Impact of HERA-II data on the ZEUS PDF fits: a first look

HERA-LHC workshop working group week

Wednesday 19th January

Claire Gwenlan

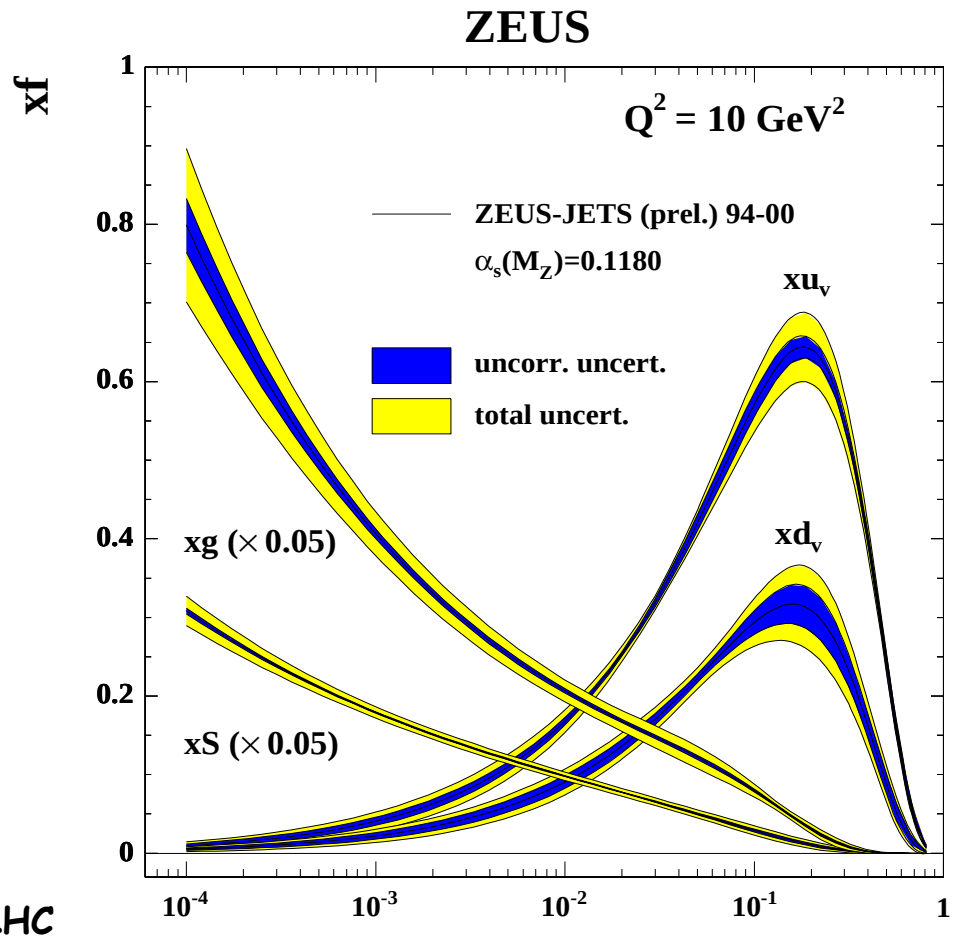
- The ZEUS-JETS fit (a brief reminder)
- Impact of HERA-II data on the fit
- Summary

The ZEUS-JETS PDF fit

Latest ZEUS QCD analysis uses the full set of HERA-I data

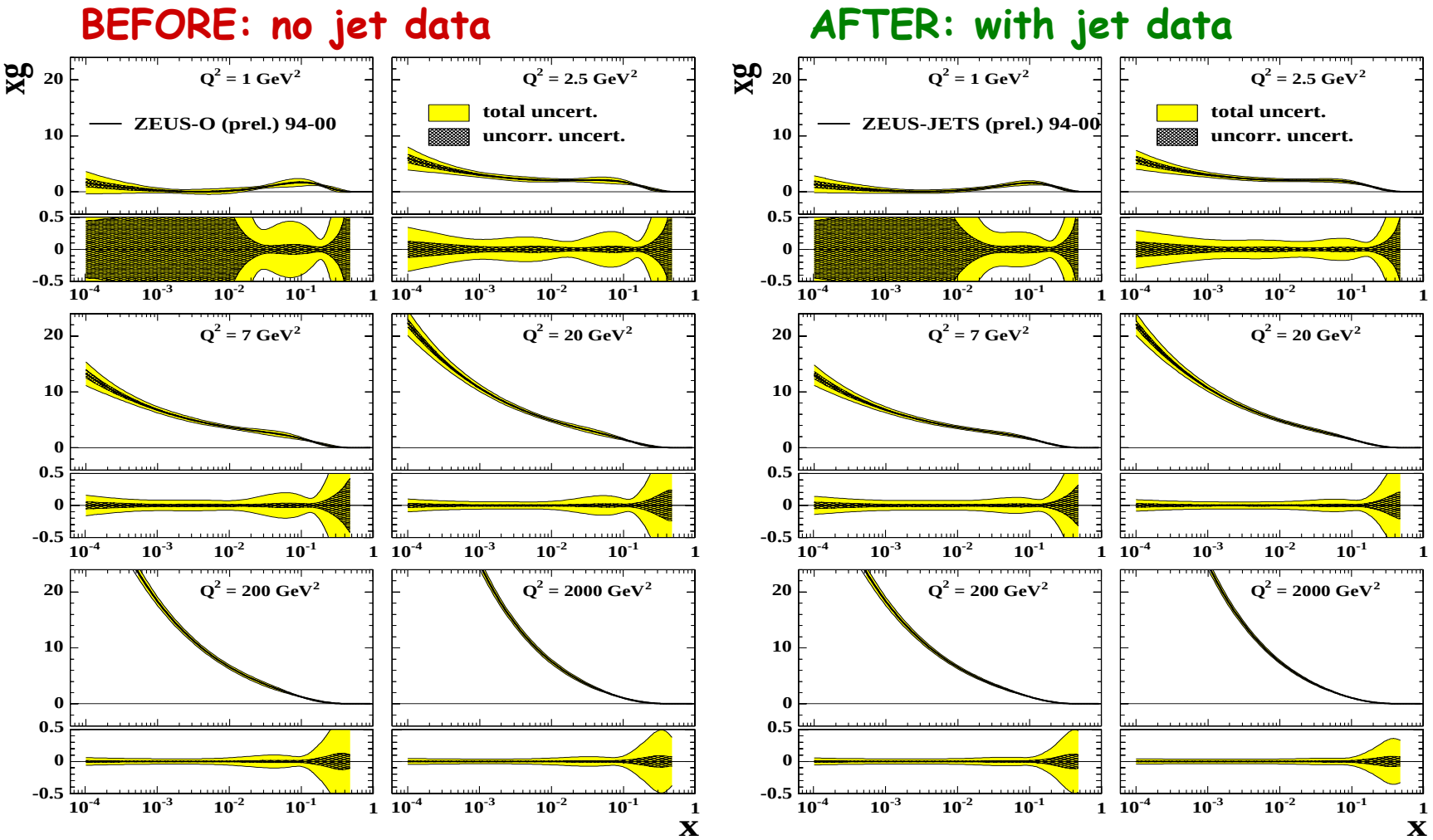
- e+p luminosity: ~115 pb^{-1}
- e-p luminosity: ~15 pb^{-1}

Data Set	Ndata
NC e+p 96-97	242
CC e+p 94-97	29
NC e-p 98-99	92
CC e-p 98-99	26
NC e+p 99-00	90
CC e+p 99-00	30
DIS jets e+p 96-97	30
γp two-jets e+p 96-97	38



NOTE: Full details of the ZEUS-JETS fit have been presented previously (see HERA-LHC PDF subgroup meeting, "Addition of jet data to the ZEUS QCD Fit", C. Gwenlan, June 2004)

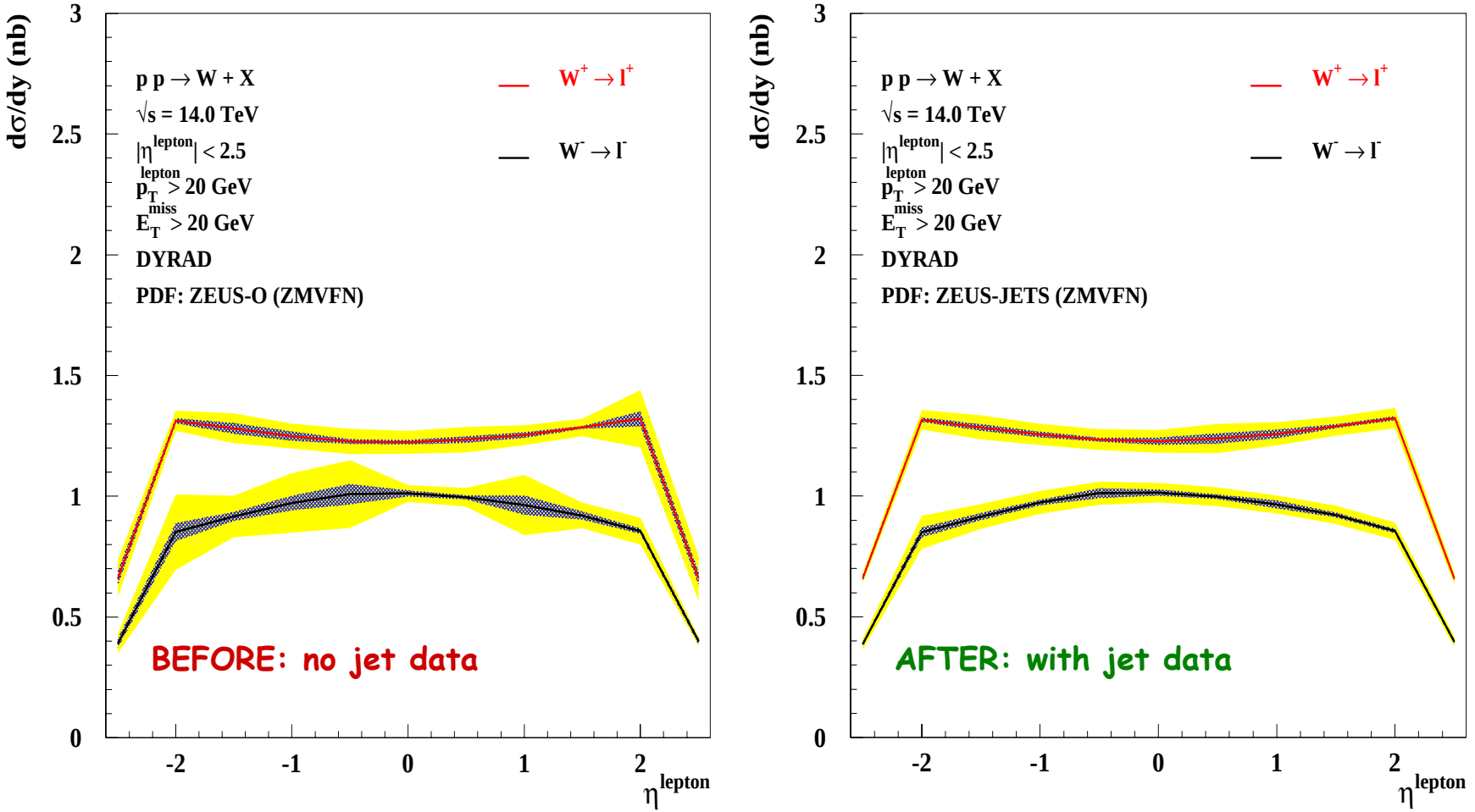
Impact of jet data on gluon distribution



- Addition of jet data significantly improves knowledge of gluon

Impact on the LHC (an example)

$W^{\pm}$ production (plots from Kunihiro Nagano)



- Smaller uncertainties from improved knowledge of gluon from jet data

HERA-II data

Want to estimate the impact of adding HERA-II data

- This is a first look - only a very simple approach used:
  - reduce statistical uncertainties on current HERA data
    - assume maximum HERA-II integrated luminosity of 1 fb^{-1}

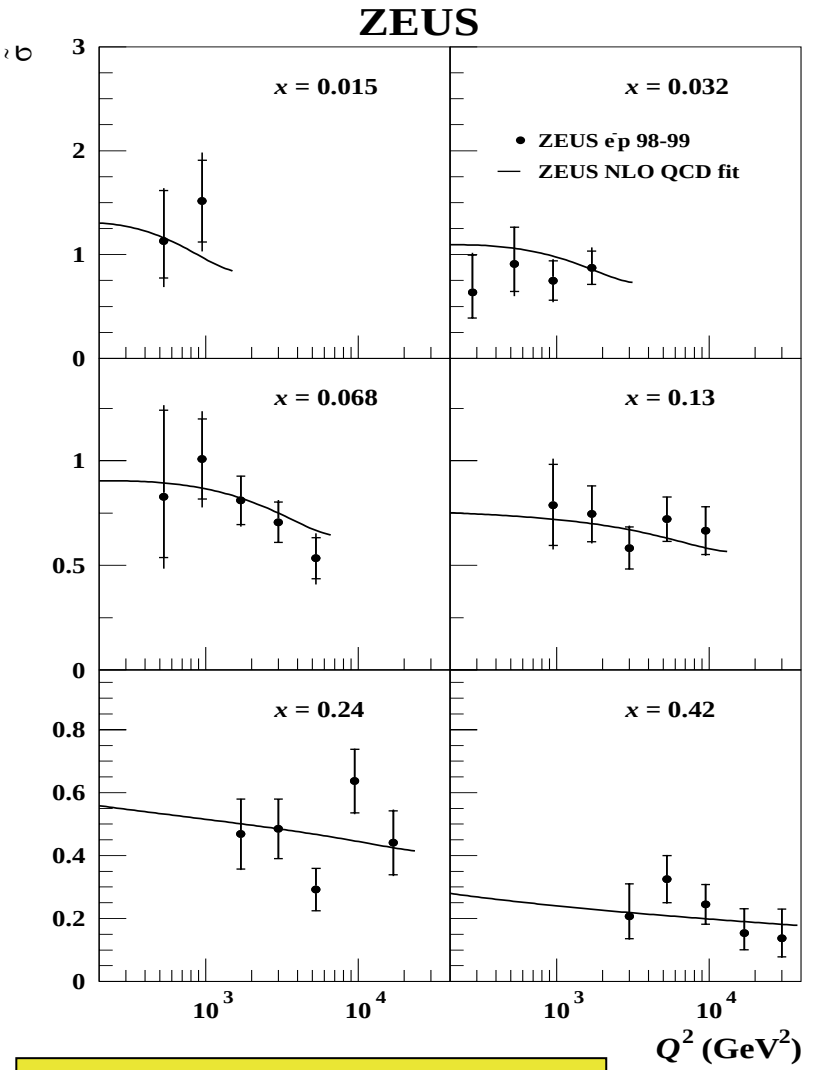
Have studied the impact of four different samples:

	Sample of data	Luminosity assumed in fit	c.f. data in ZEUS-JETS
I	Inclusive e- NC/CC	100 pb^{-1}	15 pb^{-1}
II	Inclusive e+/e- NC/CC	500/500 pb^{-1}	115/15 pb^{-1}
III	DIS/γp jet data	500 pb^{-1}	40 pb^{-1}
IV	Charm in DIS	500 pb^{-1} (+ improved systs.)	None in current fit

- Limitations of this approach:
  - statistical fluctuations enhanced (no attempt made to "smooth" data)
  - No accounting for new HERA-II measurements (polarised leptons, optimised jet cross sections, F_L(?))

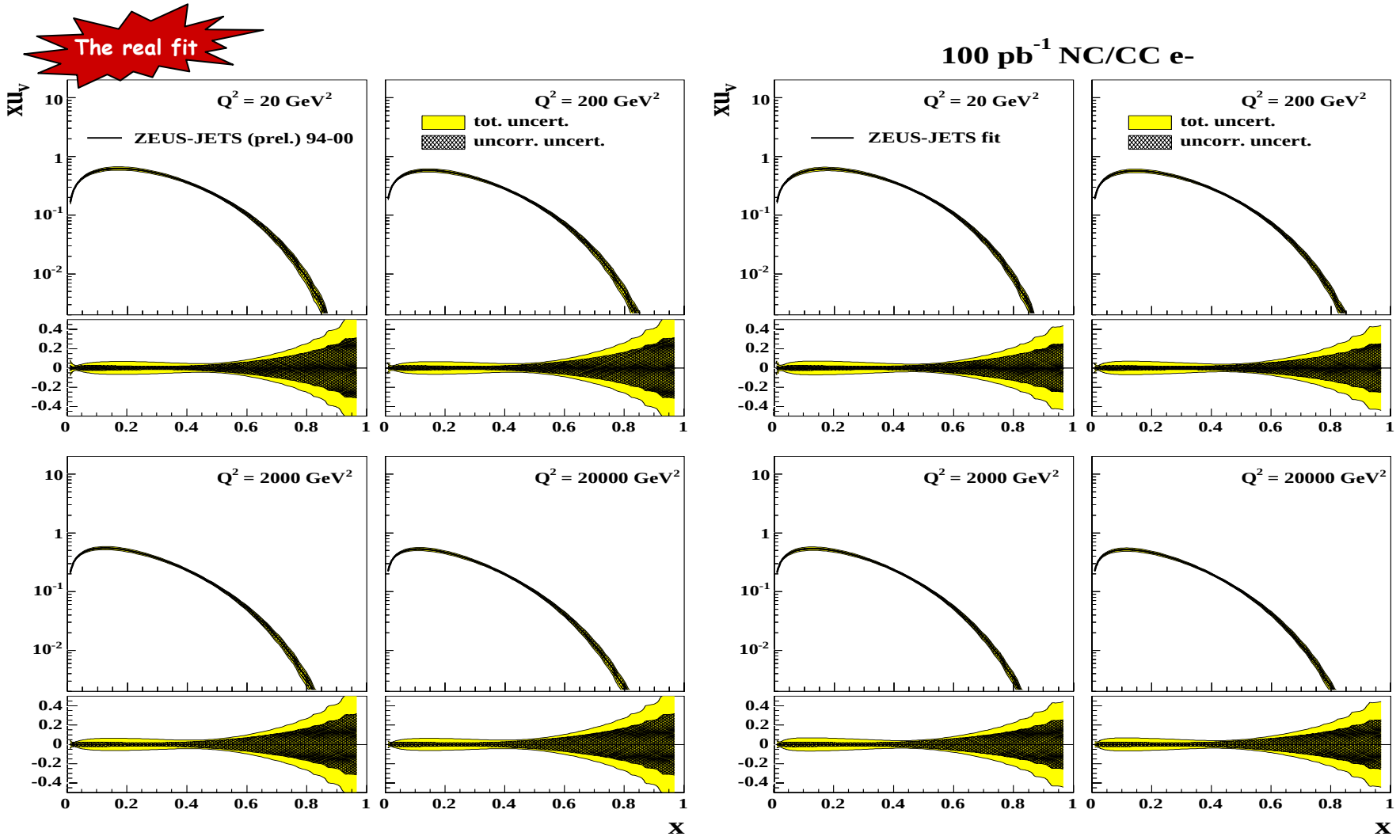
I) Impact of e- NC/CC inclusive data

- ZEUS-JETS fit uses full HERA-I set of inclusive NC/CC e- data (~15 pb^{-1})
  - measurements statistics dominated
- HERA now running with electrons again so we will soon see increase in statistical precision with HERA-II e- data
- Here, assume 100 pb^{-1} inclusive NC/CC e- data, giving approx. same amount of e- as we already have e+
  - Increase in statistical precision applied to both NC and CC



