HEAVY FLAVOUR PRODUCTION IN PHOTON-PHOTON COLLISIONS AT LEP

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Measurements of charm and bottom quarks production in two-photon collisions at LEP are presented. The $b\bar{b}$ cross section, the charm structure function $F_{2,c}^{\gamma}$ and the high energy behaviour of $\sigma(\gamma\gamma \to c\bar{c})$ cross section as function of $\gamma\gamma$ centre-of-mass energy are measured for the first time in two-photon collisions.

1 Introduction

The production of heavy quarks in two-photon collisions consists mainly of charm quarks. Because of their smaller electric charge and larger mass, the production of b-quarks is expected to be suppressed by more than two orders of magnitude relative to the production of charm quarks. The resolved photon cross section is dominated by the photon-gluon fusion diagram $\gamma \mathrm{g} \to \mathrm{c}\bar{\mathrm{c}}, \mathrm{b}\bar{\mathrm{b}}$. At LEP energies, the direct and resolved processes are predicted to give comparable contributions to the cross section [1]. Measurements of charm production in two-photon collisions were done at LEP by ALEPH[2], L3[3] and OPAL[4] collaborations. Beauty production has been measured by L3[3] for the first time in gamma-gamma collisions.

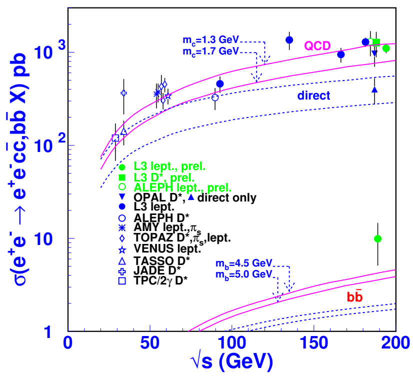

Figure 1: Charm and beauty production in two-photon collisions.

2 Charm production

Both charm and beauty quarks were identified by the L3 collaboration using tagging by electrons and muons from semileptonic charm and beauty decays [3]. Charm particles in the final state were also identified by the reconstruction of charged D^* meson decays by ALEPH, L3 and OPAL. ALEPH has also used muon tag for charm measurement [2]. The OPAL collaboration measured the direct and single-resolved charm cross sections separately. The scaled D^* transverse momentum $\mathrm{x}_\mathrm{t}^{\mathrm{D}^*}$ which is the ratio of $P_t^{D^*}$ to $W_{vis}/2$ is sensitive to the ratio of the direct and the single-resolved process. The fit to the OPAL D^* data gives about 1:1 for the ratio in the data, which translates into the direct process contribution to the total cross section to be (401 ± 124) pb and the single-resolved contribution to be (562 ± 202) pb. The total inclusive charm cross sections are plotted in Figure 1 together with previous measurements. The data are compared to the theory predictions of Ref.[1]. The dashed line corresponds to the direct process, NLO QCD calculation, while the solid line shows the QCD prediction for the sum of the direct and the resolved processes calculated to NLO accuracy. The cross section increases with energy as expected by QCD predictions. The cross section of charm production with a D^* tag is in agreement with the lepton tag measurement.

The L3 collaboration measured the cross sections $\sigma(e^+e^- \rightarrow e^+e^-c\bar{c}X)$ and $\sigma(\gamma\gamma \rightarrow c\bar{c}X)$ in the interval 5 GeV $\leq W_{\gamma\gamma} \leq$ 70 GeV. Figure 2 shows the preliminary $\sigma(\gamma\gamma \rightarrow c\bar{c}X)$ as function of $W_{\gamma\gamma}$ at $\sqrt{s} = 189 - 202$ GeV. The continuous line is the fit by parametrization of A.Donnachie and P.V. Landshoff $\sigma_{\rm tot} = A\,s^{\epsilon} + B\,s^{-\eta}$, with fixed value of $\eta = -0.34$ (PDG98). The dashed curve shows the expectation from the PYTHIA Monte Carlo. The expected slope is smaller than the slope observed in the data. The dotted curve is the measured by L3 total cross section $\sigma(\gamma\gamma \rightarrow$ hadrons) scaled by factor 1/20. The fit gives for the 'pomeron' slope $\epsilon = 0.400 \pm 0.062$(stat). A steeper rise with energy is observed as compared to hadron-hadron cross sections and to $\sigma(\gamma\gamma \rightarrow \mathit{hadrons})$.

