

High energy neutron production and three nucleon collisions in intermediate heavy ion collisions

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In our previous works in Ref.[1,2], the role of the Fermi-momentum fluctuation in collision process (FM Boost) and three nucleon collision (3NC) process are studied for the high energy proton production at the incident energy around 44-137 MeV/nucleon, incorporating the FM Boost and 3NC terms in the anti-symmetrized molecular dynamics (AMD) of Ono *et al.* [3]. We now extend these works for the high energy neutron production at higher incident energies.

The experimental data are taken from Refs. [4] and [5]. In both experiments, performed by two groups in the HIMAC facility of NIRS in Japan in 10 years apart, neutron energy spectra were measured by the time of flight technique using a plastic scintillator as a start and liquid scintillators as the stop timing detectors. In their experimental setups and reaction systems studied were slightly different, but some were overlapped. Here we used their results of $^{12}\text{C}+^{12}\text{C}$, $^{12}\text{C}+^{16}\text{O}$ at 290 MeV/nucleon.

AMD simulations are performed using the same code as that in Ref. [2] (AMD-FM(3N)) with 3NC or without 3NC. The simulated results are shown in Fig.1 for $^{12}\text{C}+^{12}\text{C}$ and in Fig.2 for $^{12}\text{C}+^{16}\text{O}$ both at 290 MeV/nucleon. Without 3NC, the results are denoted as AMD/DC-FM (blue histograms) and those with 3NC are as AMD/DC-3NC (red histograms) and compared with the experimental results in Refs. [4] and [5]. The experimental results are well reproduced with those of simulated ones with 3NC except for a small number of angles, these are 5° and 10° in Fig.1 and 75° in Fig.2. Since the FM Boost is ineffective

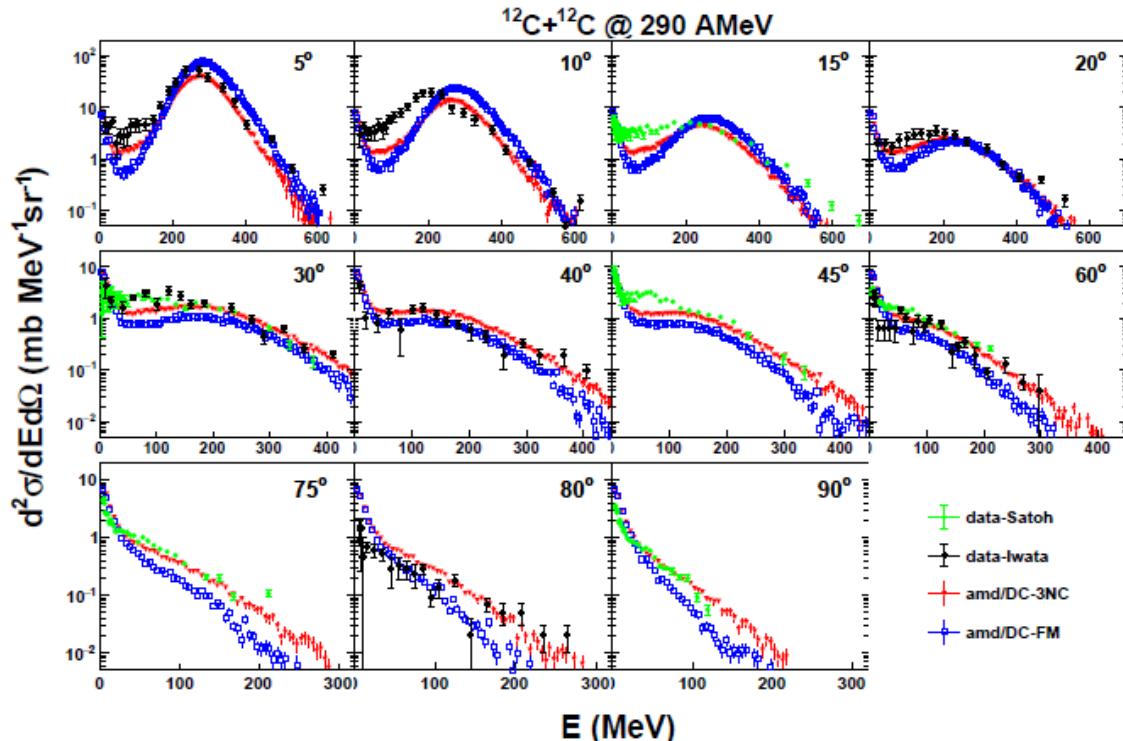


Fig. 1. Blue histograms represents the results of AMD/DC-FM and red histograms those of AMD/DC-3NC. The experimental data taken from ref.[4] are shown by black symbols and those from Ref.[5] by green symbols.

for the high energy neutron production above 50 MeV/nucleon as discussed in Ref. [2], these results strongly support the fact that these high energy neutrons are mainly produced by the 3NC process.

The 3NC terms are also sensitive to the nuclear stopping and now an investigation of the 3NC effect on the nuclear stopping is underway.

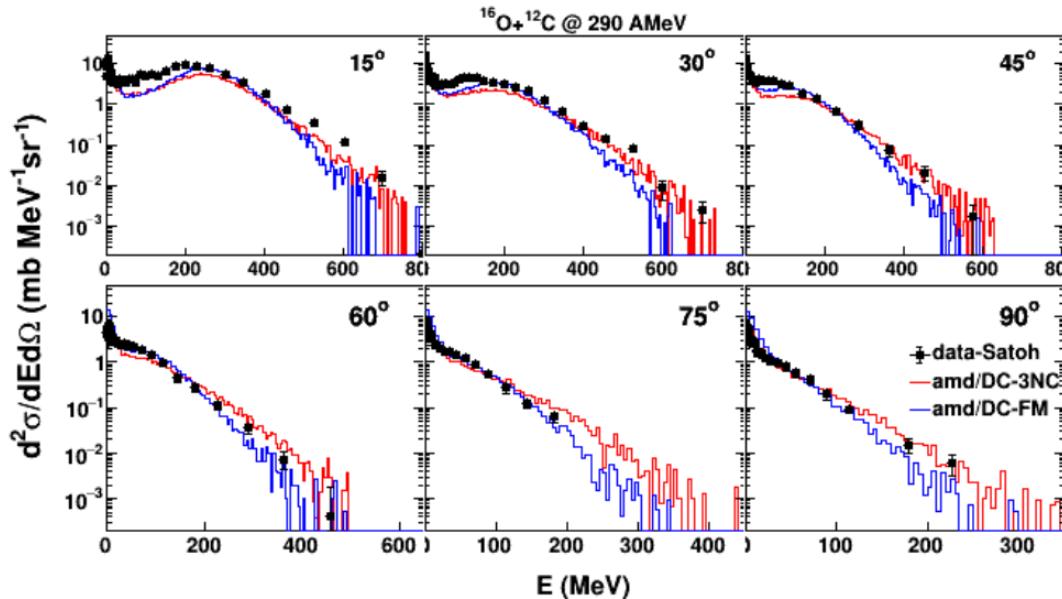


Fig. 2. Similar plots as Fig.1, but for 12C+16) at 290 MeV/nucleon. The same symbols and colors are used in Fug.1 for the experimental and simulated results.

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