PROCEEDINGS OF SCIENCE

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

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The measurement of jet production in $e^{\pm}p$ scattering at HERA is an important input for the understanding of QCD and a well established tool to test perturbative QCD predictions. Jet cross sections can be used to precisely determine the strong coupling constant and its correlation to the gluon distribution function of the proton.

A new measurement of inclusive jet cross sections in neutral current deep inelastic scattering using the ZEUS detector at the HERA collider is obtained. The data were taken at HERA 2 at a center of mass energy of 318 GeV and correspond to an integrated luminosity of 347 pb^{-1}. Massless jets, reconstructed using the $k_{\perp}$-algorithm in the Breit reference frame, are measured as a function of the squared momentum transfer Q^2 and the transverse momentum of the jets in the Breit frame $p_{\perp,\mathrm{Breit}}$.

The measured jet cross sections are compared to previous measurements as well as NNLO QCD theory predictions. The measurement is used in a QCD analysis at NNLO accuracy to perform a simultaneous determination of parton distribution functions of the proton and the strong coupling constant, resulting in a value of $\alpha_s(M_Z^2) = 0.1138 \pm 0.0014\,(\mathrm{exp/fit})\,^{+0.0004}_{-0.0008}\,(\mathrm{model/param.})\,^{+0.0008}_{-0.0007}\,(\mathrm{scale})$. A significantly improved accuracy is observed compared to similar measurements of the strong coupling constant.

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1. Cross sections

The double-differential inclusive jet cross sections are shown in figure 1. The ZEUS data are very well compatible with the corresponding measurement from the H1 collaboration[4], which is also shown in the figure. Both measurements show similar trends relative to the NNLO QCD predictions, as calculated by the NNLOJET program[5]. Within the combined uncertainty the NNLO QCD predictions agree well with the measured cross sections.

2. Determination of the strong coupling constant

A QCD fit with free $\alpha_s(M_Z^2)$ is performed at NNLO accuracy. The input to the fit consisted of the H1+ZEUS combined inclusive DIS dataset, previous inclusive jet and dijet measurements at

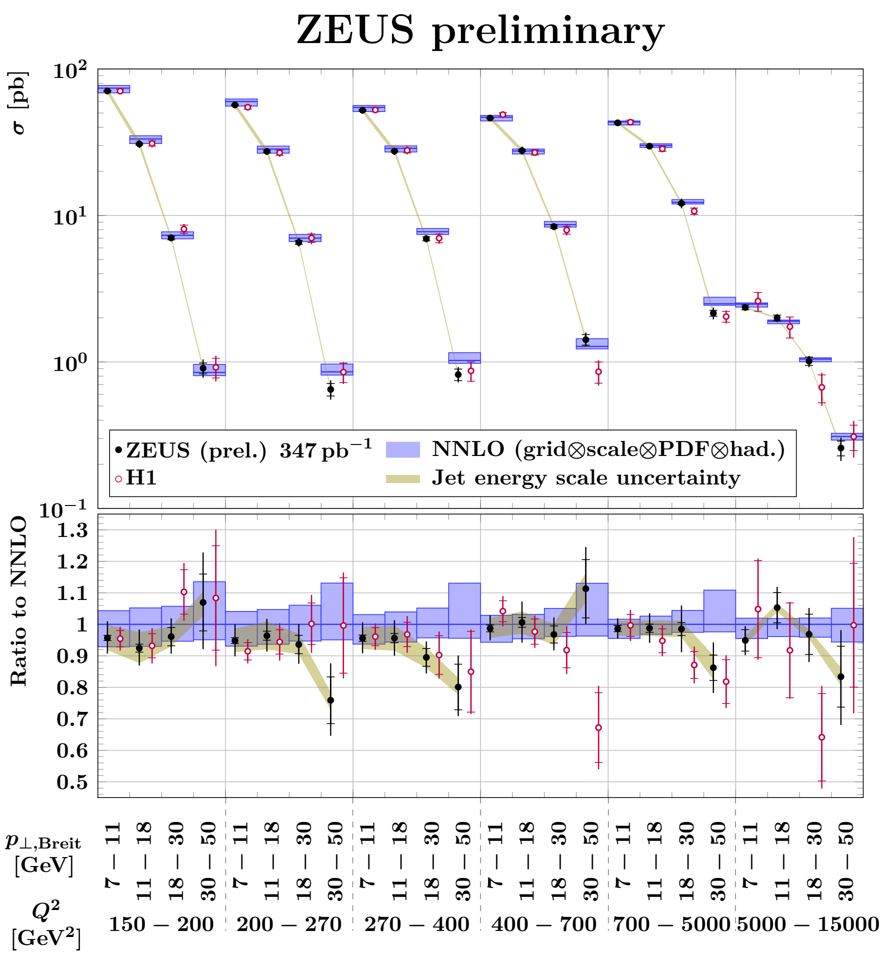

Figure 1: The measured double-differential inclusive jet cross sections. Shown are the present measurement from ZEUS (full dots, black), the corresponding measurement from H1 (open dots, red) [4] and the NNLO QCD predictions using $\alpha_s(M_Z^2) = 0.1155$ (blue band). The inner error bars of the measurements represent the statistical uncertainty and the outer error bars the total statistical and systematic uncertainty. For the ZEUS measurement, the shaded band shows the uncertainty associated with the jet energy scale.

