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FORMATION AND DECAY OF HOT NUCLEI

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Résumé - Les corrélations angulaires entre fragments de fission pour le système ^{58}Ni + ^{232}Th à 20, 25 et 30 MeV/u montrent une persistance de la bosse correspondant aux grands transferts qui suggère que sa disparition pour le système ^{40}Ar + ^{232}Th à 44 MeV/u n'est pas due à une limitation en énergie d'excitation et que la taille et la vitesse du projectile ont aussi un rôle important. De grandes vitesses relatives sont observées pour les fragments de fission pour les grands transferts (~ 9,5 GeV/c) qui pourraient provenir d'un mécanisme de fission plus exotique des noyaux chauds.

Abstract - Fission fragment angular correlations for the system ^{58}Ni + ^{232}Th at 20, 25 and 30 MeV/u show still a bump for large momentum transfers which suggest that its disappearance for the ^{40}Ar + ^{232}Th system at 44 MeV/u is not due to a limitation in the excitation energy and that the size and velocity of projectiles are also important. High relative velocities of fission fragments are measured for large transfers (~ 9.5 GeV/c), this could be due to more exotic fission of hot nuclei.

The aim of the present investigation is to determine the entrance channel conditions to form nuclei as hot as possible and also to study their decay properties. The technics used is the angular correlation measurement.

A report of the results on the ^{40}Ar induced fission on ^{232}Th target at energies ranging from 31 to 44 MeV/u is given elsewhere /1/ and the main features of the angular correlations shown in the left part of Fig. 1 can be summarized : i) A prominent peak is observed at relative angle $\theta_{ff} \simeq 170°$ corresponding to sequential fission induced by quasi-elastic collisions ($\bar{p}_{\parallel} \simeq 0.8$ GeV/c). ii) A bump located at high momentum transfer ($\theta_{ff} \simeq 110°$ corresponding to $\bar{p}_{\parallel} \simeq 7$ GeV/c) which can be attributed to central collisions. These events result from incomplete fusion process since their recoil velocities are lower than the one corresponding to full momentum transfer (arrows in Fig.1) Two aspects are very striking : the disappearance of the bump at 44 Mev/u and the fixed average momentum transfer with incident energies.

The different nature of the two main processes have been also illustrated in /1/ ; namely the constant behavior with the increase of the energy of the measured masses and cross sections for the peripheral collisions and a decrease of the total masses for the fusion-fission processes evidencing an increase of the violence of the collisions associated with a decrease of cross sections.

In order to check if the washing out of the bump at 44 MeV/u is due to the maximum excitation energy acceptable by nuclei or, to entrance channel conditions, we studied the Ni + Th system which allows the introduction of more momentum and excitation energies into the target nuclei at the same relative velocities than Ar projectiles.

Experimental results are presented in the right of fig. 1. The main difference is that now the bump corresponding to central collisions is located at $\bar{p}_{\parallel} \simeq 9.5$ GeV/c which implies in the massive transfer framework, fissioning nuclei with A ~ 270 and about 900 MeV excitation energy. This result suggests that the disappearance of the bump observed at 44 MeV/u Ar is not due to a limiting excitation energy in the con-

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[+] Experiment performed at the GANIL facility.

posite like system since in both Ni and Ar induced incomplete fusion a temperature of about 5 MeV is reached ; hence entrance channel properties play an essential role in fixing the central collision yields.

