Proton PDFs at the LHeC and FCC-eh

LAL Orsay 2018

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Description of data

LHeC Data

Data simulated by Max Klein, full description available:
http://hep.ph.liv.ac.uk/~mklein/lhecdata/

E_e/GeV	E_p/TeV	e Charge	e Polarisation	Luminosity/fb^{-1}
60	1	-1	0	100
60	7	+1	0	100
60	7	-1	0.8	300
60	7	-1	-0.8	1000

All datasets include neutral current (NC) and charged current (CC) interactions.
Also testing data with 1/10 luminosity → constraints on PDFs after just one year of running. This data does not include low energy set.

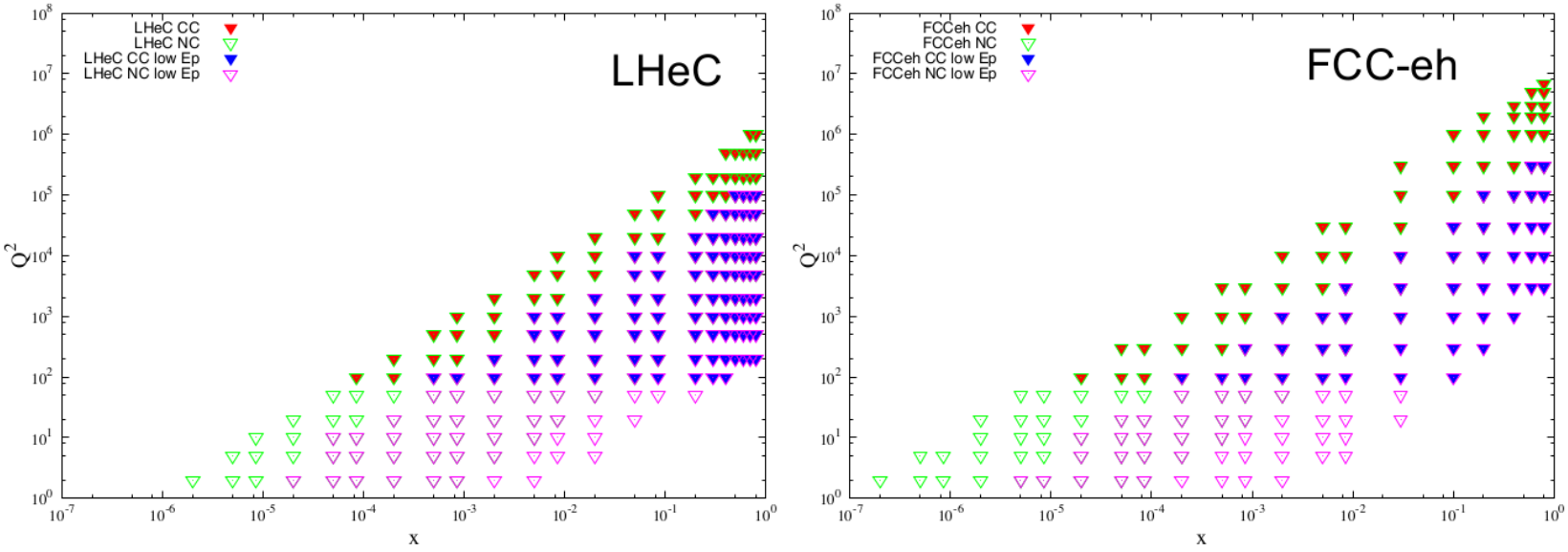
FCC Data

Data simulated by Max Klein, full description available: http://hep.ph.liv.ac.uk/~mklein/fccdata/

E_e/GeV	E_p/TeV	e Charge	e Polarisation	Luminosity/fb^{-1}
20	7	-1	0	100
60	50	+1	0	100
60	50	-1	0.8	300
60	50	-1	-0.8	1000

All datasets include neutral current (NC) and charged current (CC) interactions.

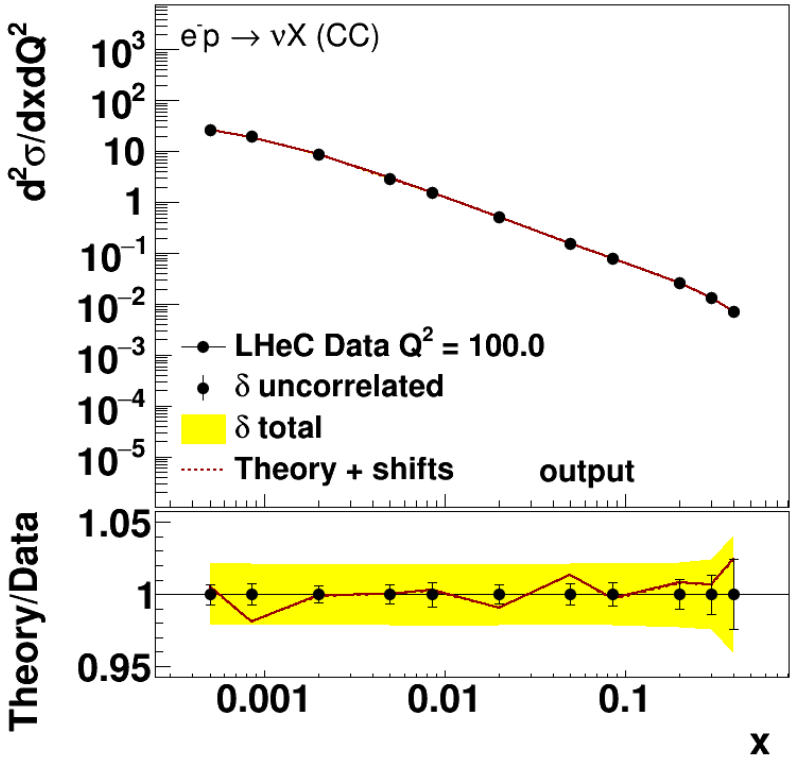
Kinematic plane



LHeC data to $x = 10^{-6}$
FCC data to $x = 10^{-7}$
LHeC higher concentration at high-x.

LHeC data

- Data provided to LO in pQCD - what we're really interested in is error.
- Provided data shifted to HERA PDF theory line (error retained as a percentage).
- Data then perturbed randomly (gaussian dist.).



Framework

Version 2.0.0 “Frozen Frog”

HERAPDF parameterisation ansatz used:

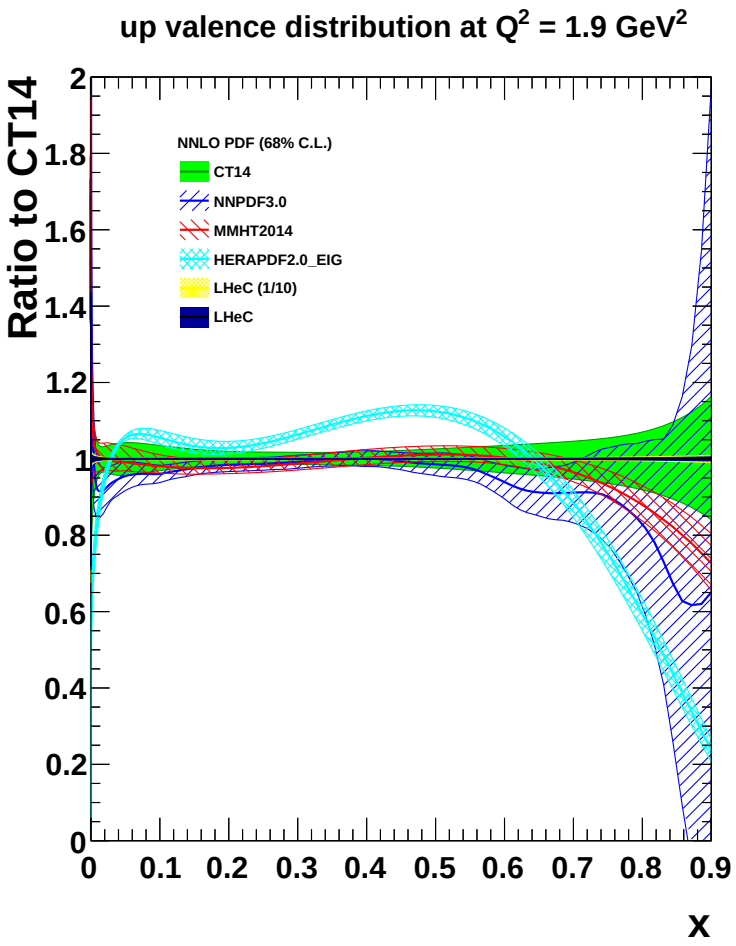
$$xq_i(x) = A_i x^{B_i}(1-x)^{C_i} P_i^{(n)}(x)$$

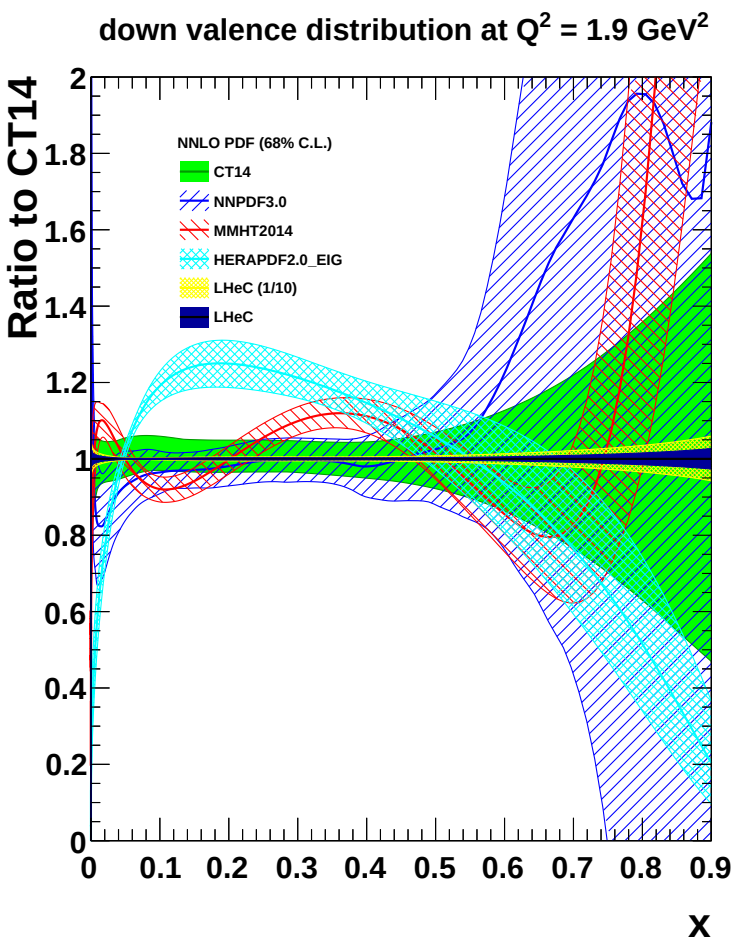
Primed gluon terms removed from fit.

PDFs

LHeC Global Comparison

PDF results compared to status today.

