DIS07

XV International Workshop on Deep-Inelastic Scattering and Related Subjects

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Summary of α_s determinations at ZEUS

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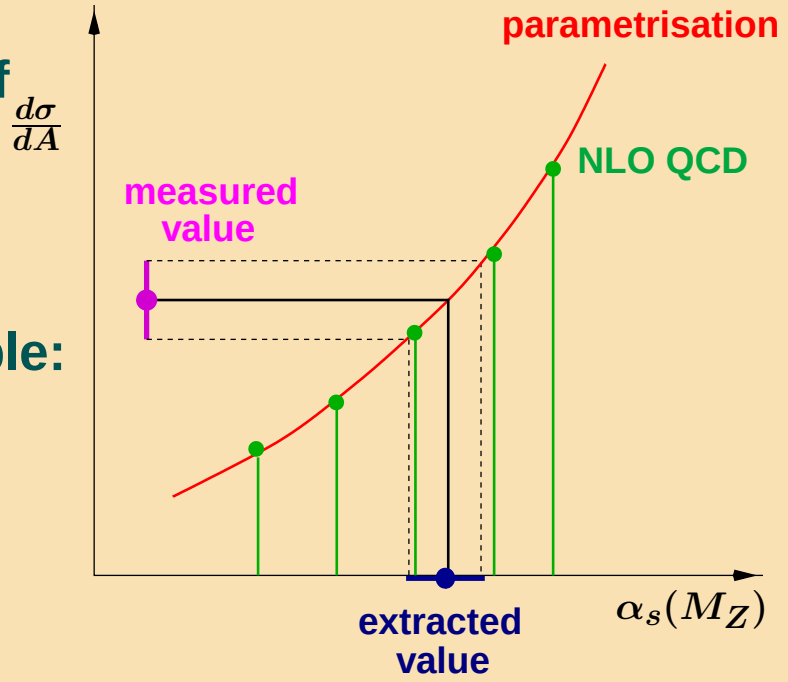
ZEUS Collab.

The method to determine α_s from jet observables

- The procedure to determine α_s from jet observables used by ZEUS is based on the α_s dependence of the pQCD calculations, taking into account the correlation with the PDFs:
  - perform NLO calculations using different sets of proton PDFs
  - use as input in each calculation the value of $\alpha_s(M_Z)$ assumed in each PDF set
  - parametrise the α_s dependence of the observable:

$$A(\alpha_s(M_Z)) = A_i^i\,\alpha_s(M_Z) + A_2^i\,\alpha_s(M_Z)^2$$

  - determine $\alpha_s(M_Z)$ from the measured value using the NLO parametrisation



- This procedure handles correctly the complete α_s-dependence of the NLO calculations (explicit dependence in the partonic cross section and implicit dependence from the PDFs) in the fit, while preserving the correlation between α_s and the PDFs

$\alpha_s(M_Z)$ from jet cross sections

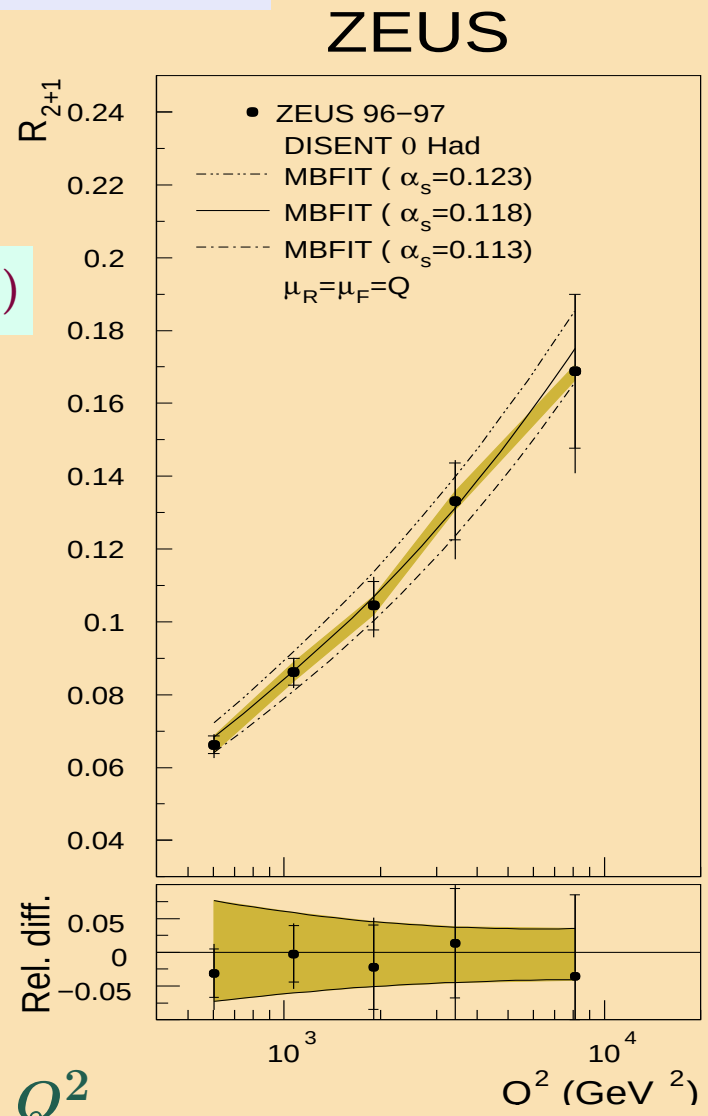
Ratio of dijet to total cross sections in NC DIS

- From the measured $R_{2+1}(Q^2)$ for $Q^2 > 470$ GeV^2 a value of $\alpha_s(M_Z)$ has been extracted:

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

- Experimental uncertainties:
  - $\longrightarrow$ dominated by jet energy scale uncertainty
- Theoretical uncertainties:
  - $\longrightarrow$ terms beyond NLO: $\Delta\alpha_s/\alpha_s = ^{+4.7}_{-3.6}\%$
  - $\longrightarrow$ uncertainties from the pPDFs: $\Delta\alpha_s/\alpha_s = ^{+1.0}_{-0.9}\%$
  - $\longrightarrow$ hadronisation corrections: $\Delta\alpha_s/\alpha_s = \pm 0.4\%$

$\longrightarrow$ Need improvement in theoretical calculations to obtain a more precise determination of $\alpha_s(M_Z)$ from dijet cross sections in the Breit frame at high Q^2



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$\alpha_s(M_Z)$ from jet cross sections

