

Hadron Physics at KLOE and KLOE-2

Camilla Di Donato¹ on behalf of KLOE and KLOE-2 Collaborations

I.N.F.N. Sezione di Napoli

Complesso Universitario M.S.A., Via Cintia ed.6

I-80126 Napoli, ITALY

The KLOE Collaboration completed the full data taking on March 2006, acquiring $2.5 fb^{-1}$ at the peak of the ϕ and other $240 pb^{-1}$ off-peak. A new Collaboration is working on a new project, called KLOE-2, to refine and extend the KLOE physics program.

We present here some preliminary and published results from the KLOE Collaboration on the pseudoscalar η meson and the study of $\gamma\gamma$ processes, that are among the main points of the KLOE-2 physics program.

1 Introduction

The KLOE experiment has collected $2.5 fb^{-1}$ at the peak of the ϕ resonance at the e^+e^- collider DAΦNE in Frascati. KLOE has performed several precision measurements, here we present the preliminary analysis of the $\eta \rightarrow \pi^+\pi^-\gamma$ decay channel to study box anomaly and the recently published branching ratio measurement of $\eta \rightarrow e^+e^-e^+e^-$ decay channel, never observed before. Pseudoscalar production at the ϕ -factory associated to internal conversion of the photon into a lepton pair allows the measurement of the form factor $F(q_1^2 = M(\phi)^2, q_2^2 > 0)$ of pseudoscalar mesons in the kinematical region of interest for the VMD model: a preliminary study of $\phi \rightarrow \eta e^+e^-$ is based on $739 pb^{-1}$, using the $\eta \rightarrow \pi^+\pi^-\pi^0$ final state.

From a sample of $240 pb^{-1}$ taken off the ϕ resonance, a preliminary analysis of the $e^+e^- \rightarrow e^+e^-\eta$ process, without e^\pm tagging in the final state has been performed. The same data set has been used to search for the $f_0(600)$ produced in $\gamma\gamma$ interactions via the reaction $e^+e^- \rightarrow e^+e^-\pi^0\pi^0$.

The KLOE detector is being upgraded with small angle tagging devices, to detect both high and low energy e^\pm in $e^+e^- \rightarrow e^+e^-X$ events. The inner tracker and small angle calorimeters are scheduled to be installed in a subsequent step, providing wider acceptance for both charged particles and photons. This is the new KLOE-2 project [1]: the detector is successfully rolled in the new DAΦNE interaction region, with a new beam crossing scheme allowing for a reduced beam size and increased luminosity. The main goal of KLOE-2 is to collect an integrated luminosity of about $20 fb^{-1}$ in 2-3 years in order to refine and extend the KLOE physics programme.

¹didonato@na.infn.it

2 The Pseudoscalar η meson

The decays $\eta, \eta' \rightarrow \pi^+ \pi^- \gamma$ are supposed to get contribution from the anomaly accounted by the Wess Zumino Witten term into the Chiral Perturbation Theory Lagrangian [2]. Those anomalous processes, known as box anomalies, proceed via a vector meson resonant contribution (VDM) and maybe via a direct term. The presence of this direct term affects the partial width value in the case of the $\eta \rightarrow \pi^+ \pi^- \gamma$ and the dipion invariant mass distribution, in the case of $\eta' \rightarrow \pi^+ \pi^- \gamma$.

A comparison of the experimental $M_{\pi^+ \pi^-}$ spectra and partial width for η, η' meson with theoretical predictions is mandatory to clarify the role of non-resonant contribution to the processes. The $\eta \rightarrow \pi^+ \pi^- \gamma$ decay has been measured in 1970 by Gormley et al. (7250 events) [3] and in the 1973 by Layter et al. (18150 events) [4]. Theoretical papers trying to combine the two measurements found discrepancies in data treatment and problems in obtaining consistent results [2]. In 2007 CLEO Coll. has published the measurement $\Gamma_{\eta \rightarrow \pi^+ \pi^- \gamma} / \Gamma_{\eta \rightarrow \pi^+ \pi^- \pi^0} = 0.175 \pm 0.007 \pm 0.006$, based on 859 $\eta \rightarrow \pi^+ \pi^- \gamma$ events [5], which is more than 3σ below the old measurements. KLOE result [6], obtained using 558 pb^{-1} , gives $\Gamma_{\eta \rightarrow \pi^+ \pi^- \gamma} / \Gamma_{\eta \rightarrow \pi^+ \pi^- \pi^0} = 0.1838 \pm 0.0005_{stat} \pm 0.0030_{syst}$, in agreement with the latest CLEO evaluation, providing strong evidence in favour of the box anomaly/direct term.

The knowledge of the η meson coupling to virtual photons is important for calculation of anomalous magnetic moment of the muon, because the pseudoscalar exchange is the major contribution to the hadron light-by-light scattering [1]. In the $\eta \rightarrow e^+ e^- e^+ e^-$ process we have conversion decays, which offer the possibility to precisely measure the virtual photon 4-momentum, via the e^+ and e^- 4-momenta and we are directly sensitive to the η meson transition form factor because there are no hadrons among the decay products. The first theoretical evaluation dates from 1967 [7] and predicts a branching ratio $BR(\eta \rightarrow e^+ e^- e^+ e^-) = 2.59 \times 10^{-5}$. Double lepton-antilepton η decays have been searched by CMD-2 and WASA, obtaining upper limits at level of the theoretical expectation. KLOE has published the first observation of the $\eta \rightarrow e^+ e^- e^+ e^-$ decay, analysing $1.7 fb^{-1}$ and identifying 362 ± 29 events which results in a branching ratio of $(2.4 \pm 0.2_{stat+bkg} \pm 0.1_{syst}) \times 10^{-5}$, in agreement with theoretical predictions [8].

