Unveiling the dynamics of little-bang nucleosynthesis

K.J. Sun,[1,2] R. Wang,[1,3] C.M. Ko, Y.G. Ma,[1,2] and C. Sen[4,5]

[1]*Key Laboratory of Nuclear Physics and Ion-beam Application (MOE), Institute of Modern Phys, Fudan University, Shanghai 200433, China*

[2]*Shanghai Research Center for Theoretical Nuclear Physics, NSFC and Fudan University, Shanghai 200438, China*

[3]*Shanghai Institute of Applied Physics, Chinese Academy of Sciences, Shanghai 201800, China*

[4]*Department of Physics and Astronomy, Wayne State University, Detroit, MI 48201, USA.*

[5]*RIKEN BNL Research Center, Brookhaven National Laboratory, Upton, NY 11973, USA*

We have shown in a recent study via the relativistic kinetic approach that the post-hadronization dynamics plays an important role in the little-bang nucleosynthesis during high-energy heavy-ion collisions [1]. Specifically, we have found, as shown in Fig. 1, that the triton number produced from the created QGP

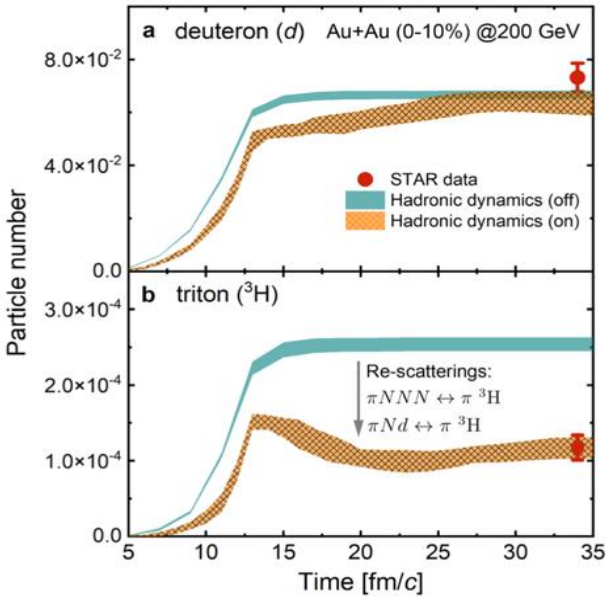

FIG. 1. Time dependence of deuteron (a) and triton (b) numbers in mid-rapidity ($|\boldsymbol{y}| < \mathbf{0.5}$). Experimental data with combined statistical and systematic uncertainties from Refs. [2,3] are denoted by filled symbols, while theoretical results with statistical uncertainties are shown by shaded bands.

in central Au + Au collisions is reduced by about a factor of 1.8 during the subsequent hadronic matter expansion, although the deuteron number is essentially not affected. These distinct hadronic effects on deuteron and triton production are in excellent agreement with recent measurements by the STAR Collaboration at RHIC [2,3] as shown in Fig. 2 and are further supported by the latest measurement by the ALICE Collaboration at the LHC [4,5] as shown in Fig. 3. Our study thus shows the inadequacy of the statistical hadronization model for understanding triton production in these collisions [6]. In contrast to the

