Unpolarized Proton PDFs constraint at EIC

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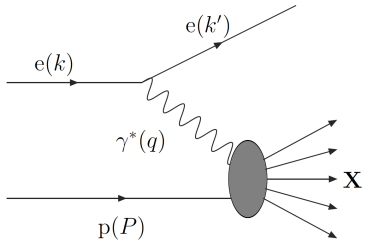
EIC Yellow Report meeting

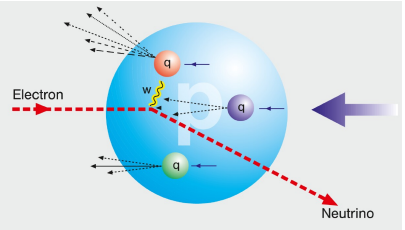
How to access partons in ep

Neutral Current: Preliminary results



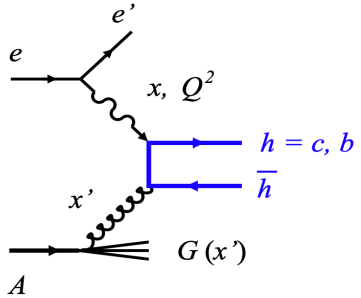
Detect scattered lepton, limited flavor separation

Charge Current: Preliminary results

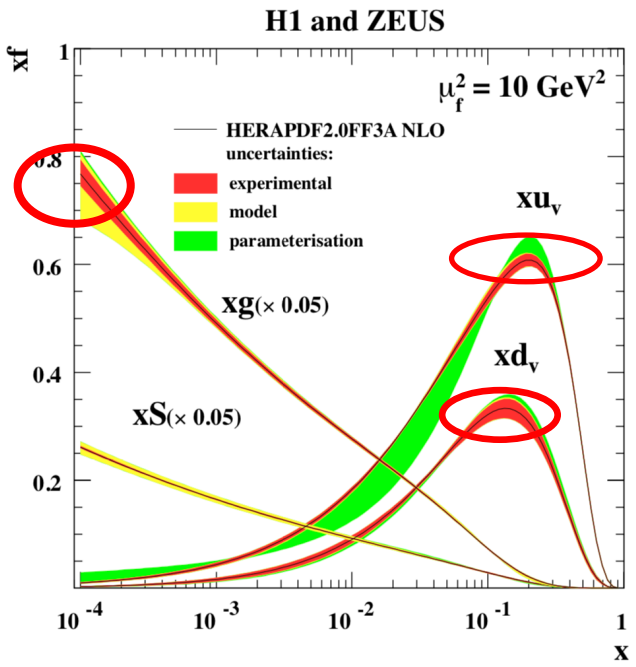


W-exchange: direct access to the quark flavor
Detector: large rapidity coverage and large √s range

Open Charm: Working on



Experimental identification of c through fragmentation into Kaons
Excellent sensitivity to gluons
Observables: Differential cross section, inclusive F^{cc}



If EIC data + HERA data

1) at low x by measuring NC events
2) at high x through CC events
3) especially through charm production process to probe gluon distributions, gaining of much higher Lumi?

Schematic of PDF fits

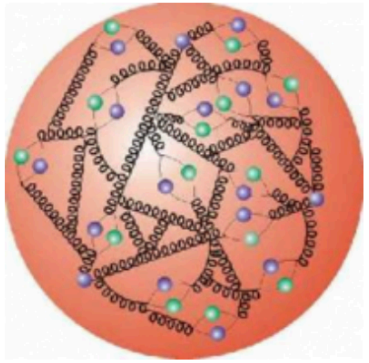
PDFs $\otimes$ Partonic cross section

$$\sigma_{pp\to X} = \sum_{i,j} \int dx_1 dx_2 \, f_i^p(x_1,\mu) f_j^p(x_2,\mu) \times \sigma_{i,j}$$

measure

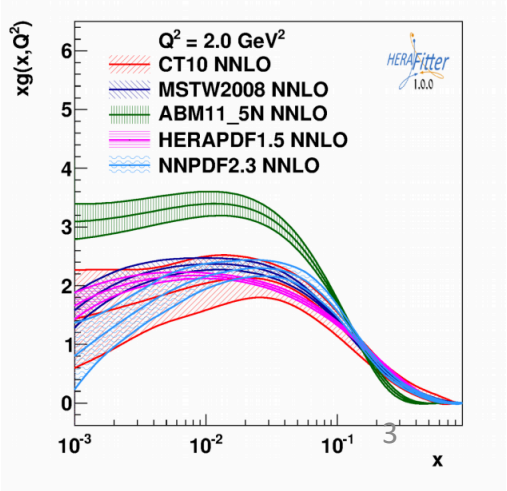
calculate

extract from data



Global fit is performed to extract Proton PDFs: xFitter

- xFitter provides a framework for investigation of various methodologies in PDF fits
- Assess the impact of new data on PDF



How xFitter works

Full fit
Projection

Input data

Cov Matrix, nuisance parameters

χ^2 test

Theory predictions

Partonic cross sections ⊗ **PDF evolved at all scales**

APPLGRID, FastNLO

QCDNUM

DGLAP evolution

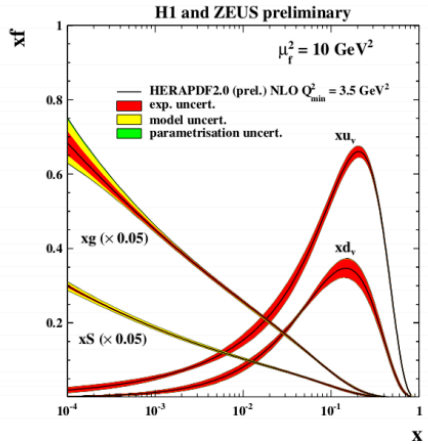
Minimisation (Fit) of the PDF parameters at the starting scale

PDF parametrisation at the starting scale ~ 1 GeV with ~ 20 free parameters

Q^2_0~ 1 GeV^2

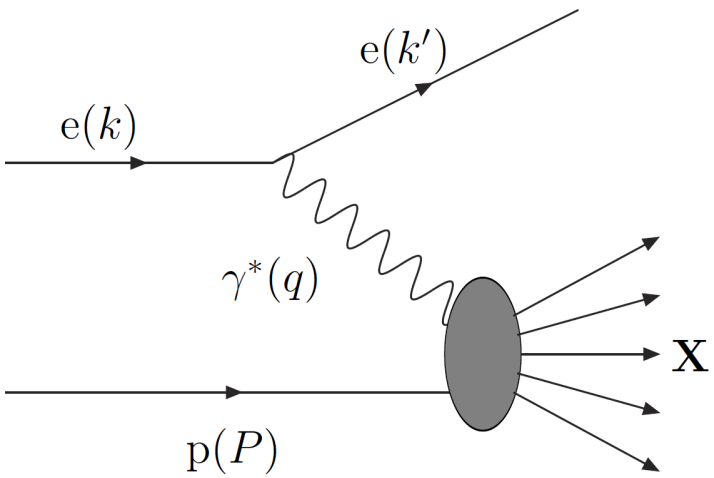
Various flexible parametrization forms:
HERAPDF

