Meson Spectroscopy in Few-body Decays (E99-005)
Extension Request (2001 Run)

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Abstract

Experiment 99-005 was approved by PAC 15 to take data during the g6b running period of CLAS. E99-005 studies photo-production of mesons decaying to three-meson final states. It concentrates in the search for exotic mesons and strangonium states. The importance of this physics for JLab has been clearly indicated by the PAC, the JLab user community and several recent workshops and town meetings. Based on preliminary analysis of data taken during the 1999 run shown here, E99-005 will be able to produce a partial wave analysis of similar statistics to those obtained by the most successful experiments in the field, for example, E852 at Brookhaven. To achieve this goal, however, we will need to run longer than originally proposed. We are requesting an extension of our scheduled running time for 2001. Based on the analysis of the data from 1999, we believe that a total number of 12 days will give us the necessary statistics.

1 Introduction

Much progress has been made recently in the theoretical description of hadrons lying outside the scope of the constituent quark model. QCD 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] Irrefutable experimental evidence for an exotic meson would be the determination of quantum numbers $J^{PC} = 0^{--}, 0^{+-}, 1^{-+}, 2^{+-}$, etc. since a $q\overline{q}$ pair cannot form a spin-parity state with such quantum numbers in the quark model.

In June of 1998, the E852 collaboration at Brookhaven National Laboratory announced the observation of a $J^{PC} = 1^{-+}$ isovector exotic meson decaying to $\pi^+\pi^-\pi^-$ with a mass of about 1600 MeV[Ad98]. The data is shown in figure 1. It has also been suggested within the context of the flux-tube model, such states should be produced copiously in a photon beam.

E99-005 [Ad99] is a CLAS experiment to search for photo-produced meson states. The focus is on the $\rho\pi$ and K^*K states in the 1-2 GeV mass range. The required incident beam energy is $\geq 5\ GeV$. The main goals are the search for mesons with explicitly exotic quantum numbers and the determination of the quantum numbers of $s\bar{s}$ states. The experiment first ran during the CLAS-g6b period of July-August, 1999. A total of 800 million triggers were taken during the run, which also included E-93-031 with an independent trigger configuration. The trigger rate was constant at 2500 Hz; 60% of the triggers were E99-005 triggers. About 480 M E99-005 triggers were taken in the equivalent of six days of running. The analyses of the 1999 data are in progress. Four days of running are still pending (of the approved 10 days). They are scheduled for July-August 2001. A brief summary of the current status of the 1999 data analyses follows.

2 Analyses Status

2.1 $\gamma p \rightarrow n\pi^+\pi^+\pi^-$

We have two possible topologies for the study of this channel. In the first, we measure the three pions in CLAS, and reconstruct the neutron through the missing mass technique. Figure 2 shows the missing mass squared spectrum off of the three reconstructed pions. The neutron is clearly discerned. After a mass cut around the neutron mass, we are left with 40106 events. The $\pi^+\pi^-$

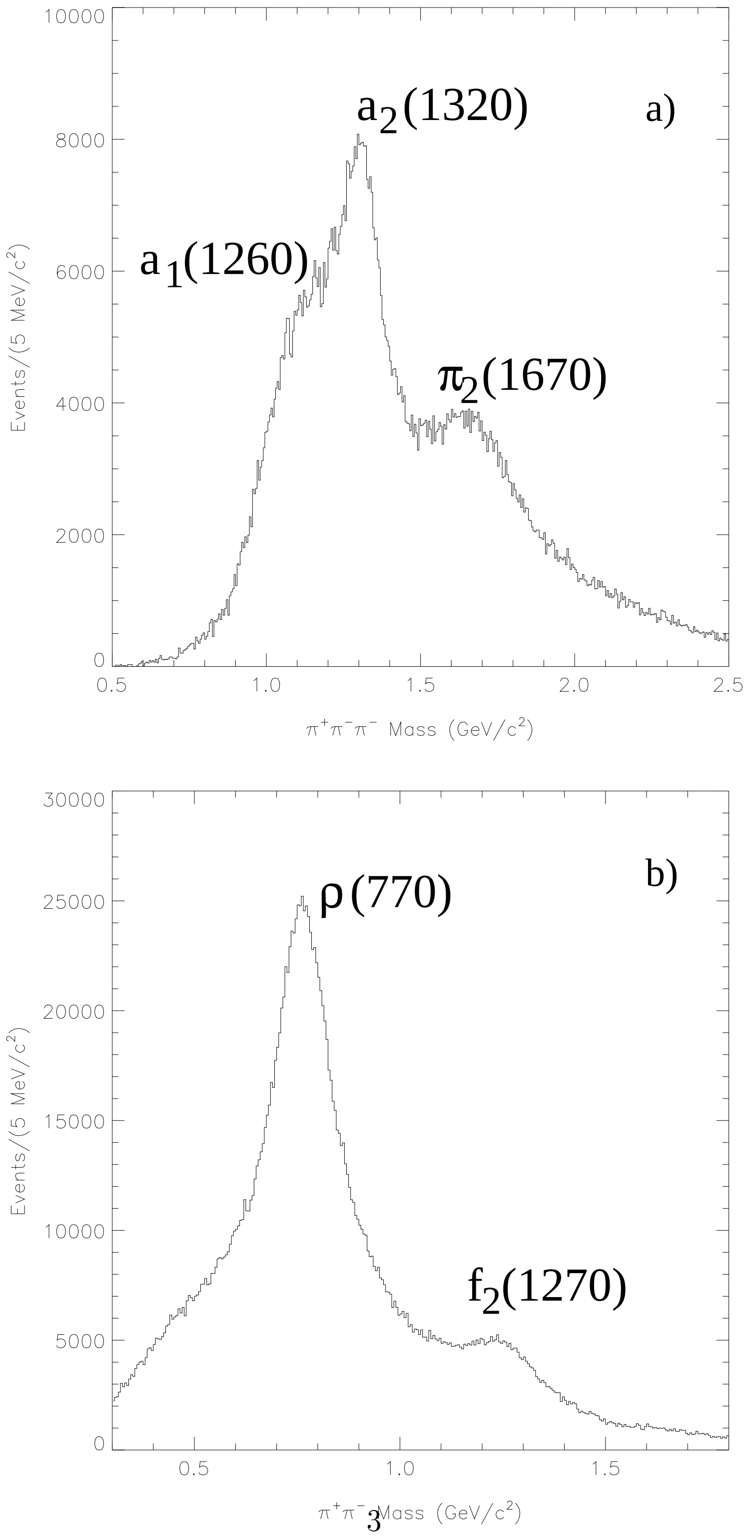

Figure 1: E852 $\pi^+\pi^+\pi^-$ data

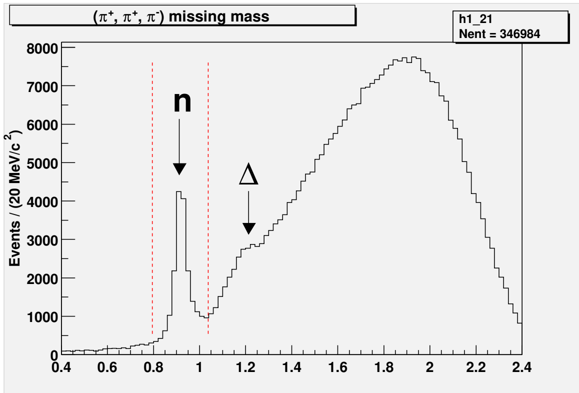

Figure 2: mm^2 off of $\pi^+\pi^+\pi^-$

mass spectrum of these events is shown in figure 3. The ρ^0 and $f_2(1270)$ are both clearly evident in the mass spectrum.

