

STUDY OF REACTION MECHANISMS IN HEAVY ION  
REACTIONS AT  $\sim 20$  MeV/NUCLEON

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The nucleus-nucleus interaction is of special interest in the region of a few tens MeV/nucleon, since at these energies the Pauli principle loses its importance. One therefore expects a transition between the dominance of two body interactions at lower energies and single nucleon-nucleon collisions at much higher energies.

We have studied the emission of light particles especially nucleons with the hope to find indications for the underlying reaction mechanisms. Since we work in a transition region we have to deal most probably with more than one mechanism. This becomes evident from a contour plot of Galilei invariant cross sections as function of the momenta parallel and perpendicular to the beam axis, for protons emerging from the bombardment of  $^{197}\text{Au}$  with 400 MeV  $^2\text{Ne}$  ions<sup>1)</sup> (fig. 1). Occurrence of a moving and isotropically emitting source would show up in concentric semicircles, which were clearly not in the data. There are indications of at least three sources: one moving with beam velocity, one moving with approximately half the beam velocity and a third one with velocity of the compound nucleus. The latter velocity was calculated under the assumption of full linear momentum transfer.

In this study we are not interested in compound nucleus decay. We will therefore focus on the two other components. The component having approximately beam velocity must be attributed to projectile-like fragments.

It has been shown by particle-X-ray measurements<sup>2)</sup> and by particle-particle-coincidence measurements<sup>3)</sup> that the dominating mode is of two step nature, i.e. the sequential decay from projectile-like fragments being in long-living excited states. The other component having much smaller velocity may be attributed to pure non-equilibrium multi-step processes.

This situation reminds us to light ion induced reactions<sup>4)</sup>. There, we have decomposed the observed light particle yield into two parts which have been assumed to stem from incoherent processes: projectile fragmentation and pre-equilibrium contribution. The former has been calculated in a DWBA approach<sup>4)</sup> while the latter has been calculated in the framework of the exciton coalescence model<sup>5)</sup>. In the case of heavy ion induced reactions at least two problems occur: the fragmentation process is of two step nature and therefore not capable by the DWBA approach. Model parameters like the initial degree of freedom in the exciton model are unknown quantities. To account for the fragmentation yield in a phenomenological manner we can fit a Gaussian momentum distribution in the rest frame of the excited projectile-like fragments to the data. Figure 2 shows such a

