Universität Münster

SMU

Jefferson Lab

EIC early science runs: A nuclear PDF perspective

EIC early science workshop – CFNS – Stony Brook

Peter Risse

nCTEQ

nuclear parton distribution functions

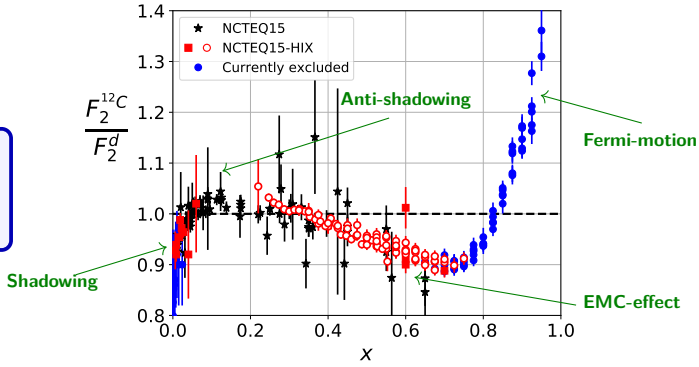
Structure of nuclei

- Nuclear binding energy $\sim 1\%$ of mass
- First approximation:
  nuclei consist of free protons & neutrons

$$F_2^A(x) \approx\neq Z F_2^{p,free}(x) + N F_2^{n,free}(x)$$

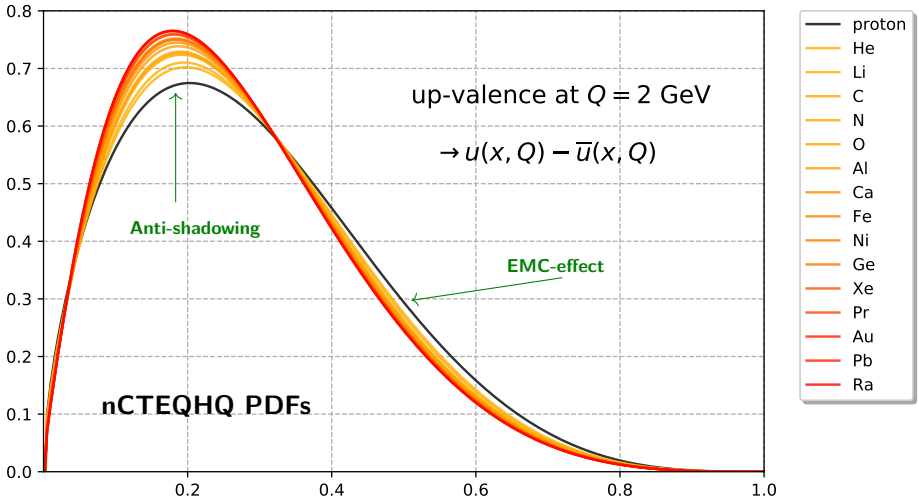
$\Rightarrow$ **does not work**

- Cross-sections in nuclear collisions are modified
- Can we translate these modifications into **universal** quantities?