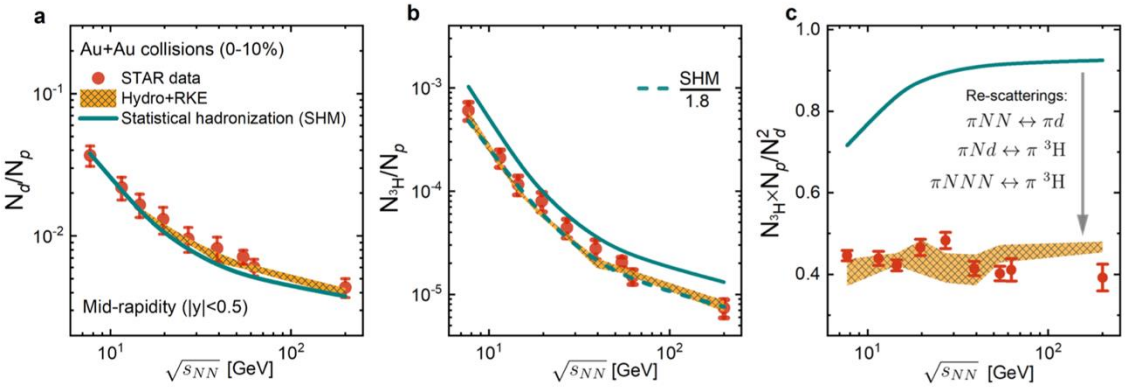

FIG. 2. Collision energy dependence of hadronic re-scattering effects on light nuclei yield ratios $\mathbf{N_d/N_p}$ (a), $\mathbf{N_{3He}/N_p}$ (b) and (c). Theoretical results with and without hadronic dynamics are from Hydro + RKE (shaded bands) and SHM [5] (lines), respectively. Experimental data points with combined statistical and systematic uncertainties are from the STAR Collaboration [2,3].

big-bang nucleosynthesis, in which photonuclear reactions dominate its dynamics, our model-to-data comparison unveils the importance of pion-catalyzed multi-body reactions on the dynamics of the little-bang nucleosynthesis in relativistic heavy- ion collisions.

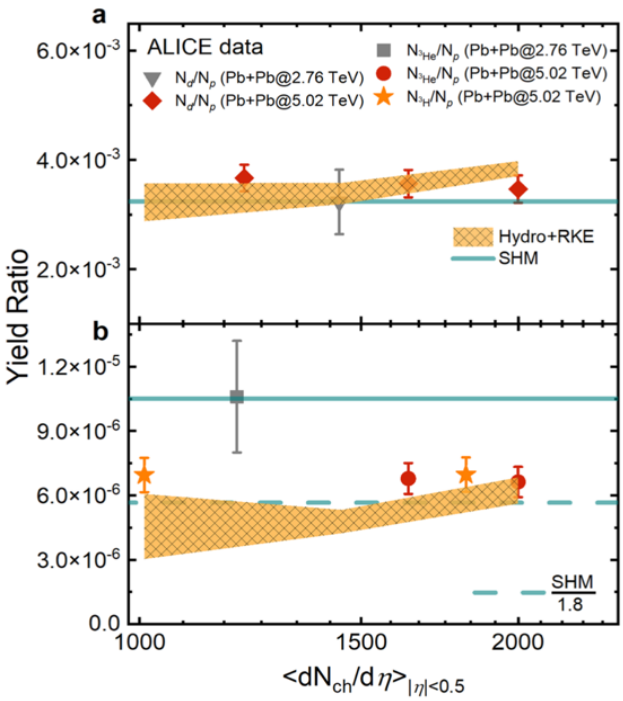

FIG. 3. Charged-particle multiplicity ($\mathbf{dN_{ch}/d\eta}$) dependence of hadronic re-scattering effects on light nuclei yield ratios $\mathbf{N_d/N_p}$ (a), $\mathbf{N_{3He}/N_p}$ and $\mathbf{N_{3H}/N_p}$ (b). Theoretical results with and without hadronic dynamics are from Hydro+RKE (shaded bands) and SHM [6] (lines), respectively. Experimental data points with combined statistical and systematic uncertainties are from the ALICE Collaboration [4,5].

[1] K.J. Sun, R. Wang, C.M. Ko, Y.G. Ma, and C. Sen, Nature Comm. **15**, 1975 (2024).
[2] M. Abdulhamid *et al.*, Phys. Rev. Lett. **130**, 202301 (2023).
[3] J. Adam *et al.*, Phys. Rev. C **99**, 064905 (2019).
[4] S. Achary *et al.*, Phys. Rev. C **107**, 064904 (2023).
[5] J. Adam *et al.*, Phys. Rev. C **93**, 024917 (2016).
[6] A. Andronic, P. Braun-Munzinger, K. Redlich, and J. Stachel, Nature **561**, 321 (2018).