Parton densities in nuclei at the EIC

P. Zurita

CIPANP2022

September 2nd 2022, Orlando, FL, EE.UU.

Universität Regensburg

Outline

- Brief recap of nuclear PDFs.
- Current efforts.
- Nuclear densities at the EIC.
- Summary.

Brief recap on PDFs:

- They give us all the information about the internal structure of hadrons.

- We can identify several families of PDFs (***collinear***, TMD, GPDs, FFs, etc.)

Brief recap on PDFs:

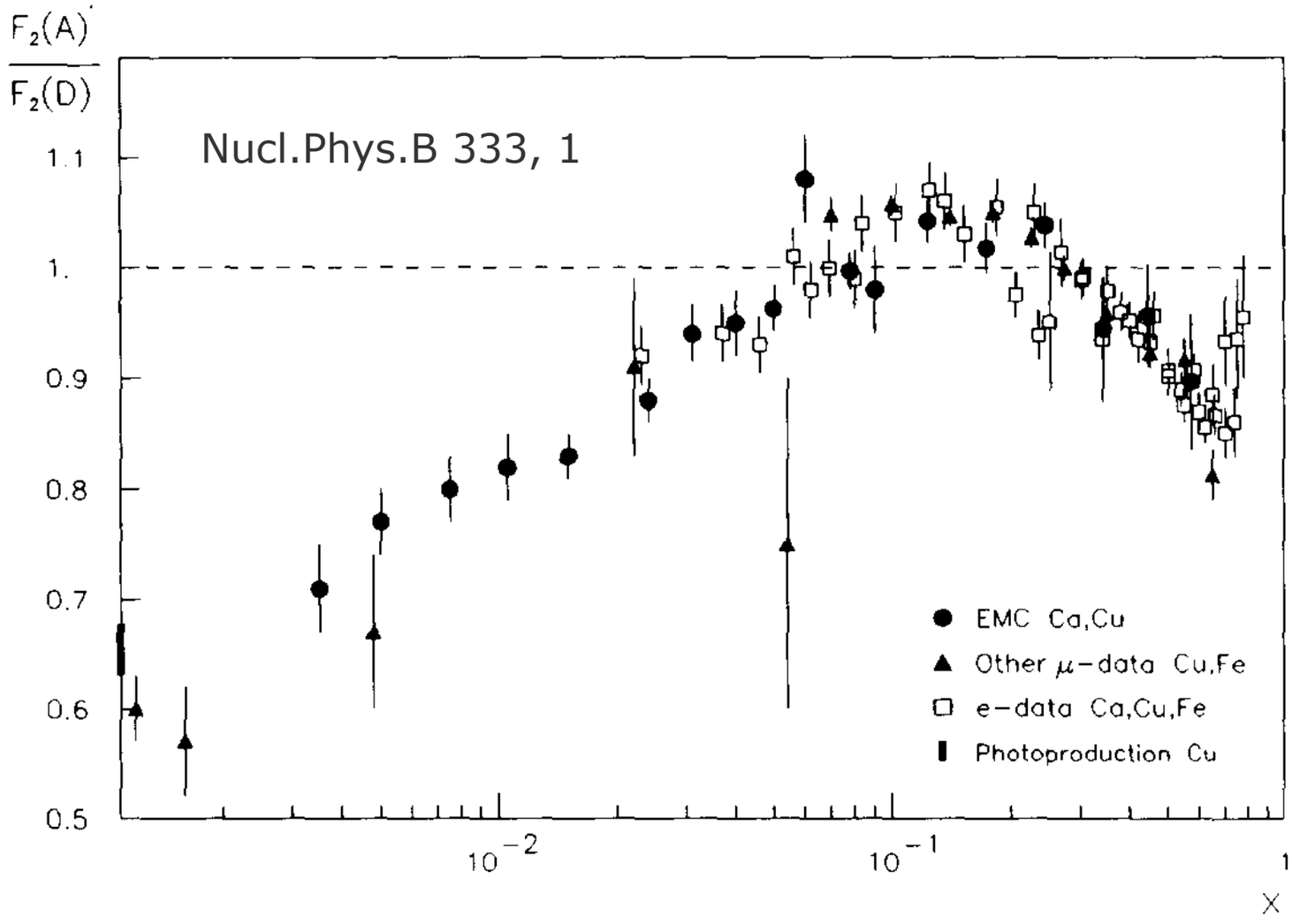
- They give us all the information about the internal structure of hadrons.

- We can identify several families of PDFs (***collinear***, TMD, GPDs, FFs, etc.)

- PDFs are ***universal*** and have a ***calculable dependence*** on the scale(s).

- In perturbative QCD they ***can't be computed*** from first principles. Must be ***inferred*** from data.

- In an experiment involving nuclei we see things like this:



$$\frac{d^2\sigma^{DIS}}{dxdQ^2} \propto F_2 - \frac{y}{1+(1-y)^2}F_L$$

- **Genuine modification of the initial state** due to the medium.

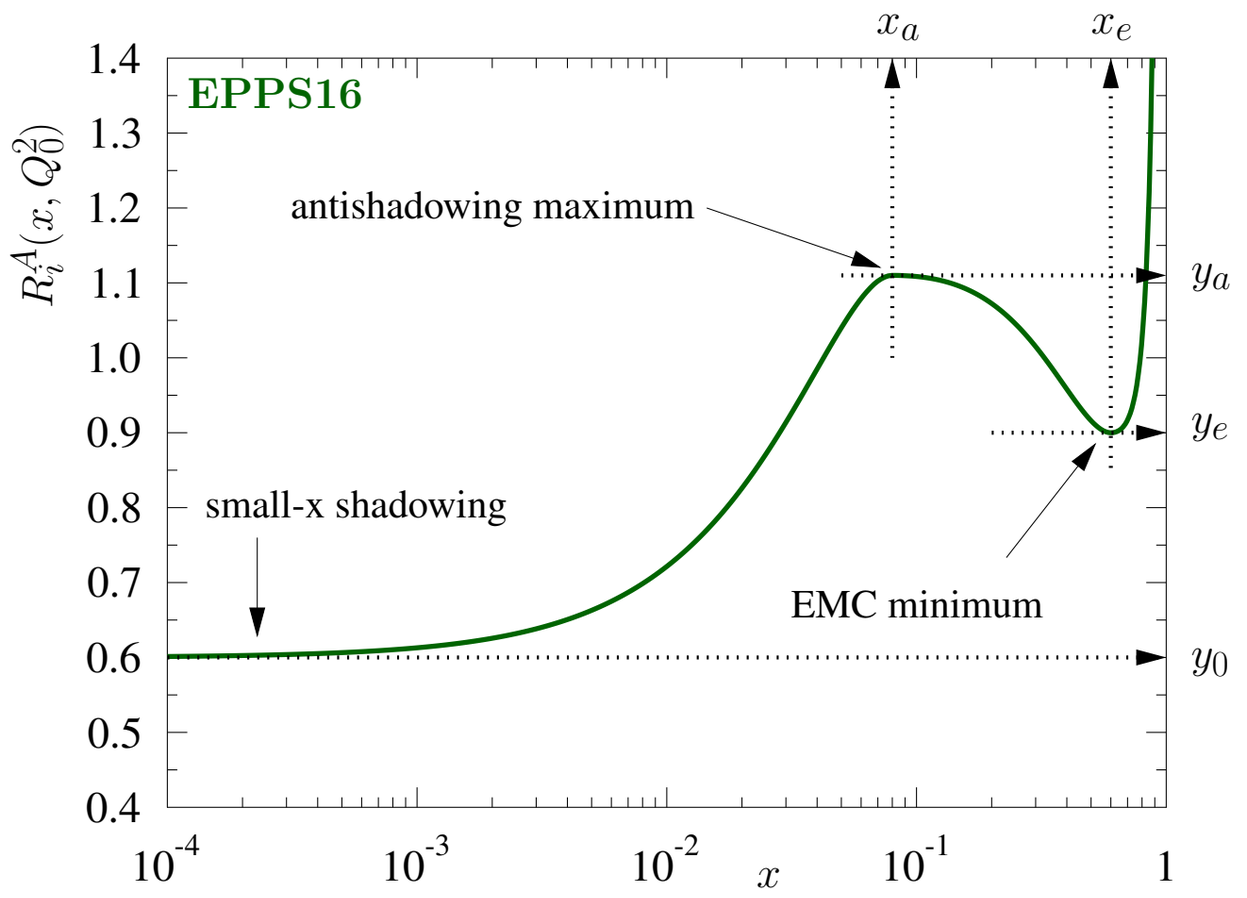
- If we assume that we can apply pQCD just as in the "proton" case, then the only thing that we can modify is the soft part.

