RECENT RESULTS FROM THE KLOE EXPERIMENT AT DAPHNE

THE KLOE COLLABORATION[a]

Presented by ANTONIO PASSERI

INFN Sezione Roma III and Dipartimento di Fisica, Universitá Roma Tre, via della Vasca Navale 84, 00146 Roma, Italy

Recent results from the KLOE experiment at the DAΦNE e^+e^- collider are presented. KLOE has collected $\sim 500pb^{-1}$ of data in the years from 2000 to 2002. Preliminary results are obtained using wide samples of the full statistics and include: the BR of the K_{e3} decay of the K_S and the first measurement of its charge asymmetry, the ratio BR$(K_S \to \pi^+\pi^-(\gamma))$/BR$(K_S \to \pi^0\pi^0)$, the ratio BR$(K_L \to \gamma\gamma)$/BR$(K_L \to 3\pi^0)$, a detailed study of the decay $\phi \to \pi^+\pi^-\pi^0$, the ratio BR$(\phi \to \eta'\gamma)$/BR$(\phi \to \eta\gamma)$ and the pseudoscalar mixing angle φ_P, the $\phi \to f_0\gamma$ and the $\phi \to a_0\gamma$ BR's.

1 Introduction

DAΦNE[1] is an e^+e^- collider working at the ϕ resonance peak, and located in the Frascati INFN laboratories. The ϕ meson is produced essentially at rest and decays abundantly ($\sim 34\%$) to K_SK_L, which is a pure $J^{PC} = 1^{--}$ quantum state. Thus DAΦNE provides two highly pure, almost monochromatic, back-to-back K_S and K_L beams.

[a]The KLOE Collaboration: A. Aloisio, F. Ambrosino, A. Antonelli, M. Antonelli, C. Bacci, G. Bencivenni, S. Bertolucci, C. Bini, C. Bloise, V. Bocci, F. Bossi, P. Branchini, S. A. Bulychjov, R. Caloi, P. Campana, G. Capon, T. Capussela, G. Carboni, G. Cataldi, F. Ceradini, F. Cervelli, F. Cevenini, G. Chiefari, P. Ciambrone, S. Conetti, E. De Lucia, P. De Simone, G. De Zorzi, S. Dell'Agnello, A. Denig, A. Di Domenico, C. Di Donato, S. Di Falco, B. Di Micco, A. Doria, M. Dreucci, O. Erriquez, A. Farilla, G. Felici, A. Ferrari, M. L. Ferrer, G. Finocchiaro, C. Forti, A. Franceschi, P. Franzini, C. Gatti, P. Gauzzi, S. Giovannella, E. Gorini, E. Graziani, M. Incagli, W. Kluge, V. Kulikov, F. Lacava, G. Lanfranchi, J. Lee-Franzini, D. Leone, F. Lu, M. Martemianov, M. Matsyuk, W. Mei, L. Merola, R. Messi, S. Miscetti, M. Moulson, S. Müller, F. Murtas, M. Napolitano, A. Nedosekin, F. Nguyen, M. Palutan, E. Pasqualucci, L. Passalacqua, A. Passeri, V. Patera, F. Perfetto, E. Petrolo, L. Pontecorvo, M. Primavera, F. Ruggieri, P. Santangelo, E. Santovetti, G. Saracino, R. D. Schamberger, B. Sciascia, A. Sciubba, F. Scuri, I. Sfiligoi, A. Sibidanov, T. Spadaro, E. Spiriti, M. Testa, L. Tortora, P. Valente, B. Valeriani, G. Venanzoni, S. Veneziano, A. Ventura, S. Ventura, R. Versaci, I. Villella, G. Xu.

The KLOE experiment [2] is designed to exploit the unique features of a ϕ-factory environment for the measurement of CP and CPT violation in the $K^0 - \bar{K}^0$ system, and more generally for the study of kaons' decays. In particular, KLOE has the unique capability of tagging the presence of a K_S (K_L) by detecting a K_L (K_S) flying in the opposite direction. K_S and K_L are easily distinguishable on the basis of their lifetimes: due to the small boost, K_S's have a mean decay path $\lambda_S \sim 6\,mm$ and they all decay near the interaction point, while $\lambda_L \sim 340\,cm$. Other abundant ϕ decay modes are K^+K^- ($\sim 49\%$), for which a tagging technique can be applied similar to the neutral kaon case, and $\rho\pi$ ($\sim 15\%$).

The DAΦNE collider has been commissioned in 1999, when it delivered its first 2 pb^{-1} of data, and it has been operated with continously improving luminosity up to 2002, when it reached a maximum peak luminosity of $7.8{\cdot}10^{31} cm^{-2} s^{-1}$. The total integrated luminosity collected by KLOE amounts now to 500 pb^{-1}. The 25 pb^{-1} year 2000 data sample has been fully analized and results have been recently published [6,7,8,9,10]. Year 2001 (190 pb^{-1}) and 2002 (300 pb^{-1}) data samples are now being analyzed and some preliminary results are presented here.

