NNPDF3.1luxQED

based on arXiv:1712.07053

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CERN, 28th March 2018.

European Organization for Nuclear Research (CERN)

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Introduction

Motivation

The **NNPDF2.3/3.0QED** fits were data-driven determinations of the photon PDF $\gamma(x, Q)$, parametrised in terms of an Neural Network, and constrained by **LHC Drell-Yan measurements**.

[NNPDF '13, Bertone and SC '15]

Data-driven QED fits are not competitive with the analytic calculation of the **photon PDF using the LUXqed formalism**.

[Manohar, Nason, Salam, Zanderighi '16, '17]

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Data-driven QED fits are not competitive with the analytic calculation of the **photon PDF using the LUXqed formalism**.

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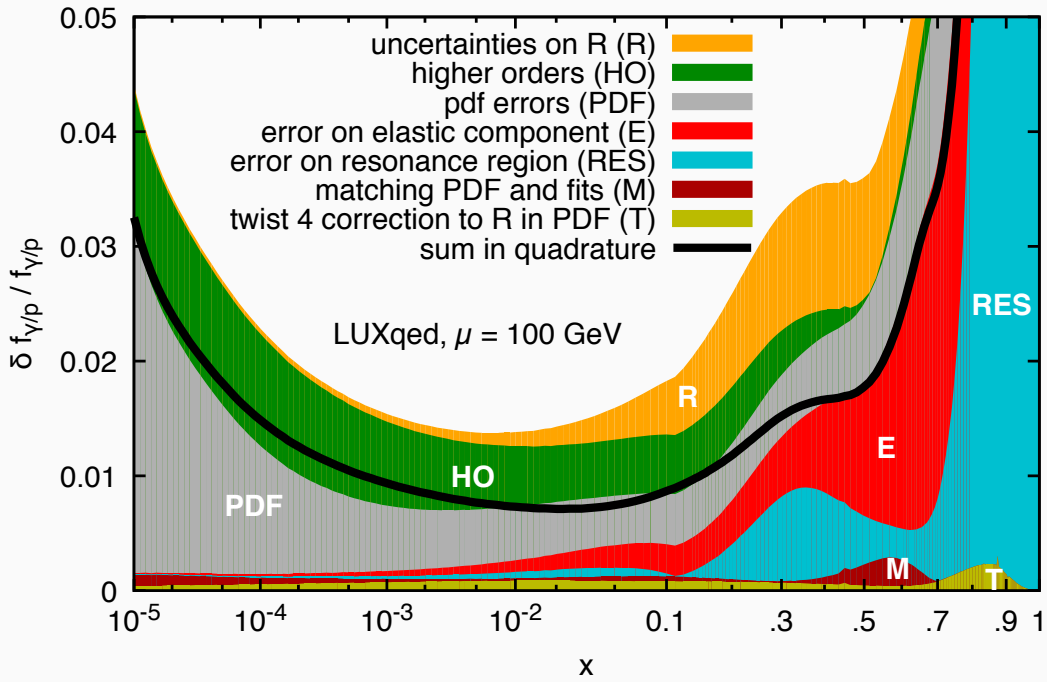
NNPDF3.1luxQED goals:

- impose the LUXqed photon PDF constraint in a NNPDF3.1 global fit
- use NLO QED theory and DGLAP evolution

LUXqed summary

In the LUXqed procedure, the photon PDF can be expressed in terms of the lepton-proton scattering inclusive structure functions F_2 and F_L by means of an exact QED calculation.



$\rightarrow$ Few-percent PDF uncertainties on $\gamma(x, Q)$.

[Manohar, Nason, Salam, Zanderighi '16, '17]

Methodology

NNPDF3.1luxQED strategy

In order to include the LUXqed constraint we have to:

- implement the LUXqed photon calculation [libfiatlux/APFEL]
- compute predictions with QED effects [APFEL/MG5_aMC]

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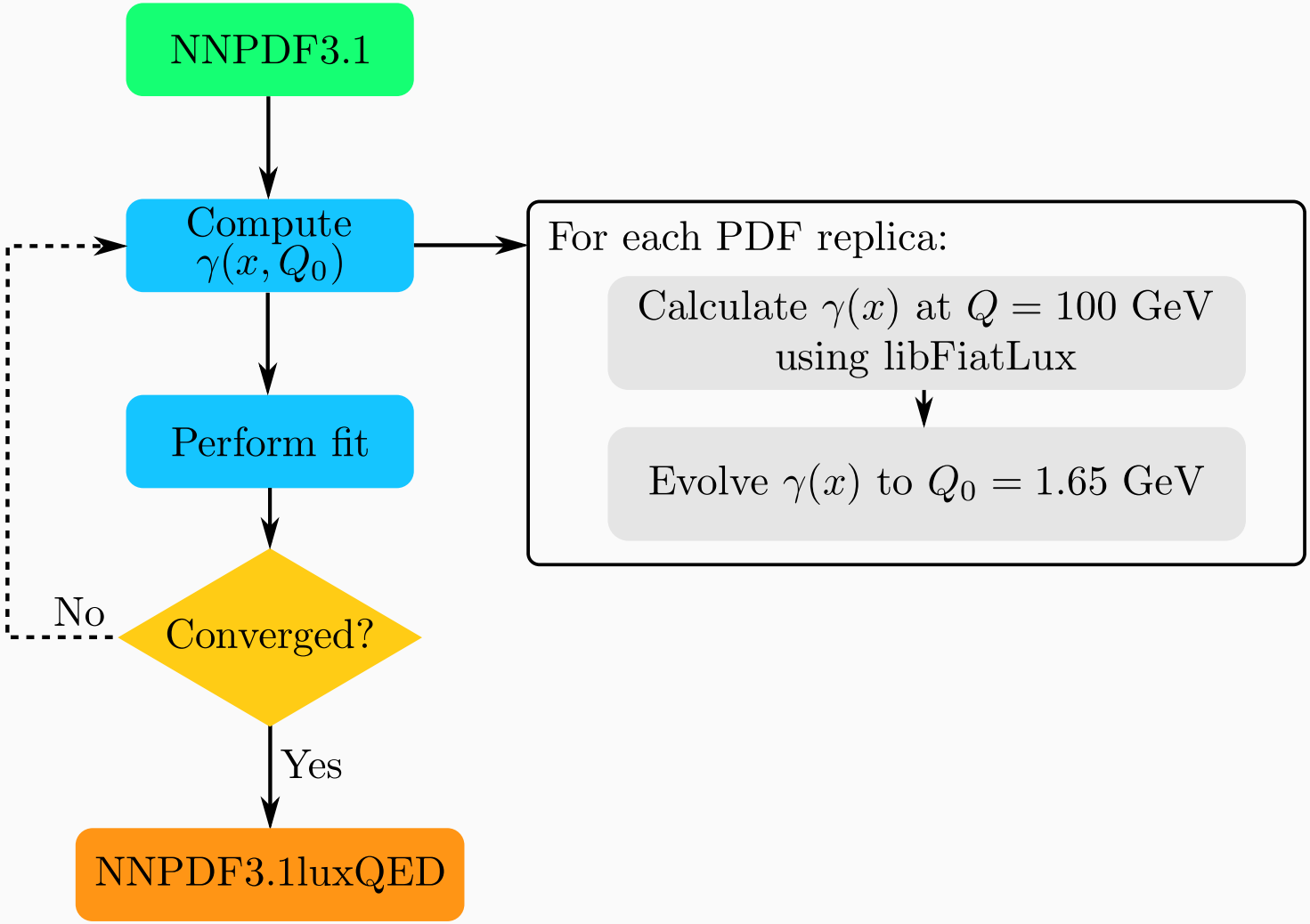
Modifications at the level of the fit strategy are also required:

