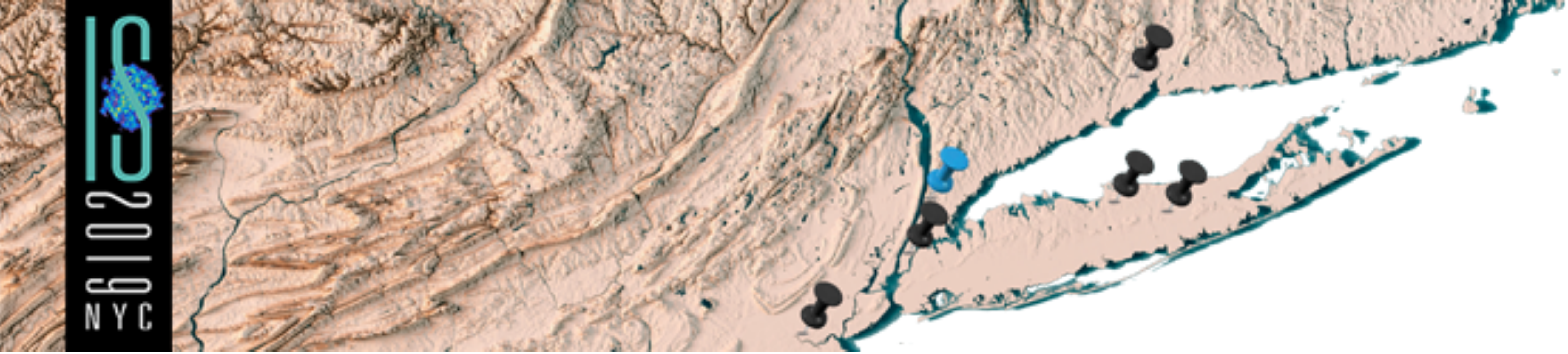


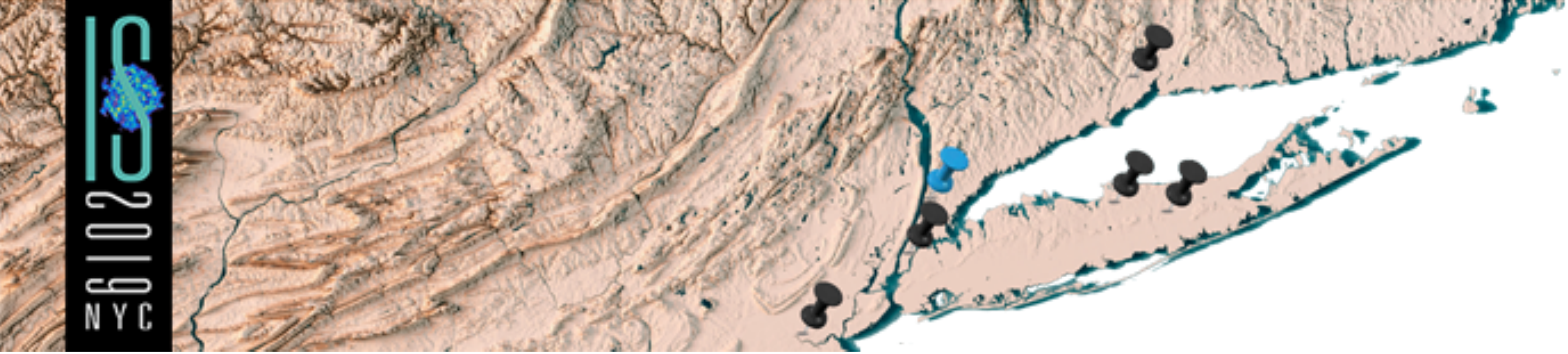
SEMI-INCLUSIVE DIS, PDFs AND FFs AT A FUTURE EIC

Ignacio Borsa
Universidad de Buenos Aires

Initial Stages 2019 New York, June 26th

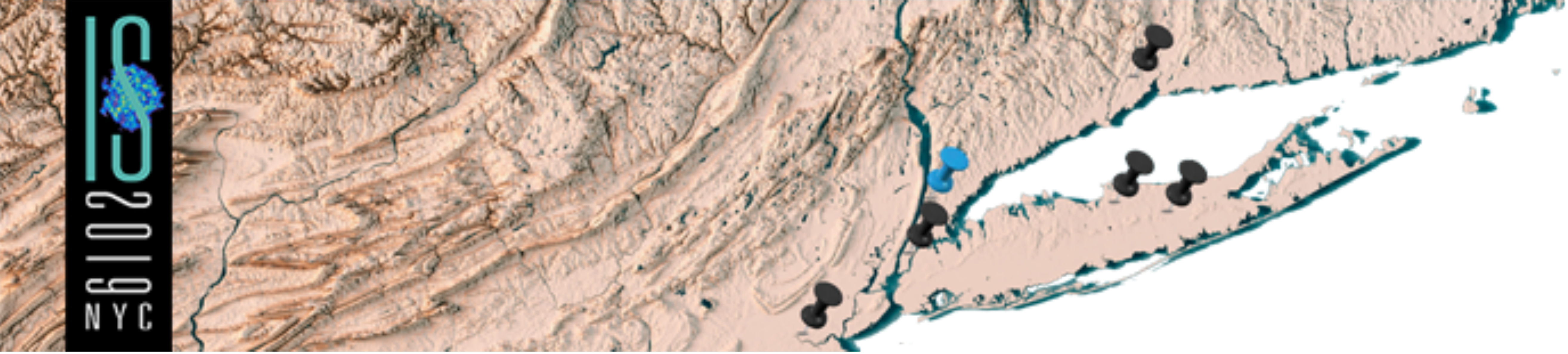
CONICET

universidad de buenos aires - exactas
departamento de física



PDFs Selected Highlights

How well do we know the sea quarks?



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Semi-Inclusive processes in Global Fits

New insights from SIDIS
Combined extraction of PDFs & FFs

IB, R. Sassot, M.Stratmann
Phys. Rev. D 96, 094020 (2017)

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Parton Distributions @ EIC
A case of study

E. Aschenauer, IB, R. Sassot, C. Van Hulse
Phys. Rev. D 99, 094004 (2019)

PDFs SELECTED HIGHLIGHTS

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Remarkable progress in the last decades:

- NNLO extractions
- High precision LHC measurements now included in fits (ATLAS/CMS W,Z production)
- Uncertainties reduction to a few percent points (and expected to be further constrained by the HL-LHC).

PDFs SELECTED HIGHLIGHTS

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- High precision LHC measurements now included in fits (ATLAS/CMS W,Z production)
- Uncertainties reduction to a few percent points (and expected to be further constrained by the HL-LHC).

We have a pretty clear image of how the quarks and gluons are distributed inside the proton

PDFs SELECTED HIGHLIGHTS

Remarkable progress in the last decades:

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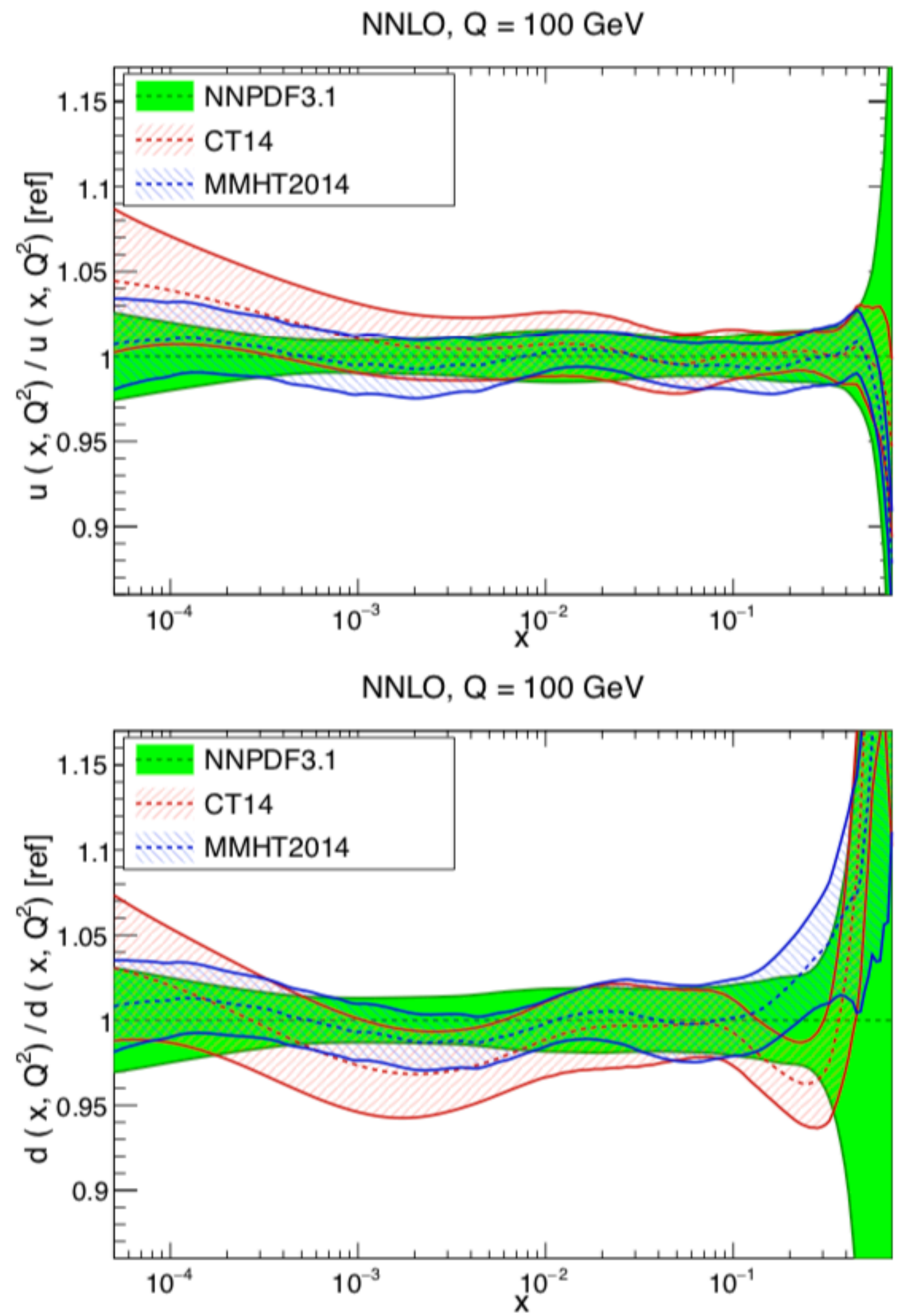
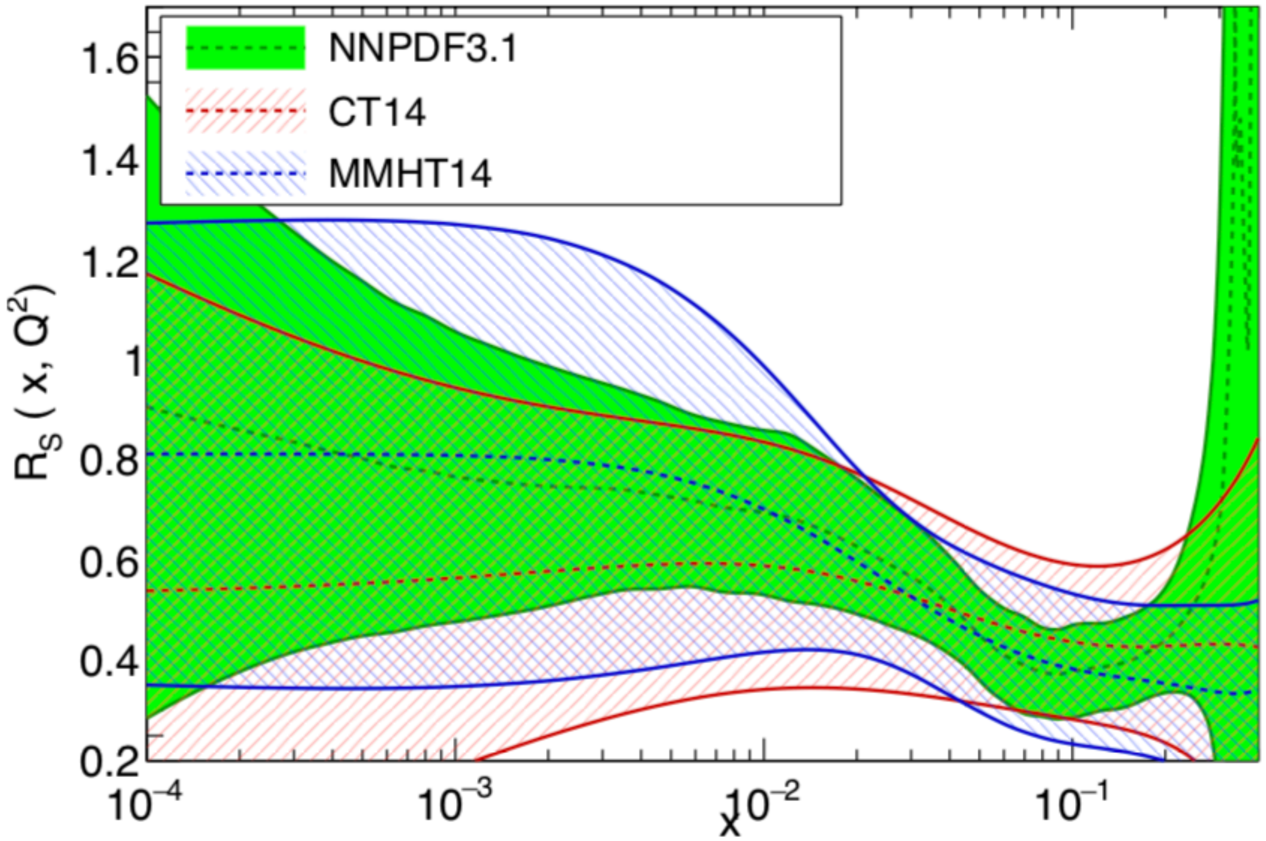


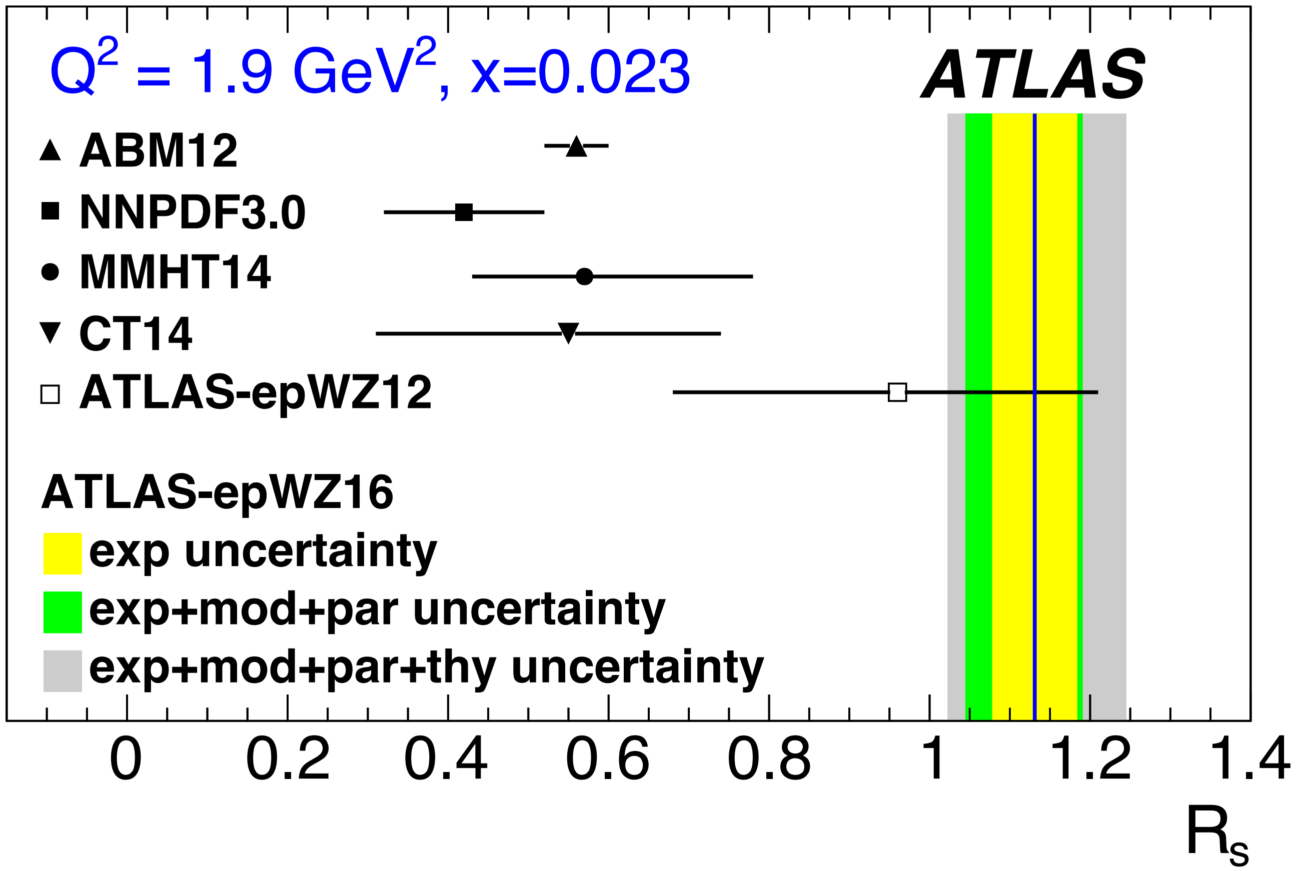
NNPDF3.1 Eur.Phys.J. C77 (2017) no.10, 663

HOW WELL DETERMINED ARE THESE PARTON DISTRIBUTIONS?

The strangeness puzzle

$$R_s(x,Q^2) = [s(x,Q^2)+\bar{s}(x,Q^2)]/[\bar{u}(x,Q^2)+\bar{d}(x,Q^2)]$$





- Strange content of the proton not so well constrained.
- Tension in strangeness driven by disagreement between collider data and neutrino DIS

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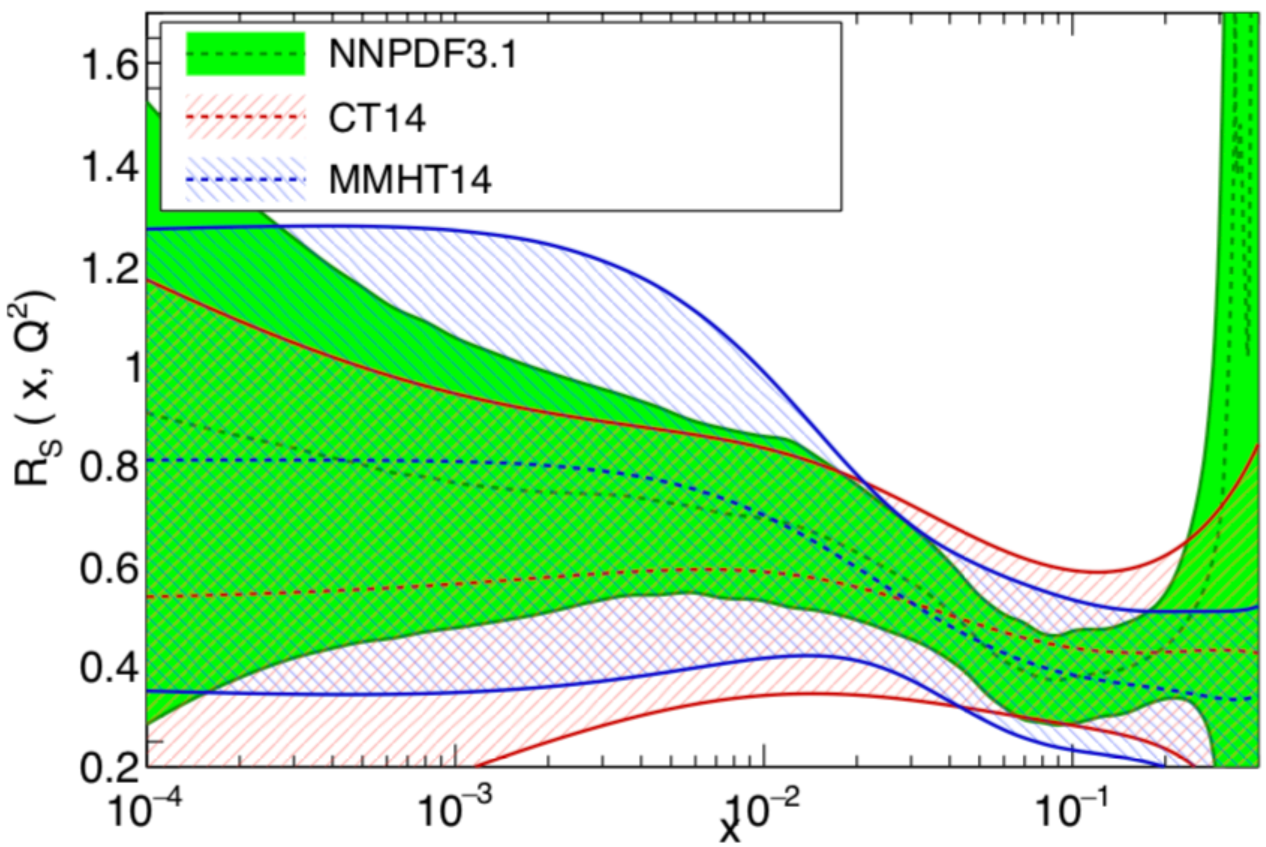

