

Summary of the ZEUS physics results



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Monica Turcato
Hamburg University



on behalf of
the ZEUS Collaboration

XVIII International Workshop on Deep-Inelastic Scattering
and Related Subjects

Florence, Italy

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Monica Turcato



DIS 2010

Outline

- Inclusive NC and CC cross sections
- Jets cross sections, α_s
- Heavy Flavours
- Diffractive PDF fits



ZEUS(+H1) results for DIS 2010

Inclusive:

- High- Q^2 CC K. Oliver
- NC at high-x R. Ingbir
- NC/CC and PDF fits S. Habib
- Combined F_L J. Grebenyuk
- QCD fits with low energy data V. Radescu

- QCD fits with charm data

A. Cooper-Sarkar

HFL:

- Incl. beauty in DIS P. Roloff
- Incl. beauty in PHP V. Aushev
- Charm mesons in DIS M. Lisovyi
- Inelastic J/ψ helicity A. Bertolin

QCD:

- Jets with anti- k_T and SISCone, (di)jets in NC DIS C. Glasman
- Three subjets J. Terron
- Jets in PHP D. Lontkowskyi
- Scaled momenta K. Olkiewicz
- Prompt photon D. Saxon

Diffraction:

- Diffractive PDFs M. Wing
- J/ψ at high t A. Bruni

EW/searches:

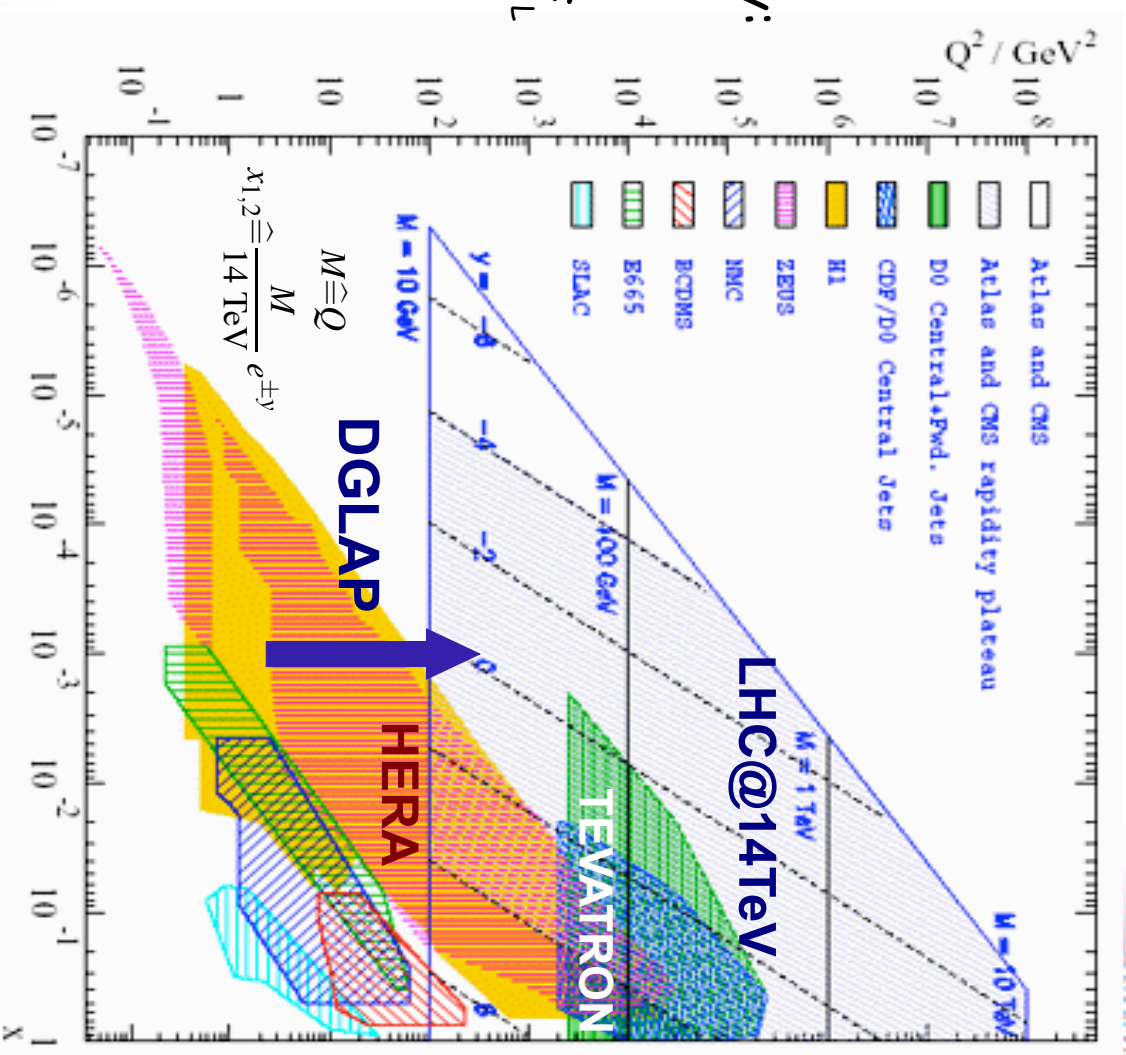
- Isolated leptons D. South
- Multi-leptons A. Parenti
- LQ and CI I. Panagoulas

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 (see K. Krueger)
- Inclusion of jet data and HFL data → sensitivity to the gluon



Provide precise input to QCD fits





H1+ZEUS combined cross sections

see Shiraz Habib [169]



- NC and CC cross sections from H1 and ZEUS combined

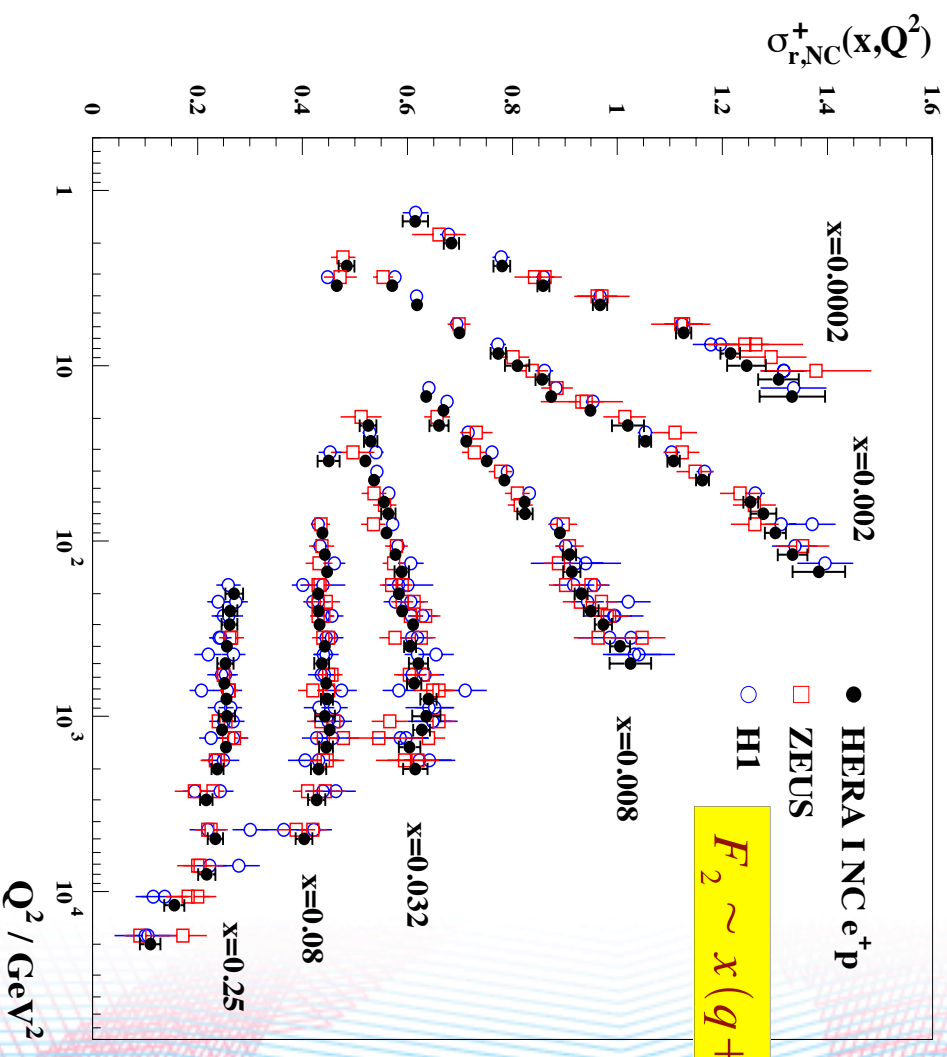
- **Data are now published**

- **Precision of 1-2%**

- Gluon density from **scaling violations**

$$\frac{\partial F_2}{\partial \ln Q^2} \propto \alpha_s(Q^2) xg(x, Q^2)$$

- **DGLAP** drives the evolution in Q^2 at fixed x



Data available to be used in PDF fits!

JHEP01(2010)109





H1 and ZEUS

- NC and CC and ZEUS
- **Data are r**

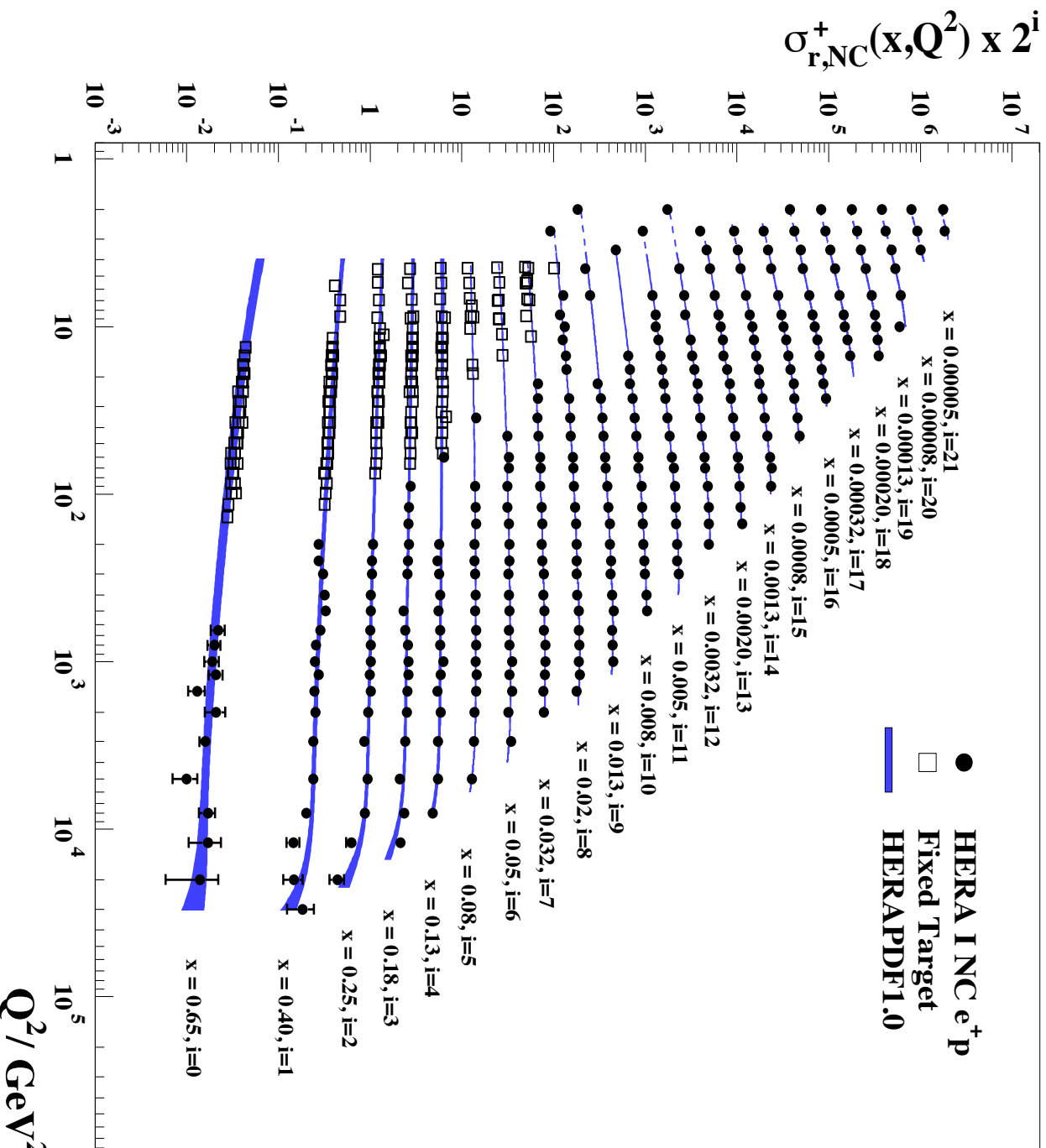
Precision

- Gluon densi violations

$$\frac{\partial F_2}{\partial \ln Q^2} \propto$$

- **DGLAP** driv at fixed x

Data an

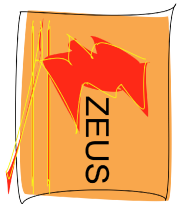


$$c(q + \bar{q})$$



GeV²



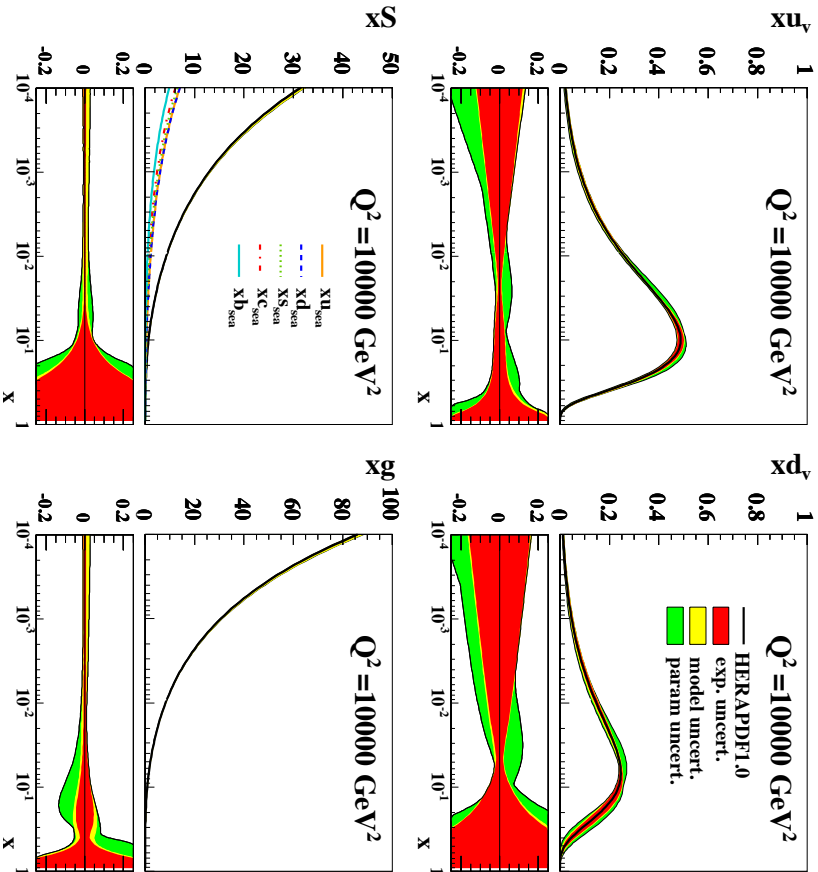


HERAPDF1.0

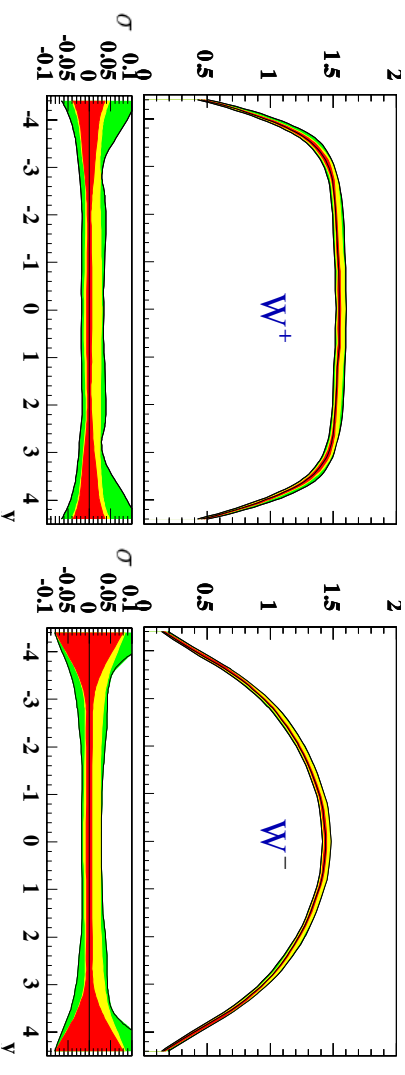
see Shiraz Habib [169]

