

NNPDF3.1 LUXQED

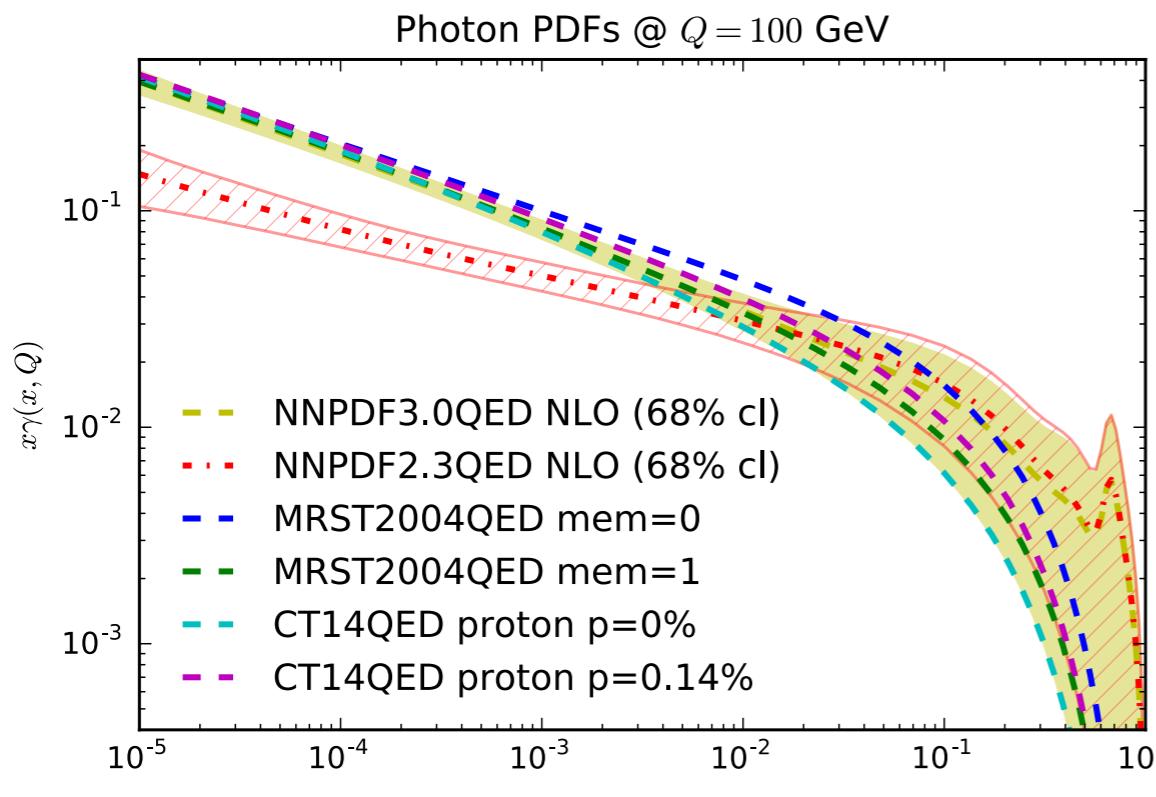
Based on arXiv:1712.07053, V. Bertone, S. Carrazza, NH, J. Rojo

*Nathan Hartland
Nikhef / VU Amsterdam*

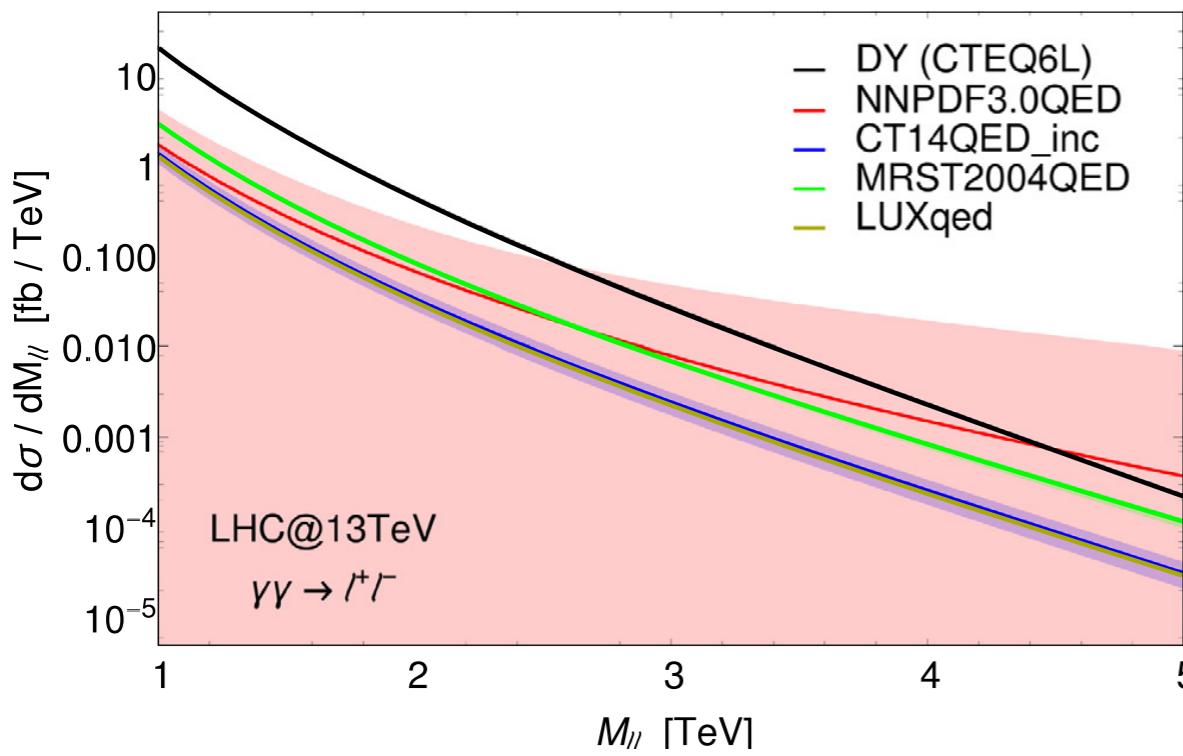
*DIS 2018
Kobe, 19/04/18*



THE PHOTON DISTRIBUTION



V. Bertone, S.Carrazza [1606.07130]



E. Accomando et al [1612.08168]

$\gamma(x)$ previously determined via

Physical model

e.g radiation from model valence quarks

- MRST2004 QED
- CT14 QED

- Sensitivity to underlying model

Data driven model

e.g independently parametrised photon distribution

- NNPDF2.3 QED
- NNPDF3.0 QED

- Lack of sensitive data to provide constraint

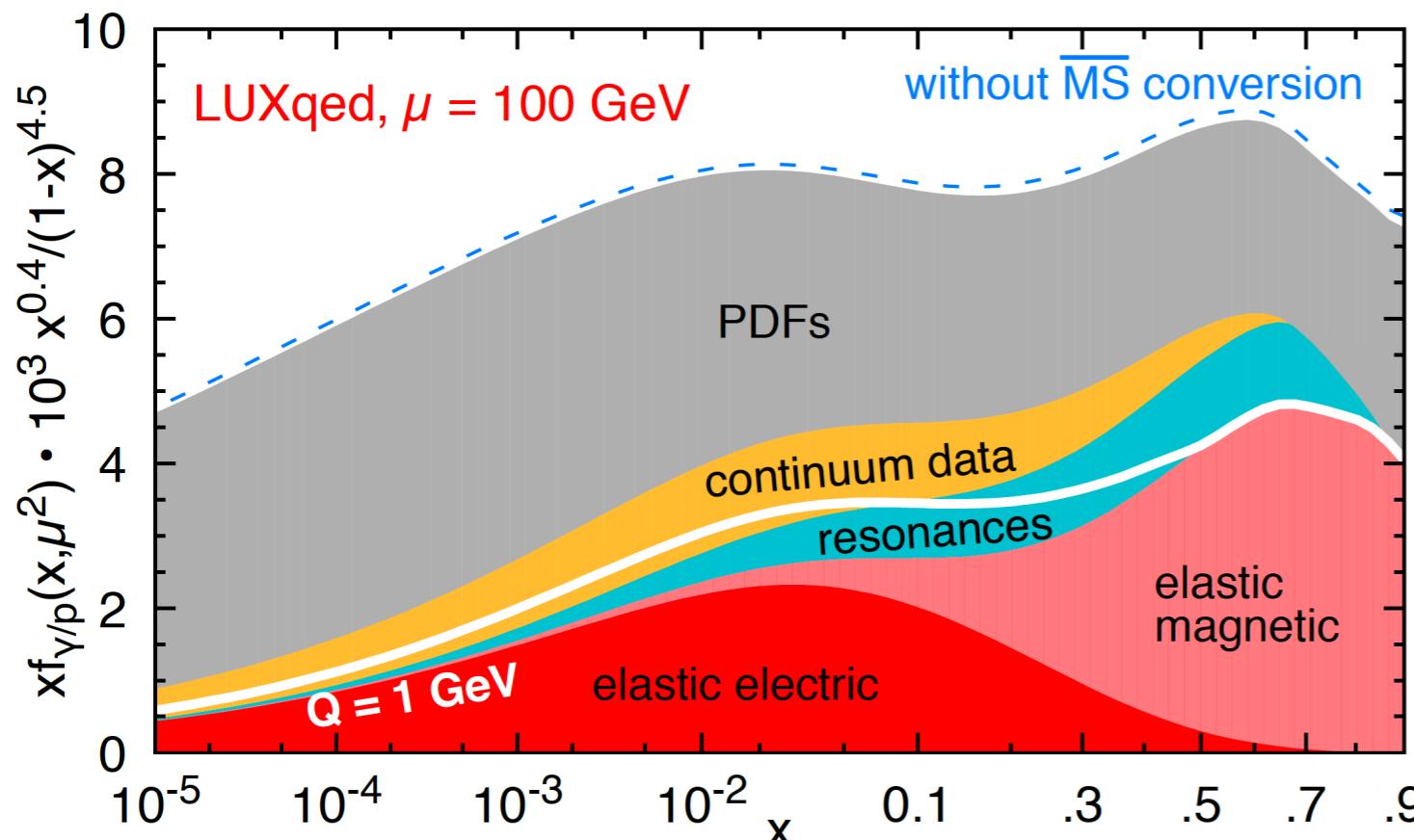
Express the photon PDF directly in terms of proton structure functions

$$x\gamma(x, \mu) = \frac{1}{2\pi\alpha(\mu)} \int_x^1 \frac{dz}{z} \left\{ \int_{Q_{\min}^2}^{\mu^2/(1-z)} \frac{dQ^2}{Q^2} \alpha^2(Q^2) \left[-z^2 F_L(x/z, Q^2) \right. \right.$$

