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Manifestation of the Berry phase in the atomic nucleus ^{213}Pb

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We obtained some fascinating results on the ^{213}Pb neutron-rich nucleus studied using the unique availability of a primary 1 GeV A ^{238}U beam and of the FRS-RISING setup at GSI. The products of the uranium fragmentation were separated in mass and atomic number and then implanted for isomer decay γ-ray spectroscopy. A level scheme from the decay of the $21/2^+$ isomer, based on γ intensities, γ-γ coincidences and state lifetimes was built up and the $E2$ transition probabilities from the $21/2^+$ isomer to two low-lying $17/2^+$ levels were also deduced.

This experimental data has evidenced one of the best examples of a semi-magic nucleus with a half-filled isolated single-j shell where seniority selection rules are obeyed to a very good approximation. In the most simple shell-model approach ^{213}Pb can be described as five neutrons in the $1g_{9/2}$ orbital on top of the ^{208}Pb core. Large scale shell-model calculations in the full valence space beyond ^{208}Pb confirm that although the $1g_{9/2}$ orbital is not isolated in energy, it is found to carry the dominant component in the wave function of the low-energy states. The experimental level scheme and the reduced transition probabilities are in good agreement with the theoretical description that predicts the existence of two $17/2^+$ levels of a very different nature: one with seniority $\upsilon = 3$, while the other with $\upsilon = 5$. The absence of mixing between the two $17/2^+$ states follows from the self-conjugate character of ^{213}Pb, where the particle-hole transformation defines an observable Berry phase that leads to the conservation of seniority for most but not all states in this nucleus.

The Berry phase [1], which is a gauge-invariant geometrical phase accumulated by the wavefunction along a closed path, is a class of observables that are not associated with any operator. It is a key feature in quantum-mechanical systems, that has far reaching consequences, and has been found in many fields of physics since its postulation in the eighties. In the atomic self-conjugate nucleus ^{213}Pb, the quantized Berry phase is evidenced by the conservation of seniority under the particle-hole conjugation transformation. In atomic nuclei no experimental signature of the Berry phase was reported up to now.

[1] M. V. Berry, Proc. Roy. Soc. A392, 45 (1984).

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