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MEASUREMENT OF THE RATIO OF NEUTRINO TOTAL CROSS SECTIONS ON HYDROGEN AND DEUTERIUM IN THE BROOKHAVEN 7-ft. BUBBLE CHAMBER*

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We present charged current neutrino interactions obtained in hydrogen and deuterium as a function of charged track multiplicity. The ratio of neutrino fluxes in the two exposures is obtained from the two samples of the reaction $\nu p \to \mu^- p \pi^+$. The ratio of total charged current cross sections on hydrogen and deuterium is thus obtained and presented as a function of neutrino energy. The result obtained for neutrino energies above 2 GeV is:

$$\sigma(H_2) \ / \ \sigma(D_2) = 0.40 \pm 0.10$$

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INTRODUCTION

The data sample and the initial event selection procedure for the study of charge current interactions in hydrogen and deuterium were identical to those discussed previously with regards to the neutral current study[1]. The visible momentum vector for each event was calculated and events with

$$P_{vis} \geq 400 \text{ MeV/c}$$
$$/\lambda_{vis}/ \leq 35^o$$
$$/\phi_{vis}/ \leq 35^o$$

were accepted as beam associated events. Charged current candidates were then defined as events which satisfied the above cuts and had a possible μ^- track. A total of 93 events in hydrogen and 211 events in deuterium were obtained from 62K pictures in hydrogen and 68K in deuterium. The actual breakdown of the events into the number of visible prongs is shown in Table I.

To calculate the hydrogen and deuterium cross section ratio, it is necessary to establish the relative flux normalization of the two sets of data. This was done by measuring the number of unique

$$\nu p \to \mu^- p \pi^+$$

events in each case. The procedure for selecting these events in both liquids is discussed. Then the method for calculating the neutrino energy is outlined and the cross section ratio as a function of energy calculated.

SELECTION OF $\mu^- p \pi^+$ EVENTS

In hydrogen the selection of unique

$$\nu p \to \mu^- p \pi^+$$

was made using the variable

$$EMPX \equiv (Ev - Mp) - Pvx$$

where Ev, Pvx are the total visible energy and the component in the beam direction of the visible momentum. If there are no neutrals missing EMPX $\underset{\sim}{\sim}$ 0 while for neutrals missing EMPX is driven negative. Furthermore, for events with no neutrals missing the visible momentum vector should point approximately in the beam direction. In hydrogen then $\mu^- p\pi^+$ final states with no neutrals missing were defined to be $\mu^- p\pi^+$ events for which

$$/EMPX/ \leq 30 \text{ MeV}$$

$$\theta_{vis} < 6^o,$$

where θ_{vis} is the angle between the visible momentum vector and the neutrino beam direction (Fig. 1). A plot of the $p\pi^+$ mass for the 59 selected events shows a clear Δ^{++} signal (Fig. 2).

A similar selection procedure was applied in deuterium. However, here the presence of a spectator particle causes a broadening of the EMPX distribution. From a study of the quasi-elastic events without a visible spectator

$$\nu d \rightarrow \mu^- p(p_s)$$

a width of 140 MeV for the EMPX distribution was determined. Unique $\mu^- p\pi^+$ final states in deuterium were defined to be $\mu^- p\pi^+$ events for which (Fig. 3)

$$/EMPX/ \leq 140 \text{ MeV}$$

$$\theta_{vis} < 8^o$$

Again 59 events satisfy these criteria and the $p\pi^+$ mass distribution (Fig. 4) shows a clear Δ^{++} signal.

CALCULATION OF THE NEUTRINO ENERGY

A number of assumptions are required in the calculation of the neutrino energy for each event. The first set of assumptions cover the spectators in the deuterium data. If the conditions

$$\text{EMPX} \leq 140, \ \theta_{vis} < 8^{o}$$

were satisfied for the event, then it was assumed that no spectator was visible. In this case the energy was calculated as in the hydrogen film. If a spectator was observed, then the correct deuterium energy momentum equations were used in calculating the neutrino energy.

