Recent results from the KLOE experiment at DAΦNE

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The physics program of the KLOE experiment at DAΦNE is described, and recent results are presented. Preliminary measurements obtained using $\sim$17 pb^{-1} of data from the year 2000 include those of the ratio of branching ratios $\mathrm{BR}(K_S \to \pi^+\pi^-)/\mathrm{BR}(K_S \to \pi^0\pi^0)$, the BR for the K_{e3} decay of the K_S, the ratio $\mathrm{BR}(\phi \to \eta'\gamma)/\mathrm{BR}(\phi \to \eta\gamma)$ and the pseudoscalar mixing angle φ_P, and the BR's for the decays $\phi \to f_0\gamma$ and $\phi \to a_0\gamma$. Future directions for the KLOE physics program are summarized.

1. THE KLOE PHYSICS PROGRAM

The Frascati ϕ factory, DAΦNE, is an e^+e^- storage-ring collider with a working point at the mass of the ϕ resonance. The ϕ meson decays abundantly (BR = 33.8%) to a C-odd K_SK_L state. At DAΦNE, ϕ's decay essentially at rest. DAΦNE collisions are thus a source of highly pure, nearly monochromatic, back-to-back K_S–K_L beams. This fact allows tagged measurements to be performed at DAΦNE, wherein the observation of a K_S (or K_L) signals the presence of a $K_L(K_S)$ in an event.

The KLOE experiment is designed to exploit the unique features of DAΦNE for the measurement of CP- and CPT-violation parameters in the K_SK_L system. Since at KLOE, the K_S and K_L are observed in the same event, one possibility is to study the interference patterns in the relative time distributions of decays into various final states [1]. KLOE can also measure $\mathrm{Re}\,(\epsilon'/\epsilon)$ using the traditional double ratio,

$$1 - 6\,\mathrm{Re}\,(\epsilon'/\epsilon) = \frac{K_L \to \pi^0\pi^0}{K_L \to \pi^+\pi^-} \cdot \frac{K_S \to \pi^+\pi^-}{K_S \to \pi^0\pi^0}.$$

The manner in which this expression is written is meant to be suggestive of the fact that, at KLOE, cancellations of experimental systematics are sought principally in the ratios of the BR's for charged and neutral decay modes. In principle, the exact normalization of the integrated K_S and K_L fluxes afforded by tagged measurements at KLOE allows the precision measurement of the absolute BR's for all four modes in the double ratio. The tagged K_S beam in particular may make possible the study of various rare K_S decays, such as those into $\pi^\pm e^\mp \bar{\nu}(\nu)$, $\gamma\gamma$, and 3π final states.

As an example of the statistics needed in order to carry out this program, consider that a competitive measurement of $\mathrm{Re}\,(\epsilon'/\epsilon)$ via the double ratio would require an integrated luminosity of a few fb^{-1}. This corresponds to one or two years of running at the design luminosity,

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$5 \cdot 10^{32}\ \mathrm{cm}^{-2}\,\mathrm{s}^{-1}$, and lifetime. The KLOE integrated luminosity in 1999 was only about 2 pb^{-1}. In 2000, it was a bit more than 20 pb^{-1}. At the time of writing, the DAΦNE luminosity is consistently in the neighborhood of 4–$5 \cdot 10^{31}\ \mathrm{cm}^{-2}\,\mathrm{s}^{-1}$, and KLOE is collecting data at the rate of about 2 pb^{-1}/day. KLOE has so far this year collected a total of $\sim$150 pb^{-1}, the vast majority of which has arrived in the last four months.

While KLOE cannot make competitive measurements of CP-violation parameters with the current data set, the KLOE physics program is rich with topics that can be studied at intermediate statistical levels. About 17 pb^{-1} collected during the year 2000 have been used to obtain the results on K_S decays and on radiative decays of the ϕ presented in this report.

It is encouraging that the DAΦNE luminosity has improved by two orders of magnitude since KLOE data taking began in April 1999. Major work on DAΦNE to increase the luminosity, including an overhaul of the KLOE interaction region, is scheduled for mid-2002.

