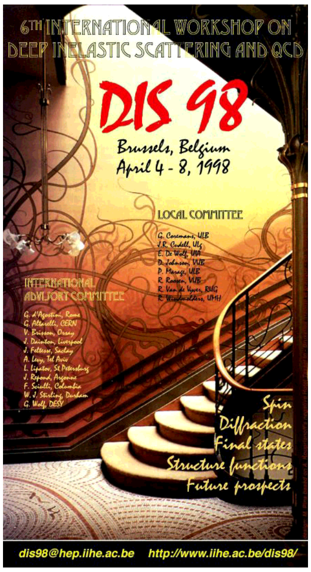
Structure functions of the photon at LEP

Richard Nisius (CERN) April, 5 ’98



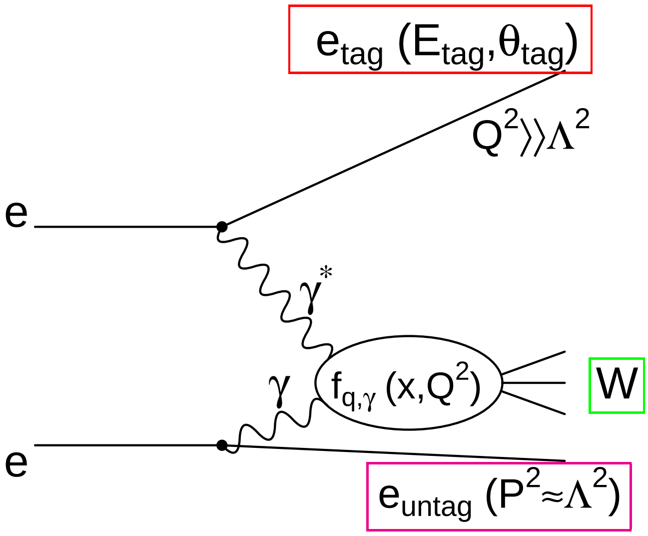
- Introduction

1. QED structure functions
2. The hadronic $F_2^{\gamma}(x, Q^2)$

- Conclusions

For the γ OPAL γ Collaboration

Electron-Photon Scattering



$$\frac{d^2\sigma_{e\gamma\to eX}}{dx dQ^2} = \frac{2\pi\alpha^2}{x\,Q^4} \cdot$$

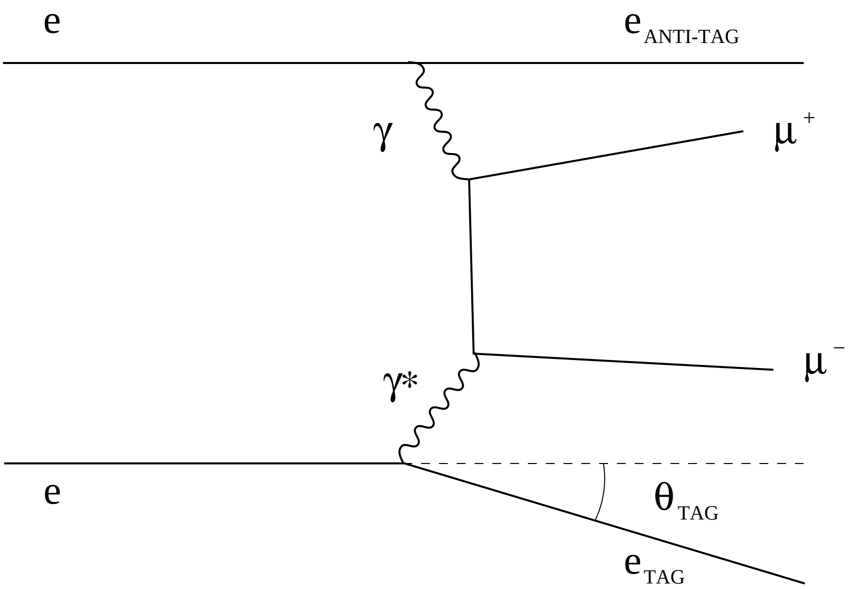
$$\left[(1 + (1-y)^2)\, F_2^\gamma(x, Q^2) - \underbrace{y^2 F_L^\gamma(x, Q^2)}_{\to 0} \right]$$

$$Q^2 = 2\,E_\mathrm{b}\,E_\mathrm{tag}\,(1 - \cos\theta_\mathrm{tag}) \gg P^2$$

$$x = \frac{Q^2}{Q^2 + W^2 + P^2}$$

$$y = 1 - \frac{E_\mathrm{tag}}{E_\mathrm{b}} \cos^2\left(\frac{\theta_\mathrm{tag}}{2}\right) \ll 1$$

The production of lepton pairs



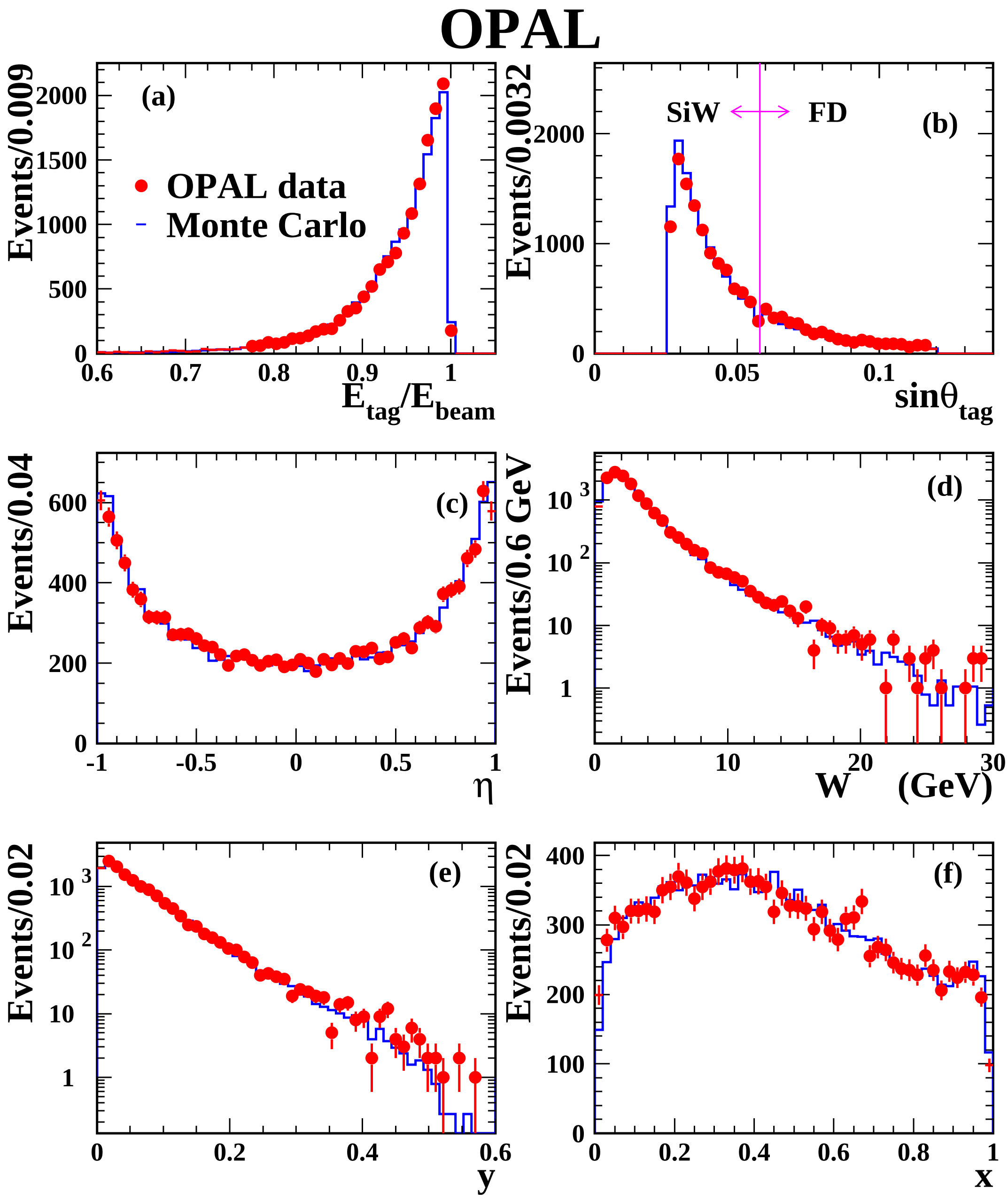
$$\frac{d^2\sigma_{e\gamma\to e\mu^+\mu^-}}{dx\,dQ^2} = \frac{2\pi\alpha^2}{x\,Q^4}\left[\left(1+(1-y)^2\right)F^{\gamma}_{2,\mathrm{QED}} - y^2 F^{\gamma}_{\mathrm{L,QED}}\right]$$

