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Evidence for a New Pseudoscalar Resonance at 1.26 GeV.*

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ABSTRACT

We present further results from an isobar-model phase shift analysis of the $\eta\pi^+\pi^-$ system produced in $\pi^- p \rightarrow \eta\pi^+\pi^- n$ at 8.45 GeV/c. ~~We find,~~ in addition to the narrow ($\Gamma \sim 25$ MeV) D meson with $IJ^P = 01^+$ at 1.275 GeV, a broad ($\Gamma \sim 100$ MeV) 00- object centered near 1.26 GeV and decaying mainly into $\delta\pi$. There is an indication of a second broad pseudoscalar near 1.40 GeV decaying into $\epsilon\eta$.

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DISCLAIMER

In an earlier paper[1] submitted to this Conference we presented first results from an isobar-model phase shift analysis of the $\eta\pi^+\pi^-$ final state produced in $\pi^-p \rightarrow \eta\pi^+\pi^-n$, $\eta \rightarrow \gamma\gamma$, at 8.45 GeV/c. The main result of that paper was the very strong evidence for assigning $IJ^P = 01^+$ quantum numbers to the D meson. Rapid phase motion through nearly 180^o was shown by the 01^+ wave relative to a 11^+ background.

In that analysis the non-η background (i.e., the background of events for which $\gamma\gamma$ did not come from an η) was treated approximately by including the $IJ^P = 00^-$ $\varepsilon\eta$ wave, which resembles phase space, incoherently with the other waves to absorb this background. Although the number of events assigned by the fit to this background was not totally unreasonable, it appeared to be somewhat larger than the estimated background under the η and contained suggestions of structure.

Since that paper was written, we have made substantial improvements in the analysis:

1) Optimum cuts were found which reduced the non-η background by 40% at the expense of 10-15% in signal loss.

2) Careful fits to the $\gamma\gamma$ mass spectrum were done for several bins of $\gamma\gamma\pi\pi$ mass to determine the actual amount of background under the η peak. It was found that the spectrum of "pure background" events having $0.40 \leq M(\gamma\gamma) \leq 0.48$, when multiplied by a suitable normalizing factor (0.29), describe the non-η background as a function of $M(\eta\pi\pi)$ very well. Figure 1a shows the resulting $\eta\pi\pi$ spectrum and the correctly-normalized non-η background. The fraction of background as a function of $M(\eta\pi\pi)$ is shown in Figure 1b.

It can be seen that although the events below 1.1 GeV are mostly background, the background fraction above 1.2 GeV is typically $\sim$ 17%.

3) An amplitude analysis was done on the "pure background" events to determine their partial-wave content. It was found that the background is indeed well-described by the $00^-\varepsilon\eta$ wave, with only a 10-15% mixture of other waves necessary. Thus in each bin of $M(\eta\pi\pi)$ both the amount and the partial wave content of the background are known.

4) The amplitude analysis program was modified to allow three incoherent sets of waves rather than two. One of these is assigned to background; the others correspond to the two states of relative initial and final nucleon helicity.

The partial wave analysis was then redone, holding the background fixed in amount and wave content in each bin of $M(\eta\pi\pi)$. A solution with improved likelihood was found which contained substantial pseudoscalar contribution. This new solution is shown in Figures 2 and 3. In this mass region we have used the δ isobar[2] in $\eta\pi$, and the ε and ρ isobars in $\pi^+\pi^-$. The notation for the partial waves is IJ^P = isospin, spin, parity; M^η = magnetic substate and naturality of the exchange in the t-channel.

The axial vector and vector partial waves for the new solution are shown in Figure 2. The results for the $IJ^P = 11^+$ and 11^- waves are very similar to those in Reference 1: there is no obvious B peak in $11^+\delta\pi$, and the $11^-\eta\rho$ contribution rises toward a peak near 1.6 GeV which may be associated with the ρ' (1600). The $IJ^P = 01^+\delta\pi$ wave has a narrow peak at 1.275 GeV, and its phase relative to the $11^+\delta\pi$ wave (both with $M^\eta = 0^+$) has a rapid phase variation through almost 180°. Thus, the new solution also definitely assigns $IJ^P = 01^+$ to a narrow D meson. However, this D peak in

01^+ is even narrower than in the old solution[1], and contains only half as many events. The $M^\eta = 1^-$ substate of the D, which was formerly a 20% contribution, is no longer statistically significant.