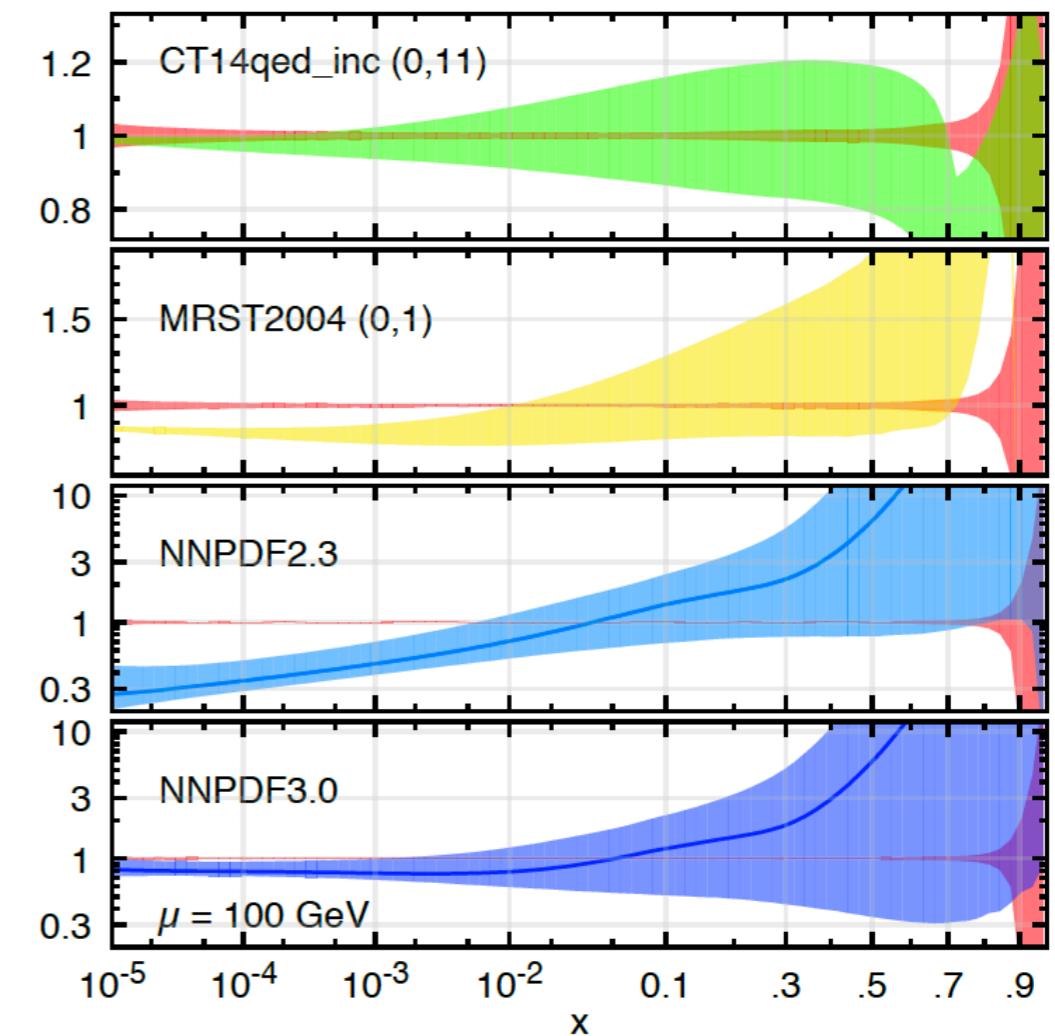
$$\left. \left. + \left(zP_{\gamma q}(z) + \frac{2x^2 m_p^2}{Q^2} \right) F_2(x/z, Q^2) \right] - \alpha^2(\mu) z^2 F_2(x/z, \mu^2) \right\} + \mathcal{O}(\alpha\alpha_s, \alpha^2)$$

Contributions from

- Elastic scattering (data)
- Low-Q inelastic (data)
- High-Q inelastic (PDFs)



A. Manohar et al [1607.04266]



<https://github.com/scarrazza/fiatlux>

fiatlux

API for LUXqed methodology in global PDF fits.

DOI [10.5281/zenodo.11117325](https://doi.org/10.5281/zenodo.11117325)

Project summary and aim

The aim of `libfiatlux` is to provide a blackbox tool which computed the photon PDF at a given Q value using the LUX approach by Manohar, Nason, Salam and Zanderighi in [arXiv:1607.04266](https://arxiv.org/abs/1607.04266) and [arXiv:1708.01256](https://arxiv.org/abs/1708.01256). The output of this repository is a C++ library which can be imported and shared to other programs.

The library implements following features:

- Computes LUX photon by subdiving in elastic, inelastic and msbar components
- Allow variations of parameters to estimate uncertainties
- Generic interface to F2, FL and alpha QED: you can plug APFEL or any other evolution code.

Open source implementation of the LUXqed photon
Simplifies inclusion of a LUXqed photon into a PDF fit

LUXQED PHOTON IN NNPDF

Aim: an NNPDF3.1 fit consistently including the LUXqed photon

- LUXqed generates a photon based on an input QCD PDF set
- Why do we want to include the photon in the fit?

The photon can modify results of a QCD PDF fit in several ways

1. Momentum sum rule

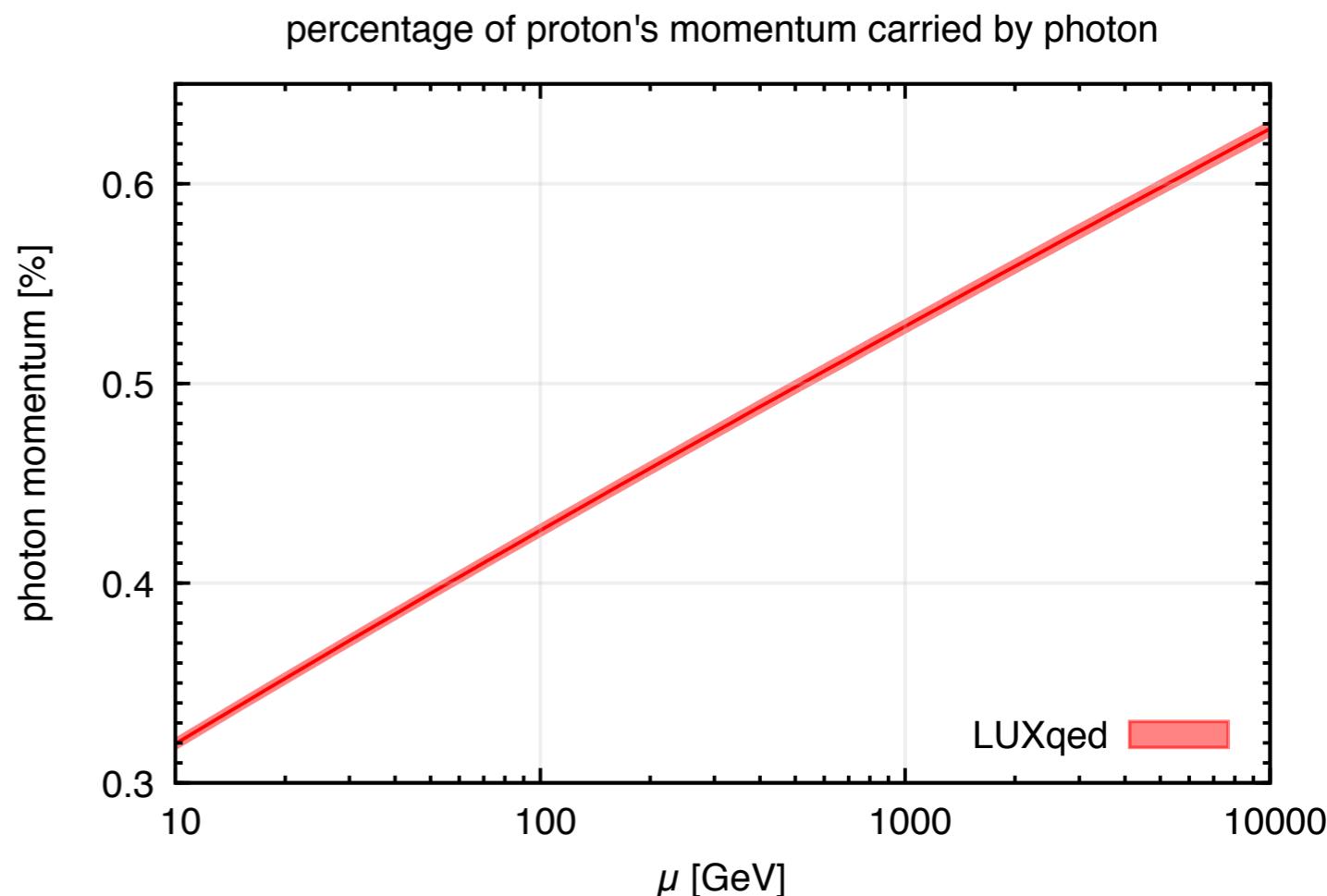
$$\int_0^1 dx x (\Sigma(x, Q_0) + g(x, Q_0) + \gamma(x, Q_0)) = 1$$

2. QED-corrected PDF evolution

- DGLAP: $\mathcal{O}(\alpha)$ $\mathcal{O}(\alpha\alpha_S)$ $\mathcal{O}(\alpha^2)$

3. Photon-induced (PI) processes

- DIS structure functions $\mathcal{O}(\alpha)$
- NNPDF3.1 dataset (PI cuts)