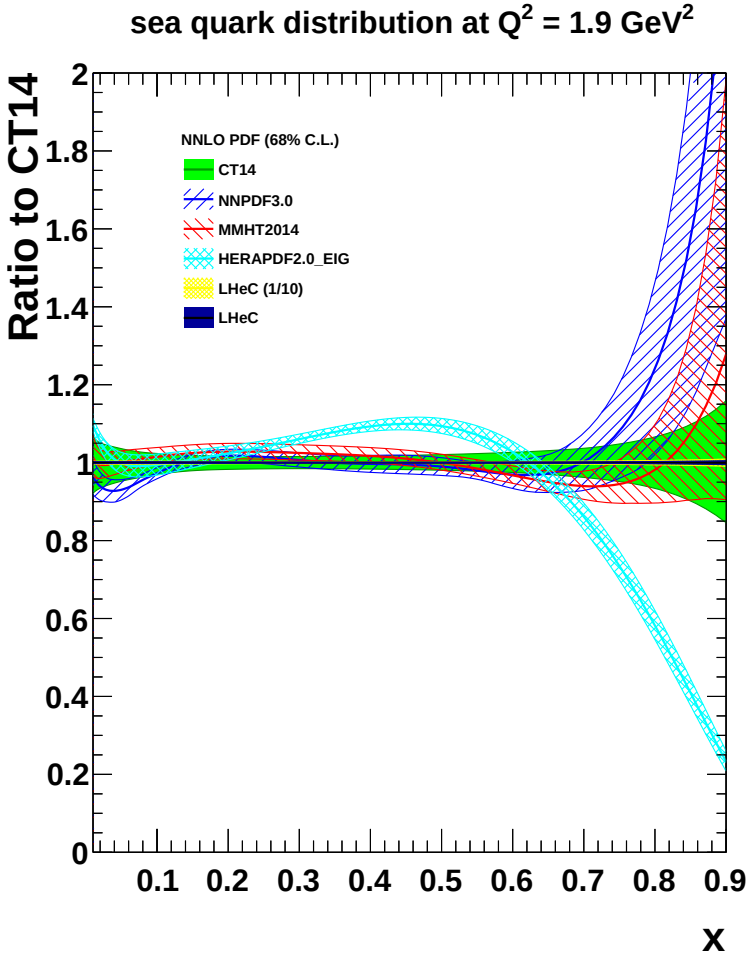




Valence quark ratios at full and 10% luminosity.

LHeC Global Comparison

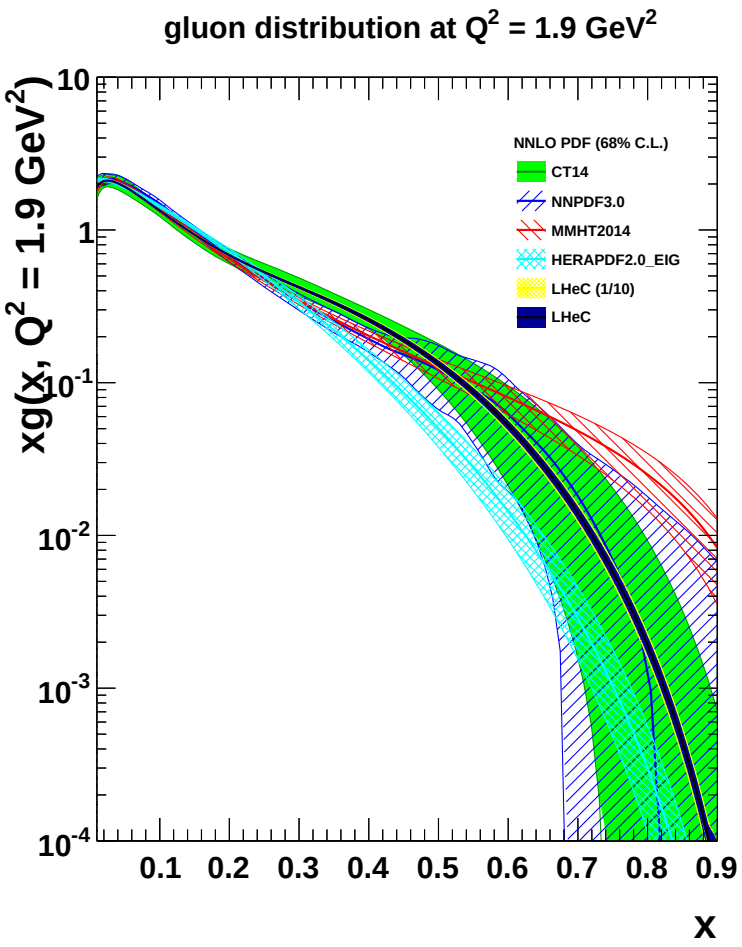
PDF results compared to status today.

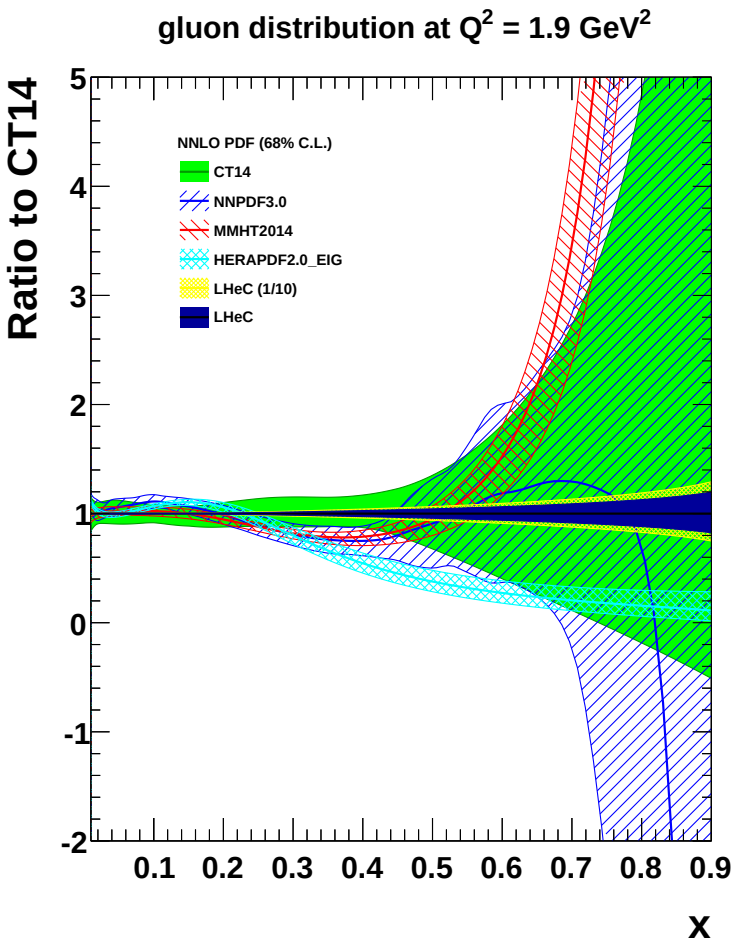


Sea ratios at full and 10% luminosity.

LHeC Global Comparison

PDF results compared to status today.

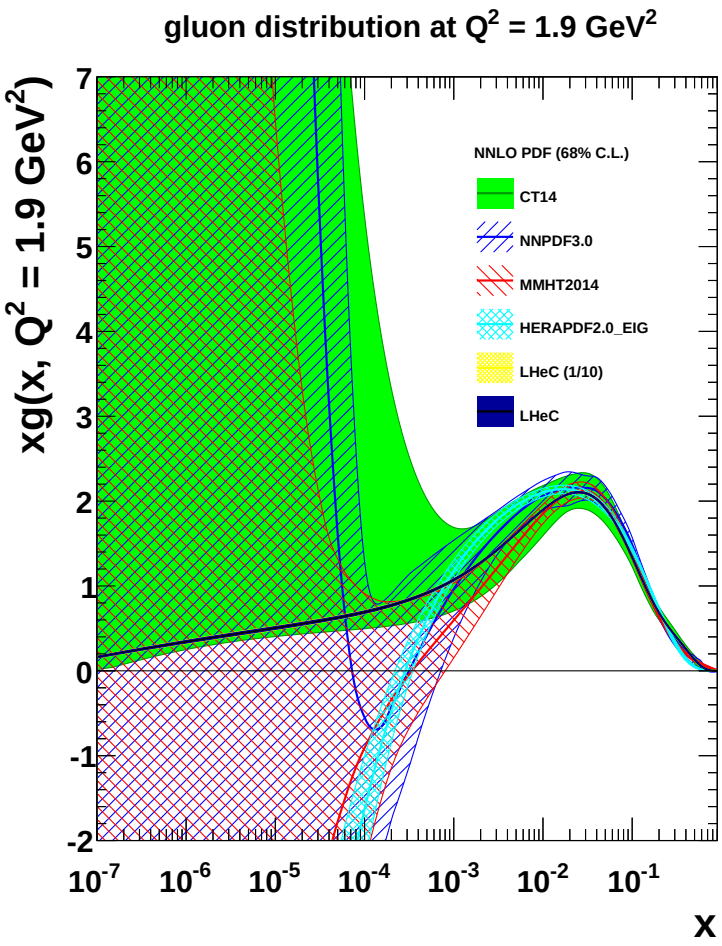


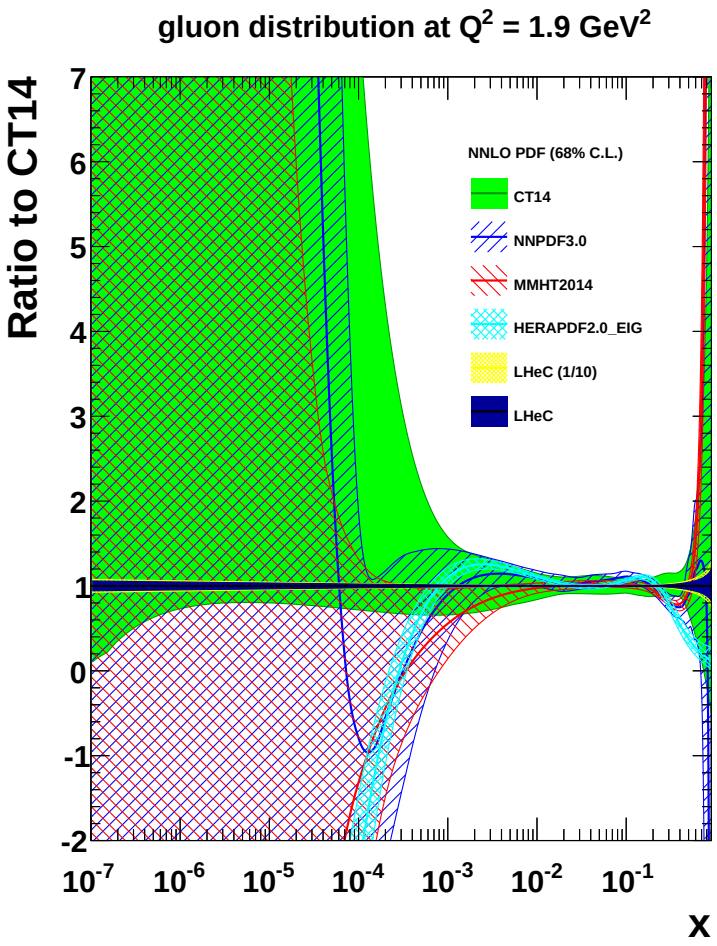


Gluon linear distributions.

