Studies of Proton Structure from Photo- and Electro-Production of ρ^0 Mesons

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Abstract

The analysis of light vector meson production by a high-energy electron or photon beam in a particle accelerator provides insight into the composition of the proton, further expanding the fundamental understanding of physics. The electro-production of light vector mesons off of protons happens when a high virtuality photon interacts with a quark, which can be studied to extract the Generalized Parton Distributions (GPDs). These functions provide access to the correlation between the longitudinal momenta of partons and their transverse position. They can be further interpreted to obtain multidimensional images of the proton. Vector mesons are particularly sensitive to the GPDs H and E and allow for flavor decomposition of the proton's GPDs. We implemented the rho vector meson ρ^0 in a generator used in simulations for Jefferson Laboratory (DEEPGen) and for EIC (DEEPSim). Our goal is to contribute to the development of future Hard Exclusive (light) Vector Meson experiments for Jefferson Laboratory and EIC. We will discuss the physical interest of measuring light vector mesons for accessing GPDs, then present our work with the event generator and our projections for future experiments.

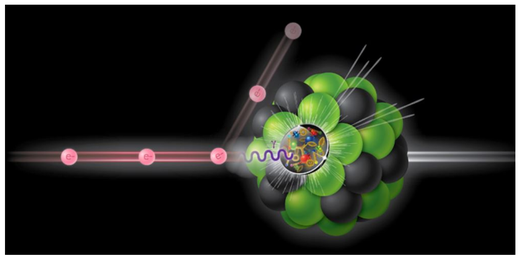

Figure 1:Artist's rendition of hadron collision experiments.

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Introduction

We use an event generator to develop a model for testing Hard Exclusive Meson Production (HEMP) in hadron colliders such as JLab and EIC.

- By using low, "soft" energy levels, we may be able to resolve the three quarks that make up the proton as point-like particles (naïve model).
- Using high, "hard" energy levels, we can see details of the internals of the proton, revealing a "sea" of quarks and gluons (more complex model).
- The HEMP reaction in a hadron collider involves a high-energy beam of electrons or photons that react with a stationary proton to exclusively produce mesons (such as ρ^0).
- The reaction is split into the calculable "hard" process, and the low-energy sea quark interactions, described by a Generalized Parton Distibution (GPD) function.
- Measuring energy in and out of the "hard" process gives us insight into the more complicated GPD, and therefore the internal structure of the proton.
- The outgoing mass-energy forms a distribution, where certain values associated with specific mesons are more likely.
- By separating the ρ^0 meson distribution from others using an event generator, we can obtain a clearer picture of the factors that affect meson generation by comparing the data to experimental evidence.

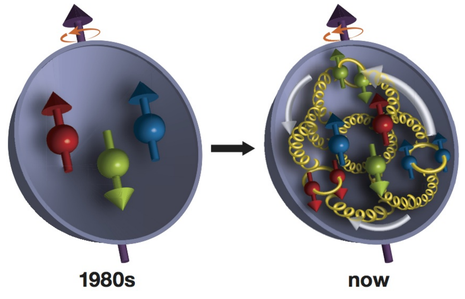

Figure 2:Protons contain three quarks, described by two models: The naïve model of quarks as point-like particles, and the modern, more complex model of a "sea," of quarks and gluons in the proton.

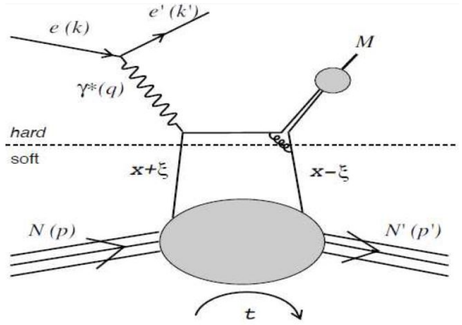

Figure 3:The Feynman diagram of the HEMP reaction shows the separation of the calculable "hard" process, and the complex "soft" process, described by a GPD.

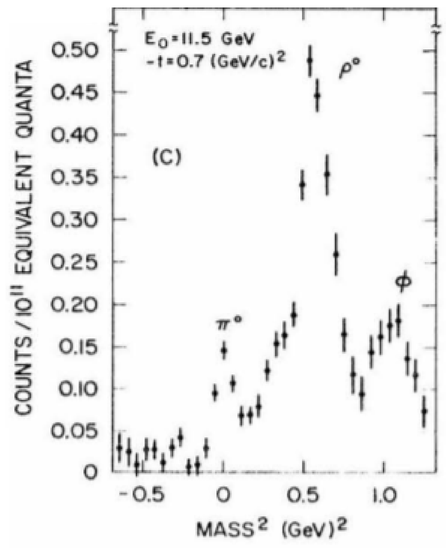

Figure 4:The mass-energy output of the HEMP reaction is a distribution, with peaks corresponding to mesons such as π^0, ρ^0, and ϕ.

Methods

- Event generator written in C++ using CERN's ROOT functions
- ρ^0 meson distribution based on relativistic Breit-Wigner distribution
- The distribution shape was weighted with the cross-section for the photo- or electro-production of ρ^0. The proper cross-section is applied depending on user input.

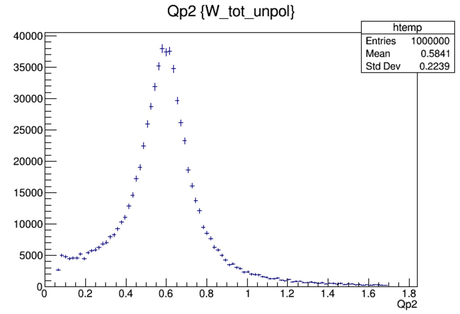

Figure 5:Generated mass-energy (Q'^2) output distribution for ρ^0 meson production. Graph shows Q'^2 vs. counts.

Conclusion

- The generated distribution follows a relativistic Breit-Wigner distribution, with the cross-section weight skewing the distribution to the left.
- By limiting the scope of the output energy to include only the ρ^0 peak, we may isolate its production in physical experiments at JLab or EIC to make more accurate measurements for specific meson production, providing insight to the GPDs.

References

- https://bnl.gov/eic
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