The interplay between PDF fits and heavy New Physics searches

Luca Mantani

In collaboration with:
PBSP collab: Maria Ubiali, Elie Hammou, James Moore, Mark Costantini, Manuel Morales, Maeve Madigan, Zahari Kassabov

UNIVERSITY OF CAMBRIDGE

CMS EFT workshop

European Research Council
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Motivation

The parton model for the proton

We search for NP at the LHC, where protons are smashed

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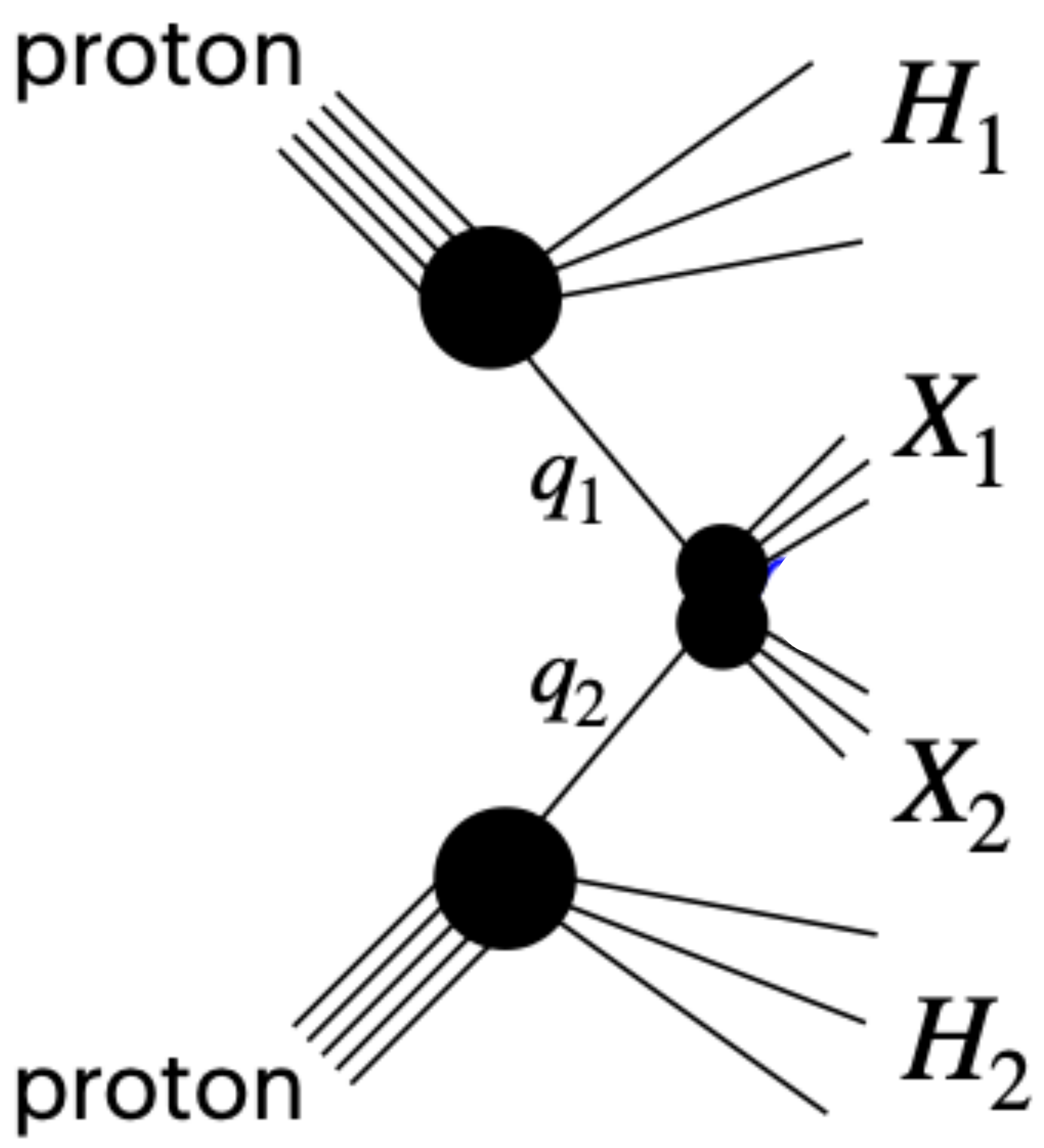

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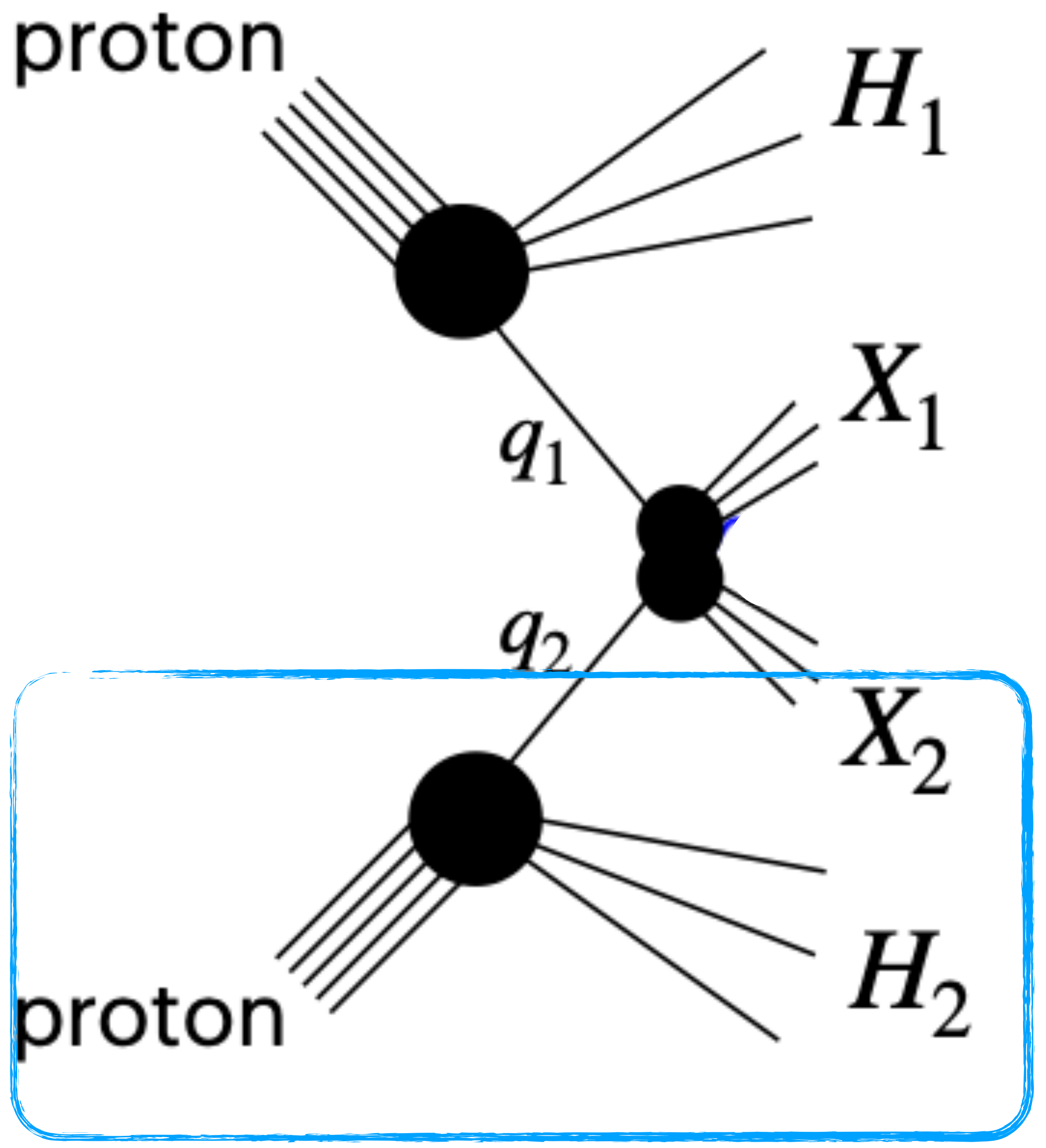

parton distribution function (PDF)

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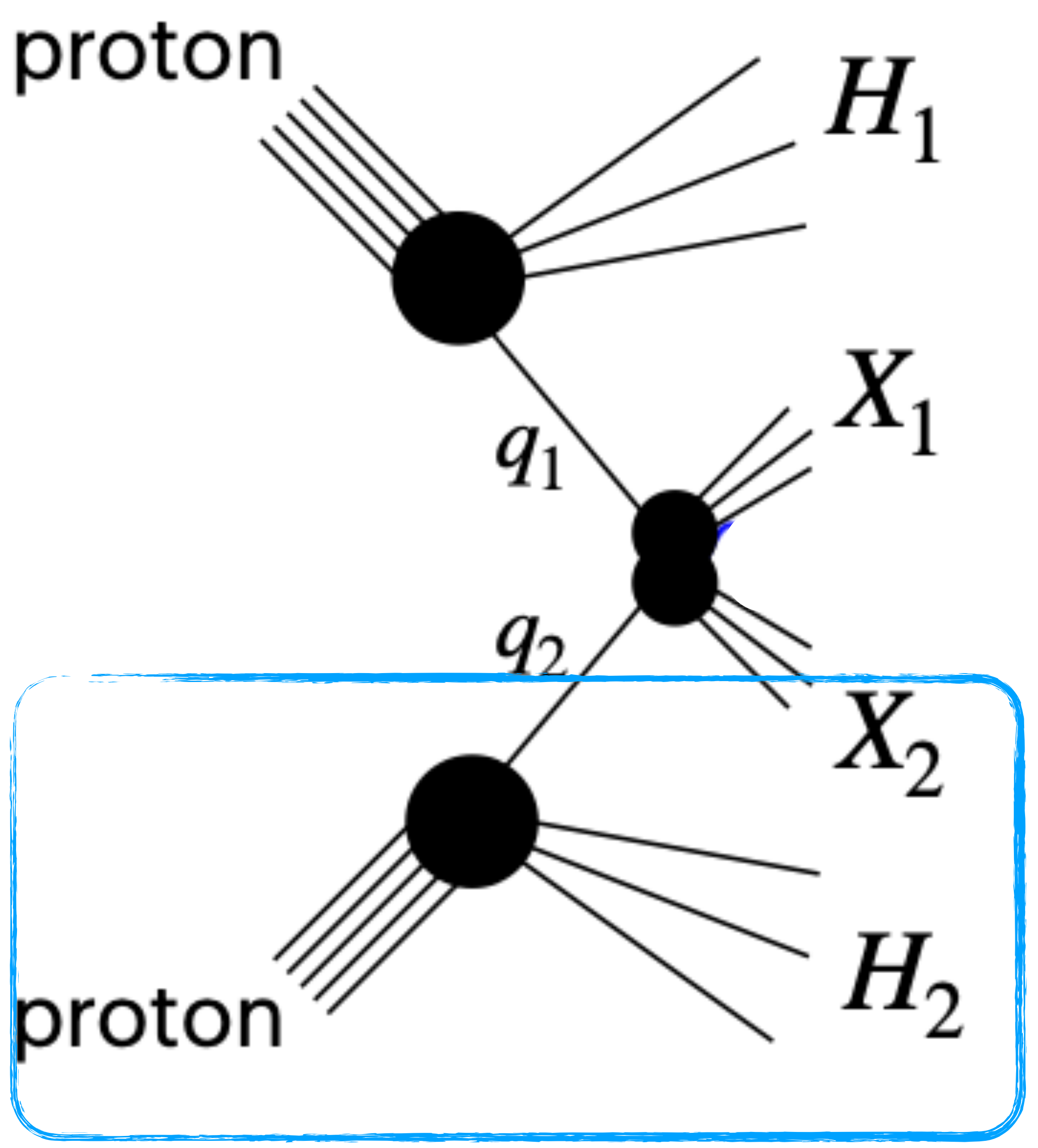

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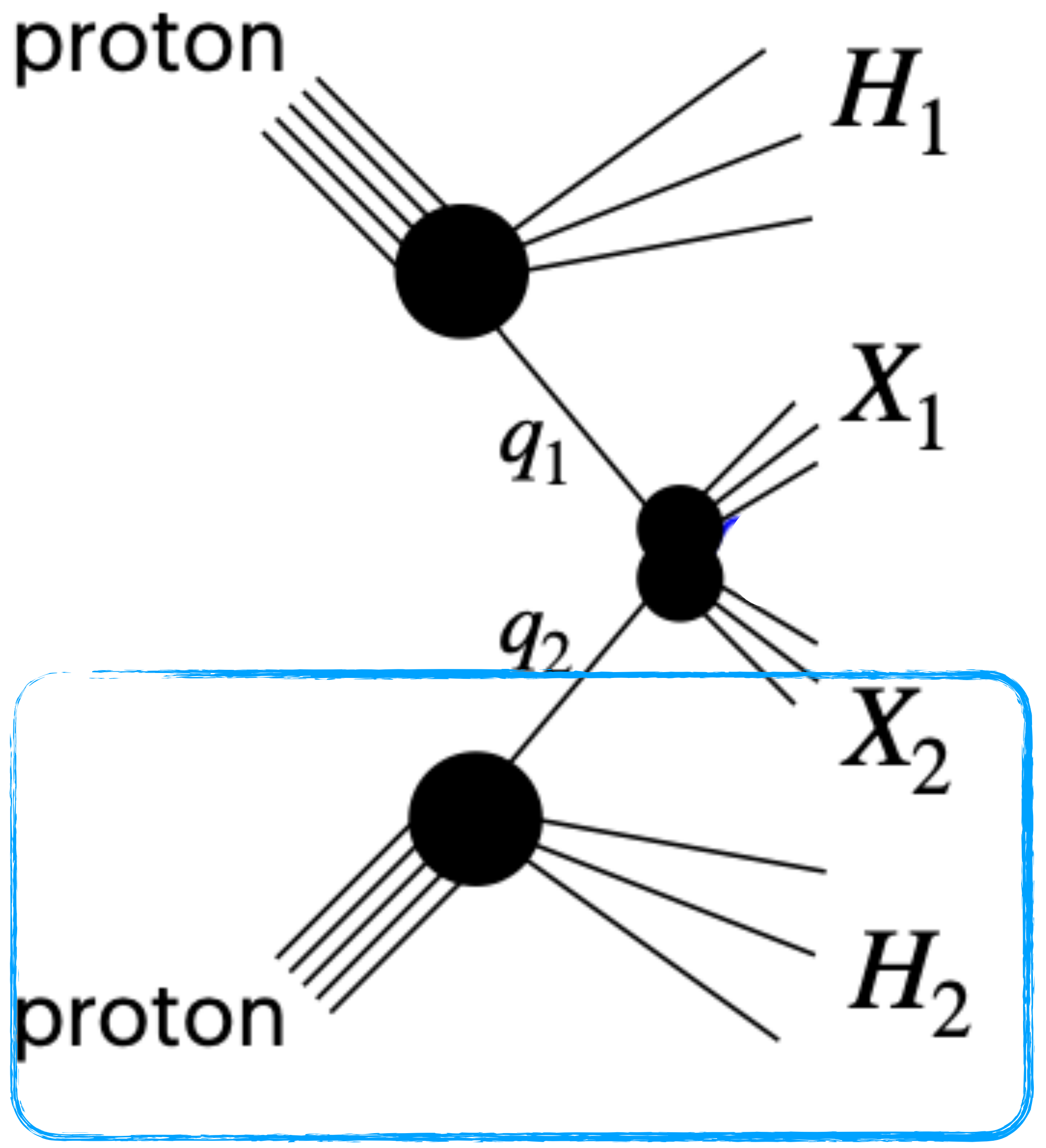

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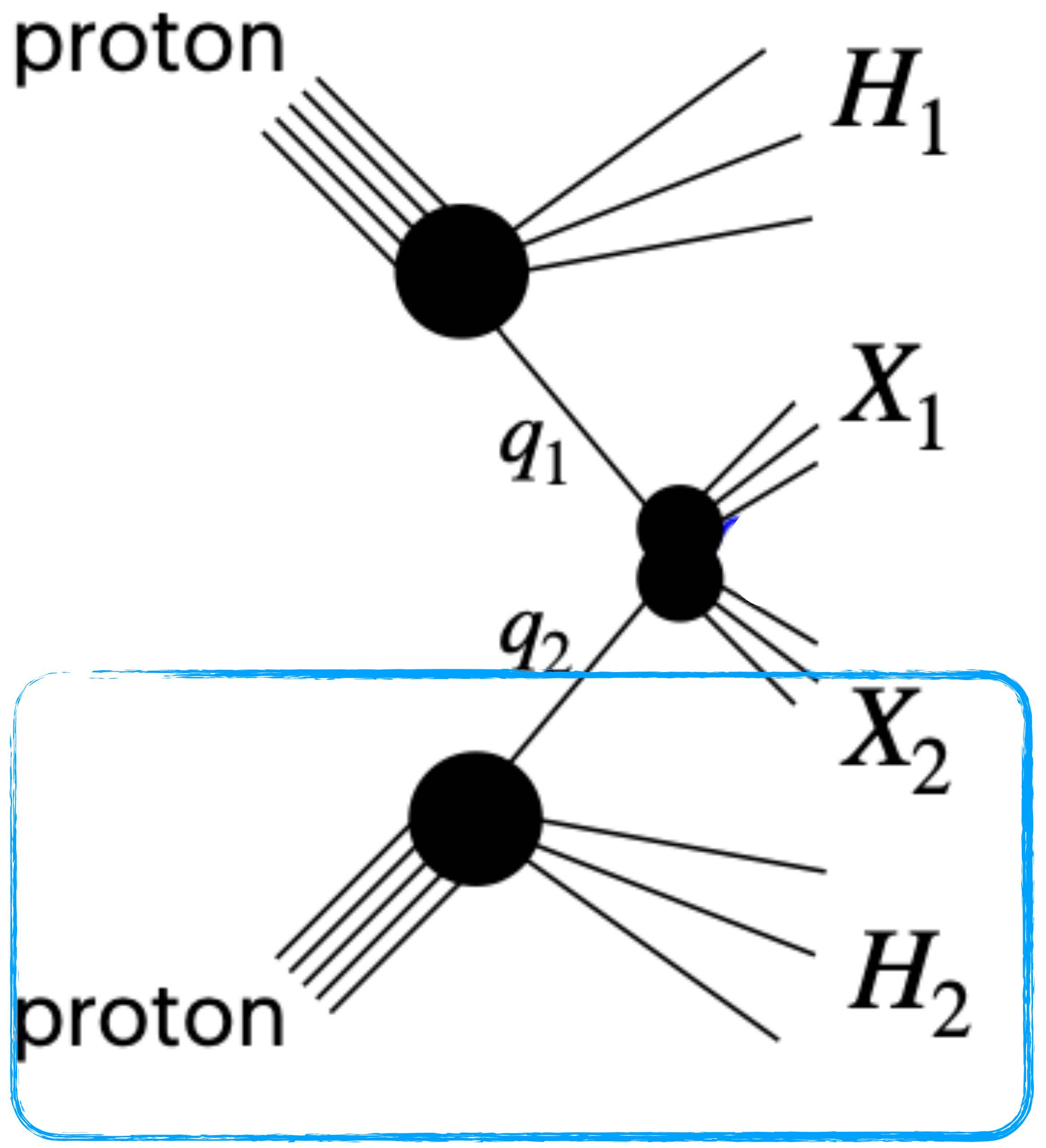

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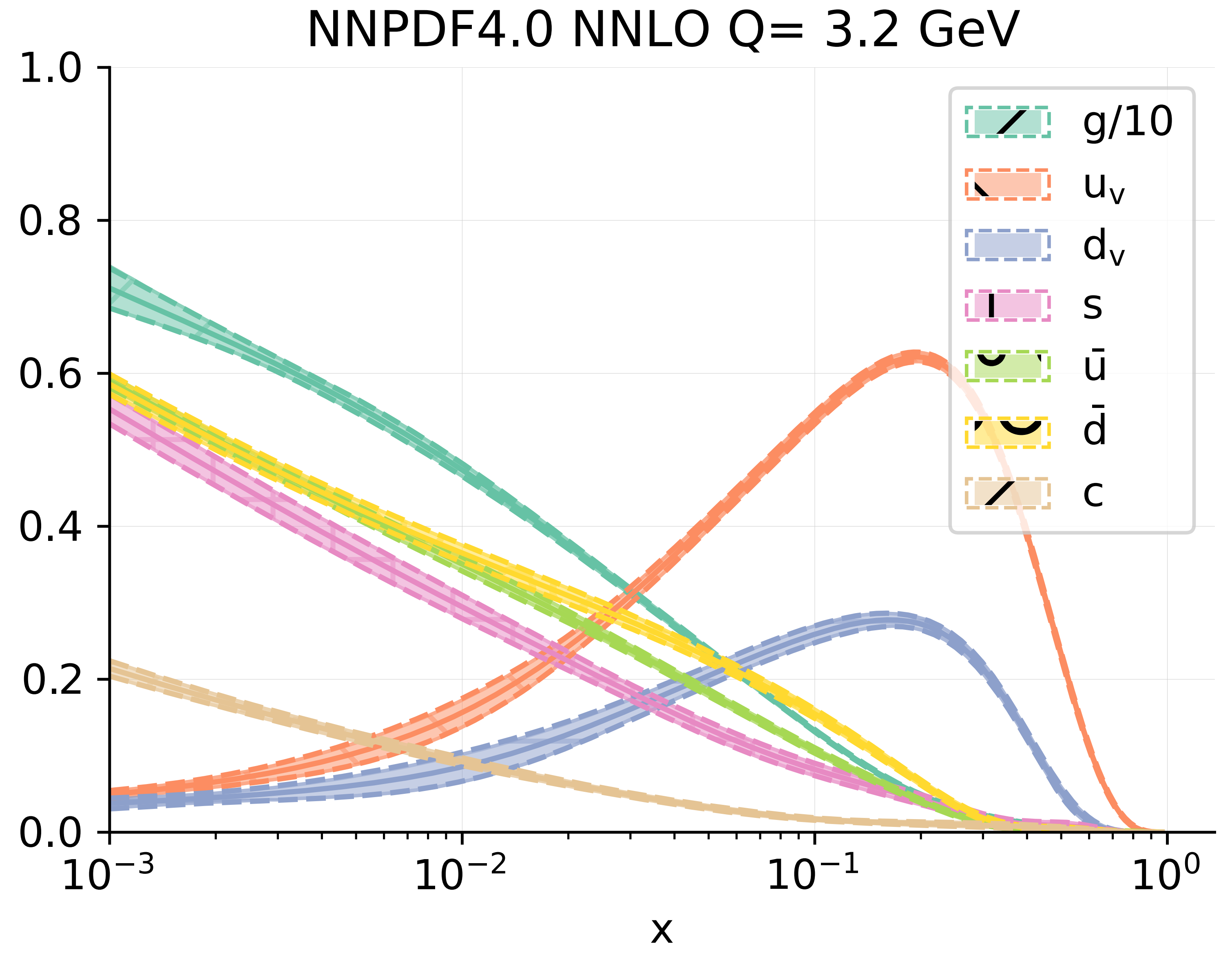
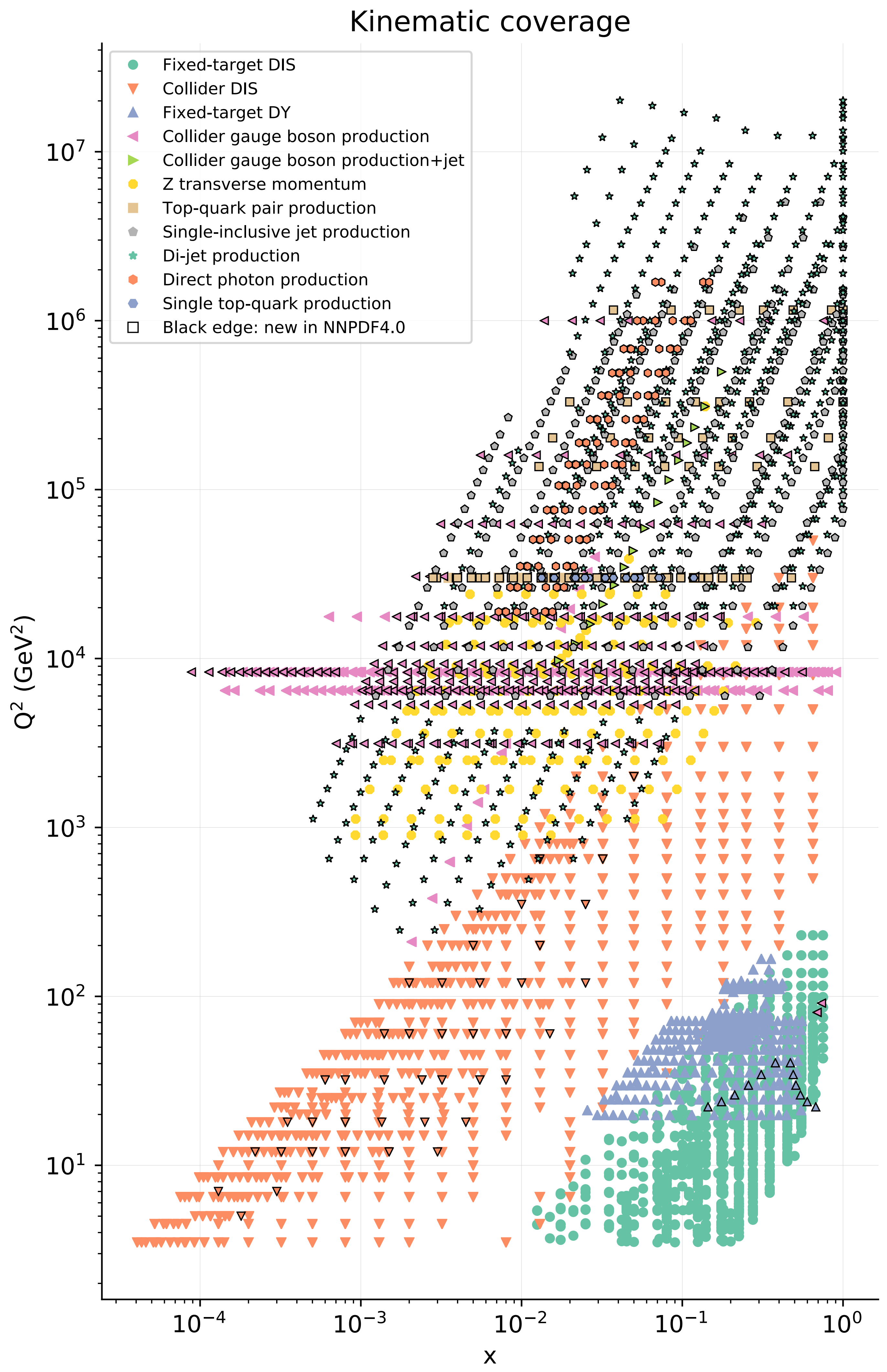


