# EVOLUTION OF THE FUSION LIKE PROCESS AROUND THE FERMI ENERGY

E. Pollacco, J. Alarja, Y. Cassagnou, B. Chambon, B. Cheynis, M. Conjeaud, R. Dayras, A. Douchy, D. Drain, A. Giorni, et al.

JOURNAL DE PHYSIQUE
Colloque C4, supplément au n° 8, Tome 47, août 1986 

# EVOLUTION OF THE FUSION LIKE PROCESS AROUND THE FERMI ENERGY

E.C. POLLACCO[+], J. ALARJA[*], Y. CASSAGNOU[+], B. CHAMBON[**], B. CHEYNIS[**], M. CONJEAUD[+], R. DAYRAS[+], A. DOUCHY[*], D. DRAIN[**], A. GIORNI[*], J. GOMEZ DEL CAMPO[+***], S. HARAR[+], R. LEGRAIN[+], C. MORAND[*], J.B. VIANO[*] and C. VOLANT[+]

[+]*Service de Physique Nucléaire, Basse Energie, CEN-Saclay, F-91191 Gif-sur-Yvette Cedex, France*
[*]*Institut des Sciences Nucléaires, F-38026 Grenoble, France*
[**]*Institut de Physique Nucléaire, Université Claude Bernard, Lyon I, F-69622 Villeurbanne Cedex*
[***]*Oak Ridge National Laboratory, Oak Ridge, TN 37831, U.S.A.*

Résumé - L'étude des résidus d'évaporation du système Ne + Ag montre un changement qualitatif dans le mécanisme de réaction aux alentours de l'énergie de Fermi. A 20 MeV/u le projectile est essentiellement absorbé par la cible tandis qu'à 30-37 MeV/u on observe un transfert de masse continu accompagné d'un grand moment transverse.

Abstact - The study of evaporation residue from the Ne + Ag system shows that there is qualitative change in the reaction mechanism in the Fermi energy domain. At 20 MeV/u the projectile is mostly absobered by the target, while at 30-37 MeV/u a continious range of mass transfer with a large transverse momentum is observed.

Investigation of the evaporation residue after collisions involving large momentum transfers plays an important role in the determining the change in the reaction mechanism in the Fermi energy domain.

The reaction $^{20}Ne$ + Ag at 20, 30 and 37 MeV/u was studied using the SARA facility. The evaporation residues were detected using a time of flight consisting of a MCP system and a triple detector telescope to give a flight path of 42 cm. Recoil mass versus velocity spectra were measured for angles between 4° and 35°, relative to the beam axis. The contour plot for the velocity as a function of mass is shown in fig. 1. As seen, the majority of the events in the choosen velocity region consists mainly of residus which are characterised by their mass (∿ 100 amu). These events are easily discriminated against fission and low energy projectile like fragments. Of interest is that at 30 MeV/u, a large fraction of the events lie below the compound nucleus velocity $V_{CN}$.

The mass projection at 20, 30 and 37 MeV/u are essentially Gaussian in shape and have mean values of 106, 100 and 95 amu respectively. This suggests that the overall excitation energy, $E^*$ increases with bombarding energy. In fact using mean values of the invariant velocity spectra (V > 0.4 cm/ns) and the massive transfer description gives an increase of approximatly 100 MeV in $E^*$ between 20 and 37 MeV/u.

In fig. 2 the invariant velocity spectra at the three energies are superimposed. At 20 MeV/u the spectrum shows a peak corresponding to 70 % of $V_{CN}$, which in a massive

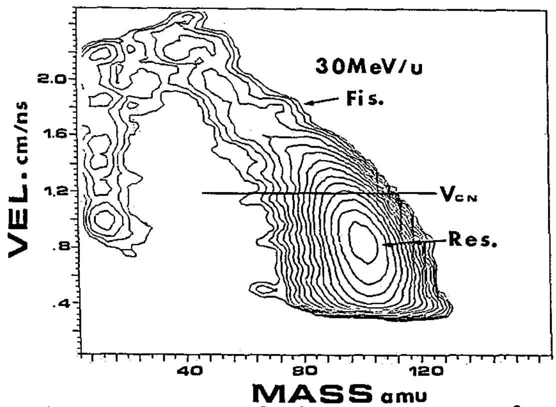

Fig. 1 - Mass vs velocity spectrum at 10°.