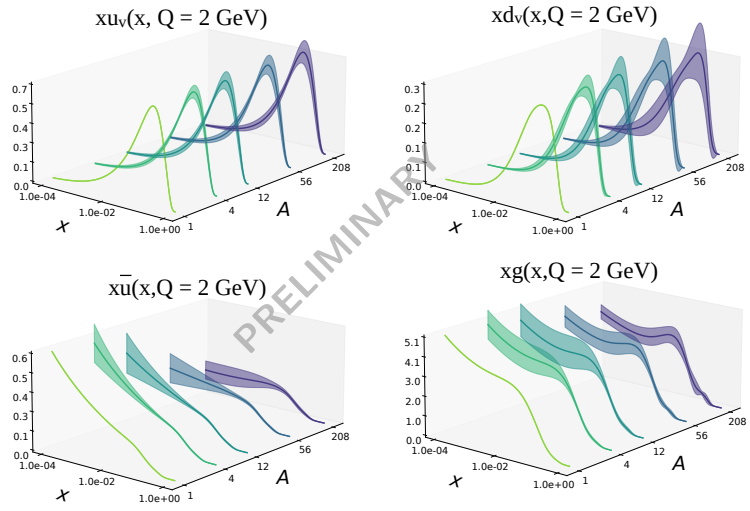


$\Rightarrow$ **nuclear PDFs**

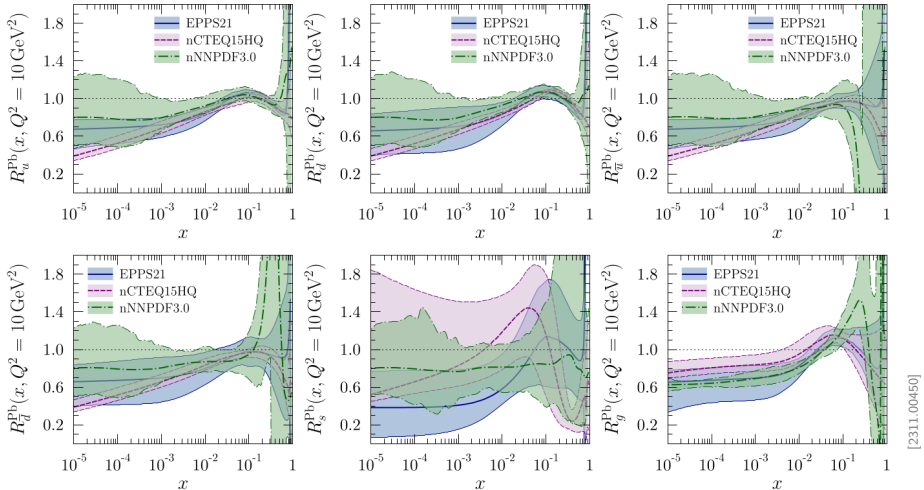
Nuclear modification: free proton vs bound proton



