Jets and Event Shape Studies in QCD at HERA

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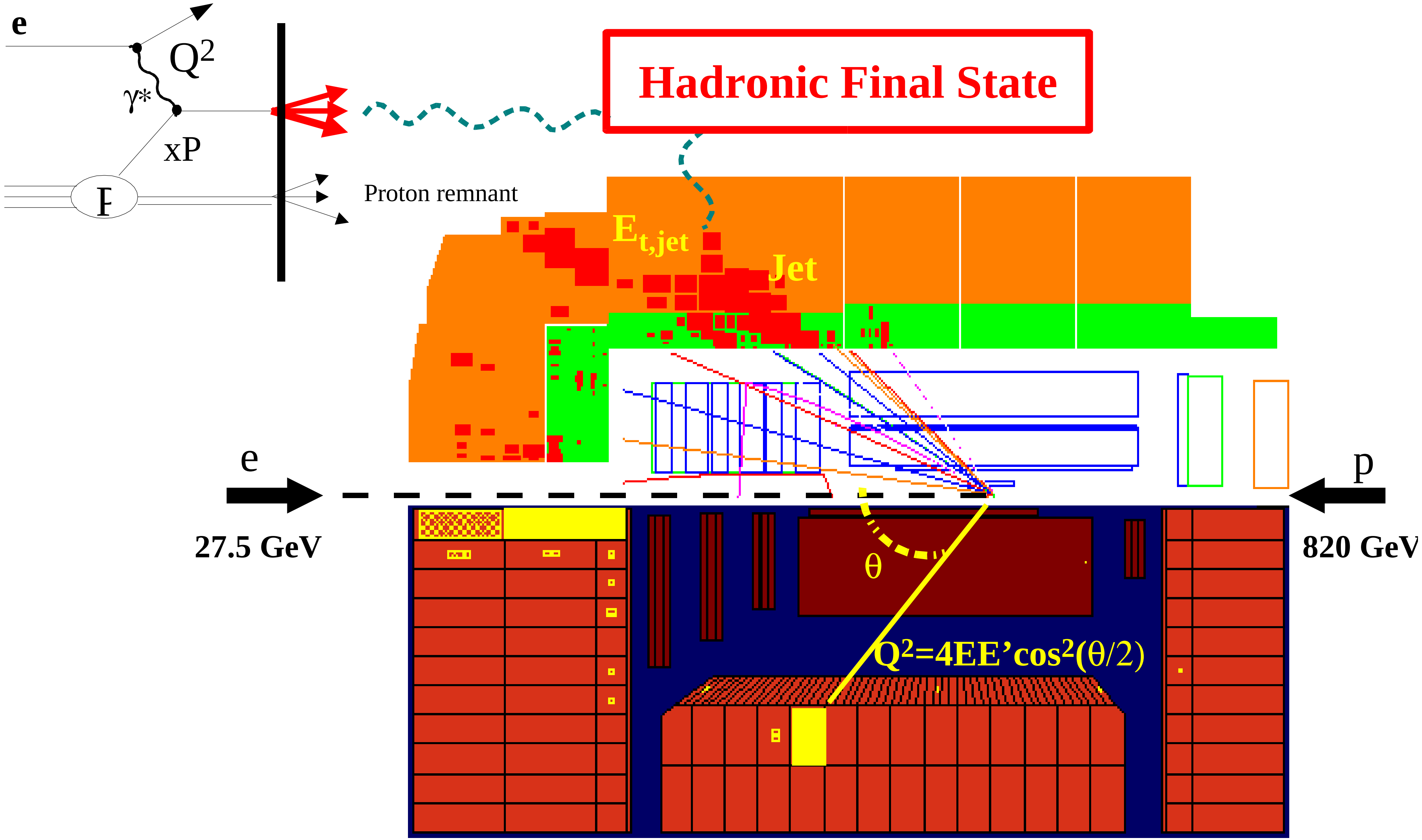
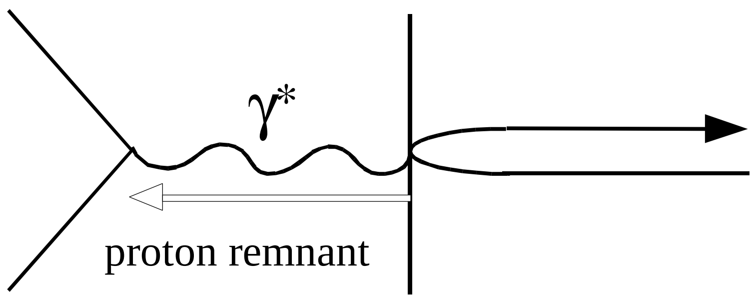
- Introduction
- Event Shapes and Power Corrections
- Jets at high Q^2 and pQCD
- α_s from jets