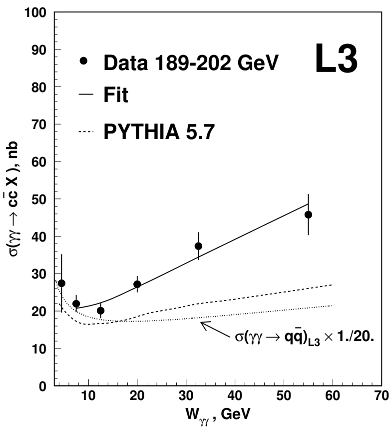

Figure 2: Cross section $\sigma(\gamma\gamma \rightarrow c\bar{c})$ by L3.

Using a sample of single-tagged events OPAL measured $F_{2,c}^{\gamma}$ photon structure function at $\langle Q^2 \rangle = 20$ GeV^2. HERWIG and Vermaseren (direct only process) Monte Carlo event generators have been used in the study. Within limited statistics of 30 ± 6 D^* mesons in events, where one beam electron is scattered into detector, both Monte Carlo generators are in agreement with the data distributions. The data suggest nevertheless a cross-section which is above the purely point-like component, i.e. the hadron-like component of $F_{2,c}^{\gamma}$ is non-zero.

3 Beauty production

Leptons from b semi-leptonic decays are more energetic than from charm semi-leptonic decays and non-charm two-photon processes. To select $b\bar{b}$ events L3 apply cuts on the lepton momentum and transverse momentum p_t with respect to the closest jet defined by excluding the lepton from the jet. The preliminary beauty production cross section in $\gamma\gamma$ collisions has been measured to be $\sigma^{ee \to eebbX} = 9.9 \pm 2.9$ (st) $\pm$ 3.8 (sys) pb.

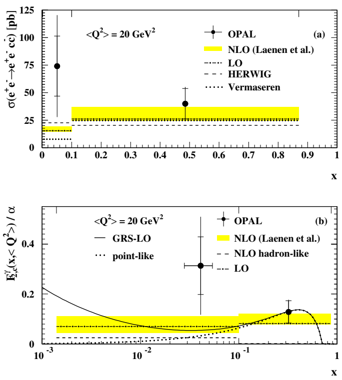

Figure 3: The $\sigma(\mathrm{e^+e^-} \to \mathrm{e^+e^-c\bar{c}X})$ and $F^{\gamma}_{2,c}$ at $\langle Q^2 \rangle$ =20 GeV^2 by OPAL.

4 Summary

The direct process $\gamma\gamma \to \mathrm{c\bar{c}}, \mathrm{b\bar{b}}$ is insufficient to describe the data, even if real and virtual gluon corrections are included. The cross sections and the event distributions require contributions from the resolved processes which are dominantly $\gamma\mathrm{g} \to \mathrm{c\bar{c}}, \mathrm{b\bar{b}}$. The data therefore require a significant gluon content in the photon. The measured total charm cross sections for real photons agree well with NLO QCD expectation. A steeper rise with energy is observed for $\sigma(\gamma\gamma \to c\bar{c})$ as compared to hadron-hadron cross sections and to $\sigma(\gamma\gamma \to hadrons)$. The charm structure function $F^{\gamma}_{2,c}$ measurement shows the hadron-like component of photon is needed. The measured b cross section lie somewhat above QCD predictions.

The data suggest that a bigger gluon component in parton density function of photon is needed.

References

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