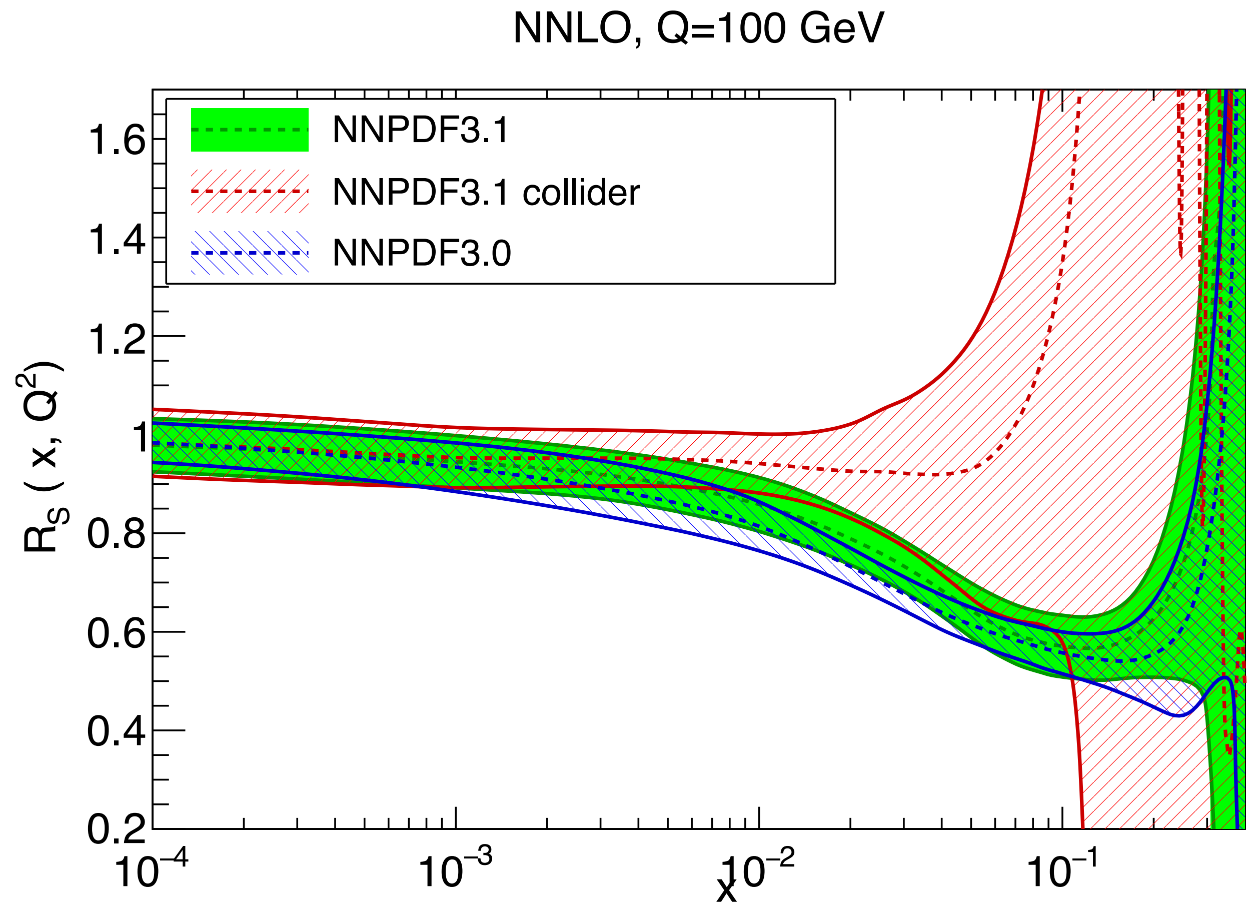

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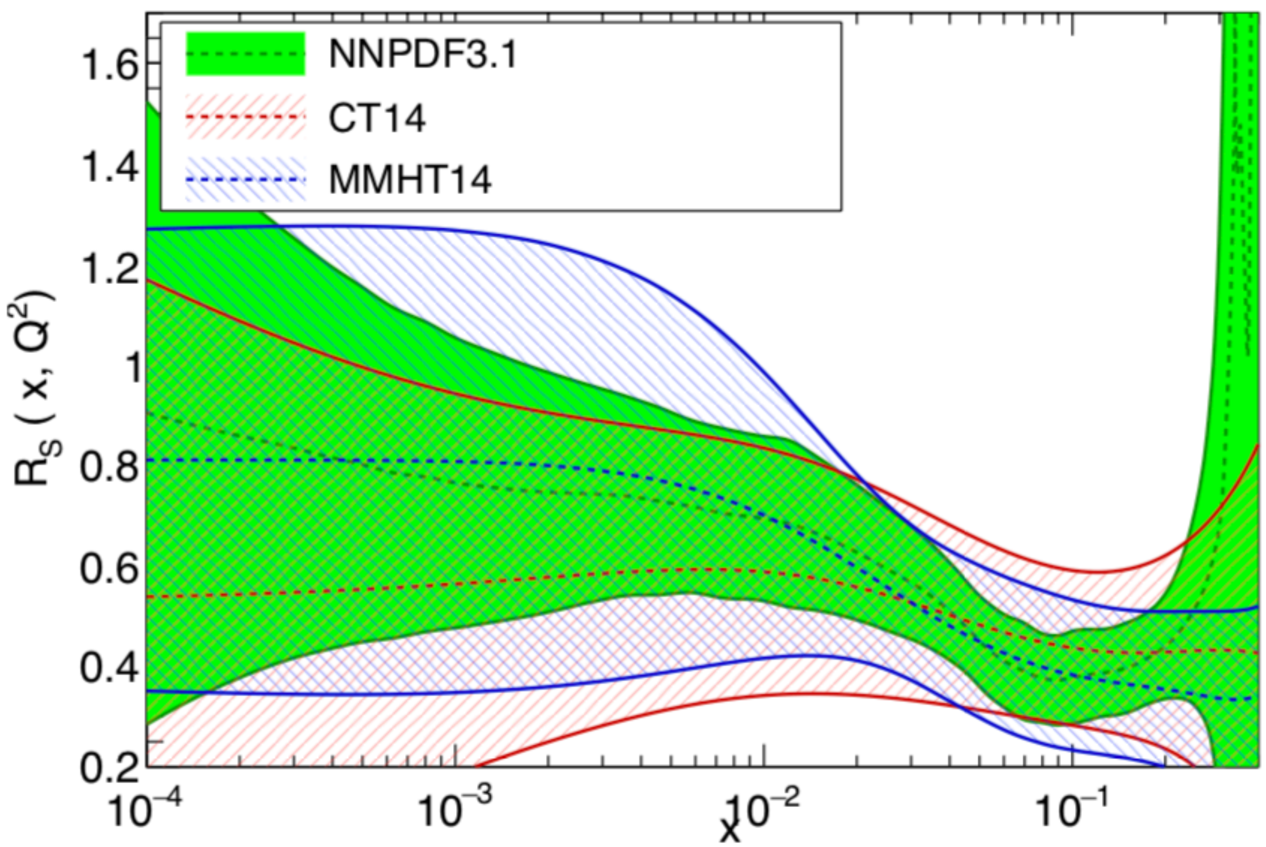
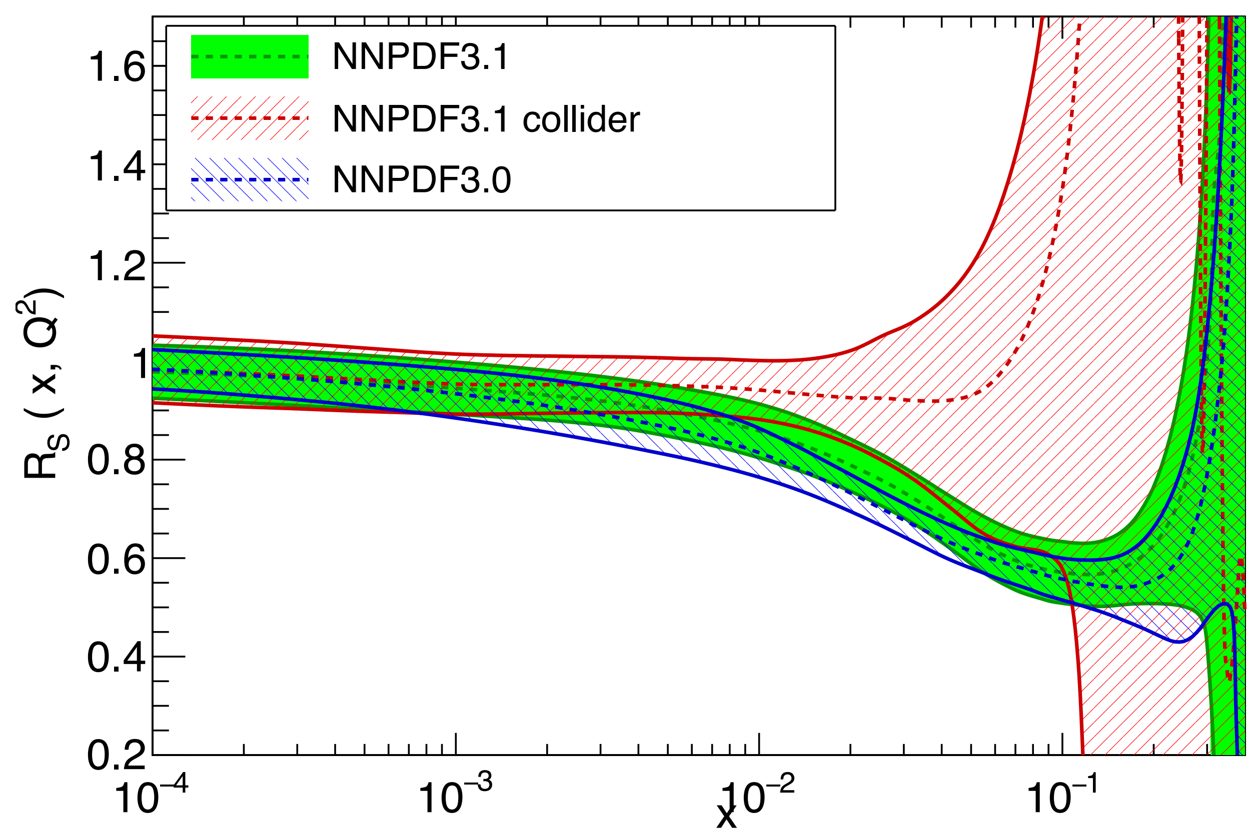
NNLO, Q=100 GeV





- Strange content of the proton not so well constrained.
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There is still a lot of room for PDFs improvement

NNPDF3.1 Eur.Phys.J. C77 (2017) no.10, 663

HOW WELL DETERMINED ARE THESE PARTON DISTRIBUTIONS?

The strangeness puzzle

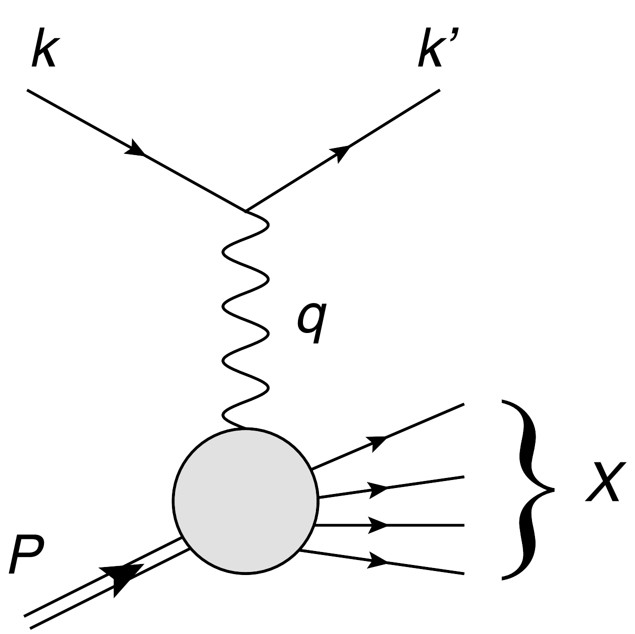
How can we improve our knowledge of the PDFs?

What can we learn from a future Electron-Ion Collider?

HOW CAN WE IMPROVE OUR KNOWLEDGE OF THE PDFS?

Which are the experiments constraining the strangeness in the proton?

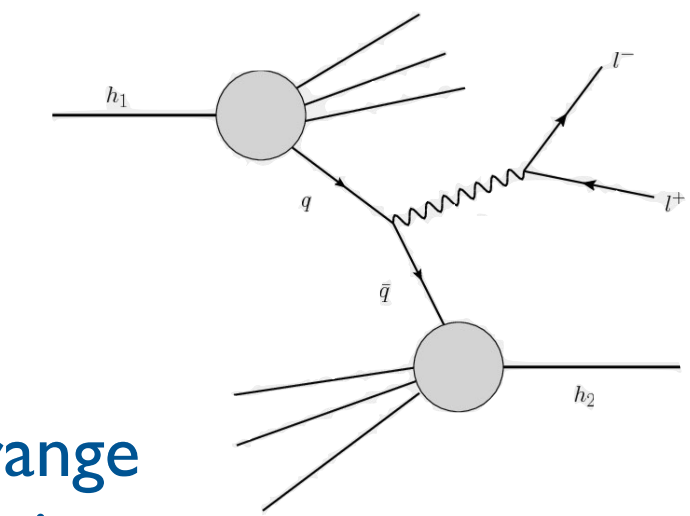
Traditional approach: completely inclusive DIS data

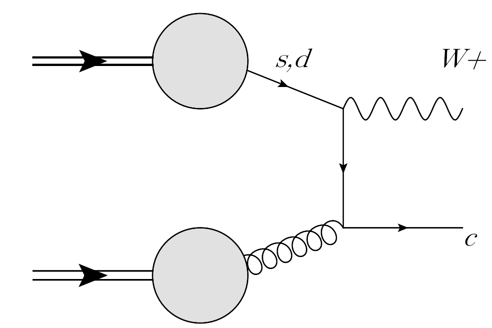


$$[f_q^P(x)+f_{\bar{q}}^P(x)]$$

Deuterium + Flavor symmetries for flavor separation

For strange distributions





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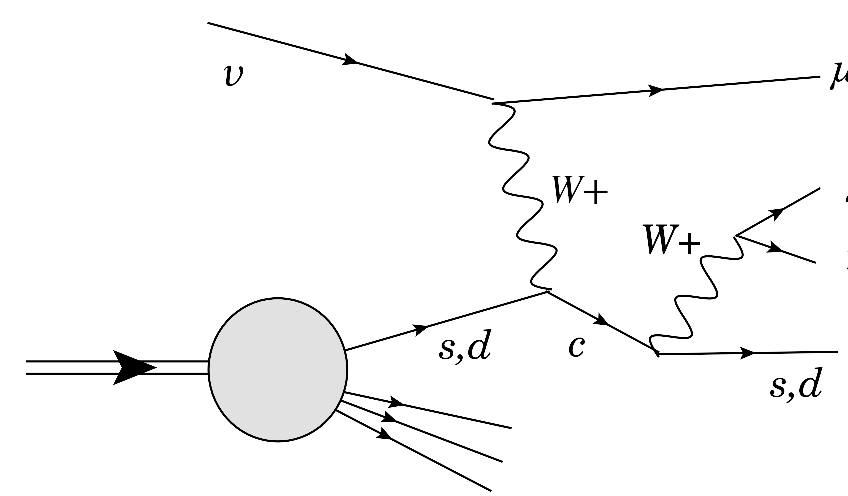

- DIS with electroweak currents
- W/Z production in p-p

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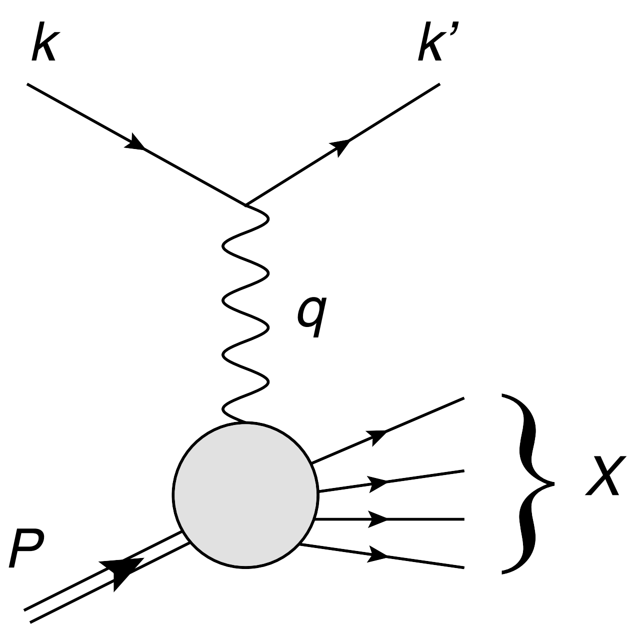

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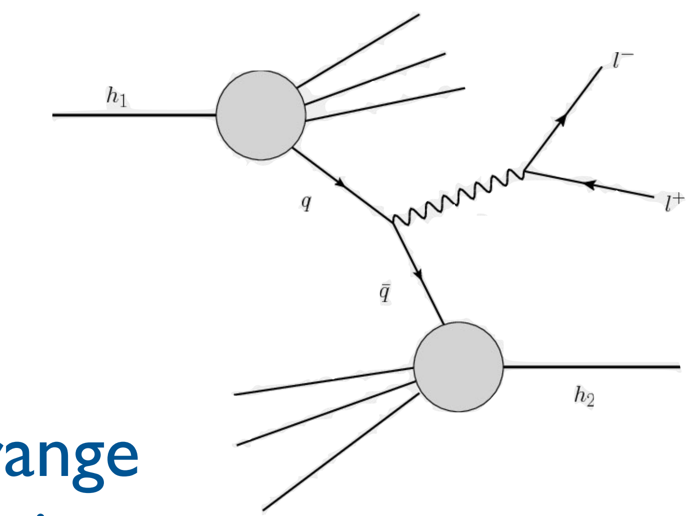

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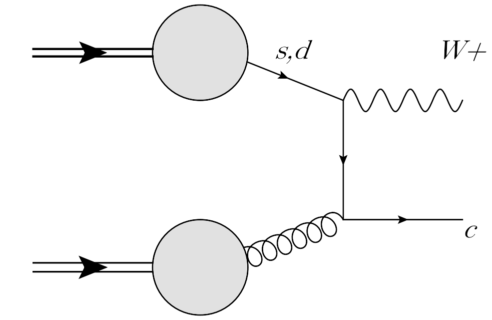
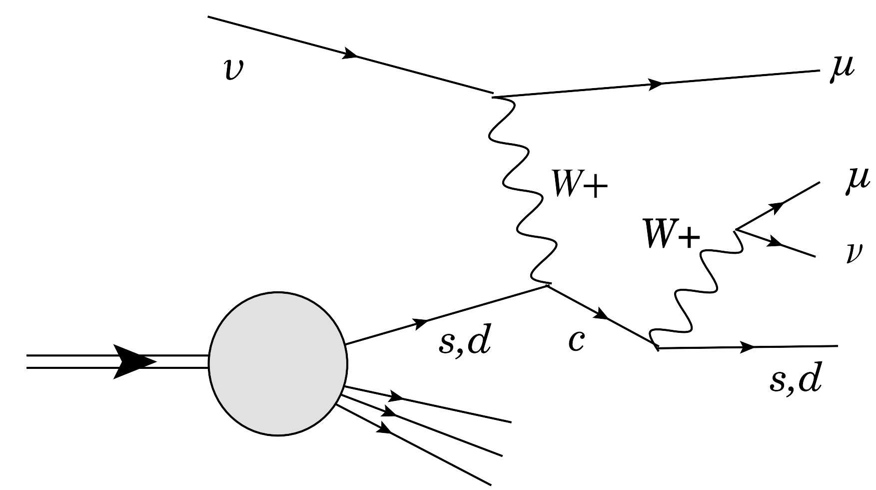
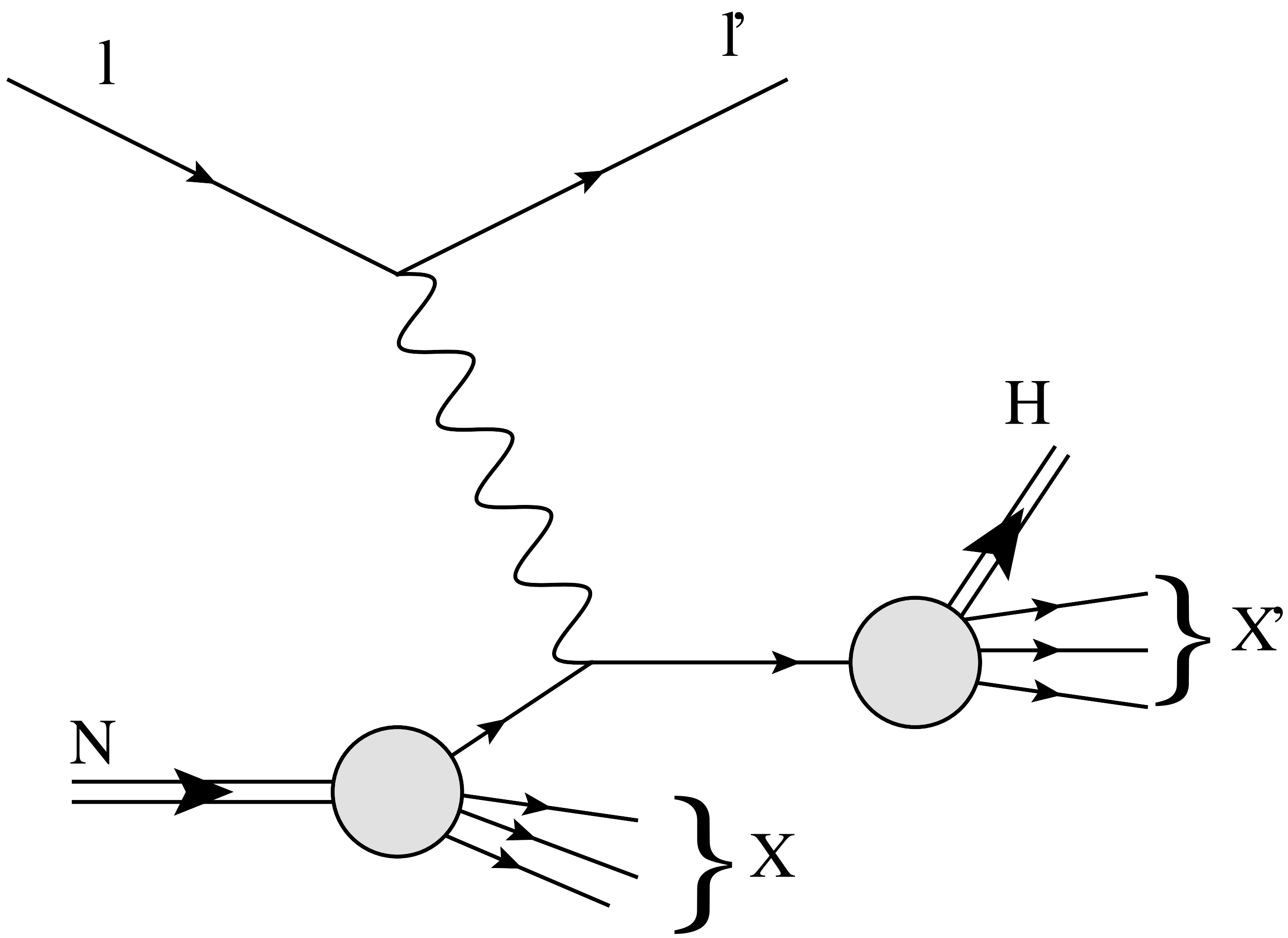




Indirect sensitivity to the strange content of the proton

IDENTIFIED FINAL STATE PARTICLES OBSERVABLES

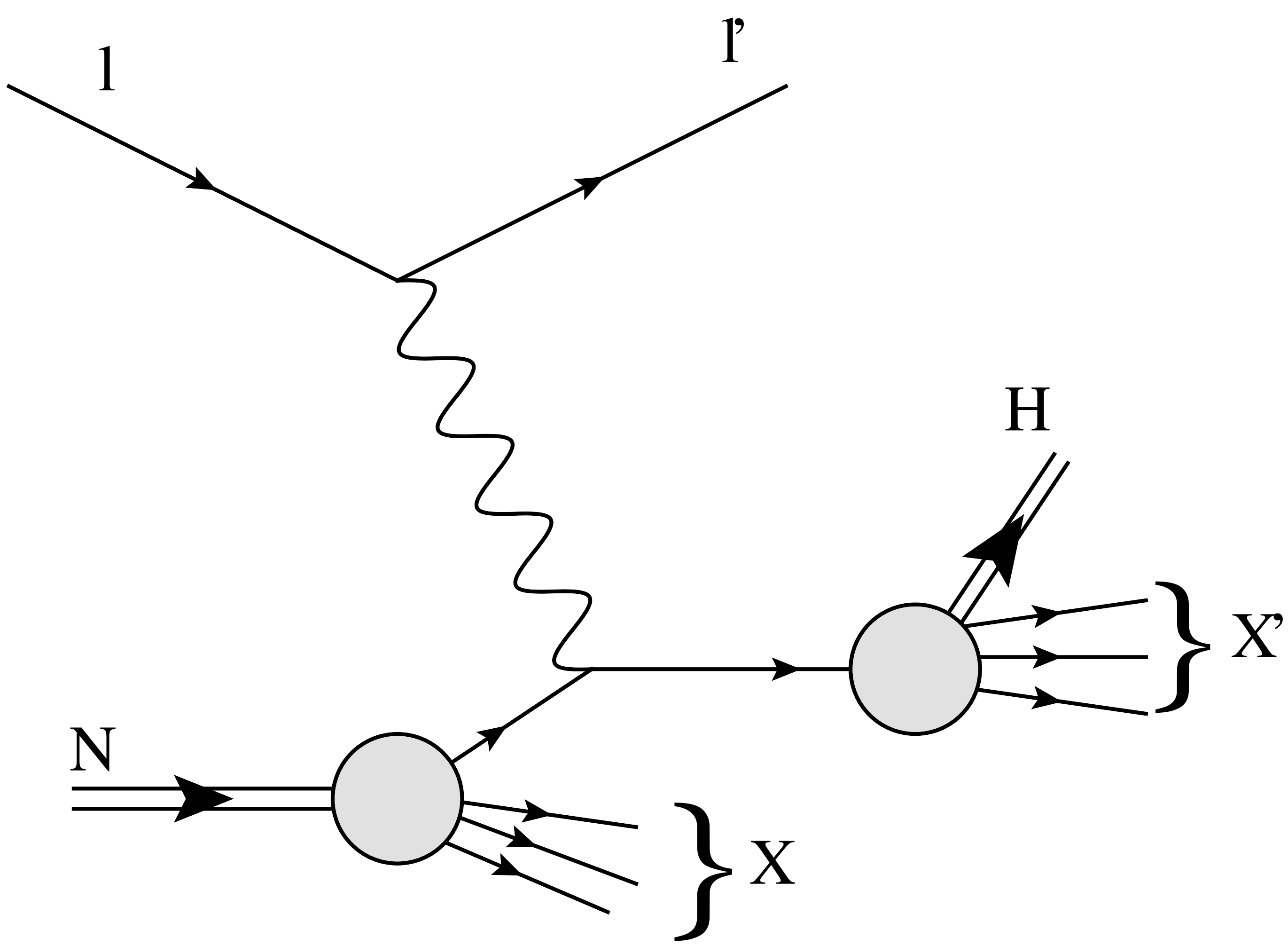
SIDIS as a tool to probe the sea quark distributions



$$\sum_q e_q^2 \, D_q^H(x, Q^2) \otimes f_q(x, Q^2)$$

IDENTIFIED FINAL STATE PARTICLES OBSERVABLES

SIDIS as a tool to probe the sea quark distributions



FFs acting as an effective charges, allowing for flavor a separation

$$\sum_q \boxed{e_q^2 D_q^H(x,Q^2)} \otimes f_q(x,Q^2)$$

IDENTIFIED FINAL STATE PARTICLES OBSERVABLES

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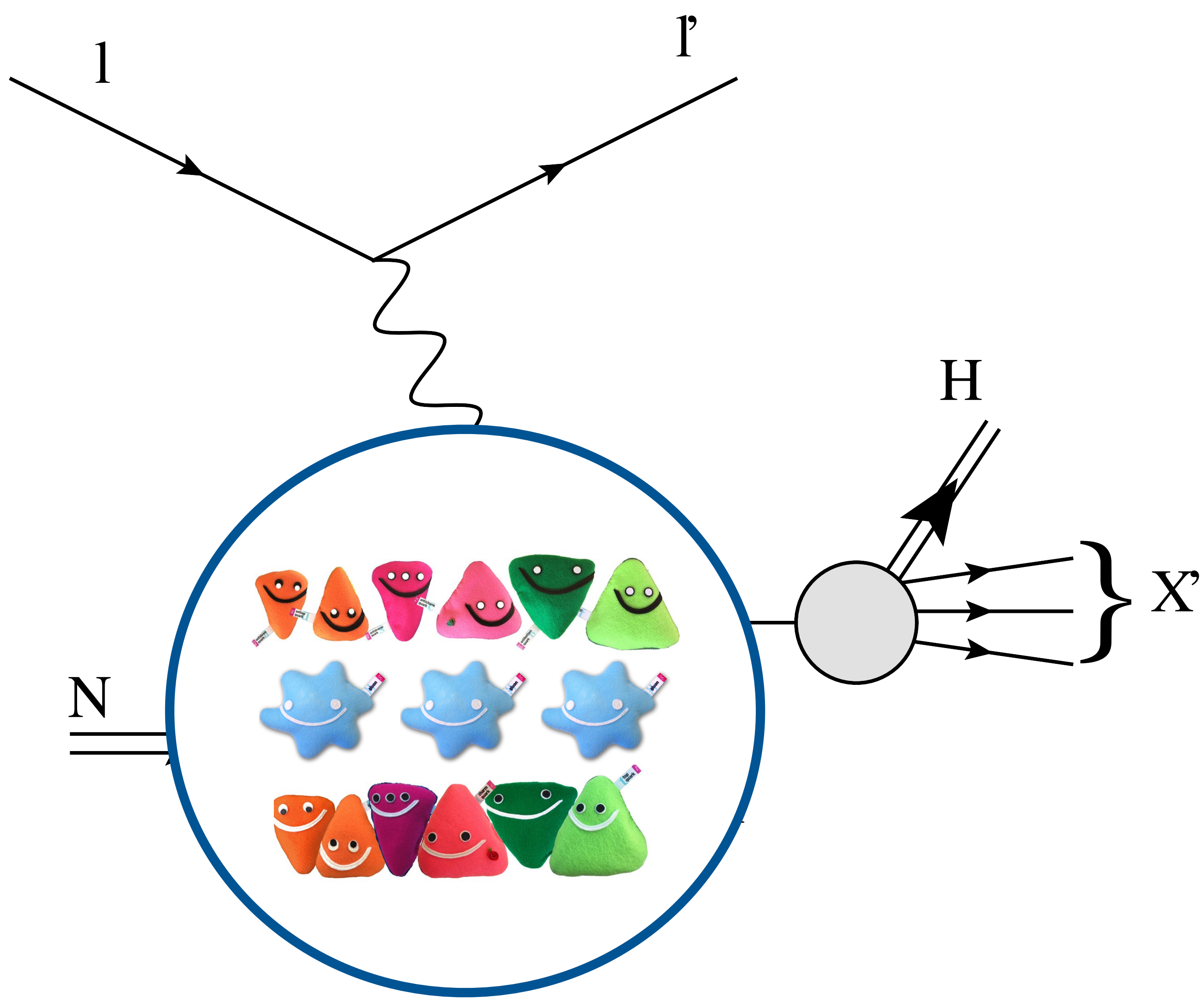

