Combined H1-ZEUS α_s fit

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HERA α_s Working Group

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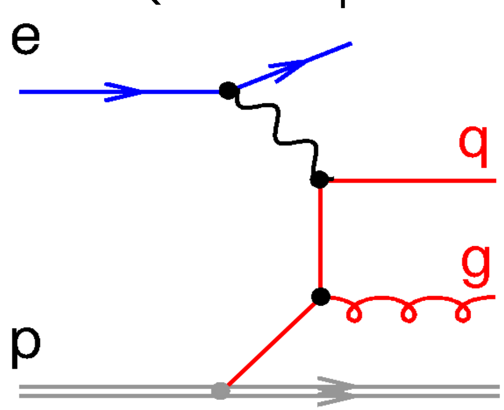
Motivation

- strong coupling α_s : free parameter of perturbative QCD
- least precisely known of the standard model couplings
- determinations of α_s performed since ~20 years
- challenge to improve precision further
- HERA: α_s fits to structure function and final states/jets data
- started program towards **the** HERA α_s
- 2004: average of several α_s fits from HERA
- now: combined H1/ZEUS fit of one observable: inclusive jet cross section

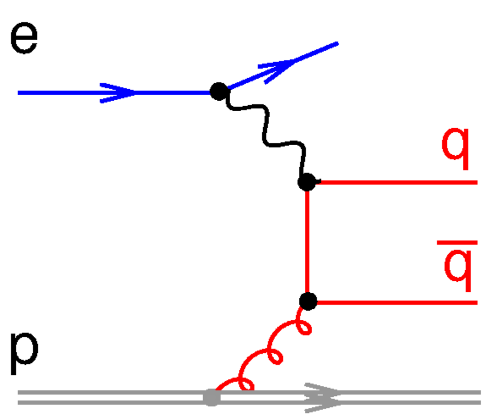
What to fit

- most precise determination now:
- inclusive jets at high Q^2, k_T jet-algorithm in Breit frame, R=1
- directly sensitive to α_s
- NLO prediction describes data, hadronisation effects smallish
- scale (sqrt$\epsilon\sqrt{Q^2}$ or E_T) spans some range for running of coupling
- can optimise measurement to either exp. or theo. error

QCD-Compton



Boson-Gluon Fusion



Lowest Order Graphs for Inclusive Jet Production in DIS in the Breit System of Reference

H1 Data

- Event sample HERA I
  (HERA II see M.Gouzevitch talk)

  1999-2000, $e^{+}p$, $\mathscr{L}_{int}=65pb^{-1}$

- Event selection NC DIS

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

- Jet selection

  inclusive k_T algorithm, R=1.0

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

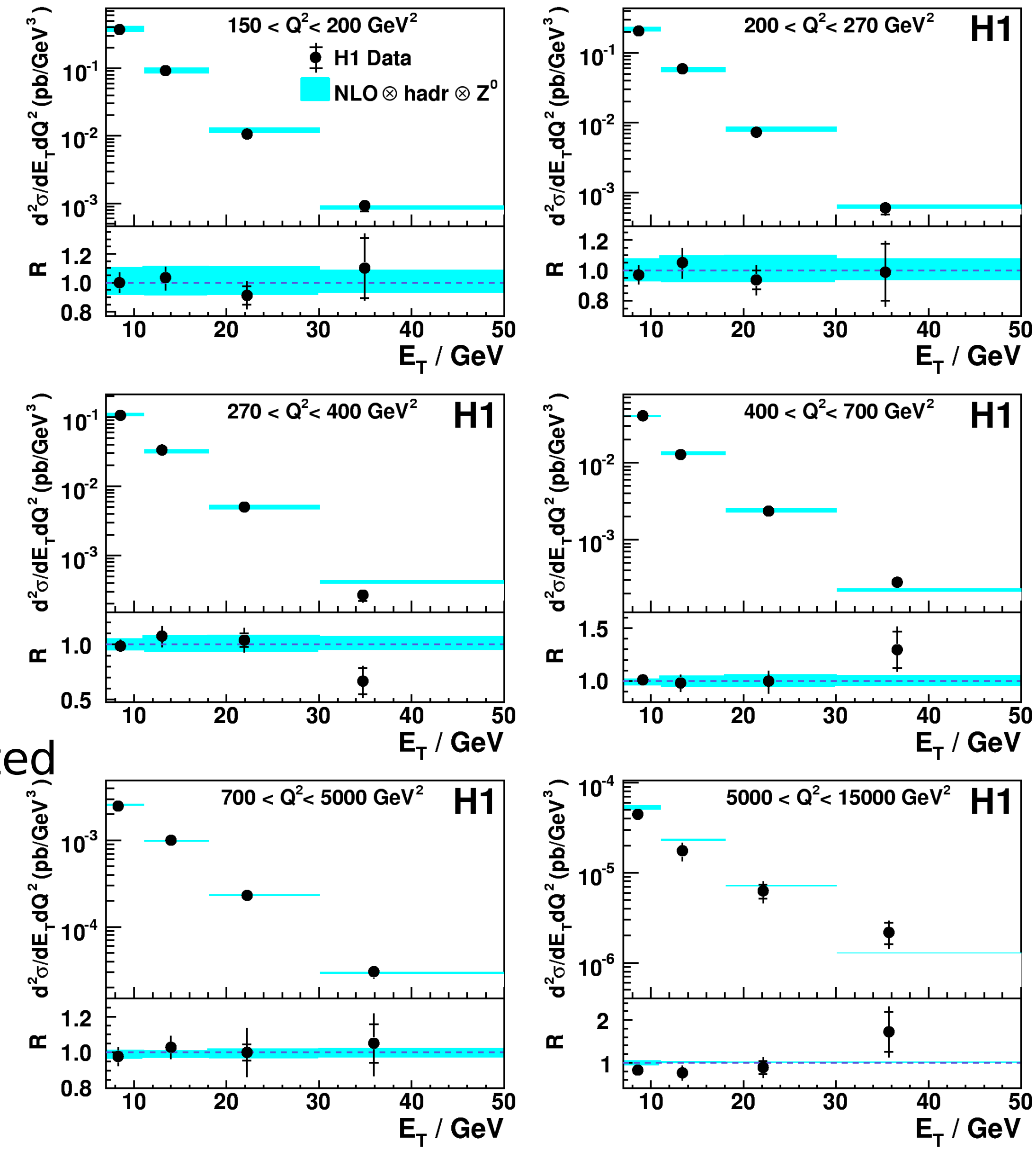
  $7 < E_T^{BREIT} < 50$GeV

- Good description by theory corrected for hadronisation and Z_0 exchange

- DIS last year:

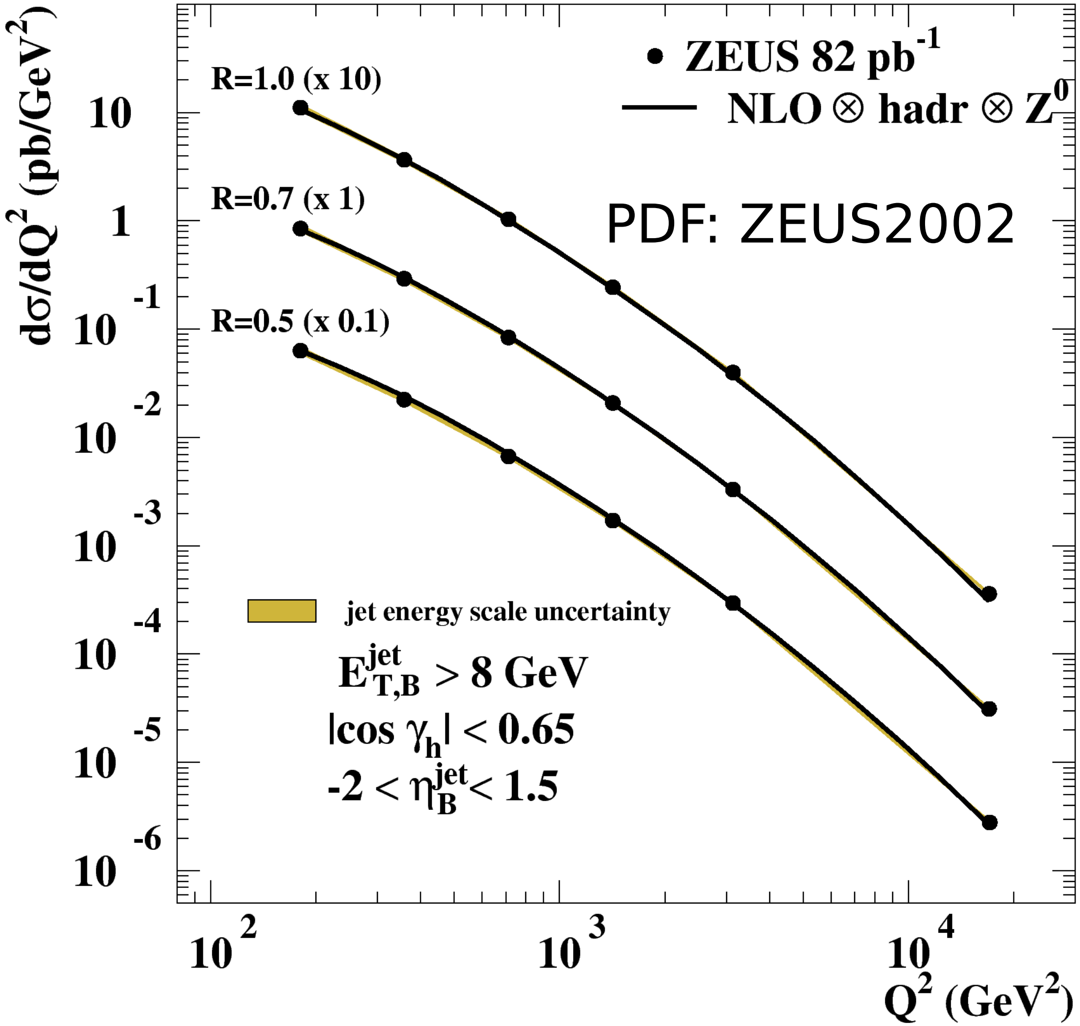
  improved exp. precision using normalised cross sections

Inclusive Jet Cross Section



ZEUS Data

- Event sample HERA I
  1998-2000, $e^{\pm}p$, $\mathscr{L}_{int}$=82pb^{-1}
- Event selection NC DIS
  Q^2 >500GeV^2(used in fit)
- Jet selection: inclusive k_T algorithm analysis done for three jet radii: R=0.5, 0.7, 1.0
  used for α_s fit: R=1.0
- Good description by theory corrected for hadronisation and Z_0 exchange



Fits

QCD Fits to the cross sections yield:

ZEUS $\alpha_s(M_Z) = 0.1207 \pm 0.0014\ (\text{stat.})\ ^{+0.0035}_{-0.0033}\ (\text{exp.})\ ^{+0.0022}_{-0.0023}\ (\text{th.})$

H1 $\alpha_s(M_Z) = 0.1179\ \pm 0.0024\,(\text{exp.})\ ^{+0.0052}_{-0.0032}\,(\text{th.})\ \pm 0.0028\,(\text{pdf})$

Compatible results, but why different size of errors?