LHeC Global Comparison

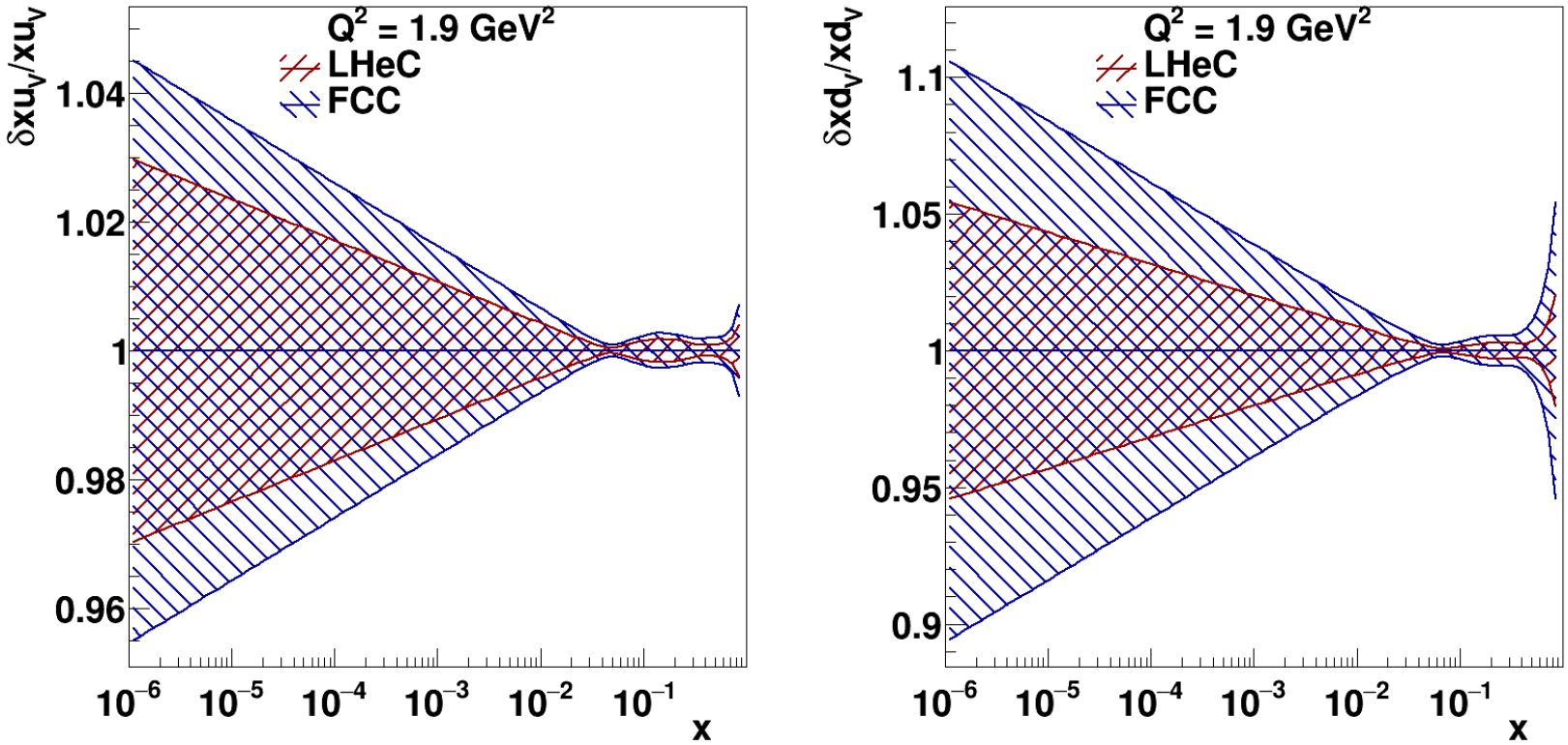
PDF results compared to status today.





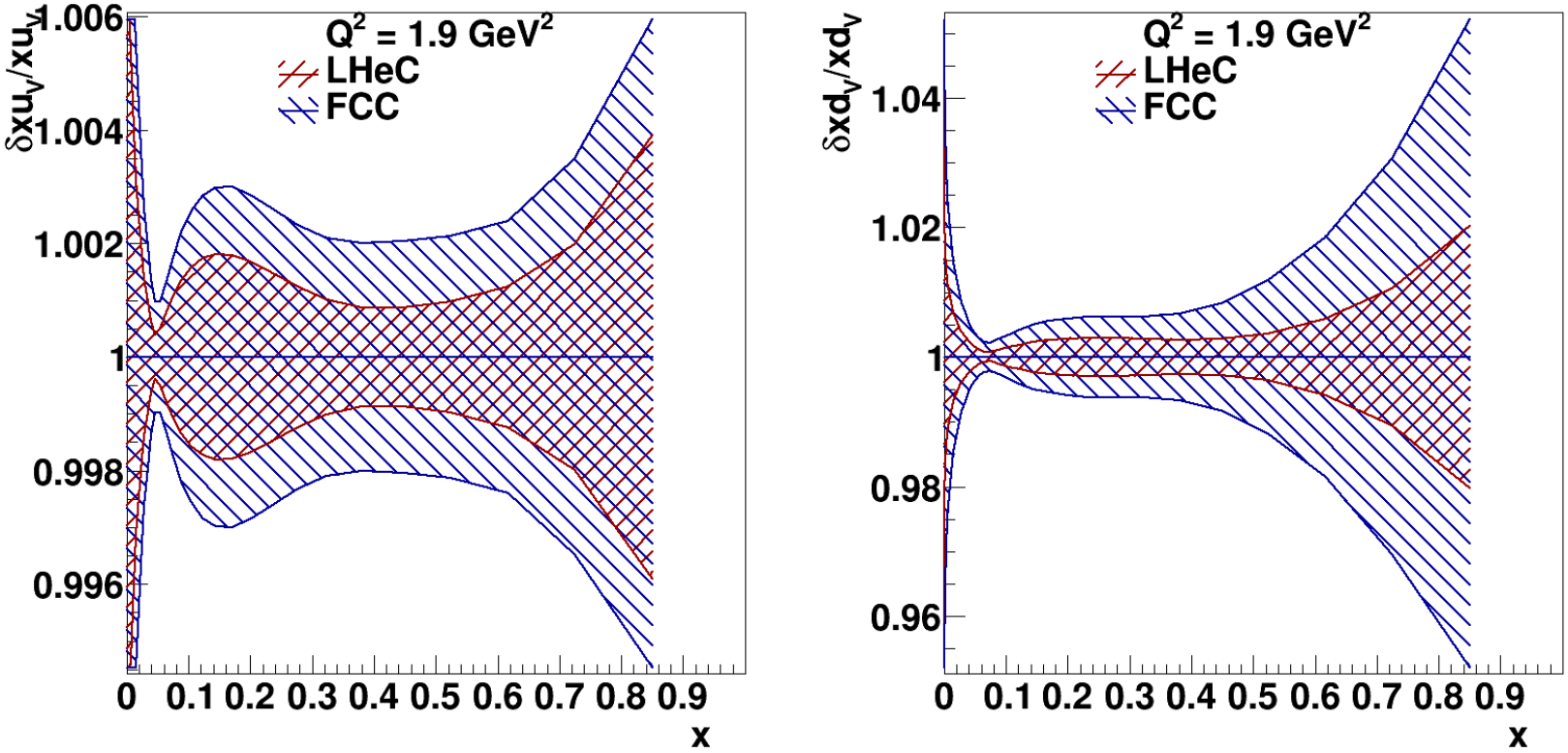
Gluon log-x distributions.

Direct comparison



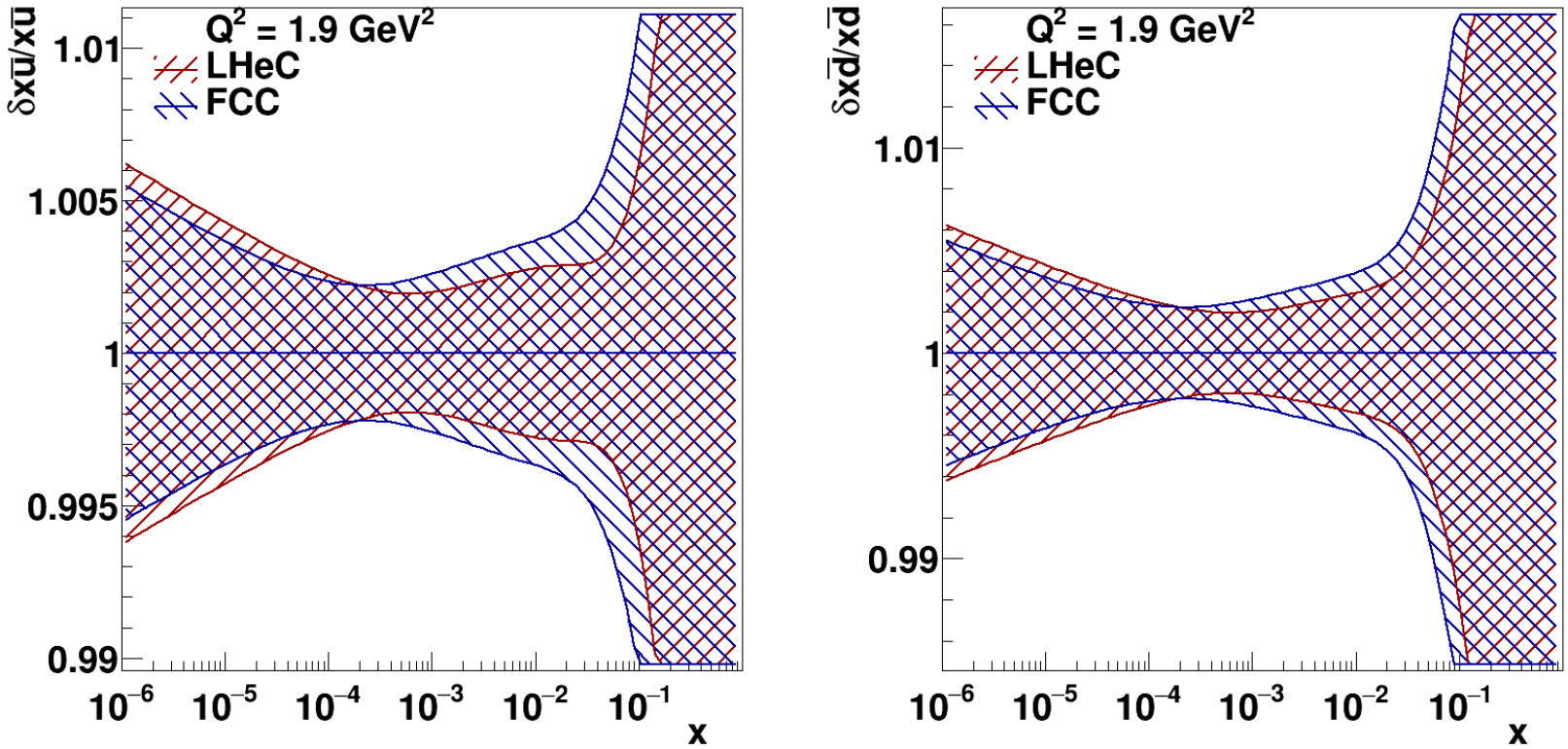
Valence distributions at low x.

