DIS 2001, Bologna

Jet production in NC DIS and determination of α_s

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on behalf of the

ZEUS Collaboration

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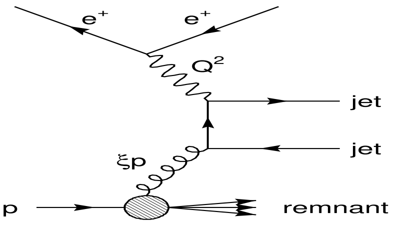
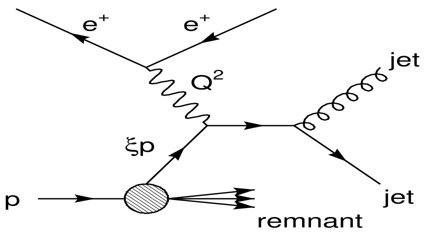
Not covered here:

- Dijet production at low Q^2 (Osaka 888)
- α_s from subjets multiplicities (O. Gonzalez)

Introduction





(Multi)-jet cross sections in DIS at HERA:

⇒ Testing ground of pQCD, direct sensitivity to α_s and $g(x)$

Cross section:

$$d\sigma_{\mathrm{jet}} = \sum_{a=q,\bar{q},g} \int dx\, f_a(x, \mu_f^2; \alpha_s)\, d\hat{\sigma}_a(x, \alpha_s) \cdot (1 + \delta_{hadr})$$

Partonic cross section:

$$d\hat{\sigma}_a = \sum_n {\alpha_s}^n c_{a,n}$$

DGLAP equations:

$$\frac{d\, f_a(x, \mu_f^2)}{d \ln \mu_f^2} = \frac{\alpha_s}{2\pi} \sum_{b=q,\bar{q},g} \int_x^1 \frac{dz}{z}\, f_b(x/z, \mu_f^2) P_{ab}(z, \alpha_s)$$

- predicted by QCD - process specific
  - $c_{g,n}$ and $c_{q,n}$: calculable in pQCD (NLO)
  - δ_{hadr} : MonteCarlo hadronization models
- free parameters - process independent (universal)
  - strong coupling constant: $\alpha_s(M_Z)$
  - parton densities: $f_g = g$ and $f_q = q$

Dijet cross sections at high Q^2

- Analysis now final: hep-ex/0102042 (accepted by PLB)

Goals:

- Test di-jet production in a phase-space region where theo./exp. uncertainties are small
- Determination of α_s from $R_{2+1} = \sigma_{2+1}/\sigma_{tot}$

QCD analysis assumes proton's PDFs but:

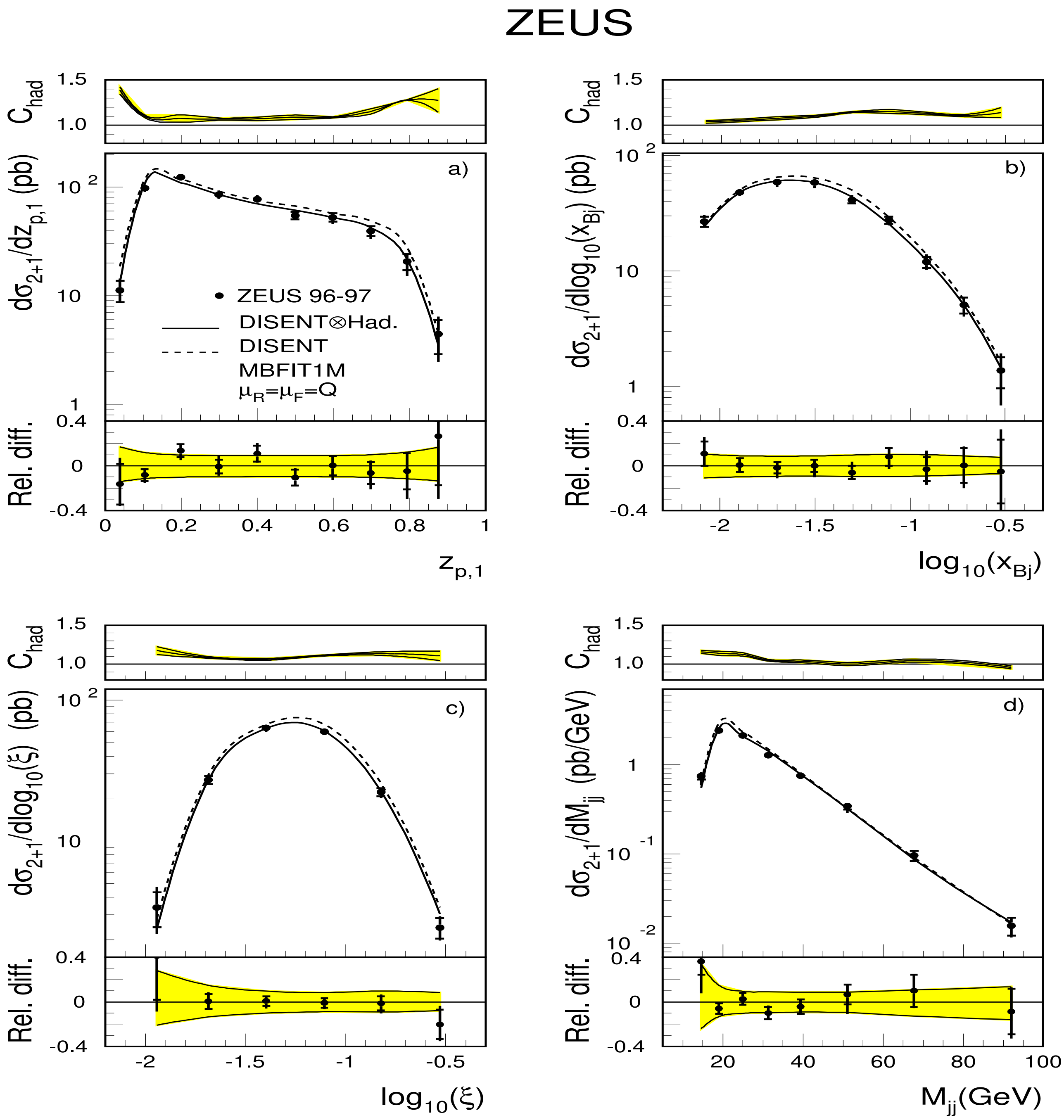
- α_s dependence in the PDFs fully taken into account
- Realistic estimate of the PDF-related uncertainties

Phase-space:

Analysis in the Breit frame (inclusive $k_\perp$ algorithm)
Exactly two jets with:

