Rencontres de Moriond
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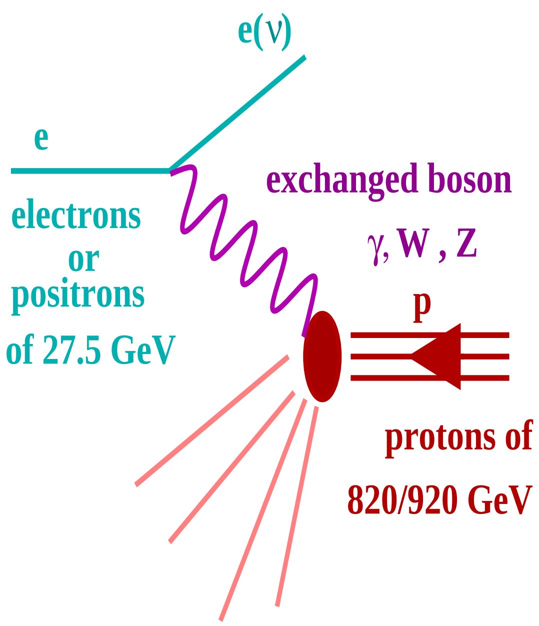
Proton, Photon, and Virtual Photon Structure at HERA

(ZEUS + H1)

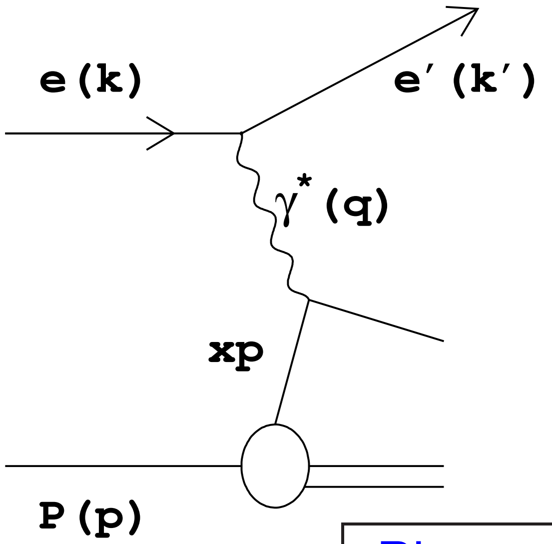
- HERA introduction
- proton structure
- real photon structure
- virtual photon structure
- summary



http://giroz.desy.de/~kcira/show.php3?p=talks

Deep Inelastic Scattering

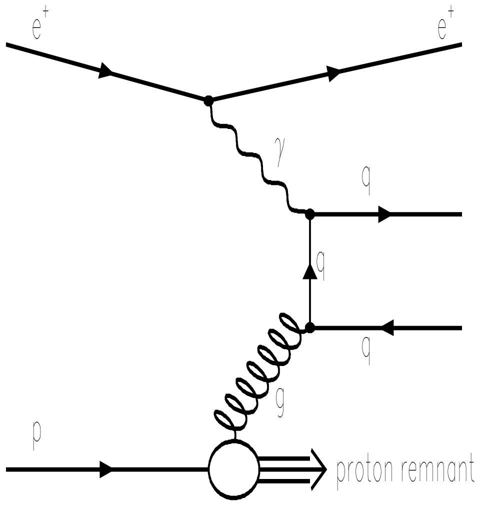
$Q^2 >> 1 GeV^2$: probing proton structure via pointlike virtual photons



