



Inclusive-jet cross sections in photoproduction

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Outline:

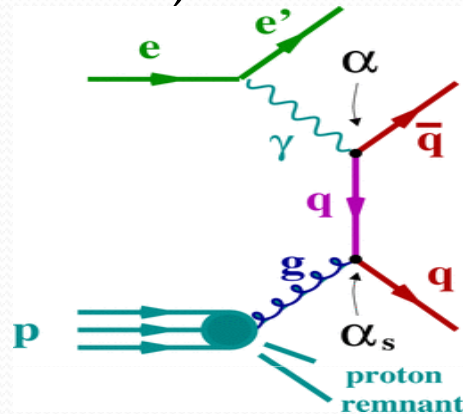
1. Motivation
2. Definition of the measurements
3. Fixed-order QCD calculations
4. Results
5. α_s extraction
6. Summary

On behalf of the ZEUS collaboration

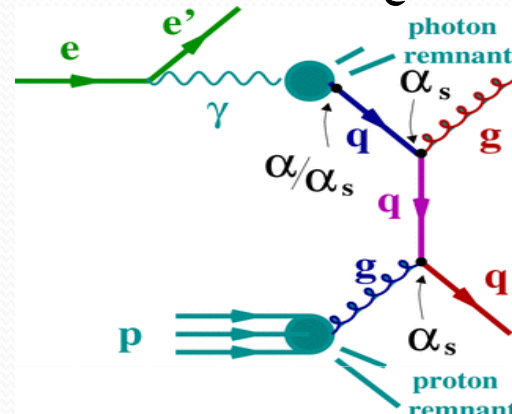


Motivation

- Photoproduction is the main source of jets at HERA. Two processes contribute to the jet cross sections at lowest-order QCD.



Direct process



Resolved process

In pQCD:

$$d\sigma_{ep}^{jet} = \sum_{a,b=q,\bar{q},g} \int dy f_{\gamma/e}(y) \iint dx_p dx_\gamma f_p(x_p, \mu_F) f_\gamma(x_\gamma, \mu_F) d\hat{\sigma}_{ab}(x_p, x_\gamma, \mu_R)$$

- Jet cross sections in photoproduction provide a testing ground for pQCD:
 - extraction of $\alpha_s(M_Z)$ and test of the running of α_s ;
 - constraints on the proton PDFs: inclusion of jets in photoproduction in ZEUS-jets PDF fit provided constraint of gluon density at medium to high x ;
 - constraints on the photon PDFs.

Definition of the cross sections and phase space

- Inclusive jet cross sections
(every jet of hadrons in each event)

$\frac{d\sigma}{dE_T^{\text{jet}}}$	$\frac{d\sigma}{d\eta^{\text{jet}}}$ for different E_T^{jet} thresholds
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$\frac{d\sigma}{dE_T^{\text{jet}}}$	in different regions of η^{jet}
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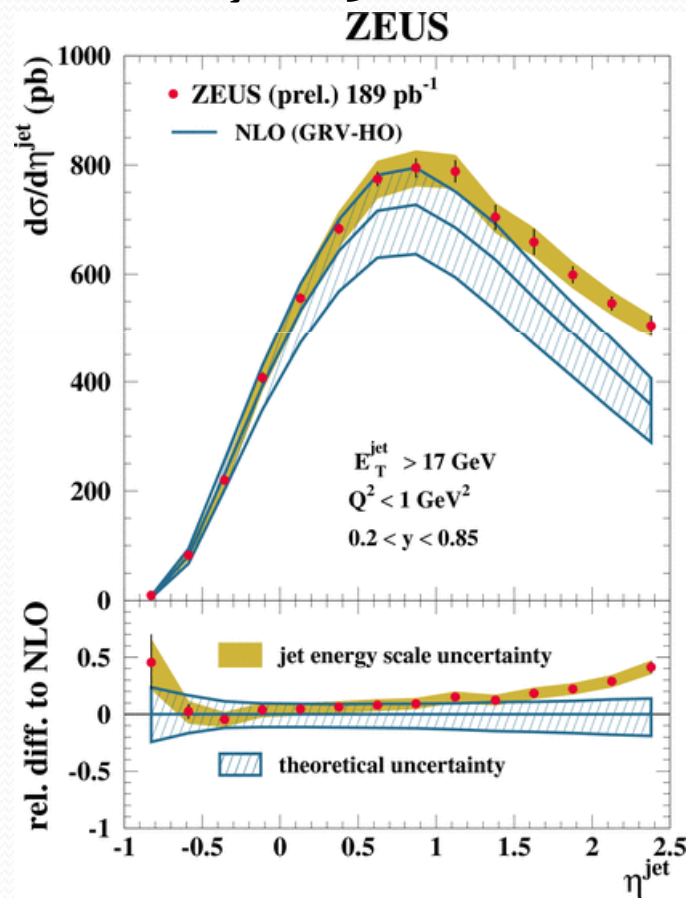
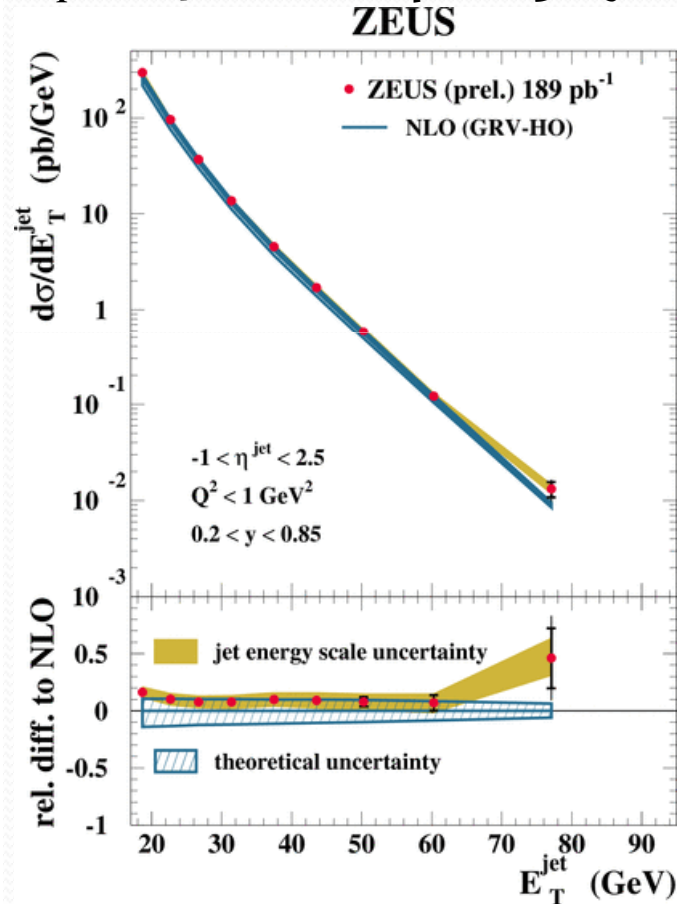
- Kinematic region:
 - $Q^2 < 1 \text{ GeV}^2$ – photon virtuality;
 - $0.2 < y < 0.85$ – inelasticity
($W_{\gamma p} = \sqrt{s \cdot y}$ – γp center-of-mass energy).
- At least one jet reconstructed with k_T cluster algorithm in the longitudinally invariant inclusive mode (Snowmass convention).
- $-1 < \eta^{\text{jet}} < 2.5$ and $E_T^{\text{jet}} > 17 \text{ GeV}$.

