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Recent results and perspectives for KLOE and KLOE-2

Fabio Bossi[∗†]
INFN Frascati
E-mail: fabio.bossi@lnf.infn.it

While preparing for a long high luminosity run with an upgraded detector, the KLOE-2 Collaboration has continued analysing the old KLOE data set. A collection of new results on eta meson decays, two-photon interactions as well as on the searches for unconventional light neutral boson is presented.

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∗Speaker.
†On behalf of the KLOE-2 Collaboration

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After the succesful data taking campaign of years 2000-2006, the KLOE-2 Collaboration is preparing to start a new run with an upgraded detector, with the goal of collecting a data set larger by a factor 2-4 with respect to that already on tape. New subdetectors are being built and will be installed on the beam line by summer 2013, with the purpose of improving vertex reconstruction as well as increasing the acceptance for photons.

In the meanwhile, the old data are still being analysed to produce new results in several different physics field. This "old" set corresponds to $\sim$ 2 fb^{-1} of $e^+ - e^-$ collision data taken at the ϕ(1020) resonance peak and of $\sim$240 pb^{-1} taken at $\sqrt{s}$=1000 MeV.

In the following, I will briefly present some of the most recent results, concerning rare ϕ, K^0_S and η mesons decays and studies of $\gamma - \gamma$ interactions.

1. $\phi \to \eta e^+ e^-$

Although vector meson dominance (VMD) is able to describe well many electromagnetic interactions of hadrons, it however fails in describing all of them. For instance $\omega \to \pi^0$ transitions are poorly described by VMD [1]. Dalitz decays of the ϕ to η or π^0 can be very useful to clarify the matter and test alternatives to VMD. Moreover they turn out to be also relevant in the searches for light non conventional vector bosons (the so called U bosons).

In the following, I describe the studies on $\phi \to \eta e^+ e^-$ transitions at KLOE, performed by identifying the η through both its $\pi^+\pi^-\pi^0$ and $3\pi^0$ decay channels.

The two analysis chains proceed parallely requiring either 4 tracks and two photons, or two tracks and 6 photons with kinematics compatible to the searched decays. The two electrons are identified using time of flight, while conversions of photons on the detector materials are rejected by dedicated search algorithms. After all analysis cuts, $\sim$14000 events survive in the charged channel and $\sim$ 29000 in the neutral one. The efficiency corrected spectra of these events, as a function of the invariant mass of the electron-positron pair (M$_{ee}$) are shown in figure 1.

They can be fit using a properly parametrized form factor function whose slope, $b_{\phi\eta}$, is predicted to be equal unity in the VMD model, while measured to be (3.8$\pm$1.8) GeV^{-2} by a previous low-statistics experiment [2]. The fit on the two KLOE samples give results in agreement between each other. Since some systematic studies have still to be performed, no final conclusion can be reached yet, however, at present, it seems that VMD is favoured by KLOE.

These $V \to Pe^+e^-$ transitions (V and P are vector and pseudoscalar mesons, respectively) are also useful to search for light non standard vector bosons (U bosons) weakly coupled with ordinary matter through a kinetic mixing between the U and the photon. The strenght of the mixing is given by a parameter ε, to be determined experimentally and such that $BR(V \to PU) = \varepsilon^2 BR(V \to P\gamma)$ [3]

Searches for the U boson are also performed using e^+e^- collision data as well as fixed target $e - N$ scattering [4],[5], and are mainly motivated by data driven dark matter models [3] [6].

In the present case, a U boson is identified by the presence of a sharp peak in the M$_{ee}$ distribution. Since no peak is observed in neither of the two data sets, a limit on the existence of the U, as a function of ε and of its mass (M$_U$) can be set as shown in figure 2. In the figure the KLOE-2 limit is reported for two different and extreme choices for the $b_{\phi\eta}$ parameter, as well as together with the limits obtained by the experiments in references [4],[5].