$$F^{\gamma}_{2,\mathrm{QED}}(x,Q^2,P^2)/\alpha \approx \frac{x}{\pi}\left[1-2x(1-x)\ln\frac{W^2}{m_\mu^2+x(1-x)P^2} -1+8x(1-x)-\frac{x(1-x)P^2}{m_\mu^2+x(1-x)P^2}\right]$$

$$F^{\gamma}_{\mathrm{L,QED}}(x,Q^2,P^2=0)/\alpha \approx \frac{4}{\pi}x^2(1-x)$$

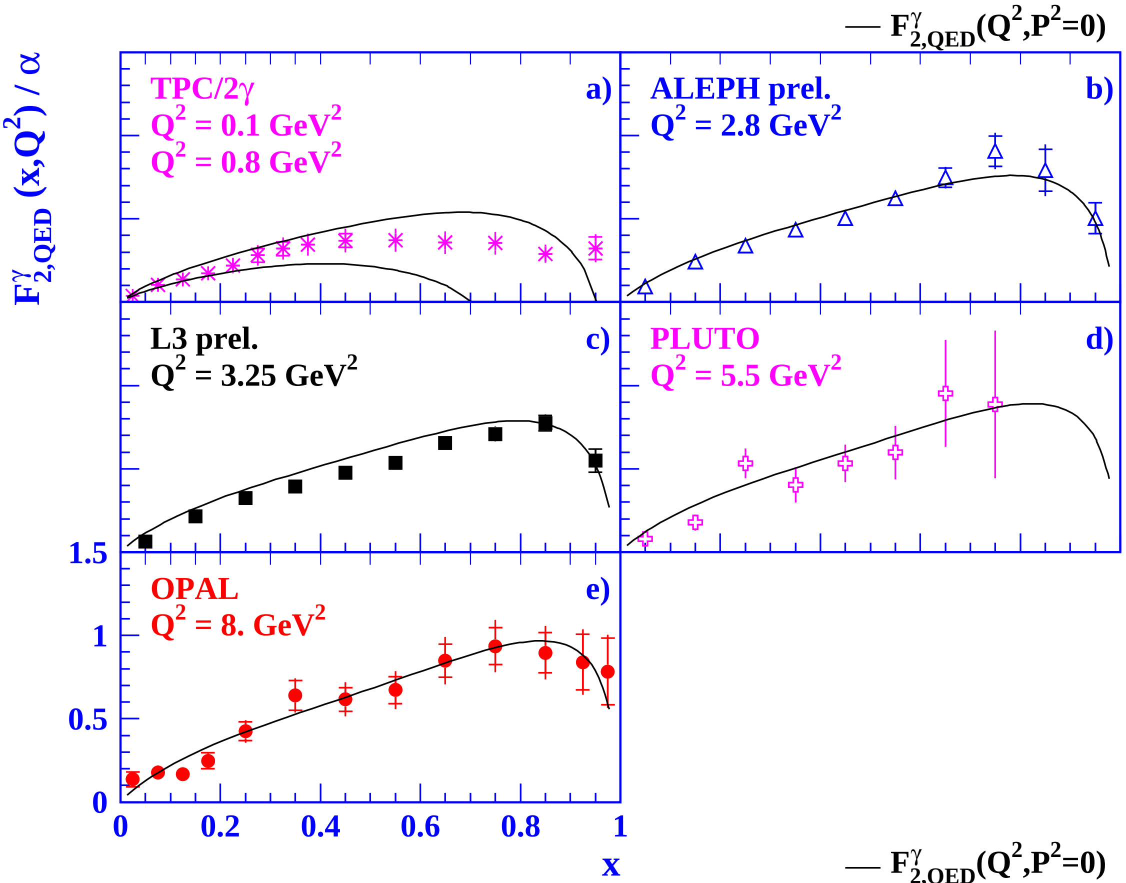
$\Rightarrow$ **QED is a well suited study ground for structure function analysis**

