Comment on Evidence for the H Meson*

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It is shown that the contamination due to η' decaying into $\rho^0\gamma$ cannot explain the H enhancement in the 3π system reported earlier in the reaction $\pi^+d \to pp\pi^+\pi^-\pi^0$ for an incident pion momentum of 3.65 GeV/c. A more likely explanation is provided by the suggestion that the enhancement is primarily due to the distortion of the phase space by a ρ-band cut.

THE strongest evidence for the isoscalar H meson decaying into $\rho\pi$ is found in the experiment of Benson *et al.*,[1] who analyzed the final state $\pi^+d \to pp\pi^+\pi^-\pi^0$ at 3.65 GeV/c in the 20-in. BNL bubble chamber. They reported a resonance in the $(\rho\pi)^0$ system of mass 998 ± 10 MeV/c^2, width 45 ± 30 MeV/c^2, and production cross section 75 ± 15 μb. Subsequently Fung *et al.*[2] suggested that this enhancement was due to the distortion of phase space introduced by the requirement that at least one dipion combination of the three-pion final state give an effective mass in the region of the ρ meson. Barbaro-Galtieri and Söding[3] suggested that events contributing to the H enhancement were largely due to the reaction $\pi^+d \to pp\eta'$, where the η' decays into $\rho^0\gamma$. At energies at which the H was reported, the kinematical fitting programs are unable to distinguish between a γ and a π^0 in a one-constraint fit. The substitution of a π^0 for a γ would then produce a peak in the $\rho^0\pi^0$ mass distribution, at a mass higher than the η' mass of 958 MeV/c^2. It should be noted, however, that Benson *et al.* took into account the effects of the ρ cut and the η' contamination in evaluating their data on the H enhancement.

To investigate further the possibility of η' contamination, we have remeasured the original events on which the results of Benson *et al.* were based. For the analysis we used the three-view geometry program TVGP and the kinematical fitting program SQUAW. Only events with 3π masses less than 1200 MeV/c^2 were remeasured. The remeasurements were fitted to the following reactions:

$$\pi^+d \to pp\pi^+\pi^-\pi^0 \quad (1)$$

$$\to pp\pi^+\pi^-\gamma \quad (2)$$

$$\to pp\pi^+\pi^-. \quad (3)$$

The kinematical fitting yielded the following results: 968 fits to reaction (1) of which 909 events also fitted reaction (2); seven events fitted only reaction (2); 45 events were assigned to reaction (3) (which is a four-constraint fit); 70 events did not fit any of the hypotheses tried, in spite of multiple remeasurement.

Figures 1(a) and 1(b) show the effective mass of the $\rho\pi$ system for the original and remeasured data with the same selection criteria as in Ref. 1 (see figure caption). In Fig. 1(c) we have combined the data of Fig. 1(b) with additional data obtained by us from a similar exposure in the 30-in. ANL deuterium bubble chamber at the same incident momentum.

It is seen that the distinct peaking in Fig. 1(a) broadens out in the remeasured data. From Figs. 1(b) and 1(c) alone it would be difficult to assert the presence

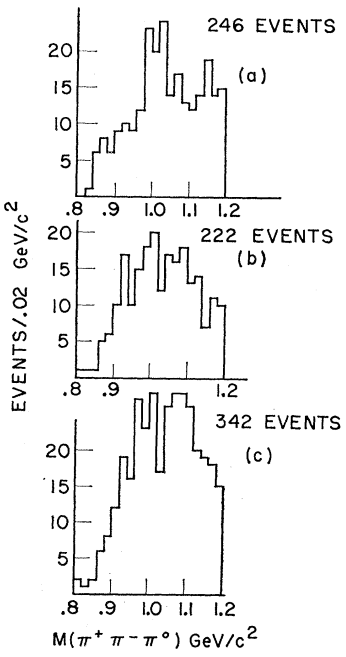

FIG. 1. (a) Original data of Benson *et al.* (Ref. 1) for invariant mass of $\pi^+\pi^-\pi^0$ system. All events have at least one dipion combination in the ρ band and the square of the four-momentum transfer from beam to three-pion system $|t(3\pi)|$ is less than 0.85 (GeV/c)^2; events with $\rho^+\Delta^0$ or $\rho^-\Delta^+$ were removed if $|t(\rho)|<0.2$ (GeV/c)^2, where ρ is defined by $650<M(\pi\pi)<850$ MeV/c^2 and Δ is defined by $1140<M(p\pi)<1340$ MeV/c^2. (b) Results of remeasurement with same selection criteria as (a). (c) Data of (b) combined with additional data from 30-in. ANL chamber.

