Development of SAMURAI-TPC for the Study of Nuclear Equation of State†

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[Nuclear equation of state, symmetry energy, unstable nuclei]

The nuclear Equation of State (EoS) is a fundamental property of nuclear matter and describes the relationships between the parameters of a nuclear system, such as energy and temperature. Understanding the nuclear EoS has been one of the major goals of nuclear physics. This understanding can help us to learn the properties of the nucleus and dense nuclear matter, and to learn the nature of neutron stars.

The energy per nucleon in the isospin asymmetric nuclear matter is usually expressed as $E(\rho, \delta) = E(\rho, \delta = 0) + E_{sym}(\rho)\delta^2 + O(\delta^2)$, where ρ is the baryon density ($\rho = \rho_n + \rho_p$), δ is the relative neutron excess ($\delta = (\rho_n - \rho_p)/(\rho_n + \rho_p)$), $E(\rho, \delta = 0)$ is the energy per nucleon in the symmetric nuclear matter, and $E_{sym}(\rho)$ is the bulk nuclear symmetry energy ($E_{sym}(\rho) = \frac{1}{2}\frac{\partial^2 E(\rho,\delta)}{\partial \delta^2}|_{\delta=0}$). Experimental information, such as the particle flow in heavy-ion collisions and nuclear giant monopole, impose constraints on the symmetric term of the nuclear EoS ($E(\rho, \delta = 0)$). However, the experiments are performed only with stable nuclei, and there are no strong constraints on any of the EoS terms, depending on the isospin asymmetry($E_{sym}(\rho)$).

An international collaboration, the so-called Symmetry Energy Project, for studying the nuclear EoS has been formed in FY2009. The collaboration planned to install a Time Projection Chamber (TPC) into the SAMURAI dipole magnet installed at the Radioactive Ion Beam Facility (RIBF). At the RI beam energy levels that can be achieved at the RIBF, a nuclear density of $\rho \sim 2\rho_0$ is expected to be achieved. In addition, stronger constraints on the EoS isospin asymmetry term would be obtained[1].

With the TPC, we plan to perform experiments for measuring charged pions, protons, and light ions concurrently as probes for studying the asymmetric nuclear matter. In transport calculations, the π^+/π^- ratios are expected to give strong constraints on the EoS asymmetry term at supra-normal density[2].

Figure 1 shows a schematic view of SAMURAI-TPC. The design is based on EOS-TPC used at the BEVALAC accelerator[3]. We are planning to employ Multi-Wire Drift Chamber (MWDC) type wire amplification with a cathode-pad readout for the induced signals for obtaining good position resolution. The target will be located near the TPC entrance. Table 1 lists the specifications of SAMURAI-TPC.

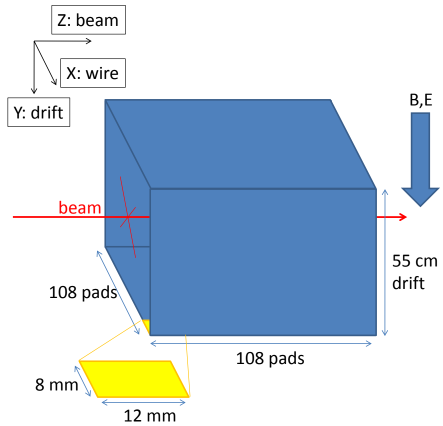

Fig. 1. Schematic view of SAMURAI-TPC.

SAMURAI-TPC is designed to measure ions ranging from pions to oxygen ions, corresponding to a wide range of stopping powers and, consequently, a wide range of induced signals on the pads. RHIC-STAR readout electronics[4] with more than 10k channels will be employed for the first commissioning of SAMURAI-TPC. The dynamic range of the STAR electronics is 10 bit, which will be upgraded to 12 bit for performing the simultaneous measurement of pions and charged fragments. After using the STAR electronics for the first SAMURAI-TPC experiment, it will be replaced with GET (General Electronics for TPC, 12 bit ADC).

To optimize the design of SAMURAI-TPC, a simulation scheme has been developed. The simulation scheme consists of five parts: event generation, detector response, digitization, track reconstruction, and

Table 1. Specifications of SAMURAI-TPC

pad size	8 mm × 12 mm
number of pads	11664 (108 × 108)
drift length	55 cm
chamber gas	P10 (Ar-90% + CH_4-10%)
magnetic field	0.5 T
pressure	∼1 atm
electric field for drift	120 V/cm

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