Measurements of the Photon and Electron Structure Functions at LEP

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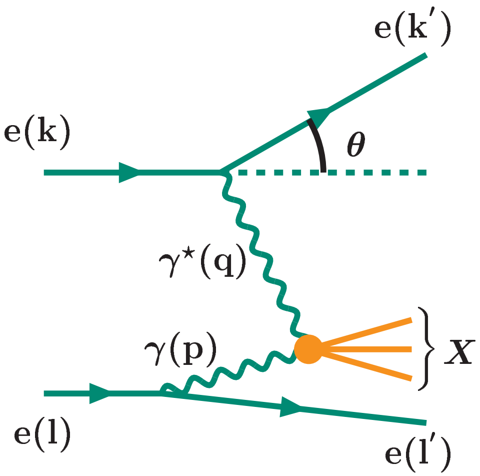
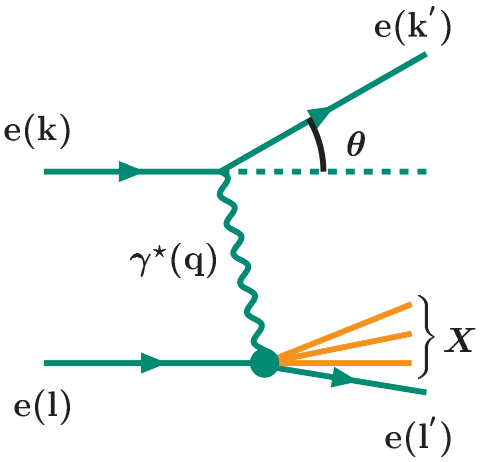
- Kinematics and theoretical framework.
- Progress on measurements of F_2^γ at LEP.
- First measurement of F_2^e.
- Conclusions.

Kinematics of $e^+e^- \to e^+e^-\gamma^\star\gamma \to e^+e^-X$





$$Q^2 \equiv -q^2 = -(k-k')^2 > 0,$$
$$P^2 \equiv -p^2 = -(l-l')^2 \approx 0.$$

$$s = (k+l)^2 \qquad W^2 = (q+p)^2$$
$$y_e = \frac{l\cdot q}{l\cdot k} \qquad x = \frac{Q^2}{2q\cdot p} \qquad z = \frac{Q^2}{2q\cdot l}$$

$$Q^2 = 2EE_b(1-\cos\theta)$$
$$y_e = 1 - \frac{E}{E_b}\cos^2(\theta/2)$$
$$z = \frac{Q^2}{y_e s} \qquad x = \frac{Q^2}{Q^2+W^2+P^2}$$

The cross section for the process

$$e^+e^- \to e^+e^-\gamma^\star\gamma \to e^+e^-X$$

Cross section in terms of photon structure functions:

$$\frac{\mathrm{d}^4\sigma_{ee}}{\mathrm{d}x\mathrm{d}Q^2\mathrm{d}z\mathrm{d}P^2} = \frac{2\pi\alpha^2}{x^2Q^4}\Big[\left(1+(1-y_\mathrm{e})^2\right)F_2^\gamma(x,Q^2,P^2)- - y_\mathrm{e}^2F_L^\gamma(x,Q^2,P^2)\Big]\,\hat{f}_\gamma^e(z/x,P^2)$$

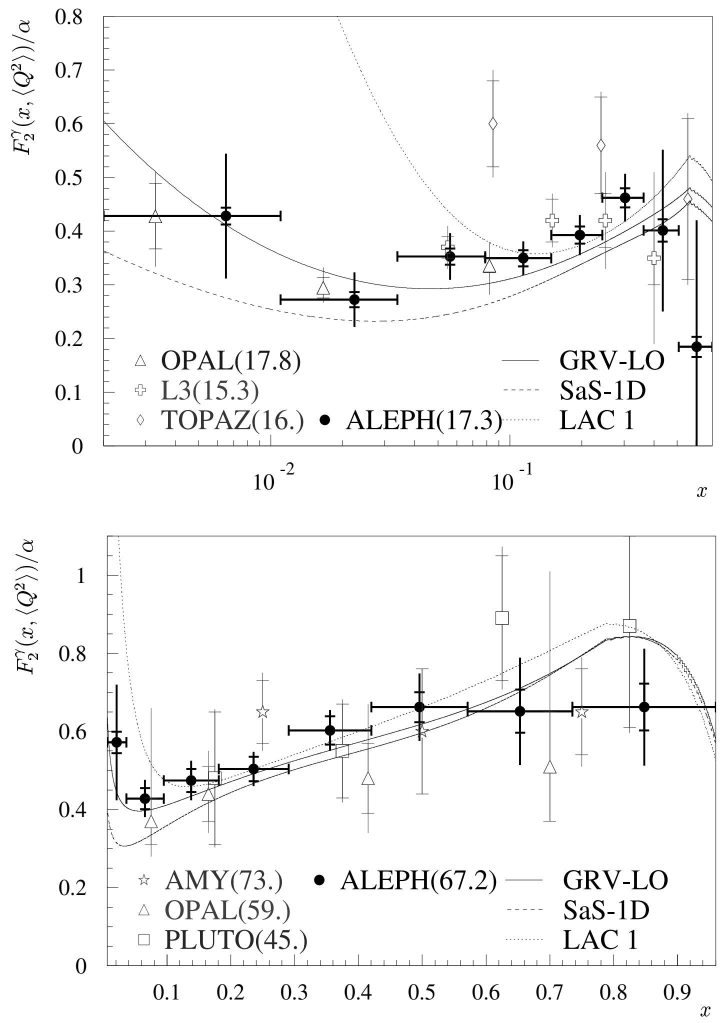
Cross section in terms of electron structure functions:

$$\frac{\mathrm{d}^2\sigma_{ee}}{\mathrm{d}z\mathrm{d}Q^2} = \frac{2\pi\alpha^2}{zQ^4}\Big[\left(1+(1-y_\mathrm{e})^2\right)F_2^e(z,Q^2) - y_\mathrm{e}^2F_L^e(z,Q^2)\Big]$$

Relation between photon and electron structure functions:

$$F_2^e(z,Q^2) \equiv \int_z^1 dx \int_{P^2_{\mathrm{min}}(z/x)}^{P^2_{\mathrm{max}}} dP^2\,\frac{z}{x^2}F_2^\gamma(x,Q^2,P^2)\hat{f}_\gamma^e(z/x,P^2)$$

New measurement of F_2^γ from ALEPH



Analysis is based on data collected at $\sqrt{s_{ee}} = 189 - 207$ GeV with integrated luminosity of 548.4 pb^{-1}.