Integrated luminosity $L = 189 \text{ pb}^{-1}$
 Number of jets $\sim 400,000$

Results

$L = 189 \text{ pb}^{-1}$

Single-differential inclusive-jet photoproduction cross sections as functions of E_T^{jet} and η^{jet}
 $E_T^{\text{jet}} > 17 \text{ GeV}$, $-1 < \eta^{\text{jet}} < 2.5$, $Q^2 < 1 \text{ GeV}^2$, $0.2 < y < 0.85$



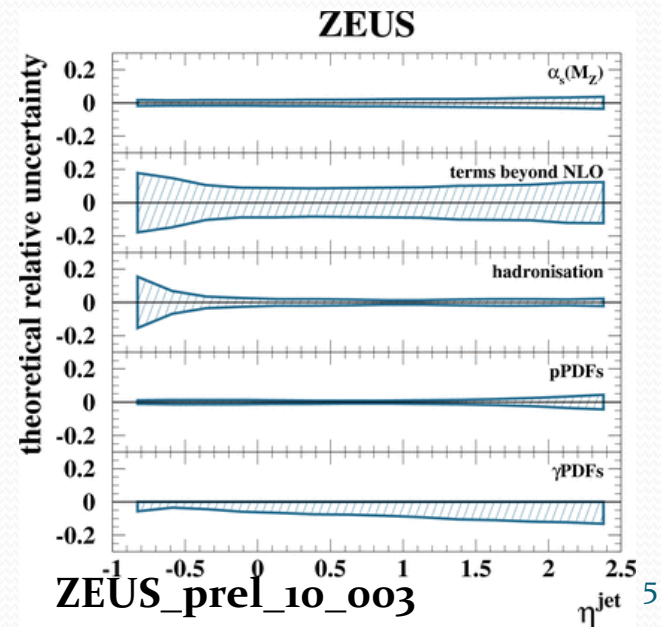
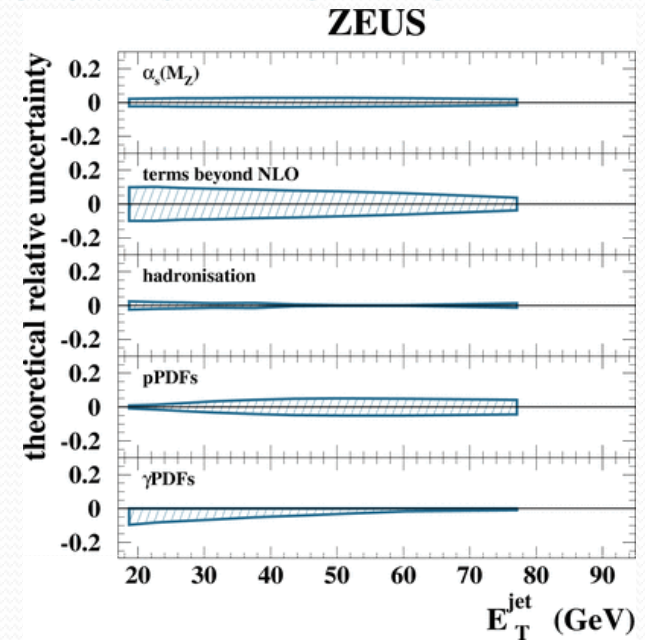
Small experimental uncertainties:

- uncorrelated
- $\pm 2\%$ (low E_T^{jet})
- $\pm 7\%$ ($E_T^{\text{jet}} \sim 60 \text{ GeV}$)
- jet-energy scale
- $\pm 4\%$ (low E_T^{jet})
- $\pm 8\%$ ($E_T^{\text{jet}} \sim 60 \text{ GeV}$)

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Fixed-order QCD calculations

