Hadronic structure of the photon at LEP

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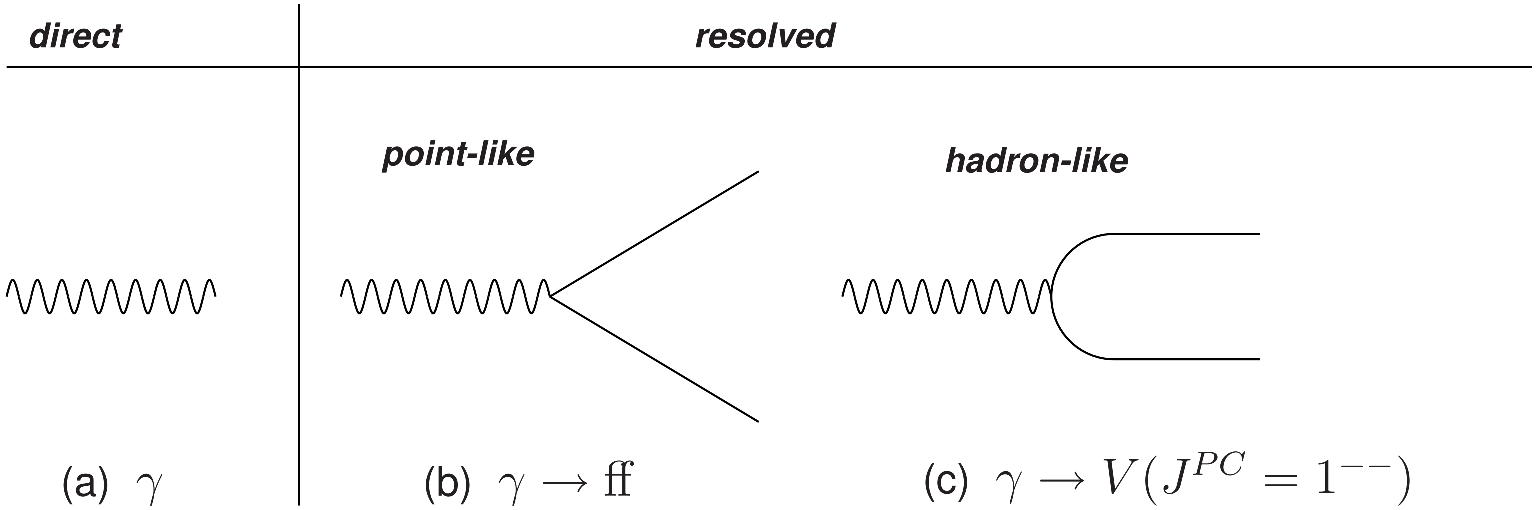
- Introduction
- Improvements of experimental methods
- Structure function at low x
- Structure function at high Q^2
- Charm content of the photon

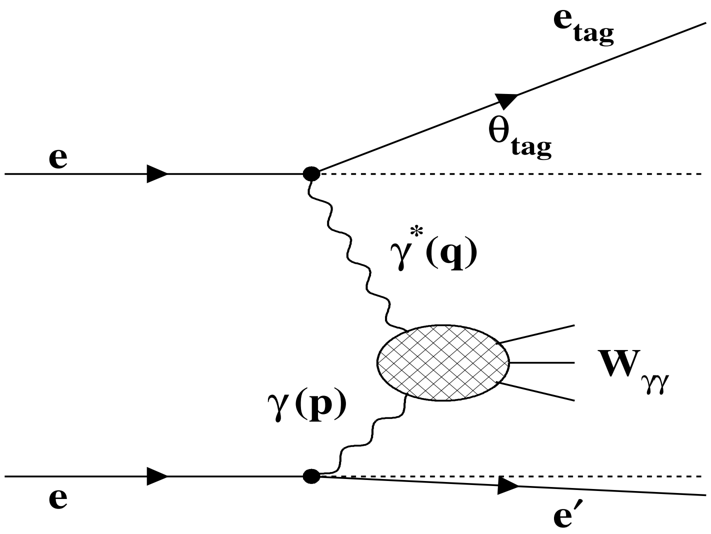
Why photon structure?

