Investigation of prompt photon asymmetries using the MPC-EX detector at Brookhaven National Laboratory

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Measurements of transverse single spin asymmetries (TSSA) and theoretical predications for them did not match during the 1980s and 1990s. These experiments showed that, at energies on the order of 10 GeV, TSSAs were not as small as predicted by collinear QCD. The results of these experiments persisted even at energies as high as 500 GeV and it seemed that they would not go away.

Such observations have shown that a further development of QCD and pQCD is required in order to understand the possible sources of these TSSAs. Developments in pQCD have shown that both initial state and final state effects can give rise to transverse spin asymmetries. The initial state effects include the Sivers Transverse Momentum Dependent (TMD) PDF picture and collinear higher twist effects. The Sivers TMD picture arises from the correlation between the proton spin and the transverse momentum of the quark.

The focus of our project is to measure the Sivers Effect and other effects to the TSSAs will be neglected here. In order to measure the Sivers effect the prompt (direct) photon asymmetries (A_N) will have to be measured. The prompt photons are the result of the $p+p$ collision itself and not the result of any photons that may arise as a result of a decay from the various other products of such a collision. This asymmetry will say something about the direction the quarks were moving with respect to the proton's spin (i.e. Sivers effect) since the direct photon products will be sensitive to this motion.

In Run 15 at Brookhaven National Labs (BNL) such a measurement was taken using an upgrade to the existing Muon Piston Calorimeter (MPC) at the PHENIX detector. This upgrade is an extension of the MPC detector and aptly named MPC extension (MPC-EX). During Run 15 the MPC-EX ran and collected data for $p+p$ collisions at $\sqrt{s} = 200$ GeV energy as well as $p + Au$ collisions at the same energy. BNL is able to produce transversely polarized proton beams which is ideal for measuring A_N since the Sivers effect requires transversely polarized protons.

The main issue in measuring direct photons is eliminating the photon signal that occurs as a result of photons that have decayed from other products of the collision. The main decay mode that is troubling is $\pi^0 \to \gamma + \gamma$. Since the energy of the collisions is so high that the two photons produced as a result of this decay will have a very small angle between them. The MPC is able to distinguish π^0s with energies up to 20 GeV. The MPC-EX has the advantage over the MPC in that in can distinguish π^0s up to 80 GeV thus eliminating a greater portion of this decay mode and will allow much better isolation of the direct photon signal.

Our analysis has and will consist of trying to eliminate the π^0 decays first. The simulated data is currently being used to find the best method to do this and will be compared to the real data in the coming year. In order to reconstruct the π^0, the energies and hits in the MPC-EX need to be calibrated and aligned with the MPC data. This data will then be used to obtain the photon energies and momenta which can then be used to find out if they came from a π^0 or not. Once the π^0 signal has been eliminated then the prompt photons can be studied and the asymmetry calculated.

My analysis thus far has consisted at looking at minimum ionization peaks (MIP) in the MPC-EX and using that to make cuts on where to search for the hits. Once the hits were identified this led to trying to find tracks in the detector in Hough space. Hough space is easier to work with since it normalizes the z-coordinate (direction of motion) to one, which allows for an easier way to work with the tracks since we have reduced our space coordinates by one and only need to worry about the other directions. Once the track is identified the other directions (x and y) will say something about the showers that developed and make it easier to track their size and energy.

My focus currently is to reconstruct single track π^0s using the showers and hits from the detector. This task is made difficult by the fact that as the showers grow they will eventually overlap with the track and showers created from another photon. The challenge will be in trying to distinguish these kind of events. Even after distinguishing most of these events there will still remain some events that are the result of a π^0 but did not get rejected either because the signal was at the edge of the detector or because of the resolution of the detector. Once the location of the photon signals for a π^0 decay have been determined the opening angle between the photons can be used to reconstruct the origin of the π^0 and its energy. Thus leading a way for the calculation of A_N.

Reference

1) S. Campbell *et al.* [PHENIX Collaboration], arXiv:1301.1096 [nucl-ex].

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