Photon structure as revealed in ep collisions

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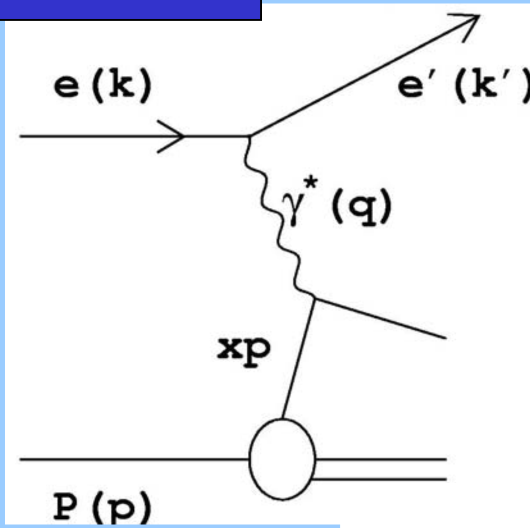
On behalf of the H1 and ZEUS collaborations

Deep inelastic scattering

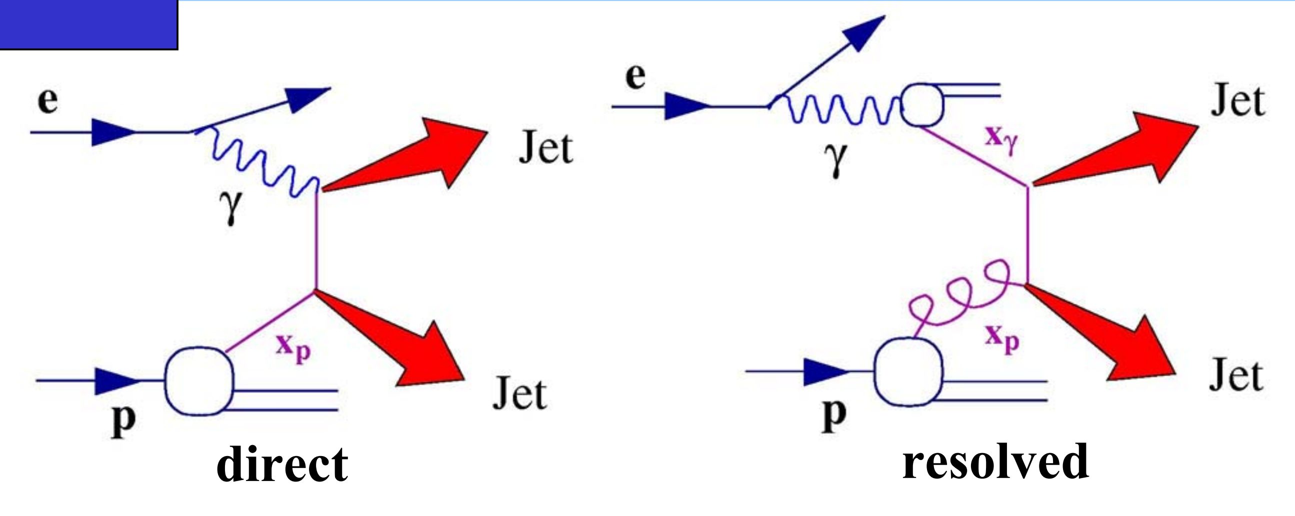
$Q^2 >> 1$ GeV^2: probing proton structure via pointlike virtual photons



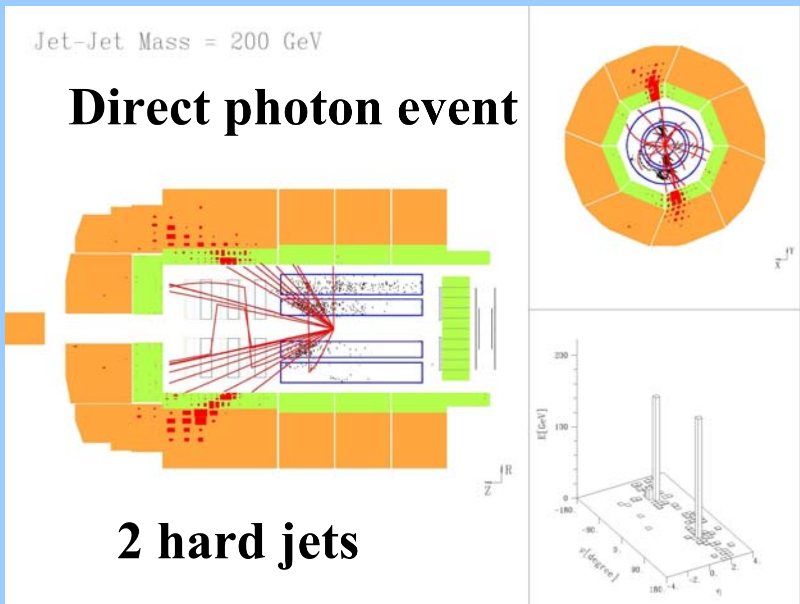
$$Q^2 = -q^2$$
$$y = \frac{q \cdot p}{k \cdot p}$$
$$Q^2 = sxy$$
$$W^2 = Q^2 \left(\frac{1-x}{x}\right)$$