Preliminary results: A-dependence

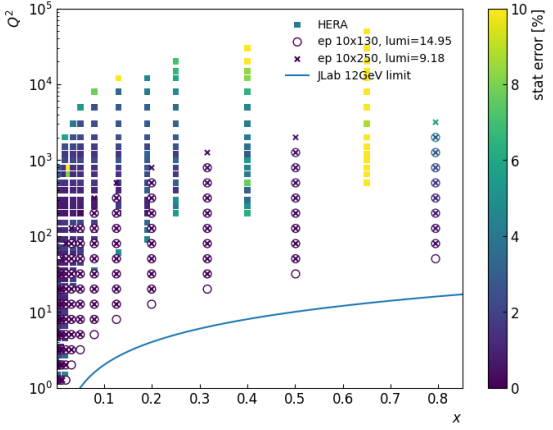


Nuclear ratio of EPPS21 vs. nNNPDF3.0 vs. nCTEQ15HQ

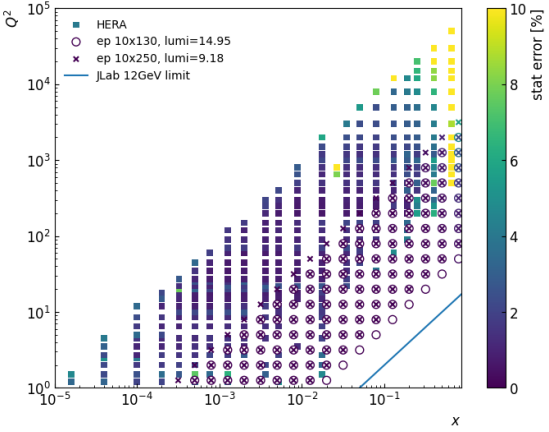


the case for eP runs

eP runs: kinematics & statistics



- improved precision at large-x



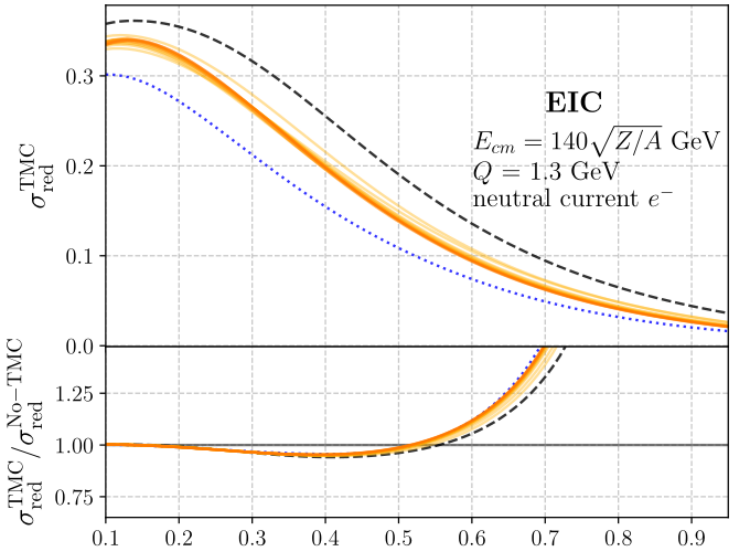
- improved precision at low-x

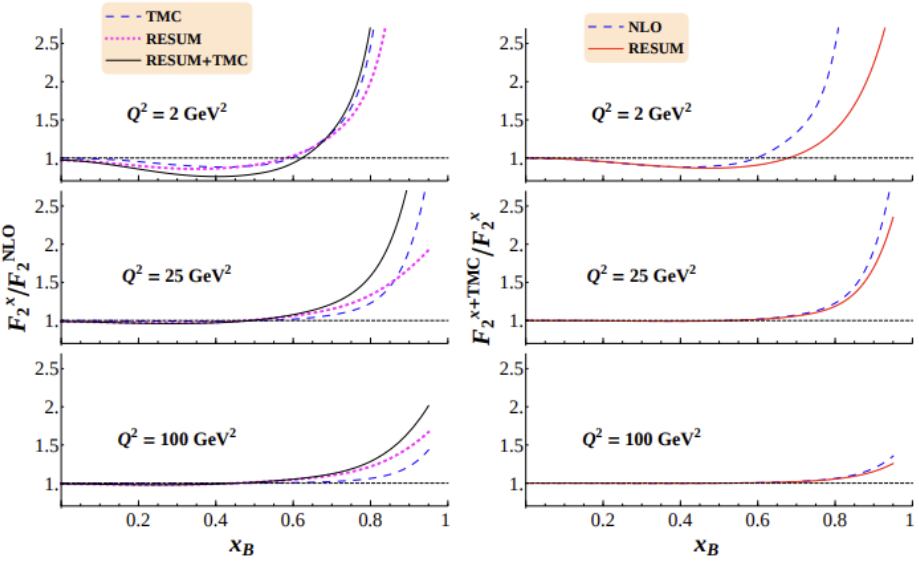
large-x region

The large-x region

There are several (theoretically) distinct effects at large-x, but the all look fairly similar!

- Target Mass corrections
- higher twist effects
- large-x resummation
- nuclear effects


EIC
$E_{cm} = 140\sqrt{Z/A}$ GeV
$Q = 1.3$ GeV
neutral current e^-
$\sigma_{\rm red}^{\rm TMC}$
$\sigma_{\rm red}^{\rm TMC} / \sigma_{\rm red}^{\rm No-TMC}$
0.3
0.2
0.1
0.0
1.25
1.00
0.75
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9


TMC
RESUM
RESUM+TMC
NLO
RESUM
$Q^2 = 2$ GeV^2
$Q^2 = 25$ GeV^2
$Q^2 = 100$ GeV^2
F_2^x/F_2^{NLO}
F_2^{x+TMC}/F_2^x
x_B
2.5
2.
1.5
1.
0.2
0.4
0.6
0.8
1

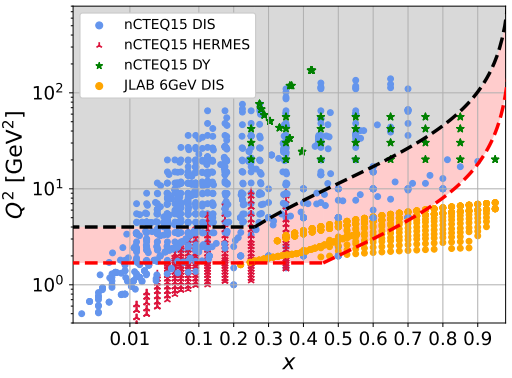
Enlarged kinematic cuts

Kinematic variables:

$$Q^2 \quad \& \quad W^2 = Q^2 \frac{1-x}{x} + M_N$$

Requires proper treatment of:

- deuteron corrections
  [PRD 93, 114017 (2016)]
- target mass corrections (TMCs)
  [Prog.Part.Nucl.Phys. 136 (2024) 104096]
- higher twist effects
  [PRD 93, 114017 (2016)]



nCTEQ15

$Q > 2$ GeV
$W > 3.5$ GeV
$N_{\text{data}} = 708$

nCTEQ15HIX

$Q > 1.3$ GeV
$W > 1.7$ GeV
$N_{\text{data}} = 1679$

[PRD 103, 114015 (2021)]

low-x region

The low-x region

- need for precise proton baseline
- only way of finding saturation from PDF fits is by carefully disentangling the different effects as precise as possible
- problems with the HERA data
- problems with theoretical predictions
- ...

