PROCEEDINGS OF SCIENCE

Particle Production in Two-Photon Collisions at Belle

H. Nakazawa*
National Central University (Taiwan)
E-mail: nkzw@post.kek.jp

We report recent measurements of the $\gamma\gamma \to \eta\eta$ process in the energy range, 1.096 GeV $<$ W $<$ 3.8 GeV and in scattering angle, $|\cos\theta^*| \leq 0.9$ or ≤ 1.0 depending on W, where W is the energy of the two-photon center-of-mass system and θ^* is the η scattering angle. In the lower energy region, we perform a partial wave analysis to the differential cross section and extract resonance parameters. In the higher energy region, (differential) cross section is compared with QCD predictions. We also present a study of $\eta_c(2S)$ production with 6-prong final states in two-photon collisions.

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*Speaker.

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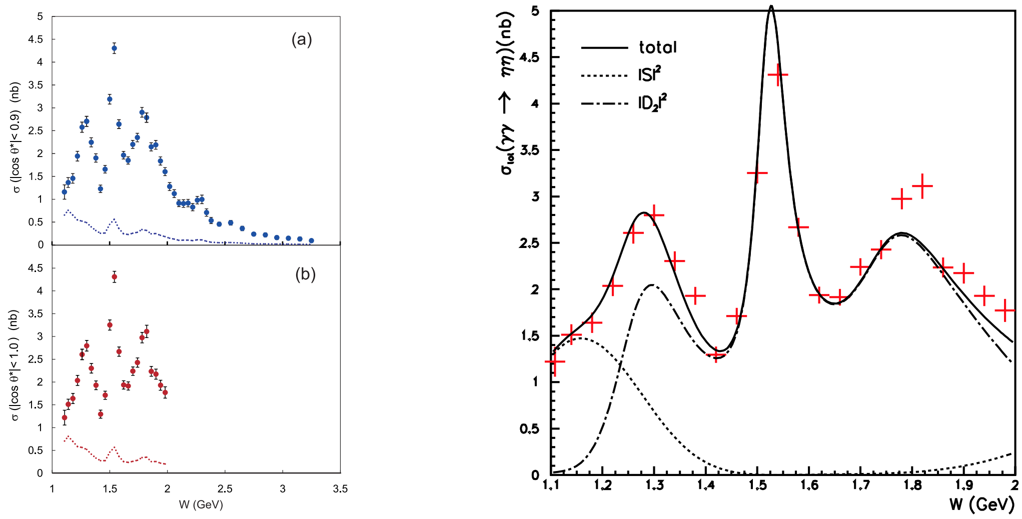

Figure 1: Left: Cross section of the $\gamma\gamma \to \eta\eta$ process integrated over $|\cos\theta^*| < 1$ ($W < 2.0$ GeV) or $|\cos\theta^*| < 0.9$ ($W > 2.0$ GeV). Errors are statistical only. The dotted curve shows the size of the systematic uncertainty. Right: The total cross section ($|\cos\theta^*| < 1.0$) and fitted curves. Dotted (dot-dashed) curves are $|S|^2$ ($|D_2|^2$) from the fit.

1. Introduction

Two-photon production of exclusive hadronic final states provides useful information about resonances and pertubative and nonperturbative QCD. From theoretical viewpoint, two-photon process is attractive because of the absence of strong interactions in the initial state and the possibility of calculating $\gamma\gamma \to q\bar{q}$ amplitudes. In addition, the quantum numbers of the final state are restricted to states of charge conjugation $C = +1$ with $J = 1$ forbidden.

We have measured production of charged meson pairs [1], neutral meson pairs [2], proton antiproton pair [3] and D-meson pair [4] in two-photon collisions. This paper reports recent measurements of $\gamma\gamma \to \eta\eta$ [5] and $\gamma\gamma \to \eta_c(2S) \to 6$ prong.