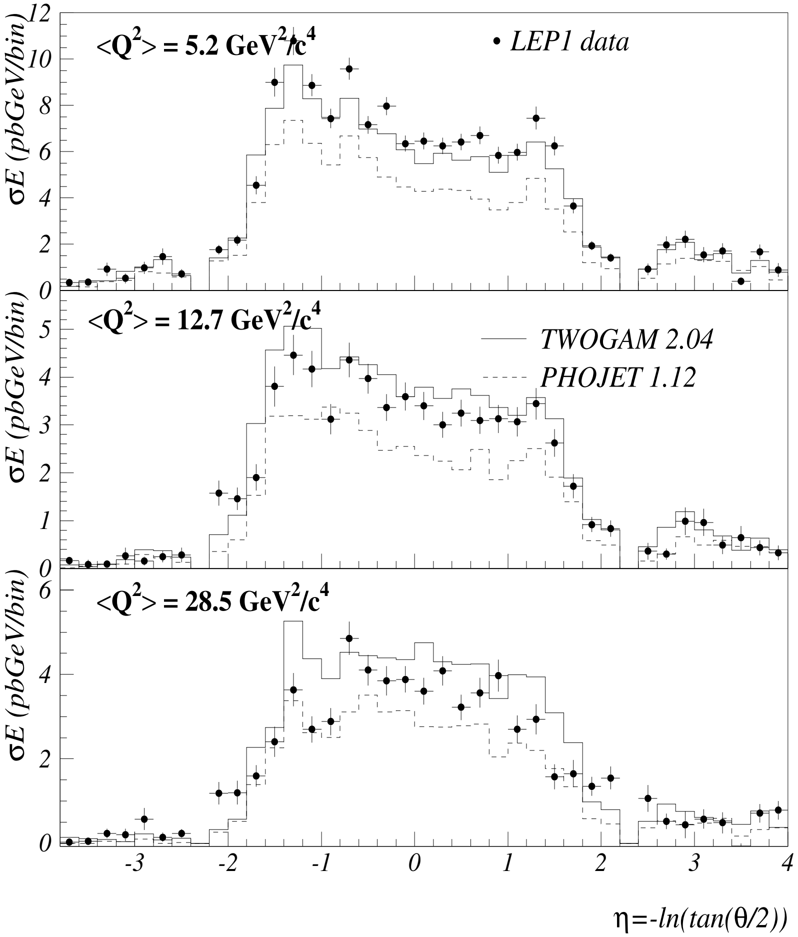
Data unfolded in two ranges of Q^2 with luminosity weighted average values of $\langle Q^2\rangle = 17.3$ GeV^2 and $\langle Q^2\rangle = 67.2$ GeV^2.

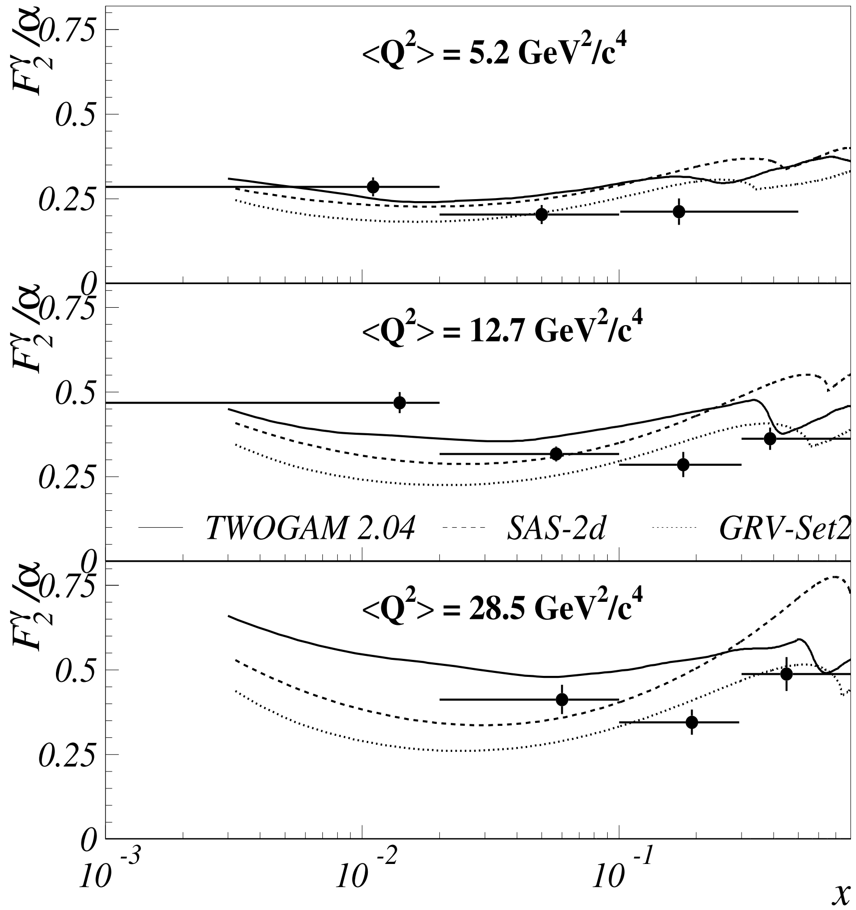
Measurement of F_2^γ for $x > 0.1$:

$$F_2^\gamma(0.1 < x < 0.5, \langle Q^2\rangle = 17.3\,\text{GeV}^2)/\alpha = \\ = 0.41 \pm 0.01\,(stat) \pm 0.08\,(sys)$$

$$F_2^\gamma(0.1 < x < 0.7, \langle Q^2\rangle = 67.2\,\text{GeV}^2)/\alpha = \\ = 0.52 \pm 0.01\,(stat) \pm 0.06\,(sys)$$

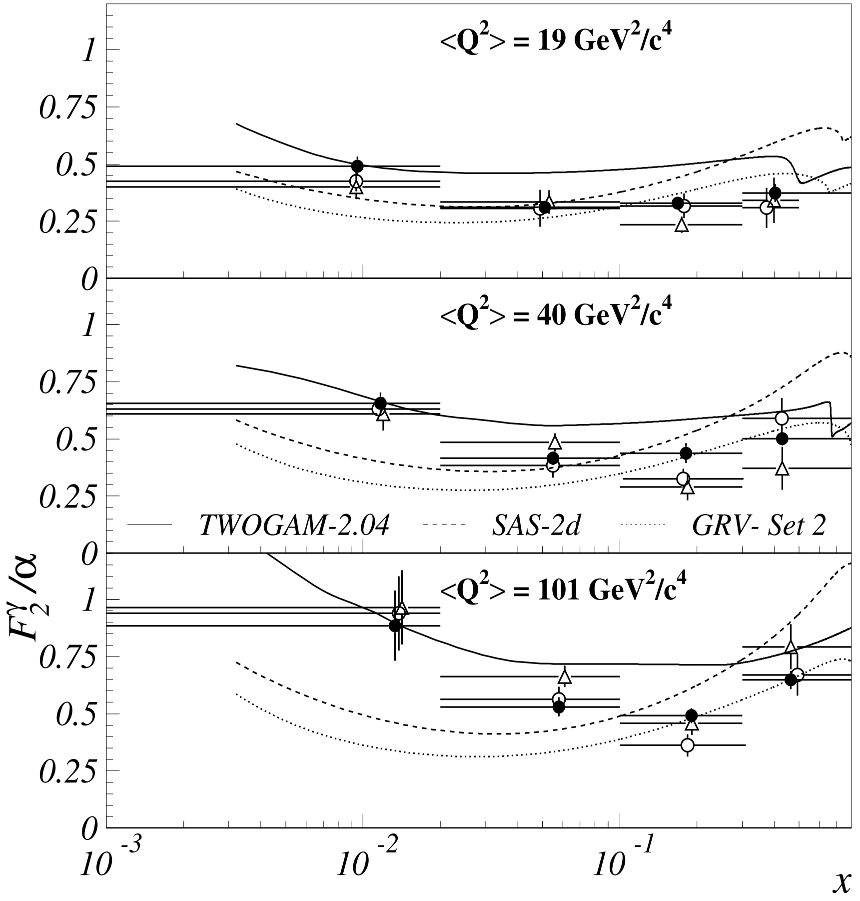
New measurement of F_2^γ from DELPHI – LEP1

