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PRODUCTION OF FOUR π-MESONS IN e^+e^- COLLISIONS AND PCAC

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PRODUCTION OF FOUR π -MESONS IN e^+e^- COLLISIONS AND PCAC

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The reaction $e^+e^- \to \rho\pi^+\pi^-$ has been considered taking into account partial conservation of axial current and identical final pions. The energy dependence of the total cross-section is consistent with the experiment. The ratio of the cross-sections $\sigma(\rho\pi^+\pi^-)/\sigma(\rho\pi^0\pi^0)$ has been calculated.

Recently Orsay and Novosibirsk groups reported new measurements of the reaction $e^+e^- \to 2\pi^+ 2\pi^-$ in the energy region $\sqrt{s}$ from 915 up to 1340 Mev using e^+e^- colliding beam facilities ACO and VEPP-2M /1,2/. The value of the cross-section as well as its energy dependence differ notably from theoretical predictions of /3-6/. This paper deals with the reaction $e^+e^- \to \rho \to \rho\pi^+\pi^- \to 2\pi^+ 2\pi^-$ with the account of identical final pions in contrast with the quasitwobody or quasithreebody approach of previous considerations /3-6/. Besides that the validity of the Adler selfconsistency condition is assumed and it is shown that due to these circumstances the energy dependence of the total cross-section is more smooth if compared to that of /3-6/.

The matrix element written with account of the Adler selfconsistency condition for soft pions was discussed in detail in our paper /7/ for a similar process $\psi' \to \psi\pi\pi$. The amplitude for a $\rho \to \rho\pi\pi$ transition is written as

$$M = g_{\rho\rho\pi\pi}\,[(\epsilon_1\epsilon_2)(k_1k_2) - (\epsilon_1k_2)(\epsilon_2k_1)](p_1p_2), \qquad (1)$$

where $\epsilon_{1,2}, k_{1,2}$ - ρ -meson 4-polarizations and 4-momenta respectively, $p_{1,2}$ - 4-momenta of π -mesons. Transmutations of identical pions in the diagram of Fig.1 give the following

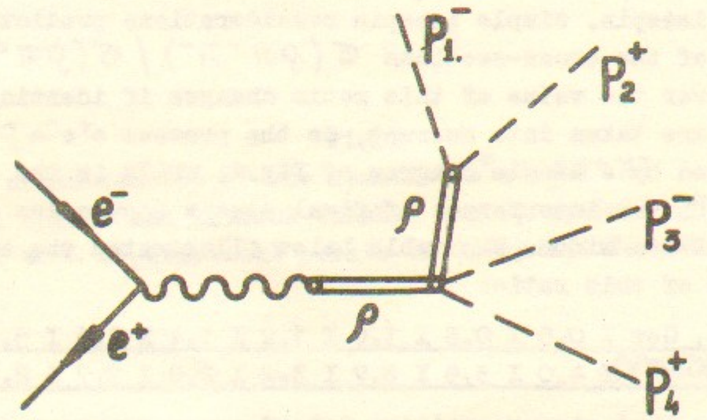

Fig.1

expression for the squared absolute value of the matrix element averaged over polarizations of initial leptons:

$$\overline{|M|^2} = 2 g_{\rho\rho\pi\pi}^2 \sum_{i,k=1}^{4} T_i T_k^* [Q^2 (R_i R_k) + (q R_i)(q R_k)], \quad (2)$$

where $T_1 = (P_3 P_4) / [m_\rho^2 - (P_1+P_2)^2 - i m_\rho \Gamma_\rho]$,
$R_{1\mu} = (Q P_2) P_{1\mu} - (Q P_1) P_{2\mu}$, $Q = P_+ + P_-$, $q = P_+ - P_-$;
$T_i, R_{i\mu}$ at i=2,3,4 are obtained from $T_1, R_{1\mu}$ by transmutations of 4-momenta of identical pions, $p_{1,3}$ - 4-momenta of π^--mesons, $p_{2,4}$ - 4-momenta of π^+-mesons, $p_\pm$ - 4-momenta of $e^\pm$, m_ρ, Γ_ρ - ρ-meson mass and width. Integration over the phase space of four pions was performed by the Monte-Carlo method using the algorithm of random stars generation suggested in /8/.

