ICHEP 2000, Osaka.

The strong coupling and the gluon density from jet production in DIS at HERA

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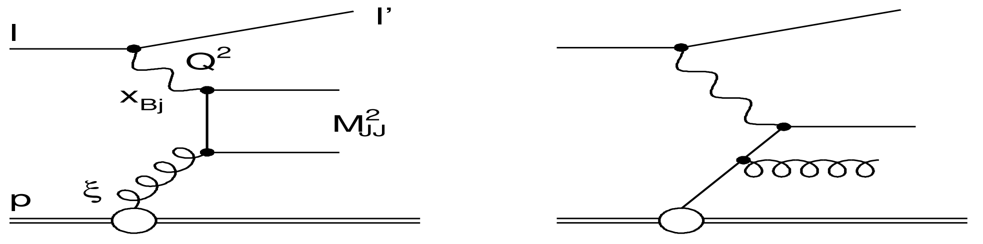
on behalf of the

H1 and **ZEUS** Collaborations

Contents

- Theoretical framework
- Determinations of α_s
- Determination of the gluon density
- Simultaneous Determination of α_s and g
- Conclusions

Theoretical framework



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

⇒ direct sensitivity to α_s, $g(x)$ and $q(x)$

Cross section:

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

Partonic cross section:

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

DGLAP equations:

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

- 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 $f_q = q$

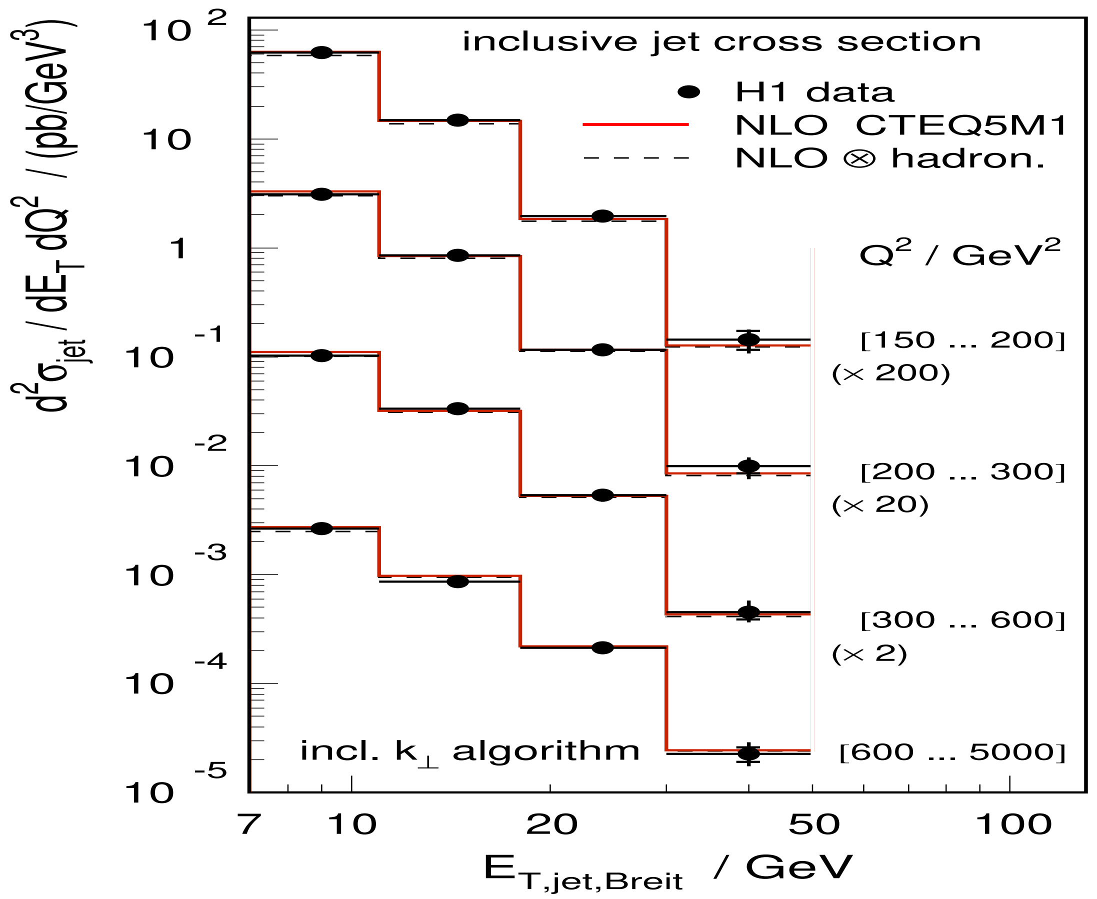
Strategies for a QCD analysis

- Determine α_s (assuming PDFs from global fits)
  - Simple (only one free parameter)
  - World knowledge on PDFs for free

  But the PDFs depend on α_s ...