The second set of assumptions refer to the absence or presence of neutral particles in the final state. As discussed previously, if in hydrogen

$$/\text{EMPX}/ \leq 30 \text{ MeV}, \ \theta_{vis} \leq 6^{o}$$

or in deuterium

$$/\text{EMPX}/ \leq 140 \text{ MeV}, \ \theta_{vis} \leq 8^{o}$$

then no neutral particles are assumed to be present in the final state. If these conditions are not satisfied, then it is assumed that only one neutral particle is missing. If a proton has been observed then a π^{o} is assumed to be missing, but if no proton is present a neutron is assumed and the neutrino energy calculated accordingly in each case.

HYDROGEN-DEUTERIUM CROSS SECTION RATIOS

The calculated cross section ratio for hydrogen and deuterium as a function of energy is shown in Fig. 5. At low energy ($\lesssim$ 1.5 GeV) the total corss sections are composed almost entirely of the quasi-elastic and the Δ^{++} final states. The cross section ratio for these channels is calculated from the measured cross sections[2] and shown as the solid curve in the figure. The predicted ratio from the quark parton model[3] is 0.39. If one considers data with neutrino energy above 2 GeV to be in the scaling region, then the measured cross section ratio in this region is found to be:

$$\frac{\sigma(H_2)}{\sigma(D_2)} = 0.40 \pm 0.10$$

References

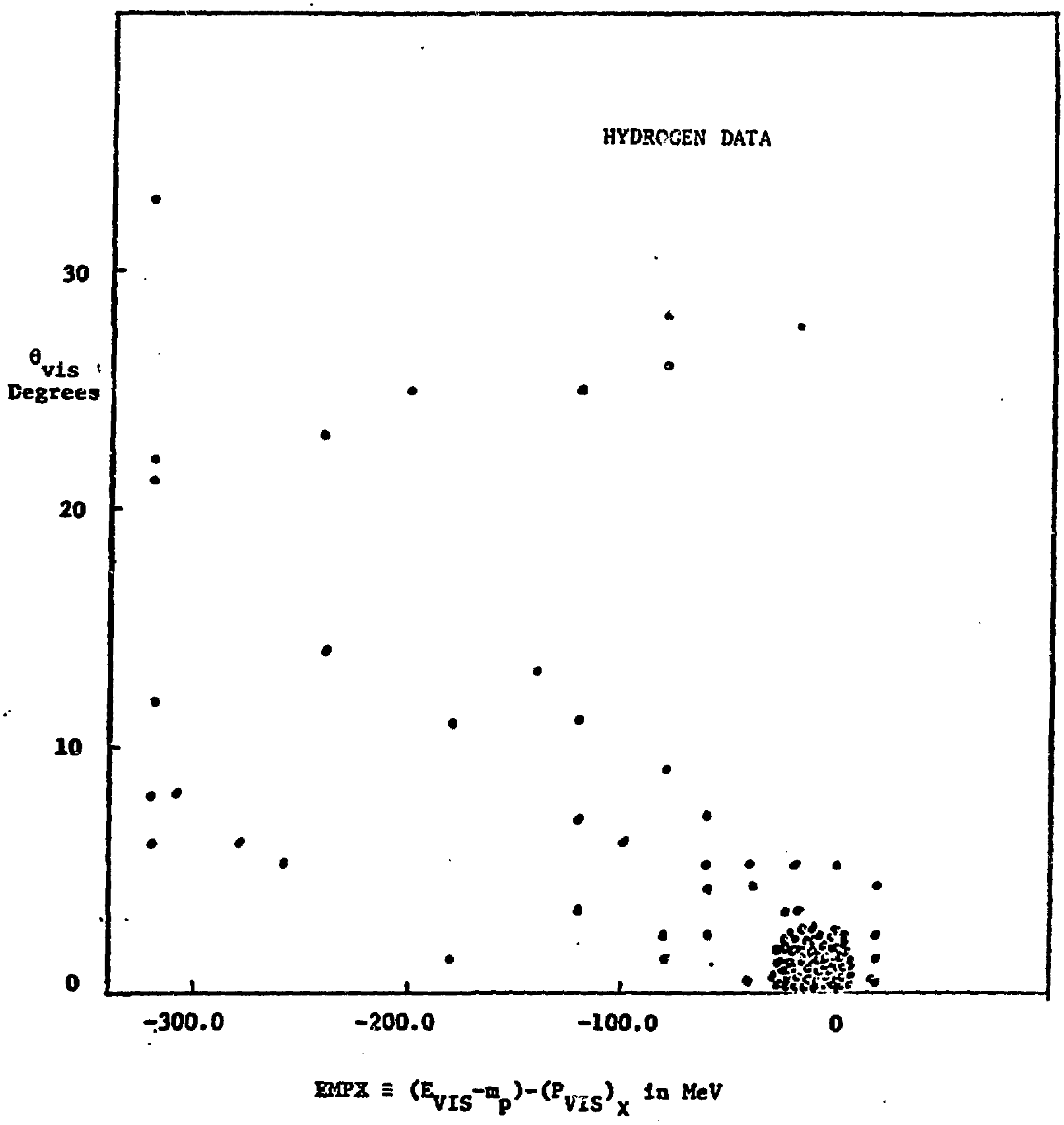
1. Study of Neutral Current Interactions in the 7-ft. Bubble Chamber, E. G. Cazzoli, et al., reported at this conference.
2. J. Cambell, et al., Phys. Rev. Letters, Vol. 30, p. 335 (1973); W. A. Mann, et al., Phys. Rev. Letters, Vol. 31, p. 844 (1973).
3. A. de Rujula, et al., Rev. of Modern Phys., Vol. 46, p. 391 (1974).

