ϱπ-RESONANCES

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In this letter we present a study of the distributions of two-pion effective masses from the decay of the A^+ meson [1], now resolved into two peaks [2, 4] A and R. These distributions show evidence against the spin and parity assignments 0^-, 1^-, 2^+ and 1^+ ($l = 2$) for the lower mass peak, A, and against 0^- and 1^+ ($l = 2$) for the upper mass peak, R. We also observe a possible enhancement in the $\pi^+\pi^-$ mass spectrum at 550 MeV.

After analyzing about 5500 four prong events produced by 3.5 GeV/c π^+ in the Brookhaven National Laboratory 20-inch hydrogen bubble chamber we identified

1918 events as $\pi^+ + p \to \pi^+ + p + \pi^+ + \pi^-$.

The details of the analyzing methods have been described elsewhere. The $M_{\pi^+\pi^+\pi^-}$ enhancements of these events have been shown to be associated both with ϱ^0 production and low momentum transfer, Δ^2, to the proton. The data of Fig. 1, c in which the selection required at least one ϱ and $\Delta^2 < 36\mu^2$ as well as no N^*, suggest two peaks in agreement with the previous work of references [2, 4]. The solid curve is the expected phase space distribution for $\pi p \to \varrho\pi p$ averaged over the ϱ mass, including the effect of the selection $\Delta^2 < 36\mu^2$. It has been normalized to the number of events above 1.53 GeV. We take the region 1040 GeV to 1210 MeV to represent the A peak and 1210 MeV to 1380 MeV to represent the R peak. Fig. 1, a is a Dalitz plot of those events in the A peak (dropping the ϱ requirement) Fig. 1, b is a similar Dalitz plot for the events in the R peak. The events have been plotted twice, once above the diagonal and once below it. This has the advantage of presenting the ϱ band as a straight line rather than having it make a 90° bend at the diagonal. Of course, the significance of the data must be judged on one-half of the plot only. The solid lines outline a band 0.2 GeV^2 wide and centered on the ϱ.

The observed distribution of Fig. 1, c is presumably a mixture coming from $\pi^+ + p \to A^+(R^+) + p$, $\pi^+ + p \to p + 3\pi$ phase space; and $\pi^+ + p \to p + \varrho^0 + \pi^+$ without A^+ or R^+ formation. The last process is neglected in the following, since we do not observe it outside the A$^+$ and R^+ regions. Boson symmetrization requirements modify the two-pion effective mass spectrum from the decay of the A^+ or R^+ meson depending on the spin and parity (J^P) of the A^+ or R^+. These calculations have been made assuming that the A or R decay 100 percent of the time to $\varrho^0 + \pi^+$ [3]. The effects are displayed by a curve representing the profile of the Dalitz plot along the center of the ϱ band. This profile has been calculated by taking the decay amplitude to be a sum of the two terms, $A^+(R^+) \to \varrho^0 + \pi_1^+$ and $A^+(R^+) \to \varrho^0 + \pi_2^+$. The resulting density distribution has been averaged over the $A^+(K^+)$ mass region, corrected for finite experimental resolution (estimated full-width-half-maximum = 25 MeV) and integrated over the 0.2 GeV^2 wide band in the Dalitz plot. Fig. 2, a shows the distribution of events along the bands of Fig. 1, a, b respectively. Care has been taken to avoid duplication of points in the cross over region. For the A^+ region, we see that $J^P = 1^-$ or 2^+ is a very poor fit, as is 0^- or 1^+ ($l = 2$), while 1^+ ($l = 0$) or 2^- is certainly satisfactory. The addition

	J^P	Percent 3π phase space	
		0	25
R^+	1^-, 2^+	.005	.01
	2^+	.008	.10
	1^+ ($l=0$), 2^-	.07	.10
	0^-, 1^+ ($l=2$)	$<$.001	$<$.001
A^+	1^-, 2^+	$<$.001	$<$.001
	1^+ ($l=0$), 2^-	.70	.70
	0^-, 1^+ ($l=2$)	$<$.001	.09

of 3π phase space to the theoretical curves will not appreciably improve the fits except for the 0^- case, but it is still not favored. Table shows the χ^2 probabilities obtained for 25%

