Perspectives on hadron physics at KLOE with 2.5 fb^{-1}.

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The status of the KLOE data taking and the topics related to the η, η' physics which will be addressed by the analysis of a sample of 2.5 fb^{-1} of integrated luminosity at the Frascati ϕ-factory, DAΦNE, are summarized.

1 KLOE data taking

The KLOE experiment has integrated a total luminosity of 2.2 fb^{-1}. At present, typical DAΦNE currents in collision are $\sim$1.4 A for positrons and $\sim$1.7 A for electrons, in 109 bunches. With these values, a peak luminosity of 1.4×10^{32} cm^{-2} s^{-1} has been achieved. The performance has been obtained thanks to the continuous work aimed at increasing beam currents while keeping low background rates [1].

By the end of year 2005 KLOE, as it is now, will complete its data taking at the ϕ resonance peak, with a total integrated luminosity of about 2.5 fb^{-1}, corresponding to a sample of 10^8 η and 5x10^5 η' mesons.

In year 2006 a scan in energy, between 1010 and 1030 MeV, is scheduled for the precise measurement of the ϕ lineshape, on the basis of about 100 pb^{-1}. Further 250 pb^{-1} will be collected at 1000 MeV, mostly to reduce the systematic error on the hadronic cross section near threshold for 2-pion production [2].

2 The KLOE detector

The KLOE detector is composed of a large drift chamber and a hermetic electromagnetic calorimeter immersed in the 0.52 T field of a superconducting solenoid.

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The requirements for the tracking system are very demanding to guarantee good resolution for low-momentum tracks and low absorption for photons over the large volume needed to have reasonable acceptance for the K_L decays, since the mean decay length of the K_L at DAΦNE is 3.4 m.

The drift chamber [3], 2 m radius, 4.2 m length, for a gran total of 52140 stereo wires, provides a spatial resolution of about 2 mm in the beam direction and 150 μm in the transverse plane. The requirement of high transparency poses severe constraints in the choice of materials and thickness of the chamber walls, in Carbon fibers. The drift chamber is filled with a He-based gas mixture that has been chosen to reduce the effects of multiple scattering, photon conversion and kaon regeneration. The transverse momentum resolution, σ(p)/p, is better than 0.4% for large-angle tracks ($40° \leq \theta \leq 140°$).

The lead-scintillating fiber calorimeter [4] has been designed to detect photons with energy as low as 20 MeV, and to accurately measure their energy and time of flight. Particularly relevant is the performance in term of time resolution, σ_T = 57 ps/$\sqrt{E(GeV)}$. The calorimeter consists of the barrel and the end-caps; the modules of the end-cap are C-shaped to minimize dead zones, a solution which allows the 98% coverage of full solid angle. The trigger [5] for Data Acquisition (DAQ) is provided by energy deposits in the calorimeter or by hit wires in the DC. Trigger logic is very efficient for ϕ-decays and residual dependences of the efficiency on event topologies can be directly measured comparing DC and calorimeter triggers, that rely on independent criteria.

3 The η/η' physics

At the ϕ-factory, visible cross section for ϕ production is about 3.3μb and the η (η') mesons are produced in the 2-body decays $\phi \to \eta(\eta')\gamma$ with a branching ratio (BR) of 1.3% (6x10^{-5}).

The monochromatic photon coming from ϕ decays, γ_ϕ, can be used to select the η (η') events. This kind of signature is very effective in the case of the η-meson sample, due to the γ_ϕ energy of 363 MeV, higher than the energy of the photons coming from the other processes (except those from $e^+e^- \to \gamma\gamma$). The worst case is the $\eta \to \gamma\gamma$ decay whose photons show an energy distribution partially overlapping the γ_ϕ reconstructed energy.