ZEUS higher Q^2: exp. ↑, theo. ↓

H1 Hessian method: exp. ↓

H1 theo. offset method: theo. ↑

ZEUS PDF ZEUS2002: theo. ↓

Allow correlated systematical parameters to vary during Fit

Theory "calibrates" experiment

Repeat fit with shifted systematics

No assumption of Gaussian distribution of systematic parameters -> conservative

Combined Fit Method

Minimise $\chi^2(\boldsymbol{\alpha}_s(\boldsymbol{M}_Z))$ defined as:

correlated version of $\sum$(difference/error)^2

$$\chi^2 = \vec{V}^T \cdot M^{-1} \cdot \vec{V} + \sum_k \varepsilon_k^2$$

penalty term for fitted systematics
"Hessian" method

$$M = M^{\text{stat.}} + M^{\text{uncor.}}$$

correlated for some bins

uncorrelated systematics

$$V_i = \sigma_i^{\text{exp.}} - \sigma_i^{\text{theo.}}(1 - \sum_k \Delta_{ik}\varepsilon_k)$$

bin #

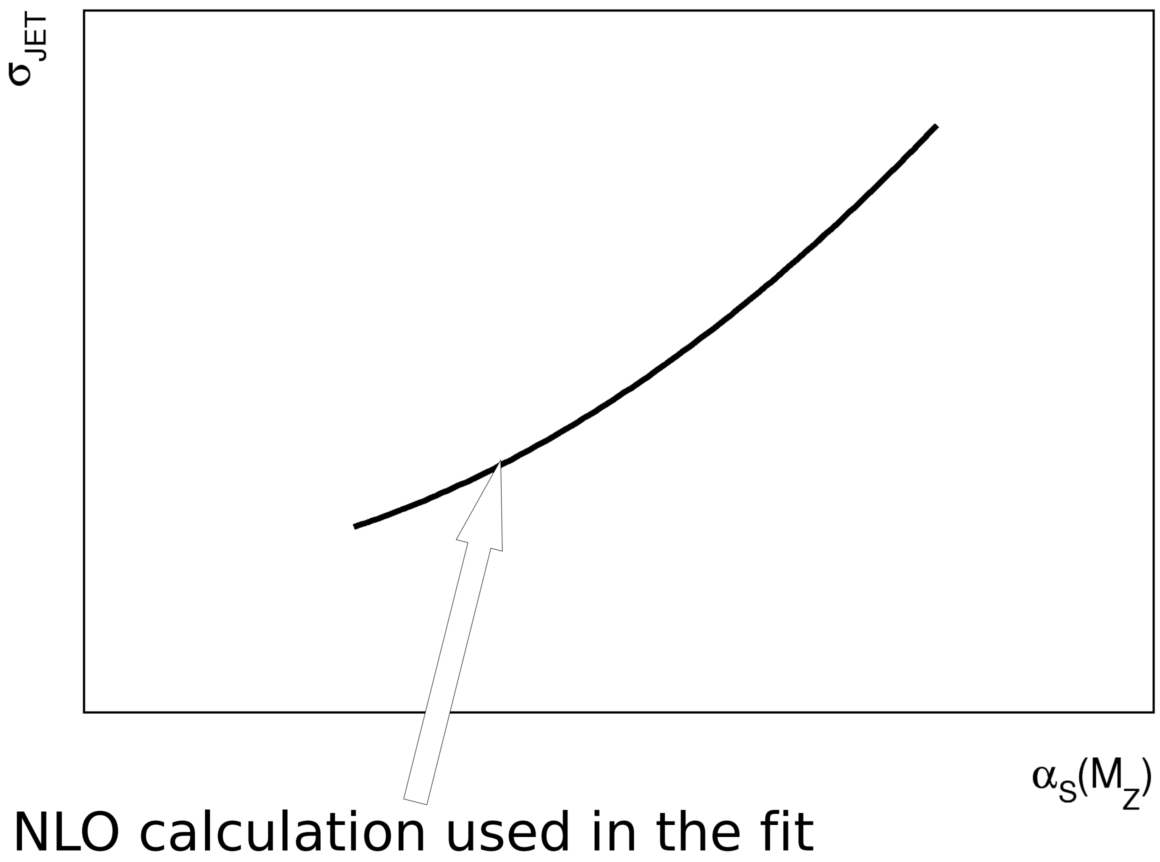
correlated systematical error #k

parameter in fit, pull
"Hessian" method

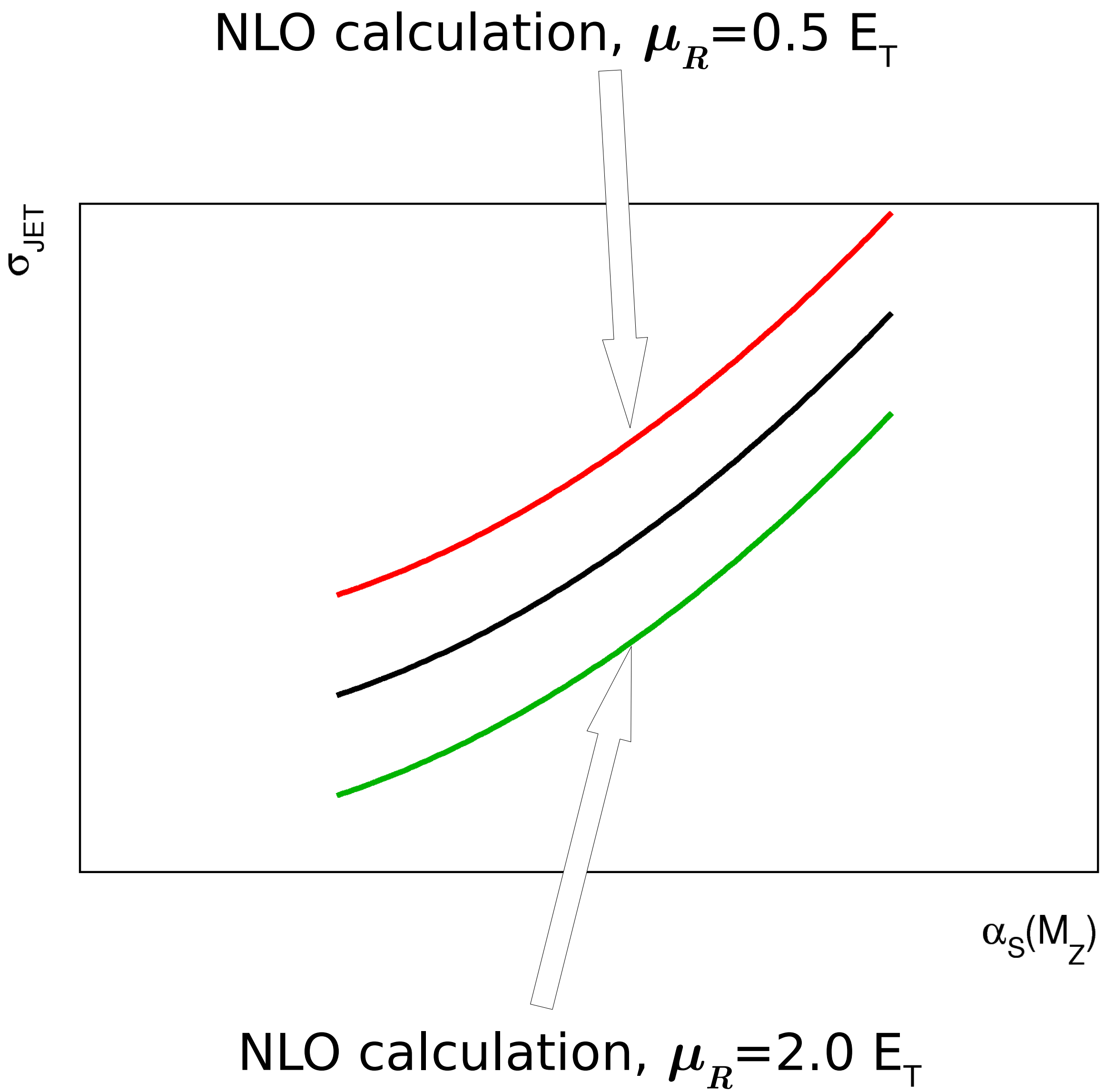
Exp. uncertainty of fit defined as $\boldsymbol{\alpha}_s$ interval upto minimum χ^2+1

Theory Error

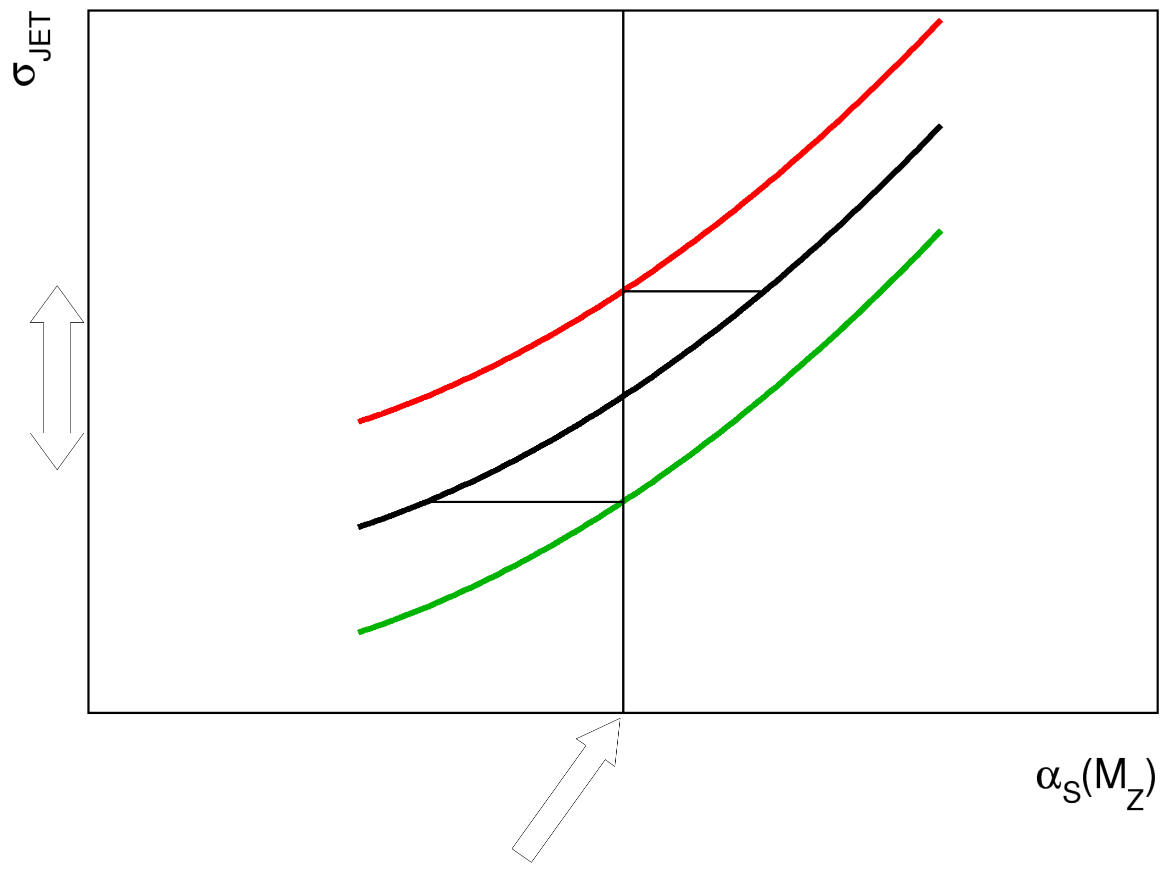
- Overestimate theo. error by repeating fit with μ_R scaled by 0.5 and 2 due to limited statistics in the data?
- Use alternative method, estimation of theoretical error using theory only (no refit of data) [Jones et al., JHEP122003007]



