Determination of the Gluon Density and the Strong Coupling Constant in Jet Production in DIS at HERA

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on behalf on the
H1 and ZEUS Collaborations

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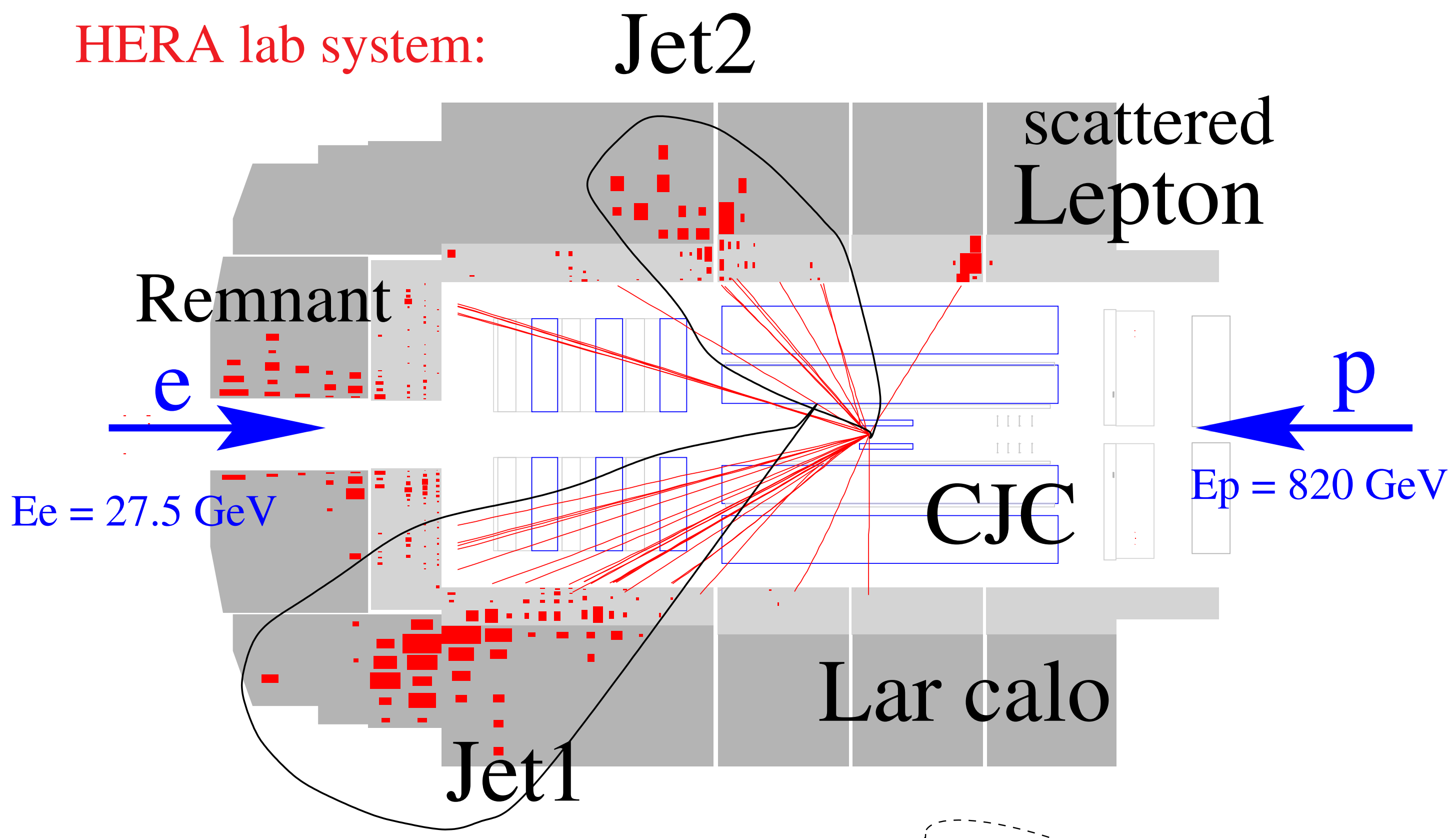
Jet Production in DIS at HERA

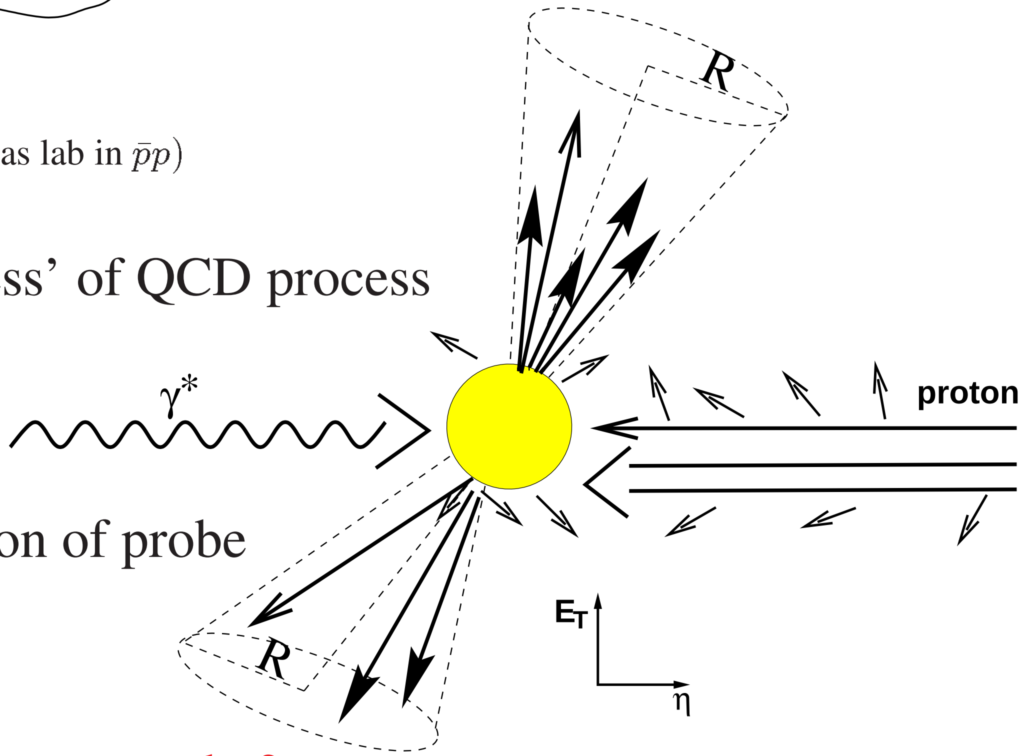
HERA lab system:



Breit system: (as lab in $\bar{p}p$)

$\vec{\gamma}^* + 2\, x_{bj}\, \vec{p} = 0$

$E_T \leftrightarrow$ 'hardness' of QCD process



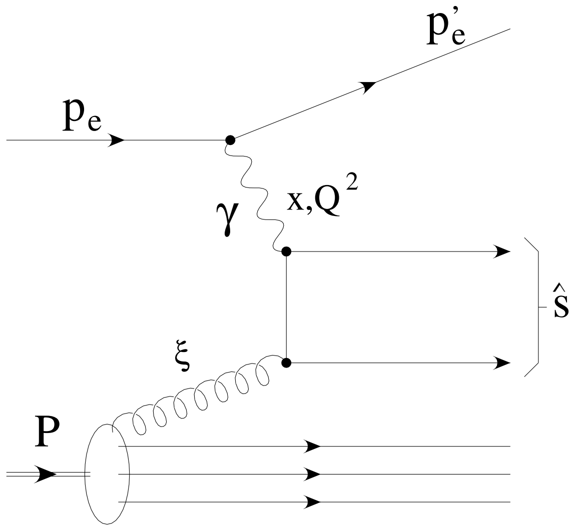
$Q^2 \leftrightarrow$ resolution of probe

What is the relevant scale ?