Deep Inelastic Scattering at HERA

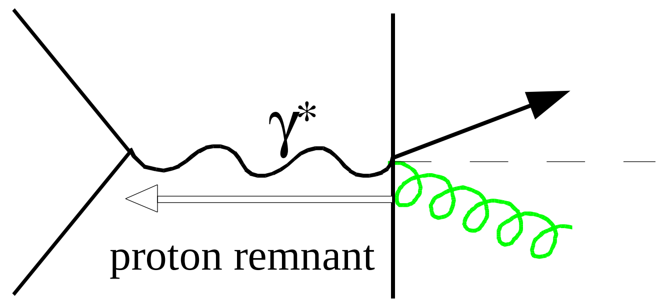


Variables and observables in the Breit Frame

QPM



QPM + QCD



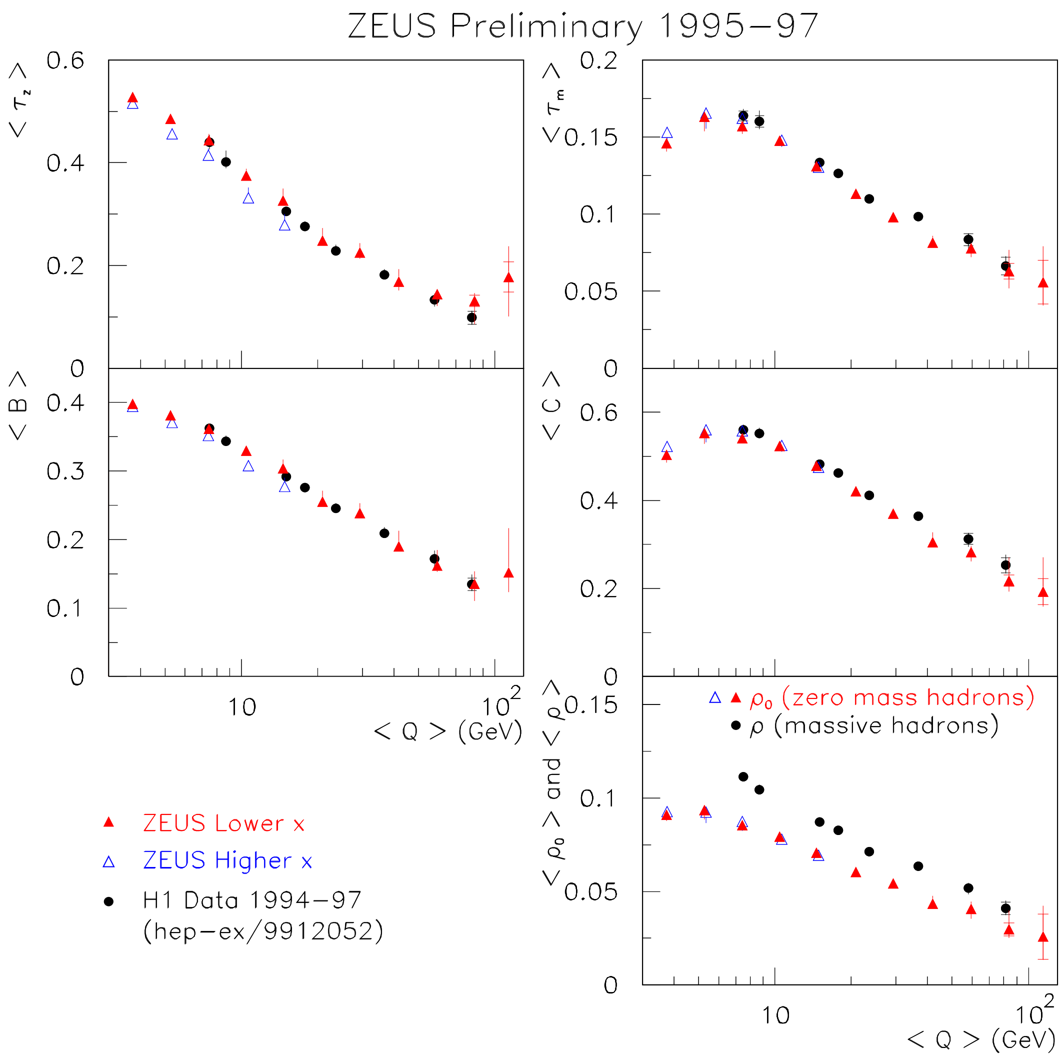
Event Shapes

Definition	Observable	QPM		QPM + QCD
$\tau_z = 1 - \frac{\sum p_{z,h}}{\sum_h \lvert\mathbf{p}_h\rvert}$	Thrust	$\tau_z = 0$	$\rightarrow$	$\tau_z > 0$
$B = \frac{\sum p_{t,h}}{\sum_h \lvert\mathbf{p}_h\rvert}$	Jet Broadening	$B = 0$	$\rightarrow$	$B > 0$

Jet Observables

Definition	QPM		QPM + QCD
$E_{t,jet}$	$E_{t,jet} = 0$	$\rightarrow$	$E_{t,jet} > 0$

