PRODUCTION AND DECAY OF THE ρ AND ω MESONS IN ANTIPROTON ANNIHILATION

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(presented by M. Derrick)

Further results on the production and decay of the ρ meson and of the neutral ω meson have been obtained by a study of the annihilation of antiprotons which stopped in the Saclay 81 cm hydrogen bubble chamber. A scan for final states of four charged pions, that is

$$p+\bar{p}\rightarrow\pi^+ +\pi^+ +\pi^- +\pi^- +n\pi^0 \qquad (1)$$

was made and about 2000 events were measured. Events in this class were kinematically fitted by a least squares apex fitting programme [1] in order to determine the values of n. The number of events with $n = 0$ and 1 were found to be 231 and 921 respectively.

For the final state with no neutral pions the distribution of the invariant mass of all $\pi^+\pi^-$ pairs is shown in Fig. 1. The ρ meson appears, but we have no evidence for the ζ meson [2] although the phase space mass distribution is slowly varying near 550 MeV.

The invariant mass distributions for all $\pi^+\pi^-$ and $\pi^+\pi^0$, $\pi^-\pi^0$ pairs have been calculated for events with $n = 1$. The distributions are given by the histograms in Figs. 2 and 3. The ρ peak does not seem to have a simple shape, particularly in the $\pi^+\pi^-$ combination.

The production of the ω meson in the reaction

$$p+\bar{p}\rightarrow\omega^0+\pi^+ +\pi^- \qquad (2)$$

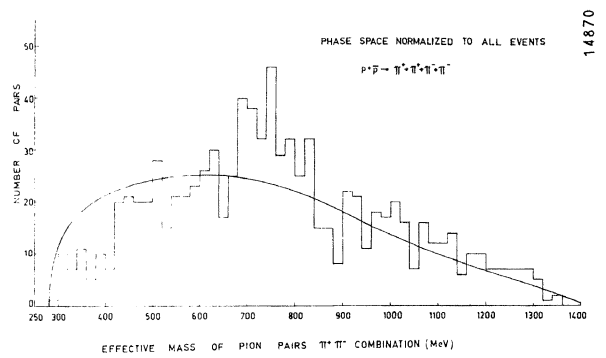

Fig. 1 Two pion ($\pi^+\pi^-$) invariant mass distribution for 231 events of the class $p+\bar{p}\rightarrow\pi^+ +\pi^+ +\pi^- +\pi^-$. The curve is the distribution calculated from the exact Lorentz invariant phase space factor, normalized to all the events.

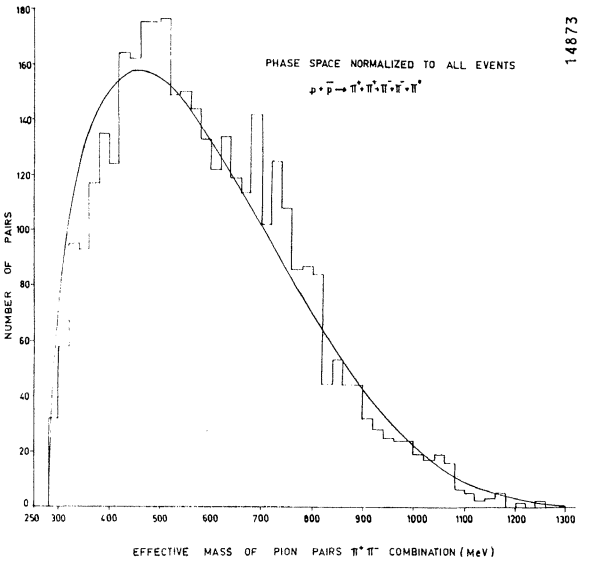

Fig. 2 Two pion ($\pi^+\pi^-$) mass distribution for 921 events of the class $p+\bar{p}\rightarrow\pi^+ +\pi^+ +\pi^- +\pi^- +\pi^0$.