Direct comparison



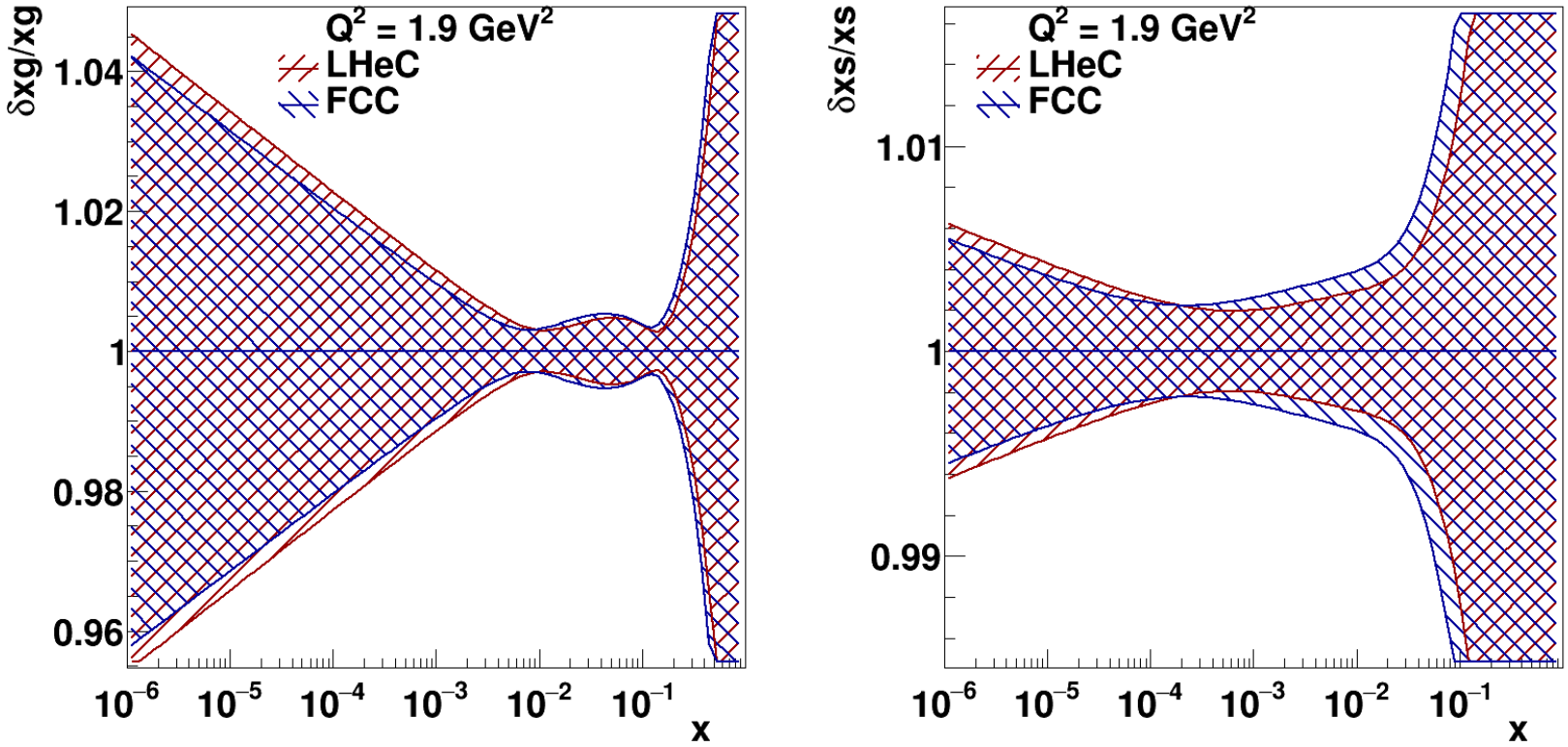
Valence distributions at high x.

Direct comparison



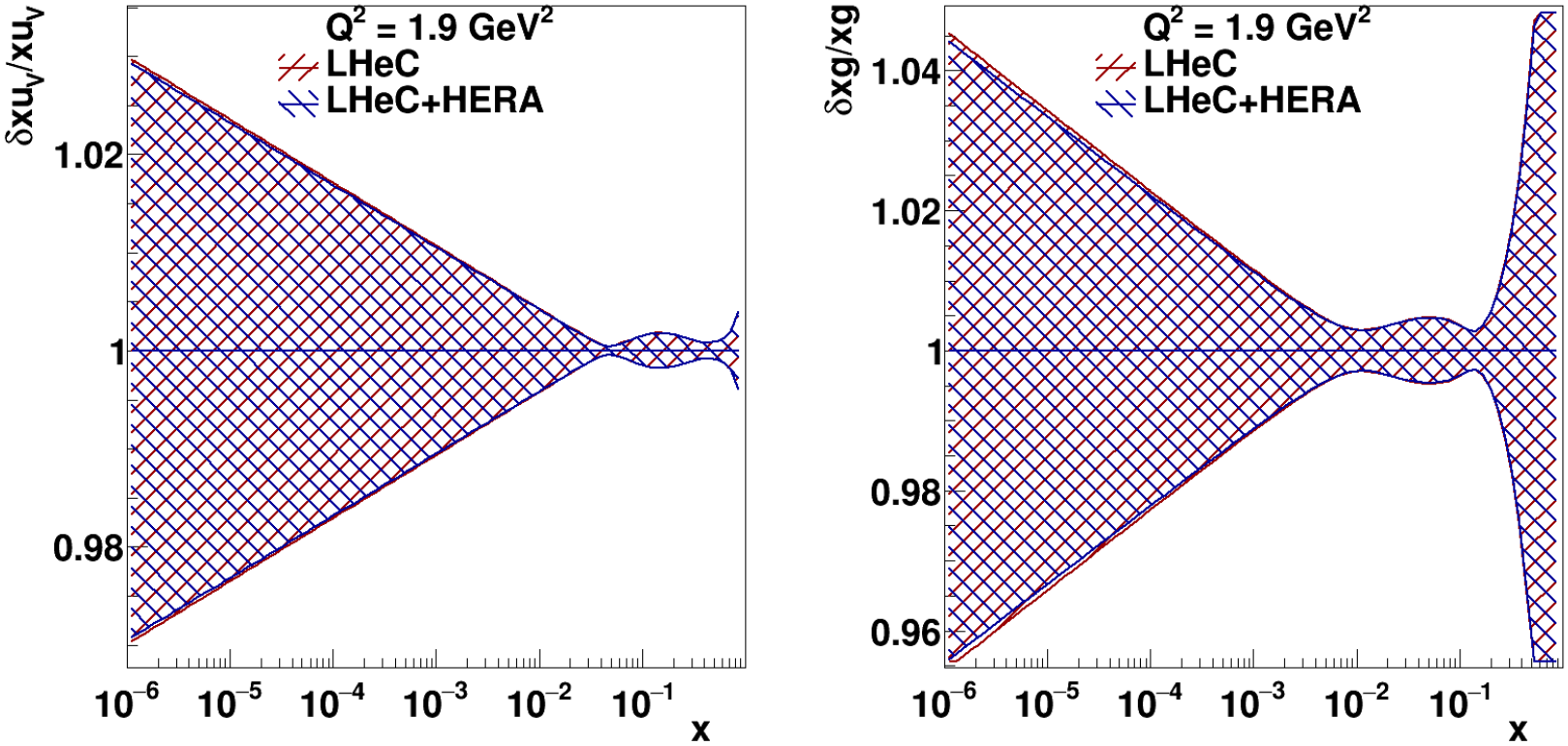
$\bar{u}$ and $\bar{d}$ distributions at low x.

Direct comparison



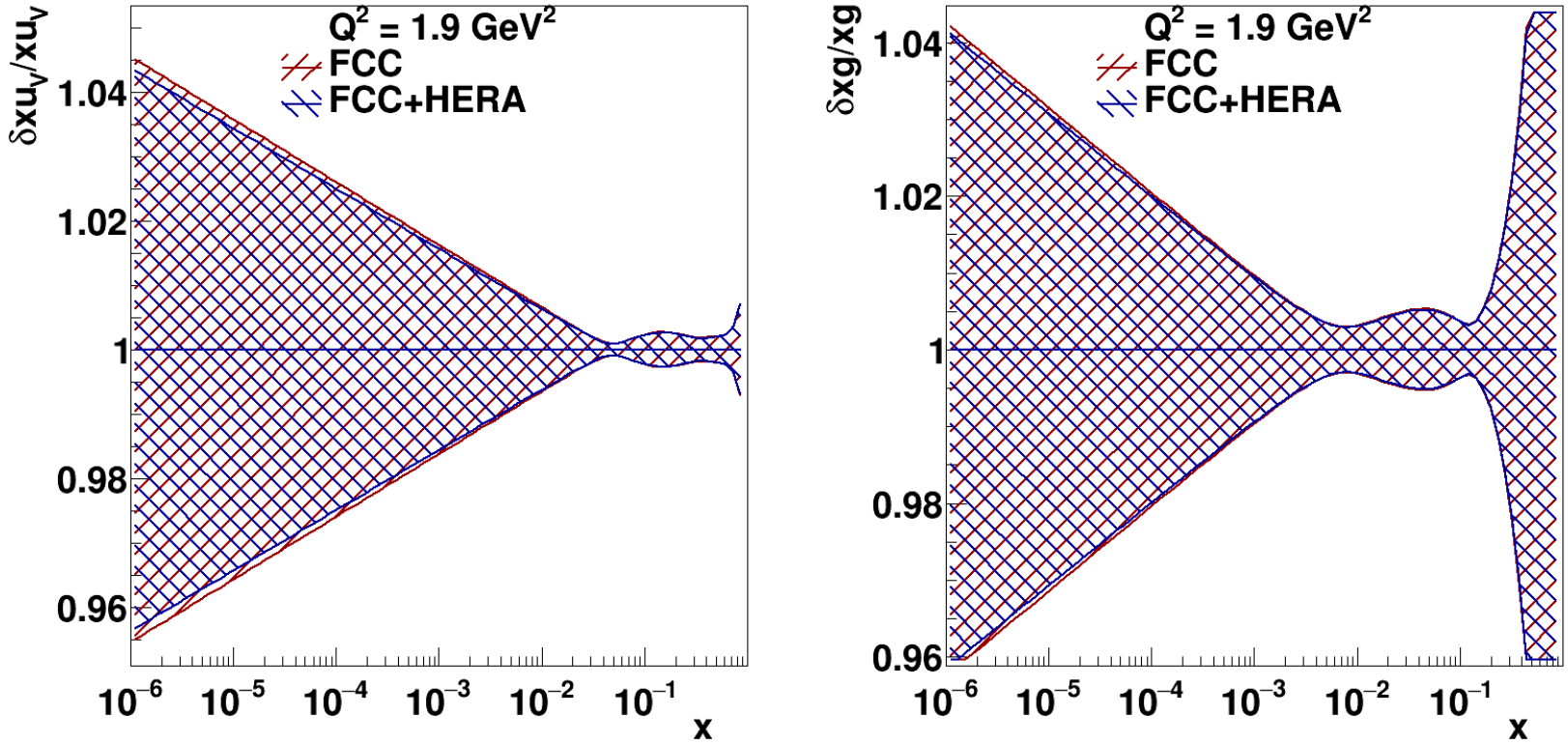
Gluon and strange distributions at low x.

Does HERA make a difference any more?



LHeC with and without HERA DIS data.

Does HERA make a difference any more?



FCC with and without HERA DIS data.

Initial fit summary/discussion

- Sea and gluon: LHeC performs better at high-x, FCC at low-x.
  - Both data sets have the same luminosity.
  - When FCC probes lower x (higher COM), it is balanced by a loss at high-x.
- Valence: LHeC performs better at all x.
  - Same argument as above.
  - Valence quarks dominated by high-x.
- HERA DIS data makes minimal difference.
- Most LHeC constraining power comes from first 10% of data.
  - Study dominated by systematics.

Relaxing constraints

$$xu_v = A_{u_v} x^{B_{u_v}} (1-x)^{C_{u_v}}$$

$$xd_v = A_{d_v} x^{B_{d_v}} (1-x)^{C_{d_v}}$$

$$x\bar{u} = A_{\bar{u}} x^{B_{\bar{u}}} (1-x)^{C_{\bar{u}}} (1 + D_{\bar{u}} x)$$

$$x\bar{d} = A_{\bar{d}} x^{B_{\bar{d}}} (1-x)^{C_{\bar{d}}}$$

$$xg = A_g x^{B_g} (1-x)^{C_g}$$

$$x\bar{s} = A_{\bar{s}} x^{B_{\bar{s}}} (1-x)^{C_{\bar{s}}}$$

With constraints:

$A_{\bar{u}} = A_{\bar{d}}$

$B_{\bar{s}} = B_{\bar{d}} = B_{\bar{u}}$

which ensure $\bar{u} = \bar{d}$ as $x \to 0$.