Photoproduction

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

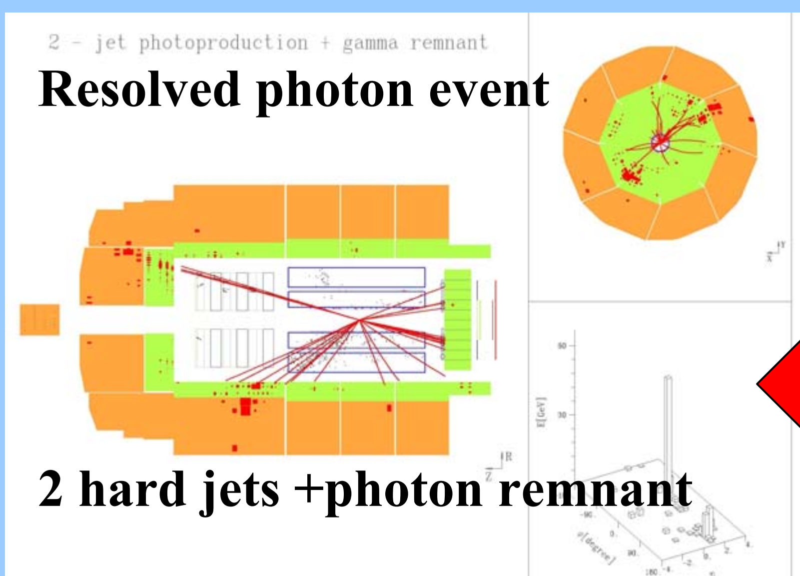


Photoproduction events in H1 detector



Direct photon event

2 hard jets



Resolved photon event

2 hard jets +photon remnant

x_γ - fraction of photon's momentum in hard subprocess

$$x_\gamma = \frac{\sum_{jets} E_{T,i} e^{-\eta_i}}{2yE_e} \quad \text{or} \quad \frac{\sum_{jets}(E_i - p_{z,i})}{\sum_{had}(E_h - p_{z,h})}$$

E_T, η – transverse momentum and pseudorapidity of jets

$$x_\gamma = 1$$

$$x_\gamma < 1$$

Probes photon structure via dijet system

σ_{ep} is convolution of partonic cross sections and pdf's:

$$\frac{d\sigma_{ep}}{dQ^2} = \gamma_{flux}(y, Q^2) \otimes PDF_\gamma(x_\gamma, Q^2, \mu) \otimes PDF_p(x_p, \mu) \otimes d\sigma_{ij}(\theta^*, Q^2, \mu)$$

flux of photons — **pdf of the photon** — **pdf of the proton (experimentally constraint)** — **cross section of the subprocess- calculable**

x_p - fraction of proton's momentum in hard subprocess

$$x_p = \frac{\sum_{jets} E_{T,i} e^{\eta_i}}{2E_p}$$

Q^2 – virtuality of γ^* and y - inelasticity

E_T, η – transverse momentum and pseudorapidity of jets

Θ^*- angle of dijet system in 2-jet CMS

$\mu \to E_T$ is the hard scale

At HERA the photon structure can be probed at higher scales than at LEP

Photon structure from HERA

The measured of dijet cross section →
the parton densities in the photon

Two different approaches:

- ❖ **Extraction:** **extracting the pdf, treating the measured cross section, the known pdf of proton and QCD matrix element as input**

  → fundamental, parton level quantity

  (but difficult and only LO procedure)

- ❖ **Universality test:** **checking if existing parametrizations of pdf are adequate for the description of the dijet cross section within NLO QCD**

  → NLO approach

  (but hadronization corrections should be known (small))

