Studies of Isospin in ^{58,64}Ni + ^{70,64}Zn Reactions

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The ^{58,64}Ni on ^{70,64}Zn reactions have been studied with the HERACLES multidetector [1] at 40 MeV per nucleon. Energy calibrations and particle identification have been previously described [2]. The present report is an update on the first analysis of physics results.

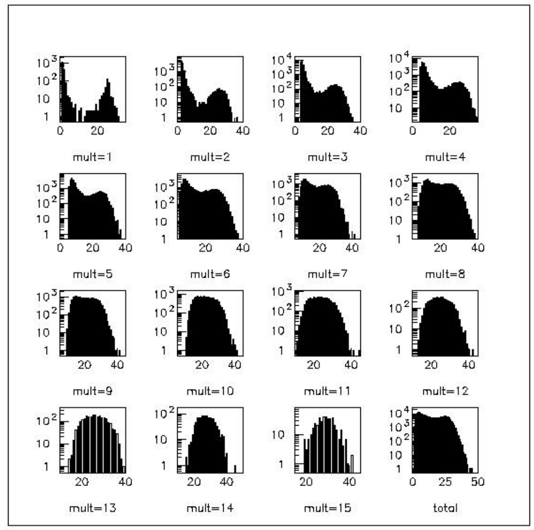

Figure 1: Total event charge distributions for the ^{58}Ni + ^{64}Zn reaction. The distributions are cut on the multiplicity values shown.

Figure 1 shows the distribution of total charge detected for each event for the ^{58}Ni + ^{64}Zn reaction. The total charge distribution is plotted in the bottom right window. The remaining windows plot the distribution with cuts on event multiplicity with values from one to fifteen.

There are clearly two main types of events detected by the HERACLES array. There are low multiplicity events characterized by a multiplicity less than five where the charge distribution shows characteristic peaks composed of low-Z fragments and high-Z projectile-like-fragments. These events account for the majority of the events. The events with a multiplicity of ten or above are characterized by a single broad peak with a maximum centered around the beam charge. The charge distributions for intermediate multiplicity values show a transition from one event profile to the other. Further examination of the individual particle charge distributions and velocity spectra will be needed to further characterize the nature of the events to allow for better impact parameter selection.

An interesting observable related to isospin effects is the ratio of ^{3}H/^{3}He associated with the quasi-projectile (with the condition Vz_{cm} >0). The ^{3}H/^{3}He ratios obtained in CsI(Tl) detectors mounted between 24^{o} and 46^{o}, versus the reconstucted impact parameter is displayed on Figure 2a. The data comes from two reactions: ^{64}Ni+^{64}Zn and ^{58}Ni+^{70}Zn at 40 MeV per nucleon, having the same number of protons

