Study of the $e^+e^- \to \pi^+\pi^-\pi^+\pi^-$ reaction at 2E up to 1.4 GeV

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The reaction $e^+e^- \to \pi^+\pi^-\pi^+\pi^-$ was studied in the energy interval 0.64–1.40 GeV. The reaction cross section increases rapidly with energy and exceeds the prediction of the vector-dominance model with one $\rho(770)$. The upper bounds on the relative probabilities for the decays $\rho, \omega \to \pi^+\pi^-\pi^+\pi^-$ have been obtained.

In this letter we are reporting the results of an experimental study of the reaction $e^+e^- \to \pi^+\pi^-\pi^+\pi^-$. The experiment was carried out on the VEPP-2M storage ring with use of the OLYa detector. The statistical base was acquired by scanning the energy interval 0.64–1.40 GeV in steps equal to the c.m. energy spread (0.5–0.7 MeV). The luminosity built up in the experiment amounted to 1540 nb^{-1}. The preliminary results for the energy interval 1.0–1.4 GeV were published previously.[1]

To analyze the reaction which we are considering, we selected the events with three or four tracks which were outside the interaction range of the beams and which did not contain γ-ray quanta. In the case of the three-track events, it was additionally required that all three tracks should lie in different quadrants and that the minimum

angle of discollinearity of the pair of tracks in the plane perpendicular to the beams should be larger than 5°. Under the given selection criteria we have identified 1791 events with three tracks and 676 events with four tracks. The amplitude spectra of the detector's scintillation counters indicate that the charged particles in the selected events are primarily π mesons.

The γ-ray conversion in matter before the coordinate system and the Dalitz π^0-meson decay account for the fact that the detected three-track events contain an admixture of background processes $e^+e^- \to e^+e^-\gamma$, $\pi^+\pi^-\pi^0$, and $\pi^+\pi^-\pi^0\pi^0$. The probability that these background processes would be detected as four-track events is much lower. Analysis of the ratio of the number of three-track events to the number of four-track events shows that up to an energy of 1.0 GeV the observed cross section can be explained by phonon processes and at a high energy a new channel arises $e^+e^- \to \pi^+\pi^-\pi^+\pi^-$.

In the case of four-track events under the assumption that the observable particles are pions from the reaction $e^+e^- \to \pi^+\pi^-\pi^+\pi^-$ we can find, by making use of the conservation laws, their momenta from the angle of emission of the particles; i.e., the kinematics of the events can be reconstructed completely. Analysis of the invariant-mass distribution of a pair of π mesons shows that at the maximum energy of the experiment there are indications of the presence of a ρ meson (Fig. 1). The statistical base of our experiment does not allow us to choose between the two analyzed produc-

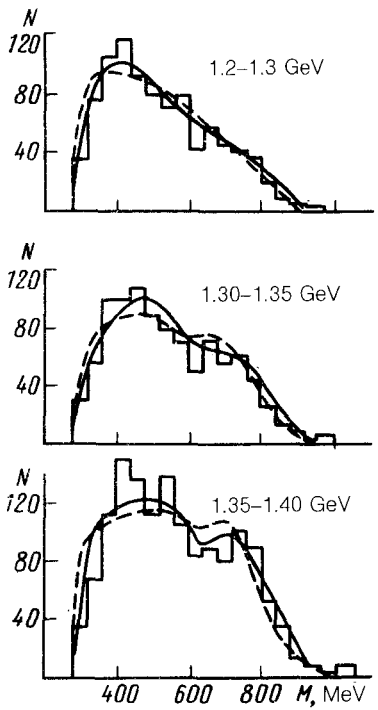

FIG. 1. Invariant-mass distribution of the pion pair. Histogram—Experimental; solid curve—simulation of $\rho^0\pi\pi$; dashed curve—simulation of $A_1\pi$.

tion mechanisms: $A_1\pi$ and $\rho^0\pi\pi$. The production mechanism in the other experimental studies of $\pi^+\pi^-\pi^+\pi^-$ in e^+e^- annihilation[2-4] and photoproduction[5] has not been identified. At the same time, in the $\pi^+\pi^-\pi^0\pi^0$ channel—in the isospin partner $\pi^+\pi^-\pi^+\pi^-$—both our data[6] and the data on photoproduction[7] show that $\pi^0\pi^0\pi^0$ is small in comparison with $\rho^\pm\pi^\pm\pi^0$; i.e., these data show that we are dealing with a $A_1\pi$ (or $\pi'\pi$) mechanism.

