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Searches for physics beyond the Standard Model at KLOE

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Abstract. The KLOE detector, operating at the DAΦNE ϕ-factory facility of INFN Frascati, has contributed in several ways to the confirmation of the Standard Model, while searching at the same time for direct or indirect hints for new physics signals. Among those, I will discuss briefly the long-standing effort for the precise determination of the hadronic contribution to the muon magnetic anomaly, and the searches for a new, light, neutral vector boson.

1. Introduction

Built in the late 90's, KLOE is a multi purpose apparatus designed to optimise the detection efficiency for decays of K_L^0 produced at the DAΦNE ϕ-factory of INFN Frascati. Between years 2000 and 2006, DAΦNE has delivered to KLOE 2.5 fb^{-1} of e^+e^- collision data at the $\phi(1020)$ peak, plus additional 240 pb^{-1} at 1000 MeV.

Using these data KLOE has taken part to the recent years effort of confirmation and consolidation of the Standard Model, while searching at the same time for direct or indirect hints for its breakdown. Among the main KLOE results one can list:

- The complete set of neutral and charged kaon decay parameters to allow the precision measurement of V_{US}, setting the best unitarity limit for the CKM matrix.
- A precise determination of the hadronic contribution to the muon magnetic anomaly.
- The most detailed studies on the nature of scalar mesons.
- The measurement of some of the rarest branching ratios of the K_S^0 and η mesons.
- Several precision tests of fundamental discrete symmetries conservation (C, CP, CPT) as well as precision test of quantum mechanics.

In the following I will briefly discuss a few of the above measurements, relevant for searches of physics beyond the Standard Model.

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2. Indirect searches

The hadronic contribution to the muon magnetic anomaly a_μ cannot be calculated on the basis of first principles. It can be however evaluated by means of a dispersion integral over the e^+e^- cross section to hadrons. The latter is dominated by the contribution below $\sim$1 GeV.

At DAΦNE, this can be measured using $\pi^+\pi^-\gamma$ final state events, where the energy of the radiated photon determines the effective q^2 of the hadronic system. KLOE has contributed to this determination using different data sets and different data selection techniques:

- Using 140 pb^{-1} of data collected in 2001, selecting events with the photon emitted at small polar angles [1]
- Using 240 pb^{-1} of data collected in 2002, same "small angle" selection [2]
- Using 230 pb^{-1} of data collected in 2006 with c.m. energy of 1000 MeV, where the photon is now selected at large angle [3]
- Using 240 pb^{-1} of data of 2002, where, differently from all of the previous analysis, the $\pi\pi$ sample is normalized with respect to the $\mu^+\mu^-$ cross section [4].

The results obtained by these statistically independent analysis are in good agreement between each other and confirm the $\sim$3.5 σ deviation between the calculated value of a_μ and the measured one. This is the largest discrepancy registered so far between a measured quantity and Standard Model predictions. The nature of this potential new physics signal is unsofar a mistery.

3. Direct searches

One of the possible ways to account for the a_μ puzzle mentioned in the previous section, is to postulate the existence of a new light neutral boson (known as U boson, dark photon, A' or γ') very weakly coupled to ordinary matter. Interestingly, this hypothesis might help interpreting also several recent astrophysical observations which fail an explanation in terms ok know astrophysical sources (see, for instance [5–7]).

KLOE has contributed to the search for such new particles using different categories of events:

- The process $\phi \to \eta e^+e^-$
- Continuum events with a radiative photon, in particular $\mu^+\mu^-\gamma$ final states
- Continuum events with U boson production in pair with a new light neutral scalar (a "higgs-like" particle).

