Jet Production at HERA and determination of α_s

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On behalf of the H1 and ZEUS collaborations

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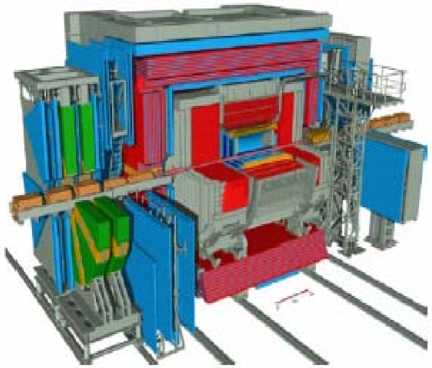
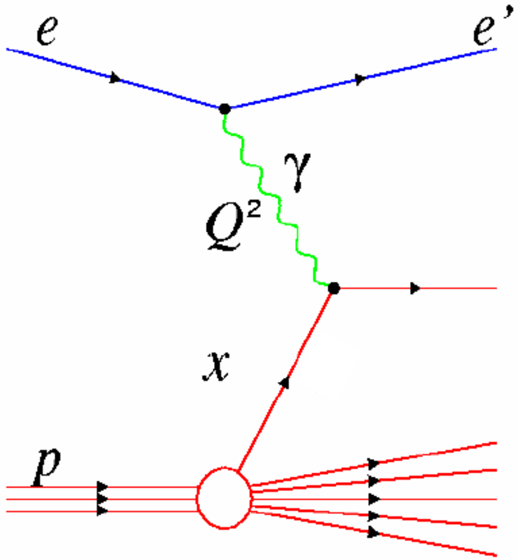
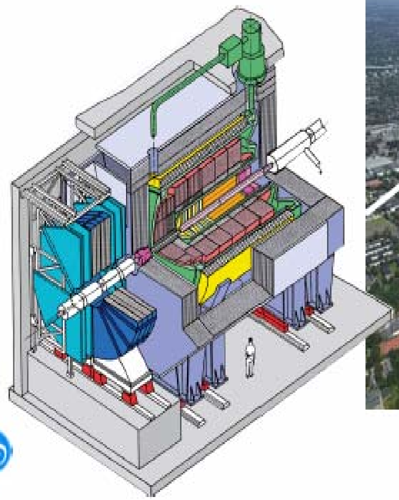
HERA experiments

- ep collider:
- $e^{\pm}$ energy: 27.6 GeV
- p energy: 920 GeV
- Center of mass energy: 319 GeV
- 2 collider experiments: H1 and ZEUS
- Integrated luminosity: ~0.5 fb^{-1} (per experiment)







Q^2 – photon virtuality
x – Bjorken scaling variable
y – inelasticity

Jet Production

Jet production in ep collision at HERA is a testing ground for perturbative QCD (pQCD).

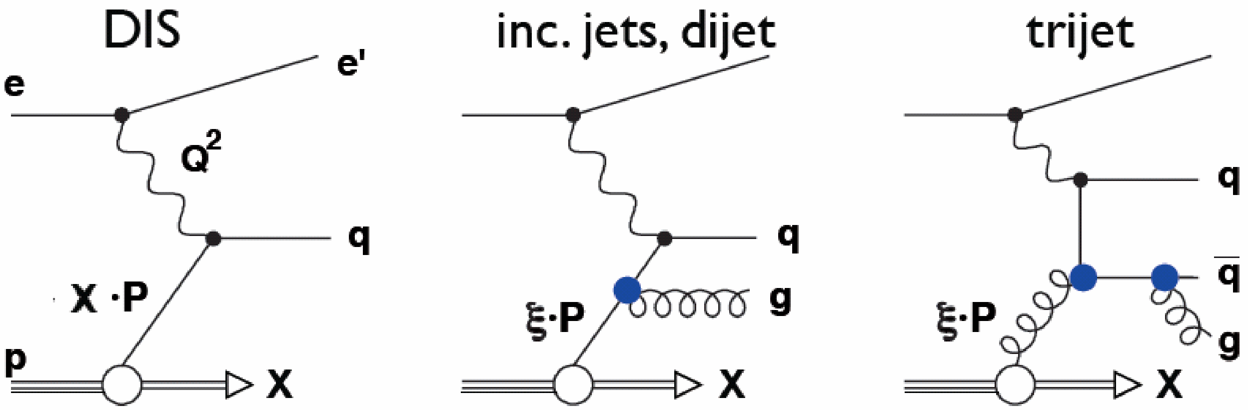
Jet cross sections

- inclusive jet (contribution of every jet in event),
- dijet and trijet (contribution of events with more than two and three jets correspondingly),