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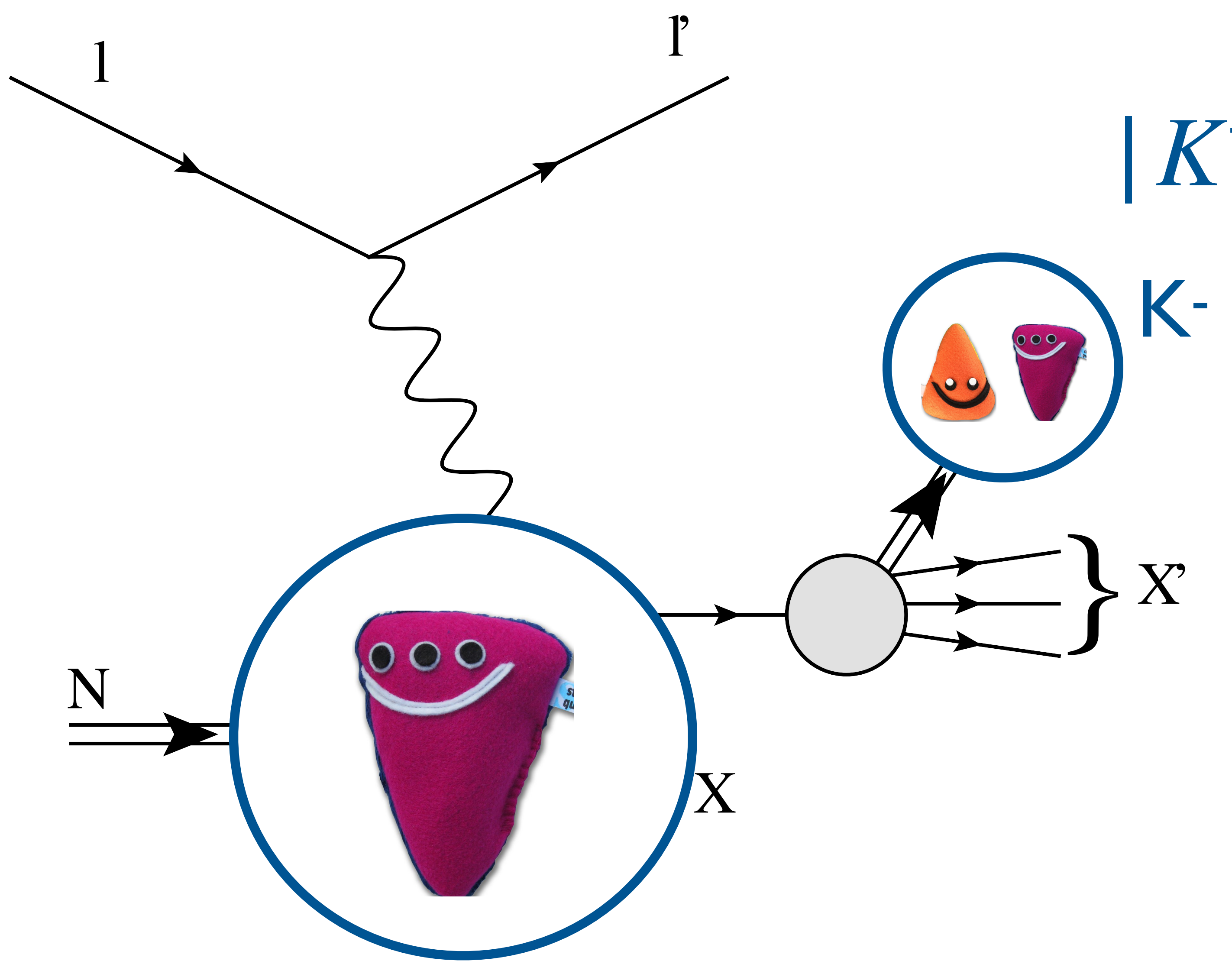
IDENTIFIED FINAL STATE PARTICLES OBSERVABLES

SIDIS as a tool to probe the sea quark distributions

$$|K^+\rangle = |u\bar{s}\rangle \quad |K^-\rangle = |\bar{u}s\rangle$$

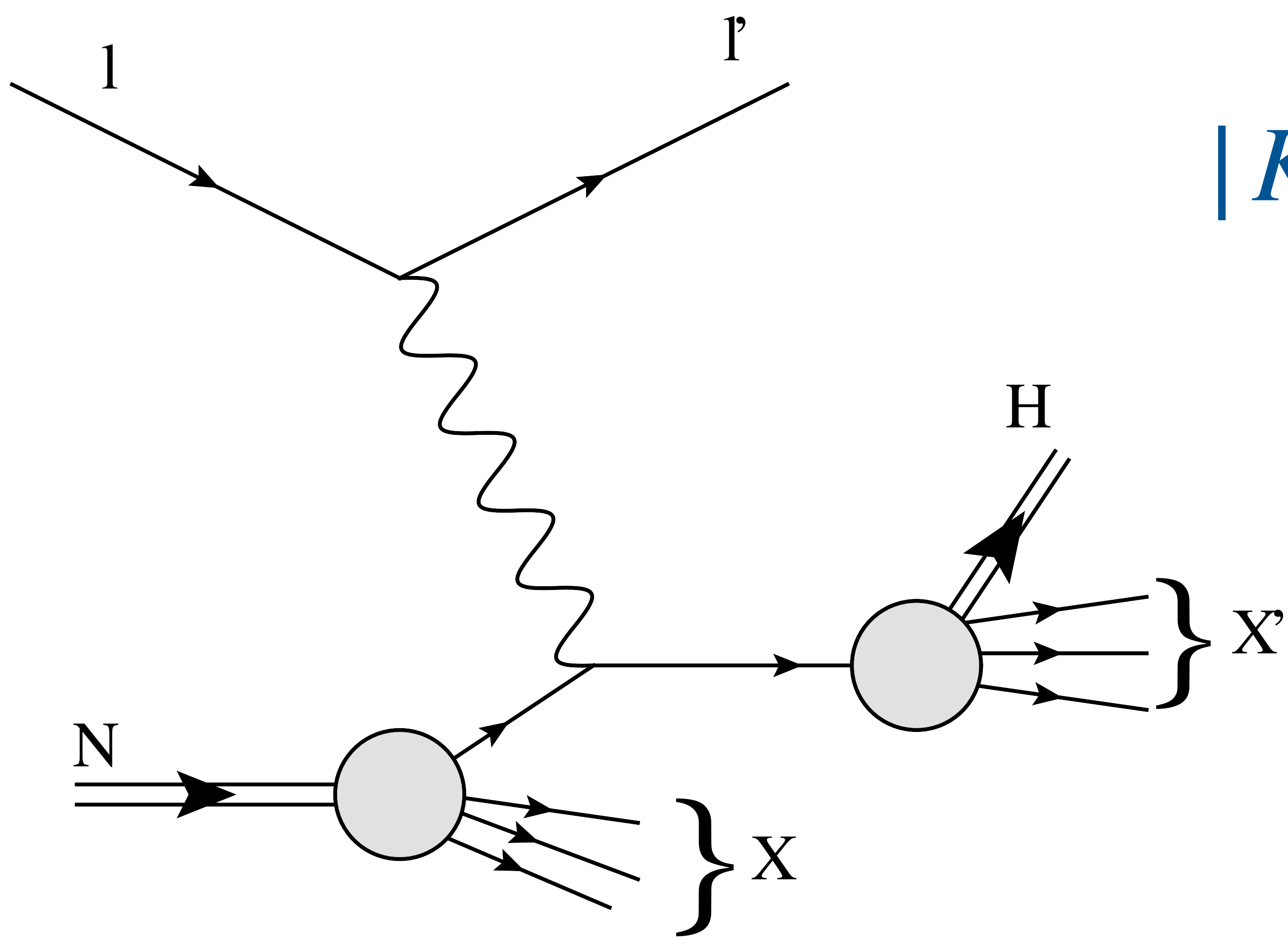


Kaon production as a tool to pin down the strangeness in the proton

$$\sum_q e_q^2 D_q^H(x, Q^2) \otimes f_q(x, Q^2)$$

IDENTIFIED FINAL STATE PARTICLES OBSERVABLES

SIDIS as a tool to probe the sea quark distributions



$$|K^+\rangle = |u\bar{s}\rangle \quad |K^-\rangle = |\bar{u}s\rangle$$

Semi-inclusive observables as a tool to probe the sea quark of the proton

$$\sum_q e_q^2 \, D_q^H(x, Q^2) \otimes f_q(x, Q^2)$$

PDFs & FFs global fit?

IDENTIFIED FINAL STATE PARTICLES OBSERVABLES

PDFs & FFs Combined Global Extraction: Cross-Talk between non perturbative quantities

Big number of parameters to fit

IDENTIFIED FINAL STATE PARTICLES OBSERVABLES

PDFs & FFs Combined Global Extraction: Cross-Talk between non perturbative quantities

Big number of parameters to fit

Factorial-like increase in the number of iterations needed

IDENTIFIED FINAL STATE PARTICLES OBSERVABLES

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Different Phase Space/ Precision

IDENTIFIED FINAL STATE PARTICLES OBSERVABLES

PDFs & FFs Combined Global Extraction: Cross-Talk between non perturbative quantities

~~Big number of parameters to fit~~

~~Factorial-like increase in the number of iterations needed~~

~~Different Phase Space/ Precision~~

IDENTIFIED FINAL STATE PARTICLES OBSERVABLES

PDFs & FFs Combined Global Extraction: Cross-Talk between non perturbative quantities

~~Big number of parameters to fit~~

~~Factorial-like increase in the number of iterations needed~~

~~Different Phase Space/ Precision~~

Some effort made in this direction:

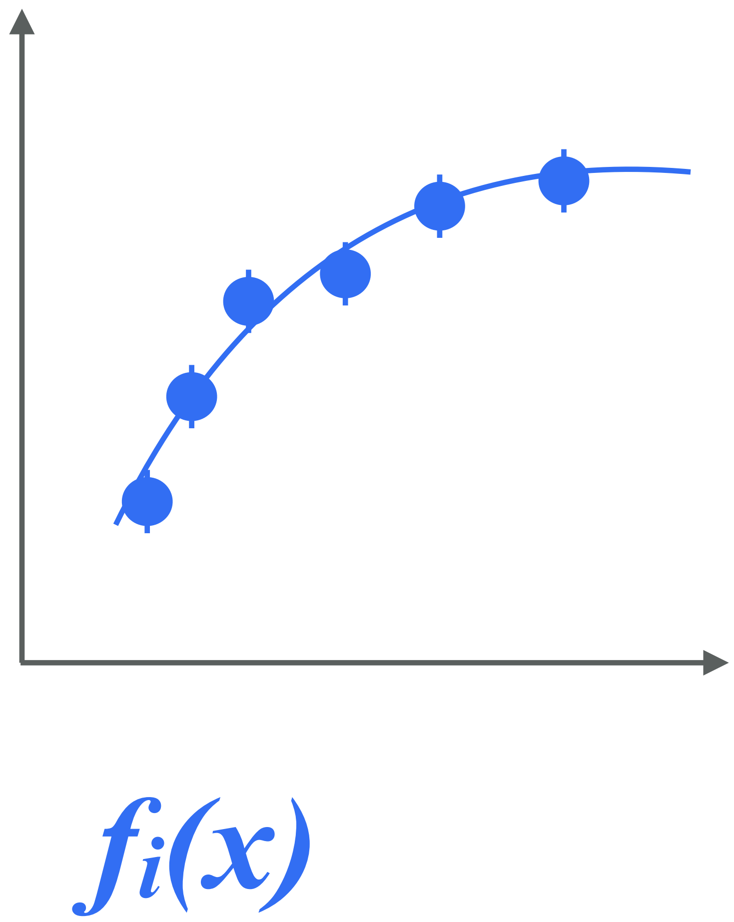
JAM Collaboration PDFs+FFs
arXiv:1905.03788

JAM Collaboration polPDFs+FFs
Phys.Rev.Lett. 119 (2017)

IDENTIFIED FINAL STATE PARTICLES OBSERVABLES

A different approach: Bayesian Inference

Based on the previous generation of replicas of the PDFs/FFs



NNPDF: Nucl.Phys. B849 (2011)112-143

IDENTIFIED FINAL STATE PARTICLES OBSERVABLES

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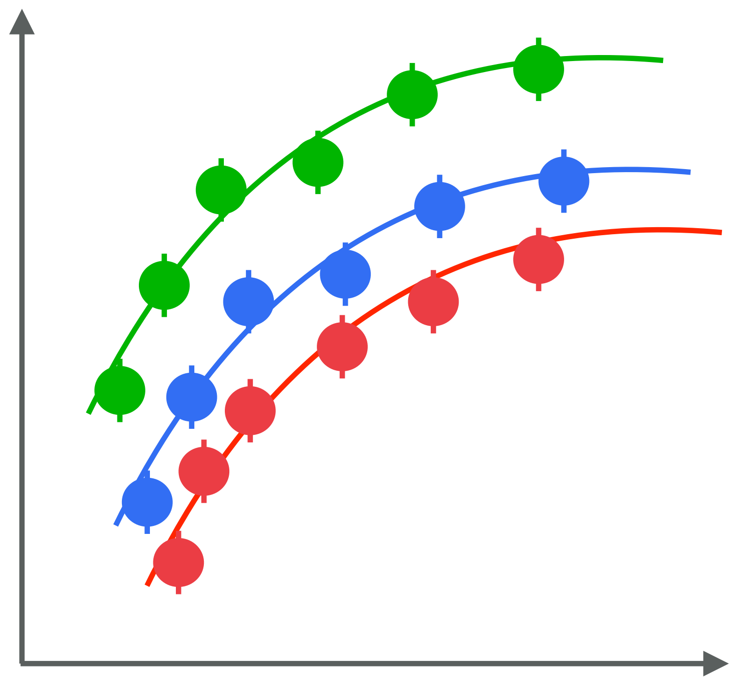

$f_i(x)$

$f_i(x)$

$f_i(x)$

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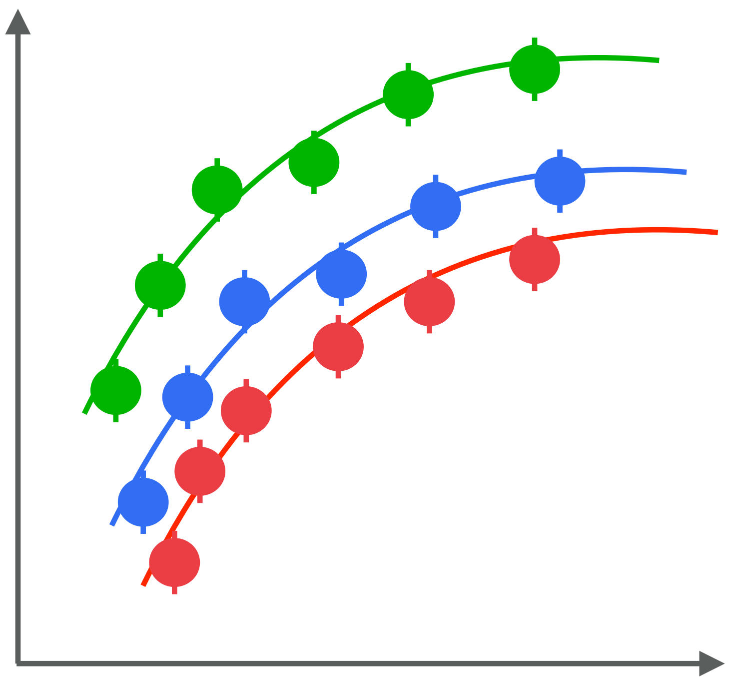

Statistically sound uncertainties

Allows for the inclusion of new data without a refit

$f_i(x)$

$f_i(x)$

$f_i(x)$

$$\langle \mathcal{O} \rangle = \frac{1}{N_{rep}} \sum_{k=1}^{N} \mathcal{O}[f(k)]$$

$$\Delta \mathcal{O}^2 = \frac{1}{(N_{rep} - 1)} \sum_{k=1}^{N} (\mathcal{O}[f(k)] - \langle \mathcal{O} \rangle)^2$$

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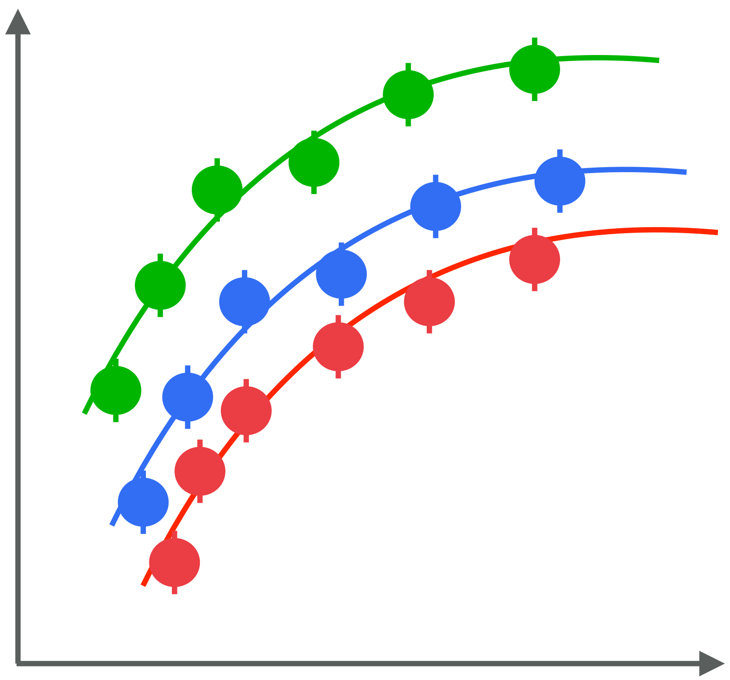

$f_i(x)$ $w(k)$

$f_i(x)$ $w(k)$

$f_i(x)$ $w(k)$

We can include new information in the fit:

$$\chi^2(y,f) = \sum_i \frac{(y_i - y_i[f])^2}{\sigma_i^2}$$

$$w(k) \propto e^{-\frac{1}{2}\chi^2(f_k)}$$

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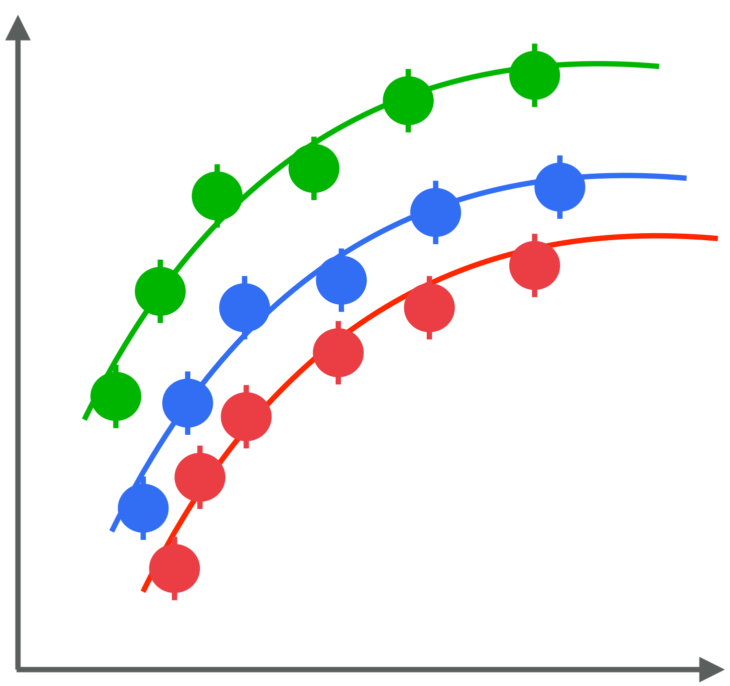

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$f_i(x)$ $w(k)$

$f_i(x)$ $w(k)$

$f_i(x)$ $w(k)$

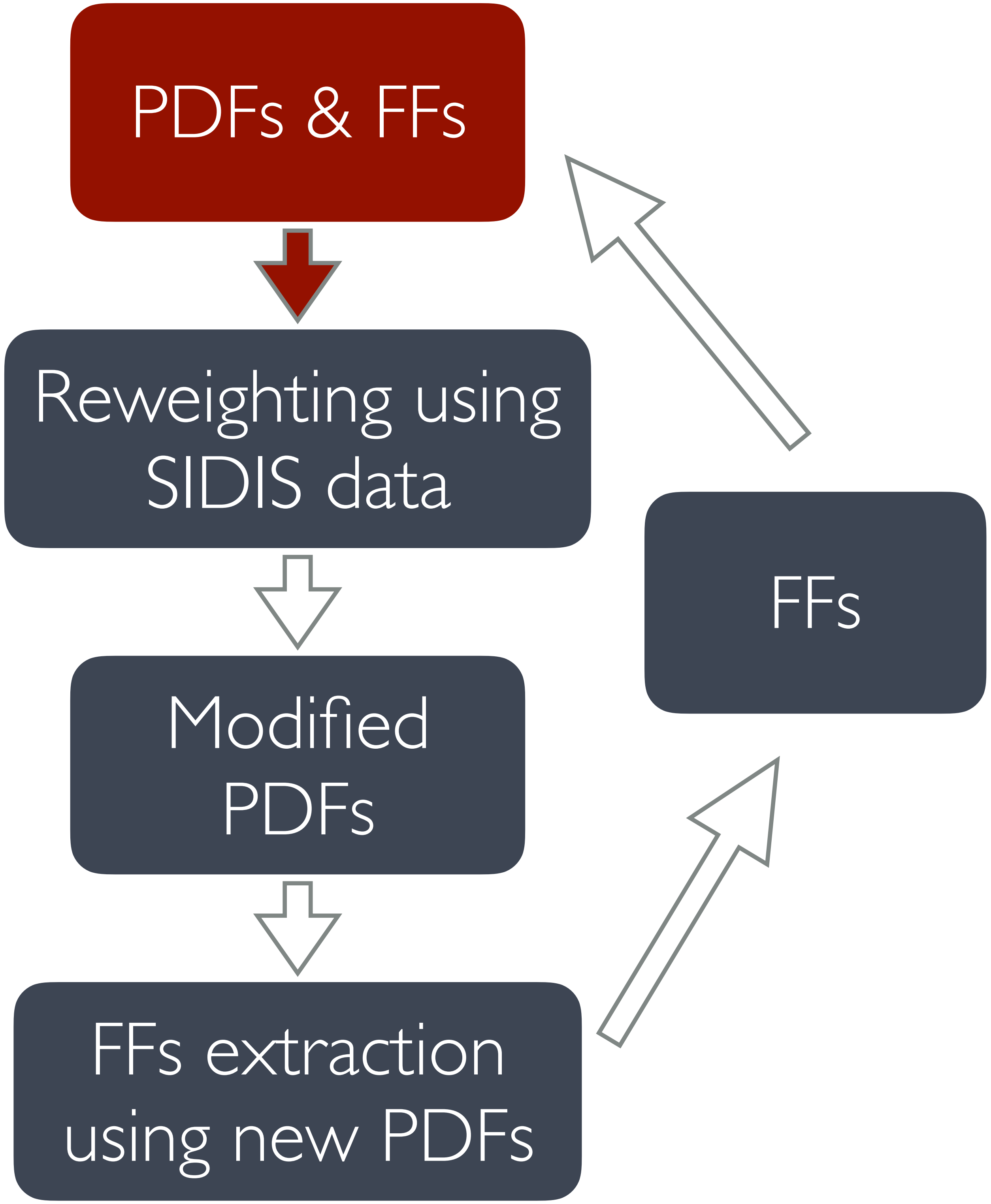
$$\langle \mathcal{O} \rangle_{new} = \frac{1}{N_{rep}} \sum_{k=1}^{N} \mathcal{O}[f(k)] \cdot w(k)$$

$$\Delta \mathcal{O}^2_{new} = \frac{1}{(N_{rep} - 1)} \sum_{k=1}^{N} (\mathcal{O}[f(k)] - \langle \mathcal{O} \rangle)^2 \cdot w(k)$$

