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EVIDENCE FOR THE EXISTENCE OF A NARROW $\eta^{o}\pi^{\pm}$ RESONANCE AT 975 MeV, INTERPRETED AS A DECAY OF THE $\delta^{\pm}$ MESON, AND EVIDENCE FOR A $\delta^{\pm}\pi^{\mp}$ DECAY OF THE D^{o} MESON.

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Abstract

Two peaks are observed in $\eta^{o}\pi^{\pm}$ and $\eta^{o}\pi^{+}\pi^{-}$ effective mass distributions near 975 MeV and 1310 MeV respectively, in events fitting the reaction $\bar{p}p \rightarrow 3\pi^{+}3\pi^{-}\pi^{o}$.

The narrow $\eta^{o}\pi^{\pm}$ peak is interpreted as a new evidence for the existence of the $\delta^{\pm}$ meson. The second peak is strongly correlated to the first one and is interpreted as evidence for the decay $D^{o} \rightarrow \delta^{\pm}\pi^{\mp}$.

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The results reported in the present paper are based on an analysis of 200.000 pictures taken in a 1.2 GeV/c $\bar{p}$ beam in the 81 cm H.B.C. at CERN.

3.500 reactions $\bar{p}p \rightarrow 3\pi^+3\pi^-\pi^o$ (1 constraint fit) were found among 8.700 6-prong annihilations of antiprotons (Ref. 1).

Fig. (1a) shows the effective mass distribution of the $\pi^+\pi^-\pi^o$ combinations. One can clearly see the abundant ω^o production. The η^o does not show up at first sight, but the shoulder visible around 550 MeV suggests its presence (see insert to Fig. 1a).

Selecting the $\pi^+\pi^-\pi^o$ combinations in the η^o region, 528-568 MeV, and calling them "η^o", we obtain the "η^o"$\pi^{\pm}$ and "η^o"$\pi^+\pi^-$ effective mass spectra shown in Fig. 2 (histograms "B"). The former exhibits a narrow enhancement at about 970 MeV, the width of which is compatible with the experimental resolution (~25 MeV), the latter exhibits a peak at 1310 MeV in addition to the X^o enhancement at 960 MeV. In both cases, the statistical significance, with respect to a freely drawn smooth curve, is of the order of 3 standard deviations. Moreover the lack of corresponding significant bumps respectively in the $\pi^+\pi^-\pi^o\pi^{\pm}$ and $\pi^+\pi^-\pi^o\pi^+\pi^-$ effective mass distributions suggests that these effects are essentially related to the initial "η^o selection" (Fig. 1b and 1c).

To reinforce this interpretation we have selected the $\pi^+\pi^-\pi^o$ combinations in two effective mass ranges, below and above the "η^o region": 480-520 MeV, 570-610 MeV, and formed the corresponding $(\pi^+\pi^-\pi^o)\pi^{\pm}$ and $(\pi^+\pi^-\pi^o)\pi^+\pi^-$ effective mass distributions (Fig. 2, histograms A and B). The enhancements at 970 MeV and 1310 MeV are strongly attenuated.

It is suggestive to associate these two enhancements with the $K\bar{K}$ and $K\bar{K}\pi$ effects observed in the annihilation $\bar{p}p \rightarrow K\bar{K}3\pi$ at 1.2 GeV/c. One of the striking results of the analysis of this reaction was the observation of the D^o meson: $\bar{p}p \rightarrow D^o\pi^+\pi^-$, $D^o \rightarrow K_1^oK^\pm\pi^\mp$, where the decay was characterized by an enhancement of the $(K_1^oK^\pm)$ mass spectrum at threshold (Ref. 2).

We recall that the I = 1 $K\bar{K}$ effect was tentatively interpreted (ref. 2) as due to the existence of a narrow resonance with mass = $(975\ {}^{+15}_{-10})$ MeV corresponding most probably to the δ^- meson (ref. 3) and which, because of its quantum numbers, I, $J^{PG} = 1,0^{+-}$, might decay through the $\eta^o\pi$ channel.

Prompted by this we have selected the "η^o"$\pi^\pm$ combinations in the $\delta^\pm$ mass range (975 ± 20 MeV), and obtained the mass distribution ("$\delta^\pm$"$\pi^\mp$) shown in Fig. 3B. This distribution exhibits indeed a significant enhancement at the apparent mass value 1310 MeV, exactly as the histogram drawn in Fig. 2B ("η^o"$\pi^+\pi^-$ combinations). This bump appears to be a 3 standard deviation effect above a smooth curve.

