A Benchmark study of the PDF dependence of Higgs cross section in gluon fusion

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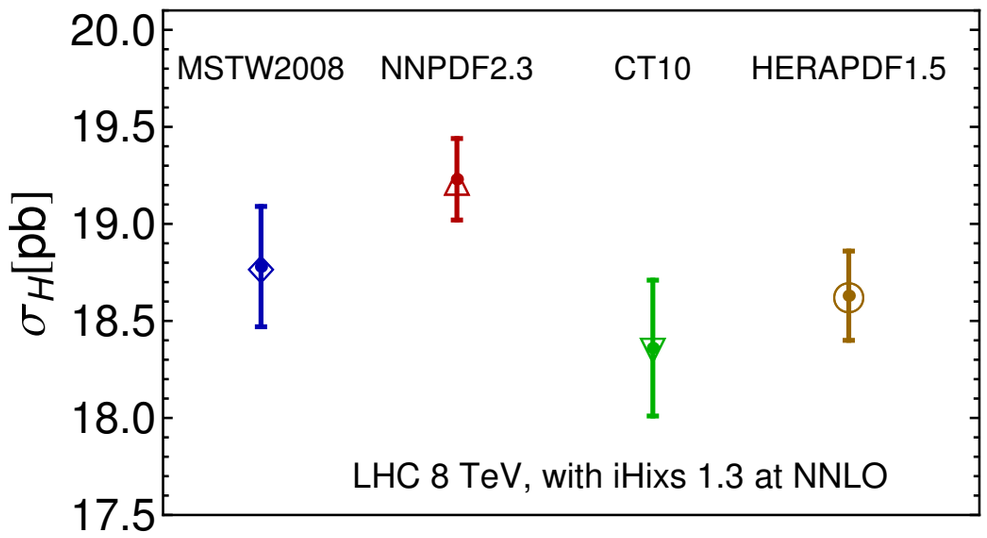
Motivation

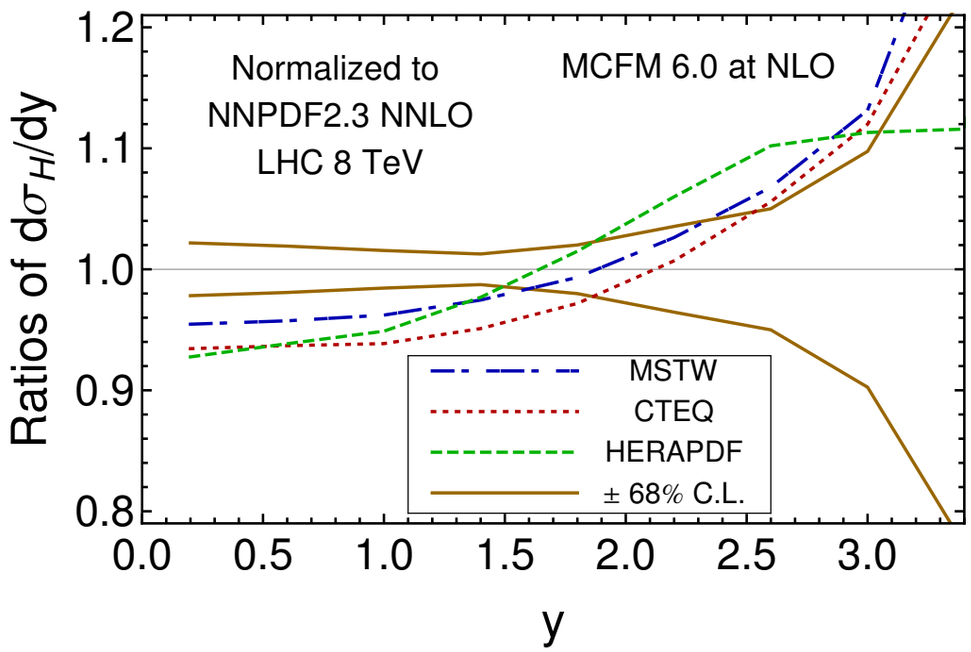
- Uncertainty of the gluon PDF is a major limitation for the extraction of the Higgs couplings at the LHC

  - compatible predictions from groups utilizing GM-VFNS
  - PDF uncertainties are small for individual global analyses, 1~2%
  - moderate spread ~4% between the central predictions, NNPDF-CT10~2σ (if adding in quadrature)
  - even larger differences for rapidity distributions

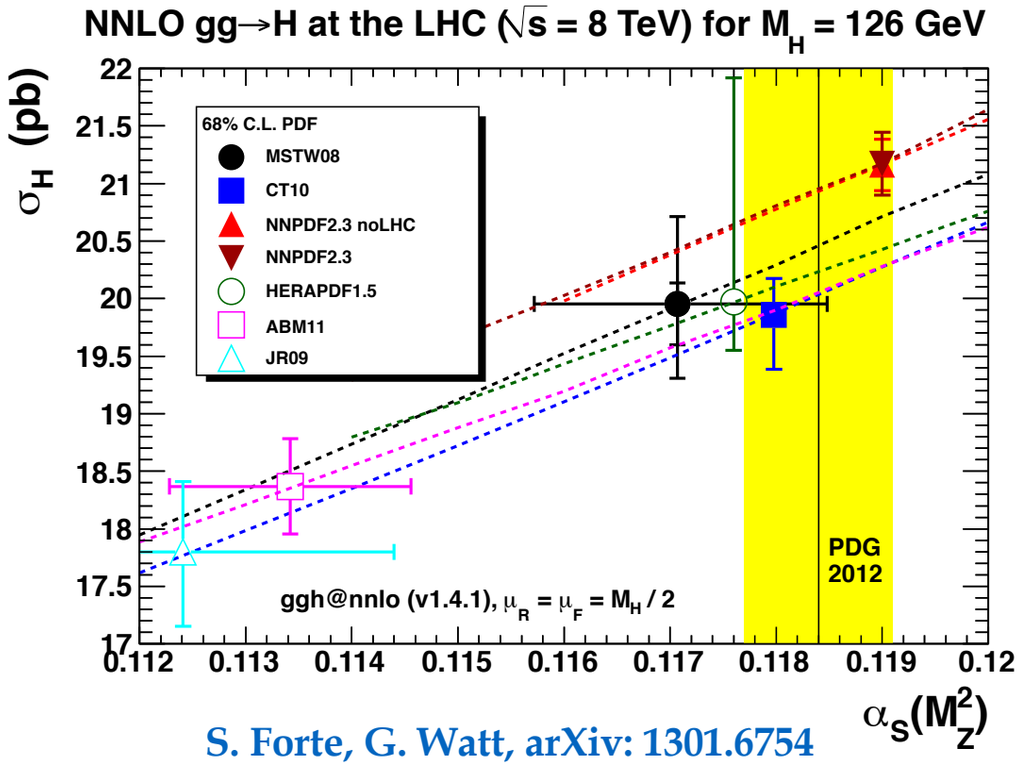
#?: origin of the discrepancies, theory, data selection, fitting method; reducible or not; correlation with the "PDF unc."