NNPDF: Nucl.Phys. B849 (2011)112-143

ITERATIVE PDF & FF EXTRACTION

IB, R. Sassot, M.Stratmann Phys. Rev. D 96, 094020 (2017)



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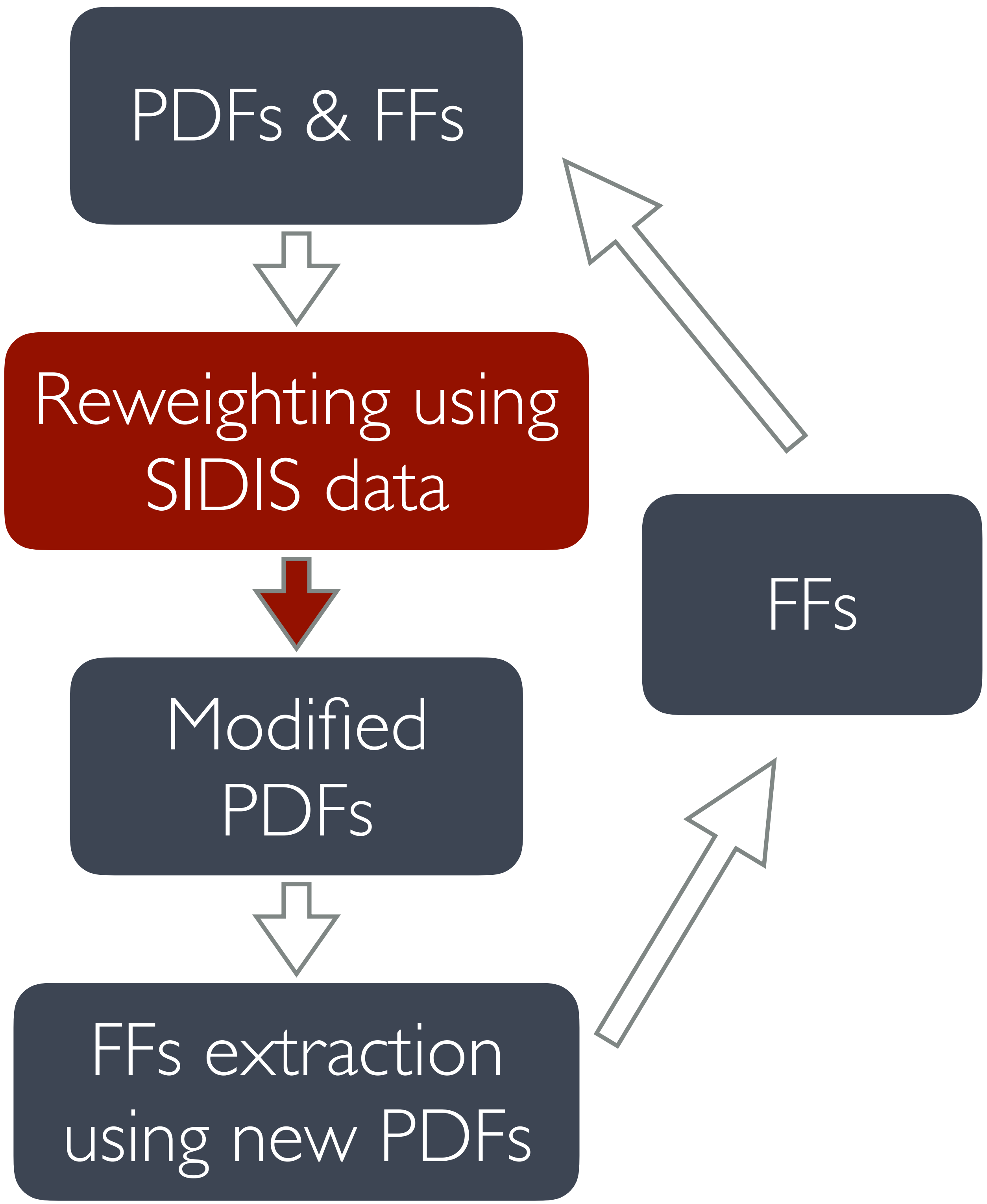

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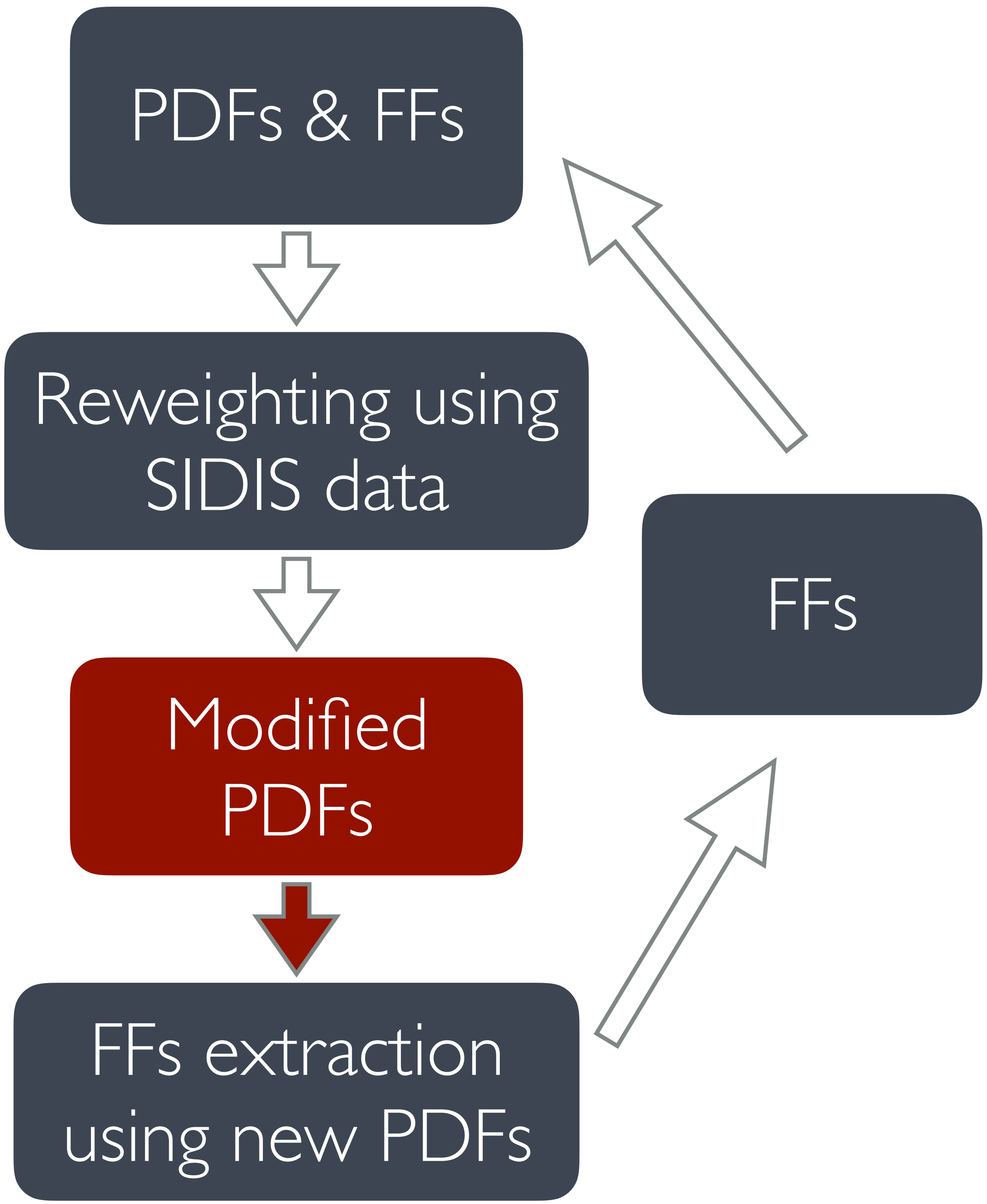

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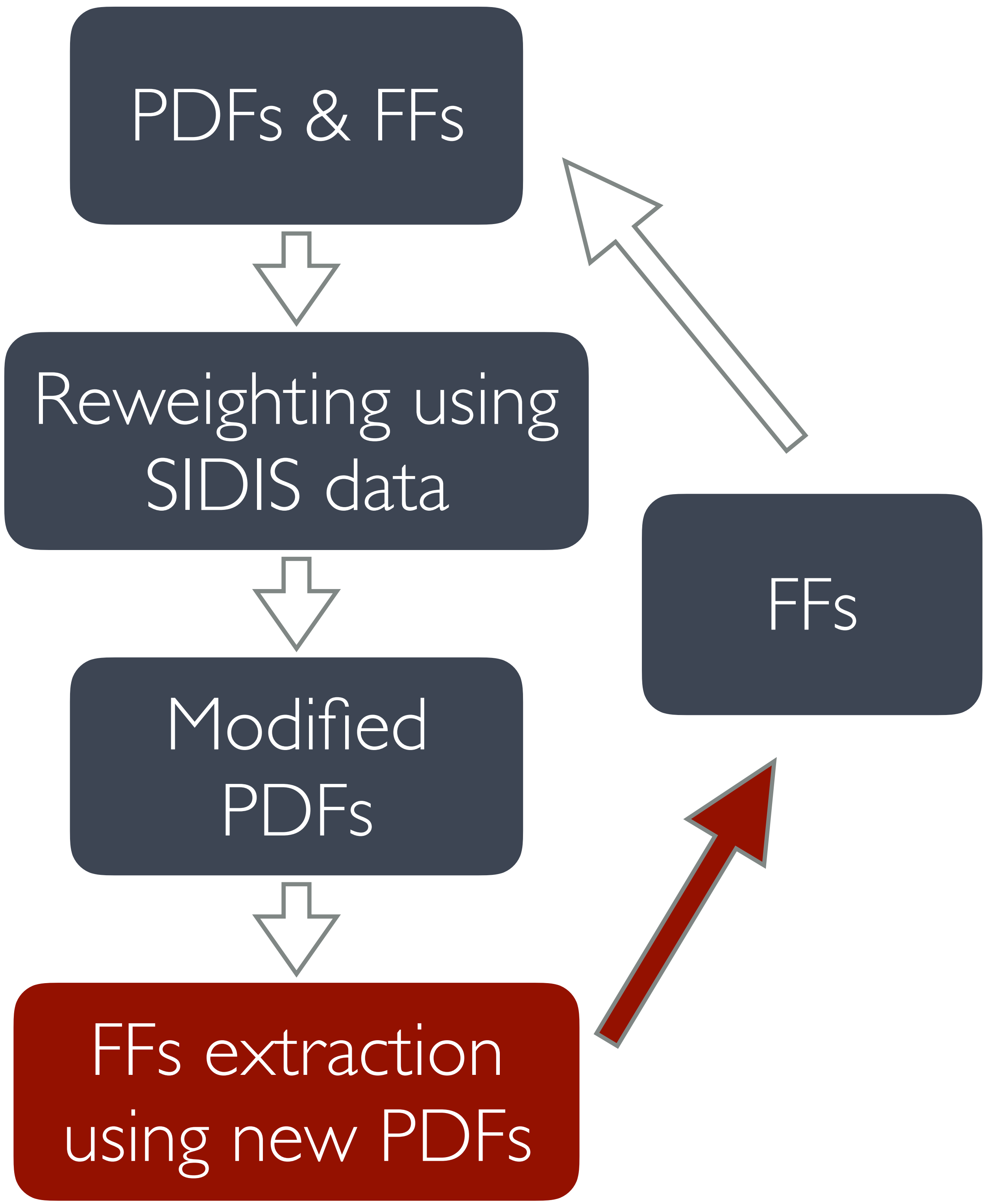

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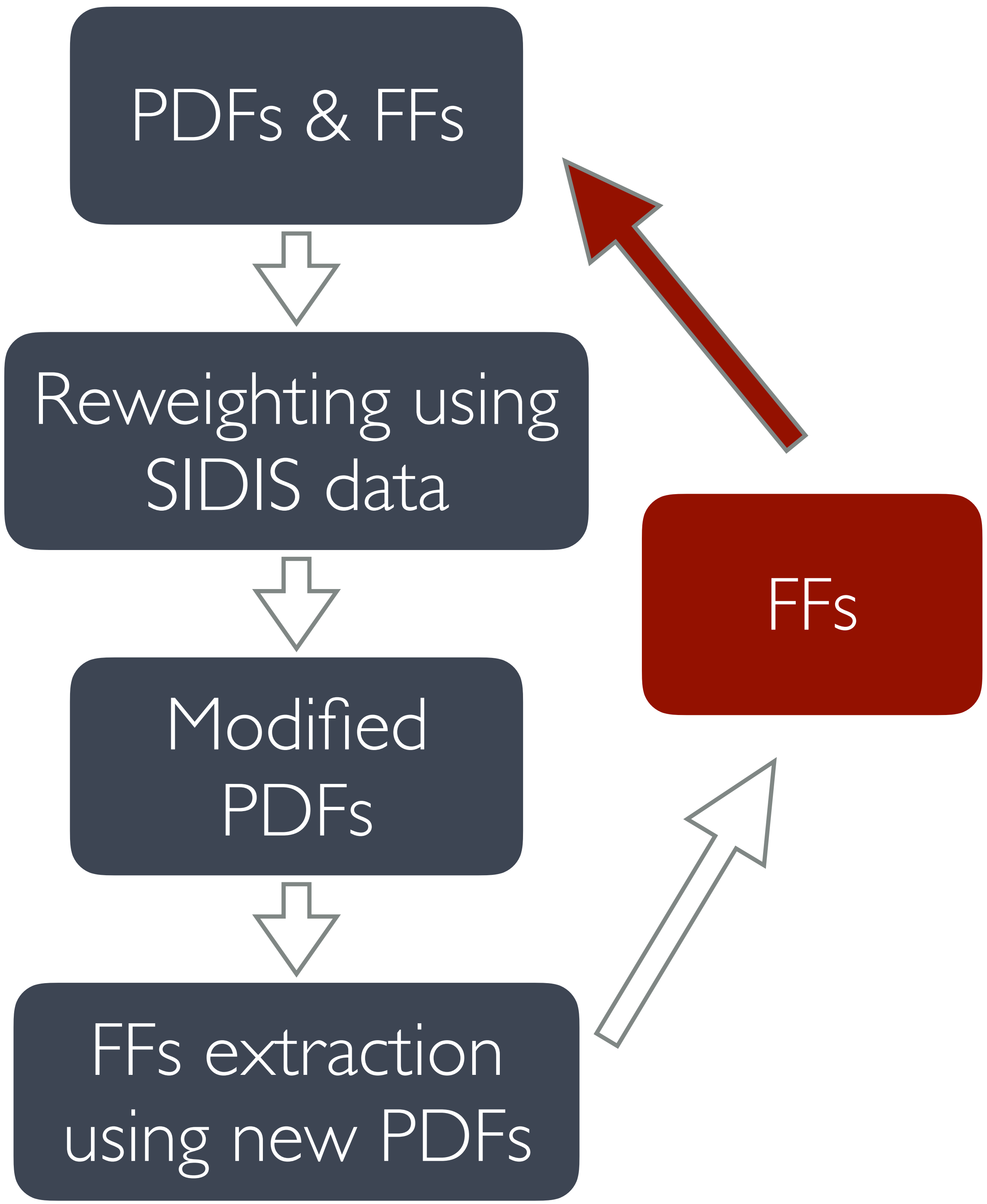

Combined PDFs & FFs extraction including COMPASS & HERMES π and K SIDIS data

Robust

Fast convergence

Independent of the PDFs set used

COMBINED PDFS & FFS EXTRACTION FROM EIC

E. Aschenauer, IB, R. Sassot, C. Van Hulse. Phys.Rev. D99 (2019) no.9, 094004

What can we learn from SIDIS @ EIC?

Reweighting with EIC $\pi^{\pm}$ & $K^{\pm}$ SIDIS pseudo-data

10^3 NNPDF3.0 replicas
10^5 DSS14 & DSS17 replicas

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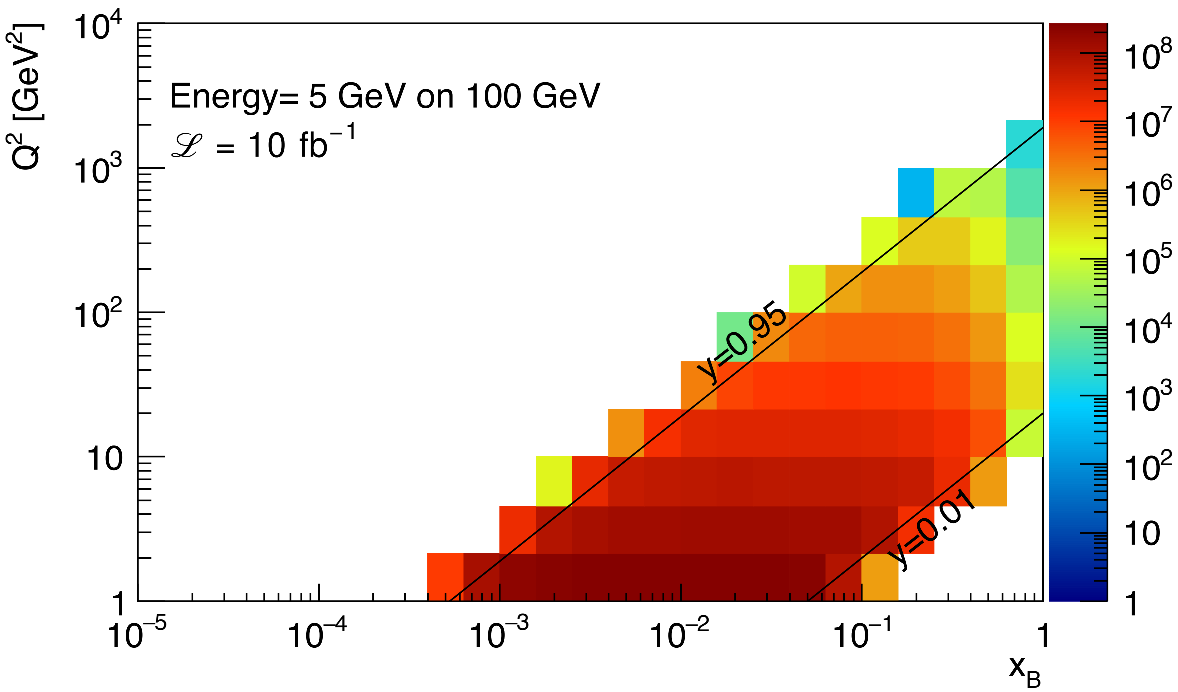

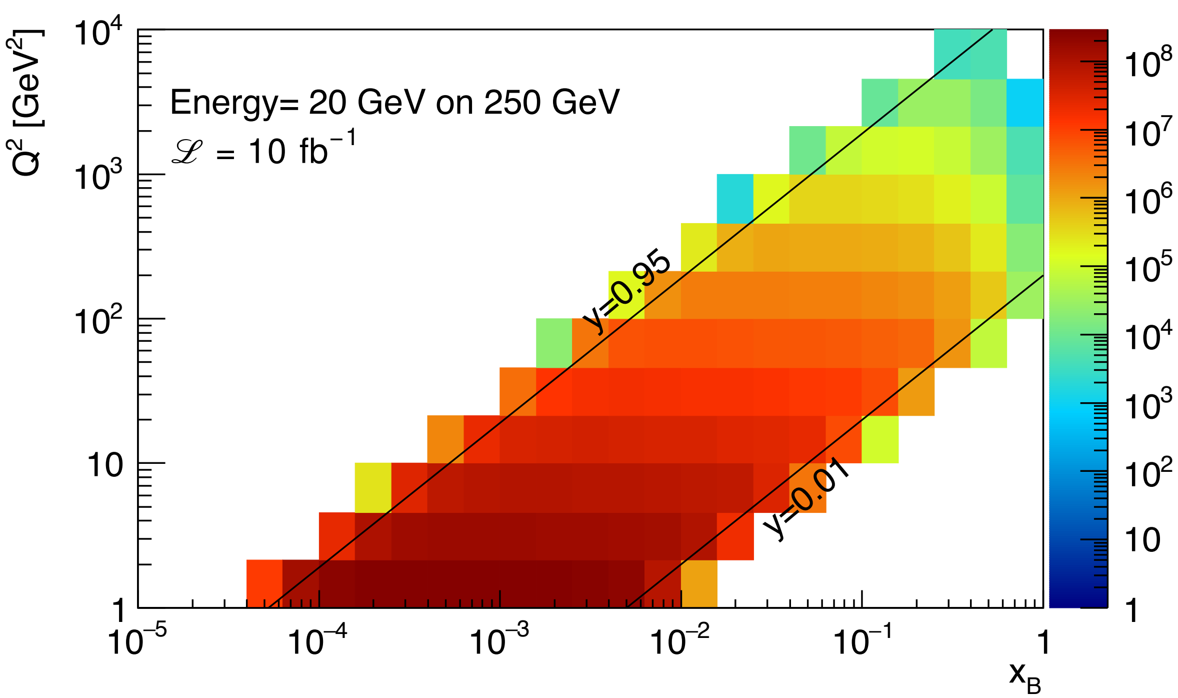

Wide coverage in $\{x, Q^2\}$

5 GeV x100 GeV $\sqrt{s} = 45$ GeV

20 GeV x250GeV $\sqrt{s} = 140$ GeV

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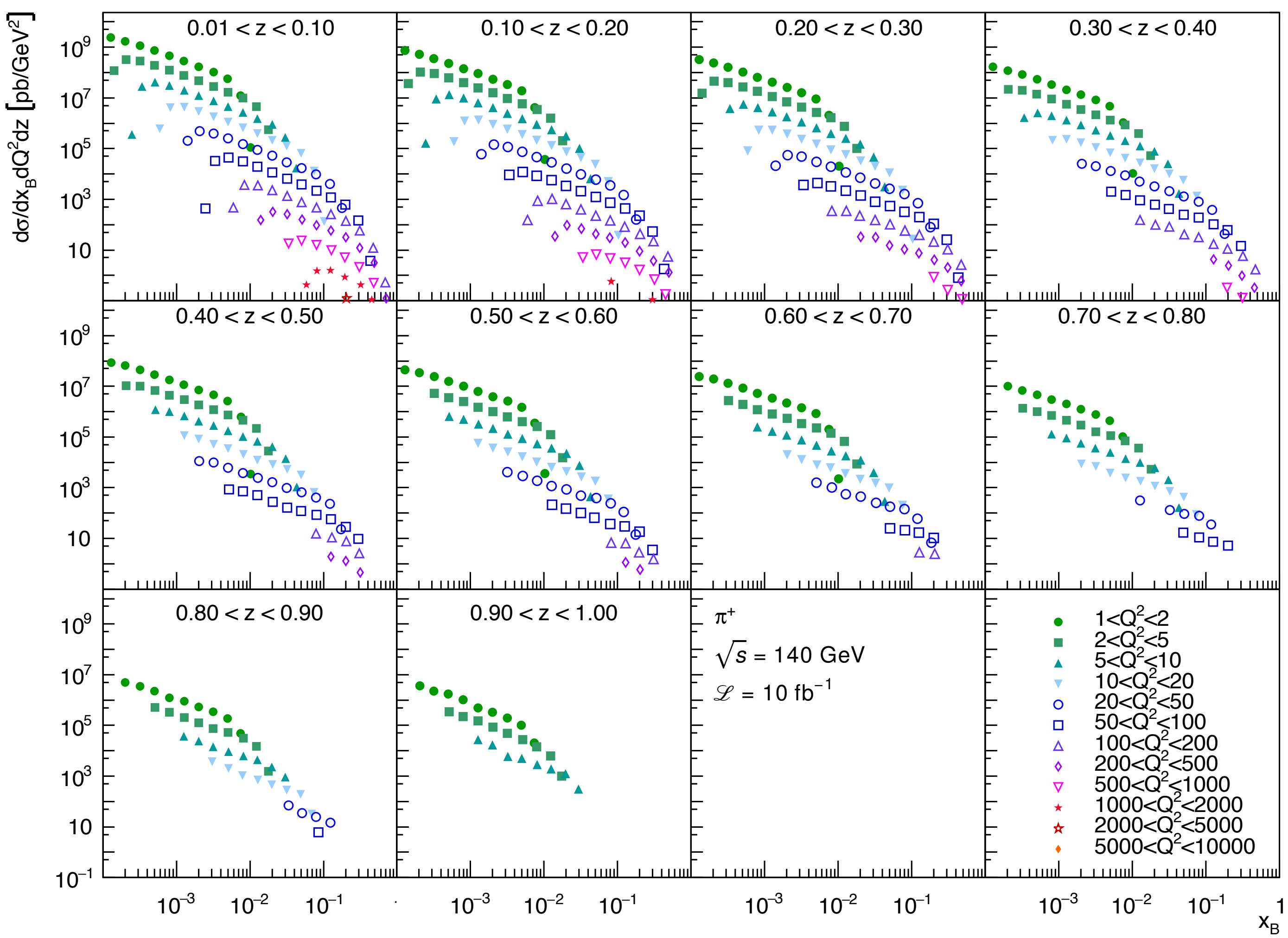