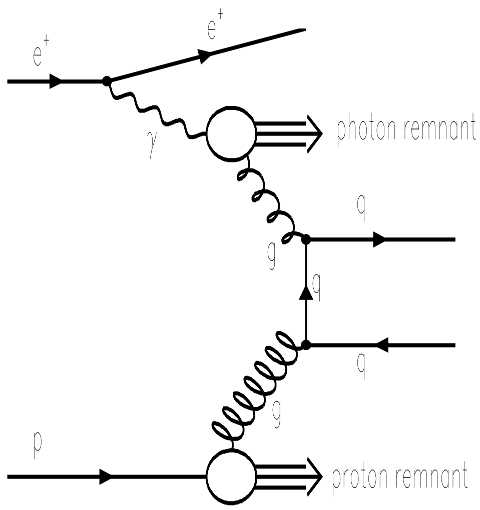
$$Q^2 = -q^2$$
$$y = \frac{q \cdot p}{k \cdot p}$$
$$Q^2 = sxy$$
$$W^2 = Q^2 \left(\frac{1-x}{x}\right)$$

Photoproduction

$Q^2 \simeq 0$: probing photon structure via dijet system



Direct $x_\gamma = 1$

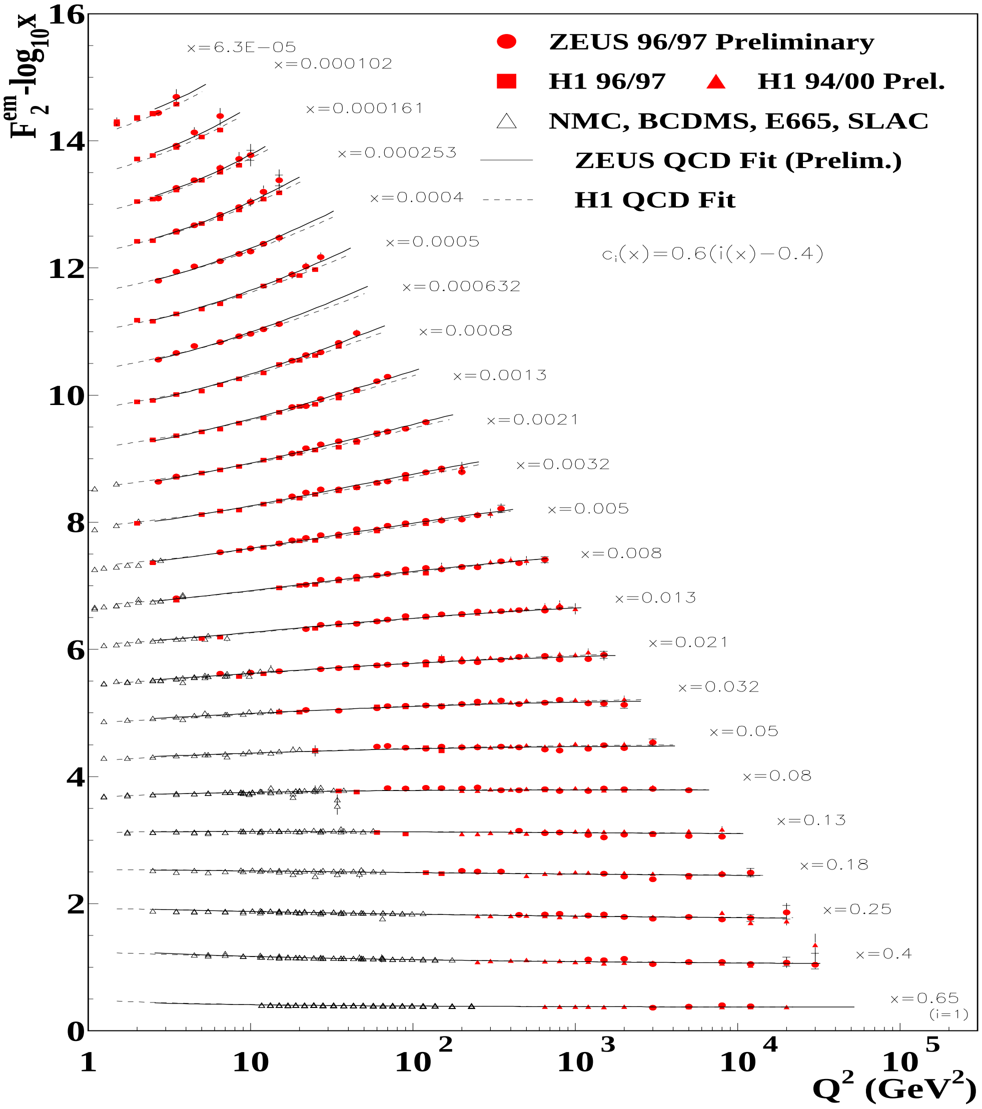


Resolved $x_\gamma < 1$

Proton Structure

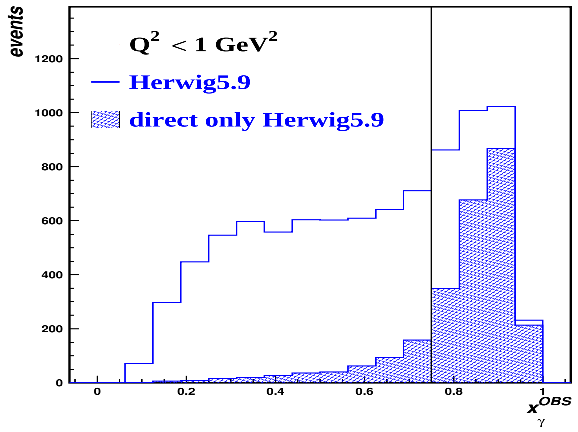