High E_T dijets → motivation

Soft physics supressed (hadronization corrections small)

High E_T jets provide hard scale for perturbative QCD calculations

Test perturbative QCD at NLO

Test parametrizations of proton pdf→gluon in the proton,$0.05<x_p<0.6$

Test parametrizations of photon pdf →q/g in the photon, $0.1<x_\gamma<1.$
gluon poorly constrained by F_2^γ measured in e^+e^- collisions at LEP,
jets at HERA sensitive to gluons already at LO

Dijets in photoproduction: H1 and ZEUS

H1 cuts:

$Q^2 < 1$ GeV^2
$0.1 < y < 0.9$
$E_{tmax} > 25$ GeV, $E_{tsec} > 15$ GeV
$-0.5 < \eta < 2.5$
$M_{jj} > 65$ GeV

k_t long.inv. jet algorithm

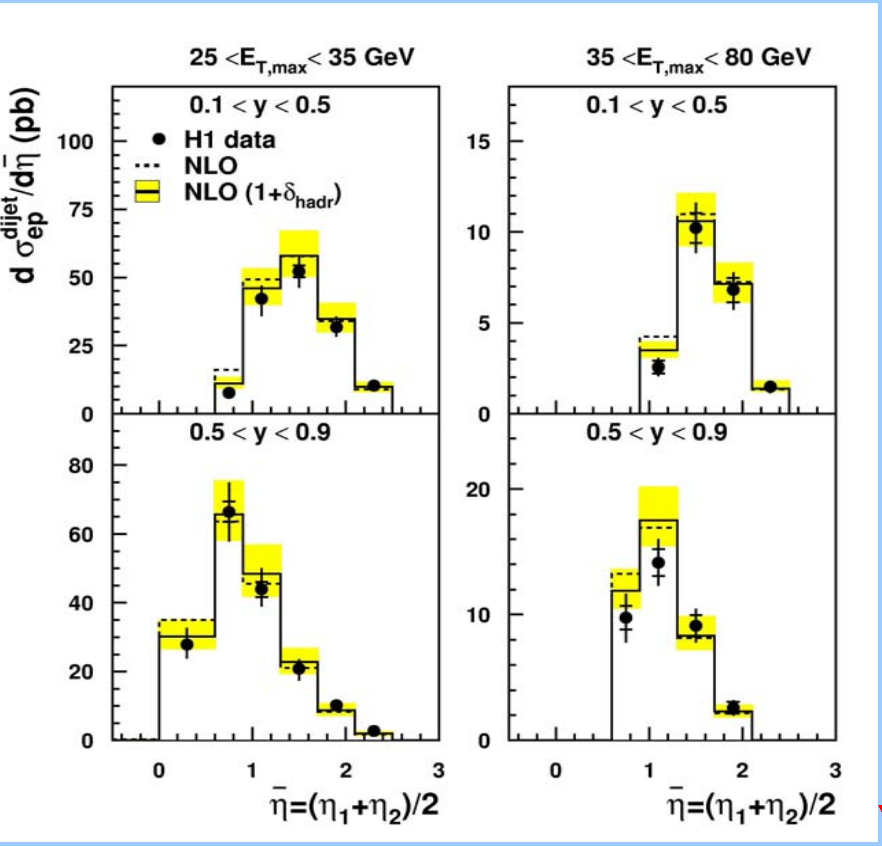
ZEUS cuts:

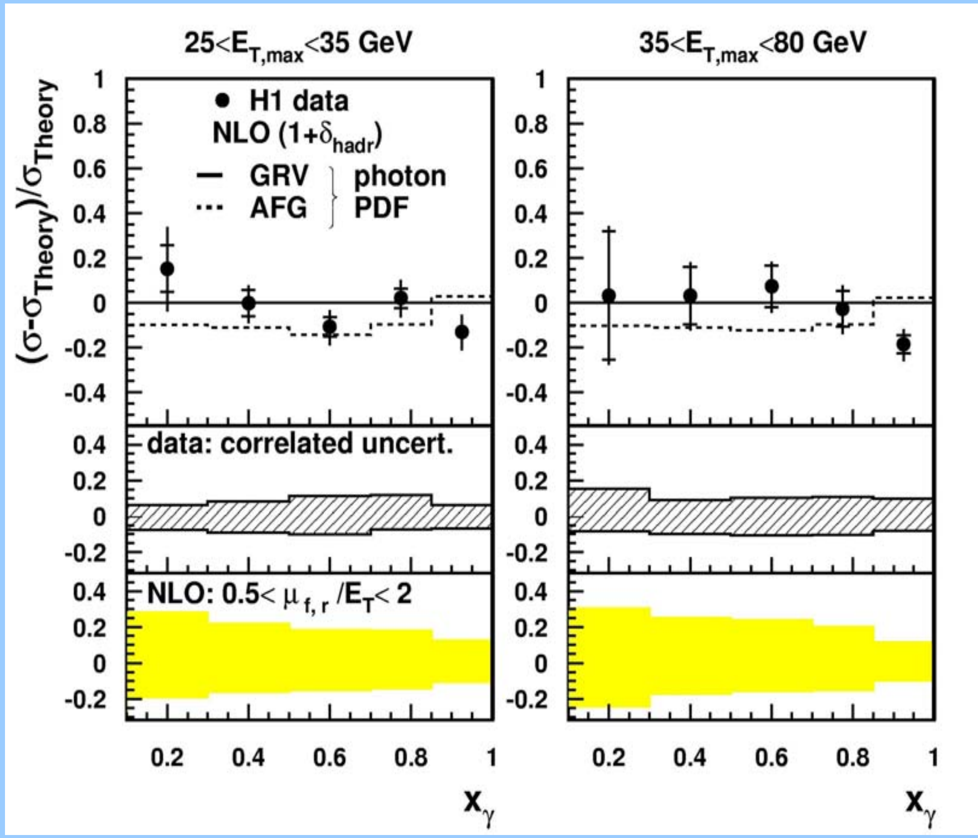
$Q^2 < 1$ GeV^2
$0.2 < y < 0.85$
$E_{tmax} > 14$ GeV, $E_{tsec} > 11$ GeV
$-1. < \eta < 2.4$
$0.1 < \eta_{mean} < 1.3$
$M_{jj} > 39$ GeV