Virtual fluctuations add structure to the bare photon



direct	no structure
point-like	perturbative QCD
hadron-like	non-perturbative VMD

Deep inelastic eγ scattering at LEP — single-tag $\gamma\gamma$ events



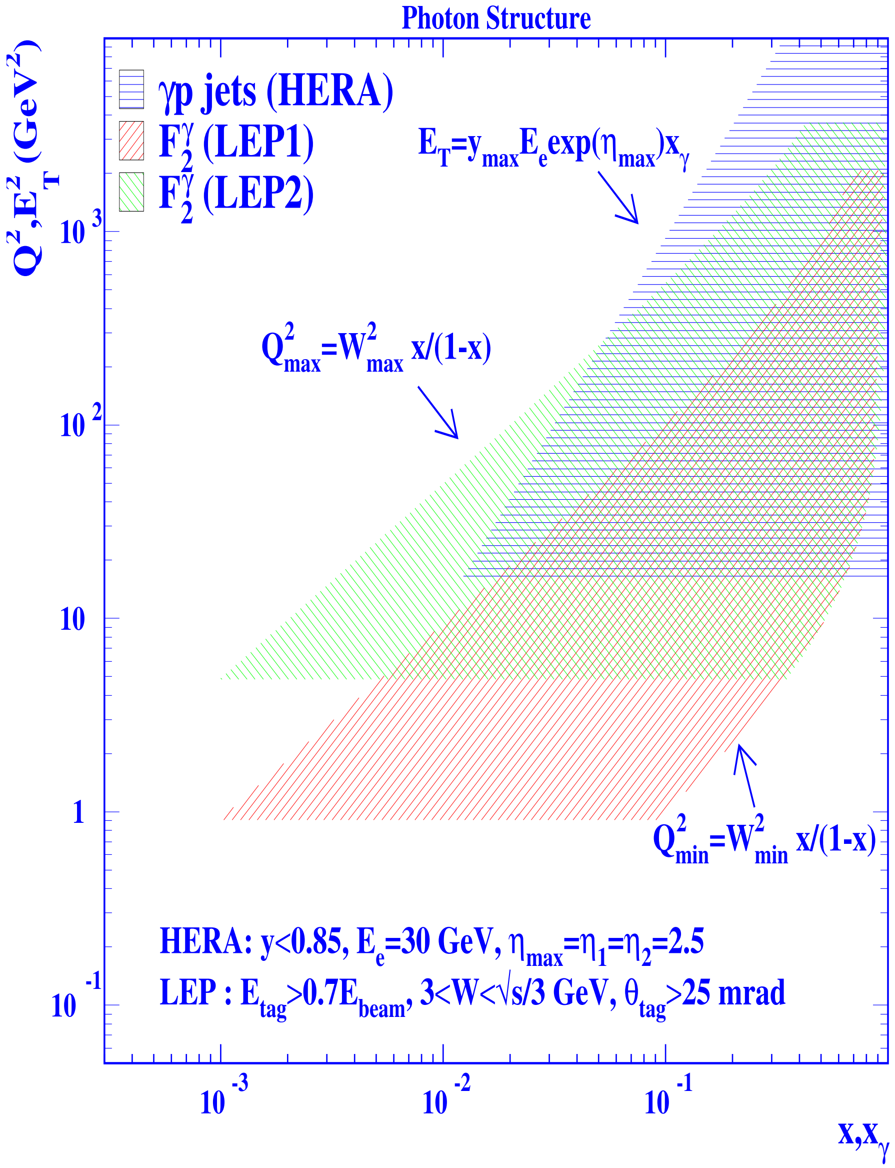
$$\frac{d^2\sigma_{e\gamma\to eX}}{dx\,dQ^2} = \frac{2\pi\alpha^2}{x\,Q^4}\left[\left(1+(1-y)^2\right)F_2^\gamma(x,Q^2) - y^2 F_L^\gamma(x,Q^2)\right]$$

