Re-evaluation of stable Sn-isotopes: Probing of B(E2↑) values

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The longest isotopic chain between two doubly magic nuclei is the Sn isotopes which are accessible for nuclear structure studies, an ideal region for testing nuclear structure models and exploring the isospin-dependence of nucleon-nucleon interactions. In recent years, several experimental studies have been focused probing various fundamental properties of the stable as well as exotic Sn-isotopes [1].

The constant 2^+ excitation energies of even-even tin isotopes is well described by the seniority scheme. For the seniority scheme one expects a symmetric distribution of the B(E2) values between the two doubly magic nuclei ^{100}Sn and ^{132}Sn with a maximum collectivity at mid-shell (^{116}Sn). However, in a recent Doppler Shift Attenuation (DSA) measurement [2], a reduced collectivity was observed for the mid-shell Sn nuclei, as shown in Fig-1. In order to draw firm conclusions on the B(E2 ↑) pattern and to resolve the large experimental disagreements a series of Coulomb excitation experiments were performed at IUAC, New Delhi.

Highly enriched targets (~0.40-0.50mg/cm^2) of ^{112,116,118,120,122,124}Sn isotopes were bombarded with ^{58}Ni ions at an incident energy of 175 MeV, which is well below the Coulomb barrier to ensure pure electromagnetic interaction. In these experiments both projectile and target nucleus were excited and the excitation strength of the 2^+ state in ^{112,116,118,120,122,124}Sn was determined relative to first excited 2^+ state in ^{58}Ni.

The scattered projectiles and recoils were detected in a newly developed annular gas-filled parallel plate avalanche counter (PPAC) [6], subtending an angular range of 15º ≤ θ_{lab} ≤ 45º. The detector was position sensitive in both the polar as well as azimuthal angles, θ & φ, respectively.

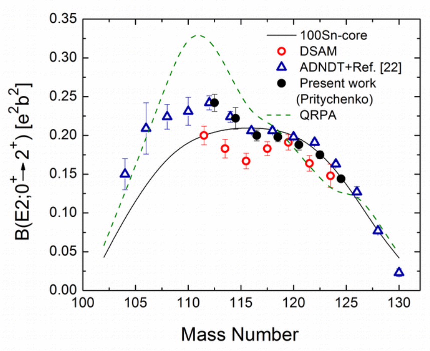

Fig- 1. Experimental/theoretical B(E2↑) values of Sn-isotopes with the mass number.

The cathode signals were collected from the innermost and outermost rings of PPAC and the 'tan θ' information was derived from the time difference of the delayed cathode and prompt anode signals. However, the azimuthal angle, φ, was obtained from the anode foil which was divided into 16 radial sections of 22.5º each. Ni projectiles and Sn ejectiles could not be distinguished with PPAC, but they belonged to different scattering regions (e.g. 22.1º ≤ θ_{cm} ≤64.6º, ^{58}Ni detected in PPAC) and (e.g. 90º ≤ θ_{cm} ≤150º, Sn detected in PPAC), which are essential for Doppler correction.

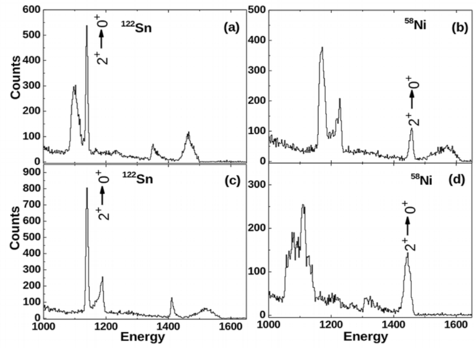

Fig- 2. Doppler shift corrected γ-ray spectra for the ^{58}Ni+^{122}Sn system at 175 MeV. Fig-2 (a) & (b) correspond to distant collision while Fig-2 (c) & (d) correspond to close collision, for the target and projectile excitation respectively.

The de-excited γ-rays were measured with four Clover detectors mounted in backward direction at θ_γ ~145º with respect to the beam direction. The ϕ_γ angles for the Clover detectors were ± 45º and ±145º with respect to the vertical direction. Individual energies and timing signals of the 16 Ge-crystals of the four Clover detectors were recorded in coincidence with the PPAC anode and cathode signals on event by event basis. Doppler corrected spectra for ^{122}Sn are shown in Fig-2.

From the intensity of the Doppler corrected γ-ray lines corresponding to the $2^+ \rightarrow 0^+$ transitions, the target as well as projectile excitations could be extracted for distant collisions. These γ-ray yields are a direct measure of the B(E2; $0^+ \rightarrow 2^+$) values and show almost no feeding from higher excited states. The experimental γ-ray ratios were corrected for the different Ge detectors efficiencies (< 1.2%) and target enrichments (< 4.2 %). In order to obtain high precision results, the B(E2↑) values of ^{112,116,118,120,122,124}Sn were determined relative to the B(E2; $0^+ \rightarrow 2^+$) = 0.0650 (12) e^2b^2 value of ^{58}Ni [3].

The Coulomb excitation calculations were performed using the Winther-de Boer Coulex code [7]. The interaction of the nucleus with the magnetic moment of the atomic shell originated the deorientation of the particle-γ correlation was also determined experimentally. For the short lived 2^+ states ($T_{1/2}$ < 1ps) of tin isotopes the deorientation effect is expected to be very small.

Table 1: Comparison of the measured B(E2↑) values of Sn isotopes.

Iso-tope	B(E2;$0^+ \rightarrow 2^+$) Present	B(E2;$0^+ \rightarrow 2^+$) Ref. [8]	B(E2;$0^+ \rightarrow 2^+$) Ref. [2]
^{112}Sn	0.242(11)	0.250(10)	0.200(12)
^{114}Sn	0.222(14)	0.229(9)	0.183(12)
^{116}Sn	0.200(7)	0.205(8)	0.167(10)
^{118}Sn	0.198(6)	0.203(9)	0.183(9)
^{120}Sn	0.188(7)	0.210(9)	0.191(10)
^{122}Sn	0.175(5)	0.198(9)	0.164(10)
^{124}Sn	0.144(4)	0.165(7)	0.148(15)

The B(E2; $0^+ \rightarrow 2^+$) values were determined with high precision (~3%) relative to ^{58}Ni projectile excitation. Our obtained B(E2↑) values agree well with the Coulomb excitation results obtained in a recent measurement (Ref. [8]) and the adopted values in recent atomic data tables by B. Pritychanko et al. [3], and thus confirming the disagreement to the DSA lifetime data [2], and is presented in Table-1. So, it can be concluded that the stable Sn isotopes show no evidence of reduced collectivity and thus, reconfirm the non-symmetric behavior of reduced transition probabilities with respect to the mid-shell A = 116.

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