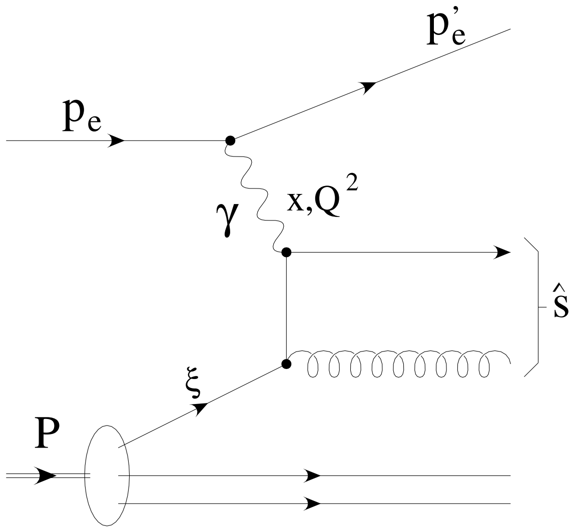
Q^2 ? E_T^2 ?

Jet DIS Cross Section in pQCD

Leading order $\mathcal{O}(\alpha_s)$ diagrams :



Photon-gluon fusion



QCD-Compton

$$\sigma_{jet} = \sum_n \alpha_s^n \left(C_{g,n} \otimes g \ + \sum_f c_{f,n} \otimes q_f \right)$$

$\Rightarrow$ test pQCD in presence of two hard scales Q^2, E_T^2

$\Rightarrow$ direct sensitivity to α_s and the parton densities in proton

strong anti-correlation: $\alpha_s \leftrightarrow$ gluon

Program:

1) Test, if data are described by NLO QCD

2) Take independent information on α_s (e.g. LEP)

$\Rightarrow$ fit parton densities to F_2 (quarks !) data and
jet cross section (gluons !)

3) Take quark and gluons from global fits

$\Rightarrow$ fit α_s and estimate introduced uncertainty

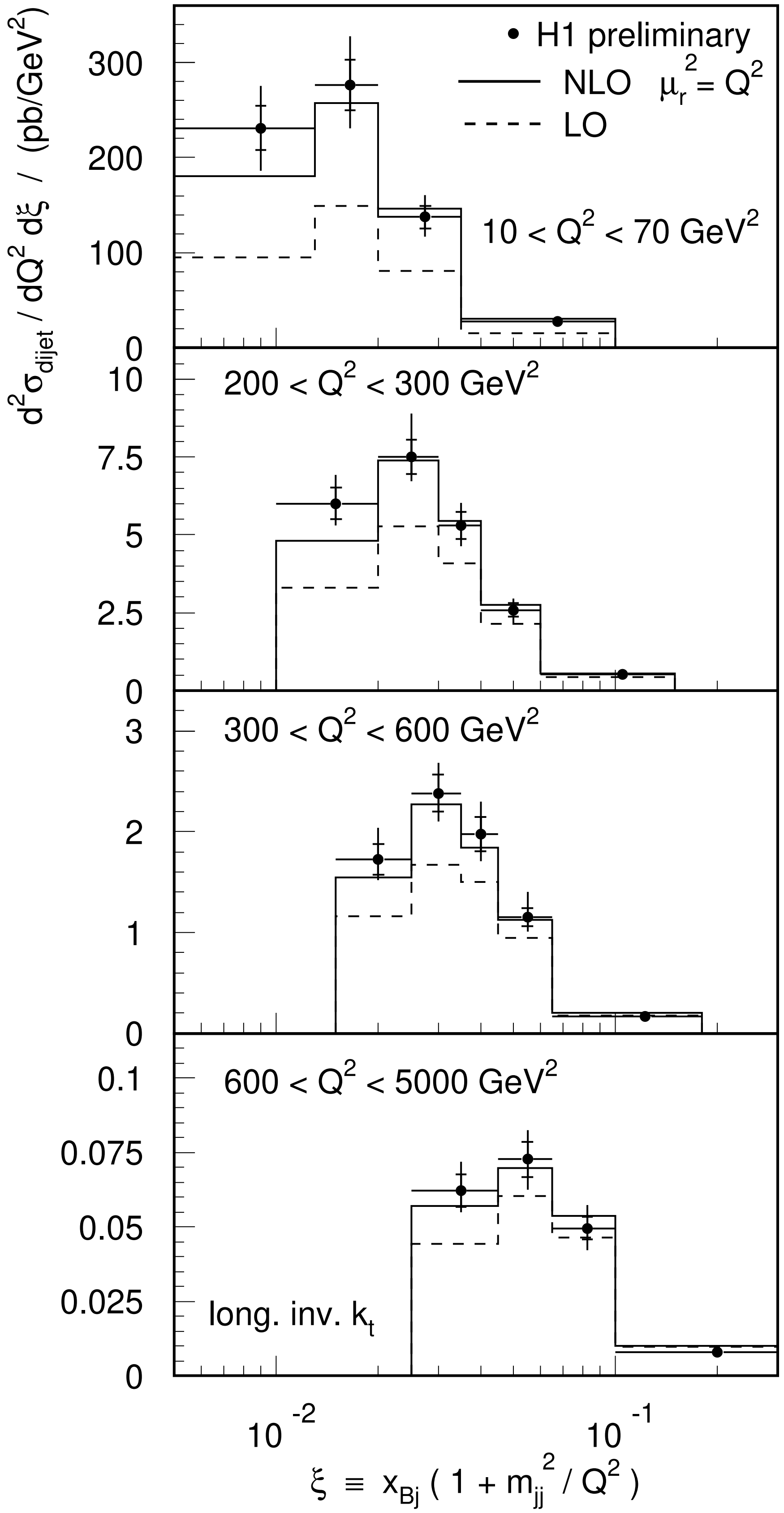
4) Final aim: combined QCD fit (jet and F_2 data)

Fractional parton momentum from Dijets

Phase space: $10 < Q^2 < 5000\ \mathrm{GeV}^2 \quad 0.2 < y < 0.6$

Dijet definition with inclusive K_T algorithm:

$E_{T1} > E_{T2} > 5\ \ \mathrm{GeV},\ E_{T1} + E_{T2} > 17\ \ \mathrm{GeV},\ -1 < \eta_{lab} < 2.5$



Parton momentum
$\xi = x_{\mathrm{Bj}}\,(1 + M_{\mathrm{jj}}^2/Q^2)$
$5 \cdot 10^{-3} < \xi < 0.3$

