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

D.M. Anderson, Y. Liu, S. Mioduszewski, and the STAR Collaboration

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.

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-g 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, $|h_{jet}| < 1-R_{jet}$, where R_{jet} is the jet resolution parameter associated with the radial size of the jet. For the baseline measurement, data from Run-9 p+p collisions have been analyzed. In the past year, we have advanced the baseline measurement toward finalization. The following work has been completed.

1) The energy scale of the trigger has been determined, which is crucial for comparing to theoretical calculations, including PYTHIA [6].

2) Corrections for detector effects calculated from embedding of di-jet Pythia events in Run-9 p+p zero-bias data have been applied. The corrections of jet momentum is done via unfolding of the raw

jet spectrum using a response matrix of detector-level jet momentum vs. particle-level jet momentum. The efficiency for finding jets is applied to the unfolded jet-momentum spectrum.

3) The response matrix has been "smoothed", in order to remove large fluctuations in the response due to limited statistics in the embedding sample.

4) The R=0.2 and R=0.5 jet spectra have been unfolded and are currently being compared to PYTHIA calculations, taking into account the trigger energy scale by weighting to match the true sampled trigger energies.

Unraveling Cold Nuclear Matter Effects in J/Y 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, 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+A 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 have settled on using the number of primary tracks matched to a TOF hit in underlying event region (NMPTUE) as a measure of the event activity. The NMPTUE was chosen based on the following criteria. The number of tracks matched to TOF was found to be more robust for rejecting pile-up than other track-quality cuts. In order to remove the auto-correlation of centrality with the physics being measured as a function of the centrality, tracks are counted only in the underlying-event region, a region transverse to the direction of the reconstructed particle.

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