Inclusive-jet cross sections in photoproduction

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2. Definition of the measurements
3. Fixed-order QCD calculations
4. Results
5. α_s extraction
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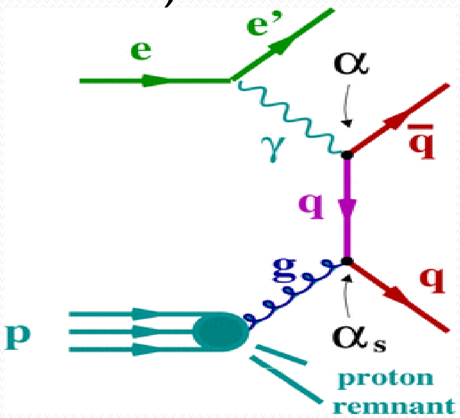
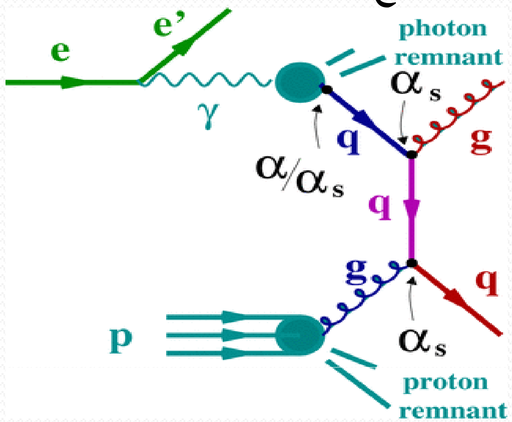
On behalf of the ZEUS collaboration

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)

$\frac{d\sigma}{dE_T^{jet}}$	$\frac{d\sigma}{d\eta^{jet}}$ for different E_T^{jet} thresholds
$\frac{d\sigma}{dE_T^{jet}}$ in different regions of η^{jet}	

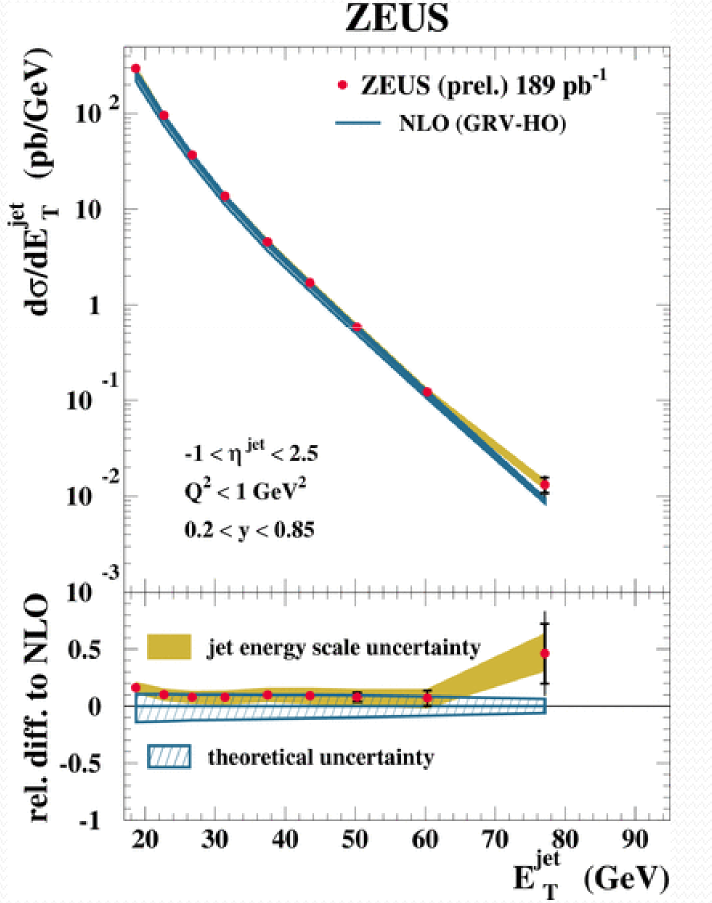
Integrated luminosity L = 189 pb^{-1}
Number of jets ~400,000

