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R. Bernabei, S. D'Angelo, P. Spillantini and V. Valente :

THE DECAY SCHEME OF THE $\rho'(1600)$ MESON.

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ABSTRACT.-

An analysis of ($\pi^+\pi^-\pi^+\pi^-$) events from e^+e^- annihilation at 2.0 GeV shows that in the decay scheme $\varrho'(1600) \rightarrow \varrho^0\pi^+\pi^-$ the two π's appear coupled on the S^* resonance.

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The cross section of the process $e^+e^- \rightarrow \pi^+\pi^-\pi^+\pi^-$, investigated with the Frascati storage ring, Adone, has shown an energy dependence[1] (see Fig. 1) that has been interpreted as evidence for a new vector meson resonance $\varrho'(1600)$[2,3,4]. At the energy corresponding to the maximum of the cross section, about 1.6 GeV, the final state interactions among the π's have been studied in order to achieve information on the decay modes of the $\varrho'(1600)$[5]. The result was that only a $\varrho^o\text{-}\varepsilon^o$ final state could explain the experimental data.

In the present work we give the result of a similar analysis carried out at a total energy 2E = 2.0 GeV. The reconstructed events[4] available at this energy are 11.

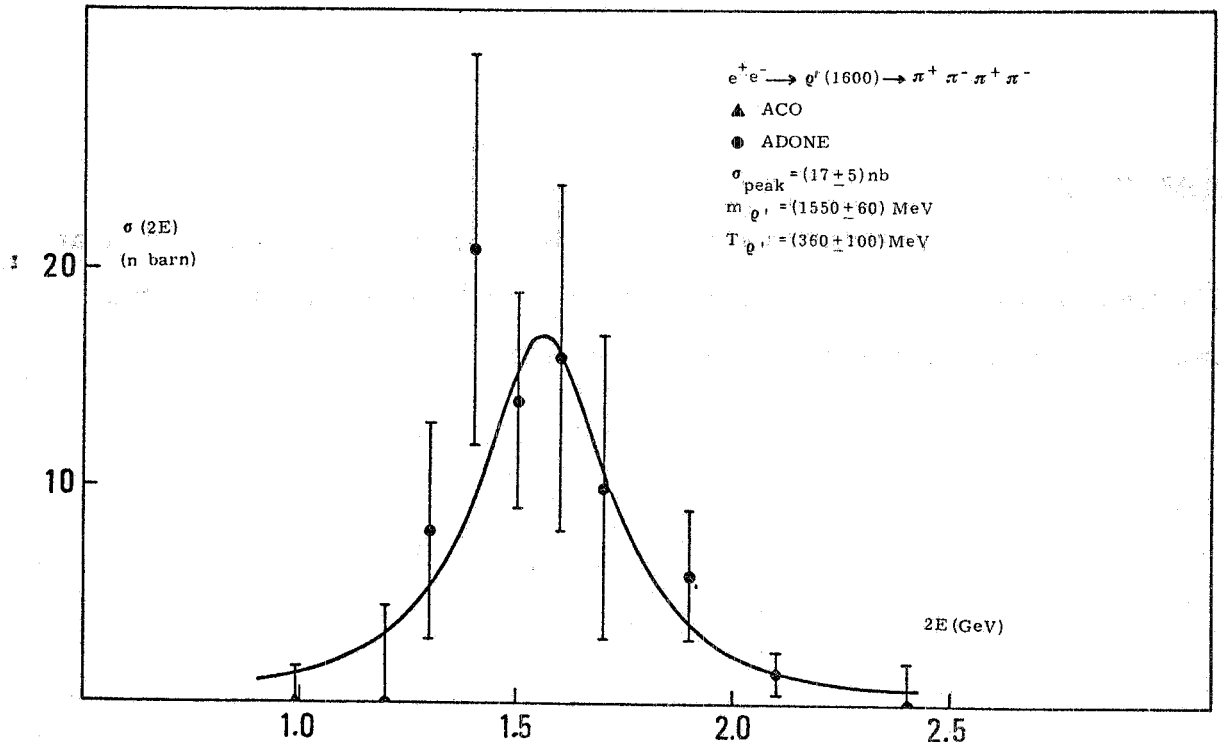

FIG. 1 - Energy dependence of the cross section for the reaction $e^+e^- \rightarrow \pi^+\pi\ \pi^+\pi^-$. (From ref. (1)).

The distribution of the invariant mass of pion pairs is compared in Fig. 2a) with the prediction of a pure invariant phase space calculation (IPS). A signal in the ϱ^o-region is observed. We recall here that the experimental apparatus[4] does not distinguish the charge of the particles. Therefore the signal of the physical ϱ^o is depressed because of the double charged combinations. Another structure is observed around a mass of 1 GeV; as can be seen in Fig. 2b), such a structure cannot be produced in the final states $\varrho^o \varepsilon^o$, $A_1^{\pm} \pi^{\mp}$.

