Study of $\eta_c$ production in two-photon collisions

TASSO Collaboration

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Abstract. Production of the $\eta_c$ meson in $e^+ e^-$ quasi-real two photon collisions has been looked for in three channels. The data were obtained from an integrated luminosity of 189 pb$^{-1}$. An $\eta_c$ signal is observed in two decay modes ($K^0_s K^\pm \pi^\mp$, $\pi^+ \pi^- \pi^+ \pi^-$) with a combined statistical significance of 3.5 standard deviations. Using the known $\eta_c$ branching ratios to these channels and to $K^+ K^- \pi^+ \pi^-$, the combined partial $\eta_c$ width to $\gamma\gamma$ is $\Gamma_{\gamma\gamma}(\eta_c) = 19.9 \pm 6.1 \pm 8.6$ keV. The first error is statistical, and the second one includes the systematic and branching ratio errors. Calculated as an upper limit we obtain $\Gamma_{\gamma\gamma}(\eta_c) < 36$ keV (95% C.L., including the systematic error).

1 Introduction

We have looked for $\eta_c$ production by two-photon collisions in the reactions

$$e^+ e^- \to e^+ e^- K^0_s K^\mp \pi^\mp, \quad (1)$$
$$e^+ e^- \to e^+ e^- \pi^+ \pi^- \pi^+ \pi^-, \quad (2)$$
$$e^+ e^- \to e^+ e^- K^+ K^- \pi^+ \pi^-, \quad (3)$$

where branching ratios of the $\eta_c$ are available [1]. These reactions allow measurement of the two-photon partial width of the $\eta_c$, $\Gamma_{\gamma\gamma}(\eta_c)$, which is important for the understanding of the dynamics of the charmonium system. So far $\Gamma_{\gamma\gamma}(\eta_c)$ has been only poorly determined, with very large errors:

1. The PLUTO Collaboration [2] saw 7 $\eta_c$ events produced in reaction (1) at PETRA in a data sample corresponding to an integrated luminosity of 45 pb$^{-1}$. They reported the product of $\Gamma_{\gamma\gamma}(\eta_c) B(\eta_c \to K^0_s K^\pm \pi^\mp)$  $= 0.5^{+0.2}_{-0.15} \pm 0.1$ keV. Using the current value [1] of $B(\eta_c \to K K \pi) = (5.4 \pm 1.8)$%, and from $I$-spin and Clebsch-Gordan considerations, this value corresponds to $\Gamma_{\gamma\gamma}(\eta_c) = 28 \pm 15$ keV.

2. The MARK II Collaboration [3] at PEP observed 4 events in the same channel, and obtained a preliminary result of $\Gamma_{\gamma\gamma}(\eta_c) = 8.0 \pm 5.0 \pm 2.0$ keV.

3. An ISR experiment [4], intersecting a cooled coating antiproton beam with a molecular hydrogen jet, found an enhancement in the excitation curve of the reaction $\bar{p}p \to \gamma\gamma$ at the $\eta_c$ mass region. Using the published value [5] of $B(\eta_c \to \bar{p}p)$, they obtain the result $\Gamma_{\gamma\gamma}(\eta_c) = 4.3^{+3.4}_{-3.7} \pm 2.4$ keV.

4. Results of the TPC/Two Gamma Collaboration [6] searching for $\eta_c$ in various four-prong final states in $\gamma\gamma$ collisions yielded for a data sample of 69 pb$^{-1}$ $\Gamma_{\gamma\gamma}(\eta_c) = 6.4^{+5.0}_{-3.4}$ keV or $1.7$ keV $< \Gamma_{\gamma\gamma}(\eta_c) < 15.5$ keV (95% CL).

5. The MD-1 experiment at Novosibirsk has done a missing-mass measurement [7] in the reaction $e^+ e^- \to e^+ e^- X$ with a data sample of 23.5 pb$^{-1}$ they see no $\eta_c$, and give a preliminary result: $\Gamma_{\gamma\gamma}(\eta_c) < 11$ keV (90% CL).

6. Similar preliminary results have been recently presented from the final state $K^0_s K^\pm \pi^\mp$ by the JADE Collaboration [8]: $\Gamma_{\gamma\gamma}(\eta_c) < 11$ keV (95% CL) and by the CELLO Collaboration [9]: $\Gamma_{\gamma\gamma}(\eta_c) < 12$ keV (95% CL).

Theoretical estimates of $\Gamma_{\gamma\gamma}(\eta_c)$ are generally obtained from a simple relation with the leptonic $J/\psi$ decays, since both are proportional to the square of the wave function at the origin, and in the simplest approximation these wave functions are assumed to be the same for both cases [10], yielding $\Gamma_{\gamma\gamma}(\eta_c) = 6 - 7$ keV. Corrections have been applied to account for relativistic effects [11-13], QCD corrections [13, 14], gluon condensates [14], and changes in the wave function due to spin-dependent forces [11] or hyperfine mass splitting [15], where the most recent calculations [13, 15] give values of 9 - 15 keV. The results are in a confused state, with different treatments differing not only in the magnitude but also in the direction of the correction to the simple model, and span the region between $\Gamma_{\gamma\gamma}(\eta_c) = 3 - 15$ keV.

2 Data selection and analysis

In this experiment, a combined study of three known $\eta_c$ decay channels has been performed. Our data sample consists of 2 run periods: An integrated luminosity of 83 pb$^{-1}$ was taken at PETRA during 1979-1982 at various beam energies where most of the data is around $E_b = 17$ GeV. An integrated luminosity of 106 pb$^{-1}$ was taken in 1986 at a fixed beam energy of $E_b = 17.5$ GeV. The 1986 data has an improved resolution of track parameters due to the TASSO high precision vertex detector (VXD). A general description of the TASSO detector and the vertex chamber can be found in [16-17] respectively. No requirement has been made on the detection of the scattered $e^+$ and/or $e^-$ in the final state.

The most effective trigger for low multiplicity events required two track candidates in the central drift chamber (DC) found by a hardware pre-processor, containing hit information from the DC, the time-of-flight (TOF) counters, the central proportional chamber (CPC), and, for the second run period, the vertex detector (VXD). In addition the information on the $z$ coordinates of tracks from the CPC-cathode