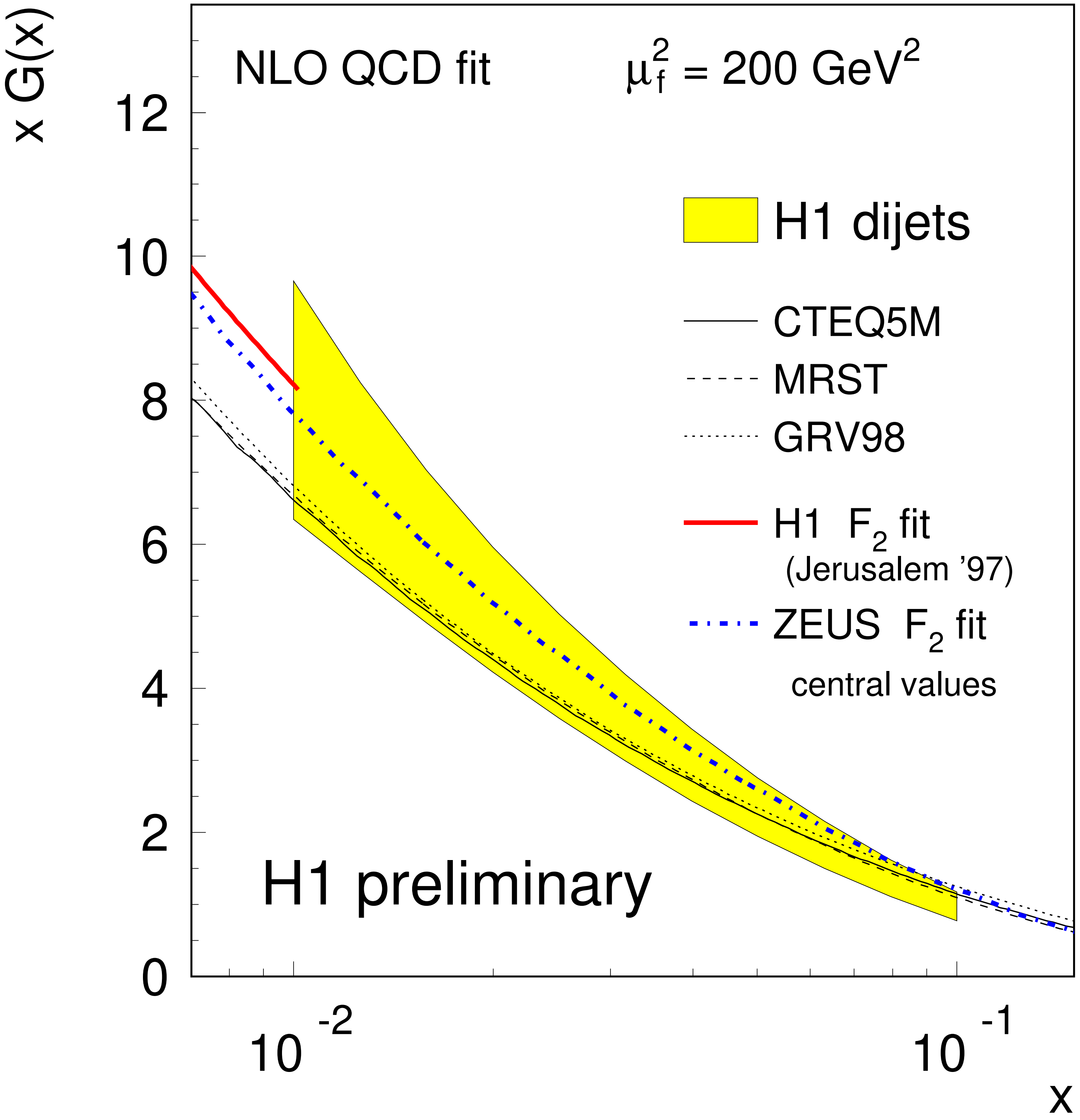
had. corrections:
$\approx 10 - 15\%$

good overall description
by NLO pQCD
data higher at smallest ξ
$\Rightarrow$ higher parton densities?

$\Rightarrow$ Fit dijet data (gluons !)
combined with
F_2 (fix quarks !)
at $\mu_f^2 = 200\ \mathrm{GeV}^2$

Direct Gluon Density from Dijets

determined for $\alpha_s(M_Z) = 0.119 \pm 0.005$ and $\mu^2_{ren} = Q^2 + E_T^2$



Consistent with indirect determination from F_2 (scaling violations)
Constrains gluon at large $x \rightarrow$ LHC !
First steps to develop technique to give error band on PDFs
Independent, e.g. of nuclear shadowing corrections
from fixed target experiments at low energies

Dijet Cross Section at High Q^2

Phase space: $470 < Q^2 < 20000$ GeV^2 $\quad 0 < y < 1$
Dijet definition with inclusive K_T algorithm:
$E_{T1} > E_{T2} > 5$ GeV, $E_{T1} + E_{T2} > 17$ GeV, $-1 < \eta_{lab} < 2$

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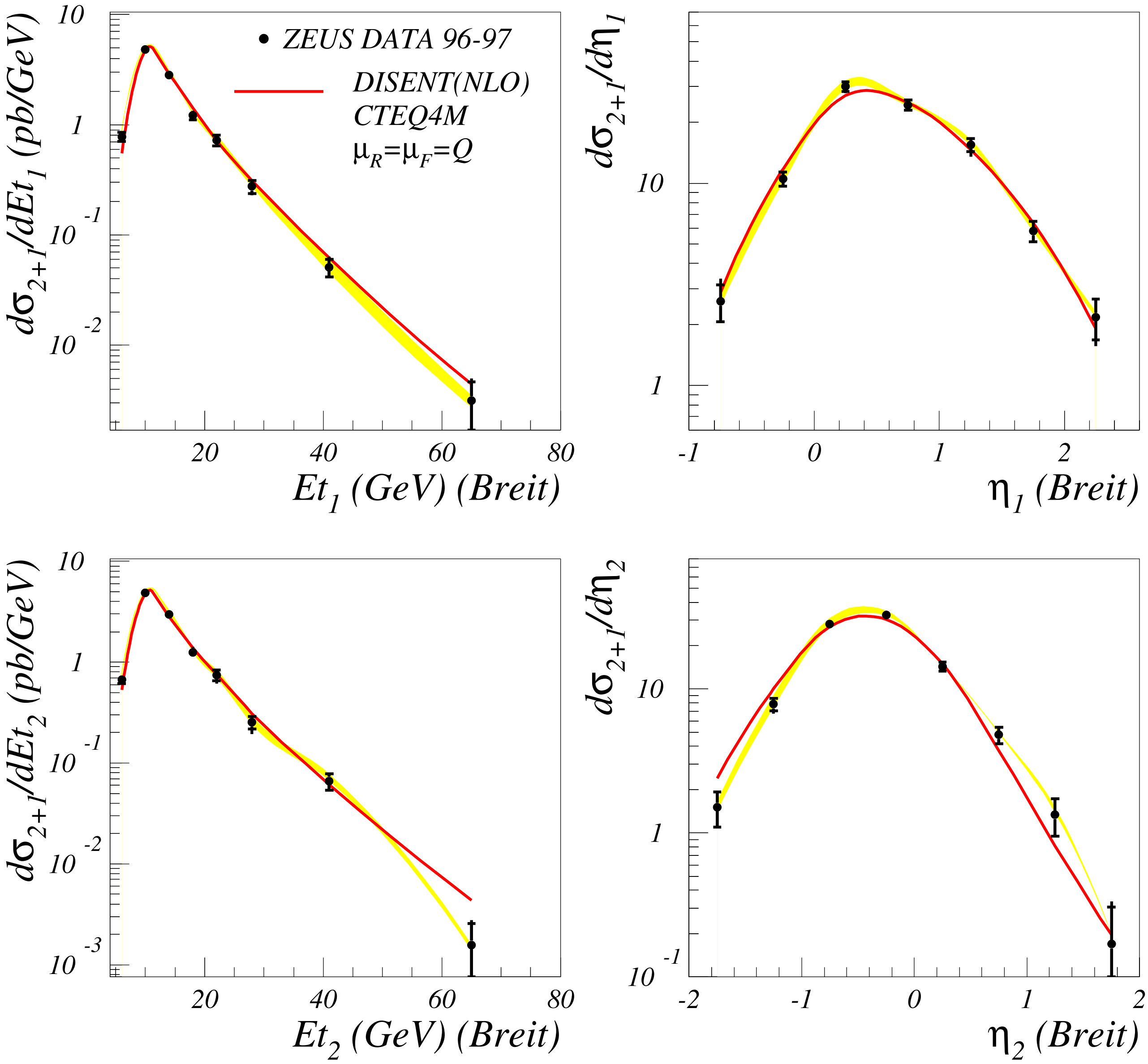