$$Q^2 = -q^2 = 2EE_{\rm tag}(1-\cos\theta_{\rm tag})$$

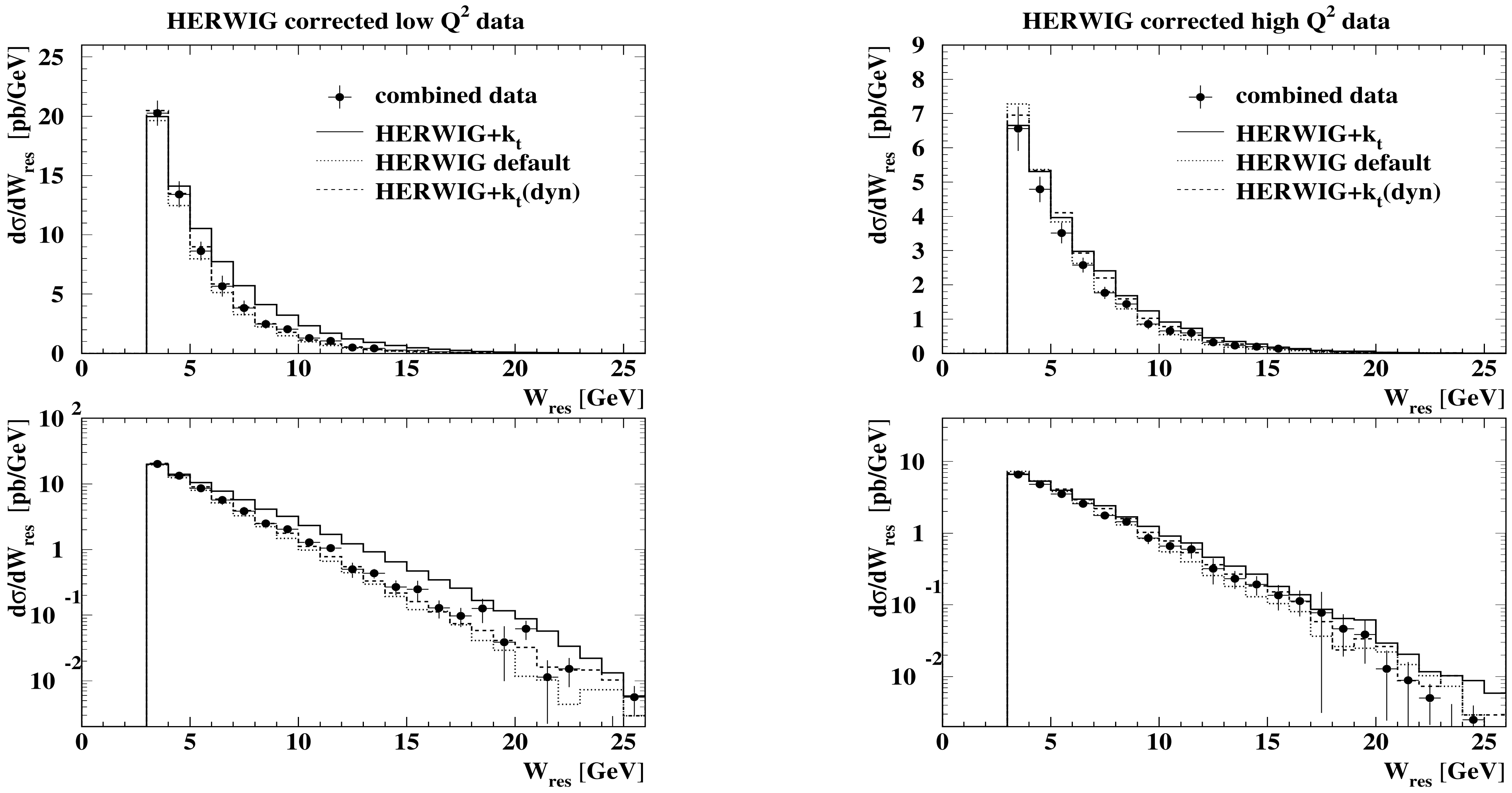
$$P^2 = -p^2 \approx 0$$

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

$$y = 1 - \frac{E_{\rm tag}}{E}\cos^2\theta_{\rm tag} \ll 1$$



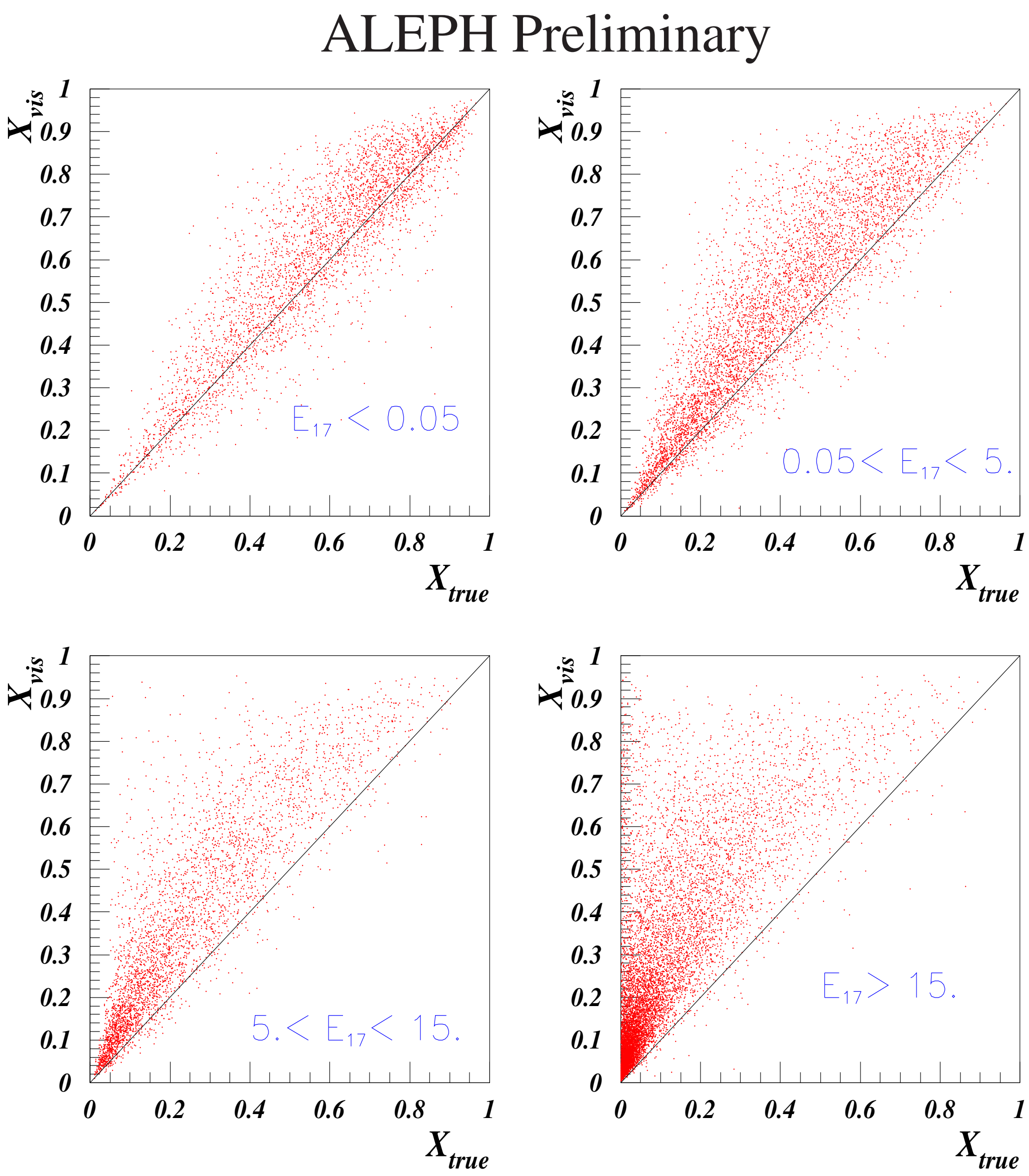
Improved MC description of the hadronic final state



Combined ALEPH, L3 and OPAL data compared to generators (CERN preprint)