$$\frac{d^2\sigma^{\pm}_{NC}}{dx\,dQ^2} = \frac{2\pi\alpha^2}{xQ^4} \times$$
$$\times \left[Y_+ F_2(x,Q^2) - y^2 F_L(x,Q^2) \mp Y_- xF_3(x,Q^2)\right]$$

with $Y_\pm = 1 \pm (1-y)^2$, $F_2 = F_2^{em}(1+\delta_Z)$



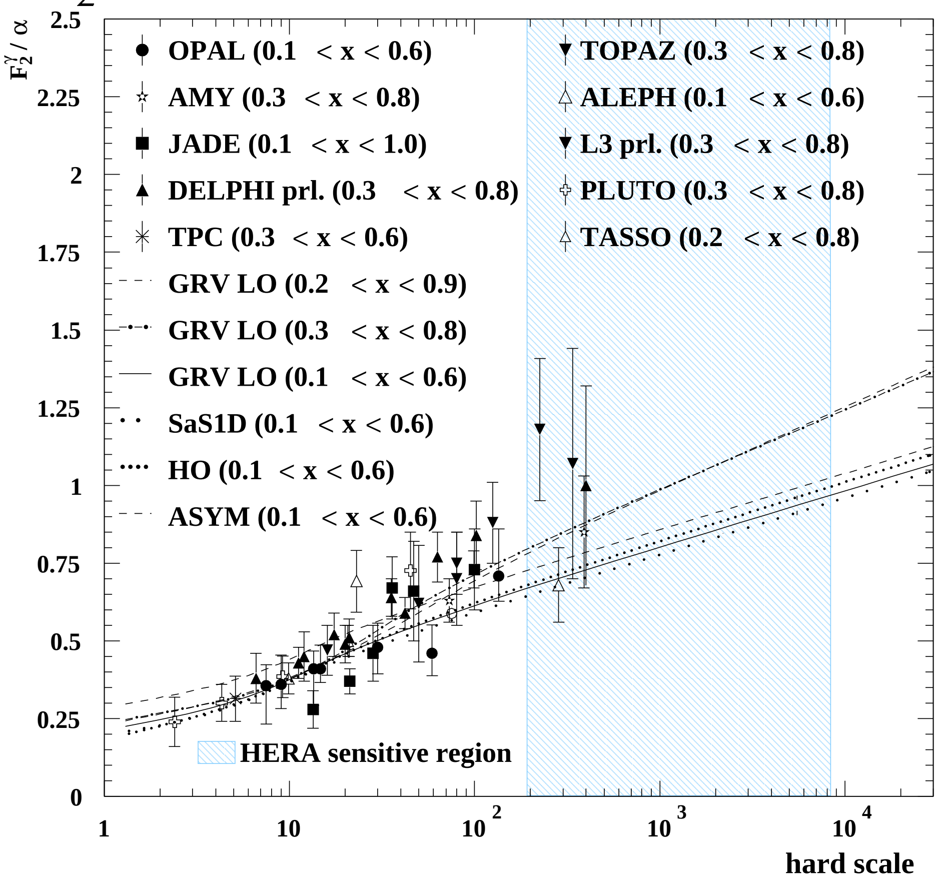
Proton structure is well constrained from HERA data over a very large region of kinematic variables.

