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Abstract

Results from the Fermilab 15 ft. bubble chamber on the charged particle multiplicity distributions produced in high energy charged current neutrino-proton interactions are presented. The mean charged hadronic multiplicity $<n_c>$ does not appear to depend strongly on neutrino energy or on momentum transfer squared at fixed hadron mass W. $<n_c>$ increases linearly with $\ell n\ W^2$ and a fit to the data gives $<n_c> = (1.09\pm.38) + (1.09\pm.03)\ \ell n\ W^2$. Comparisons are made to γp, ep, μp, and inclusive pp scattering. The mean hadronic multiplicity appears to depend only on the mass of the excited hadronic state, independent of the mode of excitation.

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We present results on multiplicity distributions obtained in charged current neutrino interactions in the Fermilab 15 ft. hydrogen filled bubble chamber. The analysis is based on 62,000 pictures obtained with a broad-band neutrino beam produced by 300 GeV/c protons. The film was scanned for events with 3 or more prongs for which no track was within 70° of the anti-beam direction. The events within a 21 m^3 fiducial volume which have visible longitudinal momentum greater than 10 GeV/c were selected for further analysis. The procedures used to identify the muon and to obtain an estimate for the neutrino energy, E_ν, together with further details of the experimental arrangement, are given in Ref. 1.

Imposing the further requirement, in order to minimize background, that the neutrino energy exceed 15 GeV/c reduces the data sample to ~ 450 events. We estimate that 85% of these are charged-current neutrino events with correctly identified muon and the remaining 15% are background composed of charged-current events with the wrong track chosen as the muon, neutral current events, anti-neutrino events, and neutral hadron-induced events.

Table I displays the multiplicity probabilities P_n for producing n prongs for various ranges of W^2, the square of the hadronic mass. The probability for producing 3-prongs decreases with increasing W^2, while the probability of producing 7 or more prongs increases. A similar behavior is seen in Fig. 1, where the charged hadronic multiplicity distribution is plotted for various E_ν

intervals. The increase with energy of the probability for producing the higher multiplicities causes the mean charged hadronic multiplicity $< n_c >$ and width σ to increase. Table II indicates however, that for a fixed value of W^2, $< n_c >$ is independent of E_ν. Thus in Fig. 1 the increase of $< n_c >$ with E_ν is due to the increase in the range of kinematically allowed W.

In Fig. 2 we have plotted the mean hadronic multiplicity as a function of Q^2, the momentum transfer squared between the leptons, for various W^2 ranges. The dashed lines are the overall $< n_c >$ for the W^2 intervals. We see that there is no pronounced Q^2 dependence for fixed W^2. Hence the primary dependence of $< n_c >$ is on W^2 and a fit to all the data over the W^2 range from 4 to 200 $(GeV/c^2)^2$ gives

$$< n_c > = (1.09 \pm .38) + (1.09 \pm .03) \ln W^2 .$$

The mean hadronic multiplicity as a function of W^2 is plotted in Fig. 3 along with data for $Q^2 > 1$ $(GeV/c)^2$ from photoproduction and electroproduction experiments.[2,3,4,5,6] The neutrino data lie above the photo(electro)-production data by about 1/2 unit. This is perhaps attributable to the +2 charge of the hadronic final state in the neutrino experiment compared to the +1 charge in photo(electro)-production. Within errors the slope of the W^2 dependence of $< n_c >$ is the same for neutrino data and the photo(electro)-production data.

A similar situation occurs in hadron scattering as shown in Fig. 4. Here we have compared our mean charged hadronic multiplicity as a function of W^2 with similar results from inclusive proton production in pp scattering at Fermilab energies.[7,8] As in the comparison with photoproduction and electroproduction, the neutrino data have approximately the same slope as the proton data, but lie about 1/2 unit above.

The data indicate that the mean number of charged hadrons produced in the excitation of a proton by a wide variety of particles is independent of the nature of the interaction and depends only on the mass of the excited hadronic system.

