OROS application: global fit with NN models

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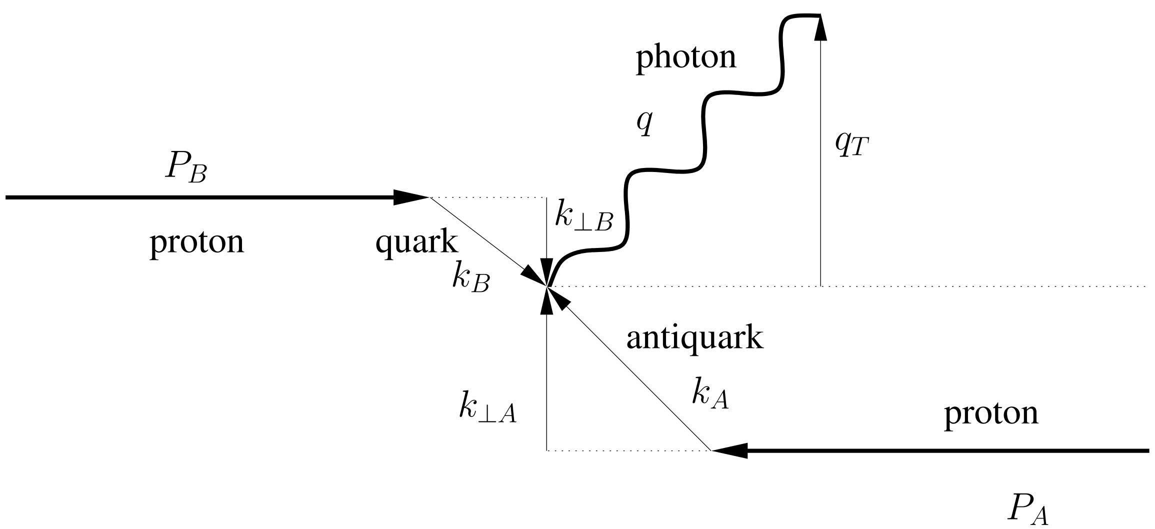
MAP Meeting

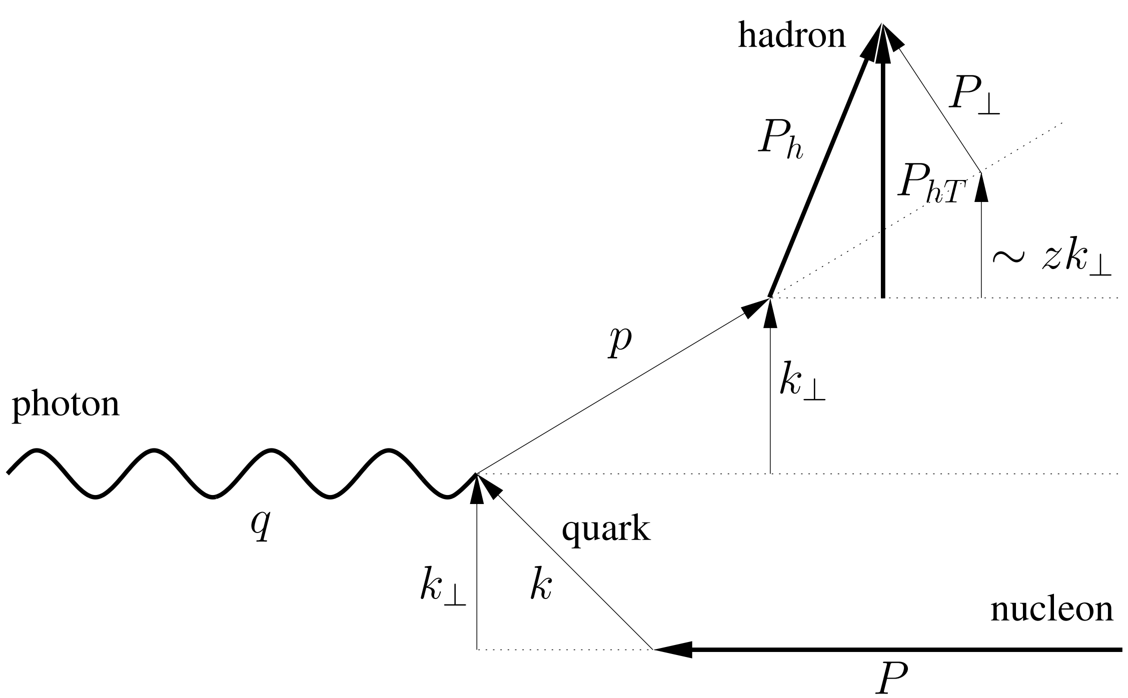
Pavia, 28/04/2026

Global fits of TMDs



Drell-Yan/Z-boson production

$$d\sigma \simeq f_1^q(x_1, k_{\perp 1}) \otimes f_1^{\bar{q}}(x_2, k_{\perp 2})$$