Less stringent is the signature for the η' sample: the monochromatic photon has an energy of 60 MeV and good separation from photons of the η' decay is obtained only in the case of the decay $\eta' \to \eta\pi^+\pi^-$ with $\eta \to \gamma\gamma$. In this case the photons from η decay have an energy distribution with $E_\gamma \geq 150$ MeV, definitely higher than the energy of the monochromatic photon from ϕ decay.

η decay	BR (%)	η' decay	BR (%)
$\gamma\gamma$	39.43±0.26	$\eta\pi^+\pi^-$	44.3 ± 1.5
$\pi^0\pi^0\pi^0$	32.51±0.29	$\gamma\pi^+\pi^-$	29.5 ± 1.0
$\pi^+\pi^-\pi^0$	22.60±0.40	$\eta\pi^0\pi^0$	20.9 ± 1.2
$\pi^+\pi^-\gamma$	4.68±0.11	$\omega\gamma$	3.03±0.31
		$\gamma\gamma$	2.12±0.14

Tab. 1. Main BR's for η and η' decays [6].

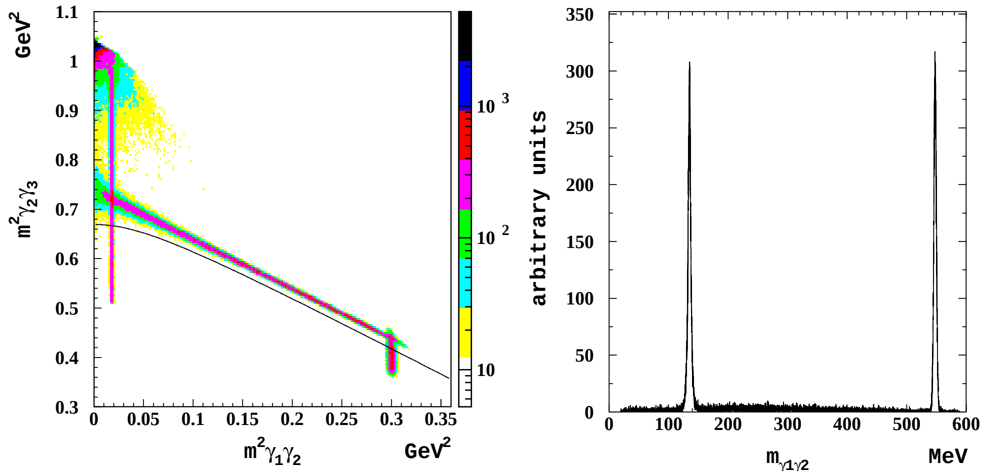

Fig. 1. Three-photons final state for a KLOE sample of 50 pb^{-1}. Left-side: Dalitz-plot distribution with photon indices ordered by increasing energy. Right-side: projection on $M_{\gamma_1\gamma_2}$ axis of the events below the solid line drawn in the Dalitz-plot.

The η major decay channels reported in tab.1 have been extensively studied at KLOE. The $\eta \to \gamma\gamma$ decays shown in fig.1 have been used for the measurement of the η mass [7]; the 3-pion decays have been studied for extracting the Dalitz plot parameters [8], and the $\eta \to \pi\pi\gamma$ channel has been currently analyzing to obtain the di-pion spectrum of interest for χPT [9]. The selection of $\eta \to \pi\pi\gamma$ decays is affected by background contaminations from Bhabha and $\phi \to \pi^+\pi^-\pi^0$ events; however good background rejection, leading to signal over background ratios S/B ≈460, has been obtained cutting on both, the reconstructed energy of the γ_ϕ, and the invariant mass of the 2-pion system.

We expect to improve also the precision in the knowledge of the cross section $\sigma(e^+e^- \to e^+e^-\eta)$, directly related to the width $\Gamma(\eta \to \gamma\gamma)$. For the study of the $\gamma - \gamma$ processes the "off-peak" data-taking planned in year 2006 is helpful, giving the opportunity to study the process without backgrounds from ϕ decays.

