PROPOSAL No. 215

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Experimental Proposal to N.A.L

Study of 400 GeV $\pi^- p$ Interactions in the Bare 30" Bubble Chamber

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The analysis of the data from our 48K photo 205 GeV $\pi^- p$ exposure of the bare 30-inch hydrogen bubble chamber (Experiment No. 137) has pointed up the desirability of another run at substantially higher energy. We therefore request another exposure in the same chamber of at least comparable statistics (50K photos) at approximately double the beam momentum. We estimate that with 460 GeV accelerated protons we can get a sufficient flux of 400 GeV π^-. Details are given in the appended note. Such an exposure should produce some 800 elastic scatters and about 6000 inelastic events from which one can measure total and elastic cross sections, and study multiplicity distributions, diffractive processes, strange particle production, inclusive distributions and gross characteristics of copiously produced channels. We give further details below.

1. Total $\pi^- p$ Cross Section

Our preliminary result at 205 GeV, $\sigma_T = 24.0 \pm 0.5$ mb (Fig. 1) is compatible with the previous highest energy point ($\sigma_T = 24.23 \pm 0.09$ mb at 60 GeV from Serpukhov)[1]. With an exposure of comparable statistics at 400 GeV we anticipate a measurement of σ_T with an uncertainty of at most ±2%. We consider this measurement to be important and appropriate for a bubble chamber for several reasons:

(i) It may be the only measurement of $\sigma_T(\pi^- p)$ at such a high energy to exist for some time to come.

(ii) ISR measurements indicate a rise in the pp total cross section above 200 GeV.[2] Data from our present and proposed experiments plus the results of the approved exposures at 100 and 300 GeV may give the first indication as to whether the $\pi^- p$ cross section also rises. It is clear that the best information on this point will come from data at the highest possible energy.

(iii) By using a bubble chamber to observe a possible cross section rise, we may be able to obtain information on what channels or processes are responsible for the rise.

2. Elastic $\pi^- p$ Scattering

We have measured, at 205 GeV, both the elastic cross section $\sigma_{el} = 3.2 \pm 0.3$ mb (Fig. 2) and the elastic slope $b = 9.2 \pm 0.8$ GeV^{-2} (Fig. 3). We anticipate significant improvement in the accuracy of both of these numbers in the near future as we add data from the second half of our run. The separation of the elastics from other two-prong events presented no serious difficulty with a fiducial region of 40 cm along the beam direction. Although a somewhat smaller fiducial region in the upstream part of the bubble chamber may be required, there should be no great problem in the separation of elastics from other two-prong interactions at 400 GeV. At our present energy the ratio of elastic to inelastic two-prongs is about 2/1; at 400 GeV this ratio is expected to be even larger and hence the background difficulties should be less important.

3. Multiplicity Distributions and Cross Sections

We anticipate little difficulty in obtaining charged-particle multiplicity distributions at 400 GeV comparable to those shown in Fig. 4 (half our statistics at 205 GeV). By restricting our fiducial volume somewhat, if necessary, we should be able to do as well at 400 GeV as we did in our present run. Figure 5 shows the charged multiplicity cross sections as a function of incident energy up to 205 GeV. It seems likely that the peak will, at 400 GeV, be near 10 prongs.

It is worth noting that our average charged multiplicity $\langle n_c \rangle = 8.00 \pm 0.18$ lies close to but distinctly above the 205 GeV pp value, namely 7.65 ± 0.17, and that the shapes of the multiplicity distributions are very similar. It will be interesting to make a comparison at 400 GeV.

By analysis of converted gammas and Dalitz pairs, it should be possible to determine π^o multiplicities and their relationship to the charged-pion multiciplities as we are currently doing at 205 GeV.

Production of neutral strange particles in the backward hemisphere of the $\pi^- p$ center of mass will be readily accessible to study.

4. Diffractive Cross Sections

At 205 GeV, our studies of inelastic diffractive processes have so far focused on the four-prong final state $\pi^- p \pi^+ \pi^-$. We have been able to partially separate these events from those with one or more π^o in the final state by using 4-constraint fits. This will undoubtedly be more difficult at 400 GeV, particularly for the pion dissociation events, for two reasons: (i) momenta will be more difficult to measure, and (ii) all angles will be decreased by a factor of two. We hope however to counteract these difficulties with some loss in statistics by reducing our fiducial volume.

