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Study of ρ^0 Production in High Multiplicity pp Interactions at 300 GeV/c.*

by

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ABSTRACT

We have searched for ρ^0 production in 85 high multiplicity events with 18 or more charged particles. We observe an enhancement at the ρ^0 mass but with a considerably narrower width. Ignoring this narrow width, the cross section for $pp \rightarrow \rho^0 + n$ charged particles with $n \geq 16$ is 1.81 ± 0.46 mb. The ratio between the number of ρ^0's and π^-'s is observed to increase from 0.08 ± 0.04 for $p_T < 0.6$ GeV/c to 0.88 ± 0.23 for $p_T > 0.6$ GeV/c.

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Studies of high energy data from Fermilab and ISR revealed that there were strong correlations between particle pairs of all charge configurations[1]. These results may be interpreted as due to the formation of clusters which may or may not be resonances. However very little data on resonance production other than the baryon resonances in the target region ($x < -0.5$)[2] have been available so far. Recently it was observed at lower energies that ρ^o's are produced at large transverse momentum[3]. If this trend continues at high energies, the ρ^o could be an important source of the observed direct lepton production at high transverse momentum[4]. In view of the above, and the facts that there is a linear correlations between the production of charged particles and π^o's,[5] and the previous studies of ρ^o production[6] were primarily based on events with low or intermediate multiplicities, we were motivated to search for ρ^o production in high multiplicity interactions.

The data of this analysis come from a 34000 picture exposure of the Fermilab 30-inch hydrogen bubble chamber to a 300 GeV/c proton beam. The experimental details and the procedures for scanning and measuring the film were reported in a previous publication[7]. The measured events were required to lie in a fiducial volume that corresponded to approximately the upstream half of the visible chamber. This fiducial restriction was necessary in order to provide at least 30 cm of measurements on the outgoing tracks in the forward direction. However, only a random sample of the high multiplicity events in this fiducial volume were measured. Table 1 lists the number of scanned and measured high multiplicity events. All the measurements were performed on the high magnification measurement tables at the Fermilab. View to view track matching was performed during the measurements using bubble patterns as guide. Extraordinary care was taken in measuring these complicated events, and usually it required one shift (7 hours) to measure a full event. The measurements were geometrically

reconstructed using TVGP. Out of the 89 events measured, 4 events failed to balance charge due to poor measurements on one or more of the faster tracks and were not used in this analysis.

Approximately 25% of the tracks have low enough laboratory momentum so that proton identification using ionization is possible ($p_{lab} < 1.4$ GeV/c). However, not one of the tracks has ionization consistent with that of a proton. Therefore we conclude that, in contrast to the lower multiplicity interactions, there are no leading protons in these high multiplicity events. In the following search for ρ^o production we will assume that all charged particles are pions. The possible contamination from $\Delta^o(p\pi^-)$ and $K^*(K^+\pi^-$ or $K^-\pi^+)$ production to the $\pi^+\pi^-$ invariant mass distribution is negligible since there is no evidence for any Δ^o or K^* enhancement[8].

Fig. 1 shows the invariant mass distribution of all the $\pi^+\pi^-$ combinations[9]. Since there are on the average 100 such combinations per event, and previous results at these energies indicate that there are less than one ρ^o produced per interaction[6], we expect to observe, if at all, a small ρ^o enhancement over a large combinational background. The distribution in Fig. 1 indicates just such an enhancement at the ρ^o mass. A fit was performed over the mass interval from 0.59 to 1.2 GeV using a second order polynomial background plus a simple Breit-Wigner with a fixed mass (765 MeV) and a variable width. The width giving the best χ^2 is 60 ± 20 MeV, which is much narrower than the value generally accepted for the ρ^o. Nevertheless a similar width has been observed in inclusive ρ^o production in 200 GeV/c pp interactions[10]. In this letter we will ignore this narrow width and proceed with the assumption that this enhancement is the ρ^o. The curve in Fig. 1 shows the resulting fit which has a χ^2 of 0.97 per d.o.f. The number of ρ^o's is 131 ± 36 corresponding to a cross-section of 1.81 ± 0.46 mb.

