

NNPDF3.0 parton distributions for the LHC run II



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OUTLINE

INTRODUCTION

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- NNPDF Approach

- Current PDFs

NNPDF3.0

- New Data

- Methodology

CLOSURE TESTS

- Implementation

- Results

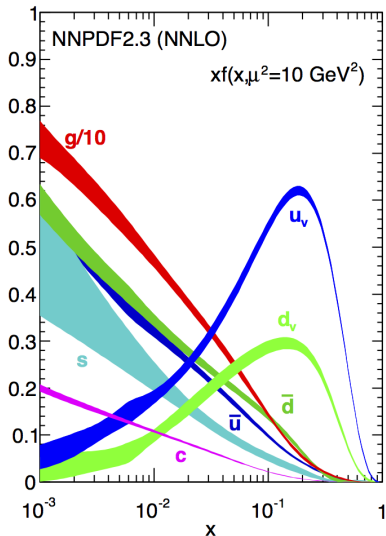
PRELIMINARY RESULTS

- Parton Distributions

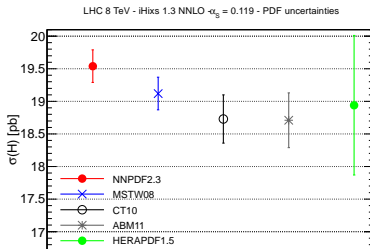
CONCLUSIONS

PARTON DISTRIBUTION FUNCTIONS

- ▶ PDF characterize parton content of the proton
- ▶ Important input into calculations of LHC observables
- ▶ PDFs are fit from data, and LHC input is important

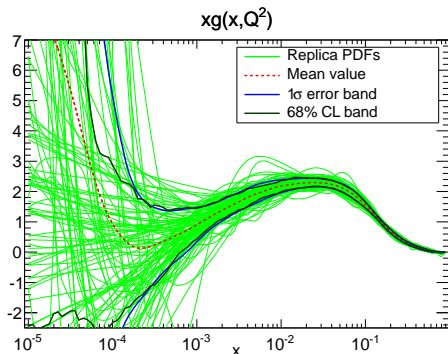


Plot from PDG2013 update

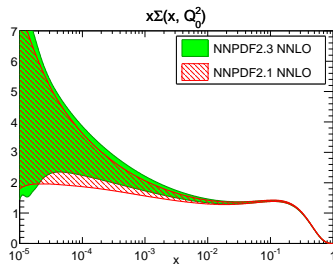
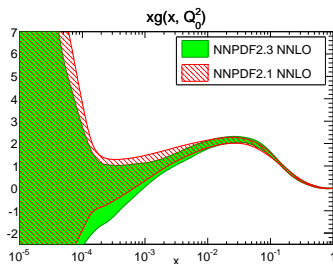


NNPDF APPROACH

- ▶ **Global Fit**, determined using a wide range of observables (DIS, Drell-Yan, Inclusive jets...)
- ▶ **Monte Carlo Replica PDFs** provide uncertainties
- ▶ **Neural Networks** used as unbiased interpolaters
- ▶ **Genetic Algorithm** to efficiently obtain best fit PDFs



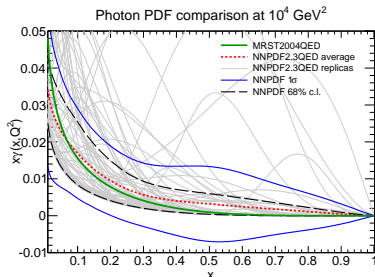
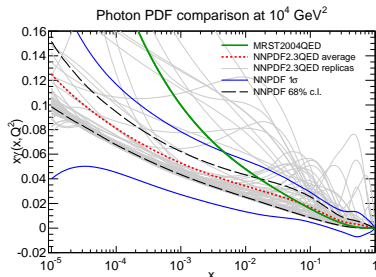
CURRENT PDFs – NNPDF2.3 [ARXIV:1207.1303]



- ▶ First public PDF set use LHC data in the determination
- ▶ Includes all relevant LHC sets available with full correlations (at the time)
 - ▶ ATLAS W and Z lepton rapidity
 - ▶ ATLAS 7 TeV inclusive jets
 - ▶ CMS W electron asymmetry
 - ▶ LHCb W rapidity
- ▶ Default PDF set in Madgraph5_aMC@NLO, Pythia 8, used in new Monash 2013 tune
- ▶ Available in LHAPDF5.9 and 6.0