Inclusive-jet cross section in photoproduction

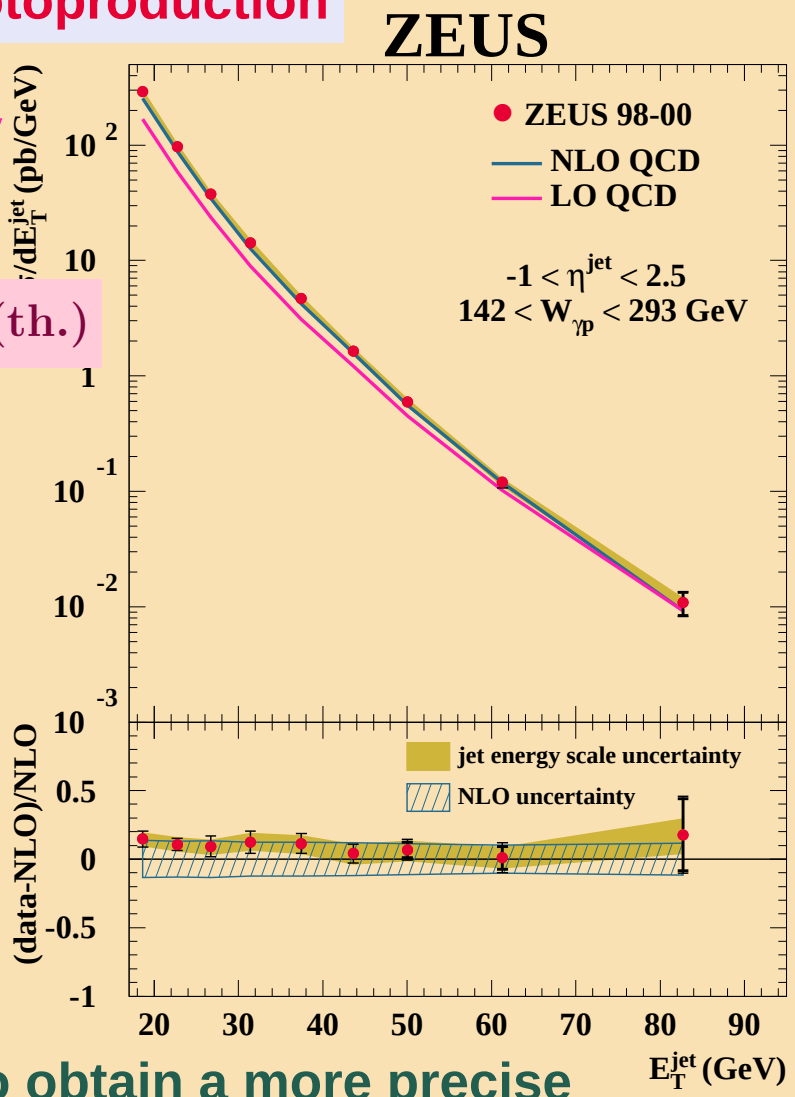
- From the measured $d\sigma/dE_T^{\rm jet}$ for $E_T^{\rm jet} > 17$ GeV a value of $\alpha_s(M_Z)$ has been extracted:

$$\alpha_s(M_Z) = 0.1224 \pm 0.0001\ (\text{stat.})\ ^{+0.0022}_{-0.0019}\ (\text{exp.})\ ^{+0.0054}_{-0.0042}\ (\text{th.})$$

- Experimental uncertainties:
  - → dominated by jet energy scale uncertainty:

$$\Delta\alpha_s/\alpha_s = \pm 1.5\%$$

- Theoretical uncertainties:
  - → terms beyond NLO: $\Delta\alpha_s/\alpha_s = ^{+4.2}_{-3.3}\ \%$
  - → uncertainties from pPDFs: $\Delta\alpha_s/\alpha_s = \pm 0.9\%$
  - → hadronisation corrections: $\Delta\alpha_s/\alpha_s = +0.8\%$
  - → uncertainties from γPDFs: $\Delta\alpha_s/\alpha_s = +0.7\%$



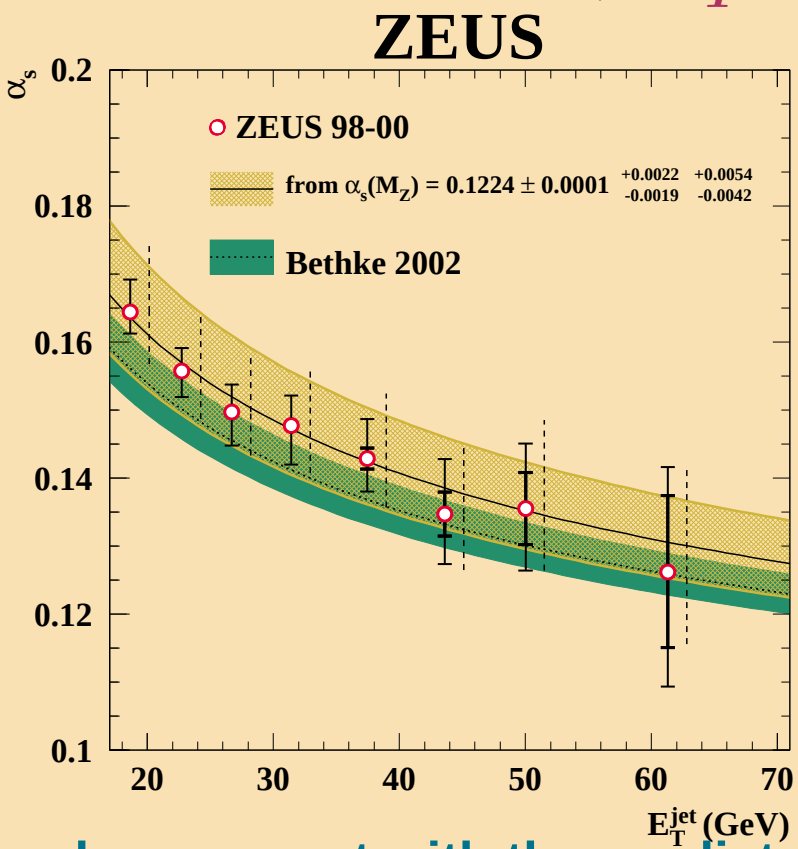
→ Need improvement in theoretical calculations to obtain a more precise determination of $\alpha_s(M_Z)$ from inclusive jet cross sections in photoproduction