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5 GeV ×100 GeV $\sqrt{s} = 45$ GeV

20 GeV ×250GeV $\sqrt{s} = 140$ GeV

Pseudodata generation:

$Q^2 > 1$ GeV^2

$0.01 < y < 0.95$

$W^2 > 10$ GeV^2

$-3.5 < \eta < 3.5$

PYTHIA6

10 fb^{-1}

COMBINED PDFS & FFS EXTRACTION FROM EIC

E. Aschenauer, IB, R. Sassot, C. Van Hulse.   Phys.Rev. D99 (2019) no.9, 094004

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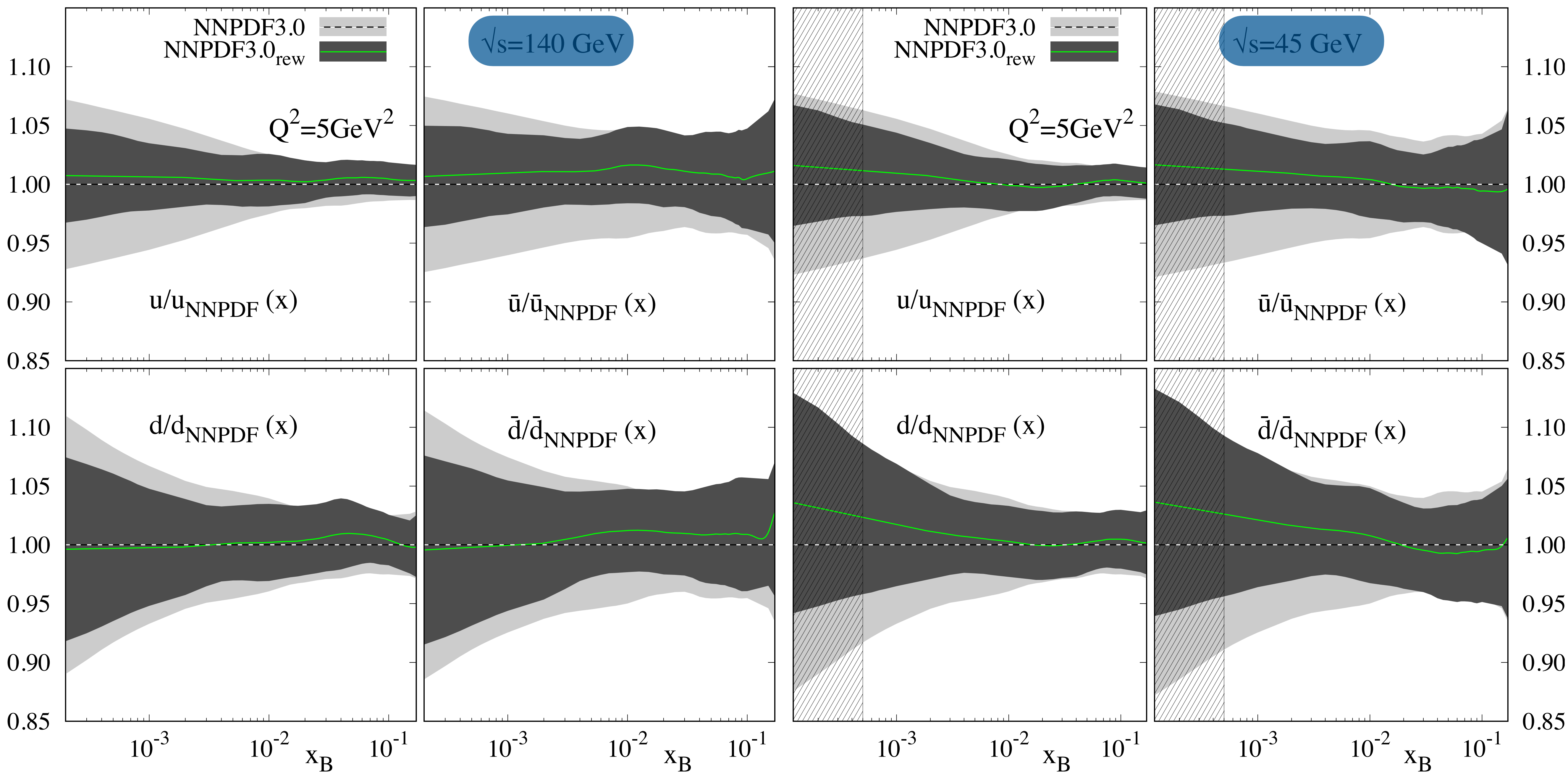

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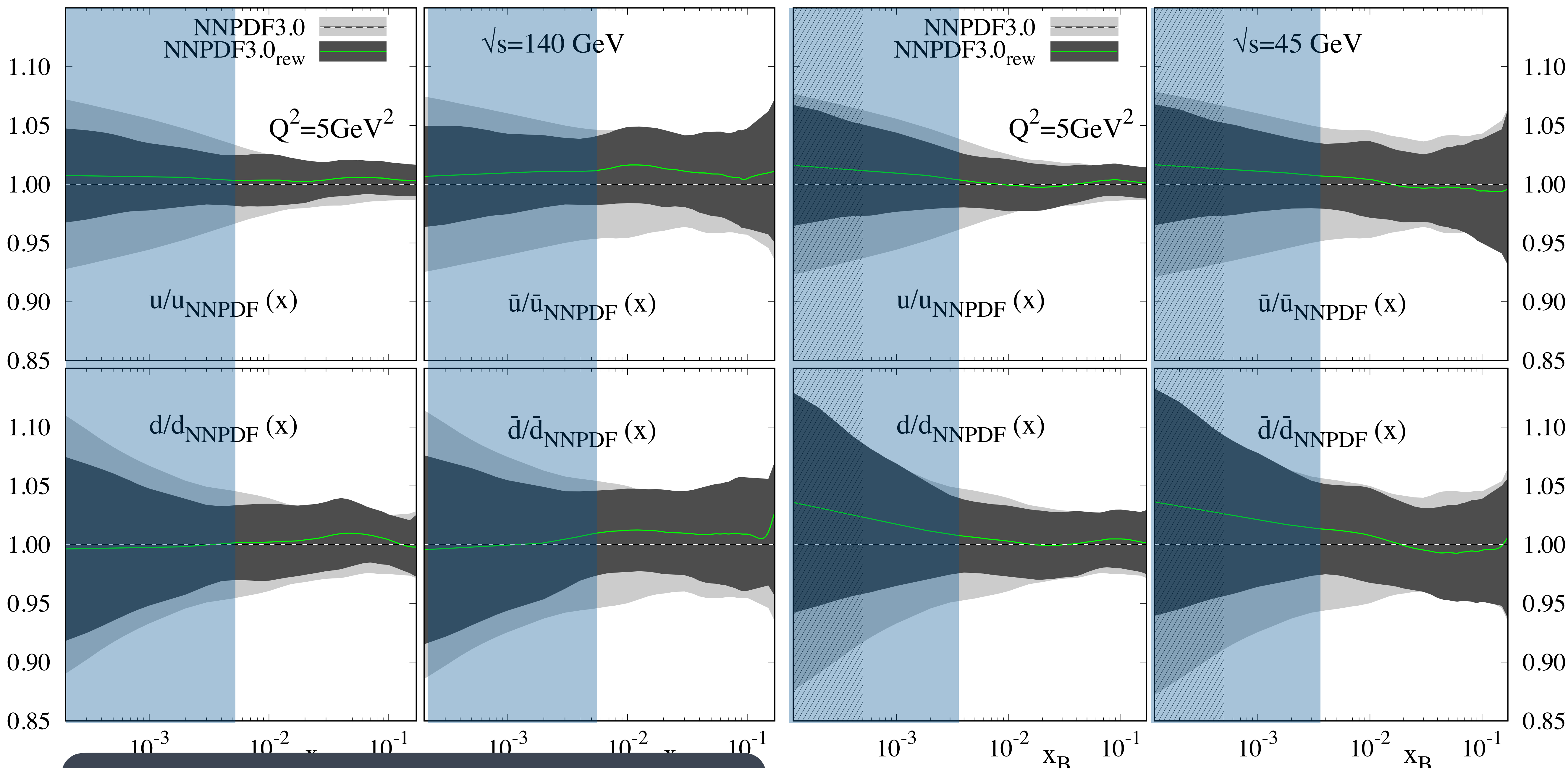

30% uncertainty reduction for u
20% uncertainty reduction for d

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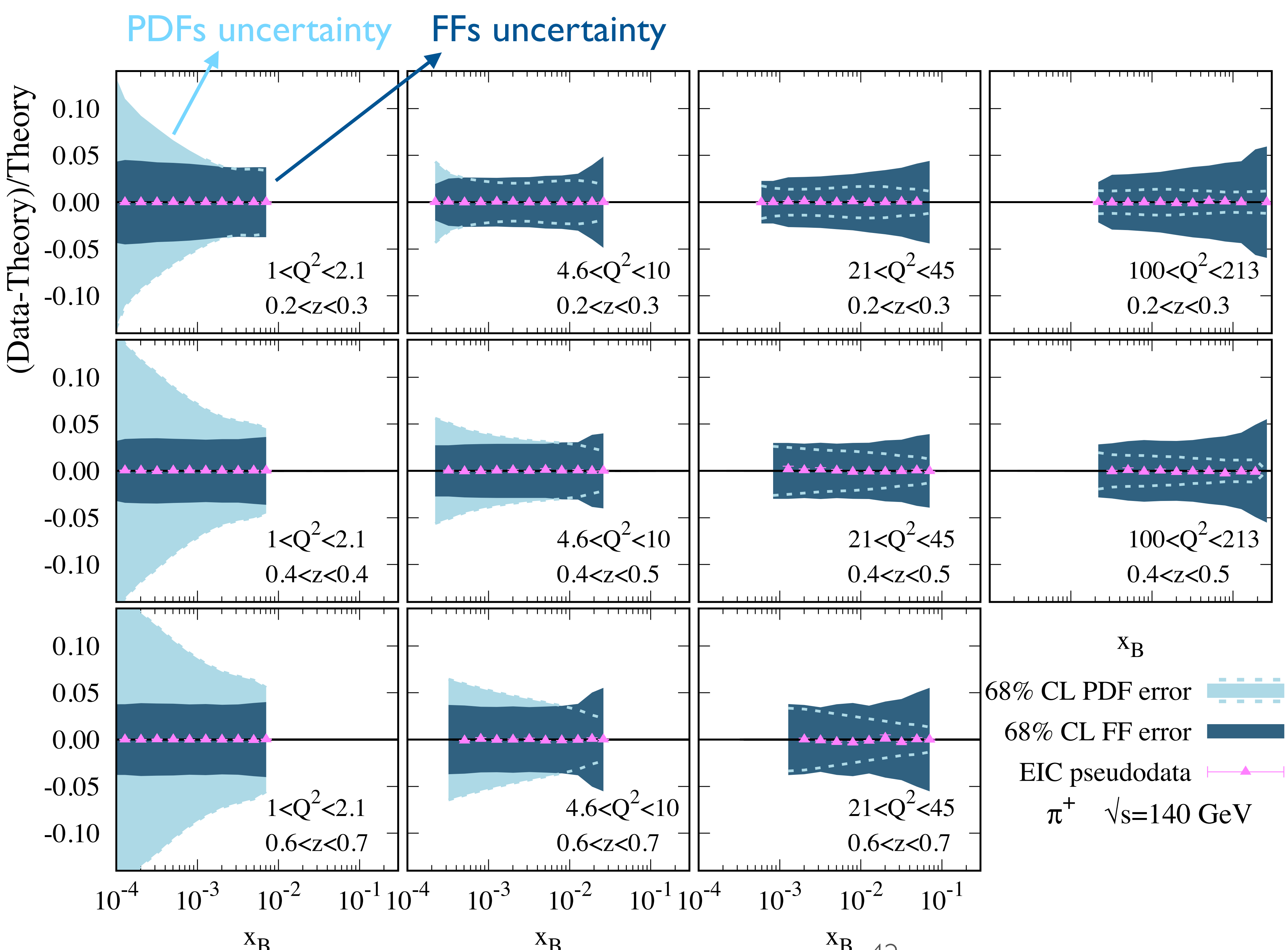

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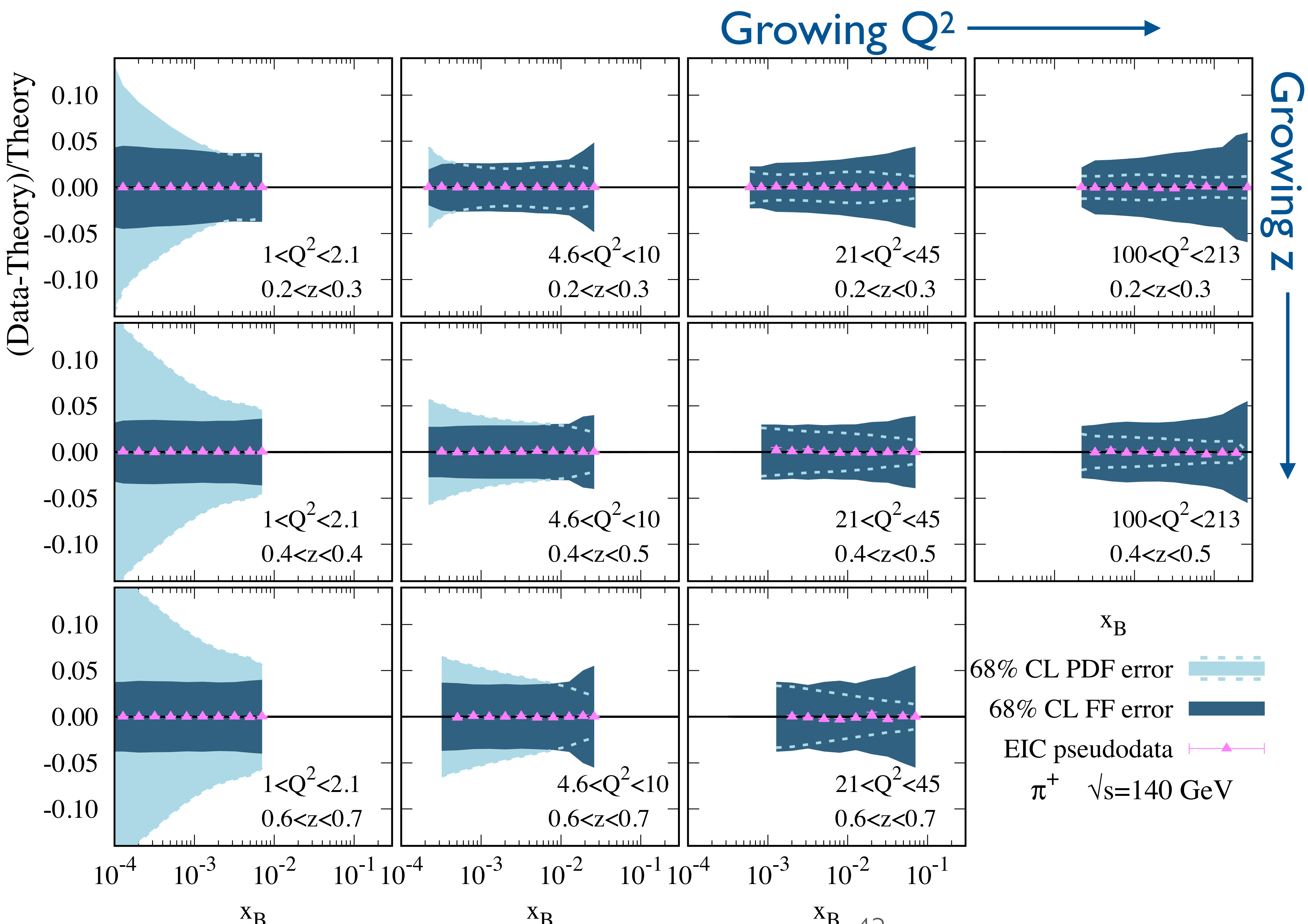
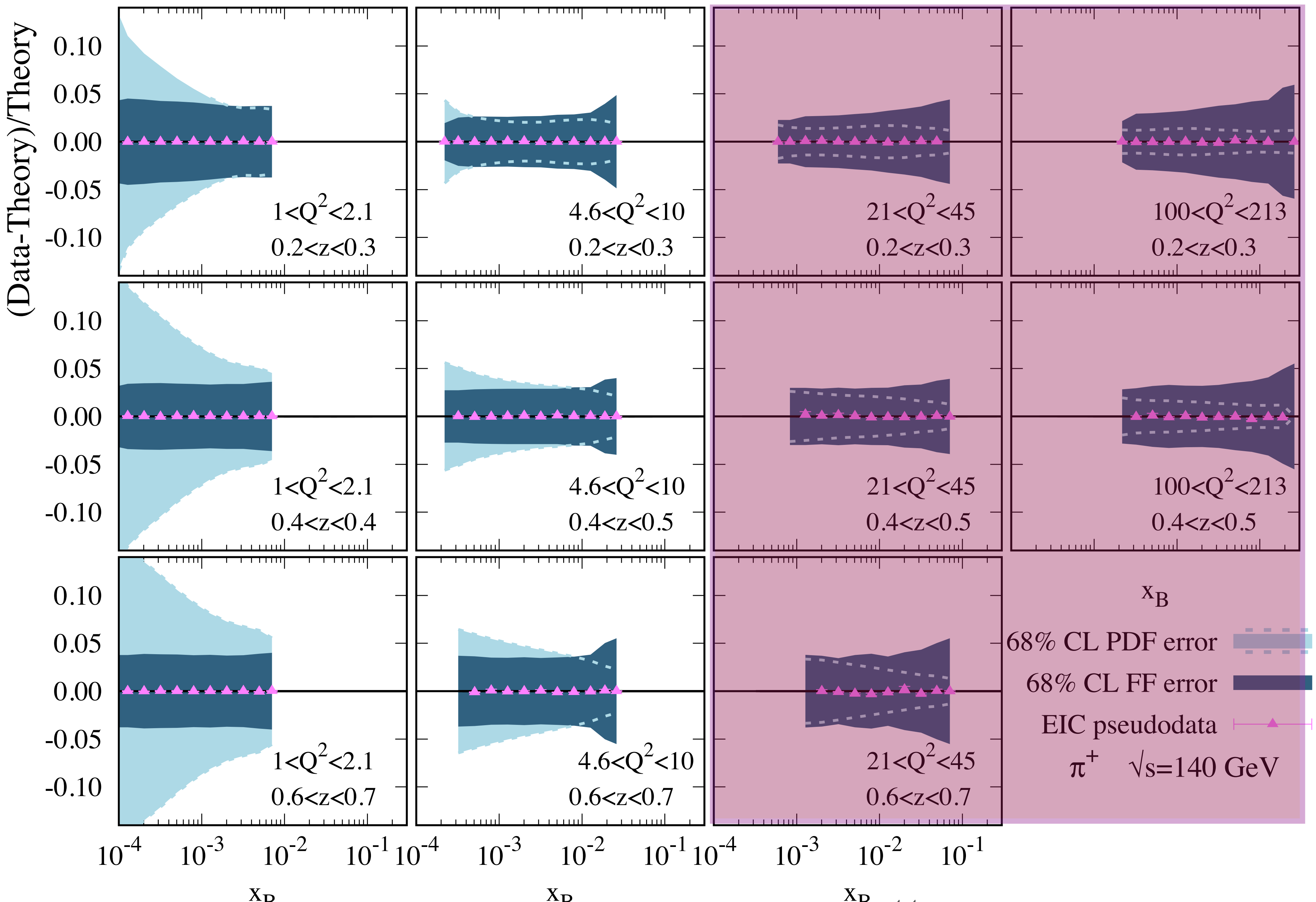


COMBINED PDFS & FFS EXTRACTION FROM EIC

E. Aschenauer, IB, R. Sassot, C. Van Hulse. Phys.Rev. D99 (2019) no.9, 094004

What can we learn from SIDIS @ EIC?

Dominated by PDFs uncertainty **Dominated by FFs uncertainty**



$$\chi^2(y,f) = \sum_i \frac{(y_i - y_i[f])^2}{\sigma_i^2}$$

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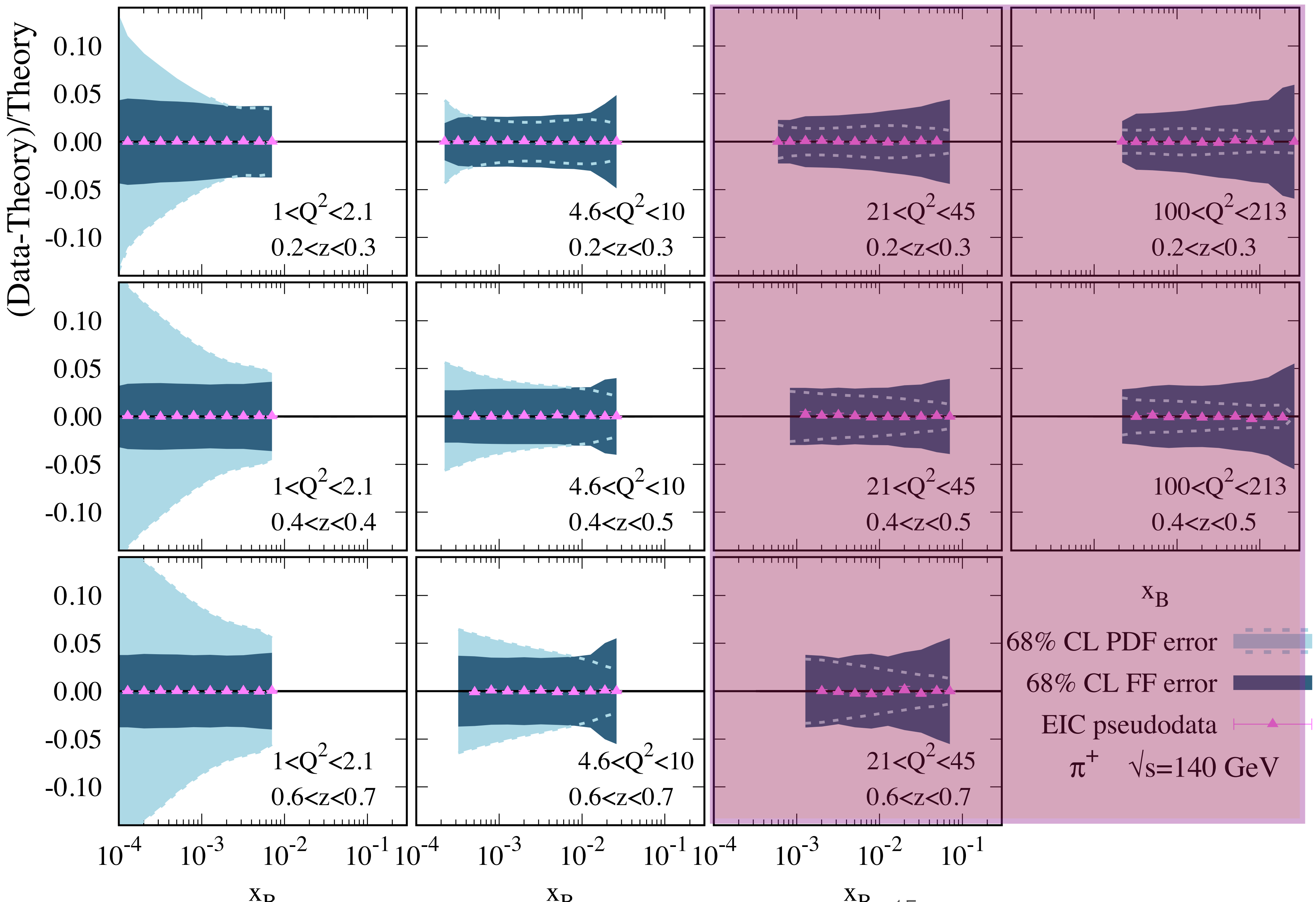

$$\chi^2(y,f) = \sum_i \frac{(y_i - y_i[f])^2}{\sigma_i^2}$$

Must include FF's uncertainty

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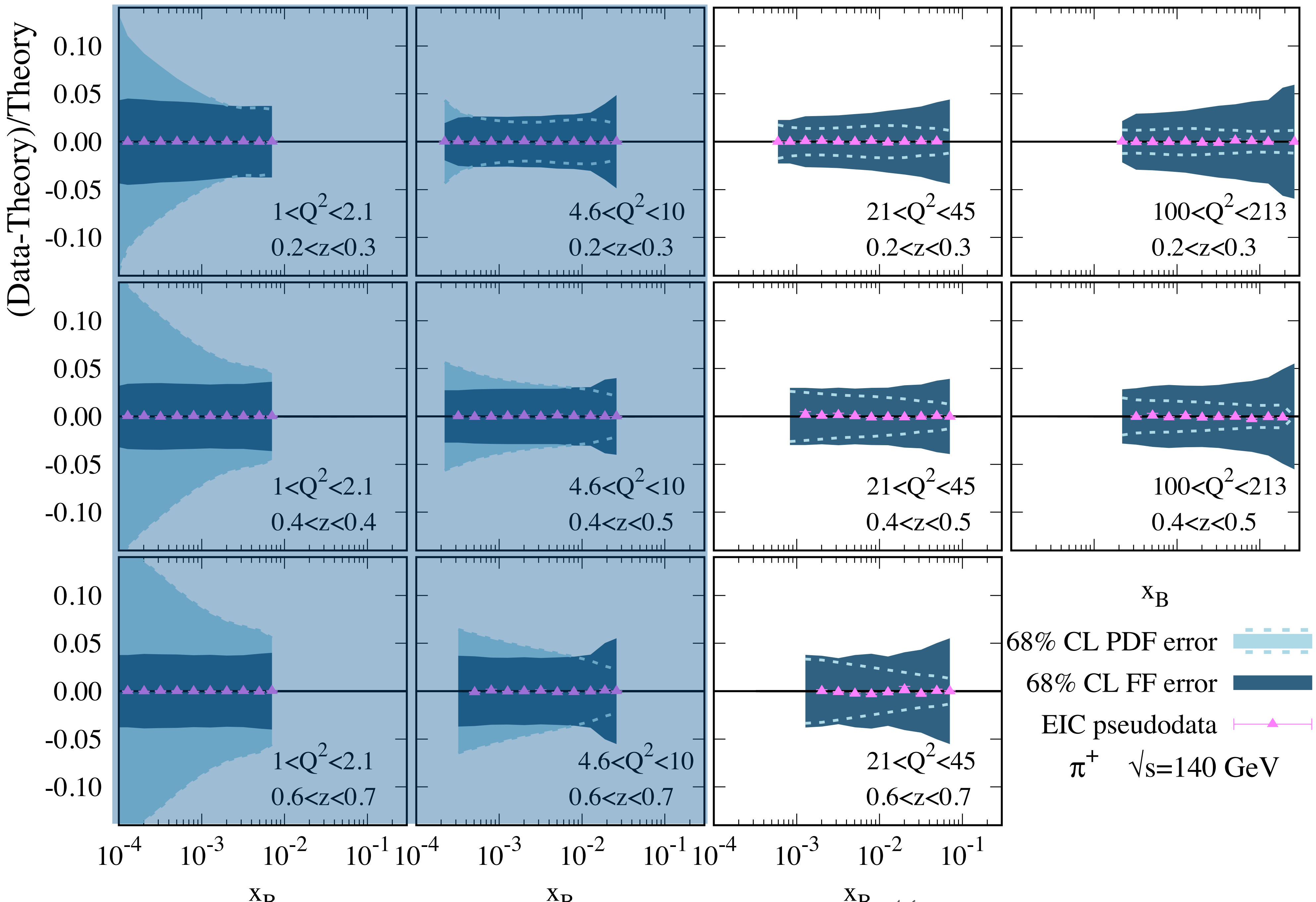