Using the same procedure as above, we have formed the "$\delta\pi$" effective mass distribution by selecting the "η^o"$\pi^\pm$ combinations below and above the "δ" region: 915-955 MeV, 995-1035 MeV (Fig. 3). The comparison of the $\delta^\pm$ enhancement in Figure 2 and 3 and of the D^o enhancement in Figure 2 (70, 50 and 110 combinations above background, respectively), suggests that a large part of the D^o decay goes through the $\delta^\pm\pi$ channel and that the $\delta^\pm$ comes mainly from the D^o decay. It leads to an estimation of the D^o production of the order of 3 % of all $\bar{p}p \rightarrow 3\pi^+3\pi^-\pi^o$ annihilations.

Going back to the $(\pi^+\pi^-\pi^o)$ histogram, (Figure 1) a more careful examination shows that it is quite possible to make evident the presence of about 200 η^o's above a curve fitting the histogram above and below the mass range of the η^o. This number is compatible with the estimated number of D^o's (110) and X^o's (70).

Furthermore in order to make sure that these enhancements are not kinematical reflections of the ρ^o, ω^o, η^o, X^o mesons which are produced in the final state (ref. 1) and with the intention to improve the analysis, we have generated Monte Carlo events taking into account the above mentioned resonances. In addition we found necessary to introduce a broad $\rho^{\pm}\pi^{\mp}$ resonance at M ~1100 MeV, to obtain a good representation of the $\rho\pi$ effective mass distribution.

Fitting simultaneously to the $M(\pi^+\pi^-\pi^o)$, $M(``\eta^o"\pi^{\pm})$, $M(``\eta^o"\pi^+\pi^-)$, $M(``\rho^o"\pi^o)$, $M(``\rho^o"\pi^{\pm})$ and $M(``\rho^{\pm}"\pi^{\mp})$ distributions the theoretical curves representing $\omega^o 4\pi$, $\rho^o 5\pi$, $\omega^o\rho^o 2\pi$, $\eta^o 4\pi$, $X^o 2\pi$ and "$\rho\pi$"4π production without interference except for Bose symmetrization, and without kinematical effect due to angular momentum conservation, we obtained the curves α drawn on Fig. 2. Using these curves to estimate the background below the $\delta^{\pm}$ and D^o enhancements, we find 4.0 and 5.0 standard deviations for these effects, respectively.

Adding in our fits the possibility of $\delta^{\pm}3\pi$ and $D^o 2\pi$ production with the D^o decaying into $\delta^{\pm}\pi^{\mp}$ and into $\eta^o\pi^+\pi^-$, we obtained the curves β drawn on Figure 2.

The improvement obtained on the χ^2 computed for the $\eta\pi$ and $\eta\pi\pi$ distributions is significant: $\chi^2_\alpha = 53$, $\chi^2_\beta = 40$, (expected $\chi^2 = 49$) for the $\eta\pi$ distribution. $\chi^2_\alpha = 84$, $\chi^2_\beta = 45$, (expected $\chi^2 = 25$) for the $\eta\pi\pi$ distribution.

This fit is not very sensitive to the relative weight of the two D^o decay modes: $D^o \to \eta\pi\pi$, $D^o \to \delta\pi$. It gives a global D^o production equal to (2.4 ± 0.4) % of all $\bar{p}p \to 3\pi^+3\pi^-\pi^o$ annihilations.

Although the analysis of the total reaction we present here is mainly given to justify the background estimations for the $\delta^{\pm}$ and D^o production, we give, for completeness, the results obtained for the other channels:

$$\omega^{o}\rho^{o}2\pi : 72\ \%,\ \rho^{o}5\pi : 17\ \%,\ ``\rho\pi"4\pi : 7\ \%,\ X^{o}4\pi : 1.7\ \%$$

This solution is obtained with $M(\delta^{\pm}) = 975$ MeV, $\Gamma(\delta^{\pm}) = 25$ MeV and $M(D^{o}) = 1310$ MeV, $\Gamma(D^{o}) = 40$ MeV. These widths include the experimental mass resolution.

We believe that all these results give a good evidence for the existence of a narrow $(\eta\pi)$ resonance at 975 MeV, which can be identified with the so-called δ. This reinforces the interpretation of the threshold $I = 1$ $(K\bar{K})$ effect as due to a 975 MeV virtual bound state.

