Spin Physics with STAR at RHIC

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and the STAR Collaboration

When the past year began, RHIC Run 9 was underway. The primary STAR goal for Run 9 was to collect a high-statistics sample of jet and di-jet data in longitudinally polarized *pp* collisions in order to constrain the gluon polarization in the proton. Our group played a significant role in the STAR Run 9 data taking. One of us (Gagliardi) served as chair of the STAR Trigger Board, which is responsible for ensuring that STAR records the data necessary to achieve the goals that the Collaboration set in the STAR Beam Use Request. Another group member (Djawotho) was responsible for monitoring the performance of the Barrel and Endcap Electromagnetic Calorimeters (BEMC/EEMC) and the corresponding parts of the Level-0 trigger, using code that was described in last year's progress report. Since the run ended, we have focused our efforts on optimization of the STAR jet analysis procedures in anticipation of the analysis of the Run 9 data, and on analysis of transversely polarized *pp* data that were recorded by the Forward Meson Spectrometer (FMS) and Forward Time Projection Chamber (FTPC) during Run 8.

Jets in STAR are reconstructed using a mid-point cone algorithm with a radius of 0.7 in pseudorapidity (η) and azimuthal angle (φ) space. The jet finding algorithm starts with a list of seeds, which can be charged tracks measured with the Time Projection Chamber (TPC) or neutral calorimeter towers from the BEMC/EEMC. All tracks and towers in the vicinity of a seed and within the cone radius are built into four-momenta and added to the seed in a covariant fashion. The Lorentz vectors for tracks assume the mass of the charged pion (a reasonable approximation that avoids inefficiencies associated with high-p_T particle identification), and tower Lorentz vectors are assumed to be massless photons. This scheme poses a potential problem. When electrons or hadrons are tracked through the TPC, then deposit a significant fraction of their energies in the calorimeter, that energy can be double-counted in the jets.

Traditionally, STAR Spin analyses have corrected for this double counting by applying a so-called "MIP subtraction", where the energy equivalent of a minimum-ionizing particle is subtracted from the energy of each calorimeter tower reached by a charged track. During the past year, we developed an alternative technique to correct the jet energy. We subtract a fixed fraction of the total momentum of a charged track from the hit tower. If the requested subtraction would result in a tower with negative energy, the tower is simply removed from the jet, and no further correction is applied. The algorithm was tuned through detailed comparisons of the true vs. reconstructed jet energies in high-statistics PYTHIA+GEANT simulations. We find little difference between 50% and 100% subtraction procedures. Both perform much better than the MIP subtraction. Fig. 1 shows the RMS of the difference between the true and reconstructed jet energies for the MIP scheme and for 50% and 100% subtractions. The 100% subtraction procedure leads to a significant improvement in the jet p_T resolution compared to the MIP subtraction. The 100% subtraction procedure also provides the smallest average difference between the true and reconstructed jet transverse momenta. This scheme has now been adopted by the Collaboration for the analysis of the 2009 jet data.

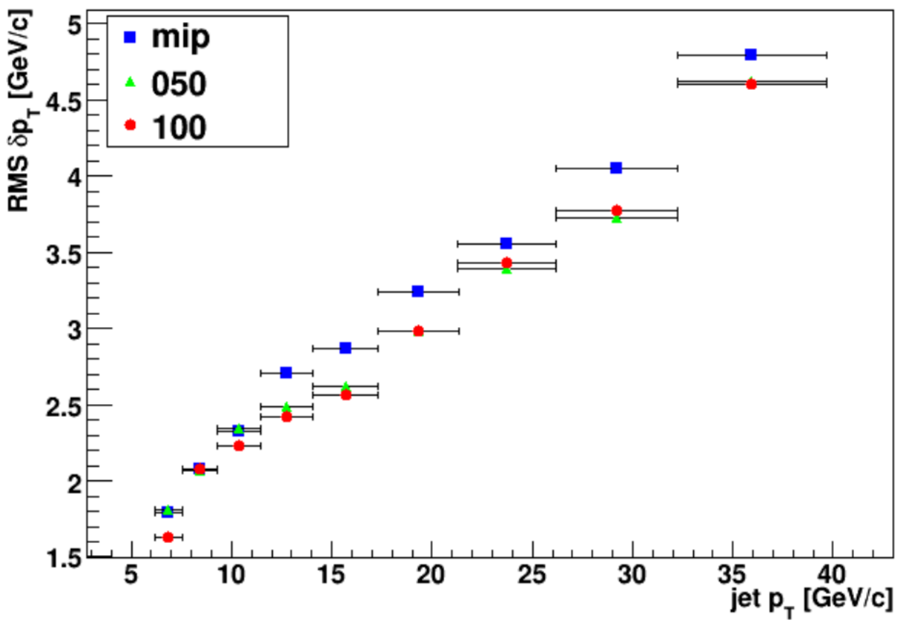

FIG. 1. RMS difference between true and reconstructed jet transverse momenta as a function of the reconstructed jet p_T, measured with 200 GeV *pp* PYTHIA events that have been processed through a detailed GEANT simulation of the STAR detector.