  - The QCD analysis has to take this into account...
  - $(\Delta\alpha_s)_{(\mathrm{PDFs})}$ has to be fully quantified
- Determine gluon density (assuming $\alpha_s(M_Z)$)
  - Perform a DGLAP fit including HERA jet data
  - Which is the effect on the gluon density ?
- Simultaneous Determination of α_s and PDFs
  - What we are all aiming at...
  - A first attempt from H1

α_s from NC DIS inclusive jet cross section

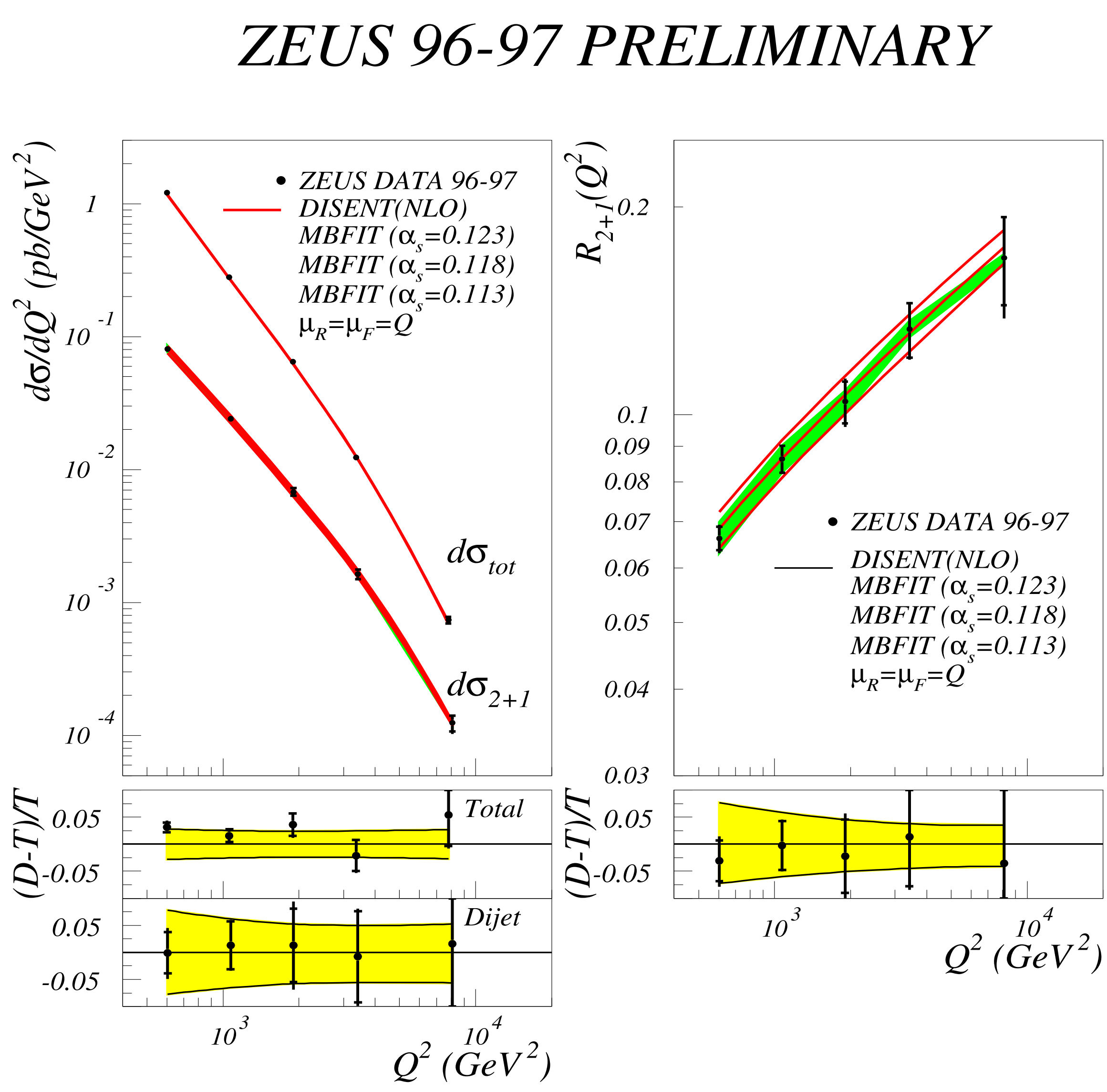


