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The Belle Collaboration

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Abstract

The production of $K^0_S K^0_S$ pairs in two-photon collisions is studied using 5 fb^{-1} data collected by the Belle detector at KEKB. The $K^0_S K^0_S$ invariant mass spectrum is dominated by the $f'_2(1525)$ tensor meson. In addition, evidence for destructive $f_2(1270) - a^0_2(1320)$ interference is seen, and an enhancement is observed around 1750 MeV.

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I. INTRODUCTION

A high-luminosity electron-positron collider is a good place to study meson resonances produced by two-photon collisions. The well established two-photon resonance in kaon-pair final states is the $f_2'(1525)$ meson [1,2], which is classified as an almost pure $s\bar{s}$ meson. The L3 Experiment at LEP has also reported a resonance-like peak around 1750 MeV in the $K_S^0K_S^0$ final state [3].

Meson spectroscopy in the 1.5 – 2.0 GeV region is important since glueballs are expected to be found in this mass range. Glueball candidates around 1.7 and 2.2 GeV have been reported in $J/\psi \to \gamma K\bar{K}$ decays by the BES Experiment at BEPC [4]. Glueball searches are complicated by excitations of $q\bar{q}$ mesons that also populate the same region. Since gluons do not couple to photons, the two-photon partial decay widths ($\Gamma_{\gamma\gamma}$) of pure glueball states are expected to be very small. Two-photon processes, therefore, play an important role in the search for glueballs. Indeed, null results from the CLEO Experiment at CESR [2] lend some support for the glueball interpretation of the $f_J(2220)$, while the L3 result suggests the 1700 MeV region should be studied in further detail.

Here we report preliminary results from the study of the process $\gamma\gamma \to K_S^0K_S^0$, where the two-photon C.M. energy (W) is in the range 1.1 GeV $< W <$ 2.8 GeV. This is done primarily to illustrate the physics potential of the Belle experiment, but our results are already comparable to those from L3. The measurement of the $\gamma\gamma \to K^+K^-$ process for a similar mass region is given in a separate paper [5].

II. EXPERIMENT

The analysis is based on data taken by the Belle detector [6] at the KEKB [7] asymmetric e^+e^- collider in the period from October, 1999 to June, 2000. The integrated luminosity of the data set analyzed is approximately 5 fb^{-1}. Since the beam-energy dependence of two-photon processes is very small, we combine data taken at the $\Upsilon(4S)$ resonance ($\sqrt{s}$ = 10.58 GeV) with data collected at $\sqrt{s}$ values 50 MeV and 60 MeV lower.

Almost all the signal events used in the analysis were triggered by requiring two or more tracks in a 50 layer Central Drift Chamber (CDC) [8]. The charged tracks were reconstructed using data from the CDC and a 3 layer double sided Silicon Vertex Detector (SVD) [9].

III. EVENT SELECTION

Only events where both K_S^0's decay to $\pi^+\pi^-$ are considered. To select events in which the K_S^0's were produced in two-photon collisions, we require that:

- The scalar sum of track momenta ($\sum |p|$) in an event is smaller than 6 GeV.
- The sum of calorimeter energies in an event ($E_{\rm tot}$) is smaller than 6 GeV.
- There are exactly four reconstructed charged tracks with a net charge of zero.
- The total momentum imbalance in the transverse plane satisfies $P_t^2 \equiv |\sum \mathbf{p}_t^*|^2 <$ 0.1GeV^2. This selects events with small incident photon virtuality.

TABLE I. Selection cuts for K^0_S in various momentum ranges. The parameters are Δz, the distance between the two tracks in the z-direction at the reconstructed K^0_S vertex; d_r, the closest distance of the two pion tracks from the interaction point in the transverse plane; $\Delta\phi$, the difference between the azimuthal angles of the momentum and the vertex; and fl, the K^0_S flight length from the interaction point in the transverse plane.

	Δz	d_r	$\Delta\phi$	fl
$P < 0.5$ GeV	$\Delta z < 0.8$ cm	$d_r > 0.05$ cm	$\Delta\phi < 0.3$	-
$0.5 < P < 1.5$ GeV	$\Delta z < 1.8$ cm	$d_r > 0.03$ cm	$\Delta\phi < 0.1$	fl > 0.08 cm
$P > 1.5$ GeV	$\Delta z < 2.4$ cm	$d_r > 0.02$ cm	$\Delta\phi < 0.03$	fl > 0.22 cm

The charged tracks are assumed to be pions. A pair of oppositely charged tracks are combined to form a K^0_S candidate if their reconstructed vertex is displaced from the primary interaction vertex. The tracks are then refit with the constraint that they come from the reconstructed vertex. They are kept if the resulting invariant mass for the pair is within 10 MeV of M_{K^0} [10] and the combined momentum vector points back to the interaction vertex.

