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FNAL Experimental Proposal

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Hybrid Bubble Chamber Studies of K^+p and K^-p Interactions at 75 GeV/c

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Summary:-

We propose to expose the FNAL 30" liquid hydrogen bubble chamber to K^+ and K^- beams both at 75 GeV/c. Each exposure consists of 100,000 equivalent K pictures.

We plan to use the upstream tagging system currently in place and a downstream spectrometer with acceptance considerably increased over that of the current PWC system. This new downstream system will also be equipped with a lead glass photon detector with good spatial and energy resolution.

We will study comparison of K^+ and K^- results, as well as results from π^+, π^-, and $\bar{p}$ beams at this energy which are the subject of ~~a~~ separate proposals. In particular we plan to examine

1. Particle multiplicities.
2. Leading particle effects and diffraction dissociation.
3. Double leading effects and long range correlations.
4. Strange particle production.
5. Resonance production.
6. Multiparticle production in the central region.

I. Nature of the Experiment:

The results of W. W. Neale(1) show that it should be possible to have beams of K^+ and K^- mesons enriched to at least 20% transported to the 30" bubble chamber in the forseeable future. These beams will be produced through a combination of retargetting and filtering techniques. We propose to aid in whatever way possible in the development of these beams and to use them in this experiment. Specifically we propose exposures of K^+ and K^- at 75 GeV/c in the 30" bubble chamber-proportional wire hybrid system. We are proposing runs for each K^+ and K^- with 100,000/F pictures each, where F is the enrichment factor.

Data are available(2),(3) which show that the upstream tagging system presently in place in the N3 beam line is capable of reliably selecting incident K^+ and K^- mesons even when they comprise only 2% of the total flux. Physics results have been obtained with these Kaons but only as a sidelight to what are basically π^+ and π^- exposures, and clearly are of very limited statistical accuracy.

We are now proposing studies of reasonable statistics - over 10,000 events for each K^+ and K^-. We propose this experiment at 75 GeV/c as a companion to ~~an~~other stud~~y~~ies of π^+, π^-, and $\bar{p}$ using the same system and same analysis techniques at this energy. Thus we will see clearly which of the physics effects we plan to study are influenced by the choice of beam particle. The energy of 75 GeV/c was chosen as one intermediate between the energies available in older accelerators, and the highest at which such an experiment could reasonably be performed at FNAL.

Since the total cross section for K^+ is rising in this energy region while for K^- it is decreasing, there may well be significant differences in the results of these two exposures.

We plan to improve the downstream PWC system. In particular, drift chambers are under construction of size 1m x 1m to replace some of the 12" x 12" PWC's currently in use. The implementation of these new chambers together with some redesign of the exit area of the bubble chamber assembly should result in considerable increase in acceptance of the downstream system. With this increase the system should be useful in measuring a large fraction of the particles produced in the forward hemisphere, even at the relatively low beam momentum of 75 GeV/c.

The energy resolution of this new system will be at least as good as that of the current one, which has proven satisfactory in measuring leading π^- in a 150 GeV/c experiment (Fig. 3).

Another important piece of the improved system is a total absorption lead glass photon detector. This device, currently under construction, is designed to detect most photons produced in the forward direction and to measure their energy to ±3%. Also under construction is a vertex detector, essentially a lead glass-scintillator hodoscope, capable of locating the center of photon-induced showers to an accuracy of 3mm. The intention is that with the detection of these photons, π^0's produced in the forward direction will be reliably detected and measured with an accuracy of the same order as that of the charged particles.

II. Participants:

The participants from The Johns Hopkins University, Rutgers University/ Stevens Institute of Technology, and the University of Tennessee/Oak Ridge National Laboratory have been instrumental in the design, construction, testing, and early running of the beam tagging system and the current downstream spectrometer. They are also involved in the construction of the improved downstream system. Through work in Experiment 154 (π^- on p at 150 GeV/c) and Experiment 299 (π^-, π^+, and p on p at 150 GeV/c) they are experienced in both the data reduction and physics analysis from such a system.

Due to this experience within our group, preliminary results from the exposures proposed should be available a few months after the actual exposures and should provide feedback on the value of further work in producing enriched beams, as well as on the K-meson physics worthy of further study.

III. Physics Justification:

The physics topics we plan to pursue as of the present time consist of:

1. Particle multiplicities.
2. Leading particle effects and diffraction dissociation.
3. Double leading effects and long-range correlations.
4. Strange particle production.
5. Resonance production.
6. Multiparticle production in the central region.