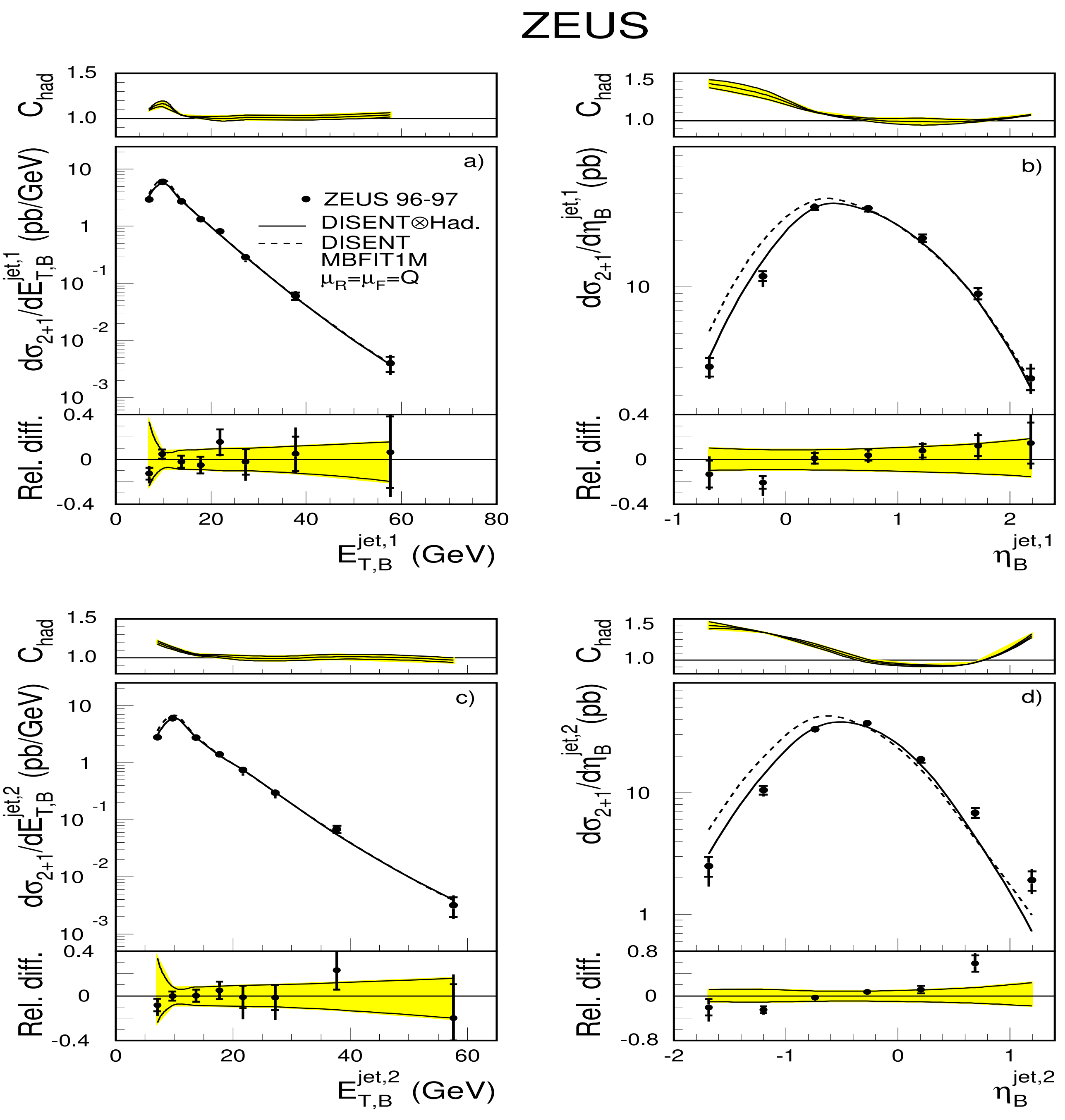
- $E_{T,B}^{\mathrm{jet},L} > 8$ GeV (leading)
- $E_{T,B}^{\mathrm{jet},l} > 5$ GeV
- $-1 < \eta_L^{\mathrm{jet}} < 2$
- $470 < Q^2 < 20000$ GeV^2

Dijet cross sections



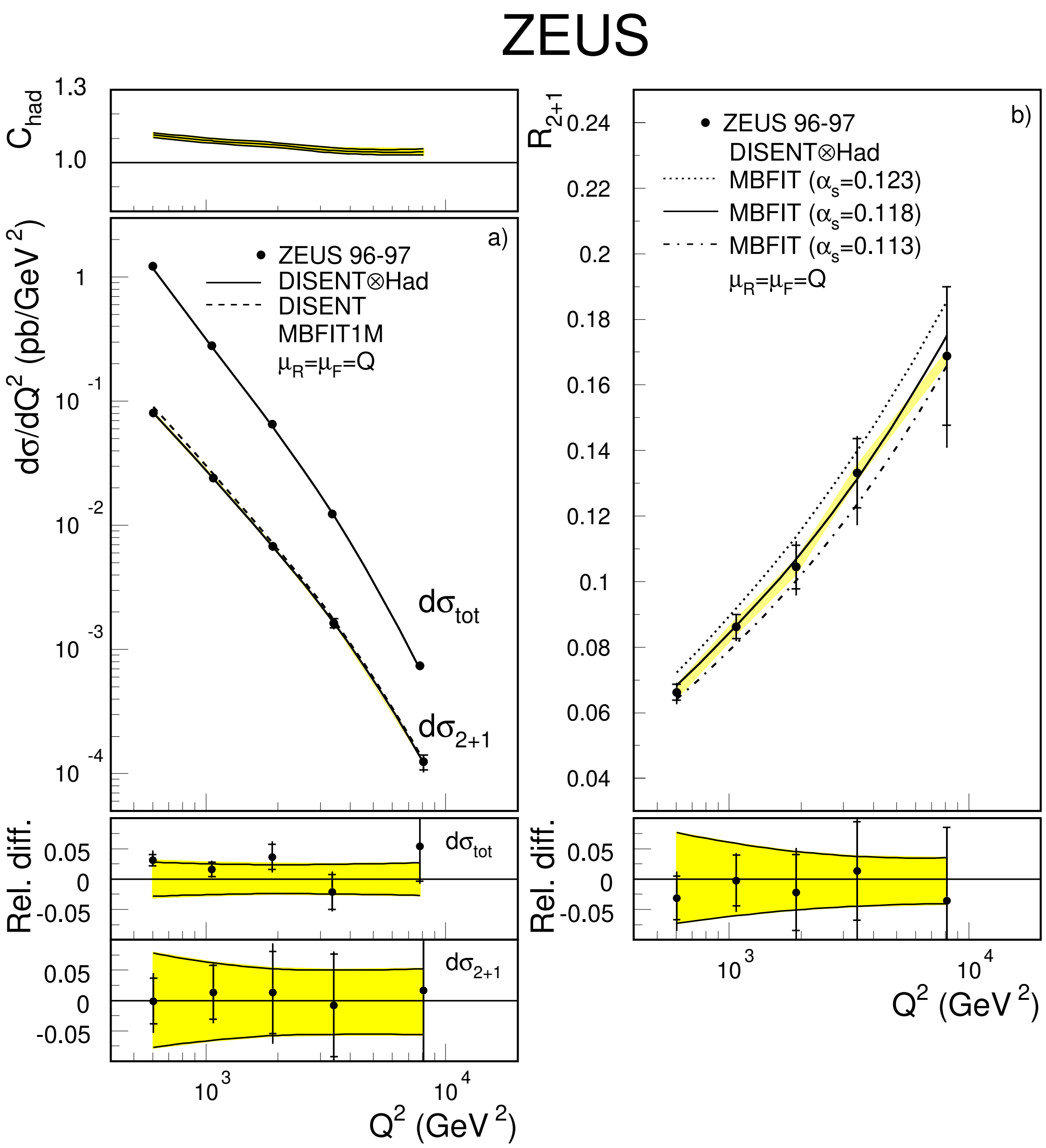
NLO pQCD calculations describe well the measured cross sections

Dijet cross sections



- $E_{T,B}^{\rm jet}$ ⇒ Well described by NLO pQCD calculations
- $\eta_B^{\rm jet}$ ⇒ Large hadronisation corrections

Dijet fraction



R_{2+1} well suited for the α_s determination:
- smaller sensitivity to PDFs
- common exp. unc. largely cancel

QCD fit:

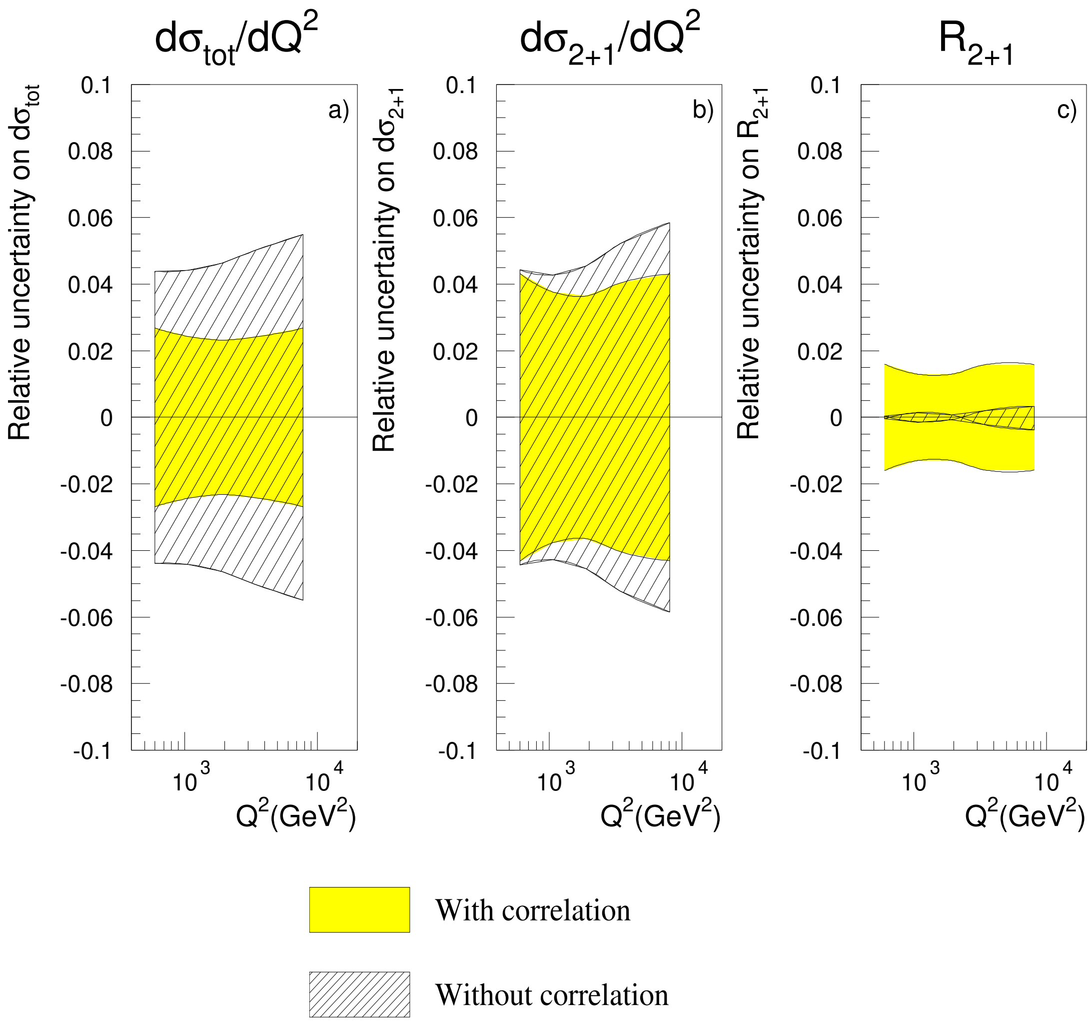
Use NLO calculations with different α_s in the PDFs and partonic cross sections to parameterise R_{2+1} α_s-dependence:

$$R^i_{2+1}(\alpha_s(M_Z)) = A^i_1 \cdot \alpha_s(M_Z) + A^i_2 \cdot \alpha^2_s(M_Z)$$

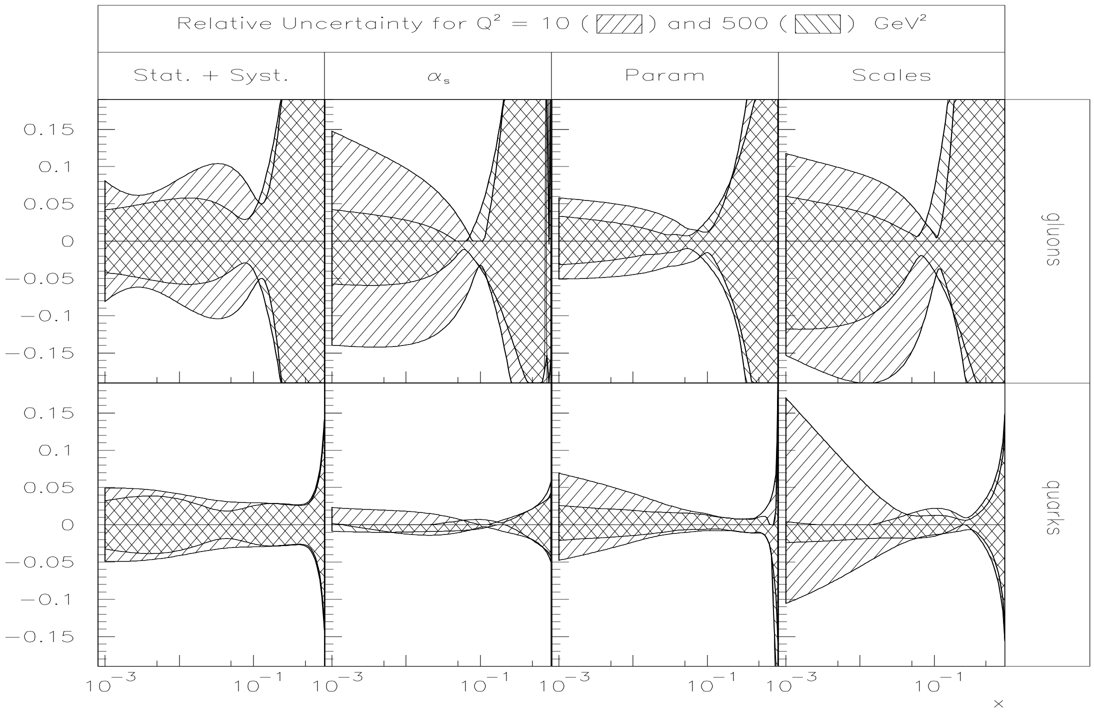
PDF-related Uncertainties

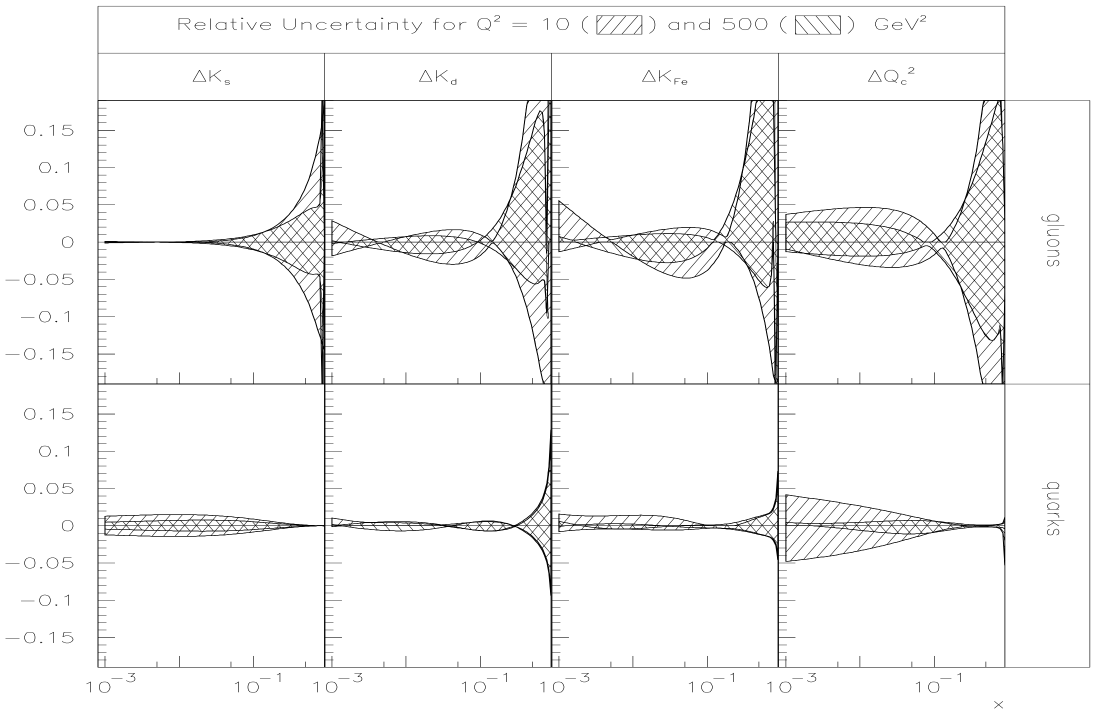
Estimated using EPDFLIB by M. Botje (E.P.J. C14 (2000) 285)