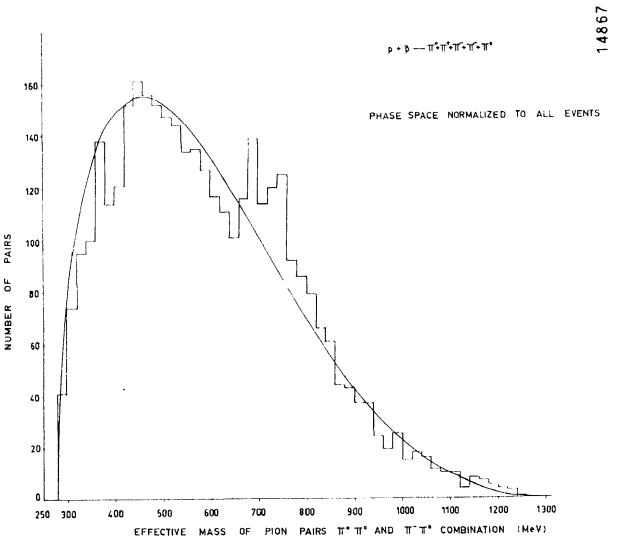

Fig. 3 Two pion ($\pi^+\pi^0$ and $\pi^-\pi^0$) mass distribution for 921 events of the class $p+\bar{p}\to\pi^++\pi^++\pi^-+\pi^-+\pi^0$.

and the decay through the mode

$$\omega^0\to\pi^++\pi^-+\pi^0 \qquad (3)$$

have been studied by calculating the invariant mass for each combination $\pi^+\pi^-\pi^0$.

The results are shown in the histogram of Fig. 4. The curve is the distribution resulting from the exact Lorentz invariant phase space factor calculated for five pions. The peak between 770 MeV and 800 MeV shows the production of the ω. The mass of the ω defined to be the position of the maximum in a gaussian ideogram of the histogram in Fig. 4, was found to be 783 MeV. We are unable to exclude the possibility of a systematic error in our mass value of 5 MeV or less. The experimental resolution was estimated by calculating the gaussian ideogram of a δ function mass distribution at 783 MeV. This ideogram, shown in Fig. 4, has a full width of 16 MeV, and is consistent with the experimental points. The results are therefore consistent with the ω having zero width.

We estimate the proportion of final states with $n = 1$ which are reached through ω production and decay to be at least 0.13.

For a preliminary study of the decay of the ω we have used the simple matrix elements of Stevenson *et al.*[3]. If the ζ meson of unit isotopic spin exists [4], Feinberg [5] has estimated that the width for the decay

$$\omega\to\zeta+\pi \qquad (4)$$

could be as great as 15 MeV. We have taken the 242 events having mass values between 770 MeV and 800 MeV and have formed the invariant mass of all pion pairs shown in Fig. 5. The results are consistent with the absence of the decay mode (4) and, therefore, confirm that the ω is not formed from the ζ and π by the Peierls-Nauenberg-Pais mechanism [6, 7]. The absence of (4) is accordant with the idea that the