In Figs. 2a and b the $\pi^+\pi^-$ invariant mass combinations are shown in two rapidity intervals, $|Y_{CM}| < 1$ and $|Y_{CM}| > 1$ respectively, where Y_{CM} is the center of mass rapidity of the $\pi^+\pi^-$ system. Figs. 2c and d show the same invariant mass combinations in two p_T intervals, $p_T < 0.6$ GeV/c and $p_T > 0.6$ GeV/c respectively, where p_T is the perpendicular momentum of the $\pi^+\pi^-$ system. The curves in the figures are the results of fits with a second order polynomial background and a simple Breit-Wigner of fixed mass and width ($m = 765$ MeV, $\Gamma = 60$ MeV). The numerical results of the fits are listed in Table 1. These results indicate that most of the ρ^o's are produced in the central region with relatively high average transverse moemnta. Whereas the rapidity dependence is consistent with the behavior of most particles produced in high energy interactions, the p_T dependence is, on the other hand, strikingly different[11]. This is shown in Table 2 by the ratio, R, between the number of ρ^o's and π^-'s produced in these two p_T intervals.

The p_T dependence of this ratio is consistent with the values for the low energy data reported in Ref. 3 ($R \simeq 0.8$ at $p_T \simeq 1$ GeV/c). Assuming that the ρ^o is the only source of direct lepton production, Monte Carlo studies show that the present data can account for a electron-pion ratio of $(2.0 \pm 0.8) \times 10^{-5}$ for $p_T > 0.6$ GeV/c. This is to be compared with the observed lepton-pion ratio of $\sim 10^{-4}$ in Refs. 4. However we emphasize that our data are from high multiplicity events only, and therefore are not inclusive.

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8. The possible contamination from Δ^0 ($p\pi^-$) and K^*($K^+\pi^-$ or $K^-\pi^+$) production was studied by appropriately interpreting one of the charged particles as proton or $K^\pm$. The resulting two body mass distributions showed no obvious Δ^0 or K^* enhancement. Furthermore the overlap between the ρ^0 mass region and the Δ^0 or K^* mass region is small for different mass interpretations of the same two body system.
9. The typical errors shown in the figures are statistical only. Monte Carlo studies were made to investigate the additional errors caused by the multiple entries of the same particle via different combinations. The results show that this additional contribution is negligible.
10. R. Singer et al., submitted to Physics Letters.
11. See,for example,J. Whitmore, Physics Reports 10C, 274 (1974).

Table 1

n_c	No. of Scanned Events	No. of Measured Events
18	171	28
20	67	24
22	47	18
24	11	8
26	9	7
Total	305	85

Table 2

	$\lvert Y_{CM}(\pi^+\pi^-)\rvert < 1$	$\lvert Y_{CM}(\pi^+\pi^-)\rvert > 1$	$p_T(\pi^+\pi^-) < 0.6$ GeV/c	$0.6 < p_T(\pi^+\pi^-)$
χ^2/d.o.f.	1.16	1.54	1.20	0.55
$\sigma(\rho^o)$mb	1.40 ± 0.42	0.47 ± 0.25	0.71 ± 0.35	1.27 ± 0.29
$\frac{\text{No. of } \rho^o}{\text{No. of } \pi^-}$	--	--	0.08 ± 0.04	0.88 ± 0.23

