NSCL

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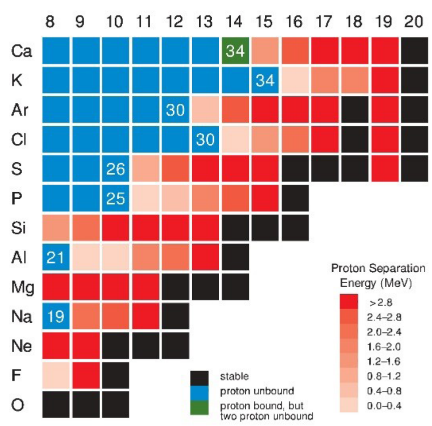
NEW PREDICTIONS OF THE PROTON DRIPLINE

Contributed by Aaron Magilligan and Alex Brown

The nuclear shell model describes the structure of the nucleus in terms of energy levels. It begins with single-particle degrees of freedom, and then allows them to combine to form complex combinations of configurations. The wave functions and energies for these are determined by nuclear interactions between the configurations called the configuration-interaction (CI) Hamiltonian. One starts with an ab-initio Hamiltonian based on constraints from nucleon-nucleon scattering data and the properties of three and four nucleon systems (helium-3, helium-4, and hydrogen-3). When applied to heavy nuclei one can add further constraints based upon the observed properties of the nuclei in the mass region of interest.



One of these mass regions of interest is called the "sd shell" that pertains to nuclei with neutron number N, and proton number Z, from 8 to 20. In the 1980's a "universal" Hamiltonian for the sd shell called USD was obtained from constraints to energies in a limited set of nuclei with N greater than or equal Z. In 2016 all data of this type was used to obtain refined versions called USDA and USDB. These previous versions did not explicitly contain the Coulomb interaction and did not consider the properties of proton-rich nuclei. These USD Hamiltonians are used to calculate quantities that are important for the study of nuclear astrophysics and fundamental interactions involving nuclei in the sd-shell mass region.

Theorists in the Lab are working on the creation of USDC, a CI Hamiltonian that incorporates Coulomb (and other isospin breaking contributions) directly. With this new method data for all N and Z values with measured energies can be used for the Hamiltonian constraints.

With USDC we are particularly interested in understanding the properties of the proton-rich nuclei. The figure shows the new predictions for proton-rich nuclei obtained by calculations using USDC. The figure is labeled by the isotope name on the left (with Z=8-20) and the neutron number N along the top. The proton drip line is defined by the boundary between those inside the proton drip line whose ground states must beta decay, and those outside the drip line whose ground states can emit one or two protons. The red shaded area shows the proton-bound nuclei inside the proton drip line. The nuclei that lie outside the proton drip line are shown in blue and green. The numbers in these squares are the heaviest atomic masses A of those that are just outside the proton drip line. These results match very well with the known proton drip line.

A unique occurrence in this figure in calcium-34. It is bound for single proton emission but unbound two proton emission. Experiments to study the two-proton decay properties of calcium-34 are being proposed.

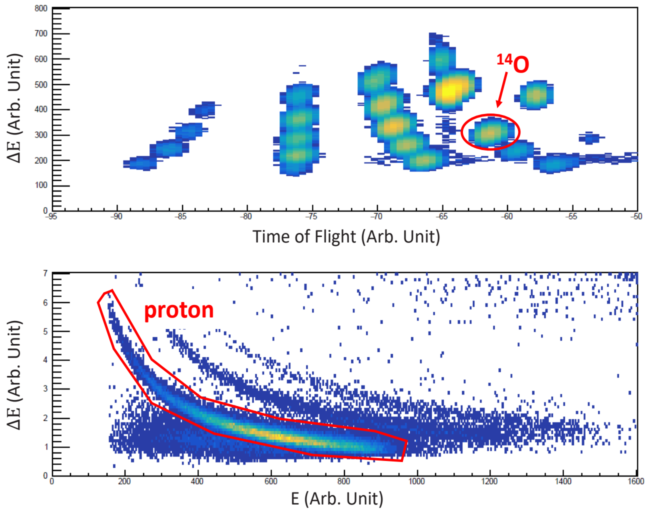
Phosphorus-26 is another proton rich nucleus of note. USDC predicts that the ground state should be unbound to proton emission by a few hundred keV. But by correcting for the Thomas-Ehrman shift (TES) we conclude that the ground state is bound. The TES is caused by the least bound proton being further away from the center of the nucleus forming a proton halo or skin, which causes a reduction in the Coulomb energy thereby increasing the binding energy.