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

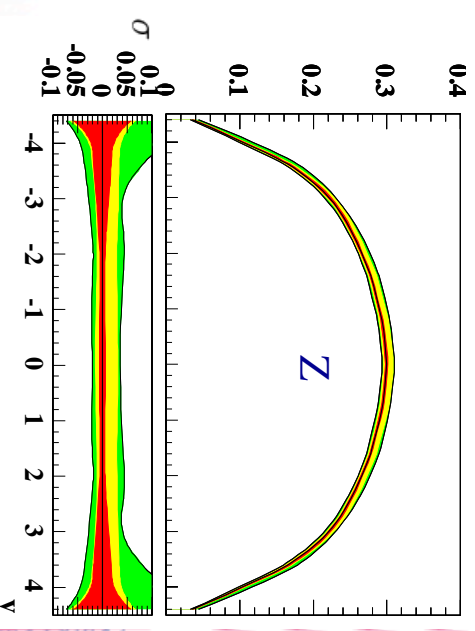
H1 and ZEUS



W and Z rapidity distributions



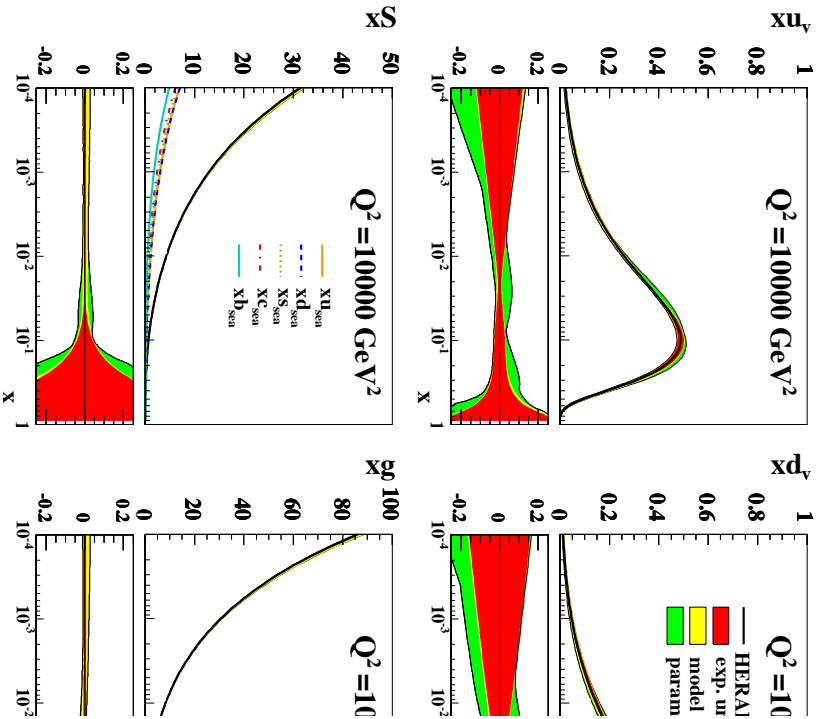
Precision of $\sim 5\%$
in the central
rapidity region
for W and Z





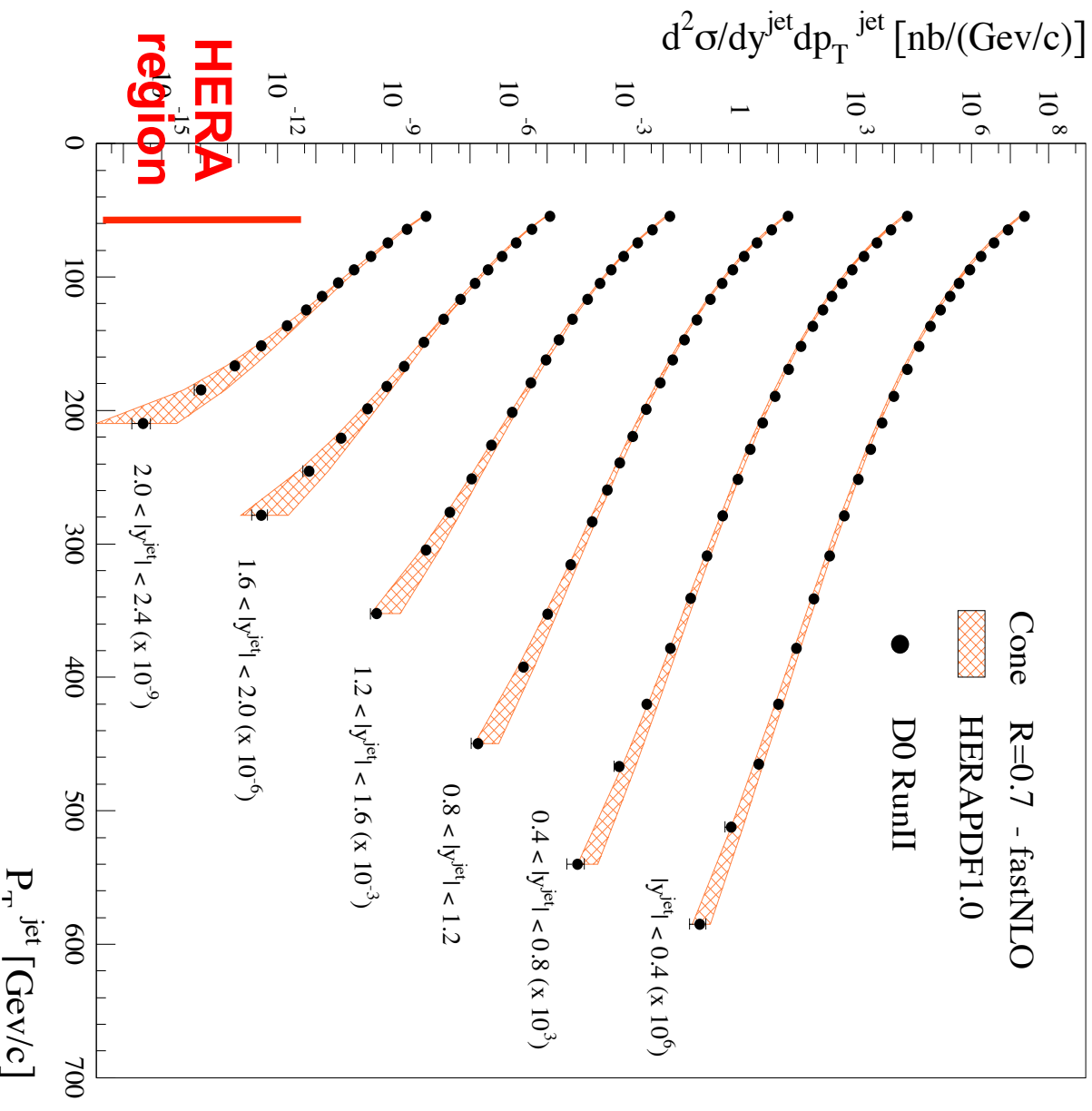
The combined HERA data extraction of the HERAPDF

H1 and ZEUS



Tevatron Jet Cross Sections

Sae Shiraz Habib F1601



HERAPDF1.0 able to describe high-x jet production

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Dns

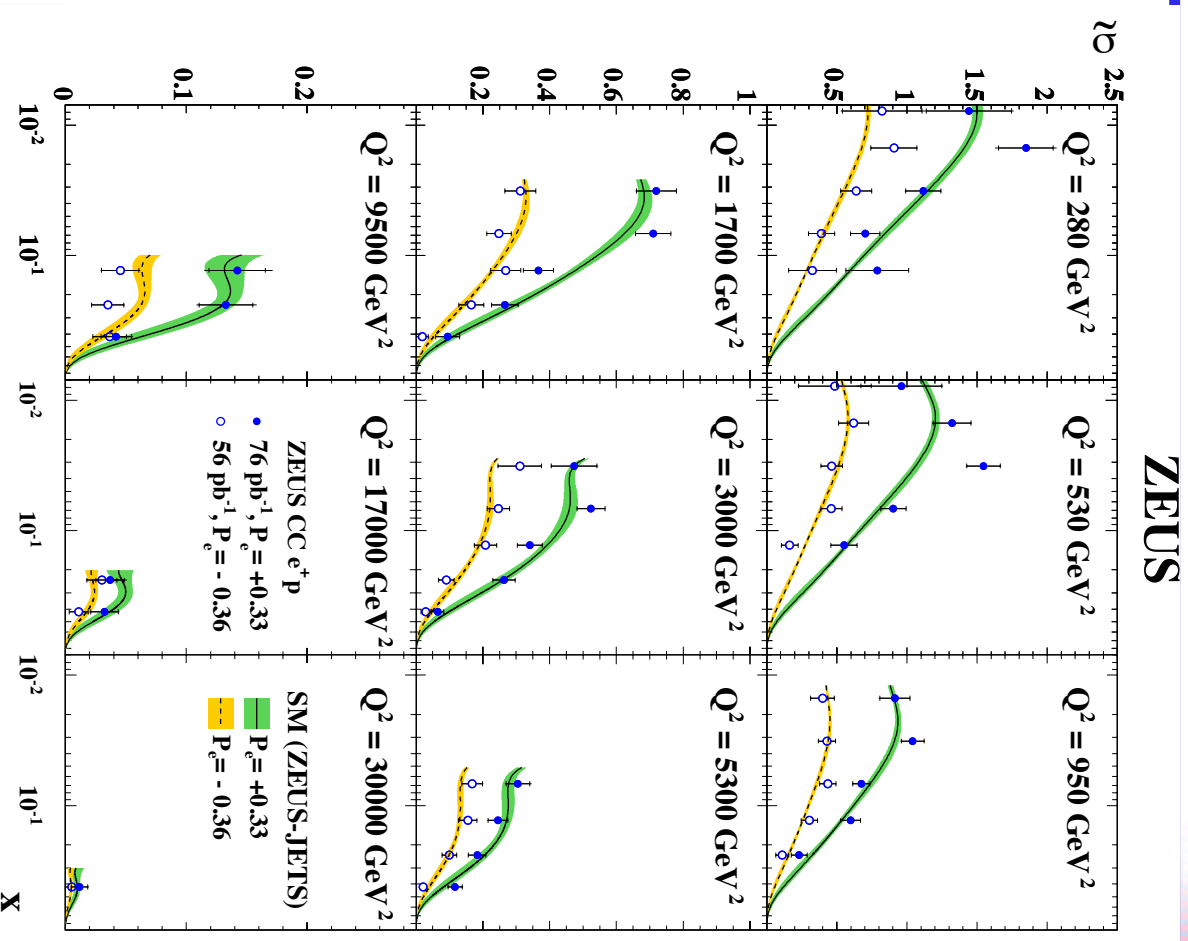
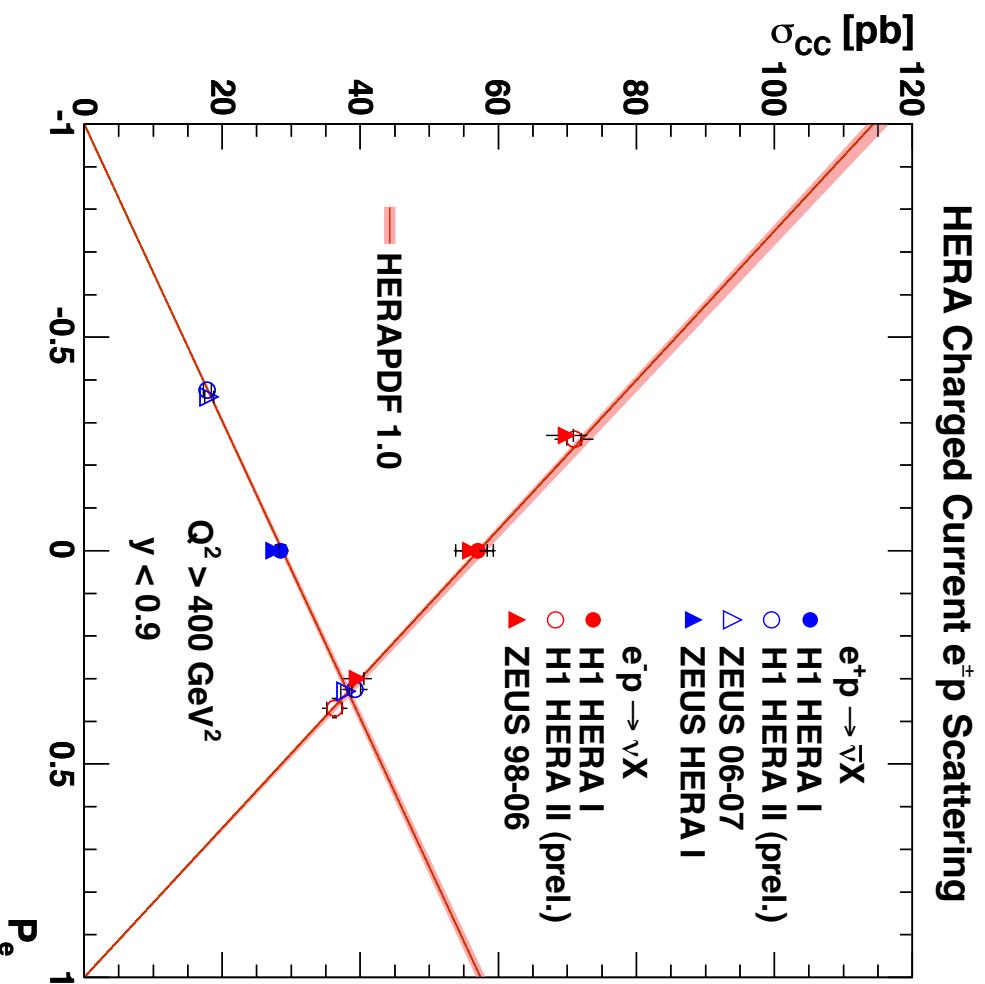


High- Q^2 CC from e^+p data

Final results on e^+p data, $L=1332 \text{ pb}^{-1}$.