Gluon fusion cross sections from NNLO PDFs with as=0.118





- Current prescription for estimation of the total PDF+as uncertainties based on CT10, MSTW08, and NNPDF2.3



S. Forte, G. Watt, arXiv: 1301.6754

channel	*(pb)*	*Scale(%)*	*PDF+as(%)*
ggF (NNLO)	*19.27*	*+7.2 -7.8*	*+7.5 -6.9*
VBF(NNLO)	*1.58*	*+0.2 -0.2*	*+2.6 -2.8*
tth(NLO)	*0.129*	*+3.8 -9.3*	*+8.1 -8.1*

Higgs Handbook 3, 8 TeV, 125 GeV, arXiv:1307.1347

- uses updated 2010 PDF4LHC recommendations with new PDFs
- envelope prescription proposed in the 2012 PDF benchmarking study
- uses a MC combination/META PDF-like prescription instead of envelopes

PDF dependence of Higgs cross sections

- Les Houches 2013 PDF study: first step of a benchmarking exercise of GM-VFNS fits aimed at advancing the control of PDF dependence of the gluon fusion cross section

  - theoretical calculations of NC DIS cross sections were benchmarked and found to be in very good agreement

  - reduced fits with only HERA-1 data and common settings were performed and compared

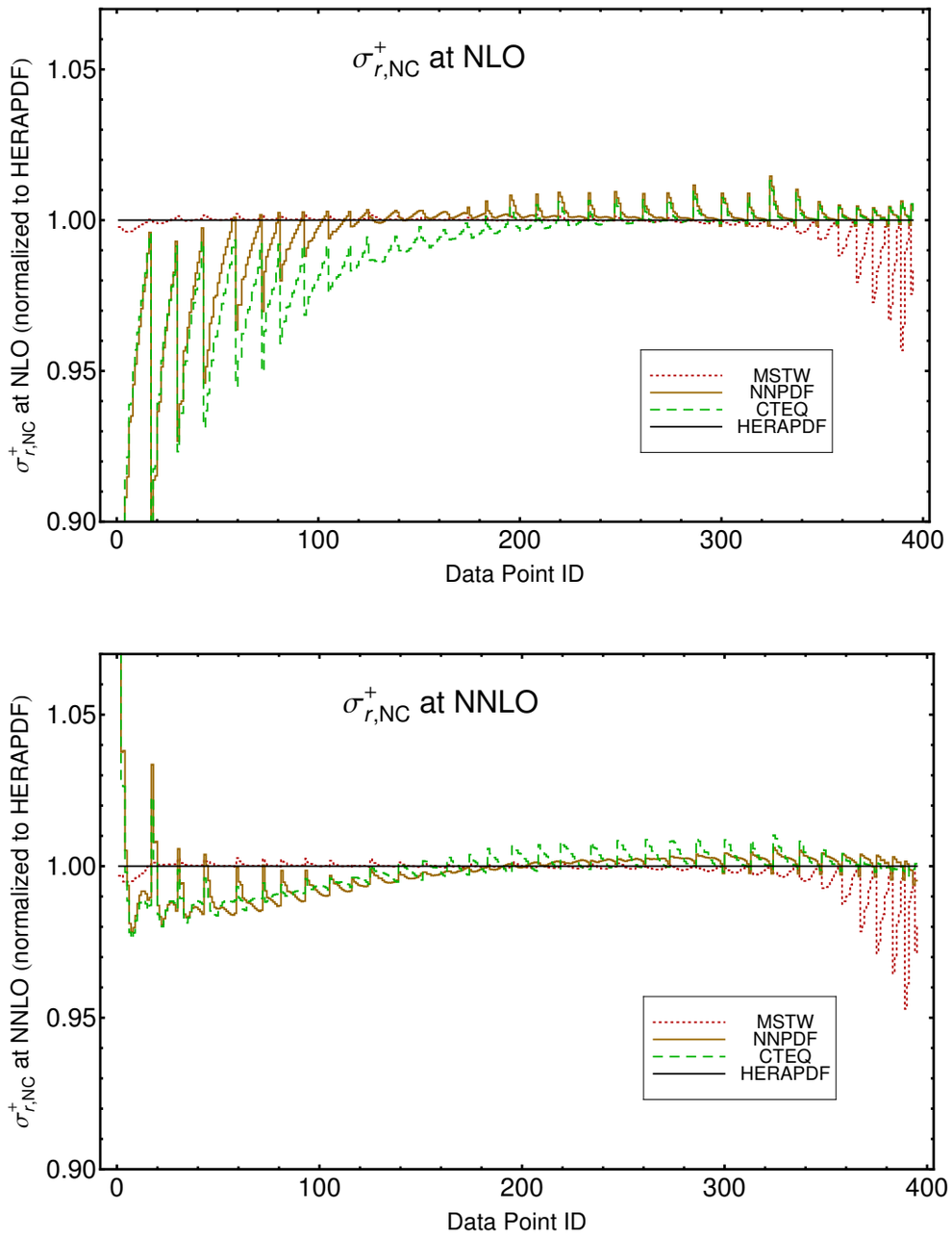
  - effects of various input assumptions were studied for the HERA-1-only fits

  - to be followed up by comparisons of theoretical calculations of CC DIS cross sections, including for dimuon production

  - add data sets on top of the HERA-1-only fit or remove data sets from the global fits

NC DIS cross sections

- Numerical implementations from four groups were compared for S-ACOT-chi, optimal TR′, and FONLL, at NLO and NNLO, based on the LH toy PDF grid with 4 flavors



- predicted reduced cross sections for HERA-1 kinematics, ordered in increasing Q^2 (2.7 GeV^2), then increasing x

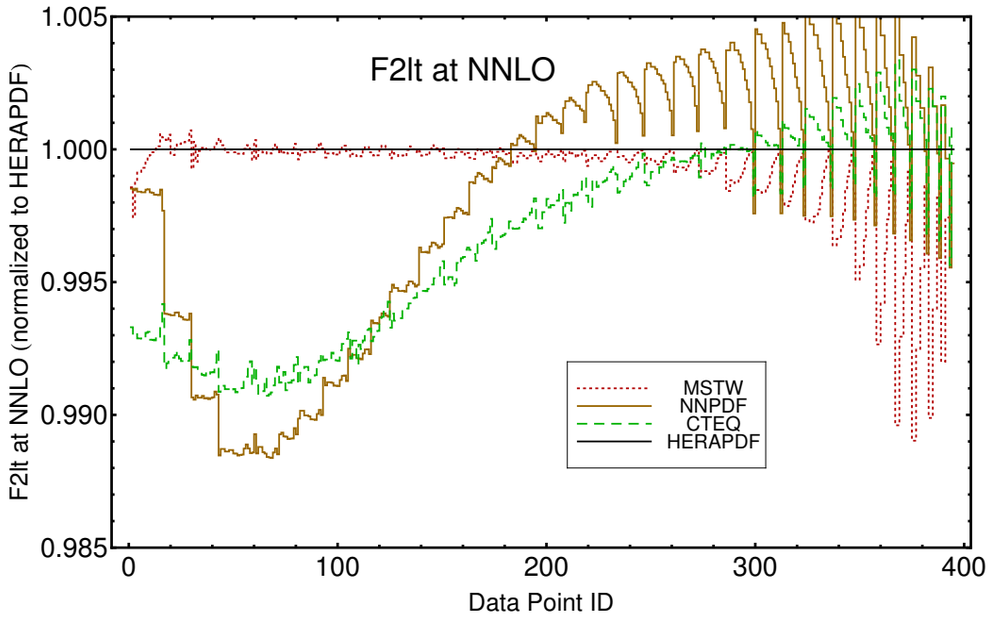
- 4 codes agree better at NNLO than at NLO

