Proton efficiency function for high-multiplicity events in the SπRIT-TPC investigated by the embedding technique

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The SπRIT-time projection chamber (TPC)[1] project aims to constrain the high-density nuclear symmetry energy by using heavy-ion collisions. We measured light charged particles emitted from central Sn + Sn collisions at 270 MeV/nucleon, which have been predicted to provide sensitive probes of the symmetry energy at supra-saturation densities.[2] In this report, we describe the reconstruction efficiency of protons in central ^{132}Sn + ^{124}Sn collisions.

The Sn target is placed approximately 1 cm upstream from the TPC; hence, the charged particles emitted in forward angles are mainly observed. In central Sn + Sn collisions producing high charged-particle multiplicity, signals induced by charged particles can interfere with each other, causing the tracks to be merged and/or broken. As it would be difficult to fully simulate realistic situations, the embedding technique[3] is applied. The digitized signal of a single proton traversing the TPC is generated based on a Monte Carlo simulation. Subsequently, the generated signal is embedded into real events, which are analyzed by the same track reconstruction algorithm as for the physical tracks. The proton's reconstruction efficiency with a given track multiplicity can be estimated by comparing the embedded tracks and the reconstructed tracks.

The spectrum of transverse momentum p_{T} vs. scaled rapidity $y_0 = y/y_{\mathrm{NN}}^{\mathrm{c.m.}} - 1$ of protons is corrected by the following procedure, where y and $y_{\mathrm{NN}}^{\mathrm{c.m.}}$ are the rapidity of the detected proton and the center-of-mass rapidity of the nucleon-nucleon system, respectively. It is noted that the momentum resolution of the TPC can distort the measured spectrum. To consider this bin-smearing effect in the efficiency calculation, the distribution of embedded protons needs to be properly weighted. First, the measured p_{T}-y_0 spectrum is used as the weighting factor. The efficiency as a function of p_{T}-y_0 is obtained as the ratio of reconstructed protons to embedded ones. Subsequently, the corrected p_{T}-y_0 spectrum of protons is obtained as the raw spectrum divided by the efficiency. In the next iteration, the corrected spectrum is used as the weighting factor. This process is iterated until the correction converges.

As shown in Fig. 1, the correction converged after two iterations. Since we limited the azimuthal angle of tracks to $-30° \leq \phi \leq 20°$ in the analysis, which is expected to be the efficient region of the TPC, the reconstruction efficiency of protons is estimated to be approximately 90%. The efficiency exceeds 100% at $y_0 > 1.8$ because the original statistics of protons is quite low at such a high y_0 and overcounting occurs owing to the smearing of the proton rapidity at a lower y_0. In addtion to protons, the p_{T}-y_0 spectra of deuterons and tritons are also corrected, which are being compared with theoretical predictions to extract physics statements for publications in the future.

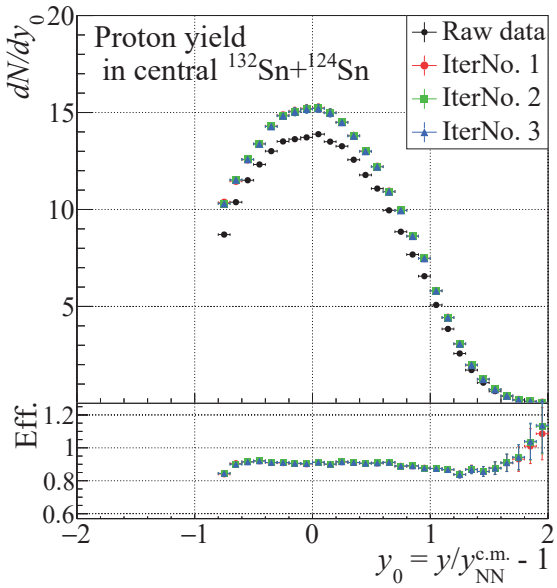

Fig. 1. The top panel shows p_{T}-integrated dN/dy_0 spectra of protons in central ^{132}Sn + ^{124}Sn collisions with and without efficiency corrections (colored and black markers, respectively). The bottom panel shows the efficiency obtained with respect to their ratios.

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