TABLE I

CHARGED CURRENT EVENT SAMPLE

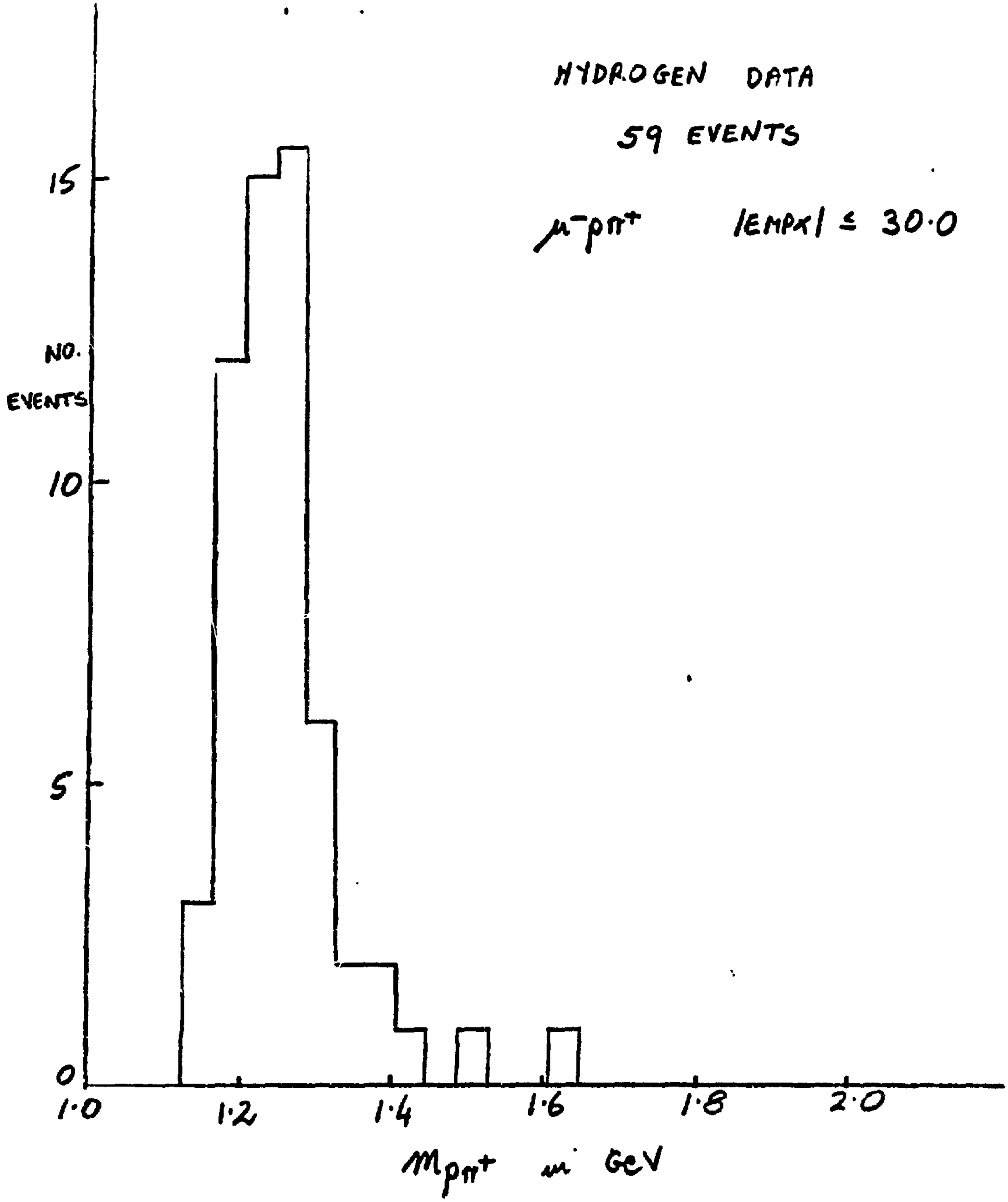
# Prongs	H_2	D_2 (raw)	D_2 (corrected*)
2		65	95
3	87	118	98
4		13	16
5	5	12	9
6		2	2
7	0	1	1
8		0	0
9	1	0	0