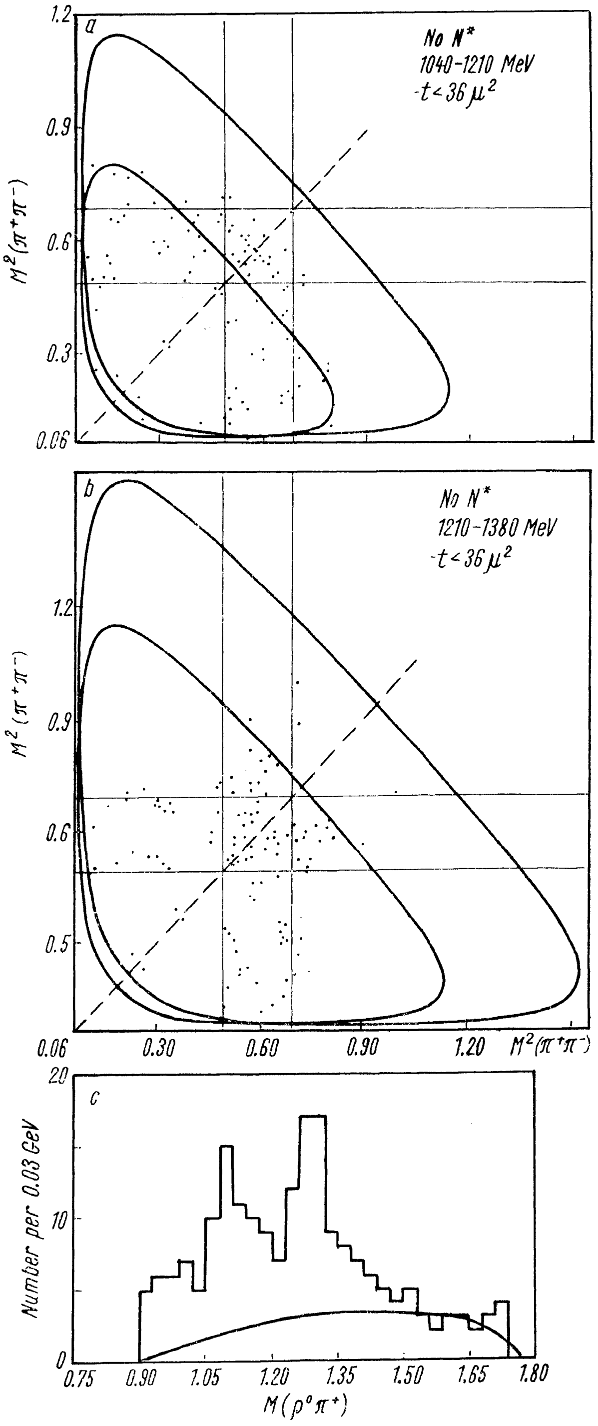

Fig. 1. (a) Dalitz plot of the three pions from the events with no N^* (1120—1320), $-t\,(p,\ p) < 36\ \mu^2$ and 1040 MeV $< M\,(\pi^+\pi^+\pi^-) <$ 1210 MeV; (b) Similar to 1 (a) but with 1210 MeV $< M\,(\pi^+\pi^+\pi^-) <$ $<$ 1380 MeV; (c) Effective mass plot of those events with no N^* (1120—1320), $-t\,(p,\ p) < 36\ \mu^2$ and $\varrho\,(\pi^+\pi^-)$ present.