Ball et. al, NNPDF4.0, 2109.02653

PDF determination



Data driven determination

Theory assumptions

Measurements

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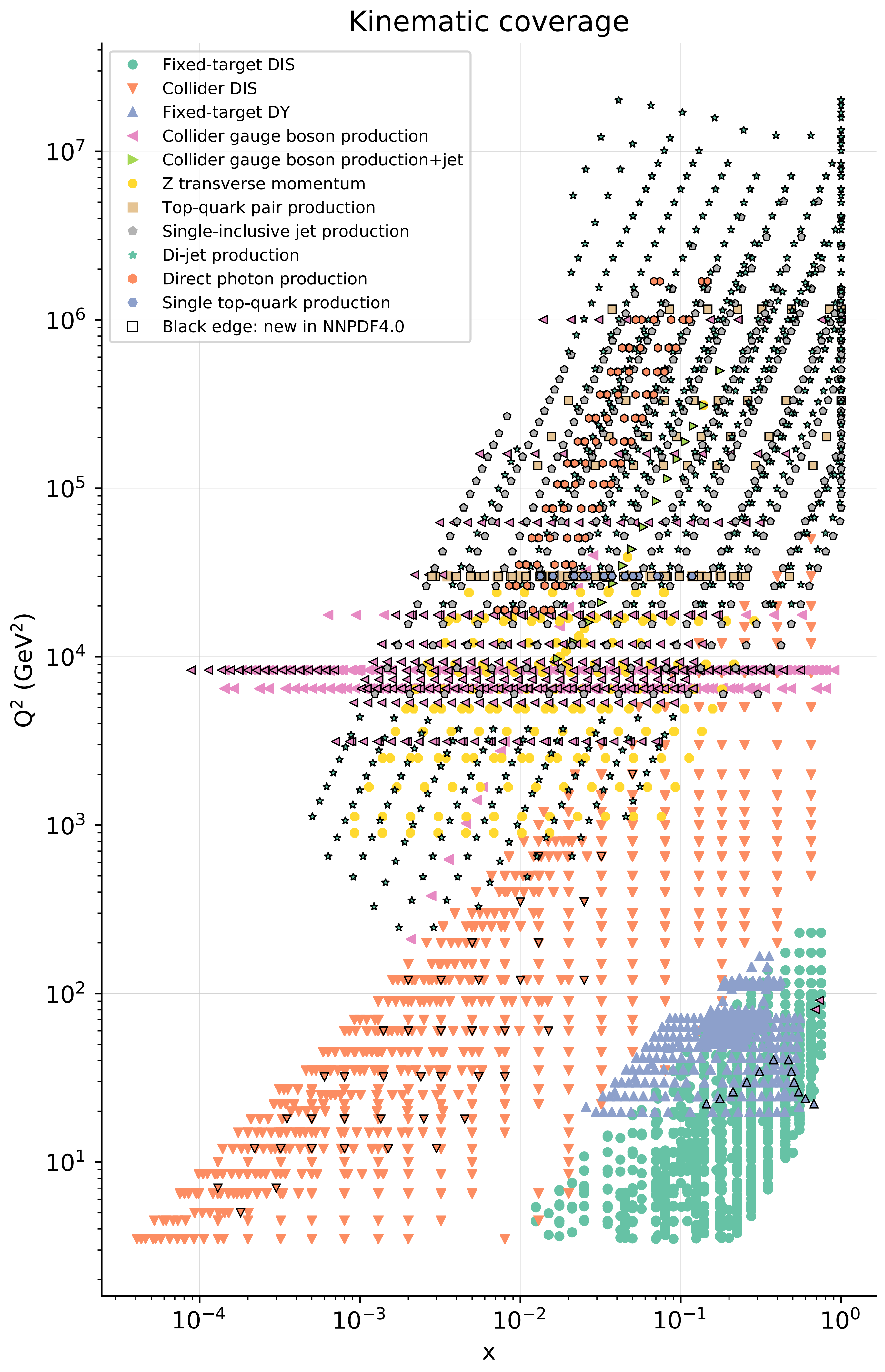

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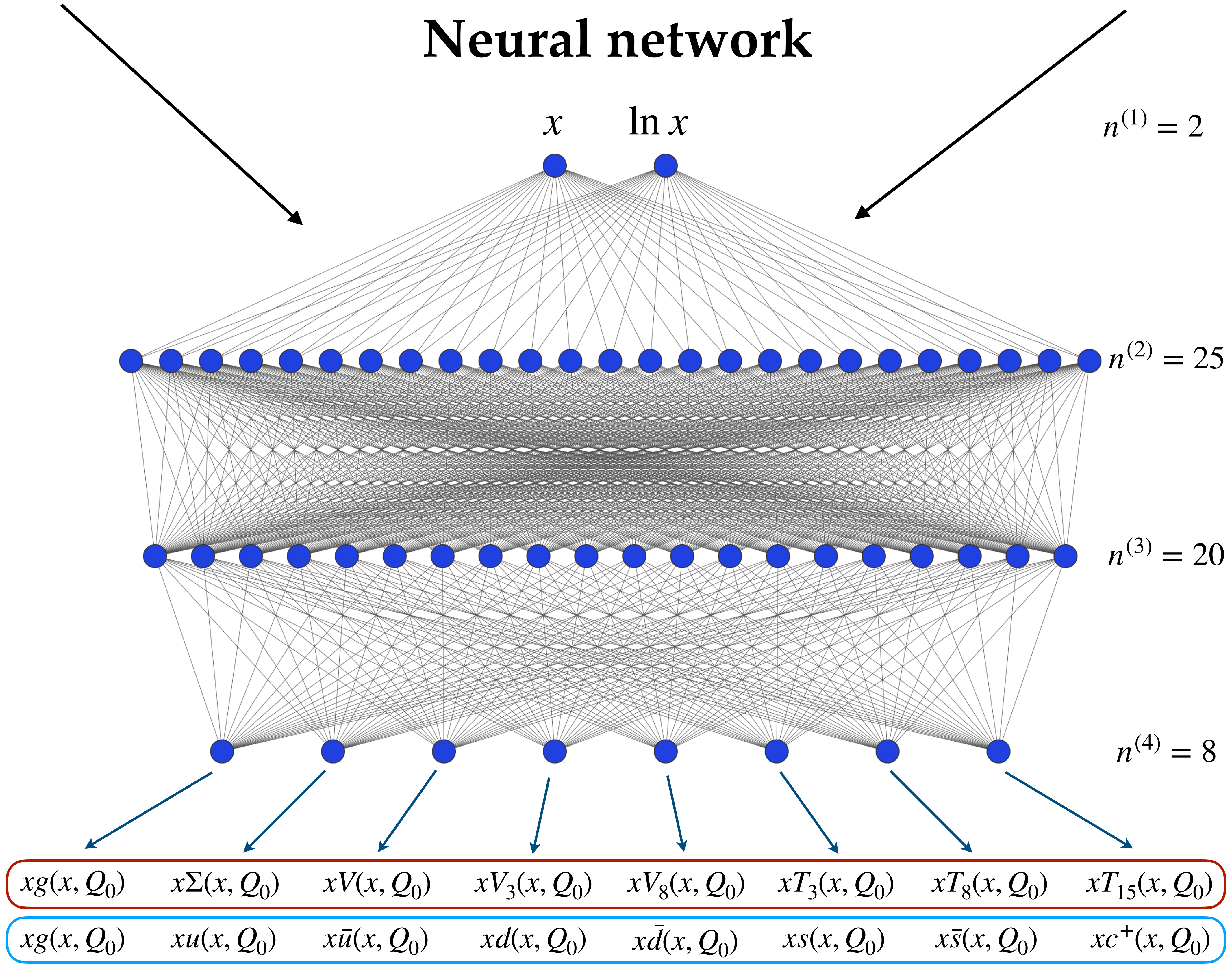

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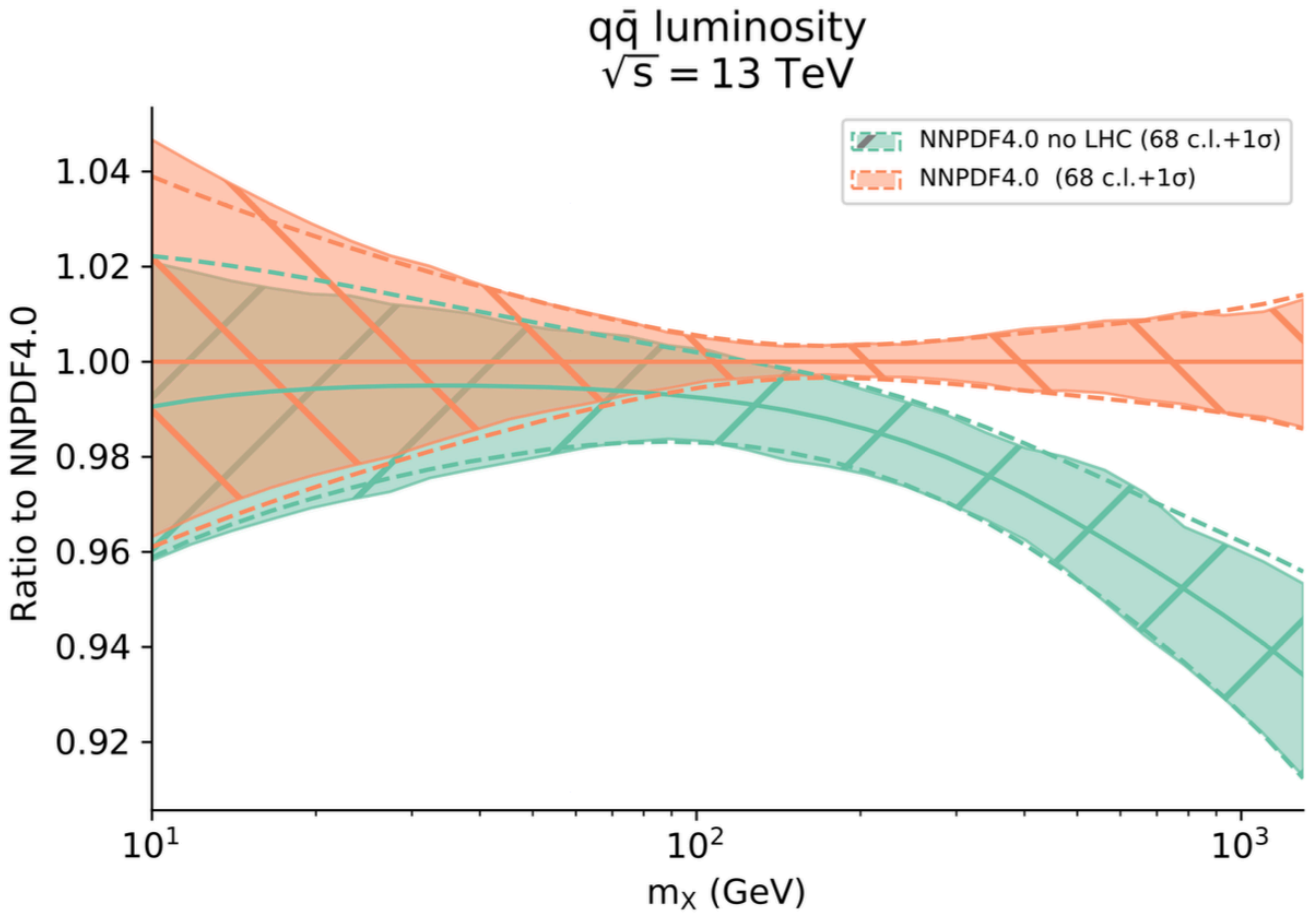

PDF parametrisation
is flexible… extrapolation is tricky

Central value/uncertainty
pre-LHC badly estimated

Separating datasets
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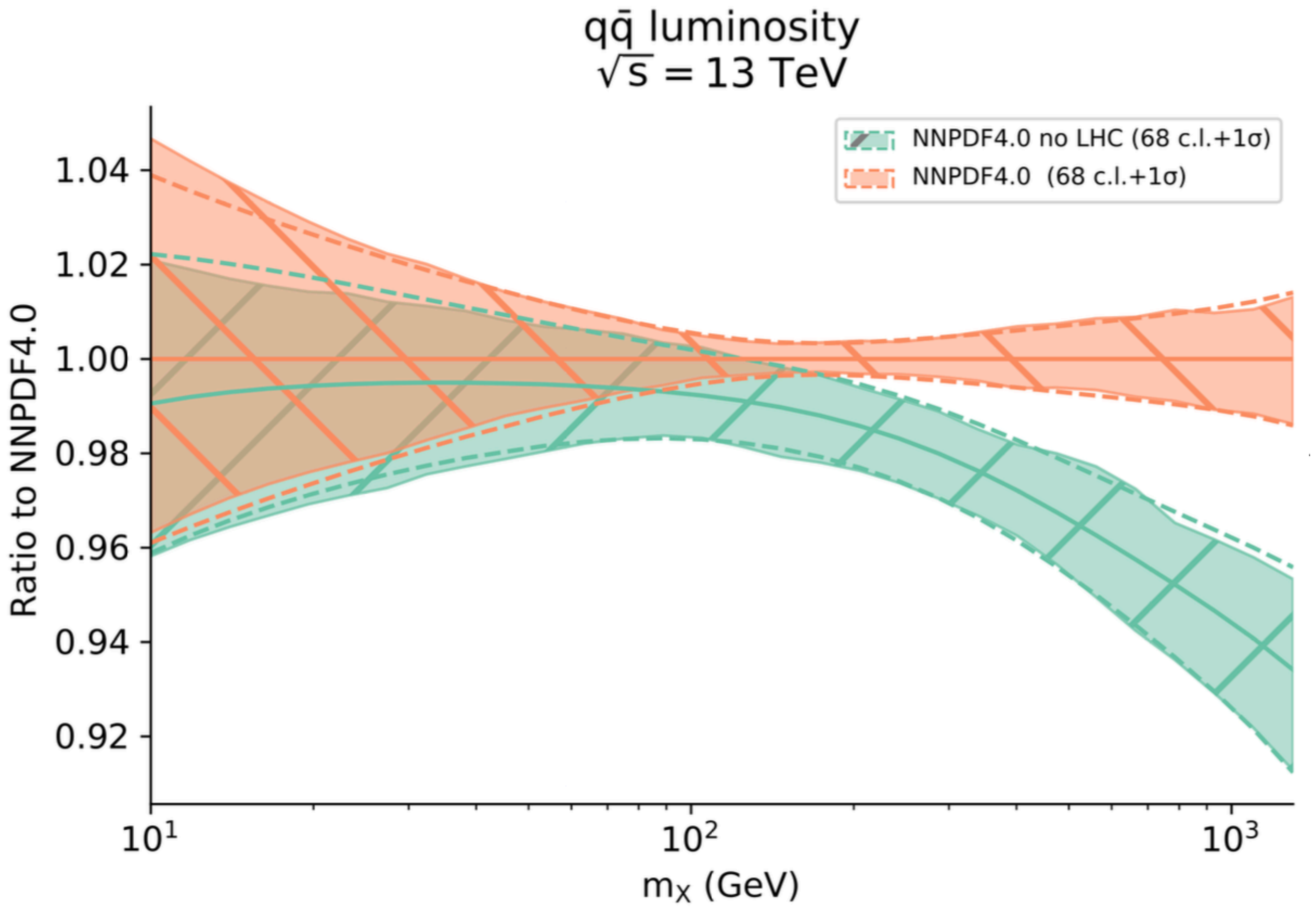

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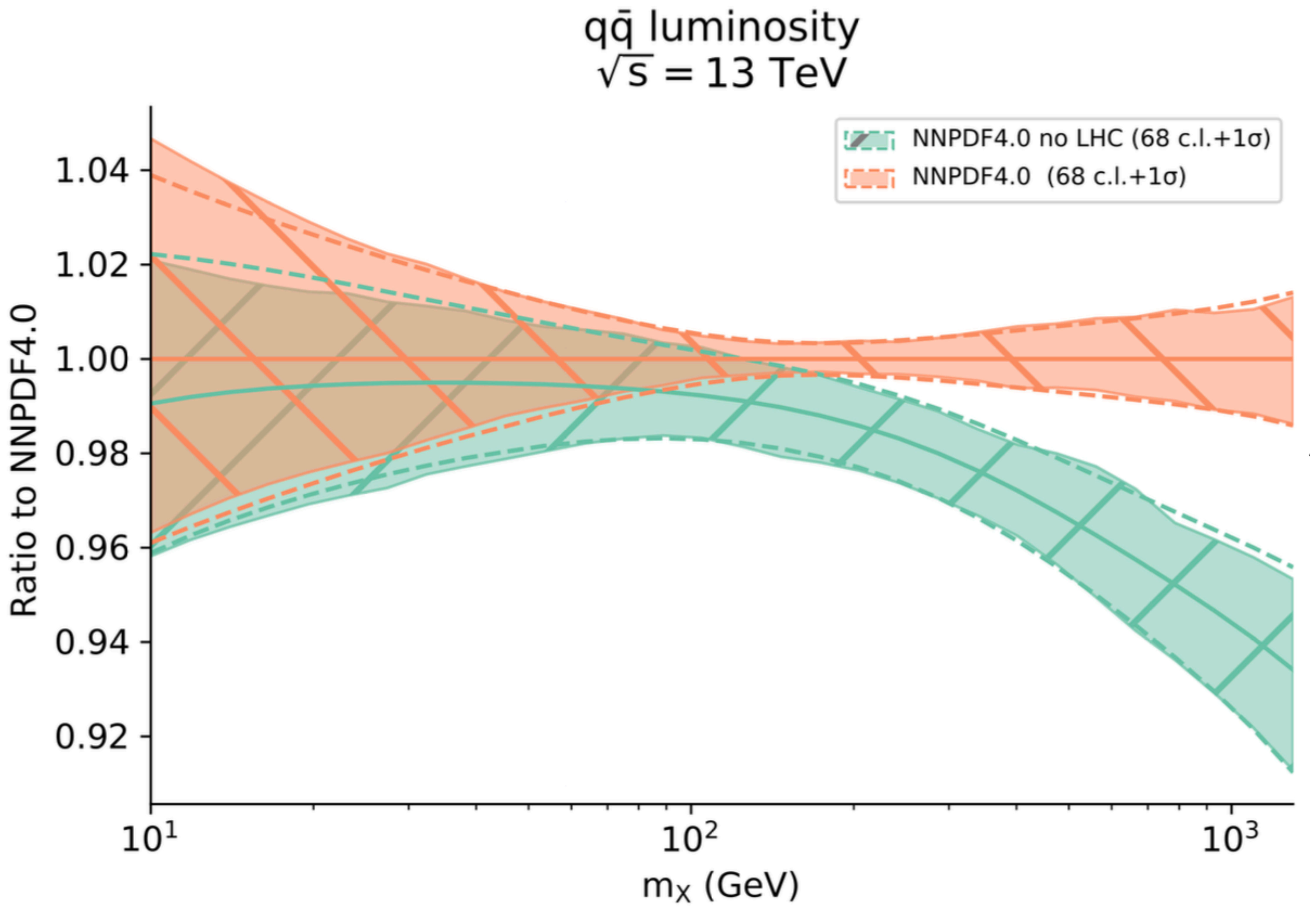

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Is it possible that NP is being absorbed in the proton?

The common approach

Typically fits of physics parameters and PDFs do not talk

$$\sigma(C,\theta) = f_1(C,\theta) \otimes f_2(C,\theta) \otimes \hat{\sigma}(C)$$

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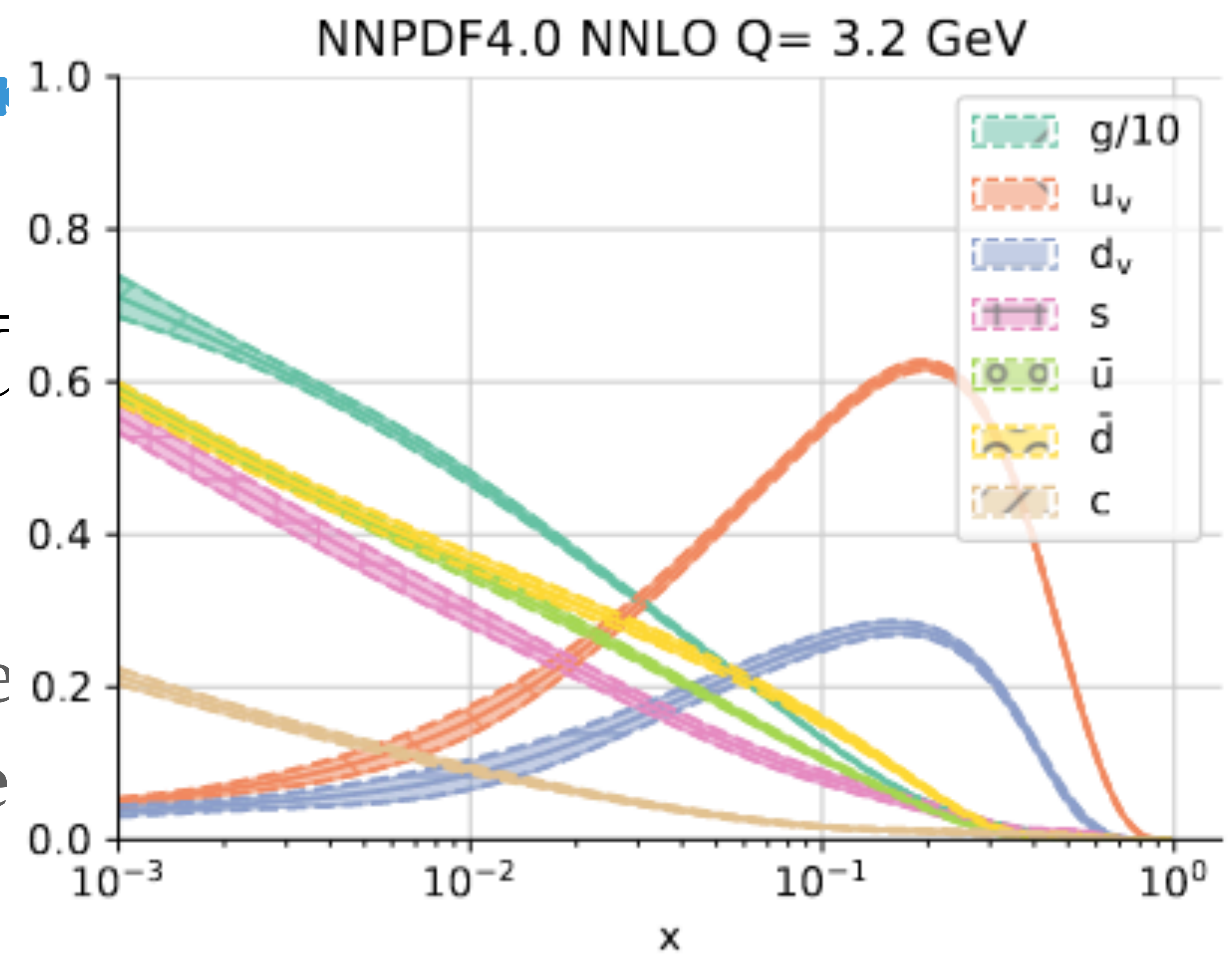

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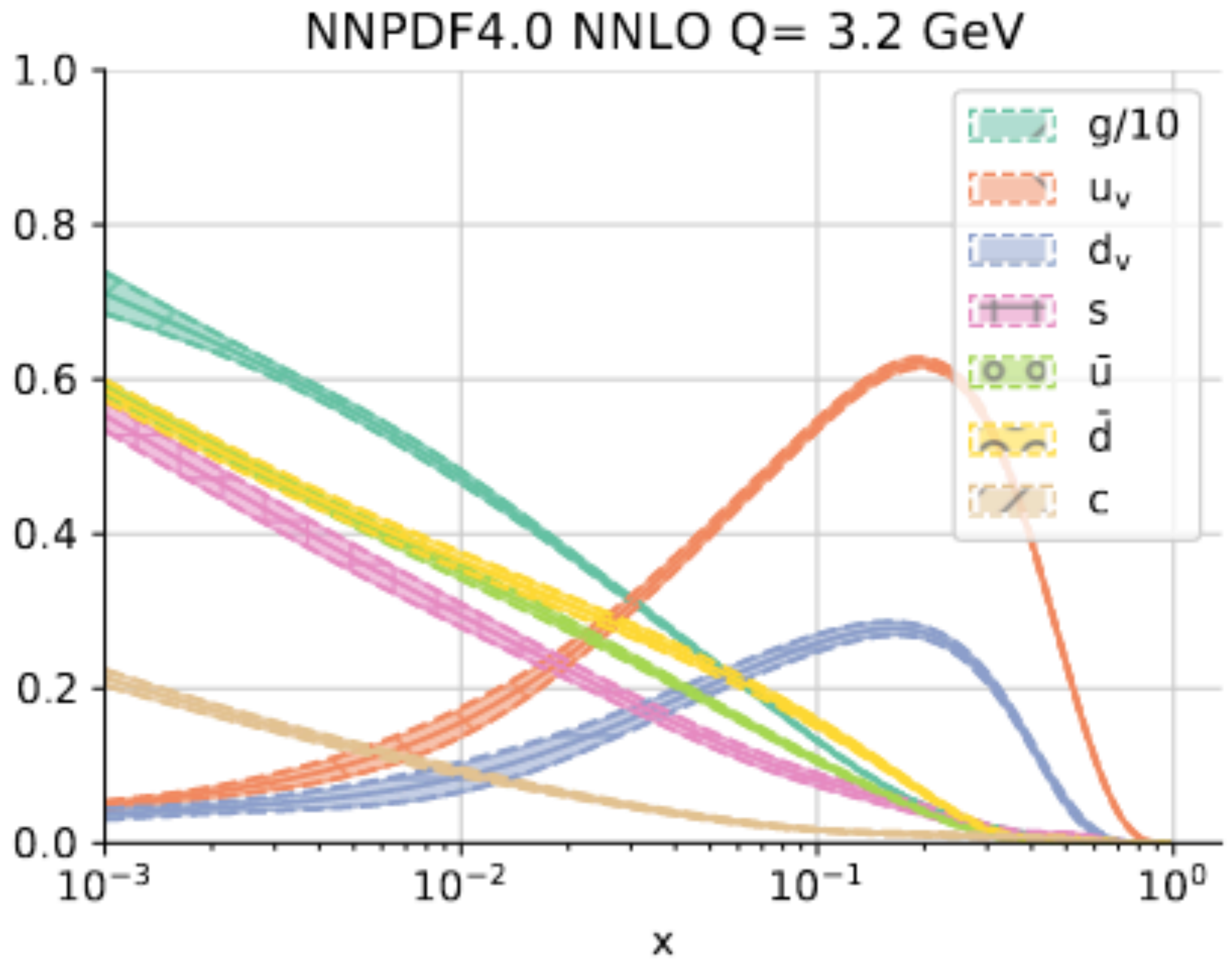

