Production of the δ_0° phase of $\pi\pi$ scattering in the range extending from the threshold to $m_{\pi\pi} = 1$ GeV

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The δ_0° phases of $\pi\pi$ scattering extending from the threshold to 960 MeV, which were determined from the reaction $\pi^- p \to \pi^- \pi^+ n$, are presented. The scattering length is calculated, taking into account the subthreshold zero $\alpha_0^\circ = (0.26 \pm 0.04)\mu^{-1}$.

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A study of reactions such as $\pi N \to \pi\pi N$ at incident-pion momentum p_π ranging from 2 to 17 GeV/c has been the main source of information on $\pi\pi$ interaction for a long time. As a result of these investigations, comprehensive information has been obtained on $\pi\pi$ scattering in the dipion mass region $500 < m_{\pi\pi} < 1000$ MeV. The phases near the threshold were generally determined by an approximation in this re-

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gion, which, as has now become clear, often gave incorrect results (especially for the δ_0^0 phase). Moreover, the scattering lengths cannot be correctly estimated without knowledge of the phases near the threshold.

Recently, a number of papers has been published (see, for example, Ref. 1), in which the values of the δ_0^0 phase near the threshold (for $m_{\pi\pi} \leqslant 350$ MeV) were determined from a large volume of statistical data. However, the technique of obtaining the results of these investigations differed in many ways from that used in the region of larger $m_{\pi\pi}$ (a different reaction–K decay, a different method of approximating the data, use of other theoretical models, etc.). In addition, the intermediate range of $m_{\pi\pi}$ values, in which the δ_0^0 phase was not determined, remained unfilled. It is, therefore, very important to determine the values of δ_0^0 from the same reaction and use the same method in a continuous and sufficiently broad range of dipion masses, beginning with the threshold.

We have determined the values of the δ_0^0 phase of $\pi\pi$ scattering from the reaction $\pi^- p \to \pi^- \pi^+ n$ in the region extending from the threshold to $m_{\pi\pi} = 960$ MeV. We have used 495 reaction events at a kinetic energy of π^- mesons $200 < T_\pi < 260$ (Ref. 2) and 12000 events at a momentum $p_\pi = 4.5$ GeV/c [~3000 events with $|t| < 0.3$ (GeV/c)^2].[3] By analyzing these results we were able to determine the δ_0^0 phase in two neighboring regions of dipion masses $280 < m_{\pi\pi} < 320$ and $320 < m_{\pi\pi} < 960$ MeV. The average spherical harmonics were calculated in all the events as functions of the four-momentum transfer t; they were subsequently extrapolated to the pion pole. The $\pi\pi$-scattering cross section $\sigma_{\pi\pi}$ was calculated in a pseudoperipheral approximation by extrapolating the function $F'(t) = F(t)/t$. The experimental procedure in the near-threshold region was described in detail elsewhere.[4] The phases for the events in the region $320 < m_{\pi\pi} < 980$ MeV were determined by using the iteration

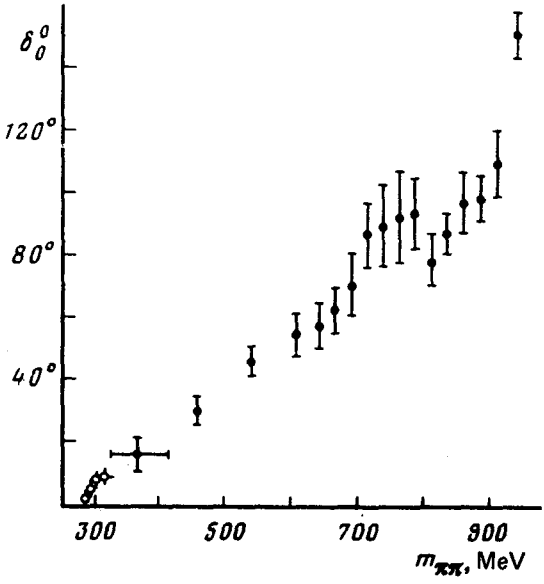

FIG. 1. The values of the δ_0^0 phase extending from the threshold to $m_{\pi\pi} = 960$ MeV. The open circles represent the results of evaluation of the events of the reaction $\pi^- p \to \pi^- \pi^+ n$ at $200 < T_\pi < 260$ MeV; the dark circles denote the events of the same reaction at $p_\pi = 4.5$ GeV/c.

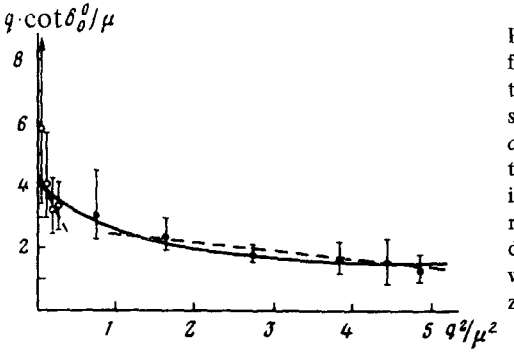

FIG. 2. Experimental values of the $q \cot \delta_0^0/\mu$ function. $\overset{\downarrow}{\phi}$, The results of an investigation in the near-threshold region; $\overset{\downarrow}{\phi}$, data of the analysis of the reaction $\pi^- p \to \pi^- \pi^+ n$ at $p_\pi = 4.5$ GeV/c. The dashed curves represent an approximation using the formula for the effective radius in the near-threshold region and in the energy region $450 \leqslant m_{\pi\pi} \leqslant 750$ MeV. The solid line denotes an approximation using a formula which takes into account the sub-threshold zero.

method and the values $\sigma_{\pi\pi}, \langle Y_L^0 \rangle, L = 1, \ldots, 4$. The interaction was assumed to be elastic and the phases of the waves with $I = 2$, δ_0^2, and δ_2^2 were assumed to be known and were taken from the data of Ref. 5. The δ_0^0, δ_1^1, and δ_2^0 phases were free parameters.

Figure 1 shows the obtained values of the δ_0^0 phase. We can see that the near-threshold values match well the other values.

Figure 2 shows the values of the $q \cot \delta_0^0$ function; q is the secondary-pion momentum in the rest frame of the dipion. The dashed curves represent an approximation in the effective-radius approximation for $m_{\pi\pi} < 320$ MeV and $450 \leqslant m_{\pi\pi} \leqslant 725$ MeV (for the interval which was generally used to determine a_0^0 in an experiment with large p_π). The corresponding scattering lengths are $a_0^0 = (0.24 \pm 0.07)\mu^{-1}$ and $a_0^0 = (0.39 \pm 0.07)\mu^{-1}$. The discontinuity, clearly illustrated in Fig, 2, confirms that $q \cot \delta_0^0$ behaves nonlinearly in the investigated region. The solid line was obtained by using a formula proposed by Serebryakov,[6] which takes into account the sub-threshold zero

$$q \cot \delta_0^0 = \frac{m}{2} \frac{1 + B_0 q^2}{a_0^0 + D_0 q^2},$$

where a_0^0, B_0, and D_0 are free parameters. We obtained the value $a_0^0 = (0.26 \pm 0.04)\mu^{-1}$ for such parametrization.

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