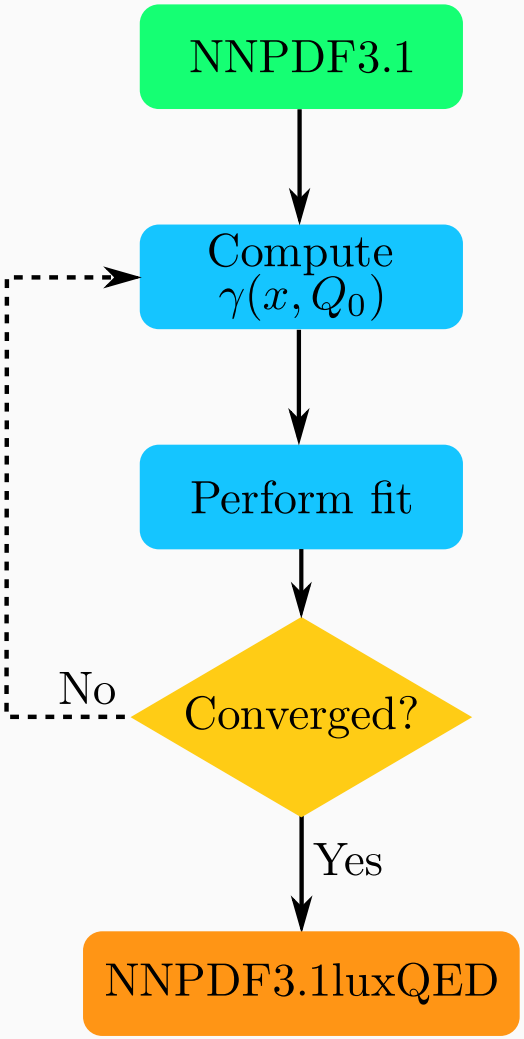
- establish an iterative procedure for the photon PDF determination
- include the photon PDF extra uncertainties from LUXqed17

Adapt the previous points to a Monte Carlo PDF approach.