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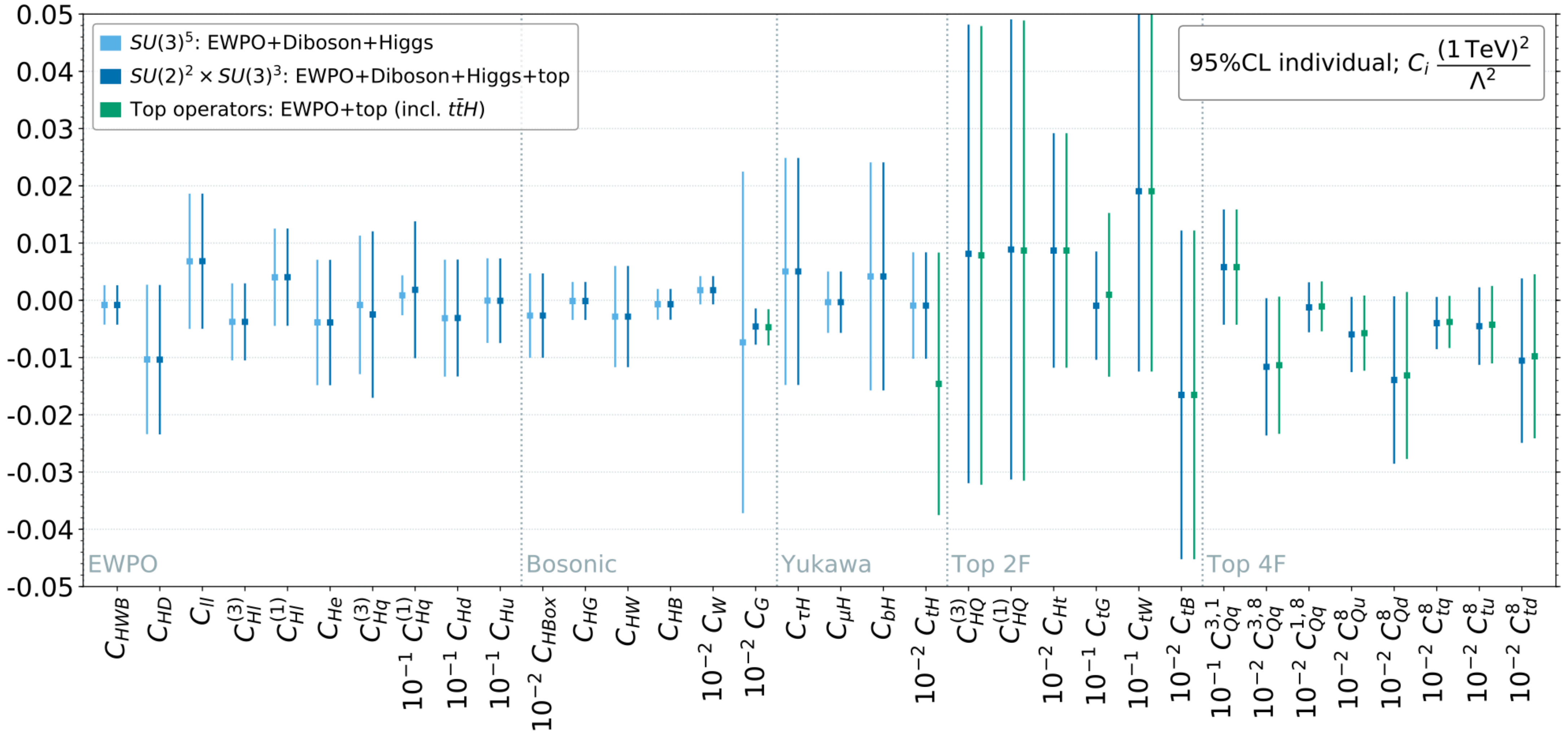
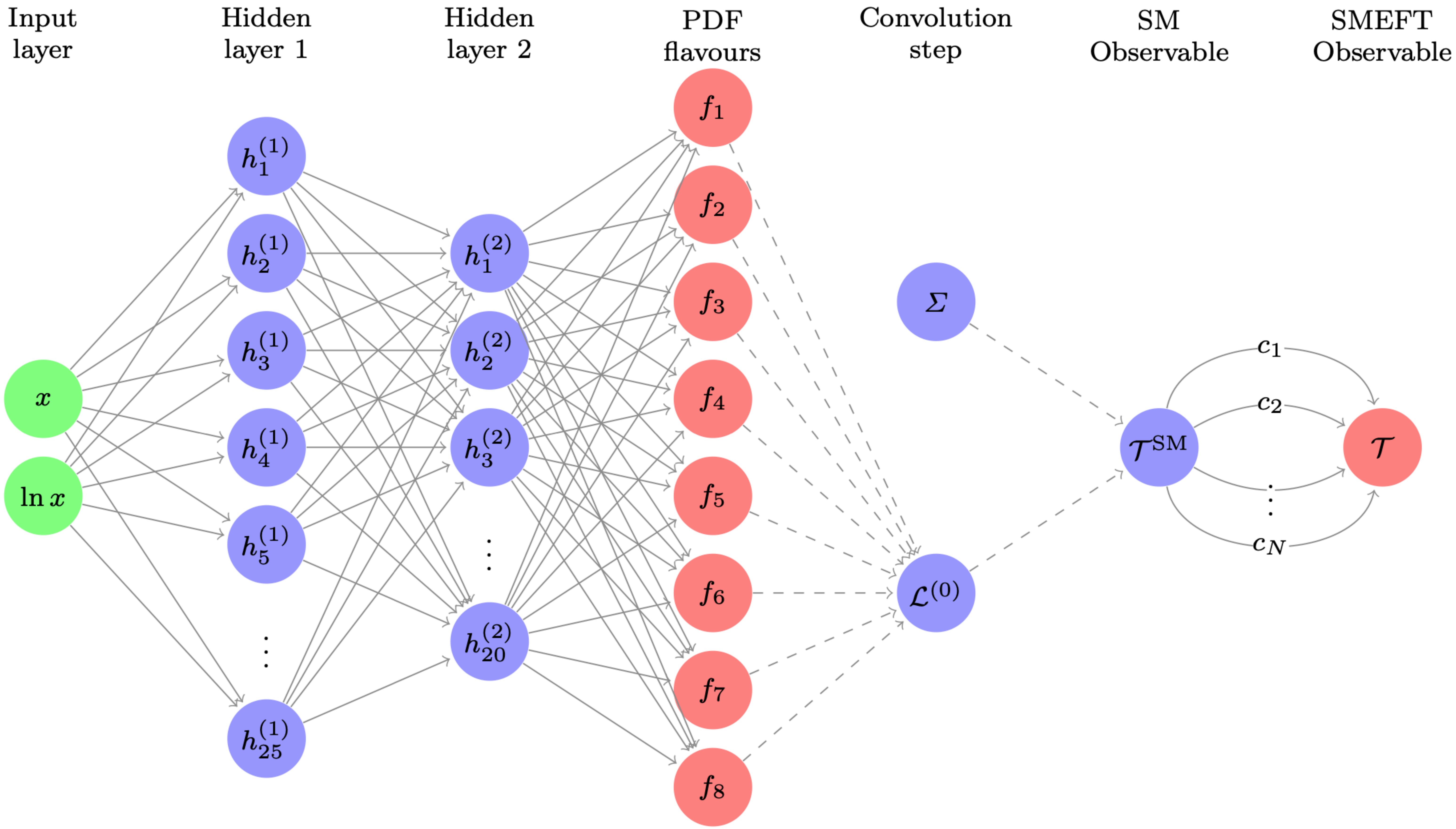


FitMaker [2012:02779]

SIMUnet

An extended methodology

Extension of the NNPDF framework



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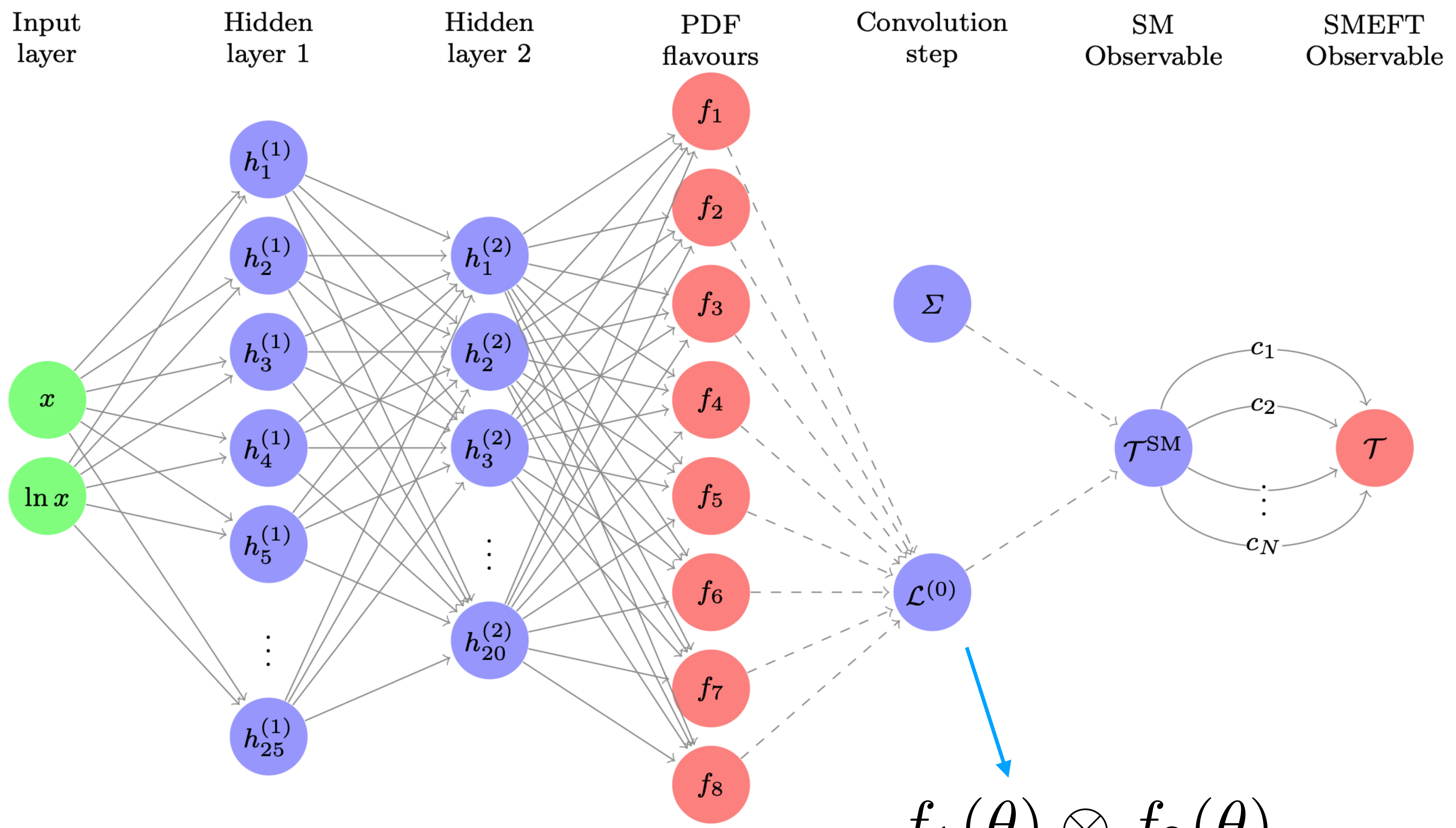

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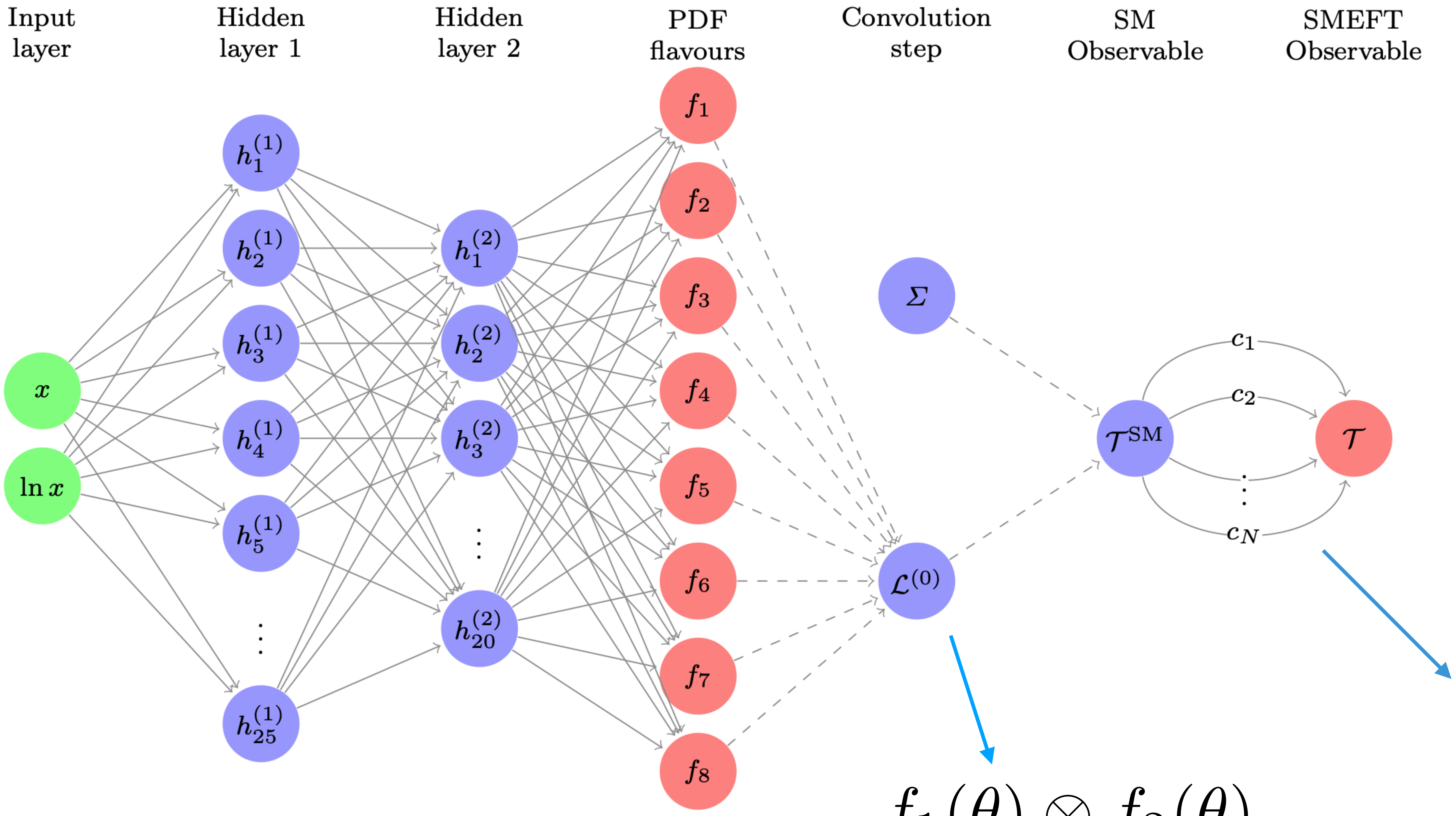

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EFT K-fact

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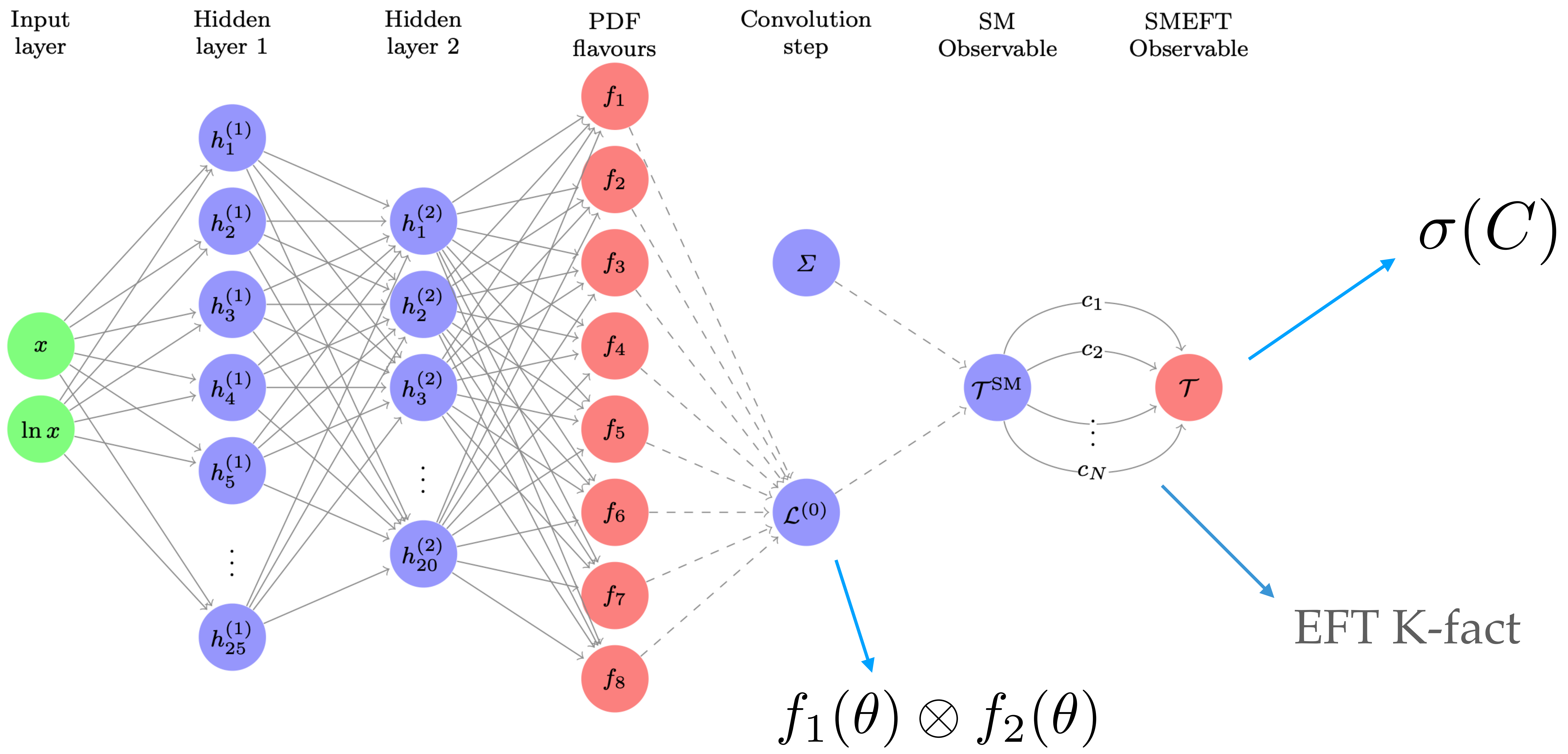

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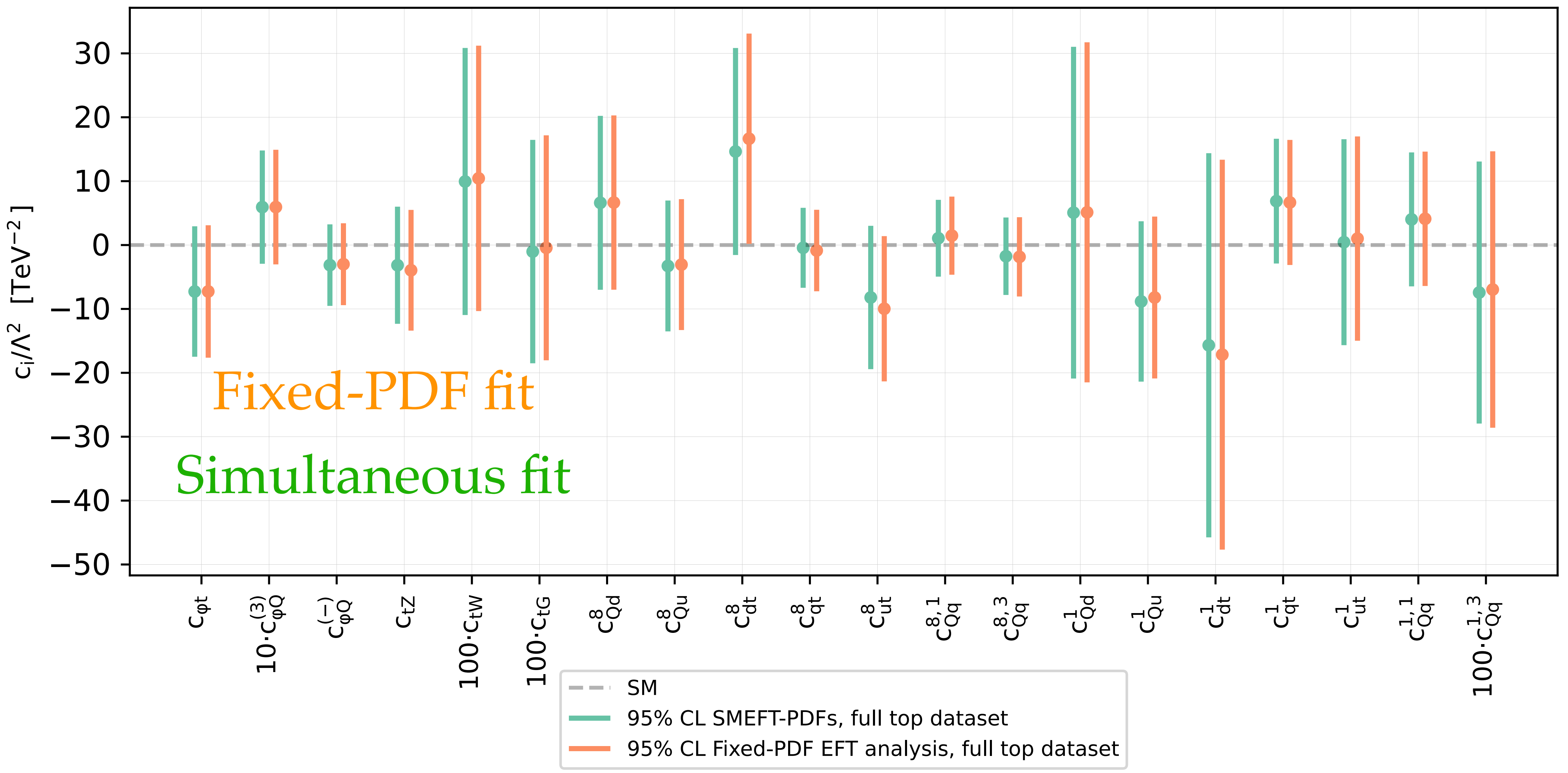
Going beyond: simultaneous fits

SMEFT-PDF interplay in top quark sector

Moderate effect on WC, ~ 5-10%



$\mathcal{O}(1/\Lambda^2)$ fit

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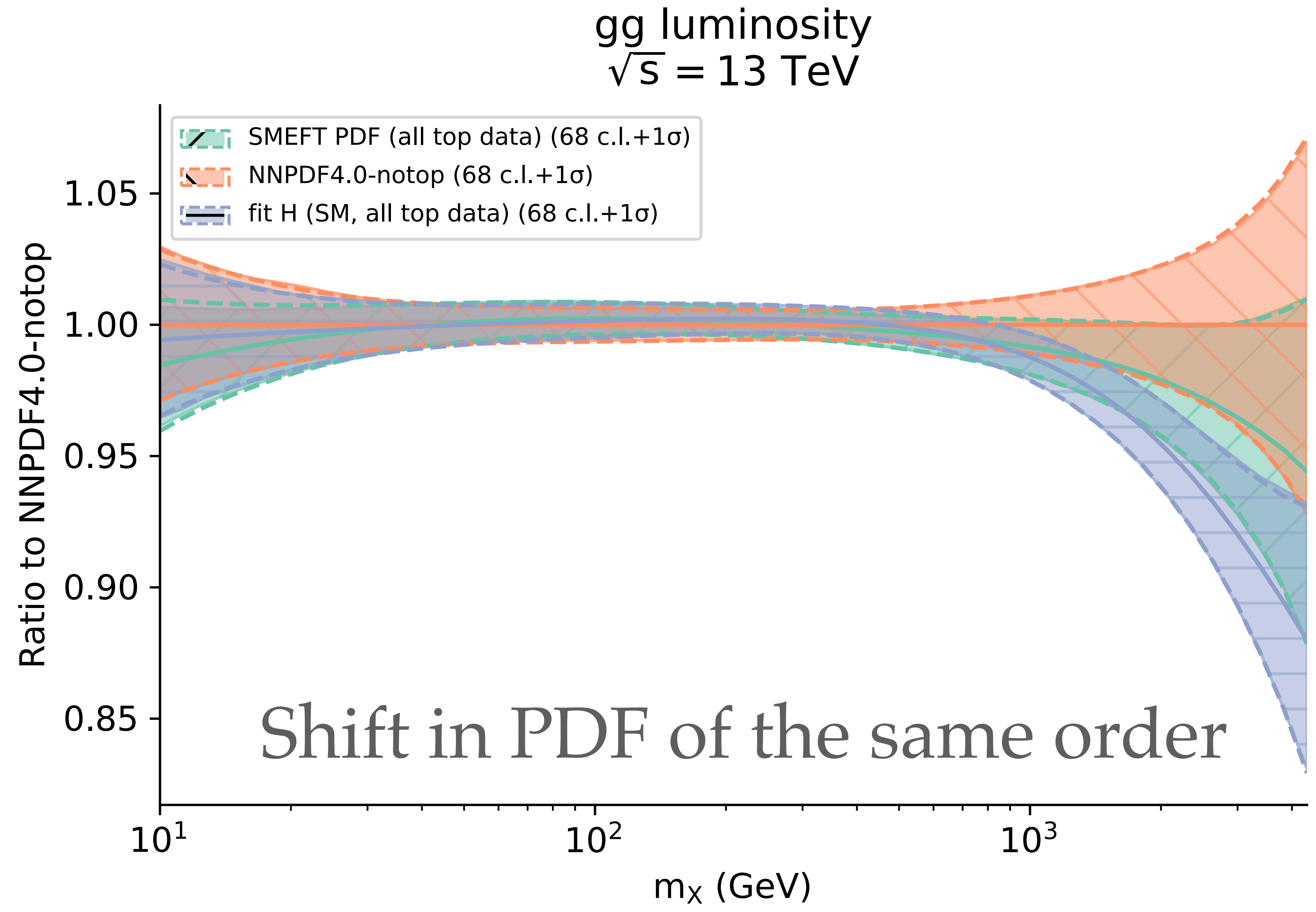

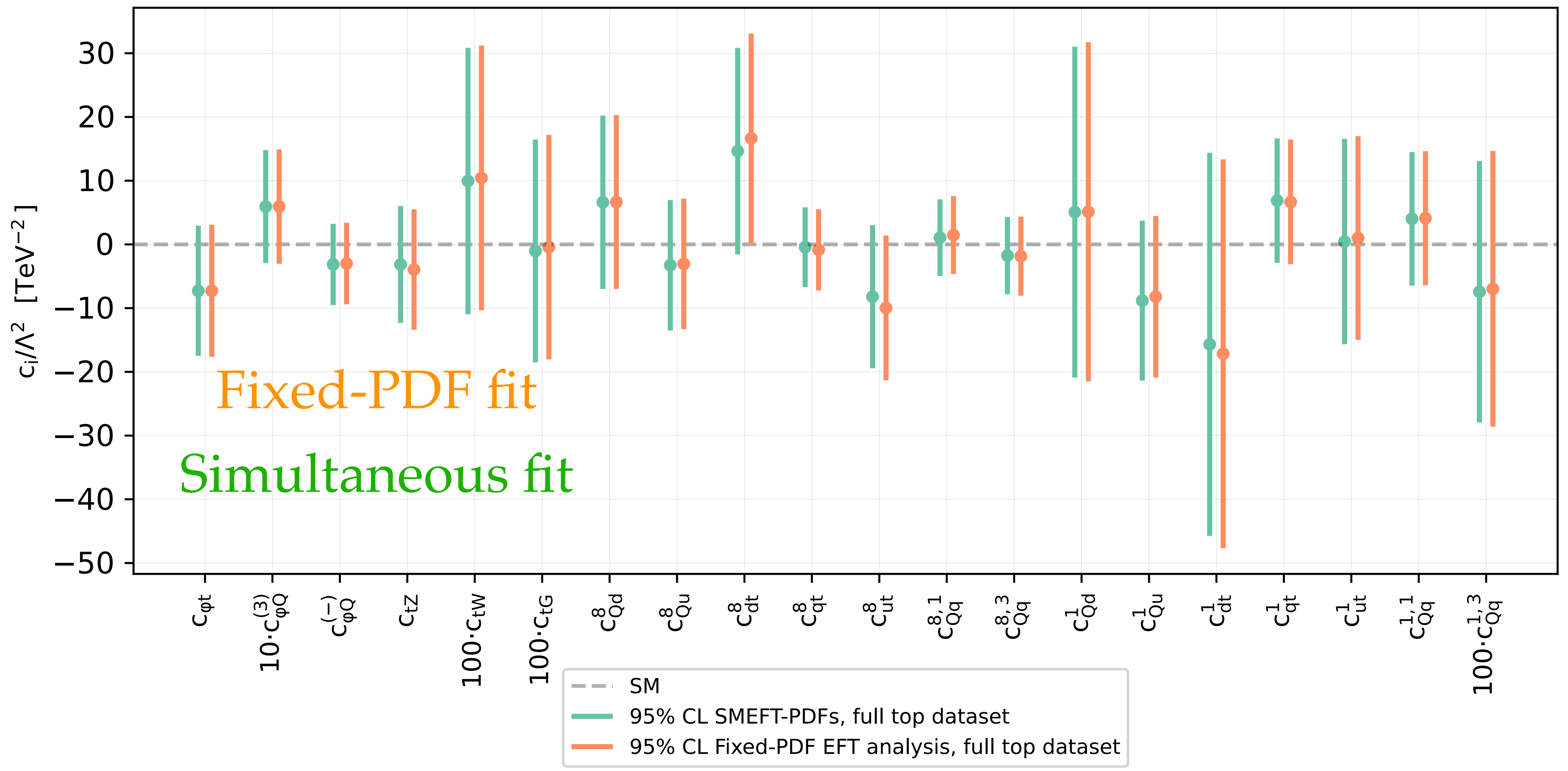

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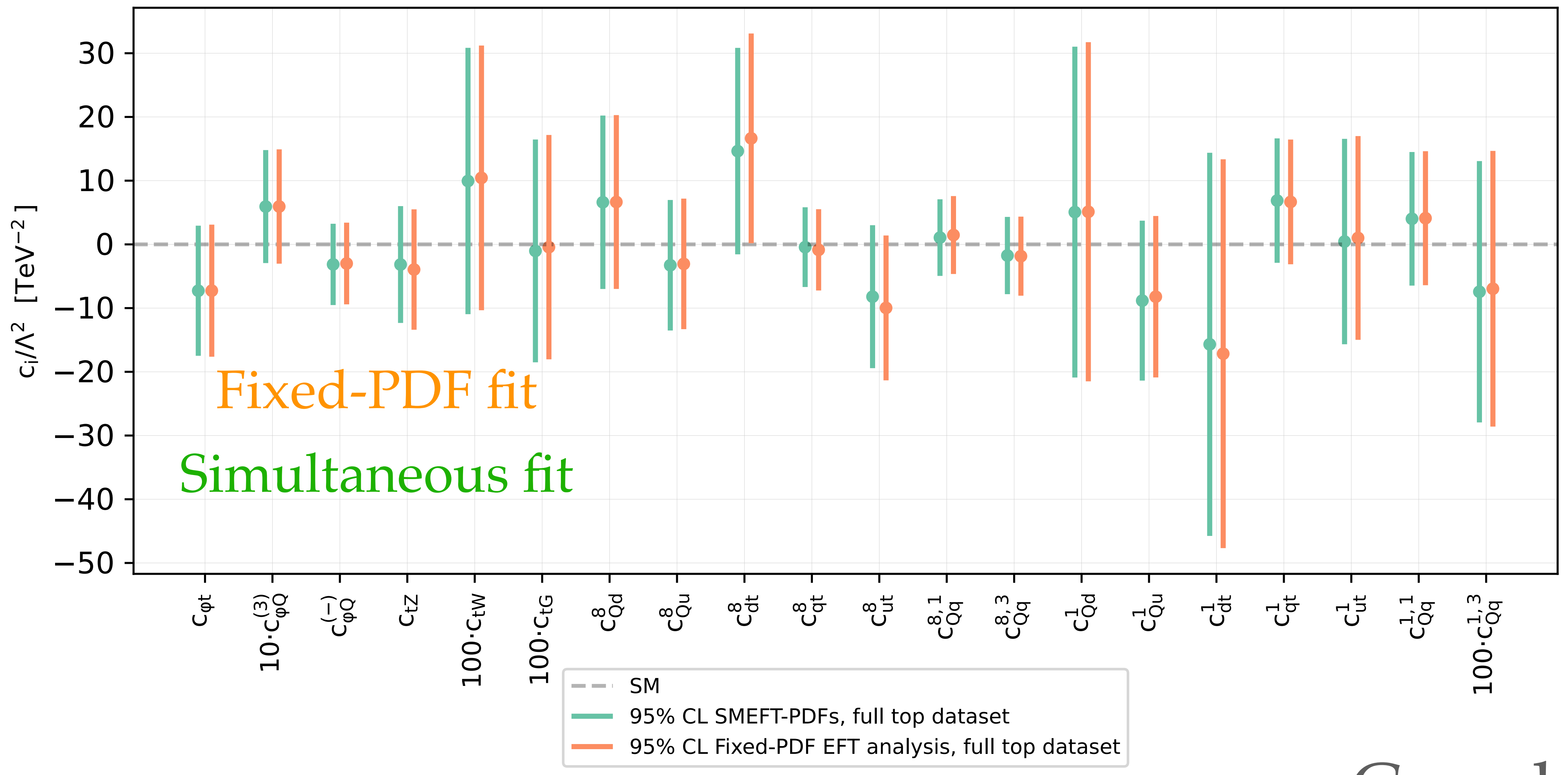