Result:
$f(x,Q^2)$
at all scales



Observables: NC and CC cross sections

NC



$$\sigma_{r,NC} = \frac{d^2\sigma_{NC}^{ep}}{dx_{Bj}dQ^2} \cdot \frac{Q^4 x_{Bj}}{2\pi\alpha^2[1+(1-y)^2]}$$

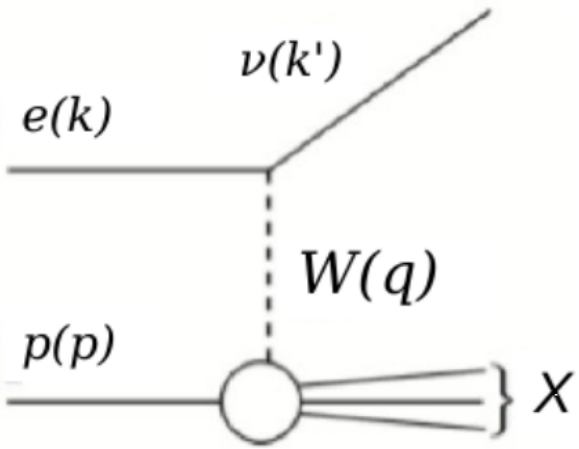
$$= F_2(x,Q^2) - f(y) \cdot F_L(x,Q^2)$$

α is the fine structure constant

$f(y) = y^2/[1+(1-y)^2]$

Q^2, x and y are reconstructed by the scattered electron

CC



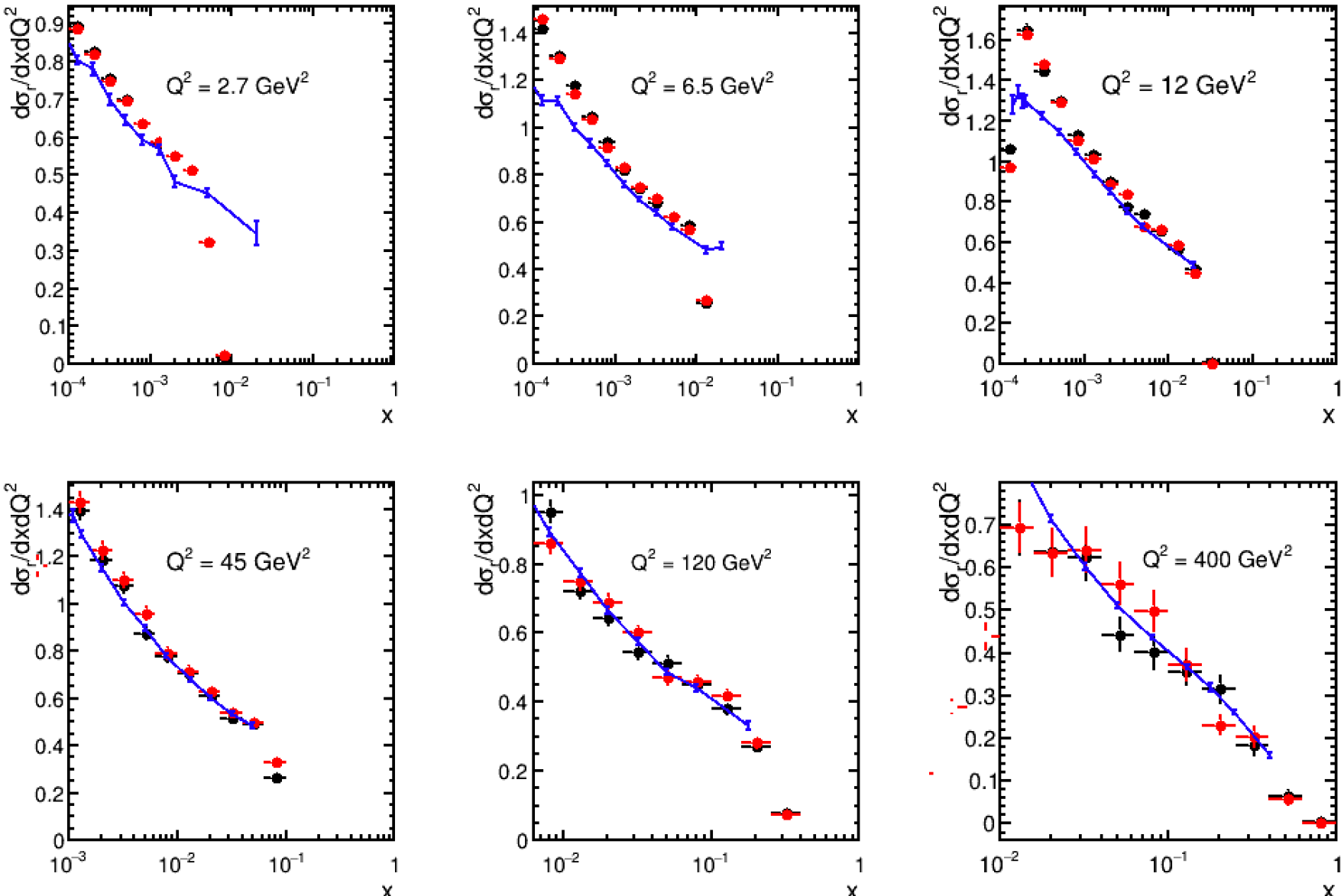
$$\sigma_{r,CC} = \frac{d^2\sigma_{CC}^{ep}}{dx_{Bj}dQ^2} \cdot \left[\frac{M_W^2+Q^2}{M_W^2}\right]^2 \cdot \frac{2\pi x_{Bj}}{G_F^2}$$

$G_F = 1.16 \times 10^{-5} GeV^2$ and $M_W = 80.385$ GeV

Q^2, x and y are reconstructed from the final hadronic system through Jacquet-Blondel method

Observable: NC

Reproduce HERA data by Pythia (1)