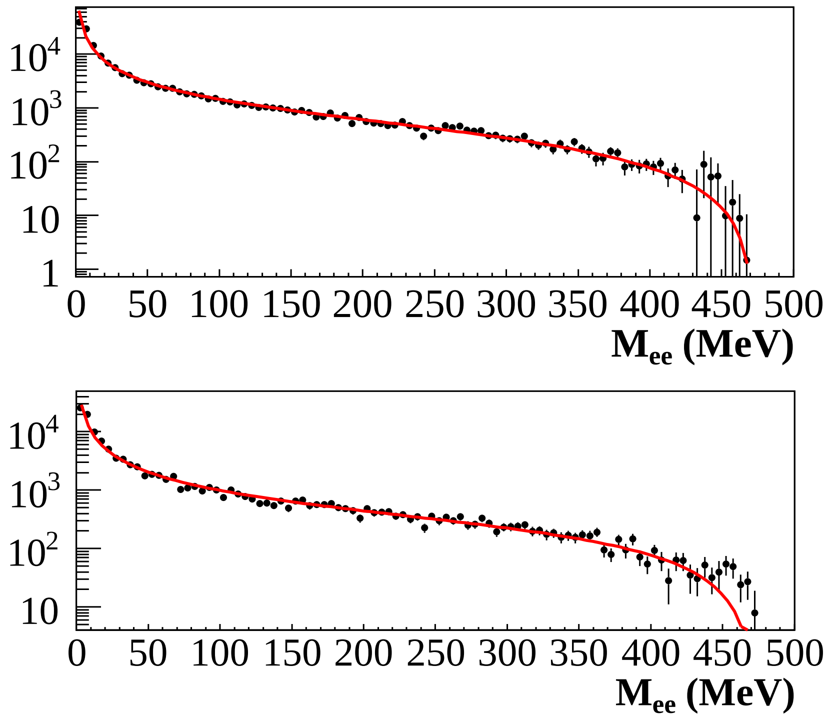

Figure 1: Efficiency corrected invariant mass distribution of the e^+e^- pair for $\phi \to \eta e^+e^-$ events, with $\eta \to 3\pi^0$ (top) and $\eta \to \pi^+\pi^-\pi^0$ (bottom).

2. $K_S \to 3\pi^0$

The $K_S \to 3\pi^0$ decay is a purely CP violating one. The corresponding decay rate can be easily evaluated using the measured value of ε, the parameter which describes CP violation in the $K^0 - \overline{K^0}$ mixing, providing a branching ratio of $\sim$2x10^{-9}.

At the ϕ peak K_S^0's are produced in pairs together with a K_L^0 meson. Given the dimensions of the detector and the average decay length of a K_L^0 at this energy, $\sim$3.5 m, about 50% of the K_L^0 have still not decayed when reaching the KLOE calorimeter. Therefore, at KLOE, the presence of a K_S^0 can be tagged by observing the interactions of the accompanying K_L^0 in the electromagnetic calorimeter. These so called "K-crash" events are characterized by the presence of a relatively energetic neutral cluster with a timing compatible with it being produced by a slowly moving (β=0.22) neutral particle.

Candidate events are selected by looking for 6 prompt photons associated to a K-crash tag. The main physical background is due to $K_S \to 2\pi^0$ decays with two fake photons, due to splittings of a single photon cluster or to beam-related accidentals. This background is removed by two kinematic fits using signal and background hypothesis, respectively.

KLOE has already published a limit on this branching ratio, using a data sample corresponding to an integrated luminosity of $\sim$ 400 pb^{-1}. This result, $BR(K_S \to 3\pi^0) < 1.2x10^{-7}$ at 90% CL, resulted from the observation of 2 candidate events with 3.1 events of expected background [9].

The new analysis, makes use of the entire KLOE statistics and of an improved algorithm to