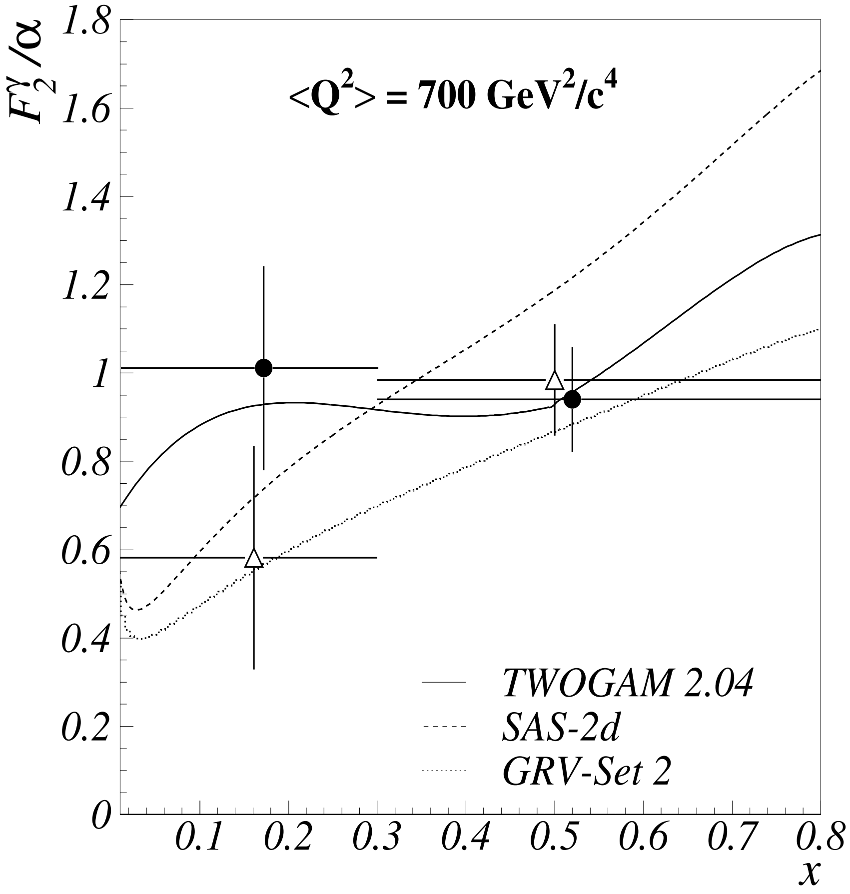




Luminosity 78 pb^{-1} (LEP1). Better description by TWOGAM than by PHOJET. Data fitted with different cross section components: QPM, QCD and VMD.

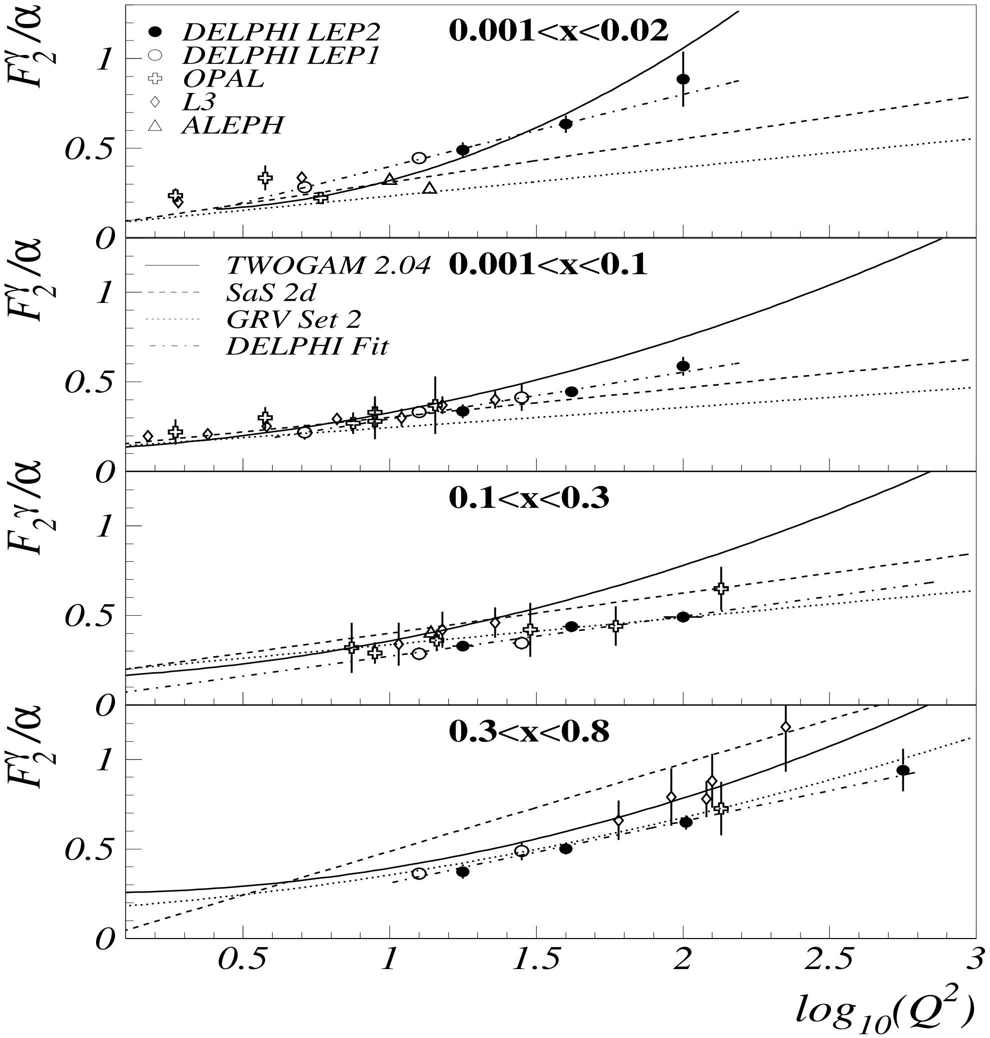
New measurement of F_2^γ from DELPHI – LEP2





Luminosity 548 pb^{-1} (LEP1). Different values of F_2^γ obtained using different hadronic models.

