

Combined H1-ZEUS α_s fit



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for the H1 and ZEUS Collaborations



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HERA α_s Working Group



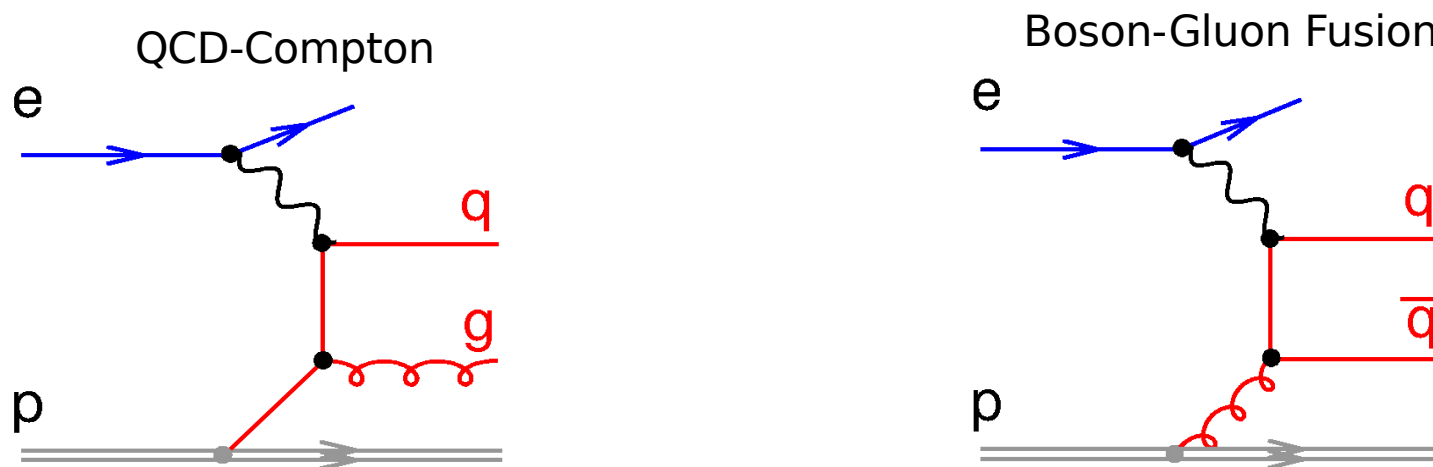
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Motivation

- 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 ($\sqrt{s} \sqrt{Q^2}$ or E_T) spans some range for running of coupling
- can optimise measurement to either exp. or theo. error



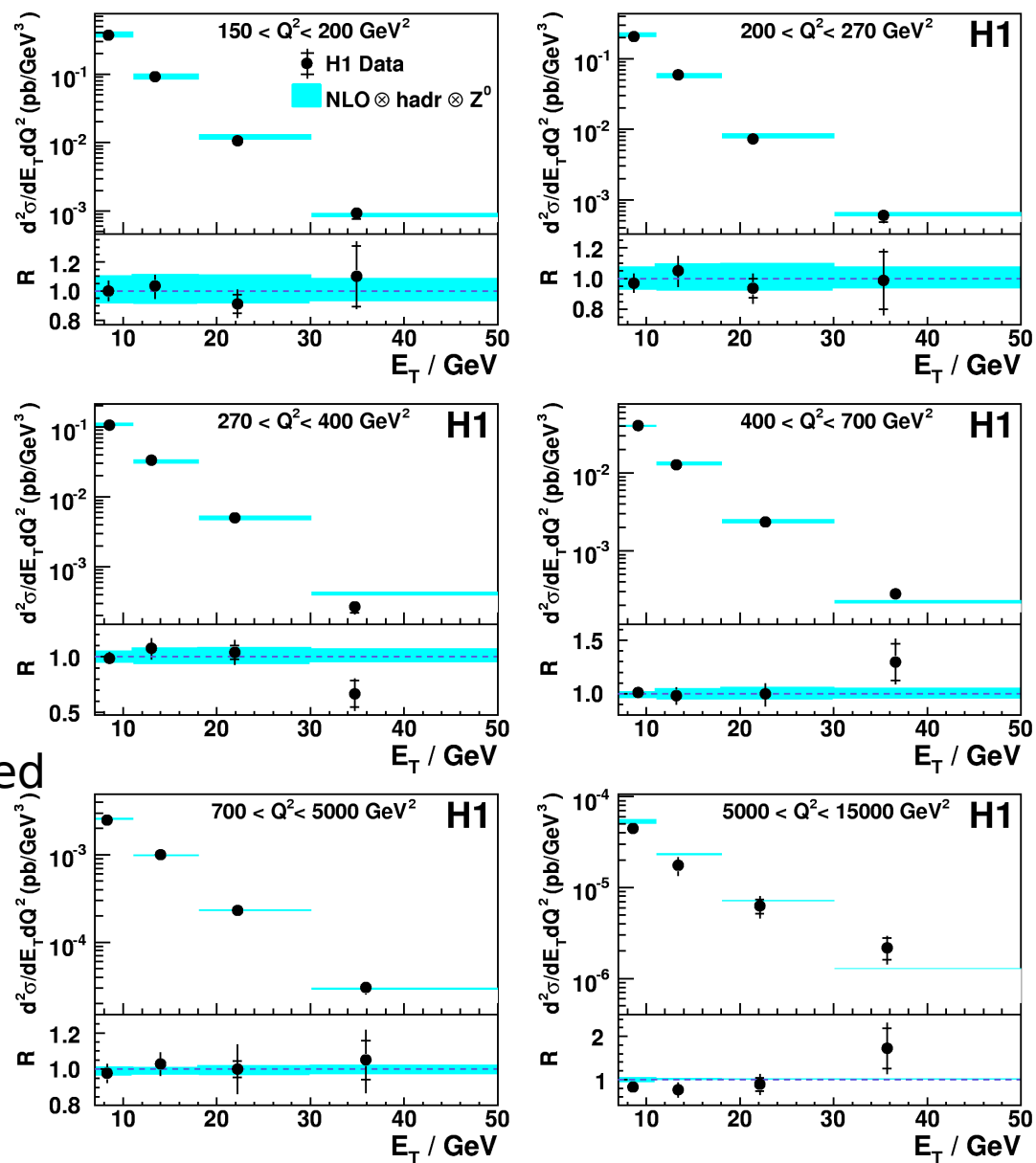
Lowest Order Graphs for Inclusive Jet Production in DIS in the Breit System of Reference

