Expected energy resolution and its trigger dependence for very forward neutron measurements in $\sqrt{s} = 510$ GeV polarized proton-proton collisions at the RHICf experiment

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The single spin asymmetry, A_N, of very forward neutrons in polarized proton-proton collisions plays an important role in the study of the production mechanism of very forward neutrons, particularly diffractive and non-diffractive interactions. A_N is a left-right asymmetry,

$$A_N = \frac{d\sigma^{\uparrow} - d\sigma^{\downarrow}}{d\sigma^{\uparrow} + d\sigma^{\downarrow}} \tag{1}$$

for yields observed with proton polarization, where $d\sigma^{\uparrow}(d\sigma^{\downarrow})$ is the production cross section when the protons are polarized up (down). To measure the A_N of very forward neutrons precisely, an electromagnetic calorimeter was installed in front of the ZDC hadron calorimeter[1)] at the STAR experiment to improve the limited position resolution of ZDC ($\sim$ 1 cm). This detector was originally developed for the LHCf experiment[2)] at CERN and will be called the RHICf detector[3)] hereafter. RHICf is not designed to provide good energy resolution to neutrons with an interaction length of 1.6 λ. However, its energy resolution can be well recovered by compensating for the shower leakage of RHICf caused by ZDC, the interaction length of which is 2 λ. Here, we report the result of a Monte-Carlo (MC) study of the expected performance of neutron energy measurement when both RHICf and ZDC are used together as well as its trigger dependence with respect to the threshold energy.

In the MC study, 10^6 neutrons with energies of 100, 150, 200, 250, and 350 GeV were generated as it passed through the center point of the first GSO plate and their energies were reconstructed using the correlation between energy to energy deposit (edep) sum of RHICf and the total number of photoelectrons (Npe) of ZDC. Energy resolution was evaluated in the following three cases: 1) RHICf only, 2) ZDC only, and 3) the combined system.

Simulation results for the threshold energy dependence of neutron energy resolution and the ratio of the selected to the total events at 250 GeV are shown in Fig. 1 (a). A higher threshold energy results in lower trigger efficiency and better energy resolution. The red dashed line indicates the intrinsic ZDC resolution (18.2%). The energy resolution becomes as good as the intrinsic resolution of ZDC even though the shower leakage of RHICf is measured by ZDC and combined later.

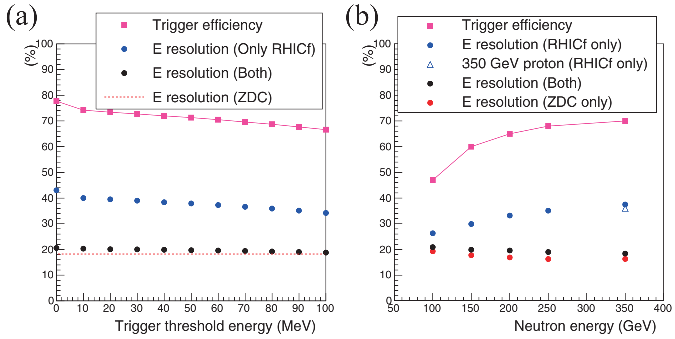

Fig. 1. (a) Trigger-threshold-energy dependence of the expected neutron energy resolution and the trigger efficiency. (b) Incident-neutron-energy dependence at a trigger threshold energy of 90.6 MeV.

The energy resolution at different neutron energies is plotted in Fig. 1 (b). The threshold energy of the trigger was set at 90.6 MeV in order to compare with a previous LHCf test result of 350-GeV protons shown as a blue open triangle. However, it will be optimized later for only the RHICf experiment. The MC prediction, 37.5 %, for 350-GeV neutrons shows good consistency with the LHCf result, 36.0 %, within statistical error. A better energy resolution is obtained with a lower neutron energy because the same threshold energy was applied to the trigger. When only ZDC is used, the resolution at 100 GeV also shows good agreement with a previous experimental result for polarized pp collision at $\sqrt{s} = 200$ GeV.[4)] Finally, because the simulation result corresponds with experimental results in both the 1) RHICf only and 2) ZDC only cases, for neutrons with an energy of 100-250 GeV in the RHICf experiment, we expect an energy resolution of approximately 20% with a threshold of 90.6 MeV when both detectors are used.

References

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