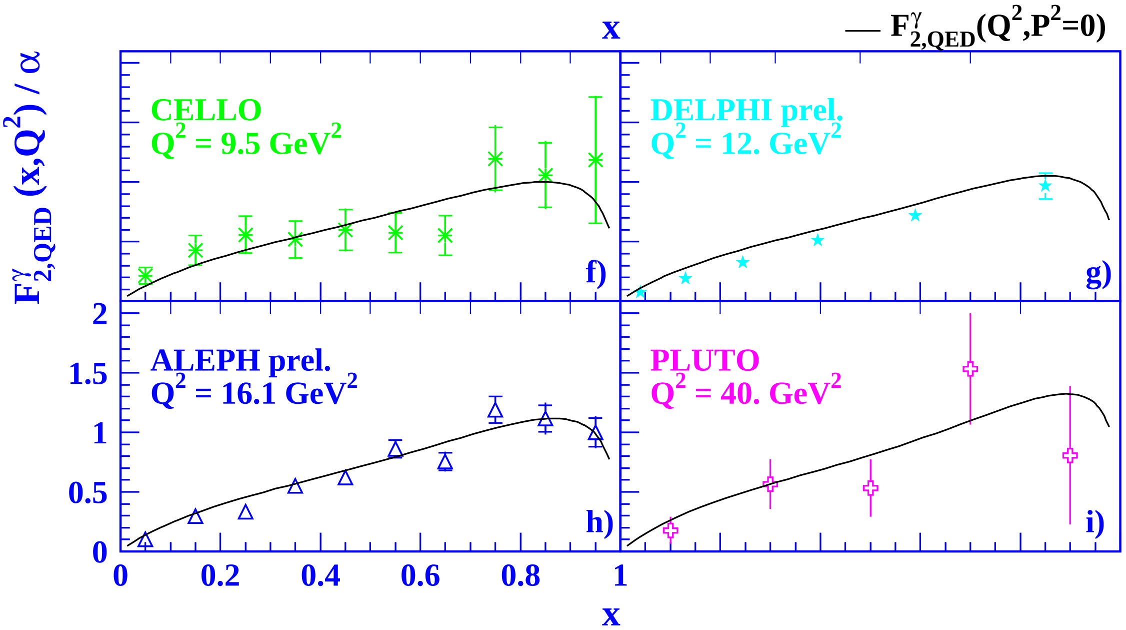
Some check distributions



The data is well described by the QED Monte Carlo

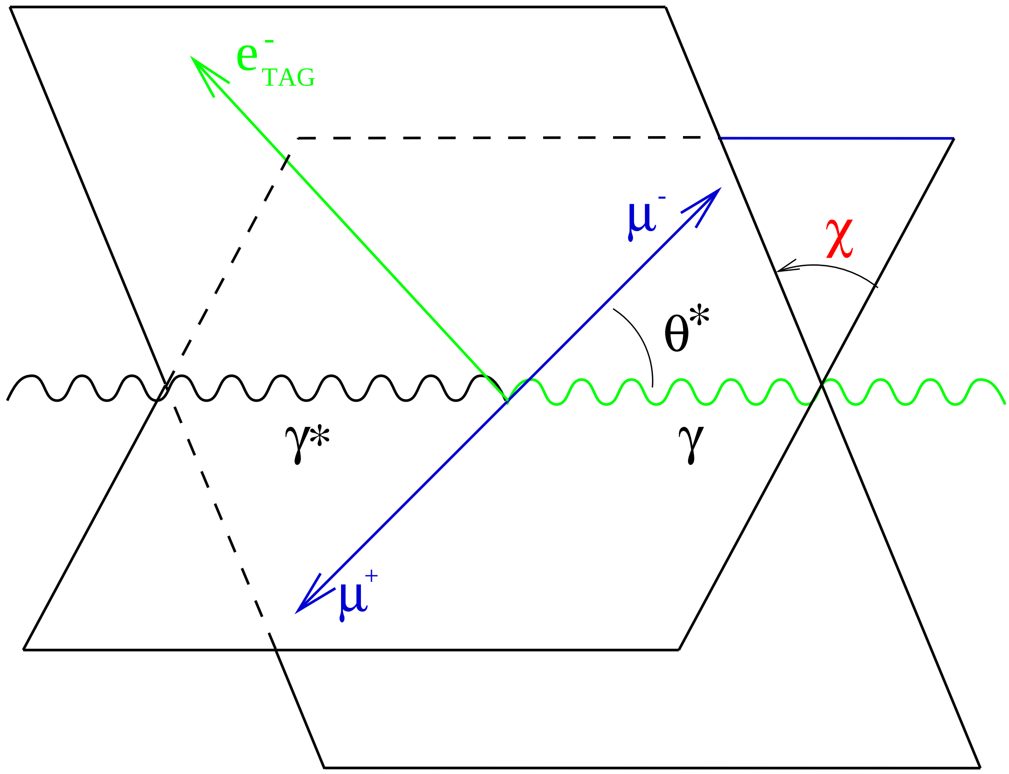
Measurements of $F^{\gamma}_{2,\mathrm{QED}}$





All results are according to expectations from QED

Azimuthal Correlations



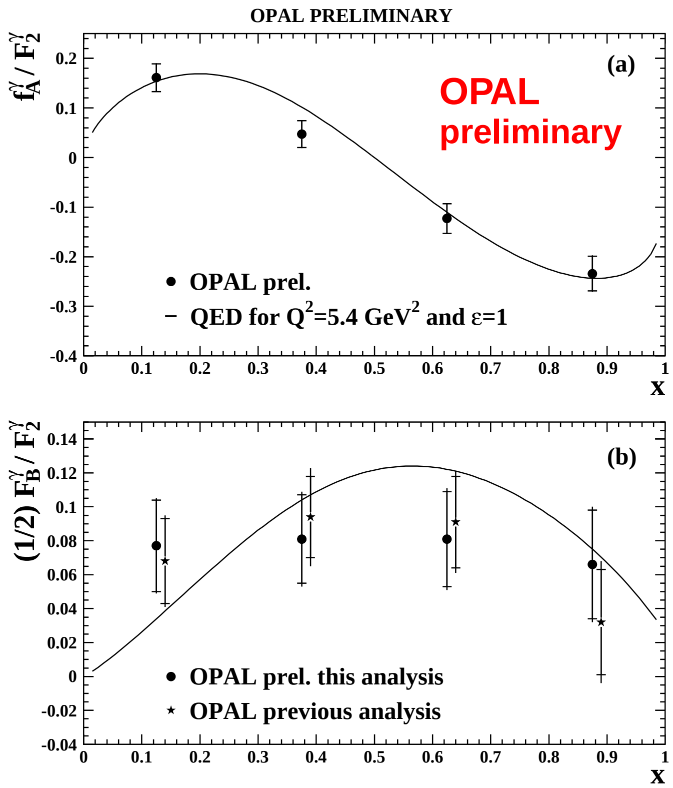
$$\boxed{e\gamma \to e\mu^+\mu^-}$$

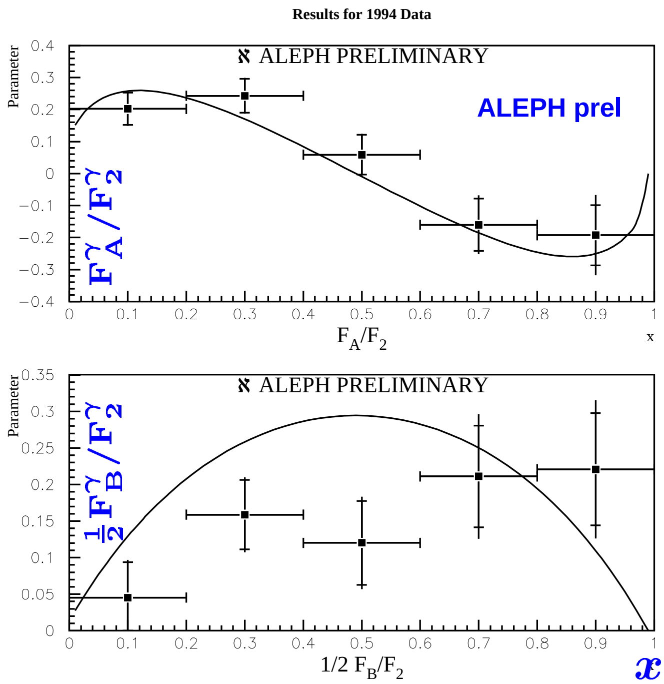
$$d\sigma \quad \propto \quad \left(1 + (F_A^\gamma / F_2^\gamma) \cdot \cos\chi + \frac{1}{2}\epsilon(F_B^\gamma / F_2^\gamma) \cdot \cos 2\chi\right)$$

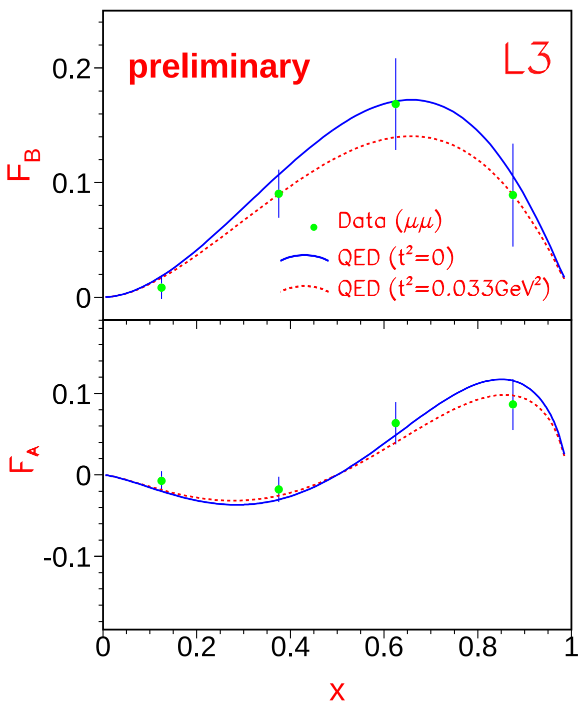
$$\frac{1}{2}\epsilon = \frac{(1-y)}{1+(1-y)^2} \approx 1$$

The χ dependence gives access to other structure functions besides $F^\gamma_{2,\mathrm{QED}}$