Measurement of Mean Event Shapes



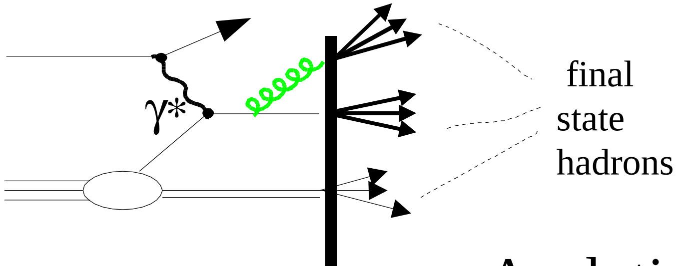
- **Events more collimated with increasing Q**
- **Here H1 and ZEUS agree within errors (different definition of ρ)**
- **ZEUS Data allow for investigation of *x*−dependency of event shapes e.g. τ_z, *B***

$$\tau_m = 1 - \mathbf{max}\frac{\sum_h |\mathbf{p}_h \cdot \mathbf{n}_t|}{\sum_h |\mathbf{p}_h|} \qquad C = 3\frac{\sum_{i,j} |\mathbf{p}_i||\mathbf{p}_j|\sin^2(\vartheta_{i,j})}{2(\sum_i |\mathbf{p}_i|)^2} \qquad \rho = \frac{(\sum_h |p_{h,t}|)^2}{(2\sum_h |E_h|)^2}$$

Theoretical Framework

$O(\alpha^2_s)$

$$\langle F \rangle = \langle F \rangle^{\mathrm{pQCD}} + \langle F \rangle^{\mathrm{Power\ Corr.}}$$



'Naive' Power Corrections

$$\langle F \rangle^{Power\ Corr.} = \frac{\lambda_1}{Q}$$ and $$\langle F \rangle^{Power\ Corr.} = \frac{\lambda_2}{Q^2}$$

Fit Result for e.g. *C*:

$\lambda_1 = 2.33 \pm 0.03$ χ^2 / **dof = 66**

$\lambda_2 = 20.8 \pm 0.4$ χ^2/ **dof = 328**

⇒Data cannot be described by simple approach

Analytical Power Corrections

à la Dokshitzer & Webber

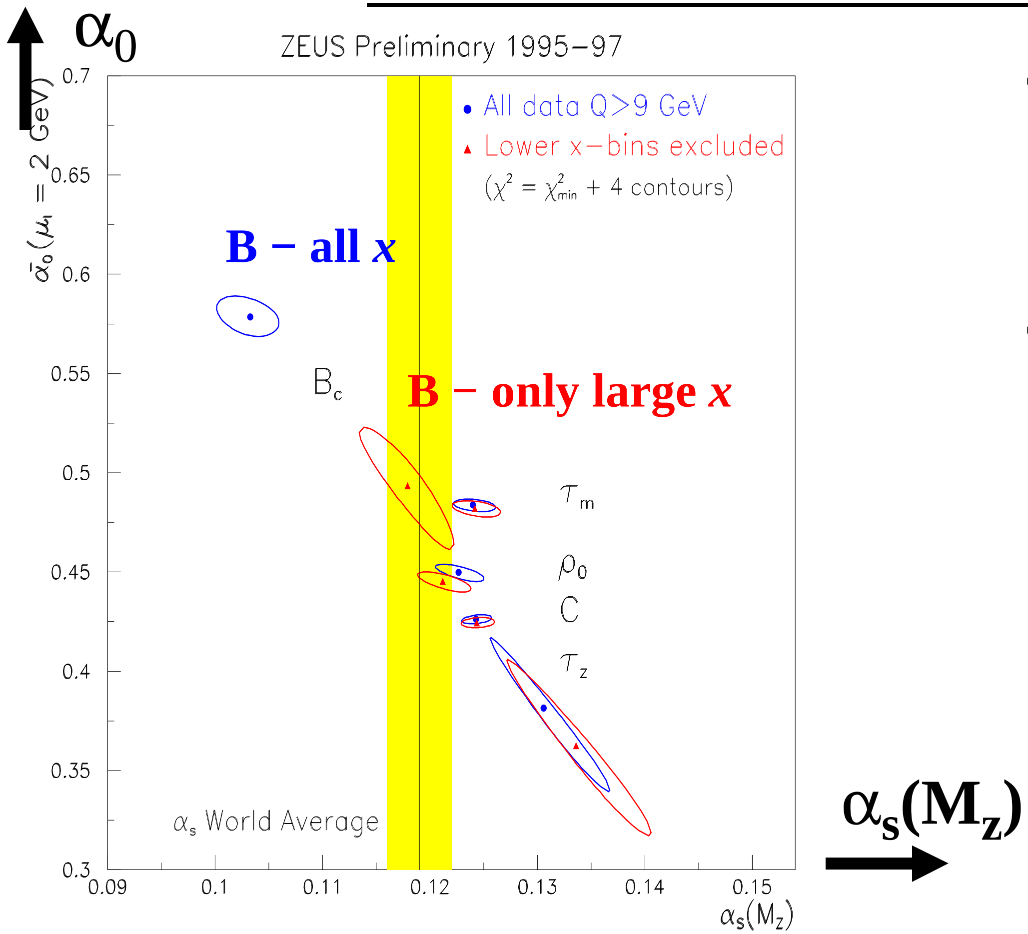
Introduce universal (?) α_{p-1}, here p=1

