Rencontres de Moriond 2008 QCD and High Energy Interactions

Jet measurements and determinations of α_s at HERA

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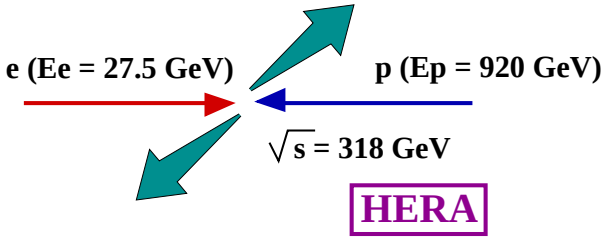
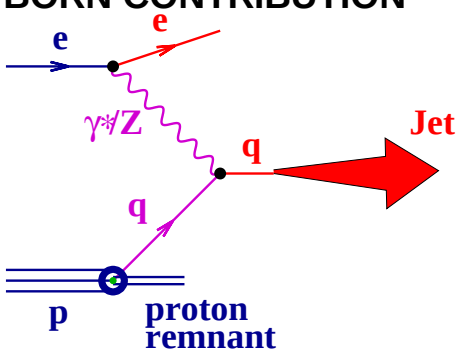


On behalf of H1 and ZEUS collaborations

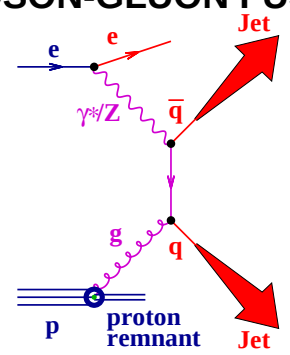
DIS cross section

- The production of jets in DIS at HERA provides a testing ground for pQCD
- Up to LO in α_s, these are the diagrams that contribute to the jet production cross section in DIS ($Q^2 \gg \Lambda^2_{QCD}$):

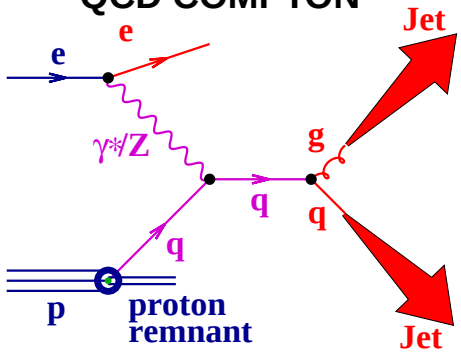
BORN CONTRIBUTION



BOSON-GLUON FUSION



QCD COMPTON

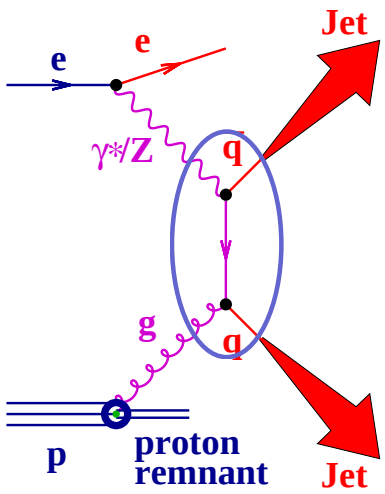


- The cross section in pQCD is given by:

$$d\sigma_{\text{jet}} = \sum_{a=q,\bar{q},g} \int dx\, f_a(x,\mu_F)\, d\hat{\sigma}_a(x,\alpha_s(\mu_R),\mu_R,\mu_F)$$

- f_a are the experimentally determined parton distribution functions
  $\longrightarrow$ long-distance structure of the interaction
- $d\hat{\sigma}_a$ is the subprocess cross section, calculable in pQCD
  $\longrightarrow$ short-distance structure of the interaction

Motivation and Outline



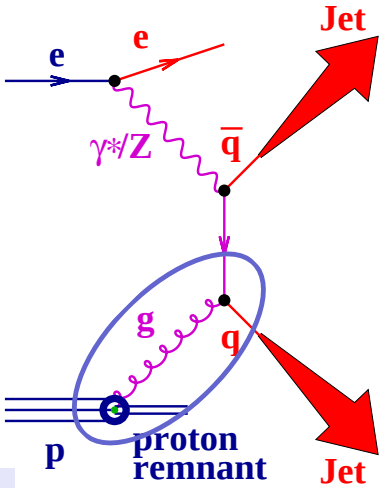
- **In regions where the PDFs are well constrained**

→ Low Q^2 region provides high statistics

→ test general aspects of pQCD

→ High Q^2 region has smaller theoretical uncertainties

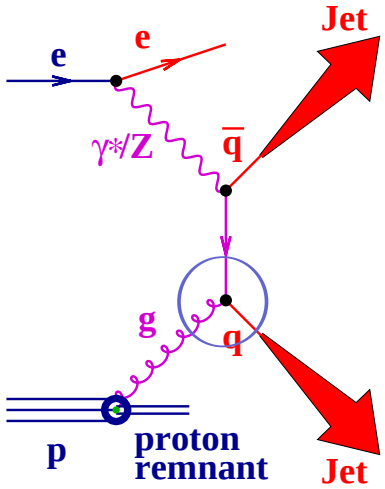
→ study jet algorithm



- **In regions where the PDFs are not as well constrained**

→ e.g. Gluon PDF at mid-to-high x

→ Jet cross sections help constrain gluon pPDF



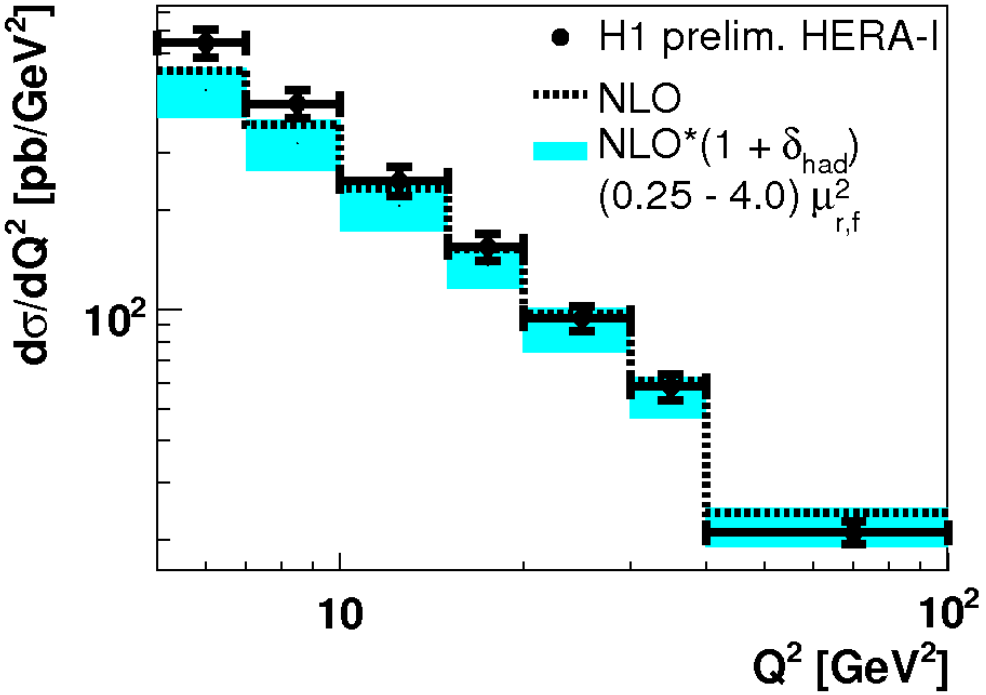
- **Variables that allow smallest theoretical and experimental uncertainties**

→ Inclusive-jet cross sections at high Q^2

→ extraction of α_s with high precision

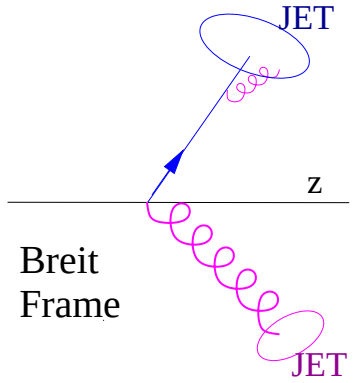
→ test scale-dependence of α_s

INCLUSIVE JET PRODUCTION AT LOW Q^2 DIS (H1)



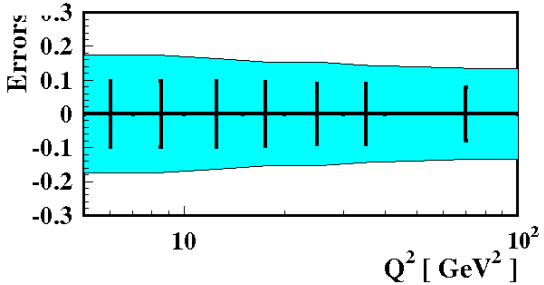
- Motivation: how low in Q^2 and E_T is pQCD at NLO reliable?
- Kinematic region:
- $5 < Q^2 < 100$ GeV^2
- $E^{\text{jet}}_{T,\text{B}} > 5$ GeV