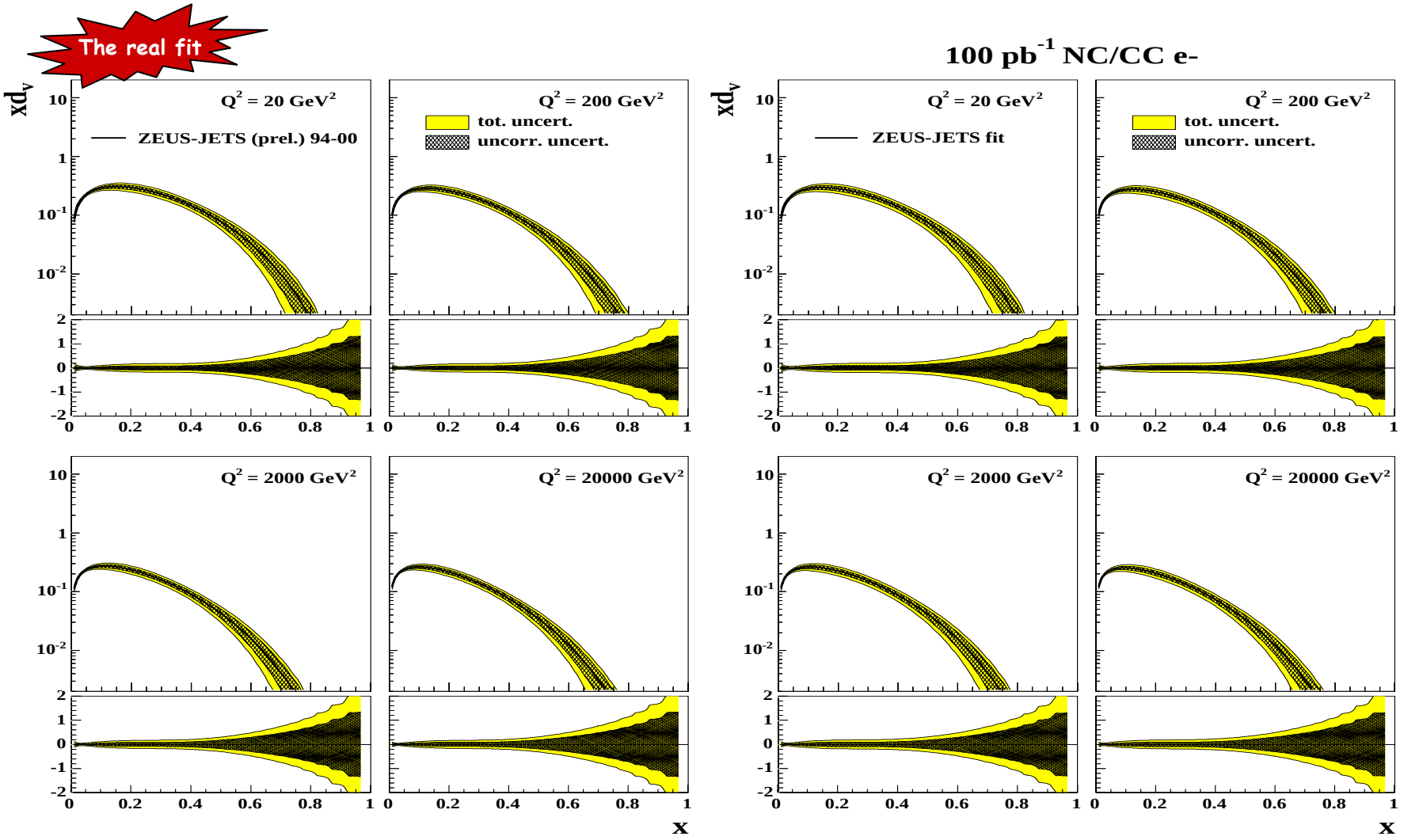
Example: HERA-I CC e- data

Impact on u-valence distribution



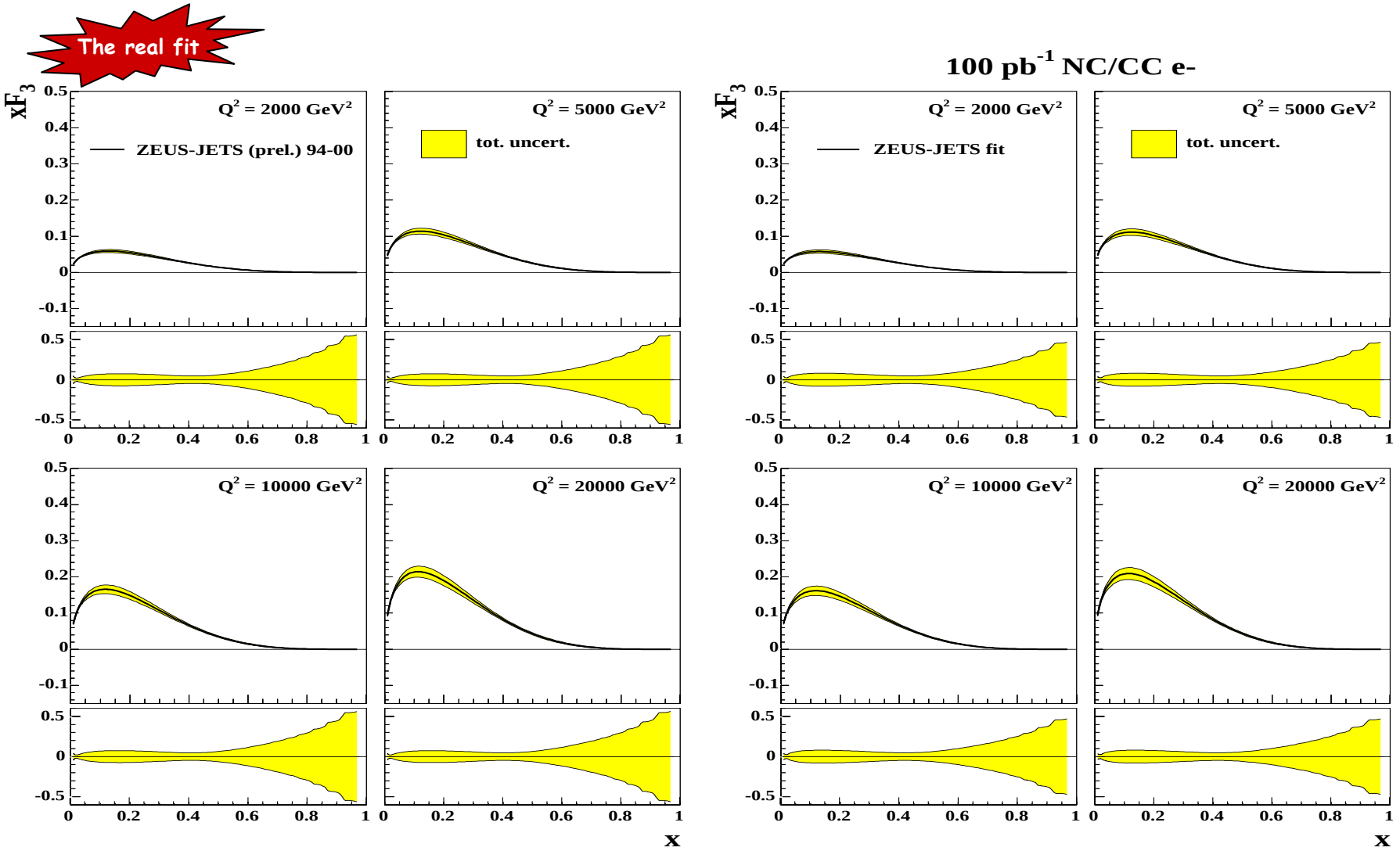
- Some improvement at high-x (max. uncertainty reduced from over 50% to 40%)

Impact on d-valence distribution



- Little noticeable improvement in d-valence

Impact on xF3 ~ Σx(q-qbar)

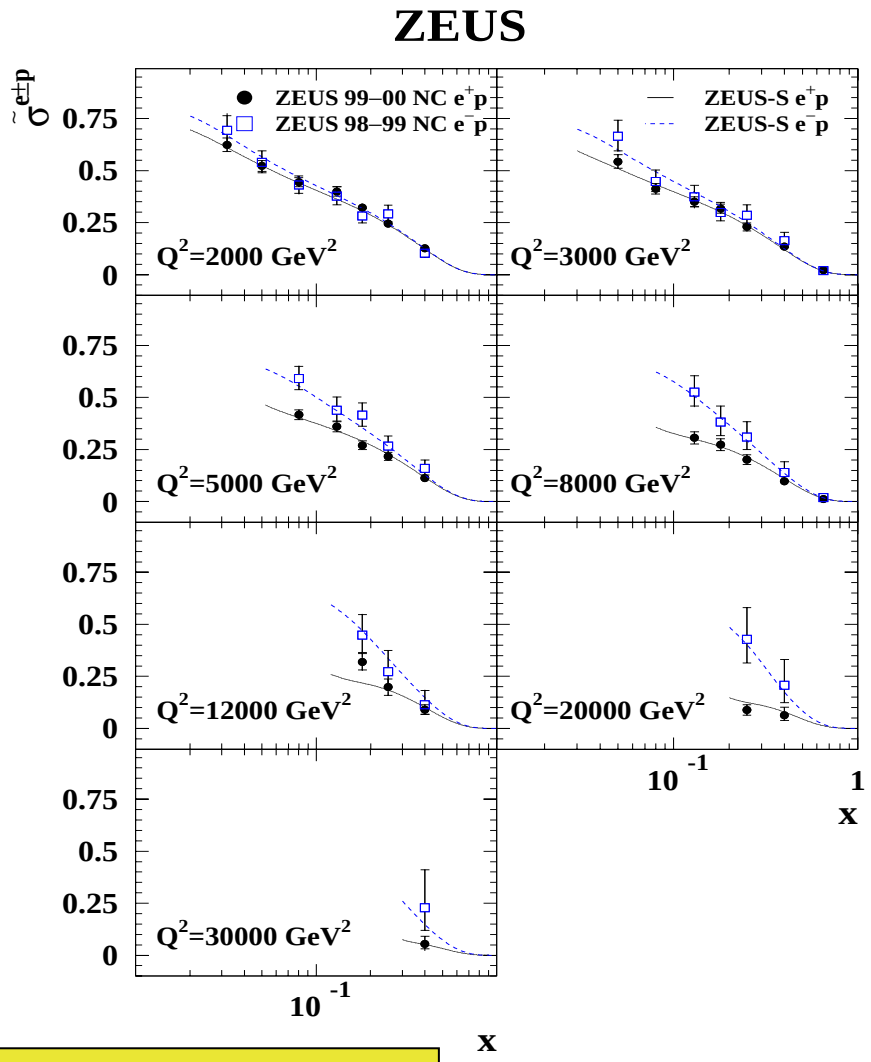


- Some improvement at high-x (maximum uncertainty reduced from ~60-50%)

II) Impact of e+/e- inclusive data

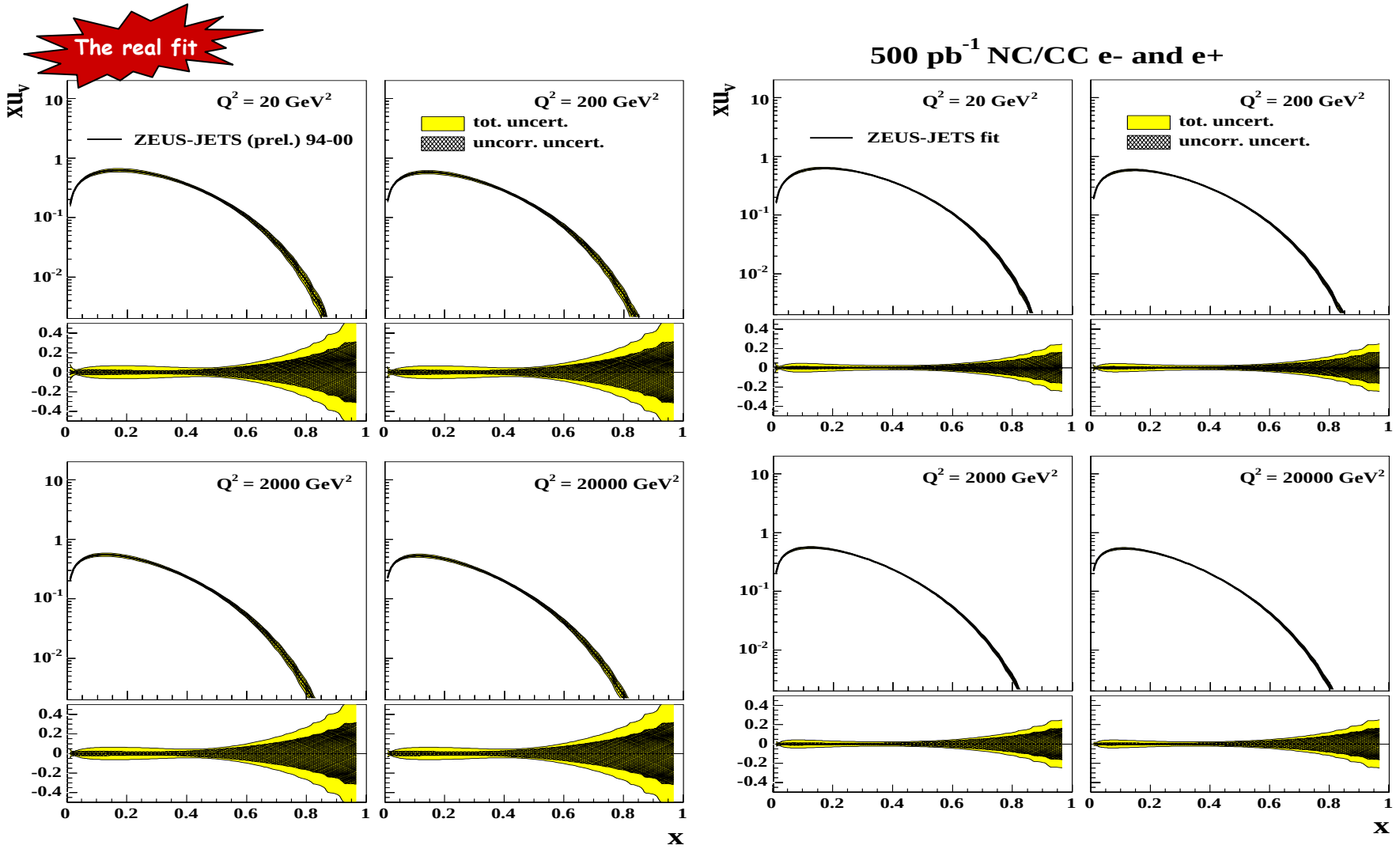
- ZEUS-JETS fit uses full set of HERA-I inclusive NC/CC e+/e- data (130 pb^{-1} divided unequally (115:15) in e+:e-)
  - measurements at high Q^2 are statistics dominated
- Here, assume 500 pb^{-1} inclusive NC/CC data of both e+/e-
  - Increased statistical precision applied to both NC/CC

