High E_T Jets and PDFs at HERA

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Low x Workshop, Helsinki, 1 September 2007

- **Introduction**
- **New Jet Measurements HERA**
- **Application in PDF fits**
- **Summary**

Introduction

what are “high” E_T jets?

in this talk: ~7...100 GeV

this (and appropriate kinematics) means that

.....we are not interested in

- hadronisation
- multi parton interactions
- parton dynamics
- calibration headaches

.....but in

- plain perturbative QCD, DGLAP regime

typical jet selection:

inclusive k_T algorithm

p_T recombination scheme, R=1.0

$-1.0<\eta^{LAB}<2.5$

$7 < E_T^{BREIT} < 50$GeV

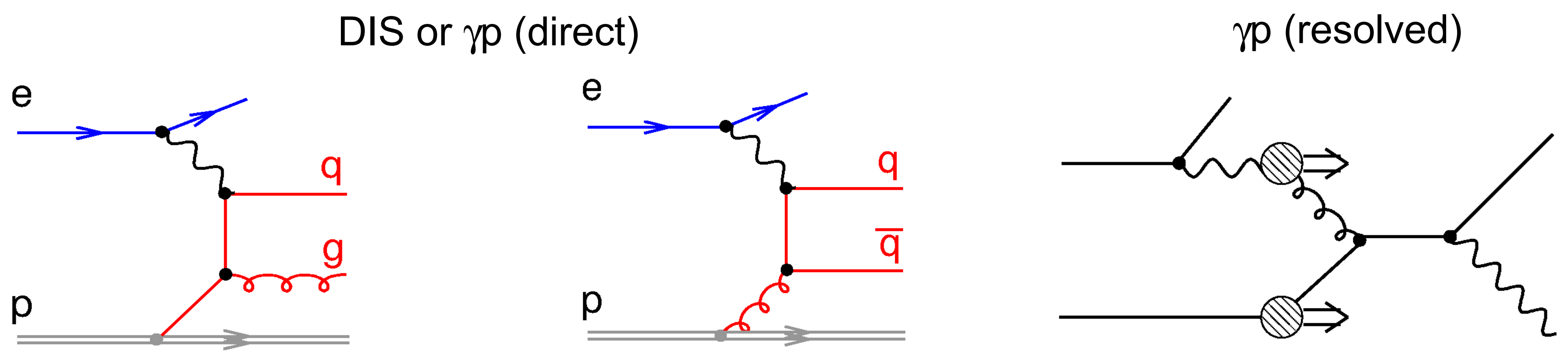
Motivation

Jet production in DIS and photo production

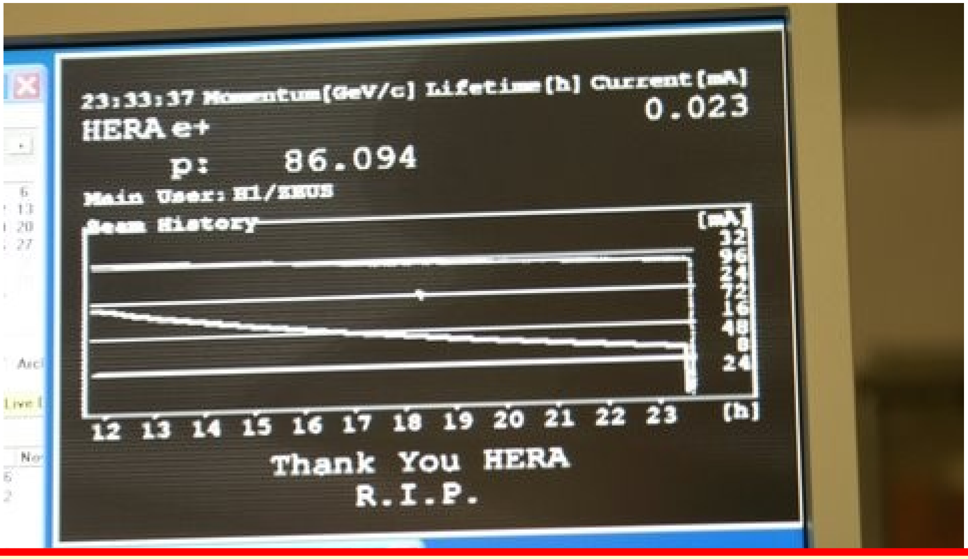
cross section depends on

- strong coupling α_S
- parton density functions of the proton
- QCD matrix elements

e.g. dijet production



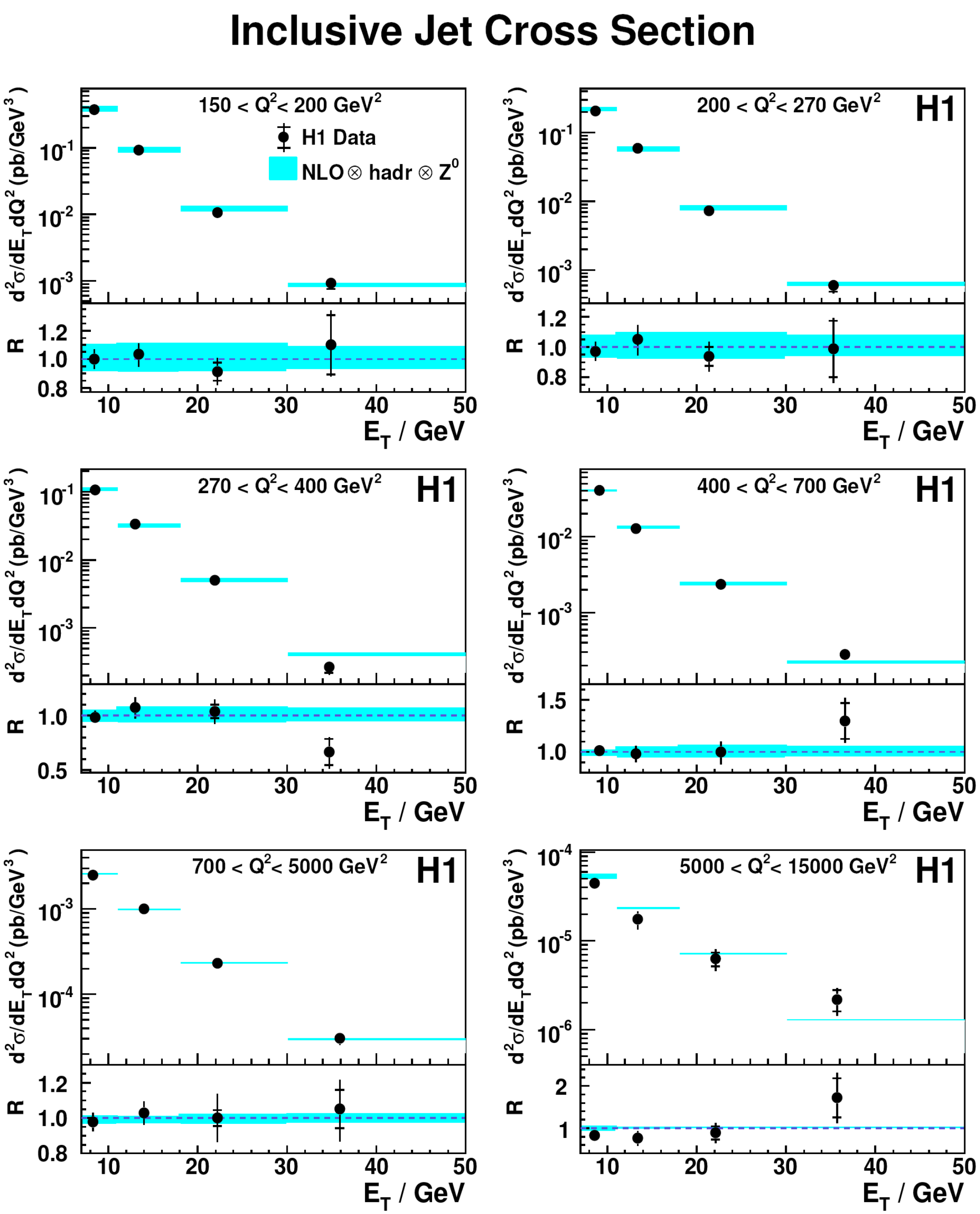
HERA Data Sets



- HERA switched off June 30, two periods:
- HERA I
  - jet analyes typically use ~60-100pb^{-1}
  - mostly published
- HERA II
  - preliminary results for (high energy) data set of ~320pb^{-1}
  - work ongoing to improve systematics, had. E-scale, luminosity

