Measurement of the damping mechanisms of the GDR at high excitation energy using the GARFIELD and HECTOR setup

O. Wieland[1], A. Bracco[1], F. Gramegna[2], F. Camera[1], A. Maj[3], A. Airoldi[1], S. Barlini[2], G. Benzoni[1], N. Blasi[1], S. Brambilla[1], M. Brekiesz[3], M. Bruno[4], G. Casini[5] , M. Chiari[5],M. D' Agostino[4], E. Geraci[4], A. Giussani[1], M. Kmiecik[3] , S. Leoni[1], A. Lanchais[2], P. Mastinu[2] , B. Million[1], A. Moroni[1],A. Nannini[5], A. Ordine[6], R. Sacchi[1], G. Vannini[4], L. Vannucci[2]

1 Dipartimento di Fisica, Universita' di Milano, and INFN sez. Milano via Celoria 16, I - 20133 Milano, Italy 2 Laboratori Nazionali di Legnaro, Legnaro Italy 3 The Henryk Niewodniczański Institute of Nuclear PhysicsPL - 31-342 Kraków, ul. Radzikowskiego 152, Poland 4 Dipartimento di Fisica, Universita' di Bologna and INFN sezione di Bologna, Bologna, Italy 5 INFN sezione di Firenze,Firenze, Italy 6 INFN sezione di Napoli, Napoli, Italy

I. INTRODUCTION

The damping mechanisms of the Giant Dipole Resonance (GDR) in the high temperature region (high excitation energy) are still not well understood [1].

The two main relaxation mechanisms giving rise to the measured damping width which have been identified are the collisional damping and the thermal large-amplitude fluctuations of the nuclear shape. The phenomenon of collisional damping is essentially connected with the coupling of the giant modes with the quantal fluctuations of the nuclear surface. Various models of the collisional damping width exist some predicting a constant behaviour with temperature (refs [2-4]), and one predicting an increase with temperature [5]. The second important mechanism at work in the breaking of the strength of the GDR is the coupling of the vibration to the large amplitude fluctuations (shape fluctuations) of the nuclear surface which are induced by temperature [6,7].

In fusion-evaporation reactions at low energies corresponding to $T \leq 2$ MeV, the width of the GDR built on excited states is observed to increase rapidly with bombarding energy (by approximately a factor of 2 by going from 0 to 2 MeV) due to increasing spin-induced deformation, and increasing thermal shape fluctuations [8]. In this regime the global systematics of the GDR width are reasonably well described by calculations made within the thermal shape fluctuation model and using the T=0 value of the collisional damping width (namely the intrinsic width of the photo-absorption line shape) [6,7]. Beyond the bombarding energy at which the maximum angular momentum that the nucleus can sustain without fissioning saturates, one expects that the GDR width would increase more slowly.

At excitation energy larger than $E^* \geq 100$ MeV there is the open question whether the width of the GDR saturates or increases. This has been newly addressed particularly in relation to the problem of how well one can determine the excitation energy of the nucleus on which the GDR is built. Up to now a large number of the performed measurements are essentially inclusive and therefore at the highest excitation energies more exclusive measurement are necessary for the understanding of this problem.

Recently, measurements were made using the HECTOR [9] and GARFIELD [10] setup, in which both high energy gamma-rays and charged particle emission in coincidence with evaporation residues were recorded. In order to evaluate the roll of the preequilibrium emission we have chosen two different reactions leading to the same excitation energies, but at different value of the bombarding energies. The measured reactions were the most symmetric and asymmetric reactions in the entrance channel, namely ^{64}Ni + ^{68}Zn at E_{beam} = 500 and 400 MeV (corresponding to 200 and 150 MeV of nominal excitation energy) and ^{16}O + ^{116}Sn at E_{beam} = 250 MeV (with E*=200 MeV, as deduced from kinematics for complete fusion).

II. THE EXPERIMENT

The experiment was made using the GARFIELD set up combined with the BaF_2 detectors of the HECTOR array. The GARFIELD vacuum scattering chamber was equipped with one of the two drift chambers of the GARFIELD apparatus (gaseous microstrips coupled with CsI(Tl) crystals) from theta=30° to 90°, while the BaF_2 were positioned at backward angles. In the forward direction, between 4° and 12°, two couples of PSPPACs were positioned symmetrically with respect to the beam. Some SiLi detectors were positioned between each PSPPAC couple at the larger angles. So far we have concentrated in the measurements of ^{132}Ce at two energies (corresponding to E^*= 150 and 200 MeV), the higher measured using the two different reactions ^{64}Ni + ^{68}Zn and ^{16}O + ^{116}Sn. The pulsed beam was provided by the TANDEM+ALPI accelerator system. With the system GARFIELD + HECTOR we could measure both γ-rays and charged particles in coincidence with residual nuclei detected in the PSPPAC detectors.

