Improved small-x PDFs and cross sections

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1st FCC Physics Workshop, CERN
16/1/17

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PDF4BSM
Parton Distributions in the Higgs Boson Era

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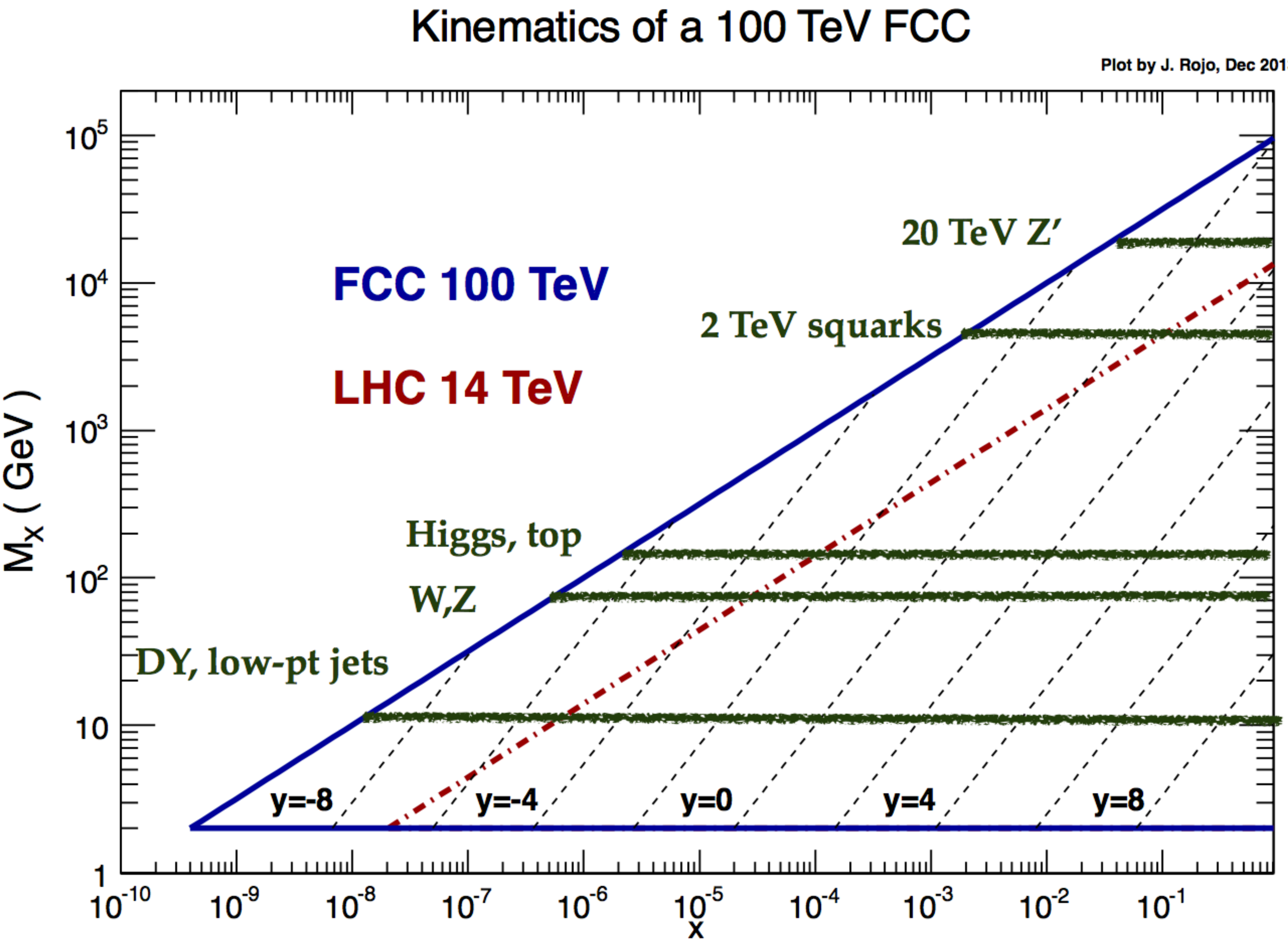


Kinematics of a 100 TeV FCC
Plot by J. Rojo, Dec 2013
FCC 100 TeV
LHC 14 TeV
20 TeV Z′
2 TeV squarks
Higgs, top
W,Z
DY, low-pt jets
y=-8
y=-4
y=0
y=4
y=8
M_X (GeV)
x

PDFs at small-x at the FCC

- At the FCC we can probe the ultra-low x region $x \lesssim 10^{-5}$ in the central region and in the forward region $y \simeq 5,$ down to $x \simeq 10^{-7}$

- Therefore even for inclusive cross sections small-x PDFs are relevant at the FCC and therefore must be sensibly behaved in this region

- Lack of direct experimental observation at ultra low-x means there are large associated uncertainties

PDFs at small-x at the FCC

- At the FCC even for inclusive cross sections the PDF uncertainty is large

- If we impose no kinematic cuts we get 7% uncertainty on inclusive W+ production

NNPDF 3.0

$\sigma(pp \to V \to l_1 l_2)$ [nb] $(\pm\delta_{\rm pdf}\sigma)$	14 TeV		100 TeV		
	No cuts	LHC cuts	No cuts	LHC cuts	FCC cuts
W^+	11.8 (1.9)	6.4 (2.0)	73.5 (7.0)	27.8 (2.9)	52.8 (4.9)
W^-	8.8 (1.8)	4.7 (1.4)	61.9 (5.5)	26.0 (3.0)	44.1 (3.6)
Z	2.0 (1.7)	1.5 (1.8)	14.1 (5.1)	7.9 (3.2)	12.5 (4.1)