2 The KLOE detector

A schematic side view of the KLOE detector is shown in fig.1. It consists mainly in a large volume drift chamber surrounded by an electromagnetic calorimeter. A superconductiong coil provides a 0.52 T solenoidal magnetic field.

The calorimeter [3] is a fine sampling lead-scintillating fiber one, composed by 24 barrel modules and 2x32 end modules, with photomultiplier readout at both sides. Module thickness is 23 cm ($\sim 15X_0$) and the total solid angle coverage is 98% . The energy resolution, as measured using $e^+e^- \to e^+e^-\gamma$ events, is $\sigma_E/E = 5.7\%/\sqrt{E(GeV)}$. The intrinsic time resolution, as measured using $e^+e^- \to e^+e^-\gamma$ and $e^+e^- \to 2\gamma$ events, is $\sigma_t = 54\,ps/\sqrt{E(GeV)} \oplus 50\,ps$. Two smaller calorimeters, QCAL [4], made with lead and scintillating tiles are wrapped around the low beta quadrupoles to complete the hermeticity.

The drift chamber [5] is a cylinder, 3.3 m long and having 4 m diameter, strung with ~ 52000 wires (of which ~ 12000 are sense wires) in an all stereo configuration. In order to minimize multiple scattering and K_L regeneration and to maximize detection efficiency of low energy photons, the chamber works with a 90% helium - 10% isobutane gas mixture, while its walls are made of light materials (mostly carbon fiber composites). The momentum resolution for tracks at large polar angle is $\sigma_p/p \leq 0.4\%$, the spatial resolutions are $\sigma_{r,\phi} \approx 150\mu m$ and $\sigma_z \approx 2mm$.

3 K_S decays

The presence of a K_S is tagged by identifying the interactions of the K_L in the calorimeter. Approximately 30% of the K_L's produced in $\phi \to K_S K_L$ events reaches the calorimeter before decaying and interacts therein. Such an interaction, referred to as K_L *crash*, has a very clear signature consisting of a high energy ($E > 200\,MeV$) cluster in the calorimeter, which is also neutral (i.e. not associable to any track in the event) and delayed ($\sim 30\,ns$ after all other clusters in the event, due to K_L small velocity, $\beta \sim 0.22$). The cluster position, exploiting the ϕ decay kinematics, provides the momentum of the K_S. Moreover about 40% of the K_L crashes independently satisfy the trigger conditions, thus facilitating trigger efficiency studies.

3.1 $BR(K_S \to \pi^+\pi^-(\gamma))/BR(K_S \to \pi^0\pi^0)$

This ratio is the first part of the double ratio used to measure $\Re(\epsilon'/\epsilon)$.

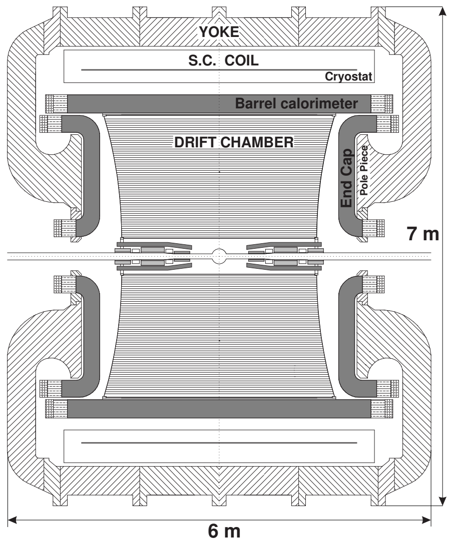

Figure 1: Schematic view of the KLOE detector.

$K_S \to \pi^+\pi^-$ decays are identified, in the sample tagged by K_L crash, by requiring the presence of two oppositely charged tracks, originating from the interaction region and satisfying loose cuts in momentum p and polar angle θ. Such cuts define the acceptance for the decay, which is evaluated using Monte Carlo simulation (MC), while the single track reconstruction efficiency is evaluated directly from subsamples of $K_S \to \pi^+\pi^-$ events, in (p,θ) bins. The ratio of data and MC efficiency is found to be constant over all the acceptance region, and MC efficiency is scaled accordingly. The previous selection includes also $K_S \to \pi^+\pi^-\gamma$ events, with an efficiency decreasing with increasing E_γ (or with decreasing $\pi^+\pi^-$ invariant mass). Such efficiency is obtained from simulation down to 20 MeV photons, extrapolated to $E_\gamma = 0$ and folded with the theoretical photon spectrum [11] to obtain the overall efficiency. No threshold is applied to E_γ.

$K_S \to \pi^0\pi^0$ decays are selected (still in the K_S tagged sample) by requiring the presence of at least 3 prompt neutral clusters in the calorimeter. A cluster is defined to be prompt when $|T_{cl} - R/c| < 5\sigma_t$, where T_{cl} is the cluster time of flight, R is the calorimeter radius and σ_t is the measured time resolution. Loose cuts in energy and polar angle are applied to each cluster, thus defining the acceptance for the decay, which is then obtained from simulation. The photon detection efficiency is evaluated using $\phi \to \pi^+\pi^-\pi^0$ events, in which one photon and the two pions tracks are used to determine the kinematics of the remaining photon, which is then searched for.