H1 Data



Inclusive Jet Cross Section

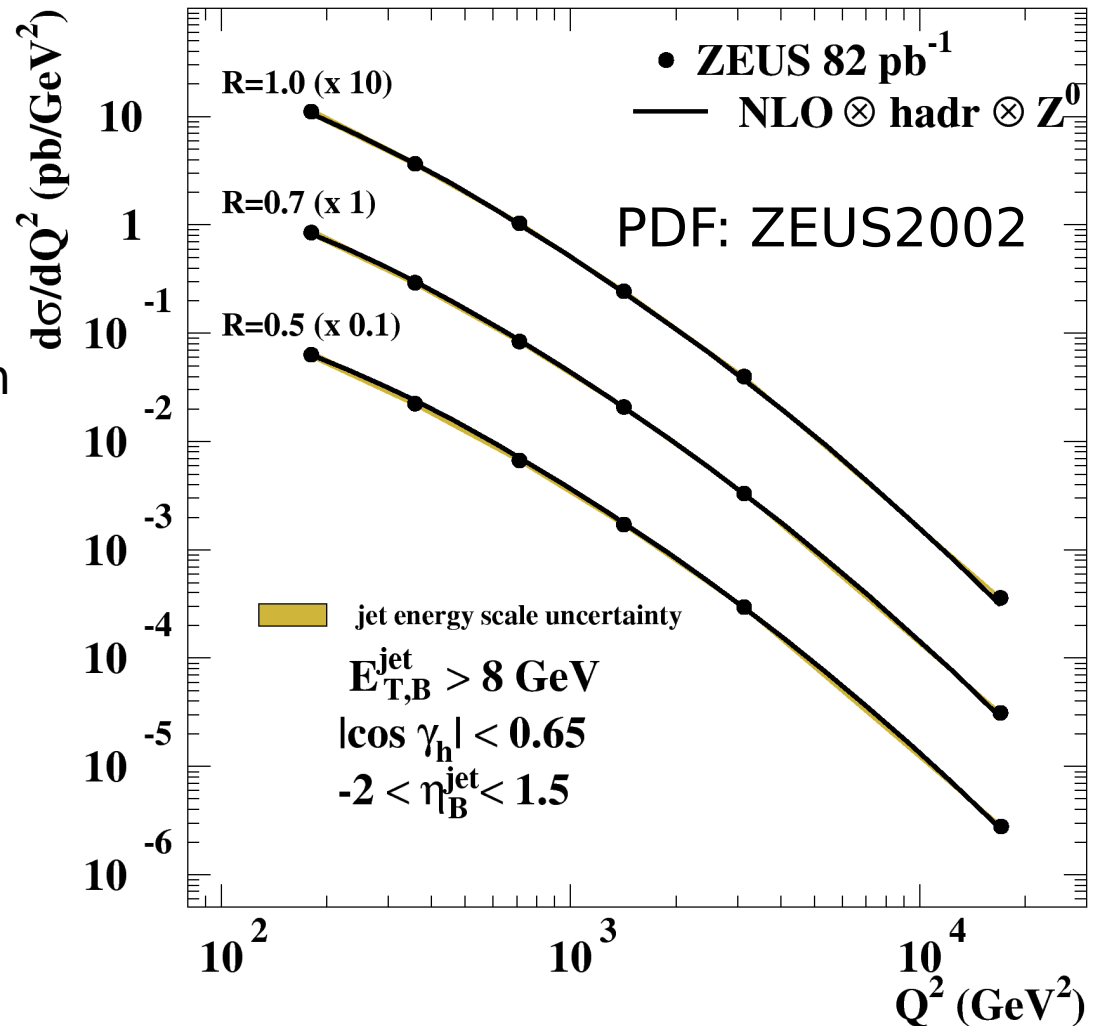
- Event sample HERA I
(HERA II see M.Gouzevitch talk)
1999-2000, e^+p , $\mathcal{L}_{\text{int}} = 65\text{pb}^{-1}$
- Event selection NC DIS
 $150 < Q^2 < 15000 \text{ GeV}^2$, $0.2 < y < 0.7$
- Jet selection
inclusive k_T algorithm, $R=1.0$
 $-1.0 < \eta^{\text{LAB}} < 2.5$
 $7 < E_T^{\text{BREIT}} < 50\text{GeV}$
- Good description by theory corrected
for hadronisation and Z_0 exchange
- DIS last year:
improved exp. precision using
normalised cross sections



