Jets in Deep Inelastic Scattering at HERA

and Measurement of α_s

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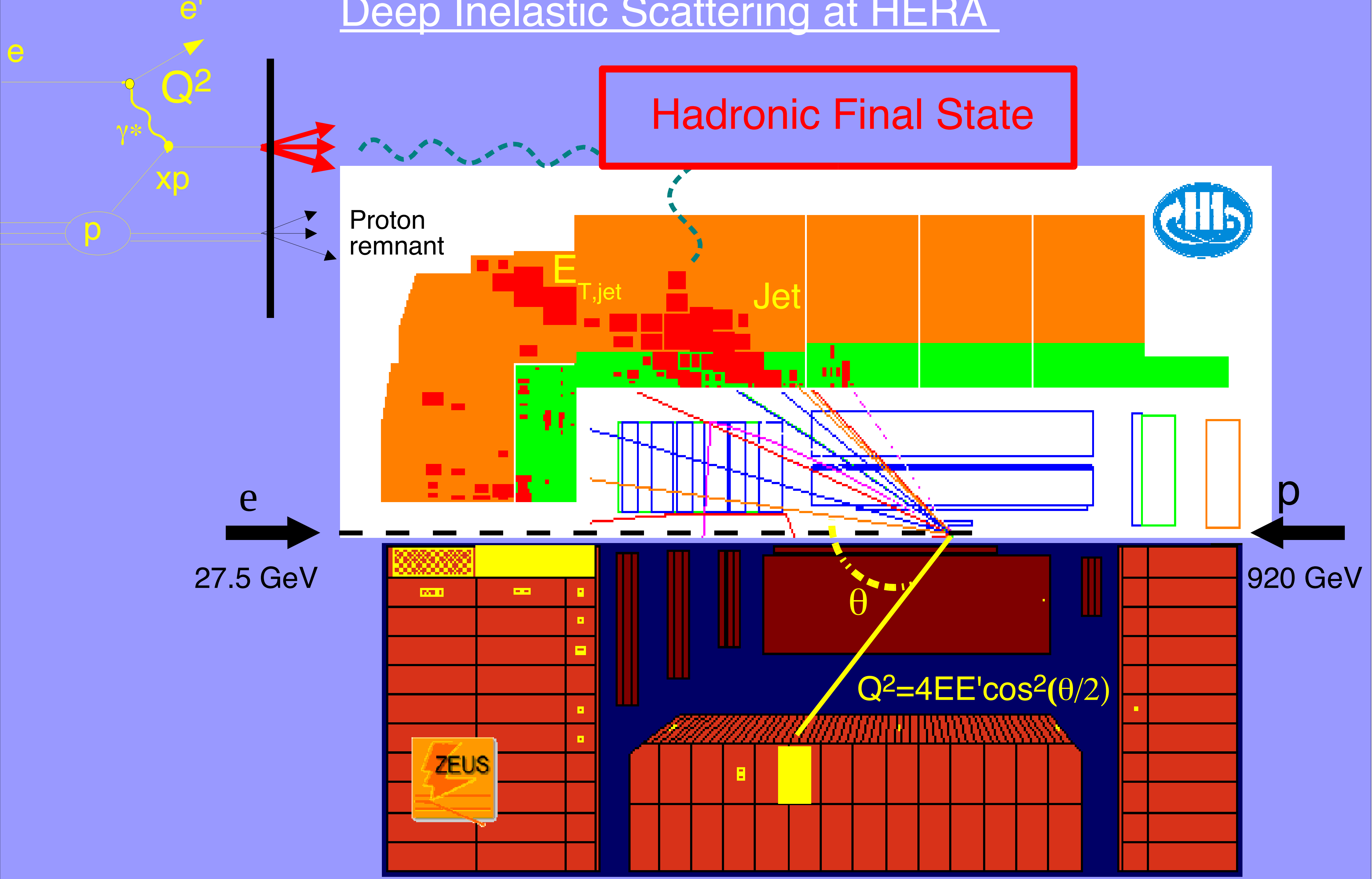
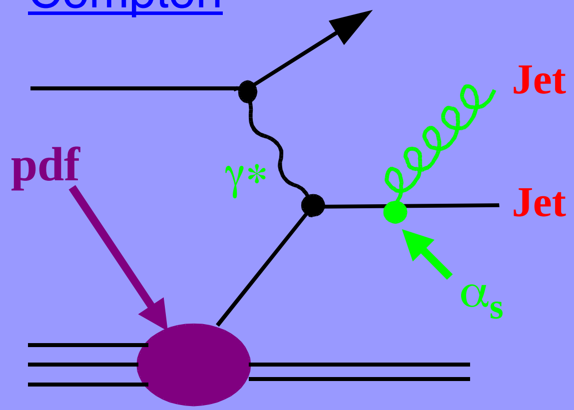
Deep Inelastic Scattering at HERA

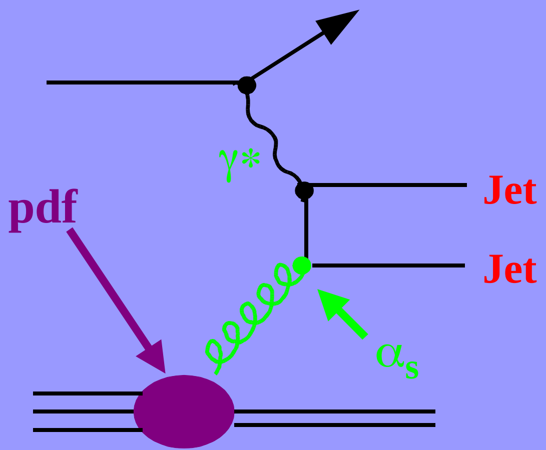


Jet Cross Sections in DIS

QCD-Compton



Boson Gluon Fusion



$$\sigma_{jet} = \sum_n \alpha_s^n(\mu_r) \sum_{i=G,q} \hat{\sigma}_{jet}(\mu_r,\mu_f) \otimes \mathrm{pdf}(\mu_r,\mu_f)$$

