Progress in Nuclear Physics Studies through Spins and Nuclear Moments

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Nuclear moments play an important role as tests of nuclear structure models due to the well-known form of the electromagnetic operator. The magnetic dipole moment has sensitivity to the relative amplitudes of different orbital components of the nuclear wave function and can serve as a severe assessment of the nuclear shell model. The electric quadrupole moment, on the other hand, provides a direct measure of the deviation of the nuclear charge distributions from spherical symmetry, helping to discriminate between global microscopic-macroscopic models, which aim to reproduce nuclear shapes over the full nuclidic chart. Access to nuclear moments far from the valley of stability, where nuclei may exhibit unusual features due to small binding energies, has been advanced in recent years by the application of nuclear magnetic resonance on beta-emitting nuclei produced by fragmentation reactions. The required nuclear polarization is achieved in the fragmentation process, where tuning the primary beam off the normal beam axis biases the transmission of reaction products with favorable nuclear spin polarization[1].

At the NSCL, our β-NMR program is aimed to the study of isospin symmetry and nuclear shell structure in medium-mass mirror nuclei. We have recently deduced the ground state magnetic dipole moments of the neutron-deficient nuclides ^{35}K (T_z=-3/2) and ^{57}Cu (T_z=-1/2). Nuclear polarization in these systems was achieved using single-proton pickup reactions at intermediate energies[2]. The small value of the ^{57}Cu magnetic moment is suggestive of shell breaking of the ^{56}Ni "doubly-magic" core[3]. The magnetic moment of ^{35}K, together with its mirror partner ^{35}S, agrees surprisingly well with the trends of the mirror moments near the stability line[4], even though ^{35}K has a proton separation energy of only ~78 keV. We will soon expand the β-NMR program at the NSCL to include measurements of ground state nuclear quadrupole moments.

We also have evolving programs to measure magnetic moments of excited nuclear states. A transient hyperfine field method applied to fast beams has been used to deduce the magnetic moments of the first 2^+ states in the neutron-rich, even-even S isotopes[5]. The near zero magnetic moments of ^{38,40}S suggest that protons and neutrons play equal roles in defining the onset of deformation in these nuclides. The time-dependent perturbed angular distribution method has been employed to determine the magnetic moments of isomeric states in the neutron-rich Ni isotopes. The results[6] confirm the dominant neutron $(g_{9/2})^2$ character of the long-lived 8^+ yrast state in ^{70}Ni and the subshell closure at N = 40 for the Ni isotopes.

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