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Spectroscopy of N=82,83 $^{136.137}$Xe Isotopes From ^{248}Cm Fission

P. Bhattacharyya[1], C.T. Zhang[1], P.J. Daly[1], Z.W. Grabowski[1], R. Broda[1*], B. Fornal[1*], I. Ahmad[2], T. Lauritsen[2], L.R. Morss[2], W.R. Phillips[3], J.L. Durell[3], M.J. Leddy[3], A.G. Smith[3], W. Urban[3†], B.J. Varley[3], N. Schulz[4], E. Lubkiewicz[4¶], M. Bentaleb[4], J. Blomqvist[5]

[1] *Purdue Univeristy, West Lafayette, IN 47907, USA.*
[2] *Argonne National Laboratory, Argonne, IL 60439, USA*
[3] *University of Manchester, M13 9PL Manchester, UK*
[4] *Institut de Recherches Subatomiques, Universite Louis Pasteur, F-67037 Strasbourg, France*
[5] *Royal Institute of Technology, S-10405 Stockholm, Sweden*

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Abstract. Prompt γ-ray cascades in neutron-rich nuclei around doubly magic ^{132}Sn have been studied at Eurogam II using a ^{248}Cm fission source. Here we report results for the four-valence-proton N=82 nucleus ^{136}Xe and for its N=83 neighbor ^{137}Xe. For both nuclei, the yrast level spectra have been considerably extended, and empirical nucleon-nucleon interactions have been used to assign probable shell model configurations for most of the observed levels.

The advent of large multidetector γ-ray arrays has made it possible to study prompt and delayed γ-ray cascades in fission product from actinide sources [1]. We have been investigating the yrast excitations of few-valence-particle nuclei around doubly magic ^{132}Sn by analyzing fission product γ-ray data recorded at Eurogam II using a ^{248}Cm source. First results for the two- and three-proton N=82 nuclei ^{134}Te and ^{135}I [2], for the two-neutron nucleus ^{134}Sn [3], and for the N=83 nuclei ^{134}Sb, ^{135}Te, and ^{136}I [4] have already been published.

We have now extended these studies to the four-valence-proton N=82 nucleus ^{136}Xe, and to its N=83 neighbor ^{137}Xe. The investigation of ^{136}Xe faced initial difficulties since its predicted yield in ^{248}Cm fission is only 0.4%, and the 3 μs half-life of the ^{136}Xe yrast 6^+ state ruled out the possibility of identifying higher-lying γ-rays from the $\gamma\gamma\gamma$ data. A second 6^+ state in ^{136}Xe, known from β-decay [5,6], de-excites to the 6^+ isomer by a 370 keV M1/E2 transition but no states with I > 6 have been placed in ^{136}Xe scheme up to now. In the present work, double gating on 381 and 1313 keV γ-rays de-exciting the lowest 4^+ state in ^{136}Xe showed in coincidence (Fig. 1(a)) a few strong ^{136}Xe γ-rays, which feed the 4^+ state directly,

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as well as cross coincident $^{106-109}$Mo γ-rays from complementary fission fragments. Indeed the strongest peaks in Fig. 1(a) are the 193, 371 and 527 keV γ-rays of ^{108}Mo, the 4n fission partner of ^{136}Xe. Double gating on ^{108}Mo γ-rays showed in coincidence (Fig. 1(b)) known γ-rays of ^{108}Mo, ^{136}Xe, ^{137}Xe and ^{138}Xe, and some other lines. Of these, the 370 keV γ-ray in Fig. 1(b) was taken to be the ^{136}Xe $6_2^+ \rightarrow 6_1^+$ transition previously mentioned, while the 968 and 975 keV γ-rays also appeared attractive candidates for placement in ^{136}Xe above the 3 μs isomer; the 370 and 968 keV γ-rays were subsequently found to be in prompt coincidence. Double gating on the 370 and 968 keV γ-rays gave the Fig. 1(c) coincidence spectrum, where the relative intensities of cross-coincidence $^{106-109}$Mo γ-rays are seen to be closely similar to those in Fig. 1(a), thus providing vital support for placement of the 370 and 968 keV γ-ray pair in the ^{136}Xe scheme. Additional γ-rays now assigned to ^{136}Xe are also labelled in Fig. 1(c). These and other coincidence spectra showed

