PROCEEDINGS OF SCIENCE

First Experiment of SπRIT-TPC at SAMURAI in RIKEN-RIBF

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Investigation of nuclear Equation of State (EoS) is an attractive subject not only for nuclear physics but also astrophysics. The SAMURAI Pion-Reconstruction and Ion-Tracker-Time-Projection Chamber (SπRIT-TPC) project is proposed to investigate isospin symmetry dependence of nuclear EoS at supra-saturation density using heavy ion collisions. The first experiments of SπRIT-TPC were performed at SAMURAI spectrometer in RIBF-BigRIPS, RIKEN. For systematic studies, neutron rich and deficient Sn beams, ^{132,124,112,108}Sn, impinging on stable ^{112,124}Sn isotopes with 300 MeV/u were employed. Observables of π^-, π^+, n, p, t, and ^{3}He, which are predicted to be sensitive to the symmetry energy, were measured. The correlation between the reconstructed vertex and beam track and the target indicated success of track reconstructions and synchronization of two DAQ systems.

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1. Introduction

Understanding of nuclear Equation of State (EoS) is a common subject for both astrophysics and nuclear physics. Especially, constraining EoS above the saturation density ($\rho_0 \approx 0.16$ fm^{-3}) is important to reduce large uncertainties on theories and the observation of neutron star mass and radius relations. Isospin symmetry energy term is expected to influence on the EoS at high density, however, a fundamental knowledge is poor because of lack of experimental observations.

The SAMURAI Pion-Reconstruction and Ion-Tracker-Time-Projection Chamber (SπRIT-TPC) project is proposed to investigate isospin symmetry dependence of nuclear EoS at supra-saturation density using heavy ion collisions. It is designed to measure production yield ratios of π^-/π^+, n/p, and t/^{3}He and flow, which is predicted to sensitive to the symmetry energy[1, 2]. For systematic studies with different isospin asymmetry systems, neutron rich and deficient Sn beams, ^{132,124,112,108}Sn, impinging on stable ^{112,124}Sn isotopes with 300 MeV/u were employed. The SπRIT-TPC campaign experiments were performed at SAMURAI in RIKEN-BigRIPS in the Spring of 2016. The performance of the SπRIT-TPC examined in terms of track reconstruction and vertex reconstruction will be shown here.

2. Experimental Setup

The SπRIT-TPC was installed inside Superconducting Analyzer for MUlti-particles from RAdioIsotope beams (SAMURAI) dipole magnet in RIKEN as shown in Fig.1. It was designed to maximize an acceptance in the SAMURAI magnet and constructed at NSCL-MSU[3]. The field cage has a dimension of 864(W) x 1344(L) x 530(H) mm and charge sensitive silicon pads were located on top for the readout of signals. The electric field was applied vertically with anti-parallel to the magnetic field. The drifting electrons were amplified in a avalanche region and corrected by 12096 pads with a size of 12(L) x 8(W) mm. The pad signals were amplified and processed through General Electronics for TPC (GET)[5]. The DAQ trigger rate of ~60Hz were realized with a full read-out mode. A gating grid driver was developed to protect anode wires from a damage due to unnecessary electrons going through to the amplification region.

In order to trigger central collision events, Kyoto-Array and KrAkow Trigger Array with amplitude discrimiNAtion (KATANA) were installed surrounding the TPC. The Kyoto-Array consisted of two sets of 30 plastic scintillation paddles and each paddle was read through a wave length shifter attached by a Multi-Pixel Photon Counter (MPPC) on one edge. The Kyoto-Array covered side windows of the TPC with 450(H) x 1500(L) on both left and right. The analog signals from MPPCs were processed by the VME-EASIROC[6] and provided a trigger logic signal according to multiplicity selection.

The KATANA consisted of three thin (1 mm^t) plastic scintillation paddles (KATANA-Veto) and 12 thick (10 mm^t) paddles (KATANA-Multi) with a dimension of 100(W) x 400(H) mm. A signal from each paddle was read through MPPC. The KATANA-Veto and -Muti were located down stream of the TPC ext window and the KATANA-Veto was aligned to the beam trajectory. When a beam or a fragment heavier than Z $\sim$ 20 reached to the KATANA-Veto, it provided a veto signal to reject non reaction beam or a peripheral collision. For the selection of central collision events, multiplicity >= 4 in the Kyoto-Array and Z < 20 in KATANA-Veto were required.

