TEXAS A&M UNIVERSITY
Cyclotron Institute

https://cyclotron.tamu.edu

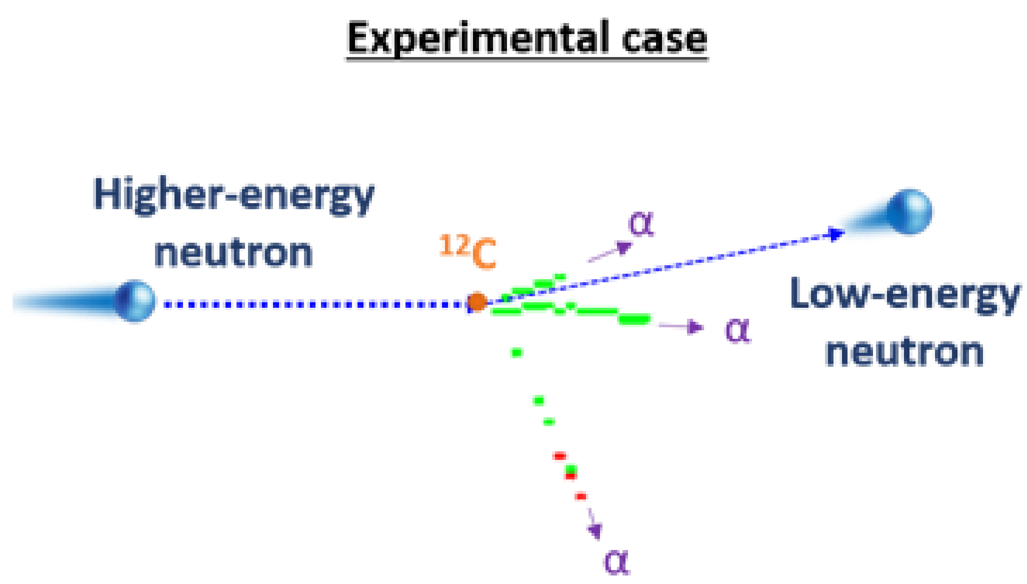
The Life and Death of Stars

Viewing nuclear reactions to understand the universe around us

THE SCIENCE
Advances in technology have enabled scientists to produce extremely precise snapshots of nuclear reactions. Time Projection Chambers (TPCs) enable scientists to study the interactions of rare nuclei that are accelerated to a fraction of the speed of light and that then collide with gas. Next, rsearchers study the resulting nuclear reactions with exotic nuclei and observe rare radioactive decay. These studies give us insights into the nuclear force, the strongest and least-understood of the four fundamental forces in the standard model of particle physics. Many experiments that can now be performed with a TPC were impossible or very difficult with previous technologies.

THE IMPACT
Researchers are using TexAT, a TPC at Texas A&M University, to study important reactions in stars by measuring the "time-reverse" scenario of nuclear processes. This process involves studying a mirror image version of extremely high-speed processes in stars. This reverse sequence is easier to observe. While firing a beam of neutrons into the TPC, researchers looked at the breakup of carbon in carbon dioxide gas into three radioactive alpha particles in the form of helium-4 nuclei. Measuring the likelihood of this reaction tells us how something scientists call the 'triple-alpha process' can increase stars' production of carbon. These studies help us understand whether stars create carbon during their normal lives, or whether they also create carbon during nucleosynthesis in supernovae or neutron star collisions. Researchers have also used the TexAT TPC in experiments involving the exotic nuclei carbon-9 and beryllium-13. These studies help us understand how nuclear structure changes as we add more protons or neutrons to already exotic and unstable nuclei.

SUMMARY
TexAT is a gas-filled Time Projection Chamber. Sending radioactive nuclei into the detector causes them to interact with the gas. Any products from the reaction that are charged (i.e. protons, deuterons, or alpha particles) will produce electrons as they interact with the gas. Researchers can then record images of the nuclear reactions that occur and can reconstruct a three dimensional image of any products created from these reactions. This allows for sensitive studies of the different reactions that are important for understanding how stars live and die.



Snapshot of a nuclear reaction showing a high-energy neutron causing a carbon-12 atom to break apart into three alpha particles, leaving a low-energy neutron. In nature, this reaction would occur in reverse.

Jack Bishop

Grigory Rogachev

PUBLICATIONS

Bishop, J. et al., "Beta-delayed charged-particle spectroscopy using TexAT," Nuclear Instruments and Methods in Physics Research Section A 964, 163773 (2020).

Bishop, J. et al., "Almost medium-free measurement of the Hoyle state direct-decay component with a TPC," Physical Review C 102, 4 (2020).

Hooker, J. et al. "Structure of 9C through proton resonance scattering with the Texas Active Target detector," Physical Review C 100, 054618 (2019).

Koshchiy, E., et al., "Texas Active Target (TexAT) detector for experiments with rare isotope beams," Nuclear Instruments and Methods in Physics Research Section A 957, 163398 (2020).

FUNDING

This work was supported by the U.S. Department of Energy Office of Science, the Office of Nuclear Physics, the National Nuclear Security Administration through CENTAUR, and the Texas A&M Nuclear Solutions Institute.

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.*