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

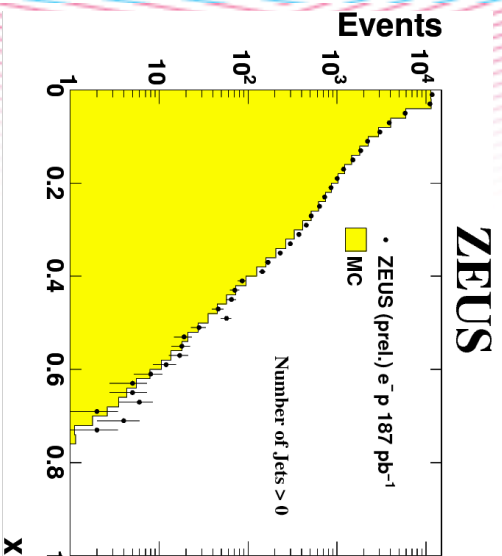
Precise input to QCD fits \rightarrow high x



NC cross sections at high-x

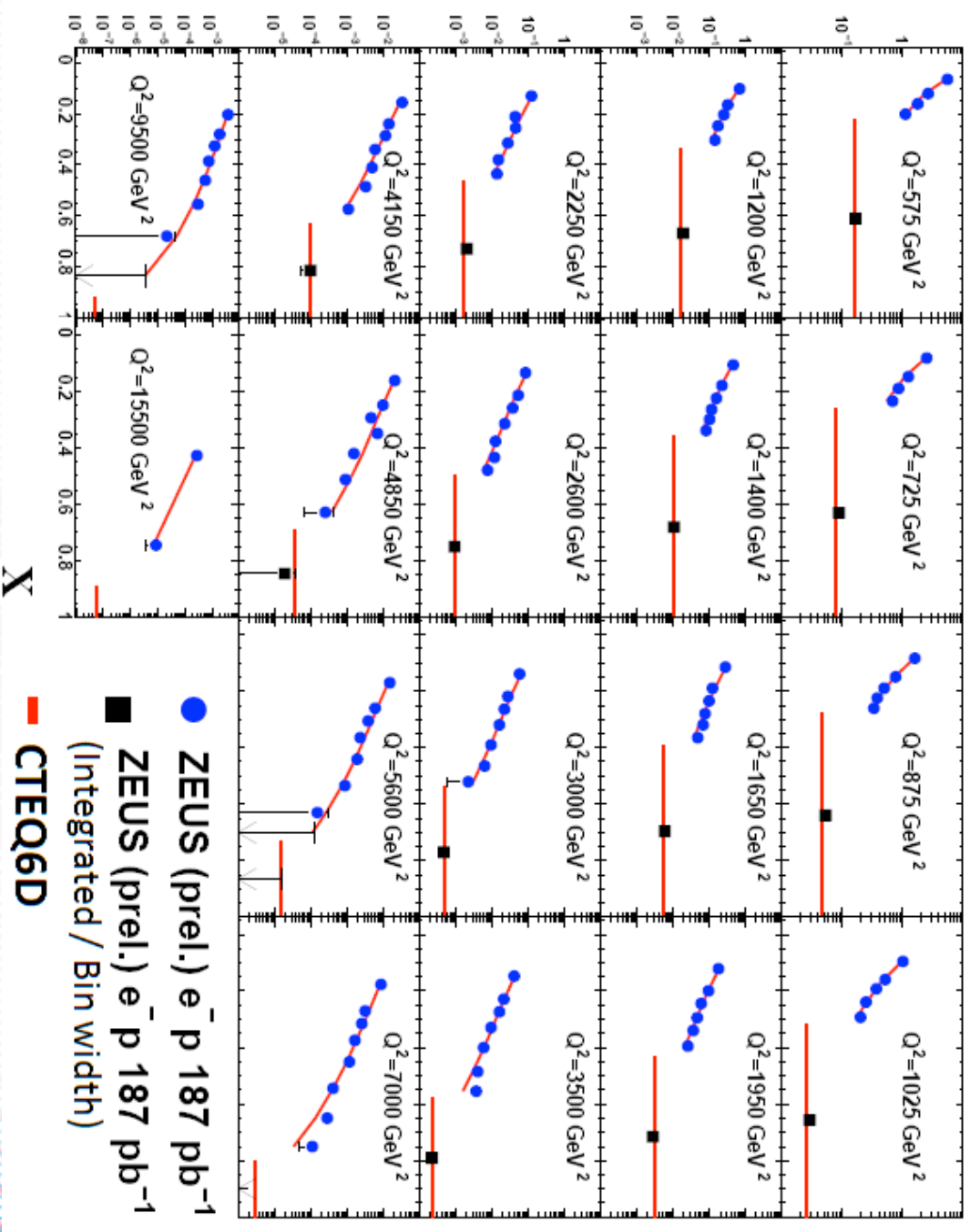
see Ronen Ingbir [36]

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



Sensitivity to the
high-x region.

$d^2\sigma/dx dQ^2$ [pb/GeV²]



ZEUS-prel-10-007

DIS 2010

10

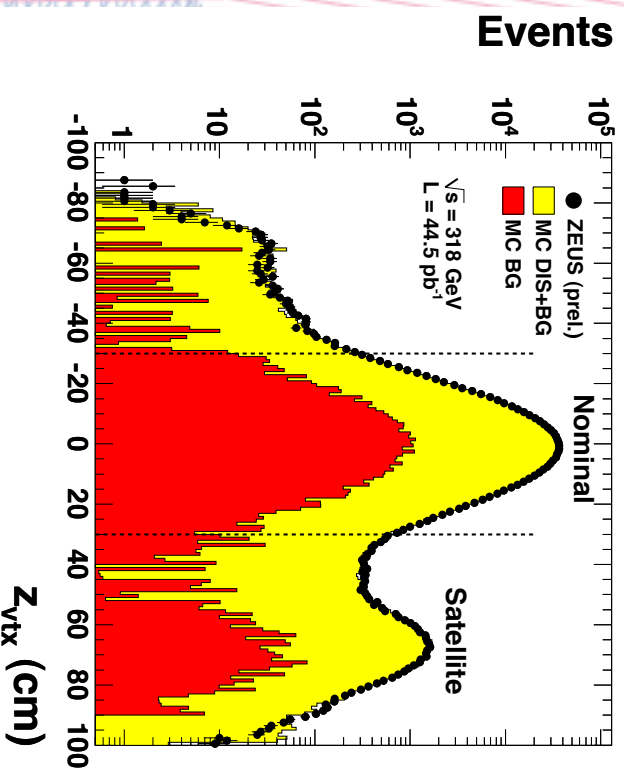
High, medium and low energy cross section at high Y

HERA NC cross sections from data collected at $E_p=920, 460$ and 575 GeV for

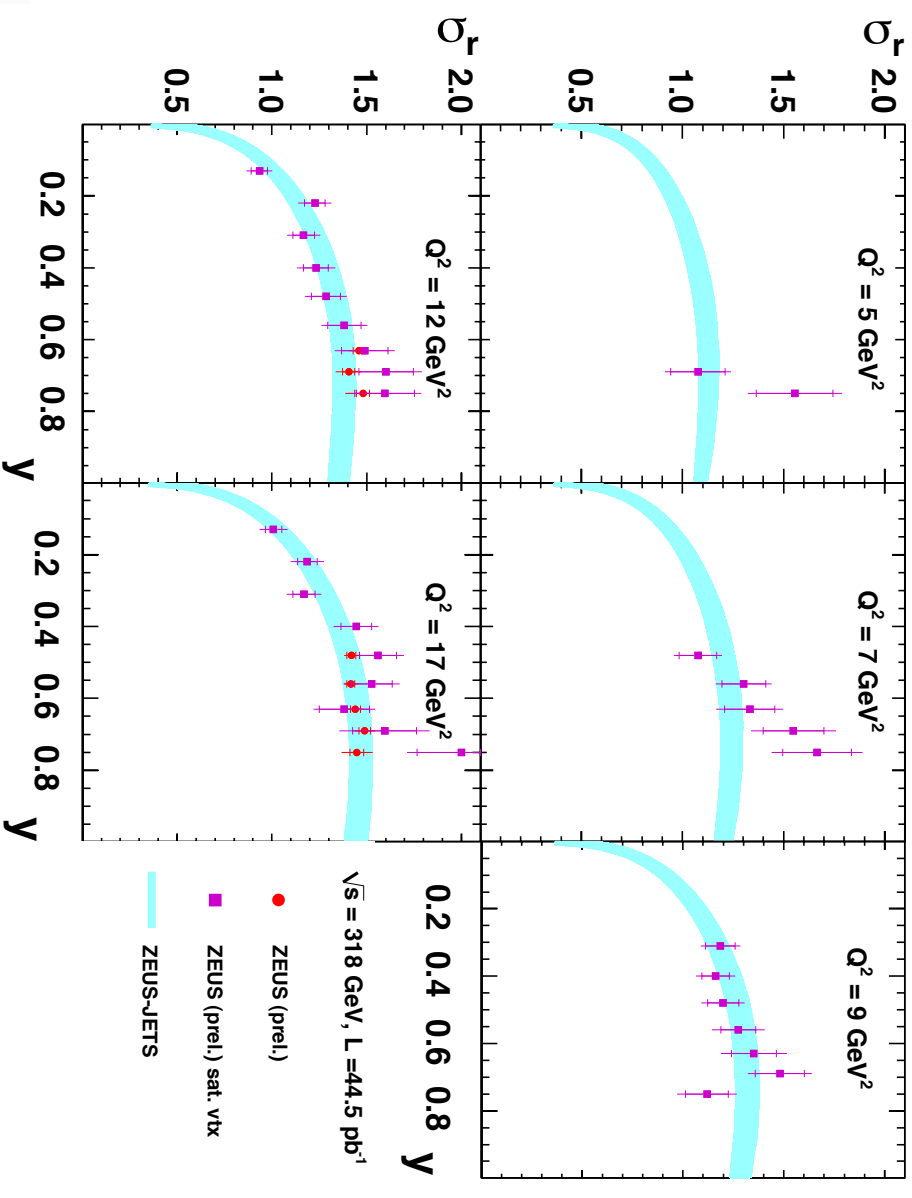
the F_L determination used in PDF

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

ZEUS

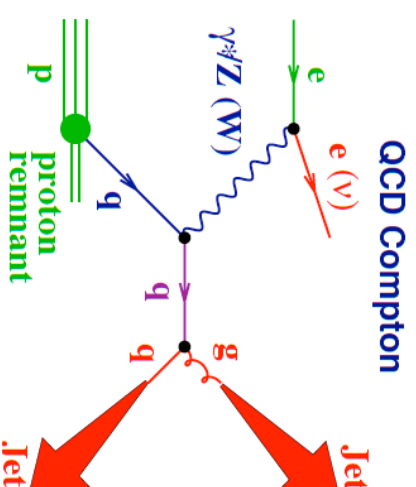
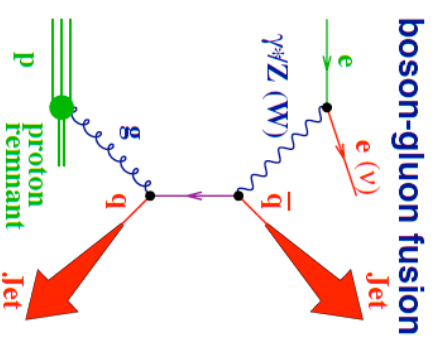


ZEUS



Jet cross sections

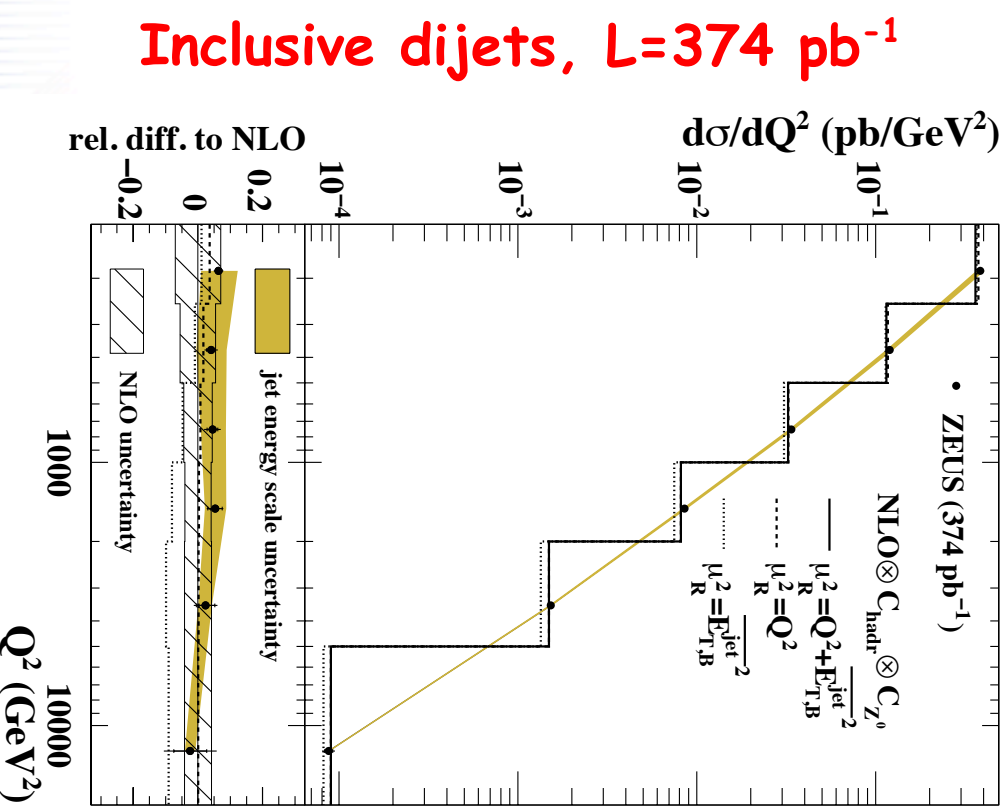
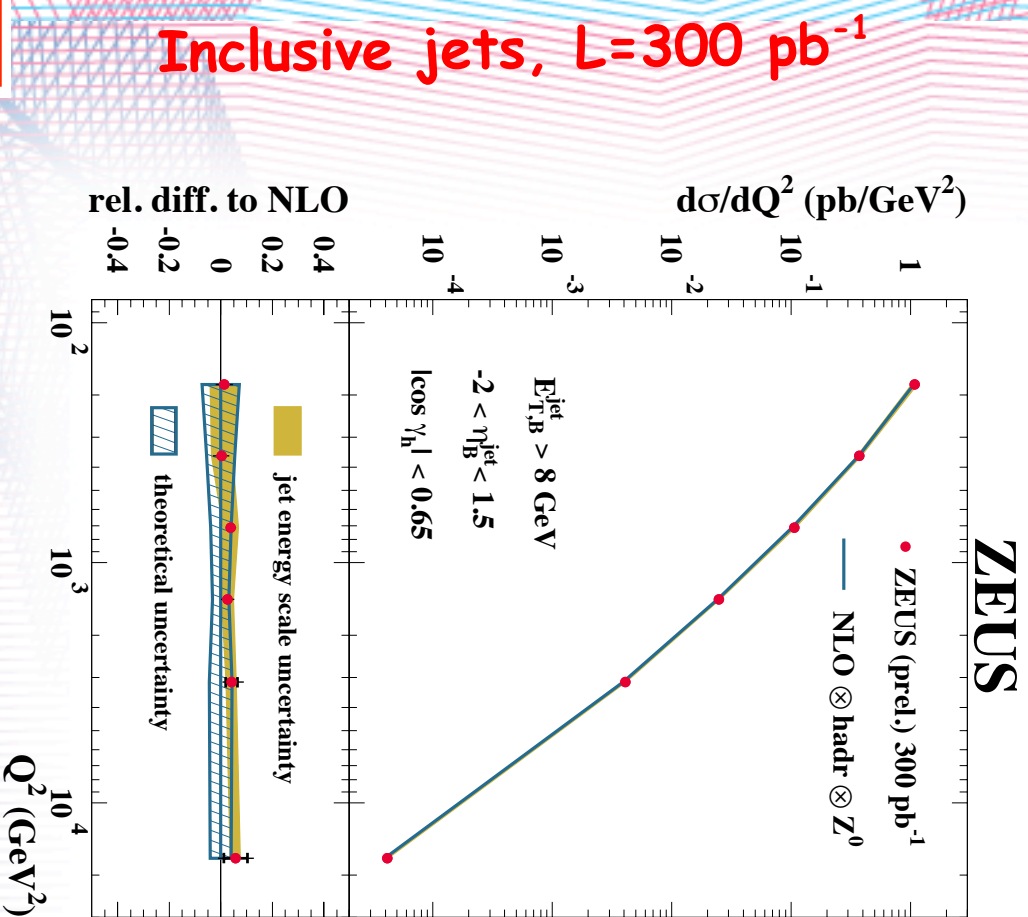
- Stringent test of perturbative QCD
- Sensitivity to the gluon in the proton, precise input to QCD fits.



