Inclusive Jet Production in DIS at High Q^2 and Extraction of α_s at HERA

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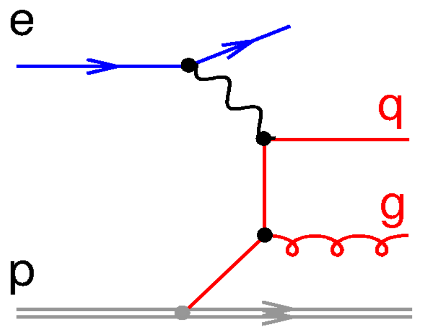
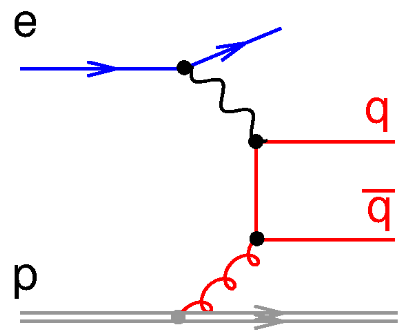
- **Motivation**
- **Data analysis**
- α_s **extraction**
- **Summary**

Motivation

Jet production in DIS at high Q^2 and E_T: handle to pQCD

Examples for contributing graphs





Analysis Strategy

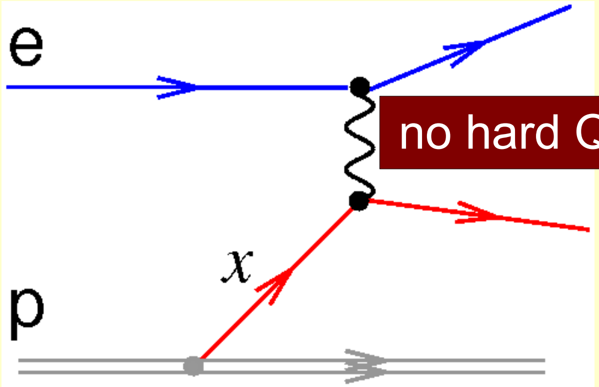
- count all jets in phase space as function of Q^2 and E_T
- cross section depends on
  - QCD matrix elements
  - strong coupling α_S
  - parton density functions of the proton
- determine α_S by fitting the theory to data

Jet Observable

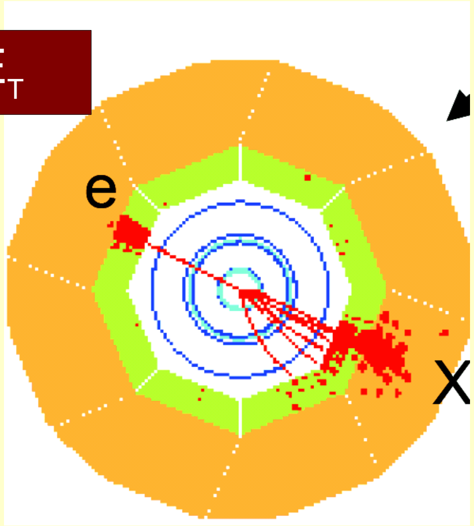
- No unique definition of a jet, here: incl. k_t cluster algorithm
  - similar to e^+e^- algorithms
  - favoured by theory over (most) cone algorithms
  - infrared and collinear safe at all orders
  - factorisable
- For DIS: ⇒ boost particles to Breit frame of reference

Breit Frame

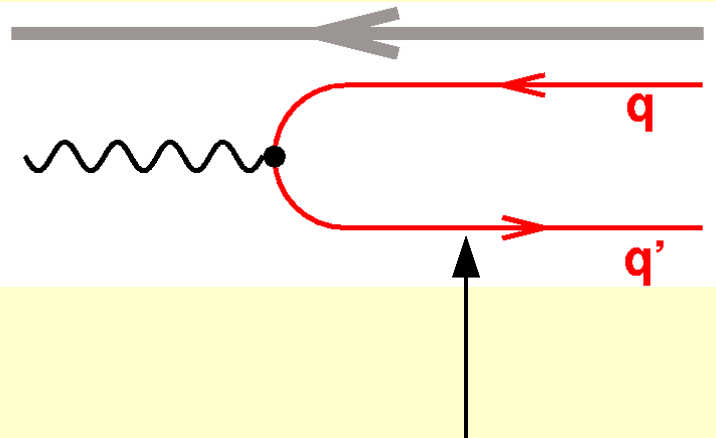
- Born level of deep inelastic scattering, the electron recoils a single jet



