

PREEQUILIBRIUM EMISSION OF NEUTRONS IN SYMMETRIC HEAVY-ION
COLLISIONS[†]

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Preequilibrium light-particle emission offers an excellent tool to study the energy and momentum dissipation in the early stages of heavy-ion collisions before global equilibrium is reached. Light particles can be emitted throughout the course of the heavy-ion reaction and their energy spectra and angular distributions should yield information on the approach to statistical equilibrium. Especially the intermediate energy domain from about $E/A=15$ MeV to 150 MeV bombarding energy allows for an investigation of the competition between mean-field dynamics, dominant at lower energies, and successive nucleon-nucleon collisions, known from the relativistic regime.

This talk concentrates on preequilibrium neutron emission in central collisions of mass symmetric systems. Experiments so far have been performed with very asymmetric systems¹. Theoretical precompound models (the exciton model, Fermi-jets, hot spots, the diabatic approach) mainly differ in predictions for the differential preequilibrium neutron multiplicities at larger angles (with respect to the beam axis) which is due to different assumptions concerning the role of two-body collisions².

Mass symmetric systems offer the advantage that all possible sources of particle emission rest in the over-all c.m. system. Thus the problem of different source velocities in asymmetric systems which enter as fit parameters in part of the data analyses can be avoided. We present for the

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first time results for neutron emission in central collisions of a mass symmetric system on the example $20 \text{ MeV/u } ^{40}\text{Ar} + ^{40}\text{Ca}^3$. Double differential neutron multiplicity distributions in coincidence with evaporation residues were taken over a large angular range. On top of an equilibrium component (with nuclear temperature $T = 5 \pm 0.3 \text{ MeV}$ and multiplicity $M_n^{\text{EV}} = 6 \pm 0.2$) resulting from statistical evaporation from heavy residues there is clear evidence in forward and backward direction for a preequilibrium excess yield with angle-integrated multiplicity $M_n^{\text{PE}} = 2 \pm 0.5$. The data are compared to a quantal phase-space model^b which includes time-dependent mean-field dynamics as well as two-body collisions and Pauli-blocking in the nuclear medium. All data at all angles can be consistently described by taking into account a calculated preequilibrium yield with multiplicity $M_n^{\text{PE}} = 2 \pm 0.2$, in accord with the experiment.

Since the phase-space model^b yields a very good description of the data we adopt the characteristic value of $\lambda = 3.5 - 4 \text{ fm}$ for the mean free path of energetic nucleons and $\tau = 4.6 \times 10^{-23} \text{ s}$ for the average local equilibration time. With these numbers the average number of collisions prior to emission is 1.8 (more than three collisions lead already to an isotropic (equilibrium) distribution). The probability of a fast nucleon to escape without scattering is then 16.5%.

According to our present understanding our findings are incompatible with a hot spot or Fermi-jet approach. Instead, the energetic nucleons observed have to be traced back to quantum effects, i.e. to high momentum components in the nuclear groundstate wave function. The results demonstrate the importance of two-body processes for the emission of light particles even at these energies.

¹ E. Holub et al., Phys. Rev. C33 (1986) 143.

² W. Cassing, Nucl. Phys. A438 (1985) 253.

³ W. Röscher et al., J. de Physique C4 (1986) 389.

^b W. Cassing, Phase-Space Dynamics of Nucleus-Nucleus Collisions, in: Phase Space Approach to Nuclear Dynamics, M. Di Toro, W. Nörenberg, M. Rosina, S. Stringari, eds. (World Scientific, Singapore, 1986) pp. 64-93.

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