Update on META distributions

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Status update, 2015-10-27

After the 30-member set was published as a part of the PDF4LHC recommendation in arXiv:1510.03865, based on the META analysis method developed in arXiv:1401.0013, our current focus is on the release of

1. New reduced META PDF sets for Higgs cross sections and other LHC cross sections, following the "data set diagonalization" approach proposed in 2014
2. Extension of the PDF4LHC-30 set to low Q of ≈ 2 GeV

The new META sets will be published at **metapdf.hepforge.org**, together with the Mathematica package MP4LHC for the analysis of META PDFs

1. Reduction of the error PDFs

The number of final error PDFs in the META approach can be made much smaller than in the input ensembles

In the **META2.0/PDF4LHC-2015** study:
508 CT'14, MMHT'14, NNPDF3.0 error sets

⇒ 900 MC replicas for reconstructing the combined probability distribution

⇒ 30 Hessian META sets for most LHC applications and symmetric PDF uncertainties, 60 Hessian sets for asymmetric uncertainties

⇒ 10 META sets for LHC Higgs production observables and symmetric errors, 20 for asymmetric errors (**reduced ensemble** LHCH)

META LHCH PDFs, 2015

The **unpublished** LHCH1.0 set was presented at the PDF4LHC meeting in November 2014 and used input CT10, MSTW'08, and NNPDF2.3 PDFs. It validated the methodology of DSD reduction

Numerous updates will go into the anticipated new generation of META LHCH PDFs:

- CT14, MMHT'14, NNPDF3.0 PDFs as the input PDFs
- More robust parametrizations based on Bernstein polynomials and larger number of parameters
- Support of asymmetric Hessian errors
- Methodological improvements introduced during the PDF4LHC study

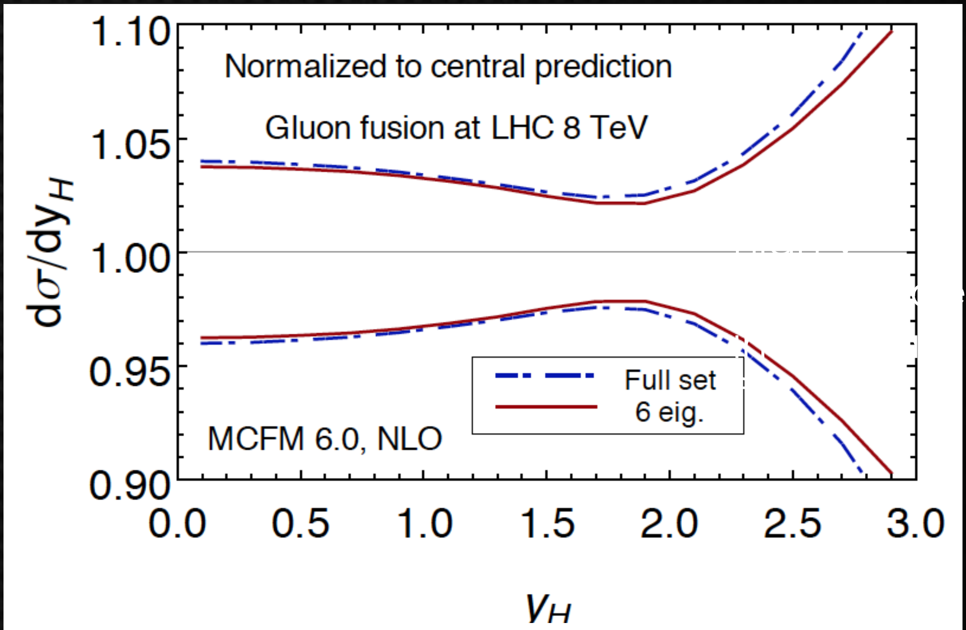
Reduced META ensemble

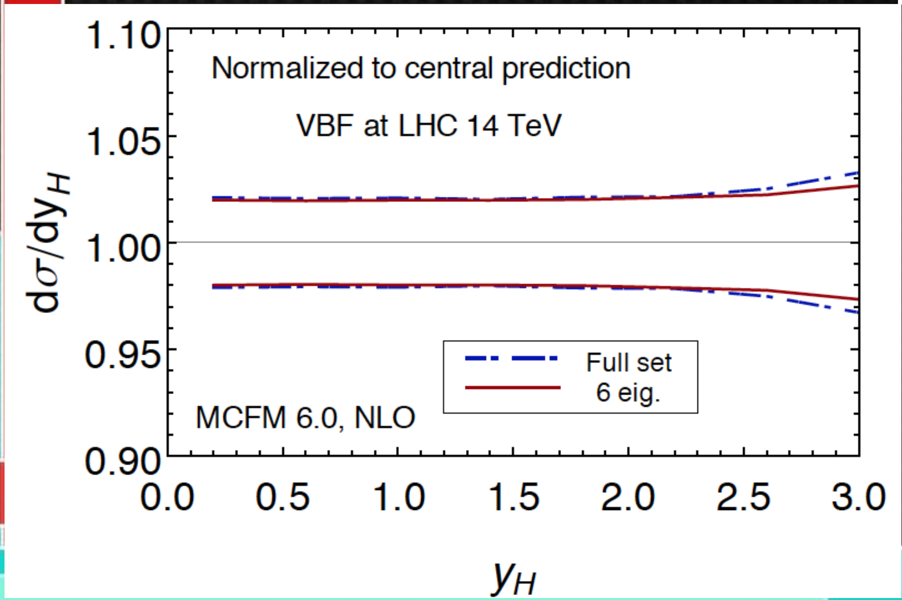
- Data set diagonalization pick out a few (6-10) eigenvector directions important for Higgs physics or another class of LHC processes. This approximation adequately reproduces the PDF uncertainty in these processes, but keeping only essential eigenvectors
- Select global set of Higgs cross sections at 8 and 13 TeV (46 observables in total; more can be easily added if there is motivation)

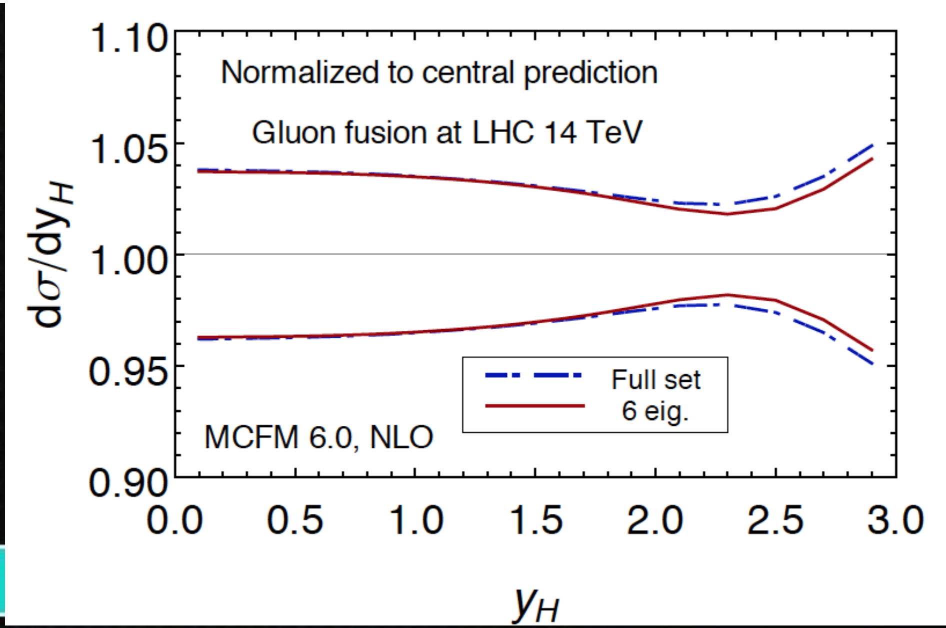
production channel	$\sigma(inc.)$	$\sigma(\lvert y_H\rvert > 1)$	$\sigma(p_{T,H} > m_H)$	scales
$gg \to H$	iHixs1.3 [32] at NNLO	MCFM6.3 [33] at LO	—	m_H
$b\bar{b} \to H$	iHixs at NNLO	—	—	m_H
VBF	VBFNLO2.6 [34] at NLO	same	same	m_W
HZ	VHNNLO1.2 [35] at NNLO	CompHEP4.5 [36] at LO	CompHEP at LO	$m_Z + m_H$
$HW^\pm$	VHNNLO at NNLO	—	—	$m_W + m_H$
HW^+	CompHEP at LO	same	same	$m_W + m_H$
HW^-	CompHEP at LO	same	same	$m_W + m_H$
$H + 1jet$	MCFM at LO	same	same	m_H
$Ht\bar{t}$	MCFM at LO	CompHEP at LO	CompHEP at LO	$2m_t + m_H$
HH	Hpair [37] at NLO	—	—	$2m_H$