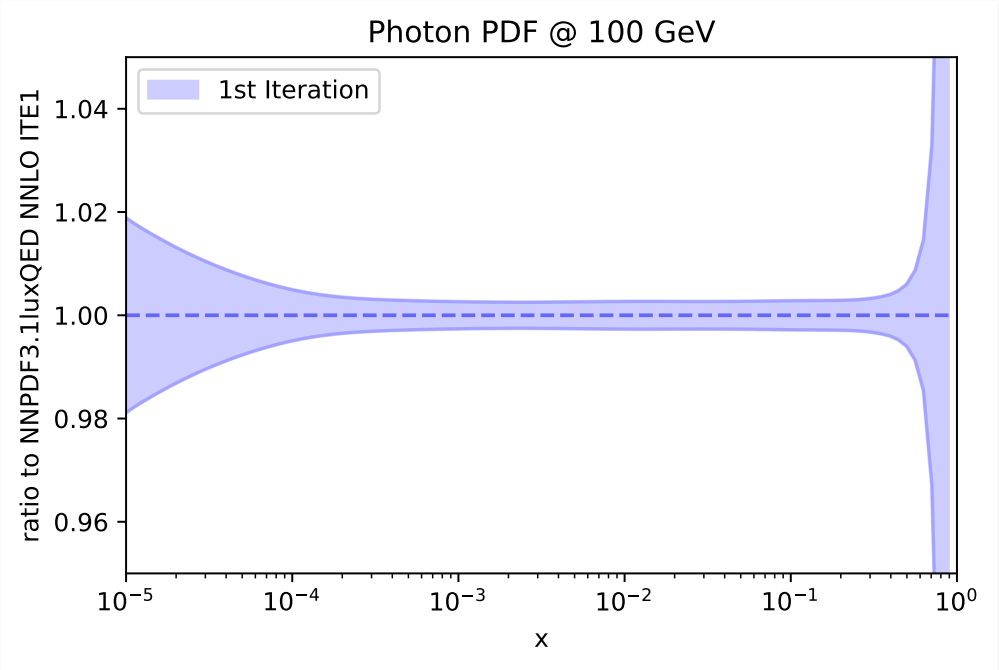
The iterative procedure



The iterative procedure

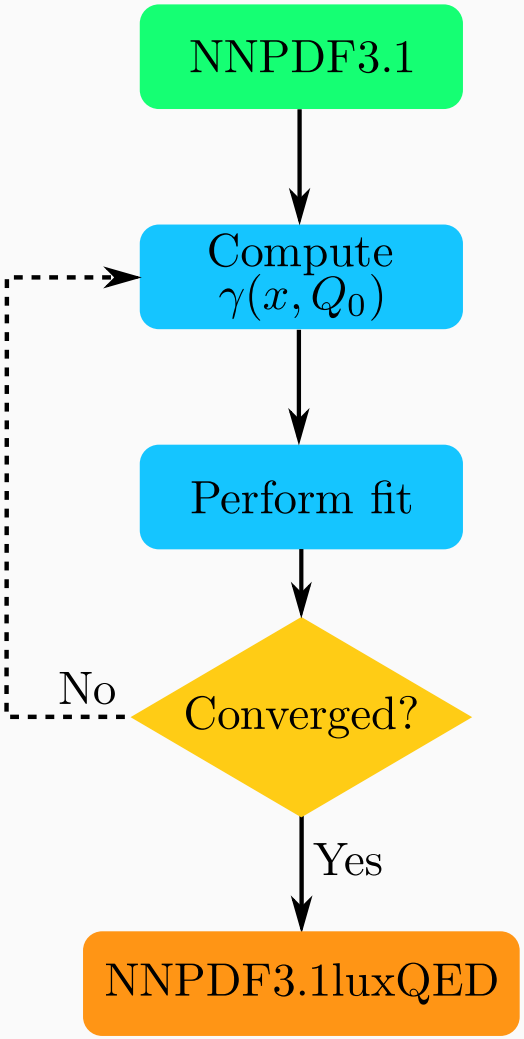


1st Iteration

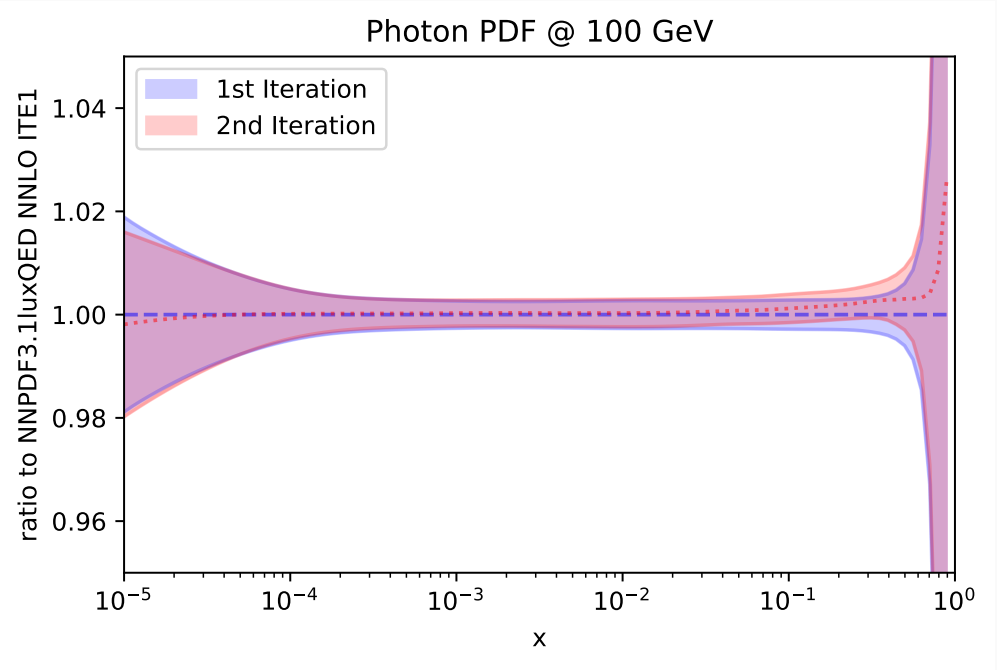


We perform the first iteration and obtain a photon PDF with PDF-only uncertainties.

The iterative procedure

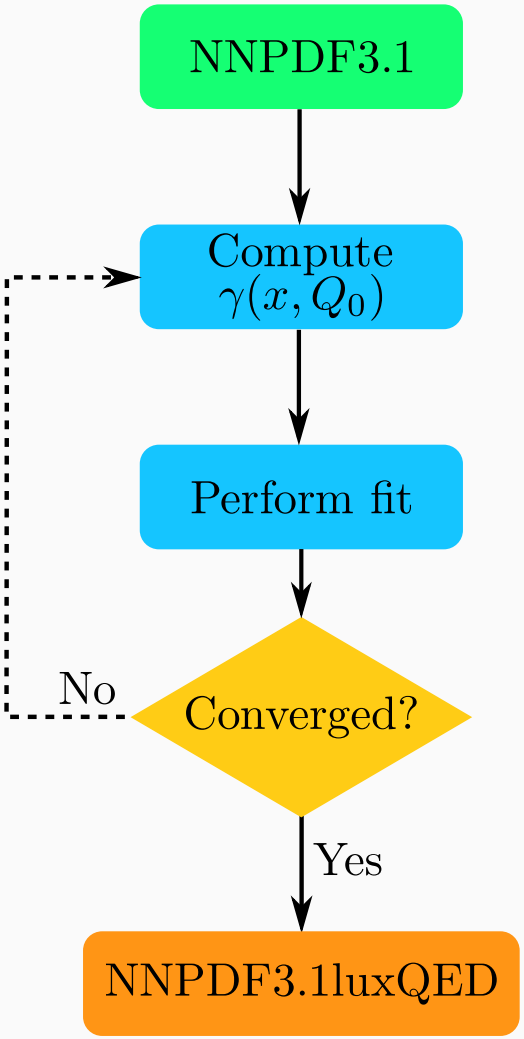


2nd Iteration

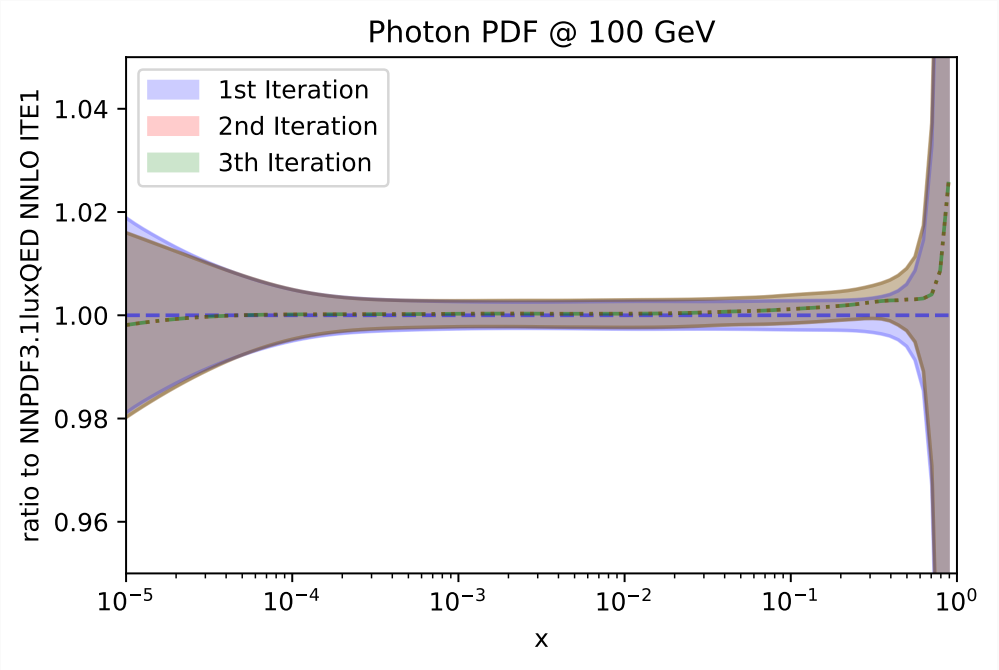


The 2nd iteration propagates NLO QED effects to the fit.