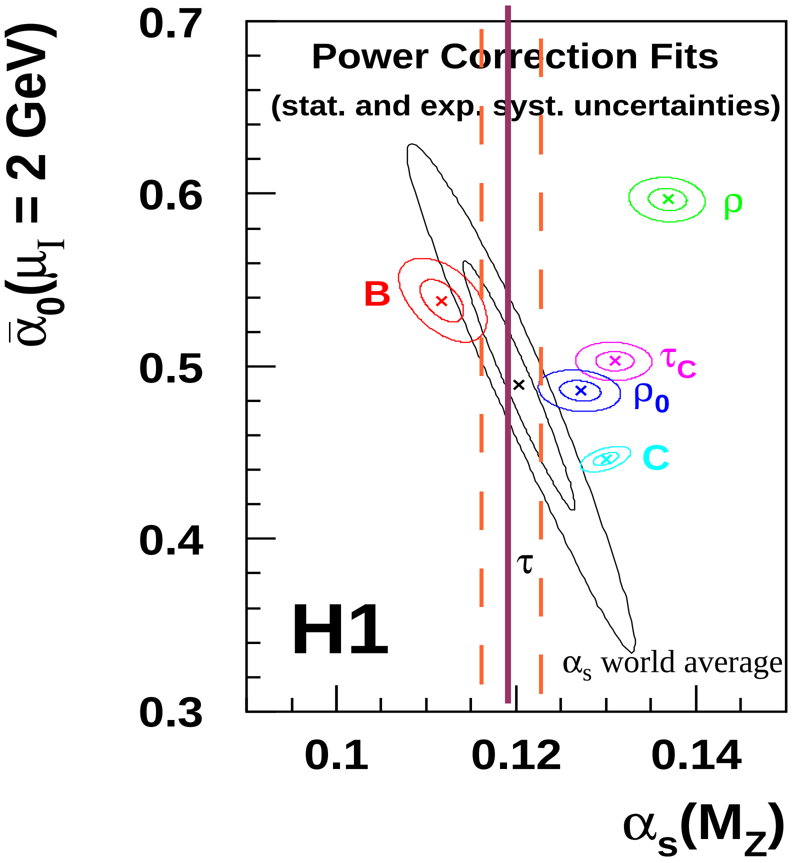
→ Mean of α_s for $0 < \mu_I < 2$ GeV

$$\langle F \rangle^{Power\ Corr.} = a_f \frac{16M'}{3\pi p}\left(\frac{\mu_I}{Q}\right)^p \times \left[\alpha_{p-1} - \alpha_s(Q) - \frac{\beta_0}{2\pi}\left(\ln\frac{Q}{\mu_I} + \frac{K}{\beta_0} + \frac{1}{p}\right)\alpha_s^2(Q)\right]$$

Fit results with χ^2 / dof ≅ 1 →

Fit Results as Test of Analytical Power Corrections





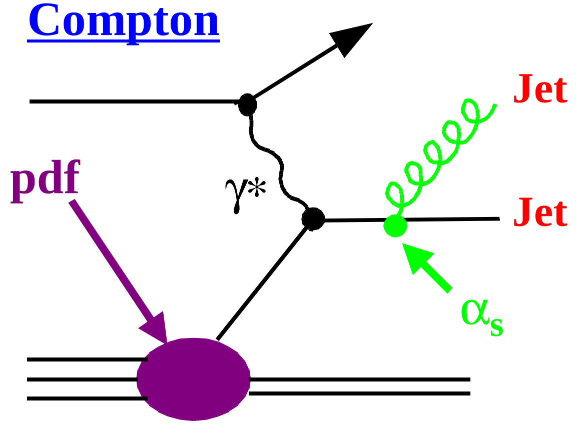
- **Strong x−dependence of B−Parameter**
- **Fit Results reveal descrepancies between H1 and ZEUS**

  Fits might be very sensitive to slope of measured distributions

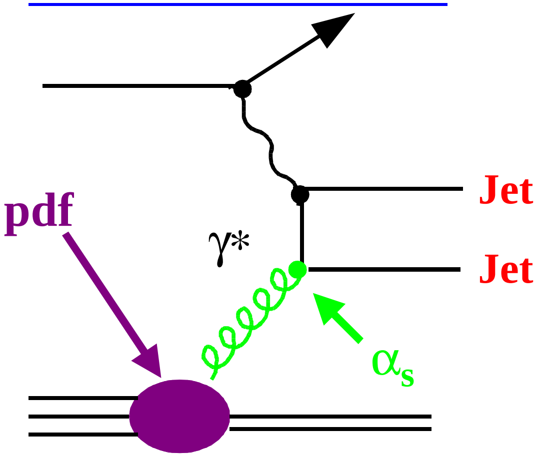
- **α_s broadly consistent among H1 and ZEUS (except B); spread due to missing higher order corrections ? Slightly larger α_s than world average**
- **Fit results suggest universal $\alpha_0 \cong 0.5$ But inconsistencies remain**

