Eur. Phys. J. A **3**, 5–8 (1998)

THE EUROPEAN PHYSICAL JOURNAL A

Short note

Band structures in ^{108}In

R.S. Chakrawarthy[1,2], B.S. Nara Singh[1], R.G. Pillay[1]

[1] Tata Institute of Fundamental Research, Homi Bhabha Road, Mumbai 400 005, India
[2] Institut für Kernphysik, Universität zu Köln, Zülpicher Str 77, D-50937 Köln, Germany

Received: 16 June 1998
Communicated by B. Herskind

Abstract. High spin states in ^{108}In have been established upto $\sim$ 8 MeV in excitation energy and to a tentative spin of (23^-). The data were obtained by in-beam γ-ray spectroscopy using the reaction ^{93}Nb(^{19}F, p3n)^{108}In at a beam energy of 86 MeV. Four sequences of dipole bands and a normal rotational band of E2 γ-transitions have been placed in the level scheme.

PACS. 21.10.Hw Spin, parity and isobaric spin – 25.70.Gh Compound nucleus – 27.60.+j $90 \leq A \leq 149$

The wealth of excitation modes in the near spherical In, Sn and Sb nuclei makes them particularly interesting systems to study. The recent theoretical and experimental investigations of nuclei in this mass region have helped to elucidate the concepts of magnetic rotation [1] and smooth band termination [2]. The nucleus ^{108}In has been a subject of former studies [3–6].

We performed two experiments with the gamma spectrometer at Tata Institute of Fundamental Research, in Mumbai, India, to populate states in ^{108}In. In the first experiment the target consisted of a 800 μg/cm^2 thick ^{93}Nb foil backed by a 10 mg/cm^2 thick Au. In the second experiment the target consisted of a self supporting foil of a 10 mg/cm^2 thick ^{93}Nb. Gamma rays emitted from the reaction products were detected using four Compton suppressed high purity germanium detectors (CS-HPGe) and a segmented high purity germanium detector (CLOVER detector[1]). This array was used in conjunction with a 14 element NaI multiplicity filter. In the γ-γ coincidence experiment the four CS-HPGe detectors were in a planar geometry at angles $\pm30°$, 40° and 90° to the beam axis. The CS-HPGe detectors were at a distance of 25 cm from the target. The CLOVER detector was positioned at 90° with respect to the beam and at a distance of 50 cm from the target. The individual counting rates in each of the CS-HPGe detectors were less than 8 kHz, while the counting rate of individual elements of the CLOVER detector was about 2.5 kHz.

The γ-γ coincidence data was collected at a beam energy of 86 MeV, comprising of two fold Ge events, qualified by a hardware trigger of multiplicity greater than three NaI detectors. A total of 30 million and 90 million coincidence events were accumulated in the two experiments, respectively. The energy and efficiency calibrations of the CS-HPGe detectors were done using a radioactive source of ^{152}Eu. The γ-γ coincidence data from the four CS-HPGe detectors were sorted off-line by gain matching each of the detectors using the ^{152}Eu data. The two fold γ-γ coincidence events due to combinations of CLOVER and the CS-HPGe detectors were sorted separately. Compton scattered events from the CLOVER detector, corresponding to two hits in the vertical and horizontal segments were added. In the add-back mode about 7 million two fold coincidences between the CLOVER and a CS-HPGe detector were recovered. In addition the Compton events scattered in the plane perpendicular and parallel to the beam axis were histogrammed separately. This data was used to deduce linear polarization of some of the γ-transitions. The two fold coincidence data was background corrected and the projected spectra generated with gates on the gamma transitions were used to construct the level scheme. The ratio of directional correlation of oriented states (R_{dco}) of the γ-transitions was constructed by the following procedure [7],

$$R_{dco} = \frac{(I_{\gamma_1} \ at \ 30° \quad gated \ \ by \quad \gamma_2 \ at \ 90°)}{(I_{\gamma_1} \ at \ 90° \quad gated \ \ by \quad \gamma_2 \ at \ 30°)}, \tag{1}$$

where the gating γ-transition has either a pure dipole or quadrupole multipolarity. When gated by a quadrupole γ-transition the R_{dco} value was close to 1.0 for stretched $E2$ transitions and close to 0.5 for stretched dipole γ-transitions, respectively. The R_{dco} values were calibrated using known γ-transitions. In another experiment the angular distribution of the γ-rays were measured with the four CS-HPGe detectors at angles 15°, 30°, 44° and 90°