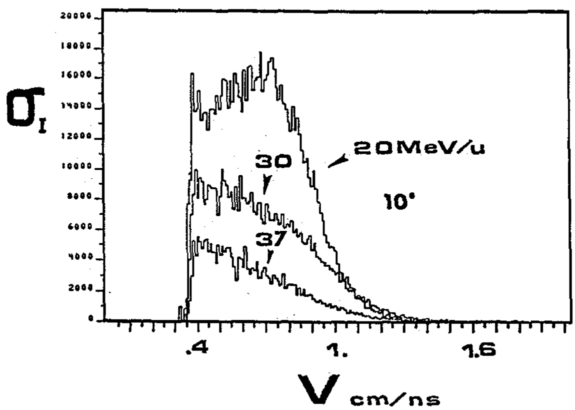

Fig. 2 - Invariant velocity spectra at 10° for $^{20}$Ne + Ag at 20, 30, 37 MeV/u).

transfer picture translates into 14 amu being embedded into the target. What is singularly interesting is that increasing the energy to 30 MeV/u leaves only a minor evidence of this peak. At 37 MeV/u the peak disappears completely. The same description is shown when plotting the invariant cross section in a parallel versus perpendicular velocity plane (fig. 3). Again a strong source is present at 20 MeV/u, while at 30 MeV/u the events are spread over a large range of sources.

Before dealing with the angular distribution it will be pertinent to remark that comparing the 20 MeV/u with other systems, namely $^{16}$O + Al, Ca, Ni at different energies /1/ shows, in a Viola plot that the Ne data is approximatly 12 % below the trend.

The angular distributions were obtained by integrating the evaporation residue events for velocities larger then 0.4 cm/ns and are presented in fig. 4. Again there exists a strong difference between 20 and 30 MeV/u and strickingly enough little change between 30 and 37 MeV/u. Thus at 20 MeV/u the events are concentreted in the forward angles as expected from a quasi-full momentum transfer process. At 30 and 37 MeV/u the data is shifted to large angles and implies that a strong transverse momentum

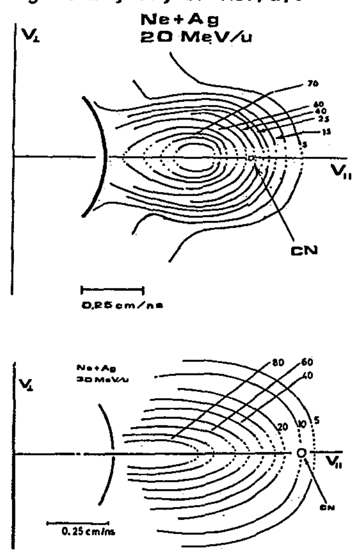

Fig. 3 - Invariant velocity contour plots.

is present. To investigate further the distributions the same data was plotted for different velocity gates and given fig. 5. At 20 MeV/u as clearly seen, the shape is essentially independent of velocity and with the maximum in the distribution remaining stationary with velocity window. Again the 30 MeV/u data is quite different. With the low velocity window, the distribution is very wide and the maximum lies at large angle. The most probable angle decreases with increasing recoil velocity, an effect which is strongly reminescent of two body processes. Namely, the more mass is transfered the larger is the focussing in the distribution.

