Title

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Publication Date

2014

DOI

10.1016/j.nuclphysbps.2013.10.060

Recent results from KLOE

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We report the newest results from the KLOE experiment on hadronic physics, such as the parameters of scalars f_0 and a_0, the η meson mass measurements and dynamics, the first observation of the $\eta \rightarrow \pi^+ \pi^- e^+ e^-$ rare decay, and study of $e^+e^-\rightarrow\omega\pi^0$cross section around the ϕ resonance.

1 The KLOE experiment

The KLOE experiment [1] runs at the Frascati ϕ factory DAΦNE, a high luminosity e^+e^- collider working at $\sqrt{s} \sim 1020$ MeV, corresponding to the ϕ meson mass.
The KLOE detector consists of a large cylindrical drift chamber [2], surrounded by a sampling lead-scintillating fiber electromagnetic calorimeter [3]. Both detectors operate inside a uniform magnetic field of ~ 0.5 T provided by a superconducting coil. In the whole data taking $(2001-2006)$ KLOE has collected an integrated luminosity of 2.5 fb^{-1} corresponding to about 8 billions of ϕ produced, plus some *off-peak* data (200 pb^{-1} at 1 GeV). The KLOE trigger system [4] is highly efficient on most of the ϕ decay.

2 Scalar physics

At KLOE the scalar mesons are produced through $\phi\rightarrow S\gamma$ radiative decays . This allows to observe the f_0, σ and a_0 members of the light scalar mesons multiplet.

KLOE has already published measurements related to decays $f_0\rightarrow\pi\pi$, for neutral [5] and charged [6] final states. Different techniques has been used to analyze the two channels: fit to the Dalitz plot density and fit to the di-pion invariant mass, respectively. In both cases two different phenomenological models have been used, Kaon-Loop [7] (KL) and "no structure" [8] (NS). Agreement between the f_0 parameters extracted from the two channels in the cited analyses are modest. A much better agreement between the two channels is found using an improved version of the KL model. The update preliminary for the two channels are shown in Tab.1. Currently, we are performing a combined fit of the two spectra.

Table 1: Updated results for f_0 parameters.

Channel	Mass [MeV]	g_{f_0KK} [GeV^2]	$g_{f_0\pi\pi}$ [GeV^2]	R = $(g_{f_0KK}/g_{f_0\pi\pi})^2$
$f_0 \rightarrow \pi^+\pi^-$	983.7	4.74	-2.2	4.6
$f_0 \rightarrow \pi^0\pi^0$	984.7±2.1	3.97±0.46	-1.82±0.2	4.76± 0.78

The a_0 meson has been studied [10] using the dominant decay $a_0 \rightarrow \eta\pi^0$. Two different η decay modes have been selected: $\eta \rightarrow \gamma\gamma$ and $\eta \rightarrow \pi^+\pi^-\pi^0$. The two samples are independent

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and have very different background contaminations. Since the interfering $\phi \to \rho\pi^0 \to \eta\gamma\pi^0$ background is small, it is possible to extract the branching fraction (BR) directly from event counting after the residual background subtraction:

$$BR(\phi \to a_0\gamma)_{\gamma\gamma} = (6.9{\pm}0.1{\pm}0.2){\times}10^{-5} \qquad BR(\phi \to a_0\gamma)_{\pi^+\pi^-\pi^0} = (7.2{\pm}0.2{\pm}0.2){\times}10^{-5} \quad (1)$$

In order to determine the a_0 relevant parameters the $\eta\pi^0$ invariant mass spectrum, after background subtraction, are being fitted with KL and NS parametrisation not reported here.