Dijet Cross Section

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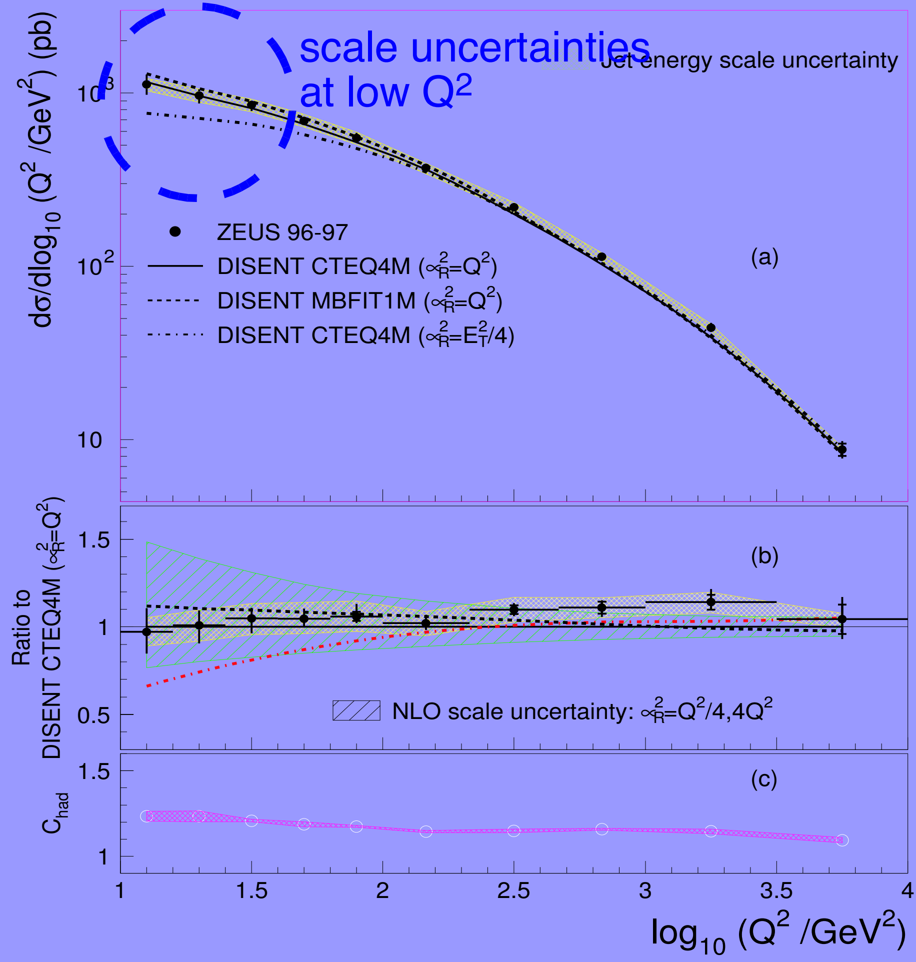
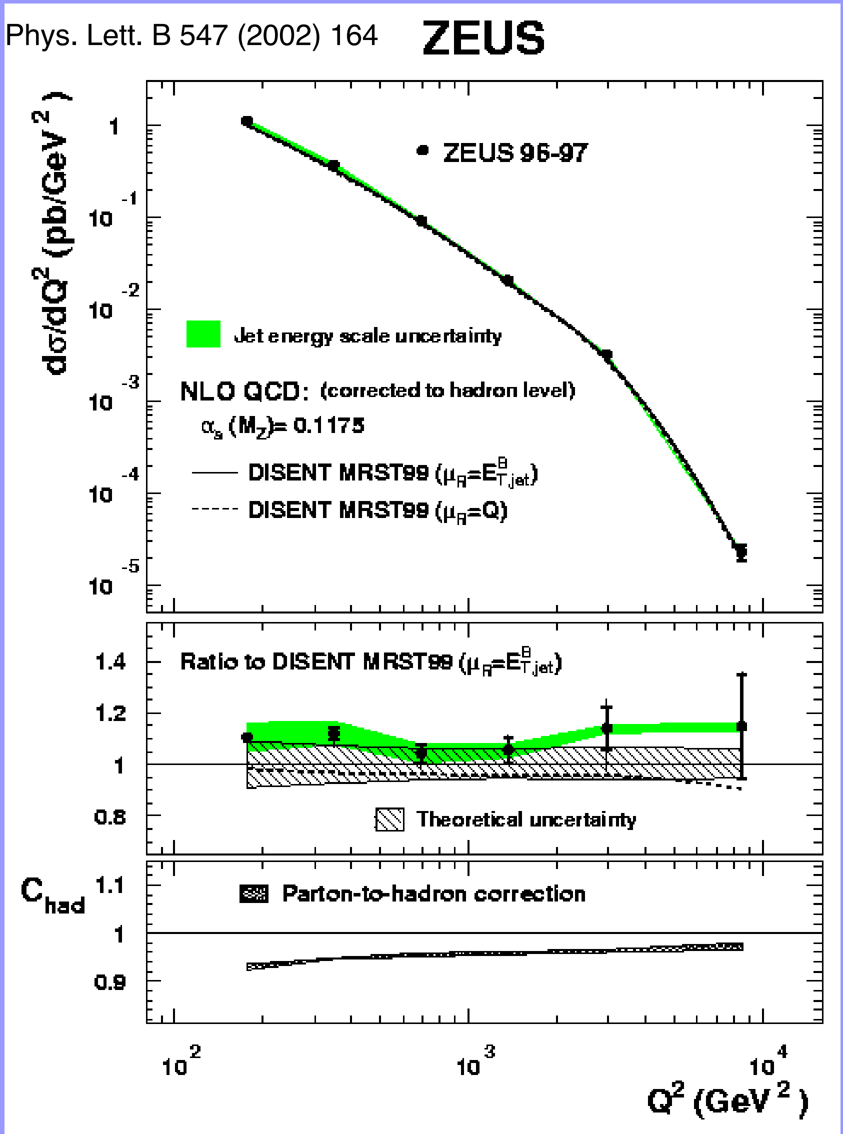


Description of data by NLO-QCD [$O(\alpha_s^2)$]
if $Q^2 > 150\ \mathrm{GeV}^2$ with small scale uncertainties

