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Meson production in $\gamma\gamma$ interactions at DAΦNE

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Summary. — A data sample of $240\,\mathrm{pb}^{-1}$ collected at $\sqrt{s} = 1\,\mathrm{GeV}$ with the KLOE detector at the DAΦNE ϕ-factory has been analyzed in order to study the $e^+e^- \to e^+e^-X$ reactions, X being the $\pi^0\pi^0$ or η states produced in the scattering of two quasi-real photons.

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1. – Introduction

Studies of $\gamma\gamma$ interactions are of great interest as photons coupling to hadrons can provide information on their internal structure and help in clarifying the nature of scalar mesons. The analyses presented here focus on light scalar (σ) and pseudoscalar (η) mesons production, using data collected out-of-peak, at $\sqrt{s} = 1\,\mathrm{GeV}$, where the background from ϕ decays is highly reduced. The measurement is done in no-tagging mode, with final state $e^\pm$ going along the beam pipe and escaping detection. In this case the virtual photons are quasi-real and the overall cross section can be factorized as the $\gamma\gamma$ subprocess cross section times a $\gamma\gamma$ luminosity function [1]. The search for σ is done in the neutral decay mode, $\sigma \to \pi^+\pi^-$ being affected by large background (non-resonant production, radiative return to ρ mass, e^+e^- annihilation to pions).

2. – $\gamma\gamma \to \pi^0\pi^0$

The main goal of this analysis is to investigate the low $\pi^0\pi^0$ invariant mass region, just above the production threshold, where a contribution from the $\sigma(600)$ scalar meson as a resonant intermediate state is expected. The main background processes are annihilation reactions to states with four or more prompt photons: $e^+e^- \to K_SK_L, \eta\gamma, \omega\pi^0, f_0\gamma, a_0\gamma$. In addition, due to the possibility of cluster splitting the $e^+e^- \to \gamma\gamma$ process is also considered as a source of background. Events with 4 prompt photons with polar angle $23^o < \vartheta < 157^o$ and energy $E_\gamma > 15\,\mathrm{MeV}$ are selected. The photons are paired choosing

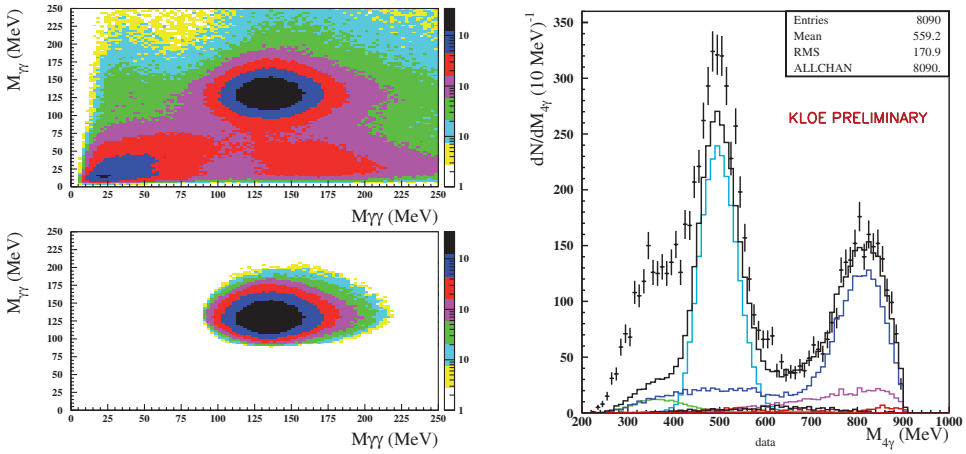

Fig. 1. – (Colour on-line) $\gamma\gamma \to \pi^0\pi^0$ analysis. Left: scatter plots in two-photon pairs invariant masses before (up) and after rejecting bad $\chi^2_{\gamma\gamma}$ events (down); selected events have both photons pairs invariant masses centered around π^0 mass value. Right: 4γ invariant mass spectrum for data (points with error bars) and background Monte Carlo. Colour code: light blue = K_SK_L, blue = $\omega\pi^0$, violet = $f_0\gamma$, green = $\eta\gamma$, red = $\gamma\gamma$ (preliminary plot).

the combination which minimizes the variable

$$\chi^2_{\gamma\gamma} = \frac{(m_\pi - m_{ij})^2}{\sigma^2_{ij}} + \frac{(m_\pi - m_{kl})^2}{\sigma^2_{kl}}, \tag{1}$$

where m_{ij} are the two-photon invariant masses and σ_{ij} the resolutions. Events with bad $\chi^2_{\gamma\gamma}$ are rejected: the effect of this selection is shown in fig. 1 (left). Events with no tracks in the drift chamber are selected; cuts on photons energies and on transverse momentum of the four-photon system are applied; a cut is applied on the ratio of the sum of the energies of four photons to the total energy deposit in the calorimeter, to reject K_SK_L events where large amount of non-prompt energy is released in the detector.

