Measuring the Cross Section of the $^{12}$C(n,2n)$^{11}$C Reaction for the 20-30MeV Energy Interval

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I. Abstract
The behavior of the (n, 2n) reaction in $^{12}$C and other light nuclei is known with much less certainty than for heavy nuclei. The published cross section data for the $^{12}$C(n, 2n)$^{11}$C reaction is bifurcated in the energy range of 20-30 MeV. The difference is to measure the $^{12}$C(n,2n)$^{11}$C cross section for these neutron energies has been performed using the Ohio University Tandem Accelerator. Deuterons from the accelerator struck a tritium foil releasing neutrons via the T(d, n)He reaction. Deuteron bombarding energies between 3.3-8.7 MeV resulted in neutrons with energies between 20-26 MeV. The geometry of the experiment was chosen so that the incident neutron energy would not vary by more than 0.5 MeV across the graphite target. After neutron bombardment, the decay of the $^{11}$C nucleus by positron emission was measured with NaI detectors to determine the half-life of the sample. The neutron flux through the carbon was measured using a particle telescope to detect protons from the $^{11}$B(n, p) reaction in a polyethylene target, allowing the absolute cross section for the $^{12}$C(n, 2n)$^{11}$C reaction to be determined. Funded in part by a grant from the DOE through the Laboratory for Laser Energetics.

II. Motivation
National Ignition Facility
The tertiary neutron yield is a good indicator of the success of an ICF burn. The yield can be determined by the neutron activation of graphite through the $^{12}$C(n, 2n)$^{11}$C reaction.

III. Theory

\[ D_{\mu} + T_{\mu\nu} \rightarrow a + n \]
Primary neutrons are roughly 14.1 MeV
\[ a + D_{\mu} \rightarrow a + D_{\mu} \]
Producing 0-12.5 MeV knock-ons
\[ D_{\mu} + T_{\mu\nu} \rightarrow a + n \]
Producing 12-30 MeV tertiary neutrons

The number of tertiary neutrons is related to $|\nu|^{2}$ or $|\rho|^{2}$ parameter

Due to the 20.3 MeV threshold, only tertiary neutrons from the burn contribute to the $^{12}$C(n, 2n)$^{11}$C reaction (insensitive to primary and scattered neutrons)

\[ a + ^{12}C + 2a + ^{11}C \rightarrow ^{12}C + b + e^{+} + e^{-} \]
Threshold for Carbon Activation

IV. Experiment

Ohio University Accelerator Lab
Deuterons were accelerated to energies between 3.5 and 8.285 MeV and allowed to strike a titanium tritide foil. Beam currents were typically between 0.5 and 1.0 µA. Before striking the target, the deuteron beam was defocused by a pair of quadrupole magnets and allowed to pass through a collimator, reducing the risk of creating a hot spot on the target.

V. Decay Counting

After an activation period of approximately 6 half lives, the targets were removed to a counting station. The rate of back-to-back gamma rays resulting from positron annihilation was used to determine the number of $^{11}$C nuclei present.

VI. Analysis and Results

For preliminary cross sections (at right), many assumptions were made about the neutrons leaving the tritium target. We are in the process of determining corrections to these results before collecting more data.

A decay curve with a constant background produced the initial number of measured $^{11}$C decays. Transport time, dead time, and detector efficiency were accounted for, resulting in the total number of original carbon activations.