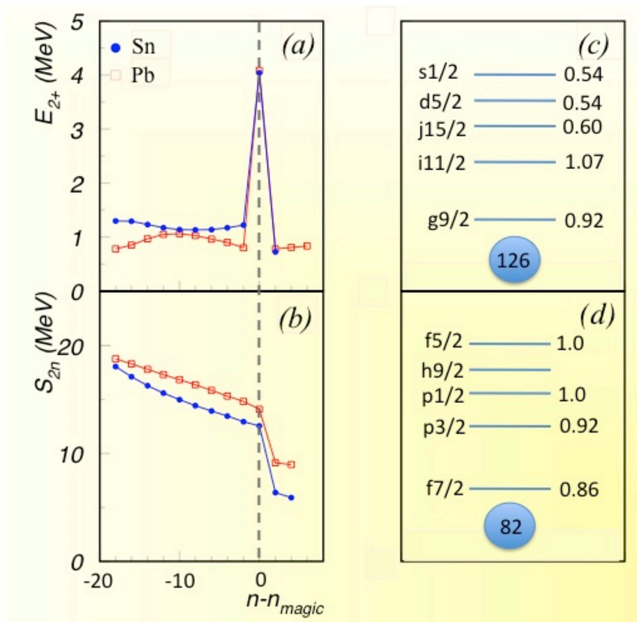
The magic nature of ^{132}Sn

The chemical properties of atoms are dictated by the number of electrons resident in the outermost electron shell. For example, sharp discontinuities in ionization energies and chemical reactivity are observed between the noble gases, with closed shells of electrons, and alkali metals with an additional electron past the closed shell. Nuclei, comprised of neutron and protons, have an analogous shell structure. The shells closures in nuclei are observed where the number of neutrons or protons is equal to a magic number (2, 8, 28, 50, 82, and 126 for neutrons). Only ten nuclei with the standard magic numbers for both neutrons and protons, the doubly magic nuclei, have been observed to date.



One strong signal of a doubly magic nucleus is its reluctance to being excited. Panel (a) of the figure shows the amount of energy required to excite the lowest 2^+ state for different isotopes in the magic tin and lead chains. When the magic neutron number is met ($n\text{-}n_{magic} = 0$) the energy of this 2^+ state jumps up rapidly. Conversely, once the shell closure is crossed the amount of energy required to remove a pair of neutrons reduces greatly, just as ionization energies in atoms fall steeply past the shell closure. Fundamental to the study of nuclei are the properties of single-particle states, most interestingly in the vicinity of the magic nuclei. The purity or fragmentation of these states in nuclei one neutron beyond the shell closure reflects how robust the shell closure is. The energies, spins and parities of the single-particle states are also important tests of nuclear models required to extrapolate to exotic nuclei out of the reach of current experiments.

Researchers at the HRIBF measured a single-neutron transfer reaction on a beam of doubly magic ^{132}Sn ($T_{1/2}$ = 39.7 s). Measurement of protons emerging from the reaction revealed a new single-particle state in ^{133}Sn at E_x = 1363 keV. The angular distributions of protons from the population of two low angular momentum single-particle states have allowed the spins and parities of these states in ^{133}Sn to be confirmed. Relative spectroscopic factors, a measure of the purity of a single-particle state, have been extracted for all four states populated in the reaction and are all compatible with one. The spectroscopic factors for ^{133}Sn (panel c) are close to or higher than those seen in ^{209}Pb, one neutron outside the benchmark doubly magic nucleus ^{208}Pb, signaling that ^{132}Sn is an extremely good example of a doubly magic nucleus.