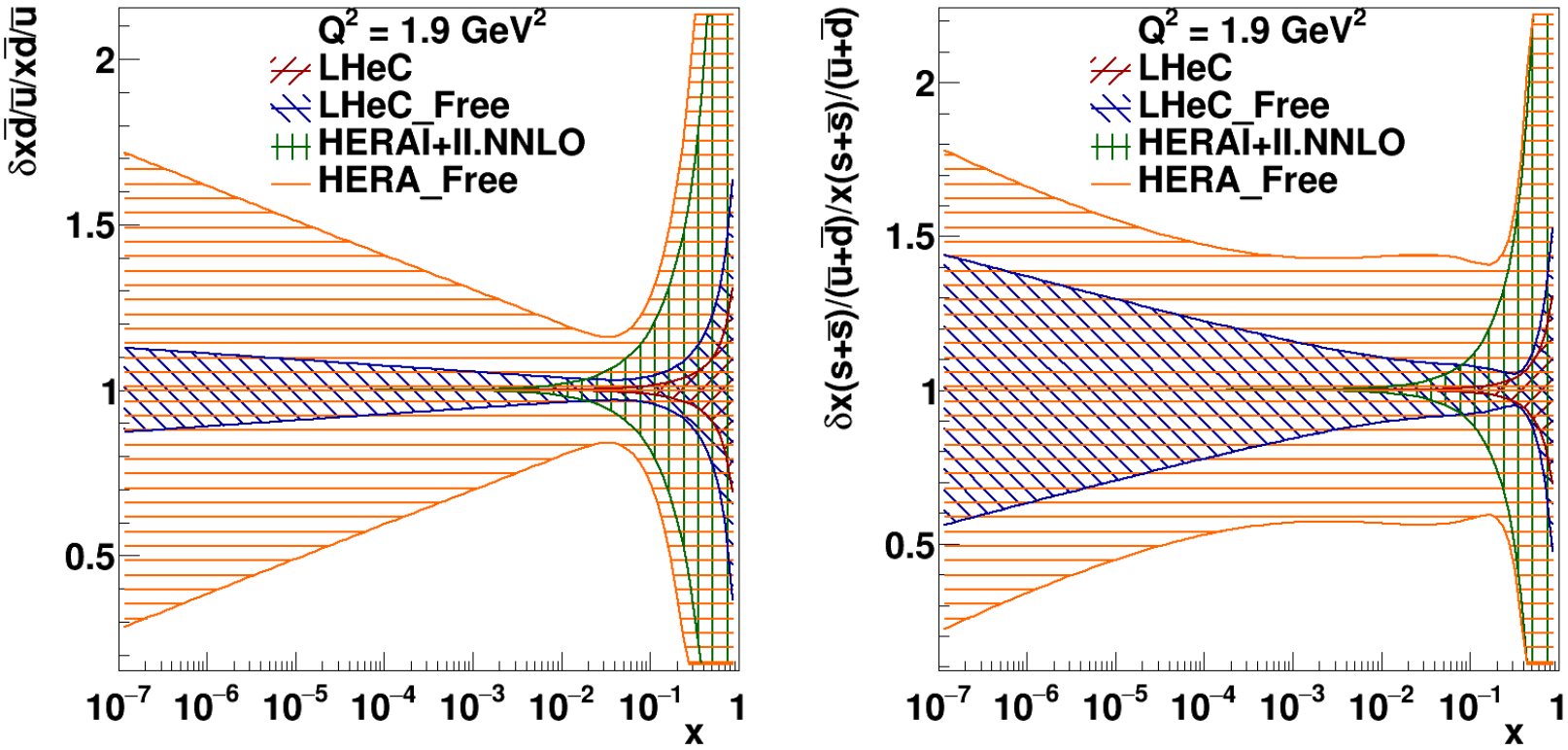
A_g (momentum sum rule)

A_{u_v}, A_{d_v} (number sum rule)

$f_s = (s + \bar{s})/(\bar{u} + \bar{d}) = 0.4$

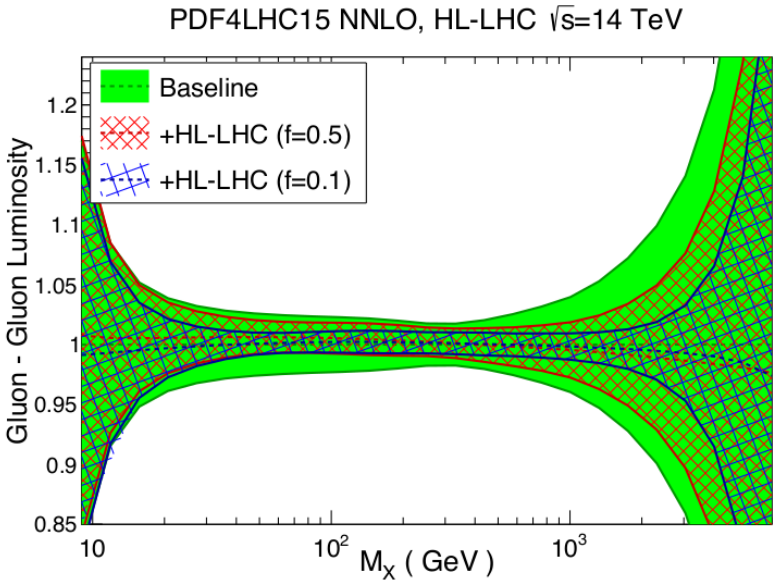
Relaxing sea constraints

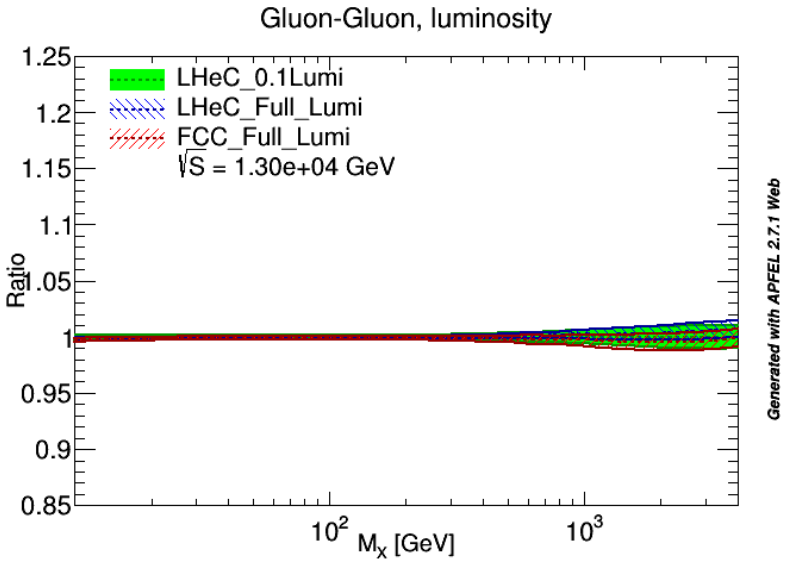
Free parameters $A_{\bar{u}}, B_{\bar{u}}, B_{\bar{d}}, B_{\bar{s}}, f_s$.



$\bar{d}$ and $\bar{u}$; strange quark.

Comparison to full HL-LHC PDF fit

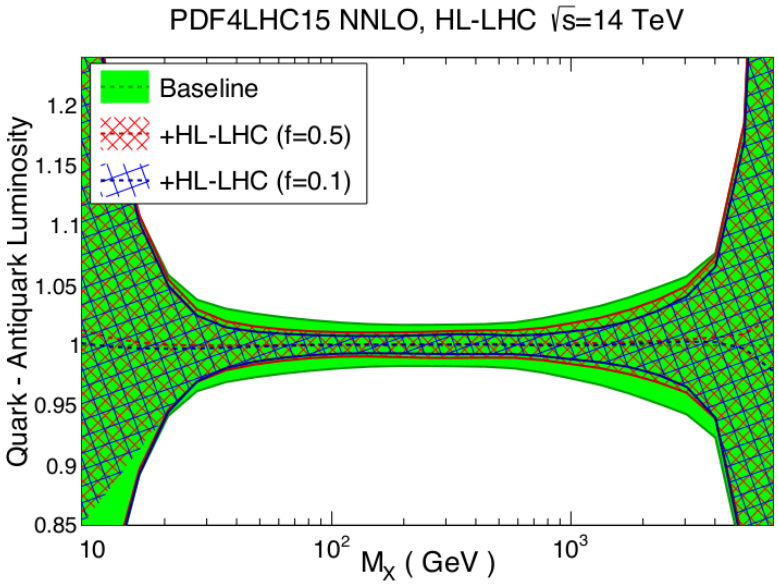


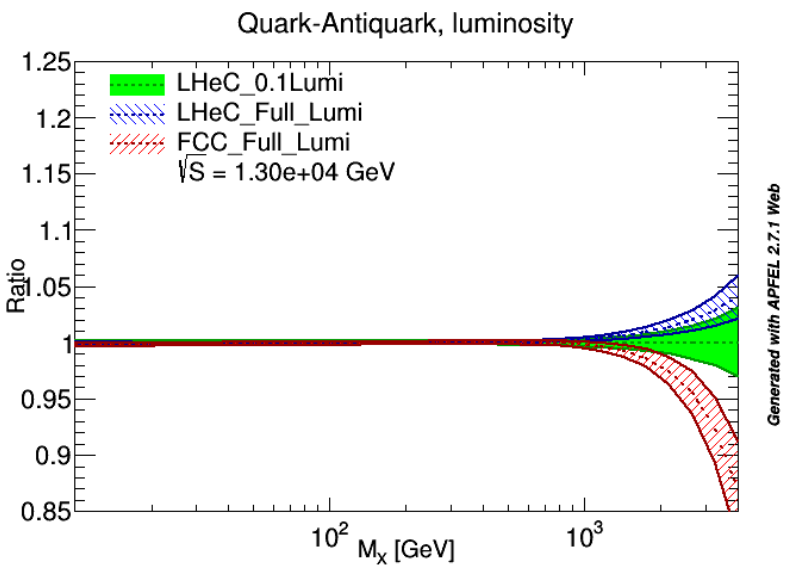


Preliminary results.