Inclusive Jets at High Q^2

- HERA I, e^+p
- NC DIS: $150<Q^2<15000$ GeV^2
- exp. error ~5%, mainly due to hadronic energy scale and model dependence
- 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%)



Phys.Lett.B(2007), hep-ex/0706.3722

Inclusive Jets at High Q^2

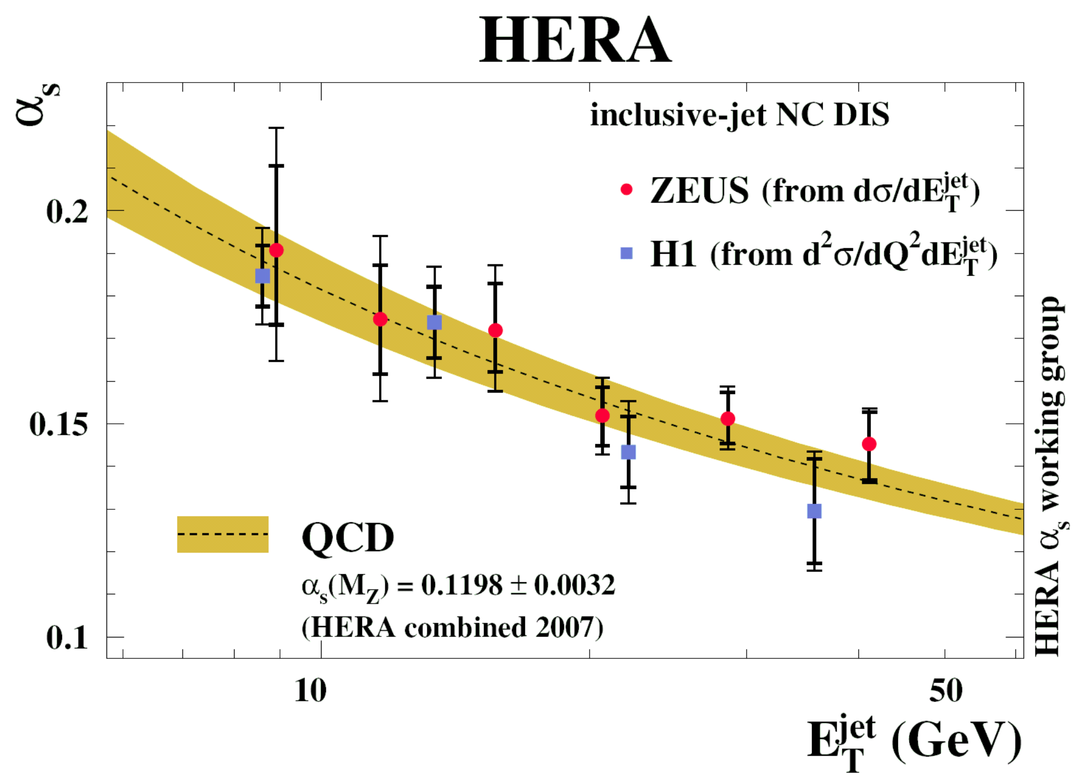
similar results from ZEUS

both used in simultaneous fit of α_S

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

competitive precision and consistent with world average

plus: observation of asymptotic freedom from HERA jets alone



HERA α_s Working Group

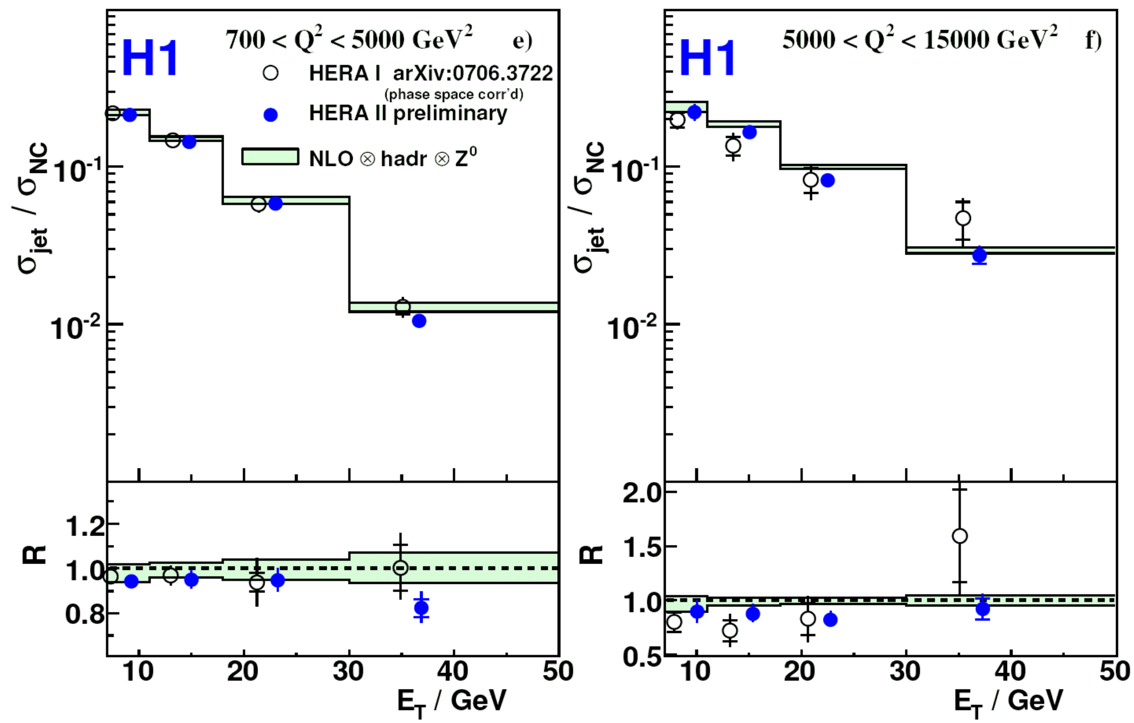
submitted to EPS2007

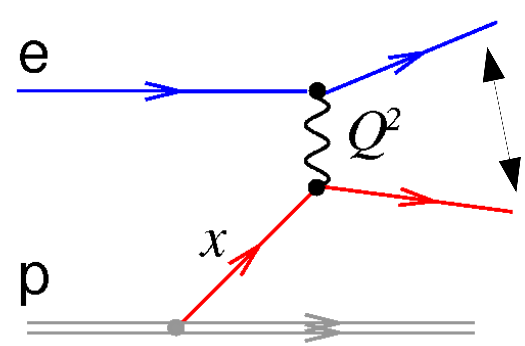
Inclusive Jets at High Q^2

- jet cross section normalised to neutral current DIS
  - partial cancellation of experimental systematics
- significant improvement of exp. uncertainties with HERA II at high Q^2 and high E_T
- work ongoing for best hadronic calibration
  - HERA I: 2% scale unc.
  - HERA II: aim for <=1.5%
- at highest Q2 and ET data will still be statistically limited

