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. An experiment 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 $T(d, n)^4He$ 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 nuclei by positron emission was measured with an array of NaI detectors to determine the activity of the carbon sample. The neutron fluence through the carbon was measured using a particle telescope to detect protons from the $^1H(n, p)$ 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. Unfortunately, published cross sections for this reaction are bifurcated in the energy range of interest.

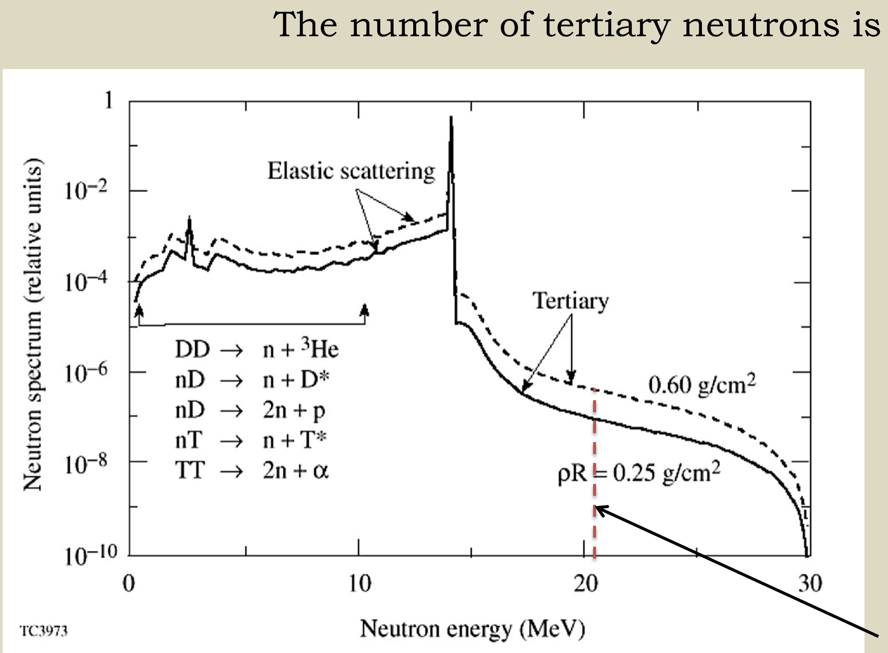
III. Theory

$D_{fuel} + T_{fuel} \rightarrow \alpha + n$ Primary neutrons are roughly 14.1 MeV

$n + D_{fuel} \rightarrow n' + D_{ko}$ Producing 0 – 12.5 MeV knock-ons

$D_{ko} + T_{fuel} \rightarrow \alpha + n^{**}$ Producing 12 - 30 MeV tertiary neutrons

The number of tertiary neutrons is related to $(\rho r)^2$ or ρr parameter



Threshold for Carbon Activation

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)

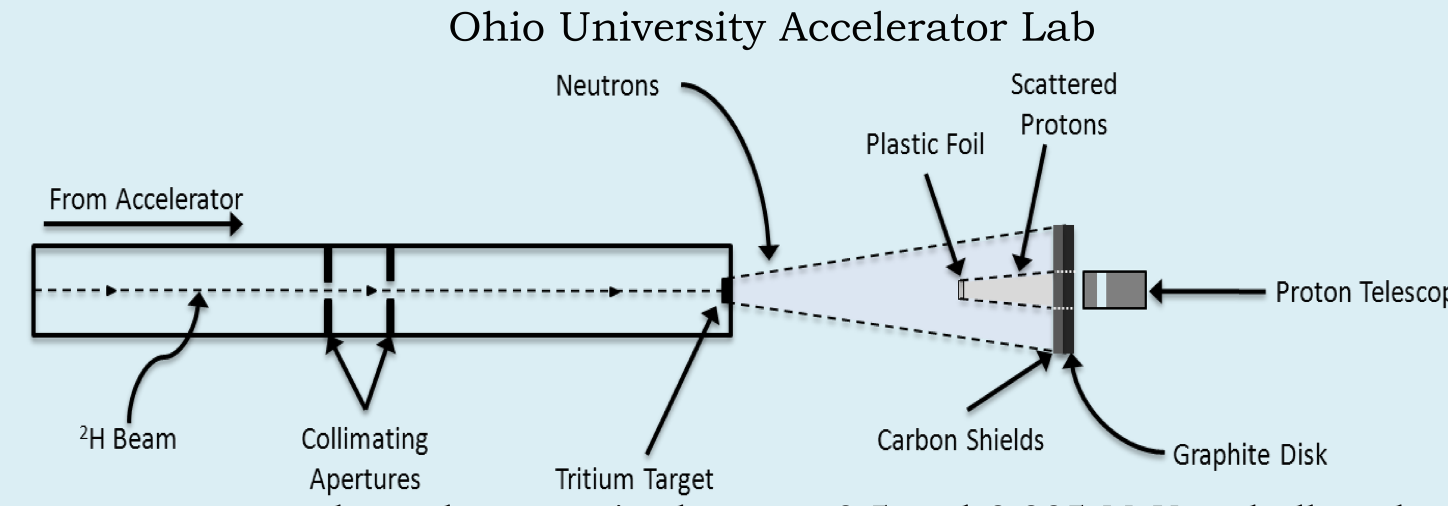
$n^{**} + {}^{12}C \rightarrow 2n + {}^{11}C$