Higgs eigenvector set

- The reduced META eigenvector set does a good job of describing the uncertainties of the full set for *typical* processes such as ggF or VBF
- But actually does a good job in reproducing PDF-induced correlations and describing those LHC physics processes in which $g,\ \bar{u},\ \bar{d}$ drive the PDF uncertainty (see next slide)







process	$\sigma_{cen.}$	δ_{Full}	$\delta_{Diag.}$	$\sigma^{\alpha_s}_{0.116}$	$\sigma^{\alpha_s}_{0.120}$
$gg \to H$ [pb]	18.77	$^{+0.48}_{-0.46}$	$^{+0.48}_{-0.44}$	18.11	19.46
	43.12	$^{+1.13}_{-1.07}$	$^{+1.13}_{-1.04}$	41.68	44.61
VBF [fb]	302.5	$^{+7.8}_{-6.7}$	$^{+7.6}_{-6.7}$	303.1	301.4
	878.2	$^{+19.7}_{-17.9}$	$^{+19.2}_{-17.3}$	877.3	878.4
HZ [fb]	396.3	$^{+8.4}_{-7.3}$	$^{+8.1}_{-7.4}$	393.0	399.7
	814.3	$^{+14.8}_{-13.2}$	$^{+13.8}_{-13.0}$	806.5	823.3
$HW^{\pm}$ [fb]	703.0	$^{+14.4}_{-14.4}$	$^{+14.3}_{-14.1}$	697.4	708.9
	1381	$^{+28}_{-22}$	$^{+26}_{-22}$	1368	1398
HH [fb]	7.81	$^{+0.33}_{-0.30}$	$^{+0.33}_{-0.30}$	7.50	8.10
	27.35	$^{+0.78}_{-0.72}$	$^{+0.78}_{-0.68}$	26.48	28.22
$t\bar{t}$ [pb]	248.4	$^{+9.1}_{-8.2}$	$^{+9.2}_{-8.1}$	237.1	259.5
	816.9	$^{+21.4}_{-19.6}$	$^{+21.4}_{-18.4}$	785.5	848.1
$Z/\gamma^*(l^+l^-)$ [nb]	1.129	$^{+0.025}_{-0.023}$	$^{+0.024}_{-0.023}$	1.113	1.147
	1.925	$^{+0.043}_{-0.041}$	$^{+0.040}_{-0.037}$	1.897	1.959
$W^+(l^+\nu)$ [nb]	7.13	$^{+0.14}_{-0.14}$	$^{+0.14}_{-0.13}$	7.03	7.25
	11.64	$^{+0.24}_{-0.23}$	$^{+0.22}_{-0.21}$	11.46	11.84
$W^-(l^-\bar{\nu})$ [nb]	4.99	$^{+0.12}_{-0.12}$	$^{+0.12}_{-0.11}$	4.92	5.08
	8.59	$^{+0.21}_{-0.20}$	$^{+0.19}_{-0.18}$	8.46	8.74
W^+W^- [pb]	4.14	$^{+0.08}_{-0.08}$	$^{+0.08}_{-0.07}$	4.04	4.20
	7.54	$^{+0.15}_{-0.14}$	$^{+0.14}_{-0.12}$	7.39	7.57
ZZ [pb]	0.703	$^{+0.016}_{-0.014}$	$^{+0.015}_{-0.014}$	0.695	0.713
	1.261	$^{+0.026}_{-0.024}$	$^{+0.024}_{-0.022}$	1.256	1.277
W^+Z [pb]	1.045	$^{+0.019}_{-0.018}$	$^{+0.019}_{-0.017}$	1.039	1.068
	1.871	$^{+0.033}_{-0.031}$	$^{+0.029}_{-0.027}$	1.850	1.898
W^-Z [pb]	0.788	$^{+0.020}_{-0.019}$	$^{+0.019}_{-0.018}$	0.780	0.795
	1.522	$^{+0.034}_{-0.032}$	$^{+0.033}_{-0.031}$	1.509	1.549