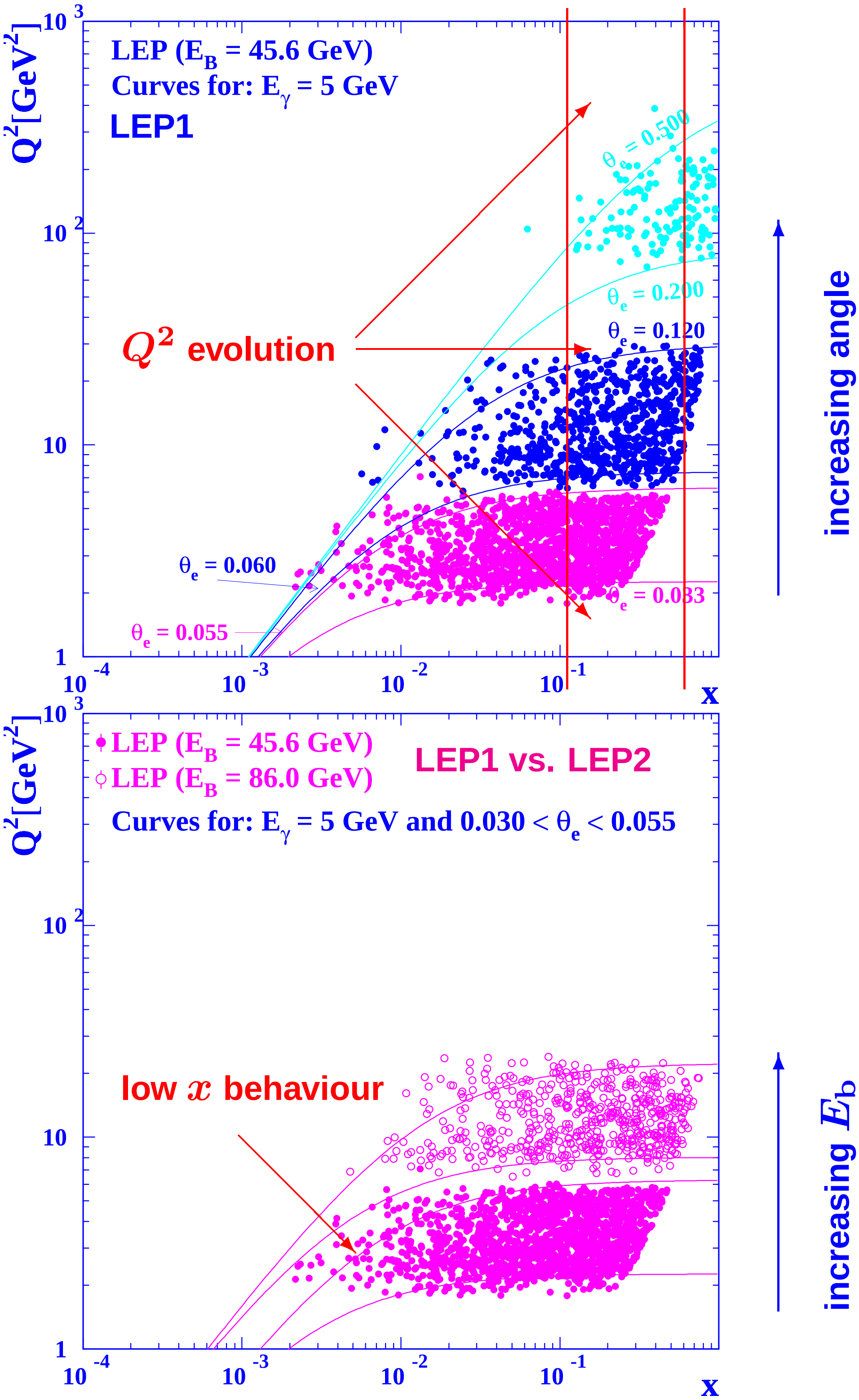
Other QED structure functions





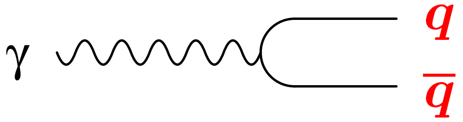


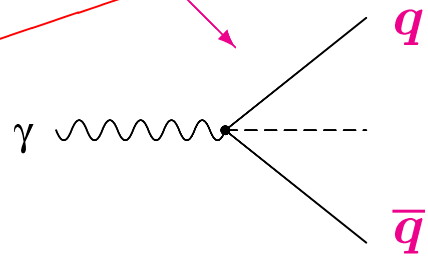
The $x - Q^2$ plane



The contributions to $F_2^{\gamma}(x, Q^2)$

$$F_2^{\gamma}(x, Q^2) = x \sum_{c,f} e_q^2 \, \underline{f_{q,\gamma}(x, Q^2)}$$





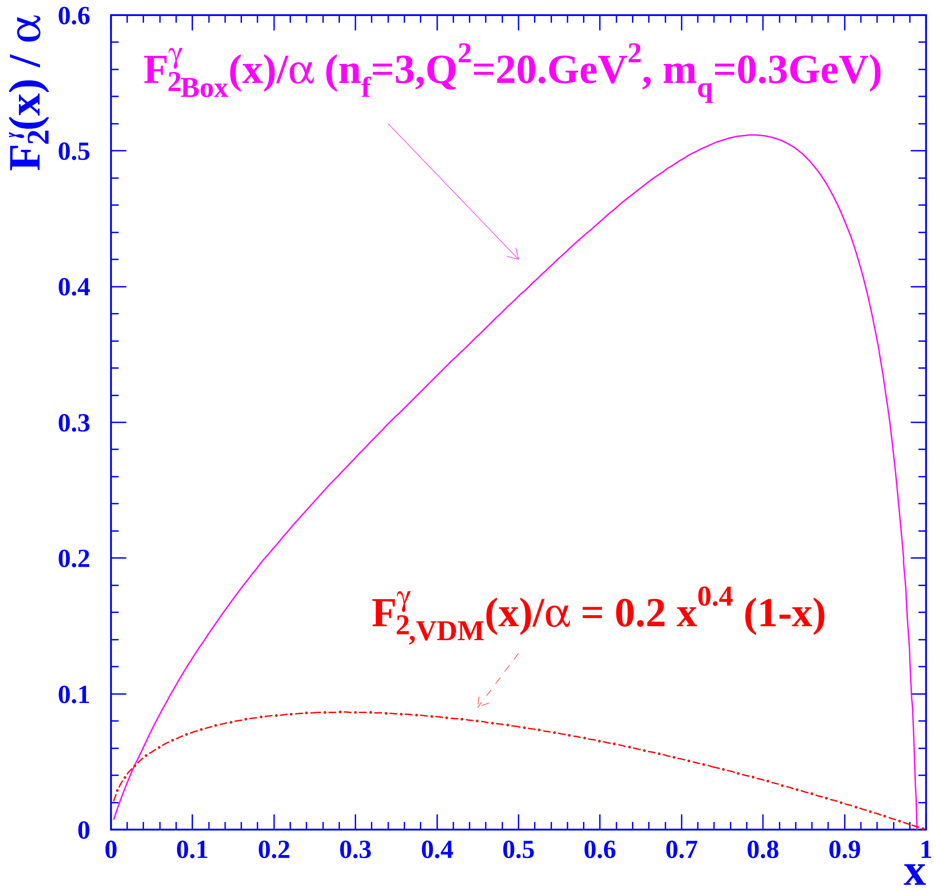
'hadronic', p_T = "small"

non–perturbative

VDM (ρ, ω, ϕ)