Fit the measured $d^2\sigma_{\mathrm{jet}}/dE_T dQ^2$ to NLO $\otimes$ Had. calculations (DISENT) with CTEQ5M1

Results:

Running $\alpha_s(E_T)$ and $\alpha_s(M_Z)$

α_s from Dijet rate in NC DIS at high Q^2



Fit the measured $R_{2+1}(Q^2) = d\sigma_{2+1}/d\sigma_{\rm tot}$ to NLO $\otimes$ Had. calculations (DISENT) with MBIFIT PDFs

Results:

Running $\alpha_s(Q)$ and $\alpha_s(M_Z)$

PDF Uncertainty

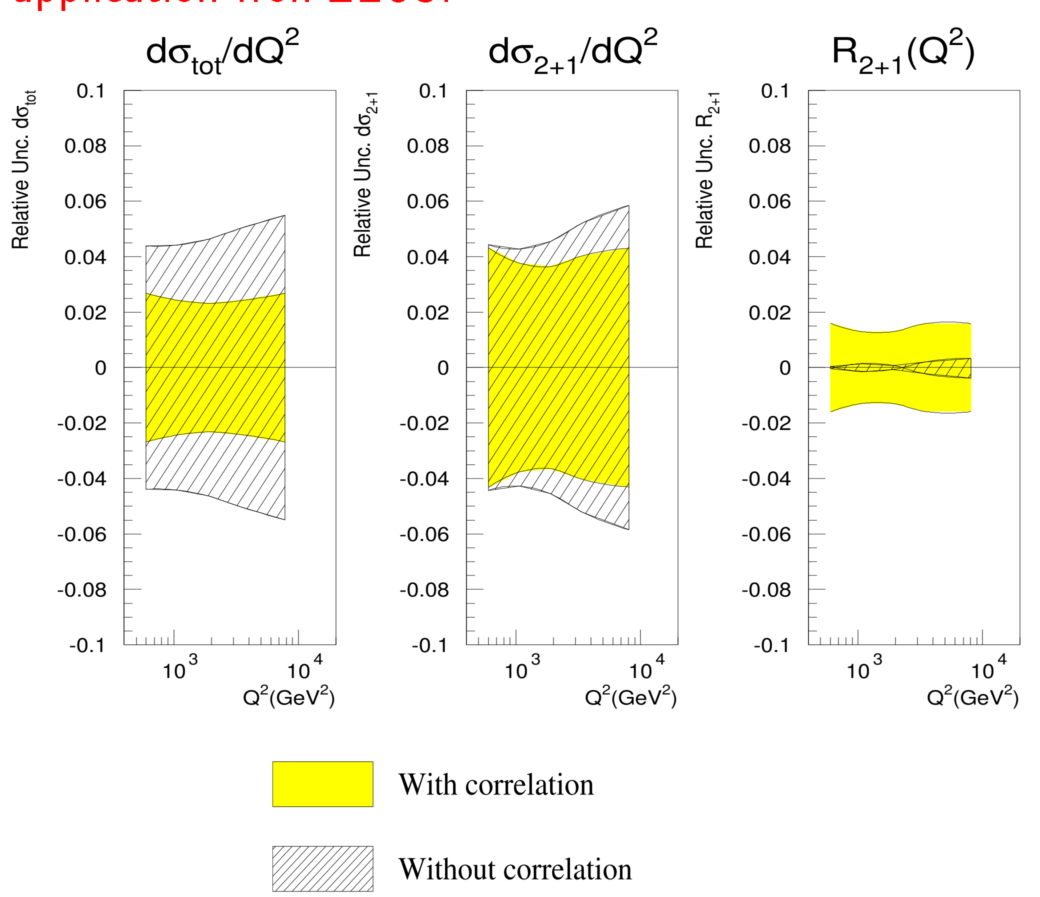
- Mostly estimated by using different PDFs
- Newly available:

