Measuring Structure Functions of the Photon with Azimuthal Correlations at OPAL

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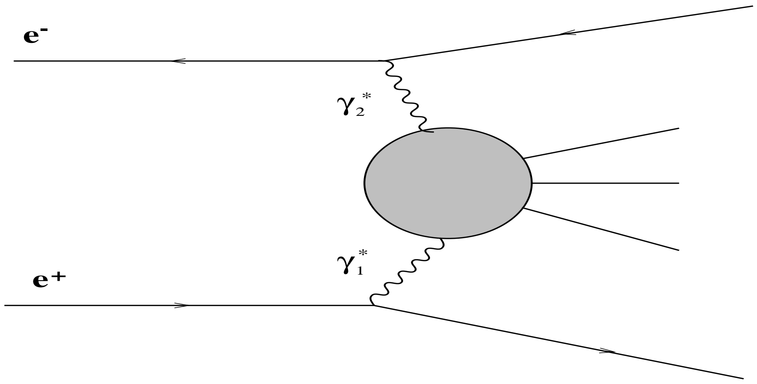
Structure of the Photon

We can study the structure of the photon by looking at $e^+e^- \to e^+e^- X$ events.



We write the cross-section in terms of structure functions :

$$\frac{d\sigma(\mathrm{e}\gamma \to \mathrm{e}X)}{dx\,dQ^2} = \frac{2\pi\alpha^2}{xQ^4}\left[\left(1+(1-y)^2\right)F_2^\gamma(x,Q^2) - y^2 F_L^\gamma(x,Q^2)\right].$$

$$\begin{aligned} Q^2 &= 2E_{\mathrm{beam}}E_{\mathrm{tag}}(1-\cos\theta_{\mathrm{tag}}) \\ x &= Q^2/(Q^2+W^2) \\ y &= 1-\frac{E_{\mathrm{tag}}}{E_{\mathrm{beam}}}\cos^2\frac{\theta_{\mathrm{tag}}}{2} \\ W &= M(\gamma^*\gamma) \end{aligned}$$

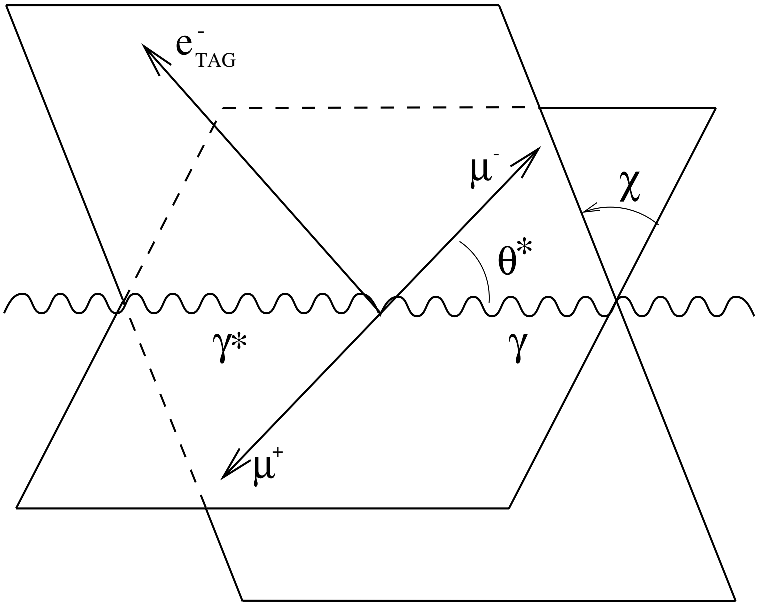
In this cross-section, F_2^γ dominates because of small y.

There have been some F_2^γ measurements, but there has been no measurement of F_L^γ yet.

We can measure other structure functions by looking at azimuthal correlations...

What are azimuthal correlations...

We will consider the azimuthal angle χ between the muon axis and the tag direction relative to the two-photon axis in the $\gamma^*\gamma$ centre-of-mass.