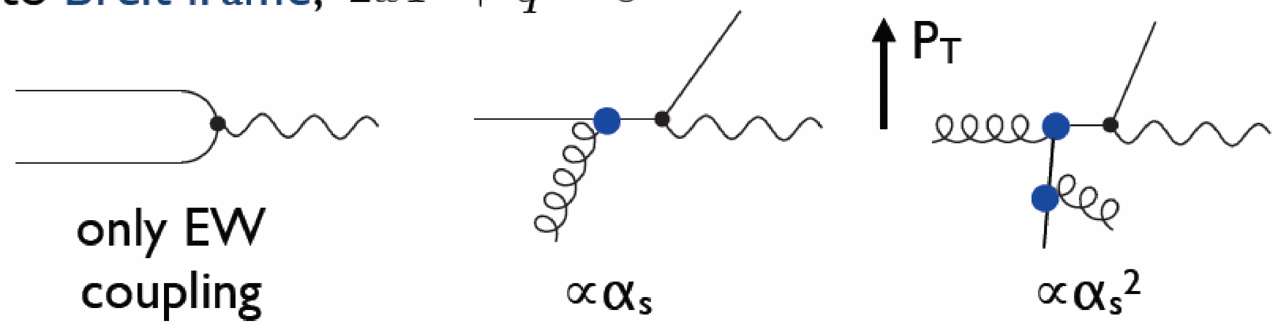
as well as normalised to neutral current (NC) DIS jet cross sections (which have significantly reduced, compared to absolute ones, correlated systematical and lumi uncertainties)

1. used to test pQCD
2. provide a precise determinations of $\alpha_s(M_Z)$
3. restrict gluon PDF-s

Jet Production in DIS



Boost to Breit frame, $2xP + q = 0$



Momentum fraction of struck parton (in LO): $\xi = x\left(1 + \frac{M_{12}^2}{Q^2}\right)$

Jet production at large P_T in Breit is sensitive to α_S directly

Jet Measurements in DIS (H1)

Simultaneous measurement of inclusive, dijet, trijet cross sections and normalised to DIS cross sections (DESY-14-0891) with:

- photon virtuality $150 < Q^2 < 15000$ GeV^2
- inelasticity $0.2<y<0.7$
- jet transverse momentum $P_T > 7$ GeV (inclusive) and $P_T > 5$ GeV (dijet and trijet).

High Statistics:

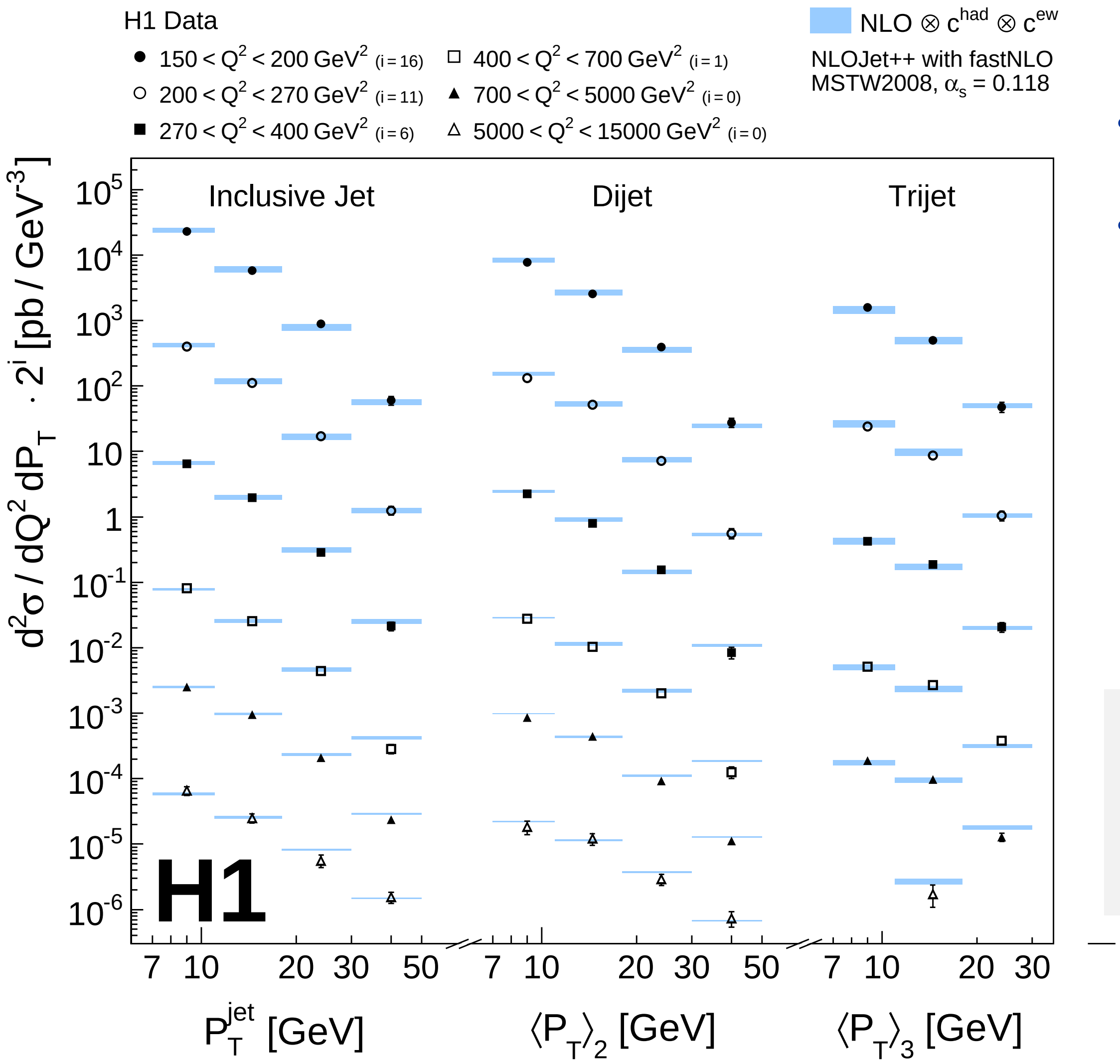
L =351pb^{-1} (small statistical uncertainties even at large Q^2 and P_T)

