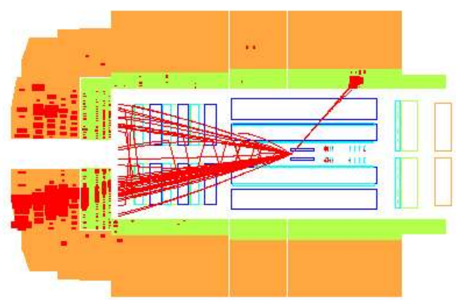
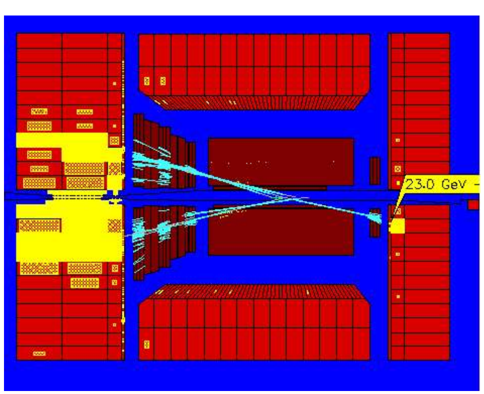
40th anniversary rencontres de Moriond

Jet Measurements and Determination of α_s at HERA

Christoph Wissing

Universität Dortmund



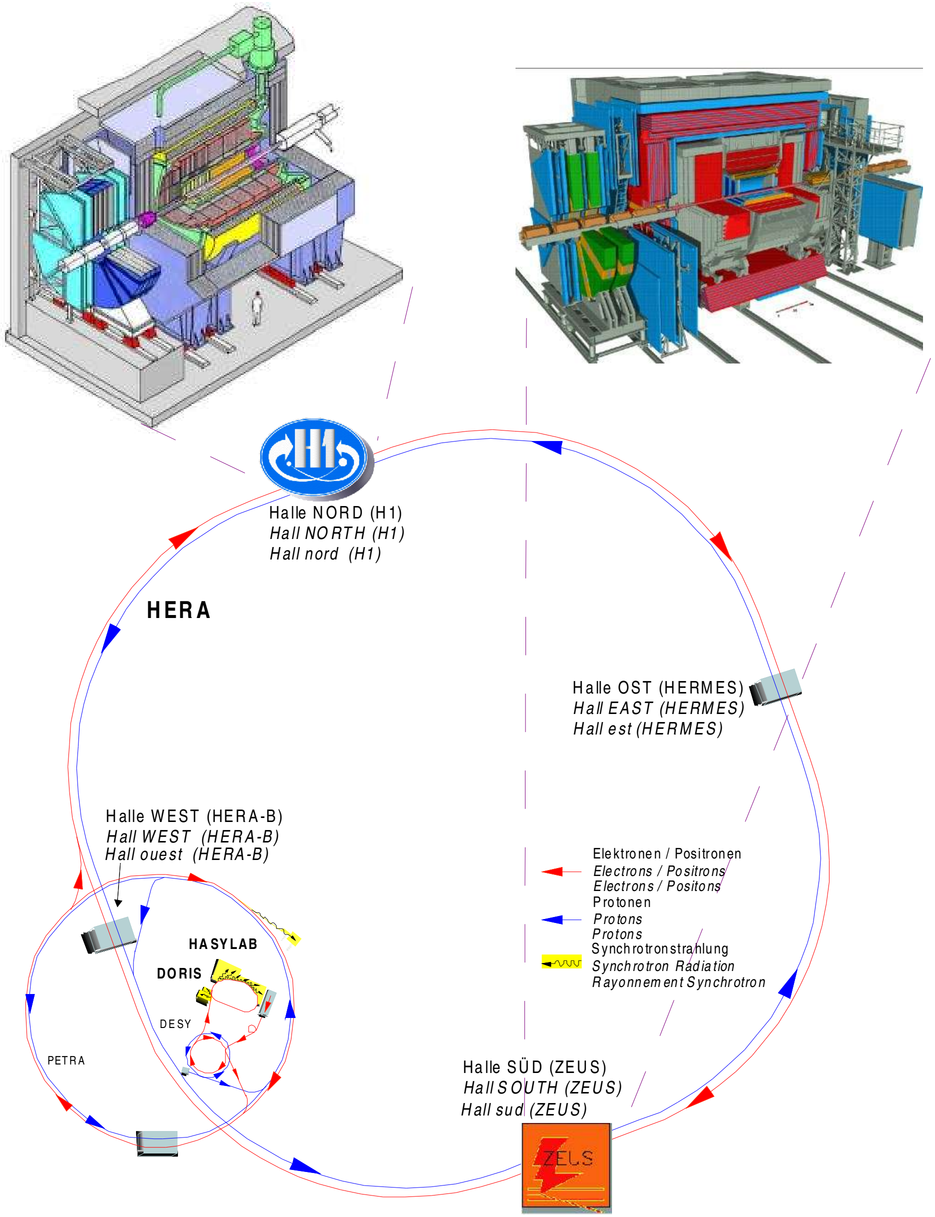


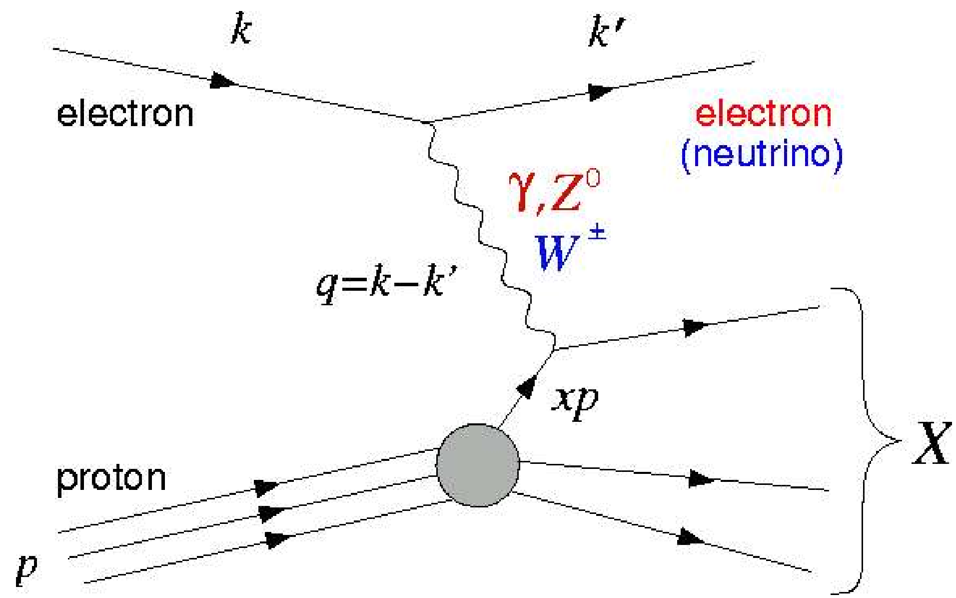
On behalf of the collaborations H1 and ZEUS

H1

ZEUS

Deep Inelastic Scattering at HERA





Kinematics:

CMS energy

$$s = (p + k)^2$$

Momentum transfer

$$Q^2 = -q^2$$

Bjorken x

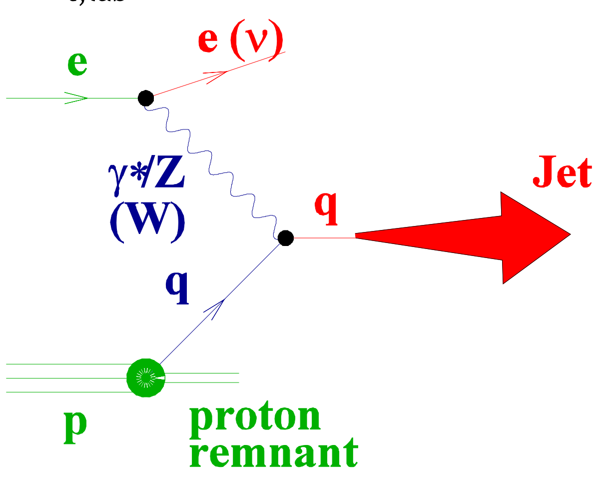
$$x = \frac{Q^2}{2q \cdot p}$$

Inelasticity

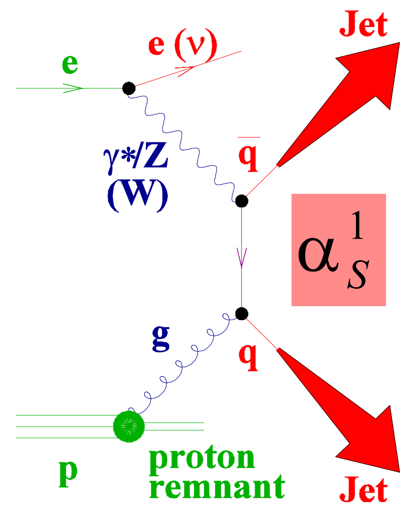
$$y = \frac{q \cdot p}{k \cdot p}$$

Jet Production in DIS

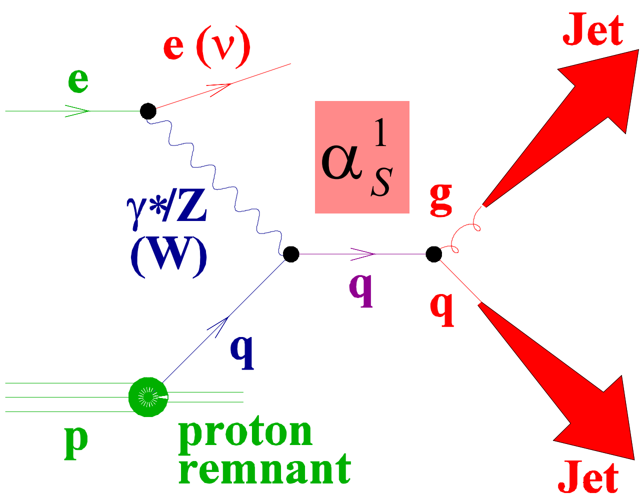
Quark Parton Model
$E_{t,lab}$ balanced by e



Boson Gluon Fusion

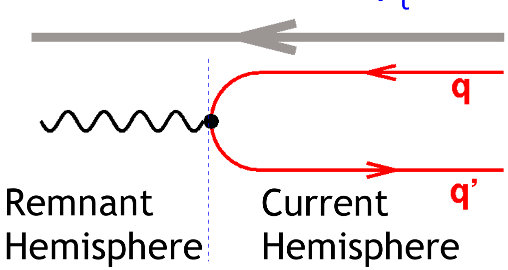


QCD Compton

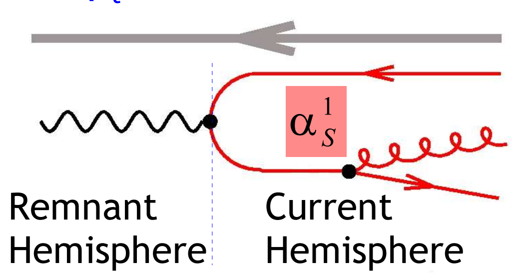


Breit Frame: $2x\vec{p} + \vec{q} = 0$

No intrinsic p_t

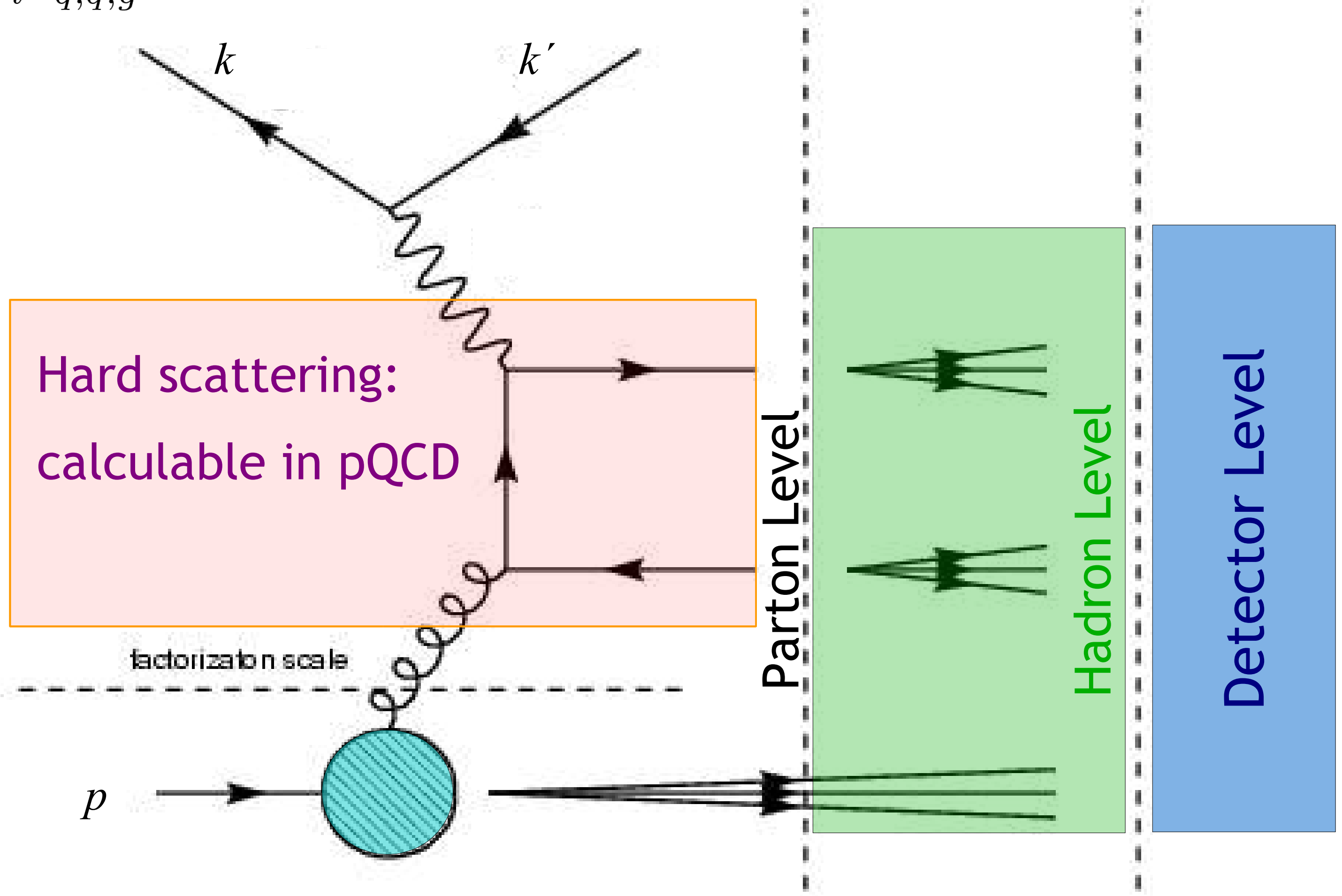


p_t from QCD effects



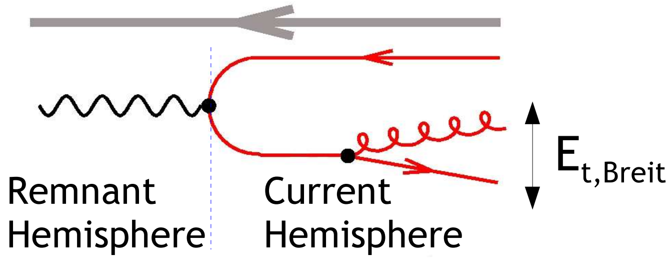
Jet Cross Section

$$\sigma_{jet} = \sum_{i=q,\bar{q},g} \int dx\, f_i(x,\mu_F,\alpha_s) \cdot \hat{\sigma}_{QCD}(x,\mu_F,\mu_R,\alpha_S) \cdot (1+\delta_{had})$$



Inclusive Jets in DIS (1)

Select Jet(s) in the Breit Frame:

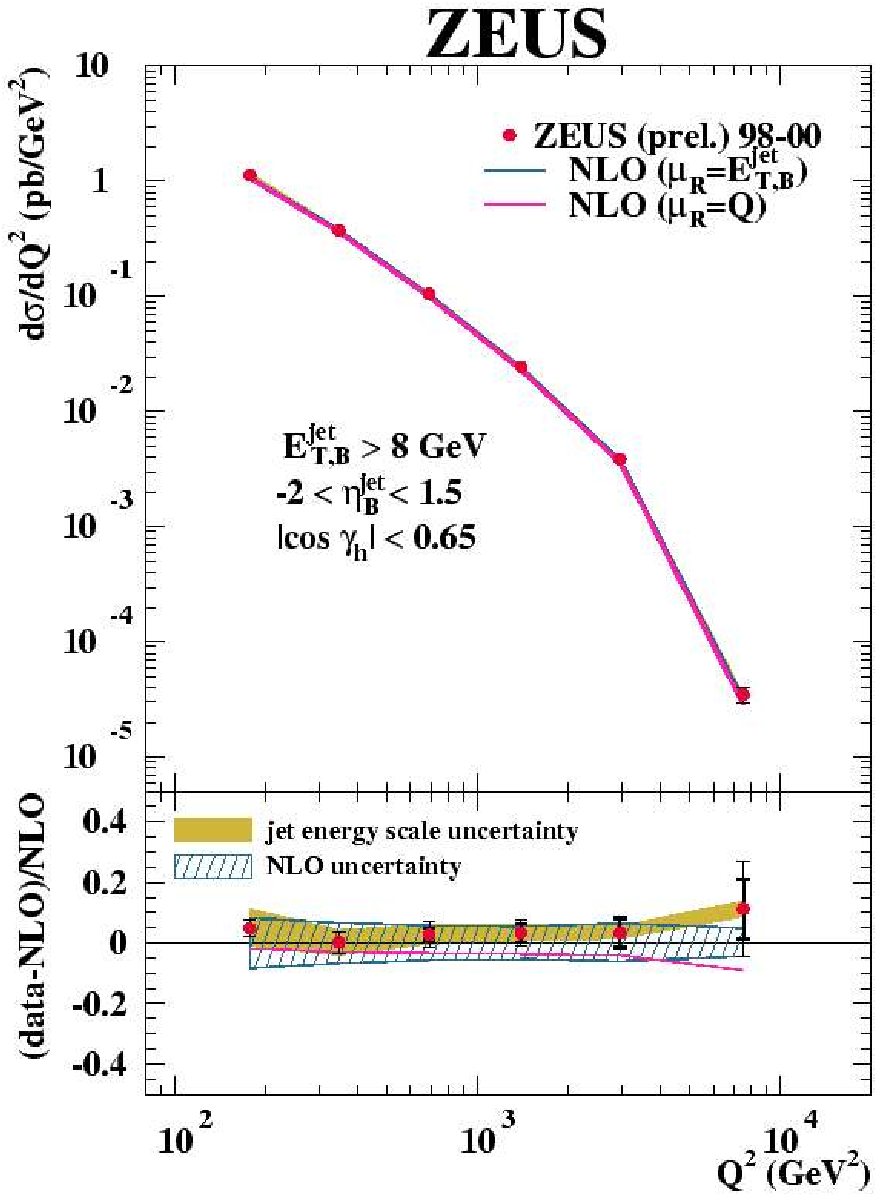


At least one Jet with $E_{t,Breit}$ > 8 GeV

Luminosity: 81.7 pb^{-1}
(HERAI 1998-2000)

Q^2 > 125 GeV^2

NLO pQCD: DISENT
Scales: $\mu_F = Q$, $\mu_R = E_t$ (or Q)
PDFs: MRST99



Inclusive Jets in DIS (2)

Good agreement data ↔ theory

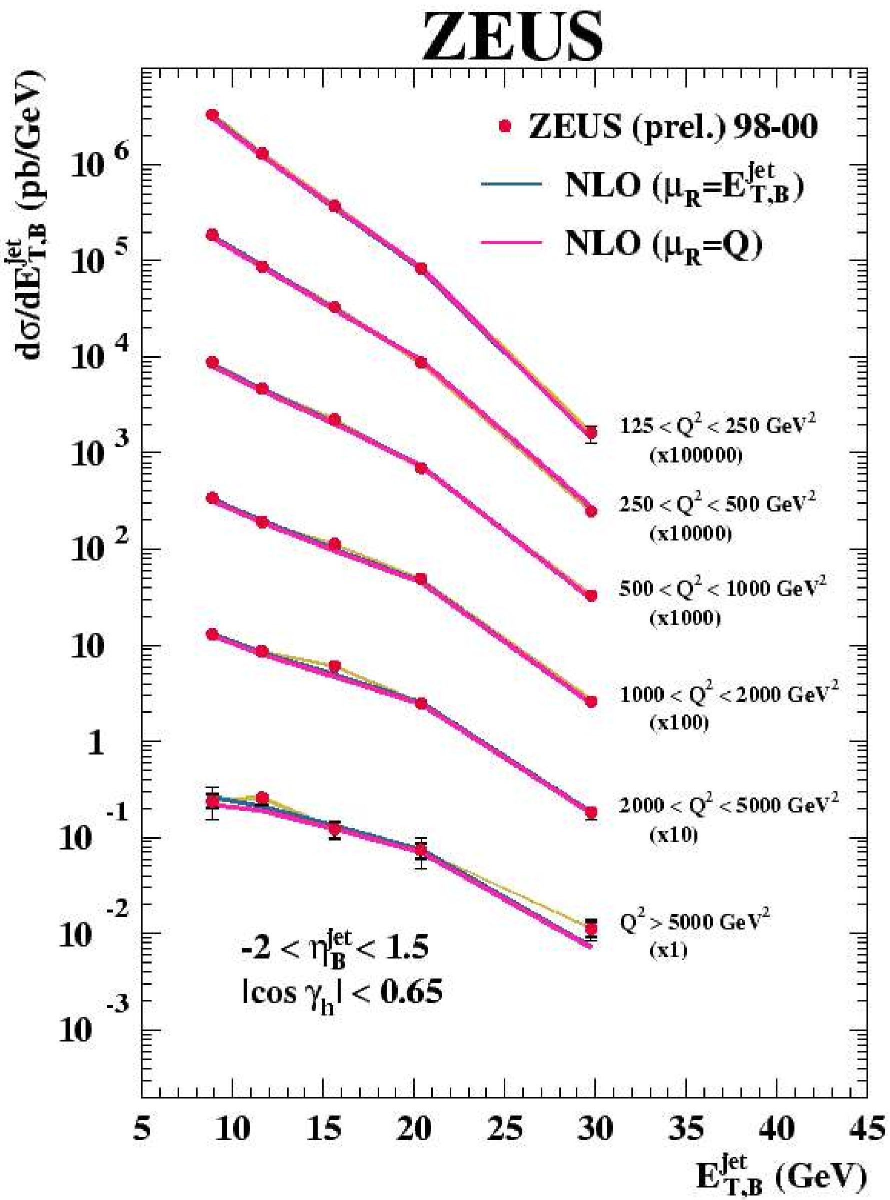
in all differential distributions

$d\sigma_{jet}/dE_t$, $d\sigma_{jet}/dQ^2$ and $d\sigma_{jet}/d\eta_B$

Main uncertainties:

Exp: Calorimeter energy scale

Theo: Missing higher orders, PDFs

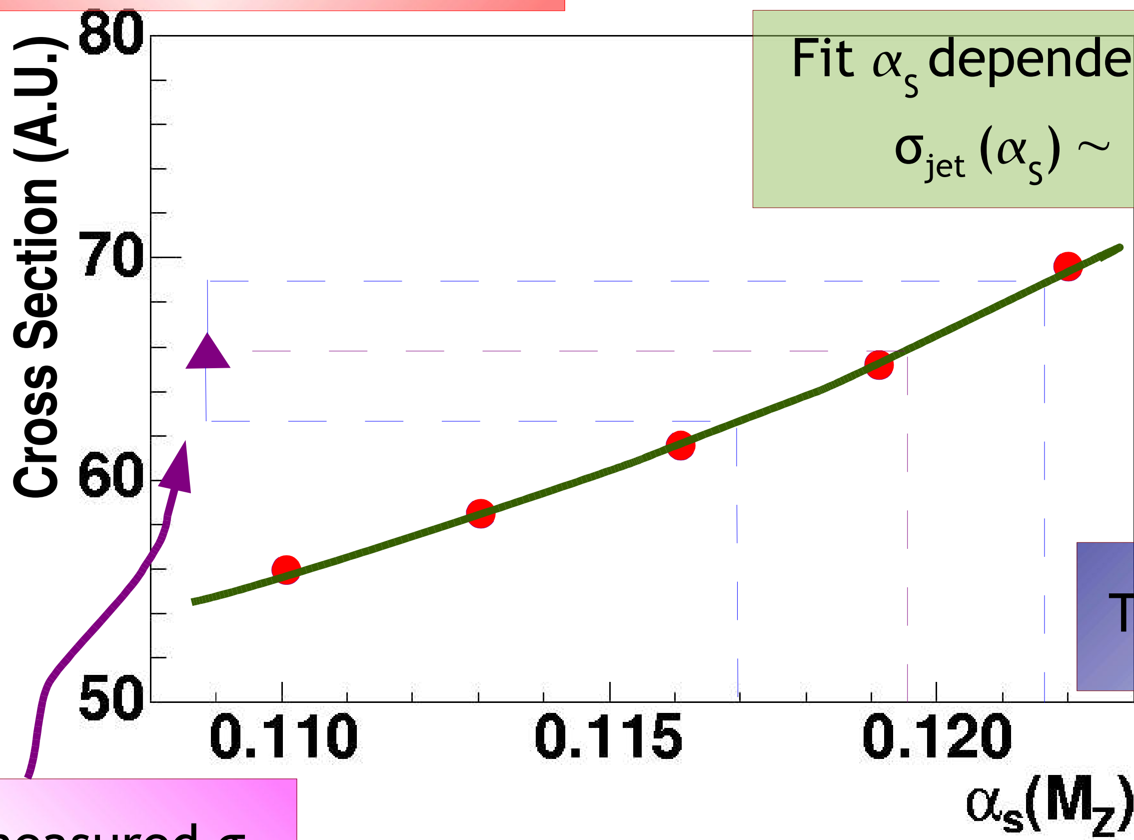


Extraction of α_s

1. Generate σ_{jet} for various α_s

2. Fit α_s dependence in each bin:

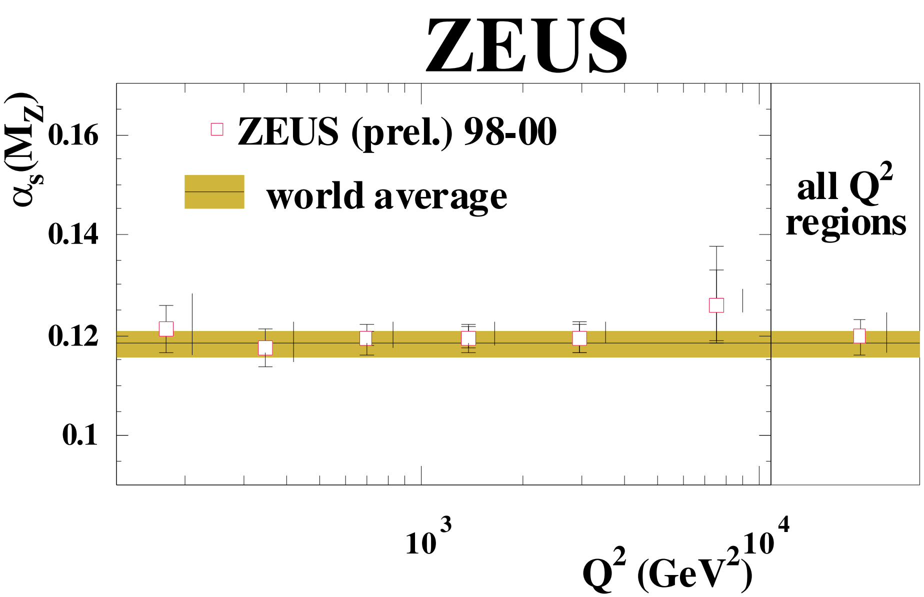
$$\sigma_{jet}(\alpha_s) \sim A \cdot \alpha_s + B \cdot \alpha_s^2$$

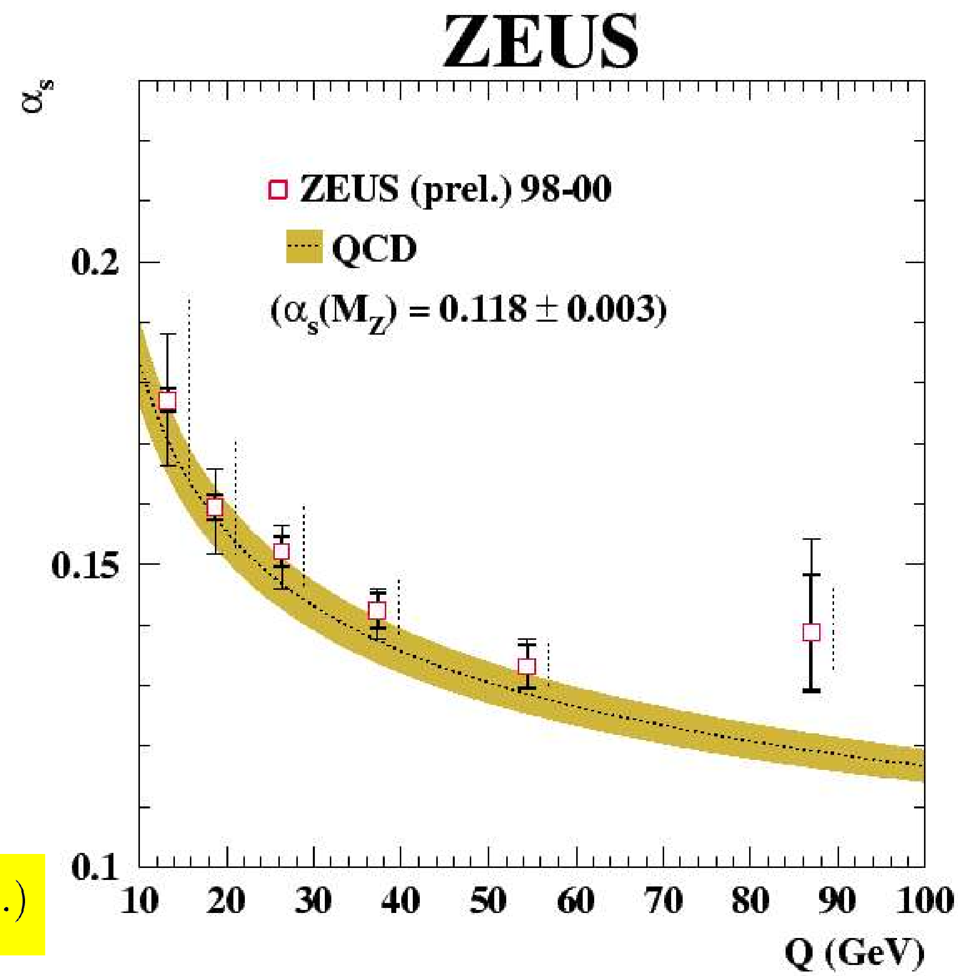


3. "Compare" to measured σ_{jet}

4. Treat uncertainties

α_s from Inclusive Jets





Fits to $d\sigma_{jet}/dE_t$ and $d\sigma_{jet}/dQ^2$

Best result for $Q^2 > 500$ GeV^2

$$\alpha_S(M_Z) = 0.1196 \pm 0.0011(\text{stat.})^{+0.0019}_{-0.0025}(\text{exp.})^{+0.0029}_{-0.0017}(\text{th.})$$