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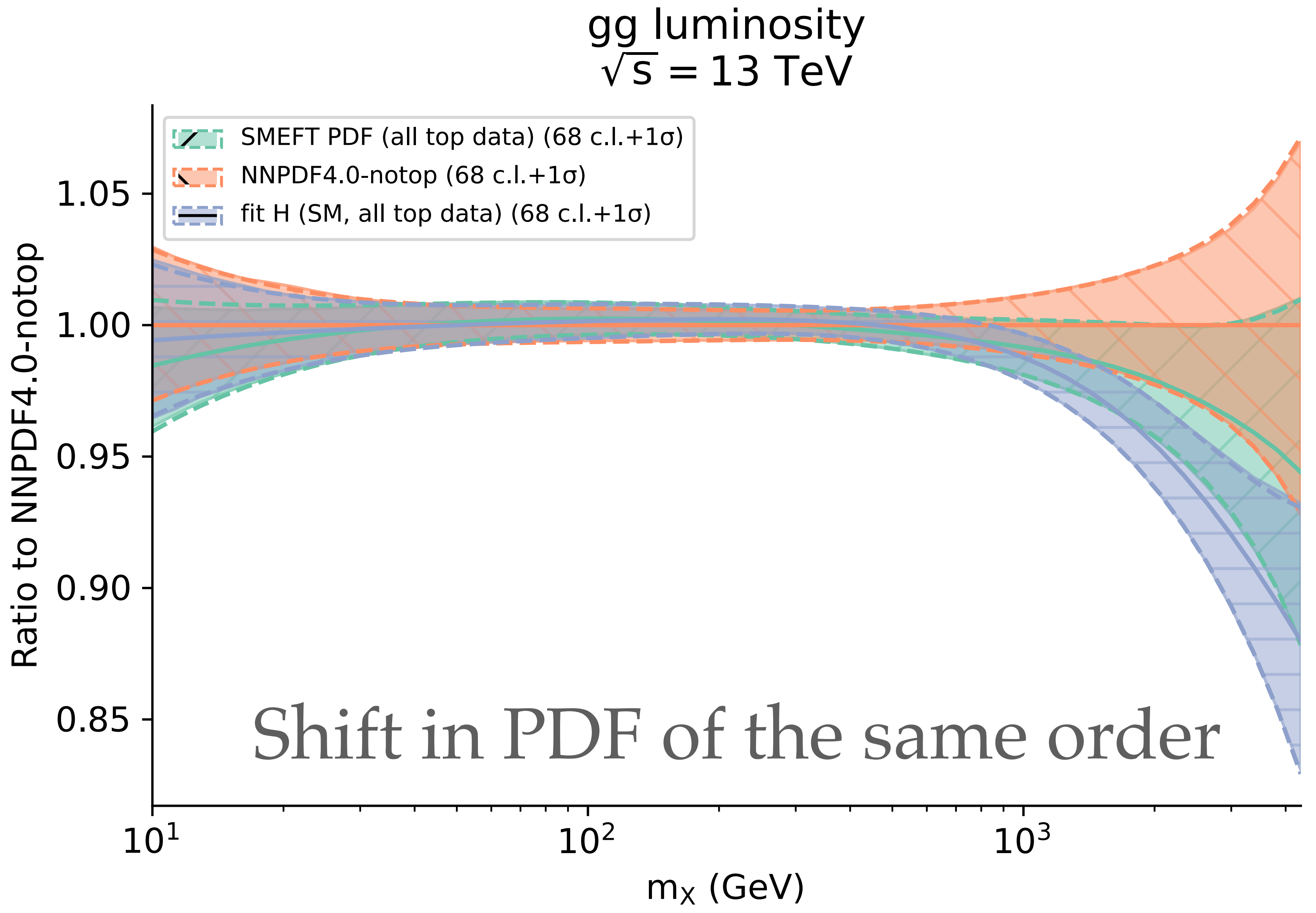
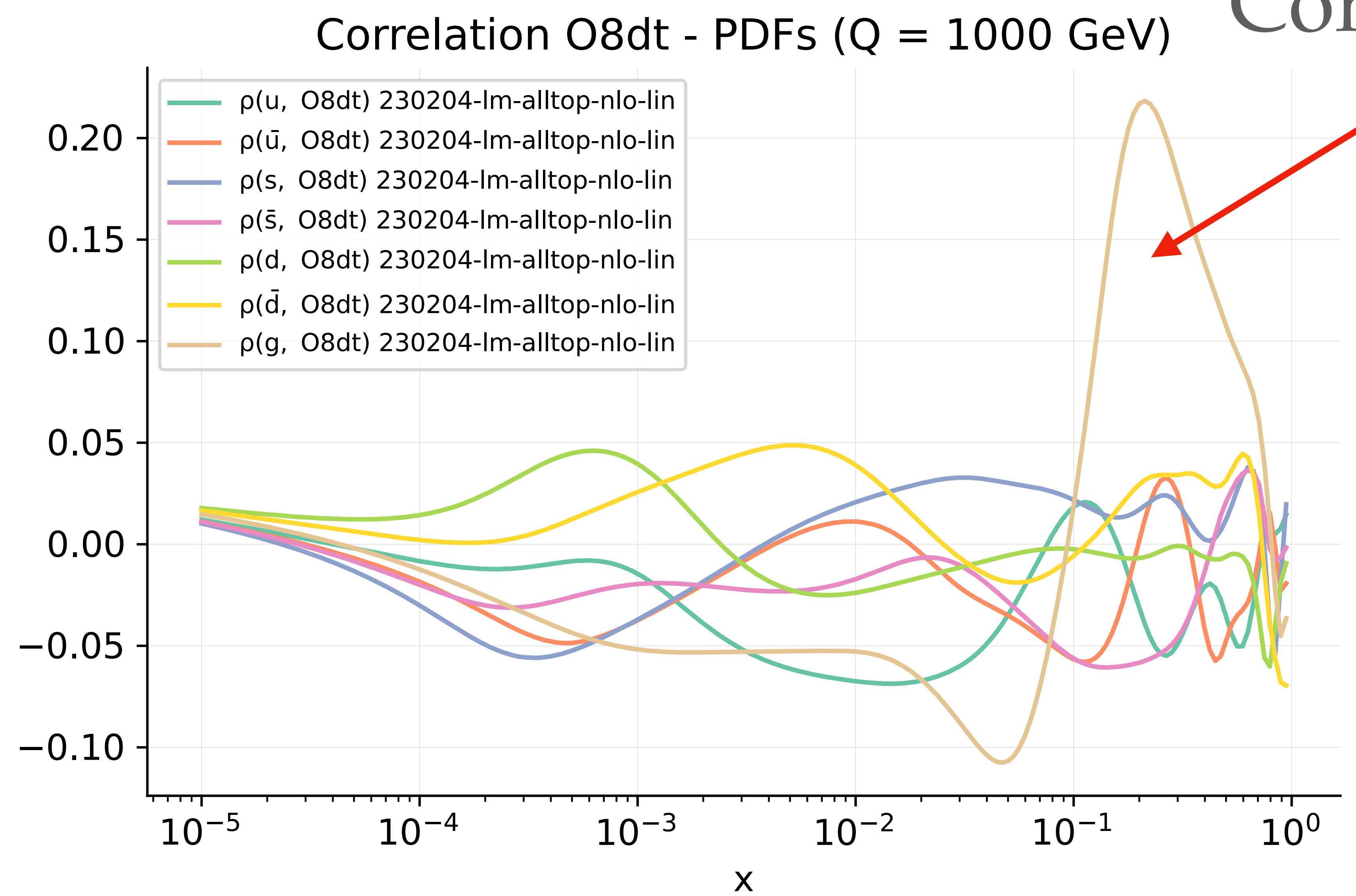


Shift in PDF of the same order



Correlation gluon-EFT

NP contaminated fits

SIMUnet allows for generation of pseudodata containing NP

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Functional form parameters (e.g. NN weights)

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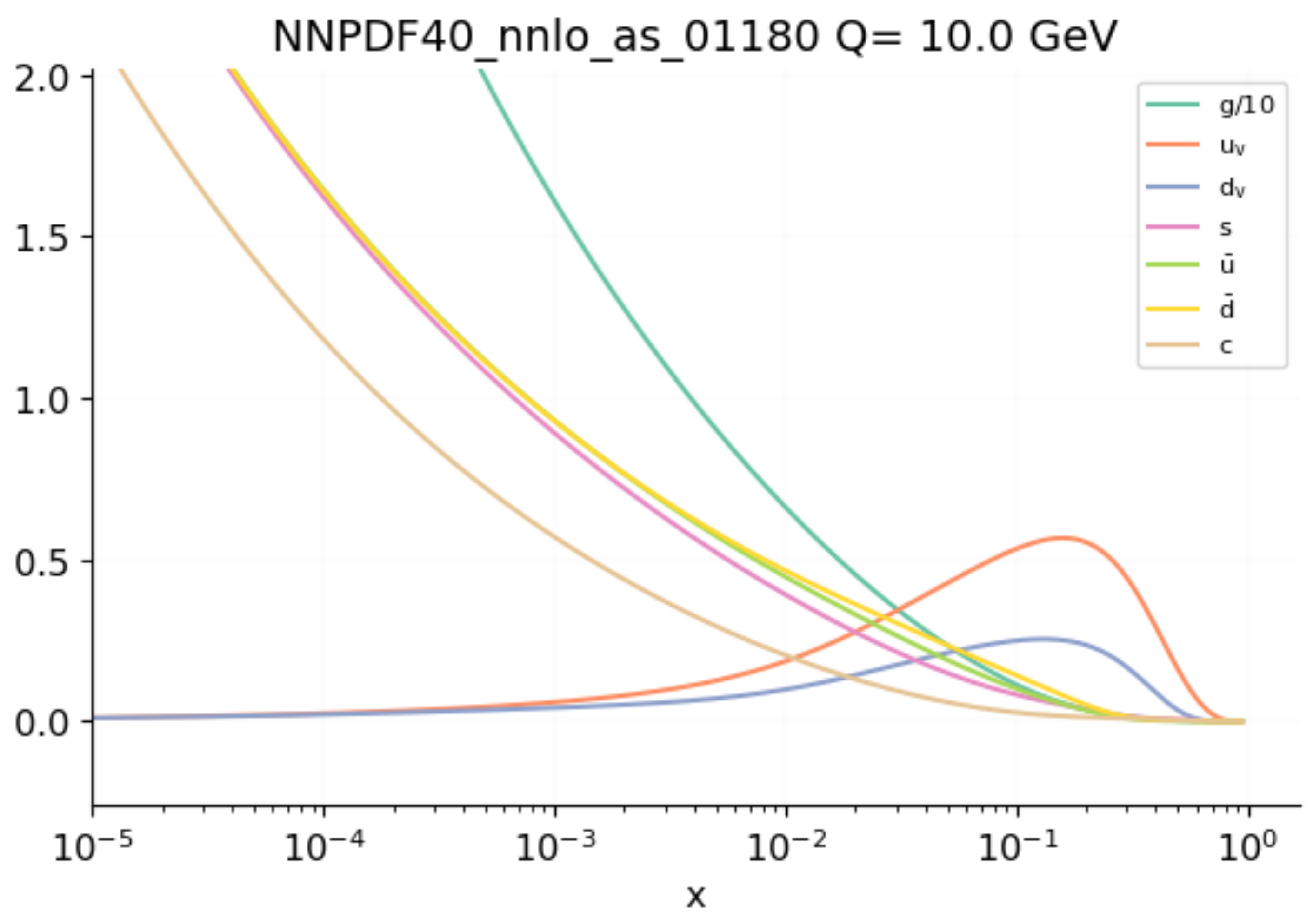
Assess whether we can mimic the modified interactions with "wrong" PDFs!

A case study: heavy W′

Can the W' hide in the proton?

Suppose the underlying laws of nature are



"Real" proton structure

$$\bigotimes$$

$$J_L^{a,\mu} = \sum_{f_L} \bar{f}_L T^a \gamma^\mu f_L$$

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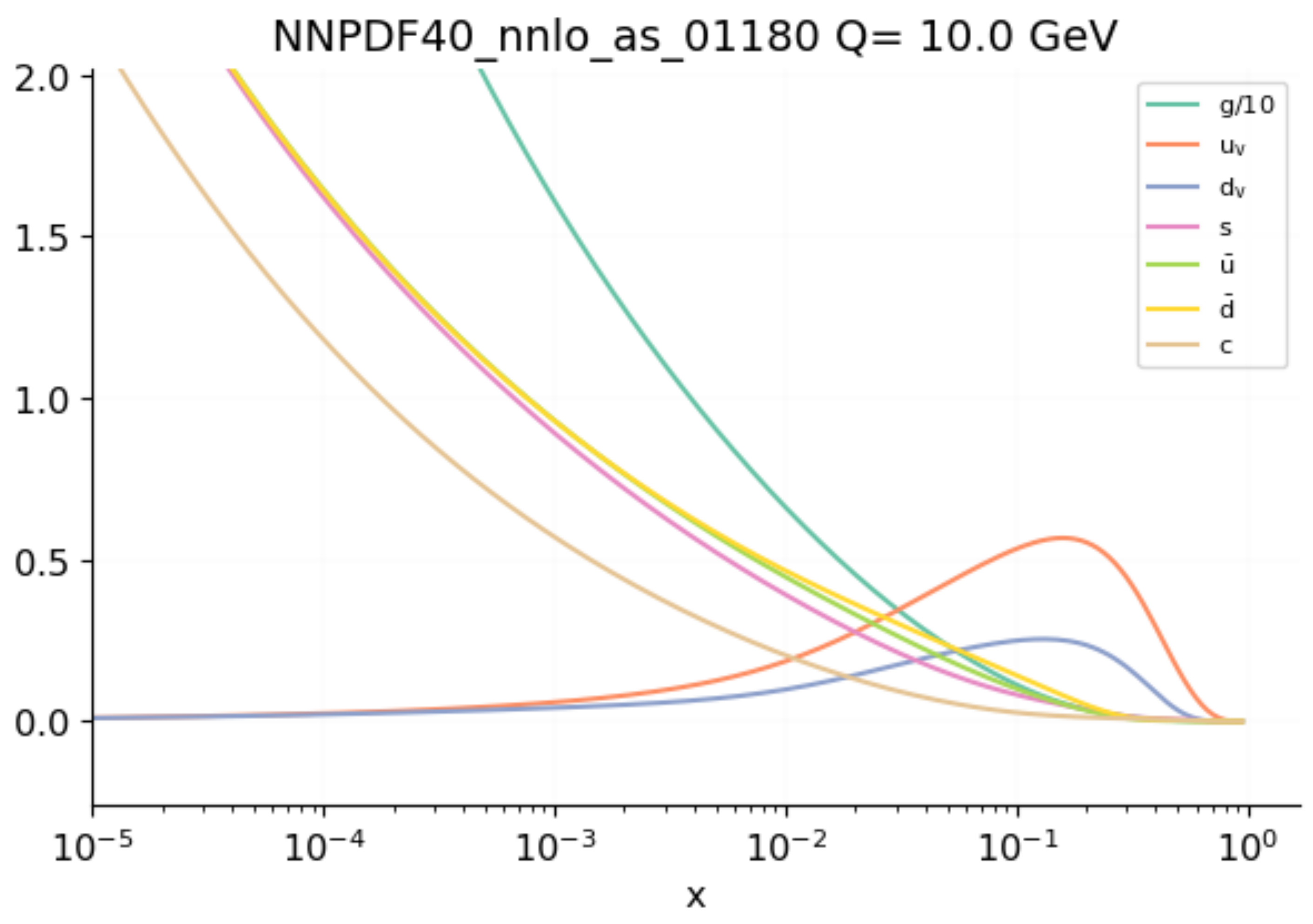

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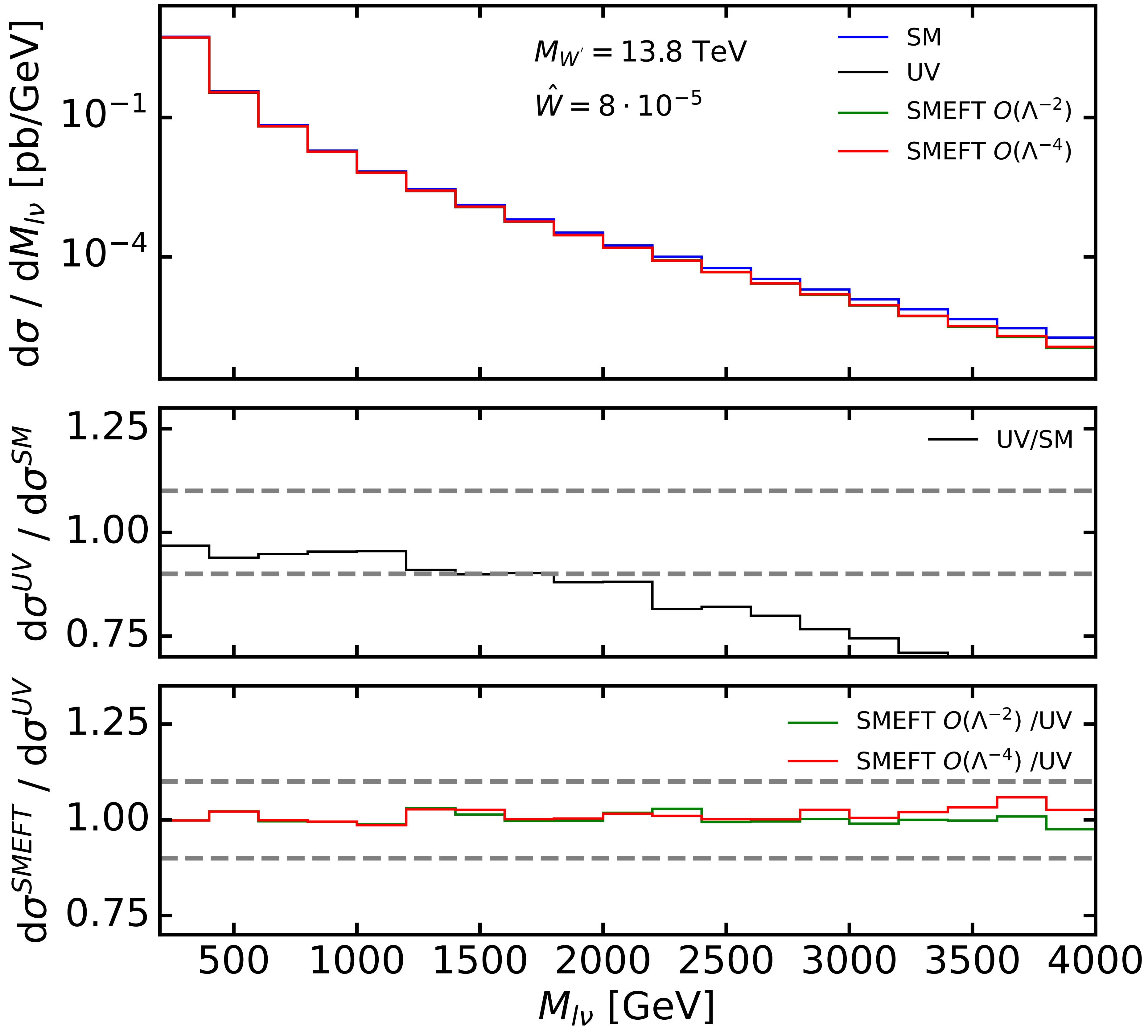

Both CC and NC DY affected

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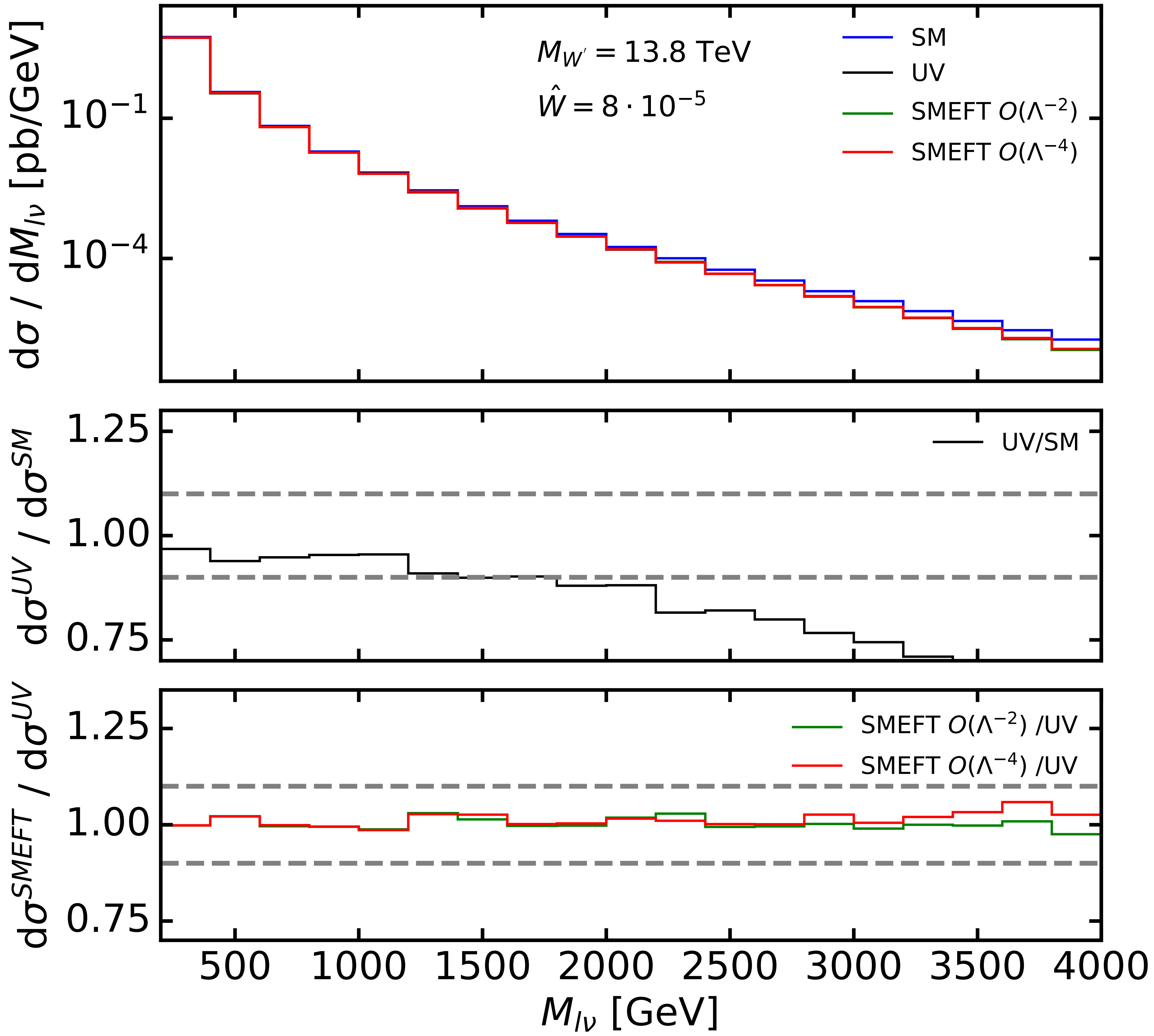