ZEUS Data



- Event sample HERA I
1998-2000, $e^\pm p$, $\mathcal{L}_{\text{int}} = 82 \text{ pb}^{-1}$
- Event selection NC DIS
 $Q^2 > 500 \text{ GeV}^2$ (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 $\alpha_s(M_Z) = 0.1207 \pm 0.0014$ (stat.) $^{+0.0035}_{-0.0033}$ (exp.) $^{+0.0022}_{-0.0023}$ (th.)

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

Compatible results, but why different size of errors?

ZEUS higher Q^2 : exp. \uparrow , theo. \downarrow

H1 Hessian method: exp. \downarrow

H1 theo. offset method: theo. \uparrow

ZEUS PDF ZEUS2002: theo. \downarrow

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 $\chi^2(\alpha_s(M_Z))$ defined as:

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

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

*penalty term for fitted systematics
"Hessian" method*

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

correlated for some bins

uncorrelated systematics

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

bin #

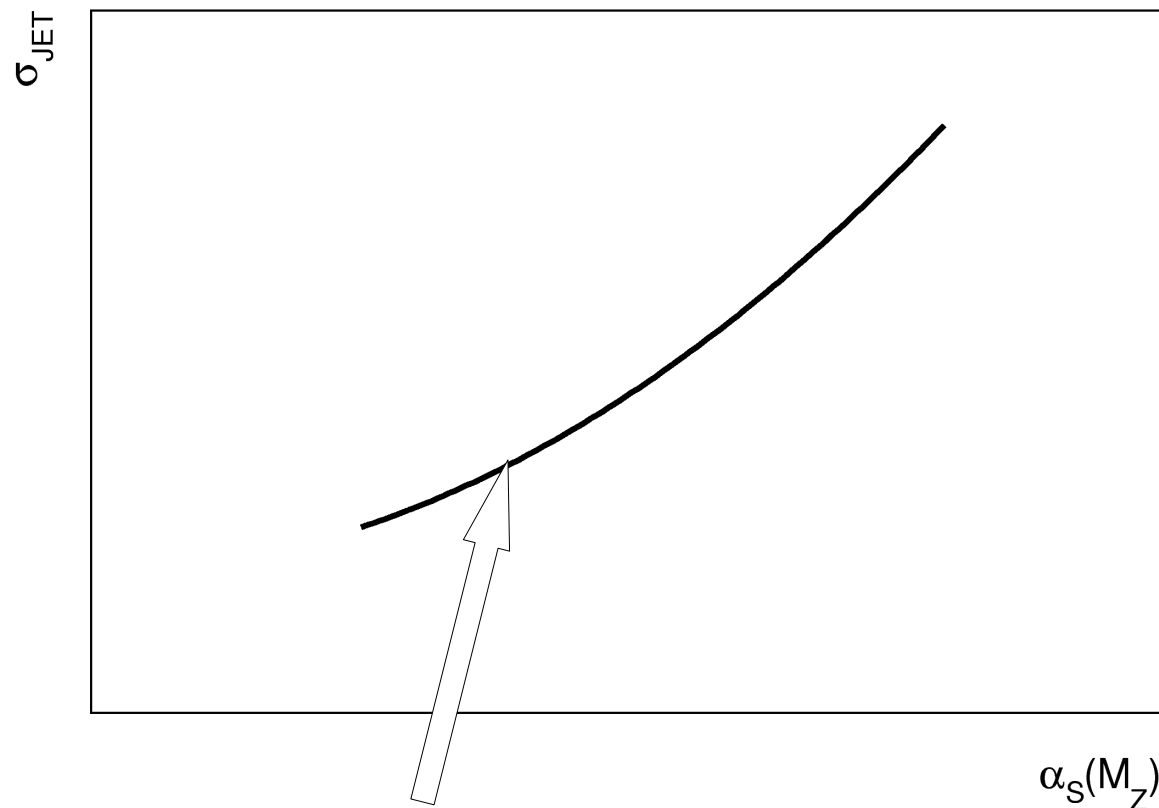
correlated systematical error #k

*parameter in fit, pull
"Hessian" method*

Exp. uncertainty of fit defined as α_s interval upto minimum χ^2+1

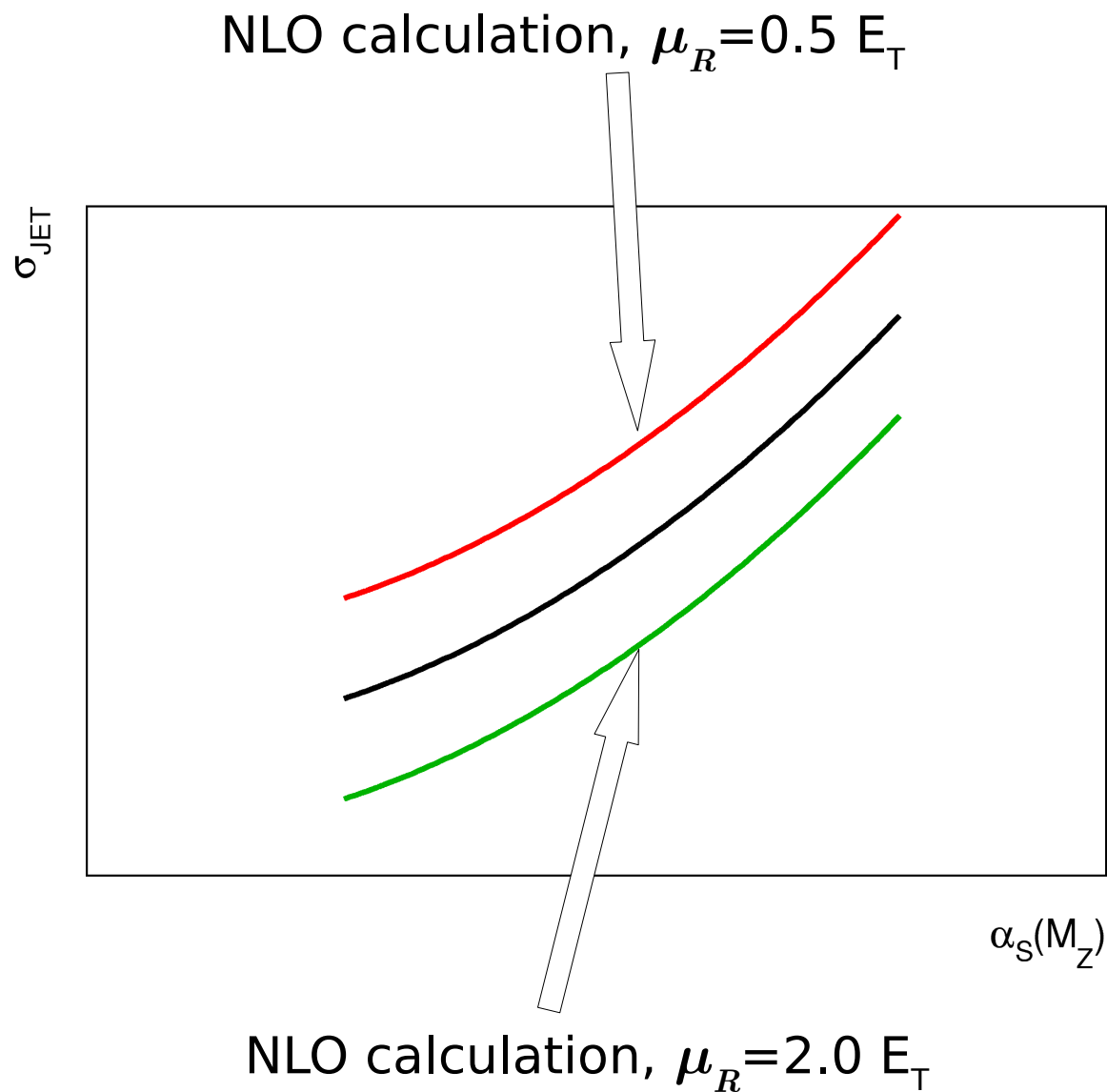
Theory Error

- 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]

