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Study of the Pygmy Dipole Resonance in ^{124}Sn with AGATA

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Abstract. The γ decay of the pygmy dipole resonance of ^{124}Sn was measured with the AGATA demonstrator coupled to an array of 9 large volume $LaBr_3$:Ce scintillators. This resonance was populated by the inelastic scattering reaction ^{17}O+^{124}Sn at 20 MeV/u. With AGATA, the γ decay up to the neutron separation energy was measured with high resolution. The angular distribution was measured both for the γ rays and the scattered ^{17}O ions. The present results are presented in comparison with the previous findings for (γ, γ') and (α,α'γ).

1. Introduction

In atomic nuclei the electric-dipole strength is exhausted to a large extent by the Giant Dipole Resonance (GDR). However a few percent of the E1 strength is taken by the so-called Pygmy Dipole Resonance (PDR), a concentration of 1^- states around the neutron separation threshold [1]. The study of the Pygmy Dipole Resonance (PDR) is particularly relevant to investigate the nuclear structure and also in connection with photo-disintegration reaction rates in astrophysical scenarios [2, 3, 4, 5, 6, 7]. Its description within the hydrodynamical model corresponds to a vibration of the neutron skin against a N=Z core [8]. In recent years, the study of the PDR has attracted particular attention and moreover its microscopic structure is presently under discussion. Efforts in the direction of understanding its nature require its excitation using different probes. Indeed, recent works comparing results of photon and α-scattering experiments show the presence of a different behaviour in the population of these states [9, 10, 11]. While a set of states at lower energy is excited with both types of reactions, the other set at higher energies is not populated by α scattering. This interesting finding has motivated further work based on the use of another probe with strong isoscalar character as ^{17}O [12] used in this work.

2. Experimental setup

The experiment was performed at the Legnaro National Laboratories (LNL), in Italy. The Giant Resonance modes were excited by inelastic scattering of ^{17}O ions at 20 MeV/u, in the laboratory frame, on a ^{124}Sn target (3 mg/cm^2 thick, enriched to 99%). ^{17}O has been chosen since it is loosely bound (being the neutron separation energy 4.1 MeV), and thus it allows to have a γ-spectrum mainly containing target de-excitation, particularly in the region of interest $E^* >$ 4.5 MeV. The detection of the scattered ions was performed with two ΔE-E silicon telescopes mounted inside the scattering chamber. The detectors used in this experiment are the prototypes

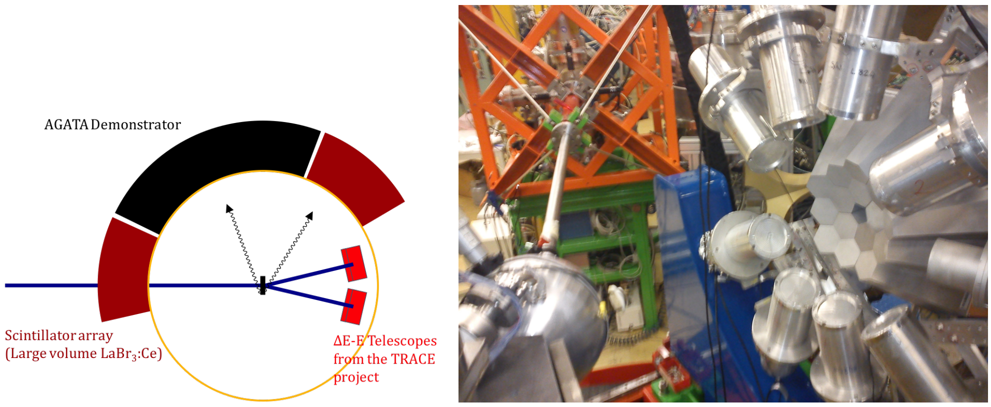

Figure 1. Left panel: Schematic view of the experimental setup, comprising five triple clusters of AGATA, an array of 9 LaBr$_3$:Ce detectors named HECTOR$^+$ and two E-ΔE Silicon telescope of the TRACE projects. Right panel: Picture of the experimental setup.

