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

M. Cervantes, Y. Liu, S. Mioduszewski, N. Sahoo, and the STAR Collaboration

The focus of this project is the study of high-energy heavy-ion collisions at the Relativistic Heavy Ion Collider (RHIC). Two valuable probes of the matter created in these collisions are direct-photon-triggered (jet) correlations and heavy-quarkonium production.

Measurement of γ-Jet at low z_T and high trigger p_T

Direct photons produced in hard collisions, early in the evolution of a heavy-ion collision, are promising probes [1], as they do not interact via the strong force. Jet correlations (of the recoiling parton) with a direct-photon trigger can give information about the parton energy loss in the medium. The correlations with a photon trigger are compared to those measured with a π^0 trigger because of the difference in expected surface biases. While direct photons are not affected by the medium and can originate from anywhere in the medium without bias, π^0 triggers are likely to have a bias of production near the surface of the medium. Therefore, on average, one would expect that the away-side jet for a π^0 trigger has a larger path length to traverse and experiences larger energy loss than the away-side jet of a γ^{dir} trigger. Because of the increased sensitivity to the path-length dependence of partonic energy loss at low fractional jet momentum z_T ($z_T = p_T^{assoc}/p_T^{trig} < 0.4$, according to theoretical predictions [2]), we have extended the kinematic reach of our previous measurement [3] to lower z_T. In the past year, we carried out the analysis with higher statistics data sets: Run-11 Au+Au data and Run-9 p+p data. We lowered the $p_{T,assoc}$ cut down to 1.2 GeV/c, and raised the $E_{T,trig}$ cut to 12 GeV. This extended our z_T down to 0.1.

Fig. 1 shows the latest result for I_{AA} as a function of z_T. A full systematic study has been performed for these data points, and the derived uncertainties are included in this plot. This result is expected to be close to final. A manuscript presenting these results is in preparation. Although the uncertainties are large, there does seem to be a hint of less suppression at low z_T. This may indicate the recovery of lost energy when including the lower momentum particles in the jet. However, the difference expected in π^0-triggered away-side suppression and γ^{dir}-triggered away-side suppression, due to geometry, is not seen within our uncertainties.

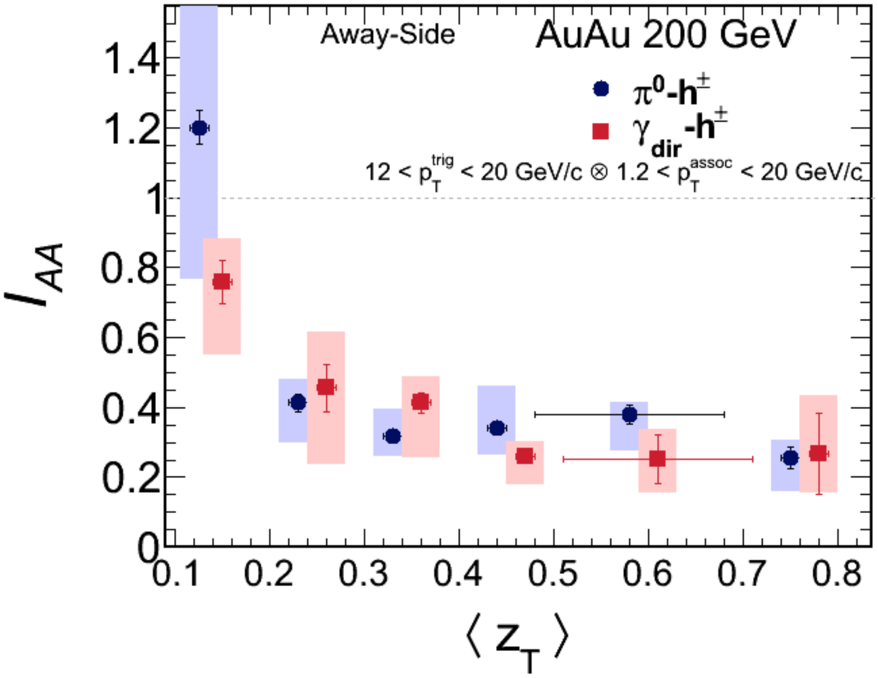

FIG. 1. I_{AA} vs. z_T for π^0-triggered away-side yields (blue) and γ^{dir}-triggered away-side yields (red) from Run-9 p+p and Run-11 central Au+Au data.

