Proposal to measure $A_{LL}$ of EM clusters at sPHENIX in 2021

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We propose to measure the double helicity asymmetry ($A_{LL}$) of electromagnetic (EM) clusters in $\sqrt{s} = 200$ GeV polarized $p + p$ collisions with partially installed sPHENIX detector in 2021. The measurement includes both EM clusters from $\pi^0$ decay and the direct photon. The sPHENIX detector will be fully installed in 2022. For the $A_{LL}$ measurement in 2021, we need the EM calorimeter for energy measurement, and minimum number of internal silicon trackers, e.g. inner pixel layers + new 2 or 3 outer layers for charge veto and isolation cut of the EM clusters. In addition, we need a trigger detector that provides the minimum-bias trigger and vertex measurement, and ZDC for relative luminosity measurement. We also need a high-$p_T$ trigger with the EM calorimeter.

In the previous runs of longitudinal polarization at $\sqrt{s} = 200$ GeV in 2005+2006+2009, we’ve recorded about 20 pb$^{-1}$ integrated luminosity at PHENIX [1]. In 2021, we expect 630 pb$^{-1}$ delivered luminosity and 175 pb$^{-1}$ recorded at sPHENIX (35% 10-cm vertex cut and 80% detector up-time). Since the granularity of the EM calorimeter at sPHENIX $\Delta \eta \times \Delta \phi \sim 0.024 \times 0.024$, we will be able to identify $\pi^0$ from two photon decay up to $p_T = 8$ GeV/$c$. The sPHENIX acceptance is about 8 times as large as that of the PHENIX EM calorimeter (EMCal). Thus we will be able to measure the $A_{LL}$ of $\pi^0$ up to 8 GeV/$c$ with effectively 70 times of the final statistics of the PHENIX measurement. This will provide a very good measurement of the $A_{LL}$ of $\pi^0$ as is shown in Fig. 1.

Above $p_T > 8$ GeV/$c$, it becomes difficult to separate two photons from $\pi^0$ decay and single photon of the direct photon $^2$. In this $p_T$ range, we can measure the $A_{LL}$ of EM clusters which are mixture of $\pi^0$s and direct photons. At higher $p_T$, direct photon / $\pi^0$ ratio is higher. To enhance the

1The efficiency to identify $\pi^0$ is approximately 50% at $p_T = 8$ GeV/$c$, and higher at for lower $p_T$.
2We may apply a shape analysis of the EM clusters to distinguish $\pi^0$s and direct photons at more than $p_T > 8$ GeV/$c$.
fraction of the direct photon, we will apply the isolation cut which requires limited charged particles and other photons around the direct photon \(^3\). To find the charged particles, we need tracking detectors, e.g. internal silicon trackers with some magnetic field.

By these measurements, we’ll be able to obtain high statistics \(A_{LL}\) data of \(\pi^0\) up to \(p_T = 8\, \text{GeV}/c\) and that of EM clusters (inclusive or isolated) at higher \(p_T\). High \(p_T\) EM cluster data is important because not only it gives an additional statistics to investigate the gluon polarization at high \(x_T\) but also systematically different data from existing jet \(A_{LL}\) data [2]. Note that isolated EM clusters above 10 GeV/c are dominated by direct photons. The direct photon process is a clean process dominated by the gluon Compton process, so that it is a golden channel for the gluon polarization measurement.

Figure 2 shows projection of the \(A_{LL}\) measurement of EM clusters in \(\sqrt{s} = 200\, \text{GeV}/c\) polarized \(p + p\) collisions at sPHENIX compared with the NLO calculation of direct photon and \(\pi^0\) by W. Vogelsang. We assumed 175 pb\(^{-1}\) luminosity and 60% polarization for the measurement.

In order to estimate the isolation cut, we assumed isolated direct photon ratio of \(0.4 + 0.05 \times p_T\) (GeV/c) \((p_T < 10\, \text{GeV}/c)\) or 0.9 \((p_T > 10\, \text{GeV}/c)\) from the all direct photon, and isolated \(\pi^0\) ratio of 0.4 \((p_T\) independent) from the all \(\pi^0\) based on PHENIX measurement of the direct photon and \(\pi^0\) in 2006 [3]. Here we assume the \(A_{LL}\) doesn’t change after the isolation cut. Figure 3 shows projection of the \(A_{LL}\) measurement of EM clusters after the isolation cut compared with the NLO calculation of isolated direct photon

\(^3\)We may also apply the anti-isolation cut to enhance the fraction of \(\pi^0\).
Figure 2: (Left) Cross section ratio of direct photon and $\pi^0$. (Right) NLO calculation of $A_{LL}$ of direct photon (red), $\pi^0$ (green), and mixture of direct photon and $\pi^0$ (black), and projection of the $A_{LL}$ measurement.

Figure 3: (Left) Cross section ratio of isolated direct photon and isolated $\pi^0$. (Right) NLO calculation of $A_{LL}$ of isolated direct photon (red), isolated $\pi^0$ (green), and mixture of isolated direct photon and $\pi^0$ (black), and projection of the $A_{LL}$ measurement with the isolation cut.

and $\pi^0$.

References