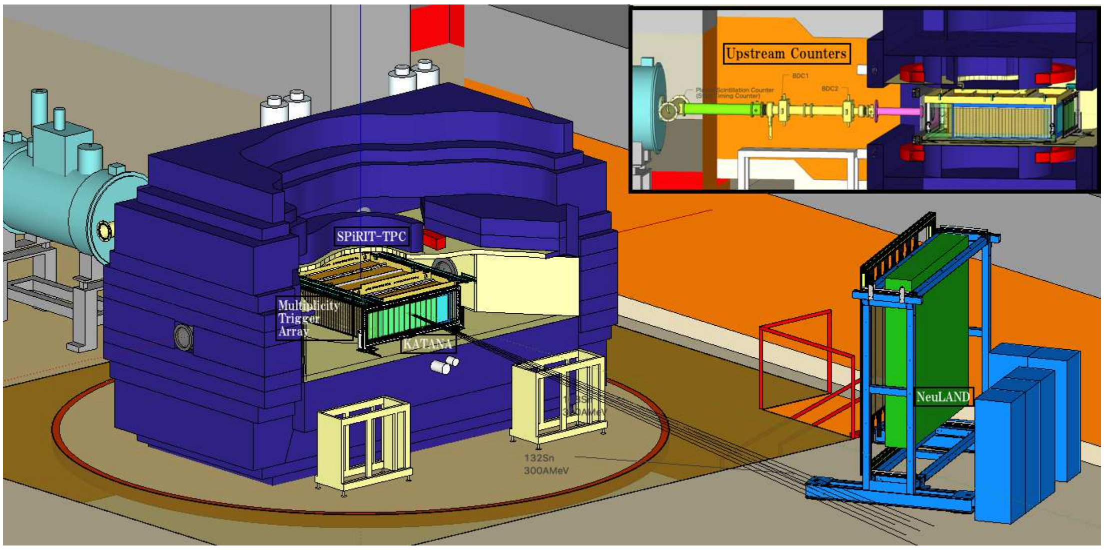

Figure 1: Experimental setup of SπRIT-TPC experiment in 2016. The insertion in the right top shows configuration of upstream counters.

For the start timing and position determination for beams passing through the target, two plastic scintillation counters and two beam drift chambers (BDC) were placed on the beam line in front of the SAMURAI magnet as shown in a insertion of Fig.1 Additionally, four active collimator made of the plastic scintillator read through MPPCs worked to reject beams hitting out of the target.

The ^{112}Sn and ^{124}Sn targets were placed 8.9 mm in front of the field cage, whose position was remotely changeable in X and Z directions.

A new Large-Area Neutron Detector (NeuLAND)[7] was prepared to measure correlations between neutrons and charged particles. The NeuLAND was setup at ∼8 m distance from the target and covered an angle from 22 to 43 deg in laboratory frame.

An absolute position measurement of each detector was done utilizing a photogrammetric measurement system, V-STARS, provided by Geodetic Systems, Inc (GSI)[4]. Since SπRIT-TPC was placed inside the magnet and surrounded by the trigger devices, limited portion of the TPC was visible, thus an outer frame of the TPC was measured precisely in the open space. The position of entire TPC was obtained by superimposing to visible reference points marked on the TPC.

The SπRIT-TPC campaign experiments were performed for the first time in 2016 Spring. The neutron rich and deficient Sn isotopes with 300 MeV/u were produced by Radioactive Isotope Beam Facility (RIBF) in RIKEN and delivered selectively through BigRIPS to the SAMURAI. The configurations of beams and targets were listed in Table.1. The first commissioning was carried out out of the magnetic field to test all read out systems and the second one was done in the 0.5 T magnetic field to test a complete version of the SπRITROOT analysis framework officially. Following that, experiments for beams of ^{132,124,112,108}Sn onto two enriched targets of ^{112,124}Sn were performed for the comparison among various nuclear isospin symmetry.

Table 1: Beam and target configurations for SπRIT-TPC campaign experiments in 2016

Purpose	Primary Beam	Secondary Beam	Target
commissioning I (out of magnet)	^{238}U	^{79}Se	natural Al, Sn
commissioning II	^{238}U	^{132}Sn	natural Sn
neutron deficient	^{124}Xe	^{108}Sn	^{112}Sn
reference	^{124}Xe	^{112}Sn	^{124}Sn
neutron rich	^{238}U	^{132}Sn	^{124}Sn
reference	^{238}U	^{124}Sn	^{112}Sn
calibration	^{238}U	Z = 1, 2, 3	empty

3. Results

Typical event displays with a top view were shown in Fig.2. The beam came from the left side and hit the target located outside of the field cage. Positively charged fragments bended clockwise toward the right direction. On contrary, a negative charged particle (π^-), which bend counter-clockwise, is seen in Fig.2(a). The beam reacted with ionization gas (P10), which is so called active-target event, is also shown in Fig.2(b). The reaction vertex is identified visibly from the event display.

The performance of the SπRIT-TPC was examined in terms of track reconstruction and vertex reconstruction. A track reconstruction were done with SπRITROOT analysis framework newly developed for this project. A reaction vertex was obtained as an intersection of multiple extrapolated tracks event by event. The reactions taking place at the target were chosen if Z position of the reaction vertex indicated the target position. In Fig.3, X and Y correlations at the target between reconstructed vertexes and beam positions measured by BDCs are shown. Clear correlations indicate success of vertex reconstructions and synchronization of two DAQ systems. The beam position would enable us to improve the momentum resolution especially for low momentum particles. It was also confirmed that the TPC was aligned within 200 μm accuracy from the non-magnetic field data.

4. Summary

The first SπRIT-TPC experiments were carried out in the Spring of 2016. The data were accumulated successfully. The negative charged particles, (π^-) were obvious in the 2D event display. The SπRITROOT analysis framework newly developed were tested. The correlation between the reconstructed vertex and beam track and the target indicated success of track reconstructions and synchronization of two DAQ systems. Further analysis are on going.