ZEUS Collab, PLB 560 (2003) 7

Test of the energy-scale dependence of α_s

Inclusive-jet cross section in photoproduction

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



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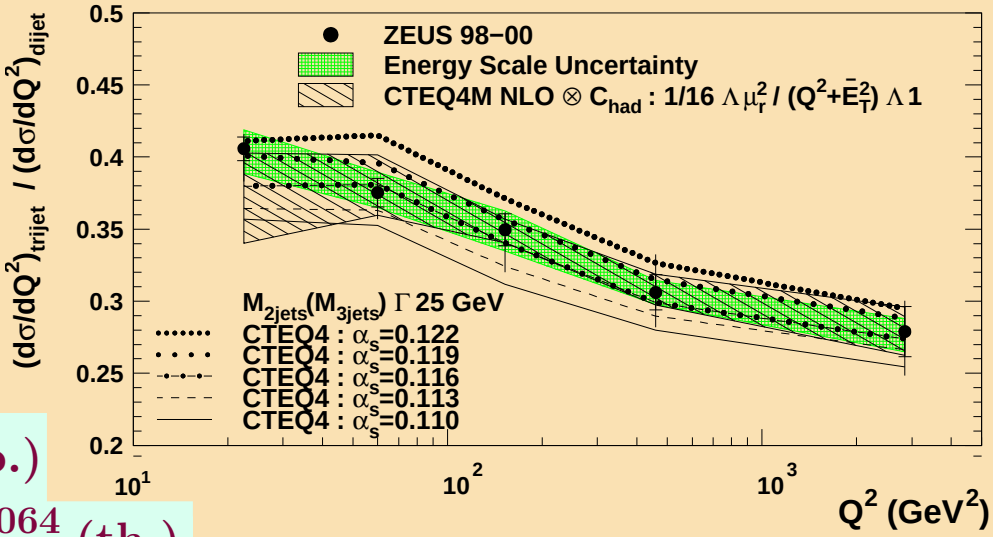
→ The results are in good agreement with the predicted running of α_s over a large range in $E_T^{\rm jet}$

$\alpha_s(M_Z)$ from jet cross sections

Ratio of trijet to dijet cross sections in NC DIS

- From the measured $d\sigma/dQ^2_{\text{trijet}}/d\sigma/dQ^2_{\text{dijet}}$ for $10 < Q^2 < 5000$ GeV^2 a value of $\alpha_s(M_Z)$ has been extracted:



$$\alpha_s(M_Z) = 0.1179 \pm 0.0013\ (\text{stat.})\ ^{+0.0028}_{-0.0046}\ (\text{exp.})\ ^{+0.0064}_{-0.0046}\ (\text{th.})$$

- Experimental uncertainties:
  → dominated by jet energy scale uncertainty:
  $\Delta\alpha_s/\alpha_s = ^{+2.0}_{-2.5}\%$
- Theoretical uncertainties:
  → terms beyond NLO: $\Delta\alpha_s/\alpha_s = ^{+5.0}_{-3.5}\%$
  → uncertainties from pPDFs: $\Delta\alpha_s/\alpha_s = ^{+1.5}_{-2.0}\%$
  → hadronisation corrections: $\Delta\alpha_s/\alpha_s = \pm 2\%$

→ Need improvement in theoretical calculations to obtain a more precise determination of $\alpha_s(M_Z)$ from multijet cross sections in NC DIS

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$\alpha_s(M_Z)$ from internal structure of jets

Integrated jet shape in NC DIS

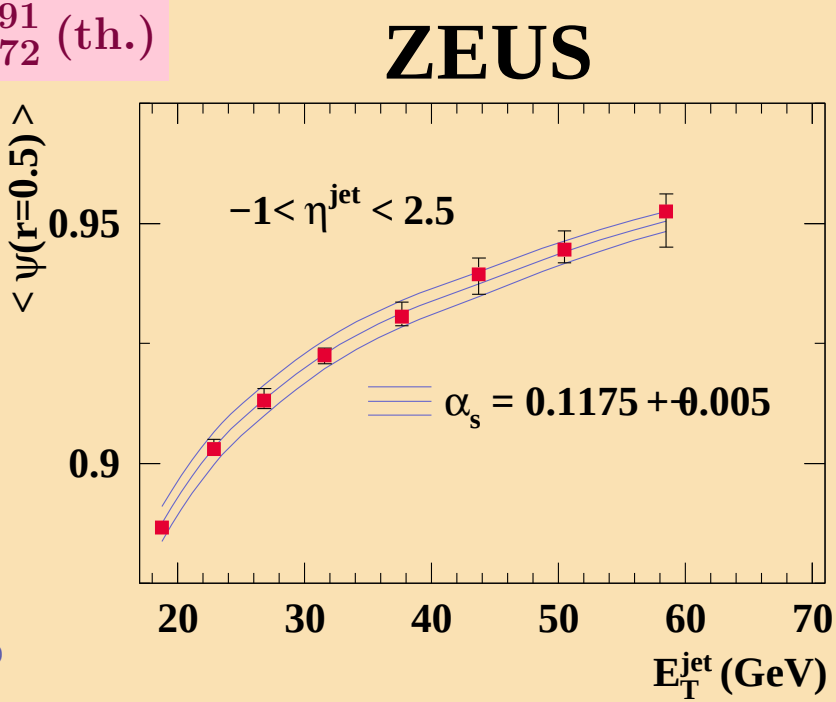
- From the measured $\langle\psi(r=0.5)\rangle$ for $E_T^{\rm jet} > 21$ GeV a value of $\alpha_s(M_Z)$ has been extracted:

$$\alpha_s(M_Z) = 0.1176 \pm 0.0009\ (\text{stat.})\ ^{+0.0009}_{-0.0026}\ (\text{exp.})\ ^{+0.0091}_{-0.0072}\ (\text{th.})$$

- Experimental uncertainties:
  - → dominated by jet energy scale uncertainty:

$$\Delta\alpha_s/\alpha_s = ^{+0.8}_{-2.2}\%$$

- Theoretical uncertainties:
  - → terms beyond NLO: $\Delta\alpha_s/\alpha_s = ^{+7.6}_{-6.0}\%$
  - → uncertainties from pPDFs: negligible
  - → hadronisation corrections: $\Delta\alpha_s/\alpha_s = \pm 1.5\%$



→ Need improvement in theoretical calculations to obtain a more precise determination of $\alpha_s(M_Z)$ from jet shape in NC DIS