- expect impact on valence



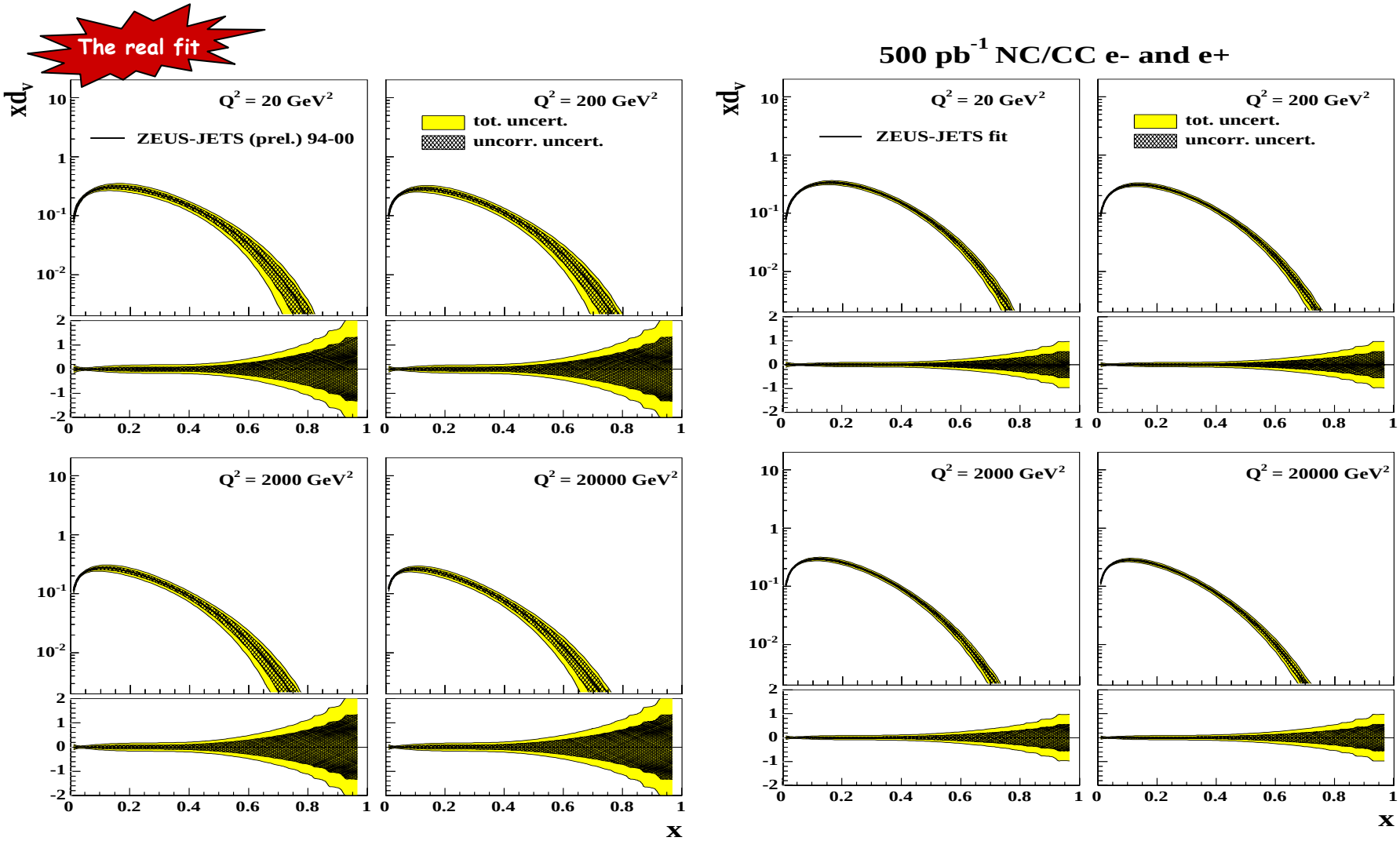
Example: HERA-I NC e+/e- data

Impact on u-valence distribution



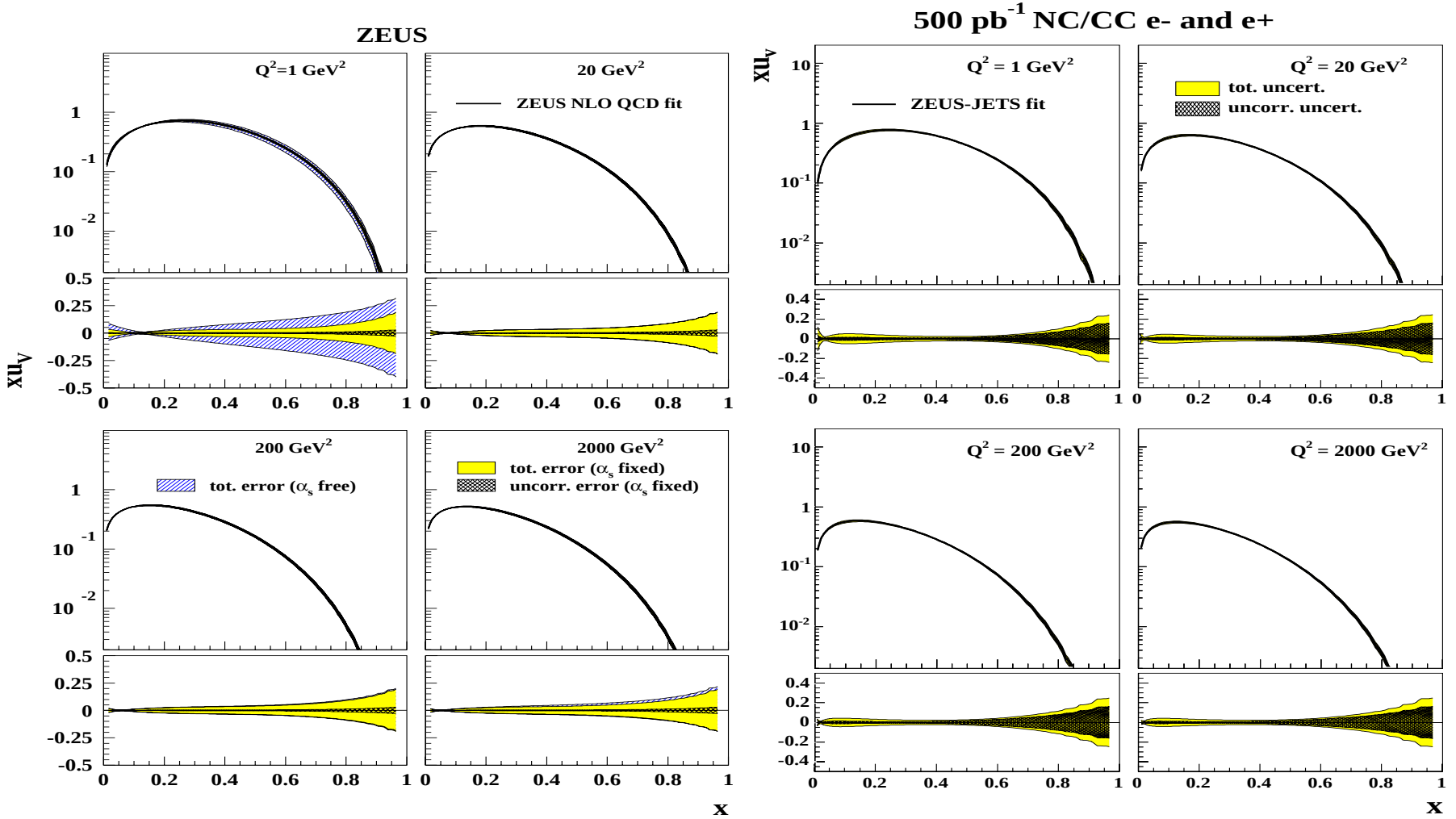
- Significant impact → uncertainties at high-x reduced from over 50% to 20%

Impact on d-valence distribution



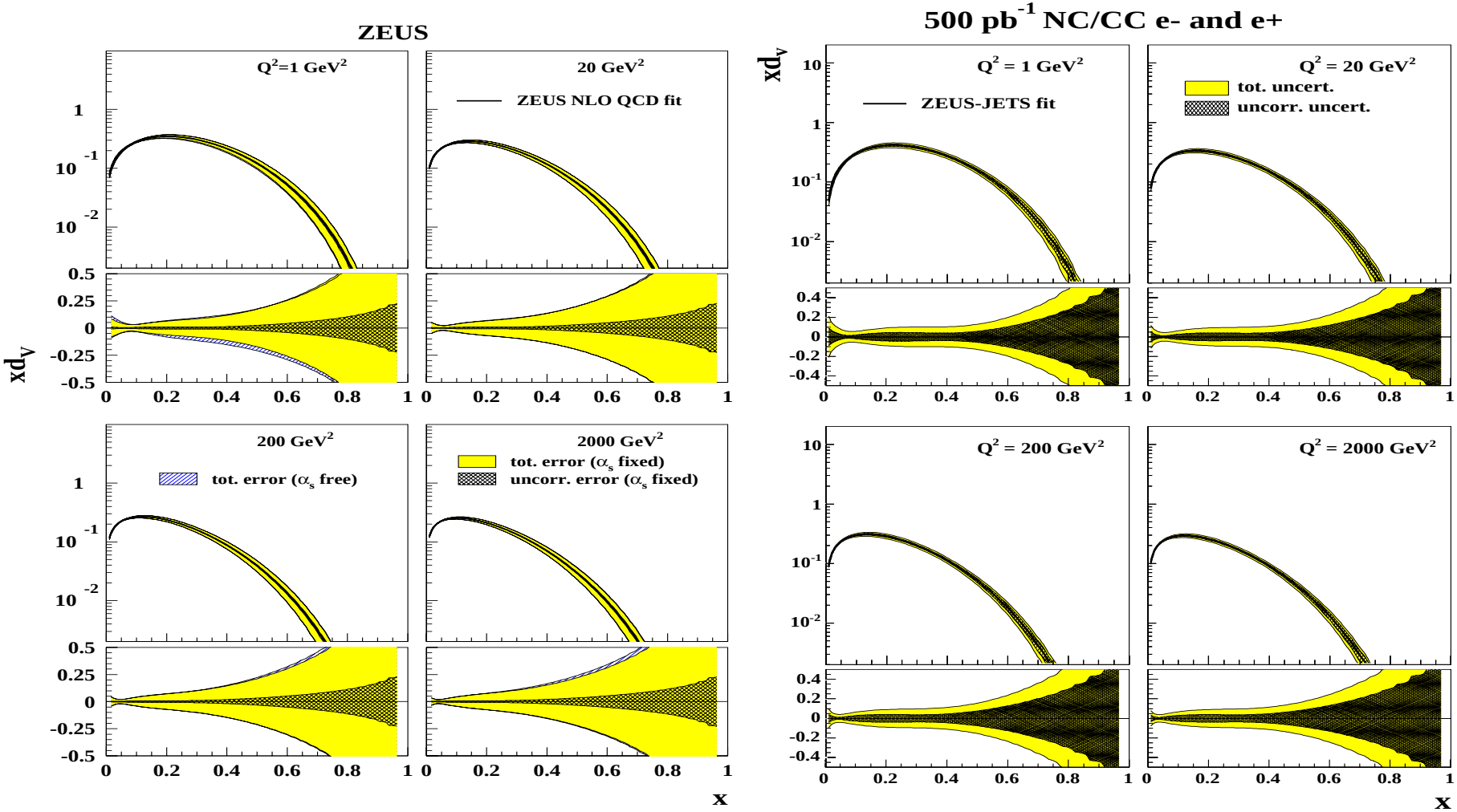
- Maximum uncertainty reduced from over 200% to 100%

Comparison with global fit (u-valence)



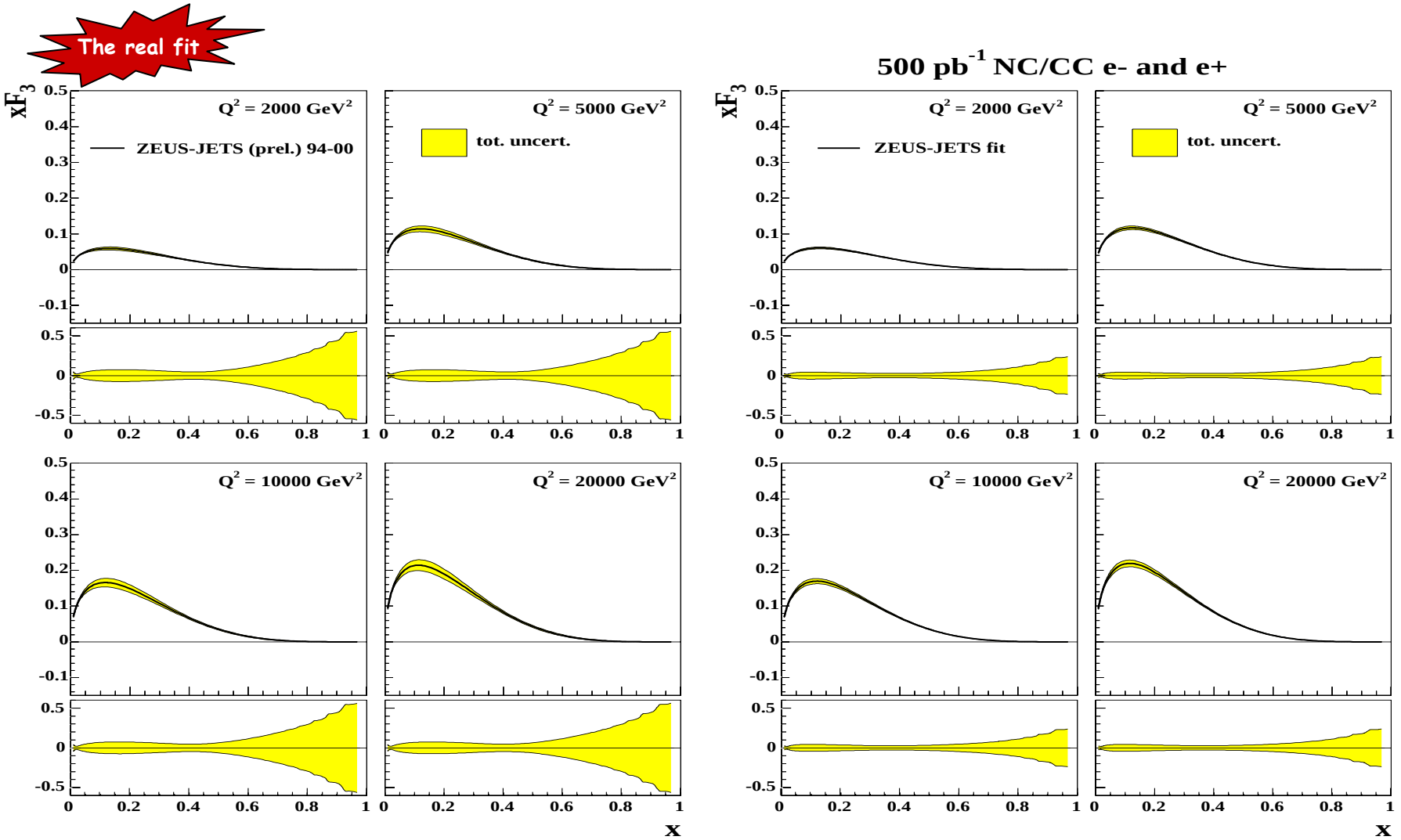
- Uncertainties with full HERA-II incl. data set comparable with global fits

Comparison with global fit (d-valence)



- Uncertainties comparable to or better than current global fits

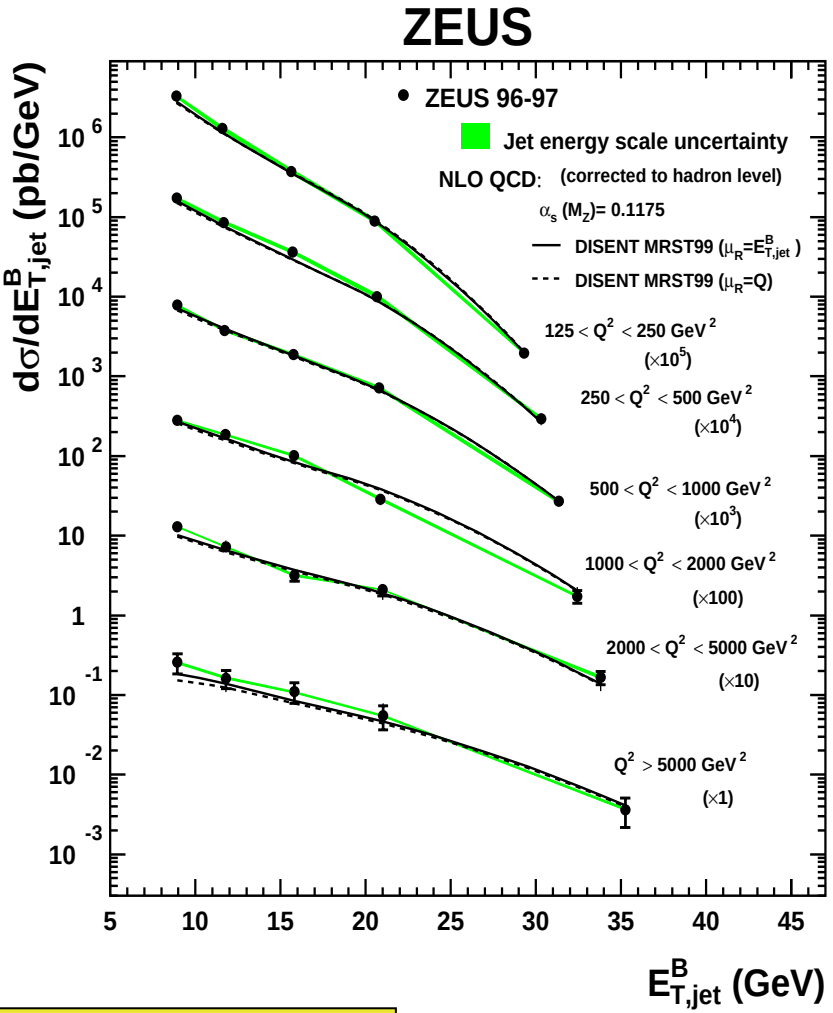
Impact on xF3 ~ Σx(q-qbar)



- <u>Significant</u> improvement in xF3 uncertainties (max. uncert. goes from ~60-20%)

