Detection of pseudoscalar and scalar mesons at DAΦNE with KLOE

S. Giovannella[a] for the KLOE collaboration*

[a]Laboratori Nazionali di Frascati dell'INFN, Via E. Fermi 40, 00044 Frascati (RM), Italy

The KLOE experiment at the DAΦNE ϕ-factory has just started collecting data. One of the first analysis items is the study of the ϕ radiative decays, which allows us to investigate the nature of light pseudoscalar and scalar mesons. An integrated luminosity of 100 pb^{-1} is expected for next KLOE run, resulting in 3×10^8 ϕ collected. A detailed simulation and full event reconstruction of both signal and background events indicates a sensitivity reach of $1 \div 2\%$ on the branching ratios. Some preliminary studies on real data are also presented, showing a good agreement with MonteCarlo distributions.

1. INTRODUCTION

The nature of light pseudoscalar and scalar mesons is still unclear. The narrow width of the $f_o(975)$ and the $a_o(980)$ are not expected in the framework of the standard quark model while the η/η' mixing angle is known with poor accuracy. The rate of the ϕ radiative decays involving these particles is sensitive to their structure[1–3].

The KLOE experiment[4] at the Frascati ϕ-factory[5] has been designed to study CP violation in $K^o\overline{K^o}$ system. The apparatus is inserted in a 0.6 T magnetic field and is made up of a 2 m radius fully stereo drift chamber (DCH) with uniform tracking and vertexing and a helium based gas mixture, surrounded by a fine sampling lead/scintillating fibers electromagnetic calorimeter (EMC) with a hermetic coverage and a very high efficiency for low energy photons. There are also two small lead/scintillator tiles calorimeters (QCAL) covering the permanent quadrupoles placed inside the detector to increase the hermeticity. The DCH resolutions are $\sigma_{p_t}/p_t = 0.5\%$, $\sigma_{r\phi} \simeq 200$ μm, $\sigma_z \simeq 2$ mm while

*The KLOE collaboration: M. Adinolfi, A. Aloisio, F. Ambrosino, A. Andryakov, A. Antonelli, C. Bacci, A. Bankamp, G. Barbiellini, G. Bencivenni, S. Bertolucci, C. Bini, C. Bloise, V. Bocci, F. Bossi, P. Branchini, G. Cabibbo, R. Caloi, P. Campana, G. Capon, G. Carboni, A. Cardini, G. Cataldi, F. Ceradini, F. Cervelli, F. Cevenini, G. Chiefari, P. Ciambrone, S. Conticelli, E. De Lucia, G. De Robertis, P. De Simone, G. De Zorzi, S. Dell'Agnello, A. Denig, A. Di Domenico, S. Di Falco, A. Doria, E. Drago, O. Erriquez, A. Farilla, G. Felici, A. Ferrari, M. L. Ferrer, G. Finocchiaro, C. Forti, G. Foti, A. Franceschi, P. Franzini, M. L. Gao, P. Gauzzi, S. Giovannella, V. Golovatyuk, E. Gorini, F. Grancagnolo, E. Graziani, P. Guarnaccia, X. Huang, M. Incagli, L. Ingrosso, Y. Y. Jiang, W. Kim, W. Kluge, V. Kulikov, F. Lacava, G. Lanfranchi, J. Lee-Franzini, T. Lomtadze, C. Luisi, C. S. Mao, A. Martini, W. Mei, L. Merola, R. Messi, S. Miscetti, S. Moccia, M. Moulson, S. Mueller, F. Murtas, M. Napolitano, A. Nedosekin, M. Panareo, L. Pacciani, P. Pagès, M. Palutan, L. Paoluzi, E. Pasqualucci, L. Passalacqua, A. Passeri, V. Patera, E. Petrolo, D. Picca, G. Pirozzi, L. Pontecorvo, M. Primavera, F. Ruggieri, P. Santangelo, E. Santovetti, G. Saracino, R. D. Schamberger, B. Sciascia, A. Sciubba, F. Scuri, I. Sfiligoi, T. Spadaro, E. Spiriti, C. Stanescu, L. Tortora, P. Valente, G. Venanzoni, S. Veneziano, Y. Wu.

EMC energy, time and position resolution can be parametrized as $\sigma_E = 5\%/\sqrt{E\,(\mathrm{GeV})}$, $\sigma_T = 50\,\mathrm{ps}/\sqrt{E\,(\mathrm{GeV})}$ and $\sigma_z = 1.2\,\mathrm{cm}/\sqrt{E\,(\mathrm{GeV})}$ respectively.

