Jet Cross Sections and α_s at HERA

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Outline

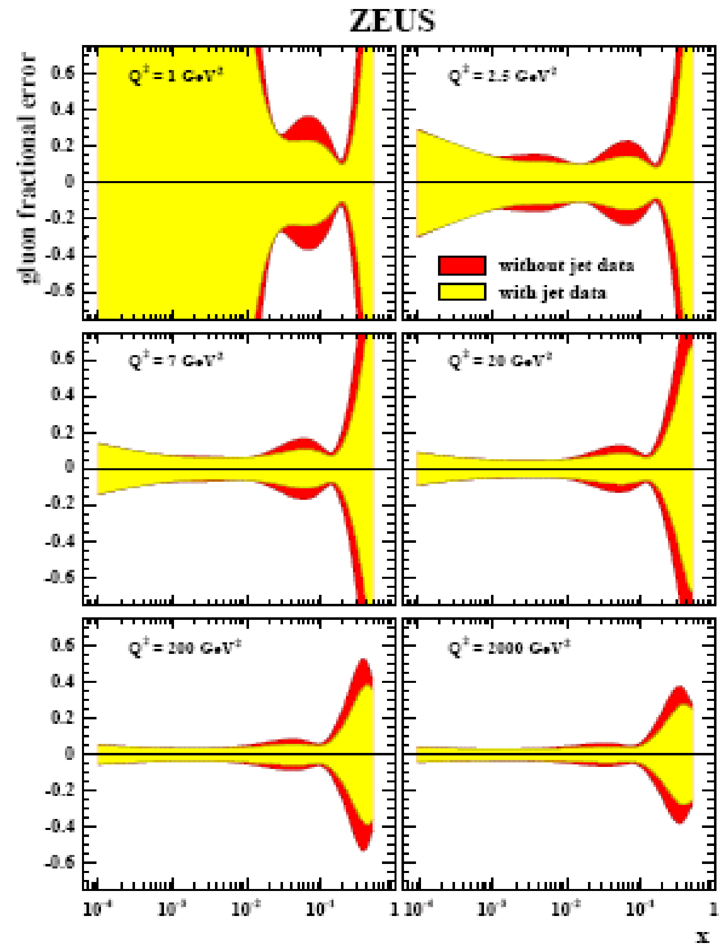
1. Cross Sections Dependence on R
2. High-E_T Dijet Photoproduction
3. Charged Current Multijets
4. Inclusive and Multijets Production
5. α_s Extraction from Low and High Q^2 Data

Low X 2008, 6-10 July
Kolimpary, Greece

Motivation

Jets physics is a powerful ground for:

- **Testing of QCD predictions in DIS**
- **Providing new phenomena for very precision α_s and PDF extraction**
- **Directly sensitive to α_s and PDF → constrain further gluon and parton densities in proton and photon**



Inclusive jets:

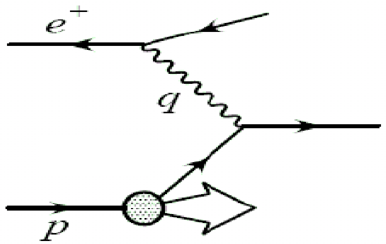
High statistics

- **IR safety**
- **Few non-perturbative complications**

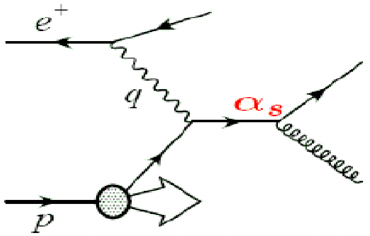
High Q^2: **small theoretical uncertainties → precision extraction of α_s**

Low Q^2: **test of QCD, check how low in Q^2 and P_T the theory can be used**

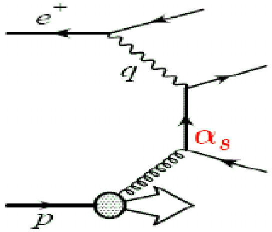
NC Jet Production in DIS



Born Level

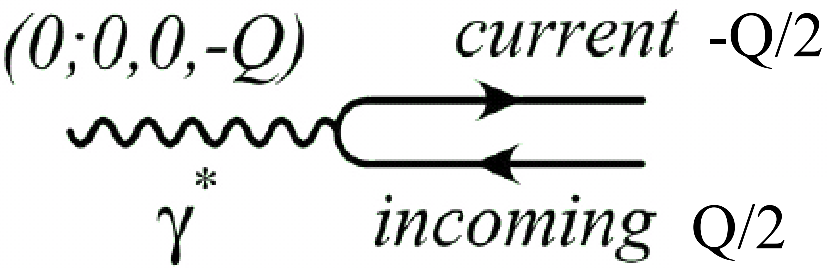


QCD Compton

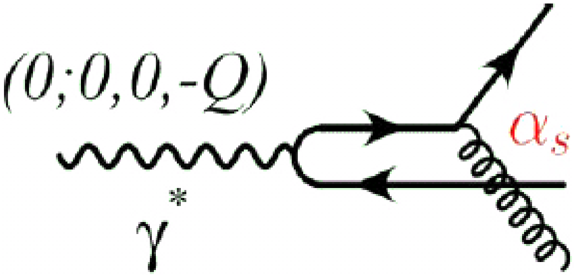


Boson Gluon Fusion

In Breit Frame



Born level process



QCD compton

For jets with E_T (> 5 GeV)

- Born level contribution is suppressed
- Jets well separated from the proton remnant ($E_T = 0$)

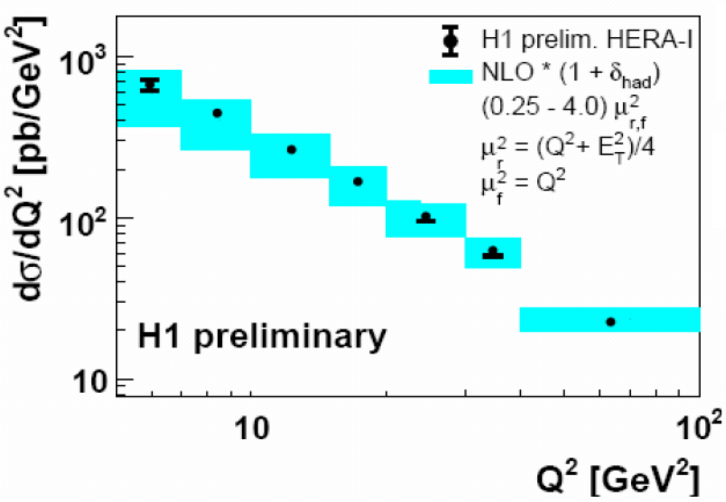
Used Jet Finder:

Longitudinal invariant inclusive k_T algorithm

- infrared and collinear safe
- factorizable

"Merging" parameter R = 1.0 (S.D.Ellis, D.E.Soper …)

$\mu_R = \sqrt{(Q^2+E_T^2)/2}$

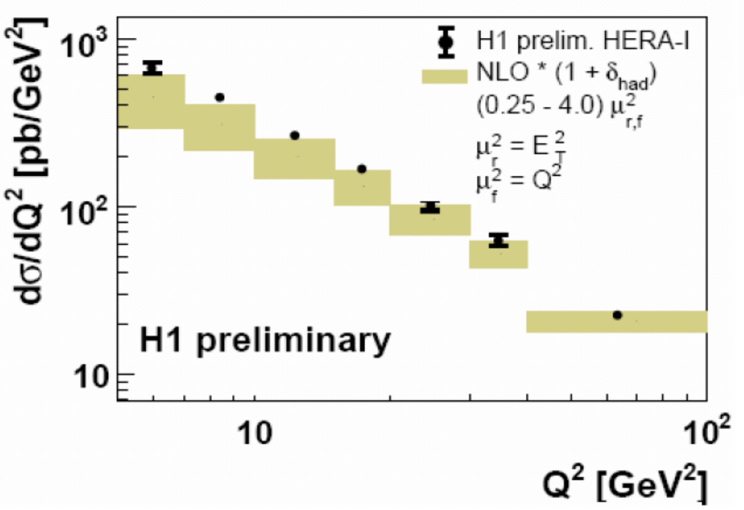


Used Theoretical Models:

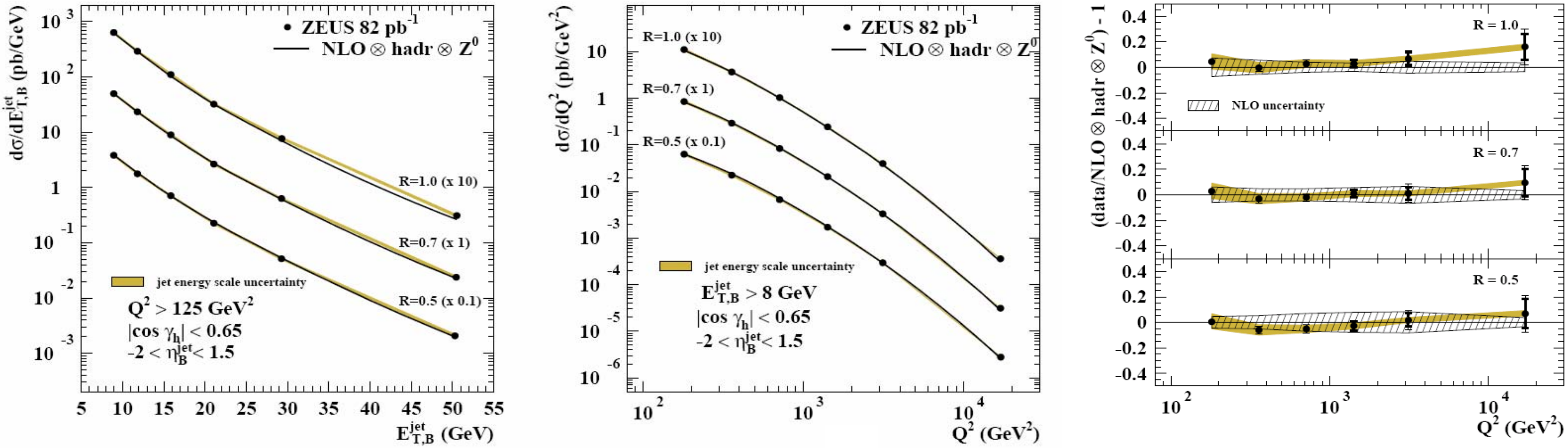
NLOJET++ / FastNLO with

- PDF CTEQ65M
- $\mu_F = Q$
- $\mu_R = \sqrt{Q^2+E_T^2}/2$ for inclusive jets
- $\mu_R = Q$ for 2 & 3- jets

$\mu_R = E_T$



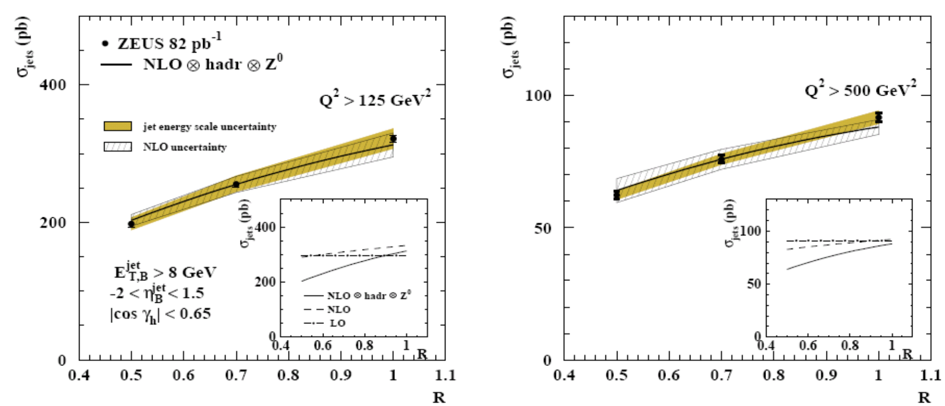
Cross Section Dependence on R



Good agreement between data and NLO for R = 1, 0.7, 0.5.

Integrated cross section linearly depends vs. R → R = 1

- Integrated jet cross sections for the regions $Q^2 > 125$ GeV^2 and $Q^2 > 500$ GeV^2

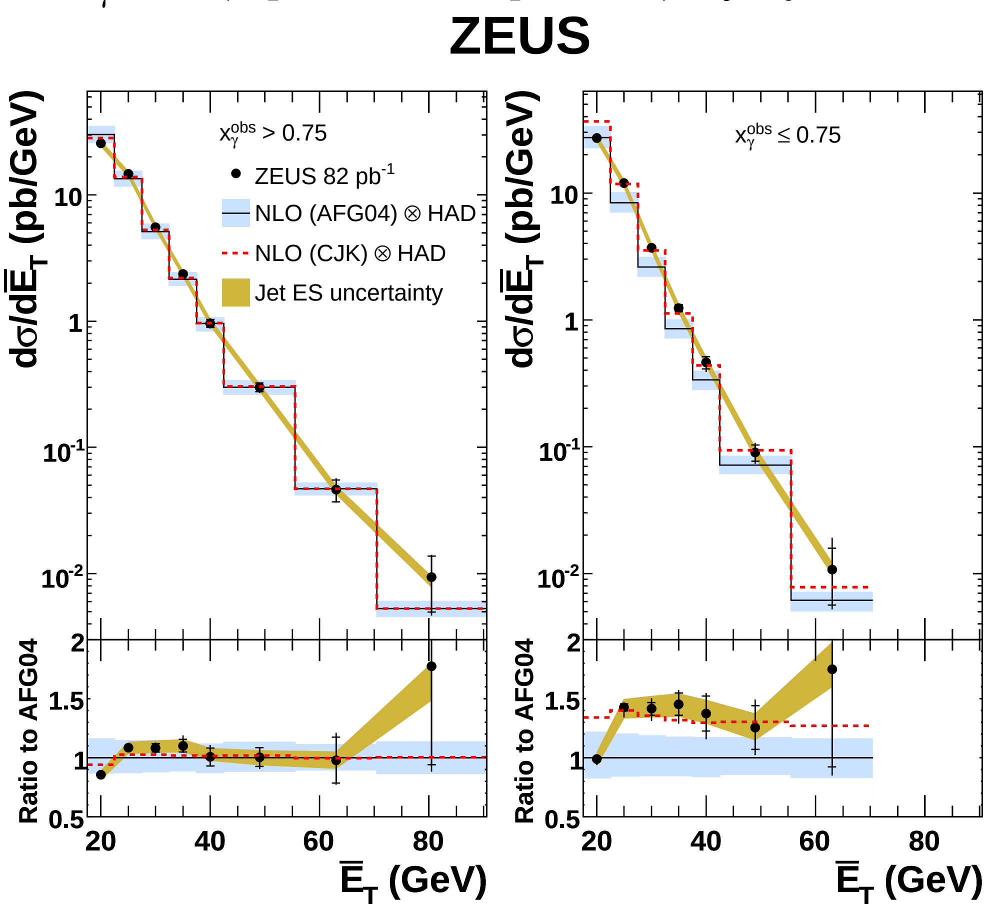


High-E_T Dijet Photoproduction

$\int L = 81.8\ pb^{-1}$, $Q^2 < 1 GeV^2$, $142 < W_{\gamma p} < 293$ GeV

Jet paremeters: $E^{jet1}_T > 20$ GeV, $E^{jet2}_T > 15$ GeV, $-1 < \eta^{jet1,2} < 3$ (at least one $-1 < \eta^{jet} < 2.5$)

$x_\gamma^{obs} = (E_T^{jet1}\ e^{-\eta 1} + E_T^{jet2}\ e^{-\eta 2})/2yE_e$ $\qquad \overline{E}_T = (E_T^{jet1} + E_T^{jet2})/2$



Good description over 4 orders of magnitude for $x_\gamma^{obs} > 0.75$.