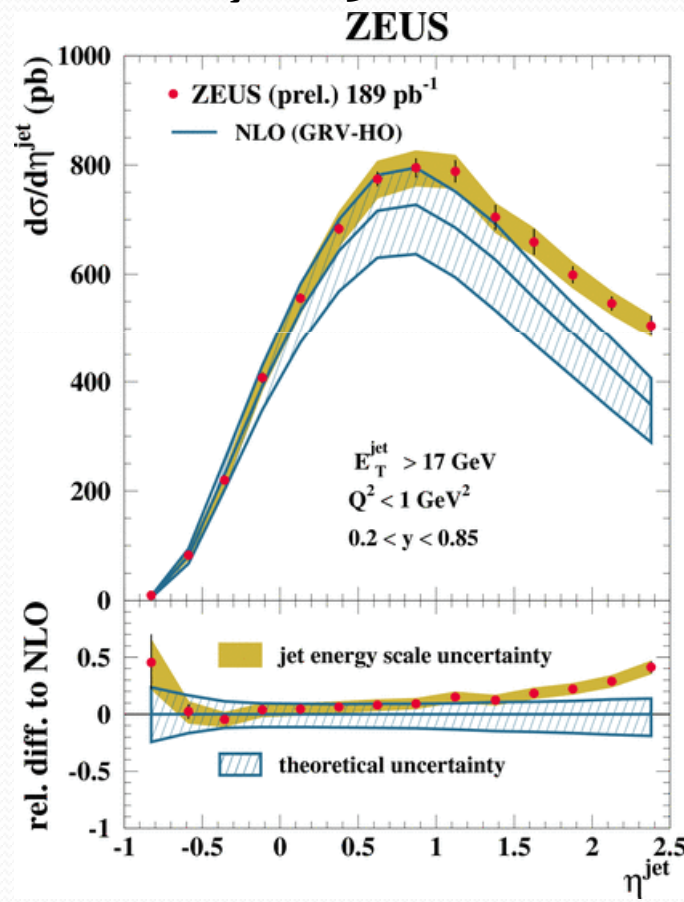
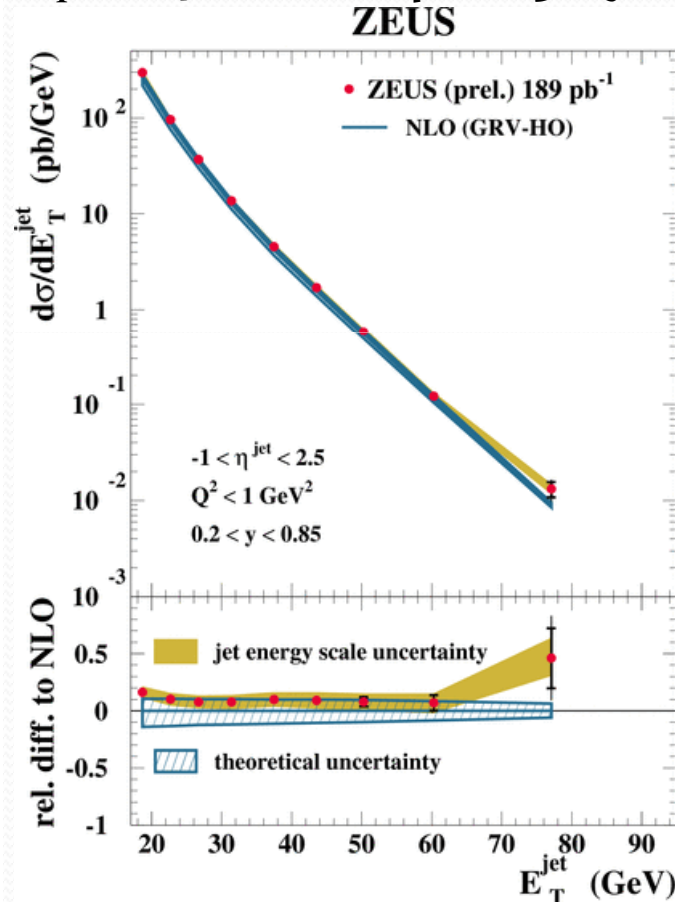
- Jet cross sections were calculated at NLO using M. Klasen, T. Kleinwort and G. Kramer [Eur. Phys. J. Direct **C** 1, 1 (1998)] program:
 - pPDFs: ZEUS-S; γ PDFs: GRV-HO;
 - Renormalization and factorization scales: $\mu_R = \mu_F = E_T^{\text{jet}}$;
 - calculations corrected for hadronization effects.
- Contribution to the theoretical uncertainty in the cross sections considered:
 - terms beyond NLO: variation of μ_R by factors 2 and $1/2$;
 - pPDFs: using error analysis from ZEUS-S sets;
 - value of $\alpha_s(M_Z)$;
 - modelling of parton shower and hadronization: PYTHIA vs HERWIG;
 - γ PDFs: using AFG04 sets.



Results

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 $E_T^{\text{jet}} > 17 \text{ GeV}$, $-1 < \eta^{\text{jet}} < 2.5$, $Q^2 < 1 \text{ GeV}^2$, $0.2 < y < 0.85$