The iterative procedure

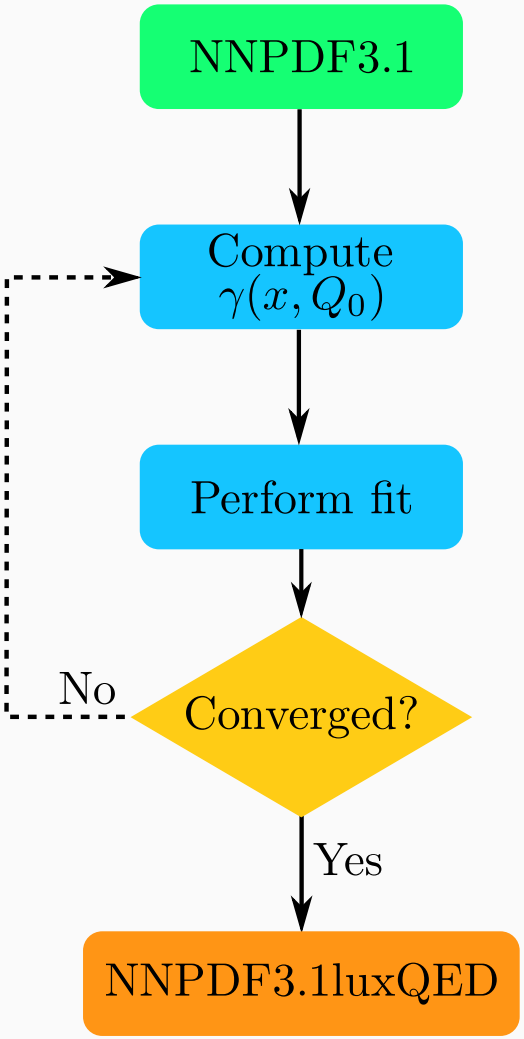


3th Iteration

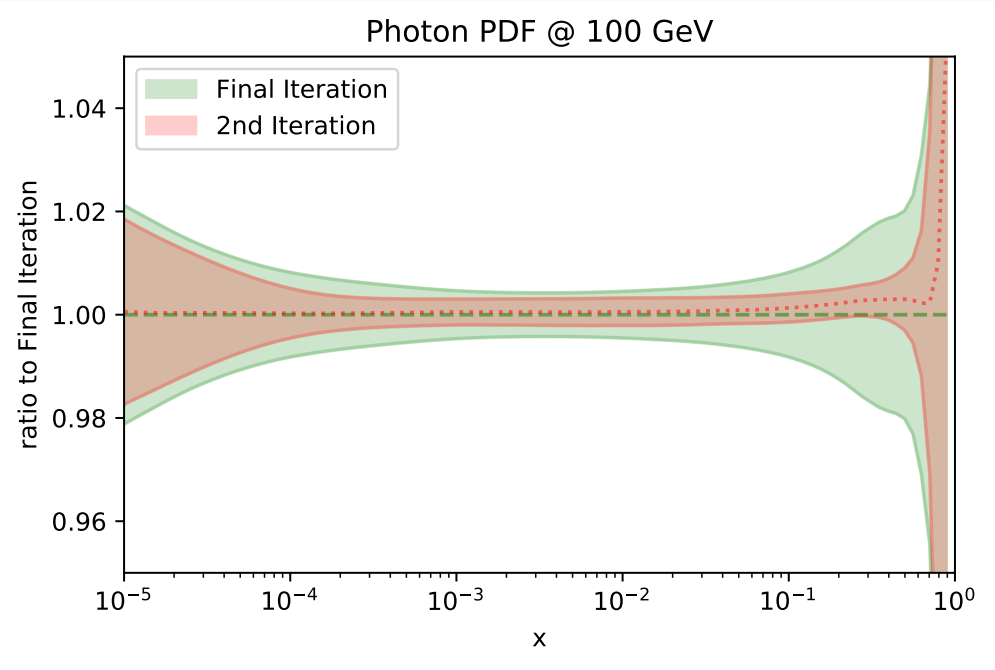


Fit converged, differences are numerically negligible.

The iterative procedure



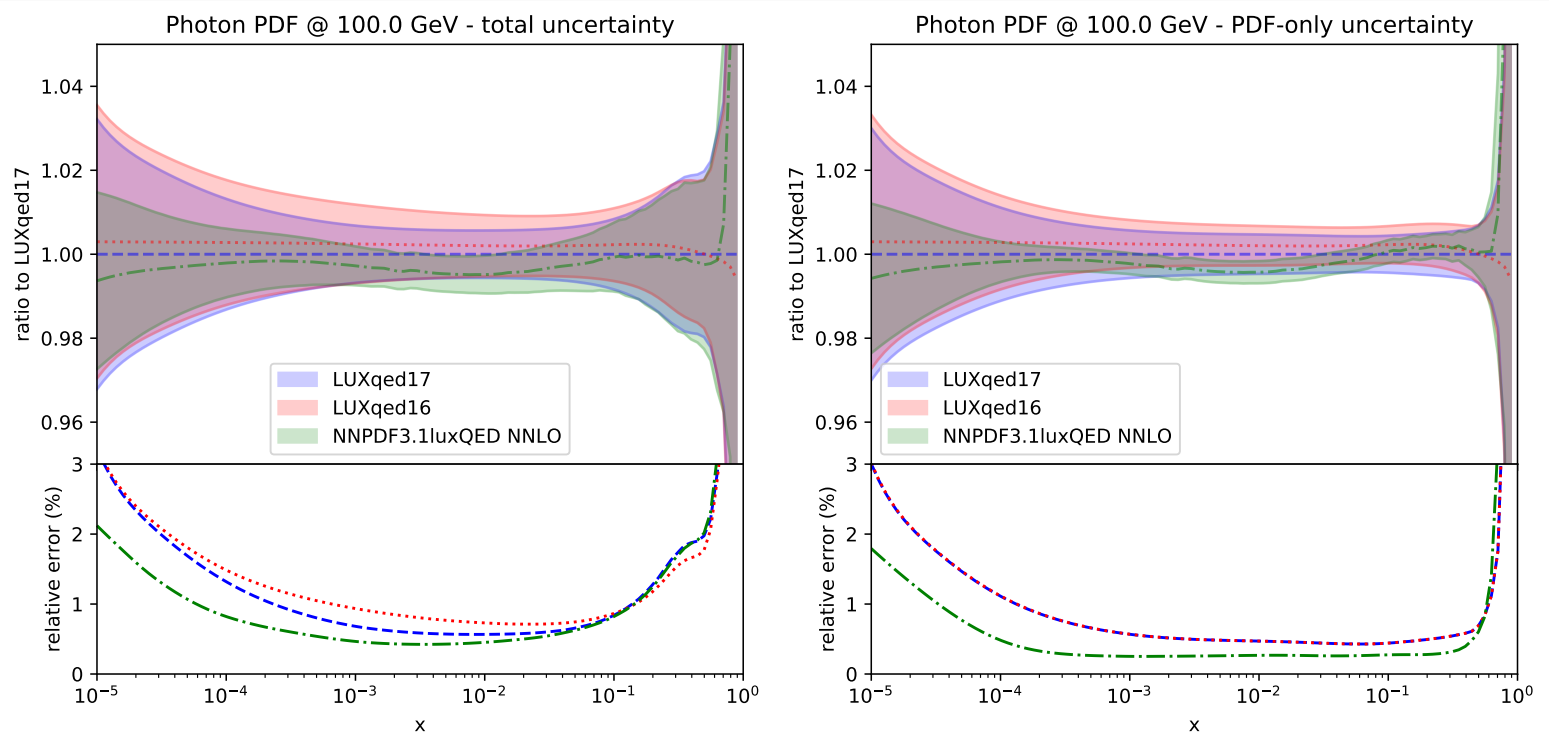
Final Iteration



In the final iteration we include the LUXqed17 extra uncertainties as statistical fluctuations with correlations in x.

