

## Toward the N3LO accuracy of parton distribution functions

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An overwhelming number of theoretical predictions for hadron colliders requires parton distribution functions (PDFs), the nonperturbative functions quantifying probabilities for finding quarks and gluons in hadrons in high-energy scattering processes. We witness a revolution in computing hard scattering cross sections in perturbative  
10 QCD to a high accuracy by including radiative contributions up to the second and third order in the small coupling constant, or N2LO and N3LO. In this letter, we emphasize importance of determination of parton distributions to accuracy that is comparable to those of N2LO and N3LO hard cross sections, which in turns necessitates continued advancements in the areas of quantum field theory, experimental measurements, and statistical methods.

Our group will explore future opportunities for determination of the PDFs and implications for future studies explored by the Snowmass Frontiers. In addition to the Snowmass proceedings contribution, we plan to pursue physics studies of N2LO/N3LO PDFs, including those described in the companion LOI's [9–12], with an eye on  
65 complementing related efforts by the PDF4LHC working group and Les Houches workshop.

New contributors are welcome! If potentially interested to join, please email me ([Nadolsky@smu.edu](mailto:Nadolsky@smu.edu)) with a subject line “N3LO PDFs LOI”

# Toward N3LO accuracy of collinear nucleon PDFs

Shown at the EF06 kick-off meeting on May 25

N3LO predictions are becoming available for Higgs and DY pair production, etc. and will eventually require N3LO PDFs

Some physics questions will require N3LO accuracy in QCD and NLO accuracy in EW: HL-LHC Higgs and EW precision studies, measurement of  $m_{charm}$  in DIS, determination of sea PDFs at large  $x$

The progress toward N3LO accuracy requires numerous advancements beyond the current frameworks for global QCD fit, on the top of implementing N3LO radiative contributions.

Many of these advancements will take time and are already necessary at NNLO to satisfy goals of the HL-LHC physics program.

Recall that it took >10 years after implementing the first NNLO contributions in global fits to obtain benchmark PDF fits at NNLO accuracy in ~2015

# PDF-related topics in Snowmass'13 [arXiv:1310.5189] and 21' studies

Topic	Status, 2013	Status and plans, 2020
Benchmarking of PDFs for the LHC	Before PDF4LHC'2015 recommendation	In progress toward PDF4LHC'2X recommendation
PDFs with NLO EW contributions	MSTW'04 QED, NNPDF2.3 QED	Needs an update using LuXQED and other photon PDFs; PDFs with leptons and massive bosons
PDFs with resummations	Small x (in progress)	Needs an update for PDFs with small-x and threshold resummations
Parton luminosities at 14, 33, 100 TeV	CT10, MSTW2008, NNPDF2.3 Update at 100 in CERN YR (1607.01831)	Need an update based on the latest PDFs
LHC processes to measure PDFs	$W/Z$ , single-incl. jet, high- $p_T$ $Z$ , $t\bar{t}$ , $W + c$ production	updates on these processes + $Q\bar{Q}$ , dijet, $\gamma/W/Z$ +jet, low-Q DY, ...
Future experiments to probe PDFs	LHC Run-2 DIS: LHeC	LHC Run-3 DIS: EIC, LHeC, ...

## NEW TASKS in THE HL-LHC ERA:

Obtain complete NNLO and N3LO predictions for PDF-sensitive processes	Improve models for correlated systematic errors	Find ways to constrain large-x PDFs without relying on nuclear targets
Develop and benchmark fast NNLO interfaces	Estimate NNLO theory uncertainties	Develop an agreement on comparing and combining PDF fits