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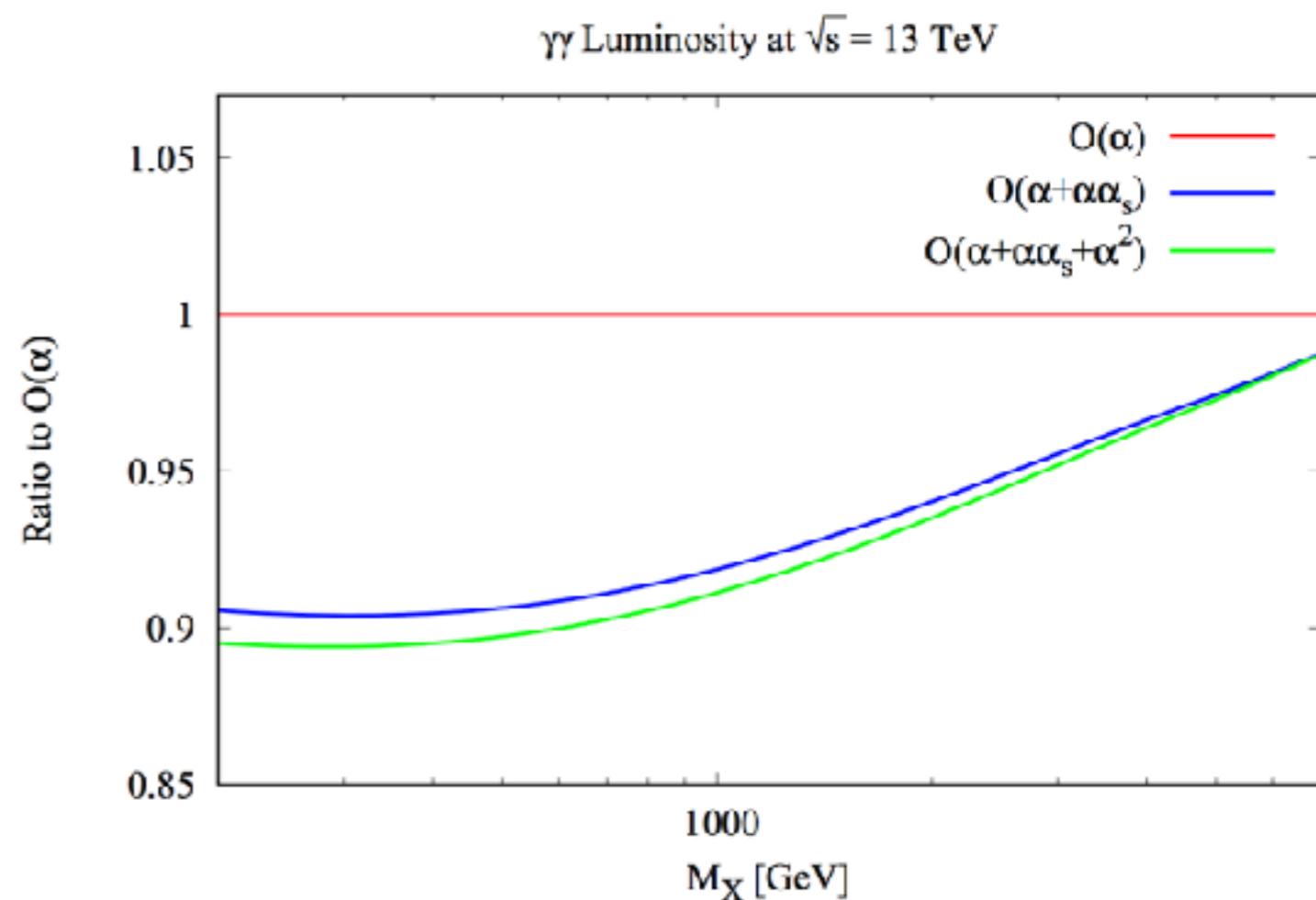
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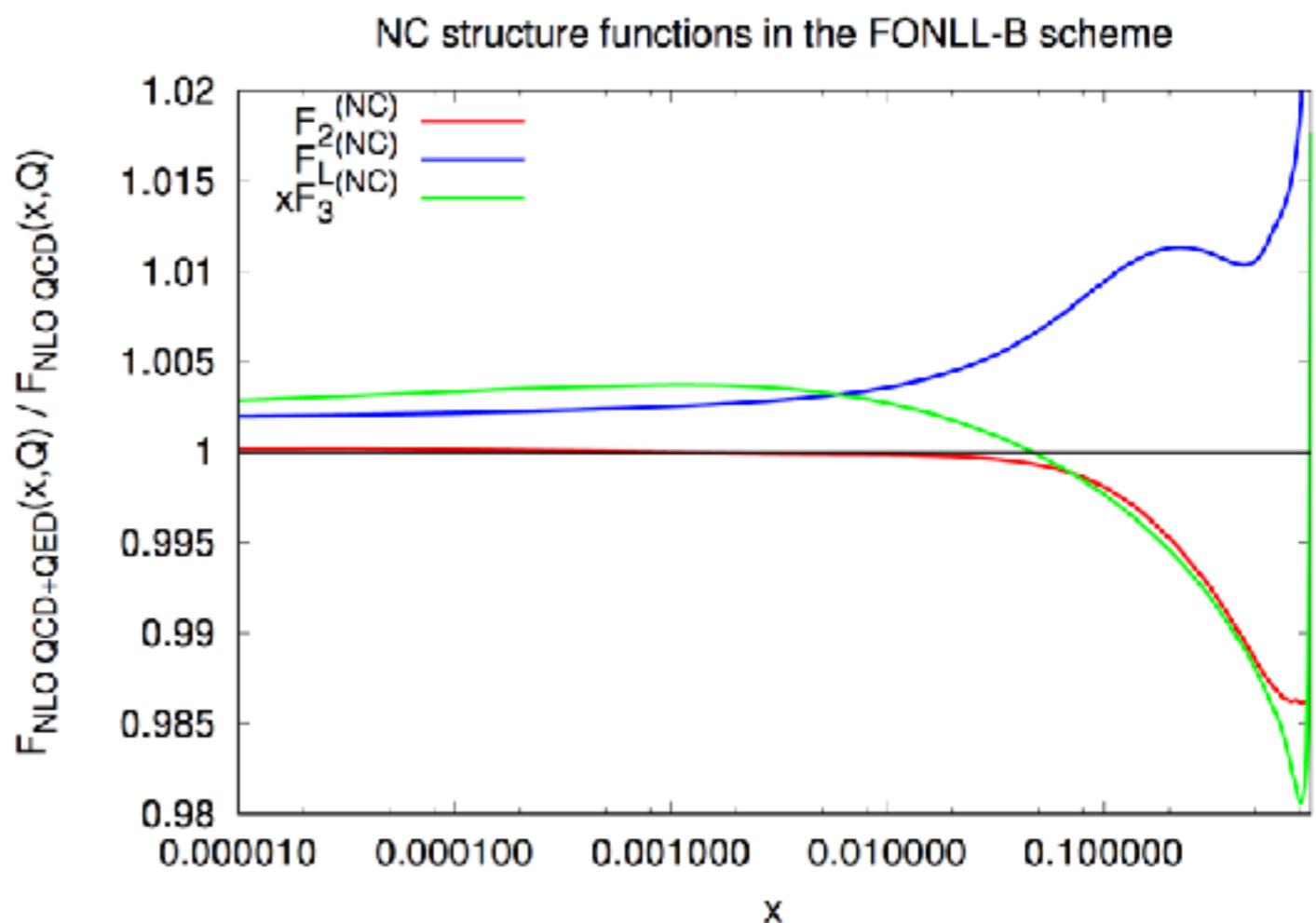
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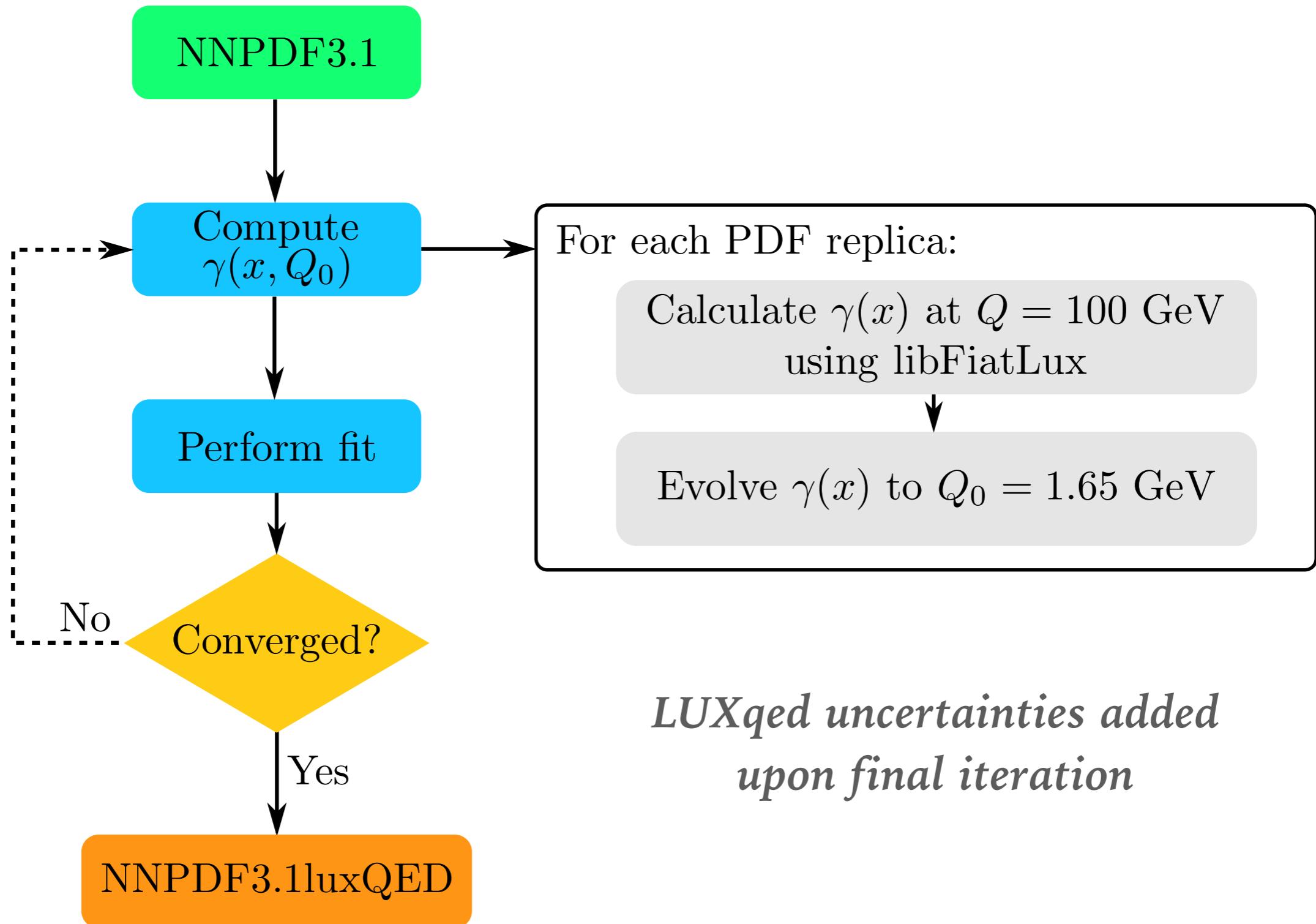
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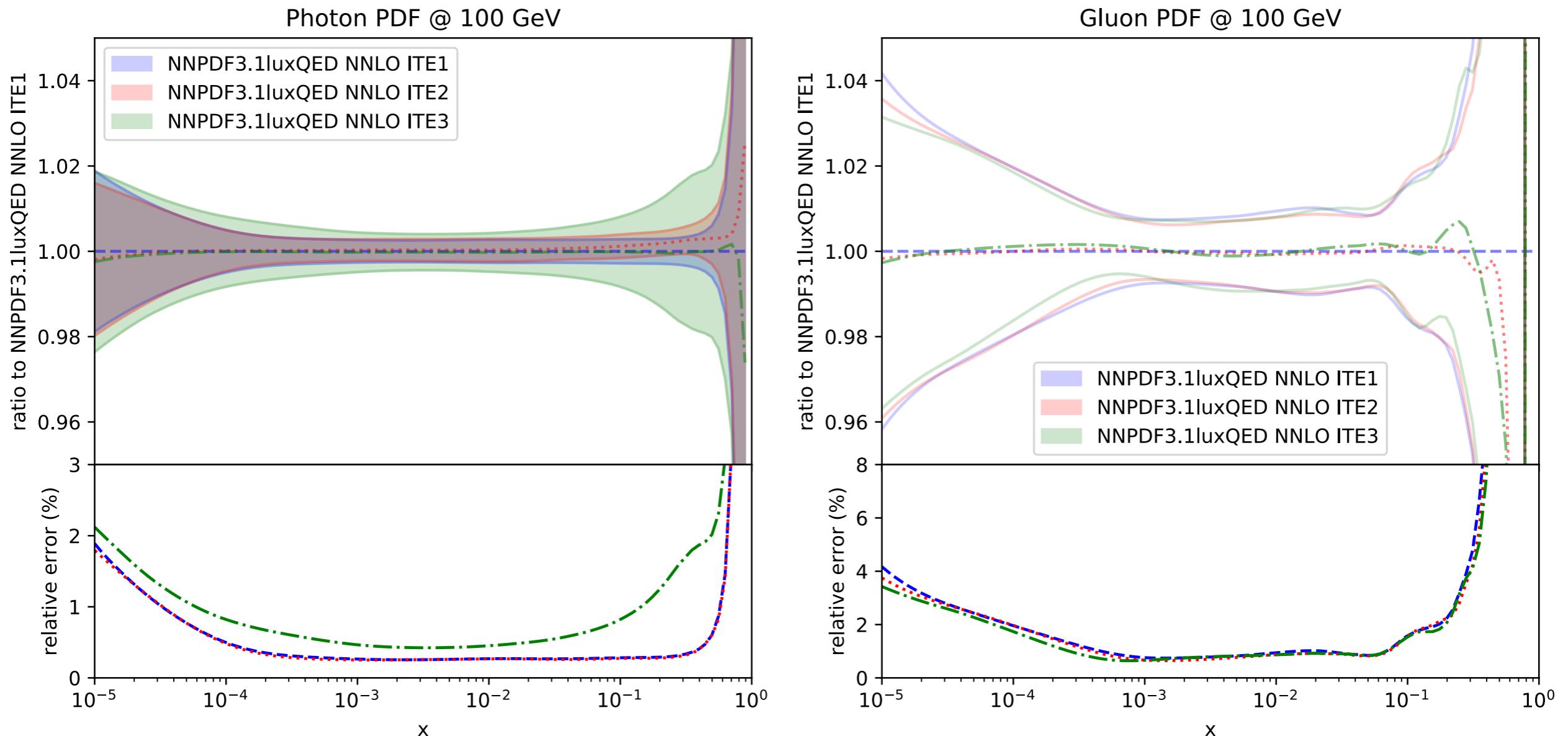
[1701.08553]

