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Measurement of transverse polarization of $\Lambda/\overline{\Lambda}$ within jet in pp collisions at STAR

Taoya Gao[a,*]**,For the STAR collaboration**

[a] *Institute of Frontier and Interdisciplinary Science & Key Laboratory of Particle Physics and Particle Irradiation(Ministry of Education), Shandong University, Qingdao, Shandong, 266237, China,*

E-mail: gao.ty@mail.sdu.edu.cn

Spontaneous polarization of $\Lambda/\overline{\Lambda}$ in unpolarized hadron interactions has been observed experimentally for nearly half a century and still eludes a definitive explanation. One possible origin is the effect arising from polarizing fragmentation functions (pFFs), which describe the production of polarized hadrons from the fragmentation of an unpolarized parton. Recently, significant transverse polarization of $\Lambda/\overline{\Lambda}$ has been observed in unpolarized e^+e^- annihilation at Belle experiment, along the normal to the plane defined by the thrust axis and Λ momentum. In unpolarized pp collisions, the measurement of transverse polarization of $\Lambda/\overline{\Lambda}$ within jet could also provide important constraints and universality test for the pFFs. In this contribution, preliminary results on the first measurement of $\Lambda/\overline{\Lambda}$ polarization within a jet in pp collision at $\sqrt{s}$ = 200 GeV are reported. The data used for this measurement were taken by the STAR experiment at RHIC in 2015.

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1. Introduction

The Λ hyperon characterized by self-analyzing weak decay has played a special role in the field of spin physics [1]. In 1976, the large transverse polarization of hyperon was first observed in unpolarized $p + Be$ scattering [2], in a direction transverse to the production plane. Based on perturbative Quantum Chromodynamics (pQCD) calculations, the contributions from the hard scattering of hadronic collisions were found to be close to zero [3]. This discrepancy came as a surprise to the community. Numerous experiments followed to study the Λ spontaneous polarization in various reactions, *i.e.*, semi-inclusive deep inelastic scattering (SIDIS), e^+e^- annihilation, hadron-hadron and hadron-nucleus scatterings [4–8]. Despite lots of efforts and progress in understanding the Λ polarization phenomenon, a definite explanation has not been identified.

One possible contribution could be from the Boer-Mulders function [9] in the initial state, which describes the correlation between the transverse spin and intrinsic transverse momentum of quarks in an unpolarized nucleon. Another possible contribution could be from polarizing fragmentation functions (pFFs) [10, 11] in the final state, which describe the production of a polarized hadron from the fragmentation of an unpolarized parton. In recent years, the study of polarizing fragmentation functions has received increasing attention as an effective tool to understand the fragmentation process [12–14], especially after the observation of the significant transverse polarization of $\Lambda(\overline{\Lambda})$ in e^+e^- annihilation at Belle [15].

In pp collisions, pFFs can be accessed by measuring polarization of Λ within a jet. And one advantage compared to a fixed energy scale in e^+e^- annihilation is that a wide jet p_T range can be obtained in pp collisions. Therefore, we can study the energy scale dependence of pFFs by measuring the Λ polarization versus jet p_T in pp collisions. Additionally, the process universality of pFFs could also be tested. The polarization direction of Λ is defined along the normal direction to the plane defined by the jet and Λ momenta as illustrated in Fig. 1, $\mathbf{S} = \mathbf{p}_{jet} \times \mathbf{p}_\Lambda$.

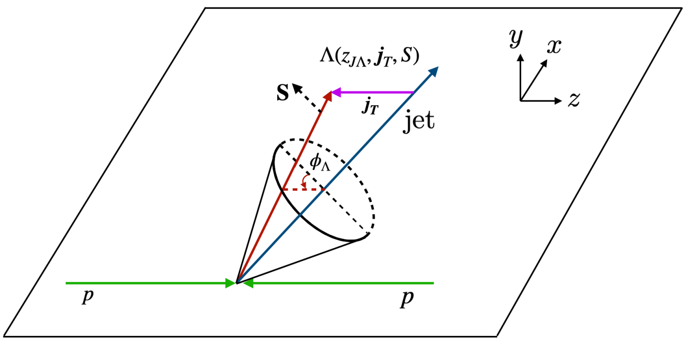

Fig. 1. The illustration of Λ hyperon production inside a jet in pp collisions, vector **S** denotes polarization direction defined by jet and Λ momentum: $\mathbf{S} = \mathbf{p}_{jet} \times \mathbf{p}_\Lambda$.