References

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Table I. Multiplicity Probabilities for Various W^2 Intervals

Multiplicity Probability P_n	W^2 $(GeV/c^2)^2$ 1.-10.	10.-20.	20.-30.	30.-50.	50.-100.	> 100.
No. Events	106	111	59	72	61	39
P_3	.68±.05	.28±.04	.14±.04	.04±.02	.13±.04	.03±.03
P_5	.27±.04	.46±.05	.46±.06	.46±.06	.43±.06	.31±.07
P_7	.04±.02	.23±.04	.34±.06	.32±.05	.21±.05	.33±.08
P_9	.01±.01	.03±.02	.05±.03	.15±.05	.15±.05	.21±.06
P_{11}			.01±.01	.03±.02	.02±.02	.12±.05
P_{13}					.03±.02	
P_{15}					.03±.02	

Table II. $< n_c >$ for Various W^2 and E_ν Intervals

E_ν (GeV)	W^2 $(GeV/c^2)^2$ 4 - 16	16 - 36	36 - 64	64 - 200
15 - 20	3.5±.3	4.4±.4		
20 - 30	3.7±.2	4.9±.2	5.2±.5	
30 - 50	3.3±.2	4.9±.2	4.9±.3	
50 - 100	3.7±.2	4.3±.4	5.2±.4	5.8±.4
> 100	3.5±.4	5.3±.6	5.7±.7	6.8±.6

Figure Captions

Fig. 1 Charged hadron multiplicity distribution in charged current neutrino proton interactions for various neutrino energy intervals.

Fig. 2 Mean charged hadron multiplicity as a function of Q^2. for various intervals of hadron mass squared. The dashed line is the mean value of $< n_c >$ for the W^2 interval.

Fig. 3 Comparison of mean charged hadron multiplicity as a function of W^2 in νp scattering to that observed in γp, ep, and μp interactions.

Fig. 4 Comparison of mean charged hadron multiplicity as a function of W^2 in νp scattering to that observed in inclusive pp scattering.

