Eur. Phys. J. A **3**, 311–312 (1998)

THE EUROPEAN PHYSICAL JOURNAL A

Short note

Gamma-spectroscopy of the ^{199}At nucleus with the Recoil Filter Detector

W. Męczyński[1], P. Bednarczyk[1], R. Chapman[2], S. Courtin[3], J. Gręboszl[1], F. Hannachi[4], P. Jones[5], J. Kownacki[6], M. Lach[1], A. Lopez-Martens[3], K.H. Maier[7], J.C. Merdinger[3], D. Middleton[2], M. Palacz[6], M.B. Smith[2], K.M. Spohr[2], N. Schulz[3], M. Zięblińskil[1], J. Styczeń[1]

[1] The Niewodniczański Institute of Nuclear Physics, Kraków, Poland
[2] University of Paisley, Paisley, Scotland, U.K.
[3] Institut de Recherches Subatomiques, Strasbourg, France
[4] Centre de Spectrométrie Nucléaire et de Spectrométrie de Masse, Orsay, France
[5] University of Jyväskylä, Jyväskylä, Finland
[6] Heavy Ion Laboratory, University of Warsaw,Warszawa, Poland
[7] Hahn-Meitner-Institut, Berlin, Germany

Received: 17 September 1998 / Revised version: 14 October 1998
Communicated by B. Herskind

Abstract. The neutron deficient ^{199}At nucleus has been studied in the ^{175}Lu+^{28}Si reaction at E_b = 141 MeV. In order to select events of interest in the presence of the very strong background caused by fission, γ-rays have been detected in coincidence with recoiling evaporation residues. The excited states of ^{199}At observed for the first time may indicate that this nucleus is deformed.

PACS. 23.20.Lv Gamma transitions and level energies – 27.80.+w $190 \leq A \leq 219$ – 29.40.Ym Other detectors

Theoretical predictions point out that a region of stable ground-state deformation should exist above the Z = 82 proton and below the N = 126 neutron shell in nuclei very far from the valley of stability [1]. In fact, in this region intruder states have been found in several nuclei showing an onset of collectivity. For example, in early experiments with the prototype of the present Recoil Filter Detector (RFD) we discovered very low-lying prolate bands in ^{186,188}Pb based on a 2p-2h configuration [2]. Also in ^{196,198}Po, collective 4p-2h excitations were observed with likely oblate character [3]. The energy of the 2^+ level drops sharply from 666 keV in ^{200}Po to 319 keV in ^{194}Po [4, 5]. In Radon nuclei, a gradual decrease of the 2^+ energy to 433 keV in ^{200}Rn has been found [6]. This all might indicate that a transformation from spherical to deformed shapes takes place. One can then expect that the collective features should be also pronounced in light Astatine isotopes (Z = 85) which have one active proton more than Polonium nuclei (Z = 84). Therefore, the ^{199}At nucleus has been chosen for our investigation.

The severe difficulty in γ-ray spectroscopic studies of the ^{199}At nucleus produced in heavy-ion fusion-evaporation reactions is due to a very strong background caused by fission. Moreover, the cross section for ^{199}At is very small (in the present experiment it is estimated as 100 μb, while the total fusion-evaporation reaction cross section is about 100 μb). In order to overcome this problem a RFD [7, 8] has been used. It measures evaporation residua (recoils) in coincidence with γ-rays detected in a Ge-detector array. The recoil selection by time of flight significantly reduces the background related to other dominant processes such as fission, Coulomb excitation and reactions with target impurities. Moreover, the determination of the recoil velocity vector for each event allows for a Doppler shift correction of γ-ray energies.

The experiment was performed at the Institut de Recherches Subatomiques in Strasbourg. It was a part of the GAREL$^+$ (**G**amma + **R**ecoil + **E**lectron +...) project devoted to in-beam nuclear structure studies with the combination of γ-recoil-e$^-$ coincidences. The 141 MeV ^{28}Si pulsed beam with 430 ns repetition time from the VIVITRON accelerator bombarded a 0.7 mg/cm^2 thick ^{175}Lu target. PACE and CASCADE calculations show that the yield of isotopes of At other than ^{199}At is negligible. The γ-rays were detected by 14 Compton-suppressed high efficiency HPGe-detectors in coincidence with the recoils separated by the RFD. The RFD was composed of 18 identical cylindrical elements mounted in outer and inner

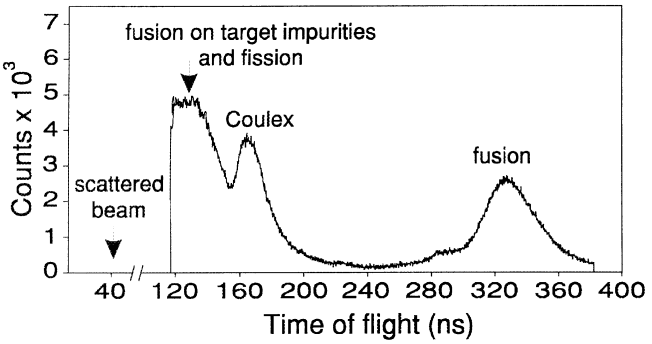

Fig. 1. Time of flight spectrum of recoils from the 141 MeV ^{28}Si + ^{175}Lu reaction measured by the RFD in coincidence with γ-rays. The scattered beam was rejected by fast linear gates

rings. They covered the angular range from 1.7° to 6.8° at the distance of 134 cm from the target. Each RFD element had a thin 2 μm aluminised Mylar foil. Ions hitting the foil knocked out electrons which were then accelerated to 20 keV and focused onto a thin, fast plastic scintillator mounted on a photomultiplier tube. The time-of-flight of the detected ion and the corresponding number of the detector element that was hit were stored simultaneously with the γ-ray data.

