FLUCTUATIONS AND DOORWAYS IN HEAVY ION REACTIONS

R. Bonetti and E. Fioretto

Istituto di Fisica Generale Applicata dell'Università di Milano, Italy

A. De Rosa, G. Inglima, M. Sandoli

Dipartimento di Fisica Nucleare dell'Università di Napoli, Italy

It is a well known feature of heavy ion induced reactions the possible simultaneous presence of stuctures in excitation functions of residual nucleus low-lying levels such as resonances and statistical fluctuations. While the latter have been traditionally attributed to compound nucleus formation, evidence has been accumulated in recent years in favour of a third type of phenomenon, the so called long-range fluctuations. These fluctuations once analyzed with statistical methods such as the Ericson autocorrelation function or the spectral density method, allow extraction of coherence widths which are not consistent with a compound nucleus picture of the reaction, being much larger (up to one order of magnitude). On the other hand, they cannot be explained in terms of resonances, being completely random and uncorrelated among the various exit channels. This effect has been first interpreted in light ion reactions(1) in terms of multistep compound fluctuations, and subsequently studied in detail in light heavy ion reactions(2) within the same philosophy. The idea is that during the equilibration process leading to compound nucleus (fusion) formation, relatively simple configurations (doorway states) of the intermediate, pre-fused system are populated in an overlapped levels regime. In analogy with traditional compound nucleus Ericson fluctuations these levels can originate cross section fluctuations having a coherence width larger (and therefore a mean life shorter) than the compound nucleus one.

Information on the quality of the doorway states being formed in such processes can be obtained upon comparison of emitted particles spectra and angular distributions with predictions given by theories describing the equilibration process such as the statistical multistep compound theory.

After the $^{12}C(^{16}O,\alpha)$ reaction (2) we have measured the $^{28}Si(^{12}C,\alpha)$ reaction in the incident energy range 33 to 40 MeV partly at Legnaro and partly at Catania Tandem Laboratories. The fluctuating excitation functions corresponding to 5 levels of ^{36}Ar residual nucleus were analyzed with the autocorrelation function method. A correlation width of $\sim$ 500 keV was extracted. This value should be compared with the compound nucleus width of $\sim$ 50 keV. From the α spectrum shape analysis it seems that the dominant doorway state is formed upon dissolution of the incident Carbon ion in 3 α particles, with the simultaneous excitation of a p-h pair. The extracted lifetime is $\sim 10^{-21}$ sec, therefore intermediate between the compound nucleus lifetime ($\sim 10^{-20}$ sec) and the nuclear transit time ($\sim 10^{-22}$ sec).

An even more clear demonstaration of the different nature of the phenomenon behind such large widths can be obtained by collecting the results extracted from the above analysis and from analogous cases present in the literature. Fig. 1 shows the widths obtained from systems in the mass range $28 \leq A \leq 40$ and the excitation energy range $27 \leq E^* \leq 50$, versus the quantity $\sqrt{A/E^*}$. The straight line gives the CN behaviour

$$\Gamma = 41 \exp\left[-6.64\sqrt{A/E^*}\right]$$

which is well followed by the "small widths" (empty dots), whenever found. The "large widths" are, on the other hand, well above such line and, more important, do not exhibit any compound nucleus-like energy and mass dependence.
Work on the theoretical calculation of these widths is in progress.

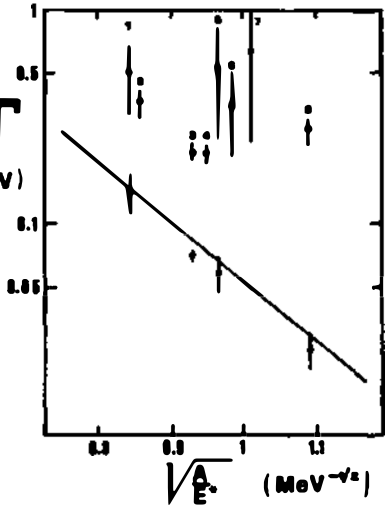

Fig. 1- Correlation widths for the reactions:

1- $^{12}C(^{24}Mg,{}^{12}C)$ $\bar{E}^* = 50$ MeV
2- $^{12}C(^{19}F,\alpha)$ $\bar{E}^* = 42$ MeV
3- $^{12}C(^{15}N,\alpha)$ $\bar{E}^* = 31$ MeV
4- $^{12}C(^{16}O,\alpha)$ $\bar{E}^* = 31$ MeV
5- $^{28}Si(^{12}C,{}^{12}C)$ $\bar{E}^* = 43$ MeV
6- $^{24}Mg(^{12}C,\alpha)$ $\bar{E}^* = 37$ MeV
7- $^{28}Si(^{12}C,\alpha)$ $\bar{E}^* = 38$ MeV
8- $^{16}O(^{16}O,{}^{16}O)$ $\bar{E}^* = 27$ MeV

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