  $\Longrightarrow$ EPDFLIB by M. Botje (E.P.J. C14 (2000) 285)

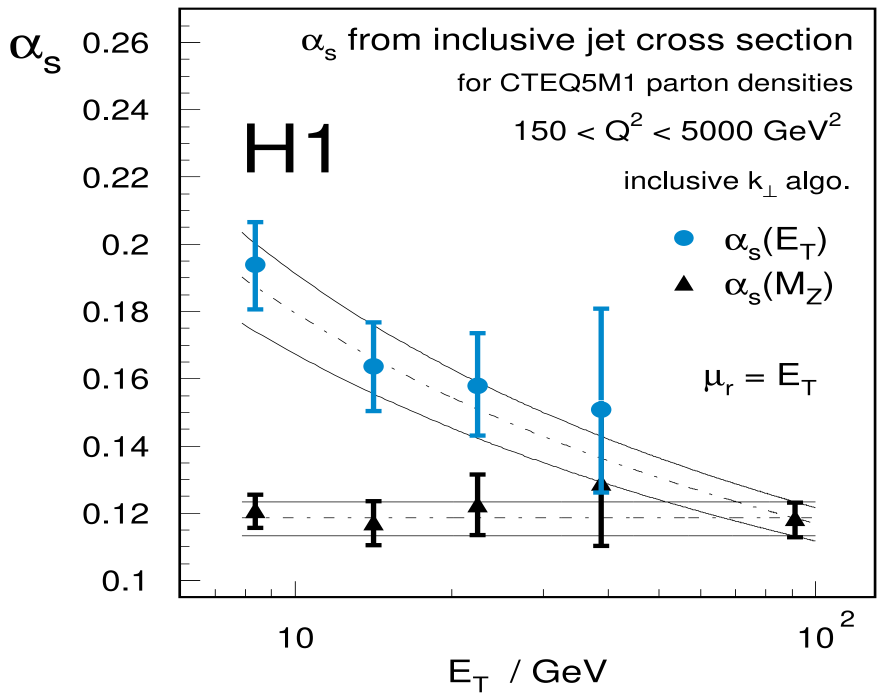
EPDFLIB contains the information (V_{ij}^{cov} and $\partial f_a/\partial \pi_i$) necessary to propagate the uncertainties of the PDFs on the NLO jet cross sections:

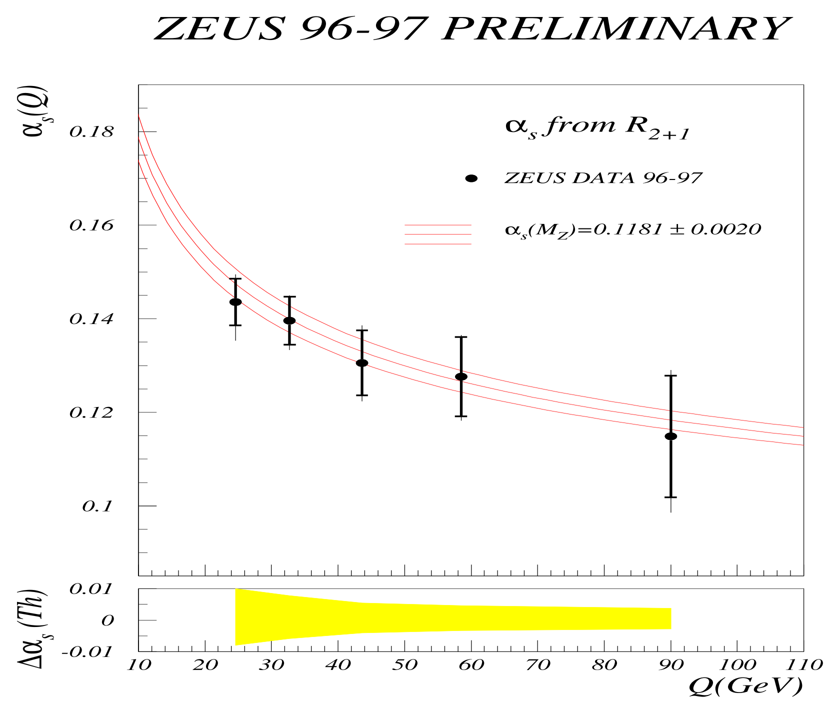
$$\Delta(d\sigma^{NLO}) = \sqrt{\sum_{i=1}^{Np}\sum_{j=1}^{Np} \frac{\partial(d\sigma^{NLO})}{\partial \pi_i}\frac{\partial(d\sigma^{NLO})}{\partial \pi_j} V_{ij}}$$