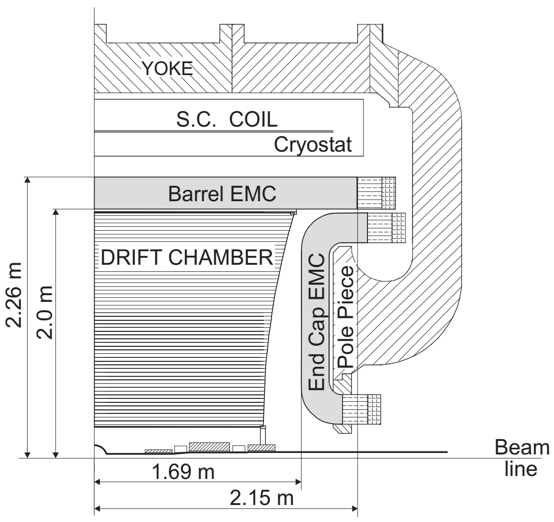

Figure 1. Schematic side view of one quadrant of the KLOE detector

2. THE KLOE DETECTOR

A schematic side view of the KLOE detector is shown in Fig. 1. The detector consists mainly of a large drift chamber surrounded by an electromagnetic calorimeter. A superconducting coil provides a 6 KG field.

The calorimeter is of the lead/scintillating fiber type, with 24 barrel modules and 2×32 endcap modules read out at both sides. The solid angle coverage is 98%. The energy resolution, as measured using $e^+e^- \to e^+e^-\gamma$ events, is $\sigma_E/E = 5.7\%/\sqrt{E(\mathrm{GeV})}$. The intrinsic timing resolution, as estimated using $e^+e^- \to e^+e^-\gamma$ and $e^+e^- \to \gamma\gamma$ events, is $\sigma_t = 54\ \mathrm{ps}/\sqrt{E(\mathrm{GeV})} \oplus 50$ ps. The calorimeter is further described in [2].

The drift chamber is 4 m in diameter and 3.3 m in length. It is strung with 52140 wires (of which 12582 are sense wires) in an all-stereo configuration. To minimize multiple scattering and K_L regeneration and to maximize the detection efficiency for soft photons, the chamber is constructed with light materials (mostly carbon fiber composites) and uses a 90% helium, 10% isobutane gas mixture. The momentum resolution for large-angle tracks is $\sigma_p/p \leq 0.4\%$. Vertices are reconstructed within the chamber with spatial resolutions $\sigma_{xy} \approx 150\ \mu$m and $\sigma_z \approx 2$ mm. The drift chamber is further described in [3].

3. $\mathrm{BR}(K_S \to \pi^+\pi^-)/\mathrm{BR}(K_S \to \pi^0\pi^0)$

The measurement of the ratio of BR's of the dominant decay modes of the K_S is fundamental to the measurement of $\mathrm{Re}\,(\epsilon'/\epsilon)$, and can also provide information on isospin breaking effects in $K \to \pi\pi$ decays, particularly if the contribution from the radiative process $K_S \to \pi^+\pi^-\gamma$ can be taken into account in the measurement.

In approximately 30% of $\phi \to K_S K_L$ events, the K_L reaches the calorimeter barrel and interacts therein. The signature of such an interaction is a high-energy ($E > 200$ MeV), neutral (*i.e.*, not associable to any track in the event) cluster on the barrel, which arrives late ($\sim$30 ns after all other clusters in the event). Such an interaction, referred to as a "K_L crash," provides a convenient tag for use in studies of K_S decays at KLOE.

Not only is such a tag relatively background-free; about 40% of the time, the K_L interaction alone causes two of the 48 sectors of the calorimeter trigger to fire, thus independently satisfying the trigger.

$K_S \to \pi^+\pi^-$ decays are identified in the sample of K_L-crash events by requiring the presence of two tracks of opposite charge from the interaction region (IR) which satisfy loose cuts on momentum, p, and polar angle, θ. These cuts only define the acceptance for the decay; the corresponding correction can be obtained from simulation. The conditional single-track reconstruction efficiency in bins of (p, θ) is obtained from subsamples of the $K_S \to \pi^+\pi^-$ events themselves. The ratio of data and Monte Carlo (MC) reconstruction efficiencies is found to be constant throughout the acceptance, and the overall MC efficiency is scaled accordingly.

$K_S \to \pi^0\pi^0$ decays are identified in the sample of K_L-crash events by requiring the presence of at least three prompt (*i.e.*, with the time-of-flight of a $\beta = 1$ particle originating in the IR) neutral clusters which satisfy cuts on energy and polar angle. Once again, these cuts only define the acceptance for the clusters; the corresponding efficiency is taken from the MC. The photon detection efficiency is studied using $\phi \to \pi^+\pi^-\pi^0$ events in which the pion tracks are detected in the drift chamber and one photon is observed. The kinematics of the decay are then closed and the remaining photon is searched for. The photon detection efficiencies measured in this way are used to tune an effective threshold in the MC, which is then used to calculate the average efficiency.

