Hadronic Final State, Jet Production and α_s Measurements at HERA

QCD06, Montpellier, France

Kaloyan Krastev

Universität Hamburg

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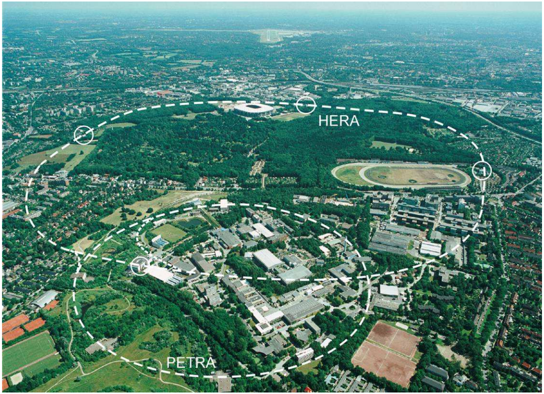
On behalf of ZEUS and H1 collaborations

OUTLINE:

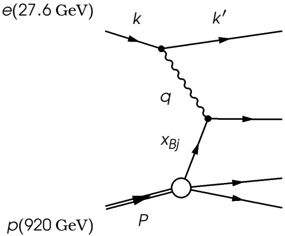
- HFS
- Tools
- Inclusive
- Multi-jets
- Event Shapes

HERA

DESY Hamburg, Germany



HERA 1992 (H1, ZEUS)



$$\sqrt{s} = 319 GeV$$

HERA kinematics:

- $Q^2 = -q^2 = -(k - k')^2$
- $x_{Bj} = \frac{Q^2}{2P \cdot q}$
- $y = 1 - E'_e / E_e$

Hadronic Final State

MOTIVATION: Test QCD and extract α_s

Jets

Event shape variables

Detector to hadron level

pQCD calculations

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

Hadronisation

small corrections factors 10%

LO MC event generators with Parton Shower/Color Dipole Model

$$(1 + \delta_{had}) = \sigma_{had} / \sigma_{part}$$

large correction factors up to 100%

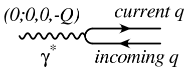
Power correction approach

Compare data with theory

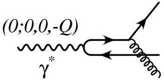
α_s fit

Tools

- Jet algorithm: inclusive K_t
  - Infrared and collinear safe at all orders
  - longitudinally invariant
  - factorisable
  - HERA standard
- The Breit frame
  - E_t^{lab} does not reflect the hardness
  - $2x_{Bj}P^{\mu} + q = 0$, $P^{\mu} = (E_p, \mathbf{p_p})$
  - E_t^B reflects the hardness (suppress Born + remnant)
  - remnant hemisphere $\eta > 0$



Born level



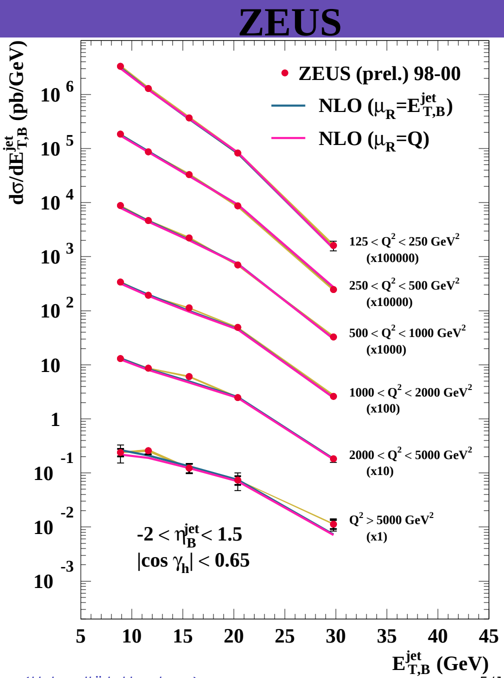
- NLO programs
  - DISENT ($\mathcal{O}(\alpha_s^2)$)
  - DISASTER++ ($\mathcal{O}(\alpha_s^2)$)
  - NLOJET++ ($\mathcal{O}(\alpha_s^3)$) three jets NLO

