Shape Coexistence in ^{118}Sn nuclei

I. Ahmed[1],* M. Saxena[2],# P.J. Napiorkowski[2], R. Kumar[1], L. Prochniak[2],
A. Stolarz[2], T. Abraham[2], A. Bezbakh[3], S. Hamada[2], C. Henrich[4], J. Iwanicki[2],
M. Kicinska-Habior[5], M. Kisielinski[2], G. Kaminski[2,4], M. Komorowska[2],
M. Kowalczyk[2], A. Korgul[5], M. Matejska-Minda[2], M. Palacz[2], W. Piatek[2],
M. Piersa[5], J. Srebrny[2], A. Tucholski[2], K. Wrzosek-Lipska[2] and H.J. Wollersheim[6]
[1]Nuclear Physics Group, Inter-University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi - 110067, INDIA
[2]Heavy Ion Laboratory, University of Warsaw, Warsaw-02-093, POLAND
[3]Joint Institute for Nuclear Research, Dubna, RUSSIA
[4]IKP, Technical University Darmstadt, Darmstadt, GERMANY
[5]Faculty of Physics, University of Warsaw, Warszawa, POLAND
[6]GSI Helmholtz Centre for Heavy Ion Research, Darmstadt, GERMANY
**email: ishtiaq@iuac.res.in , #msaxena@slcj.uw.edu.pl*

Introduction

The tin nuclei forms the longest isotopic chain between two doubly closed shell nuclei, the very neutron deficient ^{100}Sn (N, Z=50) and the neutron rich ^{132}Sn (N=82). Recent advances in radioactive ion beam facilities have made it possible to measure collective properties of such exotic nuclei and test the predictive power of theoretical models that were developed to describe nuclei close to the stability [1]. The stable nucleus ^{118}Sn with N=66 lies at the mid-shell of these two major shell closures. Several decades of experiment measurements for the stable Sn isotopes close to mid-shell have shown an interplay of single particle and collective degrees of freedom that manifests into complex shape admixtures in the low-lying states [2].

Recent measurements of transition rates in the mid-shell stable tellurium nuclei have shown clear departure from the so-called picture of simple vibrators [3]. The B(E2; $0^+ \rightarrow 2^+$) measured for ^{120}Te, 2 protons away from the closed shell, was 36 W.u., three times more than the Weisskopf estimate of ^{118}Sn (12 W.u.). ^{118}Sn is an isotone of ^{120}Te (Z=52, N=68) nuclei. This can be interpreted in terms of two additional proton above the closed tin (Z=50) core. However, the dramatic changes while going from this closed core to neighboring nuclei, needs a thorough investigation. The character of the low-lying 4^+ and 0^+ states in ^{118}Sn nuclei is very scarce due to limited experimental data available. Backlin *et. al*, [4] combined γ and electron spectrometry to measure ρ^2 (E0; $0_3^+ \rightarrow 0_2^+$) equal to 0.140. This value is larger than a typical *E*0 strength parameter ρ^2 and such result becomes even more impressive when considering that such transition are completely forbidden in the frame of the photon model. The interpretation provided by the authors was that the unexpected result was the effect of shape mixing between the spherical-vibrator and the deformed bands. Our recent Coulomb excitation measurement of ^{118}Sn aims to study the low-lying bands and investigate the phenomena of shape coexistence.

Experimental Details

This experiment was carried out with a ^{32}S beam, accelerated from the U-200P cyclotron at Heavy Ion Laboratory, Warsaw, impinging on a highly enriched, 1mg/cm^2 thick target of ^{118}Sn. The target was backed by a thin carbon foil of 10-20 μg/cm^2 thickness. The 91 MeV energy beam, which fits well into the 'safe energy' criterion [5] ensured a pure em-interaction. 15 HPGe detectors with a relative efficiency of 70% were used from the EAGLE set-up to detect the de-exciting gamma rays from the inelastic scattering of projectile and the target. BGO provided by the GAMMAPOOL with HPGe spectrometers was used as anti-compton shield. The ancillary detectors from the compact Munich chamber comprising of 48 pin diodes, each having an active area of 0.25cm^2, were placed in a range of 120° to 167° with respect to beam axis, to detect the backscattered ions from the scattering and to allow us for the particle-gamma coincidence, which is required for the necessary background removal and the precise Doppler shift correction of the gamma rays [6].