Figure 4 shows the mass spectrum of the system $\pi^+\pi^+\pi^-$ for $\gamma p \rightarrow \pi^+\pi^+\pi^- n$ exclusive events. The shape of the spectrum is determined mainly by acceptance: because the π^- is in-bending in CLAS, and most of them go through the beam pipe. High three pion masses have higher reconstruction efficiencies. At the interesting meson mass of about 1600 MeV/c^2 we currently have $\sim$ 250 events per 20 MeV/c^2 mass bin.

Another way to detect this topology is to observe the neutron in the CLAS forward calorimeter. The neutron has a high interaction probability ($\sim$ 30%) in the forward electromagnetic calorimeter. The timing information in the calorimeter is sufficient to determine the neutron momentum through time-of-flight.To check our neutron selection algorithm, we have selected a sample of exclusive $\pi^+\pi^+\pi^- n$ events where ALL particles have been detected in CLAS. Figure 5 shows the missing mass squared off of the $\pi^+\pi^+ n$ system. The π^- is clearly discernible in the spectrum with a width of $\sim$ 120 MeV/c^2 as expected from the selected sample.

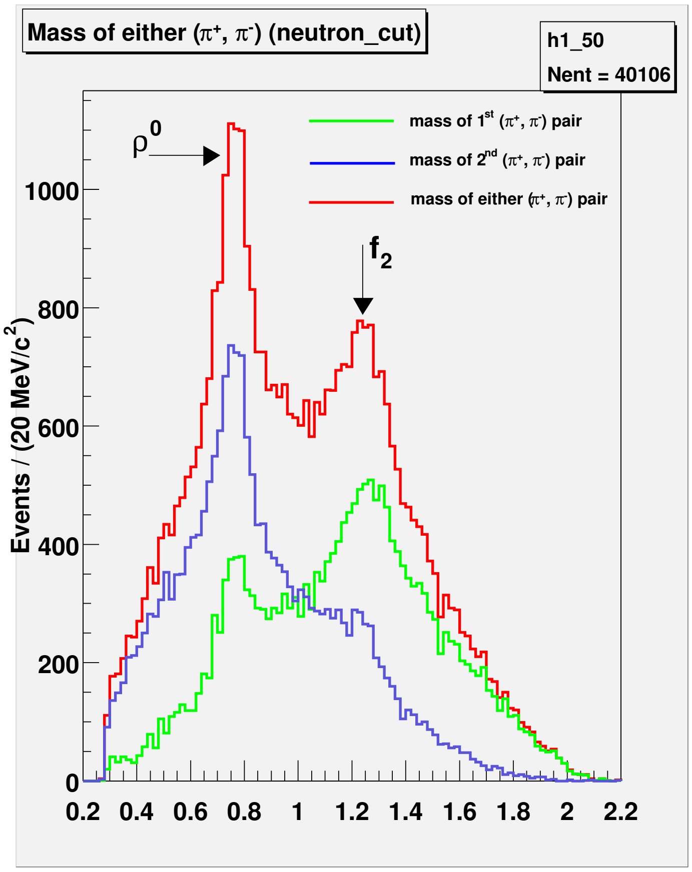

Figure 3: mass of $\pi^+\pi^-$(2 entries/event)

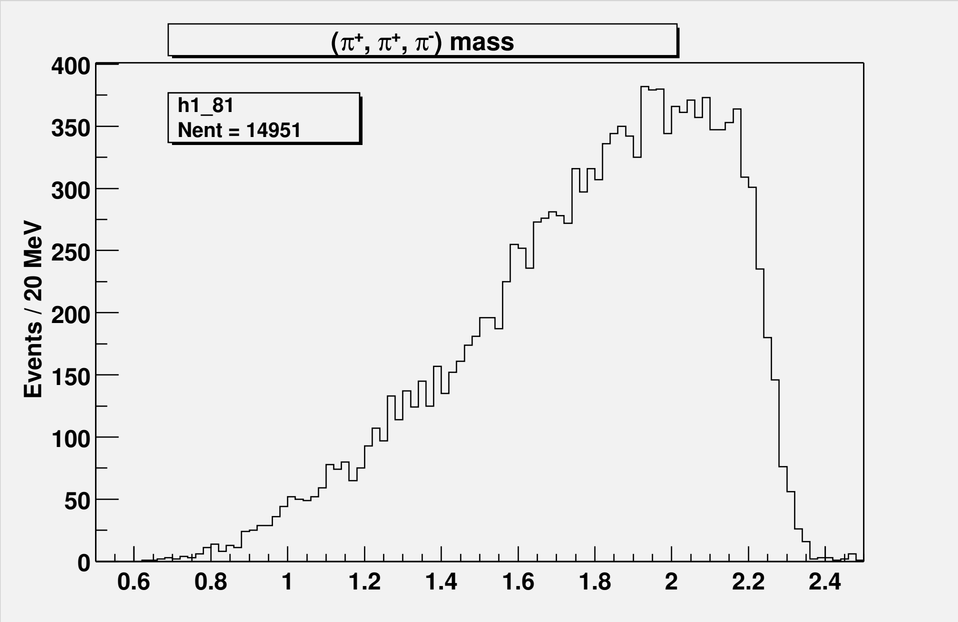

Figure 4: mass of $\pi^+\pi^+\pi^-$ for $\gamma p \to \pi^+\pi^+\pi^- n$ exclusive events

2.2 $\gamma p \to p\pi^+\pi^-\pi^0$

In this channel we observe the proton and the π^+, and in addition either the π^0 in the electromagnetic calorimeter or the π^- in the CLAS drift chambers. The two gamma mass plot, figure 6, shows a clear π^0 peak. Also, the missing mass squared off of the $p\pi^+\pi^-$, shows a clear π^0 peak.

Figure 7 shows the missing mass squared spectra off of the $p\pi^+\pi^0$,where a clear π^- is observed. Figure 8 shows the missing mass squared spectra off of the $p\pi^+\pi^-$ for the data where the π^- is observed in the CLAS detector. Here, one can see a clear π^0 signal, as well as the η and ρ^0.