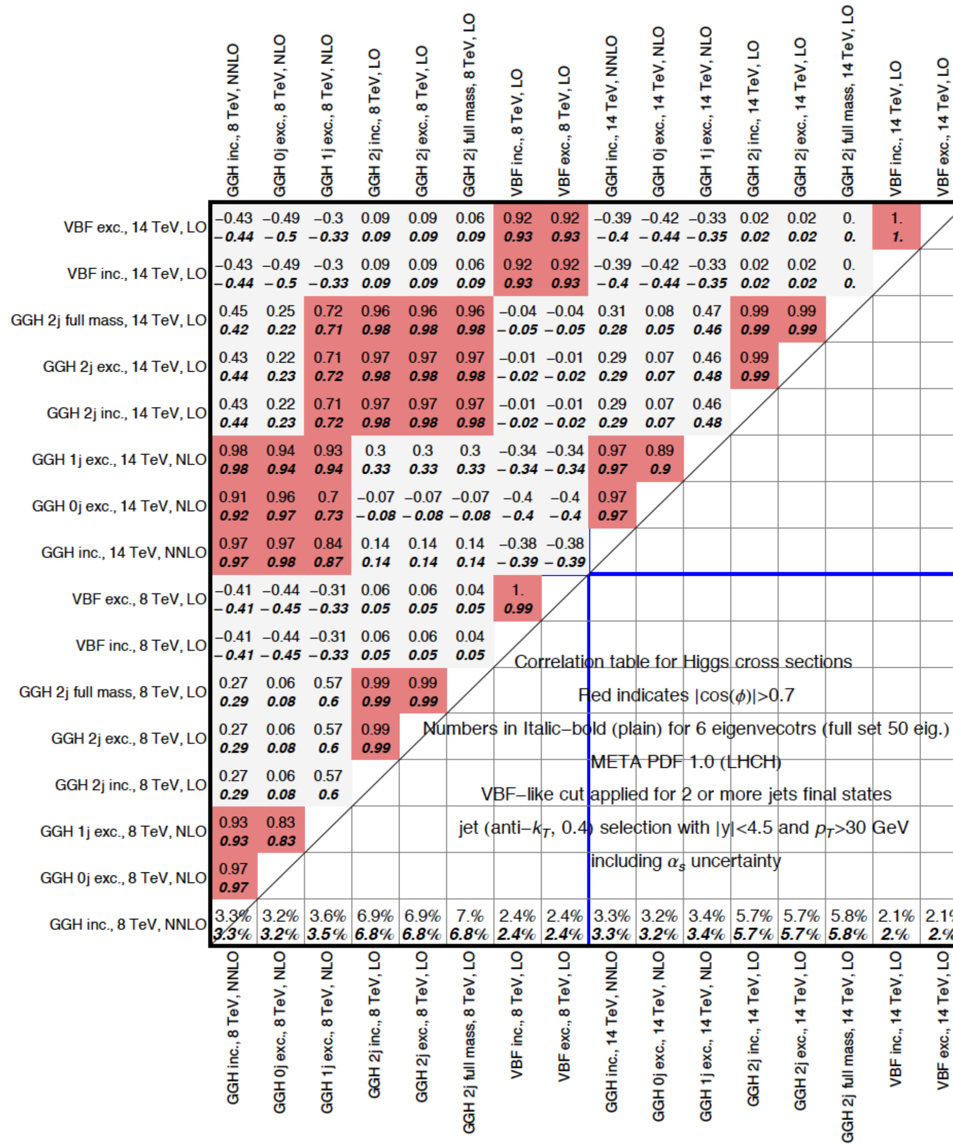


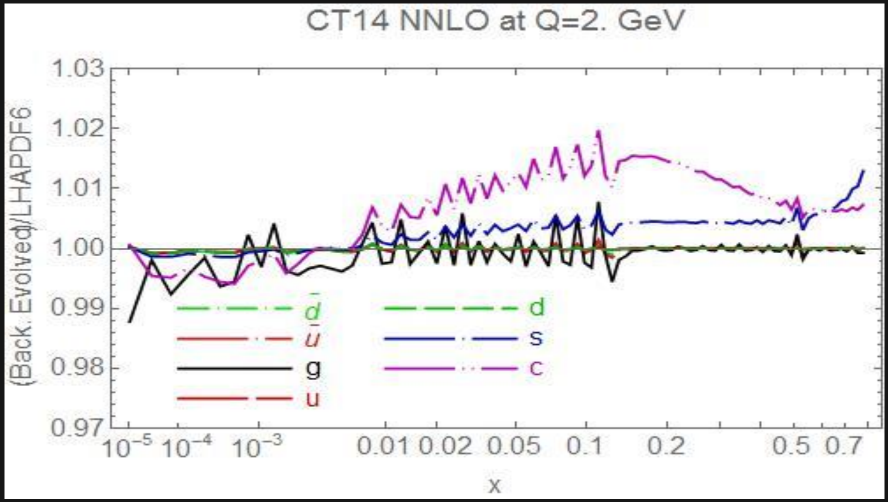
FIG. 7: Same as Fig. 5, with α_s uncertainties included by adding in quadrature.

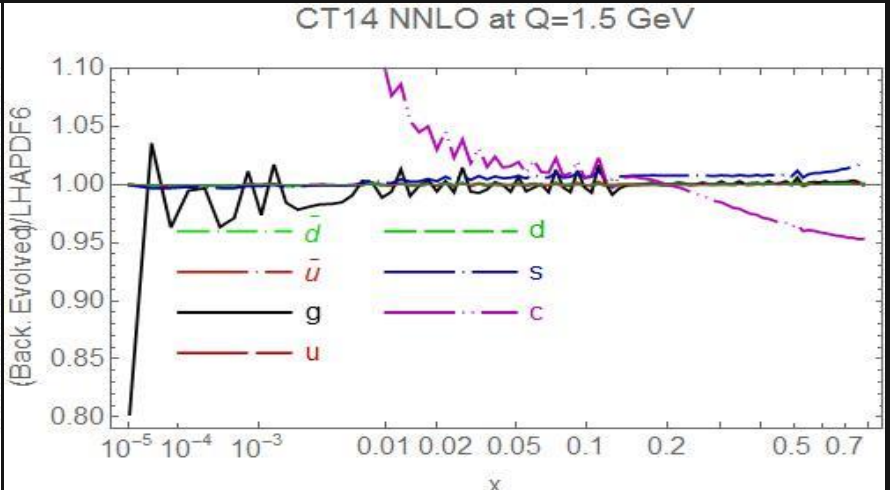
2. PDF combinations and heavy-quark contributions

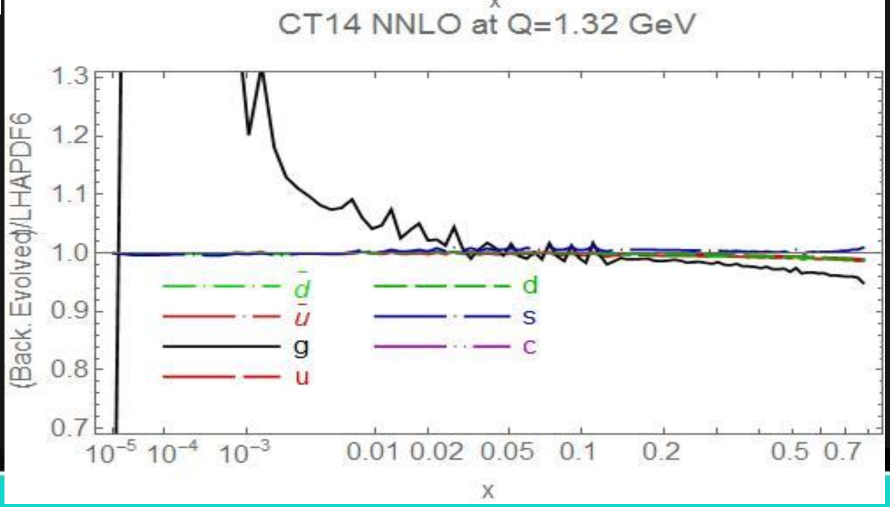
- All 3 PDF4LHC combination methods (CMC, MCH, META) are inconsistent when predicting massive-quark scattering at scales $Q < m_b$; can lose accuracy in PQCD calculations at such Q
- The input CT, MMHT, NNPDF sets employ different heavy-flavor schemes and m_b values, can be faithfully combined and used with $N_f = 5$ zero-mass cross sections only at $Q^2 \gg m_b^2$
- **For this reason, the initial scale for the PDF4LHC-30 set was chosen to be $Q_0 = 8$ GeV**, in the region where it is safe to use the combined PDFs with (N)NLO QCD cross sections.
- For matched (N)NLO+PS computations, it may still be desirable to provide the error PDFs at $Q < 8$ GeV
- **We verified that the PDF4LHC-30 grids can be extended down to $Q = 2$ GeV by backward DGLAP evolution, assuming average m_b of the input ensembles. We propose to add a subgrid for $2 \le Q \le 8$ GeV into the LHAPDF grids of the PDF4LHC-30 ensemble**

Testing backward DGLAP evolution: CT14 NNLO

- **Done in HOPPET with pole quark masses, starting from $Q_0 = 8$ GeV**
- **Accurate evolution (within 1-2%) for $Q \geq 2$ GeV, fails at Q<1.5 GeV**
- **Minor "oscillations" due to mismatch in interpolation**