HL-LHC plots: Lucian Harland-Lang, HL-LHC workshop, CERN, June 2018

Comparison to full HL-LHC PDF fit



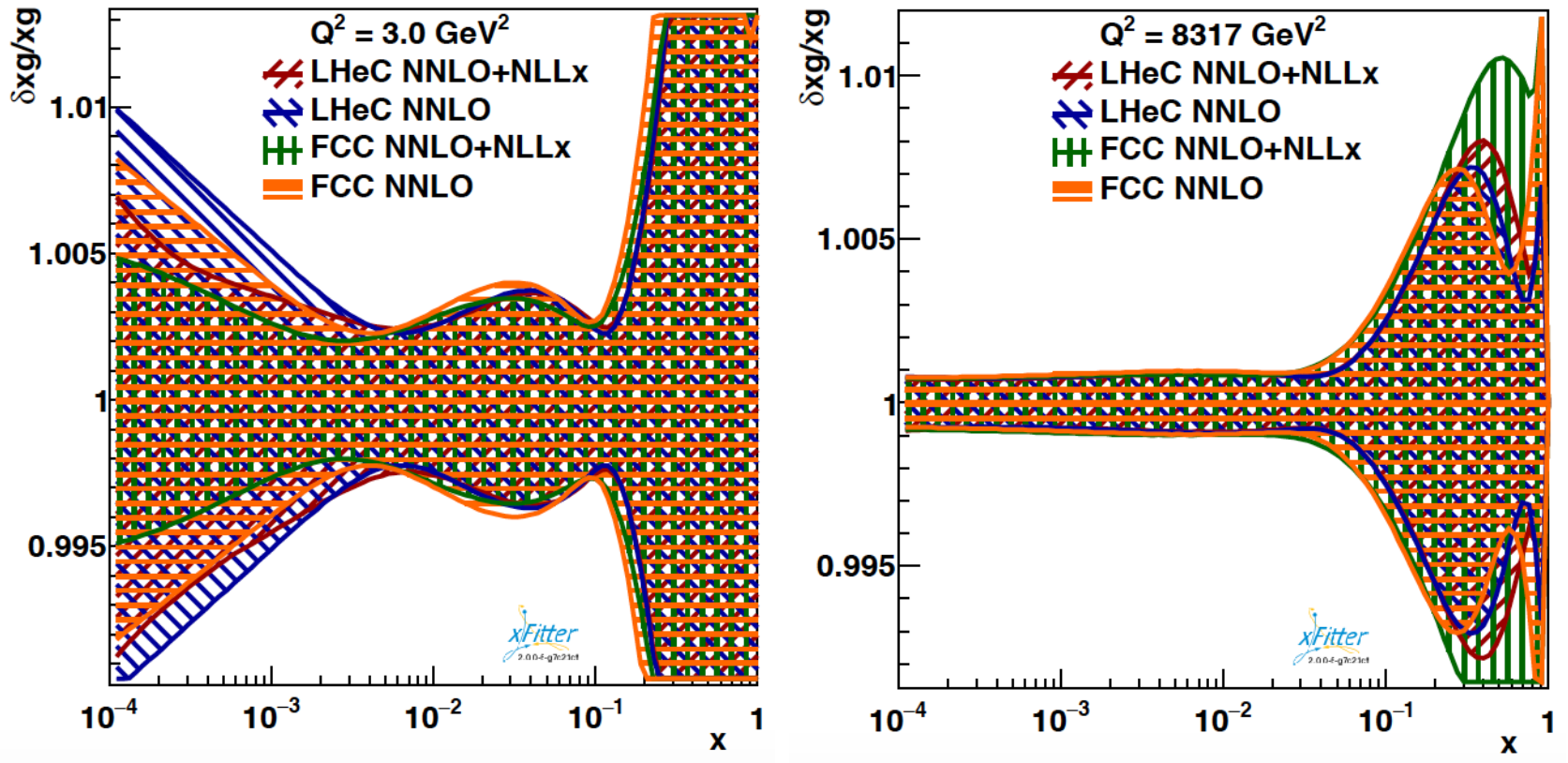


Preliminary results.

HL-LHC plots: Lucian Harland-Lang, HL-LHC workshop, CERN, June 2018

Low-x resummation

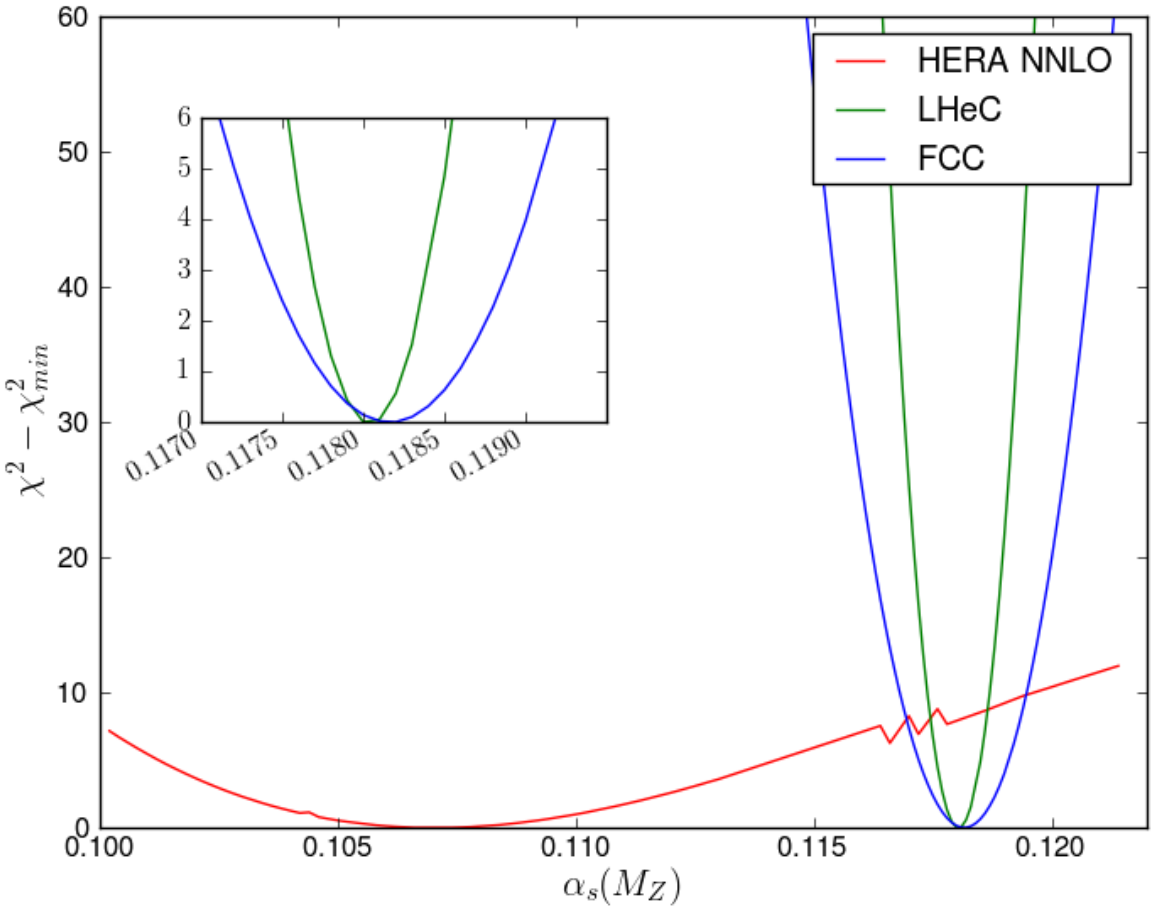
Still a work in progress...



Credit: Francesco Giuli (University of Oxford)

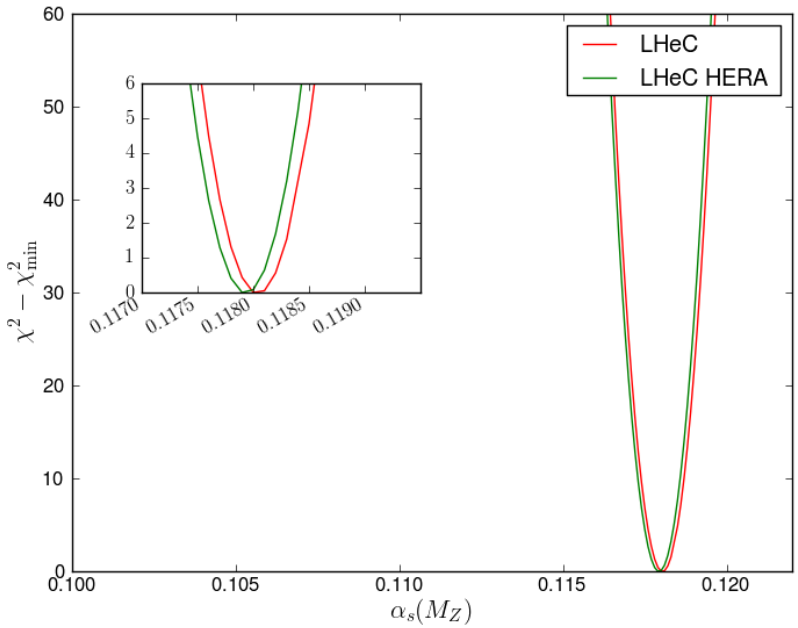
α_s studies

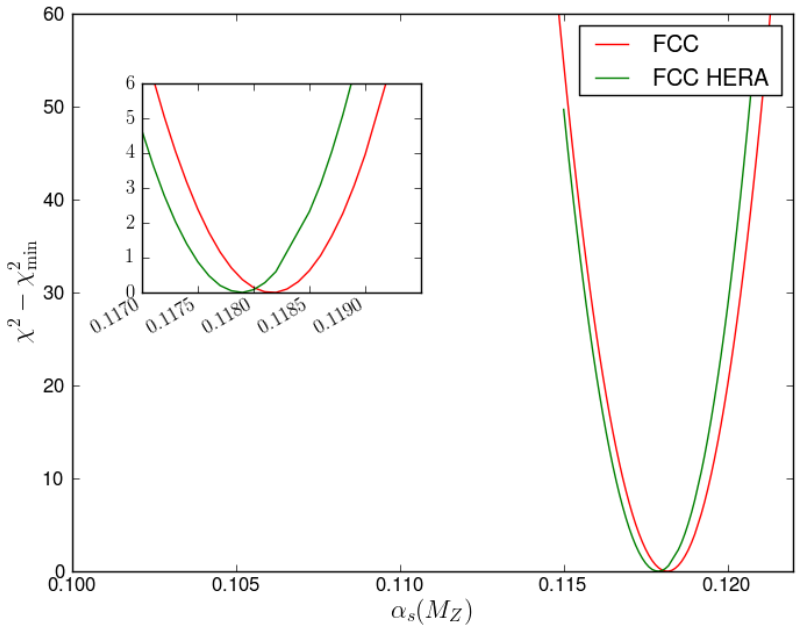
α_s scan



LHeC precision: 0.2%
FCC precision: 0.5%

What if HERA is added?