1. Particle multiplicities -

The presence of a fairly high spatial resolution and acceptance photon detector allows multiplicity distributions and moments to be studied with a considerably higher degree of sophistication than in the past. Now, not only is the charged particle multiplicity available, but the forward π^o multiplicity as well. Clearly this information is invaluable in testing the various multiperipheral and clustering models which have been proposed.

The K^+ and K^- results so far available have not indicated any clear differences between kaon and pion beams as regards the charged particle multiplicity distributions. We intend to study this point with the considerably higher statistics that we propose, and as well to test it at a different energy.

2. Leading Particle Effects and Diffraction Dissociation -

The current hybrid system has already proven successful in studying leading proton events-pion dissociation-and leading pion events-nucleon dissociation-in a $\pi^- p$ experiment (Exp. #154). These diffractive type phenomena dominate almost completely the inelastic two-prong sample of events, are a major component of the four-prongs, are of lesser importance in the six prongs, and are submerged in the higher multiplicities (Figs.1-4). We intend to test these effects with kaon beams at 75 GeV/c and in addition will add the sophistication of forward π^0 multiplicity to these studies. We will measure the t distributions to these leading particles to test whether a single exponential slope hypothesis is consistent with the data. We will compare the slopes obtained for K^+ and K^-, as well as with the other particles at this same energy. We will also compare the various slopes from the inelastic channels with those of the elastic events.

The particles which result from diffraction of the $K^{\pm}$ and proton, in particular the Q and L enhancements, will be studied. Kaons are better then pions for studying beam dissociation since the narrow and dominant K^*_{890} signal is present and gives a much clearer picture of what is happening than does the broader and often obscured ρ.

Through comparison of elastic and diffractive inelastic events we will test the factorization hypotheses at both the kaon and proton vertices.

3. Double Leading Effects and Long-Range Correlations -

It is important to have information on double leading particle effects at this energy. At higher energies such effects have been seen and interpreted as double Pomeron exchange. The energy dependence of these effects should be determined to test such a hypothesis.

Due to the good resolution we have for both the fast forward and slow backward tracks, we can study the long range correlations which so far have been difficult for both bubble chamber and counter experiments.

4. Strange Particle Production -

Strange particle production cross sections are rising through the FNAL energy region. Clearly an important step in the understanding of this effect is to see what kinds of strange particles are produced by the already $S \neq 0$ K^+ and K^-. In particular it is interesting to see if production of $S = -2$ Ξ's by K^- is in any way similar to production of $S = -1$ hyperons by pions, or whether the production is independent of the quantum numbers of the initial states. A project is currently underway to include particles from a secondary vertex in the analysis of downstream chamber data. This will be particularly useful in this experiment where one would expect a useful number of fast K^o_s's to be produced from the $K^\pm$ beams.

Needless to say, the discovery of the new ψ particles and their interpretation in terms of SU(4) and the four quark picture makes any study with varying SU(3) quantum numbers especially timely. A better understanding of the behavior of the three 'classical' quarks at high energy should lead to predictions in the SU(4) scheme.

5. Resonance Production -

As mentioned above, we expect to see considerable production of the Q enhancement from beam dissociation phenomena. From Q decay we will also see a sharp K^*_{890}. We may also see K^*_{890} produced directly by Pomeron exchange, and it is important to establish whether these K^*'s are present.

It is possible that K^*_{1420} production will be considerable at high energy. If so it will be interesting to study the decay properties of the resonance when it is produced at considerably higher energies than in previous experiments. In particular the exist~~a~~ence of a $K\rho$ decay mode when production is at lower energy seems to depend crucially on the environment of that production$^{(4)}$. If production is strong at these energies, we will be able to contribute new data to this confused situation.

There is considerable evidence at lower energies for the diffraction of $K^{\pm}$ into $K^{\pm}\omega^{(5),(6),(7),(8)}$. This phenomenon is expected to be relatively S-independent. The photon detector should allow us to detect and measure the π^{o} from such a process, and we would expect on the order of 20 such events in each of the K^{+} and K^{-} exposures. Any other production mechanism which leads to forward π^{o}'s will also lead to detected ω's and will be studied.

We will, of course, observe diffractively produced Δ and N^{*} states. It will be possible to test the hypothesis that production of these baryon states is unaffected by the type of beam particle.