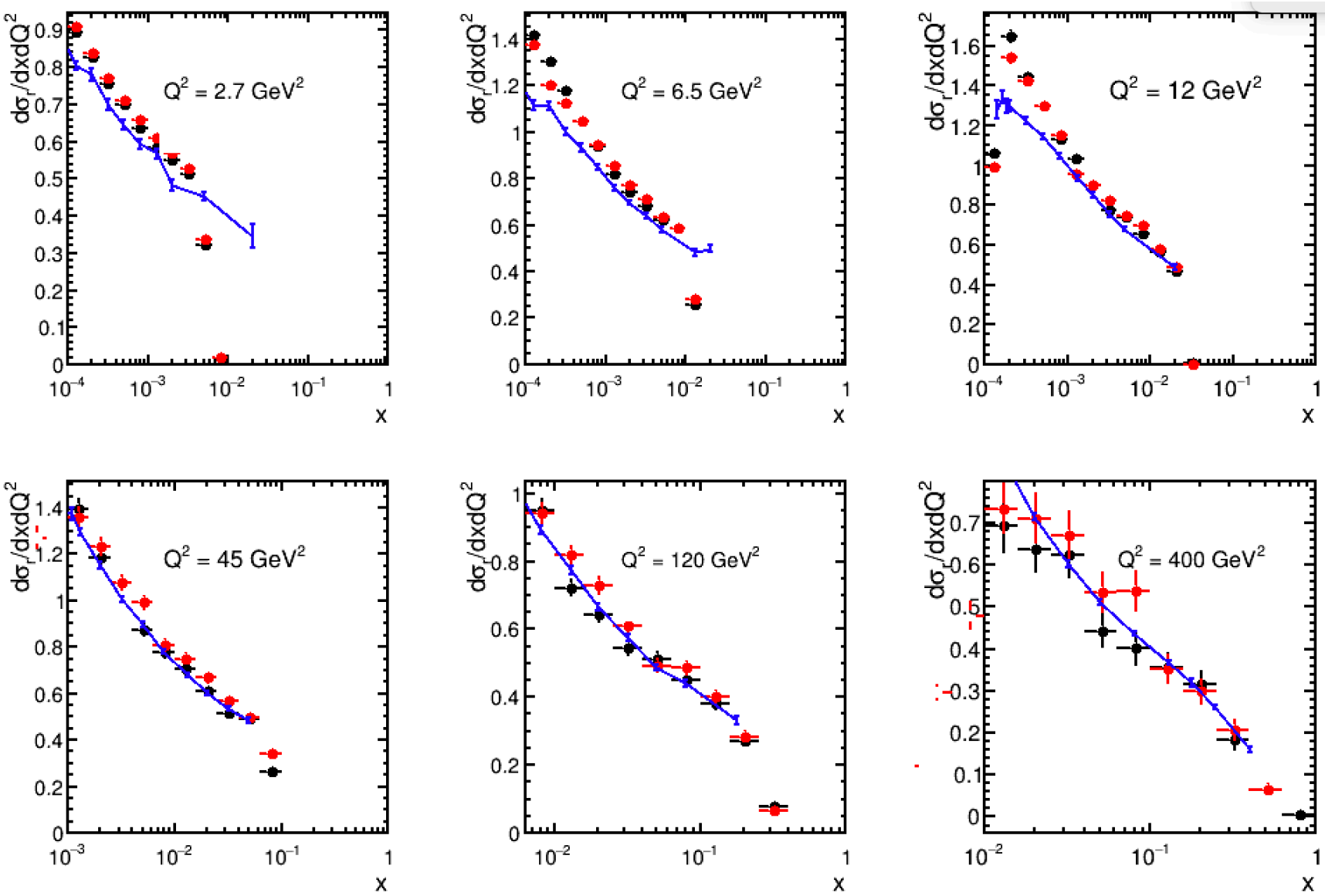
Red: HERMES tuned pythia with New RCPT
Black: HERMES tuned pythia
Blue: HERA data

Red and black are not that different.

Both red and black are using CTEQ5 as input proton PDF.

Reproduce HERA data by Pythia (2)