The characteristic feature of the experimental distribution suggests the hypothesis of a $\varrho^o S^x$ state, where S^x is the $\pi\pi$ S-wave resonance, with $M_{S^x} = 1.08$ GeV and $\Gamma_{S^x} = 0.08$ GeV[6]. The comparison between the experimental and the calculated distribution is shown in Fig. 2c); the agreement is satisfactory as the χ^2-value indicates.

A more convincing argument is based on the analysis of the scatter plot of the invariant mass of a pion pair, $M(\pi_1, \pi_2)$, versus the invariant mass of the remaining pair, $M(\pi_3, \pi_4)$. In Fig. 3a), b) the experimental distribution is compared with the calculated one in the case of IPS and $\varrho^o S^x$, respectively. In the region of the $\varrho^o S^x$ events, defined as $1.0 < M(\pi_1, \pi_2) < 1.2$ and $0.6 < M(\pi_3, \pi_4) < 0.9$, the expected population is 3.6 for IPS, 8.4 for $\varrho^o S^x$ and 4.3 for $\varrho^o \varepsilon^o$, with negligible errors attached to these figures, while the experimental number is 11 ± 3.3. If we calculate the χ^2 for the whole scatter plot, divided into the seven indicated zones, we obtain 24, 22, 9.5 for IPS, $\varrho^o \varepsilon^o$, $\varrho^o S^x$ respectively.

Comparing this result with the previous one about the decay of $\varrho'(1600)$ at $2E = 1.6$ GeV[5], the decay scheme of the $\varrho'(1600)$ appears to be the following:

$$\varrho'(1600) \longrightarrow \varrho^o + (\pi^+ \pi^-)_{S\text{-wave}} \longrightarrow \pi^+ \pi^- \pi^+ \pi^- ,$$

where $(\pi^+ \pi^-)_{S\text{-wave}}$ denotes an S-wave $\pi\pi$ system.

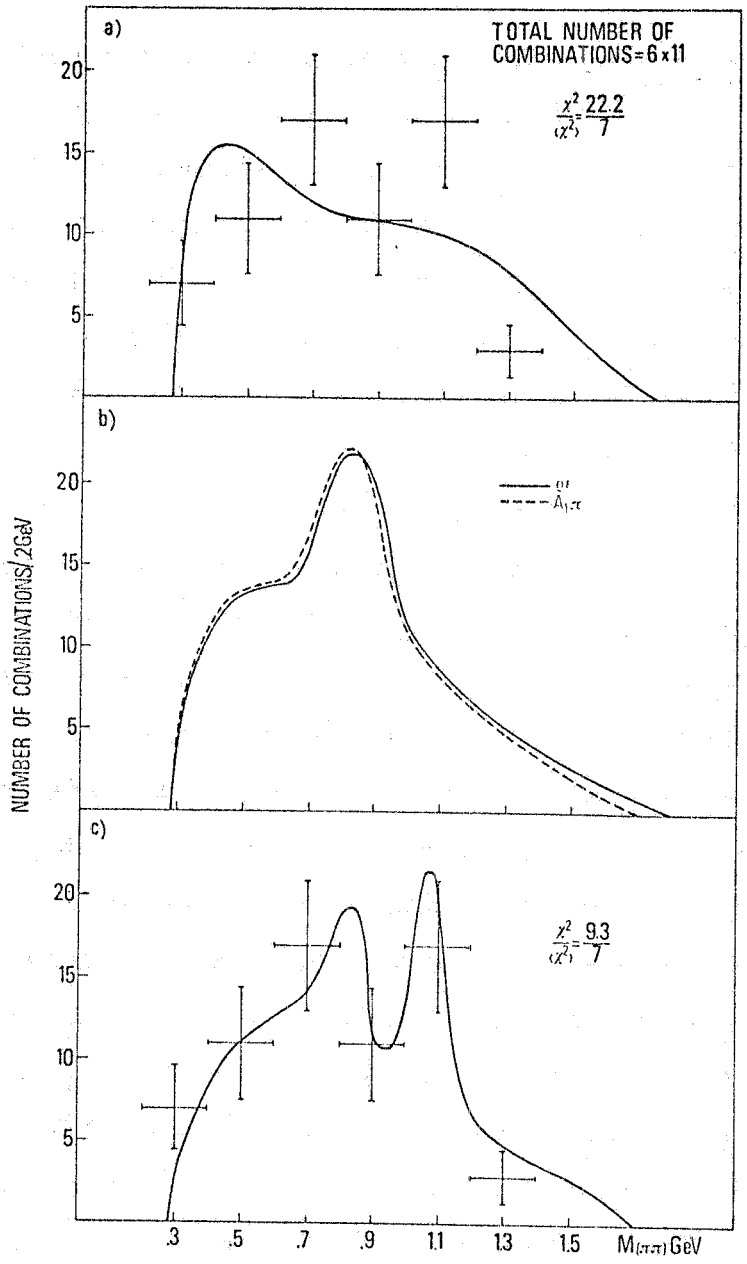

FIG. 2 - Two-pion invariant mass distribution $M(\pi\pi)$. There are six combinations per event because the apparatus does not distinguish the charge of the particles. a) The solid line is the expected normalized distribution from invariant phase space (IPS); b) the solid line is the distribution expected assuming the $\varrho^0 \varepsilon^0$ production mechanism, the dashed one is assuming the $A_1^{\pm} \pi^{\mp}$ production mechanism; c) the solid line is the expected normalized distribution, assuming $\varrho^0 S^x$ production mechanism. In Fig. 2a) and 2c) the value $\chi^2 / \langle \chi^2 \rangle$ of the ratio between the obtained and expected χ^2 is also reported.

