

ZEUS Status Report



Andrea Parenti (DESY) on behalf of the ZEUS Collaboration

- *General remarks*
- *Physics Highlights*
- *Conclusions*



Physics Activities

- 44 ongoing analyses:
 - 8 high- Q^2 , 4 SF, 10 QCD, 19 HFL, 3 Diffr.
- 12 more papers expected this year...
- ... but some high profile analyses delayed
 - High- Q^2 e^+p NC DIS (due to rate/lumi issues)
 - Leptoquarks (manpower)
- Fully committed to the combination effort, but suffering from manpower shortages



New papers since last PRC

- Measurement of beauty production in DIS and F_2^b extraction at ZEUS (DESY-10-047)
- Inclusive-jet cross sections in NC DIS at HERA and a comparison of the k_T , anti- k_T and SIScone jet algorithms (DESY-10-034)
- Scaled Momentum Spectra in deep inelastic Scattering at HERA (DESY-09-229)
- Measurement of D^+ and Λ_c production in DIS at HERA (at directorate)
- Measurement of high- Q^2 charged current deep inelastic scattering cross sections with a longitudinally polarised positron beam at HERA (after reading)
- Inclusive dijet cross sections in neutral current deep inelastic scattering at HERA (after reading)



New preliminary results since last PRC

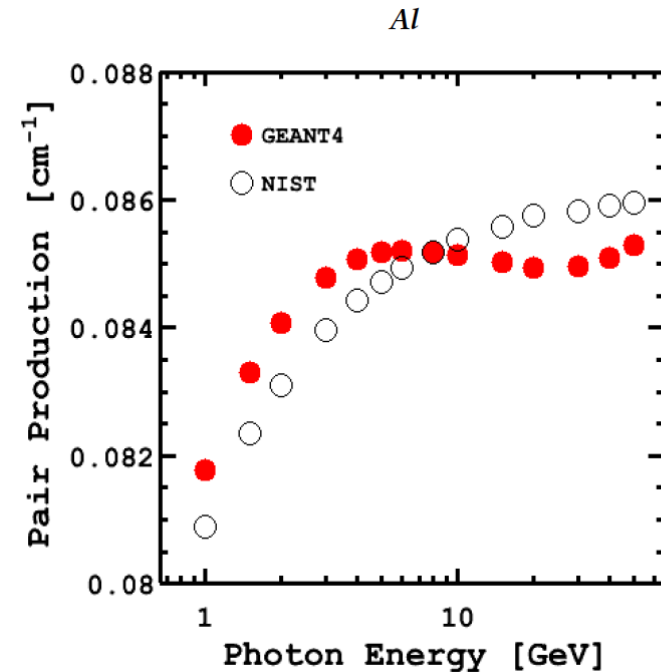
- Neutral current cross section at high x
- HER-MER-LER cross sections at high y and low Q^2
- H1+ZEUS: combined HER-MER-LER cross sections and F_L
- H1+ZEUS: QCD fits including HER-MER-LER data
- H1+ZEUS: QCD fits including charm data
- Inclusive jets in NC DIS
- Inclusive jets in PHP
- D^+ in DIS and F_2^c
- Beauty in DIS from inclusive secondary vertices



Progress on Luminosity

- theory
0.5%
- aperture and detector alignment
1%
- conversion in window
2%
- rate
0.6%
- X-position
1.1%
- all other systematics checked
negligible (< 0.5%)

2.6 %



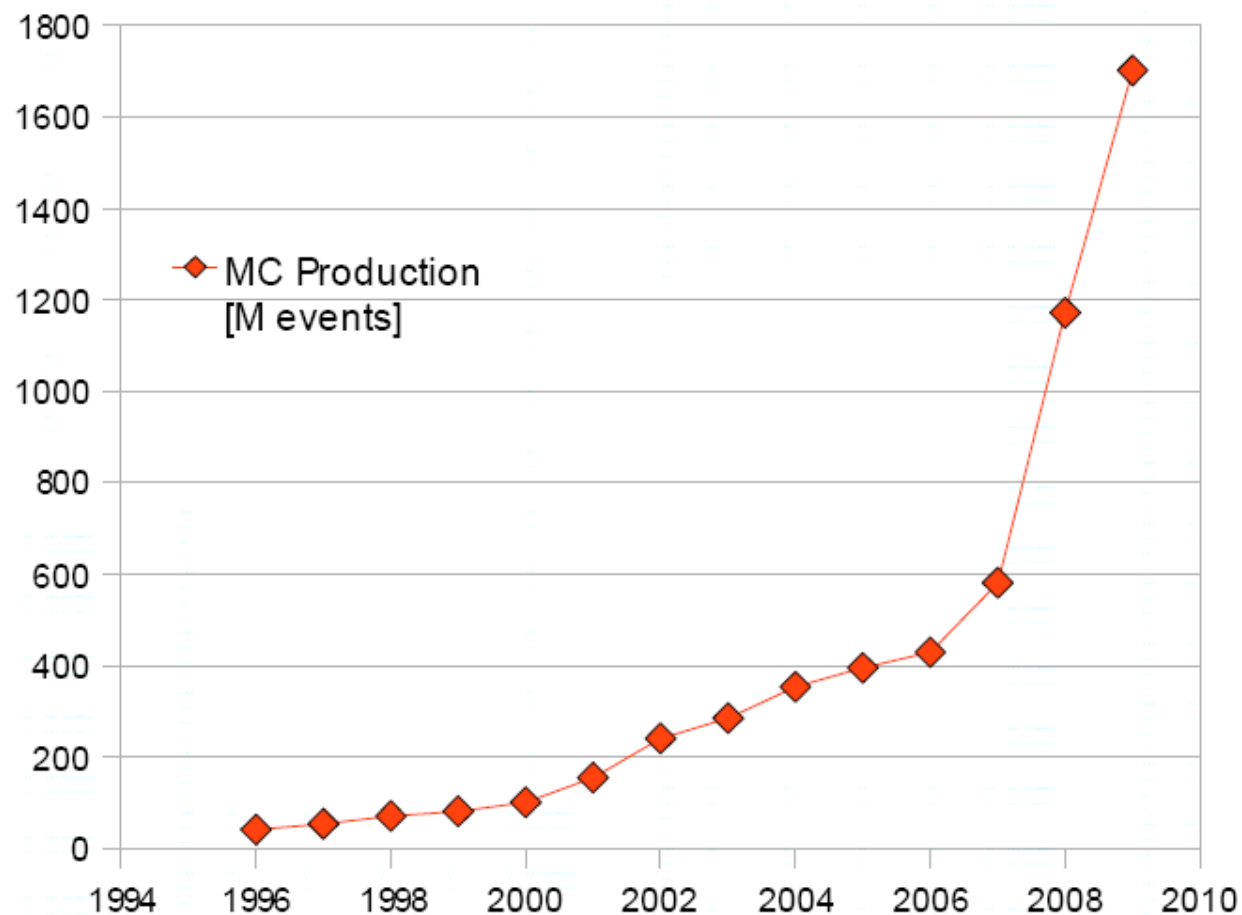
- Why? E.g. one dominant uncertainty in α_s measurement
- Theory error much better understood
 - full new α_{em}^3 calculation of Bethe-Heitler by V. Makarenko (to be publ.)
- window conversion: 2% \rightarrow 0.7%

Total error: 2.6% \rightarrow 1.8%



Monte Carlo simulations

- Monte Carlo simulations are essential for data analysis.
- Last year we produced > 1.7 billion events!
- We will need a similar production also in 2010.



Data preservation

- settled on the model (see paper to PRC)
 - common ntuple format
 - virtualized MC and analysis software
 - MC generation on the grid
- dedicated ZEUS computing support ends 12/2011
- Data custody goes to IT
- Governance to be defined
- Schedule is aggressive!
- Work is needed:
 - What resources will be available?



ZEUS Management

- Physics Coordinators
 - M. Turcato (HH) , E. Tassi (Cosenza) → A. Geiser (DESY), B. Reisert (MPI)
- Spokesperson
 - T. Haas (DESY) → A. Levy (Tel Aviv)
- Collaboration structure after 2011 still under discussion



ZEUS(+combined) talks at DIS 2010

Inclusive:

High- Q^2 CC

NC at high- x

NC/CC and PDF fits

Combined F_L

QCD fits with low energy data

QCD fits with charm data

HFL:

Incl. beauty in DIS

Incl. beauty in PHP

Charm mesons in DIS

Inelastic J/ψ helicity

QCD:

Jets with anti- k_T and SIScone, (di)jets in NC DIS

Three subjects

Jets in PHP

Scaled momenta

Prompt photon

Diffraction:

Diffractive PDFs

J/ψ at high t

EW/searches:

Isolated leptons

Multi-leptons

LQ and CI

Apologies for not being able to cover all the topics due to time





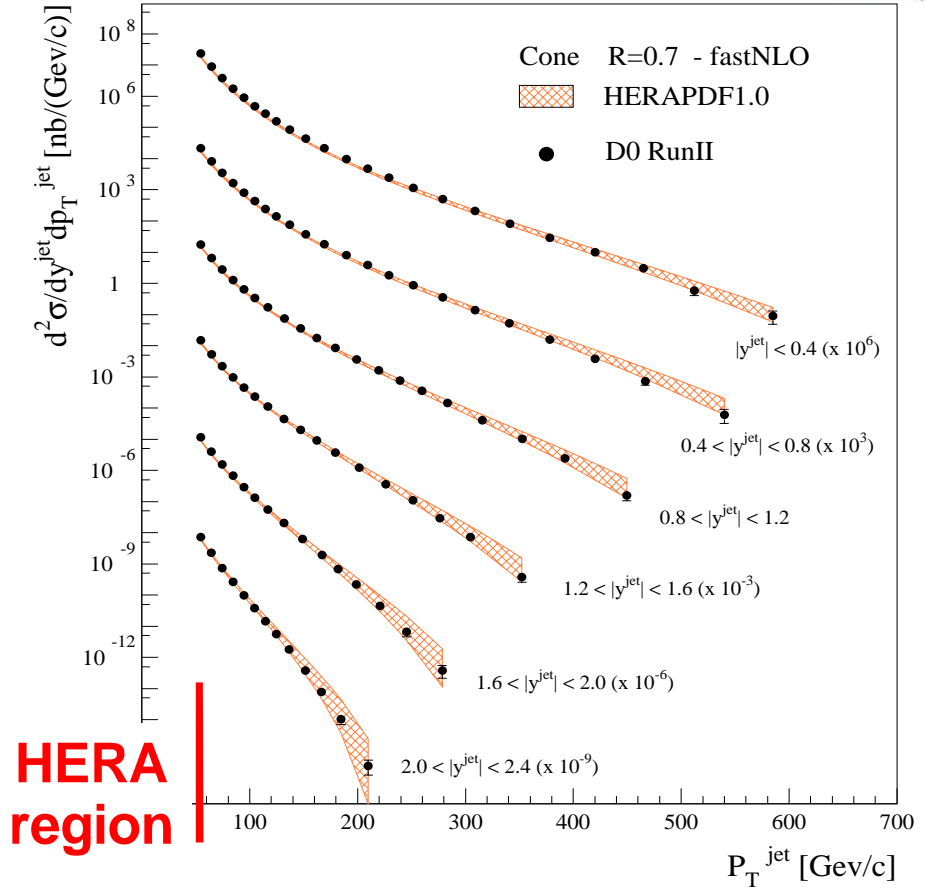
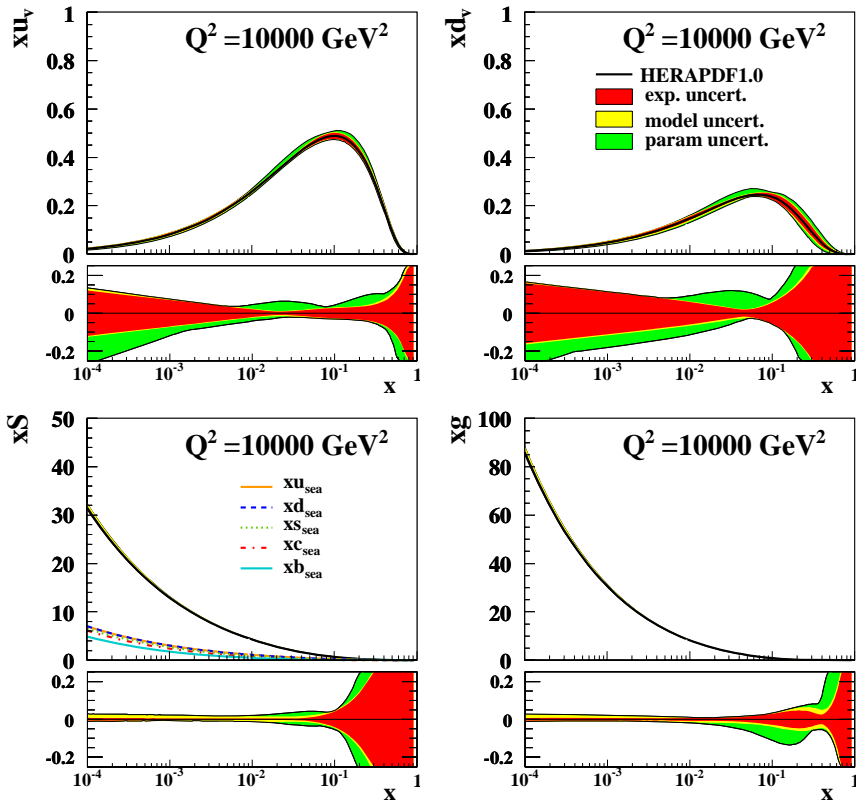
HERAPDF1.0

The combined NC and CC HERA data have been used as the sole input for the extraction of the HERAPDF1.0.

Tevatron Jet Cross Sections



H1 and ZEUS



HERA region

JHEP01(2010)109

Demonstration of universal nature of the PDFs



Andrea Parenti

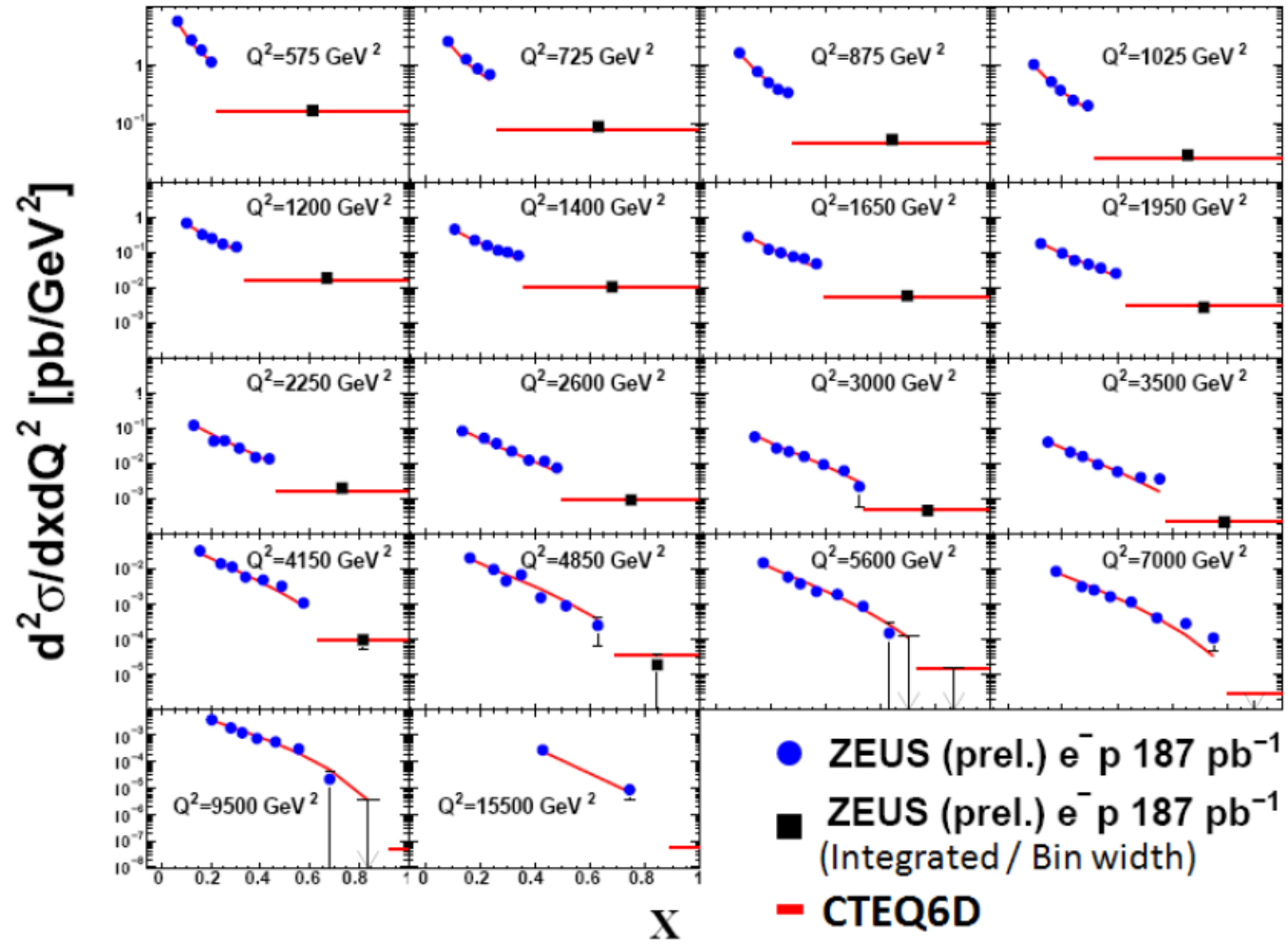
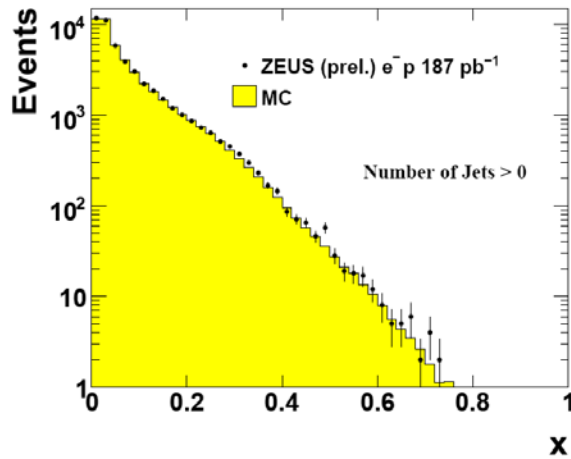
69. PRC – Open session

10

NC cross sections at high-x

$Q^2 > 450 \text{ GeV}^2$, 0-, 1- and multi-jet events selected.

