Light Charged Particle Emission and the Giant Dipole Resonance in Ce Nucleus

S. Barlini1, V.L. Kravchuk1, O. Wieland2, F. Gramegna1, A. Bracco2, A.L. Lanchais1, A. Moroni2, G. Casini3, G. Benzoni2, N. Blasi3, S. Brambilla5, M. Brekiesz4, M. Bruno5, F. Camera2, M. Chiari5, G.E. Geraci1, B. Guiot5, M. Kmieciek3, S. Leoni2, A. Maj1, P.F. Mastinu1, B. Million2, A. Nannini3, A. Ordine5, G. Vannini5, L. Vannucci1

1 INFN, Laboratori Nazionali di Legnaro, 2 Dipartimento di Fisica and INFN, Milano, 3 INFN, Firenze, 4 The Niewodniczanski Institute of Nuclear Physics, Krakow, Poland, 5 Dipartimento di Fisica and INFN, Bologna, 6 INFN, Napoli

I. INTRODUCTION

The $^{132}\text{Ce}$ compound nucleus was formed in fusion reactions $^{64}\text{Ni} + ^{68}\text{Zn}$ and $^{16}\text{O} + ^{116}\text{Sn}$ at different excitation energies. High energy $\gamma$ rays have been measured in coincidence with Evaporation Residues (ER) in these reactions. At the same time Light Charged Particles (LCP) were measured with the same gate on ER for all the reactions in order to verify and compare the amount of pre-equilibrium emission using mass-symmetric and mass-asymmetric entrance channels.

One of the best known collective modes, which is built on excited states at high excitation energy corresponding to temperatures greater than 2 MeV [1] is, in fact, one of the outstanding problems. Under this limit the width is increasing rapidly with bombarding energy due to the increasing spin induced deformation and increasing thermal shape fluctuations. In this regime, therefore, the global systematics is reasonably well described by the shape fluctuation calculation in which the quadrupole deformation of the nucleus is assumed to couple adiabatically to the GDR vibration [2-4]. But beyond the bombarding energy, where the angular momentum saturates (that is the maximum angular momentum the nucleus can sustain), it has been argued that the width should grow much more slowly. Many experiments have been interpreted in terms of a saturating width and at a higher energy a saturating GDR $\gamma$-ray multiplicity. It is, however, very difficult to reliably reconstruct the excitation energy in this bombarding energy range, because different phenomena start to compete with the complete fusion process.

II. EXPERIMENT

Recently measurements have been performed using the GARFIELD and HECTOR detection systems [5], in which both high energy gamma rays and charged particles emitted in coincidence with ER have been measured. In order to evaluate the role of the pre-equilibrium emission at higher energies we have chosen a system formed through the two different entrance channel mass asymmetries with the different bombarding energies.

The preliminary results of the present work suggest that very interesting information can be derived. The $\gamma$-ray spectra for the studied reactions are shown in ref. [10]. Comparing the two $\gamma$-ray yields derived from the reactions at higher bombarding energies of the Ni beam, the difference in the high energy part of the $\gamma$-ray spectra results compatible with the simulation prediction. The low energy (statistical) part of the $\gamma$-ray spectra is very much the same. On the contrary, comparing the two reactions leading to the same compound nucleus at the same nominal excitation energy, reached through the Ni or O entrance channel, even the statistical part appears to be different. Possible interpretation of this result is linked to the non-equilibrium effects in $\gamma$-ray emission when the system is formed through the mass-asymmetric channels [12,13]. Analysis is still in progress.

The analysis of $\alpha$ - particle spectra through a moving source fit analysis (see Fig.1), clearly shows that at low energy (up to 400 MeV incident energy for the Ni induced reactions) the whole part of the measured cross section gated on ER presents an evaporative behavior from a source with expected emission parameters. In fact, from the moving source fit a value of temperature $T = 4.2$ MeV, an average Coulomb barrier $E_c = 13.2$ MeV and a source velocity $V_s = 1.7$ cm/ns have been obtained in agreement with the statistical model calculations (PACE4 [11]). For the Ni case at 500 MeV bombarding energy the situation is very similar: the fit parameters (in this case $T = 4.5$ MeV, $E_c = 12.4$ MeV and $V_s = 1.9$ cm/ns) are still very close to the predicted. This shows that in the mass-symmetric case almost no pre-equilibrium emission is present at these energies. Therefore, the GDR data obtained in measurements performed through mass-symmetric entrance channels should correspond to the decay of an equilibrated nucleus. The analysis of the Oxygen induced reaction is still in progress: preliminary investigation in the 250 MeV bombarding energy case shows (see Fig.2) that a large part of the cross section cannot be described by only evaporative component. An excess yield due to pre-equilibrium (fast) emission seems to be present. This is partly in agreement with...
the previous work by Kelly et al., eventhough we want to stress that further analysis is in progress to quantify better such effects.

Interesting results have been obtained from the very exclusive measurements of the high energy γ rays from GDR and LCP in coincidence with ER emitted in the de-excitation of the compound system $^{132}$Ce. The measurements were performed for the different projectile energies and for the different mass asymmetries in the entrance channel. For the system formed through the mass-symmetric channels no pre-equilibrium emission is observed up to the higher energy. It means that the excitation energy of the compound nucleus can be confirmed at the nominal value of 250 MeV corresponding to complete fusion and the decay is dominantly statistical. When more mass-asymmetric projectile-target combination is used and, therefore, the entrance energy per nucleon increases, pre-equilibrium emission starts to be evident in the higher energy range confirming, at least qualitatively, the results by Kelly et al. Analyses are in progress and we expect to achieve a consistent picture of such phenomena.

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