Evolution of F_2^γ with Q^2– DELPHI

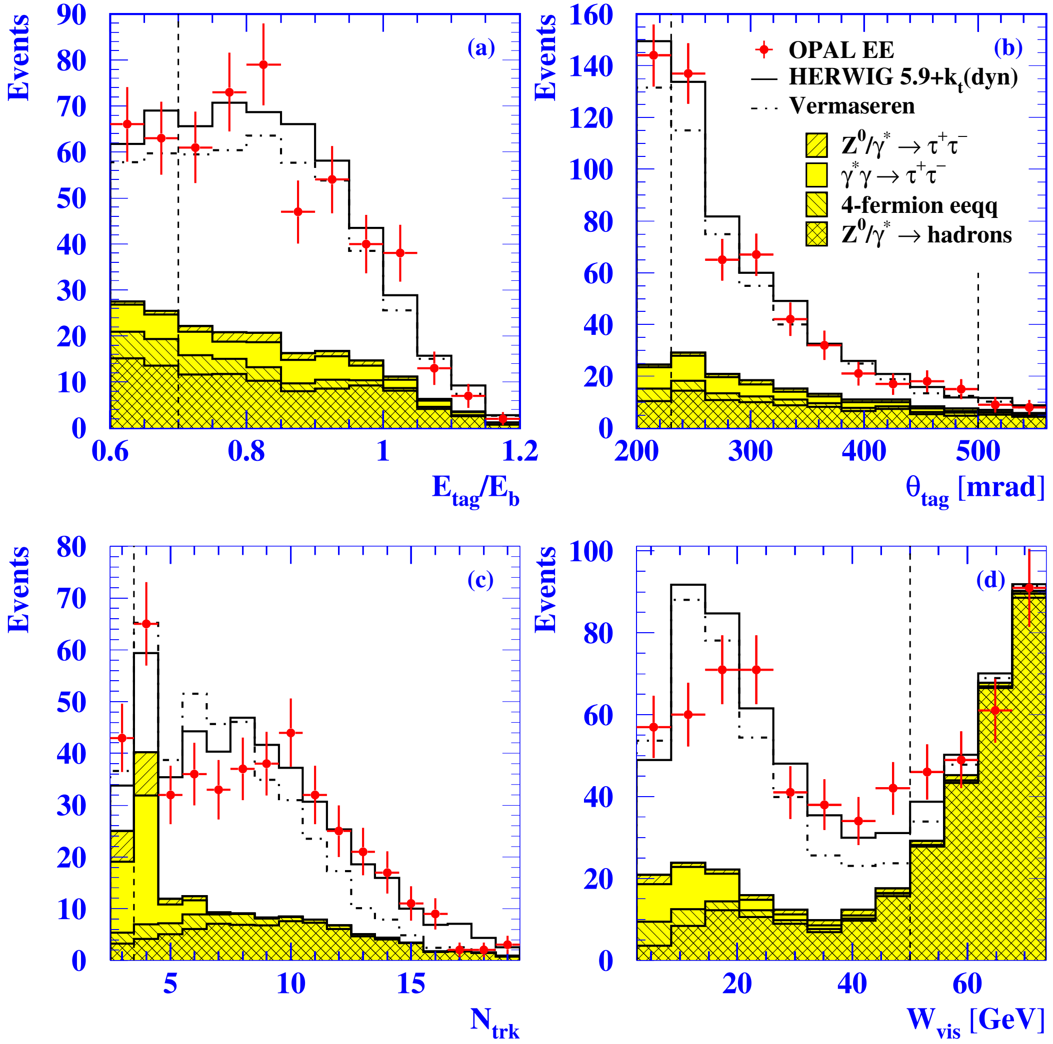


F_2^γ averaged over different x intervals as a function of Q^2.

DELPHI points have been extracted using TWOGAM model.

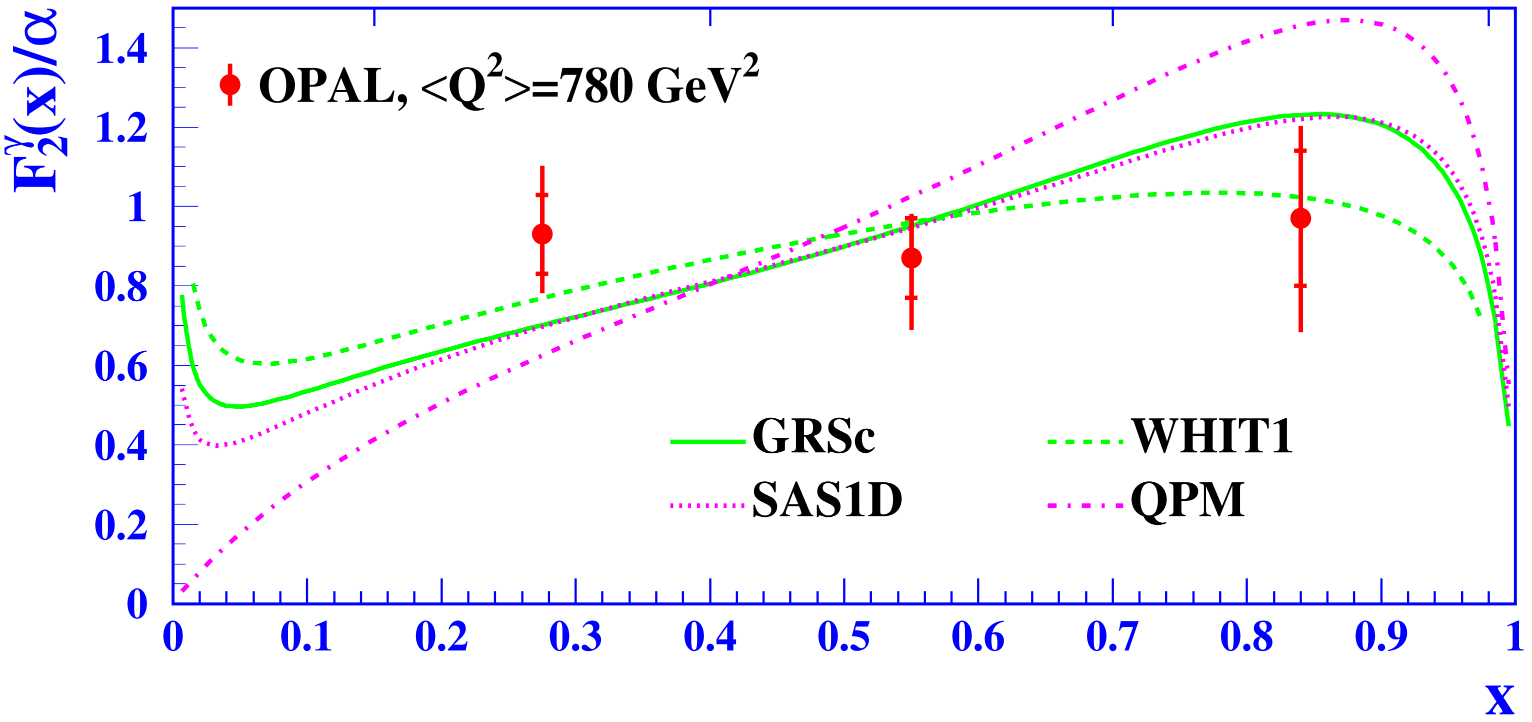
Systematic errors due to different hadronisation models are not shown.