LUXQED PHOTON IN NNPDF

Strategy: Include LUXqed photon via an iterative procedure



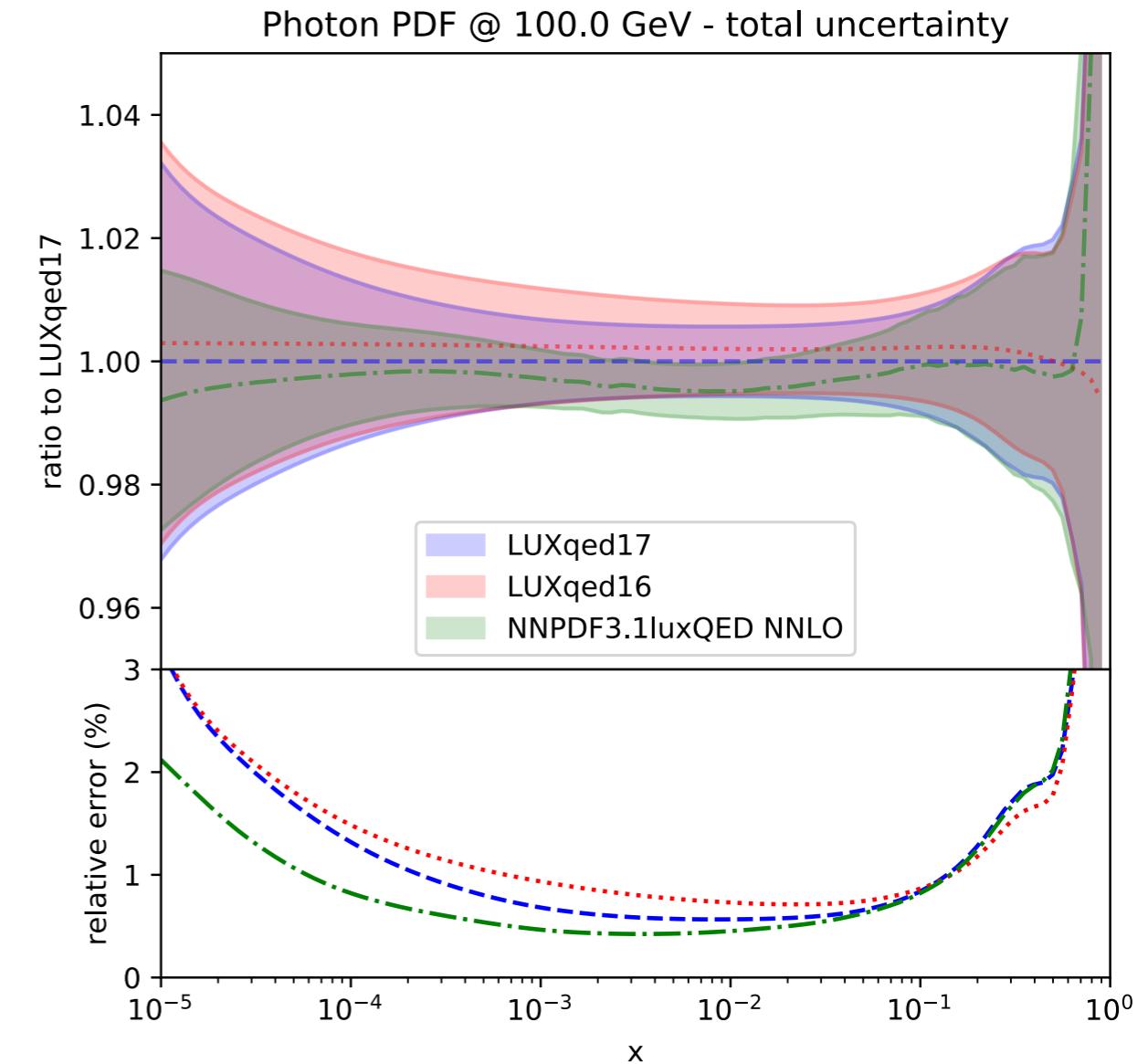
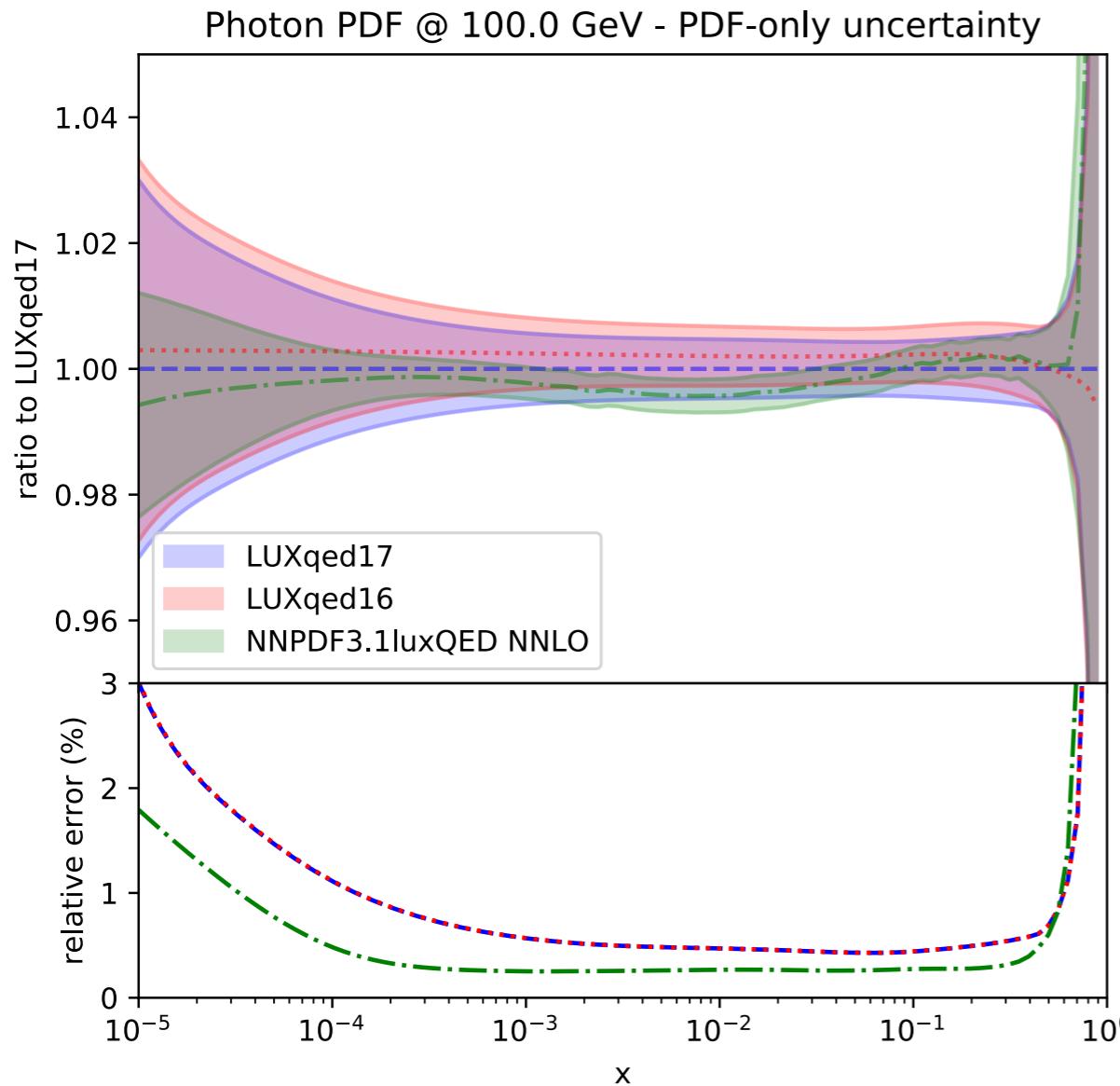
CONVERGENCE OF ITERATIVE PROCEDURE



Procedure converges quickly (note LUXqed uncertainties in third iteration)

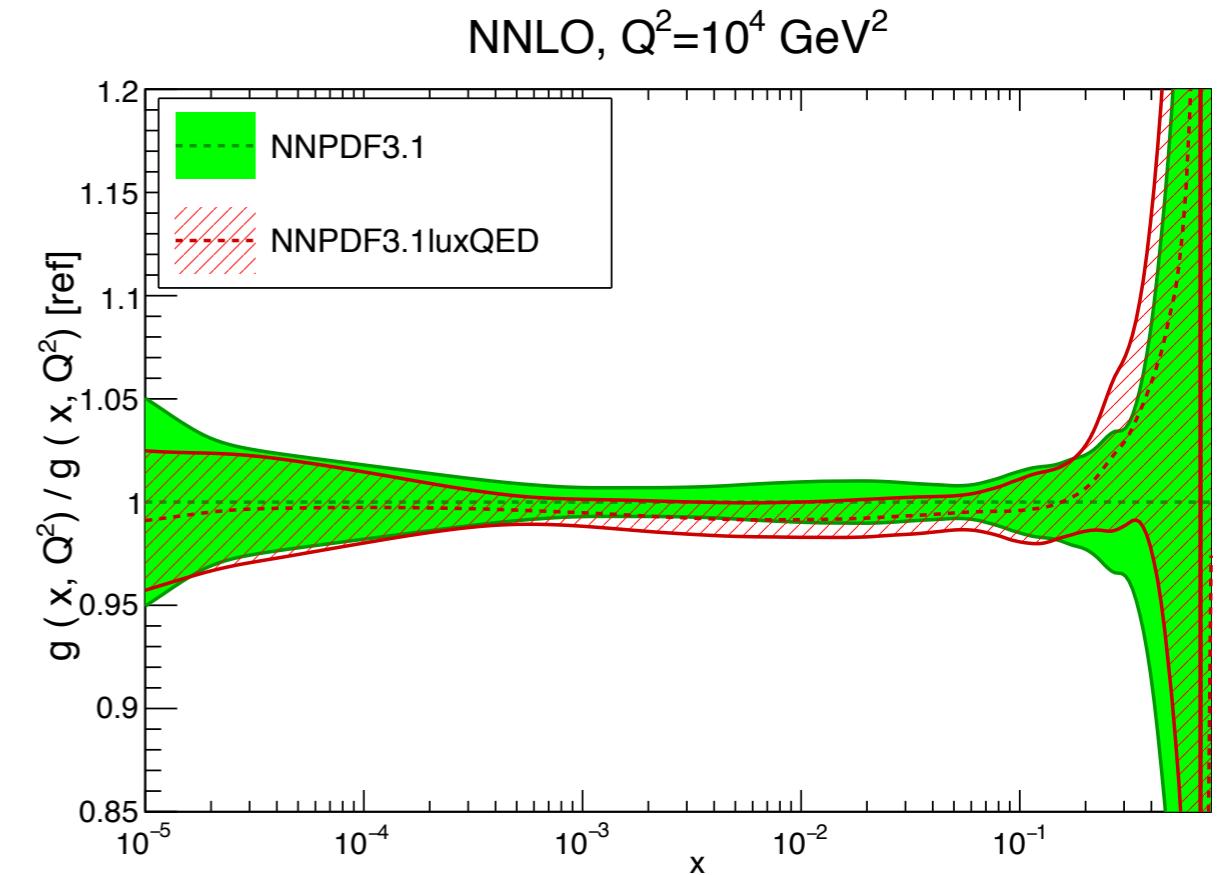
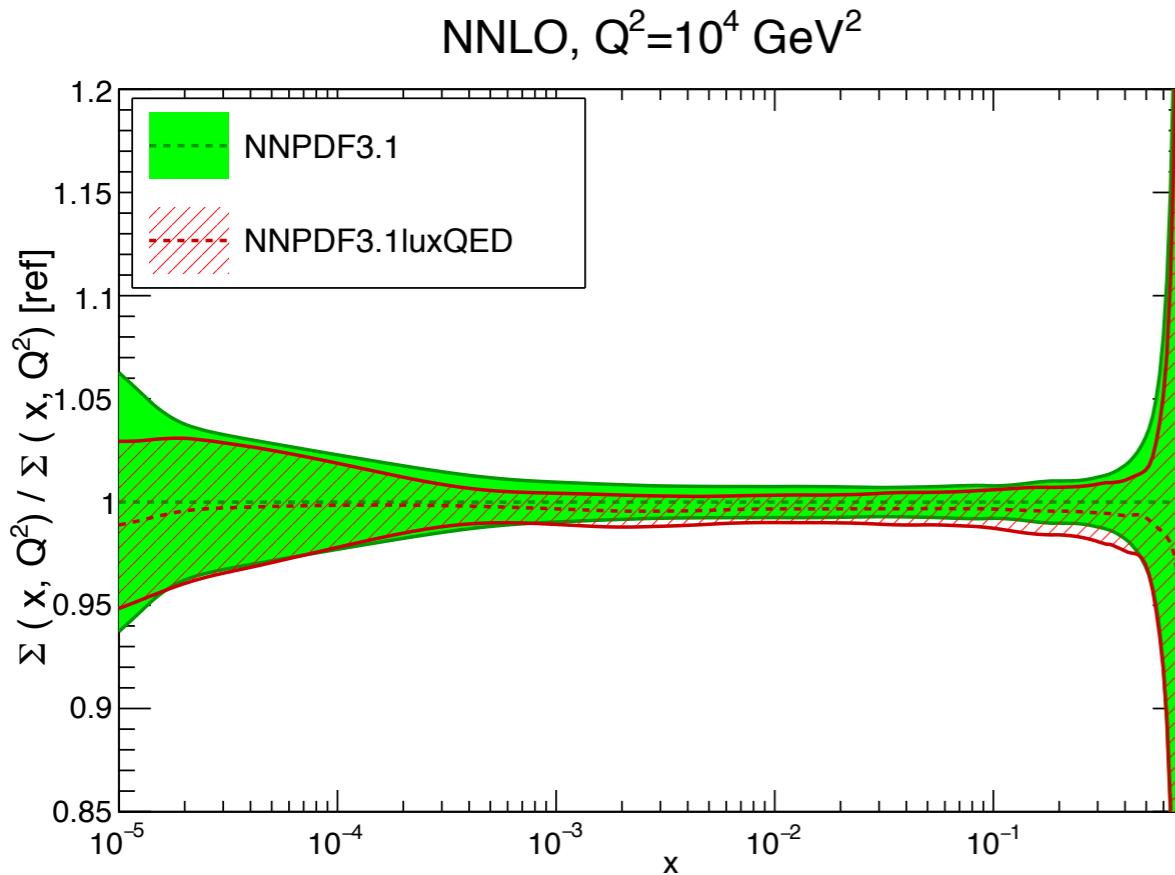
NNPDF3.1QED - THE PHOTON

