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η_c and η_b in two-photon collisions

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Abstract. Recent results on formation of $\eta_c(2980)$ meson at LEP 1 and LEP 2 energies and search for η_b at LEP 2 are presented. $\eta_c(2980)$ is seen in different decay modes and its two-photon radiative decay width is measured.

1 Introduction

Among all $\gamma\gamma$ induced final states, those with exclusive meson resonance production play an important role, since the measurement of the production cross section and the corresponding radiative width provide information on the quark-gluon structure of the particle. The mesonic resonances built up of heavy quarks, for example η_c or η_b, are particulary interesting objects as one can describe them with nonrelativistic models. In particular, a precise measurement of the two-photon partial width for charmonium states would provide valuable information on QCD corrections to $c\bar{c}$ quarkonium.

The η_b pseudoscalar meson, the ground state of the $\bar{b}b$ system, is not yet discovered [1,2]. The mass of the η_b is estimated by many theoretical models [3]

In Sect. 2 the formation of $\eta_c(2080)$ in DELPHI, L3 at LEP and E835 at Fermilab is discussed. Results of the search for η_b meson in DELPHI, L3 and ALEPH aer reported in Sect. 3. The conclusions are summarized in Sect. 4.

2 $\eta_c(2980)$ formation

Various theoretical predictions for the radiative width of η_c are given in [4]. They range from 3 to 14 keV. We report recent experimental results on the radiative width of the η_c observed in different decay modes from the DELPHI and L3 experiments.

The selection criteria for exlusive final states of $\gamma\gamma$ interactions are based on P_T balance of the decay products because the interacting photons are quasi-real and their momenta are along the electron and positron beam axis. The typical cut on visible P_T of the event is 200 MeV. Charged hadrons are identified using information from TPC and Cherenkov detectors. K^0 are identified using V^0 reconstruction.

In DELPHI the four decay modes were analysed: $K_sK^{\pm}\pi^{\mp}$, $K^+K^-K^+K^-$, $K^+K^-\pi^+\pi^-$ and $\pi^+\pi^-\pi^+\pi^-$.

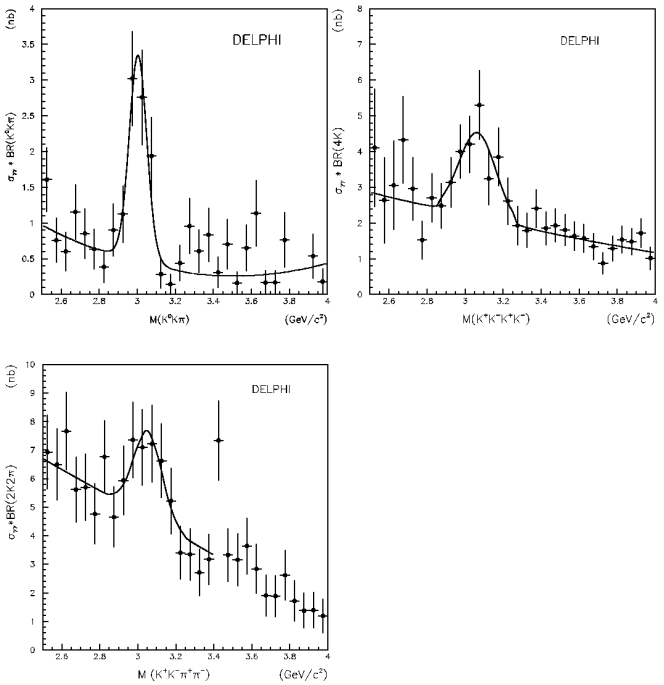

Fig. 1. DELPHI invariant mass distributions of $K_SK\pi$, 4K and $2K2\pi$ systems

The invariant mass distributions for the first three ones are shown in Fig. 1.

The radiative widths for these individual decay modes are

$\Gamma_{\gamma\gamma} = 13.3 \pm 2.6(stat.) \pm 2.0(syst) \pm 3.5(BR)$ keV for $K^0K\pi$,

$\Gamma_{\gamma\gamma} = 16.5 \pm 4.3(stat.) \pm 2.7(syst) \pm 9.4(BR)$ keV for $K^+K^-K^+K^-$,

$\Gamma_{\gamma\gamma} = 14.2 \pm 4.9(stat.) \pm 2.9(syst) \pm 4.9(BR)$ keV for $K^+K^-\pi^+\pi^-$.