$\rightarrow \mathcal{L} = 44$ pb^{-1}

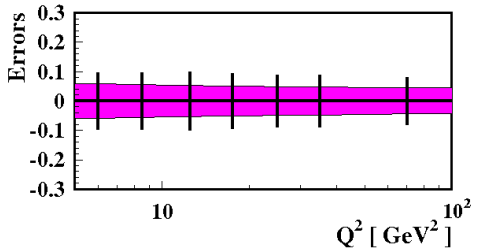


- k_T clustering algorithm in the Breit frame

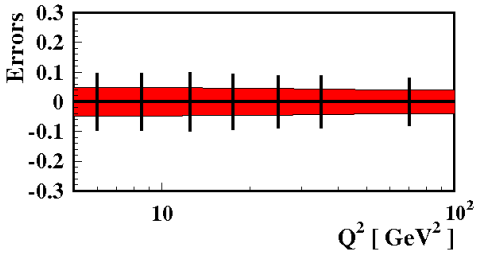
- Discrepancies from pQCD observed at $Q^2 < 10$ GeV^2 and $E^{\text{jet}}_{T,\text{B}} < 10$ GeV
- Contributions to the uncertainty mean NNLO needed!



unc from μ_r ($\sim 20\%$!)



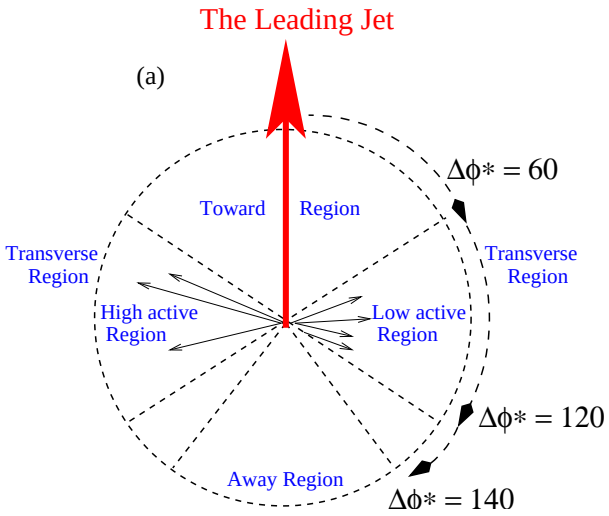
unc from PDFS



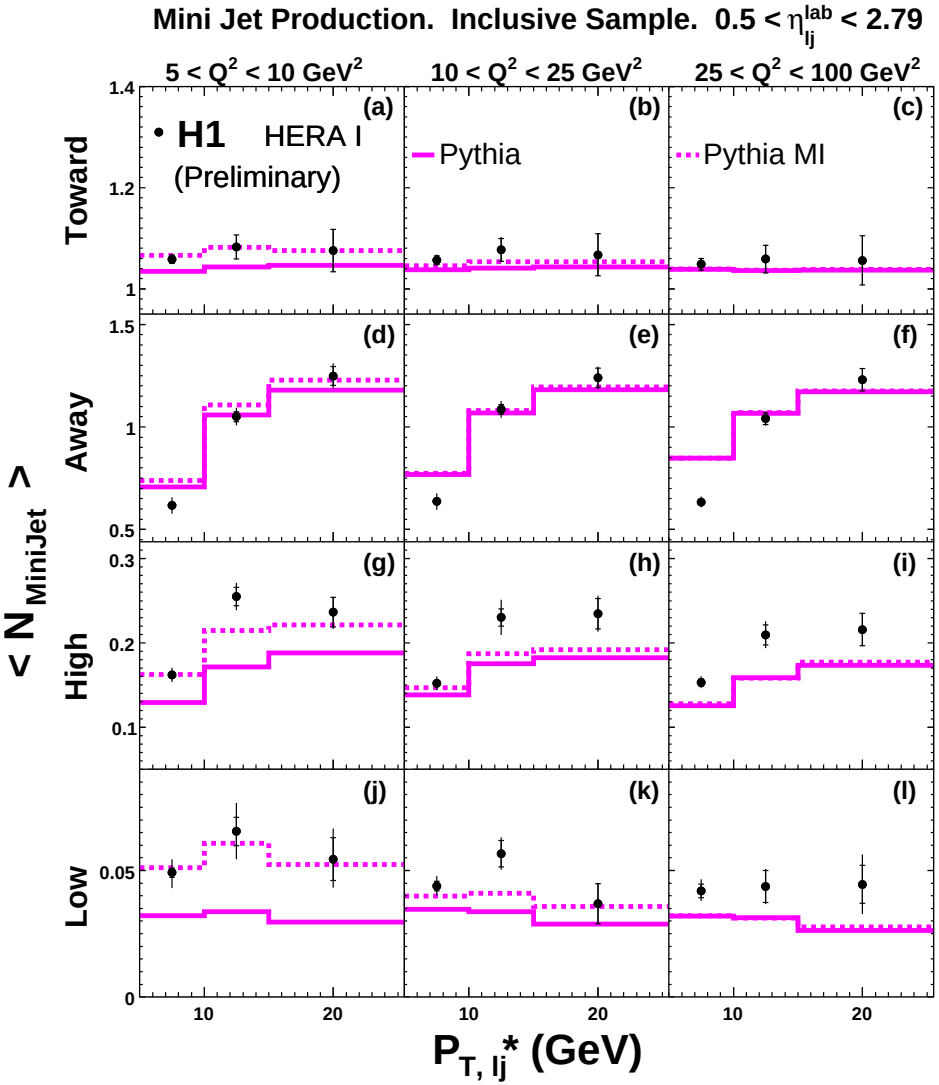
unc from $\alpha_s(M_Z)$

Mini-Jets in DIS (H1)

- **An analysis has been made using minijets, low E_T jets ($E_T^{h.c.m} > 3$ GeV)**
- **The idea is to study hadronic activity in excess to primary interaction in a well understood environment → useful for LHC**

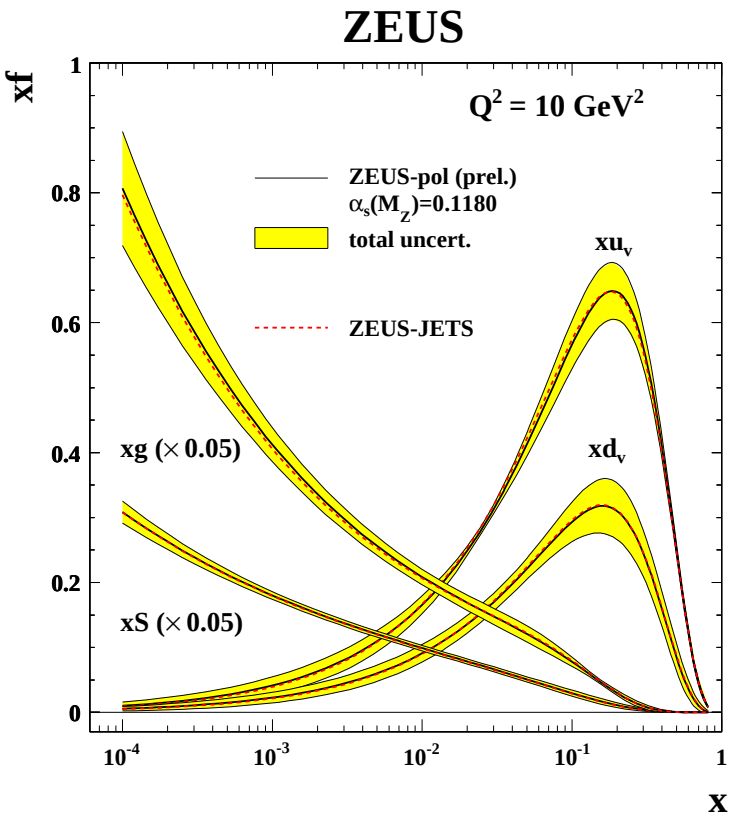


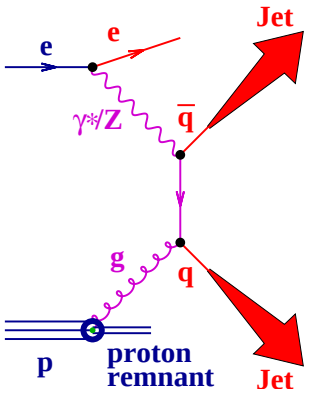
- **Inclusive and Dijet samples compared to RAPGAP, ARIADNE, PYTHIA (MI), HERWIG (SUE)**
- **General agreement, but MI/SUE needed especially in 'low active region'**

