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

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This project is a study of high-energy heavy-ion collisions at the Relativistic Heavy Ion Collider (RHIC). The focus of the study is on two probes of the dense, partonic matter created in these collisions: 1) direct-photon-triggered jets (and their correlations) and 2) heavy-quarkonium production and suppression.

1 Investigating Energy Loss through Photon-Triggered Jet Measurements

The hard production of a direct photon back-to-back with a jet (γ-jet) is a probe of the parton energy loss in heavy-ion collisions [1]. In the "γ-jet" coincidence measurement, the measured energy of the trigger particle (the photon) serves as a calibrated baseline for the total energy of the jet particles on the recoil side (i.e. opposite in azimuth) of the trigger. The mean-free path of the γ in the medium is large enough so that its momentum is preserved, regardless of the position of the initial scattering vertex. Thus it does not suffer from the geometric biases, i.e. the non-uniform spatial sampling of hadron triggers due to energy loss in the medium, of e.g. π^0 triggers. Because of the difference in path length traversed, on average, between a direct-γ and a π^0 trigger, comparisons of γ-jet to hadron(π^0)-jet measurements can provide insight into the path-length dependence of the energy loss.

As the dominant background to direct photons are π^0 (decaying to two photons), the Barrel Shower Maximum Detector (BSMD) has provided the capability of distinguishing direct photons from neutral pions via the transverse shower shape. Our group has used this method in the measurement of direct photon+hadron correlations [2]. The γ-hadron correlation studies can be extended to studies of γ-triggered jet reconstruction measurements (as has been done at the LHC [3, 4]). The away-side jet will then be reconstructed in coincidence with triggers selected as direct photon candidates or (for p_T<20 GeV using the shower shape with the BSMD) identified π^0 triggers. The advantage of this should be the ability to reach lower energy fragments in the jet to study jet-shape modification and possible redistribution of energy.

The Run-14 photon-triggered data set in Au+Au collisions has been fully analyzed for charged jets recoiling from a high-energy neutral (π^0 or γ) trigger. We have chosen to concentrate initially on charged-particle jets, for simplicity, recoiling from the trigger particle. Charged-jet reconstruction is performed using the anti-k_T algorithm from the Fastjet package [5]. A fiducial cut in jet pseudorapidity, $|\eta_{\mathrm{jet}}| < 1-R_{\mathrm{jet}}$, where R_{jet} is the jet resolution parameter associated with the radial size of the jet.

Fig. 1 shows the ratio (I_{AA}) of per-trigger charged recoil-jet yields in Au+Au collisions to those in PYTHIA [6] for π^0 triggers and γ triggers. The comparison of I_{AA} for Rjet=0.2 and Rjet=0.5 seems to indicate recovery of the lost energy at larger radii. However, this conclusion depends on the PYTHIA, and we have found that different settings in PYTHIA result in different conclusions. It is therefore essential to have the measurement in p+p collisions. As a baseline measurement, we have analyzed Run-9 p+p collisions. We are currently finalizing the determination of the energy scale and systematic uncertainties for this measurement.

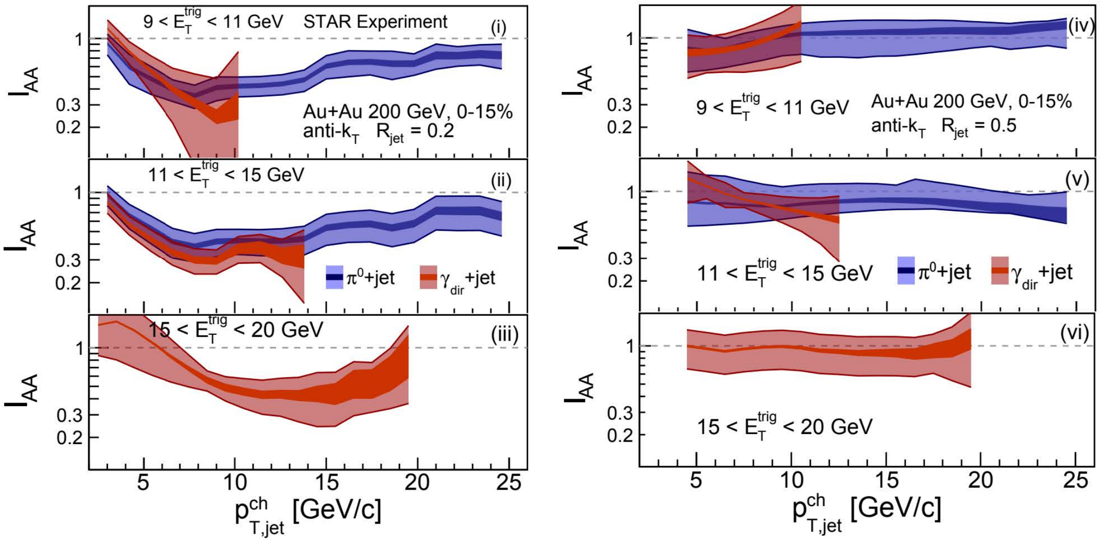

Fig. 1. Ratio ($\mathrm{I_{AA}}$) of charged recoil-jet yields Au+Au collisions to those in PYTHIA (p+p collisions). The left panel are for jet resolution parameter R_{jet}=0.2, and the right panels are for R_{jet}=0.5. The blue bands are for π^0 triggers, and the red are for γ triggers. In the top panels the trigger energy E_T=9-11 GeV, in the middle panels E_T=11-15 GeV, and in the lower panels E_T=15-20 GeV.

