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FAST-TIMING MEASUREMENT IN ^{96}Pd :
IMPROVED ACCURACY FOR THE LIFETIME
OF THE 4_1^+ STATE*

A. YANEVA^{a,b}, S. JAZRAWI^{c,d}, B. DAS^{b,e}, M. MIKOLAJCZUK^{b,f}
M. GÓRSKA^b, P.H. REGAN^{c,d}, B. CEDERWALL^e, J. JOLIE^a
G. BENZONI^g, H.M. ALBERS^b, S. ALHOMAIDHI^{b,h,i,j}, T. ARICI^b
A. BANERJEE^b, M.M.R. CHISHTI^c, T. DAVINSON^k, J. GERL^b
O. HALL^k, N. HUBBARD^{b,h,i}, I. KOJOUHAROV^b, A.K. MISTRY^{b,h,i}
M. POLETTINI^{g,l}, M. RUDIGIERⁱ, E. SAHIN^{b,h,i}, H. SCHAFFNER^b
A. SHARMA^m, H.J. WOLLERSHEIM^b, P. BOUTACHKOV^b, T. DICKEL^b
E. HAETTNER^b, H. HEGGEN^b, CH. HORNUNG^b, R. KNÖBEL^b
D. KOSTYLEVA^b, N. KURZ^b, N. KUZMINCHUK^b, I. MUKHA^b
S. PIETRI^b, W.R. PLASS^b, Zs. PODOLYAK^c, C. SCHEIDENBERGER^b
Y.K. TANAKAⁿ, J. VESIC^o, H. WEICK^b, U. AHMEDⁱ, Ö. AKTAS^e
A. ALGORA^{p,q}, C. APPLETON^k, J. BENITO^r, A. BLAZHEVA^a
A. BRACCO^{g,l}, A. BRUCE^s, M. BRUNET^c, R. CANAVAN^{c,d}
A. ESMAYLZADEH^a, L.M. FRAILE^r, G. HÄFNER^{a,t}, K.P. HUCKAⁱ
P.R. JOHNⁱ, D. KAHL^k, V. KARAYONCHEV^a, R. KERNⁱ, G. KOSIR^{o,u}
R. LOZEVA^t, P. NAPIRALLAⁱ, B.S. NARA SINGH^v, R.D. PAGE^w
C.M. PETRACHE^t, N. PIETRALLAⁱ, J.-M. REGIS^a, H. RÖSCHⁱ
P. RUOTSALAINEN^x, V. SANCHEZ-TEMBLE^r, L. SEXTON^k
R. SHEARMAN^d, M. SI^t, V. WERNER^{h,i}, J. WIEDERHOLDⁱ
K. WIMMER^b, W. WITTⁱ, P. WOODS^k, G. ZIMBA^x

on behalf of DESPEC Collaboration

^aInstitut für Kernphysik der Universität zu Köln, 50937 Köln, Germany

^bGSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany

^cDepartment of Physics, University of Surrey, Guildford, GU2 7XH, UK

^dNational Physical Laboratory, Teddington, Middlesex, TW11 0LW, UK

^eKTH Royal Institute of Technology, Stockholm, Sweden

^fFaculty of Physics, University of Warsaw, 00-681 Warsaw, Poland

^gINFN, Sezione di Milano, Milano, Italy

^hTechnische Universität Darmstadt, Department of Physics
Institute for Nuclear Physics, Schlossgartenstr. 9, 64289 Darmstadt, Germany

ⁱHelmholtz Forschungsakademie Hessen für FAIR (HFHF)

GSI Helmholtzzentrum für Schwerionenforschung

Campus Darmstadt, 64289 Darmstadt, Arheilgen

^jKing Abdulaziz City for Science and Technology (KACST)

P.O. Box 6086, Riyadh 11442, Saudi Arabia

^kSchool of Physics and Astronomy, University of Edinburgh
Edinburgh EH9 3FD, UK

^lDipartimento di Fisica, Università degli Studi di Milano, Milano, Italy

^mDepartment of Physics, Indian Institute of Technology Ropar
Rupnagar 140001, Punjab, India

ⁿHigh-Energy Nuclear Physics Laboratory, RIKEN, 351-0198 Saitama, Japan

^oJožef Stefan Institute, Jamova cesta 39, 1000 Ljubljana, Slovenia

^pInstituto de Física Corpuscular, CSIC-Universidad de Valencia
46071 Valencia, Spain