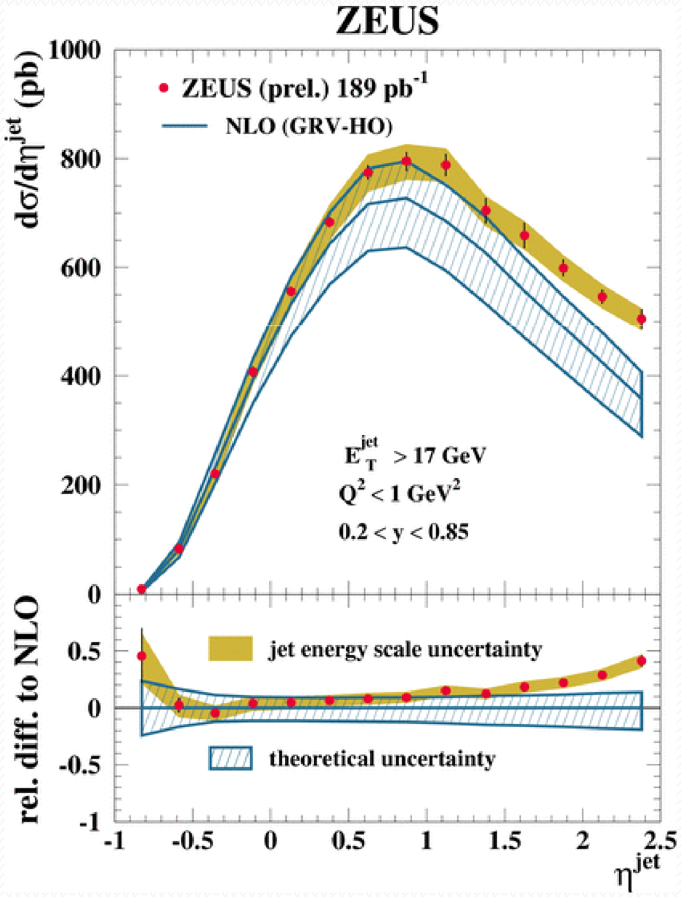
- Kinematic region:
  - $Q^2 < 1\ GeV^2$ – photon virtuality;
  - $0.2 < y < 0.85$ – inelasticity
    ($W_{\gamma p} = \sqrt{s \cdot y}$ – γp center-of-mass energy).
- At least one jet reconstructed with k_T cluster algorithm in the longitudinally invariant inclusive mode (Snowmass convention).
- $-1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

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

Single-differential inclusive-jet photoproduction cross sections as functions of E_T^{jet} and η^{jet}

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





Small experimental uncertainties:

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

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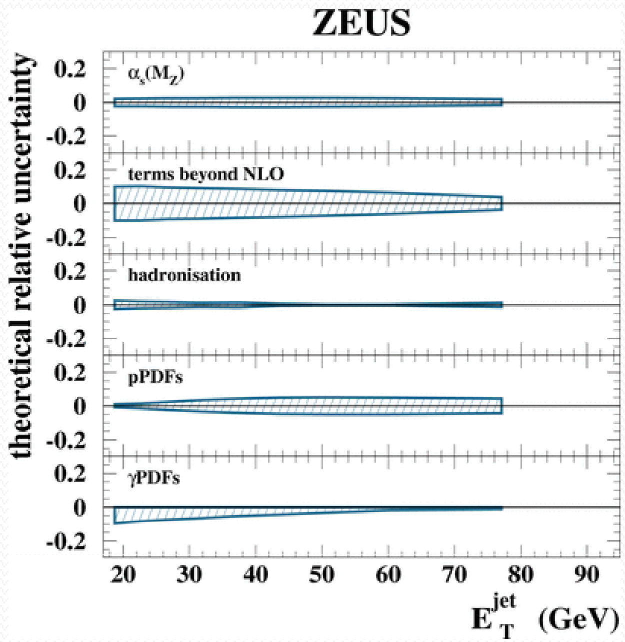
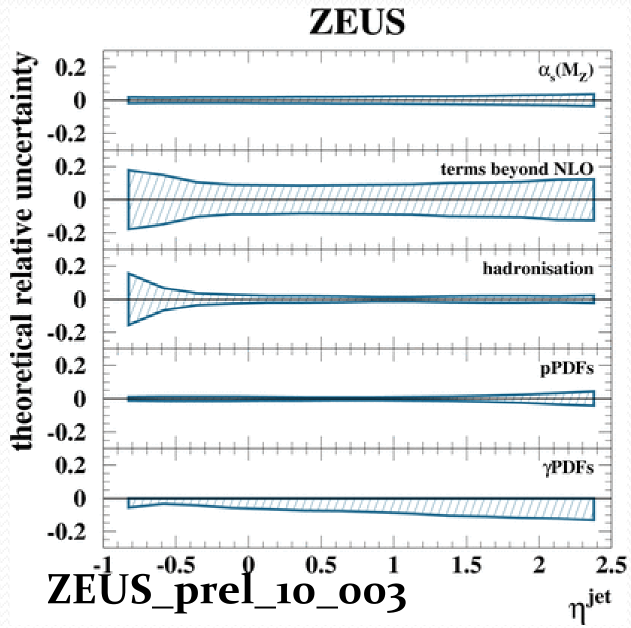
Fixed-order QCD calculations

- 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; γPDFs: GRV-HO;
  - Renormalization and factorization scales: $\mu_R = \mu_F = E_T^{jet}$;
  - calculations corrected for hadronization effects.