In calculating the cross section we used the probability for the detection of the $A_1\pi$ mechanism. The contribution from the background was accounted for theoretically. The radiative corrections, determined on the basis of a procedure used in Ref. 8, varied from 11% at 1.0 GeV to 7% at 1.4 GeV. The systematic error in the cross section, which is no greater than 20%, is attributed to the inexact determination of the production mechanism.

At energies $2E \sim M_{\rho,\omega}$ the observable number of events is in agreement, as noted above, with that expected for the background processes. We used thirteen four-track events in the energy interval from 0.67 GeV to 0.90 GeV to determine the relative probability of the decays $\rho,\omega \to \pi^+\pi^-\pi^+\pi^-$. A fit of the energy dependence of the events gave the following values of the upper limits $B(\rho^0 \to \pi^+\pi^-\pi^+\pi^-) < 2\times 10^{-4}$ and $B(\omega \to \pi^+\pi^-\pi^+\pi^-) < 10^{-3}$ with a 90% confidence level. The upper limit for the decay $\omega \to \pi^+\pi^-\pi^+\pi^-$ was obtained for the first time. The best constraint imposed on the decay $\rho^0 \to \pi^+\pi^-\pi^+\pi^-$ amounts to[9] 1.5×10^{-3}, i.e., an order of magnitude worse than that obtained by us.

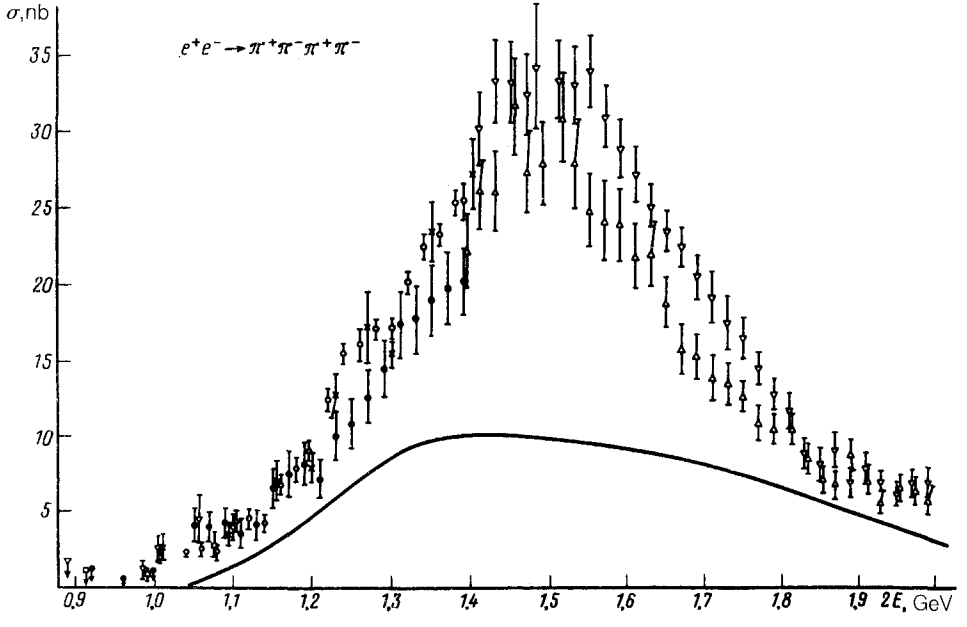

FIG. 2. Total cross section of the reaction $e^+e^- \to \pi^+\pi^-\pi^+\pi^-$, obtained in the following experiments: ▼—Refs. 2 and 11; ▲—Ref. 3; ×—Ref. 4; ■—Ref. 10; ○—Ref. 12; ●—our results. Solid curve—Prediction of Ref. 13.

Figure 2 shows the total cross sections and the data of other groups obtained at energies below 2 GeV (Refs. 2–4 and 10–12). The cross section increases rapidly with energy and exceeds markedly the predictions of the vector-dominance model[13,14] with a single ρ (770). We see that ρ (1600) plays the dominant role in this energy range. Its parameters, however, cannot be determined because of the systematic errors of the individual experiments.

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