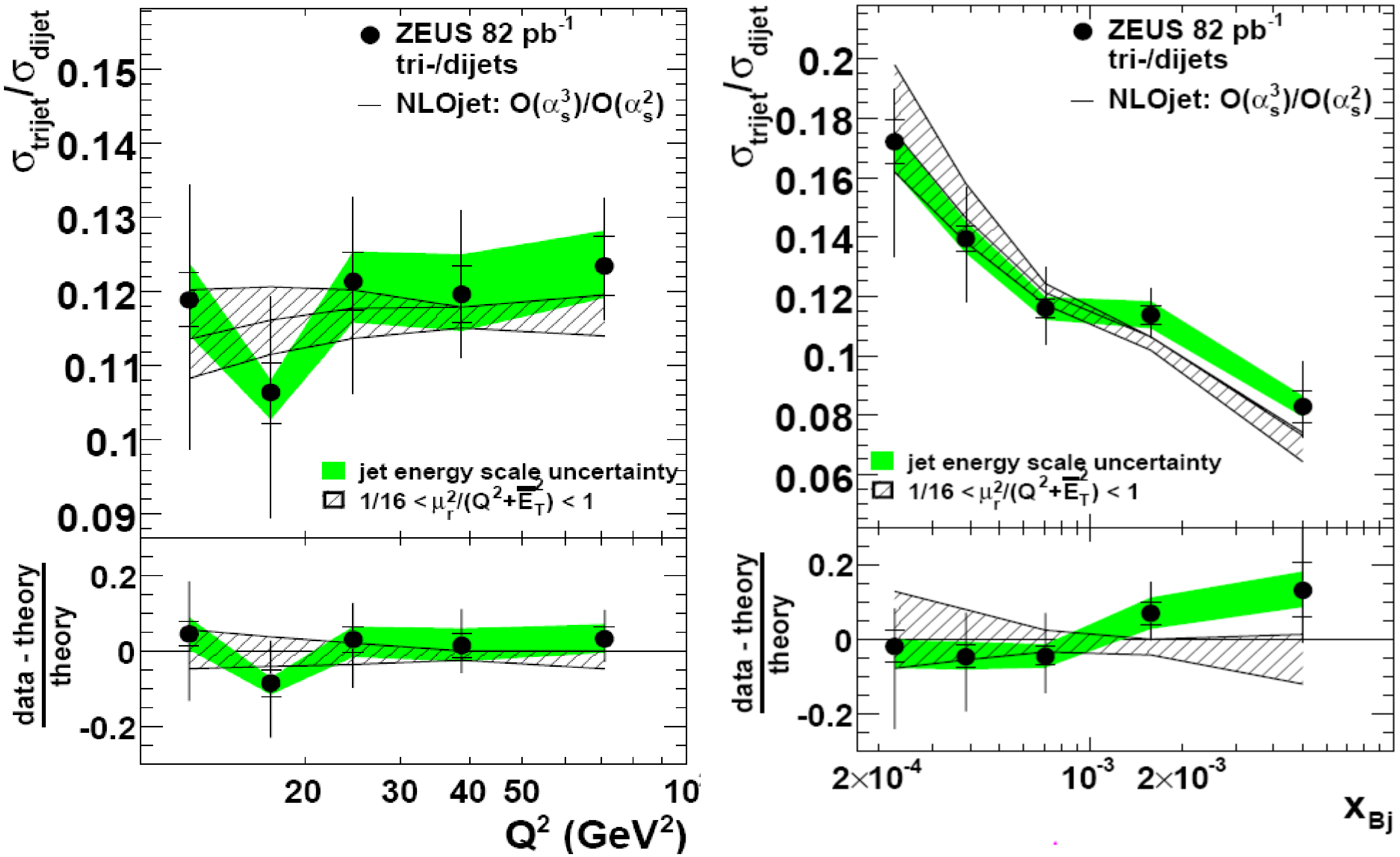
For $x_\gamma^{obs} < 0.75$ γ PDF differ by up to 40% → potentially to constrain γ PDF.

In many cases: CJK (Cornet et al.) described data the best..

Multijet Production at Low x_{Bj}

Kinematics range:
$10 < Q^2 < 100$ GeV^2
$10^{-4} < x_{Bj} < 10^{-2}$
$0.1 < y < 0.6$

Jet parameters:
$-1.0 < \eta^{jet1,2(,3)}_{Lab} < 2.5$
$E_{T,HCM}^{jet1} > 7$ GeV
$E_{T,HCM}^{jet2(,3)} > 5$ GeV



- *Hatched band - QCD renormalization scale uncertainty*
- *Green band - jet energy scale uncertainty*