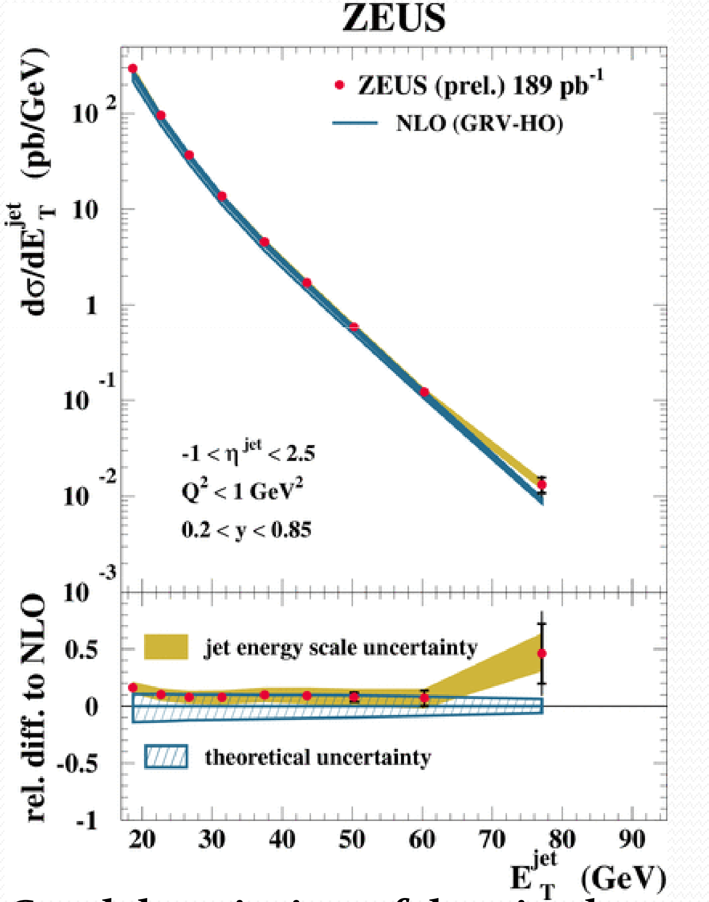
- Contribution to the theoretical uncertainty in the cross sections considered:
  - terms beyond NLO: variation of μ_R by factors 2 and ½;
  - pPDFs: using error analysis from ZEUS-S sets;
  - value of $\alpha_s(Mz)$;
  - modelling of parton shower and hadronization: PYTHIA vs HERWIG;
  - γPDFs: using AFG04 sets.

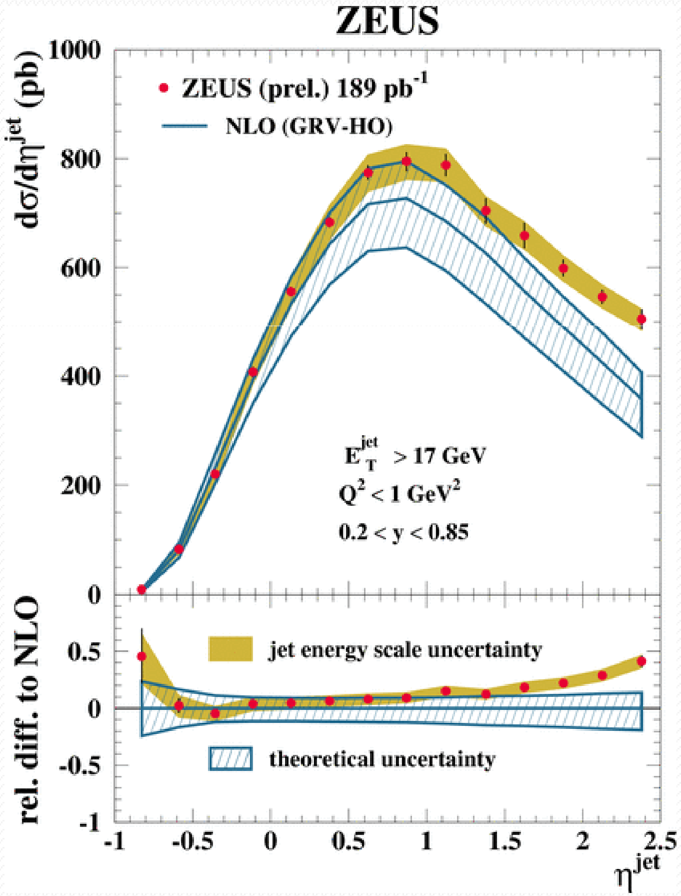


Results $L = 189\ pb^{-1}$

Single-differential inclusive-jet photoproduction cross sections as functions of E_T^{jet} and η^{jet}