- Contains the information ($V_{ij}^{\rm cov}$ and $\partial f_a/\partial\pi_i$) necessary to propagate the exp. uncertainties of the PDFs on the NLO jet cross sections
- Additional PDF sets are provided to quantify DGLAP-specific uncertainties

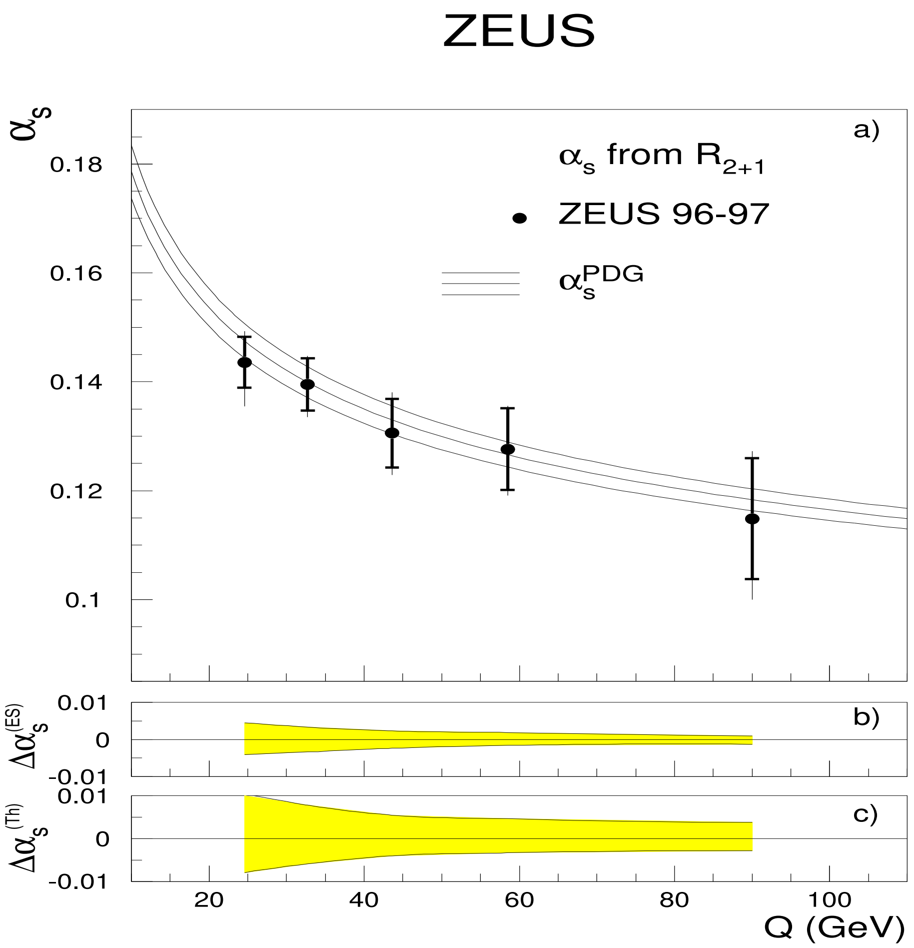


MBFIT PDFs


Relative Uncertainty for Q² = 10 ( ) and 500 ( ) GeV²
Stat. + Syst.
αs
Param
Scales
gluons
quarks
0.15
0.1
0.05
0
−0.05
−0.1
−0.15
10⁻³
10⁻¹
x


Relative Uncertainty for Q² = 10 ( ) and 500 ( ) GeV²
ΔKs
ΔKd
ΔKFe
ΔQc²
gluons
quarks
0.15
0.1
0.05
0
−0.05
−0.1
−0.15
10⁻³
10⁻¹
x

α_s from dijet production



$$\alpha_s(M_Z) = 0.1166 \ \pm 0.0019(\text{stat.})\ {}^{+0.0024}_{-0.0033}\,(\text{exp.})\ {}^{+0.0057}_{-0.0044}\,(\text{th.})$$

- Value in excellent agreement with the world average
- Competitive uncertainty (5-6%)
- Running checked over a large range in Q
- Limited by theory ($\Rightarrow$ NNLO)

Inclusive jet production

Various benefits in considering inclusive jet cross sections:

- Infrared insensitive
- Better suited to test resummed calculations
- Smaller theoretical uncertanties ?

Goals:

- Test of NLO pQCD (larger Q^2 region)
- Determination of $\alpha_s(M_Z)$
- Azimuthal asymmetries from a jet cross section

Phase-space:

Analysis in the Breit frame (inclusive $k_\perp$ algorithm)

Kinematic cuts:

- $Q^2 > 125$ GeV^2
- $-0.7 < \cos\gamma_h < 0.5$

At least one jet with:

- $E_{T,B}^{\rm jet} > 8$ GeV
- $-2 < \eta_B^{\rm jet} < 1.8$

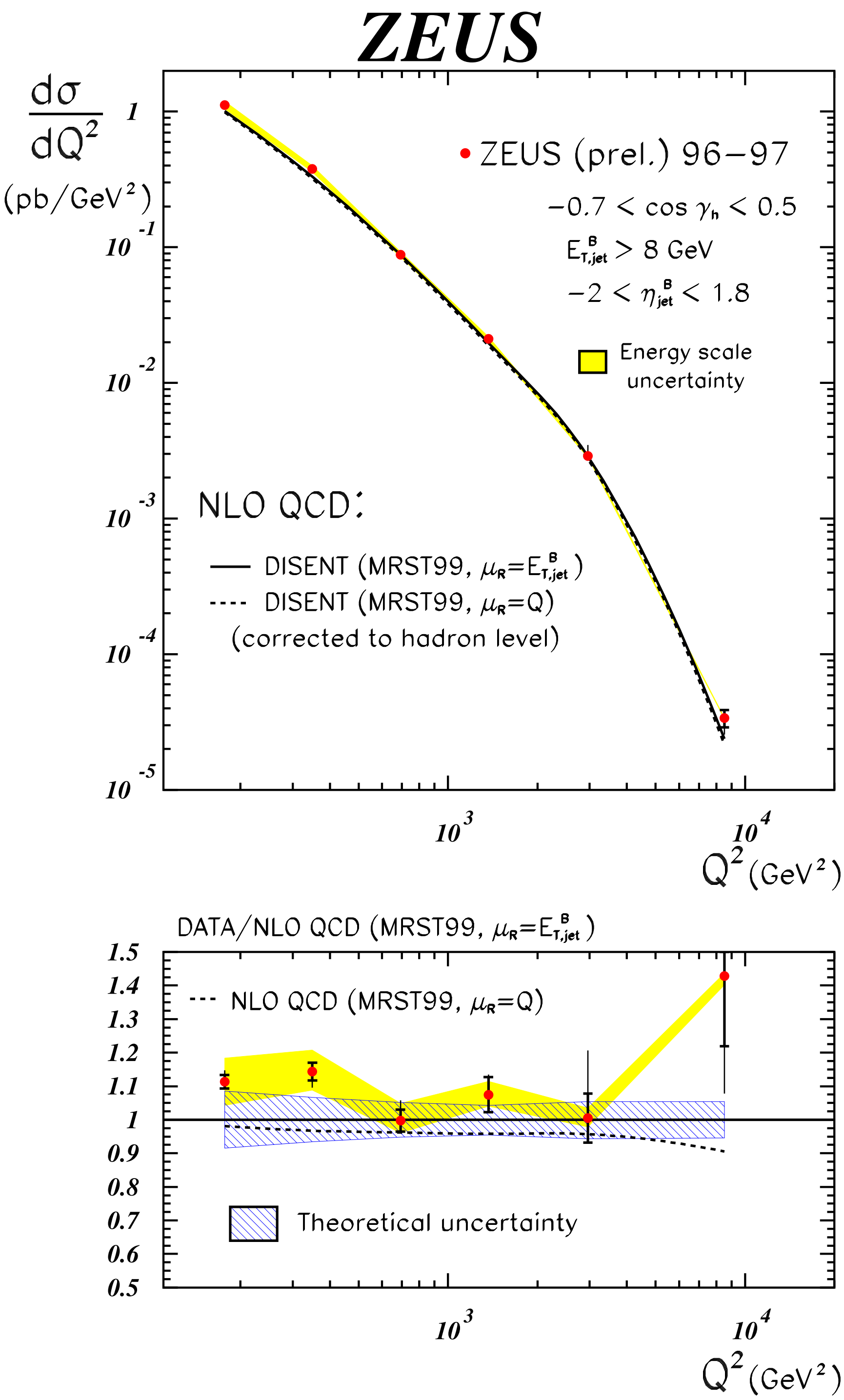
No cuts are applied to the jets in the laboratory frame:

$\Rightarrow$ azimuthal asymmetry, resummation

α_s extraction and PDF-related uncertainty:

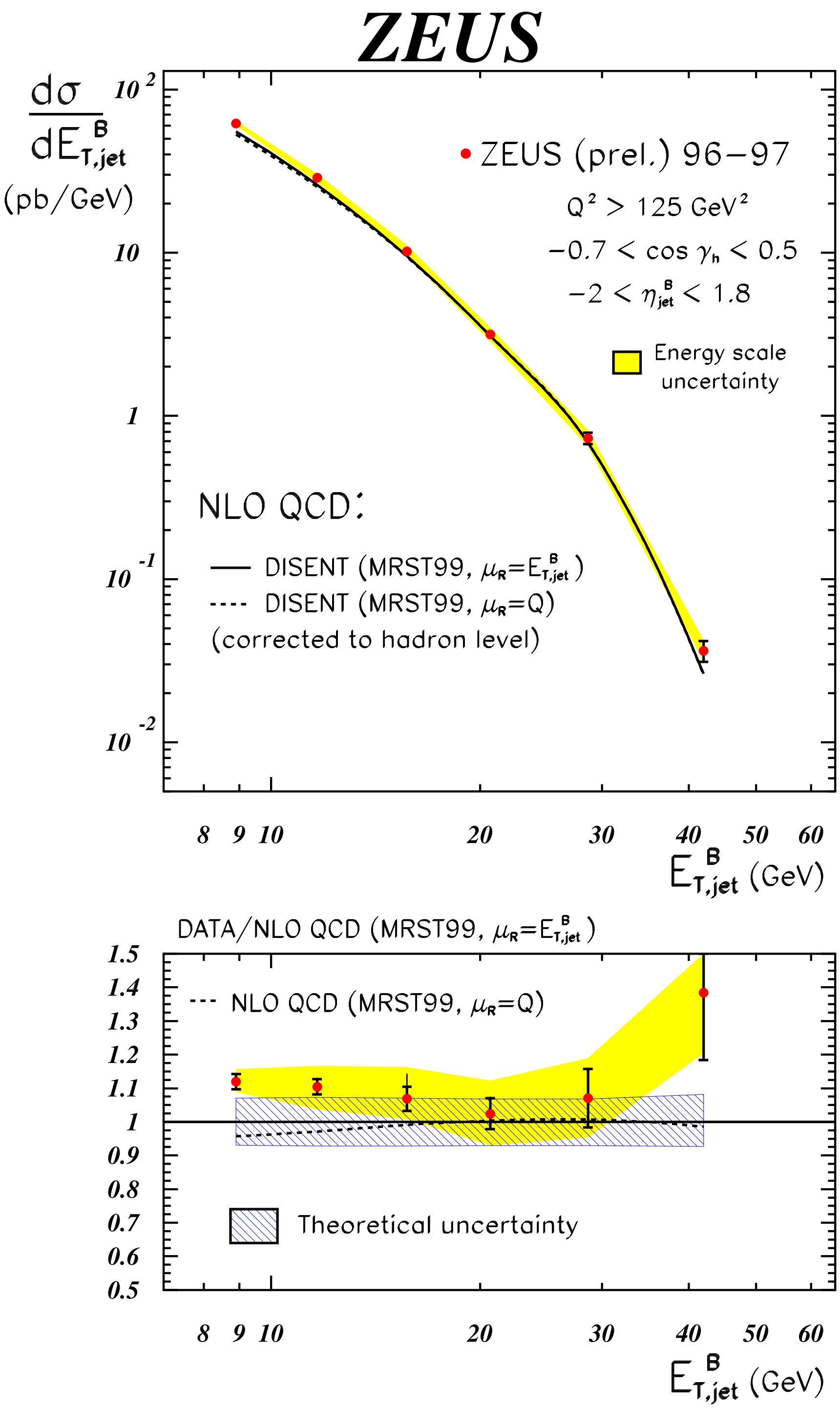
Same method as in the dijet analysis has been used

Inclusive jet production



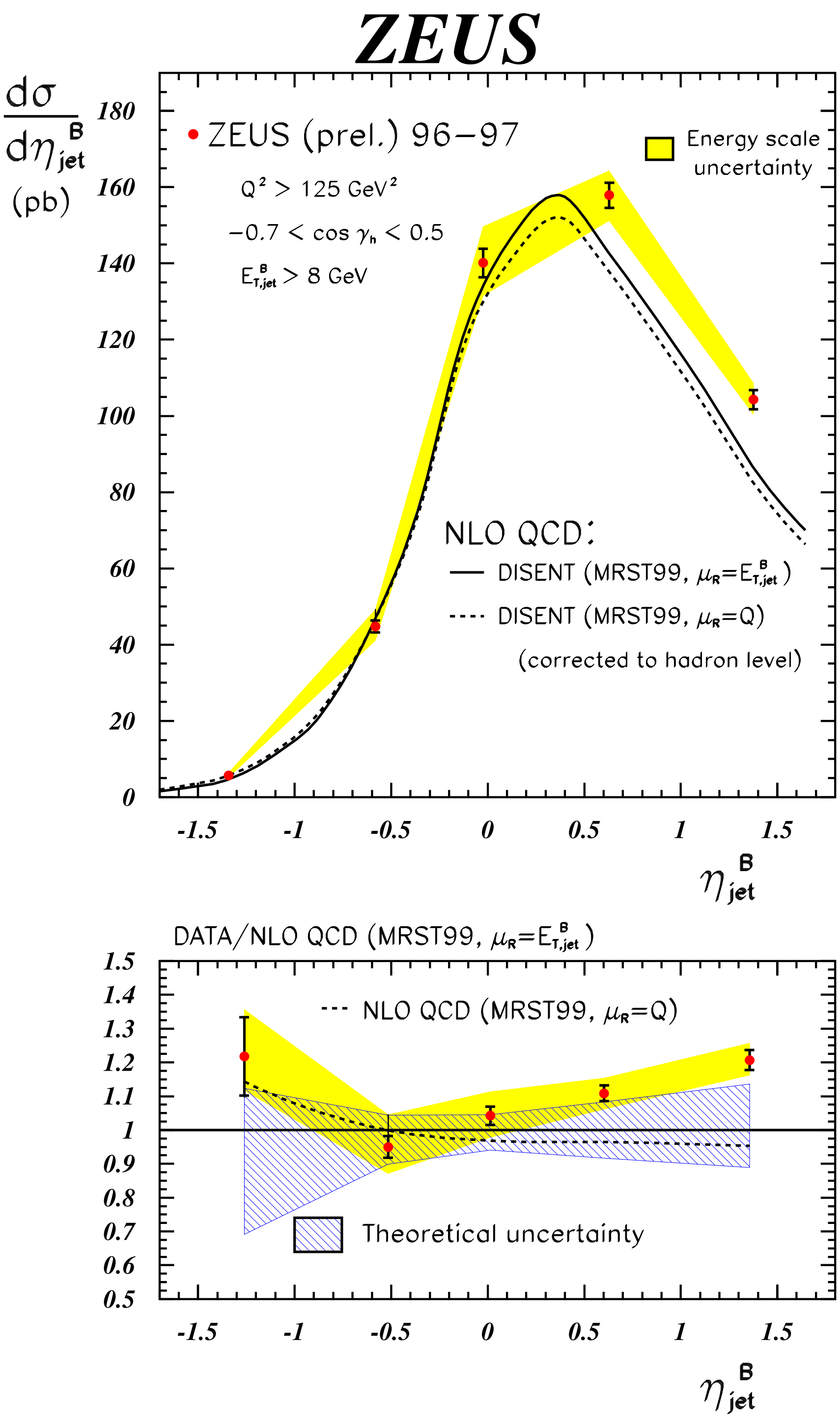
Data slightly above NLO predictions in the low-Q^2 region