^qInstitute for Nuclear Research (ATOMKI)
Bem ter 18/c, 4026 Debrecen, Hungary

^rGrupo de Física Nuclear and IPARCOS, Universidad Complutense de Madrid
CEI Moncloa, 28040 Madrid, Spain

^sSchool of Computing Engineering and Mathematics, University of Brighton
BN2 4AT Brighton, UK

^tUniversité Paris-Saclay, IJCLab, CNRS/IN2P3, 91405 Orsay, France

^uFaculty of Mathematics and Physics, University of Ljubljana, Ljubljana, Slovenia

^vSchool of Computing, Engineering and Physical Sciences
University of the West of Scotland, PA1 2BE Paisley, UK

^wDepartment of Physics, Oliver Lodge Laboratory, University of Liverpool
Liverpool L69 7ZE, UK

^xUniversity of Jyväskylä, Seminaarinkatu 15, 40014 Jyväskylän yliopisto, Finland

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Direct lifetime measurements via γ - γ coincidences using the FATIMA fast-timing LaBr₃(Ce) array were performed for the excited states below previously reported isomers. In the $N = 50$ semi-magic ⁹⁶Pd nucleus, lifetimes below the $I^\pi = 8^+$ seniority isomer were addressed as a benchmark for further analysis. The results for the $I^\pi = 2^+$ and 4^+ states confirm the published values. Increased accuracy for the lifetime value was achieved for the 4^+ state.

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1. Introduction

In March 2020, the first experiment of the DEcay SPEcTrosCOPy (DE-SPEC) setup [1] as part of the FAIR Phase-0 campaign was performed at the GSI Helmholtzzentrum für Schwerionenforschung. The focus of this experiment was the measurement of electromagnetic transition rates between excited states below known isomers using the fast-timing technique [2–5]. In particular, the main goal was an investigation of the decay of the 14^+ , $T_{1/2} = 499(13)$ ns isomer in ⁹⁴Pd [5–8]. In the same experiment, lifetimes in several $N = 50$ isotones were studied for the first time [9, 10]. In addition, the known isomeric decay of the $I^\pi = 8^+$ state in ⁹⁶Pd was observed and used as a reference case for other lifetime measurements in order to verify the

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setup and the analysis method. Indeed, ^{96}Pd , with its four proton holes in the doubly-magic ^{100}Sn core, has proven to be attractive for nuclear structure studies in the last four decades [3, 11–13]. However, the lifetimes of the intermediate states below the isomer were reported only recently [12] and the conservation of the seniority quantum number was addressed. The last work indicated a seniority breakdown based in particular on the lifetime measurement of the 4^+ state, which, therefore, called for independent experimental verification.

2. Experimental details

The isomeric states in the nuclei of interest were produced by the fragmentation of a ^{124}Xe primary beam at 982 A MeV impinging on a 4 g/cm² thick ^9Be target [7]. The cocktail beam of secondary particles was analyzed in the FRagment Separator (FRS) [14]. Standard tracking detectors and separation methods were used to select and identify the species of interest on an event-by-event basis in terms of their mass-to-charge ratio (A/Q) and atomic number (Z).

Ions arriving at the final focal plane of the FRS were implanted in the Advanced Implantation Detector Array (AIDA) active stopper [15]. AIDA is situated in the center of the DESPEC setup in between two β -plastic scintillation detectors for fast β -decay time reference [1]. For registering γ -rays, 36 LaBr₃(Ce) detectors (FATIMA) [16] and 6 triple cluster HPGe detectors (GALILEO) [17, 18] were used surrounding the implantation setup. The FATIMA array served for fast-timing spectroscopy, while GALILEO provided precise energy information.

3. Data analysis

The specific isotopes of interest were unambiguously selected by gating on Z and A/Q obtained from the FRS, thus enabling the study of the delayed γ -ray transitions in ^{96}Pd (see Fig. 1). To determine the lifetimes of intermediate states populated in the decay of the 8^+ isomer, the $E_{\gamma}-E_{\gamma}-\Delta t$ correlations were analyzed. Two methods were used to obtain the lifetimes of the 4^+ and 2^+ states: a fit of the exponential decay curve to the data, and the Generalized Centroid Difference Method (GCDM) [19].