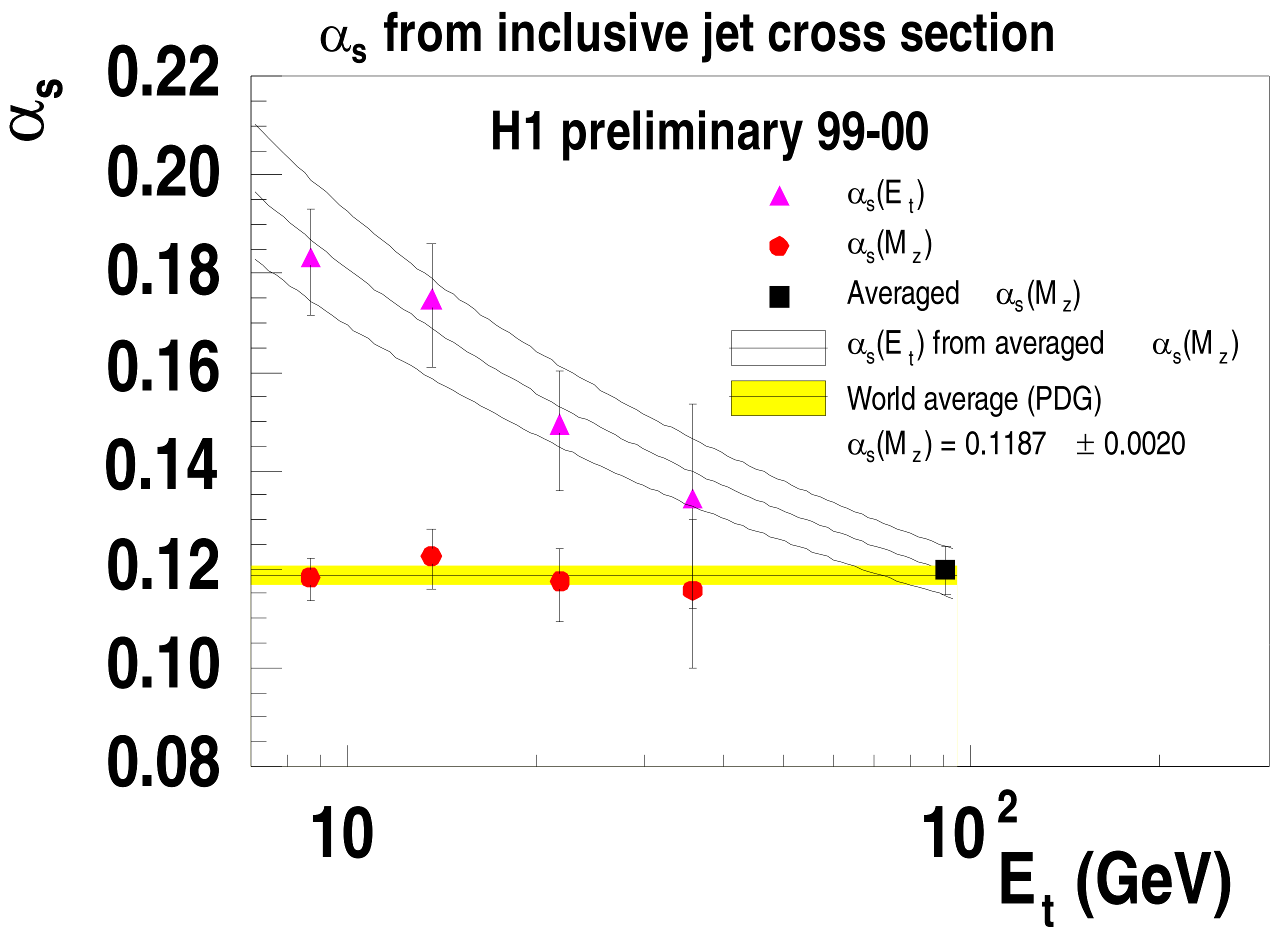
Good agreement with world average α_s

Small Errors

Running of α_s:

Fit $\alpha_s(\langle E_t \rangle)$ or $\alpha_s(\langle Q \rangle)$ parametrized pQCD

α_s from Inclusive Jets



Luminosity: 61.25 pb^{-1}
(HERAI 1999-2000)

$150 < Q^2 < 5000$ GeV^2

$E_{t,Breit} > 7$ GeV

NLO pQCD: **NLOJET++**
Scales: $\mu_R^2 = E_t^2$, $\mu_F^2 = Q^2$
PDFs: CTEQ5M1

Running of α_S:
Evolution to $\alpha_S(E_t)$ by
Renormalization Group Equation

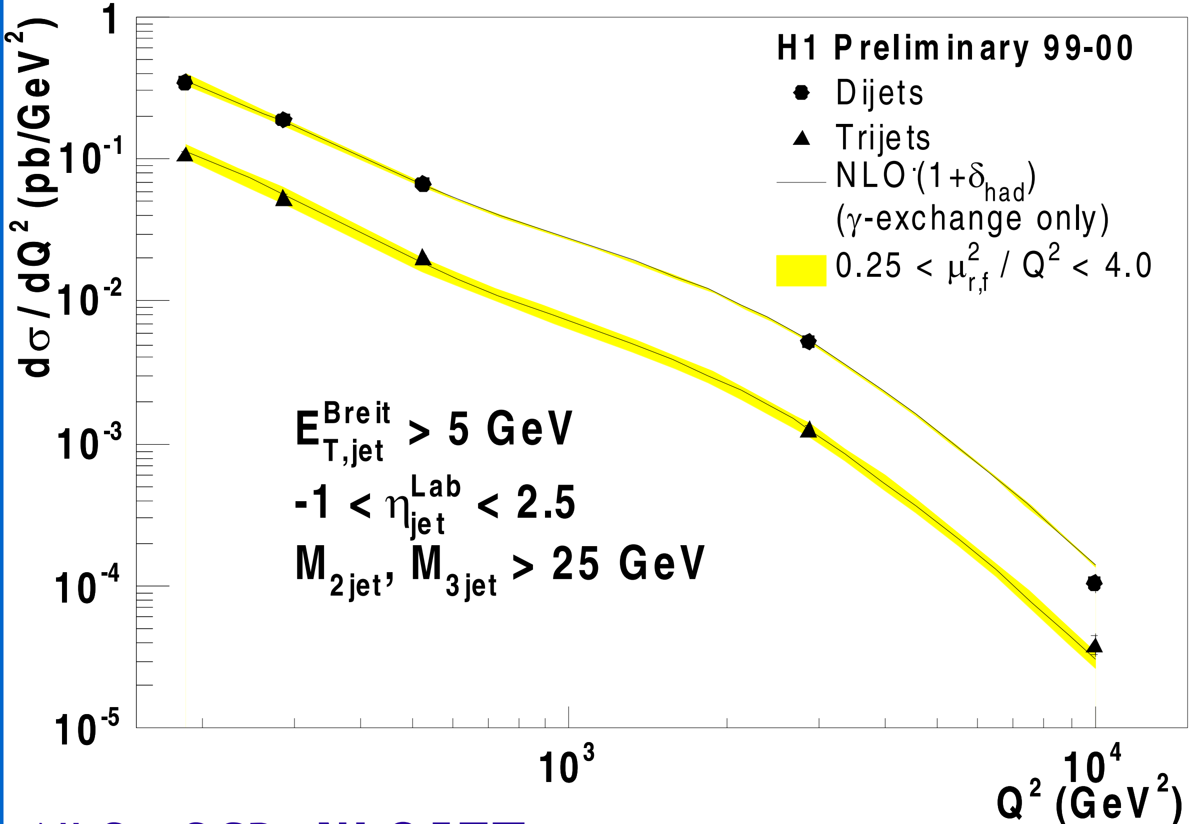
$$\alpha_S(M_Z) = 0.1197 \pm 0.0016(\mathrm{exp.})^{+0.0046}_{-0.0048}(\mathrm{th.})$$