Result: an NNPDF3.1 set with a consistent photon PDF



- Photon in good agreement with LUXqed result
- Smaller uncertainties at low-x (where PDF errors dominate)

NNPDF3.1QED - QUARK AND GLUON DISTRIBUTIONS

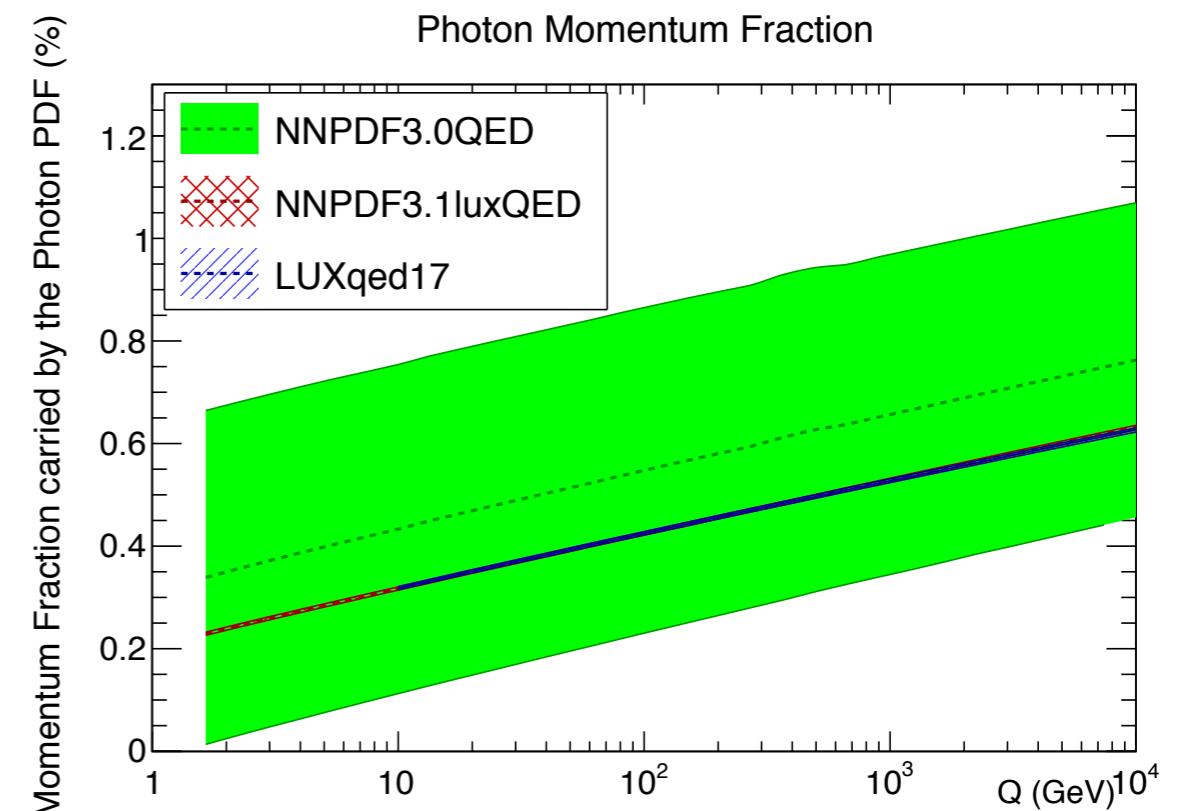
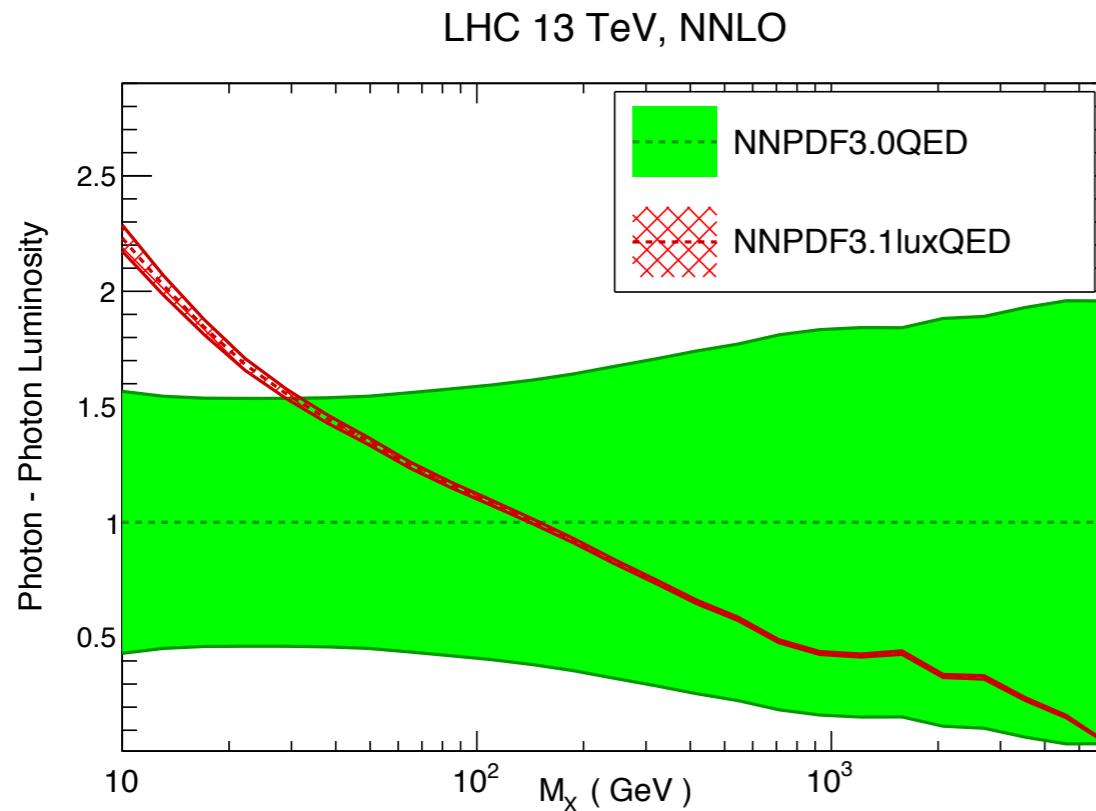


Inclusion of the LUXqed photon has a moderate impact

- As required, a small reduction in overall momentum for gluon, quarks
- Broad consistency in shape across the kinematic range

Future inclusion of PI-sensitive data should provide additional constraints

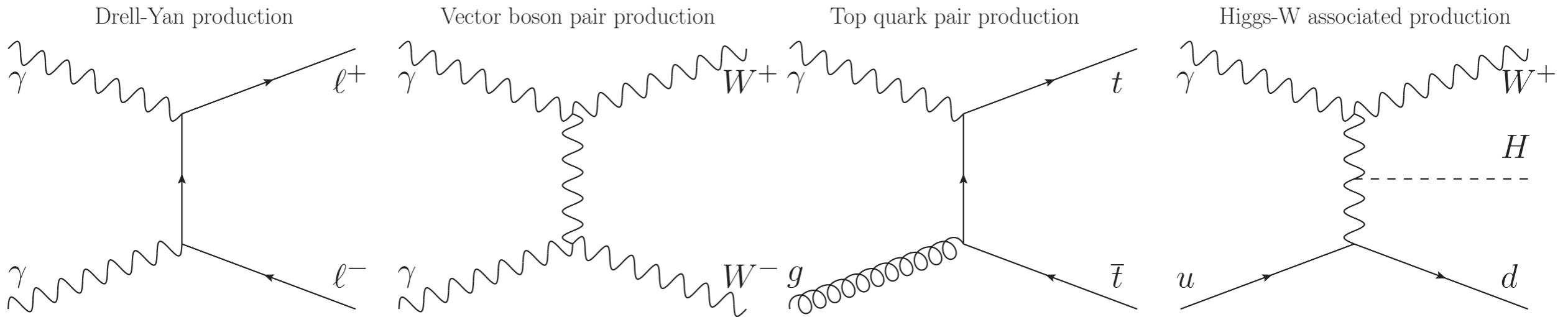
COMPARISON TO 3.0QED



Uncertainties in photon distribution considerably reduced

- *Results consistent within large data-driven uncertainties*
- *At low- x , low- M , differences due to modified DGLAP evolution*

