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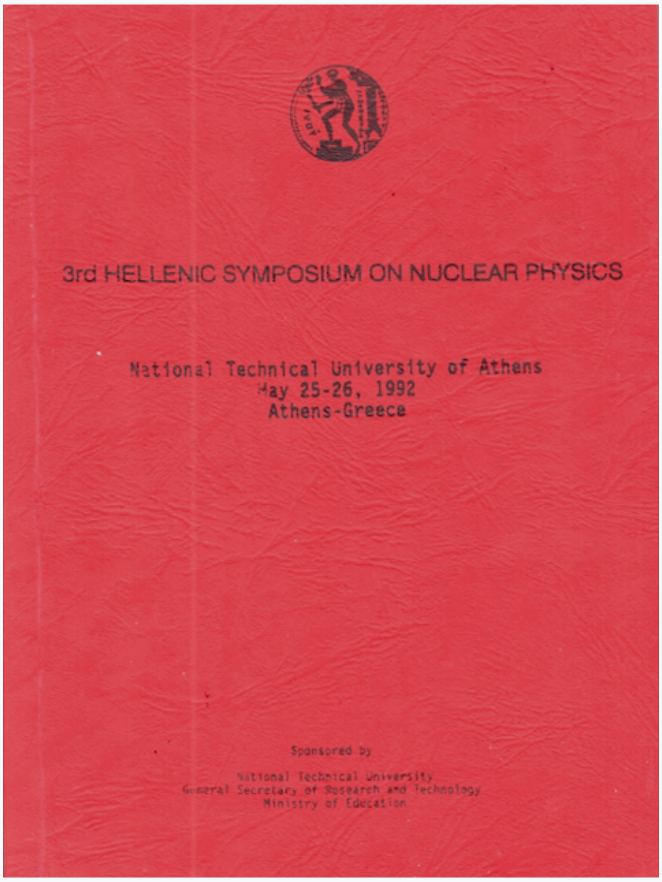


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# Level Scheme of $^{102}$In first observed

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## Abstract

Neutron deficient nuclei close to $^{100}$Sn have been investigated in-beam by particle and γ-ray spectroscopic methods using the NORDBALL detector array following the bombartment of a $^{54}$Fe target with a beam of 270 MeV $^{58}$Ni. Protons and α particles were identified with a 4π ΔE-type Si-multidetector and neutrons with a 1π liquid-scintillator-detector-assembly placed in the forward derection. Excited states of $^{102}$In were identified for the first time. The level scheme constructed from γ-γ-particle-coincidence and γ angular correlations is discussed and compared to the structure of neighboring nuclei in the framework of the nuclear shell model.

## 1. Introduction

Since $^{100}$Sn is the heaviest self-conjugate double magic nucleus nuclei close to it are of greate interest in testing the validity of the nuclear shell model. Recently several such nuclei have been identified in-beam like $^{104}$Sn[1], $^{105}$Sn, $^{103}$In[2], and $^{100,101}$Cd[3]. In the present work we try to extend our knowledge in the $^{100}$Sn region by using the NORDBALL suitably improved for this purpose.

## 2. Experiments and results.

In order to reach nuclei closer to $^{100}$Sn than achieved earlier, a beam of 270 MeV $^{58}$Ni was used to bombard a target of $^{54}$Fe(10mg/cm$^2$, 99.8%). The experiment was performed at the Tandem Accelerator Laboratory of the Niels Bohr Institute at Riso-Denmark. The NORDBALL detector array [4] was optimised to yield high selectivity for defferent reaction channels and consisted of 15 Ge-BGO detectors (one being a LEP detector) for γ-ray identification ,a 4π detector system comprised 21 ΔE-type Si-detectors [5] optimised for proton and α particle identification, a 1π neutron wall which comprised 11 liquid scintillator detectors in the downstream hemisphere [6] and a 2π γ-ray calorimeter composed of 30 $BaF_2$ crystals covering the upstream hemisphere. A major emphasis was put on the performance of the neutron detector system. The reason is that the compound nucleus $^{112}$Xe is very neutron deficient and the evaporation of neutrons (being of course rare) produce the most exotic nuclei which are of the greatest interest. The neutron-γ separation was improved by almost an order of magnitute compared to the pulse shape discrimination technique by combining this technique with neutron time of flight. A total of 420 million γ-γ-coincidence events containing information about the detected γ rays, neutrons, protons and α particles were collected.