- The popular way: introduce *A*-dependent ***nuclear PDFs***, to be obtained from data.

- If we assume that we can apply pQCD just as in the "proton" case, then the only thing that we can modify is the soft part.

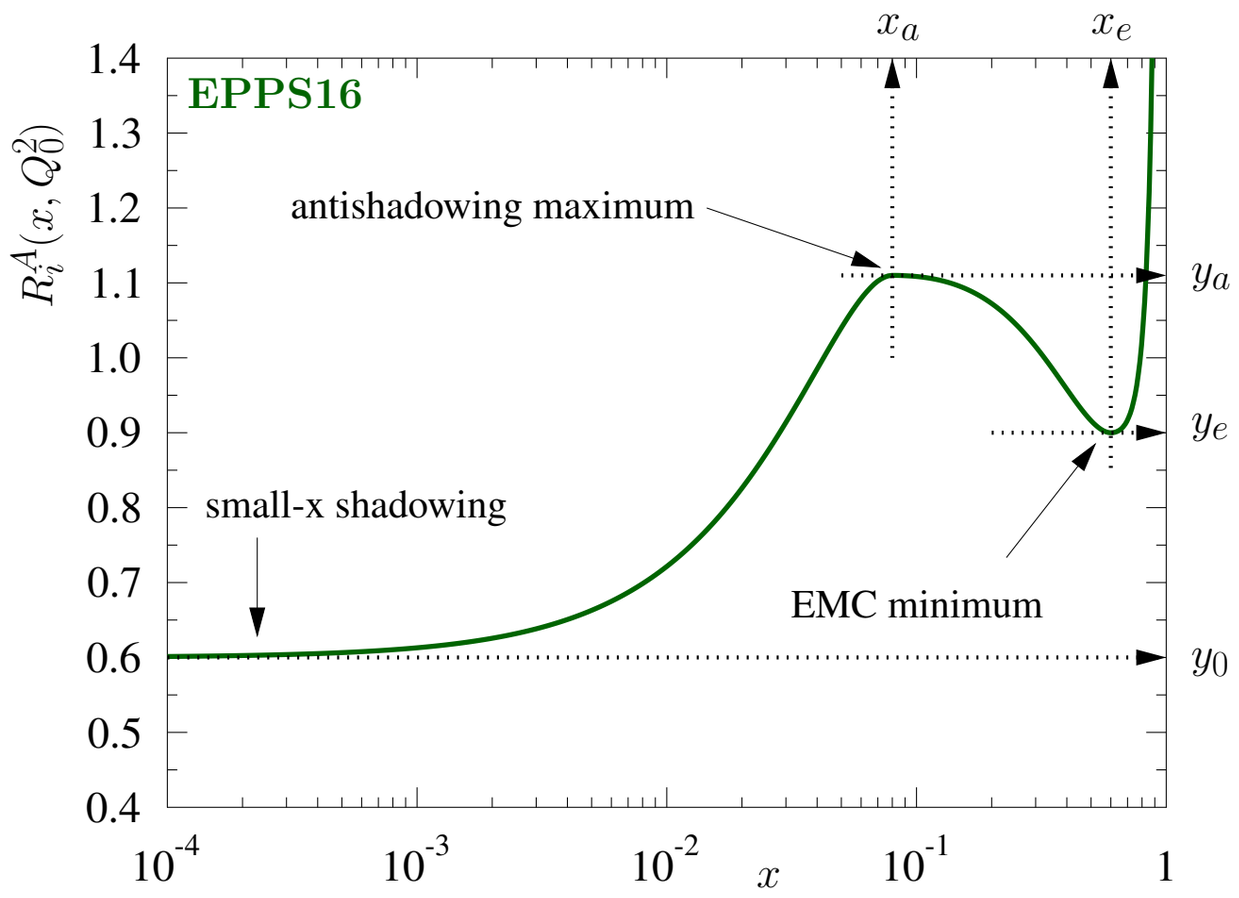
- The popular way: introduce *A*-dependent ***nuclear PDFs***, to be obtained from data.

- $f_{i/p/A}(x, Q_0^2, A) = f_{i/p}(x, Q_0^2) R_i(x, A)$
- $f_{i/p/A}(x, Q_0^2, A) = f_{i/p}(x, Q_0^2, A)$
- $f_{i/p/A}(x, Q_0^2, A) = f_{i/p}(x, Q_0^2) \otimes R_i(x, A)$
- $f_{i/p/A}(x, Q_0^2, A) = NN$



- If we assume that we can apply pQCD just as in the "proton" case, then the only thing that we can modify is the soft part.

- The popular way: introduce *A*-dependent ***nuclear PDFs***, to be obtained from data.



- $f_{i/p/A}(x, Q_0^2, A) = f_{i/p}(x, Q_0^2) R_i(x, A)$
- $f_{i/p/A}(x, Q_0^2, A) = f_{i/p}(x, Q_0^2, A)$
- $f_{i/p/A}(x, Q_0^2, A) = f_{i/p}(x, Q_0^2) \otimes R_i(x, A)$
- $f_{i/p/A}(x, Q_0^2, A) = NN$

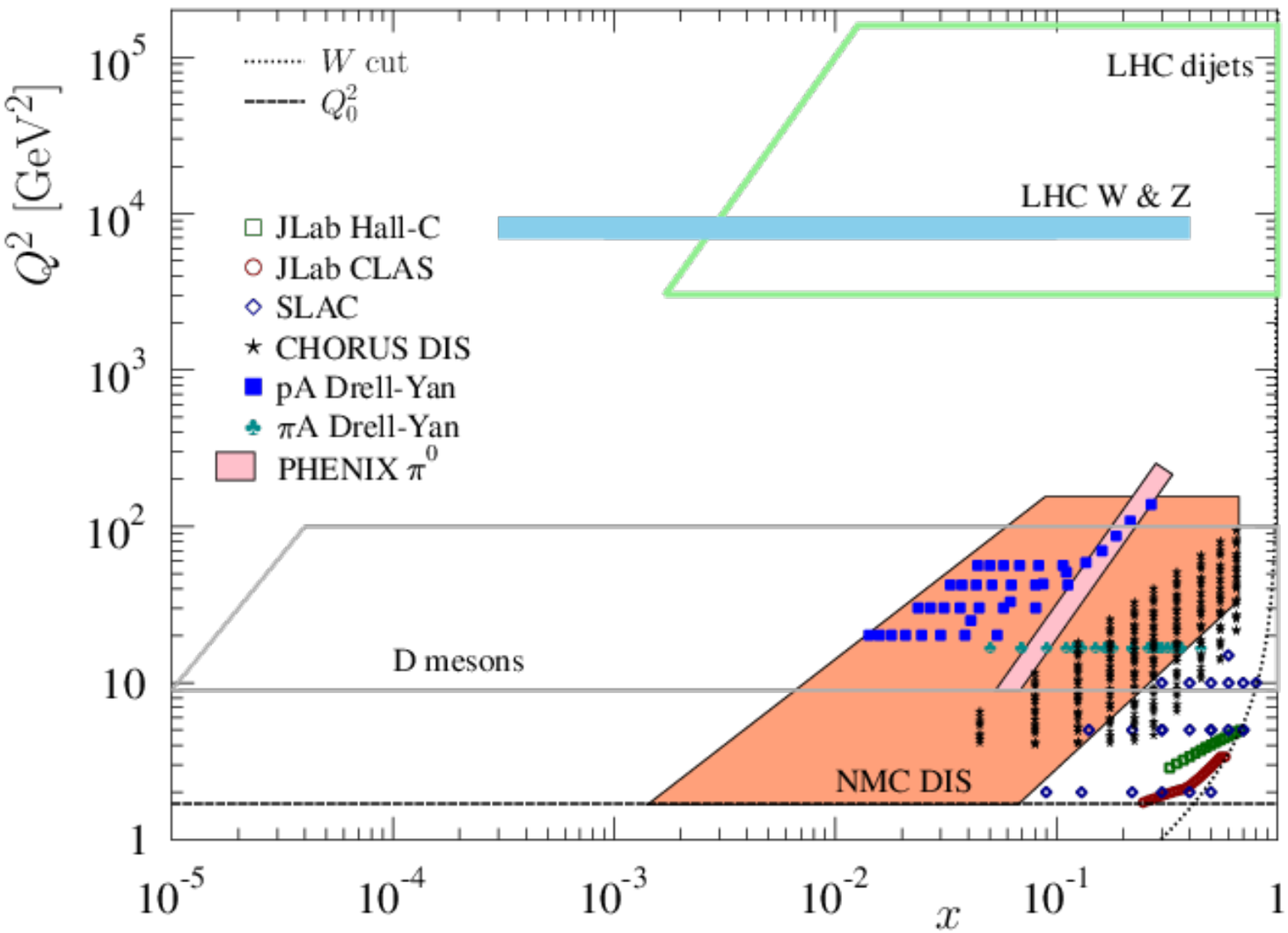
$$f_{i/A}(x, Q^2) = \frac{Z}{A} f_{i/p/A}(x, Q^2) + \frac{(A - Z)}{A} f_{i/n/A}(x, Q^2)$$