HERA II

submitted to EPS2007





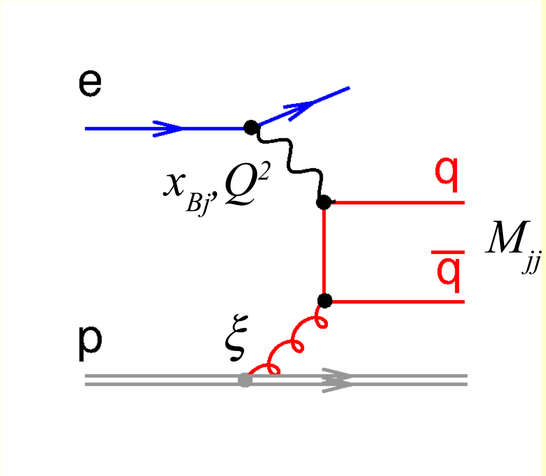
calibrate jet E_T with well measured scattered electron

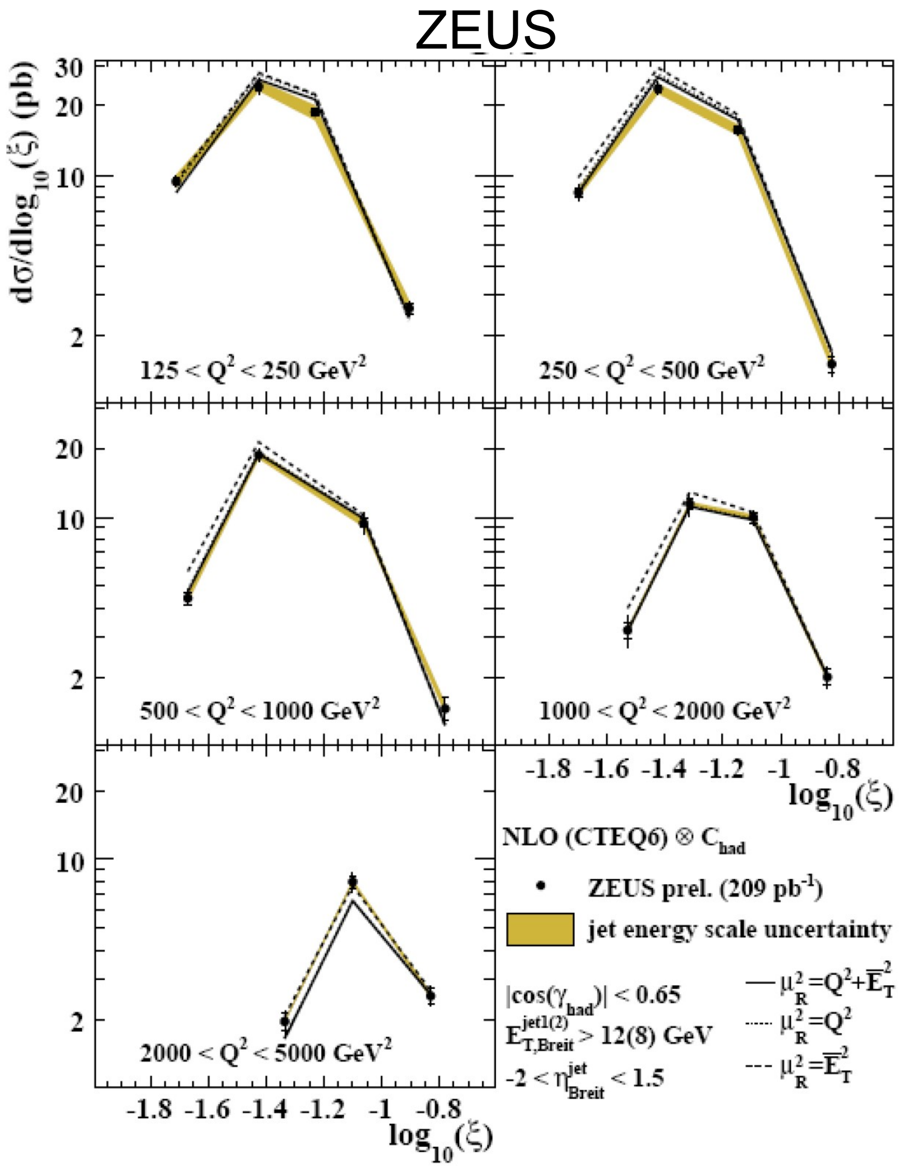
Dijets at High Q^2

HERA I + part of HERA II data: 209pb^{-1}

- data wanted for more precise gluon at high x (LHC needs this)
- dijets in DIS probe PDFs:

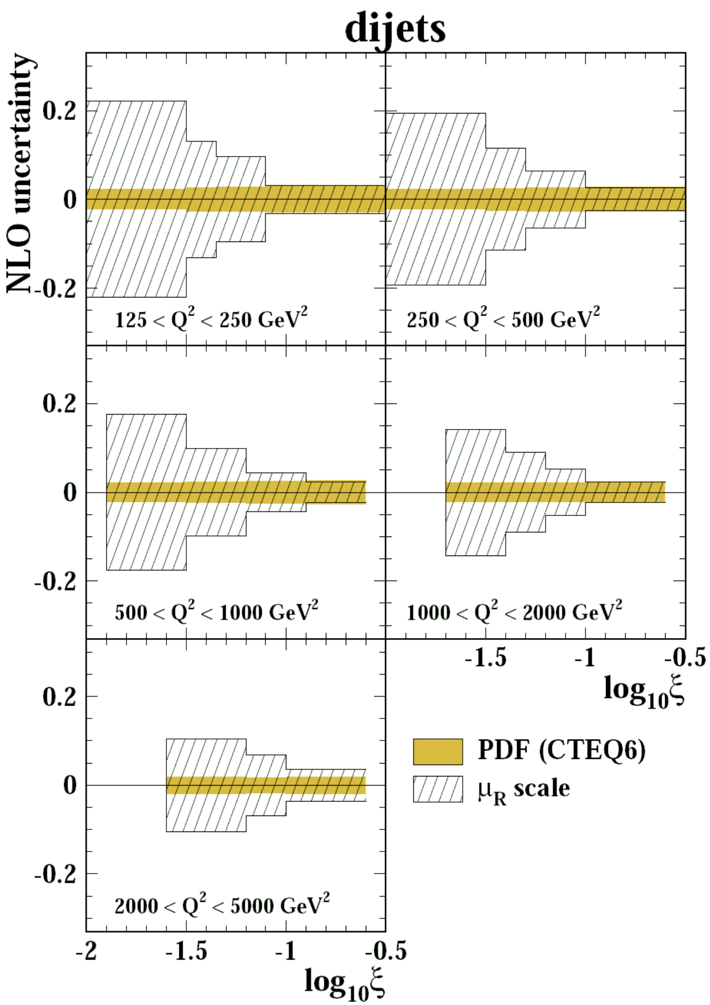
$$\xi \equiv x_{\rm Bj}\left(1+\frac{M_{\rm jj}^2}{Q^2}\right)$$

