RECENT RESULTS ON HADRON PHYSICS AT KLOE

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One of the basic motivations of the KLOE and KLOE-2 collaborations is the test of fundamental symmetries and the search for phenomena beyond the Standard Model via the hadronic and leptonic decays of ground-state mesons and via their production in the fusion of virtual gamma quanta exchanged between colliding electrons and positrons. This contribution includes brief description of results of recent analysis of the KLOE data aimed at (i) the search for the dark matter boson, (ii) determination of the hadronic and light-by-light contributions to the g-2 muon anomaly and (iii) tests of QCD anomalies.

1 Introduction

The KLOE detector consists of a ~ 3.5 m long cylindrical drift chamber with a diameter of about 4 m surrounded by the sampling electromagnetic calorimeter [1,2,3]. Both these detectors are immersed in the axial magnetic field (~ 0.5 T) provided by the superconducting solenoid. The detector surrounds the crossing region of the positron and electron beams circulating in the rings of the DAΦNE collider [4].

Results presented in this contribution have been obtained using the data sample collected by the KLOE collaboration. Search for the U boson, and studies of the box anomaly and $e^+e^- \to \pi^+\pi^-$ process were based on the data taken at the center-of-mass energy of $\sqrt{s} = 1.02$ GeV corresponding to the mass of the ϕ meson, whereas the studies of the $\gamma^*\gamma^* \to \eta$ process were based on the data sample taken at the center-of-mass energy of $\sqrt{s} = 1$ GeV, where background from ϕ meson decay is suppressed.

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2 Search for the dark matter boson

There are many astrophysical obsrevations indicating existence of dark matter. For example: an excess of the e^+e^- annihilation γ quanta from the galactic center observed by the INTEGRAL satellite [5], the excess in the cosmic ray positrons reported by PAMELA [6], the total electron and positron flux measured by ATIC [7], Fermi [8], and HESS [9], and the annual modulation of the DAMA/LIBRA signal [10]. The origin of this kind of enhanced stream of radiation may be explained assuming [11] that positrons are created in an annihilation of the dark matter particles into e^+e^- pairs, and that this process is mediated by the U boson with mass in the GeV scale. The existence of such U boson can manifest itself as a maximum in the invariant mass distribution of e^+e^- pairs originating from the radiative decays as e.g. $\phi \to \eta e^+e^-$. In this case a light dark-force mediator (U boson) may contribute to this process via following decay chain: $\phi \to \eta\gamma^* \to \eta U \to \eta\gamma^* \to \eta e^+e^-$. In Figure 1 we present results of the analysis of data sample of 1.7 fb^{-1} where no structures are observed in the e^+e^- invariant mass distribution over the background. Therefore, we set only an upper limit at 90% C.L. on the ratio between the U boson coupling constant and the fine structure constant of $\alpha'/\alpha < 1.7 \times 10^{-5}$ for $30 < M_U < 400$ MeV and $\alpha'/\alpha \leq 8 \times 10^{-6}$ for the sub-region $50 < M_U < 210$ MeV [14].

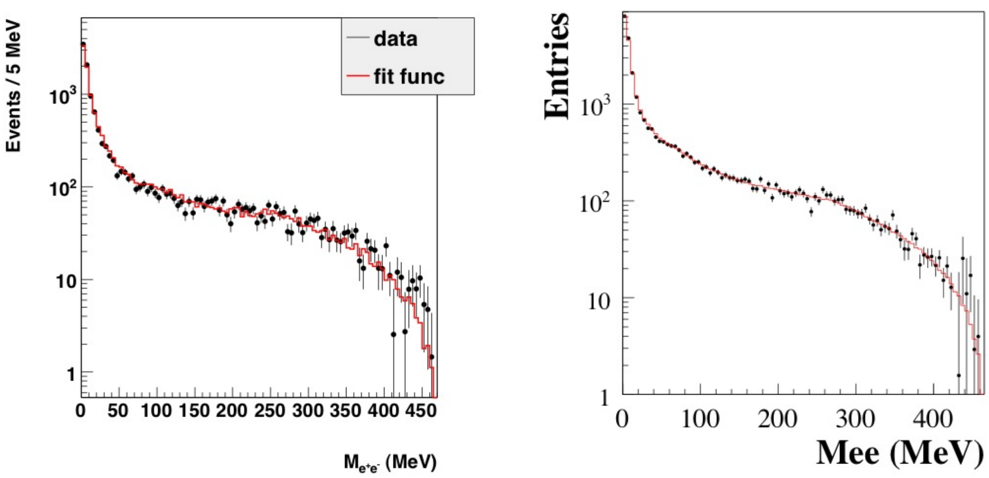

Figure 1: e^+e^- invariant mass spectrum for $\phi \to \eta e^+e^-$ decay with $\eta \to \pi^+\pi^-\pi^0$ (left) and with $\eta \to 3\pi^0$ (right). Solid lines indicate result of the fit performed assuming the Vector Meson Dominance expectations for the $\phi\eta\gamma^*$ transition form factor.

3 KLOE contribution to the determination of the g-2 anomaly

Comparison of measured and calculated value of the muon magnetic moment anomaly $a_\mu = (g_\mu - 2)/2$ constitutes one of the most precise test of the Standard Model, since a_μ was measured with the precision of 0.5 ppm [12], and FNAL experiment [13] plans to improve this accueracy to 0.14 ppm in the near future. The predictions of the value of a_μ based on the SM are however limited by the accuracy of the determination of the hadronic contributions which in 70% originates from the two pion contribution due to the $\gamma^* \to \pi^+\pi^-$ process. Therefore, we have conducted the independent measurement of the $e^+e^- \to \pi^+\pi^-(\gamma)$ cross section below 1 GeV, which is particularly important to test the Standard Model calculation for the (g-2) of the muon, where a long standing 3 sigma discrepancy is observed.