Inclusive Jet Cross Sections

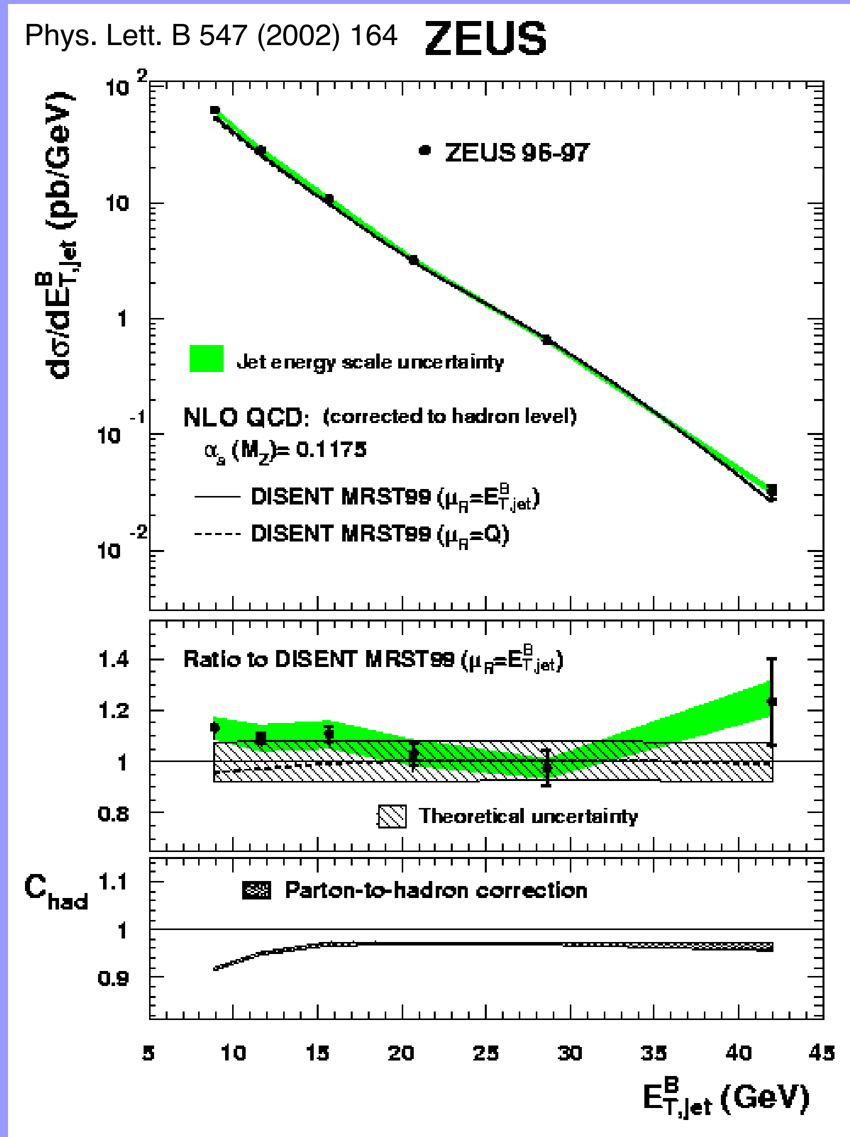
Theoretical and experimental advantages



Experimental and theoretical uncertainties O(7%)

Best agreement between data and theory at large Q^2, E_T

Small hadronisation corrections at large Q^2, E_T



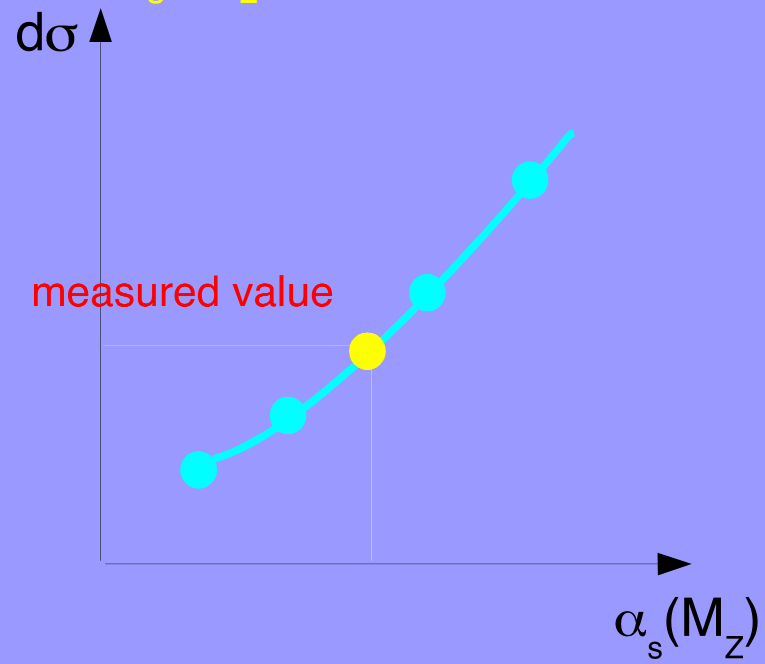
Extraction of α_s possible at large values of Q^2 and E_T

Determination of α_s

- Parameterize jet cross section as power series of $\alpha_s(M_z)$

$$d\sigma \sim A \cdot \alpha_s + B \cdot \alpha_s^2$$

Based on NLO-QCD predictions which employing different values of $\alpha_s(M_z)$



- Extract from measured cross section 'true' value of α_s

- Result from inclusive cross section $d\sigma/dQ^2$ $Q^2 > 500$ GeV^2

$\alpha_s(M_z) = 0.1212$ $+0.0017$ ← Stat.

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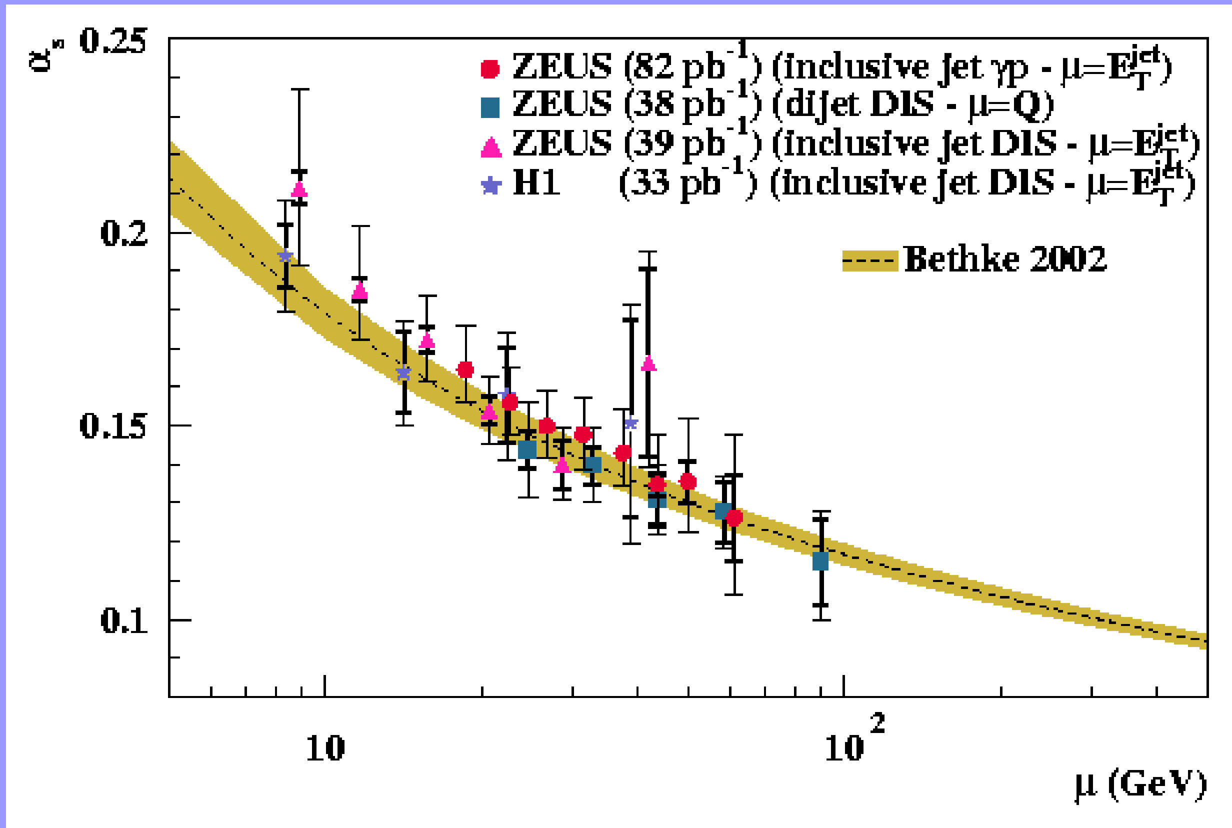
$^{+0.0023}_{-0.0031}$ ← Exp.: Jet Energy Scale