Excellent control of systematical uncertaities:

electron energy scale 0.5-1% => effect on cross sections < 2%
jet energy scale 1% => effect on cross sections 2-6%
acceptance correction: 4-5% uncertainty

Trigger uncertainty - 1%
Luminosity uncertainty - 2.5%

Multijet Cross Sections in NC DIS at High Q^2



- **Data measured** - using regularised unfolding
- **NLO Calculation** - NLOJet++ corrected for hadronisation effects

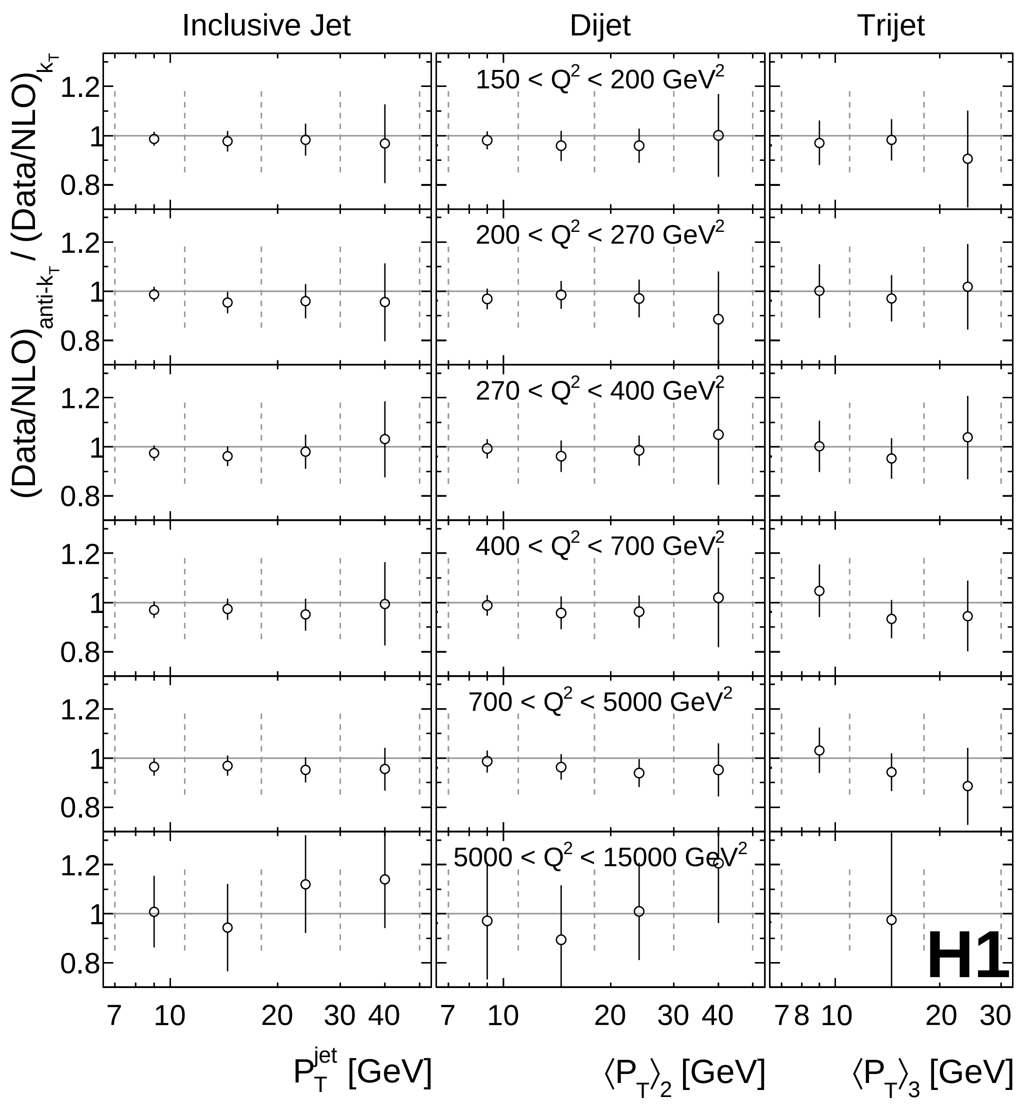
Scale Choice:

$\mu_f^2 = Q^2$

$\mu_r^2 = (Q^2 + P_T^2)/2$

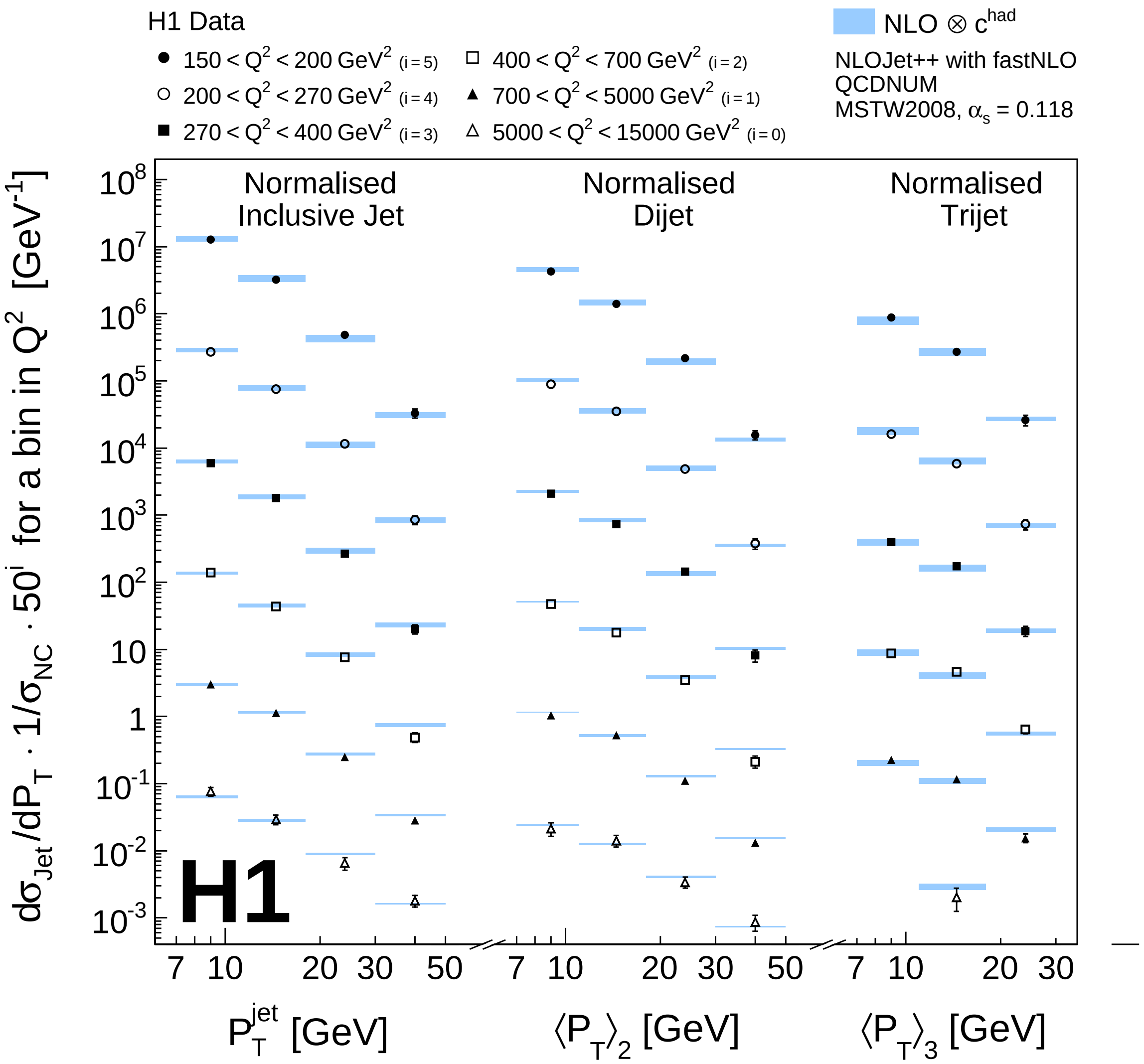
NLO QCD with MSTW2008 describes well inclusive jet, dijet and trijet differential cross sections