HERWIG+k_{t}(dyn) — tuned to HERA data — gives significant improvement

Improved unfolding

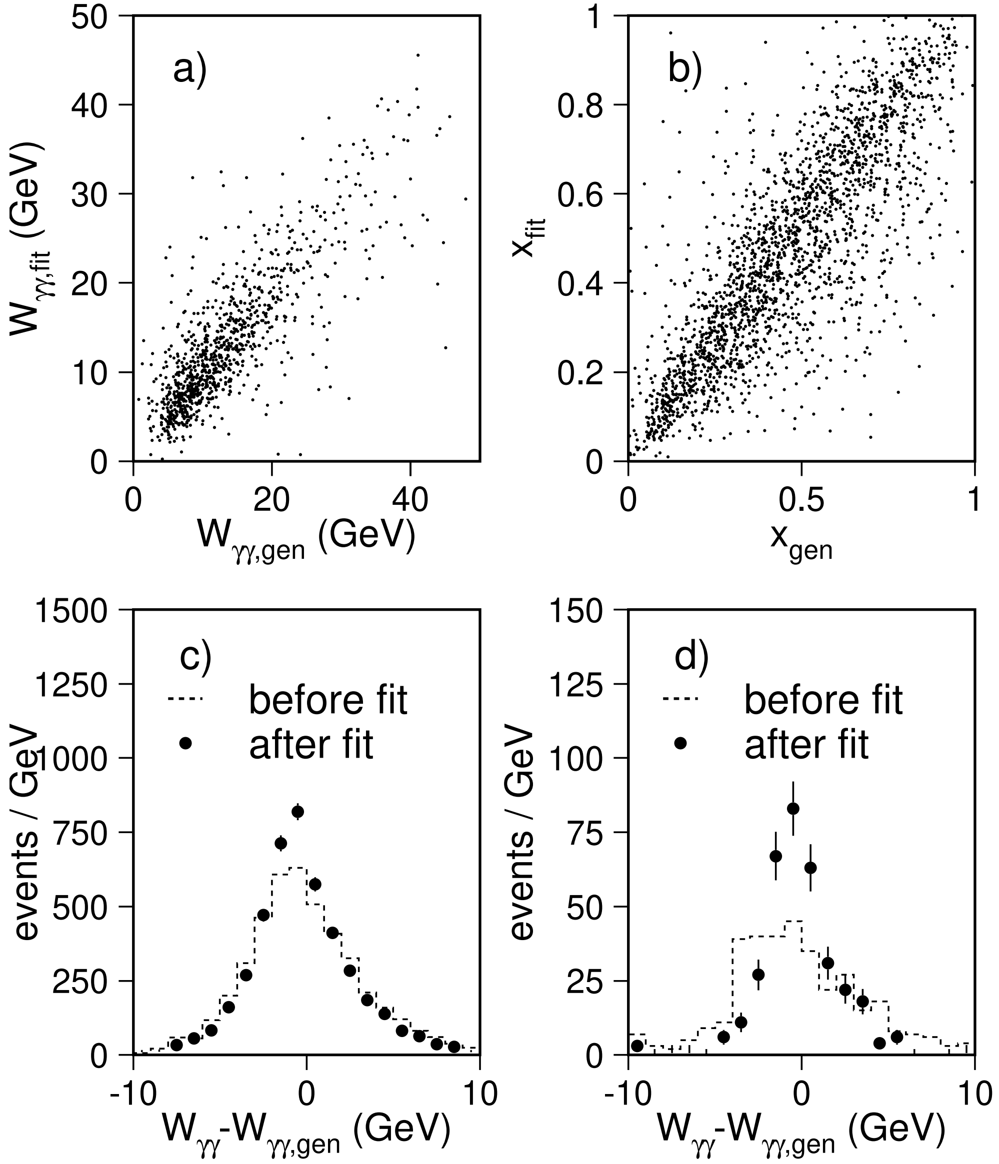


Unfolding needed because part of the hadronic final state is not contained in the detector

- Different methods for regularised unfolding
  - maximum entropy method
  - singular value decomposition
- Two-dimensional unfolding
  - ALEPH: E_{17}
  - OPAL: $E_{\mathrm{T}}^{\mathrm{out}}/E_{\mathrm{tot}}$
- Improved treatment of the forward hadronic energy

