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PREEQUILIBRIUM EMISSION OF NUCLEONS IN THE SYSTEM $^{40}\text{Ar} + ^{40}\text{Ca}$ AT 20 MeV/u\(^\text{1}\))

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Résumé - Pour le système symétrique $^{40}\text{Ar} + ^{40}\text{Ca}$ à 20 MeV/u nous avons mesuré les neutrons et les particules légères chargées en coincidence avec les résidus d'évaporation. Une composante de prééquilibre est présente tant dans le spectre d'énergies que dans la distribution angulaire. Nous avons aussi mesuré les multiplicités. Les données ont été comparées avec des calculs avec un modèle qui tient compte de l'espace de phase.

Abstract - In the mass symmetric system $^{40}\text{Ar} + ^{40}\text{Ca}$ at 20 MeV/u neutrons and light charged particles were measured in coincidence with evaporation residues. The shape of the neutron energy spectra and their angular distribution show a preequilibrium component. Multiplicities were determined. The data are compared to phase-space calculations.

I - INTRODUCTION

The equilibration process of finite systems of fermions and the related problem of the competition of mean field dynamics and successive nucleon-nucleon collisions are of great interest in heavy ion physics. A tool to study these questions are the emitted light particles. Especially neutrons are suited for the investigation of the equilibration process, since they do not underly Coulomb interactions. Experiments designed to measure preequilibrium emission have been done up to now only for asymmetric systems /1/. The interpretation is complicated due to the different velocities of the particle emission sources. In symmetric systems the source velocities are all the same and preequilibrium components can be extracted from angular distributions and the shape of the neutron energy spectra.

II - EXPERIMENTAL METHODS

In fig.1 the experimental set-up is shown. The pulsed $^{40}\text{Ar}$ beam (300 ps) from the UNILAC of GSI with an energy of 20 MeV/u has hit a $^{40}\text{Ca}$ target (800 $\mu$g/cm\(^2\)) and was dumped in a shielded Faraday cup. Fast neutrons, protons and deuterons were measured in coincidence with evaporation residues (trigger for central collisions). The evaporation residues were detected by surface barrier detectors in the angular range of $-3^\circ$ to $-11^\circ$ and their masses were determined by the time of flight method. The neutrons were measured in two position sensitive neutron detectors (PSNC1, PSNC2) and three standard neutron detectors (N1, N2, N3). Position sensitive plastic scin-
illators placed in front of the neutron counters served as detectors for the highly energetic protons and deuterons. This set-up allowed measurement of a complete angular distribution.

Fig. 1 Experimental set-up

Fig. 2 Neutron energy spectra

III - RESULTS

In fig.2 the yield of neutrons measured in coincidence with evaporation residues in the angular range $\theta_{cm} = 28^\circ$ to $50^\circ$ is shown as a function of the neutron energy in the center of mass system. Emission from an equilibrated nucleus at a temperature of 6 MeV (dashed line), which was obtained universally over the whole angular range, can account for the low energy part of the spectrum. At higher energies we find an additional component in the neutron spectrum. The experimental data can be reproduced by adding a preequilibrium component (dotted line) calculated according to a phase-space model to the thermal emission yields. The fully drawn line shows the sum of the two components.

In fig.3 the angular distribution of neutrons in coincidence with the evaporation residues is shown together with calculations (solid line) from a phase-space model /2/. The dashed lines are the limits of the model predictions.

The angular distribution of the neutrons of energy 20 MeV is nearly isotropic in the center of mass system. At 30 MeV and 40 MeV there is a clear forward and backward peaking. This result can be interpreted by a superposition of an isotropic equilibrium component, and a preequilibrium yield, which is significantly enhanced at higher energies and oriented along the beam axis.

The cross section for the production of evaporation residues is about a factor 2 higher than expected from trajectory model calculations /3/ extrapolated to higher energies. This enhancement can be explained by particle emission in the early stage of the reaction.
The total neutron multiplicity is 12. Taking the relative yield of the phase-space model calculations into account, a multiplicity of 2 for preequilibrium neutrons is derived.

In summary, the double differential neutron yield in coincidence with evaporation residues indicates that neutrons might well serve as a probe for nonequilibrium nuclear dynamics. Energy spectra show very energetic neutrons which cannot be described by classical Fermi-jet models /4/ and require a quantum-mechanical treatment of the emission process /2/. Furthermore, the angular distributions demonstrate that up to two successive nucleon-nucleon collisions must be considered in the nonequilibrium component, indicating a rather fast equilibration process in the reaction zone of finite nuclei.

REFERENCES