KLOE has just started collecting data. An integrated luminosity of 100 pb^{-1} is expected for next run, providing a large number of ϕ radiative decays that can clarify the present experimental situation. For this reason MonteCarlo studies of signal and background events has been performed for both neutral and charged final states.

2. MONTECARLO STUDY OF FULLY NEUTRAL DECAYS

2.1. Sample selection

The final state of fully neutral radiative decays consists of a certain number of "prompt" photon, depending on the decay channel. The event selection then requires the proper number of in-time EMC clusters (*i.e.* $|T - R/c| < 5\sigma_T$, where T and R are the reconstructed time and centroid position respectively). In order to disregard events with γ's starting their shower in QCAL, an acceptance cut requiring all photons angle to be above the QCAL angular region ($\theta_\gamma > 21°$) has been used. A kinematic fit is then performed.

2.2. The $\phi \to \eta\gamma \to \gamma\gamma\gamma$ decay

Since the energy of the radiative photon ($E_{\gamma_{\mathrm{rad}}} = 360$ MeV) is inside the energy range of the γ's coming from the η ($150 < E_{\gamma_\eta} < 500$ MeV), the kinematic fit is performed for the three possible photons combinations. The combination with smallest χ^2 is then selected.

The only relevant background for this channel comes from the $\phi \to \pi^o\gamma$ decay, which has four times smaller rate than the signal. The fit can reconstruct it as an $\eta\gamma$ final state by wrongly combining the radiative photon ($E_{\gamma_{\mathrm{rad}}} = 500$ MeV) with a γ coming from the π^o ($E_{\gamma_{\pi^o}} < 500$ MeV). This gives a peculiar distribution of the energy difference between the two photons assigned to the η (see Fig. 1a), the background can therefore be easily rejected requiring $|E_{\gamma_1} - E_{\gamma_2}| < 330$ MeV.

The analysis efficiencies are listed in Tab. 1 together with the number of expected events for next KLOE run (N_{exp}). The corresponding statistical error for the signal is 0.3%.

Table 1
Summary results for $\phi \to \eta\gamma \to \gamma\gamma\gamma$ decay

Channel	$\varepsilon_{\mathrm{trigger}}$	$\varepsilon_{\mathrm{analysis}}$	N_{exp}	S/B ratio
Signal	96%	67%	9.6×10^5	—
$\pi^o\gamma$	91%	7×10^{-4}	2500	380

2.3. The $\phi \to f_o\gamma \to \pi^o\pi^o\gamma$ decay

The energy spectrum of the final photons consists of a flat distribution below 500 MeV with a peak at 45 MeV superimposed, due to the radiative γ.

Two kinds of backgrounds have been considered: the one with the same 5γ's final state ($e^+e^- \to \omega\pi^o \to \pi^o\pi^o\gamma$, $\phi \to \pi^o\pi^o\gamma$, $\phi \to \rho\pi^o \to \pi^o\pi^o\gamma/\eta\pi^o\gamma$, $\phi \to a_o\gamma \to \eta\pi^o\gamma$) and the $\phi \to \eta\gamma \to \pi^o\pi^o\pi^o\gamma$ decay which can simulate the signal in case of photons losses or cluster merging. The last background category is fully rejected by selection procedure and fit while the first one survives, forcing the event to result in a completely different energy spectrum for the assigned radiative photon. An energy cut $E_{\gamma_{\rm rad}} < 100$ MeV efficiently rejects the background while still maintaining a good efficiency on the signal (see Tab. 2). The resulting statistical error is 0.9%.

Table 2
Summary results for $\phi \to f_o\gamma \to \gamma\gamma\gamma$ decay

Channel	$\varepsilon_{\rm trigger}$	$\varepsilon_{\rm analysis}$	$N_{\rm exp}$	S/B ratio
Signal	98%	41.1%	13300	—
$\omega\pi^o$	98%	1.8%	1150	12
$\pi^o\pi^o\gamma$	98%	7.7%	340	40
$\rho\pi^o$	98%	0.7%	70	195
$a_o\gamma$	98%	0.6%	60	230
$\eta\gamma$	99%	10^{-4}	120	110

3. MONTECARLO STUDY OF CHARGED DECAYS

3.1. Sample selection

The signature of charged decays is a $\pi^+\pi^-$ pair together with a certain number of "prompt" photon. The event selection then requires a vertex near the interaction point with two associated tracks and the proper number of in-time EMC clusters. After the selection a kinematic fit, containing also track parameters, is performed.