The detailed cut values for different K^0_S momentum ranges are summarized in Table I. Figure 1 shows the K^0_S mass spectrum after these selection cuts. The mass resolution is 2.6 MeV. The pairs are again fit, constraining the mass of each K^0_S candidate to the nominal PDG value [10].

Since the two K^0_S's are produced back-to-back in the transverse plane, the angle between the flight directions of the two K^0_S candidates in this plane is required to be larger than 160°. A legoplot of the two unconstrained pion-pair masses is shown in Figure 2. There is a strong enhancement at $(m_{K^0_S}, m_{K^0_S})$ and the background fraction is very low. After applying all the selection cuts, 738 events are found in the data sample.

IV. ANALYSIS

A Monte-Carlo simulation was performed to study the detection efficiency and resolution. The signal process $e^+e^- \to e^+e^-K^0_SK^0_S$ was generated using the TREPS program [11]. The response of the Belle detector was simulated using the GEANT3 program [12] and the resulting events were processed in the same manner as the real data. To study the signal efficiency in different $K^0_SK^0_S$ invariant mass regions, several samples were generated, each with a discrete value for the $K^0_SK^0_S$ invariant mass. Figure 3 shows the selection efficiency versus the mass. The efficiency changes smoothly as a function of the mass. It is lower for smaller mass due to smaller acceptance for lower momentum tracks. In order to evaluate the resolution of the detector, a Monte Carlo resonance was generated with a mass of 1525 MeV and zero total width. The measured mass was then fit with a Gaussian function, which gives a value of $\sigma = 3.5$ MeV.

Figure 4 shows a legoplot of $K^0_SK^0_S$ invariant mass versus P_t^2 for real data without the P_t balance cut. A concentration of $K^0_SK^0_S$ events around zero P_t^2 shows that most of the selected events are from collisions of two real photons. The resulting $K^0_SK^0_S$ invariant mass spectrum is shown in Figure 5. The spectrum obtained is similar to the one reported by

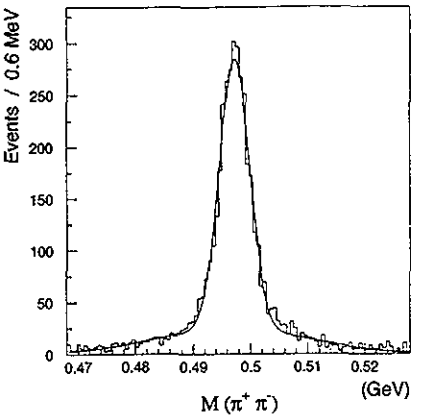

FIG. 1. The $\pi^+\pi^-$ invariant mass distribution for selected K^0_S candidates. Fitting this distribution with a double Gaussian, the mass peak is 497.2 MeV and the resolution is 2.6 MeV.

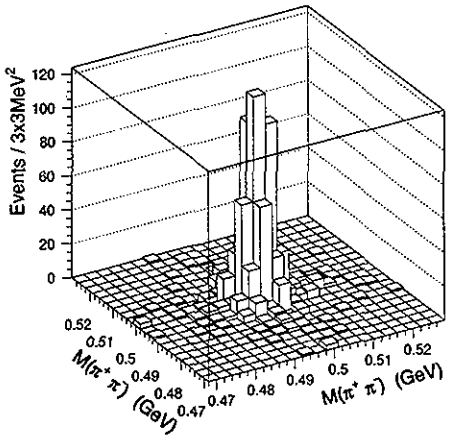

FIG. 2. $m_{\pi^+\pi^-}$ of one K^0_S candidate versus $m_{\pi^+\pi^-}$ of the other. There is a strong enhancement near the $(m_{K^0_S}, m_{K^0_S})$ point over a very small background.

