Recent results of collective flow for SπRIT-TPC experiment

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The SAMURAI Pion-Reconstruction and Ion-Tracker-Time-Projection Chamber (SπRIT-TPC)[1] project aims to constrain a nuclear equation of state (EoS) at supra-saturation density using heavy ion collisions. The SπRIT-TPC was designed to measure π^-/π^+ production ratio depending on isospin asymmetry. Since the pions are expected to be produced through the Δ resonance formation, π^-/π^+ ratio is related to some kind of nuetron-to-proton squared ratio which is then supposed to be sensitive to the symmetry energy at high densities.[3]

Additionally, measurements of collective flow with proton and neutron are proposed as a useful probe[2] to nuclear EOS, because neutrons are repelled from dense region as a result of the repulsive isospin symmetry potential with increase of density, while protons are opposite.

The first experiment had been performed in April 2016 with ^{132}Sn and ^{108}Sn beams at 270 MeV/nucleon on ^{112}Sn and ^{124}Sn targets at SAMURAI in RIBF. Neutrons were detected by NeuLAND[4] covering the mid-rapidity region. In this paper, recent results of the collective flow for proton and neutron will be discussed.

A track reconstruction was done using SπRITROOT software and particle identification ability is discussed in Ref. 5).

An orientation angle of reaction plane, Ψ was determined with summing up a transverse momentum of light charged fragments, p, d, t, ^{3}He, and ^{4}He event by event, as following.

$$\vec{Q} = \begin{pmatrix} Q\cos\Psi \\ Q\sin\Psi \end{pmatrix} = \sum_{k=1}^{N} \omega_k \begin{pmatrix} \cos\phi_k \\ \sin\phi_k \end{pmatrix} \quad (1)$$

$$\omega_k = \begin{cases} 1 & \text{if rapidity in the center of mass} > 0 \\ -1 & \text{otherwise} \end{cases}$$

Since the distribution of Ψ was distorted due to a rectangular shape of SπRIT-TPC, it was corrected applying a re-centering and a shifting method.[6] The azimuthal angle distributions with respect to Ψ were plotted for protons measured with ^{132}Sn + ^{124}Sn in Fig. 1. In these plots, Ψ was determined with all light fragments excluding itself to avoid auto correlation. Red lines shows fitting results with a formula

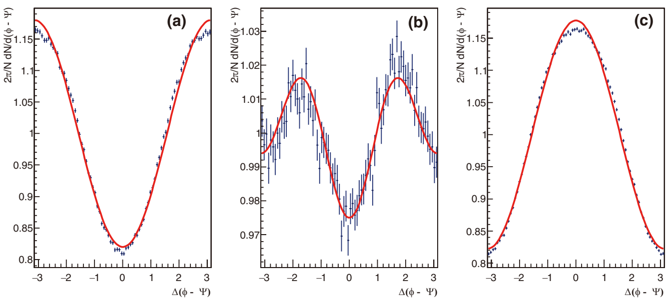

Fig. 1. Azimuthal angle distributions of proton with respect to Ψ. The rapidity coverages in the center of mass are (a) target-rapidity: $-4.0 \sim -0.06$, (b) mid-rapidity: $-0.06 \sim 0.06$, and (c) Beam-rapidity: $0.06 \sim 4.0$). Red lines indicate fitting with Eq. (2).

$$\frac{2\pi}{N}\frac{dN}{d\phi} = 1 + 2v_1\cos(\phi) + 2v_2\cos(2\phi) + ... \quad (2)$$

The negative and positive v_1 were observed in the target (a) and beam rapidity region (c), which is the evidence of directed flow. The negative v_2 was observed in the mid rapidity region (b), which indicates out-of-plane elliptic flow of protons. The strength of v_1 and v_2 are needed to be corrected with a reaction plane resolution to compare between ^{132}Sn + ^{124}Sn and ^{108}Sn + ^{112}Sn collisions. Neutron's collective flow was also observed within a limited acceptance. Simulation and further analysis are necessary to extract EoS information. Addition to neutron to proton ratio, ^{3}H to ^{3}He analysis is ongoing, which is expected to serve in resolving ambiguities caused by the effective-mass splitting between neutrons and proton.

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