The trigger efficiency is evaluated as the combined probability of the K_S decay and of the K_L-crash to satisfy the trigger condition. Events in which the K_L-crash alone is enough to satisfy the trigger are used to estimate the trigger probability of the K_S decay, and vice versa. Using only a 17 pb^{-1} data sample, collected in year 2000, the final result is obtained[7]

$$\frac{\Gamma(K_S \to \pi^+\pi^-(\gamma))}{\Gamma(K_S \to \pi^0\pi^0)} = 2.239 \pm 0.003_{stat} \pm 0.015_{syst}. \tag{1}$$

This measurement is compatible with the world average [12] at 2.7σ level, and it has the best statistical significance ever reached. It is also the first that takes fully into account the photon radiation. The ratio in (1) can be expressed in terms of the transition amplitudes between states of $\Delta I = 0$ (A_0) and $\Delta I = 2$ (A_2), and of their phase shift $\delta_2 - \delta_0$. Such phase shift can be predicted from chiral perturbation theory[13] to be $(45 \pm 6)^\circ$, while from $\pi\pi$ scattering[14]

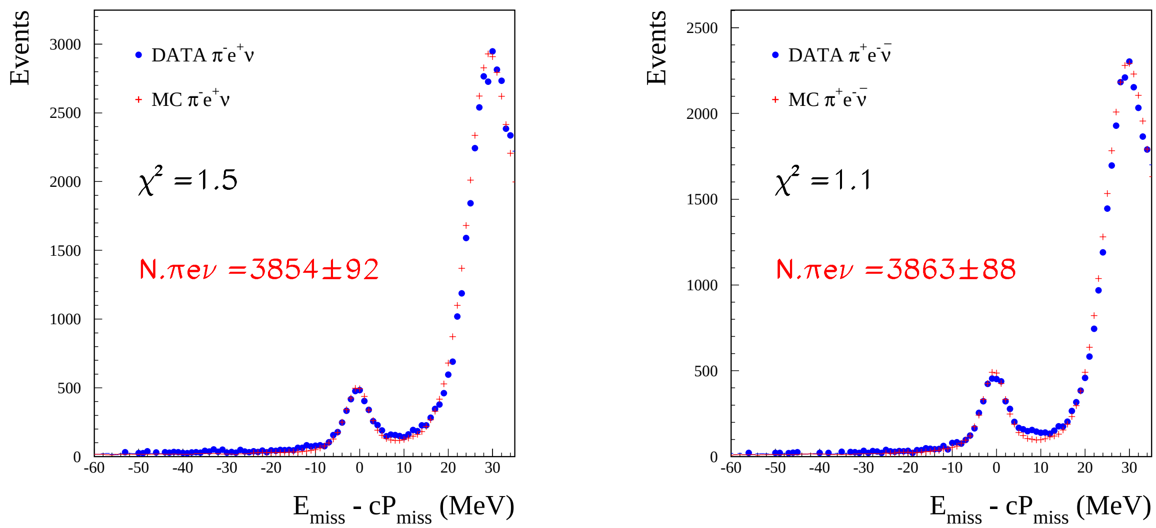

Figure 2: $E_{miss} - P_{miss}$ distribution for $K_S \to \pi e \nu$ candidates. Solid markers represent data, crosses are the MC based fit.

it is estimated to be $(47.7 \pm 1.5)^\circ$. If then it is assumed $(A_0/A_2)^2 = (3\tau_S/4\tau)BR(K^\pm \to \pi^\pm\pi^0)^{-1} - 1 = (22.2 \pm 0.07)^2$, the PDG value for $\Gamma(K_S \to \pi^+\pi^-)/\Gamma(K_S \to \pi^0\pi^0)$ yields $\delta_2 - \delta_0 = (56.7 \pm 3.8)^\circ$, while using the present KLOE measurement we obtain $\delta_2 - \delta_0 = (48 \pm 3)^\circ$, in good agreement with predictions.

3.2 $BR(K_S \to \pi^\pm e^\mp \bar{\nu}(\nu))$

Assuming CPT conservation and the $\Delta S = \Delta Q$ rule, the K_S and K_L partial widths for the K_{e3} decay must be equal[15], and the corresponding K_S branching ratio can be easily obtained from that of the K_L. KLOE has performed a direct measurement of this K_S branching ratio[6] using the year 2000 data sample. The update of such measurement with 2001 data is presented here.

$K_S \to \pi e \nu$ events are selected, in the K_L-crash tagged sample, by requiring the presence of two oppositely charged tracks which extrapolate and form a vertex in the interaction region. Loose momentum and angular cuts are applied, and the vertex invariant mass, evaluated in the hypothesis that both tracks belong to pions, is required to be smaller than 490 MeV, thus rejecting 95% of the $K_S \to \pi^+\pi^-$ decays. Vertex reconstruction and preselection efficiencies are evaluated by MC.