The four-photon invariant mass spectrum for the selected data sample is shown in fig. 1 (right) together with the normalized background Monte Carlo simulations. A clear excess of events in the low invariant mass region is an indication of the signal of $\pi^0\pi^0$ production processes. A $e^+e^- \to e^+e^-\sigma \to e^+e^-\pi^0\pi^0$ Monte Carlo simulation (with $\sigma(600)$ mass and width given by BES II experiment [2]) has been generated to evaluate signal efficiency. The generator [3] is based on the complete matrix element calculation and the full phase space generation.

3. – $\gamma\gamma \to \eta \to \pi^0\pi^0\pi^0$

This analysis is quite similar to the previous and therefore provides a tool to check the $\gamma\gamma$ events generator. Main background processes are again annihilation reactions with six or more prompt photons: $e^+e^- \to \eta\gamma, \omega\pi^0, K_SK_L$. Events are selected with six prompt photons; after pairing, events with bad $\chi^2_{\gamma\gamma}$ are rejected. A kinematic fit is performed asking for the six-photon invariant mass to be equal to the η mass and the space-time relation $t - |r|/c = 0$ to be satisfied for each photon; a cut is then applied on the value of the kinematic fit χ^2. Events with tracks in the drift chamber are rejected; a cut is applied on the energy of the most energetic photon, to reject $\eta\gamma$ events.

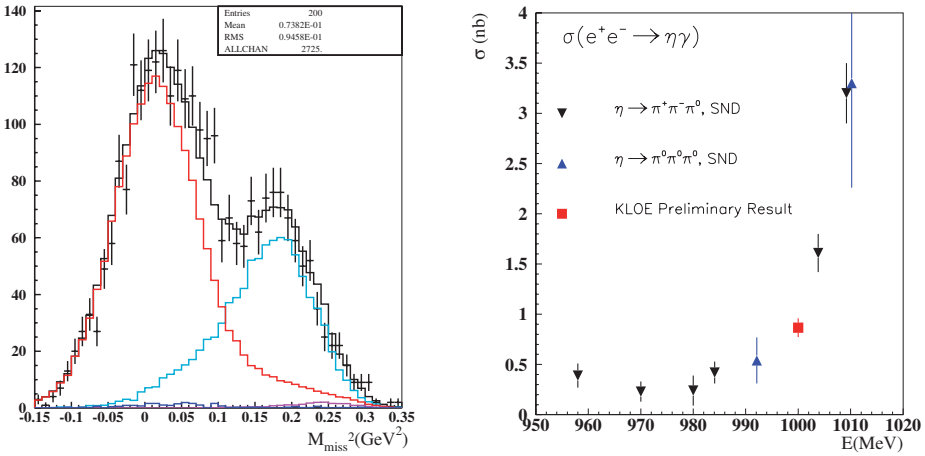

Fig. 2. – (Colour on-line) $\gamma\gamma \to \eta \to \pi^0\pi^0\pi^0$ analysis. Left: squared missing mass distributions for data (points whith error bars) and Monte Carlo normalized according to fit result (histograms). Colour code: red = $\eta\gamma$, light blue = signal, blue = $\omega\pi^0$ (preliminary plot). Right: preliminary KLOE value for $\sigma(e^+e^- \to \eta\gamma)$ at $\sqrt{s} = 1\,\text{GeV}$, (red point, with statistical uncertainty only) and SND results [4] at several values of $\sqrt{s}$.

The squared missing mass distribution shows an excess of events which is well fitted by the $\gamma\gamma \to \eta \to \pi^0\pi^0\pi^0$ Monte Carlo. The fit gives normalization for the signal and the background distributions (fig. 2 on the left). From $\eta\gamma$ normalization one obtains a preliminary value for the cross section

$$\sigma(e^+e^- \to \eta\gamma, \sqrt{s} = 1\,\text{GeV}) = (0.866 \pm 0.009_{\text{stat}} \pm 0.093_{\text{syst}})\,\text{nb}. \tag{2}$$

The value (2) is shown in fig. 2 (right) among other experimental results [4] as a function of $\sqrt{s}$.

4. – Conclusions

Both analyses presented here point out a clear excess of events in the region where the signal ($\pi^0\pi^0$ or η production) is expected. In the case of $\gamma\gamma \to \eta$ our signal Monte Carlo fits data spectrum very well. In the $\gamma\gamma \to \pi^0\pi^0$ analysis work is in progress to determine the signal efficiency and the $\gamma\gamma$ luminosity function in order to extract the cross section and compare our result with the only previous measurement [5]. The forthcoming data taking with KLOE-2 detector, equipped with small angles taggers for final state $e^{\pm}$, will give precious additional information on $\gamma\gamma$ hadron production at low energy [6].

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