${}^{11}C \rightarrow {}^{11}B + e^+$

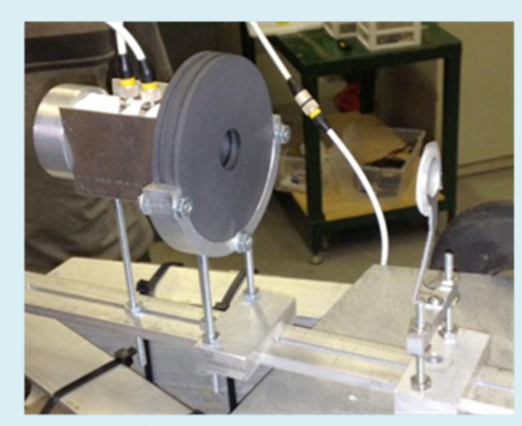
$e^+ + e^- \rightarrow 2\gamma_{511keV}$

IV. Experiment

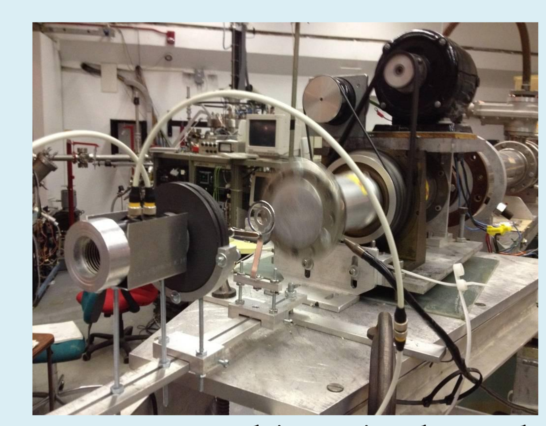
Ohio University Accelerator Lab



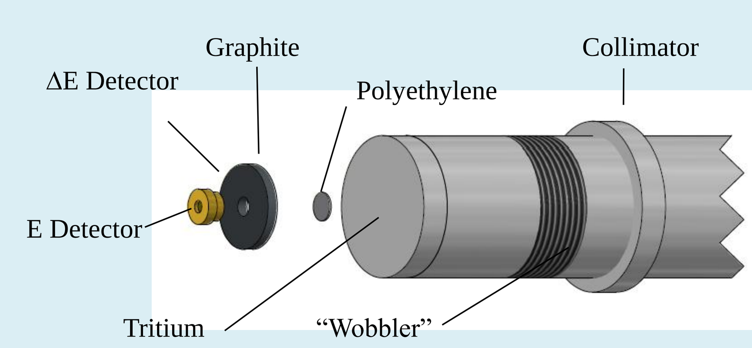
Deuterons were accelerated to energies between 3.5 and 8.285 MeV and allowed to strike a titanium tritide foil. Beam currents were typically between 0.5 and 1.0 μA. Before striking the target, the deuteron beam was defocused by a pair of quadrupole magnets and allowed to pass through a collimator, reducing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