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

Inclusive jets and dijets in NC DIS

Kinematic range $Q^2 > 125 \text{ GeV}^2$. Good agreement with QCD at NLO.

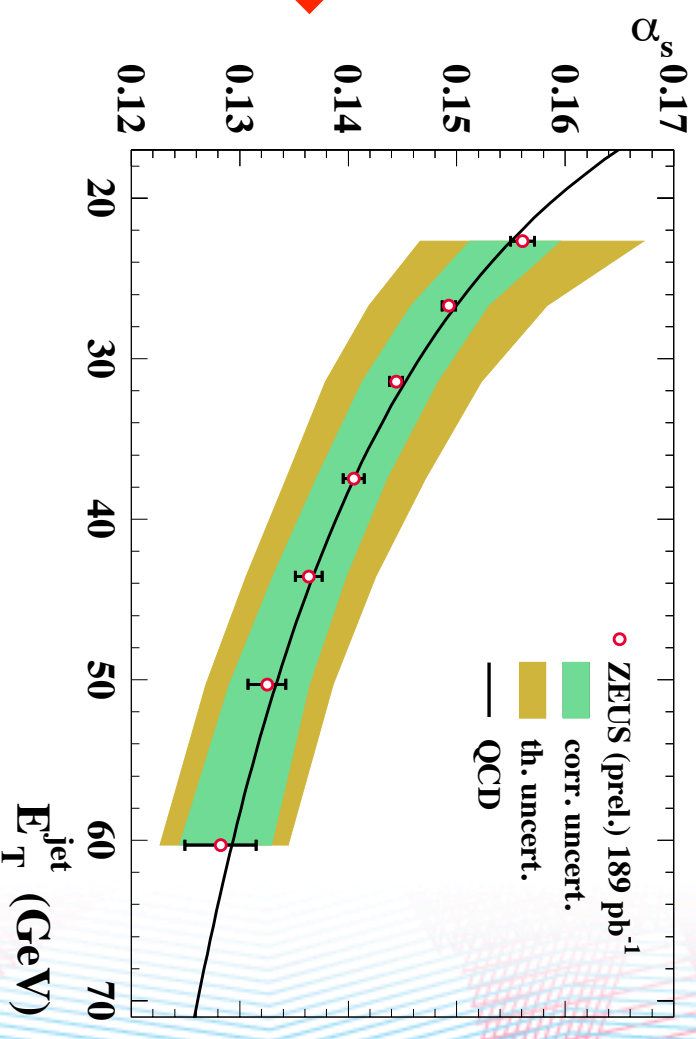
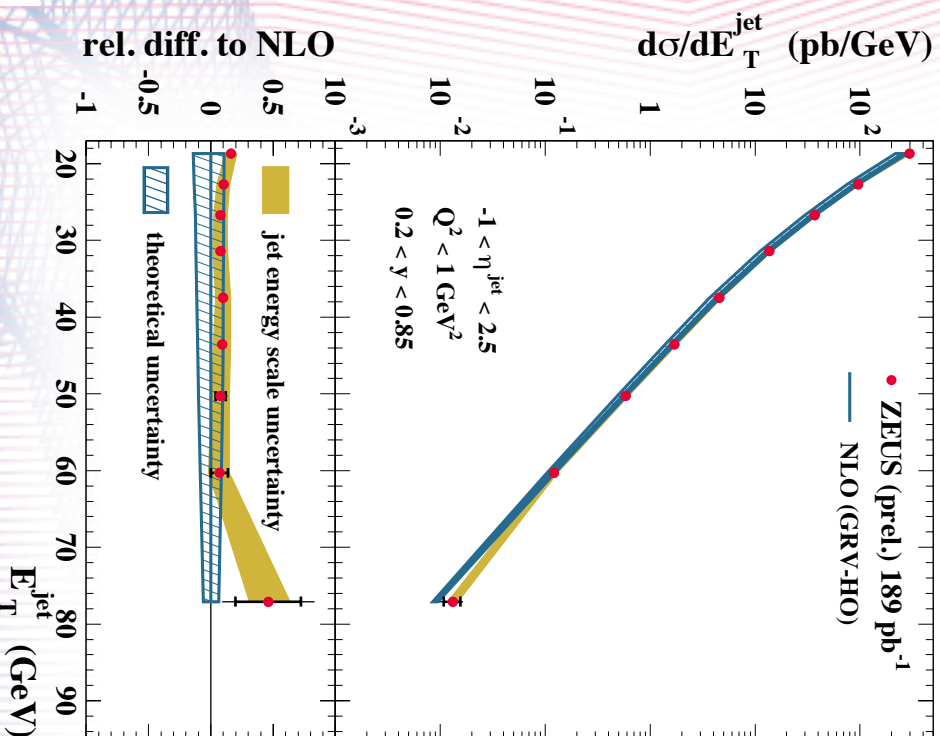


Inclusive jets in PHP

$Q^2 < 1 \text{ GeV}^2$, $0.2 < \gamma < 0.85$

At least one jet with

$E_T^{\text{jet}} > 17 \text{ GeV}$, $-1 < \eta_{\text{jet}} < 2.5$



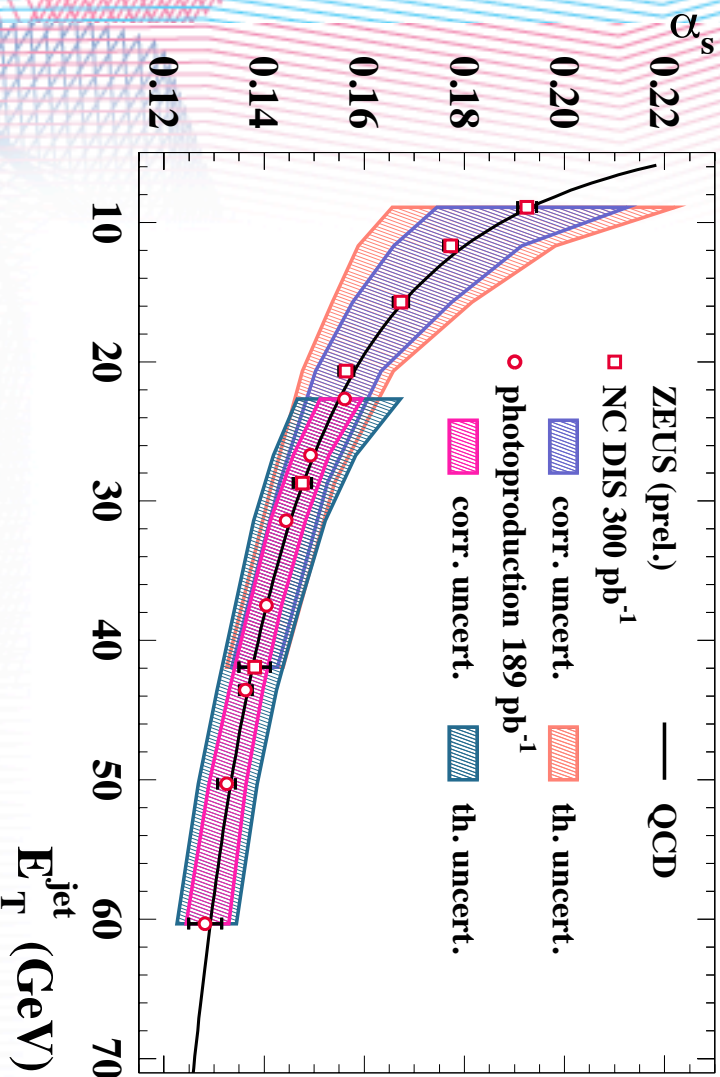
α_s extracted from the dependence of the cross section on E_T . Jets in PHP gave the most precise α_s measurement at ZEUS, now extended to HERAII

Test of the running of α_s .

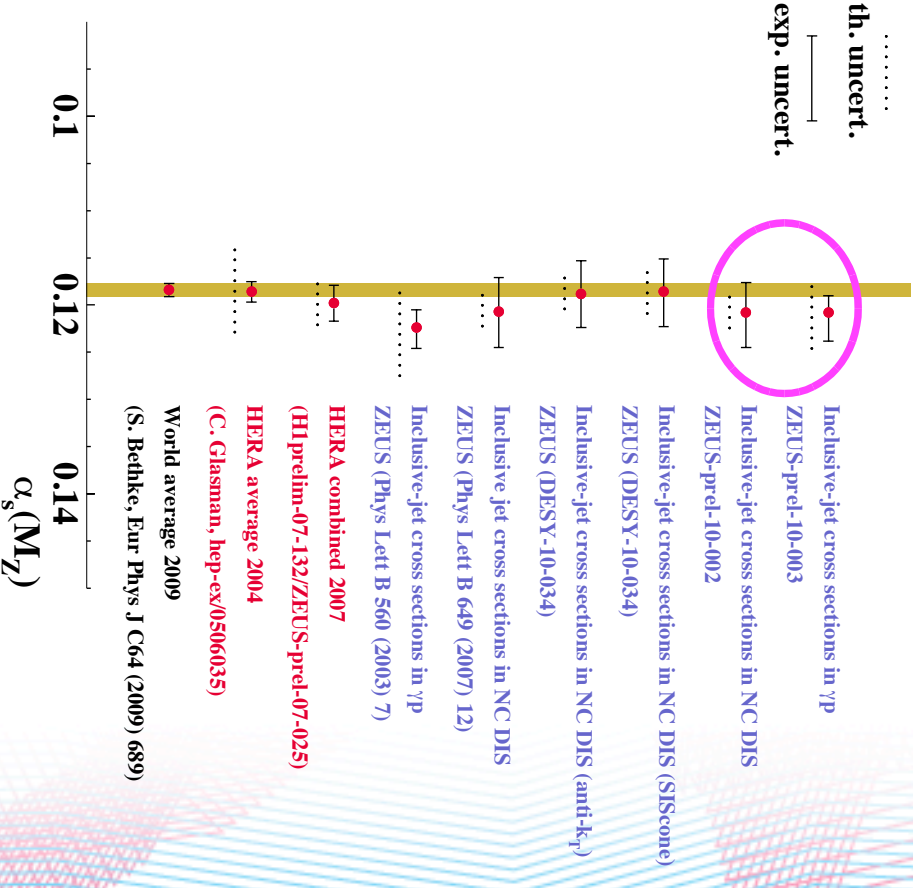
α_s running from PHP to DIS

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

ZEUS



th. uncert.
exp. uncert.

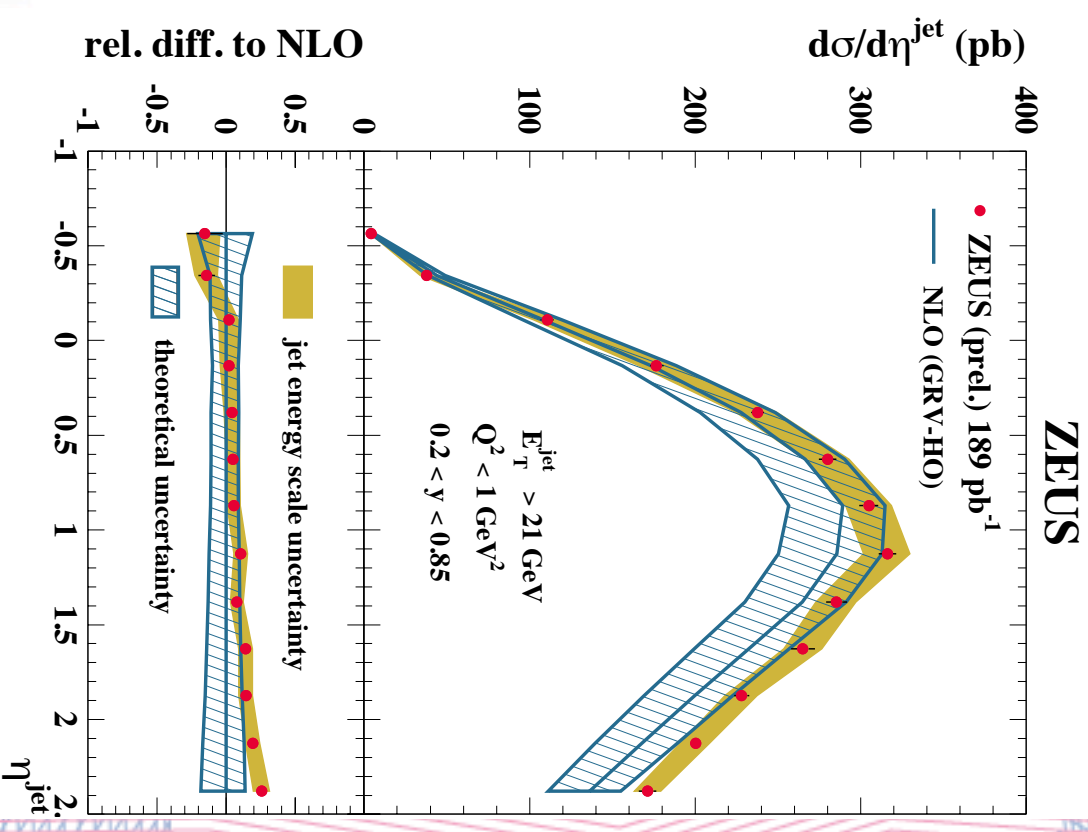
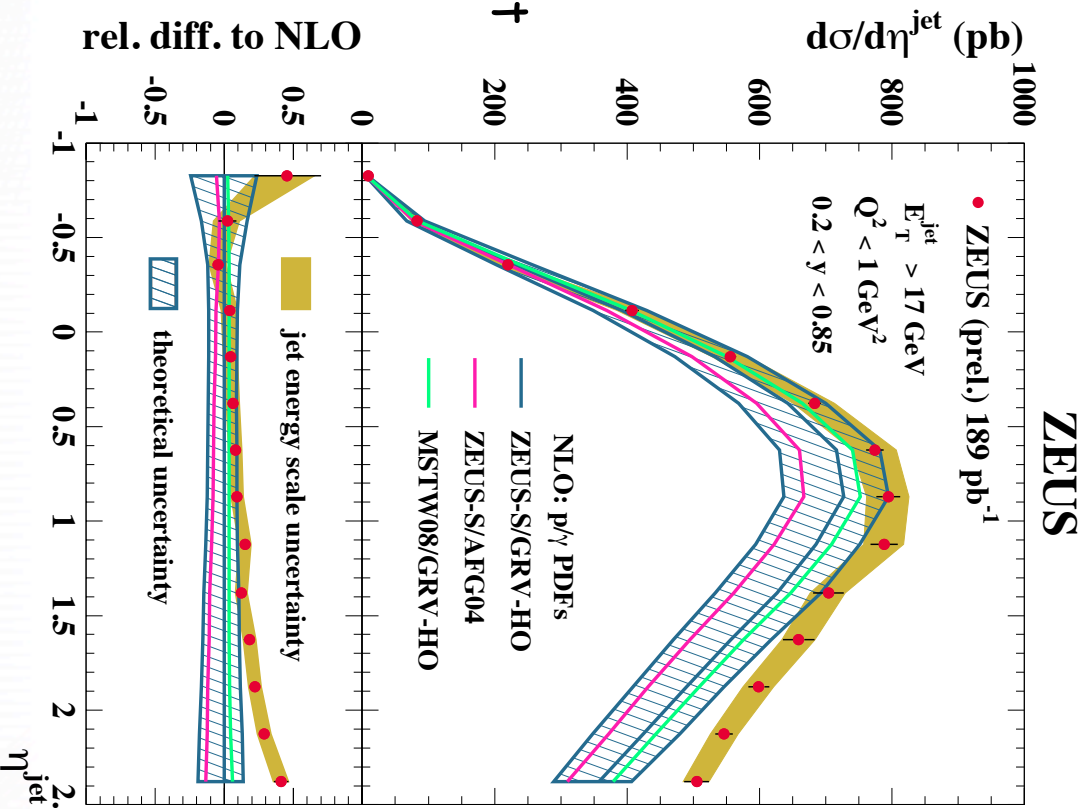


Two new precise α_s measurements from DIS and PHP in agreement with the world average.