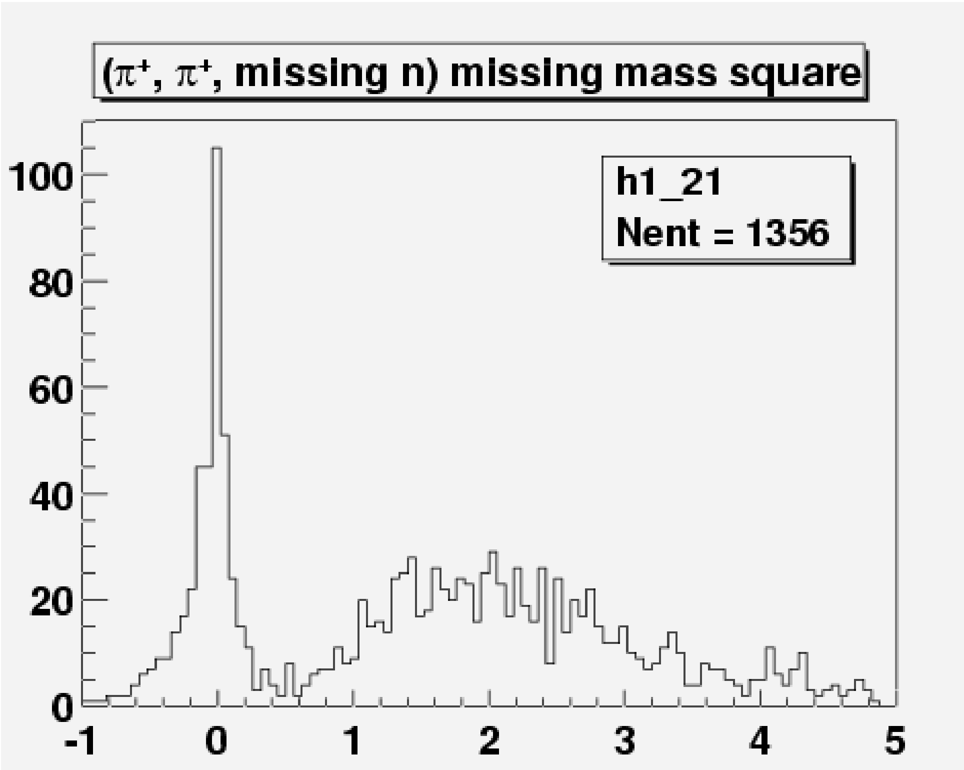

Figure 5: mm^2 off of $\pi^+\pi^+n$

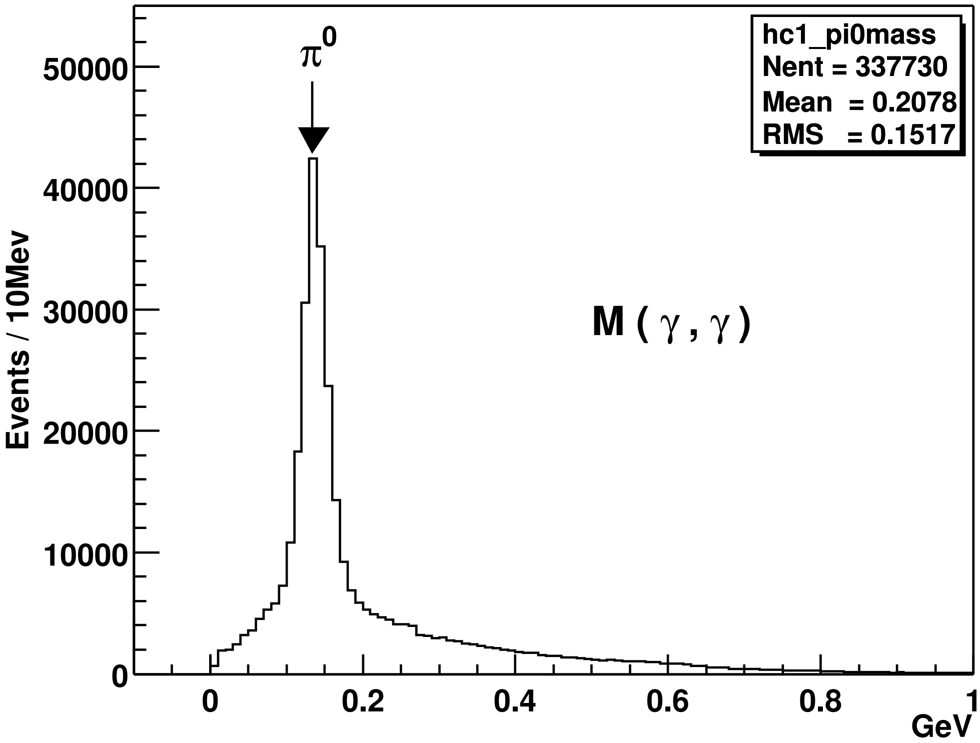

Figure 6: $\gamma\gamma$ effective mass

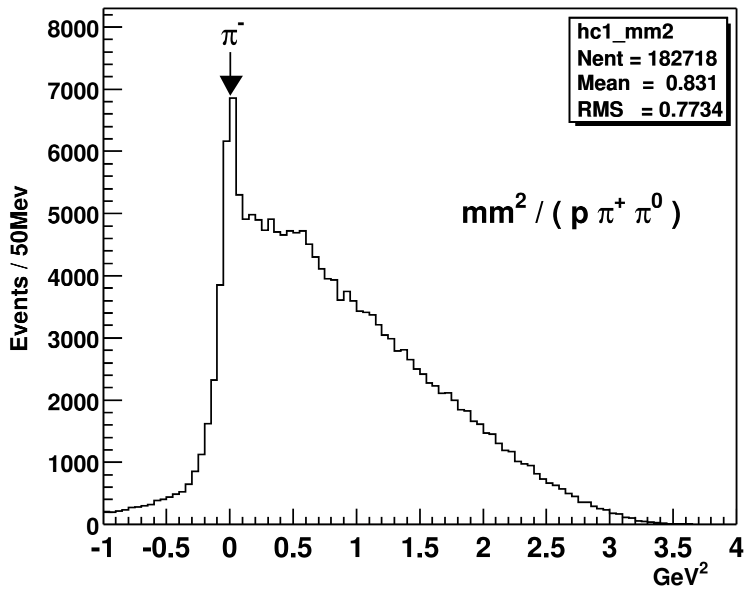

Figure 7: MM^2 off of $p\pi^+\pi^0$

Figure 9 shows the $p\pi^+$, $p\pi^0$, and $p\pi^-$ mass distributions for the $p\pi^+\pi^0$ missing π^- topology, showing baryon resonances. Only the Δ^{++} resonance is clearly seen in the mass spectra. Figure 10 shows the same mass distributions for the $p\pi^+\pi^-$ missing π^0 topology. In this topology the baryon resonance mass spectra is richer. A cut of ± 70 MeV/c^2 around the Δ^{++} mass has been imposed to clean the meson sample.