ZEUS-prel-10-007



Sensitivity to the high-x region.

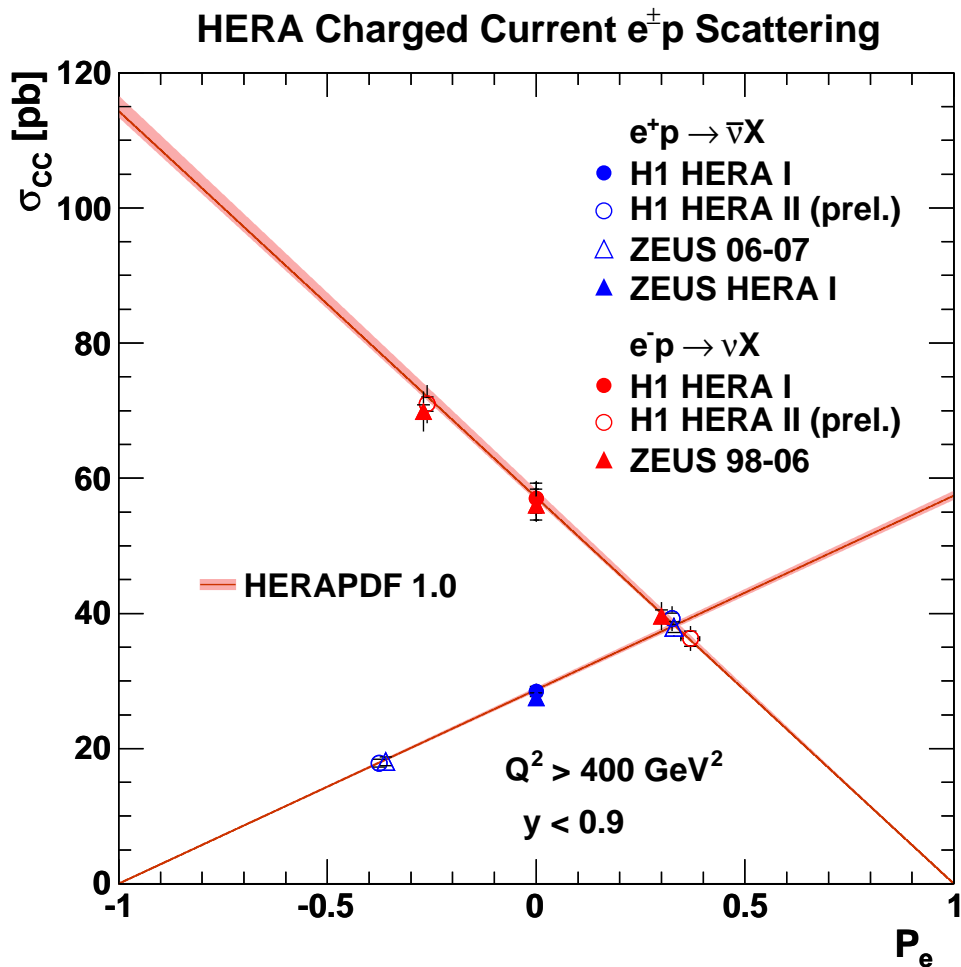
Impact on the PDFs still to be checked out.

High- Q^2 CC from e^+p data

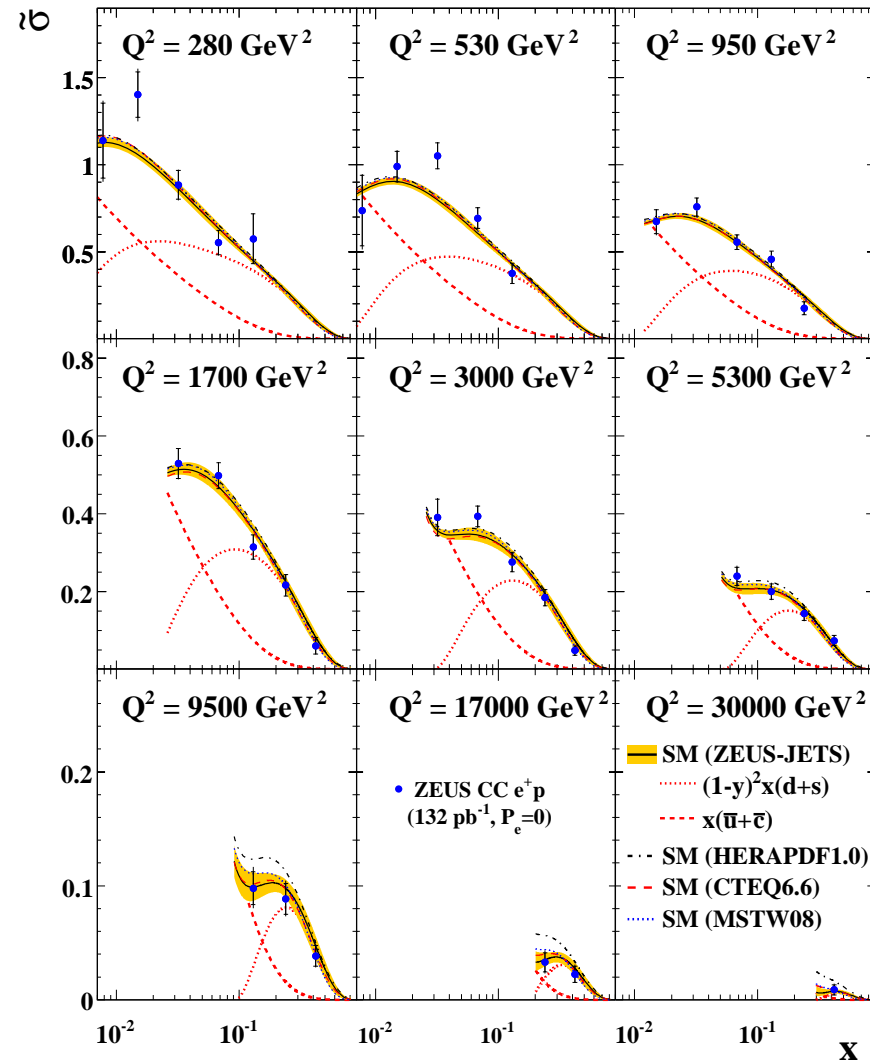
Final results on e^+p data, $L=132 \text{ pb}^{-1}$.

$200 < Q^2 < 60000 \text{ GeV}^2$

Precise input to QCD fits \rightarrow high x



ZEUS

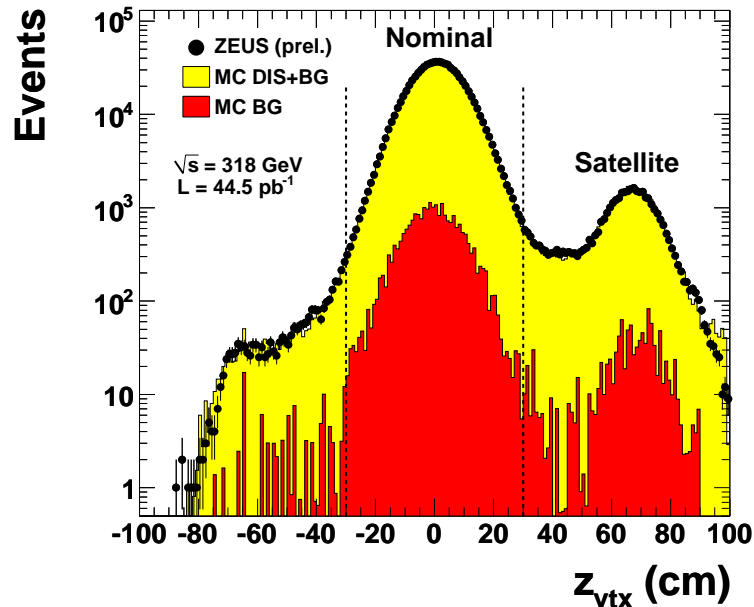


High, medium and low energy cross section at high y

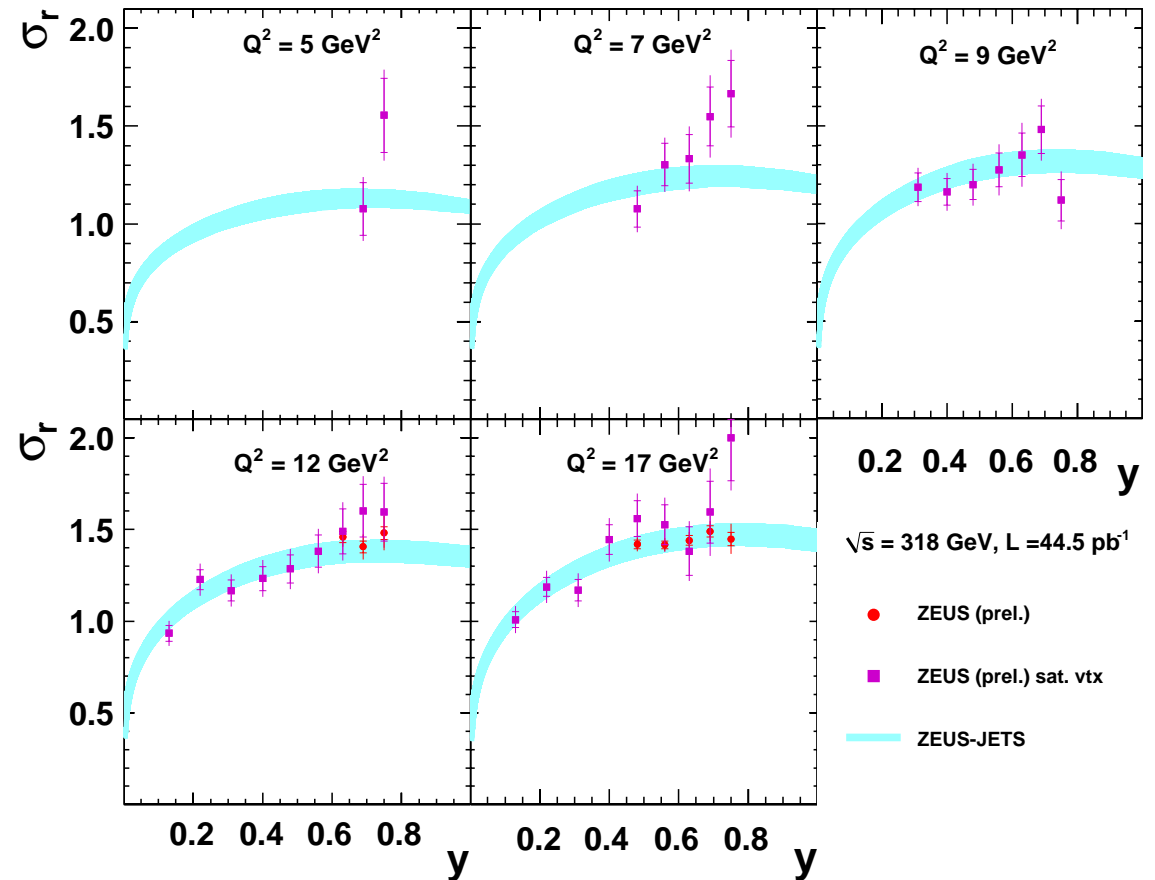
HERA NC cross sections from data collected at $E_p = 920, 575$ and 460 GeV for the F_L determination used in PDF fits.

ZEUS extends its Q^2 region for all energies, down to 5 GeV^2 for HER also using shifted vertex data.

ZEUS



ZEUS



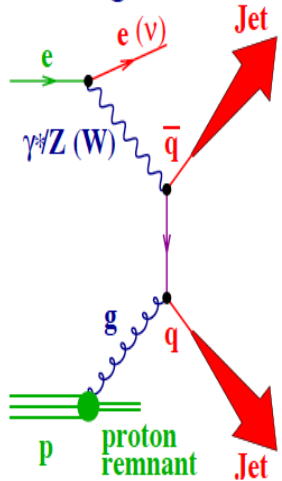
Inclusive jets in NC DIS

Inclusive jets, $L=300 \text{ pb}^{-1}$

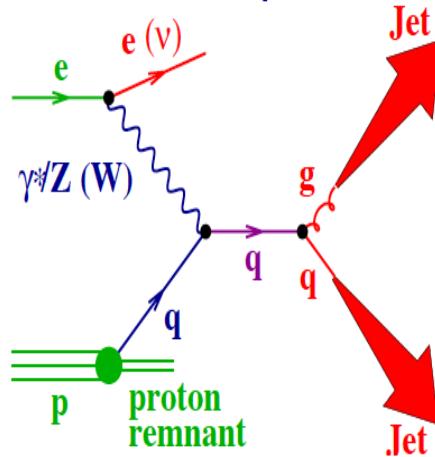
Kinematic range $Q^2 > 125 \text{ GeV}^2$.

Good agreement with QCD at NLO.

