Status of collective flow analysis for SπRIT-TPC experiment

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The successful observation of gravitational waves from a neutron star merger[1)] highlights the importance of the nuclear Equation of State (EoS). Heavy ion collisions are an appropriate tool to evaluate the nuclear EoS at supra-saturation. In nuclear EoS at a density more than that of normal nuclear matter ($\rho > 2\rho_0$), the isospin symmetry energy term includes large uncertainly in theory, because of the lack of experimental data. In a previous work, the π^-/π^+ production ratio was a super soft EoS;[2)] however, the proton and neutron collective flow analysis[3)] was inconsistent.

The SAMURAI Pion-Reconstruction and Ion-Tracker-Time-Projection Chamber (SπRIT-TPC) project was proposed to constrain the EoS using different isospin asymmetry systems with ^{132}Sn and ^{108}Sn beams at 270 MeV/u on ^{112}Sn and ^{124}Sn targets at SAMURAI in RIBF. Multiple observations, such as π^-/π^+ production ratio, proton and neutron collective flow, and H^3/He^3 production ratio, will be obtained to study the EoS for heavy ion collisions.

The collective flow of neutron and proton is expected to be sensitive to the isospin symmetry potential because it could minimize the influence of the isoscalar potential.[4)] In this paper, recent results for the collective flow analysis will be discussed.

The SπRIT-TPC is described in Ref. 5) NeuLAND was installed 8.8 m downstream from the target to detect neutrons emitted around the mid-rapidity region. Trigger devices, KATANA array[6)] and Multiplicity array[7)] were installed surrounding the SπRIT-TPC.

The strength of the collective flow is analyzed from the azimuthal distribution with respect to a reaction plane. The reaction plane orientation angle, Ψ, is determined event by event. The azimuthal angle of the reaction plane is defined as the sum of the transverse momentum unit vector.

$$\Psi = \frac{\sum_i^m \omega_i \sin(n\phi_i)}{\sum_i^m \omega_i \cos(n\phi_i)} \tag{1}$$

$$\Delta\Psi_{sub} = \Psi_A - \Psi_B \tag{2}$$

The coefficient ω is 1 if rapidity is larger than the center of rapidity, otherwise it is -1.

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The geometrical acceptance of the SπRIT-TPC is limited and asymmetric in the azimuthal angle, so it was necessary to apply a flattening correction.[8)] Tracks were randomly selected from independent events to create "mixed" events. To check the feasibility of determining the reaction plane with this flattening correction applied, two sub-events of equal multiplicity were formed event by event. The reaction planes Ψ_A and Ψ_B were measured from the sub-events, and the opening angle of two sub-events, $\Delta\Psi_{sub}$, is plotted in Fig. 1. The real events are plotted as red circles, which show an enhancement at $\Delta\Psi_{sub} = 0$ indicating the ability of determining the reaction plane from the measurements. The mixed events are plotted as green circles, which show a flat distribution indicating that the detector bias has been removed. It was confirmed that the reaction plane could be determined using sub-event correlations with SπRIT-TPC. More detailed analysis is on going.

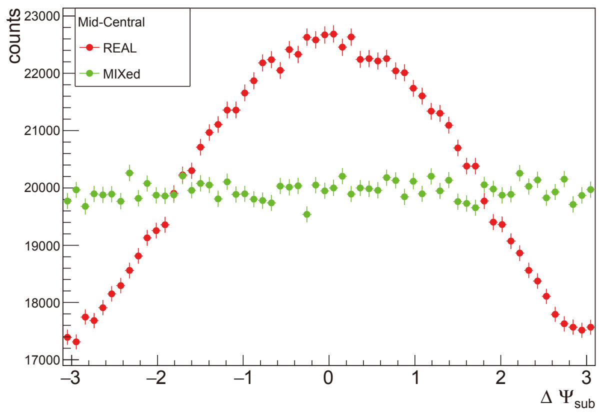

Fig. 1. Opening angle of reaction planes determined by two sub-events Red and green circles show real and mixed events, respectively.

References
1) B. P. Abbott *et al.*, Phys. Rev. Lett. **119**, 161101 (2017).
2) Bao-An Li *et al.*, Phys. Rev. C **71**, 014608 (2005).
3) P. Russotto *et al.*, Phys. Lett. B **471**, (2011).
4) B.-A. Li *et al.*, Phys. Rev. Lett. **85**, 4221 (2000).
5) R. Shane *et al.*, Nucl. Instrum. Methods A **784**, 513 (2015).
6) P. Lasko *et al.*, Accel. Prog. Rep. **50**, 173 (2017).
7) M. Kaneko *et al.*, Accel. Prog. Rep. **50**, 172 (2017).
8) J.-Y. Ollitrault *et al.*, Nucl. Phys. **638**, 195c (1998).