QUARKONIUM PRODUCTION IN TWO-PHOTON COLLISIONS AT LEP2 ENERGIES

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Inclusive J/ψ production and formation of $\eta_c(2980)$ in photon-photon collisions has been observed and the η_b meson has been searched for at LEP2 beam energies. Based on a study of the event shapes of different types of $\gamma\gamma$ processes in the PYTHIA program, it is shown that $(74\pm22)\%$ of the observed J/ψ events are due to 'resolved' photons, the dominant contribution of which is most probably due to the gluon content of the photon. $\eta_c(2980)$ formation is seen in different decay modes and its two-photon radiative decay width is measured. Results of the search for η_b meson at LEP2 are discussed.

1 Introduction

Two-photon collisions are the dominant source of hadron production at LEP2. These events are characterized by low visible invariant mass and low energy deposition compared to beam energy. This allows to separate them from other processes. Typical contamination of the events from different processes is a few per cent only. In section 2 we will report on the inclusive production of J/ψ in the DELPHI experimint. In section 3 the formation of $\eta_c(2080)$ in DELPHI and L3 is discussed. Results of the search for η_b meson in DELPHI, L3 and ALEPH are reported in section 4.

2 Inclusive J/ψ production

It has been pointed out that two-photon production of inclusive J/ψ mesons is a sensitive channel for investigating the gluon distribution in the photon [1].

There are two important processes leading to inclusive J/ψ production: the vector-meson dominance and the so-called 'resolved' contribution of the photons, in which the intermediate photons are 'resolved' into their constituent partons. The second process requires production of a 'resolved' gluon (g_γ) from both photons. Thus, this production mechanism provides a sensitive probe of the gluon content of the photon.

The analysis presented here is based on the data taken with the DELPHI detector [2] during the years 1996–2000. The centre-of-mass energies $\sqrt{s}$ for LEP ranged from 161 to 207 GeV. The total integrated luminosity used in the analysis is 617 pb^{-1}.

The selection of events requires at least four charged tracks in the event and the visible invariant mass of the event to be smaller than 35 GeV/c^2. A total of 274510 events remain in the data sample after applying all cuts.

J/ψ candidates have been selected from the $\mu^+\mu^-$ decay channel. The muon selection is based on the muon chambers and hadronic calorimeter information.

In Fig.1 is given the invariant mass distribution for the identified $\mu^+\mu^-$ pairs. A least squares fit to the $M(\mu^+\mu^-)$ distribution with a Gaussian for the signal and a polynomial for the background provides the number of J/ψ events $N = 36 \pm 7$.

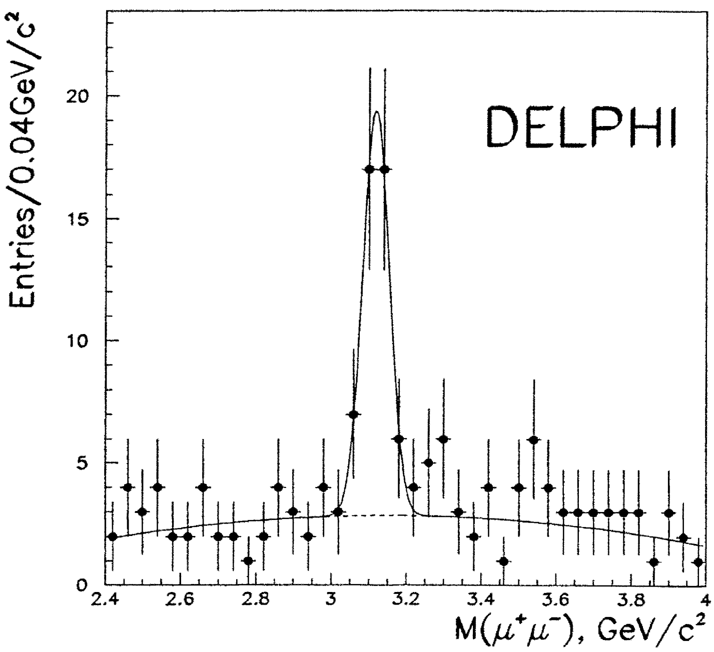

Figure 1: $M(\mu^+\mu^-)$ distribution from the LEP II DELPHI data. The solid curve corresponds to a Gaussian fit over a second order polynomial background.