Structure of Real Photons $Q^2 \simeq 0$



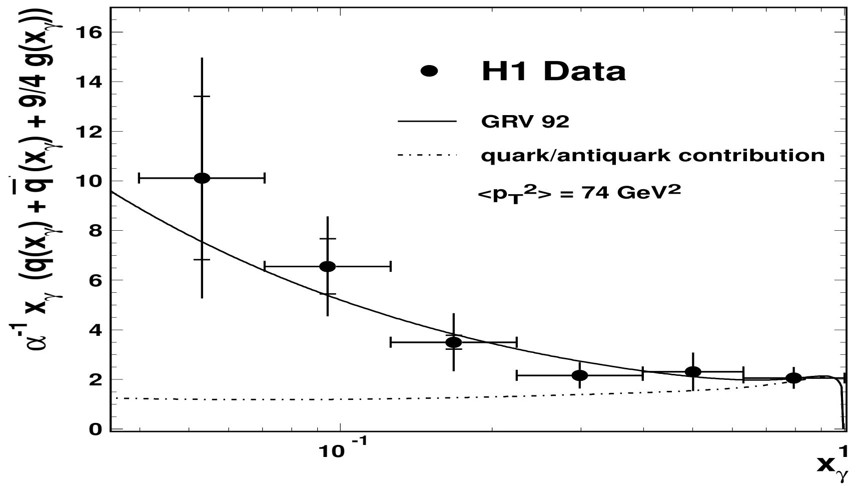
$$x_\gamma^{OBS} = \sum_{jets} \frac{E_T e^{-\eta}}{2yE_e}$$

- HERA can probe higher scales than DIS $e\gamma$
- universality is tested by applying extracted PDFs from fits to F_2^γ to ep measurements

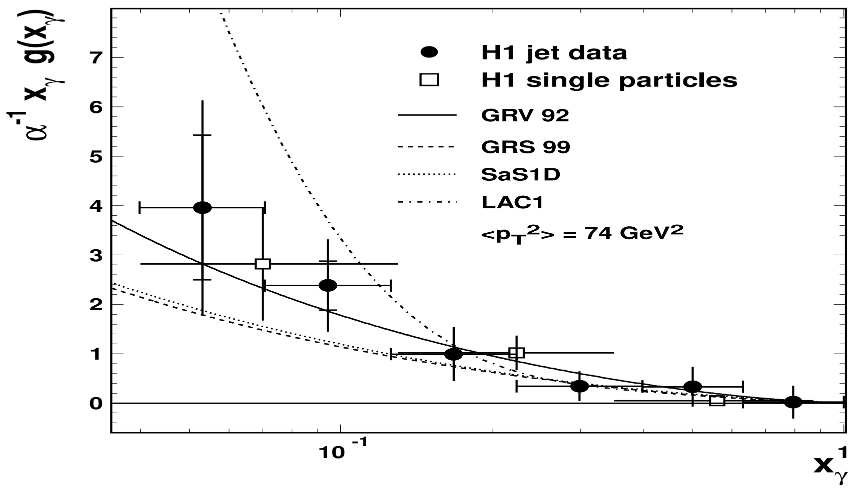


LO: Structure of Real Photons $Q^2 \simeq 0$

- using cone dijet events with $E_T^{jet} > 6.GeV$ effective parton distribution function of the photon at LO are extracted



