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STRUCTURE OF HEAVY Fe NUCLEI AT THE POINT OF TRANSITION AT $N \sim 37$*

H. Mach[a,b,c], A-M. Baluyut[d], E. Ruchowska[e], U. Köster[f,g]
L.M. Fraile[c,g], R. Boutami[h], H. Bradley[a,i], N. Braun[j]
C. Fransen[j], J. Jolie[j], J. Nyberg[a], V. Ugryumov[k]

[a]Department of Physics and Astronomy, Uppsala University
PO Box 535, 75121 Uppsala, Sweden
[b]Institute for Structure and Nuclear Astrophysics, University of Notre Dame
Notre Dame, IN 46616, USA
[c]Facultad de Físicas, Universidad Complutense, 28040 Madrid, Spain
[d]Department of Physics, University of Notre Dame, Notre Dame, IN 46616, USA
[e]The Andrzej Sołtan Institute for Nuclear Studies, P05-400 Świerk, Poland
[f]Institut Laue-Langevin, B.P. 156, 38042 Grenoble Cedex, France
[g]ISOLDE, PH Department, CERN, 1211 Geneva 23, Switzerland
[h]Instituto de Estructura de la Materia, CSIC, 28006 Madrid, Spain
[i]School of Physics, University of Sydney, New South Wales 2006, Australia
[j]Institut für Kernphysik, Universität zu Köln, 50937 Köln, Germany
[k]Nuclear Physics Institute, AS CR, CZ 25068, Rez, Czech Republic

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We have studied energy levels in ^{63}Fe populated in the β-decay of ^{63}Mn. A new (preliminary) level scheme of ^{63}Fe includes 10 excited states connected by 21 γ-rays. The first excited states at 357 and 451 keV have the level half-lives of 110 ps and 780 ps, respectively. Three states, at 357, 451, and 1132 keV, are strongly β-fed with log $ft \sim 5$, while there is only a very week β-feeding, if any at all, to the ground state. The new results imply that ^{63}Fe departs from a simple shell model structure observed for heavier $N = 37$ isotones of ^{65}Ni and ^{67}Zn.

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1. Introduction

Limited experimental information exists on the heavy neutron-rich Fe and Co nuclei located just below the shell closure at $Z = 28$. For nuclei in the heavy Cu–Ge region there seems to be a shell effect at $N = 40$ evident

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from the systematics of the energies of the first excited 2^+ states and the related B(E2) values. On the other hand, for nuclei below Ni, like heavy Fe, there is a sudden increase in the collectivity above $N = 37$, as observed from the lowering of the energies of the 2^+ states in the even–even Fe and Cr nuclei. The increase in collectivity is caused by occupation by neutrons of the $1g_{9/2}$ orbit as demonstrated in the calculations by Caurier *et al.,* [1]. We have applied the ultra-fast timing method [2–4] to systematically study transition rates in the neutron-rich Fe nuclei. In this presentation, we discuss new results on ^{63}Fe located at $N = 37$, thus exactly at the point of transition from spherical to collective structures.

2. Experimental details

Measurements were performed at the ISOLDE facility at CERN. Levels in ^{63}Fe were populated in the β-decay of ^{63}Mn. The Mn nuclei were obtained as fission products from the bombardment of a natural uranium target by 1.4 GeV protons. They were selectively ionized using the Resonant Laser Ion Source, extracted and separated using the High Resolution Separator providing almost pure ^{63}Mn beam. Details of the experimental procedures and results will be given in [5]. The detector setup was the same as used in the study by White *et al.,* [6]. It included five detectors arranged in a close geometry around the point of a continuous beam deposition. A thin plastic scintillator served as a fast-response β detector providing the START signal for subnanosecond lifetime measurements, while two fast-response γ scintillators: one BaF_2 of the Studsvik design and one cylindrical 2.5×2.5 cm $LaBr_3$ crystal, provided the STOP signals. The setup included also two Ge detectors of 100% relative efficiency.

Double coincidence $\beta\gamma(t)$ events and triple coincidence $\beta\gamma\gamma(t)$ events were collected using different combinations of γ detectors. These data sets were sorted off line and provided information on the γ-ray energies, intensities and $\gamma\gamma$ coincidences which helped to identify γ lines and build the level scheme of ^{63}Fe. Double and triple coincidences involving the fast-response detectors allowed for a determination of the level lifetimes.

3. Results on ^{63}Fe

The results presented here are preliminary. The level scheme of ^{63}Fe identified in this study, see Fig. 1, includes 10 excited states and 21 γ transitions. The 357 keV line was previously observed in-beam [7] via multinucleon transfer reactions. Moreover, seven γ-rays from the decay of ^{63}Mn were reported by Gaudefroy [8]. Our data confirm the placement of six of them in the level scheme, including one previously placed tentatively.

