High energy neutron emission and short range correlation

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High energy neutron emission from ^{40}Ar,^{20}Ne+Cu reactions at 400 to 600 A MeV is studied, examining a possible signature of nucleon-nucleon short range correlations (SRC) in the high energy/momentum tails in the neutron spectra, using available experimental data sets of Iwata *et al.* [1]. Semi-relativistic antisymmetrized molecular dynamics (SrAMD) with a three nucleon collision (3NC) term [2,3] is utilized, where the Fermi-boost is also applied [4]. In AMD, the Fermi motion is only taken into account as an average value when the equation of motion is solved for the time evolution of wave packets and there is no Fermi motion in the initial nuclei. In order to take into account the Fermi motion in collision processes, momentum fluctuations, which is calculated along the Gaussian momentum distribution in the wave packets, are added to two colliding nuclei for the Pauli-allowed binary collision (2NC) process, which is called “Fermi boost” [4]. This Fermi boost is also applied for the ternary collision (3NC) process in [2,3].

Single-nucleon momentum distributions in nuclei show high momentum tails (HMTs) beyond the Fermi momentum. Theoretically, such HMTs have been calculated in models with realistic nucleon-nucleon interactions with two- and three-body terms [5]. The extracted shape of the HMT is almost identical for all nuclei from deuteron to very heavier nuclei and HMT varies approximately according to K^{-4}, where K is nucleon momentum in unit of the Fermi momentum. In order to study a possible effect of the short range correlation in the high energy neutron spectra, the single nucleon motion in hot nuclear matter is expressed as a Gaussian Fermi motion plus an empirical high momentum tail (HMT) with a function of K^{-4} distribution and used in the Fermi boost when a collision occurs. In Fig.1, calculated

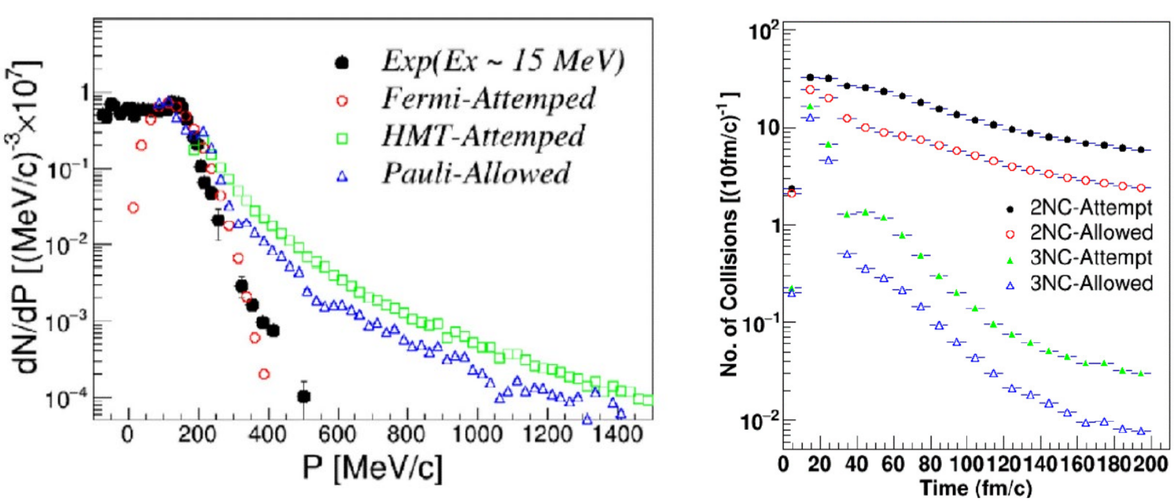

Fig. 1. (Left) Single-nucleon momentum distribution. Black dots are the experimental data. Red circles and green squares are the Fermi distribution and HMTfor attempted collisions, respectively. The blue triangles are those for the Pauli-allowed collisions. (Right) Number of nucleon-nucleon collisions (2NC) and ternary collisions (3NC) are plotted as a function of the reaction time for ^{49}Ar+^{63}Cu at 400 AMeV. Closed black circles and filled green triangles are those of the attempted collisions and open red circles and open blue triangles are those of the Pauli-allowed collisions. The numbers are calculated at every 10 fm/c.

single nucleon motion with HMT is plotted on the left and the number of 2NC and 3NC is plotted on the right. Since SRC should occur at an early stage of the reaction, where a high density nuclear matter is produced, HMT is only taken into account for the 3NC process.

