PROCEEDINGS OF SCIENCE

KLOE/KLOE-2 results and perspectives on dark force search

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During the last years several Dark Sector Models have been proposed in order to address striking astrophysical observations which fail standard interpretations.
In the minimal case a new vector particle, the so called dark photon or U-boson, is introduced, with small coupling with Standard Model particles. Also, the existence of a dark Higgs boson h' is postulated, in analogy with the Standard Model, to give mass to the U-boson through the Spontaneous Symmetry Breaking mechanism.
The experiment KLOE, working on the DAΦNE e+e- collider in Frascati, searched for the existence of the U-boson in a quite complete way, investigating several different processes and final states. Tight limits on the model parameters have been set at 90%CL. Further improvements are expected in terms of sensitivity and discovery potential with the new KLOE-2 detector working on the improved DAFNE e+e- collider.

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1. Introduction

The Standard Model (SM) does not provide a definitive model of all elementary particles. In particular, some astrophysical observations [1, 2, 3, 4, 5, 6, 7, 8] and the muon magnetic discrepancy a_μ are examples of possible physics beyond the SM. Extensions of the SM [9, 10, 11, 12, 13] claim to explain the afore-mentioned anomalies by means of dark matter models, with a Weakly Interacting Massive Particle (WIMP) belonging to a secluded gauge sector. The new gauge interaction would be mediated by a new vector gauge boson, the U boson or dark photon, which could interact with the photon via a kinetic-mixing term ε^2. In the following, some of the U boson searches, carried out with the KLOE detector, are described.

2. U-boson search in $e^+e^- \to U\gamma$ with $U \to e^+e^-$

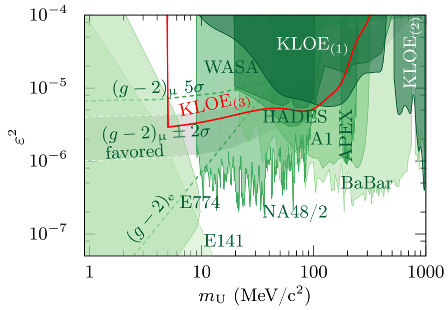

Figure 1: Exclusion limits on the kinetic-mixing parameter, ε^2, from KLOE: KLOE$_1$, KLOE$_2$ and KLOE$_3$ (in red) correspond to the combined limits from the analysis of $\phi \to \eta e^+e^-$, $e^+e^- \to \mu^+\mu^-\gamma$ and $e^+e^- \to e^+e^-\gamma$, respectively. The results are compared with the limits from E141, E774 [21], MAMI/A1 [22], APEX [23], WASA [24], HADES [25], NA48/2 [26] and BaBar [27]. The grey band indicates the parameter space favored by the $(g_\mu - 2)$ discrepancy.

The study of the reaction $e^+e^- \to U\gamma$, $U \to e^+e^-$ has the characteristic that allows to investigate the low mass region close to the di-electron mass threshold [18]. The signal of the U boson would be then expected as a resonant peak in the di-electron invariant mass. Since no signal was observed, the upper limit of the kinetic-mixing parameter as a function of m_U was evaluated with the CLs technique setting a limit on the U-boson signal at 90% confidence level Fig. 1. The integrated luminosity corresponds to $L_{integrated} = 1.54\,\text{fb}^{-1}$ from the 2004-2005 data campaign.

3. U-boson search in $e^+e^- \to U\gamma$ with $U \to \pi^+\pi^-$

The leptonic channels investigated by KLOE loose sensitivity in the $\rho - \omega$ region due to the dominant branching fraction into hadrons. The effective coupling of the U boson is predicted to be given by the product of the virtual-photon coupling and the kinetic-mixing parameter $\varepsilon^2 eF_\pi(q^2)$ [17]. For this search, a total integrated luminosity of 1.93 fb^{-1} was analyzed [28]. No signal was observed and a limit at the 90% CL was set on the coupling factor ε^2 in the energy range between 527 and 987 MeV with a larger sensitivity than previous limits in the $\rho - \omega$ region and above, see Fig. 2.

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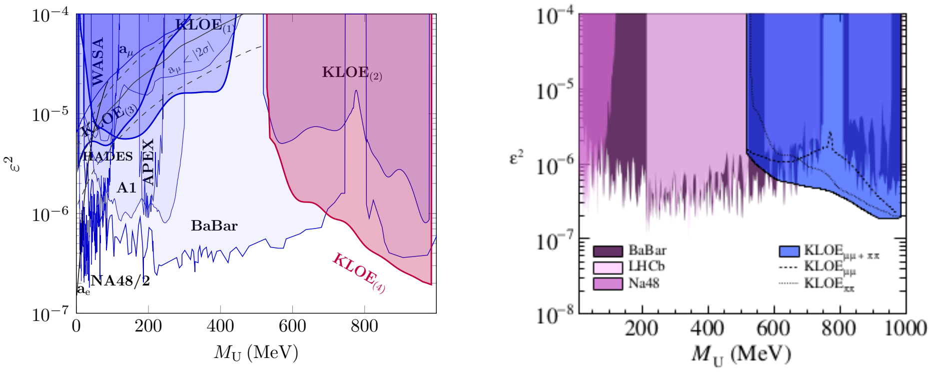

Figure 2: Left: 90% CL upper limit exclusion plot for ε^2 as a function of the U-boson mass ($KLOE_{(4)}$). **Right:** 90% CL exclusion plot for ε^2 as a function of the U-boson mass for the $e^+e^- \to U\gamma$ process. The $U \to \mu^+\mu^-$ limit (dashed line), the $U \to \pi^+\pi^-$ [28] constraint (solid line), and the $U \to \mu^+\mu^-$, $\pi^+\pi^-$ combination (blue area) at full KLOE statistics are presented in comparison with the competitive limits by BaBar [20], NA48/2 [26] and LHCb experiments [30]. The limits are shown together with previous KLOE results as well as other experiments at the moment of publication.