2. Λ and jet reconstruction

The pp collision data at $\sqrt{s} = 200$ GeV used for this measurement were collected by the STAR experiment at RHIC in 2015. The STAR detector comprises a variety of subdetectors. The Time

Projection Chamber (TPC) [16], Barrel Electronmagnetic Calorimeter (BEMC) and Endcap Electronmagnetic Calorimeter (EEMC) [17, 18] are used in this analysis. The TPC provides charged-particle tracking and particle identification. The BEMC and EEMC are used for electromagnetic energy measurement and event triggering. In this analysis, only events triggered by JP1, one of the STAR jet-patch triggers with the threshold of 5.4 GeV, are used.

The $\Lambda(\overline{\Lambda})$ candidates are reconstructed via the weak decay channel: $\Lambda \rightarrow p + \pi^-$ ($\overline{\Lambda} \rightarrow \overline{p} + \pi^+$). A set of topological selection criteria is applied to pair two tracks with opposite charges to suppress the background, following similar procedure as in Ref. [19] except that the Time of Flight hit matching is not required for the pion track. The residual background from random track combinations and wrong particle identification is estimated to be about 10% by using the side-band method and also subtracted.

In order to measure the transverse Λ polarization inside a jet, we need to reconstruct a jet including $\Lambda/\overline{\Lambda}$ particle. Such jet reconstruction is based on the TPC primary tracks, BEMC/EEMC tower energies and the reconstructed $\Lambda/\overline{\Lambda}$ [19], using anti-k_T algorithm with R = 0.6 and $p_T^{jet} > 5$ GeV/c. To suppress the edge effects, jet p_T is further required to be larger than 8 GeV/c. To take into account the contributions from pile-up events or other background to jet reconstruction in pp collisions, the off-axis method [20] is used to correct for the underlying event.

3. Results

The transverse polarization of Λ is extracted via the angular distribution of the daughter particle in the Λ rest frame:

$$\frac{dN}{d\cos\theta^*} \propto A(\cos\theta^*)(1 + \alpha_{\Lambda(\overline{\Lambda})} P_{\Lambda(\overline{\Lambda})} \cos\theta^*), \tag{1}$$

where $A(\cos\theta^*)$ is the acceptance function, θ^* is the angle between Λ polarization direction and its daughter p in the Λ rest frame, $\alpha_{\Lambda/\overline{\Lambda}} = \pm\, 0.732$ is the decay parameter [21] and $P_{\Lambda(\overline{\Lambda})}$ is transverse polarization of Λ.

The angular distribution in Eq. (1) is sensitive to the detector acceptance which has to be corrected for. The detector acceptance function is estimated based on Monte-Carlo simulation by passing the pp events generated by PYTHIA6.4.28 through GEANT3 framework of STAR detector. In addition, the same analysis procedure is applied to the MC sample as it is to the data. After acceptance correction, the polarization is extracted through fitting $\cos\theta^*$ distribution by a linear function. Limited by the size of the Monte-Carlo sample, the statistical uncertainties of the acceptance function dominate the uncertainties of the extracted transverse polarization.

Figure 2 shows the preliminary results on the transverse polarization of $\Lambda(\overline{\Lambda})$ versus jet p_T in pp collisions at $\sqrt{s}$ = 200 GeV. The average value of jet p_T is about 11 GeV/c. Both Λ and $\overline{\Lambda}$ indicate a hint of negative transverse polarization and also a weak dependence of jet p_T at current precision. The magnitude of $\overline{\Lambda}$ polarization has a trend of increasing with jet p_T. This is the first hint of non-zero transverse polarization of $\Lambda(\overline{\Lambda})$ inside jet in unpolarized pp collision.