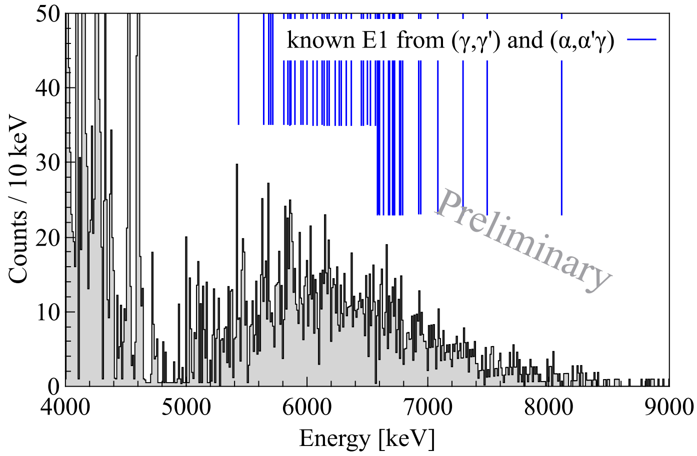

Figure 2. AGATA energy spectrum of the ^{124}Sn in the PDR region with the gating condition that the energy of the scattered ^{1}7O is equal to the γ-ray energy of the de-exciting nucleus as described in the text.

for the TRACE array [13, 14]. The main feature of these detectors is the identification in charge and mass of the scattered ions. Thanks to the use of these detectors, the excitation energy transferred to the target nucleus was measured with medium resolution (1.5 MeV). The γ rays produced during the de-excitation of the reaction participants were measured using an array of HPGe segmented detectors (the AGATA demonstrator [14, 15, 16]) coupled to an array of 9 large volume LaBr$_3$:Ce scintillators, (the HECTOR$^+$ array [17]) used to increase the detection efficiency for high-energy γ rays. A picture of the experimental setup is shown in the right panel of Fig. 1; the AGATA Demonstrator detectors are in the centre surrounded by the HECTOR$^+$ array. A schematic view of the complete experimental set-up is shown in the left panel of Fig. 1.

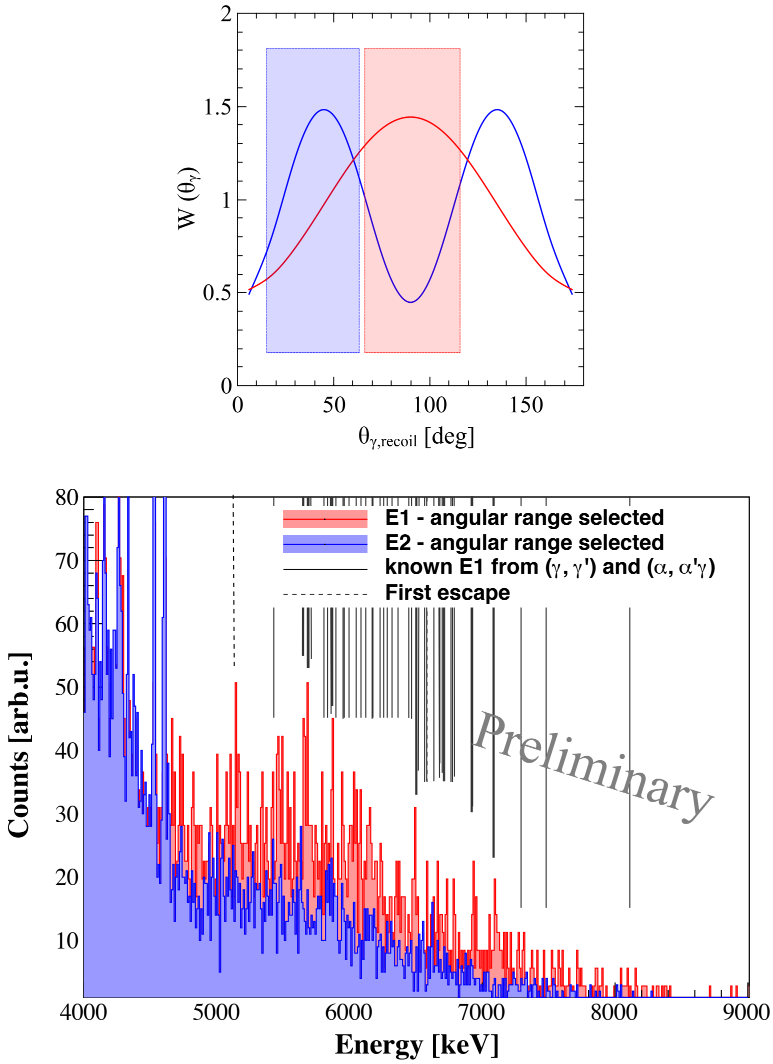

Figure 3. Top panel: expected angular distributions for an E1, red solid line, and E2, blue solid line, transition. The highlighted blue and red region represent the angular gate used to enhanced the E2 and E1 transitions respectively. Bottom panel: γ-rays spectra of ^{124}Sn in the PDR energy region measured with the AGATA demonstrator. The red spectrum is gated on 65°-115° angular range (red region of the top panel) in order to enhanced the E1 transitions while the blue spectrum is gate on 15°-65° angular range (blue region of the top panel) to enhanced the E2 transitions.