A comparison of the k_T and anti− k_T algorithms



Double differential double ratios of anti-k_T jet cross sections to NLO calculations divided by the ratio of k_T jet cross sections to their theory predictions equal to one within their unsertainties

Normalised to NC DIS Multijet Cross Sections at High Q^2



- **Data measured –** using regularised unfolding
- **NLO Calculation -** NLOJet++ and QCDNUM corrected for hadronisation effects

Scale Choice:

$\mu_f^2 = Q^2$

$\mu_r^2 = (Q^2 + P_T^2)/2$

Benefit:

partial cancellation of experimental and theoretical uncertainties

- Small experimental uncertainties
- Good NLO description of the data

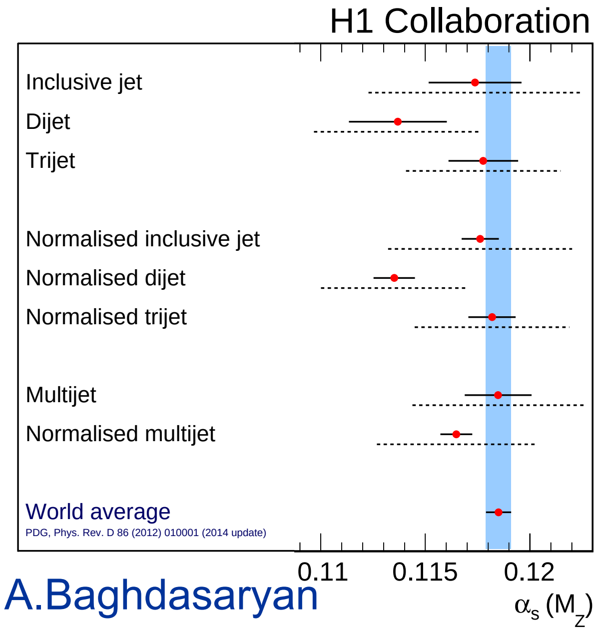
Determination of $\alpha_s(M_Z)$

The measured absolute and normalised cross sections based on k_T anti-k_T jet algorithms were used to determine $\alpha_s(M_Z)$ values.

The best experimental precision on $\alpha_s(M_Z)$ is obtained from a fit to normalised multijet cross sections, yielding:

$$\alpha_s(M_Z) = 0.1165\ (8)_{exp}\ (5)_{PDF}\ (7)_{PDFset}\ (3)_{(PDF)(\alpha s)}\ (8)_{had}\ (36)_{\mu r}\ (5)_{\mu f}$$
$$= 0.1165\ (8)_{exp}\ (38)_{pdf,theo}$$

A very similar result is obtained when using anti-k_T algorithm.