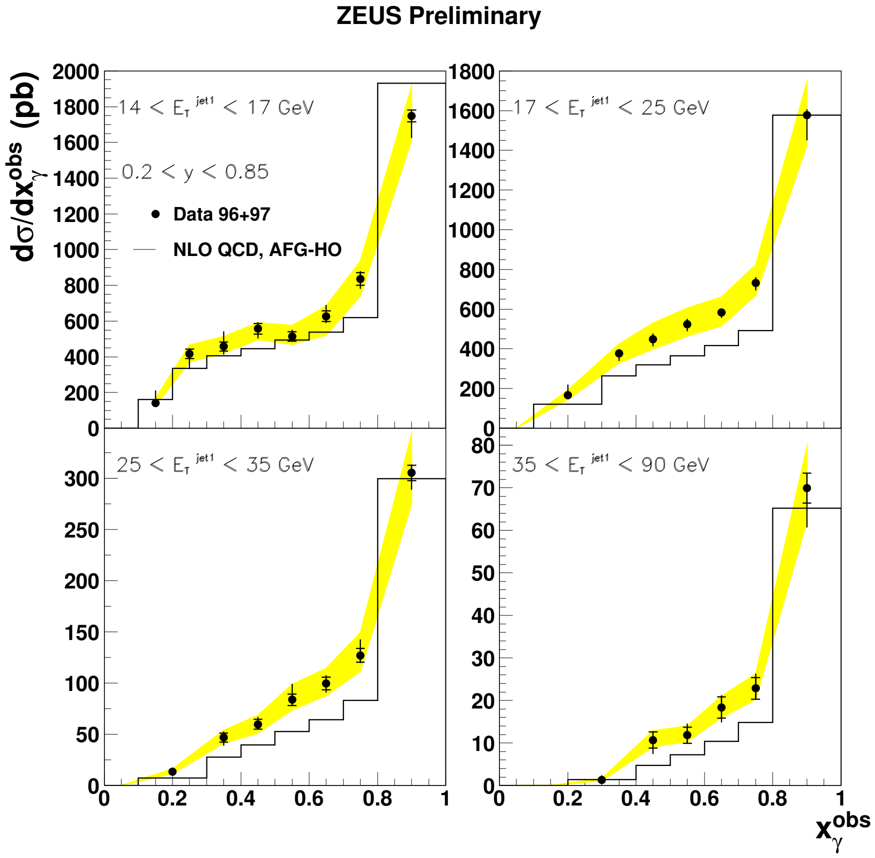
- gluon distribution extracted by subtracting quark content measured in e^+e^-