Current efforts

- 🇺🇸 and 🇺🇸-🇩🇪: **nCTEQ15**: PRD 93, 085037. **nCTEQ15WZ**: EPJC 80, 968. **nCTEQ15HiX**: PRD 103, 114015.
- 🇦🇷 and 🇦🇷-🇩🇪: **nDS**: PRD 69, 074028. **DSSZ**: PRD 85, 074028.
- 🇫🇮-🇩🇪: **nTuJu19**: PRD 100, 096015. **nTuJu21**: PRD 105, 094031.
- 🇫🇮-🇪🇸: **EKS**: EPJC 9, 61. **EPS09**: JHEP 0904, 065. **EPPS16**: EPJC 77, 163. **EPPS21**: EPJC 82, 413.
- 🇯🇵: **HKM**: PRD 64, 034003. **HKN07**: PRC 76, 065207.
- 🇮🇷 and 🇮🇷-🇩🇪: **KA15**: PRD 93, 014026. **KSASG20**: PRD 104, 034010.
- **NN**: **nNNPDF1.0**: EPJC 79, 471. **nNNPDF2.0**: JHEP 09, 183. **nNNPDF3.0**: EPJC 82, 507.

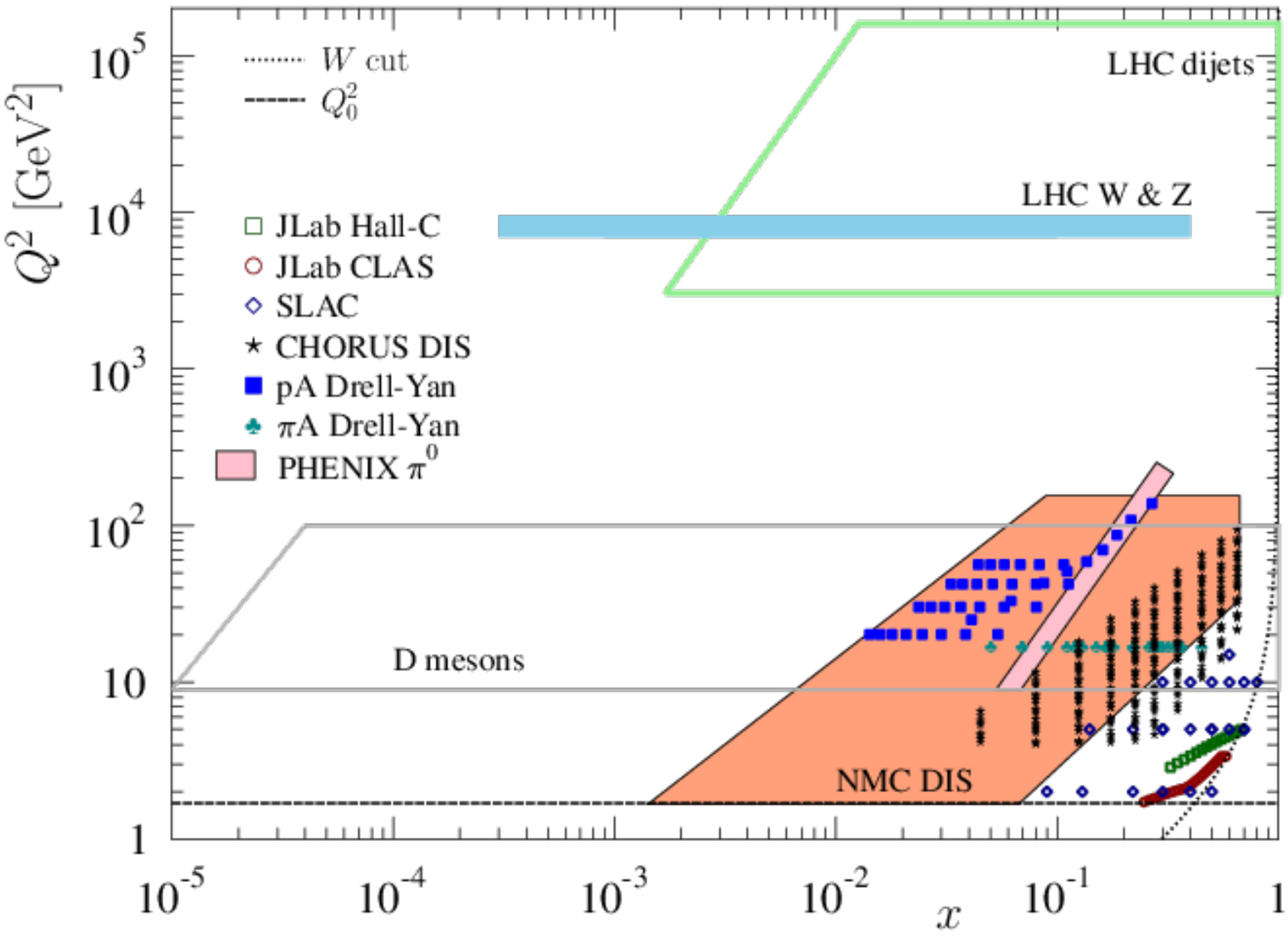
For a detailed presentation on the current status of nPDFs, please use your bilocation+time travelling skills to attend Pit Duwentäster's talk in today's QCD-PDF session.

- Just like for any other PDF family, the sets differ on the choices made during fitting.
- The extraction of a distribution is constrained by the data.



Eur.Phys.Jour. C 82, 413

- Just like for any other PDF family, the sets differ on the choices made during fitting.
- The extraction of a distribution is constrained by the data.