CURRENT PDFs – NNPDF2.3QED [ARXIV:1308.0598]

- ▶ PDF set based on NNPDF2.3 with QED corrections and addition of photon PDF with uncertainty
- ▶ Photon-induced LHC processes included via reweighting
 - ▶ LHCb low-mass Z/γ^*
 - ▶ ATLAS inclusive W and Z production
 - ▶ ATLAS high-mass Z/γ^*
- ▶ Both sets are available on LHAPDF at NLO and NNLO with α_S variations



NNPDF3.0

New PDF set, due for release this summer

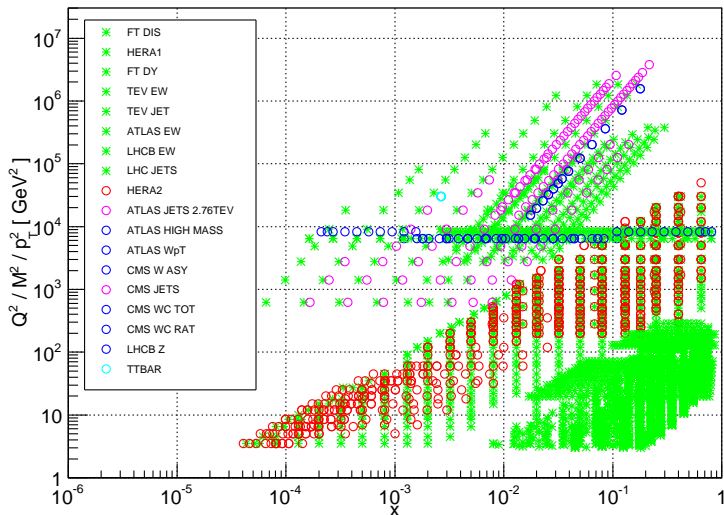
- ▶ 1000 new datapoints from HERA-II and LHC, for a total of 4000 datapoints
- ▶ Completely rewritten C++ code, with improved structure
- ▶ Extensively upgraded fitting methodology, refined and validated using closure tests
- ▶ Improved cross-validation to control overfitting
- ▶ Extended set of positivity constraints

NNPDF3.0 – NEW DATA

- ▶ HERA-II
 - ▶ H1 high Q^2 NC and CC data [[JHEP 1209 \(2012\) 061](#)]
 - ▶ H1 low Q^2 , high y NC data [[Eur.Phys.J. C71 \(2011\) 1579](#)]
 - ▶ ZEUS NC and CC positron beam data
[[Phys.Rev. D87 \(2013\) 5, 052014](#)] [[Eur.Phys.J. C70 \(2010\) 945-963](#)]
 - ▶ HERA combined charm production [[Eur.Phys.J. C73 \(2013\) 2311](#)]
- ▶ ATLAS
 - ▶ Inclusive jets $\sqrt{s} = 2.76$ TeV (correlated with ATLAS 7 TeV jets) [[Eur.Phys.J. C73 \(2013\) 2509](#)]
 - ▶ High Mass Drell-Yan [[Eur.Phys.J. C70 \(2010\) 945-963](#)]
- ▶ CMS
 - ▶ Inclusive jets $\sqrt{s} = 7$ TeV [[Phys.Rev. D87 \(2013\) 11, 112002](#)]
 - ▶ Double differential Drell-Yan [[JHEP 1312 \(2013\) 030](#)]
 - ▶ Muon charge asymmetry [[arXiv:1312.6283](#)]
 - ▶ $W + \text{charm}$ [[JHEP 1402 \(2014\) 013](#)]
- ▶ LHCb
 - ▶ Large rapidity $Z \rightarrow ee$ [[JHEP 1302 \(2013\) 106](#)]
- ▶ $t\bar{t}$ total σ from ATLAS and CMS 7 TeV & 8 TeV

NNPDF3.0 DATA

NNPDF3.0 NLO dataset



NEW THEORY

Progress in theory are an important part of reducing PDF uncertainties.