Optimize PDF, HERMES tuned pythia



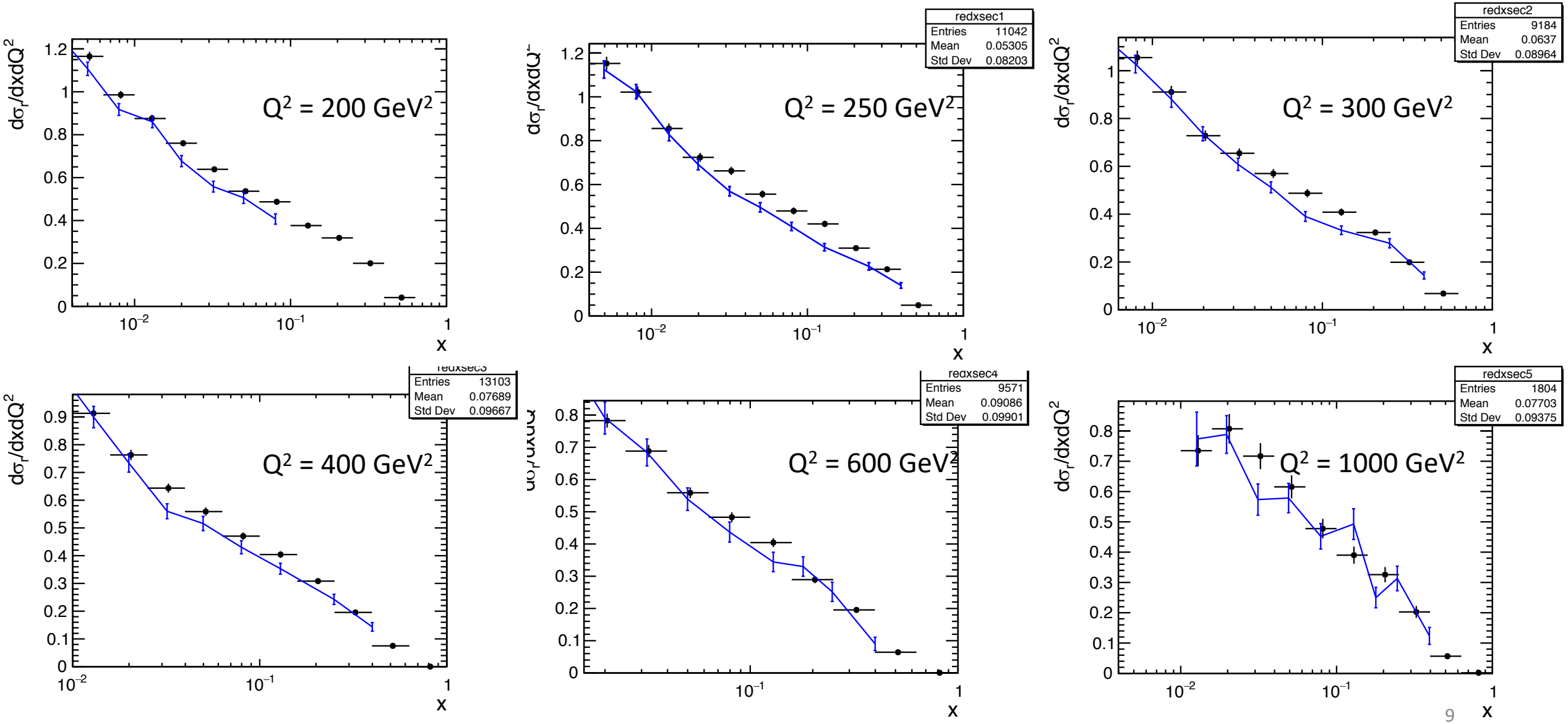
Black: CTEQ5
Red: HERAPDF2.0 LO

HERAPDF improves results a little at Q^2 = 6.5 and 12 GeV^2

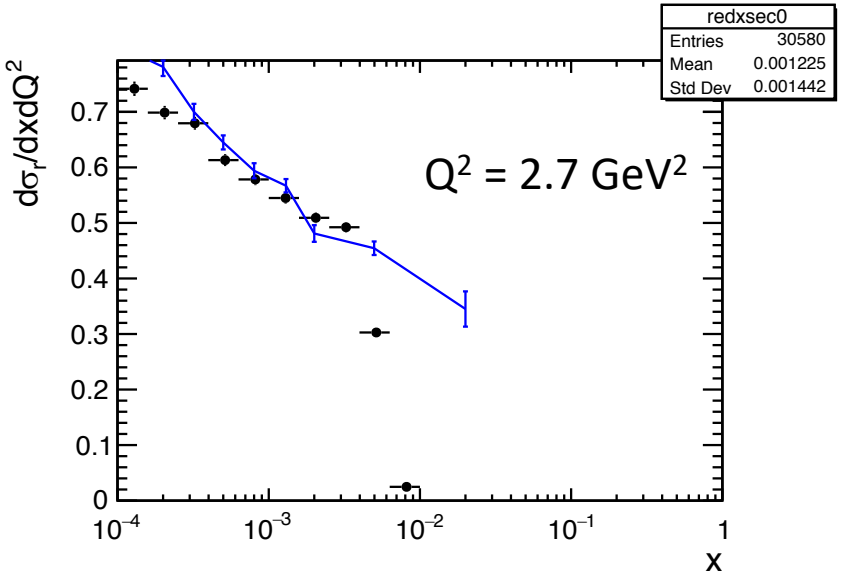
Contrary to modern PDFs CTEQ5 is not frozen at its input scale Q^2_0, but allows description of the partonic structure of the proton at $Q^2 \leq Q^2_0$.

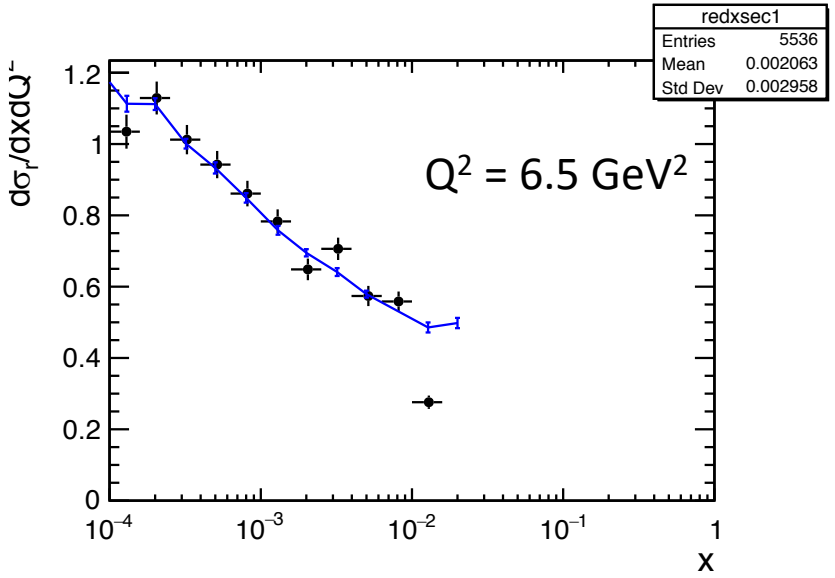
For Q^2>1, different ones like HERAPDF and so on and the difference is minimal.

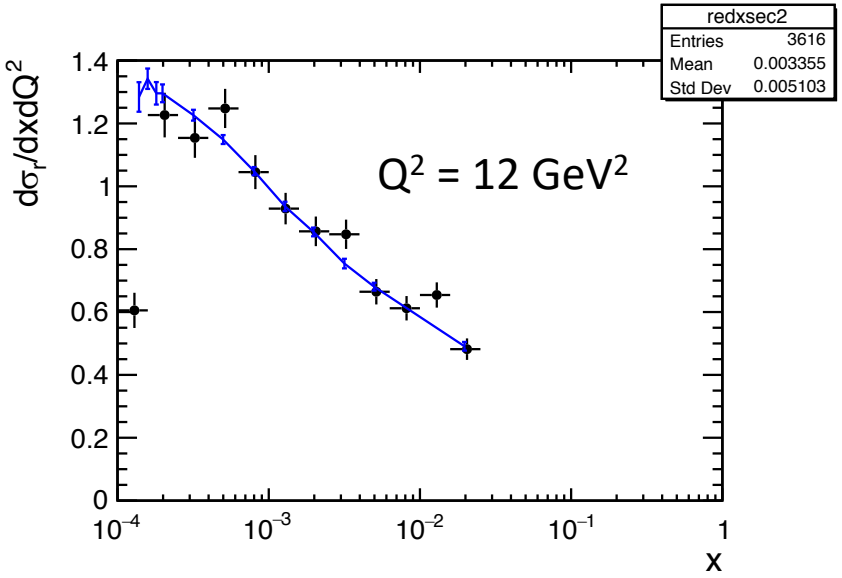
Reproduce HERA data by Djangoh (1)