E_T^{jet} > 17 GeV, -1< η^{jet} <2.5, Q^2 < 1 GeV^2, 0.2<y<0.85





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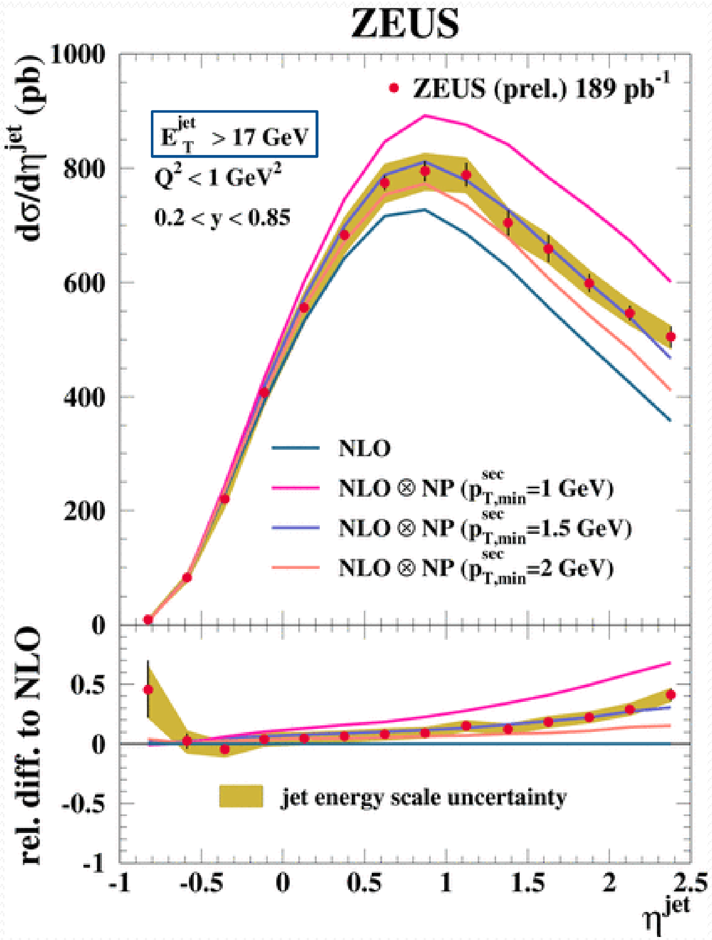
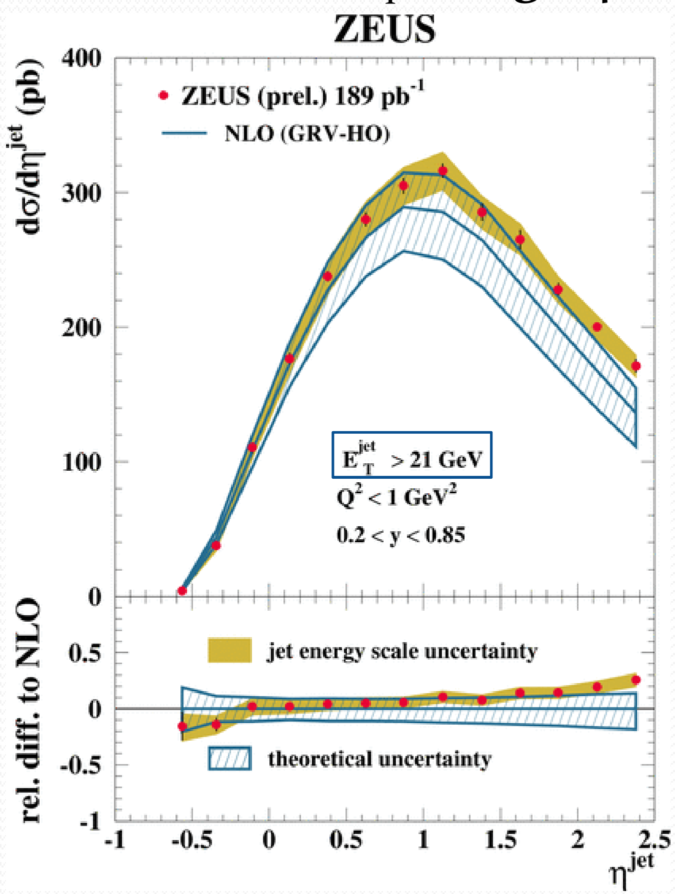
Good description of data in shape and normalization by NLO QCD except low E_T^{jet} and high η^{jet}