Upsilon (ϒ) Production Mechanism through Spin-Alignment ("Polarization") Measurement

We are interested in studying heavy quarkonium production in p+p collisions. The systematics of prompt production of heavy quarkonium is not fully described by common production models, e.g. the Color Singlet Model (CSM) and the Color Octect Model (COM). Historically, CSM calculations grossly under-predicted production cross-sections of heavy quarkonium, but recent development with higher-order corrections can describe data better [4]. The COM can describe the p_T spectra of heavy quarkonia, but the spin-alignment ("polarization") prediction disagrees with experimental data from Fermilab experiments [5].

A measurement that puts constraints on theoretical models of the production mechanism is the spin-alignment (or "polarization") of the ϒ. Here, the angle between the direction of the e^+ momentum is measured in the ϒ's rest frame with respect to the ϒ's direction of motion, i.e. the "polarization axis". The distribution of ϒ's as a function of this angle θ is then fit with the function $dN/d\cos\theta = A(1+\lambda_\theta\cos^2\theta)$, where λ_θ is the polarization. The value of λ_θ can vary from -1 to 1; with -1 corresponding to a fully longitudinal polarization, 0 no polarization, and +1 fully transverse polarization.

The most difficult part of the analysis has been removing the backgrounds due to Drell-Yan and $b\bar{b}$ production, which may have their own polarization (i.e. θ dependence) and their own acceptance corrections. We have made significant progress on this task in the past year. From simulation/theory studies, as well as a fit to the mass line-shape, we concluded that, while at $\sqrt{s}$ =200 GeV the backgrounds from Drell-Yan and $b\bar{b}$ are comparable, at $\sqrt{s}$ =500 GeV the background is dominated by (open) $b\bar{b}$ pair production. This background has now been carefully subtracted, and the systematic uncertainties have been assessed. The systematic uncertainties include the simulation of the trigger cuts, the input polarization for the embedded Υ's used for the acceptance correction, and the particle-identification cuts (which affect the purity of the electrons).

The finalized physics result is shown in Fig. 2. This result will be included in a manuscript that also includes additional physics results from other groups in the STAR experiment that are not yet finalized. Therefore, publication of the result will wait for the completion of the other corresponding analysis.

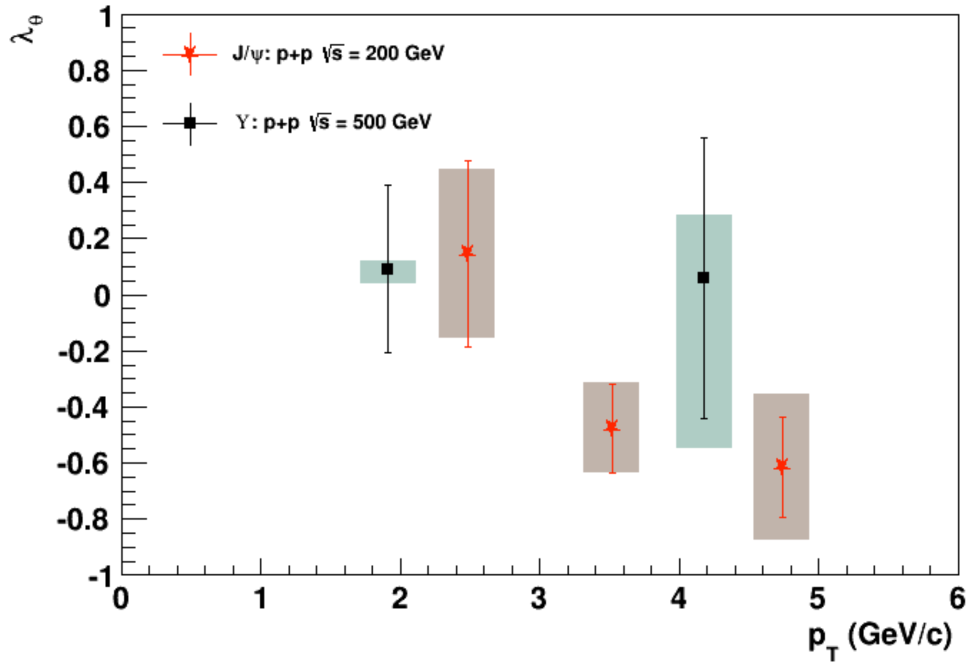

FIG. 2. Polarization parameter λ_θ as a function of p_T, measured in Run-11 500-GeV p+p collisions, for Υ particles (our results), compared to J/ψ particle measured in 200-GeV collisions (another STAR group's published results [6]).

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