Jets in PHP: non perturbative effects

Check non perturbative effects (low E_T^{jet}), important for the LHC

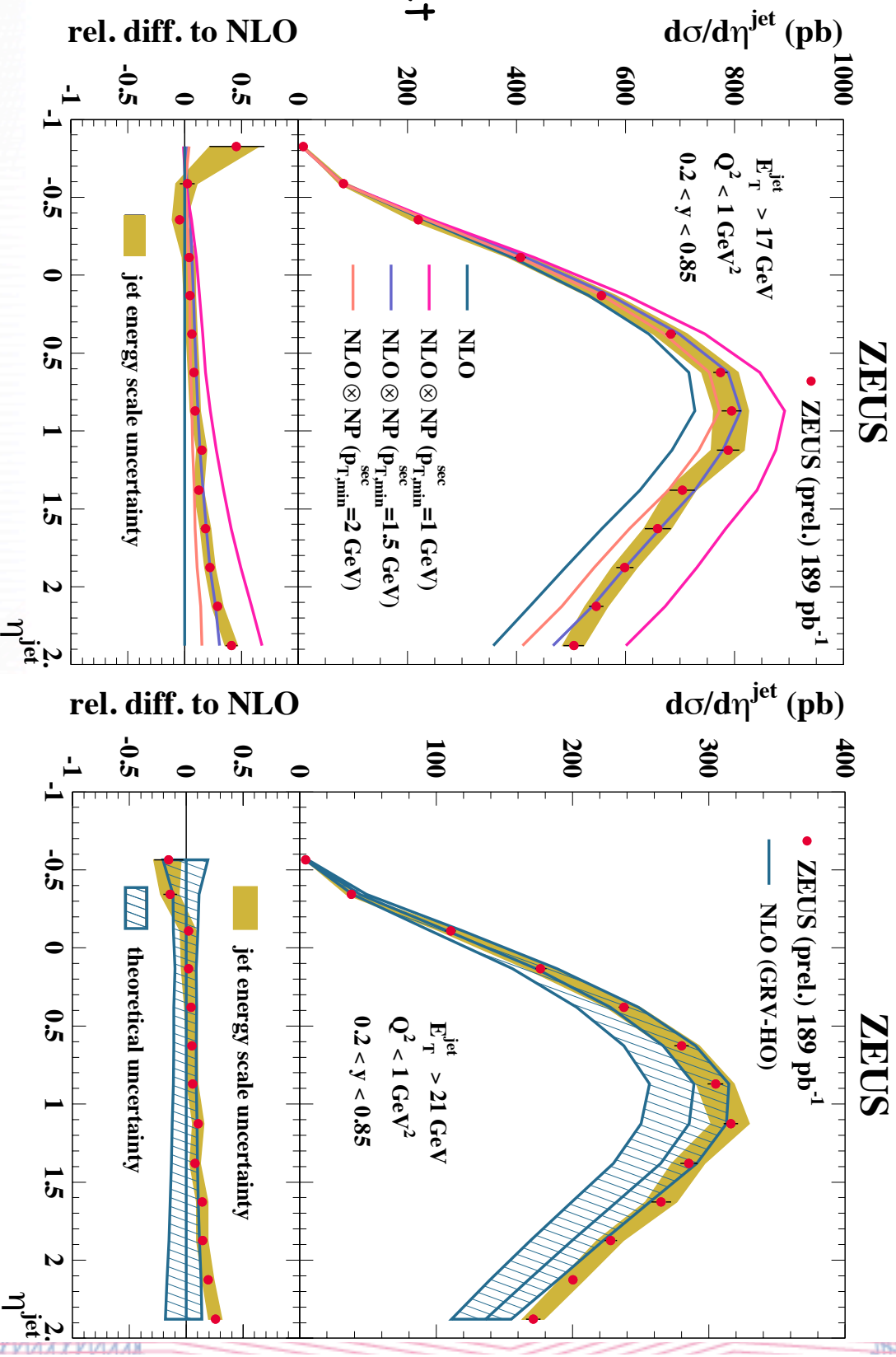
This can also be influenced by the jet algorithm, new developments being tested for the LHC (anti- k_r , SIScone...)



Jets in PHP: non perturbative effects

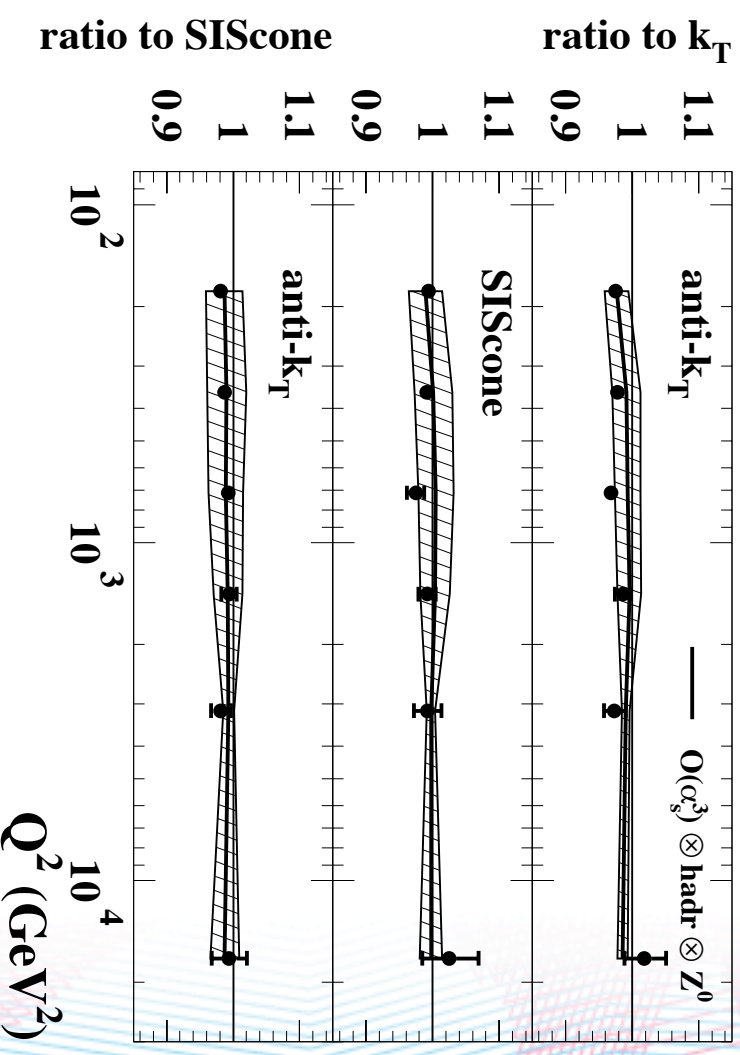
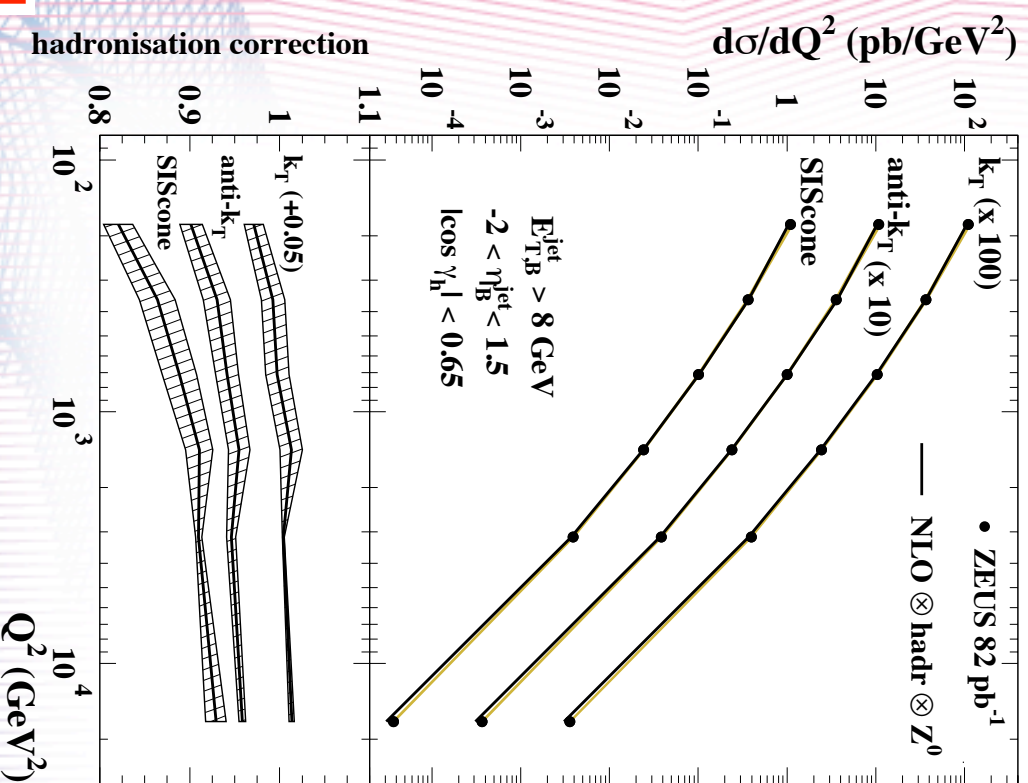
Check non perturbative effects (low E_T^{jet}), important for the LHC

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)

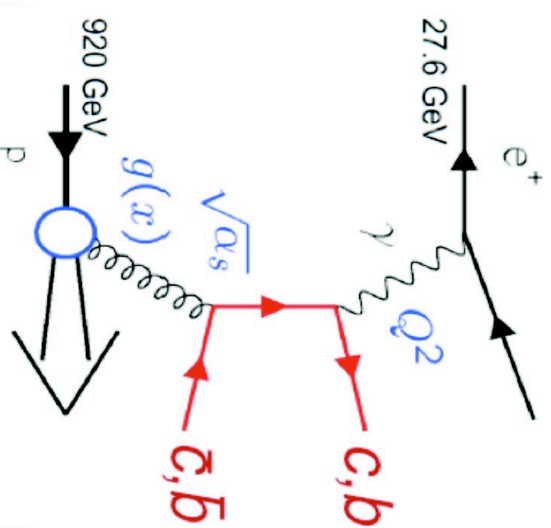


Data very well described by NLO and all the algorithms.
 Similar precision (slightly worse for SIScone)
 Ratios evaluated up to order α_s^3

First test on data,
important for LHC

Charm and beauty production

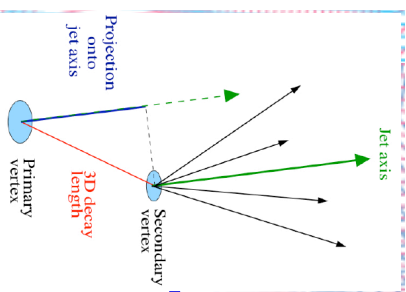
- Stringent test of perturbative QCD, sensitivity to the gluon in the proton.
- Multi-scale problem (mass, p_T , Q^2)
- Check of the QCD fits dependence on the heavy flavour treatment



Beauty in DIS

L=354 pb⁻¹

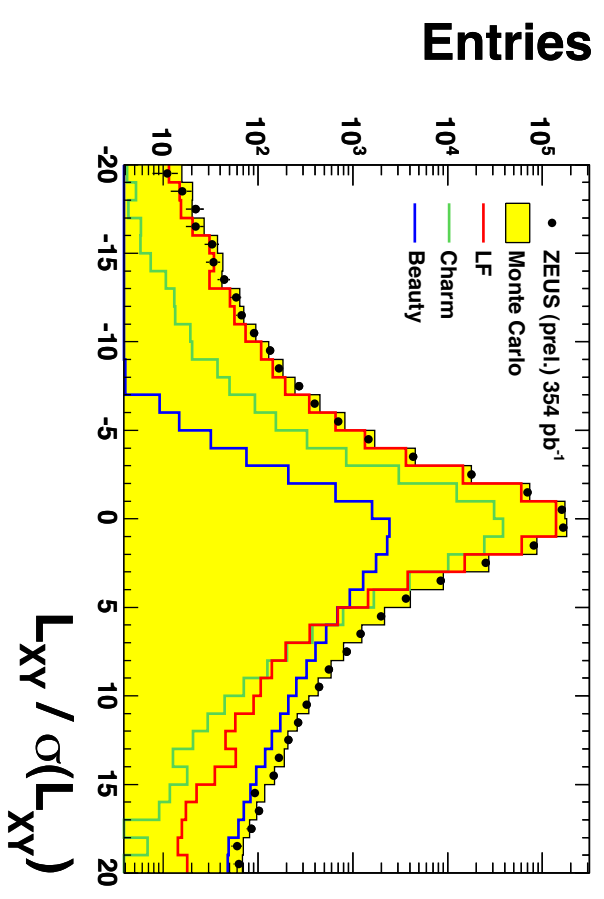
Beauty reconstructed from jets with secondary vertices.



