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

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RHIC at Brookhaven National Laboratory has been providing high energy heavy-ion collisions since the year 2000, with the current program capitalizing on the high luminosity through measurements of rare probes. Two of these are direct photon correlations and heavy-quarkonium production.

Measurement of γ-Jet at lower z_T and higher trigger p_T

A measurement of hadrons correlated with a high-p_T direct photon is an ideal means to investigate the path-length dependence of partonic energy loss in the dense matter created at RHIC. With increased sensitivity to the path-length dependence expected at low $z_T=p_{T,assoc}/p_{T,trig}$ (less than 0.4), our current efforts focus on extending the published measurement down to $z_T = 0.2$. In the last year, we have reproduced the Run-6 published results with the same cuts in Run-9 p+p data, we applied the higher trigger p_T cut necessary to extend the measurement to lower z_T. Fig. 1 shows the new result from Run 9 compared to the published result from Run 6. The left panel has the trigger p_T cut at 8-16 GeV/c, which was used in the publication, showing that we can reproduce previous results. The right panel has the 15 GeV/c cut applied in the Run-9 data, extending the z_T range down to 0.2.

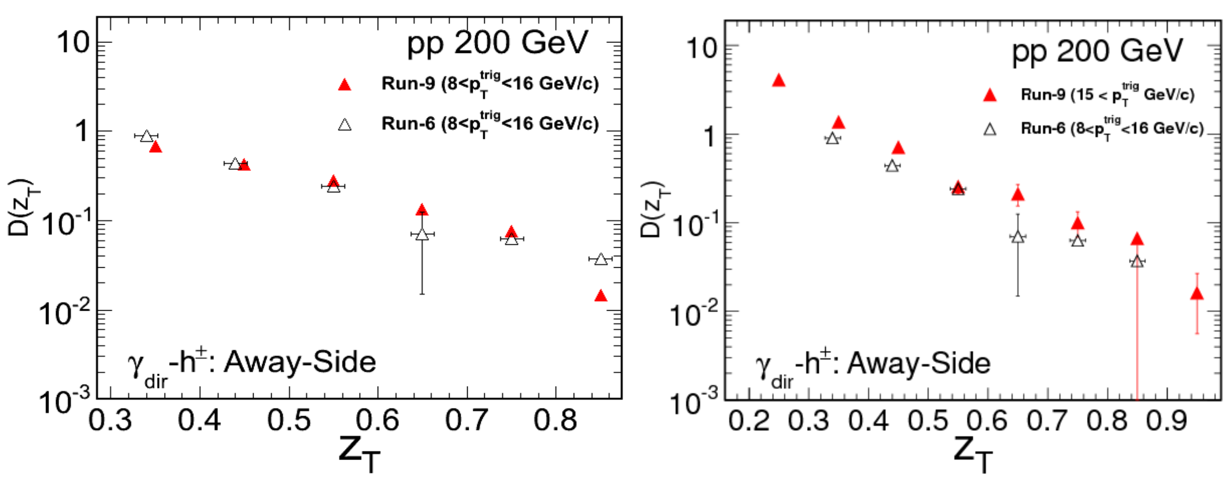

FIG. 1. (Left) Run-9 vs. Run-6 (from STAR publication) direct-photon-triggered yields on recoil side of the direct photon. The p_T trigger cuts, for this comparison, are the same in both data sets. (Right) Run-9 data with a higher p_T trigger cut, compared to the published result, extending the measured range to lower z_T.

We are currently working on the Run-11 Au+Au data, which will provide the numerator in our I_{AA} measurement extended to lower z_T.

Direct-γ v_2 (dependence of γ yields on direction with respect to the reaction plane)

At large transverse momentum, where collective flow is no longer operative, the azimuthal anisotropy (v_2) measured for particles, i.e. the dependence of particle yields on the direction of the particles emitted with respect to the reaction plane, is considered to be a measure of the path-length dependence of energy loss, due to the asymmetric overlap region in Au+Au collisions. The measurement was performed with our former postdoc, Dr. Hamed, and is shown in Fig. 2. The left panel is a result using Run-7 Au+Au data and the full TPC for the reaction-plane determination, while the right panel is a new result from the Run-11 Au+Au data using the forward TPC (FTPC). Using a detector at more forward rapidity should decrease the likelihood of jet particles entering into the reaction-plane determination, which can bias the reaction-plane determination.