ZEUS Collab, NPB 700 (2004) 3

$\alpha_s(M_Z)$ from jet cross sections

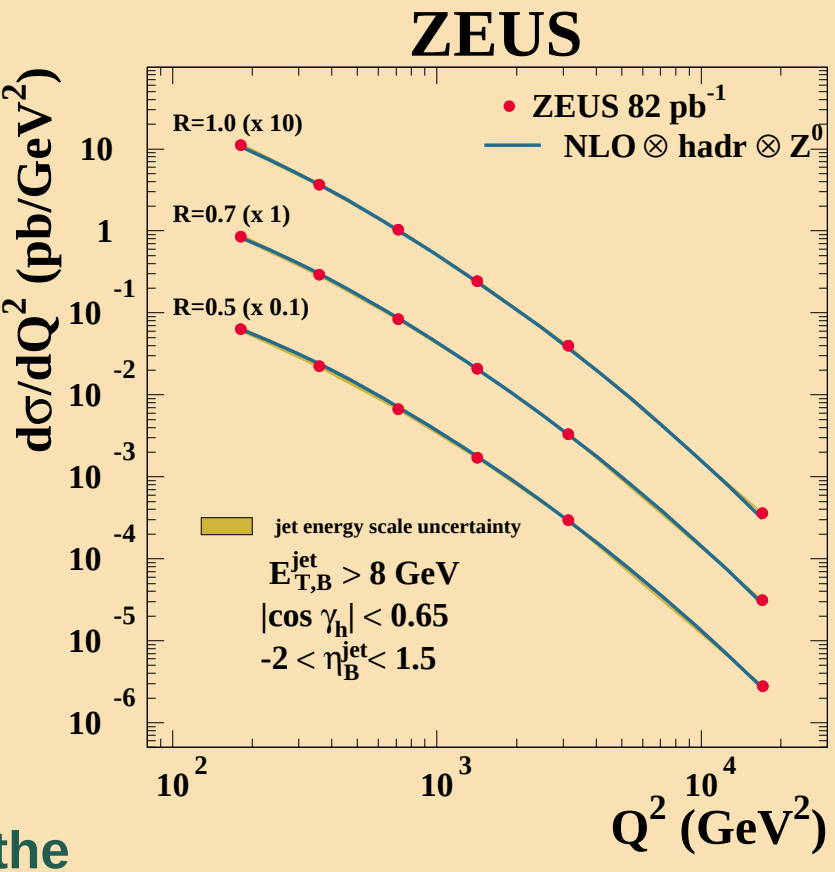
Inclusive-jet cross section in NC DIS

- From the measured $d\sigma/dQ^2$ for $Q^2 > 500$ GeV^2 and $R = 1$ a value of $\alpha_s(M_Z)$ has been extracted:

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

- Experimental uncertainties:
  - → dominated by jet energy scale uncertainty: $\Delta\alpha_s/\alpha_s = \pm 2\%$
- Theoretical uncertainties:
  - → terms beyond NLO: $\Delta\alpha_s/\alpha_s = \pm 1.5\%$
  - → uncertainties from pPDFs: $\Delta\alpha_s/\alpha_s = \pm 0.7\%$
  - → hadronisation corrections: $\Delta\alpha_s/\alpha_s = \pm 0.8\%$

→ $\alpha_s(M_Z)$ from inclusive jet cross sections in the Breit frame: most precise determination at HERA (theoretical uncertainty: $\sim 1.9\%$)



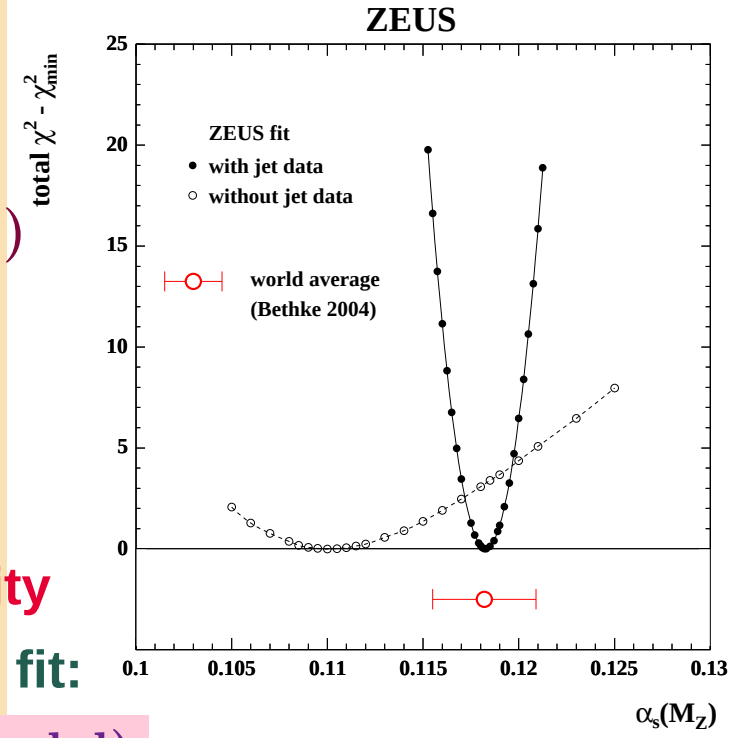
ZEUS Collab, DESY-06-241

$\alpha_s(M_Z)$ from structure functions

NLO QCD fit to inclusive and jet data

- Simultaneous determination of the proton PDFs and $\alpha_s(M_Z)$
- Jet cross sections are directly sensitive to $\alpha_s(M_Z)$ via $\gamma^{(*)}g \rightarrow q\bar{q}$ (coupled to gluon density) and via $\gamma^{(*)}q \rightarrow qg$ (NOT coupled to gluon density)

$\rightarrow$ The inclusion of the jet cross sections allows an extraction of $\alpha_s(M_Z)$ from structure functions that is NOT strongly correlated to the gluon density



- Determination of $\alpha_s(M_Z)$ from the ZEUS-JETS-α_s fit:

$$\alpha_s(M_Z) = 0.1183 \pm 0.0016\ (\text{norm.}) \pm 0.0008\ (\text{model})$$

- Estimation of the uncertainty due to terms beyond NLO

$$\rightarrow \Delta\alpha_s(M_Z) = \pm 0.0050$$

$\Rightarrow$ Precise determination $\boxed{\alpha_s(M_Z) = 0.1183 \pm 0.0058}$ from ZEUS data alone

ZEUS Collab, Eur Phys Jour C 42 (2005) 1

Comparison of $\alpha_s(M_Z)$ determinations at ZEUS

- Determinations of $\alpha_s(M_Z)$ by ZEUS from jet cross sections, internal structure of jets and NLO QCD fit of structure functions:

Process	Value	Stat.	Experim.	Theory	Total	(%)	
Inc. Jet NC DIS	0.1207	0.0014	$^{+0.0035}_{-0.0033}$	$^{+0.0022}_{-0.0023}$	$^{+0.0044}_{-0.0043}$	~ 3.6	*
Inc. Jet γp	0.1224	0.0001	$^{+0.0022}_{-0.0019}$	$^{+0.0054}_{-0.0042}$	$^{+0.0058}_{-0.0046}$	~ 4	*
NLO QCD Fit	0.1183	$\rightarrow$	$^{+0.0028}_{-0.0028}$	$^{+0.0051}_{-0.0051}$	$^{+0.0058}_{-0.0058}$	~ 5	
Dijet NC DIS	0.1166	0.0019	$^{+0.0024}_{-0.0033}$	$^{+0.0057}_{-0.0044}$	$^{+0.0065}_{-0.0058}$	~ 5	*
3/2 Jet NC DIS	0.1179	0.0013	$^{+0.0028}_{-0.0046}$	$^{+0.0064}_{-0.0046}$	$^{+0.0071}_{-0.0066}$	~ 6	*
Jet Shape NC DIS	0.1176	0.0009	$^{+0.0009}_{-0.0026}$	$^{+0.0091}_{-0.0072}$	$^{+0.0092}_{-0.0077}$	~ 7	*
Subjet NC DIS	0.1187	0.0017	$^{+0.0024}_{-0.0009}$	$^{+0.0093}_{-0.0076}$	$^{+0.0097}_{-0.0078}$	~ 8	
Subjet CC DIS	0.1202	0.0052	$^{+0.0060}_{-0.0019}$	$^{+0.0065}_{-0.0053}$	$^{+0.0103}_{-0.0077}$	~ 8	

$\rightarrow$ experimental uncertainties: $\sim 3\%$

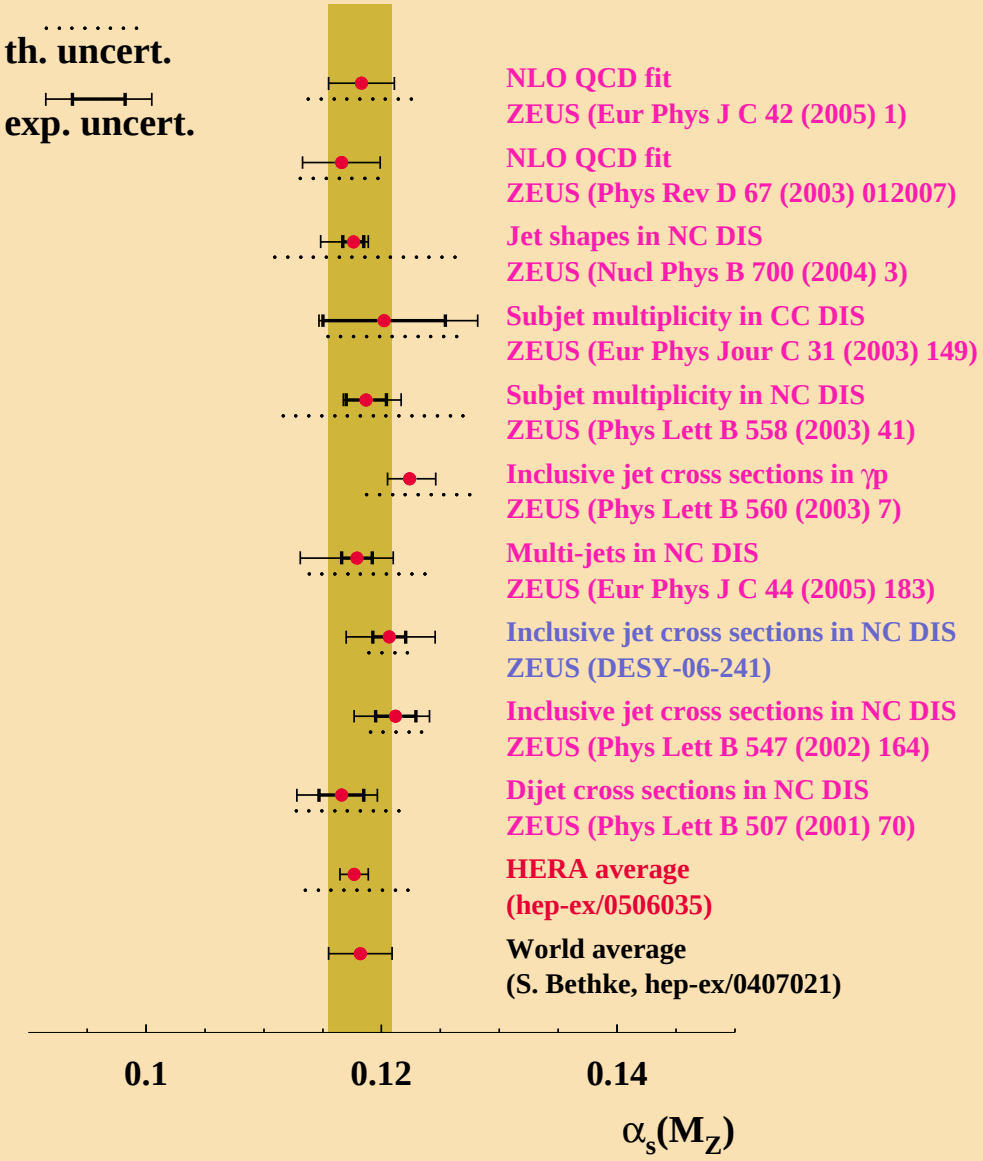
$\rightarrow$ theoretical uncertainties: $\sim 4\%$ (jet cross sections and NLO QCD fit)

$\sim 8\%$ (internal structure of jets)

Summary of determinations of $\alpha_s(M_Z)$ at ZEUS

All the measurements are consistent to each other and to the world average

New determination consistent with HERA average



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Averaging the determinations of $\alpha_s(M_Z)$ at HERA

- A proper average requires the inclusion of correlations among the different determinations:

  → Experimental uncertainties:
  - jet energy scale (highly correlated among the determinations from each experiment)

  → Theoretical uncertainties:
  - proton PDFs (correlated)
  - hadronisation corrections (partially correlated)
  - terms beyond NLO (correlated?)