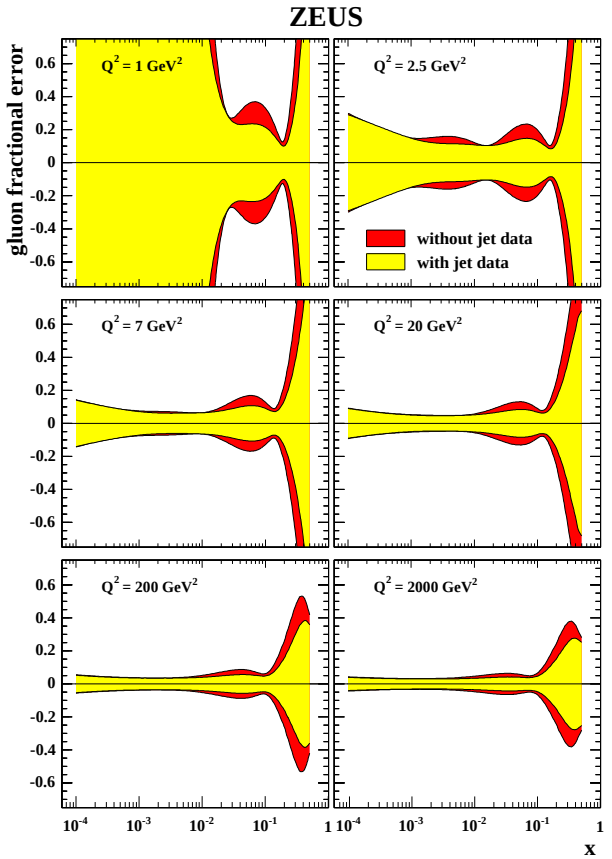


Jet measurements for QCD global fits

- As a result of including jet cross sections, the gluon PDF uncertainty was reduced





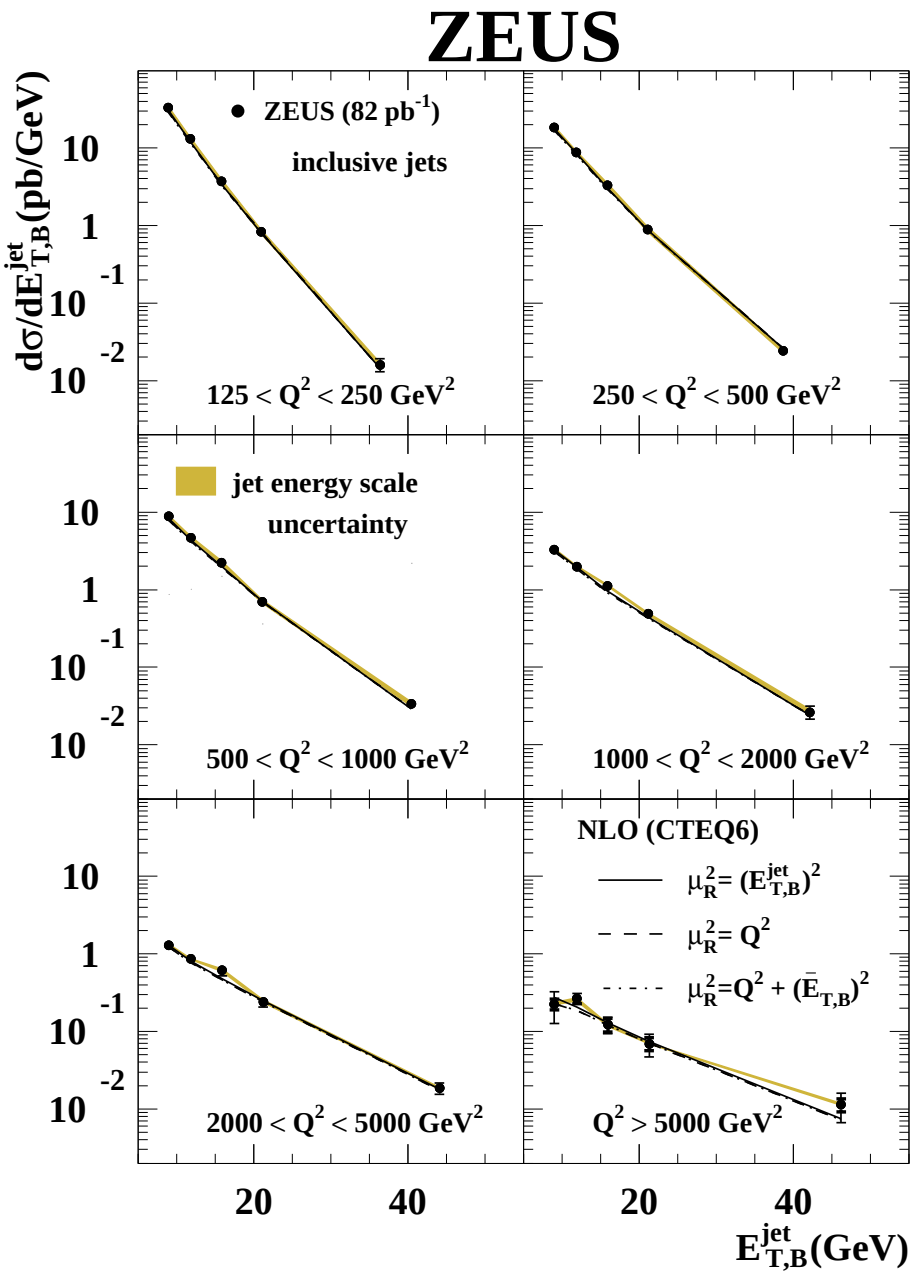


- Gluon PDFs dominate in low x region

- Jet data has large effect on the gluon PDF uncertainty in mid-to-high x region

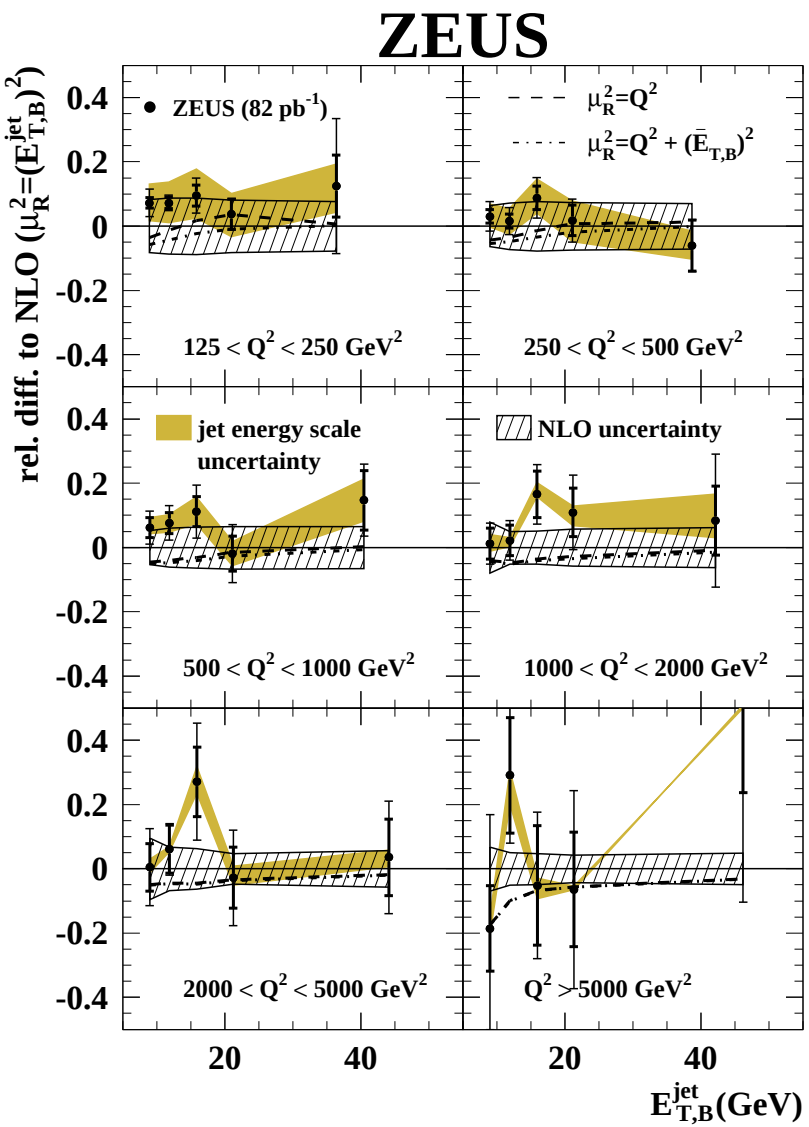
INCLUSIVE JETS AND DIJETS IN NC DIS AT HIGH Q^2 (ZEUS)