- at LO large scale dependence
- NLO $\longrightarrow$

NLO: Structure of Real Photons $Q^2 \simeq 0$

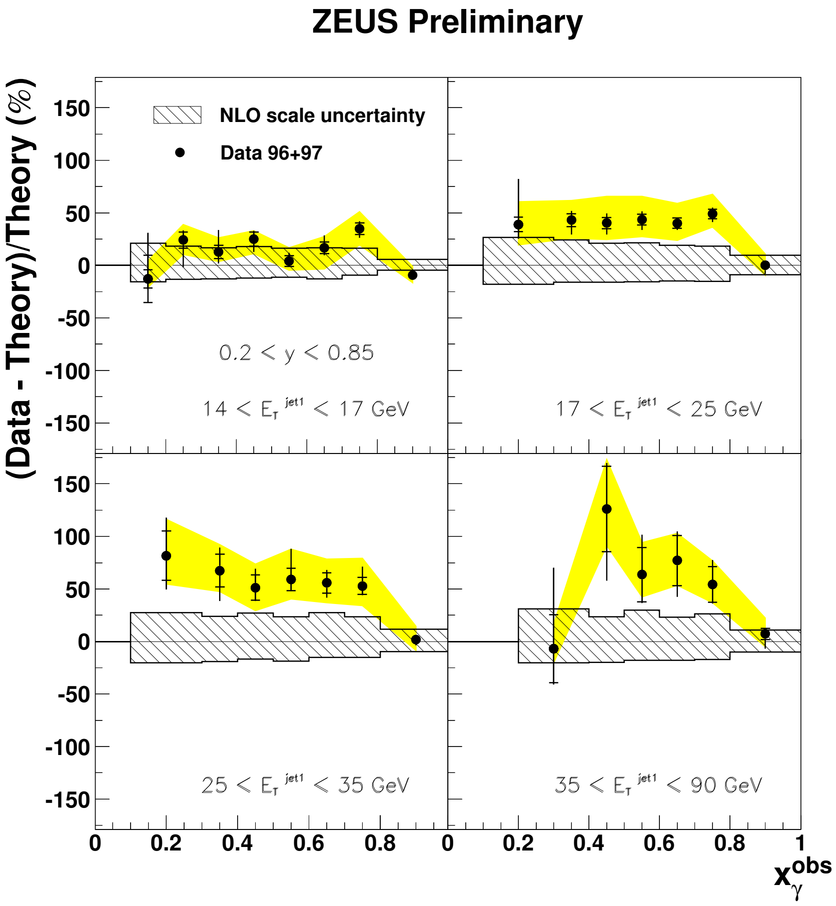
• Dijets selected with the k_T algorithm: $E_T^{jet1} > 14 GeV$, $E_T^{jet2} > 11 GeV$. pseudorapidities: $-1 < \eta^{jet} < 2$
• $0.2 < y < 0.85$, $Q^2 \leq 1 GeV^2$
• data corrected at hadron level, calculations done at parton level (hadronization corrections $10 - 15\%$)
• calculations: Frixione et al.
• AFG-HO : Aurenche, Guillet, Fontanaz. Z. Phys. C64 (1994) 621



• NLO QCD calculations using current parametrisations of the PDFs of the real photons describe measured cross section at high x_γ^{OBS}
• Data lie above NLO QCD calculations for $x_\gamma^{OBS} < 0.8$

NLO: Structure of Real Photons $Q^2 \simeq 0$

- More detailed comparison between data and NLO QCD



- largest experimental uncertainty: jets energy scale $\pm 3\%$
$\rightarrow 15\%$ on cross sections
- largest theoretical uncertainty: scale dependence of the calculations 15%
- discrepancies between data and NLO QCD calculations are larger than the uncertainties
- photon pdfs inadequate?

$\boxed{\text{Virtual Photon Structure}}$

Virtual photons have also two components:

$$\boxed{|\gamma^* >= |DIR > + |RES >}$$

The resolved component has a perturbative and a non-perturbative part. The non-perturbative part comes from $\gamma \leftrightarrow q\bar{q}$ (at HERA hard scale is $\mu^2 \approx E_T^2$.)

Both pQCD and non-pQCD components are suppressed with increasing photon virtuality Q^2.