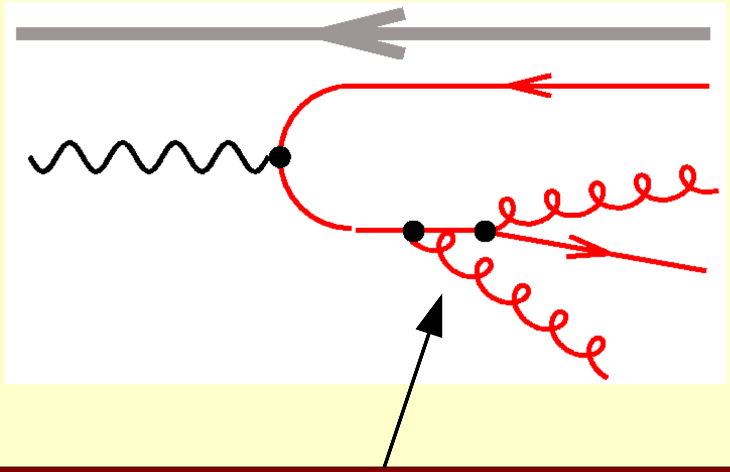
...still high jet E_T



- Boost final state to Breit system of reference



Born jets have very small E_T



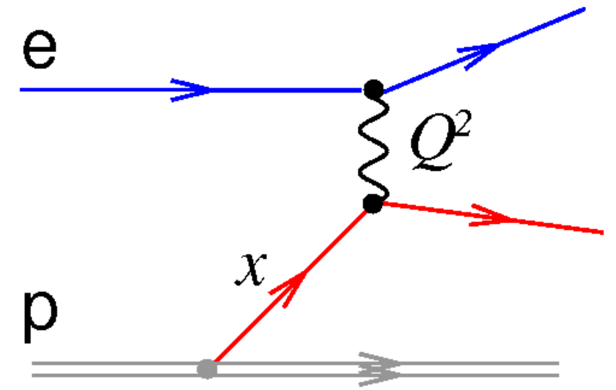
in the Breit frame, QCD radiation generates E_T

Data Set

Selection

- Event sample
  - 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, p_T recombination scheme, R=1.0
  - $-1.0<\eta^{LAB}<2.5$, $7 < E_T^{BREIT} < 50$GeV
- "inclusive jet cross section": each jet of an event contributes to the cross section

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



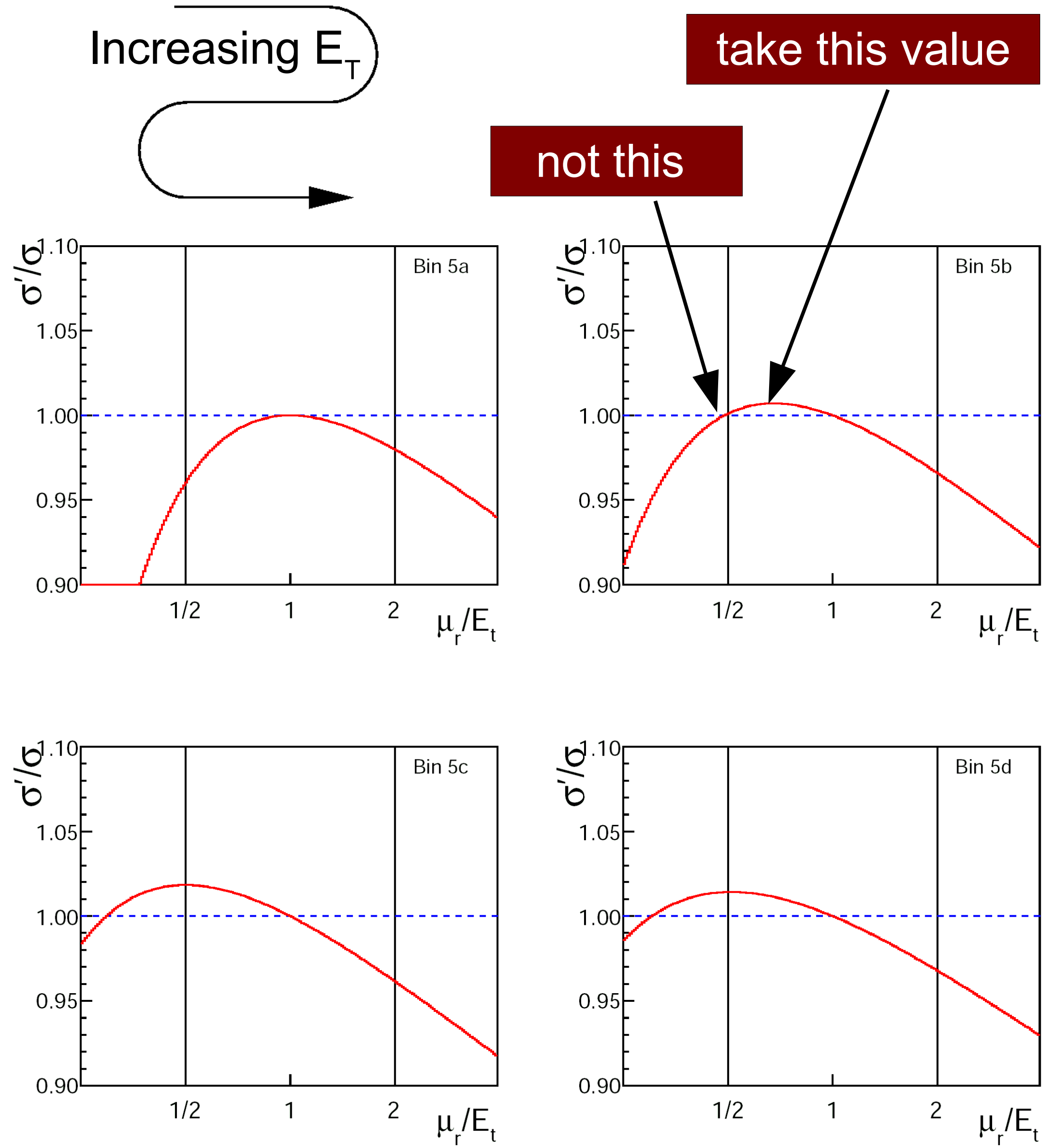
$$y = \frac{Q^2}{sx}$$

Data Correction & Systematics

- Correction for acceptance and resolution with RAPGAP (ME+PS) and DJANGO (color dipole model) <20%
- Correction for QED radiation with HERACLES <15%
- Systematic uncertainties
  - 2% hadronic energy scale -> 4% on cross section
  - model dependence (ME+PS, CDM) -> 3% on cross section
  - lepton energy scale, lepton angle, -> small
- Exp. error ~5%, mainly due to hadronic energy scale and model dependence
- Compared to previous analysis
  - twice luminosity, halved energy scale uncertainty