Higher impact for the region of low Q^2 & x_B, where the PDFs are comparatively less constrained

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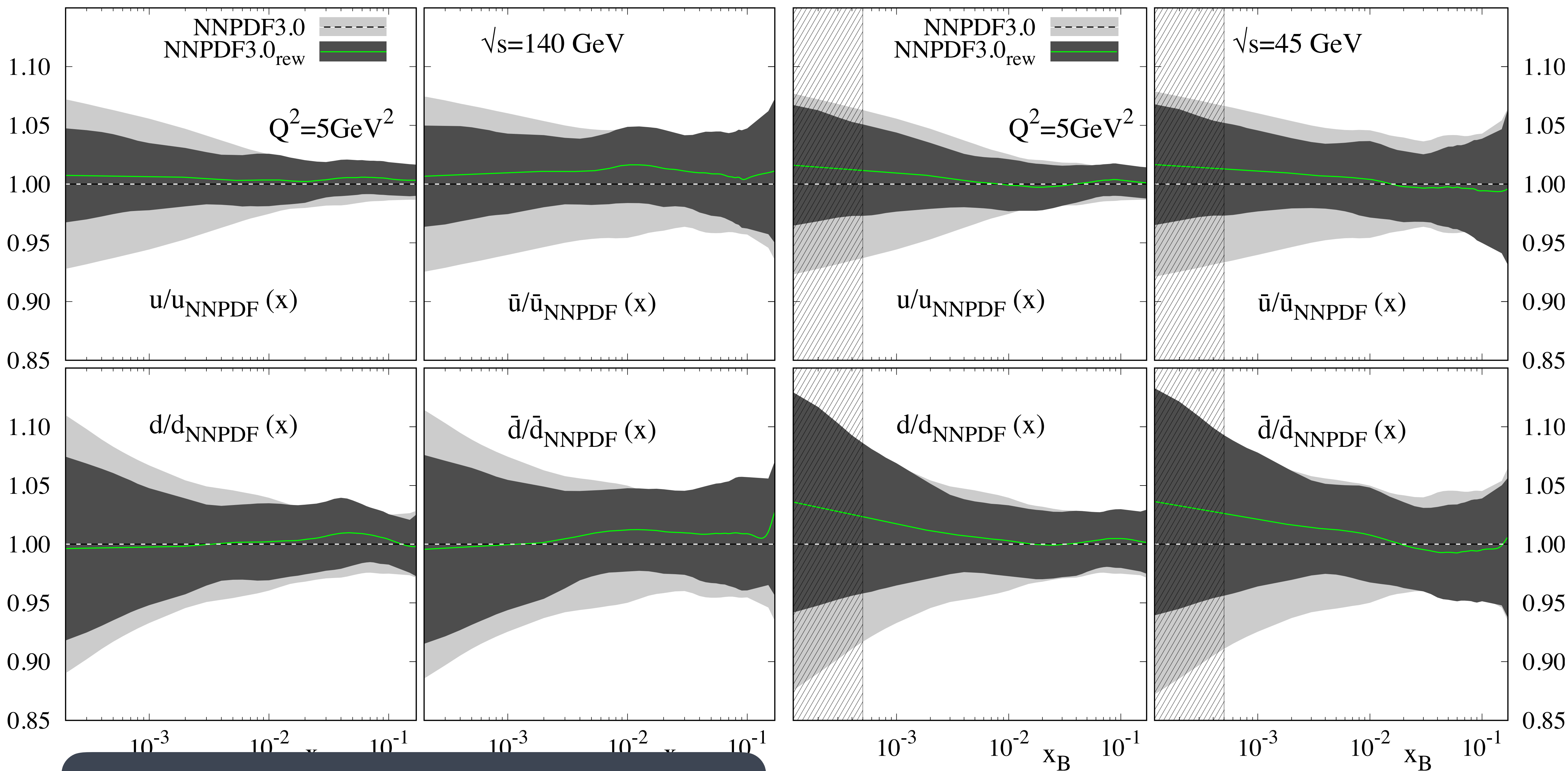

30% uncertainty reduction for u
20% uncertainty reduction for d

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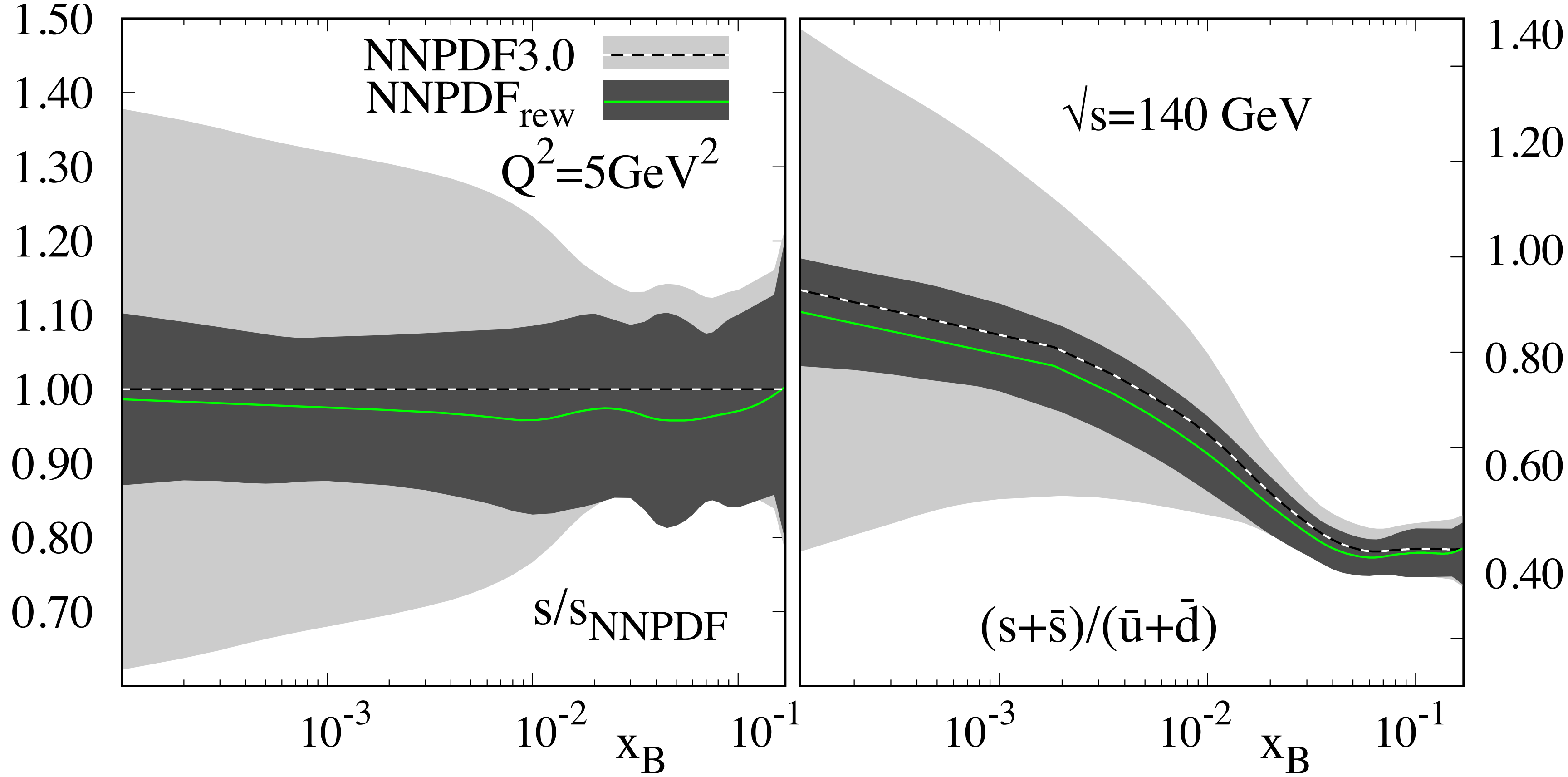

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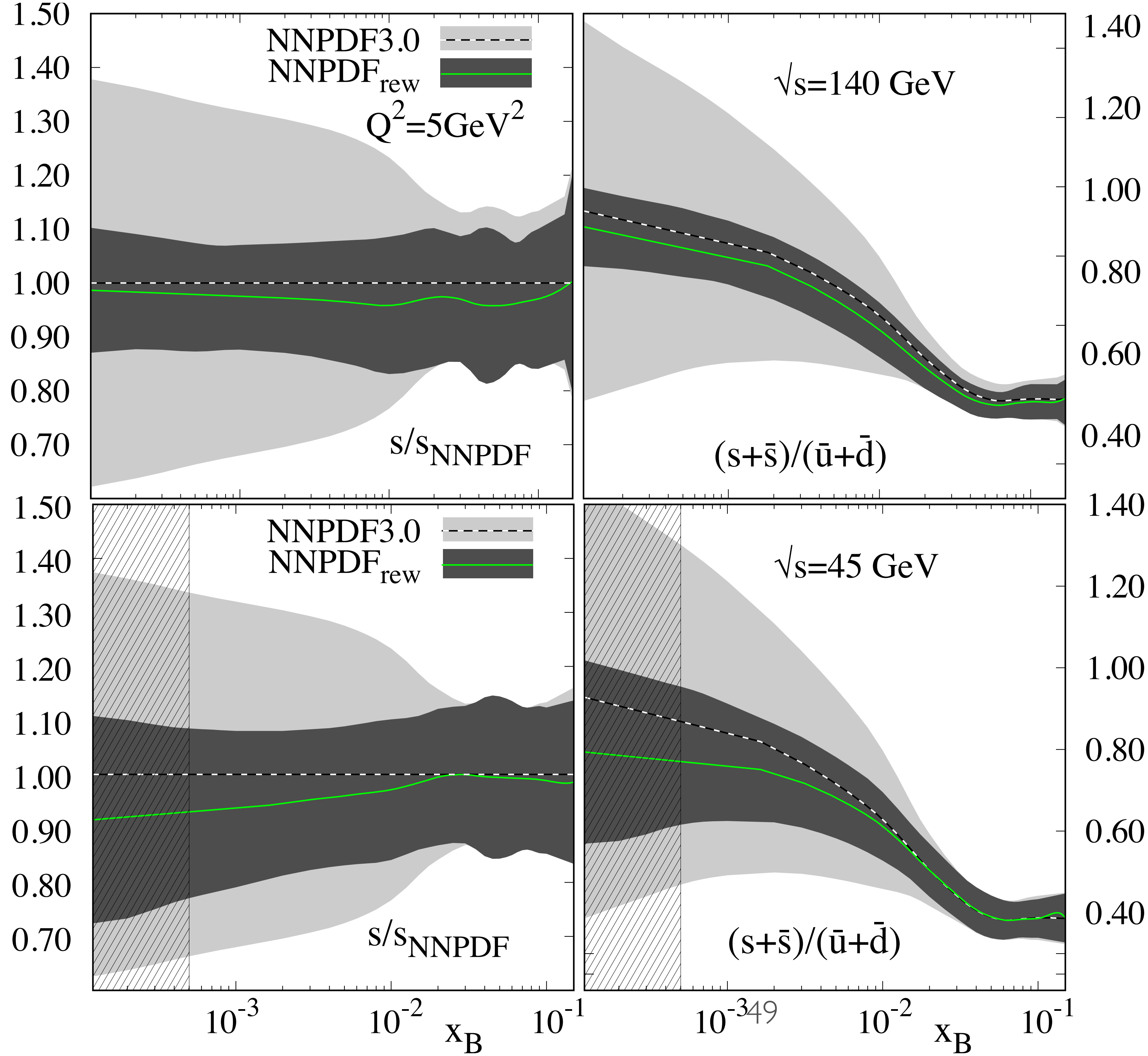

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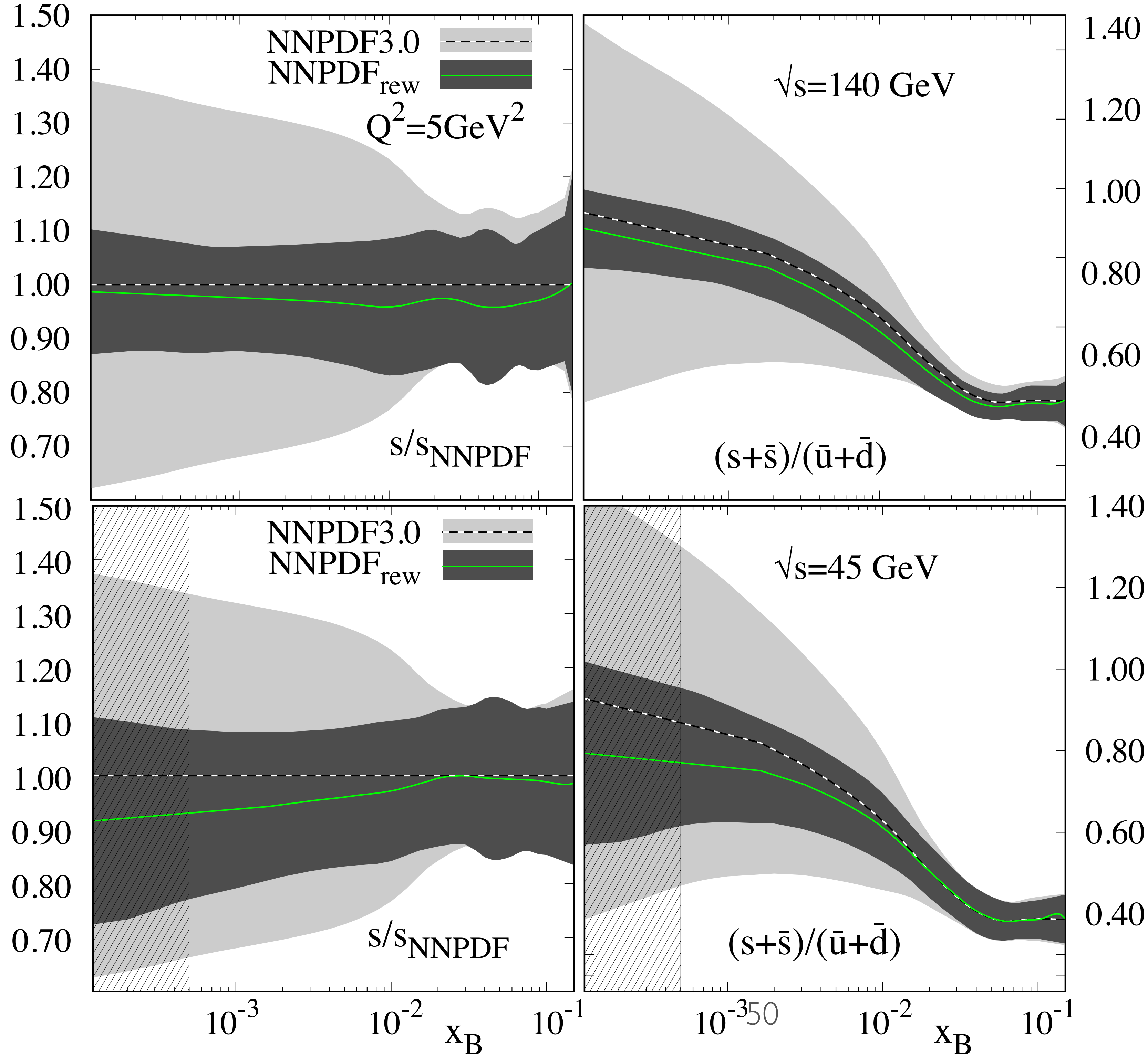

Remarkable reduction on the strangeness uncertainty driven by kaon SIDIS data

SIDIS can look into the proton's strange content

COMBINED PDFS & FFS EXTRACTION FROM EIC

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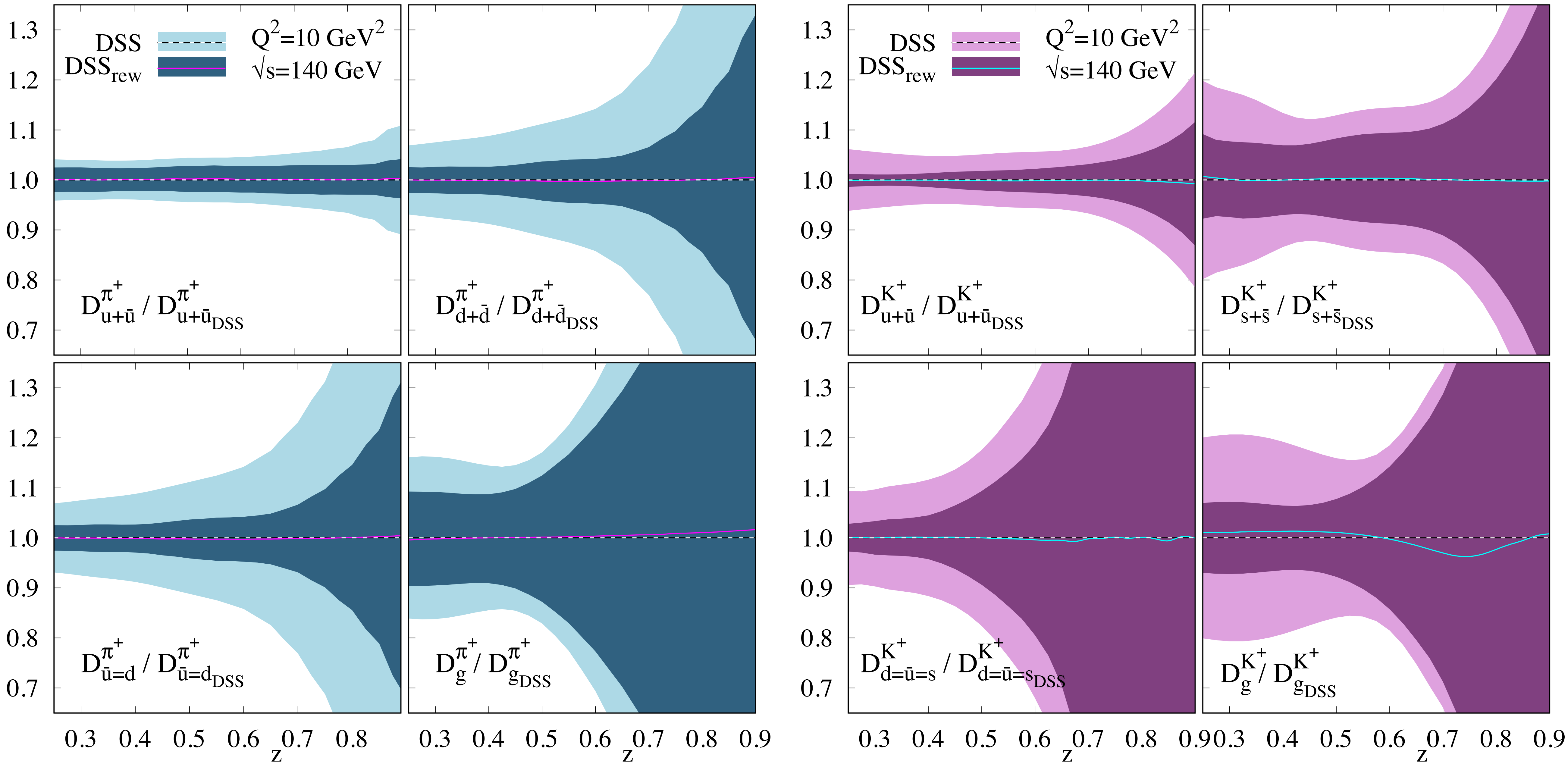
What can we learn from SIDIS @ EIC?

Effect on Fragmentations



SUMMARY

- **There is still a lot of room for PDFs improvement**
- **Semi-inclusive DIS** offers a great tool to probe the sea quark of the parton, as well as the confinement process into hadrons
    - The same analysis could be translated to nPDFs!
- **EIC semi-inclusive data** expected to provide important constrains on both PDFs & FFs, with new insights on the:
    - Proton's strange content
    - Charge (& isospin) symmetry breaking
    - Nuclear effects on PDFs & FFs

THANK YOU

BACKUP SLIDES

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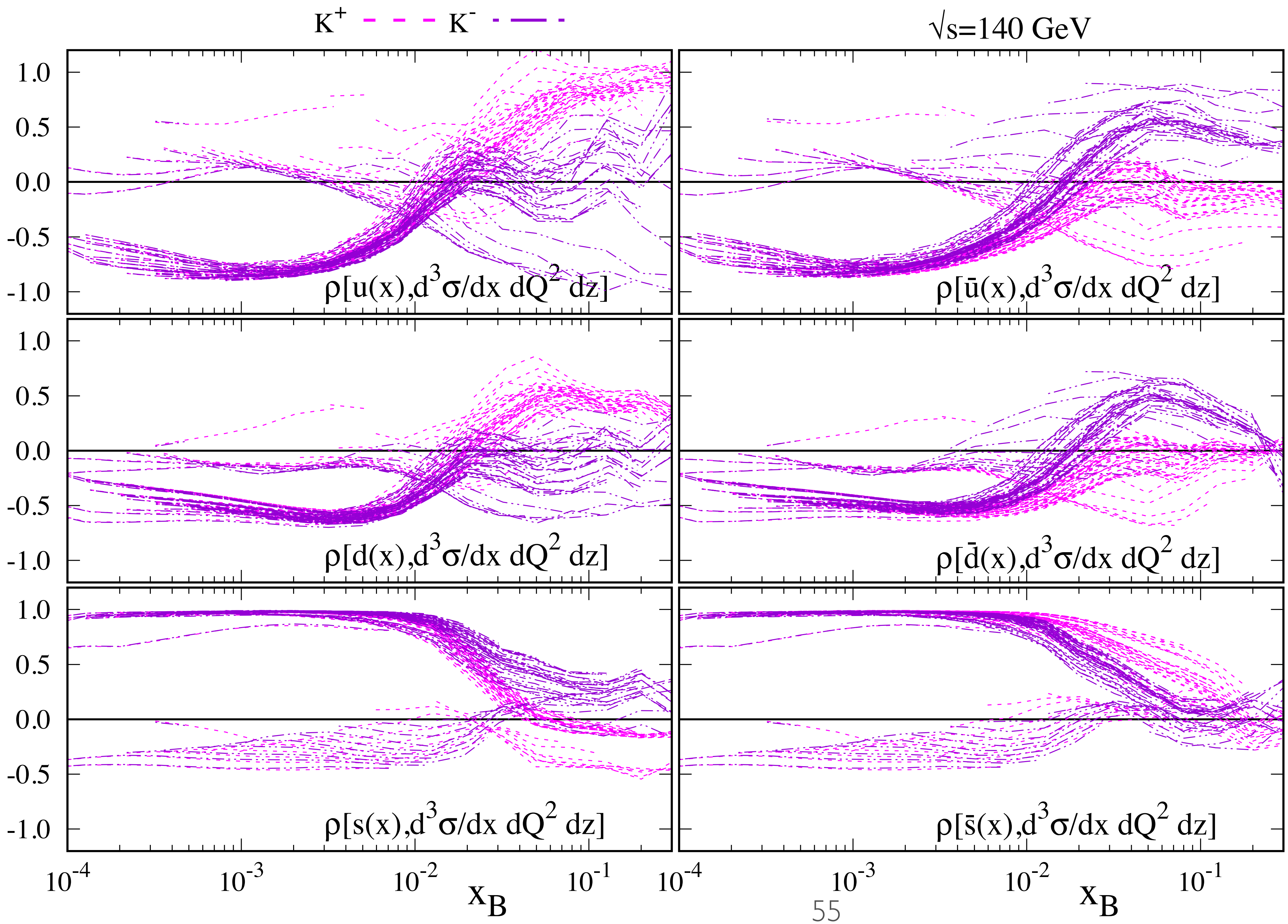
What can we learn from SIDIS @ EIC?