An application fron ZEUS:



α_s running from jet production in DIS at HERA





$\alpha_s(M_Z)$ from DIS jet production at HERA

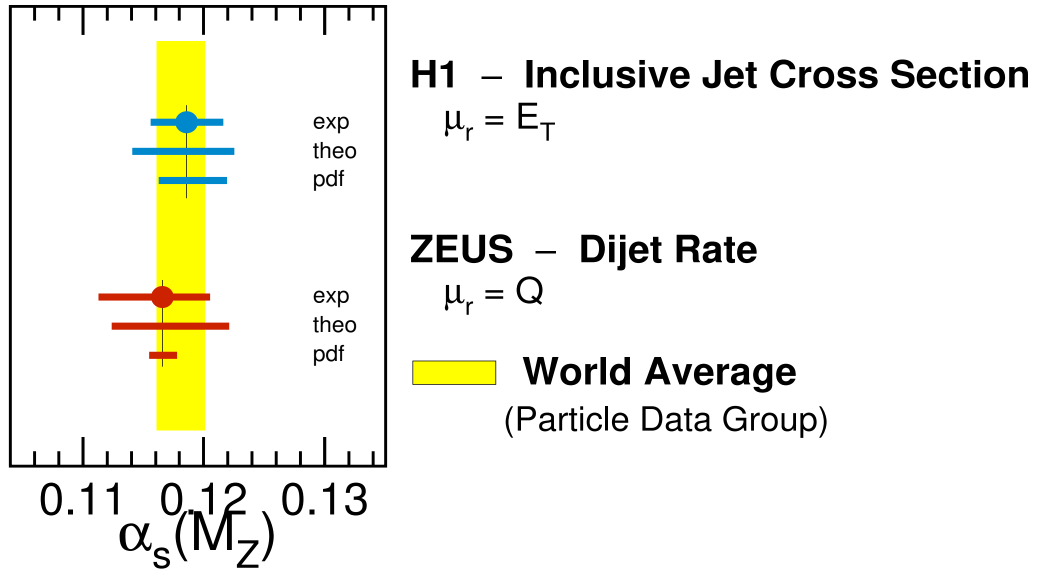
H1:

$$\alpha_s(M_Z) = 0.1186 \pm 0.0030\,(\mathrm{exp})\,{}^{+0.0039}_{-0.0045}\,(\mathrm{th})\,{}^{+0.0033}_{-0.0023}\,(\mathrm{pdf})$$

ZEUS:

$$\alpha_s(M_Z) = 0.1166\,{}^{+0.0039}_{-0.0047}\,(\mathrm{exp})\,{}^{+0.0055}_{-0.0042}\,(\mathrm{th})\,{}^{+0.0012}_{-0.0011}\,(\mathrm{pdf})$$

α_s from Jet Production in DIS at HERA



- Values in excellent agreement with the PDG value
- Competitive uncertainty (5-6%)

Determination of the Gluon density

Two major sources of information on the gluon density at HERA:

- Scaling violations in the inclusive cross section
- BGF process in jet cross sections

