Nelly Gogitidze
DESY, Hamburg and LPI, Moscow

H1 Collaboration

Measurement of Dijet Cross-Sections at Low Q^2 and the Extraction of an Effective Parton Density for the Virtual Photon

---

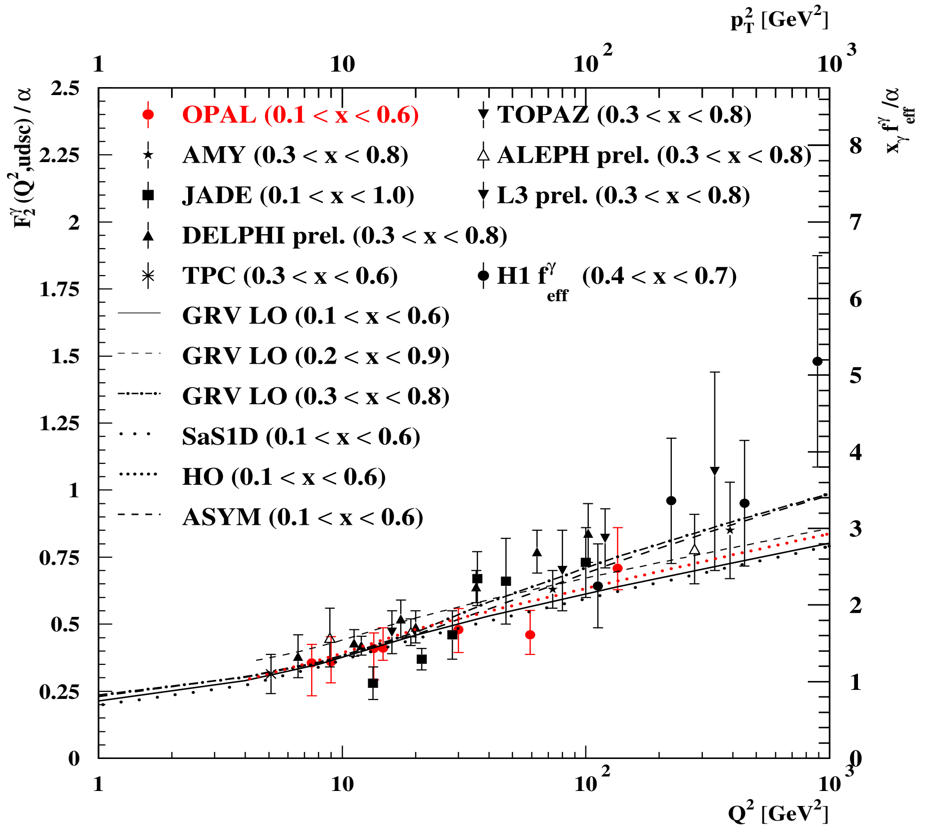
- **Introduction**
- **Triple differential dijet cross-section**
- **Effective parton density of the virtual photon**
- **Conclusions**