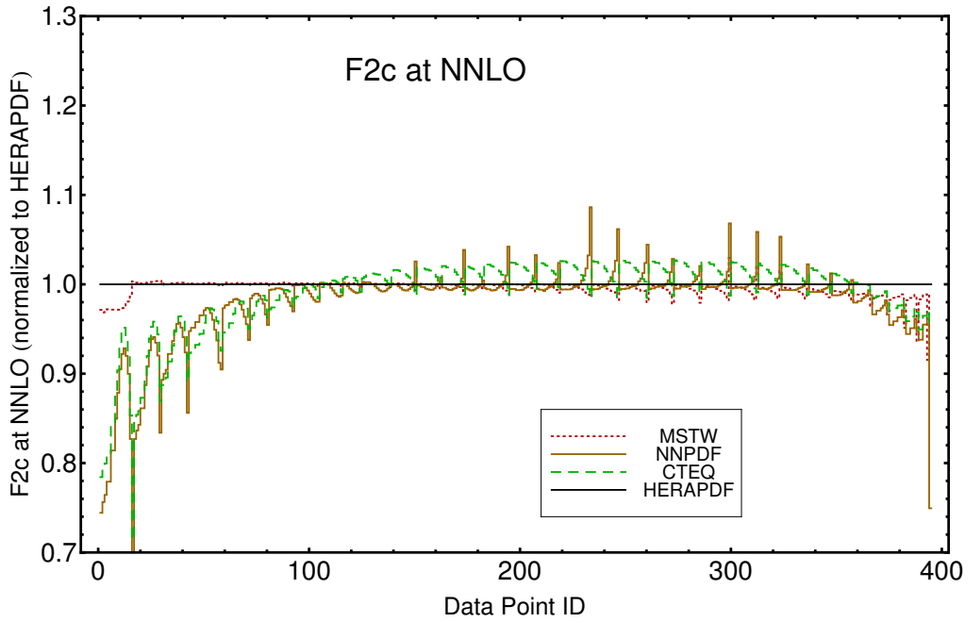
- MSTW and HERA are identical except at high Q, where EW corrections are different

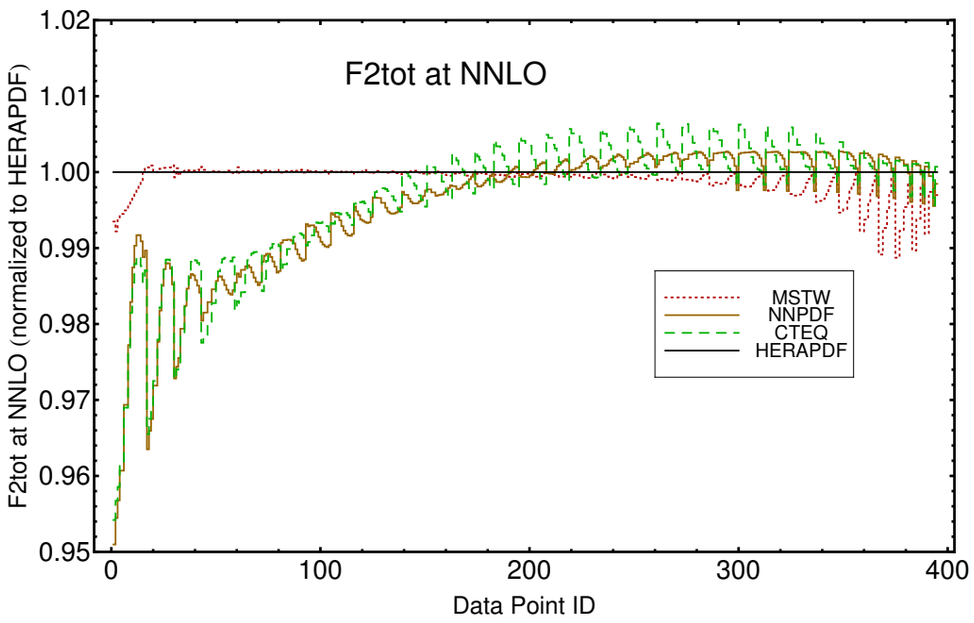
- CTEQ and NNPDF are quite close even at low Q

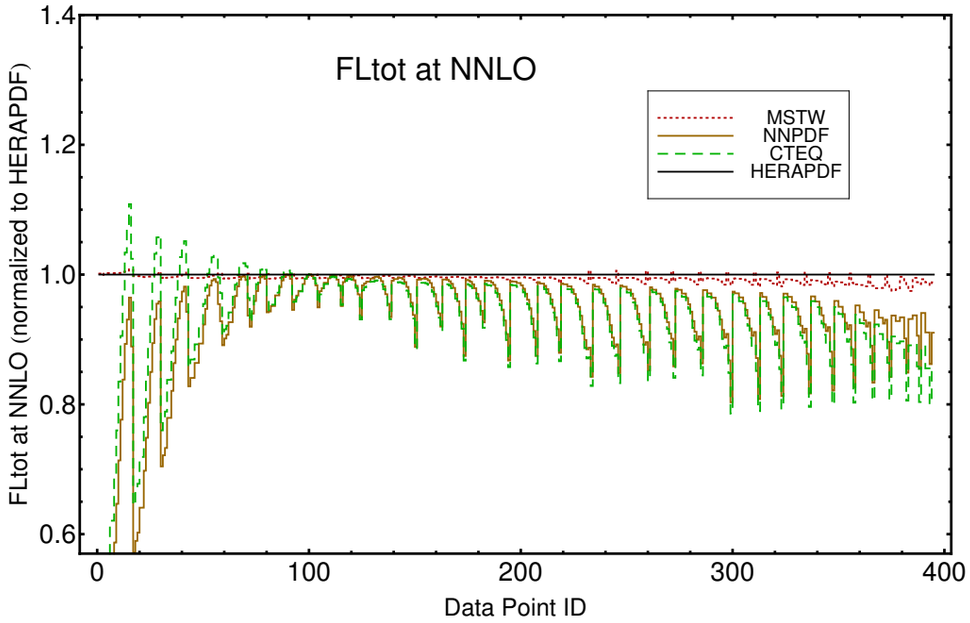
- agreement at NNLO, at low Q: ~2%; at moderate Q, ~1%

Comparison of structure functions at NNLO









- F_c is defined as a contribution proportional to the EW charges of the charm quark; and F_{lt} is defined implicitly by $F_{tot}=F_{lt}+F_c$