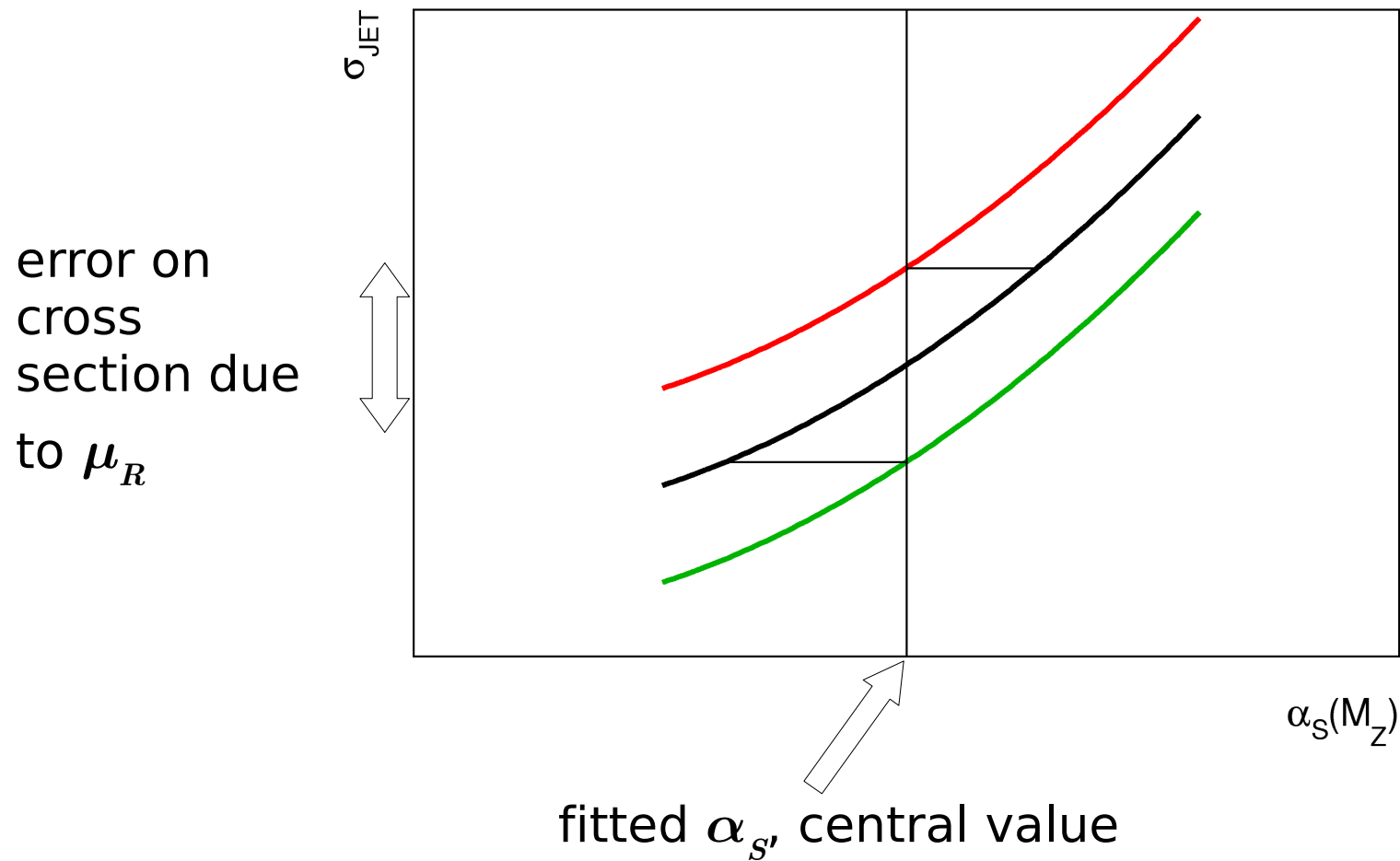


NLO calculation used in the fit

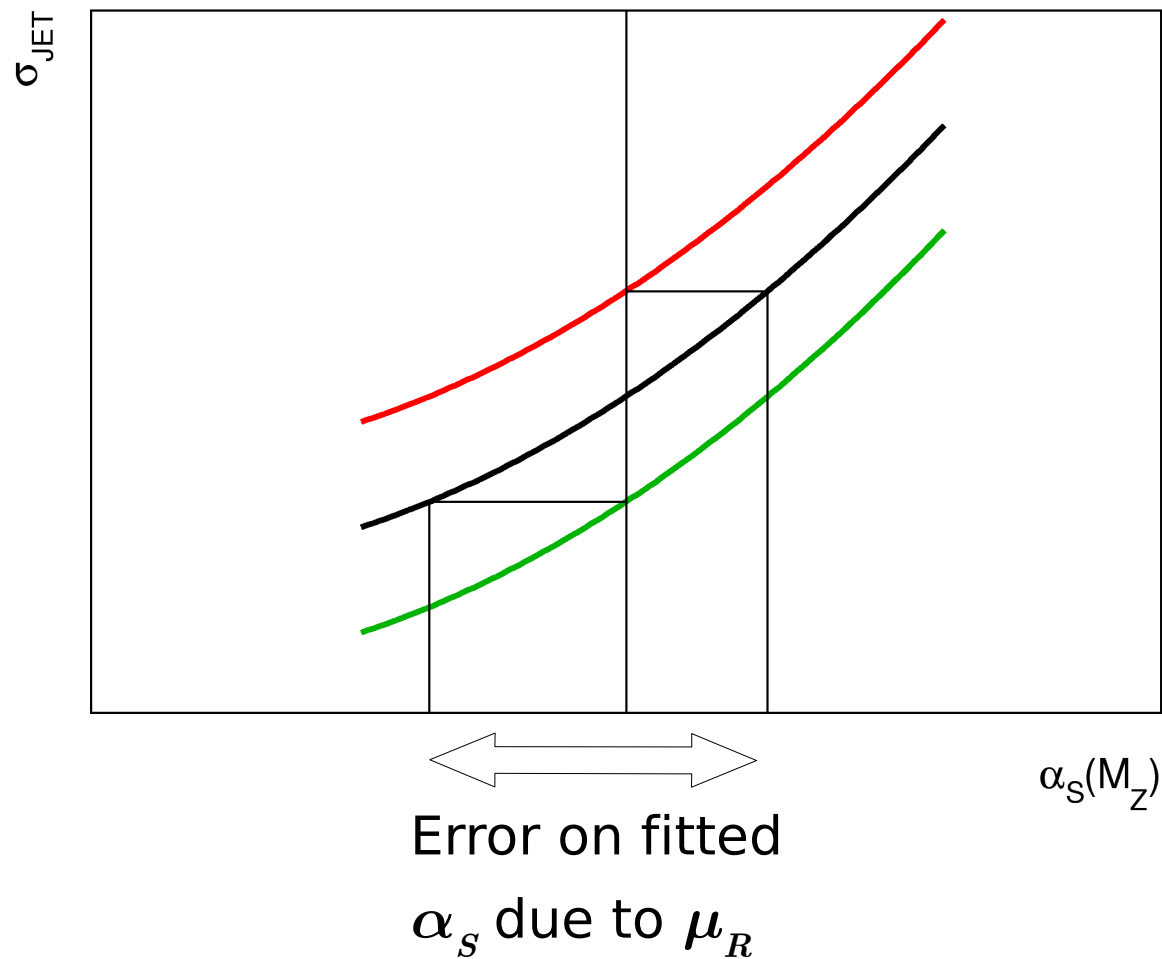
Theory Error



Theory Error



Theory Error



Result

- Simultaneous fit to 30 data points
 - 24 from H1
 - 6 from ZEUS
- Theory calculation
 - NLOJET++ (fastNLO) and DISINT (ZEUS grid program)
 - $\mu_R = E_T, \mu_F = Q$
 - PDF MRST2001

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

