ANALYSIS OF HADRONIC FINAL STATES AND THE PHOTON STRUCTURE FUNCTION F_2^γ IN DEEP INELASTIC ELECTRON-PHOTON SCATTERING AT LEP

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Deep inelastic electron-photon scattering is studied in the Q^2 range from 6 to 400 GeV^2 using the OPAL detector at LEP for e^+e^- centre-of-mass energies close to the Z^0 mass. The properties of the hadronic final states are compared with Monte Carlo models. New measurements of $F_2^\gamma(x, Q^2)$ are presented.

1 Introduction

In the singly-tagged regime the process $e^+e^- \rightarrow e^+e^- +$ hadrons can be regarded as deep inelastic scattering of an $e^\pm$ on a quasi-real photon. The cross-section for this process is expressed as

$$\frac{d^2\sigma_{e\gamma\rightarrow eX}}{dxdQ^2} = \frac{2\pi\alpha^2}{x\,Q^4}\left[\left(1+(1-y)^2\right)F_2^\gamma(x,Q^2) - y^2 F_{\mathrm{L}}^\gamma(x,Q^2)\right]. \quad (1)$$

Q^2 is the absolute value of the four momentum squared of the virtual photon x and y are the usual dimensionless variables of deep inelastic scattering, and α is the fine structure constant. In the regime studied here ($y \ll 1$) the contribution of the term proportional to $F_{\mathrm{L}}^\gamma(x, Q^2)$ is small and neglected.

Because the energy of the quasi-real photon is not known, x has to be derived from the hadronic final state. This leads to a dependence of F_2^γ on the modelling of the hadronic final states by the Monte Carlo generators.

2 Data Selection and Background Contribution

The events are divided in two samples, a low-Q^2 and a high-Q^2 one. The low-Q^2 (high-Q^2) samples require a large energy deposit in the ranges $0.06 \le \theta_{\mathrm{tag}} \le 0.12$ ($0.2 \le \theta_{\mathrm{tag}} \le 0.5$) rad of polar angle, and a visible hadronic mass in the range $2.5 \le W_{\mathrm{vis}} \le 40\,(25)$ GeV. To ensure the scattering on a quasi-real photon, an antitag requirement is applied in the hemisphere opposite to the tagged electron. The high-Q^2 sample requires in addition that the electron candidate is isolated, that the event is balanced in transverse momentum and that the missing momentum in the event along the beam axis is consistent with the beam energy. The numbers of selected events and the expected background events obtained from Monte Carlo models are listed in table 1.

Table 1: The event composition for $\mathcal{L}_{int} = 156.4$ pb^{-1}. The errors are statistical only.

sample	selected	$Z^0 \rightarrow$ hadrons	$Z^0 \rightarrow \tau^+\tau^-$	$\gamma^\star\gamma \rightarrow \tau^+\tau^-$
low-Q^2	5455	122.0 ± 12.0	2.6 ± 1.0	289.4 ± 12.7
high-Q^2	225	3.5 ± 2.0	1.5 ± 0.8	18.5 ± 3.3

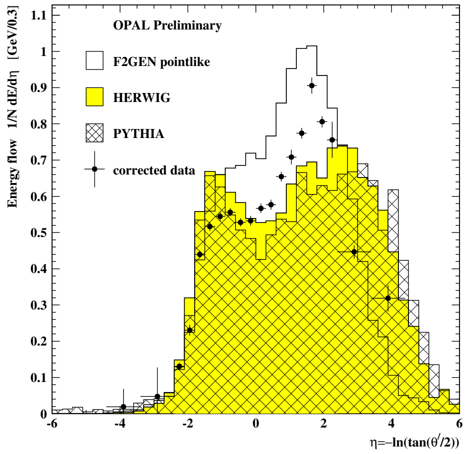

Figure 1: The corrected energy flow per event for the data, as a function of pseudorapidity η, compared to the generated energy flow from Monte Carlo models. The tagged electron, which is not shown, is always at $-3.5 < \eta < -2.8$. The vertical error bars are the sum of the statistical and systematic errors, the horizontal bars indicate the bin widths.

3 Modelling of the $\gamma^\star\gamma$ Fragmentation

The data are compared to the HERWIG [1] and PYTHIA [2] Monte Carlo models and to the more specialised F2GEN generator [3]. A significant fraction of the hadronic energy flow goes into the forward region of the OPAL detector (33% according to HERWIG). This energy, which was neglected in former analyses [4,5], is now included. About 42% of it is recovered, with a resolution of $\Delta E/E = 30\%$ of the seen energy, thereby substantially increasing the correlation of W and W_{vis} at large W, however, model dependent. The data are described reasonably well by the models for global hadronic variables such as the visible hadronic mass, the visible neutral energy, and the charged multiplicity, but there are serious discrepancies in the energy flow, figure 1, especially at low x_{vis}, between the data and any of the models at all rapidities. The data however, is precise enough to further constrain the models.

Table 2: Preliminary results on $F_2^\gamma(x)/\alpha$ as a function of x in bins of Q^2, and on $F_2^\gamma(Q^2)/\alpha$ as a function of Q^2 averaged over $0.1 < x < 0.6$, for 4 active flavours.

