$\pi^0\pi^0$ scattering amplitudes and phase shifts obtained by the π^-p charge exchange process

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The results of the analysis of the $\pi^0\pi^0$ scattering amplitudes obtained with π^-p charge exchange reaction, $\pi^-p \to \pi^0\pi^0 n$, data at 9 GeV/c are presented. The $\pi^0\pi^0$ scattering amplitudes show clear $f_0(1370)$ and $f_2(1270)$ signals in the S and D waves, respectively. The $\pi^0\pi^0$ scattering phase shifts have been obtained below $K\bar{K}$ threshold and been analyzed by the Interfering Amplitude method with introduction of negative background phases. The results show a S wave resonance, σ. Its Breit-Wigner parameters are in good agreement with those of our previous analysis on the $\pi^+\pi^-$ phase shift data.

The fact that no odd wave is presented in $\pi^0\pi^0$ scattering amplitude in comparison with $\pi^+\pi^-$ is an advantage. However experimental difficulties impaired up to now the quality of $\pi^0\pi^0$ data [1] for the analysis of $\pi\pi$ phase shifts. Only the high statistics $\pi^0\pi^0$ data of Cason et al.[2] have been used for analysis so far, but they behave differently from the $\pi^+\pi^-$[3] data below $K\bar{K}$ threshold and cannot help to solve the ambiguity of the solutions in the analysis of $\pi^+\pi^-$ data.

We have analyzed the $\pi^0\pi^0$ system produced in the π^-p charge exchange process $\pi^-p \to \pi^0\pi^0 n$ at 9 GeV/c studied by the E135 experiment with the Benkei spectrometer[4] at the KEK12 GeV PS. We have obtained the $\pi^0\pi^0$ scattering amplitudes and also the $\pi^0\pi^0$ scattering phase shifts below $K\bar{K}$ threshold.

Fig 1 shows the acceptance corrected $\pi^0\pi^0$ mass distribution reconstructed from 4γ's in the final state. The off-mass shell scattering amplitudes $T_{\pi\pi}(m_{\pi\pi}^2, \cos\theta, t)$ are extrapolated to the on-mass shell scattering amplitudes at the pion pole, $T_{\pi\pi}(m_{\pi\pi}^2, \cos\theta, m_\pi^2)$, as the process proceeds through one pion exchange. A linear extrapolation is adopted. The on-mass shell scattering amplitudes can be described, considering the S and D waves, as follows; $T_{\pi\pi}(m_{\pi\pi}^2, \cos\theta, m_\pi^2) = A_S + A_D 5(3\cos^2\theta - 1)/2$, where A_S and A_D are S and D wave scattering amplitudes, respectively.

$\cos\theta$ and t distributions are shown in Fig. 2 a) and b) respectively, for each 40 MeV wide mass bin between 0.36 and 1.64 MeV of $\pi^0\pi^0$ mass. The partial waves obtained are shown in Fig.3 a) and b) for the S and D waves, respectively. Breit-Wigner parameters are obtained above 1 GeV for the S and D waves, as follows; $M = 1278 \pm 5$ MeV and $\Gamma = 197 \pm 8$ MeV for $f_0(1370)$ and $M = 1286 \pm 57$ MeV and $\Gamma = 161 \pm 14$ MeV for $f_2(1270)$. Solid lines in Fig. c) and d) show the results of the fits. A fourth power