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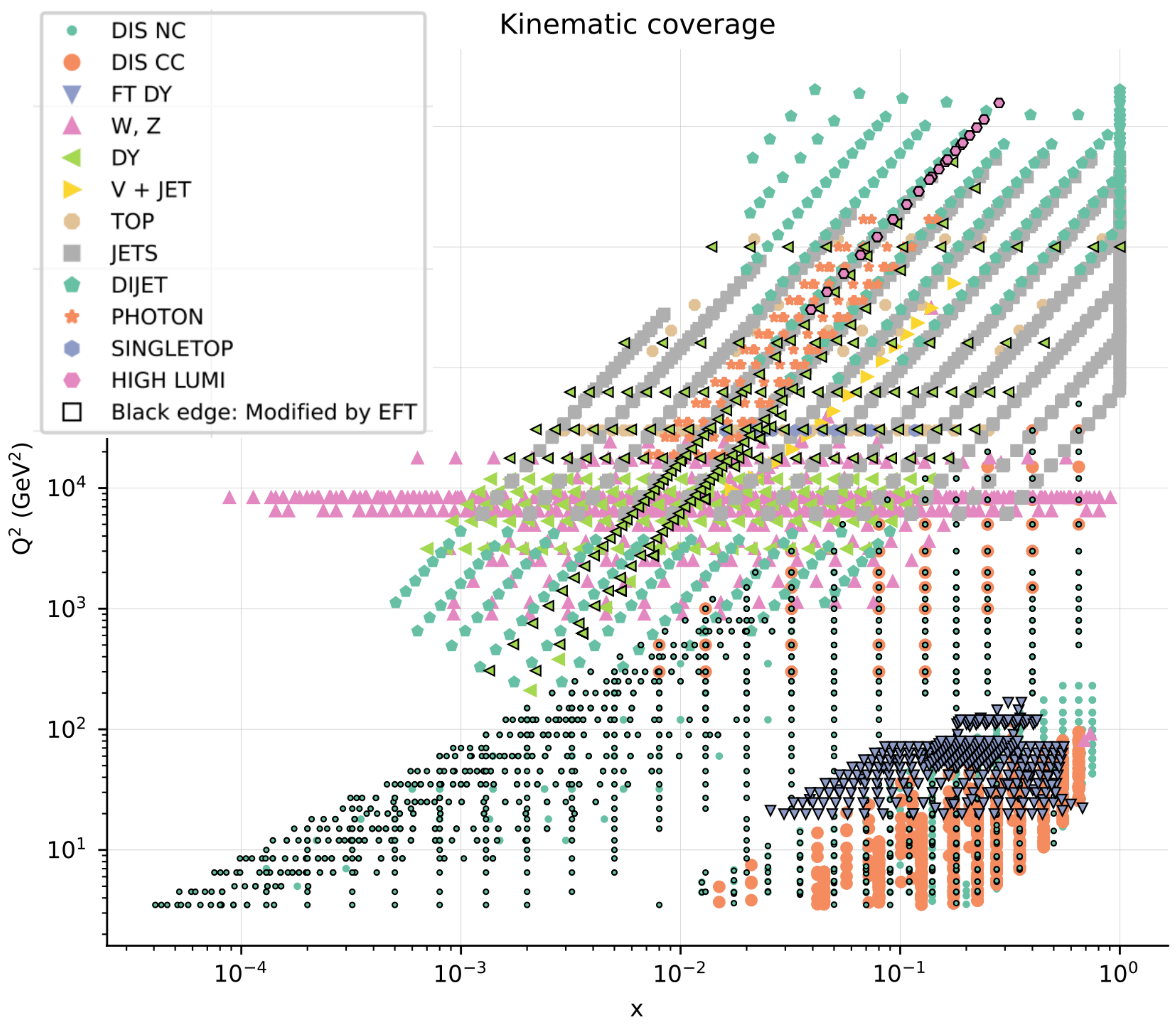
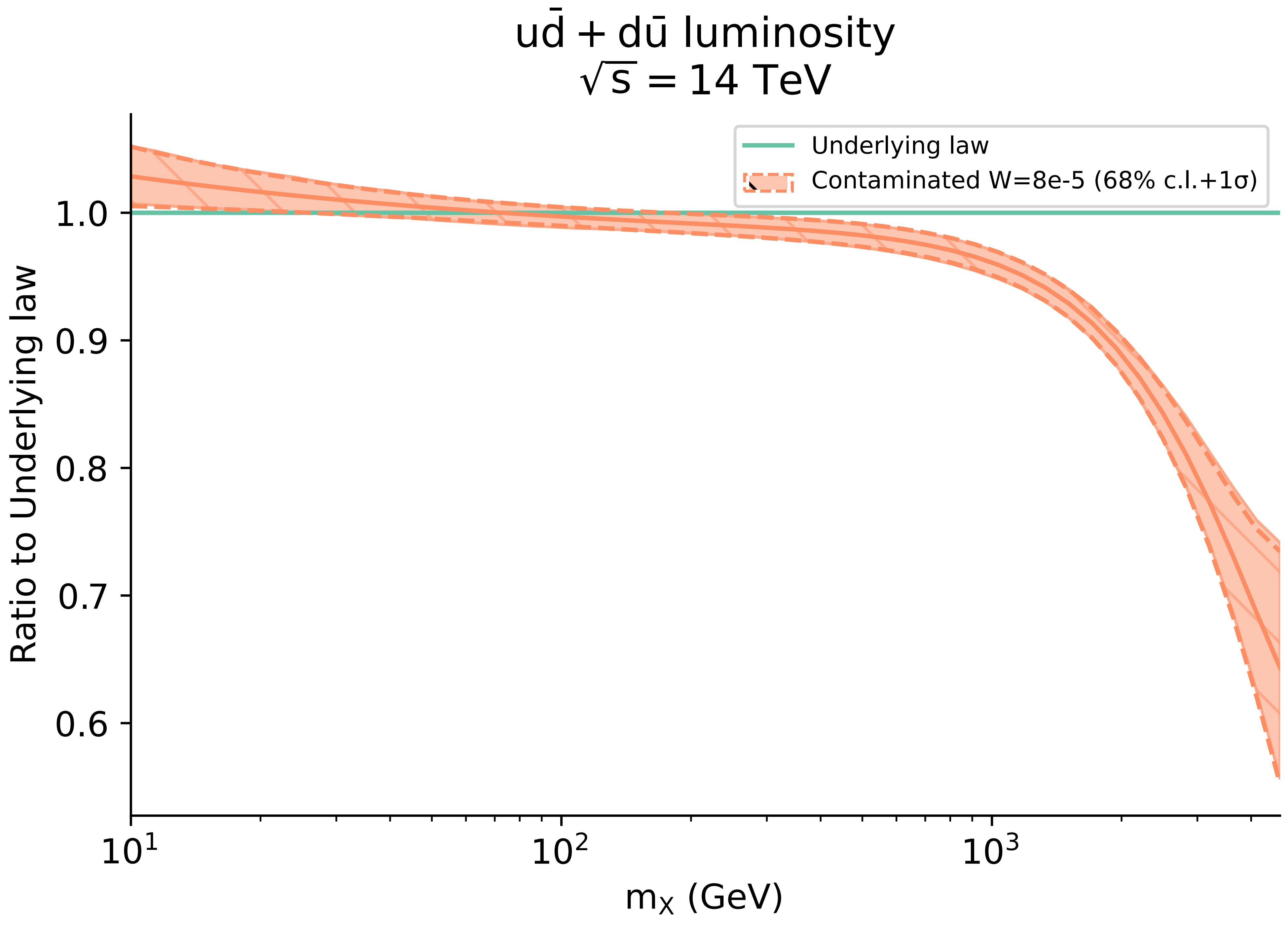
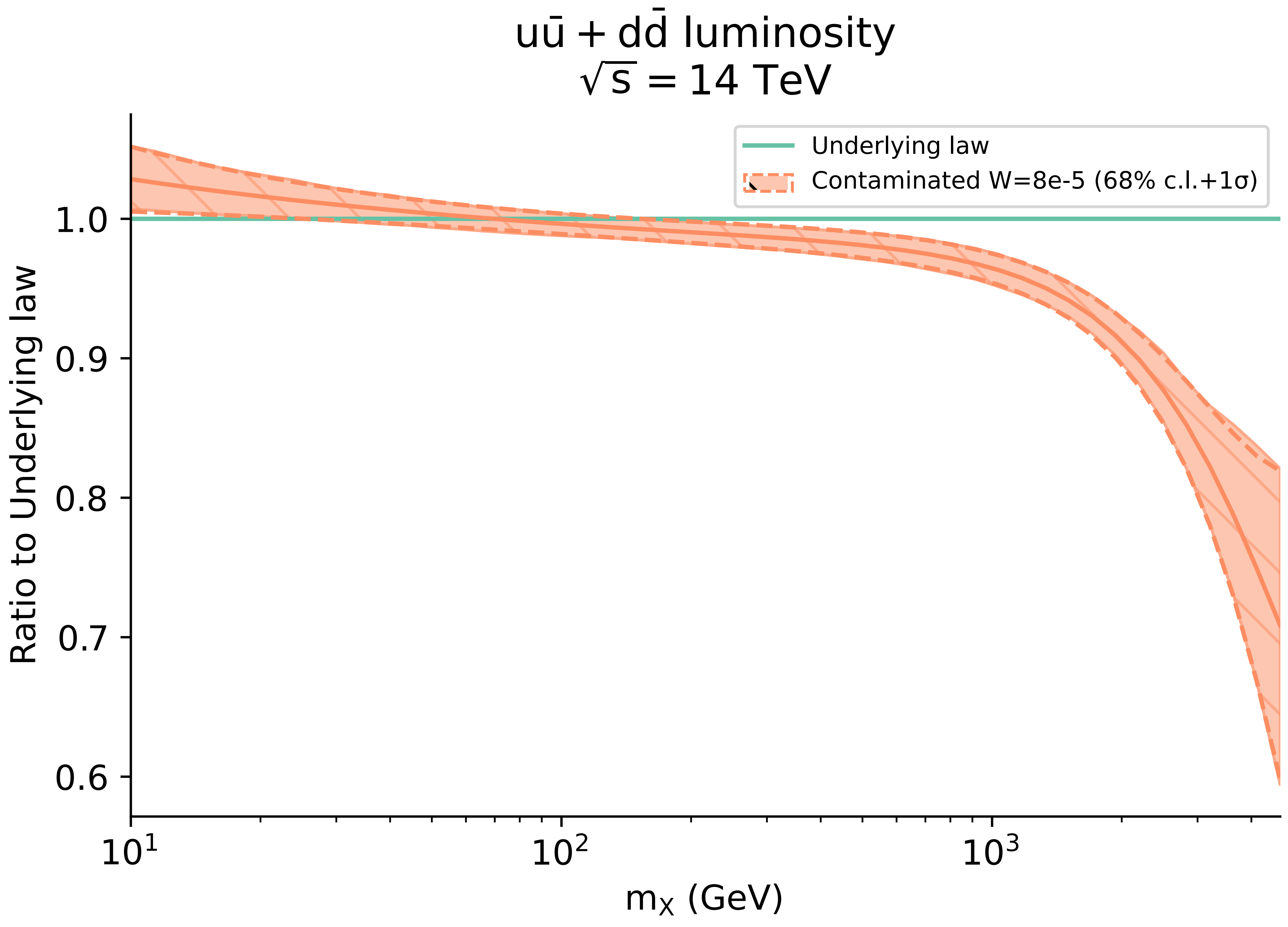
NNPDF4.0 dataset +
HL-LHC DY projections [arXiv: 2104.02723]



Data kinematic coverage is wide:
can current PDFs absorb NP
while keeping consistency across
the whole set of observables?

Contaminated PDFs





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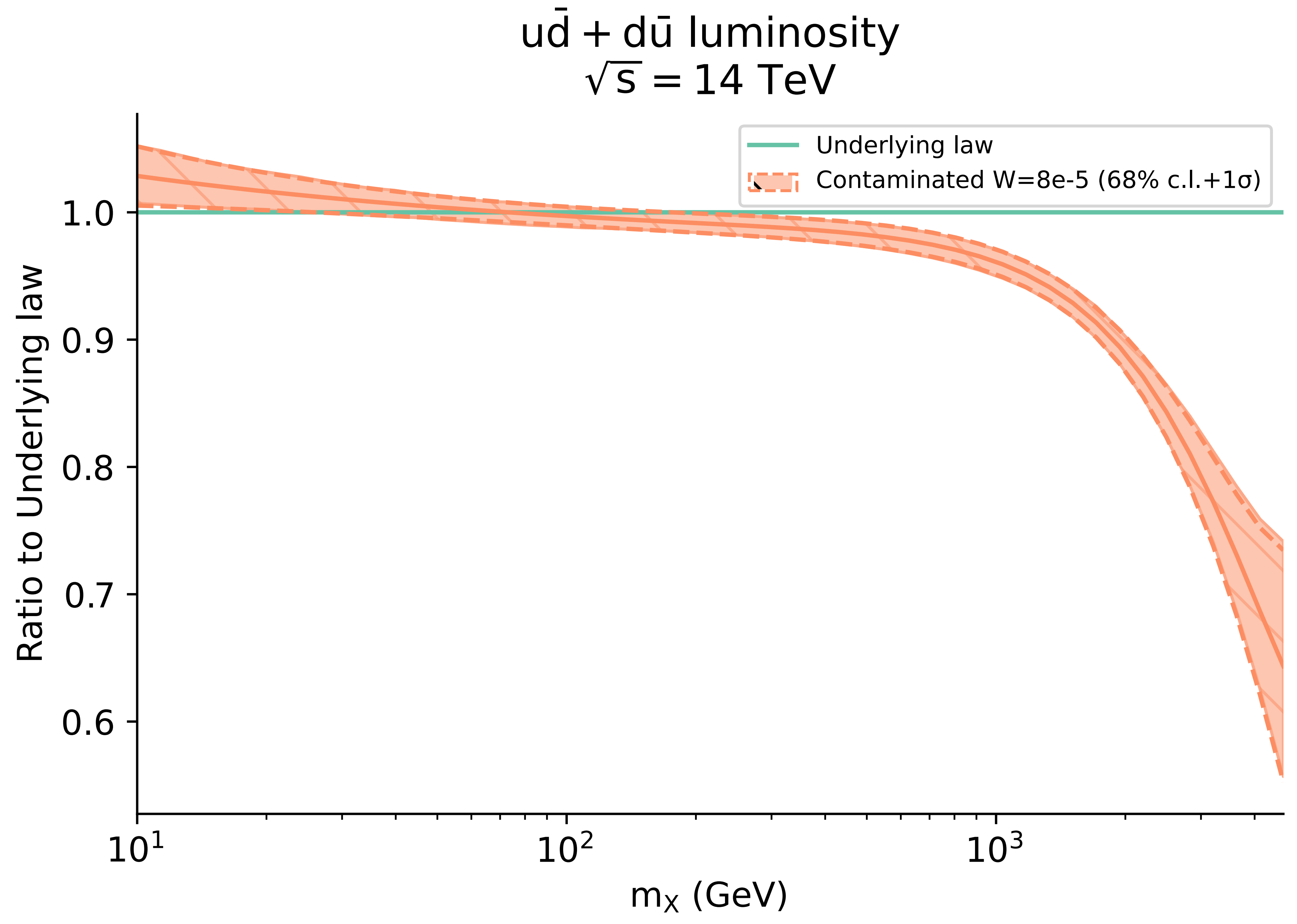

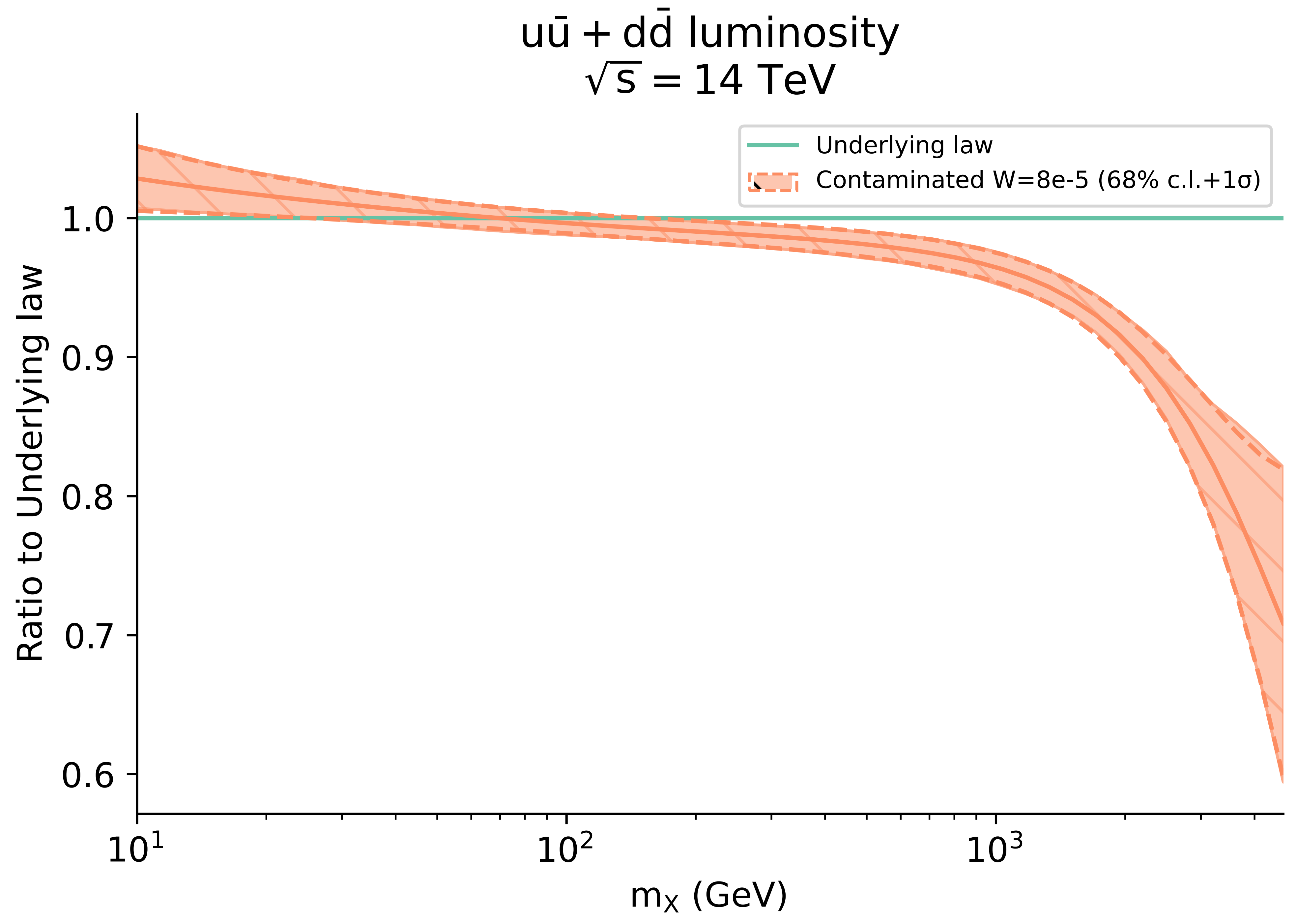

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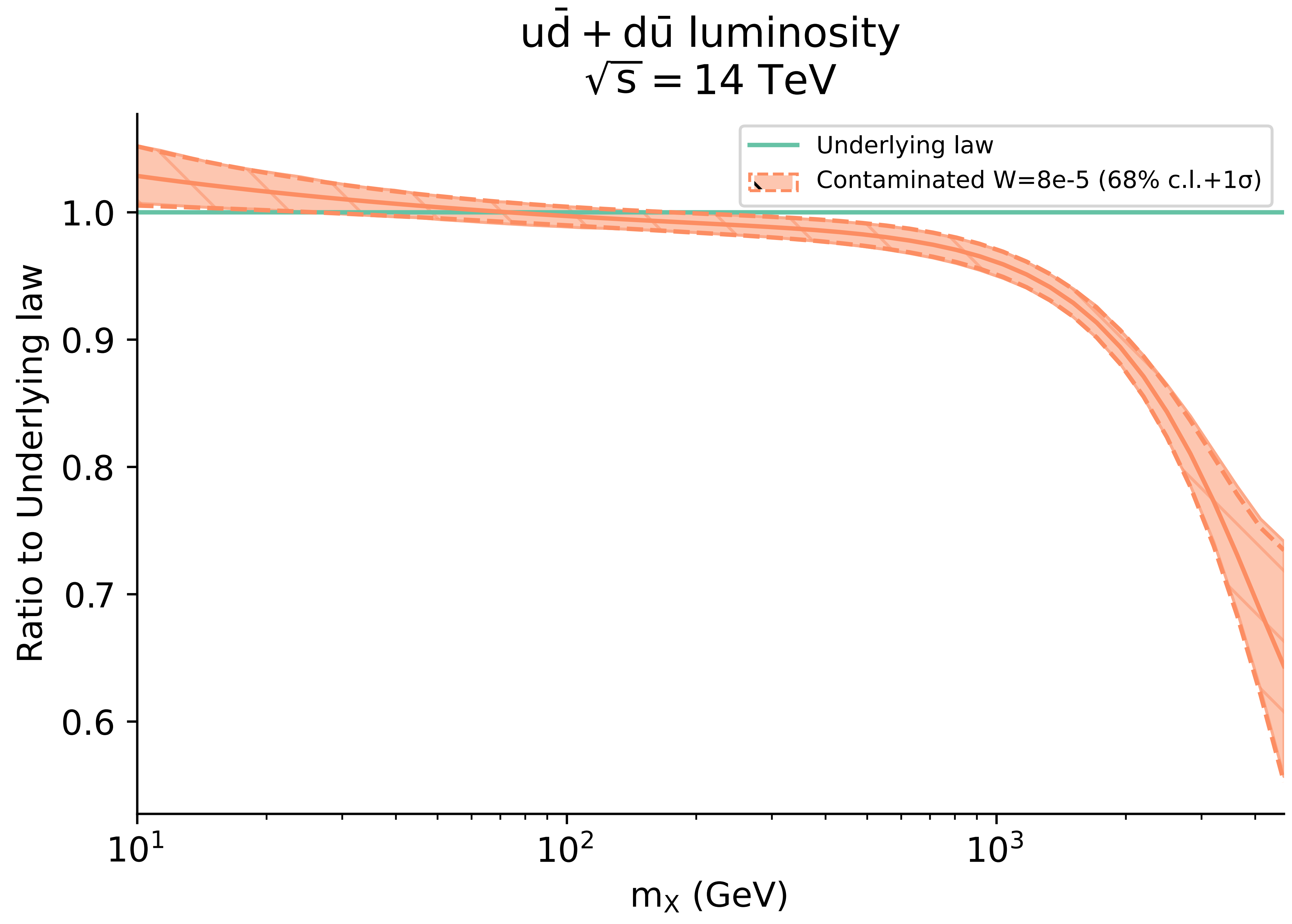

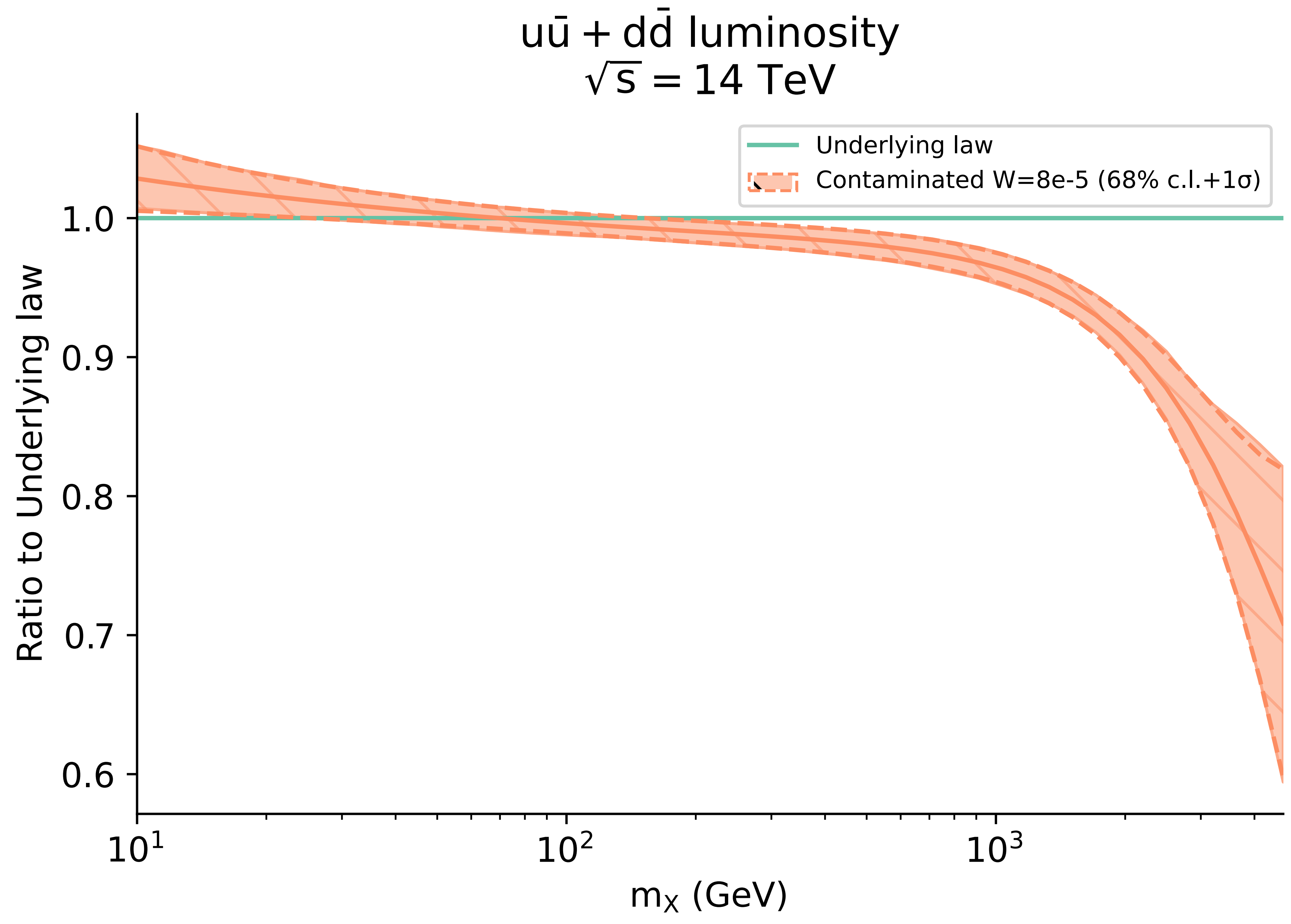

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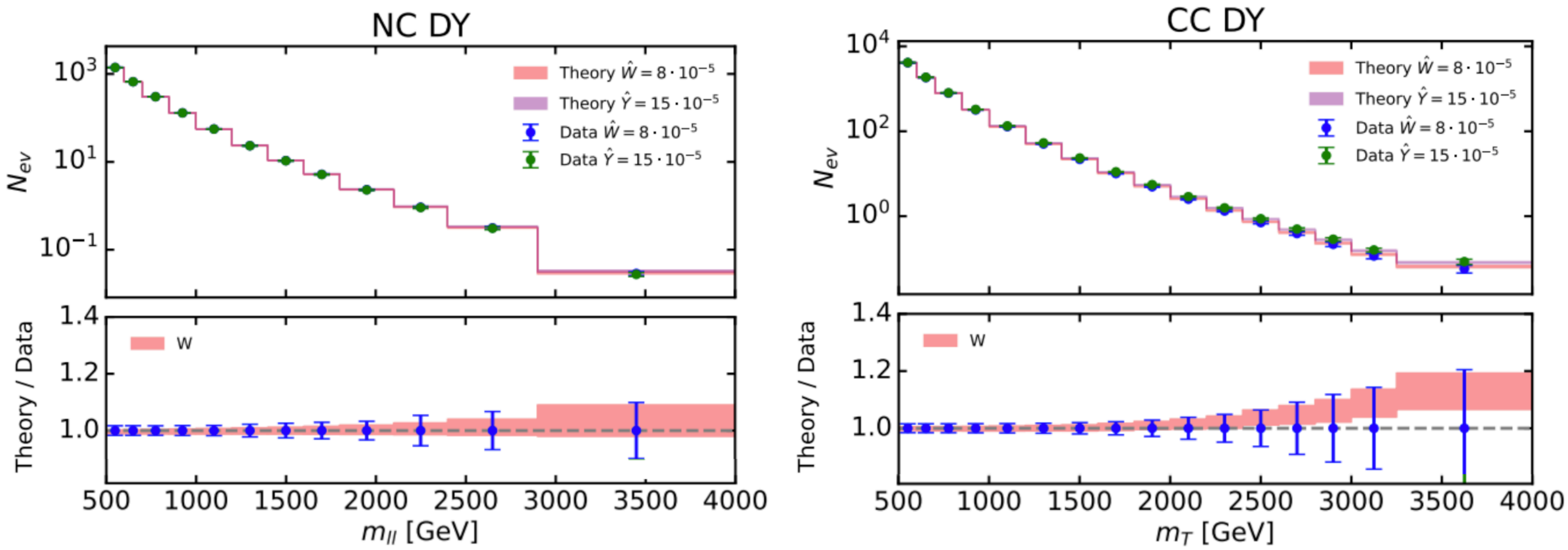
Large-x behaviour in PDFs is not constrained:
especially anti-quark PDFs allow for NP absorption

Data-theory comparison

Data: $f^{true} \otimes \hat{\sigma}_{NP}$
Theory: $f^{fit} \otimes \hat{\sigma}_{SM}$



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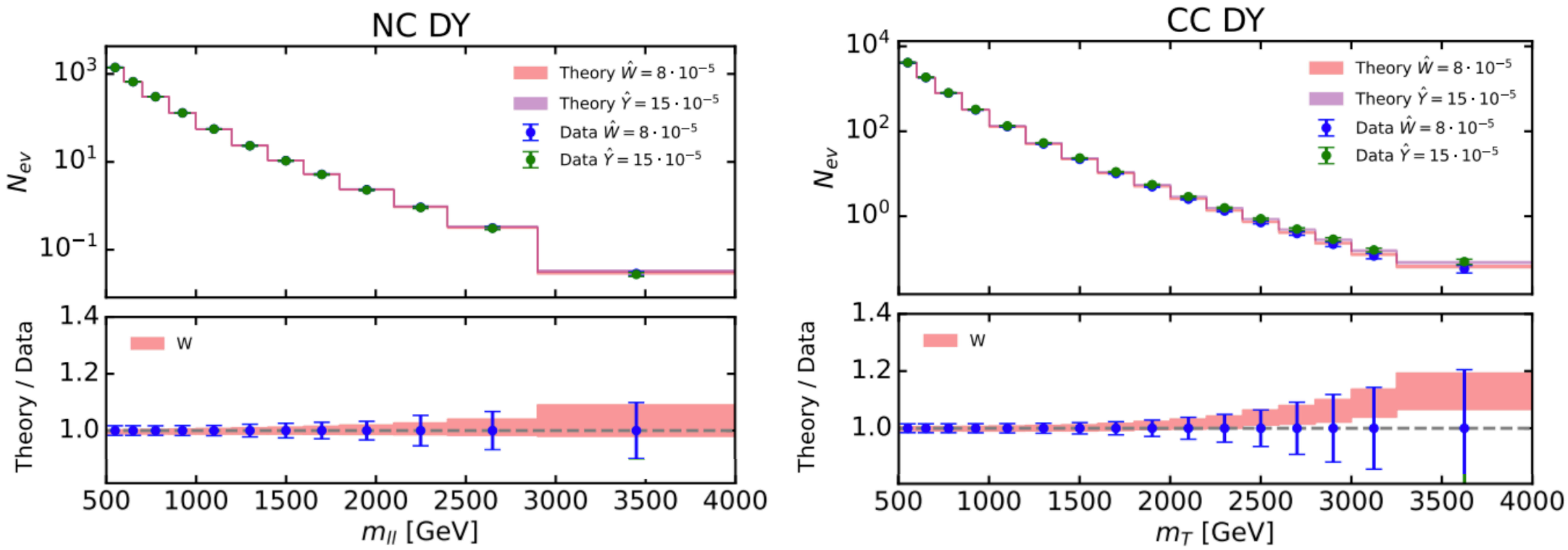

PDF shift is completely compensating the NP effect

NP concealed in the proton!!