The major new result from the improved analysis is presented in Figure 3, which displays the $IJ^P = 00^-$ partial waves. Both $\delta\pi$ and $\epsilon\eta$ decay modes were found to be needed in the mass interval 1.1 - 1.5 GeV. The contribution of the $00^-\delta\pi$ wave is almost entirely contained in a peak of width ∿ 100 MeV centered at about 1.26 GeV. This peak is thus considerably broader than the 01^+ peak of the D meson, which is ∿ 25 MeV wide, and occurs at a slightly lower mass. The $00^-\delta\pi$ wave is consistent with zero above 1.35 GeV.

The $00^-\epsilon\eta$ wave is present throughout the mass interval 1.1 - 1.5 GeV. With the present statistics it is not clear from the $00^-\epsilon\eta$ intensity whether this wave also peaks near 1.26 GeV; the peak, if present in this mode, must be superimposed on some nonresonant background. The phase of the $00^-\delta\pi$ wave relative to $00^-\epsilon\eta$ shows a modest forward motion of about 60^o across the peak, and the two waves are very nearly 180^o apart at the center of the peak. This phase behavior is at least qualitatively consistent with the idea of a resonance which couples strongly to $\delta\pi$ and less strongly to $\epsilon\eta$ with a coupling of opposite sign. The modest phase motion would then come from the presence of a falling nonresonant background in the $\epsilon\eta$ channel.

The total 00^- contribution is shown in Figure 3c. Because of the destructive interference between the $\delta\pi$ and $\epsilon\eta$ modes the 1.26 GeV peak is less prominent in this total signal than in the $\delta\pi$ projection. There is a strong suggestion of a second broad peak, occurring almost entirely in $\varepsilon\eta$, near a mass of 1.4 GeV which accounts for the bulge in the raw mass spectrum in that region. The assignment of 00^- quantum numbers to this bulge at 1.4 GeV is still somewhat tentative because of the potentially larger choice of partial waves in this region, but the 00^- fit is quite good.

The fits strongly prefer to have the 00^- waves in the opposite state of relative nucleon helicity from the 01^+ and 11^+ waves. This is consistent with the idea[3] that pseudoscalar and axial vector meson production are dominated by different states of relative nucleon helicity, as evidenced by the very different behavior of η' and B^o production[3,4] near $t' = 0$.

A schematic representation of the new solution is given in Figure 4, which shows how the various partial wave intensities combine to give the observed mass spectrum. This Figure was obtained by drawing smooth free-hand curves through the data points in Figures 2 and 3, and then adding the curves graphically. It demonstrates clearly how the broad 00^- and narrow 01^+ peaks produce the peak in the spectrum at 1.275 GeV.

REFERENCES

1. K.W. Edwards et al., "Results from a Partial Wave Analysis of the $\eta\pi^+\pi^-$ System Produced in $\pi^- p \rightarrow \eta\pi^+\pi^- n$ at 8.45 GeV/c", submitted for this Conference.

2. The parameterization used was the two-channel "cusp" version described in Ref. 1, and used for the results presented in Ref. 1.

3. K.W. Edwards et al., "Charge Exchange Production of Axial Vector Mesons", submitted for this Conference.

4. The D^o differential cross section in Ref. 3 was extracted by a subtraction procedure which assumed a slowly-varying background under the D peak. The presence of the pseudoscalar peak at nearly the same mass means that some 00^- contamination, $\sim$ 20 - 30%, is present in these cross sections.

FIGURE CAPTIONS

Figure 1. (a) Effective mass of $\eta\pi^+\pi^-$ for the events used in this phase shift analysis. The shaded curve is the normalized non-η background.

(b) Fraction of events which are non-η background versus $\eta\pi\pi$ mass.

Figure 2. Results from the phase shift analysis for axial vector and vector partial waves.

Figure 3. Results from the phase shift analysis for pseudoscalar partial waves.

Figure 4. Schematic representation of the contributions of the various partial wave intensities to the observed mass spectrum.