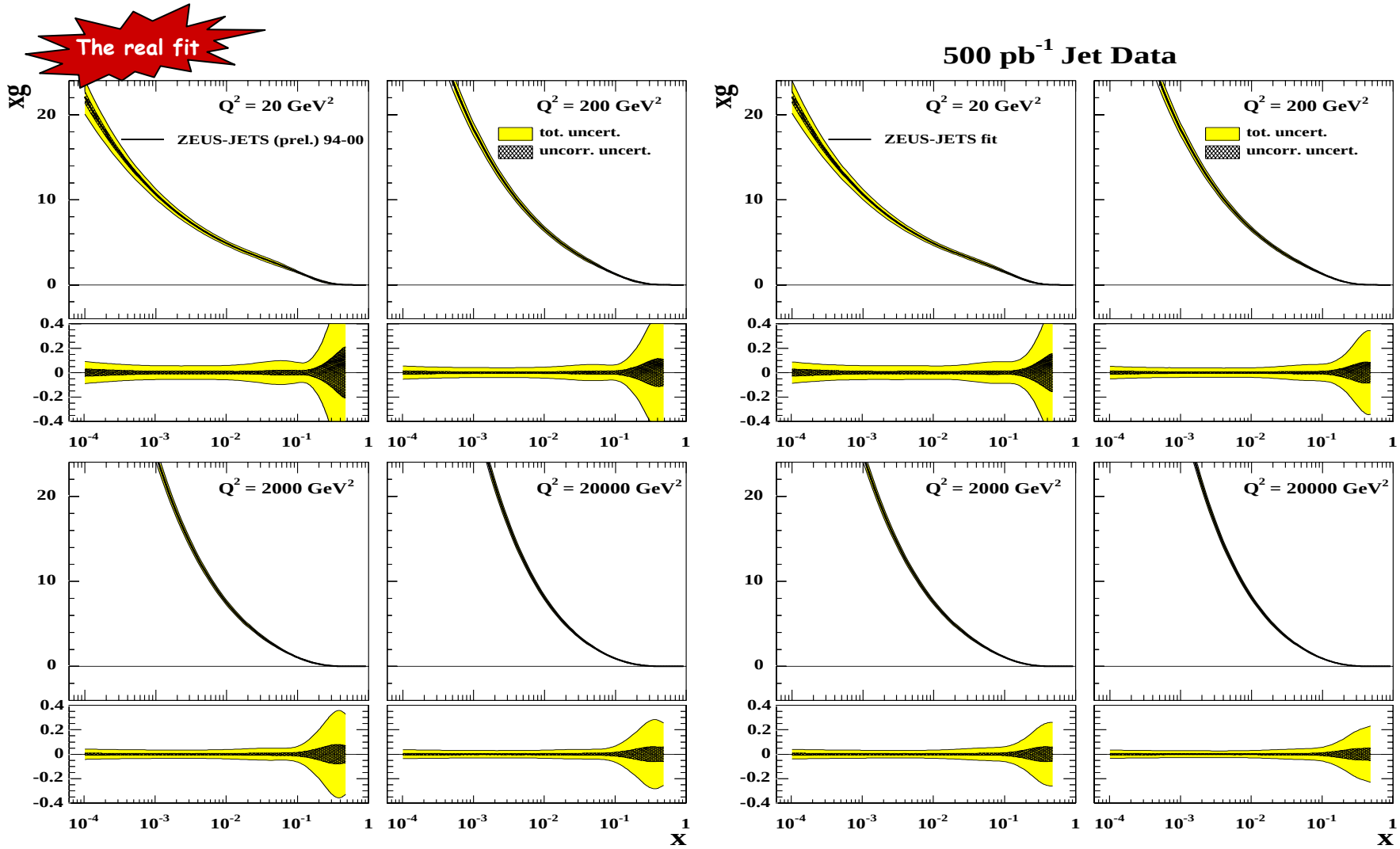
III) Impact of HERA jet data

- ZEUS-JETS fit uses ~ 40 pb^{-1} HERA-I jet data (from 96-97)
  - two measurements included:
    - inclusive jets in DIS
    - two-jet photoproduction at high E_T
- Here, assume 500 pb^{-1} jet data
  - Increased statistical precision applied to both DIS and γp data
- expect impact on gluon and (possibly) sea quark distributions



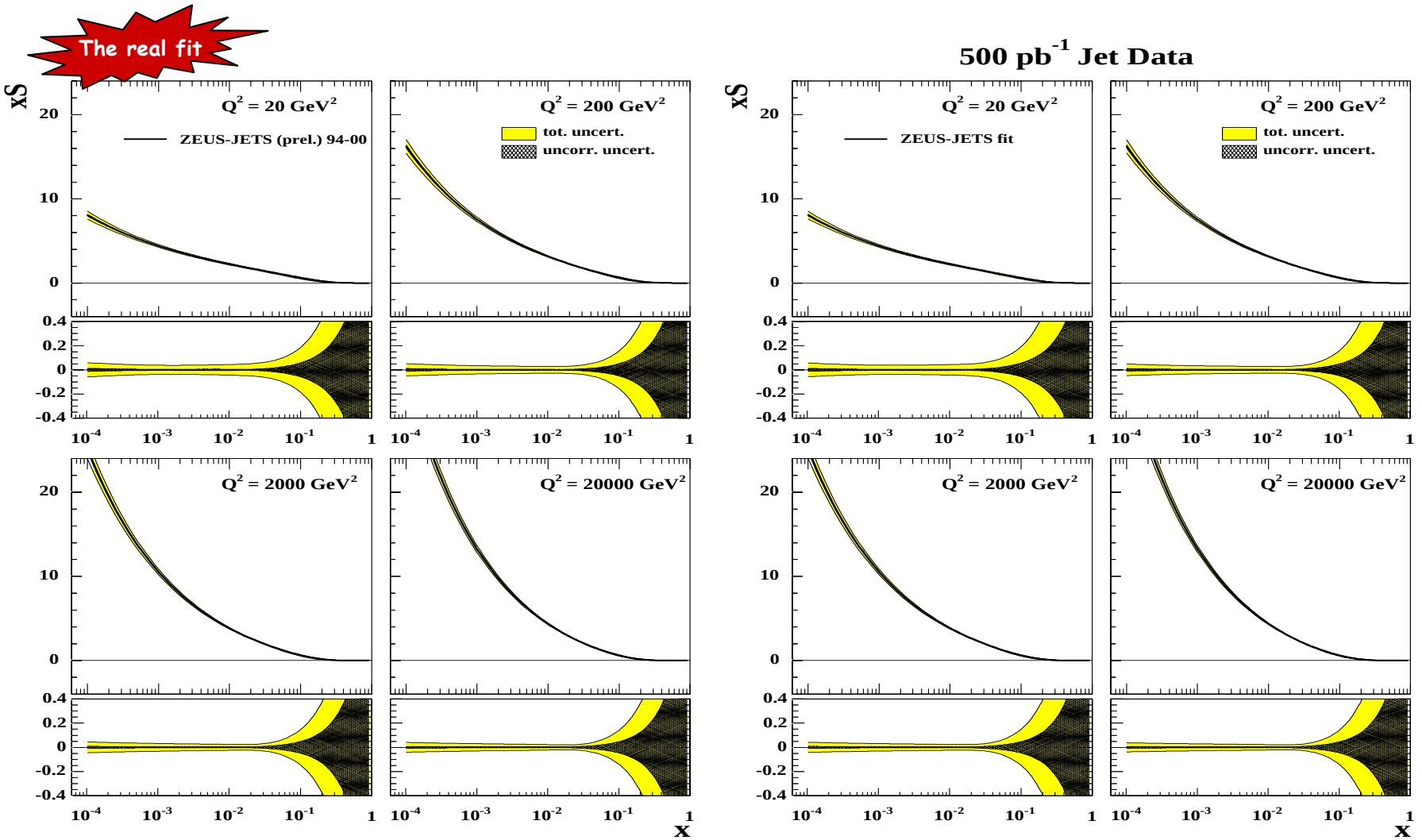
Example: HERA-I DIS jet data

Impact on the gluon distribution



- Impact at mid-to-high-x, uncertainties are further reduced

Impact on the sea quark distribution

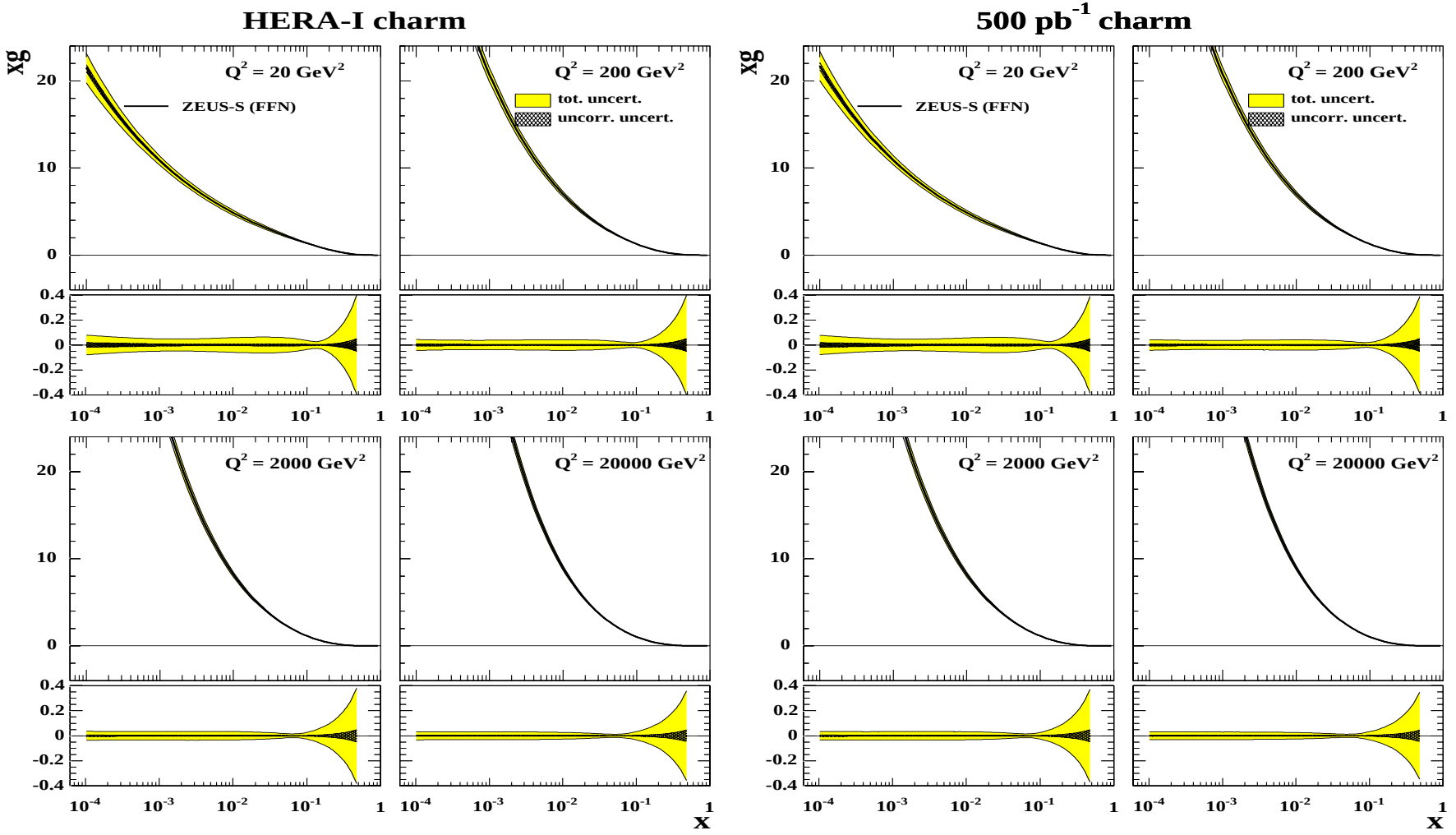


- Little visible impact on sea quark distribution

IV) Impact of charm

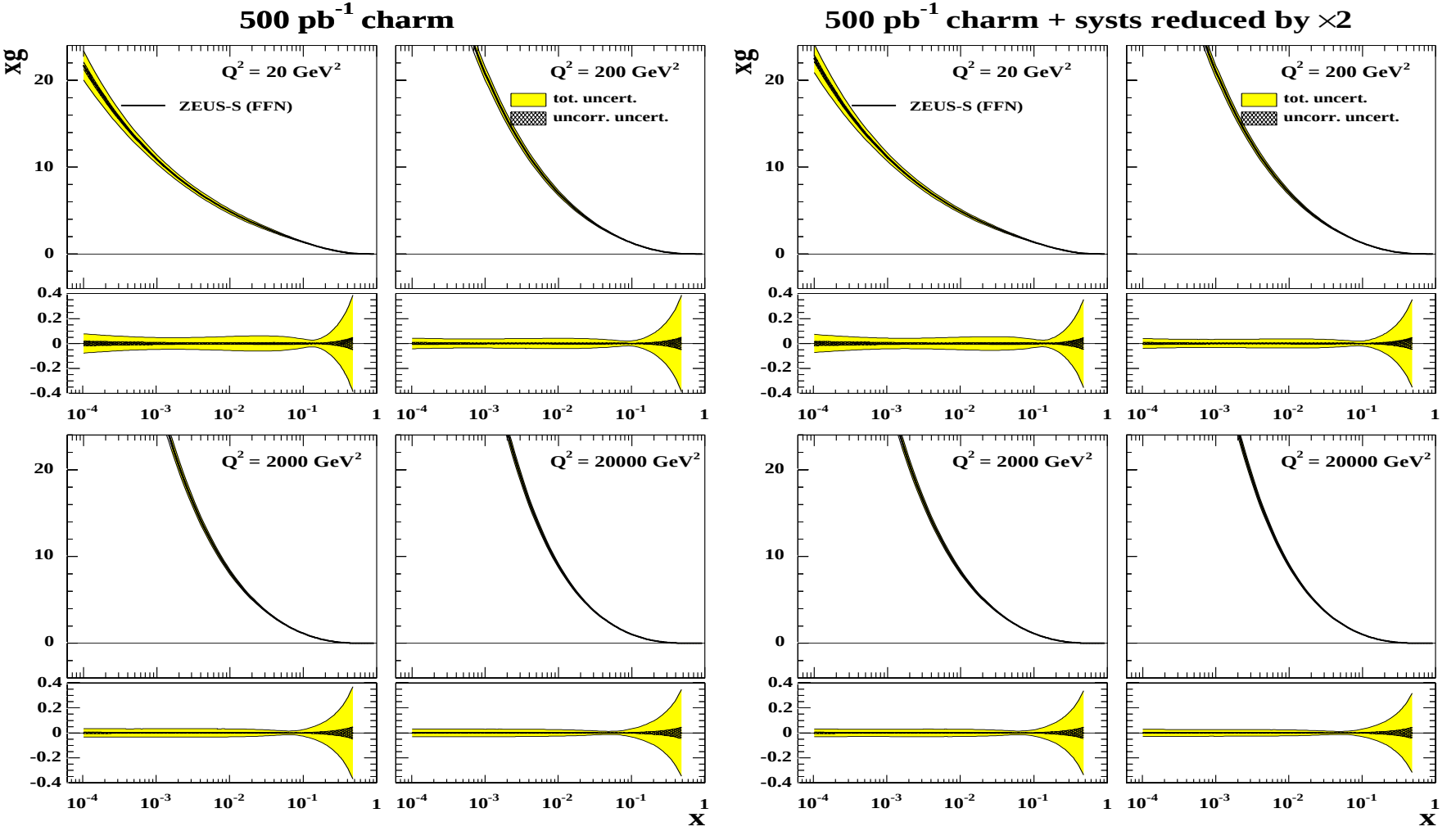
- The ZEUS fits do not currently include charm data
- In fact, the only way to consistently include charm (at the moment) is in the Fixed Flavour Number (FFN) scheme, applicable only at low Q^2 (Q^2<3000 GeV^2). This cuts out much of the HERA inclusive data, needed in HERA-Only fits! To get any sensible fit, need to include fixed target data…
  - For this check only, have used the ZEUS global fit as a basis (ZEUS-S fit: Phys. Rev. D67,012007(2003) (hep-ex/0208023))
- Here, assume 500 pb^{-1} charm in DIS
- Due to inclusion of MicroVertex Detector in ZEUS during HERA upgrade, also expect improved systematics to come from HERA-II measurements of heavy flavours
  - investigate by reducing current systematics by factors of 2-5

Impact on the gluon distribution



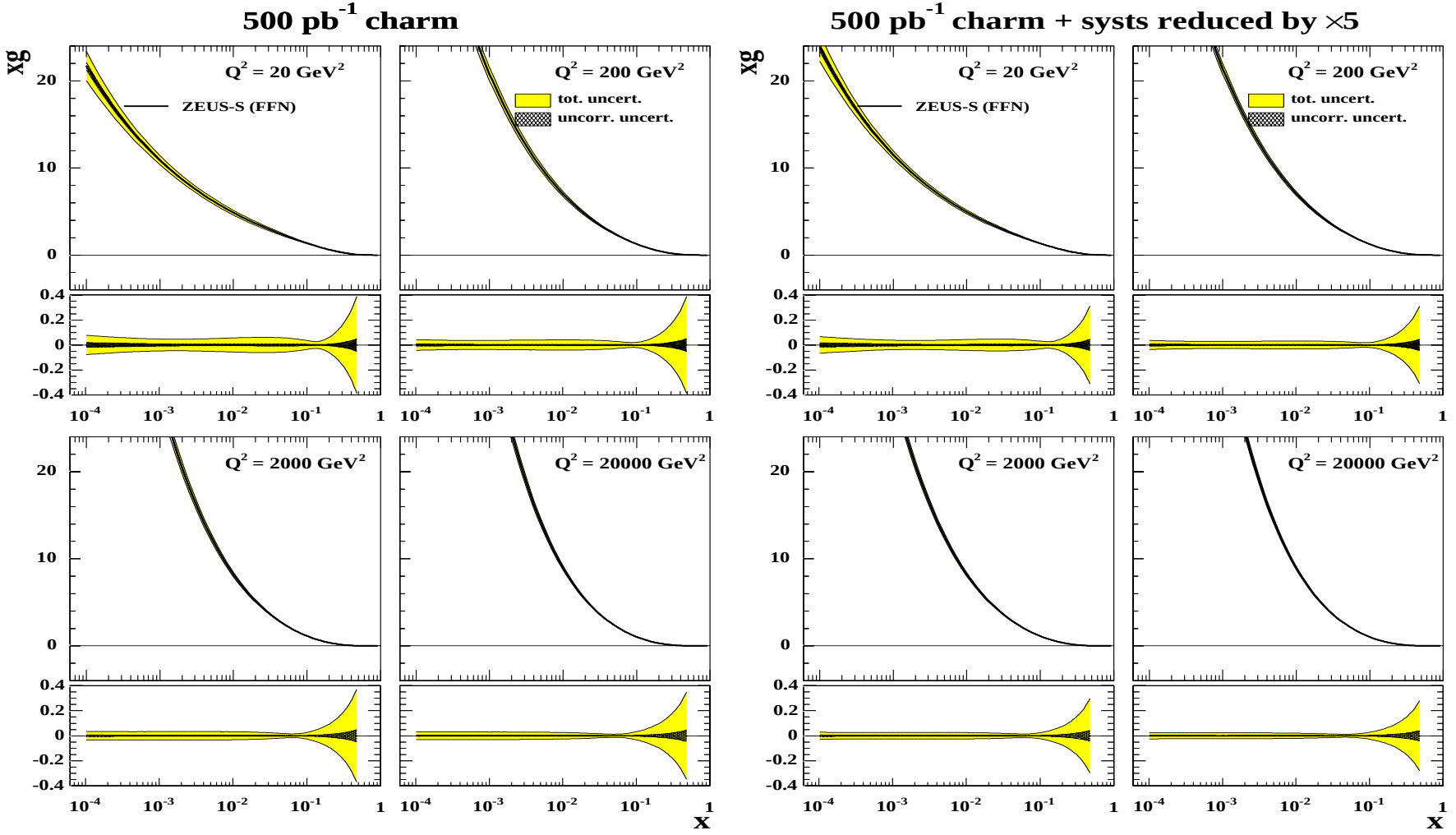
- Adding existing charm data has no impact compared to ZEUS global without charm (not shown)
- Increasing sample to 500 pb^{-1} barely noticeable (data already largely systematics dominated)