COMBINATIONS / 0.05 Gev

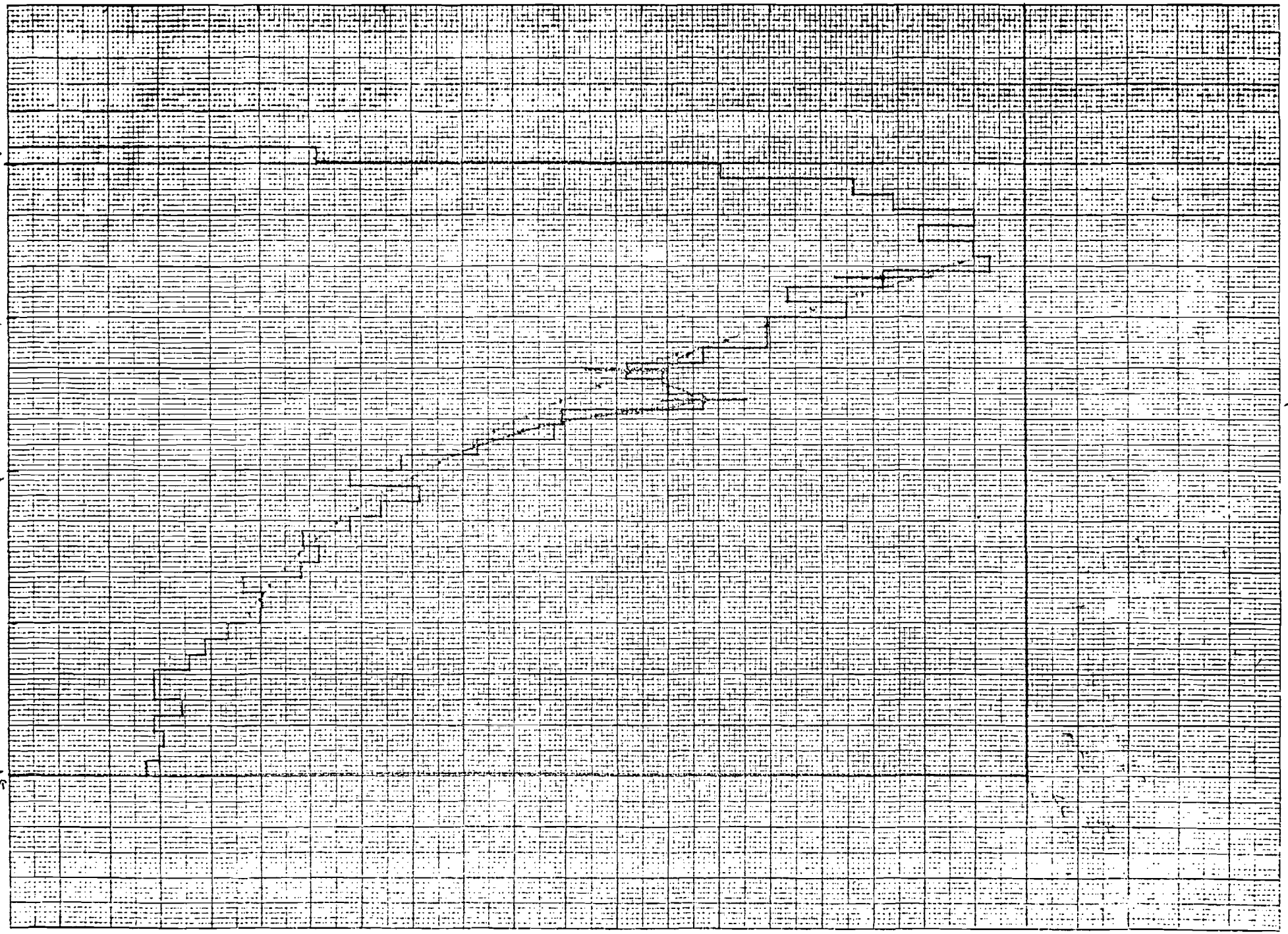
