Results on inclusive and exclusive bottom production in γγ collisions are presented. The total cross section of inclusive bottom production is investigated through its leptonic decays at LEP II energies by the experiments L3 and OPAL. The average cross section, after correction for acceptances and efficiencies, is $\sigma_{\text{tot}} = 13.3 \pm 1.5 \pm 2.3$ pb. The next-to-leading order calculations are lower than the data by a factor three, which corresponds to a difference of more than three standard deviations.

ALEPH studied the exclusive bottom production. Searching for the $\eta_b$ one candidate is found. Limits on $\Gamma_{\gamma\gamma}(\eta_b) \times \text{BR}$ for 4 and 6 charged particles are extracted. The candidate has a mass of $9.30 \pm 0.04$ GeV.

1 Introduction

The production of heavy flavour in two-photon collisions is dominated by two processes, the direct and the single-resolved process. Both contribute in equal shares to heavy flavour final states at LEP II energies. The large quark mass allows reliable perturbative calculations for the direct contribution. The single-resolved one, in addition, depends on the gluon density of the photon.

In this article the new measurements on inclusive and exclusive bottom production at LEP will be presented. The charm production in γγ collisions is discussed in a separate contribution.

2 Inclusive Bottom Production

2.1 Analysis

Open bottom production is measured by the L3 and the OPAL collaborations at LEP II energies using an integrated luminosity of 400 pb$^{-1}$. Their analysis procedures exploit the fact, that the momentum as well as the transverse momentum of leptons with respect to the closest jet is higher for muons and electrons from bottom than from background, which is mainly charm. Therefore, leptons with momenta of more than 2 GeV are selected and their momentum distribution with respect to the closest jet (obtained with the JADE jet-algorithm in L3 and KTCLUS in OPAL, while in both experiments the lepton was excluded, when defining the jet) is investigated.
The various contributions of the spectrum from signal and background are fitted, see Figure 1 as an example. In L3 both muons and electrons are selected with several percent efficiency, the b-fraction being 52% and 42%, respectively. OPAL selects their muons with a similar efficiency. The b-fraction is determined to 27%.

Similar to the studies in charm production, the bottom quarks produced in direct and single resolved events show a different behaviour in the transverse momentum distribution. The variable \( x_T^\mu = 2p_T^\mu / W_{\text{vis}} \) is well suited to demonstrate the need for both contributions: the single resolved part at low \( x_T^\mu \) and the direct part at high \( x_T^\mu \) as shown in Figure 2. The agreement between data and Monte Carlo simulation is very good.

2.2 Cross Section Results

The total cross section measurements for open bottom production are summarized in Figure 3. The results are compared to NLO calculations. The cross sections as measured by the experiments are 13.1 ± 2.0 ± 2.4 pb (L3) and 14.2 ± 2.5 ± 4.8 pb (OPAL). The calculations underestimate the data by a factor 3 corresponding to 2.5 and 2σ standard deviations, respectively.

3 Exclusive Bottom Production
3.1 Motivation

The ALEPH experiment has started a search for the still undiscovered $\eta_b$ pseudoscalar meson. Various predictions exist for the mass of the $\eta_b$, e.g., from potential models, pQCD, NRQCD, and lattice calculations. While the production can reliably be estimated (about 156 $\eta_b$ mesons were produced in ALEPH for an integrated luminosity of 700 pb$^{-1}$) the branching ratios of the meson have to be guessed. The efficiencies for the two decay modes of the $\eta_b$ under study (4 charged particles or 6 charged particles) are around 16% and 10%. For branching ratios between 2% and 5% one would expect 0.5 to 1 event in each channel. The background is estimated to be of the same order.

3.2 Results

In Figure 4, the invariant mass spectra for data are shown together with the expected signal assuming branching ratios of 100% for the decay modes under study. No event is selected in the signal region from 9.0 GeV to 9.8 GeV in the 4 charged mode, while 1 candidate is selected in the 6 charged mode. After proper mass assignment the mass of the candidate is $9.30 \pm 0.04$ GeV.

The observation of 0 and 1 candidate, being compatible with back-
ground, is converted into limits at 95%CL: \( \Gamma_{\gamma\gamma}(\eta_b) \times \text{BR}(4\text{cha}) < 57 \text{ eV} \) and \( \Gamma_{\gamma\gamma}(\eta_b) \times \text{BR}(6\text{cha}) < 128 \text{ eV} \), corresponding to \( \text{BR}(\eta_b \rightarrow 4 \text{ charged}) < 17\% \) and \( \text{BR}(\eta_b \rightarrow 6 \text{ charged}) < 38\% \).

4 Summary

The LEP experiments have provided good measurements of the inclusive bottom production in \( \gamma\gamma \) collisions. The combined result of the L3 and OPAL experiment is \( \sigma_{\text{tot}} = 13.3 \pm 1.5 \pm 2.3 \text{ pb} \). The NLO-calculations underestimate the cross section by a factor three: they differ by more than three standard deviations.

The \( \eta_b \) meson has been searched for. Both expected signal and background are about one event. With one candidate observed limits are given by the ALEPH experiment: \( \Gamma_{\gamma\gamma}(\eta_b) \times \text{BR}(4\text{cha}) < 57 \text{ eV} \) and \( \Gamma_{\gamma\gamma}(\eta_b) \times \text{BR}(6\text{cha}) < 128 \text{ eV} \). A discovery would need the effort of all 4 experiments.

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