Feasibility of the forward Λ measurement at the RHICf experiment

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In high-energy polarized $p + p$ collisions, a spin-dependent diffractive particle production mechanism can be studied in detail by measuring transverse single-spin asymmetry ($A_{\rm N}$) of forward particles. $A_{\rm N}$ is defined by a left-right cross-section asymmetry with respect to beam polarization. In June 2017, the RHICf Collaboration has installed an electromagnetic calorimeter (RHICf detector)[1] in front of the STAR zero-degree calorimeter (ZDC)[2] at the Relativistic Heavy Ion Collider for the measurement of $A_{\rm N}$. In this article, we report on the feasibility of the forward Λ measurement using the RHICf detector and ZDC to study a possible correlation between the neutral pion and neutron $A_{\rm N}$s.

The RHICf detector comprises small and large sampling towers of 20 mm and 40 mm in size, respectively. Figure 1 shows the longitudinal structure of the RHICf detector. Each tower comprises 17 layers of tungsten absorbers with a total of 44 radiation length (or 1.6 nuclear interaction length), 16 layers of Gd_2SiO_5 (GSO) scintillator plates for energy measurement, and four layers of 1-mm-wide GSO bar hodoscope for position measurement. The first 11 tungsten absorbers have 2-mm thickness for photon measurement and the rest have 4-mm for hadron measurement.

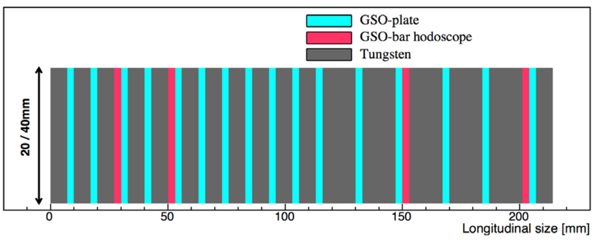

Fig. 1. Longitudinal structure of the RHICf detector.

The STAR ZDC comprises three modules with a total of 5.1 nuclear interaction length made of W-Cu alloy and optical fiber layers. If a hadronic shower is generated in the ZDC, photomultipliers mounted on the ZDC collect Cherenkov light from the optical fibers for energy measurement. A shower max detector (SMD), which is a scintillator hodoscope, is located between the first and second ZDC modules for position measurement. Since the RHICf detector has an insufficient nuclear interaction length for neutron measurement, shower leakage of the RHICf detector can be compensated by the ZDC.

We used a decay channel, $\Lambda \to n+\pi^0 \to n+\gamma+\gamma$, to reconstruct Λ. To study the feasibility of the Λ reconstruction, a Monte Carlo (MC) sample where Λs with randomized energies from 0 GeV to 255 GeV were uniformly generated on the detector was used. In most cases, the decayed neutron and photons hit the same tower because of a small opening angle. The energies and positions of the two photons were reconstructed using the forward part of the RHICf detector (up to 12th GSO plates) by requiring that the hadronic shower started to be developing from the backward part (starting from 13th GSO plates); thereby, the position of the neutron was reconstructed by one of the GSO bar layers located between 4-mm tungsten absorbers or the SMD. The energy of the neutron was reconstructed using the RHICf detector and ZDC simultaneously. The scale parameters were multiplied by the numbers of Cherenkov photons of each ZDC module to convert them to quantities that were equivalent to the energy deposit of the RHICf detector. The z-vertex position of the Λ decay was estimated so that the two-photon invariant mass was approximately 135 MeV/c^2. Then, the x- and y-vertex positions were fixed as the reconstructed Λ track headed to the collision point.

Figure 2 shows the invariant mass distribution of the decayed neutron and neutral pion in the MC sample. A clear peak is observed around 1115 MeV/c^2, which means that it is certainly possible to reconstruct Λ using the RHICf detector and ZDC. Currently, a detailed study on the background of the Λ reconstruction is underway.

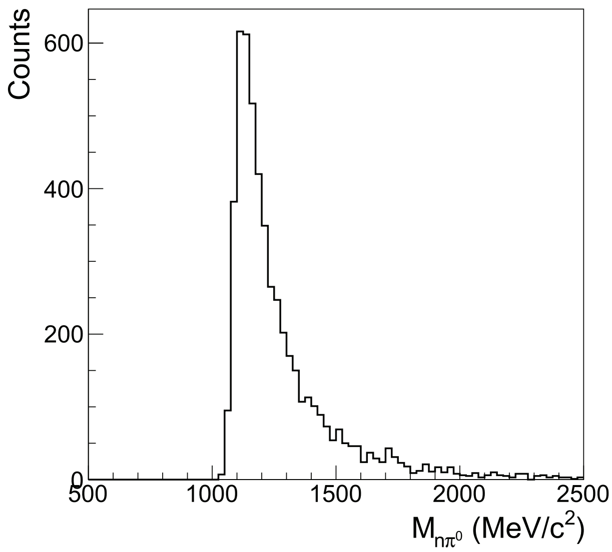

Fig. 2. Reconstructed invariant mass distribution of the decayed neutron and neutral pion in the MC sample.

References
1) RHICf Collaboration, J. Instrum. **16**, P10027 (2021).
2) C. Adler *et al.*, Nucl. Instrum. Methods Phys. Res. A **470**, 488 (2001).

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DOI:10.34448/RIKEN.APR.57-080