CORE EXCITATIONS ACROSS THE NEUTRON SHELL GAP IN ^{207}Tl*

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Deep-inelastic collisions of a ^{208}Pb beam on a ^{208}Pb target were performed using the ATLAS accelerator at Argonne National Laboratory. Prompt and delayed γ-rays from the reaction products were detected using the GAMMASPHERE detector array. The cross-coincidence method was used to identify transitions in ^{207}Tl, by gating on γ-rays from its better-characterised reaction partner ^{209}Bi. A number of new transitions were found in ^{207}Tl.

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1. Introduction

^{208}Pb is the heaviest known doubly-magic nucleus. Information regarding the spectroscopic properties of neutron-rich nuclei located to the 'south-east' of ^{208}Pb, in the area of the chart of nuclides enclosed by $Z \leq 82$ and $N \geq 126$, is scarce. The deep-inelastic collisions of a beam and a target both composed of ^{208}Pb exploit cross-coincidences between reaction partners, such that yrast states in these relatively unknown nuclei may be found. It was for this purpose that an experiment was performed at Argonne National Laboratory, using a thick ^{208}Pb target and a ^{208}Pb beam.

^{207}Tl is a one proton hole nucleus, with its low energy level structure being dominated by single proton hole states $\pi s_{1/2}^{-1}$, $\pi d_{3/2}^{-1}$, and $\pi h_{11/2}^{-1}$ [1]. Higher energy excited states along the yrast line are formed by breaking the $N = 126$ neutron core. In addition, this region is characterised by octupole vibrational states (*e.g.* the 3^- first excited state in ^{208}Pb is at 2615 keV). It is expected that the first yrast state above the $\pi h_{11/2}^{-1}$ $11/2^-$ isomer has a collective octupole character.

2. Experiment

A 1446 MeV ^{208}Pb beam impinged on a 75 mg/cm^2 ^{208}Pb thick target. The beam and target were chosen to maximise the statistics of the nuclei populated around ^{208}Pb in a deep-inelastic collision. Reaction products are stopped within the target. The experiment ran for $\sim$ 168 hours, with an average beam intensity of ~ 0.25 pnA. The γ-rays produced were detected by the GAMMASPHERE array, consisting of $\sim$ 100 high-purity germanium (HPGe) detectors, covering a solid angle of nearly 4π sr. The HPGe detectors were Compton suppressed using bismuth germanate (BGO) detectors. The GAMMASPHERE array has an energy resolution of < 2.4 keV at 1.33 MeV, with a photopeak efficiency of $\sim 10\%$ for the same energy [2]. Tantalum, cadmium and copper absorbers were placed between the HPGe detectors and the target chamber in order to reduce the yield of characteristic x-ray peaks.

There is a natural pulsing of the ^{208}Pb beam, which is due to the fundamental frequency of the bunching system. This means that a sub-nanosecond pulse occurs once every 82.5 ns. The pulses may be deflected. For the prompt data, no pulses were deflected; for the delayed data, four out of five pulses were deflected, allowing the detection of isomers with a half-life of the order of magnitude of this period. In ^{207}Tl no delayed transitions have been observed in these data, so only the prompt data are discussed.

Deep-inelastic collisions are known to populate yrast and near-yrast states in the reaction products [3]. Nucleons are exchanged between the nuclei of the beam and of the target. Neutron evaporation may also occur. Therefore, deep-inelastic reactions produce two excited nuclei, one of which is beam-like, while the other is target-like. In the case of this experiment, both beam-like and target-like nuclei are in the vicinity of ^{208}Pb, thereby improving the statistics in the nuclei of interest in comparison to experiments which do not use a beam and target of the same material.

3. Results

The level scheme of ^{209}Bi, in comparison to its reaction partner of ^{207}Tl, is well known [4]. By gating on the known transitions in ^{209}Bi, we can detect gamma lines corresponding to ^{207}Tl (see Fig. 1). The 2465 keV transition previously observed by Rejmund *et al.* in ^{207}Tl depopulates the expected collective $E3$ octupole phonon state and it decays into the long-lived, $T_{1/2}$ =1.33 s, $11/2^-$ isomeric state at 1348 keV excitation energy [3]. Gating on the 2465 keV transition, as shown in Fig. 2, several new yrast and near-yrast transitions in ^{207}Tl can be observed. These transitions can be placed above the $17/2^-$ state depopulated by the 2465 keV line, and they identify states in which the neutron core is broken.

