A Letter of Intent for Meson Spectroscopy at CLAS

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1 Introduction

We intend to extend spectroscopy studies of mesons, started at JLab by CLAS experiments E99-005 [Ad99] and E01-017 [Ad01], using the CLAS detector in Hall B. Early preliminary results of these experiments show the viability of these studies using CLAS. This letter presents our intention of submitting to the PAC a proposal for a long photoproduction run in Hall B. Our goal is to measure cross sections and spin-parity quantum numbers of meson resonances in the mass range of approximately 1 to 2 GeV. CLAS is able to measure multi-charged and multi-photon particle final states with good acceptances. We plan to obtain the high statistics that will be needed to access channels with four observed particles in the final state. We will study light-quark mesons, higher strangonia excitations, and exotic mesons. The importance of meson spectroscopy in intermediate energy physics, and for Jefferson Laboratory, has been clearly indicated by past PACs. We intend to submit a proposal after careful study of the necessary CLAS running conditions and required running times using simulation and analysis of the recent obtained data. Also, we want to have on hand results from the partial wave analysis of E01-017 data.

2 Physics

The study of mesons lying in the mass region between 1 to 2 GeV is particularly important for the study of strong interactions (QCD). QCD based theoretical models of hadrons lying outside the scope of the constituent quark model predicts the existence of multi-quark $q\overline{q}q\overline{q}$ and hybrid $q\overline{q}g$ mesons as well as purely gluonic states, referred to collectively as exotic mesons [Is85, Ko85], particularly in this mass region. Gluons play a central role in strongly interacting matter- quark confinement is due to gluonic forces. The most fundamental experimental signature for the presence and dynamics of gluons is the spectrum of gluonic excitations of hadrons. Gluonic excitations of mesons with "exotic" quantum numbers would be the most direct evidence for the discovery of these states, and determining their properties sheds light on the underlying dynamics of quark confinement. The addition of non-standard mesons to the list of normal constituent quark model mesons expected in these masses, makes for a difficult theoretical interpretation. Most of the data up to now has been obtained using hadronic beams at BNL E852, VES, and Crystal Barrel collaborations. Resonant signatures were observed for two JPC= 1^{-+} states, $\pi_1(1370)$ [Ch99] and $\pi_1(1600)$ [Ad98, Iv01]. The masses of these states are somewhat lower than one expects for isovector hybrids [Mo01], therefore, it is possible that one (or both) of these could be primarily a multi-quark state or even a dynamically generated object (e.g. final state interaction).

In order to establish the spectroscopy of these exotic states, whatever their nature, it is necessary to study a wide range of production and decay channels. There is very little experimental information on photoproduction of mesons at these masses, and it is noteworthy that JLAB has identified this area of research as the main objective in its upgrade proposal [Je01]. Photoproduction data will open the window on new production mechanisms and help the theoretical understanding of the meson spectrum. We have been developing partial wave analysis software that is now ready for these studies. The "intermediate region" links the physics of heavy quark decay calculations, which are based on perturbative calculations (HQET), and that of light quark decays understood under more phenomenological models ($^3P_0$). A successful theoretical description of that mass region will produce important insights into non-perturbative QCD calculations.

The first radially and orbitally excited states of isospin zero mesons

containing $s\bar{s}$ pairs (strangeonia) are also contained in the 1-2 GeV mass range. They are poorly identified experimentally. Predictions for masses and widths of all these excitations are available. Decays have been calculated in the $^3P_0$ model [Bar97]. However, the production mechanisms are not fully understood.

A ϕ radially excited state, which is believed to be the first $s\bar{s}$ radial excitation, has been observed in e^+e^- and photo-production, but its identification is still uncertain. The $\phi(1680)$ has been studied in three decay channels. One is photo-produced high-mass K^+K^- pairs. A peak in the K^+K^- mass spectrum was observed at FNAL [Bus89] and at CERN [Ast81]. The OMEGA collaboration reports no evidence for the photo-produced $\phi(1680)$ in this channel [Atk86], but it has been observed in e^+e^- production [Bis88]. There is, then, an inconsistency between the e^+e^- and photo-production data in the $(K\bar{K}^* + \bar{K}K^*)$ channel. More data are necessary to resolve this inconsistency and firmly establish the purely $s\bar{s}$ resonances. We also plan to access the $\gamma p \to \eta\phi p$ channel, as only a pure $s\bar{s}$ state can decay through this channel.