Photon 99

Freiburg, May 23-27, 1999

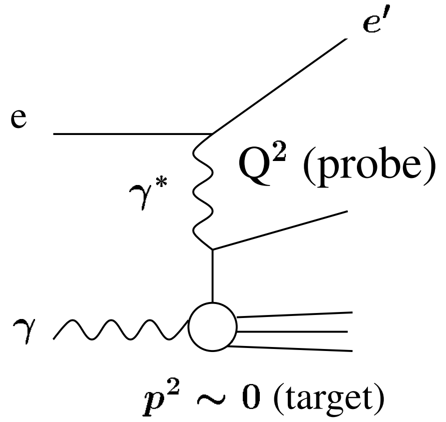
Introduction

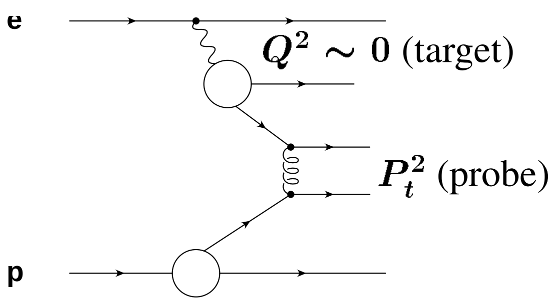
Real Photon



LO pQCD: $f_{q/\gamma} \sim \ln \frac{\mu^2}{\Lambda^2_{QCD}}(x^2 + (1-x)^2)$

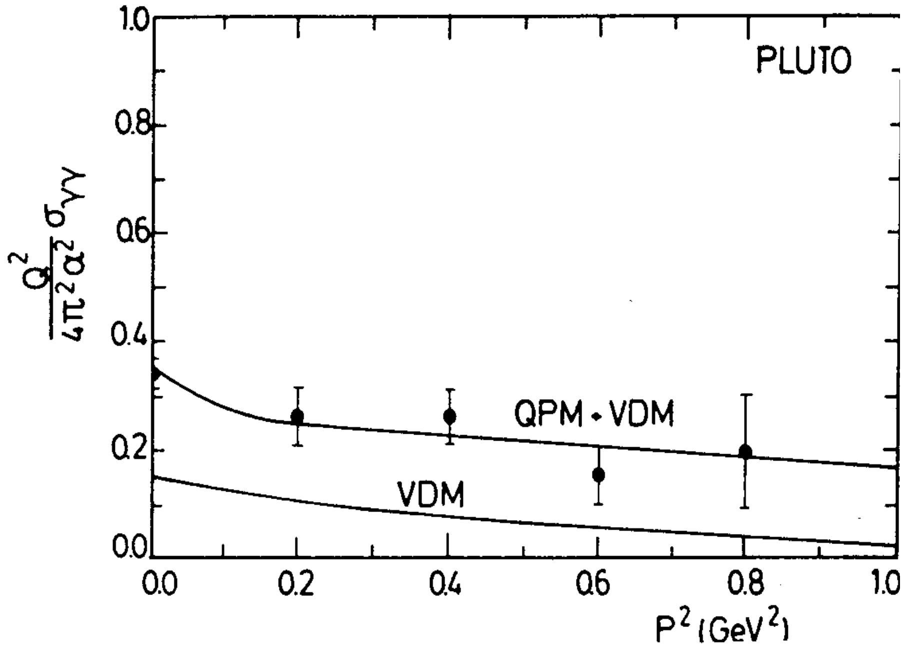