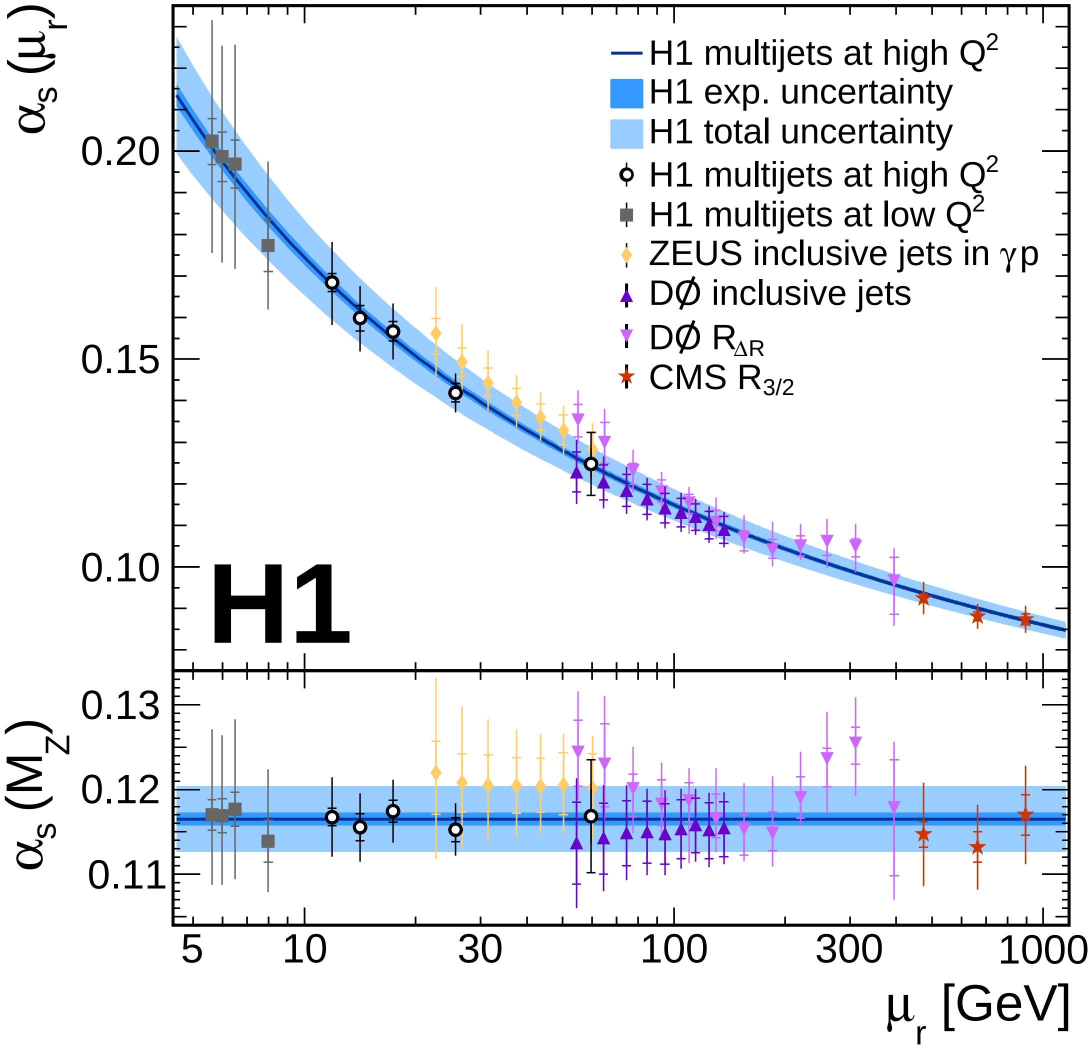
Experimental Uncertainties

Theoretical Uncertainties

The extracted $\alpha_s(M_Z)$-value is experimentally the most precise α_s from jet data. It is compatible within uncertainties with the world average value and with $\alpha_s(M_Z)$-values from other data.

Theoretical uncertainties are larger than the experimental

Running of α_s



The running of $\alpha_s(\mu_r)$, determined from the normalised multijet cross sections is consistent with the expectation from the renormalisation group equation and with values of $\alpha_s(\mu_r)$ from other jet measurements

Trijet Cross Sections in NC DIS (ZEUS)

Trijet production in neutral current DIS has been measured (ZEUS-prel-14-008) with:

- photon virtuality $125 < Q^2 < 20000\ \mathrm{GeV}^2$
- inelasticity $0.2<y<0.6$
- jet transverse momentum $E^{jet}_{T,B} > 8$ GeV.

Statistics:

$L = 295\mathrm{pb}^{-1}$

A major source of systematic uncertainties:
jet energy scale ~1% (3%), for jets with $E^{jet}_{T,L}$ >10GeV (<10GeV)

NLO Calculation -
NLOJet++ corrected for hadronisation effects
Used PDF - HERAPDF1.5

Scale Choice:

$\mu_f^2 = Q^2$

$\mu_r^2 = Q^2 + \overline{E^{jet}_{T,B}}^2$

$\overline{E^{jet}_{T,B}}$ is average transverse momentum of the first three leading jets.