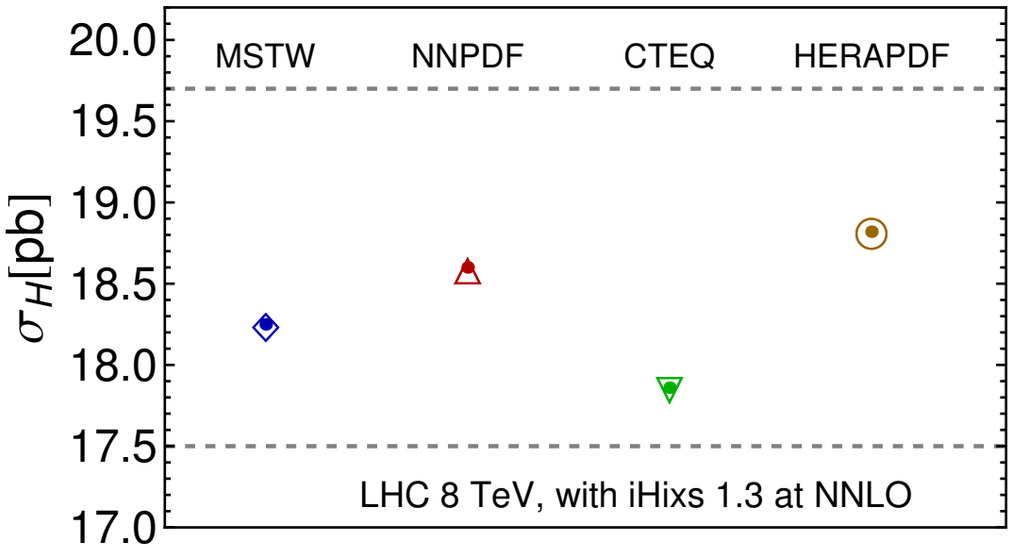
HERA-1-only fits

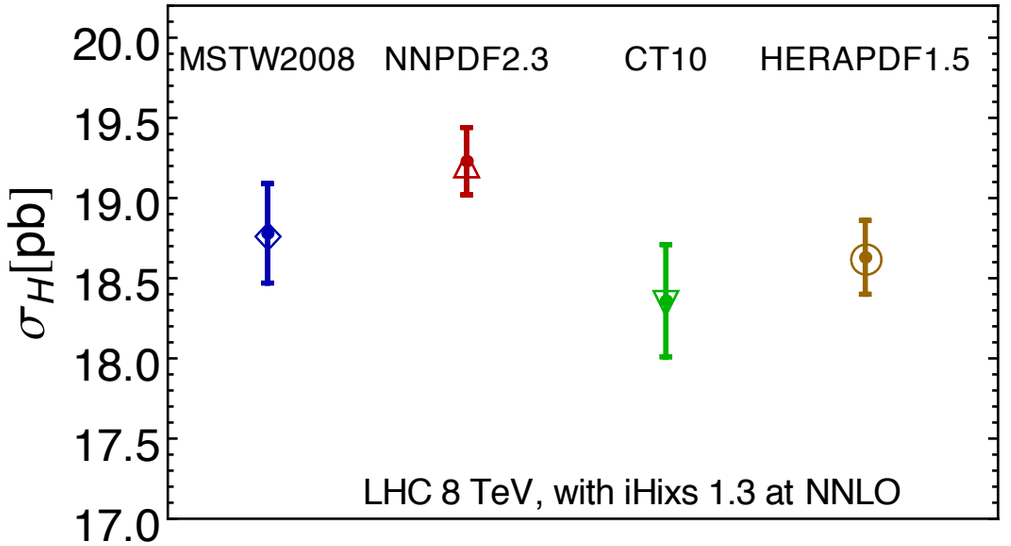
- Baseline fits: NNLO fits to the HERA-1 combined inclusive DIS data with common settings

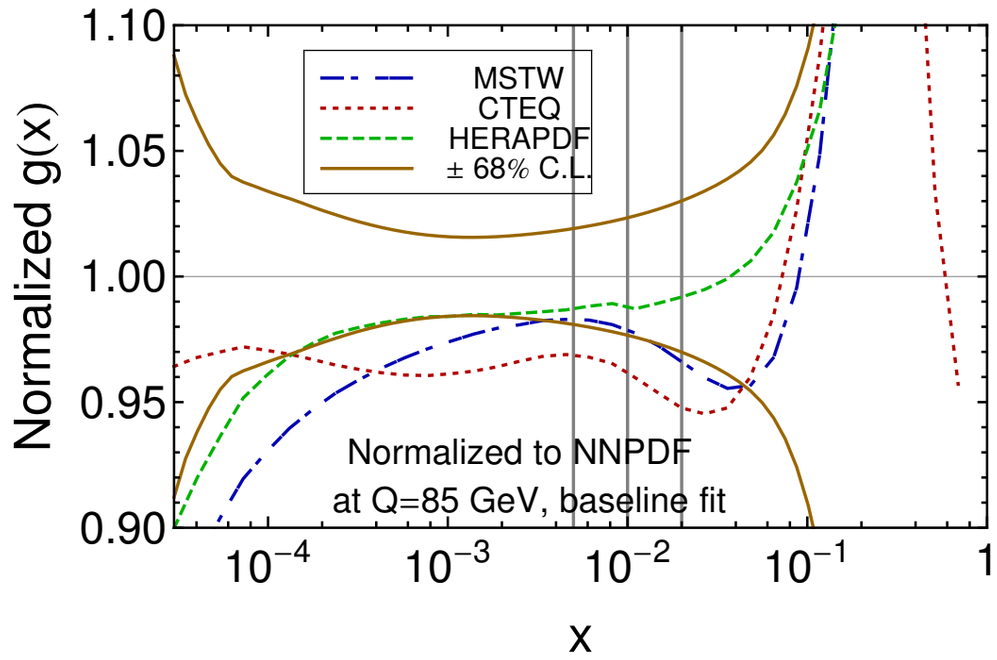
566 data points	CTEQ	MSTW	NNPDF	HERAPDF
χ^2	521.8	514.8	548.5	535.0
lum. shift	-0.19	0.27	0.16	0.18
max. shift	1.64	1.51	1.82	1.81
σ_H[pb], 8 TeV	17.86	18.25	18.60±1.10	18.82
σ_H[pb], 14 TeV	46.37	47.38	48.76±2.26	48.78

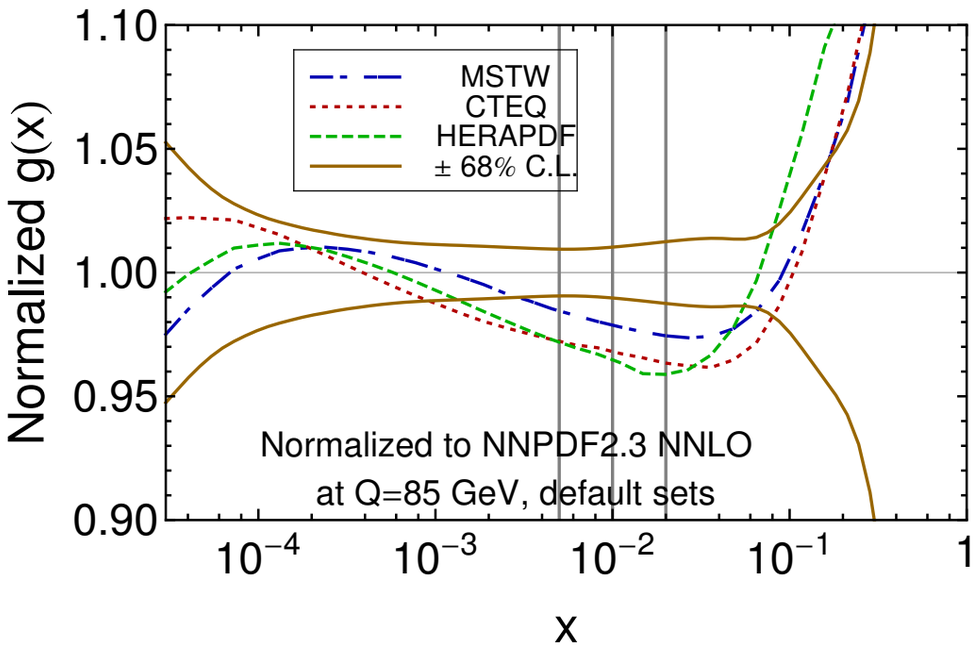
- a common Q2 cut (5 GeV^2), as (0.118) and $m_{c,p}$ (1.4 GeV) choices
- same definition of chi2 in the fitting (d4, see the backup)
- heavy quark schemes and PDF parametrization forms are retained from individual groups
- unconstrained flavor combinations are fixed to optimal values except for NNPDF