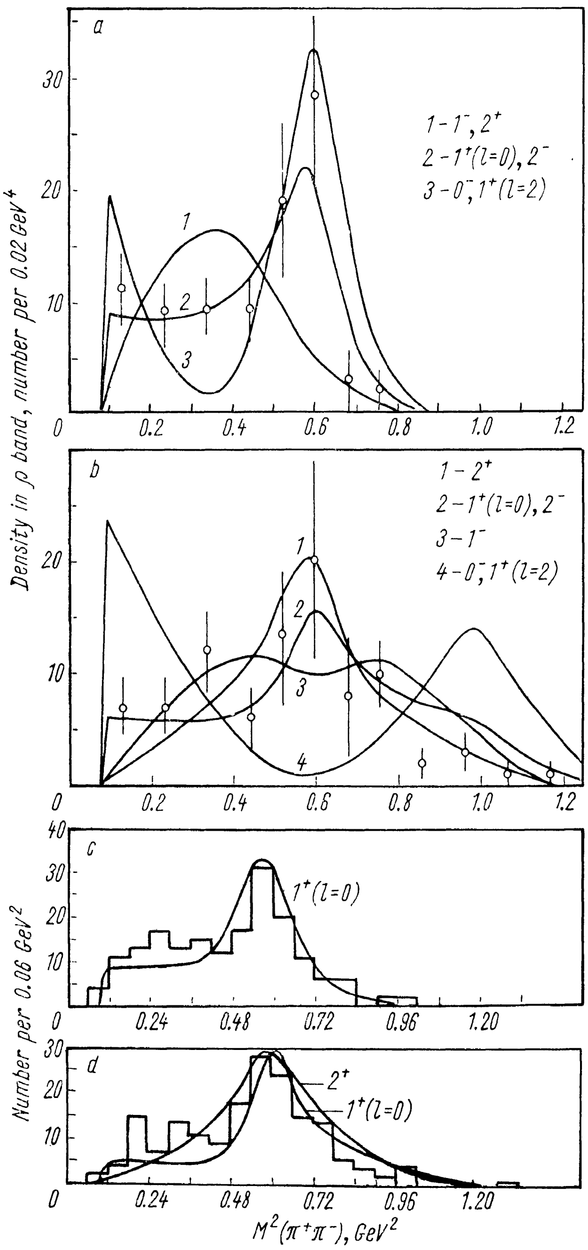

Fig. 2. (a) Distribution of the density of points on the Dalitz plots of Fig. 1 (a) within a band centered on the ϱ and 0.2 GeV² wide. The curves are theoretical expectations assuming $A \to \varrho + \pi$ without background; (b) Similar to 2 (a) but for the data of Fig. 1 (b); (c) Projection of the Dalitz plot of Fig. 1 (a); (d) Projection of the Dalitz plot of Fig. 1 (b).

3π phase space bacground. For the R^+ region the assignment 0^- or 1^+ ($l = 2$) is very unlikely, 1^- is better but also unlikely, 1^+ ($l = 0$)

or 2^- is quite possible, and 2^+ is also quite possible with the addition of 3π phase space background. The 0^- assignment is not appreciably improved by mixtures of 3π background. The 1^- assignment is possible with the addition of 3π background, although 1^+ and 2^+ seem favored. Fig. 2, *c* and 2, *d* show the projections of the two Dalitz plots along with the theoretical curves for the more likely J^P choices.

If the $K\overline{K}$ enhancement [2] at 1300 MeV is an alternate decay mode of the *R*, then 2^+ is the lowest assignment allowed. The data reported here do not seriously contradict this assignment. However, the choice 0^- for the *A* peak is favored by the data of Chung et al. [2], while our data do not lend much support at all to this assignment. Further, the $\eta\pi$ enhancements proposed by Aderholz et al. [4] require $J^P = 0^+, 1^-, 2^+, 3^-, 4^+$, ———, with the 0^+ forbidden if these $\eta\pi$ enhancements represent alternate decay modes of the same resonances (*A* and *R*) which decay to $\varrho + \pi$. The A^+ data of Fig. 2, *a* disagree rather strongly with 1^- and 2^+. Nauenberg and Pais [5] have discussed the possibility for peaks in meson systems due to the Peierls mechanism. They predict an enhancement in the πp system at 1090 MeV*. If the A^+ is this kind of peak, it would not have definite angular momentum and our analysis would not apply.

The Bronzan-Low quantum number [6] for a $\varrho\pi$ state is -1, while for a $K\overline{K}$ it is $+1$. Thus the $K\overline{K}$ mode reported for the *R* meson would violate the conservation of this quantum number in strong interactions. The ratio $\left(\frac{R^+ K^+ K^0}{R^+ \to \varrho\pi}\right)$ would indicate how much this quantum number is violated.