Using 1.4 fb^{-1} of the KLOE data, a search [11] for the decay $\phi{\to}K\bar{K}\gamma$ has been performed. In this decay the $K\bar{K}$ pair is produced with positive charge conjugation (*e.g.* $|i\rangle \propto |K_SK_S\rangle + |K_LK_L\rangle$) and a limited phase space due to the small mass difference between the ϕ and the production threshold of two neutral kaons (995 MeV). The signature of this decay is provided by the presence of either 2 K_S or 2 K_L and a low energy photon. In the reported analysis, only the K_SK_S component has been used, looking for double $K_S{\to}\pi^+\pi^-$decay vertex.
Theory predictions on the BR($\phi{\to}K\bar{K}\gamma$) spread over several orders of magnitude. The latest evaluations essentially concentrate in the region of 10^{-8} (Fig. 1-bottom right). Several of them are ruled out by our result.
At the end of the analysis we observe 1 candidate with 0 expected background. The upper limit of the signal expectation is evaluated to be $S_{UL} = 3.9$ @ 90% $C.L.$ which correspond to an upper limit on the BR of:

$$BR(\phi \to K\bar{K}\gamma) < \frac{2 \cdot S_{UL}}{L_{\rm int} \cdot \sigma_\phi \cdot BR^2(K_S \to \pi^+\pi^-) \cdot \varepsilon} = 1.8 \cdot 10^{-8}, \qquad (2)$$

where the factor 2 accounts for the multiplicity in the initial state, ε is our signal efficiency, $L_{\rm int}$ is the integrated luminosity and σ_ϕ is the ϕ production cross section.

3 η physics

In this paper, we report the best measurement of the η mass to date using the $\phi \to \eta\gamma$ decay. This decay chain, assuming the ϕ meson at rest, is a source of monochromatic η-mesons of 363 MeV/c, recoiling against a photon of the same momentum. Detection of such a photon tags the presence of the η-meson. Photons from $\eta \to \gamma\gamma$ cover a continuum flat spectrum between $147 < E_\gamma < 510$ MeV in the laboratory reference frame. The accuracy of the kinematic reconstruction of the event is due to the precise measurement of the photon emission angles. Due to the stability of the calibration for the detector and the very large sample of η-mesons collected, we have been able to obtain a very precise measurement of the η-mass [12].
The systematic uncertainties are from to detector response and alignment, event selection cuts, kinematic fit and beam energy calibration. We obtain the most accurate measurement so far:

$$m_\eta = (547.873\ \pm 0.007_{\rm stat}\ \pm 0.031_{\rm syst}) \quad {\rm MeV}, \qquad (3)$$

The decay of the isoscalar η into three pions occurs through isospin violation and thus is sensitive to the up-down quark mass difference. Neglecting electromagnetic corrections, the decay amplitude is parametrised in terms of kinetic energy of the three pions[15]. Following the conventional notation, the decay amplitude is expanded around the center of the Dalitz plot (X=Y=0) in powers of X and Y as: $|A(X,Y)|^2 \simeq 1 + aY + bY^2 + cX + dX^2 + eXY + fY^3 + ..$ and the parameters $(a, b, c, d, e, f, ..)$ of the expansion are fitted to the experimental data. The KLOE results in 10^{-3} units are:

$$a = -1090 \pm 5^{+8}_{-19} \qquad b = 124 \pm 6 \pm 10 \qquad d = 57 \pm 6^{+7}_{-16} \qquad f = 140 \pm 10 \pm 2 \qquad (4)$$

The f parameter was totally unexpected, and the value of the b is lower of what expected in the current algebra assumption ($b = a^2/4$). In addiction, this study allows us to set the most accurate limit on the Dalitz plot asymmetries which are sensitive to charge conjugation violation.

The $\eta \to 3\pi^0$ decay is a major decay mode of the η despite the fact that is a G–parity forbidden transition. This decay is due almost exclusively to the isospin breaking part of QCD. For the decays into three identical particles, it is possible to use a symmetrical Dalitz plot where the event density is described as a function of a single variable z: $|A_{\eta \to 3\pi^0}(z)|^2 \sim 1 + 2\alpha z$. α represents the difference from pure phase space. The lowest order predictions of Chiral Perturbation Theory quote a zero value for α. KLOE results has been obtained using the Dalitz density normalized with the MC expectation for pure phase space decay (Fig. 1-top right). The preliminary result [16] is:

$$\alpha = -0.027 \ \pm 0.004_{\rm stat} \ {}^{+0.004}_{-0.006}{}_{\rm syst} \tag{5}$$