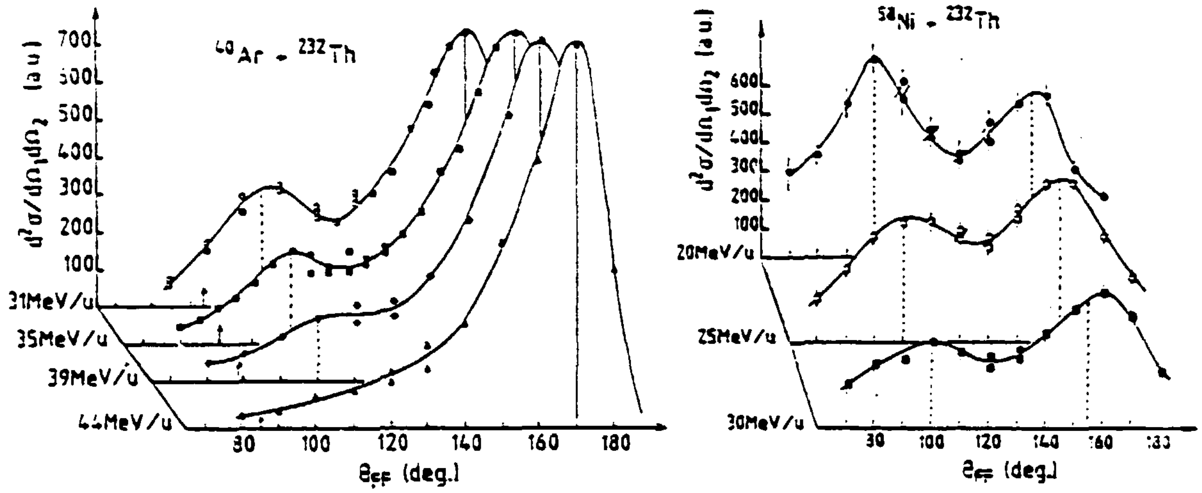

Fig. 1

At this stage, several remarks can be pointed out : i) The washing out of the bump at 44 MeV/u Ar does not mean that fission events corresponding to high momentum transfers ($\bar{p} > 7$ GeV/c) cannot be produced by such entrance channels. In fact, for the Ar induced fission on ^{165}Ho for which peripheral collisions are strongly suppressed because of the fission barrier height, one observes that high momentum transfers are imparted to target /2/. Several reaction mechanisms are probably involved in central collisions induced by both nucleus-nucleus and nucleon-nucleon interactions. The present data could indicate that the one body dissipation is vanishing for such entrance channel while two body dissipation still contributes to the population of hot nuclei. ii) The relative velocity of 44 MeV/u Ar projectiles is not sufficient to explain such transition since higher velocity projectiles such as ^{12}C (ref./3/) and ^{14}N (ref./4/) at 60 MeV/u on Th can induce a shoulder in the central collision region. It is probably both the velocity and size of the projectiles which determine the nature of mechanisms involved in these central collisions. iii) Average momentum transers are saturated at 2.6 GeV/c, 7 GeV/c and 9.5 GeV/c for ^{14}N, ^{40}Ar and ^{58}Ni respectively. These values are not significantly dependent of the target nuclei for masses > 165 a.m.u. Then one observes a remarkable scaling of momentum imparted to target nuclei with the projectile masses since $P_\parallel \simeq (180 \pm 20)$ MeV/c. This result is very important since it indicates that the whole projectile interacts with the target nuclei and that each escaping nucleon carries away more than 180 MeV/c in average.

In order to have more insight in the origin of the limitation we performed some calculations using the exciton model /5/ which are presented in table 1. The total momentum transfers fit quite well the experimental results and excitation energies are compatible with those deduced from masses of the fission fragments /1/.

In the framework of a naīve massive transfer picture, using as input the experimental $\bar{p}_\parallel$ values, one deduces quite similar excitation energies (Table 1) as obtained with the preequilibrium model, while the basic assumptions are very different. This is traced to the fact that in the exciton model the escaping nucleons carry away approximately the same total energies (kinetic plus binding energies) as the spectator nucleon in the massive transfer picture. However, the determination of the origin of the momentum transfer saturation needs further studies.

Another fascinating aspect concerns the recoil properties of fission fragments. Two dimensional plots of the coincident fission fragment masses are presented in Fig. 2 for both low and high momentum transfers. In these two conditions, the fission region is well defined, but for central collisions the mass asymmetry becomes rather large. The relative velocities (T_{ff}) vs the total detected masses presented in Fig.2 are well fitted by the Viola's systematics showing that we observed normal fission process for peripheral collisions. In contrast for biolent collisions, the velocity distribution is shifted towards higher values and shows a tail up to 2 cm/ns which represents quite abnormal total kinetic energies for fission processes. This effect might be due to a compact configuration at he saddle point and partly to angular momentum effect.