Theory Error



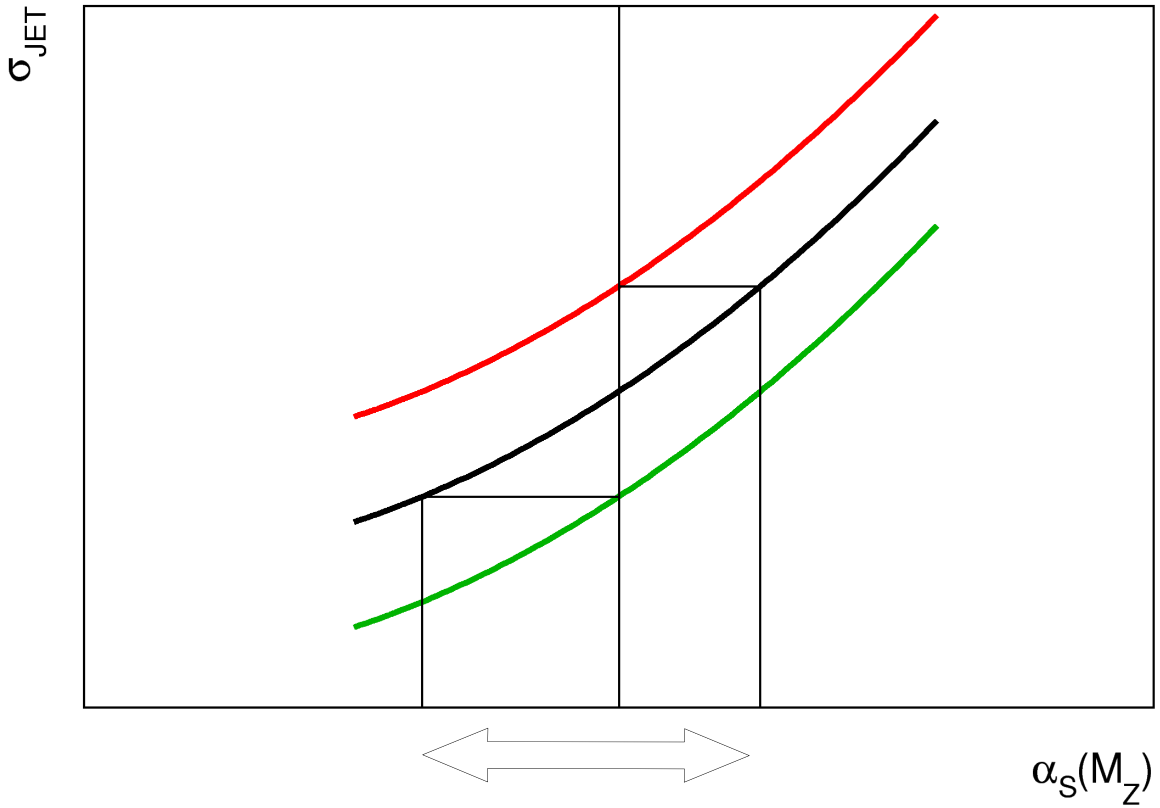
Theory Error



error on cross section due to $\boldsymbol{\mu}_R$

fitted $\boldsymbol{\alpha}_S$, central value

Theory Error



Error on fitted

α_s due to μ_R

Result

- Simultaneos fit to 30 data points
  - 24 from H1
  - 6 from ZEUS
- Theory calculation
  - NLOJET++ (fastNLO) and DISENT (ZEUS grid program)
  - μ_R=E_T, μ_F=Q
  - PDF MRST2001