- Baseline fits: hierarchy of Higgs cross sections (left) compared to the published NNLO fits (right)





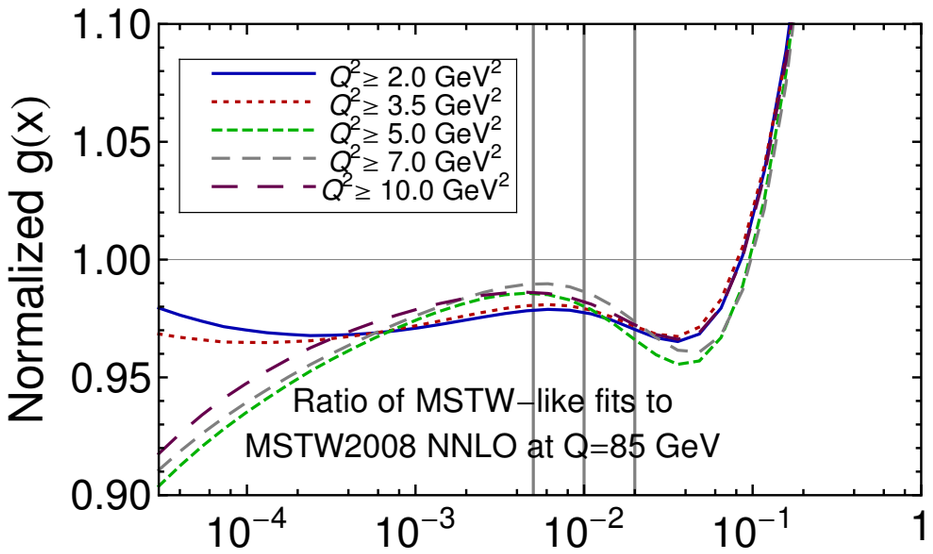




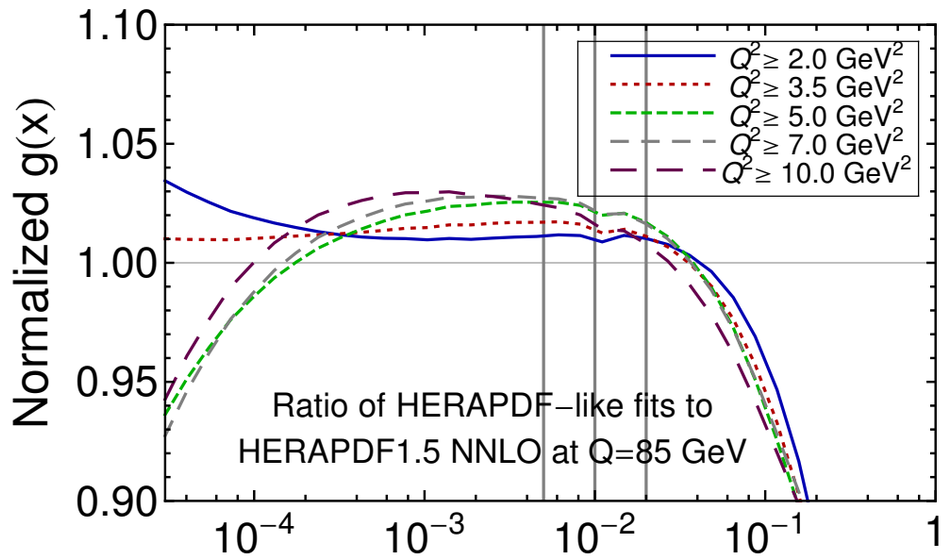
❖ same hierarchy preserved though now well within the PDF uncertainty