6. Particle Production in the Central Region -

The production of particles in the central region of rapidity will be studied. This is a difficult task as the data are dominated by the high multiplicity events for which the data reduction is a difficult task. We have experience with these problems from past experiments and feel that the physics results are worth the extra effort required. In particular we plan to study whether this central production is at all dependent on the type of beam particle. While for diffraction one generally expects little particle dependence, for central production the result is not so clear.

We will study the inclusive single particle distribution and compare with lower energy results and whatever reliable data are available at higher energy to give a detailed test of scaling. We will study the two body correlations to see whether the results currently available for pion and proton beams also hold for kaons. In particular these results are that there are short range - 1, 2 units of rapidity - positive correlations in the central region and that effects seen in inclusive data generally do not hold up for any given multiplicity.

We will add to these studies by having available the rapidity distribution for a meaningful fraction of the π^o's. Thus we can study correlations between charged and neutral pions and amongst charged pions as a function of π^o multiplicity, as well as charged multiplicity.

Although in events without leading particles it will not in general be possible to determine which tracks of the event carry the incident strangeness, when the incident $K^{\pm}$ materializes as a K_s^o in the final state. This will be possible and its inclusive properties will be given special attention.

References

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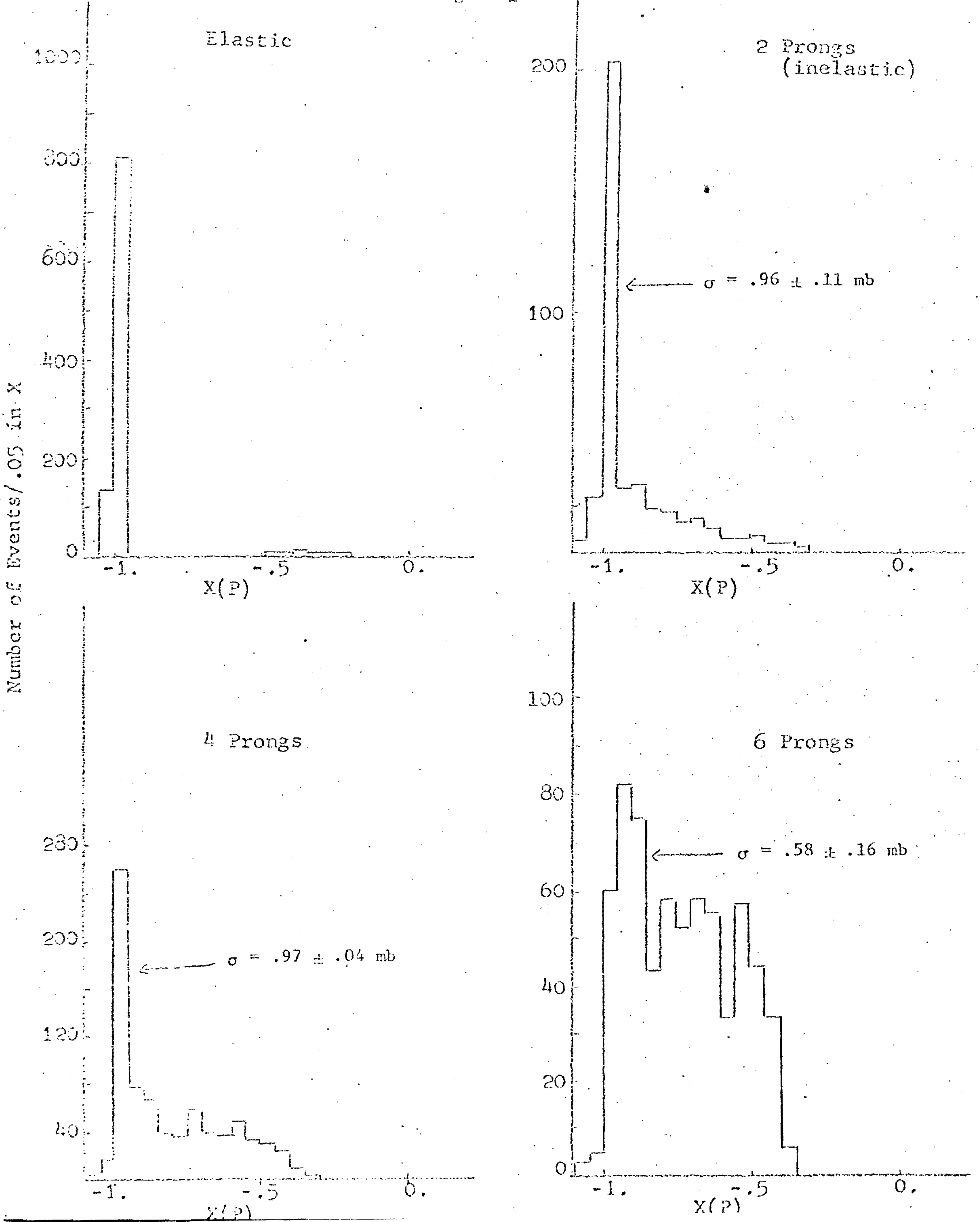
Figures