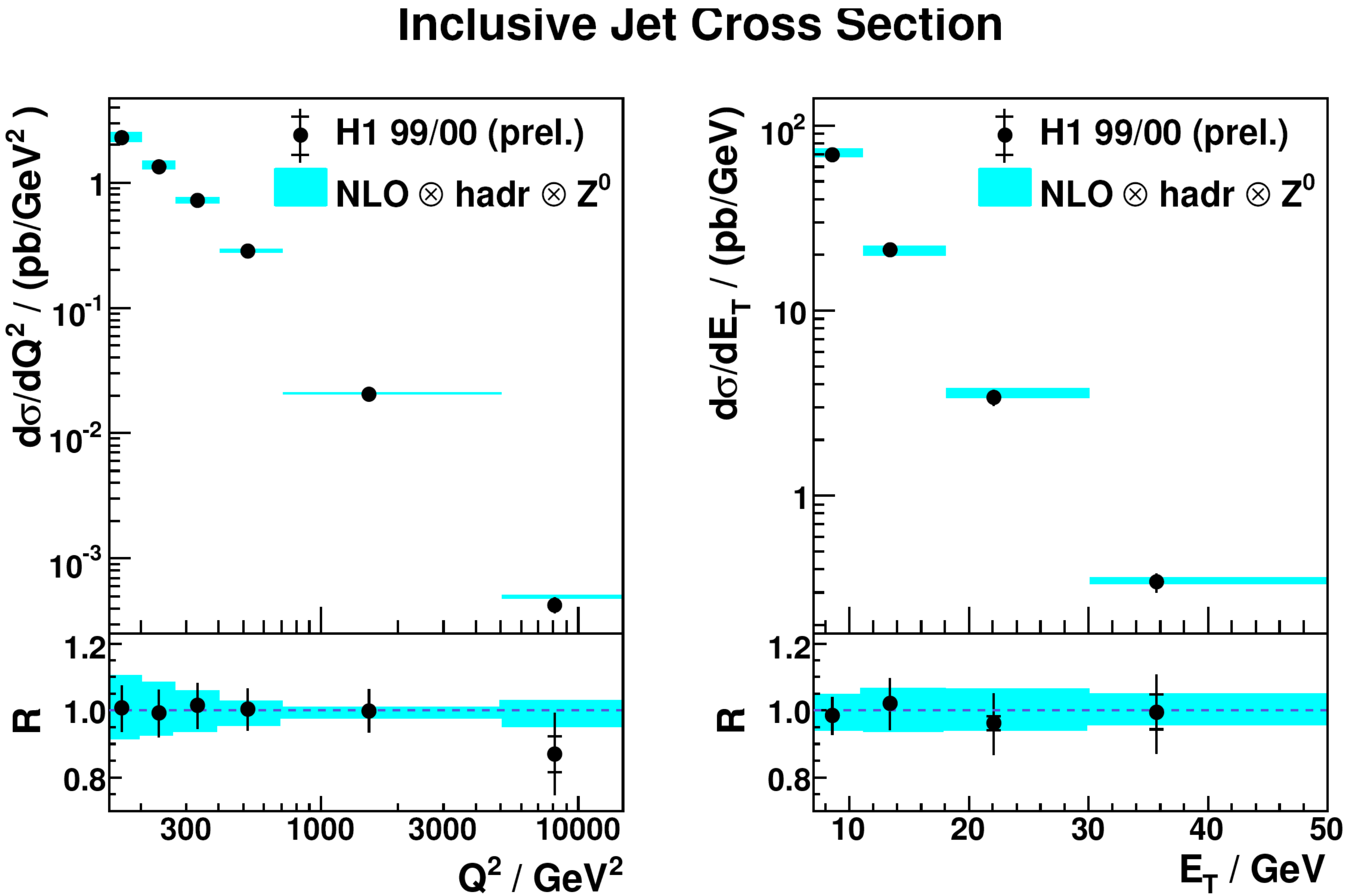
Theory Calculation

- NLOJET++ v2.0.1 for NLO matrix element integration
- fastNLO for PDF convolution and α_s
- Proton PDFs: CTEQ6.5
- Hadronisation corrections obtained with MC event generators DJANGO, RAPGAP
- Electro weak corrections with LEPTO/HERACLES
- $\mu_r = E_T$, $\mu_f = Q$, varied by factor 2 to estimate uncertainty