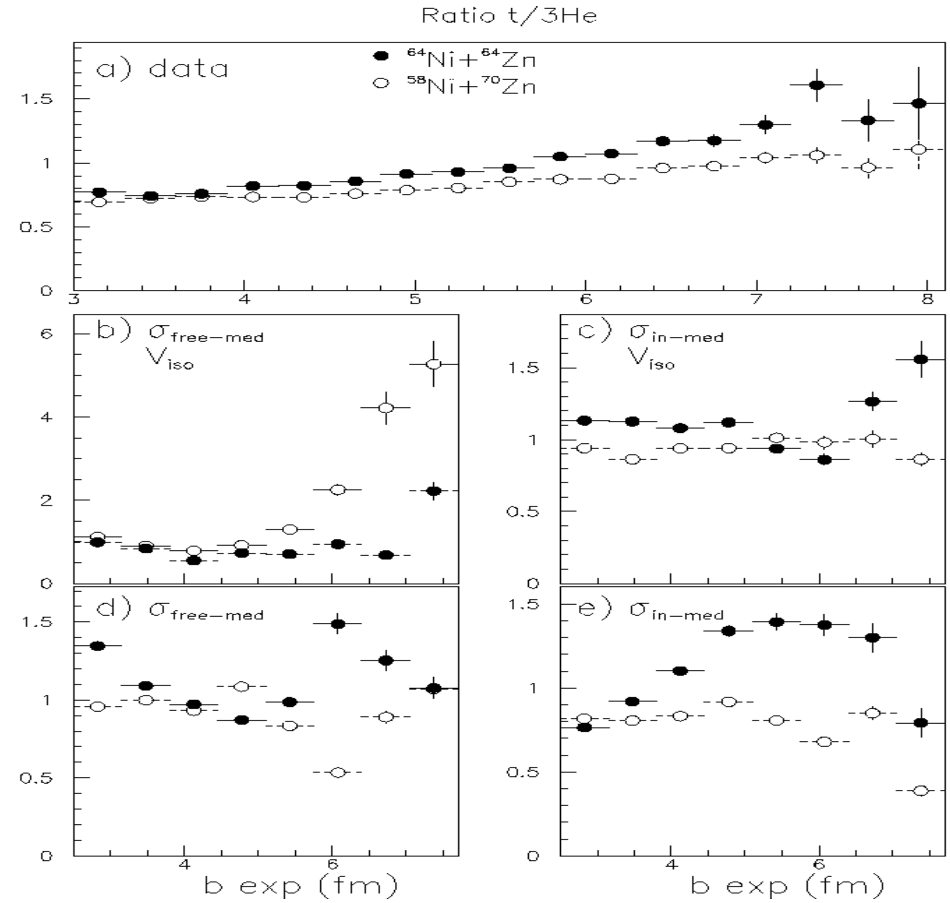

Figure 2: ratio t/3He. Figure 2a represents experimental data while 2b, 2c, 2d, 2e represent four cases of simulation, where $\sigma_{free\text{-}med}$ and $\sigma_{in\text{-}med}$ stand for free-medium and in-medium cross-section. Note that the scale is different for Figure 2b.

and neutrons but not the same ratio N/Z in the projectile.

In the experimental data (Fig 2a) we see that the ratio is higher for ^{64}Ni at high impact parameter, while at smaller impact parameter, the ratio is the same for ^{64}Ni and ^{58}Ni. At high impact parameter, the quasi-projectile is similar to the projectile. Since ^{64}Ni is more neutron rich than ^{58}Ni, the ratio ^{3}H/^{3}He is higher for ^{64}Ni. The magnitude of the ratio is smaller at small impact parameter, possibly because the multiplicity of fragments is higher and that the quasi-projectile is more proton-rich.

The data has been compared to simulations using a BUU[3] code. The code was optimized to conserve energy, using the Lattice Hamiltonian Vlasov method [4] with the symmetry term (related to isospin) included in the nuclear potential. The symmetry term introduced has the following form [5]:

$$V_{iso} = C\, \tau_z\, (\rho_n - \rho_p)/\rho_0$$

where ρ_n,ρ_p,ρ_0 represent respectively neutron, proton and saturation density, τ_z is the third component of isospin and C is a constant equal to 32 MeV. A clusterization code based on the proximity of nucleons in phase space in a statistical way, has been built to construct fragments in the final distribution of BUU. The fragments are then inserted in a deexcitation code based on the Hauser-Feshbach formalism (GEMINI)[6]. An experimental filter, modeling geometry and energy thresholds of the detectors, was used to compare simulation results with experimental data. Figure 2b-e represents four situations of simulations. V_{iso} means that the symmetry term has been included in the simulation, $\sigma_{free\text{-}med}$ is the free-medium cross-section and $\sigma_{in\text{-}med}$ is the in-medium cross-section.

In the Figure 2b, the $^3H/^3He$ ratio is inverted relative to the data. The nucleon transfer was too high; the free-medium cross-section increases the number of collisions and V_{iso} tends to equilibrate the medium in isospin. In the opposite situation (Figure 2e), $\sigma_{in\text{-}med}$ was used but not V_{iso} : the nucleon transfer is then at a minimum. The central collisions have good behavior in Fig. 2e, but the ratio diverges too much for the peripheral collisions. In Figure 2c, where the symmetry term was introduced, the ratio seems to have a good behavior for peripheral collisions, but not for mid-peripheral and central collisions. It will then be very interesting to use a symmetry term with a non-constant value C, meaning C(ρ), as [7]:

$$C(\rho) = A+B\rho$$

Relative to C=32 MeV, C(ρ) should be negligeable at high density (central collisions), less important for mid-peripheral collisions but important at lower density (peripheral collisions).

In conclusion, the results seem to show the necessity of $\sigma_{in\text{-}med}$ to reproduce data. Also, the symmetry term should be higher for peripheral collisions, where the density is lower. This symmetry term is important because it has a great influence on equation of state of nuclear matter.

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