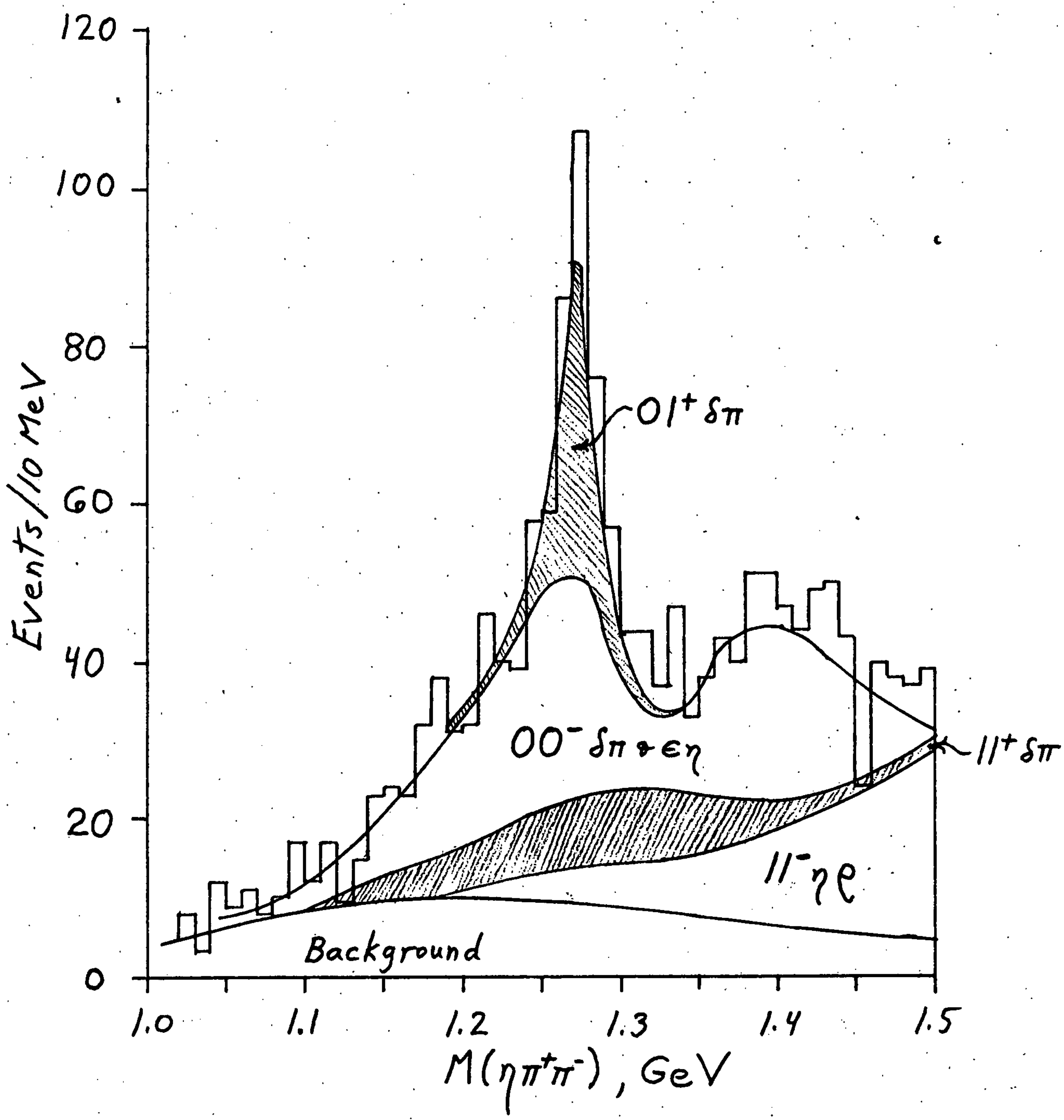
120
100
80
60
40
20
0
Events/10 MeV
01⁺ δπ
00⁻ δπ + εη
11⁺ δπ
11⁻ ηρ
Background
1.0
1.1
1.2
1.3
1.4
1.5
M(ηπ⁺π⁻), GeV