The PYTHIA 6.156 generator [3] was used to estimate the efficiency. The process where both photons are VDM photons we will call 'diffractive' and the process without VDM photons we will call 'resolved'.

The PYTHIA Monte Carlo prediction for the $p_T^2(J/\psi)$ distribution is more sharply peaked near zero for the 'diffractive' events than for the 'resolved' events. The experimental $p_T^2(J/\psi)$ distribution was fitted as a function of the two categories of PYTHIA events: diffractive and resolved. The fit attributes $(26 \pm 22)\%$ of the events to the diffractive processes. The PYTHIA study shows that the experimental efficiencies are very different for the two categories: it is $0.98 \pm 0.04)\%$ for diffractive and $3.87 \pm 0.09)\%$ for resolved processes.

Under the assumption that PYTHIA captures the kinematical features of the resolved and diffractive processes, but not their absolute cross-sections, the cross-section for inclusive J/ψ production is: $\sigma = 45 \pm 9(\mathrm{stat}) \pm 17(\mathrm{syst})$ pb,. The systematic uncertainties include both the efficiency and the branching ratio contributions but not those inherent to the PYTHIA program.

The shapes of kinematical variables of J/ψ events such as visible invariant mass, charged and total multiplicity, rapidity of J/ψ are well reproduced by PYTHIA.

3 $\eta_c(2980)$ formation

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. 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.

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

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 $K^+K^-K^+K^-$,

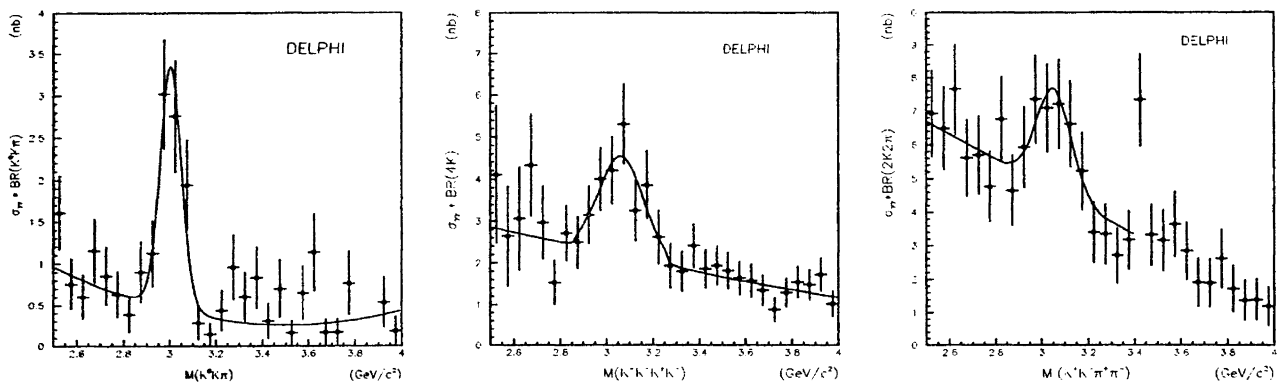

Figure 2: Invariant mass distributions of $K_S K\pi$, 4K and $2K2\pi$ systems.

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

No η_c signal is observed neither by DELPHI nor L3 in the four pion decay mode. Taking into account the η_c to 4π branching ratio [5] 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 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 [6] 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 at the PHOTON'03 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.

4 Search for η_b

The η_b pseudoscalar meson is the ground state of the $\bar{b}b$ system, not yet discovered. Recently ALEPH published the results of their search for η_b with one candidate found in the expected mass range for η_b [7]. Different models predict the mass of η_b in the range between 9.33 and 9.45 GeV/c^2. 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 in the DELPHI 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. Similar search was performed by L3 with the same result that no deviation from background (as predicted by PYTHIA) is observed. 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.

References

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