- Dependence of the HERA-1-only fits on input assumptions: Q2 cut

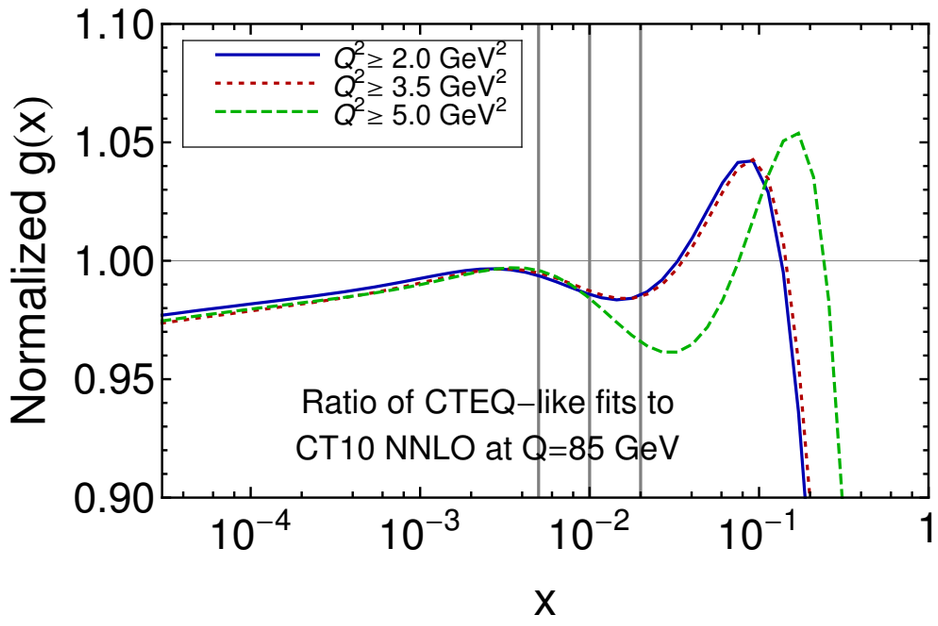
Δσ/σ~0.9%



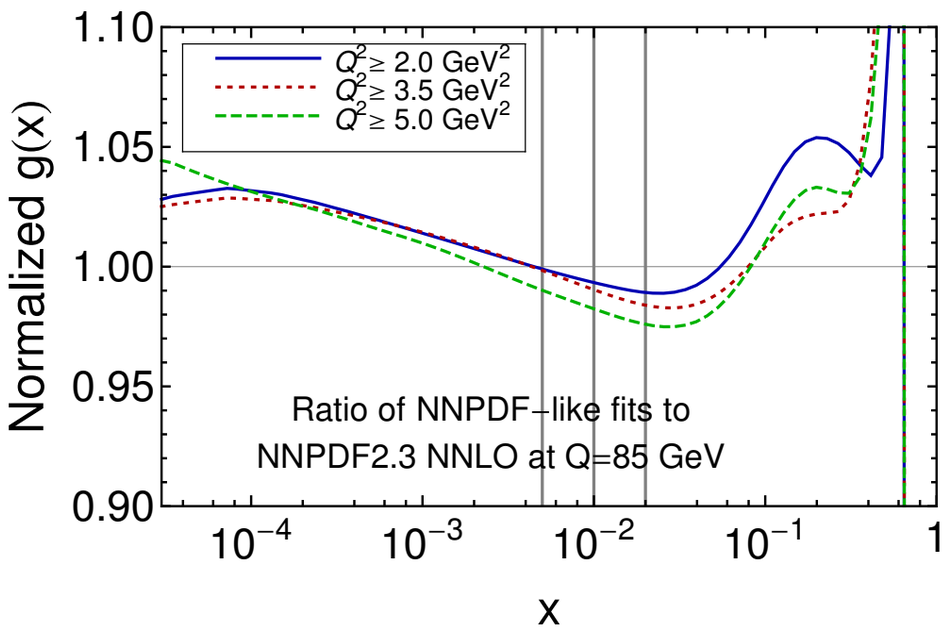
Δσ/σ~1.1%



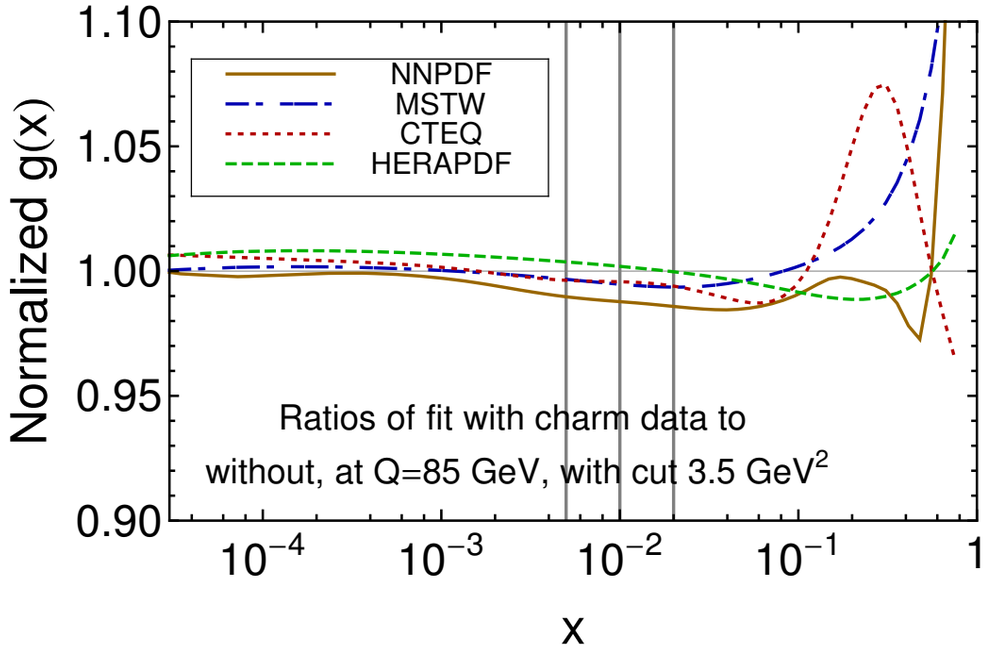
Δσ/σ~1.3%

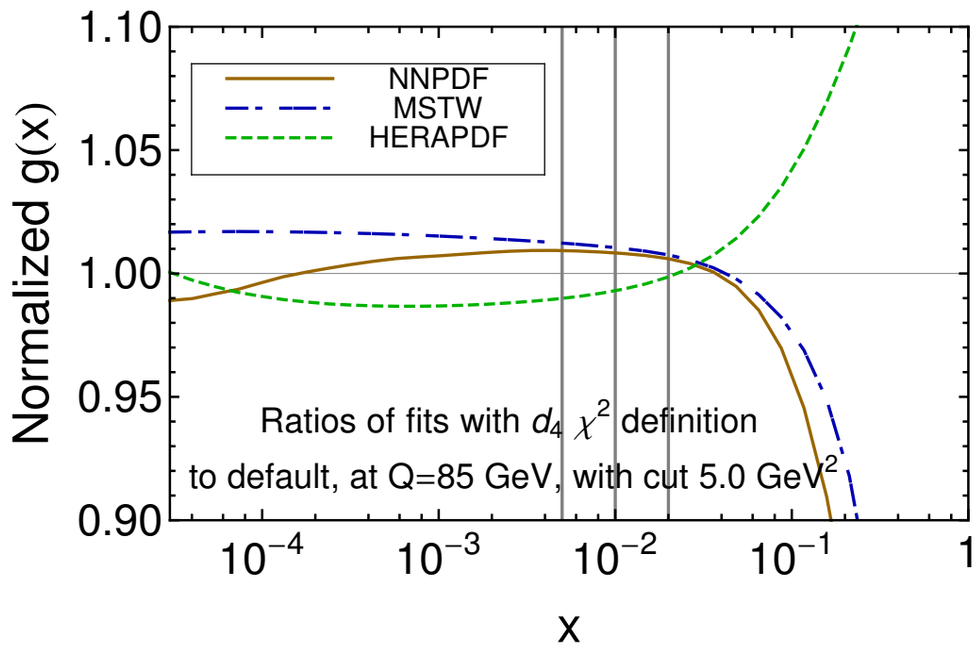


Δσ/σ~2.6%



- Dependence of the HERA-1-only fits on input assumptions: inclusion of HERA charm data, definition of chi2, parametrization forms





cross section shifts after including charm data

	CTEQ	MSTW	NNPDF	HERAPDF
$\delta\sigma_H/\sigma_H$ [%], LHC 8 TeV	-0.7	-0.4	-2.0	-0.2
$\delta\sigma_H/\sigma_H$ [%], LHC 14 TeV	-0.5	-0.4	-1.9	0.2

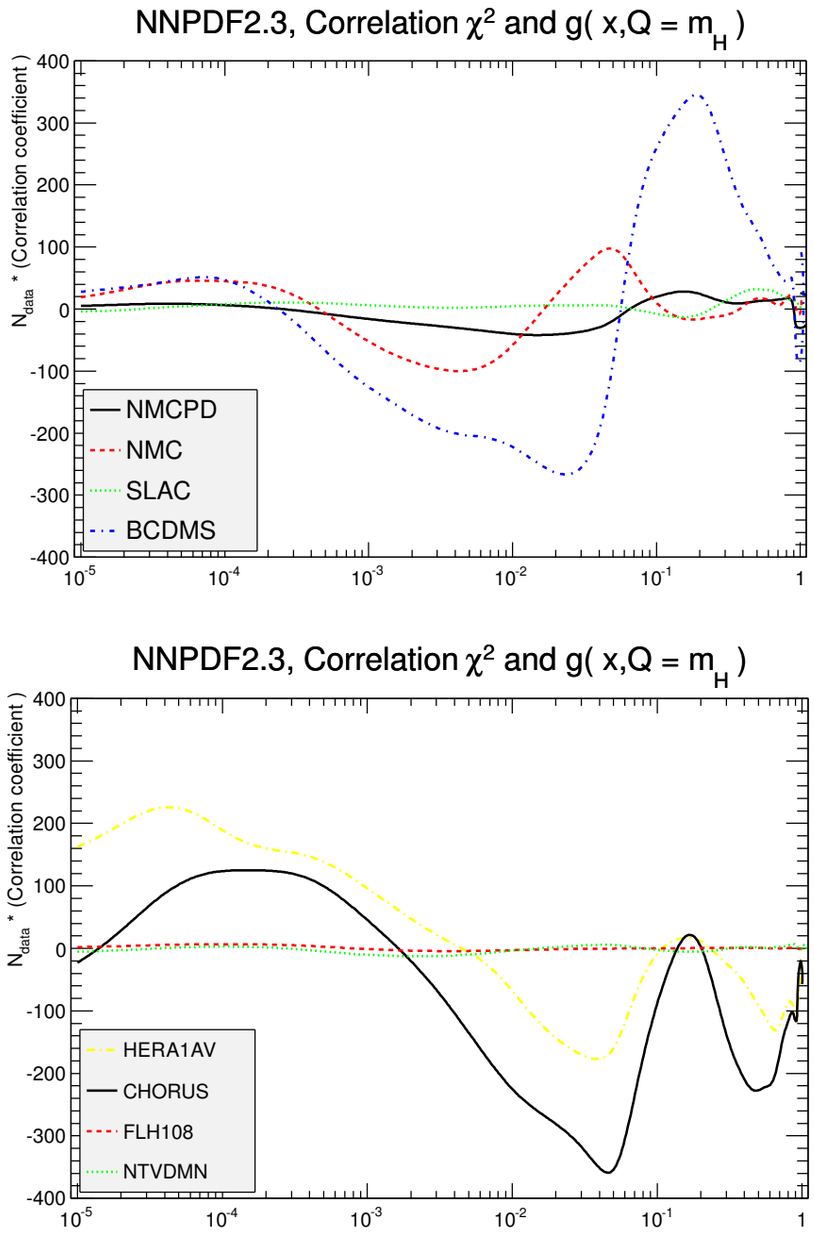
cross section shifts when changing from default chi2 definition to d4