The mass acceptance for these three topologies is considerably different. The mass spectra of the $\pi^+\pi^-\pi^0$, for each topology, is shown in figure 11. The same data, cutting on ρ events is shown in figure 12.

2.3 $\gamma p \to pp\bar{p}$

We have recently begun the analysis of the $pp\bar{p}$ channel, which was not included in the original proposal. In this channel, two protons are detected in the CLAS drift chambers and TOF system, and we observe the $\bar{p}$ by missing mass. Figure 13 shows a visible peak at the mass of the $\bar{p}$. Cutting on the $\bar{p}$

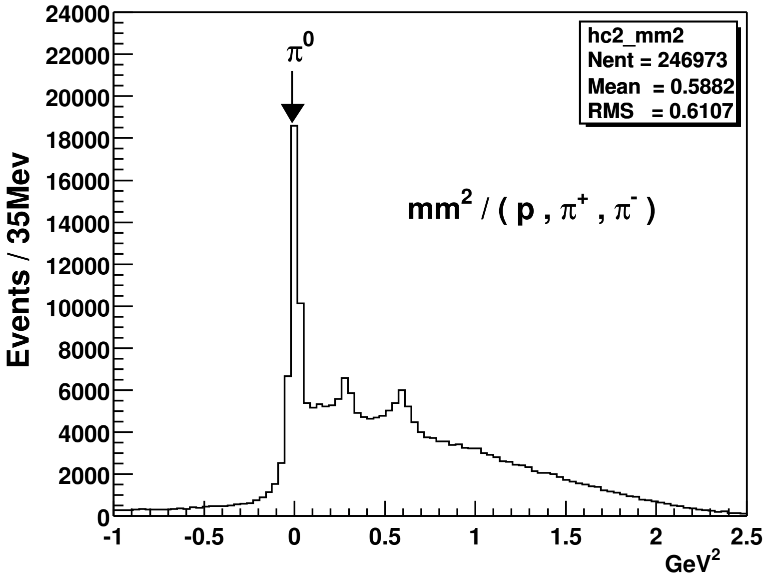

Figure 8: MM^2 off of $p\pi^+\pi^-$

mass, in figure 14 we show the $p\bar{p}$ masses, and the corresponding momentum transfer. No structure is obvious in these mass plots.

2.4 K identification Algorithm (Kid)

In order to achieve the highest statistics needed for the spin-parity identification of meson states, g6b was run at a high rate ($\sim 5 \times 10^7$ photons/second). As a result, the data is plagued by a high accidental rate. In particular, many triggers result from an interaction in one RF bucket, while the triggering tagged high-energy photon comes from another RF bucket. Since the start time for time-of-flight (TOF) measurement is determined by the tagger, all TOF measurements for these events are distorted by $\sim$ 2 nanoseconds. This results not only in a large background under pion events, but also significant leakage of pions into the kaon, which completely obscures the kaon signal (see figure 15). We have developed an algorithm which looks at two particle correlations in the β vs p curve to determine if the tagger time cor-

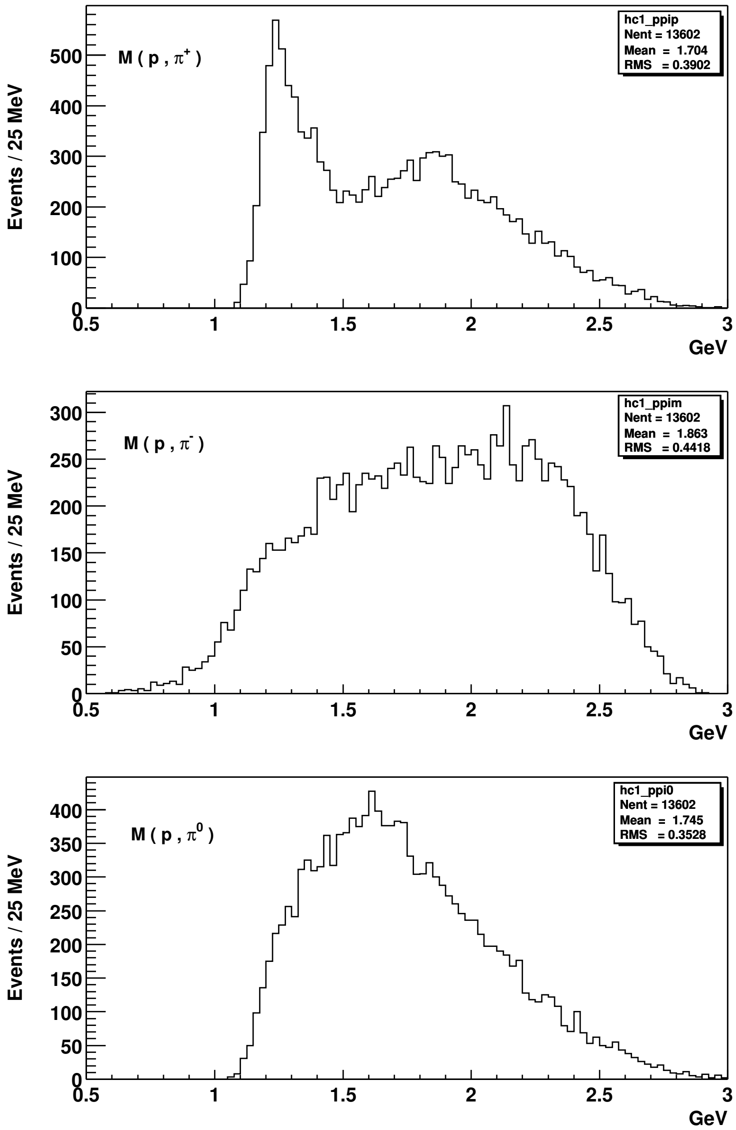

Figure 9: $p\pi$ mass distributions: $p\pi^+\pi^0$ detected.