2. $\gamma\gamma \to \eta\eta$

The results are based on a 393 fb^{-1} data sample collected with the Belle detector [6] at the KEKB e^+e^- collider [7]. η is reconstructed with a photon pair. This pure neutral final states are selected with energy sum and cluster counting triggers, both of which information are provided by a CsI(Tl) electromagnetic calorimeter. We subtract background by studying sideband events in two-dimensional $M_1(\gamma\gamma)$-$M_2(\gamma\gamma)$ distributions. Further background effects are studied using $|\sum \vec{p}_t|$ distribution and taken into account as systematic errors. Fig. 1 (Left) shows the total cross sections.

For the lower energy region 1.16 GeV $<$ W $<$ 2.0 GeV, we apply a partial wave analysis to the differential cross section (Fig. 1 (Right)). In addition to the known $f_2(1270)$ and $f_2'(1525)$, we introduce a tensor meson $f_2(X)$ to describe D_2 wave, which may correspond to $f_2(1810)$ state [8], and the mass, width and product of the two-photon decay width and branching fraction $\Gamma_{\gamma\gamma}\mathscr{B}(\eta\eta)$ for $f_2(X)$ are obtained to be 1737 ± 9 MeV/c^2, 228^{+21}_{-20} MeV and $5.2^{+0.9}_{-0.8}$ eV, respectively. In the

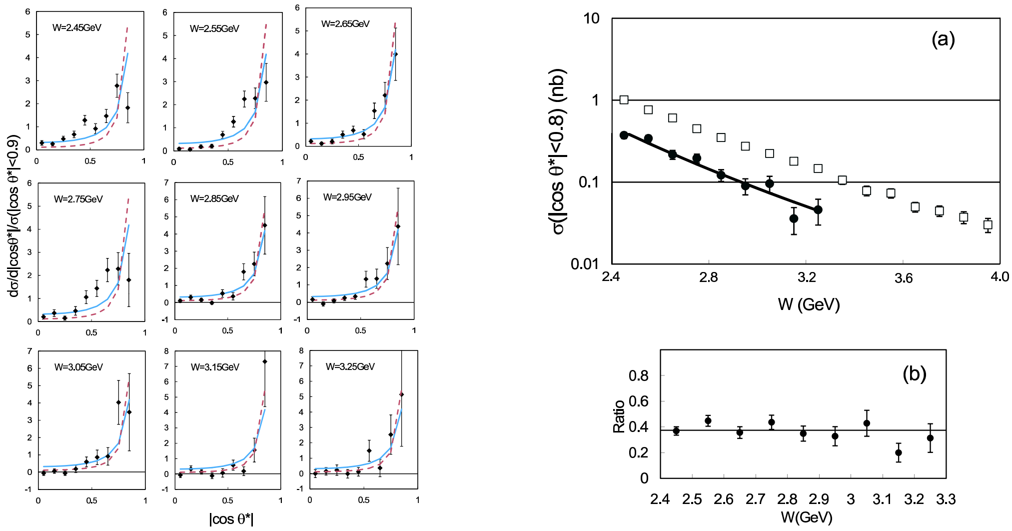

Figure 2: Left: Angular dependence of the differential cross sections in different W regions. The solid and dashed curves are proportional to $1/\sin^4\theta^*$ and $1/\sin^6\theta^*$, respectively. All of them are normalized to have unit area. Right: (a) The W dependence of the cross sections ($|\cos\theta^*| < 0.8$) for the $\pi^0\pi^0$ (open squares) and $\eta\eta$ (closed circles) processes. The curve is the power-law fit for $\eta\eta$. (b) The W dependence of the cross section ratio of $\eta\eta$ to $\pi^0\pi^0$ ($|\cos\theta^*| < 0.8$). The line is the average in the 2.4 - 3.3 GeV range.

higher energy region 2.4 GeV $<$ W $<$ 3.2 GeV where effects from resonances are small, we compare the (differential) cross section with (pertubative) QCD ((p)QCD) predictions. In our previous studies for $\pi^+\pi^-$, K^+K^-, $\pi^0\pi^0$ and $\eta\pi^0$ modes, the angular dependence in $W \gtrsim 3.0$ GeV were consistent with $1/\sin^4\theta^*$ while pQCD predicts $1/\sin^4\theta^*$ only for charged meson pair. We find that the angular dependence of $\eta\eta$ is in better agreement with $1/\sin^6\theta^*$ than $1/\sin^4\theta^*$ (Fig. 2 (Left)). The total cross section is fitted with a power-low function, W^{-n} and $n = 7.8 \pm 0.6 \pm 0.4$ is obtained (Fig. 2(a)). Fig. 2(b) shows the W dependence of the ratio between the measured cross section integrated over $|\cos\theta^*| < 0.8$ of $\gamma\gamma \to \eta\eta$ to $\gamma\gamma \to \pi^0\pi^0$. The averaged value of $0.37 \pm 0.02 \pm 0.03$ can be compared with the (p)QCD predictions [9].