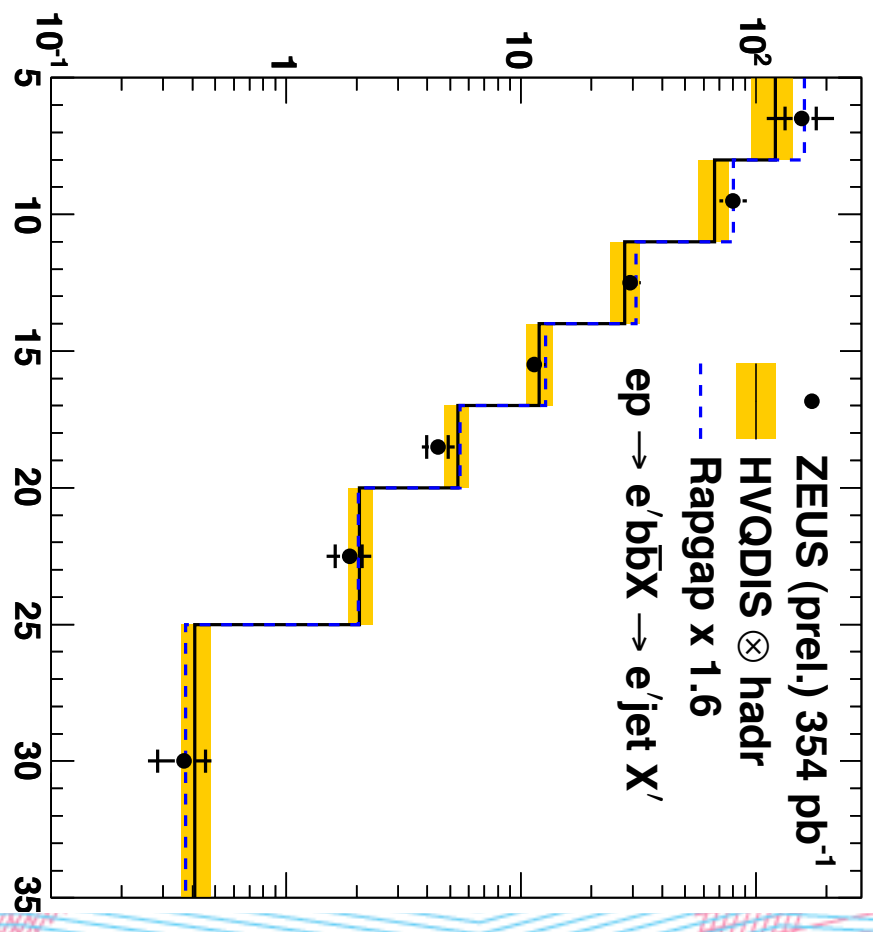
$$5.0 \text{ GeV}^2 < Q^2 < 1000.0 \text{ GeV}^2, 0.02 < y < 0.7$$

$$E_T(\text{Jet}) > 5.0 \text{ GeV}, -1.6 < \eta(\text{Jet}) < 2.2$$

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$d\sigma / dE_T^{\text{jet}}$ (pb / GeV)



Data will be used for the extraction of $F_2^{b\bar{b}}$

90000 beauty events available

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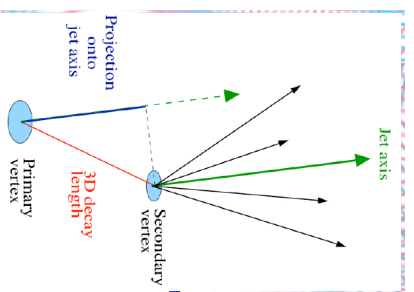
DIS 2010

ZEUS-prel.-10-004

Beauty in DIS

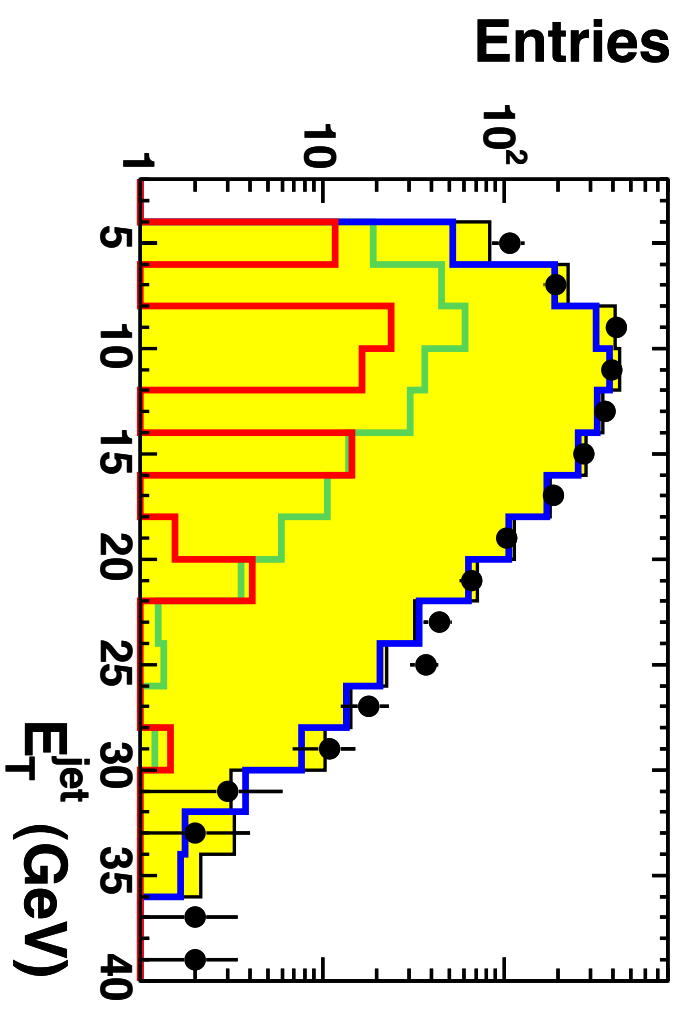
L=354 pb⁻¹

Beauty reconstructed from jets with secondary vertices.

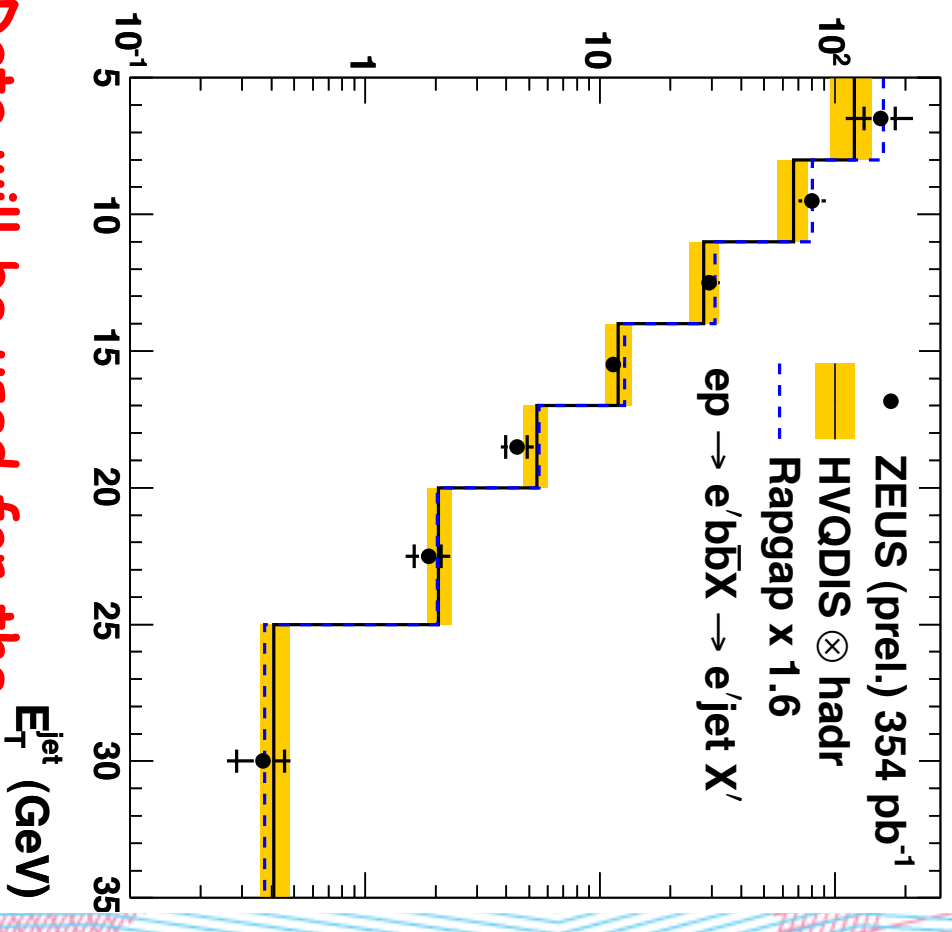


$$5.0 \text{ GeV}^2 < Q^2 < 10000.0 \text{ GeV}^2, 0.02 < y < 0.7$$

$$E_T(\text{Jet}) > 5.0 \text{ GeV}, -1.6 < \eta(\text{Jet}) < 2.2$$



$d\sigma / dE_T^{\text{jet}}$ (pb / GeV)



Data will be used for the extraction of F_2^{bb}

Very high purity at high mass and significance

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DIS 2010

ZEUS-prel-10-004

D⁺ in DIS

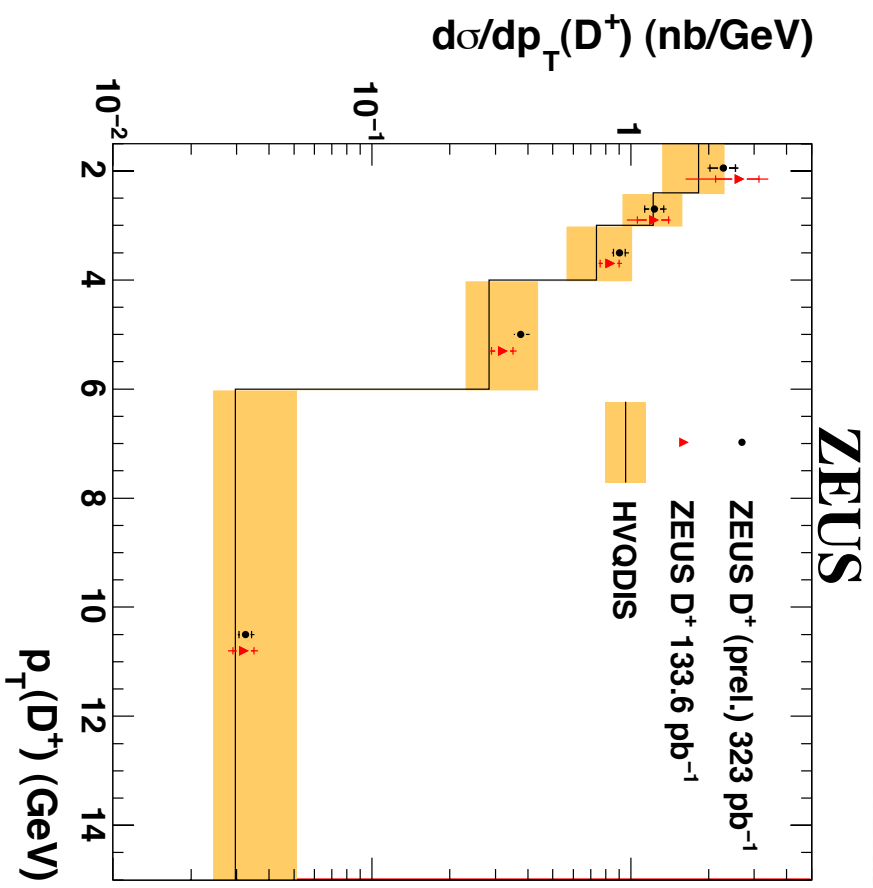
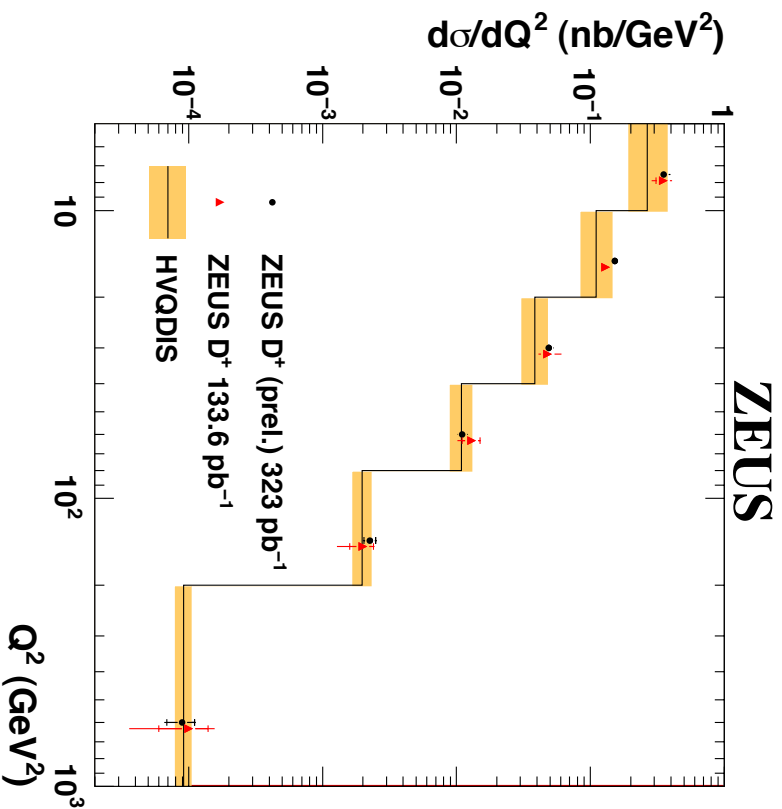
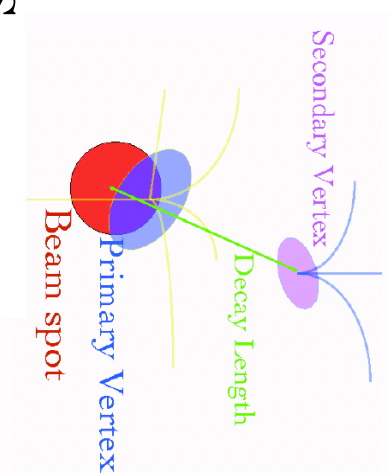
D⁺ reconstructed using lifetime information. $L=323 \text{ pb}^{-1}$.

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

$$0.02 < Y_{DA} < 0.7$$

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

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



~ 7200 D⁺ events available

Precision comparable to D^{*} in HERAI

DIS 2010

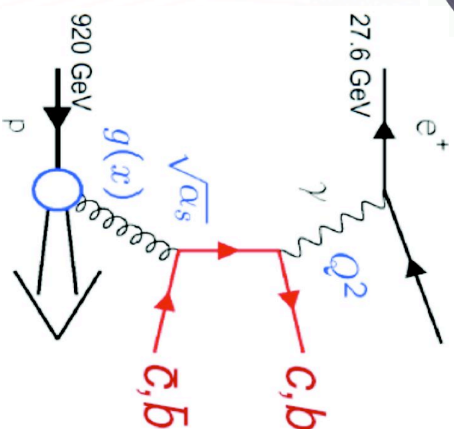
ZEUS-prel-10-005





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

see Mikhaylo Lisovyi [29]

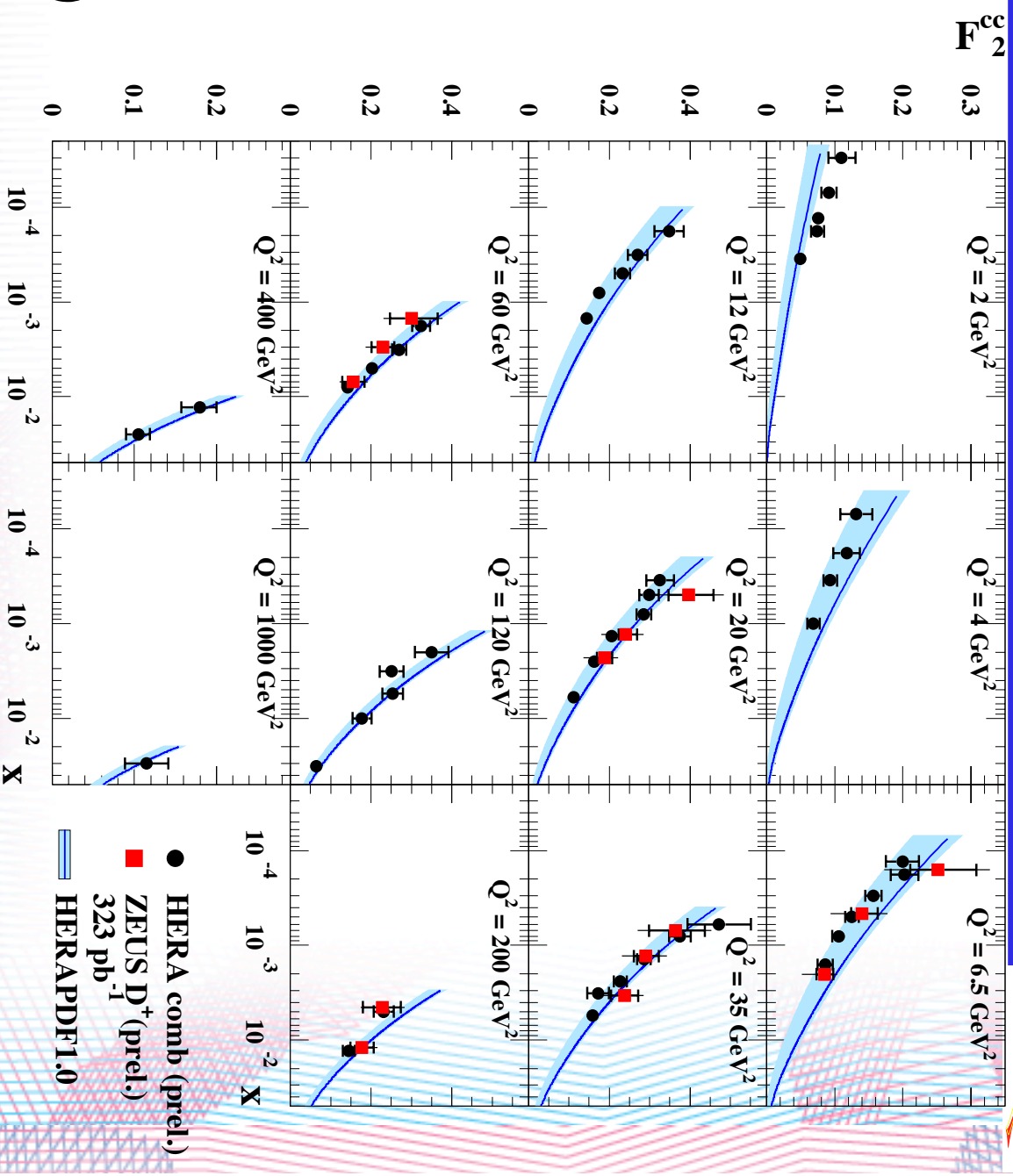


Sensitivity to the gluon.

