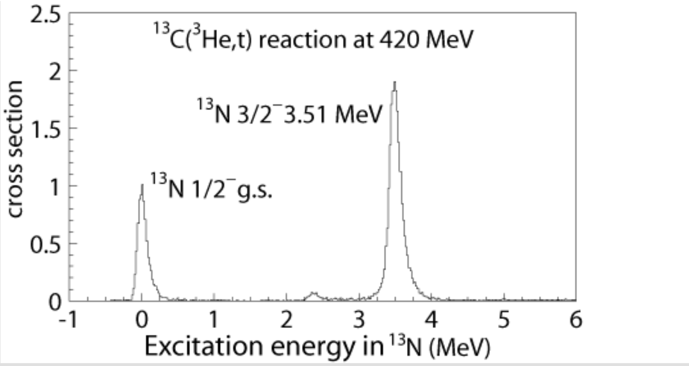
The Joint Institute for Nuclear Astrophysics

JINA

Gamow-Teller transitions in A=13 nuclei and the implications for thermonuclear supernovae



Energy spectrum of the (^{3}He,t) reaction on a target of Carbon-13, populating low-lying states in ^{13}N. The most prominent peaks are the ground state (g.s) and the excited state at 3.51 MeV. The goal of the study was to measure the transition strength to the latter state and to investigate the effects on reactions that take place in the simmering stage of white dwarfs, just before they explode as Type Ia supernovae.

In recent work by MSU graduate student David Chamulak and his collaborators, the role of the consumption of electrons in the simmering stage (~1000 years before it explodes as a supernova) of a white dwarf was studied (see JINA highlight "Simmering white dwarfs consume electrons"). One of the important reactions was the capture of electrons on Nitrogen-13, populating states in Carbon-13. The probability of capturing to the ground state of Carbon-13 was well known from experiment, but the same was not true for the other relevant transition, namely to an excited state in Carbon-13, located at an energy of ~3.5 MeV.
The transition strength from the ground state of Nitrogen-13 to Carbon-13 is not easy to measure directly, since Nitrogen-13 is not stable. However, using symmetry arguments, it can be deduced from measuring the transition from Carbon-13 (which is stable) to the excited state at 3.51 MeV in ^{13}N, which is an analog of the state of relevance in Carbon-13. This 'mirror' transition had been measured before using the (proton-neutron) charge-exchange reaction on Carbon-13, but the discrepancy with theoretical predictions was unusually large.
Therefore, a new measurement was performed at the Research Center for Nuclear Physics in Osaka, Japan by an international team of researchers from the US, Japan and Europe, but this time by using the (Helium-3,Hydrogen-3) charge-exchange reaction. By combining the new experimental data with detailed calculations of the reactions involved, the researchers found that likely a large systematic error was made in extraction of the transition strength to the excited state at 3.5 MeV in previous experiments. By calibrating the transition strength in a different manner, the issue was resolved and the data nearly consistent with the theory.
Together with Ed Brown and David Chamulak from MSU, the experimental data were then used to study in detail the electron-capture rates and heat deposition associated with this reaction during the simmering stage of white dwarfs.

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Related Web Sites:
http://groups.nscl.msu.edu/charge_exchange/

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