Our preliminary cross section at 205 GeV for the reaction $\pi^- p \rightarrow \pi^- p \pi^+ \pi^-$ is 0.7±0.1 mb, a figure remarkably close to the value of 0.89±0.08 mb determined at 20 GeV by Ioffredo et al.[3] Approximately 2/3 of the events involve $\pi \rightarrow 3\pi$ diffractive dissociation and almost all of the remaining 1/3 consist of $p \rightarrow p\pi\pi$ nucleon dissociations. A few percent of the events seem to involve high mass values for both 3π and $p\pi\pi$ mass combinations and may involve more complicated production processes.[4] Distributions of $M(3\pi)$ and $M(p\pi^+\pi^-)$ for our present sample of 4-constraint fits (half of the total data) are shown in Fig. 6. We are currently studying diffractive processes in the higher multiplicity final states, and see evidence of pion and nucleon dissociation in 6-prong and perhaps 8-prong events.

One of the principal goals of our proposed experiment is to study the onset of diffractive processes for higher multiplicities as the incident energy is increased. The pion beam gives us a unique opportunity to study pion dissociation. Indications from ISR data[5] are that in proton dissociation, the diffractive peak scales like M^2/s. We shall be in a position to investigate this for pions for two significantly different values of s.

5. Inclusive Distributions and Correlations

Although we may not be able to finish our measurement program in the nominal 6 months available, we expect to be able to measure negative and positive outgoing track spectra (p_L, p_T, x, y, etc.) as a function of multiplicity for at least a sample of the film. Fig. 7, for example, shows p, π^+ and π^- rapidity distributions for $p\pi^+\pi^-\pi^-$ 4C events (~ half our statistics). These measurements will be more difficult and time consuming at 400 GeV than at 205, and we may not be able to extend them in practice to as high a multiplicity, but they will give a first look at inclusive spectra and the reactions responsible for them, as well as at correlations as a function of multiplicity at the highest available $\pi^- p$ energy. Data on inclusive proton spectra ($\pi^- p \rightarrow p$+ anything) may permit an estimate of the triple Pomeron coupling.[6] For such an analysis, the higher the energy the better, and, indeed, comparison of 400 GeV data with results at lower energies should be very instructive.

6. Other Physics

The analysis of our 205-GeV data carried on so far has principally focused on diffractive processes and 4C fits. However as our sample of measured events of a variety of topologies grows, it is quite likely that other interesting features may show up. Comparisons between 200 and 400 GeV for such features will undoubtedly be of great interest in developing our understanding.

Just as was done in our present experiment we shall search for negative quarks in our beam by scanning for low-bubble-density tracks. The presence of proportional wire chambers in the incident beam line permits the recording of the arrival time of each beam particle on magnetic tape. Hence one can verify whether or not a low bubble density track corresponds to an on-time particle. This system which was already used in our 205-GeV experiment will also be in operation for the proposed 400 GeV run.

The groups participating in the present 205-GeV experiment will have available at least equivalent scanning, measuring, computing and analysis power. Consequently results should be available soon after the exposure.

References

1. S. P. Denisov et al., Paper submitted to XVIth International Conference on High - Energy Physics, Batavia (1972).
2. U. Amaldi et al., to be published.
3. M. L. Ioffredo et al., Phys. Rev. Letters 21, 1212 (1968).
4. G. Chew has suggested that analysis of such events may give some information on the Pomeron-Pomeron-π-π vertex.
5. G. Goldhaber et al., Aachen-CERN-Harvard-Genova-Torino group at the ISR, to be published. Also M. G. Albrow et al., CERN-Holland-Lancaster-Manchester group at the ISR, to be published.
6. G. Chew, Private Communication, also H.D.I. Abarbanel, et.al, PRL 26 937 (1971).

Figure Captions

Fig. 1 - $\pi^{\pm}p$ total cross section as functions of incident momentum.

Fig. 2 - $\pi^{-}p$ elastic cross section as a function of incident momentum.

Fig. 3 - Differential cross section for $\pi^{-}p$ elastic scattering at 205 GeV.

Fig. 4 - Multiplicity distributions for $\pi^{-}p$ and pp at 205 GeV.

Fig. 5 - $\pi^{-}p$ cross sections for various charged multiplicities as a function of incident momentum.

Fig. 6 - Distributions of $M(3\pi)$ and $M(p\pi^{+}\pi^{-})$ for $\pi^{-}p \to \pi^{-}p\pi^{+}\pi^{-}$ events. Events marked with a cross in the $M(3\pi)$ spectrum are those which do not belong to the shaded regions corresponding to either pion or nucleon diffractive dissociation.

Fig. 7 - Rapidity distributions for final particles in $\pi^{-}p \to \pi^{-}p\pi^{+}\pi^{-}$ events.