To provide further constraints for the pFFs, the transverse polarizations of Λ and $\overline{\Lambda}$ are also measured as functions of j_T and z, as shown in Fig. 3. As illustrated in Fig. 1, j_T is the transverse momentum of $\Lambda/\overline{\Lambda}$ w.r.t. the jet axis, while z is the momentum fraction of jet carried by $\Lambda/\overline{\Lambda}$. From

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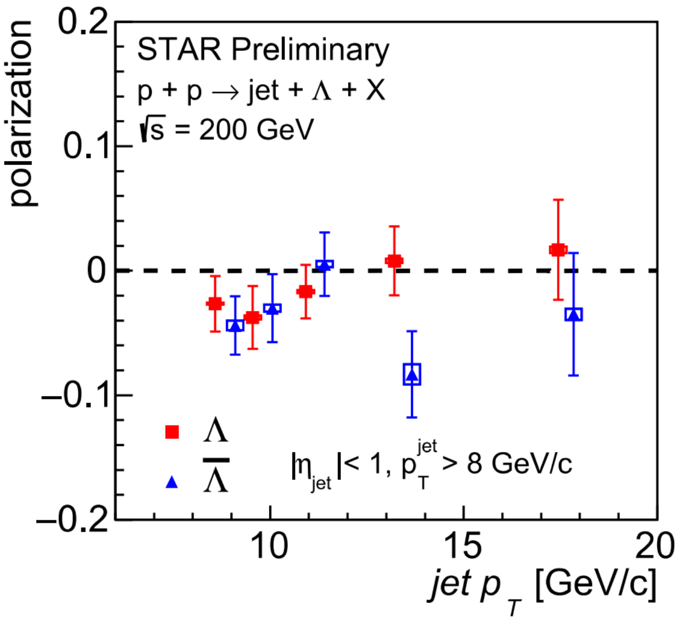

Fig. 2. Preliminary results Λ and $\overline{\Lambda}$ polarization within a jet versus jet p_T in unpolarized pp collisions at $\sqrt{s}$ = 200 GeV at STAR.

the left panel of Fig. 3, no j_T dependence are observed for the transverse polarization of either Λ or $\overline{\Lambda}$. The right panel of Fig. 3 shows the transverse polarization as a function of z. There is a weak trend that the magnitude of the measured polarization increase with z for both Λ and $\overline{\Lambda}$.

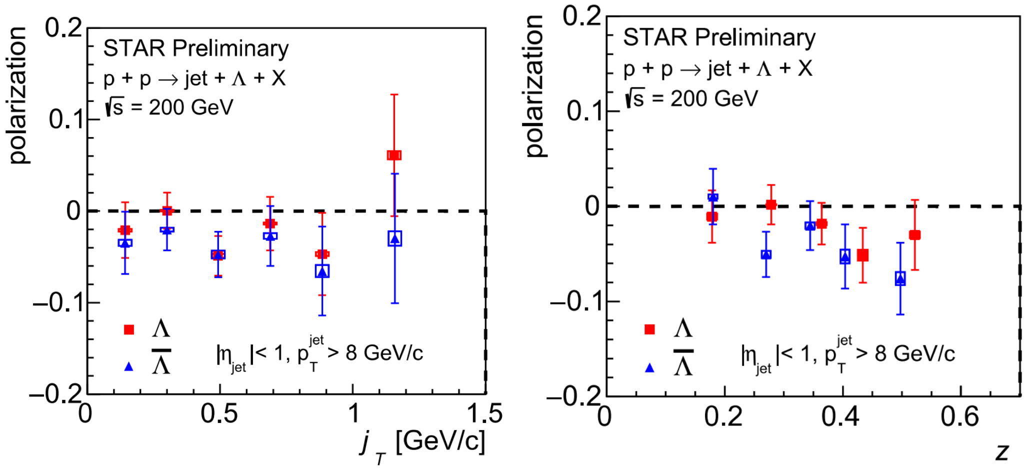

Fig. 3. Preliminary results of Λ and $\overline{\Lambda}$ polarization within a jet as a function of transverse momentum j_T (Left), and jet momentum fraction z (Right) in unpolarized pp collisions at $\sqrt{s}$ = 200 GeV.

4. Summary

The polarizing fragmentation functions (pFFs) is one of the most possible origins of the Λ spontaneous polarization and can be accessed by measuring polarization of $\Lambda(\overline{\Lambda})$ inside a jet in pp

collision at RHIC. In this contribution, we present the preliminary results on the first measurement of the transverse polarization of $\Lambda(\overline{\Lambda})$ within a jet in pp collision at $\sqrt{s}$ = 200 GeV. We observe a hint of negative polarization of $\Lambda(\overline{\Lambda})$ inside a jet, which also has a weak jet p_T dependence with the current statistical precision. The transverse polarization as a function of j_T and z is also presented. These measurements could provide important constraints on pFFs like the scale evolution and the universality test. Improving the precision of the measurement, in particular the acceptance function is underway.

Acknowledgements

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