$$\mu^2 = Q^2, p_t^2$$





Introduction

Virtual Photon



LO pQCD: $f_{q/\gamma^*} \sim \ln \frac{P_t^2}{Q^2}(x^2 + (1-x)^2)$

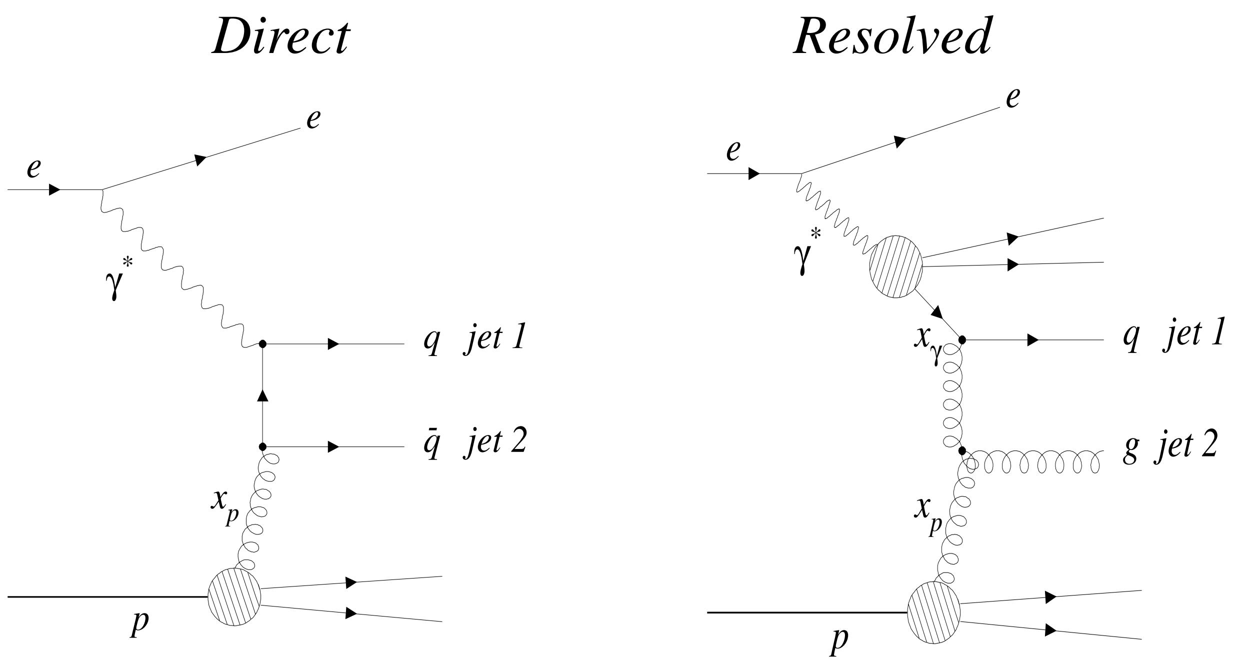
What happens for larger target masses, i.e.
beyond $P^2 = 1$ GeV^2 ?