The ratio predicted by phase space is about 1.0 We have analyzed the $\pi^+ p \to pK^+K^0$ events in our data [7]. We do not observe the K^+K^0 peak at the region of the *R* (due perhaps to limited statistics) but can set an upper limit of 15 μb, which combined with the lower limit of 100 μb for $R(\varrho^0\pi^+)$ gives an upper limit $\sim \frac{1}{13}$ for the $(K^+K^0/\varrho\pi)$ branching.

If we remove the requirements that a ϱ be present and that $\Delta^2 < 35\mu^2$ and plot the $M^2(\pi^+\pi^-)$ distributions for the A^+ and R^+ mass regions, we observe, in each case, an enhan-

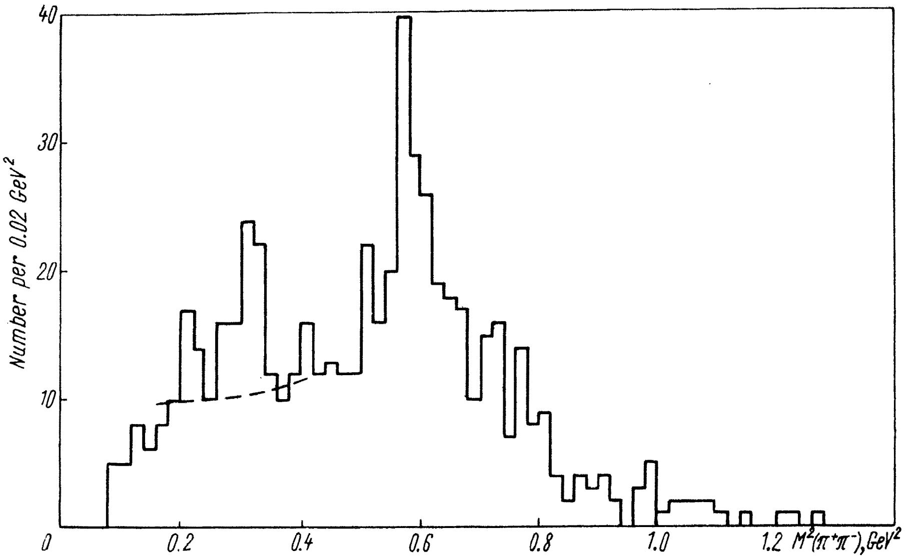

Fig. 3. Plot of the square of the effective mass $M^2(\pi^+\pi^-)$ of the π^+ and π^- from those events with no N^* (1120—1320) and with $1040 < M(\pi^+\pi^+\pi) < 1380$, 2×294 combinations.

* We have looked at the reaction $\pi^+ + p \to p + \pi^+ + MM$ at 3,5 GeV/c where *MM* means two or more π^+ mesons, and plotted the effective mass $M(\pi^+, MM)$ of the π^+ and the missing mass and observe the *R* (1310) but not the *A* (1090) in agreement with the prediction of the Peierls mechanism. On the other hand, our observations disagree with the predicted (R. J. Oakes, A. Pais, private communications) distribution in the $\pi - \varrho$ scattering angle for the *A* events in this paper. See D. Carmony et al. Proceeding of Dubna Conference, 1964.

cement in the region . 26 $GeV^2 < M^2(\pi^+\pi^-) <$ $<$. 34 GeV^2. Combining the data, we obtain the histogram of Fig. 3. As can be seen from the examples in Fig. 2, *a*, *b*, the theoretical curves for $A^+ \to \varrho + \pi$ and $R^+ \to \varrho + \pi$ do not produce this bump. We have studied the effect of mixing 3π phase space with these curves and conclude that the expected distribution in the 550 region will not deviate appreciably from the dotted curve of Fig. 3. There are 36 ± 9 events above this line (shaded region). This peak is not observed in the events with M^2 $(+ + -)$ above the R^+ peak, but its failure to appear in the low Δ^2 data argues against its association with the A and R peaks.

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