For each channel, the probability that at least one K_S secondary complements the K_L-crash cluster to satisfy the trigger is estimated from events in which the K_L crash alone satisfies the trigger criteria.

The preliminary KLOE measurement of $\mathrm{BR}(K_S \to \pi^+\pi^-)/\mathrm{BR}(K_S \to \pi^0\pi^0)$ is $2.192 \pm 0.003_{\mathrm{stat}} \pm 0.016_{\mathrm{syst}}$. This measurement is competitive in overall significance with the value obtained from fits to and averages of world data in [4]; its statistical significance has never before been reached. When the 2001 data are analyzed, the systematic errors will be significantly reduced, partly because the current errors on some of the efficiencies are dominated by the statistics of the control samples, and partly because of improvements already implemented in the selection of K_L-crash events at the reconstruction level.

$K_S \to \pi^+\pi^-\gamma$ decays are counted in the $\pi^+\pi^-$ sample. The event selection criteria cause the detection efficiency to decrease with increasing E_γ, or alternately, decreasing $M(\pi^+\pi^-)$. The effect on the measurement is estimated by integrating the product of the theoretical description of the E_γ spectrum from [5] and the energy-dependent detection efficiency. Inclusion of this effect changes the measured ratio by -0.0034 with respect to the value quoted above. The statistics of the 2001 data set should allow $d\Gamma(K_S \to \pi^+\pi^-\gamma)/dE_\gamma$ to be measured.

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

The equality of the partial widths for the K_{e3} decays of the K_S and K_L is required by the $\Delta S = \Delta Q$ rule and CPT-invariance. Only a single measurement of $\mathrm{BR}(K_S \to \pi^\pm e^\mp \bar{\nu}(\nu))$ currently exists [6], and it is based on the observation of 75 ± 13 events.

At KLOE, $K_S \to \pi^\pm e^\mp \bar{\nu}(\nu)$ events are selected by requiring the presence of a K_L crash and a vertex with two tracks of opposite charge in the IR. The observation of the K_L crash determines the momentum of the K_S: $\mathbf{p}_S = \mathbf{p}_\phi - \mathbf{p}_L$. The invariant mass at the vertex is calculated assuming both tracks are from pions, and the total momentum is calculated in the K_S rest frame. Loose preselection cuts, which mainly eliminate $K_S \to \pi^+\pi^-$ events, are imposed on these quantities. At the moment, the MC is used to evaluate the vertex reconstruction and preselection efficiencies.

$K_S \to \pi^\pm e^\mp \bar{\nu}(\nu)$ decays can be identified and the π/e assignments made on the basis of the difference between the times-of-flight for the two tracks. In particular, $K_S \to \pi^+\pi^-$ events, for which the tracks have similar times-of-flight, can be efficiently rejected. The π/e identification efficiency is obtained from samples of $K_L \to \pi^\pm e^\mp \bar{\nu}(\nu)$ events in which the K_L decays near the IR. A high-purity ($> 99.7\%$) sample of such decays can be isolated with kinematic cuts alone (*i.e.*, without using the calorimeter times). In order to use time-of-flight π/e identification, both tracks from the vertex (or their daughters, in the case of $\pi \to \mu\nu$ decays) must be associated to calorimeter clusters. The track-to-cluster association efficiency includes the probability that the particle reaching the calorimeter (π^+, π^-, $e^\mp$, or $\mu^\mp$) deposits enough energy to register a cluster, and is evaluated using samples of $\phi \to \pi^+\pi^-\pi^0$ and $K_S \to \pi^+\pi^-$ events, and $K_L \to \pi^\pm e^\mp \bar{\nu}(\nu)$ events in which the K_L decays near the IR. In all of these topologies, the reconstruction of the event is possible without regard to the presence or absence of a cluster from one of the tracks (or its secondary). The efficiency is properly parameterized and averaged over the MC kinematics. The trigger efficiency is calculated as the probability that one of the clusters complements the K_L-crash cluster to satisfy the trigger requirement. The overall efficiency for the detection of signal events is 0.219 ± 0.009.