Relative difference between the data and theory

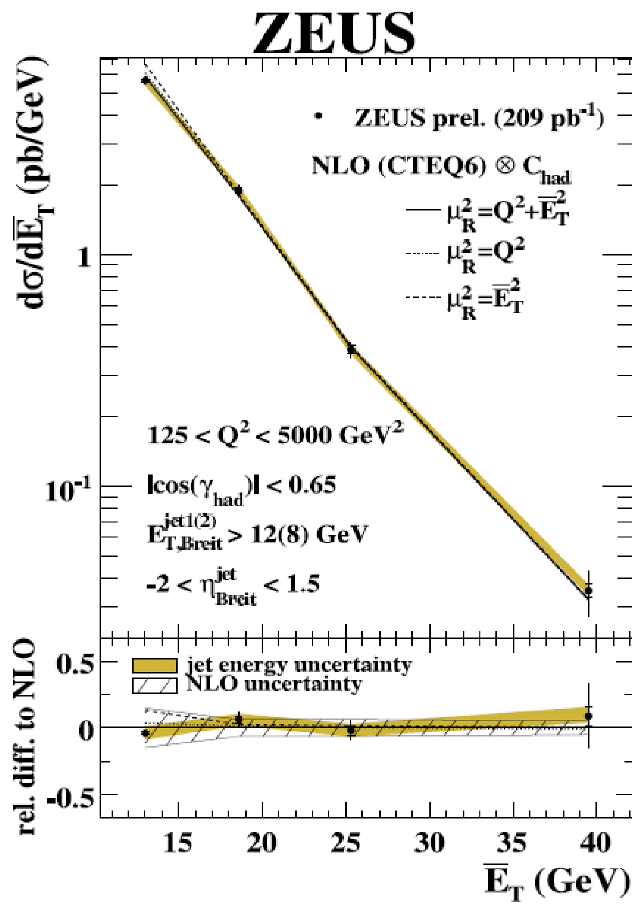
High E_T Neutral Current Dijets

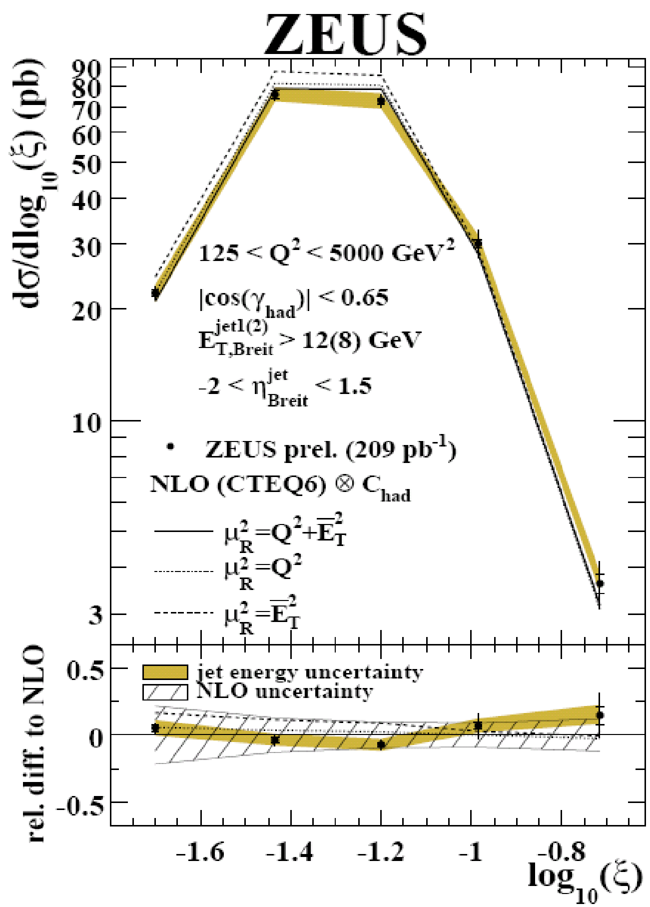
HERA-II:

- $125 < Q^2 < 5000$ GeV^2
- $E_T^{jet1(2)} > 12(8)$ GeV

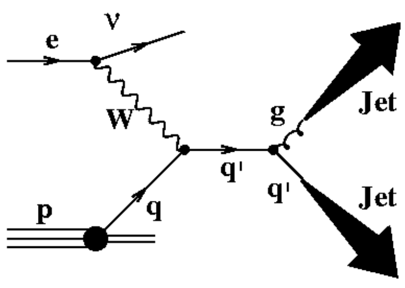
$\xi = x\,(1+M^2_{ij}/Q^2)$

The data well described with NLO. Theoretical uncertainties dominate in many bins.



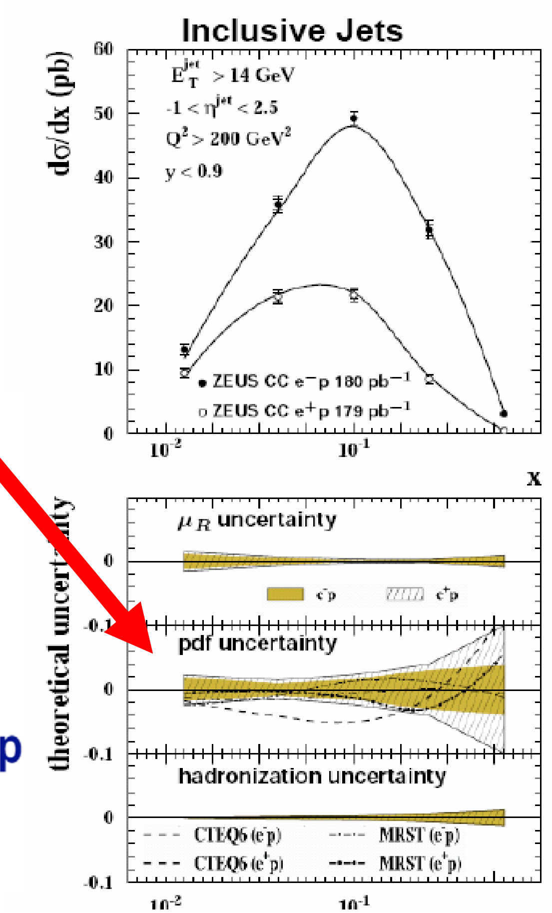


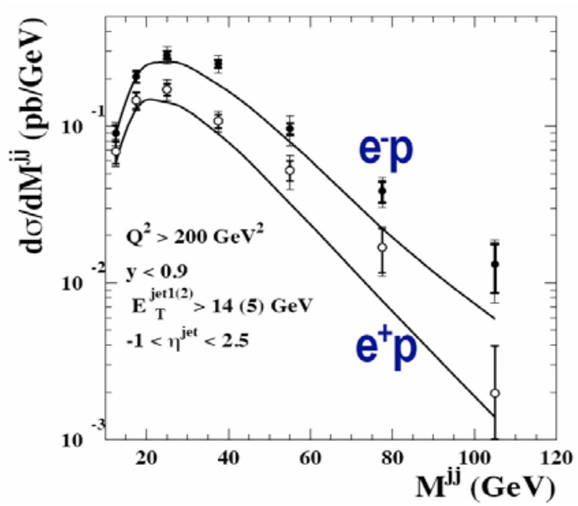
Charged Current Multijets

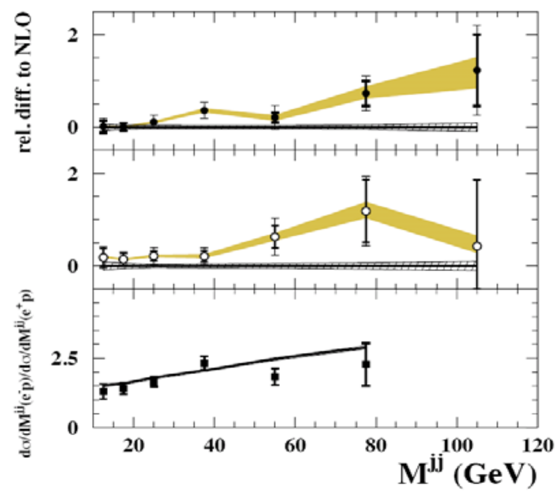


HERA-II,

- $\int L$ = 359 pb^{-1} polarized $e^{+-}p$ data.
- $Q^2 > 200\ GeV^2$, $y < 0.9$
- $E_T^{jet1(2,3)} > 14(5)$GeV, $-1 < \eta^{jet} < 2.5$
- NLO QCD based on MEPJET, with ZEUS PDF set
- $W^{-(+)}$ coupled primarily to u(d) → possibly constrain d-quark PDF







- NLO fails to describe $d\sigma/dM^{jj}$ for dijets?
- Ratio e-p/e+p described reasonably well.