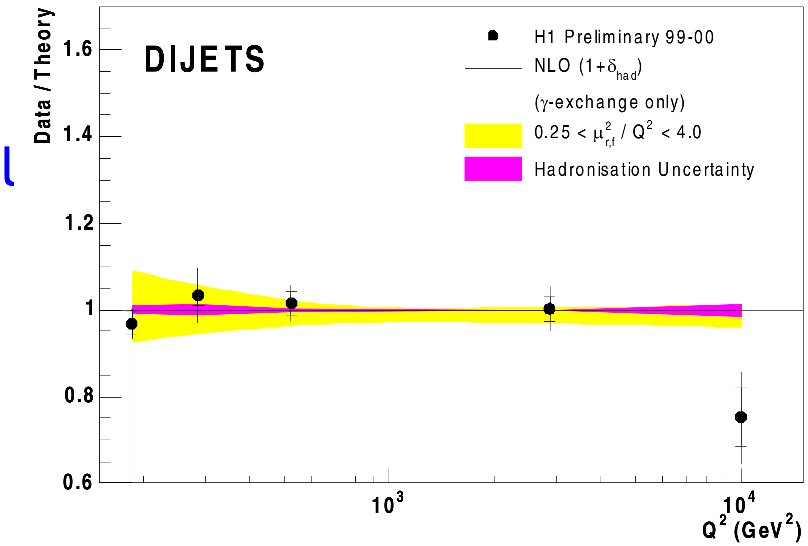
Error dominated by theory

Multi Jet Cross Sections

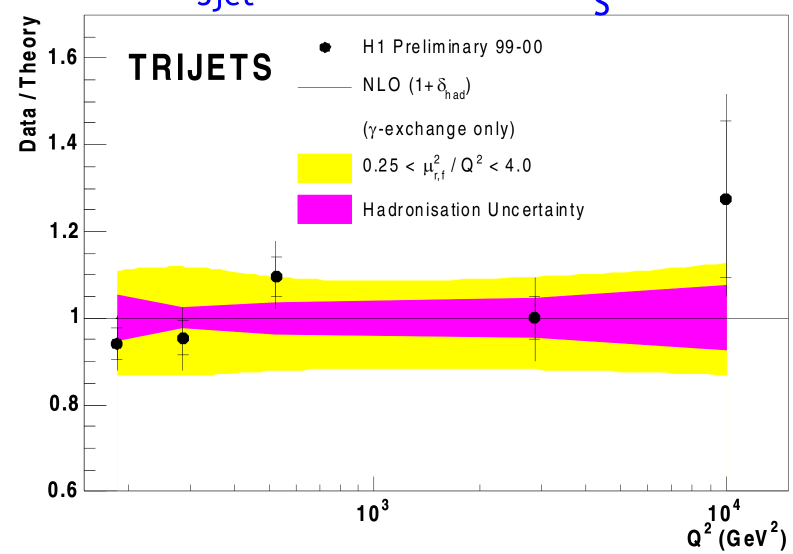
Disadvantage: Less statistics

Advantage: $\sigma_{3jet}/\sigma_{2jet}$ many uncertainties cancel





σ_{3jet} sensitive to α_s^2



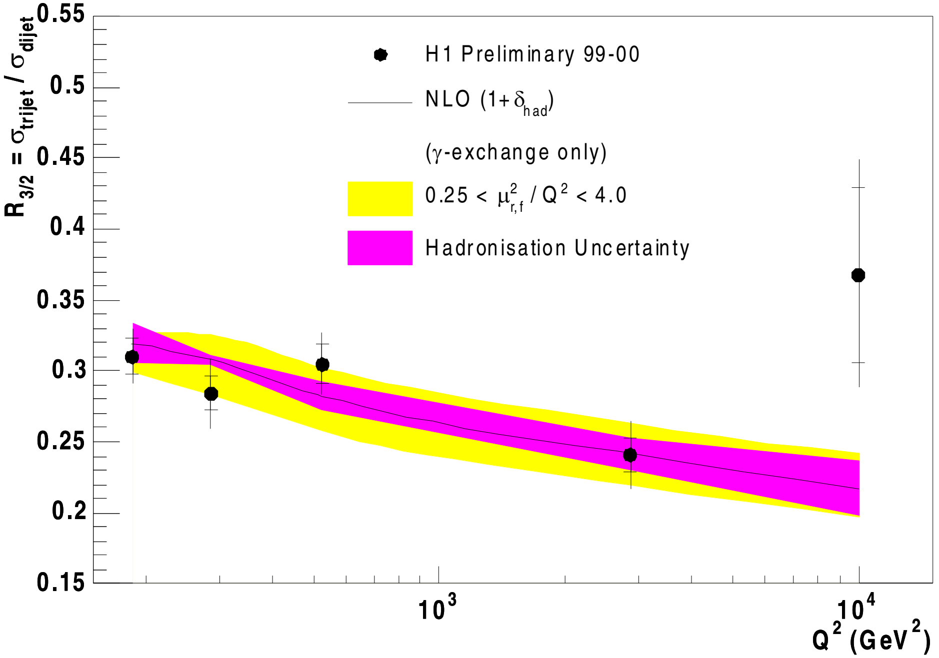
NLO pQCD: **NLOJET++**

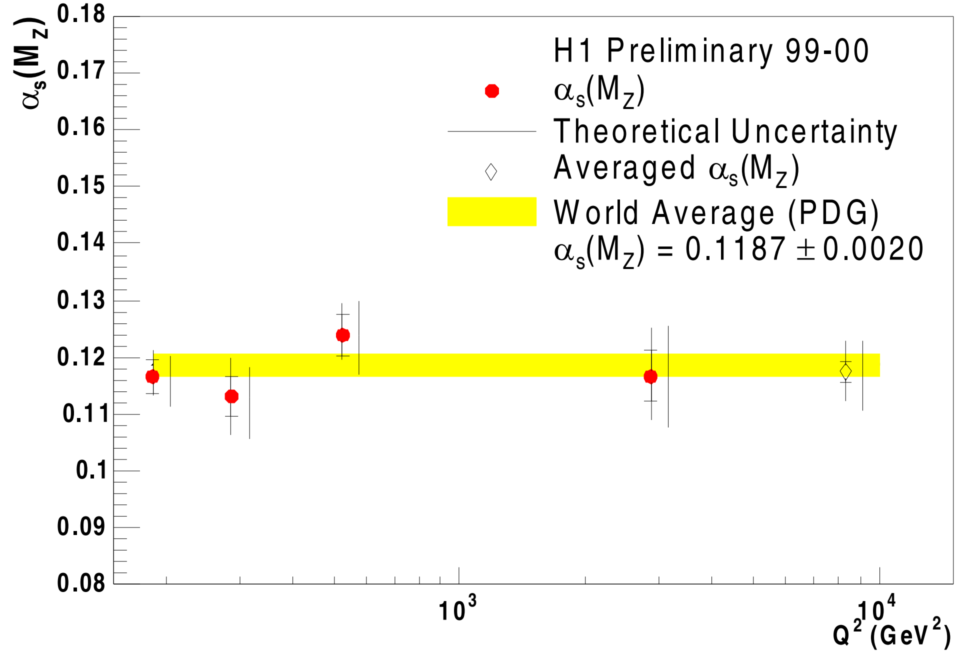
Scales: $\mu_R^2 = Q^2$, $\mu_F^2 = Q^2$

PDFs: CTEQ5M (CTEQ4A)

Issues @high Q^2
(missing Z^0 in NLO calc)

α_s from the Trijet to Dijet Ratio $R_{3/2}$





Highest Q^2 bin has large uncertainty → exclude from α_s fit

$$\alpha_S(M_Z) = 0.1175 \pm 0.0017(\text{stat.}) \pm 0.0050(\text{sys.})^{+0.0054}_{-0.0068}(\text{th.})$$

Event Shape Variables

Investigate particle flow in final state → sensitivity to hadronisation

Breit frame: Maximal separation between current jet and remnant

Thrust: ("Longitudinal momenta")

$$\tau = 1 - T \qquad T = \frac{\sum_i |\vec{p}_{z,i}|}{\sum_i |\vec{p}_i|}$$

$$\tau_C = 1 - T_C \qquad T_C = \max(\vec{n}_T) \frac{\sum_i |\vec{p}_i \cdot \vec{n}_T|}{\sum_i |\vec{p}_i|}$$

Broadening: ("Transverse momenta")

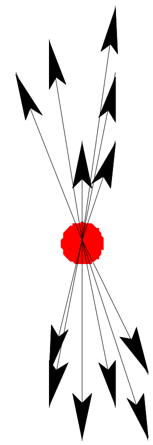
$$B = \frac{\sum_i |\vec{p}_{t,i}|}{2\sum_i |\vec{p}_i|}$$

Squared Jet Mass:

$$\rho = \frac{(\sum_i E_i)^2 - |\sum_i \vec{p}_i|^2}{2(\sum_i E_i)^2}$$

"C-Parameter"

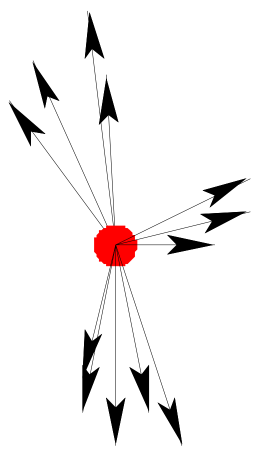
$$C = \frac{3\sum_{ij} |\vec{p}_i||\vec{p}_j| \cos^2(\theta_{ij})}{2(\sum_i |\vec{p}_i|)^2}$$



"Narrow Events":

$F \to 0$

[QPM: 1 collimated jets]



"Broader Events":

$F > 0$

[QCD: Gluon radiation]

Power Corrections

Hadronisation (non-perturbative):

- "Usually" phenomenological models (many parameters)
- Power corrections (Dokshitzer & Webber) analytic approach