The study of the $\eta \ \to \ \pi^+ \ \pi^- \ e^+ \ e^-$ decay allows to probe the internal structure of the η meson [17] and could be used to compare different theoretical predictions [18]. Moreover, it would be possible to study CP violation not predicted by the Standard Model [19]. This can be experimentally tested by measuring the angular asymmetry between pions and electrons decay planes. The preliminary measurement presented here is based on 600 pb^{-1}, and is the first observation of such a process. The number of selected signal events ($N_{events} = 733 \pm 62$) has been determined using MC shapes for signal and backgrounds (Fig. 1-top left), we obtain:

$$BR(\eta \ \to \ \pi^+ \ \pi^- \ e^+ \ e^-) = (24 \ \pm 2_{\rm stat} \ \pm 4_{\rm syst}) \times 10^{-5}. \tag{6}$$

The selection efficiency of our signal, ϵ, is evaluated by MC to be $\epsilon = 0.1175(5)$.

KLOE has studied the η/η' mixing [13] using the measured $R_\phi = BR(\phi \to \eta'\gamma)/BR(\phi \to \eta\gamma)$ following the prescription of Bramon *et al.* [14]. In our analysis we allow for a gluonium content in the η' meson wave function even if the model parameters used in the analysis was calculated with the opposite assumption by Bramon (*e.g.* no gluonium content). Further checks has been performed to validate our previous results. Up to now the fraction of gluonium in the wave function is stable whit respect to the variation of the model parameters.

4 Continuum process

Using $\sim$ 600 pb^{-1} collected at center of mass energies between 1000 and 1030 MeV, the cross sections of $e^+e^- \to \omega\pi^0$ in two different final states have been studied [20]: $\pi^+\pi^-\pi^0\pi^0$ and $\pi^0\pi^0\gamma$. In this energy region, the production cross section for both final states is largely dominated by the non-resonant processes $e^+e^- \to \rho/\rho' \to \omega\pi^0$. However, in a region closer to M_ϕ, a contribution from the decay $\phi{\to}\omega\pi^0$ could be observed as an interference with the non-resonant processes.The cross section as a function of $\sqrt{s}$ can be parametrized in the form [21]:

$$\sigma(\sqrt{s}) = \sigma_0(\sqrt{s}) \cdot |1 - Z\,(m_\phi \Gamma_\phi \Pi_\phi)|^2 \qquad \Pi_\phi = (m_\phi^2 - \sqrt{s}^2 - i\sqrt{s}\Gamma_\phi)^{-1} \tag{7}$$

where Z is the complex interference parameter (i.e. the ratio between the ϕ decay amplitude and the non resonant processes), $\sigma_0(\sqrt{s})$ is the non-resonant cross section while m_ϕ, Γ_ϕ and D_ϕ are the mass, the width and the inverse propagator of the ϕ meson respectively. For $\sigma_0(\sqrt{s})$ a linear approximation has been used. The measured visible cross section for both final state are fitted with Eq. 7 convoluted with radiator function [22] (Fig. 1-bottom left).
Using the cross section, the partial decay width ratio has been obtained: $\Gamma(\omega \to \pi^0\gamma)/\Gamma(\omega \to \pi^+\pi^-\pi^0) = 0.093 \pm 0.002$
Since these two final states correspond to the 98% of the ω decay width, we use the ratio together with the unitarity [23] to extract the main ω branching fractions:

$$BR(\omega \to \pi^+\pi^-\pi^0) = (89.94 \pm 0.23)\% \quad BR(\omega \to \pi^0\gamma) = (8.40 \pm 0.19)\% \tag{8}$$

The measured parameters for $\omega\pi^0$ cross section in $\pi^+\pi^-\pi^0\pi^0$ final state and the peak value of the bare production cross section for the ϕ resonance [24] are related to the BR($\phi{\to}\omega\pi^0$) through the relation:

$$BR(\phi \to \omega\pi^0) = \sigma_0(m_\phi)|Z|^2/\sigma_\phi = (5.63 \pm 0.70) \times 10^{-5} \tag{9}$$

Results 8 and 9 improves by a factor two the accuracy whit respect to the previous determination.

