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Measurement of γ+jet and π^0+jet in central Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV with the STAR experiment

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We present the semi-inclusive measurement of charged jets recoiling from direct-photon and π^0 triggers in central Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV, using a dataset with integrated luminosity 13 nb^{-1} recorded by the STAR experiment in 2014. The photon and π^0 triggers are selected within transverse energy (E_T^{trig}) between 9 GeV and 20 GeV. Charged jets are reconstructed with the anti-k_T algorithm with resolution parameters R = 0.2 and 0.5. A Mixed-Event technique developed previously by STAR is used to correct the recoil jet yield for uncorrelated background, enabling recoil jet measurements over a broad $p_{T,jet}$ range. We report fully corrected charged-jet yields recoiling from direct-photon and π^0 triggers for the above two jet radii and also discuss the jet R dependence of in-medium parton energy loss at the top RHIC energy.

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Jet quenching arises from partonic interactions in the Quark-Gluon Plasma (QGP) formed in heavy-ion collisions [1]. A valuable observable to probe the QGP is the coincidence of a reconstructed jet recoiling from a high transverse energy (high $E_{\mathrm{T}}^{\mathrm{trig}}$) direct photon ($\gamma_{\mathrm{dir}}$) [2], since γ_{dir} does not interact strongly with the medium. A comparison of γ_{dir}+jet and π^0+jet measurements may elucidate the color factor and path-length dependence of jet quenching [3]. In addition, a comparison of recoil jet distributions with different cone radii provides a probe of in-medium jet broadening.

In these proceedings, we present the analysis of fully-corrected semi-inclusive distributions of charged jets recoiling from high-$E_{\mathrm{T}}^{\mathrm{trig}}$ γ_{dir} and π^0 triggers in central Au+Au collisions at $\sqrt{s_{\mathrm{NN}}}$ = 200 GeV. The data were recorded during the 2014 RHIC run with a trigger requiring an energy deposition greater than 5.6 GeV in a tower of the STAR Barrel Electromagnetic Calorimeter (BEMC), corresponding to an integrated luminosity of 13 nb^{-1}. We compare the measured recoil jet yield in Au+Au collisions to a *pp* reference via PYTHIA simulation and corresponding yield suppression is then further compared with theoretical calculations. We express the suppression in terms of jet energy loss and compare to other in-medium jet measurements at RHIC and the LHC.

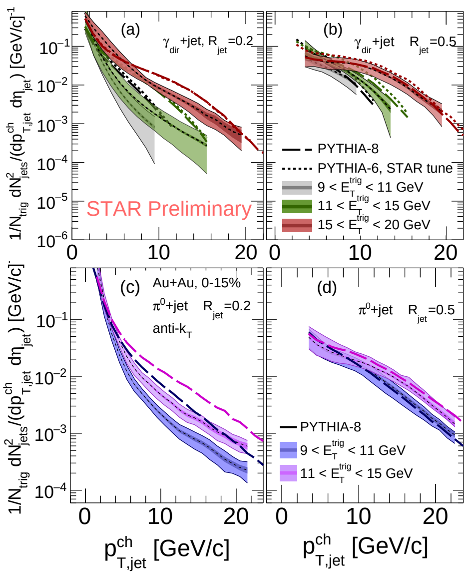

Figure 1: Semi-inclusive distributions of charged jets recoiling from γ_{dir} (upper) and π^0 (lower) triggers. Light and dark bands represent systematic and statistical uncertainties, respectively. Broken and dotted lines represent calculations based on PYTHIA-8 and PYTHIA-6 STAR tune.

The offline analysis selects events corresponding to the 0-15% most central Au+Au collisions, based on uncorrected charged-particle multiplicity within $|\eta| < 1$. The BEMC Shower Max Detector (BSMD) was used offline to select clusters in the range $9 < E_{\mathrm{T}}^{\mathrm{trig}} < 20$ GeV that have an enhanced population of direct photons (γ_{rich}) or π^0 (π^0_{rich}). A Transverse Shower Profile (TSP) method is used to discriminate between π^0_{rich} and γ_{rich} triggers [3]. The purity of direct photons in the γ_{rich} sample is 65–85% in the range $9 < E_{\mathrm{T}}^{\mathrm{trig}} < 20$ GeV. The final corrections are applied on both γ_{rich} and π^0_{rich} to get the fully corrected recoil jet yields. Charged jets are reconstructed with the anti-k_{T} algorithm [4, 5] for $R = 0.2$ and 0.5, using charged particle tracks measured in the Time Projection Chamber (TPC) with $0.2 < p_{\mathrm{T}} < 30$ GeV/c and $|\eta| < 1$. The jet acceptance is $|\eta_{\mathrm{jet}}| < 1$-$R$.