The PYTHIA+GEANT event sample that was used to evaluate the trigger and reconstruction bias in the 2006 *pp* jet analysis included nearly 5M events generated over a period of 3 months. The dataset was further subdivided into partonic p_T bins, *i.e.* bins of the transverse momentum of the outgoing partons in the partonic center-of-mass frame. This allowed for extra sampling of the underrepresented population of high-p_T jets with low production cross sections. However, at low p_T, a different problem arises. While the jet production cross sections there are rather large, only a tiny fraction of the jets fire the STAR online trigger. For example, at a partonic p_T of 2-3 GeV/c, only about 0.18% of the events actually satisfy any trigger of interest to the Spin Physics Working Group. The traditional method of generating Monte Carlo would produce the entire sample, then subsequent analyses would apply the trigger simulator. This process can be very costly, both in CPU usage and disk storage required.

This past year, we developed a trigger filter that makes possible substantial savings in CPU time and disk footprint. The idea is to filter out those events that would have failed the hardware trigger at a much earlier stage of the simulation. The PYTHIA events are generated and records saved regardless of trigger condition. They can then be used later for normalization and bias estimation. The events are then run through the GEANT simulation of the STAR detector, but not the TPC slow simulator. At this point, calorimeter ADCs are available and used by the trigger simulator to mimic the STAR trigger system. If the event fails the trigger, further processing is aborted. Otherwise, the full event is reconstructed, including simulation of the TPC response. This procedure reduces the required CPU time for aborted events by a factor of ~20. The current plan is to apply the trigger filter to all Monte Carlo samples below partonic p_T of 15 GeV/c. This will reduce the number of fully simulated events by 60% and shorten the production time significantly, while allowing a much larger total luminosity to be simulated.

For many years, STAR has assumed a 5% uncertainty on the ability of our simulations to estimate the tracking efficiency of the TPC. This represents the largest single contribution to the current uncertainty on the reconstructed jet energy scale at high p_T. The 5% uncertainty was derived from studies of identified-particle tracking in central Au+Au collisions that were performed many years ago. Jet analyses in 200 GeV *pp* collisions represent a far more benign environment, so it is likely that the standard STAR simulations reproduce the tracking efficiency more accurately than has been assumed. We have developed a technique to take the track kinematics from a jet in one event, embed a track with the same relative kinematics into a jet in a different event, and then see if the track is successfully reconstructed or not. Preliminary results indicate that the PYTHIA+GEANT simulations that have provided the basis for all Run 6 jet analyses reproduce the true Run 6 tracking efficiency to within at least 2%.

Members of our group are working toward the goal of reconstructing jets at forward rapidity using the Run 8 transverse spin data from the FMS together with the west FTPC. One of the primary difficulties in this analysis is dealing with detector inefficiencies. During the 2008 RHIC run, the FMS employed a high-tower trigger, where the detector information was read out once a particular FMS tower reached a certain ADC threshold. Due to insufficient detector shielding, magnet ramps caused the trigger thresholds to be effectively much higher than anticipated. This resulted in "holes" in the FMS triggers, with a handful of towers dominating the trigger. By itself, this would not be a major issue. However, the FTPC also had hardware issues during the Run 8 *pp* collision period, which render complete sectors dead. To work around these issues, we have developed a mixed-event technique to determine the effective acceptance distribution. When this is divided out of the raw correlation distribution, a clear correlation distribution is obtained, with a near-side peak centered around $\Delta\varphi=0$, and an away-side peak centered around $\Delta\varphi=\pi$. The next step will be to clean up the background, which remains quite large at the moment.

Our group continues to carry a number of administrative tasks for the STAR Collaboration. This past year, Dr. Djawotho was named the Embedding Coordinator for the Spin Physics Working Group. Dr. Gagliardi is serving on the Trigger Board for Run 10. Mr. Drachenberg and Drs. Djawotho, Gagliardi, and Tribble have all served on god-parent committees, and Drs. Gagliardi and Tribble have chaired three of them. Finally, late this past year activities began to prepare a new Decadal Plan for the STAR Experiment. The STAR Spokesperson has appointed Dr. Gagliardi to chair this effort.