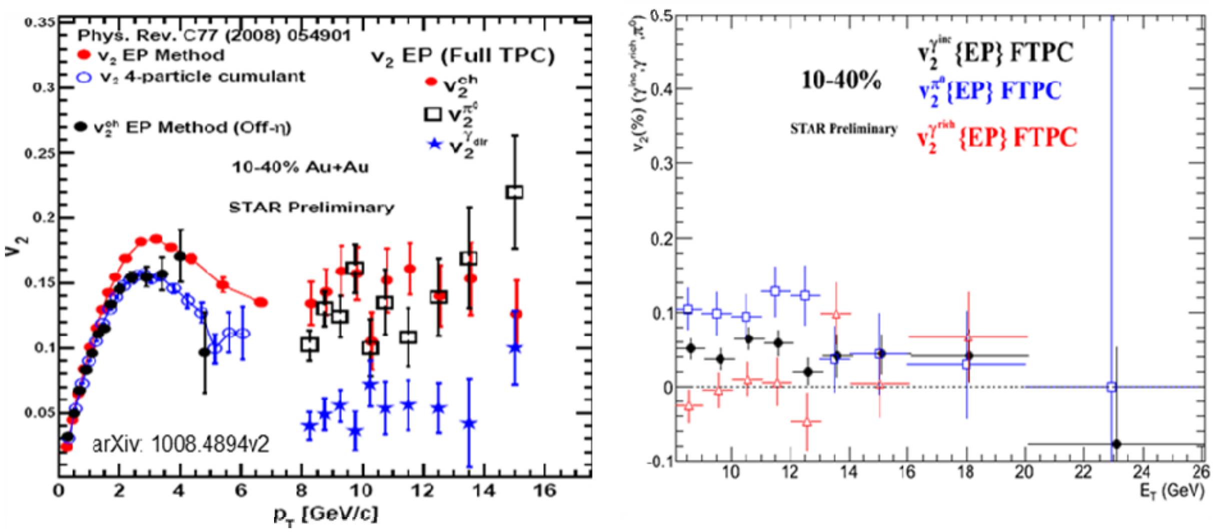

FIG. 2. Azimuthal anisotropy (v_2) measured as a function of particle p_T. For p_T<7 GeV/c, the results are shown for charged particles from minimum-bias triggered events using 3 different methods, the Event-Plane Method (EP) using the full TPC, a 4-particle cumulant, and the EP Method with a rapidity gap (Off-η). The data shown for p_T>8 GeV/c are from "high-tower" triggered events and show the v_2 of charged particles (red) compared to that of π^0 and direct photons. The left panel uses the TPC to calculate the reaction plane, and the right panel uses the Forward TPC.

The lower p_T (p_T<7 GeV/c) data in the left panel is presented to show that we can reproduce previous results from a STAR publication of v_2 measured for charged particles. The methods, labeled as "4-particle cumulant" and "EP Method (Off-η)", use multiple-particle correlations or a pseudo-rapidity gap in the reaction-plane determination, respectively, in order to reduce the bias due to the presence of jets. Our result is the "EP Method (Off-η)" and agrees with the 4-particle cumulant method. At high p_T, we performed the analysis with neutral clusters (rather than charged particles) from the high-tower-triggered data. We find the v_2 of π^0 is at an approximately constant value of 0.12 using the TPC-determined reaction plane (left panel) and closer to 0.10 using the FTPC-determined reaction plane (right panel). The direct photon v_2 is measured to be approximately 0.04 in the left panel and 0 in the right panel. This indicates that a remaining bias in the TPC-determined reaction-plane (due to the presence of an away-side jet, in the case of direct photons) was eliminated in the FTPC reaction-plane determination. Systematic uncertainties are yet to be finalized.

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). 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 as a function of this angle θ is then fit with the function $dN/d\theta = A(1 + \alpha\cos^2\theta)$, where α is the polarization. The value of α can vary from -1 to 1; with -1 corresponding to a fully longitudinal polarization, 0 no polarization, and +1 fully transverse polarization. The current version of our main physics result is shown in Fig. 3, with efforts now focused on better subtraction of the Drell-Yan background.

