Preliminary Results on $\gamma\gamma \to K_s K^\pm \pi^\mp$ from e^+e^- Scattering at CLEO

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We analyzed 13.8 fb^{-1} of the integrated e^+e^- luminosity collected at 10.6 GeV center-of-mass energy with the CLEO II and II.V detectors to study exclusive two-photon production of single hadronic resonances. We searched for hadrons decaying into $K_s K^\pm \pi^\mp$ when both leptons remain undetected. In this analysis we studied the detection efficiency and evaluated systematic errors using independent data samples. We estimated 90% CL upper limits on the products of the two-photon partial widths of (pseudo)scalar hadrons with masses below 1.7 GeV/c^2 and their branching fractions into $K_s(\pi^+\pi^-)K^\pm\pi^\mp$. Our preliminary results are marginally consistent with the first observation of $\eta(1440)$ in two-photon collisions by the L3 experiment.

1. Introduction

A key to understanding the phenomenon of quark and gluon confinement in Quantum Chromodynamics (QCD) would be an experimental observation and the analysis of the properties of unusual hadronic bound states predicted by Lattice QCD (LQCD), Flux Tube and other models. For example, the Flux Tube model and LQCD (even when the quenching approximation is lifted) predict a large number of light glueballs – bound states of the carriers of strong interaction and hybrids – hadrons composed of three constituents, two quarks and a gluon. A large number of proposed candidates for these new states of matter have been observed over the past 35 years in many experiments[1]. In our opinion, most of these candidates need to be confirmed and remain to be understood. One such candidate is the infamous $\eta(1440)$ first observed in 1967 in $p\bar{p}$ annihilation at rest into $K\bar{K}\pi\pi^+\pi^-$. This resonance has also been sighted in radiative decays of J/ψ into $K\bar{K}\pi$ and in charge-exchange hadronic reactions $\pi^- p \to \eta\pi\pi n$. Until recently $\eta(1440)$ has been observed only in gluon-rich environments and this established it as a prominent glueball candidate. Another hypothesis for $\eta(1440)$'s internal structure is that it is simply a radially excited η meson.

One way to discriminate the ground state meson, radial excitation, and glueball hypotheses is to measure the two-photon partial width of $\eta(1440)$. Assuming that quantum numbers allow a two-photon decay, its partial width would be of a keV order for a ground state meson, approximately an order of magnitude smaller for a radial excitation[2], and of a vanishingly small value for a true glueball because photons couple to gluons only through an intermediate quark loop. Finally, it is also possible that light glueballs and mesons are mixed and their parameters should be obtained from global fits to light hadrons spectrum, which recently became an interesting research topic in its own right. In 2001 a new piece was added to the $\eta(1440)$ puzzle when the L3 experiment reported[3] the first observation of the $\eta(1440)$ in two-photon collisions and measured its two-photon partial width to be 212 ± 50 (stat.) $\pm$ 23 (sys.) eV, assuming 100% branching fraction to $K\bar{K}\pi$. In our analysis we tried to verify the claim made by L3 and to measure the two-photon partial width of $\eta(1440)$ with better precision.

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2. Experimental Apparatus, Data Sample and the Analysis Procedure

The results presented here were obtained from the data accumulated at the Cornell Electron Storage Ring (CESR) with the CLEO series of detectors. These results are based on statistics that correspond to the integrated e^+e^- luminosity of 13.8 fb^{-1} collected at and 60 MeV below the Υ(4S) energy. The first third of the data was recorded with the CLEO II detector[4] which consisted of three cylindrical drift chambers placed in an axial solenoidal magnetic field of 1.5T, a CsI(Tl)-crystal electromagnetic calorimeter, a time-of-flight (TOF) plastic scintillator system and a muon system (proportional counters embedded at various depths in the steel absorber). Two thirds of the data were taken with the CLEO II.V configuration of the detector where the innermost drift chamber was replaced by a silicon vertex detector[5] (SVX) and the argon-ethane gas of the main drift chamber was changed to a helium-propane mixture. This upgrade led to improved resolutions in momentum and specific ionization energy loss (dE/dx) measurements.

