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The Breakup Cross Section of the D+D Reaction at 6.94 MeV

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Abstract. The D+D reactions are well known and widely used for a variety of purposes, mainly because of the use of the $D(d,n)^3He$ reaction as a mono-energetic neutron source. The least studied of the D+D reactions is the $D(d,n)pD$ reaction known as the deuteron breakup reaction, which produces a continuum of neutrons at energies below the mono-energetic peak. The neutron energy distribution as a function of angle for the cross section, $\frac{d^2\sigma}{d\Omega dE}$, of the D*(d,n)*pD reaction has been measured using a 6.94-MeV pulsed deuteron beam incident upon a D_2 gas target. The time-of-flight technique was used to determine the energy of the neutrons detected in an array of two lithium glass scintillators and one NE-213 scintillator. The breakup cross section was determined as low as 225-keV neutron energy in the lithium glass detectors.

1 Introduction and Experiment

The D+D reactions yield mono-energetic neutrons from the $D(d,n)^3He$ reaction and a continuum of low-energy neutrons from the $D(d,n)pD$ reaction for 7-MeV incident deuterons. The $D(d,n)pD$ reaction occurs when the incident deuteron energy is above the threshold of 4.45 MeV, causing one of the deuterons to break up into its constituent particles, the proton and the neutron. This reaction produces a continuum of neutrons at energies lower than the mono-energetic neutrons from the $D(d,n)^3He$ reaction.

In this work, the D*(d,n)*pD reaction has been studied for the purpose of use as a neutron source for the active interrogation of hidden fissile materials. The D+D reaction yields mono-energetic neutrons up to approximately 8 MeV based upon the incident deuteron energy and yields breakup neutrons at lower energies. The D+D reaction, as a neutron source, is attractive because unlike mono-energetic neutron sources that use radioactive materials, such as tritium, special regulations are not required. Neutrons from the $D(d,n)^3He$ reaction have been fully characterized, but neutrons resulting from the breakup reaction have not received this level of attention. Prior to this work, the D*(d,n)*pD cross section was not measured below a neutron energy of 1.5 MeV, where a substantial contribution to the cross section occurs.

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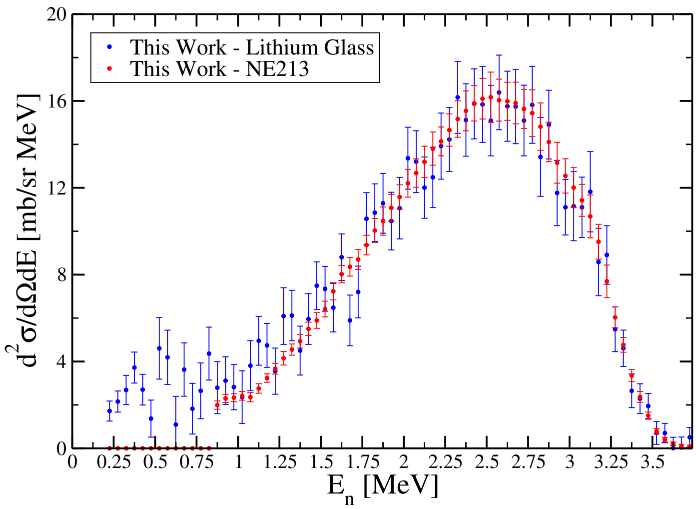

Figure 1. The measured neutron energy distribution of the cross section of the D*(d,n)*pD reaction at 0° for an incident deuteron energy of 6.94 MeV. The data were measured using NE-213 and lithium glass detectors.

2 Results and Discussion

The neutron energy distribution as a function of angle for the cross section, $\frac{d^2\sigma}{d\Omega dE}$, of the D*(d,n)*pD reaction has been measured at the Edwards Accelerator Laboratory of Ohio University, using a 6.94-MeV pulsed deuteron beam incident upon a D_2 gas target. Data for the cross section range between laboratory angles of 0° to 60°, in 5° increments. The 0° distribution is shown in Fig. 1. The time-of-flight technique was used to determine the energy of the neutrons detected in an array consisting of two lithium glass scintillators and one NE-213 scintillator. The NE-213 scintillator has a good neutron detection efficiency over a wide energy range and is practical for use down down to about 1 MeV. Lithium glass scintillators have a non-zero efficiency below 1 MeV, and were utilized to detect continuum neutrons from the breakup reaction down to 225 keV.

The breakup cross section was determined for neutron energies as low as 225 keV in the lithium glass detectors, well below the previous limits. Preliminary results from this work can be found in [1]. Simultaneous fits to the $\frac{d^2\sigma}{d\Omega dE}$ to test the self-consistency of the data are underway, which will allow for extrapolating cross section results to other laboratory angles and neutron energies as well as interpolating between existing results.

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[1] A.L. Richard, Master's thesis, Ohio University, Athens, Ohio, 2014.