Samples of $\eta' \to \eta\pi^+\pi^-$ and $\eta' \to \eta\pi^0\pi^0$ have been selected for the measurement of the ratio R_η = BR($\phi \to \eta'\gamma$)/BR($\phi \to \eta\gamma$), proportional to $\cot^2\phi_P$ [10]. From the data set of 450 pb^{-1} collected in years 2001-2002 we have obtained an almost background-free sample of 3,400 events currently under study, shown in fig.2. These events have the same final state with two charged and three neutral π's, coming from $\eta' \to \eta\pi^+\pi^-$ and $\eta' \to \eta\pi^0\pi^0$ with, respectively, $\eta \to \pi^0\pi^0\pi^0$ and $\eta \to \pi^+\pi^-\pi^0$. R_η measurement is at present limited by the accuracy in the knowledge of the BR($\eta' \to \eta\pi^+\pi^-$) [7]. To overcome this limitation we intend to include in the analysis all main decay channels.

One of our goals is to perform the concurrent measurement of all the major branching ratios for both, the η, and the η' mesons to obtain a significant improvement in the precision levels, desirable for progressing in the knowledge, for example, of the η-η' mixing angle [10].

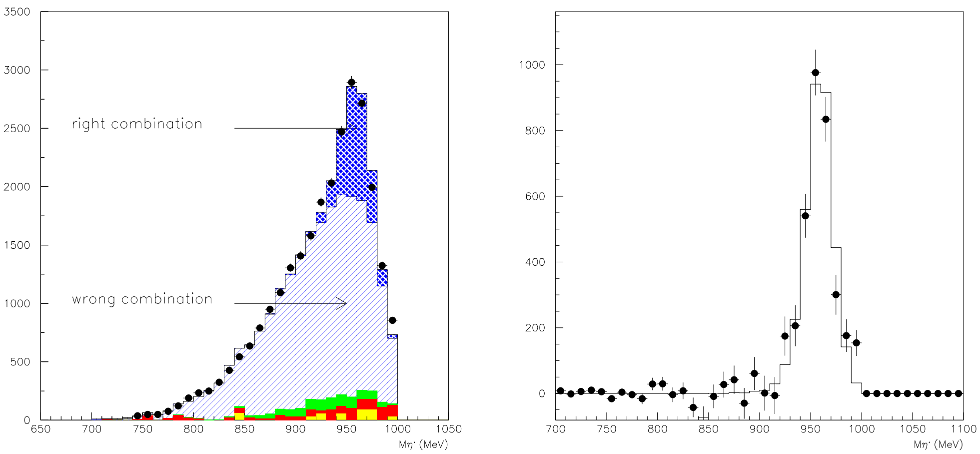

Fig. 2. $\eta' \rightarrow \eta\pi^+\pi^-(\pi^0\pi^0)$ decays with $\eta \rightarrow \pi^0\pi^0\pi^0(\pi^+\pi^-\pi^0)$. Left-side: distribution of the invariant mass of all possible photon combinations; right-side: invariant mass distribution after background subtraction.

The statistics, of the order of 10^8 η's, and the clean environment allow also the study of the η rare decays summarized in tab.2.

The analysis of the $\eta \rightarrow \pi^0\gamma\gamma$, relevant for testing high-order contributions of the P-expansion of the chiral Lagrangian, is well advanced and the preliminary results are presented in these proceedings [7]. With the entire statistics of 2.5 fb^{-1} the precision in the BR (at present ΔBR = 3×10^{-5}) will improve almost by a factor of 2 and we will attempt the first measurement of the $\gamma\gamma$ invariant-mass distribution.

With data collected in 2001-2002, i.e. 450 pb^{-1}, we have improved the upper limit for the $\gamma\gamma\gamma$ [11] and the $\pi^+\pi^-$ [12] C,CP-violating final states. These results are background-limited so that we expect with the analyses of the entire sample to reach the upper limits reported in tab.2.