The $K_S \to \pi e \nu$ decays are identified and the π/e assignement is made by means of the time of flight of the two tracks, which are then both required to be associated to a calorimeter cluster. For each track the difference $\delta_t(m) = t_{cl} - L/\beta(m)$ is computed, where t_{cl} is the time of the associated cluster, L is the measured track length and $\beta(m)$ is the particle velocity obtained from the measured momentum with a mass hypotesis $m = m_e$ or $m = m_\pi$. In order to avoid any systematics related to the T_0 determination, the selection is made on the difference $\delta_{t,ab} = \delta_t(m_a)_1 - \delta_t(m_b)_2$, where mass hypothesis a (b) is used for track 1 (2). For the correct mass assignement we expect $\delta_{t,ab} \sim 0$, therefore a cut is applied at $\delta t, ab < 1\, ns$. The π/e identification efficiency is measured in a sample of $K_L \to \pi e \nu$ in which the K_L decays near the interaction region. Such a sample can be selected with high purity (99.7%) just by means of kinematics, without using calorimeter times. The track-to-cluster association efficiency is also measured in the same K_L decays sample, in a $K_S \to \pi^+\pi^-$ sample and in a $\phi \to \pi^+\pi^-\pi^0$ sample.

In all such topologies the events are reconstructed independently on the presence or absence of a calorimeter cluster from one of the tracks. The overall efficiency to detect a $K_S \to \pi e \nu$ decays is 0.208 ± 0.004.

In fig.2 it is shown the distribution of the selected events in $E_{miss} - P_{miss}$ (the neutrino energy and momentum, if the mass assignement is correct) for the two possible charge states, obtained using 170 pb^{-1} collected in 2001 (solid markers). Signal events are included in the peak around zero, while the residual $K_S \to \pi^+\pi^-$ background shows up in the positive region. The number of signal events in the distribution is obtained from a fit, shown in the figure with crosses, which uses the MC distributions for signal and background having as a free parameter their independent normalizations. The fit yelds $N_{\pi^+e^-\bar{\nu}} = 3863 \pm 88$, $N_{\pi^-e^+\nu} = 3854 \pm 92$, and from the sum of the two distributions: $N_{\pi^\pm e^\mp \nu(\bar{\nu})} = 7732 \pm 127$. By normalizing these numbers to the number of $K_S \to \pi^+\pi^-$ in the same data sets we get the preliminary KLOE results:

$$\begin{aligned} BR(K_S \to \pi^+e^-\bar{\nu}) &= (3.44 \pm 0.09 \pm 0.06) \cdot 10^{-4} \\ BR(K_S \to \pi^-e^+\nu) &= (3.31 \pm 0.08 \pm 0.05) \cdot 10^{-4} \\ BR(K_S \to \pi^\pm e^\mp \nu(\bar{\nu})) &= (6.76 \pm 0.12 \pm 0.10) \cdot 10^{-4} \end{aligned} \tag{2}$$

On the basis of such results it is possible to build the K_S semileptonic charge asimmetry $A_S = (\Gamma_S^+ - \Gamma_S^-)/(\Gamma_S^+ + \Gamma_S^-)$, where $\Gamma_S^{+(-)}$ are the partial decay widths of the K_S into $\pi^{+(-)}e^{-(+)}\nu$. If CPT invariance holds, A_S must be equal to the corresponding K_L asimmetry A_L[15]. KLOE has performed the first measurement of A_S ever done, obtaining the following preliminary result

$$A_S = (1.9 \pm 1.7_{stat} \pm 0.6_{syst}) \cdot 10^{-2} \tag{3}$$

which is compatible with the present (much more precise) A_L measurement [16]. It is also possible to test the $\Delta S = \Delta Q$ rule, assuming the validity of CPT invariance. The relevant parameter for such test is $\Re(x^+) \approx \langle \pi^- e^+ \nu | H_{weak} | \bar{K^0} \rangle / \langle \pi^- e^+ \nu | H_{weak} | K^0 \rangle$[15], which can be extracted from the K_S and K_L semileptonic decay partial amplitudes: $\Gamma_S^{semil}/\Gamma_L^{semil} = 1 + 4\Re(x^+)$. The present KLOE measurement of $BR(K_S \to \pi e \nu)$ yields $\Re(x^+) = (2.2 \pm 5.3 \pm 3.5) \cdot 10^{-3}$, in good agrement with the previous measurement performed by CPLEAR[17].

4 K_L decays

The presence of a K_L is tagged by identifying the decay $K_S \to \pi^+\pi^-$. Such events are easily selected by requiring two oppositely charged tracks which form a vertex laying in cylindrical fiducial volume centered in the interaction region, having radius of $4\,cm$ and length of $16\,cm$. No other tracks must be connected to the vertex, and loose cuts are applied to its total momentum and invariant mass. The measured K_S momentum provides a very good estimate of the K_L one, with an angular resolution of $\sim 1°$ and a momentum resolution of $\sim 2\,MeV$. The overall tag efficiency is about 85%.