Improve systematics by x2



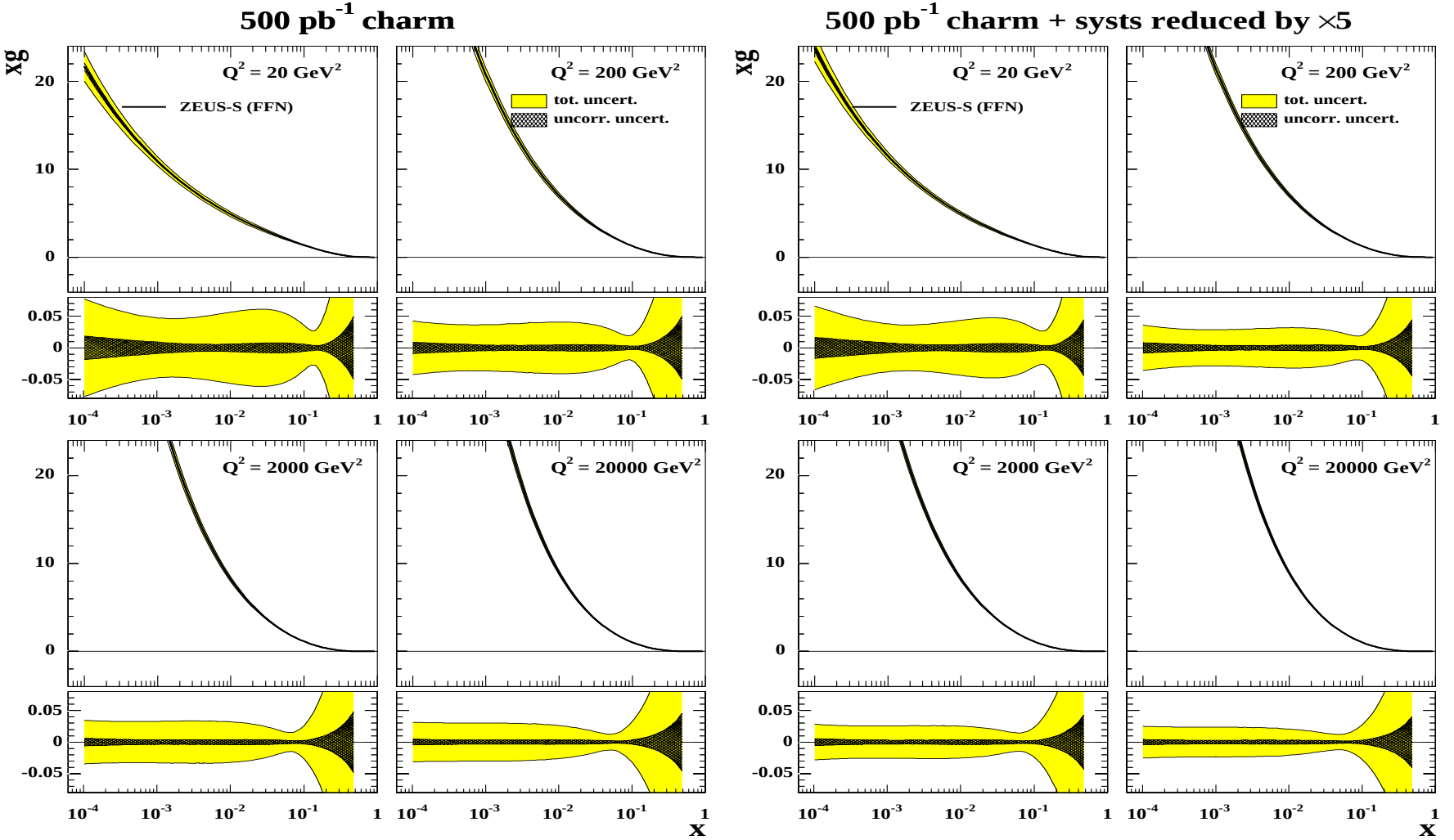
- Reducing systematics has more impact than simply increasing statistics
  - reduction of systematics by x2 is already visible at high-x (should be realisable with MVD)

Improve systematics by x5



- … but noticeably better if reduced by a factor of 5 (possible!?! not sure)

Improve systematics by x5



- … blown up scale shows there is <u>slight</u> improvement over all-x

Summary & Conclusions

- A very simple estimate of the potential impact of HERA-II data on the ZEUS PDF fits has been performed where the statistical uncertainties on existing data have been reduced
  - 100 pb^{-1} e- data (available soon), giving approximately equal e+/e- samples, shows some visible improvement in u-valence and xF3 at high-x
  - 500 pb^{-1} of (both) e+/e- inclusive data (maximum that HERA-II could provide) gives valence determination as good as in global fits
  - 500 pb^{-1} jet data provides even better gluon determination at mid-to-high-x (although little impact on sea)
  - 500 pb^{-1} charm data (in DIS) gives little visible improvement
    - BUT with improved systematics, reduction in gluon uncertainties at high-x seen

Even with this simple estimate, the potential of HERA-II is extremely significant

Summary & Future Plans

Limitations of this approach:

- No information on how new measurements from HERA-II may help (polarisation, optimised jet cross sections, F_L(?))
  - Could use simulated MC data to estimate this
- No accounting for statistical fluctuations in the data which are enhanced when uncertainties are artificially reduced
  - Could perform some kind of "smoothing" or use MC (as above)
- Also need to look at how the improvements to the PDFs effect LHC predictions (in the pipeline but not enough time for this meeting!)

By the time of the final meeting, hope to have addressed these issues

Extras…

The QCD Fit procedure

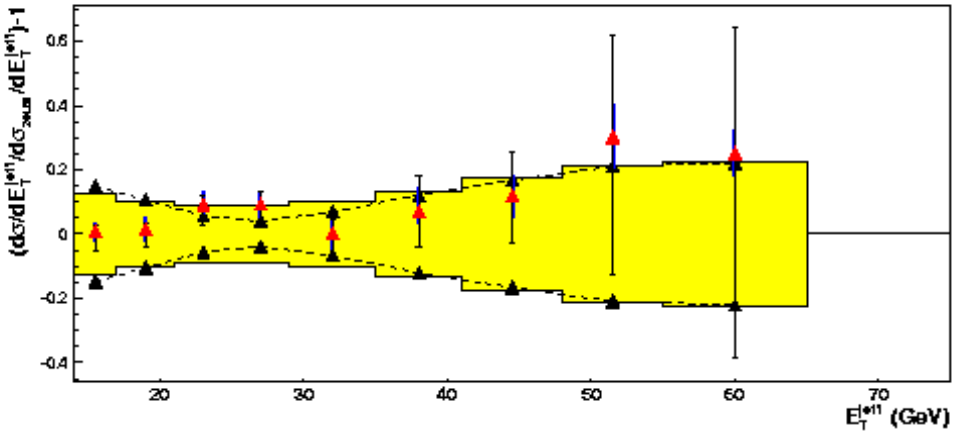
Method

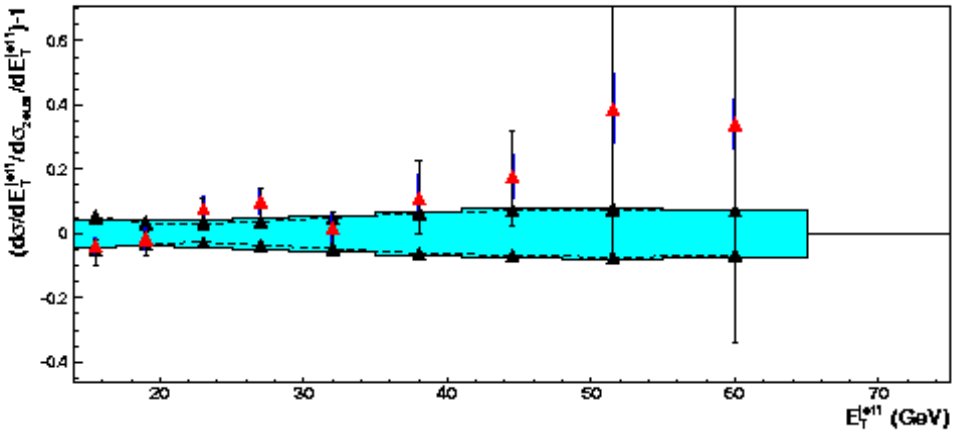
- Parameterise PDFs in x at the starting scale $Q_0^2 = 7\ GeV^2$:
  - $xf(x) = Ax^b(1-x)^c\,(1+dx)$
- Evolve PDFs with Q^2 using NLO DGLAP equations
- Convolute PDFs with coefficient functions in Robert-Thorne Variable Flavour Number Scheme to get predictions for structure functions and, hence, cross sections
- Parameterise the following PDFs:
  - u-valence (uv)
  - d-valence (dv)
  - total sea quark (S)
  - gluon (g)

Optimised jet cross sections

by Christopher Targett-Adams

Example: $1 < \eta^{jet1} < 2.4$, $0 < \eta^{jet2} < 1$, $x_\gamma > 0.75$

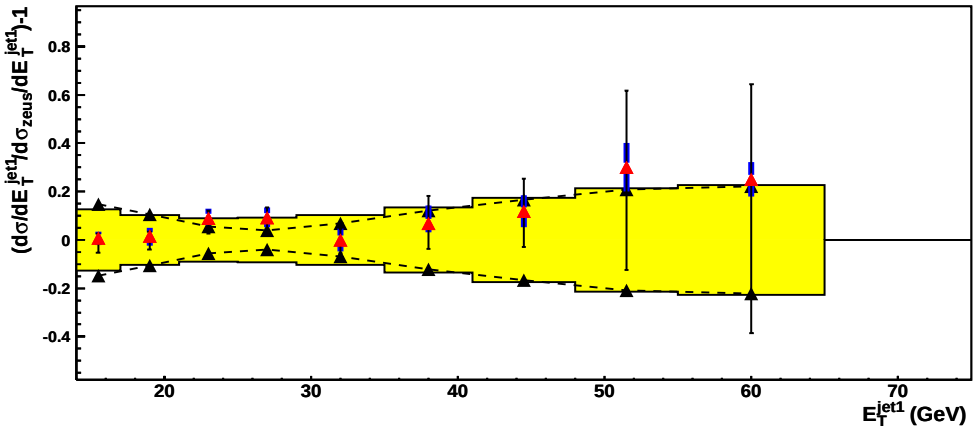




Predictions for a typical high-E_T photoproduction jet cross section
- uncertainties shown for fits with and without jets

Optimised jet cross sections

by Christopher Targett-Adams

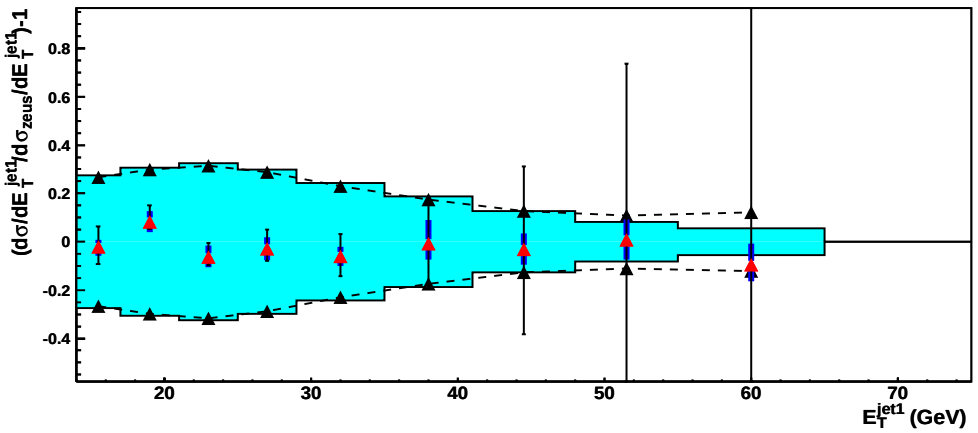


$E_T^{jet1}>14GeV$, $E_T^{jet2}>11GeV$

$x_\gamma>0.75$, $1<\eta^{jet1}<2.4$, $0<\eta^{jet2}<1$

Published

All flavors up/down error
ZEUS gluon up/down error
Data+stat+syst errors
Data+energy scale uncertainity



$E_T^{jet1}>15GeV$, $E_T^{jet2}>10GeV$

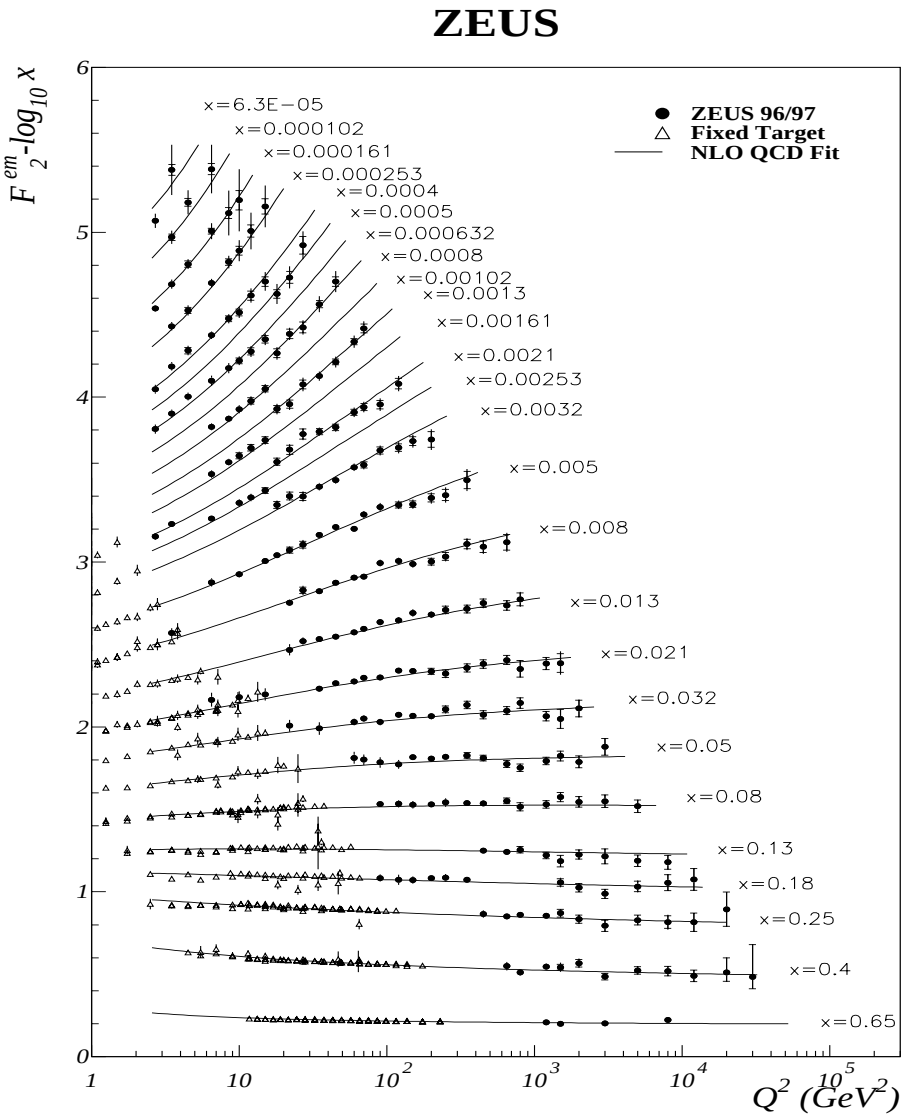
$x_\gamma<0.75$, $2<\eta^{jet1}<3$, $2<\eta^{jet2}<3$

Optimised

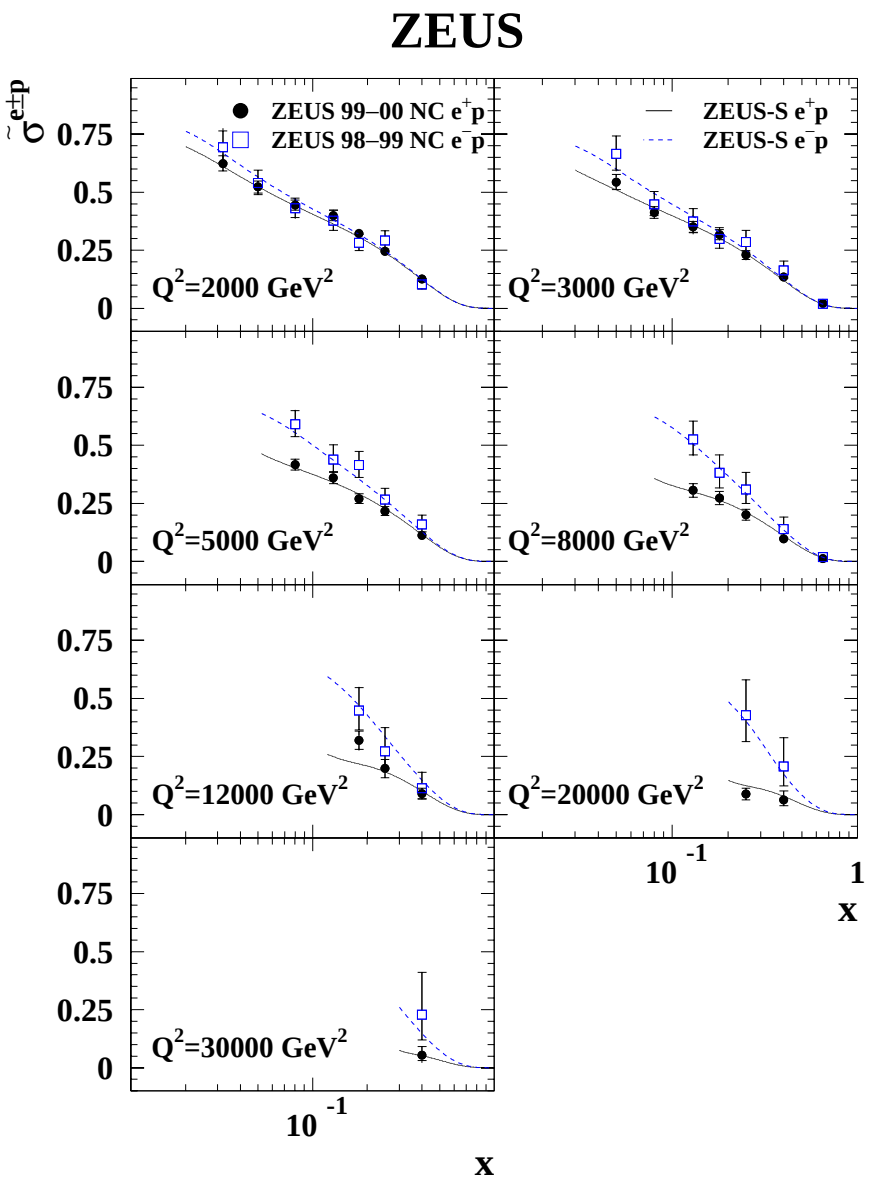
All flavors up/down error
ZEUS gluon up/down error
Data+stat+syst errors (est)
Data+energy scale uncertainity (est)