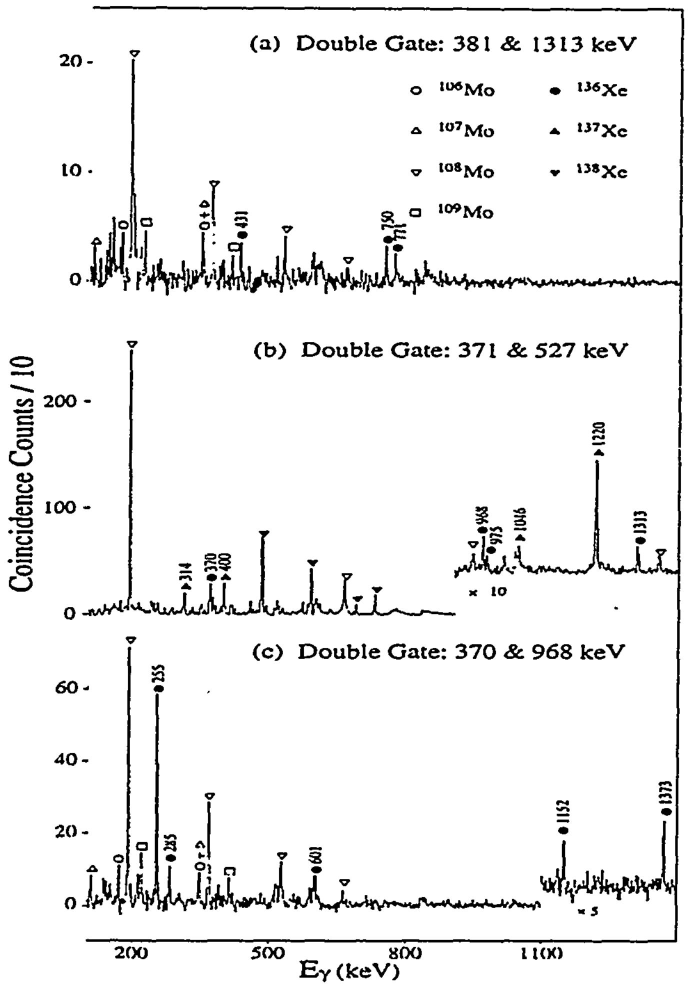

FIGURE 1. Key γ-γ coincidence spectra for the isotopic identification of ^{136}Xe transitions and construction of the ^{136}Xe level scheme.

clearly that two main cascades feed the ^{136}Xe 6^+ isomer, one consisting of 255, 968 and 370 keV γ-rays, the other in parallel of 618 and 975 keV transitions as shown in the extended ^{136}Xe level scheme (Fig. 2). Tentative spin-parity assignments and probable four-proton configurations are also indicated in Fig. 2. The highest levels located at 5953 and 6173 keV may be core-excited $\pi g^4_{7/2}\nu f_{7/2}h^{-1}_{11/2}$ states similar to the yrast 12^+ and 13^+ states at ~6 MeV in ^{134}Te.

Many years ago a study of delayed γ-rays following ^{252}Cf fission assigned to the N=83 nucleus ^{137}Xe a cascade of 314, 400, and 1221 keV γ-rays de-exciting an isomer with $t_{1/2} \sim 8$ ns [7]. The same γ-rays were previously reported in Ref. [8], where they were not assigned. The levels of ^{137}Xe populated in β^- dcay of ^{137}I includes a 1220 keV level that de-excites to the $7/2^-$ ground state [9]; this level was later identified as the $11/2^-$ level [10]. First inspection of the data from the present fission product measurements revealed strong 314.0, 400.2 and 1220.0 keV γ-rays in mutual coincidence, which provided an excellent starting point for further investigation of the ^{137}Xe yrast levels. Detailed analyses of the $\gamma\gamma\gamma$ data then led to the ^{137}Xe scheme shown in Fig. 2. In this case, the multipole order of the strongest transitions could be determined from DCO measurements and these results are also included in Fig. 2. The broad similarity between the ^{136}Xe and ^{137}Xe yrast level structures is evident as most of the levels in ^{137}Xe can be explained by the coupling of the $f_{7/2}$ neutron with the ^{136}Xe levels.

One of the main aims in studying the spectroscopy of few-valence-particle nuclei around ^{132}Sn is to characterize the nucleon-nucleon interactions in this region. To perform shell model calculations for the N=82 isotones, the simplest method is

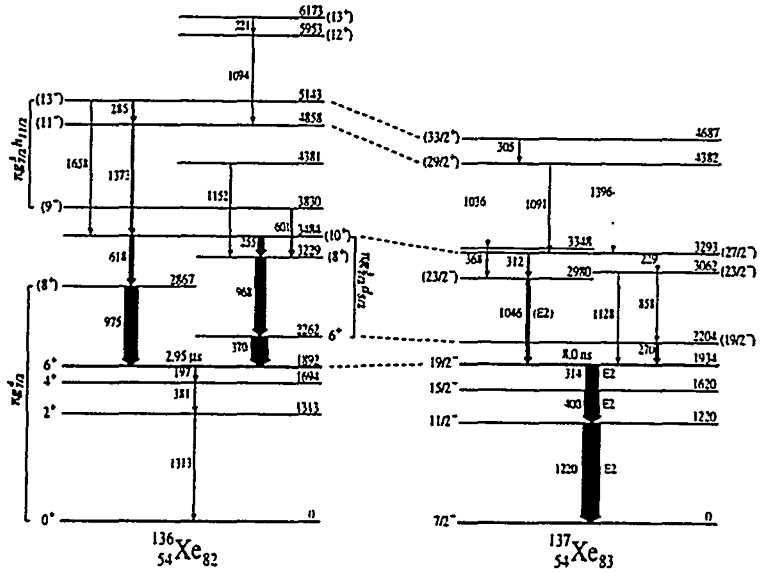

FIGURE 2. Proposed level schemes of ^{136}Xe and ^{137}Xe. The corresponding states have been connected by dashed lines.

to adopt two-body interactions from the experimental level spectrum of the two-proton nucleus ^{134}Te. This approach, which takes account of diagonal matrix elements only, and thereby neglects configuration mixing, provided valuable guidance in the interpretation of the observed ^{136}Xe levels. A few years ago, Wildenthal [11] performed comprehensive shell model calculations for all N=82 nuclei then known, and used an iterative procedure to obtain a best fit set of 160 two-body matrix elements, both diagonal and off-diagonal. When the ^{136}Xe level energies were calculated using Wildenthal's parameters rather than those directly from ^{134}Te, the mean deviation between theory and experiment decreased from 92 to 28 keV. Since the results for ^{135}I and ^{136}Xe attained in our work are significant addidtions to the data base and first results for the five-proton N=82 nucleus ^{137}Cs are forthcoming [12], it will now be possible to update the nucleon-nucleon interaction matrix elements in this region.

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[*] On leave from Institute of Nuclear Physics, PL-31342 Cracow, Poland

[†] Present address: Institute of Experimental Physics, Warsaw University, PL-00681 Warsaw, Poland

[¶] On leave from Institute of Physics, Jagellonian University, Reymonta 4, PL-30-059 Cracow, Poland

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