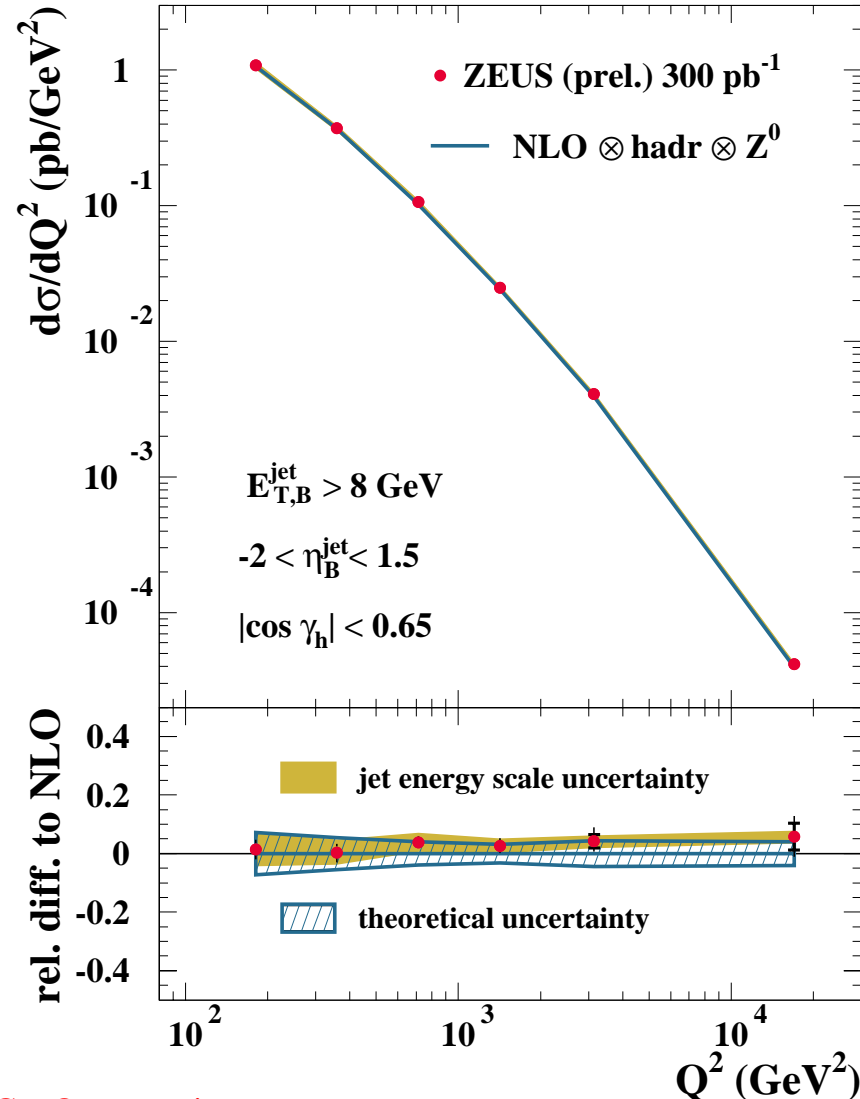
boson-gluon fusion



QCD Compton



ZEUS



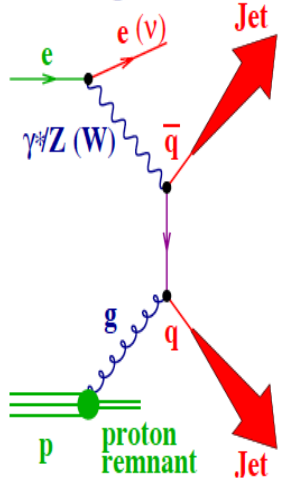
Inclusive dijets in NC DIS

Inclusive dijets, $L=374 \text{ pb}^{-1}$

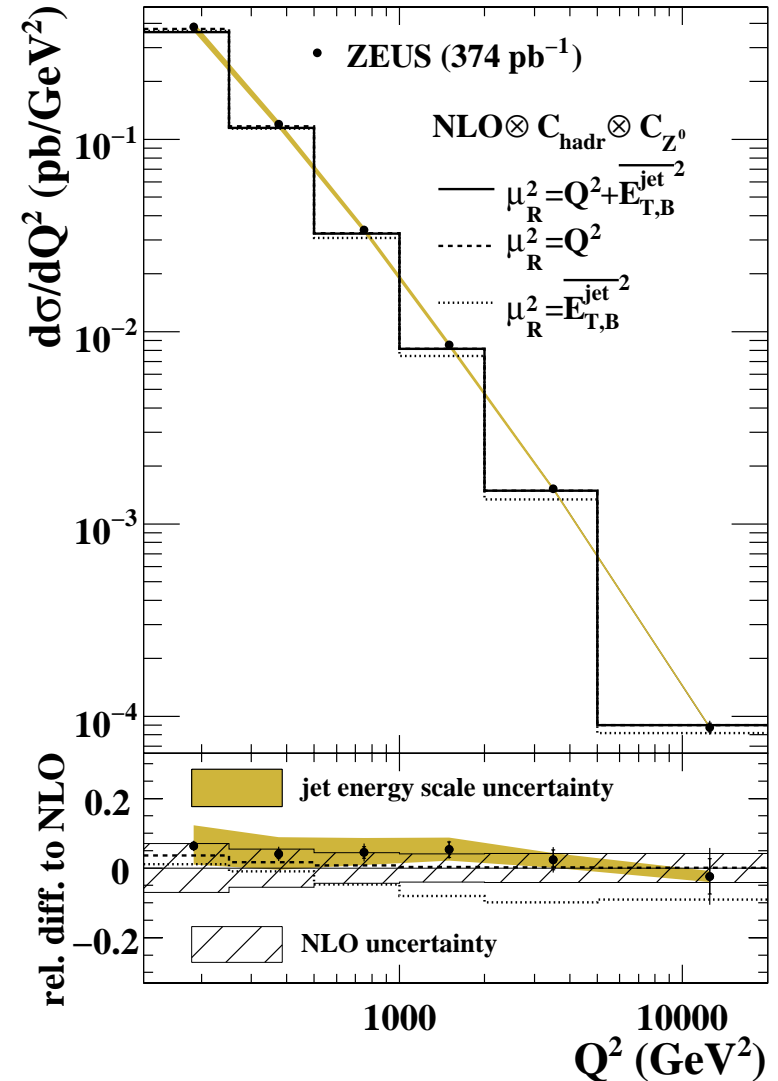
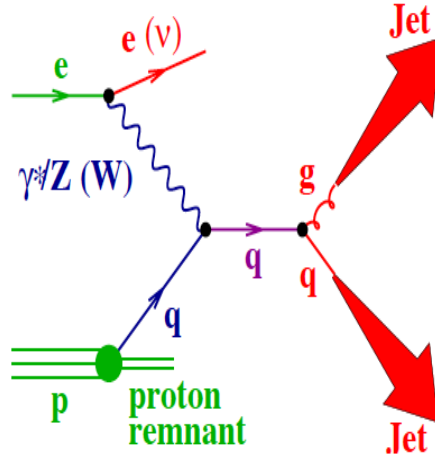
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boson-gluon fusion

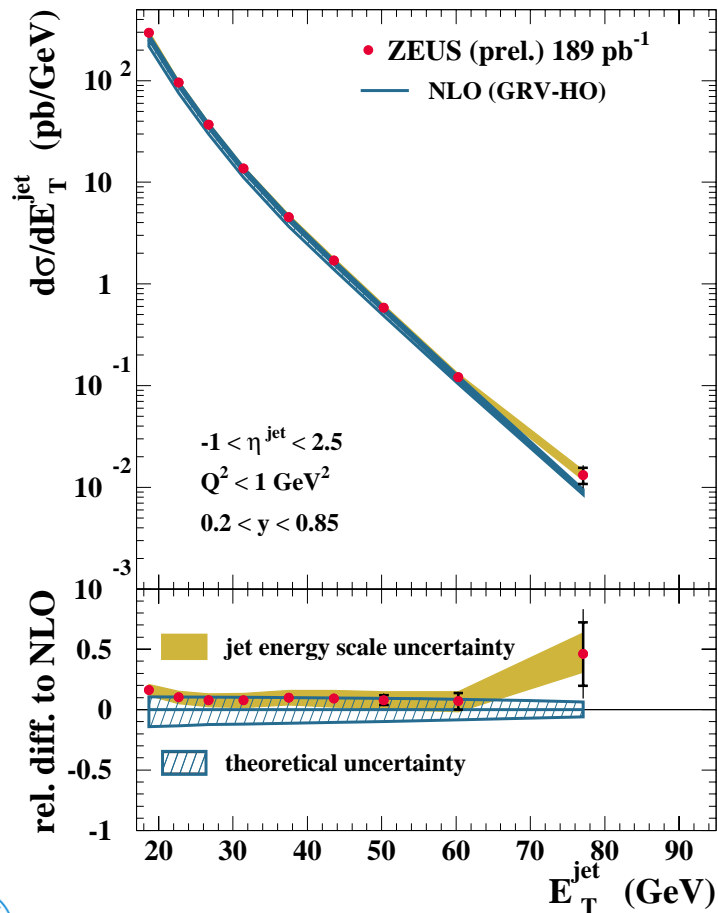


QCD Compton

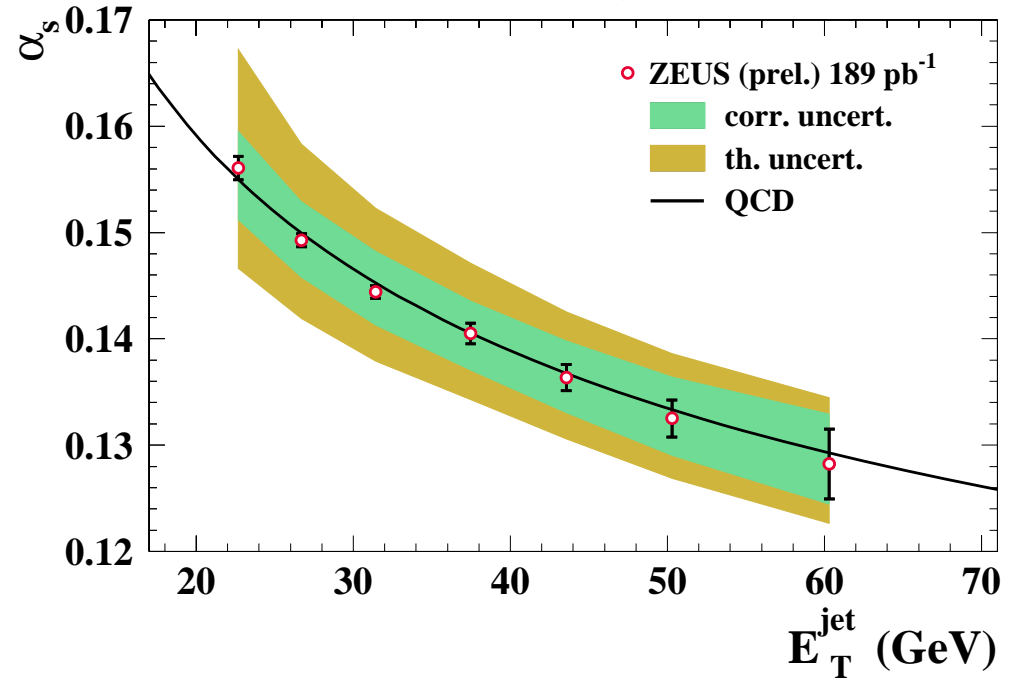


Inclusive jets in PHP

$Q^2 < 1 \text{ GeV}^2$, $0.2 < y < 0.85$
 At least one jet with
 $E_T^{\text{jet}} > 17 \text{ GeV}$, $-1 < n_{\text{jet}} < 2.5$
 ZEUS



ZEUS



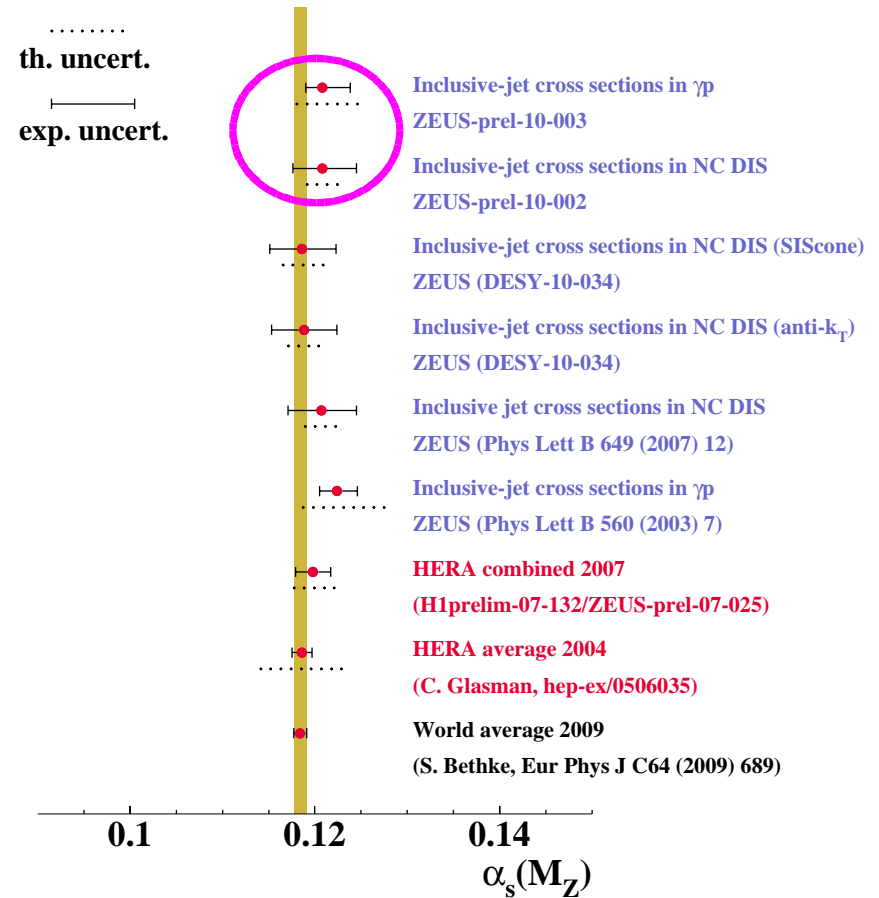
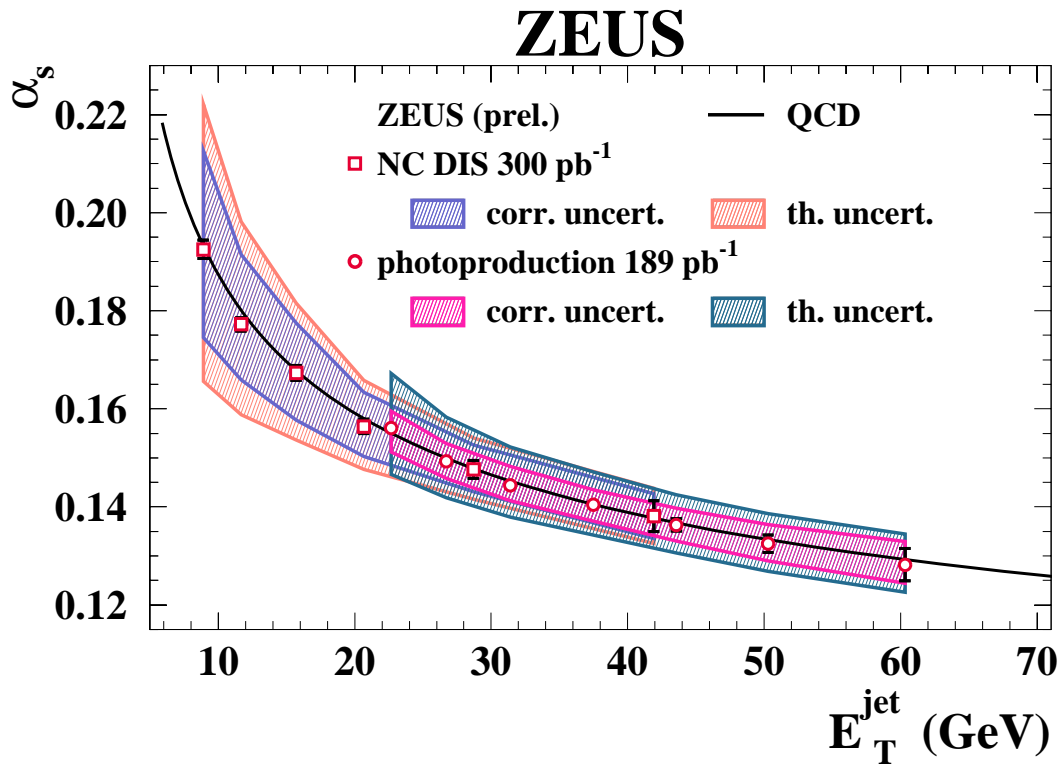
α_s extracted from the dependence of the cross section on E_T . Jets in PHP gave the most precise α_s measurement at ZEUS, *now extended to HERAII*

Test of the running of α_s .



α_s running from PHP to DIS

Running of the coupling constant with the scale tested from the low to the high Q^2 regime.



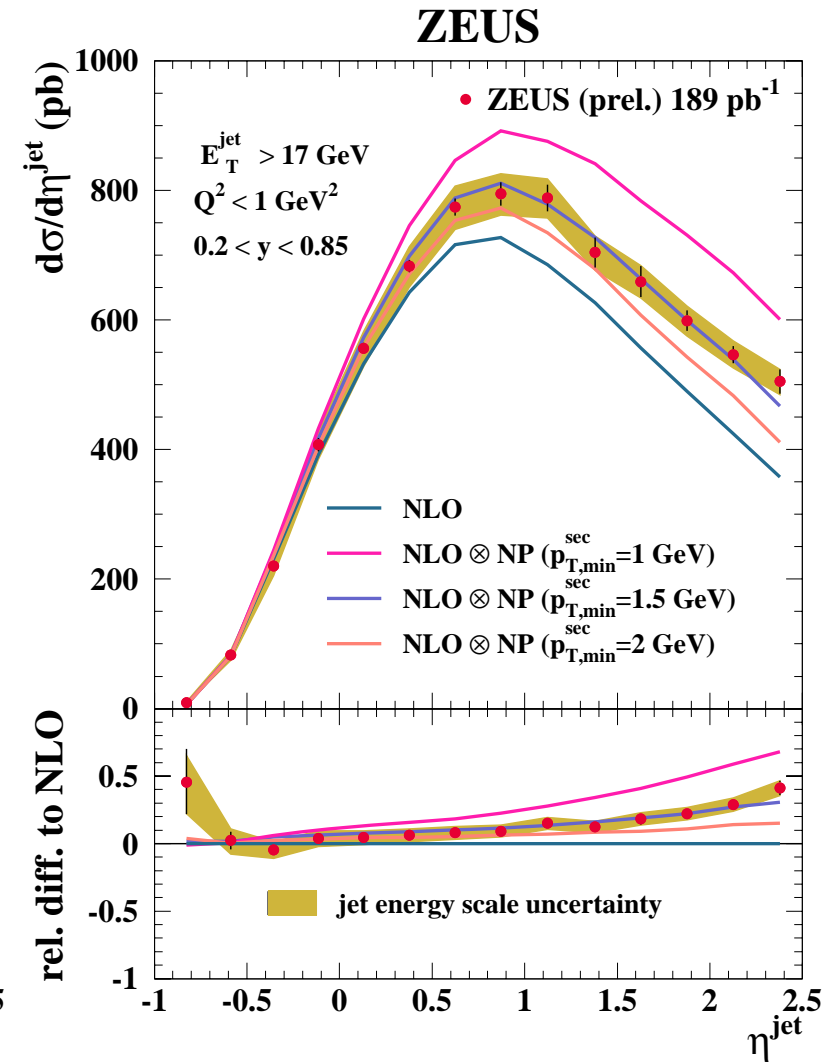
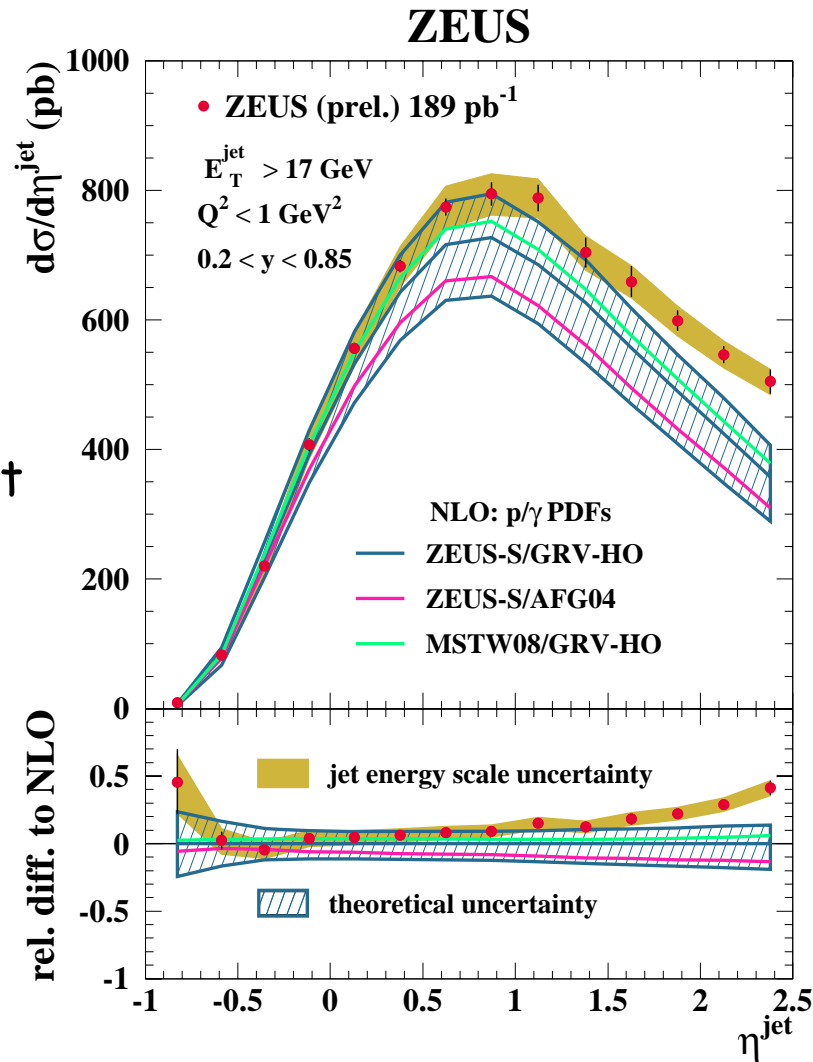
Two new precise α_s measurements from DIS and PHP in agreement with the world average.