4.1 $BR(K_L \to \gamma\gamma)/BR(K_L \to 3\pi^0)$

A measurement of the $K_L \to \gamma\gamma$ decay rate provides interesting tests of chiral perturbation theory and can be used as a constraint for the calculation of the $K_L \to \mu^+\mu^-$ decay rate. KLOE has performed such measurement using a sample of 362 pb^{-1} collected during 2001 and 2002[18]. K_L decays are searched for in a fiducial volume defined by $30\,cm < r_t < 170\,cm$ (r_t is the transverse radius) and $|z| < 140\,cm$. About 31.5% of the K_L decay in such a volume. The position of the K_L neutral decay vertex can be determined by each of the photons emitted in the decay, using the flight direction of the K_L (provided by the K_S) and the position and time of the photon cluster on the calorimeter. The final value of the K_L decay length L_K is obtained from an

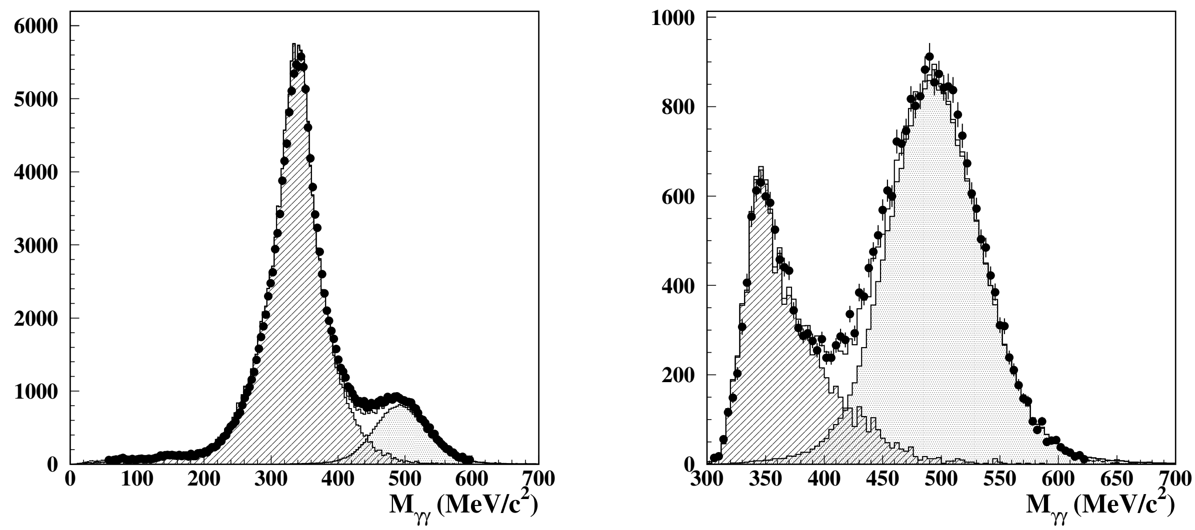

Figure 3: $M_{\gamma\gamma}$ distribution before (left) and after (right) the $K_L \to \gamma\gamma$ final selection (E' and α cuts). Dots are data, histograms are MC (full, signal and background).

energy weighted average of the $L_{K,i}$ determined by each individual photon. The accuracy of this method is tested in $K_L \to \pi^+\pi^-\pi^0$ events by comparing neutral and charged vertex positions, and its resolution is evaluated, using the neutral decay events themselves, to be $\sim 2\,cm$ with a sligth dependence on the K_L decay length. For this method to work it is crucial to correctly identify the bunch crossing that originated the event. This is done by identifying one of the two pions produced by the K_S decay and by measuring its track length l_π, momentum and time of flight of the associated calorimeter cluster t_{cl}. By requiring $|l_\pi/\beta_\pi - t_{cl}| < 2\,ns$ for at least one of the K_S pions, the probability of correct bunch crossing identification becomes $(99.4\pm\ 0.1)\%$, as measured by comparing charged and neutral vertex positions in a $K_L \to \pi^+\pi^-\pi^0$ sample.

$K_L \to \pi^0\pi^0\pi^0$ decays are selected by requiring the presence of at least 3 calorimeter clusters not associated to any tracks, with energy larger than $20\,MeV$, distance from any other cluster larger than $40\,cm$, and yielding L_K in the fiducial volume, with $|L_{K,i} - L_K| < 4\sigma_{L_K}$. The MC estimated selection efficiency is $(99.80\pm\ 0.01)\%$. Only events with 3 and 4 clusters are contaminated by background, as it turns out from a data-MC comparison of the total energy distributions. Such background is given by $K_L \to \pi^+\pi^-$ events and by misreconstructed $K_L \to \pi^+\pi^-\pi^0$ decays. In order to reject it, tighter selections are applied on energy and position of the clusters in the 3 and 4 clusters sample, and events with tracks not associated to the K_S decay and with first hit in the drift chamber nearer than $30\,cm$ to the K_L vertex are vetoed. Finally the 3 and 4 clusters samples contribute only to less than 8% of the total statistics, with a residual background contamination, evaluated by MC, of $(18.6\pm1.0)\%$ in the 3 clusters sample, and $(7.0\pm0.2)\%$ in the 4 clusters sample. The trigger efficiency, measured in data, is $(99.88\pm0.04)\%$. After background subtraction and efficiency correction, the measured number of $K_L \to \pi^0\pi^0\pi^0$ decays in our data sample is $N_{3\pi^0} = 9,802,200 \cdot (1 \pm 0.0010 \pm 0.0016)$.