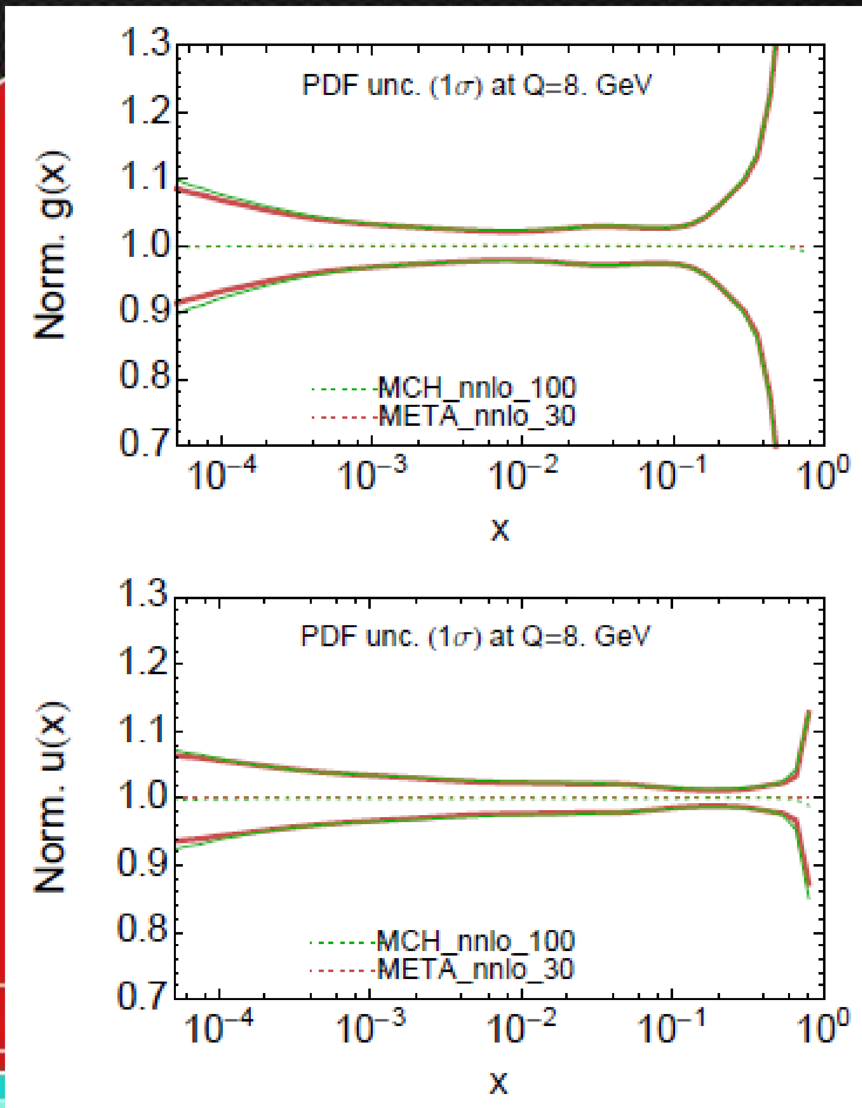




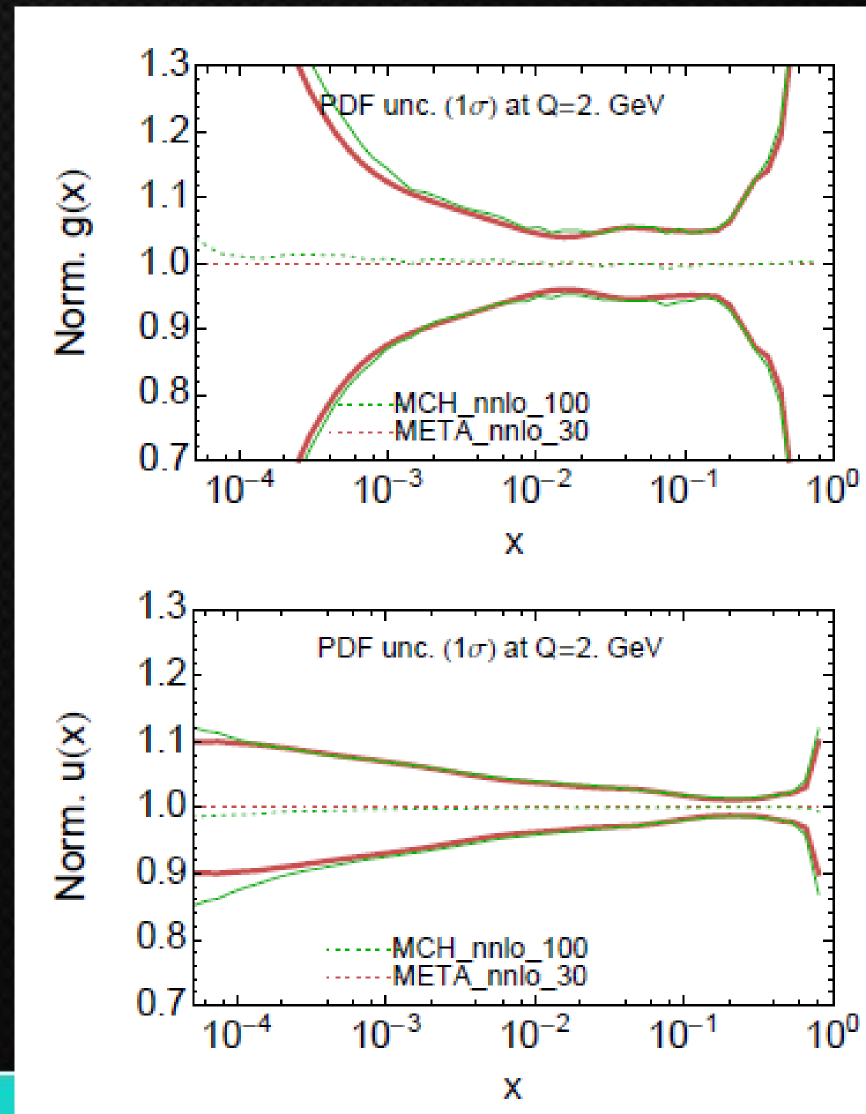
N.B. Different scales on y-axes

META-30 vs MCH-100, **NNLO**

Q=8 GeV



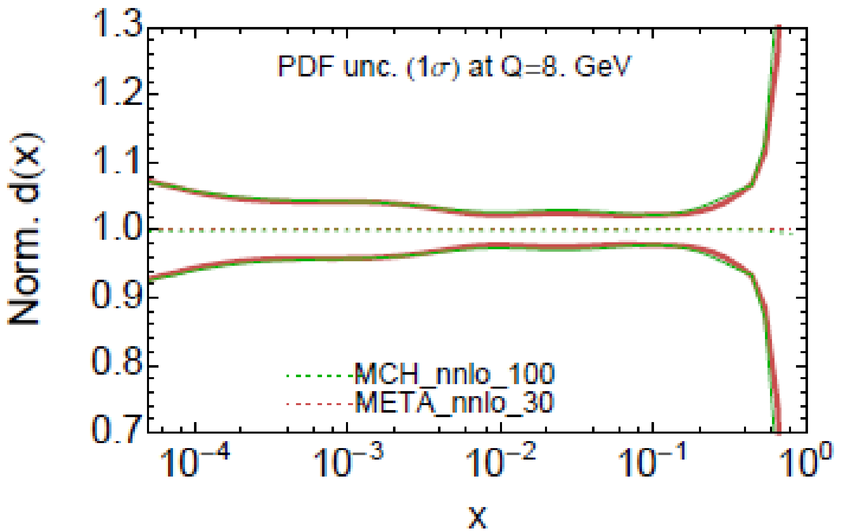
Q=2 GeV

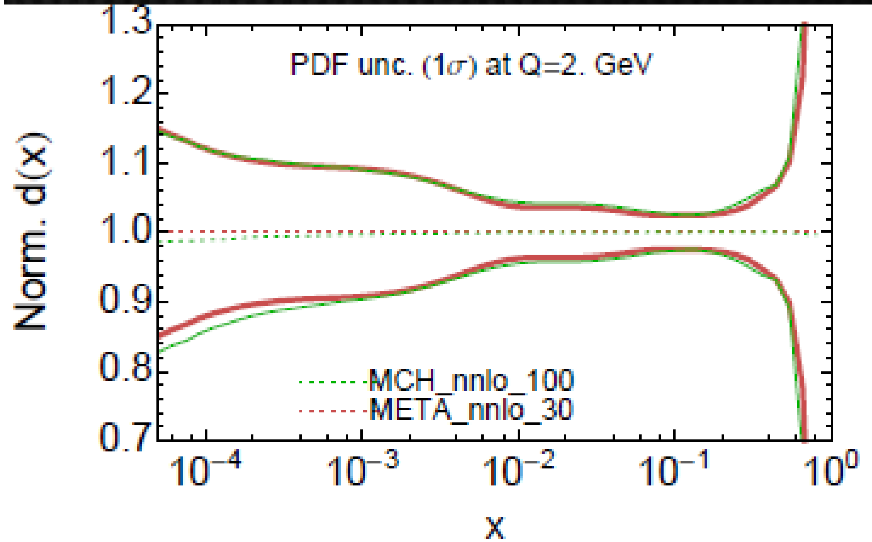


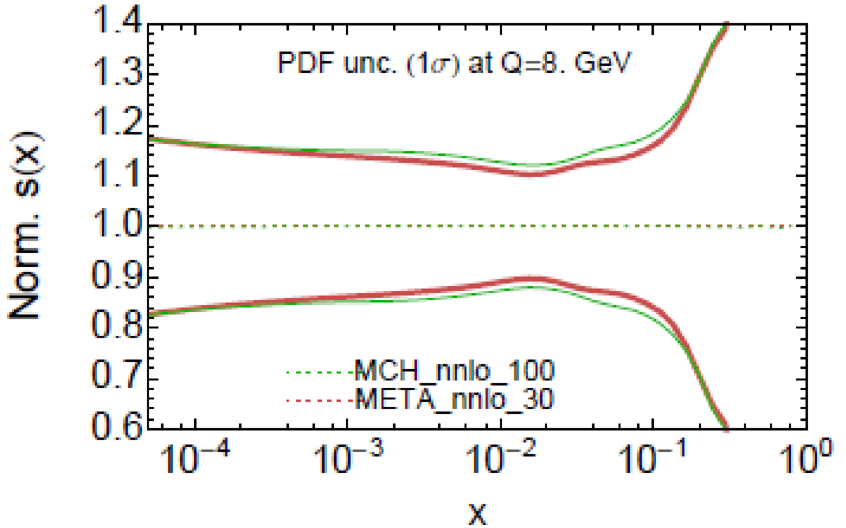
META-30 vs MCH-100, **NNLO**

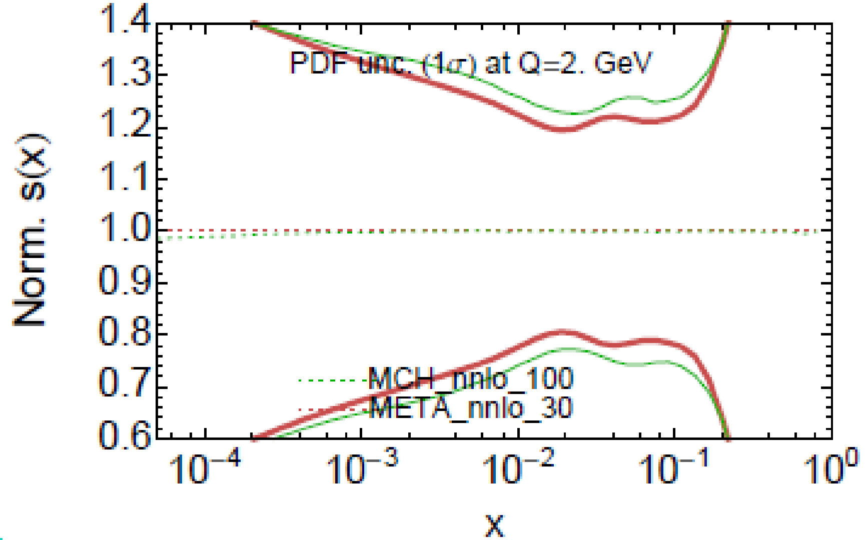
Q=8 GeV

Q=2 GeV