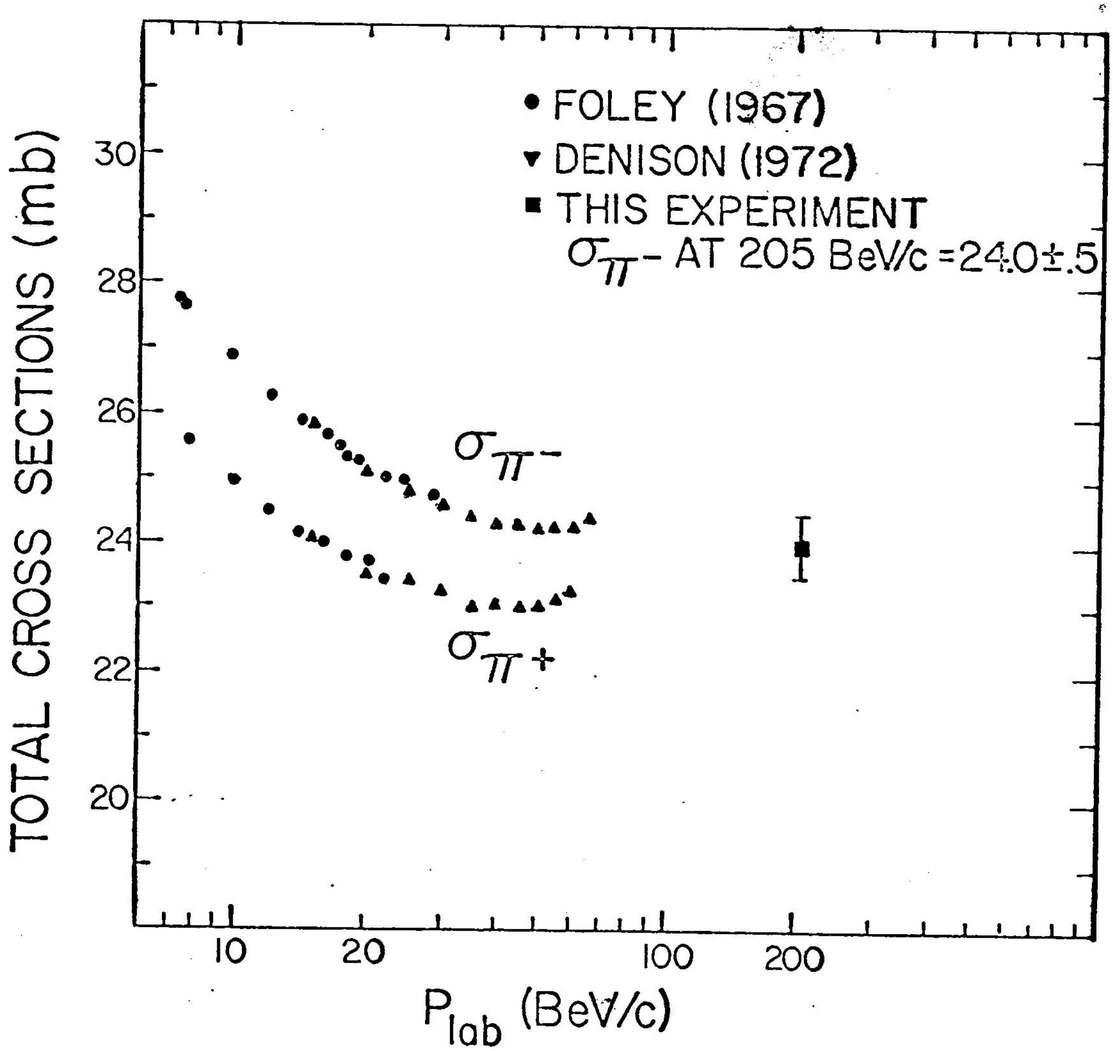


FIGURE 1.