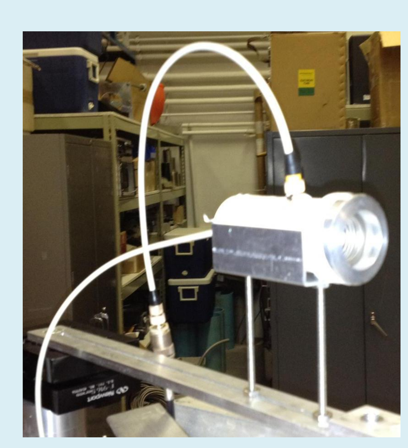
The activation setup

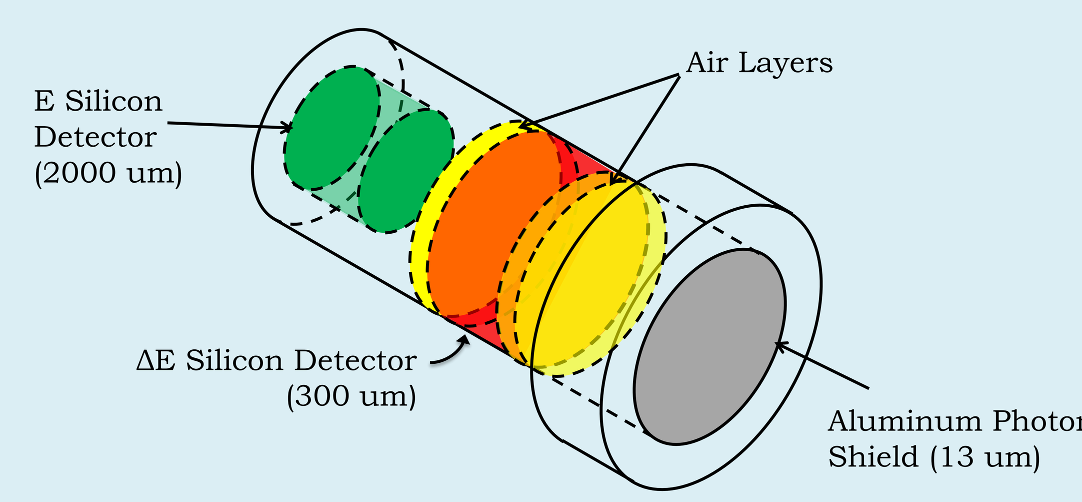


The target was moved in a circular path about the beam axis to prevent it from overheating and releasing tritium.

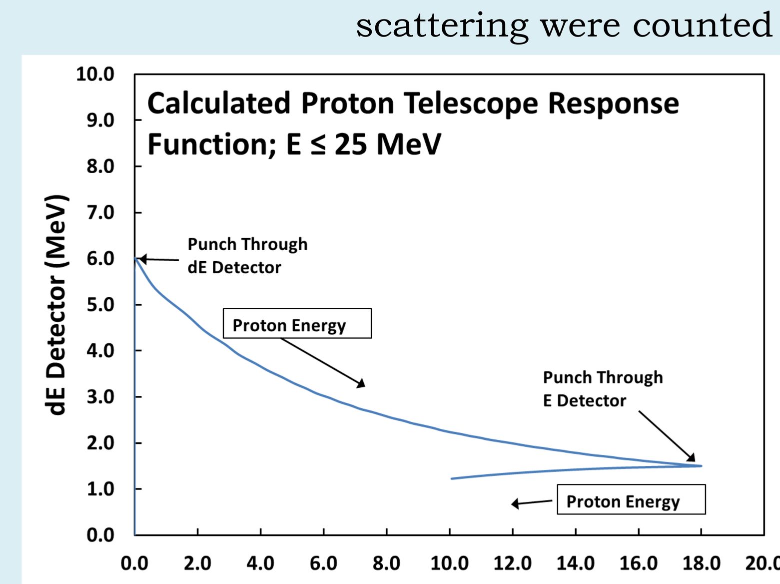


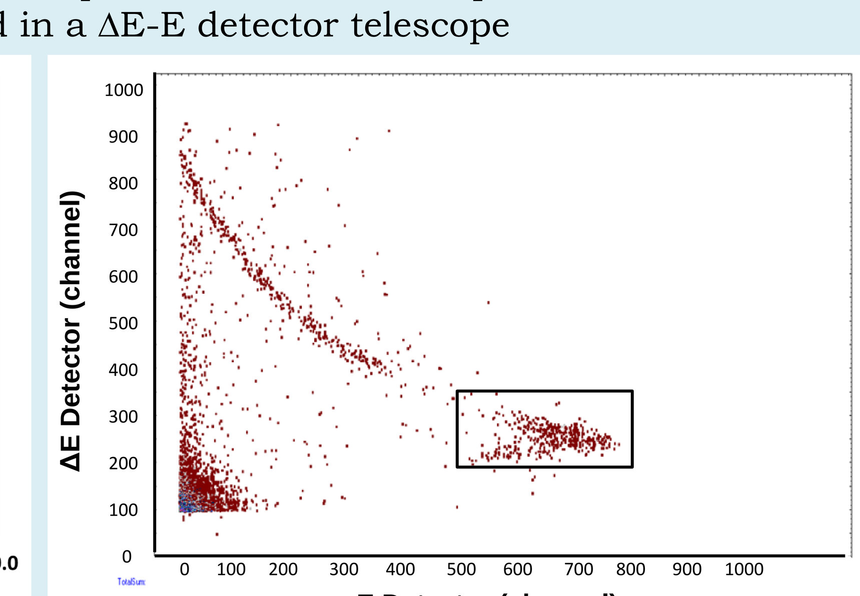
Protons produced in the polyethylene target via the p(n,p) reaction passed through a cylindrical hole in the graphite target where they were detected by the telescope.





