Interplay between nuclear shell evolution and shape deformation revealed by magnetic moment of ^{75}Cu[†]

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Exotic nuclei are characterized by a number of excess neutrons (or protons) relative to stable nuclei. Their shell structure, which represents single-particle motion in a nucleus, may vary owing to nuclear force and excess neutrons, in a phenomenon called shell evolution. This effect could be counterbalanced by collective modes causing deformations of the nuclear surface. We studied the interplay between shell evolution and shape deformation by focusing on the magnetic moment of an isomeric state of the neutron-rich nucleus ^{75}Cu,[1] where low-lying states of the Cu isotopes exhibit an intriguing behavior involving the shell evolution.[2–4]

The magnetic moment measurement was carried out at the BigRIPS at RIBF. Spin alignment as large as 30% was achieved in the isomeric state of ^{75}Cu by a scheme of two-step projectile fragmentation with a technique of momentum-dispersion matching,[5] incorporating an angular-momentum selecting proton removal from ^{76}Zn. The magnetic moment was determined using the time-differential perturbed angular distribution (TDPAD) method. Owing to the high spin alignment realized by the refined two-step scheme, the observed oscillation for the 66.2-keV γ rays in the TDPAD spectrum had a significance greater than 5σ. The magnetic moment of the 66.2-keV isomer with spin parity $3/2^-$ was determined to be $\mu = 1.40(6)$ $\mu_{\rm N}$ for the first time.
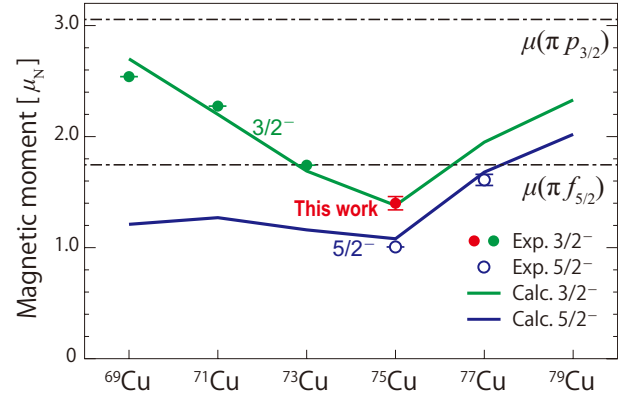

Fig. 1. Systematics of magnetic moments for odd-A Cu isotopes. Filled and open circles represent experimental data for $3/2^-$ and $5/2^-$ states, respectively. Filled red circle represents the result obtained in this work. Solid green and blue lines represent MCSM calculations for $3/2^-$ and $5/2^-$ states, respectively, with $20 \leq (N, Z) \leq 56$ model space.[6] $\mu(\pi p_{3/2})$ and $\mu(\pi f_{5/2})$ denote the proton Schmidt values for $p_{3/2}$ and $f_{5/2}$, respectively.

The magnetic moment, thus obtained, demonstrated a considerable deviation from the Schmidt value, $\mu = 3.05$ $\mu_{\rm N}$, for the $p_{3/2}$ orbital. Figure 1 shows the systematics of magnetic moments of the $3/2^-$ and $5/2^-$ states, where deviation from the Schmidt values appears to be maximal at ^{75}Cu. The analysis of the magnetic moment with the help of Monte Carlo shell model (MCSM) calculations[6] reveals that the trend of the deviation corresponds to the effect of core excitation and the low-lying states in ^{75}Cu are, to a large extent, of a single-particle nature on top of a correlated ^{74}Ni core, elucidating the crucial role of the shell evolution even in the presence of collective mode.

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