

One-Proton and Two-Proton Radioactivity of the (21⁺) Isomer in ⁹⁴Ag

E. Roeckl^a, I. Mukha^{a,b,c}, L. Batist^d, A. Blazhev^{a,e}, J. Döring^a, H. Grawe^a, L. Grigorenko^f, M. Huysse^b, Z. Janas^g, R. Kirchner^a, M. La Commara^h, C. Mazzocchi^{a,i}, S. L. Tabor^k, P. Van Duppen^b

^aGSI, Darmstadt, Germany; ^bKU, Leuven, Belgium; ^cRRC Kurchatov Institute, Moscow, Russia; ^dPNPI, St. Petersburg, Russia; ^eUniversity of Sofia, Bulgaria; ^fJINR, Dubna, Russia; ^gUniversity of Warsaw, Poland; ^hUniversità "Federico II" and INFN, Napoli, Italy; ⁱUniversity of Tennessee, Knoxville, USA; ^kFlorida State University, Tallahassee, USA

The (21⁺) isomer occurring in the lightest known isotope of silver, ⁹⁴Ag, has properties that are unmatched in the entire nuclear chart. It is characterised by a long half-life of 0.39(4) s [1], a high spin [2] and, although its dominant disintegration modes are β -delayed γ -ray [2] or proton [1] emission, the excitation energy of 6.7(5) MeV [3] makes direct one-proton (1p) and two-proton (2p) radioactivity possible. The experimental results on the latter two decay modes that have recently been published [3,4] will be summarised here.

The decay properties of the (21⁺) isomer were studied at the GSI on-line mass separator by using a ⁵⁸Ni (⁴⁰Ca,p3n) fusion-evaporation reaction. After ionisation and acceleration to 55 keV, the A=94 ions were mass separated and implanted into a tape positioned in the centre of an array of segmented silicon and composite germanium detectors. The tape was periodically removed from the implantation position in order to reduce the build-up of long-lived daughter activity. While the silicon detectors were used to record protons the germanium crystals served to 'tag' on known γ -ray transitions in the 1p daughter, ⁹³Pd, and the 2p daughter, ⁹²Rh, respectively. In this way the 1p and 2p radioactivity was identified, the decay energies and decay probabilities amounting to 0.79 MeV, 1.01 MeV and 1.9(5) %, 2.2(4) % in the former and 1.9(1) MeV and 0.5(3) % in the latter case. The cross-section for producing the 2p radioactivity in the fusion-evaporation reaction was found to be about 350 pb [5].

By comparing the experimental partial half-lives of the two 1p-decay modes with WKB estimates, very small spectroscopic factors of 1×10^{-6} and 3×10^{-7} were deduced [3]. The experimental proton-proton correlation data are displayed in Fig. 1 together with predictions obtained from the break-up model ([4] and references therein). The spectra displayed in Fig. 1 were derived out of the Si₁-Si₂- γ - γ coincidence matrix, with a total of 19 events fulfilling the triple condition set on two ⁹²Rh γ -transitions and on the 2p sum-energy in the range of 1.8–1.95 MeV.

In general, 2p decay can proceed through sequential proton emission involving intermediate ⁹³Pd states, or through a simultaneous three-particle decay mechanism. The former decay should result in narrow peaks in the

spectrum shown in Fig. 1b whose energies depend on the (unknown) energy of the ⁹²Rh state involved and should add up to a total of 1.9(1) MeV. As there is no evidence for such peaks (see Fig. 1b), the observed proton-proton correlations seem to be consistent only with ⁹⁴Ag decaying through a simultaneous 2p emission process. For ⁹⁴Ag such a 'true' 2p-decay is expected to be much slower than the sequential decay mode: However, the 2p-decay half-life estimated by using the 'simultaneous emission' model exceeds the experimentally determined half-life by a factor of $10^3 - 10^6$. Finally, the experimental results on the 2p half-life and on the proton-proton energy correlation are interpreted, on the basis of a comparison with predictions from the breakup model, as indicating a very large, prolate deformation of the parent nucleus, with the emission of protons occurring either from the same or from opposite ends of the 'cigar' [4].

All in all, it is the first time that 1p and 2p radioactivity has been identified to occur from one and the same nuclear state and it is the first time that proton-proton correlations have been observed in 2p radioactivity. The interpretation of the strong deformation of the (21⁺) isomer in ⁹⁴Ag is indeed a challenge for future experimental and theoretical work.

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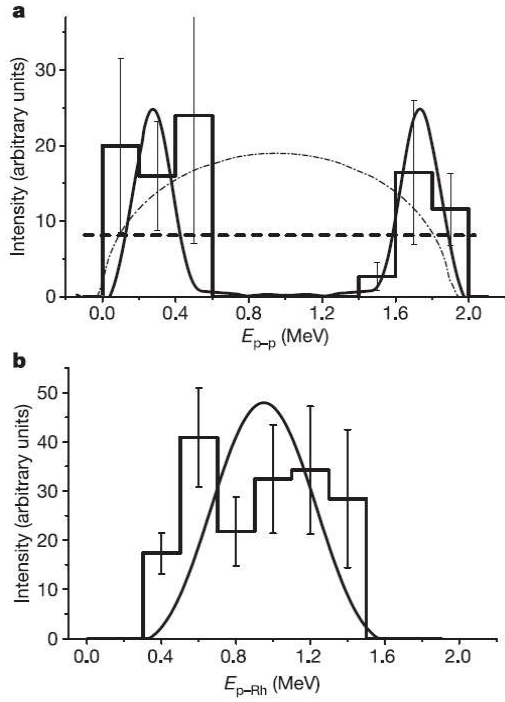


Figure 1: Correlations observed in the 2p decay of the (21^+) isomer of ^{94}Ag . Relative-energy spectra for proton-proton (E_{p-p}) and proton- ^{92}Rh (E_{p-Rh}) correlations are shown by histograms in **a** and **b**, respectively. The solid curves are the predictions of our model of simultaneous proton emission from a deformed nucleus convoluted with an experimental uncertainty of 200 keV. The dashed line represents the fit obtained with a sequential emission mechanism. The dashed-dotted curve shows the calculated distribution when the 2p decay is isotropic in the absence of the mentioned decay mechanisms [4].