The first transition is expected to occurr with a rate suppressed by a factor ϵ^2 with respect to the standard ϕ Dalitz decay process, ϵ being the effective coupling of the U boson to ordinary matter normalized to the electromagnetic α. However, the electron-positron pair invariant mass must resonate at M_U, peaking over the non-resonant background distribution. The presence of an η meson is tagged by its 3 pion decays, which accounts for more than 50% of its branching ratios. One dangerous instrumental background comes from photon conversions over the detector material, which is removed by properly developed software algorithms. In the two papers [8, 9], KLOE did not find evidence for peaks, therefore the following limits could have been set, both at 90% CL:

$$\epsilon^2 \leq 1.5 \times 10^{-5} \text{ for } 30 < M_U(\text{MeV}) < 420$$

$$\epsilon^2 \leq 5.0 \times 10^{-6} \text{ for } 60 < M_U(\text{MeV}) < 190.$$

An analysis of the $\mu^+\mu^-\gamma$ final state is also being finalised. The data set is the same of the hadronic cross section paper [4], for which a dedicated algorithm for muon identification was developed. It is worth mentioning that in our case π/μ separation is highly untrivial, since at DAΦNE energies, muons are not penetrating particles. Again, the signal should appear as a sharp peak in the dimuon invariant

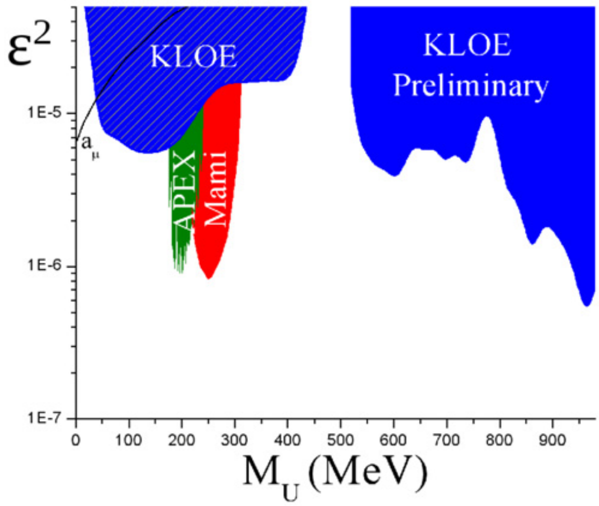

Figure 1. Exclusion plot for U boson production set by KLOE (blue regions), using ϕ Dalitz decays (left region) and $\mu^+\mu^-\gamma$ events (right region). The plot shows also limits set by previous experiments, for comparison, as well as the favoured region of the parameter space derived by the observed a_μ value.

mass distribution, over the continuum QED background. Since no peak is observed a preliminary limit on U boson production could be set, as shown in figure 1. Note that the distribution is sharply cut at $M_U \sim 500$ MeV, because of the photon angular selection.

As explained before, the U is the mediator of a new, hidden symmetry which may be spontaneously broken by some higgs-like mechanism. In this case, as in the Standard Model, a new scalar particle must exist, the h'. As for the SM Higgs, the mass of the h' is not predictable by first principles. From the phenomenological point of view this has important consequences. In fact, if $M_{h'} > M_U$, it will decay dominantly into a pair of U bosons (either both real or real-virtual), thus giving rise to events of the type $e^+e^- \rightarrow Uh' \rightarrow 6l^\pm$, where $l^\pm$ stands for all possible combinations of $e^\pm$, $\mu^\pm$, $\pi^\pm$ pairs. In the opposite case, it will decay primarily through a loop-induced process, which makes it become long-lived, thus producing $e^+e^- \rightarrow Uh' \rightarrow l^\pm + missing\, energy$ event.

The first type of events was studied by BaBar [10]. The second one is instead being searched for by KLOE, using two different data sets: the first one, the most copious, consists of about 1.7 fb^{-1} acquired at the $\phi(1020)$ resonance peak. The second, of about 240 pb^{-1}, was taken at $\sqrt{s} = 1000$ MeV, where the nasty background contamination due to $K^\pm$ decays is strongly suppressed. In none of the two samples evidence for a signal was observed, allowing KLOE to set preliminary limits on $\alpha_D\epsilon^2 < 10^{-8} - 10^{-9}$ for 200 MeV $< M_U <$ 900 MeV, 50 $< m_{h'} <$ 450 MeV (α_D is the coupling constant of the new "dark" interaction). A final paper is expected to come quite soon.

Further analysis are also been developed. In particular, the $e^+e^-\gamma$ final state is relevant, since it allows exploring U boson masses down to ~1 MeV. Also in this case, results are expected quite soon.

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