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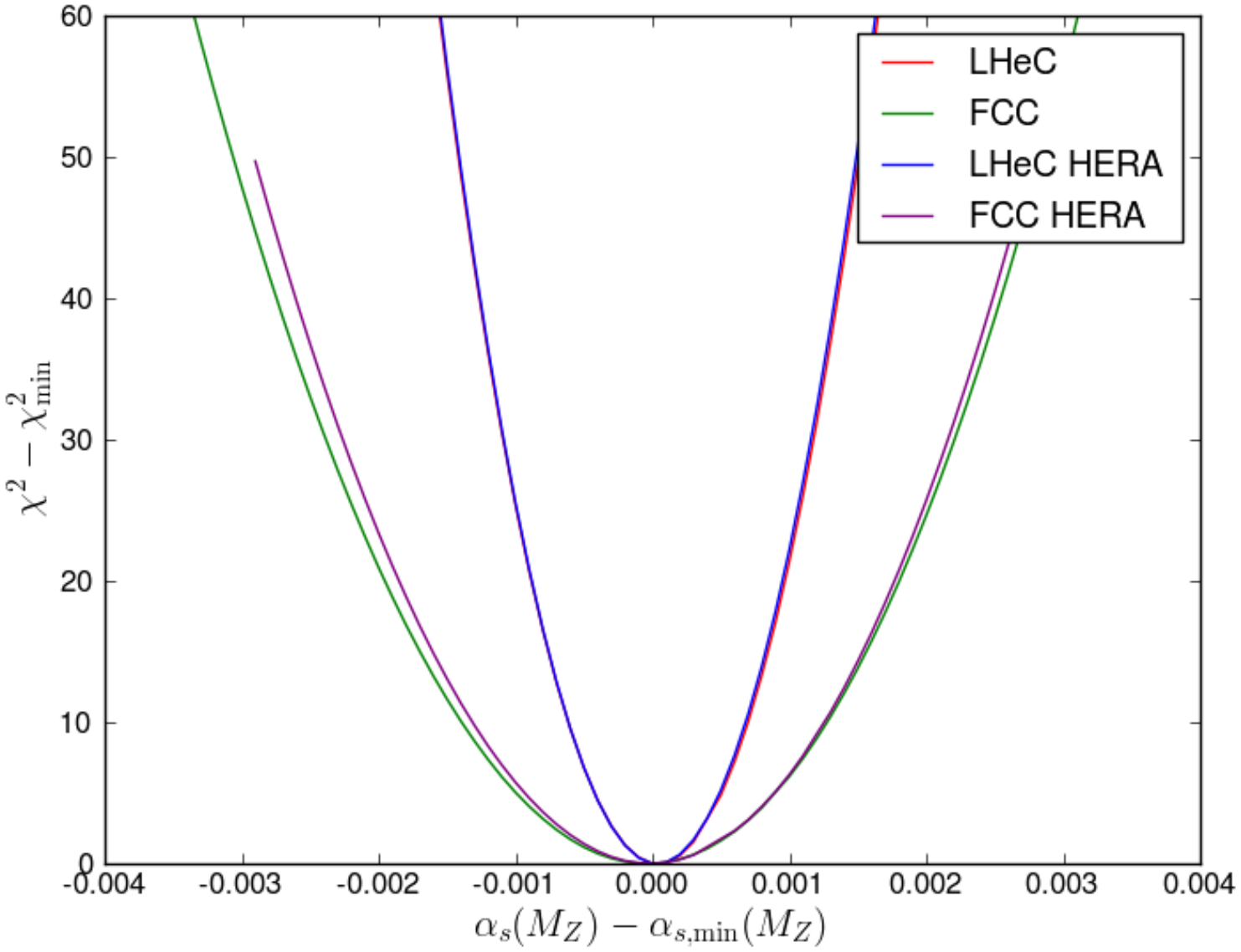
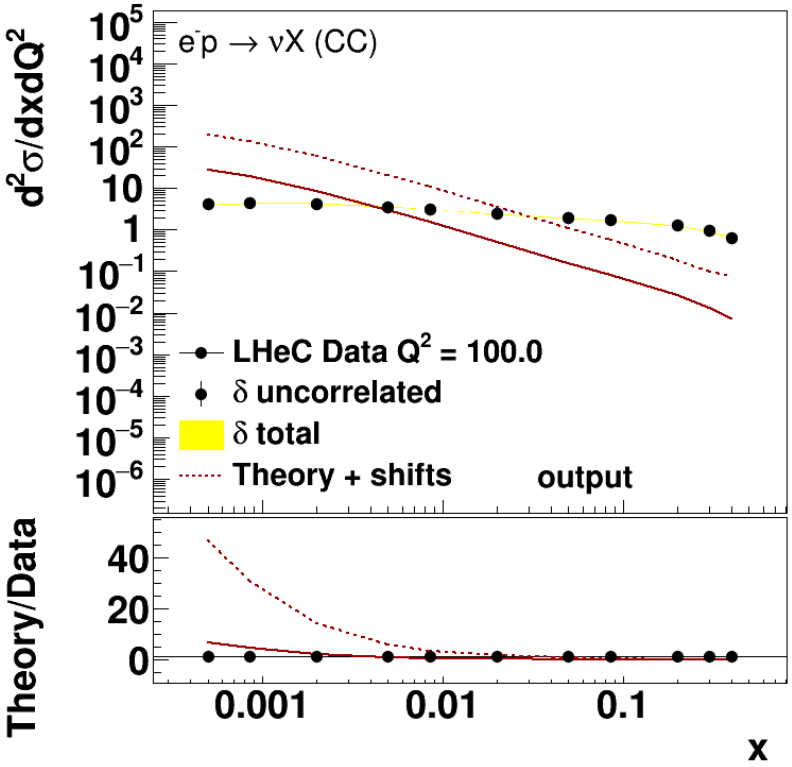


Backups

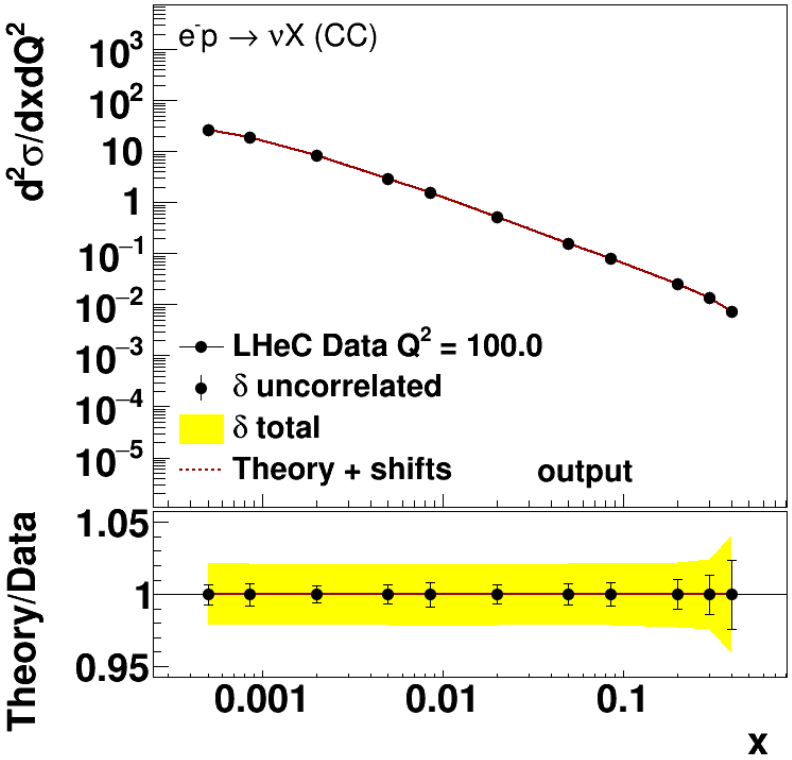
LHeC data

- Data provided to LO in pQCD - what we're really interested in is error.



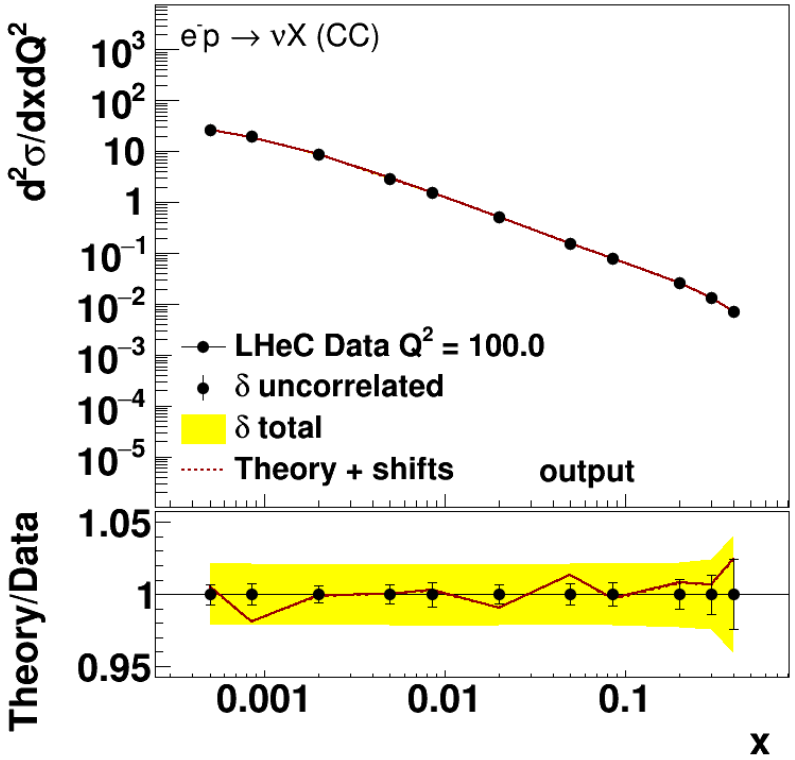
LHeC data

- Data provided to LO in pQCD - what we're really interested in is error.
- Provided data shifted to HERA PDF theory line (error retained as a percentage).

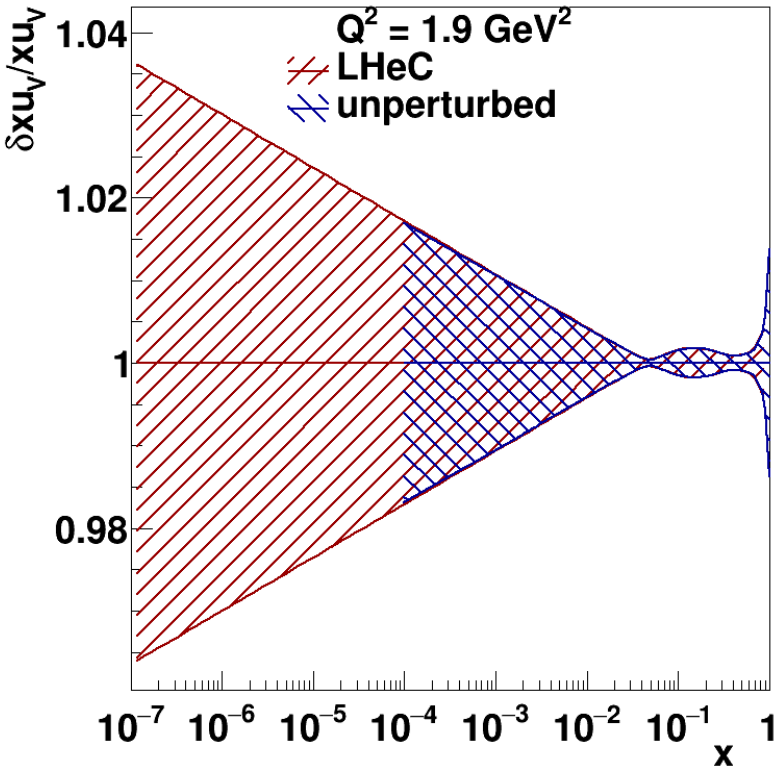


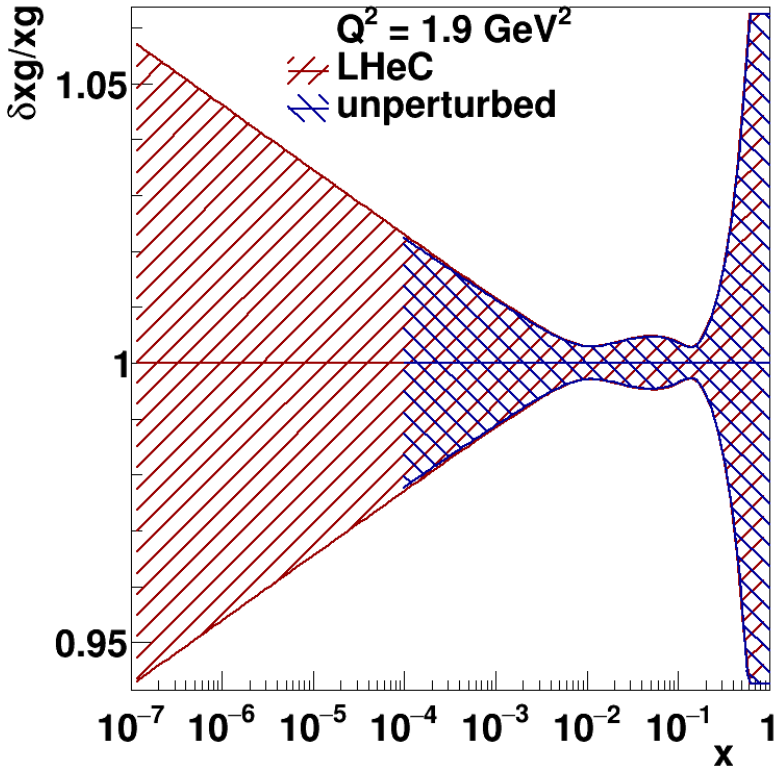
LHeC data

- Data provided to LO in pQCD - what we're really interested in is error.
- Provided data shifted to HERA PDF theory line (error retained as a percentage).
- Data then perturbed randomly (gaussian dist.).



