PROCEEDINGS OF SCIENCE

Deuteron (and cluster) production in heavy ion collisions

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We consider two mechanisms for the production of light clusters: the coalescence model and the thermal model. The first one postulates that light nuclei are formed only at late times of the fireball evolution by recombination of protons and neutrons with close positions and velocities on the kinetic freeze-out surface. On the other hand, the thermal model assumes that deuterons are chemically equilibrated with other hadrons already at hadronisation and their number does not change during cooling. Then the thermal model describes yields of all hadron species with the universal temperature of $T = 156$ MeV at LHC. This is very surprising because it is hard to imagine that loosely bound sizeable nuclei can exist in the hot and dense hadron gas. From previous studies, we know that both models predict similar deuteron yields. We try to understand the cluster production and to distinguish between the models also with the help of the anisotropic flow of the clusters.

40th International Conference on High Energy physics - ICHEP2020
July 28 - August 6, 2020
Prague, Czech Republic (virtual meeting)

*Speaker

PoS(ICHEP2020)582

1. Motivation

The yields of deuterons and antideuterons, together with other types of particles including pions, kaons, and protons can be all fitted by the Statistical Model. Thus it seems that the statistical model is universal. The question is if this is a robust feature or a result of finely tuned balance of more processes at work during the cooling phase? And what does it actually tell us? The motivation for studying deuterons and other clusters is to find answers to these questions and the fact, that clusters actually carry femtoscopic information about freeze out.

2. Thermal model vs. coalescence

In Statistical (thermal) model, particle yields are given by the temperature and chemical potentials for the conserved charges. The other alternative for the deuteron production is the coalescence model, which postulates that light nuclei are formed only after the breakup of the fireball by recombination of protons and neutrons with close positions and velocities on the kinetic freeze-out surface.

The results [1, 2] show that both the thermal model and the coalescence model predict similar deuteron yields. However, when using a blast-wave model as a representation of thermal production of the proton transverse momentum spectra and flow with simply replacing the proton mass by those of light nuclei, the data on the elliptic flows of these light nuclei [3] are not well reproduced.

3. DRAGON - coalescence production

3.1 The coalescence model

We use the coalescence model for the description the formation of composite objects. The number of created deuterons with momentum P_d is given by the projection of the deuteron density matrix onto two-nucleon density matrix. Deuteron spectrum has then the form [4]

$$E_d \frac{dN_d}{d^3 P_d} = \frac{3}{8(2\pi)^3} \int_{\Sigma_f} P_d^{\mu} d\Sigma_{\mu}(R_d) f_p\left(R_d, P_d/2\right) f_n\left(R_d, P_d/2\right) C_d(R_d, P_d) \tag{1}$$

where $C_d(R_d, P_d)$ is quantum mechanical correction factor, which involves the wave function of the deuteron. The integration runs over the whole freeze-out hypersurface Σ, $d\Sigma_\mu$ is the normal four-vector, and we assume the equilibrium distributions of protons and neutrons. Finally, $3/8$ is a spin-isospin factor.

3.2 Monte Carlo generator DRAGON

DRAGON (277 species both stable and resonances) is used for the generation of protons and neutrons. Their phase-space distribution is based on the blast-wave model. Coalescence is included as follows: for each p-n pair, the momenta and positions of p and n are boosted to the 2-particle rest-frame, the particle that decoupled earlier is propagated to the decoupling time of the other particle, deuteron candidate is selected by the conditions of $\Delta p \leq 0.200$ GeV/c and $\Delta r \leq 2.1$ fm and for each deuteron candidate spin-isospin factor $3/8$ is added.

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4. Results

First, we tune model parameters on fitting proton spectra and the elliptic flow and then we used them for describing deuterons. In Fig.1, left panels, we show the results for protons and in the right panels for deuterons. The top figures show transverse momentum spectra and the bottom figures show elliptic flow for two centralities of Pb+Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, $0-5\%$ (T = 80 MeV, $\langle v_T \rangle = 0.99$, R_b = 10 fm) and $30-40\%$ (T = 100 MeV, $< v_T >= 0.83$, R_b = 6 fm). We fitted ALICE data for energy 2.76 TeV.

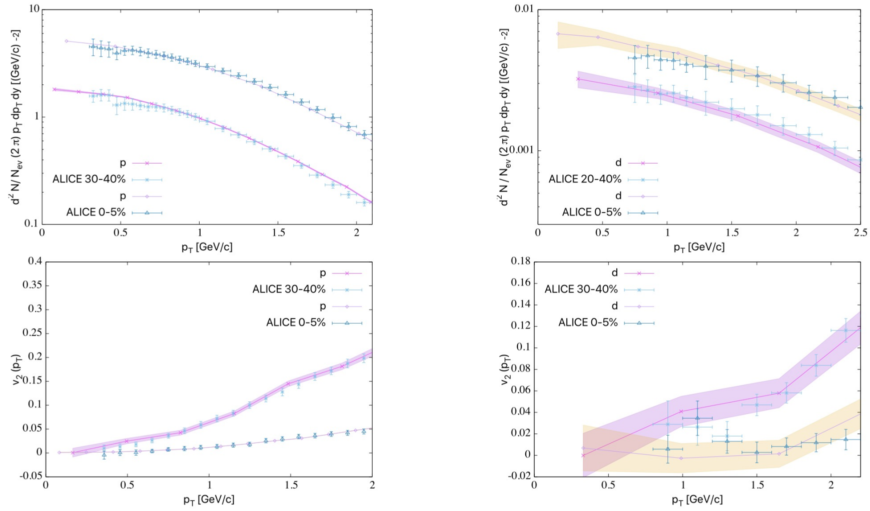

Figure 1: p_T spectra (top panels) and v_2 (bottom panels) of protons (left) and deuterons from coalescence (right) for two centralities ($0-5\%$, $30-40\%$) together with the ALICE data.

5. Conclusion

We observe that our model is able to describe p_T spectra and v_2 of protons and deuterons with the same parameters. Nevertheless, with the extracted parameters, the model is not very good for fitting v_2 of pions. This is a problem, because the pions are emitted from the same fireball as the protons. The solution to this problem could be in using different freeze-out hypersurface. Such an extension of the model is planned in the near future.

Acknowledgments

This work was supported by the project CAAS CZ.02.1.01/0.0/0.0/16_019/0000778.

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