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ENTRANCE CHANNEL EFFECTS IN THE POPULATION OF GIANT DIPOLE RESONANCES IN Sn NUCLEI*

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We have measured the high energy γ-ray spectra from the fusion reactions 130 MeV ^{16}O + ^{98}Mo and 240 MeV ^{48}Ti + ^{64}Ni, populating the ^{114}Sn and ^{112}Sn compound nuclei at the excitation energy of 108 MeV. The comparison of the spectra shows a ~38% enhancement of the γ-ray yield in the Giant Dipole Resonance region ($E_\gamma \geq 8$ MeV) when the ^{16}O induced reaction is considered. The experimental result is consistent with entrance channel effects related to the N/Z asymmetry between the target and the projectile.

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1. Introduction

It has been proposed [1] that Giant Dipole Resonance (GDR) decay from excited nuclei populated in heavy-ion reactions can be used as a probe of the properties of these systems in the early stages of their formation. Therefore, high energy γ-rays have been used to study dynamical effects in heavy-ion induced fusion reactions. The majority of the experiments performed up

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to now have searched for effects related to the predicted dependence of the fusion time on the mass asymmetry in the reaction entrance channel.

Only recently, the first experimental evidence of the excitation of a so-called dynamical dipole mode in heavy-ion reactions has been reported [2]. This dipole mode could be excited in the earlier times of a collision between a target and a projectile having different N/Z ratios [3,4]. This brings to an enhanced yield of the γ-rays above $E_\gamma = 8$ MeV when the N/Z asymmetric entrance channel is compared with an N/Z symmetric one which is predicted to depend on the beam velocity [3]. In the case of Ref. [2] bombarding energies of 4 and 5 MeV/nucleon were considered and an increase of $\sim 15\%$ vas determined for the γ-ray yield above 8 MeV in the N/Z asymmetric entrance channel populating the ^{140}Sm compound nucleus.

We present here new results obtained in this field using the GASP spectrometer of the Laboratori Nazionali di Legnaro coupled with two large volume BGO detectors for the measurements of the high energy γ-rays.

2. Experimental results

The aim of the present work is to extend the investigation on the N/Z effect in the A$\sim$ 110 mass region by a comparative study of the high energy γ-ray spectra in the 130 MeV ^{16}O + ^{98}Mo ($N/Z = 1$ and 1.33) and 240 MeV ^{48}Ti + ^{64}Ni ($N/Z = 1.18$ and 1.28) entrance channels. Such a comparison

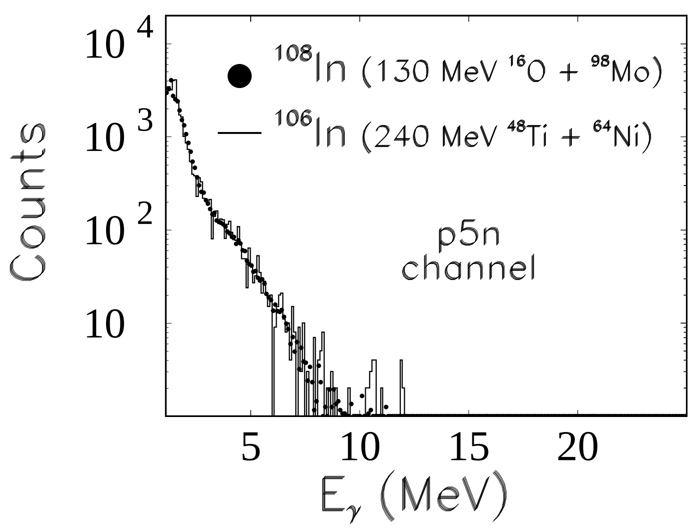

Fig. 1. Comparison of the experimental exclusive ($p5n$ decay) high energy γ-ray spectra for the ^{16}O + ^{98}Mo and ^{48}Ti + ^{64}Ni reactions. The spectra are normalized in the statistical (4 MeV $\leq$ E$_\gamma$ $\leq$ 6 MeV) region.