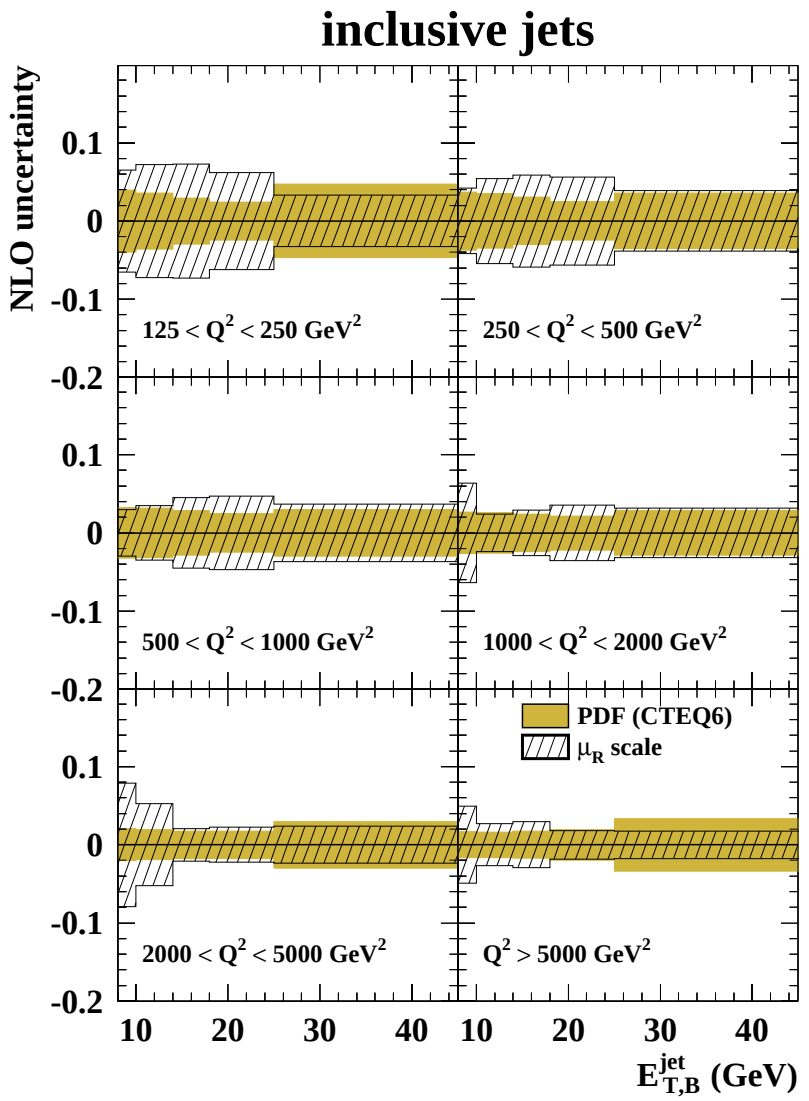
- Measurements of $d\sigma/dE^{jet}_{T,B}$ in different regions of Q^2
- Kinematic region defined by:
  - $E^{\rm jet}_{T,\rm B} > 8$ GeV
  - $|cos\gamma_h| < 0.65$
  - $Q^2 > 125$ GeV^2
- $\mathcal{L} = 82$ pb^{-1}
- Uncertainty in the data dominated by jet energy scale
  - E-scale unc. $\pm 1\%$ for $E^{jet}_{T,L} > 10$ GeV
  - E-scale unc. in cross sections $\pm 5\%$
- The dependence of $E^{\rm jet}_{T,\rm B}$ with Q^2 becomes less steep as Q^2 increases



INCLUSIVE JETS AND DIJETS IN NC DIS AT HIGH Q^2 (ZEUS)

- Comparison of $d\sigma/dE_{T,B}^{jet}$ in regions of Q^2 with NLO predictions
- PDF unc contribute most → data can help constrain PDFs in global fits





Inclusive jets in charged current DIS with HERA II data (ZEUS)

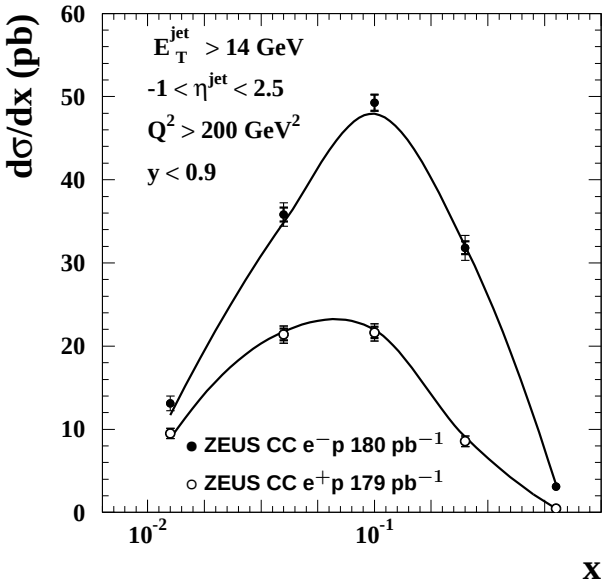
- **Measurements of polarized and unpolarized differential cross sections with HERA II**

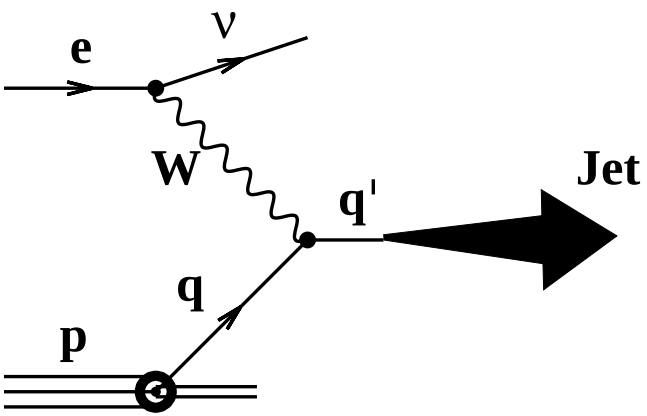
$$\longrightarrow \mathcal{L} = 360\ \text{pb}^{-1}$$

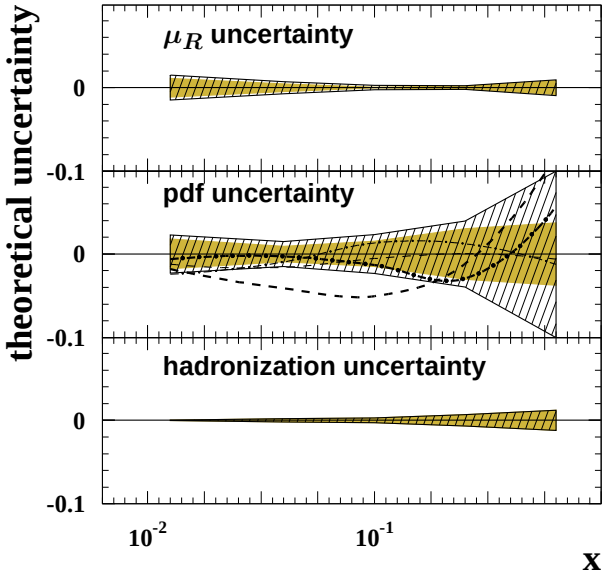
- **Good agreement found with SM over a wide range of Q^2 for $\frac{d\sigma}{dx_{Bj}}$, $\frac{d\sigma}{dQ^2}$, $\frac{d\sigma}{dE_T}$, and $\frac{d\sigma}{d\eta}$**

- **CC is sensitive to proton flavour content**

$\longrightarrow$ can help constrain further u, d PDF's







Determinations of $\alpha_s(M_Z)$ (H1)

- **Inclusive-jet cross sections at high Q^2 have small theoretical and experimental uncertainties**