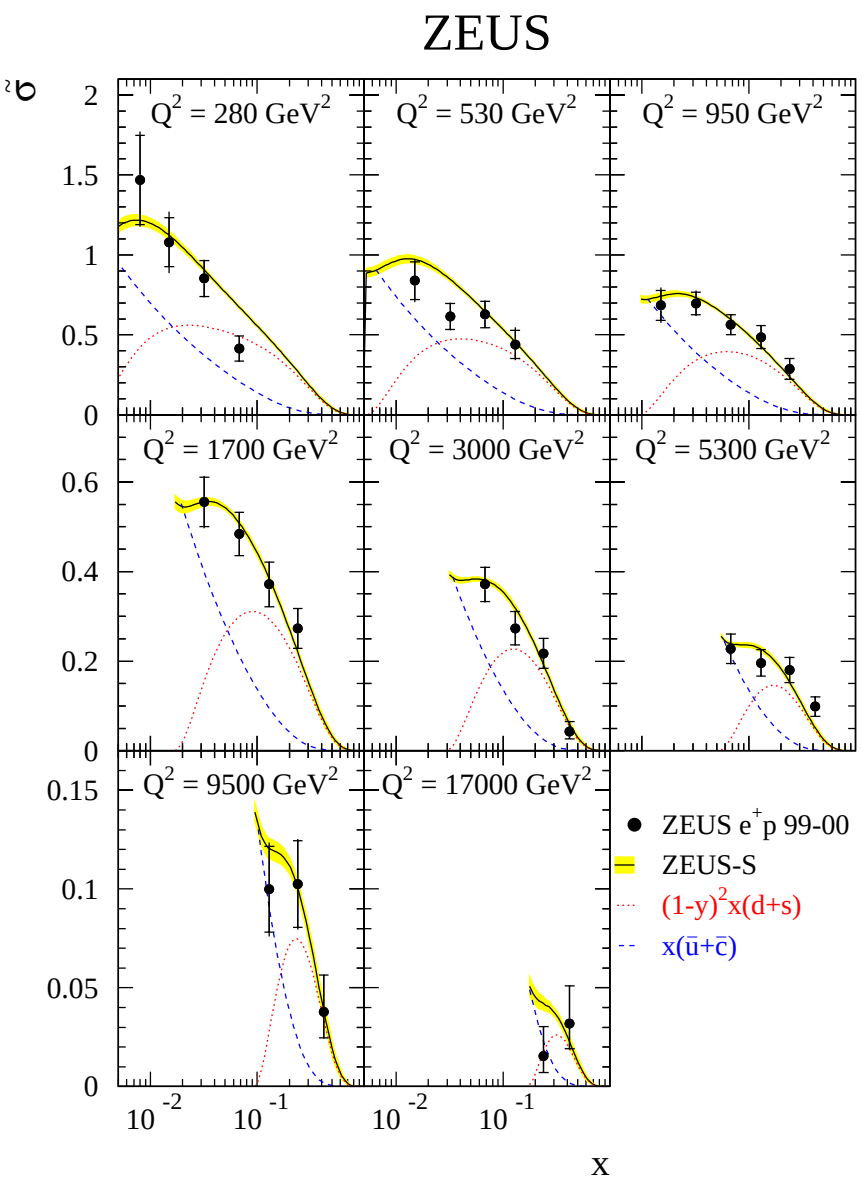
With HERA-II data, potential to measure cross sections designed to maximise sensitivity to gluon