The spectrum of $E_{\rm miss} - P_{\rm miss}$ for the remaining events is shown in Fig. 2. $E_{\rm miss}$ and $P_{\rm miss}$ are the missing energy and momentum at the vertex; the difference between these two quantities is zero for $K_S \to \pi^\pm e^\mp \bar{\nu}(\nu)$ decays. For $K_S \to \pi^+\pi^-$ decays, the energy of one of the pion tracks is calculated using the electron mass and is therefore underestimated; $E_{\rm miss}$ is overestimated in this case. The solid markers in Fig. 2 correspond to 17 pb^{-1} of year 2000 data; the crosses are the results of a fit to the sum of the MC spectra for signal and background ($K_S \to \pi^+\pi^-$) events. The free parameters of the fit are the independent normalizations of the signal and background distributions, and the finite MC statistics are taken into account in the likelihood function. According to the fit, 627 ± 30 signal events are observed. The value for BR($K_S \to \pi^\pm e^\mp \bar{\nu}(\nu)$) is obtained by normalizing this number to the number of $K_S \to \pi^+\pi^-$ events in the same data set.

The preliminary KLOE value for BR($K_S \to \pi^\pm e^\mp \bar{\nu}(\nu)$) is $(6.79 \pm 0.33_{\rm stat} \pm 0.20_{\rm syst}) \cdot 10^{-4}$. The relative error on the KLOE measurement is less than a third of that on the only other existing measurement [6]. We estimate that the overall systematic error can ultimately be reduced to the 1% level, and the statistics of the year 2001 data set should allow the overall error to be reduced to ~2%.

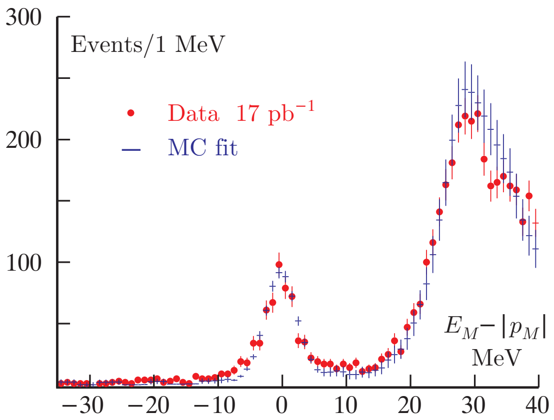

Figure 2. Spectrum of $E_{\rm miss} - P_{\rm miss}$ for $K_S \to \pi^\pm e^\mp \bar{\nu}(\nu)$ candidate events.

The KLOE value for BR($K_S \to \pi^\pm e^\mp \bar{\nu}(\nu)$) is in excellent agreement with the value expected assuming the equality of the partial widths for the K_{e3} decays of the K_S and K_L. When the year 2001 data are fully analyzed, we expect to obtain a value for the $\Delta S = \Delta Q$-rule violation parameter Re (x) of significance competitive with the current value from CPLEAR [7].

5. BR($\phi \to \eta'\gamma$)

The magnitude of BR($\phi \to \eta'\gamma$) is a probe of the $s\bar{s}$ and gg content of the η' [8]. The ratio BR($\phi \to \eta'\gamma$)/BR($\phi \to \eta\gamma$) can be related to the pseudoscalar mixing angle in the quark-flavor basis, φ_P, offering an important point of comparison for the description of the η-η' mixing in chiral perturbation theory [9].

At KLOE, 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 either case, the final state contains a π^+, a π^-, and three photons. As a result, many systematics cancel in the measurement of the ratio BR($\phi \to \eta'\gamma$)/BR($\phi \to \eta\gamma$).

For either channel, events are selected by requiring the presence of three prompt neutral clusters and two tracks of opposite charge with a vertex near the IR. A preliminary kinematic fit with constraints from global energy and momentum conservation and the requirement that $\beta = 1$ for all photons is then performed. This fit primarily rejects events selected due to reconstruction errors; the masses of intermediate particles are not used as constraints. Selected events are required to have Prob $\left(\chi^2\right) > 0.01$.

Background from ϕ decays other than to $\eta\gamma$ and $\eta'\gamma$ in the sample of selected events is mainly from $\phi \to K_S K_L$ events in which the K_L decays near the IR and at least one photon is lost, and from $\phi \to \pi^+\pi^-\pi^0$ events in which a spurious cluster is present. For the $\phi \to \eta'\gamma$ sample, these backgrounds are suppressed using simple cuts on the sums of the energies of the tracks and of the clusters, while for the $\phi \to \eta\gamma$ sample, they are suppressed by identification of the radiative photon ($E_{\rm rad} = 363$ MeV). Finally, $\phi \to \eta\gamma$ events are all but removed from the $\phi \to \eta'\gamma$ sample by cuts in the E_1-E_2 plane, where photons 1 and 2 are those with the highest energies.