At HERA we can increase the target mass
by several orders of magnitude

Introduction

HERA Kinematics

e^+ (27,6 GeV) $\longrightarrow$ $\Longleftarrow$ p (820 GeV)



- Q^2 Virtuality of the exchanged photon
- $y = 1 - \frac{E_e{}'}{E_e}\sin^2(\frac{\Theta_e{}'}{2})$ Inelasticity
- $\eta = -\ln(\tan(\Theta/2))$ Pseudorapidity

  (the polar angle Θ defined with respect to the incident proton direction)
- p_t Transverse momentum of jets

Dijets produced via direct or resolved photon processes

==> Use dijets as a probe of photon structure

Introduction

x_γ - Fraction of photon's momentum in hard subprocess

$$x_\gamma^{jets} = \frac{\sum_{jets}(E^{jet} - P_z^{jet})}{\sum_h (E^h - P_z^h)} \qquad z \equiv \gamma^* p \quad axis$$

- $x_\gamma = 1$ direct process (point-like)
- $x_\gamma < 1$ resolved process (structure + Photon remnant)

$Q^2 > 0$ GeV^2: Deep-inelastic scattering regime

- Target photon size $\sim 1/Q$
- Resolved + direct processes
- $P_t^2 >> Q^2$, virtual photon structure resolved by P_t^2

==> Obtain photon structure as $f(Q^2, P_t^2, x_\gamma)$

Q^2: target size P_t^2: probe resolution

x_γ: fractional momentum of target structure

MC simulation of Virtual Photon Processes in Dijet Production

HERWIG and RAPGAP models are used to:

- correct measured cross-sections for detector effects (unfolding)
- compare data with predictions of theoretical models

▶ Hard scattering process (in both models):

- simulated in leading order
- regulated with a minimum P_t cut-off
- initial and final state parton showers

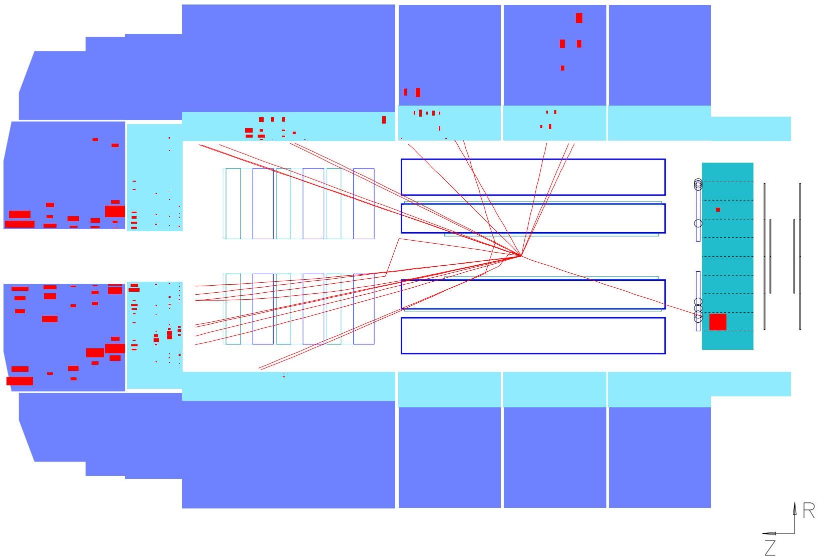
▶ Phenomenological hadronization based on Lund string model (RAPGAP), cluster model (HERWIG)