In analyzing the data we sorted γ-γ coincidence matrices gated by different multiplicities of detected neutrons, protons and α particles. From these matrices corresponding to various exit channels of the reaction we calculated and compare the intensity of the observed γ-ray transitions. Since the intensity ratio depend on the multiplicities of particles acompanying γ emission and on the particle detection efficiencies and these efficiencies depend very weakly on the reaction channel for a specific type of detected particle, comparison of such ratios with ratios for γ rays from previously known nuclei that were populated in the experiment make the assignment of the final nuclei possible. Results of such a comparison is shown in Fig.1 for the 145 keV line, which is a candidate for a transition in $^{102}$In. Using the above method a total of 29 different exit channels were identified including 7 light In, Sb, Te and I isotopes not observed before [7]. The experimental yield for $^{102}$In was estimated to be 0.03% of the total yield (0.004% for the weakest observed channel $^{100}$Cd). This shows the extremely high selectivity of the present experimental set-up.

## 3. Level scheme.

Transitions assigned to $^{102}$In are shown in Fig.2, and the proposed level scheme in Fig.3. Some transitions in Fig.2, which belong to $^{102}$In could not be placed in the level scheme (272 and 459 keV), or were placed only tentatively (382, 376, 250 and 222 keV) due to low statistics in the individual gates.

Using a simplified γ-γ correlation analysis we obtain the multipolarities of the observed transitions. In this analysis the γ transitions from the γ-γ coincidence matrices gated with the right combination of evaporated particles were sorted at three detector angles with respect to the direction of the beam i.e. 79 ,101 ,143 . The intensity ratios I(143 )/I(79 )+I(101 ) were then calculated for the transitions in $^{102}$In and compared to ratios obtained for transitions of known multipolarity. In this way it is found that all transitions observed in $^{102}$In have a dipole character (most likely M1) except for the 1137 keV transition which has a quadrupole character (most likely E2). The spins and parities of the levels in $^{102}$In were assigned assuming that all observed transitions are stretched and the ground state is a $6^+$ in accordance with $^{104}$In. Therefore the spins and parities in Fig.3 are tentative.

## 4. Discussion

The proposed level scheme of $^{102}$In resembles the low energy part of the level scheme of $^{104}$In [8] and both of them differ from $^{106-116}$In in that in $^{102}$In and $^{104}$In the negative parity states are expected to lie higher in excitation energy (as has been observed in $^{104}$In [8]) compare to the heavier In isotope. The negative parity high spin states in $^{106-116}$In were explained as a $\pi g^{-1}_{9/2} \otimes \nu h_{11/2}$ multiplet coupled to a quadrupole phonon excitation of the underlying core [9]. The $6^+$ ground states in $^{102}$In and $^{104}$In have a $\pi g^{-1}_{9/2} \otimes \nu d_{5/2}$ configuration. The lowest lying (7+) state of $^{104}$In is interpreted as the $7^+$ state of this multiplet. The $(7^+)$ and $(8^+)$ states in $^{102}$In are suggested to belong to the $\pi g^{-1}_{9/2} \otimes \nu g_{7/2}$ configuration and correspond to the second excited $7^+$ and first excited $8^+$ states in $^{104}$In. In $^{102}$In one of the $7^+$ states is not observed.

