Energetic proton emission in intermediate-energy heavy-ion collisions with IQMD

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The energetic protons emitted from intermediate-energy heavy-ion collisions are studied under the framework of the isospin-dependent quantum molecular dynamics model (IQMD model) [1-2], which is modified to take into account the Fermi motion in the process of nucleon-nucleon collision and 3N collision. Simulated energetic proton spectra are compared with those in the reactions of ^{40}Ar+^{51}V at 44 *A* MeV from ref. [3] and ^{40}Ar+^{40}Ca at 92 and 137 *A* MeV from ref. [4]. Wave packet width dependence and nucleon-nucleon cross section dependence on the energetic protons are also investigated.

In the IQMD modeling, the width of the Gaussian wave packet is traditionally set to different values for different reaction systems, to obtain the best stability of the initial nuclei. Fig.1 shows the results of the wave packet width dependence of energetic proton energy spectra of ^{40}Ar +^{51}V at 44 *A* MeV at different angles, together with free nucleon-nucleon cross section (free NNCS), screened nucleon-nucleon cross section (screened NNCS) [5] and Li-Machleidt nucleon-nucleon cross section (LM NNCS) [6] from left to right panel. The energetic proton yield decreases as the width parameter

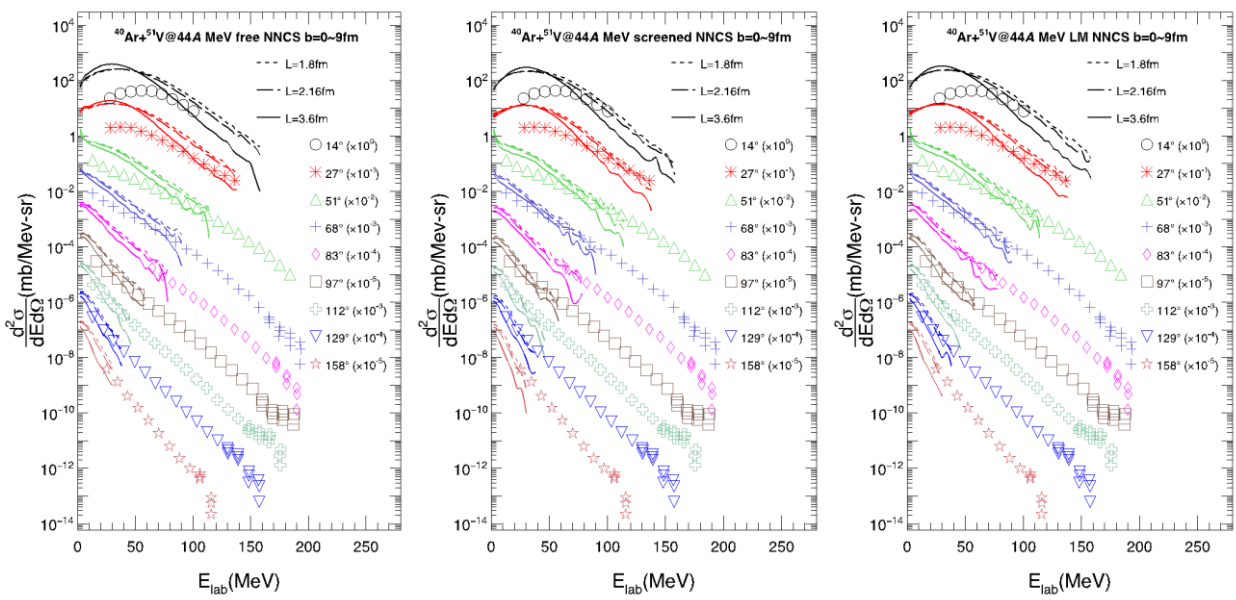

FIG. 1. The wave packet width dependence of proton energy spectra at different angles for ^{40}Ar+^{51}V at 44 A MeV, together with the free NN cross section (left), screened cross section (middle) and L-M in-medium NN cross section (right). Markers represent measured proton spectra. The calculated data are showed by lines.

increases, and decreases as the NN cross section decreases from the free NN to the screened cross section. In other words, the choice of the width parameter depends on the choice of the NN cross section used in the calculation. The calculated data is in a good agreement with the experimental proton spectra when wave packet width is equal to 2.16fm for the screened NNCS.