Results

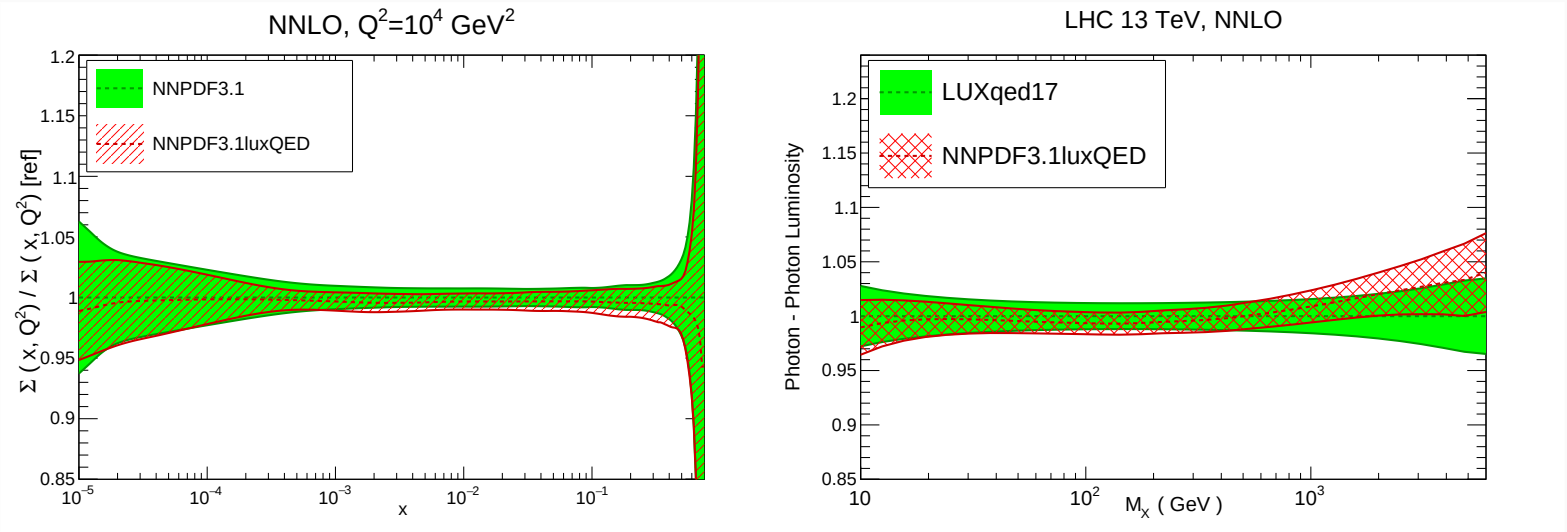
The photon PDF



- Good agreement between NNPDF3.1luxQED and the LUXqed photons.
- NNPDF3.1luxQED photon PDF has smaller uncertainties at small x.

Photon PDF properties

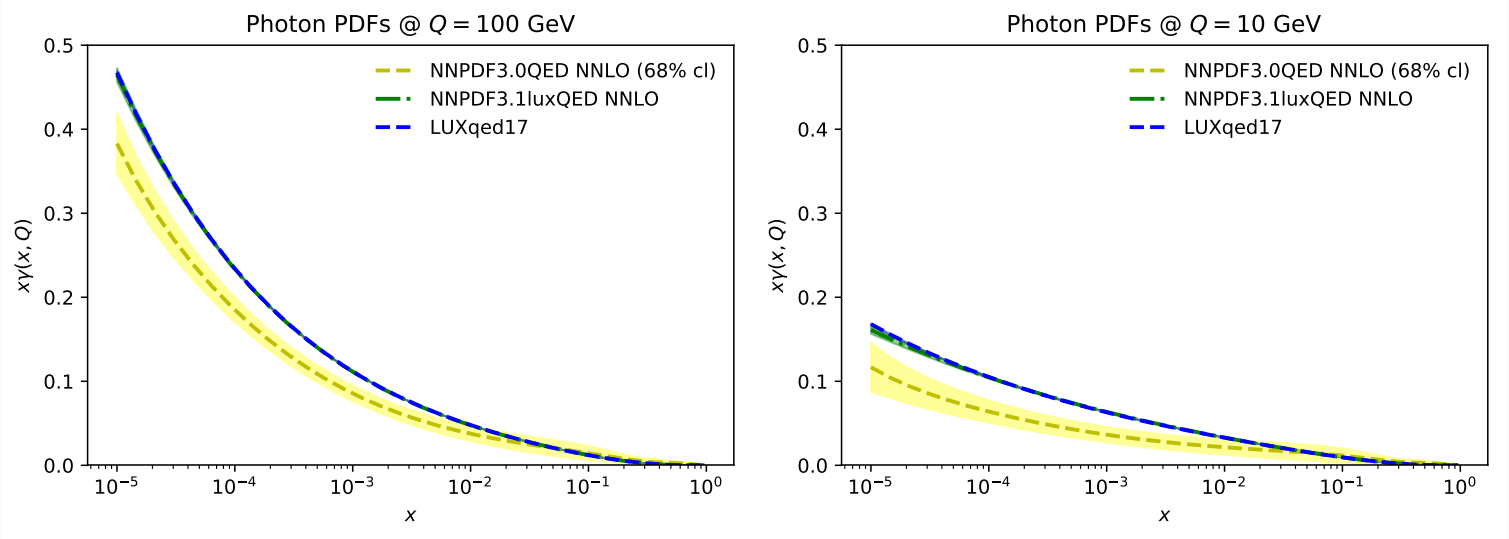
Differences between NNPDF3.1 QCD and QCD+QED fits are minimal.
The global fit quality is identical for both sets.



The momentum fraction carried by photons in the proton.

