Equation of State and Nucleon-Nucleon Cross Section in Medium

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The equation of State (EOS) and nucleon-nucleon (NN) cross section in medium have been studied, using the antisymmetrized molecular dynamics model (AMD-V) of Ono et al. [1]. The model has been successfully applied to the ^{64}Zn + ^{58}Ni reaction at 35A to 79A MeV [2].

In the previous analysis in reference [2] the Gogny force and an empirical NN cross section were used to reproduce the experimental results.

The Gogny interaction has an incompressibility K=228 MeV (soft EOS). In order to see the effect of different stiffness of the EOS on the calculated results, a modified version of the Gogny-type interaction of Haddad et al. [3] with K=360 MeV (stiff EOS) has been used (referred to D1-G3 in reference [3]). For a practical use of the D1-G3 interaction, a surface term had to be added in the Hamiltonian to get a consistent description of the ground state properties of initial nuclei. [4].

In order to show the direct effect of the different stiff-ness of the EOS, the propagation of the projectile nucleons through the target nuclear matter is examined. The nucleon propagation is evaluated by the number of nucleons which cross the Z=O point in the center of mass system (Z is the beam axis) as a function of the reaction time. This number, normalized by the projectile mass, becomes one when the target matter is totally transparent. When the projectile and target form a compound system and reach a chemical equilibrium, the number becomes 0.5. The calculated results are shown in Figure 1 for the ^{64}Zn + ^{58}Ni reaction at 35A and 57A MeV. For the soft EOS at 35A MeV, about 70% of projectile nucleons appear on the opposite side, having pass through the target at the end of the reaction. This number increases slightly at 57A MeV. This fact has been called nuclear semi-transparency in intermediate heavy ion collisions. The nuclear transparency is reduced when the nuclear matter becomes stiffer, but the difference between the two EOS becomes smaller when the incident energy increases. This difference in nuclear semi-transparency during the reaction is directly reflected in the angular distribution of the emitted fragments.

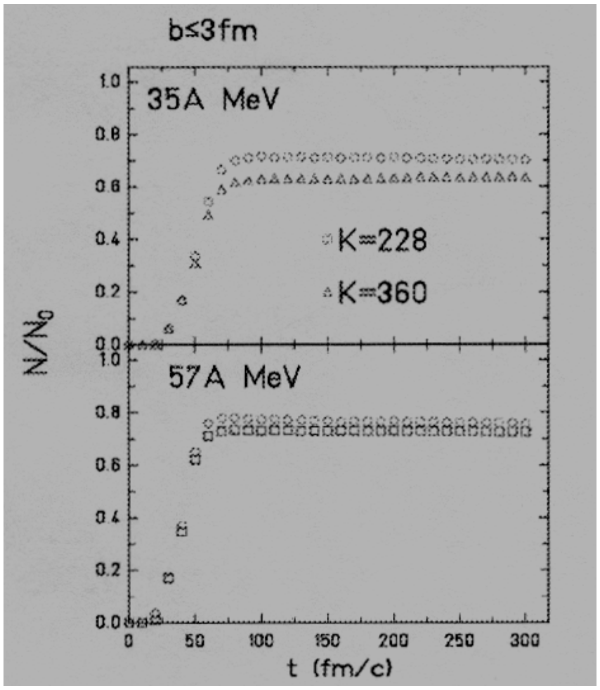

Figure 1: Number of projectile nucleons across Z=0 in the center of mass as a function of the reaction time. The events for the central collisions (0<b<3fm) are used. The number is normalized by the projectile mass No.

In Figure 2, the calculated energy spectra of fragments at different angles are compared with those of the experimental results at 57A MeV.

The results for the soft EOS are plotted by solid line histograms and those for the stiff EOS are plotted by the dashed line histograms. As one can see, the fits to the experimental