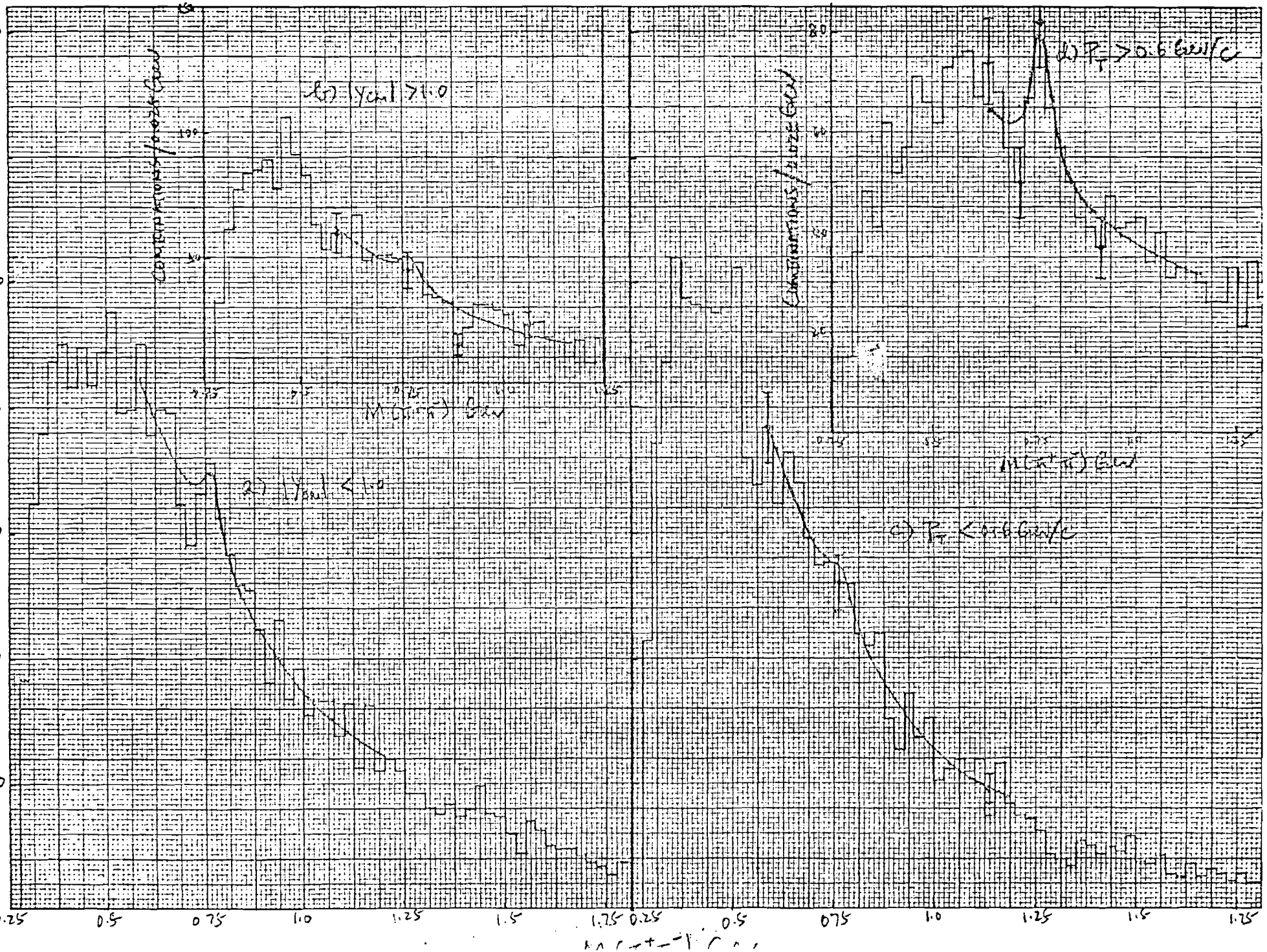