Inclusive Jet Cross Sections at Low Q^2

HERA-I: 99-00,

$5 < Q^2 < 100$ GeV^2

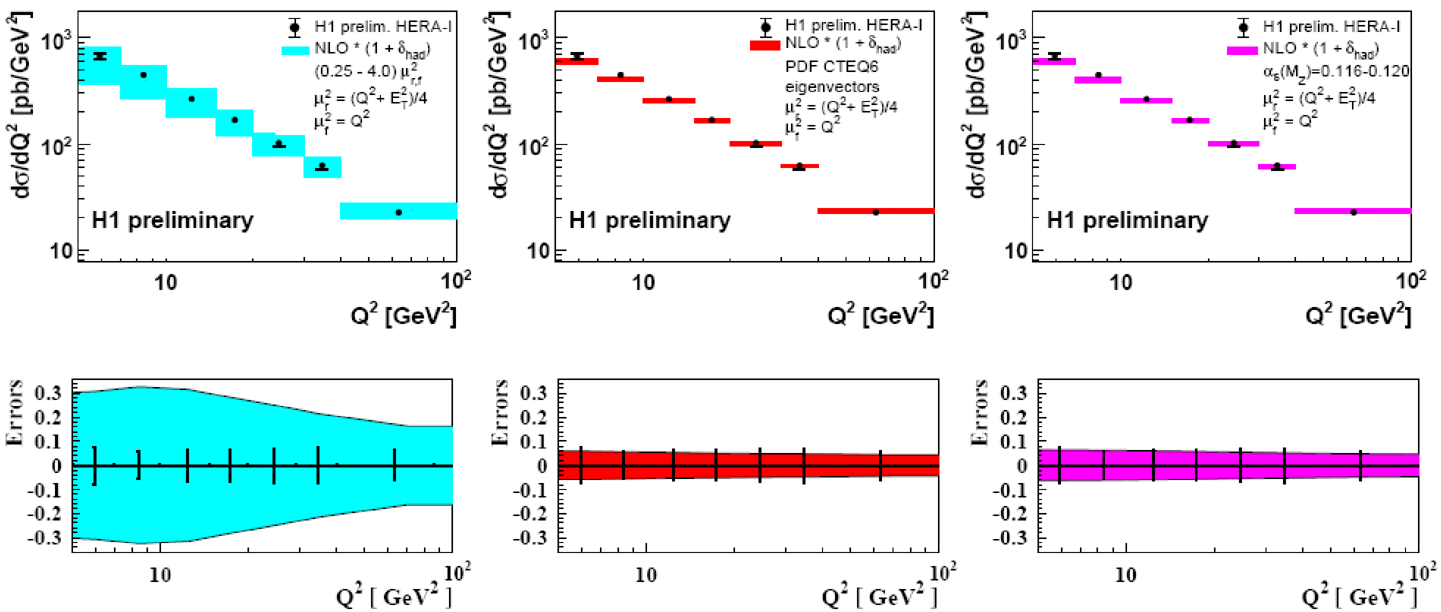
$0.2 < y < 0.7$

Inclusive jets

$E_T^{Breit} > 5$ GeV

$-1.0 < \eta^{Lab} < 2.5$

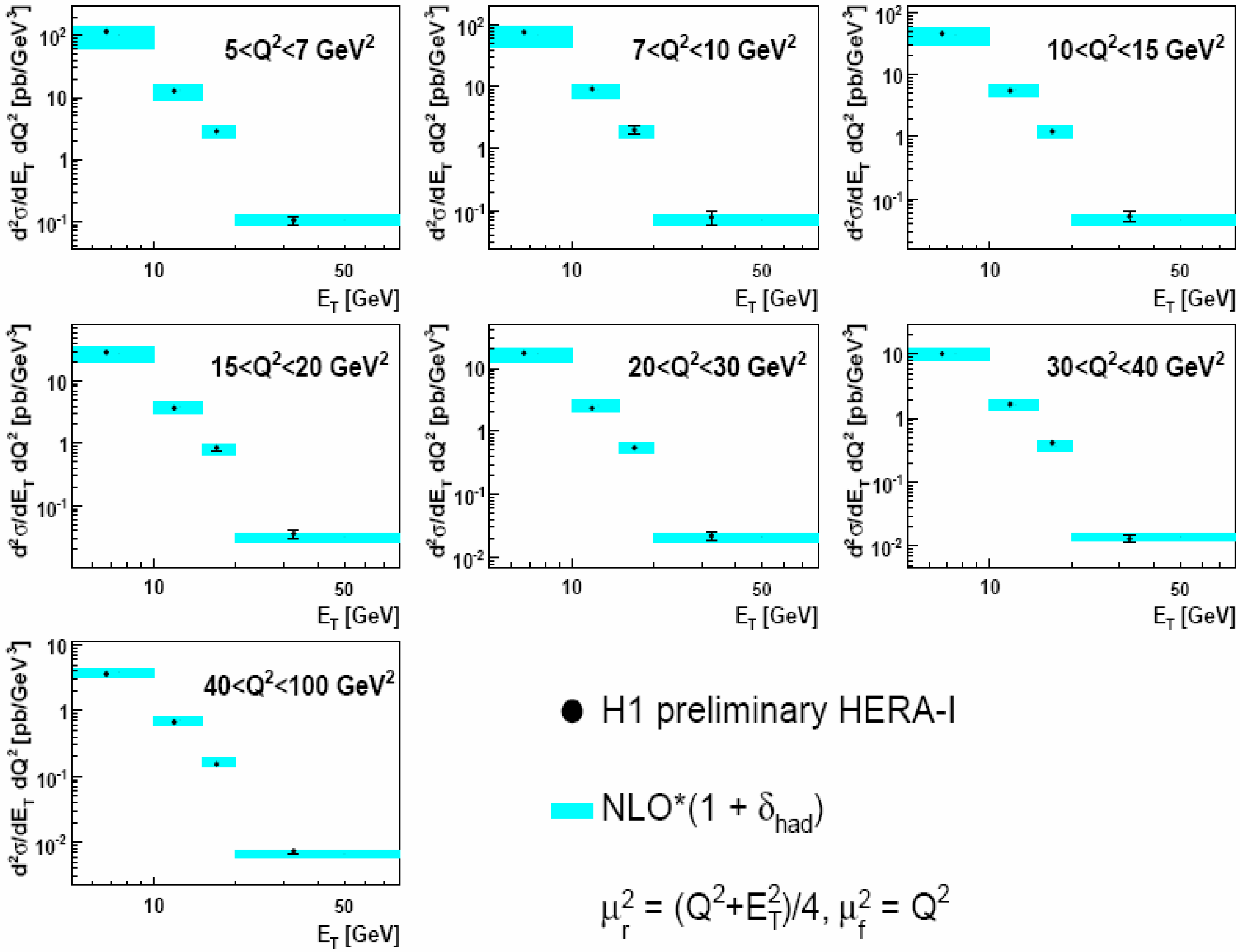
Inclusive Jet Cross Sections $\frac{d\sigma}{dQ^2}$



μ_R and μ_F uncertainties **PDF uncertainties** **α_S uncertainties**

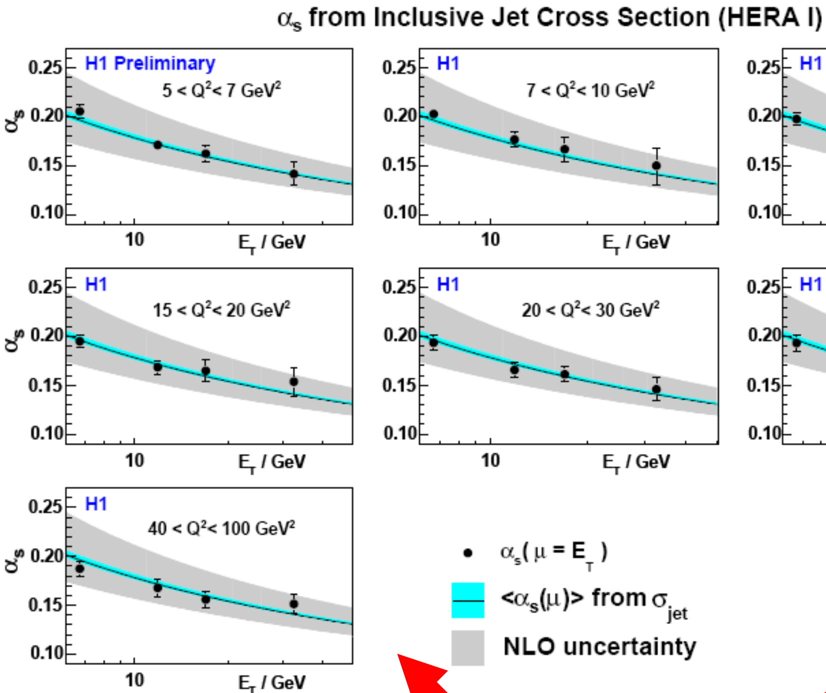
Scale uncertainties dominated over experimental errors and other theoretical uncertanties → theory improvement needed.