Total Cross Section For Pions

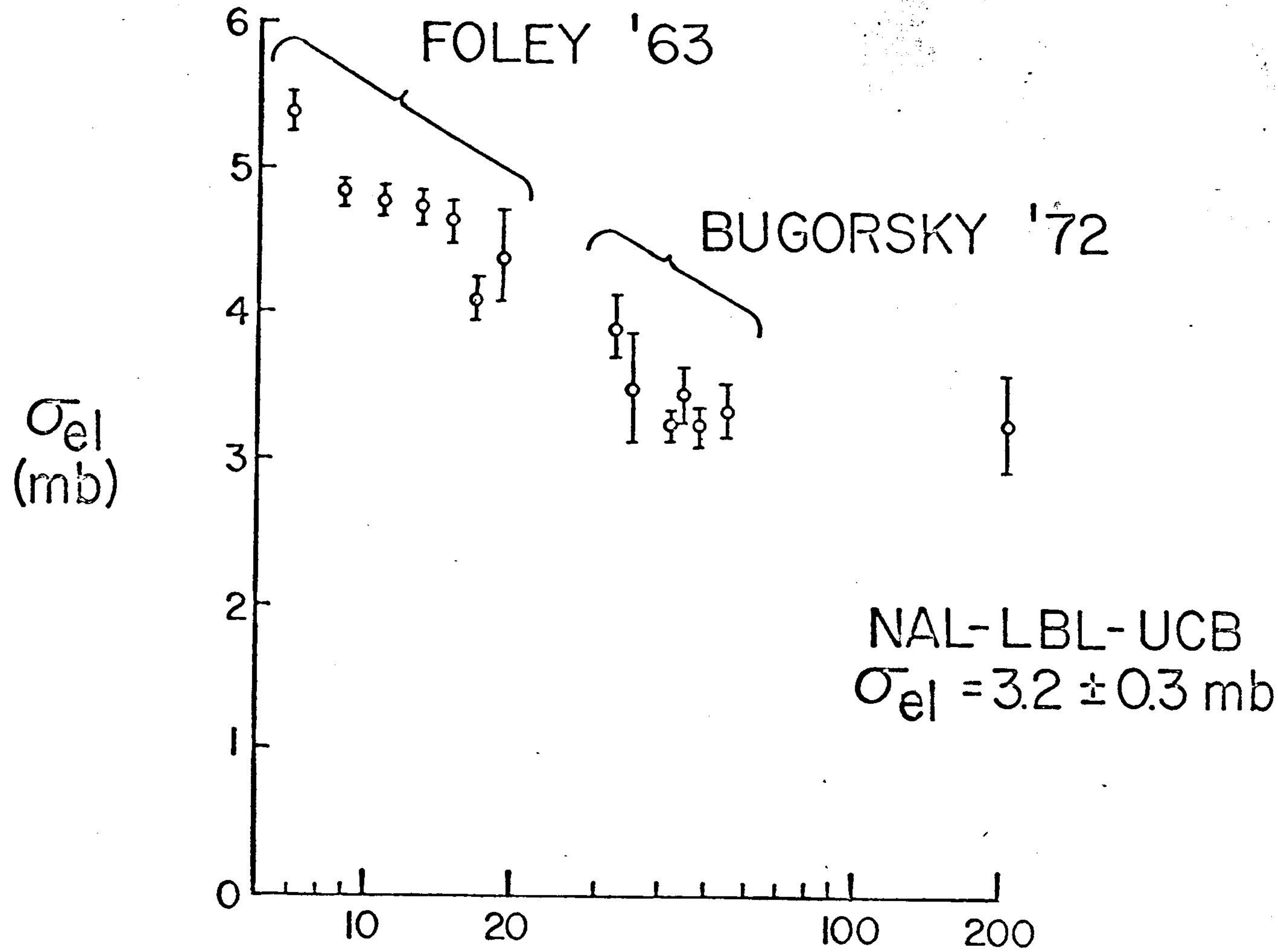


FIGURE 2.