$K_L \to \gamma\gamma$ are first preselected by requiring the presence of at least 2 calorimeter clusters not associated to tracks, with energy $E > 100\,MeV$. For the two most energetic such clusters, loose requirements are made on total energy, relative angle, time difference and compatibility of L_K determination. The preselection efficiency is 89.5% for signal events, evaluated by MC. In the left part of fig.3 the distribution of the invariant mass of the couples of clusters surviving the preselection is shown, together with the MC expectations for signal and background. At this stage a peak around M_K is already present, but not yet resolved from background. To enhance it, the photon energies are computed with better accuracy assuming $E_\gamma = M_K/2$ in the K_L center of mass and boosting them to the laboratory. The boost is obtained from $p_{\vec{K}_L} = p_{\vec{\phi}} - p_{\vec{K}_S}$ and from clusters and K_L decay vertex coordinates. The so computed total energy in the laboratory, E', is required to be $|E' - 510| < 5\sigma'$, where $\sigma' = 1.8\,MeV$ was evaluated from a fit to the experimental E' distribution. Moreover the angle α between $p_{\vec{K}_L}$ and the laboratory total $\gamma\gamma$ momentum (obtained from the recomputed photon energies and their clusters positions) is required to be smaller than 15°. The final $M_{\gamma\gamma}$ distribution is shown in the right part of fig.3. The selection efficiency was evaluated using a sample of $K_L \to \gamma\gamma$ with high purity (S/B$\sim 10^3$) selected by applying hard, uncorrelated cuts on other kinematic variables[18], and turns out to be $(81.0 \pm 0.3_{stat} \pm 0.5_{syst})\%$. The trigger efficiency was evaluated from data as for $K_L \to 3\pi^0$ decays. The number of $K_L \to \gamma\gamma$ decays was then obtained from a fit to the $M_{\gamma\gamma}$ distribution using MC shapes for signal and background. After correcting for the efficiencies we get $N_{2\gamma} = 27,375 \cdot (1 \pm 0.0076 \pm 0.0081)$, which yields

$$\frac{\Gamma(K_L \to \gamma\gamma)}{\Gamma(K_L \to \pi^0\pi^0\pi^0)} = (2.793 \pm 0.022_{stat} \pm 0.024_{syst}) \cdot 10^{-3} \qquad (4)$$

in good agreement with the recent NA48 measurement[20]. Using the known value of BR($K_L \to \pi^0\pi^0\pi^0$) and τ_L we get $\Gamma(K_L \to \gamma\gamma) = (7.5 \pm 0.1) \cdot 10^{-12} eV$, which is in agreement with the $o(p^6)$ predisctions of ChPT provided the value of the pseudoscalar mixing angle is close to our recent measurement[8].

5 Study of the decay $\phi \to \pi^+\pi^-\pi^0$

The decay of the ϕ meson to $\pi^+\pi^-\pi^0$ is dominated by the $\rho\pi$ intermediate states $\rho^+\pi^-$, $\rho^-\pi^+$, $\rho^0\pi^0$ with equal amplitudes. Additional contributions to $e^+e^- \to \pi^+ \; pi^-\pi^0$ are the so called "direct term" and $e^+e^- \to \omega\pi$ ($\omega \to \pi^+\pi^-$). Taking into account all contributions, a fit to the Dalitz plot of the process allows to determine masses and widths of the three ρ charge states[19]. CPT invariance requires equality of masses and widths of ρ^+ and ρ^-, while isospin-violating electromagnetic effects may originate possible differences in mass or width between ρ^0 and $\rho^\pm$. Starting from a 16 pb^{-1} data sample collected in year 2000, events are selected by requiring the presence of two non collinear tracks, with opposite sign curvature and polar angle $\theta > 40°$. The acollinearity cut is $\Delta\theta < 175°$, and rejects $e^+e^-\gamma$ events without affecting the signal. Then imposing the conservation of the ϕ meson energy and momentum, the missing mass M_{miss} is computed, and required to be within $20\,MeV$ of the π^0 mass. This corresponds to an effective cut of $< 20\,MeV$ on the total ISR radiated energy. Finally two neutral clusters in the calorimeter are required, with $E > 10\,MeV$ and arrival time compatible with that of a photon emitted in the interaction point. The two photon opening angle in the π^0 rest frame must have $cos\theta_{\gamma\gamma} < -0.98$. After such selection the residual background contrinution is less tham 10^{-5}, while the efficiency for the signal varies between 20% and 30% over the kinematic range of the process.