Finally, the comparison of the D^{o} production in the $\bar{p}p \rightarrow KK3\pi$ annihilations and in the $\bar{p}p \rightarrow 7\pi$ annihilations in the same sample of 1.2 GeV/c antiprotons, gives the following branching ratio for the decay mode of the D^{o}:

$$\frac{D^{o} \rightarrow K\bar{K}\pi(\text{all channels})}{D^{o} \rightarrow \eta\pi\pi(\text{all channels})} = 0.124 \pm 0.035$$

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<u>Figure Captions</u>

Fig. 1 (a): $(\pi^+\pi^-\pi^o)$ effective mass spectrum. The ω^o production is important. Although the η^o production is not visible on the main histogram, the details of the 550 MeV region, as shown by the insert, indicate its presence.
The curve corresponds to the fit described in the text.

(b): $(\pi^\pm\pi^+\pi^-\pi^o)$ effective mass spectrum.

(c): $(\pi^+\pi^-\pi^o\pi^+\pi^-)$ effective mass spectrum. No structure is observed in (b) and (c).

Fig. 2: "η"$\pi^\pm$ and "η"$\pi^+\pi^-$ effective mass spectra, where "η" denotes a $(3\pi)^o$ system with the following effective mass ranges:

A : 480 < "η" < 520 MeV
B : 528 < "η" < 568 MeV
C : 570 < "η" < 610 MeV.

An enhancement is observed in the "η"$\pi^\pm$ system, at 975 MeV, for histogram B; it is associated to the $\delta^\pm$ meson.
Two enhancements are visible in the "η"$\pi^+\pi^-$ system, at 960 and 1310 MeV, for histogram B. They are associated to the X^o and D^o mesons.
These enhancements disappear for a $(3\pi^o)$ system with a mass below or above the η^o meson (histograms A and B).
Curves α correspond to the fit described in the text: This fit does not assume $\delta^\pm$ and D^o production. Curves β correspond to the fit obtained when $\delta^\pm$ and D^o production are introduced.

Fig. 3: "$\delta^{\pm}$"$\pi^{\mp}$ effective mass spectra, where "$\delta^{\pm}$" denotes an "η"π system with the following effective mass ranges:

"η"	:	$528 < (3\pi)^{o} < 568$ MeV
A	:	$915 <$ "δ" < 955 MeV
B	:	$955 <$ "δ" < 995 MeV
C	:	$995 <$ "δ" < 1035 MeV.

An enhancement is clearly seen at M ~1310 MeV, for histogram B: it is attributed to the D^{o} meson, with the decay mode $D^{o} \rightarrow \delta^{\pm}\pi^{\mp}$, $\delta^{\pm} \rightarrow \eta^{o}\pi^{\pm}$.

This enhancement is not present in histograms A and C.