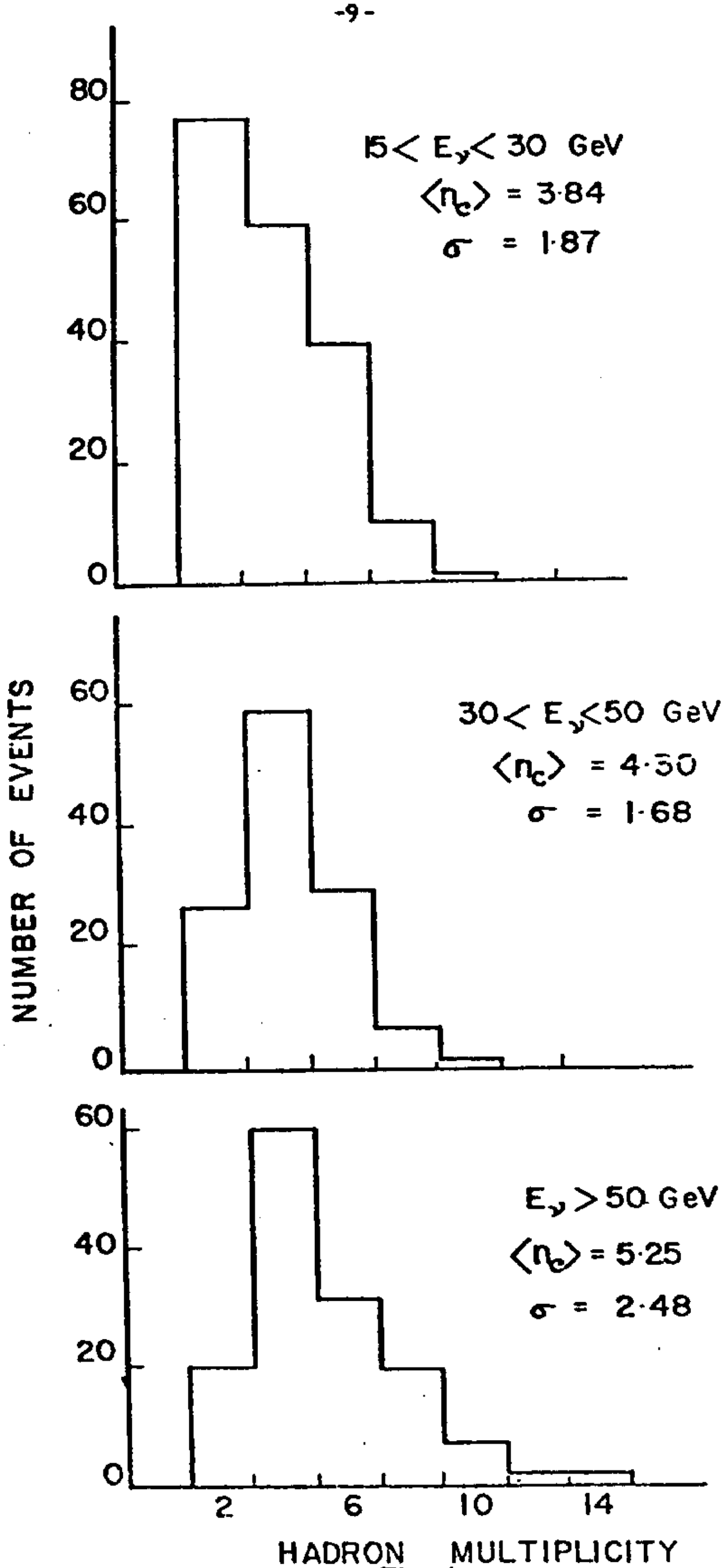

15 < E_ν < 30 GeV
$\langle n_c \rangle$ = 3·84
σ = 1·87
30 < E_ν < 50 GeV
$\langle n_c \rangle$ = 4·30
σ = 1·68
E_ν > 50 GeV
$\langle n_c \rangle$ = 5·25
σ = 2·48
NUMBER OF EVENTS
HADRON MULTIPLICITY
80
60
40
20
0
2
6
10
14

