TEXAS A&M UNIVERSITY

Cyclotron Institute

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Observation of the Most Neutron-Deficient Isotope of Nitrogen

Structure of the most exotic nitrogen isotope that barely exists

THE SCIENCE

Structure of nuclei with large proton/neutron imbalance is a major focus of research in nuclear physics since the discovery of neutron halo phenomena — the large spatial enhancement of the valence neutron wave function in some nuclei. The ^{11}Li, an isotope that has four neutrons more than the heaviest stable Lithium isotope ^{7}Li, is an iconic example of a two-neutron halo structure, that can be viewed as a loosely bound system of three constituents n+n+^{9}Li. Quantitative description of two-neutron halo phenomena hinges on better understanding of the neutron+core interaction, that is n+^{9}Li (^{10}Li) for ^{11}Li. Recent observation of ^{10}N, the nuclear mirror of ^{10}Li, provides the missing pieces of the two-neutron halo puzzle.

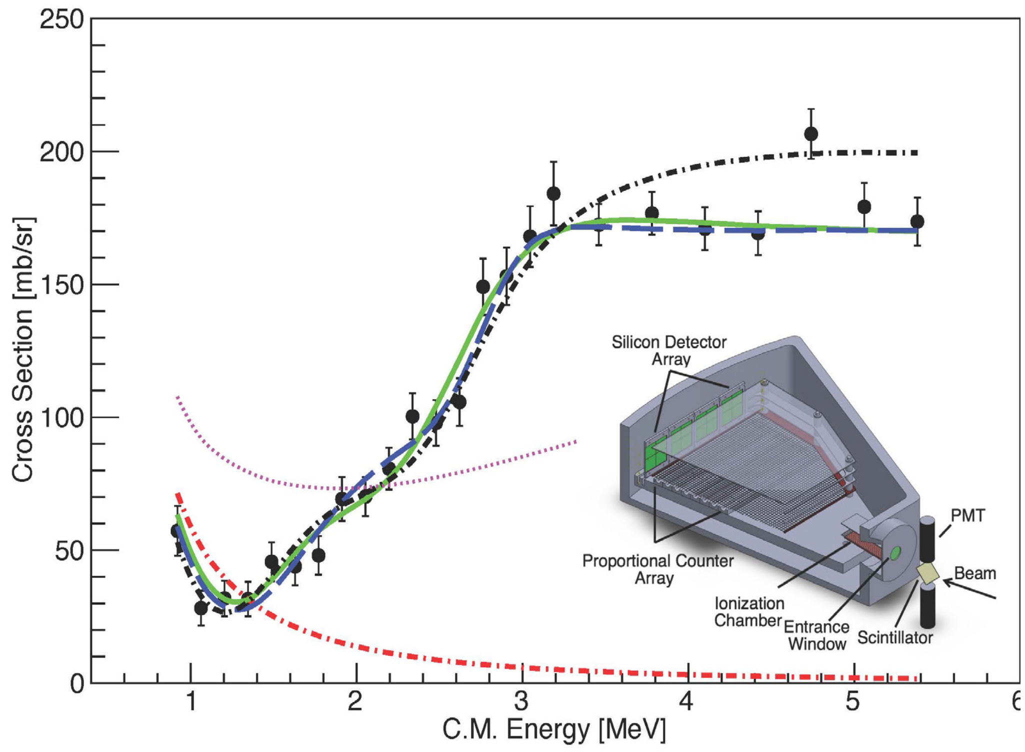
THE IMPACT

Location of the 2s1/2 shell in ^{10}N nucleus, established in this experiment, provides conclusive evidence that the ^{10}Li ground state is an almost bound s-wave state, corroborating some previous results and highlighting the important role played by s-waves in forming the neutron halo structures. This is an important benchmark to test contemporary nuclear models that combine the description of nuclear structure and reactions.

SUMMARY

Scientists at the Texas A&M Cyclotron Institute have observed the ground and the first excited states of the most proton rich Nitrogen isotope — ^{10}N. This nucleus, which has seven protons but only three neutrons, is a benchmark case because it provides stringent constrains on the structure of ^{10}Li, its nuclear mirror with three protons and seven neutrons, which in turn plays a critical role in understanding of two-neutron halo phenomena in ^{11}Li.

The ^{10}N isotope is unbound with respect to proton decay. Therefore, resonance elastic scattering of ^{9}C on protons can be used to populate all states in ^{10}N, including the ground state. The ^{10}N states will show up as resonances (peaks) in the ^{9}C+proton differential cross section. The ^{9}C is a short-lived isotope, with half-life of only 126.5 ms, and has to be produced as a radioactive beam. Using the Momentum Achromat Recoil Separator (MARS), researchers at the Cyclotron Institute were able to get 1000 ^{9}C ions per second and scatter them off of the proton target. From the characteristic shape of the resonances observed in the ^{9}C+p excitation function (differential cross section as a function of energy), they determined the excitation energy, widths and ^{9}C+proton relative orbital angular momentum of the ground and the first excited states in ^{10}N. The two low lying states were determined to be the L=0, s-wave resonances, and therefore the location of the 2s1/2 shell in ^{10}N is now well established. It is located at 2.3+/-0.2 MeV above the proton decay threshold. This information can now be used as a benchmark for state-of-the-art theoretical models that aim at describing nuclear systems from the first principles and include continuum effects.



Excitation function (cross-section as a function of energy) for resonance elastic scattering of radioactive nucleus ^{9}C of protons. Rapid increase of the cross-section from 1.7 to 3 MeV is clear evidence for two broad s-wave resonances that correspond to the ground and the first excited states of a ^{10}N nucleus – the lightest isotope of nitrogen that has never before been observed.

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PUBLICATIONS

J. Hooker, G.V. Rogachev, V.Z. Goldberg, E. Koshchiy, B.T. Roeder, H. Jayatissa, C. Hunt, C. Magana, S. Upadhyayula, E. Uberseder, A. Saastamoinen, "Structure of 10N in 9C+p resonance scattering." Physics Letters B 769, 62 (2017).

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ABOUT THE CYCLOTRON INSTITUTE: *Dedicated in 1967, the Cyclotron Institute serves as the core of Texas A&M University's accelerator-based nuclear science and technology program. Affiliated faculty members from the Department of Chemistry and the Department of Physics and Astronomy conduct nuclear physics- and chemistry-based research and radiation testing within a broad-based, globally recognized interdisciplinary platform supported by the United States Department of Energy (DOE) in conjunction with the State of Texas and the Welch Foundation. The facility is one of five DOE-designated Centers of Excellence and is home to one of only five K500 or larger superconducting cyclotrons worldwide.*