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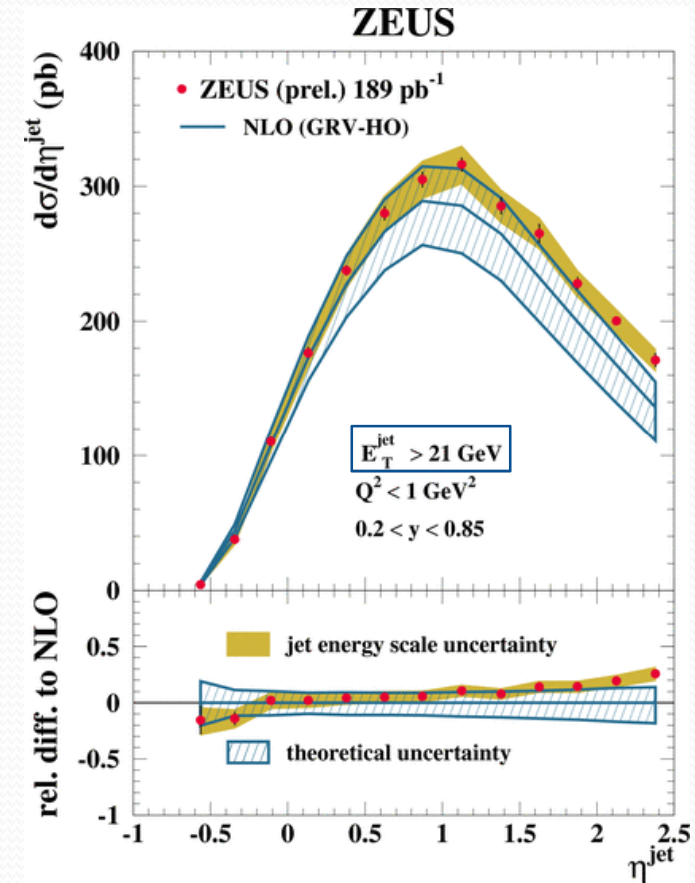
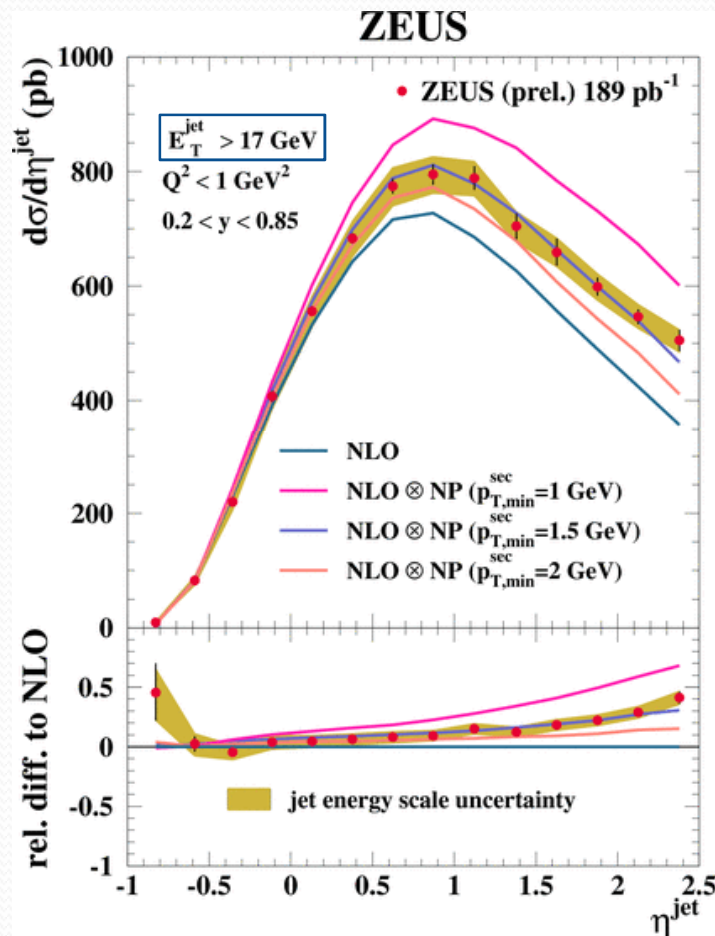
Good description of data in shape and normalization by NLO QCD except low E_T^{jet} and high η^{jet}

Discrepancies might be due to non-perturbative effects or γ PDFs parametrization 6

Results

$L = 189 \text{ pb}^{-1}$

Study of the influence of non-perturbative effects at low E_T^{jet} , high η^{jet}



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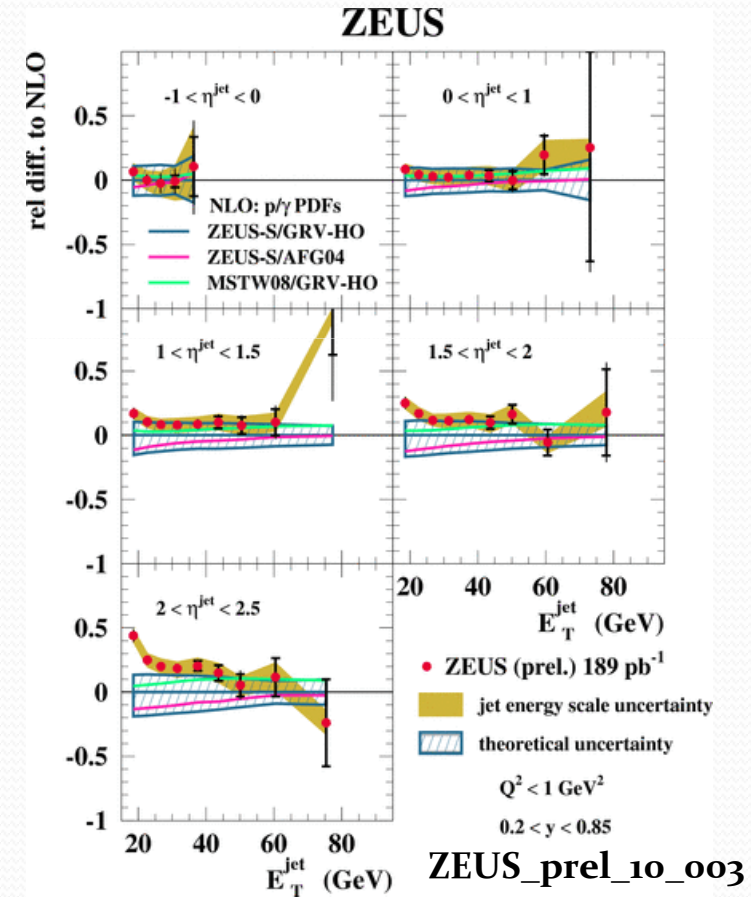
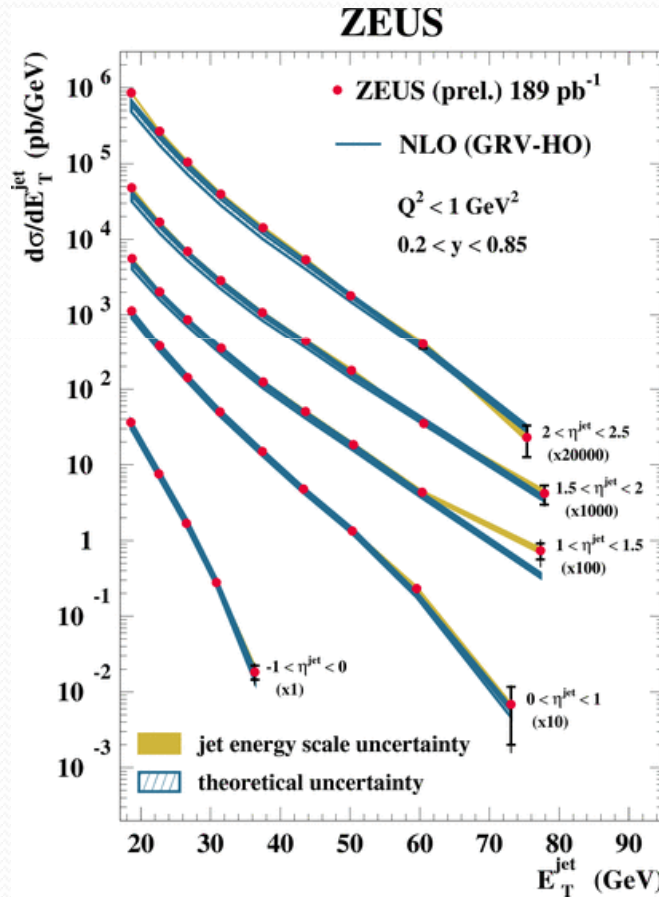
- Non-perturbative contribution increases jet rate in regions where discrepancies between data and NLO are observed.
- Disagreement between data and NLO disappears when increasing $E_T^{\text{jet}} > 21 \text{ GeV}$.