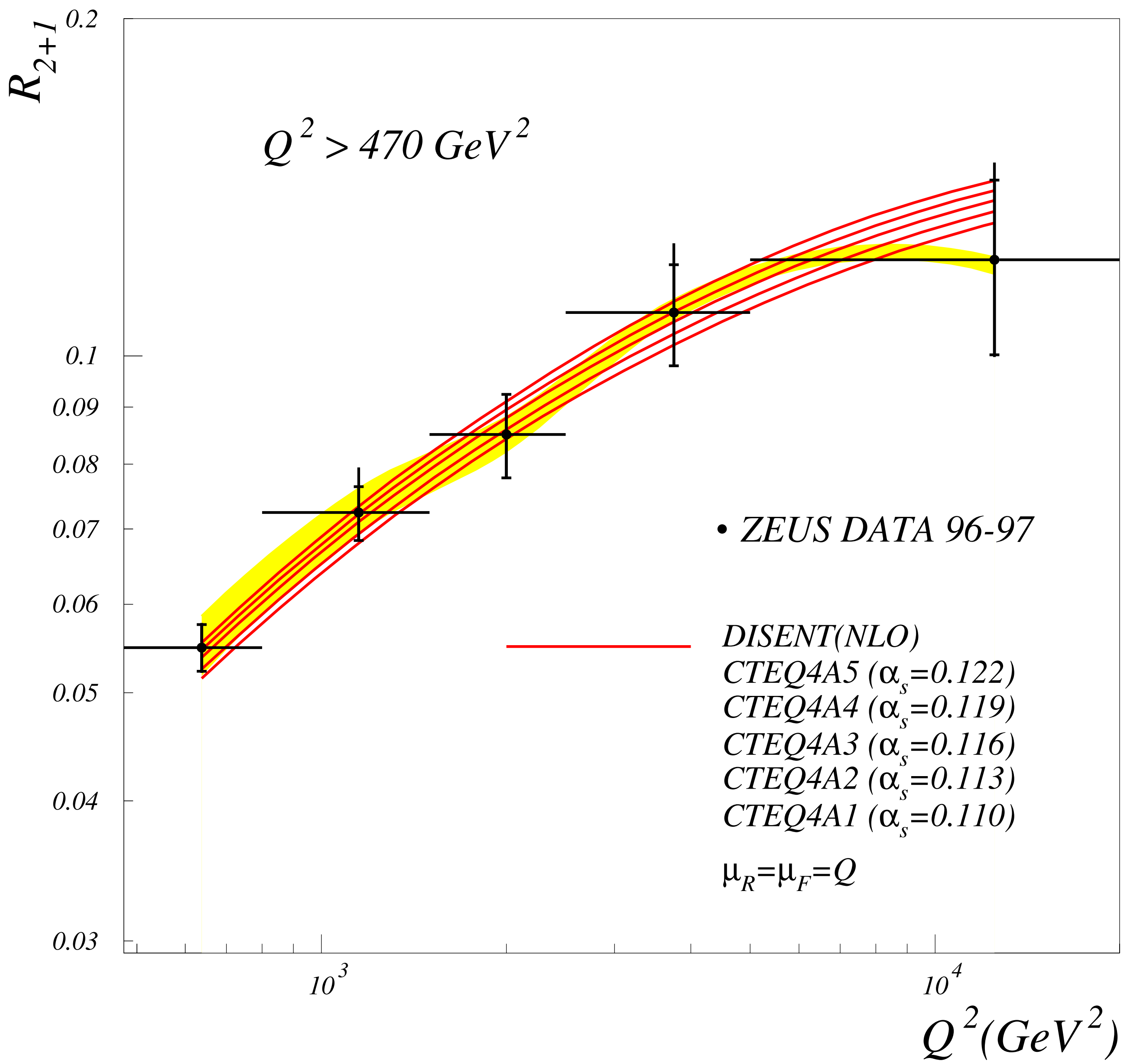
Data are corrected for detector, hadronisation (!), QED radiation and electroweak effects

Good description by NLO-QCD

Dijet Rates at High Q^2

Phase space: $470 < Q^2 < 20000$ GeV^2 $0 < y < 1$
Dijet definition with inclusive K_T algorithm:
$E_{T1} > E_{T2} > 5$ GeV, $E_{T1} + E_{T2} > 17$ GeV, $-1 < \eta_{lab} < 2$

ZEUS 96-97 PRELIMINARY

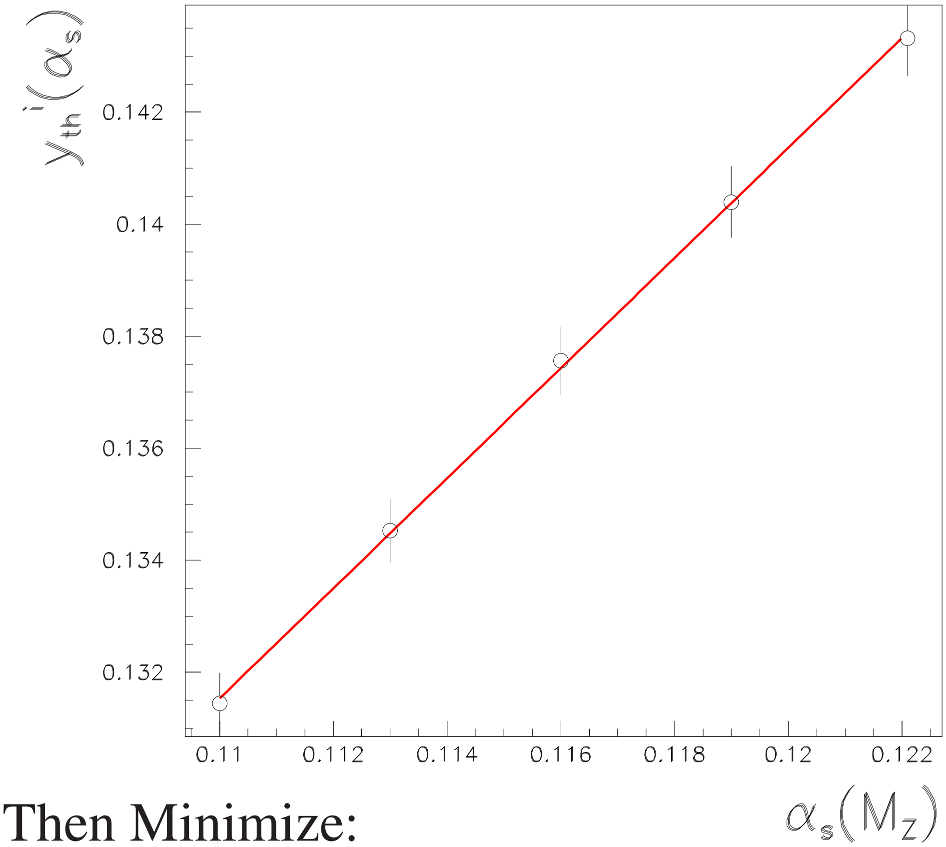


Data are corrected for detector, hadronisation (!), QED radiation and electroweak effects

$\Rightarrow R_{2+1} = \frac{\sigma_{2+1}}{\sigma_{DIS}}$ sensitive to α_s !