'pointlike', p_T = "large"

perturbative



The general procedure to measure F_2^{γ}

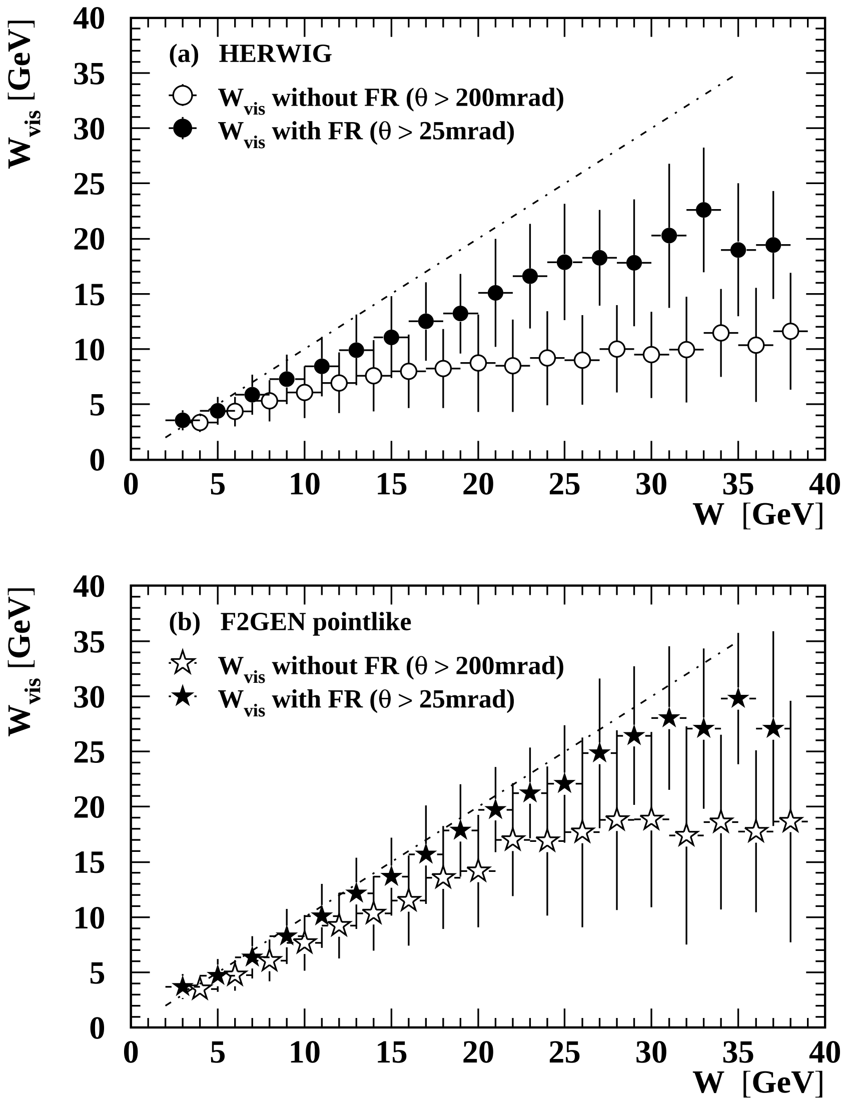
1. Events are triggered with high efficiency by the luminosity detectors nearly independent of the hadronic final state.

2. Q^2 is accurately measured from the electron.

3. E_γ is unknown and varies from event to event
   $\Rightarrow W_{\mathrm{vis}}$ has to be measured from the hadrons.
   (No electron alone method as e.g. at HERA)

4. x is obtained from x_{vis} via unfolding (Blobel, ...)
   $\Rightarrow$ Dependence on the formation of the hadronic final state as assumed by the Monte Carlo models!

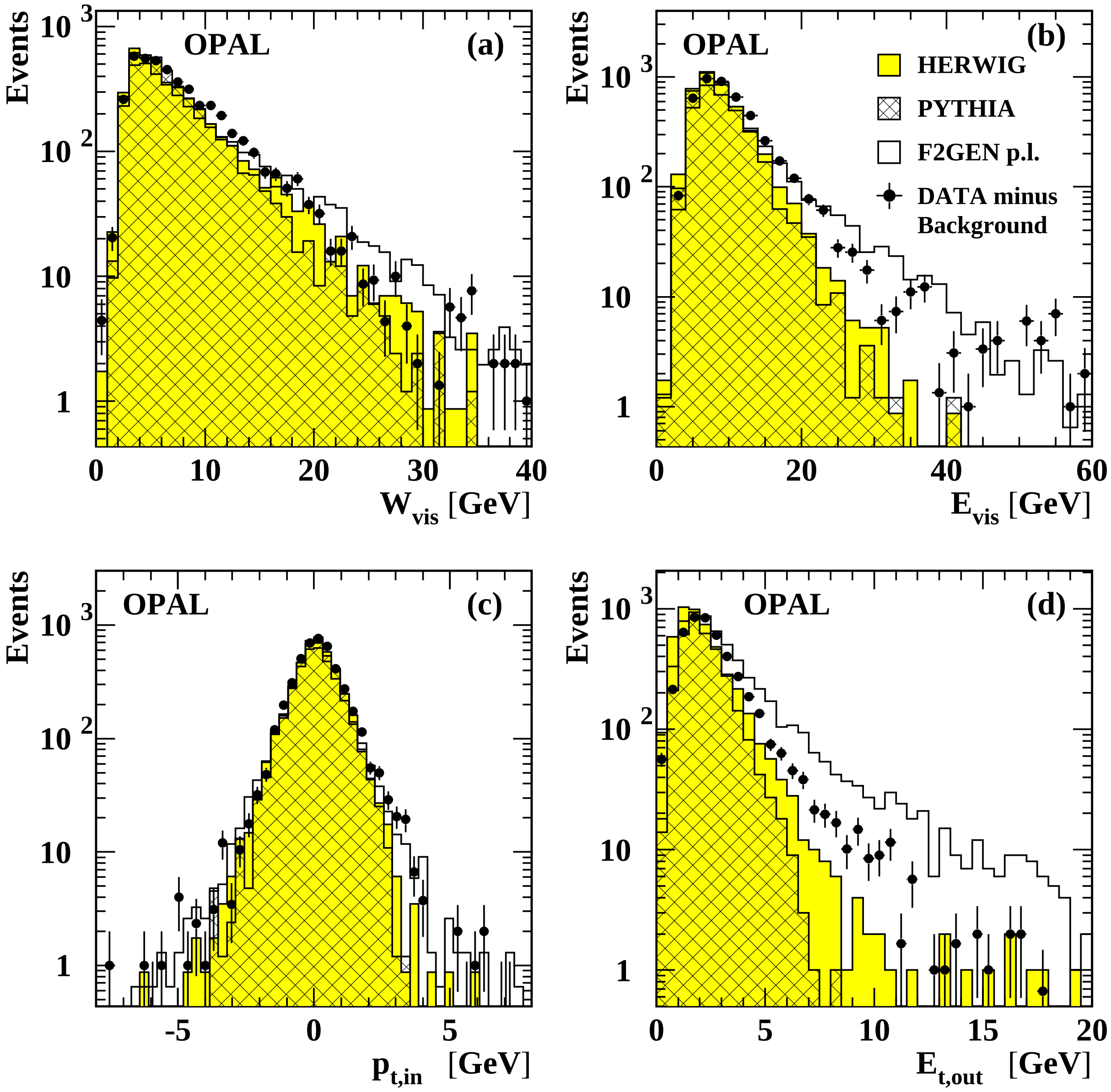
The $W - W_{\rm vis}$ correlation



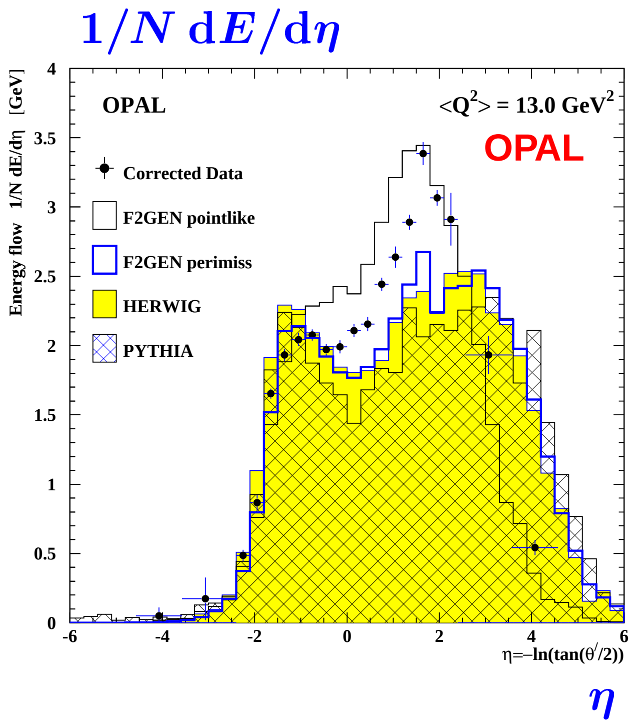
The correlation based on F2GEN is much stronger