The cross-section now looks like this :

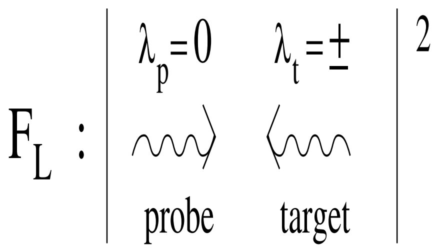
$$\frac{d\sigma(e\gamma \to e\mu\bar{\mu})}{dx dy d\Omega/4\pi} = \frac{2\pi\alpha^2}{Q^2}\frac{1+(1-y)^2}{xy} \times \left[(2x\tilde{F}_T^\gamma + \epsilon(y)\tilde{F}_L^\gamma) - \rho(y)\tilde{F}_A^\gamma \cos\chi + \frac{1}{2}\epsilon(y)\tilde{F}_B^\gamma \cos 2\chi\right],$$

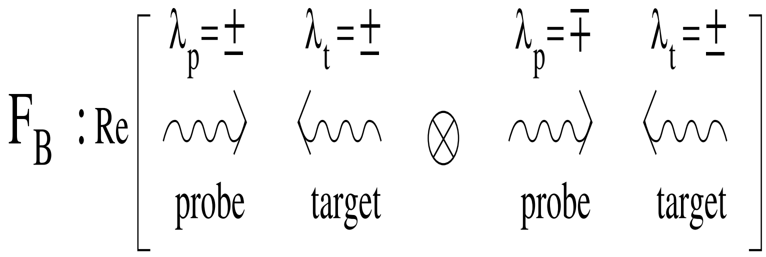
By looking at the χ distribution, we can get some information about F_A^γ and F_B^γ.

Interesting aspects of F_B^γ

In leading order and neglecting the muon mass, $F_B^\gamma = F_L^\gamma$.

But they come from different helicity states of the photons.



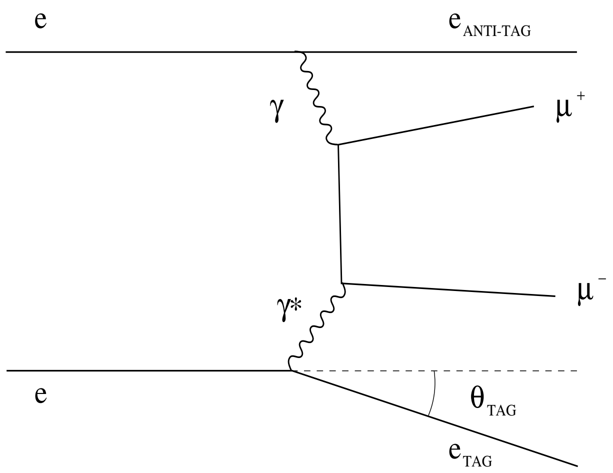


- F_L^γ describes a longitudinal probe photon,
- F_B^γ describes transverse photons only.

... but in principle we can infer information about F_L^γ from an F_B^γ measurement.

What was done...

In the present analysis, we have studied $e^+e^- \to e^+e^-\mu^+\mu^-$ events from OPAL LEP1 data.



- An electron in the region $0.026 < \sin\theta_{\mathrm{tag}} < 0.120$ with $E_{\mathrm{tag}} > 0.5E_{\mathrm{beam}}$ ($\Rightarrow 0.85 < Q^2 < 31$ GeV^2),
- two charged tracks, with a least one identified as a muon (see OPAL, Zeit. f. Phys., C60 (93) 593.).

For the 93-95 period, we have 14878 selected events.

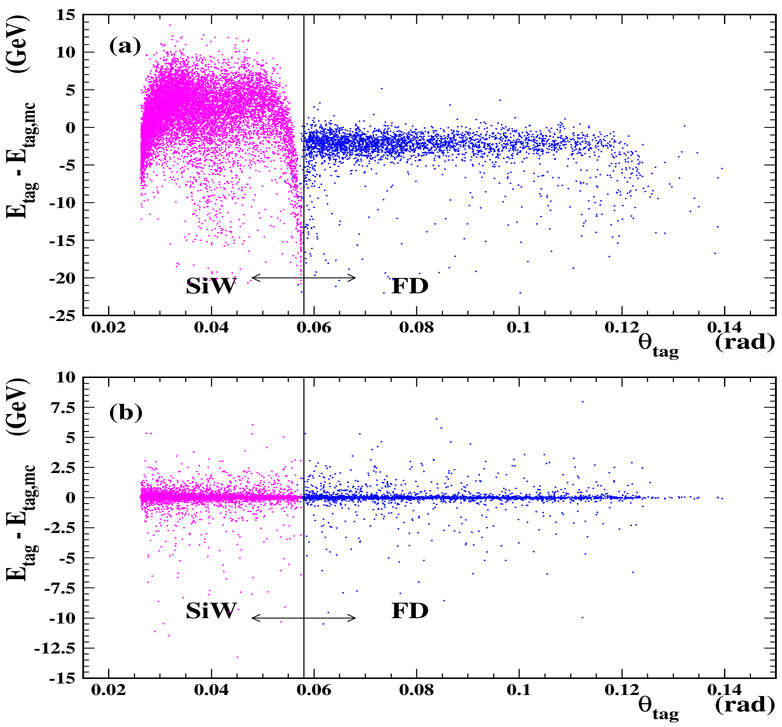
We have a background of 2.7 % coming from