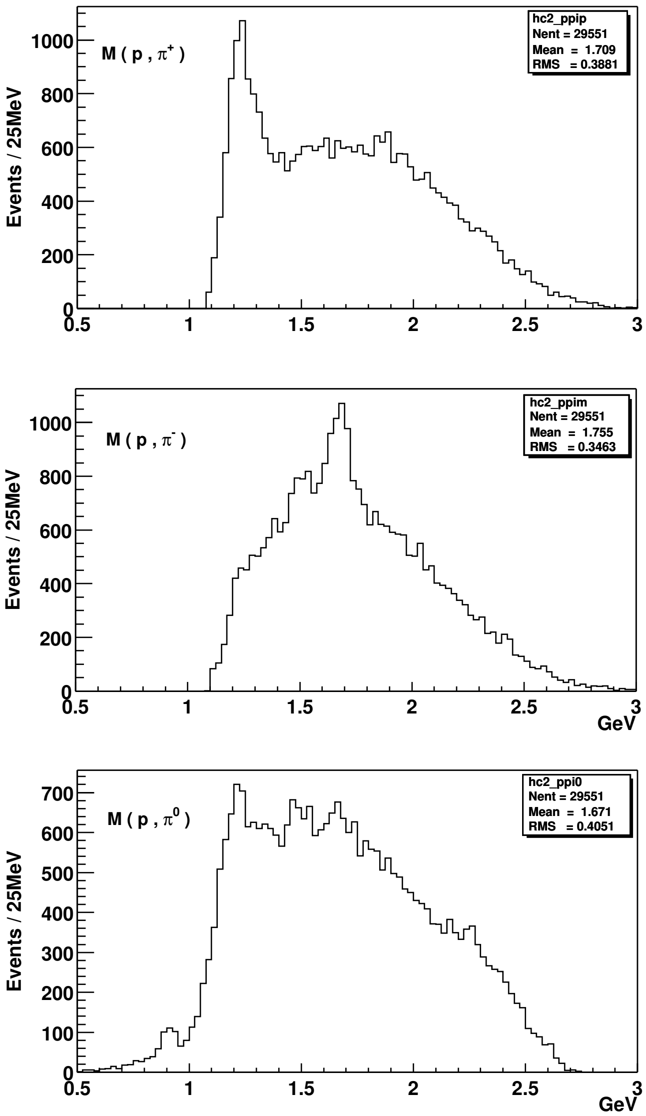

Figure 10: $p\pi$ mass distributions: $p\pi^+\pi^-$ detected.

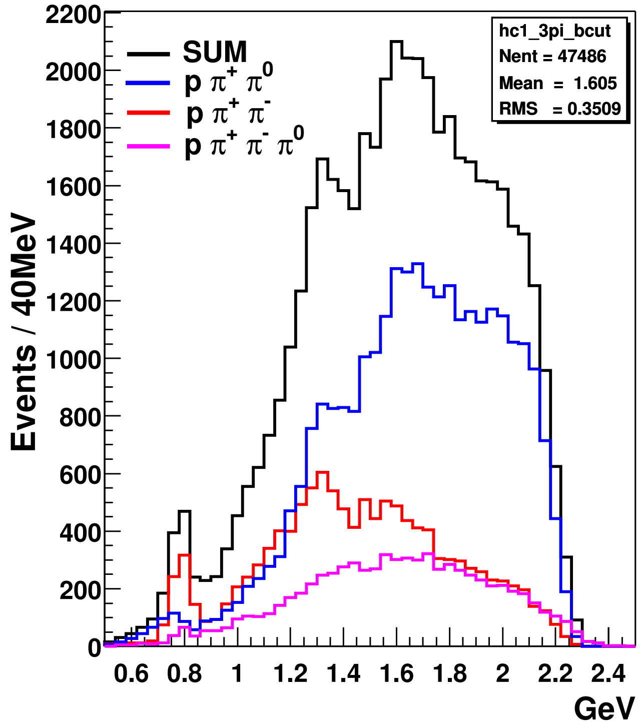

Figure 11: $\pi^+\pi^-\pi^0$ mass spectra with Δ^{++} cut (see text).

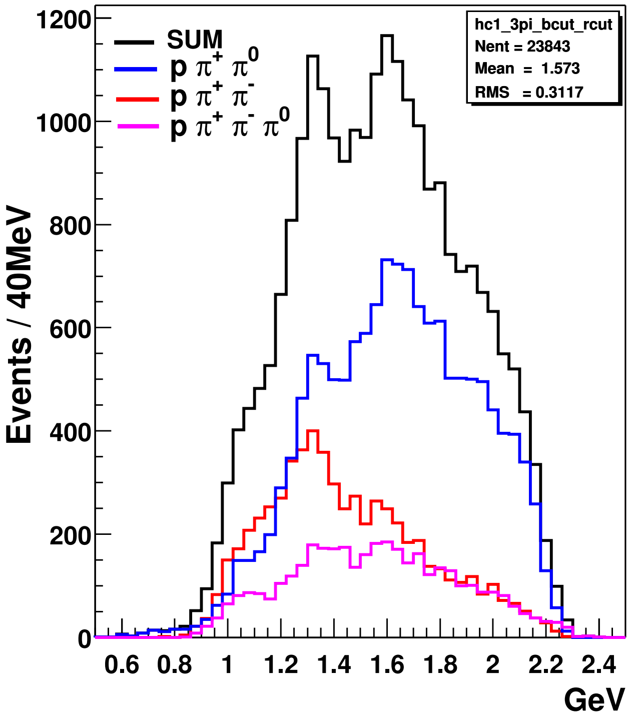

Figure 12: $\pi^+\pi^-\pi^0$ mass spectra with Δ^{++} and ρ cut

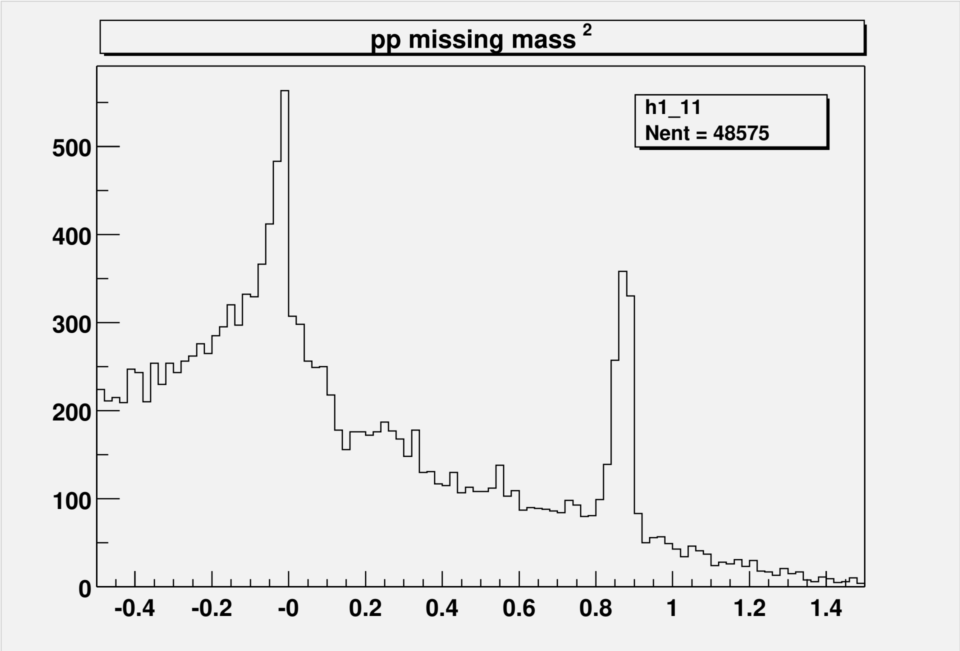

Figure 13: $MM^2/\bar{p}p$

responds to the correct time-of-flight for *both* particles. A χ^2 is calculated over the sum over both TOF masses for three different RF times, (0 and ±2 nanoseconds offset from the trigger γ). Events are retained only if the high-energy γ tagger time is identified as the most likely. Figure 16 shows the resulting β vs. p curve for all positive charged particles after this so-call Kid rejection. The kaon signal, previously obscured totally by pion leakage, is now clearly delimitated for momentum up to $\sim$ 1.5 GeV/c. The time-of-flight mass spectra is shown in figure 17 for positive particles with momenta less than 1.5 GeV/c^2.

