Calibration of the SπRIT TPC with light fragments

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The SAMURAI Pion-Reconstruction and Ion-Tracker Time-Projection Chamber (SπRIT-TPC)[1)] was constructed to measure pions and light particle fragments resulting from heavy ion collisions. While the symmetry energy of the nuclear Equation of State is constrained at sub-saturation densities, large theoretical uncertainties still exist above nuclear saturation density. In an effort to constrain the symmetry energy at high densities, two experiments were performed at RIKEN in the spring of 2016 with the TPC inserted into the SAMURAI magnet.

To calibrate the gain of the TPC, a "cocktail" beam of (p,d,t,^{3}He,^{4}He,^{6}Li) light fragments was tuned for two different $B\rho$ settings. The BigRIPS fragment separator was able to provide the species listed in Table 1 with a momentum resolution of about 0.8% as estimated by LISE++. Because the momentum of each particle was well defined, we can also determine the energy loss distribution of each particle species.

Table 1. Mean momentum and momentum resolution from the BigRIPS separator as predicted by LISE++.

Particle	momentum [MeV/c]	$\frac{dp}{p}$ [%]
p	903.6	0.77
d	886.9	0.78
t	886.9	0.82
^{3}He	1795.7	0.78
^{4}He	1782.9	0.80
^{6}Li	2652.2	0.82

The energy loss distribution of a particle depends not only on a particle's momentum, but also on the analyzed segment length and is explained in extensive detail in Ref. 1. Such a technique is implemented in other TPC's such as STAR and ALICE[2)]. For our analysis, a C++ version of the Bichsel's FORTRAN code, in Ref. 3, was made and the resulting straggling functions were compared to the original Bichsel code to check for accuracy.

As the particle traverses the detection gas volume, the energy deposited is amplified and recorded over many readout pads[1)]. Thus, the energy loss of each track is broken up into smaller analyzed segments or clusters. The straggling function for a 903.63 MeV/c proton was created with a Monte Carlo simulation, and is shown as a blue curve in Fig. 1. To calibrate the TPC, we assign the energy deposited value D to a measured ADC value Q. We assume a linear relationship and minimize Pearson's χ^2 to fit the measured straggling function to the theoretical Bichsel straggling function yielding the relationship:

$$D = 0.45 * Q + 0.48 \qquad (1)$$

The red curve in Fig. 1 shows the calibrated experimental straggling function of protons at 903.63 MeV/c.

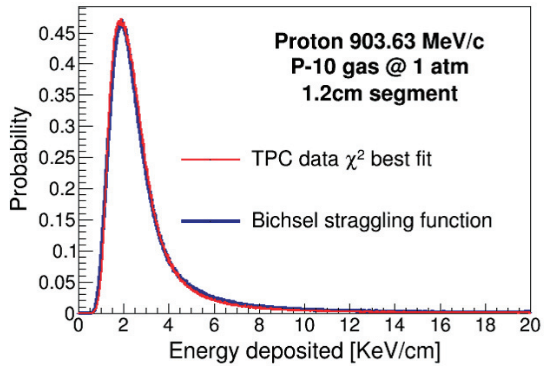

Fig. 1. Fitted TPC data and the Bichsel straggling function for P-10 gas over a track segment length of 1.2cm. Bin width is 10 [eV/cm]

In summary, good agreement between the energy loss distribution of the TPC and the expected Bichsel curve was found for the protons. In the near future, other particle species will be analyzed as well as the particles produced in the second $B\rho$ setting which provides higher momentum values.

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References
1) R. Shane et al. Nucl. Instr. Meth. A **784**, (2015) 513.
2) H. Bichsel Nucl. Instr. Meth. A **562**, (2006) 154.
3) Original code found under "Current research" section of home page http://faculty.washington.edu/hbichsel/

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