QED structure function of the photon at LEP

Claudia Cecchi

[1] Université de Genève, 24, Quai E.Ansermet, 1203 Genève, CH
E-mails: claudia.cecchi@cern.ch

Abstract

We report about the studies of the processes $e^+e^- \rightarrow e^+e^-e^+e^-$ and $e^+e^- \rightarrow e^+e^-\mu^+\mu^-$ in a single tag configuration, using data collected by the LEP experiments at $\sqrt{s} \simeq 91$ GeV.

1. Introduction

The reaction $e^+e^- \rightarrow e^+e^-l^+l^-$ $(l = e, \mu)$ is a QED process of the order $O(\alpha^4)$ [1]. We studied the single tag configuration in which one of the scattered electrons is detected. The study of this process is not only a test of QED, but also a check of the experimental procedures adopted for the analysis of the hadronic photon structure function.

The F_2^γ is extracted from the measurement of the cross section in the muon channel. The other two structure functions F_A^γ and F_B^γ, related to different helicity states, are extracted from the study of the azimuthal correlations.

2. Formalism

The lowest order Feynman diagrams which describe the reaction $e^+e^- \rightarrow e^+e^-l^+l^-$ $(l = e, \mu)$ involve different processes; multiperipheral, annihilation, bremsstrahlung and conversion [2]. The only one which gives an important contribution in the single tag configuration is the multiperipheral, which include the interaction of two virtual photons.

The probe and the target photons have four-momenta $k_{1,2} = (x_{1,2}E_{beam}, \mathbf{k_{1,2}})$ and virtualities $Q^2 = -k_1^2$,$P^2 = -k_2^2$ which are related to the energies $E_{1,2}$ and the polar angles $\theta_{1,2}$ of the scattered electrons $Q^2 \simeq 2E_{beam}E_1(1 - cos\theta_1)$. The Bjorken scaling variables are defined as:

$$x = \frac{Q^2}{Q^2+P^2+W_{\gamma\gamma}^2}, \qquad y = 1 - \frac{E_1}{E_{beam}} cos^2\frac{\theta_1}{2} \simeq x_1$$

where $W_{\gamma\gamma} = (k_1 + k_2)^2$ is the mass squared of the produced lepton pair.

The differential cross section have contributions from a transverse (T) and a longitudinal (L) photon, and can be written as:

$$\frac{d^3\sigma}{dxdQ^2dx_2} = \frac{4\pi\alpha^2}{Q^4}\frac{1}{x}\frac{dn(x_2)}{dx_2} \tag{1}$$
$$\left[\left(1 - y + \frac{y^2}{2}\right) F_2^\gamma(x, Q^2) + \frac{y^2}{2}F_L^2(x, Q^2)\right]$$

where $\frac{dn(x_2)}{dx_2}$ is the flux of the target photon.

In our configuration y is much smaller than unity, therefore measuring the differential cross section gives only informations on the F_2^γ structure function.

The scattering amplitude of the longitudinally polarised photons can be extracted by the measurement of the angular correlations in the $\gamma\gamma$ centre-of-mass system [3] [4] [5] [6]. The angle χ is the angle between the plane defined by the scattered electron and the $\gamma\gamma$ axis, and the plane defined by the direction of the μ^- and the $\gamma\gamma$ axis. In the single tag configuration, neglecting the longitudinal component of the target photon, the cross section has only three terms:

$$\frac{d^4\sigma}{dxdydzd\chi} = \frac{2\pi\alpha^2}{Q^2}\frac{1 + (1 - y)^2}{xy}[A_1(x, z) + \tag{2}$$
$$A_2(x, z) \cdot cos\chi + A_3(x) \cdot cos2\chi]$$

The terms A_1, $A2$, and A_3 are related to the three differential structure function F_2^γ, F_A^γ and F_B^γ, respectively.

3. Data analysis and results

In order to measure the differential cross section the data are corrected for accepatance and efficiency in bins of x and Q^2. The systematic errors come from selection procedure, trigger, efficiency, background subtraction and luminosity measurement.

