Prompt and decay spectroscopy of nuclei above Z=82

Sneha Das[1,2],* Soumik Bhattacharya[1], S. Bhattacharyya[1,2], R. Banik[3], Shabir Dar[1,2], S. Nandi[1,2], S. Das Gupta[4], G.Mukherjee[1,2], R. Raut[5], Indu Bala[6], S.S. Bhattacharjee[6], A. Dhal[1], Debasish Mondal[1], S. Mukhopadhyay[1,2], S. Muralithar[6], A.Sharma[7], R.P. Singh[6], V. Srivastava[6]

[1]*Variable Energy Cyclotron Centre, Kolkata - 700064, INDIA*
[2]*Homi Bhabha National Institute, Anushaktinagar, Mumbai-400094, INDIA,*
[3]*Institute of Engineering and Management, Kolkata-700091, India*
[4]*Victoria Institution (College), Kolkata – 700009, INDIA*
[5]*UGC-DAE-CSR Consortium, Kolkata-700107,INDIA*
[6]*Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi - 110067, INDIA*
[7]*Himachal Pradesh University, Shimla-171005, INDIA*
* *email: sneha.d@vecc.gov.in*

Introduction

The structure of nuclei in the vicinity of ^{208}Pb doubly magic nucleus consisting of few neutron holes in N=126 closed shell have attracted much attentions in the recent years to understand the evolution of level structures from single-particle excitations to collective nature [1, 2]. With few proton particles above Z=82, and few neutron holes below N=126, it is expected to have single-particle structures. It is interesting to explore how the collectivity can be induced in nuclei near the doubly magic shell closure with increase in number of neutron holes in N=126 shell. In this region, for most of the cases, the experimental B(E2) values for low spin states are either missing or not in well agreement with the theoretical values. Therefore, detailed studies on prompt spectroscopy as well as lifetime measurements for these nuclei are necessary.

To explore the above aspects of structure of nuclei near ^{208}Pb, prompt and decay spectroscopy of nuclei with even numbers of proton particles above Z=82 and odd numbers of neutron holes below N=126 have been investigated. The present work reports the high spin states of ^{209}Rn (Z=86, N=123), studied by in-beam gamma ray spectroscopy techniques and lifetime measurement of one of the low-lying states of ^{209}Po (Z=84, N=125) by fast timing method, following off-line decay.

Experiment

The excited states of ^{209}Rn were populated using the reaction ^{198}Pt(^{16}O, xn), at a beam energy of 102 MeV, from the Pelletron at IUAC, New Delhi. The de-exciting γ-rays from the high spin states were detected using the INGA setup, consisted of 18 Compton suppressed clover HPGe and 2 LEPS detectors. List mode data was acquired in coincidence and singles mode in CANDLE format and analyzed using LAMPS, INGASORT and RADWARE packages.

For the measurement of lifetime of the excited states, with half-lives in sub-nanosecond range, fast timing techniques have been applied with new generation inorganic scintillator detector $CeBr_3$. The low-lying states of ^{209}Po were populated via electron capture decay of ^{209}At. The parent nucleus activity was produced using the reaction ^{209}Bi(^{16}α, 4n)^{209}At at 52 MeV, from K-130 cyclotron at VECC, Kolkata. The lifetime of the excited state of ^{209}Po at 1521.9 keV ($11/2^-$) has been measured using two 1.5″x1.5″ $CeBr_3$ scintillators, coupled to the new Hamamatsu PMT R13089-100.

Analysis and Results on ^{209}Rn

To analyse the in-beam data on ^{209}Rn, obtained with INGA setup, the addback spectra of the clover detectors were generated after the energy calibration and gain matching of all crystals. The total TAC was also generated after alignment of all TDCs. Prompt and delayed γ–γ matrices have been formed by gating on prompt and delayed parts of the total TAC. A γ–γ–γ cube was also formed to check the double coincidences. Several new transitions and connecting transitions between the different

cascades have been observed from the present work. Representative coincidence spectrum from the γ–γ–γ cube, with double gates on 404 and 718 keV, is shown in Fig. 1(a). Coincidence spectrum from γ–γ prompt matrix for the gate of 234 keV is shown in Fig. 1(b). Assignment of spin-parities of the new levels is in progress.