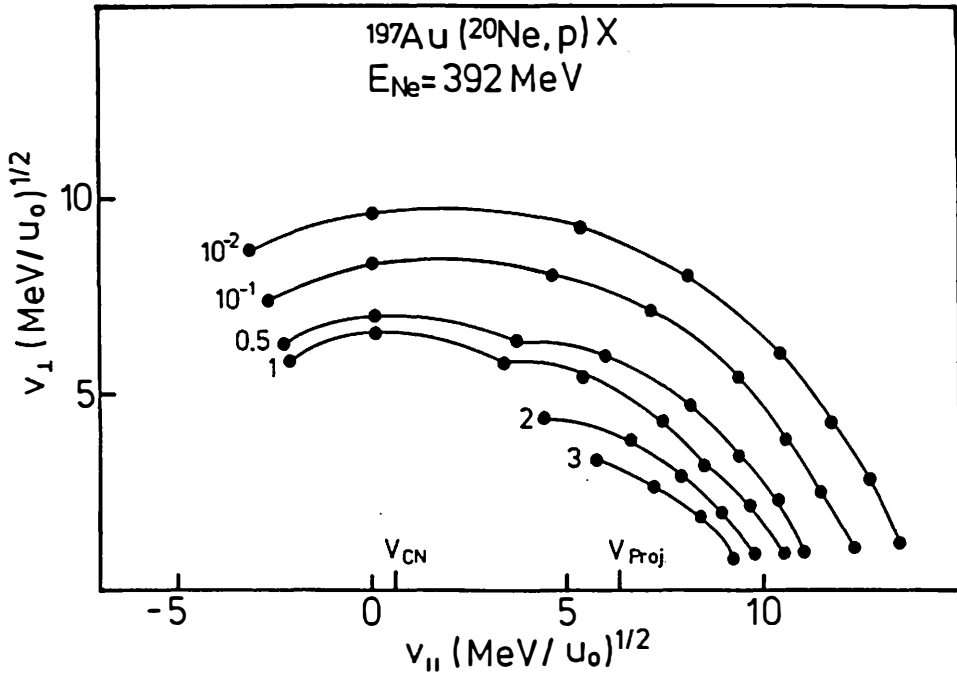


Fig. 1:  
Contour plot of Galilei invariant cross-sections for the indicated reaction. The lines are drawn to guide the eyes.

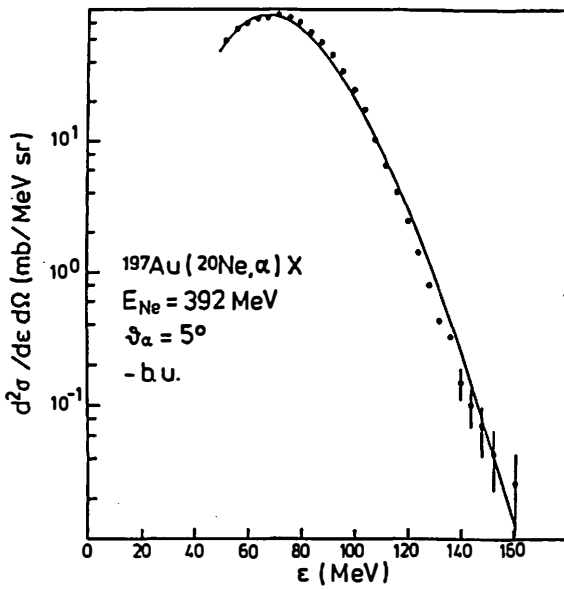


Fig. 2:  
 $\alpha$ -particle spectrum taken at  $\vartheta = 5^{\circ}$  is fitted by a moving source with statistical momentum distribution.

fit to forward angle data where the fragmentation process is expected to be the dominating one (comp. fig. 1). The pure pre-equilibrium component is then obtained by subtracting the fragmentation yield from the observed inclusive yield. Also experimentally one can get rid of this component by measuring the light particles in coincidence with evaporation residues.

The exciton coalescence model calculations have been performed by treating the initial exciton number  $n_0$  as a free parameter. The result for such a calculation is shown in figure 3 for neutron emission detected in

