PROCEEDINGS OF SCIENCE

New observation of α decay of ^{190}Pt to the first excited level of ^{186}Os

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The partial half-life of ^{190}Pt for the alpha decay to the first excited level (E_{exc}=137.2 keV) of ^{186}Os was measured using an ultralow-background HPGe-detector system located 225 m underground in the laboratory HADES (Belgium). A sample of high purity platinum (the purity grade is 99.95%) with a mass of 148.122 g was used and measured during 373 days. Preliminary, the partial half-life of ^{190}Pt is estimated as $T_{1/2} = \left[2.28^{+0.19}_{-0.16}\,(\text{stat.}) \pm 0.9\,(\text{syst.})\right] \times 10^{14}$ yr.

Particles and Nuclei International Conference (PANIC2021)
5 - 10 September, 2021
Online

*Speaker

PoS(PANIC2021)328

1. Introduction

Interest in the investigation of the alpha decay from theoretical and experimental points of view is still high. With new improvements in the experimental techniques for studying long-living rare nuclear decays, increased levels of sensitivity can be obtained. As result, new alpha decays were discovered, including some in nuclei previously considered as stable such as ^{209}Bi with $T^{\alpha}_{1/2}=1.9\times10^{19}$ yr [1].

Among platinum isotopes ^{190}Pt has the biggest energy release of Q_{α} = 3268.6(6) keV [2]. The ^{190}Pt α decay to the ground state (g.s.) of ^{186}Os was first measured in 1921 [3]; currently recommended half-live is $T^{\alpha}_{1/2}(\mathrm{g.s.})=(6.5\pm0.3)\times10^{11}$ yr [4]. The ^{190}Pt α decay to the first excited level of the daughter nuclide ^{186}Os (J^{π} = 2^{+}) was first detected by Belli et al. in [5] with half-live $T^{\alpha}_{1/2}(137\ \mathrm{keV})=(2.6\pm0.7)\times10^{14}$ yr.

The present study describes new observation of the ^{190}Pt alpha decay to the first excited level (E_{exc}=137.2 keV) of ^{186}Os using the method of ultralow-background HPGe γ-ray spectrometry.

2. Measurements

The measurements were performed in an ultralow-background HPGe-detector system located 225 m underground in the laboratory HADES (Belgium) [6]. The detector system consists of two HPGe-detectors facing each other with a platinum sample in between, see Fig. 1.

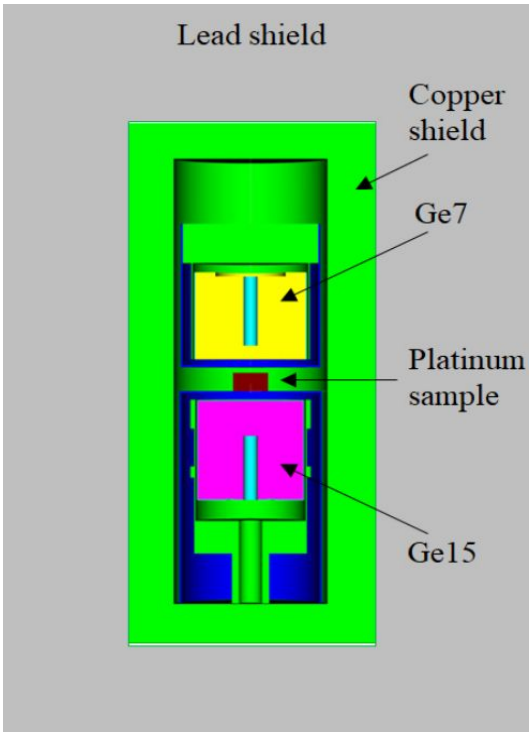

Figure 1. Schematic view of the experimental set-up with the HPGe detectors and the platinum sample, placed on the top of Ge15 detector endcap.

The sample has a disk shape with a diameter of 25.04(1) mm, a thickness of 14.07(2) mm, a mass of 148.122(1) g and with purity grade of 99.95%.

Due to a relatively big uncertainty of the representative isotopic abundance of ^{190}Pt δ = 0.012(2)% [7], mass-spectrometry measurements of the sample were performed using a sector field ICP-MS ELEMENT XR (Thermo Scientific) at the John de Laeter Centre for Isotope Research, Curtin University. A summary of the platinum isotopic composition and numbers of nuclei of the isotopes in the sample are presented in Tab. 1.

Table 1: Isotopic composition (δ) of the platinum sample measured in the present work and the numbers of nuclei of each isotope in the sample calculated by using the measured isotopic concentrations. The combined standard uncertainties of the isotopic abundances are given with a coverage factor k = 2 (approximately 95% level of confidence). The representative isotopic abundances from [7] are given too.

