Vol. 41 (2010) *ACTA PHYSICA POLONICA B* No 2

PROGRESS IN TRAP ASSISTED β DECAY SPECTROSCOPY OF ^{115}Ru*

J. Kurpeta[a], J. Rissanen[b], V.-V. Elomaa[b], T. Eronen[b]
J. Hakala[b], A. Jokinen[b], P. Karvonen[b], I.D. Moore[b]
H. Penttilä[b], A. Płochocki[a], S. Rahaman[b], S. Rinta-Antila[b]
J. Ronkainen[b], A. Saastamoinen[b], T. Sonoda[b], J. Szerypo[c]
W. Urban[a], Ch. Weber[b], J. Äystö[b]

[a]Faculty of Physics, University of Warsaw
Hoża 69, 00-681 Warsaw, Poland

[b]Department of Physics, University of Jyväskylä
P.O.Box. 35, 40351, Jyväskylä, Finland

[c]Sektion Physik, University of Munich (LMU)
Am Coulombwall 1, 85748 Garching, Germany

(Received December 15, 2009)

The use of ion trap purified rare isotope beam in combination with coincidence β and γ spectroscopy is presented. Its exemplified with the β decay of a very neutron-rich isotope ^{115}Ru. Thanks to a considerable increase of yield from the JYFLTRAP ion trap system beta decay of ^{115}Ru was reinvestigated. In consequence new gamma transitions and excited levels fed by beta decay were established in ^{115}Rh. Results of half-life measurements are also presented. The very exotic nuclei of interest were produced in proton induced fission of ^{238}U target, separated with the IGISOL mass separator and purified to monoisotopic level with a Penning trap.

PACS numbers: 07.75.+h, 23.20.Lv, 27.60.+j

1. Introduction

Exotic, neutron-rich nuclei of refractory elements, produced in light-particle induced fission of uranium target, are separated with the IGISOL [1] mass separator. The separator is coupled to the JYFLTRAP Penning trap system [2] to select ions of a desired element out of the isobaric IGISOL beam. Using the JYFLTRAP for isobaric beam purification [3] provides monoisotopic samples of very exotic nuclei which are ideal for γ–γ and β–γ coincidence spectroscopy.

* Presented at the XXXI Mazurian Lakes Conference on Physics, Piaski, Poland, August 30–September 6, 2009.

Following successful trap-assisted studies of the very neutron-rich Rh [4] isotope, use of a Penning trap in nuclear spectroscopy was extended to Mo and Tc [5].

2. Experimental procedure

The nuclei of interest were produced by 25 MeV proton induced fission of a ^{238}U target. Fission products of mass number $A = 115$ were on-line separated with the IGISOL mass separator. Gamma-ray spectrum of the $A = 115$ isobars is shown in Fig. 2(a). The isobaric beam was directed to the JYFLTRAP ion trap system for mass separation to the isotopic level. The optimal resonance frequency for making a monoisotopic beam of ^{115}Ru was found in a wide range scan presented in Fig. 1.

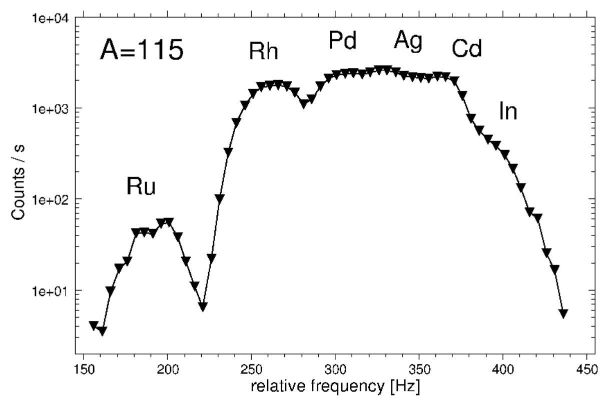

Fig. 1. Ion counts registered with the MCP detector during a wide range frequency scan of the quadrupole electric field in the trap. The well resolved atomic ions from the IGISOL isobaric beam are marked with an element symbol.