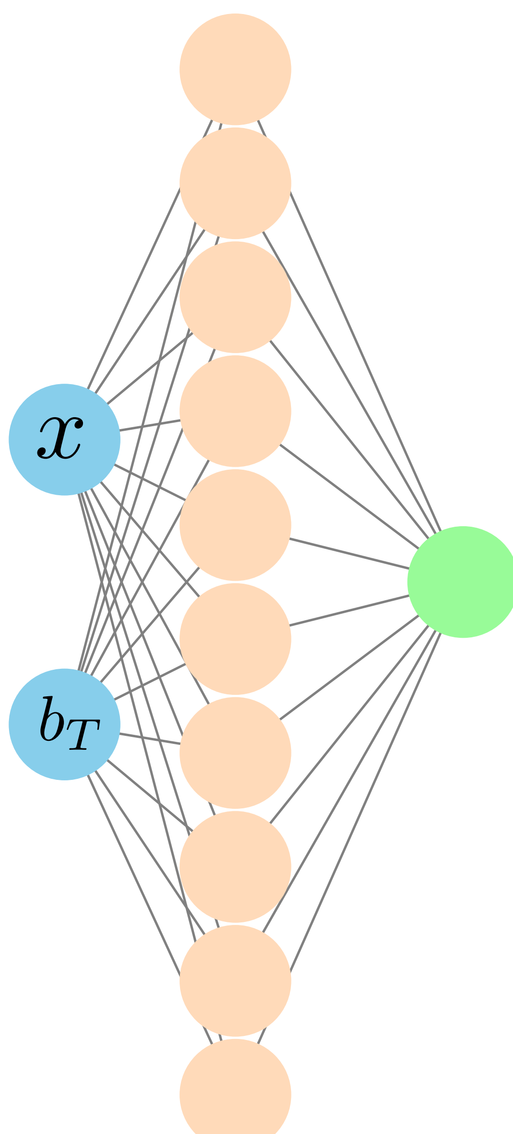
semi-inclusive DIS

$$d\sigma \simeq f_1^q(x, k_\perp) \otimes D_1^{q\rightarrow h}(z, p_\perp)$$

Implementation of NN model

$$f_{\mathrm{NP}}(x, b_T; \zeta) = \frac{\mathbb{NN}(x, b_T, \{p_i\})}{\mathbb{NN}(x, 0, \{p_i\})} \exp\left[-g_2^2\, b_T^2\, \ln\left(\frac{\zeta}{Q_0^2}\right)\right]$$

41+1 parameters



$\mathbb{NN}(x, b_T)$

only one output node because there is no flavour dependence (yet)