The Dalitz plot is built up as a function of the two variables $x = T^+ - T^-$ and $y = T^0$, where T^{+-0} are the kinetic energies of pi^{+-0} in the center of mass system. The resolution on x and y is about $1\,MeV$ over the full kinematic range. The Dalitz plot is divided in $8.75 \times 8.75\,MeV^2$ bins, for a total of 1874 bins within the kinematic boundary. The trigger and selection efficiency have been evaluated as a function of x and y using MC simulation with corrections based on data control samples. In particular the the low energy photon detection efficiency has been obtained from $e^+e^-\gamma$ events. The calibration of the momentum scale is checked across the entire kinematic range by comparing the measured M_{miss} with the π^0 mass. Three fits have been performed to the Dalitz plot density distribution: a) a fit assuming CPT and isospin

Table 1: Fitted results for ρ masses and widths (in MeV).

parameter	fit(a)	fit(b)	fit(c)
M_{ρ^0}		$775.9 \pm 0.5 \pm 0.5$	$775.9 \pm 0.6 \pm 0.5$
M_{ρ^+}	$775.5 \pm 0.5 \pm 0.3$	$775.5 \pm 0.5 \pm 0.4$	$776.3 \pm 0.6 \pm 0.7$
M_{ρ^-}			$774.8 \pm 0.6 \pm 0.4$
Γ_{ρ^0}		$147.3 \pm 1.5 \pm 0.7$	$147.4 \pm 1.5 \pm 0.7$
Γ_{ρ^+}	$143.9 \pm 1.3 \pm 1.1$	$143.7 \pm 1.3 \pm 1.2$	$144.7 \pm 1.4 \pm 1.2$
Γ_{ρ^-}			$142.9 \pm 1.3 \pm 1.4$

invariance, *i.e.* $M_{\rho^0} = M_{\rho^+} = M_{\rho^-}$ and $\Gamma_{\rho^0} = \Gamma_{\rho^+} = \Gamma_{\rho^-}$; b) a fit assuming only CPT invariance, *i.e.* $M_{\rho^+} = M_{\rho^-}$ and $\Gamma_{\rho^+} = \Gamma_{\rho^-}$; c) a fit without limitations on masses and widths. The fit results are shown in table 1. Systematic uncertainties come mainly from the fit stability with respect to the selection cuts and from the absolute momentum calibration. The ρ masses are significantly larger and the widths smaller than the PDG averages[12], but are close to the most recent measurements. The direct term and $\omega\pi$ contributions were also included in the fits, and found to be significantly different from zero. In particular the visible cross section for the process $e^+e^- \to \omega\pi^0 \to \pi^+\pi^-\pi^0$ at $\sqrt{s} = 1019.4\,MeV$ turns out to be $92 \pm 15\,pb$.

6 ϕ radiative decays

The ϕ meson radiative decays are studied in details at KLOE. Three main measurements have been performed with the year 2000 data sample: the BR($\phi \to \eta'\gamma$)[8], the BR($\phi \to f_0\gamma$)[9] and the BR($\phi \to a_0\gamma$)[10]. All such measurements are being updated with more statistics.

The $\phi \to \eta'\gamma$ decay is identified in the channel in which $\eta' \to \eta\pi^+\pi^-$ and $\eta \to \gamma\gamma$. The $\phi \to \eta\gamma$ decay is identified in the channel in which $\eta \to \pi^+\pi^-\pi^0$. In both cases the final state is $\pi^+\pi^-\gamma\gamma\gamma$, so that many systematics cancel in the ratio $BR(\phi \to \eta'\gamma/BR(\phi \to \eta\gamma)$. Events with two oppositely charged tracks and three prompt clusters are selected. Background from $\phi \to K_SK_L$ and $\phi \to \pi^+\pi^-\pi^0$ are rejected by simple cuts on particles' energy and momentum. $\eta'\gamma$ and $\eta\gamma$ decays are disentangled by a cut on the E_1, E_2 plane, the energies of the two most energetic photons. The number of $\eta'\gamma$ events is then obtained from a fit to the reconstructed η' invariant mass: in the year 2000 sample we have $124 \pm 12 \pm 5$ events in the peak, and in the 2001 sample we have already more than 700 events in the peak. The published[8] result $BR(\phi \to \eta'\gamma/BR(\phi \to \eta\gamma) = (4.70 \pm 0.47 \pm 0.31) \cdot 10^{-3}$ corresponds to a pseudoscalar mixing angle: in the flavour basis $\varphi_P = (41.8^{+1.9}_{-1.6})^\circ$, and in the singlet-octet basis $\vartheta_P = (12.9^{+1.9}_{-1.6})^\circ$. Using the PDG value for $BR(\phi \to \eta\gamma)$ we get $BR(\phi \to \eta'\gamma = (6.10 \pm 0.61 \pm 0.43) \cdot 10^{-5}$, which is compatible with zero gluonium contribution to the η' state.