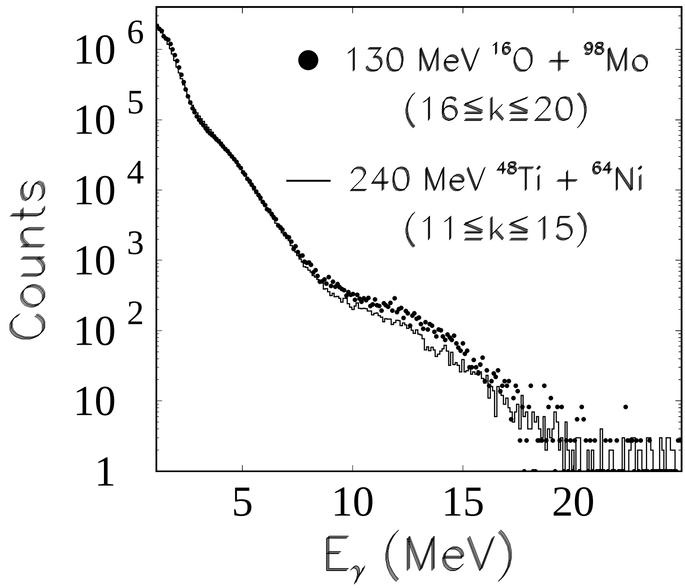

Fig. 2. Comparison of the experimental high energy γ-ray spectra for the two reactions. The spectra are normalized in the statistical (4 MeV $\leq$ E$_\gamma$ $\leq$ 6 MeV) region.

has to be done by selecting a common angular momentum region in the initial compound nucleus. This is due to the different limiting angular momentum for fusion-evaporation associated with the two reactions: $J_{\rm lim} \simeq 55\hbar$ in the ^{16}O case compared to the $J_{\rm lim} \simeq 70\hbar$ in the ^{48}Ti one. The cleanest way to achieve this task is to select the same de-excitation channel for the two hot nuclei. In the present case, the discrete γ spectra show that we can cleanly tag the $p5n$ channel which correspond to the ^{108}In (^{16}O + ^{98}Mo) and the ^{106}In (^{48}Ti + ^{64}Ni) evaporation residues. The comparison of the high energy γ-ray spectra in the $p5n$ channel reported in Fig. 1, shows that the spectra below E_γ = 8 MeV display the same slope in both entrance channels. Furthermore, the distribution of the γ-ray fold k measured in the GASP inner ball for this exclusive channel is very similar for both reactions. The average value is $\langle k \rangle = 14.6$ (14.7) for ^{106}In (^{108}In) with a corresponding FWHM of 9.5 (9.7).

All these experimental observations demonstrate that when we select the same phase space region of the initial compound nucleus, the statistical part (below E_γ = 8 MeV) of the γ-ray emission does not show any sensitivity to the particular reaction entrance channel. This is not the case when we consider the emission of γ-rays with energy above 8 MeV. This is illustrated in Fig. 2, in which we compare the inclusive (*i.e.* in coincidence with the