with activation function

$$\sigma(z) = \frac{1}{2}\left(1 + \frac{z}{1+|z|}\right)$$

physically required constraints

$f_{\mathrm{NP}} \to 1$ **for** $b_T \to 0$

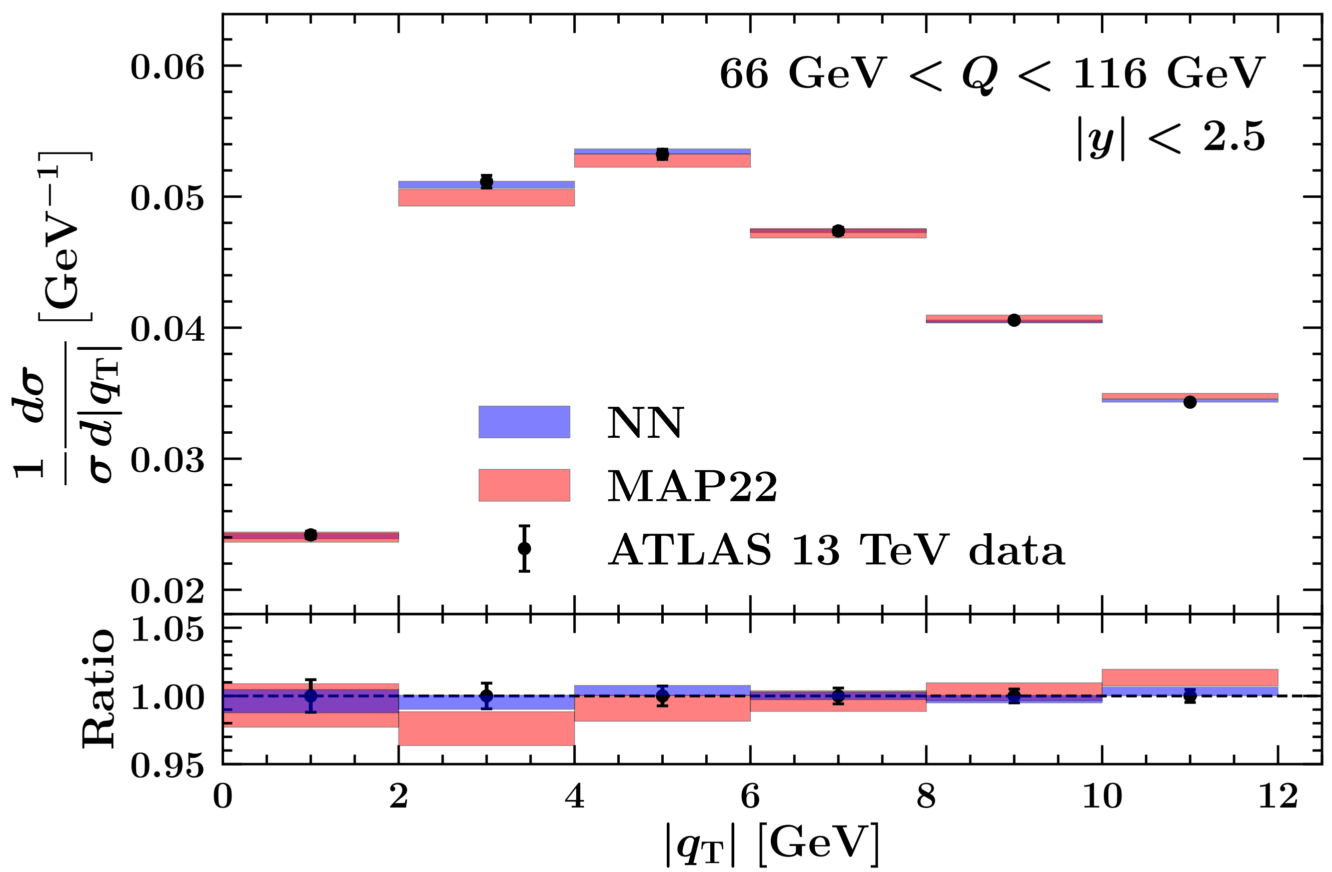
MAP Collaboration, PRL 135 (2025)

Results from last year

Theory/Data agreement

MAP Collaboration, PRL 135 (2025)

Experiment	$N_{\rm dat}$	$\overline{\chi}^2$ $(\overline{\chi}^2_D + \overline{\chi}^2_\lambda)$ NN	MAP22
Fixed-target	233	1.08 (0.98 + 0.10)	0.91 (0.70 + 0.21)
RHIC	7	1.11 (1.03 + 0.07)	1.45 (1.37 + 0.08)
Tevatron	71	0.80 (0.73 + 0.06)	1.20 (1.17 + 0.04)
LHCb	21	0.98 (0.88 + 0.10)	1.25 (1.05 + 0.20)
CMS	78	0.40 (0.38 + 0.02)	0.41 (0.35 + 0.06)
ATLAS	72	1.38 (1.09 + 0.29)	3.51 (3.03 + 0.49)
Total	482	0.97 (0.86 + 0.11)	1.28 (1.09 + 0.20)