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

Good quality of combined fit 

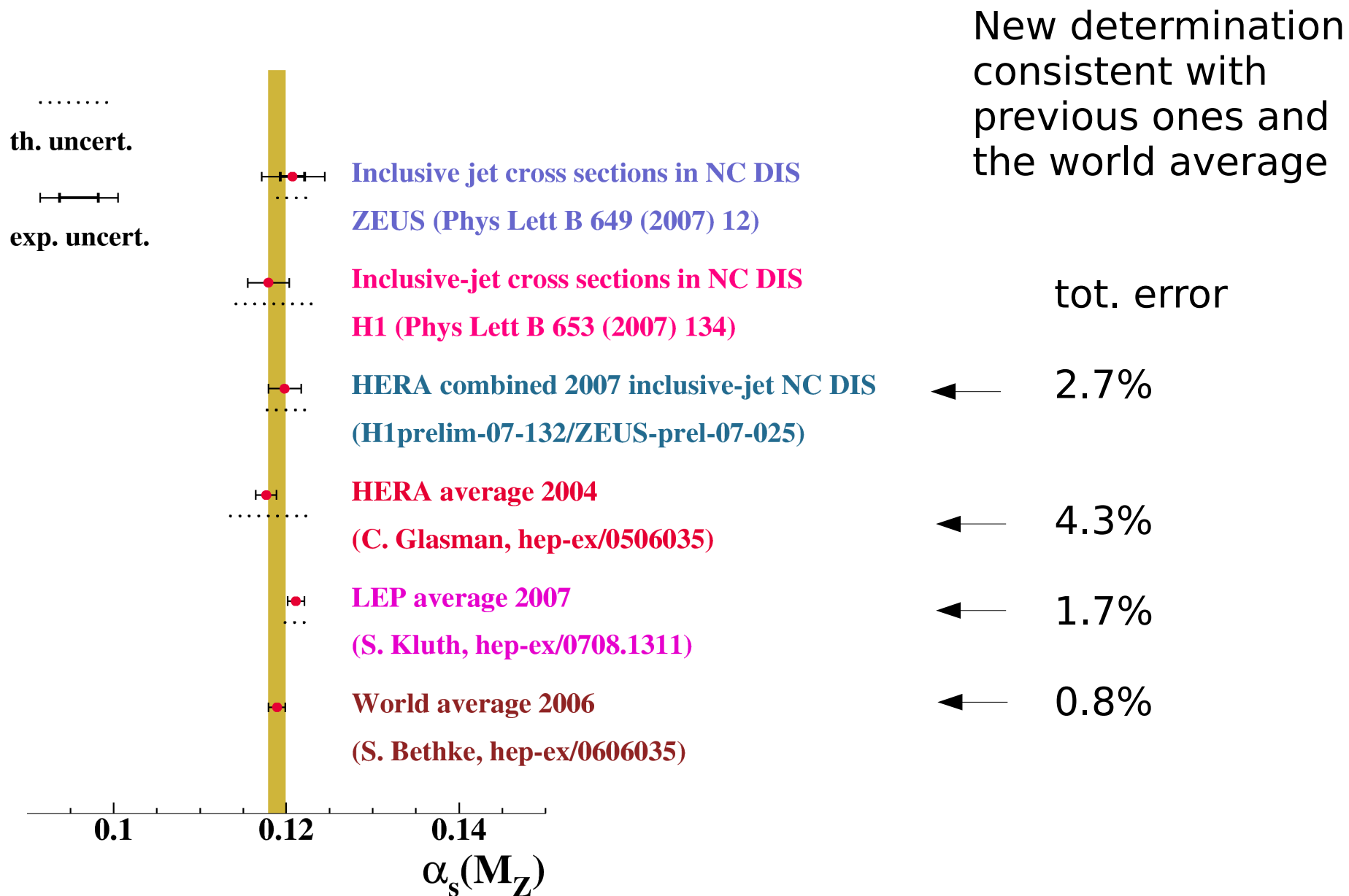
Result

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

details on uncertainties

Source	Variation (H1/ZEUS)	Effect on α_s
experimental errors		
detector correction	RAPGAP/DJANGO	} 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/DJANGO	0.0004