Low energy proton yields are significantly over-predicted, because of the instability of the initial nuclei. In order to suppress the nucleon emission from the un-stabilized initial nuclei, the Fermi motion is

decreased and the Fermi boost is incorporated in the collision process, in a similar way to that in [7] (results are still in preliminary and not shown here).

The model has been applied to the experimental spectra at ^{40}Ar+^{40}Ca at 92, 137 A MeV and the results are shown in Fig.2. We found that none of the parameter sets, the widths and the NN cross sections, can reproduce the experimental spectra in their slopes and amplitudes, similar to the conclusion in Ref. [8]. We are currently working on the incorporation of the reduced Fermi motion, Fermi boost in the two body collision term and a 3 body collision term [8]. The study is underway.

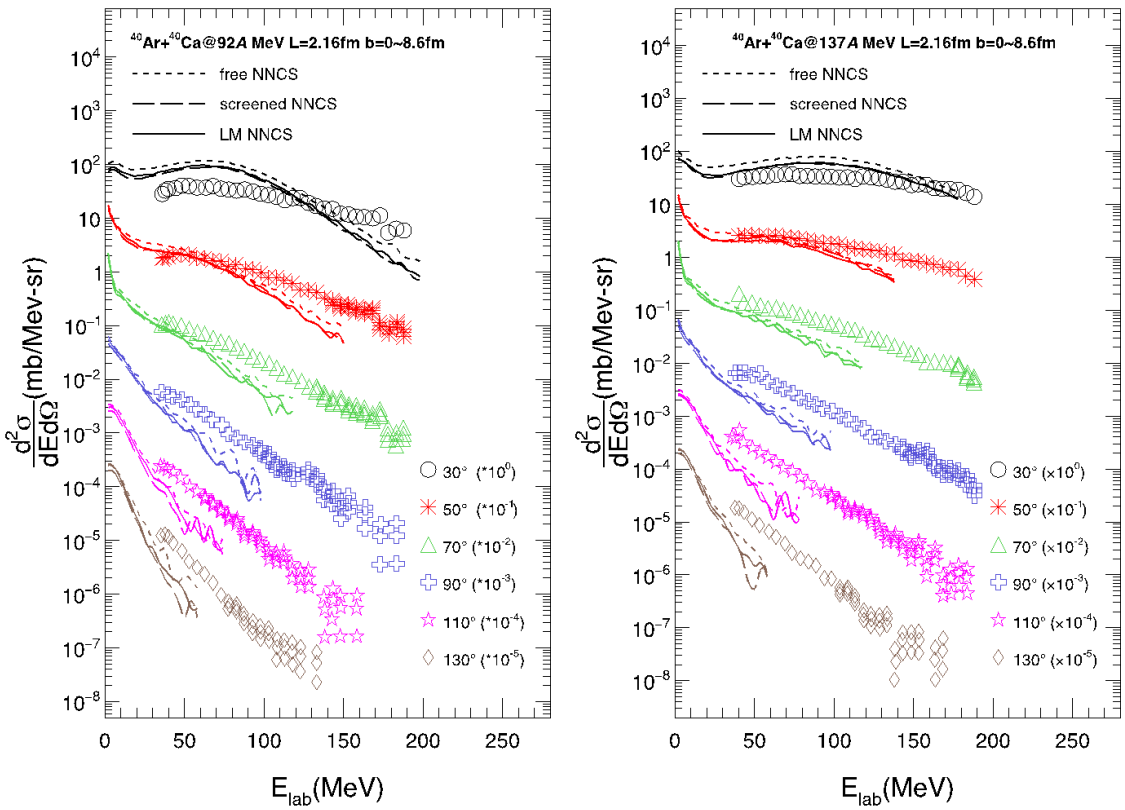

FIG. 2. The simulated results at higher incident energies.

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