Regarding the higher lying states these are mainly due to three quasi-neutrons in the $d_{5/2}$ and $g_{7/2}$ coupled to a $\pi g^{-1}_{9/2}$ proton hole if a $^{100}$Sn core is assumed. The results of advanced shell model calculations using a $^{90}$Zr core and a configuration space consisting of the $\pi g_{9/2}$, $\nu d_{5/2}$, $\nu g_{7/2}$, $\nu s_{1/2}$ and $\nu d_{3/2}$ orbitals and the same model parameters as in [1] are shown in Fig.3. Reasonable agreement between theory and experiment is concluded for $^{102}$In except for the first $7^+$ state predicted by the theory, which is not observed experimentally probably because of low statistics.

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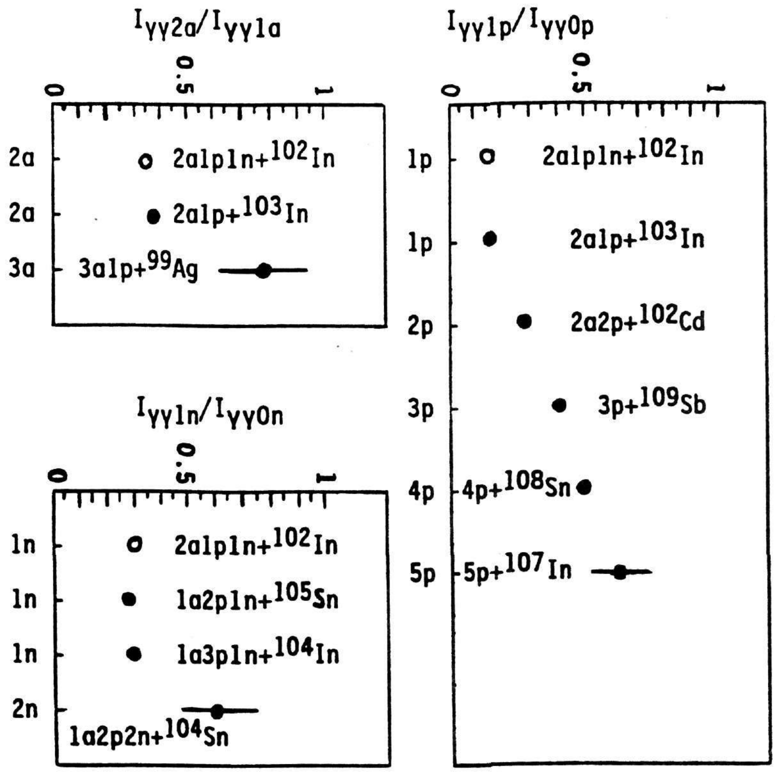


Fig.1. Intensity ratios for different proton ,neutron and α particle multiplicities. Comparison with transitions corresponding to known final nuclei clearly assign the 145 keV transition to the 2α1p1n exit channel, i.e. $^{102}$In.

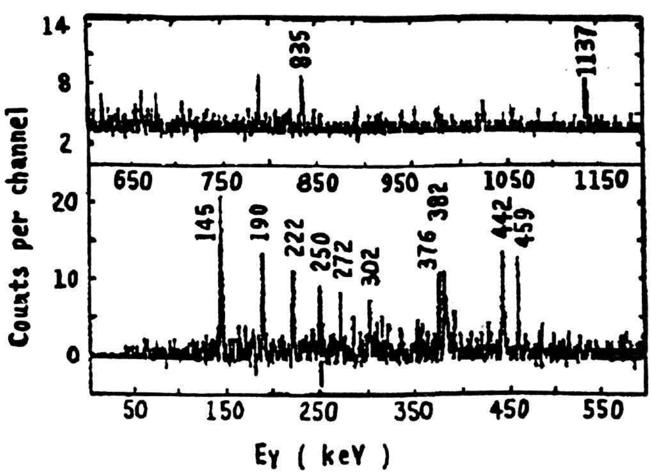


Fig.2. Summed coincidence spectrum for 102In obtained from the 2α1p1n and 2α1n gated γ-γ matrices.