In this experiment the RFD separated very well fusion-evaporation residua from other reaction products, as shown in Fig. 1. Scattered projectiles, fission fragments

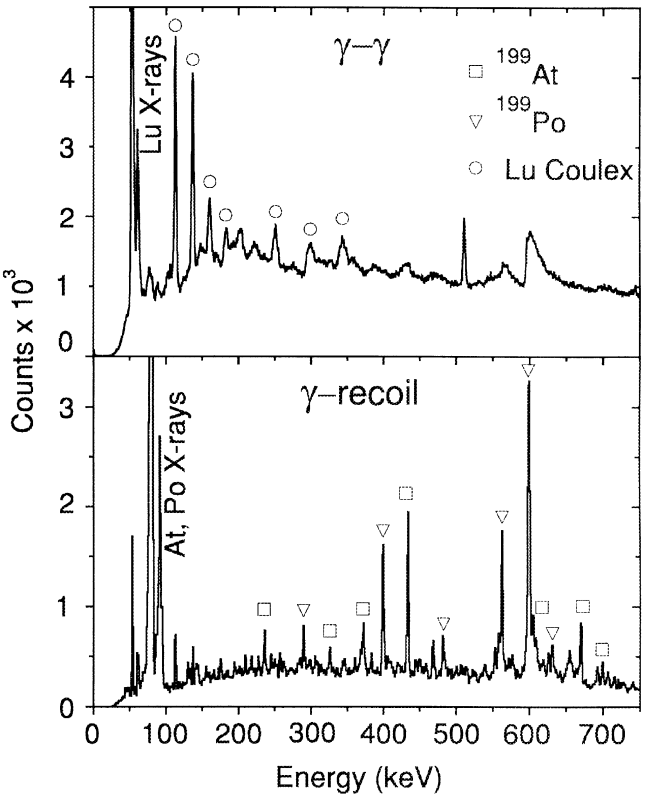

Fig. 2. The γ-γ and γ-recoil coincidence spectra (not normalised) measured with the Ge-detector array and the RFD

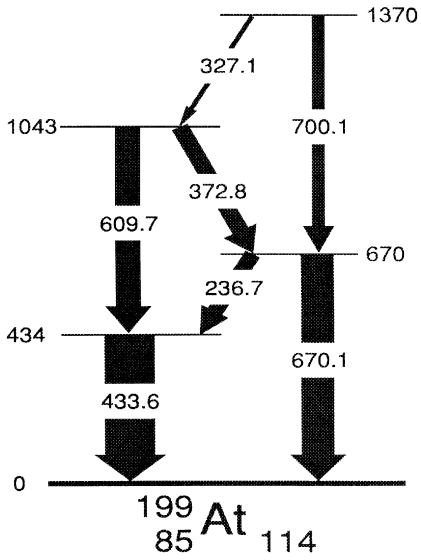

Fig. 3. The level scheme of low lying states in ^{199}At

as well as light nuclei produced in fusion reactions with target impurities were easily rejected.

Fig. 2 compares the γ-γ spectrum with the γ spectrum gated by fusion-evaporation recoils and corrected event-by-event for Doppler broadening. The RFD coincidence requirement very strongly suppresses the high fission background and the Coulex lines of the Lu target. It gives clearly resolved ^{199}Po γ-lines and previously unknown transitions in ^{199}At, invisible in the $\gamma\gamma$-projection. Gamma-lines of ^{199}At were identified by γ-X-ray coincidences. The measured efficiency of the γ-recoil coincidences was 30%.

The analysis of γ-γ coincidences with selection of the fusion products has provided the level scheme of low-lying states in ^{199}At nucleus, as shown in Fig. 3.

The energy of the first excited level in ^{199}At is 434 keV. It is significantly lowered with respect to the almost constant energy of 650 keV in the heavier odd At isotopes $^{201-207}$At [9]. This reduction in energy is an indication, similar to that observed in Po- and Rn-nuclei, of the beginning of the predicted ground state deformation region in Astatine nuclei.

References

1. P. Möller, J.R. Nix, Atomic and Nuclear Data Tables **59**, 185 (1995)
2. J. Heese et al., Phys. Lett. B**302**, 390 (1993)
3. D. Alber et al., Z. Phys. A**339**, 225 (1991)
4. N. Bijens et al., Phys. Rev. Let. **75**, 4571 (1995)
5. W. Younes, J.A. Cizewski, Phys. Rev. C**55**, 1218 (1997)
6. R.B.E. Taylor et al., Phys. Rev. C**54**, 2926 (1996)
7. K. Spohr et al., Acta Phys. Polonica B**26**, 297 (1995) and K. Spohr, PhD-thesis University of Bonn 1995, Bericht des Forschungszentrum Jülich 3171, Jan. 1996, ISSN 0944-2952
8. W. Męczyński et al., IFJ Report 1782/PL, 1997
9. K. Dybdal et al., Phys. Rev. C**28**, 1171 (1983)