Vector-meson-dominance assumption provides good description of photon coupling to hadrons, and, implementing systematic corrections to standard VMD, it correctly describes the $\omega \rightarrow \pi^0 \mu^+ \mu^-$ experimental results too. In this framework deviation from standard VMD for the $\phi \rightarrow \eta e^+ e^-$ decay spectrum is predicted. The only existing data available come from SND experiment, which has measured the M_{ee} invariant mass distribution with 213 events [9]. KLOE has selected 7000 $\phi \rightarrow \eta e^+ e^-$ with $\eta \rightarrow \pi^+ \pi^- \pi^0$ using a sample of 739 pb^{-1} . Preliminary fit to the M_{ee} using decay parametrization from [10] and $F(q^2)$ as from [11], indicates the possibility to reach a 5% error on form factor slope.

2.1 Gamma-gamma Physics

The coupling of photons to scalar and pseudoscalar mesons brings information on meson's quark structure and can be measured directly in e^+e^- colliders via the reaction $e^+e^- \rightarrow e^+e^-\gamma^*\gamma^* \rightarrow e^+e^-X$. Using the Weizsäcker-Williams approximation [12] to understand main qualitative features of the process, when no cuts are applied to the final state leptons, it is possible to evaluate the event yields: $N_{eeX} = L_{ee} \int \frac{dF}{dW_{\gamma\gamma}} \sigma_{\gamma\gamma \rightarrow X}(W_{\gamma\gamma}) dW_{\gamma\gamma}$ the L_{ee} is the integrated luminosity, $W_{\gamma\gamma}$ is the mass of the $\gamma^*\gamma^*$ and $dF/dW_{\gamma\gamma}$ the two photons flux function, defined as follows: $\frac{dF}{dW_{\gamma\gamma}} = \frac{1}{W_{\gamma\gamma}} \left(\frac{2\alpha}{\pi}\right)^2 \left(\ln \frac{E_b}{m_e}\right)^2 f(z)$ with E_b beam energy and $f(z)$ is a function of $z = \frac{W_{\gamma\gamma}}{2E_b}$.

Single π^0 or η production is accessible and this allows to improve determination of two photon decay width of these meson. In particular KLOE is looking for $e^+e^- \rightarrow e^+e^-\eta$ with $\eta \rightarrow \pi^+\pi^-\pi^0$ final state: in a preliminary analysis of 240 pb^{-1} off-peak data about 600 events from η meson, produced in $\gamma\gamma$ interactions have been disentangled, versus other processes, with a statistical accuracy on $\Gamma_{\gamma\gamma}$ comparable with existing measurements. The same off-peak data have been analysed to search for $e^+e^- \rightarrow e^+e^-\eta$ with $\eta \rightarrow \pi^0\pi^0\pi^0$ final state.

The question concerning $\sigma/f_0(600)$ meson has been debated for a long time. An indirect evidence comes from $\phi \rightarrow \pi^0\pi^0\gamma$ KLOE analysis [13]. The $e^+e^- \rightarrow e^+e^-\pi^0\pi^0$ process is a clean electromagnetic probe to investigate the question, because it is expected to be plainly affected by σ contribution. Our preliminary analysis on the off-peak data, shows a clear enhancement over estimated backgrounds at low $M_{4\gamma}$; see Fig.1. Background subtraction

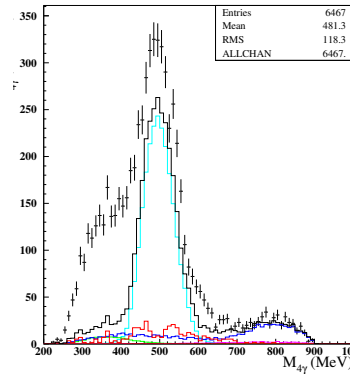


Figure 1: Preliminary spectrum of 4-photon invariant mass with KLOE: dots are data, black line is total MC background, lightblue is $K_S K_L$ decays, blue is $e^+e^- \rightarrow \omega\pi^0$ and magenta is $\phi \rightarrow f_0\gamma$; a clear evidence of $e^+e^- \rightarrow e^+e^-\pi^0\pi^0$ is given by the excess events at low $M_{4\gamma}$ invariant mass is visible

and study of differential cross section together with the understanding of the $\sigma \rightarrow \pi\pi$ contribution are in progress.

Due to large background from $e^+e^- \rightarrow \gamma\gamma(\gamma)$, information from e^\pm taggers already installed at KLOE-2, will be crucial in the analysis of new data to look for the production of σ .

The KLOE experiment with $2.5 fb^{-1}$ integrated luminosity at the peak of the ϕ resonance at the e^+e^- collider DAΦNE, has published several interesting results. In the next future a new data-taking campaign will be realized by KLOE-2 at the upgraded DAΦNE, with the aim to collect about $20 fb^{-1}$ in order to refine and extend the KLOE physics program.

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