Eur.Phys.Jour. C 82, 413

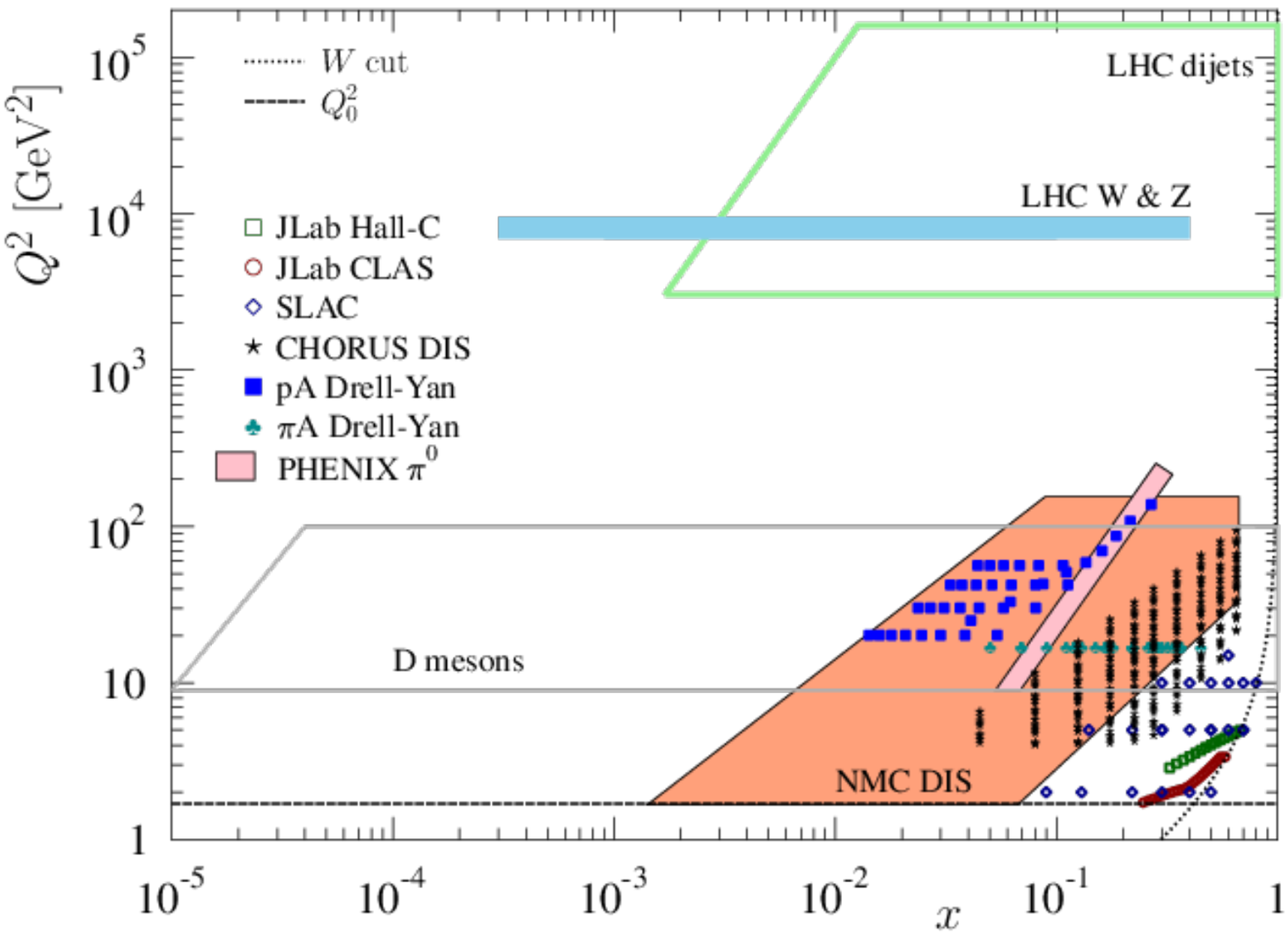
approx % of data with rel.uncer. < 1%

approx % of data with rel.uncer. < 5%

Data	w/o cut*	with W^2 cut
NC DIS	6.2 65	4.5 61
CC DIS	0 6.5	0 10

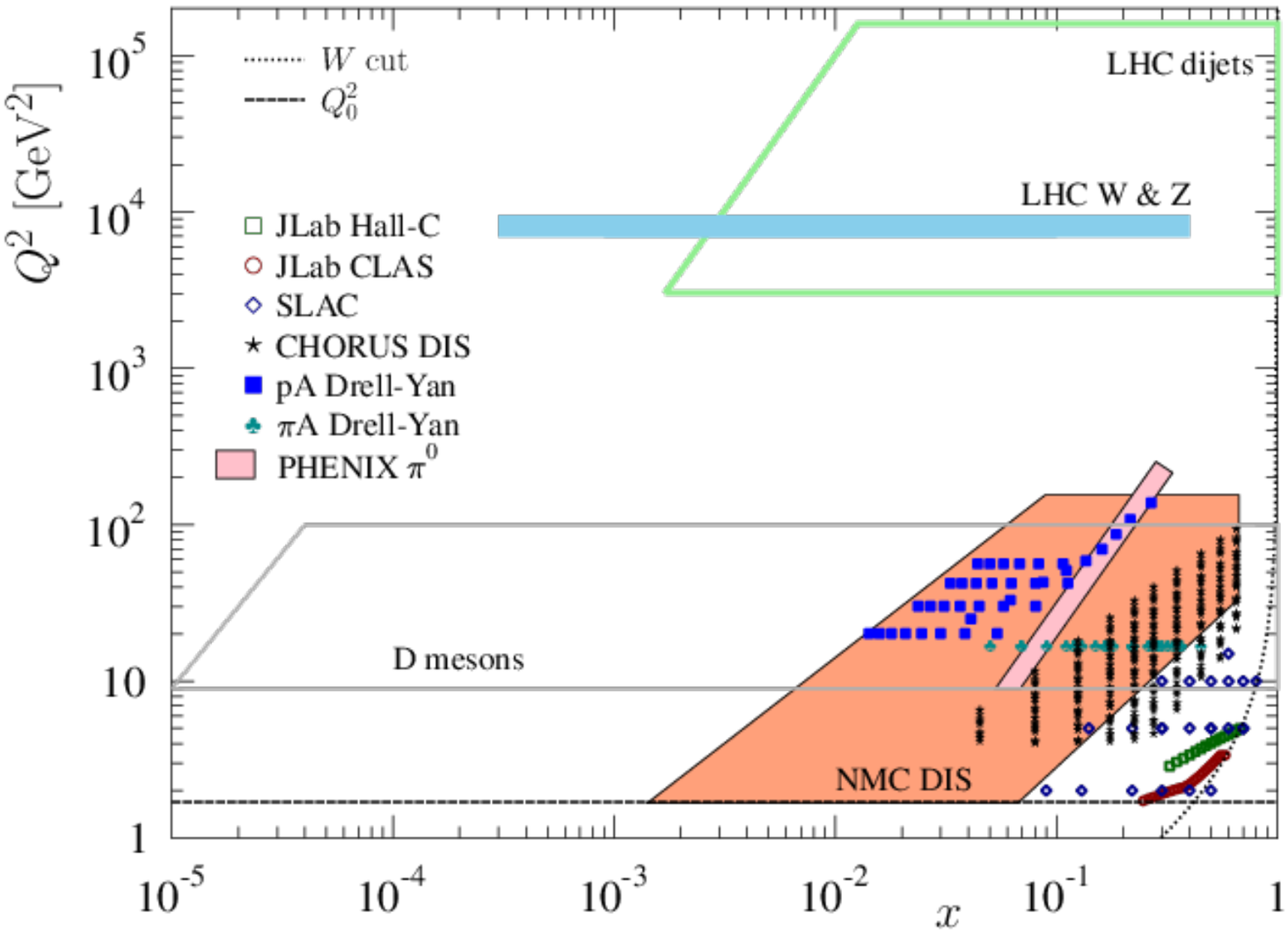
* only requiring $Q^2 > 1$ GeV^2

- Single inclusive hadron production (needs FF). **See Peter Risse's talk (QCD-PDF session)**
- Drell-Yan in fixed target $\pi + A$ collisions (needs pion PDFs).
- W and Z production, and di-jets at the LHC.
- D meson production at the LHC (needs D meson FF).
- Prompt photon at the LHC.