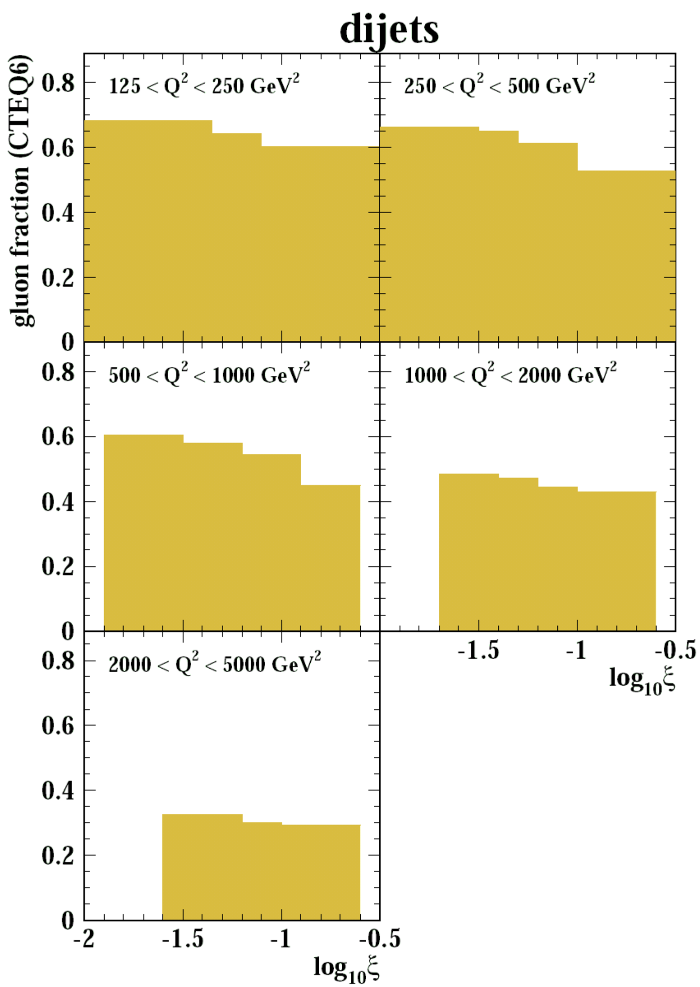




submitted to DIS07

Dijets at High Q^2





At higher ξ moderate scale uncertainty, in the order of the PDF uncertainty

Still sizable gluon fraction, even at higher Q^2

Use this data in future PDF fits to constrain gluon at high x

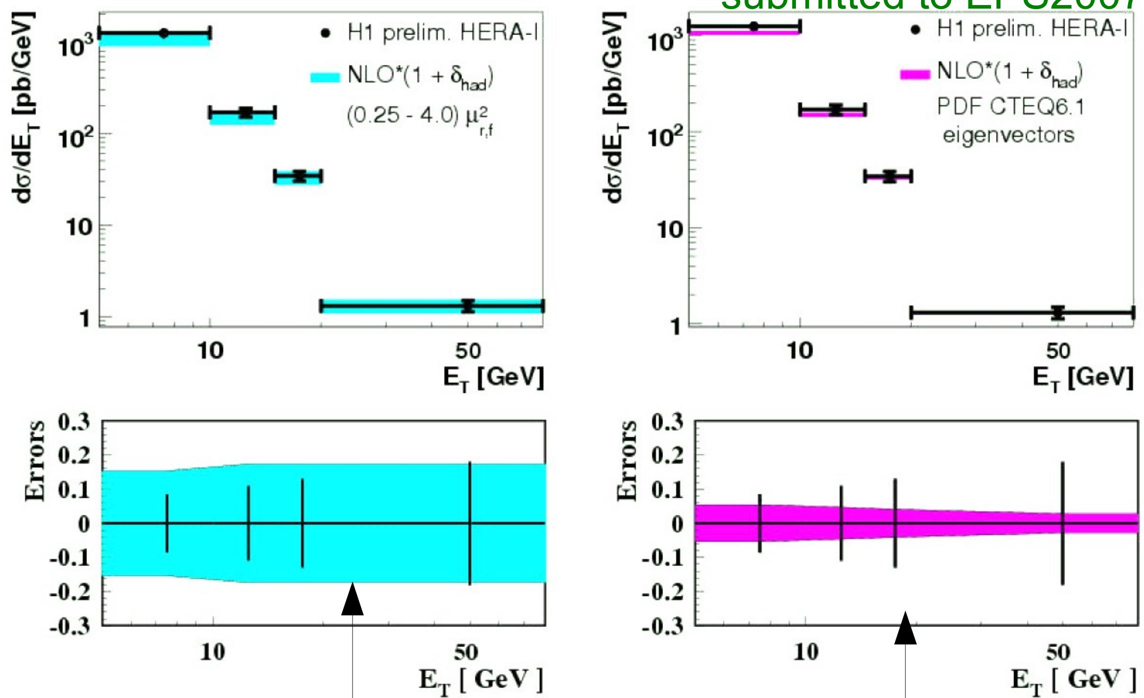
Inclusive Jets at Low Q^2

extension of phase space to lower Q^2 possible?

here: 5...100 GeV^2

(compared to >150 GeV^2)

submitted to EPS2007

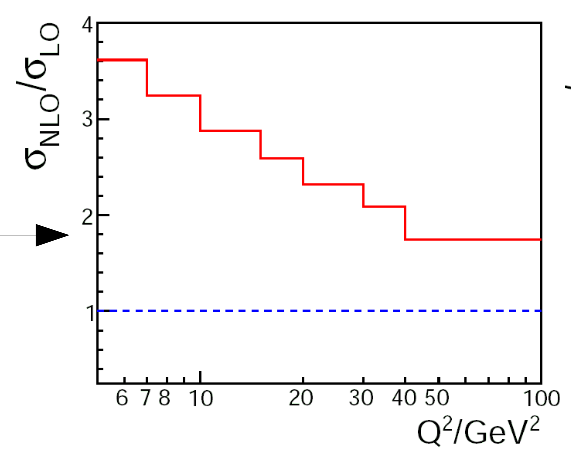


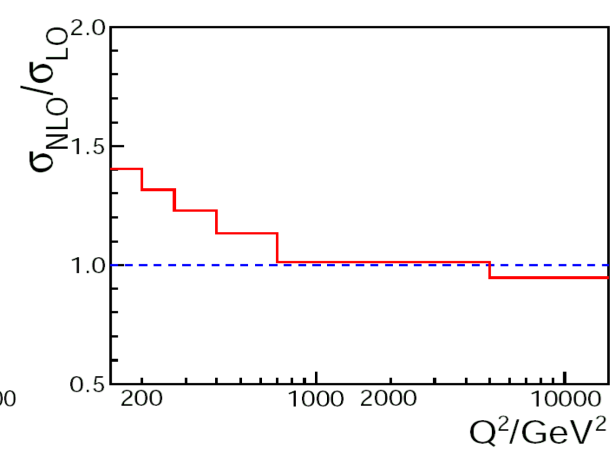
difficult, scale error large
(and larger than PDF error)

