Charged background study for A_N of forward neutron production in $\sqrt{s}$=200 GeV polarized proton-proton collisions in PHENIX experiment

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Single transverse spin asymmetry A_N is defined as

$$A_N = \frac{\sigma^\uparrow - \sigma^\downarrow}{\sigma^\uparrow + \sigma^\downarrow} \tag{1}$$

where ↑ and ↓ indicate the spin up and down of the incident beam, respectively. In 2015, A_N of forward ($6.8 < \eta < 8.8$) neutron production in p+p, p+Al and p+Au collisions at $\sqrt{s_{NN}} = 200$ GeV was measured at PHENIX using the Zero-Degree Calorimeter (ZDC) and a position-sensitive Shower Max Detector (SMD). Unexpectedly, a strong A dependence in A_N was found, which is not explained by the current theoretical framework for $p+p$ collisions[1]. In order to obtain information about the associated mechanisms, the Beam-Beam counter (BBC) correlated A_N was measured for "BBC tag" samples and "BBC veto" samples. A strong correlation with the BBC hit was observed[2].

In the previous result, one of the main systematic uncertainties of $p + p$ data comes from the proton backgrounds. In 2008, in order to reduce the charged backgrounds in the detector acceptance, a charge veto counter (CV), a plastic pad scintillator in front of the ZDC, was operated. To reduce the background uncertainty, the data taken in 2008 were analyzed. Figure 1 shows the charge distribution in the CV versus the particles x position measured by the SMD.

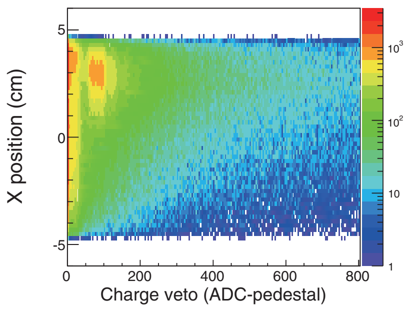

Fig. 1. The charge distribution in the CV vs the x position measured by the SMD for $p + p$ from 2008 data. One MIP peak around the 100 ADC value in the positive x region, where the proton beam bending direction, is shown.

Experimentally the asymmetry is measured by using the square-root formula as shown by Eq. (2) where $N^{\uparrow(\downarrow)}_{\phi(\phi+\pi)}$ is the number of neutrons detected at azimuthal angle ϕ ($\phi + \pi$) when the beam polarization direction is up (down).

$$A_N^{\rm fit} = \frac{1}{P}\frac{\sqrt{N^\uparrow_\phi N^\downarrow_{\phi+\pi}} - \sqrt{N^\uparrow_{\phi+\pi} N^\downarrow_\phi}}{\sqrt{N^\uparrow_\phi N^\downarrow_{\phi+\pi}} + \sqrt{N^\uparrow_{\phi+\pi} N^\downarrow_\phi}} \tag{2}$$

$$= (1-r)A_N^S + rA_N^{bg} \tag{3}$$

The signal asymmetry A_N^S and the background asymmetry A_N^B follow Eq. (3) where r is the fraction of backgrounds.

The main backgrounds are protons, generated by elastic, diffractive and hard processes. Protons from elastic and diffractive processes nearly follow the beam line, and are swept by the beam bending dipole magnet to the right side of the detectors, and a small fraction of those protons hit the right side ($x > 0$ in Fig. 1) of the detector. This background fraction is sensitive to the detector alignment, hence both the 2008 and 2015 data were measured by using the left-right asymmetry of the x distribution of particles.

Protons from hard processes are estimated by the PYTHIA event generator and GEANT Monte Carlo simulations. These protons result in even x distributions in the detector, and the same values are applied for both for the 2008 and 2015 data.

To solve Eq. (3) for two unknowns, A_N^S and A_N^B, $A_N^{\rm fit}$ and r are measured for two 2008 data samples: one from the "charge vetoed" sample, which requires a charge veto counter energy lower than half of the MIP peak, and another from the "charge not vetoed" sample, which does not require a charge veto cut. A_N^B of all BBC correlation samples is zero within statistical uncertainties. With A_N^B obtained from the 2008 data, A_N^S of 2015 data is calculated and found to be consistent with that of the 2008 data.

The resulting uncertainties on the asymmetries from the charged background are 13% for the ZDC inclusive sample, 14% for the "BBC tag" sample, and 55% for the "BBC veto" sample. The comparably large uncertainty for the "BBC veto" sample comes from the statistics and the small $A_N^{\rm fit}$. With this study, we can reduce uncertainties for ZDC inclusive and "BBC tag" samples.

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References
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