$^{+0.0028}_{-0.0027}$ ← Theory: Terms beyond NLO 3%
Parton PDFs 1%
Hadronisation corrections 0.2%

Precise Determination of α_s !

α_s from inclusive Jet and Dijet Cross Sections

Extraction of as at different energy scales μ
$\rightarrow$ Running of α_s with energy
(Basic QCD prediction)



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Results show clearly the running of α_s over wide range of μ
Consistency with global fits

Determination of the Gluon Density with Jets

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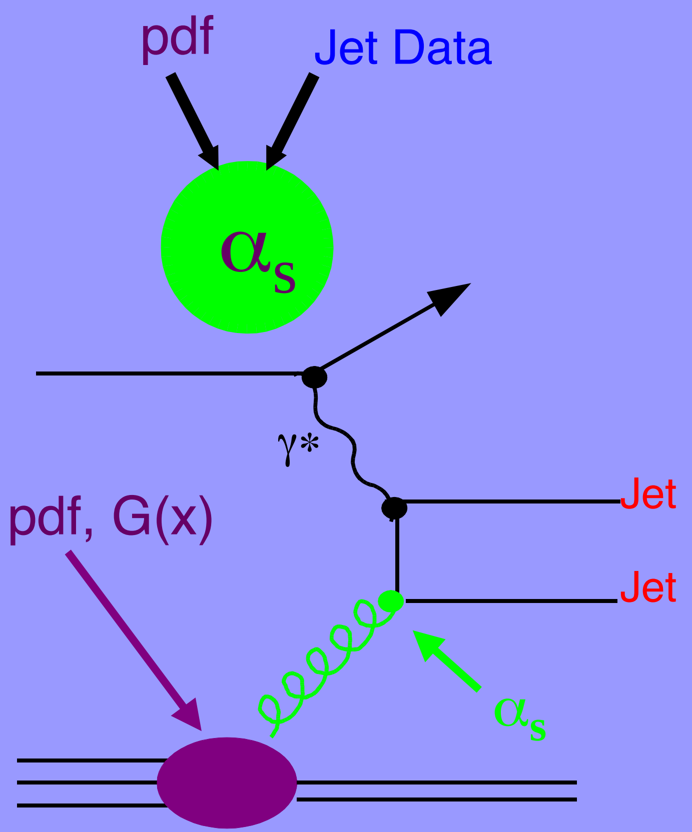

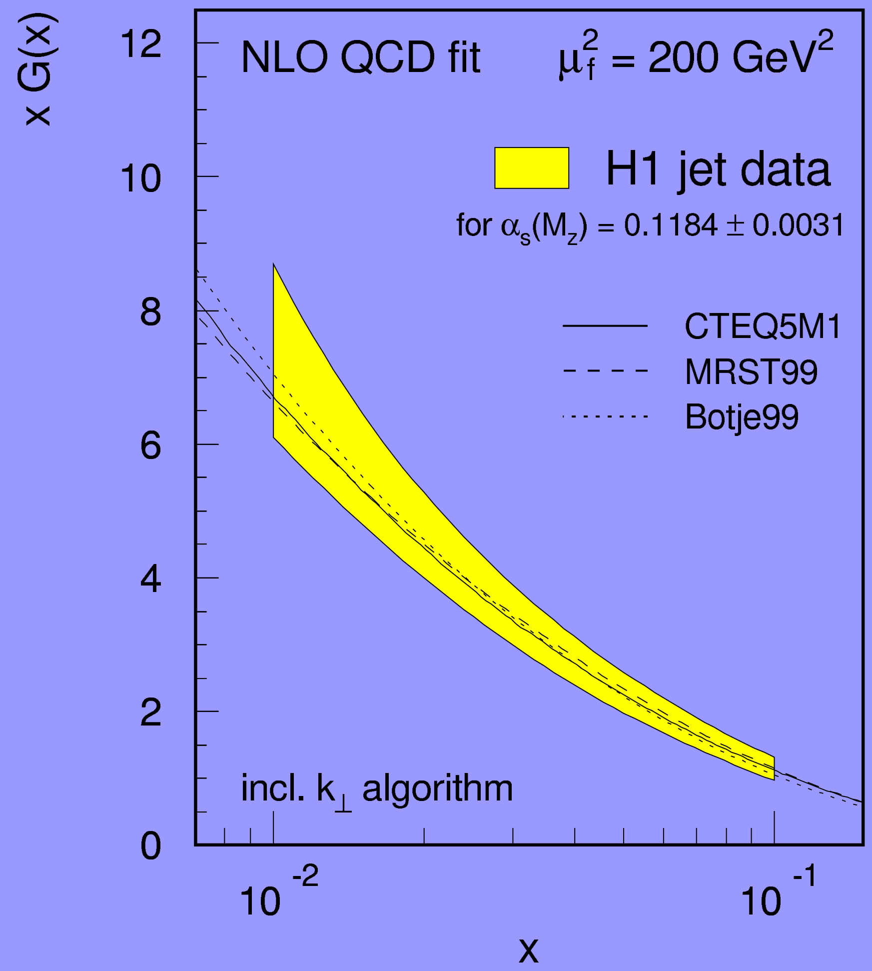

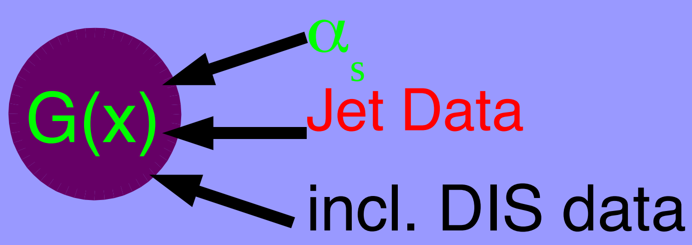

$$\int_{0.01}^{0.1} dx\, xG(x, \mu_f = 200\ \mathrm{GeV}^2) = 0.229$$

Direct determination of gluon density with jets consistent with result from global fits

Universality of gluon density !