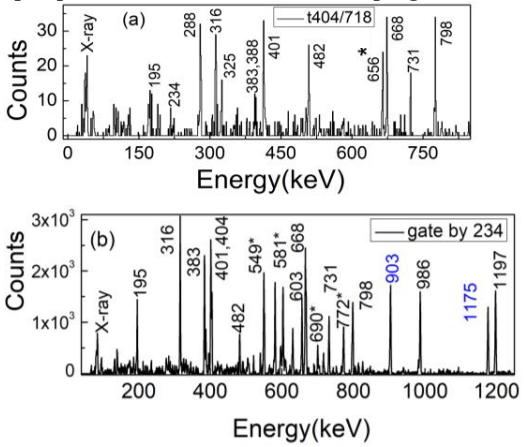

Fig. 1 Coincidence spectra of transitions in ^{209}Rn. (a) double gates of 404 and 718 keV from γ–γ–γ cube and (b) gate of 234 keV from γ–γ matrix. The γ-rays marked in '*'are newly placed in ^{209}Rn and in blue colour are of ^{209}Po, produced from ^{209}Rn decay, respectively.

Lifetime measurement of ^{209}Po

The lifetime measurement of excited state of ^{209}Po was carried out with two 1.5″x1.5″ $CeBr_3$ scintillator detectors using Mirror Symmetric Centroid Difference (MSCD) method of fast timing techniques [3]. The detectors were characterized [4] and the time-walk response [5] of the two-detector set-up has been determined from delayed and anti-delayed time distributions for various energy cascades of ^{152}Eu and ^{133}Ba radioactive sources. Fig. 2(a) shows the Prompt Response Distribution [PRD(E_γ)], obtained in the present work. The corresponding fit residuum is shown in Fig.2(b). The dashed line indicates 2σ deviation corresponding to 8 ps .

The feeding and decaying transitions of the 1521.85 keV state of ^{209}Po are 239 and 195 keV respectively. So, the lifetime of $(11/2)^-$ state has been determined considering 239-195 keV γ-ray cascade. Fig.3 shows the delayed and anti-delayed TAC spectra for (a) 779-344 keV γ-ray cascade of ^{152}Eu, used for PRD calibration and (b) 239-195 keV γ-ray cascade in ^{209}Po.

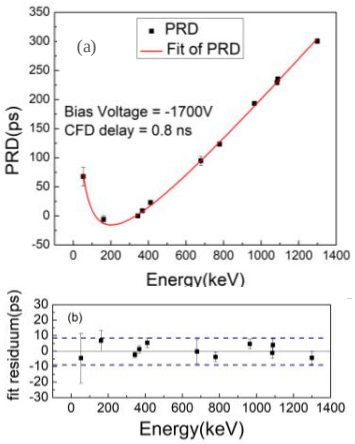

Fig. 2: (a) The PRD calibration curve and (b) the corresponding fit residuum for the PRD curve.

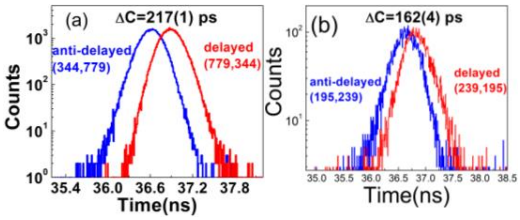

Fig.3. Delayed and anti-delayed TAC spectra for (a) 779-344 keV (^{152}Eu), (b) 239-195 keV (^{209}Po)

The mean lifetime of $(11/2)^-$ state of ^{209}Po from the present work is measured as 94(8) ps, which is in good agreement with that reported recently [2].

Summary

Spectroscopy of nuclei above Z=82 is investigated in the present work. The high spin states of ^{209}Rn are studied using INGA. The lifetime of $11/2^-$ state in ^{209}Po is measured with $CeBr_3$ scintillator using MSCD method.

References

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