The resulting distribution of $M(\pi^+\pi^-\gamma_1\gamma_2)$ in the $\phi \to \eta'\gamma$ sample is shown in Fig. 3. Very little background is observed under the η' mass peak. The form of the background shown as the shaded area in the figure is obtained from the sidebands of the signal region in the E_1-E_2 plane. The number of signal events in the peak is $124 \pm 12_{\rm stat} \pm 5_{\rm syst}$, as obtained from the fit to a function with Gaussian and polynomial terms shown as the solid curve in the figure. The ratio BR$(\phi \to \eta'\gamma)$/BR$(\phi \to \eta\gamma)$ is obtained by normalizing to the number of $\phi \to \eta\gamma$ events observed and correcting for the secondary BR's and MC detection efficiencies for each channel.

The KLOE preliminary value for the ratio BR$(\phi \to \eta'\gamma)$/BR$(\phi \to \eta\gamma)$ is $(5.3 \pm 0.5_{\rm stat} \pm 0.4_{\rm syst}) \cdot 10^{-3}$. The corresponding value for φ_P, $(40.0\,^{+1.7}_{-1.5})^\circ$, can be obtained using relations in [9,10]. Making use of the value of BR$(\phi \to \eta\gamma)$ from [4], we have BR$(\phi \to \eta'\gamma) = (6.8 \pm 0.6_{\rm stat} \pm 0.5_{\rm syst}) \cdot 10^{-5}$. This is by far and away the most precise measurement of this BR to date. The large value obtained is evidence against a significant contribution to the η' state from gluonium.

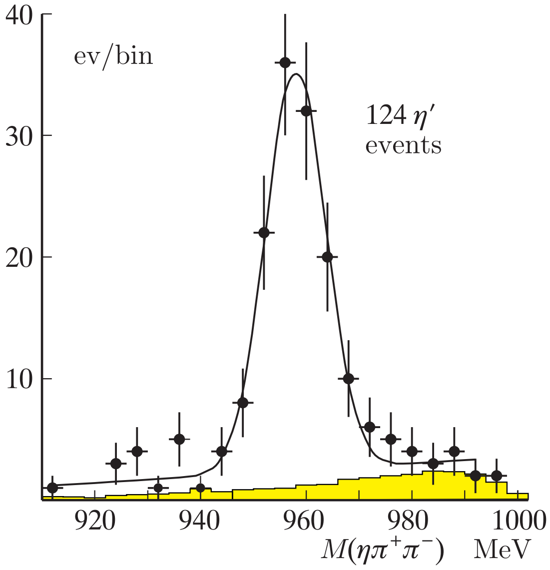

Figure 3. Distribution of $M(\pi^+\pi^-\gamma_1\gamma_2)$ for candidate $\phi \to \eta'\gamma$ events.

6. BR$(\phi \to f_0\gamma)$ AND BR$(\phi \to a_0\gamma)$

Phenomenological predictions for BR$(\phi \to f_0\gamma)$ and BR$(\phi \to a_0\gamma)$ are sensitive to assumptions regarding the nature of the f_0 and a_0. These mesons may be $qq\bar{q}\bar{q}$ states, $K\bar{K}$ molecules, or ordinary $q\bar{q}$ mesons. Precise measurements of these BR's and of their ratio may distinguish amongst the various models proposed to describe these states [11].

The neutral $\phi \to f_0\gamma$ and $\phi \to a_0\gamma$ decays are recognized at KLOE by their five-photon 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 major concerns are the resonant process $\phi \to \rho^0\pi^0$ with $\rho^0 \to \pi^0\gamma$ or $\rho^0 \to \eta\gamma$, and the continuum process $e^+e^- \to \omega\pi^0$ with $\omega \to \pi^0\gamma$ or $\omega \to \eta\gamma$. There are also contributions from three-photon final states in which two clusters are spurious, and from seven-photon final states in which two clusters are lost.