http://projects.hepforge.org/fastnlo/

Results Single Differentially

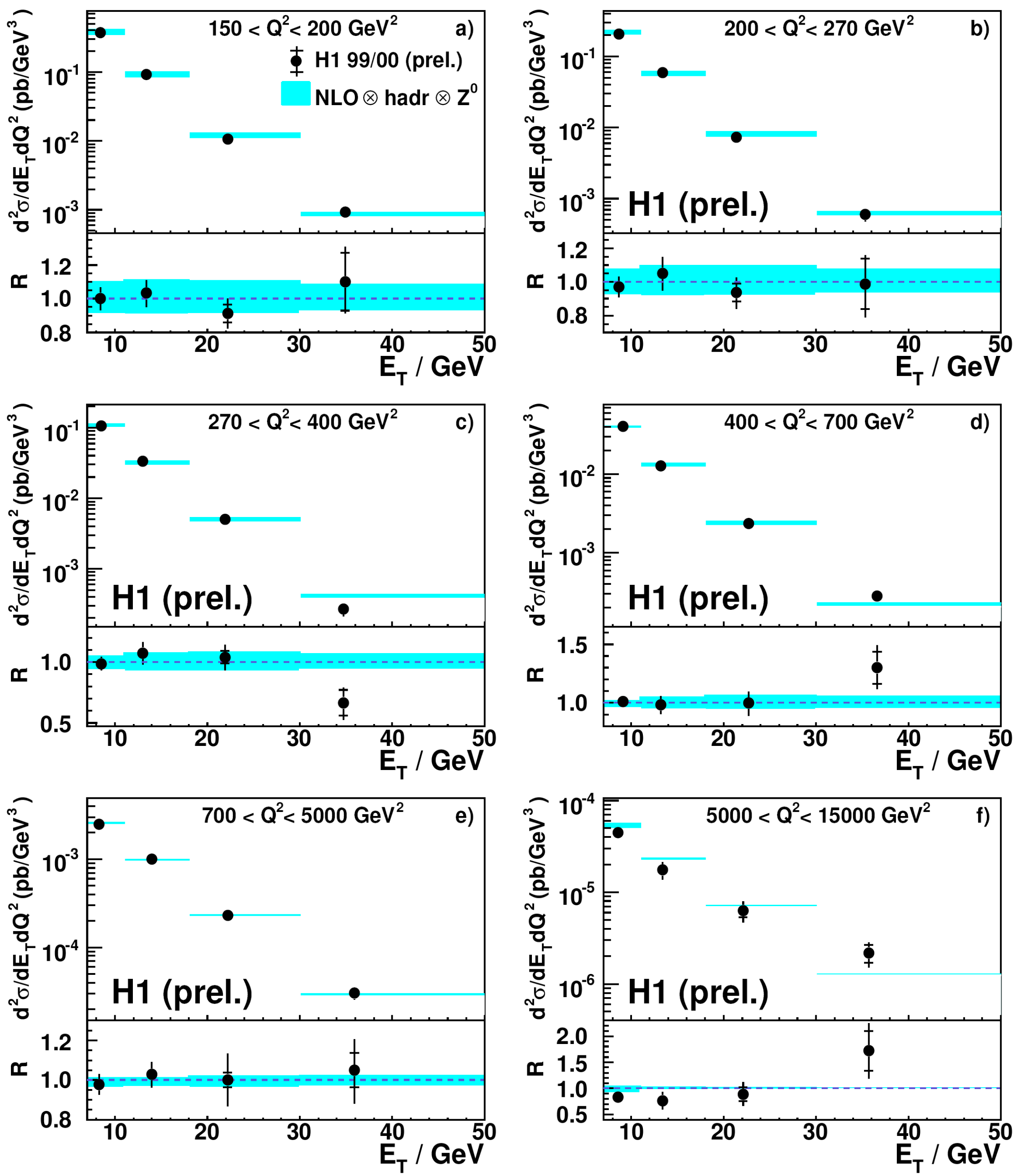


- QCD does a good job describing the jet cross section
- NLO perturbative prediction corrected for hadronisation O(10%)
- At highest Q^2 need to include also Z^0 exchange O(10%)

