E01014 Precision Measurements of Electroproduction of π^0 near Threshold: A Test of Chiral QCD Dynamics

A Commissioning Experiment for the BigBite Spectrometer

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Significant progress has been made in the application of QCD in the non-perturbative regime via the use of Chiral Perturbation Theory (ChPT). Symmetry breaking effects are introduced via perturbative expansions in terms of static and dynamic variables such as m_π/M and Q^2/M, where m_π (M) is the mass of the pion (nucleon) and Q^2 is the four-momentum transferred to the π-N system. Since it involves the well understood electromagnetic interaction and small kinematic quantities, near-threshold electromagnetic production of pions (in particular, neutral pions due to the absence of the overshadowing Kroll-Ruderman term) from nucleons provides an ideal testing ground for ChPT. As ChPT is an "effective" field theory, the description of pion electroproduction contains parameters which must be fixed by measurement, the so-called Low Energy Constants or LEC's. However, once these are fixed it should be possible to predict consistently the evolution with Q^2 and W (center-of-mass energy of the π-N system) of all observables.

Considerable effort has gone into measurements of both the photo-production $p\left(\gamma,\pi^0\right)$ and electro-production $p(e,e'p)\pi^0$ of neutral pions near threshold. Measurements at Mainz of the lowest contributing multipole (E_{0+}) to photoproduction are well reproduced by ChPT. The most recent high precision measurements of electroproduction were made at Mainz with four-momentum transfers of 0.10 $[GeV/c]^2$ and 0.05 $[GeV/c]^2$. The former measurement yielded results consistent with the predictions of ChPT so it was surprising that the latter measurements disagreed significantly. Discrepancies were observed both at threshold (the limiting value of the L_{0+} multipole was observed to be twice the predicted value) and at higher values of W where the P–wave contributions are significant. If these discrepancies which, incidentally, are also inconsistent with the predictions of the SAID analysis and MAID model, remain unresolved they will constitute a serious threat to the viability of ChPT as a useful theory of dynamical processes.

We propose to make a high precision measurement of the reaction p(e,e'p)π^0 near threshold in a fine grid of Q^2 and ΔW in the range of 0.04 $[GeV/c]^2 \le Q^2 \le 0.14\ [GeV/c]^2$ and $0\ MeV \le \Delta W \le 20\ MeV$. The ϕ dependence of the cross section will be used to extract the structure functions $\sigma_T{+}\epsilon_L\sigma_L$, σ_{TL}, and σ_{TT}. The data will also be used in a partial wave analysis to provide information on the non-resonant contribution.

The standard equipment in Hall-A together with the new septum magnet and the upgraded large acceptance BigBite spectrometer allows new measurements to be made with high statistical precision (1% at peak cross sections). Systematic uncertainties are also minimized since measurements can be made withe BigBite spectrometer at a single position. This differs greatly from previous Mainz measurements, where several spectrometer positions were required to cover the necessary angular range. The septum magnet will allow the Hall-A spectrometers to reach small scattering angles (6 degrees) with high beam energies to maximize the cross section for a given Q^2. The lead glass calorimeter provides a tool to calibrate the acceptance of BigBite. The results will provide a stringent experimental test of chiral QCD dynamics, a test made all the more critical by recent data showing disagreement with the predictions of Chiral Perturbation Theory.

In preparation for this experiment, the BigBite spectrometer will be upgraded and commissioned and be of general utility for future experiments, including a continuation of charged and neutral pion production experiments on the proton and deuteron.