Jet Cross Sections in DIS

QCD−Compton

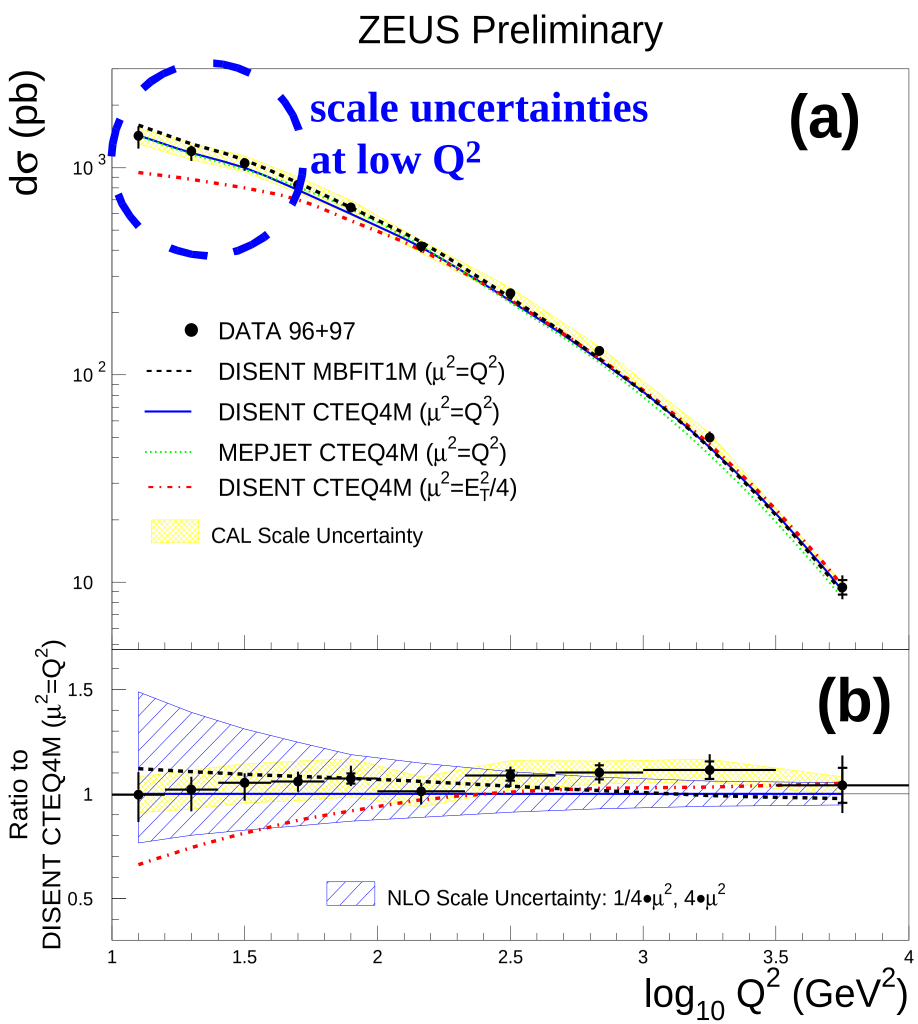


Boson Gluon Fusion



$$\sigma_{jet} = \sum_n \alpha_s^n \sum_{i=G,q} C_{i,n} \otimes \mathrm{pdf}_i$$

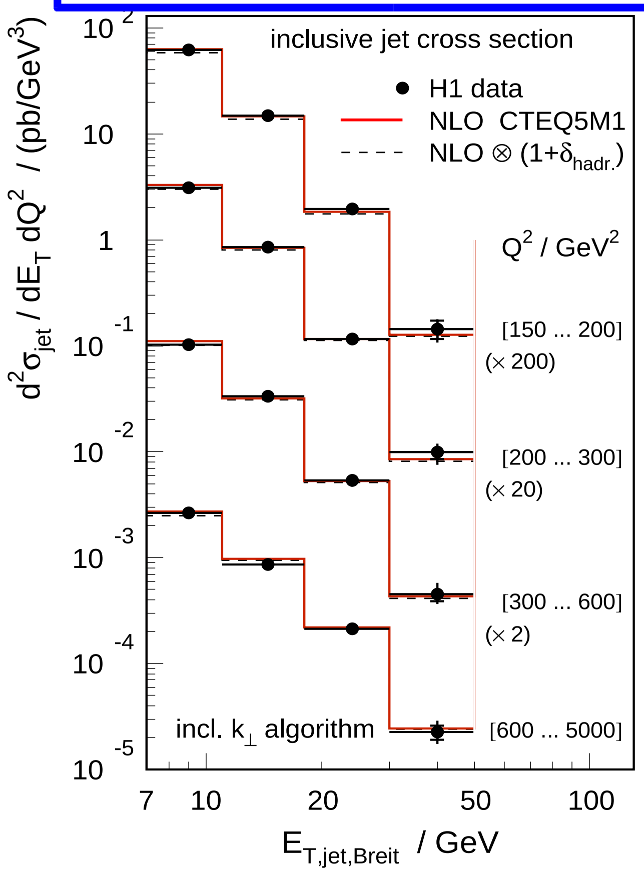
Dijet Cross Section



Description of data by NLO−QCD [O(α_s^2)] if $Q^2 > 150$ GeV² with small scale uncertainties

