NNPDF3.1 LUXQED

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

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THE PHOTON DISTRIBUTION



 $\gamma(x)$ 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

LUXQED

Express the photon PDF directly in terms of proton structure functions

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

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

Contributions from

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



https://github.com/scarrazza/fiatlux

fiatlux

API for LUXqed methodology in global PDF fits.

DOI 10.5281/zenodo.1117325

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 and arXiv: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

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

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

- **2. QED-corrected PDF evolution** \succ 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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NC structure functions in the FONLL-B scheme 1. Momentum sum rule 1.02 $\int_{0}^{1} dx \, x \left(\Sigma(x, Q_0) + g(x, Q_0) + \gamma(x, Q_0) \right) = 1$ NLO QCD+QED(X,Q) / F_{NLO} QCD(X,Q) 1.015 1.01 2. QED-corrected PDF evolution 1.005 ► DGLAP: $\mathcal{O}(\alpha)$ $\mathcal{O}(\alpha \alpha_S)$ $\mathcal{O}(\alpha^2)$ 1 0.995 3. Photon-induced (PI) processes 0.990.985 > DIS structure functions $\mathcal{O}(\alpha)$ 0.98 0.000010 0.001000 0.010000 0.100000 0.000100 ► NNPDF3.1 dataset (PI cuts)

[1701.08553]

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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



pp→tt@√s=13 TeV

p p → t t @ √s = 13 TeV



VECTOR-HIGGS ASSOCIATED PRODUCTION





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 'libfiatlux': 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

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LUXQED SOURCES OF UNCERTAINTY