Discrepancies might be due to non-perturbative effects or γPDFs parametrization

Results L = 189 pb^{-1}

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





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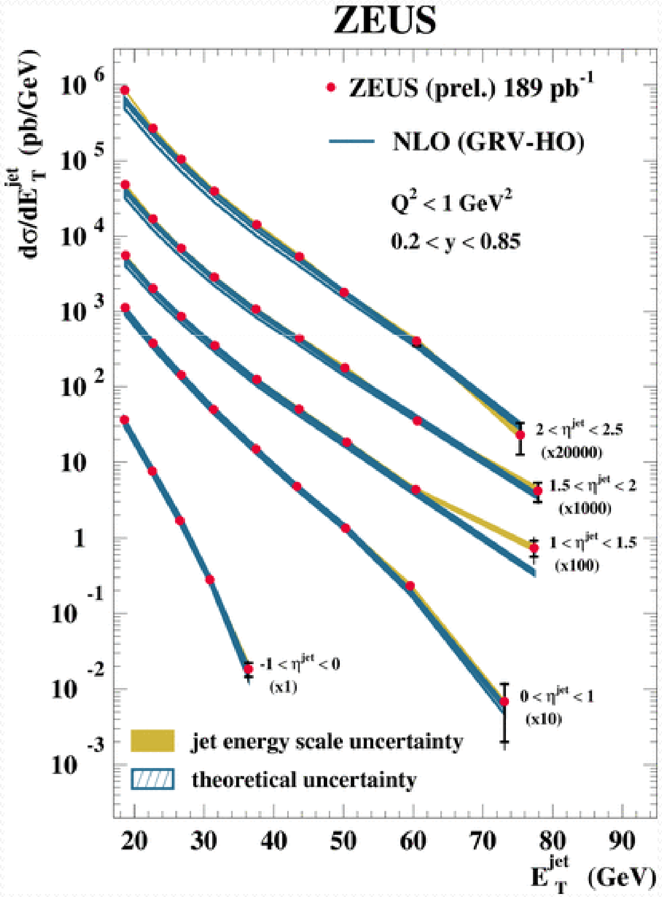
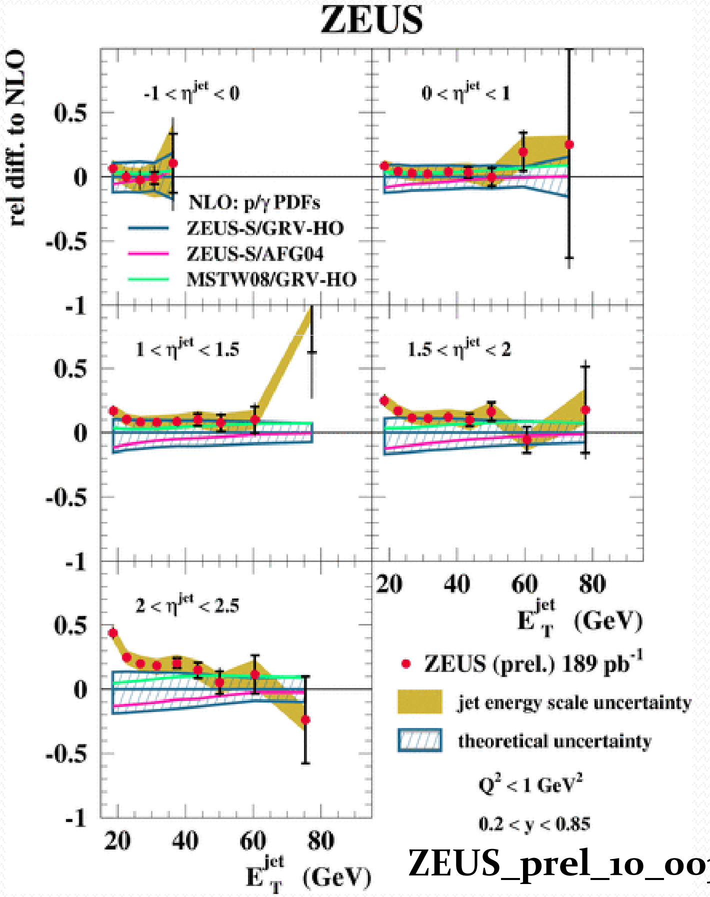
- Non-perturbative contribution increases jet rate in regions where discrepancies between data and NLO are observed.
- Disagreement between data and NLO disappears when increasing $E_T^{jet} > 21$ GeV.

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

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

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





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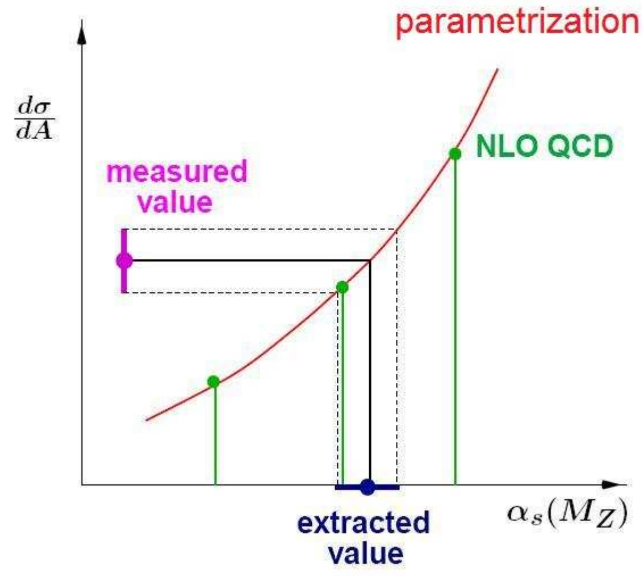
Good description of data in shape and normalization by NLO QCD except low E_T^{jet} and high η^{jet}

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:

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



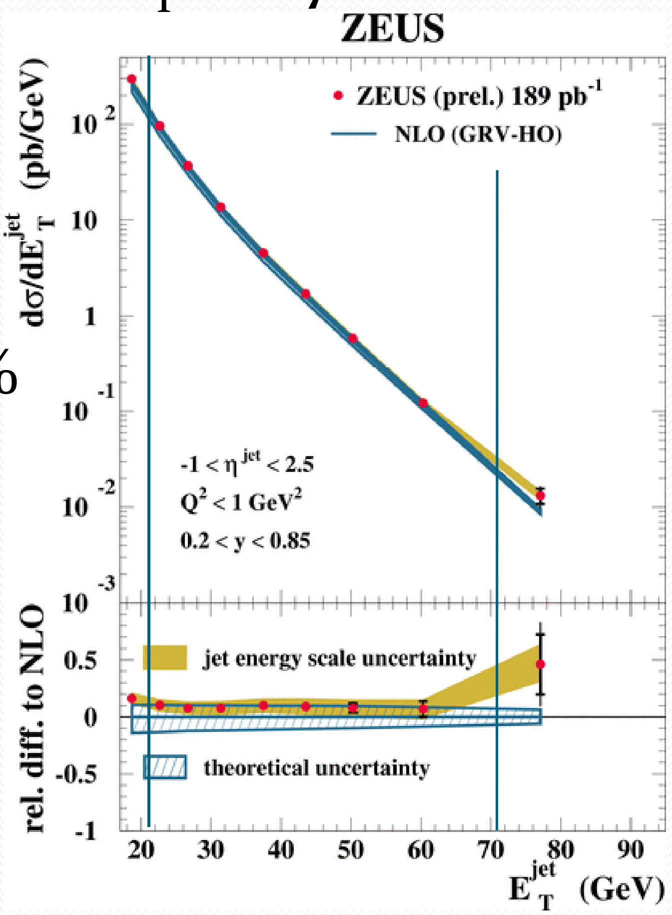
- α_s determined from the measured value using this parametrization.
- This procedure handles correctly the correlation between $\alpha_s(M_z)$ and the PDFs in the NLO calculations.