Measurement of F_2^γ at high Q^2 – OPAL



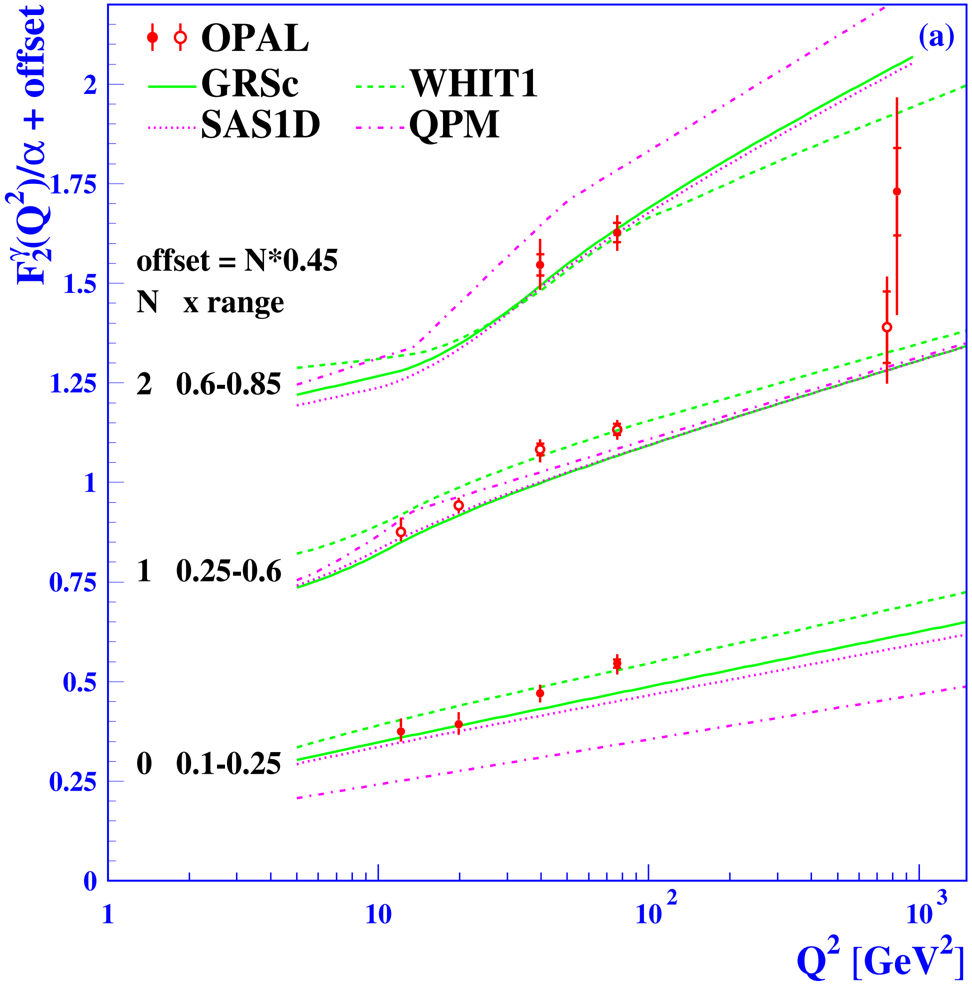
Data distributions of the energy and polar angle of the scattered electron are well described by the MC predictions.
For the variables related to the hadronic final state there are apparent differences in shape.

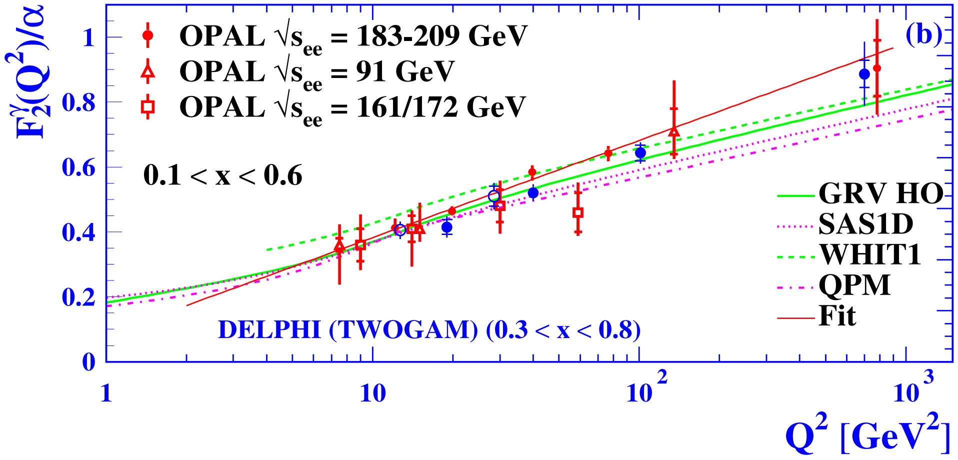
F_2^γ/α as a function of x at very high Q^2– OPAL



Data are compatible with the leading order parametrisations of F_2^γ shown in the plot within about 20%. The QPM curve is disfavoured by the data.