Kinematic constraints on W

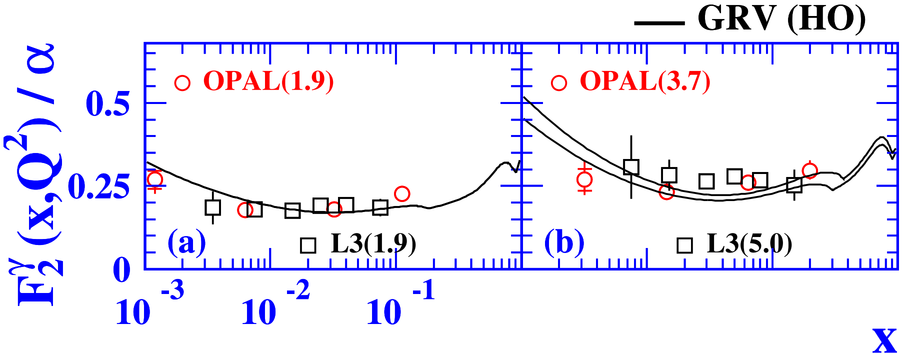
L3

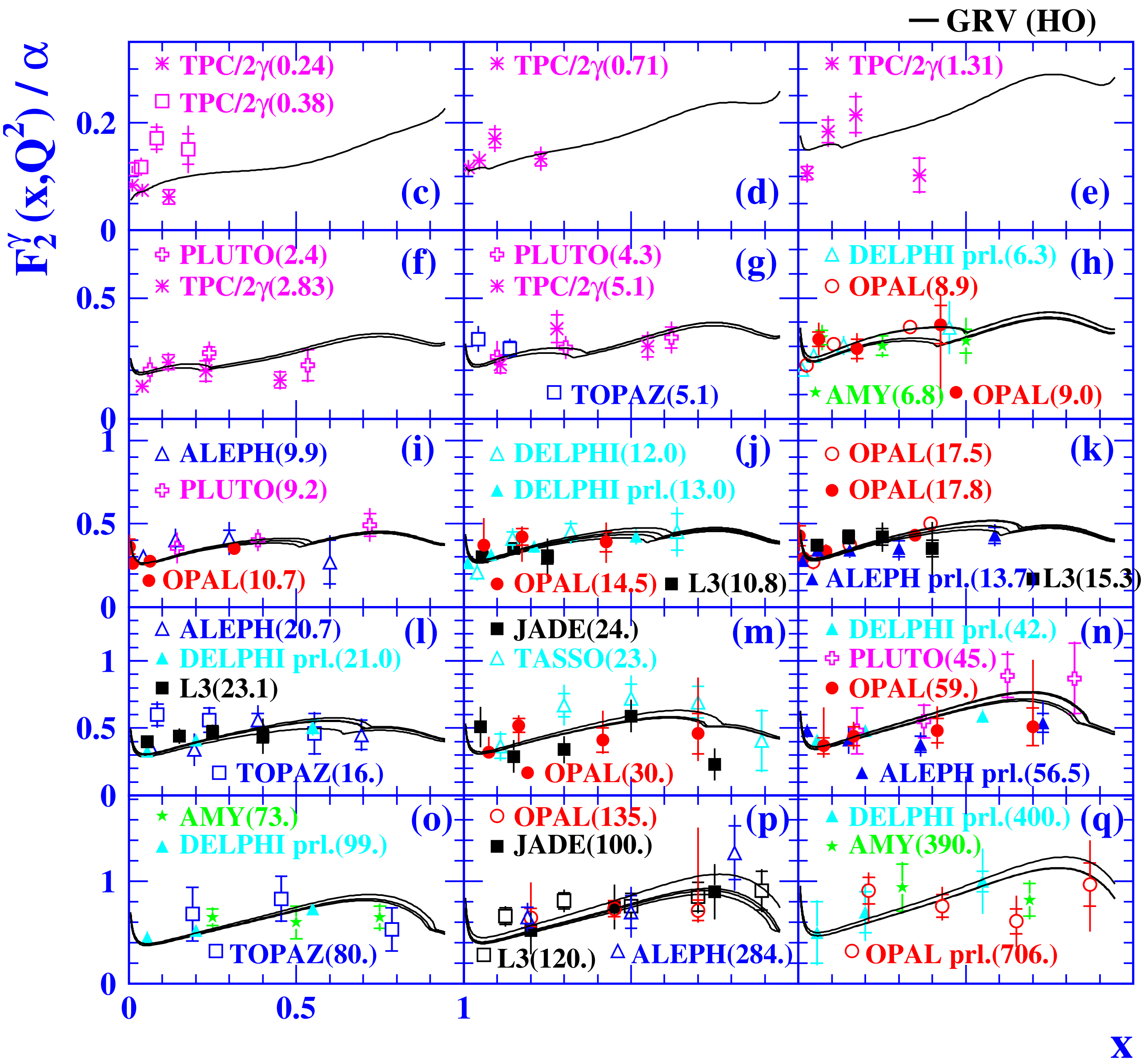


Kinematic information from the scattered electrons can be used to constrain the hadronic variables using energy and momentum conservation.