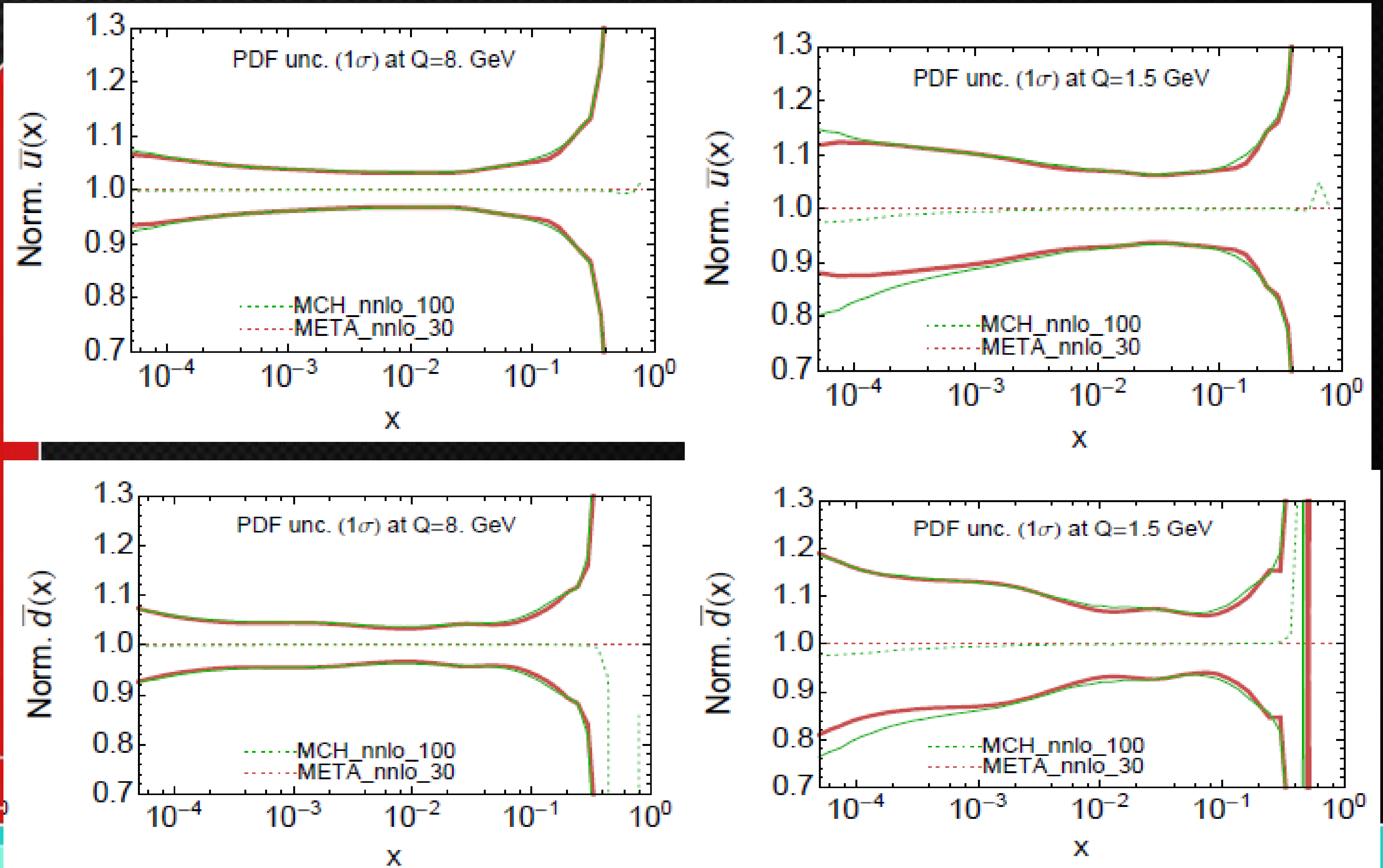






META-30 vs MCH-100, **NNLO**

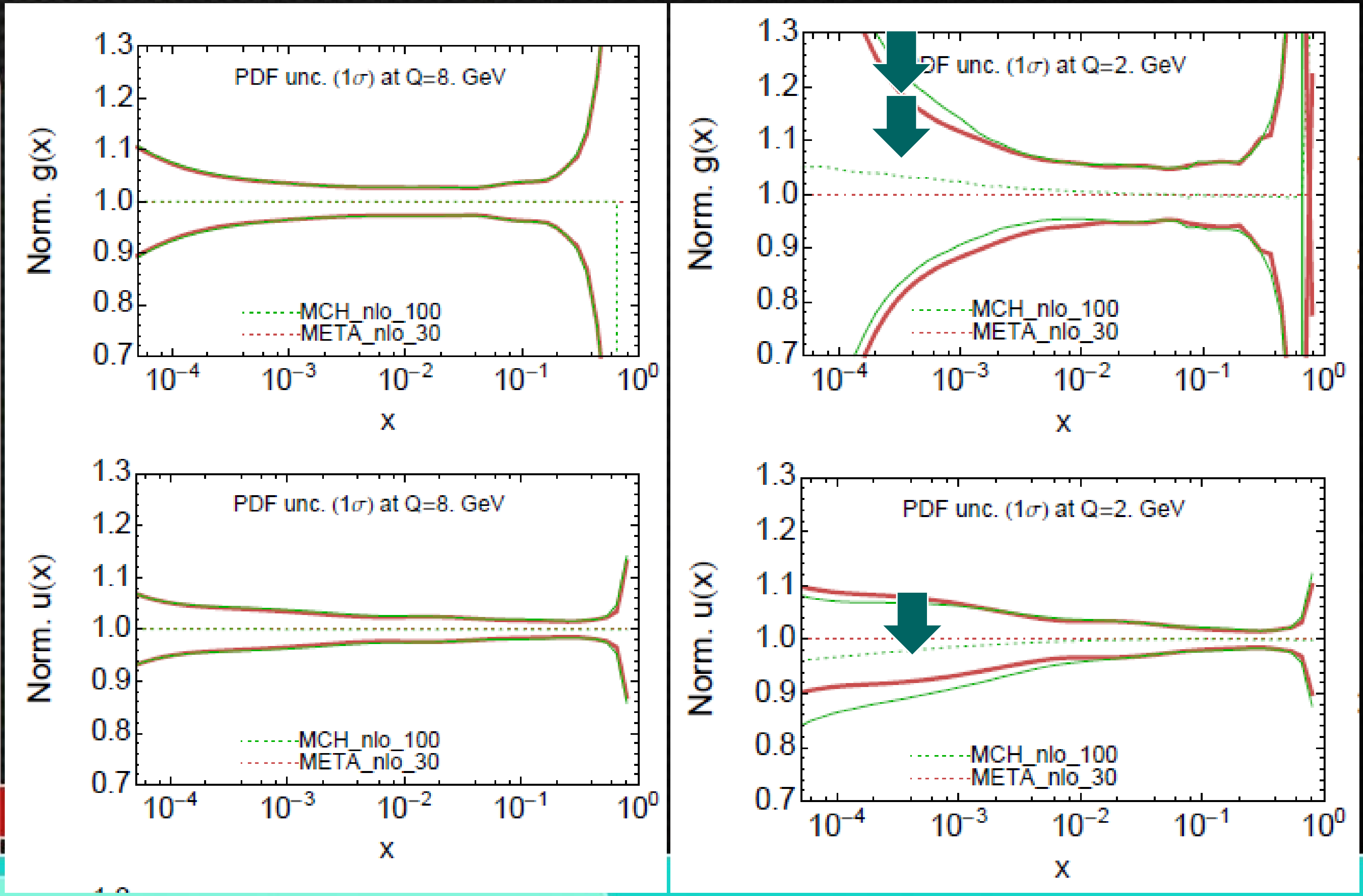
Q=8 GeV Q=2 GeV



META-30 vs MCH-100, **NLO**

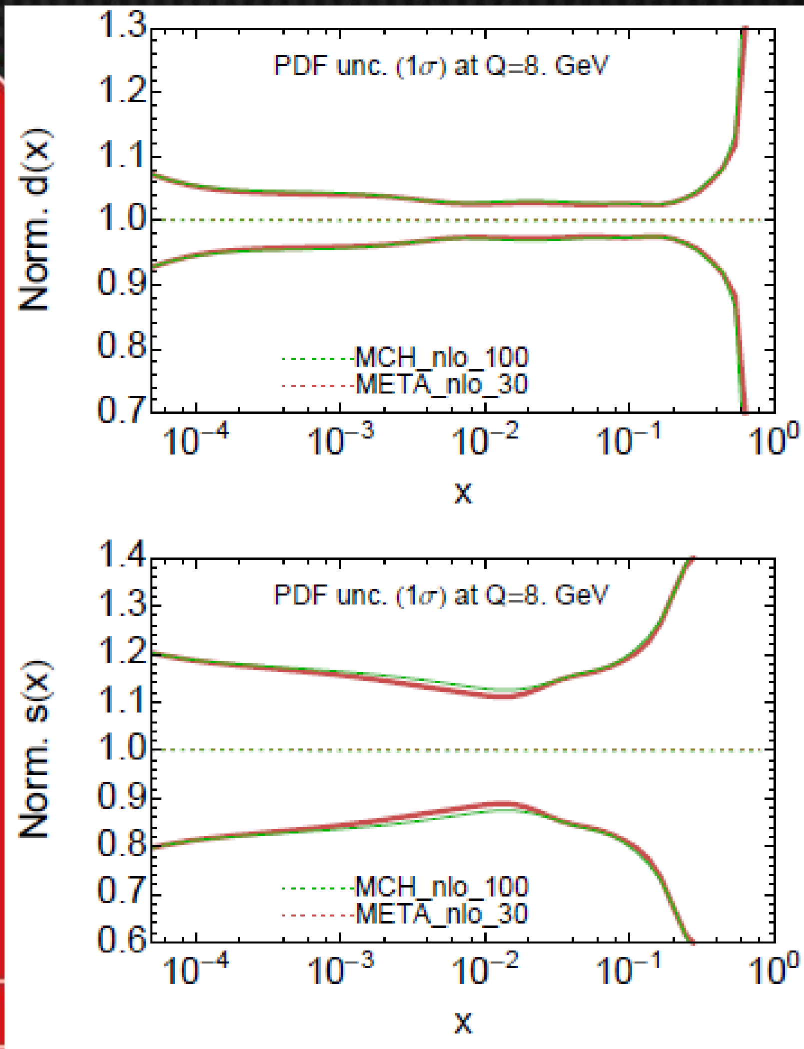
Q=8 GeV

Mismatch between HOPPET and NNPDF NLO evolution;
Is corrected for in PDF4LHC-30

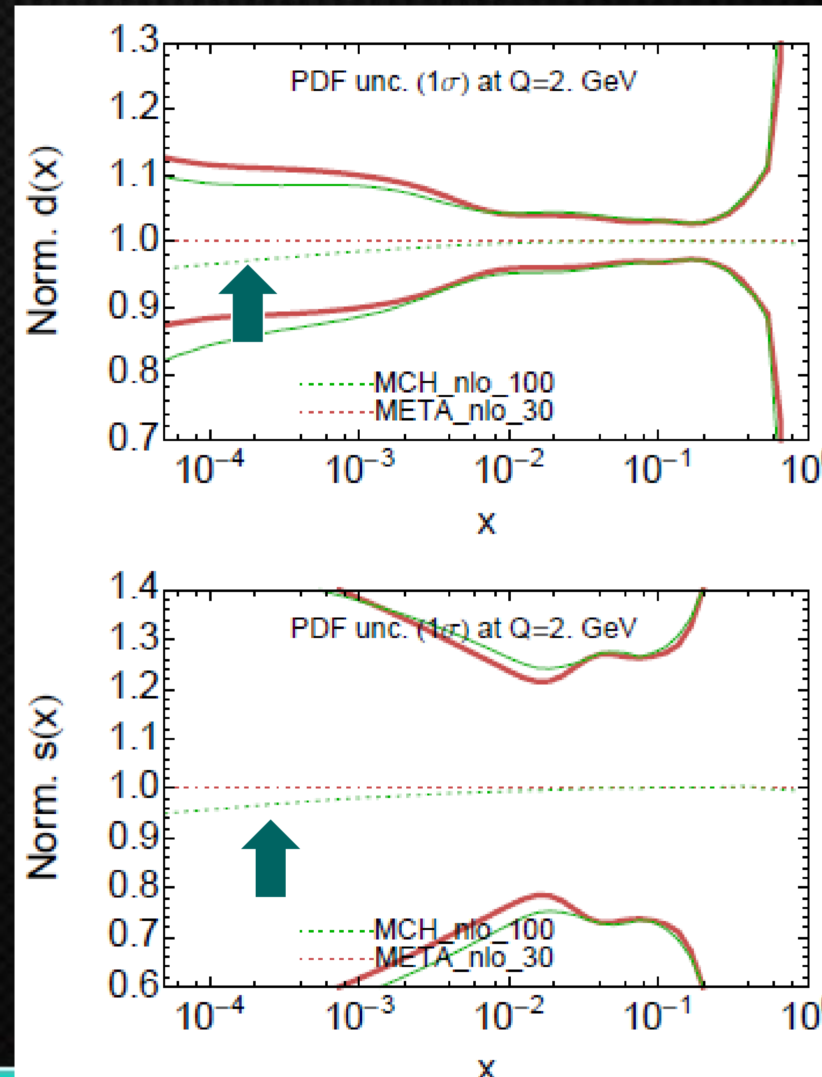


META-30 vs MCH-100, **NLO**

Q=8 GeV



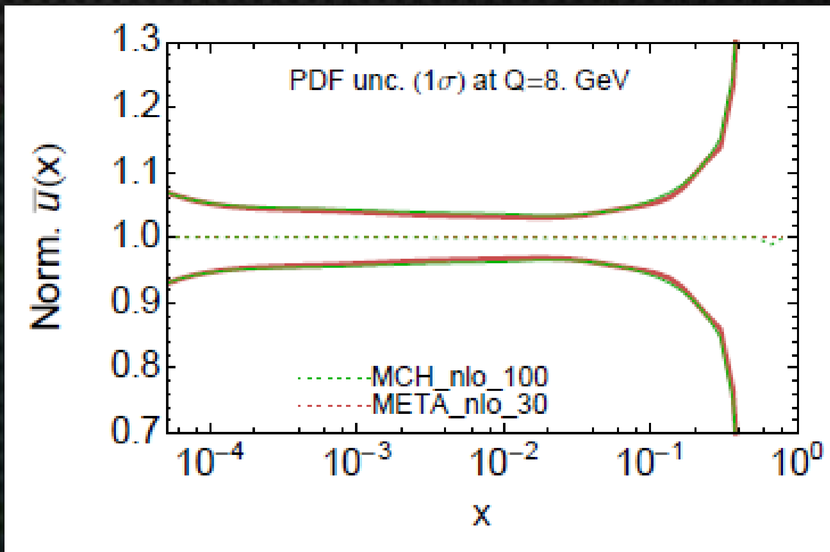
Q=2 GeV