	$\langle x\rangle_\gamma(Q = 1.65\,\mathrm{GeV})$	$\langle x\rangle_\gamma(Q = m_Z)$
NNPDF3.0QED	$(0.3 \pm 0.3)\%$	$(0.5 \pm 0.3)\%$
NNPDF3.1luxQED	$(0.229 \pm 0.003)\%$	$(0.420 \pm 0.003)\%$
LUXqed17	–	$(0.421 \pm 0.003)\,\%$

NNPDF3.1luxQED vs NNPDF3.0QED



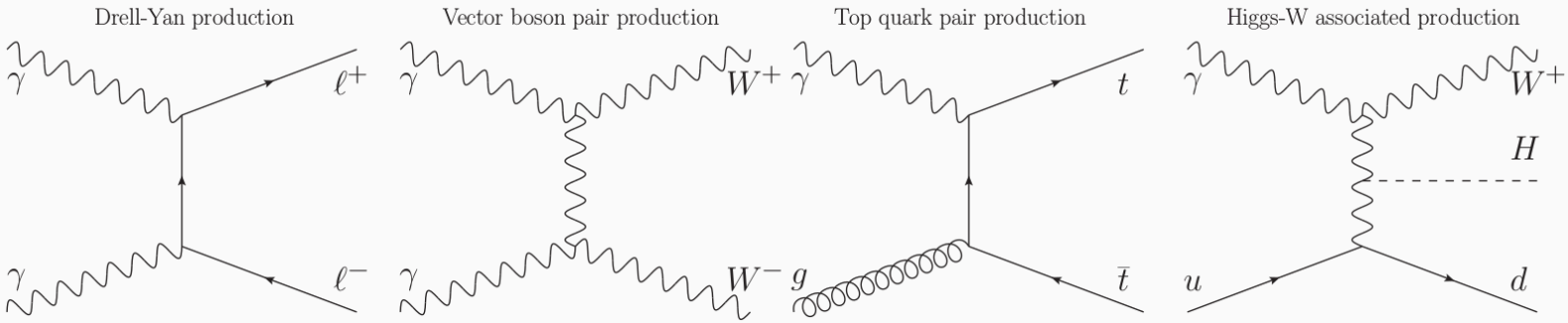
- Agreement at large-x
- For $x \lesssim 10^{-2}$ NNPDF3.0QED undershoots the 3.1luxQED due to
  - inclusion of $\mathcal{O}(\alpha^2)$ and $\mathcal{O}(\alpha\alpha_s)$ (5% effect)
  - 2.3QED initial condition determined with different DGLAP settings

Phenomenology

Phenomenology

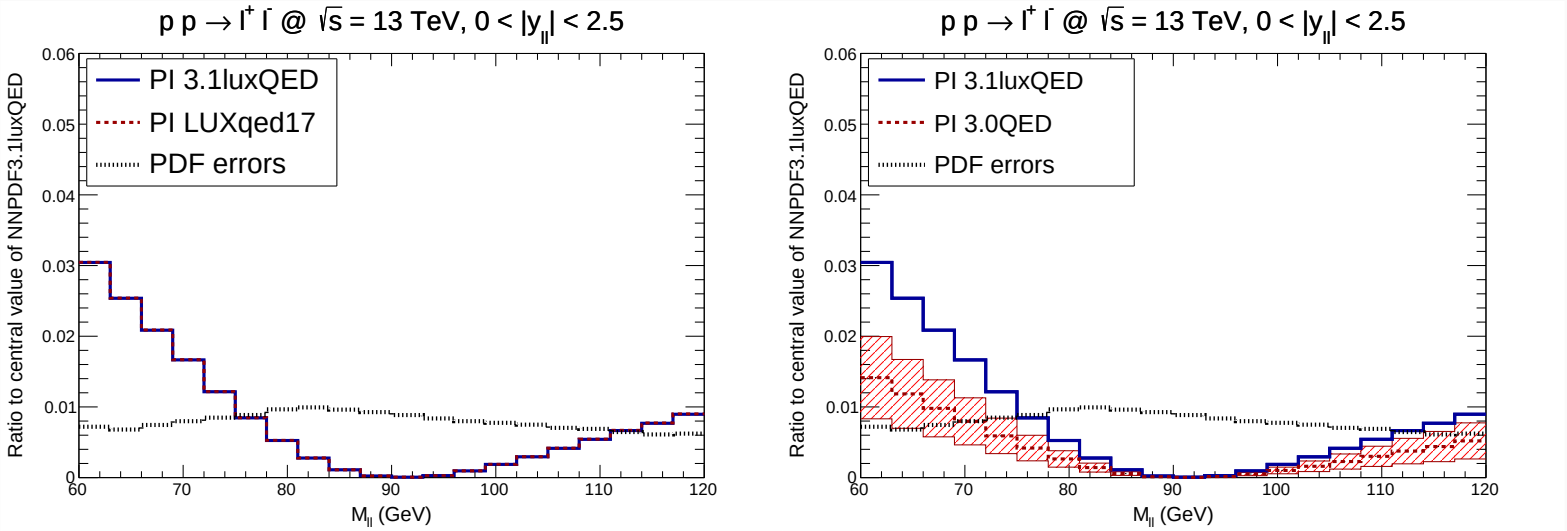
We consider the following processes with PI channel:

- Drell-Yan production
- Vector-boson pair production
- Top-quark pair production
- Higgs-production in association with a vector boson



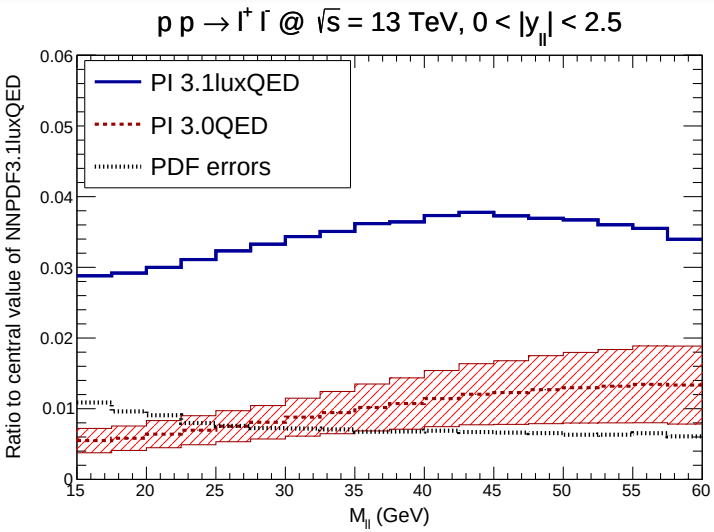
Tree-level simulations with default setup of MadGraph5_aMC@NLO 2.6.0.

