Study of the radiative decays $\phi \to f_0(980)\gamma$ and $\phi \to a_0(980)\gamma$ with the KLOE detector

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Abstract. The KLOE experiment at the electron-positron collider DAPHNE has collected in the 2001-2002 running period an integrated luminosity of 450 pb^{-1}. Through the radiative ϕ decays, large samples of the light scalar mesons $f_0(980)$ and $a_0(980)$ are available. The f_0 meson is clearly observed in $\pi^+\pi^-$ and $\pi^0\pi^0$ final states, the a_0 in the $\eta\pi^0$ final states. Invariant mass spectra and Dalitz plot densities are analyzed to investigate the controversial structure of these particels.

Keywords: e^+e^- collisions, ϕ radiative decays, scalar mesons
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INTRODUCTION

At the ϕ factory DAPHNE, the lightest scalar mesons of isospin 0 and 1 are accessible through the radiative decay $\phi \to$scalar+γ. The study of these decays is motivated by the following considerations. Since the ϕ is a pure $s\bar{s}$ state, the coupling of any meson to the ϕ is related to the s-quark content of the meson. This is an important ingredient to discriminate between the quark-antiquark and the tetraquark interpretation of these particles [1]. Moreover a comparison between the f_0 and a_0 properties, allows to study possible effects of isospin mixing in the scalar sector [2]. Finally an high statistics study of invariant mass spectra and Dalitz plot densities allows to check the existence of the $f_0(600)$.

The $f_0(980)$ is studied looking at the 2 pion decays, $\pi^+\pi^-$ and $\pi^0\pi^0$ since the $f_0 \to$KK decay is strongly disfavoured. In both cases a huge unreducible background partly interfering with the signal is present: initial and final state radiation in the case of $\pi^+\pi^-$, $e^+e^- \to \omega\pi^0$ with $\omega \to \pi^0\gamma$ in the case of $\pi^0\pi^0$.

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The $a_0(980)$ is studied looking at $\eta\pi^0$ final states using two different samples: a fully neutral one due to $\eta \rightarrow \gamma\gamma$ and a charged and neutral one due to $\eta \rightarrow \pi^+\pi^-\pi^0$. The unreducible background is in this case much lower.
DAFNE is an e^+e^--collider with a center of mass energy around 1 GeV, providing a peak luminosity of $10^{32}\mathrm{cm}^{-2}\mathrm{s}^{-1}$. The KLOE detector consists of a large-volume cylindrical drift chamber [3], surrounded by a sampling calorimeter [4] made of lead and scintillating fibers. The entire detector is located within a magnetic field B=0.52 T. The trigger [5] is based on the detection of at least two energy deposits in the calorimeter. In the following we present the analysis of the mass spectra using two distint models.

DATA ANALYSIS AND RESULTS

We search the $f_0(980)$ signal in the $\pi\pi$ invariant mass (m in the following) spectrum of $\pi^+\pi^-\gamma$ events with a photon at large polar angle ($\theta_\gamma > 45°$) to reduce the initial state radiation background. We require a vertex with two tracks at the e^+e^- interaction region and a photon matching the missing momentum of the tracks pair. The kinematics of the event, together with the time of flight signature, allows the rejection of $e^+e^-\gamma$, $\mu^+\mu^-\gamma$ and $\pi^+\pi^-\pi^0$ background events.
Fig.1 shows the m spectrum of the selected events. The distribution is dominated by the initial state radiation events characterized by the ρ^0 peak and by the ρ-ω interference pattern. In the region around m=980 MeV we observe a small bump due to the $f_0(980)$. Two fits of the full spectrum are shown according to two different approaches for the description of the f_0 amplitude: the first is based on the kaon-loop model [1] the second (called no-structure model in the following [6]) assumes the scalar amplitude as the sum of a Breit-Wigner and a polynomial continuum. A good fit is obtained in both cases by introducing one scalar meson only with a mass compatible with the $f_0(980)$ mass. Preliminary values of the parameters are given in Tab.1 for the kaon-loop fit.
We study also the charge asimmetry $A = (N(\theta^+ > 90°) - N(\theta^+ < 90°))/(N(\theta^+ > 90°) + N(\theta^+ < 90°))$ with θ^+ the polar angle of the positive pion, that is expected to be different from zero due to the presence of C-odd and C-even terms in the cross-section. The m dependence of A is shown in Fig.2 compared to the Montecarlo prediction with and without a scalar amplitude based on the kaon-loop results of the invariant mass fit shown in Fig.1. A negative bump is observed in the region around m=980 MeV in this case also. Notice that in order to have a good description of the spectrum, the inclusion of the scalar amplitude is necessary.
$\pi^0\pi^0\gamma$ events are selected by requiring no tracks and 5 photons at an angle larger than 21°. Two kinematic fits are applied: the first requiring energy-momentum conservation, and the second associating the photons and imposing the π^0 masses. The analysis strategy is partly changed with respect to the previous one [7]: $\omega\pi^0$ events are not rejected anymore since they have in principle a sizeable interference term with the signal events; moreoever in order to appreciate better the signal vs. background composition of the selected sample, a 2-dimensional analysis $m^2_{\pi^0\gamma}$ vs. $m^2_{\pi^0\pi^0}$ is performed. The resulting Dalitz plot is shown in Fig.3. The two “bands” on the left side of the diagram are due to the $\omega\pi^0$ background, the cluster of events on the right corner, is due to the f_0 signal.