The 111 ms long purification cycle was optimised to provide high count rate for the investigated, very exotic beta decay of ^{115}Ru. Gamma spectra recorded in β decay chain of ^{115}Ru monoisotopic samples are shown in Figs. 2(b) (singles) and 2(c) (β gated). One can see the γ lines 80.2, 196.3 and 206.8 keV, visible only with ion trap beam purification.

The monoisotopic ion samples released from the trap were either detected with a microchannel plate (MCP) detector, or implanted into a movable tape at the collection point. The tape was used to remove the long-lived decay products at regular intervals of about 300 s. Our spectroscopy setup, located at the collection point, consisted of two high-purity coaxial Ge detectors for gamma rays, one Ge detector for low energy gammas and a 2 mm thick plastic scintillator surrounding the implantation point for detecting electrons from β decay.

The yield of ^{115}Ru ions released from the ion trap, see Fig. 1, was several times higher than in the previous experiment [4]. Intensity increase enabled extending of the ^{115}Ru β decay scheme.

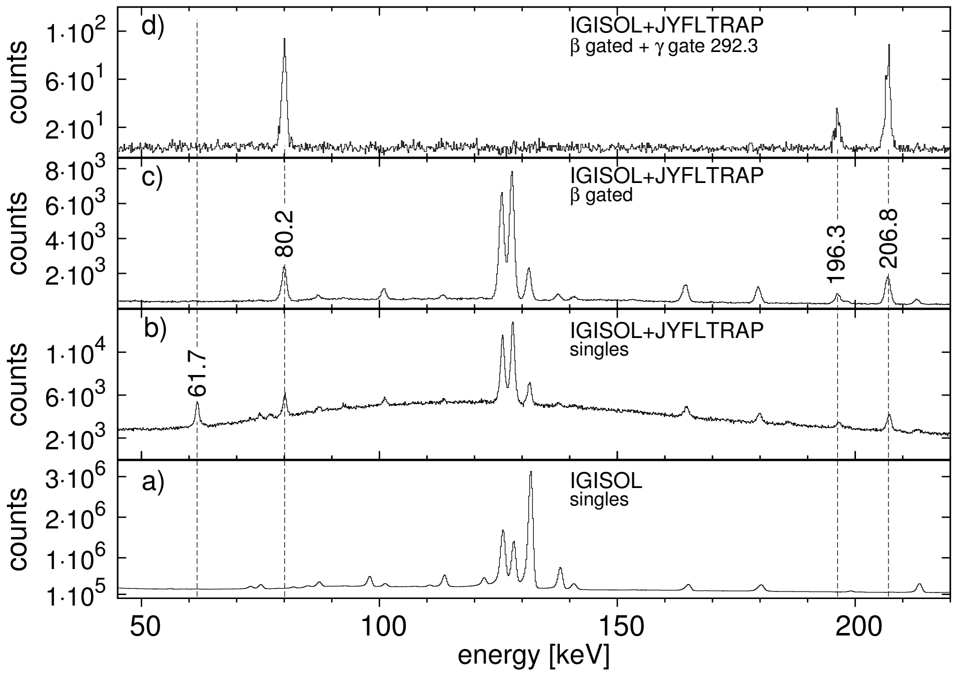

Fig. 2. Gamma spectra in a low energy Ge detector. Fig. (a) shows γ-rays emitted by nuclei in the isobaric chain $A = 115$ separated with the IGISOL only. Fig. (b) shows γ singles spectrum following beta decay of isotopically pure ^{115}Ru samples. Fig. (c) is like Fig. (b) but in coincidence with β-rays. Fig. (d) shows excellent selective power of the IGISOL mass separator coupled to the JYFLTRAP ion trap system combined with β and γ coincidence spectroscopy. The gate was set on 292.3 keV transition in ^{115}Rh.

3. Results

Preliminary analyses of γ–γ coincidences, like the one shown in Fig. 2(d), resulted in a β decay scheme presented in Fig. 3. Eight new γ transitions and five excited levels were added to the scheme as compared to the previous trap assisted study [4]. Complete analyses of ^{115}Ru β decay scheme will be published later [6].

