Light Meson Form Factors from **D**eep **E**xclusive **M**eson **P**roduction in early EIC science configurations with the ePIC Detector

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Abstract

Abstract goes here

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1 Introduction

Pions and kaons are among the most prominent strongly interacting particles next to the nucleon, since they are the Goldstone bosons of QCD. Thus, it is important to study their internal structure and how this reflects their Goldstone boson nature; a question particularly relevant for understanding the origin of mass generation in QCD.

The hard contribution to the π^+ form factor can be calculated exactly within the framework of pQCD, and at asymptotically high Q^2 it takes a particularly simple form, $F_\pi(Q^2) \xrightarrow[Q^2\to\infty]{} 16\pi\alpha_s(Q^2)f_\pi^2/Q^2$ [1], where f_π is the π^+ decay constant. In general, the pion also contains soft contributions, which are expected to dominate at lower Q^2. The actual behavior of F_π as a function of Q^2, as QCD transitions smoothly from the non-perturbative (long-distance scale) confinement regime to the perturbative (short-distance scale) regime, is an important test of our understanding of QCD in bound hadron systems. Since QCD calculations cannot yet be performed rigorously in the confinement regime, experimental data from JLab play a vital role in validating the theoretical approaches employed. In particular, due to the charged pion's relatively simple quark-antiquark ($q\bar{q}$) valence structure and its experimental accessibility, the pion elastic form factor (F_π) offers our best hope of directly observing QCD's transition from color-confinement at long distance scales to asymptotic freedom at short distances. It is worth highlighting that in QCD the difference between the kaon and pion charge form factors is of the scale of 20% at $Q^2 \sim 5$ GeV^2 [2] and disappears at asymptotic Q^2 as $\ln(Q^2)$. Thus, the acquisition of experimental data for both form factors covering a wide Q^2 range should be a high priority.

Current experimental information on the pion and kaon form factors is limited, particularly at large Q^2 [3]. Measurement of the π^+ electromagnetic form factor for $Q^2 > 0.3$ GeV^2 can be accomplished by the detection of the exclusive reaction $p(e, e'\pi^+)n$ at low $-t$. This is best described as quasi-elastic (t-channel) scattering of the electron from the virtual π^+ cloud of the proton, where $t = (p_p - p_n)^2$ is the Mandelstam momentum transfer to the target nucleon. Scattering from the π^+ cloud dominates the longitudinal photon cross section ($d\sigma_L/dt$), when $|t| \ll m_p^2$. To reduce background contributions, one preferably separates the components of the cross section due to longitudinal (L) and transverse (T) virtual photons (and the LT, TT interference contributions), via a Rosenbluth separation. A Rosenbluth separation involves the absolute subtraction of two measurements determined at high- and low-virtual photon polarization (ϵ_{Hi}, ϵ_{Lo}), corresponding to high and low electron beam energies, with very different detector rates. The resulting errors on σ_L and σ_T are magnified by $1/\delta\epsilon = (\epsilon_{Hi} - \epsilon_{Lo})^{-1}$. To keep the uncertainties in σ_L to an acceptable level, $\delta\epsilon > 0.2$ is typically required, *i.e.* an uncertainty magnification of no more than 5. The measurements require continuous, high intensity electron beams, and detectors with good particle identification and reproducible systematics. JLab Hall C is currently the only facility worldwide capable of such studies.

At the EIC, π^+ form factor measurements can be extended to significantly larger Q^2 than possible at JLab. We have written an exclusive $p(e, e'\pi^+n)$ event generator [4] and performed detailed simulations to determine the feasibility of F_π measurements at the EIC. The key questions we have addressed include: 1) detector requirements to cleanly identify exclusive $e'\pi^+n$ coincidences; 2) experimental acceptance and projected counting rates for such triple coincidences; 3) event reconstruction resolution requirements to reliably extract $F_\pi(Q^2)$ from $p(e, e'\pi^+n)$ data. Since the cross section falls rapidly as the distance from the pion pole $(t - m_\pi^2)$ is increased, this steep fall off needs to be measured to confirm the dominance of the pion cloud mechanism in the acquired data. This note describes our work addressing all of these questions.

2 Simulation Overview

Details on the simulation, event generator used, detector geometry, beam conditions etc. Details on the relevant simulation campaign. Reference other sections via Sec. 1 and cite things via [5].

2.1 Event Generator Details

Information on event generator utilised. Specify version, link to instructions for running code (should be provided for Production WG). Break out other components into subsections if desired/needed (e.g. if simulation geometry is specific/unique).

3 Event Selection

Information on your event selection procedure/process. Highlight any specific subsystems used if relevant. Outline cuts used, ordering, rationale. If a cut is "unusual" or non-standard, make sure you discuss it. When showing kinematic variables, **clarify the reconstruction method.**. If needed, include a description of the reconstruction method.

3.1 Analysis Code

Information on where to find your analysis code, how to run it. Consider adding additional details to the appendix (weird compilation quirks etc).

4 Results and Discussion

Your results with key performance plots etc. Consult checklist of key figures, see page three of this presentation as an example of plots to include.

Once triple-coincidence $p(e, e'\pi^+n)$ events are cleanly identified with ePIC, the value of $F_\pi(Q^2)$ is determined by comparing the measured $d\sigma/dt$ values at small $-t$ to the best available electroproduction model. The obtained F_π values are in principle dependent upon the model used, but one anticipates this dependence to be reduced at sufficiently small $-t$. Measurements over a range of $-t$ are an essential part of the model validation process. The JLab 6 GeV experiments were instrumental in establishing the reliability of this technique up to $Q^2 = 2.45$ GeV^2 [3, 6–13], and extensive further tests are planned as part of JLab experiment E12-19-006 [14].

GH can add more discussion later.

A Appendix

Material you wish to include in an appendix.

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