Jets in PHP: non perturbative effects

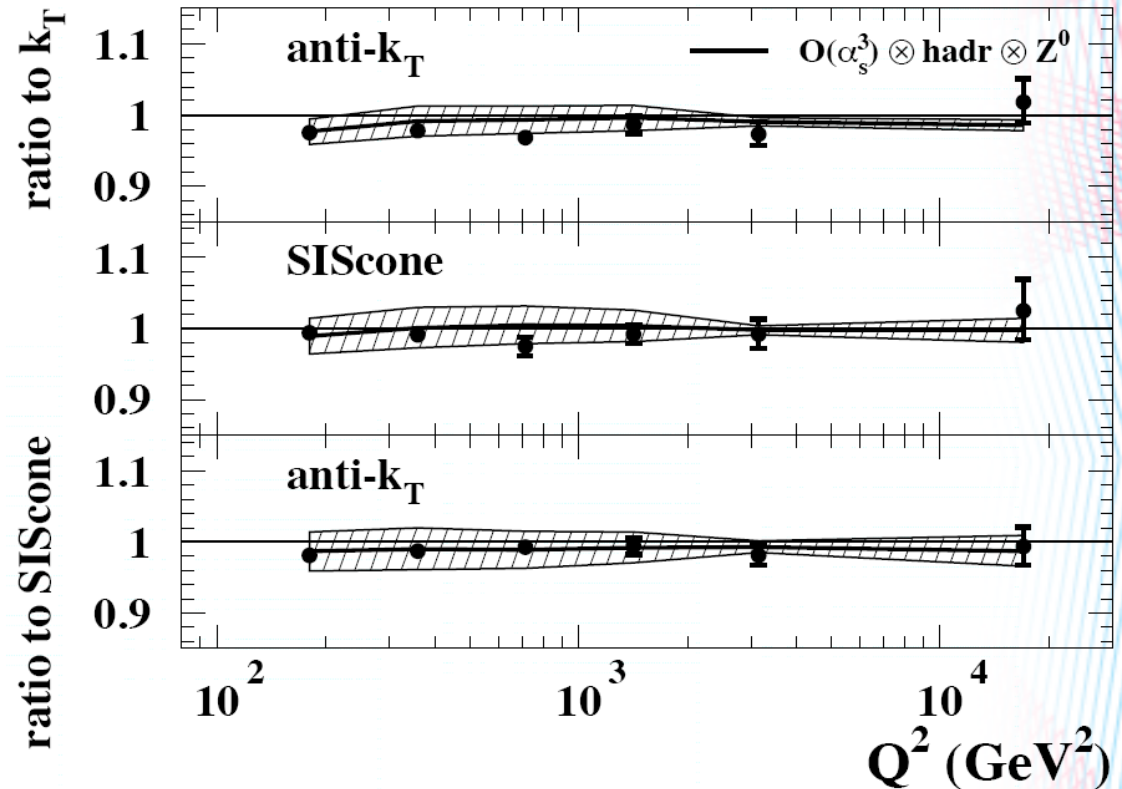
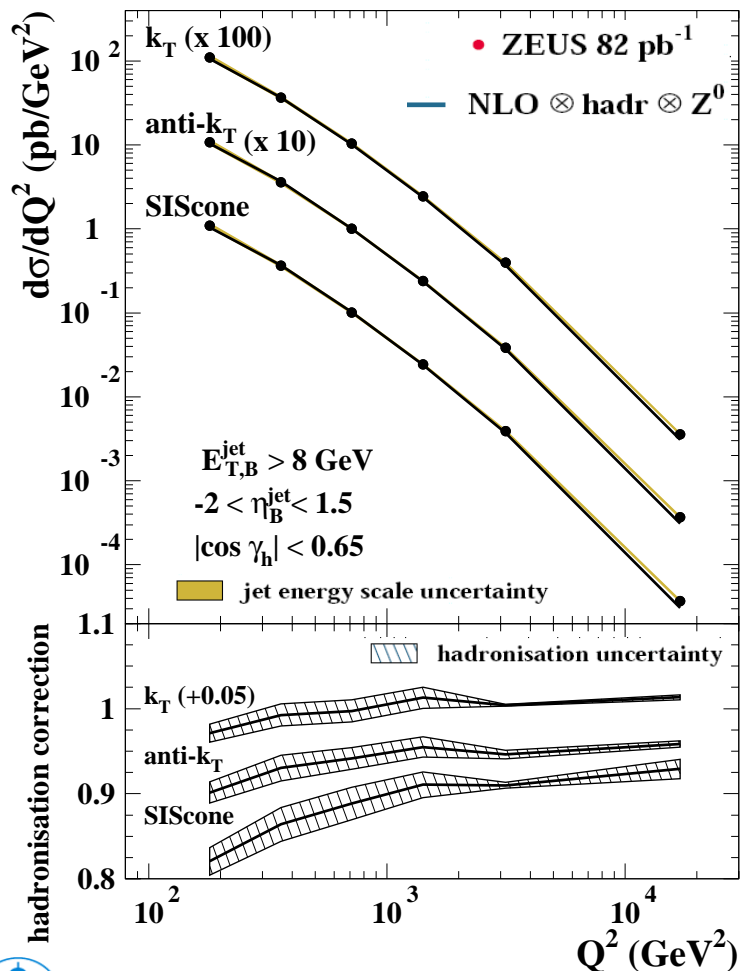
Check multiple interactions (low E_T^{jet}), important for the LHC

This can also be influenced by the jet algorithm, new developments being tested for the LHC (anti- k_T , SIScone...)



Anti- k_T and SIScone jet algorithms

Reanalysis of inclusive jets in DIS
(k_T used originally)



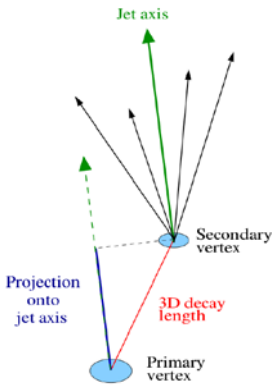
Data very well described by NLO and all the algorithms.
Similar precision (slightly worse for SIScone)

Ratios evaluated up to order α_s^3

First test on data,
important for LHC

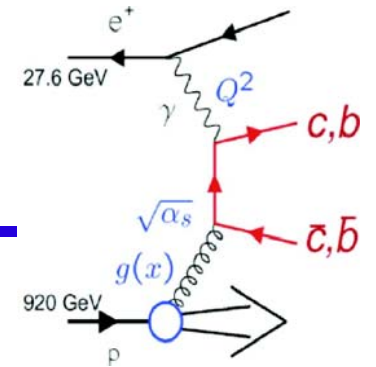


Beauty in DIS



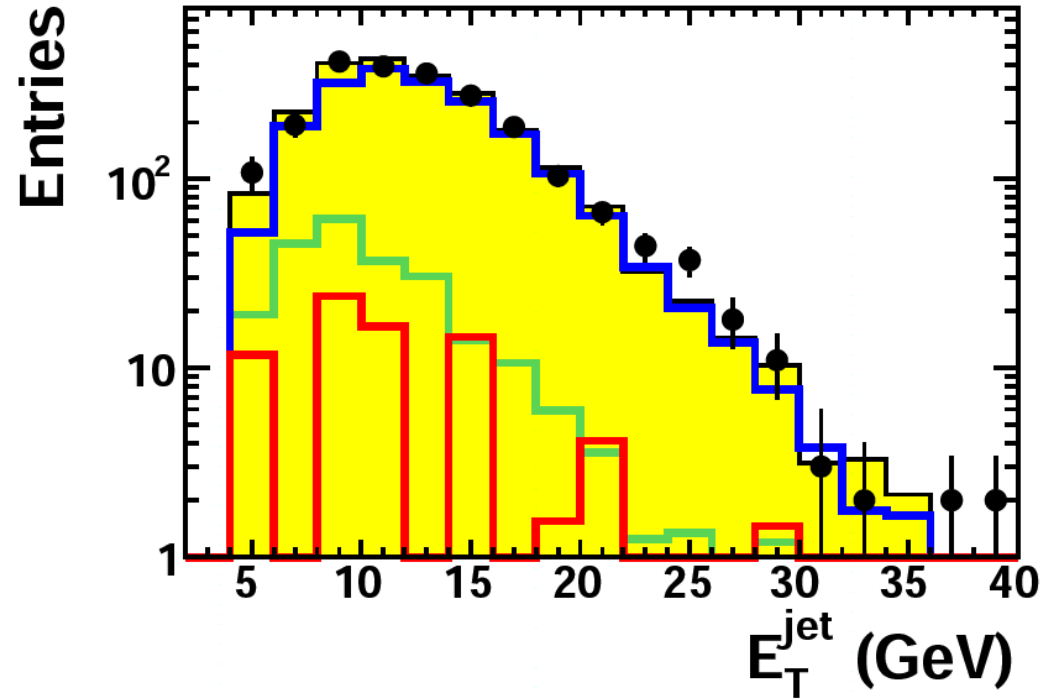
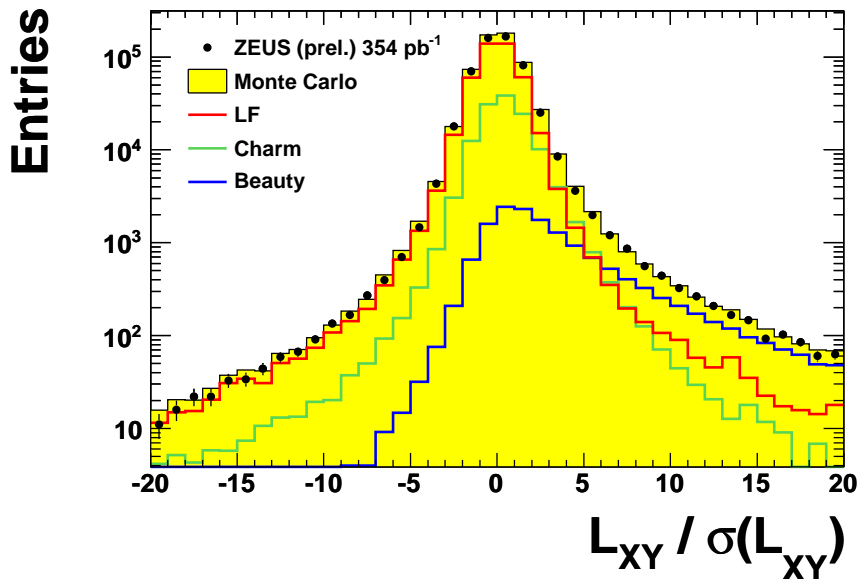
Beauty reconstructed from jets with secondary vertices.

$L=354 \text{ pb}^{-1}$



$5.0 \text{ GeV}^2 < Q^2 < 1000.0 \text{ GeV}^2, 0.02 < y < 0.7$
 $E_T(\text{Jet}) > 5.0 \text{ GeV}, -1.6 < \eta(\text{Jet}) < 2.2$

ZEUS



90000 beauty events available

Very high purity at high mass and significance

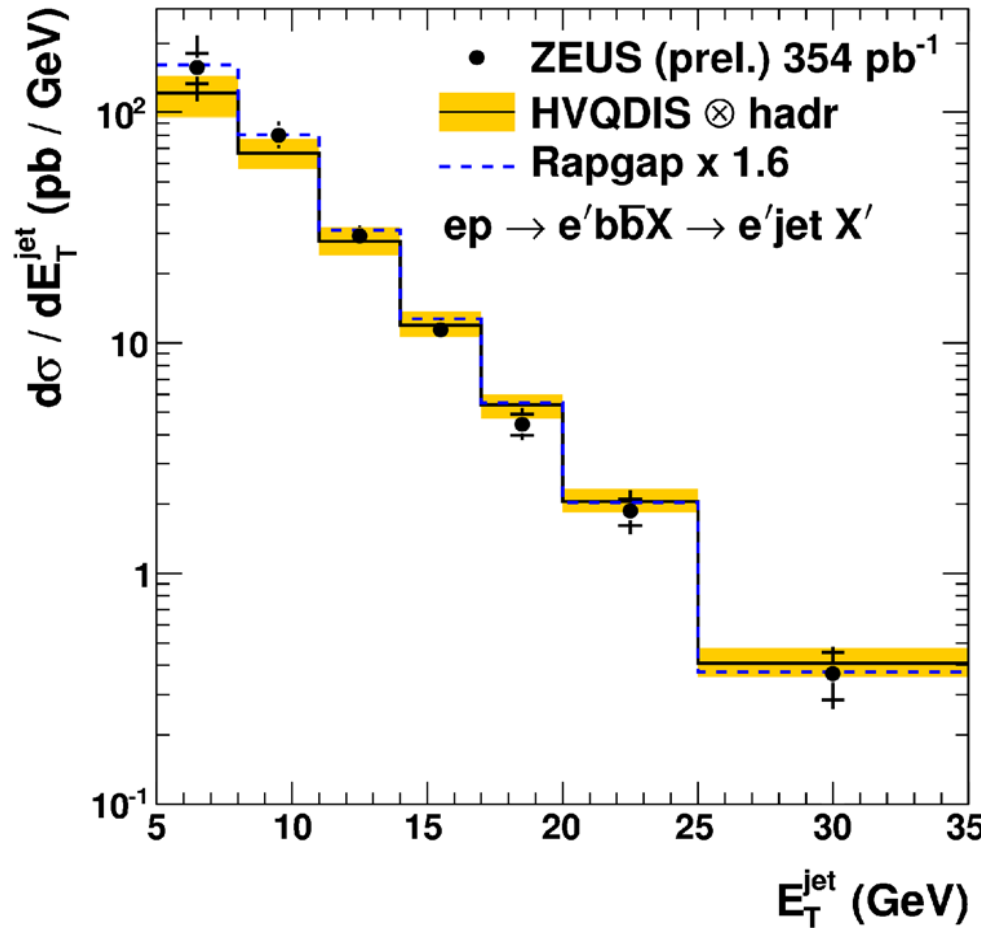


Beauty in DIS

$5.0 \text{ GeV}^2 < Q^2 < 1000.0 \text{ GeV}^2, 0.02 < y < 0.7$
 $E_T(\text{Jet}) > 5.0 \text{ GeV}, -1.6 < \eta(\text{Jet}) < 2.2$