Current data on photon structure

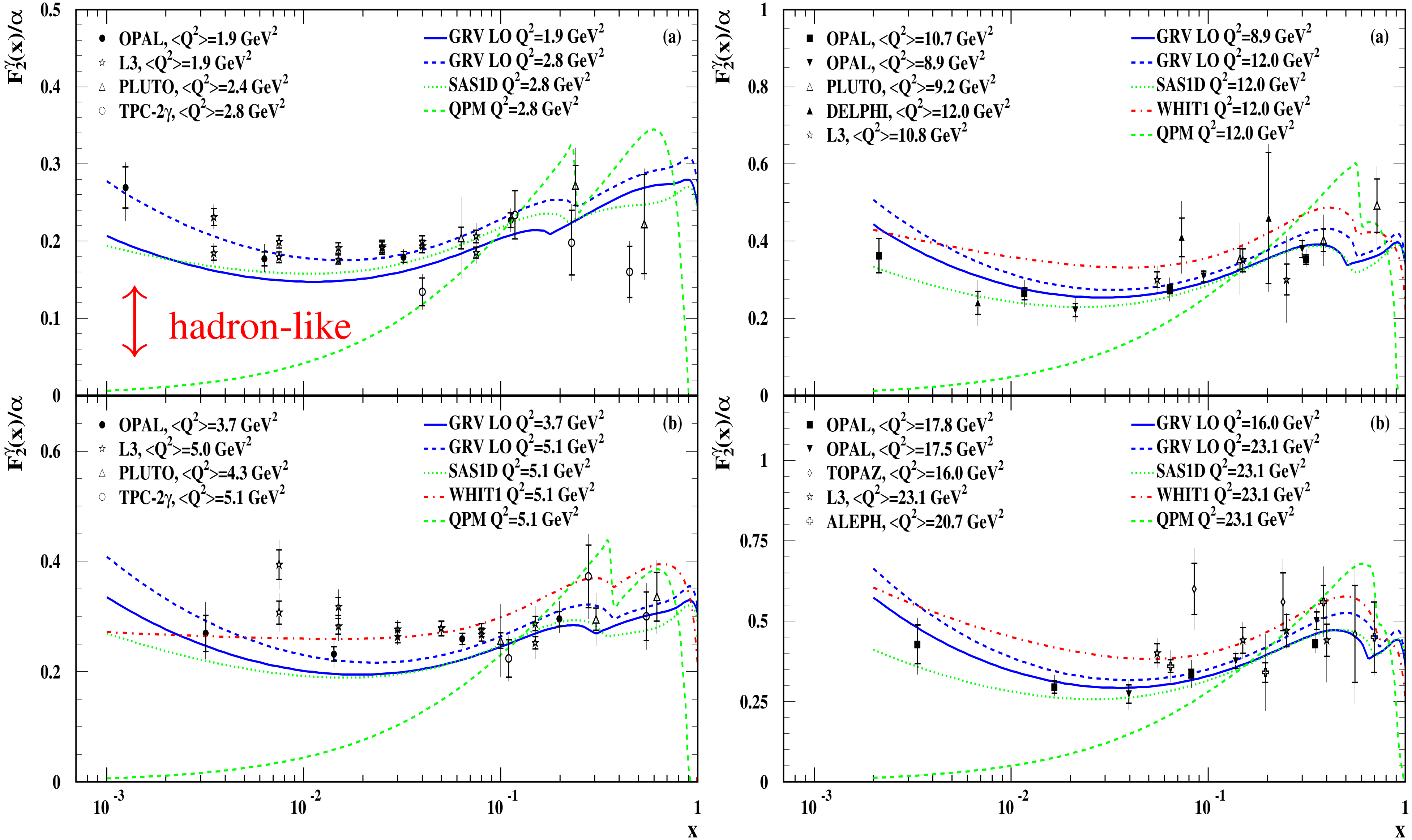
Lowest $x = 0.0012$



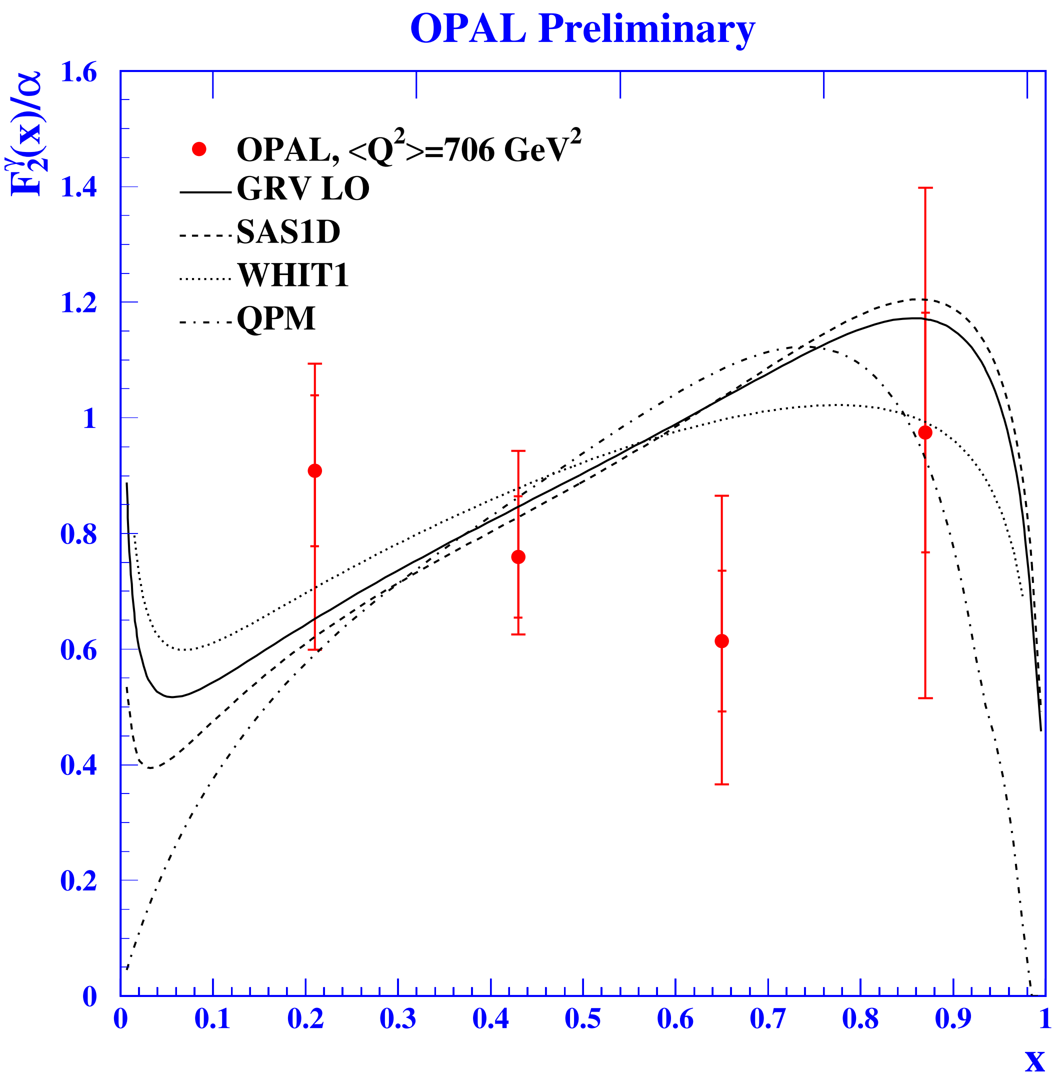


Largest $\langle Q^2 \rangle = 706\,\mathrm{GeV}^2$

Lowest x that can be measured at LEP1



Highest Q^2 measured so far

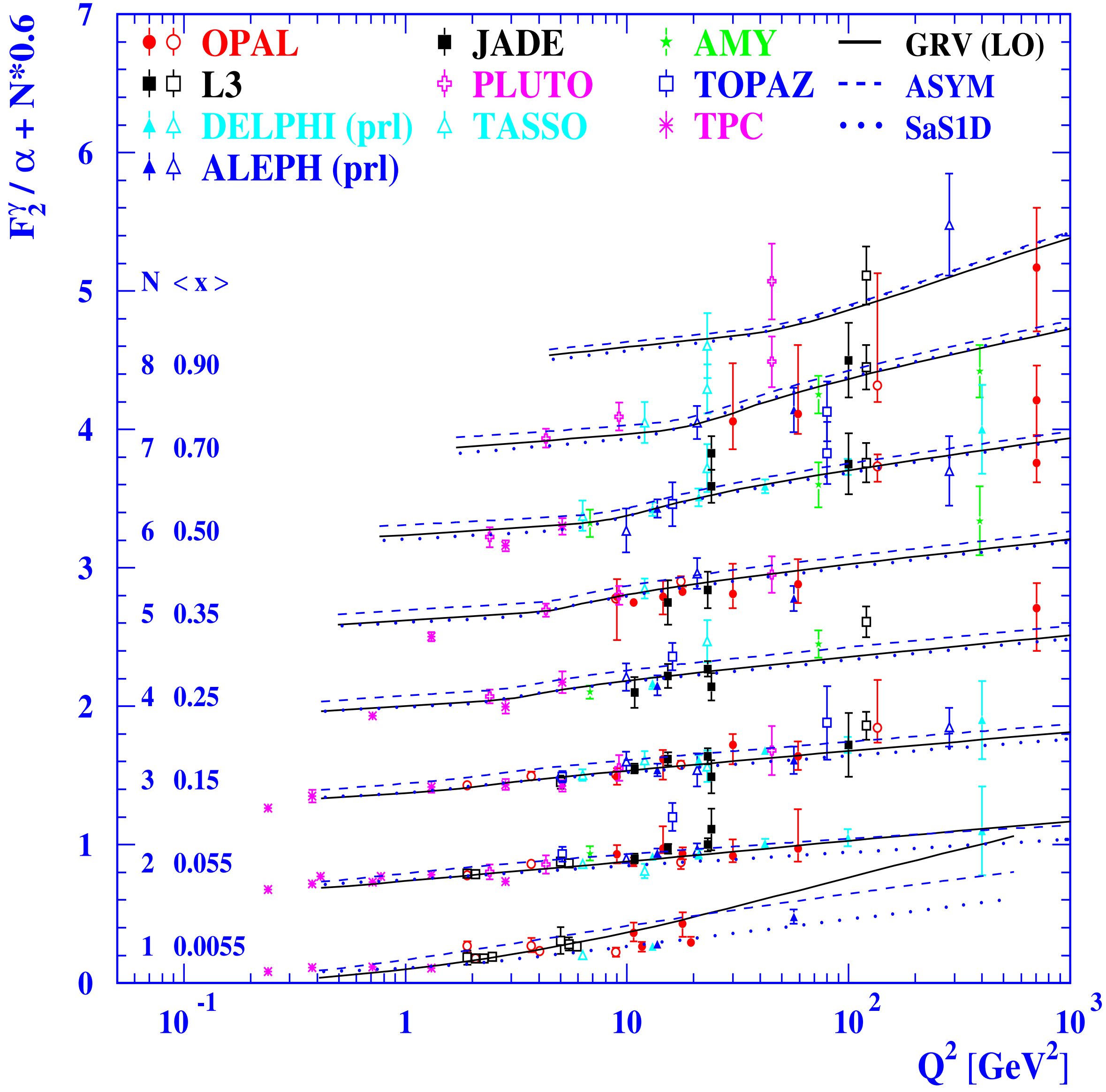


Data up to 202 GeV (1999)
more expected soon

Scattered electron detected in the electromagnetic endcap calorimeter
$0.23 < \theta_{\rm tag} < 0.5$ (rad)

Dominated by the pointlike photon component