In order to understand exotics and strangeonia, we must catalog all meson states in this mass range.

3 CLAS

Experiment E99-005, and its extension E01-017, studied few-body final states (up to three charged particles) with photon beams in the 4.8-5.5 GeV energy range. These experiments ran for very limited time, 4 days and 8 days respectively, during the g6 CLAS run periods. Conditions during the first period were not dictated by meson spectroscopy requirements, and thus produced very limited acceptance in the low-t region. E01-017, in the g6c running period however, used a set of CLAS detector conditions (torus magnet at half maximum field and target moved 1 meter upstream of its standard position) to maximize acceptance for meson spectroscopy.

As an example of CLAS ability to study multi-particle final states we present below some preliminary results from experiments 99-005 (g6b) and 01-017 (g6c). Figure 1 shows the $\pi\pi$ mass distributions from the exclusive reaction $\gamma p \to \pi^+\pi^-\pi^0 p$, where the charged particles are detected in CLAS,

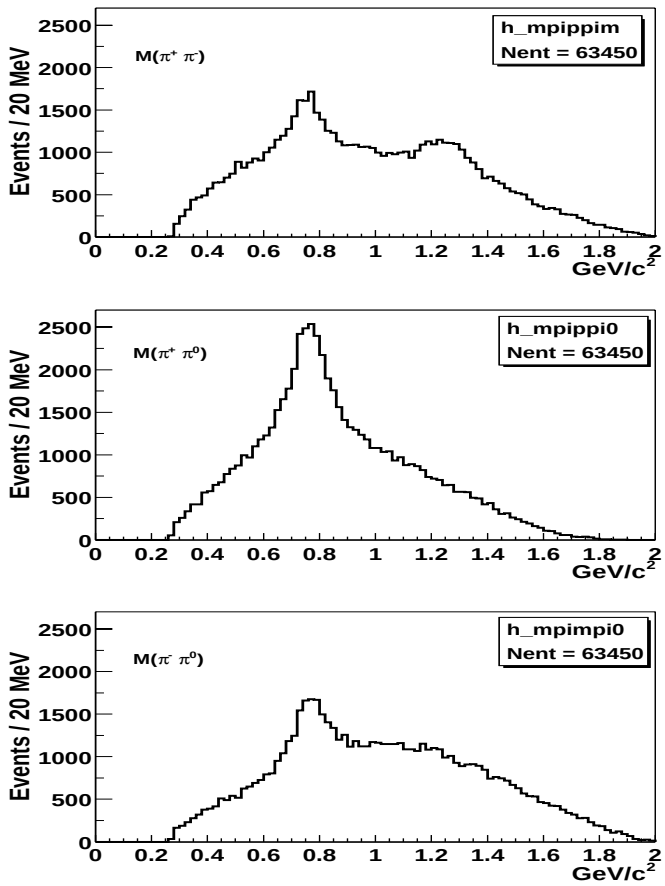

Figure 1: mass of $\pi\pi$

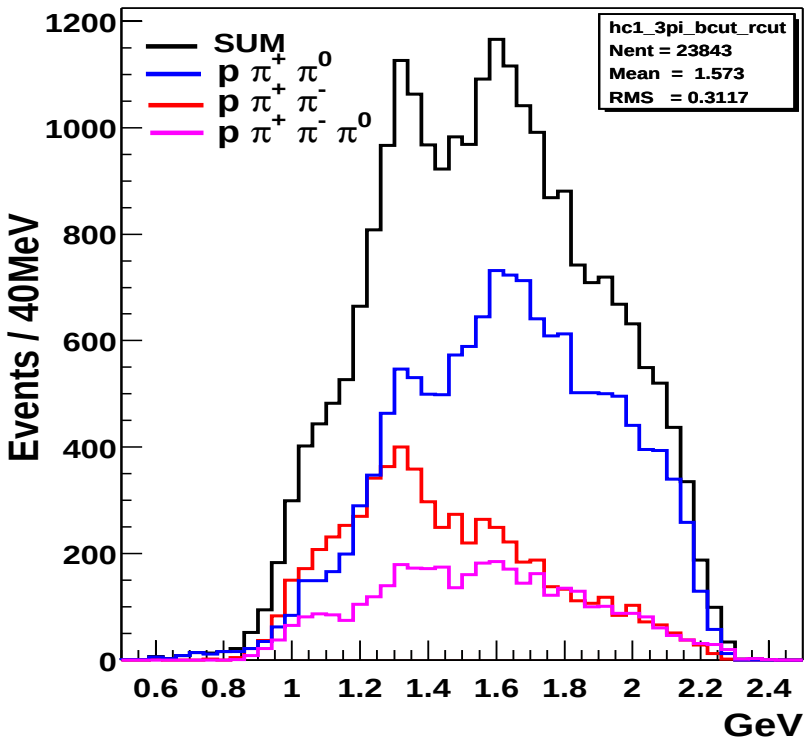

Figure 2: $\pi^+\pi^-\pi^0$ mass spectra with Δ^{++} and ρ cut

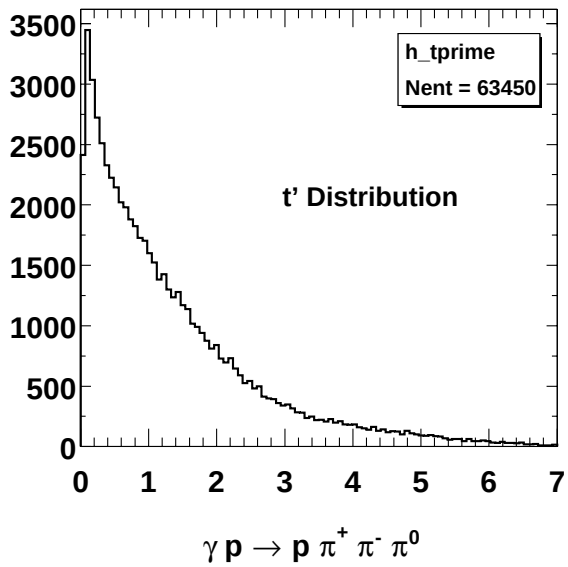

Figure 3: t' distribution for $\gamma p \to \pi^+\pi^-\pi^0 p$ events

and the π^0 is identified through missing mass. The ρ meson is seen in all three charged modes, and the $f_2(1270)$ is also seen. There is considerable Δ^{++} background in this channel from $\gamma p \to \Delta^{++}\rho$. Figure 2 show the $\pi^+\pi^-\pi^0$ mass spectrum cutting out the Δ^{++} and cutting on the ρ events. The $a_2(1320)$ is clearly evident, as well as a broad peak near $1600 MeV/c$. The t' distribution for these events is shown in figure 3, which indicates that these events are produced peripherally.

In order to achieve the highest statistics needed for the spin-parity identification of meson states, experiment E01-017 (g6c) ran with the CLAS torus magnetic field at half the maximum, the target moved 1 meter upstream of its standard position. In addition, we ran with a high photon flux, $\sim 5 \times 10^7$ tagged photons/second, and as a result the data is plagued by a high accidental rate. However, with the excellent timing resolution from CLAS, we have developed an algorithm to remove accidentals, which allows good K/π separation up to $1.7 GeV/c$. The first results from g6c are expected by next summer. However, early preliminary analyses of the K channels (already presented at DNP'2001) are very encouraging, for example, $\gamma p \to K^+K^-p$, where the kaons are observed in CLAS. Figure 4 shows