In order to determine the neutron flux, protons from neutron-proton elastic scattering were counted in a ΔE-E detector telescope





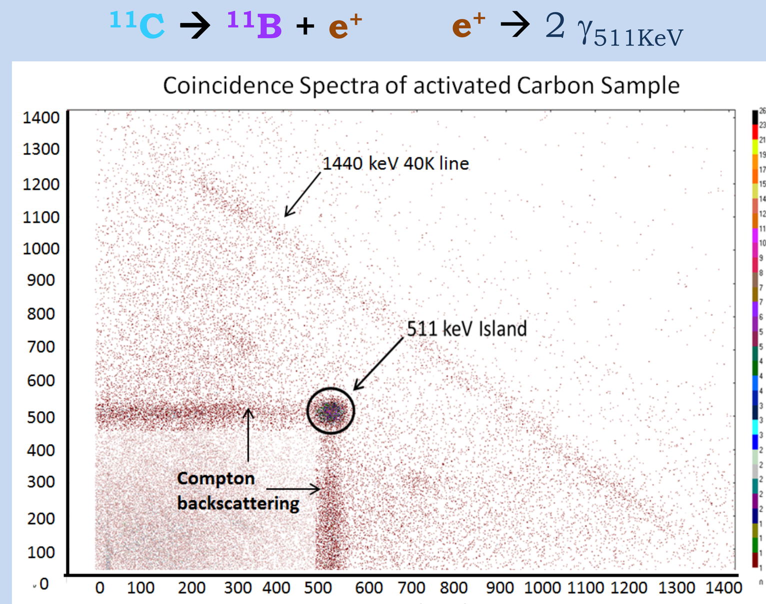
The marked region-of-interest indicates the counted protons elastically scattered by neutrons.

V. Decay Counting

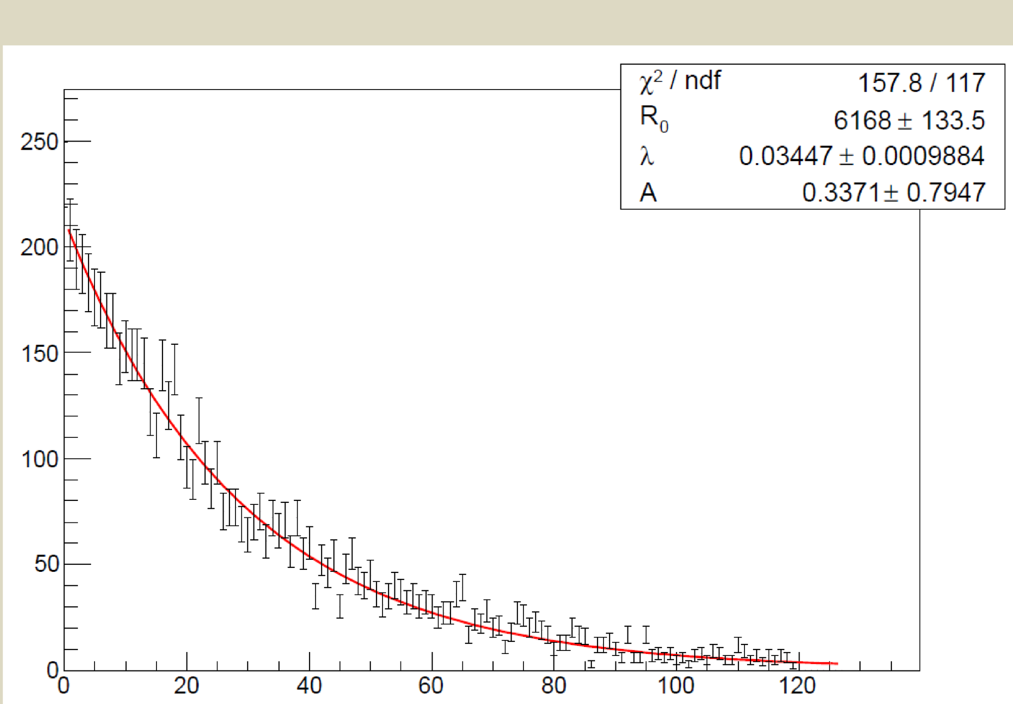
After an activation period of approximately 6 half lives, the targets were removed to a counting station. The rate of back-to-back gamma rays resulting from positron annihilation was used to determine the number of ^{11}C nuclei present.