[1] CLOVER detector supplied by Eurisys measures, France

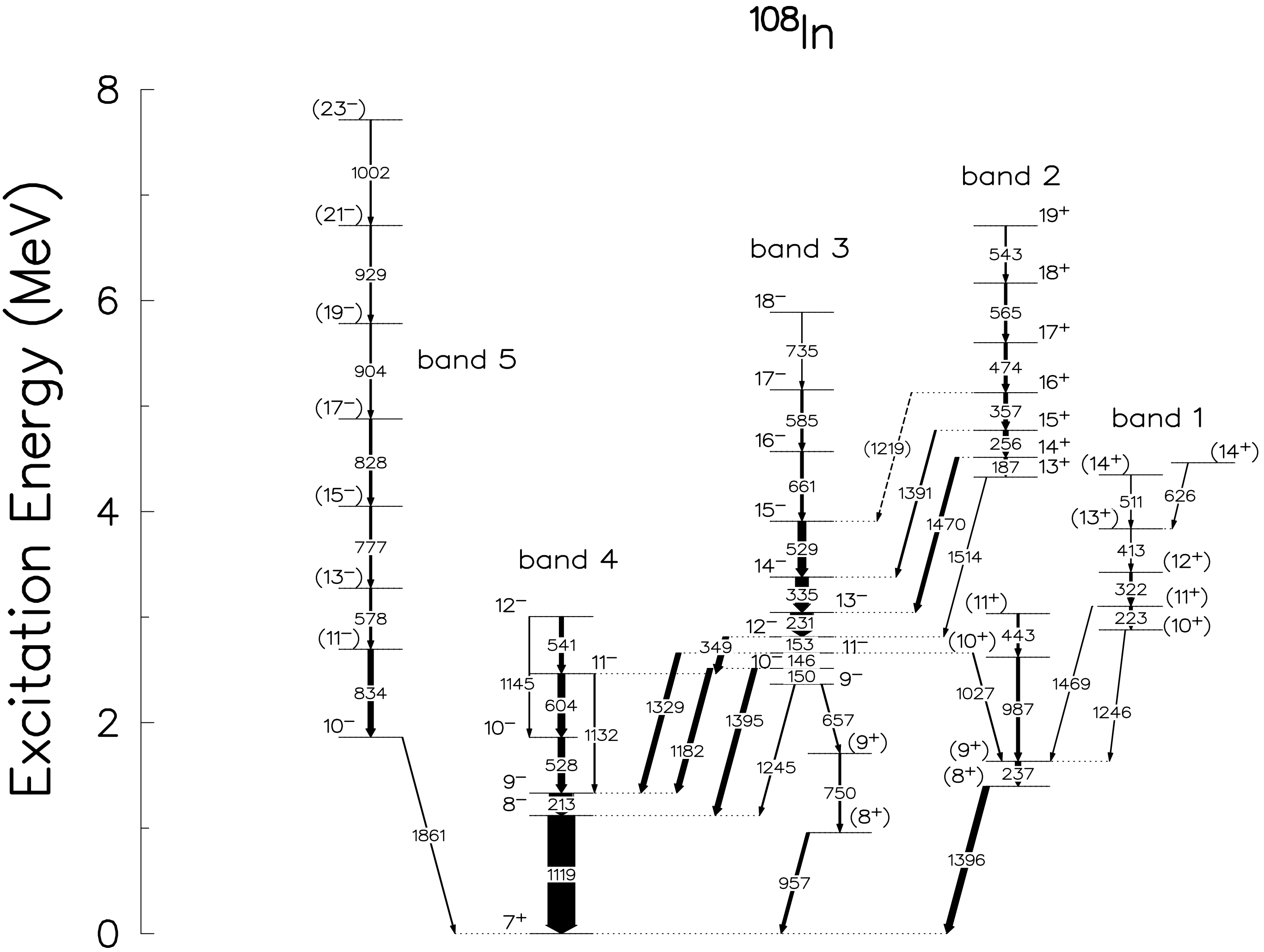

Fig. 1. Partial level scheme of ^{108}In from this work

with respect to the beam direction. They were analyzed by fitting the efficiency corrected intensities to the distribution function of Legendre polynomial,

$$W(\theta) = A_\circ + A_2 P_2(cos\theta) + A_4 P_4(cos\theta). \qquad (2)$$

The spin assignments have been made assuming that the high spin states subsequently decay to levels with a lower spin.