The information from the two outer drift chambers, the TOF system and electromagnetic calorimeter was used to make the decisions in the three-tier CLEO trigger system[6] complemented by the software filter for beam-gas rejection. The response of the detector was modeled with a GEANT-based[7] Monte Carlo (MC) simulation program. The data and simulated samples were processed by the same event reconstruction program. Whenever possible the efficiencies were either calibrated or corrected for the difference between simulated and actual detector responses using direct measurements from independent data. Our two-photon statistics in the $\eta(1440)$ mass range exceeds the statistics collected by the L3 experiment by the factor of ~ 5.

There are two groups of selection criteria we developed for this analysis. First of all we need to suppress backgrounds arising mainly from e^+e^- annihilation to hadrons and τ pairs. Further, we want to select events that are reconstructed in the region of the detector where trigger and detection efficiencies are well understood and associated systematic errors are under control. To achieve these goals we select events with four reconstructed charged tracks. We require at least one charged track with transverse momentum exceeding 250 MeV/c. This track should point in the barrel part of the calorimeter. Also, we only use events recorded with trigger configurations developed for events with at least two hadrons in the final state. The latter three requirements select events recorded with well-understood trigger. K_s candidates are identified by reconstructing secondary vertex radially displaced by at least two standard deviations (σ) from the primary interaction point. This secondary vertex should satisfy quality criteria developed and calibrated using independent data samples. The reconstructed mass of the K_s candidate should be within $\sim 5\sigma$'s from its nominal value. Signal event candidates are required to have one such K_s. The remaining two charged tracks are identified using dE/dx and TOF information. These measurements are used to form normalized (*i.e.* per a degree of freedom) χ^2 which is required to be within 3σ. There is no ambiguity associated with this selection for $\eta(1440)$'s two-photon kinematics on CLEO. Total amount of energy collected in photon-like calorimeter clusters that do not match with the projections of charged tracks should be below 100 MeV. Such clusters could often be present in signal events because of split-off effects caused by nuclear interactions of charged hadrons with the materials of the detector. Finally, we require our $K_sK^\pm\pi^\mp$ candidates to have total transverse momentum below 100 MeV/c. The latter two selection criteria are powerful in suppressing $\gamma\gamma \to K^*\bar{K}^*(\pi)$ backgrounds that feed down to our $K_sK^\pm\pi^\mp$ signal in events where some hadrons miss to be detected. The presence of these backgrounds in our data was proven by an independent analysis where we did full reconstruction of $K^*\bar{K}^*(\pi)$ final states arising from two-photon fusion.

The particular criteria values used in our event selection were optimized to provide the best discriminating power for the signal and backgrounds and/or to reduce systematic uncertainty in the final result. The optimizations have been carried using calibration data sample briefly discussed below and extensive MC samples generated for this analysis. To measure the efficiencies of our selection criteria and to evaluate systematic errors we used data events where we identified two high-quality K_s candidates. We used the distribution of these events' transverse momentum to establish their consistency with two-photon production mechanism. We measured the efficiencies of various selection criteria by imposing them on K_sK_s data and MC samples. Systematic errors were estimated by comparing the efficiencies in data and MC simulation. Overall detection efficiency of our selection is 0.84% for a hypothetical resonance with the mass $M = 1475$ MeV/c^2 and full width $W = 50$ MeV. We chose to present the efficiency measured for these values of the parameters because these are the central values reported by the L3 experiment[3]. Relative systematic error on the efficiency is 30%. The dominant sources of this error are the uncertainties in the trigger efficiency (14%), four-track event selection (21%), tight unmatched calorimeter energy (10%) and event transverse momentum (10%) requirements.