H1 Inclusive Jet Cross Sections $\frac{d^2\sigma}{dQ^2 dE_T}$

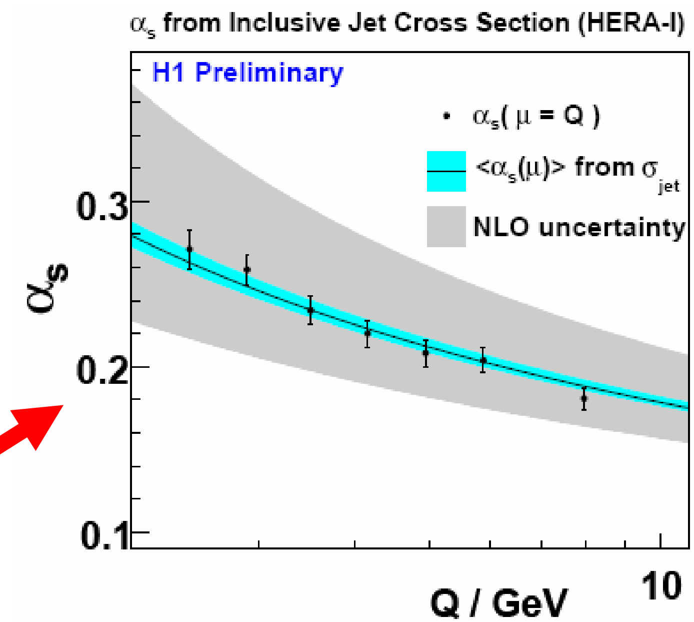


Data well described by NLO QCD. Large scale uncertainties.

α_s extraction from Low Q^2 DIS



Fit over 28 experimental points



Theoretical Uncertainties are the largest

Running of α_S vs. E_T and Q^2

α_S from low Q^2 data $\quad 0.1186 \pm 0.0014(\text{exp.})^{+0.0132}_{-0.0101}(\text{th.}) \pm 0.0021(\text{pdf})$

$\chi^2/\text{ndf} = 20.5/27$

H1-ZEUS combined QCD fit

H1:HERA-I 99-00

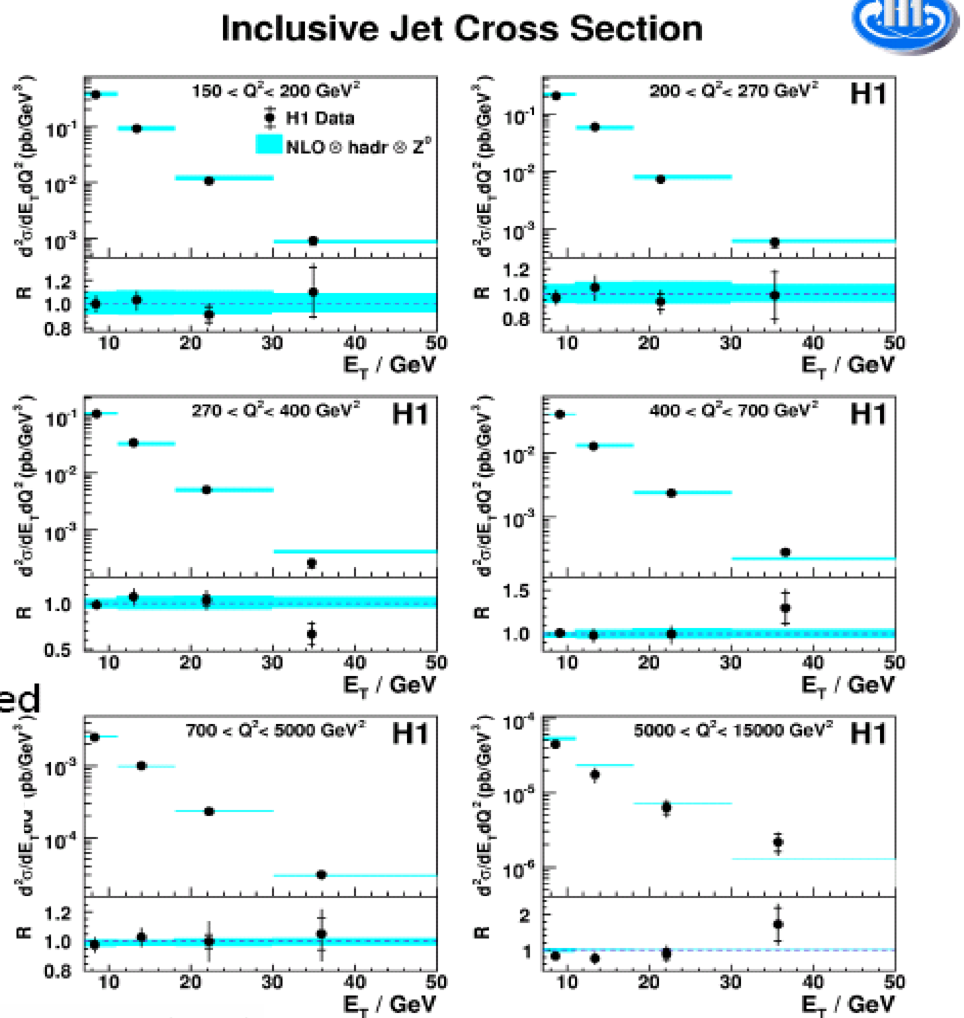
$\sqrt{S}$ =319 GeV, $\int L$ = 65 pb^{-1},

150<Q^2<15000 GeV^2, 0.2 < y <0.7

Jet Selection:

E_T^{Breit} > 7 GeV

- 1.0 < η^{Lab} < 2.5



ZEUS:HERA-I 98-00, $\int L$= 82 pb^{-1}

Q^2>500GeV^2 (used in fit)

Jet Selection:

E_T^{Breit} > 8 GeV

$|\cos\gamma_h|$ < 0.65

- 2. < η^{Breit} < 1.

ted

NLOJet++/FastNlo & DISENT (ZEUS grid program)

$\mu_R = E_T$, $\mu_F = Q$, PDF MRST2001

$$\alpha_s(M_Z) = 0.1198 \pm 0.0019\ (\text{exp.}) \pm 0.0026\ (\text{th.})$$

χ^2/ndf = 27.4/29

Inclusive and Multi Jet Cross Sections at High Q^2

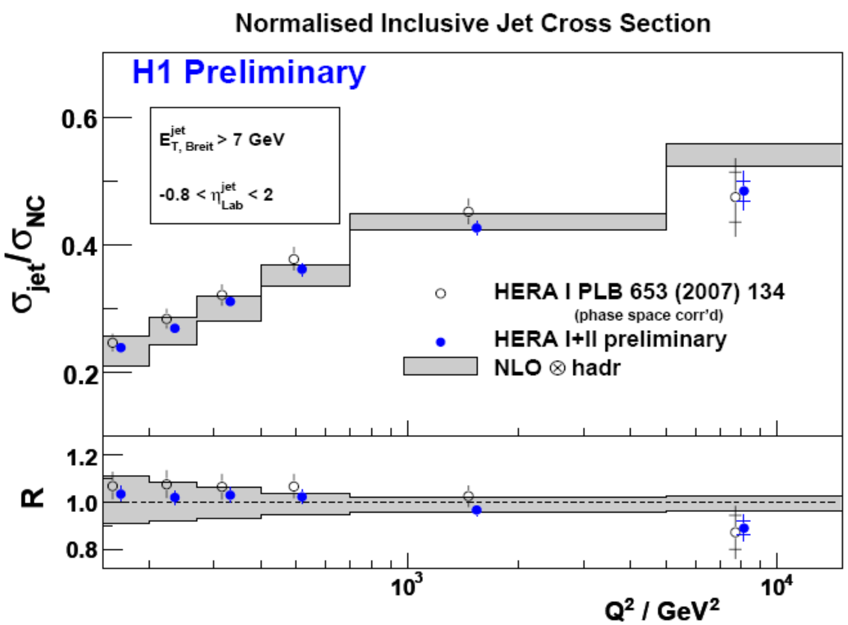
HERA-I+II: $\sqrt{S} = 319$ GeV, $\int L = 395.0\ pb^{-1}$