  → extraction of $\alpha_s(M_Z)$

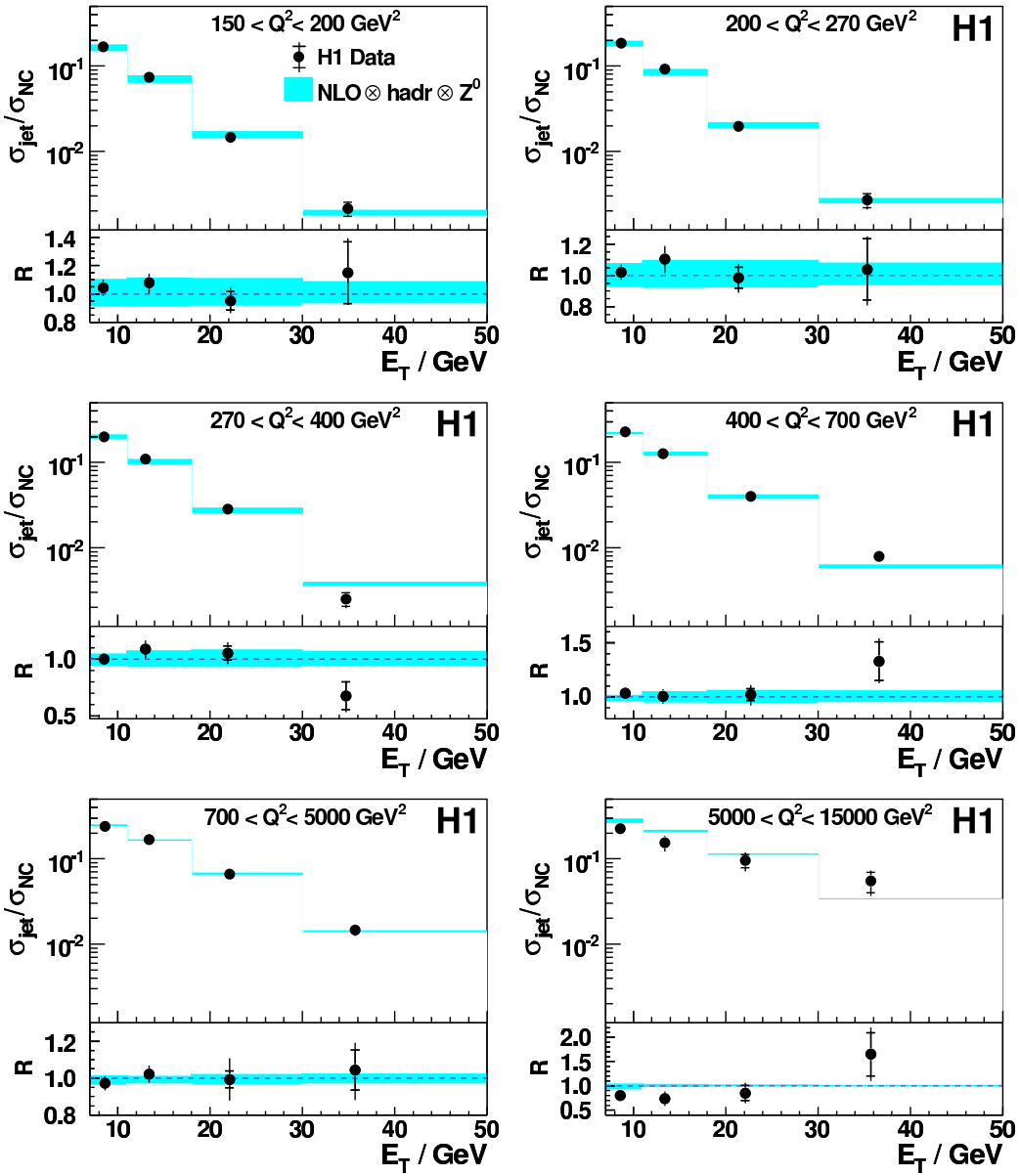
- **Normalized cross section**

  In a given bin: $\frac{\#jets}{\#events}$

- **Kinematic region defined by:**
  - $E_{T,\mathrm{B}}^{\mathrm{jet}} > 7$ GeV
  - $0.2 < y < 0.7$
  - $Q^2 > 150$ GeV^2
  - $\mathcal{L} = 65$ pb^{-1}

- **NLO ingredients:**
  - $\alpha_s(M_Z) = 0.118$
  - PDF = CTEQ6.5M
  - $\mu_R = E_{T,\mathrm{B}}^{\mathrm{jet}}$ of each jet
  - $\mu_F = Q$

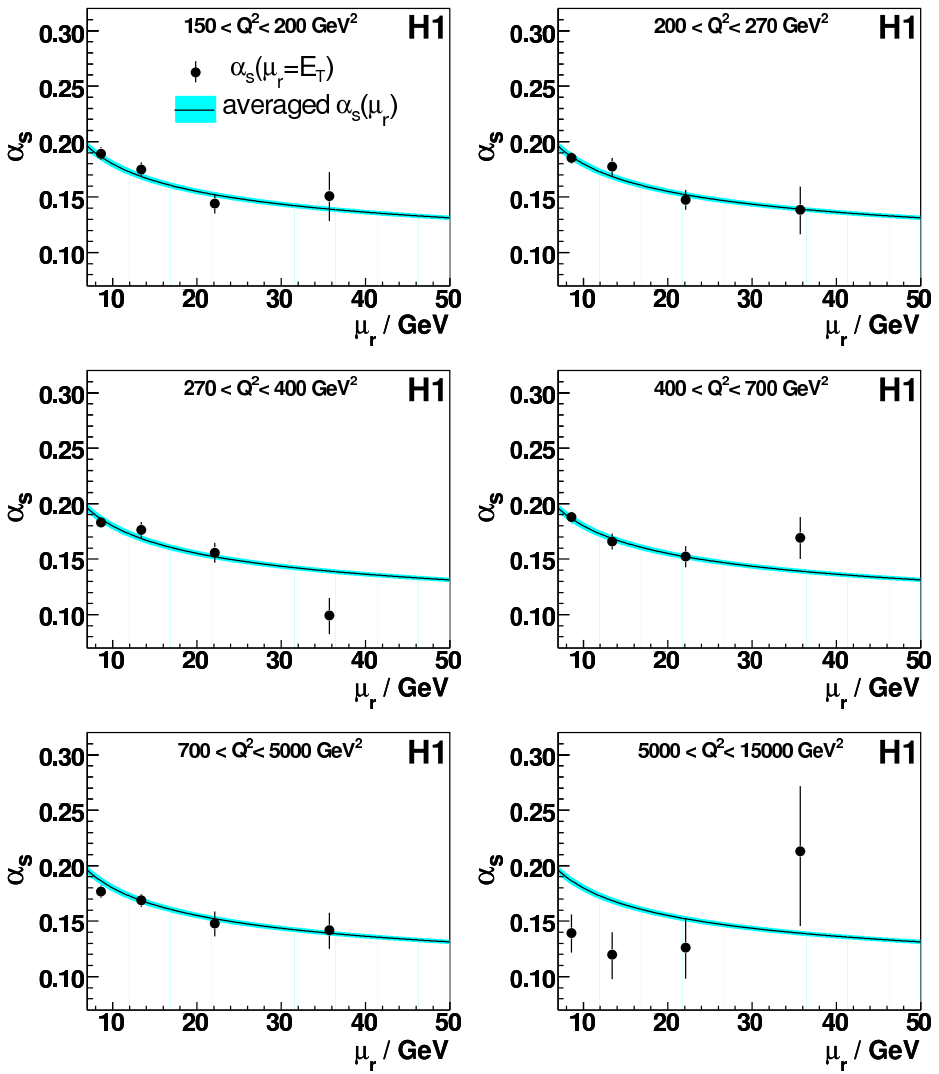
Normalised Inclusive Jet Cross Section



Determinations of $\alpha_s(E_{T,\mathrm{B}}^{\mathrm{jet}})$ (H1)

- The running of α_s has been tested in different regions of Q^2 using the normalized $d\sigma/dE_{T,B}^{jet}$
- In normalized cross sections
  - → PDF uncertainties largely cancel
  - → LUMI uncertainty cancels completely
- The 24 measurements were combined to yield a precise value of $\alpha_s(M_Z)$