▶ Soft underlying event processes: included only in HERWIG

▶ Virtual photon density: several models considered

- Drees-Godbole model (DG)
  - Suppress real photon parton densities with factor $\mathcal{L}\,(Q^2, P_t^2, \omega)$, $\omega = 0.2$
- Schuler and Sjöstrand model (SaS)
  - Decomposition of parton densities into perturbative (anomalous) and non-perturbative (VDM) pieces
  - Different evolution starting scales : SaS-1D, SaS-2D

Dijet Selection with H1



- 1996 DIS data, $\mathcal{L} \sim 6\ pb^{-1}$
- $1.6 < Q^2 < 80 GeV^2$
- $0.1 < y < 0.7$
- Jets found with inclusive K_t algorithm in $(\gamma^* p)$ frame
- $\geq$ 2 jets

  ▷ $|\eta^{jet1} - \eta^{jet2}| < 1.0$

  ▷ $-3.0 < \overline{\eta} < -0.5$

  ▷ $\frac{|(E_t^1 - E_t^2)|}{(E_t^1 + E_t^2)} < 0.25$

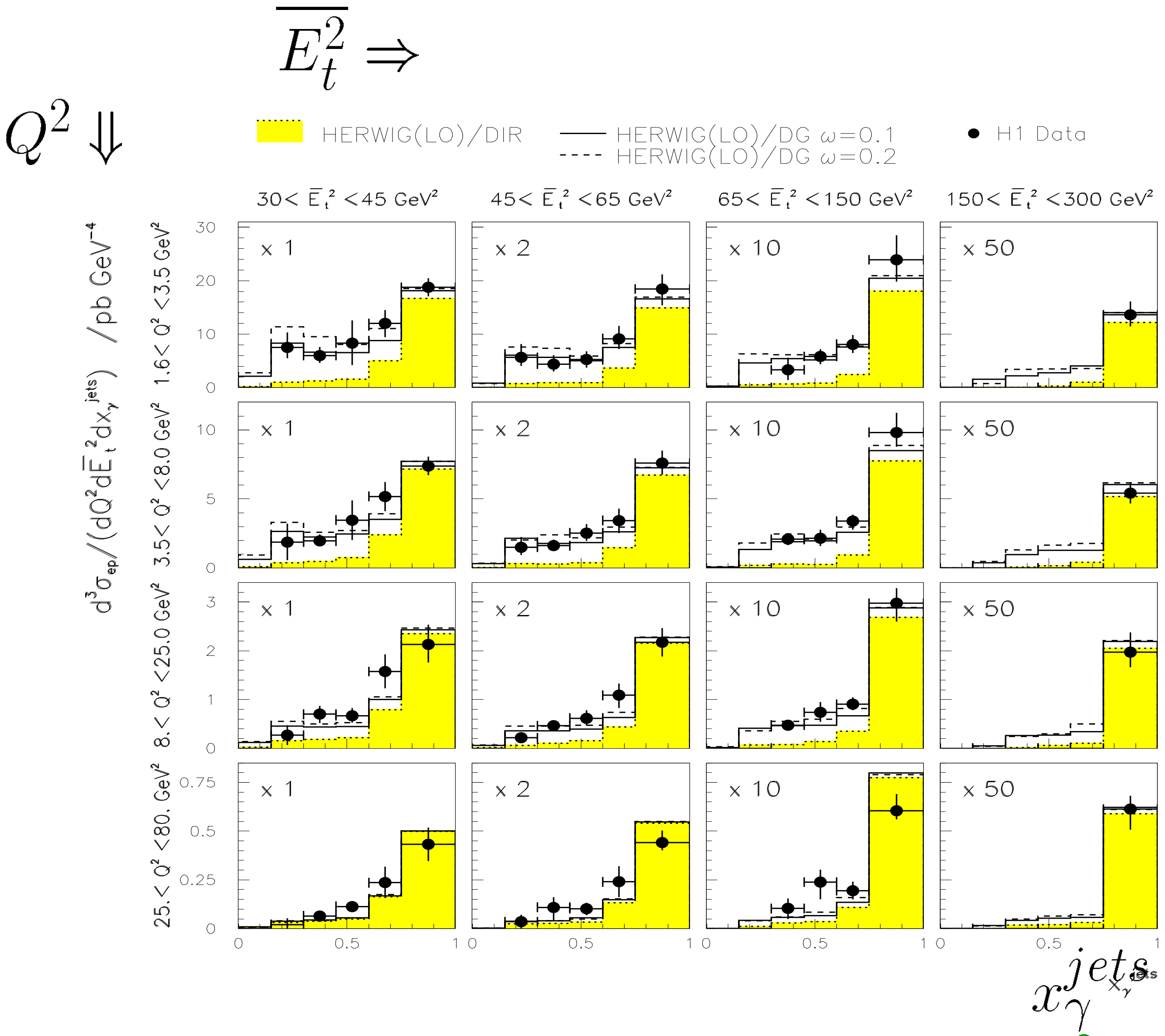
  ▷ $\overline{E}_t^2 > 30\ \mathrm{GeV}^2$