	MSTW	NNPDF	HERAPDF
$\delta\sigma_H/\sigma_H$[%], LHC 8 TeV	-0.4	-1.3	1.2
$\delta\sigma_H/\sigma_H$[%], LHC 14 TeV	0.4	-0.6	0.2

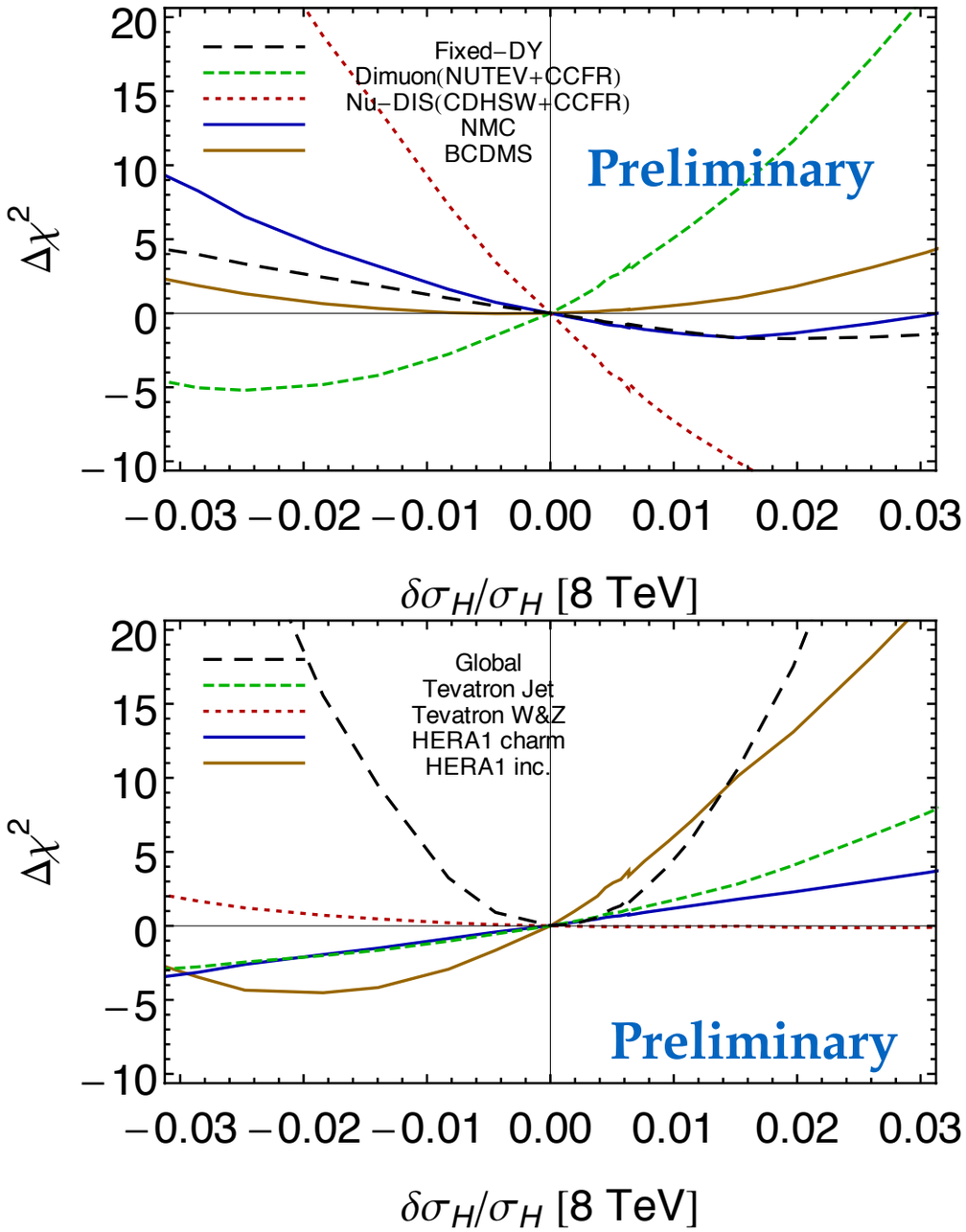
Going beyond the HERA-1 only fits

- Studies involving more data sets: identify the relevant data constraining Higgs cross sections; investigate possible tensions; look for common patterns between different groups