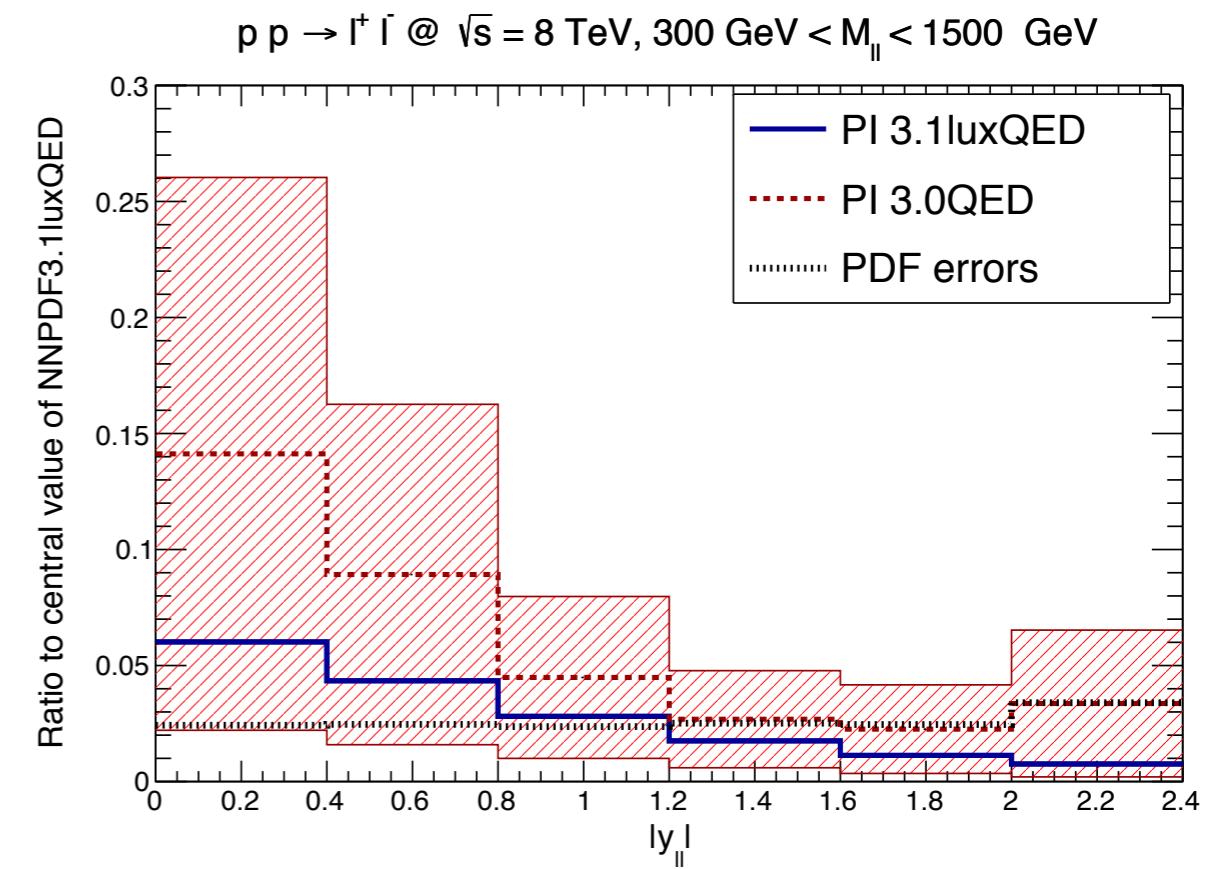
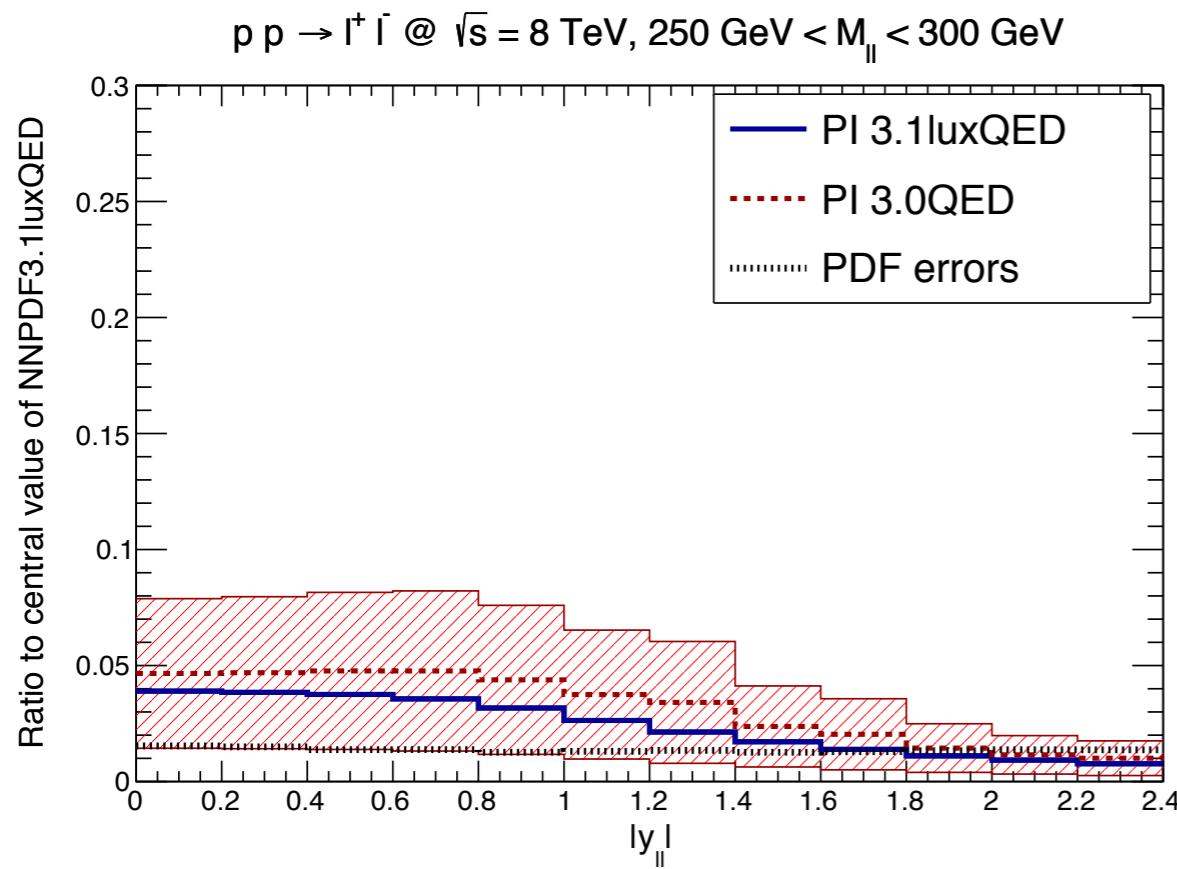
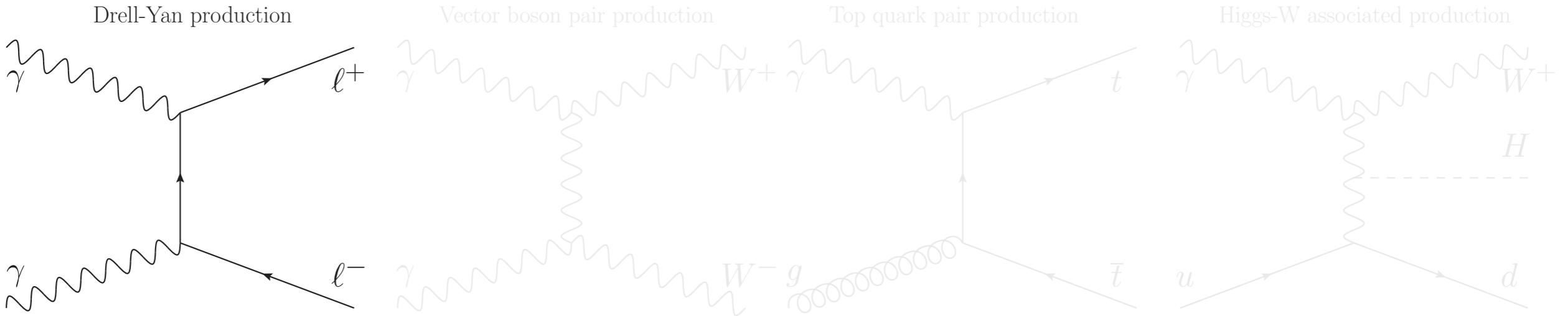
PHENOMENOLOGICAL IMPACT



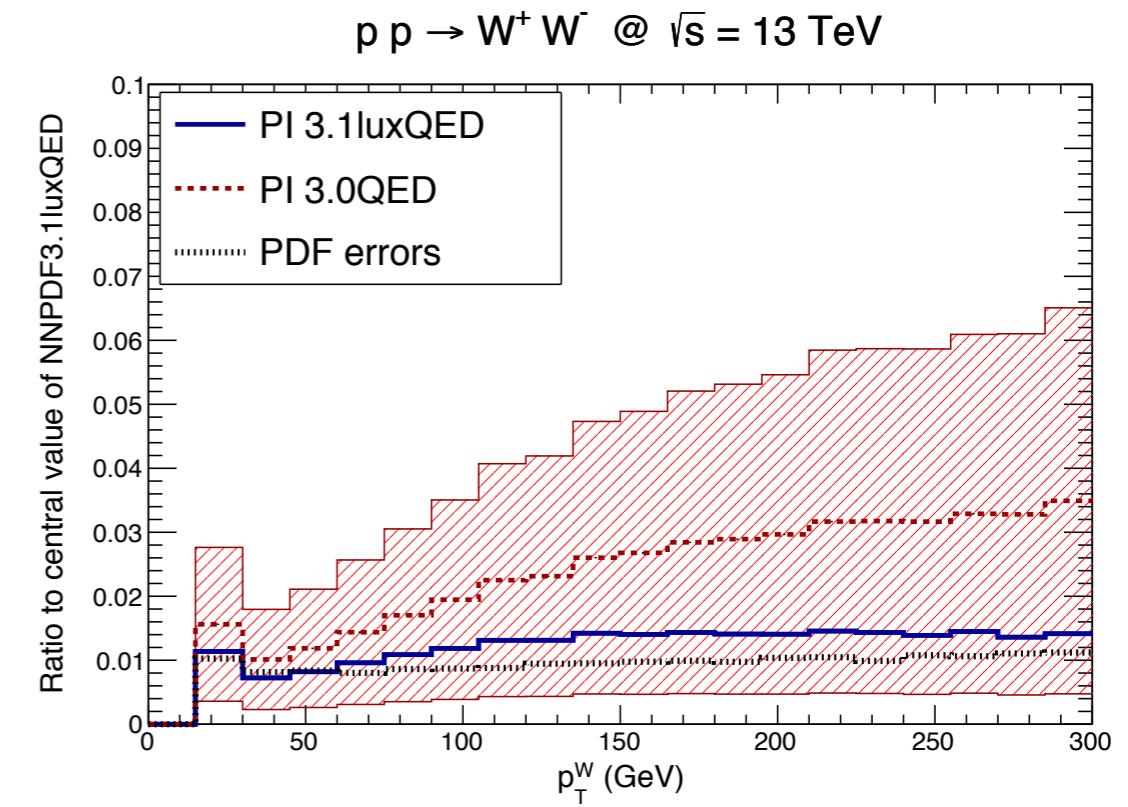
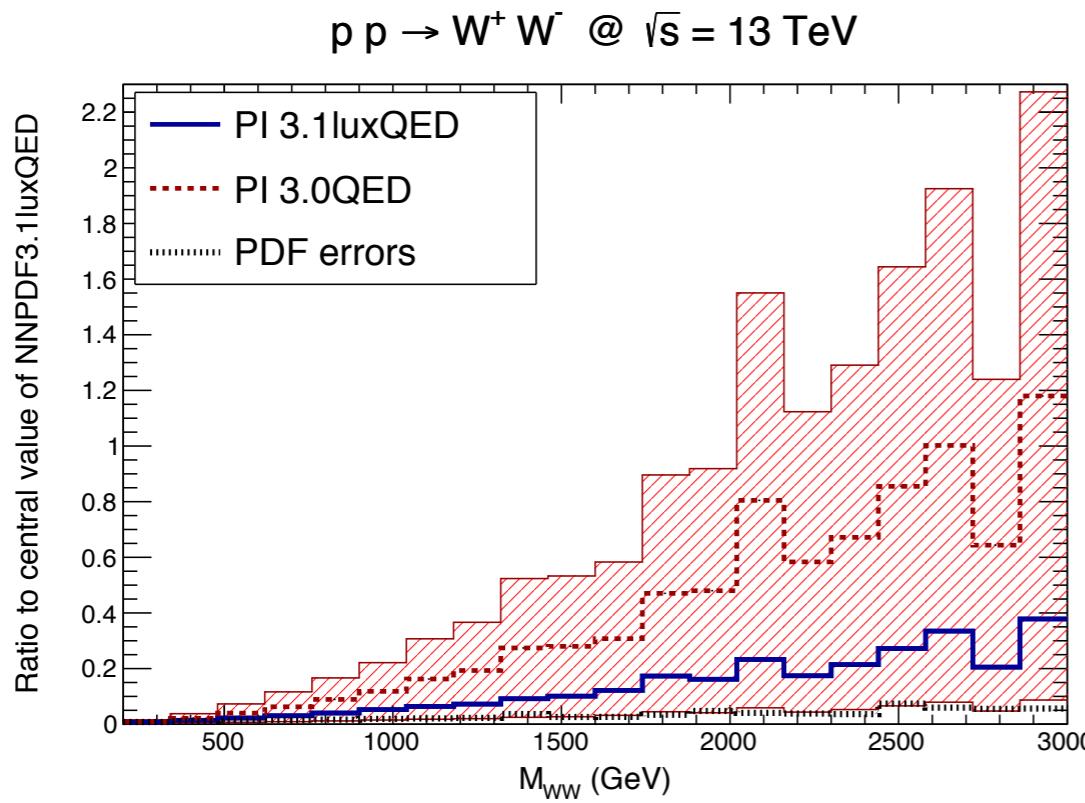
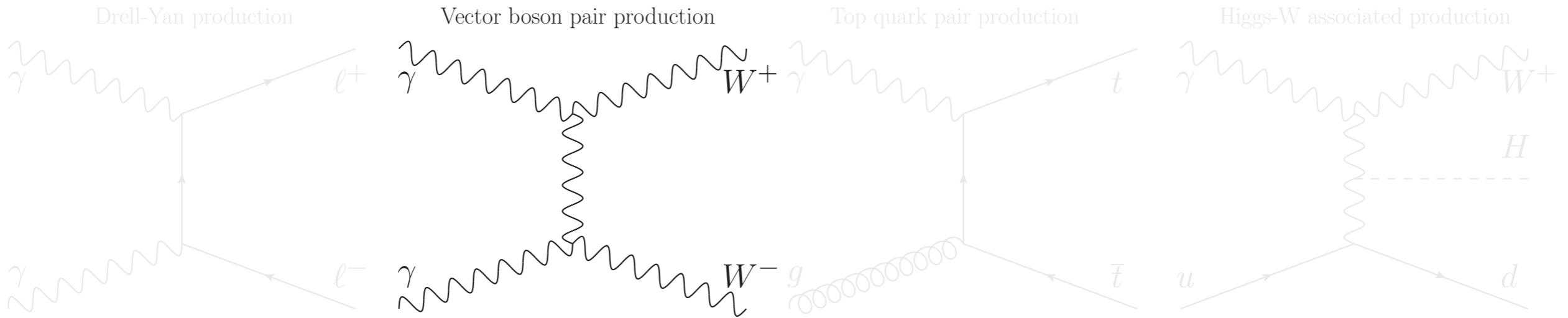
Compare predictions from NNPDF3.0QED and 3.1luxQED