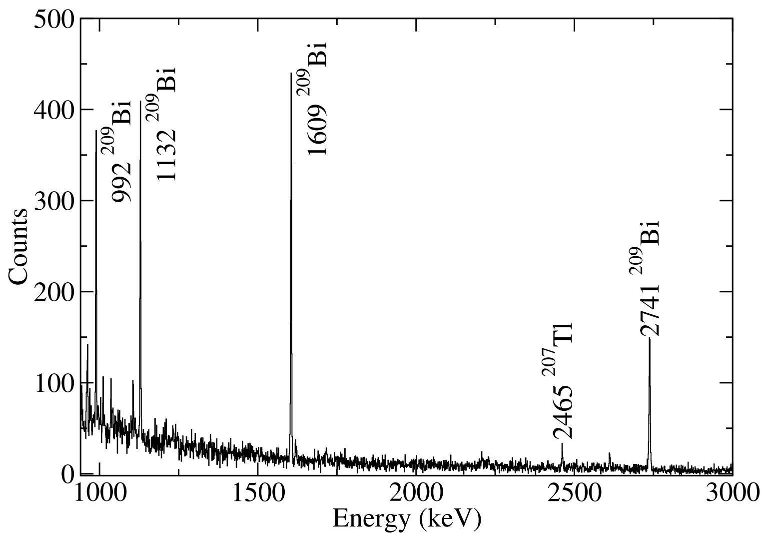

Fig. 1. Spectrum obtained from a $\gamma\gamma\gamma$ cube by gating on known ^{209}Bi transitions [4], $19/2^+ \rightarrow 15/2^+$ 246 keV and $19/2^{(+)} \rightarrow 19/2^+$ 500 keV, confirming the 2465 keV transition in ^{207}Tl by cross-coincidence. All other labelled transitions belong to ^{209}Bi.

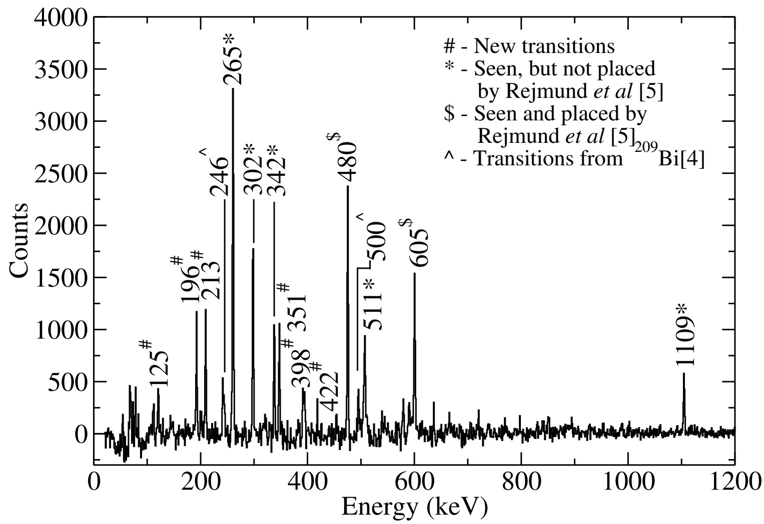

Fig. 2. Spectrum gated on the 2465 keV transition in ^{207}Tl, showing transitions above the $11/2^-$ isomer, as well as transitions in the ^{209}Bi partner nucleus. A number of new transitions have been seen in ^{207}Tl, and the existance of those seen by Rejmund *et al.* can be confirmed [5].

TABLE I

A summary of the higher-intensity peaks associated with ^{207}Tl seen in the 2465 keV-gated spectrum, with preliminary values for the intensities assigned. The column of intensities marked with a * are from this work, and are compared with the previous work [5].

E_γ (keV)	I_γ [5]	I_γ^*
124.6	—	19 (4)
196.5	—	26 (5)
213.4	—	24 (5)
264.7	58 (7)	100 (10)
302.3	40 (6)	56 (6)
342.0	26 (5)	26 (3)
351.4	—	24 (3)
398.6	—	11 (3)
422.5	—	4 (2)
479.5	100 (10)	71 (7)
511.2	30 (5)	40 (4)
604.6	53 (7)	64 (6)
1108.9	19 (5)	31 (4)

Table I shows a summary of the higher-intensity ^{207}Tl transitions seen in the 2465 keV-gated spectrum, with preliminary values for the γ-ray intensities. There is also a comparison to the γ-ray intensities deduced by Rejmund *et al.* [5].

4. Conclusion

A number of new transitions have been observed in ^{207}Tl, above the known $11/2^-$ isomeric state. Coincidence relationships as well as intensity considerations will be used to build the level scheme. A comparison with shell model calculations will also be undertaken.

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