  Total uncertainty → $\pm 4.3\%$



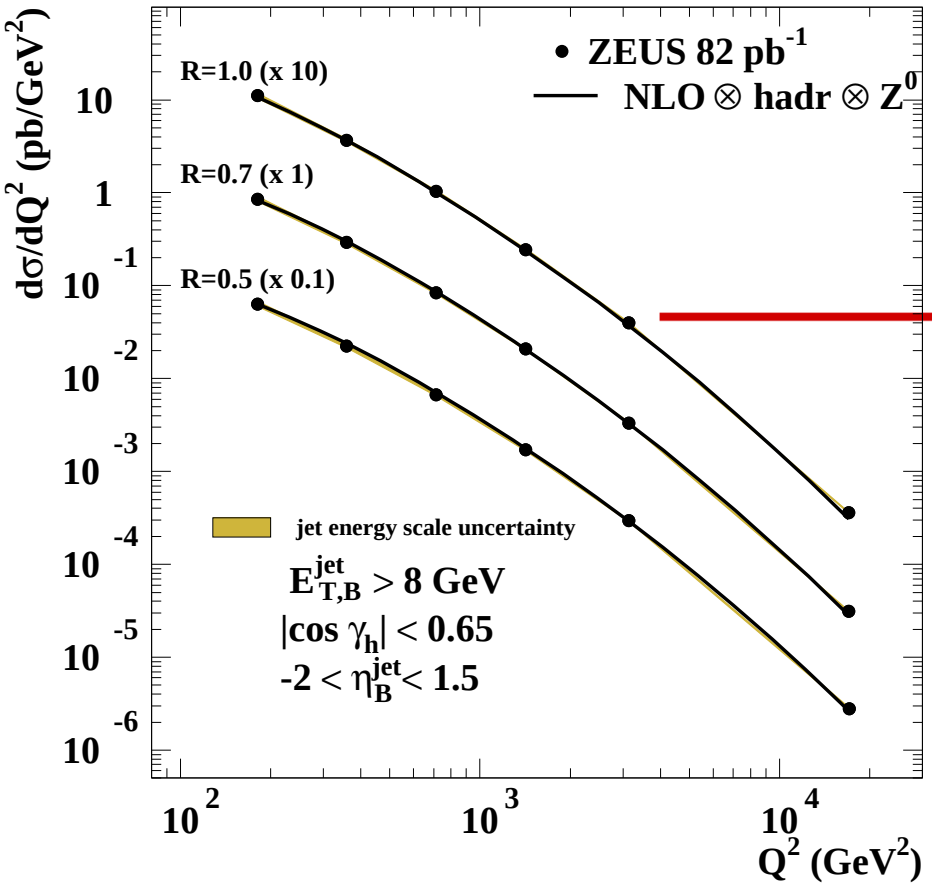
→ $\alpha_s(M_Z) = 0.1193 \pm 0.0014(exp.)^{+0.0047}_{-0.0030}(th.) \pm 0.0016(pdf)$

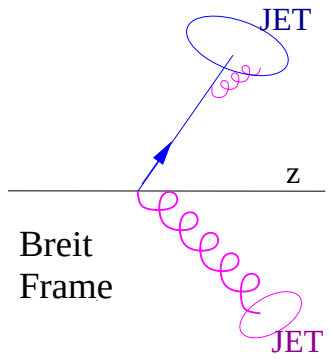
- For $Q^2 > 700$ GeV^2 → $\alpha_s(M_Z) = 0.1171 \pm 0.0023(exp.)^{+0.0032}_{-0.0010}(th.) \pm 0.0010(pdf)$ (lower theo. unc.)

Determinations of $\alpha_s(M_Z)$ and jet-radius dependence (ZEUS)

- Inclusive jet cross sections at high Q^2 used to study jet algorithm

→ DIS provides a well understood environment to study jet production dependence on R → LHC particle searches





- k_T clustering algorithm in the Breit frame

→ **R=1 used to extract $\alpha_s(M_Z)$**
(R parameter alco called 'd' in the literature)

→ Small theo unc ($\mu_R < \pm 7\%$)

→ Exp unc dominated by energy scale ($< \pm 5\%$)

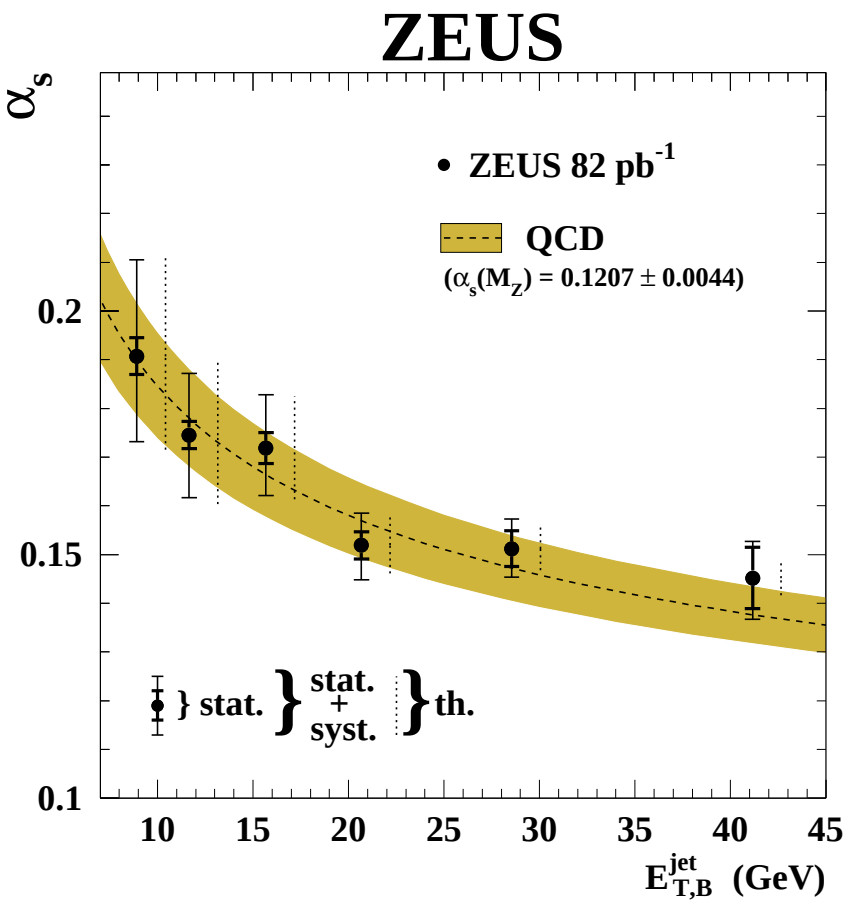
Determinations of $\alpha_s(E_{T,\mathrm{B}}^{\mathrm{jet}})$ (ZEUS)

- The measured cross sections $d\sigma/dQ^2$ and $d\sigma/dE_{T,B}^{jet}$ were used to obtain precise determinations of $\alpha_s(M_Z)$
- The region $Q^2 > 500$ GeV^2 yielded the value with the smallest uncertainty:

  $\longrightarrow \alpha_s(M_Z) = 0.1207 \pm 0.0014(stat.)^{+0.0035}_{-0.0033}(exp.)^{+0.0022}_{-0.0023}(th.)$

  $\longrightarrow$ Total uncertainty $\pm 3.7\%$

- The measured $d\sigma/dE_{T,B}^{jet}$ have been used to test the energy-scale dependence of α_s
- The running of α_s as predicted by pQCD is in agreement with the data
- Asymptotic freedom of QCD!



Combined HERA determination of $\alpha_s(M_Z)$ (H1 , ZEUS)

- A simultaneous fit to H1 and ZEUS data yields most precise $\alpha_s(M_Z)$ so far

→ 24 H1 data points from $\frac{d\sigma}{dQ^2 E_T}$ $(150 < Q^2 < 15000)$ GeV^2

→ 6 ZEUS data points from $\frac{d\sigma}{dQ^2}$ $(125 < Q^2 < 10^5)$

- NLO QCD calculations

→ pPDFs: MRST2001 sets

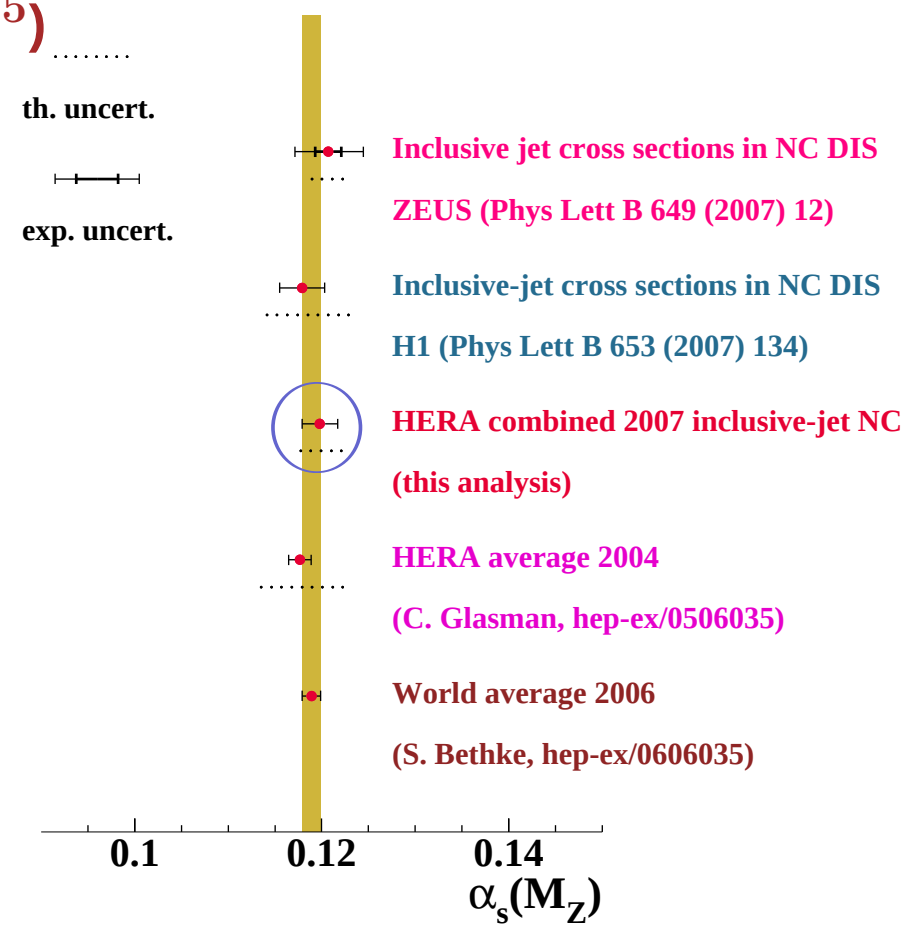
→ $\mu_r = E^{jet}_{T,B}$, $\mu_F = Q$

- Experimental uncertainties on $\alpha_s(M_Z)$

→ 0.0019 (obtained using Hessian method)