Comparison of Results



Comparison of Results

HERA average 2004

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

HERA average 2007 (incl. jets)

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

- exp. error now larger:

2004: 9 data sets

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

- theo. error now smaller:

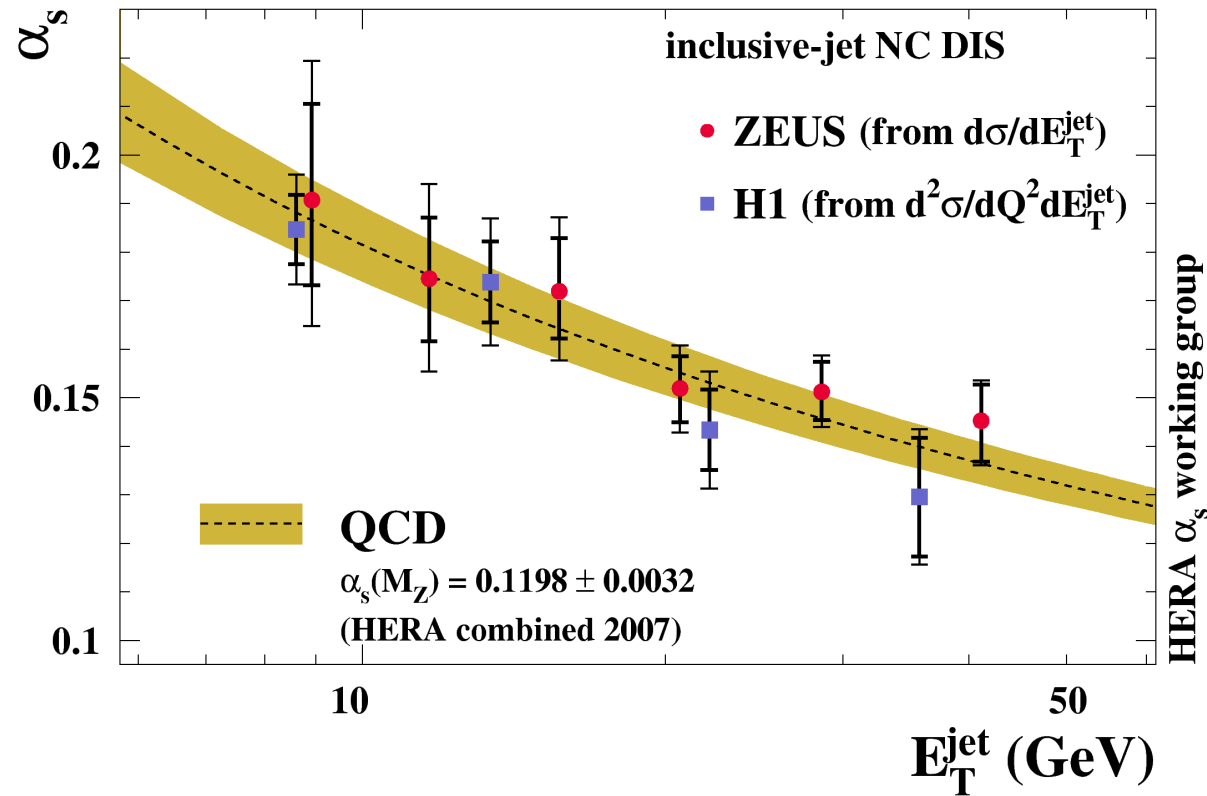
2004: assume th. fully correlated: add linearly per experiment