$150 < Q^2 < 15000\ GeV^2$, $0.2 < y < 0.7$

Normalization to σ_{NC} used for reducing errors

Inclusive Jets:

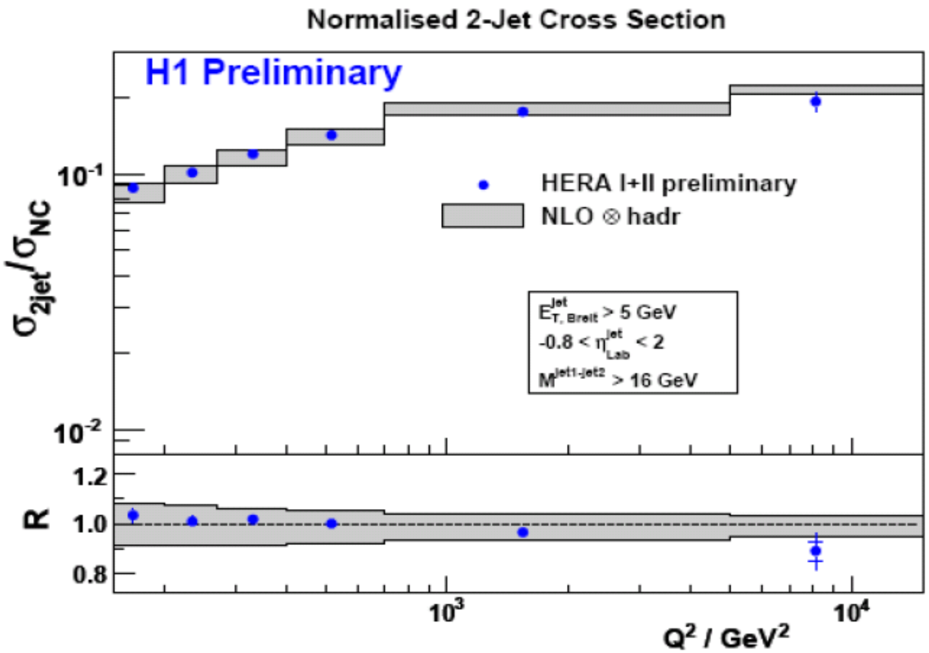
- $E_T^{Breit} > 7$ GeV
- $-0.8 < \eta^{Lab} < 2.0$

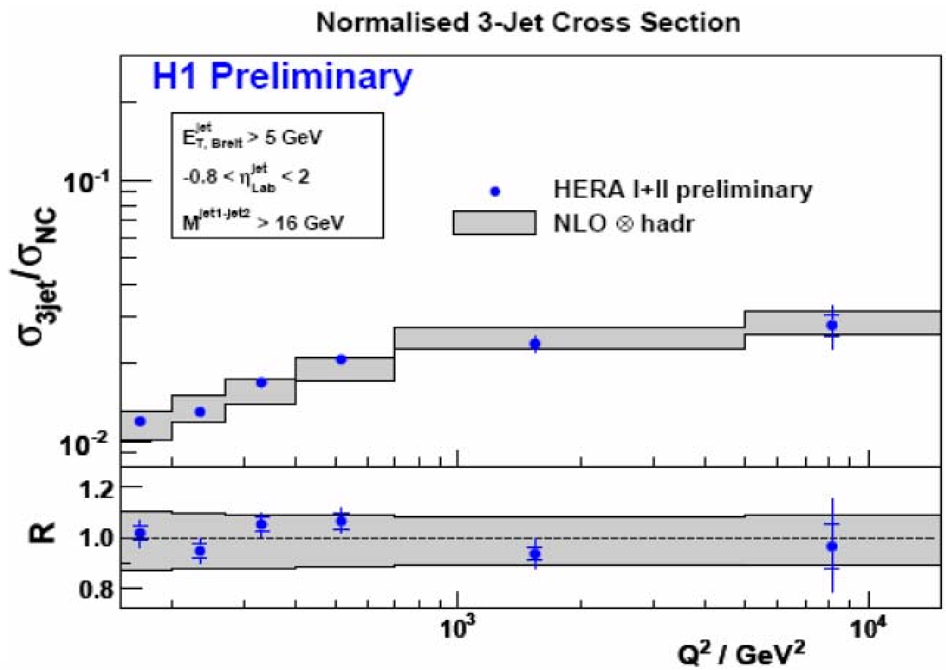


Multijets:

- $E_T^{Breit} > 5$ GeV
- $-0.8 < \eta^{Lab} < 2.0$
- $M_{jj} > 16$ GeV

Normalized Inclusive and Multijets Jet Cross Sections at High Q^2





Well described by NLO QCD prediction. Experimental uncertainties (2-6%) smaller than the theoretical ones (5-10 %).

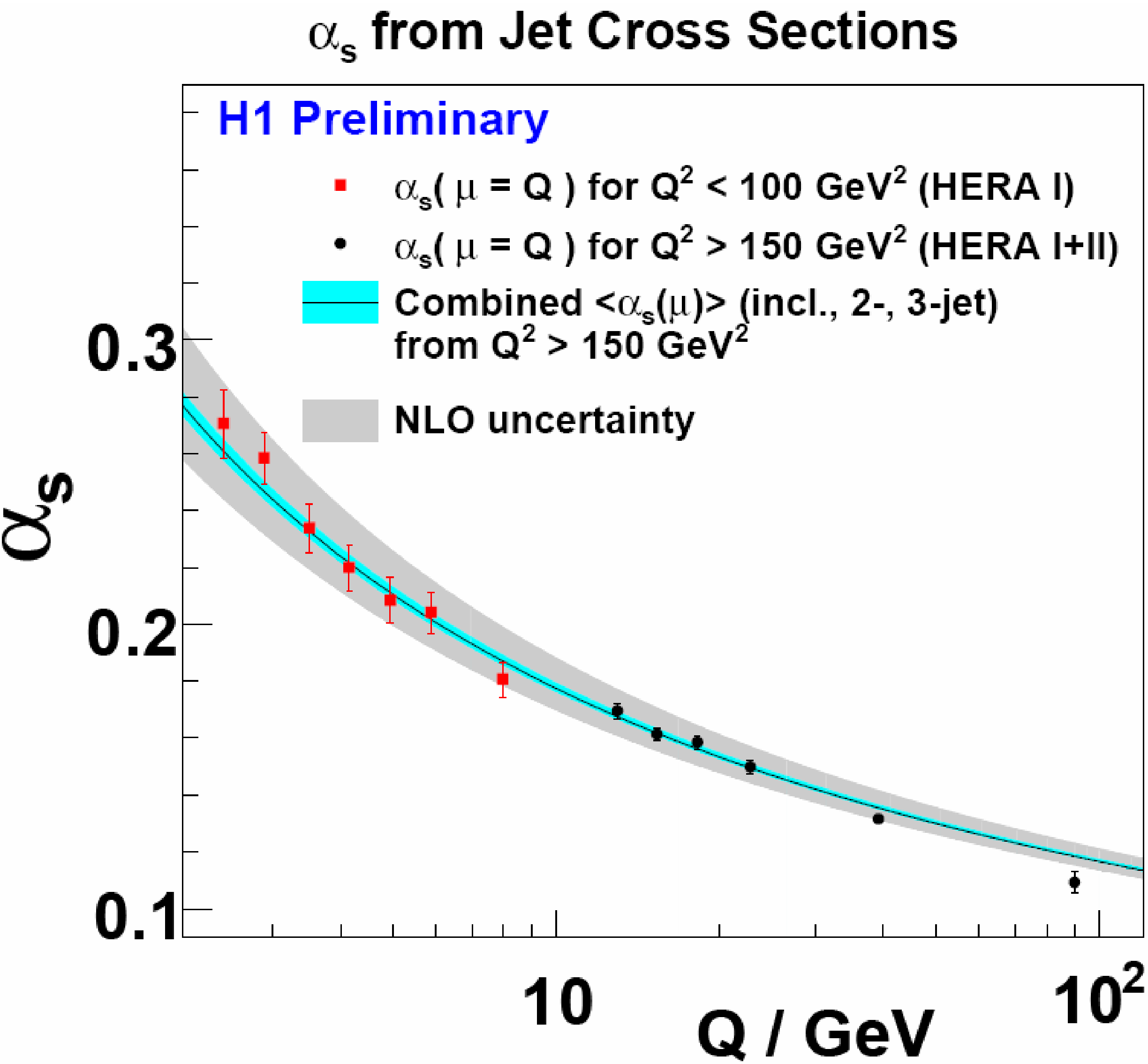
Trijets experimental uncertainties dominated by statistical errors and model dependence uncertainties. They are less than NLO QCD uncertainties.