The analysis of the four charged kaon decay channel is in agreement, within the large errors, with the result of the ARGUS Collaboration [5].

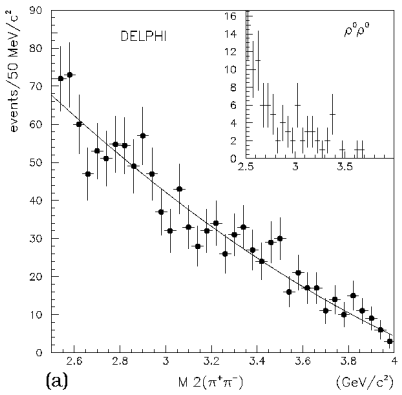

Fig. 2. DELPHI invariant mass distributions of $\pi^+\pi^-\pi^+\pi^-$ and $\rho^0\rho^0$ systems

No η_c signal is observed neither by DELPHI nor L3 in the four pion decay mode. The invariant mass distribution of the four pion system from DELPHI is shown in Fig. 2. No signal is also seen after cuts on $\rho^0\rho^0$ band in this system.

This striking result is also supported by CLEO [8].

Taking into account the η_c to 4π branching ratio [6] of $1.2 \pm 0.4\%$ one can set the upper limit for the radiative width $\Gamma_{\gamma\gamma} < 3.8$keV at 95%CL.

The observation of an $\eta_c \to \pi^+\pi^-\pi^+\pi^-$ decay mode reported by numerous experimental groups remains controversal. This decay has been found by MARK III [7], TASSO [9] (where the last one did not distinguish between the 4π and the $\rho^0\rho^0$ decay channels). Other, more recent experiment did not confirm it [10] providing only an upper limit. Good particle identification is very important since the $\pi^+\pi^-\pi^+\pi^-$ final state can be confused with the $K^+K^-\pi^+\pi^-$ decay.

The DELPHI weighted mean for the other three decay modes is $\Gamma_{\gamma\gamma} = 13.9 \pm 2.0(stat.) \pm 1.4(syst) \pm 2.7(BR)$ keV.

The result published by L3 based on the LEP1 and part of the LEP2 statistics [10] is $\Gamma_{\gamma\gamma} = 6.9 \pm 1.7(stat.) \pm 0.8(syst) \pm 2.0(BR)$ keV.

A re-analysis of the data presented for this conference for all LEP2 statistics provides a smaller value $\Gamma_{\gamma\gamma} = 3.68 \pm 0.87(stat.) \pm 0.8(syst) \pm 2.0(BR)$ keV. The invariant mass distributions for the total LEP2 statistics from L3 are shown in Fig. 3.

Recently published FNAL E835 data on proton antiproton annihilation [11] give $\Gamma_{\gamma\gamma} = 3.8^{+1.1+1.9}_{-1.0-1.0}$ keV.

3 Search for η_b

Two-photon collisions are well suited for the study of pseudoscalar mesons with $J^{PC} = 0^{-+}$. The high energy and luminosity make LEP 2 a good evironment to search for the $b\bar{b}$ pseudoscalar quarkonium state η_b which has not yet been observed. Based on the Coulomb potential approach [13] the partial width of η_b into two photons is estimated to be in the 0.4-0.5 keV range. Setting the η_b mass to 9.4 GeV gives an expected production cross-section $\sigma(e^+e^- \to e^+e^-\eta_b)$ of 0.21-0.27 pb at $\sqrt{s} = 200$ GeV.

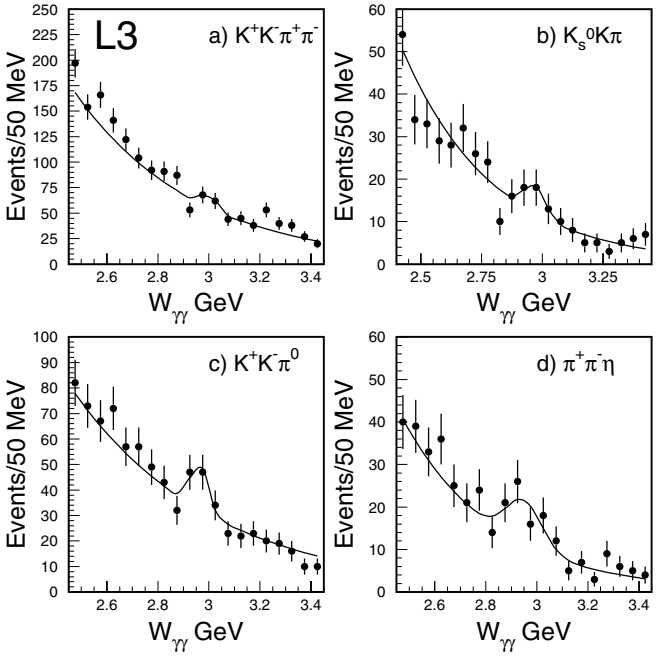

Fig. 3. L3 invariant mass distributions of $K^+K^-\pi^+\pi^-$, $K_SK\pi$, $K^+K^-\pi^0$ and $\pi^+\pi^-\eta$ systems

