in d+Au:
  - Evaluated with embedding analysis (MC detector scale jets + minimum bias data)
  - Yields in d+Au corrected to p+p energy scale with bin-by-bin unfolding
- $p_T^{rec}>9$ GeV/c reconstructed jets:
  - Fake rate determined to be $<5\%$ from data

Results

- Gaussian filter jets with p_T^{rec} from 9 to 40 GeV/c (Figure 3) have been successfully reconstructed in d+Au and p+p
- Reconstructed jet R_{dA} $\left(=\frac{(1/N_{evt}^{dAu})(dN^{dAu}/dp_T)}{\langle T_{AB}^{dAu}\rangle d\sigma^{pp}/dp_T}\right)$ measures the absolute nuclear modification relative to p+p
  - R_{dA} in central collisions (black points, Figure 4) shows a slight (10-15%) suppression at high-p_T, possibly due to nPDF effects or small initial state energy loss
  - R_{dA} in peripheral collisions (red points, Figure 4) shows a moderate (30%) enhancement at high-p_T, possibly due to Cronin effects or a not yet understood effect in the geometric scaling of peripheral d+Au collisions
  - This confirms the high-p_T behavior suggested by the statistically limited PHENIX 2003 π^0 results[3] (Figure 5)
- Reconstructed jet R_{CP} $\left(=\frac{(1/N_{coll}^{cent})(1/N_{evt}^{cent})(dN^{cent}/dp_T)}{(1/N_{coll}^{peri})(1/N_{evt}^{peri})(dN^{peri}/dp_T)}\right)$ measures the nuclear modification relative to peripheral (60-88%) collisions
  - Smaller systematics than R_{dA}, can better illustrate magnitude of the difference between centralities
  - R_{CP} shows a strong suppression from a combination of effects in the R_{dA}
  - Consistent with the magnitude and p_T-dependence of new high-statistics PHENIX 2008 π^0 and η result[4] (Figure 6)

Comparisons

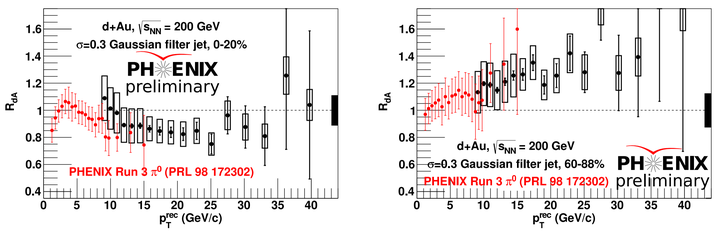

Figure 5: R_{dA} compared to PHENIX π^0 results from the RHIC 2003 run[3]. The hadron energy scale has not been corrected to the jet scale.

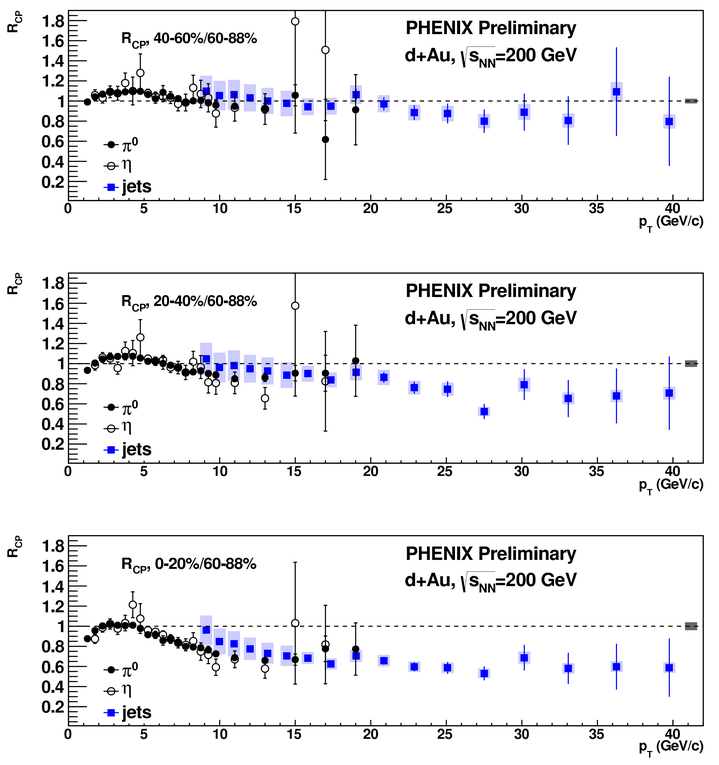

Figure 6: R_{CP} compared to new preliminary PHENIX π^0 and η results from the RHIC 2008 run[4]. The hadron energy scale has not been corrected to the jet scale.