Results Double Differentially

- the E_T spectrum gets harder with increasing Q^2
- well reproduced at NLO

Inclusive Jet Cross Section

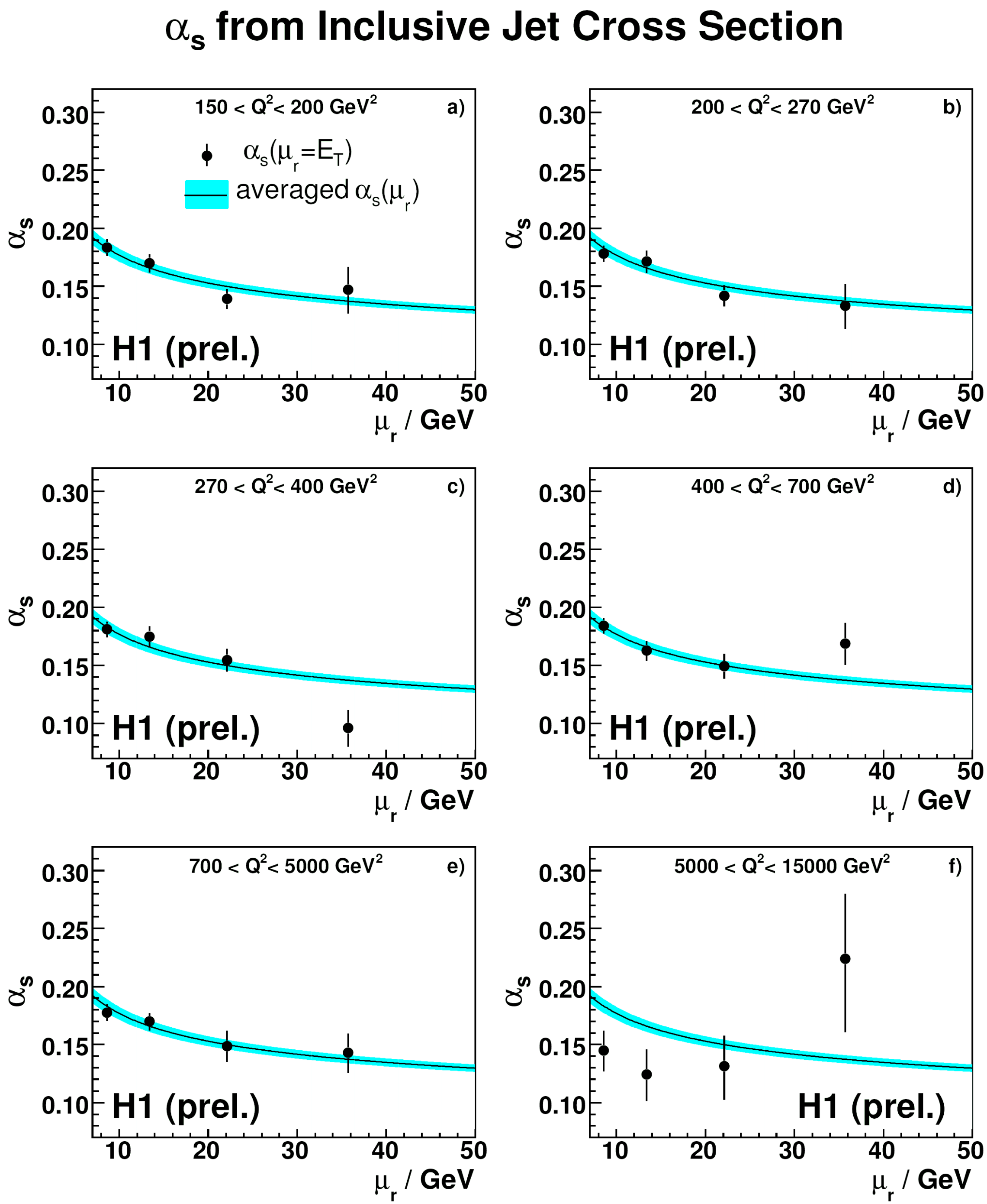


α_S Extraction Method

- Fit of strong coupling to **single** data point trivial
  - vary $\alpha_S(\mu_R)$ until theory matches data
  - check that $\alpha_S(M_Z)$ =0.118 in CTEQ6.5 does not bias the result √
- Calculating **averages**: fit takes into account correlations of systematic experimental errors
  - Hessian method, fit sources of systematic uncertainties, e.g. energy scales
  - data points differ in μ_R, evolve to common scale: fit $\alpha_S(M_Z)$
- Theory error on α_S by offset method: repeat fit with different scales and hadronisation corrections, add in quadrature