ZEUS as well as the newly measured inclusive jet cross sections[1]. The inclusion of additional jet data in the fit is expected to especially constrain the correlation between the strong coupling constant and the gluon distribution. The fit was performed similar to previous HERAPDF analyses[2, 3]. Using the standard scheme, of fully correlated scale variations, the fit resulted in a value of

$$\alpha_s(M_Z^2) = 0.1138 \pm 0.0014 \text{ (exp/fit)} \,{}^{+0.0004}_{-0.0008} \text{ (model/parameterisation)} \,{}^{+0.0012}_{-0.0005} \text{ (scale)},$$

where 'exp/fit' denotes the uncertainty of the fit, which includes the uncertainty in the experimental input.The additional model and parameterisation uncertainty was determined by repeating the fit with each of the physical input quantities in turn modified by their uncertainty.

The scale uncertainties obtained here are significantly smaller than the ones derived in similar determinations[3]. This effect arises mostly because in this analysis only jet datasets at high Q^2 were used. Due to the treatment of the cross section scale uncertainty as fully correlated across all phase space regions, the inclusion of low-scale data leads to an increased uncertainty of $\alpha_s(M_Z^2)$.

To further mitigate this problem, an alternative approach for the treatment of scale uncertainties was investigated. In this case, the scale uncertainties of the jet part were calculated under the assumption that the cross section uncertainty due to the scale variation is half correlated/half uncorrelated between bins and datasets. This is motivated by the fact that, while the scale dependence of neighbouring phase space bins is certainly very strongly correlated, the scale dependence of bins far away from each other in phase space, or for different final states, can be much less correlated or even anti-correlated. Such a half correlated/half uncorrelated correlation approach has conceptually already been used in some previous analyses[2, 4]. Using this approach, another reduction of the scale uncertainty of $\alpha_s(M_Z^2)$ is observed, resulting in a value of

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

A comparison of the current measurement to other determinations of $\alpha_s(M_Z^2)$ is shown in figure 2. Due to the small scale uncertainty, the current analysis is among the best measurements at hadron colliders so far[1].

3. Conclusions

A double-differential measurement of the inclusive jet cross section in NC DIS events at ZEUS during HERA 2 has been presented. The measured cross sections are very well compatible with previous measurements and NNLO QCD predictions and the uncertainties are competitive. The small uncertainties of the measurement and the corresponding theory calculations make the dataset an ideal ingredient for precision determinations of the strong coupling constant in future QCD fits.

The dataset has been used to determine the value of the strong coupling constant of $\alpha_s(M_Z^2)$. A significant reduction in the uncertainty is observed compared to similar determinations, which is due to the omission of low Q^2 jet data in the fit as well as, to a lesser extent, an alternative treatment of the correlations in the scale uncertainties.

References

[1] ZEUS Collaboration, ZEUS-prel-22-001 (2022).

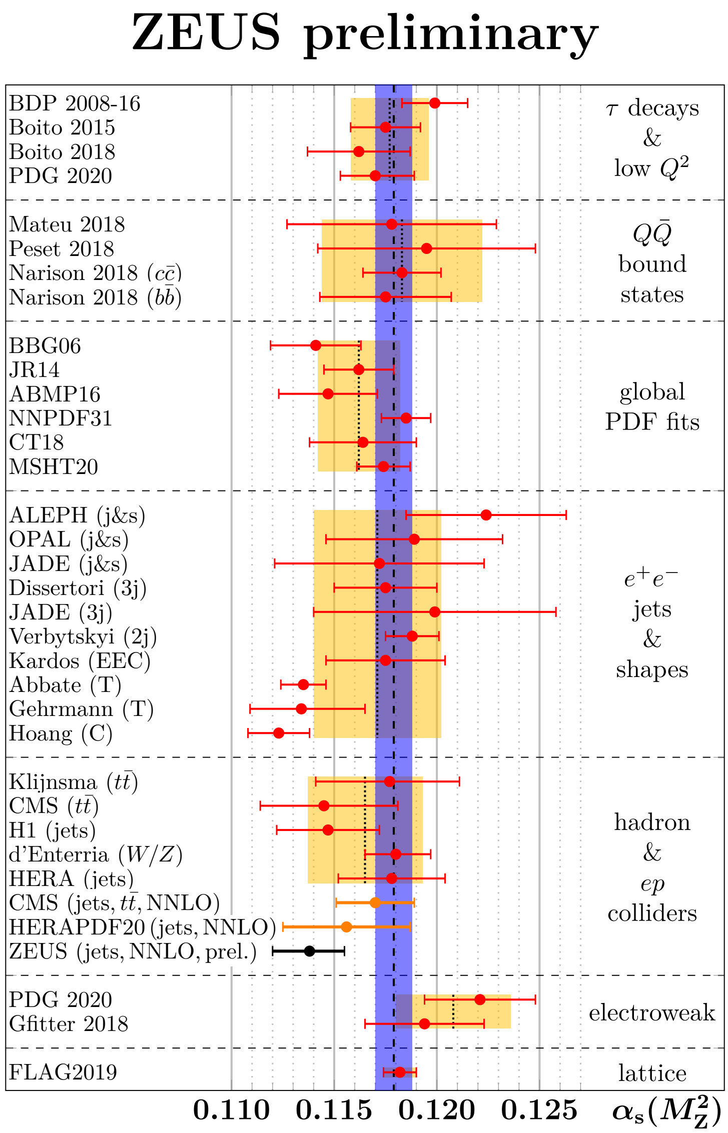

Figure 2: Summary of different determinations of $\alpha_s(M_Z^2)$ at NNLO or higher order, adapted from PDG[6]. The red points are included in the PDG world average. The averages from each sub-field are shown as yellow bands and the world average as a blue band. Recent measurements that are not yet included in the world average are shown in orange and the determination presented here is shown in black[1].

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