Version xx as of October 18, 2019
Primary authors: Carlos Yero, Werner Boeglin, Mark Jones
To be submitted to PRL
Comment to cyero002@fiu.edu by xxx, yyy

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)

(Dated: October 18, 2019)

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.

The deuteron (^{2}H) was discovered in 1931 by Harold Urey, and it remained a mystery until the discovery of the neutron by James Chadwick the following year. Since then, the deuteron has been under intensive research in an attempt to understand what binds the atomic nucleus. Being a 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.

In nuclear structure studies in general, electron-nucleon scattering serves as the most valuable tool since the interaction is described by Quantum Electro-Dynamics (QED), which is well-understood and capable of making accurate predictions. Electron scattering experiments can be separated into inclusive or exclusive scattering experiments. In the first of these, only the electron is detected in the final state (single-arm experiments), and so one studies the nucleus in question by integrating over all possible final states. In the exclusive type, one or more particles are detected in coincidence with the scattered electron which allows one to investigate properties unique to the specific reaction in question. In deuteron electro-disintegration, for example, one detects the scattered electron in coincidence with a proton and the missing neutron is reconstructed from four-momentum conservation. This reaction proves to be the most direct way of probing the internal structure of the deuteron since it is possible to deduce the internal momentum of the nucleons from the neutron missing momentum.

With the 12 GeV Upgrade at Jefferson Lab, the short-range ($\leq$ 1 fm) structure of the deuteron will become experimentally accessible via data on the deuteron wave-function beyond relative internal momenta of 400 MeV/c. At such high energies, one will be able to probe if effects due to Quantum Chromodynamics (QCD) start playing a more significant role.

This sample document demonstrates proper use of REVTEX 4 (and LATEX 2_ε) in mansucripts prepared for submission to APS journals. Further information can be found in the REVTEX 4 documentation included in the distribution or available at http://publish.aps.org/revtex4/.

When commands are referred to in this example file, they are always shown with their required arguments, using normal TEX format. In this format, `#1`, `#2`, etc. stand for required author-supplied arguments to commands. For example, in `\section{#1}` the `#1` stands for the title text of the author's section heading, and in `\title{#1}` the `#1` stands for the title text of the paper.

Line breaks in section headings at all levels can be introduced using \\. A blank input line tells TEX that the paragraph has ended. Note that top-level section head-

ings are automatically uppercased. If a specific letter or word should appear in lowercase instead, you must escape it using `\lowercase{#1}` as in the word "via" above.

This file may be formatted in both the `preprint` and `twocolumn` styles. `twocolumn` format may be used to mimic final journal output. Either format may be used for submission purposes; however, for peer review and production, APS will format the article using the `preprint` class option. Hence, it is essential that authors check that their manuscripts format acceptably under `preprint`. Manuscripts submitted to APS that do not format correctly under the `preprint` option may be delayed in both the editorial and production processes.

The `widetext` environment will make the text the width of the full page. The width-changing commands only take effect in `twocolumn` formatting. It has no effect if `preprint` formatting is chosen instead.

To cite bibliography entries, use the `\cite{#1}` command. Most journal styles will display the corresponding number(s) in square brackets: [**?**]. To avoid the square brackets, use `\onlinecite{#1}`: Refs. **?** and **? ?** . REVTEX "collapses" lists of consecutive reference numbers where possible. We now cite everyone together [**? ? ?**], and once again (Refs. **? ? ?**). Note that the references were also sorted into the correct numerical order as well.

Footnotes are produced using the `\footnote{#1}` command. Most APS journal styles put footnotes into the bibliography. REVTEX 4 does this as well, but instead of interleaving the footnotes with the references, they are listed at the end of the references. Because the correct numbering of the footnotes must occur after the numbering of the references, an extra pass of LATEX is required in order to get the numbering correct.

Inline math may be typeset using the `$` delimiters. Bold math symbols may be achieved using the `bm` package and the `\bm{#1}` command it supplies. For instance, a bold α can be typeset as `$\bm{\alpha}$` giving $\boldsymbol{\alpha}$. Fraktur and Blackboard (or open face or double struck) characters should be typeset using the `\mathfrak{#1}` and `\mathbb{#1}` commands respectively. Both are supplied by the `amssymb` package. For example, `$\mathbb{R}$` gives $\mathbb{R}$ and `$\mathfrak{G}$` gives $\mathfrak{G}$

In LATEX there are many different ways to display equations, and a few preferred ways are noted below. Displayed math will center by default. Use the class option `fleqn` to flush equations left.