III. PRELIMINARY RESULTS OF THE MEASUREMENTS

Some preliminary results of the measurements are presented in figure 1. In that figure the high-energy gamma-ray spectra measured using the reaction ^{64}Ni + ^{68}Zn (E_{beam} = 400, 500 MeV) and ^{16}O + ^{116}Sn (E_{beam} = 250 MeV) are shown.

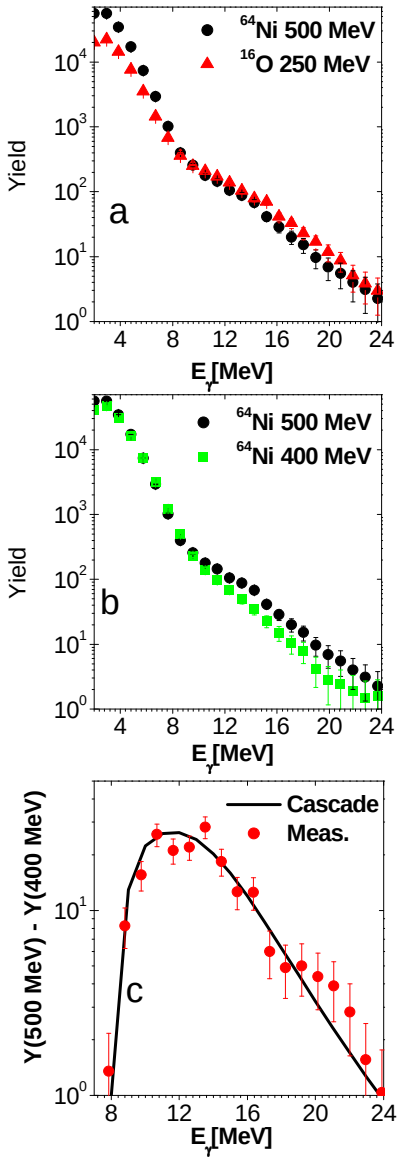

Fig.1: Panel a*: gamma-ray spectra measured for the reactions ^{64}Ni + ^{68}Zn at E_{beam} = 500 MeV and ^{16}O + ^{116}Sn at E_{beam} = 250 MeV.*
Panel b *: gamma-ray spectra measured for the reaction ^{64}Ni + ^{68}Zn at E_{beam} = 400 and 500 MeV.*
Panel c: *Spectrum obtained as a difference of spectra in panel b in comparison with a statistical model calculation.*

The spectra are in coincidence with the heavy recoiling nuclei identified with the PSPPAC detectors at forward angles. There are two important features that can be observed in these spectra. The first is that in case of the ^{64}Ni + ^{68}Zn reaction one sees an increase with excitation energy of the production yield of high energy gamma-rays which is consistent with that predicted by the statistical model and assuming 100 % of the Energy Weighted Sum Rule of the giant dipole mode.

This is shown in panel b and c of figure 1, and in particular panel c shows the difference spectrum (obtained by subtracting the data corresponding to the reactions ^{64}Ni + ^{68}Zn at E_{beam} = 400, 500 MeV) in comparison with the statistical model prediction made with the code CASCADE [11].

The second feature observed in the data concerns the reaction dependence of the gamma-ray yield. In fact, the data at the highest excitation energy for ^{64}Ni + ^{68}Zn are found to be different than those obtained with the reaction ^{16}O + ^{116}Sn in spite of the fact that kinematically these two reactions should lead to the same compound nucleus and excitation energy. In particular one can note in panel a of figure 1 that the spectral shapes are different mainly in the region of the rapidly exponential decrease. Concerning the particle emissions we have observed sizable differences for the two reactions at forward angles but we need to complete the calibration and analysis work, presently in progress, on the particle detectors before we can infer something on the possible pre-equilibrium contributions. We expect that a relevant step forward in the understanding of nuclear structure of finite temperature should be made by completing these analyses.

References:

[1] P.F. Bortignon, A. Bracco, R. Broglia, "Giant Resonances - Nuclear Structure at Finte Temperature", Contemporary Concepts in Physics, Vol. 10, Harwood Academic Publishers, 1998
[2] F.V. De Blasio et al., *Phys. Rev. Lett.* **68** (1992) 1663
[3] P.F. Bortignon et al, *Nucl. Phys.* **A460** (1986) 149
[4] O. Yilmaz et al., *Phys. Lett.* **B472** (2000) 258
[5] A. Smerzi et al., *Phys. Lett.* **B320** (1994) 216 ref. therein
[6] W.E. Ormand, *Nucl. Phys.* **A649** (1999) 145 ref. therein
[7] Y. Alhassid, *Nucl. Phys.* **A649** (1999) 109 ref. therein
[8] see e.g. *Nucl. Phys.* **A649** (1999)
[9] A. Maj et al. *Nucl. Phys.* **A571** (1994) 185
[10] F. Gramegna et al. *Nucl. Phys.* **A389** (1997) 474
[11] F. Pühlhofer *Nucl. Phys.* **A280** (1977) 267