Inclusive Jet in DIS

- Similar ZEUS/H1 phase space
- Every jet above the E_t cut enters the cross section

  differential in Q^2, E_t

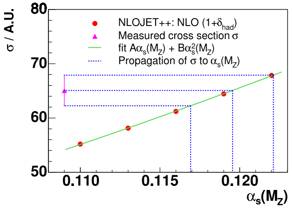
  double differential
  - ZEUS
    $Q^2 > 125$ GeV
    $E_t^{jet} > 8$ GeV
    $-2.0 < \eta_B^{jet} < 1.5$
  - H1
    $Q^2 > 150$ GeV
    $E_t^{jet} > 7$ GeV
    $-1.0 < \eta^{Lab} < 2.5$



NLO QCD DISENT
MRST99 PDFs
Small difference
over all phase space

Inclusive Jet in DIS

Determination of α_S



CTEQ5M1 PDFs in NLOJET++

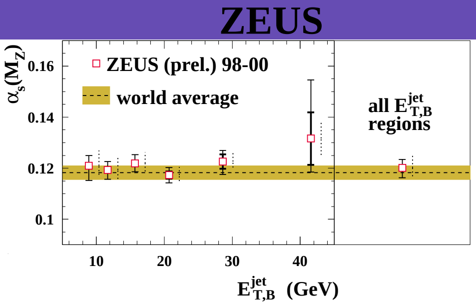
1. Cross section for various α_S
   0.111, 0.113, 0.116, 0.119, 0.122
2. $\sigma_i(\alpha_s(M_Z)) = A_i \cdot \alpha_s(M_Z) + B_i \cdot \alpha_s^2(M_Z)$
3. Map the measured value
4. Combine into an avearge value
   correlation between systematic errors - taken in account

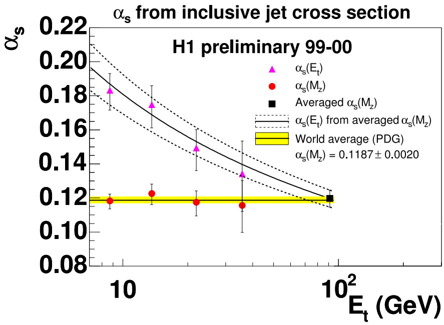
ZEUS (HEP2005)

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

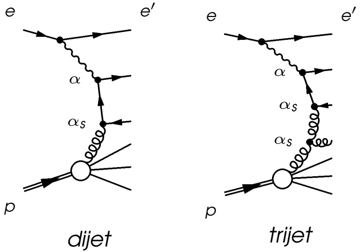
H1 (EPS05)

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

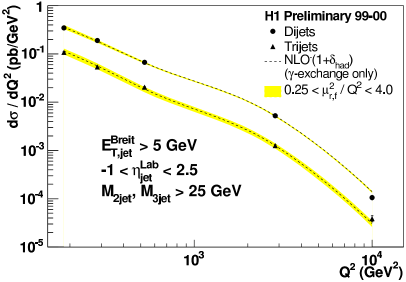


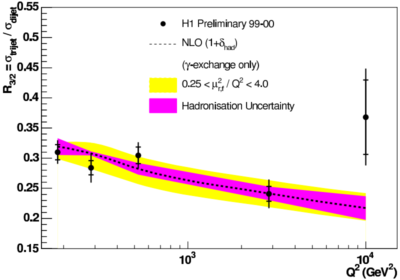


Multi-jets



- Alternative approach
  (LO) dijet ($\mathcal{O}(\alpha_s)$)
  (LO) trijet ($\mathcal{O}(\alpha_s^2)$)
  $R_{3/2} \sim \alpha_s$
- Selection
  $E_T^{jet} > 5$ GeV
  $M_{jj(jjj)} > 25$ GeV
- NLOJET++ with CTEQ5M PDFs
  $\alpha_s(M_Z) = 0.118$
  Ratio - well described
  larger experimental errors compare to inclusive

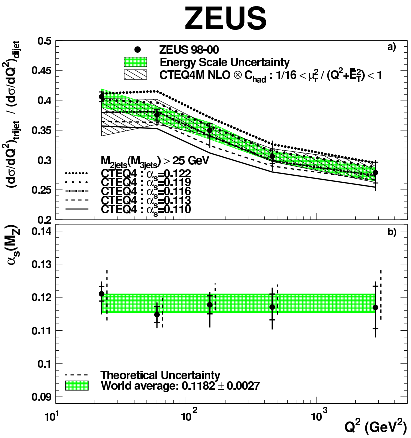




$R_{3/2}$ is sensitive to α_s

- The same fitting method as inclusive
- NLOJET
- Five sets of CTEQ4 PDFs

Correlated systematics and μ_R uncertainty largely cancel



ZEUS (European Physical Journal C44 (2005) 183-193)