Beta decay of the $1/2^+$ ^{115}Ru ground state will mainly populate $1/2^+$ and $3/2^+$ states in ^{115}Rh. This decay proceeds via allowed and first forbidden GT transitions which for decays very far from stability carry almost all decay intensity. Thus in ^{115}Rh, one should not expect such rich nuclear structures as in the neighbouring ^{113}Rh. In the latter the excited levels are fed by beta decay of $7/2^+$ ground state and $11/2^-$ isomer in ^{113}Ru [7]. Progress in the interpretation of ^{115}Rh level scheme can be achieved with new data on medium- and high-spin structures originating from spectroscopy of spontaneous fission fragments.

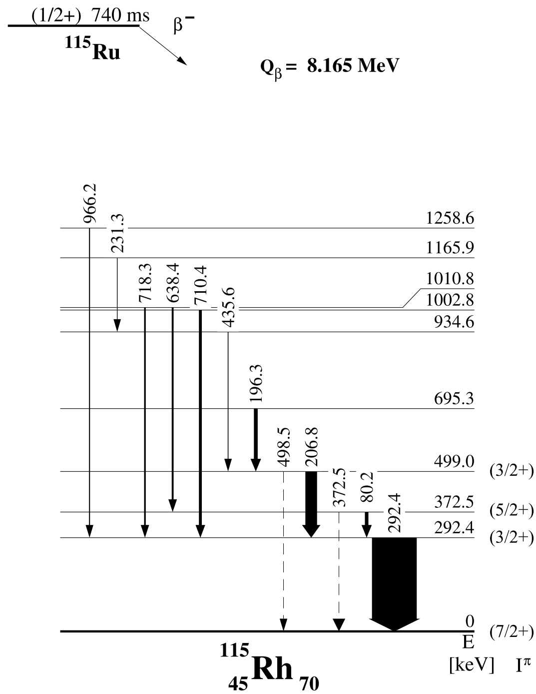

Fig. 3. A partial ^{115}Ru beta decay scheme as obtained in the present work. The 292.3 keV transition was found with the IGISOL [8], later the 80.2, 196.3 and 206.8 keV gammas were found in a trap assisted study [4].

The 61.7 keV gamma transition is present in singles spectrum (Fig. 2(b)) but not in β gated one (Fig. 2(c)). It is not present in laboratory background measured during the experiment. There is no transition of 61.7 keV energy reported for the less exotic members of $A = 115$ isobaric chain neither in the possible $A = 99$ contaminants formed as oxides. In part of our data on ^{115}Ru collected without hardware beta gating, the line 61.7 keV does not show any clear coincidence relations. Its half-life was measured as 76(14) ms, see Fig. 4.

Based on the above observations one may suspect that the 61.7 keV transition is depopulating an isomeric state. Such an isomer can be formed in ^{115}Ru if the $7/2^-$ level present in ^{111,113}Ru isotopes is located directly above the $1/2^+$ ground state of ^{115}Ru. Another possibility is the occurrence

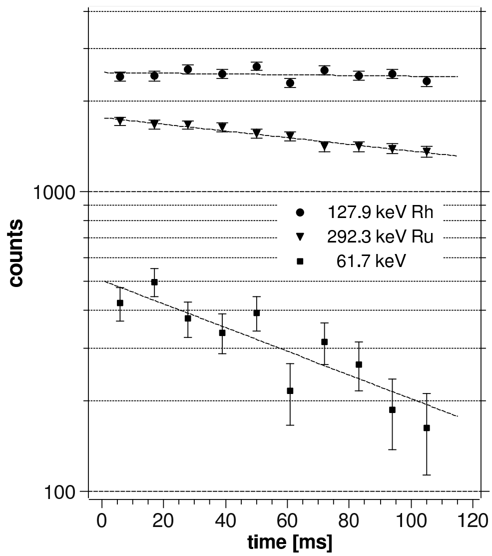

Fig. 4. Decay of 292.3 keV and 127.9 keV gamma lines which are the most intensive transitions fed in β decay of ^{115}Ru and ^{115}Rh, respectively. At the bottom the decay of 61.7 keV which may be an isomeric transition. The half-lives measured in this work are 270(38) ms for 292.3 keV and 76(14) ms for 61.7 keV.

of 61.7 keV transition in ^{115}Rh or less likely in the other $A = 115$ isobars. Final decision on the character and origin of 61.7 keV gamma cannot be made with the available statistics.