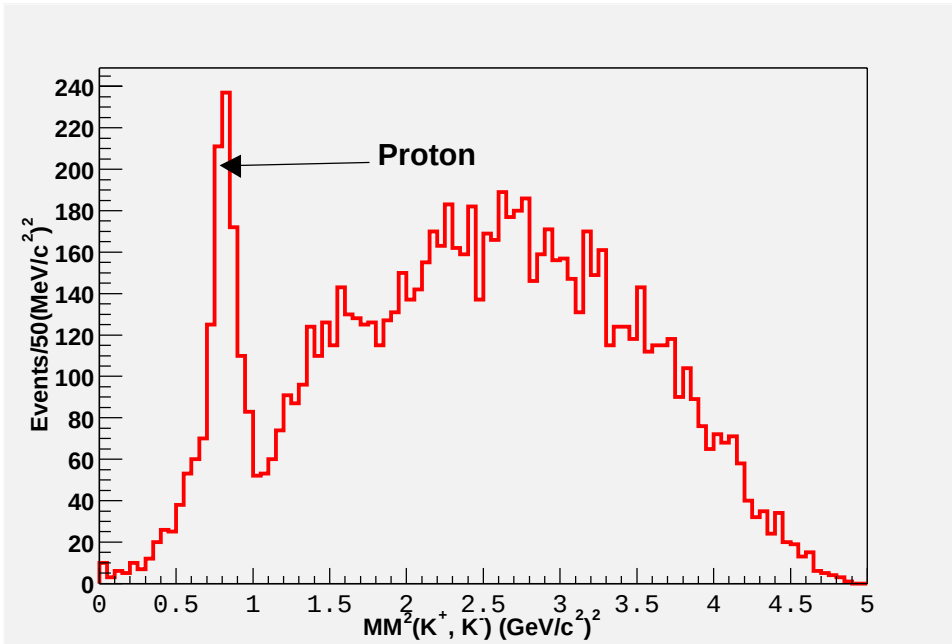

Figure 4: Squared mass plot off observed K^+K^- pairs.

the missing mass spectra off of observed K^+K^- pairs. A clean proton peak is observed. Events taken around this peak produces a pK^+K^- sample nearly devoid of pion contamination. Figure 5 shows t distributions and mass spectra of K^+K^- pairs from our pK^+K^- sample. The plot at the right of the figure shows a possible resonant peak is observed at a mass of 1680 MeV, produced at low t (left plot).

We also have preliminary results on the $K^+K^-\pi^+$ channel, showed in figure 6. These three particles are detected in the CLAS drift chambers, and the neutron is reconstructed by missing mass (top-left plot). A $K^*(890)$ resonance is clearly reconstructed from the $K^-\pi^+$ pairs. Finally, the $K^+K^-\pi^+$ system shows a peak around 1800 MeV (bottom-right plot).

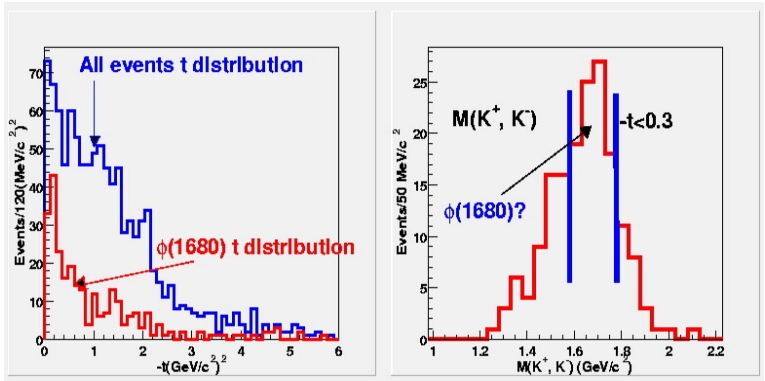

Figure 5: t distributions and mass spectra of K^+K^- pairs from our pK^+K^- sample.