α_s Extraction from Dijet Rates at High Q^2

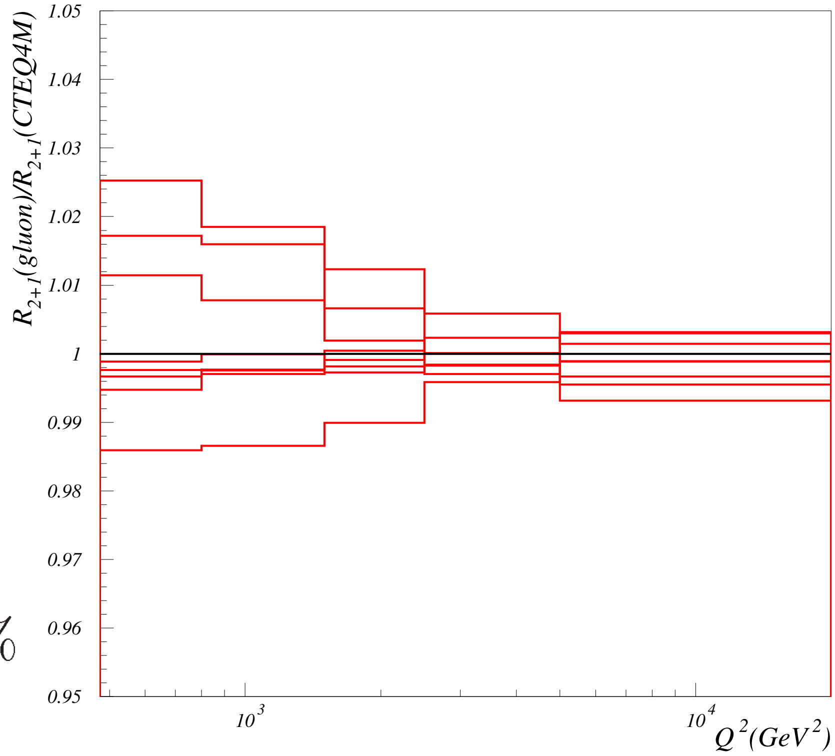
Take $\alpha_s \otimes gluon$ anti-correlation approximately into account:



Then Minimize:

$$\chi^2(\alpha_s) = \sum_i \frac{\left(y^i_{cor,data} - y^i_{theo}(\alpha_s)\right)^2}{\sigma^2_{y^i_{cor,data}}}$$

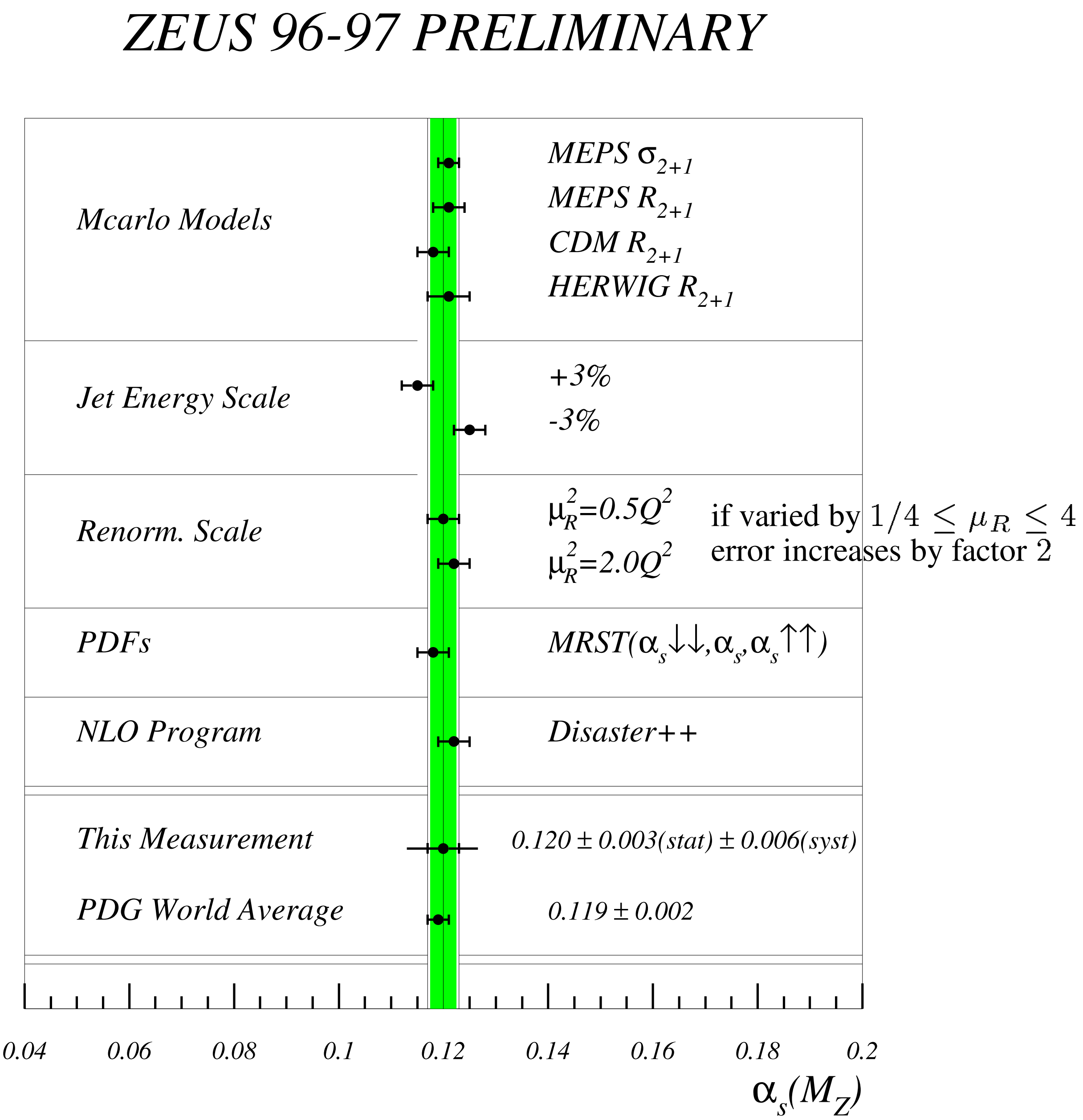
CTEQ gluon study for R_{2+1}



In addition:

Change in measured α_s: $\lesssim 3\%$
not yet included in error

Result on α_s from Dijet Rates at High Q^2



$$\boxed{\alpha_s(M_Z) = 0.120 \pm 0.003\ (stat)\ {}^{+0.005}_{-0.006}\ (exp)\ {}^{+0.003}_{-0.002}\ (theo)}$$