2 Unraveling Cold Nuclear Matter Effects in J/ψ Suppression

The J/ψ has long been considered one of the most promising direct probes of deconfinement. According to theoretical predictions in 1986 [7], the produced $c\bar{c}$ pair will not be able to form a J/ψ bound state in the QGP, if a sufficiently high temperature is reached where the screening radius is smaller than the binding radius of the J/ψ resonant state. The "Debye" screening radius is the distance at which the color charges of two quarks are screened from one another, so that the confinement force is not able to hold the quarks together. A suppression in the yield of J/ψ was first observed in Pb+Pb collisions by the NA50 experiment at the CERN SPS (see, for example, [8]).

At RHIC, the predicted suppression of J/ψ due to screening in the QGP is much larger than the suppression observed at SPS due to the higher initial density of the produced medium [9]. The RHIC measurements, however, show a level of suppression similar to NA50 at mid-rapidity [10], which is significantly smaller than expectations due to color screening effects alone. This can be understood in a scenario where charmonium is regenerated due to the large initial production of charm + anti-charm quarks at $\sqrt{s_{NN}}$= 200 GeV, in conjunction with their possible thermalization in the created medium [11]. If charm quarks (partially) thermalize in RHIC collisions, then the coalescence of $c\bar{c}$ could lead to a smaller than expected suppression [12].

With counteracting effects, it is a challenge to disentangle the suppression from the regeneration. In addition, there are cold nuclear matter effects [13], including modification of the parton distribution functions ("shadowing") and partonic multiple scattering, that also lead to suppression of heavy quarkonium and need to be disentangled from QGP suppression. In order to quantify effects of deconfinement, cold nuclear matter effects (via p+Au collisions) must be measured and disentangled

Our goal is to measure charmonium production in p+Au collisions as a function of "centrality". Ideally, centrality would be determined using the event activity in the forward region, away from the mid-rapidity region where the J/ψ is reconstructed. However, due to the performance of the STAR Beam-Beam Counters (BBC) in the p+Au running period, we have concluded that we cannot use the BBC for this purpose. Alternatively, we based the centrality determination on an event multiplicity of the number of good primary tracks (NGPT) at mid-rapidity ($|\eta|<1$). With NGPT as the centrality measure, the results are difficult to interpret due to the correlations between the physics signal and the centrality determination. Fig. 2 shows this result, which we decided not to show at the Quark Matter conference last year, because of this auto- correlation. We are currently restricting our centrality determination to the NGPT outside of the rapidity region in which the J/ψ is reconstructed and anticipate having results soon.

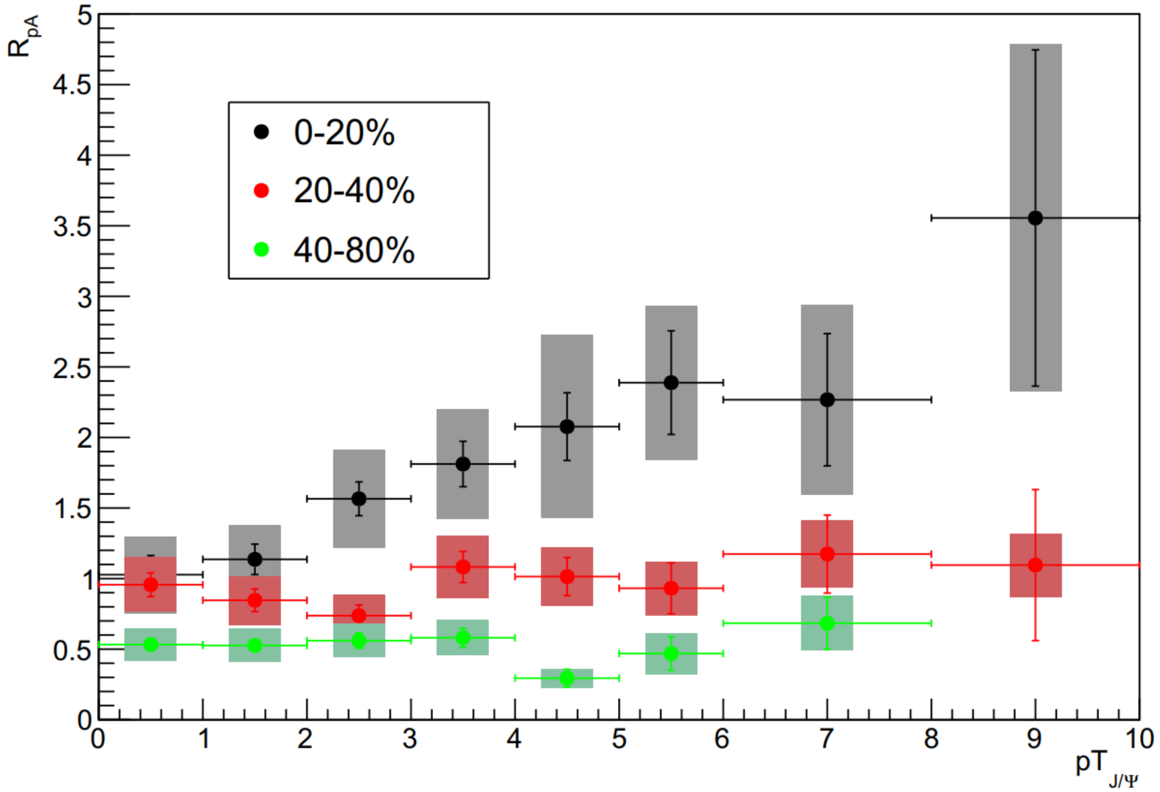

Fig. 2. Nuclear modification factor R_{pA} of J/ψ yields as a function of p_T (ratio in p+Au collisions to that in p+p collisions scaled by the mean number of binary collisions) for 3 different centrality classes. Since the centrality is determined by the multiplicity in the mid-rapidity region, there are auto-correlations with the J/ψ signal, making it difficult to interpret this result.

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