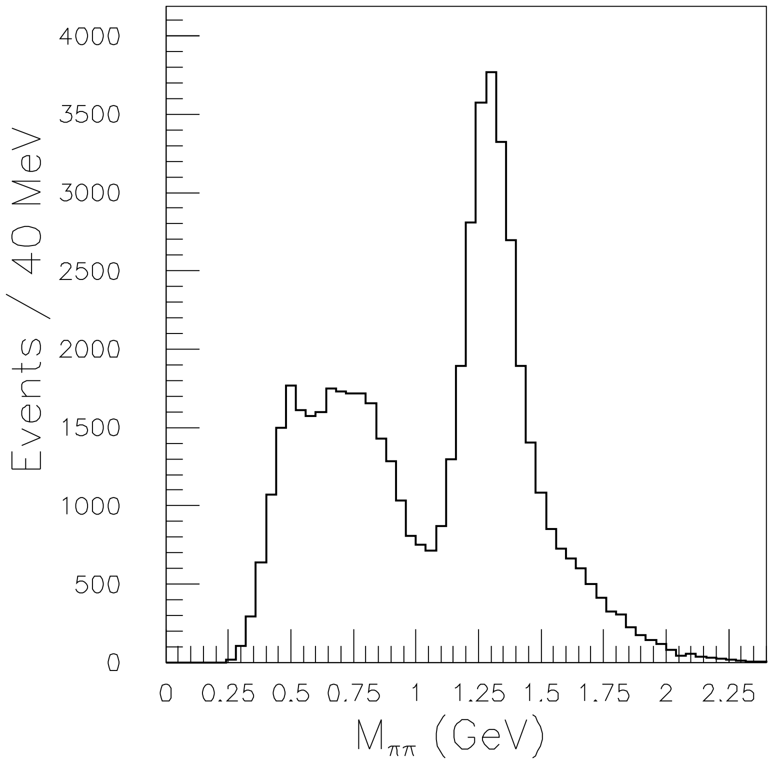

Figure 1. Acceptance corrected $\pi^0\pi^0$ mass distribution

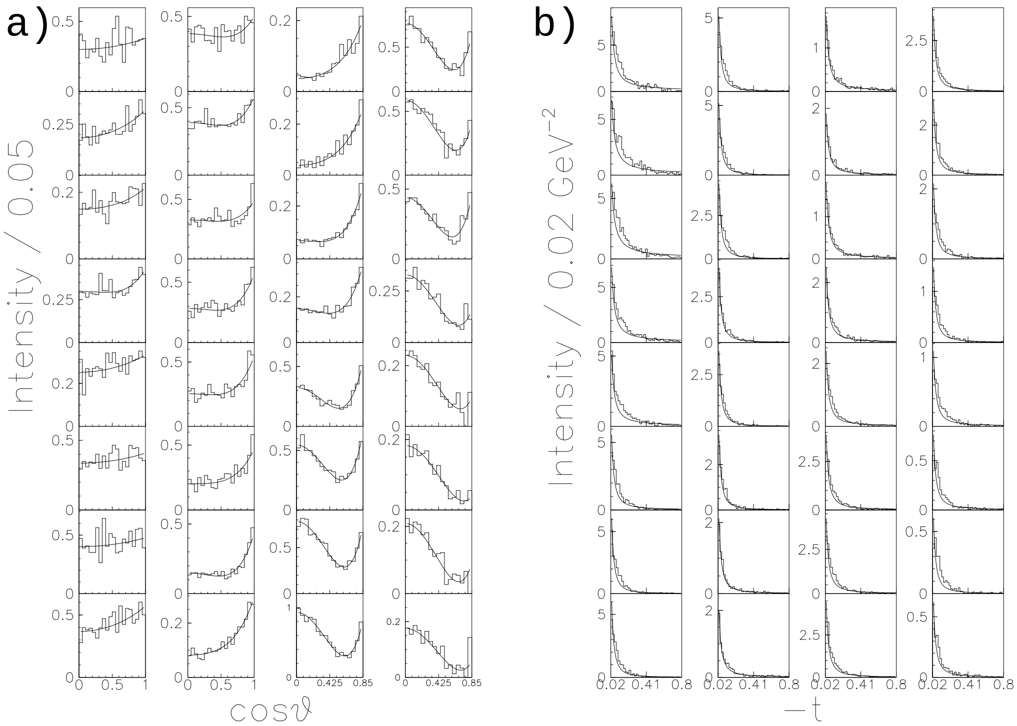

Figure 2. a) cosθ and b) t distributions for each 40 MeV mass bin between 0.36 and 1.64 MeV of $\pi^0\pi^0$ mass. Solid lines show results of the fits. Details are in the text