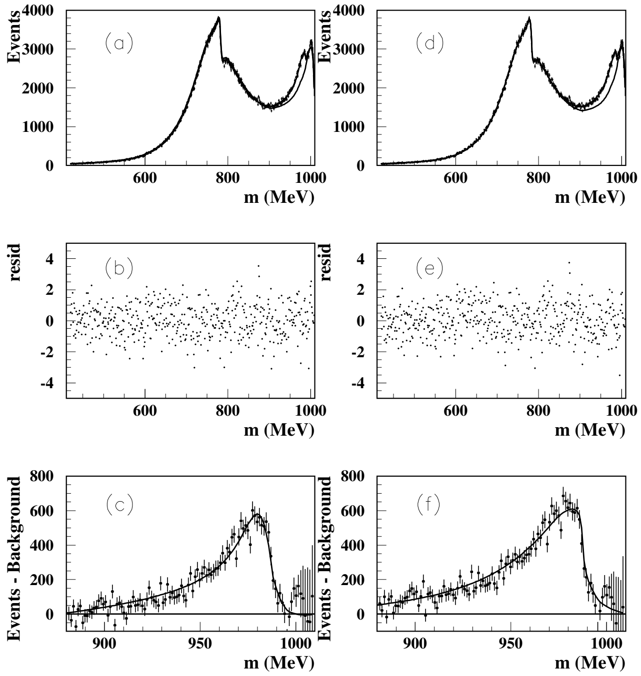

FIGURE 1. Result of the no-structure fit (a)-(b)-(c) and of the kaon-loop fit (d)-(e)-(f). (a)-(d) Data spectrum compared with the fitting function (upper curve following the data points) and with the estimated non-scalar part of the function (lower curve); (b)-(e) fit residuals as a function of *m*; (c)-(f) the fitting function is compared to the signal events obtained subtracting to the measured data spectrum the non-scalar part of the function in the f_0 region.

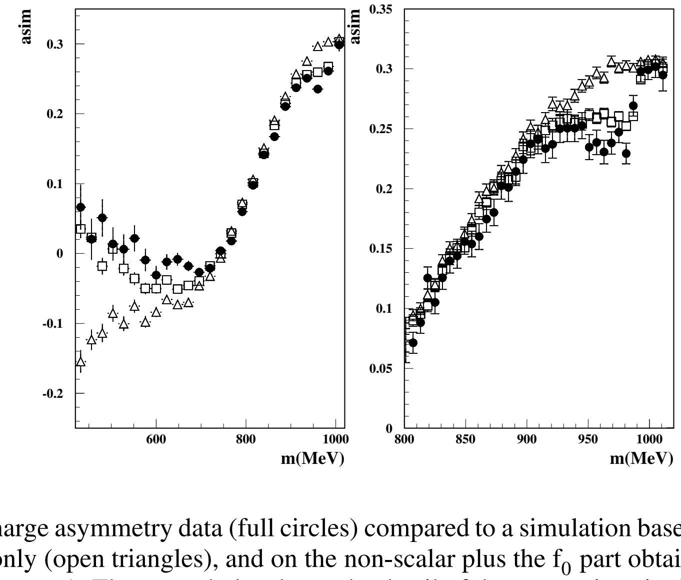

FIGURE 2. Charge asymmetry data (full circles) compared to a simulation based on the non-scalar part of the spectrum only (open triangles), and on the non-scalar plus the f_0 part obtained from the kaon-loop amplitude(open squares). The second plot shows the detail of the comparison in the f_0 region.