scale+hadronization

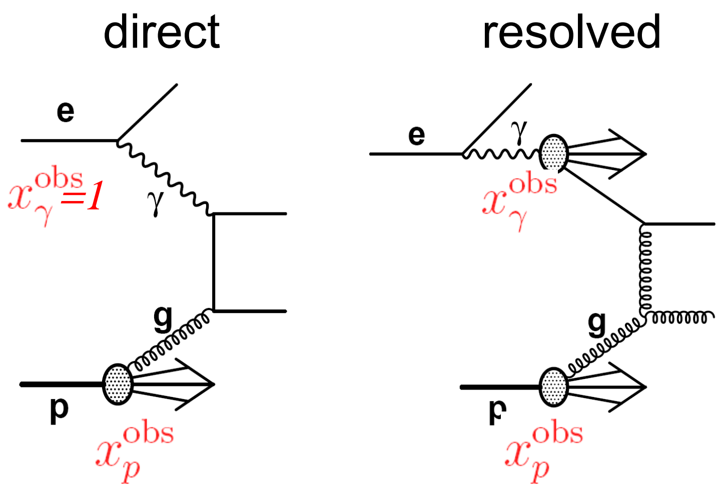
PDF

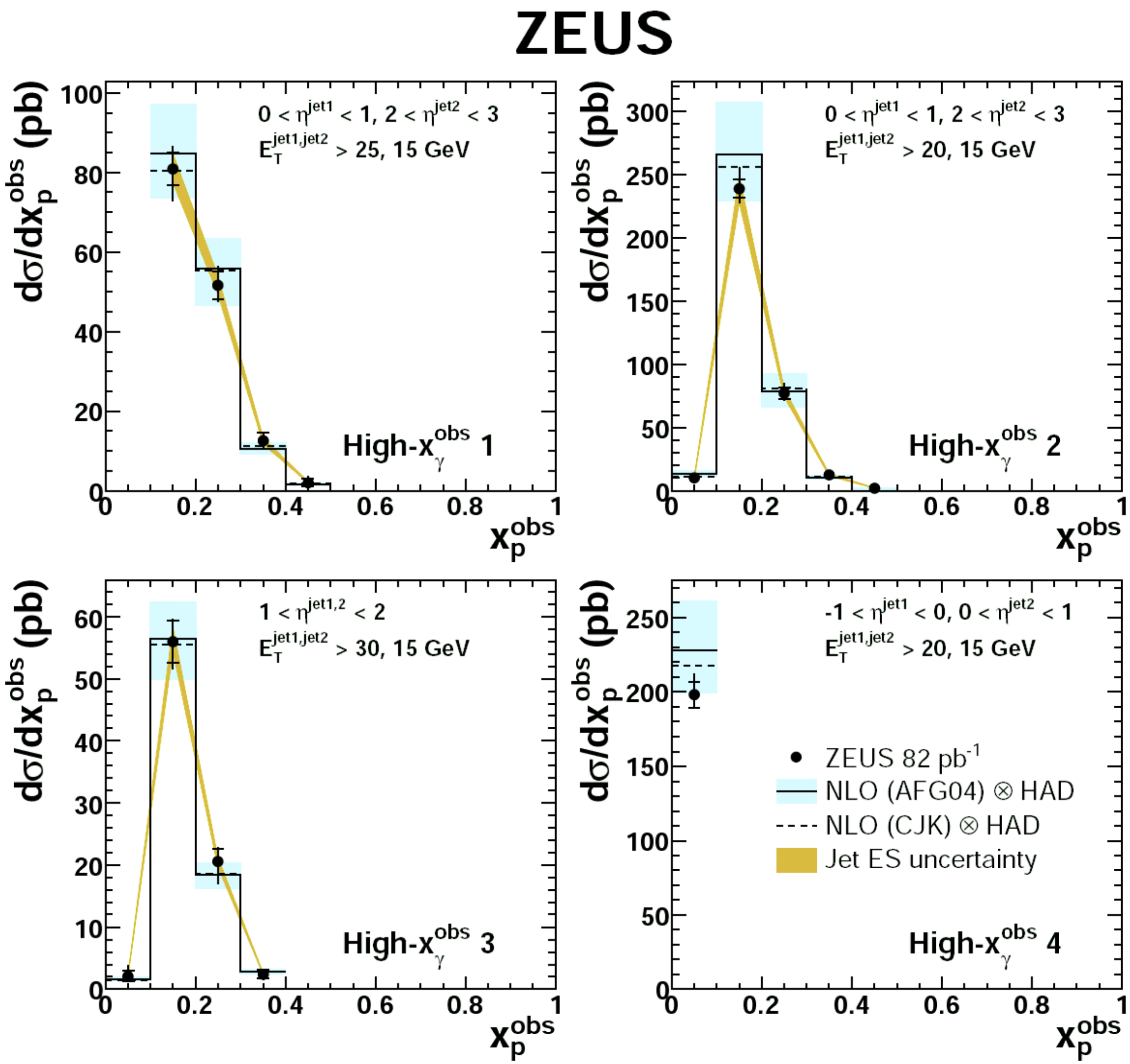
k-factors rise strongly below ~100GeV^2, need NNLO!





Dijets in Photo Production





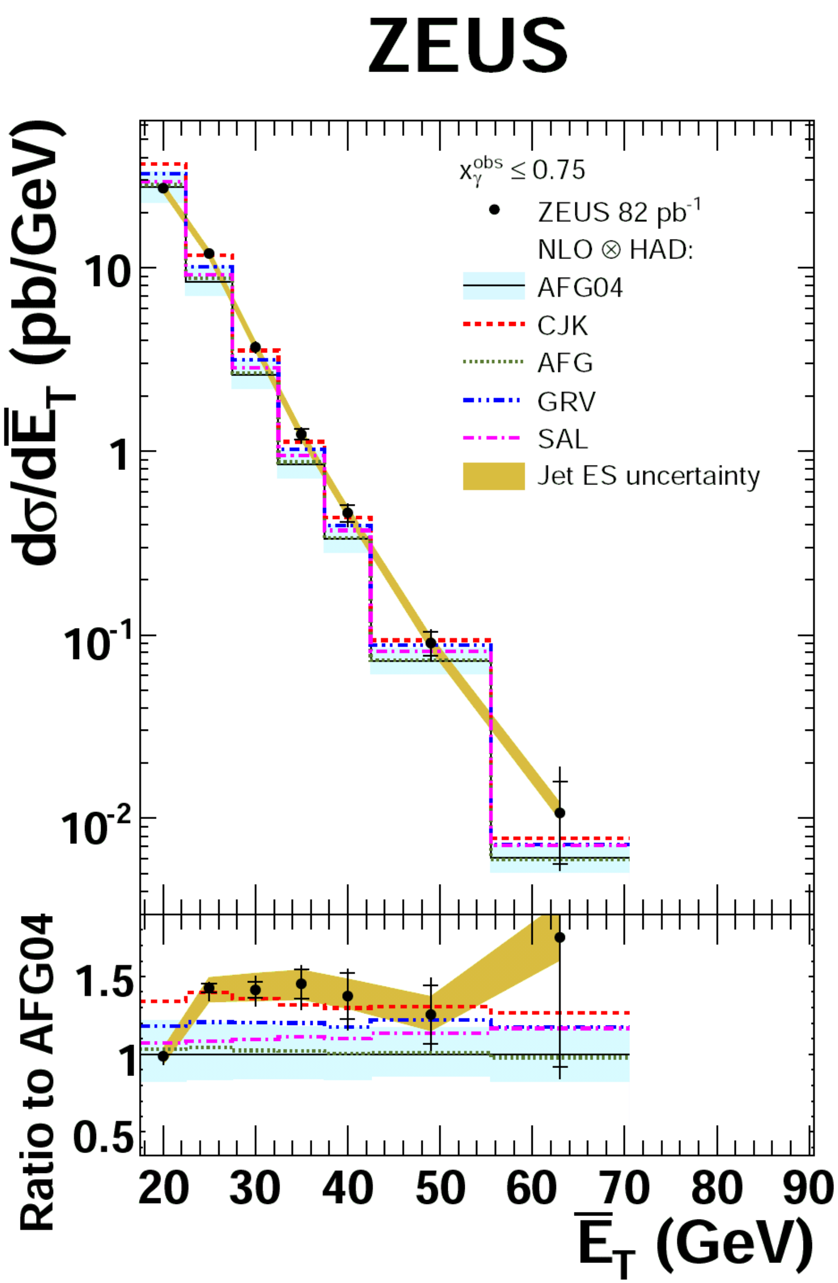
- high-x_γ^{obs} enriches direct contribution
- choose four kinematic regions with cuts optimised for largest sensitivity to gluon PDF
- NLO gives good description: use in future fit!