Extraction of $\alpha_s(M_z)$

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

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

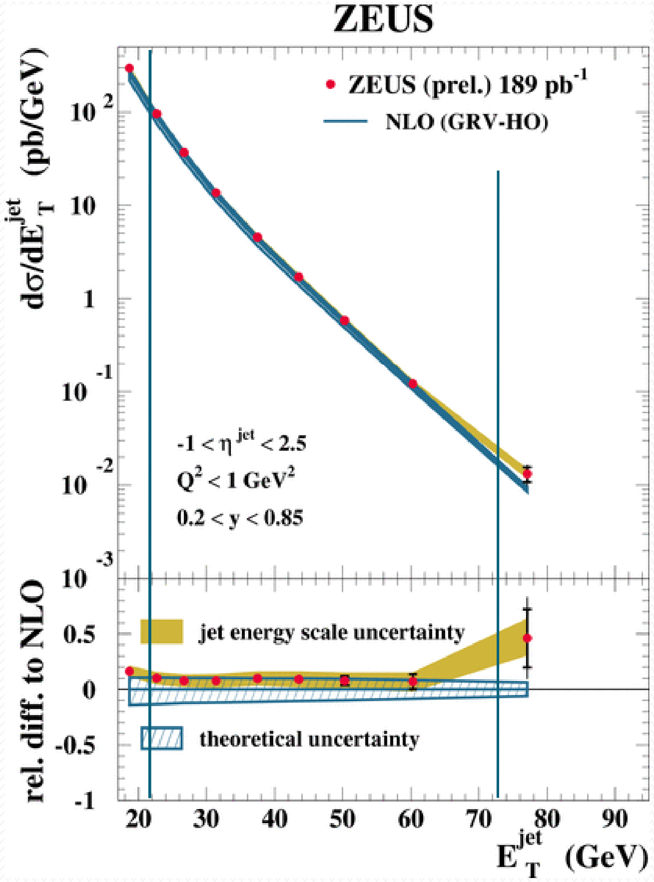
- Experimental uncertainties:
  - dominated by jet energy-scale uncertainty: $^{+2.2}_{-1.2}\%$
- Theoretical uncertainties:
  - terms beyond NLO: $^{+2.4}_{-2.5}\%$
  - uncertainties from proton PDF: $\pm 1\%$
  - uncertainties from photon PDF: $+2.4\%$
  - hadronization : $\pm 0.5\%$

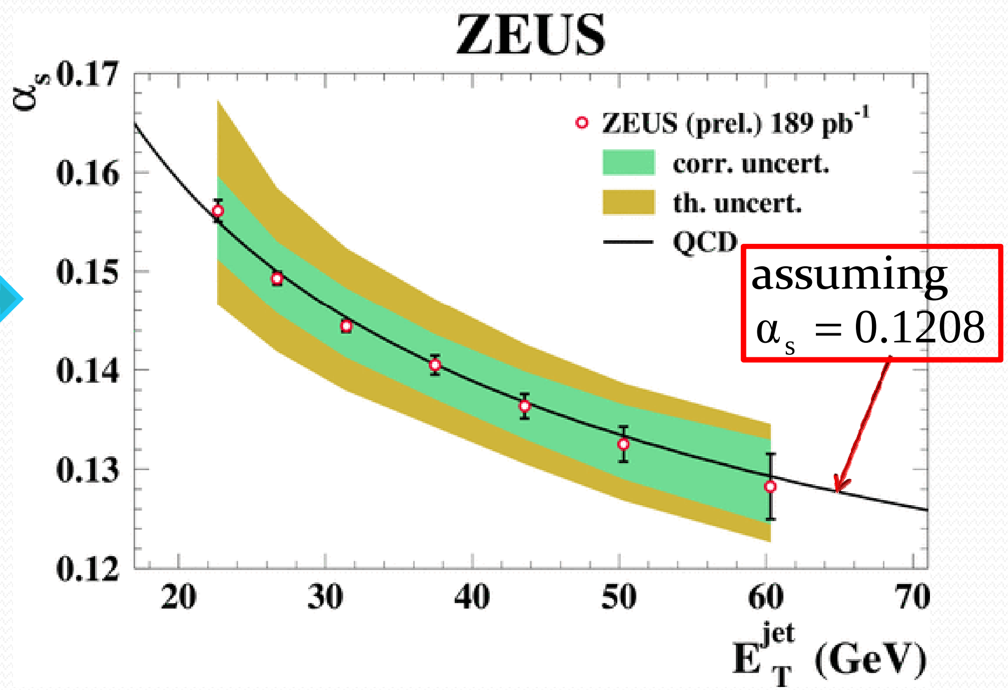


Precise value of $\alpha_s(M_z)$ from inclusive-jet photoproduction, in agreement with the world average and other determinations