Recently ALEPH published the results of their search for η_b with one candidate found in the expected mass range for η_b [12]. Different models predict the mass of η_b in the range between 9.33 and 9.45 GeV/c^2. We report on the search for the reaction $e^+e^- \to e^+e^-\eta_b$.

DELPHI searched for η_b in the 4, 6 and 8-prong decay modes for which the expected branching ratios are $BR(\eta_b \to 4\pi^\pm(\mathrm{K}^\pm)) \simeq 2\%$, $BR(\eta_b \to 6\pi^\pm(\mathrm{K}^\pm)) \simeq 2\%$, $BR(\eta_b \to 8\pi^\pm(\mathrm{K}^\pm)) \simeq 2.2\%$.

The invariant mass distributions for these modes are given in Fig. 4 together with prediction from the background processes. They are well described by the background processes obtained from PYTHIA.

The 95% upper limits of the value $\Gamma_{\gamma\gamma}(\eta_b)\cdot Br$ obtained in DELPHI are .093, .27 and .78 keV for 4,6 and 8-prong decay modes respectively. A similar search was performed by L3. They found 6 candidates while 2.5 of background are expecdted. The average mass of η_b candidates is 9.51 ± 0.30 GeV. ALEPH and L3 give their upper limits of the value $\Gamma_{\gamma\gamma}(\eta_b) \cdot Br$ for 4 and 6 charged particles decay modes which are 0.057 and .128 keV from ALEPH and .3 and .4 keV from L3.

4 Conclusions

The results of this report can be formulated as follows. $\eta_c(2980)$ is studied by DELPHI and L3 in many decay modes. Their results on $\Gamma_{\gamma\gamma}$ are not well compatible. The latest result from L3 and result from FNAL E835 are compatible and twice lower than the PDG value. No signal is seen in the four charged pion decay mode.

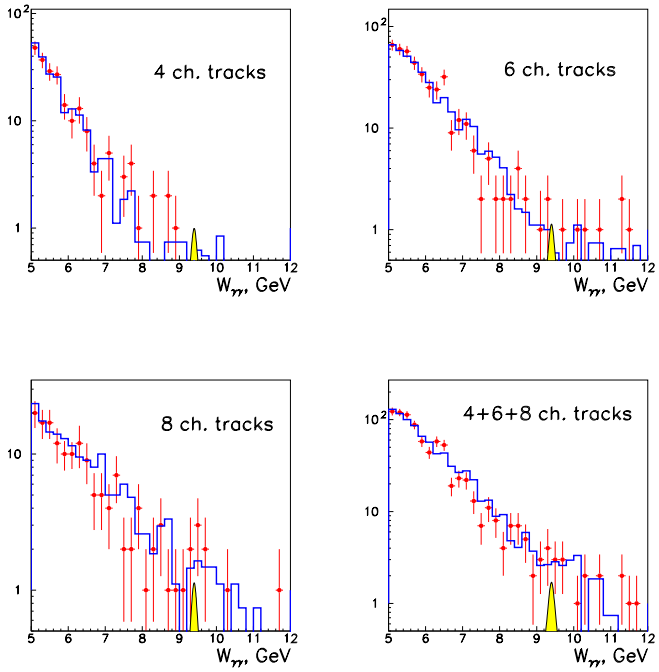

Fig. 4. DELPHI invariant mass distributions of 4,6,8-prong events and of the all events of the DELPHI sample. *Points* with *error bars* are from the data; histograms present the number of background events predicted by PYTHIA

η_b has been searched in the 4,6,8-prong decay modes by ALEPH, DELPHI and L3. Few candidates are seen in the signal region and their numbers are compatible with the expectation from background processes. Upper limits for $\Gamma_{\gamma\gamma}(\eta_b) \times BR(\eta_b)$ are obtained.

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