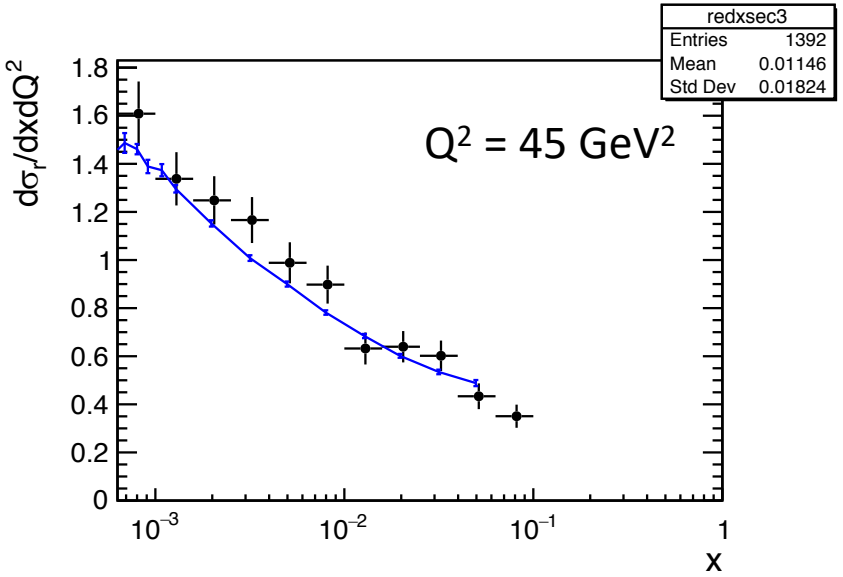


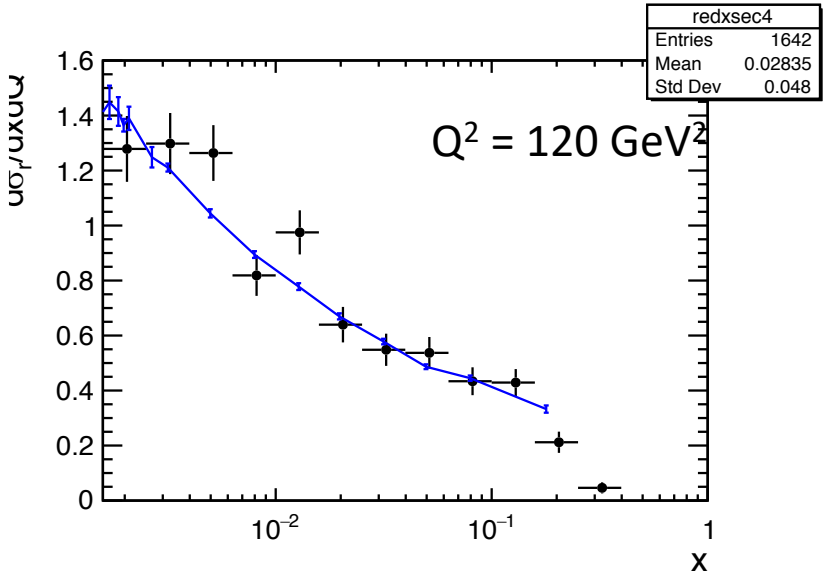
Reproduce HERA data by Djangoh (2)











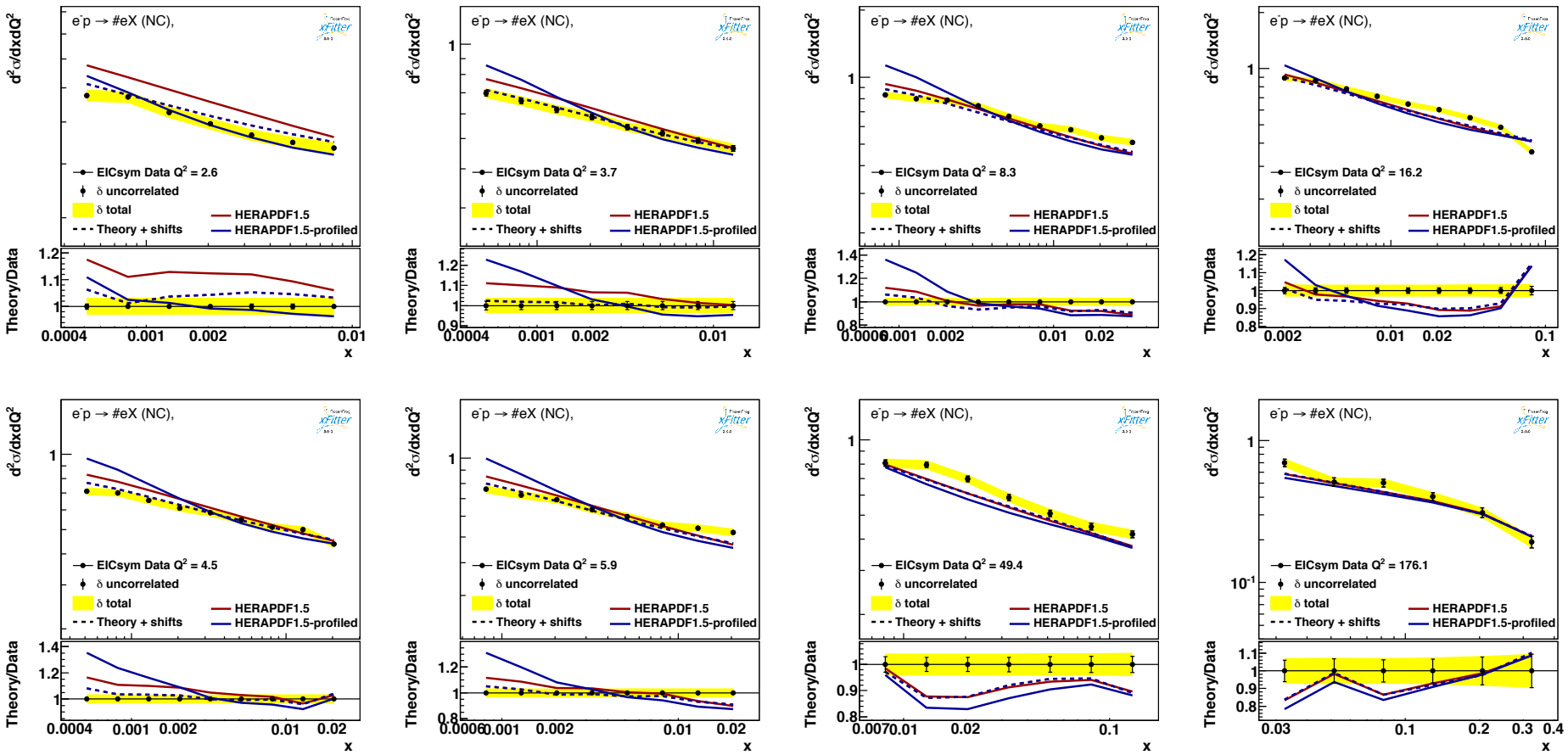
HERA data

EIC Djangoh

Djangoh works perfectly to reproduce HERA data, but it only includes DIS, however pythia contains DIS and soft processes(VMD, resolved).