In Fig.2 the experimental data and the simulated results are shown for ^{40}Ar+^{63}Cu at 400 AMeV on the left and at 560AMeV on the right. In each set of the plots, energy spectra are plotted on the left and K4 weighted momentum spectra are shown on the right. The semi-relativistic AMD with 2NC process alone is referred as 2NC, that with the additional 3NC process is as 3NC and that with HMT is referred as HMT in the figure.

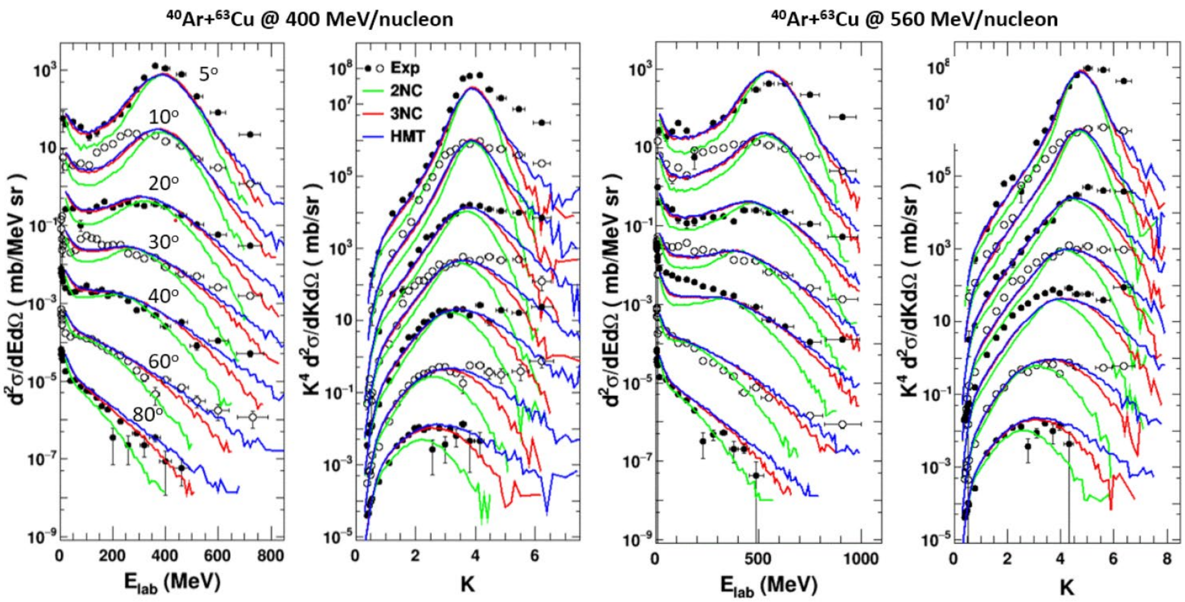

Fig. 2. Neutron double differential cross sectio for ^{40}Ar+^{63}Cu collisions at 400 Mev/nucleon on the left two spectra and at 560 MeV/nucleon on the right two spectra. In each set of spectra, energy spectrum is shown on the left and K^4 weighted momentum spectrum on the right. Simulation are made using a ^{63}Cu target.

The experimental high energy/momentum tails at $\theta \geq 40^o$ are reasonably well reproduced with the AMD simulations with HMT at 400 AMeV, but less clear at 560 A MeV. Although the positive correlations between HMT in the Fermi boost and the enhancement of the high energy/momentum tail in the neutron spectra are observed, no flattening of the momentum spectra in the K^4 weighted momentum distribution is observed in the AMD simulations. The flattening behavior was suggested in [6].

[1] Y. Iwata, T. Murakami, H. Sato, *et al.*, Phys. Rev. C **64**, 054609 (2001).
[2] R. Wada, Phys. Rev. C **96**, 031601(R) (2017)
[3] Q. Hu, G.Y. Tian, R. Wada, *et al.*, Phys. Rev. C **108**, 054907 (2023).
[4] W. Lin, X. Liu, R.Wada, *et al.*, Phys. Rev. C **94**, 064609 (2016).
[5] S.C. Pieper, R.B. Wiringa, and V.R. Pandharipande, Phys. Rev. C **46**, 1741 (1992).
[6] K. Hagel and J.B. Natowitz, arXiv:nucl-ex 2111, 09399v1 (2021).