Events with five prompt neutral clusters are first selected. A preliminary kinematic fit with constraints from global energy and momentum conservation and the requirement that $\beta = 1$ for photons is applied in order to refine the measured cluster positions, energies, and times. The best photon pairing is then obtained assuming each of various event topologies, including $\phi \to \pi^0\pi^0\gamma$, $\phi \to \eta\pi^0\gamma$, and $e^+e^- \to \omega\pi^0$. For each of these topologies, a second kinematic fit is then performed with additional constraints on the masses of intermediate η's and π^0's. The $\phi \to \pi^0\pi^0\gamma$ and $\phi \to \eta\pi^0\gamma$ samples are isolated by a variety of cuts on the reconstructed masses of the intermediate particles after the first kinematic fit and on the Prob (χ^2) values from the second series of kinematic fits.

The overall detection efficiency for $\phi \to \pi^0\pi^0\gamma$ events is obtained by tuning the MC to reproduce the observed $M(\pi^0\pi^0)$ distribution. A similar (though somewhat more preliminary) procedure is used to obtain the detection efficiency for $\phi \to \eta\pi^0\gamma$ events. The background in the $M(\pi^0\pi^0)$ and $M(\eta\pi^0)$ distributions from other five-photon final states is estimated using the MC and preliminary KLOE values for the cross section for ϕ production (measured in the $\phi \to \eta\gamma$, $\eta \to \gamma\gamma$ channel) and the process $e^+e^- \to \omega\pi^0$. The background from misreconstructed three-photon final states is estimated by embedding accidental clusters from data into MC events. No attempt is made to subtract the residual background from $\phi \to \rho^0\pi^0$ events, since neither the overall BR into the five-photon final state from this process nor the effect of the interference between this channel and the signal channels is well known.

The preliminary KLOE measurements of $\mathrm{BR}(\phi \to \pi^0\pi^0\gamma)$ and $\mathrm{BR}(\phi \to \eta\pi^0\gamma)$ are $(1.13 \pm 0.04_{\mathrm{stat}} \pm 0.06_{\mathrm{syst}}) \cdot 10^{-4}$ and $(7.7 \pm 0.5_{\mathrm{stat}} \pm 0.4_{\mathrm{syst}}) \cdot 10^{-5}$. Apart from the effects of interference from $\phi \to \rho^0\pi^0$, which have not yet been fully evaluated, the dominant systematic error on these measurements comes from the error on the ϕ production cross section (4.5%).

Under the assumptions that all $\phi \to \pi^0\pi^0\gamma$ and $\phi \to \eta\pi^0\gamma$ events come from $\phi \to f_0\gamma$ and $\phi \to a_0\gamma$ decays, that $\mathrm{BR}(f_0 \to \pi^+\pi^-) = 2\,\mathrm{BR}(f_0 \to \pi^0\pi^0)$, and that the f_0 and a_0 only decay into $\pi\pi$ and $\eta\pi^0$, a value of 4.4 ± 1.3 is obtained for the ratio $\mathrm{BR}(\phi \to f_0\gamma)/\mathrm{BR}(\phi \to a_0\gamma)$. This value is in good agreement with the results of a recent phenomenological prediction for the case in which the f_0 and a_0 are compact $qq\bar{q}\bar{q}$ states surrounded by a virtual $K\bar{K}$ "cloud" [11]. A detailed analysis of the $M(\pi^0\pi^0)$ and $M(\eta\pi^0)$ distributions is in progress.

7. $\sigma(e^+e^- \to \pi^+\pi^-\gamma)$

The recent measurement of a_μ by the E821 collaboration at BNL [12] has renewed interest in measurements of the cross section for e^+e^- annihilation into hadrons at low energy. The hadronic contribution to a_μ is not calculable at low energies, but can be related to $\sigma(e^+e^- \to \mathrm{hadrons})$ via a dispersion integral. The process $e^+e^- \to \pi^+\pi^-$ for $M(\pi^+\pi^-) < 1$ GeV accounts for about 70% of a_μ^{had}, or $5000 \cdot 10^{-11}$ [13,14]. KLOE can obtain $d\sigma(e^+e^- \to \pi^+\pi^-)/dM^2(\pi^+\pi^-)$ for $2m_\pi < M(\pi^+\pi^-) < m_\phi$ by measuring the cross section for $e^+e^- \to \pi^+\pi^-\gamma$ events in which the photon is radiated in the initial state.