- *Drell-Yan*
- *W pair production*
- *Top pair production*
- *WH production*
- *LO in QCD and QED*
- *MadGraph5_aMC@NLO*
- *APPLgrid + aMCfast*

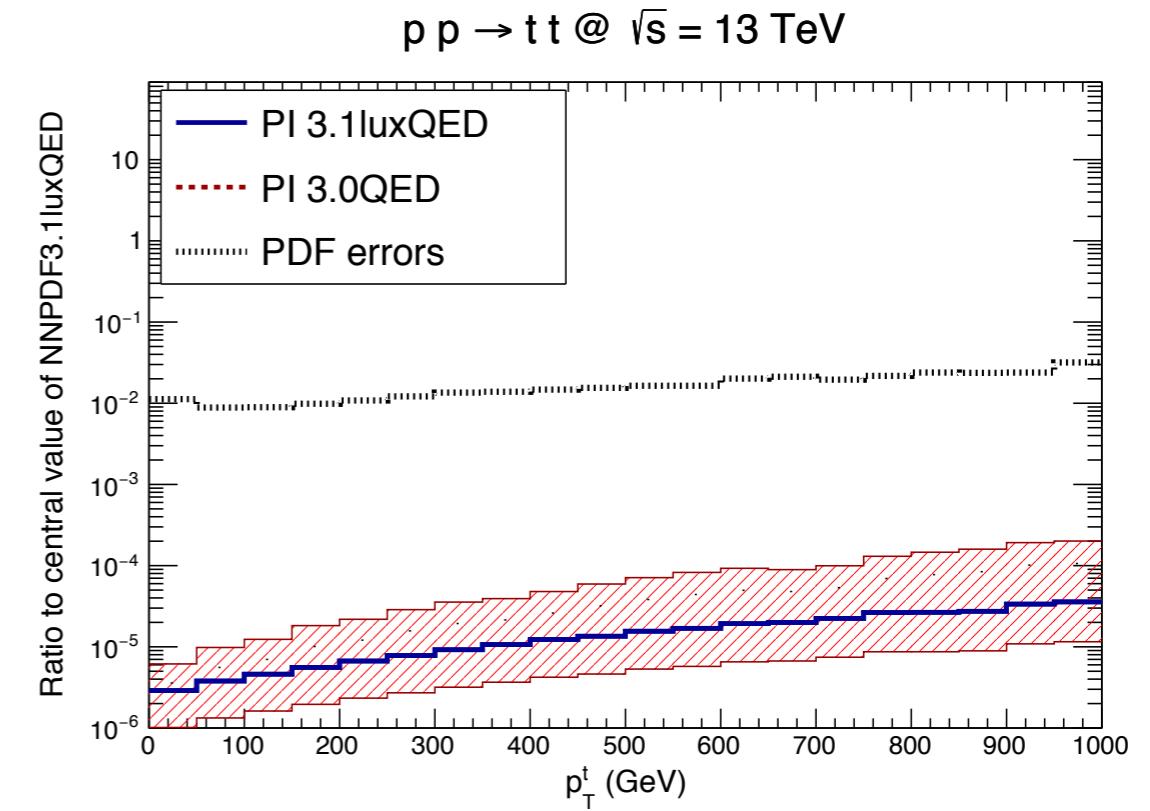
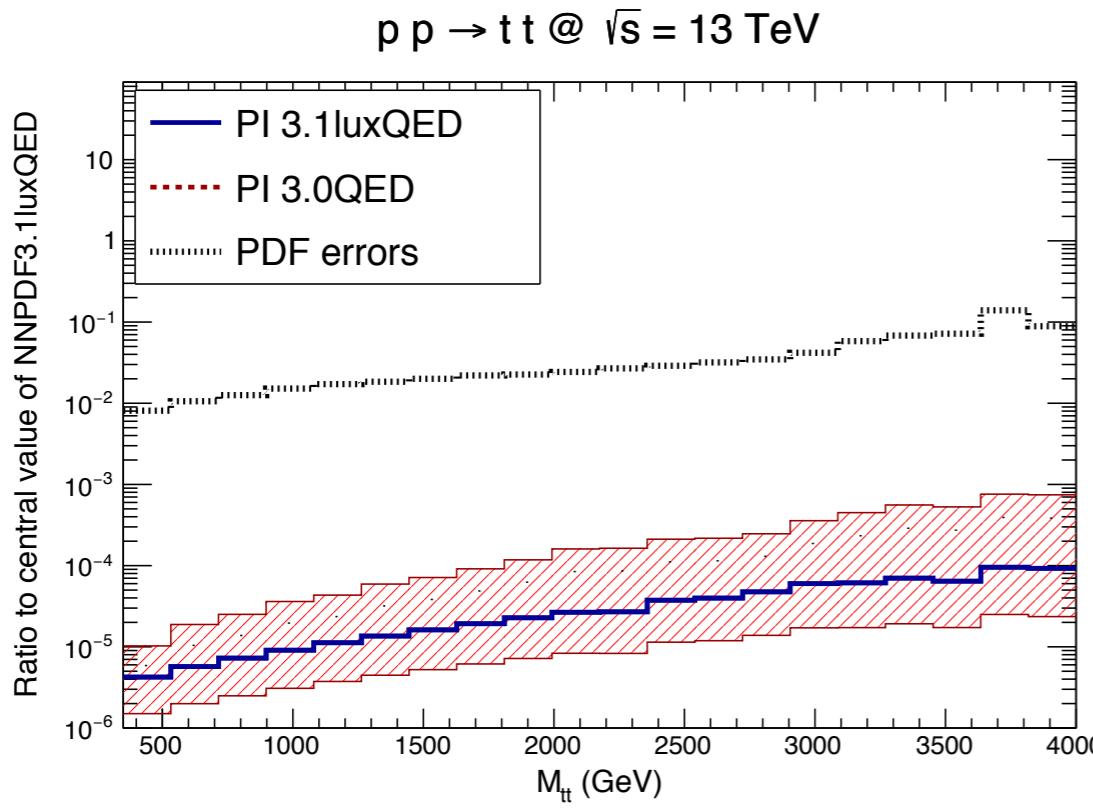
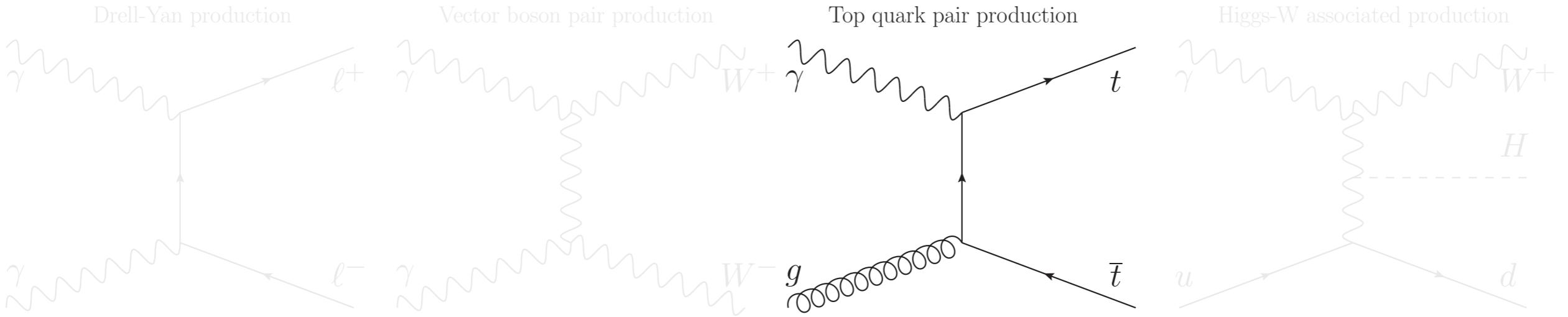
ATLAS 8 TeV HIGH-MASS DRELL-YAN



