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Primary authors: Carlos Yero, Werner Boeglin, Mark Jones
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First Measurements of the D(e,e'p)n Cross Section at Very High Recoil Momenta and Large Q^2

C. Yero and W.U. Boeglin
Florida International University, University Park, Florida 33199, USA

M.K. Jones
Thomas Jefferson National Accelerator Facility, Newport News, Virginia 23606, USA

(for the Hall C Collaboration)
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First results of cross section measurements of the $^2H(e,e'p)n$ reaction at 4-momentum transfers $4 \leq Q^2 \leq 5$ (GeV/c)^2 and neutron recoil momenta up to 1.18 GeV/c are presented. At the selected kinematics, Meson Exchange Currents (MEC) and Isobar Configurations (IC) are suppressed. Final State Interactions (FSI) have also been suppressed by choosing a kinematic region where the neutron recoil angle (θ_{nq}) is between 35 and 45 degrees with respect to the 3-momentum transfer, $\vec{q}$. In this region, the Plane Wave Impulse Approximation (PWIA) dominates and comparison to recent theoretical calculations show data to be sensitive to momentum distributions up to $\sim$ 700 MeV/c recoil momenta.

Being the most simple np bound state, the deuteron serves as a starting point to study the strong nuclear force at the subfermi level which is currently not well understood. At such small internucleon distances the NN (nucleon-nucleon) potential is expected to exhibit a repulsive core in which the interacting nucleon pair begins to overlap. The overlap is directly related to two-nucleon short range correlations (SRC) observed in $A \geq 2$ nuclei. Short-distance studies of the deuteron are also important in determining whether or to what extent the description of nuclei in terms of nucleon/meson degrees of freedom must be supplemented by the inclusion of explicit quark effects, which is an issue of fundamental importance in nuclear physics[1].

The most direct way to study the short range structure (or equivalently, the high momentum components) of the deuteron wavefunction is via the exclusive deuteron electro-disintegration reaction within the PWIA kinematics. In this approximation, the virtual photon couples to the proton which is ejected from the nucleus without further interaction with the recoiling neutron, which carries a momentum equal in magnitude but opposite in direction to the ejected proton, $\vec{p}_r = -\vec{p}_{i,p}$. This gives direct access to the deuteron momentum distributions since the scattered neutron momentum remains unchanged.

In reality, the ejected particles undergo subsequent interactions resulting in re-scattering of the proton and neutron (FSIs). Another possibility is that the photon may couple to the virtual meson being exchanged between the nucleons (MECs), or the photon may excite either nucleon in the deuteron into a resonance state (ICs) which decays back into the ground state nucleon causing futher re-scattering between the proton and neutron. The above-mentioned long-range processes alter the final neutron momentum making the deuteron momentum distributions unaccessible.

Previous deuteron electro-disintegration experiments performed at Jefferson Lab have helped dis-entangle and quantify the contributions from FSI, MEC and IC on the $^2H(e,e'p)n$ cross-section. The first of these was performed in Hall A at relatively low momentum transfers $Q^2 = 0.665$ (GeV/c)^2 and neutron recoil momenta up to $p_r = 550$ MeV/c where it was shown that for $p_r > 300$ MeV/c, the inclusion of FSI, MEC and IC was necessary in Arenhovel's calculations for a satisfactory agreement between the theory and data.

The next experiment was performed in Hall B using the CEBAF Large Acceptance Spectrometer (CLAS) which took advantage of its large detector acceptance to simultaneously measure a wide variety of kinematic settings giving an overview of the $^2H(e,e'p)n$ reaction kinematics. This was the first experiment to probe the deuteron at high momentum transfers ($1.75 \leq Q^2 \leq 5.5$ (GeV/c)^2) and presented angular distributions of cross-sections and confirmed the onset of the General Eikonal Approximation (GEA), which predicts a strong angular dependence of FSI with neutron recoil angles with FSI peaking at $\theta_{nq} \sim 70^o$. The cross-sections versus neutron recoil momenta up to 2 GeV/c were also presented with integrated over all neutron recoil angles to gain better statistical precision. As a result, it was not possible to choose kinematical regions regions in which FSI were minimal to extract the momentum distributions.

Finally, a third $^2H(e,e'p)n$ experiment was performed in Hall A at $Q^2 = 0.8, 2.5, 3.5$ (GeV/c)^2 and recoil momenta up to 550 MeV/c at kinematics which allowed the extraction of angular and momentum distributions for significantly smaller kinematical bins than in Hall B/CLAS. The angular distributions were presented as the cross-section ratio, $R = \sigma_{exp}/\sigma_{PWIA}$ versus θ_{nq}, and verified the strong anisotropy of FSI with θ_{nq}. Most importantly, for recoil neutron momentum bins, $p_r = 0.4 \pm 0.02, 0.5 \pm 0.02$ GeV/c, the ratio $R \sim 1$ for $35^o \leq \theta_{nq} \leq 45^o$

The authors would like to thank Tex, LaTeX and Friends for the answer to this question.

[1] P. Ulmer *et al.*, “Short-Distance Structure of the Deuteron and Reaction Dynamics in ^{2}H(e,e'p)n,” https://www.jlab.org/exp_prog/proposals/01/PR01-020.pdf (2001), *Jefferson Lab Proposal E01-020*.