Idea: Combine both data samples (H1 only) in a common QCD fit

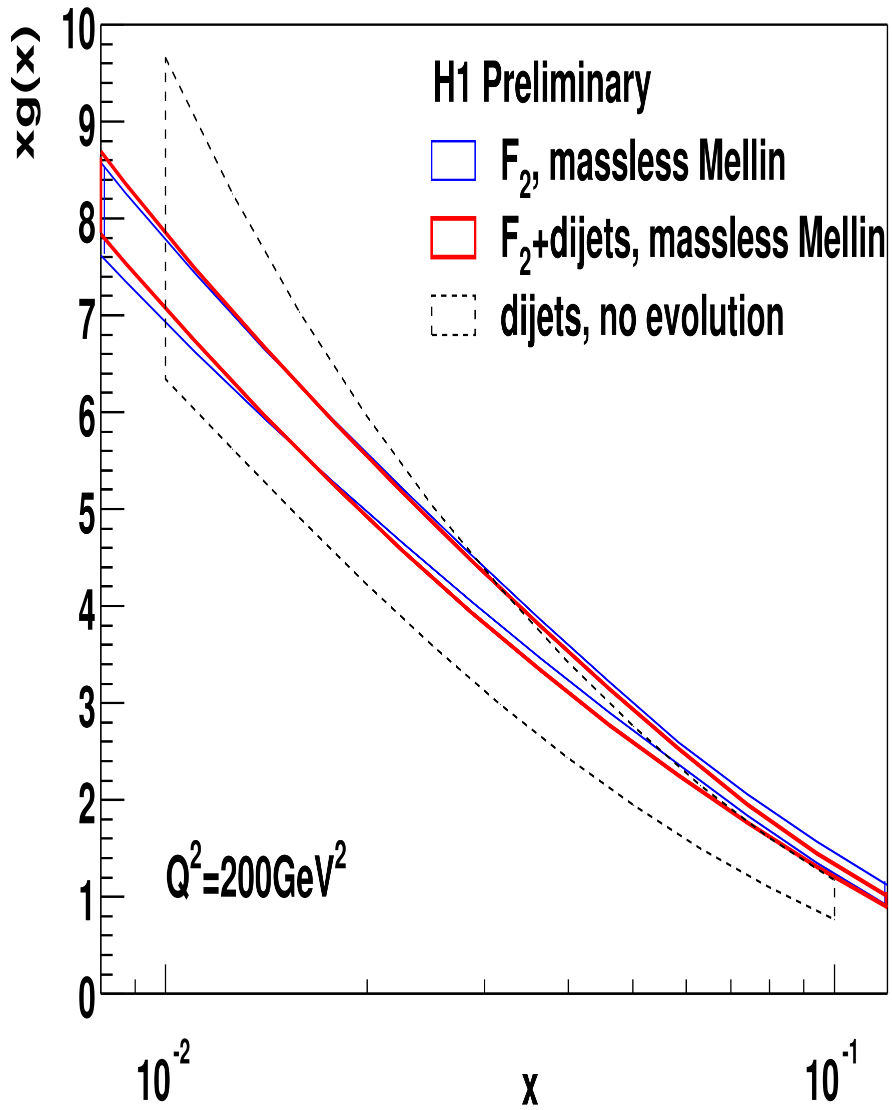
H1 measured cross sections:

- Inclusive DIS cross section for: $20 < Q^2 < 5000\ \mathrm{GeV}^2$
- Dijet cross section $\frac{d^2\sigma_{dijet}}{dQ^2 dx_{Bj}}$ for: $200 < Q^2 < 5000\ \mathrm{GeV}^2$

Fitting $g(x), u_v(x), S(x)$ at $Q_0^2 = 4\ \mathrm{GeV}^2$
Using $d_v(x) = R(1-x)^2 u_v(x)$

