Beam polarization monitor in $\sqrt{s} = 510$ GeV polarized proton-proton collisions at the RHICf experiment

M. H. Kim*1,*2 for the RHICf collaboration

A new experiment, RHIC forward[1)] (RHICf), has measured the transverse single spin asymmetry, A_N, of very forward particle productions in $\sqrt{s} = 510$ GeV polarized proton-proton collisions at the Relativistic Heavy Ion Collider (RHIC) in June, 2017.[2)] A_N is defined as a left-right asymmetry of the production cross section to beam polarization. It plays an important role in the study of the production mechanism of very forward particles, particularly from the view points of diffractive and non-diffractive interactions. The A_N of mainly very forward neutrons, π^0, and γ with a transverse momentum (p_T) up to 1 GeV/c can be studied in detail in the RHICf experiment.

In order to measure the A_N of very forward particles precisely, a new electromagnetic calorimeter (RHICf detector), which had been originally developed for the LHCf experiment at CERN,[3)] was installed in front of a hadron calorimeter[4)] (ZDC) at STAR to improve the position resolution of the detected particles. The RHICf detector consists of small (TS) and large (TL) towers. Each tower is composed of 17 layers of tungsten plates, 16 layers of GSO plates, and 4 position-sensitive layers of thin GSO bars. ZDC has been used as a polarization monitor by calculating the raw asymmetry (ϵ_N) of neutron-like events using a STAR scaler board. One scaler board is composed of 32 bits, and each bit has a flag of 0 or 1 for every entry depending on whether an event satisfies a specific condition. Finally, it gives the number of counts for each of 2^{32} types of events. However, because the ZDC was screened by the RHICf detector at operation, there was no guarantee that the ZDC monitor works as well as it used to. Owing to the non-negligible interaction length of the RHICf detector, a hadronic shower was expected to be generated in 30% of the neutrons. Therefore, we connected two scaler bits to each tower of the RHICf detector and measured the ϵ_N of each by

$$\epsilon_N = \frac{N^{\uparrow} - RN^{\downarrow}}{N^{\uparrow} + RN^{\downarrow}} \quad (1)$$

as the second beam-polarization monitor, where $N^{\uparrow}$ ($N^{\downarrow}$) is the number of scaler counts with the proton polarized up (down) when a shower is generated at the RHICf detector. Events for which three successive layers at one of the towers were greater than 45 MeV were chosen based on a Monte-Carlo study. This condition is called shower trigger hereafter. R is a correction factor that compensates for the difference in the number of collisions between up and down polarization.

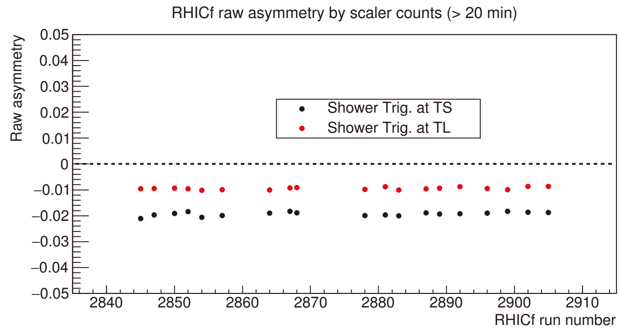

Fig. 1. Measured ϵ_N depending on run number.

Because N is proportional to the production cross section, A_N can be studied using ϵ_N.

Calculated ϵ_N with different run numbers that lasted longer than 20 minutes are described in Fig. 1. We had three types of physics runs depending on the detector positions, and each run lasted 30 minutes if there was no critical issue. This is the result when the beam height is 24 mm below the center of TS. The stability of beam polarization can be confirmed by ϵ_N, which was conserved within 10% error. If the polarization direction was changed or the ratio of polarized beam decreased, the amplitude of ϵ_N would approach to zero. Neutrons are dominant in the shower-triggered events. The signs of ϵ_N show good agreement with the negative sign of A_N for very forward neutron production.[5)] ϵ_N at TL is more diluted than at TS because the gamma contamination is more enhanced at TL than at TS.

The production cross-section asymmetry of very forward particles was studied using the RHICf detector with scaler bits. However, because there is a limit in the reconstruction of particle information with it, further issues remain in the detector data analysis.

References
1) RHICf Collaboration: LOI, arXiv:1401.1004; RHICf proposal: arXiv:1409.4860.
2) J. S. Park for the RHICf Collaboration, in this report.
3) LHCf Collaboration, JINST **3**, S08006 (2008).
4) C. Adler *et al.*, Nucl. Instrum. Meth. A **470**, 488 (2001).
5) A. Adare *et al.*, Phys. Rev. D **88**, 032006 (2013).

*1 RIKEN Nishina Center
*2 Department of Physics, Korea University