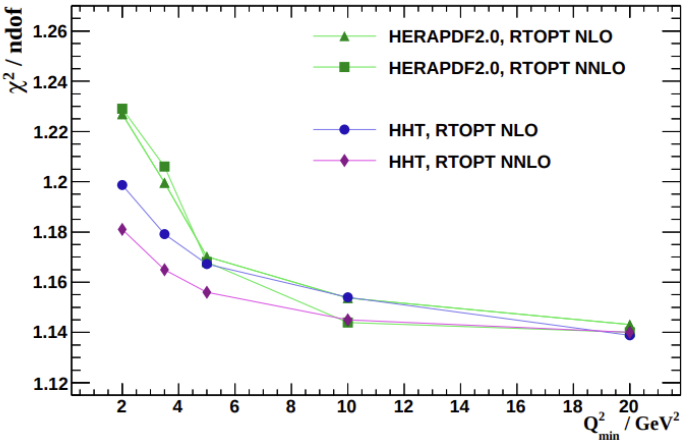
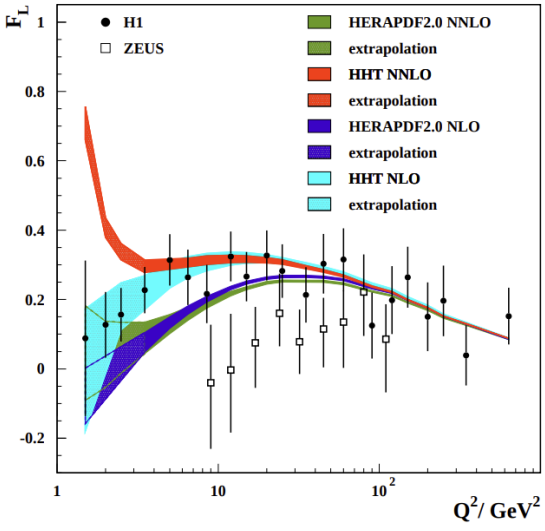
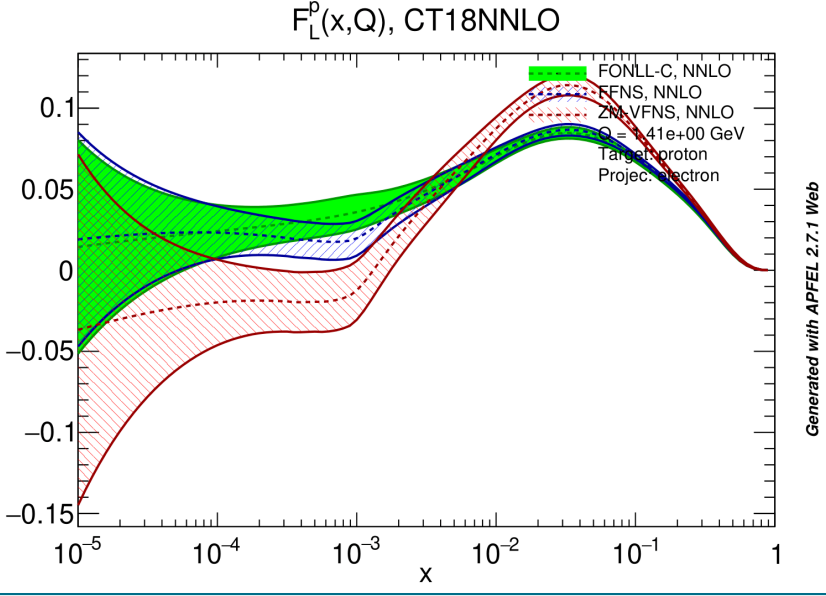


Figure 2: The χ^2/ndof versus Q^2_{min} for HHT and HERAPDF2.0 fits at NNLO and NLO.


F_L
1
0.8
0.6
0.4
0.2
0
-0.2
H1
ZEUS
HERAPDF2.0 NNLO
extrapolation
HHT NNLO
extrapolation
HERAPDF2.0 NLO
extrapolation
HHT NLO
extrapolation
1
10
10^2
Q^2/ GeV^2


$F_L^p(x,Q)$, CT18NNLO
FONLL-C, NNLO
FFNS, NNLO
ZM-VFNS, NNLO
Q = 1.41e+00 GeV
Target: proton
Projec: electron
0.1
0.05
0
−0.05
−0.1
−0.15
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1
x
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Thank you!