2.5 $\gamma p \to pK^+$ inclusive

We have a large sample of data where a proton and a K^+ are detected in CLAS and identified through time-of-flight. In figure 18 we show the missing mass squared distribution off of the proton and K^+.

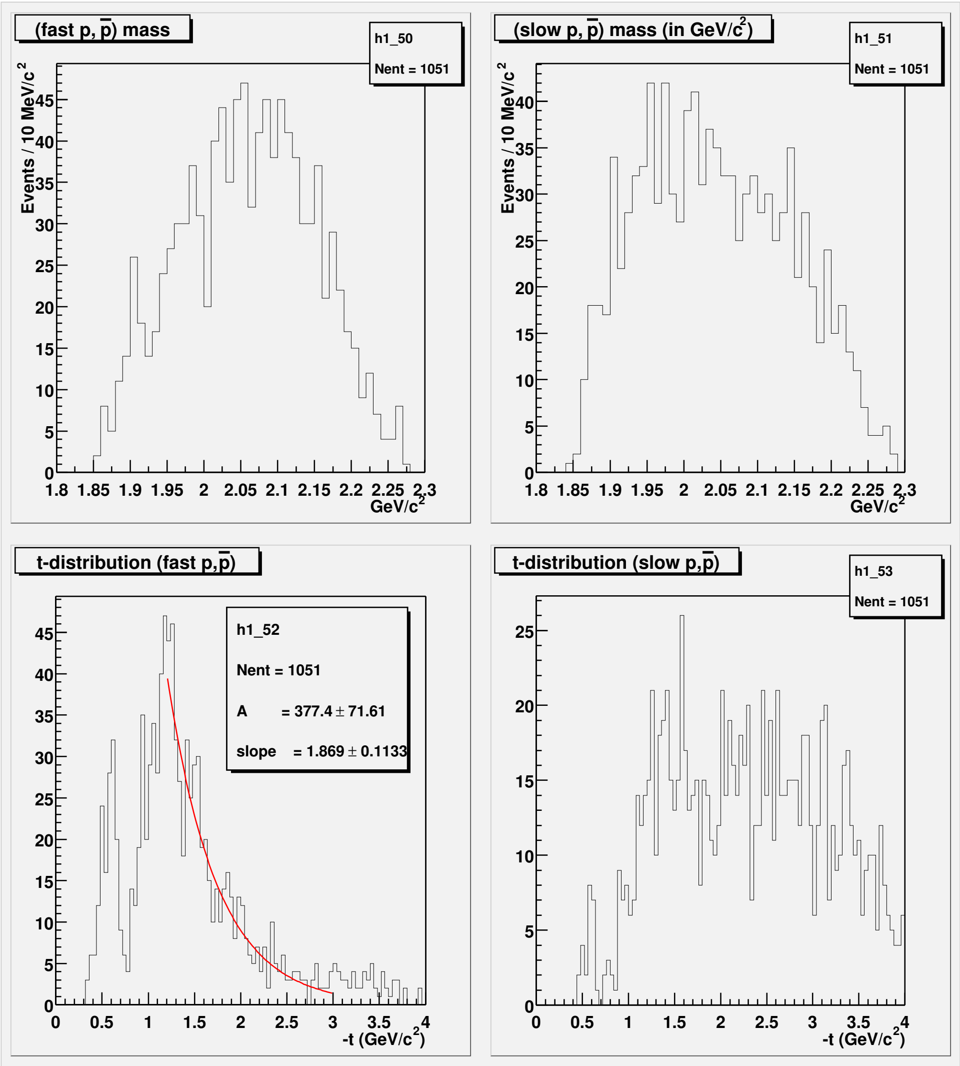

Figure 14: $m(p\bar{p})$

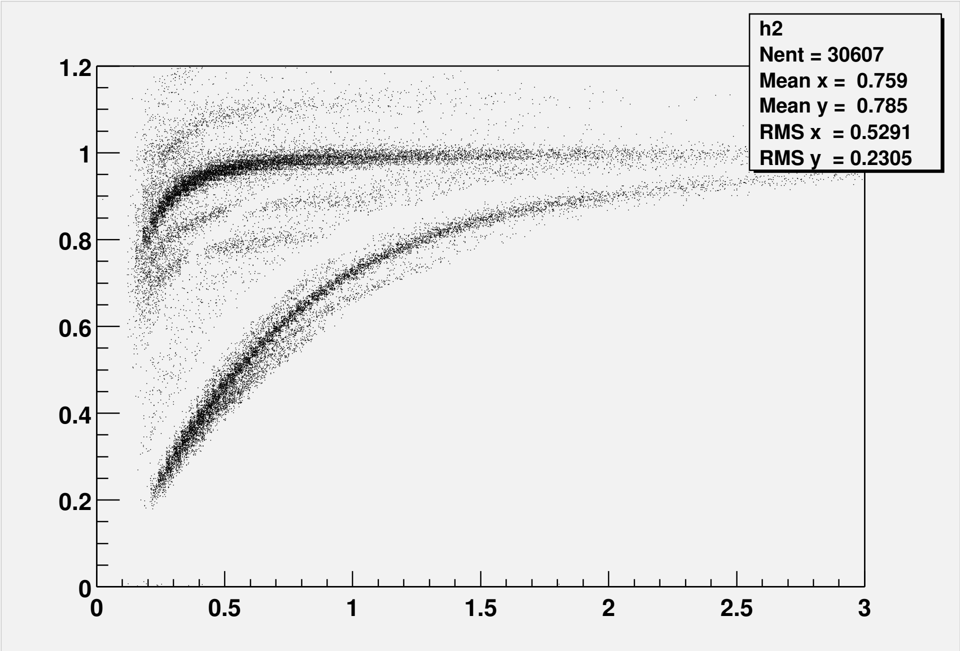

Figure 15: β vs p for all positive charged particles before Kid rejection

Here we can clearly discern the K^-, and also a bump at the $K^*(890)$. In figure 19 we show the meson mass for the K^- events (top), and $K^*(890)$ events (bottom). In the exclusive K^+K^-p events we can clearly see the $\phi(1020)$, but there are no discernible structures in the $K^+K^*(890)$ mass distribution (K^* has been poorly defined from the background). We just started the analysis of the $pK^+\pi^0$ (missing π^-) channel.