Isotope	δ (%)		Number of nuclei in the sample
	IUPAC [7]	this work	
^{190}Pt	0.012(2)	0.0127(1)	$5.81(5) \times 10^{19}$
^{192}Pt	0.782(24)	0.7759(16)	$3.548(7) \times 10^{21}$
^{194}Pt	32.864(410)	32.6511(522)	$1.4929(24) \times 10^{23}$
^{195}Pt	33.775(240)	33.6884(526)	$1.5403(24) \times 10^{23}$
^{196}Pt	25.211(340)	25.5376(419)	$1.1677(19) \times 10^{23}$
^{198}Pt	7.356(130)	7.3343(115)	$3.353(5) \times 10^{22}$

The data with platinum sample were collected starting from February 6th, 2018 over 373 d (live time) and measurements of background without sample were carried out for 28 d.

The energy calibration and stability check were performed using reference point sources containing ^{60}Co, ^{137}Cs and ^{241}Am.

3. Results

Part of the spectrum accumulated with the Pt sample in comparison with the background in the energy range of 50–1000 keV is shown in Fig. 2. The majority of the peaks can be assigned to ^{40}K and nuclides of the ^{232}Th, ^{235}U and ^{238}U decay families. There are also peaks of ^{22}Na, ^{26}Al, ^{54}Mn, ^{60}Co, ^{137}Cs and ^{110m}Ag. The traces of ^{22}Na, ^{26}Al and ^{110m}Ag that were detected are presumably reminiscence from neutron activation of minor impurities of the Pt sample during the neutron experiment in Dresden and during air-transportation.

The fit of the Pt spectrum, see Fig. 3, in the energy region 120–160 keV with a Gaussian peaks and exponential background assumption gives the 137-keV peak area S= 666 ± 51 counts.

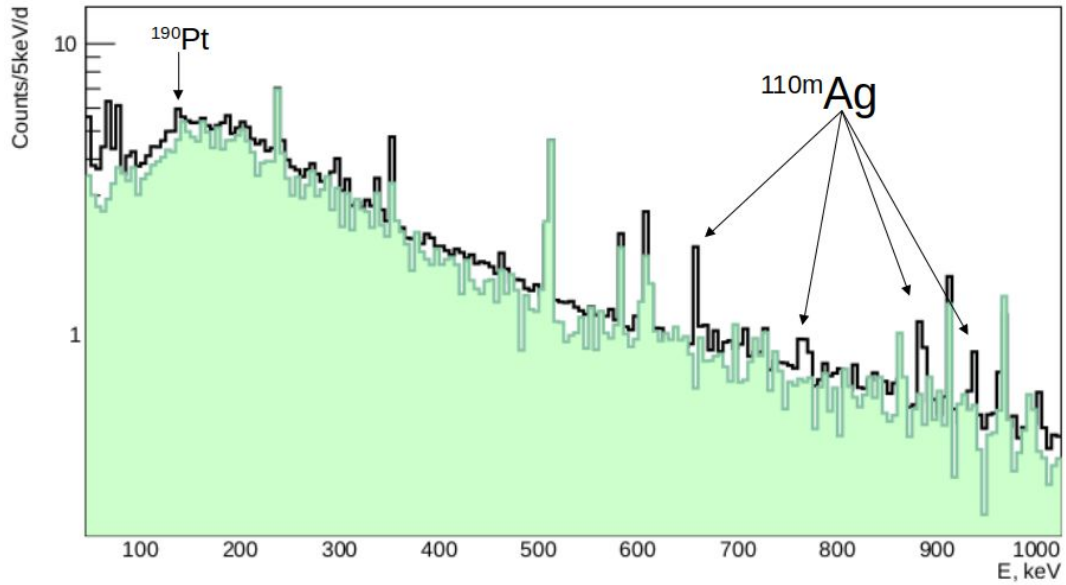

Figure 2. Energy spectrum of the Pt sample with a mass of 148 g measured during 373 d in the 50–1000 keV energy interval compared to the spectrum without sample (filled green), both normalized to time.

