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BB **Study of Short-Lived Silver Isotopes with
a Laser Ion Source**

V.N. Fedoseyev¹, P. van Duppen², G. Huber³, Y. Jading⁴,
O.C. Jonsson², R. Kirchner⁵, K.-L. Kratz⁴, M. Krieg³, E. Kugler²,
J. Lettry², T. Mehren⁴, V.I. Mishin¹, T. Rauscher⁴, H.L. Ravn²,
F. Scheerer⁴, O. Tengblad², A. Wöhr⁴ and the
ISOLDE Collaboration²

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¹ *Institute of Spectroscopy, Russian Academy of Sciences, 142092 Troitzk, Russia*

² *CERN, CH-1211 Geneva 23, Switzerland,*

³ *Institut für Physik, Universität Mainz, D-5099 Mainz, Germany*

⁴ *Institut für Kernchemie, Universität Mainz, D-55099 Mainz, Germany*

⁵ *GSI, D-64220 Darmstadt, Germany*

Abstract. A chemically selective laser ion source based on resonance ionization of atoms in a hot cavity has been applied for the study of short-lived silver isotopes at CERN/ISOLDE. Silver atoms were ionized by two resonant excitations and final laser ionization into the continuum. Decay properties of the neutron-rich isotopes ¹²¹⁻¹²⁷Ag were studied with a neutron long-counter and a β -detector.

Astrophysics and nuclear physics are inextricably entwined. In particular, the synthesis of the chemical elements takes place at various stellar sites as a result of nuclear reactions. At high neutron fluxes ($n_n \geq 10^{20} \text{ cm}^{-3}$), r-process nucleosynthesis of medium and heavy elements proceeds along paths far from stability. The final isotopic r-abundances are the result of a competition between successive neutron captures and β -decays; hence, nuclear and astrophysics input parameters must be compatible with these observables [1]. With regard to nuclear-physics data, of particular interest are the $T_{1/2}$ and P_n -values of certain "waiting-point" isotopes in the regions of the $A \approx 80$ and 130 r-abundance peaks.

Previous studies of ¹³⁰Cd₈₂ and ⁷⁹Cu₅₀ β -decay properties at ISOLDE using a hot plasma ion source were strongly complicated by isobar and molecular-ion contaminations. Therefore, it was proposed to use a chemically selective laser ion source (LIS) based on resonance ionization of atoms in a hot cavity for the investigation of neutron-rich silver isotopes, in particular the the N=82 "waiting-point" nucleus ¹²⁹Ag. Recently, a LIS has been developed for the CERN/ISOLDE on-line facility which allows to suppress the isobaric background and provides a high ionization efficiency of silver isotopes [2]. In this source, the atoms of interest were ionized by a stepwise resonant laser excitation inside a long, thin capillary connected to the target and kept at high temperature. A schematic view of the laser set-up installed at the new PS-

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Figure 1: Schematic view of the laser installation at the PS-Booster ISOLDE facility at CERN: GPS - General Purpose Separator, CVL - Copper Vapor Lasers.

Booster ISOLDE facility is shown in Fig. 1. It consists of three copper vapor tubes, one of them working as an oscillator and two as amplifiers at a pulse repetition rate of 10 kHz ($P_{total} = 55$ W), and two dye lasers equipped with microprocessor controlling of the wavelengths. Ultraviolet radiation was generated by frequency doubling with a non-linear BBO crystal. The laser beams were focussed over a distance of 20 m through a window in the separator magnet into a hole ($d_{hole} = 2$ mm) of the LIS.

The silver atoms were excited by two resonant transitions at $\lambda_1 = 328.07$ nm and $\lambda_2 = 546.55$ nm, respectively, and a transition into the continuum in the final step. The resonant transitions were deeply saturated by laser powers of 5 mW and 400 mW, respectively. The ionizing transition was not saturated, although for this step a low-divergency copper vapor laser beam ($\lambda_3 = 510.65$ nm) has been applied. Since an unstable resonator set-up consisting of a convex and a concave mirror serving for a laser beam expansion was used for the copper vapor oscillator, the divergency of the amplified radiation was reduced. Nevertheless, it was not possible to focus more than 2.5 W, only a rather small fraction of the total beam power, into the hole of the LIS.

Several test experiments with stable silver and indium isotopes have been carried out in order to find an appropriate construction of the cavity, and to define the ionization efficiency and selectivity of the LIS. Tungsten, carbon, niobium and tantalum have been tested as wall material of the capillary. Taking into account data of previous tests [2], a niobium capillary with an inner diameter of 2 mm and a length of 30 mm has been prepared for the investigation of short-lived silver isotopes.

Very recently, an experiment to study neutron-rich Ag nuclides has been carried out at ISOLDE. The isotopes were produced by proton induced fission of ^{238}U in a thick (11 g/cm^2) UC_2 -target. The temperature of target and capillary was kept at 2400-2500 K. Since within an isobaric chain only the most neutron-rich isotopes emit β -delayed neutrons, a high-efficiency 4π neutron long-counter was used for the selective detection of the Ag (and In) isotopes. In order to measure P_n -values a thin β -detector was placed inside the neutron counter. For masses $A = 121-130$, data were taken for two ion-source conditions. With the lasers off, only delayed-neutron activities from

Table 1: Comparison of experimental half-lives ($T_{1/2}$) of neutron-rich Ag isotopes with QRPA predictions [3]

A	Beta-decay half-life, $T_{1/2}$ [ms]	
	Experiment	QRPA
121	1045 (120)	405
122	528 (11)	261
123	297 (6)	117
124	171 (10)	100
125	156 (7)	117
126	97 (8)	153
127	109 (15)	80

surface-ionized $^{127-130}\text{In}$ isotopes were observed. With the lasers on, delayed neutrons of selectively ionized $^{121-127}\text{Ag}$ isotopes could clearly be detected. For $A=121-126$, the In isobars do not yet emit neutrons. From mass scans with the neutron detector, we have obtained absolute Ag and In production yields. Although the LIS conditions were not optimized, we probably have already "seen" a ^{129}Ag component underlying the ^{129}In isobar; however, with too low intensity to extract a half-life. Preliminary results for $^{121-127}\text{Ag}$ are presented in Table 1, together with recent QRPA predictions taking into account effects from the monopole p-n residual interaction in this mass region [3]. $T_{1/2}$ -values for $^{125-127}\text{Ag}$ were obtained for the first time in this run. For $^{121-124}\text{Ag}$, the accuracy of the $T_{1/2}$ -data could be improved considerably. The analysis of the P_n -values is still in progress. It should be mentioned that during the run a temperature increase of the target caused a misalignment of the capillary with respect to the laser beams. As a result, the LIS efficiency was reduced. From the yield of the long-lived isotope ^{112}Ag , the ionization efficiency of silver during the on-line experiment was deduced to be about one order of magnitude lower than expected from the test measurements. Therefore, further improvements of the LIS system have to be considered.

Nevertheless, the decay properties of $^{121-127}\text{Ag}$ obtained in the present experiment seem to indicate new information on the $N=82$ shell strength and the evolution of the $\pi g_{9/2} - \nu g_{7/2}$ residual interaction in the exotic region "southwest" of $^{132}\text{Sn}_{82}$.

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