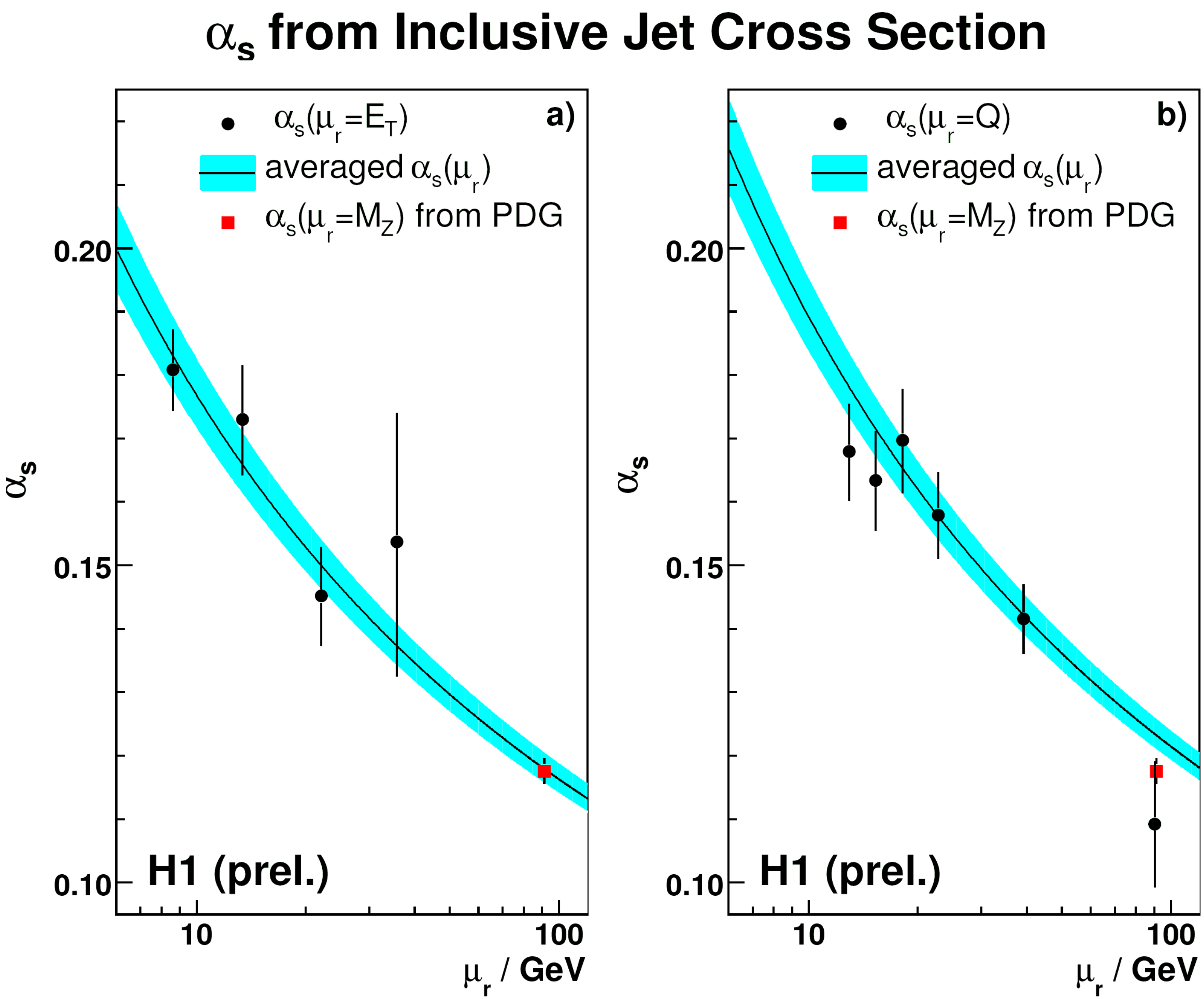
α_S Results

- Each data point yields one α_S
- Renormalisation scale chosen here: E_T of the jet
- Highest Q^2 interval statistically limited
- Running of α_S is demonstrated
- Results are compatible -> calculate the average



Asymptotic Freedom

- Points: average of E_T or Q^2 intervals
- Band: overall average
- Q as renormalisation scale yields a slightly worse description
- Errors are experimental only
  - NLO scale uncertainty → 4% error on α_S
  - NNLO will help
- Compatible with world mean



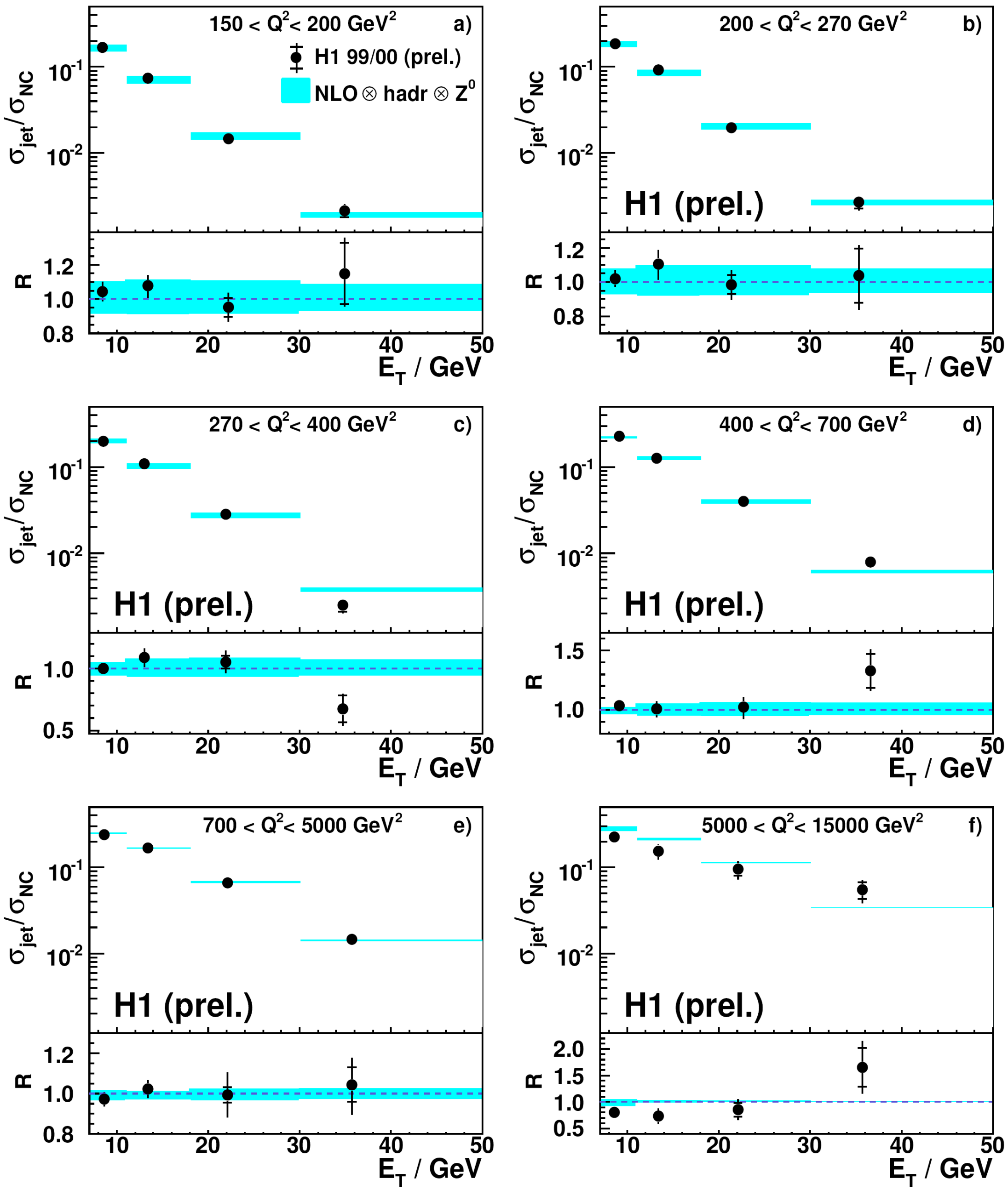
Normalised Jet Cross Section

- Jet analysis applied in NC DIS phase space (Q^2,y)
- Alternative: instead of #jets (incl. jet cross section) use #jets/#events (normalised incl. jet cross secion)
- Equals $\sigma^{jet} / \sigma^{NCDIS}$
- Ratio calculated at detector level -> systematics √
- Luminosity uncertainty cancels, exp. systematics reduced
- PDF uncertainty reduced
- Use DISENT and fastNLO for calculation of σ^{NCDIS} at NLO
- Improve precision of α_S fit