3 Next run - July 2001

E99-005 running conditions for the summer of 2001 are summarized in table 1. We are planing to run with half the torus maximum magnetic field, which will double our acceptance. We plan to double the thickness of the radiator to 2x10^{-4} radiation lengths. With an increase in beam energy, we can also increase the number of tagger's T counters in the trigger, from 8 to 14. Due to improvements in the DAQ rate, incorporating a tighter start counter require-

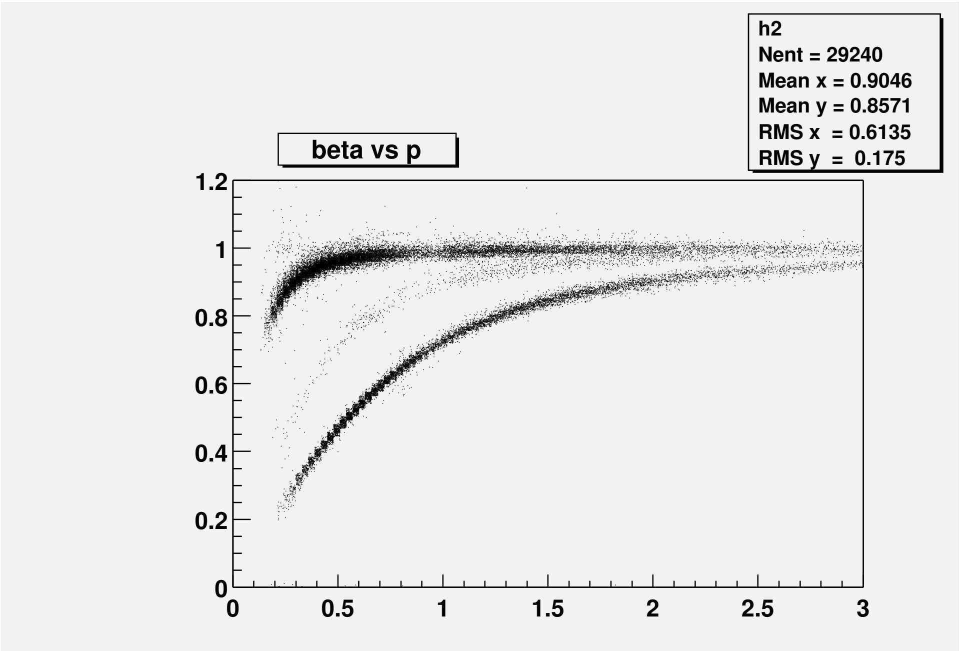

Figure 16: β vs p for all positive charged particles after Kid rejection

ment and the Level 2 trigger, we believe that it will be possible to increase the beam flux from 45 to about 60 nA. Taking into account all these factors, we feel that we will be able to improve our sensitivity an order of magnitude. For example, if we consider the $\pi^+\pi^-\pi^0$ channel. Looking in the 20 MeV/c^2 bin of figure 11 we have $\sim$ 900 events at a mass of about 1600 MeV/c^2 in six days of running. An order of magnitude more sensitivity would give us 6000 events per 20 MeV/c^2 bin in four days of running. Therefore, in the current schedule will be end with a total of about 7000 events/20 MeV bin in the 1600 MeV mass range. This is to be compared with figure 1 (a); E852 that has $\sim$ 16000 events per 20 MeV/c^2 bin[1].

A factor of 2.5 in running time (or 10 days) would give us comparable statistics with E852 in this channel.

[1] It is not completely fair to simply compare statistics between π production and photo-production in a partial wave analysis. For example, in an unpolarized photon beam there is no ϕ information in the angular distribution, while in a pion beam there is. On the other hand, in a pion beam the exotic signal is a few percent of the the total cross-section, and in a photon beam it may be much higher [Af98].

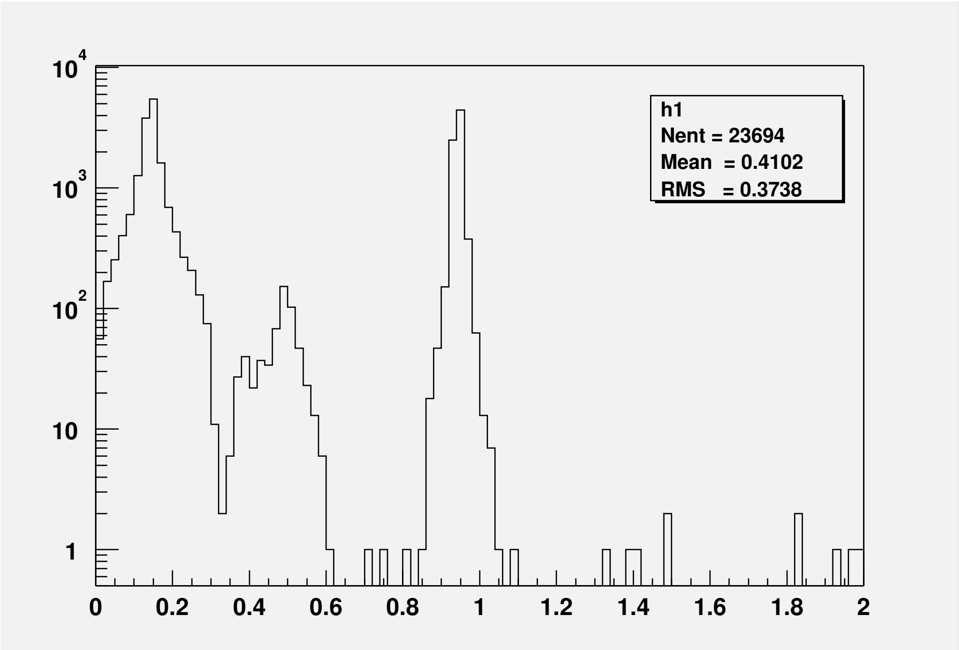

Figure 17: mass (GeV/c^2) as determined from TOF and momentum for positive tracks

E_0	$\geq$ 5.5 GeV
Target	same as g8
B field	1/2 B_{max}
Trigger	2 charged particles (any sector)
	1-14 T counters-1 of 3 StC
	Level 2
Current	about 60 nA
Radiator	2x10^{-4}
Acquisition Rate	3.0 kHz