Fig. 1

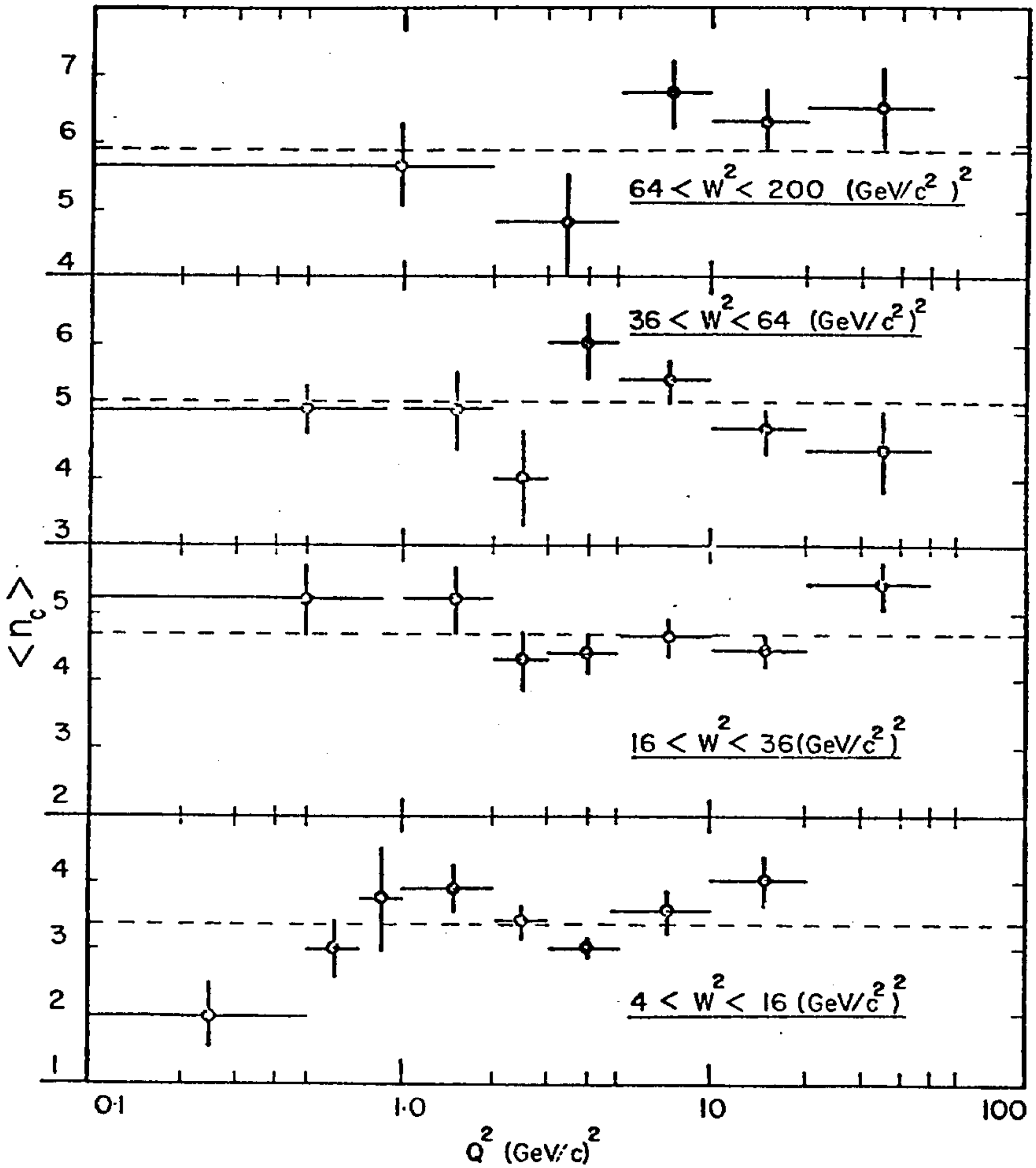
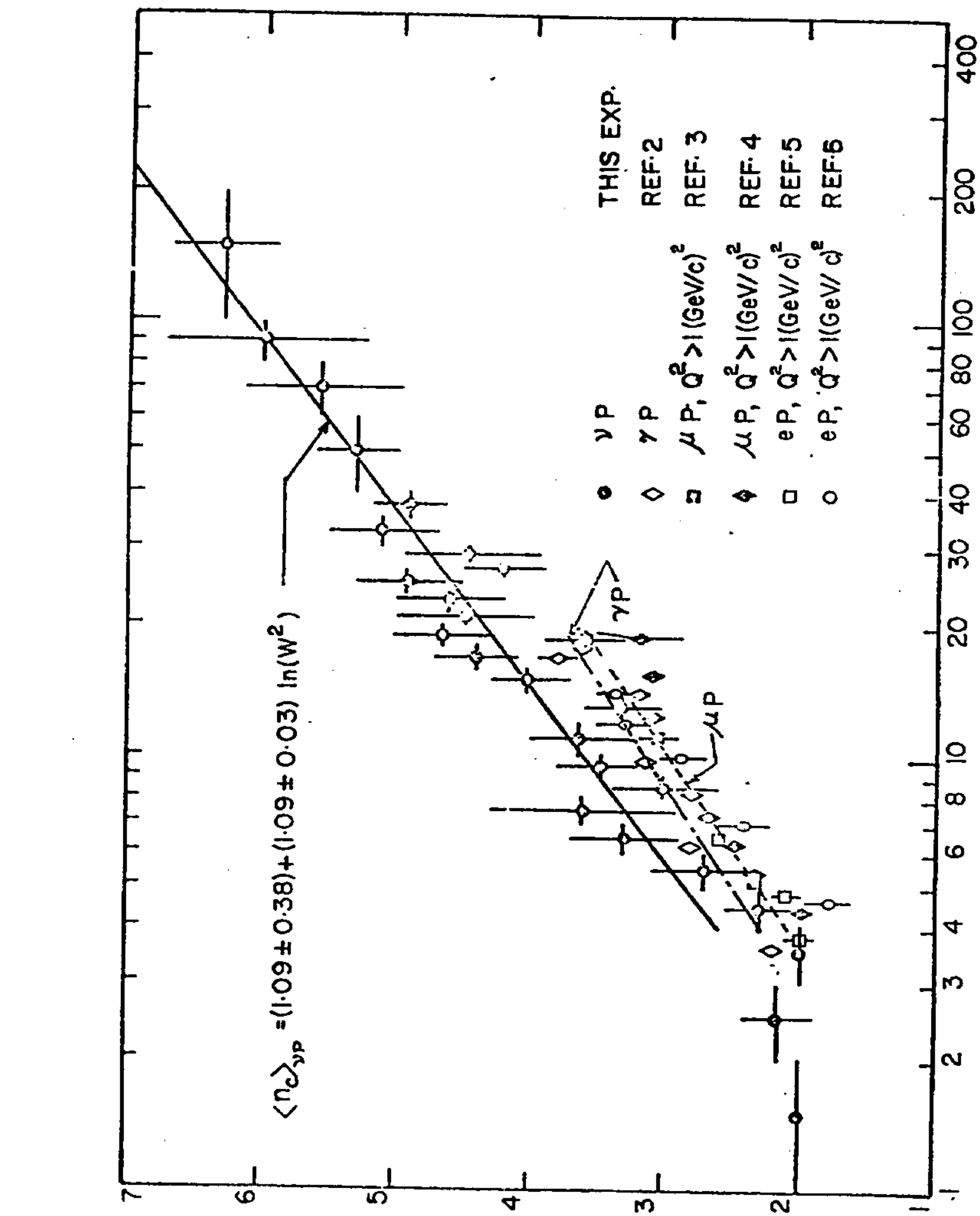
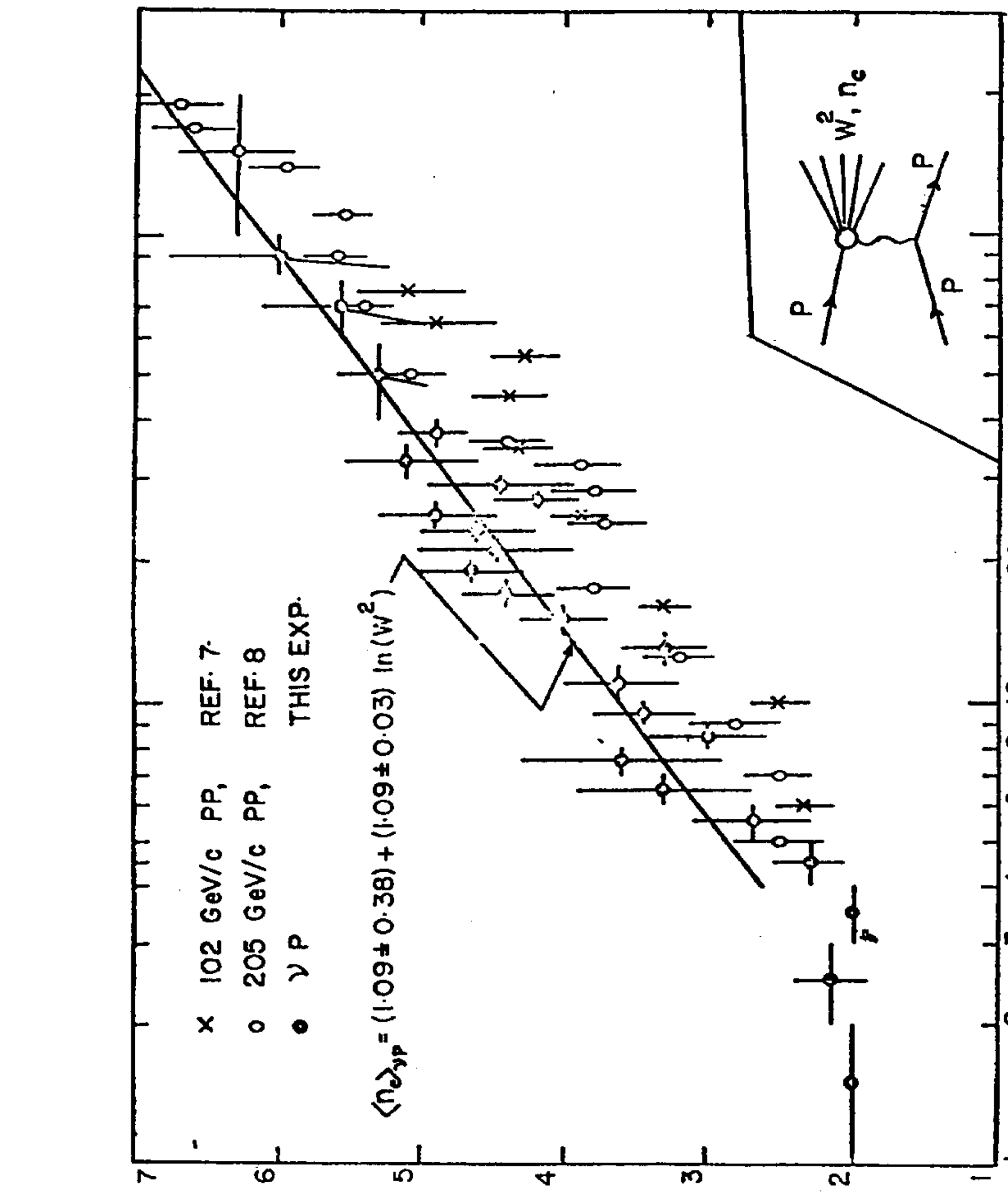

64 < W² < 200 (GeV/c²)²
36 < W² < 64 (GeV/c²)²
16 < W² < 36(GeV/c²)²
4 < W² < 16 (GeV/c²)²
<nc>
Q² (GeV/c)²
0·1
1·0
10
100

Fig. 2


$\langle n_c \rangle_{\nu p} = (1.09 \pm 0.38) + (1.09 \pm 0.03) \ln(W^2)$
νP THIS EXP.
γP REF. 2
μP, $Q^2 > 1 (GeV/c)^2$ REF. 3
μP, $Q^2 > 1 (GeV/c)^2$ REF. 4
eP, $Q^2 > 1 (GeV/c)^2$ REF. 5
eP, $Q^2 > 1 (GeV/c)^2$ REF. 6
γP
μP
$\langle n_c \rangle$
W^2 $(GeV/c^2)^2$



× 102 GeV/c PP, REF. 7
o 205 GeV/c PP, REF. 8
● ν P THIS EXP.
$\langle n_c \rangle_{\nu p} = (1.09 \pm 0.38) + (1.09 \pm 0.03) \ln(W^2)$
$\langle n_c \rangle$
W^2 $(GeV/c^2)^2$
P
P
P
W^2, n_c