NNPDF3.0 makes use of several recent improvements:

- ▶ Full NNLO top quark production cross section, differential distribution coming soon. [Czakon, Fiedler, Mitov, *Phys.Rev.Lett.* **110** (2013) 25, 252004]
- ▶ NNLO inclusive jet production in the gg channel. [Gehrmann-De Ridder, Gehrmann, Glover, Pires, *Phys.Rev.Lett.* **110** (2013) 16, 162003], which we use to determine valid region for approximate NNLO.
- ▶ QED and EW corrections provided by FEWZ3.1

NNLO and EW corrections are included in NNPDF3.0 dataset via c-factors

NNPDF3.0 METHODOLOGY

Major upgrade

- ▶ **Streamlined Genetic Algorithm** Several obsolete features removed
- ▶ **Nodal Mutations** Exploit structure of neural networks in genetic algorithm
- ▶ **Larger number of mutants** Explore a larger region of parameter space
- ▶ **Optimized Fits** are significantly faster despite larger dataset
- ▶ **Extended positivity** New positivity constraints to ensure positive definite cross-sections

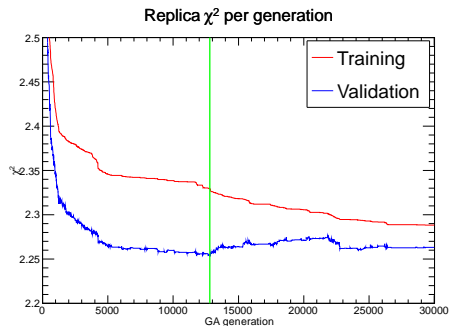
UPDATED CROSS-VALIDATION

Neural network are very flexible – need to control overfitting
In NNPDF3.0 this is done using updated Cross-Validation strategy

- ▶ Split data into two sets: training and validation
- ▶ Train networks only on training set, but record validation χ^2
- ▶ At the end of the fit, rewind to the point with the lowest validation χ^2

This ‘optimal’ point has
the best quality of fit to
unseen data

Overfitting is prevented



CLOSURE TESTS

Key Question: How do we know whether our methodology works? Or how close is our fit to the 'true' value?

Closure Tests can provide an answer: fit pseudo-data generated using known theory.

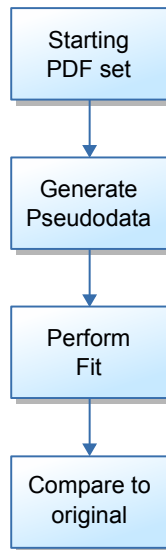
Advantages:

- ▶ Can compare result of fit directly to (artificial) underlying law
- ▶ Clean environment to test different fitting methodologies
- ▶ Possible to investigate overfitting

CLOSURE TESTS – IMPLEMENTATION

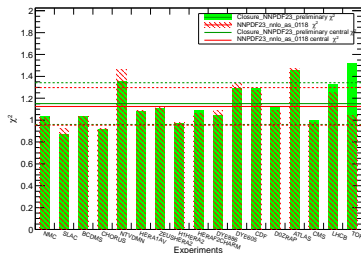
Closure test process:

- ▶ Generate observables using theory and PDF set
 - ▶ Makes use of existing tools for observables used in fits (FastKernel tables)
 - ▶ Can use any PDF set as long as it has an LHgrid
- ▶ Add statistical noise using experimental uncertainties and replace data values
 - ▶ Generates perfectly consistent data
 - ▶ Also possible create data without noise or to intentionally add inconsistencies
- ▶ Fit with standard methodology
 - ▶ Runs on same code as fit to experimental data
 - ▶ Closure test are a good testing ground for methodological improvements
- ▶ Compare fit PDFs to original PDF set
 - ▶ Since underlying law is known can directly compare how close fit PDFs are
 - ▶ Can also look at overfitting: smaller χ^2 but further away PDFs

