Current projects and recent results

5. Investigation of spins, electromagnetic moments and charge radii of radioactive nuclei by laser spectroscopy (A. E. Barzakh et al., Changes in the mean square charge radii and electromagnetic moments of neutron-deficient Bi isotopes, AIP Conference Proceedings 1681, 030011, 2015).

Understanding shape evolution and shape coexistence in atomic nuclei is one of the greatest challenges faced by theories of nuclear structure [1]. The neutron-deficient isotopes near Z = 82 exhibit the richest manifestation of shape evolution and shape coexistence phenomena. The behavior of the ground and isomeric states shape differs markedly for different Z in this region. While in Hg isotopic chain (Z = 80) jump-like odd-even shape staggering was observed at N < 106 [2], for Po nuclei (Z = 84) early onset and gradual increase of deformation was found at N < 113 [3, 4]. At the same time the neutron-deficient Pb and Tl nuclei (Z = 82, 81) remain essentially spherical, up to and beyond the neutron mid-shell at N = 104 [5, 6]. The investigations of the neutron-deficient Bi isotopes (Z = 83) play an important role in the understanding of shape evolution and shape coexistence phenomena in this region of the nuclide chart. These isotopes reveal, along with the near spherical ground states, the presence of oblate and prolate structures resulting from the occupancy of $\pi i_{13/2}$ and $\pi s_{1/2}$ orbitals (e. g., see Refs. [7, 8] and references therein). Observables that give a model-independent information on the ground and isomeric states shape are charge radius changes determined by atomic spectroscopy. So far atomic spectroscopy measurements for a restricted set of bismuth isotopes $^{202–213}$Bi [9] have been performed. The previous laser spectroscopic investigations ended at N = 119, well before N = 112 where the structural change in the adjacent Po isotopic chain occurs [5]. It is of importance to extend these studies toward the mid-shell.

In Fig. 1 the available data for the magnetic moments of different Bi nuclear states are presented and compared with the magnetic moments of the adjacent Tl isotopes/isomers with the same spin (see Refs. [6, 11]). The newly measured magnetic moments follow the isotopic trend for the heavier nuclei with the same spin fairly well. At the same time, within the error bars limits they don't differ from the magnetic moments of the corresponding Tl nuclei. It should be noted that nuclear states with the same spin in Tl and Bi have the different nature: πh9/2 state is normal for Bi and intruder (1p-2h) for Tl nuclei; $\pi s_{1/2}$ state is intruder (2p-1h) for Bi and normal for Tl nuclei. Therefore, the newly measured magnetic moments of Bi nuclei support the observation that the sensitivity of μ to the normal or intruder character of a nuclear state is very low [12].