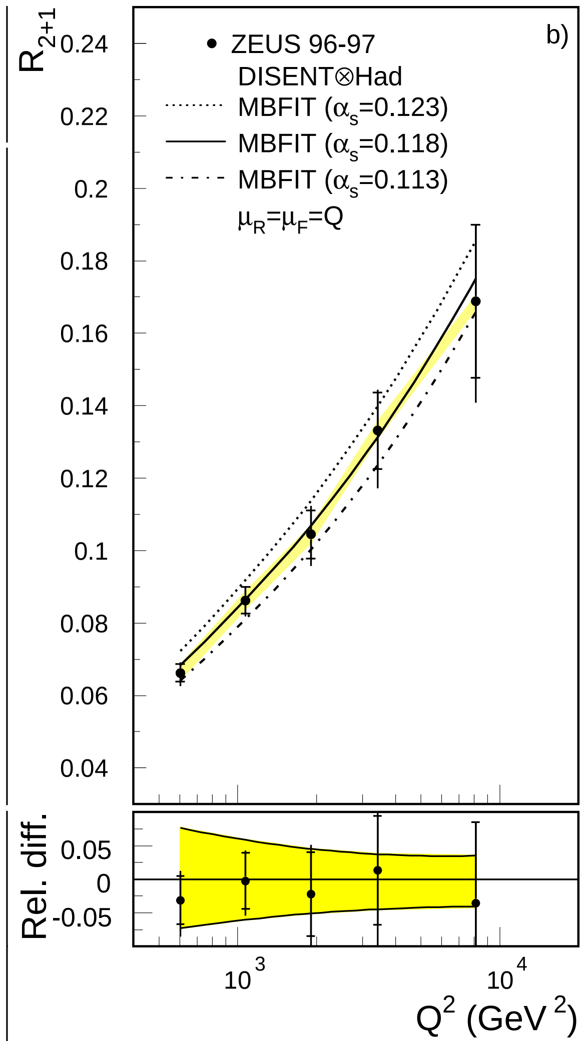
Extraction of α_s – The Cross Sections

Inclusive Jet Cross section



small hadronisation corrections δ_{hadr} ≅10%

Dijet Rate R_{2+1}

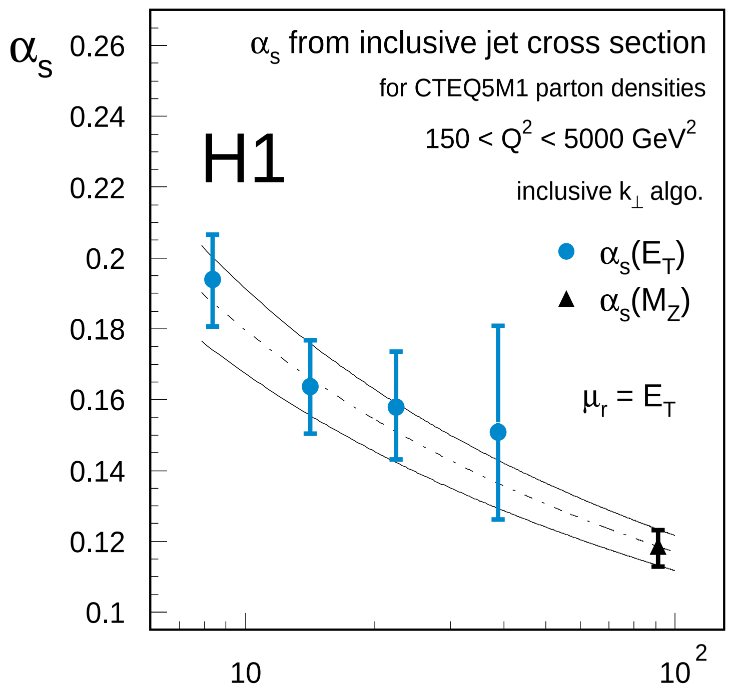


pdf uncertainties cancel in Rate in first approximation

Precise Data and Theory → Extraction of α_s

Extraction of α_s – The Results

inclusive jets



E_T[GeV]

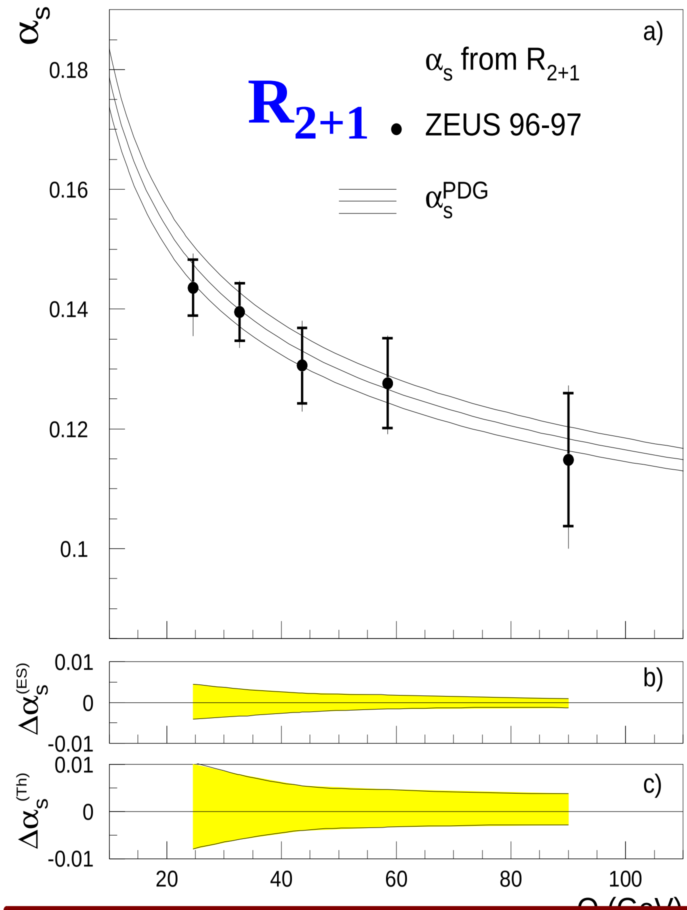
$$\alpha_s(M_Z) = 0.1186 \pm 0.0007$$ ← stat.