$0.1179 \pm 0.0013(stat.)^{+0.0028}_{-0.0046}(exp.)^{+0.0064}_{-0.0046}(th.)$

H1 (LP2005)

$0.1175 \pm 0.0017(stat.) \pm 0.0050(syst.)^{+0.0054}_{-0.0068}(th.)$

Event Shapes

- Event shape variables
- More inclusive (no E_t cut)
- Five event topological variables F

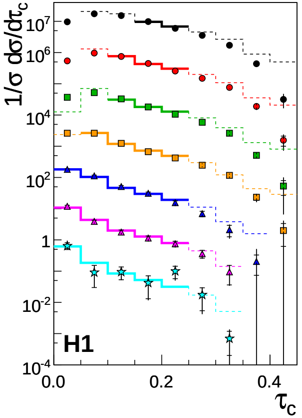
Thrust: Longitudinal momentum components projected onto the boson axis

$\tau = 1 - T$

$T = \frac{\sum_h |\vec{p}_{z,h}|}{\sum_h |\vec{p}_h|}$

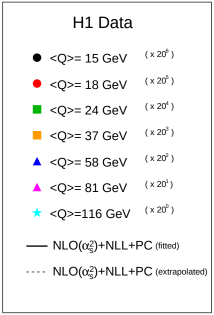
$h \in CH$

Journal-ref: Eur.Phys.J. C46 (2006) 343-356



108 000 events

No stat. limitation except for the highest Q bin



NLO not enough

(NLL approximation)
soft gluon resummation

Power corrections (hadronisation effects) proportional to $(1/Q)$
rely on α_{eff}
valid for low scales

Event Shapes

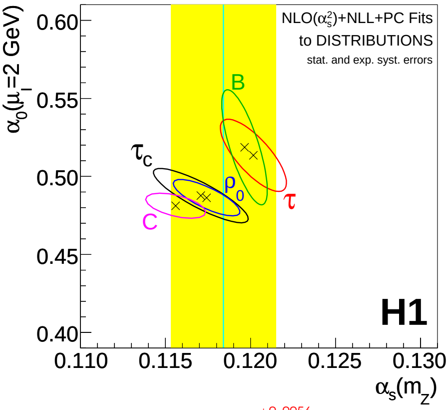
QCD Fit

Fit results in (α_s, α_0) plane

Universal non-perturbative parameter $\alpha_0(\mu_I)$

variable independent

μ_I infrared matching scale



$\alpha_s(M_Z) = 0.1198 \pm 0.0013(exp.)^{+0.0056}_{-0.0043}(th.)$

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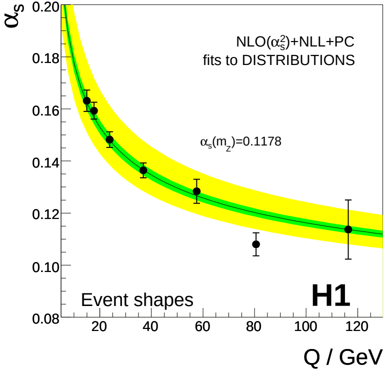
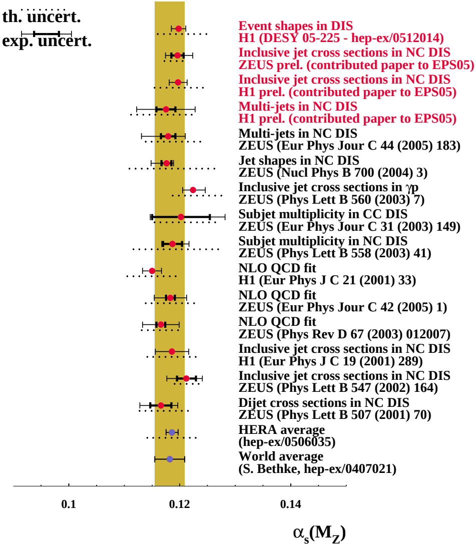


The data clearly exhibit the running of $\alpha_s(Q)$

Large scale

PC: Correct description of event shapes

SUMMARY



World average

0.1182 ± 0.0027

S. Bethke, hep-ex/0407021

HERA is consistant

$0.1186 \pm 0.0011(exp.) \pm 0.0050(th.)$

C. Glasman, hep-ex/0506035

New (with HERA jets)

0.1189 ± 0.0010

S. Bethke, hep-ex/0606035