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DYNAMICAL DIPOLE AS A PROBE OF ISOSPIN DYNAMICS*

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The γ-ray emission due to dynamical dipole oscillations during fusion process was measured for the N/Z asymmetric reaction ^{16}O + ^{116}Sn at 8.1 and 15.6 MeV/u. High-energy γ-rays and light charged particles were measured in coincidence with the recoiling residual nuclei. The measured yield of the high-energy γ-rays exceeds that of the thermalized compound nucleus and this extra-yield increases with beam energy. Data are compared with theoretical predictions of a dynamical calculation based on Boltzmann–Nordheim–Vlasov (BNV) model.

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1. Introduction

The dynamical dipole emission mechanism was predicted some years ago for N/Z asymmetric heavy-ions collisions as a dipole collective mode associated to a pre-equilibrium photon emission [1]. Experimentally, it was

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observed few times in fusion and deep-inelastic reactions [2, 3]. The isospin dynamics and the related γ-ray emission depend on the symmetry energy of the fusing system [4], a topic with relevant implications in nuclear astrophysics problems as neutron stars and elements burning in supernovae [5]. As suggested in a recent paper [6], the anisotropy of the angular distribution of the dynamical dipole emission, besides being a signature of the dipolar nature of this mechanism, is an observable sensitive to the timescale of the charge equilibration dynamics. In this respect, particularly interesting are the results of a recent experimental work [3] in the mass region $A \approx 130$, where the observed angular anisotropy is consistent with an oscillation along a preferential axis, supporting the picture of prompt dipole emission at an early stage of the fusion dynamics.

Fusion dynamics can be calculated in the framework of dynamical models as the Boltzmann–Nordheim–Vlasov (BNV) model [7], that depends critically on the N–N collision cross section in the nuclear medium and on the nuclear equation of state (EOS) with its symmetry term. In fact, being the dynamical dipole emission related to an isospin oscillation on the dinuclear system formed in the first stage of the reaction, it is affected by the value of the symmetry energy at densities lower than the saturation density. The γ emission associated to this oscillation is calculated with Bremsstrahlung formula.

The aim of this paper is to present the results of a dynamical dipole measurement with the system ^{16}O ($N/Z = 1$) + ^{116}Sn ($N/Z = 1.3$), and to compare the measured observables (in particular the measured pre-equilibrium γ-ray multiplicity) with the ones calculated with the BNV model.

2. Experimental setup

The experiment was performed at Laboratori Nazionali di Legnaro (Italy) using beams from the Tandem–Alpi accelerator complex. The apparatus consisted of the GARFIELD array for the measurement of light charged particles (LCP), the HECTOR setup made of large volume BaF_2 detectors and a set of two Position Sensitive Parallel Plate Avalanche Counter telescopes (PSPPAC). A comprehensive description of the experimental apparatus can be found in references [8–10]. For all the measured reactions the trigger condition required a coincidence of signals from the PSPPACs and an OR between LCP measured in GARFIELD array and a signal in the BaF_2 detectors. In addition, scaled down counts from the PSPPACs, GARFIELD and BaF_2 detectors in single mode were registered. Afterwards, fusion–evaporation events were selected via the Time Of Flight technique.

3. Experimental results and comparison with BNV model

In this experiment γ and light charged particles (LCP) spectra where measured for the N/Z symmetric reaction ^{64}Ni + ^{68}Zn and the N/Z asymmetric one ^{16}O + ^{116}Sn. Both reactions produce the same compound nucleus (CN) ^{132}Ce but differ in the process leading to CN thermalization. In the mass and N/Z symmetric ^{64}Ni + ^{68}Zn reaction both LCP and γ-spectra can be reproduced by the statistical model and this allowed to characterize the parameters of the Giant Dipole Resonance (GDR) for the CN ^{132}Ce [9]. Conversely, in the mass and N/Z asymmetric ^{16}O + ^{116}Sn reaction a deviation with respect to statistical model calculations was found both in LCP and γ spectra, due to pre-equilibrium emission. An estimate of the energy loss due to pre-equilibrium particle emission has been done as described in detail in [10] and made possible to deduce the excitation energy of the thermalized ^{132}Ce* CN. The pre-equilibrium γ emission was isolated by subtracting from the total measured spectra the contribution of the statistical decay of ^{132}Ce* CN at the proper excitation energy and with the GDR parameters obtained from [9] (see Fig. 1).