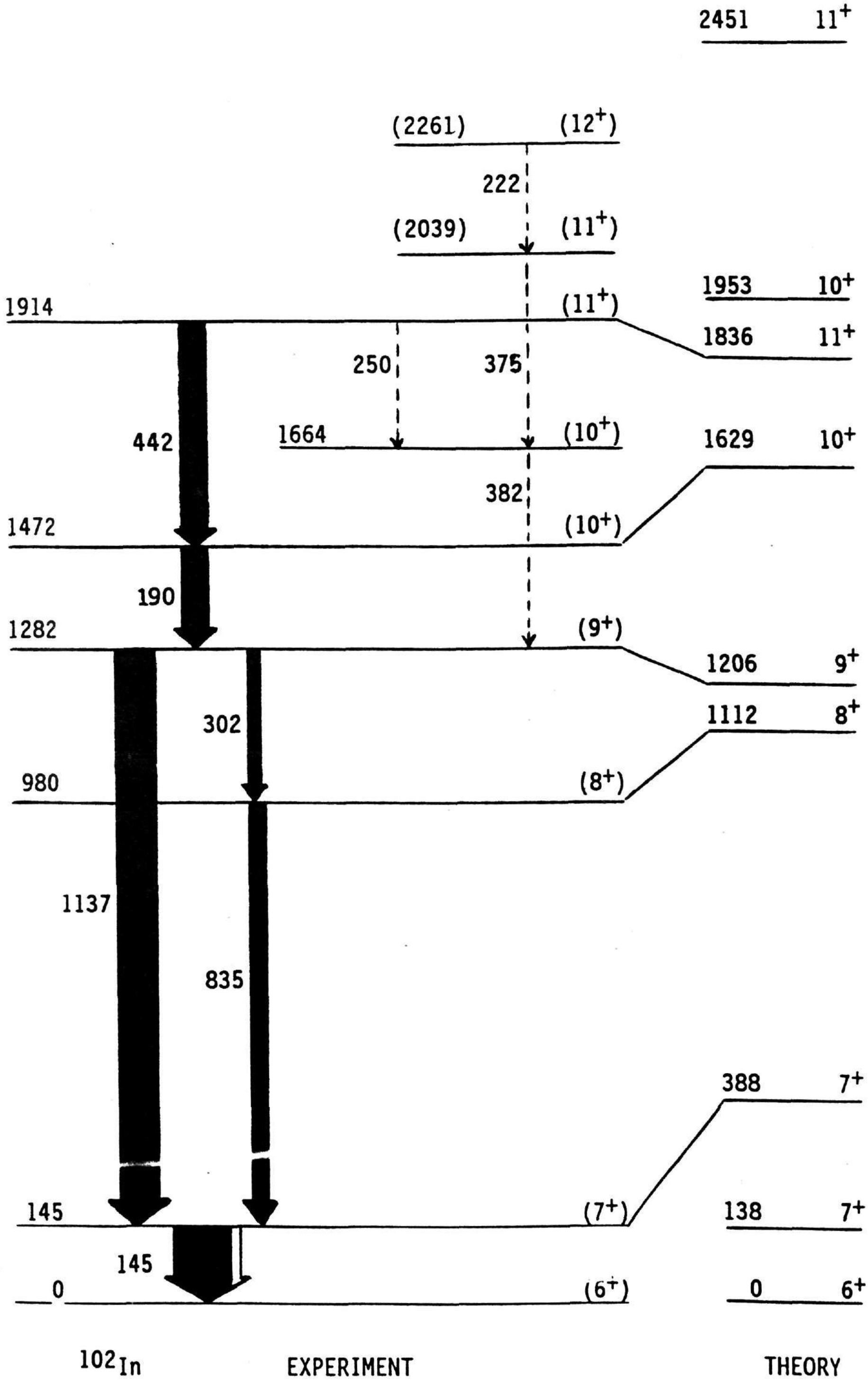


Fig.3. Experimental and theretical level schemes of $^{102}$In. The widths of the arrows show the intensities of the transitions in the coincidence projection. The white parts of the arrows show internal conversion contribution.