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

$$\chi^2/\mathrm{ndf} = 27.4/29$$

Good quality of combined fit

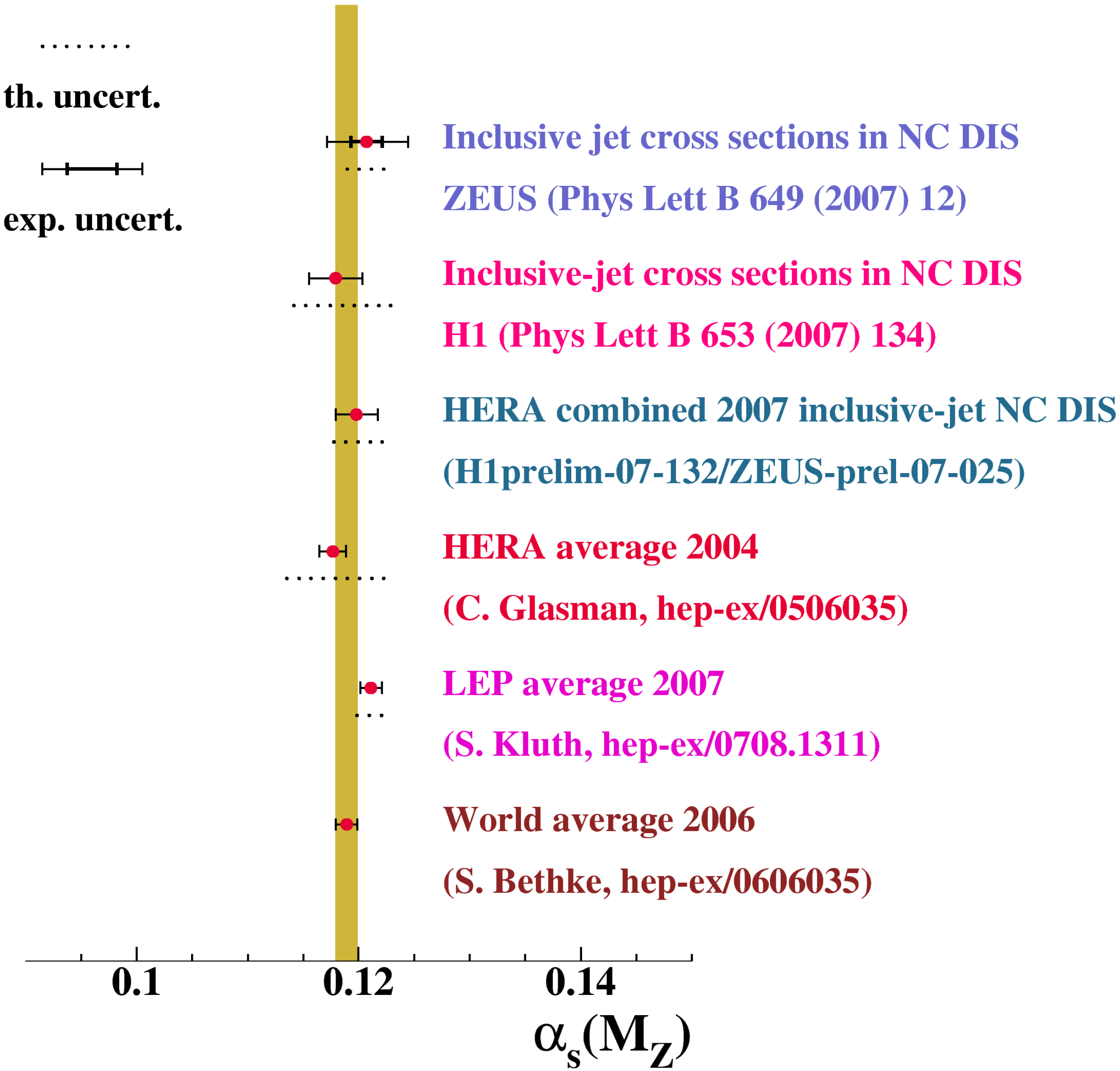
Result

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

details on uncertainties

Source	**Variation (H1/ZEUS)**	**Effect on α_s**
	experimental errors	
detector correction	RAPGAP/DJANGOH	0.0019
EM energy scale	0.7-3% / 1%	
e scattering angle	1-3mrad	
hadronic energy scale	2% / 1-3%	
luminosity	1.5% / 2.2%	
	theory errors	
renormalisation scale	scale by 0.5/2.0	0.0021
factorisation scale	scale by 0.5/2.0	0.0010
PDFs	MRST2001E	0.0010
hadronisation correction	RAPGAP/DJANGOH	0.0004

Comparison of Results



New determination consistent with previous ones and the world average

tot. error

2.7%

4.3%

1.7%

0.8%

Comparison of Results

HERA average 2004

$$\overline{\alpha}_s(M_Z) = 0.1186 \pm 0.0011\ (\mathrm{exp.}) \pm 0.0050\ (\mathrm{th.})$$

HERA average 2007 (incl. jets)

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

- exp. error now larger:

  2004: 9 data sets

  2007: 2 data sets (more involved method, will use more sets soon....)

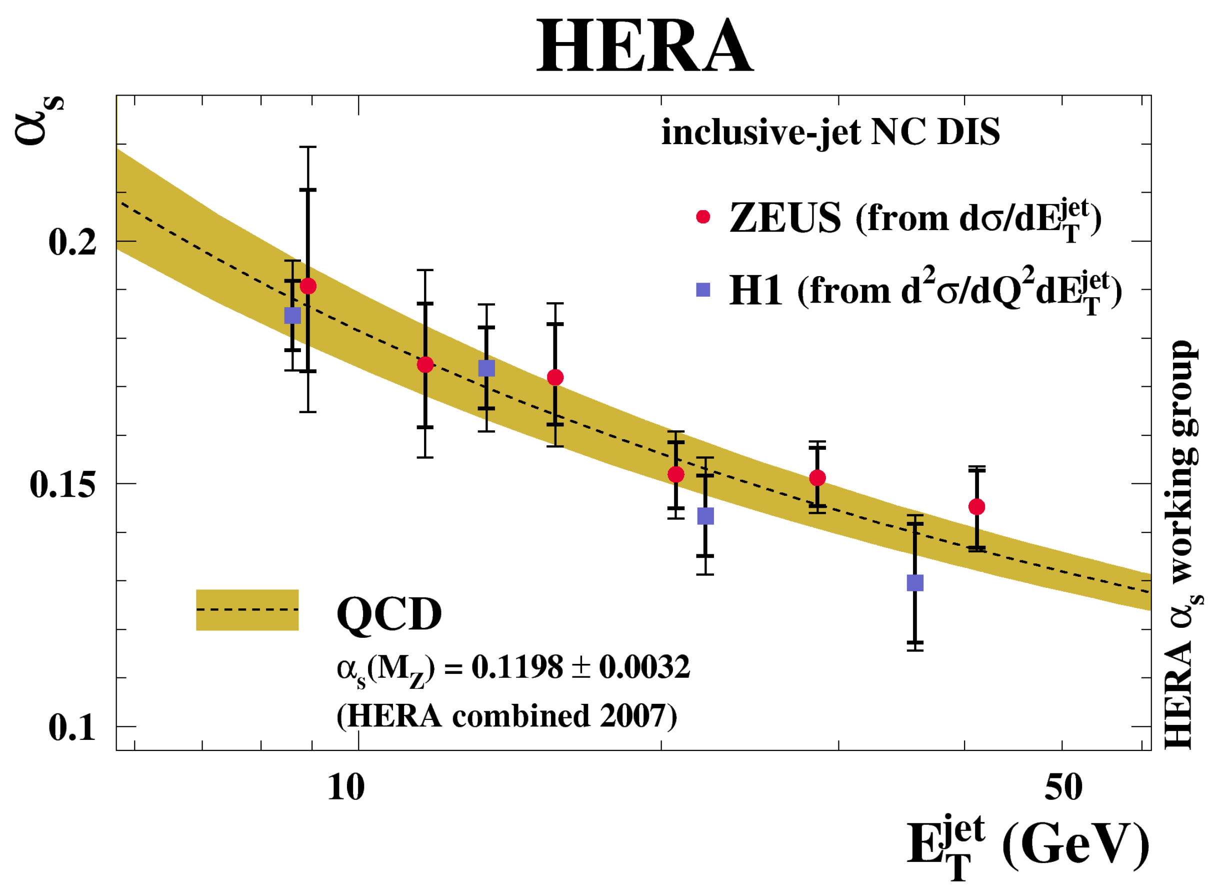
- theo. error now smaller:

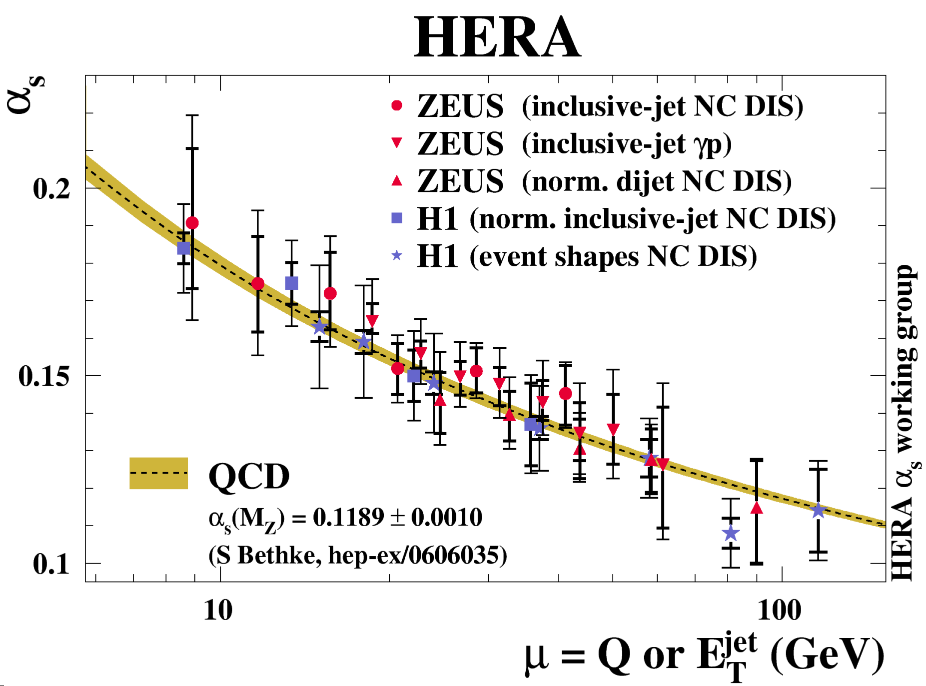
  2004: assume th. fully correlated: add linearly per experiment

  2007: combined fit of 2 measurements, only one common theory uncertainty for both

Running coupling

- Separate fits at different jet E_T
- clear observation of running
- agreement with QCD prediction of scale dependence