$$e^+e^- \to Z^0 \to \tau^+\tau^-,$$
$$e^+e^- \to e^+e^-\tau^+\tau^-,$$
$$\gamma\gamma \to \mathrm{hadrons}.$$

Calculation of E_{tag}

We can improve the E_{tag} measurement by using the fact that the final state $e^+e^-\mu^+\mu^-$ is overconstrained, and we can compute E_{tag} from θ_{tag}, the momentum of the muon system and energy-momentum conservation.

With this, we go from a resolution of about 2 GeV to a resolution of about 0.5 GeV.

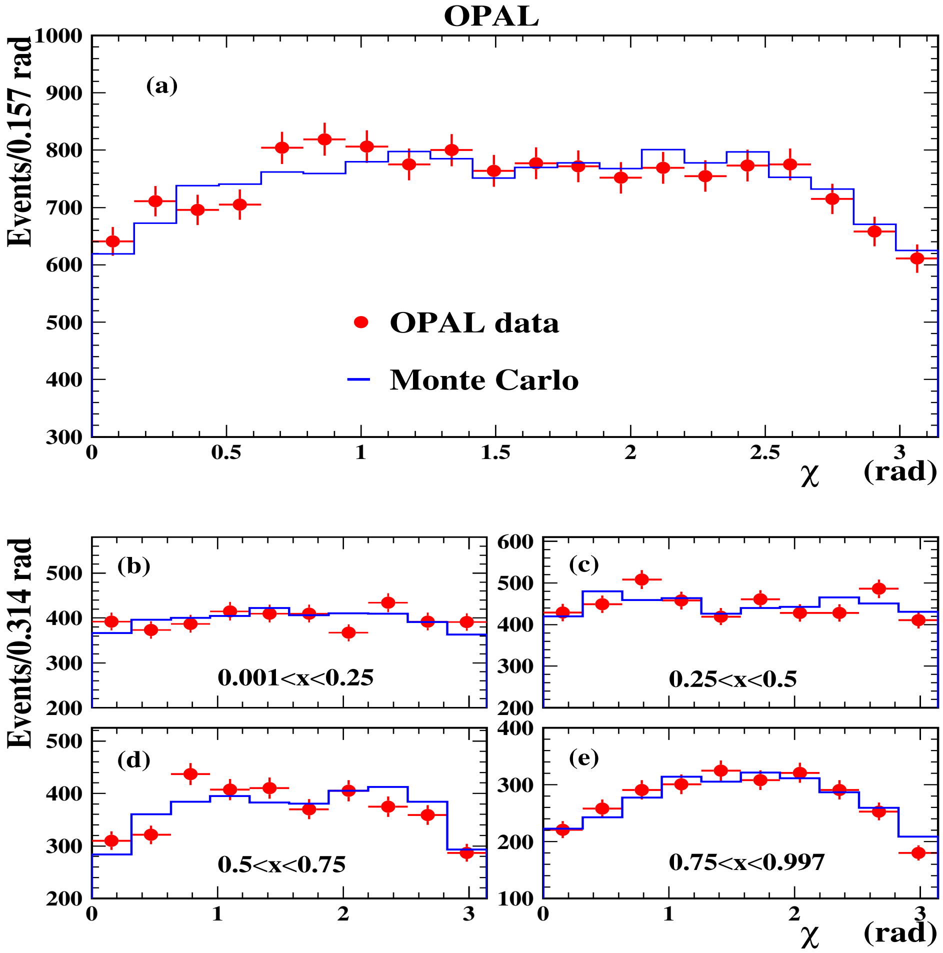


The azimuthal angle distribution

We measure the azimuthal angle χ.

We have a resolution of about $\simeq 20$ mrad, constant in χ.

We are interested in the scaling of F_B^γ with x, so we use 4 x-bins.

