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Low-lying 1^- and 2^+ states in ^{124}Sn via inelastic scattering of ^{17}O

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Abstract

The γ decay of low-lying 1^- and 2^+ states up to the neutron separation energy in ^{124}Sn populate by the inelastic scattering of ^{17}O was measured. The Angular distributions were measured both for the γ rays and the scattered ^{17}O ions. The results are presented.

The study of the Pygmy Dipole Resonance (PDR), the low-energy part of the electric dipole response in nuclei, is particularly relevant in the nuclear structure investigations and photo-disintegration reaction rates of astrophysical importance [1–3]. Its description, within the hydrodynamical model, corresponds to a vibration of the neutron skin against a isospin-saturated core [4, 5]. In recent years, the study of the PDR has attracted particular attention since its microscopic structure is presently under discussion. A dipper understanding of its nature can be achieved through its excitation using different probes [5]. Indeed, recent works comparing photon and α scattering experiments show that these reactions behave differently when populating these states [6, 7]. While a set of states at lower energy is excited by both reactions, another set of states at higher energies is not populated by α scattering. This interesting finding has motivated further work using another probe with strong isoscalar character as ^{17}O [8–10].

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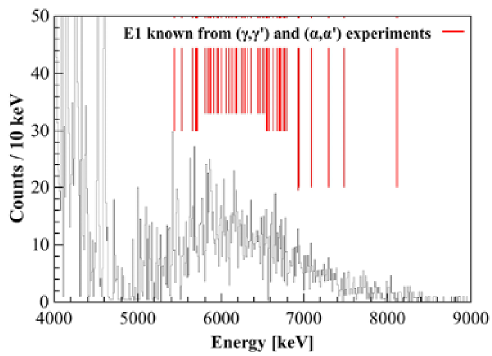

Figure 1: AGATA energy spectrum of the ^{124}Sn nucleus in the PDR region with the gating conditions as described in the text. Adapted from [10].

Building on this, a detailed investigation of the nature of the low-lying E2 strength in neutron-rich nuclei is required to understand if a neutron skin affects the excitation of other multipolarities [11, 12].

To study the low-lying 1^- and 2^+ states in ^{124}Sn, inelastic scattering of ^{17}O at 20 MeV/u was used as a probe since it preferentially enhanced the excitation of the isoscalar component of populated states [5]. The experiment was performed at Legnaro National Laboratories (LNL, Italy). The experimental setup consisted of the AGATA Demonstrator [13, 14] and an array of 9 large volume LaBr3:Ce scintillation detectors [15], for the detection of high-energy γ rays. The scattered ions were detected by the of TRACE detector system consisting of two ΔE-E silicon telescopes [14, 16]. The combination of the silicon telescopes and the AGATA Demonstrator enabled the identification of different decay paths by imposing a gate on the two-dimensional ^{17}O-γ coincidence matrix. Fig. 1 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. Since the dominant decay of these pygmy states is to the ground state, this spectrum was obtained by imposing the constraint $E_x=E_\gamma$ after selecting the inelastically scattered ^{17}O events. Since these states had a life-time of the order of the femtoseconds, a Doppler correction for the recoil motion was also needed.

The high position sensitivity of the silicon detectors and the AGATA Demonstrator allows clear identification of the multipolarity of the decaying transitions. The angular distributions of the gamma rays of the pygmy states exhibit an electric dipole character, as expected [10]. A distorted wave Born

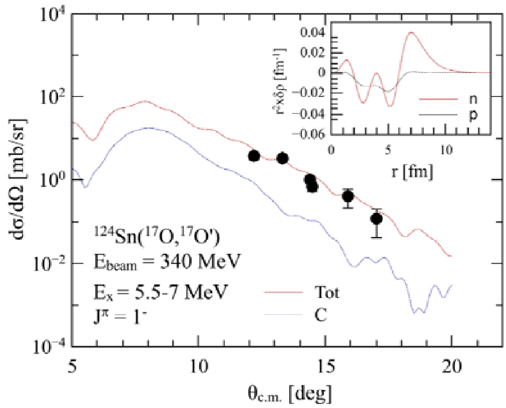

Figure 2: Differential cross sections for the 1^- states between 5.5 - 7 MeV. The blue line shows the DWBA calculation with only the Coulomb contribution while the red line uses the total microscopic form factor based on the transition densities shown in the inset of the figure. Adapted from [10].