Recoil jets are selected with a $\Delta\phi \in [3\pi/4, 5\pi/4]$, where $\Delta\phi$ is the azimuthal angle between the trigger cluster and the jet axis. The semi-inclusive distribution is defined as the yield of recoil jets in a bin of transverse momentum ($p_{\mathrm{T,jet}}^{\mathrm{ch}}$) normalized by the number of triggers. The uncorrelated background jet yield in this distribution is corrected using the Mixed-Event (ME) technique developed in [6]. Corrections to the recoil jet distributions for instrumental effects and residual $p_{\mathrm{T,jet}}^{\mathrm{ch}}$ fluctuations due to background are carried out using unfolding methods. The main systematic uncertainties arise from unfolding, ME normalization, and γ_{dir} purity.

Due to limited trigger statistics in the current analysis of STAR *pp* data, the reference distribution from *pp* collisions is calculated using the PYTHIA event generators. For $\gamma_{\rm dir}$-triggered distributions, both PYTHIA-8 [7] and PYTHIA-6 STAR tune [8] events are used, whereas for π^0-triggered distributions only PYTHIA-8 is used.

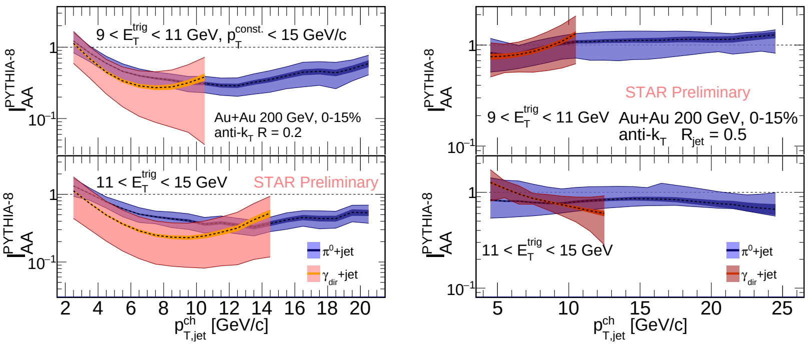

Figure 2: $I_{\rm AA}^{\rm PYTHIA-8}$ vs. $p_{\rm T,jet}^{\rm ch}$ for $\gamma_{\rm dir}$ triggers (red) and π^0 triggers (blue) with $9 < E_{\rm T}^{\rm trig}$<11 GeV (upper) and $11 < E_{\rm T}^{\rm trig}$< 15 GeV (lower) and for jets with $R = 0.2$ (left) and 0.5 (right). Light and dark bands represent systematic and statistical uncertainties.

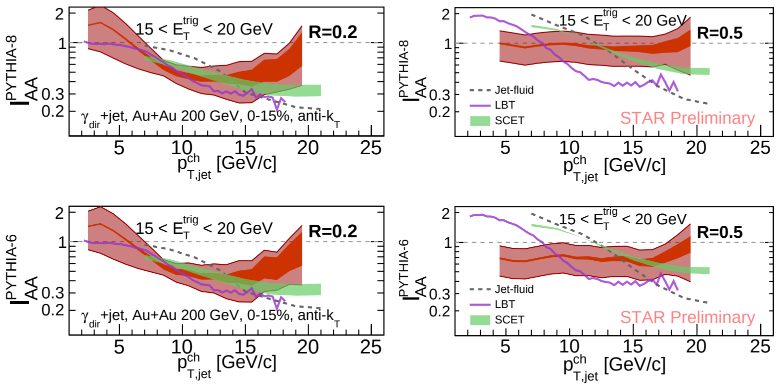

Figure 3: $\gamma_{\rm dir}$+jet: $I_{\rm AA}^{\rm PYTHIA-8}$ (upper) and $I_{\rm AA}^{\rm PYTHIA-6}$ (lower) vs. $p_{\rm T,jet}^{\rm ch}$ for $15 < E_{\rm T}^{\rm trig}$< 20 GeV and jets with $R = 0.2$ (left) and 0.5 (right). Light and dark bands represent systematic and statistical uncertainties. Theory calculations: Jet-fluid [9], LBT [10], and SCET [11].

Figure 1 shows fully corrected charged-jet $p_{\rm T}$ spectra for R = 0.2 and 0.5 recoiling from $\gamma_{\rm dir}$ in three $E_{\rm T}^{\rm trig}$ bins, and π^0 in two $E_{\rm T}^{\rm trig}$ bins, measured in central Au+Au collisions and compared to those calculated by PYTHIA for *pp* collisions. The two PYTHIA versions exhibit negligible difference for $R = 0.2$ and up to 40% difference for $R = 0.5$. The ratio of recoil jet yield measured in Au+Au collisions to PYTHIA calculations for pp collisions are denoted as $I_{\rm AA}^{\rm PYTHIA-6}$ and $I_{\rm AA}^{\rm PYTHIA-8}$ for the two versions of PYTHIA used.

Figure 2 shows $I_{\rm AA}^{\rm PYTHIA-8}$ for $\gamma_{\rm dir}$ and π^0 triggers in $9 < E_{\rm T}^{\rm trig} < 15$ GeV for R = 0.2 and 0.5. The recoil jet yields show similar suppression for both triggers for $R = 0.2$, with no significant $E_{\rm T}^{\rm trig}$ dependence. Smaller suppression is observed for $R = 0.5$ for both triggers compared to $R = 0.2$.