*Spectator proton tracks not included in # prongs.



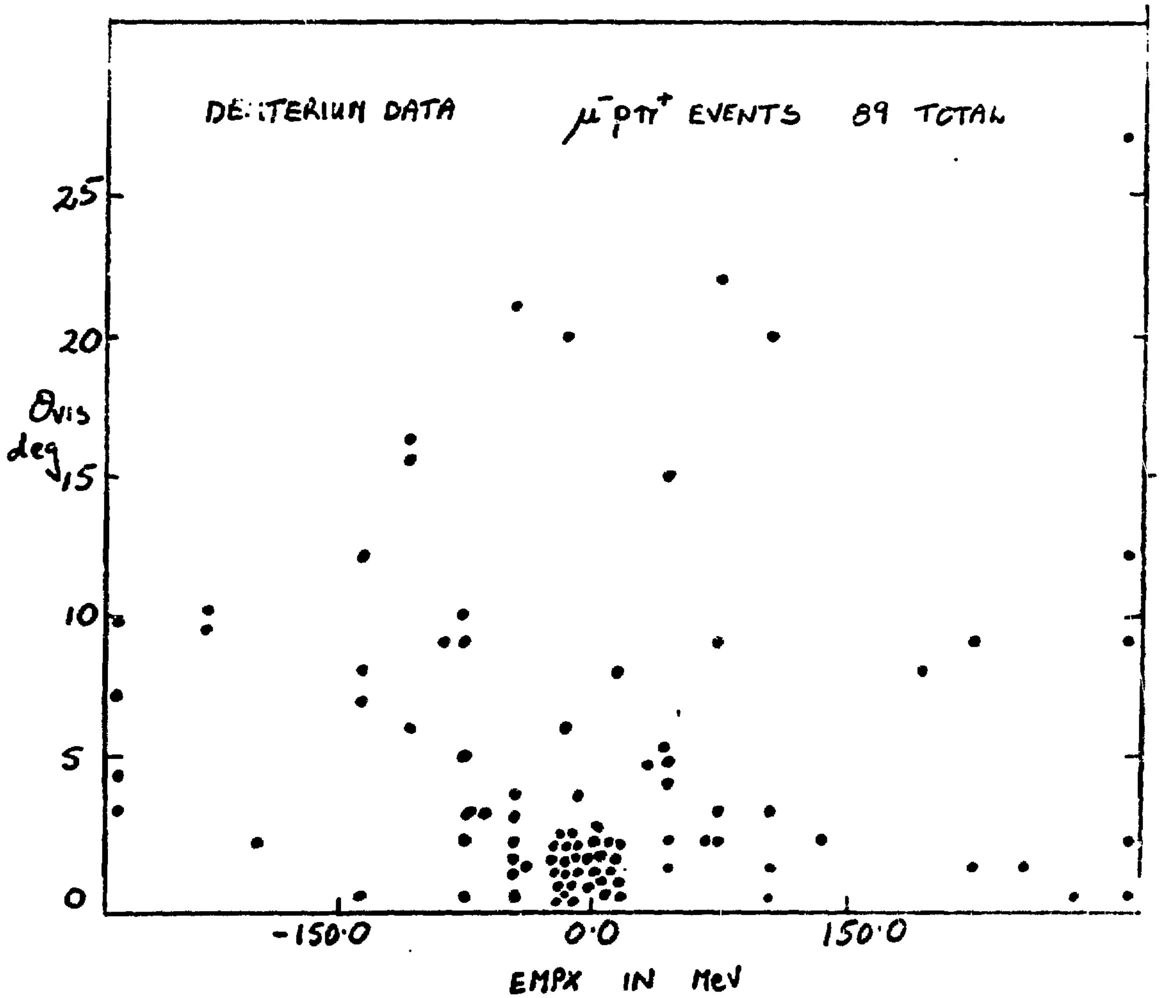
Plot of EMPX versus the Angle of the Visible Momentum Vector with Respect to the Beam Direction.