$L = 354 \text{ pb}^{-1}$

ZEUS-prel-10-004



Data will be used for the extraction of F_2^b



D⁺ in DIS

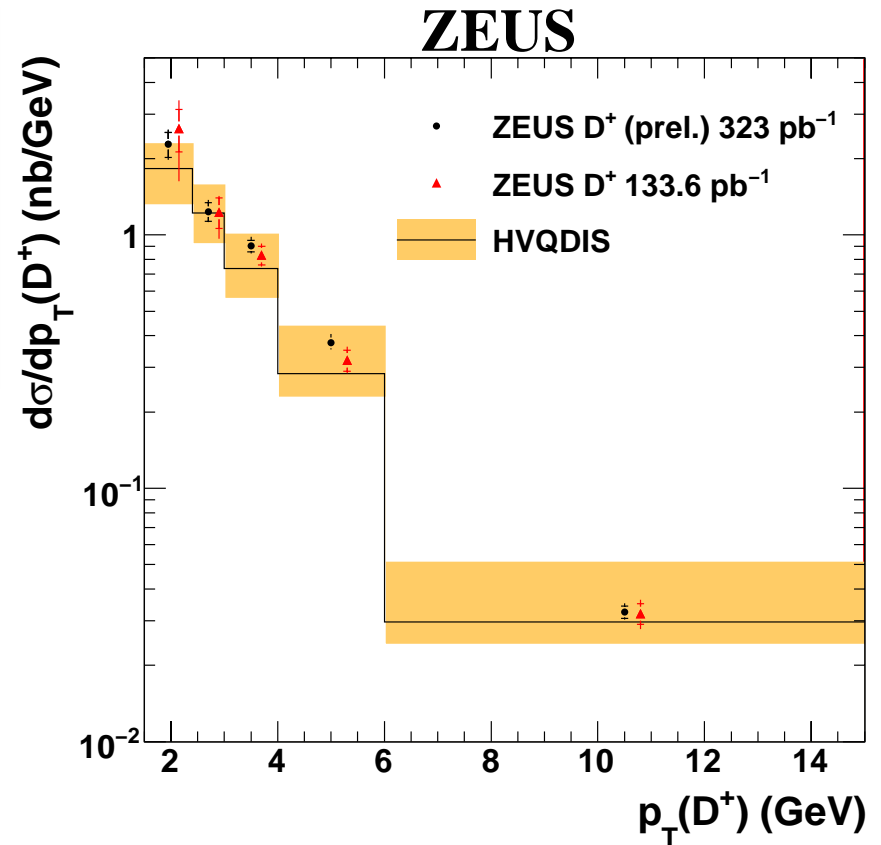
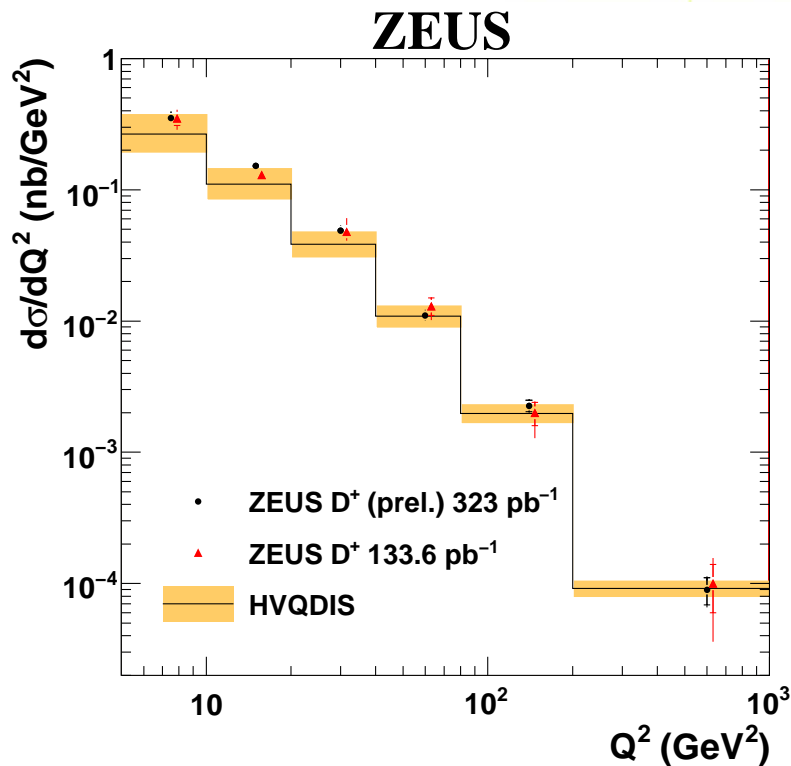
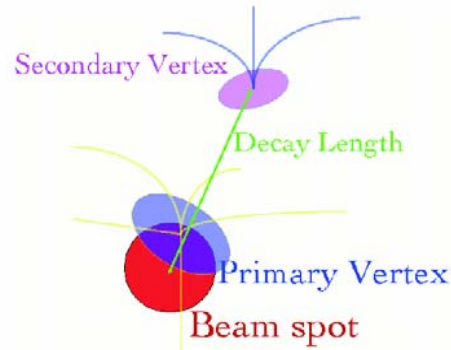
D⁺ reconstructed using lifetime information. L=323 pb⁻¹.

$$5 < Q^2_{DA} < 1000 \text{ GeV}^2$$

$$0.02 < y_{DA} < 0.7$$

$$1.5 < p_T(D^+) < 15 \text{ GeV}$$

$$|\ln(D^+)| < 1.6$$

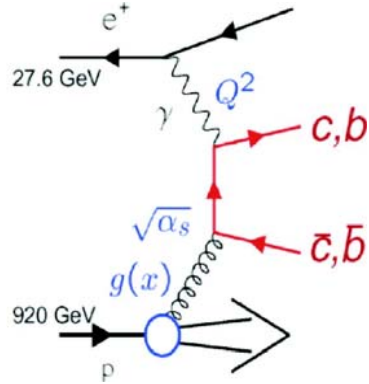


~ 7200 D⁺ events available

Precision comparable to D^{*} in HERAI



New ZEUS F_2^{cc}

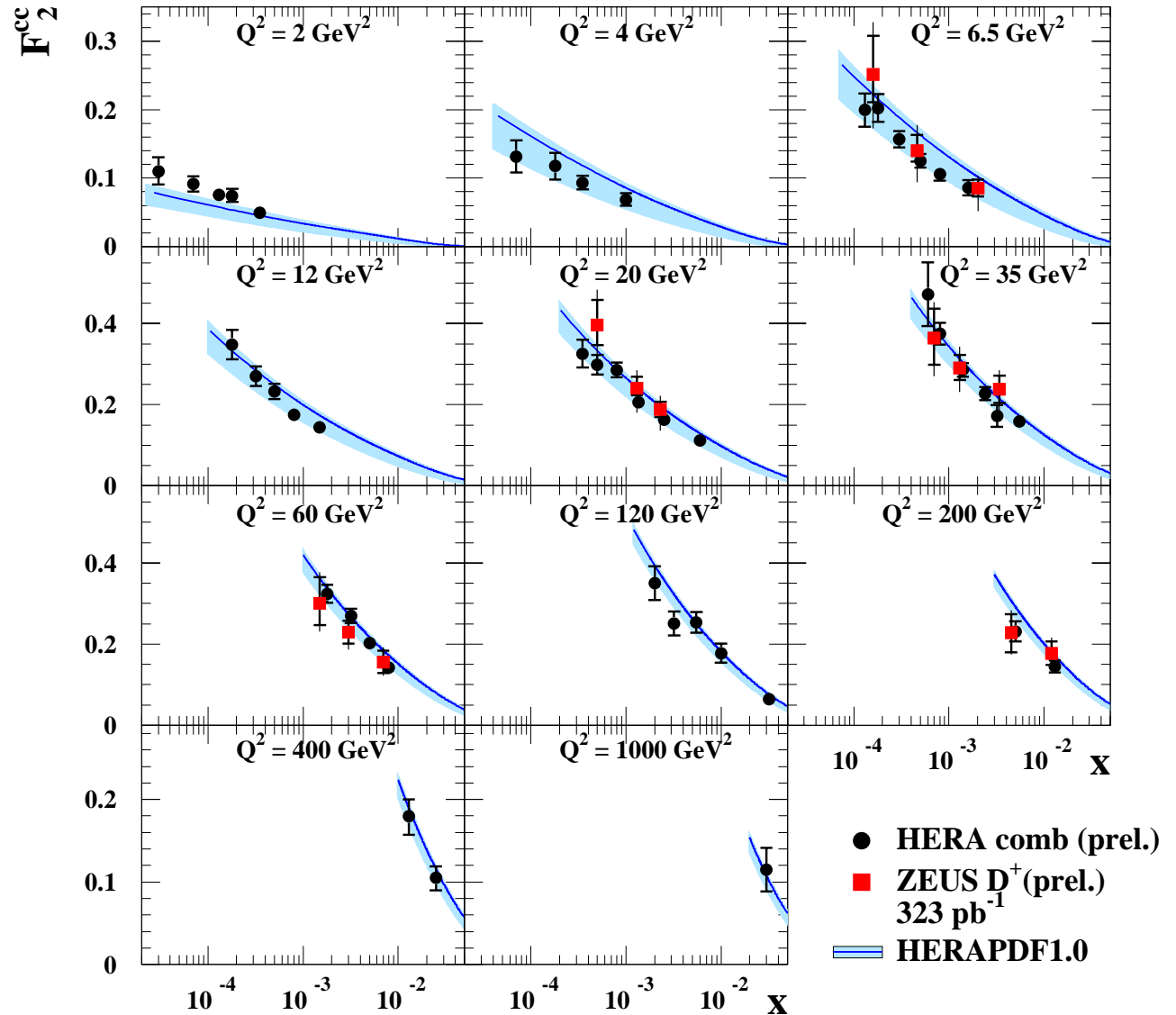


Sensitivity to the gluon.

New D^+ data used to extract F_2^c with good precision.

Here results are compared with data from H1 and ZEUS combined.

New data will help to improve the precision of the combination.



Conclusions

- Lively, active physics analyses
 - publishing many papers
 - many new preliminary results
 - fully committed to combinations
 - fighting for manpower, but clear priorities
- Still significant technical improvements
 - e. g. lumi (2.6% → 1.8% impacts on α_s)
- Plan for data preservation in hand
 - What resources will be available?



Backup



QCD at HERA

NC and CC cross sections main input to QCD fits → **HERAPDF1.0**

Extension to the high- Q^2 and x region

Extension to the low- Q^2 region at high- y :

check of DGLAP evolution

check of QCD predictions for F_L

Inclusion of jet data and HFL data → sensitivity to the gluon



Provide precise input to QCD fits

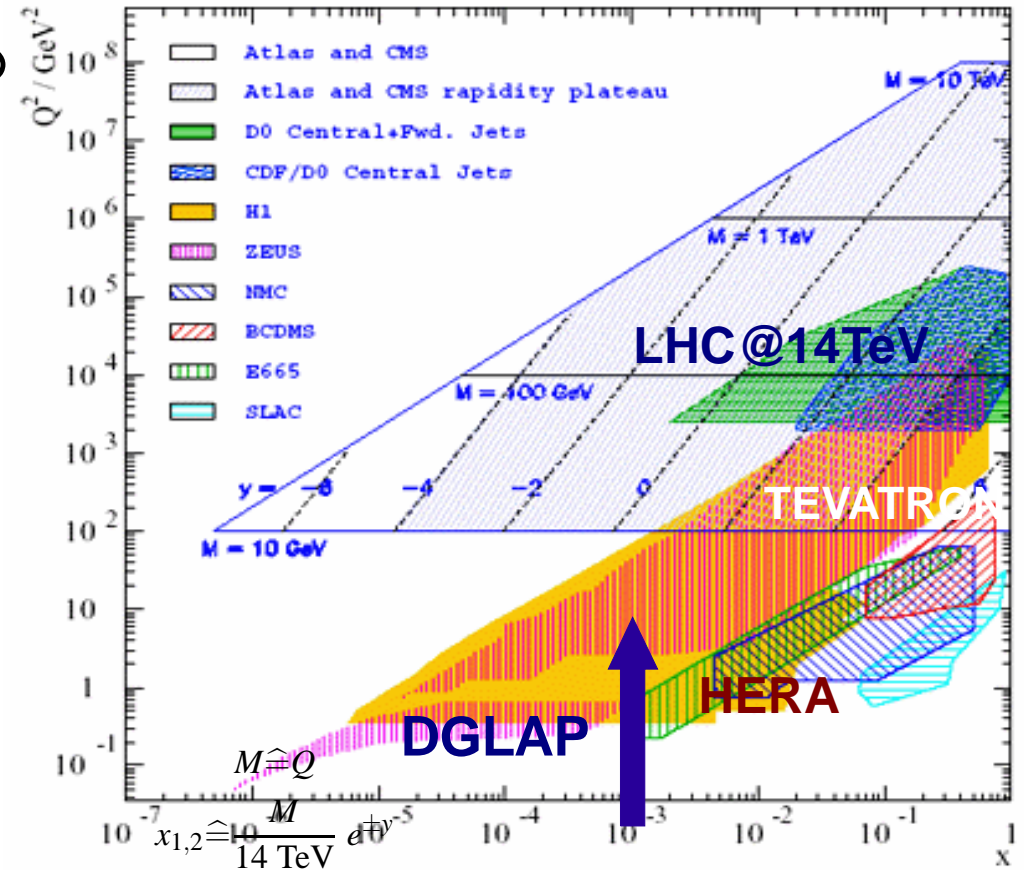


FIG. 1: Kinematic coverage of the DIS and collider pp - $p\bar{p}$ experiments. For pp and $p - \bar{p}$ colliders, the Bjorken x_1 and x_2 of the interacting quarks are related to the mass M of the Drell-Yan pair and its rapidity y as $x_{1,2} = M/\sqrt{S} \exp(\pm y)$ where S is the center of mass energy squared for the experiment.

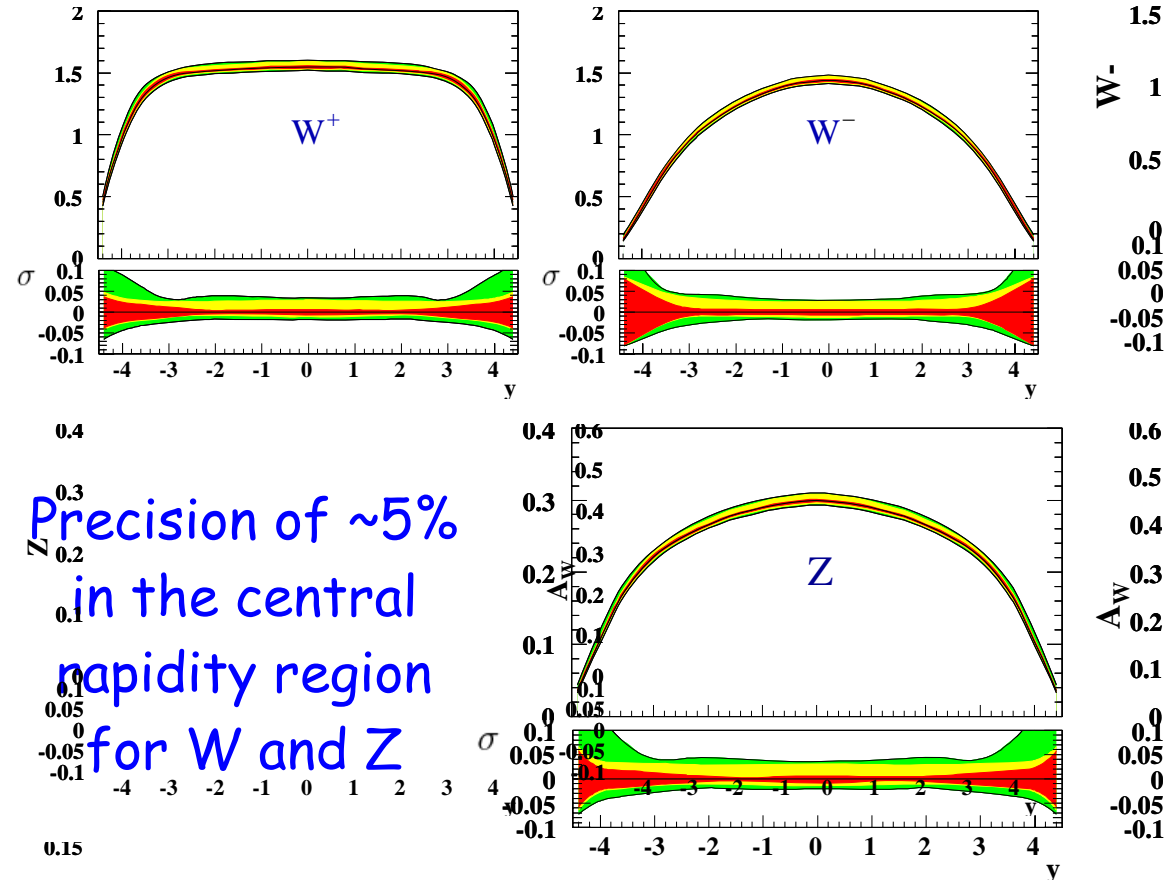
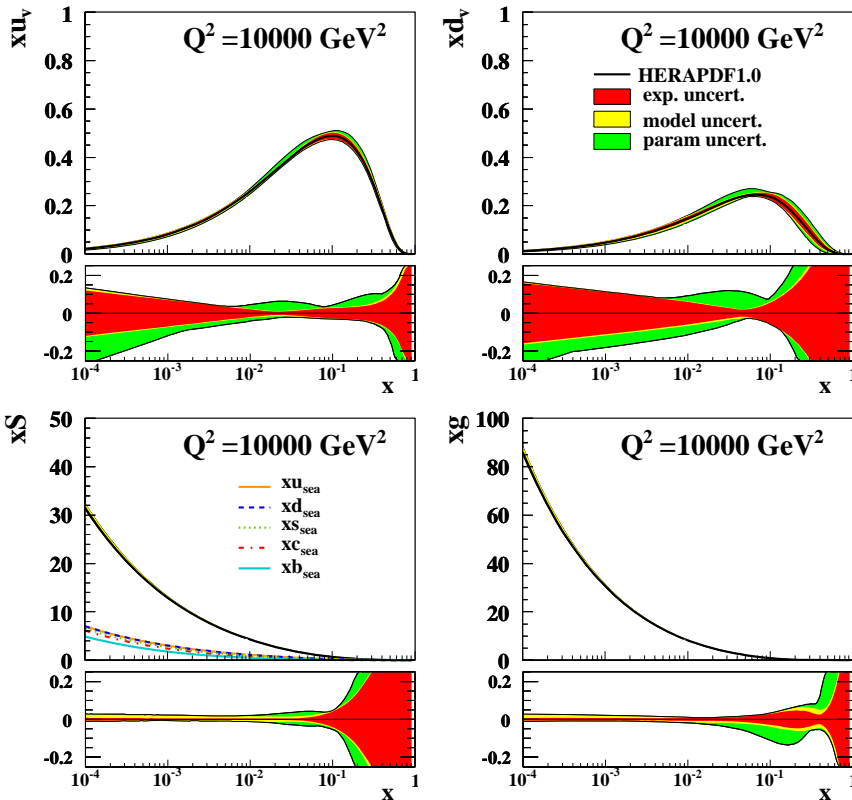