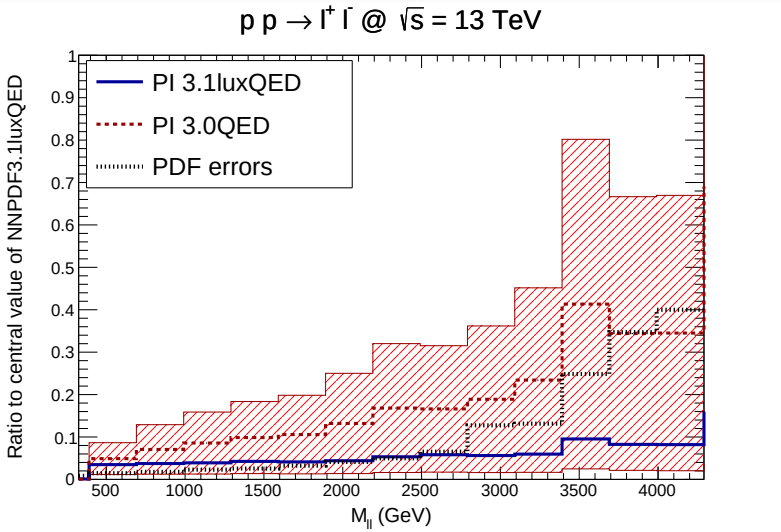
Drell-Yan production

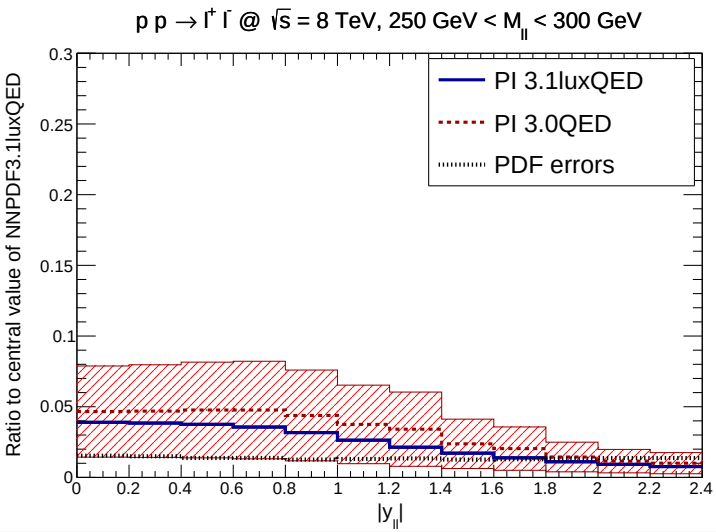


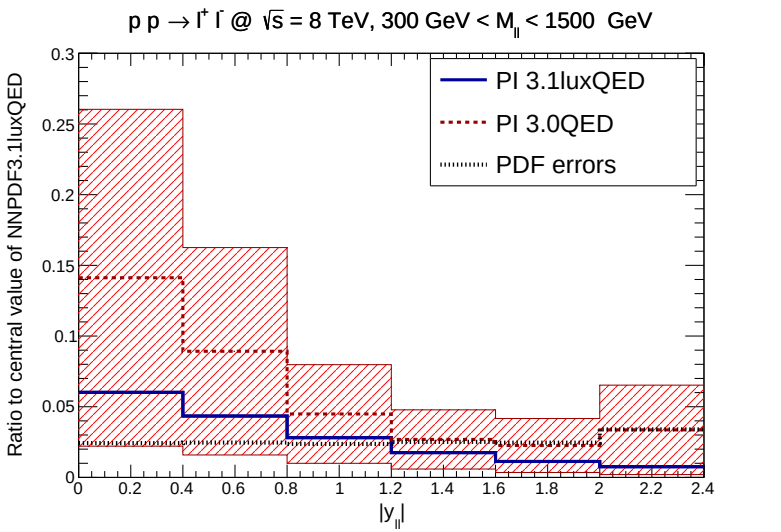
- LUXqed17 and 3.1luxQED in agreement (here and in all processes)
- 3.1luxQED lead to a larger PI contributions than 3.0QED
- 3.1luxQED PI effects:
  - Permille level at $M_{ll} \sim M_Z$
  - $\sim 3\%$ effects for $M_{ll} < 60$ GeV
  - up to 9% for $M_{ll} \sim 4$ TeV
- Moderate PI impact to the total cross-section ($\simeq 10\%$)

