$p(e,e'p)\eta$ and $p(e,e'p)\eta'$ Cross Sections From New Jefferson Lab Data

Physics 499 Project
2019/2020 Session
Dr. Garth Huber and Dr. Stephen Kay

Protons are not fundamental particles, they are themselves formed of other particles known as quarks. Quarks within the proton interact with each other via the strong nuclear force, one of the four fundamental forces of nature. However, at the energy scales involved within the proton, these interactions are very poorly understood. Experimental measurements such as electroproduction reactions off the proton, in which an incoming high energy electron beam exchanges a virtual photon with a proton within a hydrogen target to produce various reaction products, are a vital tool for studying the internal interactions and structure of protons. A recent series of such electroproduction experiments at Jefferson Lab (JLab) has yielded a wealth of data that are yet to be analysed.

There are a wide range of physics channels that can be analysed in the data. Many different reactions are possible; the different types of reactions that occur can be categorised by using a set of Lorentz-invariant quantities, s, t and u, referred to as the "Mandlestam variables". s is the invariant mass squared of the interacting particles, t and u correspond to the four momenta (squared) exchanged between different particles in the interaction. A reaction where the variable u approaches 0 would be classified as a u-channel interaction. In the electroproduction data taken at JLab, one such u-channel interaction is backward angle meson production. An example Feynman diagram of such a process can be seen in Figure 1. As well as the ω shown in this figure, other neutral flavourless mesons could also be produced in its place. Two other such mesons that could be produced are the η and η' mesons. The overall goal of this project would be to study and if possible, extract the $p(e,e'p)\eta$ and $p(e,e'p)\eta'$ cross sections at both high and low virtual photon polarisation, ϵ, from the experimental data.

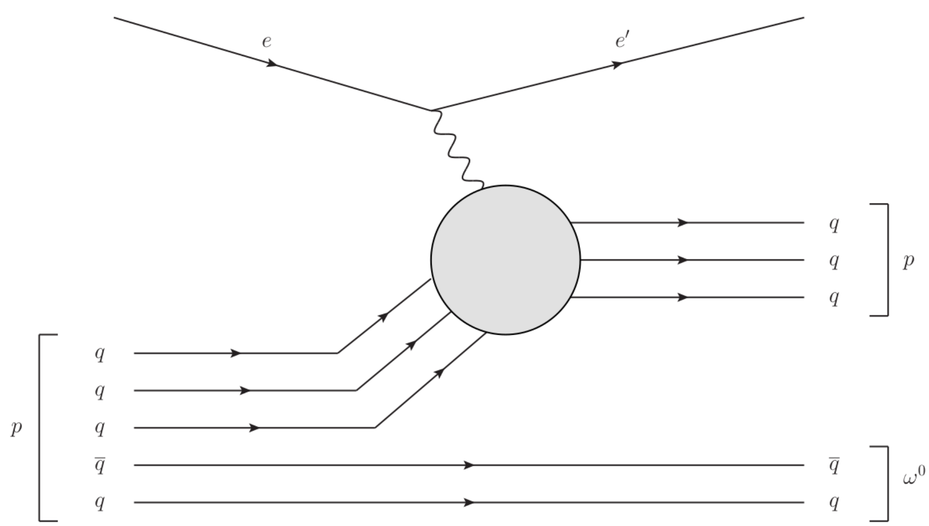

Figure 1: An incoming electron emits a virtual photon that interacts with the target proton. The three proton valence quarks are knocked out at a forward angle, leaving behind a $q\bar{q}$ from the proton "quark sea", which forms a meson. In this case an ω^0 meson is formed. [1]

It is expected that during the Fall semester, a student working on the project would familiarise themselves with the analysis framework and relevant software. This would likely involve the creation of short scripts or macros utilising the ROOT programming language to sort, filter and fit subsections of data from larger files. They would also be expected to read up on the relevant physics background and the experimental facility. This preparation should serve as excellent preparation to begin analysing the data in the Winter semester. An example plot of the proton missing mass spectrum, showing the peaks corresponding to the η and η' being produced can be seen in Figure 2. As can be observed in this figure, there is a large background around these signal peaks. The analysis carried out in this project would include refining selection cuts to minimise this experimental background and ascertaining the required fits to extract information from the signal peaks. This work would be carried out in close collaboration with other members of the research group working on a series of related projects.

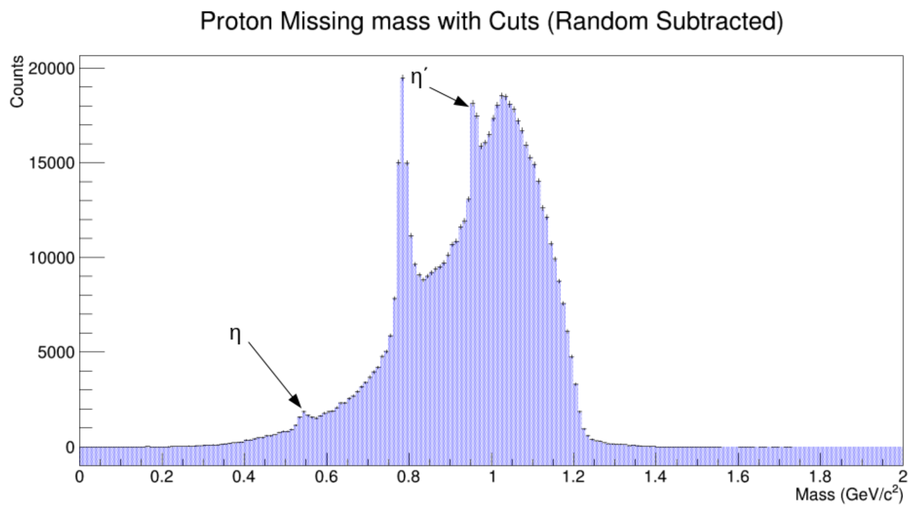

Figure 2: Missing mass spectrum for proton events, the η and η' peaks are indicated.

[1] - W. Li. *Exclusive Backward-Angle Omega Meson Electroproduction*, PhD thesis, University of Regina, 2017, available at https://misportal.jlab.org/ul/publications/view_pub.cfm?pub_id=15234