Measurement and QCD analysis of inclusive jet production in deep inelastic scattering at ZEUS

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Introduction

- Deep inelastic scattering (DIS) data from *ep* collisions at HERA are essential for exploration of proton-structure and pQCD dynamics
- Inclusive jet data from DIS events are particularly well suited to constrain the gluon PDF and the strong coupling constant $\alpha_s(M_Z^2)$, due to their small uncertainties both on the experimental and theoretical side
- NNLO QCD predictions of jet production became available recently[2]

Analysis

- Based on 347 pb^{-1} of data, recorded at a center of mass energy of 318 GeV at HERA 2 (2004-2007)
- Massless jets, reconstructed using the $k_\perp$-algorithm in the Breit reference frame
- Double-differential measurement as a function of the squared momentum transfer Q^2 and the transverse momentum of the jets in the Breit frame $p_{\perp,\mathrm{Breit}}$
- Focus on region of $Q^2 > 150\,\mathrm{GeV}^2$ and $p_{\perp,\mathrm{Breit}} > 7\,\mathrm{GeV}$
- Final remaining high Q^2 inclusive jet measurement at ZEUS

Systematic uncertainties

- Dominant uncertainty: jet energy scale
  - Arises due to uncertainty of description of the detector response to hadronic objects
  - Vary jet energy in simulation within uncertainty
  - Treated as fully correlated between bins
  - Especially dominant at low Q^2 and low $p_{\perp,\mathrm{Breit}}$
- Model uncertainty: quantify influence of Monte Carlo model on cross sections
- Other experimental sources: detector level cuts, corrections, polarisation
- Theoretical uncertainties: statistical uncertainty, PDF uncertainty, QCD scale uncertainty, hadronisation uncertainty

Simulation

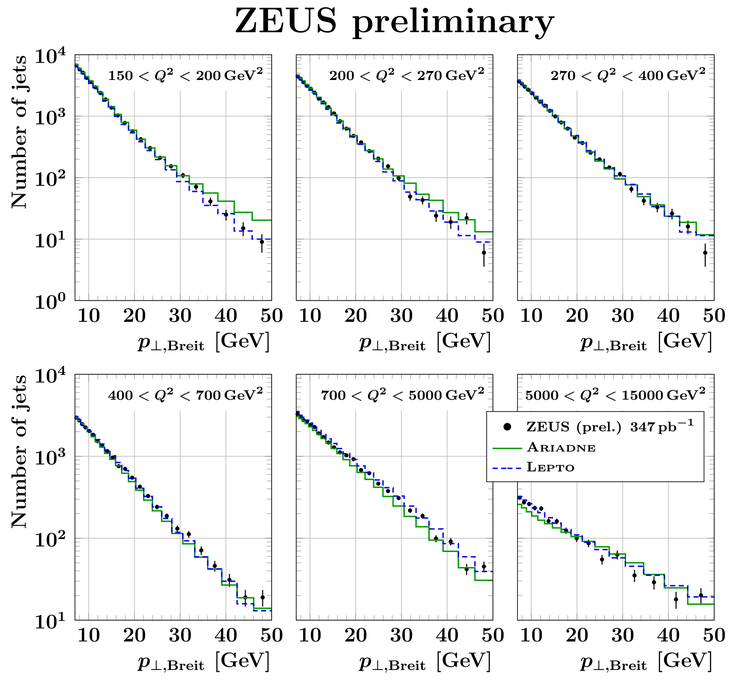
- Jets corrected to hadron level using bin-by-bin unfolding with Monte Carlo samples
  - ARIADNE: colour dipole model
  - LEPTO: matrix element + parton shower

Corrections applied to data

- Electron energy calibration
- Jet energy scale calibration

Corrections applied to simulation

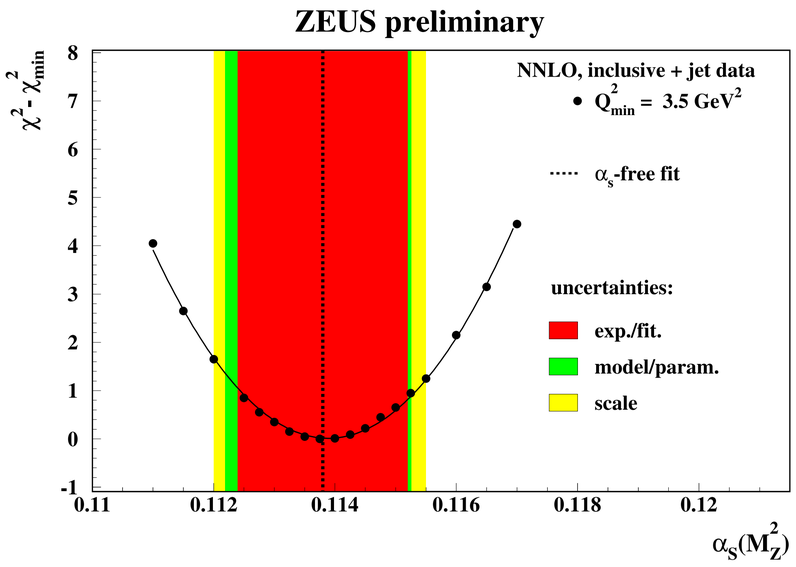
- Electron energy calibration
- Detector response to hadronic objects
- Jet energy scale calibration
- Jet distribution reweighting



Distribution of $p_{\perp,\mathrm{Breit}}$ in bins of Q^2 compared to the Ariadne and Lepto MC predictions. The error bars represent the statistical uncertainties of the data.