$$\rho_w[A,B] = \frac{\langle A - \langle A\rangle\rangle\langle B - \langle B\rangle\rangle}{\sigma_A^{th}\,\sigma_B^{th}}$$



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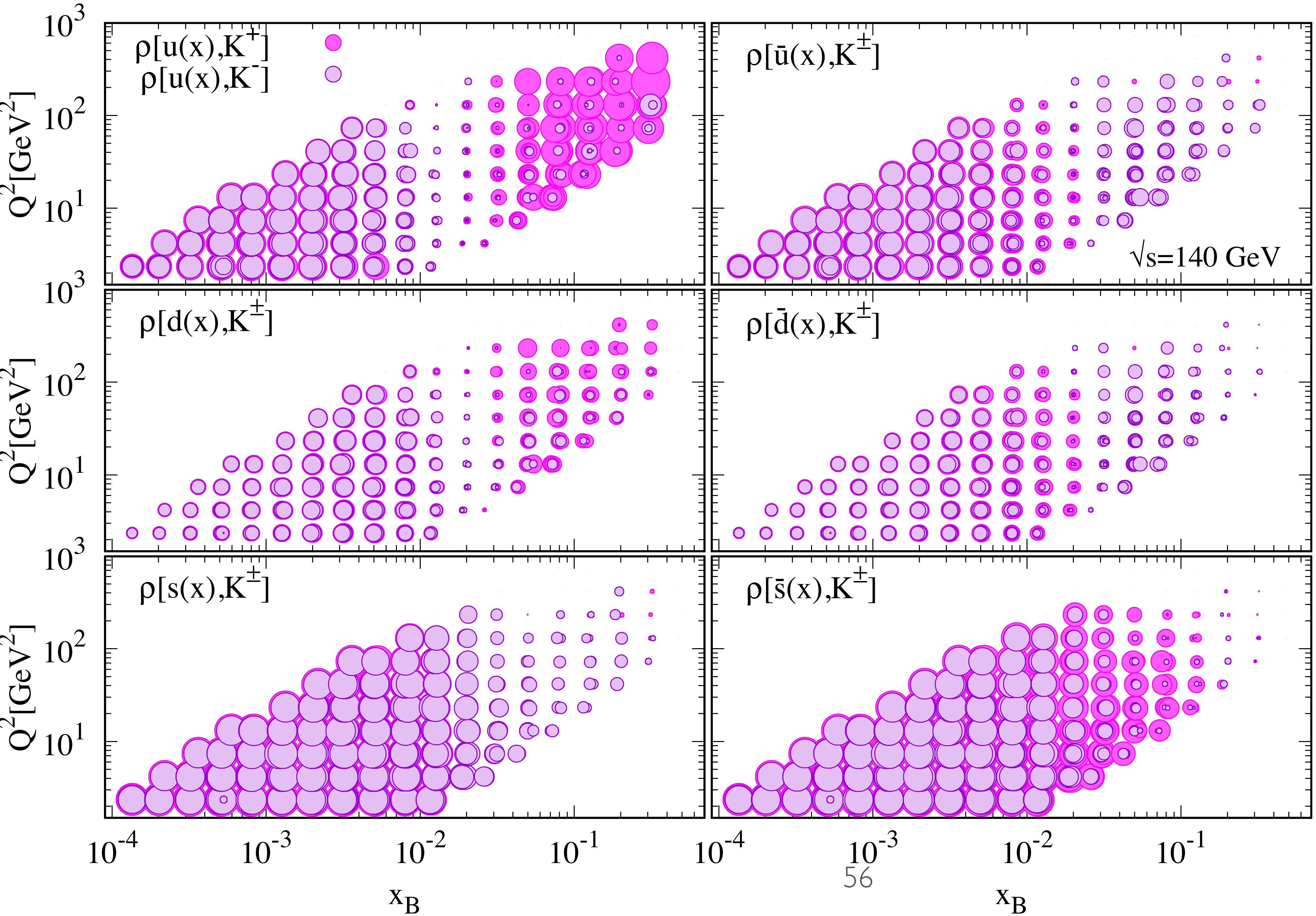

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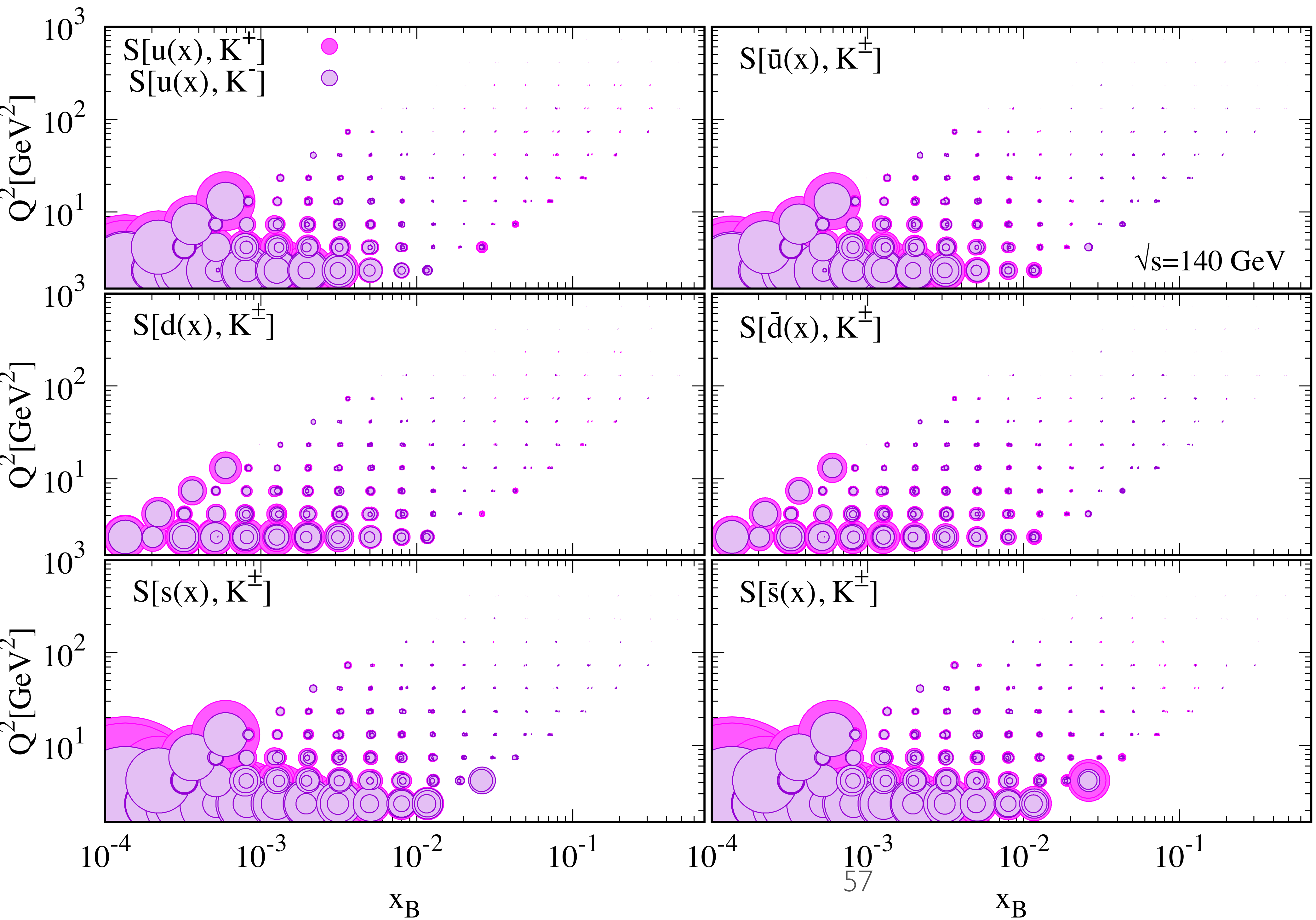
What can we learn from SIDIS @ EIC?

$$S[A,B] = \frac{\langle A - \langle A\rangle\rangle\langle B - \langle B\rangle\rangle}{\xi\, \sigma_A^{th}\, \sigma_B^{th}}$$



$$\xi = \frac{\sigma_B^{exp}}{\sigma_B^{th}}$$

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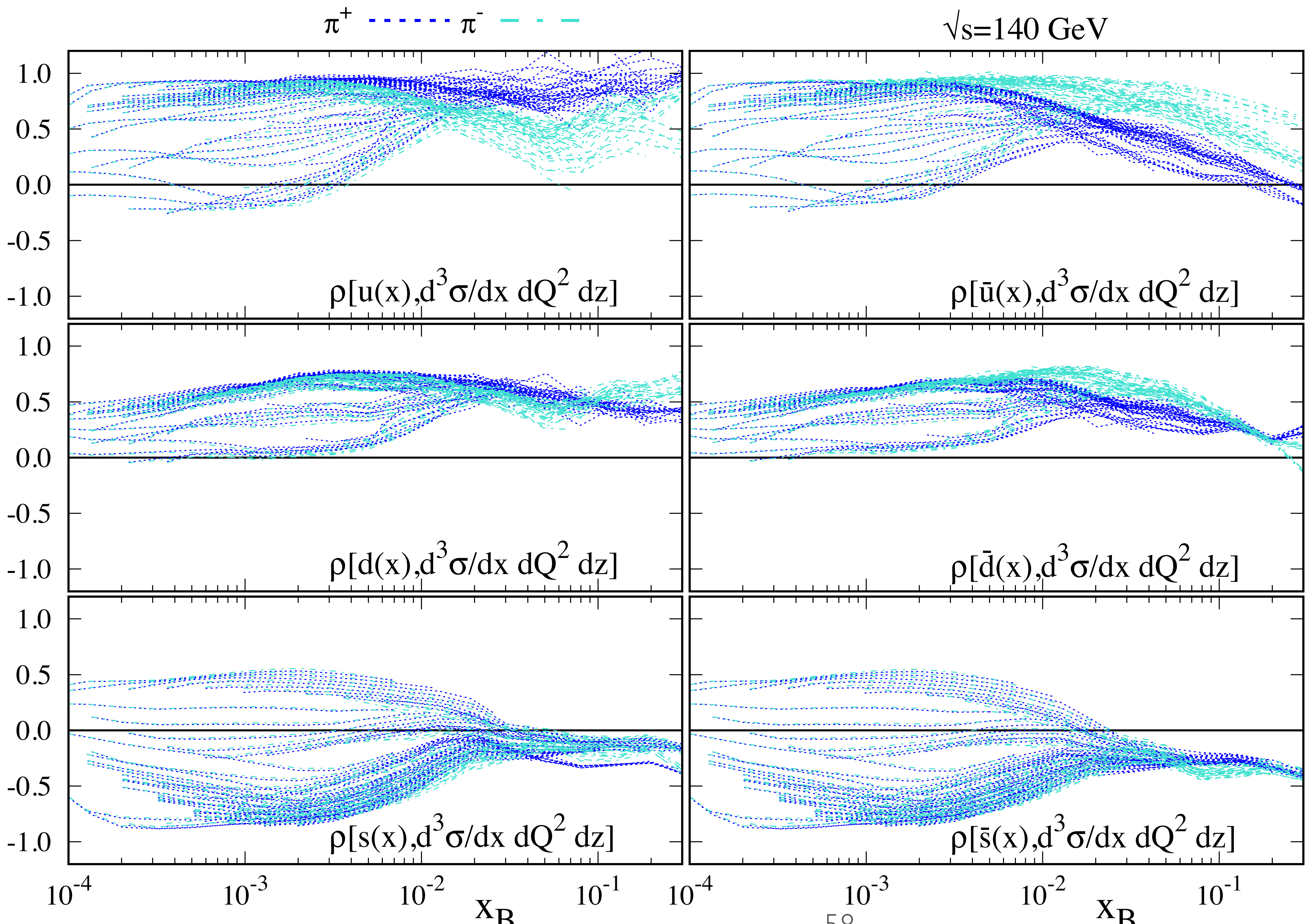

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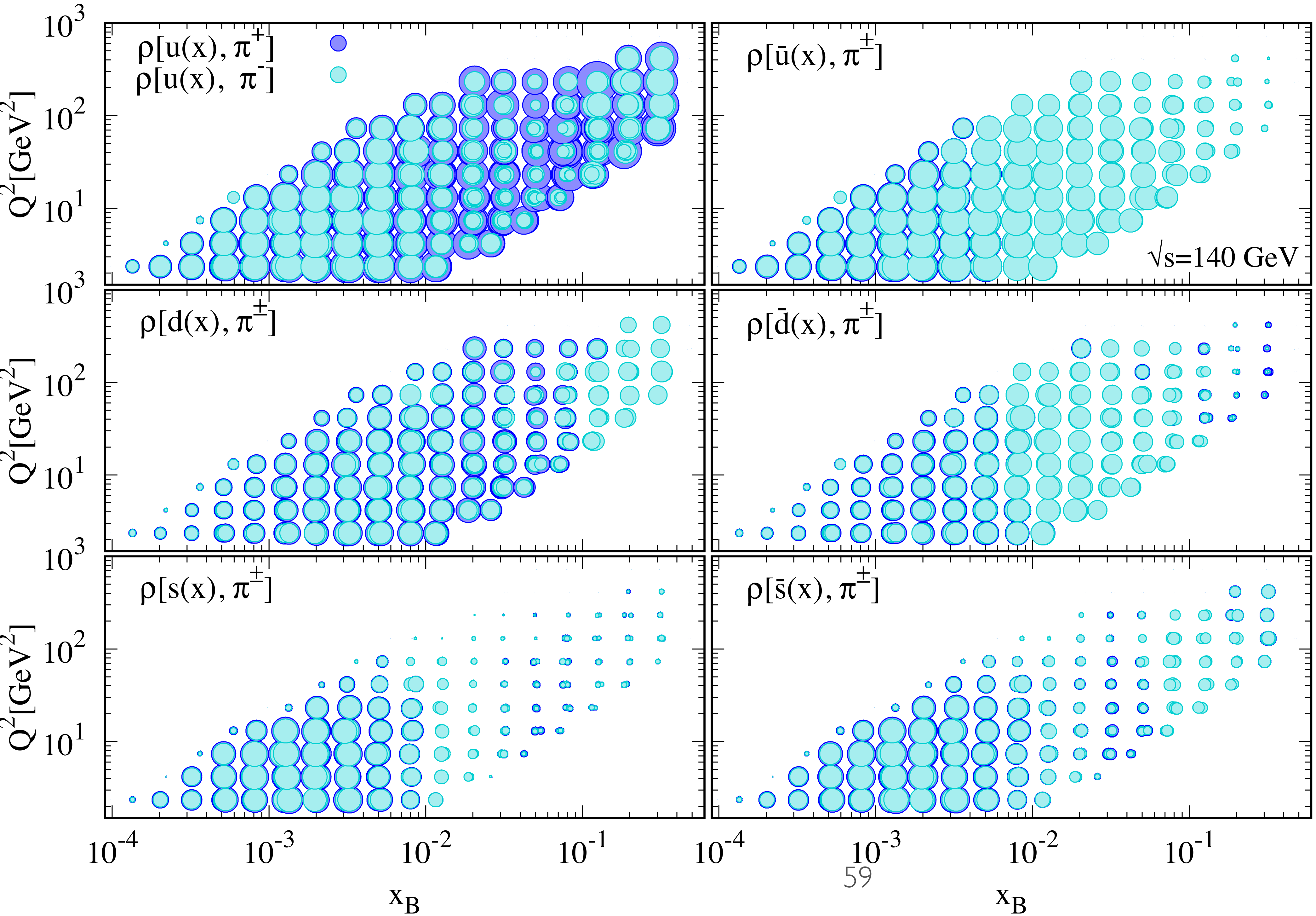

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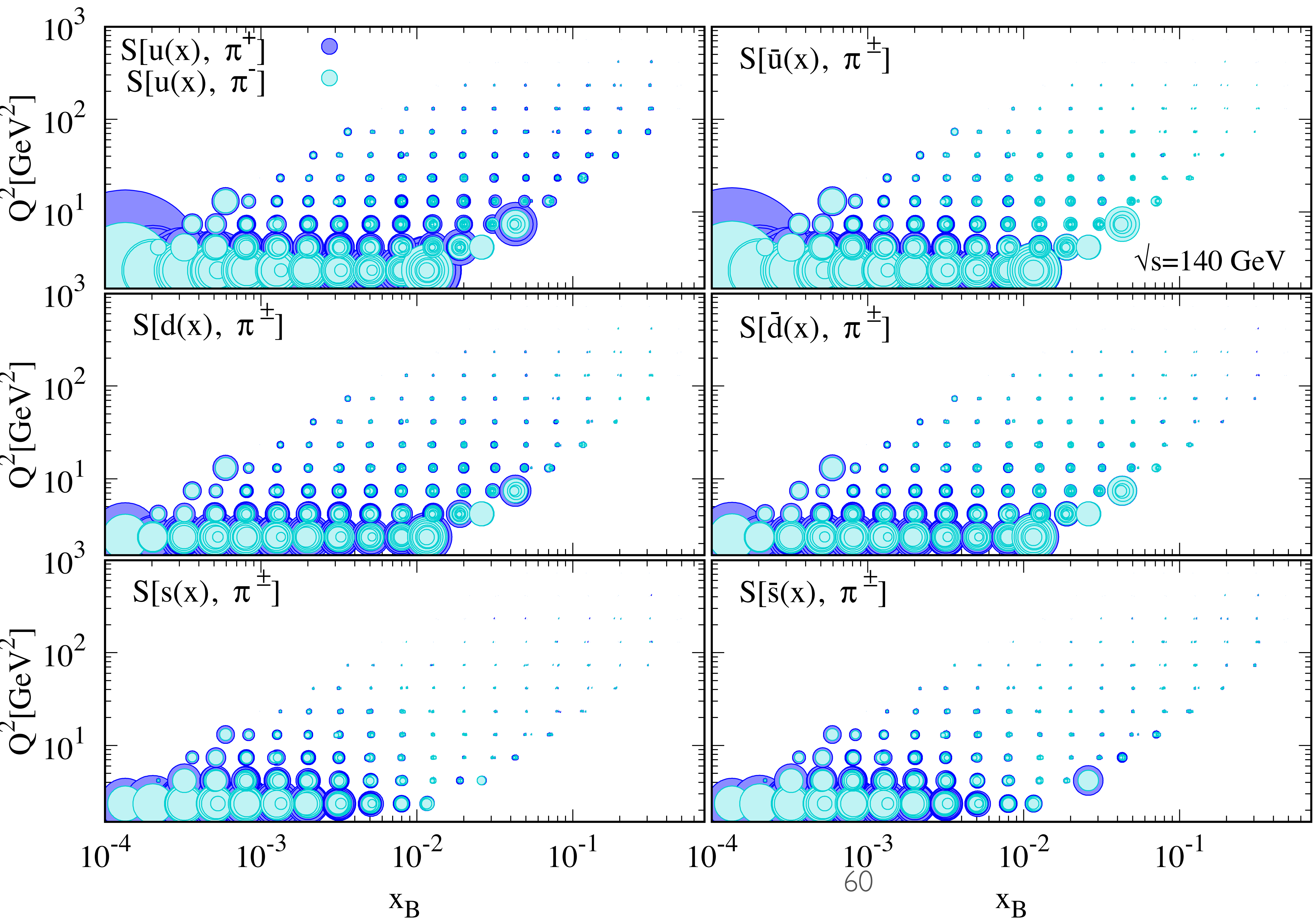
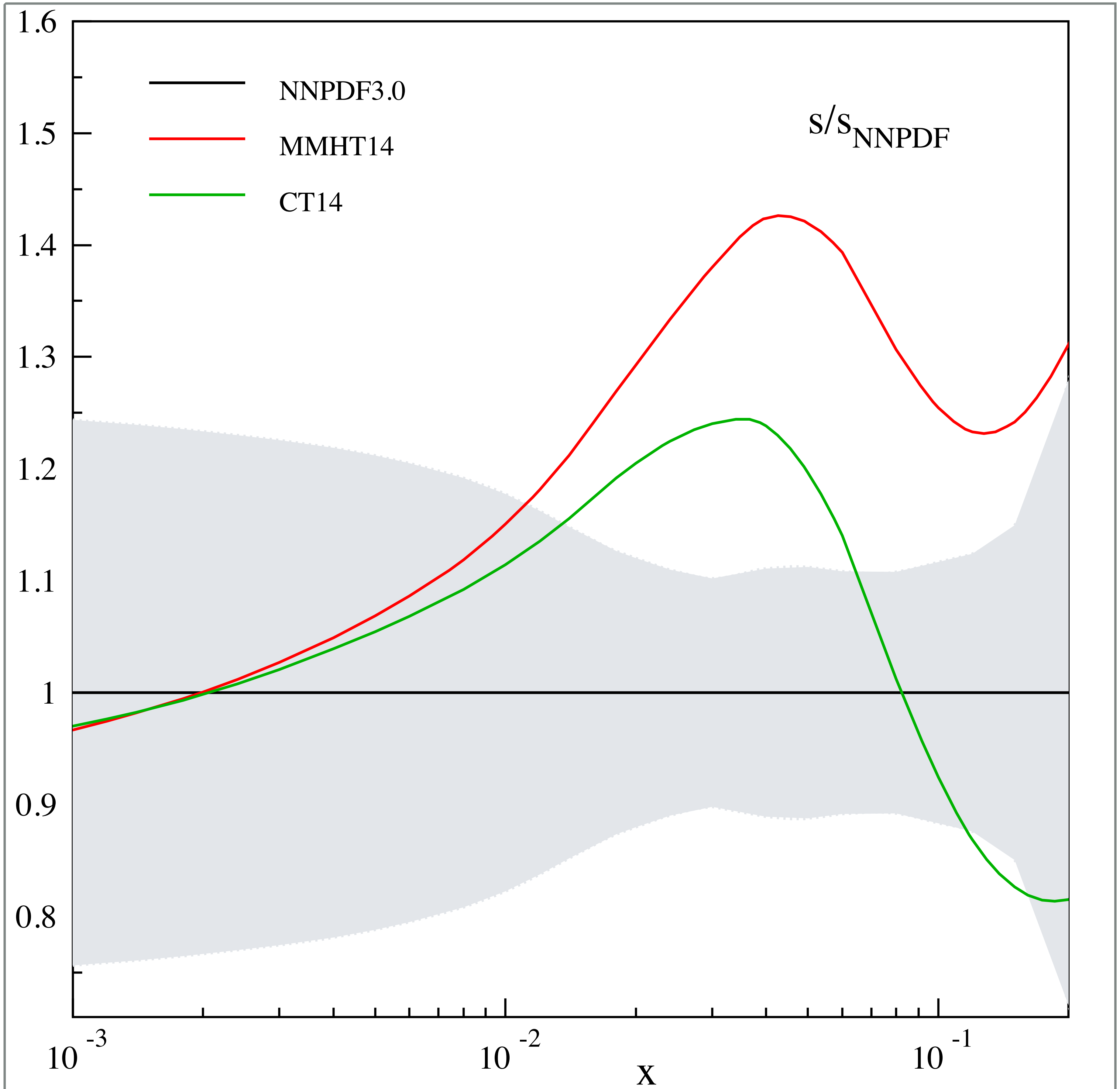