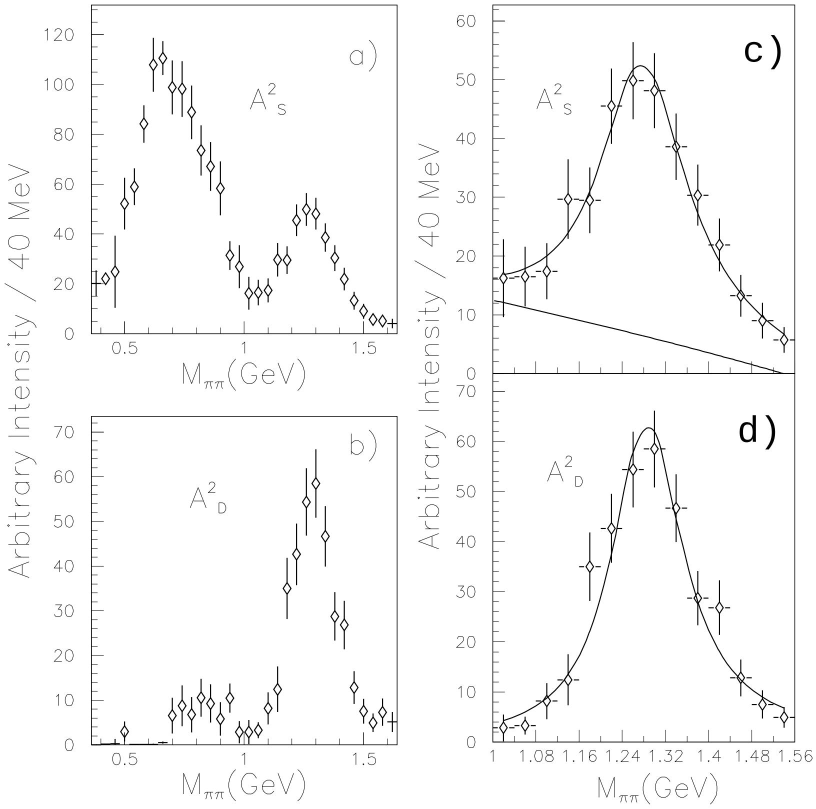

Figure 3. Results of the partial wave analysis. a) for S wave, b) for D wave. c), d) Breit-Wigner fit above 1 GeV for S and D waves, respectively. Solid lines are results of the fits.

polynomial background is used for the S wave.

The S wave $\pi^0\pi^0$ scattering amplitudes can be written $|A_S|^2 \sim \sin^2(\delta_S^0 - \delta_S^2)$ below $K\bar{K}$ threshold where δ_S^0 and δ_S^2 are the S wave scattering phase shifts of I = 0 and I = 2, respectively. We use a hard core type for δ_S^2, as $\delta_S^2 = -r_c|\mathbf{q}_1| = -r_c\sqrt{m_{\pi\pi}^2/4 - m_\pi^2}$, where r_c is the hard core radius. The parameter r_c has been obtained[5] from $\pi^+\pi^-$ data[6] so far. Fig.4 a) shows the normalized S-wave amplitude squared below 1 GeV. The S-wave $\pi^0\pi^0$ phase shifts obtained below $K\bar{K}$ threshold are shown in Fig.4 b) by solid squares. The results are consistent with $\pi^+\pi^-$ phase shift data below 650 MeV, though they appear somewhat higher than those above 650 MeV. The results are consistent with those of the down flat solution obtained in the reanalysis performed recently by Kaminski et al.[7] on the CERN-Cracow Munich polarization data.