HERAPDF1.0

The combined NC and CC HERA data have been used as the sole input for the extraction of the HERAPDF1.0 W and Z rapidity distributions

H1 and ZEUS

W and Z rapidity distributions

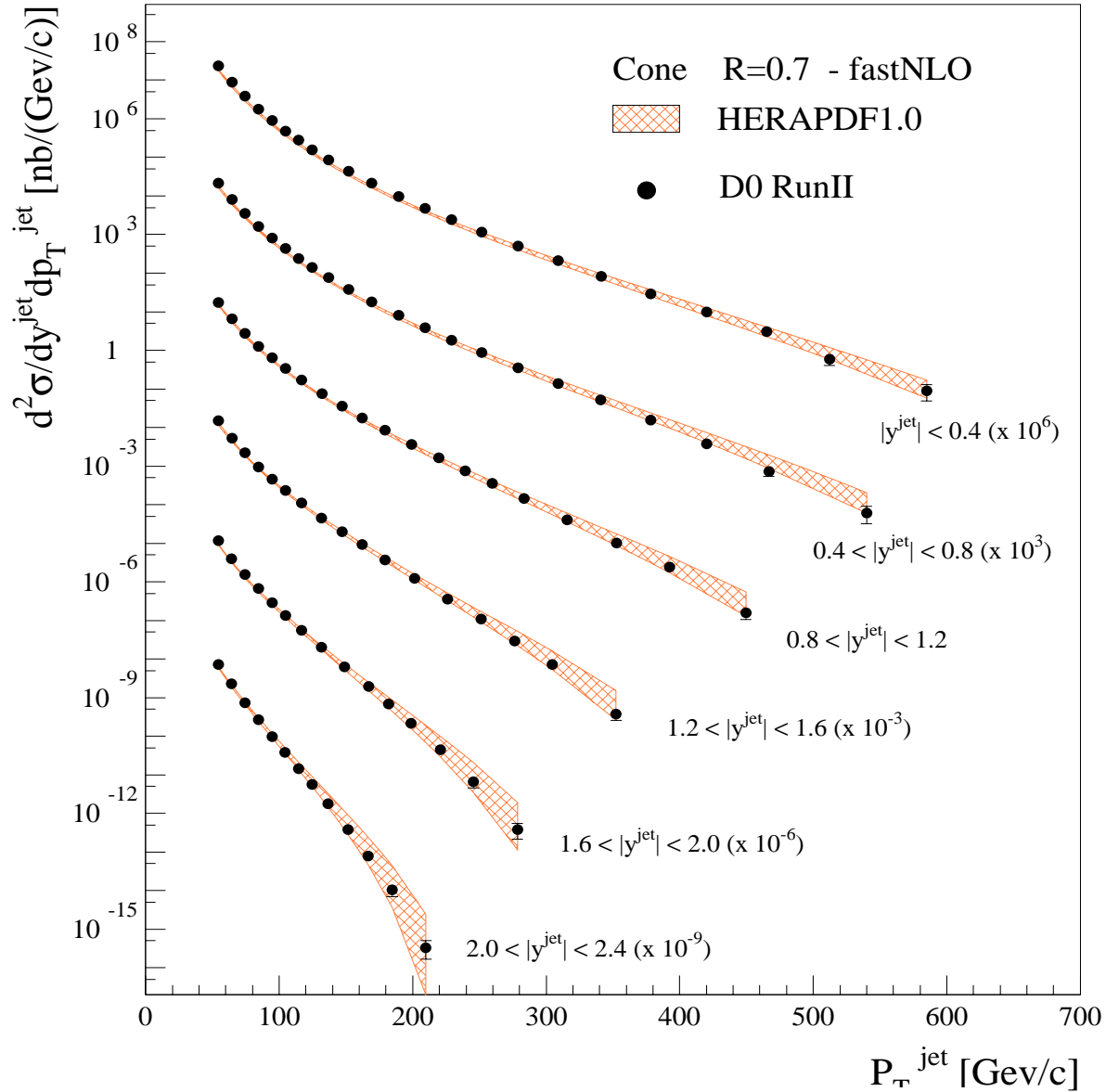
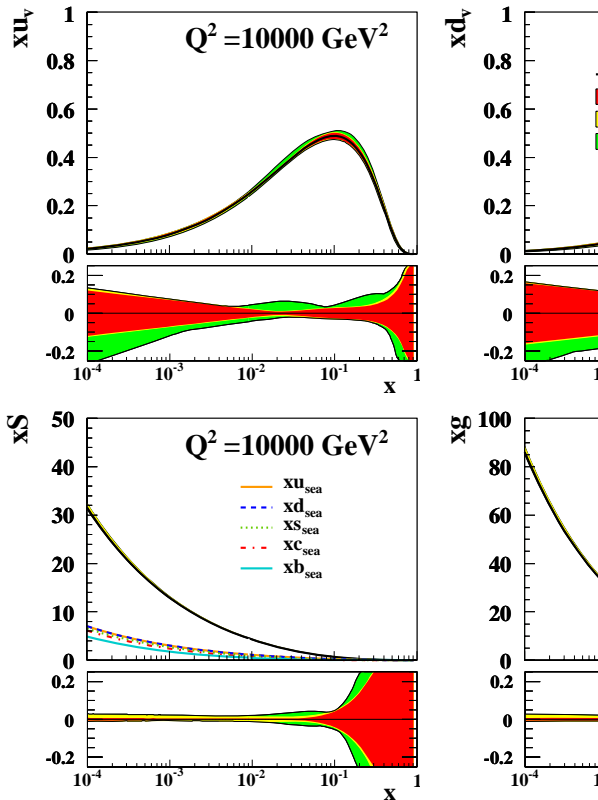




Tevatron Jet Cross Sections

The combined NC and the extraction of the

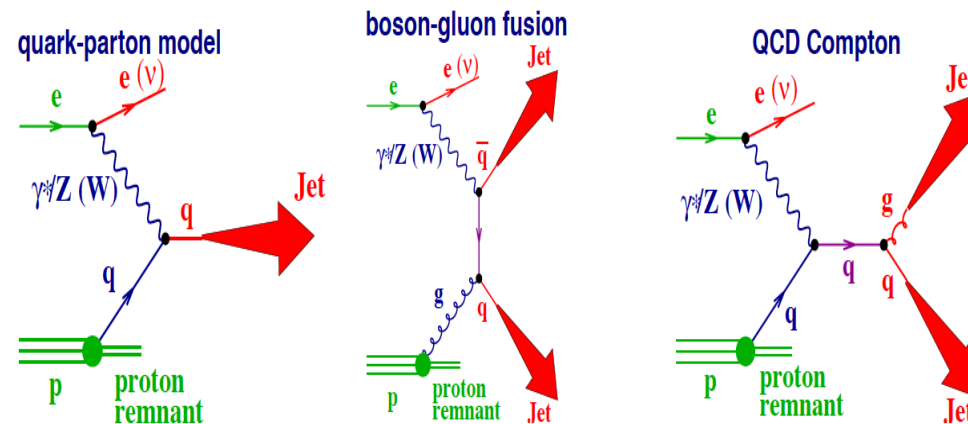
H1 and ZEUS



Jet cross sections

Stringent test of perturbative QCD

Sensitivity to the gluon in the proton, precise input to QCD fits.



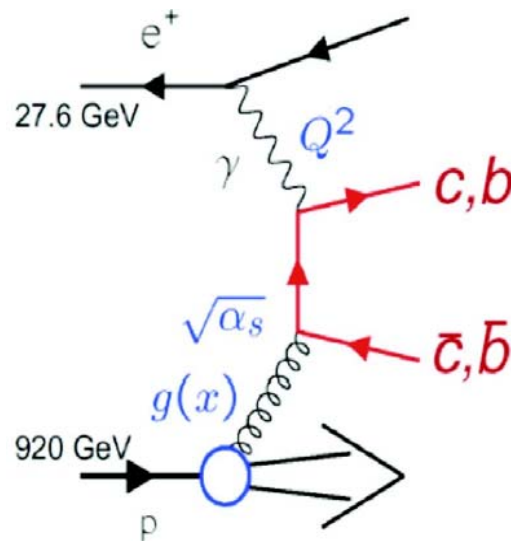
Extract α_s with high precision, check the scale dependence within a single experiment and in different regimes.

Charm and beauty production

Stringent test of perturbative QCD, sensitivity to the gluon in the proton.

Multi-scale problem (mass, p_T , Q^2)

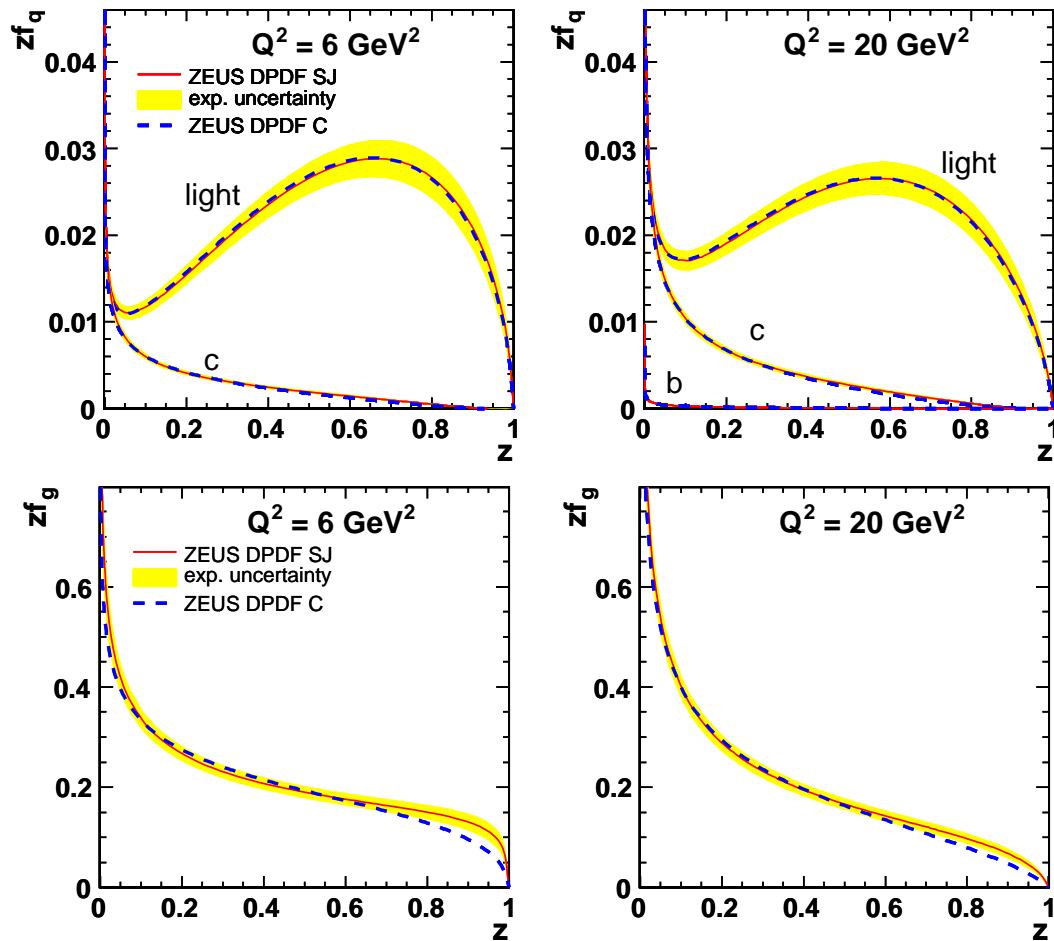
Check of the QCD fits dependence on the flavour treatment



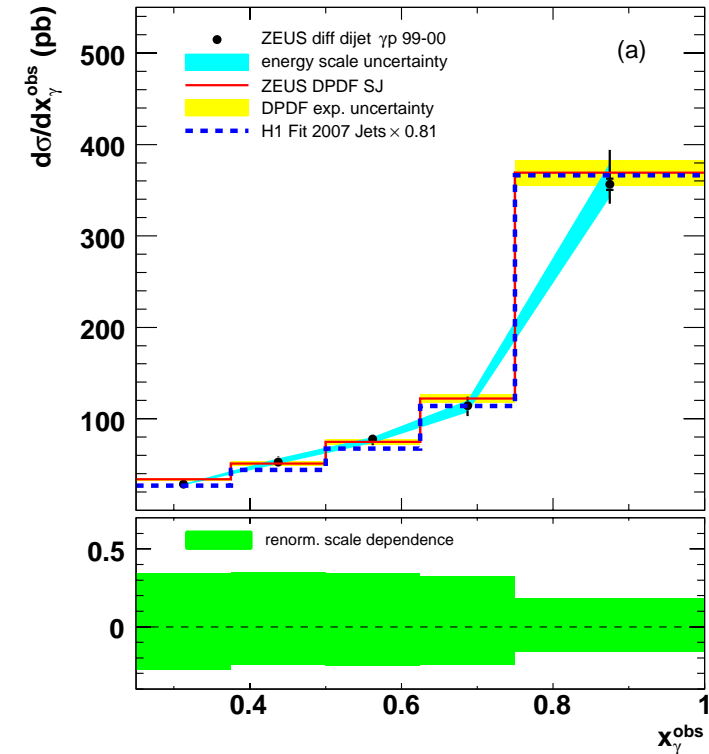
Diffractive PDF fits

Diffractive PDFs extracted from inclusive and jets cross sections in diffractive

ZEUS



ZEUS



Good description of the data obtained also for data not included in the fit (here dijets in PHP, also in the low x_γ region). No factorisation breaking.

Jet algorithms

k_T (Catani et al.)

Jet reconstruction relies on **jet algorithms**.

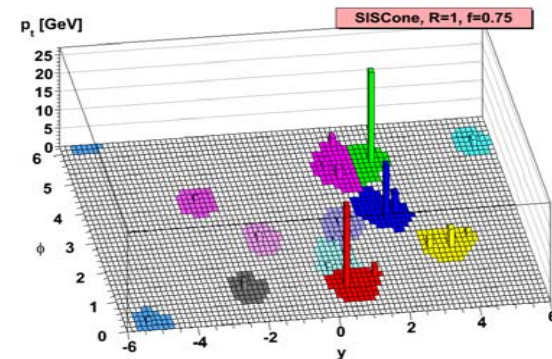
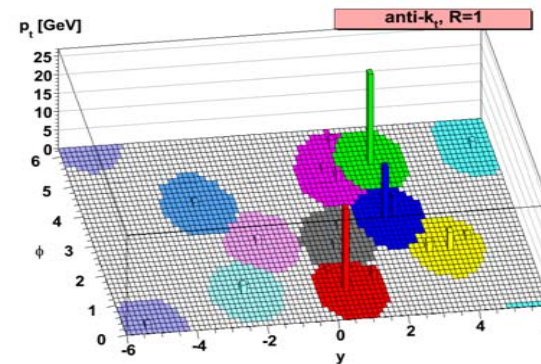
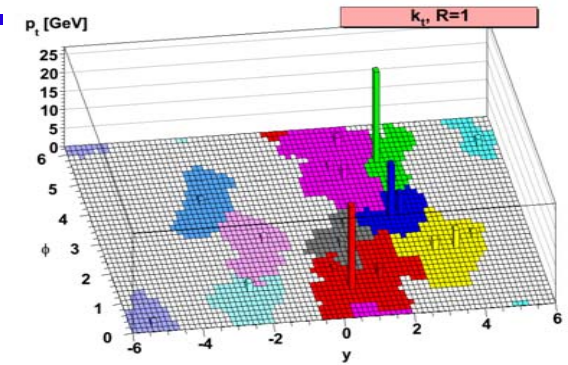
Jet algorithms should not be sensitive to soft particle emission (**infrared safe**) and collinear particle splitting (**collinear safe**).