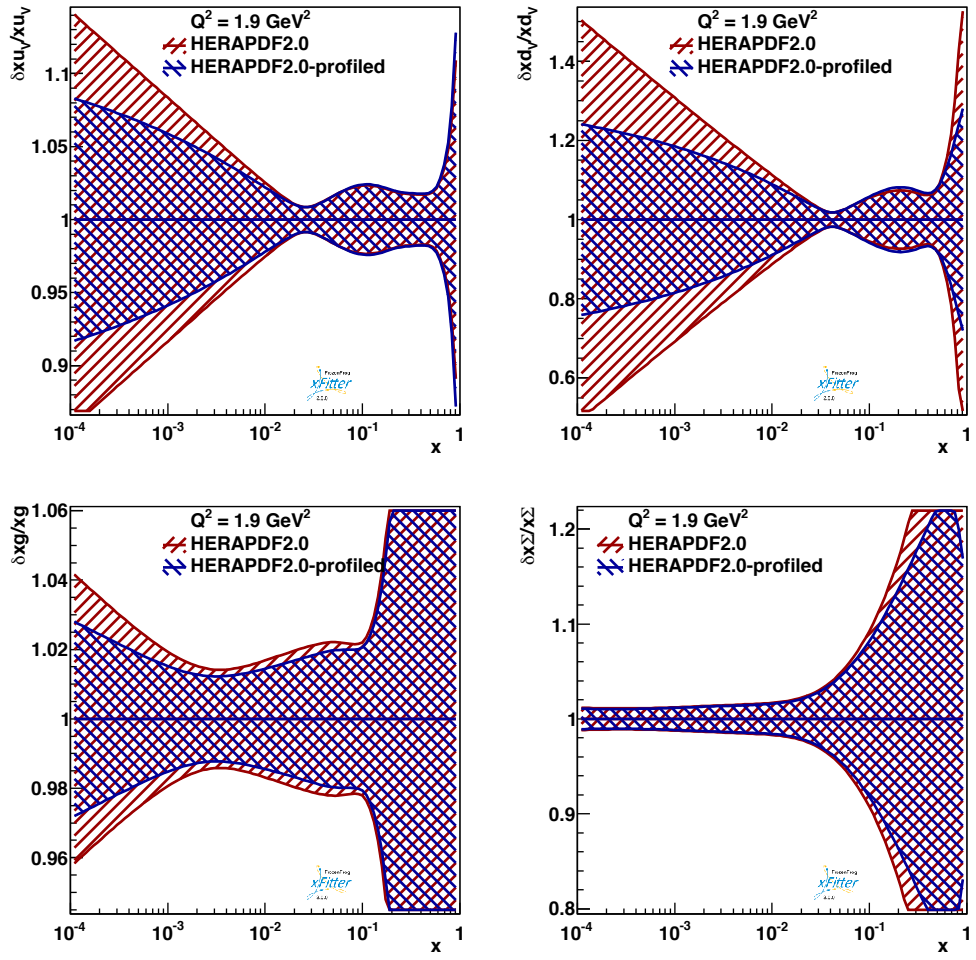
Reduced cross sections for NC at EIC

ep NC events with DJANGOH for 18 GeV x 275 GeV



Impact of NC@EIC to PDFs

5 GeV x 100 GeV 10 GeV x 100 GeV 18 GeV x 275 GeV



$$\sigma_{r,NC} = F_2(x,Q^2) - \frac{y^2}{[1+(1-y)^2]} * F_L(x,Q^2)$$

$$q(x,Q^2) - \bar{q}(x,Q^2) \qquad g(x,Q^2)$$

When y is large, one needs to measure different energies for proton to get F_L

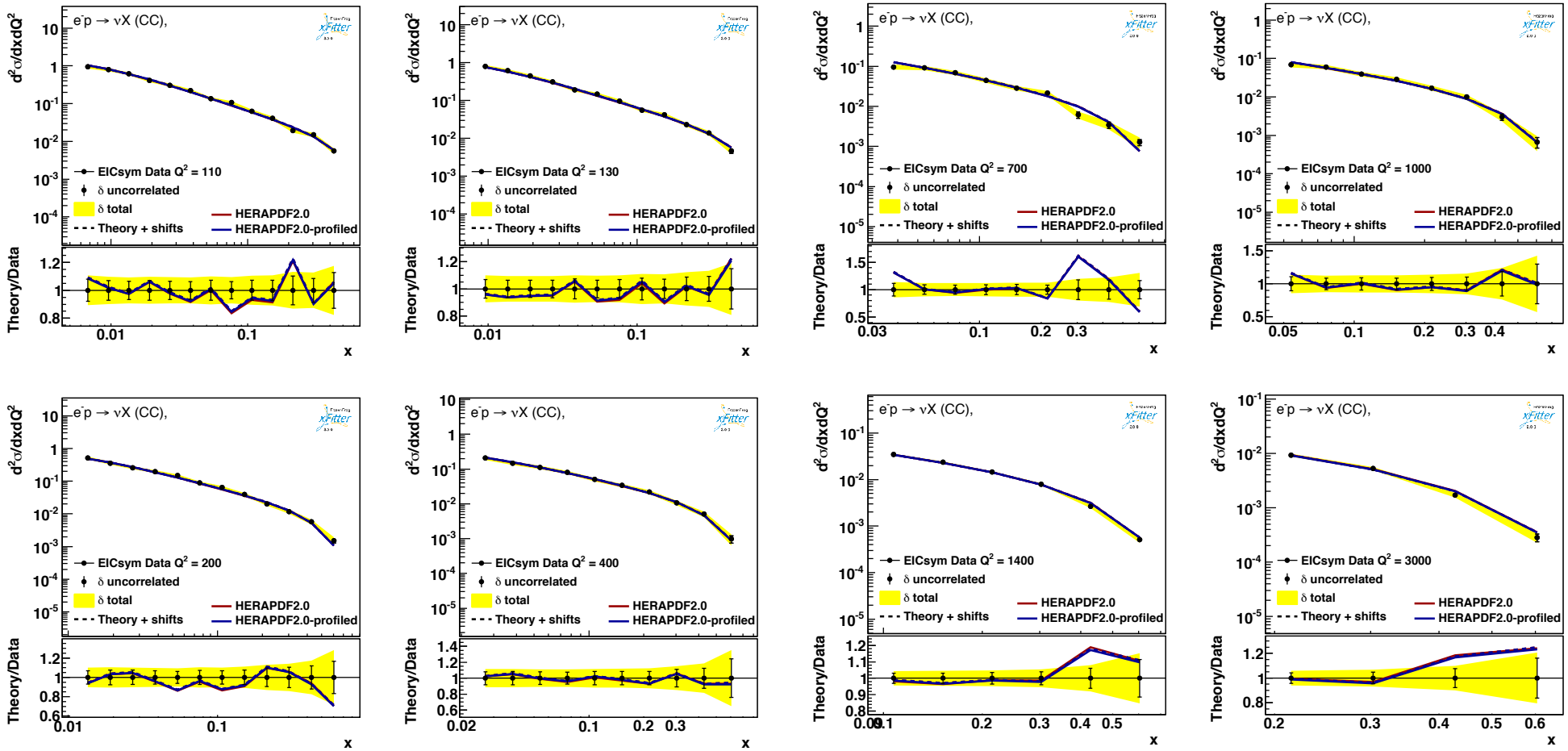
Very strong impact through the projection at highest energies.