- Theoretical uncertainties on $\alpha_s(M_Z)$

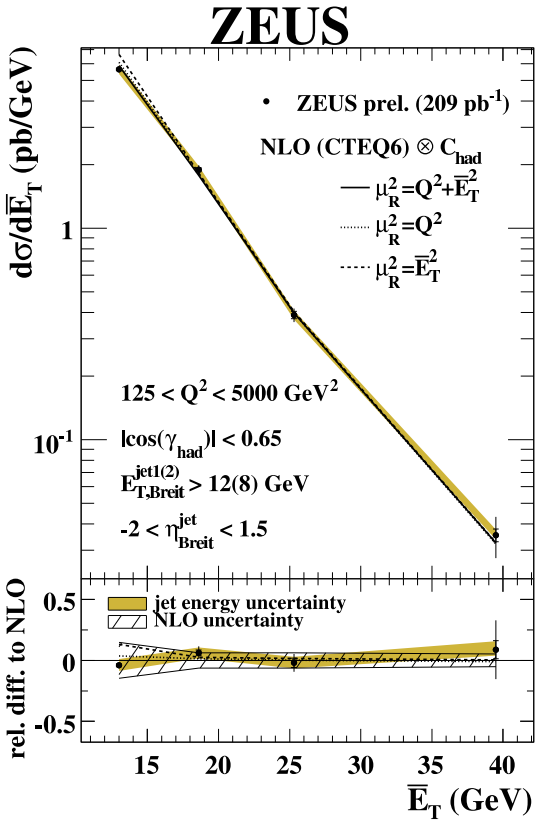
→ terms beyond NLO: 0.0021 (using Jones, et al method JHEP 122003007)



COMBINED HERA $\alpha_s(M_Z)$ DETERMINATION

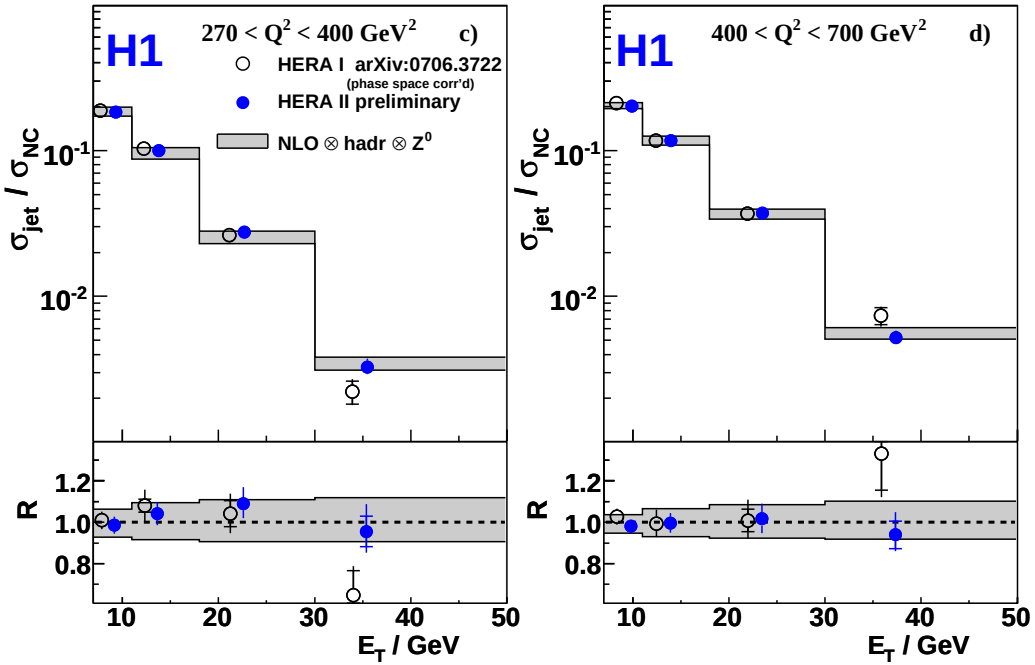
→ $\alpha_s(M_Z)$ = 0.1198 $\pm$ 0.0019(exp) $\pm$ 0.0026(th) → (2.7%)

NEW HERA II MEASUREMENTS EMERGING (H1, ZEUS)



← Measurements of dijet cross sections in NC DIS ($\mathcal{L} = 209$ pb^{-1})

Measurements of inclusive → jets in NC DIS ($\mathcal{L} = 320$ pb^{-1})



Summary

- **Jet production in DIS at HERA provides a good testing ground for QCD studies**

→ **New tests of pQCD predictions have been made**

- **Jet production at low Q^2, hadronic activity using minijets.**
- **Study of the R dependence of inclusive-jet cross sections**

→ **New input for the determination of the proton PDFs**

- **Dijet and inclusive-jet cross sections will help constrain gluon PDF in mid-to-high x region**

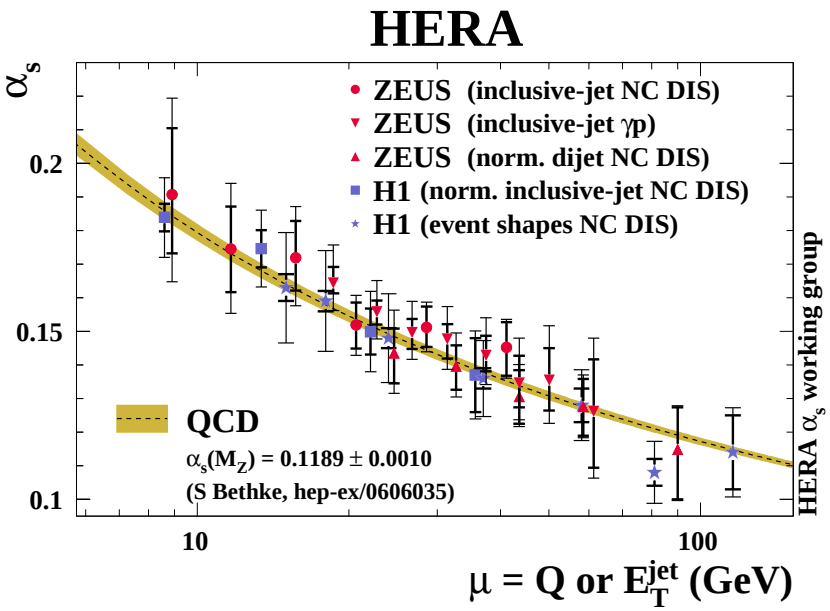
→ **New results with HERA II data → more lumi!**