Evolution of F_2^{γ}/α as a function of Q^2

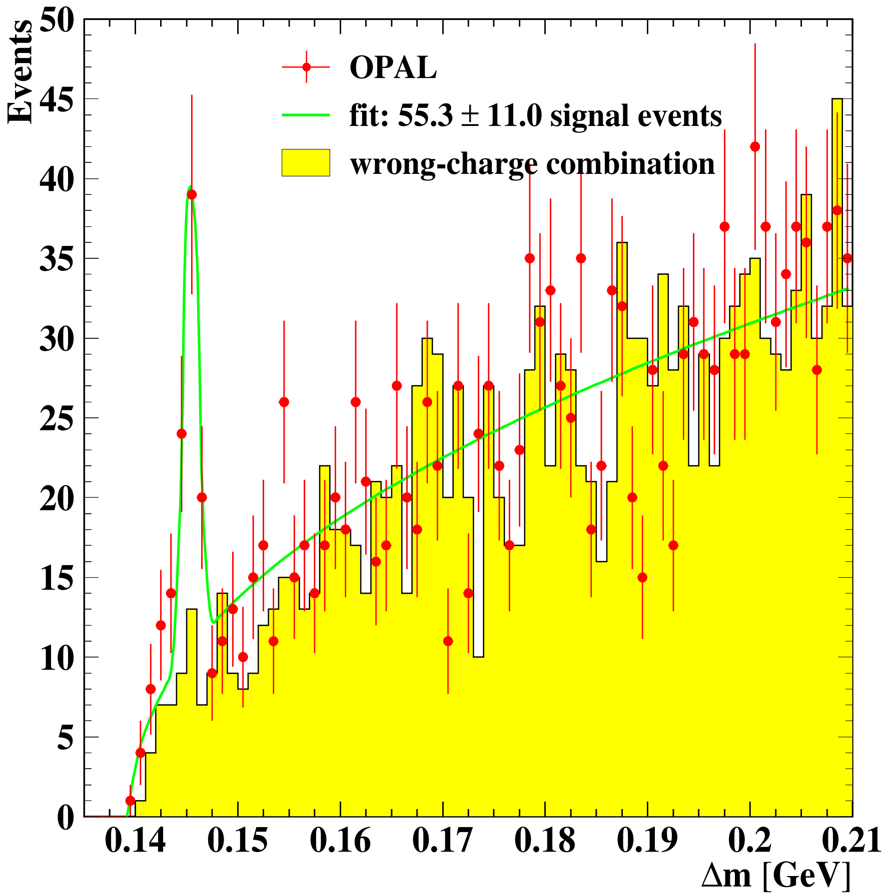


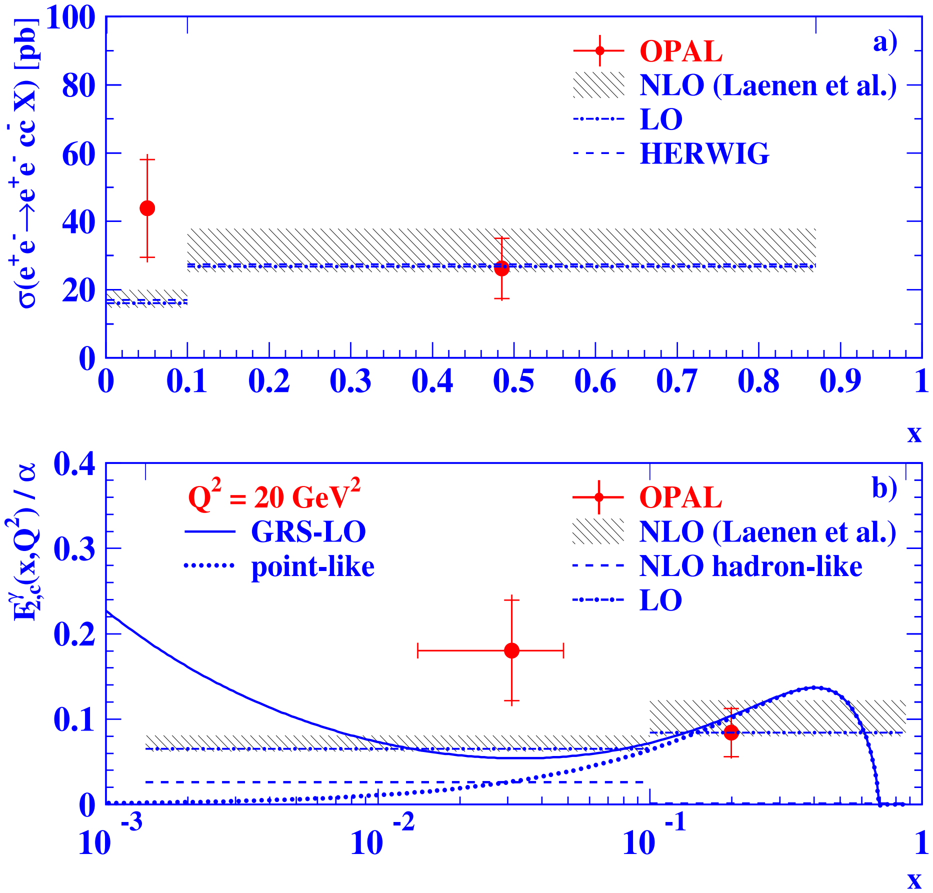


The data show positive scaling violations in all x ranges. The QCD inspired parametrisations qualitatively follow the data whereas the QPM model gives a bad description of the data, aspecially at low x.

$F_2^{\gamma}(Q^2)/\alpha = (0.08 \pm 0.02^{+0.05}_{-0.03}) + (0.13 \pm 0.01^{+0.01}_{-0.01}) \ln Q^2$

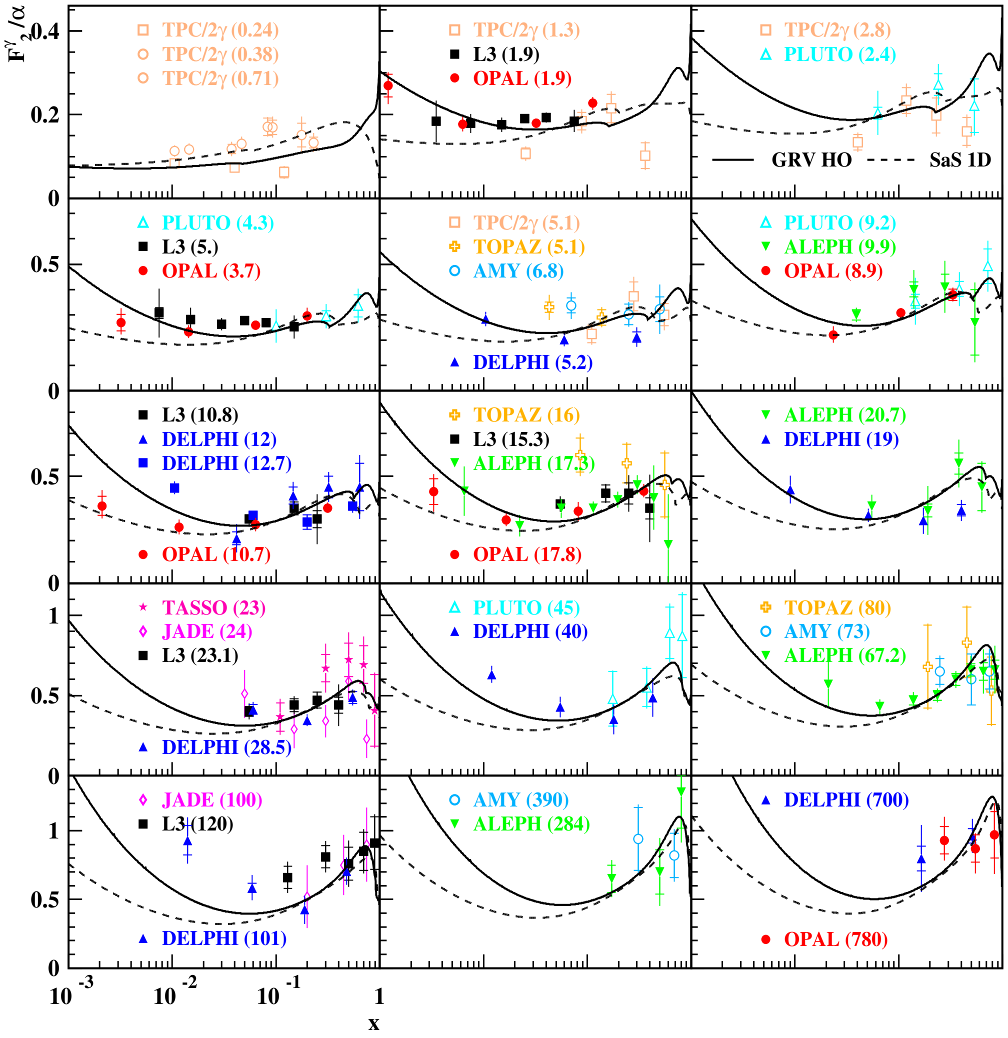
Measurement of charm structure function $F_{2,c}^{\gamma}$