Figure 1

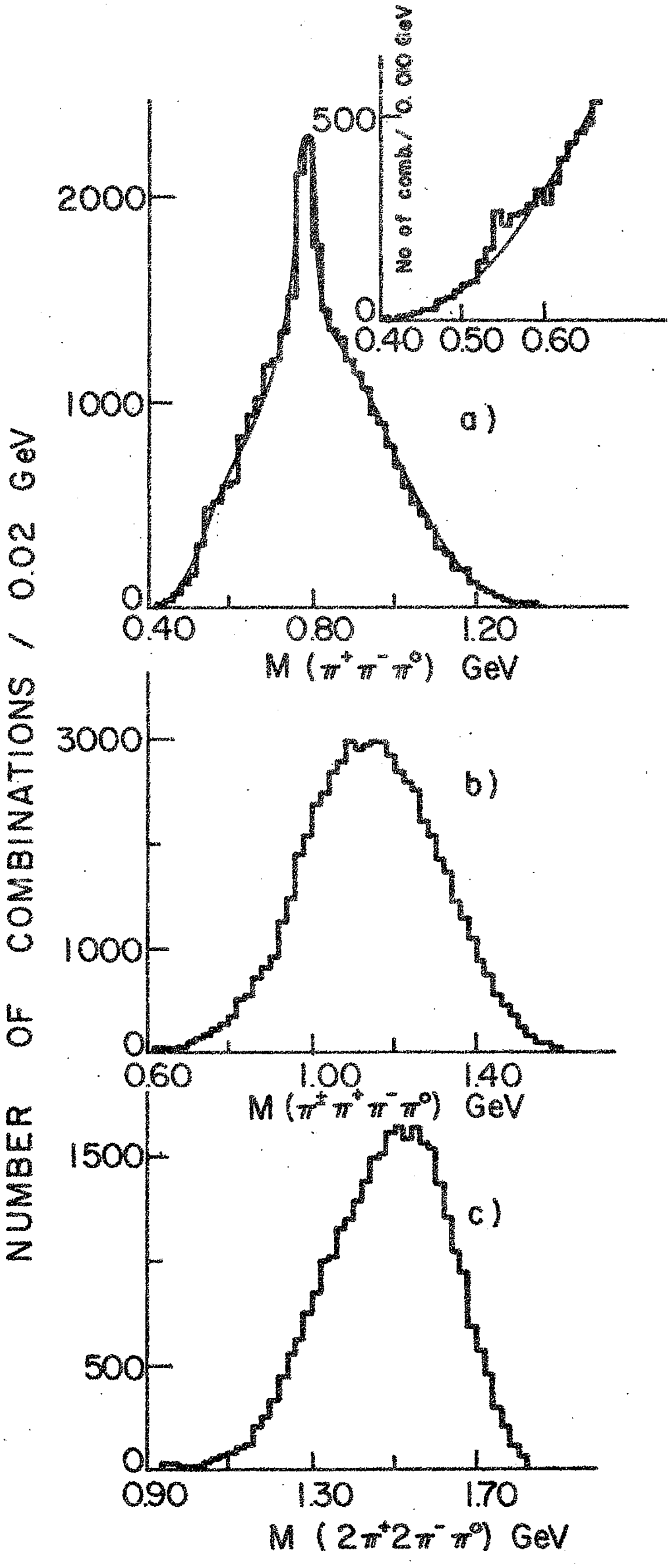

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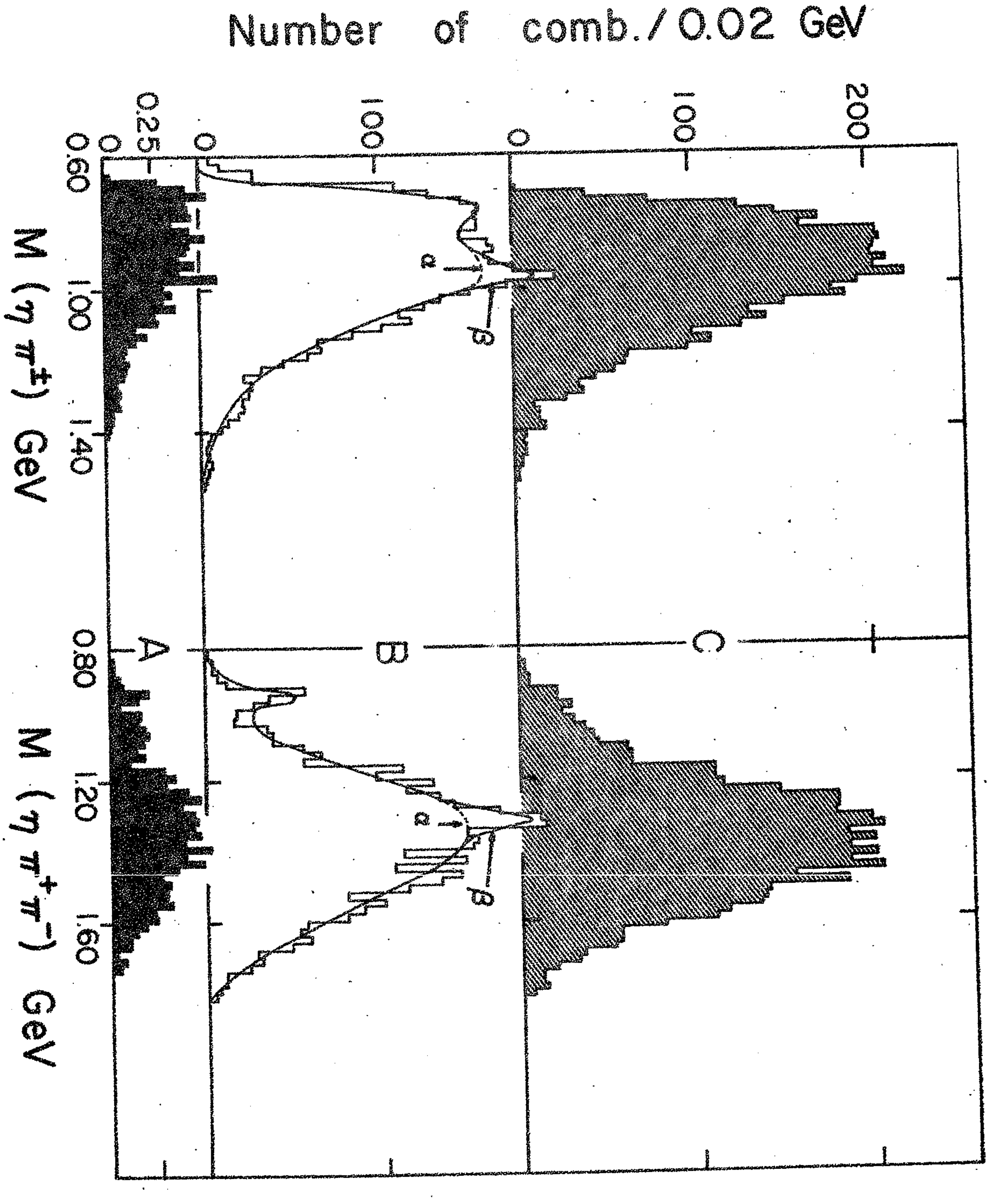
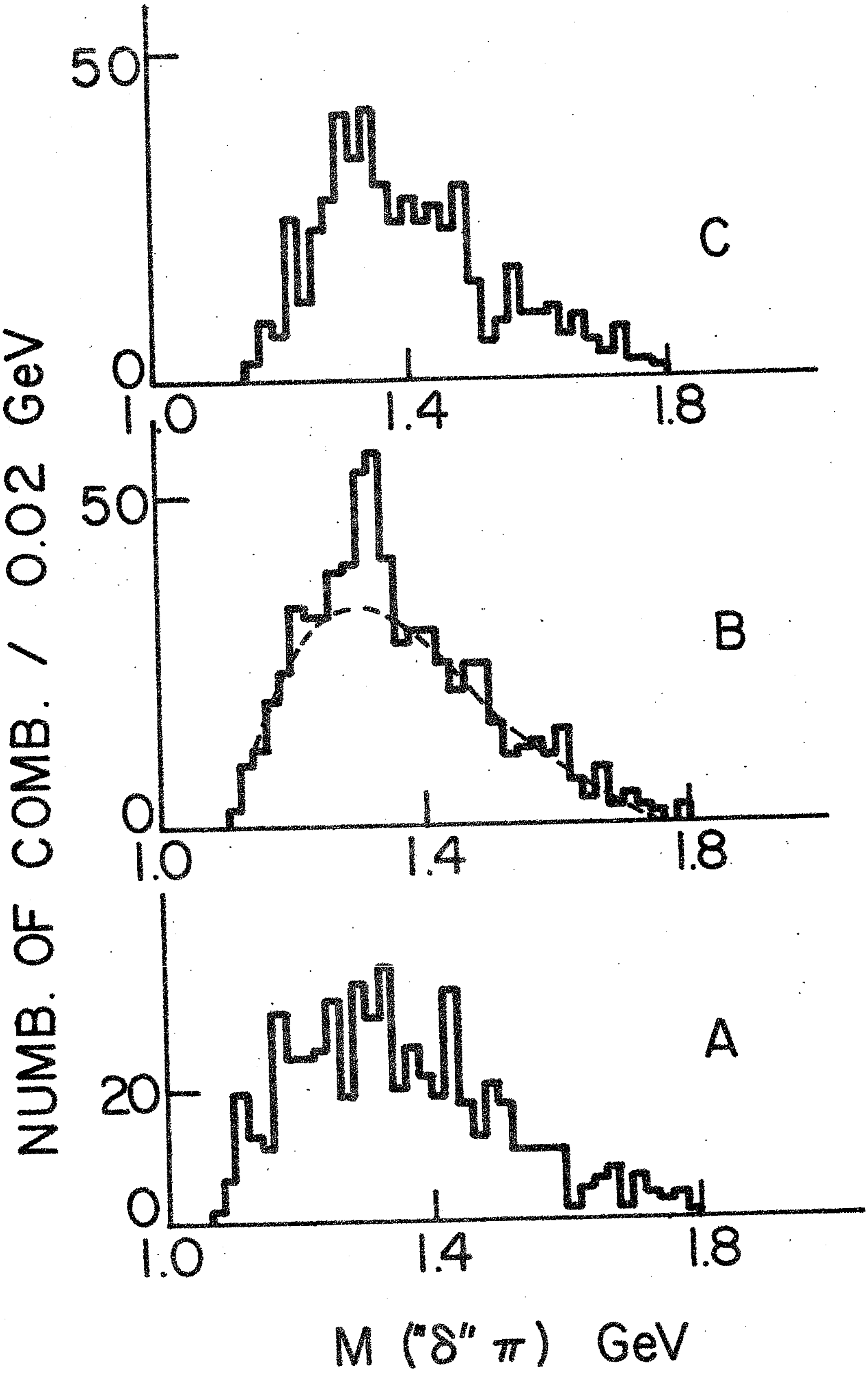
Figure 2



Number of comb./0.02 GeV
0
100
200
0
100
0
0.25
0.60
1.00
1.40
0.80
1.20
1.60
A
B
C
α
β
M (η π±) GeV
M (η π+π−) GeV

Figure 3



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