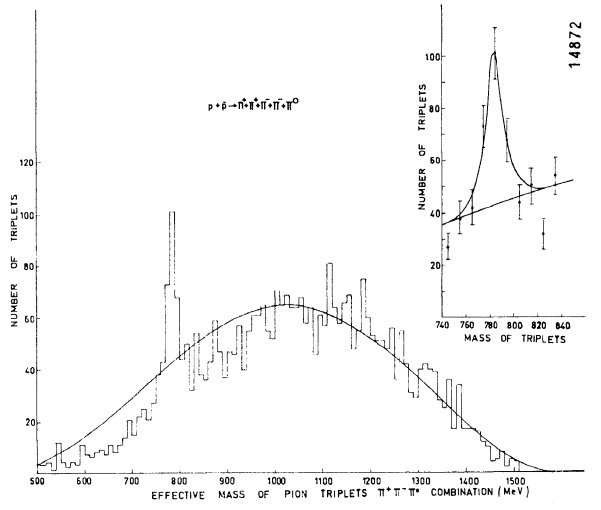

Fig. 4 Three pion ($\pi^+\pi^-\pi^0$) mass distribution from fitted events of the class $p+\bar{p}\to\pi^++\pi^++\pi^-+\pi^-+\pi^0$. The curve is the distribution calculated from the exact Lorentz invariant phase space factor. The insert shows the peak region, with the shape of a δ function mass distribution at 783 MeV predicted on the basis of our experimental resolution. The full width at half height is 16 MeV. The errors shown on the points are the square roots of the numbers of events in each interval.

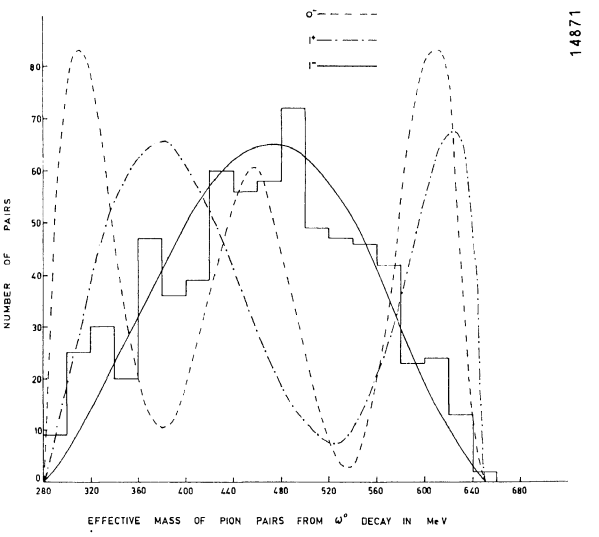

Fig. 5 Two pion mass distribution of all pion pairs from the ω decay. All events between 770 MeV and 800 MeV in Fig. 4 were used. The curves are the mass distributions calculated from the transition probabilities given in reference 6 for different values of the spin and parity of the ω.

ζ meson has the spin, parity and G parity assignments 0^{++} or 0^{+-} and, therefore, decays by an electromagnetic interaction.

To study the spin and parity of the ω, we have assumed that it has zero isotopic spin and negative G parity. The distribution of the invariant mass of pion pairs in the ω decay, calculated from the transition probabilities given in reference 3 are shown in Fig. 5 for the possibilities 0^-, 1^+ and 1^-. The histogram of Fig. 4 shows that in the peak region at least one half of the events must be the result of ω production and decay. Our results, then, strongly support the 1^- assignment of Stevenson *et al.*

For the events with $n = 1$ we have formed the invariant mass for combinations of four pions. Fig. 7 shows the total charge zero combination $(\pi^+\pi^+\pi^-\pi^-)$ and Fig. 6 the distribution of all the single charge combinations $(\pi^+\pi^+\pi^-\pi^0$, etc.). The curve is the expected distribution calculated from phase space. The agreement is good for the single charge but for the neutral combination there is a systematic disagreement with the phase space curve. If the single event below 800 MeV in Fig. 7 is ascribed to the decay

$$\rho^0 \rightarrow \pi^+ + \pi^+ + \pi^- + \pi^- \qquad (5)$$

then, using our measured value for the production of neutral ρ mesons through the reaction

$$p + \bar{p} \rightarrow \rho^0 + \pi^0 \qquad (6)$$

an upper limit to the branching ratio

$$\frac{\rho^0 \rightarrow \pi^+ + \pi^+ + \pi^- + \pi^-}{\rho^0 \rightarrow \pi^+ + \pi^-} \qquad (7)$$

of 2.5% is obtained.