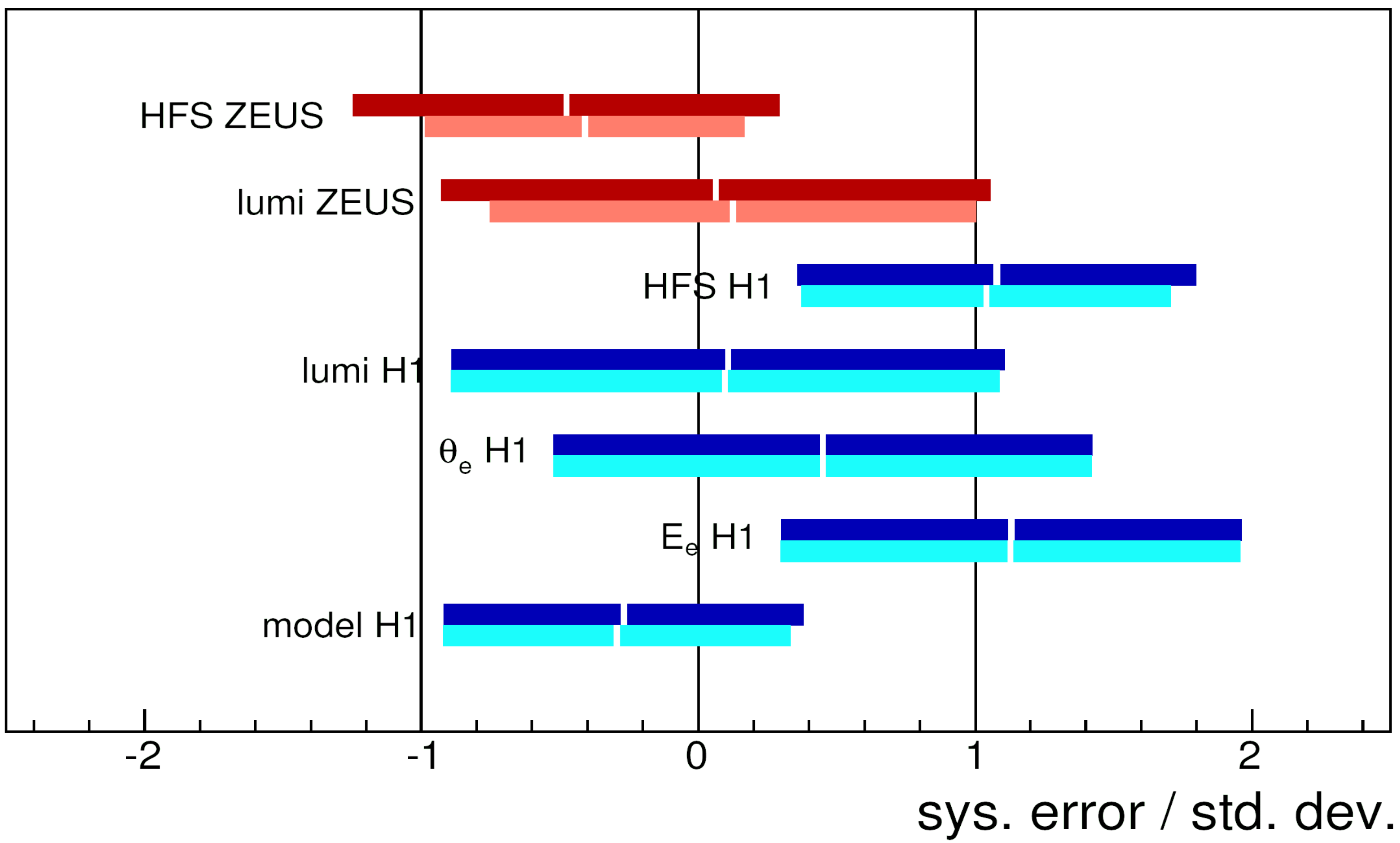
collection of further results from HERA

Conclusions

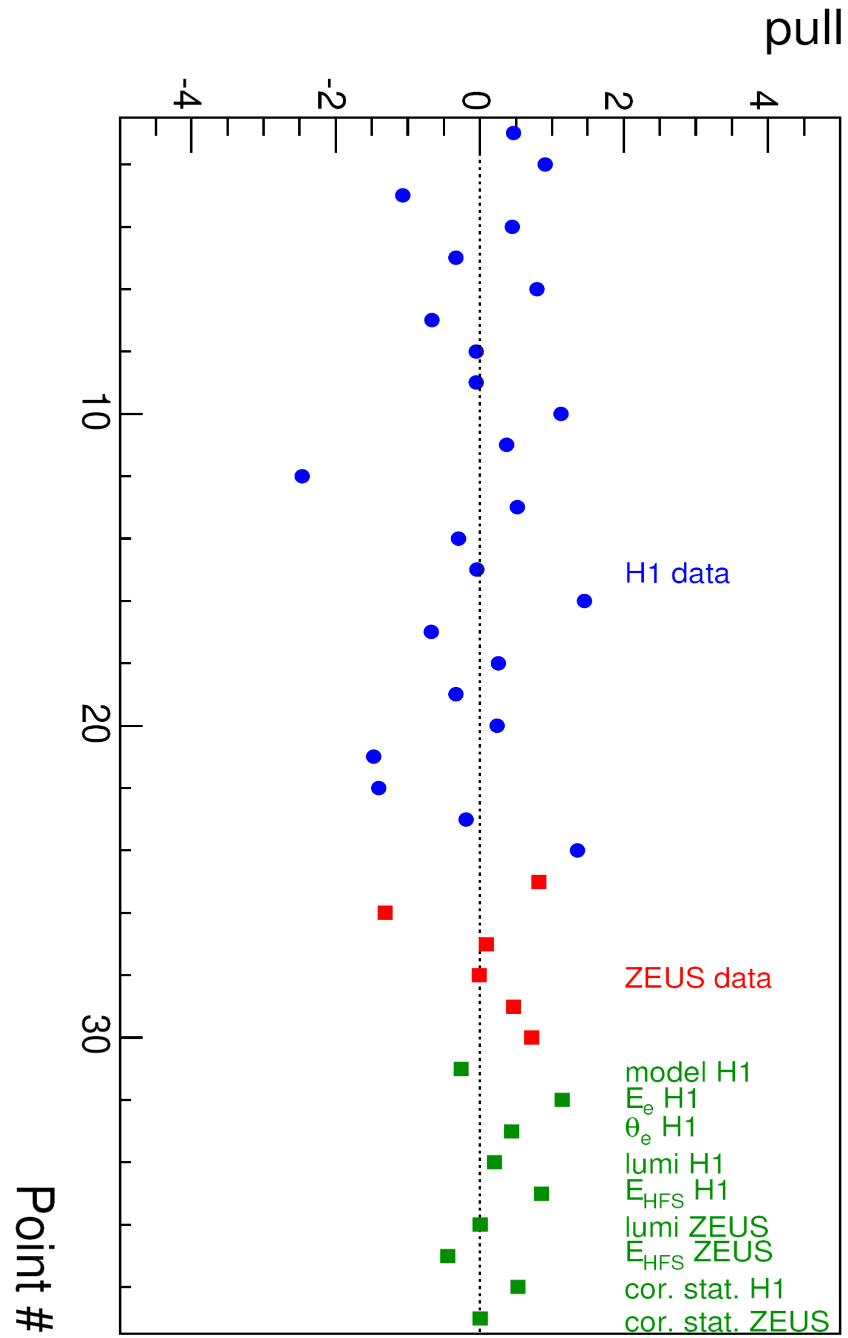
- HERA 2007 combined value $\alpha_s(M_Z) = 0.1198 \pm 0.0019\,(\mathrm{exp.}) \pm 0.0026\,(\mathrm{th.})$
- Very precise $\boldsymbol{\alpha_s}$ determination
- Running of the strong coupling from HERA alone
- Improvements reached due to
  - experimental systematics with Hessian method
  - theory error extracted from NLO calculation alone
  - combination by common fit to data points
- Future: more processes, e.g. γp jets, HERA II data set

Backup

Backup


HFS ZEUS
lumi ZEUS
HFS H1
lumi H1
θ_e H1
E_e H1
model H1
-2
-1
0
1
2
sys. error / std. dev.

Backup



pull
-4
-2
0
2
4
10
20
30
Point #
H1 data
ZEUS data
model H1
E_e H1
θ_e H1
lumi H1
E_{HFS} H1
lumi ZEUS
E_{HFS} ZEUS
cor. stat. H1
cor. stat. ZEUS