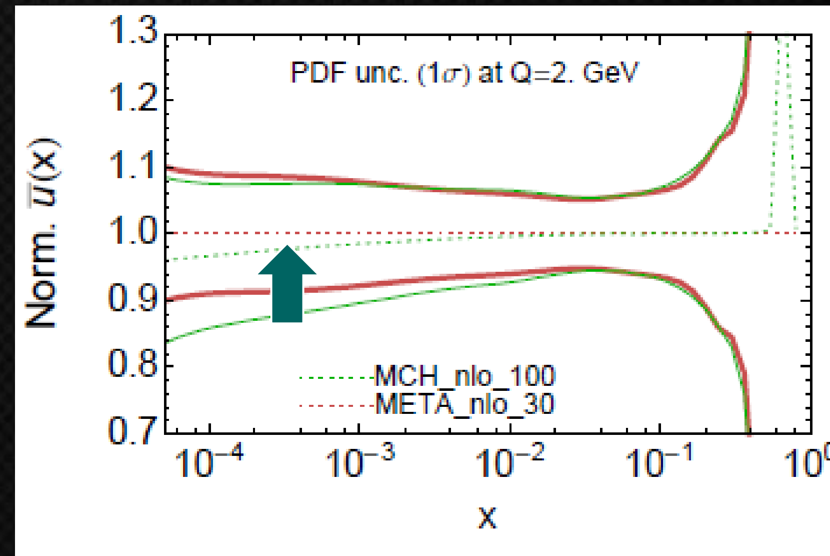


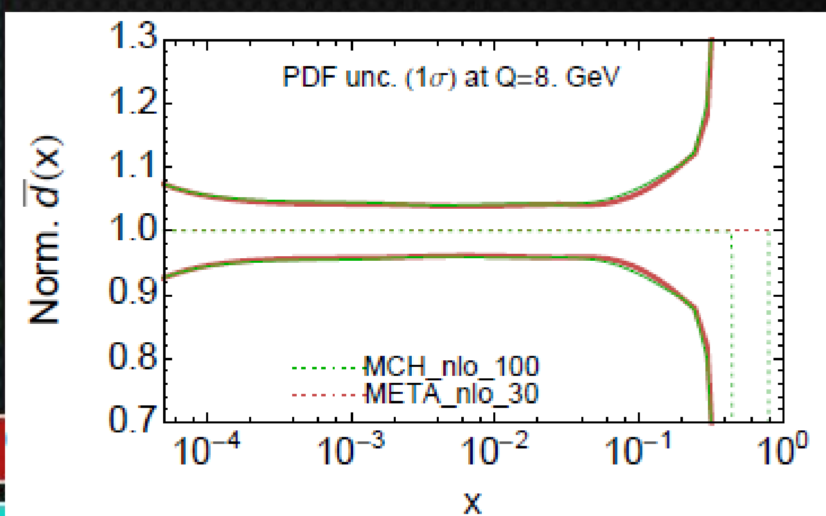
META-30 vs MCH-100, **NLO**

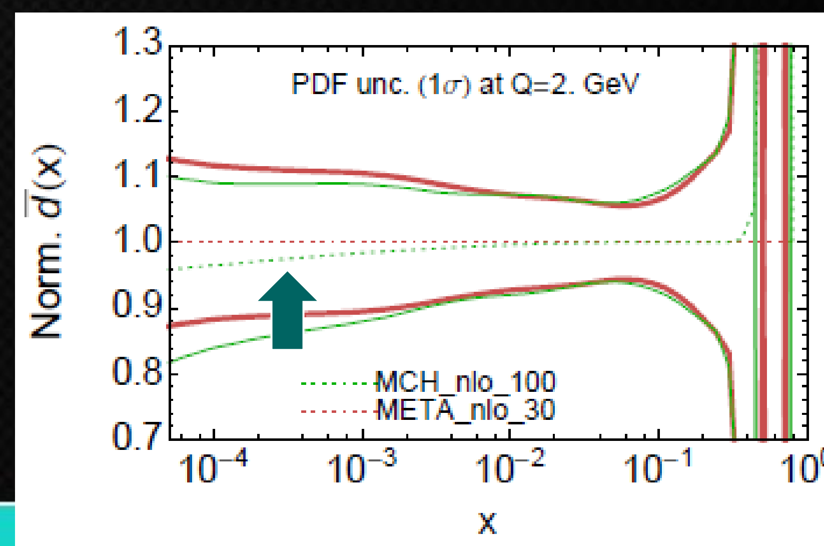
Q=8 GeV

Q=2 GeV









Summary, backward evolution

- Propose to release a 2-8 GeV subgrid for the PDF4LHC-30 ensemble. Evolve PDF to low Q assuming

$$m_b^{pole} = \frac{2 * 4.75 + 4.18}{3} \approx 4.6 \ GeV$$