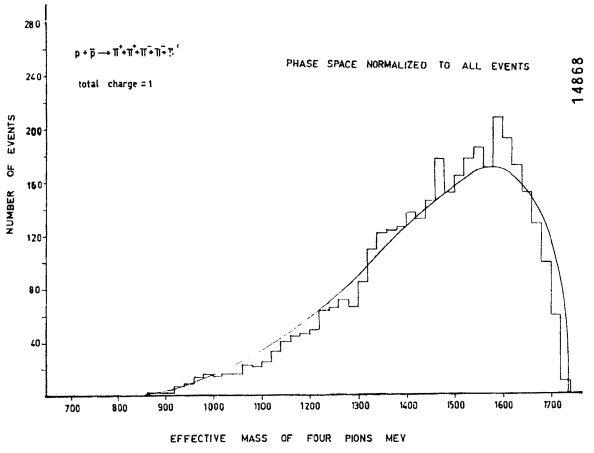

Fig. 6 Four pion mass distribution with total charge one $(\pi^+\pi^+\pi^-\pi^0$ etc.) for 921 events of the type $p+\bar{p}\rightarrow\pi^+ + \pi^+ + \pi^- + \pi^- + \pi^0$. The curve is the distribution calculated from phase space.

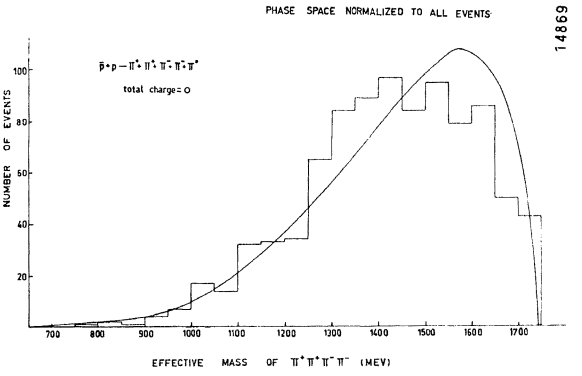

Fig. 7 Four pion mass distribution with total charge zero $(\pi^+\pi^+\pi^-\pi^-)$ for 921 events of the type $p+\bar{p}\rightarrow\pi^+ + \pi^+ + \pi^- + \pi^- + \pi^0$ The curve is the distribution calculated from phase space.

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DISCUSSION

ARMENTEROS: What is the mass and the natural width you obtain for the ϱ-meson?

DERRICK: The mass is 755 MeV and the width is 110 MeV.

W. D. WALKER: Have you looked at the $\pi^+\pi^-\pi^+$ combination in the ϱ mass region?

DERRICK: No, we have not had time to get the results ready for this Conference as regards the special combination you ask for.

MIKHUL: What is the mass of the neutral 4π combination?

DERRICK: The neutral 4π combination lies above the phase space at about 1300-1400 MeV.

FELD: Do you have a number for the relative rate of annihilation into ω-mesons?

DERRICK: The ω-production in the 5-pion events is 3% of all annihilations. There is also ω-production in the 6-prong events, which however we have not yet measured.

ELASTIC SCATTERING AND MULTIPION ANNIHILATIONS OF 3.25 GeV/c ANTIPROTONS IN HYDROGEN (*)

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(presented by J. Sandweiss)

A study has been made of 3.25 GeV/c antiproton-proton interactions producing two and four charged prongs in the 20″ Brookhaven National Laboratory liquid hydrogen bubble chamber. This experiment was performed at the AGS using an electrostatically separated antiproton beam [1].

Fifty-thousand pictures were taken at approximately 15 beam tracks per frame; these were scanned, using the facilities of BNL and Yale University, for all interactions within a restricted fiducial volume.

I. FOUR-PRONG EVENTS

1981 four prong events have been measured and analysed, although some of the data given below refer to a sub-sample of 782 events. In all cases where the smaller sample has been shown, the data are in good agreement with the result of the complete sample.

We carried out a series of investigations in order to obtain a meaningful set of criteria for the selection of multi-pion annihilation events.

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