Elastic Cross Section For Pions

$\pi^- p \rightarrow \pi^- p \quad P = 205$ GeV/c

FIGURE 3. $\frac{d\sigma}{dt}$ ELASTIC SCATTERING

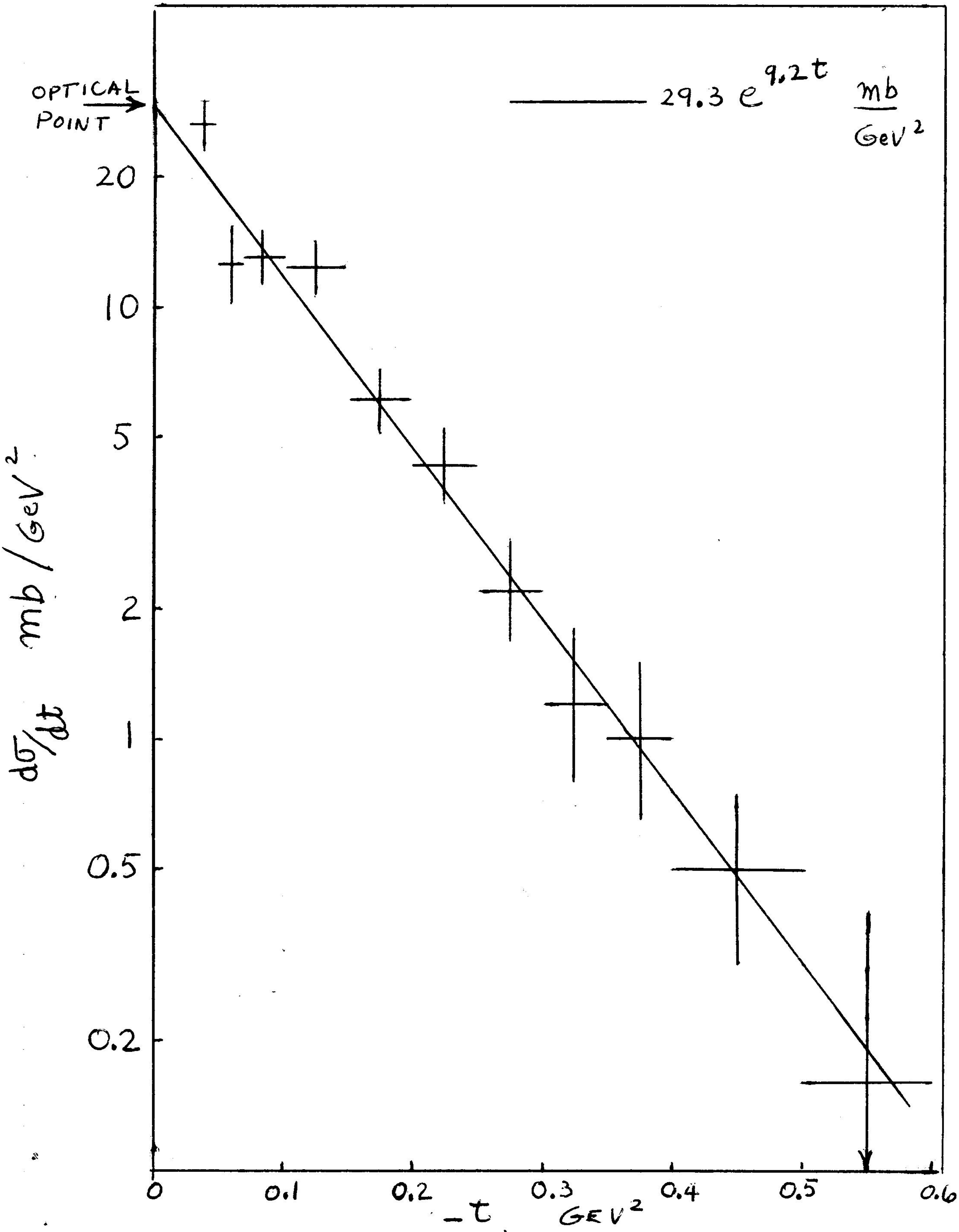
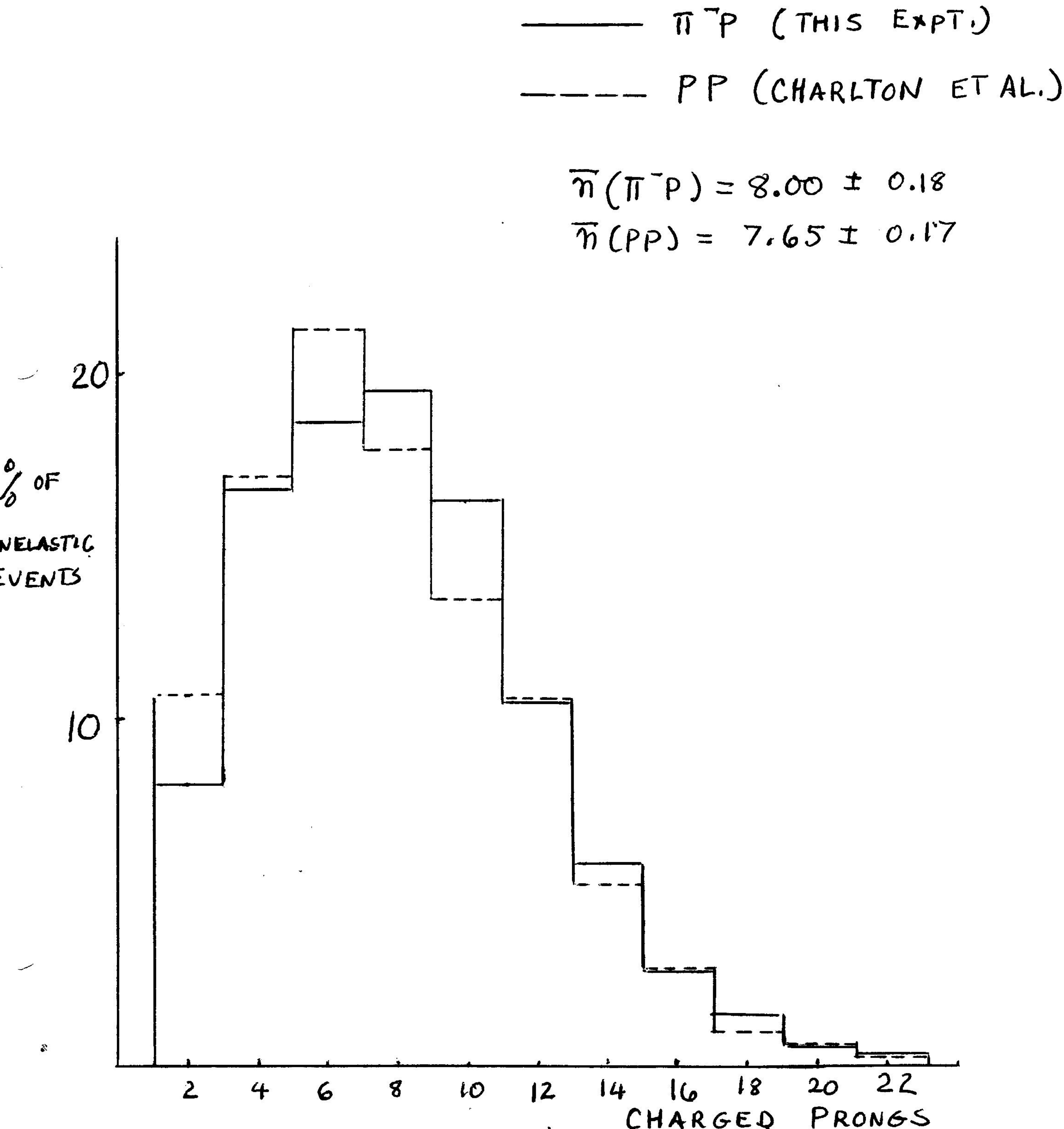