Table 1: Running conditions

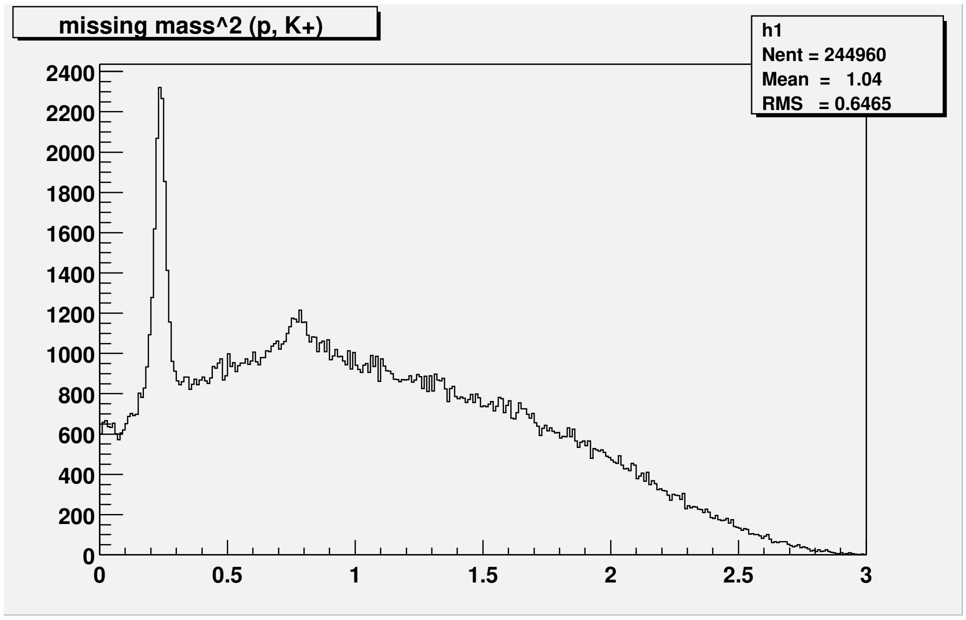

Figure 18: $MM^2/(pK^+)$

topology	1999 Data	2001 scheduled	2001 requested	E852
$p\pi^+\pi^-\pi^0$	900	6000	15000	16000
$n\pi^+\pi^+\pi^-$	250	1700	4250	

Table 2: Total Detected Rates per 20 MeV bin at about 1600 MeV mass.

4 Summary

The importance of meson spectroscopy for JLab has been clearly indicated by the PAC, the JLab administration, the JLab user community (see JLab at 12 GeV white paper), the larger scientific community in a recent workshop in Duck, NC and more recently at the DNP town meeting on Electromagnetic and Hadron physics. We believe that, based on the analysis of data taken during the 1999 run and reported in this paper, E99-005 can produce a meson spectroscopic analysis of similar quality to those of the most successful experiments in the field, for example, E852 at Brookhaven.

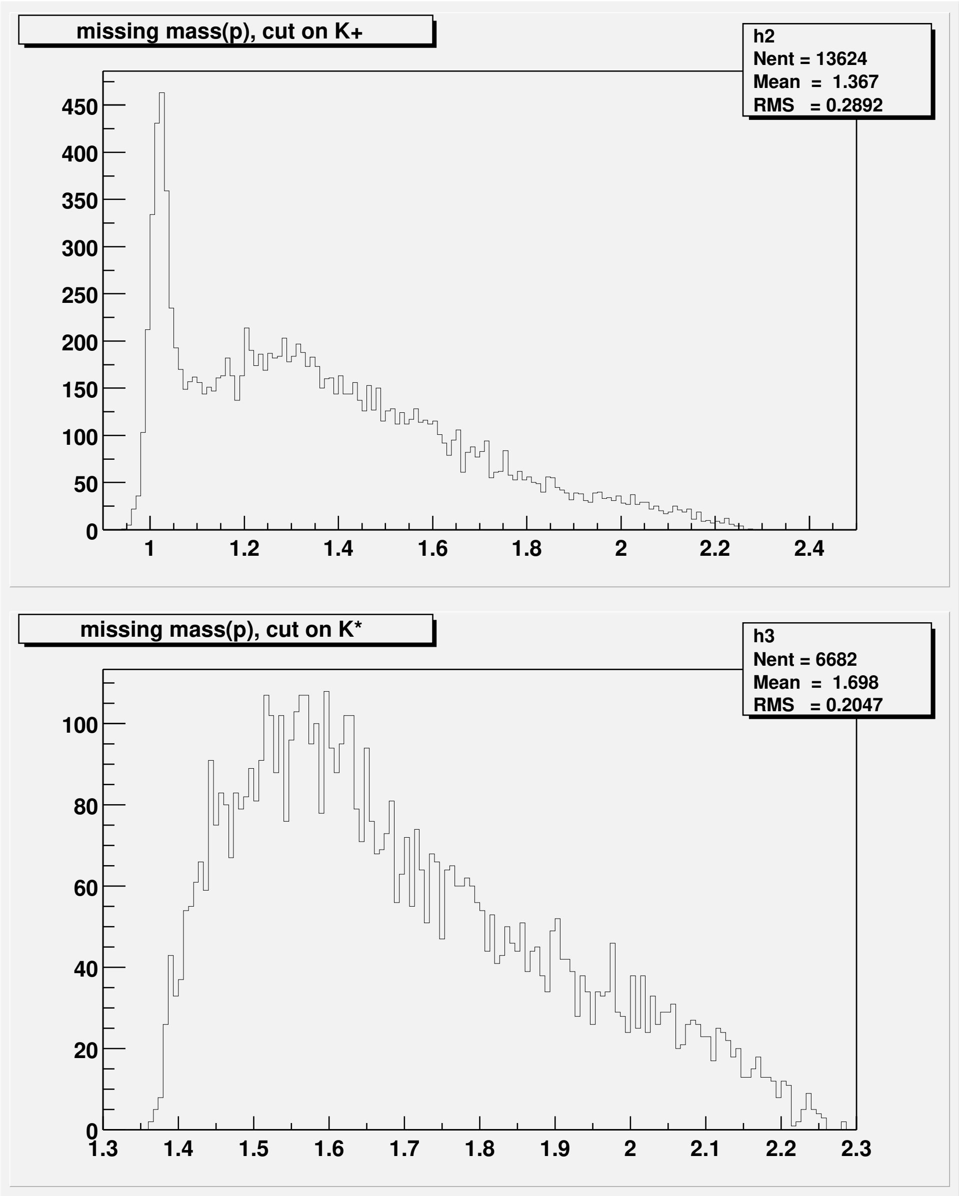

Figure 19: $m/(K^-K^+)$ (top) and $m/(K^{*-}K^+)$ (bottom)

Based in the importance of this physics and the potentially important returns, we are requesting an extension of our scheduled time allocated for 2001. We are requesting a total number of 12 days (10 running + 2 commissioning). We believe that this extension will be the most efficient venue to give closure to the physics associate with E99-005 as approved by PAC 15.

References

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