Results

$L = 189 \text{ pb}^{-1}$

Double-differential inclusive-jet photoproduction cross sections as functions of E_T^{jet} in different regions of η^{jet}

$E_T^{\text{jet}} > 17 \text{ GeV}$, $-1 < \eta^{\text{jet}} < 2.5$, $Q^2 < 1 \text{ GeV}^2$, $0.2 < y < 0.85$



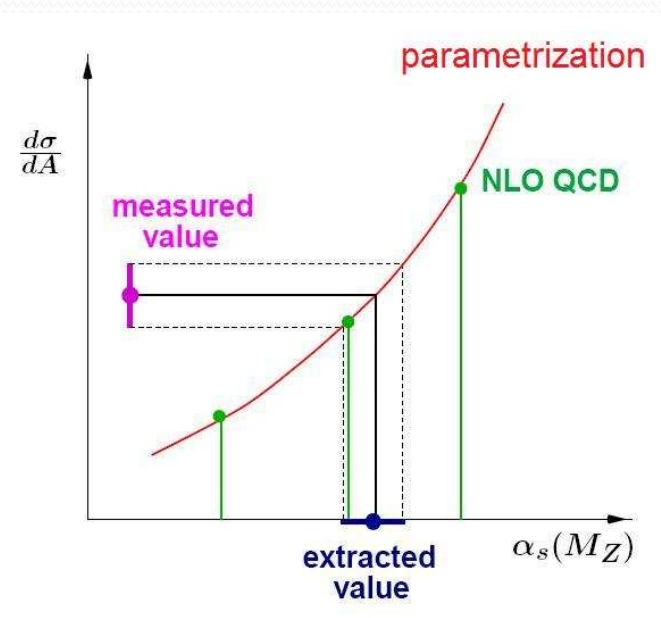
Good description of data in shape and normalization by NLO QCD except low E_T^{jet} and high η^{jet}
These precise measurements have the potential to constrain the PDFs in the proton and photon.

The method to determine α_s from jet observables

- NLO calculations based on different pPDFs using in the matrix elements the $\alpha_s(M_Z)$ value assumed in each PDF set.
- Parametrization of the α_s dependence of the prediction:

$$\frac{d\sigma^i}{dE_T^{\text{jet}}}(\alpha_s) = A_1^i \alpha_s + A_2^i \alpha_s^2.$$

- α_s determined from the measured value using this parametrization.
- This procedure handles correctly the correlation between $\alpha_s(M_Z)$ and the PDFs in the NLO calculations.

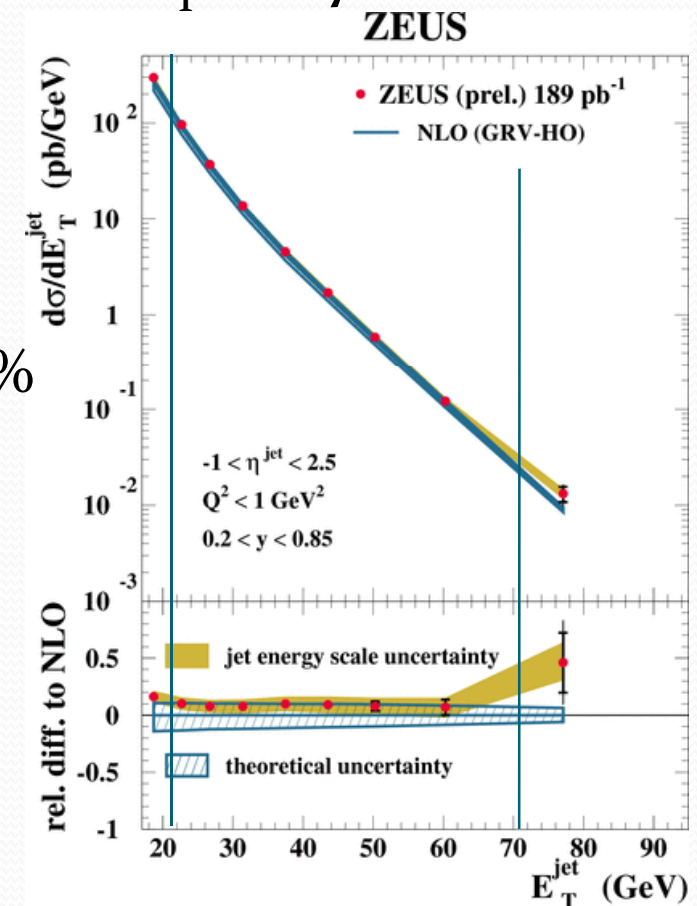


Extraction of $\alpha_s(M_Z)$

- From the measured $d\sigma/E_T^{\text{jet}}$ for $21 \text{ GeV} < E_T^{\text{jet}} < 71 \text{ GeV}$ a value of $\alpha_s(M_Z)$ was extracted:

$$\alpha_s(M_Z) = 0.1208^{+0.0030}_{-0.0018} (\text{exp.})^{+0.0044}_{-0.0033} (\text{th.})$$

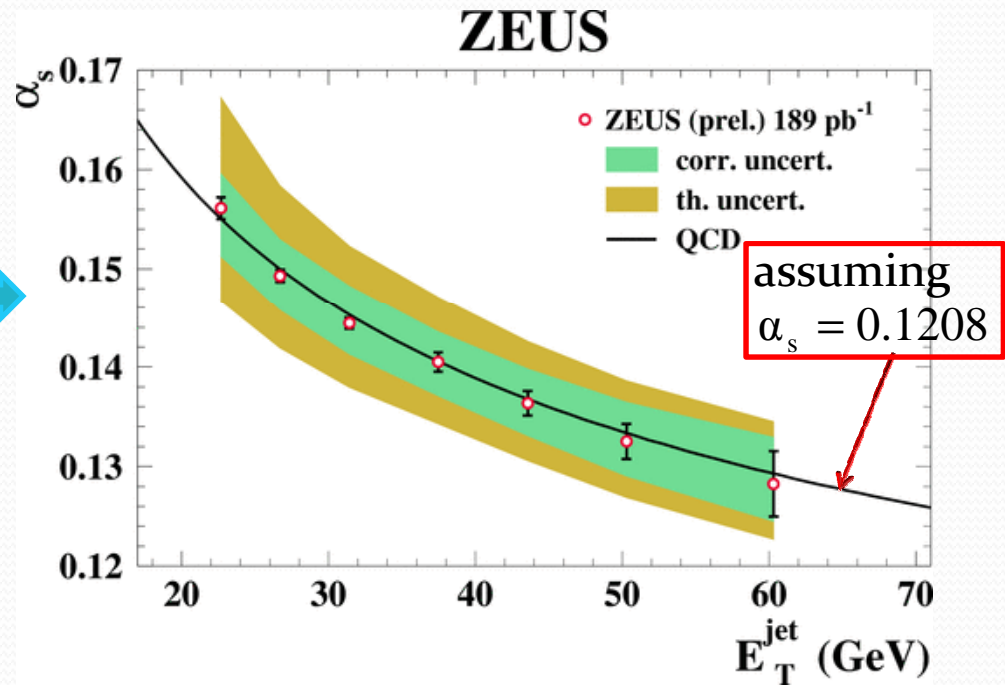
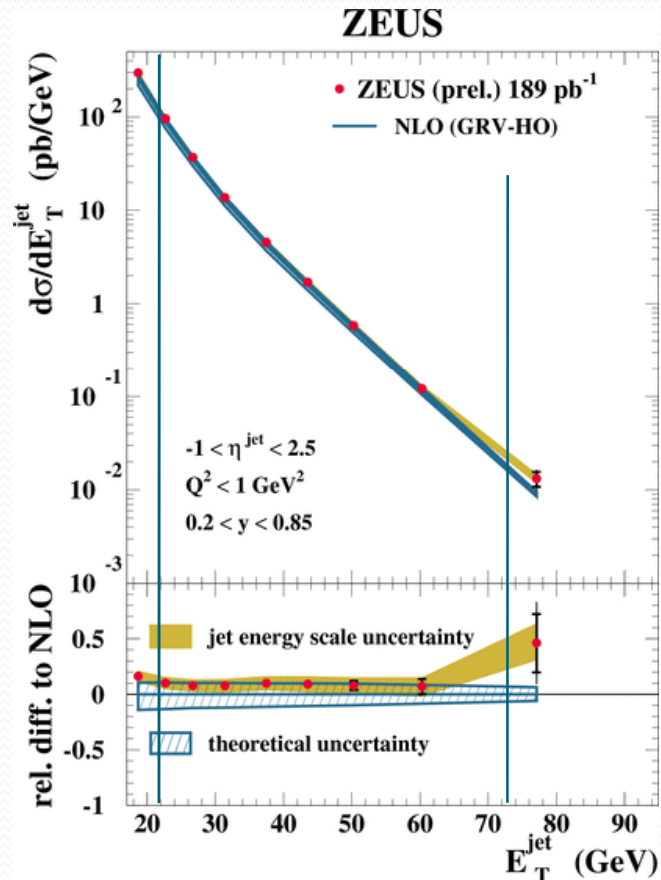
- Experimental uncertainties:
 - dominated by jet energy-scale uncertainty: $+2.2\%$ -1.2%
- Theoretical uncertainties:
 - terms beyond NLO: $+2.4\%$ -2.5%
 - uncertainties from proton PDF: $\pm 1\%$
 - uncertainties from photon PDF: $+2.4\%$
 - hadronization: $\pm 0.5\%$



Precise value of $\alpha_s(M_Z)$ from inclusive-jet photoproduction, in agreement with the world average and other determinations

Test of energy-scale dependence α_s

The QCD prediction for the energy-scale dependence of the coupling was tested by determining α_s from the measured $d\sigma/dE_T^{\text{jet}}$ at different E_T^{jet} values:

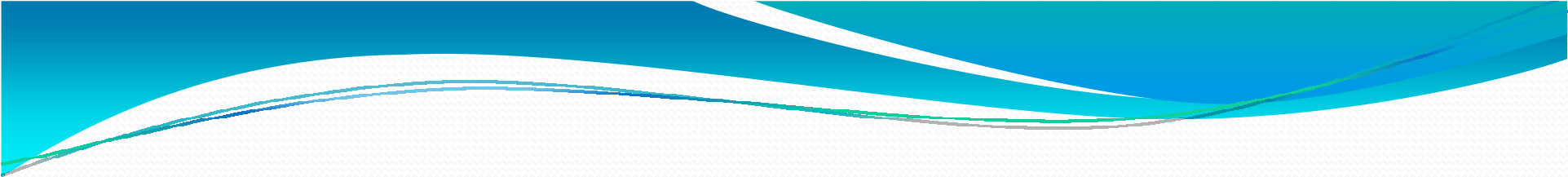


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The results are in good agreement with the predicted running of α_s over a wide range in E_T^{jet} from a single measurement

Summary

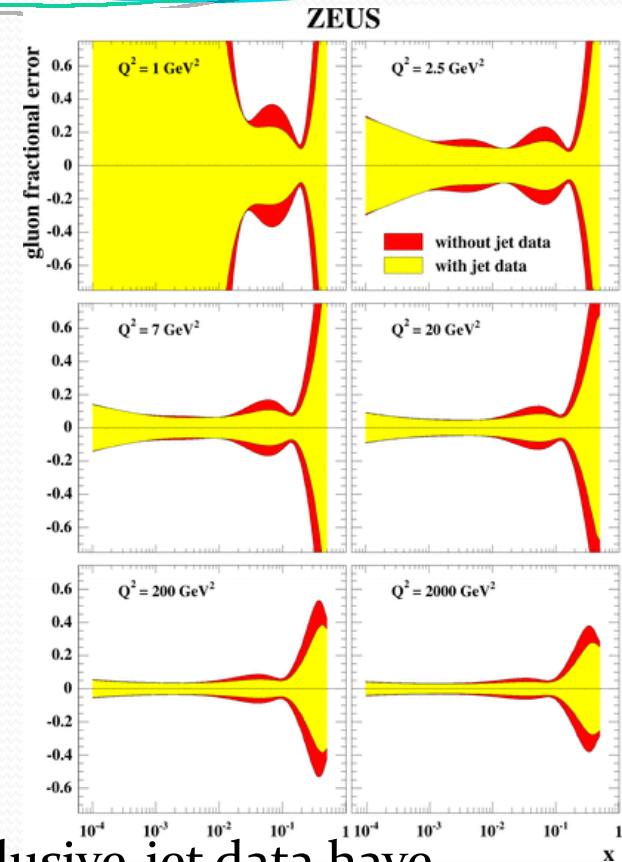
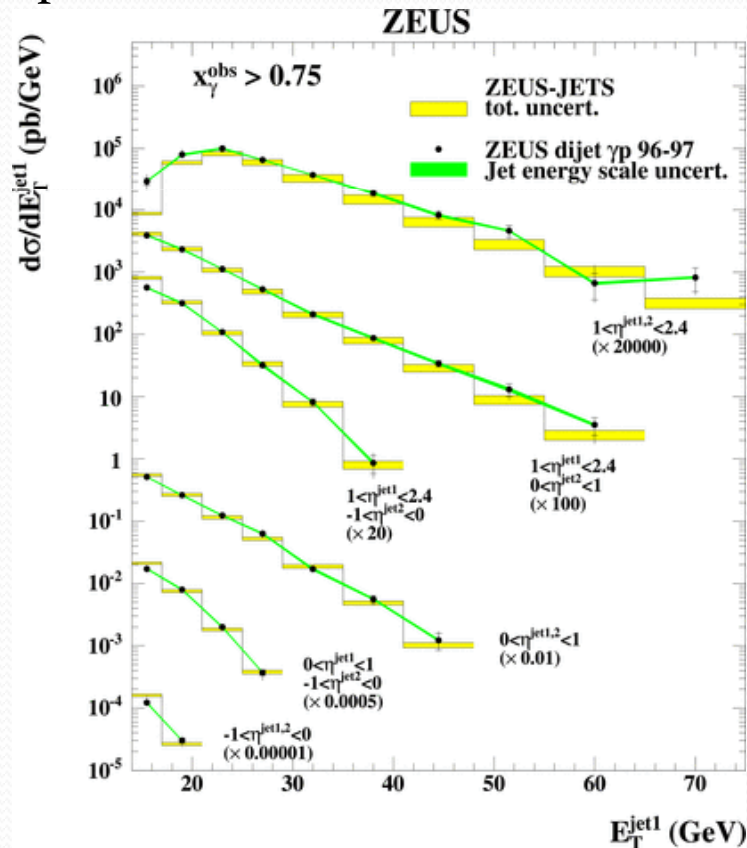
- What has been presented:
 - new precise measurements of single- and double-differential inclusive-jet photoproduction cross sections;
 - precise determination of $\alpha_s(M_Z)$;
 - precise test of the running of α_s in a wide range of E_T^{jet} .
- Inclusive-jet cross sections are well described by NLO calculations except at low E_T^{jet} and high η^{jet} .
- Excess in the high- η^{jet} and low- E_T^{jet} regions might be explained by a possible presence of non-perturbative effects or poorly constrained γ PDF.
- New $\alpha_s(M_Z)$ determination is consistent with others from ZEUS and the world average.



