Final result of nuclear dependence on A_N for forward neutron production in polarized p+A collisions at $\sqrt{s_{NN}} = 200$ GeV[†]

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In high-energy hadron collisions, most of the energy goes to the forward region. Yet the particle production mechanism in this region is not well understood, because a small momentum transfer preclude the application of perturbative QCD, and diffractive processes are not well modeled or interpreted. Therefore, measurements of forward particle production may contribute crucially to the theoretical model development. Furthermore the measurement of the transverse-single-spin asymmetry A_N[1)] can elucidate processes that are not visible in the cross-section data. In the case of forward neutron production in high-energy $p+p$ collisions, the one-pion exchange (OPE) model had been developed, and it explained cross-section data.[2)] However, A_N calculated from this model is approximately an order smaller than that measured in the PHENIX experiment.[1,2)] In order to explain these data, an interference between spin-flip π exchange and non-spin-flip a_1-Reggeon exchange amplitudes was introduced.[2)]

In 2015, RHIC achieved the world's first high-energy polarized proton-nucleus collisions. In this report, the A_N results of forward neutron production at $\sqrt{s_{NN}} =$ 200 GeV p+p, p+Al, and p+Au collisions measured in the PHENIX experiment are presented. Neutrons at $0.3< \theta <2.2$ mrad and $x_F >0.5$ are measured using the zero-degree calorimeter (ZDC), which is a Čerenkov sampling hadron calorimeter with an X-Y hodoscope consisting of plastic strip scintillators. In addition, correlation with charged particle production is measured by two beam-beam counters (BBCs), which are located in the lower pseudorapidity ±(3.0–3.9). The background fraction in p+p collision is not negligible; therefore, background asymmetry was subtracted using the data taken in 2008, when a charge veto counter was installed in front of the ZDC. The smearing of A_N due to the detector resolution is estimated by PYTHIA6 and GEANT3 simulation and then corrected.

The A dependence of A_N is shown in Fig. 1. ZDC inclusive neutrons show a strong A dependence, with a large A_N accompanying a sign change at Au. This result is unexpected from the current π and a_1-Reggeon exchange model in which the possible A dependence is from nuclear absorption.[3)] The A dependence is even more drastic when both BBCs are vetoed (ZDC⊗BBC-veto), showing an even larger A_N at Au and a sign change at Al. In contrast, when both BBCs are fired (ZDC⊗BBC-tag), the A dependence is moderate, and the sign remains negative. This work was announced through a press release by BNL and RIKEN.[4)]

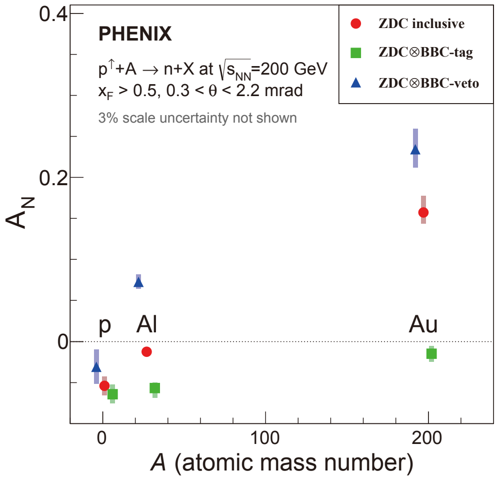

Fig. 1. A_N of forward neutrons in $p+p$, $p+$ Al, and $p+$ Au collisions for ZDC inclusive, ZDC⊗BBC-tag, and ZDC⊗BBC-veto. Color bars represent systematic uncertainties. Statistical uncertainties are smaller than the marker size.

In a recently published paper,[5)] this A dependence of A_N is explained by the contribution of electromagnetic (EM) processes as follows. In large Z nuclei, neutrons are produced from ultraperipheral collisions (UPC) as well as a decay product of Δ produced from proton excitation by a virtual photon flux from the nucleus. This process is enhanced (suppressed) in ZDC⊗BBC-veto (tag). The A_N^{UPC} is calculated with the virtual photon flux simulated by STARLIGHT and the A_N of $\gamma^*+p^\uparrow \rightarrow \pi^+ + n$ obtained from the MAID2007 unitary isobar model. The sum of A_N^{UPC} and A_N^{OPE} reproduced ZDC inclusive A_N.

In order to understand this interesting result even deeper, the measurement of p_T and energy dependence on A_N is ongoing.

References
1) A. Adare *et al.*, Phys. Rev. D **88**, 032006 (2013).
2) B. Z. Kopeliovich, I. K. Potashnikova, I. Schmidt, J. Soffer, Phys. Rev. D **84**, 114012 (2011).
3) B. Z. Kopeliovich, I. K. Potashnikova, I. Schmidt, AIP Conf. Proc., Vol.**1819** (2017), p.050002.
4) The announcement has been reported by multiple media outlets, such as Newsweek online and ScienceAlert.com.
5) G. Mitsuka, Phys. Rev. C **95**, 044908 (2017).

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