NN provide better quality than MAP22

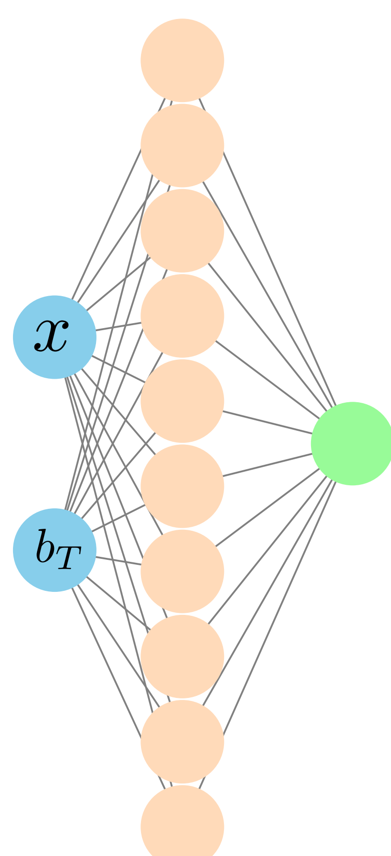
Significant improvement for ATLAS data

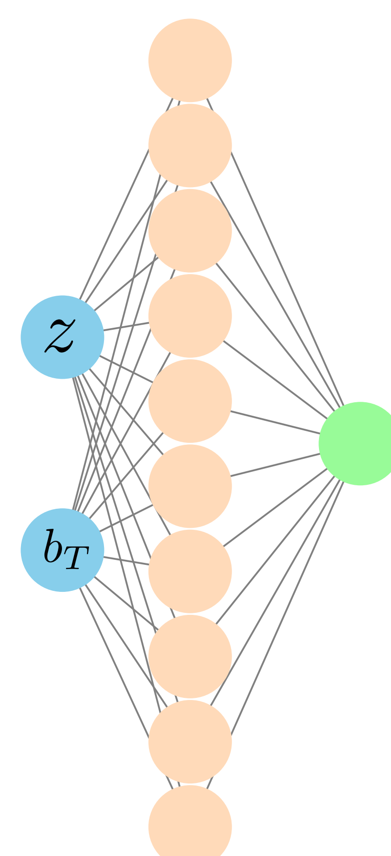
MAP22 relies more on systematic shifts ⇒ large error bands

Extension to SIDIS

$$f_{\mathrm{NP}}(x, b_T; \zeta) = \frac{\mathbb{NN}\big(x, b_T, \{p_i\}\big)}{\mathbb{NN}\big(x, 0, \{p_i\}\big)} \exp\left[-g_2^2\, b_T^2\, \ln\left(\frac{\zeta}{Q_0^2}\right)\right]$$

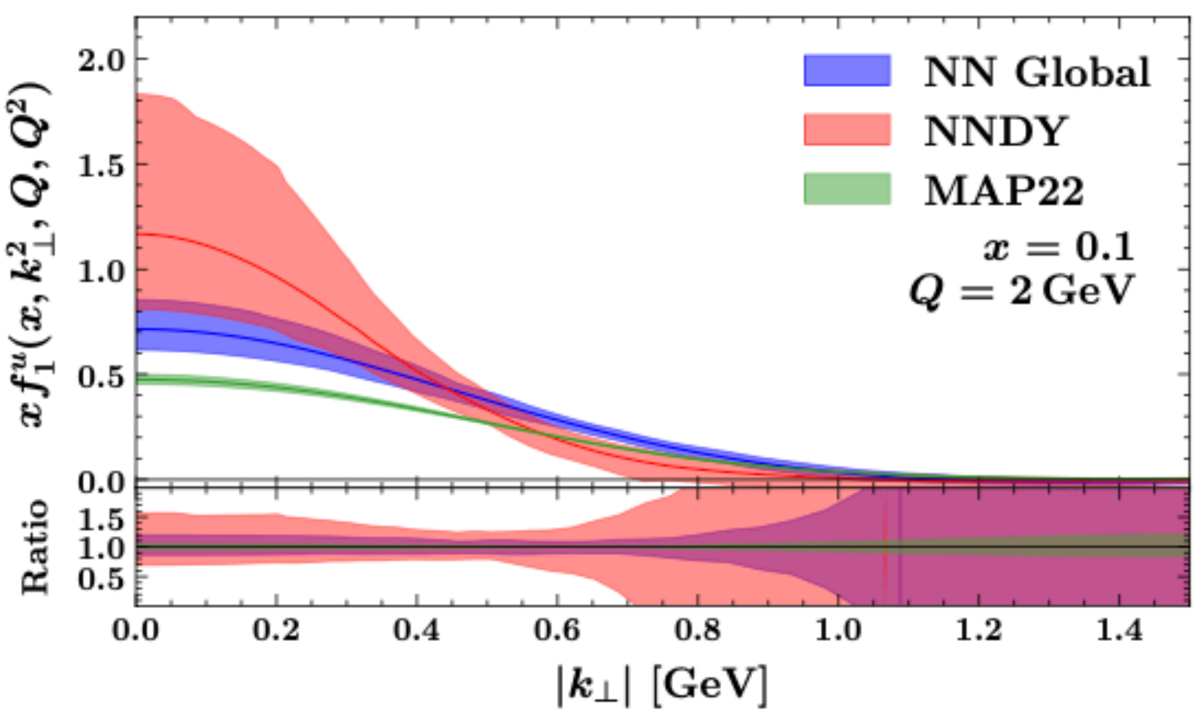
$$D_{\mathrm{NP}}(z, b_T; \zeta) = \frac{\mathbb{NN}(z, b_T, \{p'_j\})}{\mathbb{NN}(z, 0, \{p'_j\})} \exp\left[-g_2^2 b_T^2 \ln\left(\frac{\zeta}{Q_0^2}\right)\right]$$