NNPDF3.0+LHCb charm

- Using LHCb charm data leads to reduction of PDF uncertainties at small-x

$$N_X^{ij} = \frac{\mathrm{d}^2\sigma(\mathrm{X\ TeV})}{\mathrm{d}y_i^D \mathrm{d}(p_T^D)_j} \Big/ \frac{\mathrm{d}^2\sigma(\mathrm{X\ TeV})}{\mathrm{d}y_{\mathrm{ref}}^D \mathrm{d}(p_T^D)_j}$$

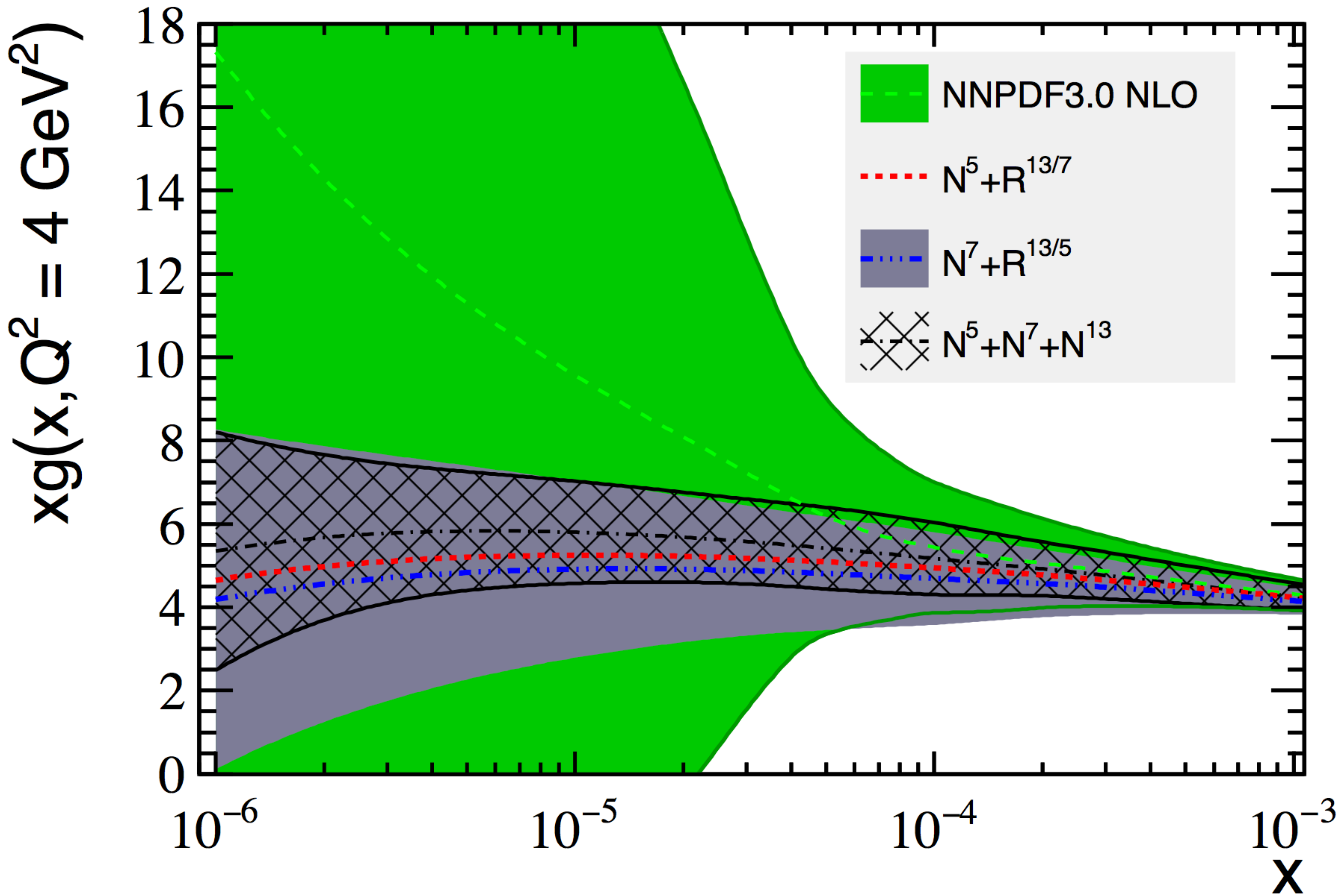
$$R_{13/X}^{ij} = \frac{\mathrm{d}^2\sigma(13\,\mathrm{TeV})}{\mathrm{d}y_i^D \mathrm{d}(p_T^D)_j} \Big/ \frac{\mathrm{d}^2\sigma(\mathrm{X\ TeV})}{\mathrm{d}y_i^D \mathrm{d}(p_T^D)_j}$$

- The combinations $N_5 + N_7 + N_{13}$ and $N_7 + R_{13/5}$ were used for representative combinations of LHCb measurements

- See also (Cacciari, Mangano, Nason, 1507.06197;
  Zenaiev et al., 1503.04581)