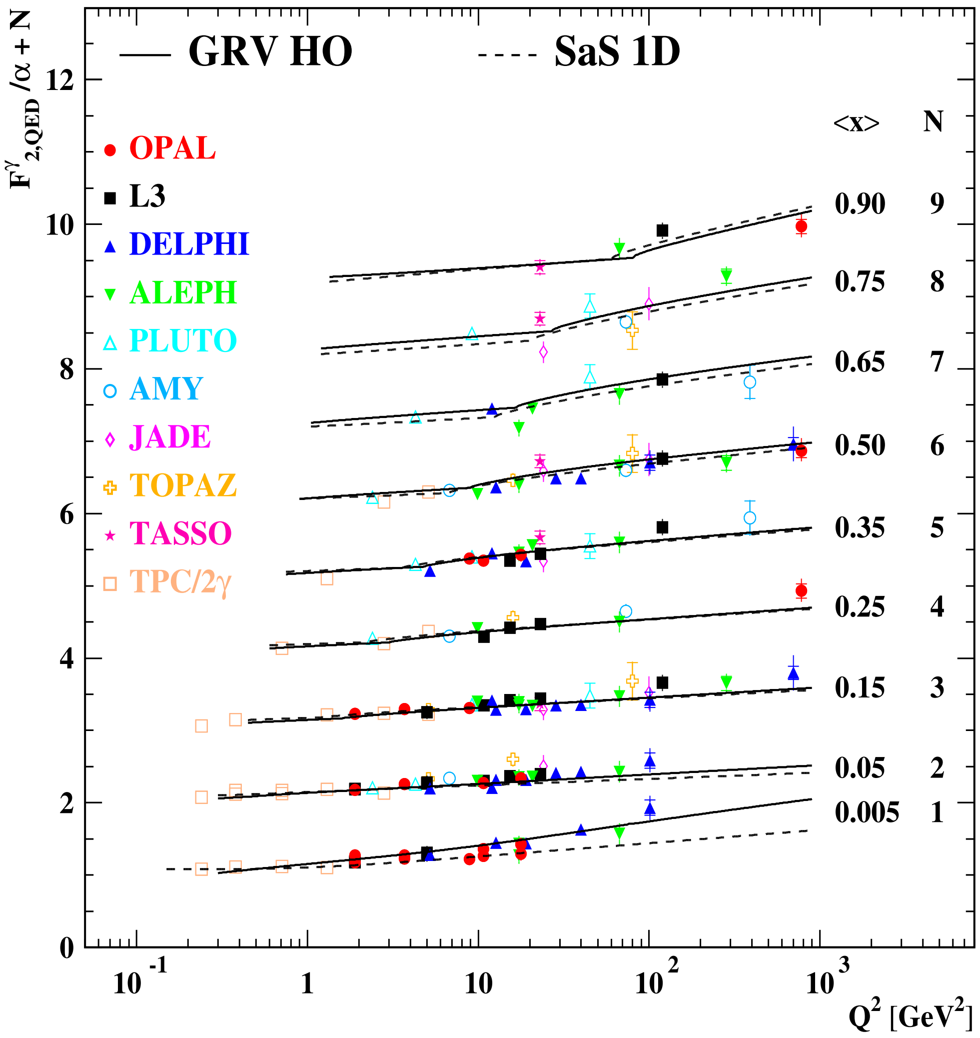
Charm production tagged by $D^{\star}$s. A clear signal in $\Delta M = M(D^{\star}) - M(D^{0})$ spectrum.
High x: well described by pQCD. Low x: Higher than predicted, but large errors.

World data on of F_2^γ



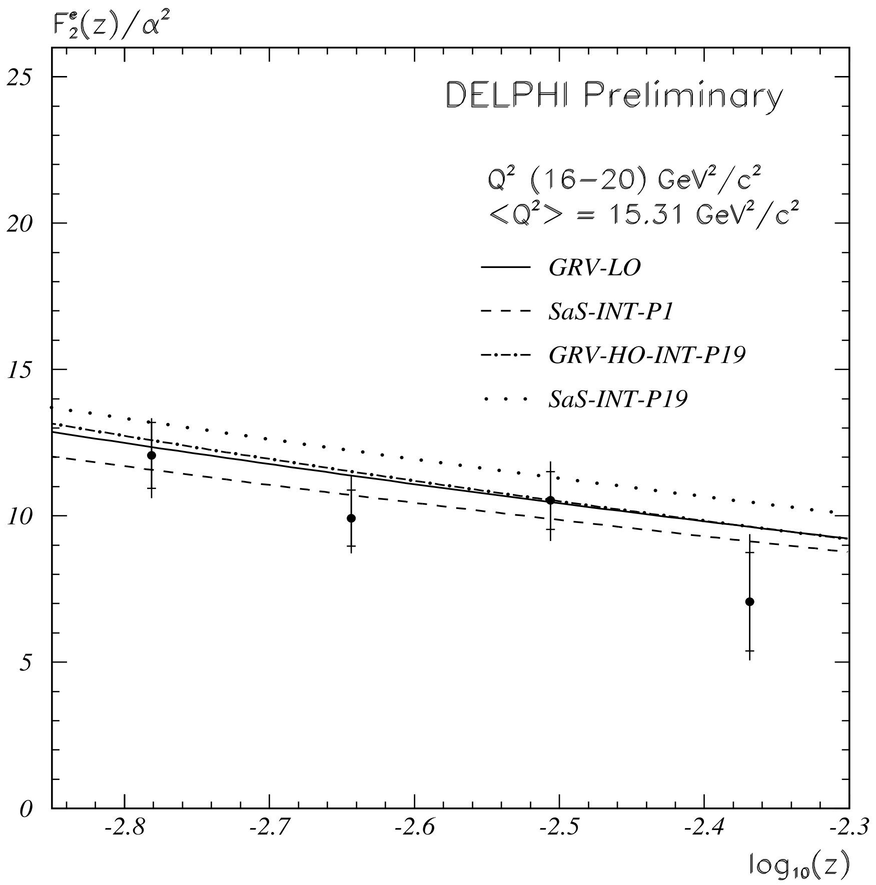
Kinematical coverage: $10^{-3} < x < 0.9$ and $0.24 < \langle Q^2 \rangle < 780$ GeV^2.