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[2] S. Fung, W. Jackson, R. T. Pu, D. Brown, and G. Gidal, Phys. Rev. Letters **21**, 47 (1968).
[3] A. Barbaro-Galtieri and P. Söding, in *Meson Spectroscopy*, edited by C. Baltay and A. Rosenfeld (Benjamin, New York, 1968).

of a resonance of width 45 MeV/c^2 at a mass of 998 MeV/c^2 (experimental resolution 38 MeV/c^2). Nevertheless, after taking into account the effects of the selection criteria on the phase-space background, Benson *et al.* found the production cross section for the enhancement in the H region to be 75 ± 15 μb above background, which corresponds to 62 events. Further, from the observed number of $\eta' \to \pi^+\pi^- + (\geq 2\pi^0)$ decays, they estimated the contamination from $\eta' \to \pi^+\pi^-\gamma$ decays to be only 6 ± 3 events.

We made two independent estimates of the η' contamination by considering the events in the H region (920–1080 MeV/c^2) in Fig. 1(b) which also lie in the η' region [$920 < M(\rho^0\gamma) < 1000$ MeV/c^2] when fitted to reaction (2). From the missing mass-squared distribution [Fig. 2(a)], we found that 10.5 η' decays and 10.5 π^0 gave the best fit to the 21 events in the overlap region. From the $\rho^0\gamma$ mass distribution [Fig. 2(b)], we obtain a best fit with 14 η' events; for the fitting, we used a Gaussian distribution of width equal to the experimental resolution and assumed a flat background. This estimate also takes into account the fact that only 21 of the 27 events in the region of Fig. 2(b) lie in the H region of Fig. 1(b). Thus, the three methods of evaluating the η' contamination give an average of ten events (with a maximum of 21) as compared to the 62 events in the H enhancement of Benson *et al.*

Barbaro-Galtieri and Söding,[3] who first suggested that the H enhancement was due primarily to contamination from η', folded in various higher nucleon and boson resonances with phase-space background (which included the ρ cuts) and obtained a production cross section of 41 ± 18 μb for the H enhancement in the data of Benson *et al.* This estimate corresponds to 24 ± 15, events, which, we note, is also consistent with no enhancement at all. Even if we use the selection criteria of Ref. 3, the three methods for estimating the η' contamination gives 6, 12, and 18 events, or an average of 12.

Thus it appears that the essential question is not whether the η' is responsible for the H enhancement, but whether the cross section for the enhancement was over-

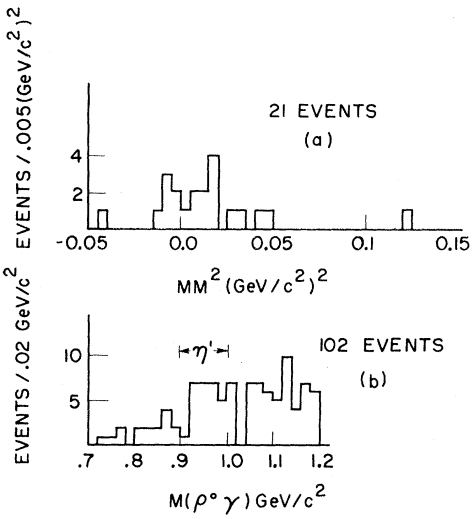

FIG. 2. (a) Missing mass squared for events of Fig. 1(b) in H region [$920 < M(\rho\pi) < 1080$ MeV/c^2] which also fitted reaction (2) with $920 < M(\rho^0\gamma) < 1000$ MeV/c^2. (b) Mass of $\rho^0\gamma$ system for events fitting reaction (2) with $t(\rho^0\gamma) < 85$ GeV/c^2 (20-in. BNL data only).

estimated by Benson *et al.* The lack of a narrow peak in Figs. 1(b) and 1(c) could be an indication that the effect of the ρ cut on the phase-space background was underestimated. In Fig. 1(a) there are 129 events with 3π masses in the H region. In the remeasured data shown in Fig. 1(b) there are still 125 events in the H region. Hence, the sharp peaking in Fig. 1(a) appears to be associated with a statistical fluctuation in the measurements. The broader enhancement we obtain lends credibility to the explanation based on the distortion of phase space by the ρ cut as suggested by Fung *et al.*[2]

Lastly, if we take the enlarged data of Fig. 1(c) and divide the events in the H region into the various $\rho\pi$ combinations using the method of Benson *et al.*, we obtain 41 $\rho^0\pi^0$, 90 $\rho^+\pi^-$, and 34 $\rho^-\pi^+$ events, from which it can no longer be concluded that we are dealing here with an isoscalar state.