Suppression of light nuclei production in collisions of small systems at the Large Hadron Collider

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Based on the coalescence model in full phase space, we have studied the dependence of deuteron, heilium-3, and triton production in nuclear collisions at energies available from the LHC on the charged particle multiplicity of the collisions [1]. For the nucleon distributions, they are assumed to come from a thermalized hadronic matter at the kinetic freeze-out of heavy-ion collisions with its temperature taken from the empirical fit to measured particle spectra and its size determined by assuming that the entropy per baryon is independent of the colliding system. We have found that the yield ratios d/p and ^{3}He/p are significantly reduced once the charged particle multiplicity is below about 100 as a result of the non-negligible deuteron and ^{3}He sizes compared to that of the nucleon emission source as shown by solid lines in the left window of Fig. 1. Our results thus provide a natural explanation for the observed suppression of deuteron and ^{3}He production in p+p collisions by the ALICE Collaboration at the LHC [2]. They also demonstrate the importance of the internal structure of light nuclei on their production in collisions of small systems. We have further found that the production of triton is 10%-30% larger than that of helium-3 in p+p collisions because of its smaller matter radius. This enhancement of ^{3}H/^{3}He ratio can be tested in future measurements.

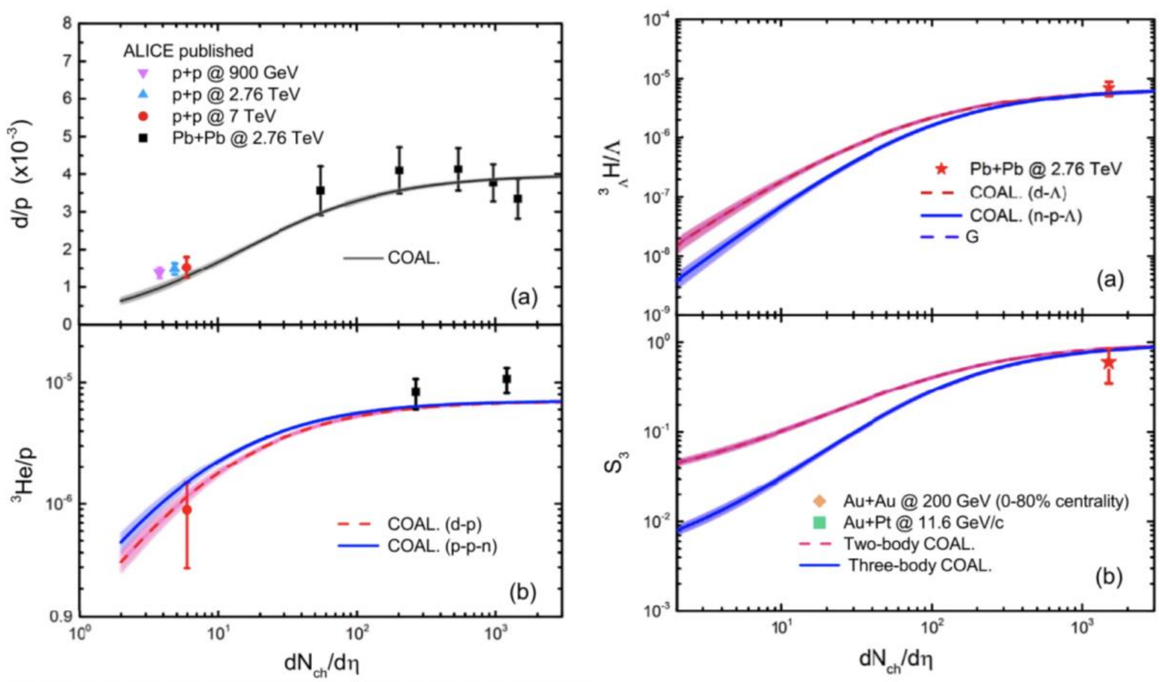

FIG. 1. Charged particle multiplicity dependence of the yield ratios d/p and ^{3}He/p (left window) as well as that of $^3_\Lambda$H/Λ and the strangeness population factor S_3 =^{3}H/(^{3}He×Λ/p) (right window). The lines denote the predictions of coalescence model with theoretical uncertainties on the emission source radius given by the shaded band. Experimental data from the ALICE Collaboration are shown by symbols with error bars [2].

We have also used this model to study the charged particle multiplicity dependence of hypertriton production in Pb+Pb collisions at the LHC by considering both the three-body process of p-n-Λ coalescence and the two-body process of d-Λ coalescence. Because of the much larger ${}^{3}_{\Lambda}$H adius than those of deuteron and ^{3}He, the yield ratio ${}^{3}_{\Lambda}$H/Λ is found to be much more suppressed in collisions with low charged-particle multiplicity, particularly for the three-body coalescence process as shown by solid lines in the upper panel of right window in Fig.1. We have further studied the charged particle multiplicity dependence of the strangeness population factor S_3 = ^{3}H/(^{3}He×Λ/p), and its value in collisions with small charged particle multiplicity is found to be significantly less than one expected in collisions with large charged particle multiplicity as shown by solid lines in the lower panel of right window in Fig.1. Future experimental measurements of the yield ratio ${}^{3}_{\Lambda}H/\Lambda$ and the strangeness population factor S_3 in collisions of low charged particle multiplicity will be of great interest because it not only can check the prediction of the present study but also provide the possibility to improve our knowledge on the internal structure of ${}^{3}_{\Lambda}$H.

[1] K.J. Sun, C.M. Ko, and B. Donigus, Phys. Lett. B **792**, 132 (2019).

[2] B. Abelev *et al.*(ALICE Collaboration), Phys. Rev. C **88**, 044910 (2013); J. Adam *et al.* (ALICE Coolaboration), Eur. Phys. J. C **75**, 226 (2015); Phys. Rev. C **93**, 024917 (2016); Phys. Lett. B **754**, 360 (2016); S. Acharya *et al.* (ALICE Collaboration), Phys. Rev. C **97**, 024615 (2018).