Normalised Jet Cross Section (2)

- Appearance very similar to inclusive jet cross section
- More jets per event with increasing Q^2
- Theory error for jet and NC DIS part assumed uncorrelated
- El. weak correction cancels only partly:
  - cut on jet E_T shifts mean Q^2 to higher values

Normalised Inclusive Jet Cross Section



Numerical Values

- Inclusive jet cross section, using 24 data points

$$\alpha_s(M_Z) = 0.1179 \ \pm 0.0024\,(\mathrm{exp.})\ ^{+0.0052}_{-0.0032}\,(\mathrm{th.})\ \pm 0.0030\,(\mathrm{pdf.})$$

- Normalised inclusive jet cross section, using 24 data points

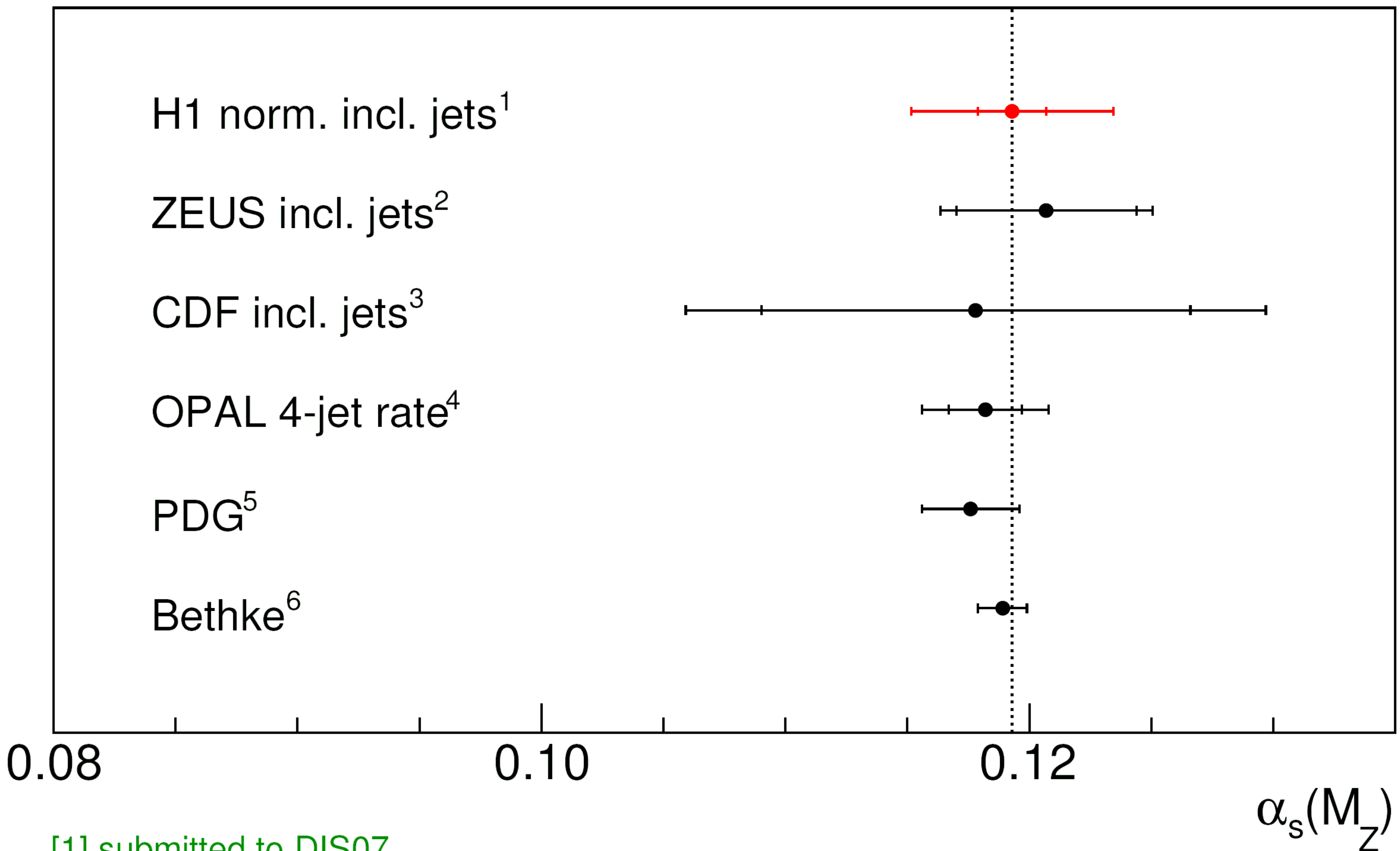
$$\alpha_s(M_Z) = 0.1193 \ \pm 0.0014\,(\mathrm{exp.})\ ^{+0.0046}_{-0.0032}\,(\mathrm{th.})\ \pm 0.0016\,(\mathrm{pdf.})$$

  - Compatible within error, significant reduction of uncertainty
- Theory error main contribution (need NNLO)
- Restricting phase space to where theory error is smallest (700-5000GeV^2)

$$\alpha_s(M_Z) = 0.1172 \ \pm 0.0021\,(\mathrm{exp.})\ ^{+0.0032}_{-0.0017}\,(\mathrm{th.})\ \pm 0.0010\,(\mathrm{pdf.})$$

  - Do not take scale error numerical value too seriously, only order of magnitude

Comparison



[1] submitted to DIS07
[2] hep-ex/0701039
[3] Phys.Rev.Lett.88:042001,2002
[4] Eur.Phys.J. C47(2006)295-307
[5] J.Phys.G33:1-1232,2006.
[6] Prog.Part.Nucl.Phys.58:351-386,2007.