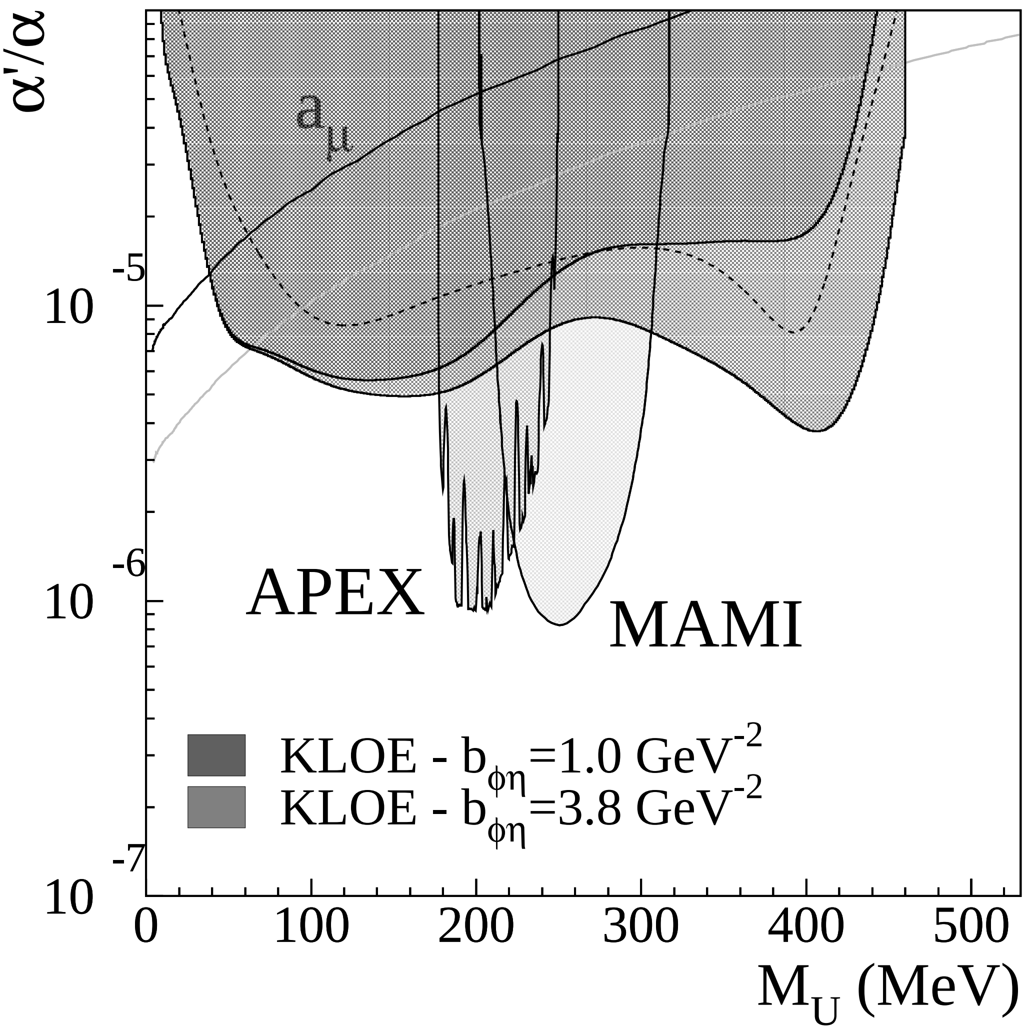

Figure 2: KLOE-2 limit in the plane M_U-$\alpha'/\alpha = \varepsilon^2$, together with the experimental limits of [4],[5]. The figure is taken from [7] and reports also our previous result [8]

reject fake photon signals. Also, the K_S tagging technique has been slightly improved. No events are observed, with zero events expected from backgrounds; the latter estimate is based on a Monte Carlo sample corresponding to a luminosity twice as large as the one of the analysed data. With the estimated detection efficiency, ∼23%, the standard model expected signal would be of 0.2 events.

Using the above numbers, a limit of $BR(K_S \to 3\pi^0) < 2.64x10^{-8}$ at 90% CL can been set, that is the best limit on this branching ratio to date.

3. $\eta \to \pi^+\pi^-\gamma$

The $\eta \to \pi^+\pi^-\gamma$ decay is expected to receive contributions by both a resonant (mostly ρ) and a contact term (CT) whose relative strengths are not fixed by the theory. The present PDG world average for $\Gamma(\eta \to \pi^+\pi^-\gamma)$=(60$\pm$4) eV favours a strong contribution of CT, since without it one would have $\Gamma(\eta \to \pi^+\pi^-\gamma)$=(100.4$\pm$2.8) eV.

A few years ago CLEO has issued a new result for the ratio $BR(\eta \to \pi^+\pi^-\gamma)/BR(\eta \to \pi^+\pi^-\pi^0)$, which differs by more than 3σ from the average of all the previous measurements [10].

In KLOE these decays are identified by looking for events with two tracks and two prompt photons. One of the photons has to have E_γ>250 MeV, since it must come from the radiative decay of the ϕ into $\eta\gamma$, which is fixed by the two body kinematics. Moreover the tracks have to have a ToF not compatible with that of an electron/positron, thus rejecting the double radiative Bhabha background. After other kinematic requirements and normalizing for the $\eta \to \pi^+\pi^-\pi^0$ decays observed in the same data sample, one obtaines $BR(\eta \to \pi^+\pi^-\gamma)/BR(\eta \to \pi^+\pi^-\pi^0)$=(0.1856$\pm$0.0005$\pm$0.0028) consistent with CLEO, but with a factor 3 better precision [11].