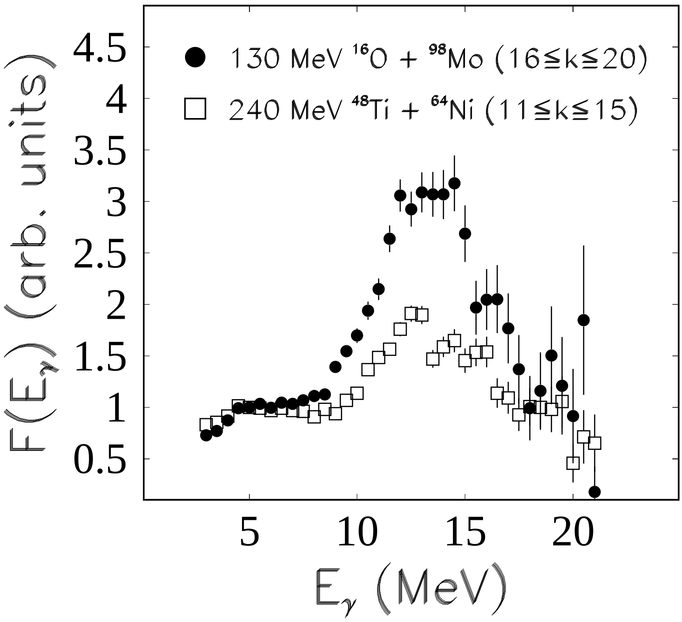

Fig. 3. Linearized plot of the experimental high energy γ-ray spectra for the ^{16}O- and ^{48}Ti-induced reactions. The spectra are normalized in the statistical (4 MeV $\leq E_\gamma \leq$ 6 MeV) region.

fold k measured in the GASP inner ball) high energy γ-ray spectra for two fold k bins corresponding to the same angular momentum region centered at $\sim 52\hbar$ and approximately $10\hbar$ wide.

As in the previous case ($p5n$ decay channel), the selection of the same angular momentum region is demonstrated by the matching of the low energy tail of the spectra. The comparison clearly show that a larger yield is present in the GDR region ($E_\gamma \geq$8 MeV) in the case of the ^{16}O + ^{98}Mo system, which is characterized by the larger N/Z asymmetry.

To estimate this extra-yield we have considered the linearized high energy γ-ray spectra obtained by dividing the experimental spectra by a theoretical one calculated with the CASCADE code with a constant $E1$ strenght function. Such linearized spectra are presented in Fig. 3. The γ-ray intensity integrated between 8 and 20 MeV in this linear representation increases by a $\sim$38% from the ^{48}Ti- to the ^{16}O-induced reaction. The same increase is obtained if we simply consider the ratio between the yields Y_γ^{GDR} and Y_γ^{stat} in the GDR ($E_\gamma \geq$ 8 MeV) and in the statistical (4 MeV $\leq E_\gamma \leq$ 6 MeV) region, respectively.

3. Summary and conclusions

In this work, we have compared the high energy γ-ray spectra from the reactions 130 MeV ^{16}O + ^{98}Mo and 240 MeV ^{48}Ti + ^{64}Ni, in coincidence with γ-ray fold windows which are supposed to select a common angular momentum region in the compound nuclei centered at $\sim 52\hbar$ and $10\hbar$ wide. The comparison show that the γ-ray yield in the GDR region increases by $\sim$38% when the ^{16}O reaction is considered. On the contrary, it is found that the statistical part of the γ-ray spectrum at $E_\gamma \leq 8$ MeV is not sensitive to the reaction entrance channel. The latter observation is confirmed by the comparison of exclusive spectra.

The enhanced γ-ray emission in the ^{16}O-induced reaction is not accounted for by Statistical Model calculations performed with the code CASCADE, which predict negligible differences in the high energy γ-ray spectra for the two entrance channels. This suggests that the extra yield evidenced in the ^{16}O + ^{98}Mo reaction is due to a source which adds to the compound nucleus decay.

The possibility that the mass asymmetry in the entrance channel could be responsible for an extra-yield can be excluded. In fact, the absence of effects related to the mass asymmetry is well documented in a recent experiment on the ^{110}Sn compound nucleus populated with the reactions 72 MeV ^{18}O + ^{92}Mo and 163 MeV ^{50}Ti + ^{60}Ni [5].

Contributions in the high energy γ-ray spectra due to incomplete fusion in the case of the light ^{16}O projectile can be also excluded as suggested by a recent investigation at beam energy of 11 MeV/nucleon [6].

In conclusion, the results from our experiments can not be explained without considering the possibility that the γ-ray yield enhancement in the GDR region is caused by the dynamics of the fusion between a target (^{98}Mo) and a projectile (^{16}O) with large N/Z asymmetry. As mentioned in the introduction, the larger value of the enhancement with respect to the findings of Ref. [2] could be related to the higher beam velocity [3] involved in the present study.

Further theoretical and experimental works are needed to exhaustively understand the dynamical effects in the fusion reactions between heavy-ions as a function of the N/Z asymmetry and the bombarding energy.

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