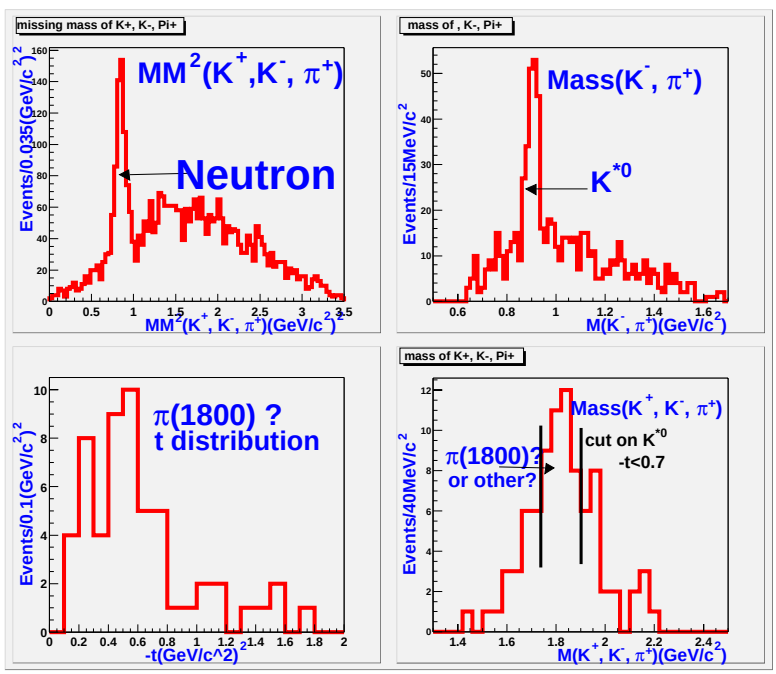

Figure 6: t distributions and mass spectra of $K^+K^-\pi^+$ of our $nK^+K^-\pi^+$ sample.

4 Summary

The importance of meson spectroscopy has been clearly indicated. The JLab PAC, the JLab administration, the JLab user community (see 'JLab at 12 GeV White Paper [Je01]), and the DNP Town Meeting on Electromagnetic and Hadron Physics have all indicated the importance of meson spectroscopy in the understanding of QCD in the confinement region. We believe that in the next five years CLAS can produce meson spectroscopic results of similar quality to those of the most successful experiments in the field, as for example, E852 at Brookhaven [Ad98], and the VES collaboration at Protvino [Do01].

Based in the importance of this physics and the potentially important returns, we intend to submit a meson spectroscopy proposal using the CLAS detector in Hall B and accelerator energies of more than 5.5 GeV.

References

[Ad99] G. S. Adams, C.W.Salgado and D.P.Weygand, PAC15/E99-005(1999).

[Ad01] G. S. Adams, C.W.Salgado and D.P.Weygand, PAC19/E01-017(2001).

[Is85] N. Isgur and J. Paton, Phys. Rev. D **31**, 2910 (1985).

[Ko85] N. Isgur, R. Kokoski, and J. Paton, Phys. Rev. Lett. **54**, 869 (1985).

[Ch99] S.U. Chung, et al., Phys. Rev. D, 60, 092001 (1999).

[Ad98] G. S. Adams *et al.*,Phys.Rev.Lett. **81**, 5760-5763 (1998).

[Iv01] E.I. Ivanov, et al., Phys. Rev. Lett. 86, 3977 (2001).

[Mo01] See the review by C. Morningstar, preprint nucl-th/0110074.

[Je01] White Paper:"The Science Driving the 12 GeV Upgrade of Cebaf",Jefferson Lab, Feb.(2001).

[Bar97] T. Barnes, Strange Higher Quarkonia (in preparation), (1997).

[Bus89] Busunitz *et al.*, Phys. Rev., **D40**, 1 (1989).

[Ast81] Aston *et al.*, Phys. Lett., **104B**, 231 (1981).

[Bis88] D. Bisello et al., (DM1), Z.der Physics, **C39**,13, (1988).

[Atk86] Atkinson *et al.*, (OMEGA), Z. Phys., **C30**,541 (1986).

[Do01] V. Dorofeev *et al.*, Proceedings of 9th International Conference on Hadron Spectroscopy (Hadron 2001), Protvino, Russia, 25 Aug - 1 Sep 2001.