EXPERIMENT OF THE WEEK

Contributed by Jin Yu, Chenyang Niu and Hui Hua

Experiment e18015 explored the spectroscopy of magnesium-18 by its four-proton decay to oxygen-14. The goal of this experiment was to study the energy level and the internal proton correlations of magnesium-18, which is further beyond the proton-drip line than the previously well-known two-proton radioactive nucleus magnesium-19. A secondary beam of magnesium-20 was produced by fragmenting magnesium-24 from the CCF on a beryllium target and purified in the A1900 fragment separator. Magnesium-18 was produced by a two-neutron knockout reaction on another beryllium target in the S800 target chamber. Particle identification spectra are shown below. Protons were detected by a silicon (S4) and cesium iodide (CsI) array, and the oxygen-14 residues were analyzed by a newly made scintillator fiber array and the S800 spectrometer. The experiment will be the major part of the Ph.D. thesis of Yu Jin, who is currently a second-year Ph.D.

student at Peking University. She and all experimenters would like to thank everyone who has helped to prepare and run the experiment. The experimenters say; "let's think like a proton, always positive!"



ADVANCED STUDIES GATEWAY AT FRIB

This year marks the 150th anniversary of the formulation of the periodic table created by Dmitry Mendeleev. Accordingly, the United Nations proclaimed 2019 as the International Year of the Periodic Table of Chemical Elements. At 150 years old, the table is still growing. In 2016, four new elements were added the periodic table: nihonium, moscovium, tennessine, and oganesson. These elements define the current upper limits of mass and atomic numbers. As such, they carry the potential to transform the way we currently understand nuclear and atomic physics, and chemistry.

All elements with atomic numbers greater than 103 are labeled as "superheavy," and are part of a vast, totally unknown territory of these nuclei that scientists are trying to uncover. Questions motivating the search for these systems include: What are the heaviest nuclei and atoms that can exist? Are superheavy systems different from lighter nuclear species? Is there an island of very long-lived nuclei? Can superheavy nuclei be produced in stellar explosions? Questions such as these provide formidable challenges for science. FRIB Chief Scientist, Witek Nazarewicz, will be giving a public talk on Saturday, March 30th to discuss these questions. All are welcome to attend at 10:30am to learn 'Is There an End to the Periodic Table of Elements?'

CCF UPDATE

Last Friday, a nuclear structure experiment ended successfully after ten days of running with magnesium fragments. In the afternoon, primary beam was sent to the N4 vault for controls and tuning development. A selenium-82 primary beam was developed overnight. On Saturday, germanium-80 fragments were separated in the A1900 and sent to the N4 vault. For the rest of Saturday and most of Sunday, germanium was extracted from first the ACGS and then the linear gas cell to prepare for an upcoming experiment. On Monday, heavy calcium fragments were developed and sent to the S2 vault for an astrophyiscs experiment that is scheduled to run through the weekend.

SEMINARS

- SATURDAY, MAR 30 AT 10:30 AM
  1300 FRIB Laboratory
  Advanced Studies Gateway
  Witek Nazarewicz, Hannah Distinguished Professor
  'Is There an End to the Periodic Table of Elements?'
- WEDNESDAY, APR 03 AT 9:30 AM
  1200 FRIB Laboratory
  Lisa Carpenter, NSCL Graduate Assistant
  'Cluster Structure and Three-Body Decay in carbon-14'
- WEDNESDAY, APR 03 AT 12:00 PM
  1200 FRIB Laboratory
  Gary Westfall, NSCL
  'The Hottest, Most Perfect Liquid'
- WEDNESDAY, APR 03 AT 4:10 PM
  1200 FRIB Laboratory
  Teresa S. Bailey, Lawrence Livermore National Lab
  'Delivering a Nuclear Science Capability at Lawrence Livermore National Laboratory'
- THURSDAY, APR 04 AT 11:00 AM
  1200 FRIB Laboratory
  Andrea Shindler, Michigan State University
  'HiP - Highlights in Progress: Nucleon Electric Dipole Moment results from lattice QCD using the Gradient Flow'

PEOPLE AT THE LAB

- Rensheng Wang is a Visiting Scholar in the Lab, hosted by Betty Tsang.
- Malina Felten joined the Lab as an ESH&Q Technician.

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