We tested our analysis technique by estimating the two-photon partial width of the η_c that we reported recently from an independent analysis of the same data sample[8]. We previously measured $\Gamma_{\gamma\gamma}(\eta_c) = (7.6 \pm 0.8 \text{ (stat.)} \pm 0.4 \text{ (sys.)})$ keV, while our current estimate yields $\Gamma_{\gamma\gamma}(\eta_c) = (6.7 \pm 0.9 \text{ (stat.)})$ keV. This proves that our selection criteria are unbiased. Our large systematic error only applies to low-mass $K_sK^\pm\pi^\mp$ final states.

3. Preliminary Results

We show the invariant mass of $K_sK^\pm\pi^\mp$ candidates in data in Fig. 1. The points with the error bars show our data, the lines and a curve show the results of the binned maximum likelihood (ML) fit described below. Two dashed curves enclosing the solid curve show the signal expectation ($\pm 1\sigma$ (stat.)) according to the results of the L3 experiment superimposed on top of background obtained from our fit. We observe no indication of $\eta(1440)$ or any other resonance in shown mass region. We conclude that our sensitivity is not sufficient to detect two-photon production of $\eta(1440)$ followed by its decay into $K_sK^\pm\pi^\mp$. To estimate the upper limit on the number of signal event candidates we assume that there is only one resonance potentially decaying into $K_sK^\pm\pi^\mp$ in the mass region between 1.3 GeV/c^2 and 1.7 GeV/c^2 and fit the distribution shown in Fig. 1 (on the left) with signal line shape for the $\eta(1440)$ and a straight line approximating background contribution. There are several steps involved in estimating signal line shape from MC: first we convolute simple relativistic Breit-Wigner for a pseudoscalar with two-photon luminosity function. Then we convolute the resulting function with the detector resolution and efficiency functions. All these functions depend on the $K_sK^\pm\pi^\mp$ invariant mass and, as the result the original Breit-Wigner shape is distorted making the higher-mass tail of signal line shape to be more significant than the lower-mass tail for the results of the fit. The number of signal events we expect to measure assuming the values of M and W reported by L3 is 112 ± 28. However, from the results of our ML fit we estimate 90% CL upper limit on the number of signal $\eta(1440)$ events to be less than 33. To estimate the upper limit on the two-photon partial width of the $\eta(1440)$ we divide this number by the overall detection efficiency reduced by 30% of itself, by the integrated e^+e^- luminosity and by numerical prediction for pseudoscalar two-photon cross section evaluated[9] assuming $\Gamma_{\gamma\gamma}(\eta(1440)) = 1$ keV This procedure gives us 90% CL upper limit on the product $\Gamma_{\gamma\gamma}(\eta(1440))\mathcal{B}(\eta(1440) \to K_s(\pi^+\pi^-)K^\pm\pi^\mp)$ in units of keV. First we perform this estimate for the mass and total width reported by L3, then we also make estimates for other values of M and W for a hypothetical hadron $\mathcal{R}$ in question. Some of our preliminary results for the upper limits on the value of $\Gamma_{\gamma\gamma}(\mathcal{R})\mathcal{B}(\mathcal{R} \to K_s(\pi^+\pi^-)K^\pm\pi^\mp)$ are 14.4 eV (1475, 50), 1.2 eV (1440, 50) and 1.3 eV (1420, 20), where the numbers in parentheses are the values of M (in MeV/c^2) and W (in MeV) used for a particular estimate. These numbers are 2.9, 4.0 and 4.0 σ's below L3 measurement $\Gamma_{\gamma\gamma}(\eta(1440))\mathcal{B}(\eta(1440) \to K_s(\pi^+\pi^-)K^\pm\pi^\mp) = (49 \pm 12\ (\text{stat.}))$ eV.

