Isoscaling in central Sn + Sn collisions at 270 MeV/nucleon[†]

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Experimental study on the early stage of heavy-ion collision is challenging as excited fragments produced from the collision decay into lighter particles before they are detected. The nuclear isoscaling phenomenon is a useful tool as the ratio of yields from two different reactions is weakly affected by the fragment de-excitation process.[1)]

Rare isotope Tin beams ^{132}Sn and ^{108}Sn were produced from RIBF and impinged onto the isotopically enriched Tin targets. Hydrogen and helium isotopes were detected in SπRIT time projection chamber[2)] placed inside the SAMRURAI dipole magnet.[3)] Particles were identified from the magnetic rigidity and mean energy loss.[4)] Most central events with impact parameter $b <$ 1.5 fm and mid rapidity range $y_0 = 0$–0.4 are chosen for this analysis.

The yield ratios between two systems R_{21} = Y(^{132}Sn + ^{124}Sn)/Y(^{108}Sn + ^{112}Sn) as a function of p_T/A are shown in Fig. 1. Given that the collision systems are thermally equilibrated, R_{21} follow the isoscaling law $R_{21} = C\exp(\alpha N + \beta Z)$ where α and β are the fit parameters. Empirically, α and β have similar values with opposite signs, therefore, particles with the same $(N-Z)$ value show similar R_{21} values. Figure 1 show isoscaling effect for $p_T < 280$ MeV/c (left side of vertical dashed line). In this region, the isoscaling fit gives $\alpha = 0.29$ and $\beta = -0.23$ (inner panel of Fig. 1). On the other hand, the triton and helium R_{21} values breakdown above this limit, and the isoscaling phenomenon vanishes. This suggests that high p_T/A particles come from the non-equilibrated environment.

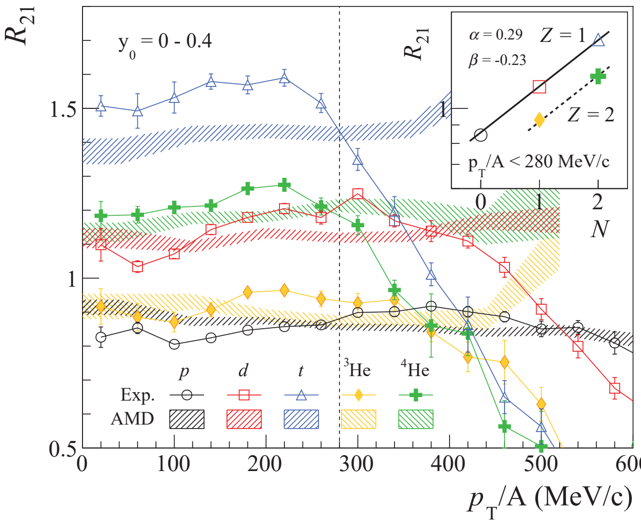

Fig. 1. The yield ratio R_{21} between two systems ^{132}Sn + ^{124}Sn and ^{108}Sn + ^{112}Sn. Experimental data (markers) are compared with AMD (shaded area). Inner panel: Isoscaling fit for $p_T/A < 280$ MeV/c.

The antisymmetrized molecular dynamics (AMD) model[5,6)] is employed with Skyrme SLy4 effective interaction and symmetry energy slope parameter L = 46 MeV. The AMD result qualitatively explains isoscaling for $p_T/A < 280$ even though AMD is a dynamical model. However, AMD underestimate triton R_{21} and do not reproduce breakdown of R_{21}.

† Condensed from the article in Eur. Phys. J. A **58**, 201 (2022)
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References

1) M. B. Tsang *et al.*, Phys. Rev. C **64**, 054615 (2001).
2) J. Barney *et al.*, Rev. Sci. Instrum. **92**, 063302 (2021).
3) H. Otsu *et al.*, Nucl. Instrum. Methods Phys. Res. B **376**, 175 (2016).
4) J. W. Lee *et al.*, Nucl. Instrum. Methods Phys. Res. A **965**, 163840 (2020).
5) A. Ono, Prog. Part. Nucl. Phys. **105**, 139 (2019).
6) M. Kaneko *et al.*, Phys. Lett. B **822**, 136681 (2021).