We have determined the ratio of $\sigma(e^+e^- \to \pi^+\pi^-\gamma)/\sigma(e^+e^- \to \mu^+\mu^-\gamma)$, using a total integrated luminosity of about 240 pb^{-1}. From this ratio we obtain the cross section $\sigma(e^+e^- \to \pi^+\pi^-)$ shown in Figure 2. From the cross section we determine the pion form factor $|F_\pi|^2$ and

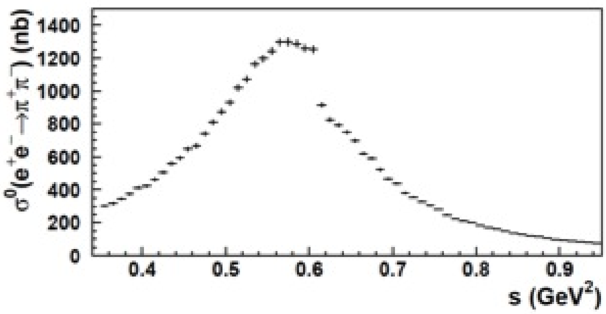

Figure 2: The bare cross section from the $\pi^+\pi^-\gamma/\mu^+\mu^-\gamma$ ratio [15].

the two-pion contribution to the muon anomaly a_μ for $0.592 < M_{\pi\pi} < 0.975$ GeV, $\Delta^{\pi\pi}a_\mu =$ $(385.1 \pm 1.1_{\rm stat} \pm 2.7_{\rm sys+theo}) \times 10^{-10}$. This result confirms the current discrepancy between the Standard Model calculation and the experimental measurement of the muon anomaly.

It is worth mentioning that the previous KLOE measurements were normalized to the luminosity using large angle Bhabha scattering, whereas the dereviation of $\sigma(e^+e^- \to \pi^+\pi^-)$ from the ratio of cross sections caused cancelation of many potential sources of uncertainty as e.g.: the radiator function, luminosity derivation, vacuum polarization corections, and to large extent also acceptance corrections [15]. In addition the influence of FSR was minimized by taking into account only small angular range for γ quanta.

Another large contribution to the uncertainty of the a_μ calculations originates from the uncertainty in determination of pseudoscalar transition form factors which dominates the precision in determination of hadronic light-by-light contributions. Therefore the precise studies of transition form factors is of importance for the SM predictions of the anomalous magnetic moment of the muon.

Studies of the conversion decays give information about the time-like region of the form-factor with positive q^2 equal to the square of the invariant mass of the l^+l^- pair [16,17]. Information about the space-like region with the negative values of q^2 is accessible via cross section of mesons production in $\gamma^*\gamma^*$ fusion realized in e.g. $e^+e^- \to e^+e^-\gamma^*\gamma^* \to e^+e^-\eta$ reaction [18]. From the measurement of the cross section of this process we derived the partial width $\Gamma(\eta \to \gamma\gamma) =$ $(520 \pm 20_{stat} \pm 13_{syst})eV$ [18], which is the most precise measurement to date.

4 Tests of QCD anomalies

The η meson is particularly suited for studies of QCD anomalies because all its strong and electromagnetic decays are forbidden in the first order [19]. The most energetically favourable strong decay of η into 2π is forbidden due to P and CP invariance. Its decay into 3π is suppressed by G-parity and isospin invariance [20], and it occurs due to the difference between the mass of u and d quarks. The first order electromagnetic decays as $\eta \to \pi^0\gamma$ or $\eta \to 2\pi^0\gamma$ break charge conjugation invariance and $\eta \to \pi^+\pi^-\gamma$ is also suppressed because charge conjugation conservation requires odd (and hence nonzero) angular momentum in the $\pi^+\pi^-$ system. Therefore, this radiative decay at a massless quark limit is driven by the QCD box anomaly.

The ratio $R_\eta = \Gamma(\eta \to \pi^+\pi^-\gamma)/\Gamma(\eta \to \pi^+\pi^-\pi^0)$ has been measured by analysing 22 million $\phi \to \eta\gamma$ decays collected by the KLOE experiment, corresponding to an integrated luminosity of 558 pb^{-1}. The $\eta \to \pi^+\pi^-\gamma$ proceeds both via the ρ resonant contribution, and possibly a non-resonant direct term connected to the box anomaly. Our result, $R_\eta = 0.1856 \pm 0.0005_{stat} \pm$ 0.0028_{syst}, points out a sizable contribution of the direct term to the total width [22]. The di-pion invariant mass for the $\eta \to \pi^+\pi^-\gamma$ decay could be described in a model-independent approach in terms of a single free parameter, α. The determined value of the parameter α is equal to $(1.32 \pm 0.08_{stat}{}^{+0.10}_{-0.09}{}_{syst} \pm 0.02_{theo})$ GeV^{-2} [22], and it is in agreement with the result of the WASA collaboration [23].

5 Perspectives

Taking atvantage of a successfuly commissioned [24] new electron-positron interaction region of DAΦNE, in the near future the data sample will be significantly increased by means of the KLOE-2 detector setup [11,21], which is a successor of KLOE upgraded with new components in order to improve its tracking and clustering capabilities as well as in order to tag $\gamma\gamma$ fusion processes [25,26,27,28,29].

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