SpiRIT TPC: first experiment and calibrations

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The SpiRIT Time Projection Chamber [1] has been used for physics measurements for the first time. The physics goal is to constrain the density dependence of the asymmetry energy in the nuclear equation of state at supra-saturation density. The SpiRIT TPC is designed to measure pions and light charged particles produced in heavy ion collisions around a few hundred MeV/nucleon. Yield ratios (π-/π+, n/p, t/h) and flow of these particles is predicted to be sensitive to the asymmetry energy [2,3,4].

The SpiRIT TPC was installed in the SAMURAI [5] magnet at RIKEN [6] to measure charged particles produced in reactions of ^{132}Sn+^{124}Sn, ^{108}Sn+^{112}Sn, ^{124}Sn+^{112}Sn and ^{112}Sn+^{124}Sn at 300 MeV/nucleon. The KATANA [7] array and the Kyoto array (both arrays of plastic scintillator paddles) were used to measure charged particle multiplicity to enable effective triggering of the TPC. In addition, neutrons and light charged particles were detected at forward angles with NeuLAND. While only the most neutron-rich reaction would be necessary if all quantities were perfectly understood, the variation of neutron and proton effective masses with the density can be studied in the same data sets by varying the neutron content of the system. Additionally, variation of the neutron content allows rational cancellation of experimental biases prior to comparison to theoretical models.

The charged particles produced in the reactions ionized the P10 gas mixture in the TPC, following curved trajectories due to the 0.5T magnetic field. The liberated electrons drifted to the TPC's pad plane, which imaged the tracks as a function of x-position, z-position (along the beam), and arrival time, producing a 3-dimensional record of the particle tracks. The (z,x) projection of one event is shown in Fig. 1. The color indicates the ionization density. The reaction vertex can be clearly deduced at the left

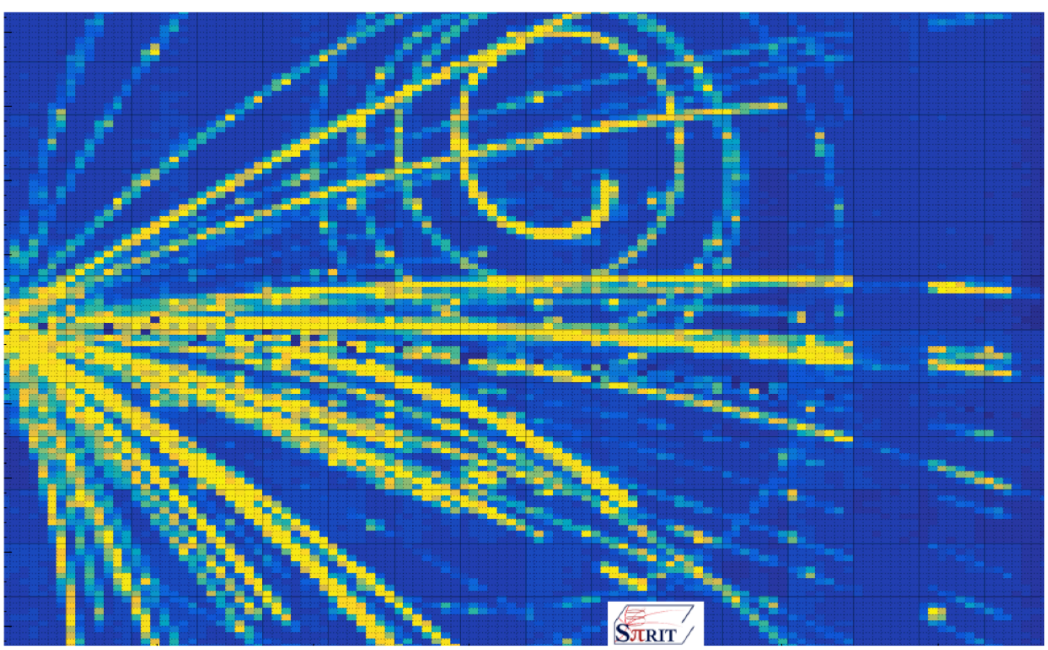

FIG. 1. 2D Projection of tracks from a single event in the SpiRIT TPC. The magnetic field is perpendicular to the plane. The counterclockwise spirals indicate negatively charged particles.

edge of the projection and corresponds to the location of the target. Most tracks (those from positively charged particles) can be seen curving clockwise in this perspective, but two notable exceptions can be seen curving in the opposite direction. Nearly all particles that curve in this way are negative pions. Two regions toward the right (downstream) that seem to show much lower ionization density actually are regions of lower electron amplification; these can allow identification of heavier charged particles. The same event is shown in Fig. 2 in a very different 2D projection to give a 3D perspective of the event.