Conclusion

- Cold nuclear matter effects in high-p_T reconstructed jets in d+Au are critical for understanding Au+Au effects such as energy loss
- Reconstructed jets complement and extend measurements from inclusive single hadrons
- The R_{dA} with respect to centrality probes the impact parameter dependence of nuclear parton distribution functions, in which there has been recent theoretical progress[5]
- We observe a mild suppression (moderate enhancement) in central (peripheral) events of jet production relative to binary-scaled p+p collisions

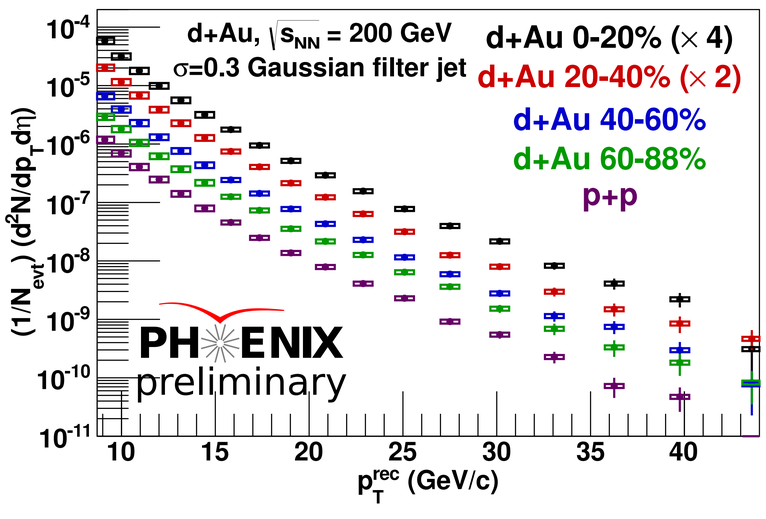

Figure 3: Invariant jet yields for d+Au and p+p jets

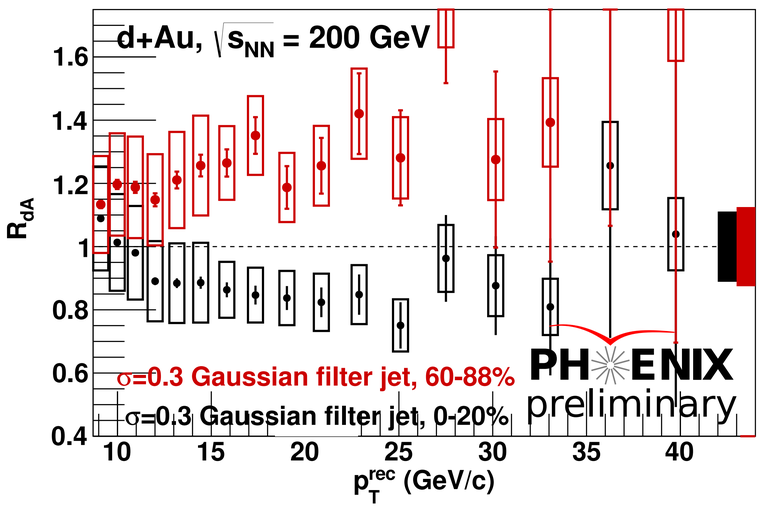

Figure 4: 0-20% (black) and 60-88% (red) R_{dA} for jets

[1] Y.S. Lai, B.A. Cole, nucl-ex/0806.1499
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[3] S.S. Adler, et. al. (PHENIX Collaboration), Phys. Rev. Lett. 98, 172302 (2007)
[4] B. Sahlmueller (PHENIX Collaboration), QM12 Parallel 3D talk
[5] I. Helenius, K.J. Eskola, H. Honkanen, C.A. Salgado, hep-ph/1205.5359

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