NNLO QCD analysis

- Simultaneous fit of $\alpha_s(M_Z^2)$ and PDF parameters, similar to HERAPDF approach[3]
- Datasets used: H1+ZEUS combined inclusive DIS, ZEUS HERA 1 inclusive jets at high Q^2, ZEUS HERA 1+2 dijets at high Q^2, ZEUS HERA 2 inclusive jets at high Q^2 (this analysis)
- Statistical correlations between datasets taken into account via correlation matrix

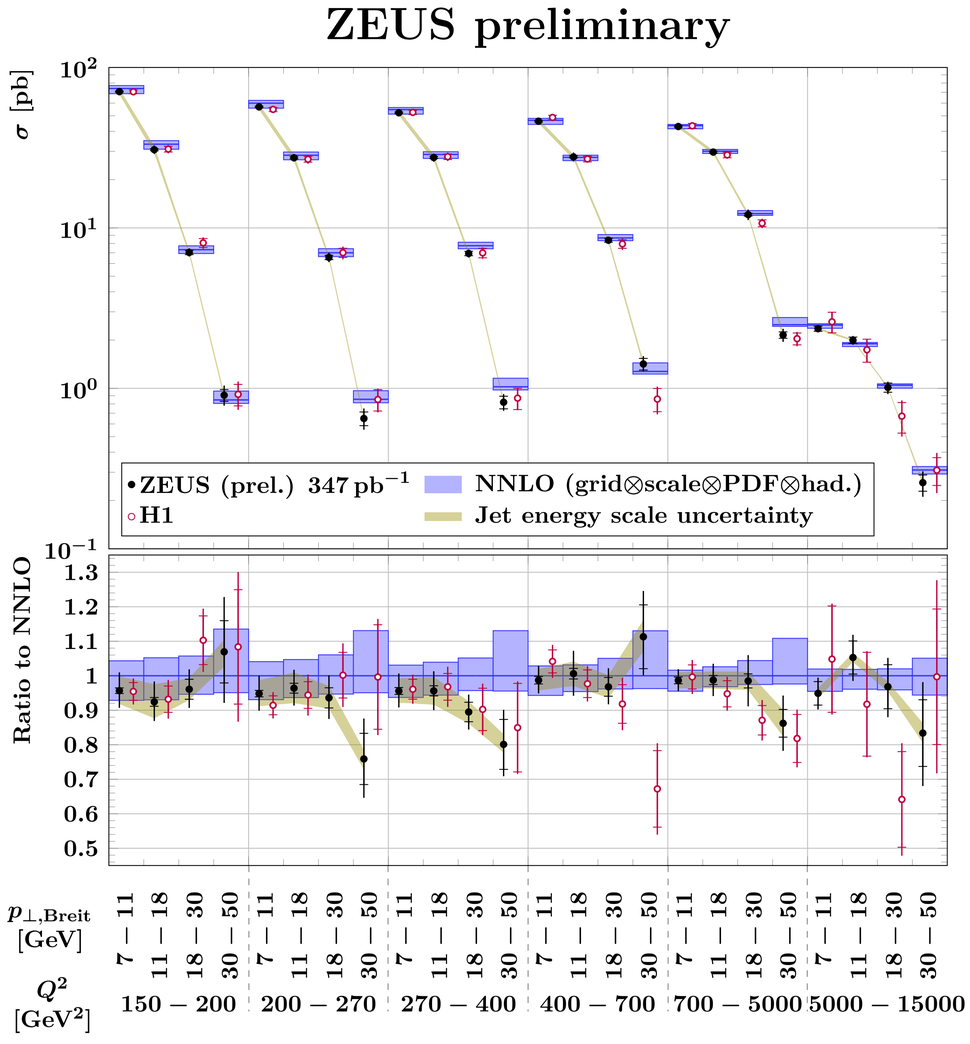


Change in χ^2 as a function of $\alpha_s(M_Z^2)$ for fits with fixed $\alpha_s(M_Z^2)$ at NNLO.

$$\alpha_s(M_Z^2) = 0.1138 \pm 0.0014\,(\mathrm{exp/fit})\ {}^{+0.0004}_{-0.0008}\,(\mathrm{model/param.})\ {}^{+0.0008}_{-0.0007}\,(\mathrm{scale})$$