→ Since the theoretical uncertainties are dominant and the biggest contribution arises from the terms beyond NLO

→ the difficulty of averaging the determinations of $\alpha_s(M_Z)$ at HERA lies on the treatment of the theoretical uncertainties arising from terms beyond NLO

Average of $\alpha_s(M_Z)$ from HERA I measurements

- **Several methods have been used to obtain an average of $\alpha_s(M_Z)$ at HERA:**
  - → **Naive method:** $\overline{\alpha_s(M_Z)} = 0.1188 \pm 0.0020$
  - → **Schmelling's method:** $\overline{\alpha_s(M_Z)} = 0.1192 \pm 0.0047$
  - → **Correlated-sources method:**

$$\overline{\alpha_s(M_Z)} = 0.1186 \pm 0.0011\ (\text{exp.}) \pm 0.0050\ (\text{th.})$$
$$= 0.1186 \pm 0.0051$$

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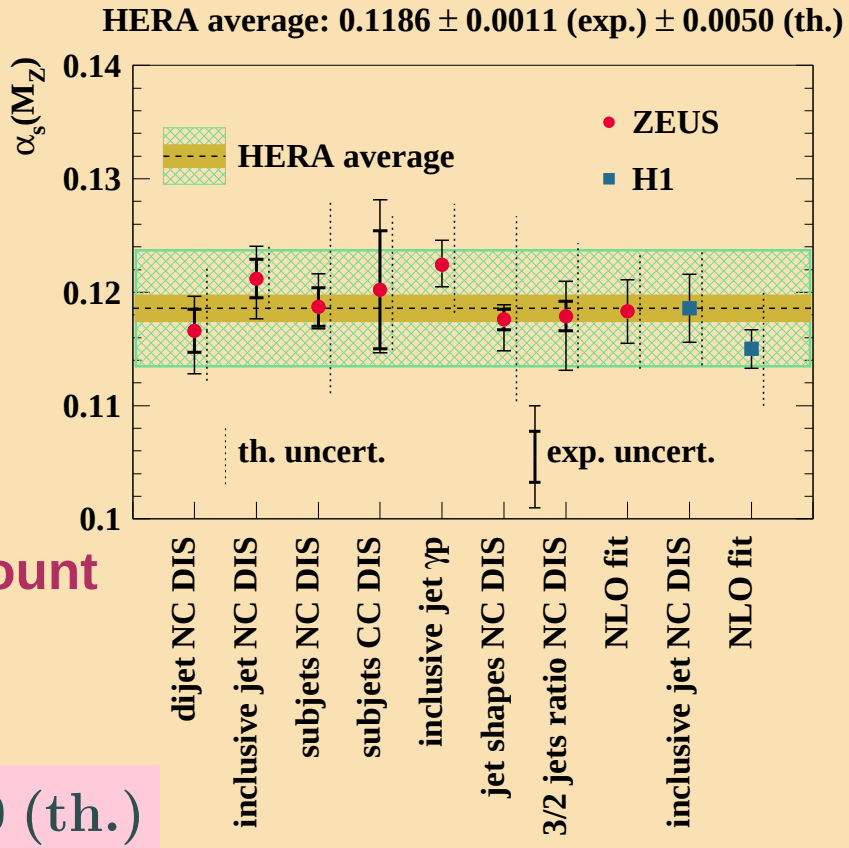


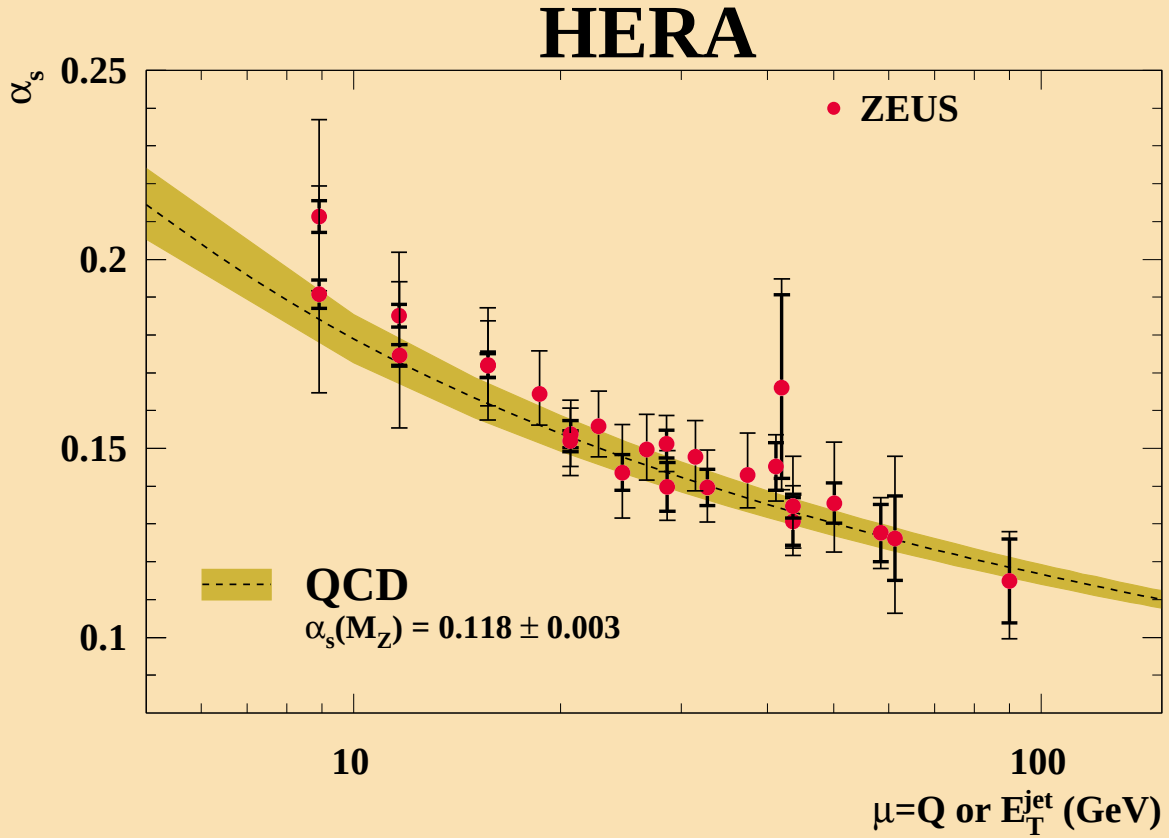
- **The last two methods give comparable uncertainties → confidence on the result**
- **The last method is considered to be the most realistic (though conservative) since the known correlations among determinations from the same experiment were taken explicitly into account**
- **The HERA average is then:**