Eur.Phys.Jour. C 82, 413

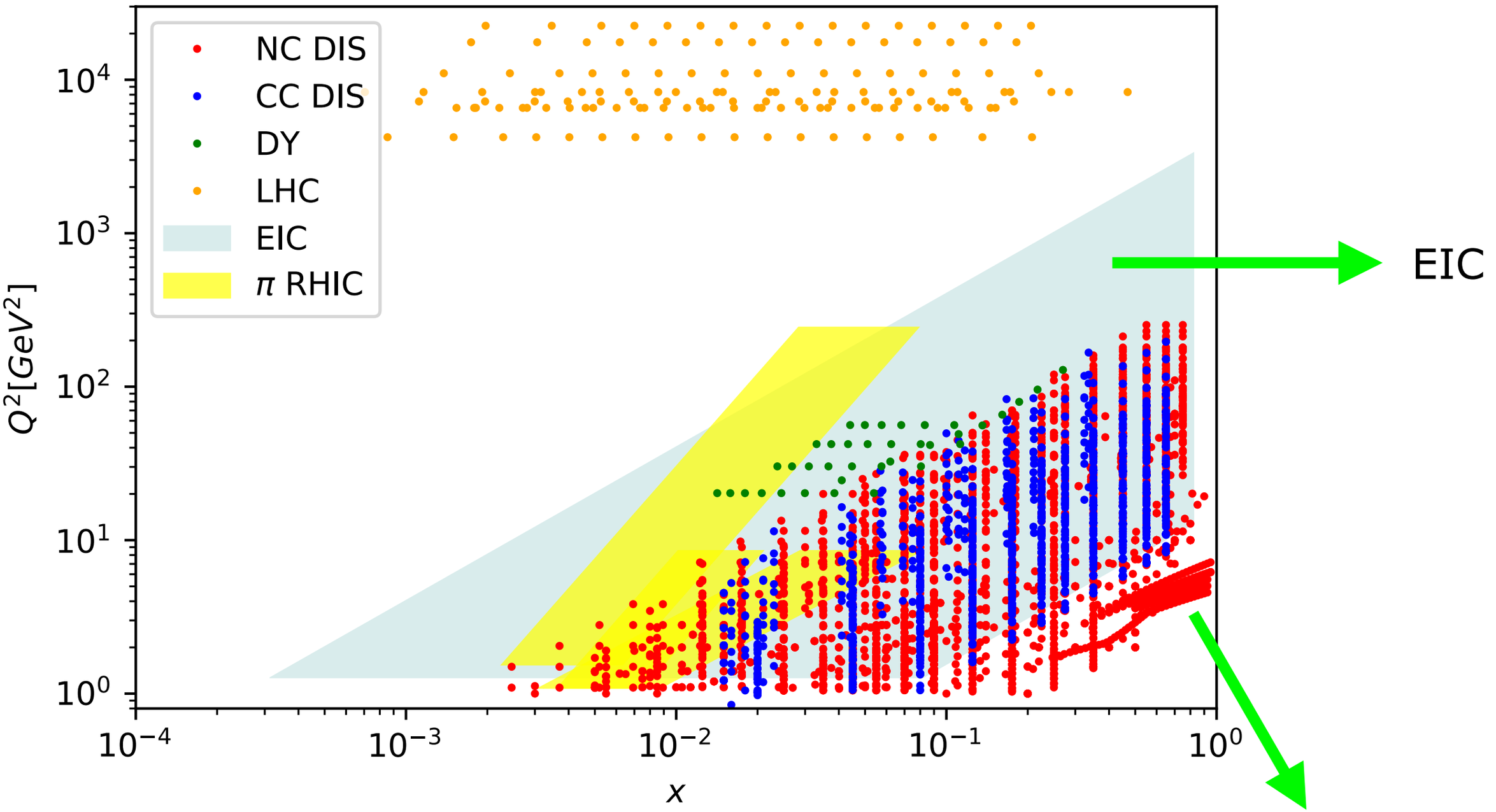
- Single inclusive hadron production (needs FF). **See Peter Risse's talk (QCD-PDF session)**
- Drell-Yan in fixed target $\pi + A$ collisions (needs pion PDFs).
- W and Z production, and di-jets at the LHC.
- D meson production at the LHC (needs D meson FF).
- Prompt photon at the LHC.



Eur.Phys.Jour. C 82, 413

- These observables complement DIS.
- **DIS** is the ***cleanest observable*** to extract PDFs (e.g. HERAPDF).

Nuclear densities at the EIC



Nucl.Phys.A 1026 (2022) 122447

- EIC will have a lager kinematic coverage than the fixed target experiments.

“This broad kinematic coverage … will revolutionize our current understanding of partonic distributions in nuclei.”

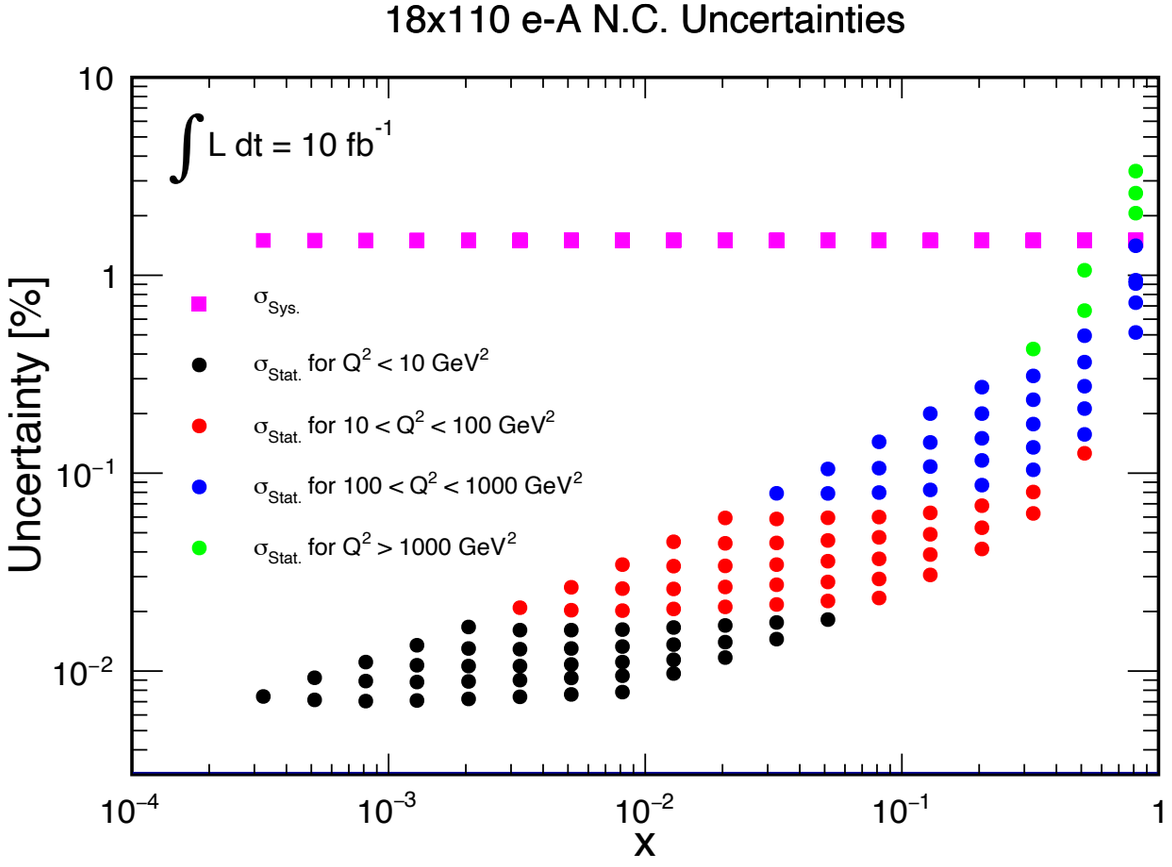
Nucl.Phys.A 1026 (2022) 122447

- EIC will have a lager kinematic coverage than the fixed target experiments.

  "This broad kinematic coverage … will revolutionize our current understanding of partonic distributions in nuclei."

  Nucl.Phys.A 1026 (2022) 122447

- More importantly, the expected uncertainties will be much smaller:

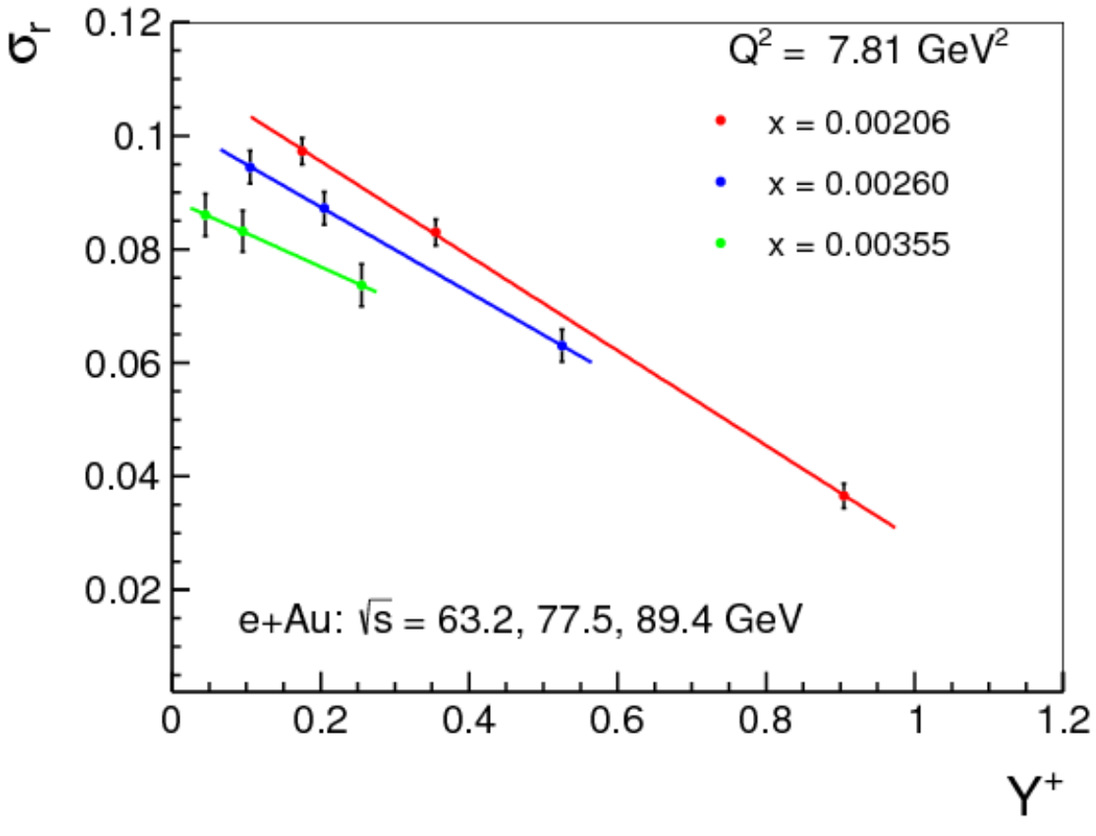


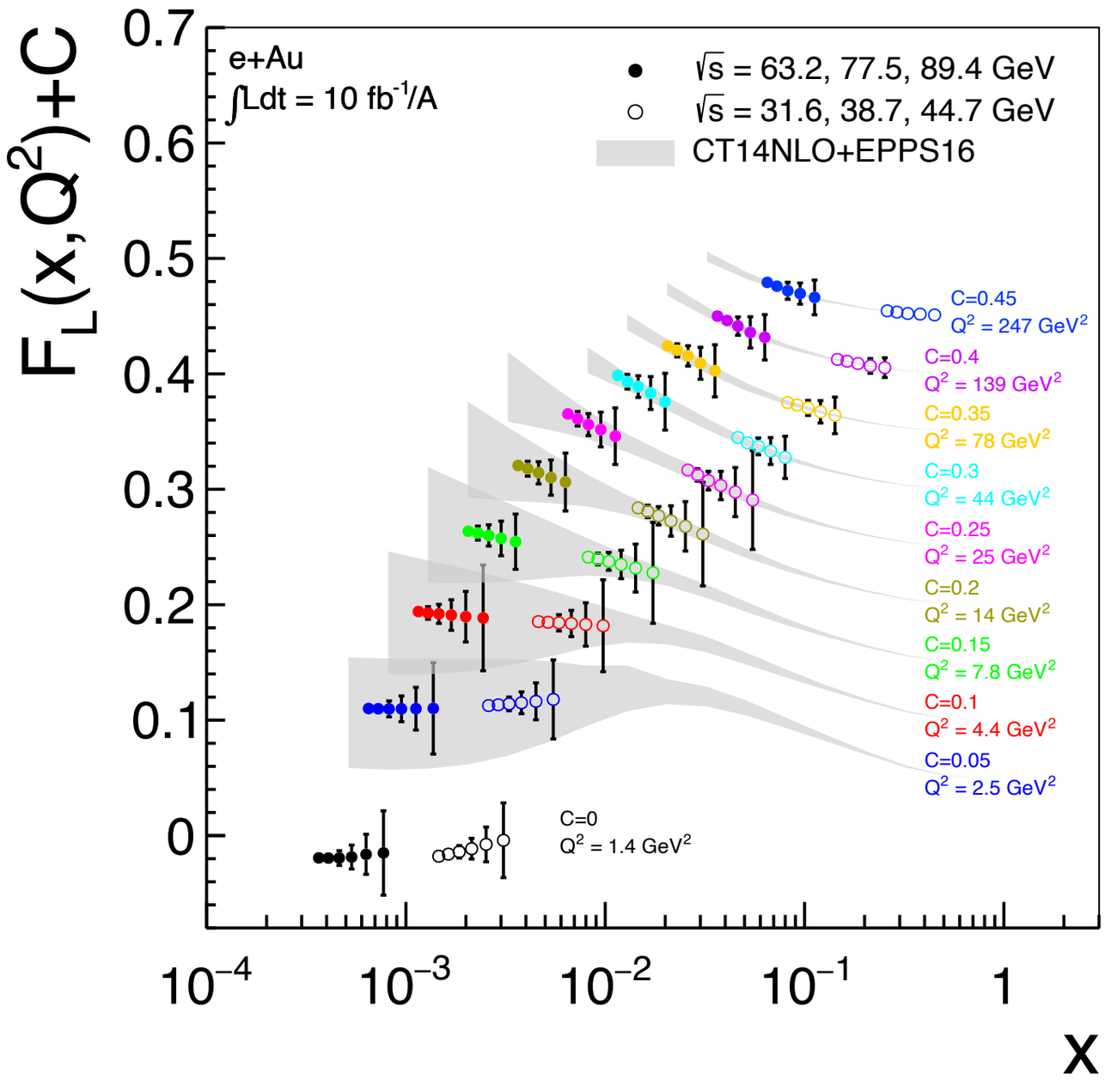
- We will be able to use the **EIC data as foundation for nPDF fits**.

- Deuterium to ^{238}U. Perhaps enough to do individual fits.

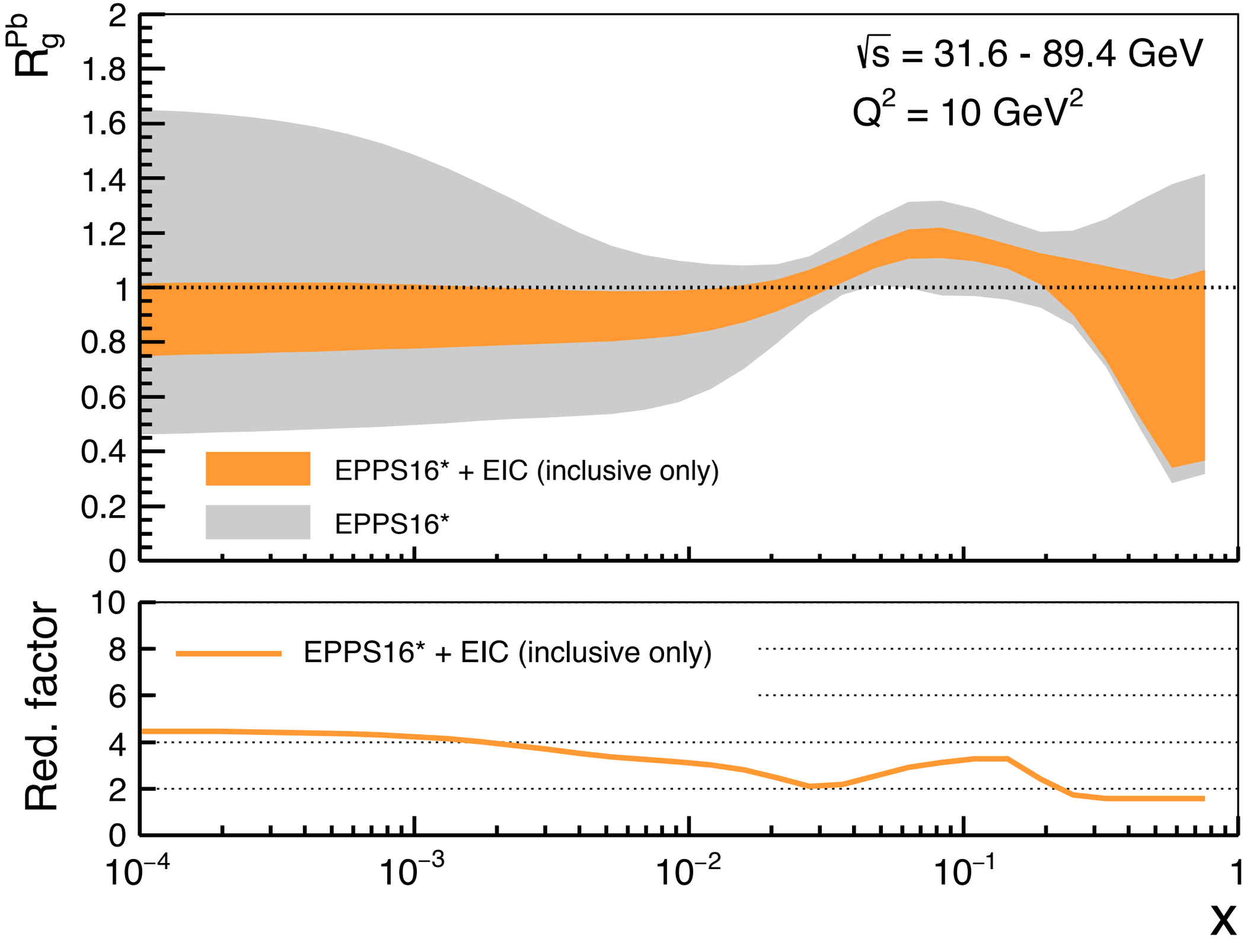
- We will also be able to properly separate the longitudinal structure function that is ***sensitive*** to the ***gluon*** density.