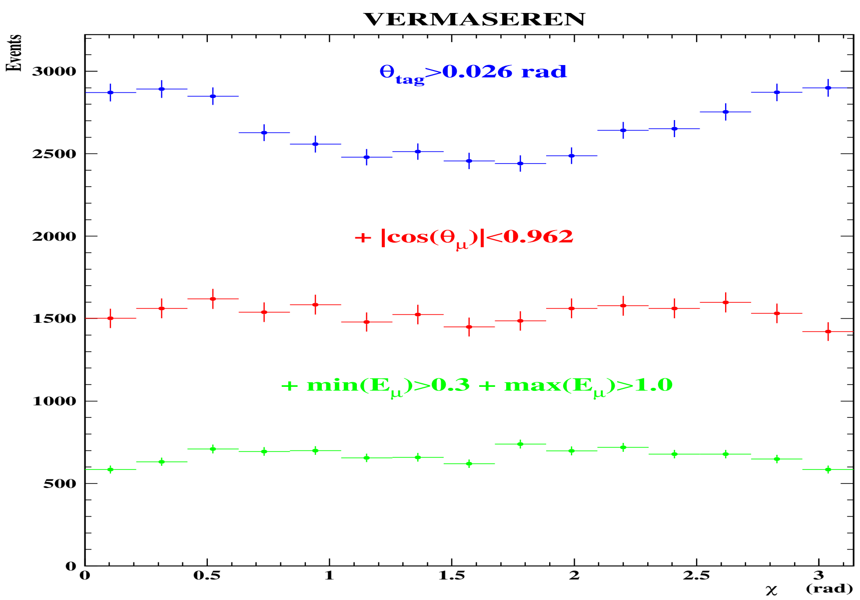


We apply a correction

Although we measure χ precisely, the acceptance of the detector changes the χ distribution with respect to the theoretical prediction.

$\Rightarrow$ We do not get a **cos 2χ** distribution.

The most important effect is the loss of muons through the forward region.

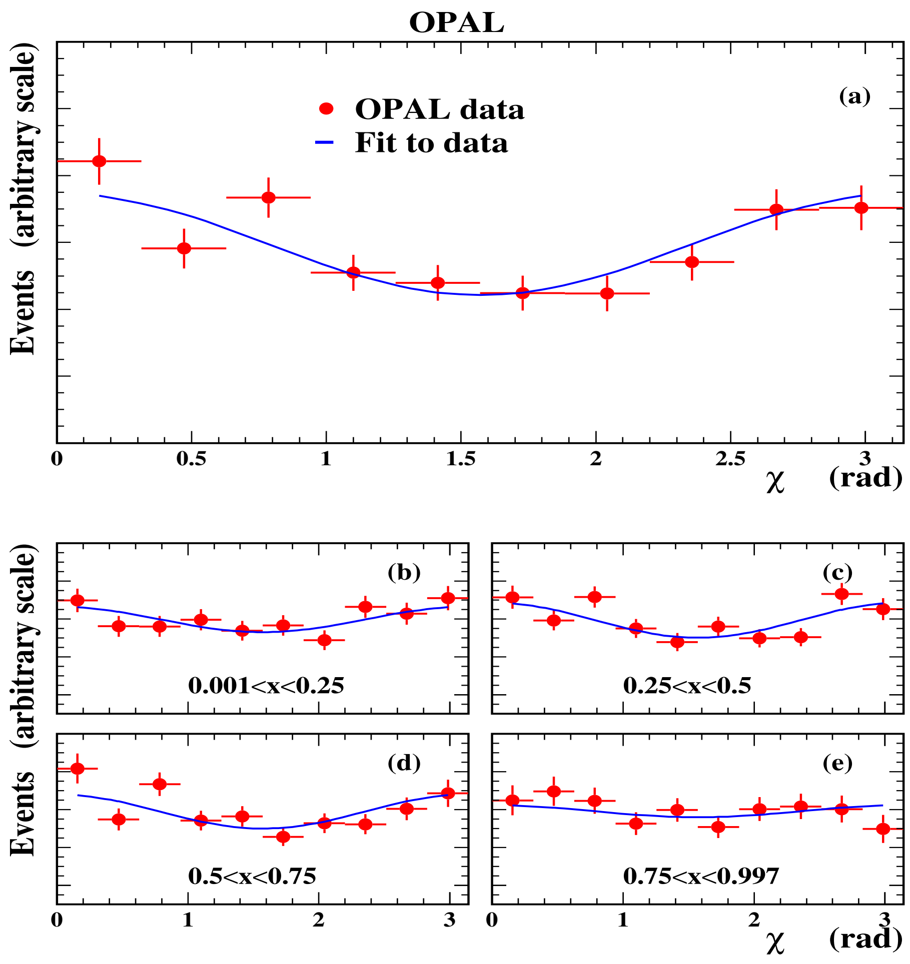


A bin-by-bin correction was found with the Monte Carlo.