5. Acknowledgement

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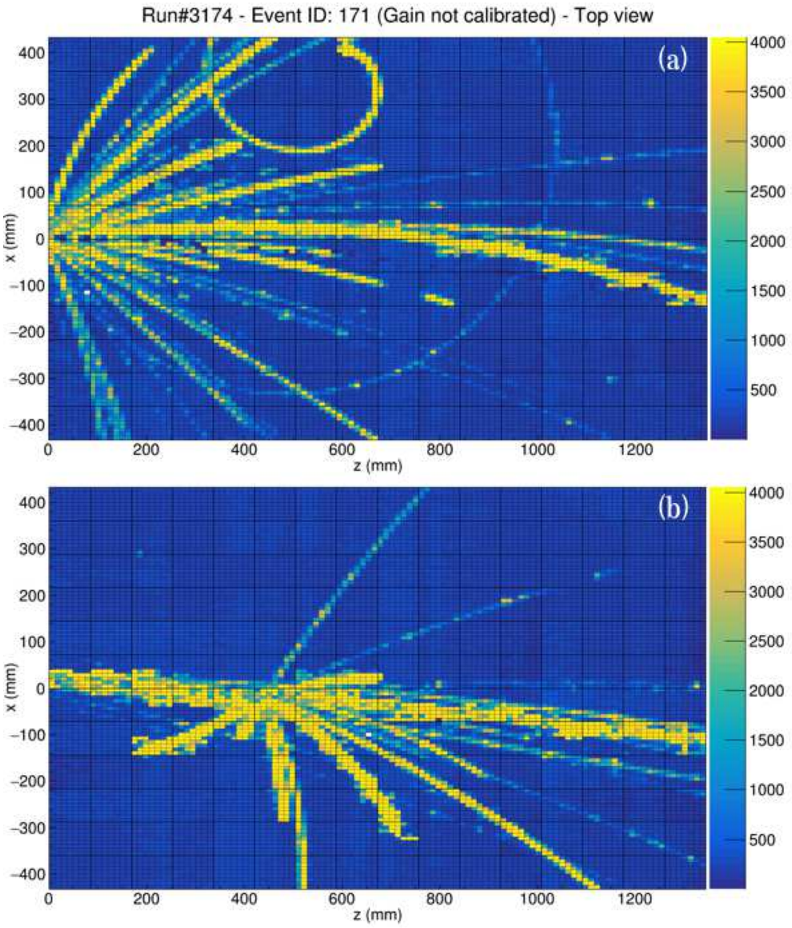

Figure 2: Top view of typical event display. (a) Track vertex comes from target and a negative charged particle (π^-) track is visible. (b) The reaction occurred in the P10 gas, which is so called a active-target event.

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References

[1] M.B. Tsang et al., Phys. Rev. C **86**, 015803 (2012).

[2] Bao-An Li, Phys. Rev. C **69** 034614 (2004).

[3] R. Shane et al.: Nucl. Instr. and Meth. A **784** (2015), 513-517.

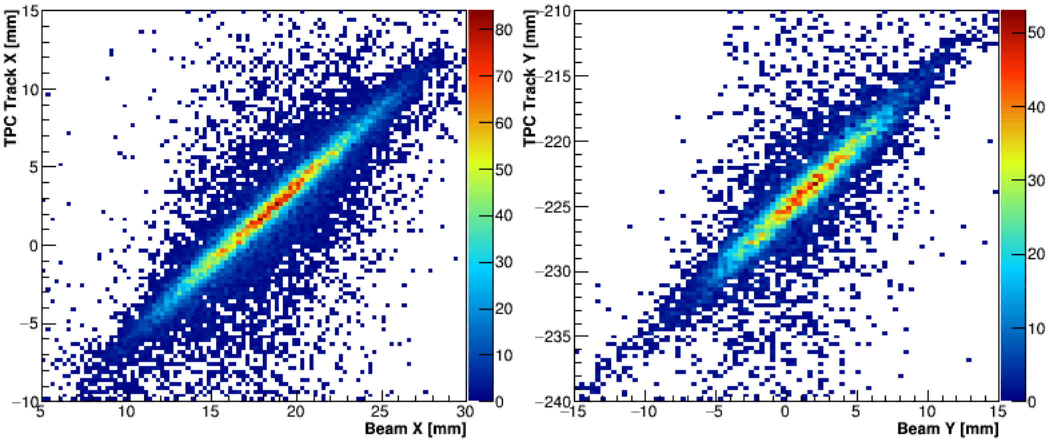

Figure 3: Correlation at the target between vertex reconstructed by SπRIT-TPC and beam position measured by BDCs. Left and right plots show X and Y correlations, respectively

[4] http://www.geodetic.com

[5] E. Pollacco et al.: Phys. Proc. **37** (2012) 1799.

[6] S. Callier et al.: Phys. Proc. **37**, 1569 (2012).

[7] K. Boretzky et al.: GSI Sci. Rep. 2014 2015-1 (2015) 200