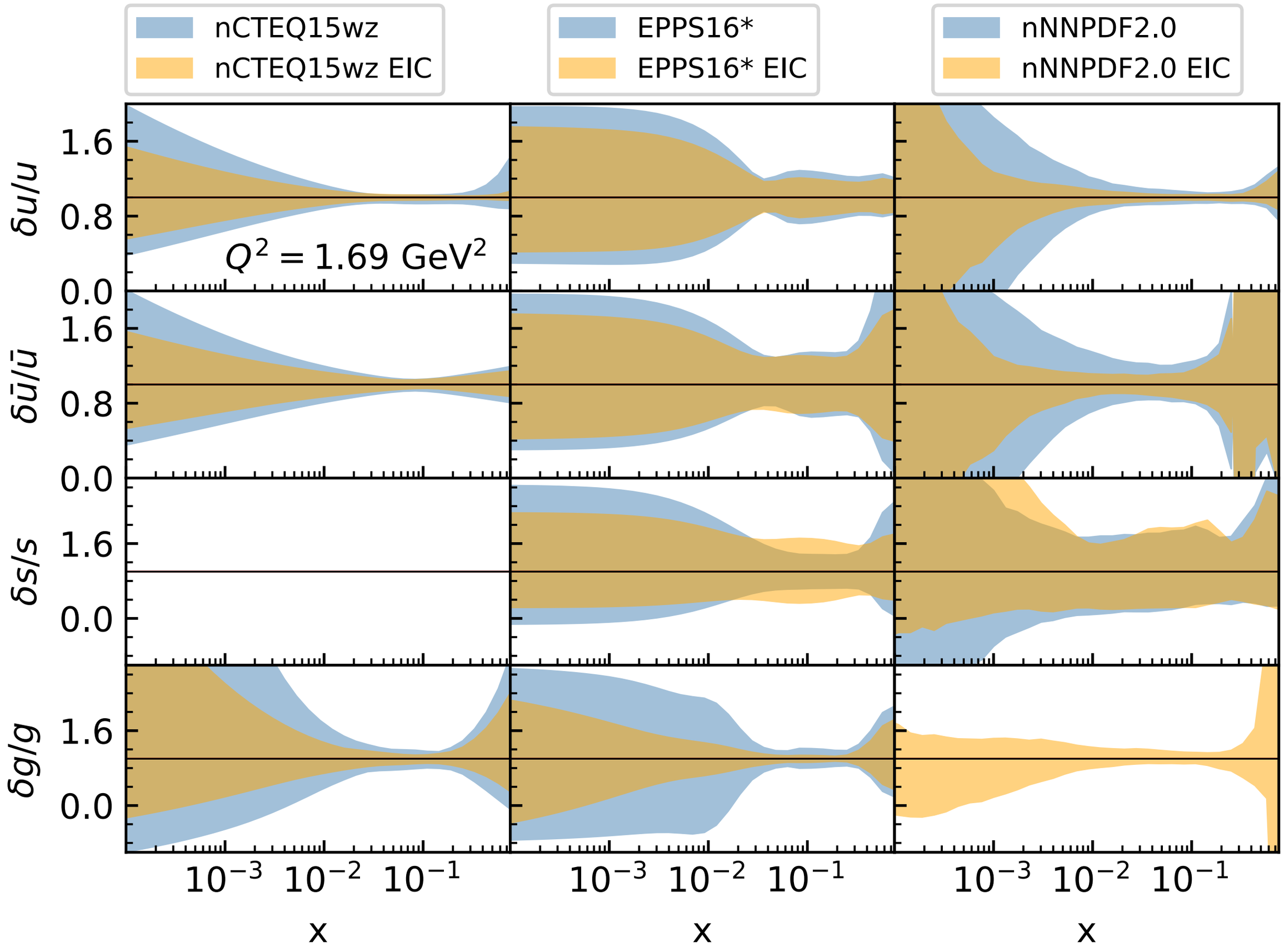
Phys.Rev.D 96 (2017) 11, 114005





Rept.Prog.Phys. 82 (2019) 2, 024301

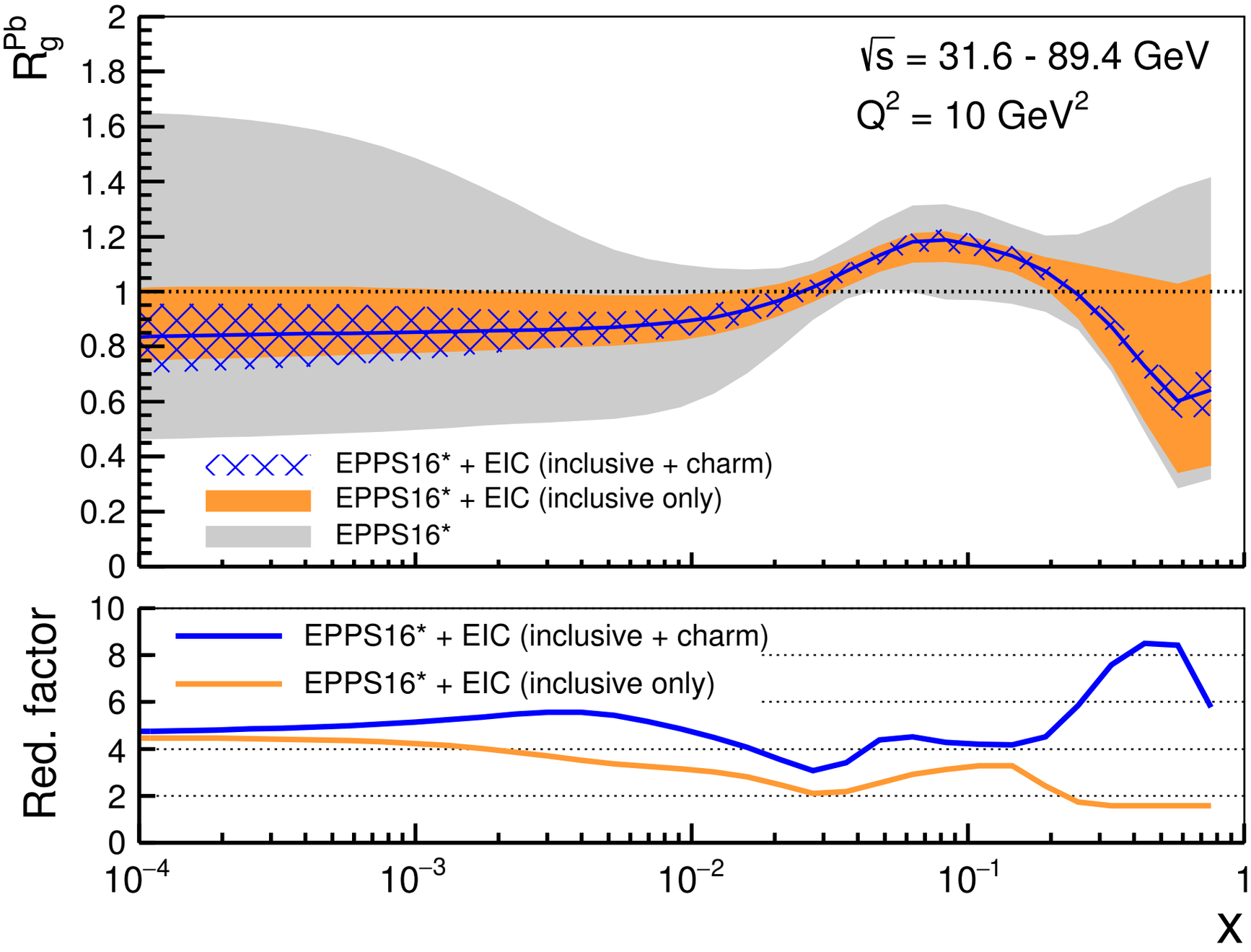




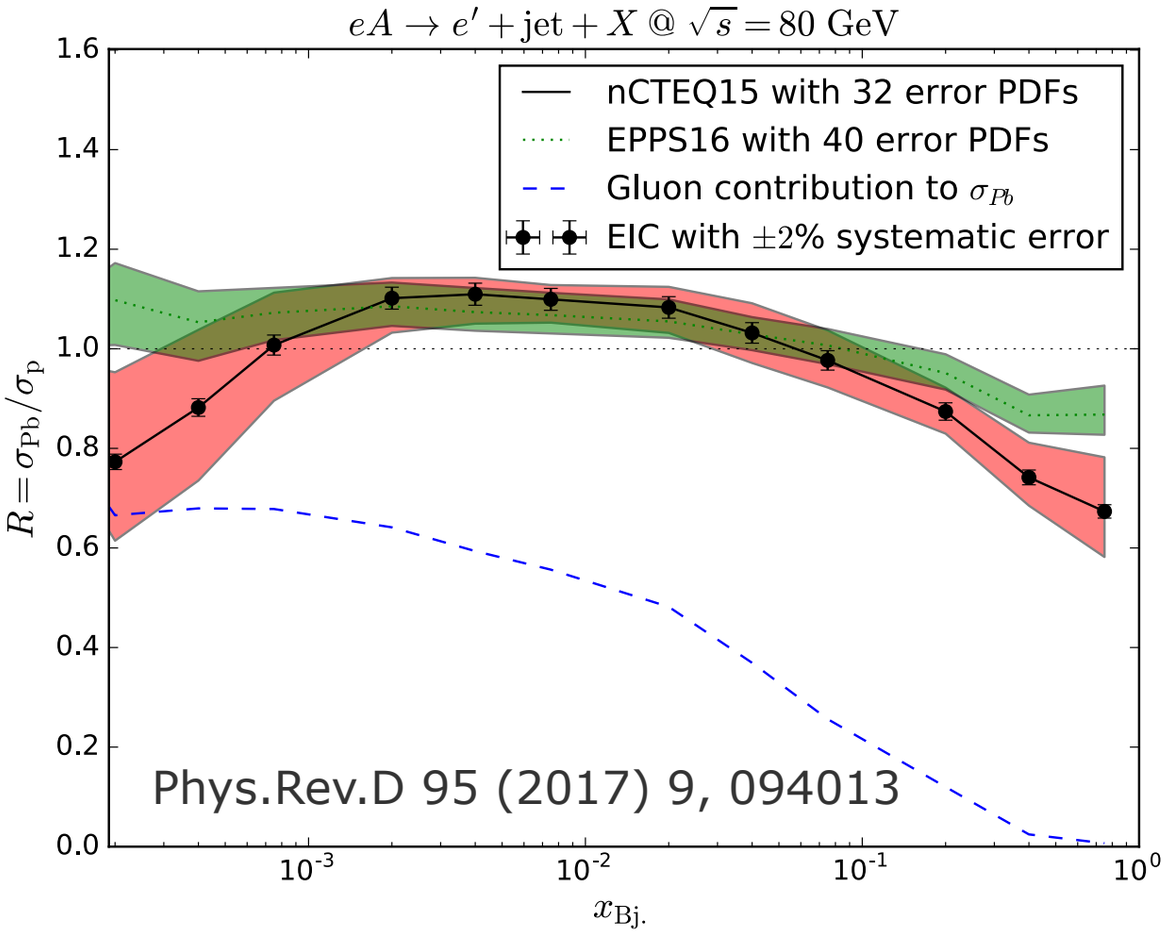
Nucl.Phys.A 1026 (2022) 122447

- Using the PID needed for SIDIS, we can identify e.g. kaons coming from *c* quarks.

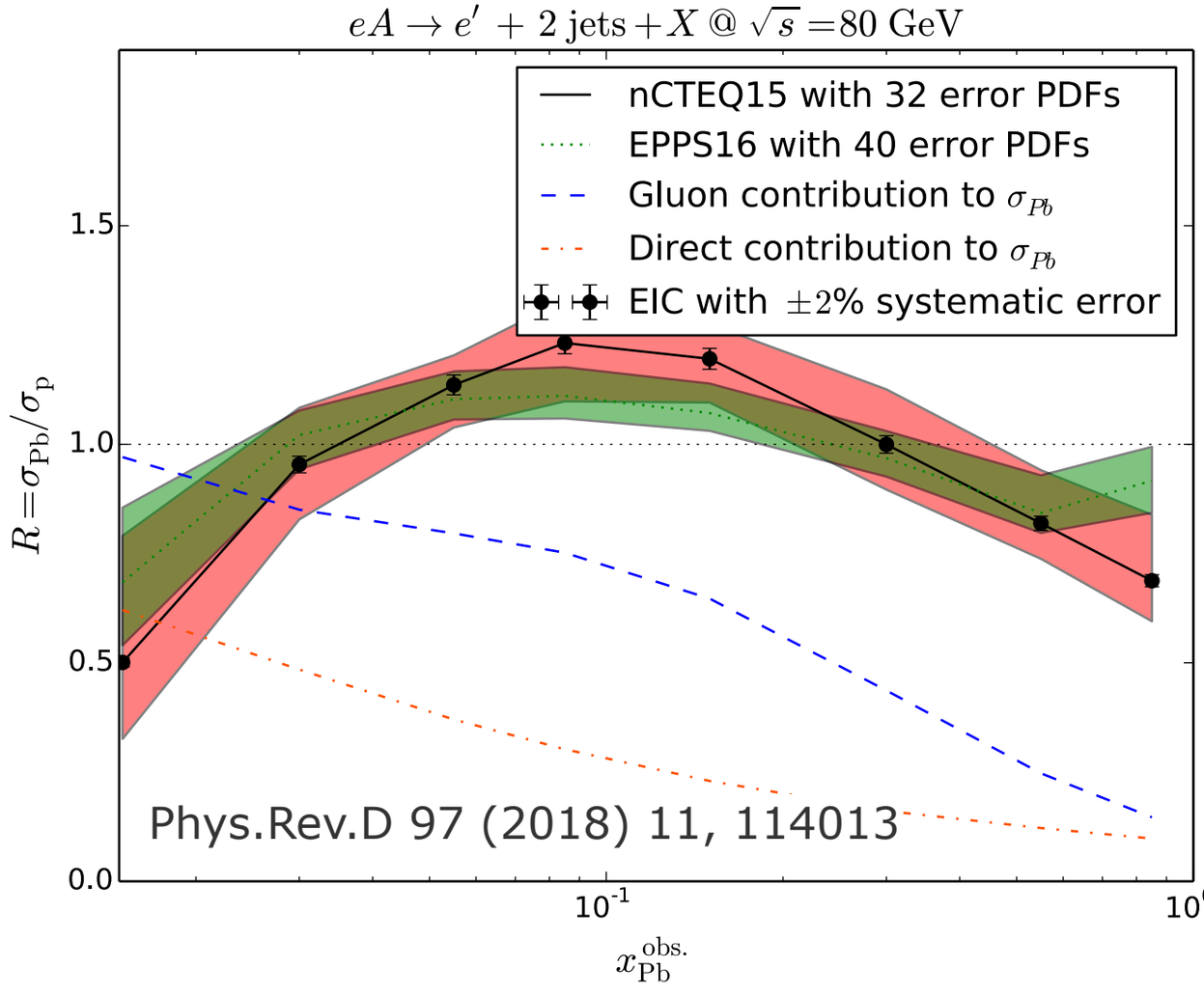
Rept.Prog.Phys. 82 (2019) 2, 024301



- For the first time we will have ***jets in e+A***!



- And di-***jets***!



Jets as precision probes in e+A at the EIC:

Phys.Rev.C 101 (2020) 6, 065204

Summary

- The EIC will be the first of its kind for the nuclear community. We will have a “nuclear” HERA.

- Just the DIS data will supersede the old fixed target experiments in quantity, precision and kin. coverage.

- For flavour separation we will continue to need complementary information.

- And we will be able to measure poorly known or unexplored observables (SIDIS, jets, etc).