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 $d\sigma/d\,E_T^{jet}$ 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

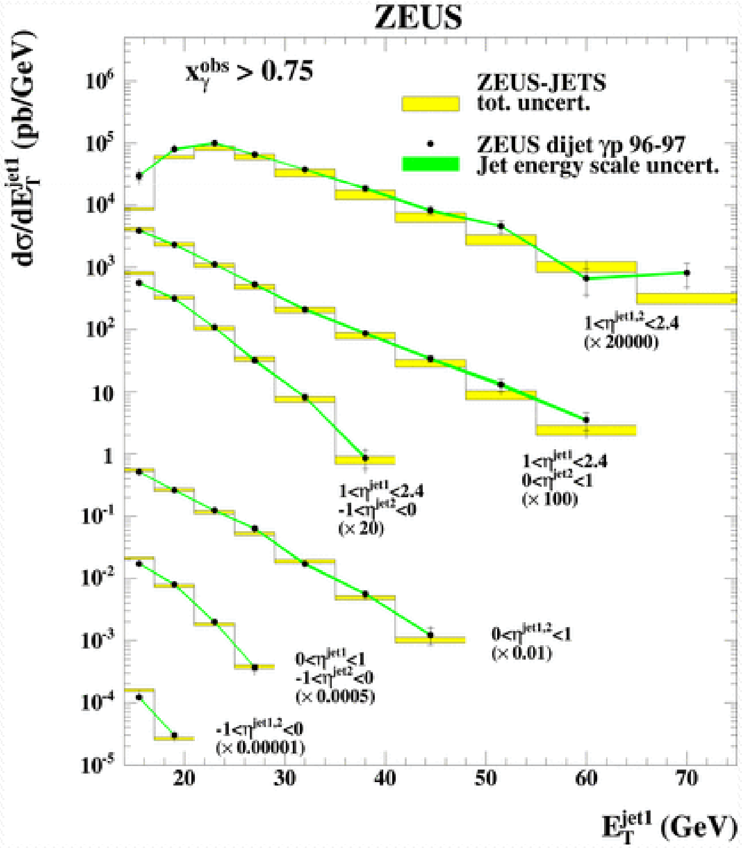
- What has been presented:
  - new precise measurements of single- and double-differential inclusive-jet photoproduction cross sections;
  - precise determination of $\alpha_s(M_Z)$;
  - precise test of the running of α_s in a wide range of E_T^{jet}.

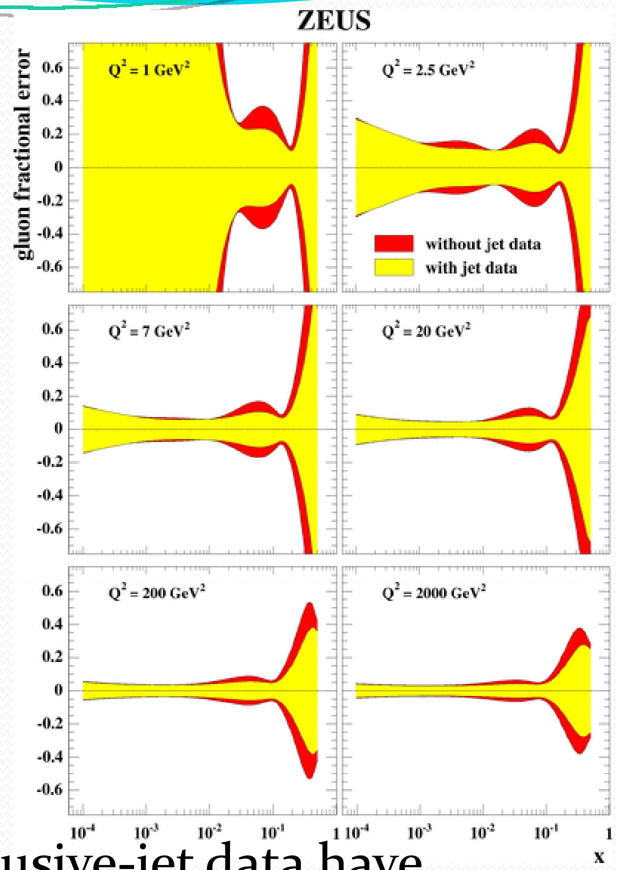
- Inclusive-jet cross sections are well described by NLO calculations except at low E_T^{jet} and high η^{jet}.
- Excess in the high-η^{jet} and low-E_T^{jet} regions might be explained by a possible presence of non-perturbative effects or poorly constrained γPDF.
- New $\alpha_s(M_Z)$ determination is consistent with others from ZEUS and the world average.