Fig. 1



HYDROGEN DATA
59 EVENTS
μ⁻pπ⁺ |EMPX| ≤ 30.0
NO. EVENTS
15
10
5
0
1·0
1·2
1·4
1·6
1·8
2·0
Mpπ+ in GeV

Fig. 2



DE::TERIUM DATA
μ⁻pπ⁺ EVENTS 89 TOTAL
25
20
15
10
5
0
θvis deg
-150.0
0.0
150.0
EMPX IN MeV

Fig. 3

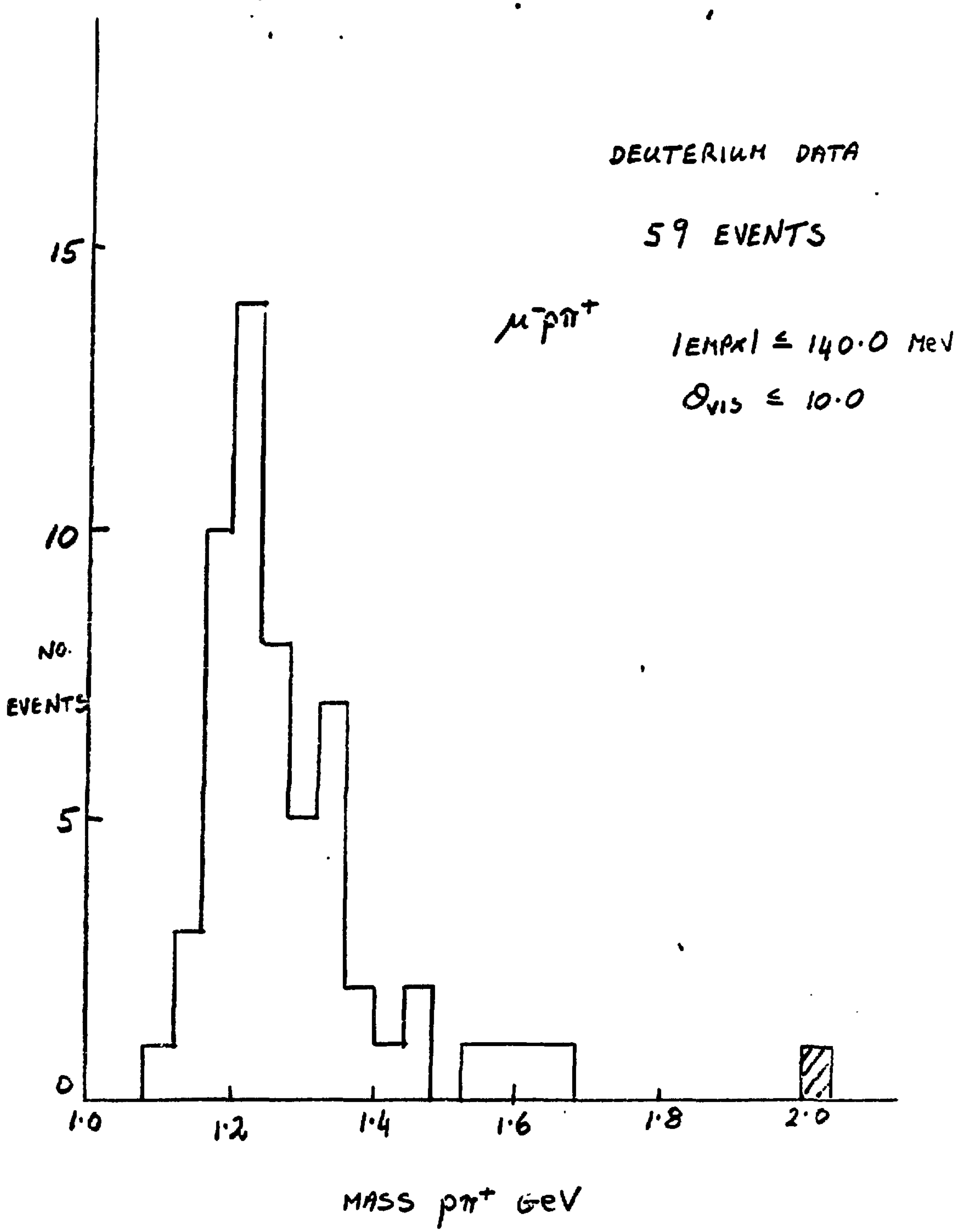