The HERA-I inclusive e+ F2 data

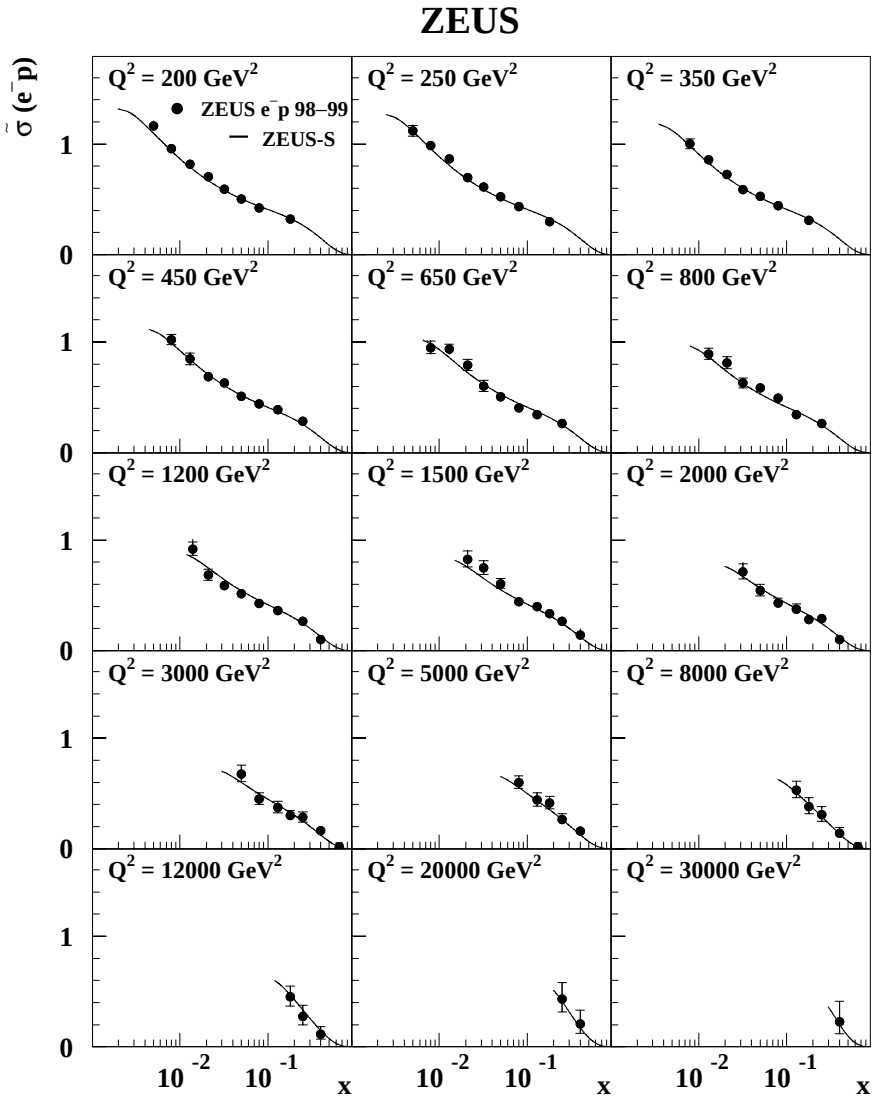


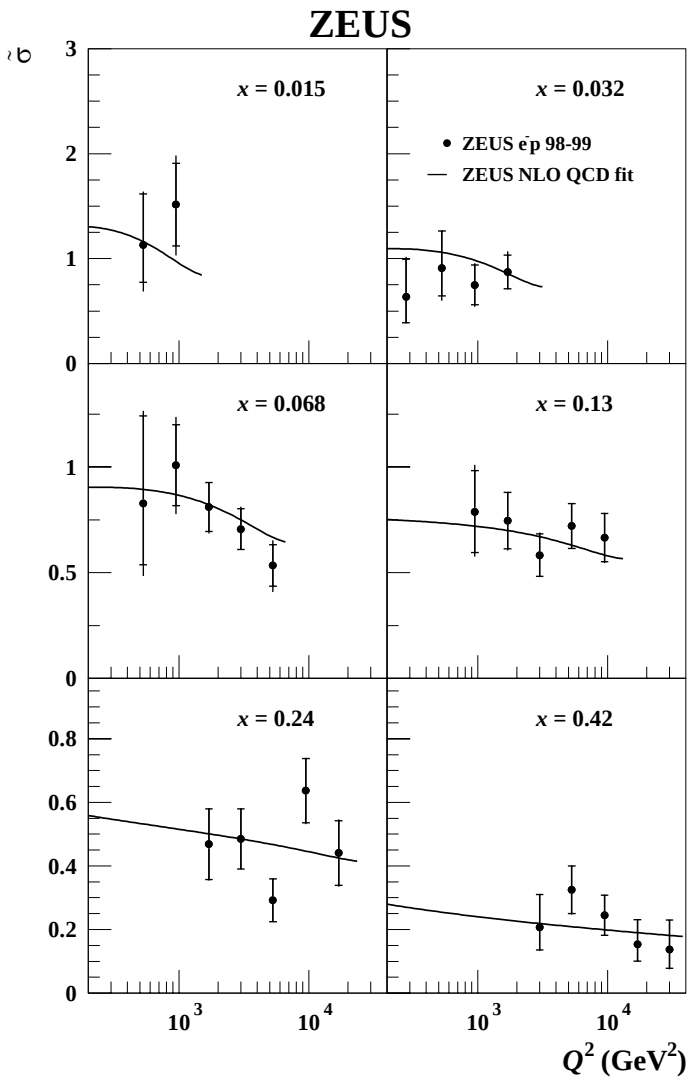
The HERA-I inclusive e+ data



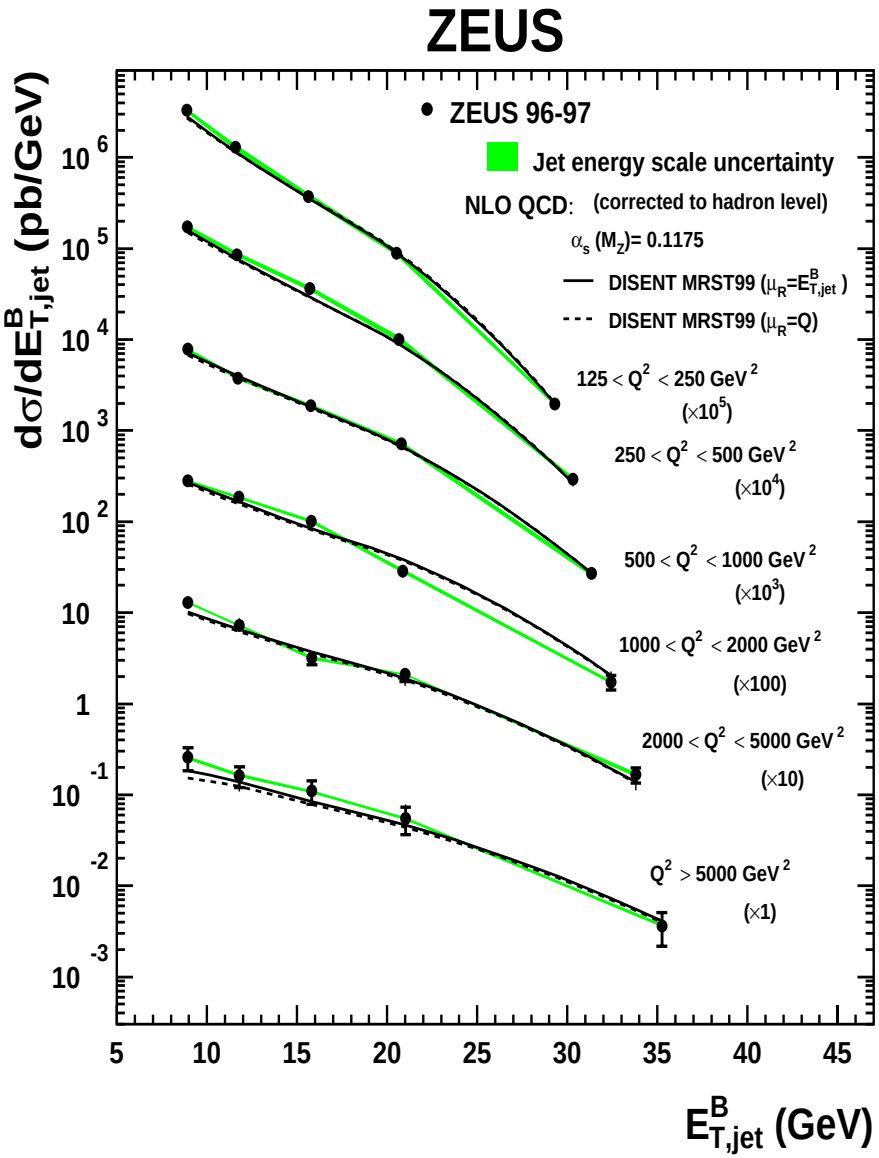


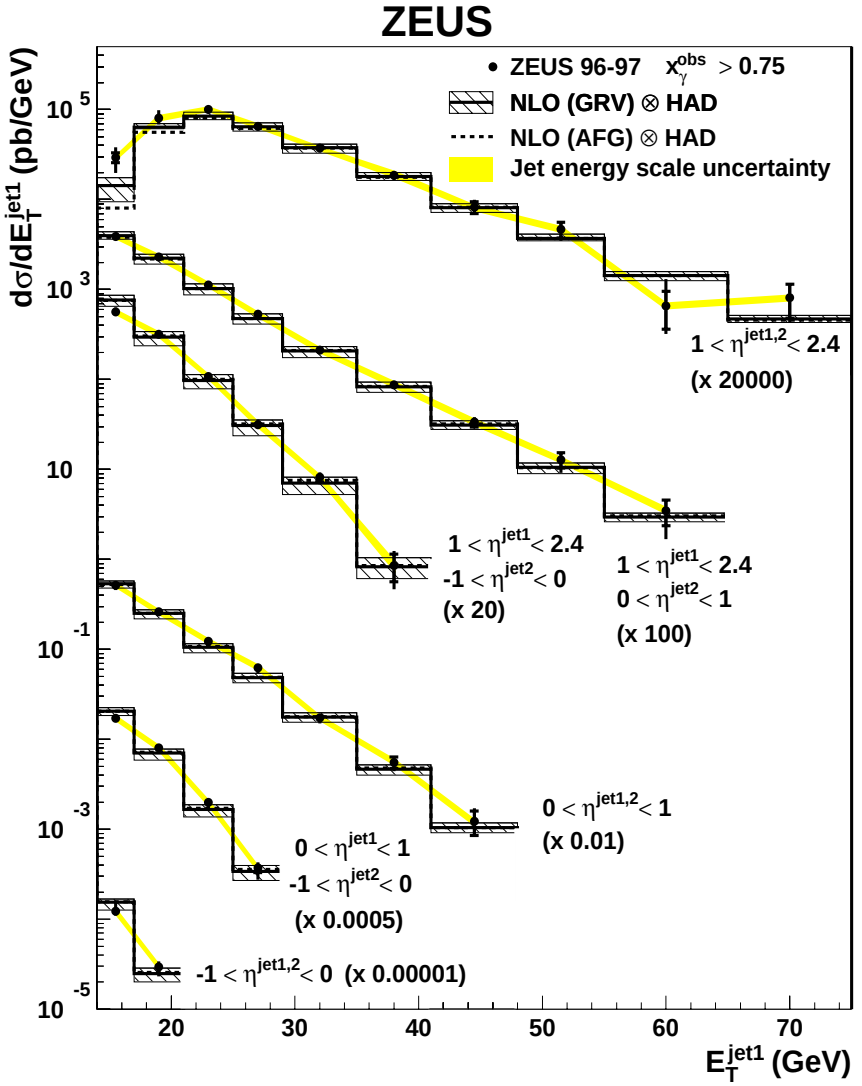
The HERA-I inclusive e- data



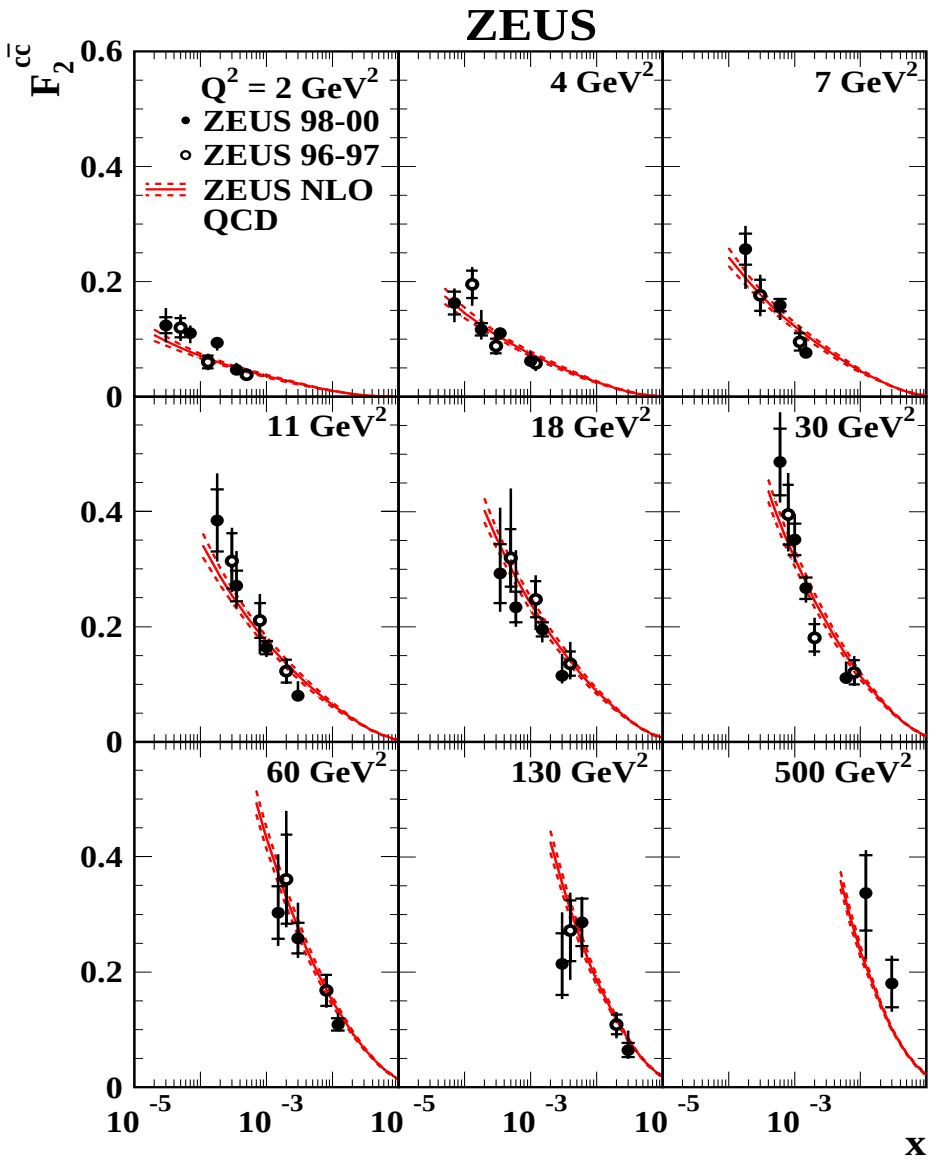


The HERA-I Jet Data

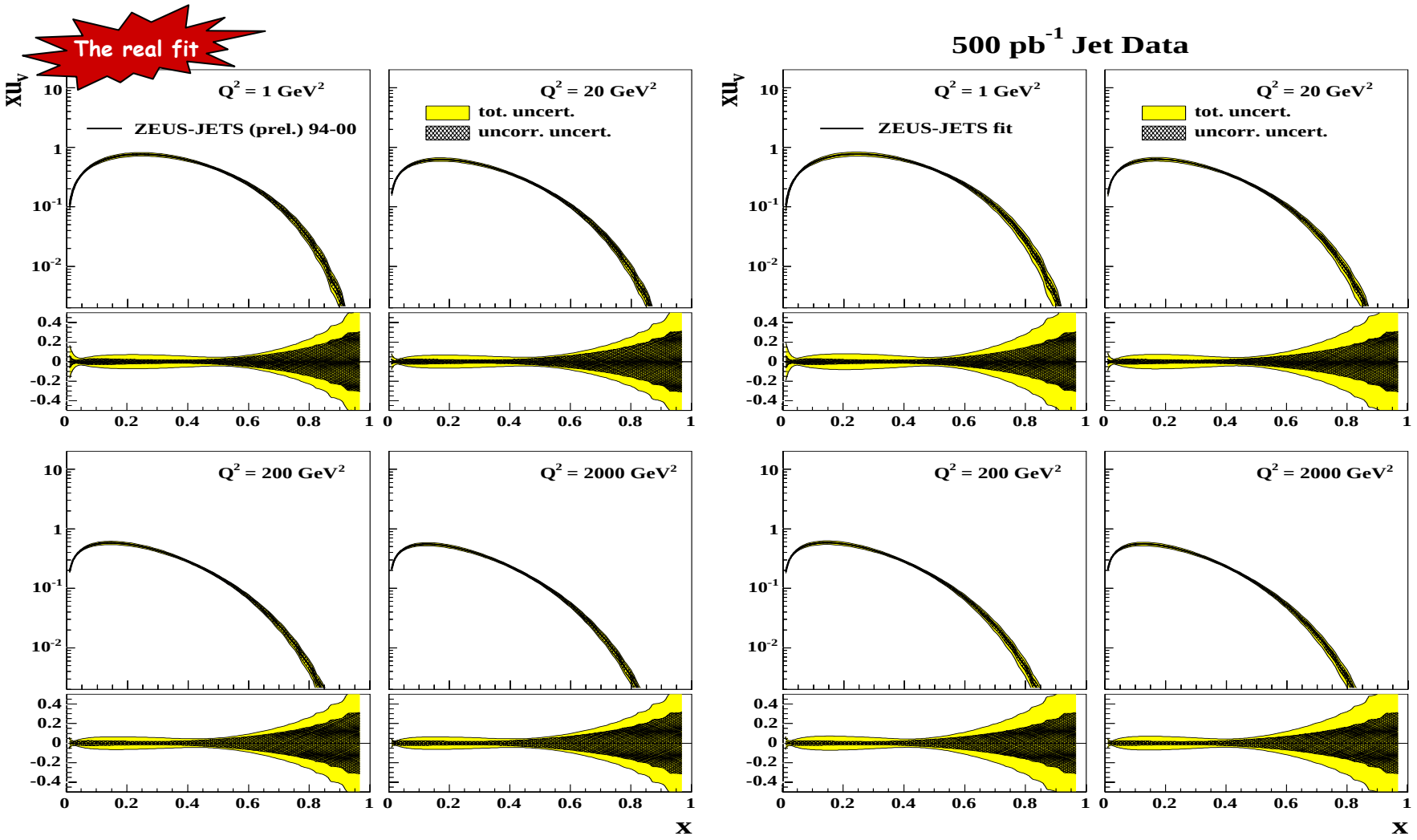




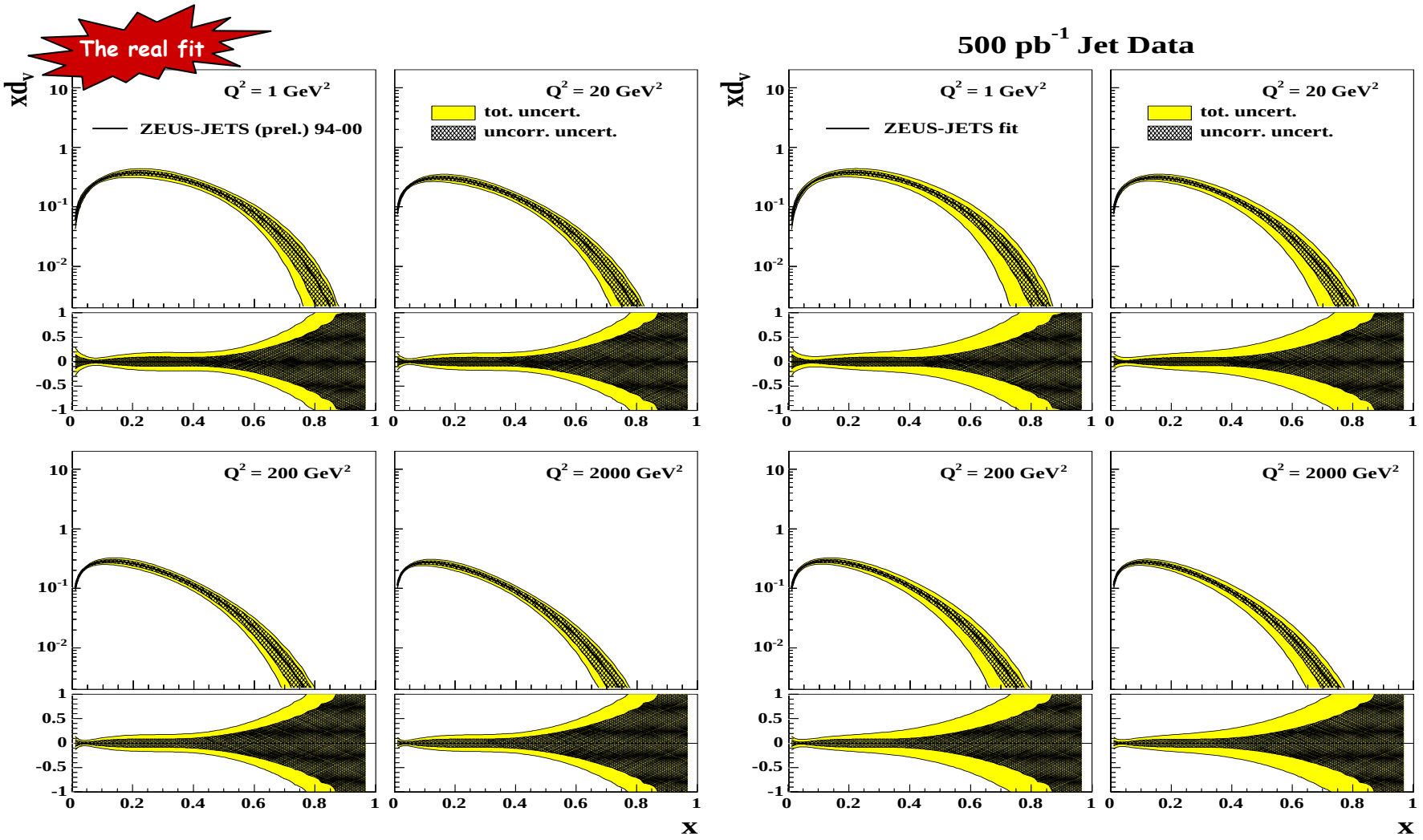
The HERA-I Charm in DIS Data



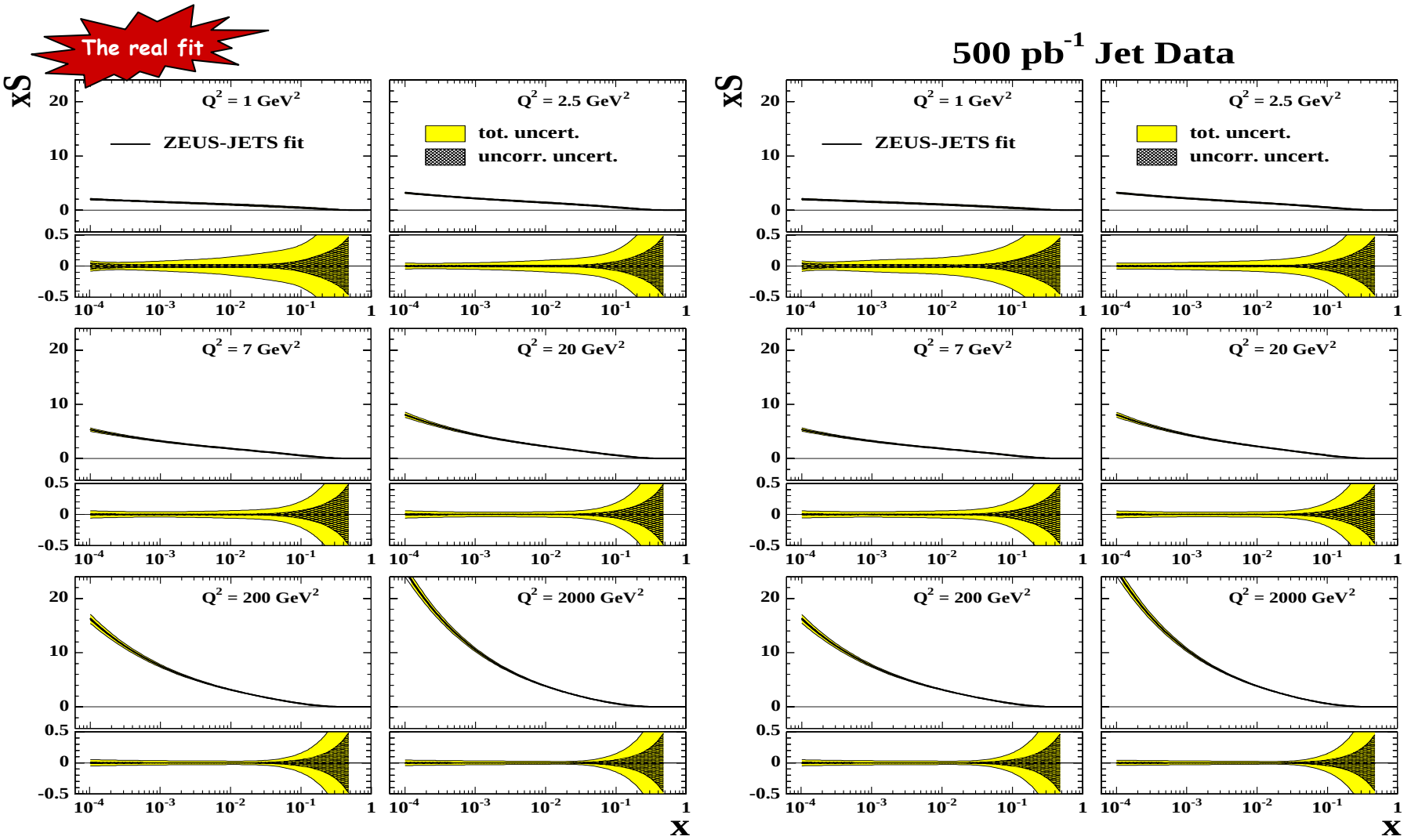
Jets: impact on u-valence distribution



Jets: impact on d-valence distribution

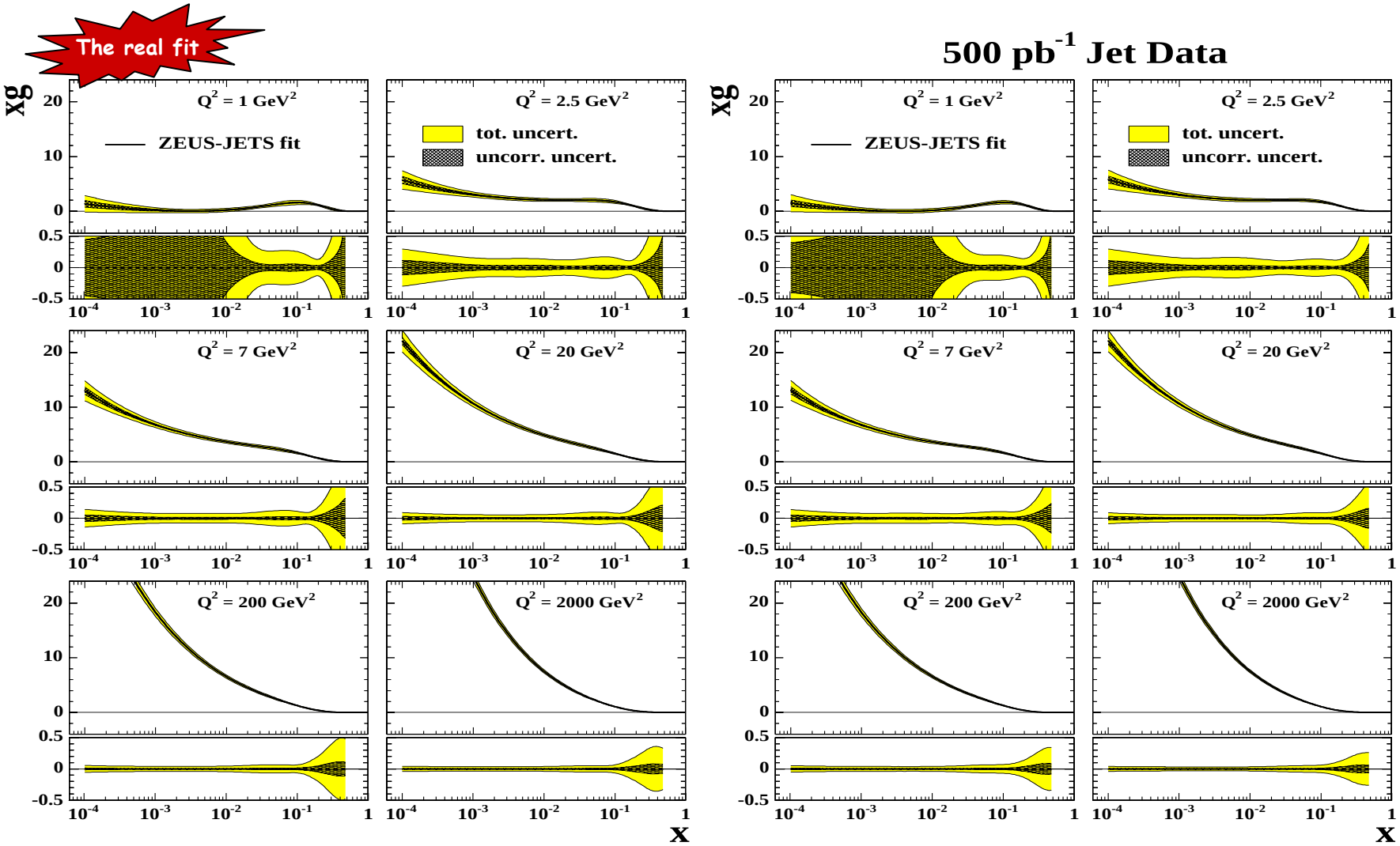


Jets: impact on the sea distribution



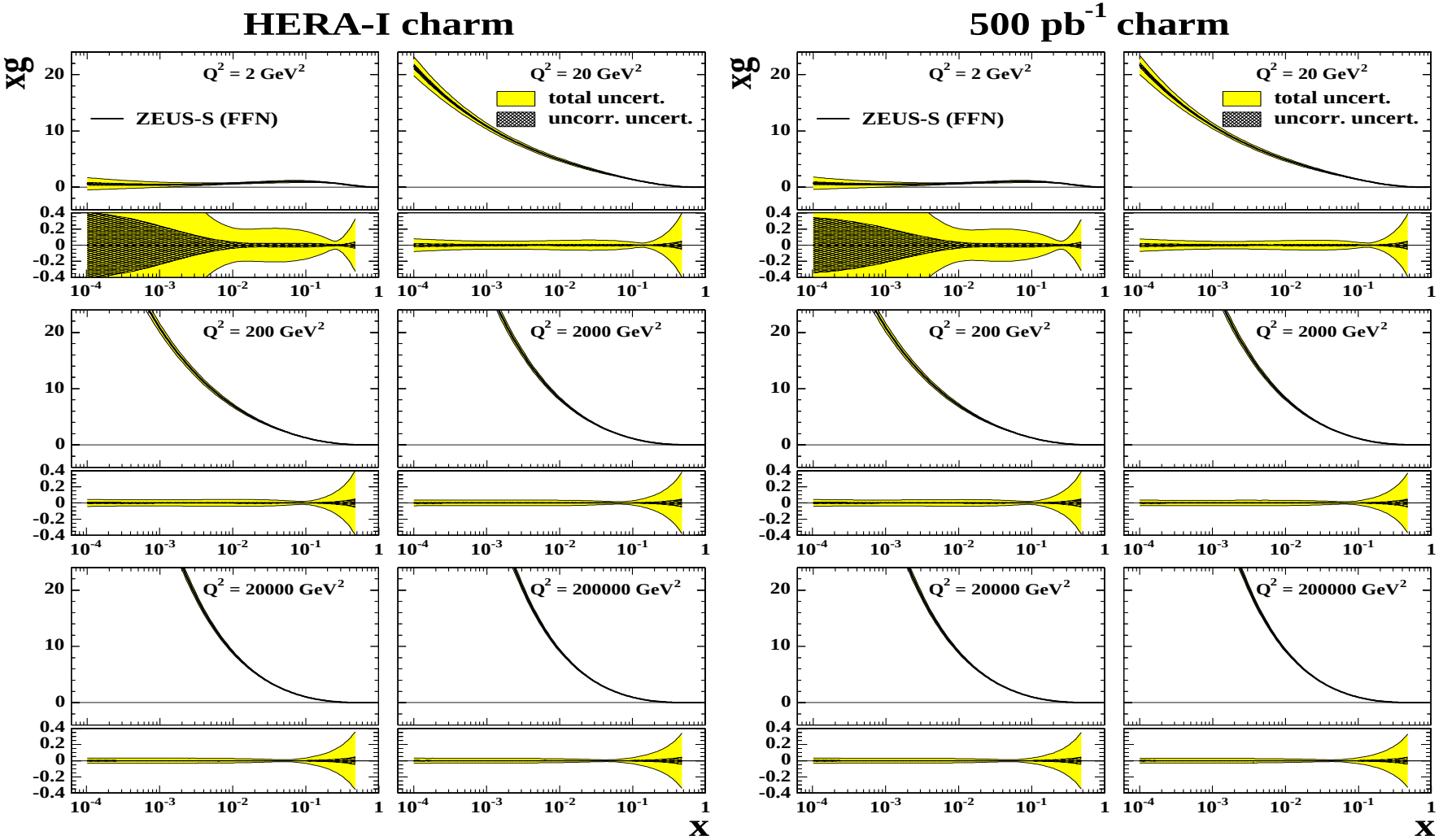
- Little visible impact on sea quark distribution