Inclusive jet production



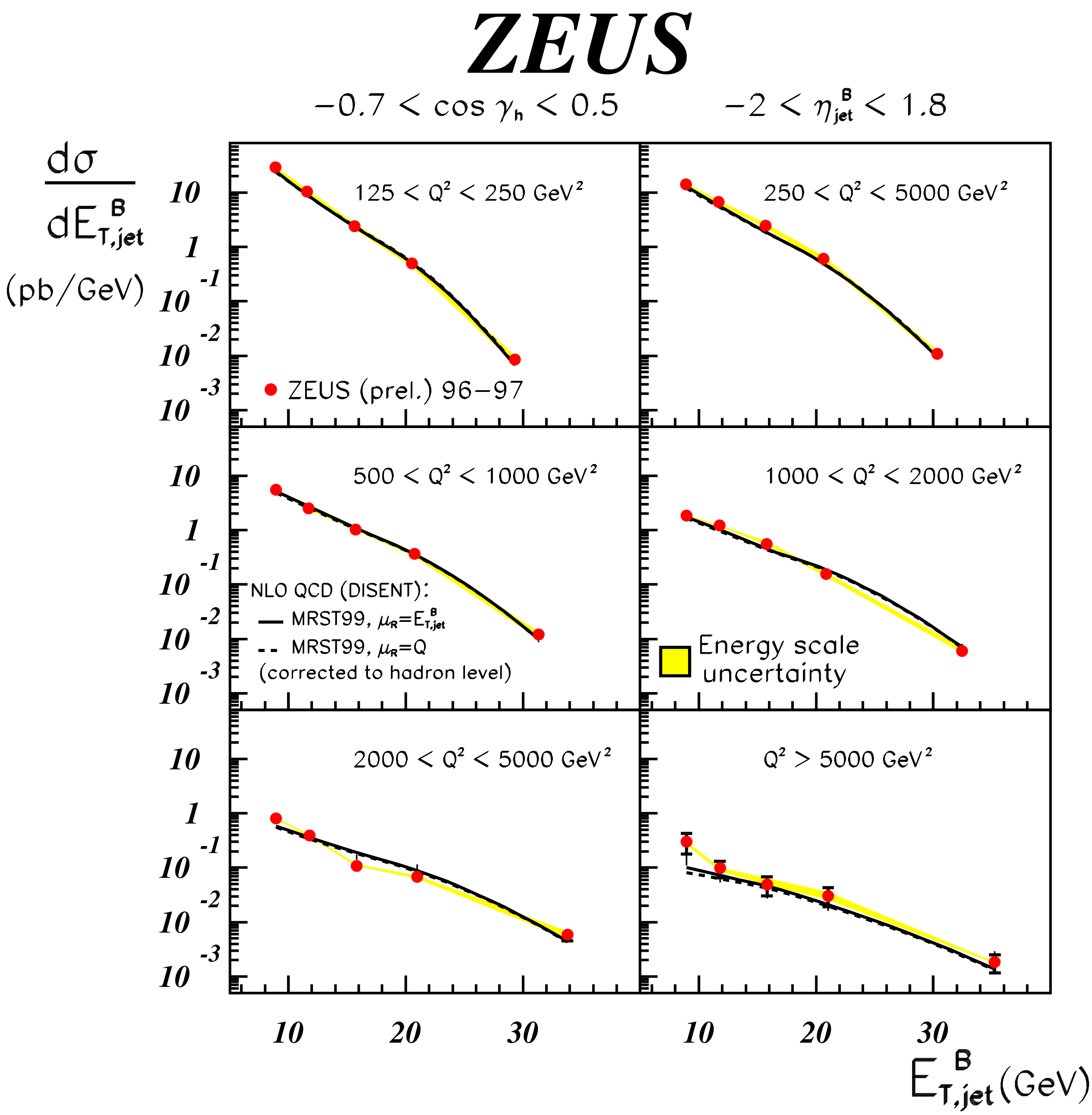
Data slightly above NLO predictions in the low-E_T region