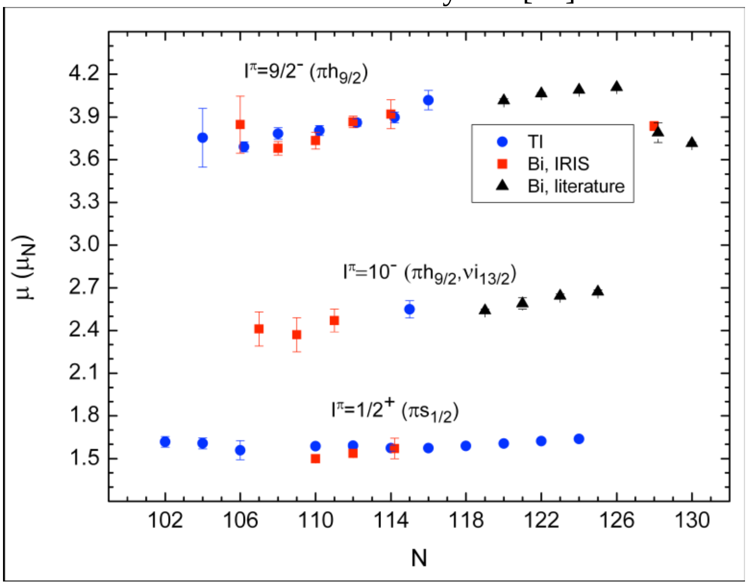
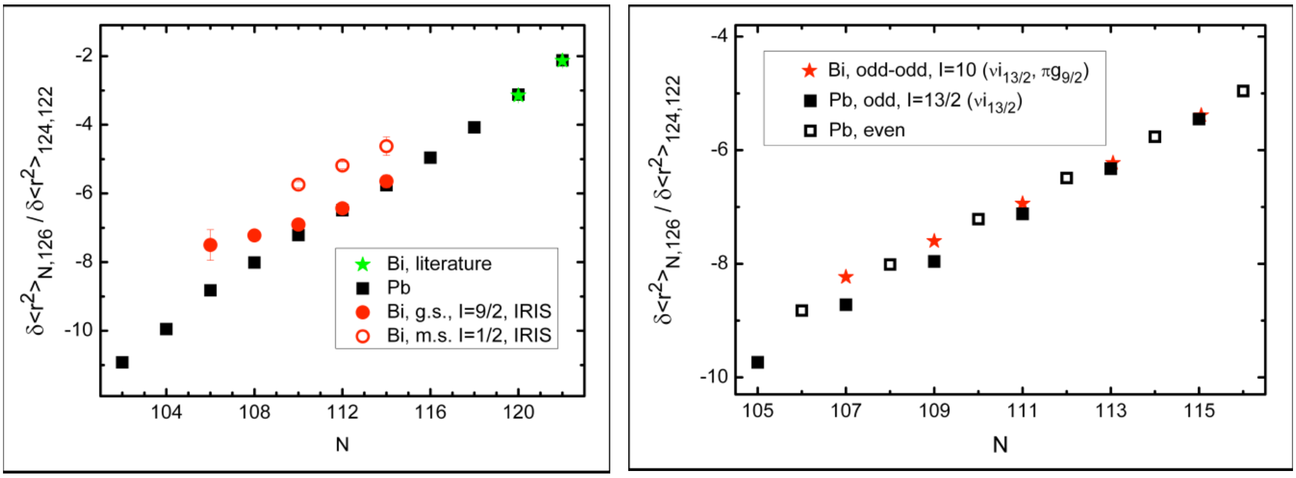


Fig. 1. Magnetic moments for Bi and Tl isotopes and isomers. Squares: Bi, present paper; triangles: Bi, literature data [10]; circles: Tl [6, 10, 11].

In Fig. 2a relative $\delta\langle r^2\rangle$ (RDRs) for even-neutron Bi isotopes are compared with RDRs for even-neutron Pb isotopes. Bismuth RDRs follow Pb-trend until N = 110 and markedly deviate from this trend at N < 110. It was shown previously that thallium RDRs perfectly follow Pb-trend even beyond the mid-shell (N = 104; see Ref. [6]) whereas polonium RDRs display substantial deviation which was interpreted as the onset of deformation at N < 113 [3, 4]. One can conclude therefore that the deformation change for even-neutron Bi isotopes is “intermediate” between the ones for ${}_{82}$Pb and ${}_{84}$Po. At the same time, RDR evolution (i.e. shape evolution) in the Bi and Tl isotopic chains differs from each other, although these chains are “mirror” in respect to the filled proton shell (Z = 82). One can see also that intruder Bi isomers (I = 1/2) have bigger radii (deformation) than corresponding ground states. The similar behavior was observed previously for Tl intruder isomers (I = 9/2; see Ref. [6]). At the same time the radii trend of the odd-neutron Bi isotopes does not deviate noticeably from the radii trend for Pb (see Fig. 2b). It is worth to note that recent shell-model calculations indicate a spherical Bi ground state down to ^{193}Bi while the deviation from the calculations, observed in the lighter isotopes was attributed to the onset of deformation [13]. Some structural change between ^{193}Bi and ^{191}Bi was also point to in Ref. [8]. These assumptions are supported by our results for $\delta\langle r^2\rangle$.



a **b**

Fig.2. Relative changes in $\delta\langle r^2\rangle$ for the even-neutron lead and bismuth isotopes. Boxes: even Pb isotopes ([5]). Full circles: odd Bi ground states with I = 9/2 (present paper). Open circles: odd Bi isomers with I = 1/2 (present paper). b. Relative changes in $\delta\langle r^2\rangle$ for odd-neutron lead and bismuth isomers. Stars: Bi isomers with I = 10, configuration ($\nu i_{13/2}$, $\pi h_{9/2}$) (present paper). Full boxes: odd-neutron Pb isomers with I = 13/2, configuration $\nu i_{13/2}$ ([5]). For completeness values for even-neutron Pb isotopes are presented also (open boxes, [5]).

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