The Q^2 evolution of F_2^γ



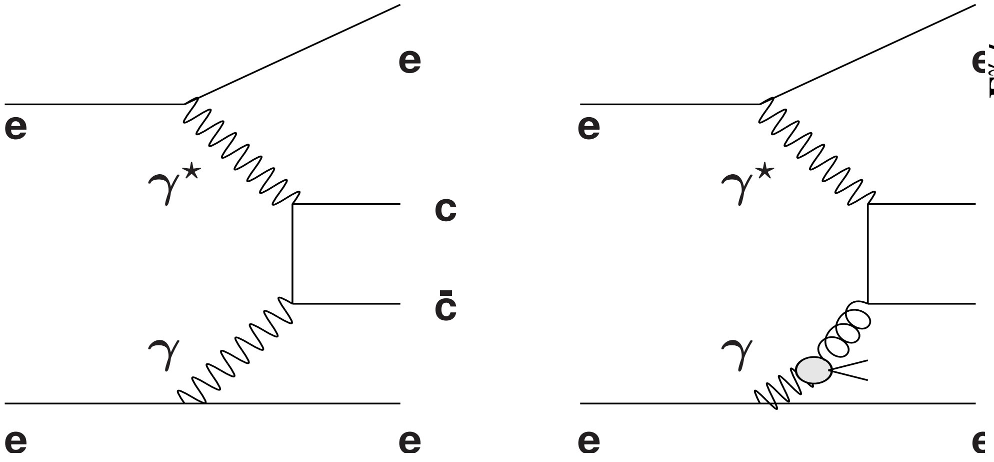
Positive scaling violation at all values of x due to the inhomogenous term from $\gamma \to q\bar{q}$ splitting

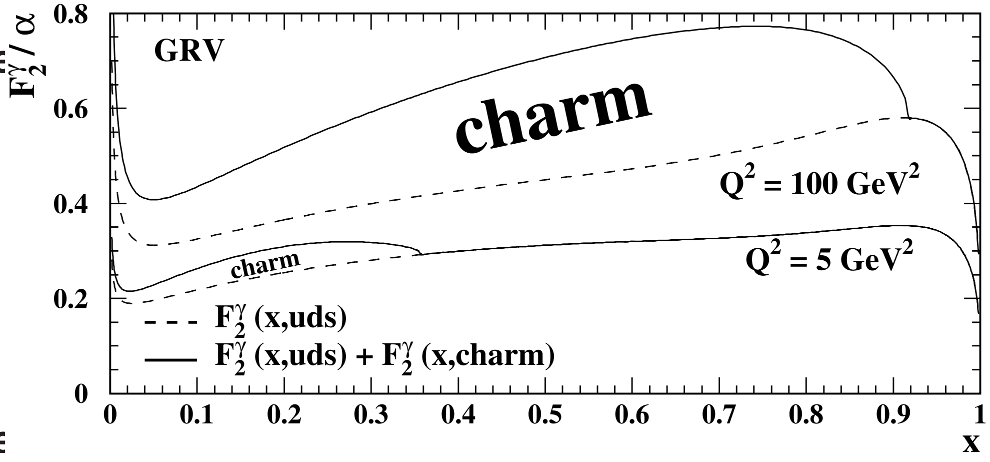
The general trend of the data is followed by the parametrisations

An increasing slope as function of x is observed

Kink at charm threshold

Charm content of the photon: $F_{2,c}^{\gamma}$





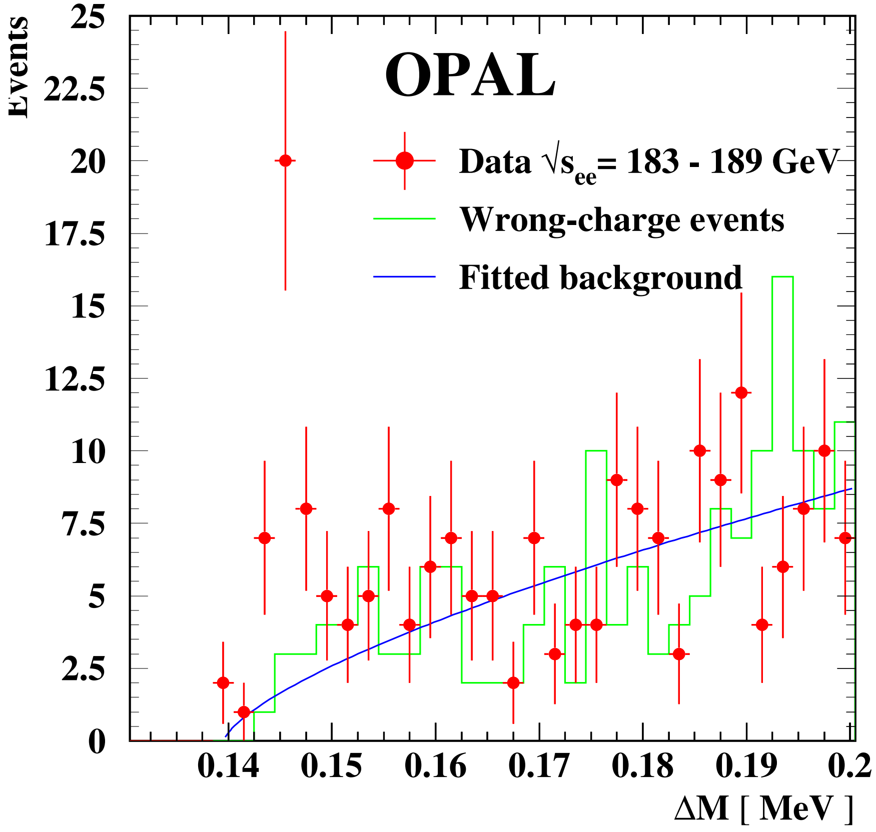
point-like component:
purely perturbative process
dominates at large x