[For future combinations, can all groups agree to use the same m_b, such as $m_b(m_b) = 4.7$ GeV, consistent with PDG?]

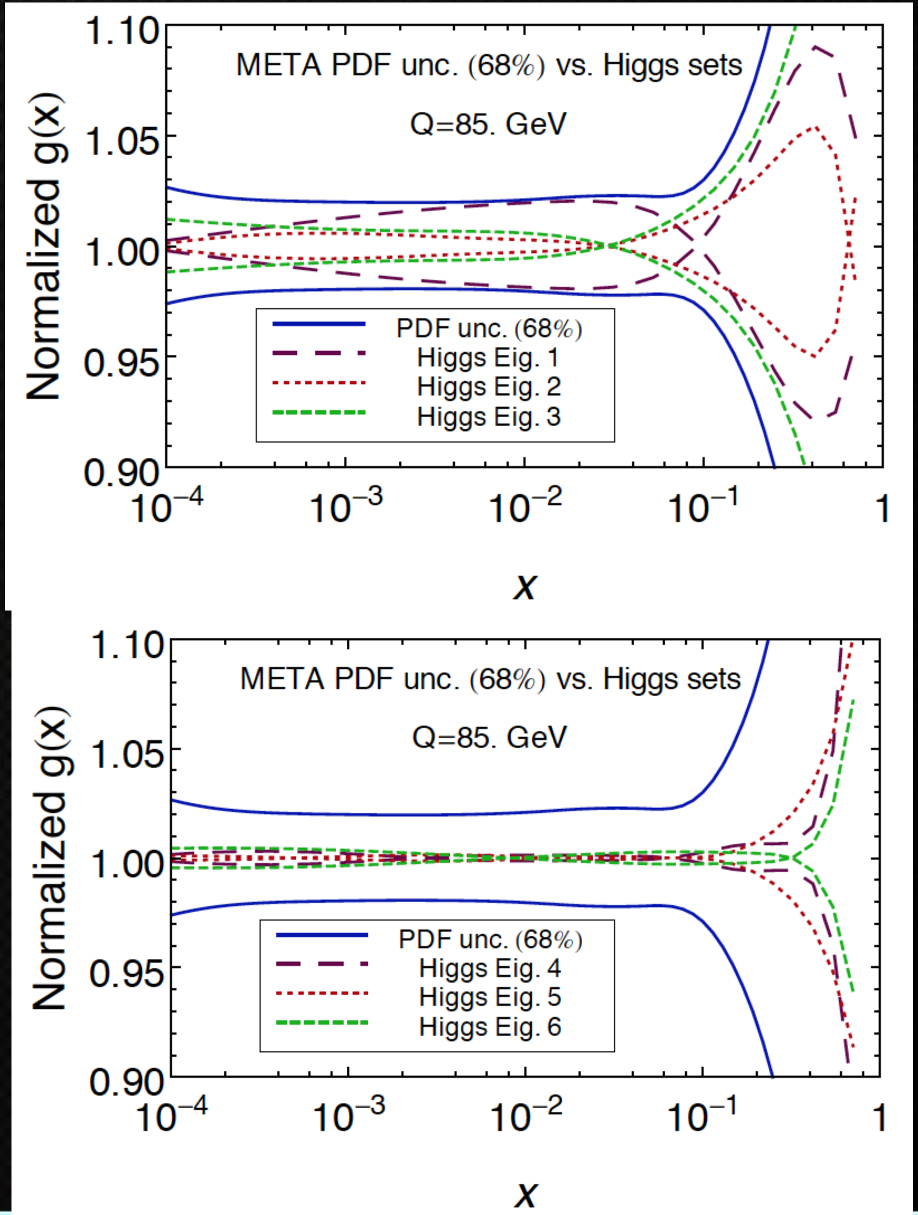
- Evolve α_s sets from 8 GeV to 2 GeV assuming the same m_b
- Correct for a small deviation in NLO evolution by NNPDF
- This solution is sufficient for parton showering programs such as SHERPA. Minor loss of accuracy happens only at very low Q, where other tunable parameters affect parton showering

Back-up slides

Re-diagonalized eigenvectors…

…are associated with the parameter combinations that drive the PDF uncertainty in Higgs, W/Z production at the LHC

- Eigenvectors 1-3 cover the gluon uncertainty. They also contribute to $\bar{u}, \bar{d}$ uncertainty.
- Eigenvector 1 saturates the uncertainty for most of the $gg \to H$ range.



u, d quark uncertainties are more distributed