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Can we use forward V production to spot the contamination?

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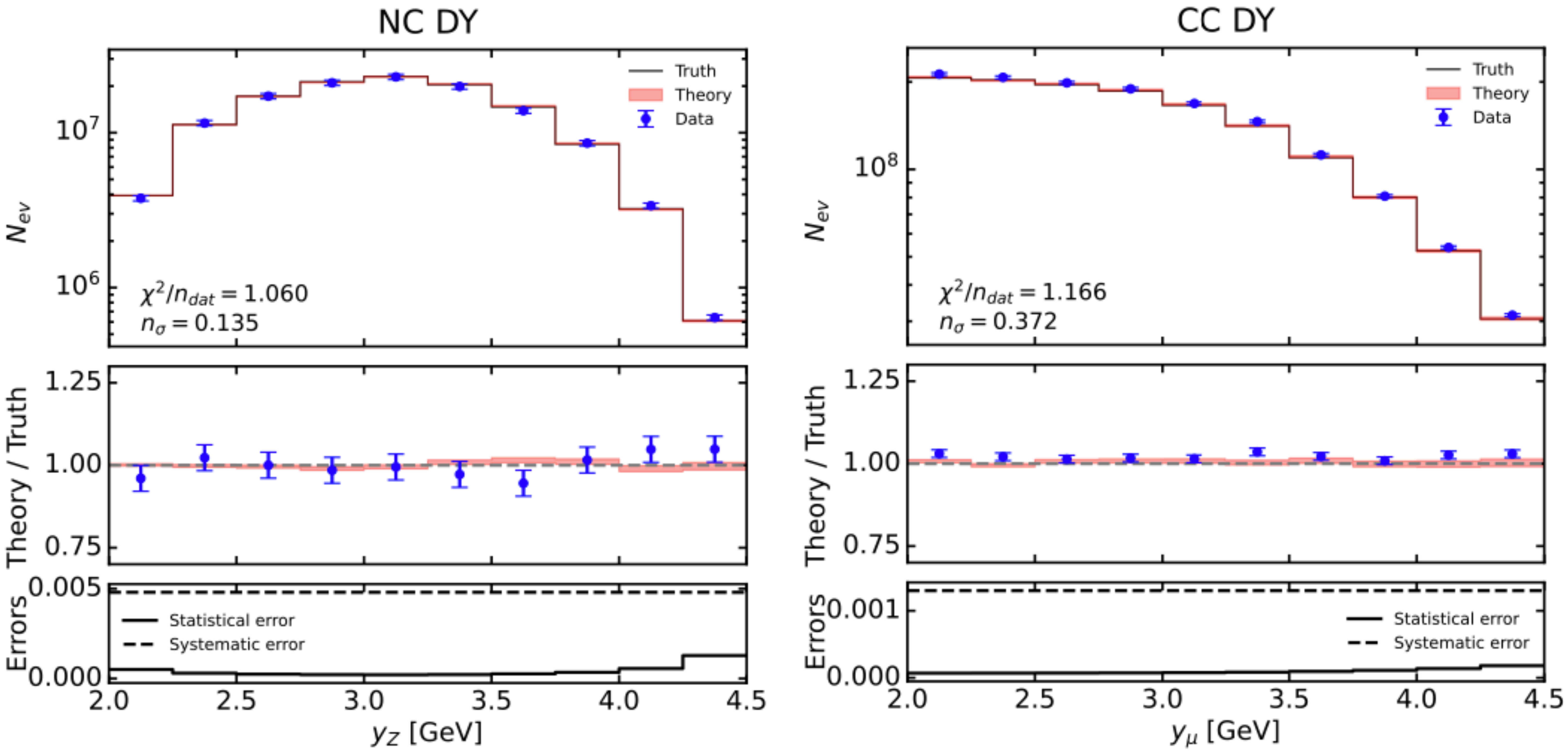

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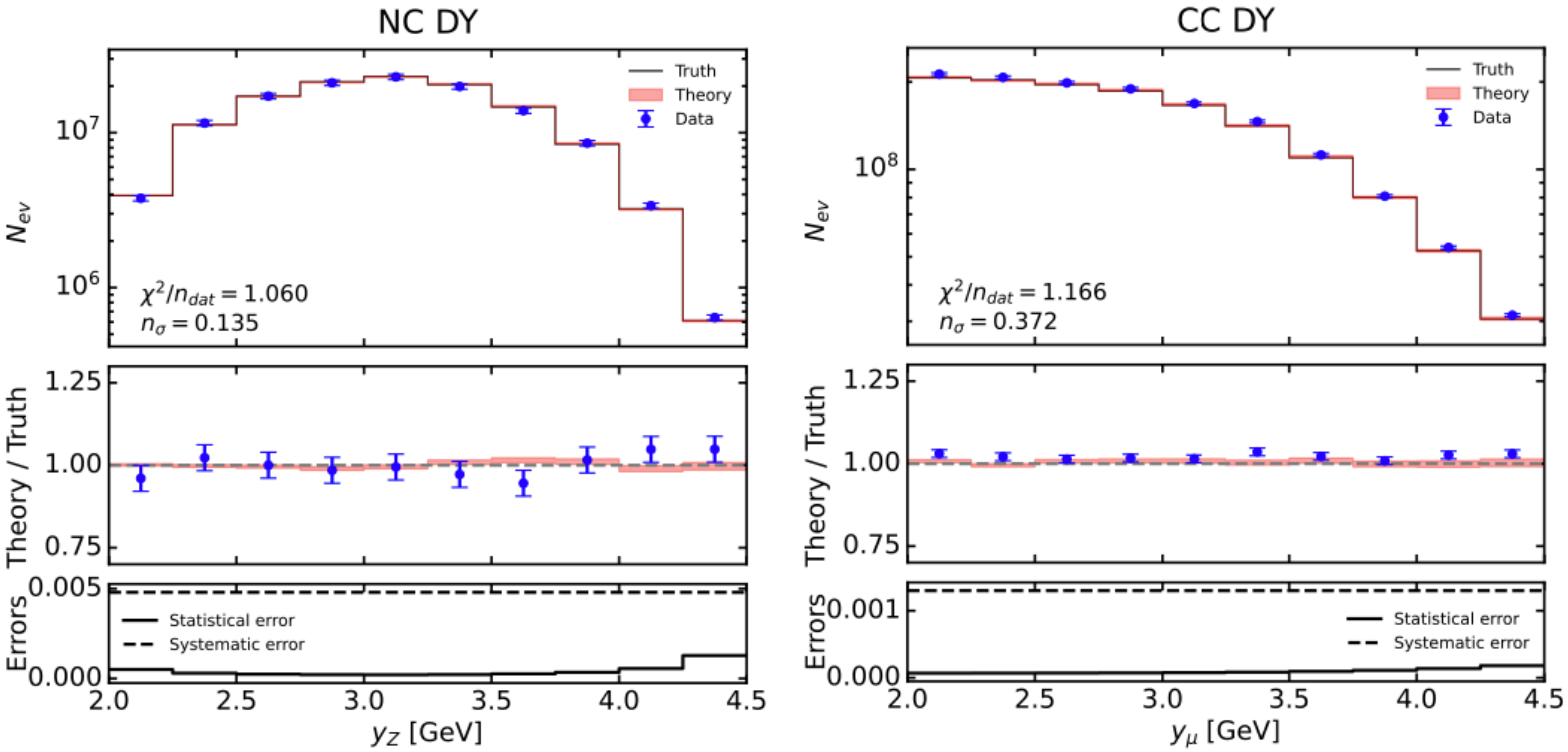

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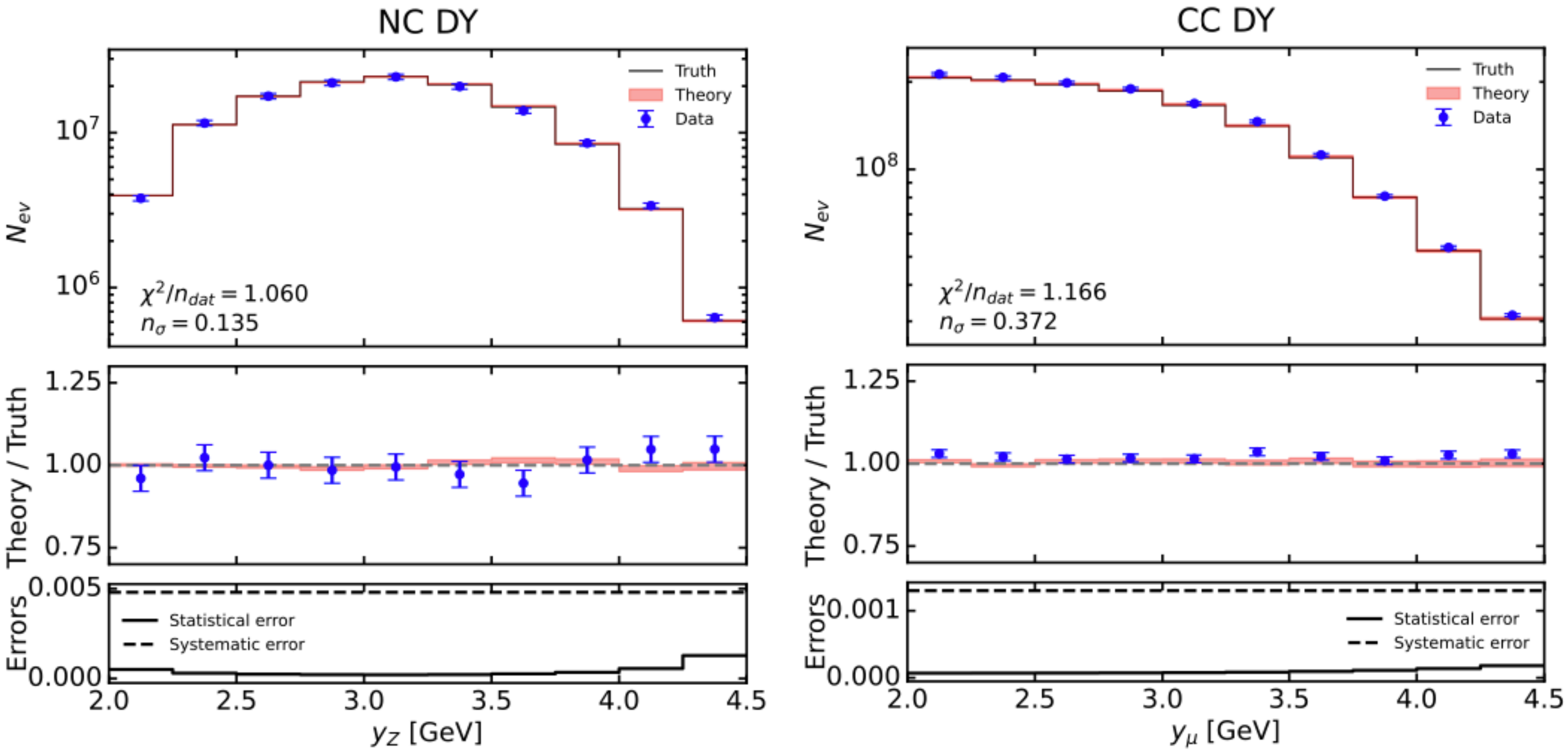

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Future low-energy measurements (e.g. EIC programme) could provide crucial input for PDFs!

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We repeat the exercise with projections from

➡ FASER, FASER2, SND and AdvSND

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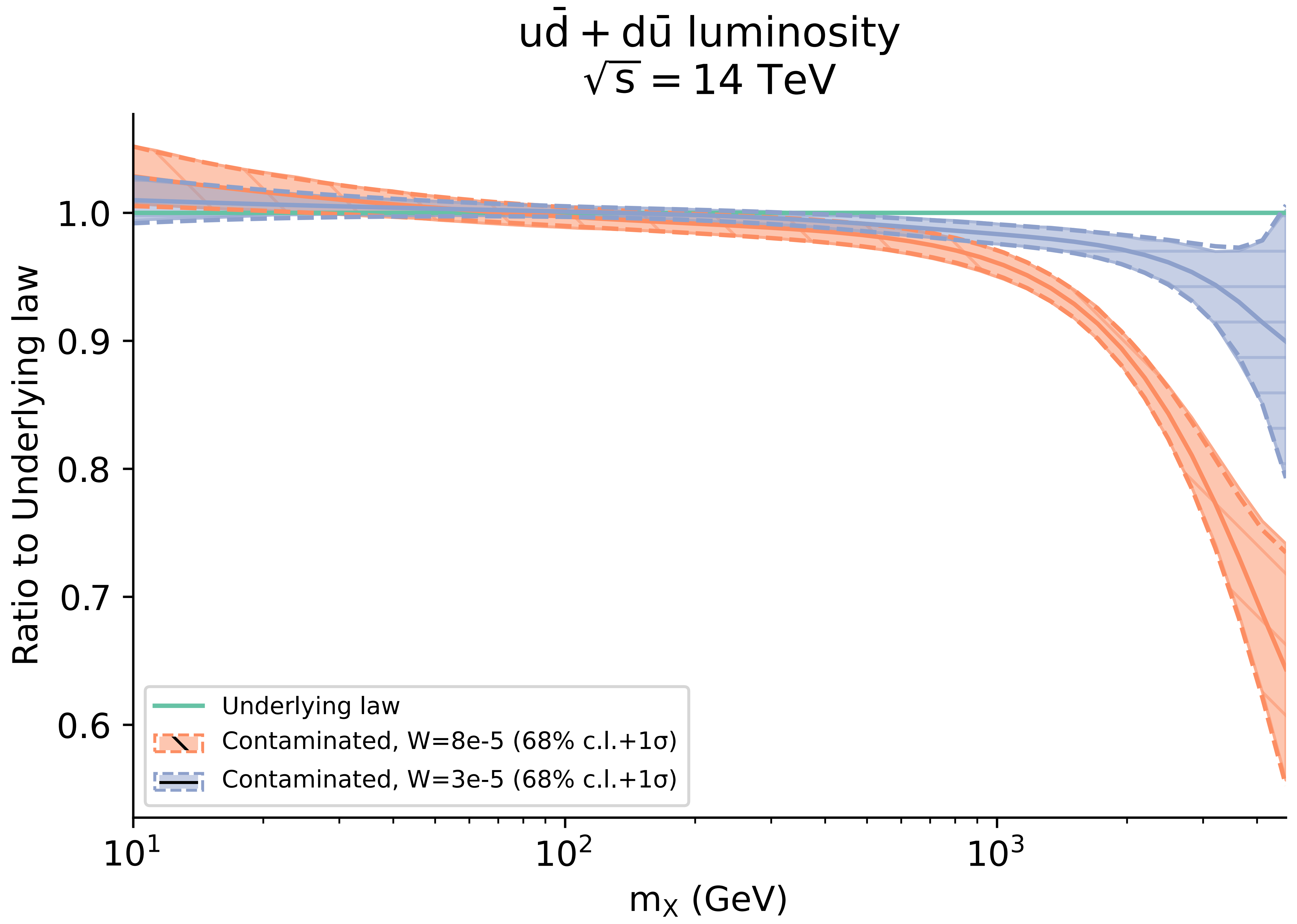

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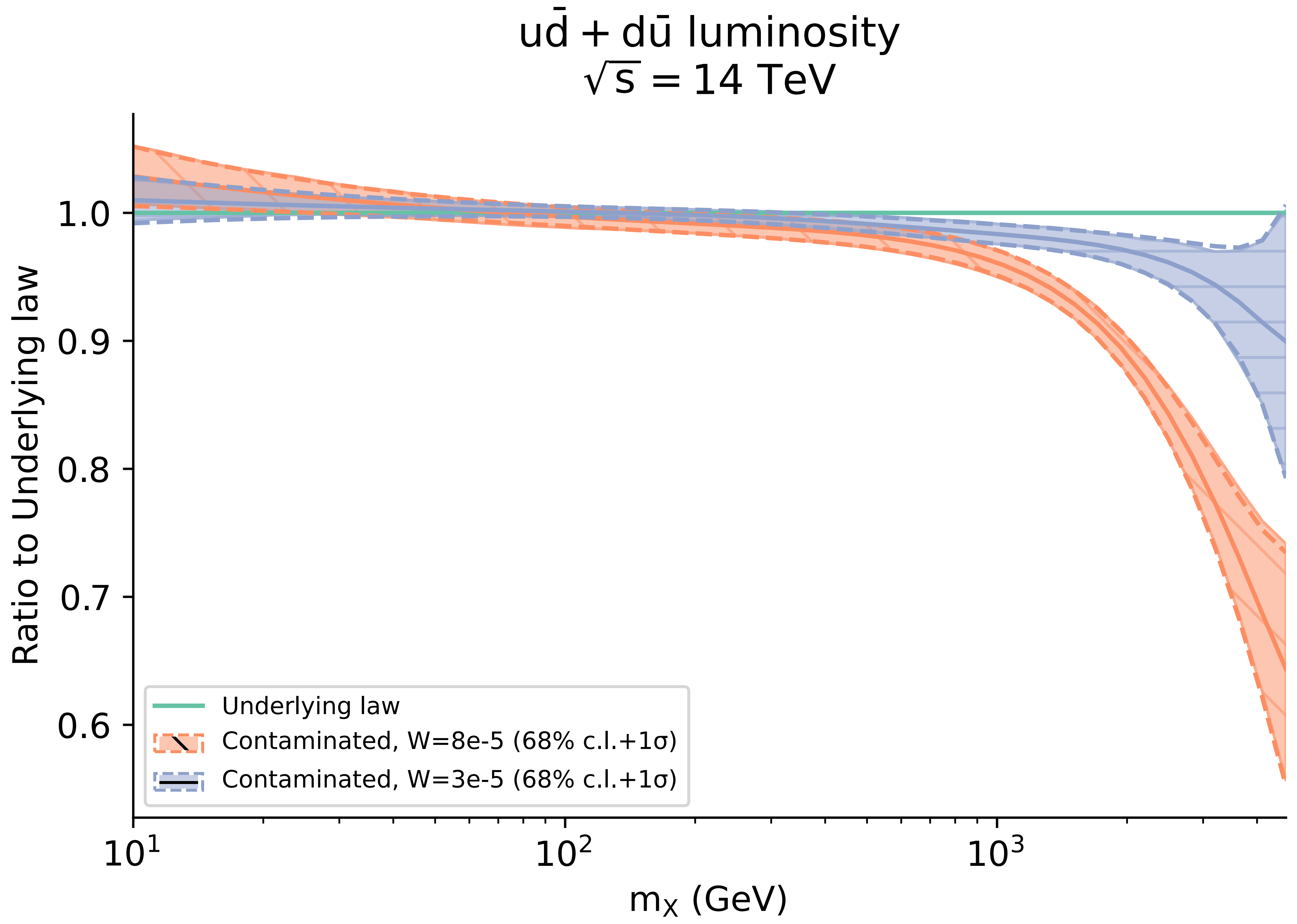

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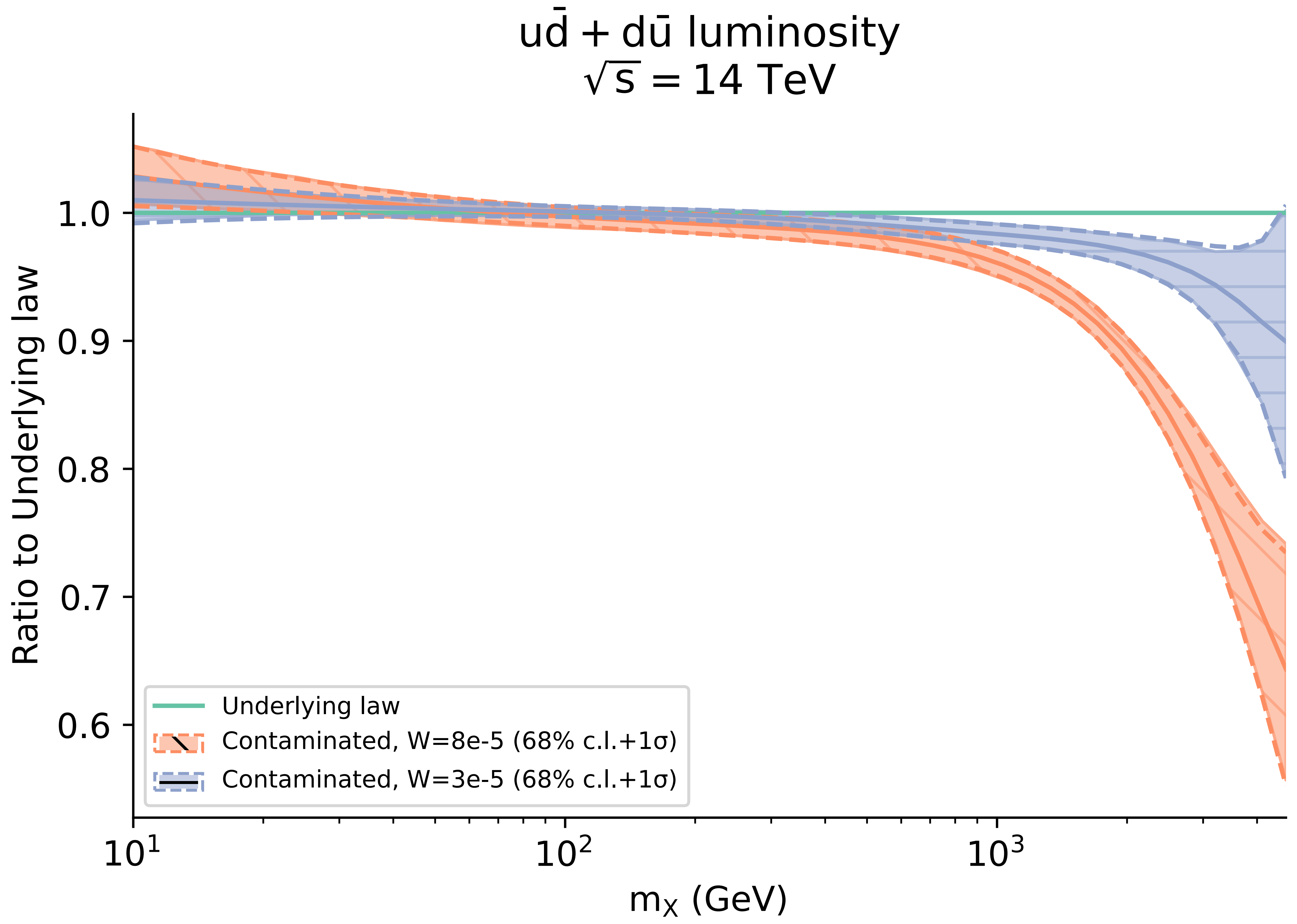

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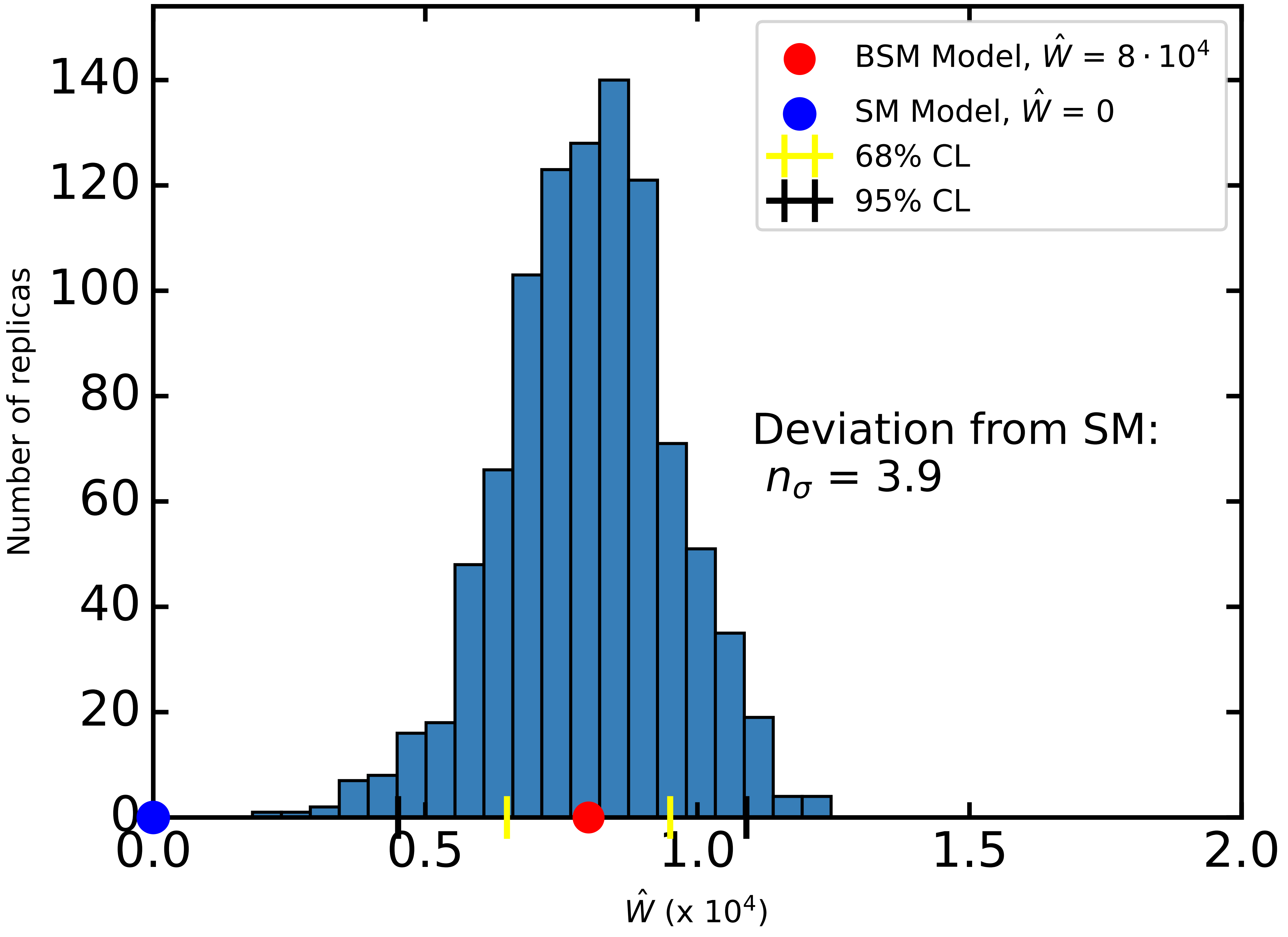
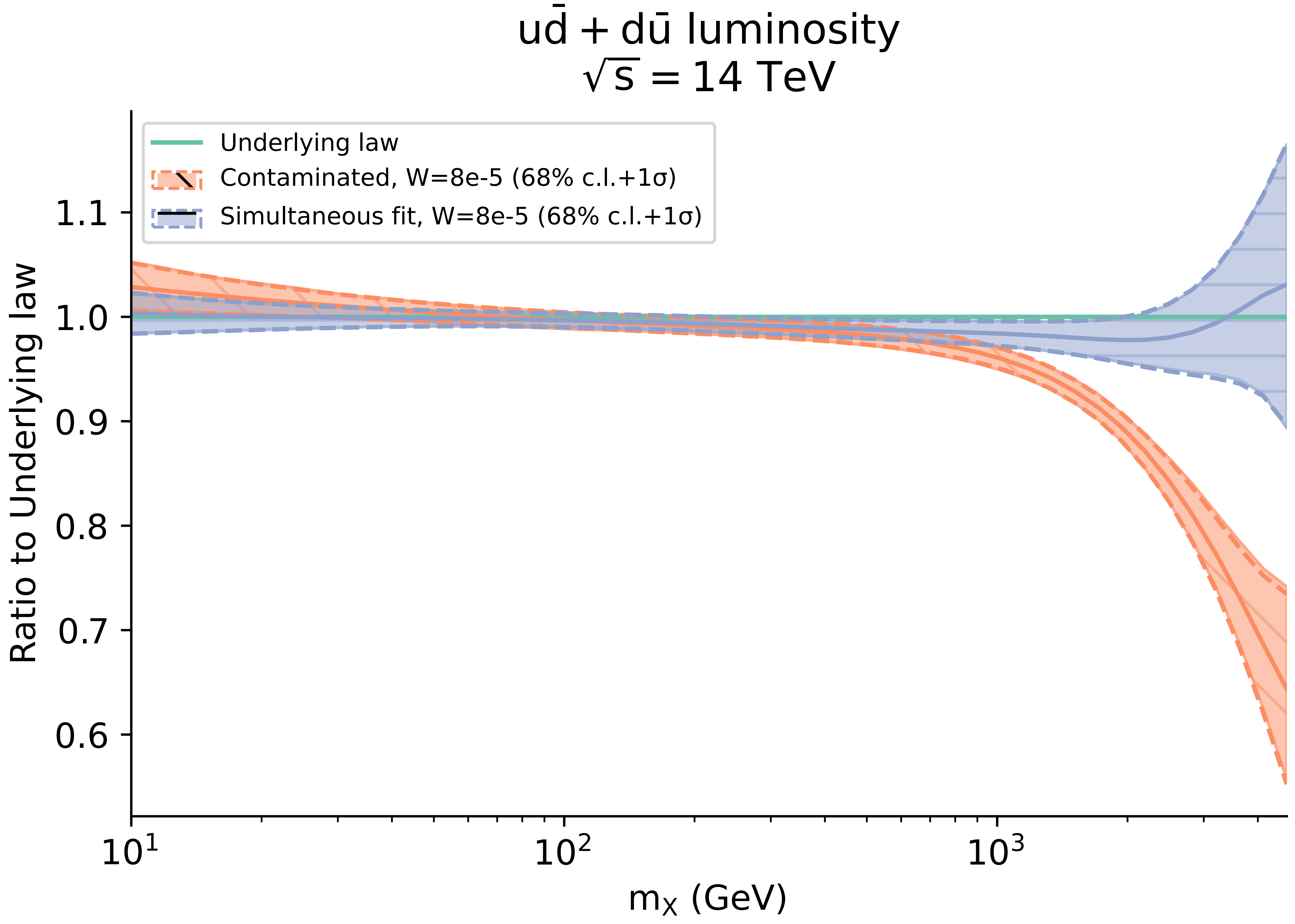
$$\boxed{M_{W'} : 14\,\text{TeV} \to 23\,\text{TeV}}$$

Disentangling with a joint fit

Simultaneous fit of PDFs and W parameter:





Conclusions

* The PDF-EFT interplay could be crucial: PDFs can in principle mimic EFT corrections.