Data from H1 and ZEUS combined.

Precision is now 5-10%.

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



● HERA comb (prel.)
 ■ ZEUS D^+ (prel.)
 323 pb⁻¹
 ■ HERAPDF1.0

DIS 2010

ZEUS-prel-10-005,
 H1prelim-09-171, ZEUS-prel-09-015



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QCD fits with charm data

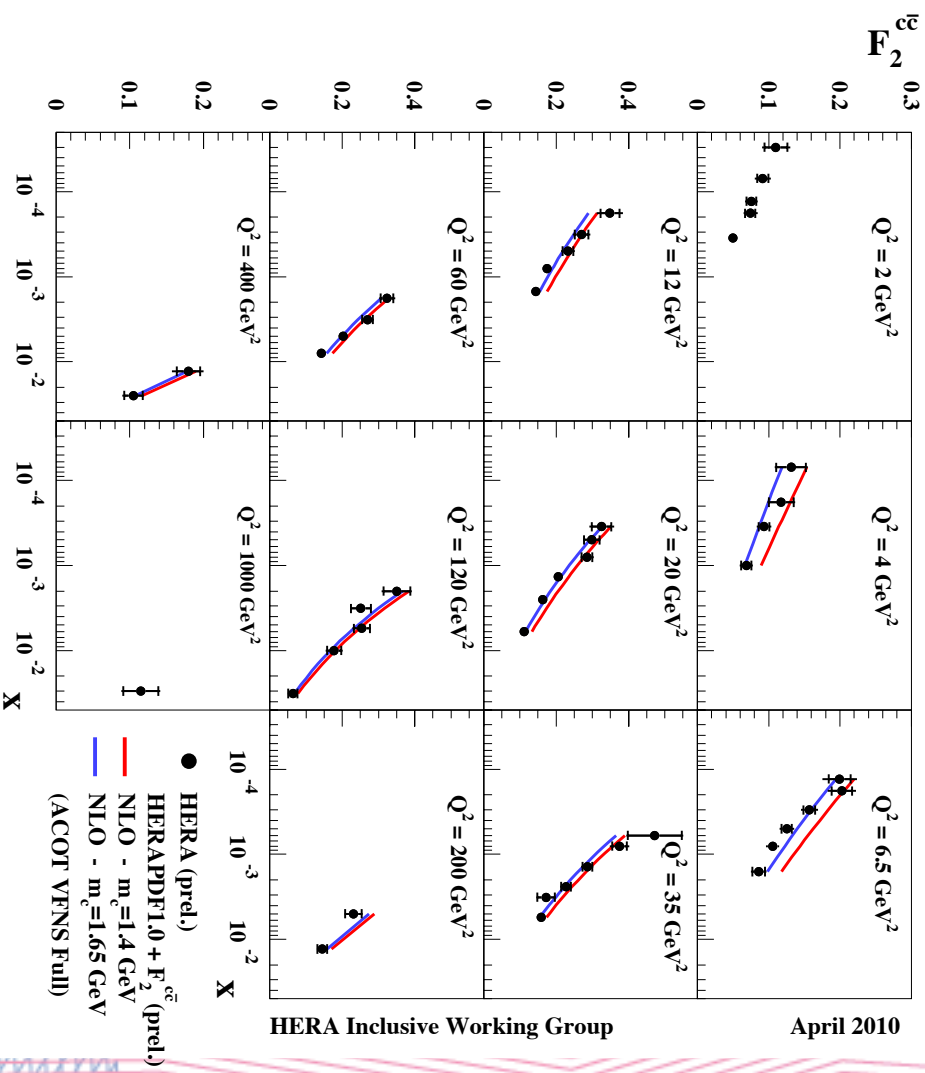
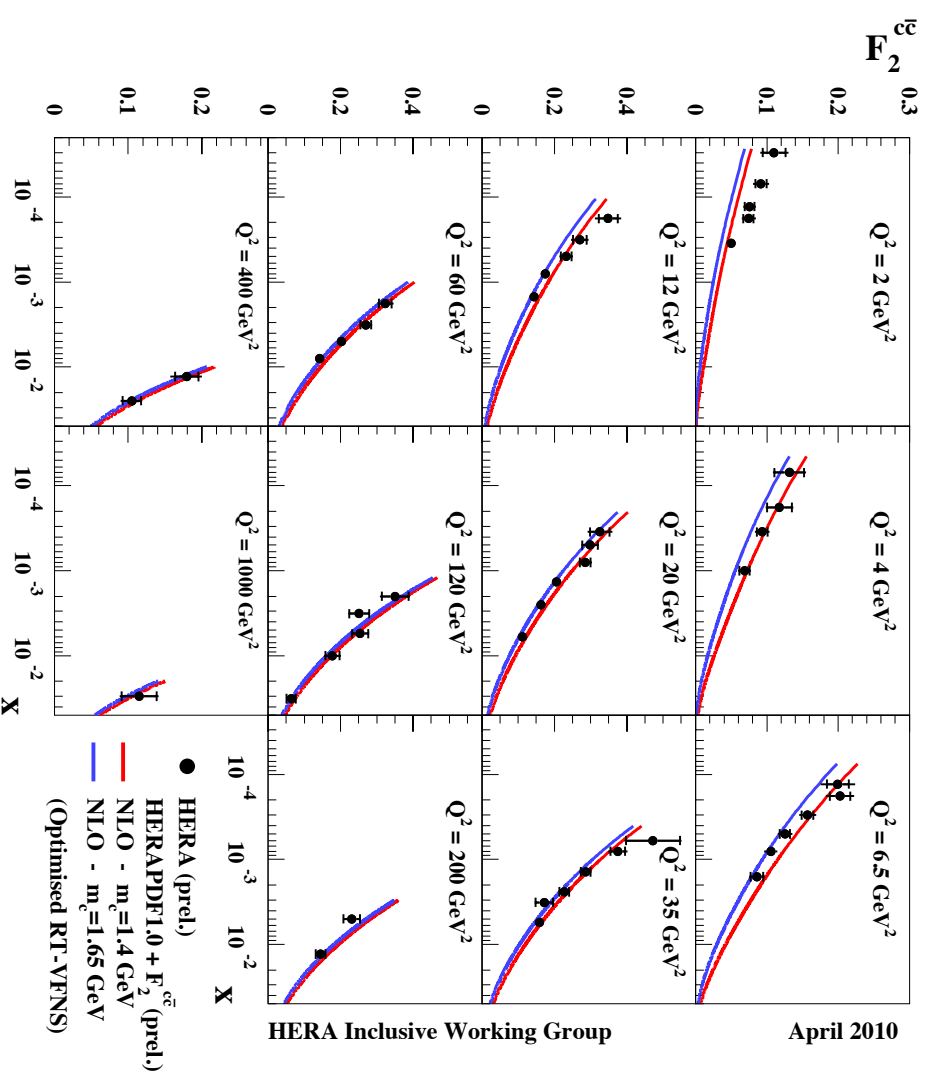
see Amanda Cooper-Sarkar [31]



F_2^c data in HERAPDF1.0 fit. DGLAP evolution sensitive to the HF treatment.

H1 and ZEUS

H1 and ZEUS



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

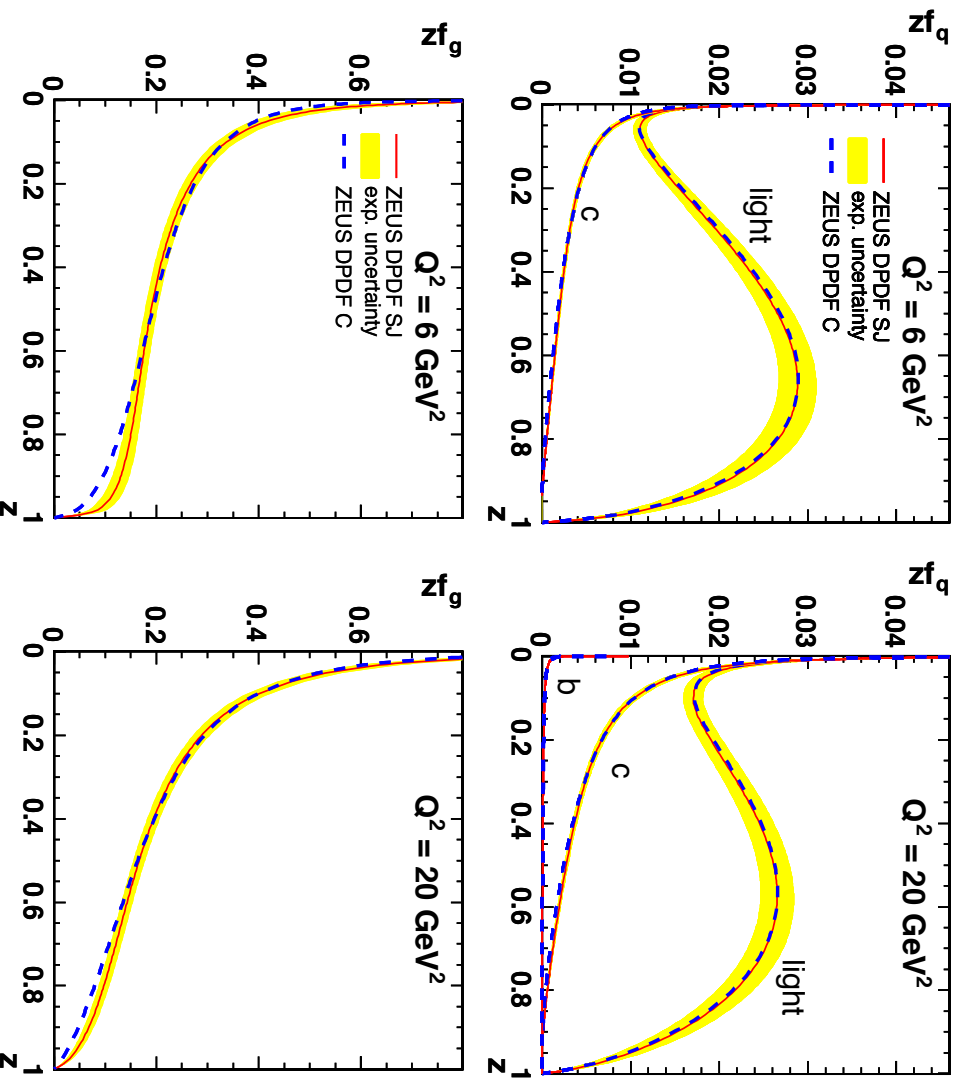
ZEUS-prel-10-009



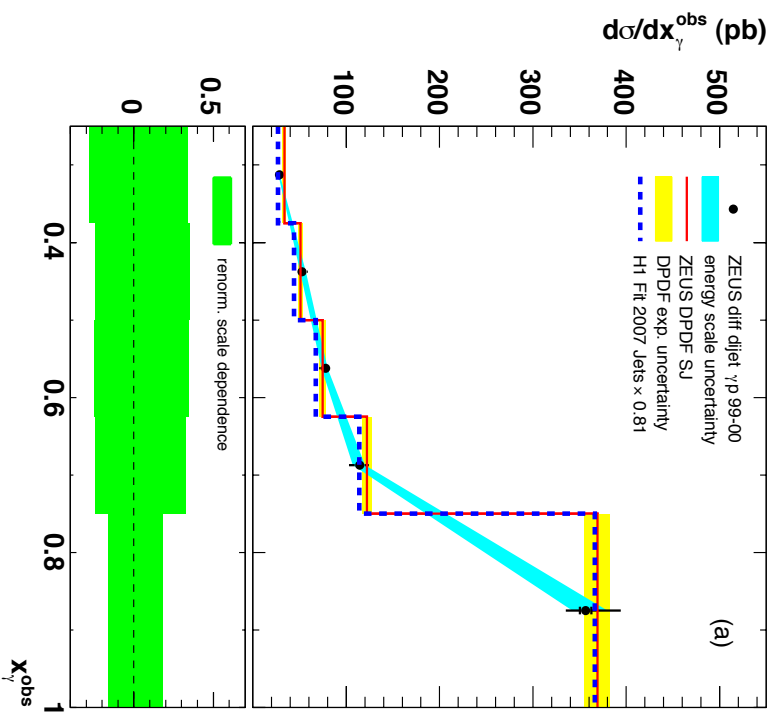
Diffractive PDF fits

Diffractive PDFs extracted from inclusive and jets cross sections in diffractive DIS.

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^b region). No suppression or factorisation breaking.

Conclusions

- New ZEUS+H1 combination measurements are providing precision data used as input in QCD fits.
- The analyses of the HERAII on NC, CC, jets and heavy flavour processes are extended to the full data statistics allowing improved precision of the results.
- The new inclusive, jets and heavy flavour data are now investigated in the context of QCD fits, allowing more stringent test on the fit formalism.
- More to come from combination also for diffraction...

**The HERA data are a valuable input to understand
QCD and therefore for the LHC physics**

Backup

Jet algorithms

k_T (Catani et al.)

Jet reconstruction relies on **jet algorithms**.

