

NUCLEAR STRUCTURE
OF HEAVY $N = 153$ ISOTONES*

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(Received January 30, 2013)

In this contribution, we report on results of recent experiments performed at the velocity filter SHIP at GSI in Darmstadt obtained for nuclei above fermium ($Z = 100$). In particular, new results are presented from an α -decay study of ^{259}Sg . These data resulted in the observation of new isomeric state in ^{259}Sg and in the improvement of the quasiparticle systematics for $N = 153$ isotones.

DOI:10.5506/APhysPolB.44.387

PACS numbers: 21.10.-k, 23.20.Lv, 23.35.+g, 27.90.+b

1. Introduction

Nuclear structure research in the trans-fermium region is an important tool for revealing information on the heaviest nuclei ($A \geq 250$). The development of sensitive experimental techniques used for α , γ and conversion electron spectroscopy gives us the chance to study their properties.

At SHIP at GSI in Darmstadt, we perform a long-term program aiming at nuclear-structure studies of trans-fermium isotopes. New nuclear-structure data for the isotopes with $Z \geq 100$ help us to extend and to improve the quasiparticle level systematics for $N = 149, 151$ and 153 isotones.

* Presented at the Zakopane Conference on Nuclear Physics “Extremes of the Nuclear Landscape”, Zakopane, Poland, August 27–September 2, 2012.

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This contribution gives a review of the results improving the systematics of $N = 153$ isotones. In particular, we present data from an α decay of ^{259}Sg .

2. Experimental setup

The isotope ^{259}Sg was produced via the fusion-evaporation reaction $^{206}\text{Pb}(^{54}\text{Cr}, 1n)^{259}\text{Sg}$ at several beam energies from 257 to 270 MeV. The experiments were performed at the velocity filter SHIP at GSI in Darmstadt [1]. The pulsed ^{54}Cr beam (5 ms on/15 ms off) was delivered by the UNILAC accelerator with typical intensity of 0.72 pμA (1 particle μA = 6.24×10^{12} particles/s). The targets were produced by evaporating layers of 450 μg/cm² PbS onto a 40 μg/cm² carbon backing (mounted upstream). Downstream the target was covered by 10 μg/cm² carbon layer. The experimental setup, the data acquisition system and the calibration procedures are described in [2].

3. Decay study of ^{259}Sg

In our experiment, we registered ≈ 400 α decays with the full energy release in the stop detector in the pauses between the UNILAC pulses (see Fig. 1). Besides the complex structure of decays at (9100–9500) keV three prominent lines are visible. From the distribution of time differences between implantations of evaporation residues and α decays we evaluated half-lives of $T_{1/2} = (335 \pm 49)$ ms for the 9035 and 9610 keV lines and of $T_{1/2} = (209 \pm 30)$ ms for the 9550 keV line. We conclude that the latter one represents the α decay of an isomeric state in ^{259}Sg , assigned to the $1/2^+[620]$ level, populating the $5/2^+[622]$ state in ^{255}Rf . We assigned the ground-state of ^{259}Sg , decaying by 9610 keV α decay to the $9/2^-[734]$ state in ^{255}Rf , to the $11/2^-[725]$ level. In addition, we observed a weak α -decay transition with an energy of 9703 keV and a half-life of 112^{+52}_{-27} ms attributed

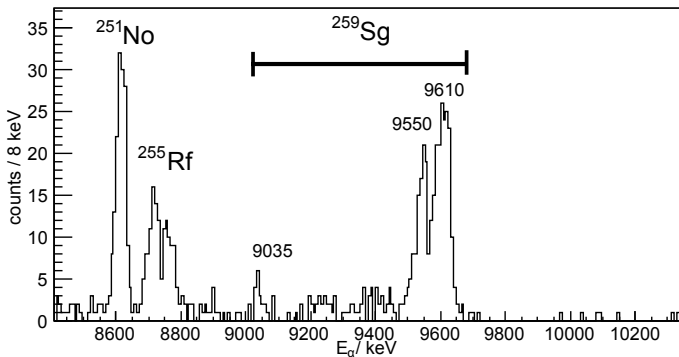


Fig. 1. Alpha-decay spectrum taken during beam pauses. Energies are in keV.

as the decay of ^{259}Sg on the basis of the time and position correlation with the decay of the daughter nucleus ^{255}Rf . We assigned this transition as α decay connecting the $1/2^+[620]$ level and $9/2^- [734]$ ground-state in ^{255}Rf .

Another strong motivation for our study was to investigate the optimum reaction for the production of ^{259}Sg . Prior to our experiment, only two reactions for the direct production of ^{259}Sg were studied. The first one was $^{207}\text{Pb}(^{54}\text{Cr}, 2n)^{259}\text{Sg}$ with a maximum production cross-section of $\sigma_{\text{max}} = (0.42 \pm 0.11) \text{ nb}$ [3]. The second one was $^{208}\text{Pb}(^{52}\text{Cr}, 1n)^{259}\text{Sg}$ with $\sigma_{\text{max}} = 0.32^{+0.11}_{-0.10} \text{ nb}$ [4]. In contrast to previous experiments, in our measurement we used the reaction $^{206}\text{Pb}(^{54}\text{Cr}, 1n)^{259}\text{Sg}$. We obtained $\sigma \approx 1 \text{ nb}$ at the maximum for the one neutron evaporation channel. This value is significantly higher than the results from reactions investigated previously [3, 4].