Figure 4

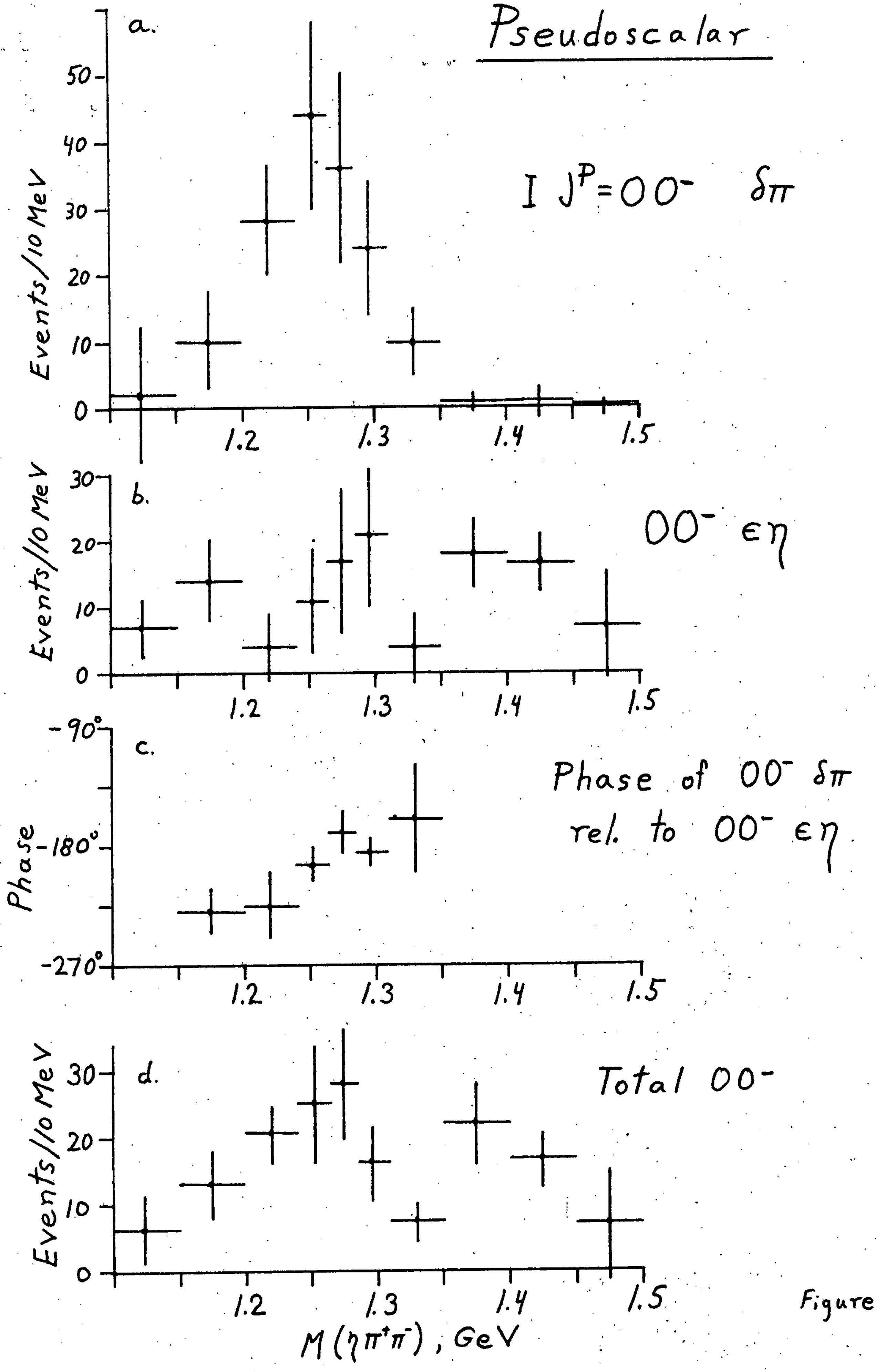
Pseudoscalar
a.
I J^P = 0 0^- δπ
Events/10 MeV
0
10
20
30
40
50
1.2
1.3
1.4
1.5
b.
0 0^- εη
Events/10 MeV
0
10
20
30
1.2
1.3
1.4
1.5
c.
Phase of 0 0^- δπ
rel. to 0 0^- εη
Phase
-90°
-180°
-270°
1.2
1.3
1.4
1.5
d.
Total 0 0^-
Events/10 MeV
0
10
20
30
1.2
1.3
1.4
1.5
M(ηπ⁺π⁻), GeV