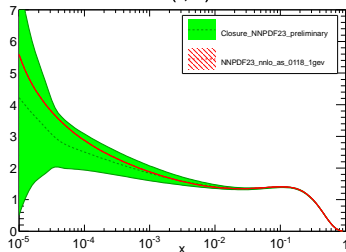


CLOSURE TEST RESULTS: NNPDF2.3

Distribution of χ^2 for experiments

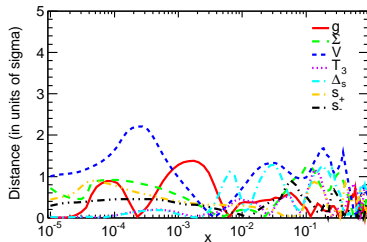


$x\Sigma(x, Q^2)$



- Closure test fit to NNPDF2.3 pseudo-data.
- χ^2 of 1.053 compared with 1.058 for NNPDF2.3 itself
- Distances (see right) compatible with PDF uncertainties

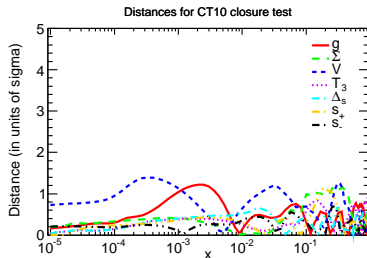
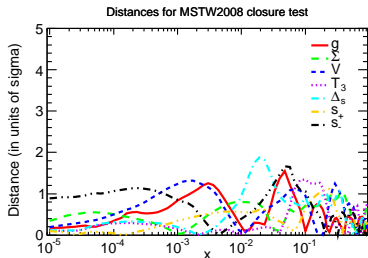
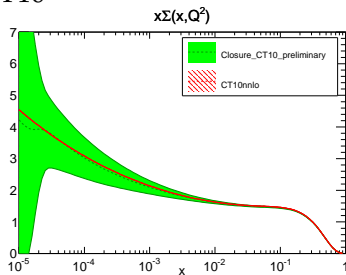
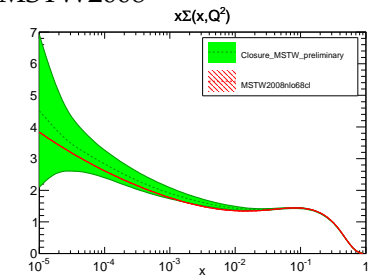
Distances for NNPDF2.3 closure test



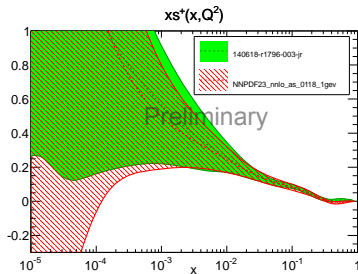
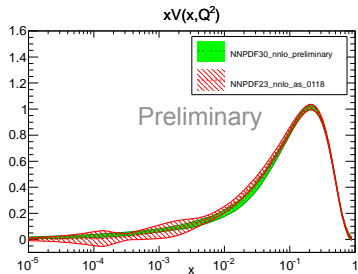
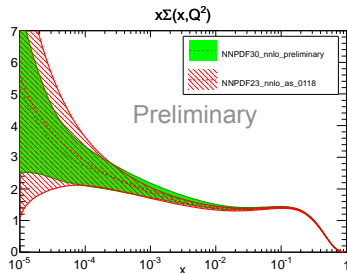
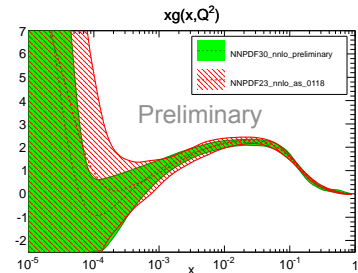
CLOSURE TEST RESULTS: OTHER SETS

MSTW2008

CT10



PRELIMINARY NNPDF3.0 RESULTS



CONCLUSIONS

- ▶ Current NNPDF releases:
 - ▶ NNPDF2.3: First public set with LHC data
 - ▶ NNPDF2.3QED: Determination with QED corrections and photon pdf with uncertainties
 - ▶ All of our fits are available on LHAPDF and on our webpage `nnpdf.hepforge.org`
- ▶ New pdf set, NNPDF3.0
 - ▶ New data from LHC, HERAII
 - ▶ Closure test demonstrate success of updated methodology
 - ▶ Available soon, followed by NNPDF3.0QED
- ▶ Additional work within NNPDF collaboration:
 - ▶ Intrinsic charm
 - ▶ Polarized NNPDFs, see arXiv:1303.7236