$$Q^2 < 1\,\mathrm{GeV}^2$$
$$E_T^{jet1} > 20\,\mathrm{GeV},\ E_T^{jet2} > 15\,\mathrm{GeV}$$

Phys.Rev.D, hep-ex/0706.3809

Dijets in Photo Production

- mean E_T of dijets shown for an resolved enriched sample
- none of the used photon PDFs describes the distribution
- all too flat at low mean E_T
- data should be used in new fits of the photon PDFs



Phys.Rev.D, hep-ex/0706.3809

PART II, Jets for PDF Fits

Jet Cross Section @ NLO for Fits

NLO calculations for jets are slow, one way out: "k-factor" method ➡

- for a given PDF: compute k-Faktors (once)
- k = sigma-NLO / sigma-LO
- in PDF fit
  - compute sigma-LO for each PDF iteration
  - multiply sigma-LO with k-Factor: get "NLO" Prediction

This is an approximation ➡

- k-Factor itself depends on the PDFs
  - different for different partonic subprocesses
  - different x-coverage in LO and NLO

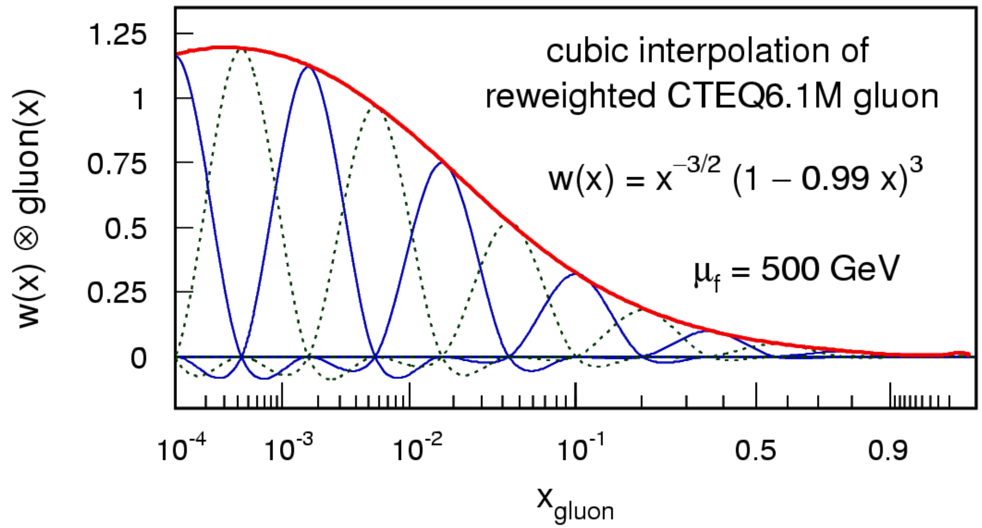
With drawbacks ➡

- procedure has systematic errors of 2-5%
- works only for "simple" cross sections (incl. jets in pp) not for pp-dijets, DIS jets, ...
- even LO computation is relatively slow (compromise wrt. stat. errors)

fastNLO

solution:

- separate and α_S and PDFs from rest
- store result in bins of x, partonic subprocess, scales,...
- use interpolation techniques for precision
- already in “Using PDF interpolation to solve the DGLAP equations” C.Pascaud, F.Zomer, LAL-94-42
- implemented e.g. in H1 EPJC 19(2001)289, ZEUS-JETS PDF, ...
- fastNLO: emphasis on efficiency and universality (ep,$p\bar{p}$,pp)
- see `http://projects.hepforge.org/fastnlo/` for calculations of 28 jet cross sections for TEVATRON, HERA, LHC, RHIC



with 8 x-bins: already 0.5% Precision
only 10 x-bins: achieve goal of 0.1% precision

used
- stretching: x->sqrt($\log_{10}$(1/x))
- reweighting: $w(x)=x^{-3/2}(1-0.99x)^3$

TK, M.Wobisch, K.Rabbertz, hep-ph/0609285

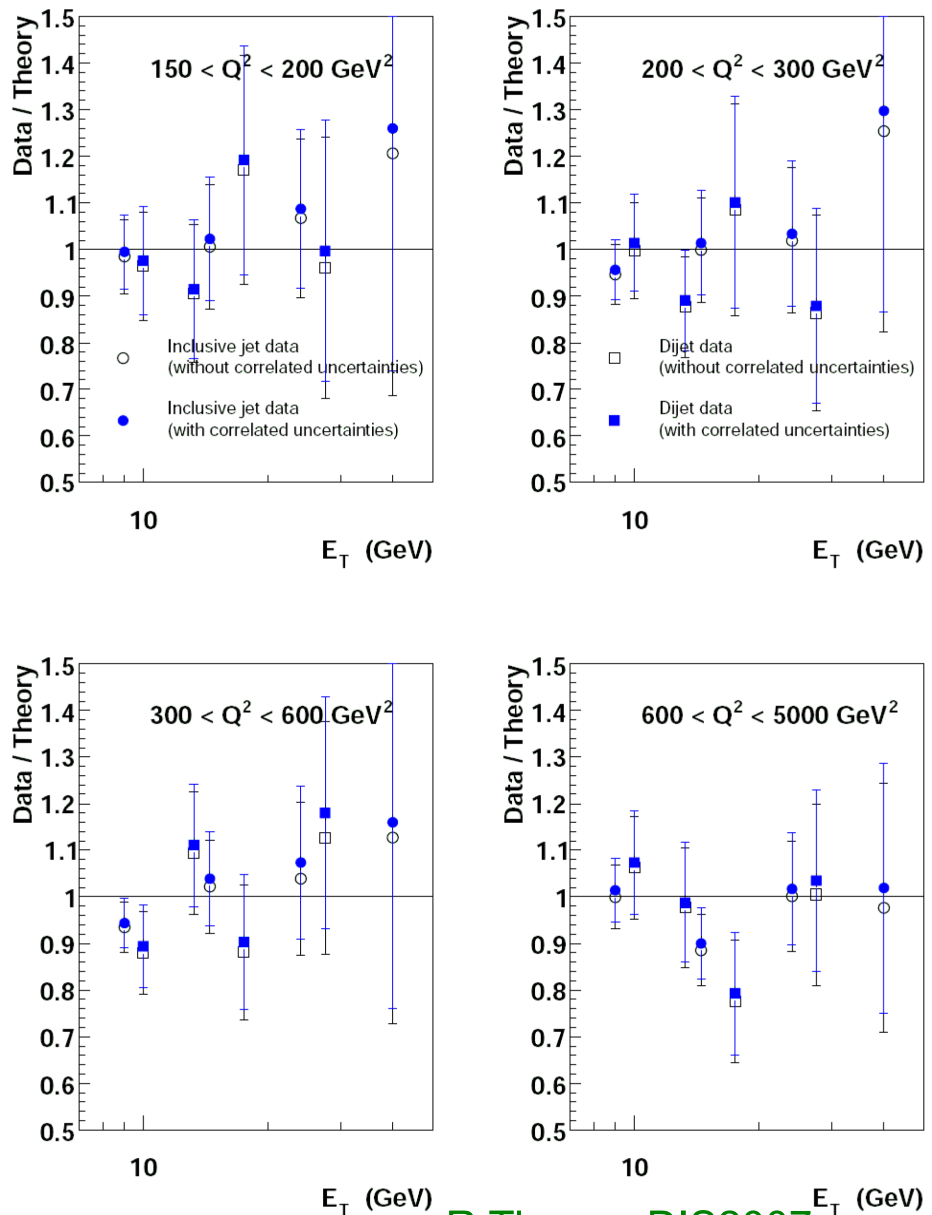
Jets for PDF Fits

- having a prediction for jet cross section as function of α_S and PDF allows for straightforward fits by minimising χ^2
- combine with inclusive NC/CC DIS data
  - state of the art for these is NNLO, not yet for jets ☹
- experimental systematics are correlated, use Hessian method = fitting the systematical parameters
- issue: theory/scale error important for jets
  - correlation of uncertainty between e.g. inclusive jets and dijets?
  - offset method (repeating fit for different scales) sensitive to fluctuations, maybe too conservative?