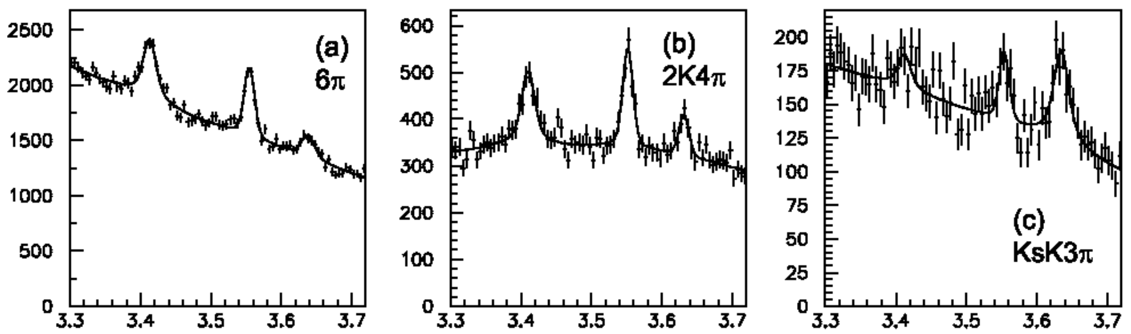

Figure 3: χ_{c0}, χ_{c2} and $\eta_c(2S)$ peaks in (a)6π, (b)$4K2\pi$ and (c)$K_SK3\pi$ mass distributions. Curves are the best fit results.

Table 1: Fit results for $\eta_c(2S)$ parameters. Errors are statistical, systematics and effects from possible interference with continuum.

Process	M (MeV/c^2)	Γ (MeV)	evts	signi.	$\Gamma_{\gamma\gamma}\mathscr{B}$ (eV)
6π	$3638.9 \pm 1.6 \pm 2.3$	10.7 ± 4.9	1485 ± 274	8.5σ	$20.1 \pm 3.7 \pm 3.2$
$2K4\pi$	$3634.7 \pm 1.6 \pm 2.8$	$1.4^{+6.3}_{-1.4}$, 13(90%C.L.)	407 ± 91	6.2σ	$10.2 \pm 2.3 \pm 3.4$
$K_SK3\pi$	$3636.5 \pm 1.8 \pm 2.4$	15.9 ± 5.7	563 ± 71	8.7σ	$30.7 \pm 3.9 \pm 3.7$
Average	$3636.9 \pm 1.1 \pm 2.5 \pm 5.0$	$9.9 \pm 3.2 \pm 2.6 \pm 2.0$			

3. $\gamma\gamma \to \eta_c(2S)$

Motivated by the fact that $\eta_c(2S)$ was not seen in our result of four-prong final states [10], we study six-prong final states with four modes, $\pi^+\pi^-\pi^+\pi^-\pi^+\pi^-$ (6π), $K^+K^-\pi^+\pi^-\pi^+\pi^-$ ($2K4\pi$), $K^+K^-K^+K^-\pi^+\pi^-$ ($4K2\pi$) and $K_SK^\pm\pi^\mp\pi^+\pi^-$ ($K_SK3\pi$), using a data sample of 923 fb^{-1}. χ_{c0}, χ_{c2} and $\eta_c(2S)$ peaks are clearly seen in 6π, $2K4\pi$ and $K_SK3\pi$ mass distributions (Fig. 2). They are the first observations except $\chi_{c0} \to 4K2\pi$ mode. We do not take interference effect with continuum into account, which is estimated as systematic error independently. Fit results for the $\eta_c(2S)$ are summarized in Table 1.

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