Cone algorithms normally used in hadron-hadron collisions are **not safe at all order in QCD**.

Example test on the same MC event:

Anti- k_T is similar to k_T but gives jets of regular shape, as SIScone (good i.e. for detector calibration).

Tested on data for the first time at ZEUS...



New developments:
anti- k_T (Cacciari,
Salam, Soyez 08)

SIScone
(Salam, Soyez 07)
both safe at all
orders



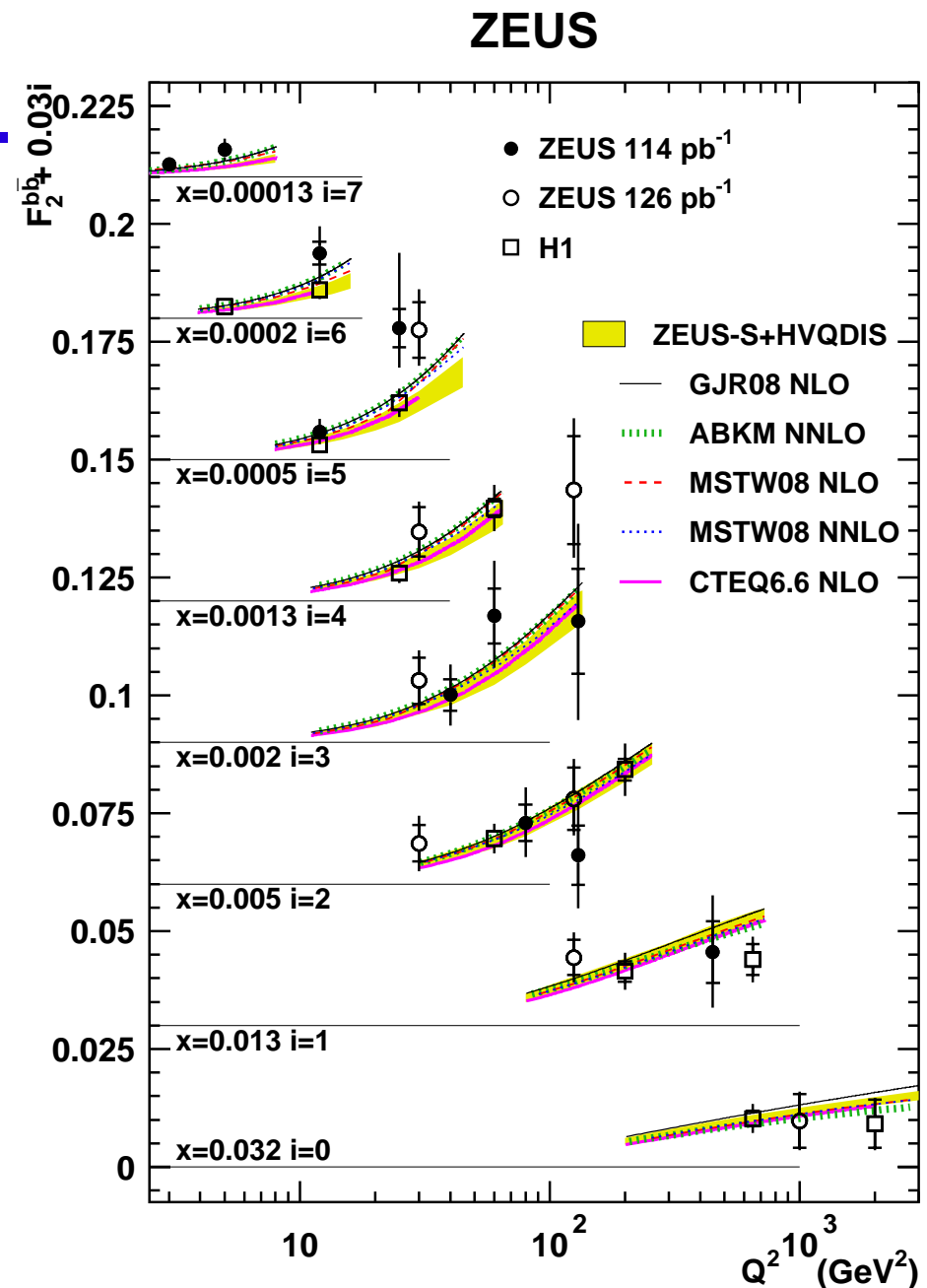
ZEUS F_2^b

Present measurements based on events with muon and jets

Precision of the data is limited

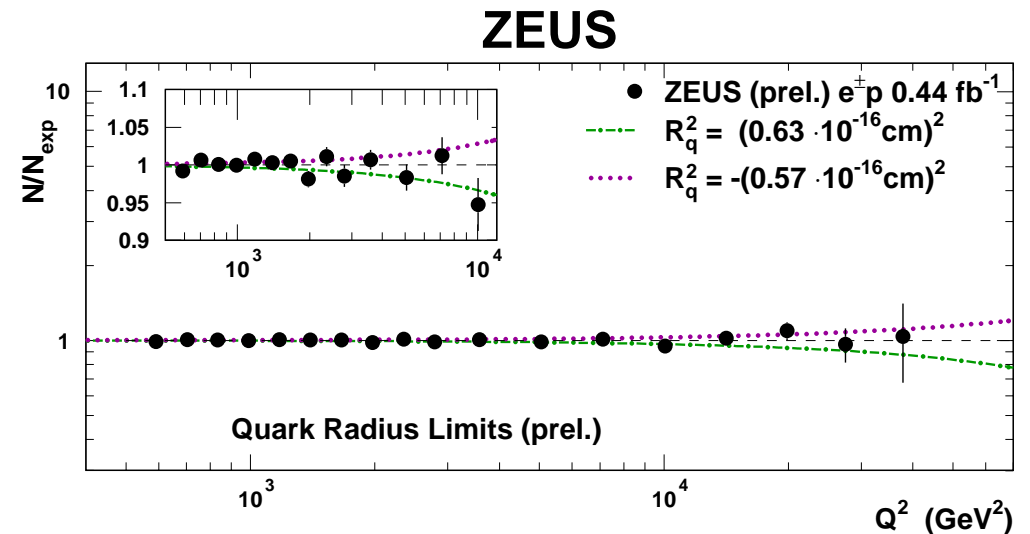
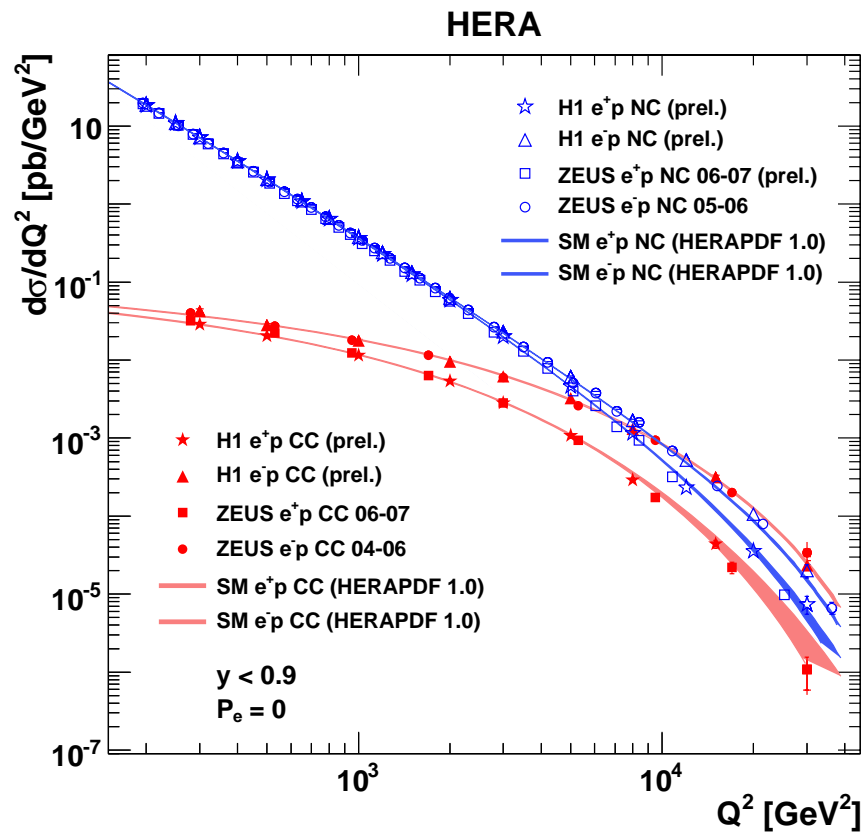
Will dramatically improved using jets from secondary vertices.

Fair agreement between the various theory predictions



Quark radius, contact interactions

Full ZEUS NC statistics used to investigate quark radius, CI models, heavy leptoquarks, large extra dimensions. **Strong limits extracted.**

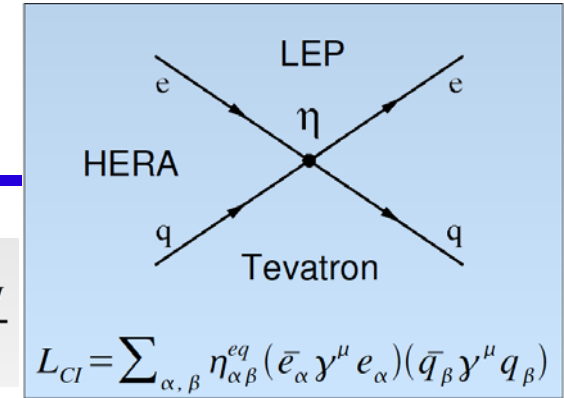


Limit on the quark radius:
 $R < 0.63 \cdot 10^{-3} \text{ fm @ 95\% CL}$

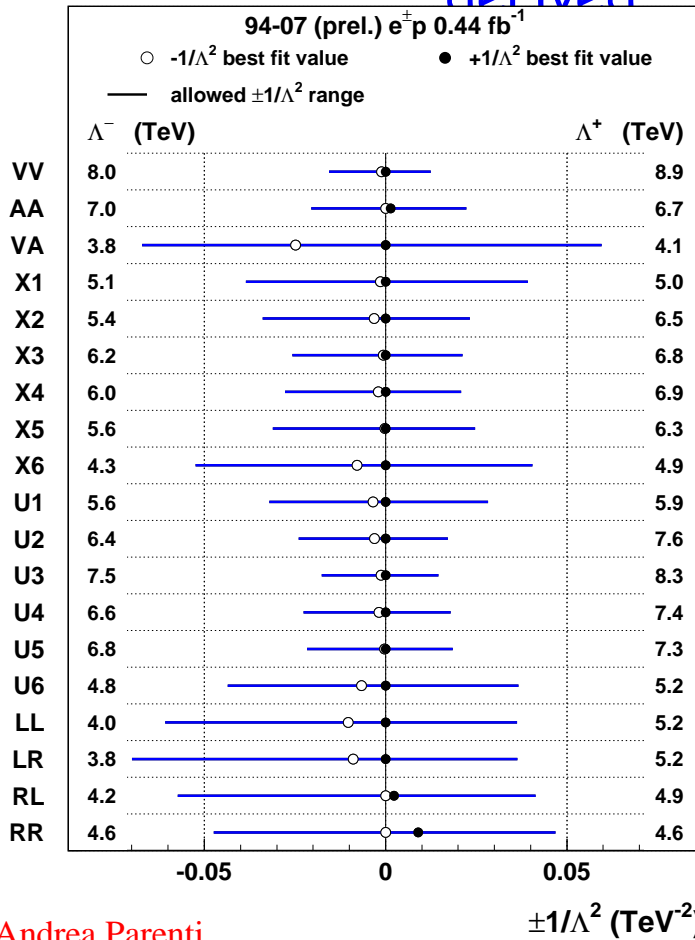
Contact interactions, quark radius

Full ZEUS NC statistics used to investigate CI models. **Strong limits on the couplings**

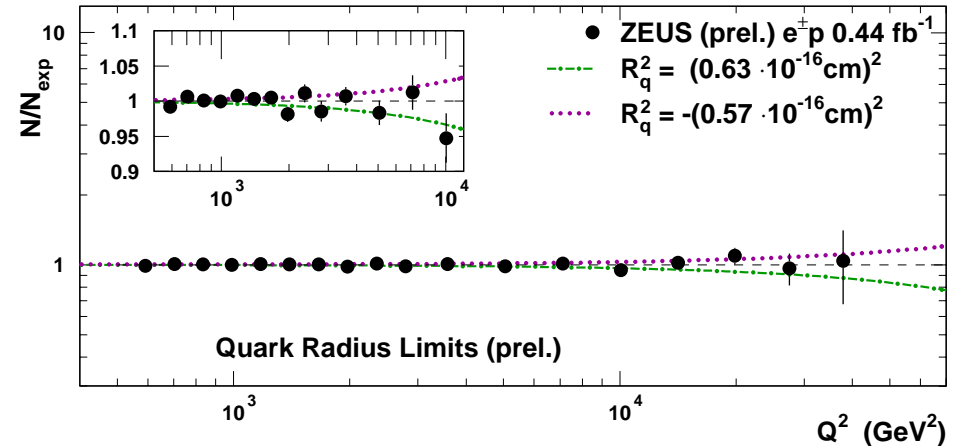
$$\eta_{\alpha\beta}^{eq} = \frac{\epsilon g_{CI}^2}{\Lambda^2}$$



ZEUS derived



ZEUS



**Limit on the quark radius:
 $R < 0.63 \cdot 10^{-3} \text{ fm @ 95\% CL}$**

ZEUS-prel-09-013



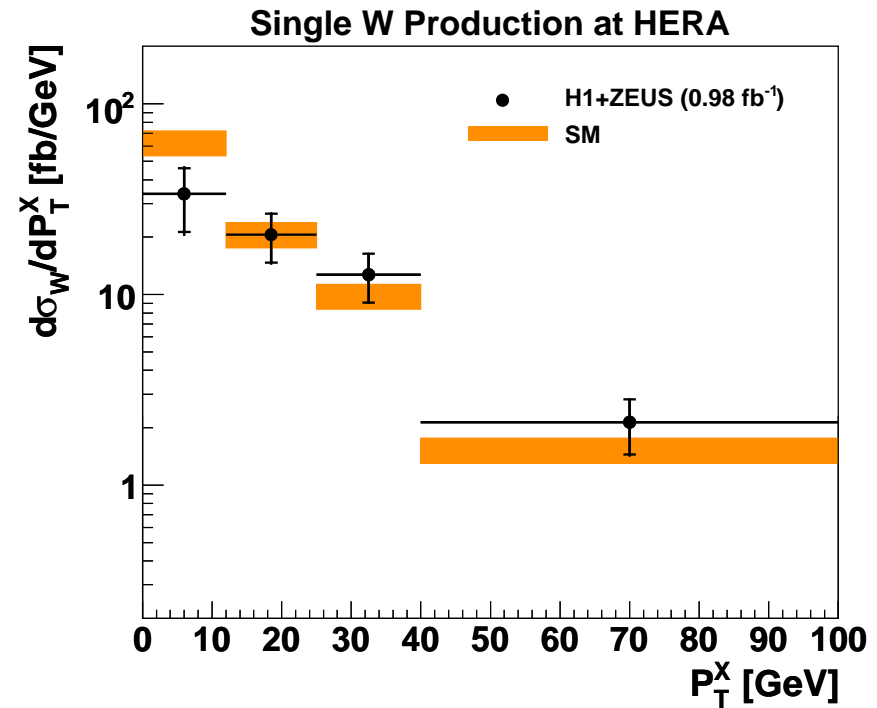
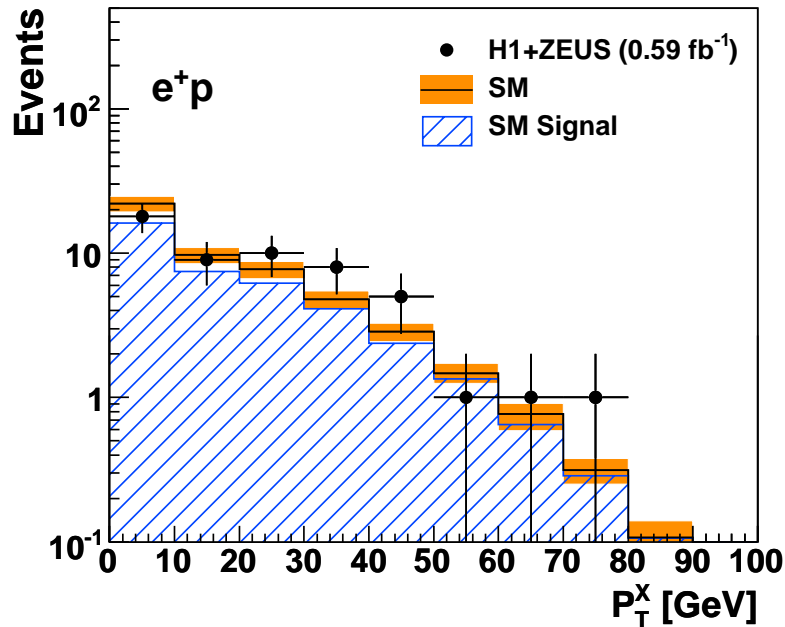
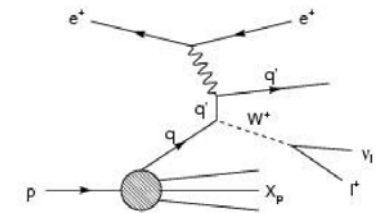


see David South[67]

Isolated leptons with missing p_T



Analysis based on the full ZEUS+H1 data sample, $L=0.98$ fb⁻¹. Dominant SM process: W production.