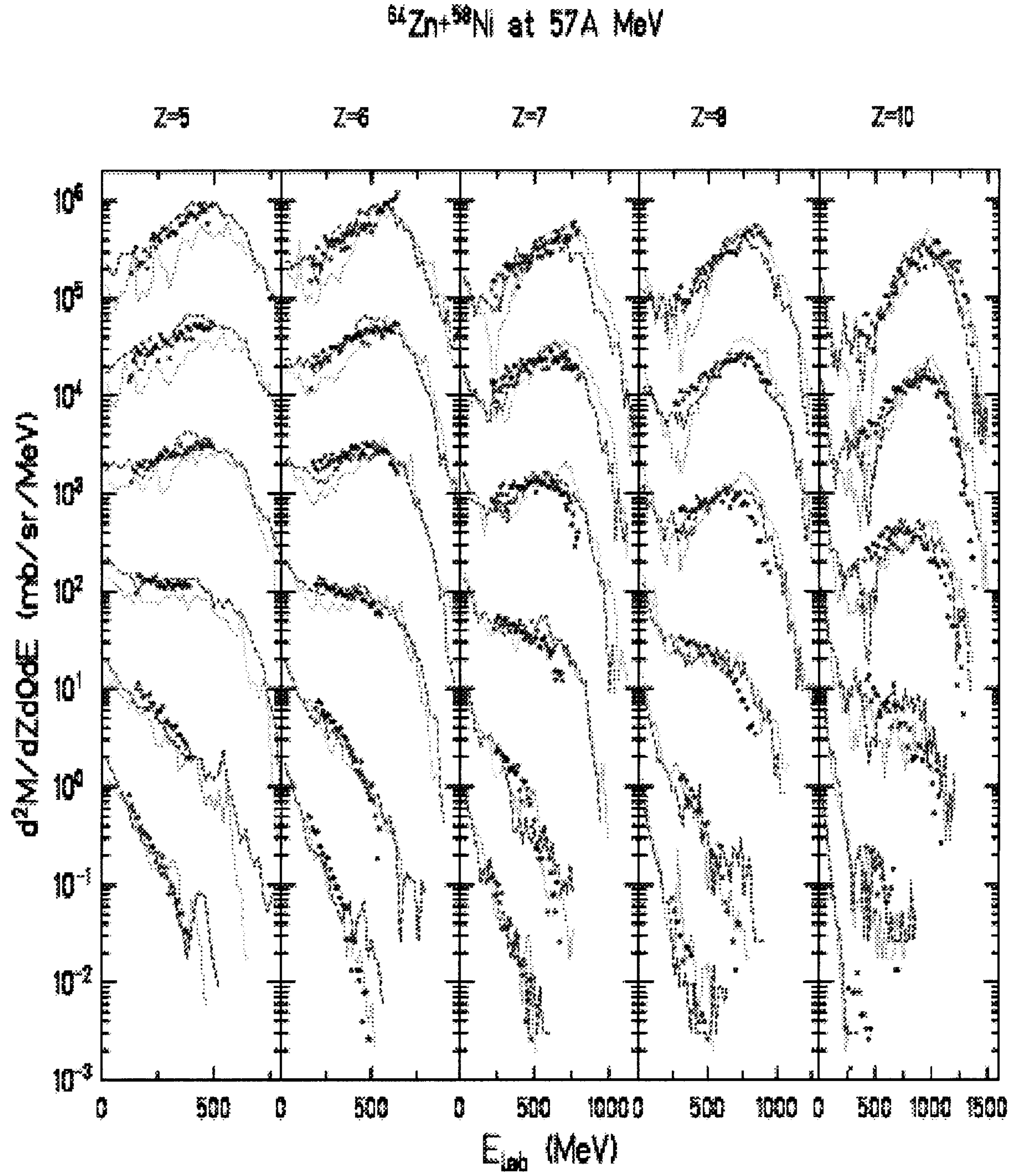

Figure 2: Energy spectra of some of fragments at 57A MeV. The experimental results are shown by dots and the calculated results are shown by solid lines (soft EOS) and dashed lines (stiff EOS). The fragments are identified by their charge at the top of each column. In each column the spectra from the top to the bottom correspond to those at angle of 4.3^{O}, $7.3\ ^{O}$, $10.9\ ^{O}$, $16.0\ ^{O}$, $22.0\ ^{O}$ and $28.5\ ^{O}$. The spectra are multiplied a factor of $I0^{n}$ (n=0, 1, 2, 3, 4, 5) from the bottom to the top.

results are apparently improved by the effective interaction with the stiff EOS, especially for the lighter fragments at forward angles. The improvement is also observed for those at all other incident energies.

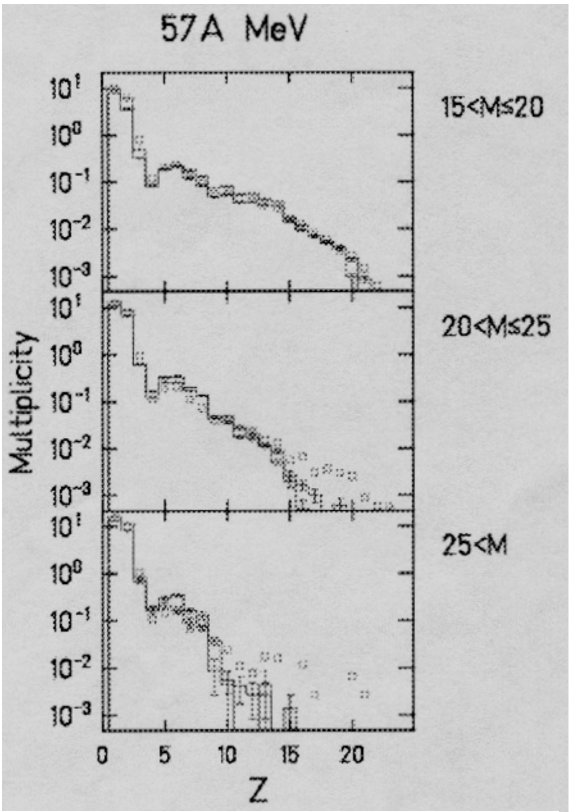

Figure 3: Charge distributions associated with different charged particle multiplicity at 57A MeV. The experimental results are shown by squares and the calculated results are shown by solid line (soft EOS) and dashed line (stiff EOS) histograms. The associated charged particle multiplicity is indicated on the right.

The difference in the semi-transparency, however, is not reflected so much in the multiplicity distribution of the final fragments. In Figure 3, calculated charge distributions for both soft and stiff EOS are compared to the experimental results at 57A MeV. The results are plotted separately for three different windows of the associated charged particle multiplicity. For all cases, no significant effect for different stiffness of the EOS is observed in the charge distributions of the final products.

The effect of the different NN cross section in medium has also been investigated. The formalism of Li-Machleidt [5] was used instead of the empirical formula to calculate the NN cross section. At normal density the new formula gives by a factor of two larger cross section for a nucleon-nucleon collision around the relative energy of 50MeV and this factor increases when the relative energy decreases and reaches to about five at 10MEV. The density dependence is similar to that of the empirical formula. The difference in the different NN-cross sections, however, does not produce notable changes on the above observables. This is probably because most of attempted collisions are significantly Pauli-blocked in this energy domain and the main mechanism of the reaction process is governed by the effective interaction. Further investigation for the NN cross section is now underway, especially focusing on nucleon flow during the reaction.

References

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