Particle production and elliptic flow of light nuclei in relativistic heavy ion collisions at RHIC

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Introduction

The RHIC program has provided remarkable evidence that coalescence of quarks is the dominating mechanism for hadronization from a deconfined plasma at the intermediate transverse momentum ($1.5 < p_T < 5$ GeV/c) [1]. However, it is experimentally difficult to study how local correlations and energy/entropy play a role in coalescence since the partonic constituents are not directly observable. In relativistic heavy-ion collisions, light nuclei and anti-nuclei are formed through coalescence of nucleons and anti-nucleons [2]. The binding energy for the light nuclei are small, hence this formation process can only happen at a late stage of the evolution of the system when interactions between nucleons and other particles are weak. This process is called final-state coalescence [2]. The advantage of nucleons over the partonic coalescence phenomena is that both the nuclei and the constituent nucleon space-momentum distributions are measurable quantities in heavy-ion collisions. By studying the elliptic flow of nuclei and comparing to those of their constituents (nucleons), we will have a better understanding of coalescence process for hadronization.

Experiment and analysis

The data presented here are from Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV and 39 GeV with STAR detector at RHIC. STAR's main Time Projection Chamber (TPC) was used for tracking and identification of charged particles in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV. In order to identify light nuclei a variable Z is defined as

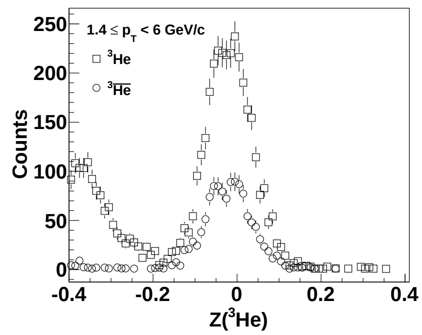

FIG. 1: Z distribution of ^3He (open square) and $^3\overline{He}$ (open circle) for $1.4 \leq p_T < 6$ GeV/c in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV.

$$Z_i = \ln\left(\frac{(dE/dx)|_{measure}}{(dE/dx)_i|_{predict}}\right), \qquad (1)$$

where $(dE/dx)|_{measure}$ is the measured mean energy loss of a track and $(dE/dx)_i|_{predict}$ is the mean energy loss predicted by Bichsel function for the given particle type i ($i = d, t$ and ^3He) [3]. Fig. 1 shows a typical Z distribution for ^3He and $^3\overline{He}$ signals for $1.4 \leq p_T < 6$ GeV/c in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV. After track quality selections, the $^3He(^3\overline{He})$ signals are essentially background free. We derive the yields by counting $^3He(^3\overline{He})$ candidates with $|Z(^3He)| < 0.2$. The elliptic flow parameter, v_2, is the second order Fourier coefficient of the azimuthal distribution of the produced nuclei relative to the reaction plane of the initial nucleus-nucleus collision. The event-plane method was used to obtain the v_2 of nuclei [4]. The $v_2 = \langle cos(2(\phi - \Psi))\rangle$, where ϕ is the azimuthal angle of the nuclei and Ψ is the estimated reaction plane (event plane) angle using TPC,

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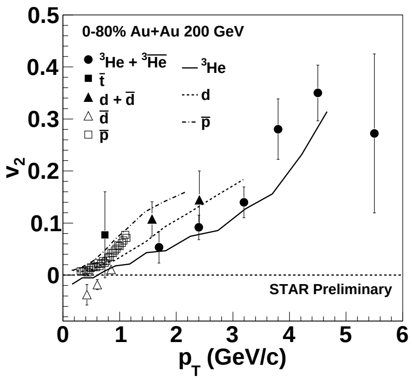

FIG. 2: v_2 as a function of p_T for $\bar{t}$ and ^3He+$^3\overline{He}$ from 0-80% of the collision centrality. $d(\overline{d})$ and $\overline{p}$ v_2 are shown in the plot as a comparison [5] . The v_2 calculations from dynamical coalescence model are shown in different lines [6].

Results

Fig. 2 shows v_2 as a function of p_T for $\bar{t}$ and $^3He + ^3\overline{He}$ in minimum-bias (0-80% centrality) Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. The v_2 of $\overline{p}$ and $d(\overline{d})$ measured by the STAR are also shown for the comparison [5]. The v_2 of $\overline{p}$, d and ^3He are well described by the dynamical coalescence model [6]. In this model, the probability for producing a cluster of nucleons (d, t and ^3He) is determined by the overlap of its Wigner phase-space density with the nucleon phase-space distributions at freeze-out. To determine the Wigner phase-space densities of the d, t and ^3He, we take their hadron wave functions to be those of a spherical harmonic oscillator. Fig. 3 shows both v_2 and transverse kinetic energy $KE_T = m_T - m$, where $m_T = \sqrt{p_T^2 + m^2}$ scaled by the number of constituent quarks (n_q) for different hadrons inluding the nuclei and anti-nuclei. The value of n_q used for $d(\overline{d})$ and $^3He(^3\overline{He})$ are 6 and 9 respectively, to account for their composite nature. The scaled results for v_2 versus KE_T for the light nuclei and anti-nuclei are consistent with the experimentally observed NCQ scaling of v_2 for baryons and mesons [7]. The data indicates that the light nuclei are formed through the coalescence of nucleons just before thermal freeze-out. This is also consistent with the picture that partonic collectivity dominates the transverse expansion dynamics of the nucleus-nucleus collisions at RHIC. Details of the analysis and physical interpretation of the observations will be discussed.

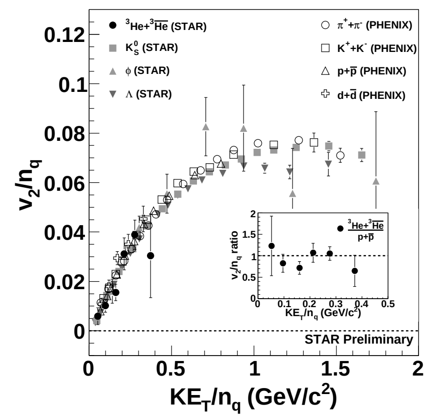

FIG. 3: v_2/n_q as a function of KE_T/n_q for different particles in minimum-bias Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. The PHENIX data are from Ref. [8]. The insert is the ratio of ^3He+$^3\overline{He}$ to $p + \overline{p}$.

References

[1] R. Fries *et al.*, Ann. Rev. Nucl. Part. Sci. **58**, 177 (2008).

[2] H.H. Gutbrod *et al.*, Phys. Rev. Lett. **37**, 667, (1976); R. Scheibl and U. Heinz, Phys. Rev. C **59**, 1585, (1999).

[3] H. Bichsel, NIMA **562** 154 (2006).

[4] A. M. Poskanzer and S. A. Voloshin, Phys. Rev. C **58**, 1671-1678 (1998).

[5] B.I. Abelev *et al.* (STAR Collaboration), arXiv:nucl-ex/0909.0566.

[6] S. Zhang *et al.*, Phys. Lett. B **684**, 224 (2010).

[7] A. Adare *et al.* (PHENIX Collaboration), Phys. Rev. Lett. **98**, 162301, (2007).

[8] A. Adare *et al.* (PHENIX Collaboration), Phys. Rev. Lett. **99**, 052301, (2007).