4. Quasiparticle level systematics for $N = 153$ isotones

Prior to the decay study of ^{259}Sg , we performed the β -decay study of ^{253}Md in which were populated states in ^{253}Fm . Using the detection of delayed electron- γ coincidences we identified a new isomeric state in ^{253}Fm . We assigned this isomeric state to the $11/2^- [725]$ level, which is isomeric also in neighbouring isotones, *i.e.* ^{251}Cf ($E^* = 370.39 \text{ keV}$, $T_{1/2} = (1.3 \pm 0.1) \mu\text{s}$) [5] or ^{257}Rf ($E^* = 70 \text{ keV}$, $T_{1/2} = (4.9 \pm 0.7) \text{ s}$) [6]. We were able to fix the relative energies of the $9/2^+[615]$, $11/2^- [725]$ and $7/2^+[613]$ levels in ^{253}Fm , however the absolute energy of the whole triplet of these states has an uncertainty of a few tens of keV. A detailed discussion on the decay scheme and the level assignments around the observed isomeric state in ^{253}Fm is presented in [2].

In Fig. 2, we show the quasiparticle level systematics for $N = 153$ isotones. In upper panel (a), results from theoretical calculation according to the Nilsson–Strutinsky approach with Wood–Saxon potential [7] are shown. It is expected that the energy for the $11/2^- [725]$ state, responsible for the existence of isomers in these nuclei, should decrease for heavier isotones. Although for the isotones ^{249}Cm , ^{251}Cf and ^{253}Fm only weak decrease was observed, a significantly lower excitation energy was obtained for ^{257}Rf [8] (see Fig. 2 (b)). On the basis of new data for ^{259}Sg , we confirmed the decrease of $11/2^- [725]$ level for heavier $N = 153$ isotones, which resulted in the change of the order for $11/2^- [725]$ and $1/2^+[620]$.

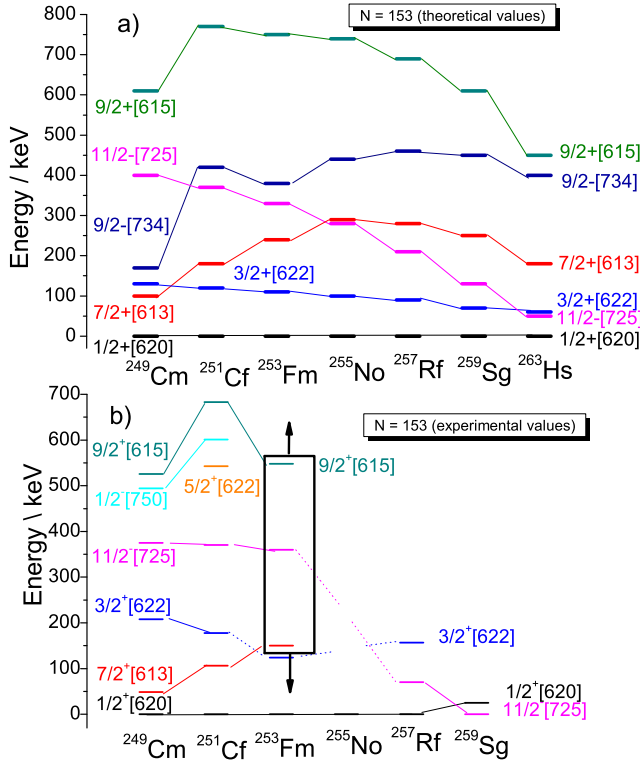


Fig. 2. Quasiparticle level systematics of $N = 153$ isotones. Panel (a) — calculated quasiparticle states [7]. Panel (b) — experimental data.

This work has been supported by the European Community FP7 Capacities, contract ENSAR No. 262010, by the Slovak Research and Development Agency (contract No. APVV-0105-10) and by Slovak grant agency VEGA (contract No. 1/0613/11). Financial support by the Helmholtz Institute Mainz is acknowledged.

REFERENCES

- [1] G. Münzenberg *et al.*, *Nucl. Instrum. Methods* **161**, 65 (1979).
- [2] S. Antalic *et al.*, *Eur. Phys. J.* **A47**, 62 (2011).
- [3] F.P. Heßberger *et al.*, *Eur. Phys. J.* **A41**, 141 (2009).
- [4] C.M. Folden III *et al.*, *Phys. Rev.* **C79**, 027602 (2009).
- [5] I. Ahmad *et al.*, *Phys. Rev.* **C3**, 390 (1971).
- [6] B. Streicher *et al.*, *Eur. Phys. J.* **A45**, 275 (2010).
- [7] S. Ćwiok, S. Hofmann, W. Nazarewicz, *Nucl. Phys.* **A573**, 356 (1994).
- [8] F.P. Heßberger *et al.*, *Z. Phys.* **A359**, 415 (1997).