In order to do so with the accuracy needed for a relevant contribution to the determination of a_μ^{had}, the initial state radiation must be understood theoretically to better than 1%. Radiation from the final state also needs to be properly taken into account. On the other hand, systematic errors due to uncertainties in the integrated luminosity and beam energy enter into the measurement only once, and not point by point as in a conventional energy scan.

KLOE can confirm and complement world data on $\sigma(e^+e^- \to \pi^+\pi^-)$ from e^+e^- annihilation and τ decays. In particular, KLOE can measure $d\sigma(e^+e^- \to \pi^+\pi^-\gamma)/dM^2(\pi^+\pi^-)$ well for $M(\pi^+\pi^-) < 600$ MeV. The e^+e^- annihilation data are scarce in this mass interval, yet the corresponding contribution to a_μ^{had} is nearly $1000 \cdot 10^{-11}$.

A taste of things to come is offered in Fig. 4, in which a preliminary KLOE measurement of $d\sigma(e^+e^- \to \pi^+\pi^-\gamma)/dM^2(\pi^+\pi^-)$ is shown for events in which $60^\circ < \theta_\gamma < 120^\circ$. The direction of emission of the photon is used to reject background from $\phi \to \pi^+\pi^-\pi^0$ events for

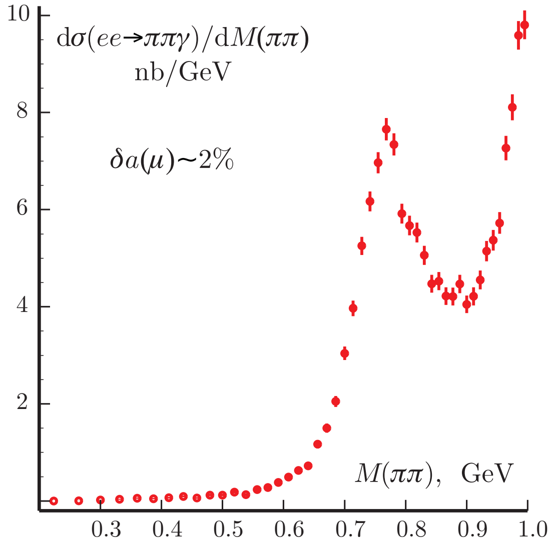

Figure 4. Preliminary KLOE measurement of $d\sigma(e^+e^- \to \pi^+\pi^-\gamma)/dM^2(\pi^+\pi^-)$ for $60° < \theta_\gamma < 120°$, based on 17 pb^{-1} of year 2000 data.

$M(\pi^+\pi^-) < 600$ MeV. At higher $M(\pi^+\pi^-)$, the photon is not required to be detected—θ_γ is determined by closing the event kinematics. What is actually plotted is the effective cross section; the data are normalized using Bhabha events with $55° < \theta < 125°$, but the corrections for acceptance and analysis efficiencies are not applied. The data in Fig. 4 would permit a determination of a_μ^{had} with a statistical error of ∼2%. With the full statistics of the 2001 data set and some further work on systematic issues, KLOE should be able to measure $\sigma(e^+e^- \to \pi^+\pi^-\gamma)$ to 1% overall accuracy.

8. OUTLOOK

The first ∼20 pb^{-1} of KLOE data have yielded preliminary measurements of the ratio $\mathrm{BR}(K_S \to \pi^+\pi^-)/\mathrm{BR}(K_S \to \pi^0\pi^0)$, $\mathrm{BR}(K_S \to \pi^\pm e^\mp \bar{\nu}(\nu))$, the ratio $\mathrm{BR}(\phi \to \eta'\gamma)/\mathrm{BR}(\phi \to \eta\gamma)$, and the BR's for the decays $\phi \to f_0\gamma$ and $\phi \to a_0\gamma$. DAΦNE performance has improved considerably during the first two years of KLOE data taking, and the additional ∼150 pb^{-1} of data collected during 2001 will allow these measurements to be extended and complete and definitive results to be obtained. The new data will also permit studies of K_S decays into $\pi^+\pi^-\pi^0$, $3\pi^0$, and $\gamma\gamma$; the measurement of the BR's for K_L decays into $\pi^+\pi^-$, $\pi^0\pi^0$, and $\gamma\gamma$; measurement of the $K_{e3}^\pm$ form factors; and a measurement of $\sigma(e^+e^- \to \pi^+\pi^-\gamma)$ to 1% accuracy. Major work on DAΦNE to further increase the luminosity is scheduled for mid-2002.

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