As shown in Fig. 2(a), the time difference distribution for the 684–1415 keV coincidence is symmetric, consistent with the expected short lifetime of the 2^+ state. Using the GCDM (Fig. 2(b)), the upper limit of $T_{1/2} \leq 14$ ps was obtained after taking into account the PRD (Prompt Response Distribution) correction. Based on the small lifetime value of the 2^+ state, the 4^+ single experimental decay was fitted to the sum of time difference distributions for the 684 keV and 1415 keV transitions with re-

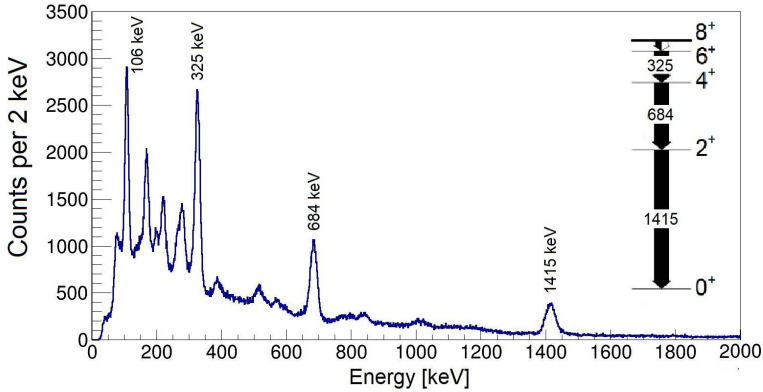


Fig. 1. Energy spectrum for isomer-delayed γ -rays obtained from FATIMA correlated to implantation of ^{96}Pd . The known transitions below the 8^+ isomer were labelled. The other peaks correspond to ^{139}La and $^{79,81}\text{Br}$ neutron-induced γ -rays and background lines. The inset shows the level scheme.

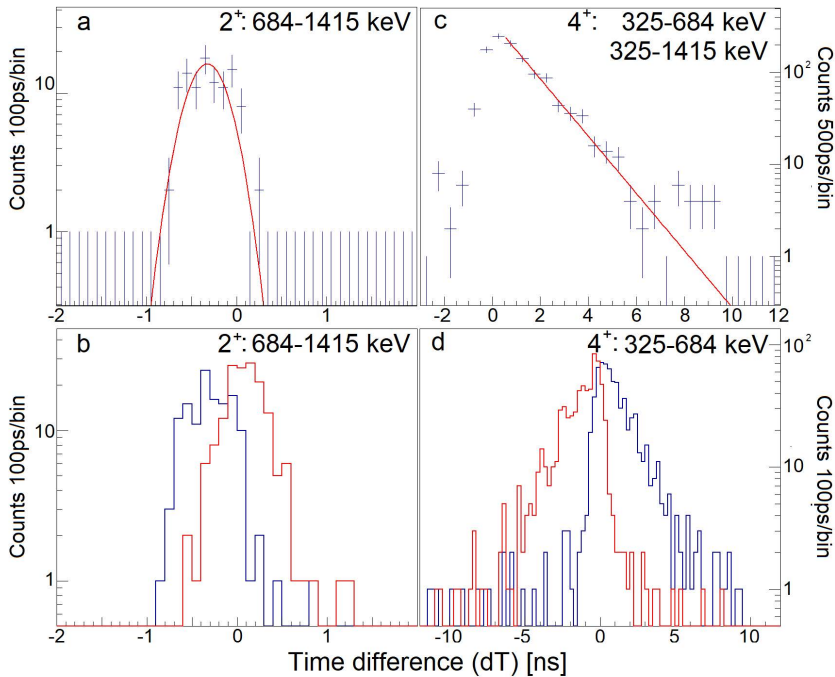


Fig. 2. (a), (c) Background-subtracted time difference distributions of γ -rays feeding and depopulating the 2^+ and 4^+ states, respectively. The spectrum for the 4^+ state is a sum of the distributions for two feeder-decay coincidences (see the text). (b), (d) Delayed and anti-delayed time distributions for the 2^+ and 4^+ states, respectively [19].

spect to the 325 keV feeder. The half-life of $T_{1/2} = 1.00(5)$ ns was obtained for the fit to the spectrum (Fig. 2(c)) as well as for the GCDM method (Fig. 2(d)). As preliminarily indicated by Jazrawi *et al.* [3], the obtained results are consistent with previously published data by Mach *et al.* (1.0(1) ns and ≤ 17 ps) [12]. Moreover, in the present analysis, the accuracy of the determined lifetime of the 4^+ state was increased.

4. Conclusion

The half-lives for the yrast 4^+ and 2^+ states of ^{96}Pd were measured using a single exponential decay fit to the data and the Generalized Centroid Difference Method. The obtained values are consistent with previously published data for these states. An increased accuracy was achieved for the lifetime of the 4^+ state.

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