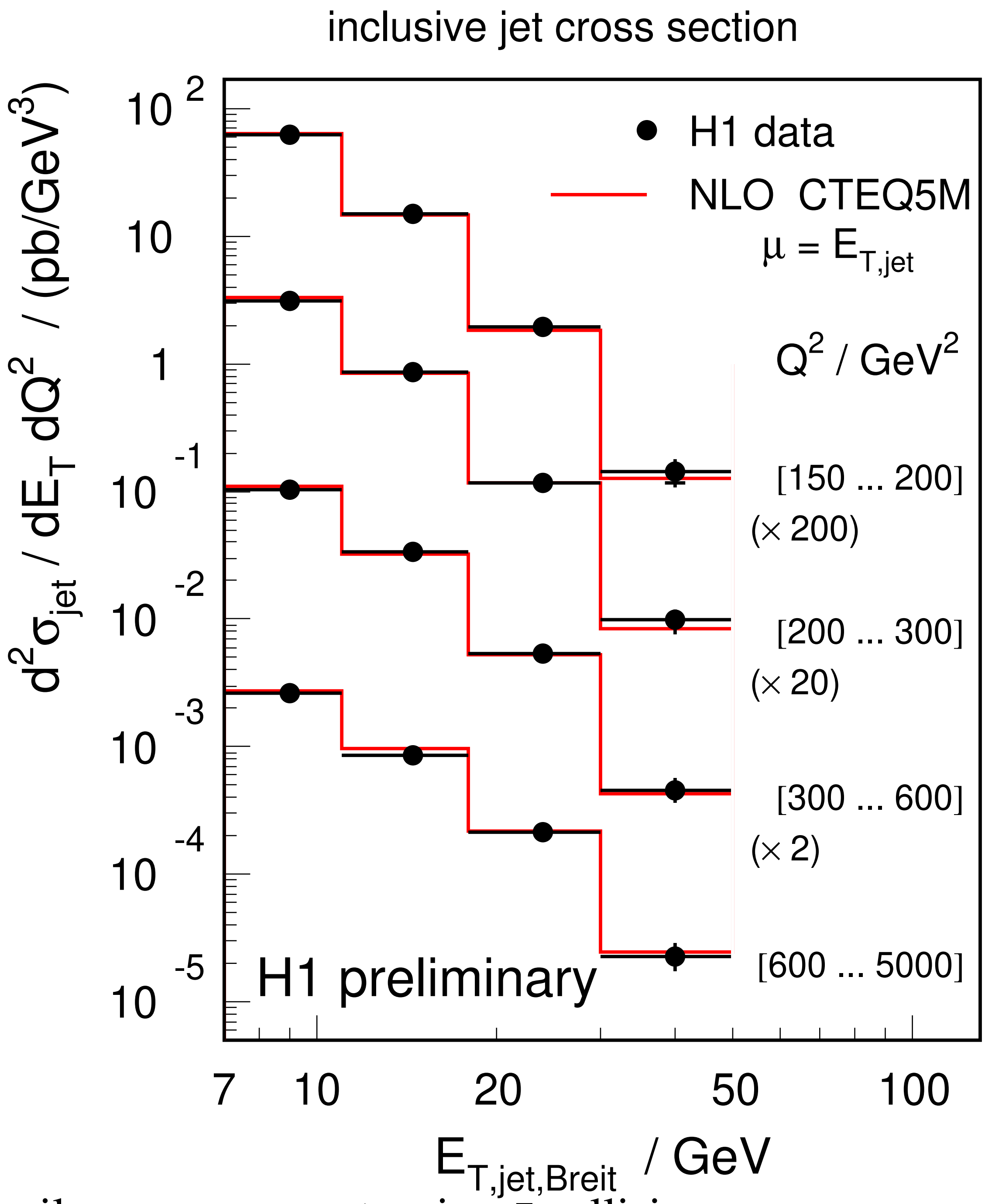
Competitive measurement !

...same result when using dijet cross sections.

Single Inclusive Cross Section - $\frac{d^2\sigma}{dQ^2 dE_T}$

Phase Space: $150 < Q^2 < 5000$ GeV^2, $0.2 < y < 0.6$

Jets: $E_T > 7$ GeV, $-1 < \eta_{lab} < 2.5$



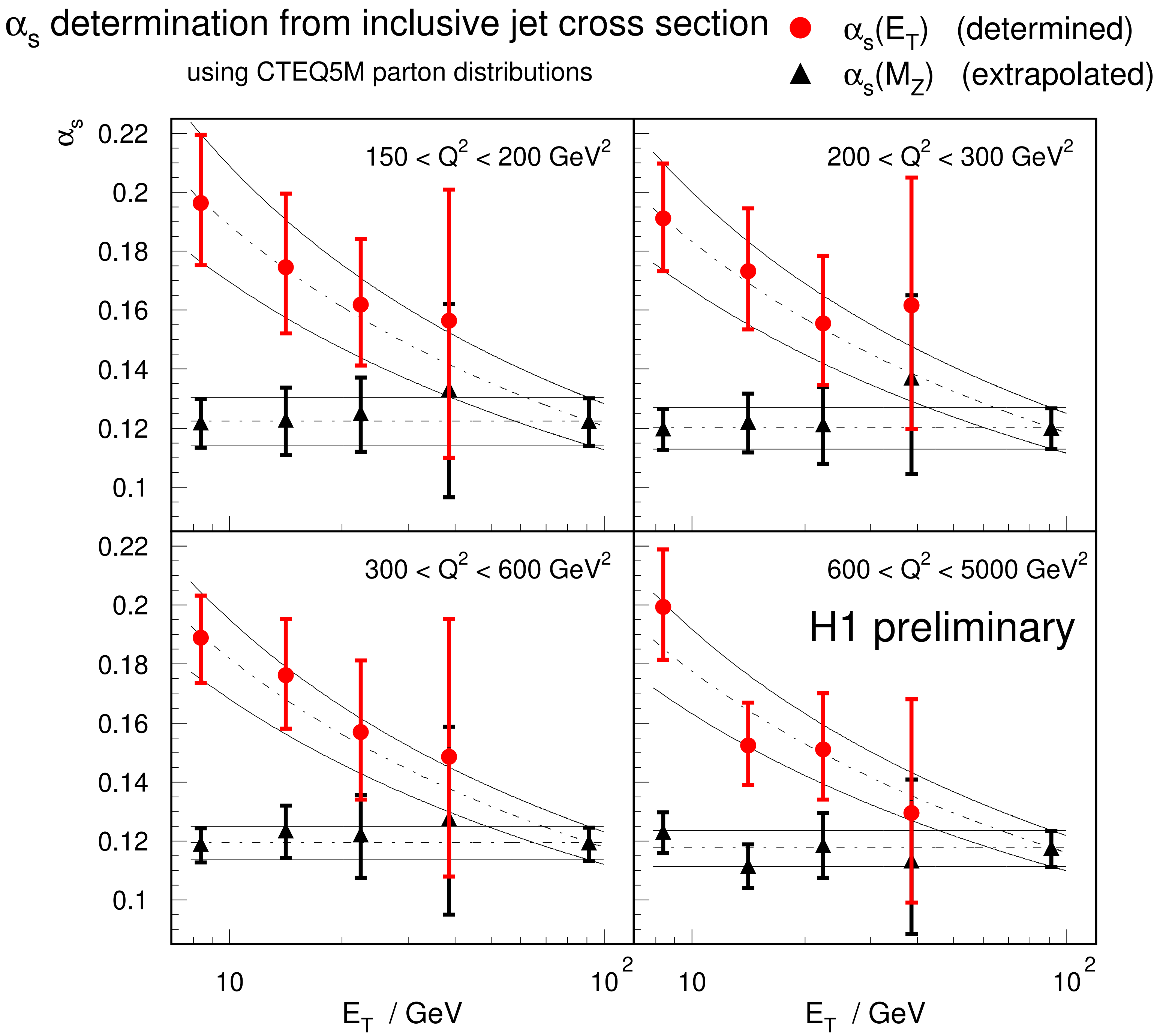
similar measurement as in $p\bar{p}$ collisions

HERA: limited E_T, but cleaner enviroment !