approximation (DWBA) analysis was performed to gain a more detailed understanding of the nature of these states. The DWBA calculations were performed using the computer code FRESCO [17]. A normalization factor deduced from the elastic scattering was used to account for the combined contribution of the beam current, target thickness and dead time. This normalization factor was kept the same for all the inelastic scattering cross sections. The optical model parameters of the Woods-Saxon potentials used for these calculations are reported in Ref. [10]. A microscopic form factor based on the transition density associated with these pygmy states was used. Fig. 2 shows the cross sections measured in our experiment together with the DWBA calculations. The use of the microscopic form factor proved crucial to reproduce the data, leading on to conclude that the main contribution to the excitation comes from the isoscalar nuclear contribution. It is clear from the transition densities that these 1^- states have a strong isospin mixing character. Furthermore, the only contribution on the surface comes from the neutrons of the skin giving rise to a isovector and isoscalar components of the same intensity.

A recent theoretical study [12] discusses the possible influence of the neutron skin on excitations of other multipolarities. The use of the silicon detectors allowed us to also investigate the low-lying 2^+ states since they measured a wide range of excitation energies. A number of 2^+ states were observed between 3 and 5 MeV. For several states the multipolaries were not

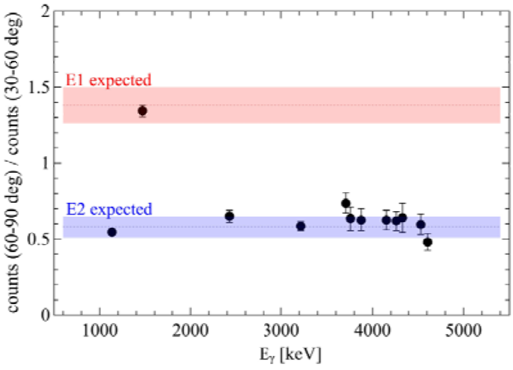

Figure 3: Ratio between the number of counts in the 60° - 90° angular interval over the number of counts in the 30° - 60° angular interval measured for different transitions of ^{124}Sn. The horizontal red and blue bands correspond to the expected ratio for E1 and E2 transitions, respectively. Adapted from [11].

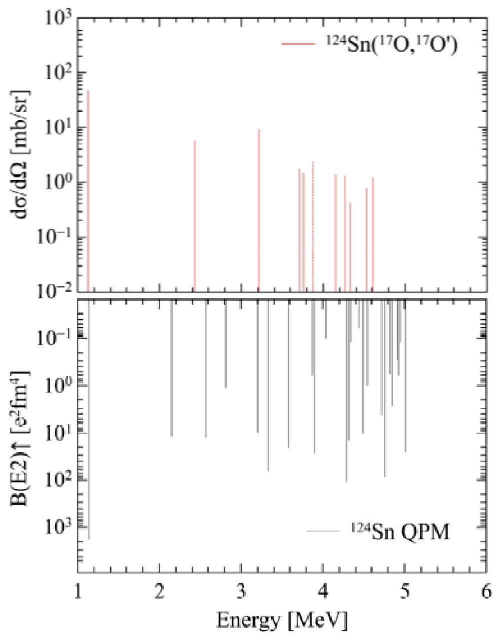

Figure 4: Comparison between the transition probabilities theoretically calculated [12] (bottom panel), and the cross sections measured in our experiment (top panel). Adapted from [11].

previously known. Through the γ-rays angular distributions extracted from our experimental data, it was possible to assign the multipolarity to these states, as can be seen from Fig. 3. The cross sections measured for the 2^+ states were extracted and compared with the Quasi-particle Phonon Model (QPM) calculations. This is shown in Fig. 4. The presence of a number of 2^+ states grouped together in the energy region 3-5 MeV supports the prediction of the HFB+QPM model. This quadrupole strength clustering appears to be similar to the known Pygmy Dipole Resonance at 5-7 MeV. Moreover, the microscopic analysis of these 2^+ states reveal that they have a unique structure closely connected with the excitation of the neutron skin. It will be important to obtain information on the transition densities of these states, the B(E2)s and to study other isotopes to learn more about the quadrupole degrees of freedom of the neutron skin.

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