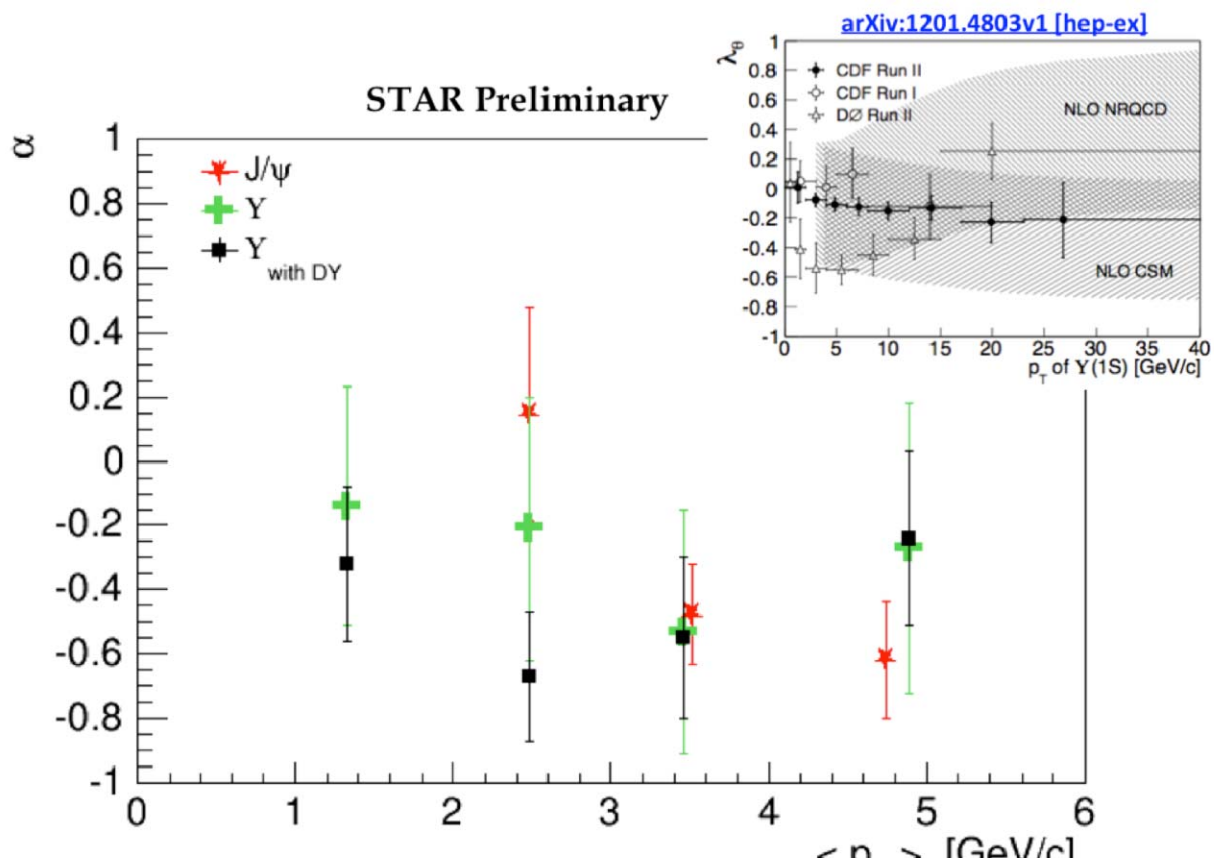

FIG. 3. Polarization parameter α as a function of p_T, measured in Run-11 500-GeV p+p collisions, for Υ particles (our results), compared to J/ψ particle measured in 200-GeV collisions (another STAR group's results currently submitted for publication). The black data points (labeled "Υ $_{\text{with DY}}$") still have ~25% contribution to the Υ measurement from Drell-Yan background, while the green data points are from an analysis in which we attempted to subtract this background as a function of angle θ. The upper right insert shows the measurements of Υ polarization from Fermilab.