R. Gauld, J. Rojo, 1610.09373

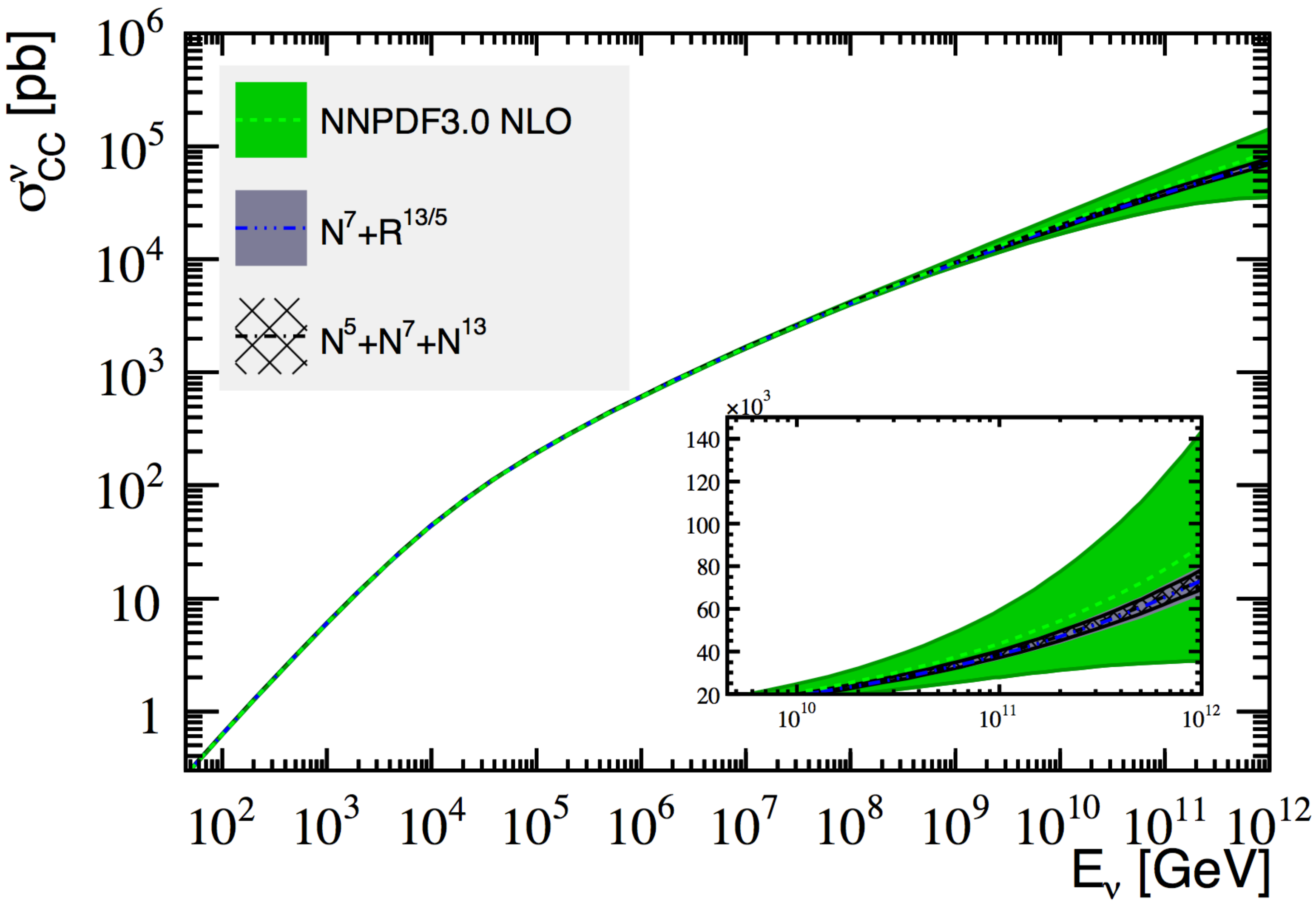
NNPDF3.0+LHCb charm



R. Gauld, J. Rojo, 1610.09373

Implications of small-x data

- UHE charged current neutrino-nucleus cross section probes down to $x \simeq 10^{-8}$



R. Gauld, J. Rojo, 1610.09373

Kinematics

- Imposing the below cuts we computed cross sections and rapidity distributions with MCFMv8.0 to determine how the improved picture at small-x affected the PDF errors for inclusive processes at 100 TeV

Process	FCC Kinematic cuts	LHC Kinematic cuts	Scale choices
W^+	$\lvert\eta_l\rvert < 5$, $p_T^l > 20$ GeV	$\lvert\eta_l\rvert < 2.5$, $p_T^l > 20$ GeV	$\mu_F = \mu_R = m_W$
W^-	$\lvert\eta_l\rvert < 5$, $p_T^l > 20$ GeV	$\lvert\eta_l\rvert < 52.$, $p_T^l > 20$ GeV	$\mu_F = \mu_R = m_W$
Z	$\lvert\eta_l\rvert < 5$, $p_T^l > 20$ GeV	$\lvert\eta_l\rvert < 2.5$, $p_T^l > 20$ GeV	$\mu_F = \mu_R = m_Z$
Direct γ	$\lvert\eta_\gamma\rvert < 5$, $p_T^\gamma > 30$ GeV	$\lvert\eta_\gamma\rvert < 2.5$, $p_T^\gamma > 30$ GeV	$\mu_F = \mu_R = p_T^\gamma$
Off-peak DY	$\lvert\eta_l\rvert < 5$, $p_T^l > 20$ GeV, 20 GeV $< m_{ll} <$ 30 GeV	$\lvert\eta_l\rvert < 2.5$, $p_T^l > 20$ GeV, 20 GeV $< m_{ll} <$ 30 GeV	$\mu_F = \mu_R = m_{ll}$

