Status of longitudinal double helicity asymmetries (A_{LL}) in $\pi^{\pm}$ productions in $\sqrt{s} = 510$ GeV polarized $p+p$ collisions in RHIC-PHENIX experiment

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The spin of the proton is 1/2 which is explained by the angular momentum sum rule in terms of quark and gluon components. Results of EMC experiments and others suggested that the quarks and anti-quarks contribute to only about 30% of the proton spin. Gluons and the orbital angular momentum of quarks and gluons probably account for the rest of the proton spin. Spin analysis using $\pi^{\pm}$ production is particularly interesting in investigating the contribution of the gluons to the proton spin.

The Relativistic Heavy Ion Collider (RHIC) is a unique facility providing longitudinally polarized $p+p$ collisions. It enables us to expore the role of gluons in the intrinsic properties of the proton.

In perturbative Quantum Chromodynomics, pion production is sensitive to the gluon helicity distributions (Δg) in the proton because their production is dominated by gluon-related interactions (q-g and g-g scatterings) in the p_T region probed in PHENIX, 4.8 GeV/c $< p_T <$ 16.5 GeV/c. The gluon helicity distribution (Δg) can be constrained by measuring the double helicity asymmetries (A_{LL}) in π^0 and $\pi^{\pm}$ production in longitudinally polarized $p+p$ collisions. The asymmetry is defined as

$$A_{LL}(p_T) = \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}} \quad (1)$$

where, $\sigma_{++(+-)}$ denotes the $\pi^{\pm}$ cross section from a collision with the same (opposite) helicity.

Yet, unlike the π^0 which can be triggered via photons in an Electro-Magnetic Calorimeter (EMCal) and Ring Imaging Cerenkov Detector (RICH), no dedicated charged hadron trigger exists and thus the $\pi^{\pm}$ statistics are less than for π^0.

However, $\pi^{\pm}$ analysis at mid-rapidity has the advantage of confirming the sign of gluon polarization (ΔG) in the proton simply by ordering the longitudinal double helicity asymmetries (A_{LL}) of the pion charges.

The result of $\pi^{\pm}$ analysis with data taken at $\sqrt{s} =$ 200 GeV has already been published in 2009[1]. In 2013, PHENIX recorded a total integrated luminosity of 145 pb^{-1} at $\sqrt{s} = 510$ GeV within a 30 cm vertex region which is 10 times higher than the previous one. The figure of merit ($\int LP_B^2 P_Y^2 dt$) considering beam polarization (P_B and P_Y) was also higher. Therefore, the result of the ongoing analysis is expected to help determine the sign of the gluon polarization (ΔG) with a higher precision.

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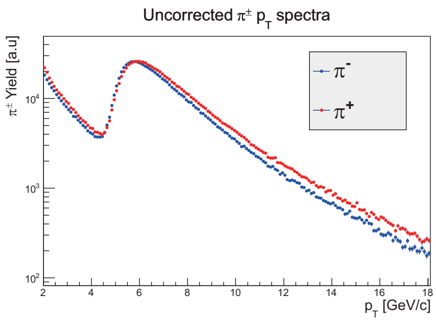

Fig. 1. p_T spectra of $\pi^{\pm}$

Charged particles including $\pi^{\pm}$ are reconstructed using the drift chamber (DC), pad chambers (PC) covering the pseudo-rapidity range $|\eta| < 0.35$, and azimuthal angle $\Delta\phi = \pi$. When a charged particle passes through a di-electric medium, CO_2 gas in the RICH, at a speed faster than the phase velocity of light in the medium, it emits the Cerenkov light which then fires the array of photomultiplier tubes (PMT). In the momentum region of interest, only e$^{\pm}$ and $\pi^{\pm}$ emit light and can thus be preselected by RICH activity. e$^{\pm}$ deposits most of its energy in the EM showers. On the other hand $\pi^{\pm}$ on average deposits only a third of their energy in the EMCal. Therefore, $\pi^{\pm}$ is separated from other particles using the RICH and the EMCal. In addition to the cuts mentioned above, the acceptance cut and the track matching with hit on the EMCal and PCs were required. Fig.1 shows $\pi^{\pm}$ p_T spectra after applying the cuts. A turn on curve is cleary observed at a p_T of 4.8 GeV/c because $\pi^{\pm}$ survives from the cut requirement. However, some background may remain, as mentioned.

(1) conversion electron reconstructed with wrong p_T
(2) $\pi^{\pm}$ originating from hadronic decay

In the PHENIX tracking algorithm, the tracks are not propagated to the decay vertex but to the event vertex. So the tracks for types (1) and (2) may not be reconstructed correctly and cuts are carefully being applied to the tracks at present. After the cut optimization, both the cross section and A_{LL} will be measured.

In summary, $\pi^{\pm}$ analysis was started at $\sqrt{s} = 510$ GeV. With more statistical data, a more precise measurement of A_{LL} in $\pi^{\pm}$ production is expected.

Reference

1) A. Adare et al. (PHENIX Collaboration), Phys. Rev. D 91, 032001 (2015).