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

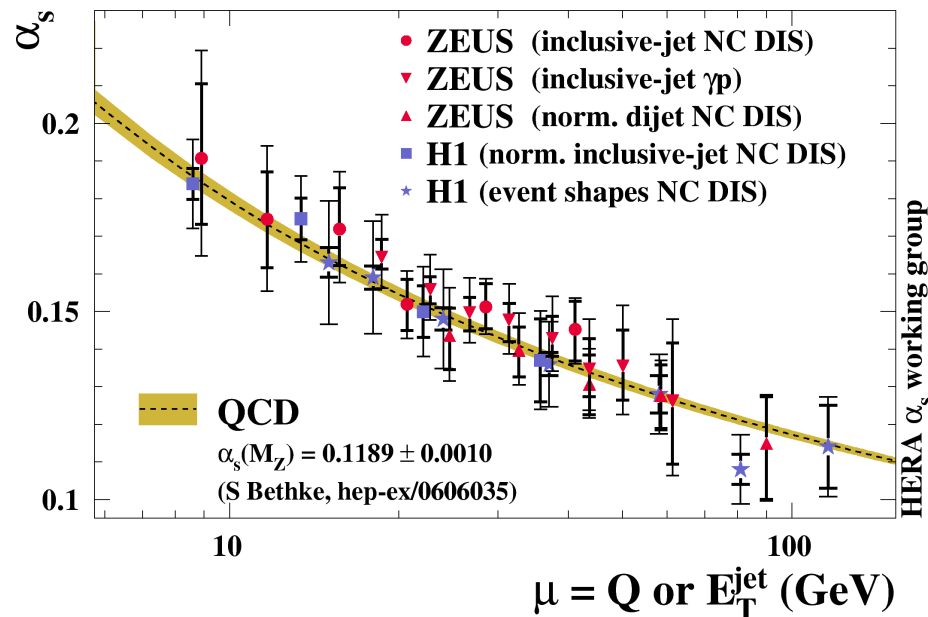
Running coupling

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

HERA



HERA



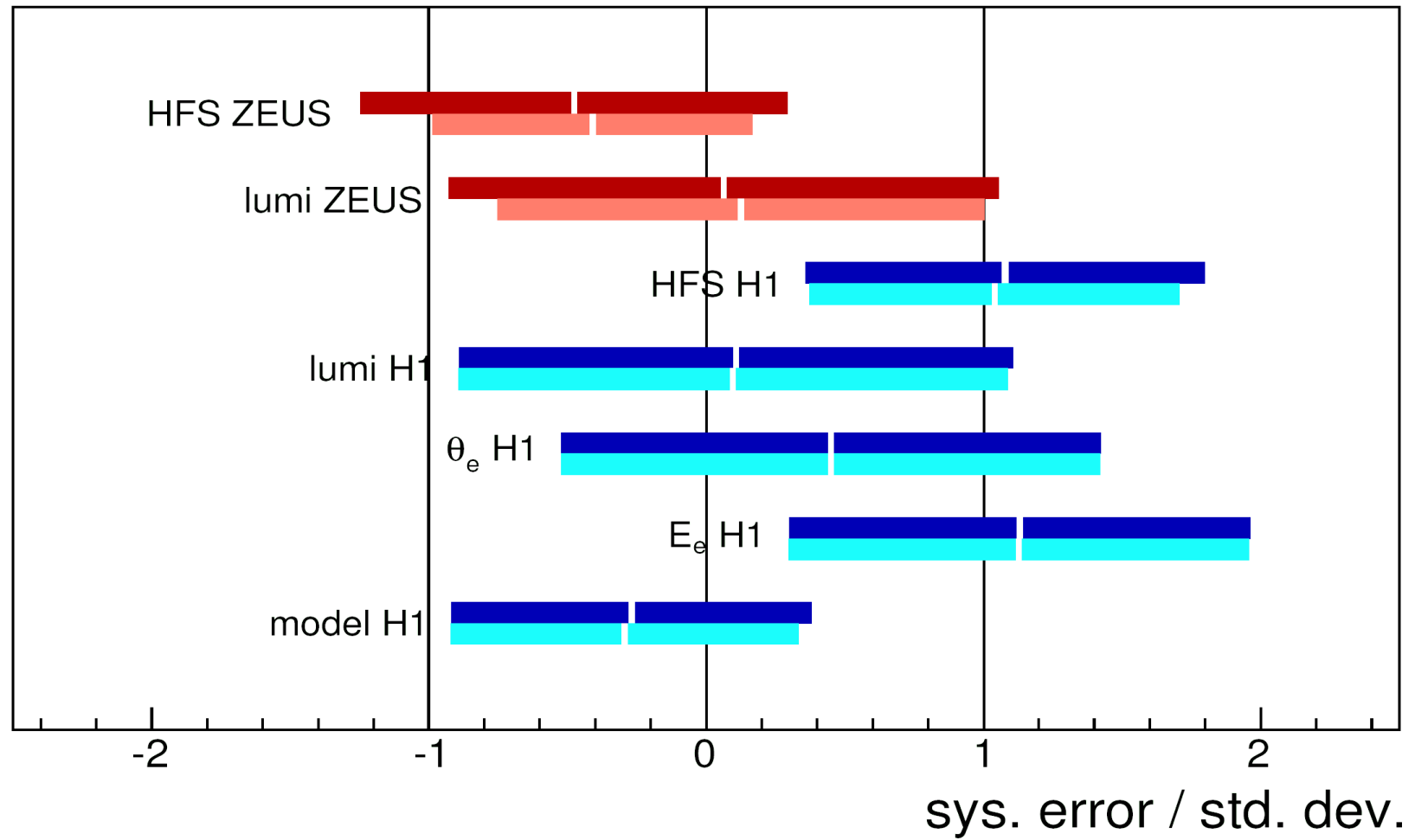
← collection of further results from HERA

Conclusions

- HERA 2007 combined value $\alpha_s(M_Z) = 0.1198 \pm 0.0019$ (exp.) ± 0.0026 (th.)
- Very precise α_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



Backup