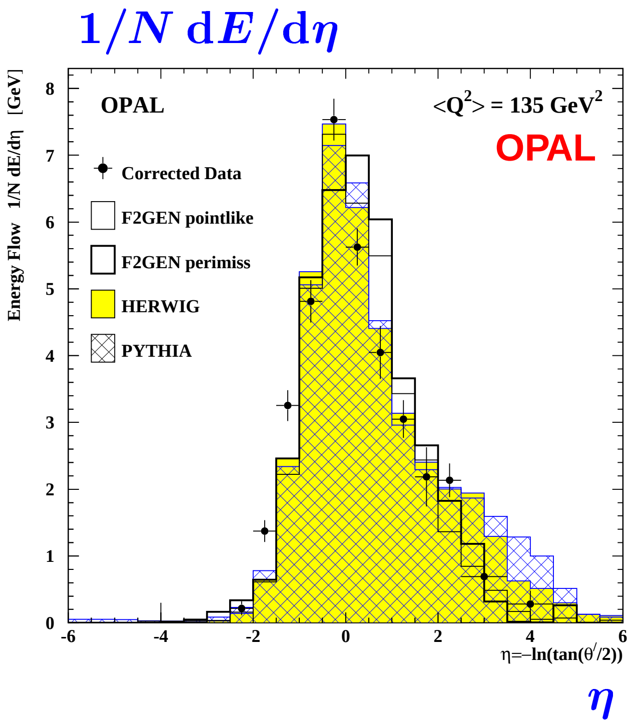
The inclusion of the Forward Region significantly improves the correlation