We needs a full fit in the next step.

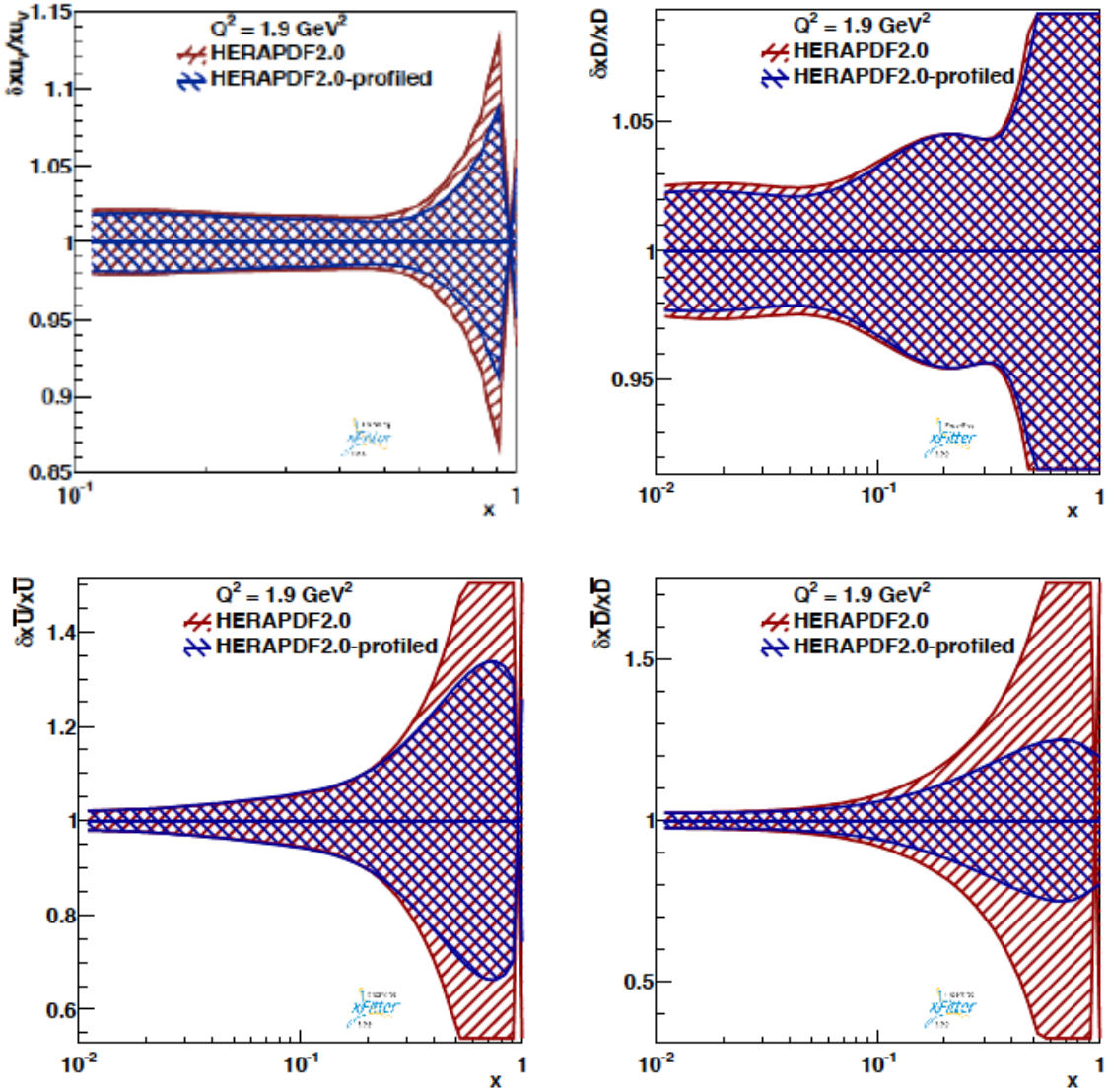
Observable: CC

Reduced cross sections for CC at EIC

Generated 4 fb^{-1} worth of ep CC events with DJANGOH for 18 GeV x 275 GeV
Good agreement between pseudo-data and prediction



Impact of CC@EIC to PDFs



$$xU = xu + xc$$
$$xD = xd + xs$$
$$x\bar{U} = x\bar{u} + x\bar{c}$$
$$x\bar{D} = x\bar{d} + x\bar{s}$$
$$xu_v = xU - x\bar{U}$$
$$xd_v = xD - x\bar{D}$$