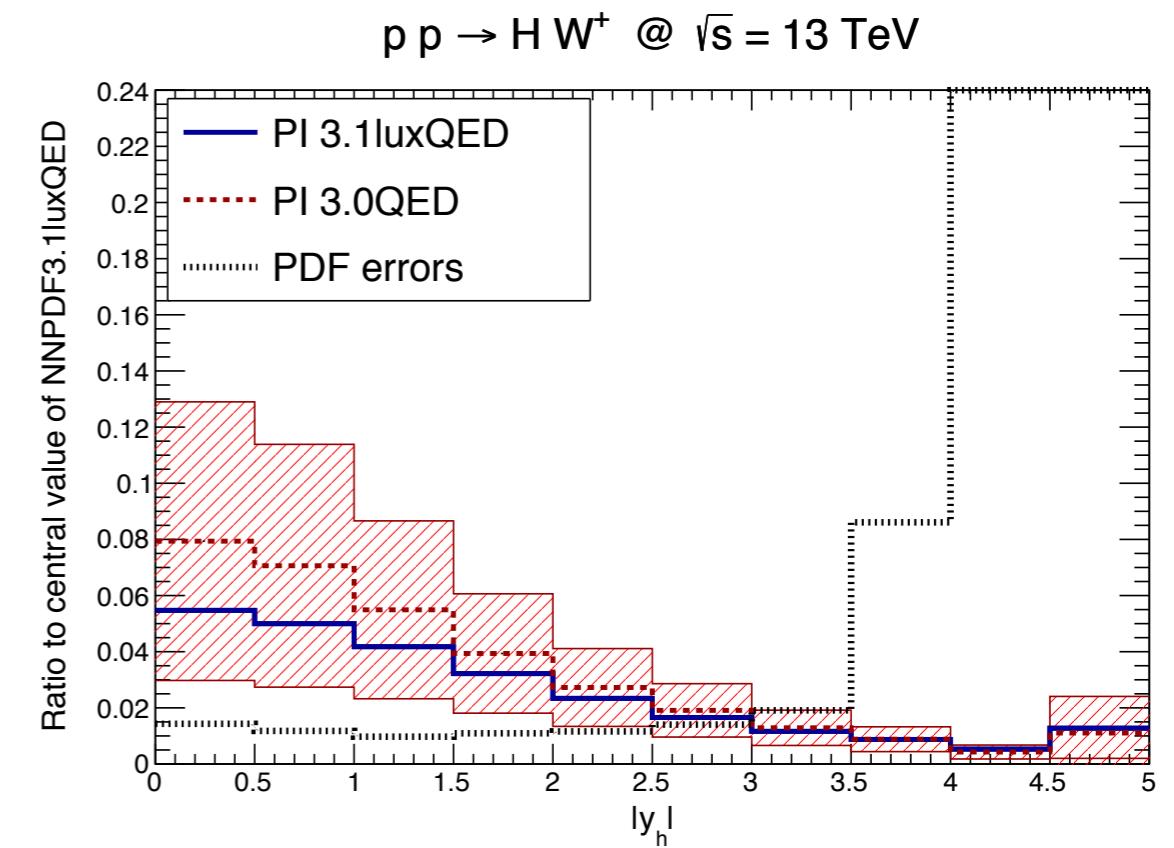
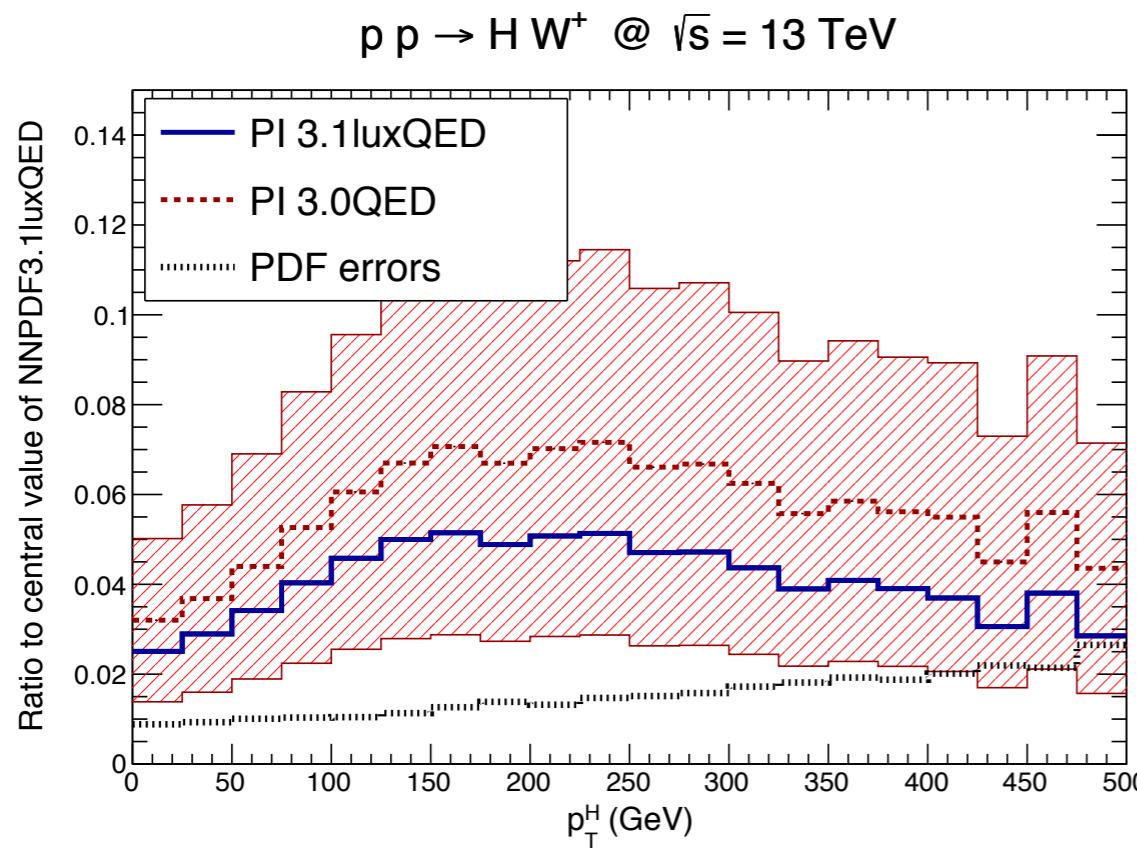
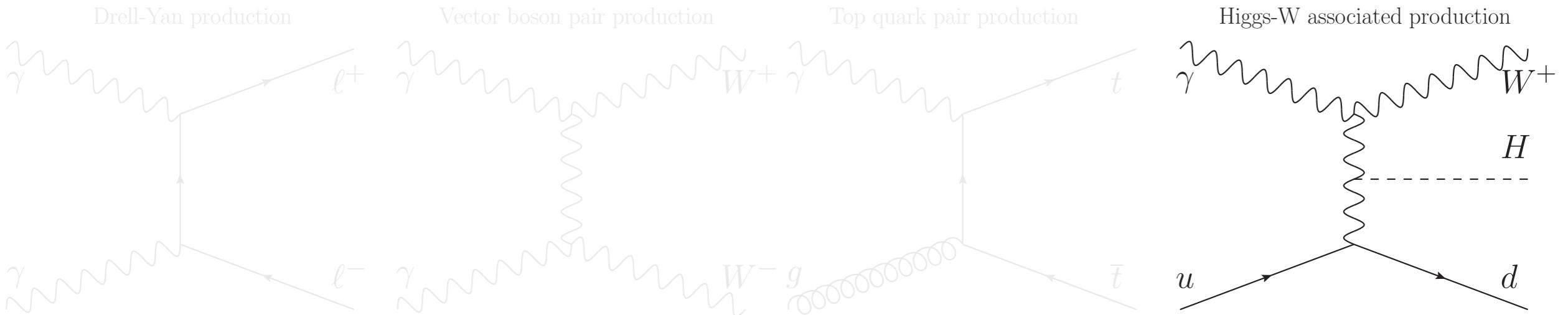
DIBOSON PRODUCTION



TOP QUARK PAIR PRODUCTION



VECTOR-HIGGS ASSOCIATED PRODUCTION



SUMMARY

NNPDF3.1 luxQED available on LHAPDF

- Consistent combination of LUXqed and NNPDF formalisms
- Momentum Sum Rule including photon enforced
- DGLAP QED+QCD evolution up to $\mathcal{O}(\alpha\alpha_S)$ $\mathcal{O}(\alpha^2)$
- DIS coefficient functions at $\mathcal{O}(\alpha)$

Included via ‘libflatlux’: open source implementation of LUXqed

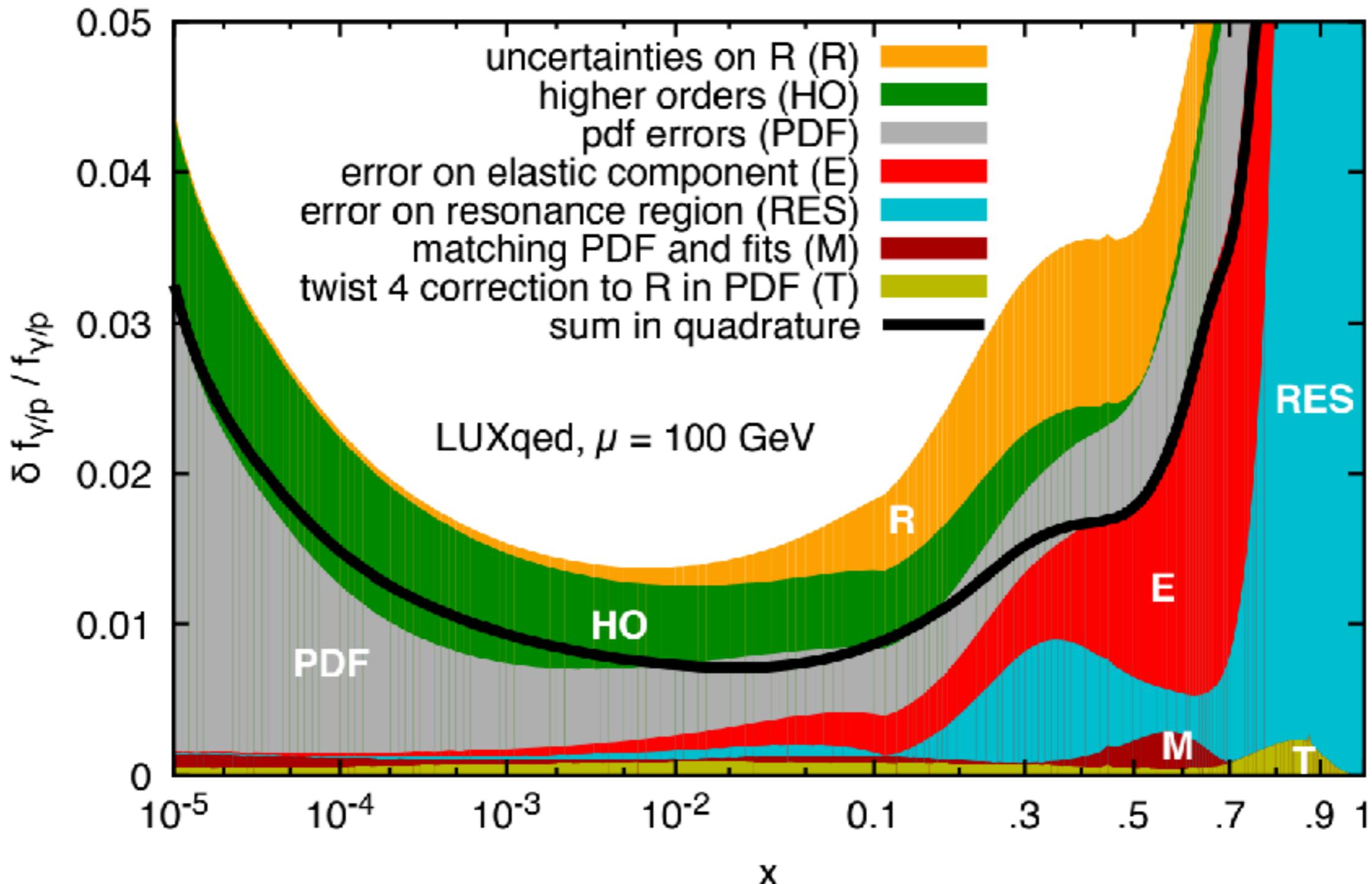
For the future

Iterative scheme permits the inclusion of PI-sensitive data

Future NNPDF sets will include a photon by default

BACKUPS

LUXQED SOURCES OF UNCERTAINTY



$$\tilde{\gamma}_{n_{\text{ite}}}^{(k)}(x, Q) = \gamma_{n_{\text{ite}}}^{(k)}(x, Q) + \sum_{j=1}^{n_{\text{sys}}} \delta \gamma_j^{(\text{lux})}(x, Q) \cdot \mathcal{N}(0, 1), \quad k = 1, \dots, N_{\text{rep}},$$