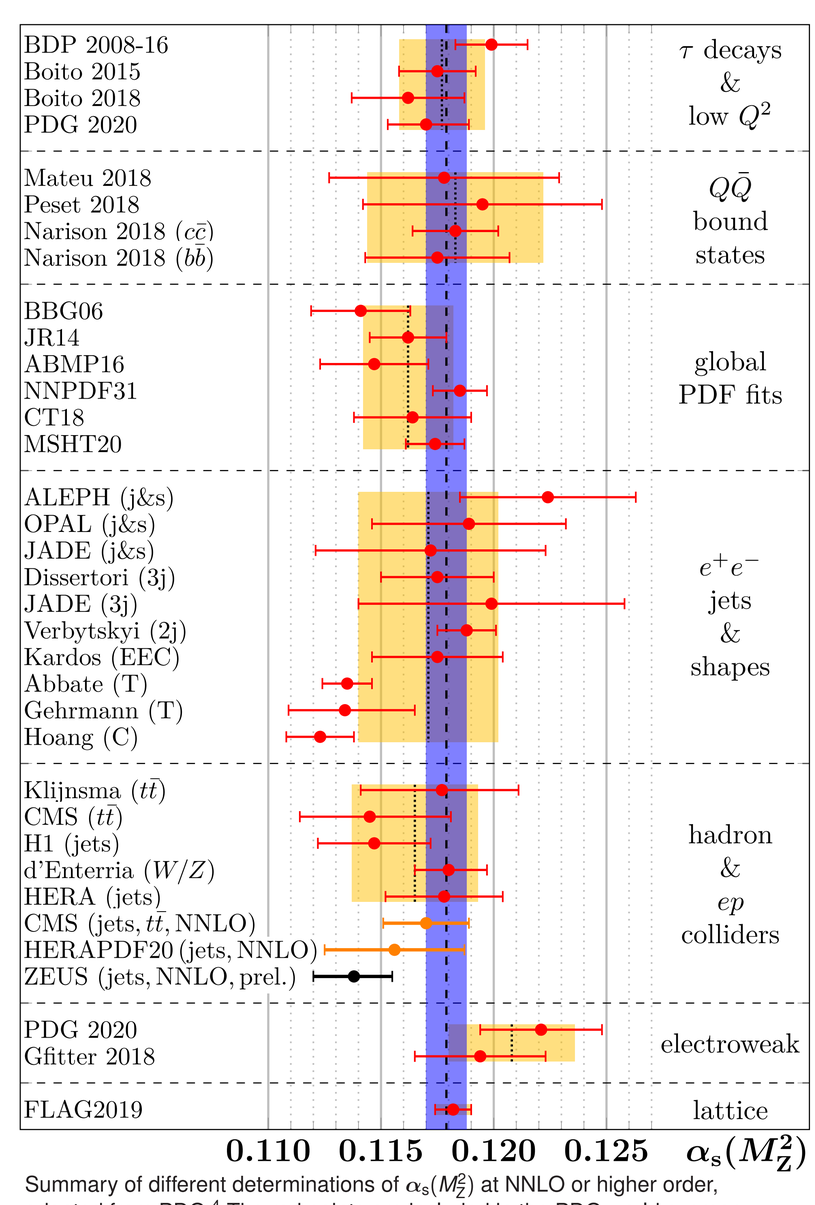
- Experimental, model and parameterisation uncertainties comparable to previous determinations at HERA
- Significantly reduced scale uncertainty compared similar determinations,[3] due to
  - Absence of low Q^2 jet data in the fit. Low scale data tends to increase overall scale uncertainty
  - To a lesser extend: alternative treatment of cross section scale uncertainties as half correlated/half uncorrelated across bins and datasets

Cross section



- Measured cross sections are compatible with previous measurement from H1 collaboration and uncertainties are comparable
- Measurements are compatible with NNLO QCD theory predictions within combined uncertainty; show similar trends relative to theory
- Uncertainty dominated by jet energy scale; at high Q^2 or high $p_{\perp,\mathrm{Breit}}$ statistical uncertainty becomes relevant
- Cross sections will be a valuable ingredient in future QCD analyses

Double-differential inclusive jet cross sections, from the present measurement from ZEUS, the corresponding measurement from H1 and the NNLO QCD predictions. The inner error bars represent the statistical uncertainty and the outer error bars the total uncertainty. Statistical uncertainties of the H1 measurement appear large, due to negative correlations between the data points, that are not shown.



Summary of different determinations of $\alpha_s(M_Z^2)$ at NNLO or higher order, adapted from PDG.[4] The red points are included in the PDG world average. Also shown is a more recent measurement from CMS using jet and $t\bar{t}$ cross sections,[5] the latest HERAPDF result[4] and the determination presented here.

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References:
[1] ZEUS Collaboration, ZEUS-prel-22-001
[2] J. Currie et al., doi:10.1007/JHEP07(2017)018, arXiv:1703.05977
[3] H1 and ZEUS Collaborations, to be submitted to Eur. Phys. J. C, arXiv:2112.0112
[4] PDG, to be published in Prog. Theor. Exp. Phys. 2022
[5] The CMS collaboration, doi:10.1007/JHEP02(2022)142, arXiv:abs/2111.10431