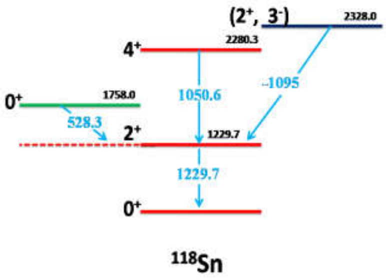

Fig. 1 Partial levels scheme of ^{118}Sn as observed in the experiment. The energies are in keV.

Results and Analysis

The data analysis was performed using a dedicated code through the ROOT based Go4 package [7]. Fig.1 shows the partial level scheme of ^{118}Sn being seen in the experiment. Events were collected under the condition that at least one γ-ray was detected in the EAGLE spectrometer in coincidence with exactly one scattered ^{32}S ion detected in the Pin-diode. Fig.2 shows typical energy calibrated gamma ray spectra for one of the Ge detector. Time coincident particle-γ data was collected within a 400ns coincidence window. A typical particle-γ coincidence spectrum is presented in Fig.3 showing the prompt & random events.

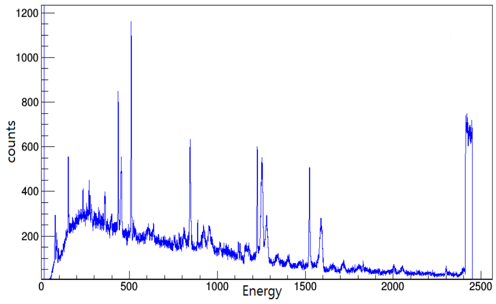

Fig. 2 Energy-calibrated, γ-ray spectrum.

The distance between the maxima present in the time spectra is related to the pulsed structure of the beam delivered by the Warsaw cyclotron. In the ongoing analysis the gamma ray intensities will be determined following the use of Coulomb excitation least-squares search code GOSIA to extract the set of reduced matrix elements from the measured gamma ray yields. The detailed results will be presented in the conference.

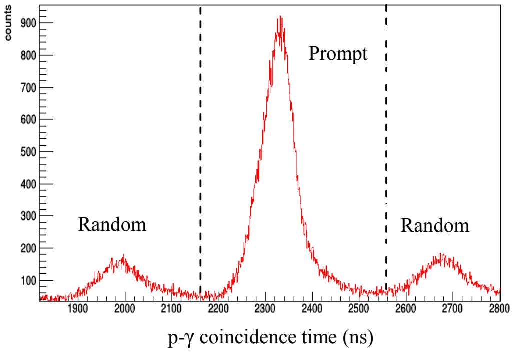

Fig. 3 Particle-γ time coincidence spectrum collected by one of the Ge detectors.

Acknowledgements

One of the author (M.S) would like to thank National Science Centre, Poland for supporting this work. This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No. 665778. We also acknowledge support from ENSAR2. The EAGLE collaboration thanks the European Gamma-Ray Spectroscopy Pool GAMMAPOOL for the loan of Ge detectors.

References

[1] H. Grawe et. al., Nucl. Phy. A693, 116-132 (2001).
[2] N.G. Jonsson *et al.*, Nucl. Phys. A 371 (1981) 333.
[3] M. Saxena et al., Phys. Rev. C 90 (2014).
[4] A. Backlin et. al., Nucl. Phy. A351 (1981) 490-508
[5] D. Cline, Ann. Rev. Nucl. Part. Sci., 36:683-716 (1986).
[6] A. Gorgen, J. Phys. G: Nucl Part. Phys. 37 (2010)
[7] https://www.gsi.de