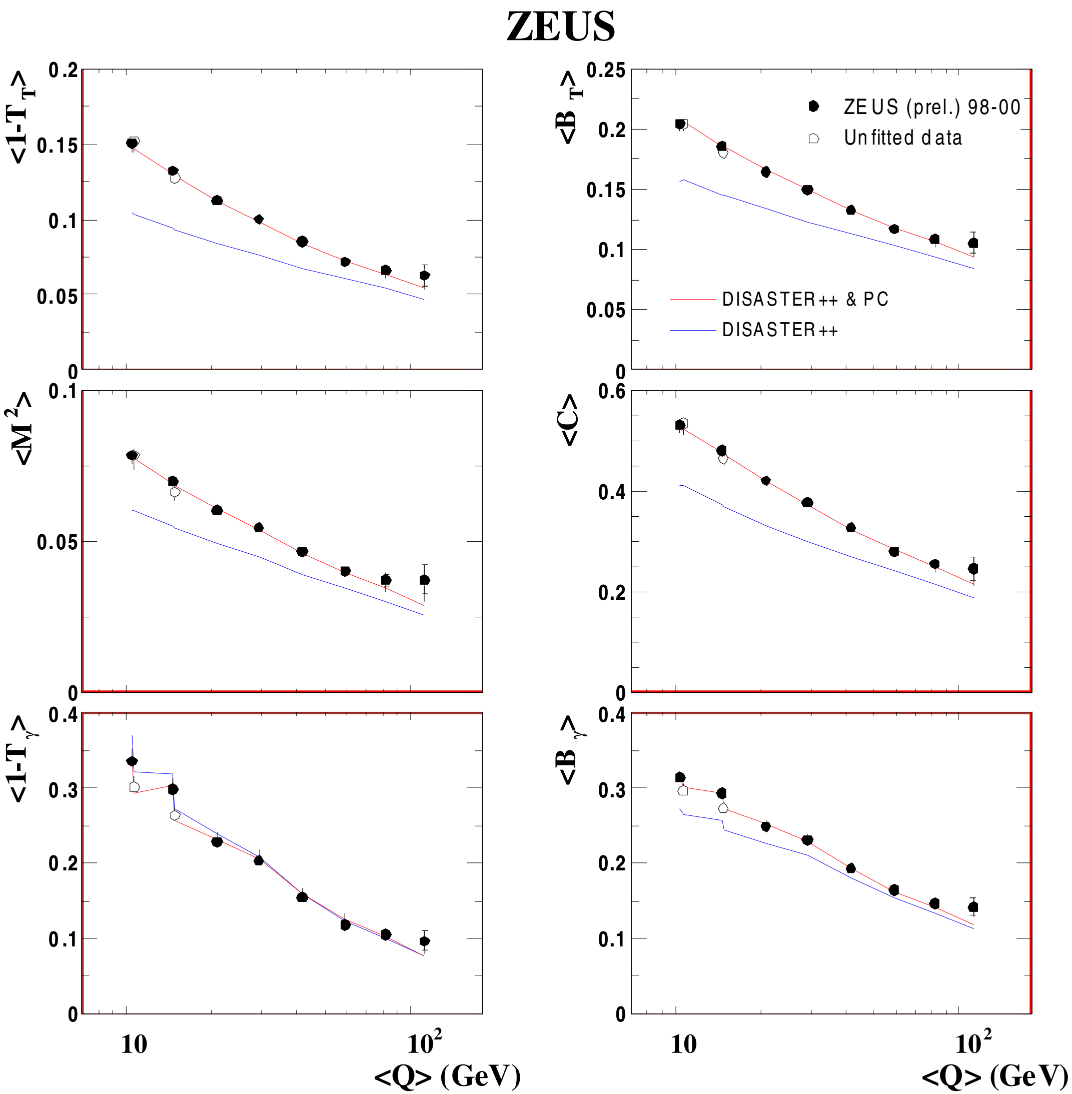
Mean or differential distribution of event shape variable F

$$\langle F \rangle = \langle F \rangle^{pQCD} + a_F \mathcal{P}$$

$$\mathcal{P} \sim \frac{A(\alpha_0, \alpha_S)}{Q}$$

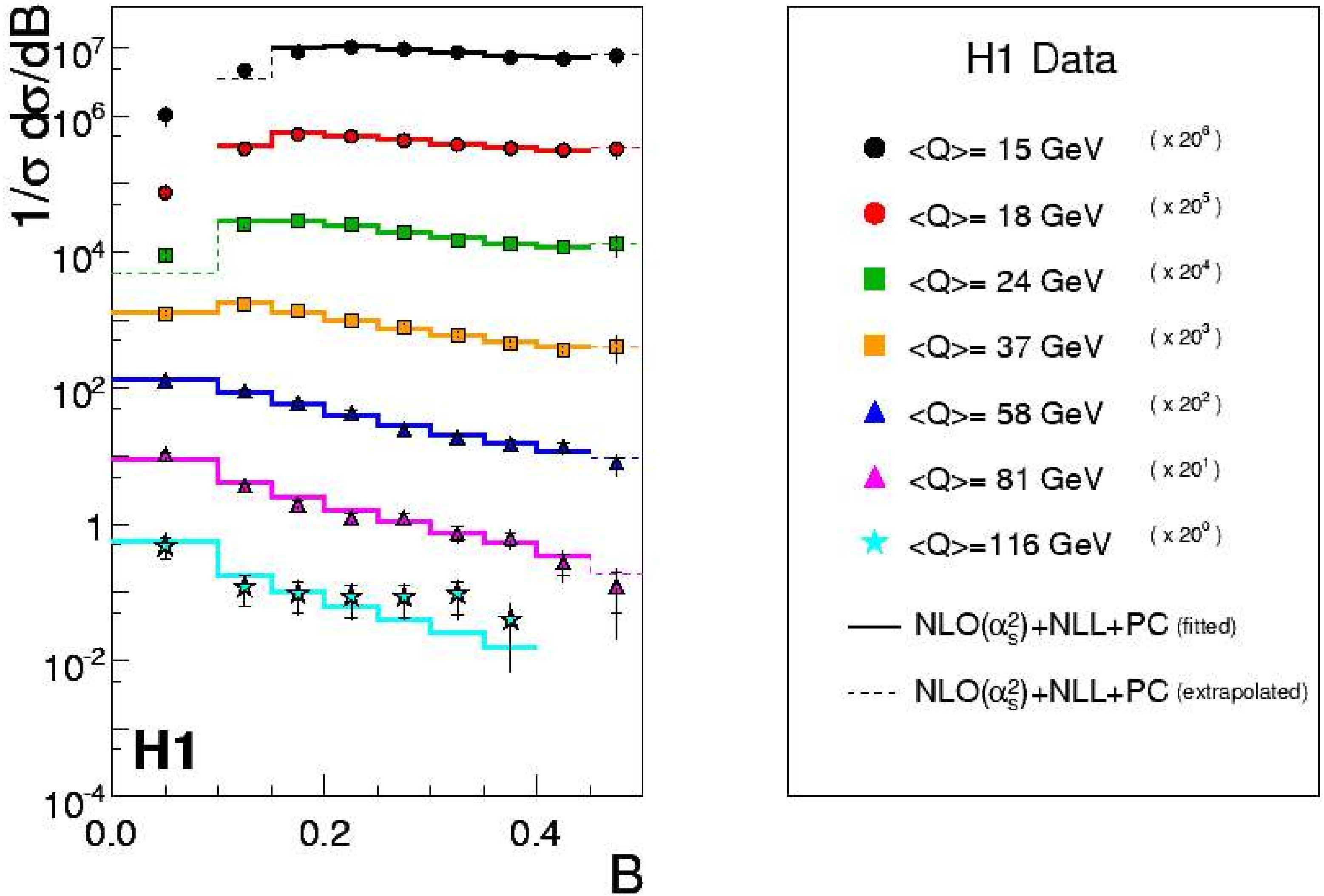
α_0:Universal Parameter

(Expected to be ≈ 0.5)