3. Preliminary results

Fig. 2 shows the γ-ray spectrum measured with the AGATA demonstrator array in the energy region above 4 MeV where the γ decay of the pygmy states is expected to be. This spectrum is obtained after selecting the inelastically scattered ^{17}O events and with the additional requirement that the energy of the γ rays equals the Total Kinetic Energy Loss (TKEL) values within a window $\pm$1 MeV wide. This requirement permits the selection of the ground-state transitions which are the dominant γ decay of the the pygmy dipole resonance. In addition, since these states had a life-time of the order of the femtoseconds a Doppler correction for the recoil motion was also needed. Finally, to reject the accidental background and the feeding from higher-lying

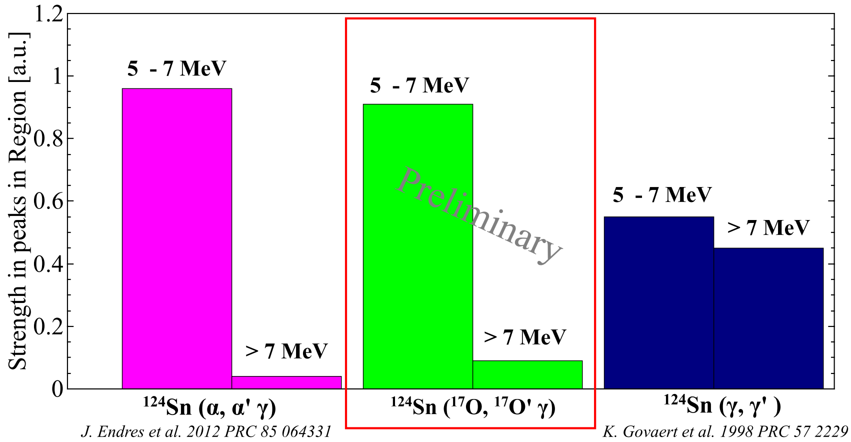

Figure 4. Ratio of the strength in peaks evaluated in the two energy region, below and above 7 MeV, for the three experiments.

states a background subtraction was applied. In Fig. 2 several E1 transitions known from (γ, γ') [9] and (α,α'γ) [11] measurements were identified and are indicated with the lines at the top of the figure.

Exploiting the position sensitivity of AGATA ($\Delta\theta \sim$ 1°) and silicon detectors ($\Delta\theta \sim$ 3°), it was possible to infer the character of the PDR. The multipolarity of the pygmy states, indeed, can be deduced by comparing the γ-ray energy spectrum gated on the angular distribution of the emitted γ rays. If we set a gate on the angular distribution, it is possible to identify the E1 and E2 components in the γ-ray spectra. The bottom panel of Fig. 3 shows the comparison between the γ-ray spectra of ^{124}Sn in the PDR energy region. The red spectrum is gated on the 65°-115° angular range (red region in the top panel of Fig. 3) in order to enhanced the E1 transitions while the blue spectrum is gate on the 15°-65° (blue region in the top panel of Fig. 3) angular range to enhanced the E2 transitions. The PDR transitions are clearly enhanced in the red spectrum, showing as expected an E1 behaviour.

An interesting question is the comparison of the pygmy states population with this reaction with those induced by the (α, α'γ) and (γ, γ'). Since the (α, α'γ) results indicated that the PDR region, seen in (γ, γ'), is split into two part, one below 7 MeV populated by both reactions and the other above 7 MeV populated only by the photon scattering, we integrated our data in these two specific regions. The comparison of the present results with the existing photon [9] and α-scattering [11] data are shown in Fig. 4. It is evident from this figure that the strength measured in the (γ, γ') experiment are almost equal in both energy ranges, which is not the case for the (^{17}O, ^{17}O'γ) and (α, α'γ) experiments. From these interesting results we can therefore say that the inelastic scattering of ^{17}O at 20 MeV/u was successfully used to measure the gamma decay from the PDR states of ^{124}Sn, and that the results confirm very well the presence of a splitting of the PDR similar to that observed with the (α, α'γ) technique. In order to be more quantitative, the isoscalar strength associated to this resonance has to be extracted and this work is in progress.

4. Conclusions

The low-lying E1 states in the ^{124}Sn nucleus were populated via inelastic scattering of a ^{17}O beam at bombarding energy of 20 MeV/u. Their subsequent γ decay was measured with the AGATA demonstrator array coupled to an array of large volume $LaBr_3$:Ce scintillators. The multipolarity of the observed gamma transitions was determined with remarkable sensitivity thanks to angular distribution measurements. The interesting result obtained from the preliminary data analysis concerns the nature of pygmy dipole resonance. Similarly to what was found using the (α, α'γ) reaction, also in this case the results seem to indicate a selectivity in the population of specific pygmy states as compared to photon-scattering results. This finding points out the more isoscalar nature of the low-energy part of this resonance. A more complete analysis can be found in [18].

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