NNPDF 3.0

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NNPDF 3.0 + N_7 + $R_{13/5}$

$\sigma(pp \to V \to l_1 l_2)$ [nb] ($\pm\delta_{\rm pdf}\sigma$)	14 TeV		100 TeV		
	No cuts	LHC cuts	No cuts	LHC cuts	FCC cuts
W^+	12.2 (1.6)	6.6 (1.7)	73.4 (3.0)	29.0 (2.7)	53.5 (2.8)
W^-	9.1 (1.6)	4.9 (1.7)	62.3 (2.9)	27.2 (2.8)	45.2 (2.8)
Z	2.1 (1.6)	1.5 (1.7)	14.3 (2.8)	8.3 (2.9)	12.8 (2.8)

NNPDF 3.0 + N_5 + N_7 + N_{13}

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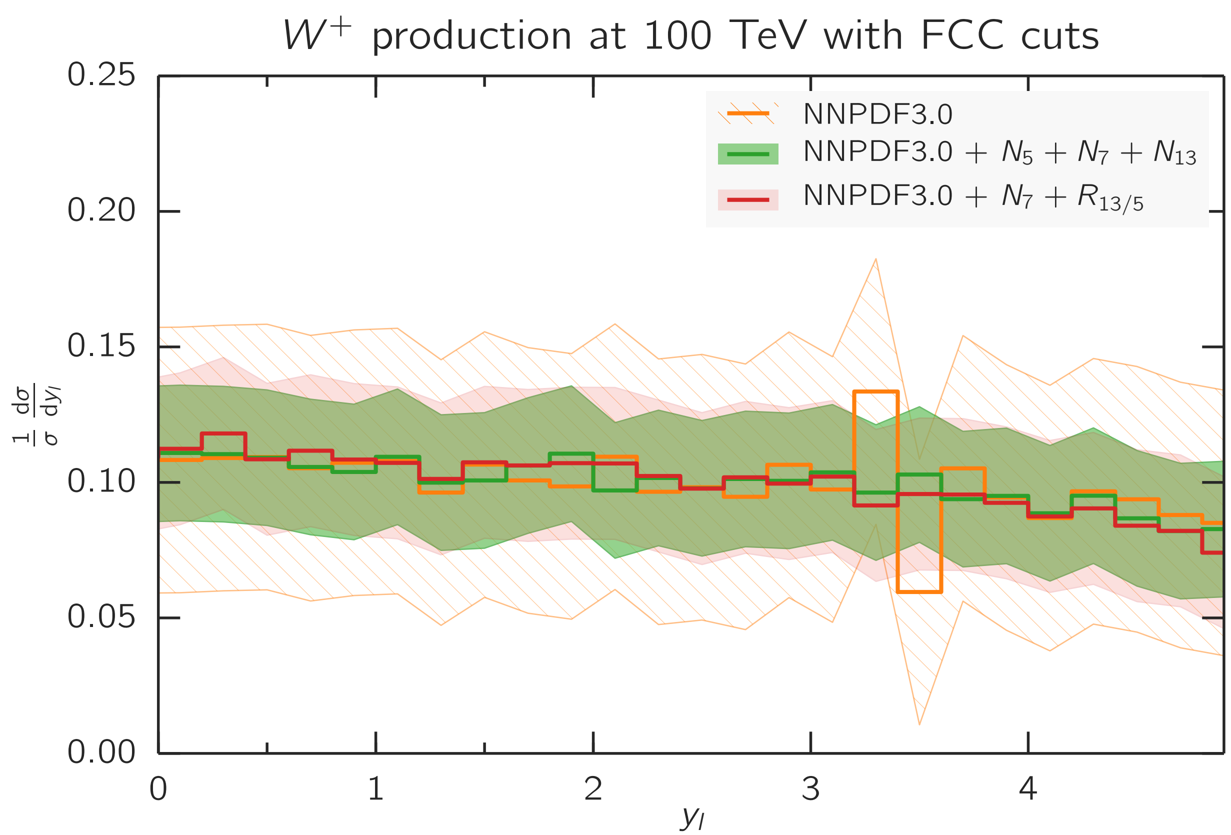
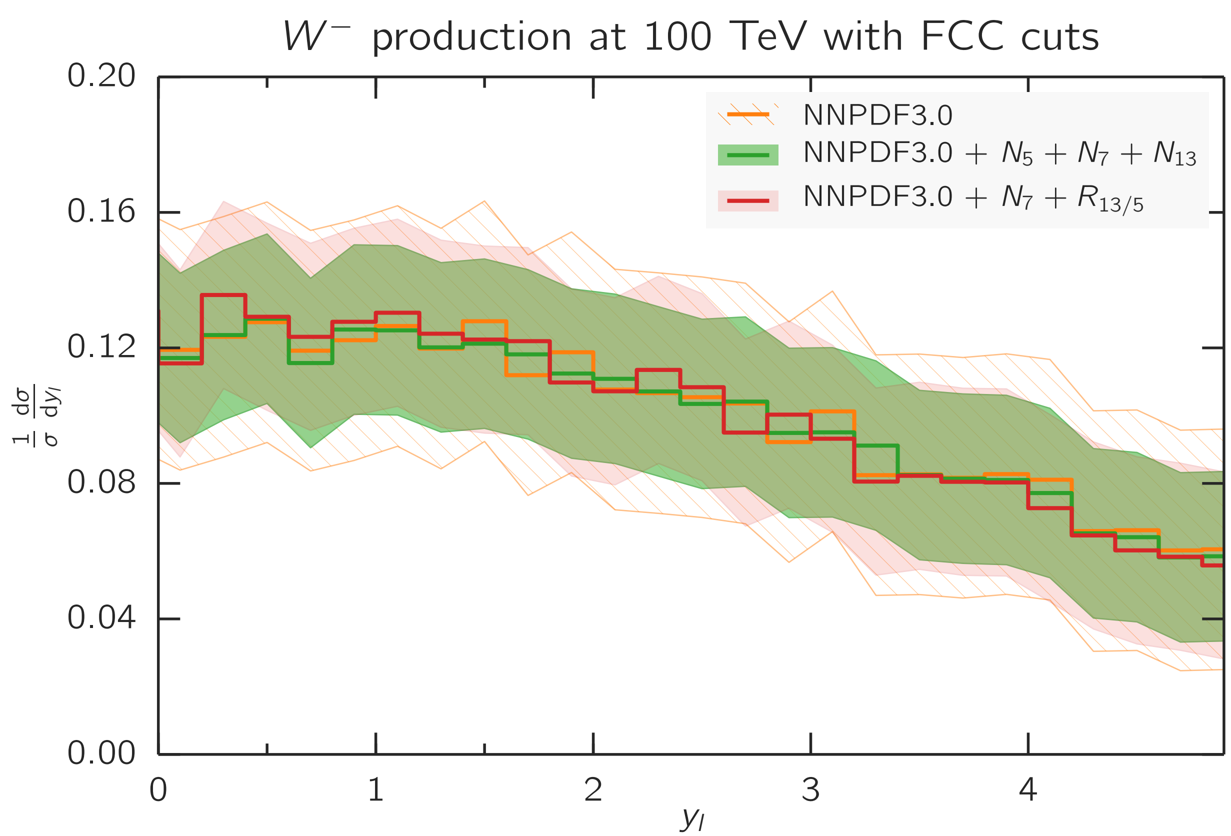
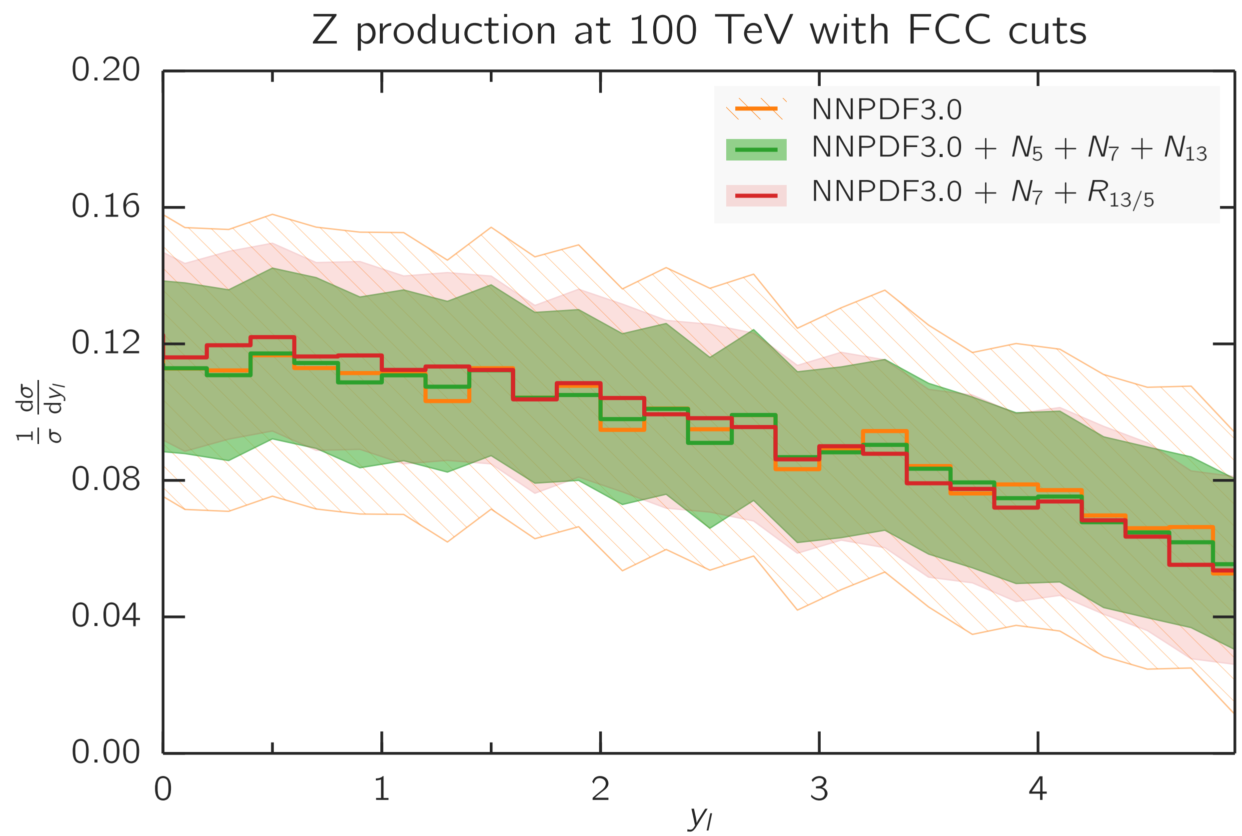
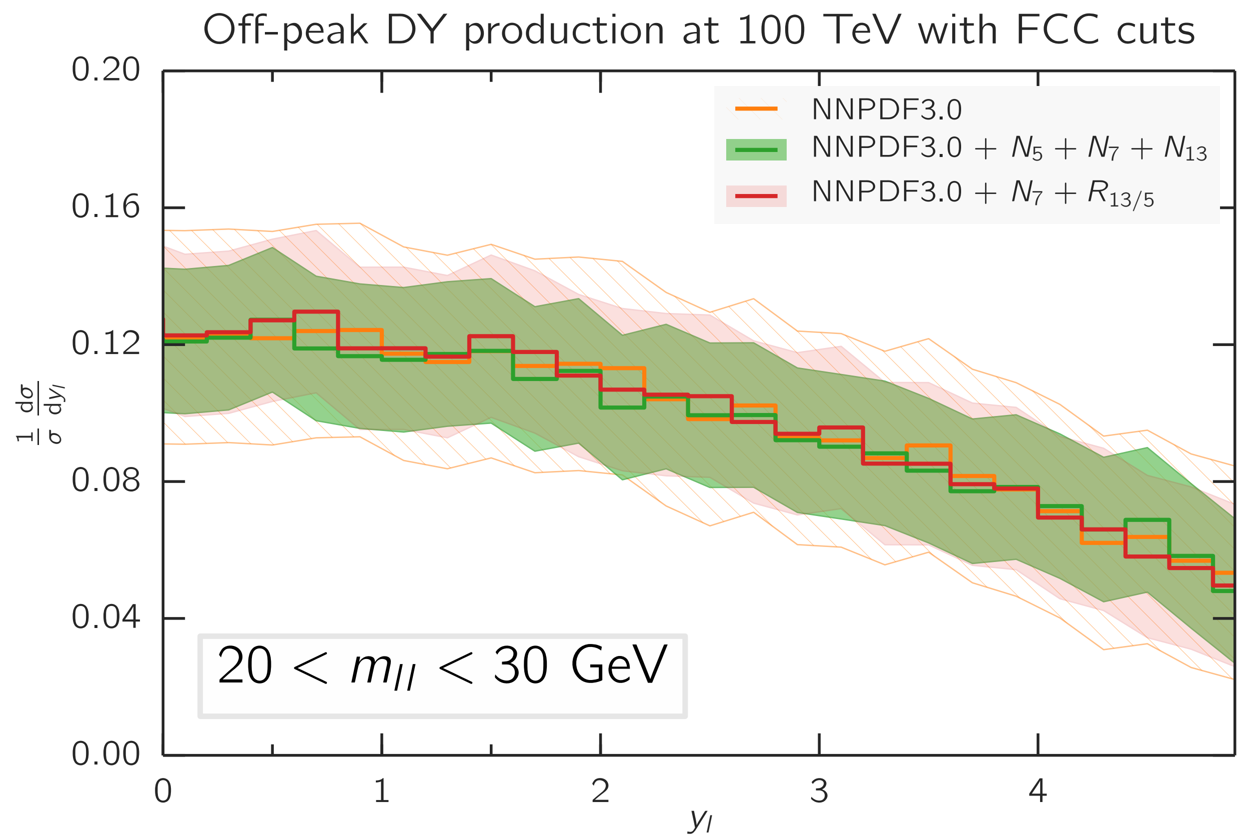
Rapidity distributions