4. Combined limit in the production of U decaying into $\mu^+\mu^-$ and $\pi^+\pi^-$

A previous search for the U boson in the decay into $\mu^+\mu^-$ [31] has been extended by using the full KLOE statistics at $L_{int} = 1.93\text{fb}^{-1}$, updating the analysis with a new estimate of the background, analogous to the one used for the $U \to \pi^+\pi^-$ search. This new search confirms the non existence of U-boson signal in the di-muon invariant mass spectrum. To increase the sensitivity in the region of the $\rho - \omega$ interference, both results on the 90% upper limit for $\mu\mu$ and $\pi\pi$ have been combined, giving the up-to-date most stringent upper limit for the mixing parameter ε^2 in the U-boson mass region 519-987 MeV. The limit is shown in Fig. 2, together with the other most competitive limits in the region.

5. Conclusions

The KLOE collaboration has extensively contributed to the U-boson searches. Up to now, no evidence for a U boson was found and limits at the 90% confidence level were set on the kinetic-mixing parameter ε^2 in the mass range $5\,\text{MeV} < m_U < 987\,\text{MeV}$. In the meantime, a new data campaign has been finalized with the KLOE-2 setup, which has collected more than $5\,\text{fb}^{-1}$ in the past three years. The new setup and the enlarged statistics could further improve the current limits on the dark coupling constant by at least a factor of two.

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References

[1] P. Jean et al., *Astrophys.* **407**, *L55 (2003).*

[2] C. E. Aalseth, et al., *Phys. Rev. Lett.* **107**, *141301 (2011).*

[3] R. Bernabei, et al., *Int. J. Mod. Phys.* **D13**, *2127 (2004).*

[4] R. Bernabei, et al., *Eur. Phys. J.* **C56**, *333 (2008).*

[5] J. Chang, et al. *Nature 456, 362 (2008).*

[6] F. Aharonian, et al., *Phys. Rev. Lett.* **101**, *261104 (2008).*

[7] F. Aharonian, et al., *Astron. Astrophys.* **508**, *561 (2009).*

[8] A. A. Abdo, et al., *Phys. Rev. Lett.* **102**, *181101 (2009).*

[9] B. Holdom, *Phys. Lett.* **B166**, *196 (1985).*

[10] C. Boehm, P. Fayet, *Nucl. Phys.* **B683**, *219 (2004).*

[11] P. Fayet, *Phys. Rev.* **D75**, *115017 (2007).*

[12] M. Pospelov, A. Ritz, M.B. Voloshin, *Phys. Lett.* **B662**, *53 (2008).*

[13] Y. Mambrini,*J. Cosmol. Astropart. Phys.* **1009**, *022 (2010).*

[14] A. Gallo, et al., *DAFNE status report, Conf. Proc.* **C060626** *(2006) 604âĂŞ606.*

[15] M. Adinolfi et al., *Nucl. Instrum. Methods* **A488**, *51 (2002)*

[16] M. Adinolfi et al., *Nucl. Instrum. Methods* **A482**, *364 (2002)*

[17] M. Reece, L.T. Wang, *JHEP* **07**, *51 (2009).*

[18] A. Anastasi, et al., *Physics Letters* **B750**, *633âĂŞ637 (2015).*

[19] L. Barzé et all., *Eur. Phys. J.* **C71**, *1680 (2011).*

[20] J.P. Lees et al., *Phys. Rev. Lett.* **108**, *211801 (2012).*

[21] J. D. Bjorken, et al., *Phys. Rev.* **D 80**, *075018 (2009).*

[22] H. Merkel et al., *Phys. Rev. Lett.* **[112**, *221802 (2014).*

[23] S. Abrahamyan et al., *Phys. Rev. Lett.* **107**, *191804 (2011).*

[24] P. Adlarson et al., *Phys. Lett.* **B726**, *187 (2013).*

[25] G. Agakishiev et al., *Phys. Lett.* **B731**, *265âĂŞ271 (2014).*

[26] J.R. Batley et al., *Phys. Lett.* **B746**, *178âĂŞ185 (2015).*

[27] J.P. Lees et al., *Phys. Rev. Lett.* **113**, *201801 (2014).*

[28] A. Anastasi et al., *Phys. Lett.* **B757** *(2016) 356-361*

[29] G. Gounaris, J.J. Sakurai, *Phys. Rev. Lett.* **21** *(1968) 244.*

[30] S. Abrahamyan et al., *Phys. Rev. Lett.* **107** *(2011) 191804.*

[31] D. Babusci et al., *Phys. Lett.* **B736**, *459-464 (2014).*