$\overline{E_t}, \overline{\eta}$ - Mean E_t, mean η of 2 highest E_t jets

$N_{events} \sim 12000$

==> Unfold differential cross-section $\frac{d^3\sigma_{ep}}{dQ^2 d\overline{E}_t^2 dx_\gamma^{jets}}$

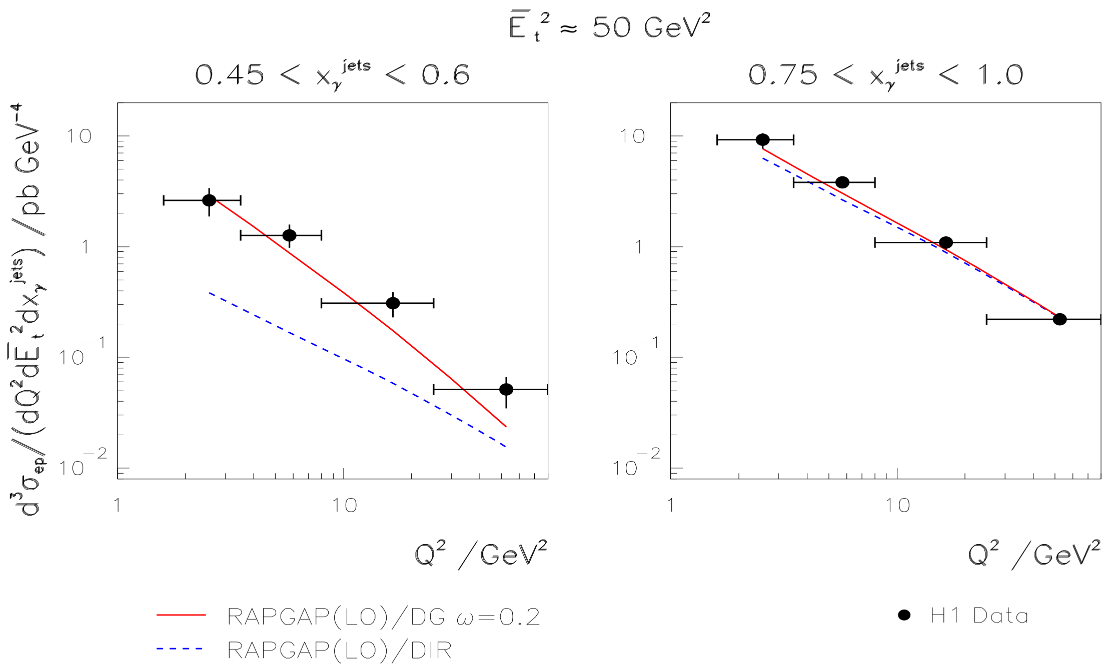
Triple Differential Dijet Cross-Section



- Significant resolved component ($x_\gamma \lesssim 0.75$) for $E_t^2 > Q^2$
- Cross-section decreases strongly with increasing $\overline{E}_t^2$
- At fixed $\overline{E}_t^2$ cross-section decreases with increasing Q^2
- For $\overline{E}_t^2 < 150$ GeV^2 the relative contribution from resolved photons decreases with increasing Q^2
- QCD inspired model (includes Q^2 suppression of photon PDFs) describes the data

Triple Differential Dijet Cross-Section

Q^2 dependence at fixed E_t^2 and two x_γ bins



- The cross-section decreases steeply with increasing Q^2
- Rate of suppression diminishes with increasing x_γ^{jets}
- At $x_\gamma^{jets} = 0.5$ and $\overline{E}_t^2 > Q^2$ the jet process is able to resolve the partonic structure of the virtual photon
- LO QCD model with direct photon component only:
  At high x_γ^{jets} range agreement with data

Single Effective Subprocess approximation

- LO cross-section for production of dijets
  by resolved virtual photons

$$\frac{d^5\sigma}{dydx_\gamma dx_p dcos\Theta^* dQ^2} \sim$$

$$\sum_{k=T,L} \frac{f^k_{\gamma/e}(y,Q^2)}{y} \sum_{i,j} \frac{f^k_{i/\gamma}(x_\gamma,P_t^2,Q^2)}{x_\gamma} \frac{f_{j/p}(x_p,P_t^2)}{x_p} |M_{ij}(cos(\Theta^*)|^2$$

- Dominant $2 \rightarrow 2$ processes:
  qq $\rightarrow$ qq   qg $\rightarrow$ qg   gg $\rightarrow$ gg   (g exchange)
  have similar $\cos\Theta^*$ dependences   (Rutherford scattering)
- M_{ij} differ only by color factors
  ==> Use a Single Effective Subprocess $M_{ij} \rightarrow M_{SES}$
- $f_{i/\gamma} \rightarrow \tilde{f}_\gamma \qquad f_{j/p} \rightarrow \tilde{f}_p$

$$\frac{d^5\sigma}{d.....} \approx$$

$$\frac{f^T_{\gamma/e}(y,Q^2)}{y} \frac{\tilde{f}_\gamma(x_\gamma,P_t^2,Q^2)}{x_\gamma} \frac{\tilde{f}_p(x_p,P_t^2)}{x_p} |M_{SES}(cos(\Theta^*)|^2$$

- Effective parton density

$$\tilde{f}_\gamma = (f_{q/\gamma} + f_{\overline{q}/\gamma}) + \frac{9}{4} f_{g/\gamma}$$