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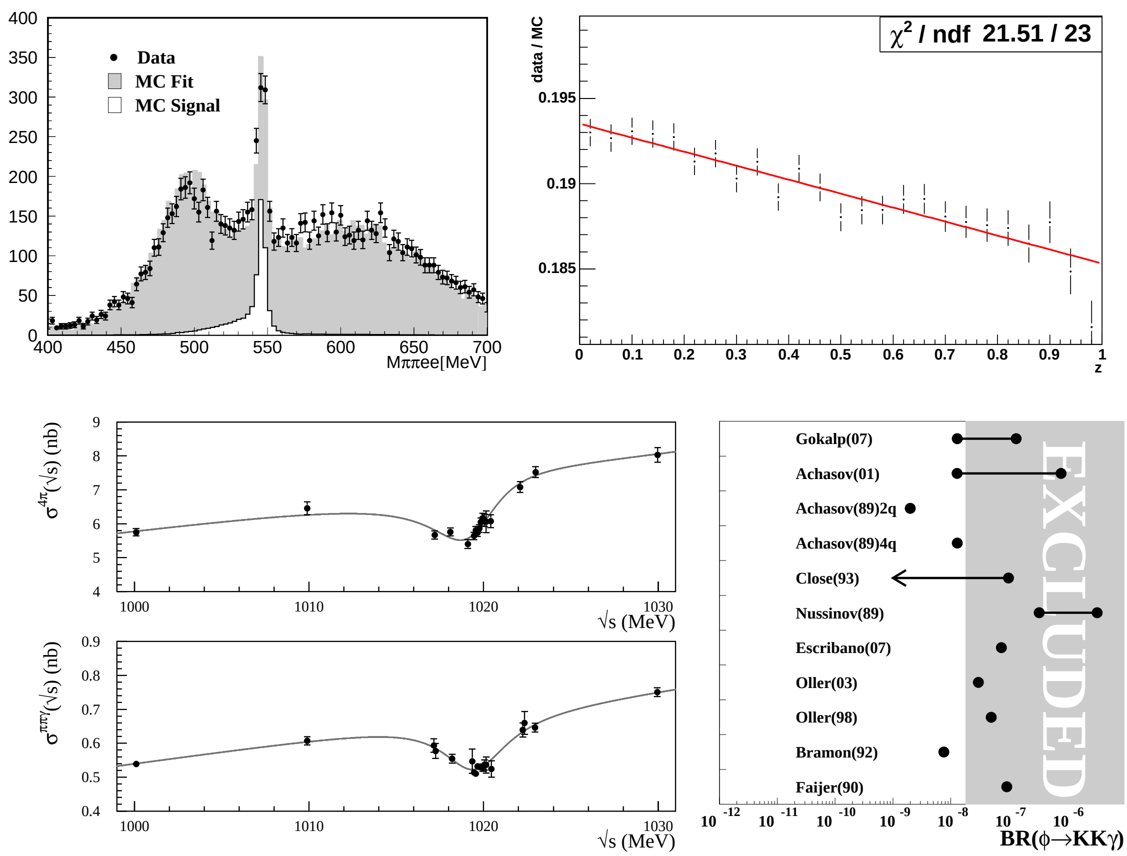

Figure 1: From top-left to bottom-right: η mass fit in $\eta \to \pi^+ \pi^- e^+ e^-$ analysis, slope α for $\eta \to 3\pi^0$, visible cross section fit for the $e^+e^- \to \pi^+\pi^-\pi^0\pi^0$(top) and $e^+e^- \to \pi^0\pi^0\gamma$(bottom) channels, UL on BR($\phi \to K\bar{K}\gamma$) exclusion plot.