Global Fits

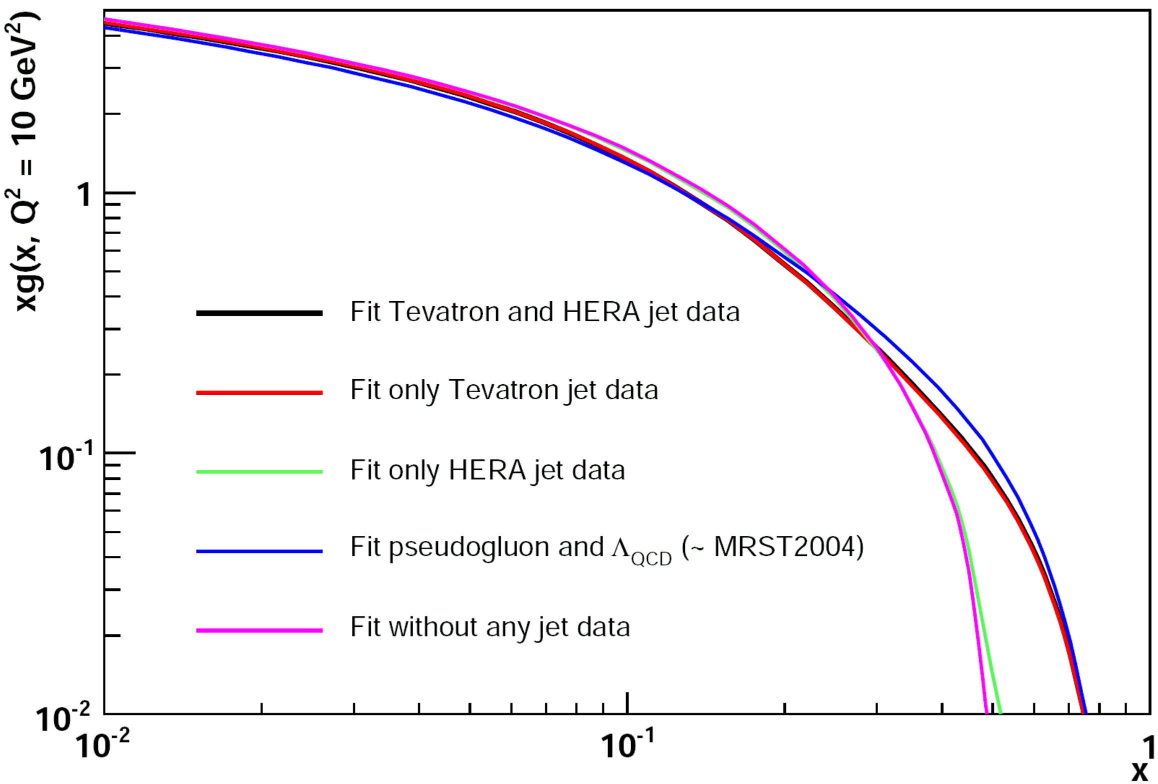
- fastNLO is used by MSTW to include jet data from TEVATRON and HERA in their new fit
- quality of fit excellent, correlations of systematics have little effect for HERA jets

H1 95-97 incl. jet and dijet data, χ^2 = 14/32 pts



R.Thorne, DIS2007

Global Fits



R.Thorne, DIS2007

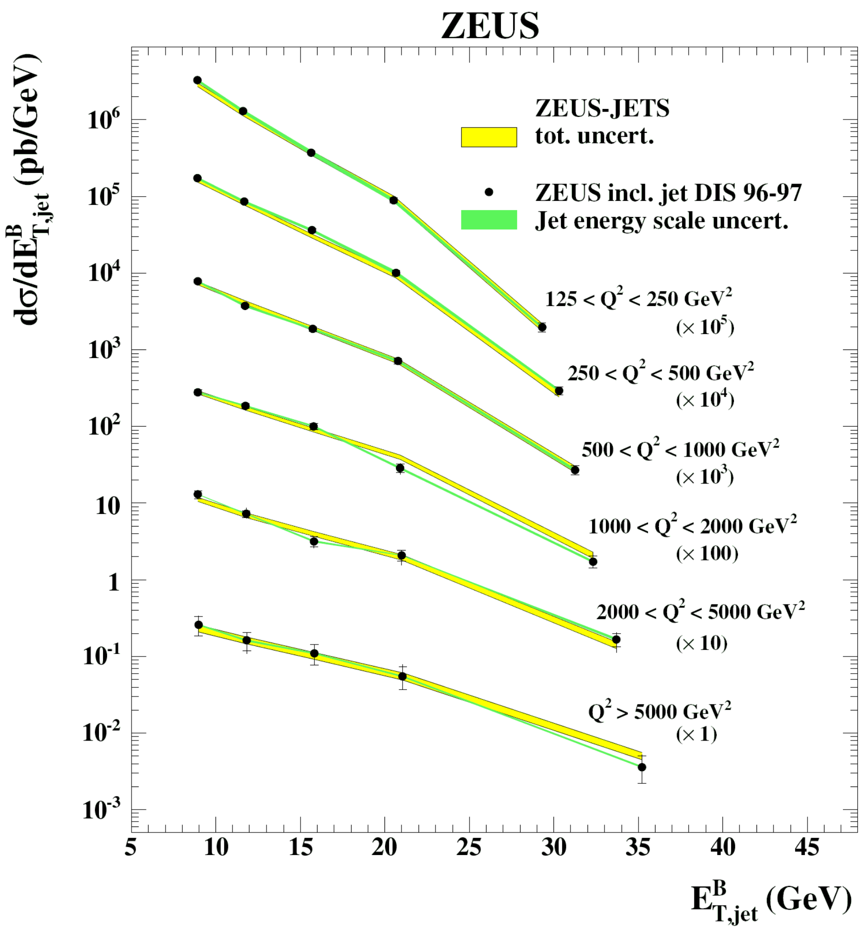
- in the MSTW fit, the HERA jets have little impact
- up to now only part of HERA I and no γp data used
- recently published (and future!) data will improve the sensitivity