Two pairs of 3 inch by 3 inch NaI detectors were used for coincidence counting

${}^{11}C \rightarrow {}^{11}B + e^+$ $\quad e^+ \rightarrow 2\ \gamma_{511KeV}$

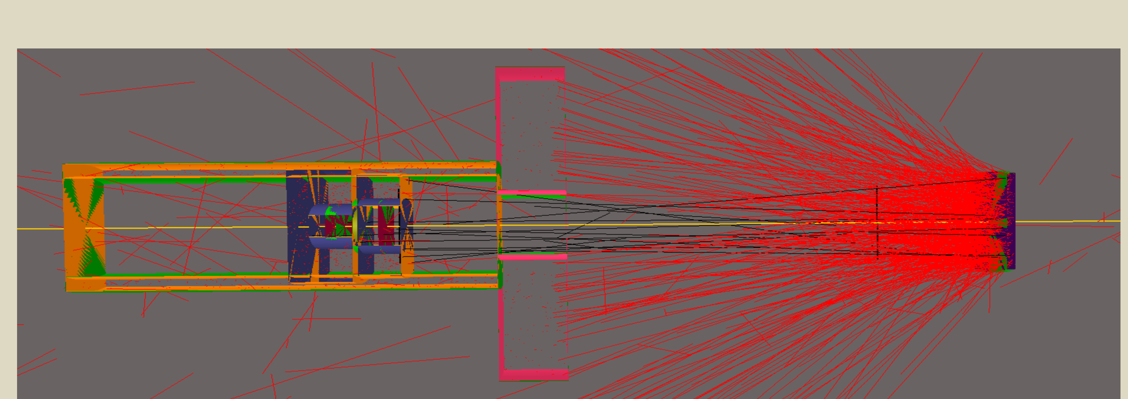


VI. Analysis and Results

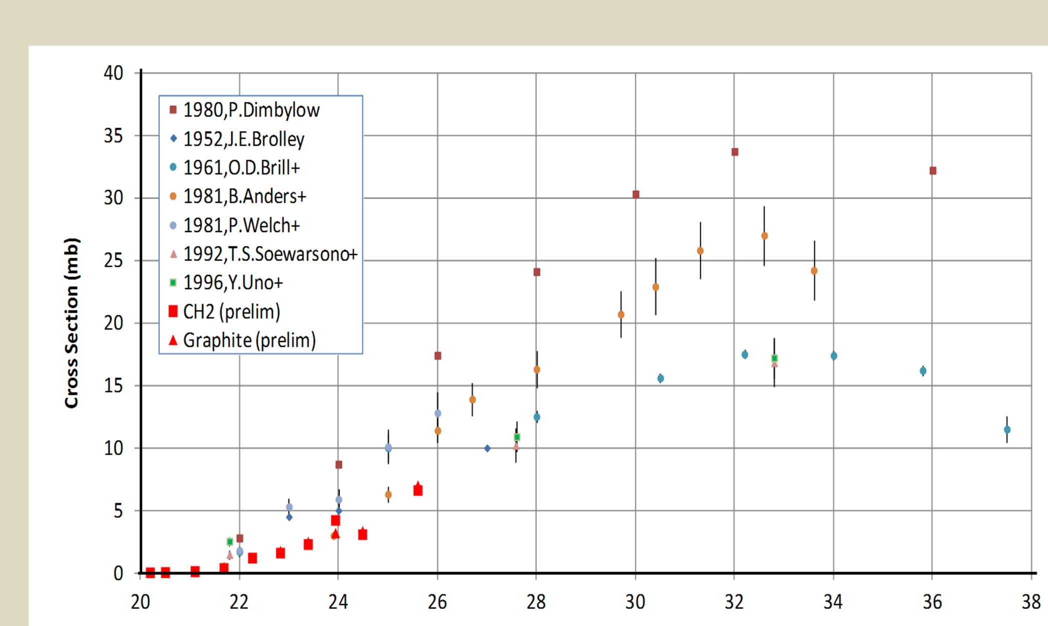


A decay curve with a constant background produced the initial number of measured ^{11}C decays. Transport time, dead time, and detector efficiency were accounted for, resulting in the total number of original carbon activations.

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 visualization of an MCNPX simulation of the experiment. Proton tracks (indicated in red), emitted from the polyethylene target (in purple), strike the graphite target (in pink). Some protons (indicated in black) pass through the hole in the graphite target where they are detected by the proton telescope (in blue).



The preliminary cross sections are shown above (in red, as squares and triangles). However, efficiency calibrations of the detector pairs need to be confirmed.