Inclusive jet production



Measured cross section above NLO pQCD prediction in the forward region

Inclusive jet production

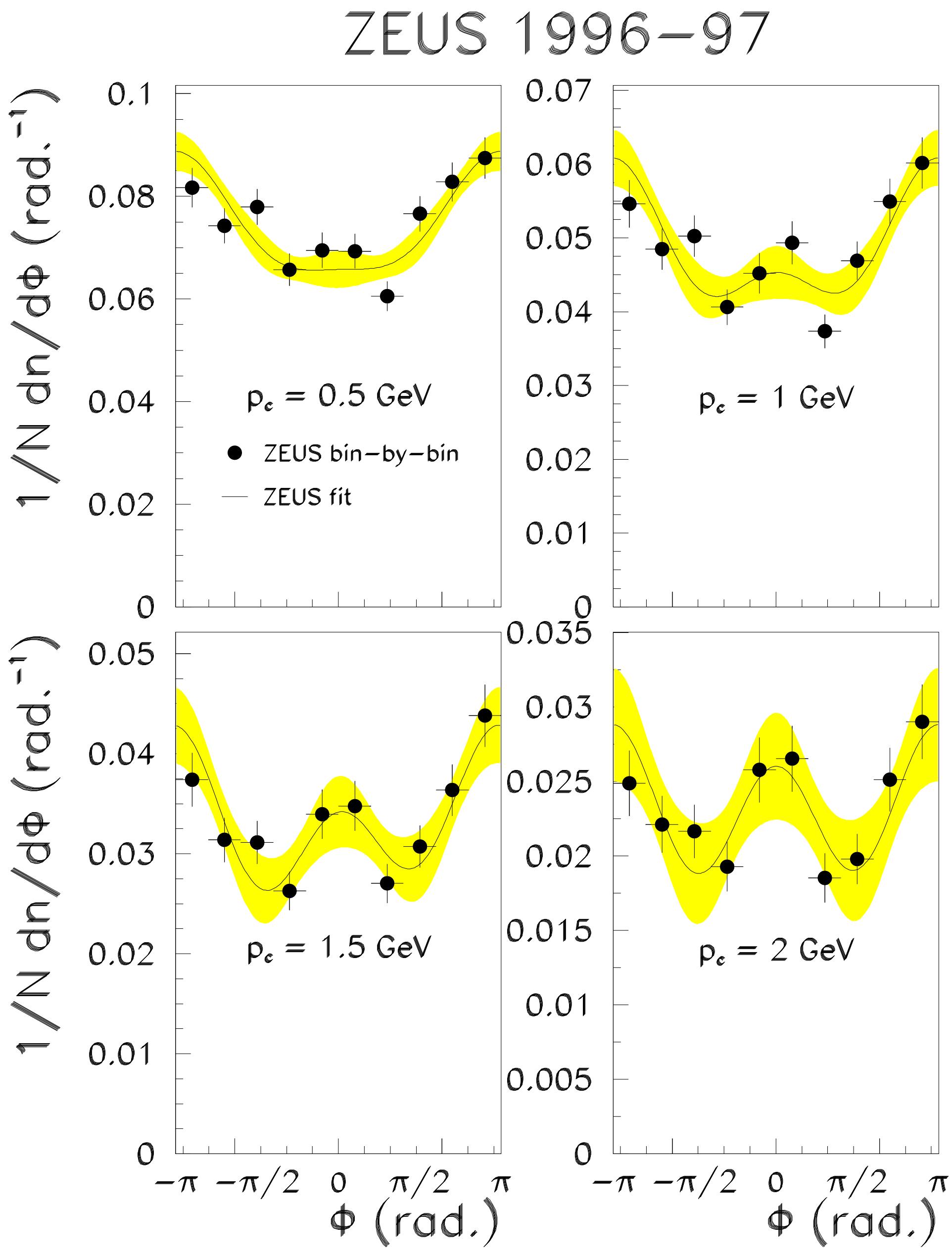


$E_{T,B}^{\text{jet}}$ dependence gets flatter with increasing Q^2

Azimuthal asymmetry

$$d\sigma/d\phi = A + B\cos\phi + C cos 2\phi$$

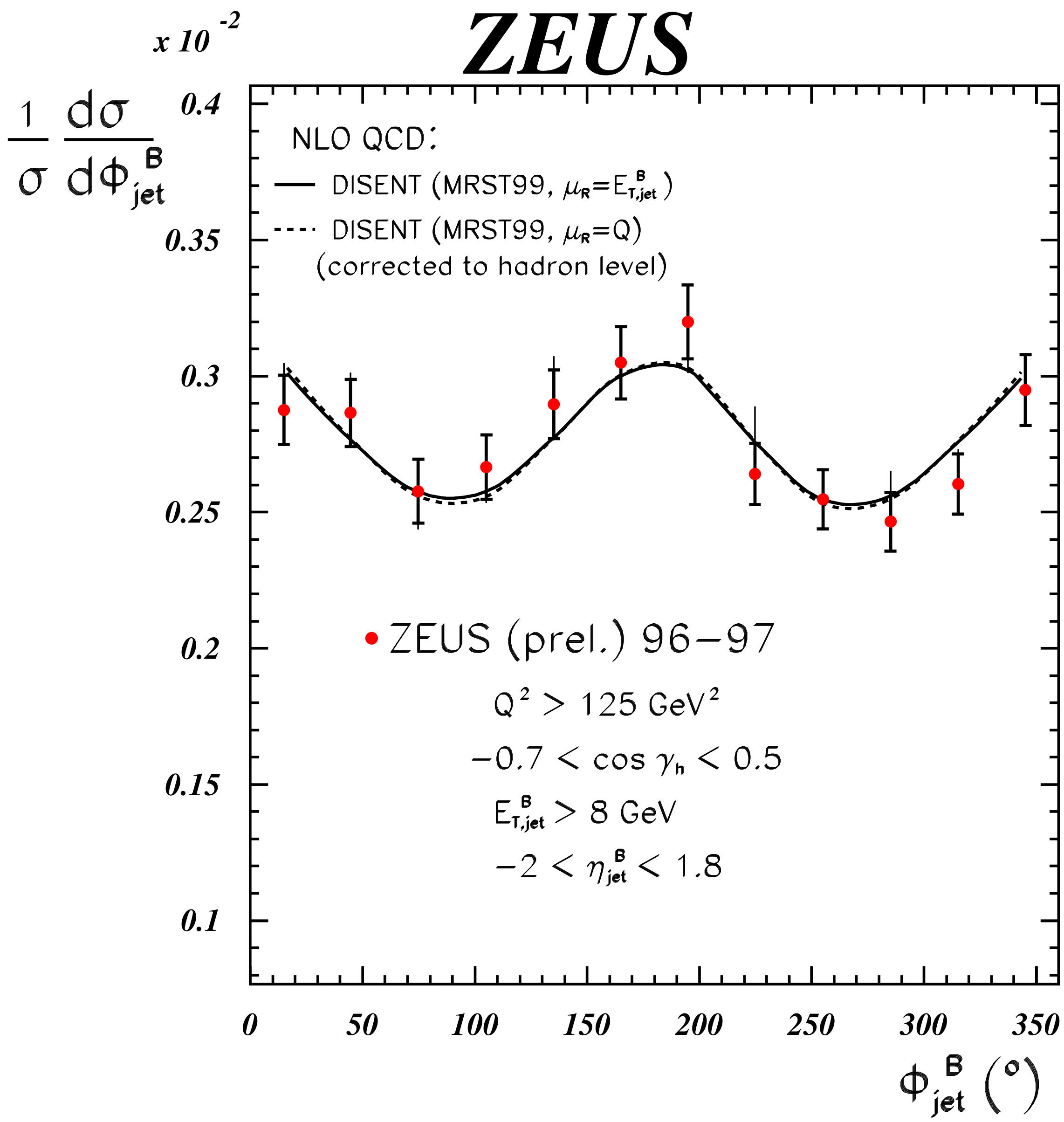
ZEUS has already published (PLB 481 (2000) 199) evidence for it based on a QCD analysis of leading charged hadrons production:



Azimuthal asymmetry (incl. jets)

Without an identification of quark/gluon initiated jets QCD predicts:

$$d\sigma/d\phi_B^{\mathrm{jet}} \sim A + C\cos 2\phi$$



- NLO shape well reproduced by the data
- First observation from a NC DIS jet cross section

α_s from inclusive jet production

Various QCD fits of $d\sigma_{\rm jet}/dQ^2$ and $d\sigma_{\rm jet}/dE_T$ have been performed:

- $\mu_r = E_T^{\rm jet}$ (default) $\mu_r = Q$ (check)
- MRST99 α_s-series (default) CTEQ4 α_s-series (check)

Results:

Full phase-space region: $d\sigma/dQ^2$

$$\alpha_s(M_Z) = 0.1241 \pm 0.0009({\rm stat.})\,^{+0.0043}_{-0.0038}\,({\rm exp.})\,^{+0.0052}_{-0.0036}\,({\rm th.})$$