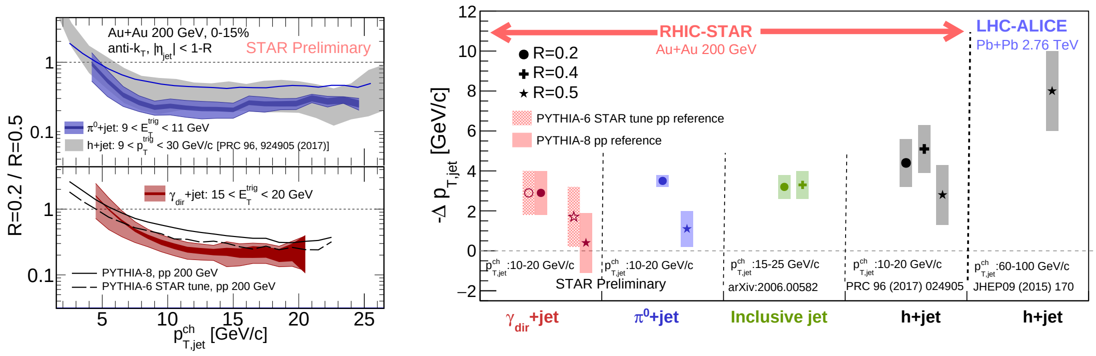

Figure 4: Left panel: Ratio of recoil jet yields for R = 0.2 and 0.5 as a function $p_{\mathrm{T,jet}}^{\mathrm{ch}}$. Upper: h+jet and π^0+jet. Lower: γ_{dir}+jet. Right panel: The $p_{\mathrm{T,jet}}^{\mathrm{ch}}$ shift (-Δ $p_{\mathrm{T,jet}}^{\mathrm{ch}}$) for γ_{dir}+jet, π^0+jet, inclusive jet, h+jet measurements at RHIC, and h+jet at the LHC. Note the different $p_{\mathrm{T,jet}}^{\mathrm{ch}}$ ranges.

Figure 3 compares $I_{\mathrm{AA}}^{\mathrm{PYTHIA-8}}$ and $I_{\mathrm{AA}}^{\mathrm{PYTHIA-6}}$ for γ_{dir} triggers with 15 < $E_{\mathrm{T}}^{\mathrm{trig}}$< 20 GeV. Comparison is also made to theoretical model calculations [9–11], which predict different p_{T} dependence to those observed in data.

Figure 4, left panel, shows the ratio of recoil jet yields for R = 0.2 and 0.5 measured in central Au+Au collisions with both γ_{dir} and π^0 triggers. This ratio is sensitive to the jet transverse profile [6, 12]. The γ_{dir}-triggered ratio is consistent with a calculation based on the PYTHIA-6 STAR tune, indicating no significant in-medium broadening of recoil jets whereas a notable quantitative difference is observed between Au+Au and PYTHIA-8. The ratios for π^0 and charged-hadron triggers measured in central Au+Au collisions are consistent within uncertainties.

Jet quenching is commonly measured by yield suppression at fixed p_{T} (R_{AA} and I_{AA}). However, these ratio observables convolute the effect of energy loss with the shape of the spectrum. To isolate the effect of energy loss alone we convert the suppression to a p_{T}-shift, -Δ$p_{\mathrm{T,jet}}^{\mathrm{ch}}$, enabling quantitative comparison of jet quenching measurements with different observables, and comparison of jet quenching at RHIC and the LHC. Figure 4, right panel, shows -Δ$p_{\mathrm{T,jet}}^{\mathrm{ch}}$ from this measurement, compared to those of inclusive jets and h+jet at RHIC, and h+jet at the LHC [6, 12–14]. The energy loss from the RHIC measurements is largely consistent for the different observables, with some indication of smaller energy loss for R = 0.5 than for R = 0.2 considering PYTHIA-8 for the vacuum expectation. In addition, the results from R = 0.2 measurements at RHIC are comparable to those from inclusive π^0 [15]. An indication of smaller in-medium energy loss is observed at RHIC than at the LHC.

In summary, we have presented the analysis of semi-inclusive charged-jet distributions recoiling from γ_{dir} and π^0 triggers in central Au+Au collisions at $\sqrt{s_{\mathrm{NN}}}$ = 200 GeV. Significant yield suppression is observed for recoil jets with R = 0.2, and a less suppression is seen for R = 0.5 using PYTHIA-8 as *pp* reference. However, the difference between PYTHIA-8 and PYTHIA-6 precludes quantitative conclusions. On the other hand, a definitive conclusion on in-medium jet broadening from the ratio of recoil jet yields at different R can be drawn when the vacuum reference will be resolved by the same measurements in *pp* collisions at 200 GeV, currently in progress. Theoretical calculations of jet quenching predict a different p_{T}-dependence of the suppression than that observed in data. Conversion of the measured suppression to a $p_{\rm T}$-shift reveals similar energy loss due to the quenching of various jet measurements at RHIC and an indication of smaller energy loss at RHIC than at the LHC.

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