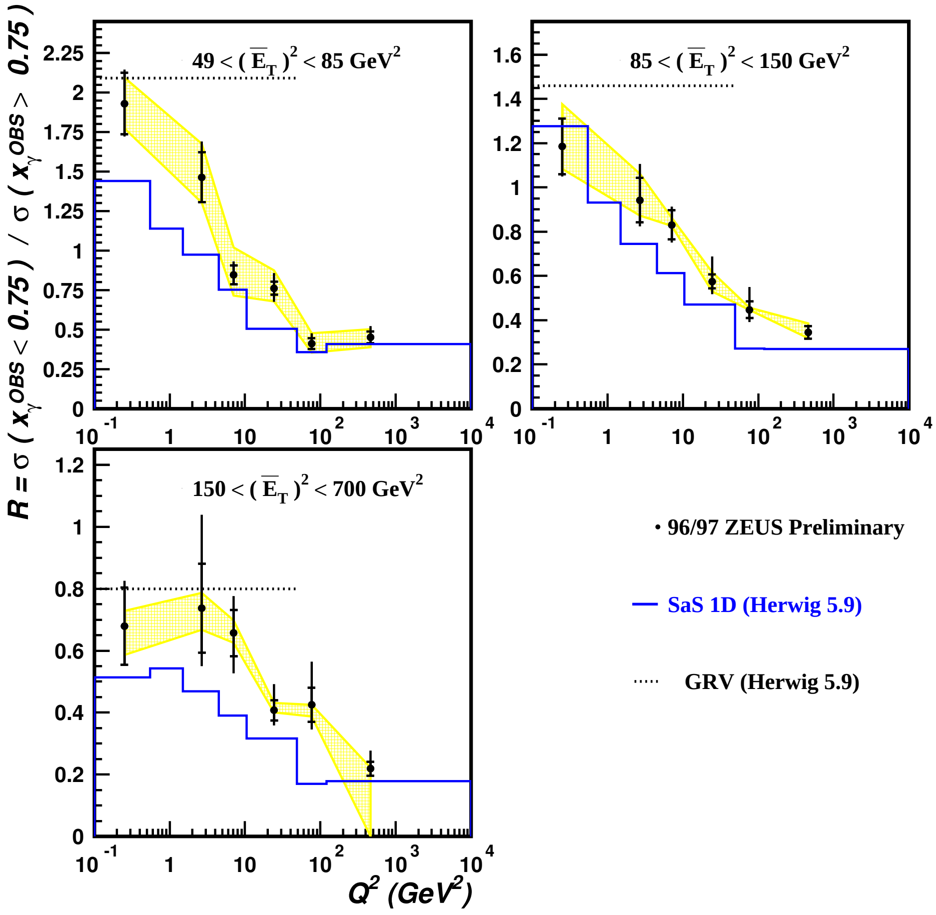
In the SaS parametrization of the virtual photon pdfs, the two resolved components are suppressed as follows:

QCD: $\sim \ln(\mu^2/Q^2)$
non-pQCD $\sim Q^{-4}$

LO: Virtual Photon Structure

- $\gamma^* p$ frame
- k_T dijets: $E_T^{jet} > 7.5, 6.5$ GeV, $-3.0 < \eta^{jet} < 0$
- $0.2 < y < 0.55$, $0.1 < Q^2 < 10^4 \mathrm{GeV}^2$
- LO pdfs:

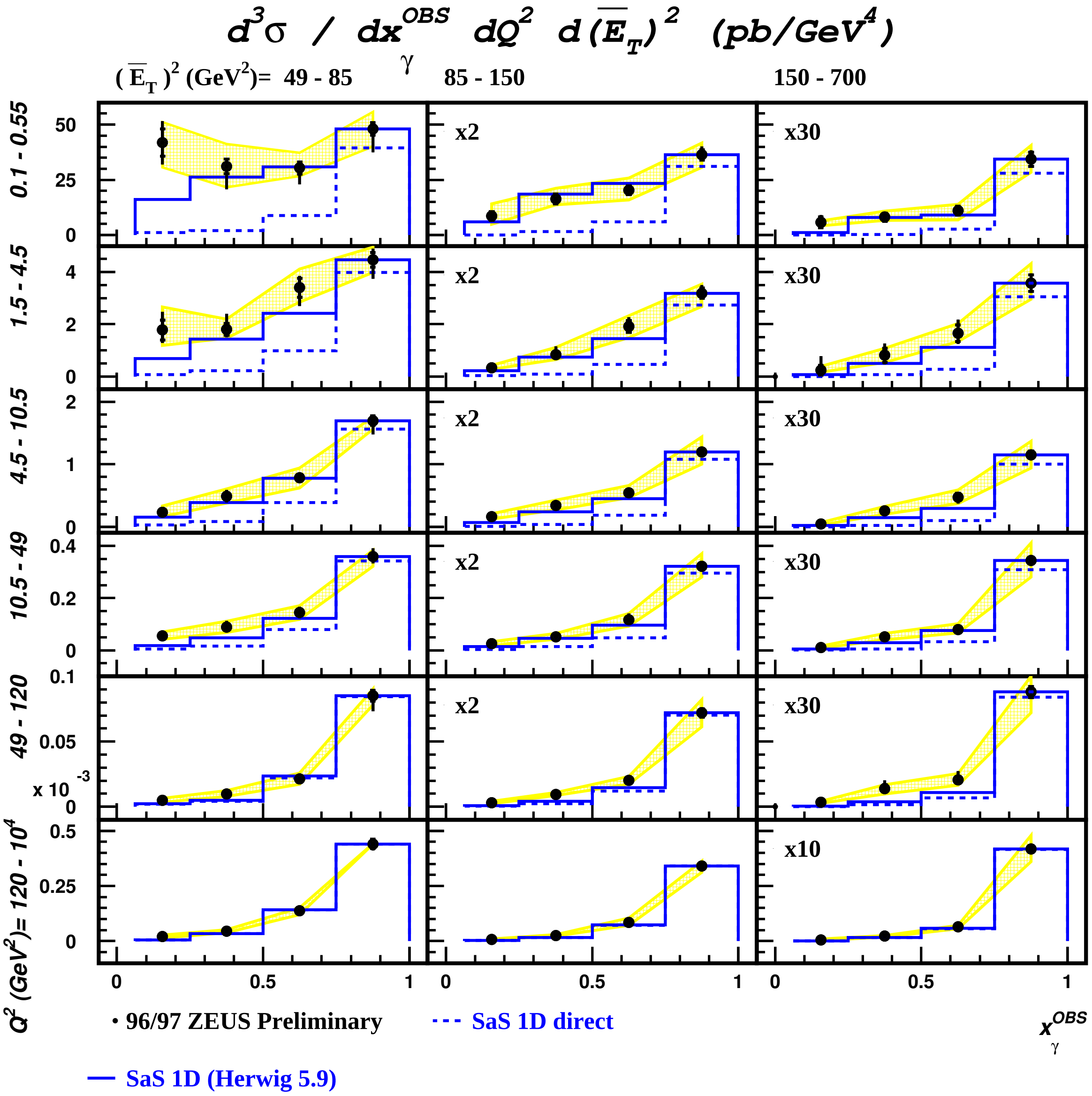
- SaS1D LO parametrization of γ^* pdfs
- GRV LO parametrization of γ pdfs



- ratio falls with increasing photon virtuality $\longrightarrow$ suppression of virtual photon seen
- calculations using SaS1D lie below the data

LO: Virtual Photon Structure

- SaS1D total normalized to highest x_γ^{OBS} data point to study shape description



- low x_γ^{OBS} falls faster with increasing Q^2 than high x_γ^{OBS}
- direct not enough to describe data for $Q^2 < (\overline{E_T})^2$
- direct enough for $Q^2 > (\overline{E_T})^2$: no resolved, data described

Summary

- Proton structure
  - well constrained from HERA data over very large range of x and Q^2 (see talk from M.Klein)

- Real photons
  - NLO calculations using current photon pdfs describe data for $x_\gamma^{OBS} > 0.8$
  - discrepancies observed for $x_\gamma^{OBS} < 0.8$

- Virtual Photons: LO
  - virtual photon structure probed along large range of virtuality and $(\overline{E_T})^2$
  - data show the suppression of the resolved component with increasing photon virtuality
  - direct only is not enough to describe data for $Q^2 < (\overline{E_T})^2$