Simultaneous fit of α_s and the gluon density xG(x)

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Basic idea:

Use three different cross sections to determine unknowns α_s, G(x), q(x)

$$\sigma_{DIS} \sim q(x)$$

$$\sigma_{jet} \sim \alpha_s \cdot (c_G G(x) + c_q q(x))$$

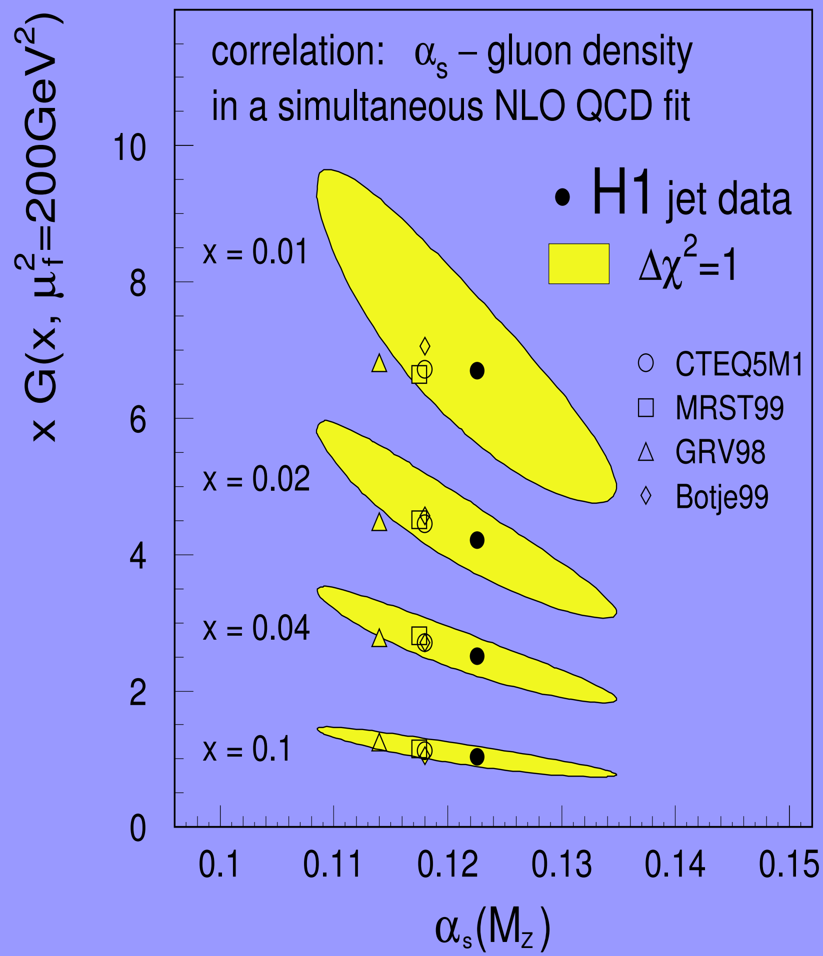
$$\sigma_{2jet} \sim \alpha_s \cdot (c'_G G(x) + c'_q q(x))$$

Kinematic range:

- DIS x-section: $150 < Q^2 < 1000$ GeV^2
- Jet x-section: $150 < Q^2 < 5000$ GeV^2

Fit:

- fixed factorization scale μ_f
- put experimental, scale and hadronization uncertainties into systematics