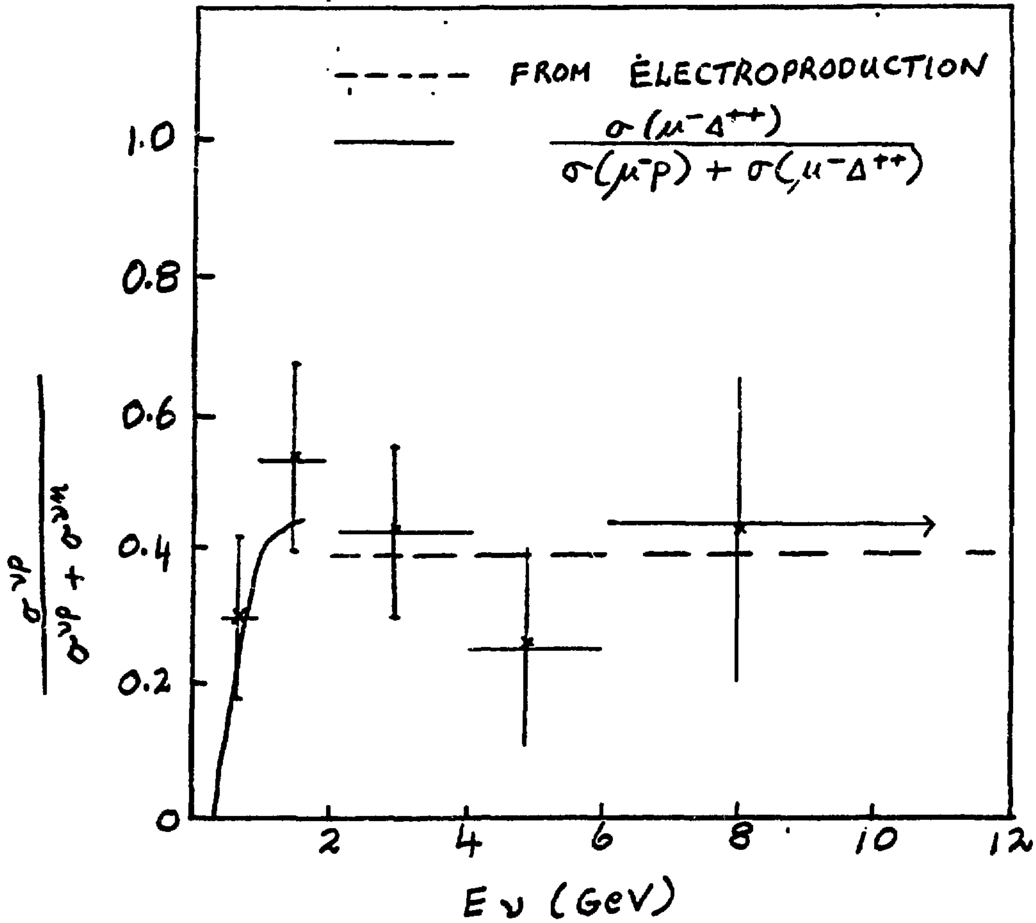

DEUTERIUM DATA
59 EVENTS
μ⁻pπ⁺
|EMPX| ≤ 140.0 MeV
θvis ≤ 10.0
15
10
NO. EVENTS
5
0
1.0
1.2
1.4
1.6
1.8
2.0
MASS pπ⁺ GeV

Fig. 4



QUARK PARTON MODEL + ELECTROPRODUCTION DATA	0.39
THIS EXPERIMENT $E_\nu > 2$ GeV	0.40 ± 0.10

Fig. 5