The level scheme deduced from the present experiment is shown in fig. 1. The level scheme has been classified into five bands (1 to 5). The previous study of Elias et al. [4] and Andersson et al. [5] have established states in ^{108}In upto 3.9 and 5.0 MeV, respectively. The present work reports a considerable extension of the earlier studies. Four dipole bands and a normal rotational band have been placed in the level scheme. The ground state spin-parity of 7^+ has been adopted from the work of Krasznahorkay et al. [6], differing from the earlier works [4, 5]. In band 4 , the dipole transitions viz 528, 604 and 541 keV are in coincidence with each other. This is consistent with the previous works. In addition we have observed the crossover $E2$ γ-transitions. This band extends to a spin of $12\hbar$. Band 3 was strongly populated in this reaction. In this band, the previously known cascade comprising of the 146, 153, 231, 335, 529 and 661 keV γ-transitions has been extended to higher spins. Two new γ-transitions, i.e., the 585 and 735 keV γ's were observed to depopulate the I^π=18^- and the I^π=17^- energy levels. The placement of the 150 keV γ-transition extends the low spin section of this band to a spin of 9^-. In the present work, the 585 keV γ-transition was found to be in coincidence with the 661 keV γ-transition differing from the earlier work of Andersson et al. [5]. Figure 2 depicts the spectra gated by the 661 keV γ-transition. No cross-over $E2$ γ-transitions were observed in this band.

Band 2 is a dipole band which decays via interband γ-transitions to the energy levels of band 3. The series of dipole γ-transitions, i.e. the 187, 256, 357, 474, 565 and 543 keV constitute members of this rotational like dipole band. In the previous work the ordering, placement and decay out of this band was incorrect [5]. In addition, the 187 and 543 keV γ-transitions have been placed in this band, extending the high and low spin section of this band. From the present analysis, this band feeds states of

