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Search for dark forces at KLOE

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Summary. — The existence of a light-dark-force mediator has been tested with the KLOE detector at DAΦNE. This particle, called U, is searched for using the decay chain $\phi \to \eta U$, with the final state $\eta \to \pi^+\pi^-\pi^0$, $U \to e^+e^-$. No evidence is found in $1.5\,\mathrm{fb}^{-1}$ of data. An upper limit on the existence of the U has been set, in the mass range $50 < M_U < 420\,\mathrm{MeV}$. We are studying other η dominant decay channels as the 2γ and the $3\pi^0$. The combined fit will extend the upper limit on the overall mass range.

PACS 14.70.Pw – Other gauge bosons.
PACS 95.35.+d – Dark matter (stellar, interstellar, galactic, and cosmological).

1. – Description

Several recent experiments, as for instance PAMELA [1], FERMI [2], and ATIC [3] have observed in cosmic ray data a large excess of electrons and positrons with energies between approximately 10 and 100 GeV. An intriguing feature of these observations is that they suggest the existence of a dark-matter weakly interacting massive particle, WIMP, belonging to a secluded gauge sector under which the Standard Model (SM) particles are uncharged. An Abelian gauge field, the U boson with mass near the GeV scale, couples the secluded sector to the SM through its kinetic mixing with the SM hypercharge gauge field. The kinetic mixing parameter, ϵ, is expected to be of the order 10^{-4}–10^{-2}, so that observable effects can be induced in Ø(GeV) energy e^+e^- colliders, as suggested by Reece and Wang [4], that proposed to search for the U in the $\phi \to \eta U$ channel. We have performed such a search as will be shown in the remaining of this paper.

2. – U boson production in ϕ decays

As discussed above, the search of the U boson can be performed at KLOE using the decay chain $\phi \to \eta U$, $U \to l^+l^-$. An irreducible background due to the Dalitz decay of the ϕ meson, $\phi \to \eta l^+l^-$, is present.

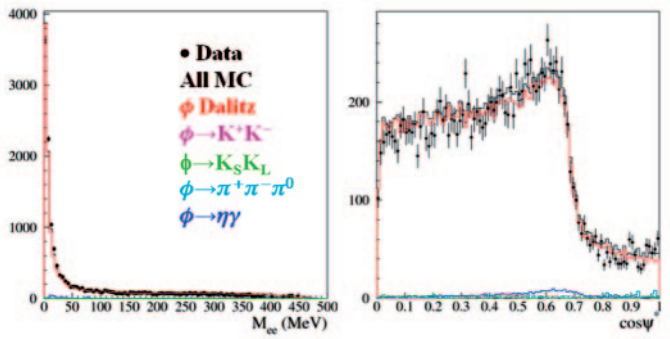

Fig. 1. – Invariant-mass distribution of the lepton pair (left) and $\cos(\Psi^*)$ distribution (right) after cuts. Dots are data, the red solid line is the MC expectations for the Dalitz decay, while signal and residual background contamination from are shown in colors.

The best channel to search the for the $\phi \to \eta U$ process at KLOE is the $U \to e^+e^-$ decay for two reasons: 1) a wider range of U boson mass can be tested; 2) e^+e^- are easily identified using the time-of-flight (ToF) measurement. The η can be tagged by the three-pion or two-photon final state, which represent $\sim 85\%$ of the total decay rate. We have performed an analysis using the $\eta \to \pi^+\pi^-\pi^0$ channel, resulting in a upper limit at 90% CL on the number of events for the decay chain. Studies are under way also for the $\eta \to 3\pi^0$ sample. We have performed an analysis using the $\eta \to \pi^+\pi^-\pi^0$ channel, which provide a clean signal with four charged tracks and two photon in the final state. We used a sample of $1.5\,\mathrm{fb}^{-1}$ of data collected in 2004–2005. We required the following preselection cut: i) four tracks in a cylinder around the interaction point (IP) plus two photon candidates; ii) best $\pi^+\pi^-\gamma\gamma$ match to the η mass using the pion hypothesis for tracks; iii) other two tracks assigned to e^+e^- pair. These simple cuts allow to clearly see the peak due to $\phi \to \eta e^+e^-$ events in the distribution of the recoil mass to the e^+e^- pair. Although a large part of the backgrounds are already rejected at this level, still remains some contamination from photon conversions and from miss-reconstructed ϕ decay channels. The former are rejected thanks to a specific photon-conversion recognition algorithm, the latter by identifying fake e^+e^- by time-of-flight to the calorimeter.

