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 DAFNE 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 \[9\] 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 $\varepsilon^2$. In the following, some of the $U$ boson searches, carried out with the KLOE detector, are described.

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

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

The study of the reaction $e^+e^- \rightarrow U\gamma$, $U \rightarrow e^+e^-$ 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 $L_{\text{integrated}} = 1.54 \text{fb}^{-1}$ from the 2004-2005 data campaign.

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

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 $\varepsilon^2e_F(e^2)$ \[17\]. For this search, a total integrated luminosity of $1.93 \text{fb}^{-1}$ was analyzed \[28\]. No signal was observed and a limit at the 90% CL was set on the coupling factor $\varepsilon^2$ 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.
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 $L_{\text{int}} = 1.93\text{fb}^{-1}$, updating the analysis with a new estimate of the background, analogous to the one used for the $U \rightarrow \pi^+\pi^-$ 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 $\epsilon^2$ 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 $\epsilon^2$ 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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