**Shell structure near the neutron dripline: The neighborhood of $^{42}$Si**

Achieving an understanding of shell structure near the neutron dripline, where the weak binding of the neutrons and the effects of the neutron continuum play a strong role, continues to be an urgent priority for the nuclear structure community. In general, it is expected that the splitting of neutron spin-orbit partners decreases in this vicinity, causing significant changes in the single particle energies of neutron orbits and changes in neutron shell closures (for example, see Refs. 1-3). At present, silicon and sulfur are the heaviest elements for which experimental studies of electromagnetic matrix elements and spectroscopic factors can be performed close to the neutron dripline. Fortunately, the isotopes of these elements with the largest neutron excesses have neutron numbers near $N=28$, which is a major shell closure in stable nuclei (for example, in $^{48}$Ca). It has now been established experimentally [4-8] that this shell closure narrows or collapses near $Z=14$, a phenomenon that makes the study of isotopes in this vicinity of the Chart of Nuclides a topic of intense continuing interest.

A collaboration of FSU, Ursinus College (led by FSU nuclear physics Ph.D. alumnus and Ursinus Associate Professor Lew Riley) and the National Superconducting Cyclotron Laboratory at Michigan State University has published a series of results on nuclei in this vicinity using the single nucleon knockout and fragmentation reactions at intermediate energies. In the first, a measurement of the $N=28$ isotope $^{43}$P via the one-proton knockout reaction from $^{44}$S [5], concentrations of $d_{5/2}$ proton strength were found at much lower excitation energies than could be explained in the framework of the shell model interaction of Ref. 9. Calculations performed with this interaction indicate that the $N=28$ shell closure remains robust, even at $Z=14$, and that the nucleus $^{42}$Si should be spherical. However, the $^{43}$P result of Ref. 5 could be explained using the interaction of Utsuno *et al.* [10], which predicts a significant narrowing the $N=28$ shell closure in neutron-rich nuclei and an oblate deformed shape for $^{42}$Si. Hence, the present Ursinus/FSU/NSCL result on $^{43}$P provided substantial support for this phenomenon, which is an important consequence of the effects of the nearby neutron dripline.

The nucleus $^{42}$Si is considered to be ground zero for the collapse of the $N=28$ shell closure, so it is interesting to see how far away from $^{42}$Si (and how close to $^{48}$Ca) symptoms of the narrowing of the $N=28$ gap can be found. The measurement of a collective $B(E2; 0_{gs}^+ \rightarrow 2_1^+)$ value in $^{44}$S by Glasmacher *et al.* [11] provided one such symptom. However, Gaudefroy *et al.* [6] recently reported the measurement of the *g*-factor of the 320 keV isomeric state in the $N=27$ isotope $^{43}$S and argued on the basis of this measurement that it provided the first "direct and unambiguous evidence" of the collapse of the $N=28$ shell closure. This assertion relied on the assumption that the $J^\pi=7/2^-$ state in this nucleus at 940 keV is a rotational excitation of the $J^\pi=3/2^-$ ground state. (The *g*-factor result of Gaudefroy *et al.* demonstrated that the 320 keV state is a spherical $f_{7/2}$ neutron state, which they said would demonstrate that shape coexistence occurs in $^{43}$S) In Ref. 8, the Ursinus/FSU/NSCL collaboration used the one-neutron knockout reaction from $^{44}$S to confirm that the 940 keV state is indeed a rotational excitation of the ground state in $^{43}$S. By doing this, we completed the argument that Gaudefroy *et al.* had begun in their Physical Review Letter.

Finally, the Ursinus/FSU/NSCL collaboration carried the search for symptoms of the narrowing of the *N=28* gap one more proton "northward" (toward $^{48}$Ca) via the one-neutron knockout reaction on $^{45}$Cl [7]. The parallel momentum distribution of the residual $^{44}$Cl nuclei upon direct population of the ground state was consistent with removal of a neutron with *l=1*, corresponding to the presence of significant $p_{3/2}$ neutron components in the ground states of both $^{44,45}$Cl. If the *N=28* shell closure was still robust in the Cl isotopes, the ground state would include only $f_{7/2}$ neutron components (which are below *N=28*) and not $p_{3/2}$ neutrons (which are above *N=28*). Therefore, the neutron knockout result demonstrated that the *N=28* was considerably narrower Cl (*Z=17*) than in Ca (*Z=20*).

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