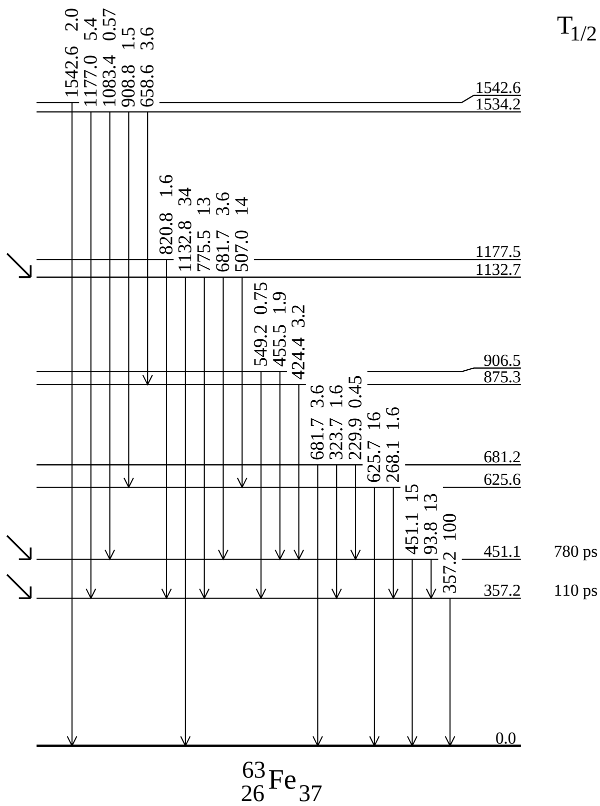

Fig. 1. Preliminary level scheme of ^{63}Fe populated in the β-decay of ^{63}Mn. Arrows on the left hand side indicate levels strongly β fed with log $ft \sim 5$.

Our measurement was done with a saturated source where the total β intensities in the decaying isobars of Mn, Fe and Co were equal. This provided an opportunity to establish absolute γ-ray intensities based on the ratio of intensities of transitions in Fe to those from the known decay of ^{63}Fe to ^{63}Co and separately from the decay of ^{63}Co to ^{63}Ni (measured in [9] and summarized in [10]). However, the decay of ^{63}Fe has incorrect absolute intensities. The sum of γ-ray intensities in the decay of ^{63}Mn to ^{63}Fe exceeded by a large factor the maximum intensity of 100% if the intensities in Fe were normalized to those from the decay of ^{63}Fe. On the other hand, the sum came to be a little more than 100% (but consistent with 100% within the error limit) if we used the second decay for intensity normalization. We conclude that the previously reported [9, 10] absolute intensities for the β-decay of ^{63}Fe are incorrect. Our data imply existence of very weak (or none) ground state to ground state β-decays from Mn to Fe and from Fe to Co. Since the β-decays in this region are dominated by strong GT transitions between neutron $f_{5/2}$ and proton $f_{7/2}$ with $\log ft$ as low as 4.7, we suggest that the spin/parity of the ground state of ^{63}Fe is not $5/2^-$. Otherwise it would have a strong neutron $f_{5/2}$ component and at least a strong β branch in the decay of ^{63}Fe to the ground state of ^{63}Co.

The half-lives of the first two excited states at 357 and 451 keV are 110 ps and 780 ps, respectively, and imply a M1 character for the 93 and 357 keV transitions with typical B(M1) values of 0.4–2.0 $\times$ 10^{-2} W.u.. Otherwise they would be exceedingly collective E2 transitions for a nucleus at the shell closure with the B(E2) values of 2000 W.u. and 60 W.u., respectively (we exclude here the possibility of an E1 type). In all odd-N nuclei in this region the lowest three lying states are due to the neutron $p_{1/2}$, $p_{3/2}$ and $f_{5/2}$ orbits and thus have spin/parities $1/2^-$, $3/2^-$ and $5/2^-$, respectively. If the ground state and the 357 and 451 keV levels are such states, then the M1 γ-ray sequence implies that the order of levels is either $1/2^-$, $3/2^-$ and $5/2^-$, or $5/2^-$, $3/2^-$ and $1/2^-$, respectively, with either $1/2^-$ or $5/2^-$ as the ground state of ^{63}Fe. However, the β feedings strongly favor the $1/2^-$ case. Consequently, in ^{63}Fe we likely have the $1/2^-$, $3/2^-$ and $5/2^-$ sequence of the lowest-lying states in contrast to the sequence $5/2^-$, $1/2^-$ and $3/2^-$ determined in the heavier $N = 37$ isotones of Ni and Zn.

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