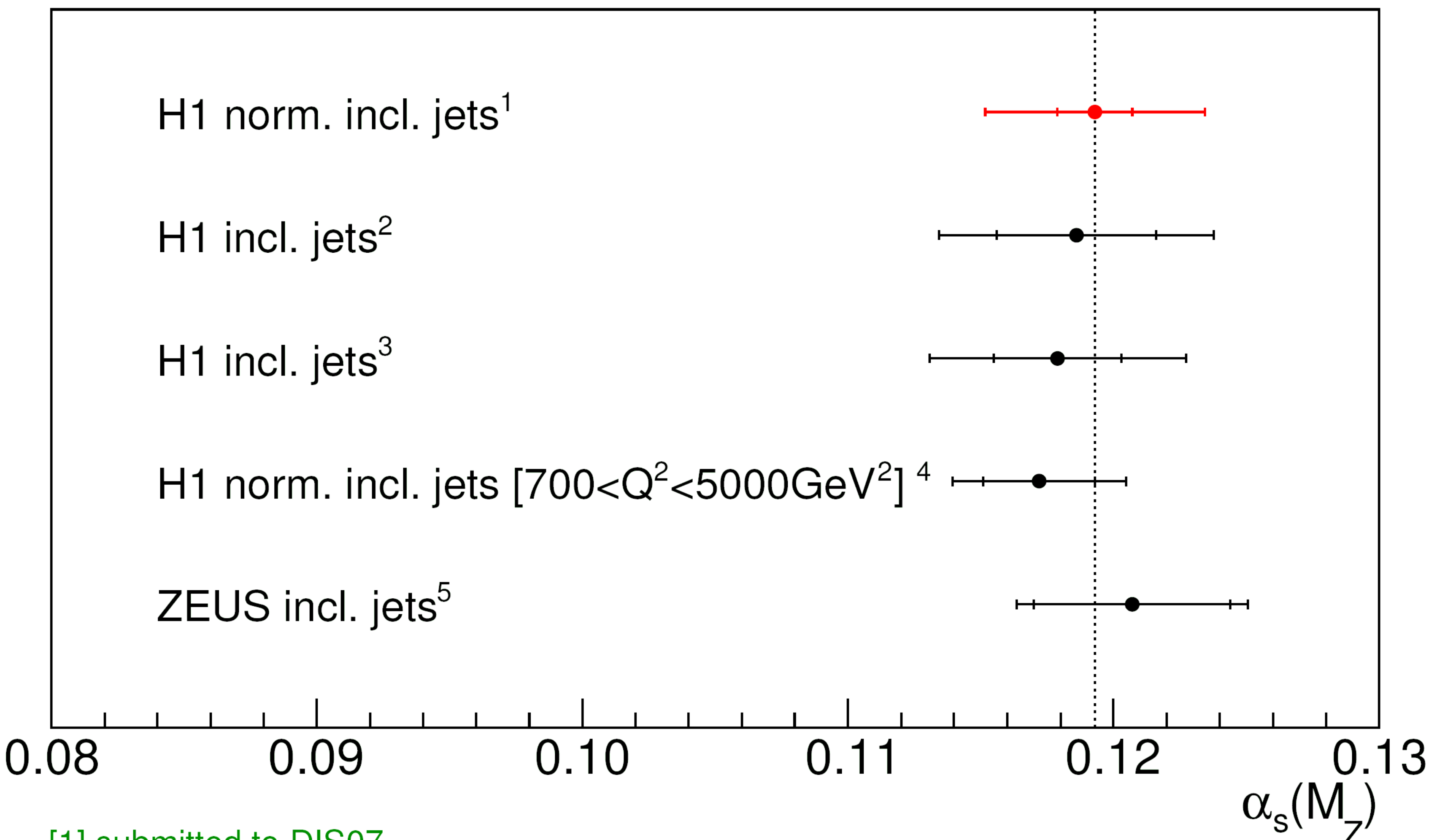
Summary

- Update on H1 inclusive jet cross section with **improved** precision
- Good description by pQCD at NLO (with hadronisation & Z^0)
- α_S fit, with small **experimental** uncertainty, large scale and pdf error
- Precision can be improved by fitting **normalised** inclusive jet cross section

$$\alpha_s(M_Z) = 0.1193 \ \pm 0.0014\,(\mathrm{exp.})\ {}^{+0.0046}_{-0.0032}\,(\mathrm{th.})\ \pm 0.0016\,(\mathrm{pdf.})$$

- exp. error at the 1% level, **competitive** and consistent with other determinations
- HERA II statistics will allow for further improvements

Backup



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[2] Eur.Phys.J. C19(2001)289-311

[3] submitted to DIS07

[4] submitted to DIS07

[5] hep-ex/0701039