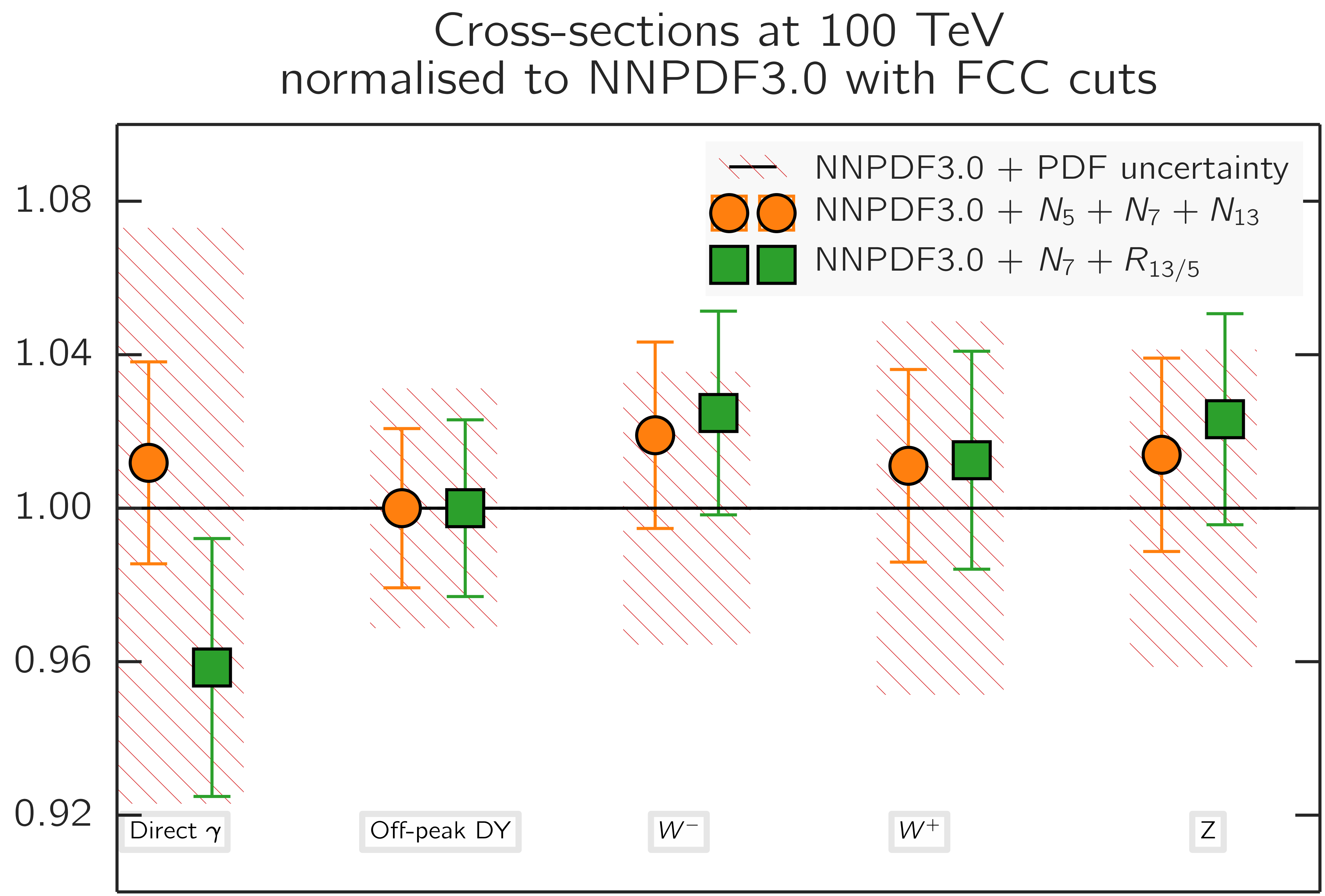




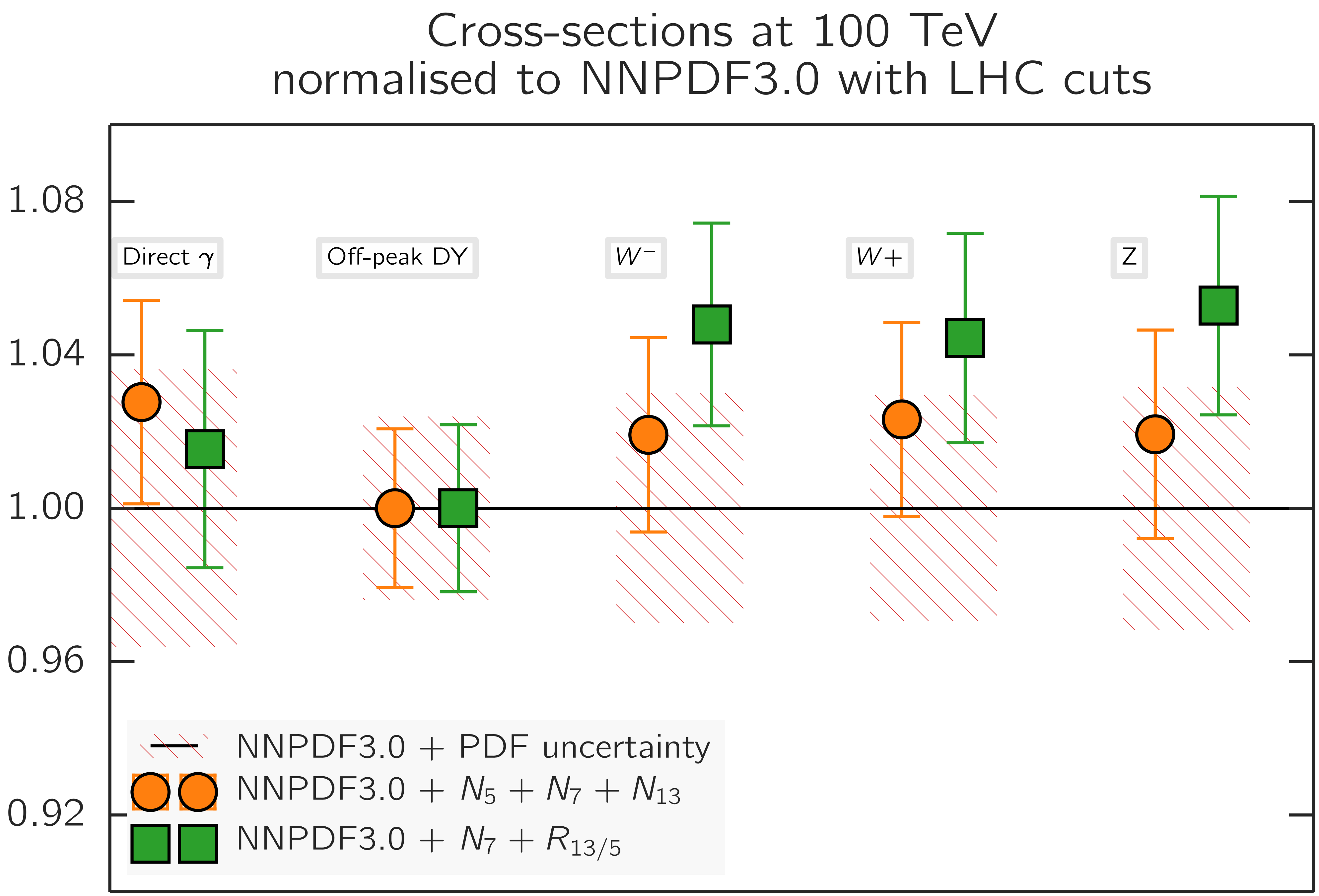
Rapidity distributions

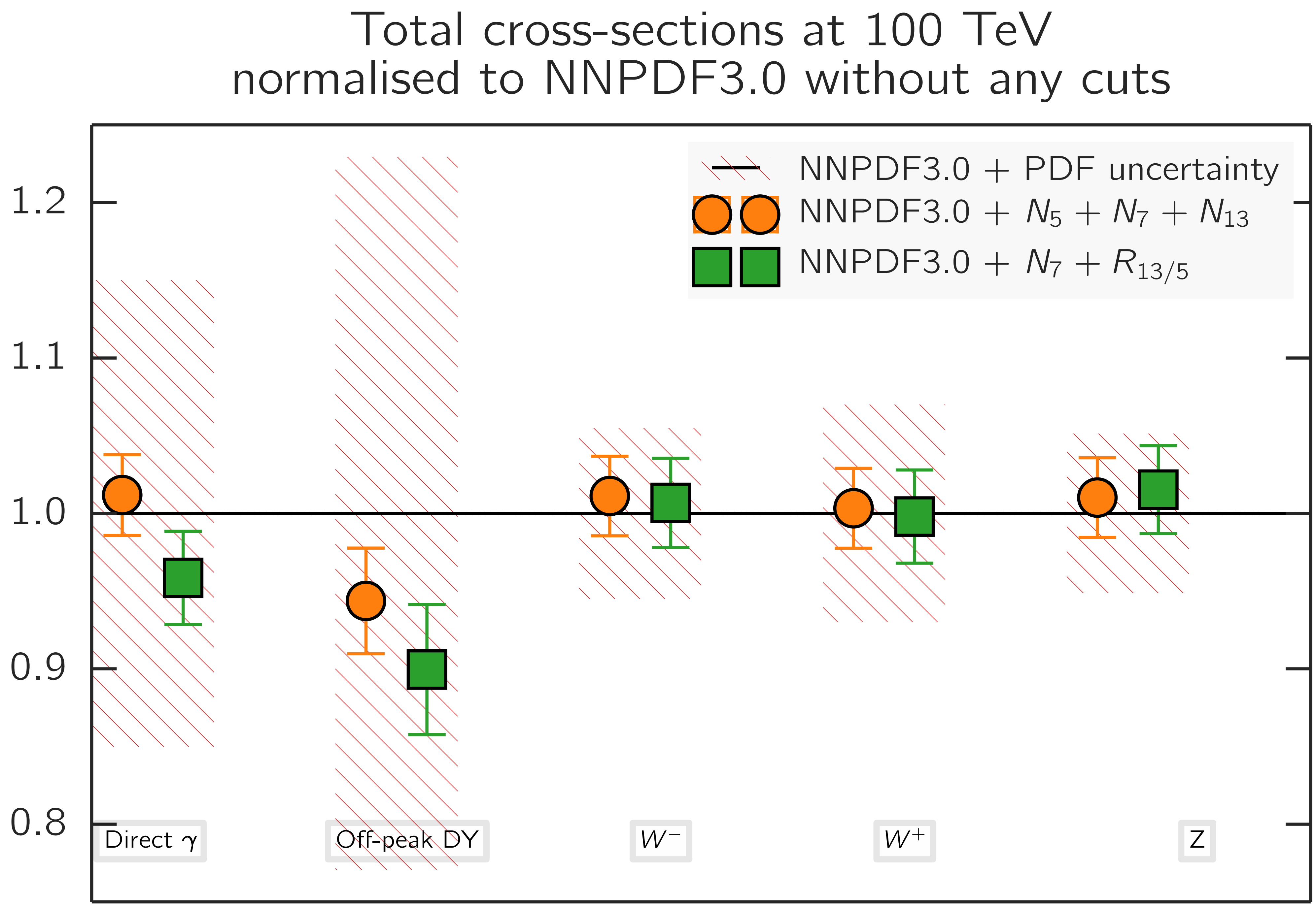






Cross-sections at 100 TeV
normalised to NNPDF3.0 with FCC cuts
NNPDF3.0 + PDF uncertainty
NNPDF3.0 + N_5 + N_7 + N_{13}
NNPDF3.0 + N_7 + $R_{13/5}$
1.08
1.04
1.00
0.96
0.92
Direct γ
Off-peak DY
W^-
W^+
Z


Cross-sections at 100 TeV
normalised to NNPDF3.0 with LHC cuts
1.08
1.04
1.00
0.96
0.92
Direct γ
Off-peak DY
W^-
$W+$
Z
NNPDF3.0 + PDF uncertainty
NNPDF3.0 + N_5 + N_7 + N_{13}
NNPDF3.0 + N_7 + $R_{13/5}$



Total cross-sections at 100 TeV
normalised to NNPDF3.0 without any cuts
NNPDF3.0 + PDF uncertainty
NNPDF3.0 + N_5 + N_7 + N_{13}
NNPDF3.0 + N_7 + $R_{13/5}$
1.2
1.1
1.0
0.9
0.8
Direct γ
Off-peak DY
W^-
W^+
Z

Summary and outlook

- Including forward charm production from LHCb improves the small-x gluon PDF
- The increase in PDF uncertainty at 100 TeV in the case of NNPDF stems the large rapidity region which probes small-x
- The kinematic coverage of the FCC means that a better understanding of ultra small-x is needed
- Next step is to extend our results to other processes such as heavy quark pair production and differential Higgs measurements (Any suggestions very welcome!)

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Thank you!