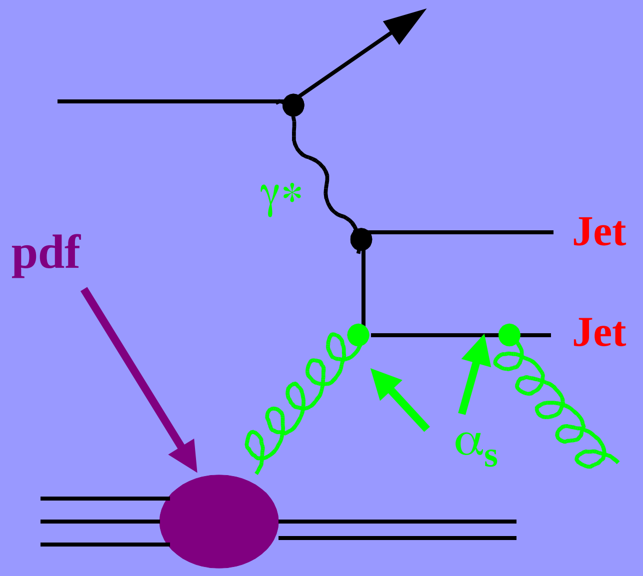


Large anti-correlation between G(x) and α_s

Result consistent with global fits

Improvement by higher statistic @ large ET

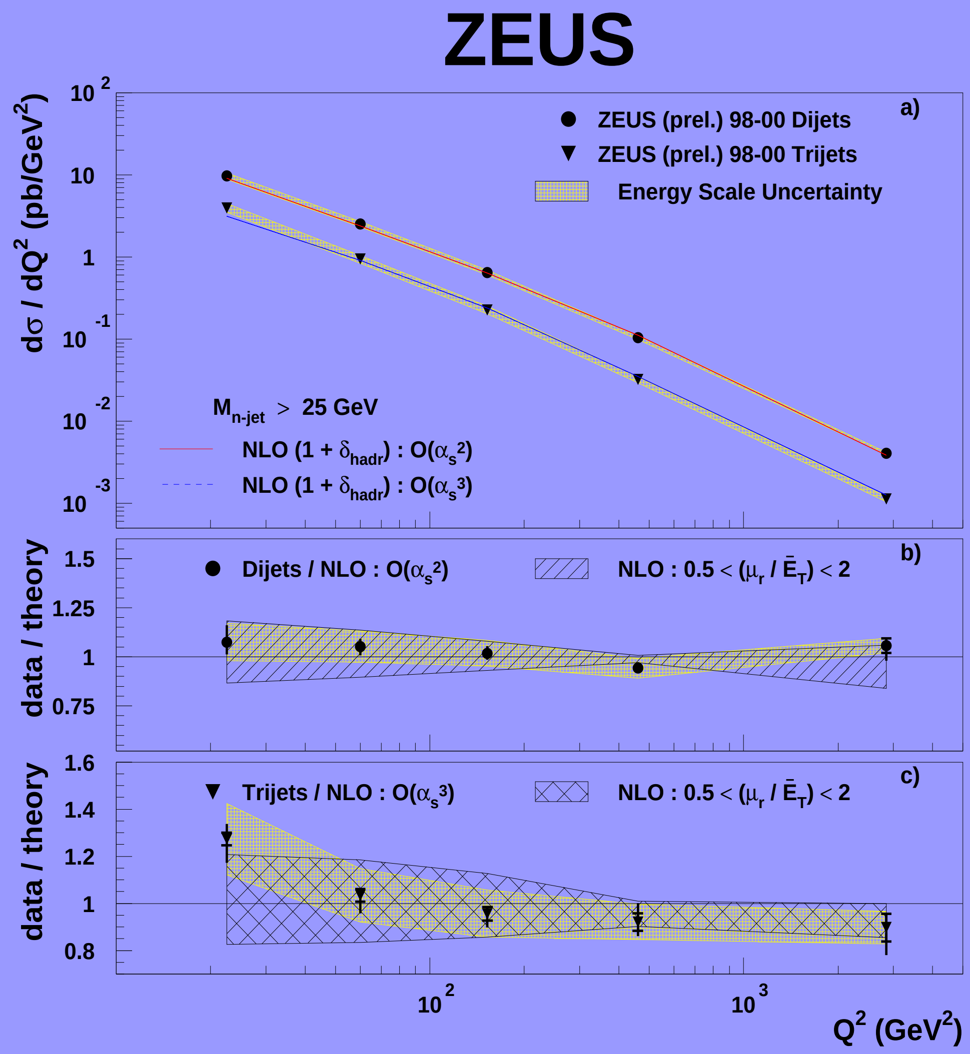
Three Jet Cross Sections in DIS



LO process proportional to α^2_s

$\Rightarrow$ High sensitivity to α_s

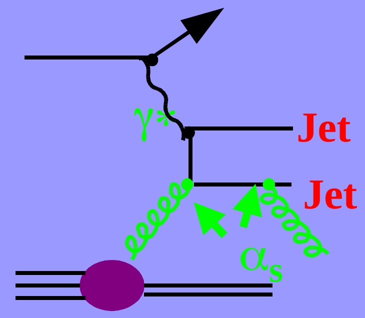
Contributed Paper to EPS '03



Dijet and three-jet cross sections well described by NLO QCD calculations
(up to α^3_s for three jets)

Potential for extraction of α_s !?

α_s measurement employing three jet cross sections



Three jet cross section

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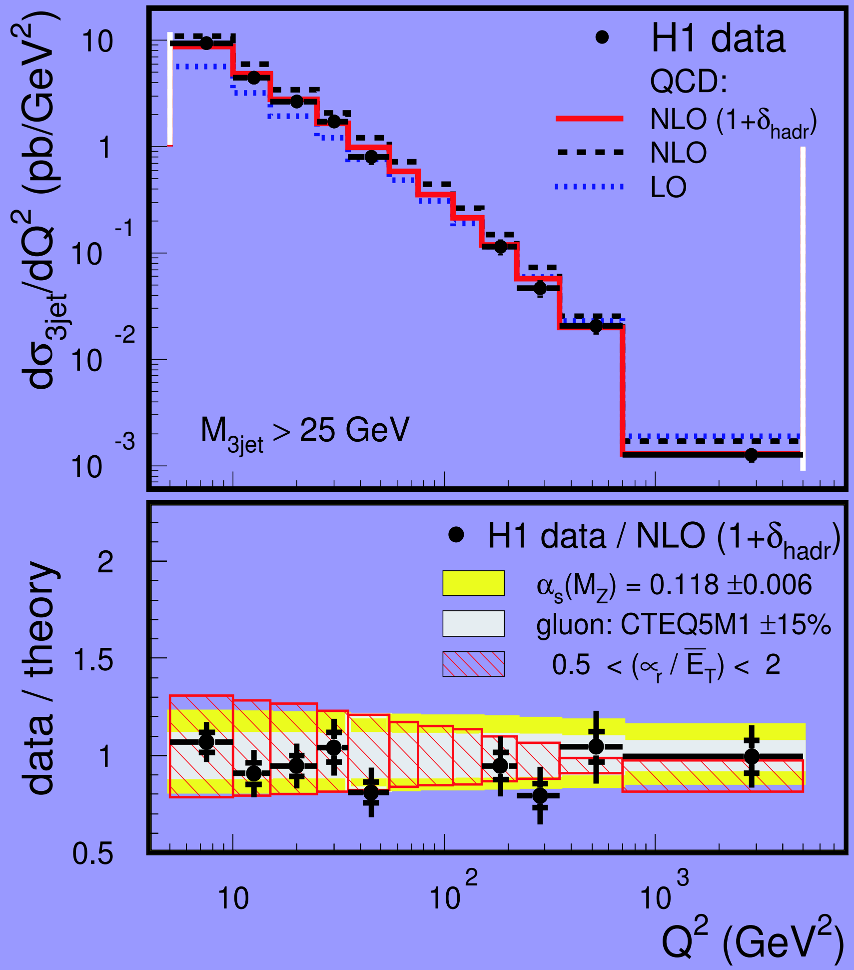