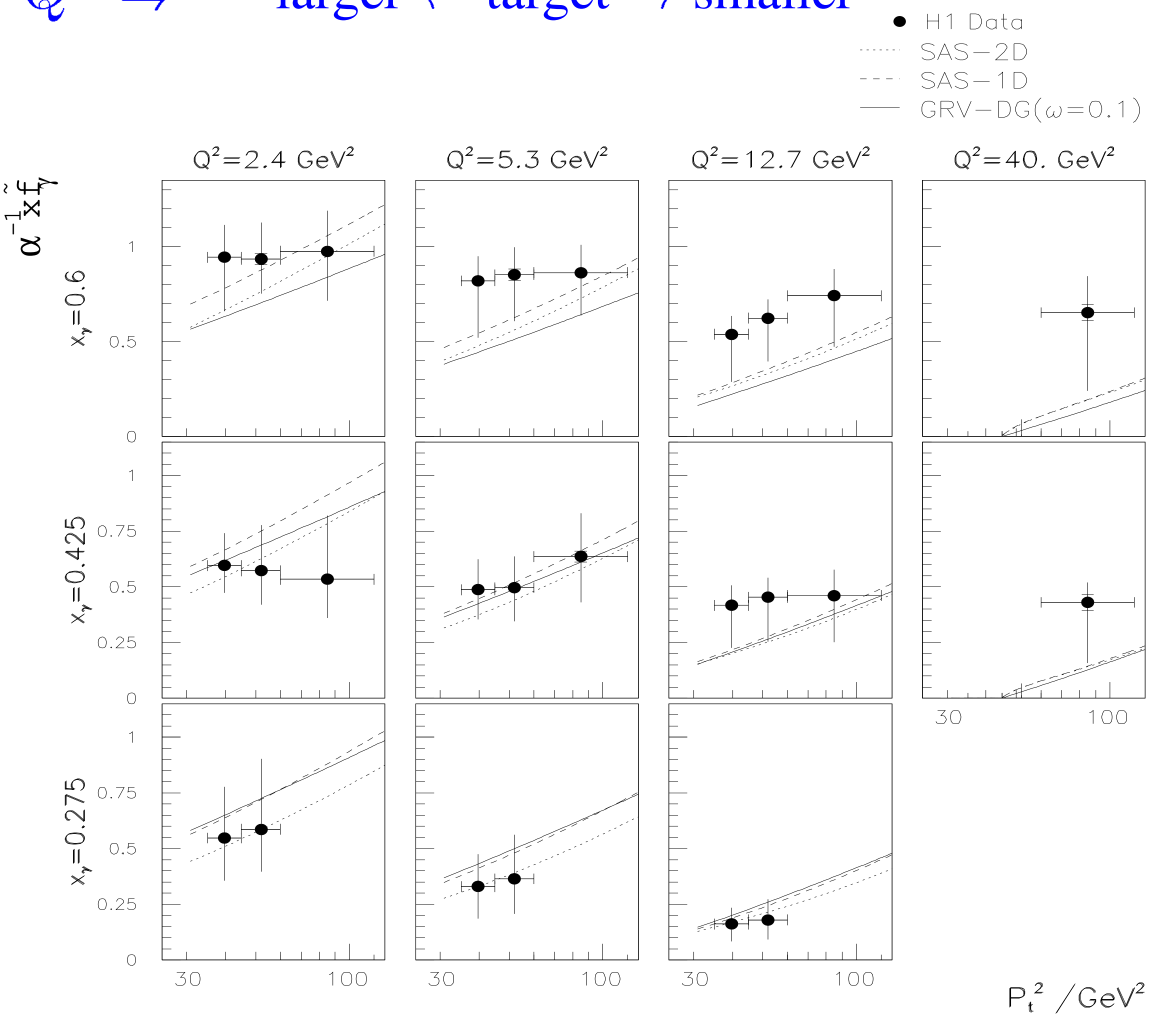
  - comparing parton level cross-sections in data and MC
  - polarisation (T+L) averaged
  - Only valid for $P_t^2 > Q^2$