23 high- p_T^X events in e^+p data,

14 ± 0.9 predicted

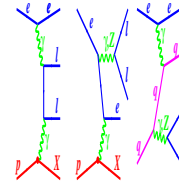
W production cross section measured



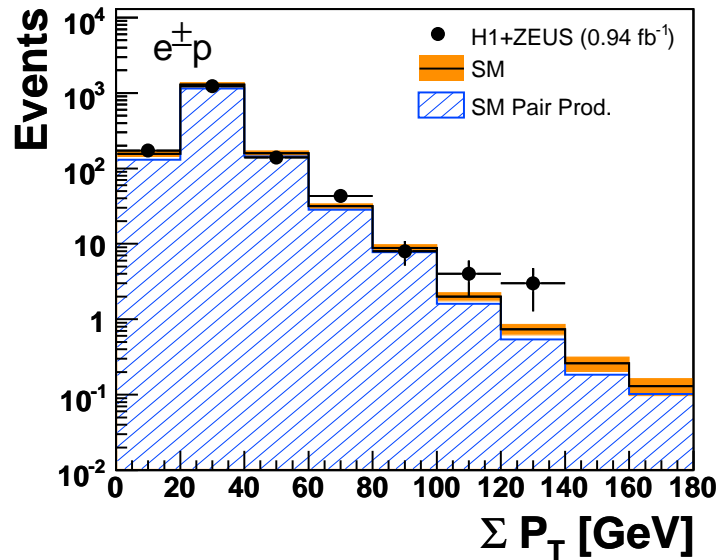
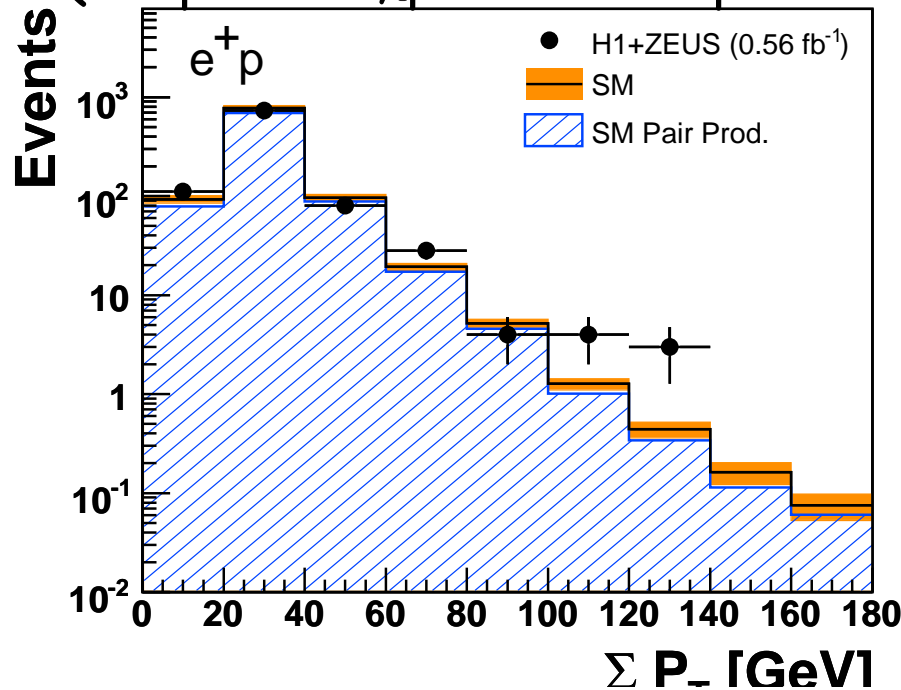


see Andrea Parenti [84]

Multi-leptons



Analysis based on the full ZEUS+H1 data sample, $L=0.94 \text{ fb}^{-1}$
QED process, precise SM predictions \rightarrow look for deviations.



7 high- Σp_T events
observed in e^+p data

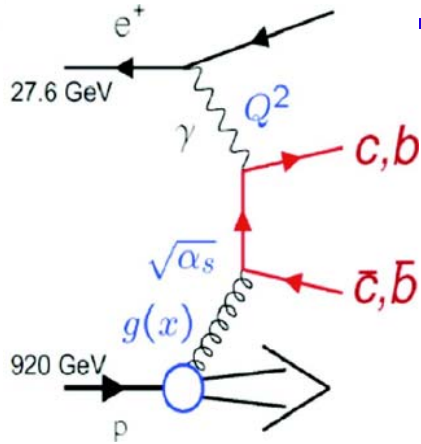
Multi-Leptons at HERA (0.94 fb^{-1})

Data sample	Data	$\Sigma P_T > 100 \text{ GeV}$		
		SM	Pair Production (GRAPE)	NC DIS + QEDC
e^+p (0.56 fb^{-1})	7	1.94 ± 0.17	1.52 ± 0.14	0.42 ± 0.07
e^-p (0.38 fb^{-1})	0	1.19 ± 0.12	0.90 ± 0.10	0.29 ± 0.05
All (0.94 fb^{-1})	7	3.13 ± 0.26	2.42 ± 0.21	0.71 ± 0.10





H1+ZEUS $F_2^{c\bar{c}}$

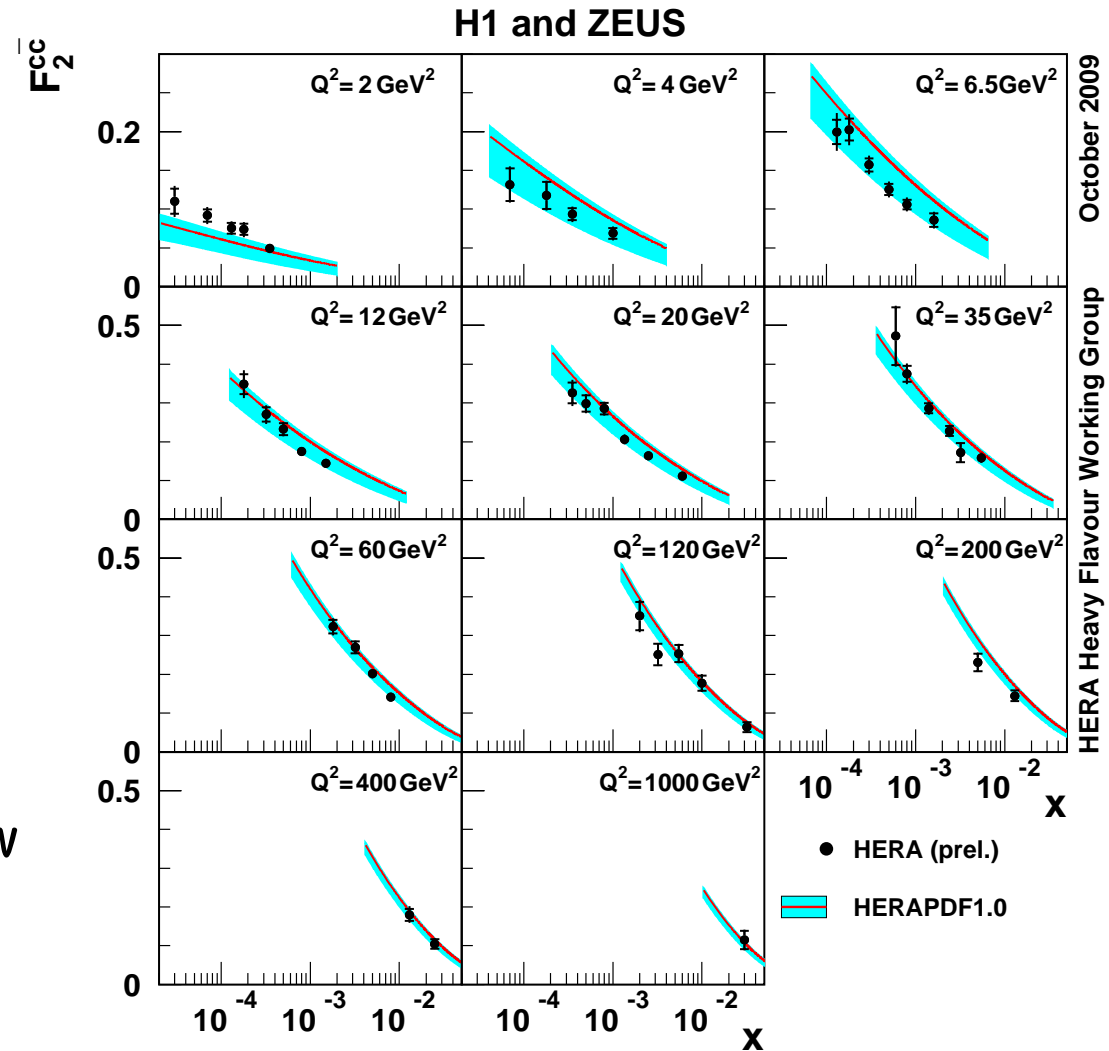


Sensitivity to the gluon.

Data from H1 and ZEUS combined.

Precision is now 5-10%.

Can be improved by adding new measurements (see comparison with new D^+ data)

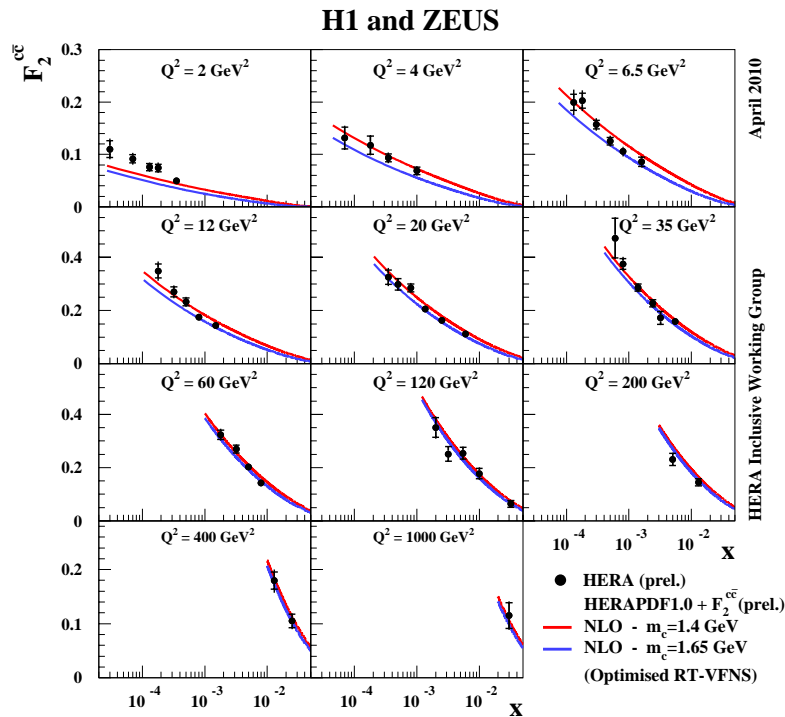




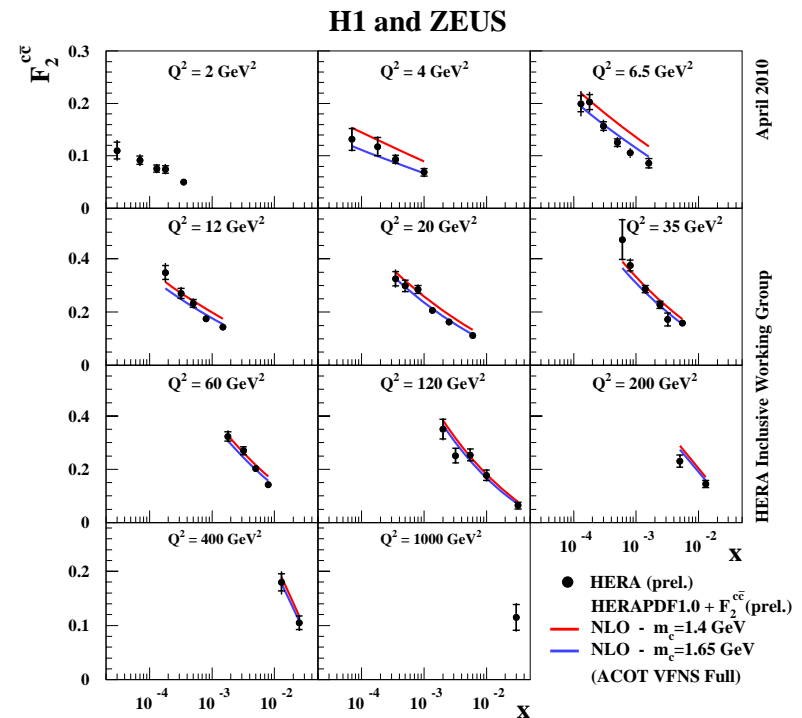
QCD fits with charm data

New F_2^c data added to the HERAPDF1.0 fit. PDF and χ^2 do not change much.

RT optimal fit, prefer $m_c = 1.4 \text{ GeV}$



ACOT fit, prefer $m_c = 1.65 \text{ GeV}$



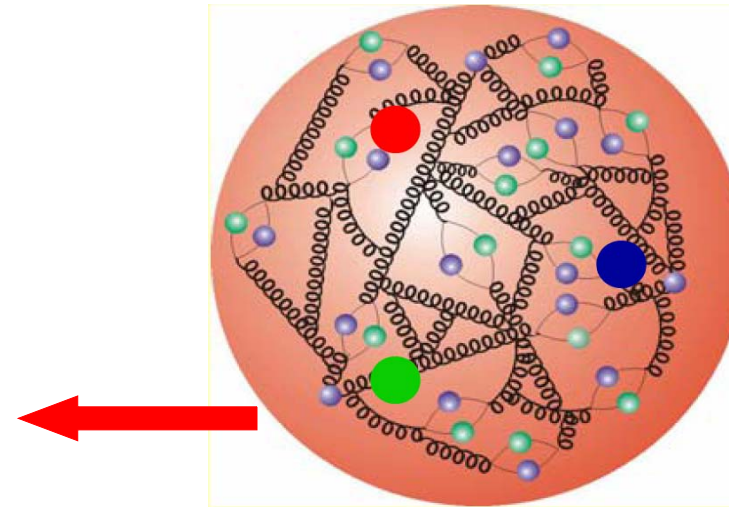
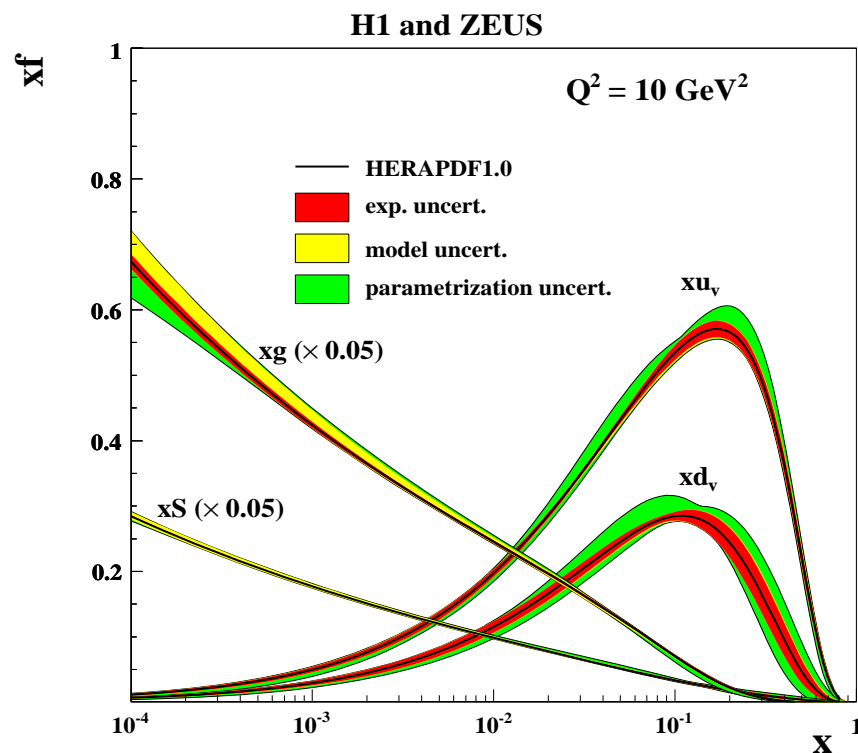
But the fits are very sensitive to the charm mass and to the heavy quark treatment. Different approaches prefer different masses.

The choice of the mass plays an important role for predictions at LHC!



HERAPDF1.0

The combined HERA data have been used as the sole input for the extraction of the HERAPDF1.0.



Gluon (and sea) scaled down by a factor 20, dominate at low x .

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Precise picture of the proton