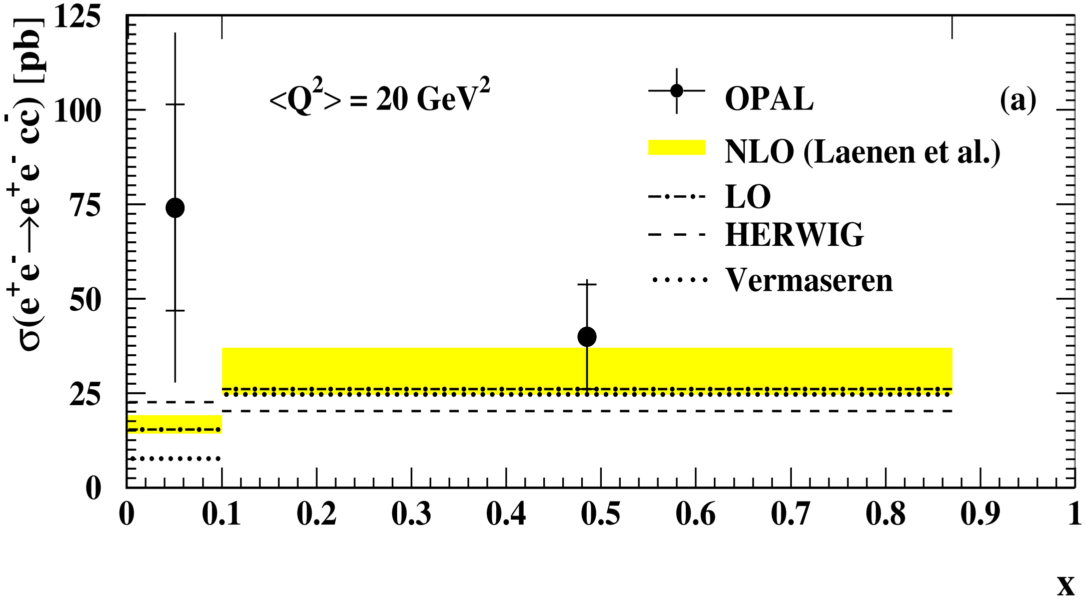
hadron-like component:
depends on the gluon content of the photon
dominates at small x

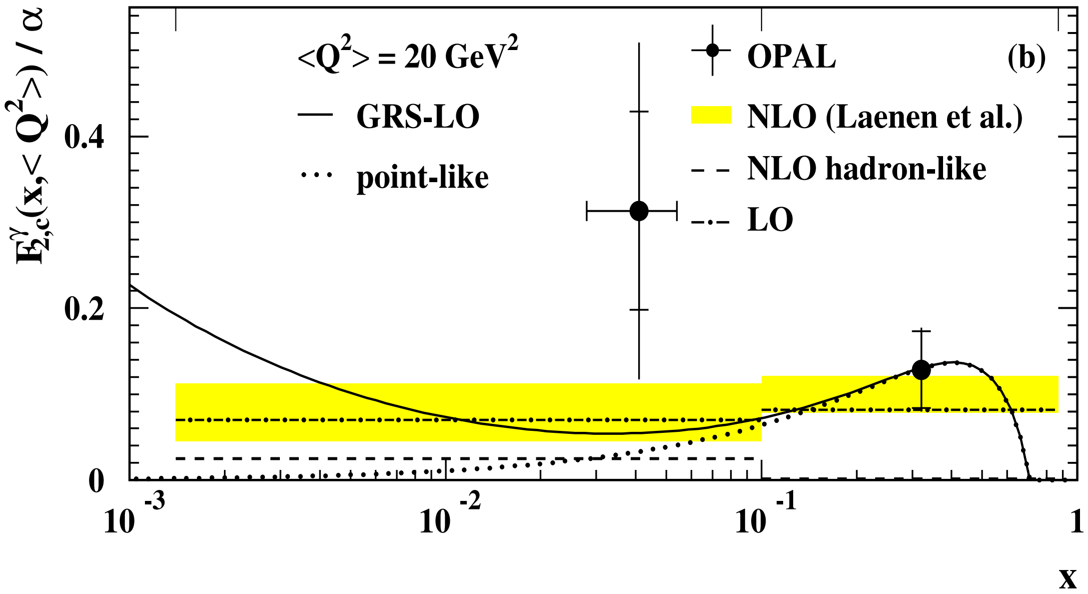
Charm contribution and production threshold increases with Q^2

Relatively large charm mass allows perturbative approach
NLO calculation is available

First measurement of $F_{2,c}^{\gamma}$







D* mass difference method is used to select charm in single-tag events

Conclusions

- Hadronic structure of the photon measured in a wide range of x and Q^2
- New experimental methods have improved data quality
- Other processes at LEP and HERA give complementary information
- The overall picture is rather consistent
- Still a vast amount of data to be analysed
- New results expected for Photon 2001 (September)