Assuming: $\alpha_\mathrm{s}(M_Z) = 0.119 \pm 0.003$

Determination of the Gluon density



Dijet cross section helps to constrain the gluon at high x

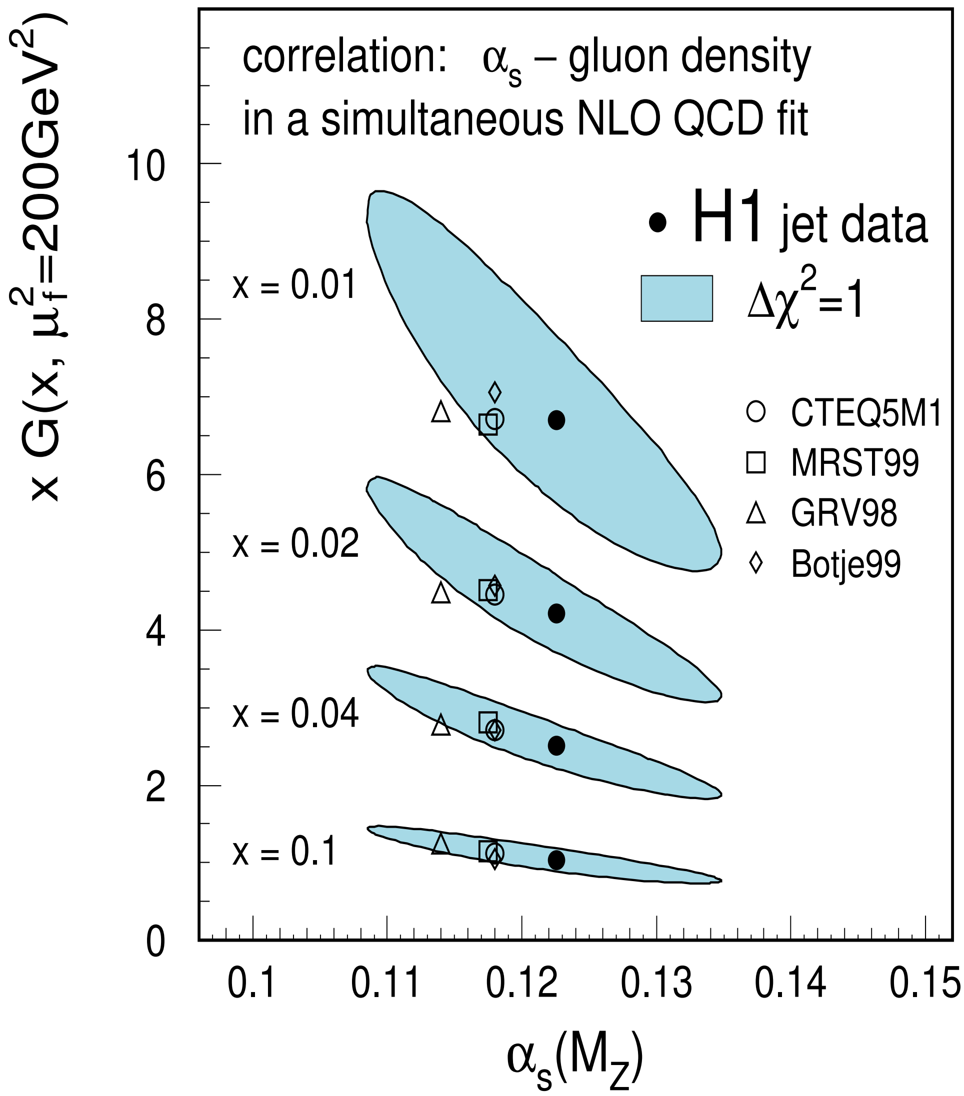
Simultaneous QCD fit of $\alpha_s(M_Z)$ and $xg(x)$

Basic idea:
Use three different cross sections to disentagle α_s, g, q:

$$\begin{aligned} \sigma_{\rm incl} &\propto q \\ \sigma_{\rm jet} &\propto \alpha_s \cdot (c_g g + c_q \cdot q) \\ \sigma_{\rm dijet} &\propto \alpha_s \cdot (c'_g g + c'_q \cdot q) \end{aligned}$$

- H1 measured cross sections:
  - inclusive cross section for: $150 < Q^2 < 1000$ GeV^2
  - inclusive jet cross section
  - dijet cross section: $150 < Q^2 < 5000$ GeV^2
- NLO pQCD calculations:
  performed at a fixed factorization scale $\mu_f^2 = 200$ GeV^2
  $\rightarrow$ no evolution of PDFs (limited Q^2 range)
- Included in the fit:
  - full experimental uncertainties
  - uncertainties due to the residual μ_r dependence
  - uncertainties on the hadronization effects
- $\Rightarrow$ Result presented as a correlation plot between $\alpha_s(M_Z)$ and the $xG(x, \mu_f^2 = 200\ \mathrm{GeV}^2)$

Correlation $\alpha_s(M_Z)$ - gluon density



- $\alpha_s(M_Z)$ and gluon density compatible, within the quoted uncertainty, with the results of global DGLAP fits
- $\alpha_s(M_Z)$ - gluon density anti-correlation clearly seen (data sensitive to $\alpha_s \cdot g(x)$!)
- Present data/theory accuracy do not yet allow a determination of both $\alpha_s(M_Z)$ and the gluon density with useful precision

Conclusions

Strong coupling constant:

- Determination from different jet observables
- Values in excellent agreement with world average
- Uncertainty on α_s competitive and mostly limited by theory
- Progress on the estimate of the PDFs-related uncertainty

Gluon density:

- Precise determination of the gluon density from inclusive and dijet cross sections
- Dijet cross sections help to constrain the gluon at high x

α_s and Gluon density:

- First interesting attempt to a simultaneous determination of strong coupling and the gluon density in the proton
- jet data very sensitive to the product $\alpha_s \cdot xg(x)$