→ $\overline{\alpha_s(M_Z)} = 0.1186 \pm 0.0011\ (\text{exp.}) \pm 0.0050\ (\text{th.})$

experimental uncertainty: $\sim 0.9\%$; theoretical uncertainty: $\sim 4\%$

Energy-scale dependence of α_s

- The QCD prediction for the energy-scale dependence of α_s has been tested by determining α_s from the measured differential cross sections at different μ:



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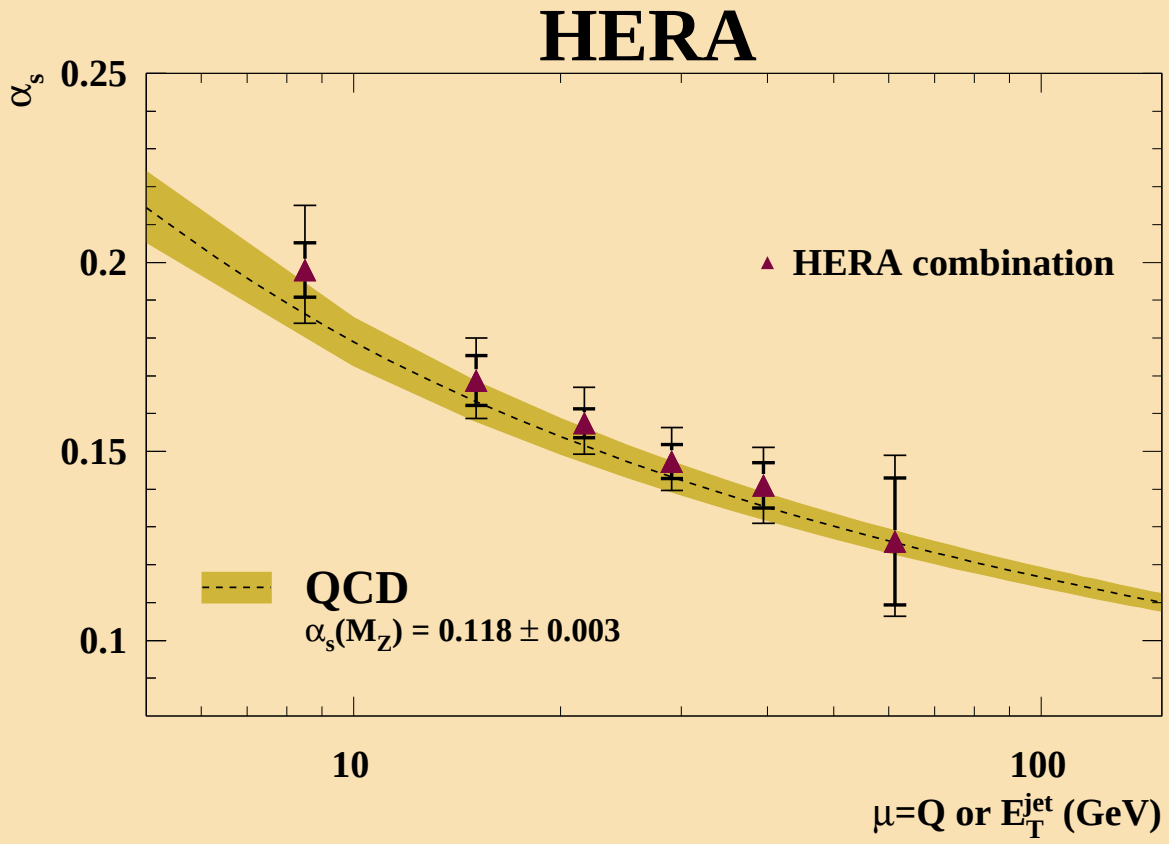
→ The determinations are consistent with the running of α_s as predicted by QCD over a large range in E_T^{jet}

C Glasman, hep-ex/0506035

Energy-scale dependence of α_s

- Determinations at similar μ were combined using the correlated-sources method:



→ **Observation of the running of α_s from HERA jet data**

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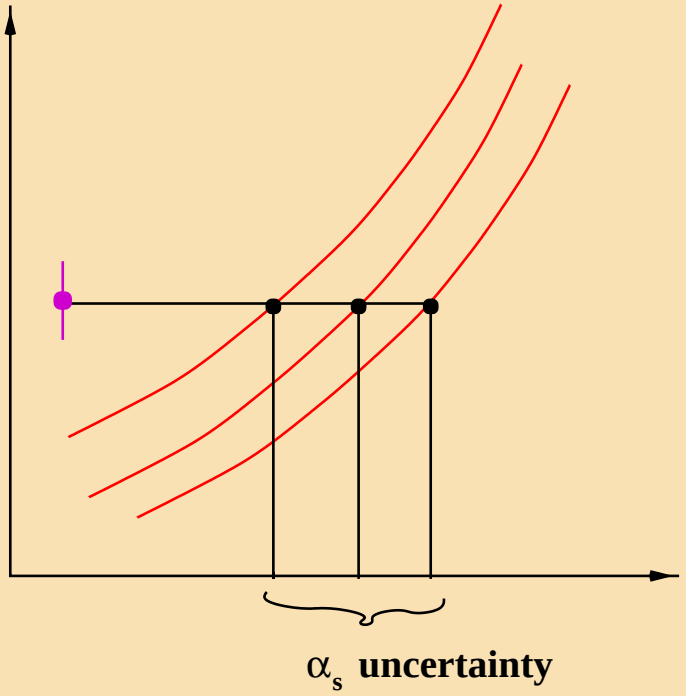
Back-up slides

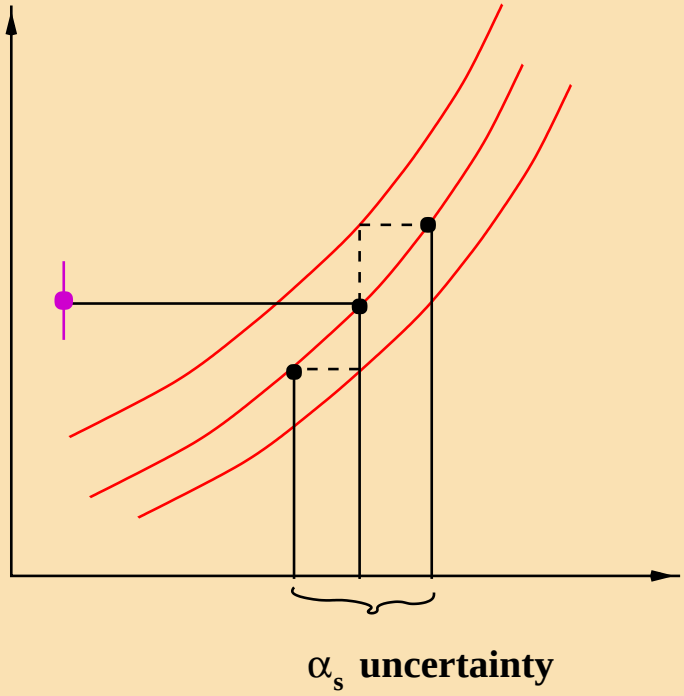
Theoretical uncertainties on $\alpha_s(M_Z)$