Back-up slides

Motivation for double-differential cross section

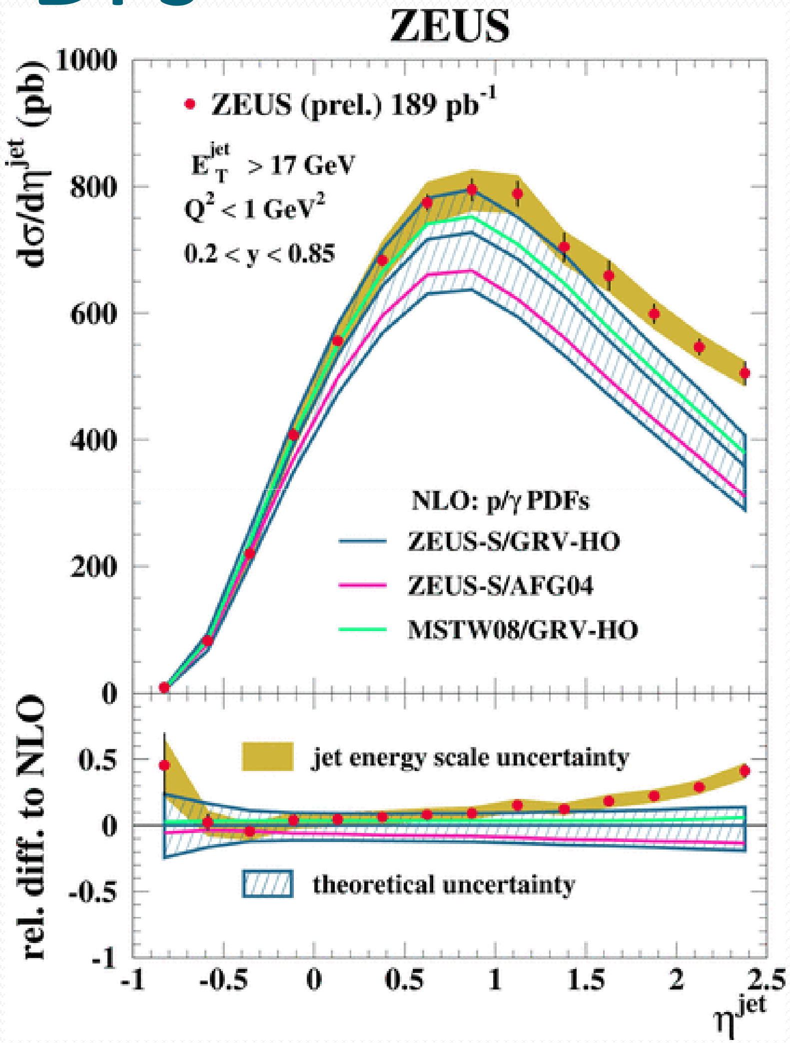
- Dijet cross sections in photoproduction have helped to constrain the gluon PDF in the proton.

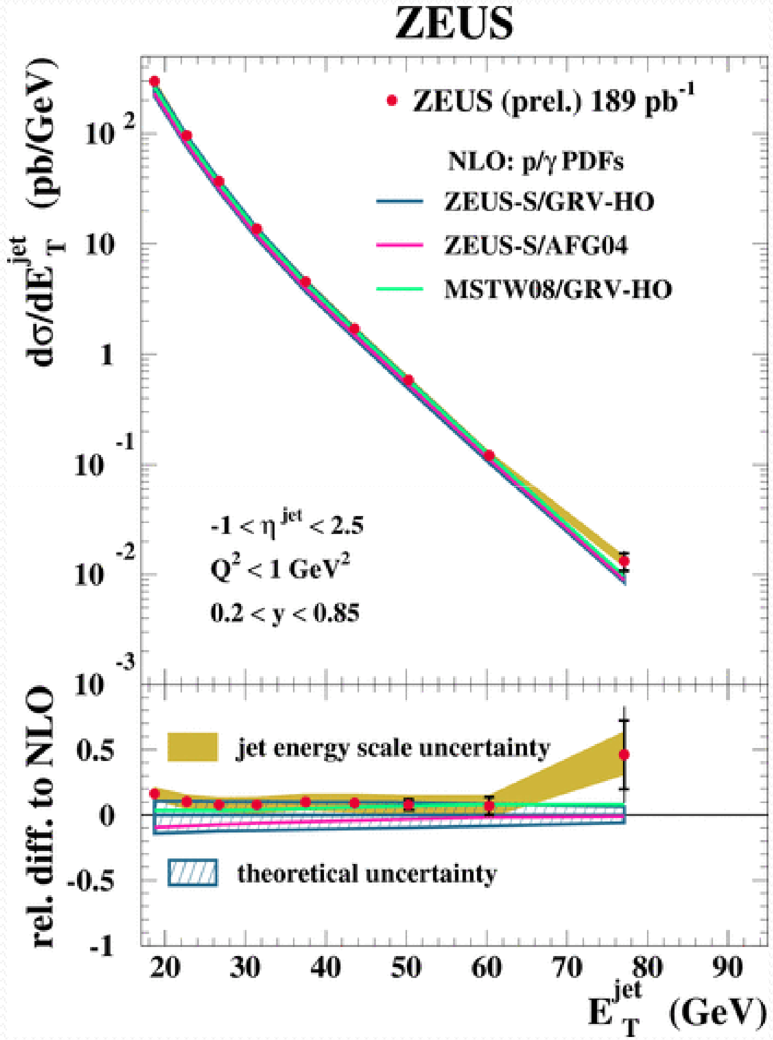




- New precise inclusive-jet data have the potential for further constraints.
- Such cross sections could also be used to constrain the γPDFs, in particular, poorly known gluon component.

Influence of the proton and photon PDFs





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