The half-life of the 292.3 keV transition, populated in ^{115}Ru β decay, was previously reported in [8] as 740(80) ms, measured on a 2.0 s long time base but with isobaric separation only. In the $A = 115$ isobaric chain there is 293.6 keV transition fed by β decay of ^{115}Pd ($T_{1/2} = 25$ s) which could partly overlap 292.3 keV making its measured half-life longer. In the present study the half-life of 292.3 keV line was estimated as 270(38) ms on a much shorter time base of 111 ms, see Fig. 4, but using a very clean source of ^{115}Ru. The 127.9 keV transition following β decay of ^{115}Rh, $T_{1/2} = 0.99(5)$ s, shows a nearly flat line as compared to the time behaviour of 292.3 keV. Due to the very exotic character of ^{115}Ru, getting a firm conclusion on the 292.3 keV half-life requires a dedicated experiment with the ion trap system optimised for decay time measurement.

Presently ^{115}Ru is the last of Ru isotopes available with the JYFLTRAP facility. The use of β and γ coincidence spectroscopy in connection with monoisotopic beams delivered by the ion trap system provides an effective way to investigate the very rare, neutron-rich fission products. Sensitivity of the method can be further improved by using more efficient, segmented Ge detectors. Getting more statistics for the ^{115}Ru β decay can provide conclusion on its half-life, origin of the possible 61.7 keV isomeric transition and set a base for the search of transitions belonging to ^{115}Rh in spontaneous fission experiments.

This work has been supported by the Polish Ministry of Science and Higher Education Grant No. N N202 007334 and by the Academy of Finland under the Finnish Centre of Excellence Programme 2006–2011 (Nuclear and Accelerator Based Physics Programme at JYFL).

REFERENCES

[1] J. Äystö, *Nucl. Phys.* **A693**, 477 (2001).

[2] A. Jokinen, T. Eronen, U. Hager, J. Hakala, S. Kopecky, A. Nieminen, S. Rinta-Antila, J. Äystö, *Eur. Phys. J.* **A25**, s01, 27 (2005).

[3] V.S. Kolhinen, S. Kopecky, T. Eronen, U. Hager, J. Hakala, J. Huikari, A. Jokinen, A. Nieminen, S. Rinta-Antila, J. Szerypo, J. Äystö, *Nucl. Instrum. Methods* **A528**, 776 (2004).

[4] J. Kurpeta, V.-V. Elomaa, T. Eronen, J. Hakala, A. Jokinen, P. Karvonen, I. Moore, H. Penttilä, A. Płochocki, S. Rahaman, S. Rinta-Antila, J. Rissanen, J. Ronkainen, A. Saastamoinen, T. Sonoda, W. Urban, Ch. Weber, J. Äystö, *Eur. Phys. J.* **A31**, 263 (2007).

[5] Annual Report 2008, Department of Physics, University of Jyväskylä, p. 14.

[6] J. Kurpeta *et al.*, in preparation.

[7] J. Kurpeta, G. Lhersonneau, A. Płochocki, J.C. Wang, P. Dendooven, A. Honkanen, M. Huhta, M. Oinonen, H. Penttilä, K. Peräjärvi, J.R. Persson, J. Äystö, *Eur. Phys. J.* **A13**, 449 (2002).

[8] J. Äystö, A. Astier, T. Enqvist, K. Eskola, Z. Janas, A. Jokinen, K.-L. Kratz, M. Leino, H. Penttilä, B. Pfeiffer, J. Żylicz, *Phys. Rev. Lett.* **69**, 1167 (1992).