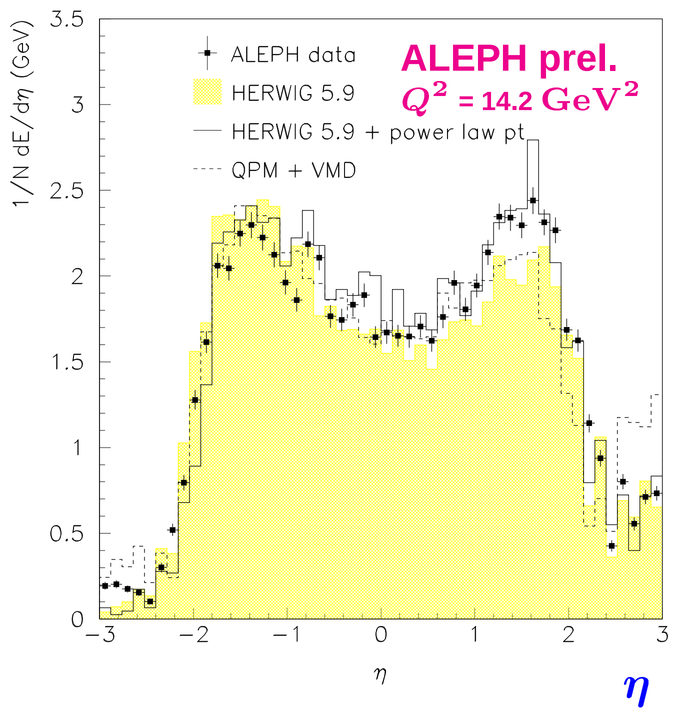
Some global quantities

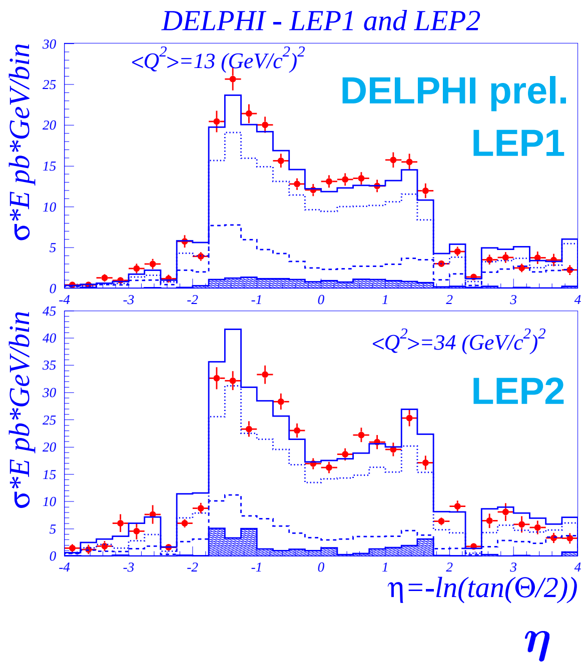


The model dependence



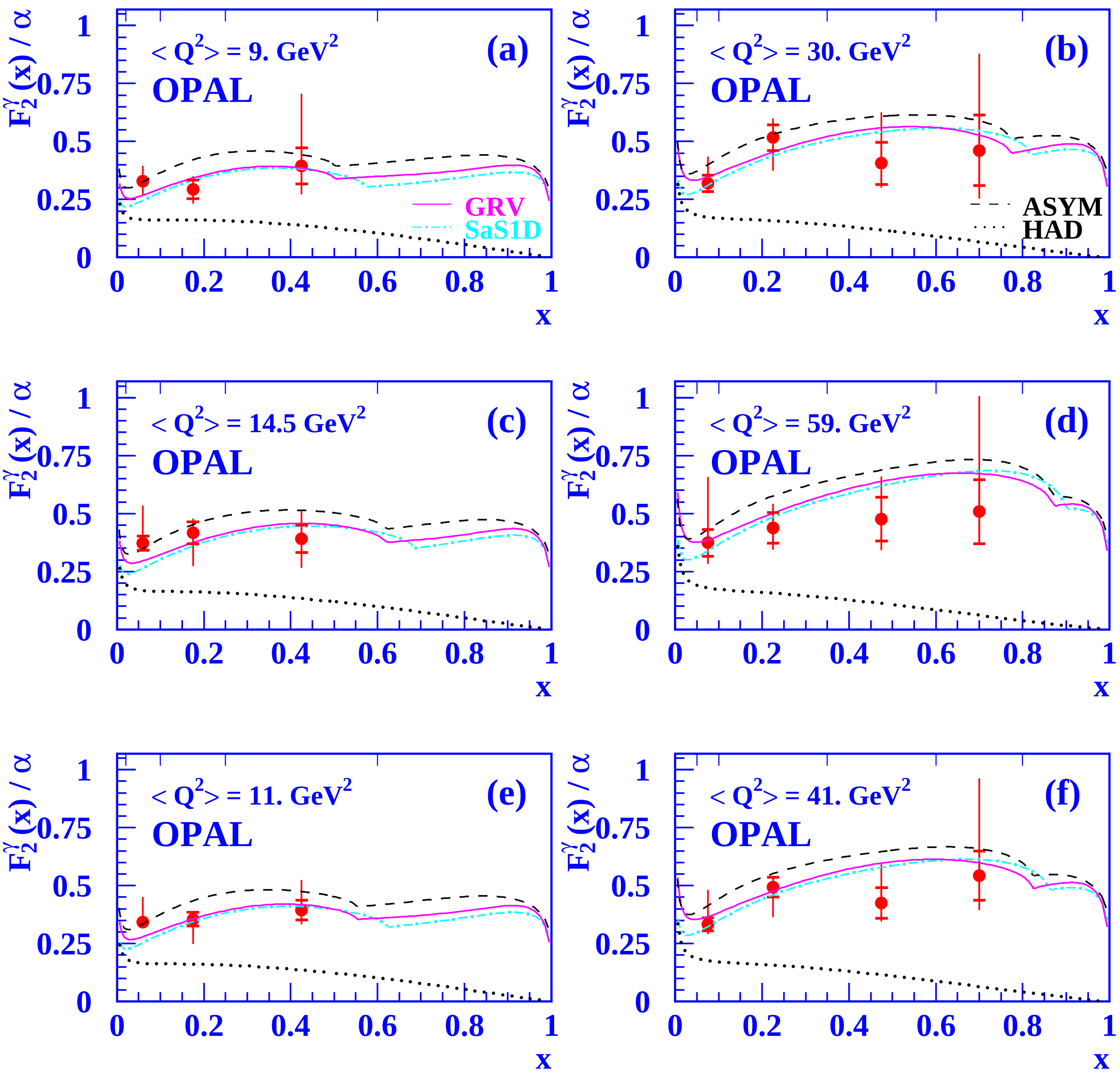






Improvements on the Monte Carlo programs are needed

F_2^{γ} compared to various predictions



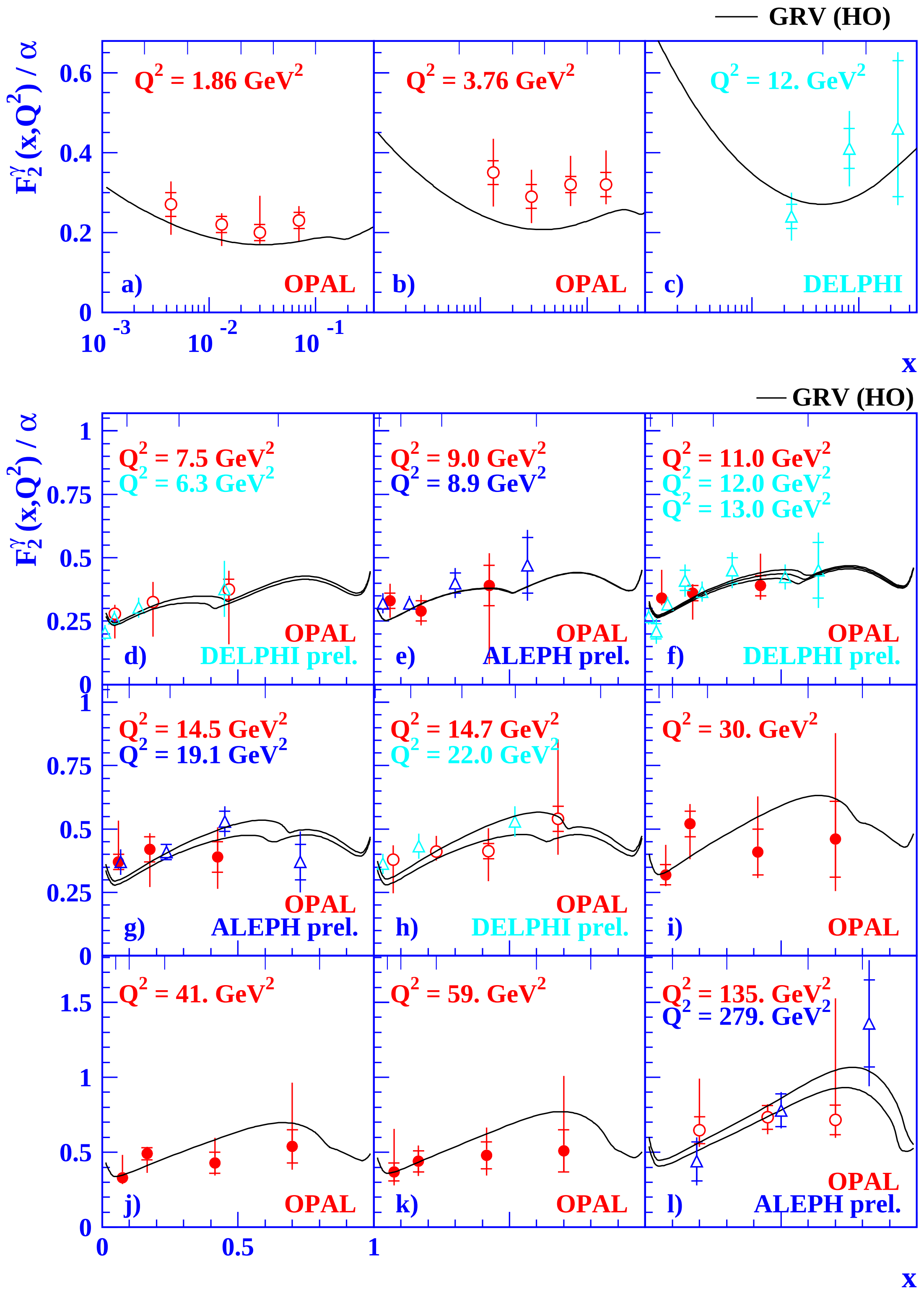
ASYM $\equiv$ asymptotic solution for n_f = 3 (Witten LO)

$\oplus$ massive charm (Bethe Heitler LO) $\oplus$ HAD (GRV VDM LO)