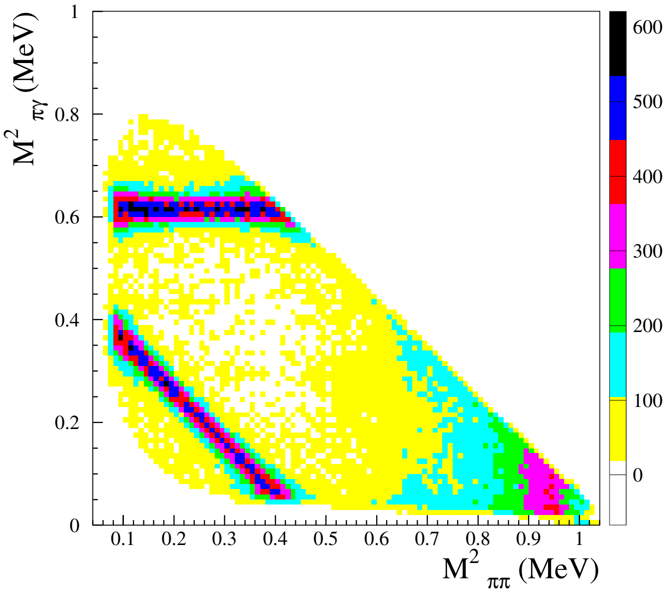

FIGURE 3. Dalitz plot distribution ($m^2_{\pi^0\gamma}$ vs. $m^2_{\pi^0\pi^0}$) of the $\pi^0\pi^0\gamma$ data sample.

TABLE 1. Preliminary results for the masses and the couplings of the f_0 and a_0 to KK, $\pi^+\pi^-$ and $\eta\pi^0$, within the kaon-loop framework.

m_{f_0} (MeV)	983	m_{a_0} (MeV)	987
g_{f_0KK} (GeV)	5.9	g_{a_0KK} (GeV)	2.3
$g_{f_0\pi^+\pi^-}$ (GeV)	3.6	$g_{a_0\eta\pi}$ (GeV)	2.6
R=$g^2_{f_0KK}/g^2_{f_0\pi^+\pi^-}$	2.7	R=$g^2_{a_0KK}/g^2_{a_0\eta\pi}$	0.8

An acceptable description of the Dalitz-plot distribution is obtained using the kaon-loop model to describe the scalar amplitude and the vector dominance model to describe the $\omega\pi^0$ background. Evaluation of the parameters is in progress.
Finally, the $\eta\pi^0$ invariant mass spectra are shown in Fig.4 for the two selected samples. A good fit is obtained using the kaon-loop model as in Ref.[8]. Preliminary values of the parameters are given in Tab.1.

SUMMARY AND OUTLOOK

The kaon-loop frame describes our entire data set. Looking at the couplings reported in Tab.1, we observe that the $f_0(980)$ is strongly coupled to kaons (R=2.7) the a_0 is less strongly coupled to kaons (R=0.8). The previous KLOE results [7, 8] are confirmed in both cases.

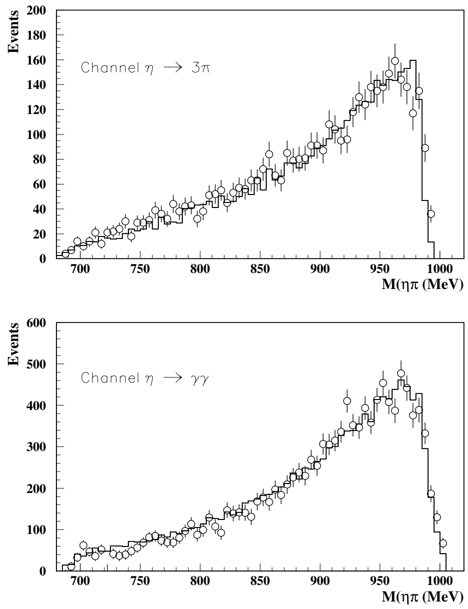

FIGURE 4. $\eta\pi^0$ invariant mass distributions (open points) from the two $\eta\pi^0\gamma$ selected samples. The histograms are the results of a combined fit of the two distributions.

The no-structure approach still requires theoretical effort. By the way it also describes in an acceptable way the observed spectra.
Finally, the $\pi^+\pi^-\gamma$ fits do not require any $f_0(600)$ to describe the data.
By the end of the year, KLOE will have collected a data sample of $\sim$2 fb^{-1} that is a factor $\sim$5 more than the data presented here. With such a statistics it will be possible to look for f_0, a_0 going to KK pairs also.

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