Jets: impact on the gluon distribution



- Impact at mid-to-high-x, uncertainties are further reduced

Charm: impact on the gluon distribution



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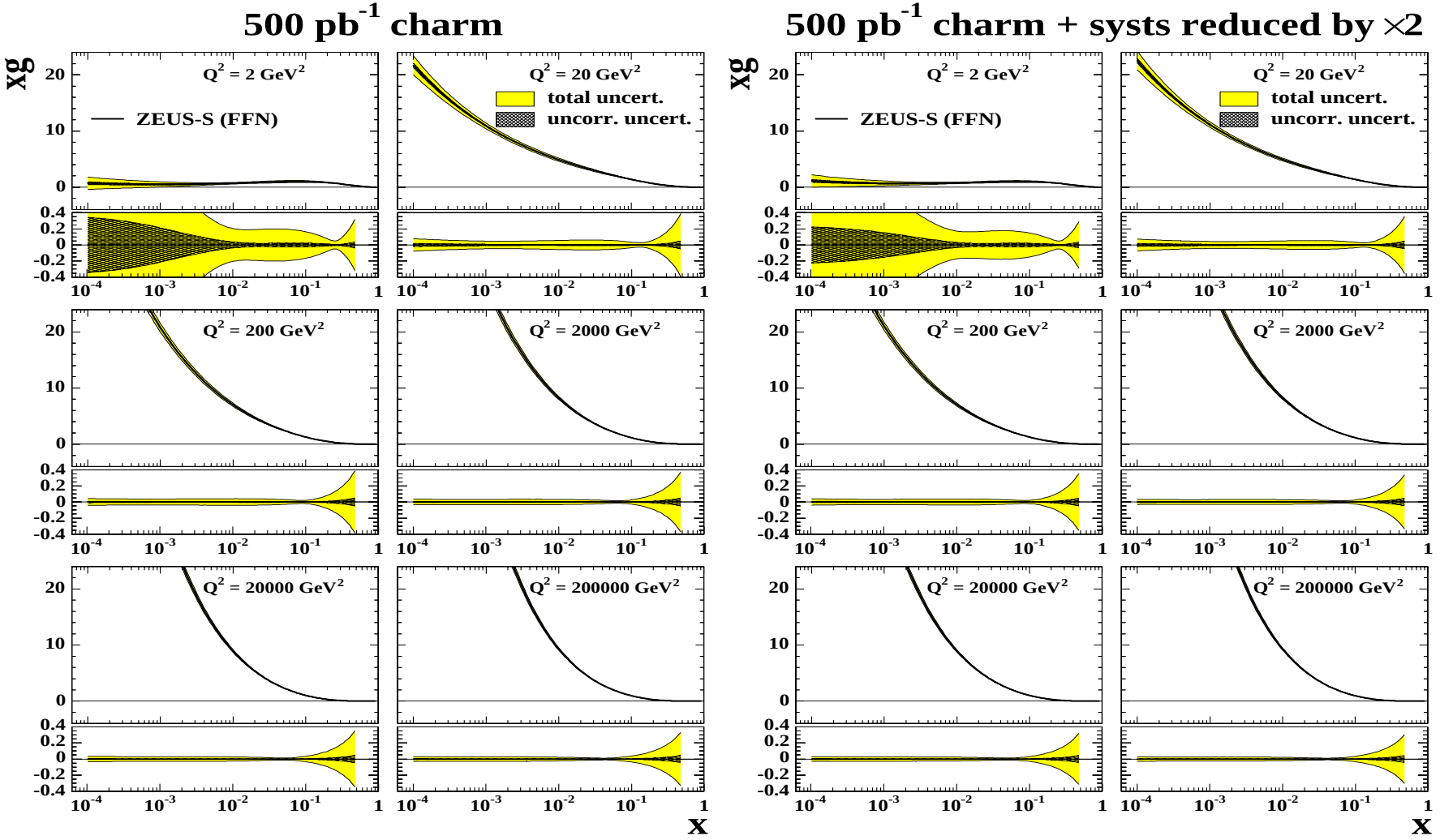
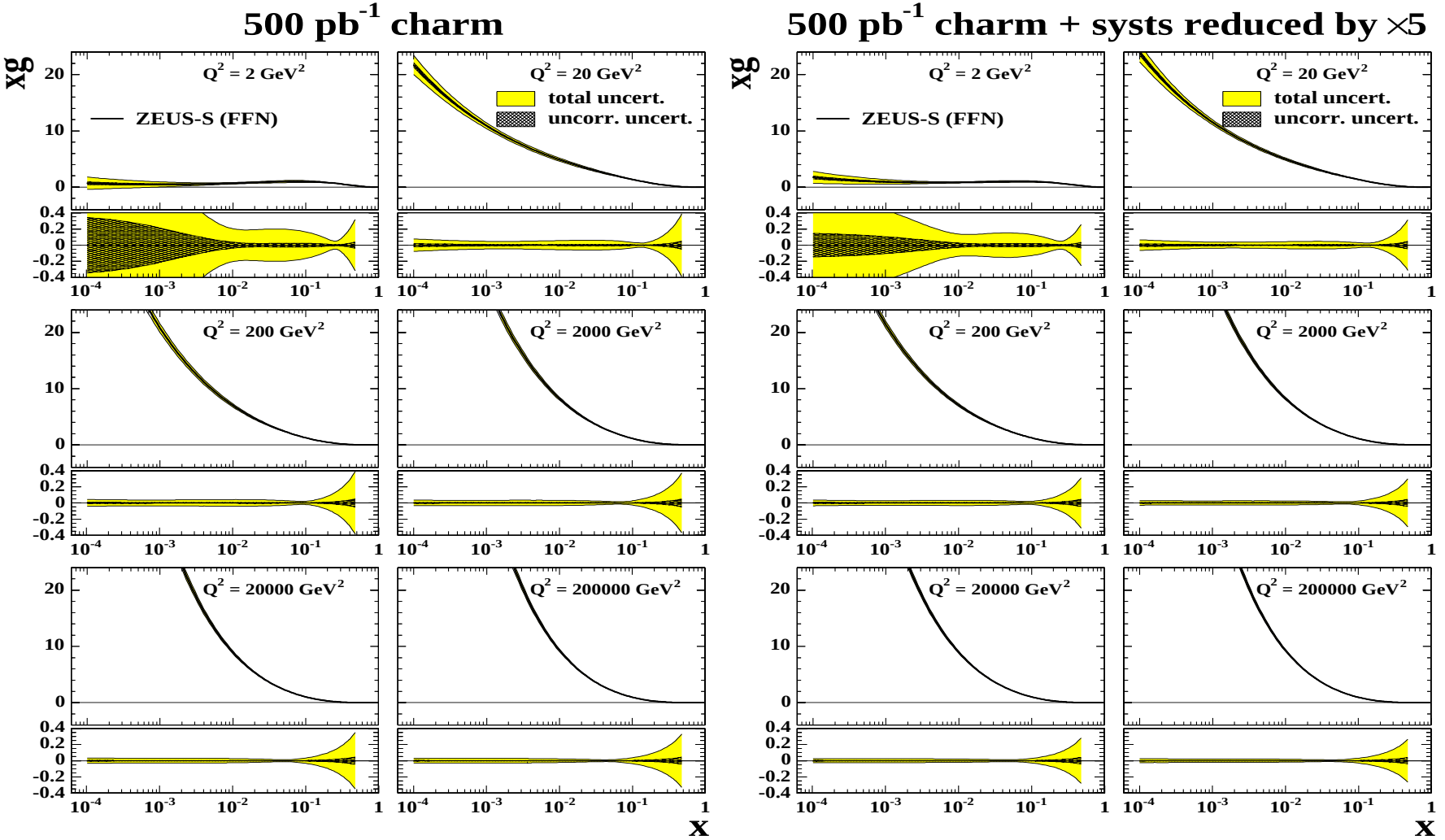
Charm: improve systematics by x2



- Reducing systematics has more impact than simply increasing statistics
  - reduction by factor of 2 is already visible (should be realisable with MVD)

Charm: improve systematics by x5



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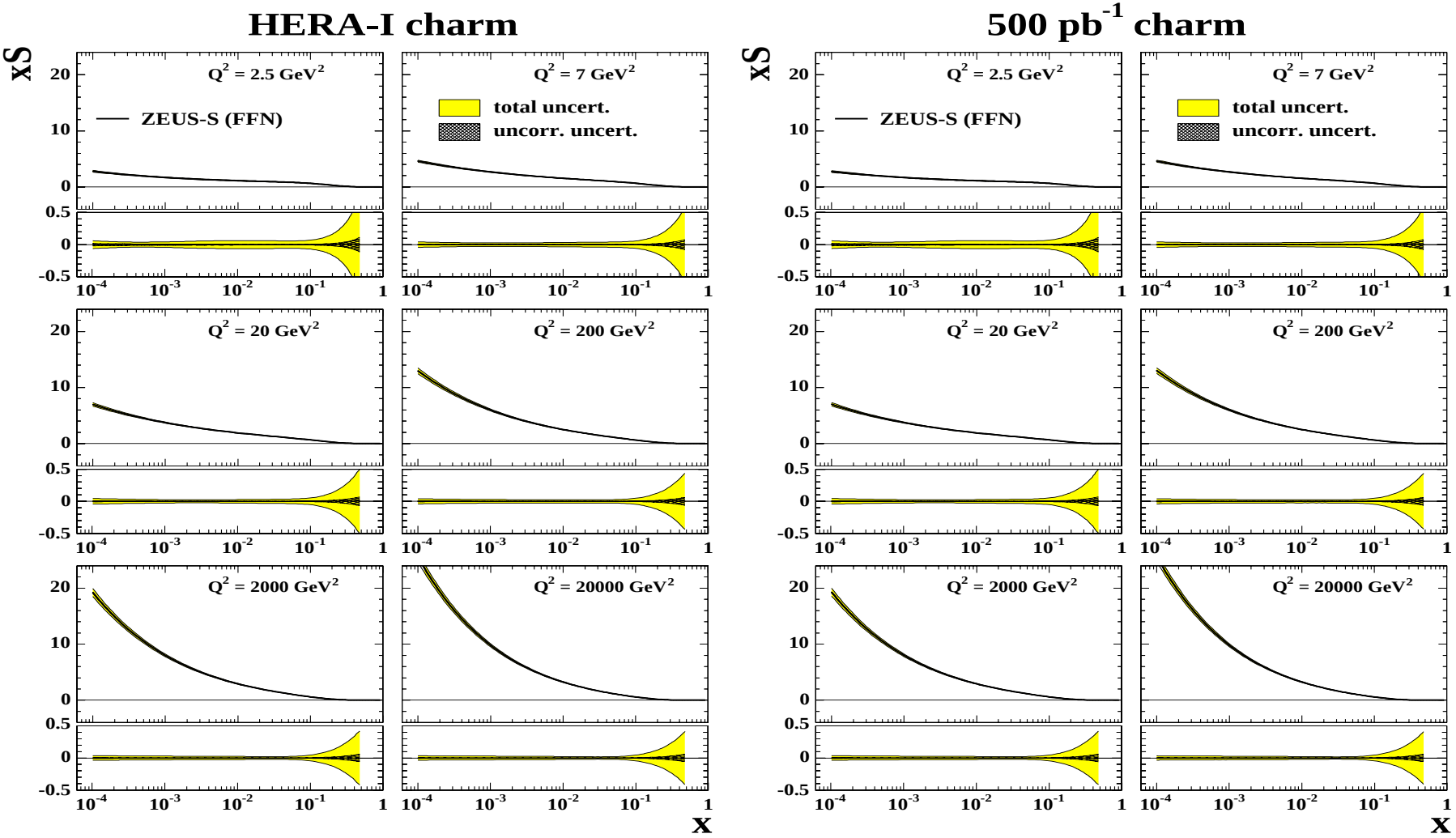
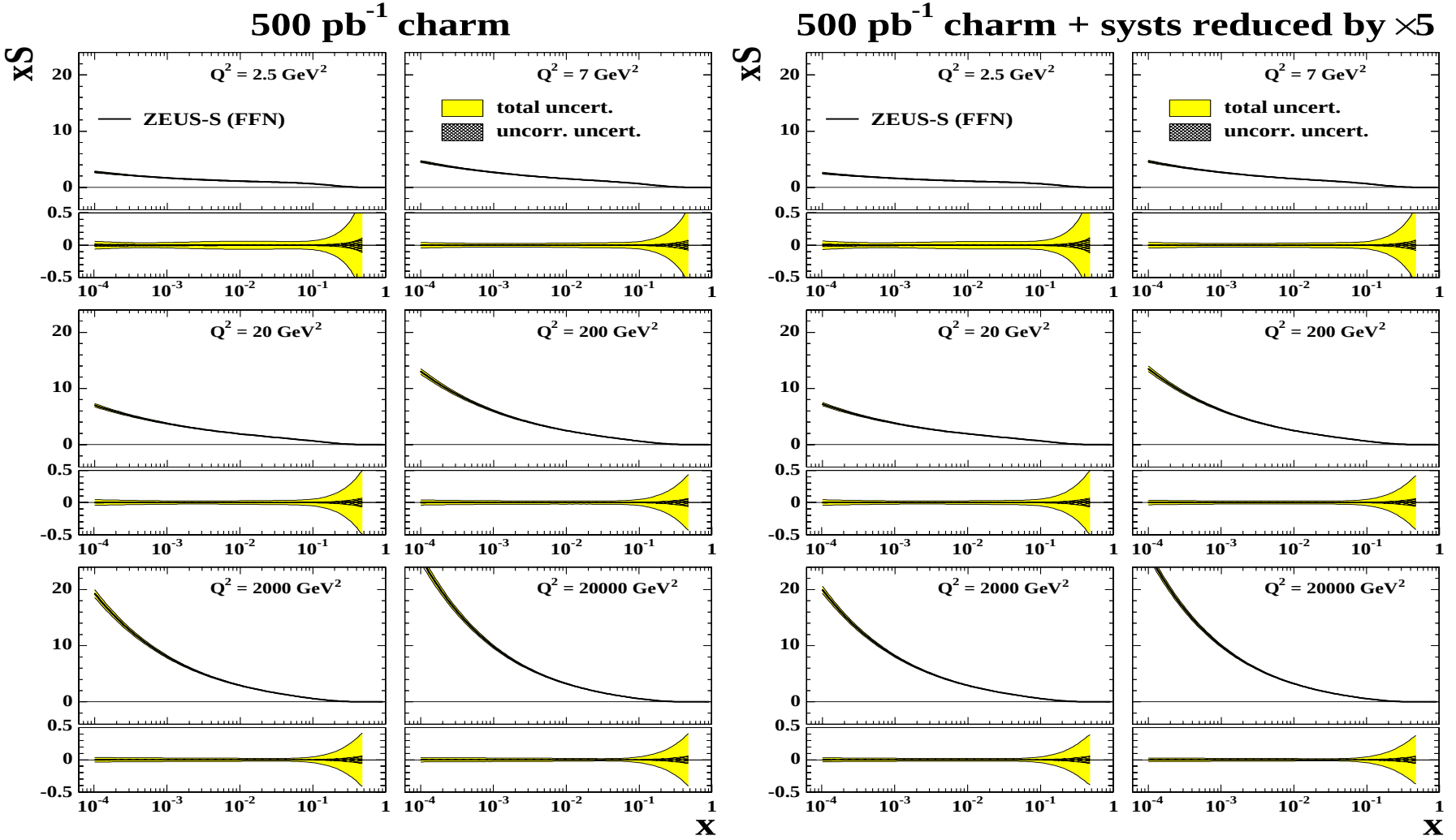
Charm: impact on sea quark distribution



- Little visible impact

Charm: Improve systematics x5



- Little visible impact