± 0.0030 ← exp.

$^{+0.0039}_{-0.0045}$ ← th.

$^{+0.0033}_{-0.0023}$ ← pdf

$\oplus \pm 0.0051$



Q^2 [GeV^2]

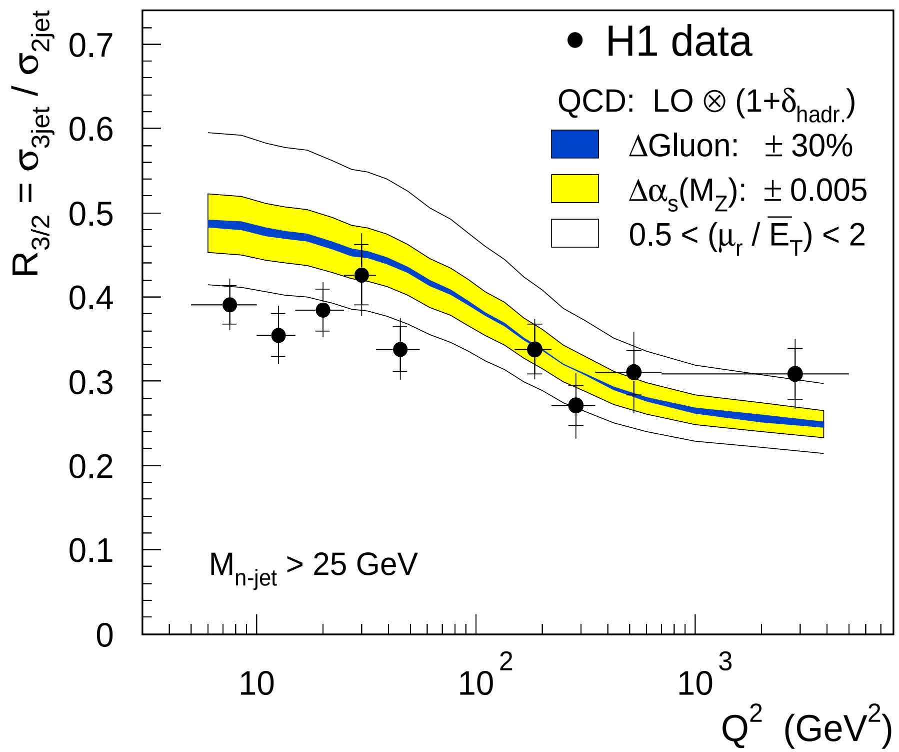
$$\alpha_s(M_Z) = 0.1166 \pm 0.0019$$ ← stat.

$^{+0.0024}_{-0.0033}$ ← exp.

$^{+0.0057}_{-0.0044}$ ← th.+ pdf

Measurement of 3−jet cross section

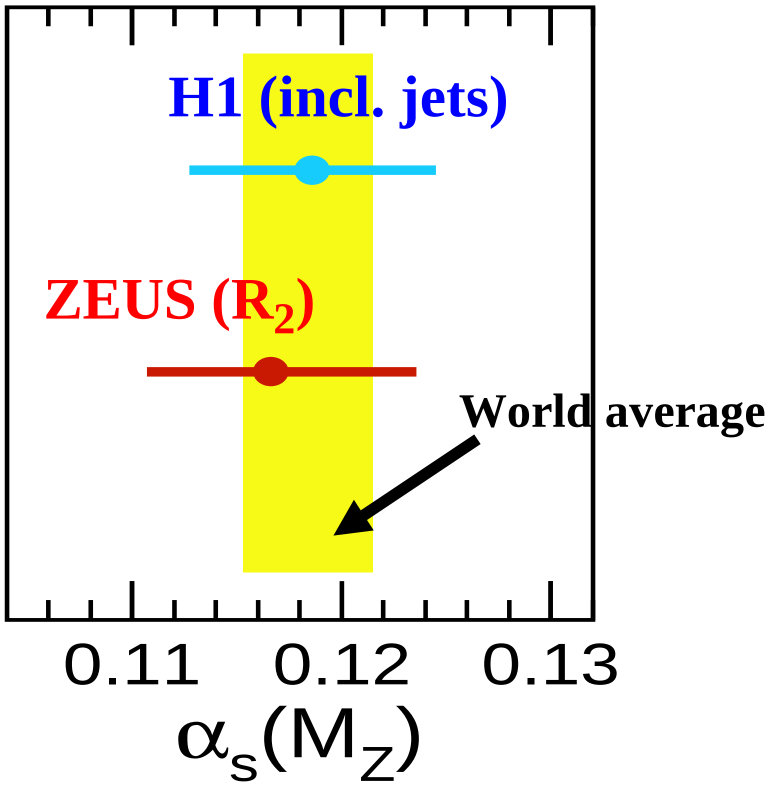
$$R_{3/2} = \sigma_{3jet} / \sigma_{2jet}$$