The analysis efficiency, estimated by MC, ranges between 10 and 20%, depending on the invariant-mass value of the e^+e^- pair. About 14000 $\phi \to \eta e^+e^-$ events survive the cuts, with a negligible background contamination. No evident peak is seen in the invariant-mass distribution of the lepton pair, see fig. 1.

In order to extract the correct upper limit on the U boson production, an accurate description of the Dalitz decay background is needed. For the purpose a fit is performed on the M_{ee} distribution, with a function taken from [5]. The binning of the fit is of 1 MeV. When considering the estimated background of a given bin, the fit is performed removing the five bins centered around it. In fig. 2 (right) the smoothed exclusion plot at 90% CL on α'/α is compared with existing limits from the muon anomalous magnetic moment $a\mu$ [6]and from a recent measurement of MAMI/A1 [7] experiment. Our result greatly improves existing limits in a wide mass range, resulting in an upper limit on the $\alpha'/\alpha = \epsilon^2$ parameter of $\leq 2 \times 10^{-5}$ at 90% CL for $50 < M_U < 420\,\mathrm{MeV}$.

Progresses in other η decay channels show a large reconstruction analysis efficiency and a reduced background and so the possibility to extend/combine the upper limit.

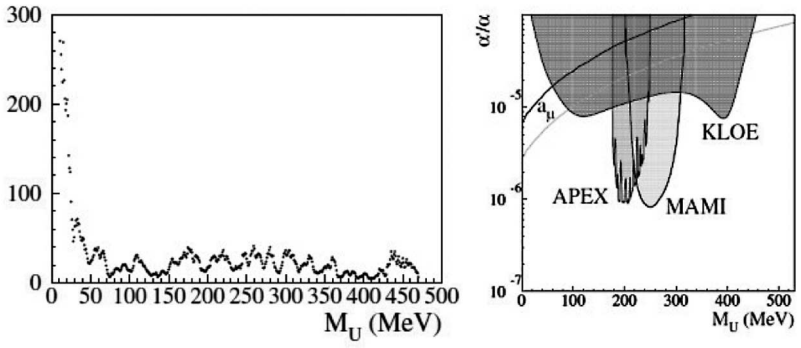

Fig. 2. – Exclusion plot on the number of events (left) at 90% CL. Exclusion plot at 90% CL for the parameter $\alpha'/\alpha = \epsilon^2$ (right), compared with existing limits in our region of interest.

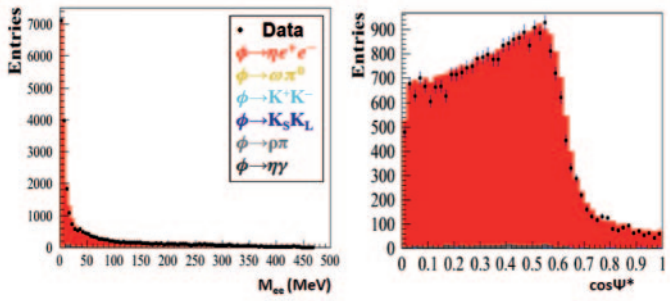

Fig. 3. – Invariant-mass distribution of the lepton pair (left) and $\cos(\Psi^*)$ distribution (right) after cuts. Dots are data, the red fill is the MC expectations for the Dalitz decay, while signal and residual background contamination from are shown in colors.

After simple cuts, we achieved about 26000 $\phi \to \eta e^+ e^-$ events survive the cuts, with a negligible background contamination. No evident peak is still seen in the invariant-mass distribution of the lepton pair, see fig. 3.

3. – Conclusions

The search for $\phi \to \eta U$ with $\eta \to \pi^+\pi^-\pi^0$, using 739 pb^{-1} of KLOE data, results in a preliminary upper limit on the ϵ parameter: $\epsilon < 3 \times 10^{-3}$ at 95% CL in the $25 < M_{ee} < 425$ MeV range. The inclusion of other final states, such as $\eta \to 3\pi^0$, will further improve this result.

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