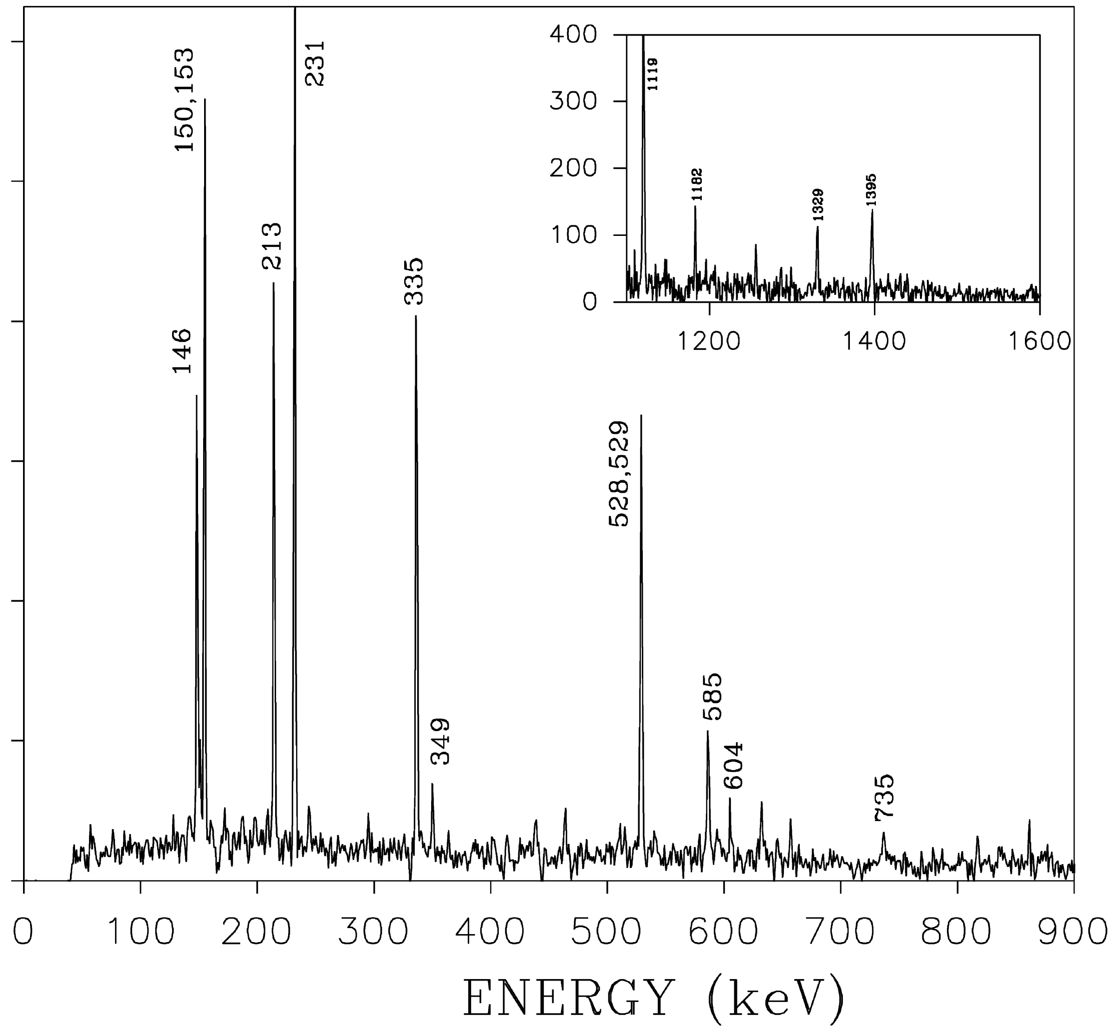

Fig. 2. Spectrum gated by the 661 keV γ-transition

band 3 via the high energy 1391, 1470 and 1514 keV γ-transitions. From the polarization data the 1391 and 1470 keV γ-transitions were deduced to be electric character and from the R_{dco} analysis a dipole multipolarity was deduced for these γ-transitions. Hence an $E1$ multipolarity has been assigned to these γ-transitions. Thus band 2 was inferred to have a positive parity. Parity change within the band is ruled out as all the band members were deduced to be magnetic dipoles. Additional support for the magnetic character of the γ-transitions within the band comes from the observed line shape in the forward and backward detectors. This implies a lifetime of the order of less than a pico-second (comparable to the stopping time in the target). Similar arguments were put forward in the work of Elias et al. [4].

Band 1 comprises of the 223, 322, 413, 511 and 626 keV γ-transitions. This band feeds the I^{π}=(9^{+}) energy level at 1.63 MeV via the high energy 1469 and 1246 keV γ-transitions. In the work of Andersson et al. this band was incorrectly placed at the I^{π}=10^{+} energy level at 1.861 MeV. The R_{dco} value of the intraband γ-transitions was close to unity and hence they have been assigned $M1$ multipolarity. In the present work the placement of this band was unambiguous, as it was found to be in coincidence with the γ-transitions depopulating the I^{π}=(9^{+}) and I^{π}=(8^{+}) states at the 1.633 MeV and 1.393 MeV energy levels, respectively. Similarly, based on coincidence relationships we assign the γ-transitions, 1396 and 237 keV to ^{108}In, which were discarded in the earlier work of Andersson et al. [5].

The analysis of the data has revealed a coincident sequence comprising of 578, 777, 828, 904, 929, and 1002 keV γ-transitions, which are members of the band 5. From the angular distribution and the R_{dco} data, a $E2$ multipolarity has been deduced for some γ-transitions in this band. This band feeds into the I^{π}=10^{-} level at 1.861 MeV via the 834 keV γ-transition. We find evidence for a $E3$ γ-transition depopulating this state to the ground state. In addition, the lack of a Doppler shifted line shape in the forward and backward detectors is indicative of a high multipolarity for this γ-transition.

Cranked shell model calculations [8] were performed to make a configuration assignment of the rotational band (band 5). The deformation parameters were β_2=0.20, β_4=0.0, and γ=0°. The calculations predict alignment due to second pair of $h_{11/2}$ neutrons at a frequency of $\hbar\omega$=0.45 MeV. The crossing frequency of 0.45 MeV/$\hbar$ and gain in alignment (about 6$\hbar$) in the data is consistent with $h_{11/2}$ neutrons. Maldeghem et al. [3] have explained the low spin states in odd-odd In nuclei as due to the coupling of the proton-neutron multiplets to the core Sn vibrational states. The experimental limits of the B($M1; I \rightarrow I-1$)/B ($E2;\ I \rightarrow\ I-2$) ratios were 50 and 30 μ_N^2/e^2b^2 in bands 3 and 2, respectively. The non-observation of $E2$ γ-transitions suggests weak collectivity in these bands. It is possible that they are obtained by coupling the proton $g_{9/2}$ hole to neutron states due to the normal and unique parity orbitals in the N=4 oscillator shell. In the neighboring odd-even nuclei truncated shell model calculations have suggested the origin of dipole bands due to this feature [1].

We thank the Pelletron accelerator staff for excellent operation of the tandem during the experiment. One of us (RSC) is grateful to the Alexander von Humboldt foundation for a research fellowship. J. Gableske and P. Petkov are thanked for carefully reading the manuscript.

References

1. S. Frauendorf and J. Reif, Nucl. Phys. A **621**, 736 (1997)
2. R. Wadsworth, et al., Phys. Rev. Lett. **80**, 1174 (1998)
3. J. Van Maldeghem, K. Heyde, J. Sau, Phys. Rev. C **32**, 1067 (1985)
4. N. Elias, et al., Nucl. Phys. A **351**,142 (1981)
5. E. Andersson, et al., Phys. Rev. C **24**, 917 (1981)
6. A. Krasznahorkay, et al., Nucl. Phys. A **499**, 453 (1989)
7. R. S. Chakrawarthy and R. G. Pillay, Phys. Rev. C **54**, 2319 (1996)
8. S. Cwiok, J. Dudek, W. Nazarewicz, W. Skalski and T. Werner, Comp. Phys. Comm. **46**, 379 (1987)