High-Q^2 region, [$Q^2 > 500$ GeV^2]: $d\sigma/dQ^2$

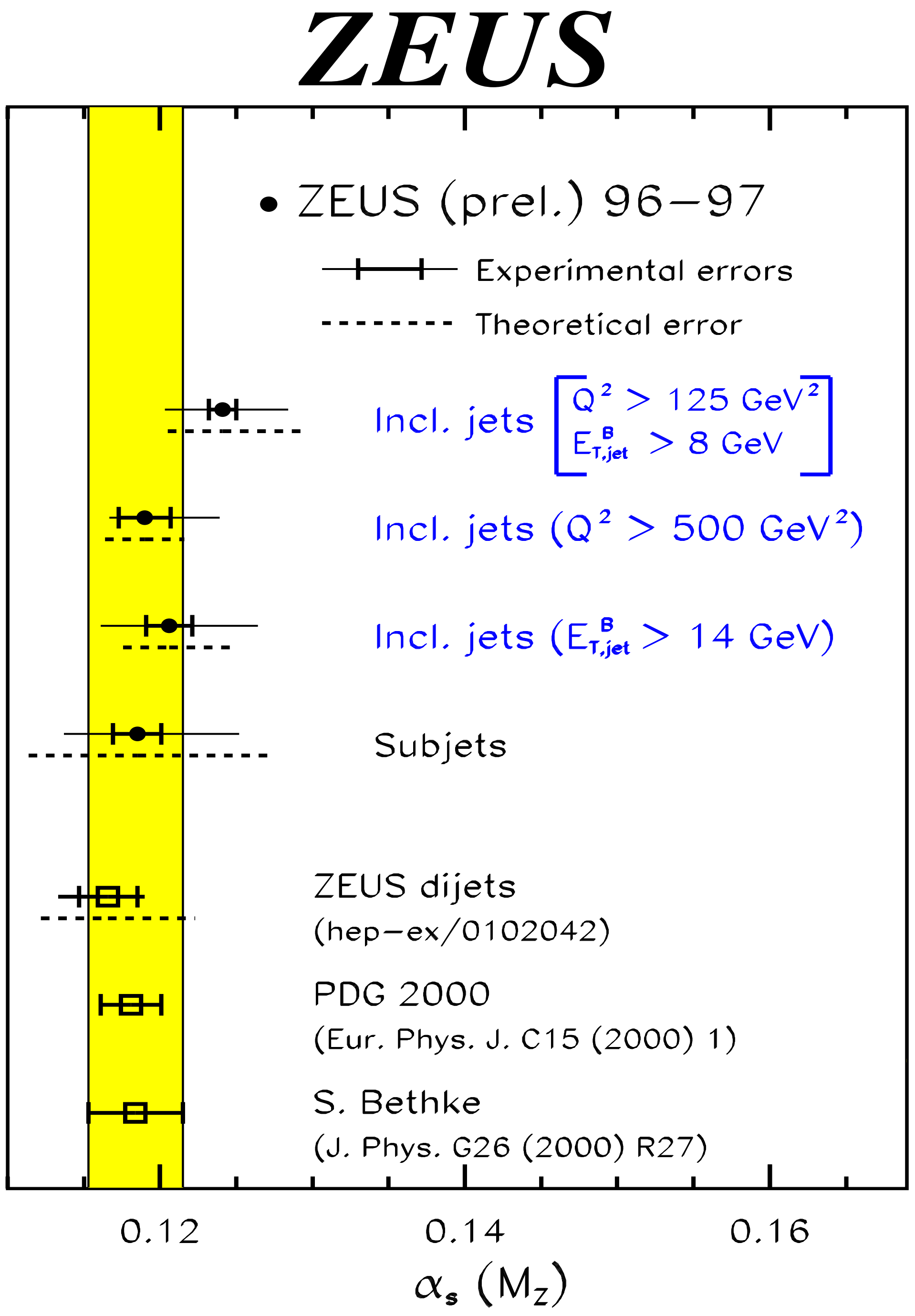
$$\alpha_s(M_Z) = 0.1190 \pm 0.0017({\rm stat.})\,^{+0.0049}_{-0.0023}\,({\rm exp.})\,^{+0.0026}_{-0.0026}\,({\rm th.})$$

High-E_T region, [$E_T^{\rm jet} > 14$ GeV]: $d\sigma/dE_T^{\rm jet}$

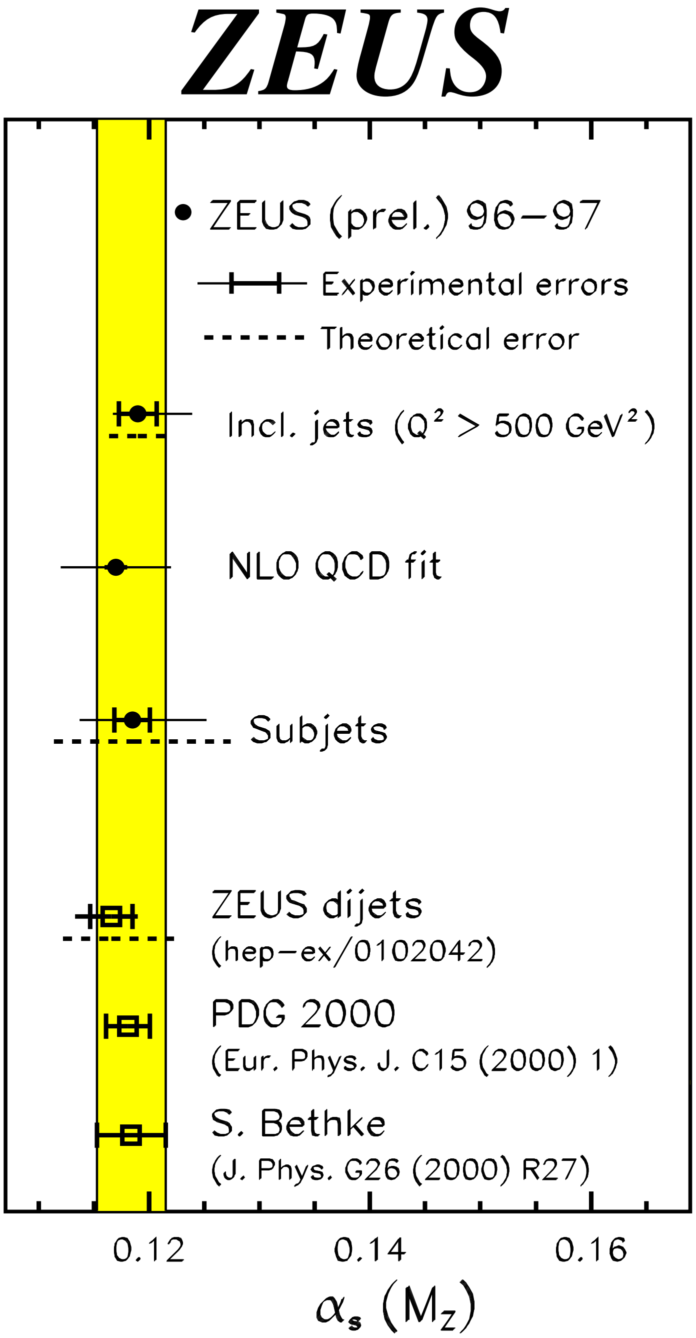
$$\alpha_s(M_Z) = 0.1206 \pm 0.0015({\rm stat.})\,^{+0.0058}_{-0.0045}\,({\rm exp.})\,^{+0.0041}_{-0.0030}\,({\rm th.})$$

- Smaller Theoretical uncertainty w.r.t dijet cross sections
- Very precise determination of α_s at high-Q^2 or high-$E_T^{\rm jet}$

α_s Summary



α_s Summary



Conclusions

Dijet production:

- Data well described by NLO pQCD calculations
- Uncertainty on α_s competitive and mostly limited by theory
- Progress on the estimate of the PDFs-related uncertainties

Inclusive jet production:

- Data slightly above NLO pQCD calculations in the low-Q^2 low-$E_{T,B}^{\rm jet}$ regions
- very precise determination of α_s at high-Q^2 or high-$E_{T,B}^{\rm jet}$
- First observation of azimuthal asymmetries from a NC DIS jet cross section

Many jet cross sections now available from ZEUS and H1...
$\Rightarrow$ Include them in global DGLAP analyses