In order to investigate the effects of the statistical evaporation in the angular distribution two calculations were performed. The first case assumed a complete fusion followed by 9 fast nucleons with angular distributions and temperature given by the code written by Blann /2/ (using 20 excitons) (1). The remaining energy is removed by normal light particle emission. In the second example (2) 12 nucleons are assumed to fuse with the target with the remaining assumed to escape at 0° with beam velocity. The excess energy is then removed by allowing evaporation of fragments up to Z=14. The calculated distribution of evaporated masses give a reasonable description to the evaporative component measured by Y. Cassagnou et al./3/ for the same system and energy. The calculation are given in fig. 6 and show that the data (0.8 0.9 cm/ns) have a considerably larger width. Thus fast particles and evaporation do not reproduce the width and thus large transverse momentum, such as two-body processes is required to explane the data.

To summarize the data at 20 MeV/u shows that the projectile is mostly absorbed by the target. At 30-37 MeV/u there is a continuous range of mass transfers and large transverse momentum. Hence a change in reaction mechanisms in the formation of residues is present between 20 and 30 MeV/u.

## REFERENCES


/1/ Chan, Y. et al., Phys. Rev. C27 (1983) 447.
/2/ Blann, M., Phys. Rev. C31 (1985) 1245.
/3/ Cassagnou, Y. et al., to be published.


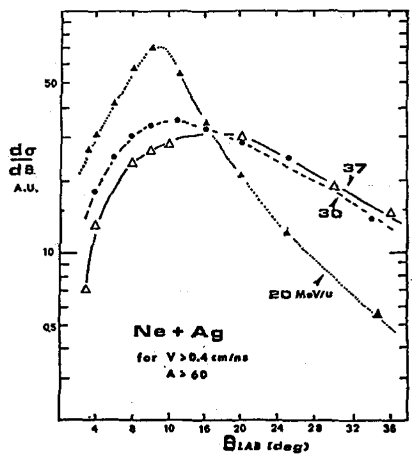


Fig. 4 - Residue angular distributions for $^{20}Ne$ + Ag at 20, 30 and 37 MeV/u.

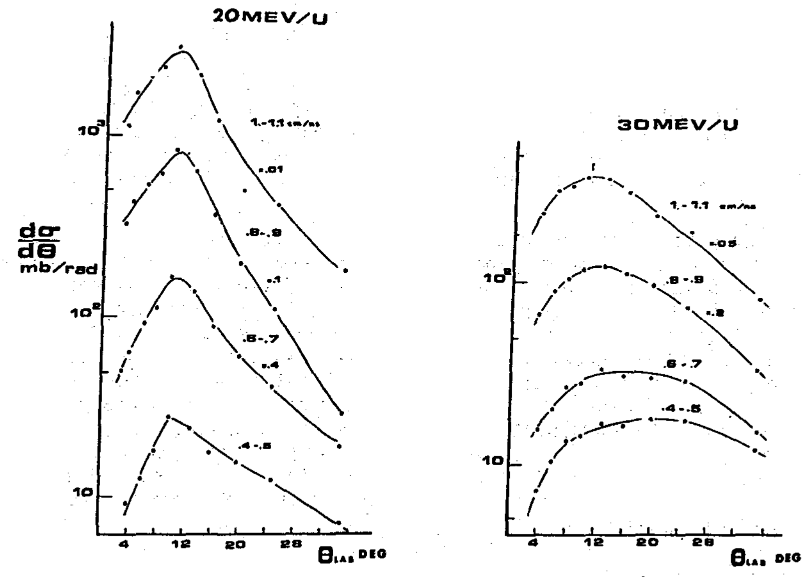


Fig. 5 - Residue angular distribution gated by the velocity.

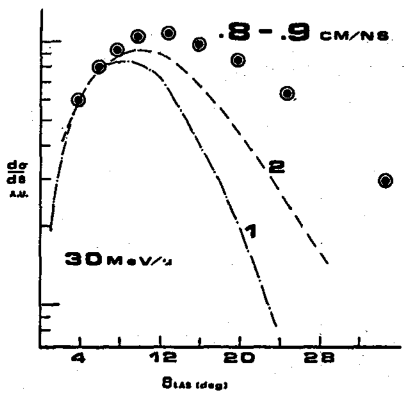


Fig. 6 - See text.