Combining this measurement with the world average value of $\Gamma((\eta \to \pi^+\pi^-\pi^0)$, one finds $(\eta \to \pi^+\pi^-\gamma)$=(54.7$\pm$3.1) eV, confirming the relevance of the contact term contribution to these transitions.

It is of interest also the study of the invariant mass distribution of the $\pi\pi$ pair, $M_{\pi\pi}$. This distribution can be described by a single parameter α within the context of the model independent approach of [12]. We determined the value of this parameter to be α=(1.32$\pm$0.08$^{+0.10}_{-0.09}\pm$0.02$_{theo}$) GeV^{-2}.

4. Two photon interactions

The study of scalar meson production in $\gamma-\gamma$ collision is particularly relevant for the determination of the light-by-light contribution to the muon g-2, and to measure the two photon width of the η, $\Gamma(\eta \to \gamma\gamma)$.

We have performed this study, using the data sample taken at $\sqrt{s}$=1000 MeV, where the background due to ϕ decays is largely suppressed. As in the previously described analyis, the η meson is observed by its $\pi^+\pi^-\pi^0$ and $3\pi^0$ decay channels. Since the two leptons, which are emitted close to the beam lines, are not detected, the two signals consist of two tracks and four photons or of six photons with kinematical variables compatible with the production of an eta meson. The most relevant background is due to $e^+e^- \to \eta\gamma$ events where the photon escapes detection. Since the cross section of this process was previously unknown, it has been measured by us, as $\sigma(e^+e^- \to \eta\gamma)$=(856$\pm$8$\pm$16) pb.

At the end of the anlysis chain, the two signals are extracted by fitting the missing mass, the longitudinal and transverse momentum distributions of the candidate η, providing $\sim$720 and $\sim$390 events for the neutral and charged channel respectively.

Combining the two results one obtains $\sigma(e^+e^- \to \eta\ e^+e^-)$=(32.72$\pm$1.27$\pm$0.70)pb, from which one derives $\Gamma(\eta \to \gamma\gamma)$=(520$\pm$20$\pm$13) eV, that is the most precise determination of this quantity to date [13].

5. Future prospects

The study of two photon interactions is a relevant part of the physics program of KLOE-2, the continuation of KLOE with an upgraded detector [14].

Actually, two pairs of dedicated tagging detectors have recently been installed with the purpose of indentifying the scattered electron and positron from $\gamma-\gamma$ reactions, improving background recjection for this type of events.

Other subdetectors, presently under construction, will be installed before summer 2013. A cylindrical internal tracker will help us improving the resolution for charged vertices close to the interaction point [15]. Two different type of calorimeters will improve detection of photons emitted at very low polar angles or hitting the low-β insertion quadrupoles of the machine [16] [17].

We expect also an improvement in the machine performance. According to a recent experiment [18] the peak luminosity of DAΦNE can increase by a factor of $\sim$3 with respect to the best value obtained in 2005. The goal of KLOE-2 is to collect a luminosity of $\sim$10 fb^{-1} within the next three years.

6. The KLOE-2 Collaboration

The KLOE-2 Collaboration is composed by: D. Babusci, D. Badoni, I. Balwierz-Pytko, G. Bencivenni, C. Bini, C. Bloise, F. Bossi, P. Branchini, A. Budano, L. Caldeira Balkeståhl, G. Capon, F. Ceradini, P. Ciambrone, F. Curciarello, E. Czerwiński, E. Dané, V. De Leo, E. De Lucia, G. De Robertis, A. De Santis, P. De Simone, A. Di Domenico, C. Di Donato, R. Di Salvo, D. Domenici, O. Erriquez, G. Fanizzi, A. Fantini, G. Felici, S. Fiore, P. Franzini, P. Gauzzi, G. Giardina, S. Giovannella, F. Gonnella, E. Graziani, F. Happacher, L. Heijkenskjöld, B. Höistad, L. Iafolla, M. Jacewicz, T. Johansson, K. Kacprzak, W. Kluge, A. Kupsc, J. Lee-Franzini, F. Loddo, G. Mandaglio, M. Martemianov, M. Martini, M. Mascolo, R. Messi, S. Miscetti, G. Morello, D. Moricciani, P. Moskal, F. Nguyen, A. Passeri, V. Patera, I. Prado Longhi, A. Ranieri, C. F. Redmer, P. Santangelo, I. Sarra, M. Schioppa, B. Sciascia, M. Silarski, C. Taccini, L. Tortora, G. Venanzoni, W. Wiślicki, M. Wolke, J. Zdebik

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