The $\pi^0\pi^0$ phase shift data are analyzed by the Interfering Amplitude (IA) method[8]. A hard core is used for the negative background. $f_0(980)$ and σ are the contributing resonant states. The fit is shown by the solid line in Fig.4 c). The fitted parameters of BW for the lower mass resonance, σ are as follows; $M_\sigma = 588 \pm 12$ MeV, $\Gamma_\sigma = 281 \pm 25$ MeV and $r_c = 2.76 \pm 0.15\text{GeV}^{-1}$. The $\chi^2/n_{d.o.f}$ value is 20.4/12. These values are in good agreement with those which we have obtained in our reanalysis[5,8] for $\pi^+\pi^-$ phase shift data. We checked also the case with no negative background (without hard core, $r_c = 0$). The $\chi^2/n_{d.o.f}$ becomes worse: 85.0/13. The BW parameters deviate from those with the hard core as follows; $M_{``\sigma"} = 890 \pm 16$ MeV and $\Gamma_{``\sigma"} = 618 \pm 51$ MeV. The results is

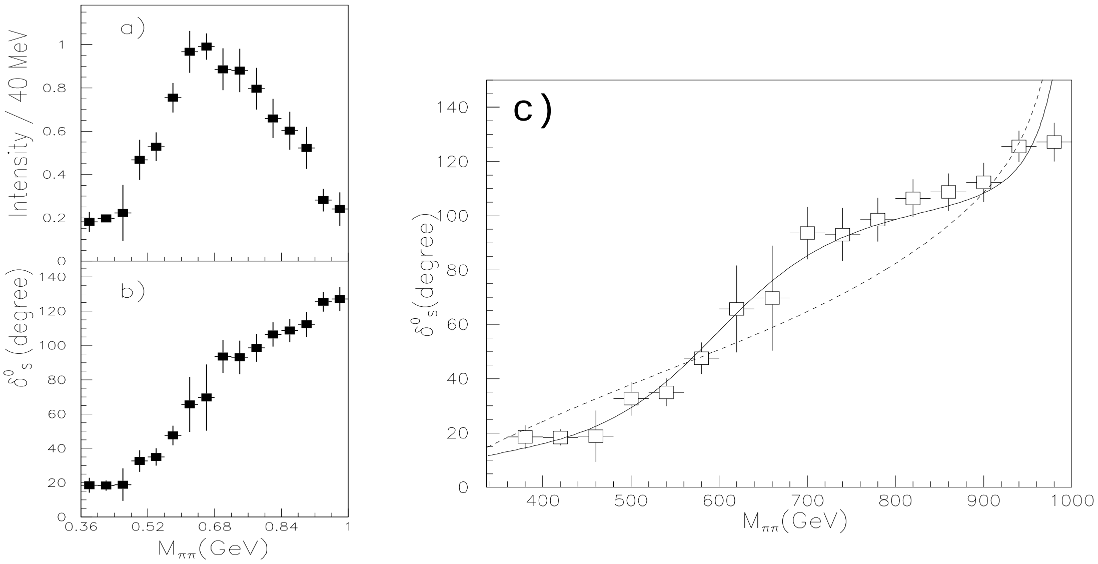

Figure 4. a) Normalized intensity of S wave amplitude squared below 1 GeV, b) S wave $\pi^0\pi^0$ scattering phase shift δ_S^0 below $K\bar{K}$ threshold and c) the result of fitting by the IA method with the hard core (solid line) and without it. (dotted line).

shown by the dotted line in Fig. 4 c).

The difference of I = 0 and I= 2 S wave phase shift, $\delta_S^0 - \delta_S^2$ at the neutral kaon mass is related to the parameters of the CP violation in the neutral K decay. We obtain a value, $\delta_S^0 - \delta_S^2 = 42.5 \pm 3°$, in agreement with the previous result, 40.6±3°[9].

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