Effective Parton Density of Virtual Photon

Scale (P_t^2) dependence

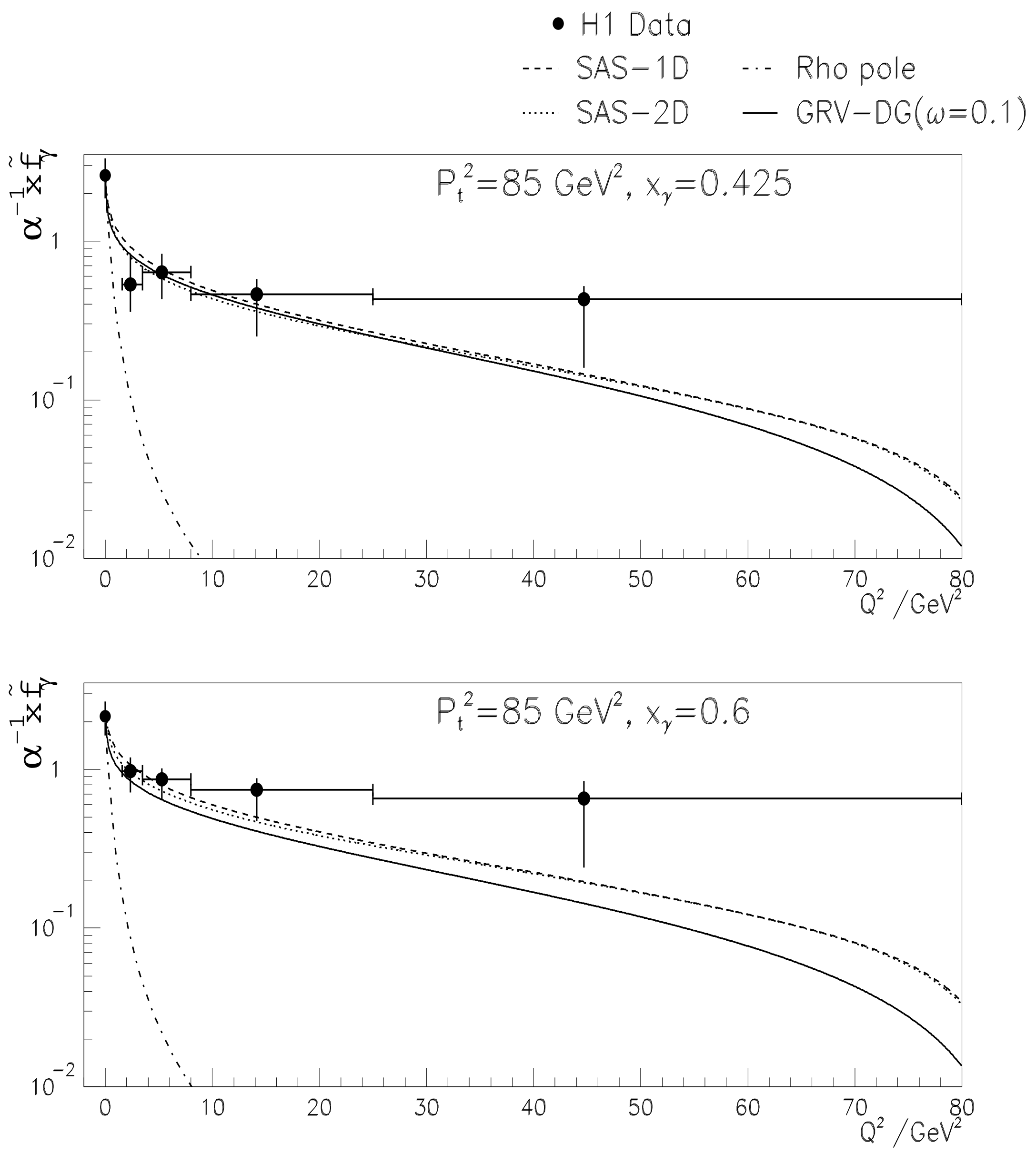
$Q^2 \Rightarrow$ larger $\leftarrow$ target $\rightarrow$ smaller

$x_\gamma \Downarrow$



- No strong dependence on $\boldsymbol{P_t^2}$
- Within errors consistent with the normalisation (specified by $\boldsymbol{Q^2}$) AND logarithmic scale dependence (specified by $\boldsymbol{P_t^2}$) predicted by pQCD for the anomalous component of the photon $\boldsymbol{F_2^{\gamma^*} \sim \ln \frac{P_t^2}{Q^2}(x^2 + (1-x)^2)}$

Effective Parton Density of Photon



- VDM clearly fails to describe the data
- Photon parton density decreases $\sim \ln Q^2$
- pQCD: With increasing Q^2
  photon structure simplifies to direct coupling to $q\bar{q}$ pair

  $\Downarrow$

  Time to develope a hadronic bound state diminishes

Conclusions

Clear evidence is shown for
virtual photon structure in DIS dijet production

- Triple differential cross-section measured

$$\frac{d^3\sigma_{ep}}{dQ^2 d\overline{E}_t^2 dx_\gamma^{jets}}$$

- QCD calculations with direct-only photon interactions fail to describe the data
- First measurement of a Leading Order effective parton density of the virtual photon
- Data consistent with scaling and virtuality dependences predicted by pQCD
- γ structure observed for $0 \leq Q^2 \leq 80$ GeV^2