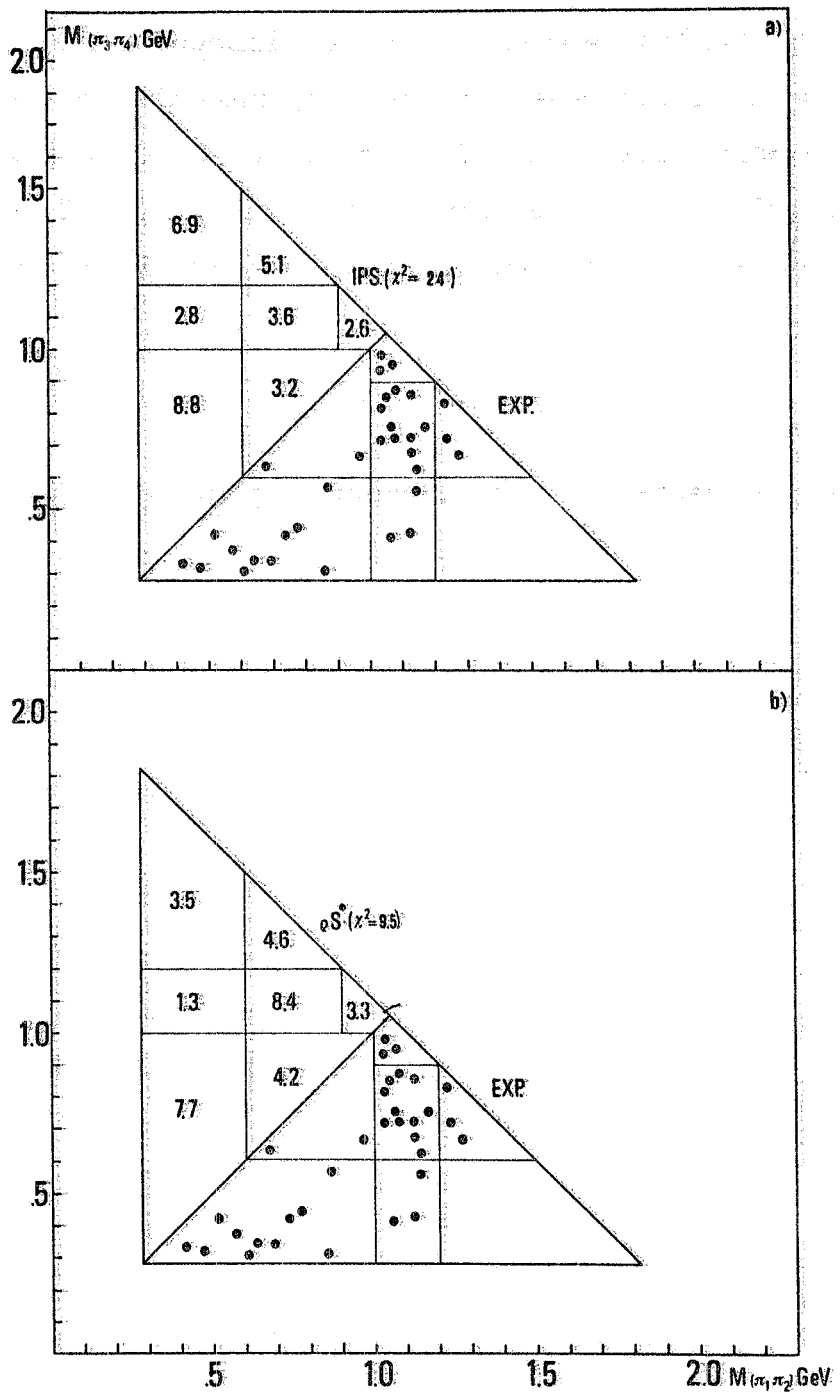

FIG. 3 - Scatter plot of the invariant mass of a pion pair, $M(\pi_1 \pi_2)$, versus the invariant mass of the remaining pair, $M(\pi_3 \pi_4)$. Each event contributes three combinations. In the upper half of the triangle the expected density assuming IPS production mechanism is indicated in Fig. 3a) and the same assuming $\varrho^0 S^x$ production mechanism in Fig. 3b).

The interaction between the two π's influences their effective mass spectrum: in particular, when energetically possible, the two π's are coupled as S-wave resonances. At $2E = 2.0$ GeV both the resonances ε^0 and S^* are possible, but the experimental results an inadequate to give their relative weights. The only indication is that S^* is preferred.

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