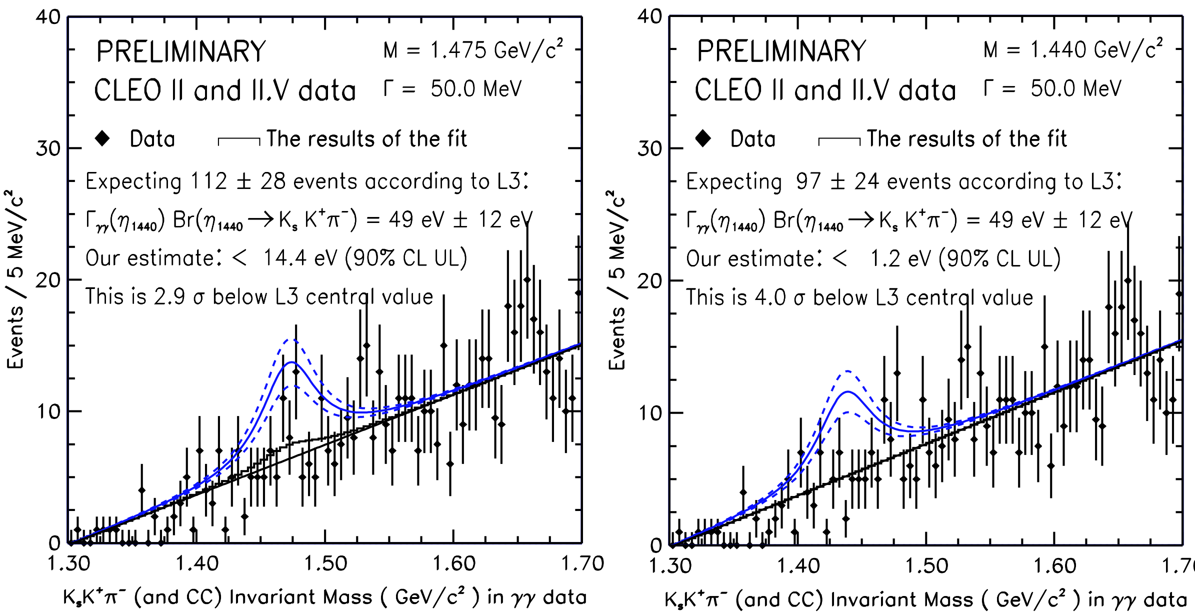

Figure 1. $K_sK^\pm\pi^\mp$ invariant mass in data, ML fit results and comparison with L3.

With the data sample that exceeds the L3 statistics by the factor of ~ 5 we do not confirm their first observation of the $\eta(1440)$ in two-photon collisions. Our upper limit on the two-photon partial width of this resonance is consistent with the glueball and the radial excitation hypotheses that we can not rule out with the sensitivity of our experiment. We expect to receive definitive answers to the $\eta(1440)$ questions with our future CLEO-c experiment[10] where we plan to analyze radiative hadronic decays of ~ 1 billion J/ψ's. We gratefully acknowledge the effort of the CESR staff in providing us with excellent luminosity and running conditions.

REFERENCES

1. K. Hagiwara *et al.*, Review of Particle Properties, *Phys. Rev.* **D66**, 010001-493 (2002).
2. T. Barnes, N. Black and P.R. Page, *arXiv* http://arXiv.org/abs/nucl-th/0208072.
3. L3 Collab., M. Acciarri *et al.*, *Phys. Lett.* **B501**, 1 (2001).
4. CLEO Collab., Y. Kubota *et al.*, *Nucl. Instrum. Methods* **A320**, 66 (1992).
5. T. Hill, *Nucl. Instrum. Methods* **A418**, 32 (1998).
6. CLEO Collab., C. Bebek *et al.*, *Nucl. Instrum. Methods* **A302**, 261 (1992).
7. R. Brun *et al.*, GEANT 3.15, CERN Report No. DD/EE/84-1 (1987).
8. CLEO Collab., G. Brandenburg *et al.*, *Phys. Rev. Lett.* **85**, 3095 (2000).
9. M. Budnev *et al.*, *Phys. Rep.* **C15** (1975), 181.
10. CLEO-c and CESR-s Working Group, CLNS 01/1742, http://www.lepp.cornell.edu/public/CLEO/spoke/CLEOc/.