Below we have numbered single-line equations; this is the most common type of equation in *Physical Review*:

$$\chi_+(p) \lesssim [2|\mathbf{p}|(|\mathbf{p}|+p_z)]^{-1/2} \begin{pmatrix} |\mathbf{p}|+p_z \\ px+ip_y \end{pmatrix}, \quad (1)$$

$$\left\{ \mathbb{1}234567890abc123\alpha\beta\gamma\delta1234556\alpha\beta\frac{1\sum_b^a}{A^2} \right\}. \quad (2)$$

Note the open one in Eq. (2).

FIG. 1. A figure caption. The figure captions are automatically numbered.

Not all numbered equations will fit within a narrow column this way. The equation number will move down automatically if it cannot fit on the same line with a one-line equation:

$$\left\{ ab12345678abc123456abcdef\alpha\beta\gamma\delta1234556\alpha\beta\frac{1\sum_b^a}{A^2} \right\}. \quad (3)$$

When the `\label{#1}` command is used [cf. input for Eq. (2)], the equation can be referred to in text without knowing the equation number that TEX will assign to it. Just use `\ref{#1}`, where `#1` is the same name that used in the `\label{#1}` command.

Unnumbered single-line equations can be typeset using the `\[`, `\]` format:

$$g^+g^+ \to g^+g^+g^+g^+ \dots , \quad q^+q^+ \to q^+g^+g^+ \dots .$$

Figures may be inserted by using either the `graphics` or `graphicx` packages. These packages both define the `\includegraphics{#1}` command, but they differ in how optional arguments for specifying the orientation, scaling, and translation of the figure. Fig. 1 shows a figure that is small enough to fit in a single column. It is embedded using the `figure` environment which provides both the caption and the imports the figure file.

Fig. 2 is a figure that is too wide for a single column, so instead the `figure*` environment has been used.

The heart of any table is the `tabular` environment which gives the rows of the tables. Each row consists of column entries separated by `&`'s and terminates with `\\`. The required argument for the `tabular` environment specifies how data are displayed in the columns. For instance, entries may be centered, left-justified, right-justified, aligned on a decimal point. Extra column-spacing may be be specified as well, although REVTEX 4 sets this spacing so that the columns fill the width of the table. Horizontal rules are typeset using the `\hline` command. The doubled (or Scotch) rules that appear at the top and bottom of a table can be achieved enclosing the `tabular` environment within a `ruledtabular` environment. Rows whose columns span multiple columns can be typeset using the `\multicolumn{#1}{#2}{#3}` command (for example, see the first row of Table **??**).

Tables **??**-**??** show various effects. Tables that fit in a narrow column are contained in a `table` environment. Table **??** is a wide table set with the `table*` environment. Long tables may need to break across pages. The most straightforward way to accomplish this is to specify the `[H]` float placement on the `table` or `table*` environment. However, the standard LATEX 2_ε package `longtable` will give more control over how tables break and will allow

FIG. 2. Use the figure* environment to get a wide figure that spans the page in `twocolumn` formatting.

headers and footers to be specified for each page of the table. A simple example of the use of `longtable` can be found in the file `summary.tex` that is included with the REVTEX 4 distribution.

There are two methods for setting footnotes within a table (these footnotes will be displayed directly below the table rather than at the bottom of the page or in the bibliography). The easiest and preferred method is just to use the `\footnote{#1}` command. This will automatically enumerate the footnotes with lowercase roman letters. However, it is sometimes necessary to have multiple entries in the table share the same footnote. In this case, there is no choice but to manually create the footnotes using `\footnotemark[#1]` and `\footnotetext[#1]{#2}`. `#1` is a numeric value. Each time the same value for `#1` is used, the same mark is produced in the table. The `\footnotetext[#1]{#2}` commands are placed after the `tabular` environment. Examine the LaTeX source and output for Tables **??** and **??** for examples.

Physical Review style requires that the initial citation of figures or tables be in numerical order in text, so don't cite Fig. 2 until Fig. 1 has been cited.

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

[1] W. U. Boeglin *et al.* (For the Hall A Collaboration), Phys. Rev. Lett. **107**, 262501 (2011).
[2] W. Boeglin and M. Sargsian, International Journal of Modern Physics E **24**, 1530003 (2015).