The measurement of the di-lepton spectrum provides information on the form factor [13] and at KLOE can be addressed by analyzing both, the $\phi \rightarrow \eta(\pi^0)e^+e^-(\mu^+\mu^-)$ processes, and the $\eta \rightarrow \gamma e^+e^-(\mu^+\mu^-)$ decays. Full KLOE data sample contains one million of Dalitz decay of the ϕ meson in $\phi \rightarrow \eta e^+e^-$, and about 50,000 $\phi \rightarrow \eta\mu^+\mu^-$ are expected, which should represent the first evidence for this decay.

Channels with Dalitz and double-Dalitz photon conversion processes can be studied on the basis of the statistics reported in tab.2, from 6×10^5 events, for the e$^+$ e$^-\gamma$ final state, to 6×10^3 events, for the e$^+$ e$^-$ e$^+$ e$^-$ decay.

Other channels can be addressed with the entire statistics, like the C-violating π^0e$^+$ e$^-$ and the LFV μe decays.

η decay	BR	Statistics or U.L. with 2.5 fb^{-1}
$e^+e^-\gamma$	$(6.0\pm0.8)\times10^{-3}$ [6]	6×10^5
$\mu^+\mu^-\gamma$	$(3.1\pm0.4)\times10^{-4}$ [6]	3×10^4
$e^+e^-e^+e^-$	$<6.9\times10^{-5}$ [6]	6×10^3
$\pi^+\pi^-e^+e^-$	$(4.0^{+14}_{-2.7})\times10^{-4}$ [6]	4×10^4
$\pi^0\gamma\gamma$	$(7.2\pm1.4)\times10^{-4}$ [6]	4×10^4
$\gamma\gamma\gamma$	$<1.6\times10^{-5}$ [11]	$<10^{-5}$
$\pi^+\pi^-$	$<1.3\times10^{-5}$ [12]	$<10^{-5}$
$\pi^0e^+e^-$	$<4.0\times10^{-5}$ [6]	$<5.0\times10^{-6}$
μe	$<6.0\times10^{-6}$ [6]	$<10^{-6}$

Tab. 2. Summary of rare η decays.

4 Conclusion

The entire KLOE data set correspond to more than 8×10^9 ϕ mesons. The radiative ϕ decays make DAΦNE a clear η and η', and also f_0, a_0 factory. Moreover, a large sample of ρ (ω) vector mesons of the order of 10^9 (10^7) events is also accessible through $\phi \to \rho\pi$ ($e^+e^- \to \omega\pi^0$) processes.

The prospects for achievements in the field of the η and η' decays have been reviewed, including precision measurements of the main branching ratios, of the Dalitz-plot parameters of the $\eta \to 3\pi$ decays, the improvement in the knowledge of rare decays and in the precision of the $\Gamma(\eta \to \gamma\gamma)$.

KLOE data taking, with the collection of 2.5 fb^{-1} at the ϕ peak, and of the order of 350 pb^{-1} "off-peak" will be completed by the end of March, 2006. The following years (2006-2007) will be devoted to the Hypernuclear Physics program of the FINUDA experiment and to the study of kaonic atoms with SIDDHARTA. The accelerator experiment to exploit the Strong Radio Frequency Focusing concept [14], although not funded yet, is expected to enrich the know-how on the high-luminosity frontier of the meson factories in the same period.

The realization during years 2009-2011 of a new ϕ-factory capable to deliver integrated luminosities of at least 30 fb^{-1} in smooth, steady running conditions, is under scrutiny.

Since the primary focus shifts from K_L decays to rare decays and K_L–K_S interferometry, substantial upgrades of the KLOE detector are desirable. In particular, it is very natural to conceive the possibility of a vertex detector to improve the resolution close to the interaction region.

The KLOE community is setting up working groups to study the project and the related physics case. This activity should eventually bring to the drafting of a letter of intent to be presented during Spring, 2006.

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