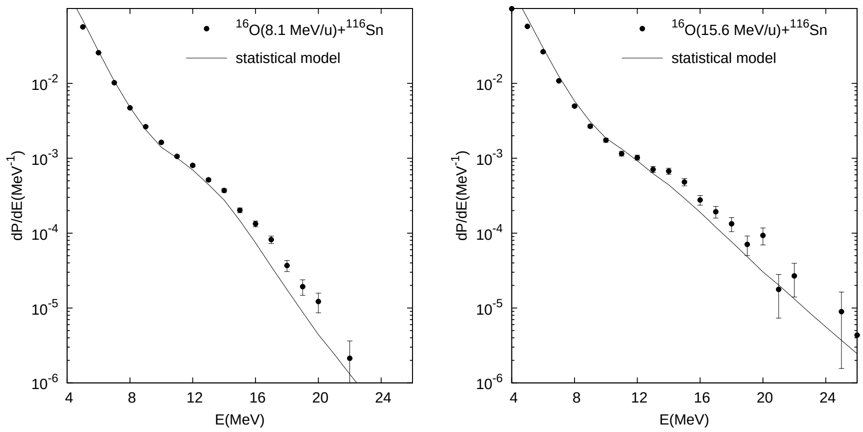

Fig. 1. Measured γ spectra of ^{16}O + ^{116}Sn reaction at beam energies 8.1 (left) and 15.6 MeV/u (right). The results of calculated statistical γ decay from the CN ^{132}Ce* at $E^* = 94$ and 165 MeV are shown with continuous lines.

This extra-yield was found to be centered at 13–14 MeV and to increase with beam energy. In Fig. 2 the experimental dynamical dipole multiplicity obtained integrating in the γ energy range 8–22 MeV is compared with the one calculated with BNV model using an asy-stiff and an asy-soft parametrization of the nuclear EOS [4,6]. BNV calculations were performed at impact parameters 0, 2, 4 and 6 fm and multiplicity was averaged with a weight given by the fusion cross section calculated with PACE4 code.

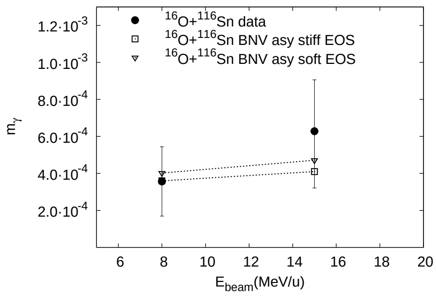

Fig. 2. Measured and BNV calculated dynamical dipole multiplicity as a function of beam energy. The error bars in the measurement reflect mainly the uncertainty in the determination of the energy loss due to pre-equilibrium particle emission.

4. Summary and conclusions

Dynamical dipole emission has been measured in the N/Z asymmetric reaction $^{16}\mathrm{O} + {}^{116}\mathrm{Sn}$. Within the error bars, its multiplicity was found to be in agreement with theoretical prediction based on the BNV model but a discrepancy was found between measured and calculated centroid energies. This is possibly due to the difficulty to extract experimentally the strenght below 12 MeV, where the yield is dominated by statistical emission. The results of this measurement, compared with others [3] in the same mass region but with different entrance channel asymmetry, strongly encourage to perform new experiments in order to achieve a better understanding of beam-energy influence on the onset and on the damping of dynamical dipole oscillation.

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