All these figures represent the results of Exp. 154 for π^- on p at 150 GeV/c with the current hybrid system.

1. Feynman X distribution for the proton of (a) elastic events, (b) inelastic two-prongs, (c) four-prongs, and (d) six-prongs. The elastic events are included as a measure of the resolution.
2. Feynman X distribution for the proton in those events with eight and greater prongs.
3. Feynman X distribution for π^- of (a) elastic events, (b) inelastic two-prongs, (c) four-prongs, and (d) six-prongs. The elastic events are included as a measure of the resolution.
4. Feynman X distribution for π^- in those events with eight and greater prongs.

FEYNMAN X FOR PROTON

Figure 1



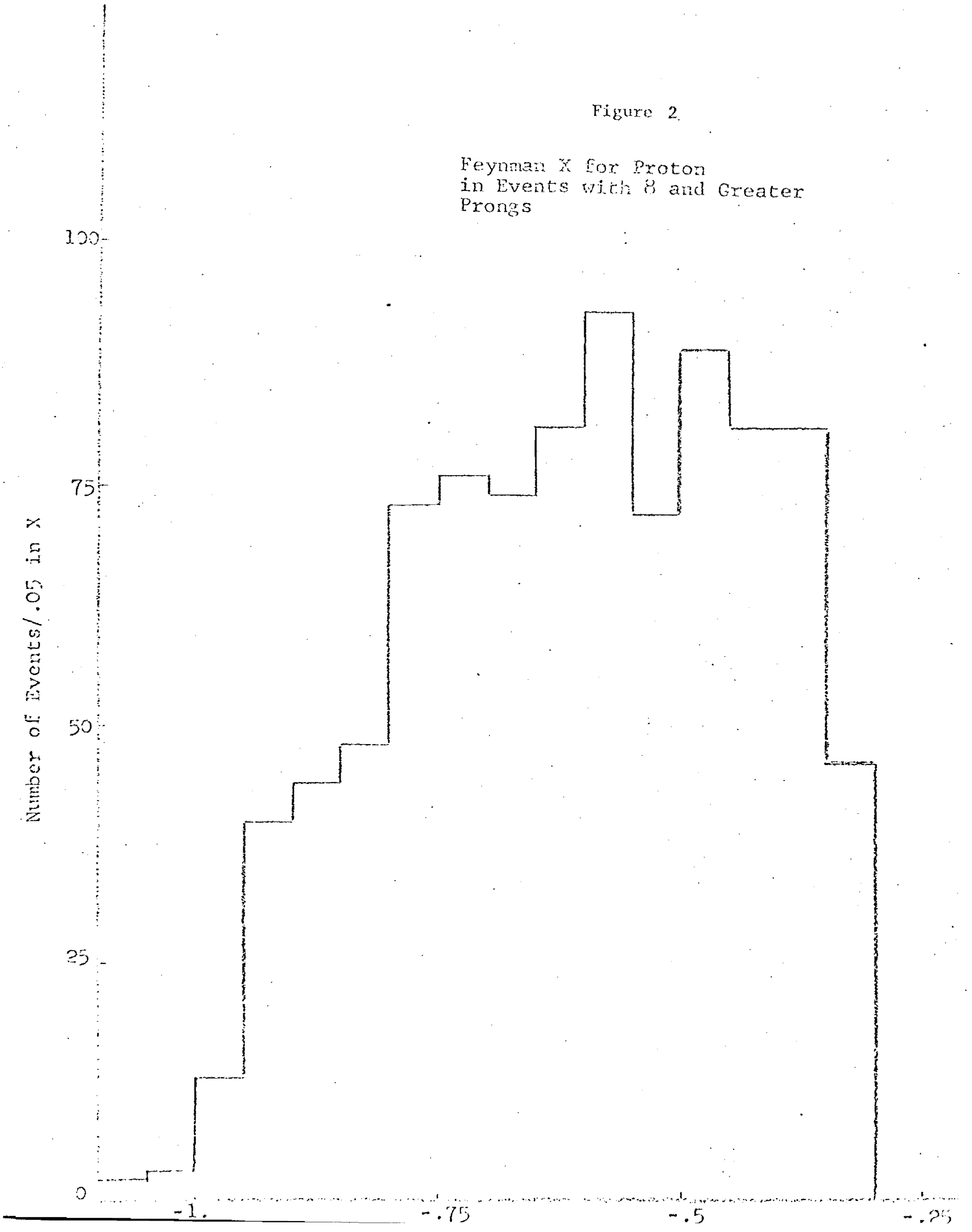


Figure 2

Feynman X for Proton
in Events with 8 and Greater
Prongs

FEYNMAN X FOR PI$^-$

Figure 3

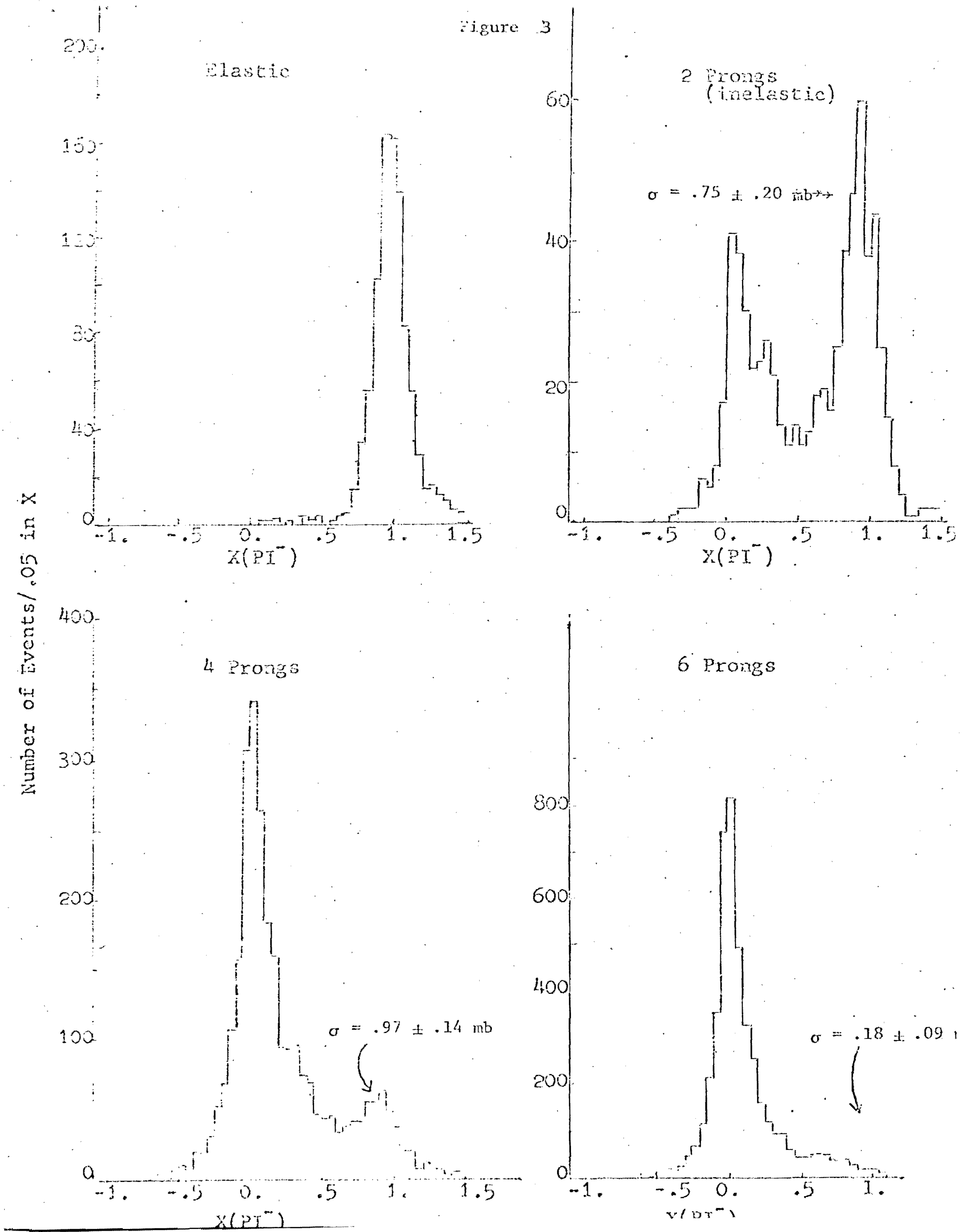
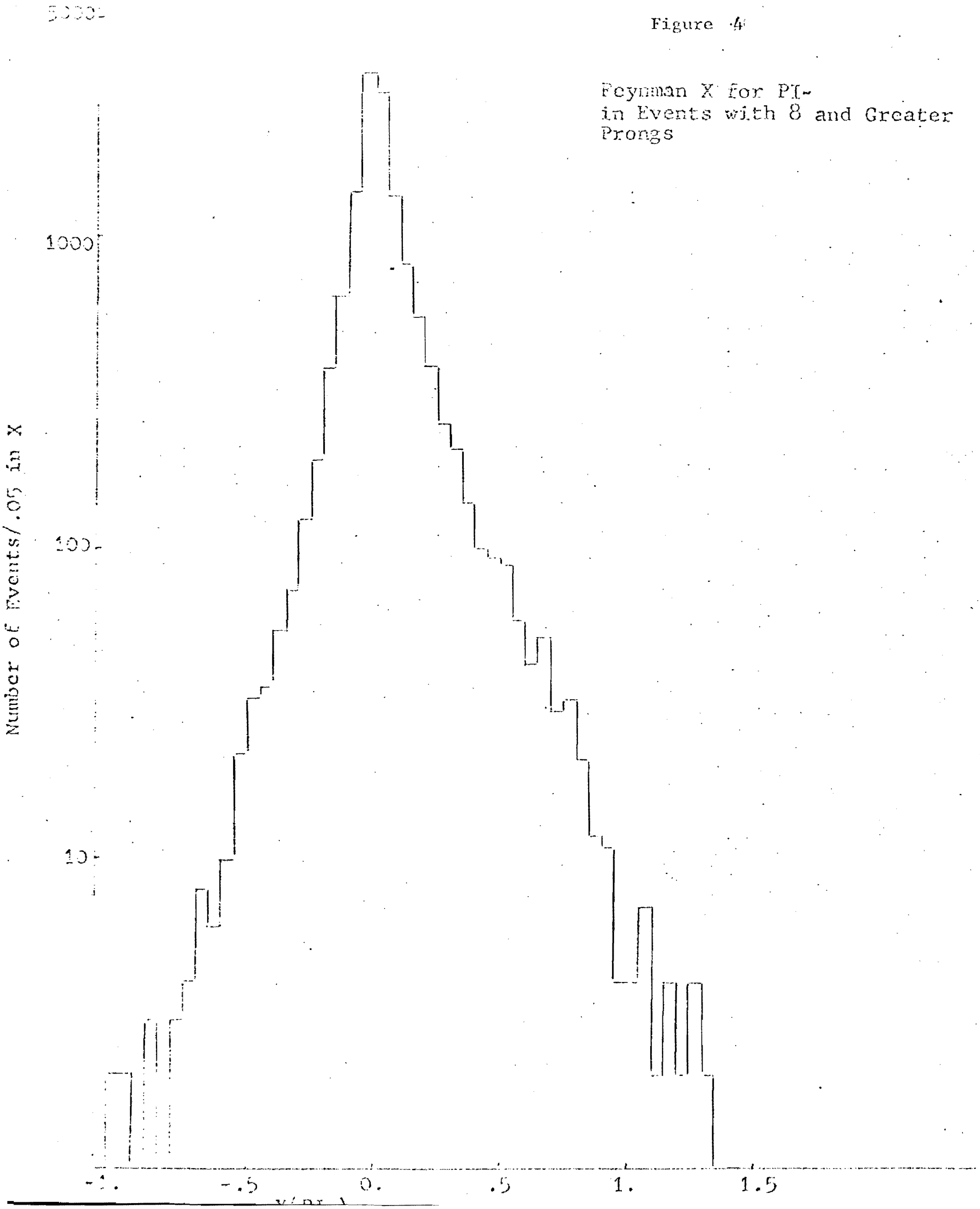


Figure 4



Feynman X for PI-
in Events with 8 and Greater
Prongs