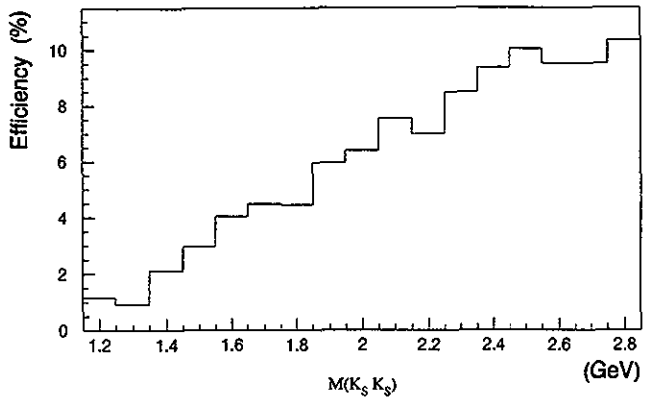

FIG. 3. Detection efficiency versus $m_{K_S^0K_S^0}$ for $\gamma\gamma \to K_S^0K_S^0$ events.

the L3 Experiment [3]. The spectrum is dominated by the $f_2'(1525)$ resonance and a clear enhancement is visible in the 1750 MeV region. The $f_2(1270) - a_2^0(1320)$ region shows the destructive interference expected in the $K_S^0K_S^0$ final state [13]. The event rate in this region is suppressed by the detection efficiency.

The $K_S^0K_S^0$ invariant mass spectrum is fitted by minimizing a χ^2 function for the expected value in the ith bin.

$$E_i = \xi_i \cdot (G_i + BW_i^{(1)} + BW_i^{(2)} + B_i)\,. \tag{1}$$

where ξ_i is the detection efficiency parameterized from the Monte Carlo. The small bump in the $f_2(1270) - a_2^0(1320)$ region is described by a Gaussian function G_i with its mean and sigma as free parameters. The peaks at $f_2'(1525)$ and 1750 MeV regions are described by Breit-Wigner functions BW_i with their masses and widths as free parameters. The background is assumed to be a constant (B_i) in the fit. The result of the fit, which has a $\chi^2/N.D.F. = 57/49$, is illustrated by the curve in Figure 5. The parameters obtained are summarized in Table II.

Our preliminary result is already comparable to that of L3. We are planing to make more detailed studies of the 1.75 GeV region by comparing the $K\bar{K}$ mass spectra in $\gamma\gamma \to K_S^0K_S^0$ and $\gamma\gamma \to K^+K^-$ [5].

V. SUMMARY

We have studied the reaction $\gamma\gamma \to K_S^0K_S^0$ using the first 5 fb^{-1} data collected by the Belle experiment at KEKB. A prominent $f_2'(1525)$ resonance and destructive $f_2(1270) - a_2^0(1320)$

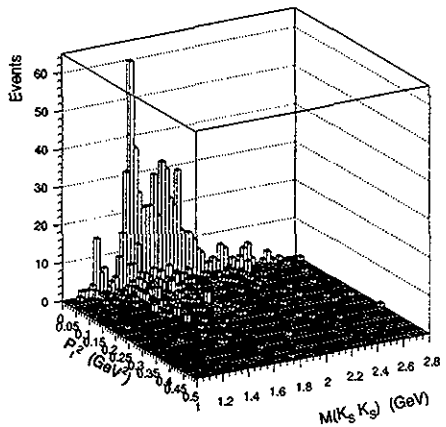

FIG. 4. $m_{K_S^0K_S^0}$ versus $P_t^2(\equiv |\sum \mathbf{p}_t^*|^2)$ distribution. A concentration of $\gamma\gamma \to K_S^0K_S^0$ events is located at zero P_t^2.

TABLE II. Results of the fit to the $K_S^0K_S^0$ mass spectrum.

	$f_2'(1525)$	1750 MeV
Mass (MeV)	1526 ± 4	1771 ± 13
Width (MeV)	52 ± 11	264 ± 29
No. of Events	194 ± 24	413 ± 39

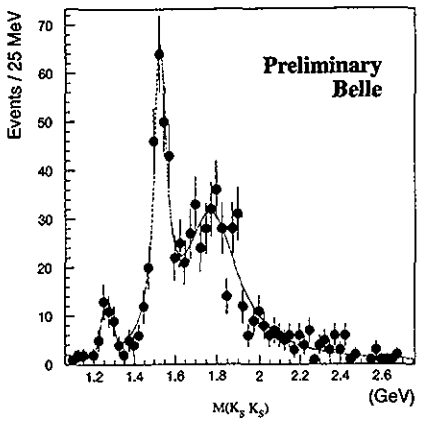

FIG. 5. The $K^0_S K^0_S$ invariant mass spectrum for the $\gamma\gamma \to K^0_S K^0_S$ process. The solid line is a fit with two Breit-Wigner functions for the $f'_2(1525)$ and 1750 MeV region, and a Gaussian for the $f_2(1270) - a^0_2(1320)$ region plus a constant background. See the text for details.

interference are observed. An enhancement around 1750 MeV is also observed. According to theoretical predictions [14], the feature near 1750 MeV may be due to a radially excited state of the f'_2. The invariant mass spectrum of our observation is consistent with that reported by the L3 experiment.

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