Light meson production in $\gamma\gamma$ interactions with KLOE

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Summary. — Preliminary studies on $\gamma\gamma$ processes with the KLOE experiment without tagging of electrons/positrons are presented.

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The coupling of the photon to scalar and pseudoscalar mesons brings information on their quark structure and can be measured directly in $e^-e^+$ colliders via the reaction $e^+e^- \rightarrow e^+e^-\gamma\gamma^* \rightarrow e^+e^-X$. Of particular interest is the measurement of the $\gamma\gamma$ partial width of the $\sigma(600)$ meson, the lowest level of the nonet of scalar mesons [1].

If the $e^+e^-$ beams have energy $E$, the cross section for production of the $X$ state is

$$\sigma(e^+e^- \rightarrow e^+e^-X) = \int \frac{dL}{dz} \sigma_{\gamma\gamma \rightarrow X}(z) dz,$$

where $z = w/2E$ and $w$ is the $\gamma\gamma$ invariant mass. In case of no $e^+e^-$ tagging, the differential $\gamma\gamma$ luminosity can be expressed in the Equivalent Photon Approximation [2,3], and for a narrow resonance of spin 0 and mass $M_X$ the resulting cross section is

$$\sigma_{e^+e^- \rightarrow e^+e^-X} = \frac{16\alpha^2\Gamma_X\gamma\gamma}{M_X^3} \left( \ln \frac{E}{m_e} \right)^2 \left( (z^2 + 2)^2 \ln \frac{1}{z} - (1 - z^2)(3 + z^2) \right).$$

DAΦNE is an $e^+e^-$ collider operating at $\sqrt{s} \approx 1$–1.02 GeV. The KLOE detector consists of a large-volume drift chamber surrounded by a lead and scintillating-fibers calorimeter. Charged-particle momenta are reconstructed with resolution $\sigma_p/p \simeq 0.4$% for large-angle tracks. Energy clusters are reconstructed with energy and time resolution of $\sigma_E/E = 5.7%/\sqrt{E(\text{GeV})}$ and $\sigma_t = 57\text{ ps}/\sqrt{E(\text{GeV})} \pm 100\text{ ps}$. The sample used for the present analyses consists of data taken by KLOE at $\sqrt{s} = 1$ GeV, which allows reduction of the background from $\phi$ decays, with an integrated luminosity of 240 pb$^{-1}$. Data are processed with a dedicated $\gamma\gamma$ filter allowing for a significant amount of missing energy. A search for the $e^+e^- \rightarrow e^+e^-\eta$ process is performed, with $\eta \rightarrow \pi^+\pi^-\pi^0$. The selection of these events asks for two photons, constrained to originate from a $\pi^0$ decay, and two tracks with
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Fig. 1. – Left: fit of the $M_{miss}^2$ distribution for the $e^+e^- \rightarrow e^+e^-\eta$ analysis. Main contributions are: $e^+e^-\gamma$ at negative $M_{miss}^2$ values due to the pion mass assigned to $e^+e^-$ tracks, $\eta\gamma$ at $M_{miss}^2 \sim 0$, signal events at high $M_{miss}^2$ values. Middle: fit of the monochromatic photon energy spectrum for $e^+e^-\rightarrow \eta\gamma$ events. The $\eta\gamma$ peak at about 350 MeV and the $\omega\gamma$ peak at about 180 MeV are visible; the broad distribution is due to $\omega\pi^0$ events. Right: $M_4^\gamma$ spectrum for events selected in the $e^+e^- \rightarrow e^+e^-\pi^0\pi^0$ data analysis, compared with the sum of the expected backgrounds from Monte Carlo. The $K_S^\pm \rightarrow \pi^0\pi^0$ peak and structures related to other processes with two $\pi^0$ are visible: $\omega(\rightarrow \pi^0\gamma)\pi^0$ and $f_0(980)(\rightarrow 2\pi^0)\gamma$. The cut on $M_4^\gamma < 900$ MeV is due to the requirement on the total energy in the calorimeter to reject $e^+e^-\rightarrow \gamma\gamma$ events.

Opposite curvature coming from the collision point. The charged pion mass is assigned to the two tracks and a least squares function based on Lagrange multipliers imposes that $\pi^+\pi^-\pi^0$ come from an $\eta$ decay. Therefore most background events are suppressed, except for the irreducible process $e^+e^- \rightarrow \eta\gamma \rightarrow \pi^+\pi^-\pi^0\gamma$, with the monochromatic photon lost in the beam pipe. Figure 1 (left) shows the distribution of $M_{miss}^2$ for data fitted with the superposition of MC shapes for signal and background. An independent fit is performed with the distribution of $p_L$. Both fits show the same yields for the background processes and more than 600 signal events. Figure 1 (middle) shows the distribution of the energy of the monochromatic photon for a control sample of $e^+e^-\rightarrow \eta\gamma \rightarrow \pi^+\pi^-\pi^0\gamma$ events, selected asking for three photons in the final state and after performing a kinematic fit requiring energy and momentum conservation. Finally, a search for $e^+e^- \rightarrow e^+e^-\pi^0\pi^0$ events is performed, motivated by the interest in the $\gamma\gamma \rightarrow \sigma$ dynamics [4]. The main requirements of the data analysis are: four photons originated from $2\pi^0$ decays, no tracks in the drift chamber, photon energy fraction $> 0.8$, $p_T^{4\gamma} < 80$ MeV, energy sum of the 2 least energetic photons $> 60$ MeV. The spectrum in the $4\gamma$ invariant mass compared with the expected backgrounds is shown in fig. 1 (right). From the plot, an excess is evident at low $M_4^\gamma$ values, consistent in shape with expectations from $e^+e^- \rightarrow e^+e^-\pi^0\pi^0$ events. These results are encouraging in view of the forthcoming data-taking campaign of the KLOE-2 project [5], when both low- and high-energy $e^\pm$ tagging devices will be available.

REFERENCES