good description by NLO QCD $\mathcal{O}(\alpha_s^2)$

hard E_T spectrum towards larger Q^2

α_s from Single Inclusive Cross Section

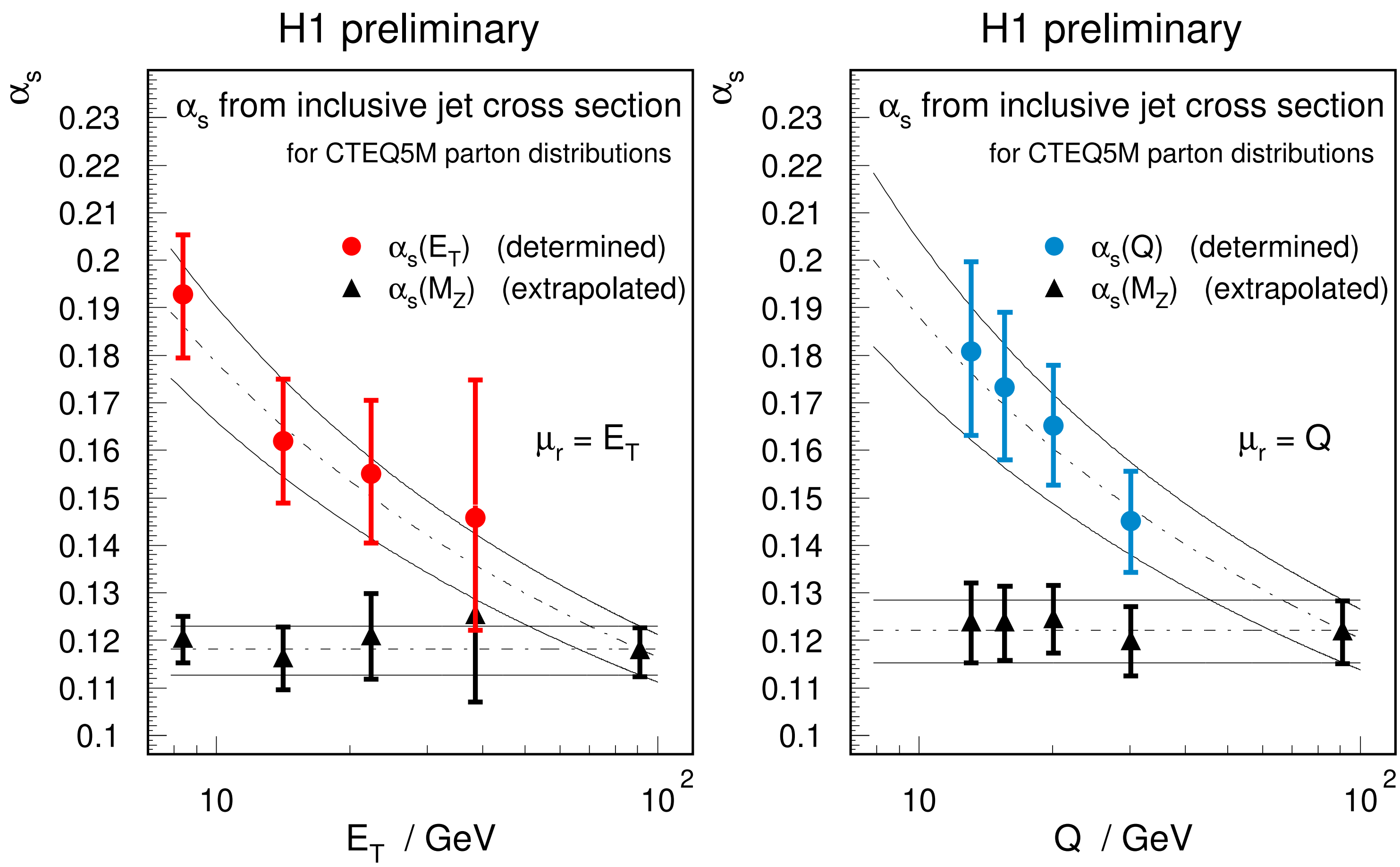


$\alpha_s(E_T)$ extracted at each E_T for 4 Q^2 bins (16 data points)

rightmost triangles from combined fit of all Q^2 regions

$\rightarrow$ consistent results for all Q^2 regions

α_s from Single Inclusive Jet Cross Section



for $\mu_{ren} = E_T$:

$\alpha_s(M_Z) = 0.1181 \pm 0.0030(\text{exp})^{+0.0039}_{-0.0046}(\text{theo})^{+0.0036}_{-0.0015}(\text{pdf})$

for $\mu_{ren} = Q$:

$\alpha_s(M_Z) = 0.1221 \pm 0.0034(\text{exp})^{+0.0054}_{-0.0059}(\text{theo})^{+0.0013}_{-0.0055}(\text{pdf})$

Largest experimental error from:

had. energy scale uncertainty

Largest theoretical error from:

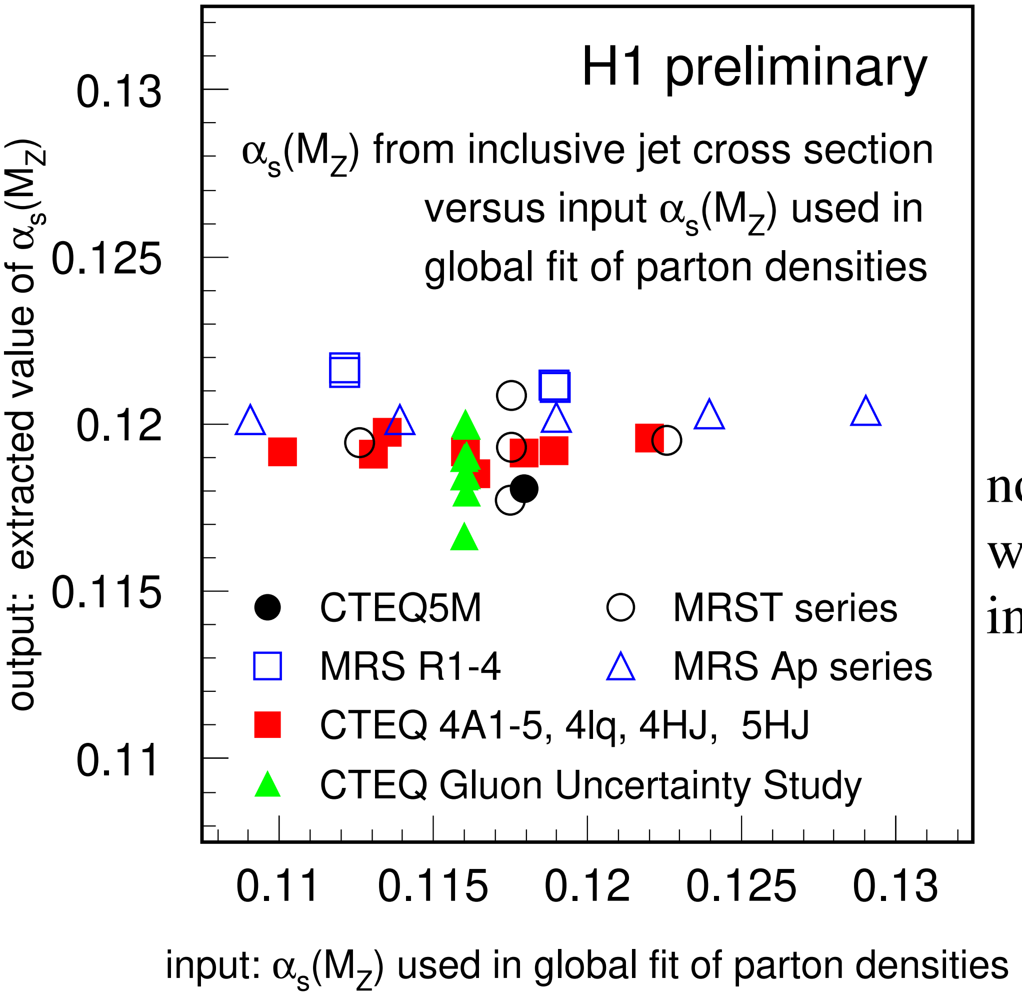
ren. scale dependence and hadronisation corrections

World average: $\alpha_s(M_Z) = 0.119 \pm 0.004$ (S. Bethke '98)