FIGURE 4.

CHARGED PRONG DISTRIBUTIONS
INELASTIC EVENTS
AT 205 GEV/C



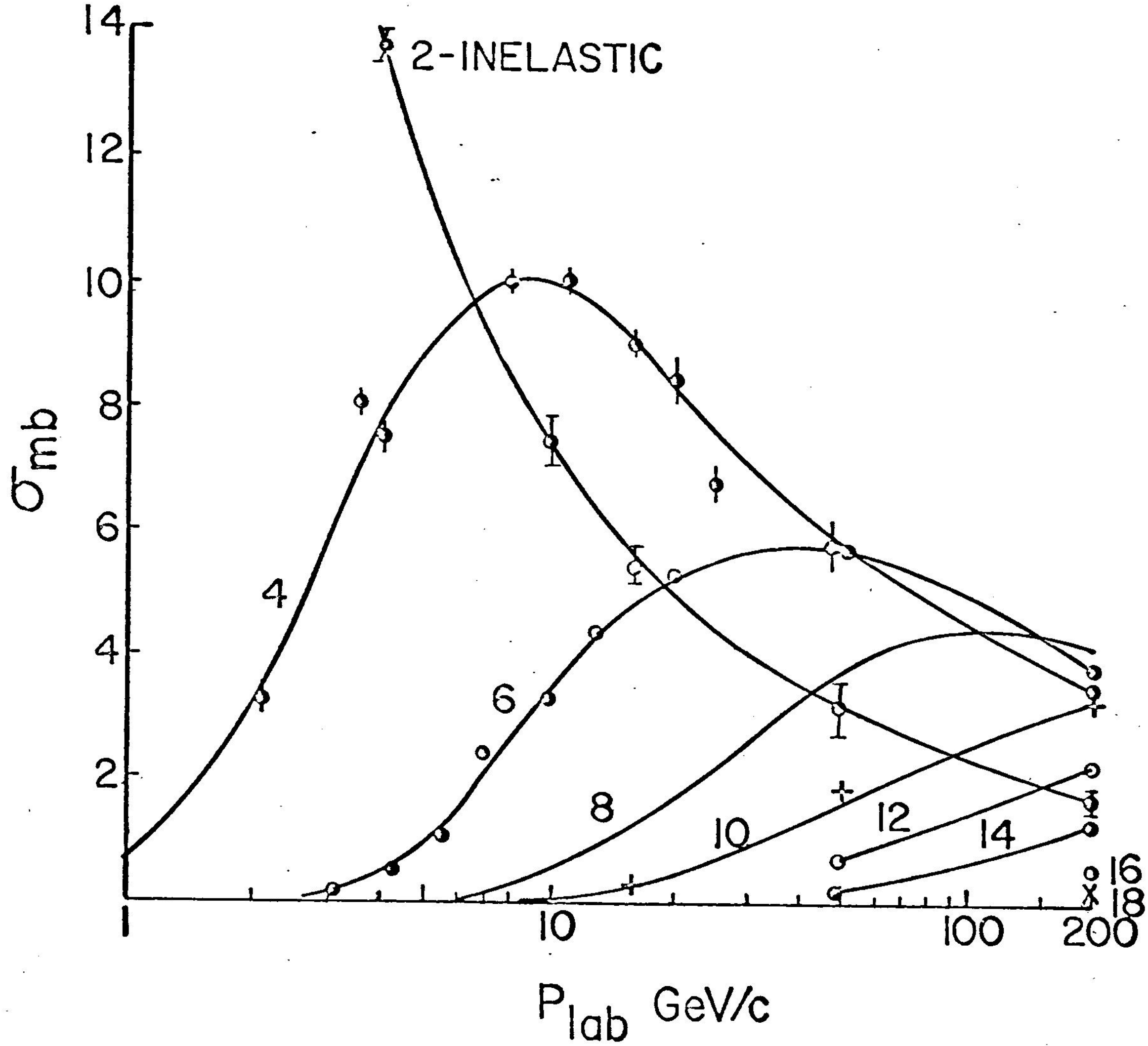


FIGURE 5.