NNPDF2.3 (as=0.119), S. Forte, J. Rojo

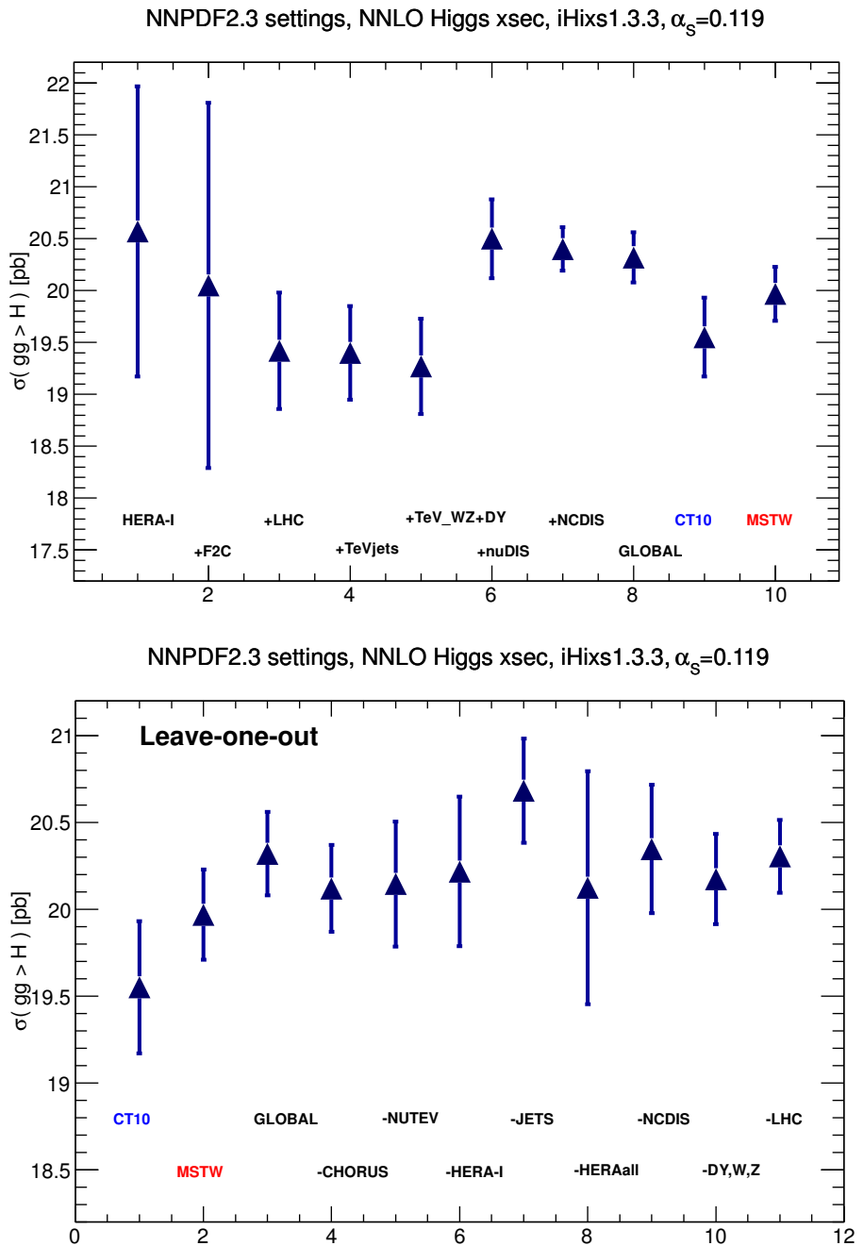


CT10 LM scan (as=0.118), S. Dulat et. al.



- Two possible approaches: adding data sets on top of HERA; removing a single or a group of data sets from global fits

NNPDF2.3 (as=0.119), S. Forte, J. Rojo



Preliminary results from CTEQ and MSTW

- Starting from the baseline fit, adding NMC, BCDMS bring the cross section up by 3~5% for MSTW, 2~3% for CTEQ; adding CDHSW and CCFR neutrino inclusive data increase 2~3% for CTEQ

- CT10, removing HERA-1 combined inclusive DIS data bring the cross section up by ~2%, down by ~3% for removing BCDMS+NMC +CDHSW+CCFR

Summary

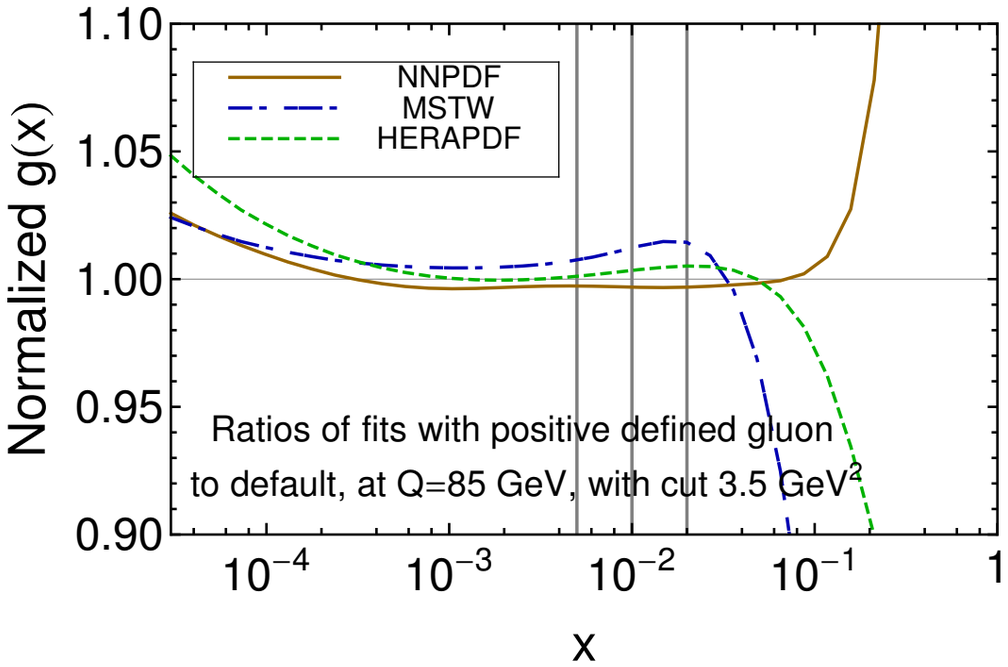
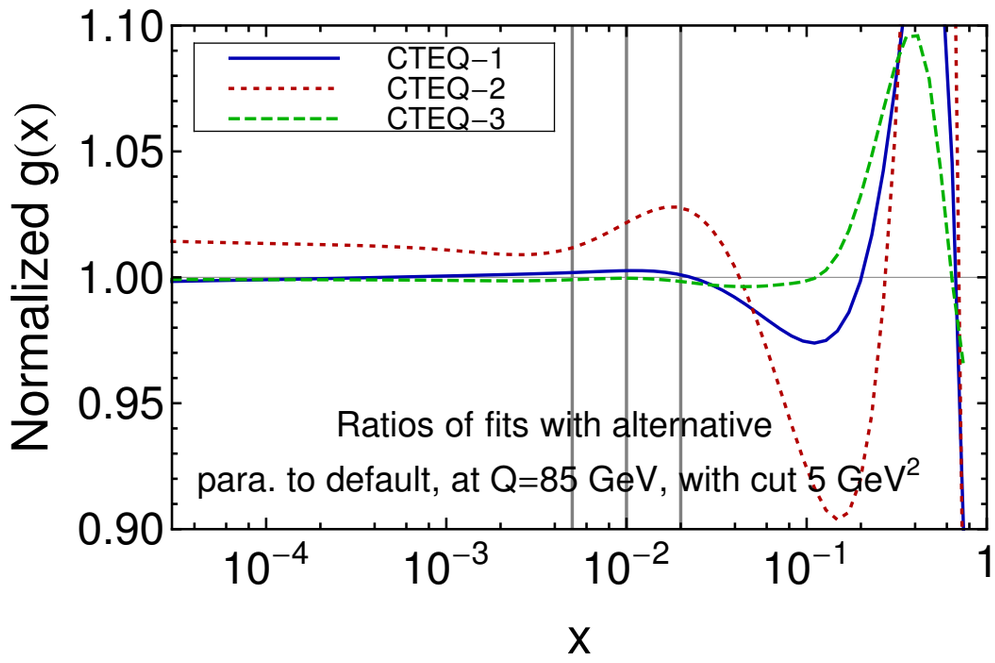
- A systematic study of the PDF dependence of the Higgs cross sections in gluon fusion is needed to understand and possibly reduce theoretical uncertainties in the Higgs coupling measurement.

- In the 2013 LH PDF study, we have shown very good agreement between theoretical calculations of the NC DIS cross sections from 4 groups utilizing GM-VFNS; outputs of Higgs cross sections from HERA-1-only fits are found to be consistent within the PDF uncertainties; we have identified a few input assumptions that may affect the cross sections in the HERA-1-only fits.

- To better understand discrepancies observed in the global analyses, further investigations on theoretical calculations, e.g., CC and dimuon cross sections, as well as effects of other data sets, e.g., various fixed-target experiments, are underway.

Backup

- Definition of chi2 in the HERA-1-only fits

	s_k (sta.)	σ_k (unc. sys.)	$\beta_{k,NL}$ (cor., not lum.)	$\beta_{k,L}$ (lum.)
d_1(exp.)	D_k	D_k	D_k	D_k
d_2(HERAPDF)	$\sqrt{D_k \cdot T_k}$	T_k	T_k	T_k
d_3(NNPDF/MSTW)	D_k	D_k	D_k	T_k
d_4(CTEQ)	D_k	D_k	T_k	T_k

- Parametrization dependence