$R_{3/2} = \sigma_{3jet}/\sigma_{2jet}$

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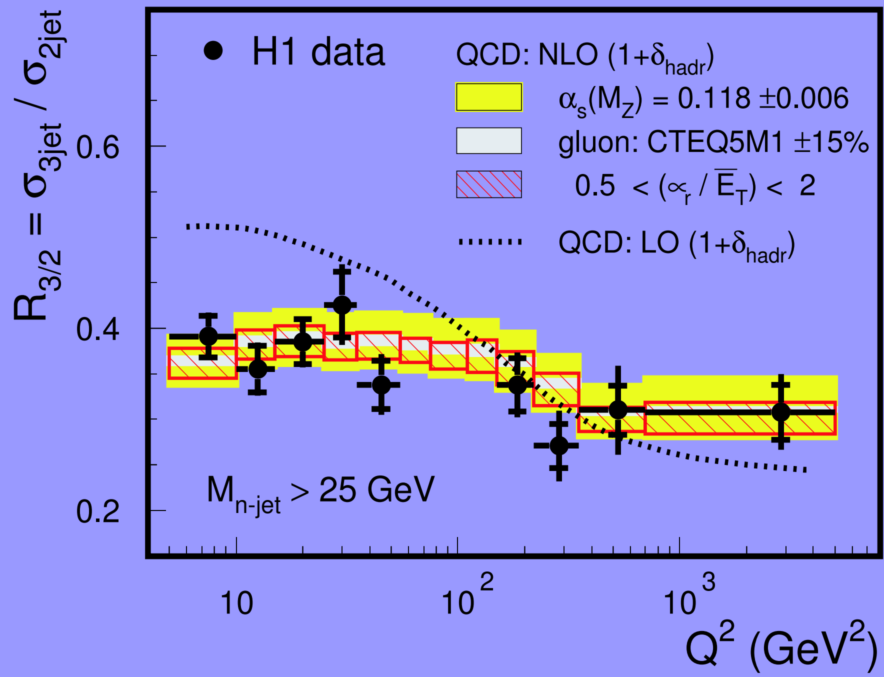
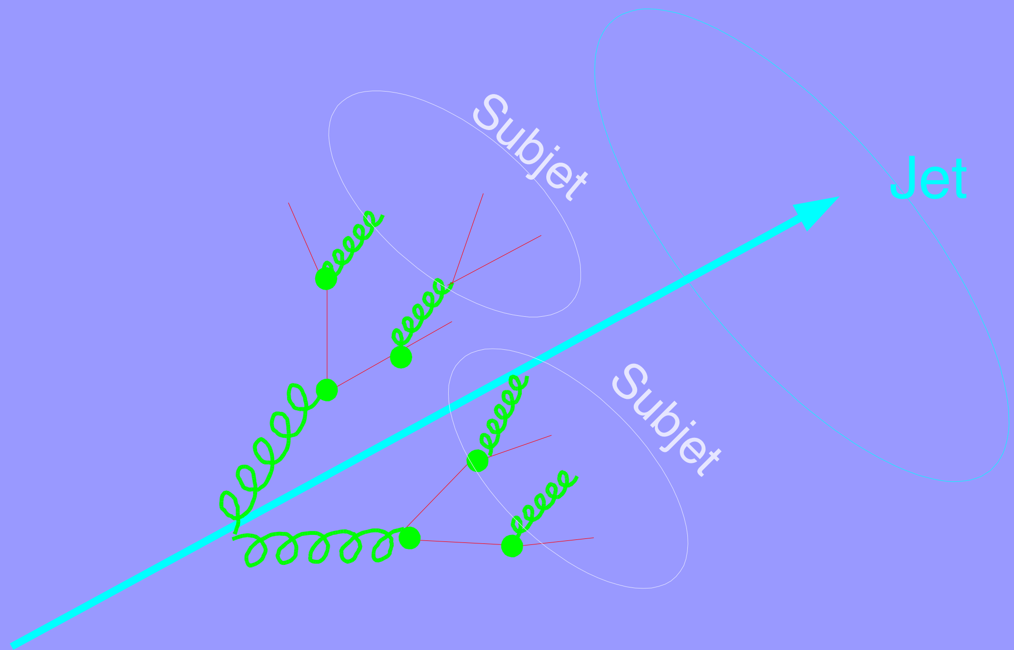


Reduced sensitivity to gluon density by ratio

Sizeable sensitivity on gluon density

Large sensitivity to small variations of α_s

Jet Substructure



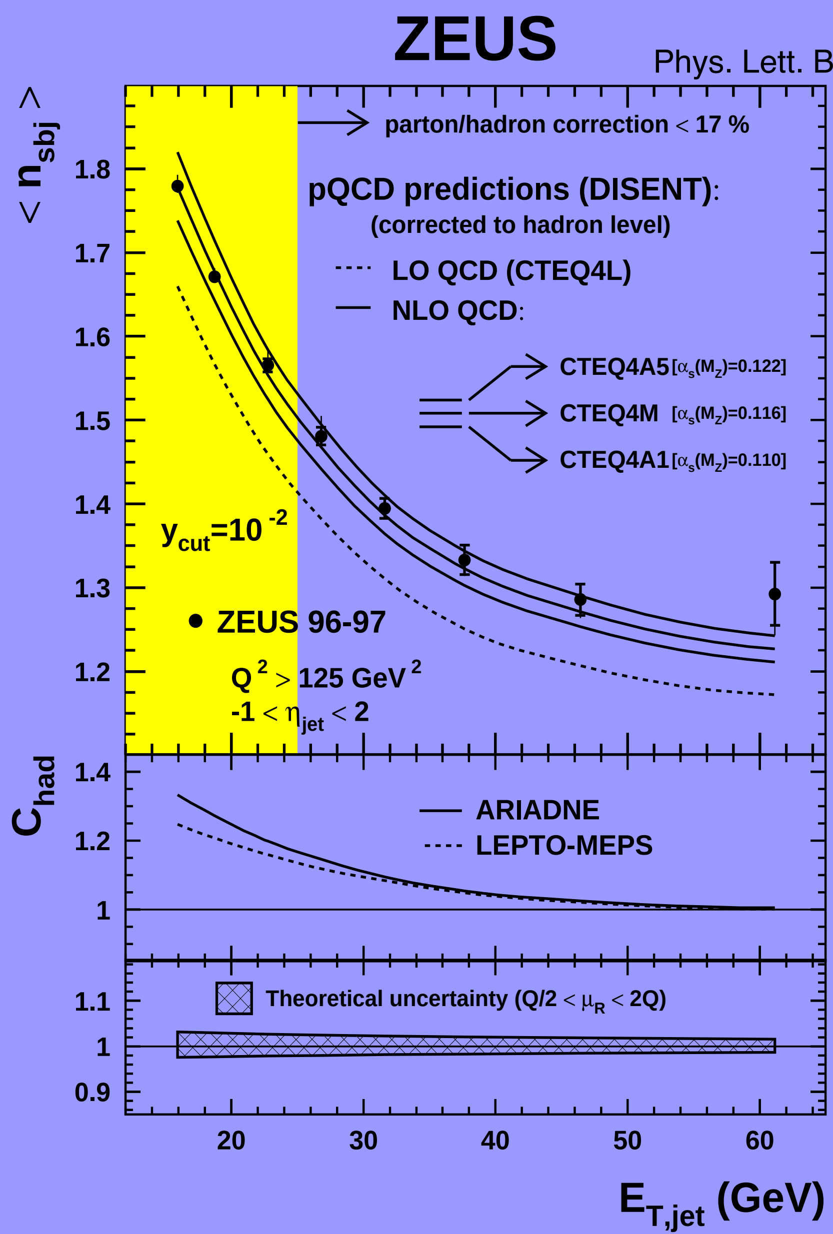
A jet can be decomposed into subjets

Formation of partons → subjets is driven by QCD

Subjet-Multiplicity sensitive to α_s

Subjet Multiplicity and Determination of α_s

Measurement in Lab. Frame



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- Number of subjets decreases as E_T of jet increases
- NLO QCD calculations descibe data
- Predictions based on different α_s 'oscillate' around data