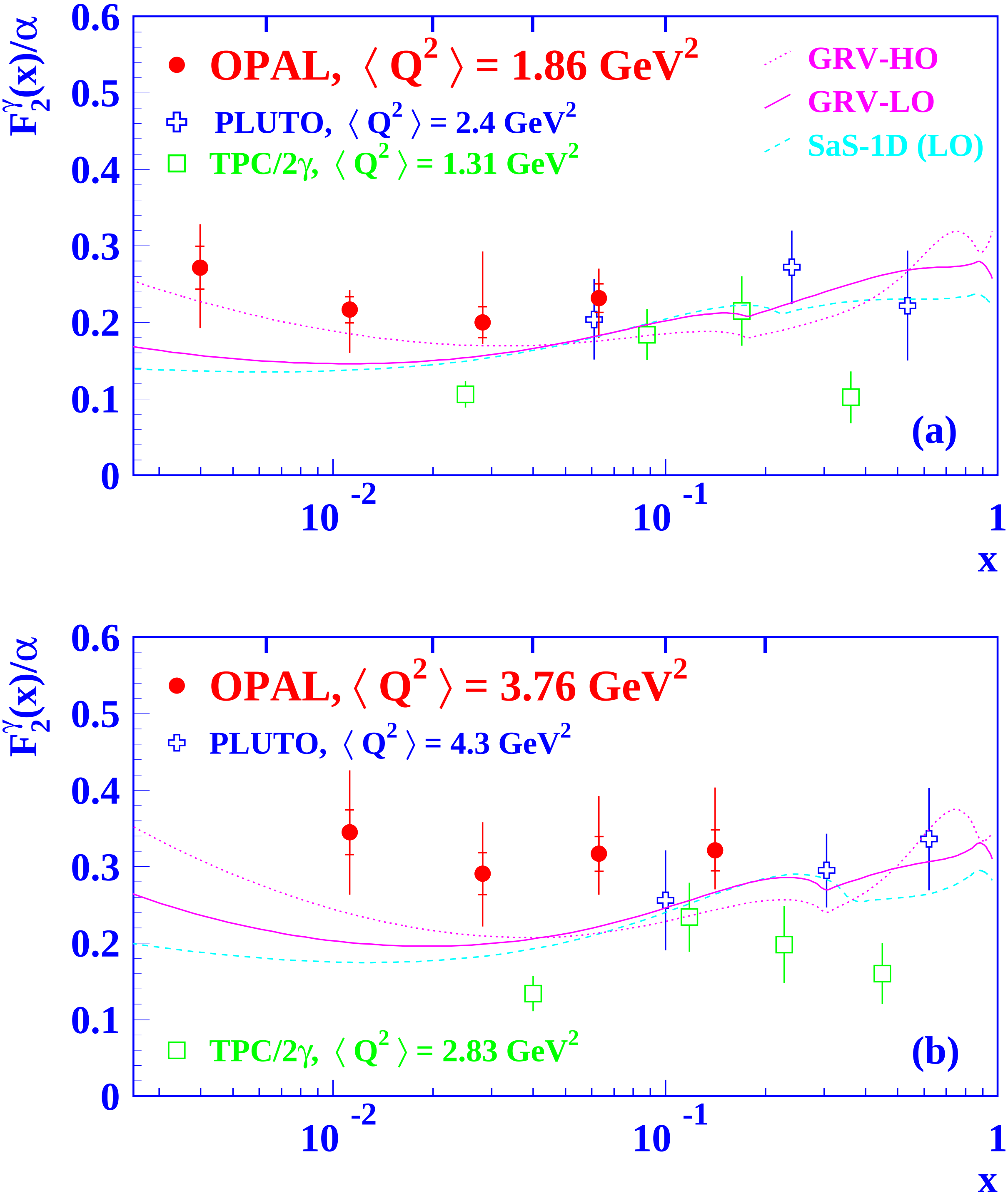
GRV $\equiv$ Glück, Reya, Vogt LO

SaS $\equiv$ Schuler, Sjöstrand SaS1D LO

The LEP data on F_2^γ

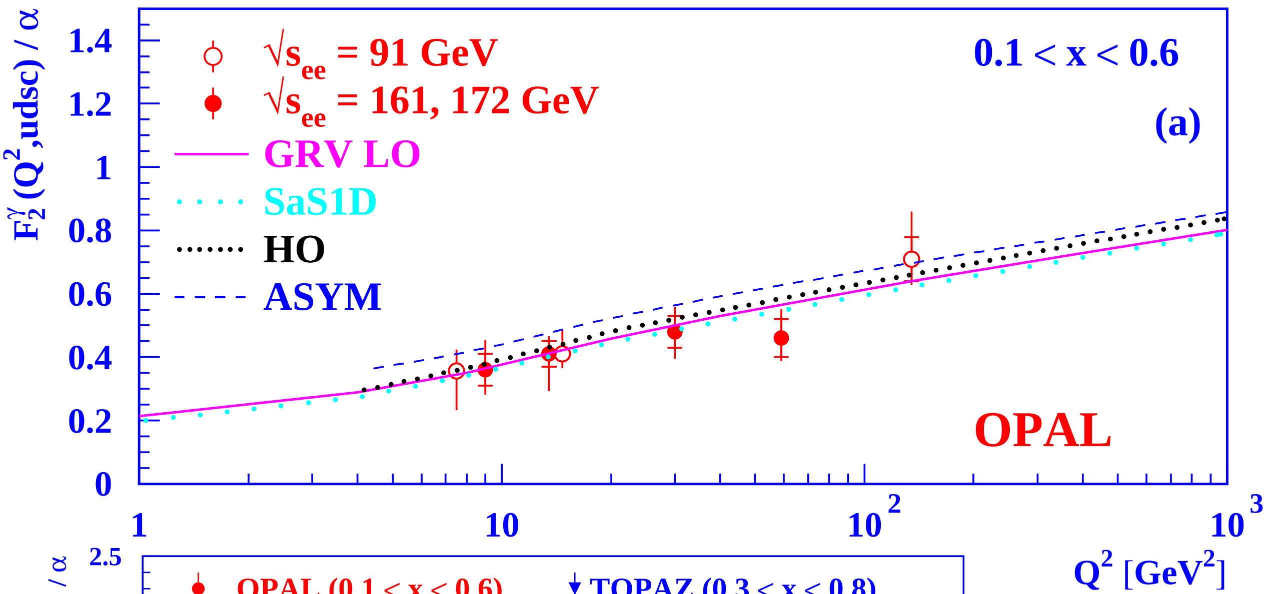


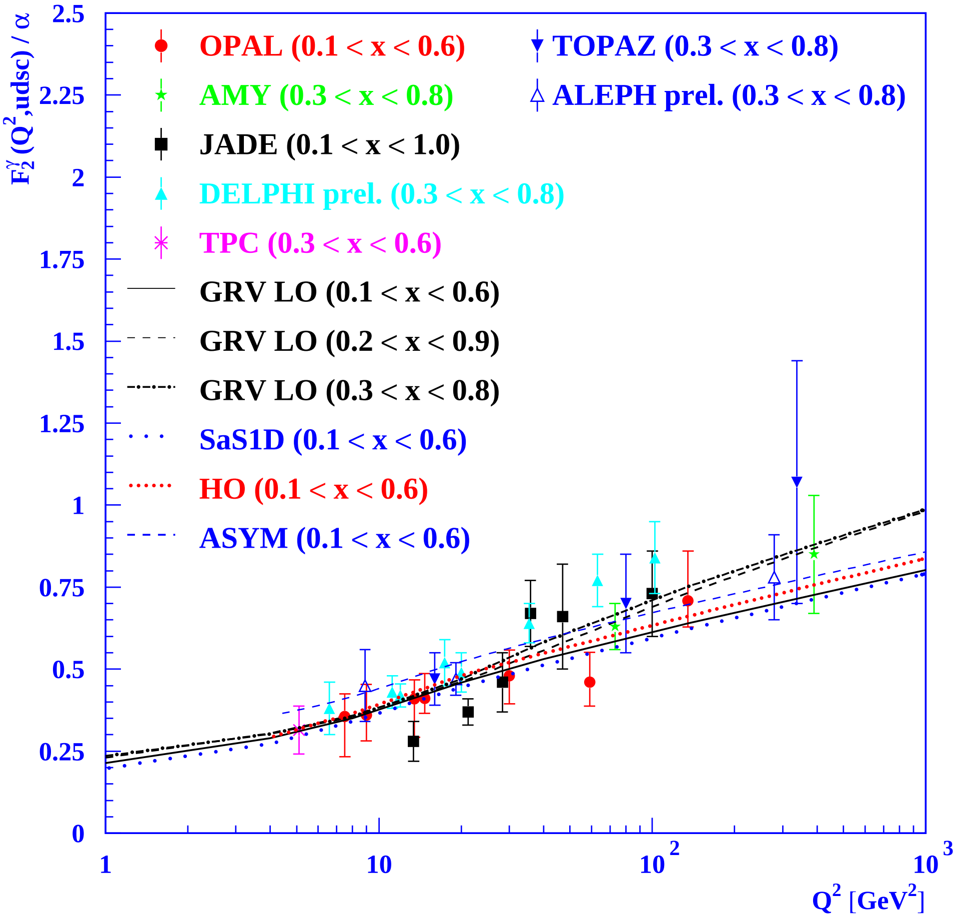
The region of low x and Q^2



The Q^2 evolution of F_2^γ

$$F_2^\gamma = (0.16 \pm 0.05^{+0.17}_{-0.16}) + (0.10 \pm 0.02^{+0.05}_{-0.02})\ \ln(Q^2/\mathrm{GeV}^2)$$





Conclusions

1. QED structure functions are in nice agreement with the data.
2. The determination of the hadronic structure function is very difficult. Monte Carlo models need to be improved to bring the systematic errors down especially for the regions of low- and high-x.
3. The measured structure function F_2^γ at low-x is higher than the theoretical expectations.
4. The evolution of F_2^γ with Q^2 is found to be logarithmic, as predicted by QCD, but precision tests of $\mathrm{d}(F_2^\gamma/\alpha)/\mathrm{d}\ln Q^2$ are not yet in sight.
5. Structure function measurements are a very active field at LEP with good prospects for the LEP2 programme.

slides, see: http://wwwcn1.cern.ch/~nisius