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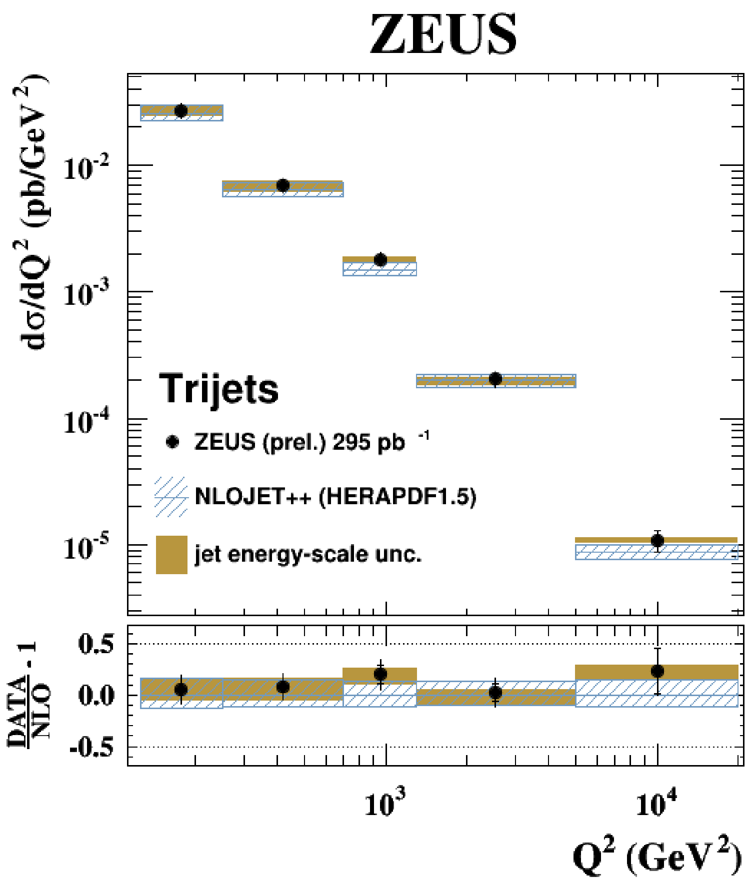
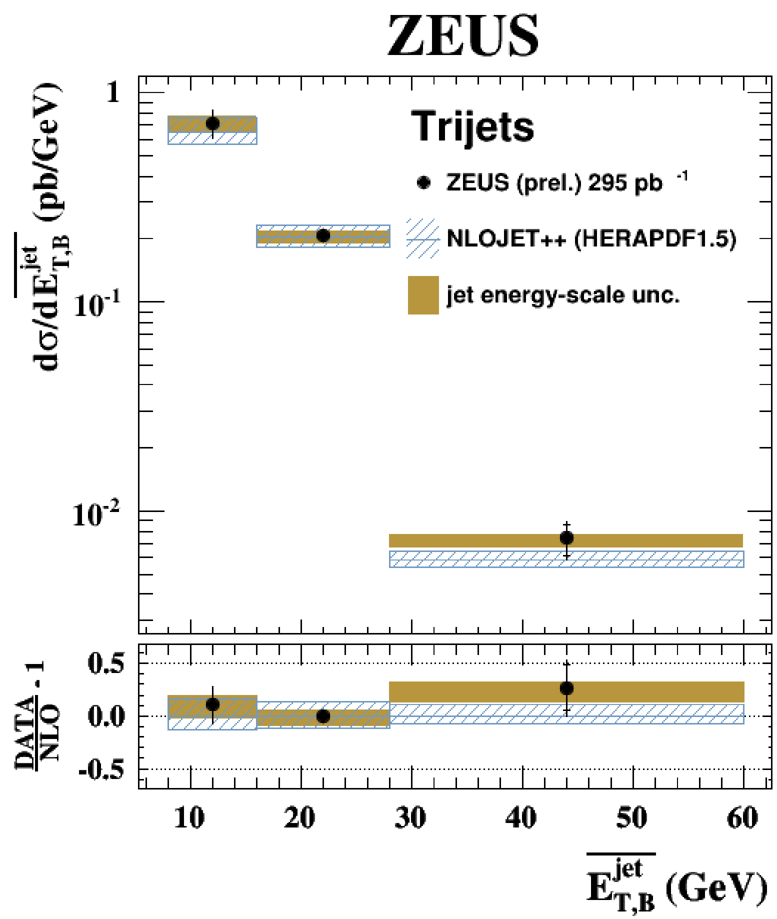
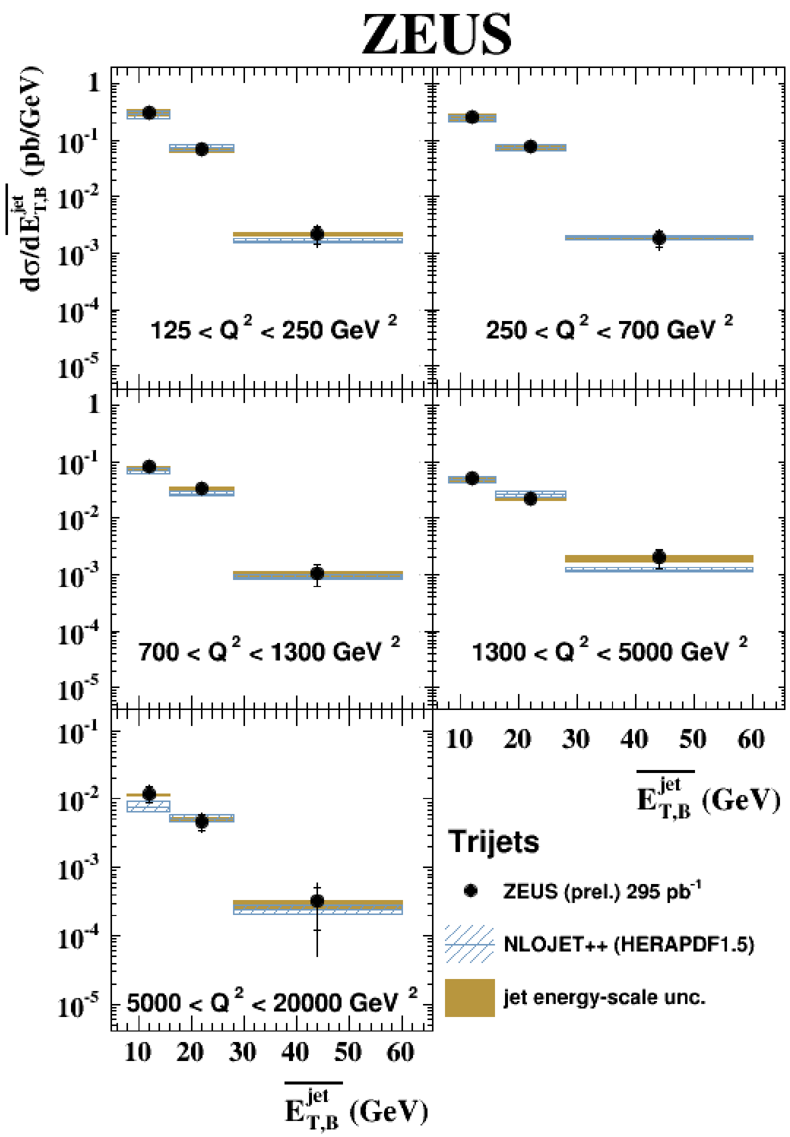
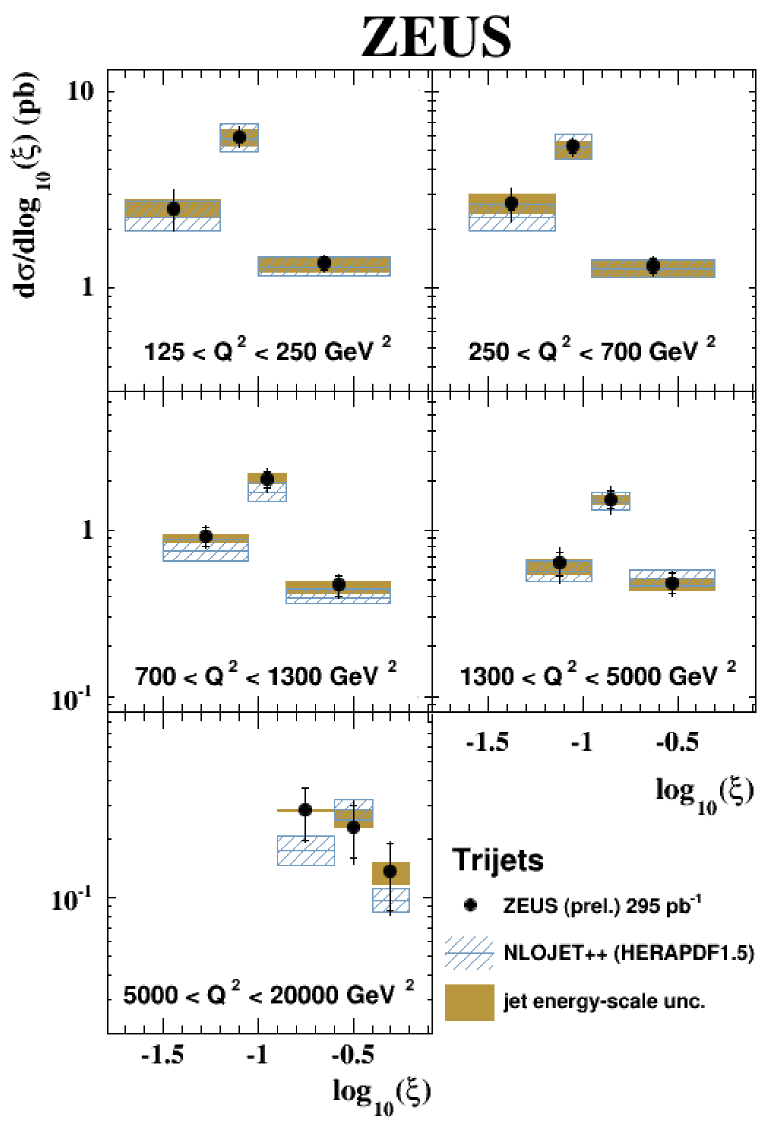
Single Differential Trijet Cross Sections





Double Differential Trijet Cross Sections





Good agreement between data and NLO calculations

Summary

Experimental Data

- Simultaneous measurement of inclusive, dijet, trijet cross sections and normalised to DIS cross sections using regularised unfolding using H1 detector is presented

- The results obtaining when using k_T algorithm are very similar to results obtaining using anti-k_T algorithm

- Measurement of trijet cross sections using ZEUS detector is presented

- pQCD calculations describe the data

Measurement of α_s

- The extracted from normalised cross sections strong coupling is experimentally the most precise α_s from jet data and is compatible with world average

Theory

- Missing the higher orders is the dominated source of uncertainty