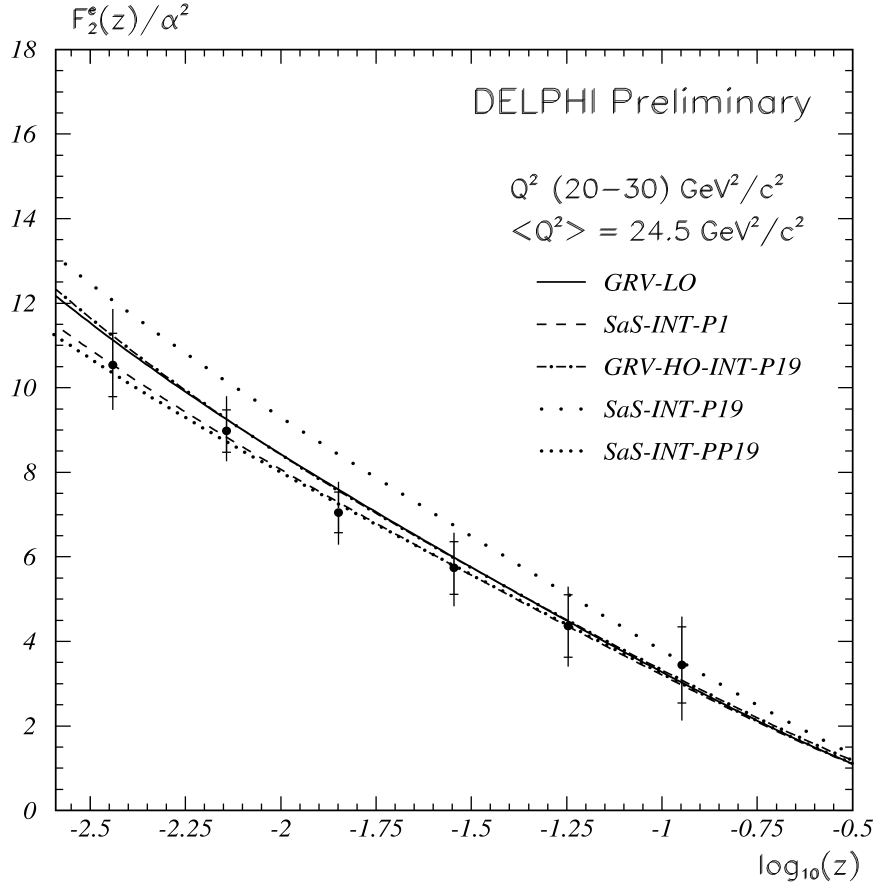
Evolution of F_2^γ as a function of Q^2



The predictions clearly follows the increasing slope for increasing x as observed in the data.

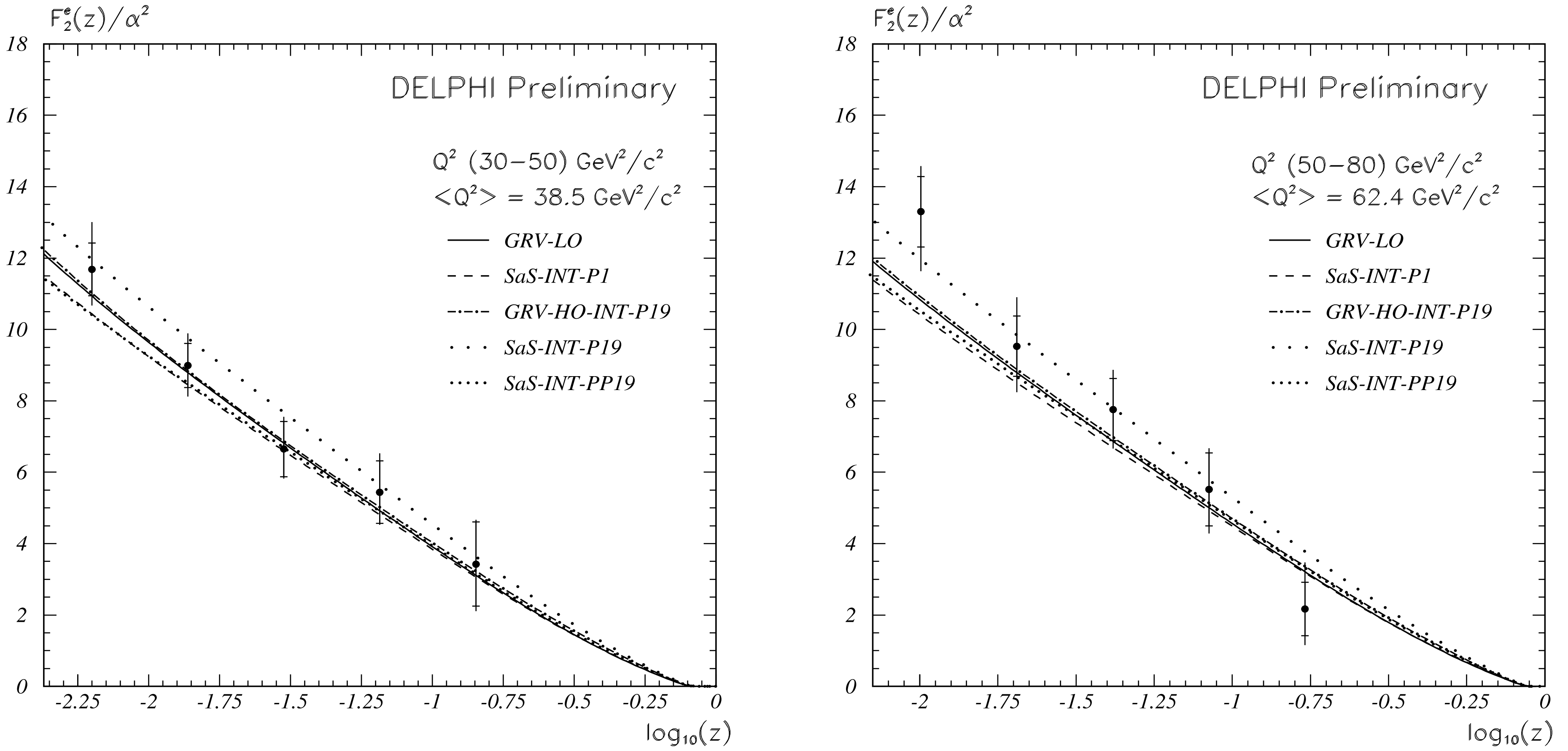
First measurement of F_2^e – DELPHI





$$F_2^e(z,Q^2) \equiv \int_z^1 dx \int_{P^2_{\mathrm{min}}(z/x)}^{P^2_{\mathrm{max}}} dP^2 \, \frac{z}{x^2} F_2^\gamma(x,Q^2,P^2) \hat{f}_\gamma^e(z/x,P^2)$$

First measurement of F_2^e– DELPHI



Measurements consistent with F_2^γ, but the photon flux obscures sensitivity to F_2^γ.
No correction due virtuality of the target photon, but large radiative corrections.

Conclusions

- The photon structure function F_2^γ has been investigated at LEP in a large kinematical range: $10^{-3} < x < 0.9$ and $1.9 < \langle Q^2 \rangle < 780$ GeV^2.
- The measured structure function F_2^γ is in qualitative agreement with LO and NLO parametrizations. The logarithmic raise of F_2^γ as a function of Q^2 has been verified in a broad range of x and Q^2. The raise of F_2^γ at low x is still controversial.
- The first measurement of $F_{2,c}^\gamma$ has been performed. The data are described by the NLO prediction.
- The hadronic structure function of the electron has been measured for the first time and serves as a valuable cross check of the photon structure function, but does not seem to have a better discriminative power.
- New measurements with improved systematics and higher statistics are still expected from LEP experiments:

  ALEPH – Possible measurement at higher Q^2,
  L3 – Analysis with full statistics,
  OPAL – Measurements of F_2^γ and F_2^e at low x and z.