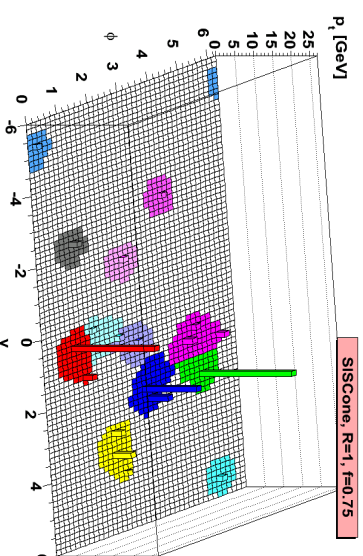
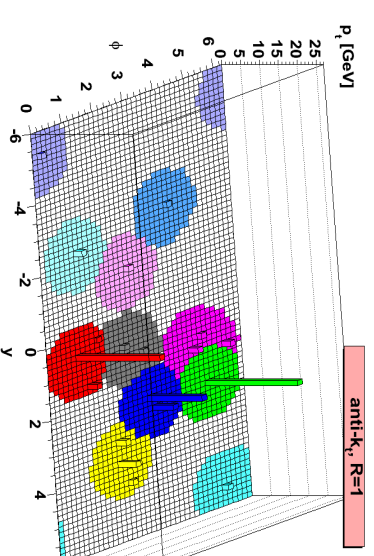
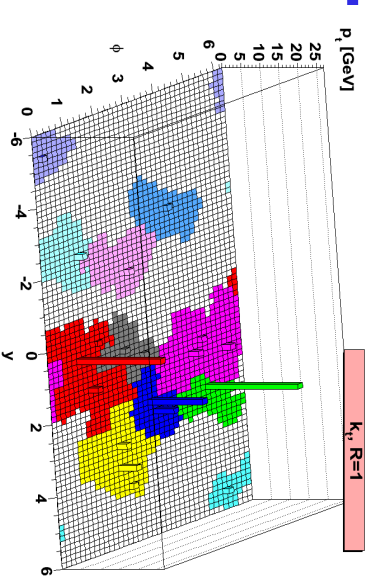
Jet algorithms should not be sensitive to soft particle emission (**infrared safe**) and collinear particle splitting (**collinear safe**).

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...

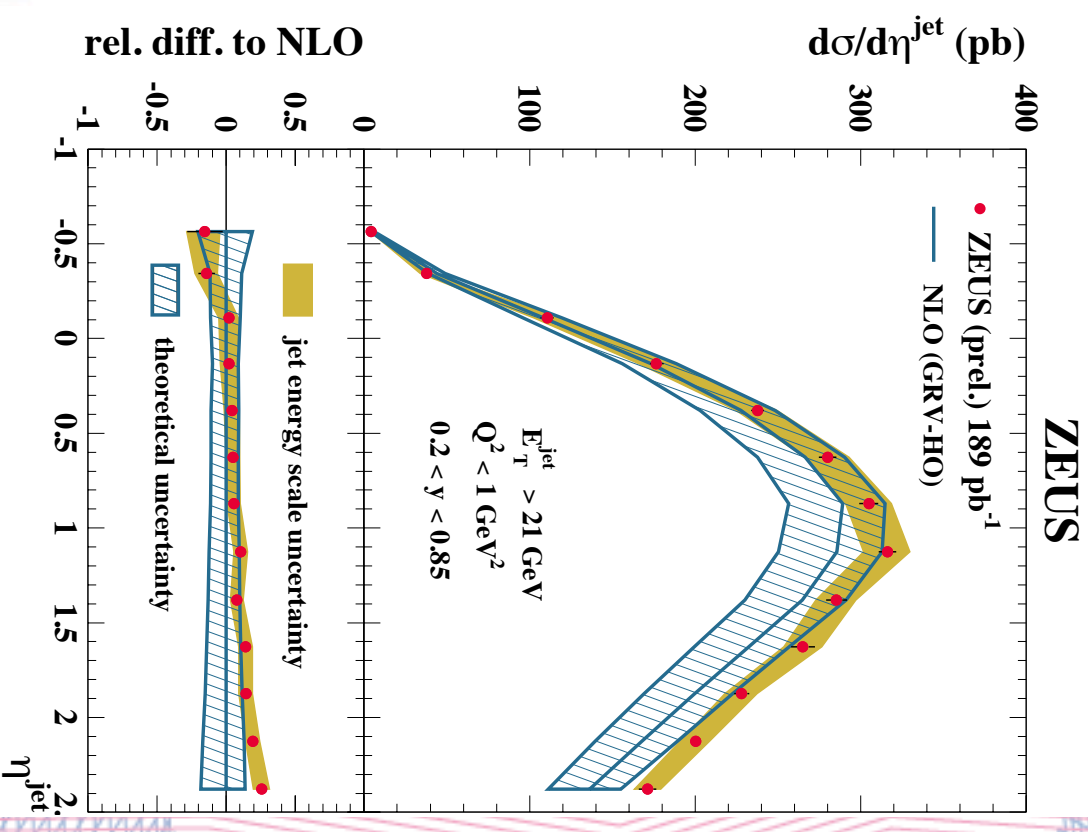
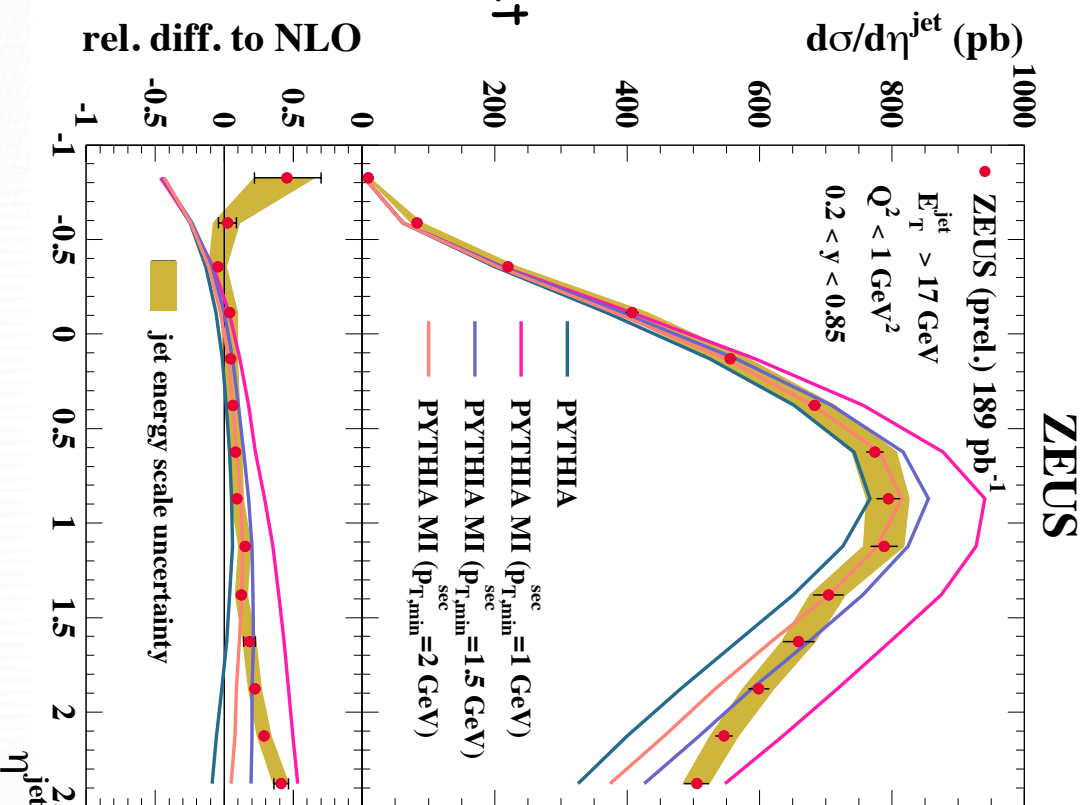


New developments:
anti- k_T (Cacciari,
Salam, Soyez 08)
SIScone
(Salam, Soyez 07)
both safe at all
orders

Jets in PHP: non perturbative effects

Check non perturbative effects (low E_T^{jet}), important for the LHC

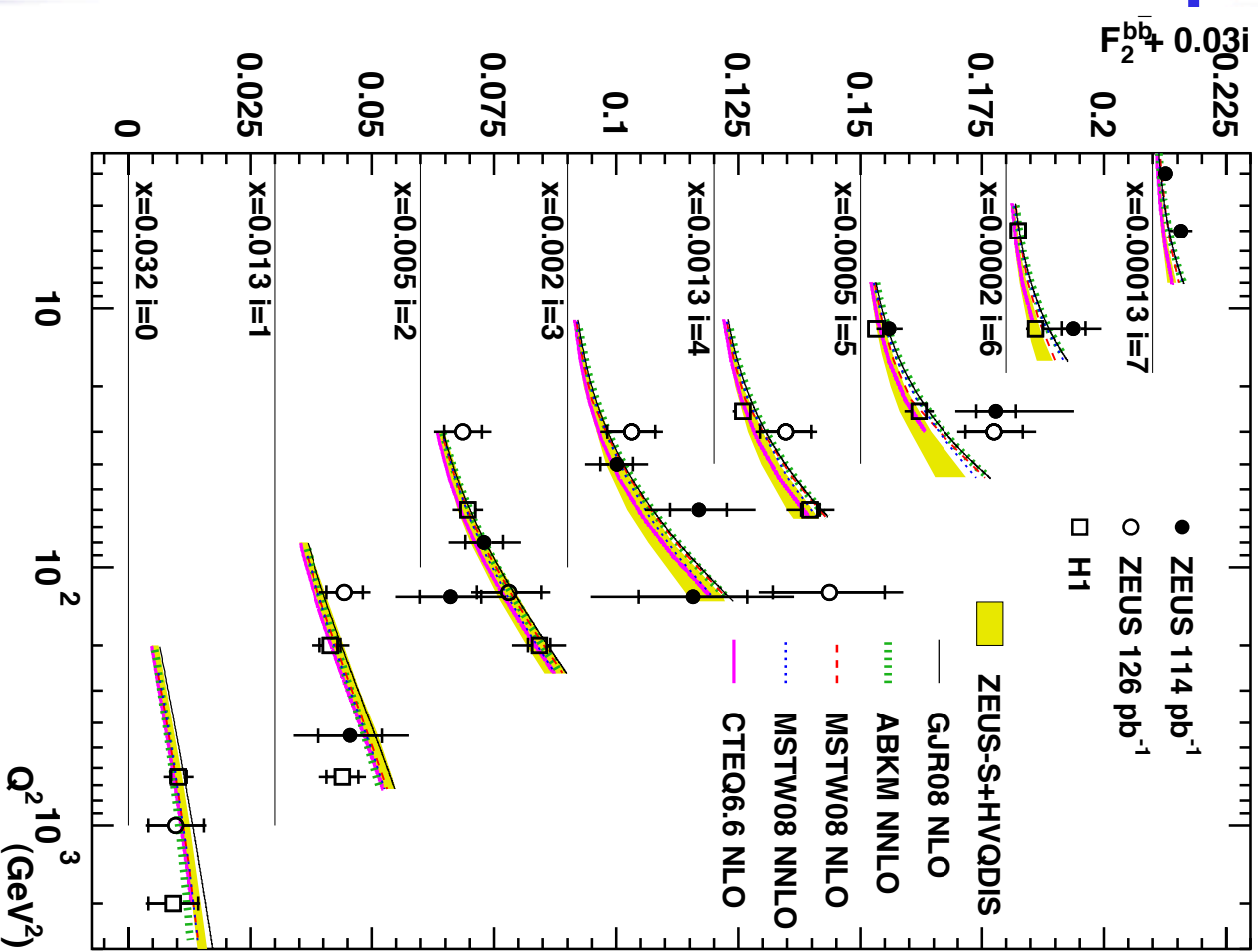
This can also be influenced by the jet algorithm, new developments being tested for the LHC (anti- k_T , SIScone...)



ZEUS F_2^b

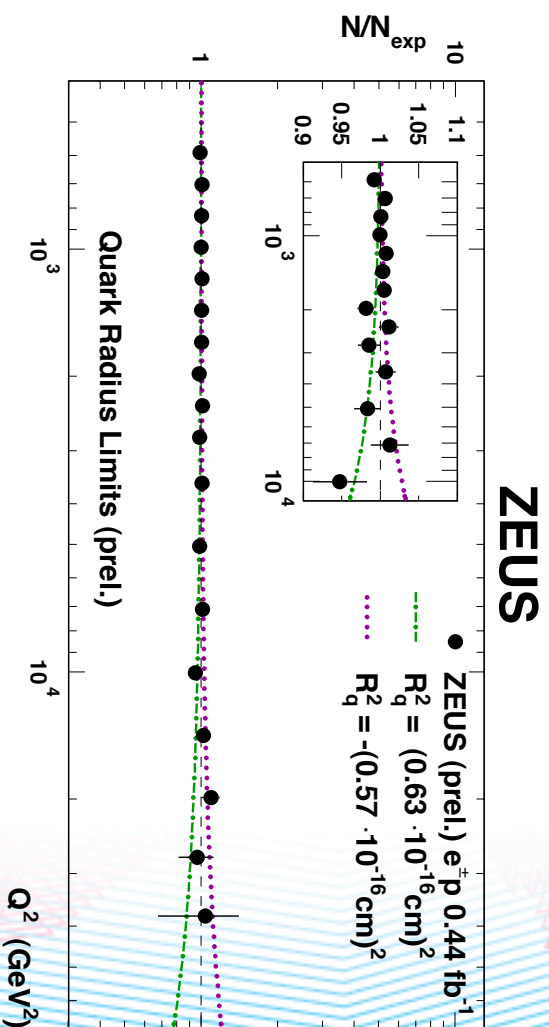
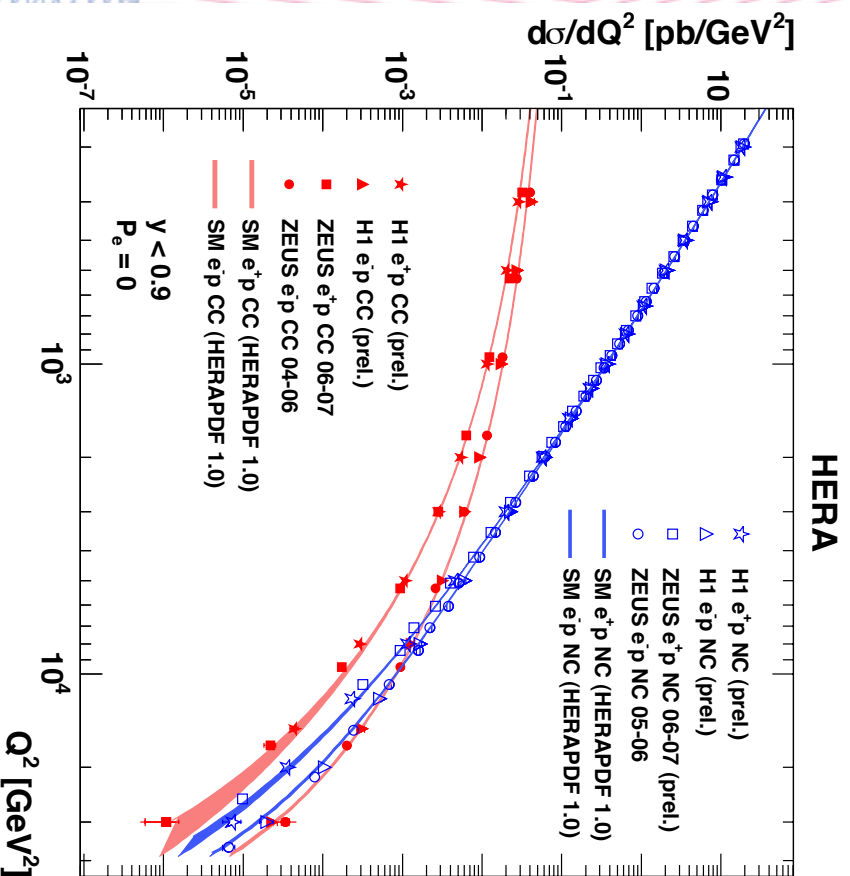
- Present measurements based on events with muon and jets
- Precision of the data is limited
- Will dramatically improved using jets from secondary vertices.
- Fair agreement between the various theory predictions

ZEUS



Quark radius, contact interactions

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



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