Study of pion-pion interaction in $K \to 3\pi$ decays

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The NA48/2 experiment at the CERN SPS is searching for direct CP cviolation in K+- decays to three pions. The experiment uses simultaneous K+ and K- beams of 60 ± 3 GeV/c momentum which overlap in the fiducial region. During 2003 and 2004 about 4 billions fully reconstructed $K^{\pm} \to \pi^{\pm}\pi^{+}\pi^{-}$ decays and more than 100 millions $K^{\pm} \to \pi^{\pm}\pi^{0}\pi^{0}$ have been collected. The results from a study of the $\pi^0\pi^0$ invariant mass distribution M_{00} in a partial sample of 30 millions decays $K^{\pm} \to \pi^{\pm}\pi^{0}\pi^{0}$ are reported, showing a cusp-like structure centerd at $M_{00} = 2M_{\pi^+}$. The experimental apparatus consists mainly of a magnetic spectrometer, with a momentum resolution $\sigma(p)/p = 1.02\%(+)0.044\%$ and a liquid Krypton calorimeter segmented transversally into 13248 2cm×2cm cells. The calorimeter is 27 X_0 thick and has and energy resolution for photons $\sigma(E)/E = 0.032/\sqrt{E}(+)0.09/E(+)0.0042$ (E in GeV) and space resolution $\sigma(x) = \sigma(y) = 0.42/\sqrt{E}(+)0.06$ cm thus allowing the accurate detection of multi-photons events. By imposing the π^0 invariant mass to pairs of photons and requiring the compatibility of a common origin for four-photon events grouped in two π^0 pairs and at the same time the Kaon invariant mass including the additional charged pion detected in the magnetic spectrometer, decays of $K^{\pm} \to \pi^{\pm}\pi^{0}\pi^{0}$ can be fully reconstructed with negligible background. The resolution in the $\pi^0\pi^0$ invariant mass near $M_{00} = 279$ MeV is typically 0.5 MeV. The distribution of the events as a function of M_{00}^2 shows a cusp like structure around $M_{00}^2 = 4M_{\pi^+}^2$ which is definitely not due to an instrumental effect, given the intrinsic smoothness of the acceptance. It is impossible to fit the distribution with the usual parametrization employed by the PDG whenever the cusp region is included in the range for the fit. A good fit, with $\chi^2 = 149/147$ d.o.f., is obtained by using the expression of the matrix element as specified in [1] which takes into account one and two-loops pion-pion scattering, in particular $\pi^+\pi^- \to \pi^0\pi^0$ charge exchange, and allowing for the contribution of the formation of pionium atoms, with their subsequent $\pi^0\pi^0$ decay, with a branching ratio as calculated by Silagadze [2]. The main ingredient of the fit is the difference $a_0^0 - a_0^2$ between the I=0 and I=2 S-wave pion-pion scattering lenghts. With the present sample the statistical error in the determination of $a_0^0 - a_0^2$ is about 4% while the systematic uncertainty is still under evaluation.

In conclusion the study of the M_{00}^2 distribution in $K^{\pm} \to \pi^{\pm}\pi^{0}\pi^{0}$ decays by the NA48/2 experiment allows for a novel and potentially more precise determination of $a_0^0 - a_0^2$ which is made possible in particular by the quality of its multi-photon detection capability.

References

[1] N. Cabibbo and G. Isidori, arXiv:hep-ph/0502130.

[2] Z. K. Silagadze, JETP Lett. **60** (1994) 689 [arXiv:hep-ph/9411382].