Back-up slides

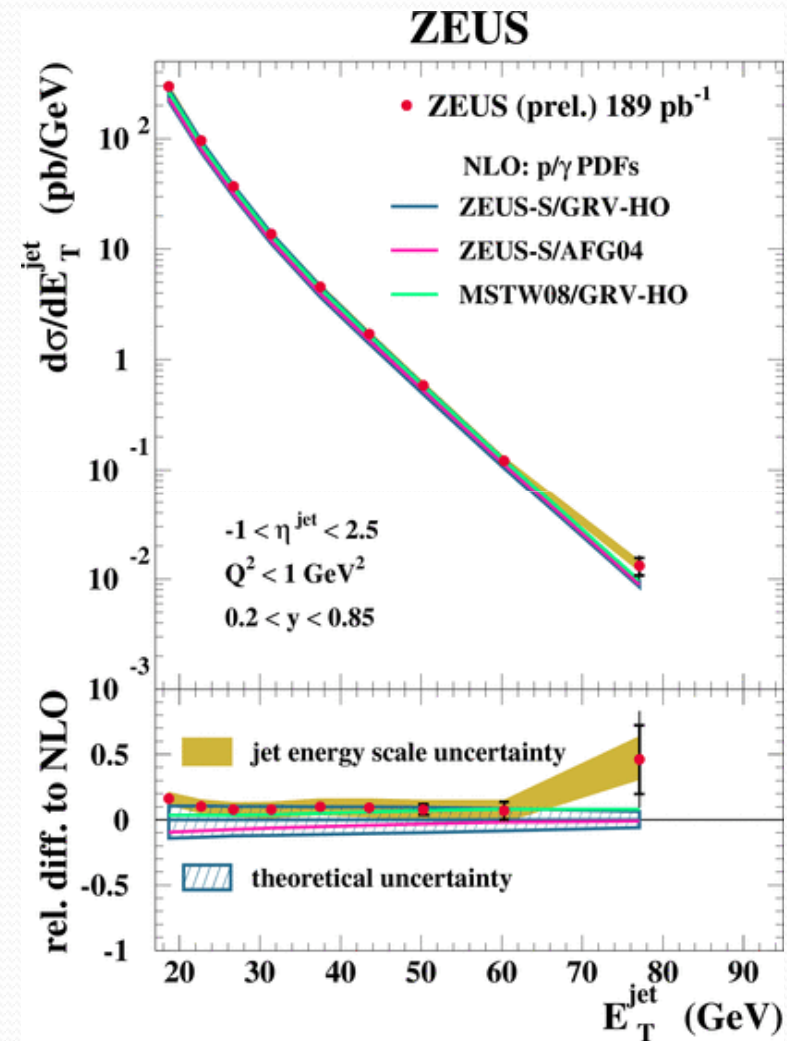
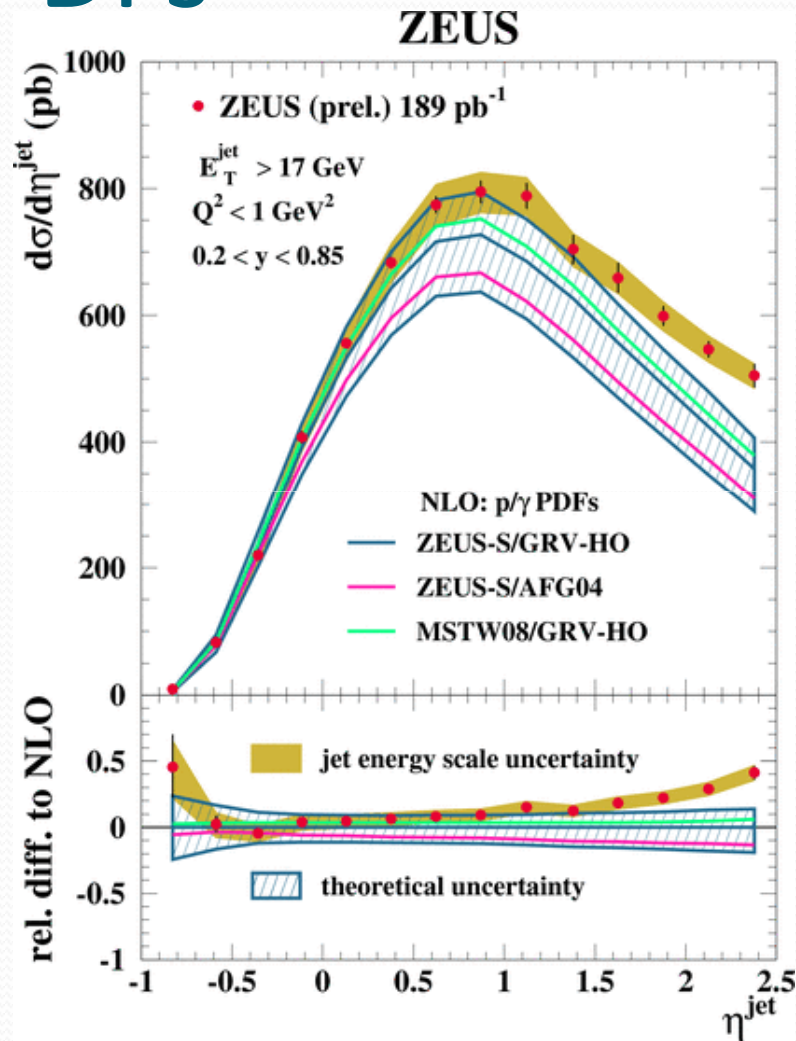
Motivation for double-differential cross section

- Dijet cross sections in photoproduction have helped to constrain the gluon PDF in the proton.



- New precise inclusive-jet data have the potential for further constraints.
- Such cross sections could also be used to constrain the γ PDFs, in particular, poorly known gluon component.

Influence of the proton and photon PDFs



Alternative photon PDFs (AFG04) lower than default (GRV-HO) at low E_T^{jet} and high η^{jet} .
 Alternative proton PDFs (MSTW08) lower than default (ZEUS-S) at high E_T^{jet} .