First Observation of Low-Lying Excited States in the Doubly-Odd Nuclei ^{230}Pa and ^{232}Pa ◇

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The actinide region is very rich in interesting nuclear phenomena (fission, super- and hyperdeformed shapes, cluster decay, superheavy elements etc.) and contains important isotopes (Th, Pa, U) also for energy production (fission). However, spectroscopic information on low-lying excited states in many nuclei in this mass range is scarce due to a lack of suitable targets enabling the use of well-established spectroscopic tools like one-particle transfer reactions. With respect to hyperdeformation, the double-odd nuclei ^{230}Pa and ^{232}Pa are of great interest. The level scheme of these isotopes is completely unknown, except for the ground states ($I^{\pi}_{gs} = 2^-$ for both nuclei [1]), although a more profound knowledge of the nuclear structure in these isotopes could be important in fixing the proton-neutron residual-interaction part of the shell model description in this mass region. So we studied the low-lying excited states in ^{230}Pa and ^{232}Pa using the (d,t) and (d,p) reactions on a radioactive ^{231}Pa target. The deuteron beam energy was E_d = 12 MeV. A 80 μg/cm^2 thick ^{231}Pa target on a 20 μg/cm^2 thin carbon backing was used.

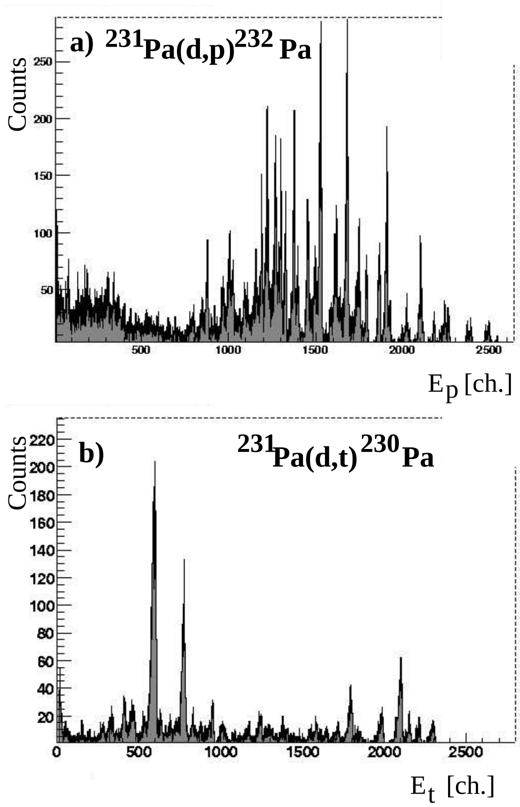

Fig. 1: a) Uncalibr. proton energy spectrum from ^{231}Pa(d,p)^{232}Pa.
b) Uncalibr. triton energy spectrum from ^{231}Pa(d,t)^{230}Pa.

The kinetic energy of the proton ejectiles was analyzed with a Q3D magnetic spectrometer placed at $\Theta_L = 140°$ relative to the incident beam, covering a solid angle of 10 msr. The position of the analyzed particles in the focal plane was measured with a position-sensitive light-ion focal plane detector with individual cathode strip readout of 890 mm active length [2]. Fig. 1 displays the (uncalibrated) proton (part (a)) and triton (part (b)) energy spectra obtained in the ^{231}Pa(d,p) and ^{231}Pa(d,t) reaction, respectively. In the measurement the Q3D magnetic field was set in order to place the proton energy of 500 keV (d,p) and 300 keV (d,t), respectively, to the center of the focal plane.

In a first analysis step the proton energy spectrum from Fig. 1a) was analyzed using the fitting program GASPAN [3]. The peak energies and relative differential cross sections were determined for 35 new excited states below 900 keV.

A typical part of the fit is shown in Fig. 2 for the upper part of the proton energy spectrum between 440 keV and 900 keV, where the preliminary energy calibration was based on the identification of the peak around channel 2500 in Fig. 1a) with the ground state of ^{232}Pa.

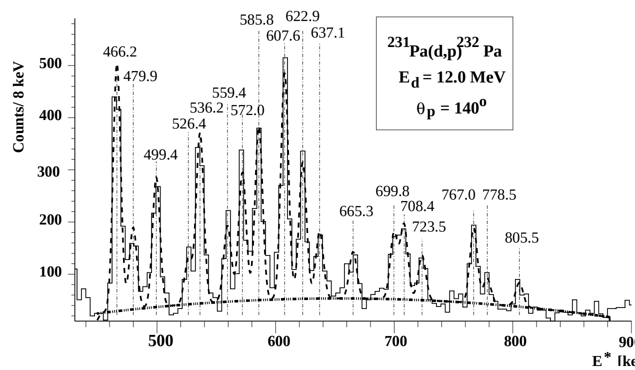

Fig. 2: Part of the proton energy spectrum from ^{231}Pa(d,p)^{232}Pa preliminarily fitted by the multi-parameter code GASPAN. The dotted lines indicate the energy values of the resulting peak positions.

The spin and parity assignments of the newly observed excited states will be the subject of further experiments focusing on angular distribution measurements. However, due to the rather large ground state spin of $I^{\pi} = 3/2^-$ for ^{231}Pa using the same (d,p) and (d,t) reactions as discussed above will not be advisable. In this case the various possible combinations for the l-transfer leading to the same final nucleus would make a conclusive interpretation of the data via DWBA fits almost impossible. In the case of ^{232}Pa an alternative is given by using the reaction ^{234}U($\vec{d}$,α)^{232}Pa, where the ground state spin $I^{\pi} = 0^+$ for ^{234}U will largely facilitate the analysis procedure.

References

[1] http://www.nndc.bnl.gov/nudat2/
[2] H.-F. Wirth, Ph.D. thesis, TU München, 2001
[3] F. Riess, Annual report 1991, p. 168

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