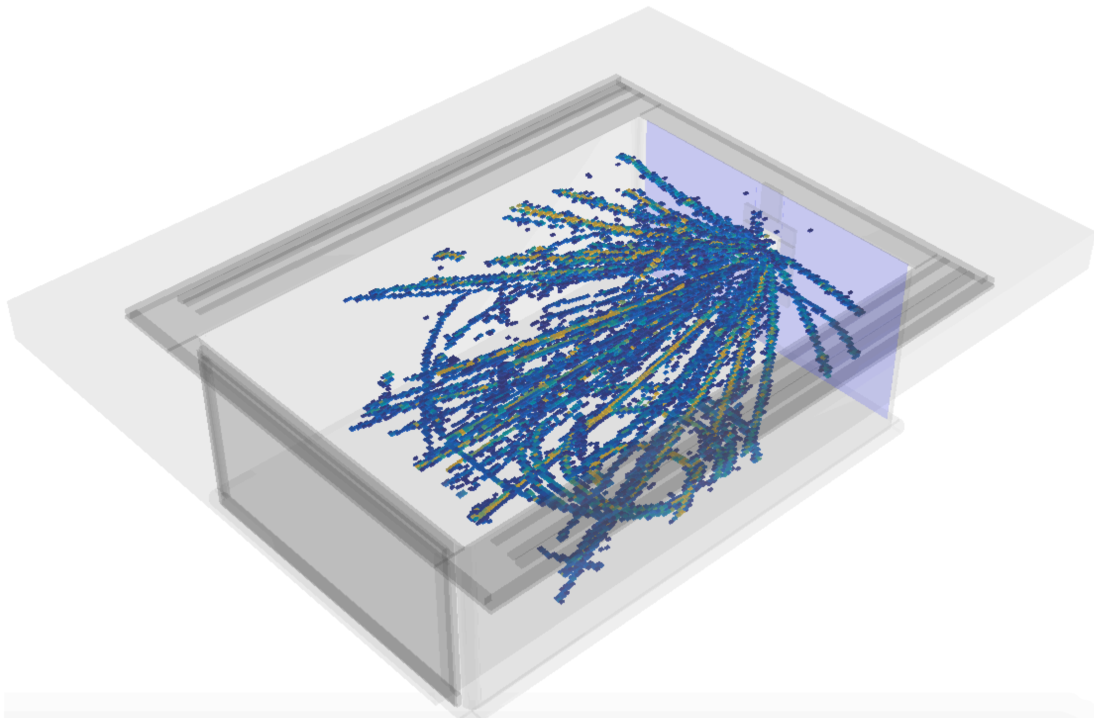

FIG. 2. Tracks in the SpiRIT TPC ("3D" view).

Charged particles are identified by their momentum (track curvature) and energy loss (ionization density). This is shown in Fig. 3. As expected, large numbers of protons, deuterons, and tritons are observed and can be distinguished. At "negative" momentum, the negative pions can be clearly seen. In roughly a mirror image, the positive pions can be seen as a peak just below the proton distribution. Improvements in the tracking algorithm may improve this effective resolution.

Calibration of the data is underway. Constraints are expected on the behavior of the asymmetry energy around twice saturation density.

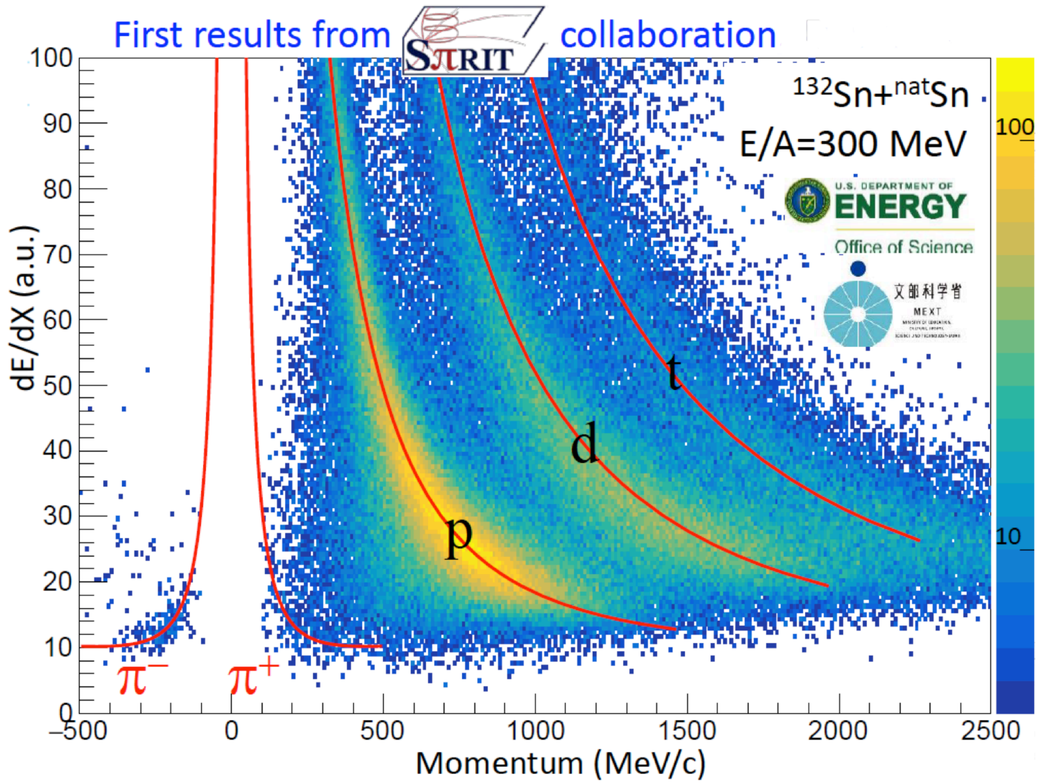

FIG. 3. Particle ID in the SpiRIT TPC.

[1] R. Shane *et al.*, Nucl. Instrum. Methods Phys. Res. **A784**, 513 (2015).

[2] B.A. Li, Phys. Rev. Lett. **88**, 192701 (2002).

[3] J. Hong and P. Danielewicz, Phys. Rev. C **90**, 024605 (2014).

[4] J. Rizzo, M. Colonna, and M. Di Toro, Phys. Rev. C **72**, 064609 (2005).

[5] T. Kobayashi *et al.*, Nucl. Instrum. Methods Phys. Res. **B317**, 294 (2013).

[6] Y. Yano *et al.*, Nucl. Instrum. Methods Phys. Res. **B261**, 1009 (2007).

[7] P. Lasko *et al.*, Nucl. Instrum. Methods Phys. Res. **A856**, 92 (2017).