Drell-Yan production

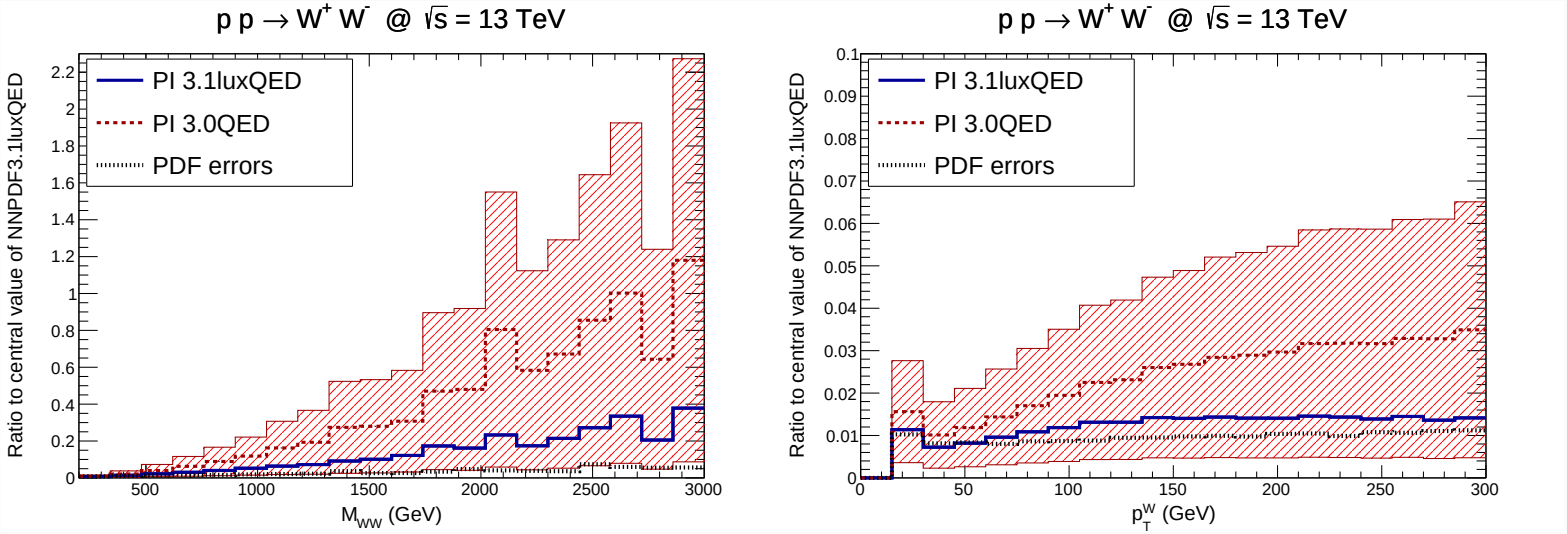






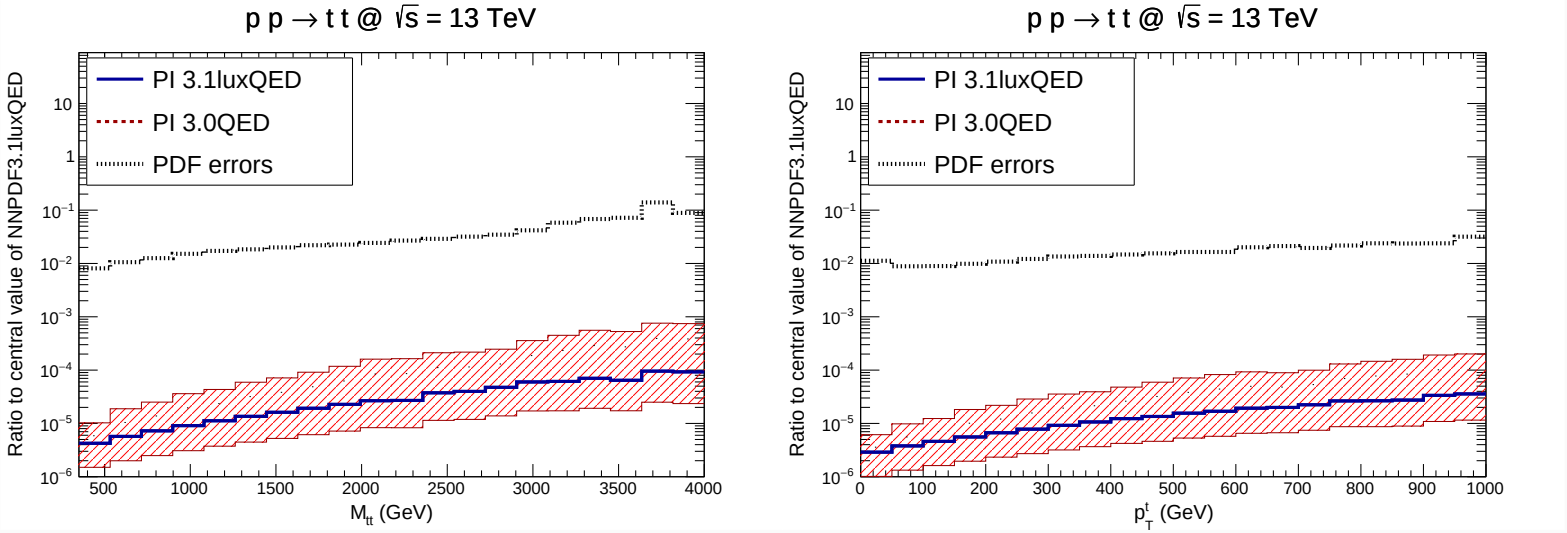


Vector-boson pair production



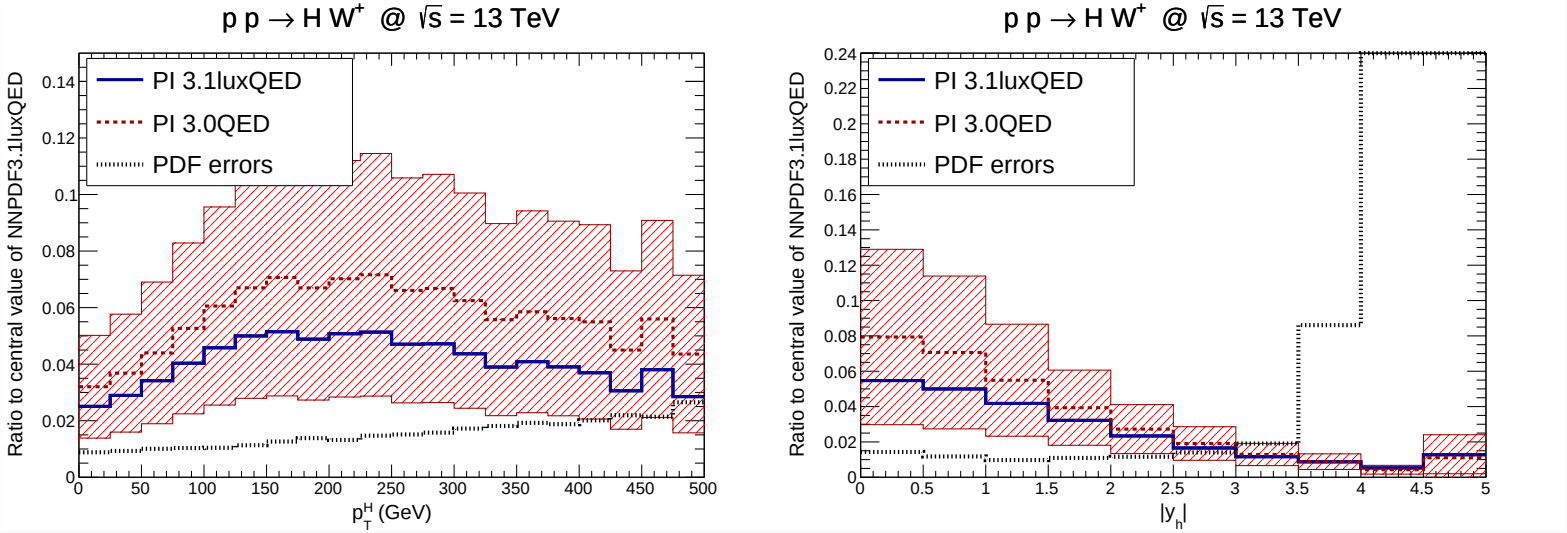
- 3.1luxQED PI effects:
  - up to 35% at $M_{WW} \simeq 3$ TeV
  - $\sim 1\%$ at $p_T^W \simeq 300$ GeV
- Minor PI impact to the total cross-section ($\simeq 1\%$)

Top-quark pair differential distributions



- PI effects below the PDF uncertainties
- Negligible PI contribution to the total cross-section ($\simeq 0.1\%$)

Higgs-production in association with a vector boson



- $pp \to hW^+$ and $pp \to hW^+j$
- 3.1luxQED PI effects:
  - up to 5% at $p_T^h \simeq 200$ GeV
  - $\sim 6\%$ in central $|y_h|$ region
- Moderate PI impact in the total cross-section

Summary

Summary

NNPDF3.1luxQED deliverables:

- NNPDF3.1luxQED sets at NLO and NNLO sets in LHAPDF
- libfiatlux: code which computes the LUXqed photon PDF

$\rightarrow$ On going future work with explorative phenomenology.

$\rightarrow$ Future NNPDF releases will include the photon PDF by default.

$\rightarrow$ Looking towards new measurements sensible to PI contribution.

Thank you!