* UV completion exist that can be absorbed in the PDF parametrisation.

* Current kinematic coverage of PDF datasets is insufficient, forward facilities will provide vital input.

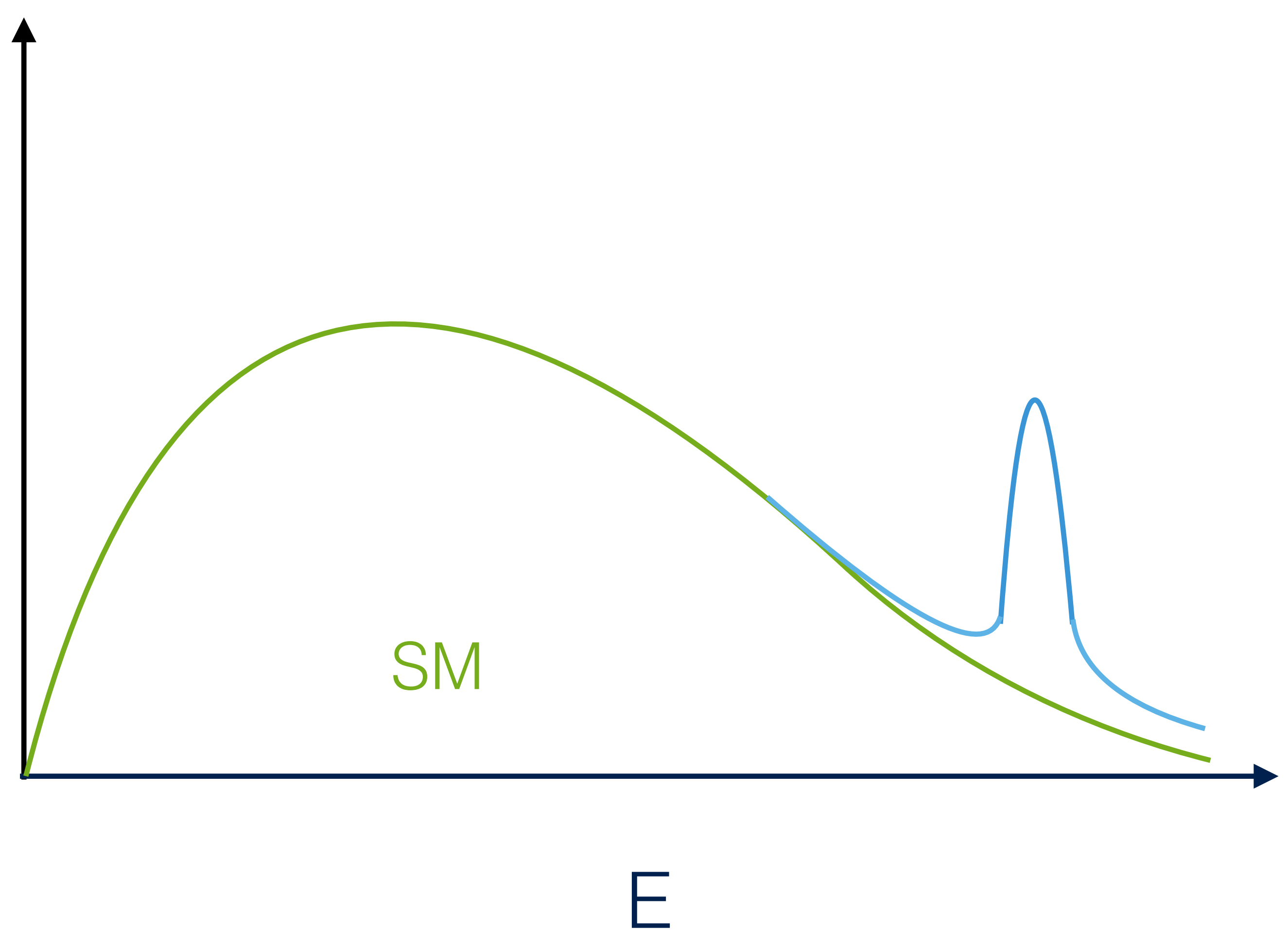
* The SIMUnet methodology offers the possibility to study such scenarios and potentially disentangle the effects.

Thank you

Back-up

The quest for New Physics

Direct search (Bumps)



The quest for New Physics

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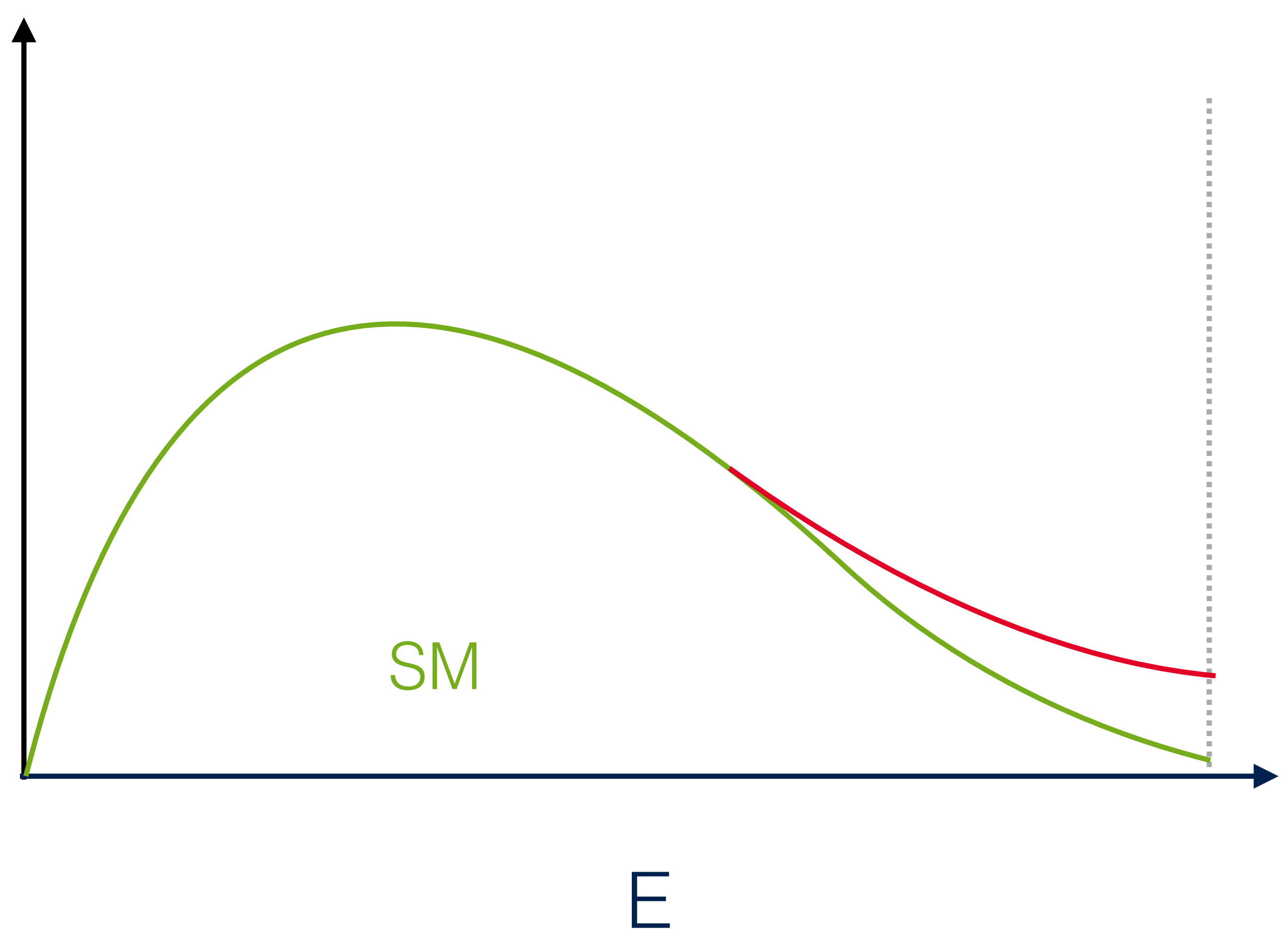
Indirect (scouting tails)



The quest for New Physics

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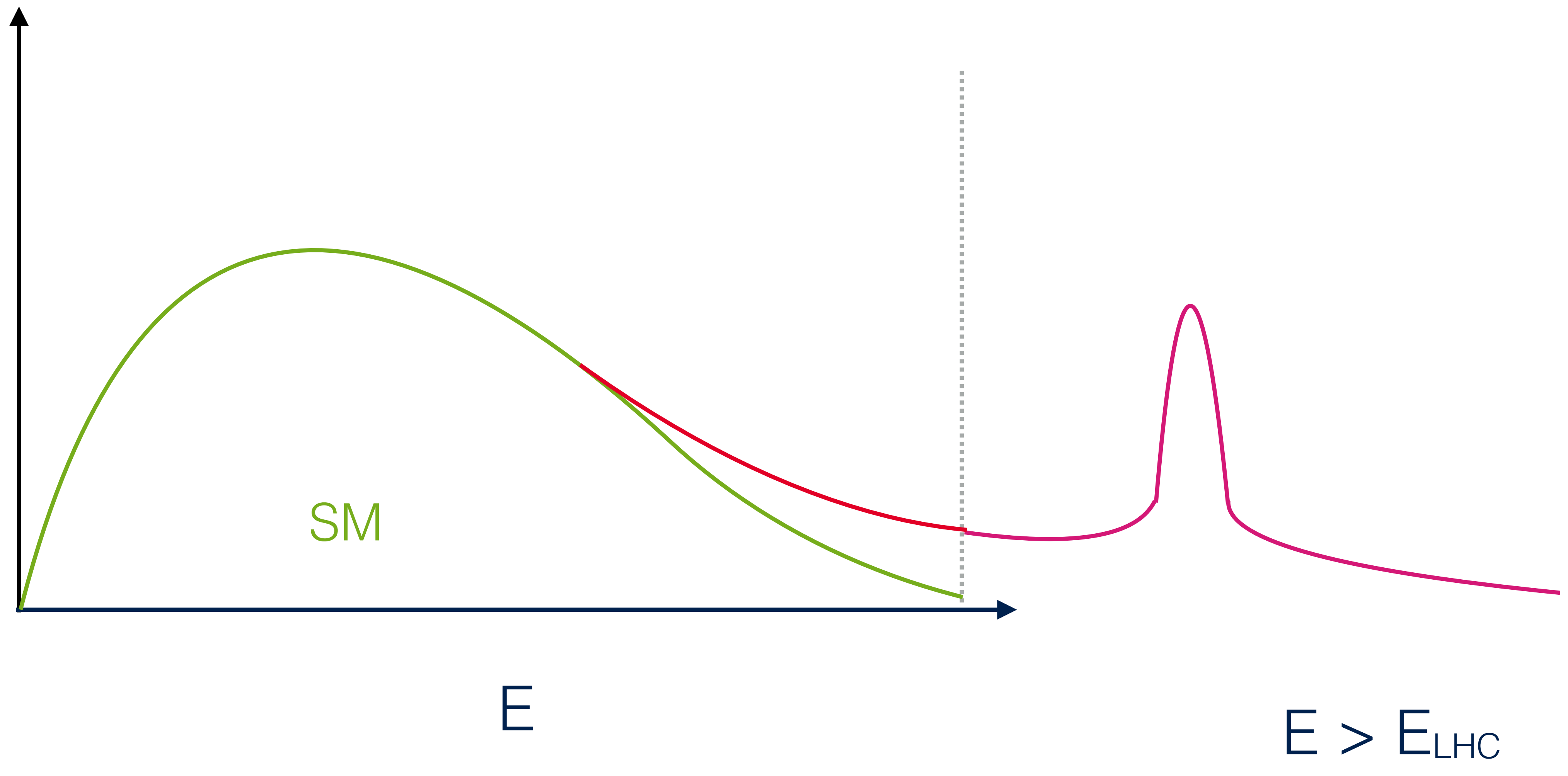
New physics is heavy



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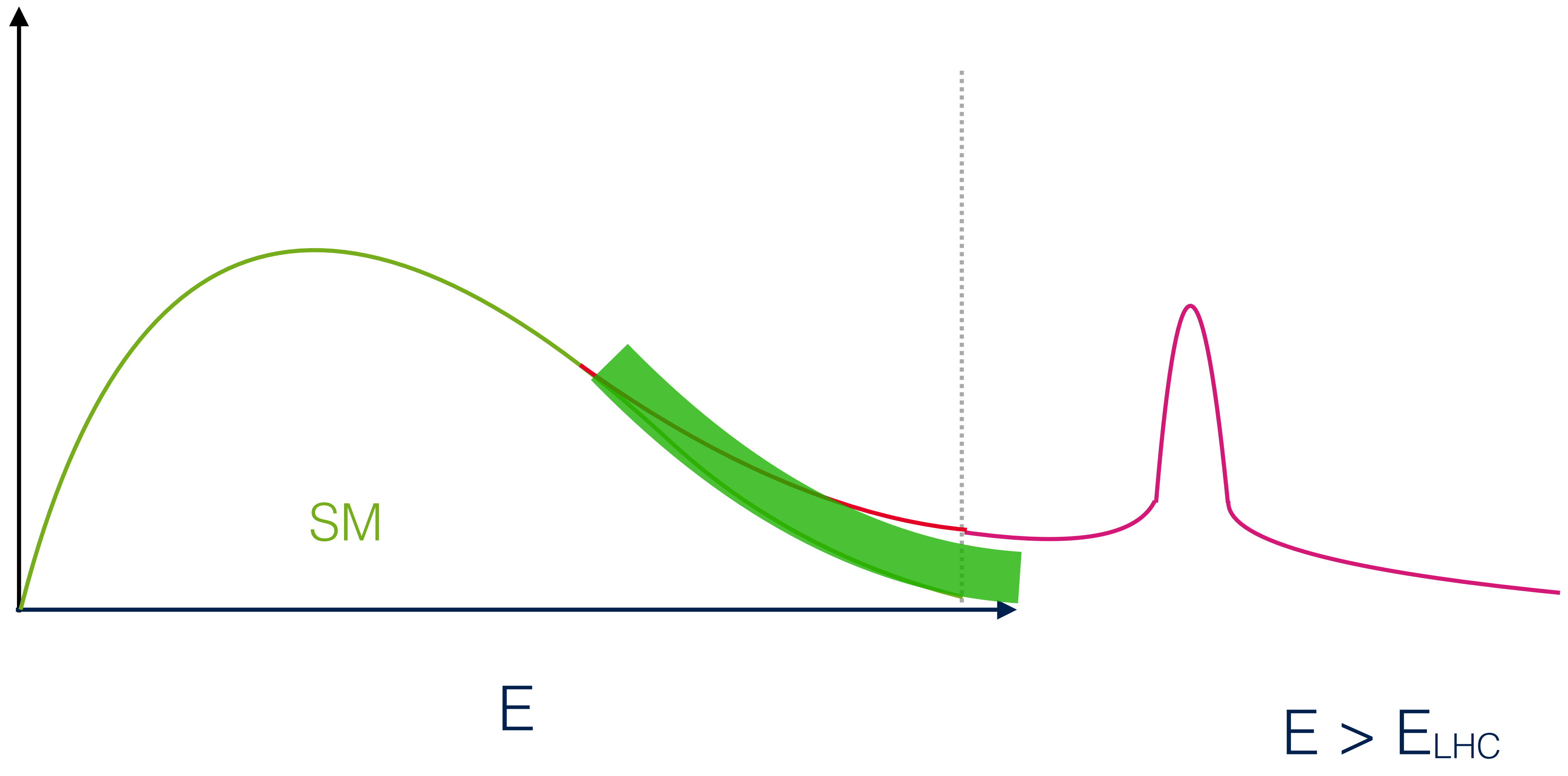

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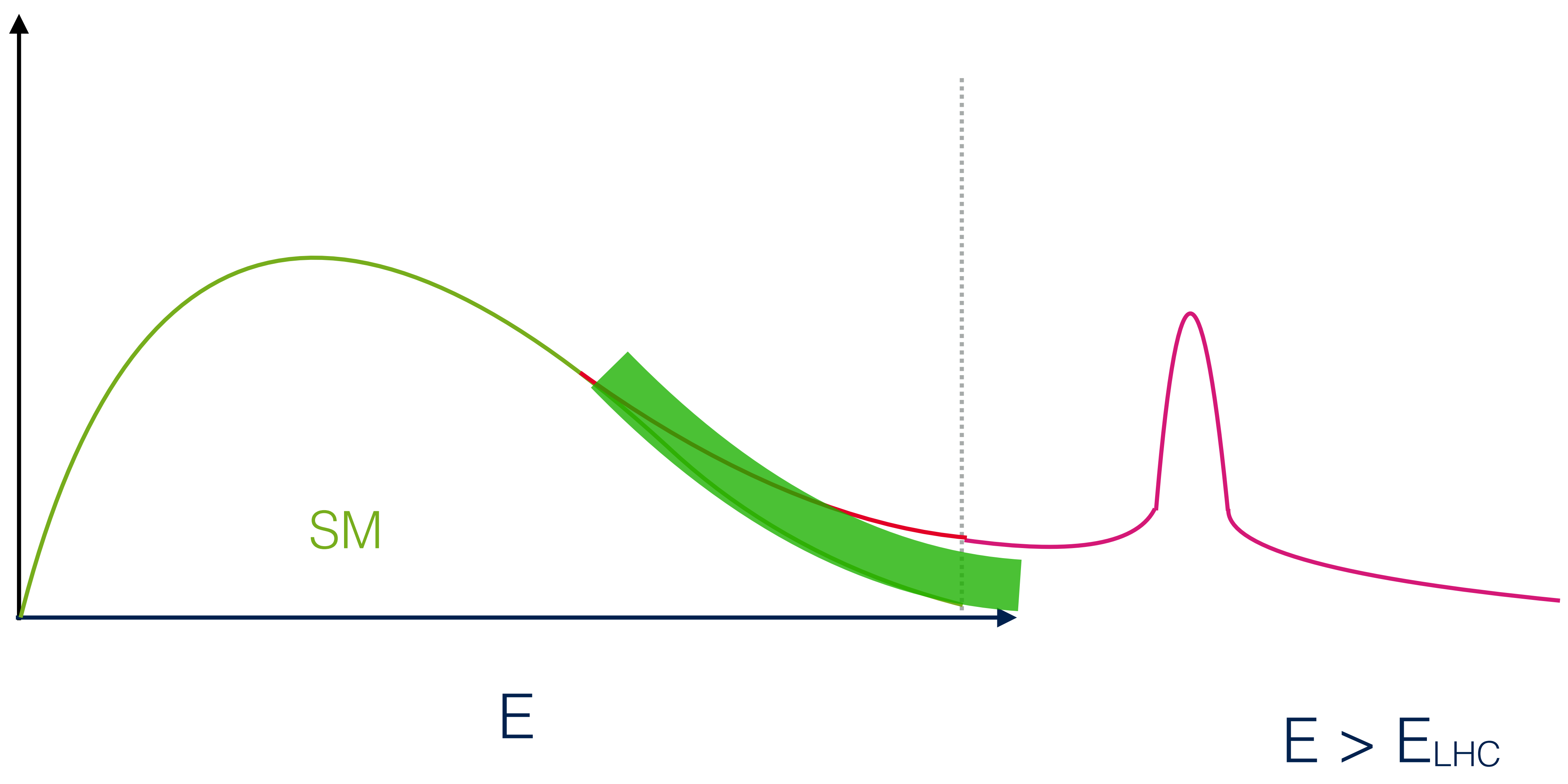

Framework to describe both precision physics and Heavy New Physics

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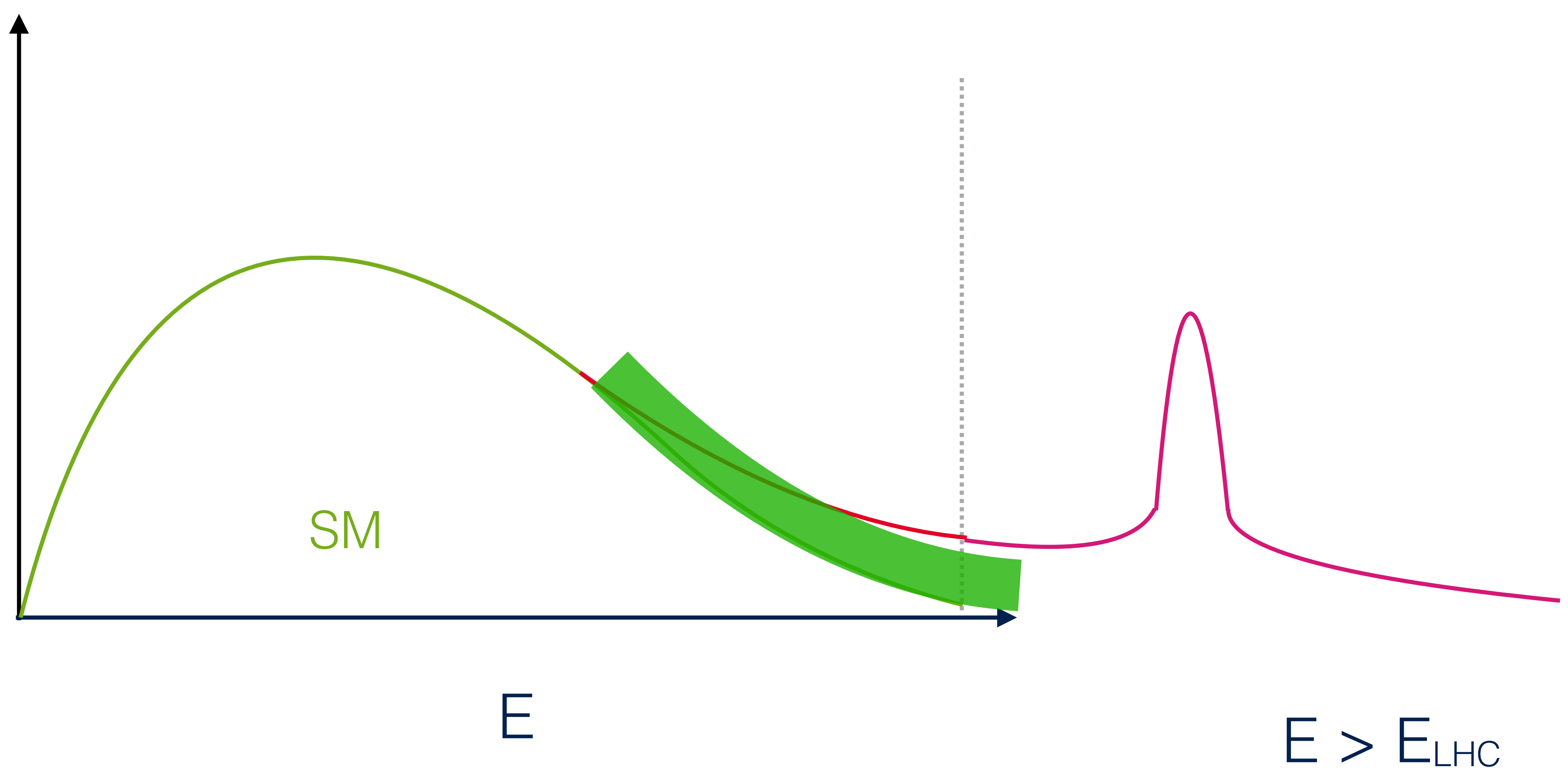
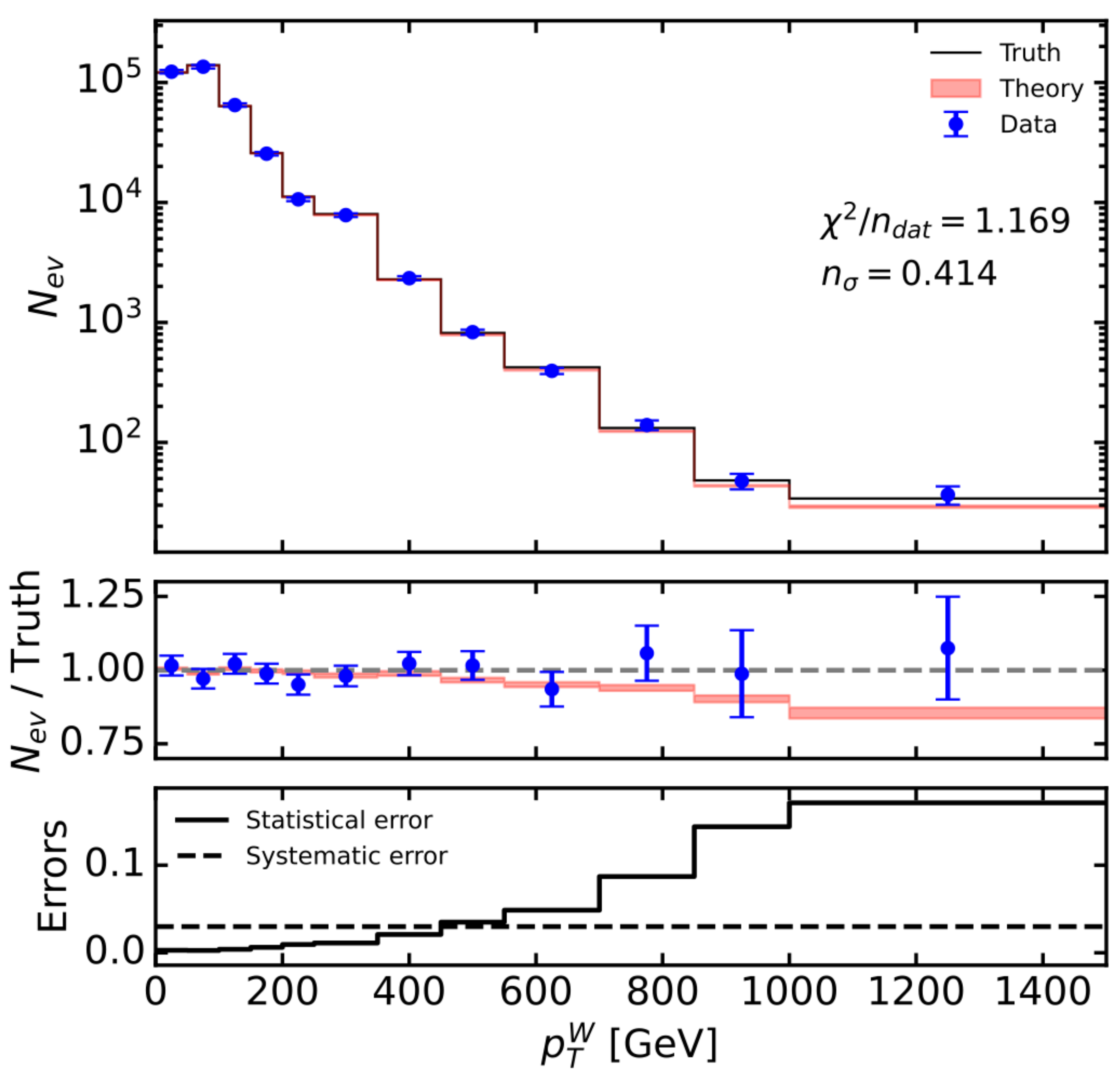