α_s extraction from High Q^2 DIS

α_S extracted for DIS normalized inclusive jets, dijets, trijets.
Theoretical uncertainties are larger then experimental ones.

Observable	α_S	Exp. error	Theory err. Scales	Theory err. PDF	X^2/NDF
$\frac{\sigma_{3JET}}{\sigma_{NC}} = f(Q^2)$	**0.1179**	0.0014	+0.0056 - 0.0034	0.0009	4.53/5
$\frac{\sigma_{2JET}}{\sigma_{NC}} = f(Q^2, \langle E_T \rangle)$	**0.1171**	0.0010	+0.0048 - 0.0036	0.0018	28.1/23
$\frac{\sigma_{JET}}{\sigma_{NC}} = f(Q^2, E_T)$	**0.1196**	0.0010	+0.0049 - 0.0036	0.0019	26.8/23
$\frac{\sigma_{1JET}}{\sigma_{DIS}}$ & $\frac{\sigma_{2JET}}{\sigma_{DIS}}$ & $\frac{\sigma_{3JET}}{\sigma_{DIS}}$	**0.1182**	0.0008	+0.0041 - 0.0031	0.0018	54.8/53

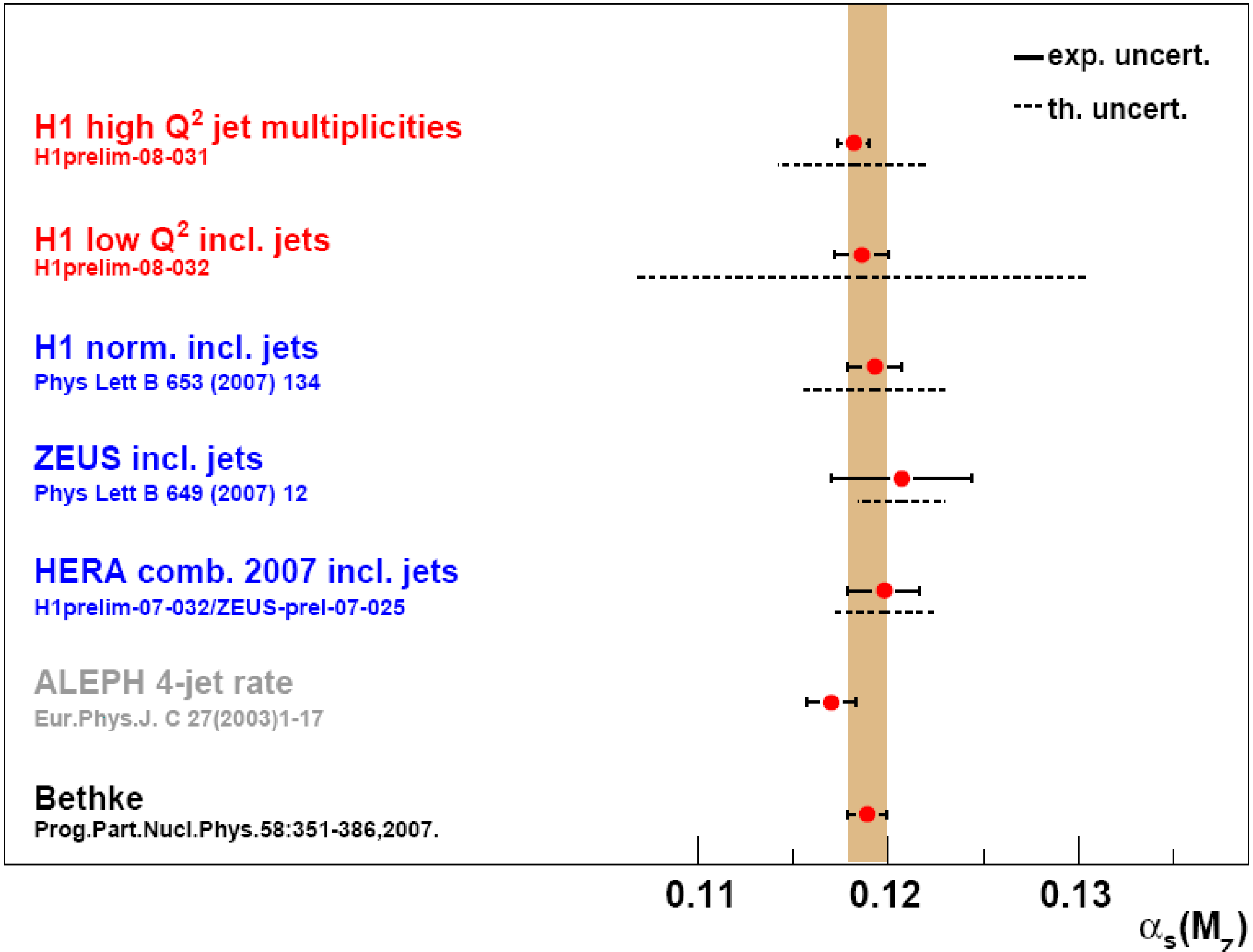
Running α_s (Q^2=5-15000 GeV^2)



Running α_S (from high Q^2).

- **NLO and $<\alpha_S(\mu)>$ extrapolated from high** (>150GeV^2) **to low** (<100GeV^2) **Q^2 region.**
- **α_S from Low Q^2 added to high Q^2 curves. A striking agreement between low and high Q^2 data observed.**

Comparison of $\alpha_s(M_Z)$ values



New α_S measurements from low and high Q^2 jets data compatible with the world average

Summary

1. Presented new measurements on jet data
   - multijet production at low x_{Bj}
   - high-E_T dijet photoproduction
   - multijet production in charged current
   - differential and double differential cross sections at low and high Q^2
   - α_S extraction at low and high Q^2
2. The jet data could constrain further the parton densities in proton and photon
3. Data well described with NLO.
4. α_S running verified over two orders of magnitude in Q ($5<Q^2<15000 GeV^2$). A striking agreement between the low and high Q^2.
5. Theory scale uncertainties dominated over experimental ones → theory improvements needed
6. HERA-II new data analysis are in progress → new high precision measurements are expected.