Topological Multiplicity For π-p

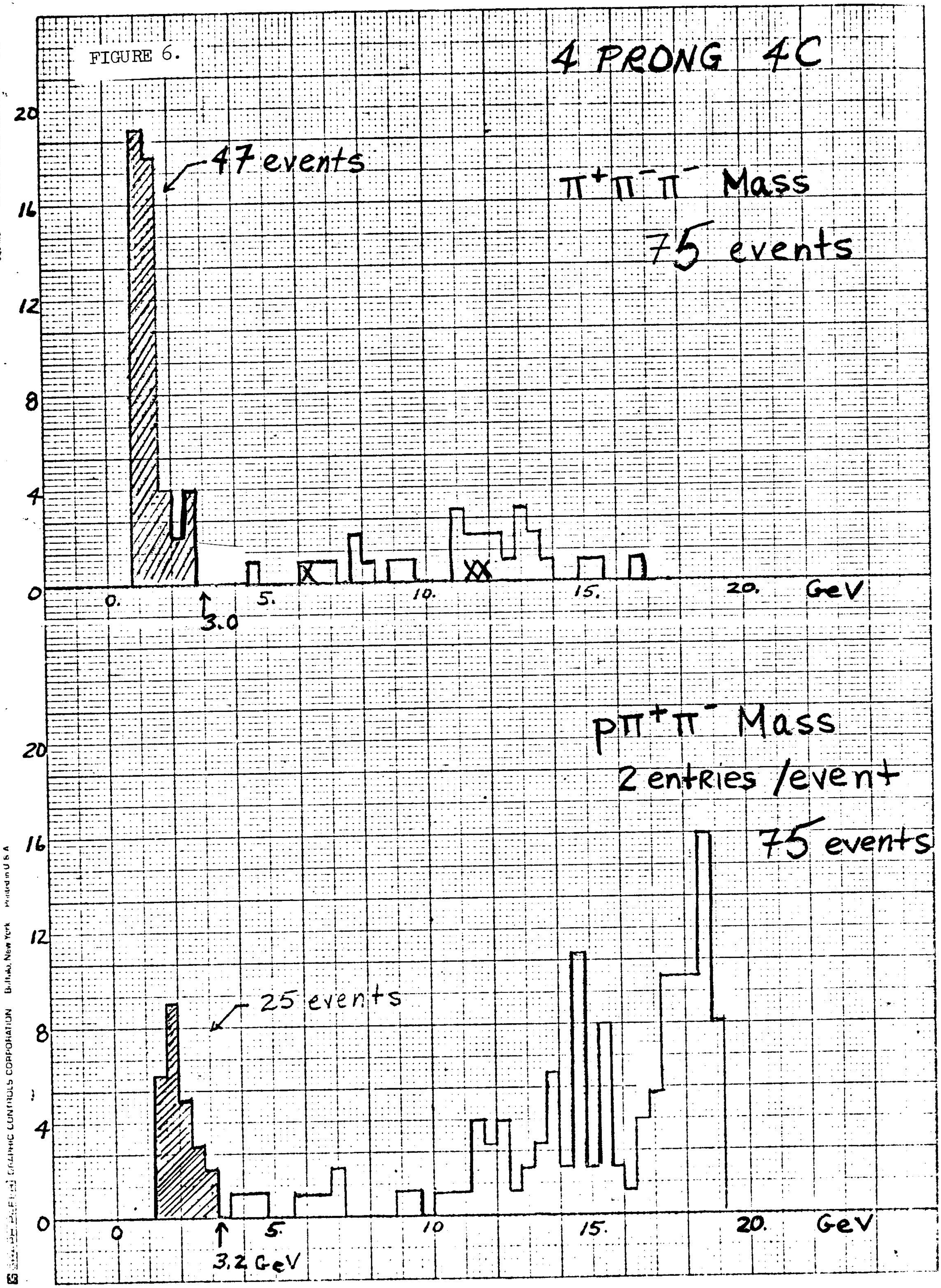
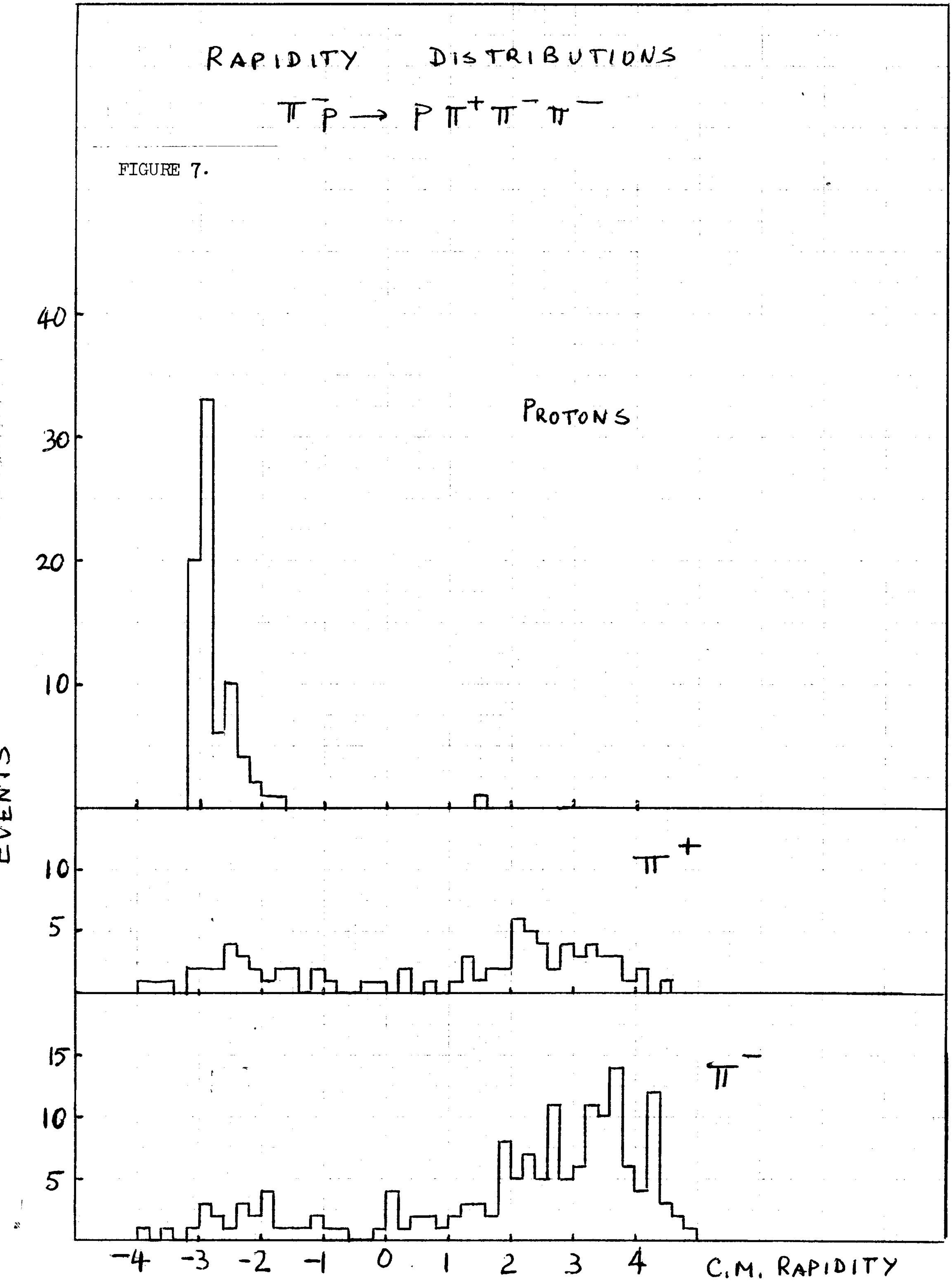

4 PRONG 4C
47 events
$\pi^+\pi^-\pi^-$ Mass
75 events
0
4
8
12
16
20
0.
5.
10.
15.
20.
GeV
3.0
$p\pi^+\pi^-$ Mass
2 entries /event
75 events
25 events
0
4
8
12
16
20
0
5.
10
15.
20.
GeV
3.2 GeV

FIGURE 6.


RAPIDITY DISTRIBUTIONS
$\pi^- p \rightarrow p \pi^+ \pi^- \pi^-$
FIGURE 7.
PROTONS
π^+
π^-
EVENTS
40
30
20
10
10
5
15
10
5
-4 -3 -2 -1 0 1 2 3 4
C.M. RAPIDITY

π^- PRODUCTION FROM PROTONS

Criteria:

Ω = .25 μstr

$\frac{\Delta p}{p}$ = 0.4%

I_{π^-} = 100 particles at chamber

I_p = 10^{10} interacting protons