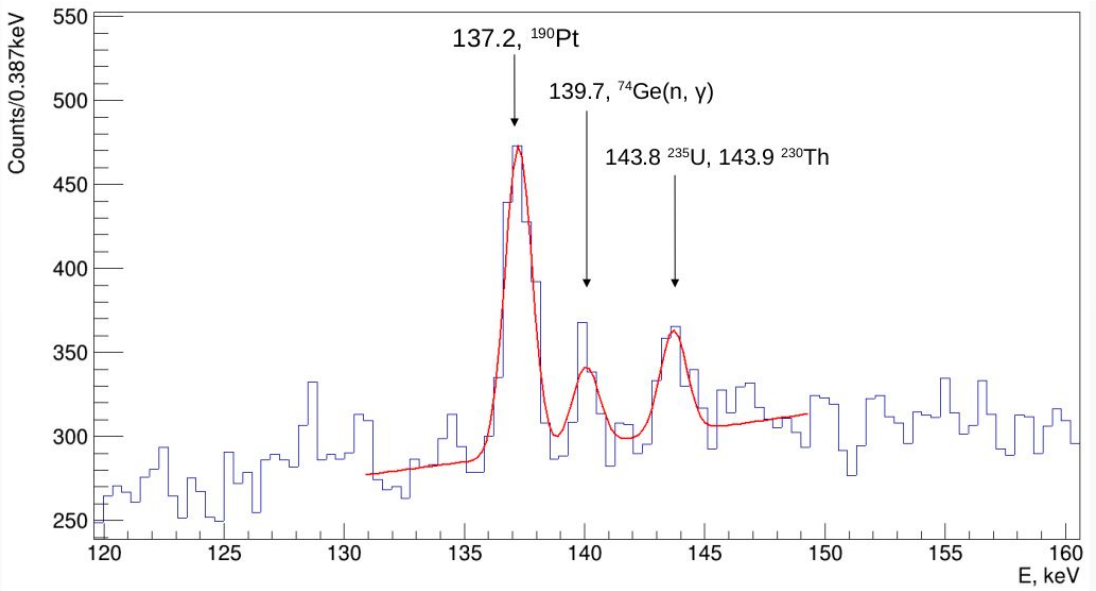

Figure 3. The energy spectrum gathered with the Pt sample in the vicinity of γ peak 137.2 keV expected in the α decay of ^{190}Pt to the the first excited level of ^{186}Os. The fit of the data is shown by solid (red) line. The energies of the background and expected γ peaks are in keV.

The 137.2-keV peak can be explained with the α decay of ^{190}Pt to the first excited level of ^{186}Os whose excitation energy is 137.159 ± 0.008 keV [4] and corresponding de-excitation emission of a γ quantum with energy E_γ =137.157 ± 0.008 keV. From the area of 137-keV peak, partial half-life for the transition to the first excited level of ^{186}Os

can be calculated as $T_{1/2}=\frac{\ln 2\cdot N_{190}\cdot\varepsilon\cdot t}{S\cdot(1+\alpha)}$, where $N_{190}=5.81(5)\cdot10^{19}$ is the number of ^{190}Pt nuclei in the 148.122(1)-g Pt sample, ε=0.0040 (0.0045) is the efficiency to detect the full energy γ for Ge15 (Ge7) detector, calculated with the EGSnrc simulation package, α=1.29 [4] is the coefficient of conversion to electrons for the given nuclear transition, t=8946 h is the live time of the measurements. Taking into account systematic uncertainties – 3.3% registration efficiency, 0.9% number of the ^{190}Pt nuclei, 1.9% approximation interval – preliminary, the partial half-life of ^{190}Pt can be estimated as $T_{1/2}[^{190}\mathrm{Pt}\rightarrow{}^{186}\mathrm{Os}(137.2\,\mathrm{keV})]=[2.28^{+0.19}_{-0.16}(\mathrm{stat.})\pm0.9(\mathrm{syst.})]\times10^{14}\,\mathrm{yr}$.

4. Conclusions

A high-purity platinum sample with mass of 148 g was measured over 8946 hours in an ultralow-background HPGe-detector γ-ray spectrometry system located 225 m underground at the HADES laboratory. The isotopic composition of the platinum sample has been measured with high precision using inductively coupled plasma mass spectrometry. The measurements allowed to reduce the uncertainty of ^{190}Pt nuclei by 20 times. Preliminary, the partial half-life of the ^{190}Pt is estimated as $T_{1/2}[^{190}\mathrm{Pt}\rightarrow{}^{186}\mathrm{Os}(137.2\,\mathrm{keV})]=[2.28^{+0.19}_{-0.16}(\mathrm{stat.})\pm0.9(\mathrm{syst.})]\times10^{14}\,\mathrm{yr}$.

Acknowledgments

This work received support from the EC-JRC open access scheme EUFRAT under Horizon-2020, project number 2018-35375-4 (PLATOS). O.G. Polischuk and M.V. Romaniuk were supported in part by the project “Investigation of double-beta decay, rare alpha and beta decays” of the program of the National Academy of Sciences of Ukraine “Laboratory of young scientists” (the grant number 0120U101838). F.A. Danevich, D.V. Kasperovych and V.I. Tretyak were supported in part by the National Research Foundation of Ukraine Grant No.2020.02/0011.

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