- **Data for $5 < Q^2 < 5000$ GeV**
- **Large Sensitivity to α_s and Small sensitivity to G(x)**
  → Attractive Potential for extraction of α_s
- **Only leading order $O(\alpha_s^2)$ available**

Analysis will benefit from larger statistics → HERA II and requires NLO calculations for 3−jet production !!!

Comparison and Discussion of Results



H1:

$\alpha_s(M_z) = 0.1186 \pm 0.0059$

ZEUS:

$\alpha_s(M_z) = 0.1166 \,^{+0.0065}_{-0.0058}$

World average:

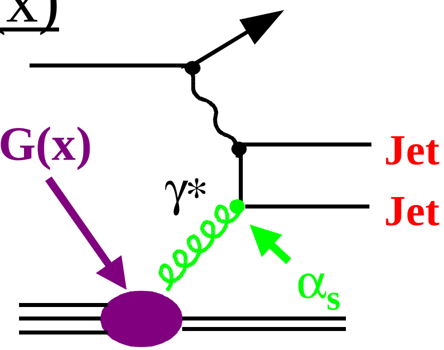
[J. Phys. G26 (2000) R27]

$\alpha_s(M_z) = 0.1184 \pm 0.0031$

- **Different Jet Observables applied to extract α_s**
- **Results agree among each other and with world average**
- **Experimental errors smaller than theoretical ones**

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

So far G(x) as input from existing pdf !



Basic idea:

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

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

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

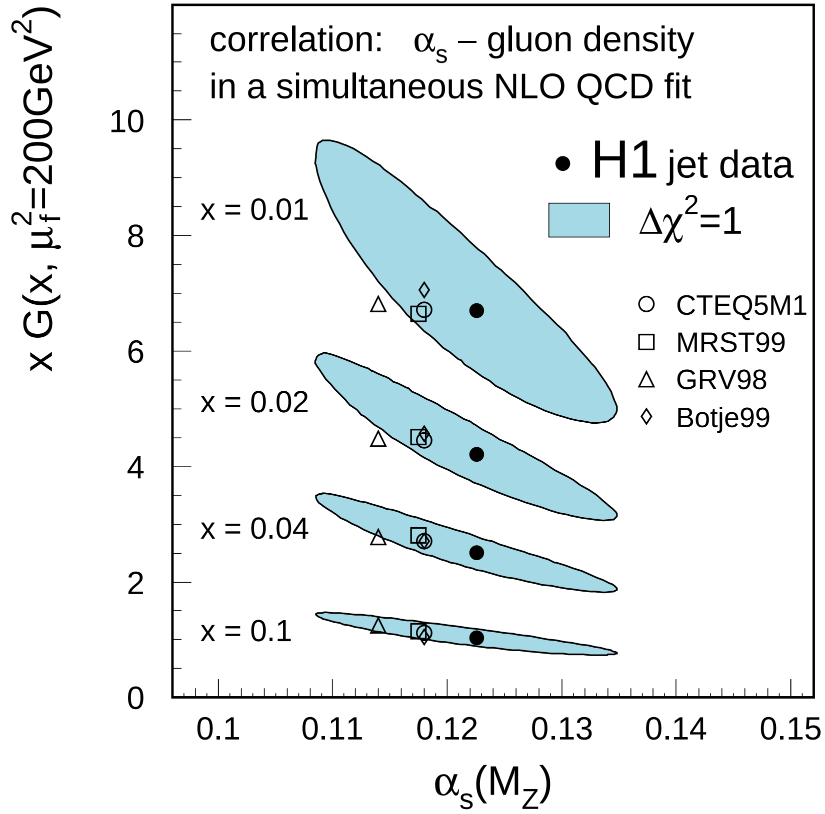
$$\sigma_{2jet} \sim \alpha_s \cdot (c'_G G(x) + c'_q q(x))$$

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**



Result consistent with frequently used parametrizations

Summary and Conclusion

Event Shapes

- Means of event shapes support concept of Analytical power corrections
- α_0 values suggest universal 0.5±20%
  Remaining inconsistencies need clarification
- Broadly consistent results for α_s value, spread suggests need for higher order corrections
- x−dependence in B−Parameter

Jets in DIS

Precision of Data and Theory allows for competitive determination of α_s for $Q^2 > 150\ \mathrm{GeV}^2$

$\alpha_s(M_z) = 0.1186 \pm 0.0059$
from inclusive jets

$\alpha_s(M_z) = 0.1166\ ^{+0.0065}_{-0.0058}$
from Dijet Rates