Figure 3

Axial Vector and Vector

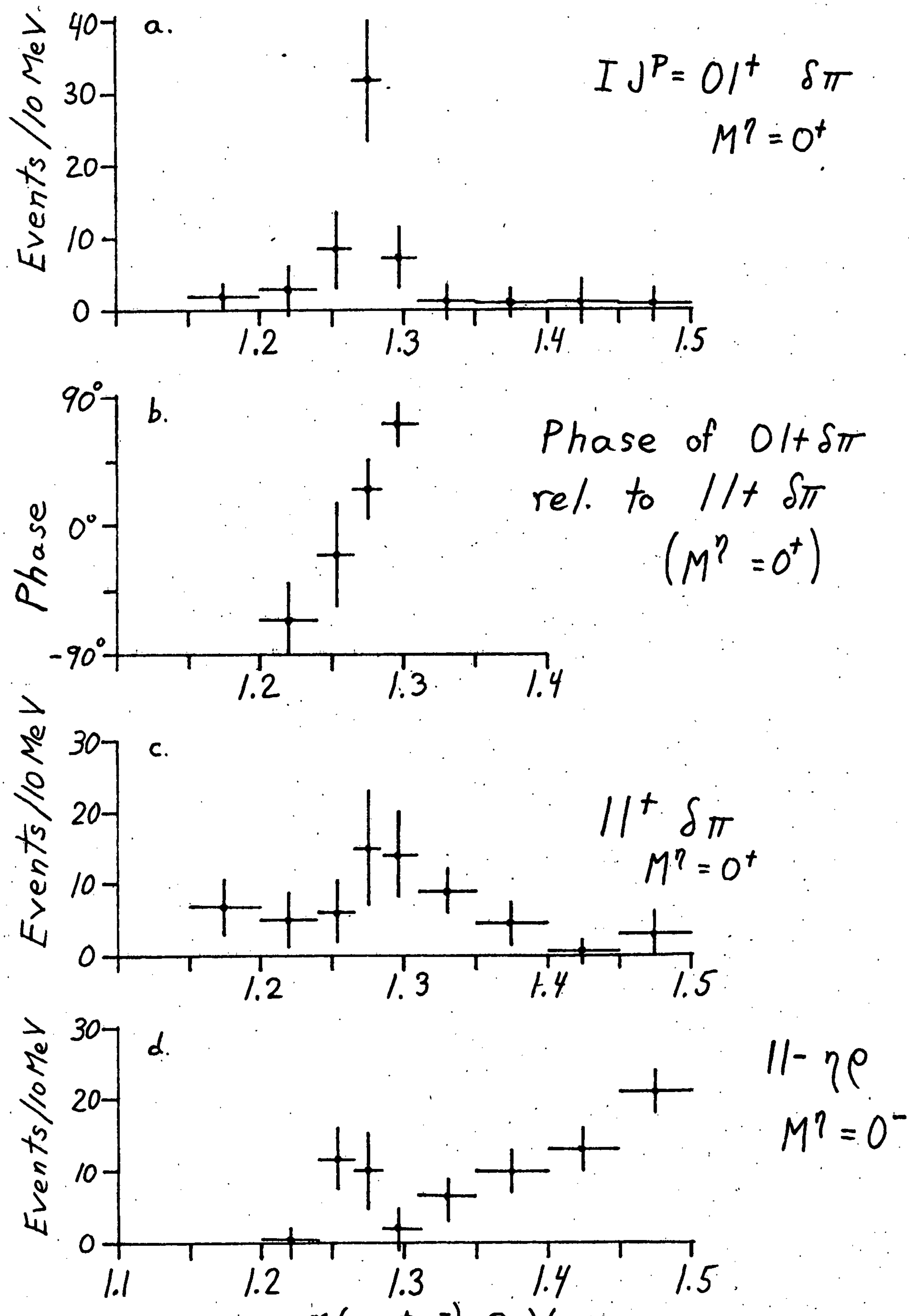

Figure 2

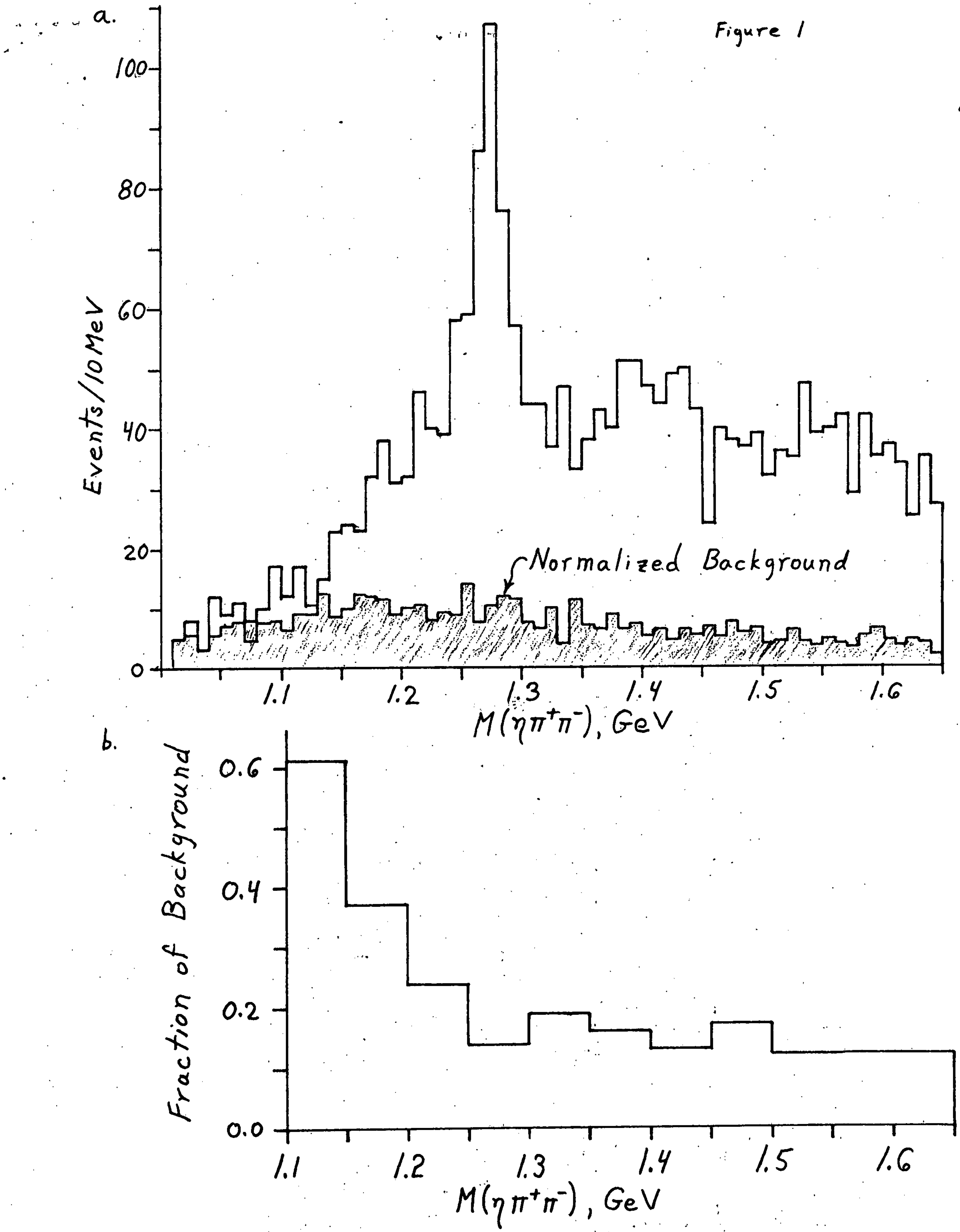
Figure 1
a.
Events/10 MeV
0
20
40
60
80
100
Normalized Background
1.1
1.2
1.3
1.4
1.5
1.6
M(ηπ⁺π⁻), GeV
b.
Fraction of Background
0.0
0.2
0.4
0.6
1.1
1.2
1.3
1.4
1.5
1.6
M(ηπ⁺π⁻), GeV