FIG 2


K•Σ 10 X 10 TO THE CENTIMETER 18 X 25 CM.
KEUFFEL & ESSER CO. MADE IN U.S.A.
(a) |y_cm| > 1.0
(b) |y_cm| < 1.0
(c) P_T < 0.6 GeV/c
(d) P_T > 0.6 GeV/c
COMBINATIONS / 0.125 GeV
M(K⁺π⁻) GeV
M(K⁻π⁺) GeV
0.25
0.5
0.75
1.0
1.25
1.5
1.75
50
100
150
200
250
300
350

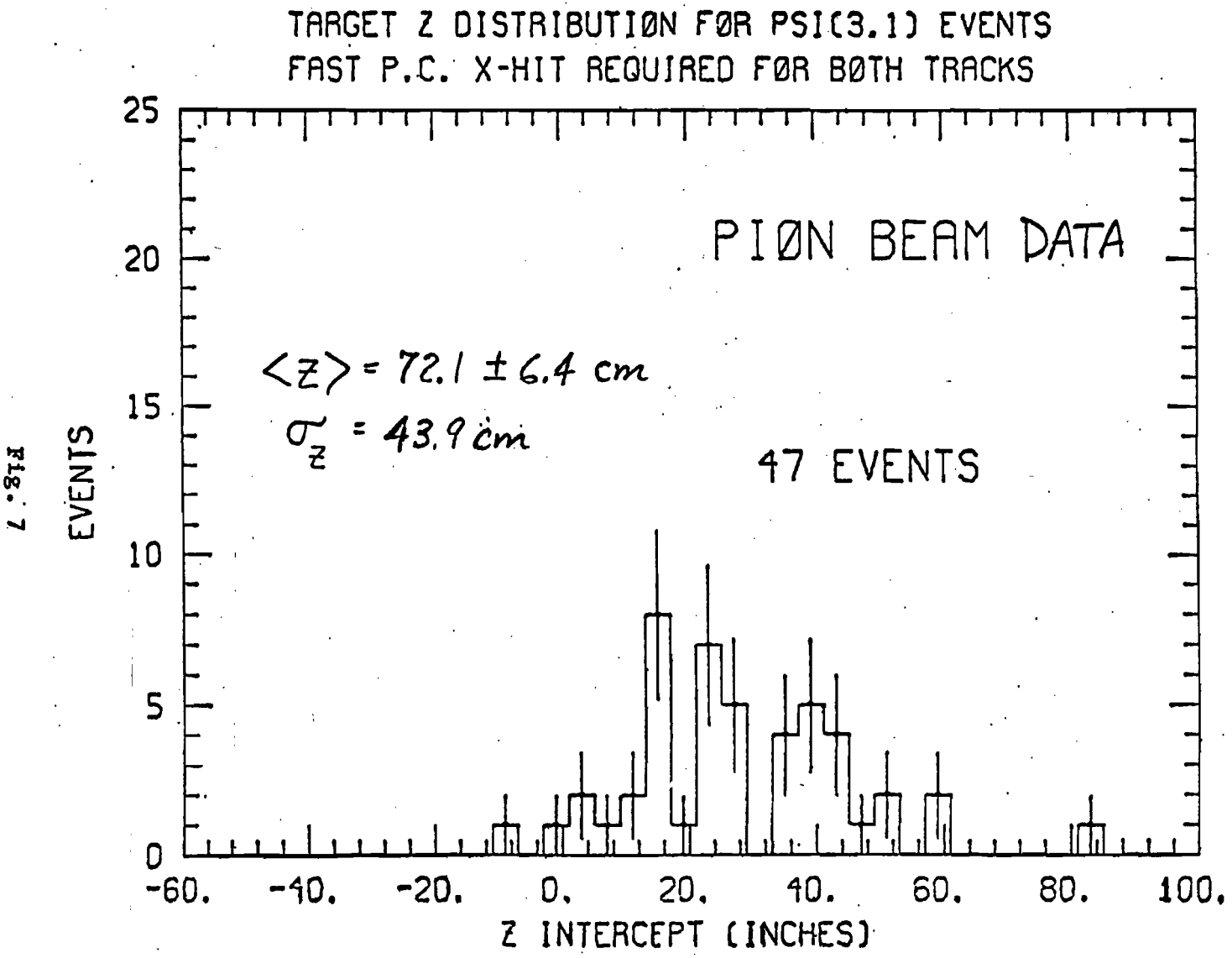

TARGET Z DISTRIBUTIØN FØR PSI(3.1) EVENTS
FAST P.C. X-HIT REQUIRED FØR BØTH TRACKS
PIØN BEAM DATA
⟨z⟩ = 72.1 ± 6.4 cm
σz = 43.9 cm
47 EVENTS
EVENTS
25
20
15
10
5
0
-60.
-40.
-20.
0.
20.
40.
60.
80.
100.
Z INTERCEPT (INCHES)

FIG. 7