The structure function F_2^γ is extracted from the

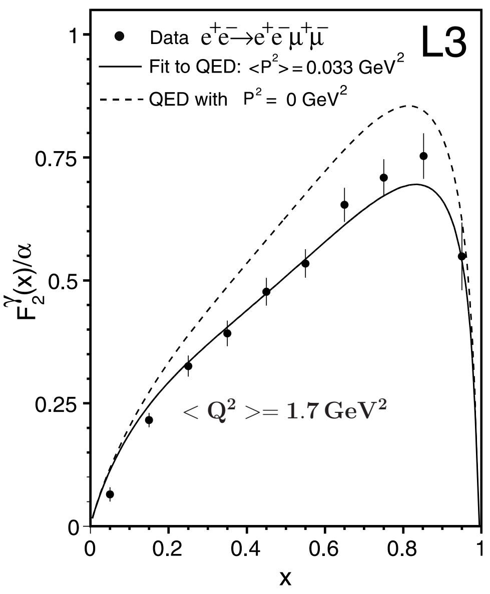

Figure 1. The leptonic structure function F_2^γ. The dashed line corresponds to QED prediction obtained with $P^2 = 0$. The solid line is the result of the fit to the mean virtuality of the target photon to the data.

cross section measurement, while F_A^γ and F_B^γ are extracted from the distribution of the azimuthal angle χ [7], [9], [8]. The results are shown in Figures 1 and 2. From Figure 1 the virtuality of the target photon is found different from zero and in agreement with QED predictions including corrections for the initial state radiation. The measurement of the structure functions F_A^γ and F_B^γ establish a presence of the longitudinal photon component in the single tag configuration of the two photons reaction.

4. Conclusions

The differential cross sections for the processes $e^+e^- \to e^+e^-e^+e^-$ and $e^+e^- \to e^+e^-\mu^+\mu^-$ at $\sqrt{s} \simeq 91$ GeV, have been measured using the data collected by the LEP experiments.
In the muon channel the leptonic structure function F_2^γ has been extracted from the differential cross section. In addition the leptonic structure functions F_A^γ and F_B^γ have been extracted studying the azimuthal angle distributions of the μ^- in the center-of-mass system of the two photons.

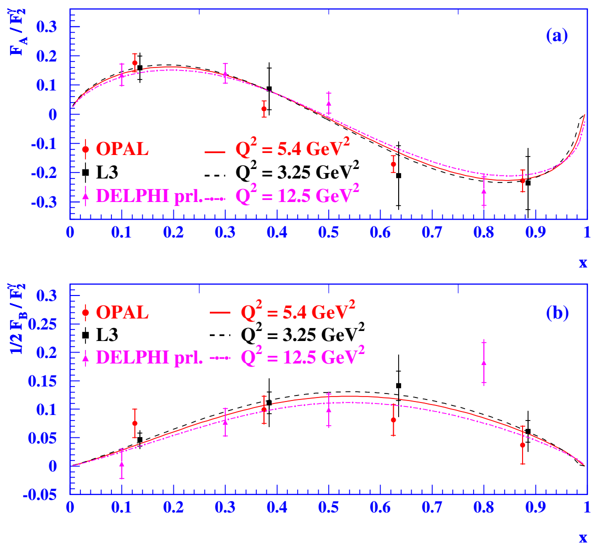

Figure 2. The leptonic structure functions F_A^γ and F_B^γ. The curves show the QED predictions, the dots are the data for the three experiments DELPHI, L3 and OPAL.

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References

[1] V.M. Budnev, I.F. Ginzburg, G.V. Meledin, V.G. Serbo, Phys. Rep. C 15 (1974) 181.
[2] L3 Collaboration, M. Acciarri et al., Phys. Lett. B 407 (1997) 341.
[3] CELLO Collaboration, H.J. Behrend et al., Phys. Lett. B 126 (1983) 384.
[4] P.Kessler, in: D.J. Miller, S.L. Cartwright, V. Khoze (Eds.), Proceedings of Photon '95, Sheffield U.K., 8-13 April 1995, World Scientific, Singapore, 1995, p.281.
[5] J.H. Field, in: D.J. Miller, S.L. Cartwright, V. Khoze (Eds.), Proceedings of Photon '95, Sheffield U.K., 8-13 April 1995, World Scientific, Singapore, 1995, p.485.
[6] C. Peterson, P.Zerwas, T.F. Walsh, Nucl. Phys. B 229 (1983) 301.
[7] L3 Collaboration, M. Acciarri et al., Phys. Lett. B 438 (1998) 363
[8] A. Zinchenko, presentation at PHOTON 99, May 23-27 1999, Freiburg.
[9] OPAL Collaboration, K. Ackerstaff et al., Zeit. fur Physik C74 (1997) 49