The $\phi \to f_0\gamma$ and $\phi \to a_0\gamma$ are recognized at KLOE by their five photons final states ($f_0 \to \pi^0\pi^0$ and $a_0 \to \eta\pi^0$, $\eta \to \gamma\gamma$). Various backgrounds are present, the main ones coming from $\phi \to \rho^0\pi^0$ and from $e^+e^- \to \omega\pi^0$, which are rejected by means of kinematic fits asumin various event topologies. Cuts are applied to the reconstructed masses of the intermediate particles and on the χ^2 probability of the fits. Published KLOE measurements are $BR(\phi \to \pi^0\pi^0\gamma) = (1.09 \pm 0.03 \pm 0.05) \cdot 10^{-4}$ and $BR(\phi \to \eta\pi^0\gamma) = (1.08 \pm 0.05 \pm 0.06) \cdot 10^{-4}$. Higher statistics analyses are being performed and are in agreement with the present results. Finally, the mass spectra of the two processes are sensitive to the nature of f_0 and a_0: the spectra measured by KLOE are compatible with a $qq\bar{q}\bar{q}$ nature for the f_0, while for the a_0 conclusions cannot be drawn up to now.

7 Hadronic cross section

The recent measurements of a_μ by the E821 collaboration[21] has stimulated new interest in the measurement of the cross section of $e^+e^- \to hadrons$ at low energy. In fact, the hadronic contribution to a_μ at low energy cannot be computed, but is related to $\sigma(e^+e^- \to hadrons)$ via a dispersion integral. The process $e^+e^- \to \pi^+\pi^-$, with $M_{\pi\pi} < 1\,GeV$ accounts for about 70% of δa_μ^{had} and for 12% of the hadronic corrections to $\alpha(M_Z)$. KLOE can measure $d\sigma(e^+e^- \to \pi^+\pi^-/dM^2_{\pi\pi}$ by studying $e^+e^- \to \pi^+\pi^-\gamma$ events in which the photon is radiated in the initial state. This has the advantage that sistematic erors due to luminosity and beam energy enter into the measurement only once, and not for each point as in an energy scan, but on the other hand it requires theoretic understanding of ISR to better than 1% . Events are selected requiring two oppositely charged tracks, with polar angle $\theta < 40°$ and forming a vertex near the interaction region. To enhance ISR, with respect to FSR and $\phi \to \pi^+\pi^-\pi^0$ background, only small angle photons are accepted. As the forward and backward angles within a cone of 15° are obscured by the QCALs, photons are not required to be detected, but the $\pi^+\pi^-$ missing momentum is required to have polar angle ¡ 15°. Moreover at least one of the two tracks has to be identified as a pion, on the basis of time of flight and shower shape in the calorimeter. Selection efficiency is better than 96%. Using a 73 pb^{-1} data sample, collected in year 2001, KLOE has now a $d\sigma(e^+e^- \to \pi^+\pi^-/dM^2_{\pi\pi}$ distribution, for $M^2_{\pi\pi}$ ranging from 0.2 to 1 GeV^2, with statistical error $\sim$ 1 in each bin. In the coming months KLOE will double the statistics and reduce the systematic errors to below the 1% level.

References

1. S.Guiducci et al., Proceedings of PAC99, New York, march 1999.
2. The KLOE Collaboration, "KLOE: a general purpose detector for DAΦNE", LNF-92/019 (IR) (1992).
3. M.Adinolfi et al., Nucl.Instr.Meth. **A482** 363-385 (2002).
4. M.Adinolfi et al.,Nucl.Instr.Meth. **A483** 649 (2002)
5. M.Adinolfi et al., Nucl.Instr.Meth. **A488** 1-23 (2002).
6. The KLOE Collaboration, Phys.Lett.**B535** 37 (2002)
7. The KLOE Collaboration, Phys.Lett.**B 538** 21-26 (2002)
8. The KLOE Collaboration, Phys.Lett.**B541** 45-51 (2002)
9. The KLOE Collaboration, Phys.Lett.**B537** 21 (2002)
10. The KLOE Collaboration, Phys.Lett.**B536** 209 (2002)
11. V.Cirigliano et al., Eur.Phys.J. **C18** (2000) 83.
12. Particle Data Group, Phyical Review D66 (2002) 1.
13. J.Gasser,U.G.Meissner, Proceeding of the Lepton Photon Symposium, Geneva 1991, vol.1,202-204.
14. G.Colangelo,J.Gasser,H.Leutwyler, Nucl.Phys. **B603** (2001) 125-179.
15. L.Maiani,The second DAΦNE physics handbook (Frascati 1992), vol.1, 21.
16. A.Alavi-Harati et al., Phys.Rev.Lett.**88** (2002) 181601.
17. A.Angelopoulos et al., Eur.Phys.J.**C22** (2001) 55-79.
18. The KLOE Collaboration, hep-ex/0305035, KLOE note n.186, 4/03.
19. The KLOE Collaboration, Phys.Lett.**B561** (2003) 55.
20. A.Lai et al., Phys.Lett.**B551** (2003) 7.
21. H.N.Brown et al., Phys.Rev.Lett. **86** (2001) 2227.