Framework to describe both precision physics and Heavy New Physics

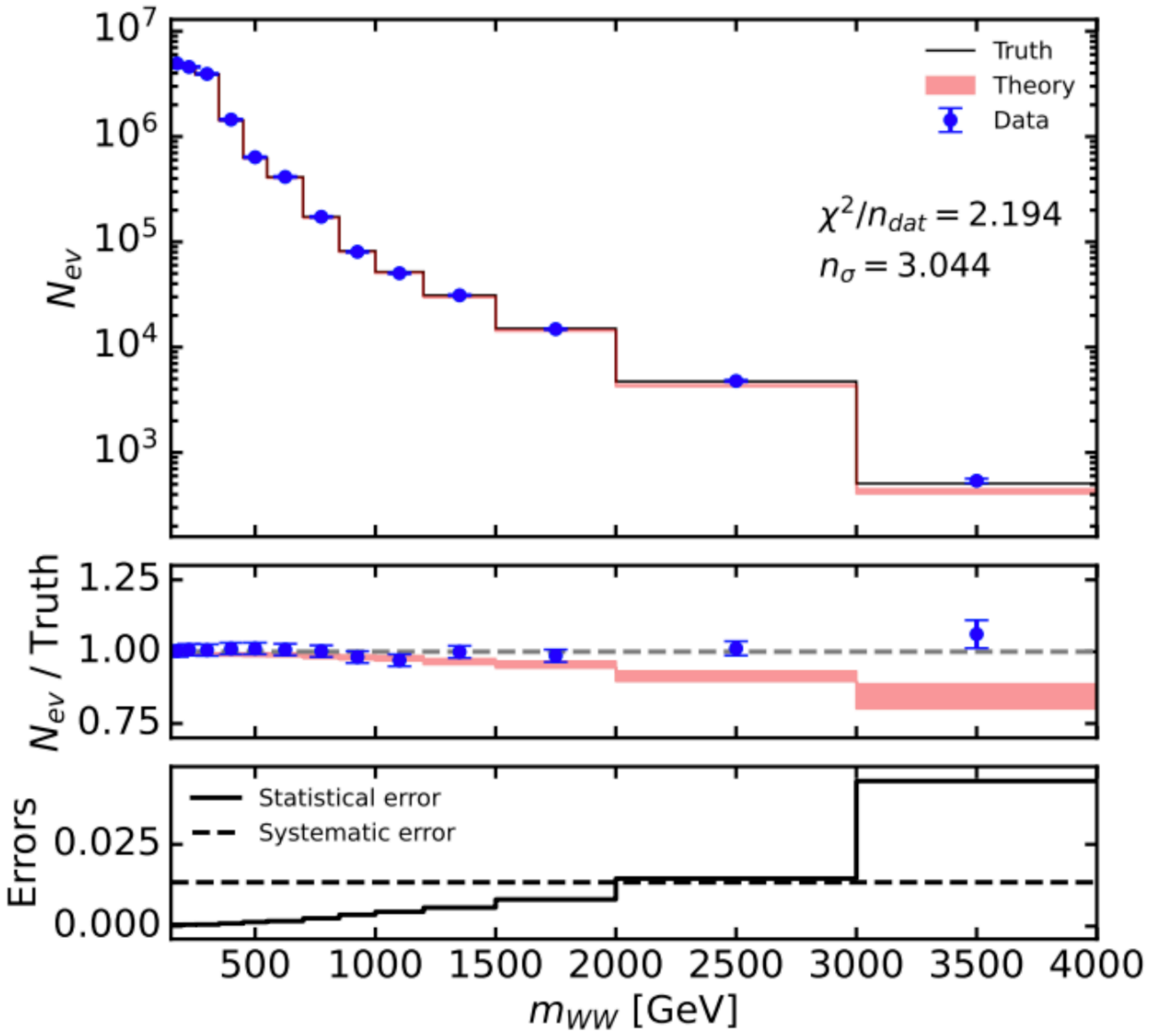
Standard Model Effective Field Theory (SMEFT)

Spurious New Physics

$pp \to W^+H$

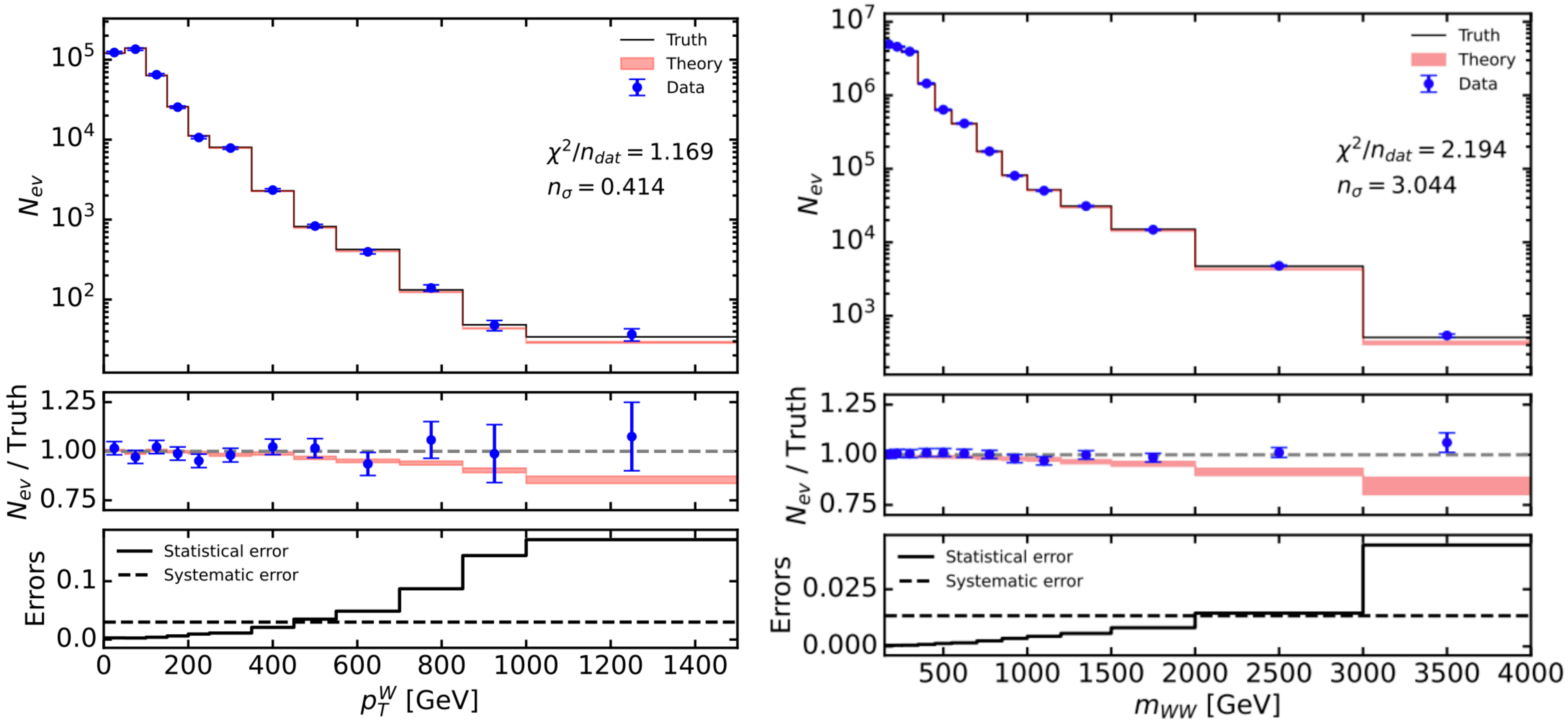


$pp \to W^+W^-$



Spurious New Physics

$pp \to W^+H$ $\qquad$ $pp \to W^+W^-$



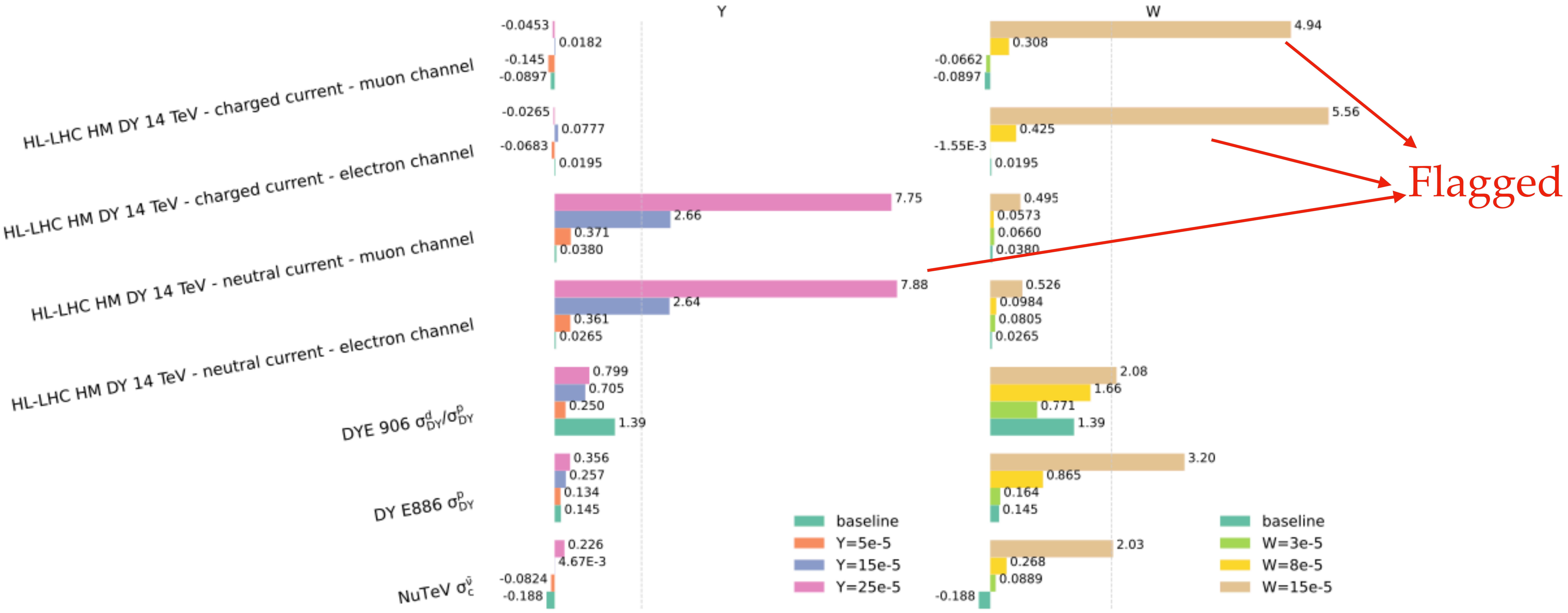
Observables
not affected by W′

Spurious NP

Fit metrics

Baseline: SM pseudodata

$$n_\sigma = \frac{\chi^2 - 1}{\sigma_{\chi^2}}$$



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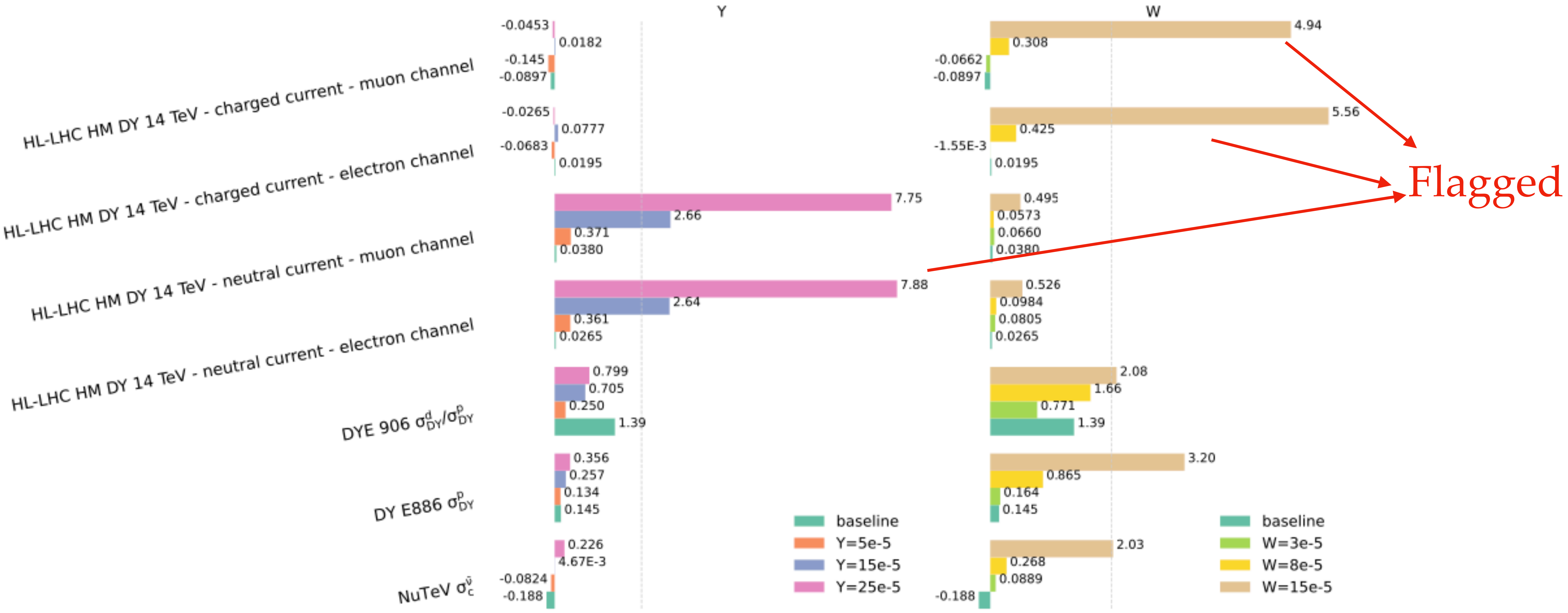
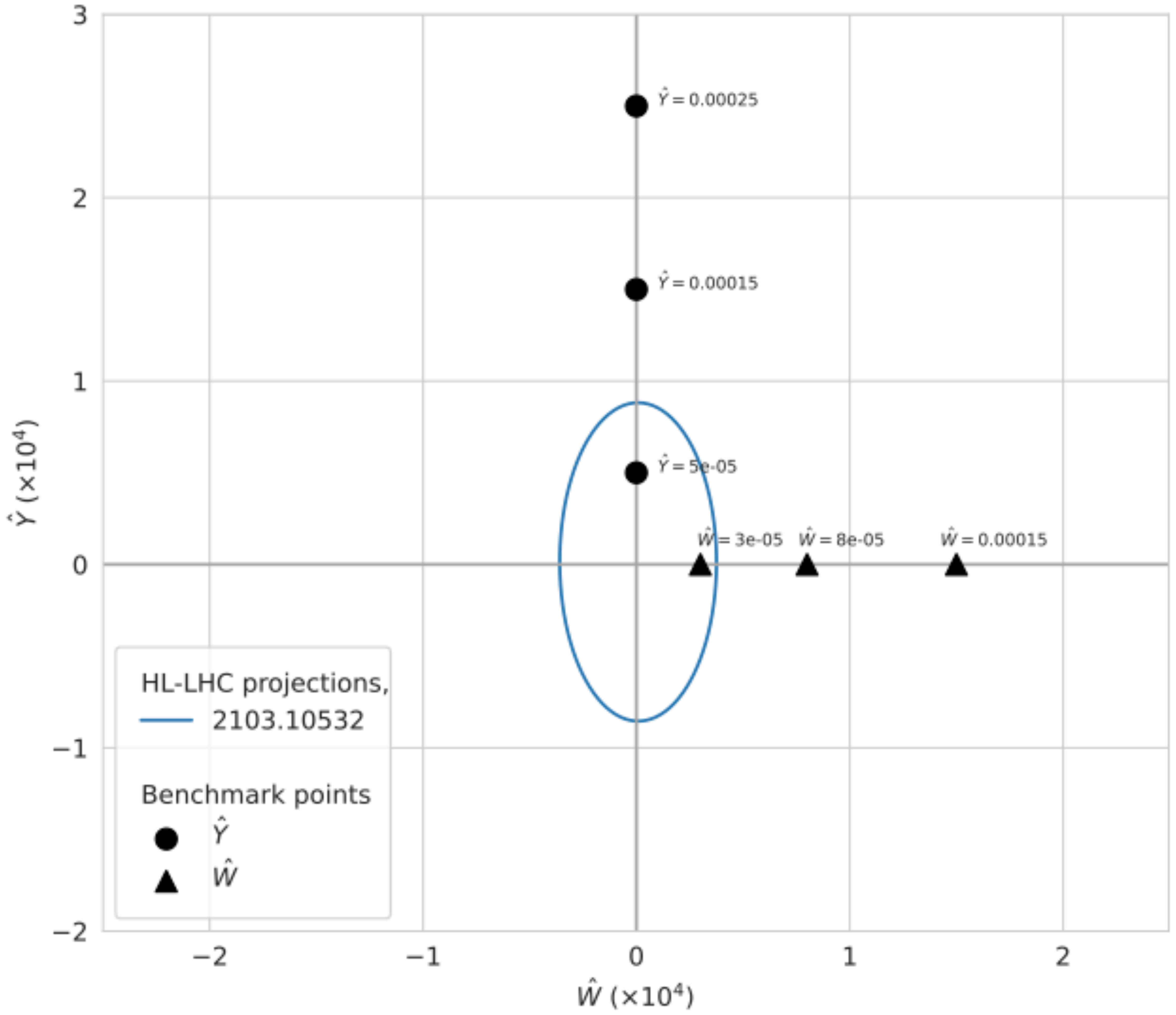


$$\hat{W} = 8 \cdot 10^{-5}, \quad M_{W'} \approx 14 \text{ TeV}$$

Absorbed

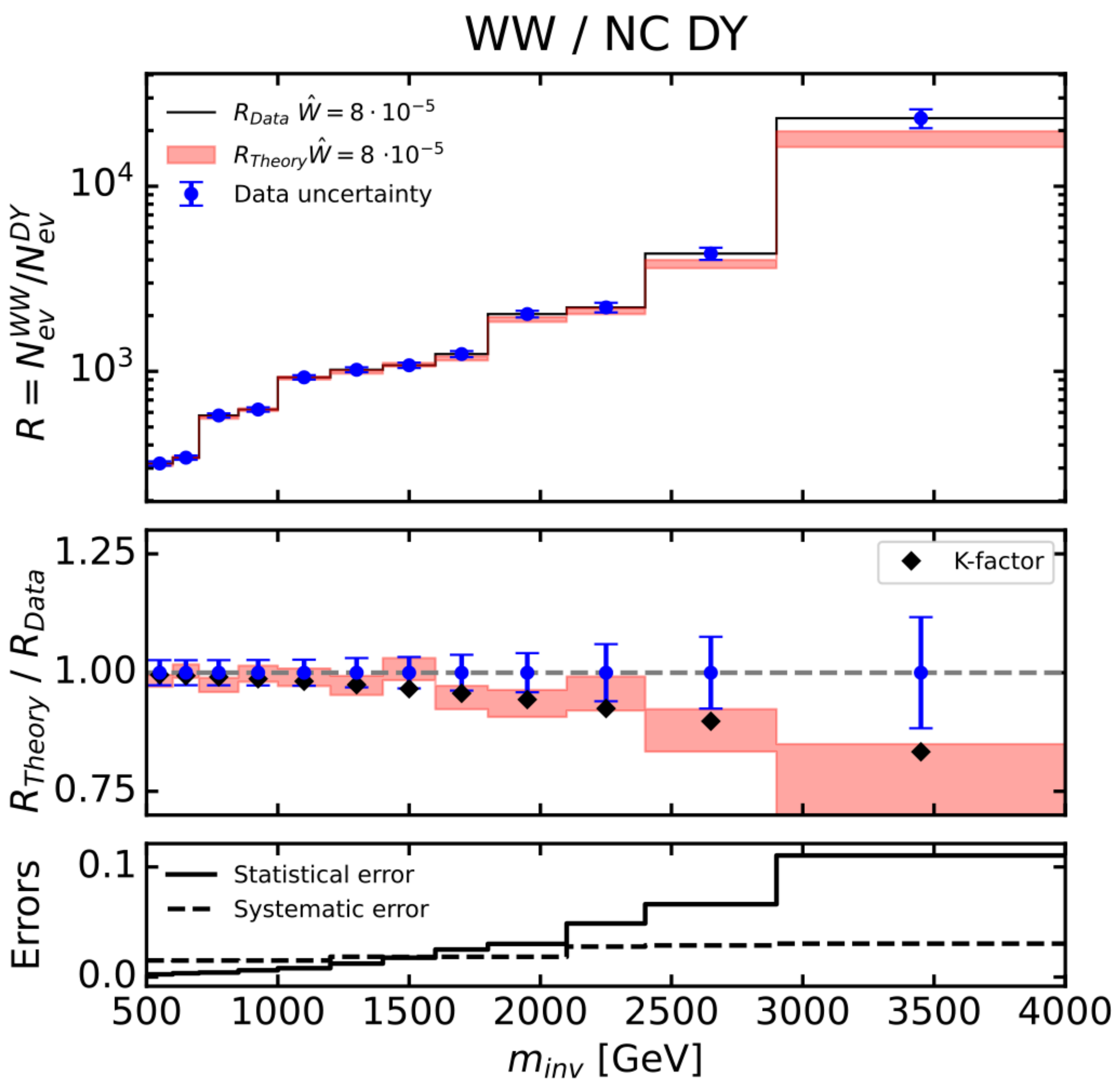
BSM scenarios



Ratio observables

Observable which is independent of PDFs

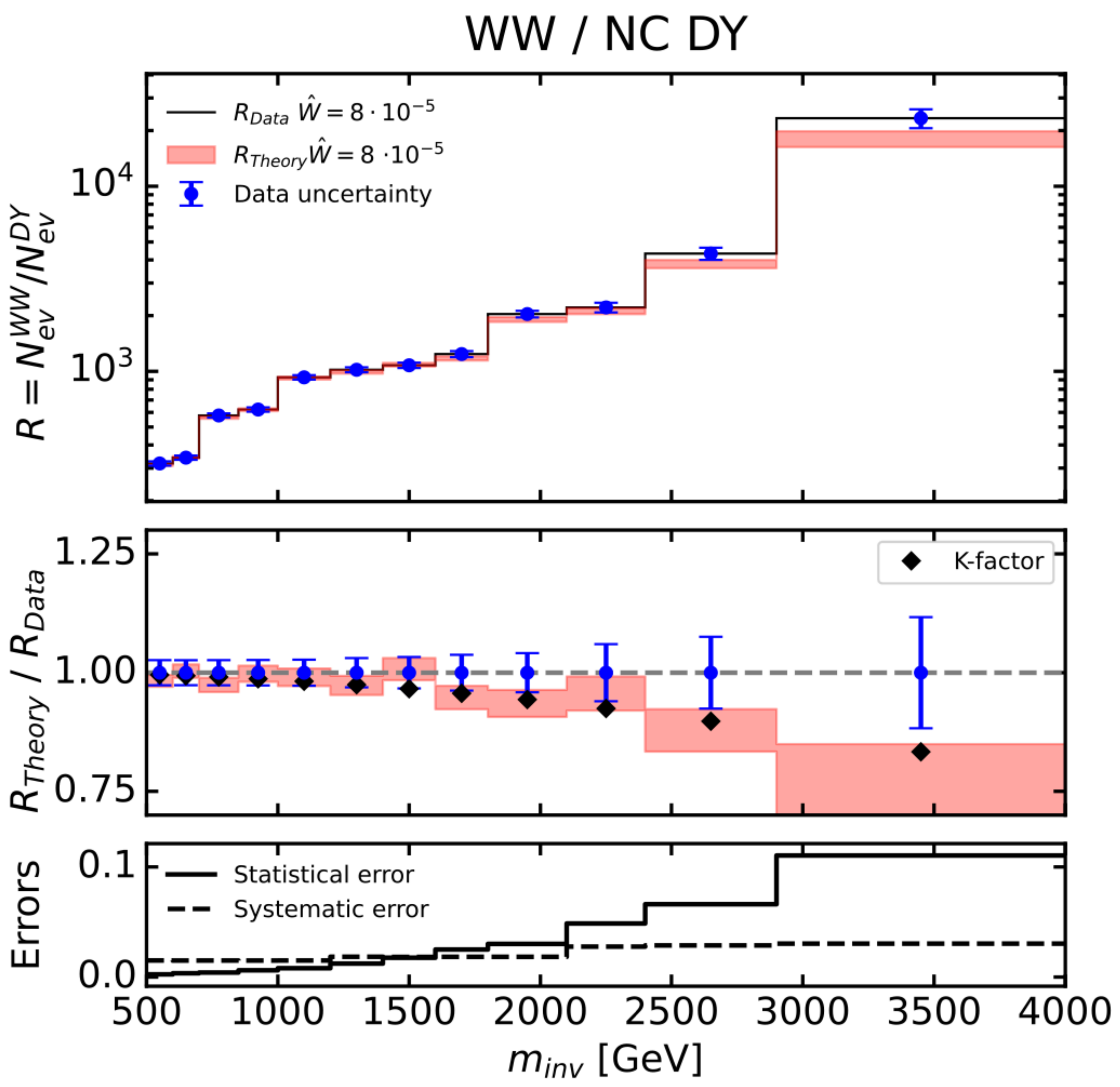
Ratio observables



Observable which is independent of PDFs

Ratio of WW and DY: prediction has suppressed dependence on PDF

Ratio observables



Observable which is independent of PDFs

Ratio of WW and DY: prediction has suppressed dependence on PDF

NP is there… but where?