REWEIGHTING IN ACTION: STRANGE QUARK DISTRIBUTION

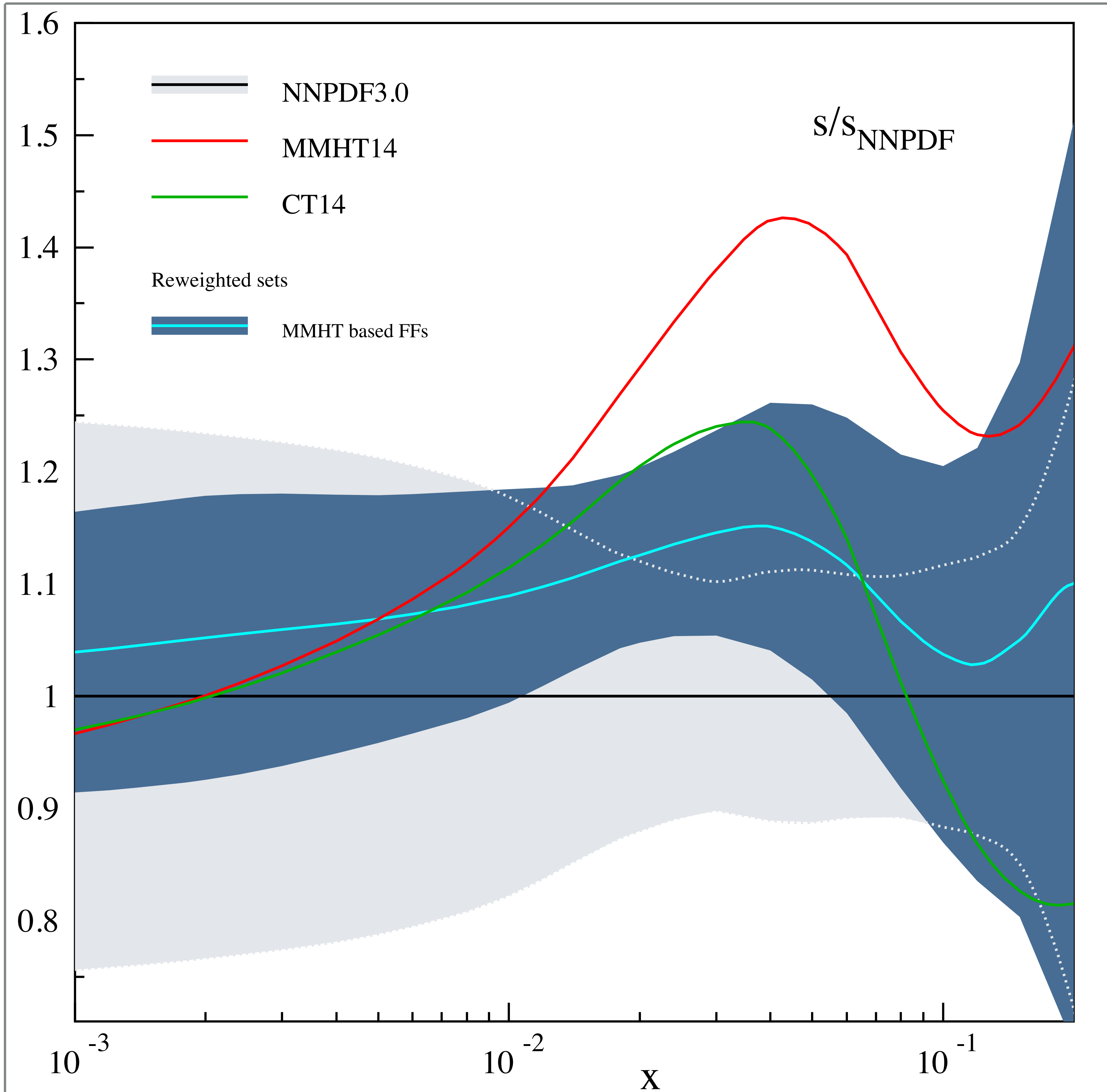
$$\chi^2_{FFs} = 1271$$



REWEIGHTING IN ACTION: STRANGE QUARK DISTRIBUTION

$$\chi^2_{FFs} = 1271$$

$$\chi^2_{FFs} = 1041$$

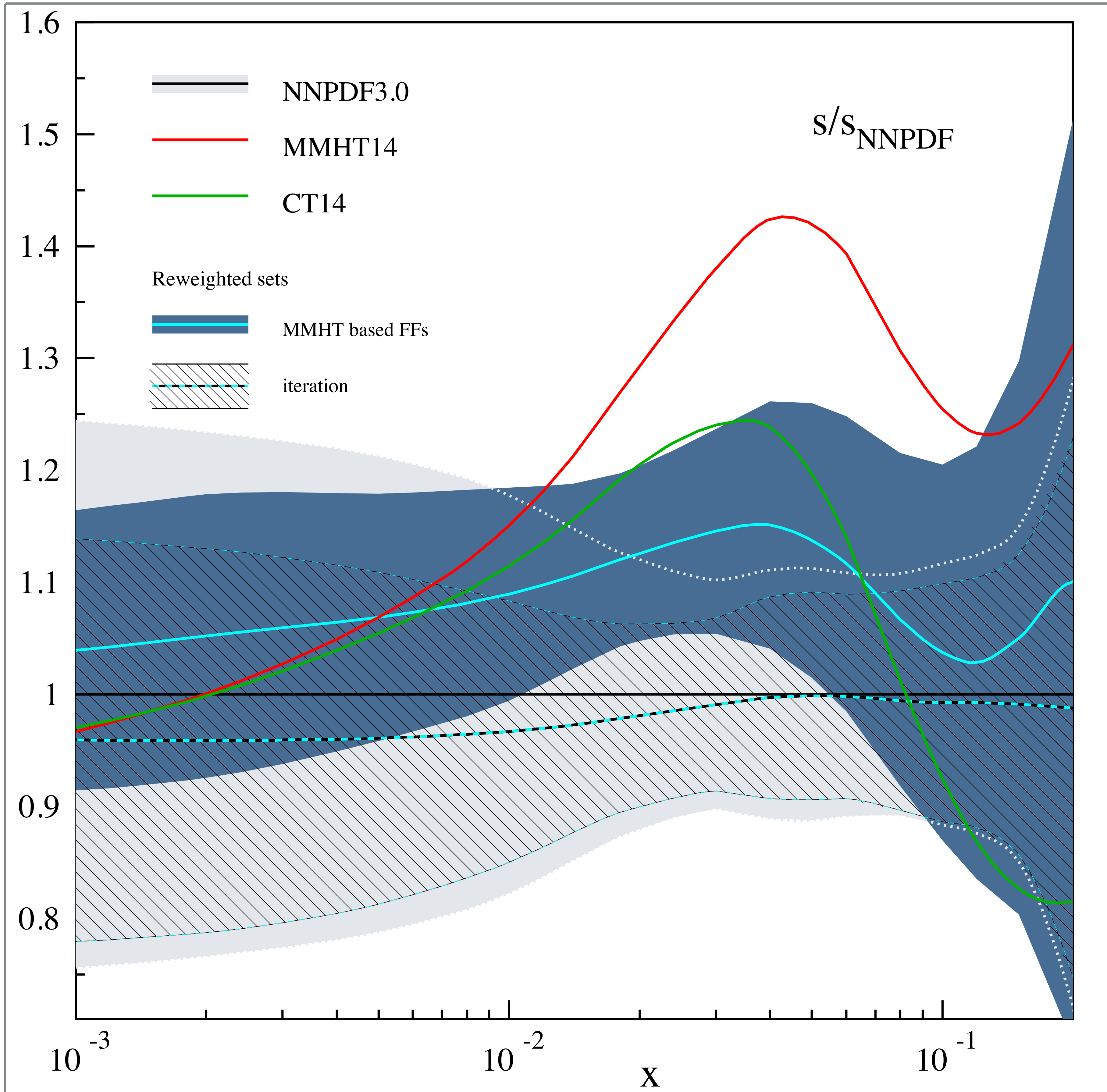


REWEIGHTING IN ACTION: STRANGE QUARK DISTRIBUTION

$$\chi^2_{FFs} = 1271$$

$$\chi^2_{FFs} = 1041$$

$$\chi^2_{FFs} = 1002$$



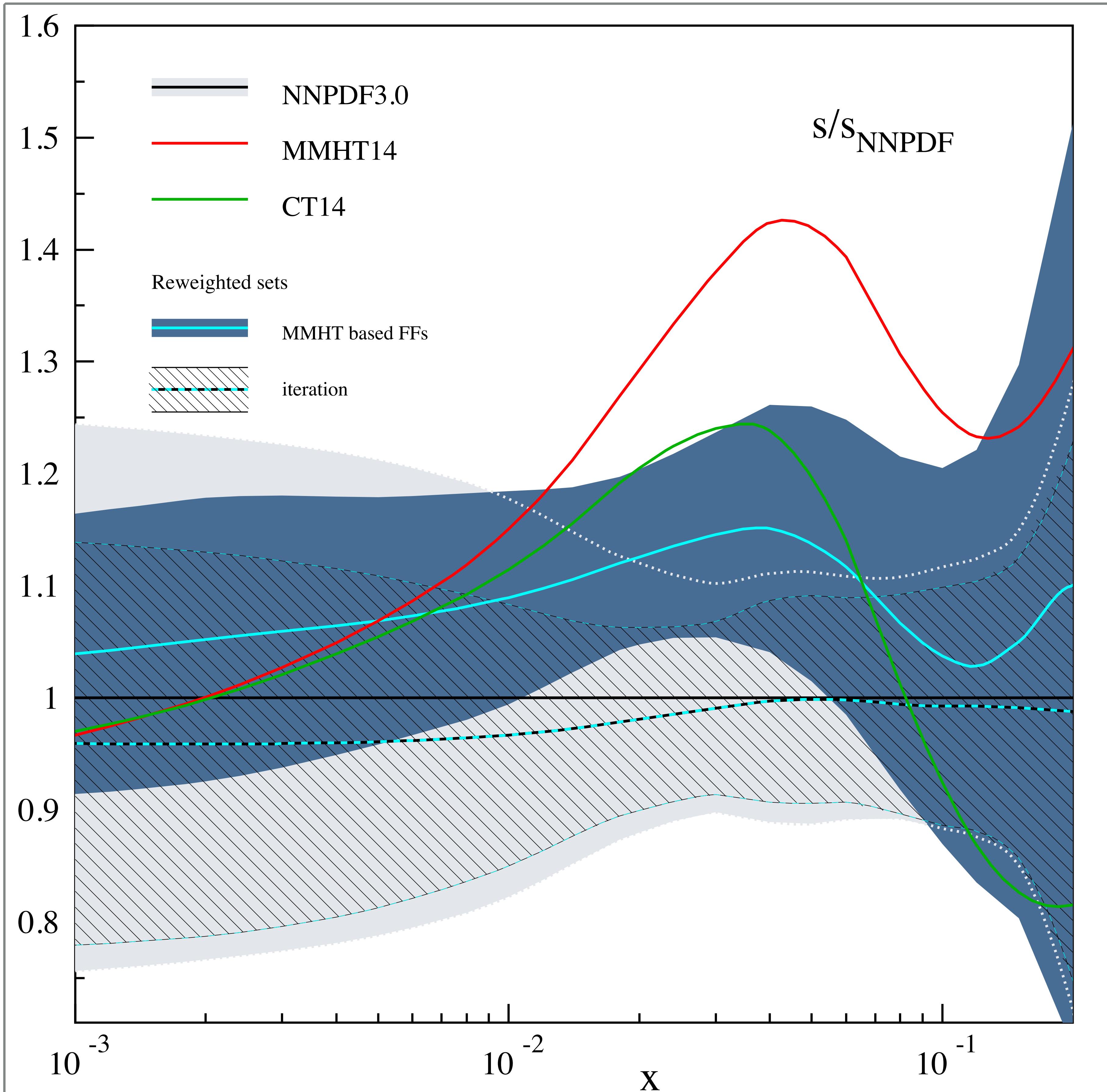
REWEIGHTING IN ACTION: STRANGE QUARK DISTRIBUTION

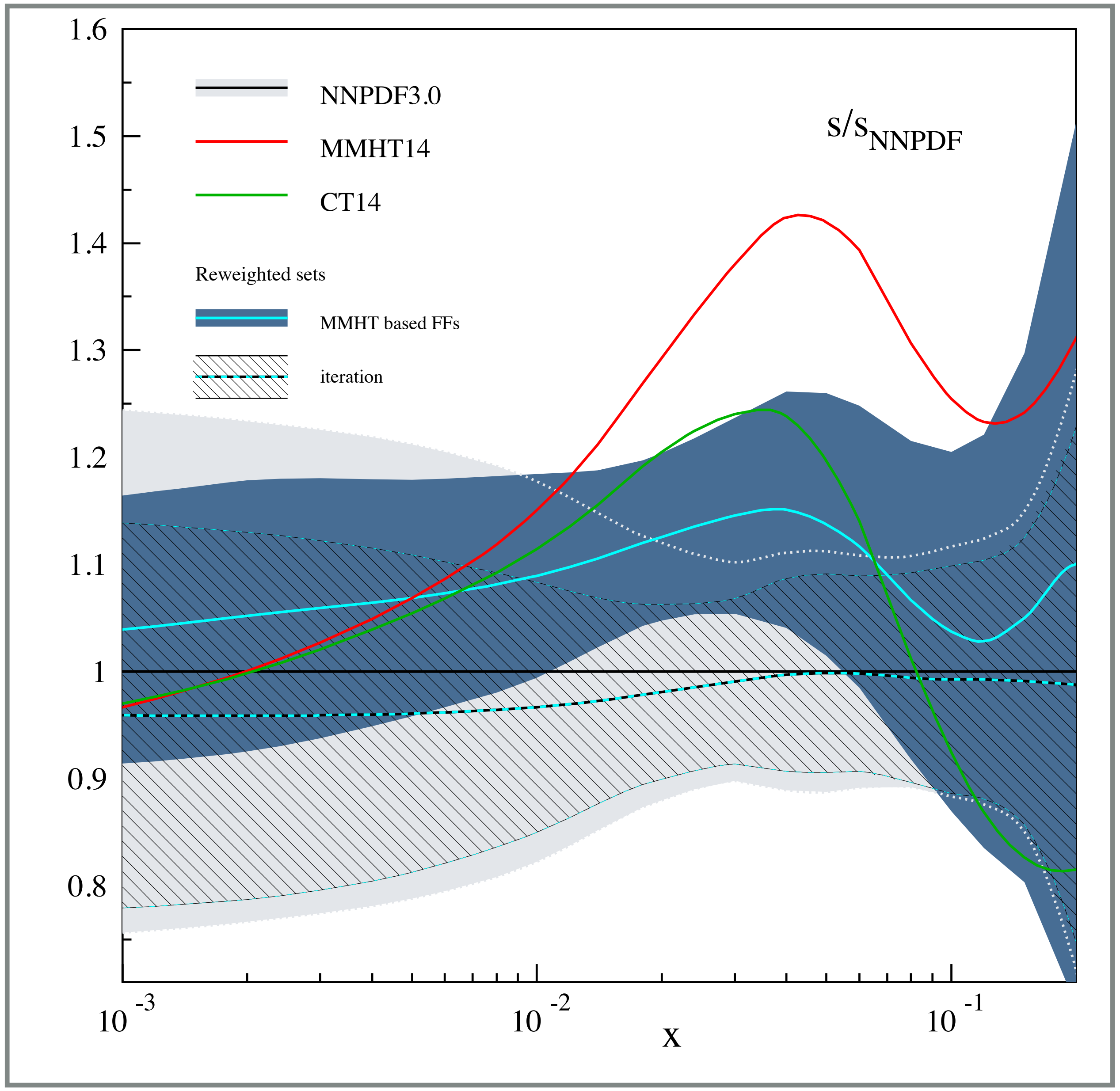
$\chi^2_{FFs} = 1271$

$\chi^2_{FFs} = 1041$

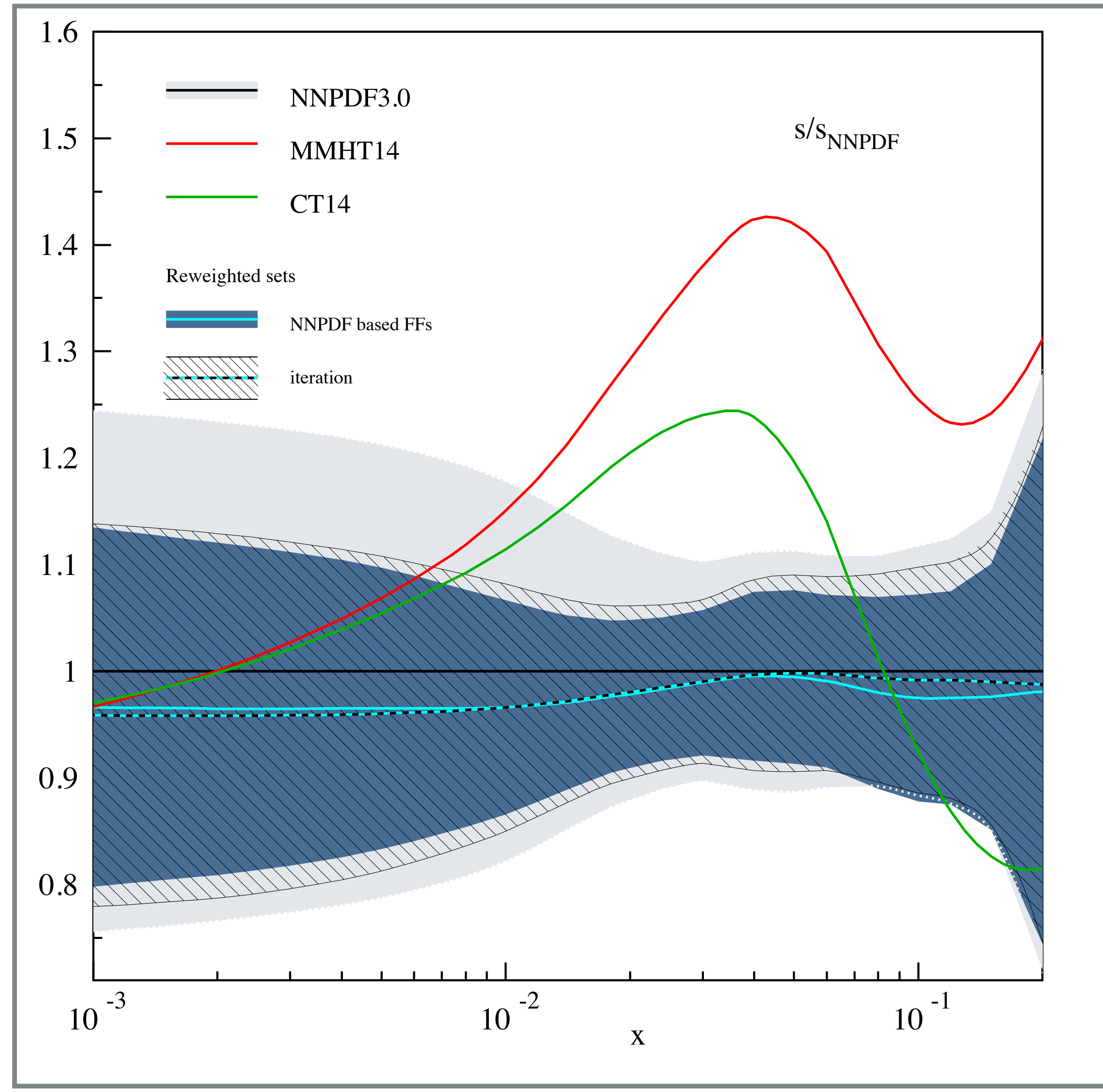
$\chi^2_{FFs} = 1002$

- Fast convergence
- Uncertainties reduction of order 10%



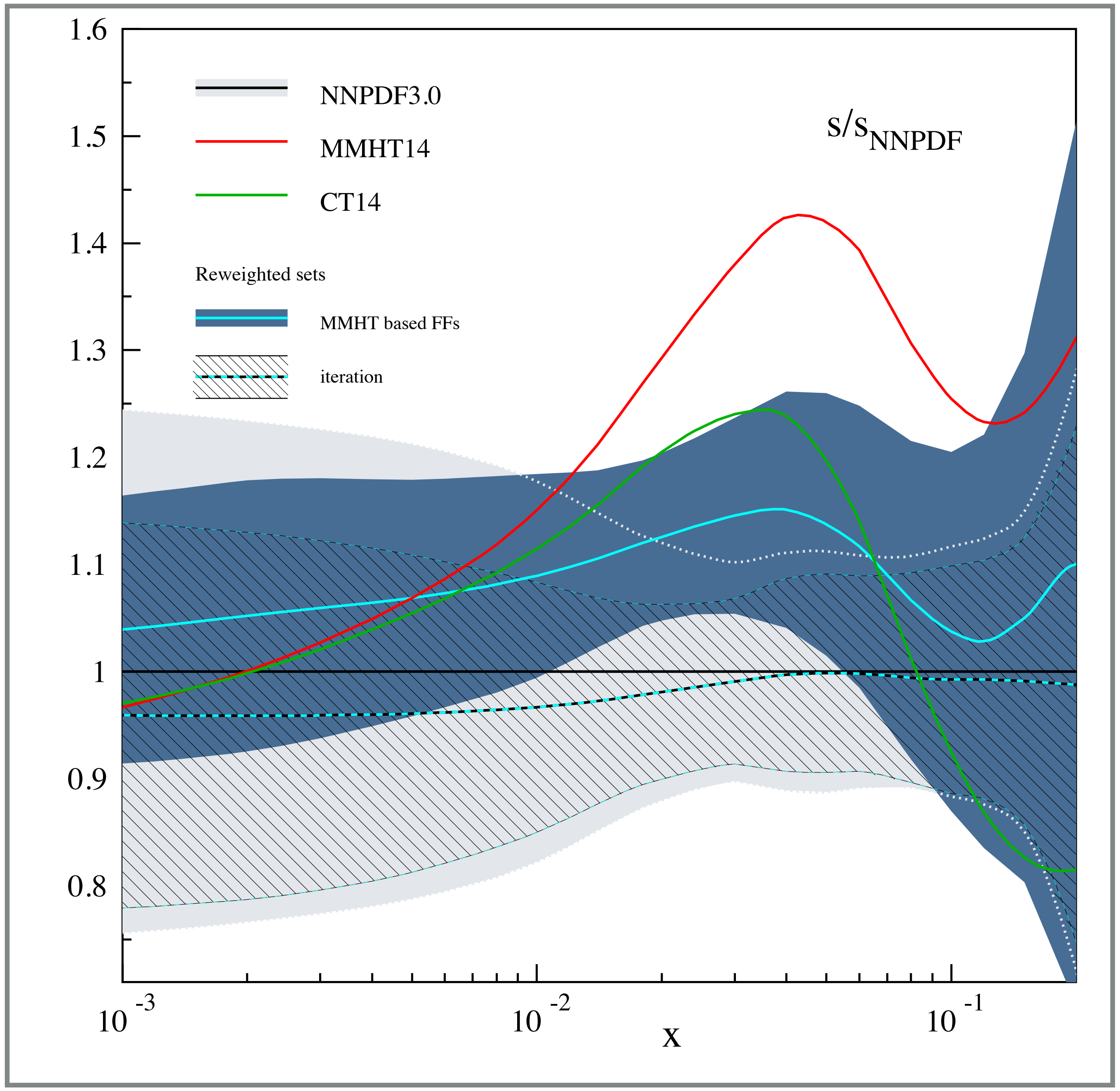


Starting from DSS based MMHT14

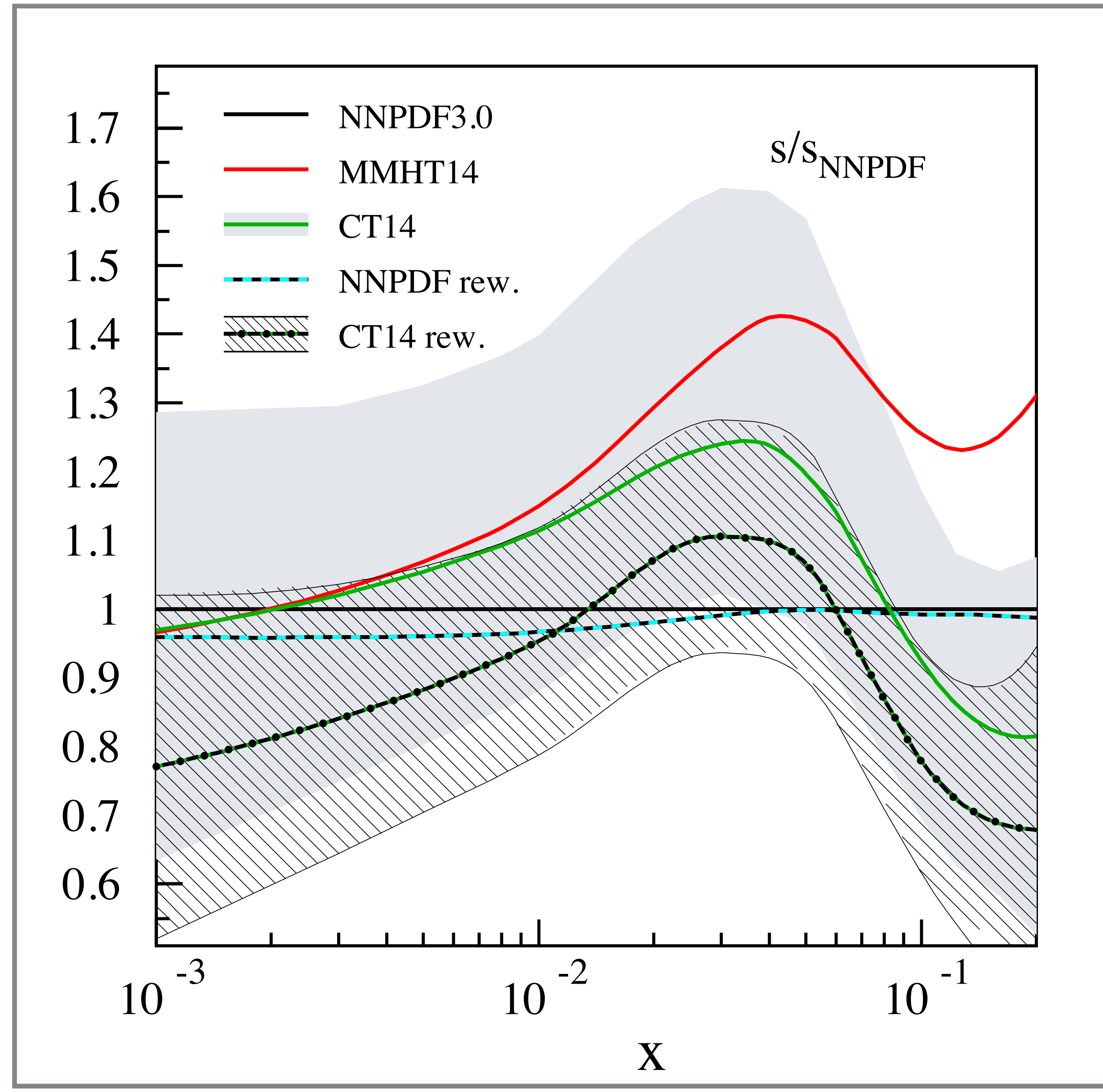


Starting from DSS based NNPDF3.0

Independency from the starting set of PDFs



Using NNPDF3.0 Replicas



Using CT14 Replicas

Independency from the set of replicas used