3.2. The $\phi \to \eta\gamma/\eta'\gamma \to \pi^+\pi^-\pi^o\gamma$ decays

These two decays differ because of their energy spectra. For the $\eta\gamma$ the radiative photon is the softest one ($E_{\gamma_{\rm rad}} = 60$ MeV) while for $\eta'\gamma$ channel is the most energetic photon ($E_{\gamma_{\rm rad}} = 363$ MeV).

The background comes from $\phi \to K_LK_S$ and $\phi \to \pi^+\pi^-\pi^o$ events that, although having different topology, can simulate the signal because of some detector inefficiency or reconstruction failure. Moreover the $\eta\gamma$ channel is the most important background source for the $\eta'\gamma$ since their rate ratio is $\sim 8 \times 10^{-3}$. The common backgrounds are rejected requiring the total photons energy to be greater than 530 MeV and the total charged tracks energy to be smaller than 420 MeV. The $\eta\gamma$ background is reduced cutting on the $\chi^2_{\eta\gamma}$–$\chi^2_{\eta'\gamma}$ plane. Final $\eta'\gamma$ efficiencies are listed in Tab. 3.

Table 3
Summary results for $\phi \to \eta'\gamma \to \pi^+\pi^-\pi^o\gamma$ decay

Channel	$\varepsilon_{\rm trigger}$	$\varepsilon_{\rm analysis}$	$N_{\rm exp}$	S/B ratio
Signal	97%	31%	2100	—
$\eta\gamma$	98%	$\sim 4 \times 10^{-5}$	~ 36	~ 58
K_LK_S	100%	$< 1 \times 10^{-5}$	< 400	> 5 (1)
$\pi^+\pi^-\pi^0$	94%	$< 1 \times 10^{-5}$	< 440	> 4.5 (1)

(1) Evaluated with 10^5 events

4. PRELIMINARY STUDY ON FULLY NEUTRAL REAL DATA

Some preliminary study on real data have been performed for $\eta\gamma$ and $\pi^o\gamma$ decays using 89 nb^{-1}. The distributions are in agreement with the simulated ones (Fig. 1) and the particle's mass peaks differ less than 1% from their PDG values ($M_\eta = 545.0$ MeV/c^2, $M_{\pi^o} = 134.6$ MeV/c^2). The number of events is within 10% the expected value.

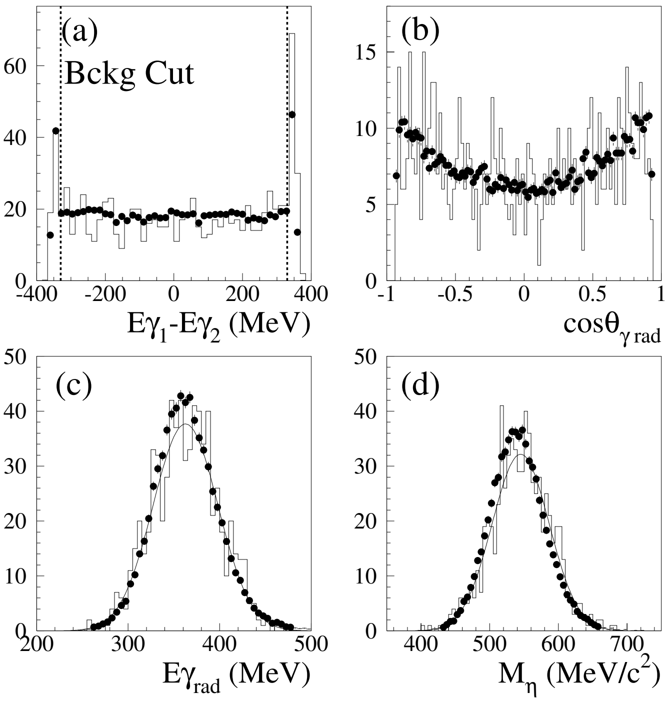

Figure 1. Comparison between data (–) and Montecarlo (•) distributions for $\phi \to \eta\gamma \to \gamma\gamma\gamma$ decay: (a) energy difference of the two photons assigned to the η - the two peaks are due to the $\phi \to \pi^o\gamma$ background; (b) angular distribution and (c) energy spectrum of the radiative photon; (d) η invariant mass.

5. CONCLUSIONS

KLOE is expected to collect 100 pb^{-1} during next run, allowing the study of ϕ radiative decays. The analysis of simulated events indicates a sensitivity of $\sim 1\div 2\%$ on the branching ratios. Preliminary study on real data shows a good agreement with MonteCarlo for fully neutral decays.

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