In summary, important amount of momentum transfers and excitation energies have been imparted to composite-like-nuclei with A = 270. A scaling for momentum transfer with the projectile mass is evidenced up to the Ni ions for central collisions. Velocity and size of projectiles play an important role as well as excitation energies deposited in fissioning nuclei, to fix the central collision cross sections. At last, high relative velocities of fission fragments have been measured and open an interesting problem on the fission properties of nuclei at high excitation energies and angular momenta.

Table I

For the massive transfer, $P_{\parallel}$ is deduced from the angular correlation, while it is predicted in the precompound model.

$^{58}Ni + ^{232}Th$

E_i (MeV/u)	Massive transfer		Precompound model		
	m_{out} (amu)	E^* (MeV)	$P_{\parallel}$	m_{pre} (amu)	E^* (MeV)
20	9	813	9.56	9.5	716
25	14.5	920	10.	13.3	830
30	18	1000	10.3	17.2	927
$^{40}Ar + ^{232}Th$					
31	11	785	7.36	11.2	734
35	13	834	7.52	13	793
39	14.5	880	7.62	14.6	851
44	16	934	7.76	16.8	914

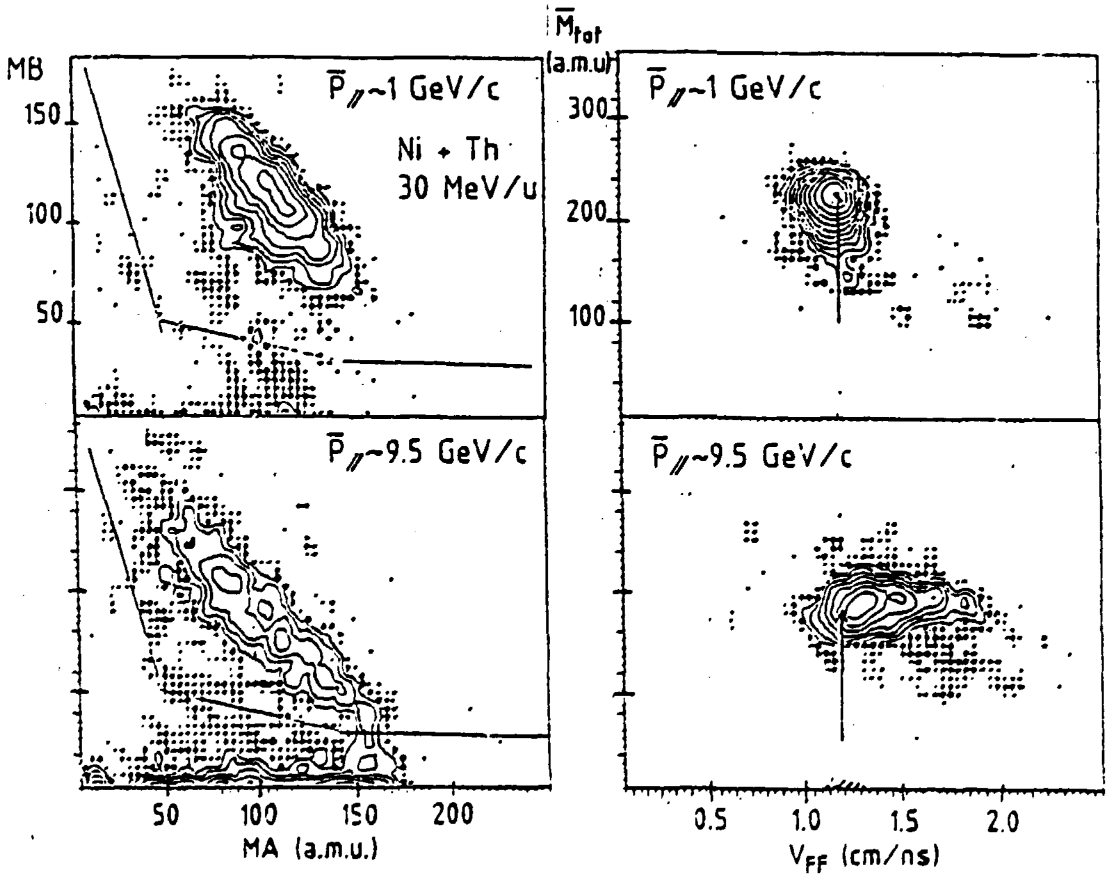

Fig. 2

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