- **CC DIS, Dijets and inclusive-jets**

→ **Improved $\alpha_s(M_Z)$ by H1 and ZEUS**

- **H1 → reduced experimental error**
- **ZEUS → reduced theoretical error**

Combined value of α_s for HERA

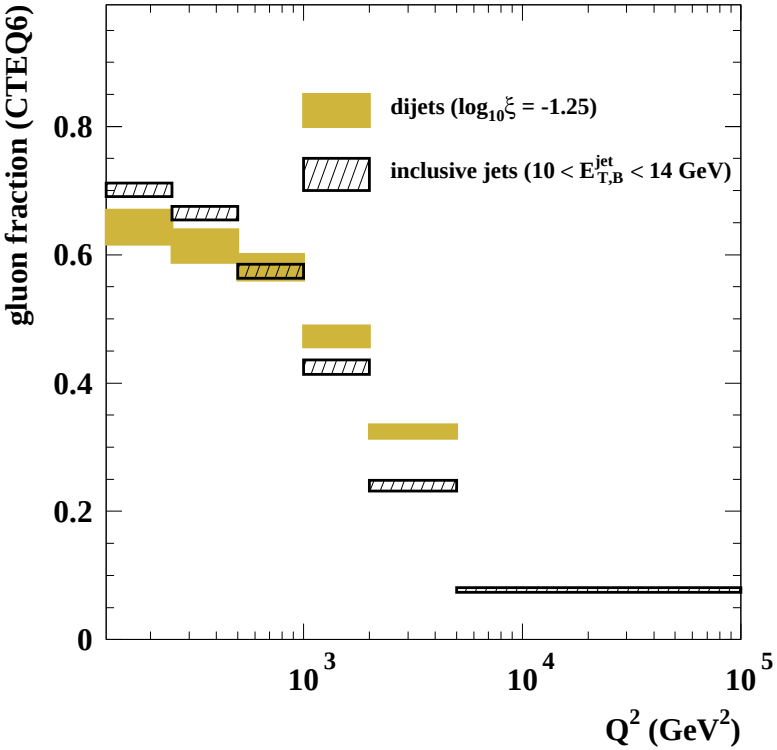


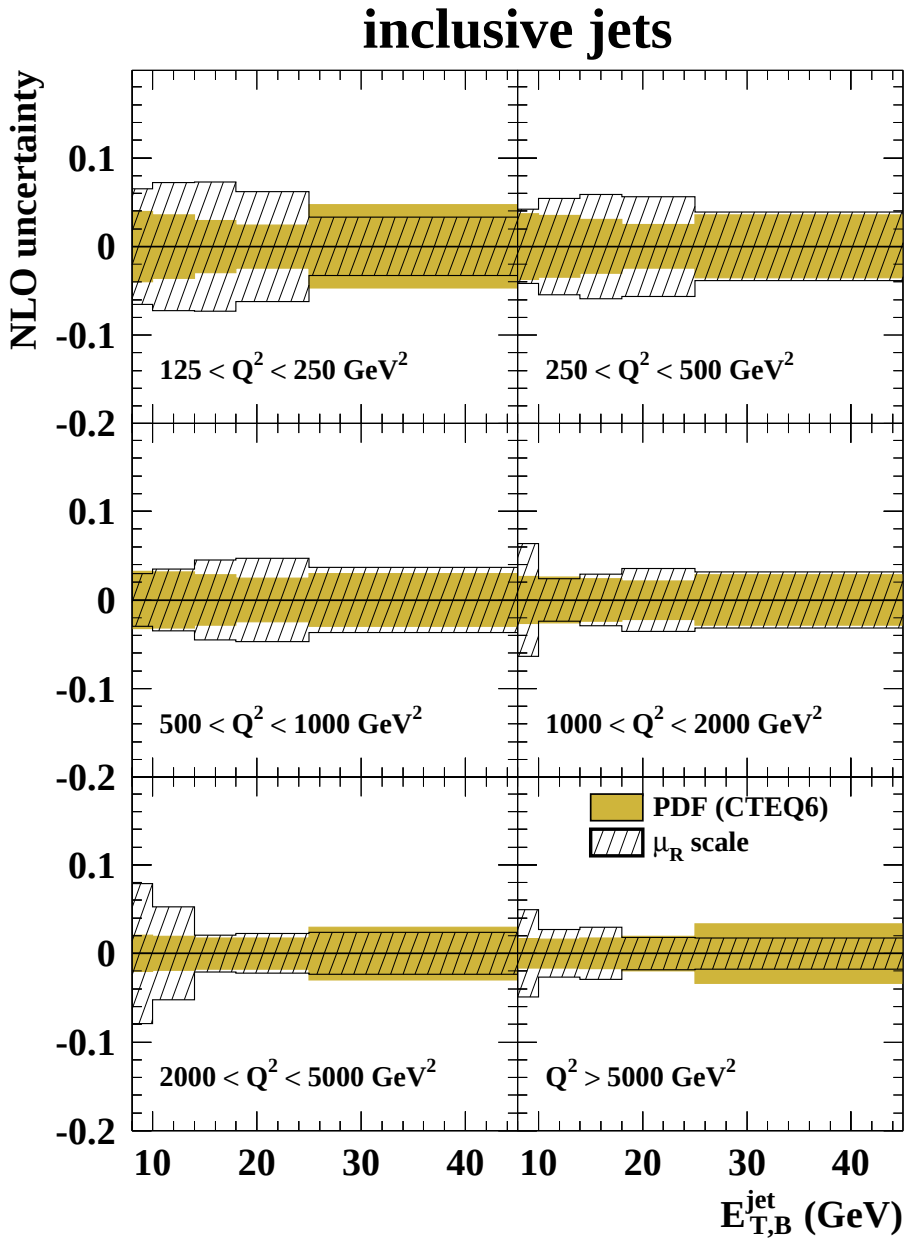
→ $\alpha_s(M_Z)$ = 0.1198 ± 0.0019(exp) ± 0.0026(th) → (2.7%)

BACK-UP SLIDE - PDF vs μ_R uncertainties in inclusive jets

- The uncertainty from that in the PDFs is large in comparison to the precision of the inclusive-jet and dijet measurements → will constrain gluon PDF further

- There is a substantial contribution from gluon initiated events to the dijet and inclusive-jet cross section



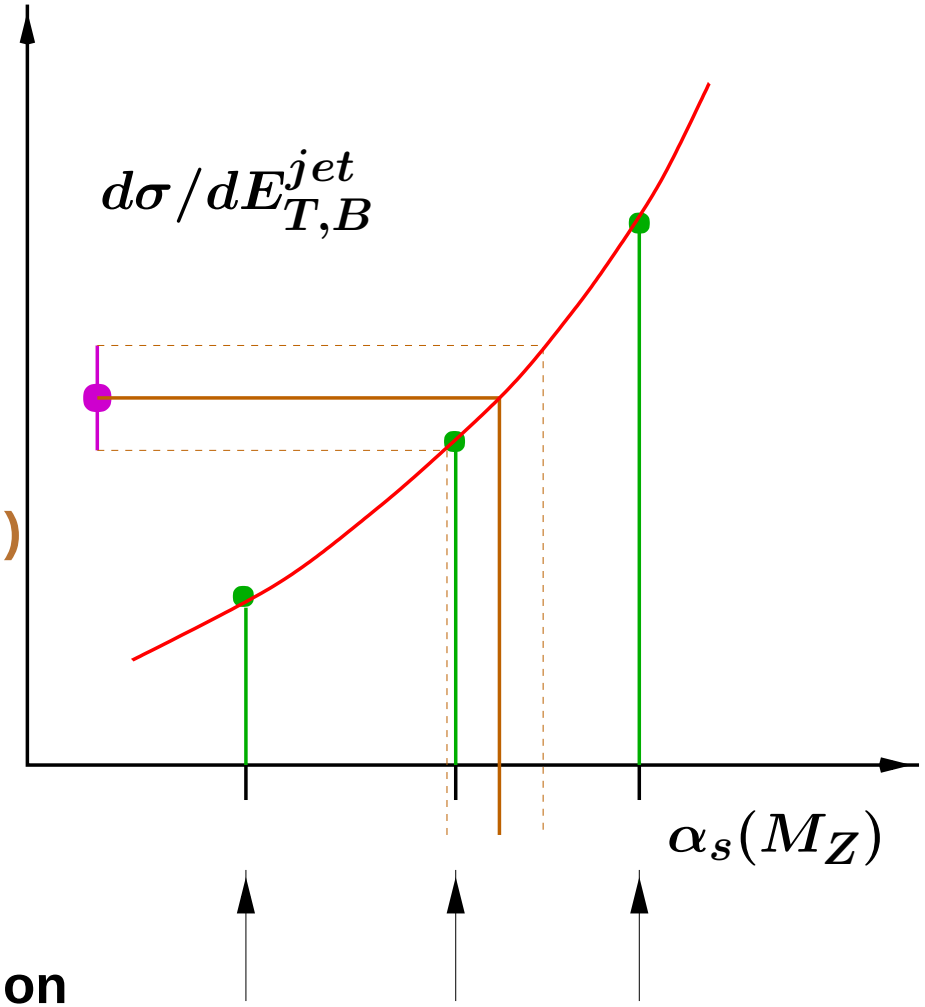


BACK-UP SLIDE - Extraction of $\alpha_s(M_Z)$ (ZEUS method)

- **Method for the determination of $\alpha_s(M_Z)$:**
- **An NLO cross section is calculated assuming different values of $\alpha_s(M_Z)$ in the PDFs**
- **Dependence of cross section (e.g. $d\sigma/dE^{jet}_{T,B}$) on $\alpha_s(M_Z)$ is parametrised according to:**

$$[d\sigma/dE^{jet}_{T,B}(\alpha_s(M_Z))] = A^i_1\alpha_s(M_Z) + A^i_2\alpha^2_s(M_Z)$$

- **$\alpha_s(M_Z)$ value given by measured cross section**



NLO calculations with different $\alpha_s(M_Z)$