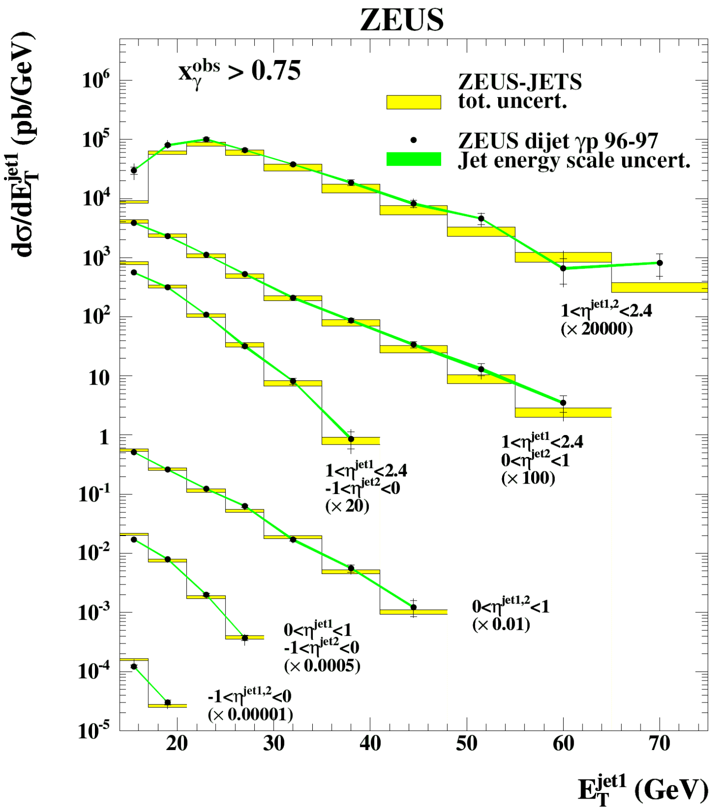
ZEUS-Jets PDF Fit

ZEUS-JETS fit uses

- incl. NC/CC (HERA I)
- DIS incl. jets (part of HERA I)
- γp dijets (part of HERA I)

uncertainties using offset method

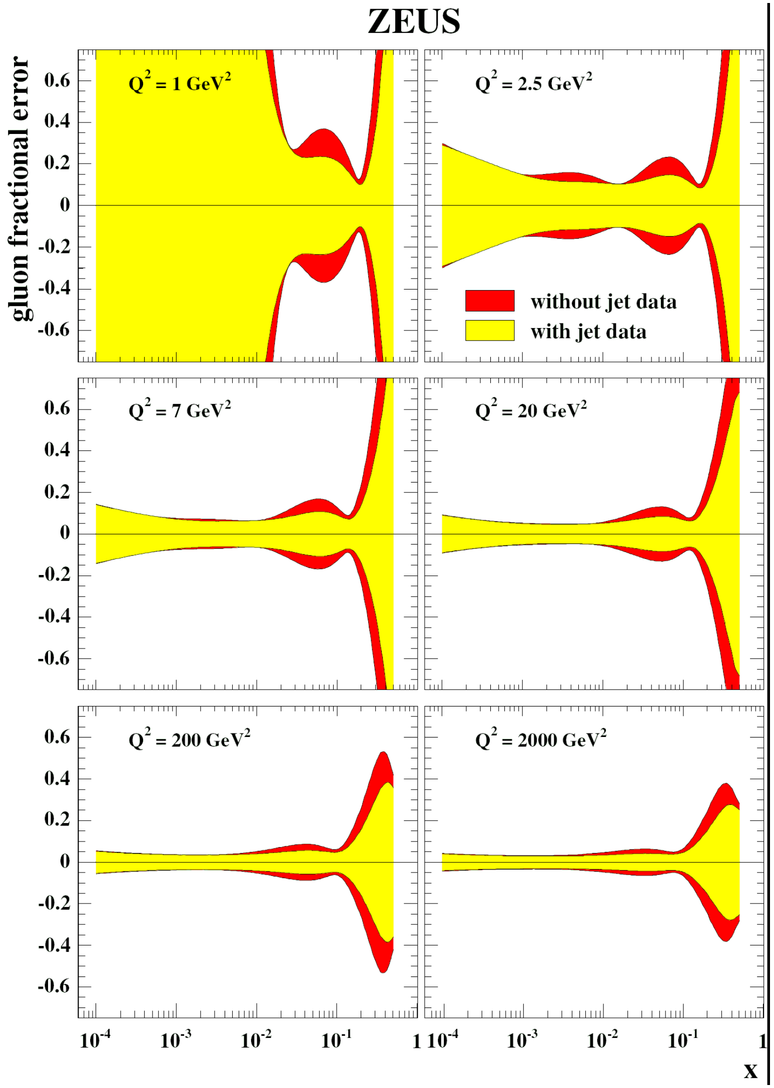


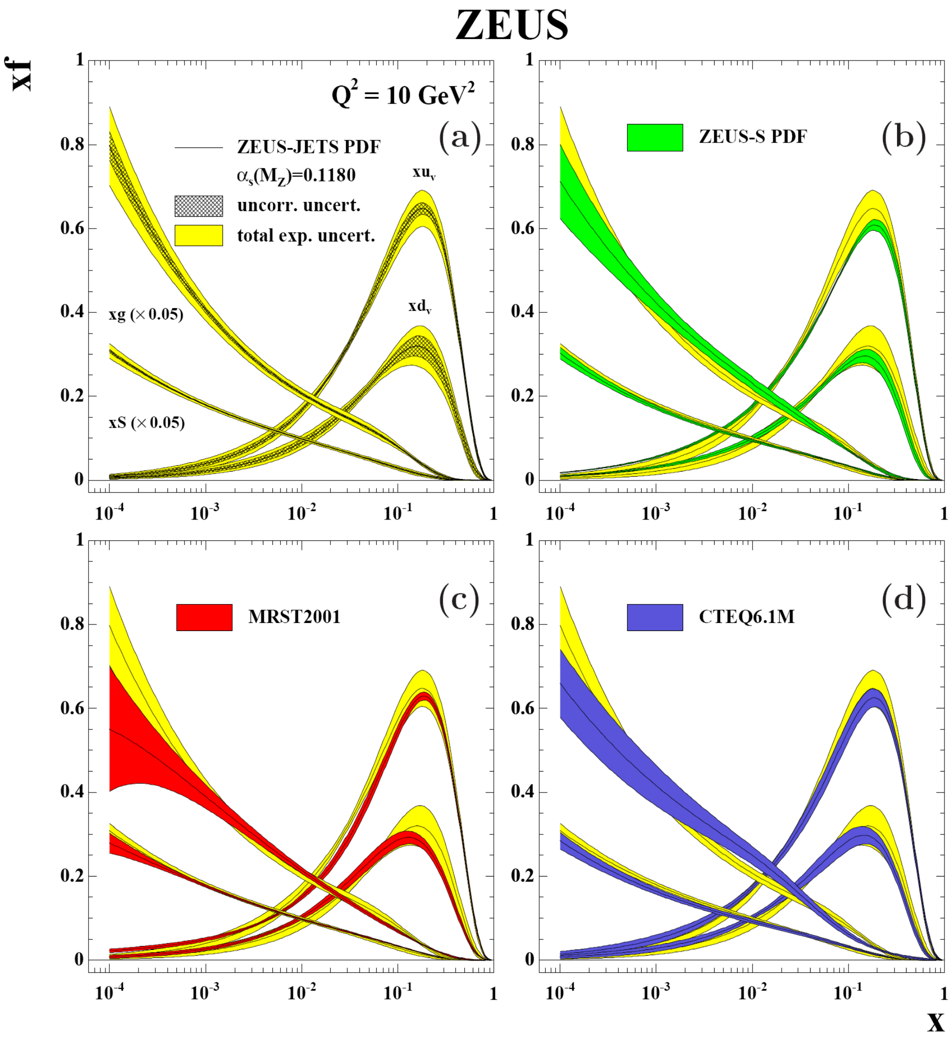


Eur.Phys.J.C42:1-16,2005

jets provide sizable reduction of gluon uncertainty at higher x

this gluon is compatible with global fits





Eur.Phys.J.C42:1-16,2005

Summary

- Wealth of new jet data from H1 and ZEUS available
- Only part of the HERA I jet data has been used in PDF fits now
- HERA II data will provide improved statistical and systematical precision
- Jets in PDF fits provide further constraints on gluon PDF at high x
- A general purpose NNLO program for jets at HERA is needed!