W^- exchanged

Very strong impact on $x\bar{D}$
significant impact on xu_v

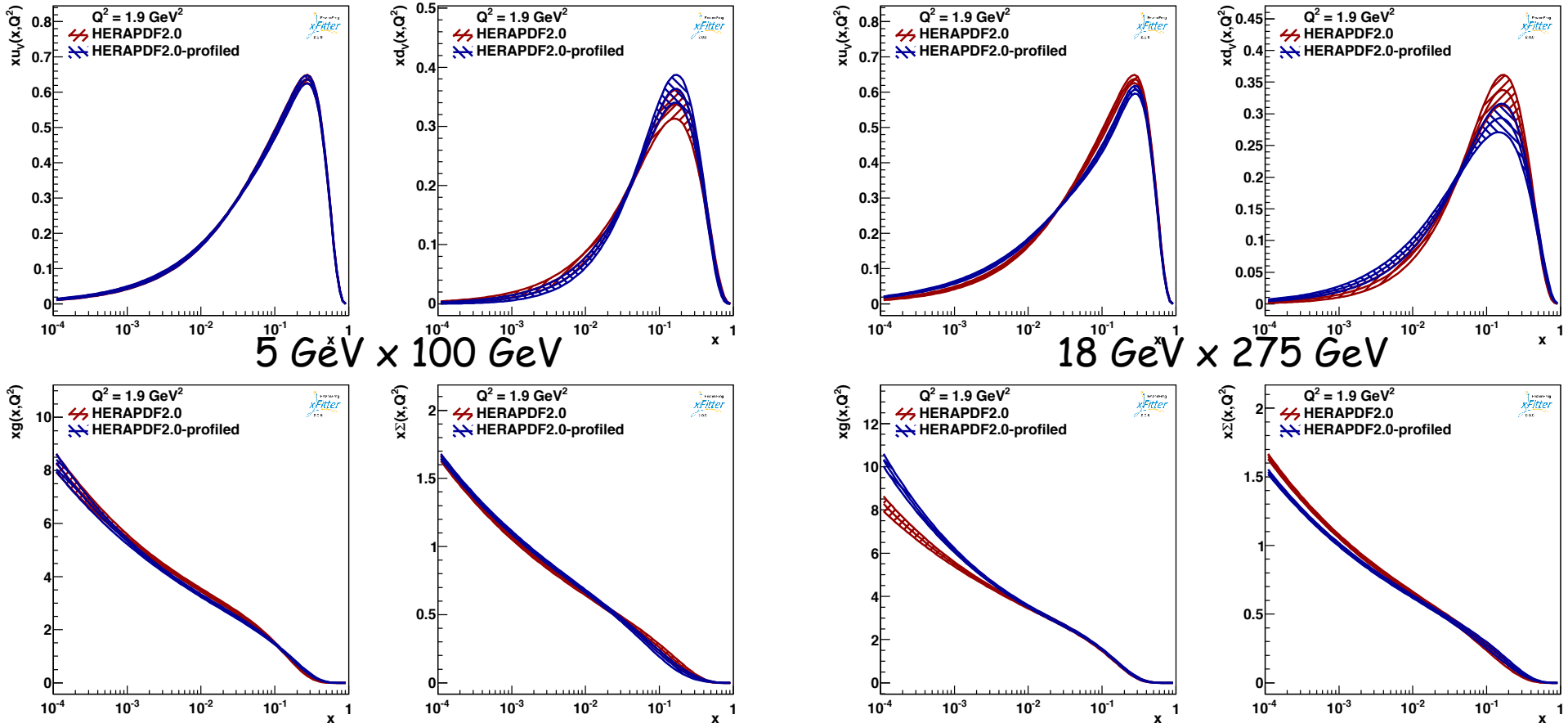
Impact on $x\bar{U}$ caused be sum rule

Summary

- Lots of the studies have been completed in our group previously, Details can be found: https://wiki.bnl.gov/eic/index.php/Main_Page
- EIC simulations are reliable to generate HERA data with our set up
- F_2 measurement is tested in both CC and NC channels with different energies
- NC and CC on deuterium and different energies for proton to get F_L
- Inclusive cross section measured at EIC will have impact on constraining Proton PDFs
- F^{cc} measurements are on the way
- Combine HERA data and all the EIC simulations to do a full fit to check EIC data impact on PDFs

Back up

EIC PDFs



Observable: CC

W-exchange:
direct access to the quark flavor

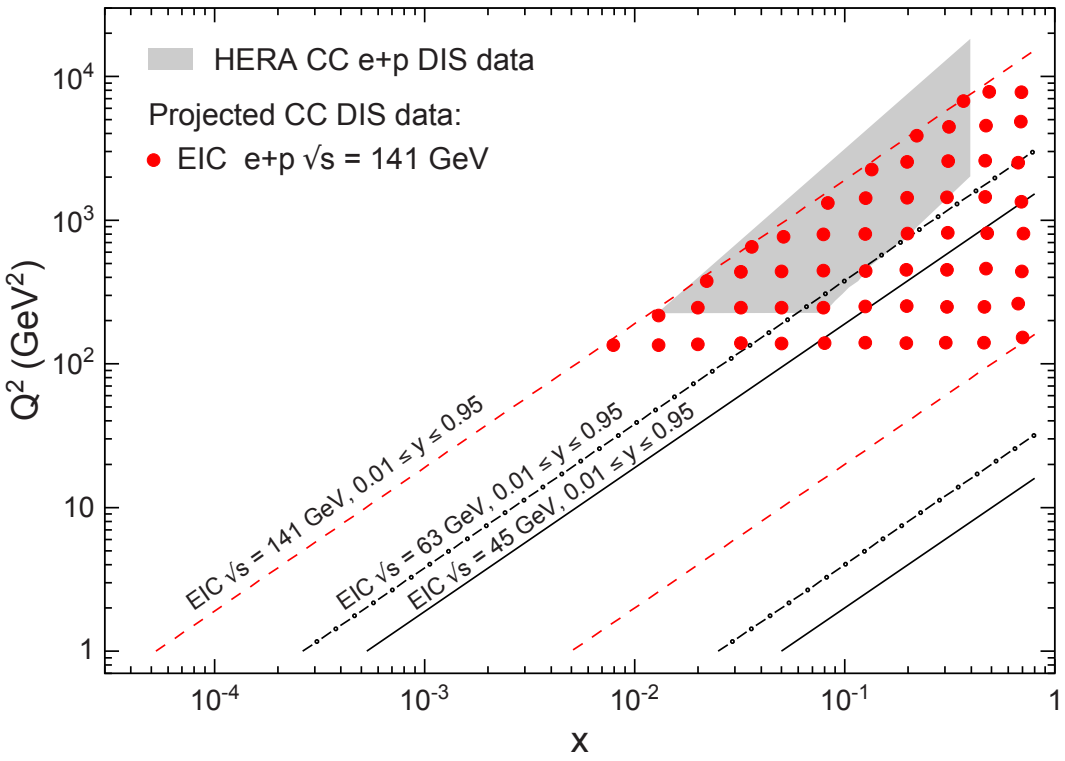
Ws are maximally parity violating
→ Ws couple only to one parton helicity

$$W^- + p \rightarrow u\bar{d}$$
$$W^- + n \rightarrow d\bar{u}$$

Complementary to SIDIS:

- high Q^2-scale: > 100 GeV^2
- best way to measure at very high x
- No Fragmentation function

→ stringent test on theory approach for SIDIS
UNIVERSALITY of PDFs



EIC has a large kinematic coverage for charge current events (○)