→ Determination of α_s

$$\alpha_s(M_Z) = 0.1187 \; +0.0017 \; {}^{+0.0024}_{-0.0009} \; {}^{+0.0093}_{-0.0076}$$

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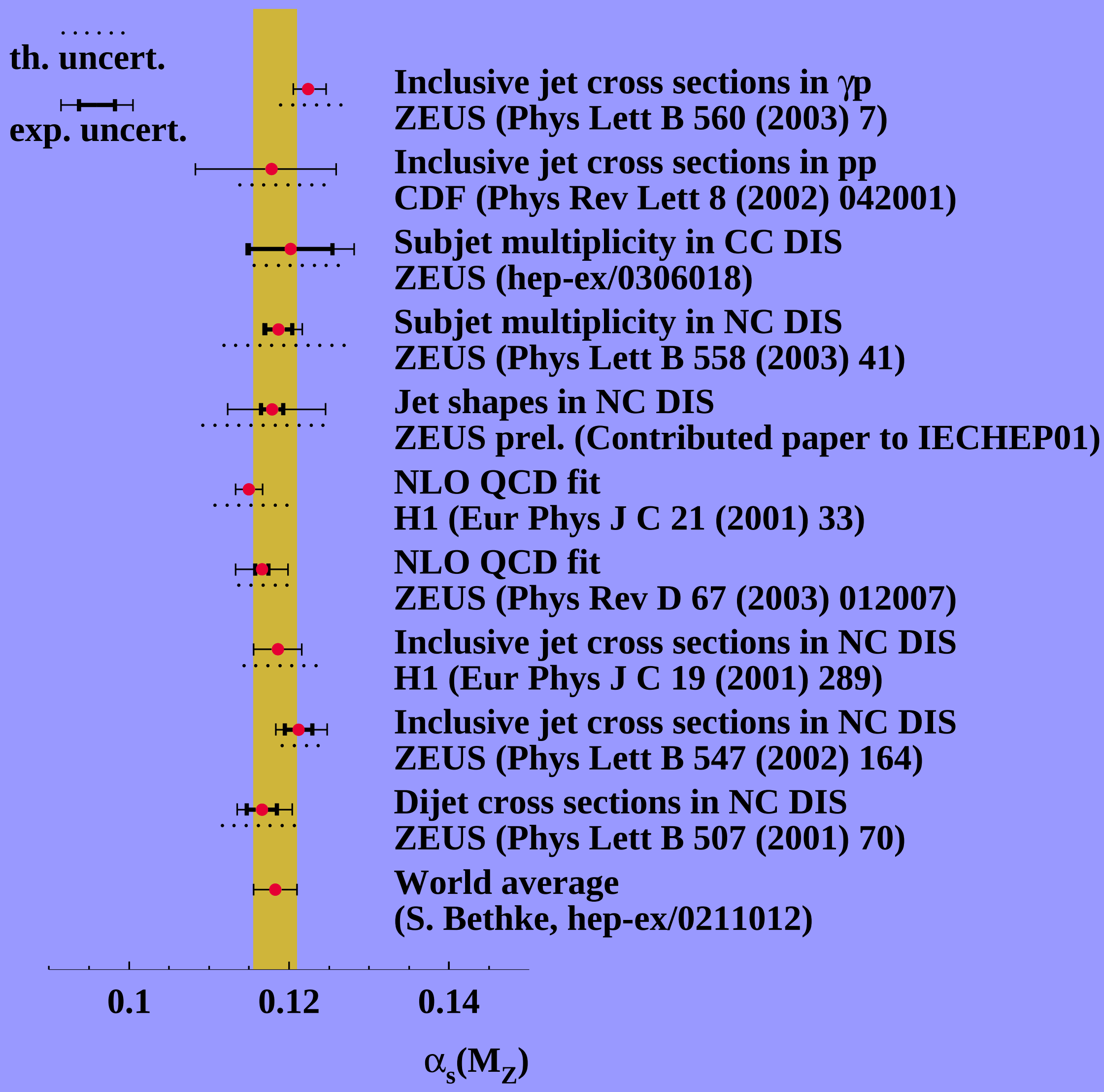
Stat. ($+0.0017$)

Exp. ($^{+0.0024}_{-0.0009}$)

Theory ($^{+0.0093}_{-0.0076}$)

Conclusions



- Multijet production in DIS at HERA allow for stringent test of QCD

- Precise determination of α_s by various jet observables

- Consistent results

- Significant impact on world average of α_s

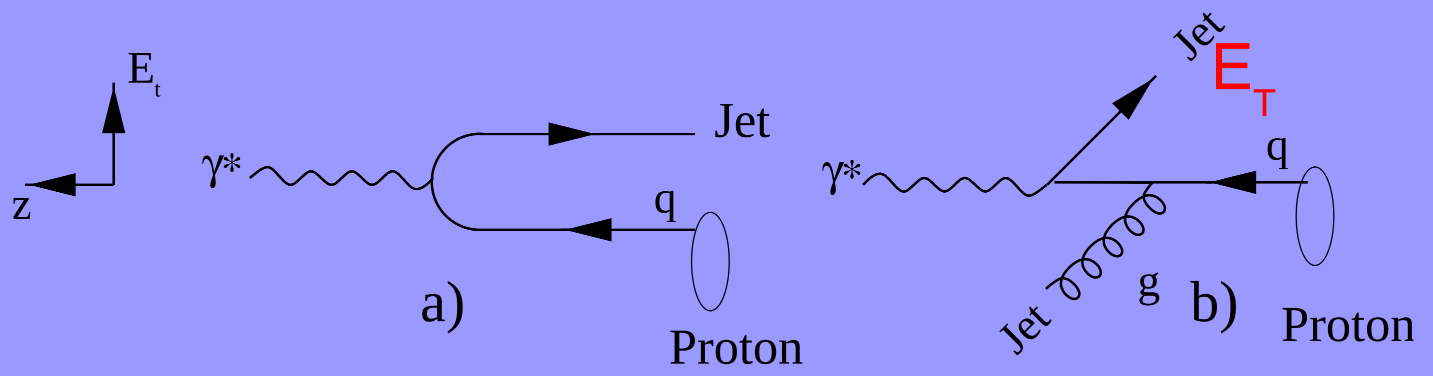
The Breit Frame

In ep lab-frame outgoing hadrons have to balance E_T of scattered e

Choose frame where transverse energy is solely produced by interesting hard scatter
Frame where proton and photon collide head on

QPM

QPM + QCD



$$2x\,\vec{P}_{proton} + \vec{q}_{\gamma} = 0$$

No transverse energy
in naive QPM

Tansverse energy E_T
by QCD process