$\langle Q^2 \rangle$	x	$F_2^\gamma(x)/\alpha$	$F_2^\gamma(Q^2)/\alpha$
7.5	$0.001 < x < 0.091$	$0.265 \pm 0.016 ^{+0.054}_{-0.045}$	$0.325 \pm 0.024 ^{+0.060}_{-0.093}$
	$0.091 < x < 0.283$	$0.313 \pm 0.023 ^{+0.086}_{-0.125}$	
	$0.283 < x < 0.649$	$0.309 \pm 0.044 ^{+0.085}_{-0.153}$	
14.7	$0.006 < x < 0.137$	$0.366 \pm 0.012 ^{+0.085}_{-0.081}$	$0.422 \pm 0.011 ^{+0.067}_{-0.055}$
	$0.137 < x < 0.324$	$0.397 \pm 0.019 ^{+0.048}_{-0.047}$	
	$0.324 < x < 0.522$	$0.416 \pm 0.031 ^{+0.076}_{-0.121}$	
	$0.522 < x < 0.836$	$0.540 \pm 0.045 ^{+0.343}_{-0.141}$	
135	$0.100 < x < 0.300$	$0.635 \pm 0.090 ^{+0.356}_{-0.147}$	$0.693 \pm 0.067 ^{+0.168}_{-0.080}$
	$0.300 < x < 0.600$	$0.717 \pm 0.079 ^{+0.096}_{-0.158}$	
	$0.600 < x < 0.800$	$0.887 \pm 0.095 ^{+0.703}_{-0.261}$	

4 The Determination of F_2^γ

F_2^γ is determined as a function of x from the $x_{\rm vis}$ distribution using the method of regularised unfolding[6], figure 2 and table 2. The F_2^γ values are not corrected for the effect of nonzero virtuality P^2 of the quasi-real photon. The uncertainty of the result is dominated by the model dependence, which is estimated by performing the unfolding using the various generators and several different parton density parametrisations (PDFs), and with the cuts varied in reasonable ranges. The systematic errors are considerably larger than in the old style analyses, such as[4]. $F_2^\gamma(Q^2)/\alpha$ as a function of Q^2 is measured in the region $0.1 < x < 0.6$, figure 2 (d) and table 2. The measurement of $\mathrm{d}(F_2^\gamma/\alpha)/\mathrm{d}\ln Q^2$ is a basic test of QCD, (see [7] for a summary). A fit was performed using the form $a + b \ln Q^2$ and uncorrelated errors. No subtraction of the charm component has been done. The result is $F_2^\gamma(Q^2)/\alpha = (0.075 \pm 0.197) + (0.128 \pm 0.071) \ln Q^2$, with $\chi^2/\mathrm{DOF} = 0.01$. The values of χ^2/DOF indicate that the errors are overestimated and a more elaborate procedure is needed. All results are well described by F_2^γ based on the GRV[8] and SaS1D[9] PDFs.

5 Summary and Conclusion

Data collected by the OPAL experiment at LEP for the $\mathrm{e^+e^-}$ centre-of-mass energies close to the $\mathrm{Z^0}$ mass have been used to study the properties of hadronic final states in deep inelastic electron-photon scattering, and to measure $F_2^\gamma(x, Q^2)$. The observed distributions of energy flow per event are very different from all

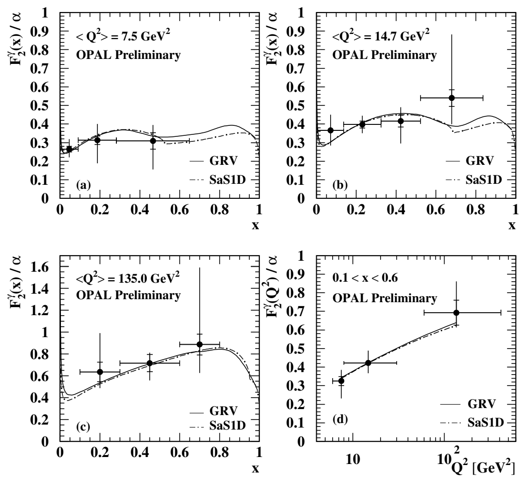

Figure 2: The preliminary measurement of F_2^γ, given at the centre of the x bin, for 4 active flavours for three values of $\langle Q^2 \rangle$, (a)-(c) and the evolution of F_2^γ as a function of Q^2 for the range $0.1 < x < 0.6$ (d). The horizontal bars indicate the bin width, the vertical error bars show both the statistical error alone and the full error.

the models, (HERWIG, PYTHIA and F2GEN) at all rapidities. $F_2^\gamma(x, Q^2)$ has been measured as a function of x in three ranges of Q^2. The measured slope of $\mathrm{d}(F_2^\gamma/\alpha)/\mathrm{d}\ln Q^2 = 0.128 \pm 0.071$ in the range $0.1 < x < 0.6$ shows the logarithmic evolution of F_2^γ with Q^2 expected from QCD. The data, over the x range studied, are well described by the GRV and SaS1D PDFs.

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