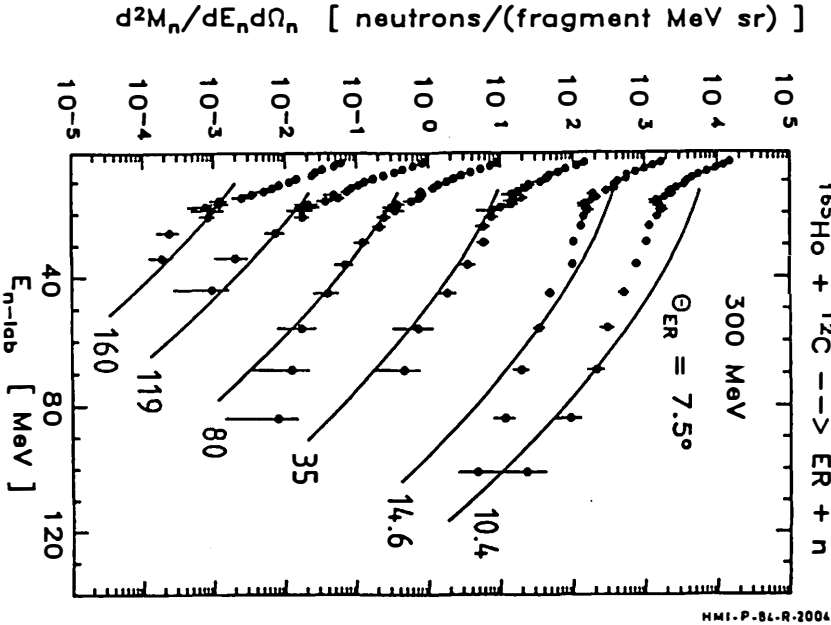
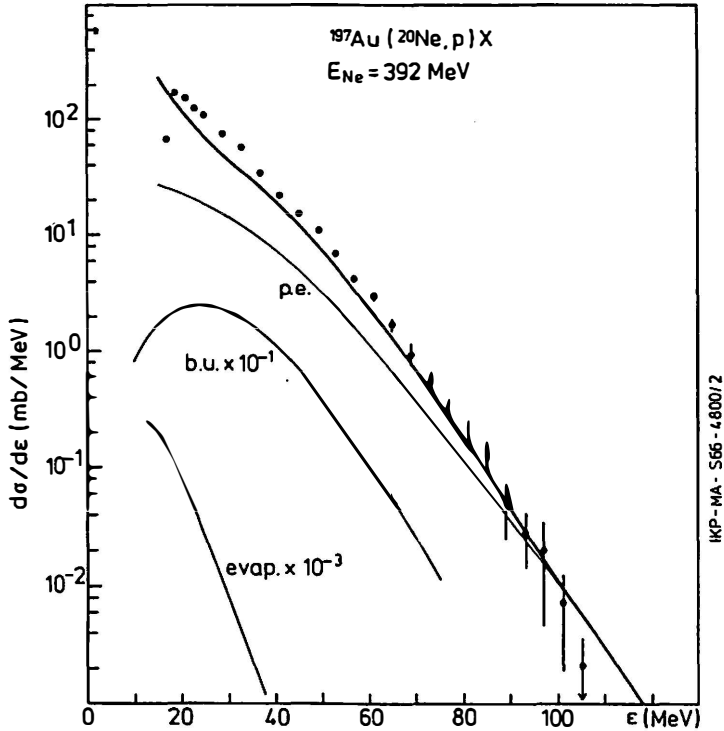


Fig. 3: Comparison of exciton model calculations with experimental spectra<sup>6)</sup> for different angles. An initial exciton number of  $n_0 = 16h + 4p$  has been used in the calculations.

coincidence with evaporation residues<sup>6)</sup>. Figure 4 shows proton data<sup>1)</sup> together with incoherently summed contributions from the compound nucleus, fragmentation and preequilibrium. It was found<sup>7)</sup> that the exciton number  $n_0$  increases with increasing bombarding energy and is independent of the target nucleus mass as long as the projectile-target system is very asymmetric.

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**Fig. 4:**

Comparisons between angle integrated cross sections and contributions from pre-equilibrium ( $n_0 = 30p + 10h$ ), projectile fragmentation and evaporation from a compound nucleus. The sum of the three calculations is shown as a thick solid line.

1. H. Machner, D. Protić, G. Riepe, H.G. Bohlen, and H. Fuchs, submitted for publication
2. H.W. Wilschut, G.J. Balster, P.B. Goldhorn, R.h. Siemssen, and Z. Zujkowski, Phys. Lett. 138B (1984) 43
3. H. Homeyer, M. Bürgel, M. Clover, Ch. Egelhaaf, H. Fuchs, A. Gamp, D. Kovar, and W. Rauch, Phys. Rev. C26 (1982) 1335
4. U. Bechstedt, H. Machner, G. Baur, R. Shyam, C. Alderliesten, O. Bousshid, A. Djaloeis, P. Jahn, C. Mayer-Böricke, F. Rösel and D. Trautmann, Nucl. Phys. A343 (1980) 221
5. H. Machner, Phys. Rev. C29 (1984) 109 and references therein
6. D. Hilscher et al., in H. Machner and P. Jahn (Edts.) Proc. Workshop on Coincident Particle Emission from Continuum States in Nuclei, World Scientific Publ. Comp., Singapore 1984
7. H. Machner, Phys. Rev. C28 (1983) 2179