- **New method of calculating uncertainty due to higher orders on $\alpha_s(M_Z)$:**
  $\rightarrow$ method proposed by Jones, Ford, Salam, Stenzel and Wicke (JHEP 12003007)

- **Old method of determining theoretical uncertainties was subject to fluctuations in the data**

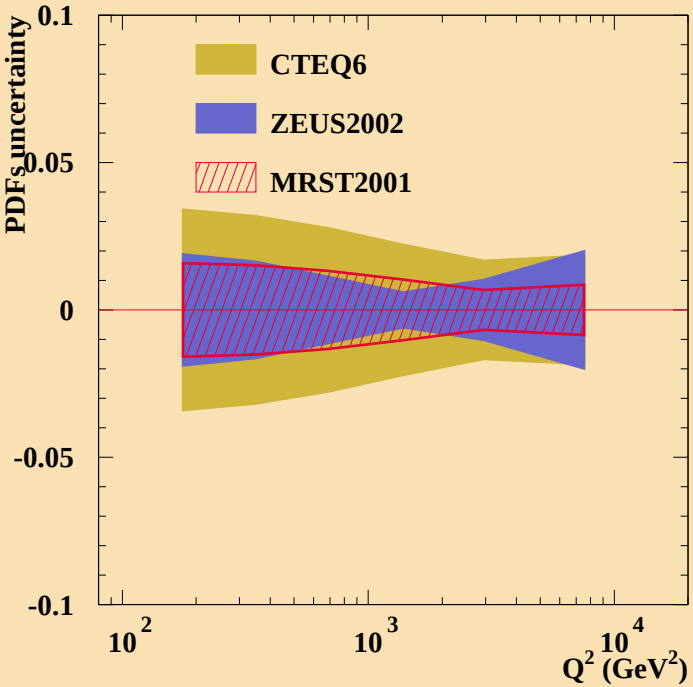


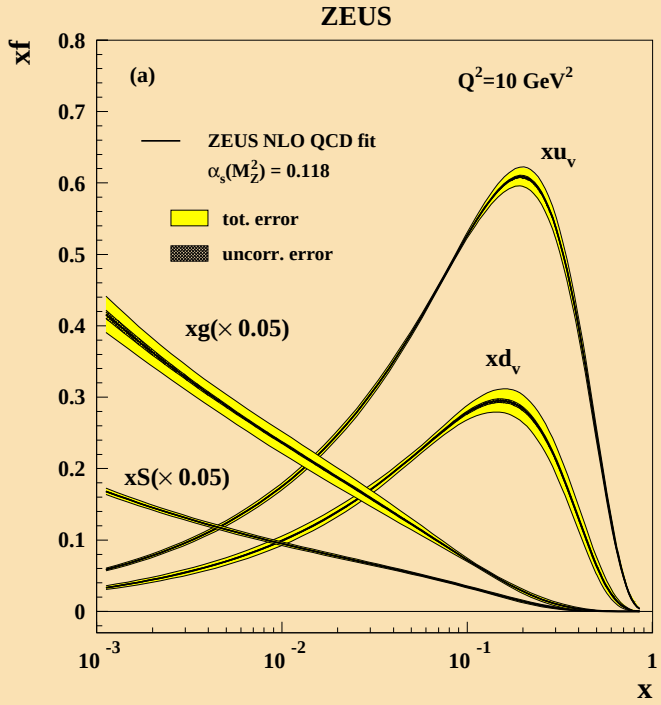
- **New method minimizes dependence on data**



Theoretical uncertainties on $\alpha_s(M_Z)$

- **PDF uncertainty of inclusive-jet cross section as a function of Q^2 for various PDF sets:**





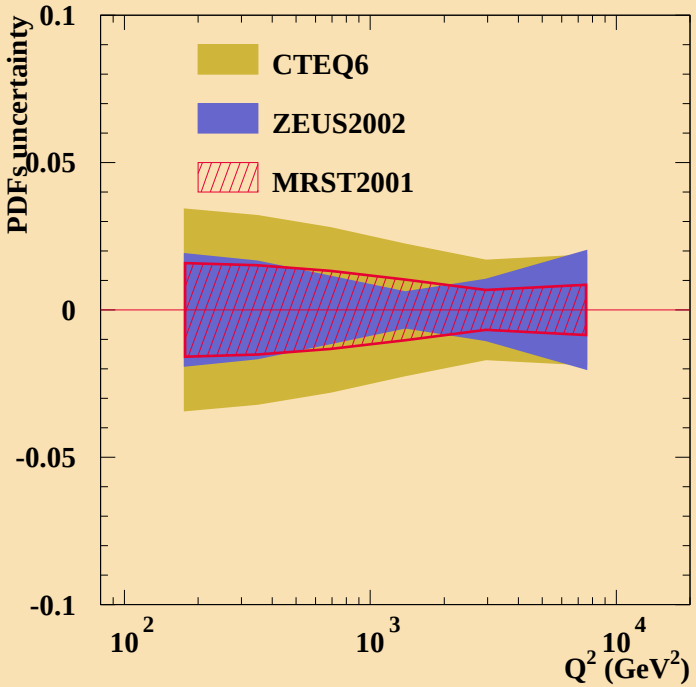
← **PDF set ZEUS2002-RT (DESY 02-105)**

← **ZEUS and fixed-target data**

← **uncertainties under control**

Theoretical uncertainties on $\alpha_s(M_Z)$

- **PDF uncertainty of inclusive-jet cross section as a function of Q^2 for various PDF sets:**



ZEUS2002-RT $\rightarrow \pm 0.7\%$

MRST-2001 $\rightarrow \pm 0.7\%$

CTEQ6 $\rightarrow \pm 1.6\%$