Assumption: CTEQ5M as PDF

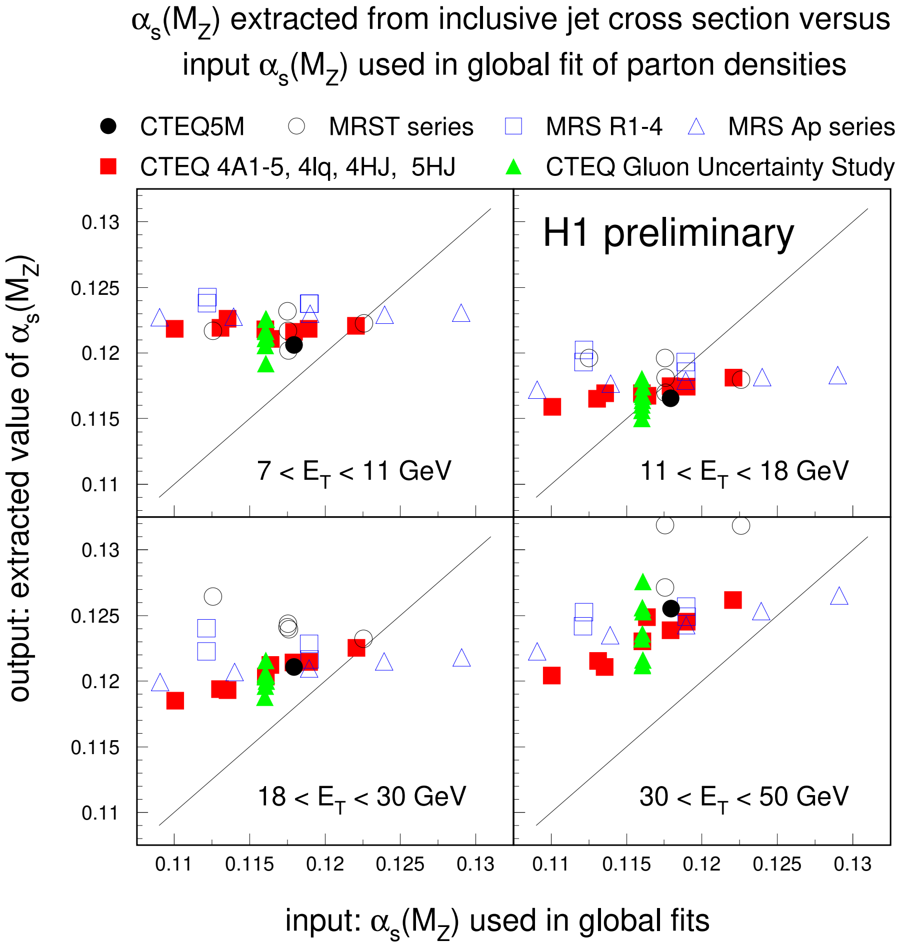
$\rightarrow$ to be checked $PDF(\alpha_s^{in})$ vs α_s^{meas}

α_s Dependence on Parton Density Functions



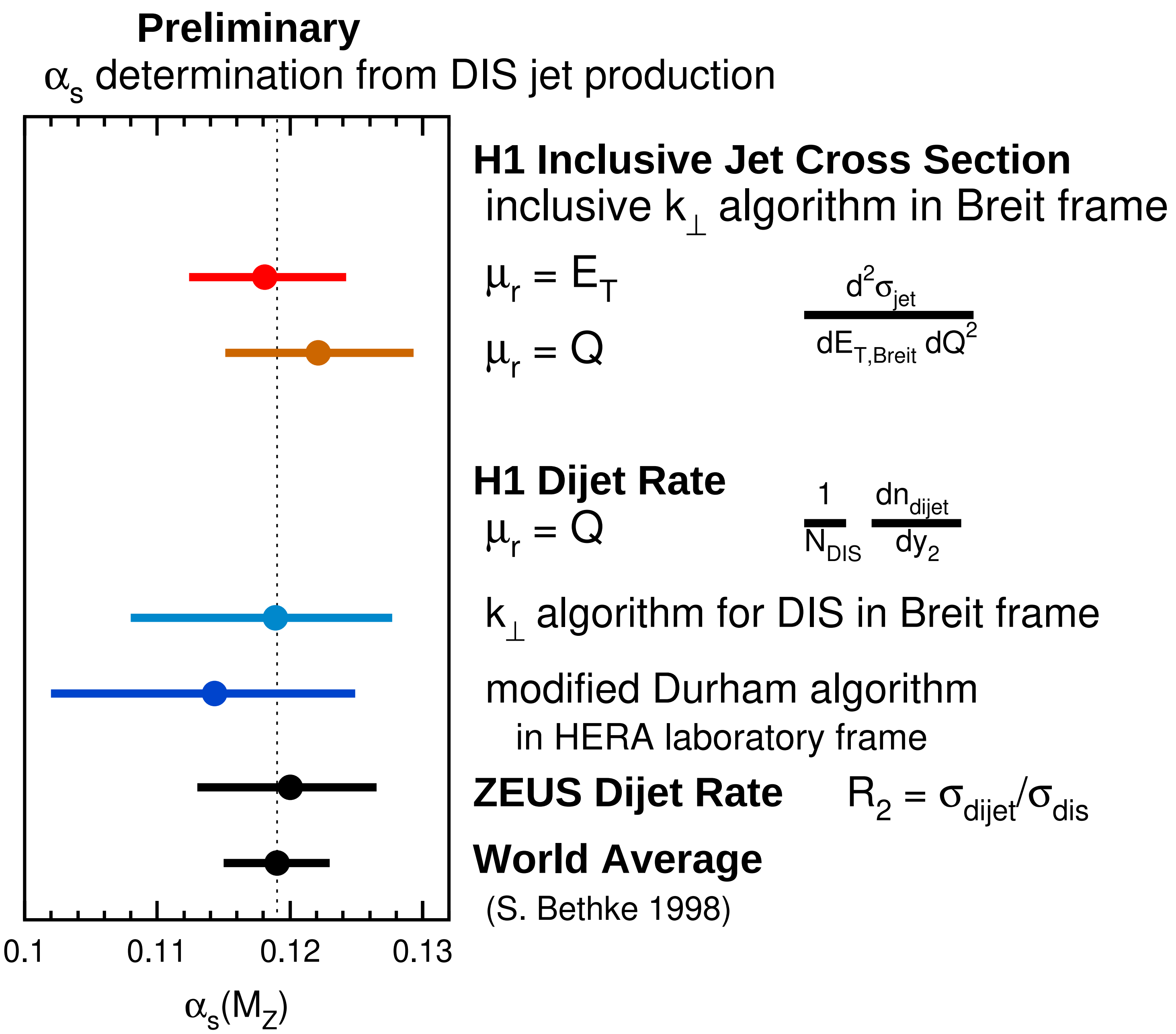
surprise !
small variation !

no change of conclusions
when MRS99
instead of MRST is used



in largest E_T bin:
increased correlation
less impact due to
small statistics

Final Results from Jet Production in DIS at HERA



Very competitive measurements !
Some improvements on experimental side still possible
Error from renormalisation uncertainty is dominant
Principle problem of unknown error from PDF,
but effect is surprisingly small
Final aim: combined fit

Conclusions

- Understanding the proton is a challenging task
- HERA is particulary well suited
- Significant progress to understand jet production
  in DIS at HERA
- Serious QCD analyses coming along,
  still room for improvement
- Gluon density with full error band for $10^{-2} < x < 10^{-1}$
  from dijet data and F_2 for $\mu_{fac}^2 = 200\ \mathrm{GeV}^2$
  $\rightarrow$ precise knowledge of gluon at high x needed at LHC
- Four new determinations of the strong coupling constant
- Compatible with world average
  competitive error, e.g. best result: ± 0.005
- Problem of unknown error of parton density functions
  calls for combined fit
- Final aim:
  Combined fit with F_2, jet and charm data