Fitting the unknown constant $g_{\rho\rho\pi\pi}$ by comparison with the experimental data one obtains the total cross-section shown by the solid curve of Fig.2 (also shown are the experimental points of Orsay and Novosibirsk). The dashed curve corresponds to the cross-section obtained without the account of the Adler selfconsistency condition in the matrix element. The solid curve is obviously in much better agreement with the experiment, implying that the account of PCAC is essential.

In the experimental determination of the cross-section of the reaction $e^+e^- \to \pi^+\pi^-\pi^0\pi^0$ it is important to know the contribution of the channel $e^+e^- \to \rho\pi^0\pi^0$. If 2π are in a state with zero isospin, simple isospin considerations predict that the ratio of the cross-sections $\sigma(\rho\pi^+\pi^-) / \sigma(\rho\pi^0\pi^0)$ is 2. However the value of this ratio changes if identical final pions are taken into account, as the process $e^+e^- \to \rho\pi^0\pi^0$ is described by a single diagram of Fig.1, while in the case of $e^+e^- \to \rho\pi^+\pi^-$ the interference of final states occurs due to the large ρ-meson width. The table below illustrates the energy dependence of this ratio:

$\sqrt{s}$, Gev	0,6	0,8	1,0	1,2	1,4	1,6	5,0
$\sigma(\rho\pi^+\pi^-)/\sigma(\rho\pi^0\pi^0)$	4,0	3,9	3,7	3,2	2,9	2,7	2,4

It is clear that strong positive interference occurs near the threshold where the ratio of the cross-sections equals 4, i.e. achieves its maximum value allowed by isotopic invariance /9/

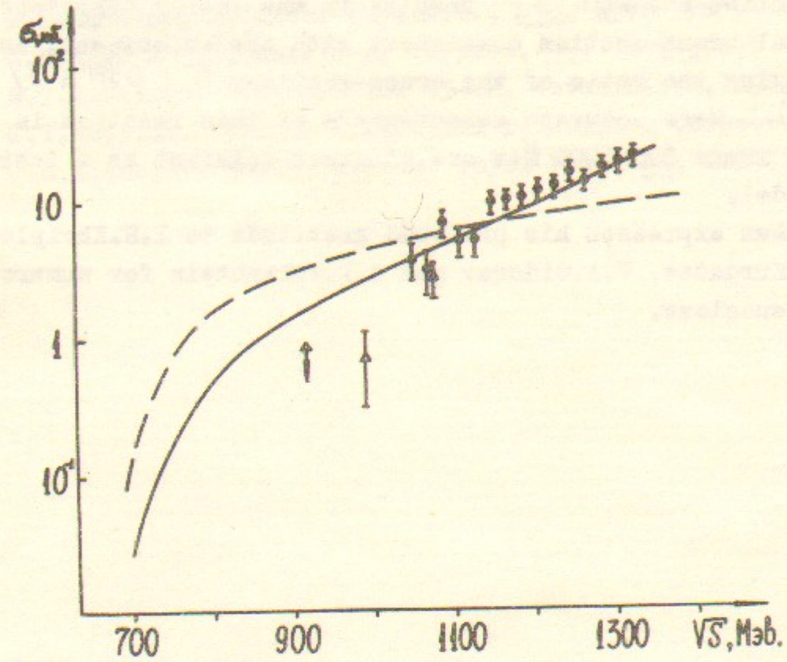

Fig.2

Total cross-section of the reaction $e^+e^- \to \rho\pi^+\pi^-$ with (solid curve) and without (dashed curve) account of PCAC, Δ and ● - experimental points of Orsay and Novosibirsk.

(production of two pion pairs in S-wave with isospin 2). The role of interference falls with energy, the ratio tending to 2 only at very high energies when the ρ -meson is produced with a large momentum.

Thus, account of PCAC and identical pions in the final state of the reaction $e^+e^- \to \rho\pi^+\pi^-$ results in the energy behaviour of the total cross-section consistent with the experiment, notably changing the ratio of the cross-sections $\sigma(\rho\pi^+\pi^-)/\sigma(\rho\pi^0\pi^0)$. More accurate measurements of this reaction in the energy range 800-1000 Mev are of great interest as a test of this model.

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