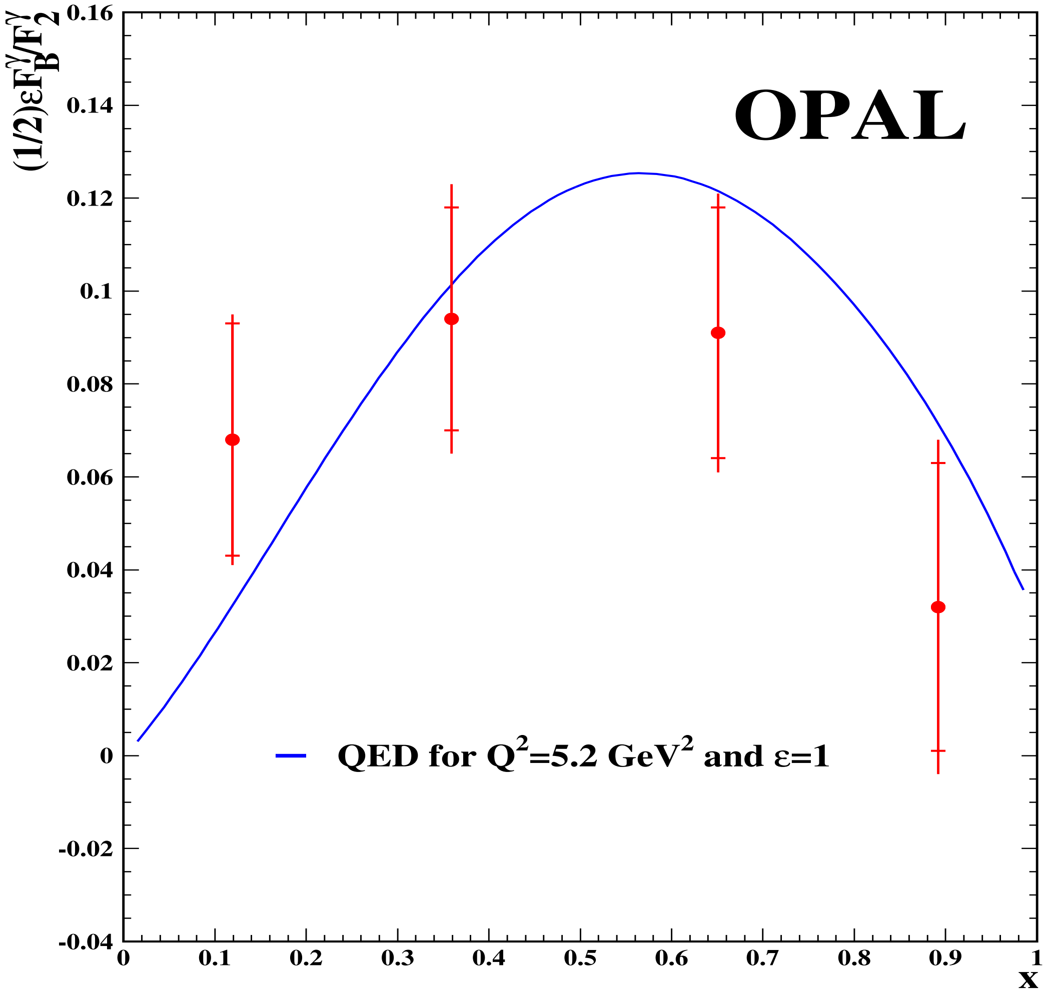
The corrected data distributions were fitted to a function

$$F(\chi) = P_1(1 + P_2 \cos 2\chi),$$

which gives $P_2 \simeq \frac{1}{2}F_B^{\gamma}/F_2^{\gamma}$.



Results



$0.5 F_B^\gamma / F_2^\gamma$(whole x range) = $0.076 \pm 0.013 \pm 0.015$

$0.5 F_B^\gamma / F_2^\gamma$(QED prediction) = 0.083

Conclusions

- Azimuthal correlations offer a way to measure more structure functions,
- We measured the azimuthal angle distribution and obtained F_B^γ / F_2^γ,
- We can measure F_B^γ / F_2^γ but the sensitivity as a function of x is limited,
- Our measurement is consistent with QED.

OUTLOOK:

We hope to be able to do such an analysis for hadronic events...