k_t long.inv.jet algorithm

H1 collab.Eur.Phys.J C25 (2002),13

H1



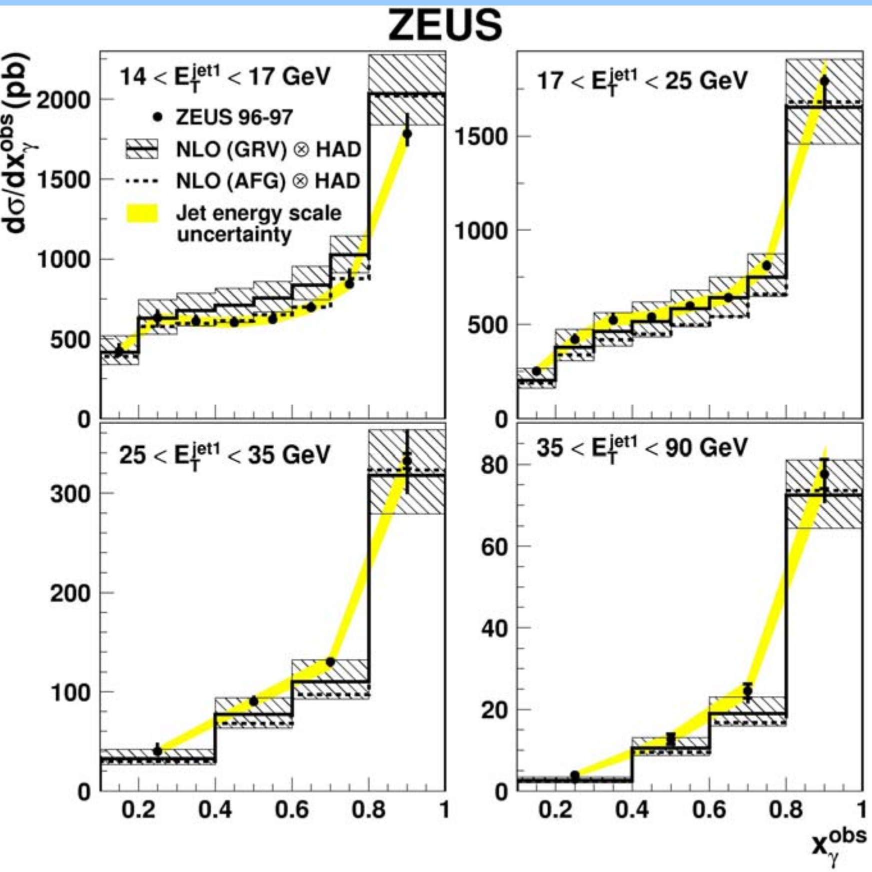


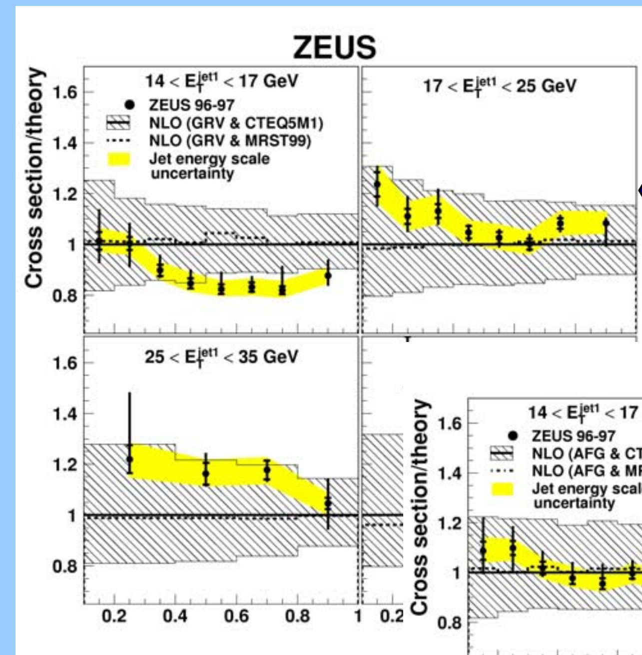
lower x_γ, higher x_p →

Data described by NLO with GRV and AFG pdf's of photon

ZEUS collab.,Eur.Phys.J C23 (2002),615

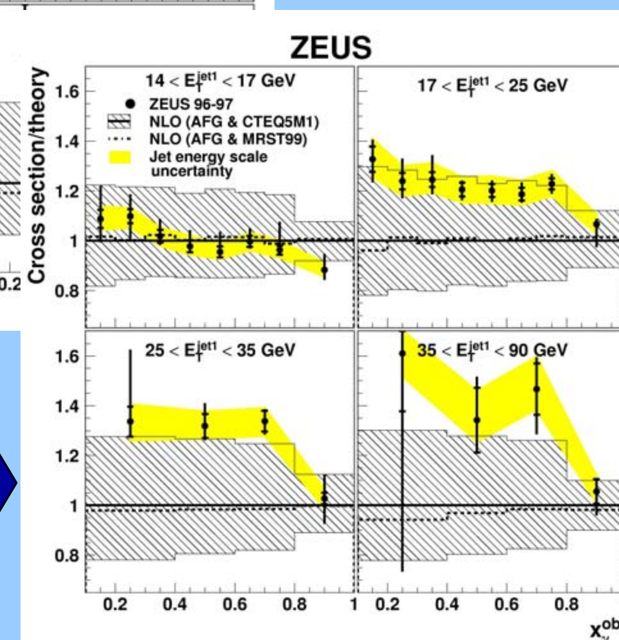
ZEUS





GRV

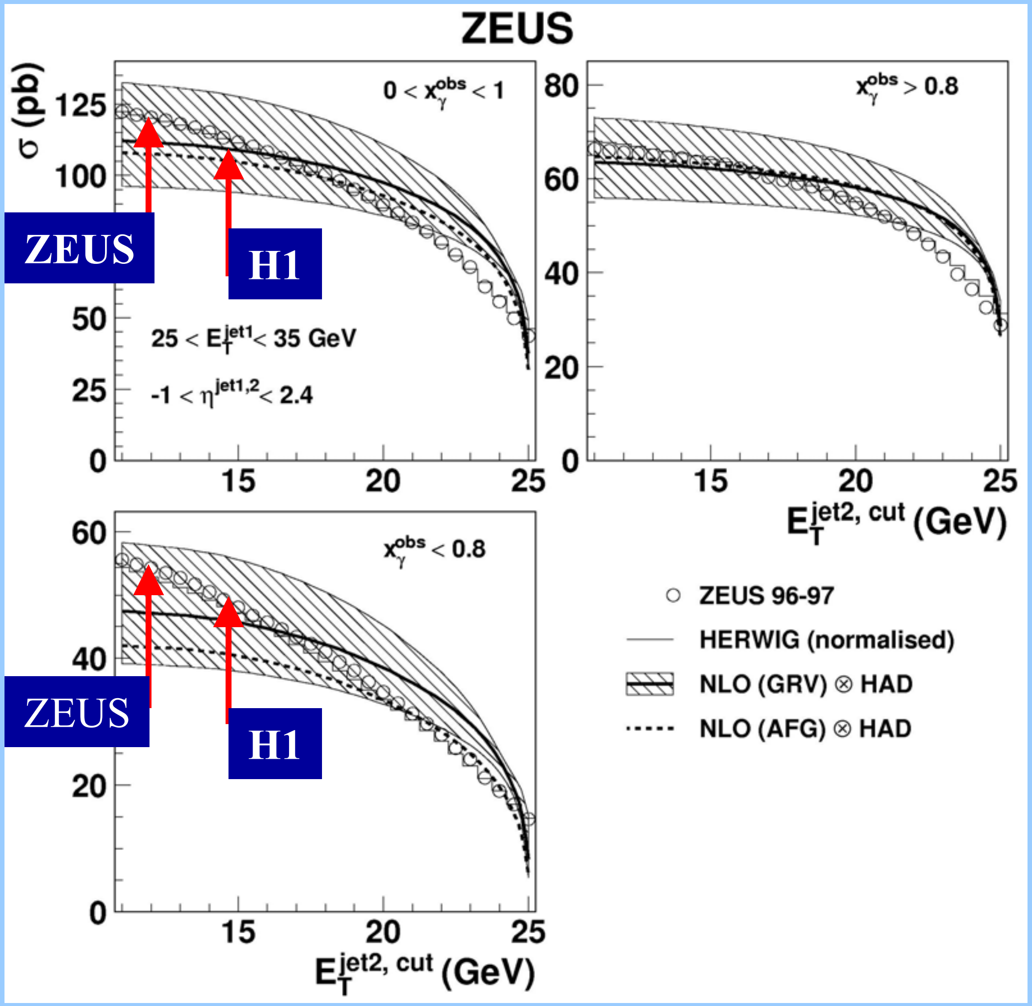
AFG



NLO describes data not too bad overall, however neither GRV nor AFG pdf's provide a perfect description everywhere

The dependence of the NLO cross section on the cuts on E_T

- Assymetric E_{T1}/E_{T2} jet cuts to avoid infrared sensitivity of NLO calculations
- dependence on E_{T2} significantly different for data and NLO
- HERWIG describes dependence quite well



Comparison of data &NLO depends on the cut value!

Theoretical progress needed!!

Inclusive jets: H1 and ZEUS

H1

two samples:

$Q^2 < 1\ GeV^2$; $E_T > 21\ GeV$, $-1 < \eta < 2.5$

$Q^2 < 10^{-2}\ GeV^2$; $5 < E_T < 21\ GeV$, $-1 < \eta < 2.5$

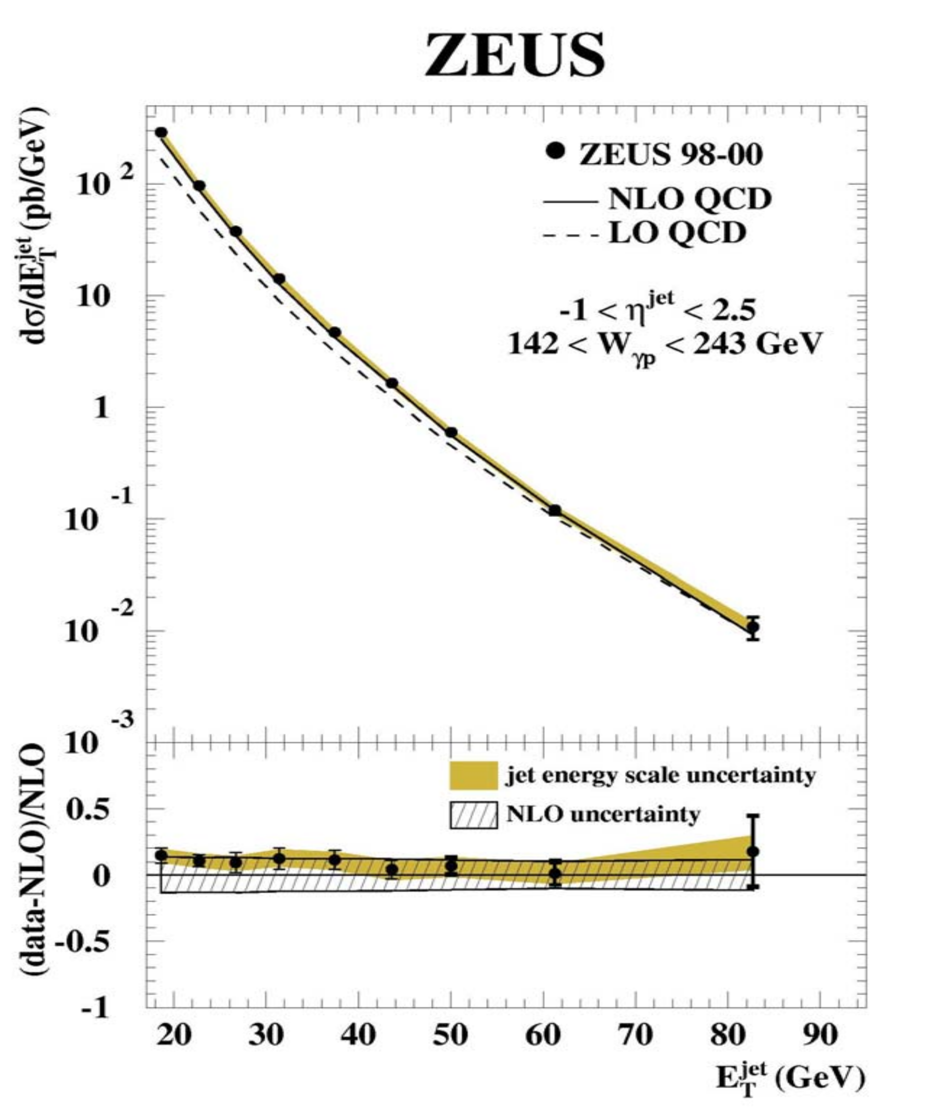
k_t long. inv. jet algorithm

ZEUS

$Q^2 < 1\ GeV^2$; $E_T > 13\ GeV$, $-1 < \eta < 2.5$

k_t long. inv. jet algorithm

Inclusive jets in photoproduction-ZEUS

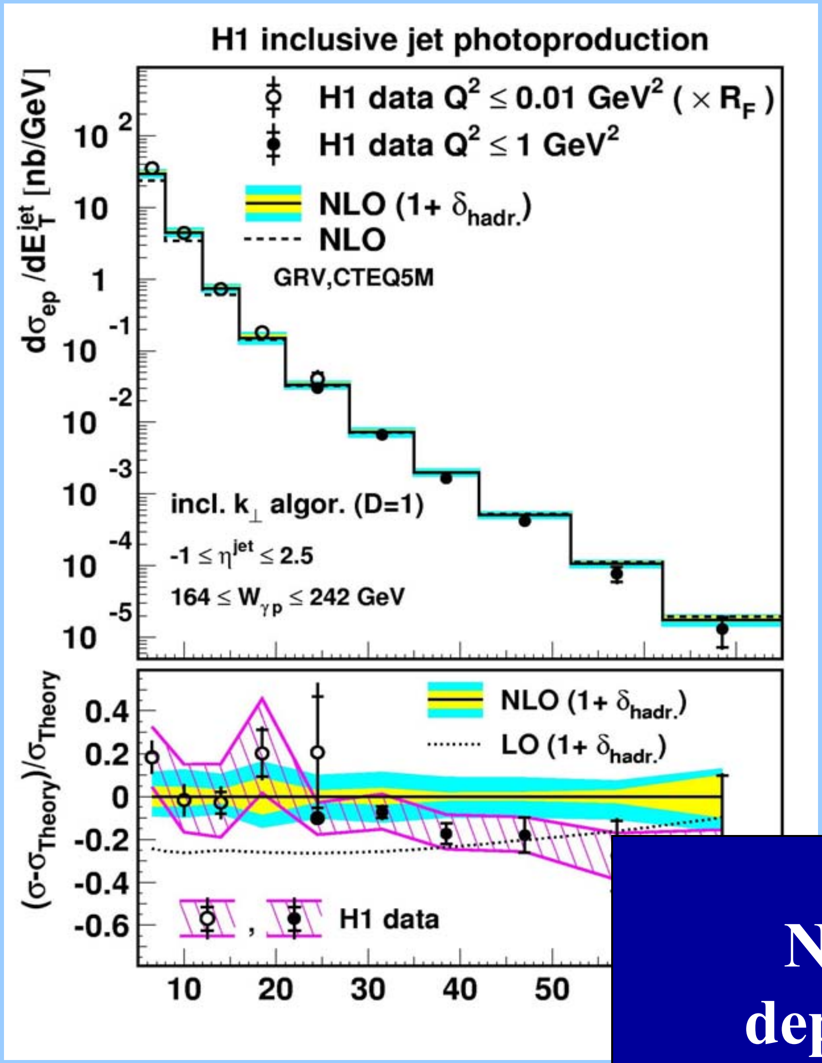


ZEUS collab.,DESY-03-012

The measured cross section falls over five orders of magnitude

NLO → a good description of the data within uncertainties

Inclusive jets in photoproduction-H1



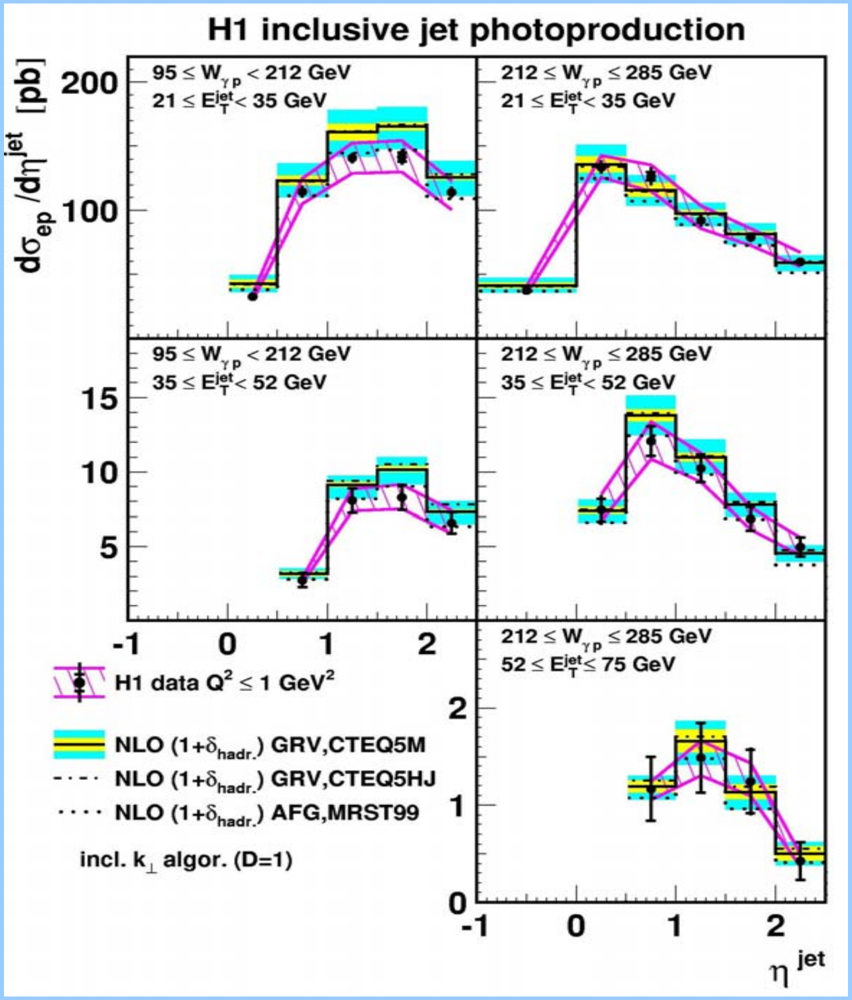
H1 collab.,DESY-02-225

Analysis of "low" E_T and "high" E_T jet sample agree well in their domain of overlap

The measured cross section falls by 6 orders of magnitude between E_T=5 and 75 GeV

NLO calculations describe E_T dependence of dijet cross section within errors quite satisfactorily

Inclusive jets in photoproduction-H1



NLO QCD with GRV-HO gives the best description of the data

AFG prediction lower by 10-15%

NLO calculations describe the measured η distribution both in normalisation and shape within uncertainties

Conclusions

- **Inclusive cross sections in photoproduction described by NLO calculations very well.**
- **Dijet cross sections described by NLO not so perfectly.**

- **Theoretical uncertainties are dominating, theoretical progress needed!!**

- **The current precision does not allow one to discriminate between different photon parton distribution functions.**