Difference made by perturbing data points...



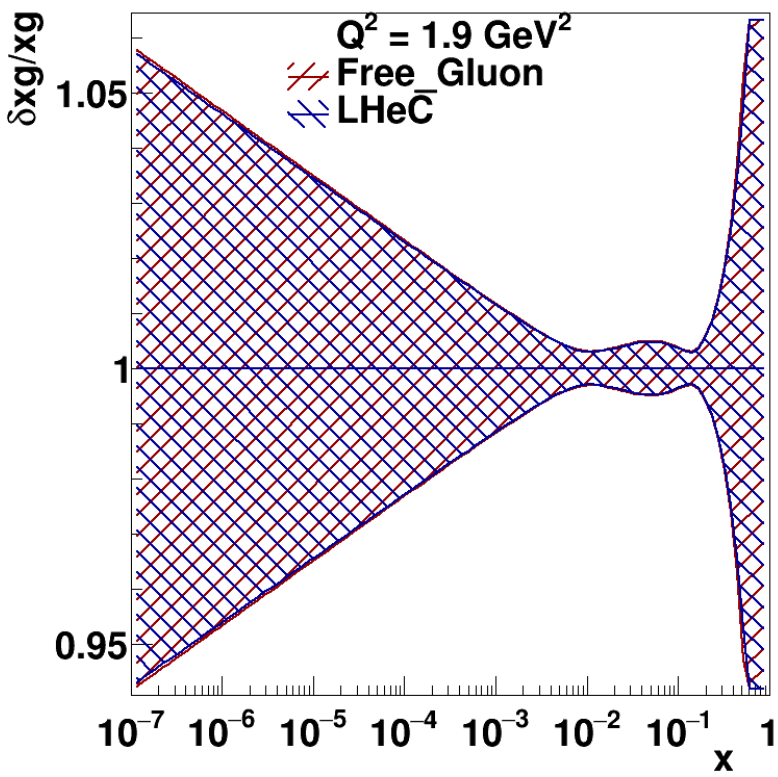


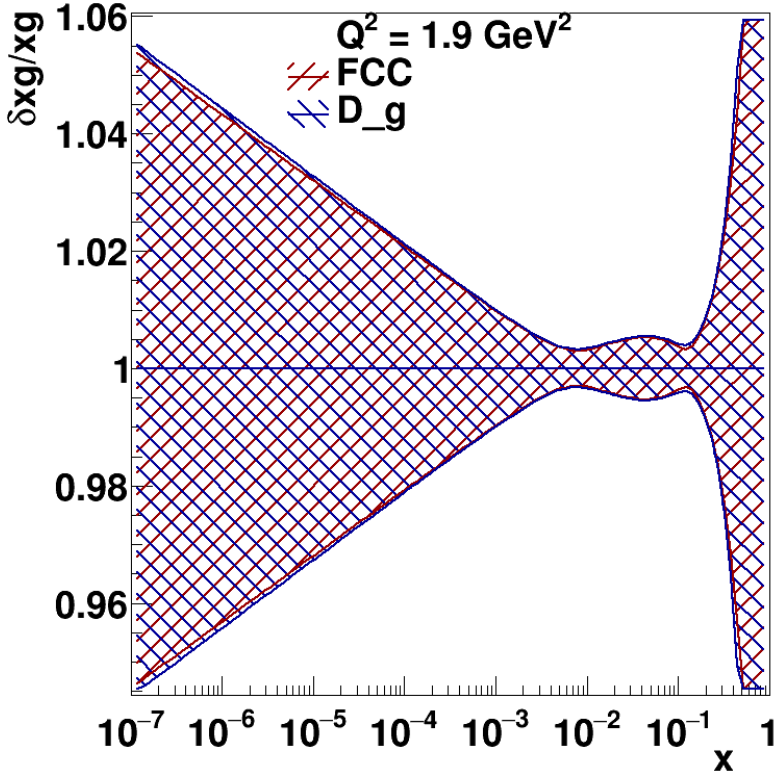
Very little.

Gluon constraints

$$xg(x) = A_g x^{B_g}(1-x)^{C_g} - \cancel{A'_g x^{B'_g}(1-x)^{C'_g}}$$

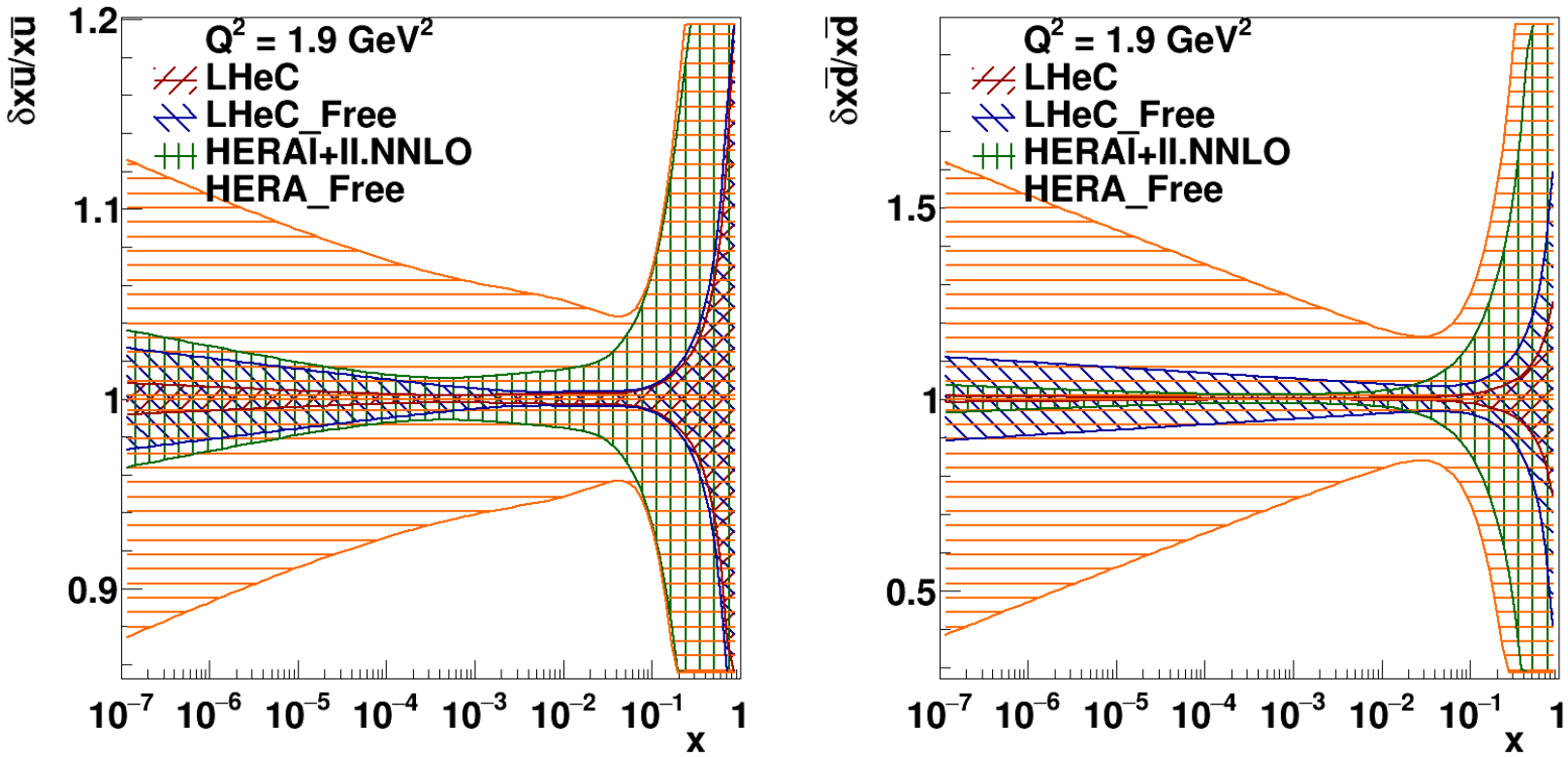
Add extra parameter D_g...





Relaxing sea quarks

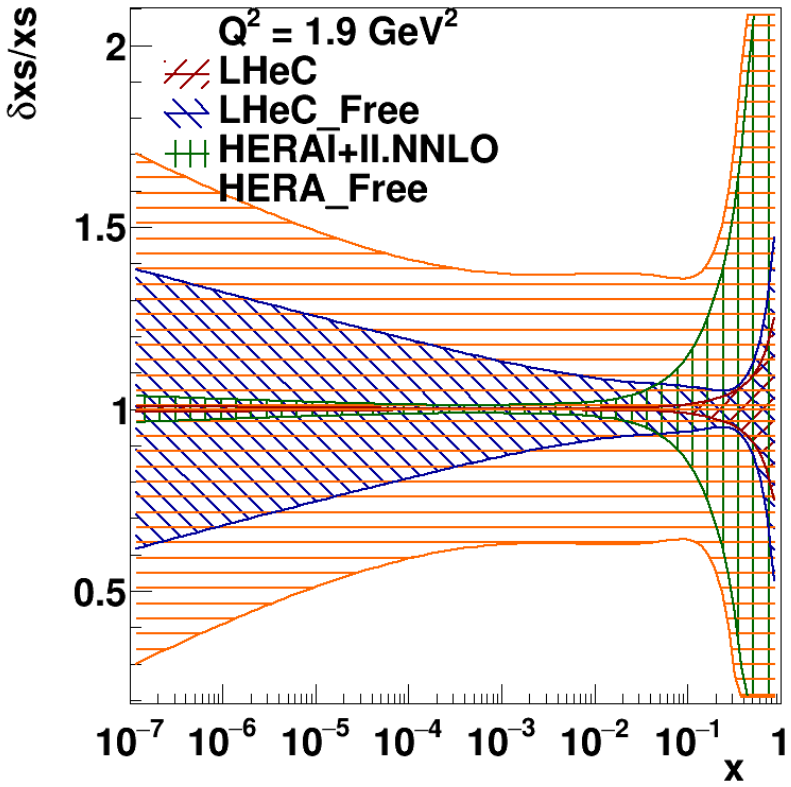
Free parameters $A_{\bar{u}}, B_{\bar{u}}, B_{\bar{d}}, B_{\bar{s}}, f_s$.



$\bar{u}$ better constrained by LHeC even with relaxed parameters.
$\bar{d}$ similar constraining power as previous HERA fit.

Relaxing sea quarks

Free parameters $A_{\bar{u}}, B_{\bar{u}}, B_{\bar{d}}, B_{\bar{s}}, f_s$.



Freeing all at once may be too brutal - more work to be done.