Data well described by NLO+PC+Fit

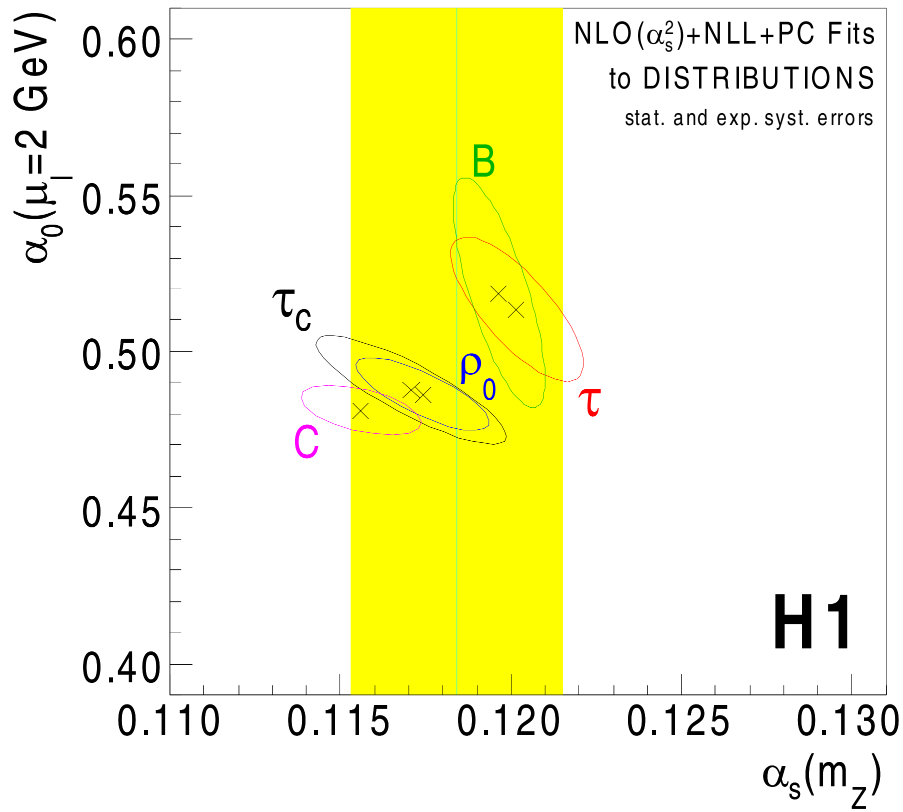
Event Shape Distributions

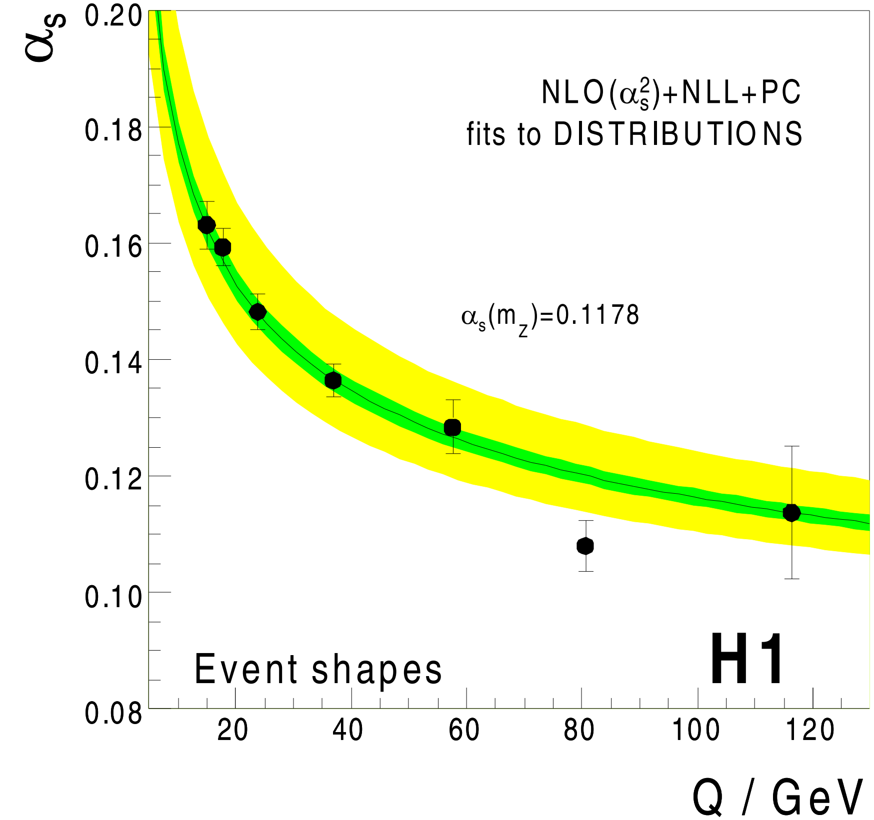


Luminosity: 106 pb^{-1}
(HERAI 1995-2000)

$196 < Q^2 < 40{,}000\ GeV^2$
$0.1 < y < 0.7$

α_s from Event Shapes





Fit each F in all bins: $m_i - t_i(\alpha_{0,}\alpha_S)$

Measurement Theorie

$$\alpha_0 = 0.476 \pm 0.008(\text{exp})^{+0.018}_{-0.059}(\text{theo}) \checkmark$$

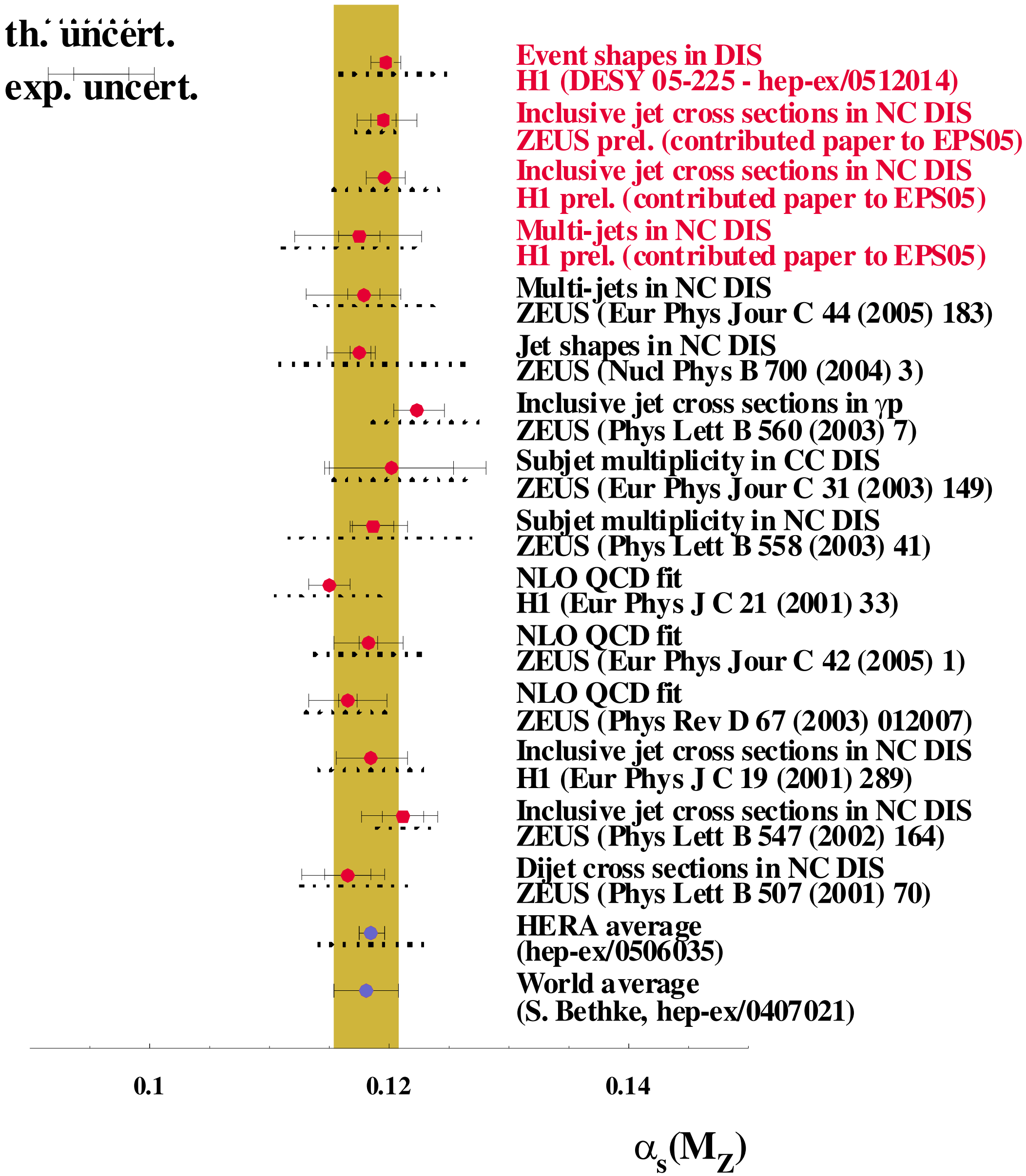
$$\alpha_S(m_Z) = 0.1198 \pm 0.0013(\text{exp})^{+0.0056}_{-0.0043}(\text{theo})$$

Fit for each F: $\{ \alpha_S(Q=Q_i), \alpha_0 \}$

Running nicely described

Consistent with α_s from jets with comparable precision

Summary



- α_s precision measurements by HERA Experiments
  - Dominating error: Theory
  - Well compatible with world average
- More data with HERAII
  - Increased statistics @high Q^2 & E_t
  - Improved detector understanding
- Expected progress in theory
  - NNLO
  - EW effects