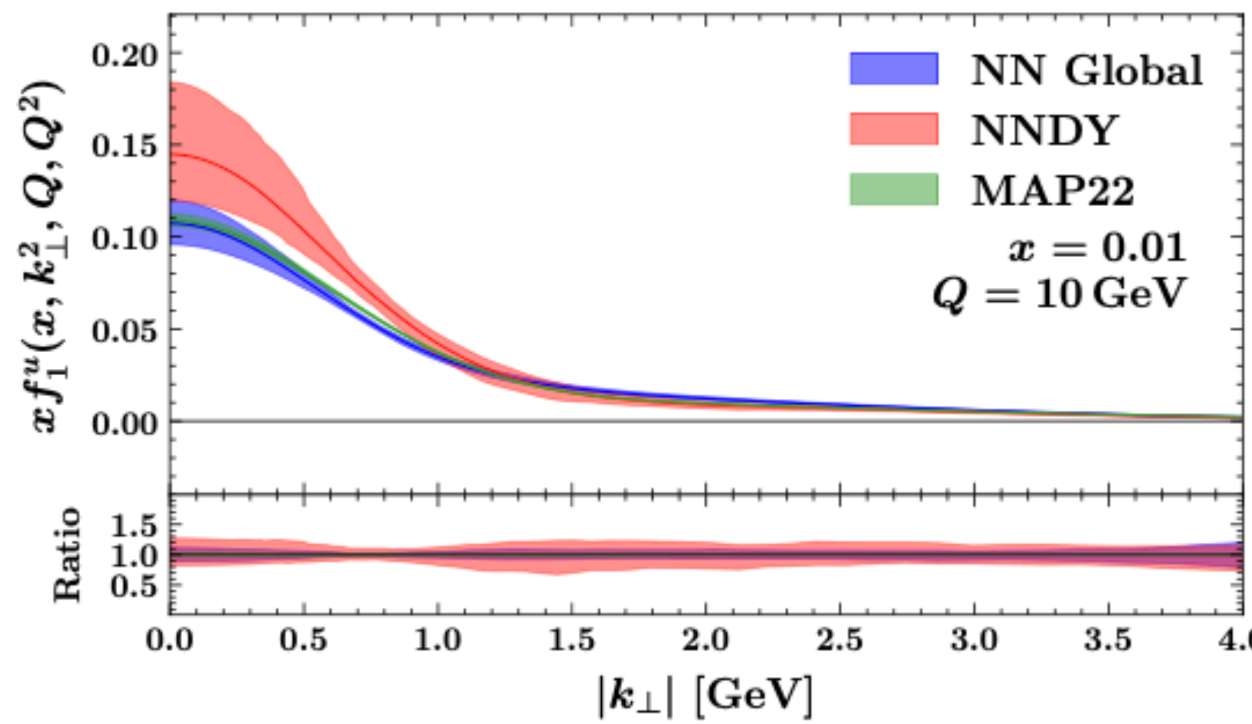




41 + 41+1 parameters

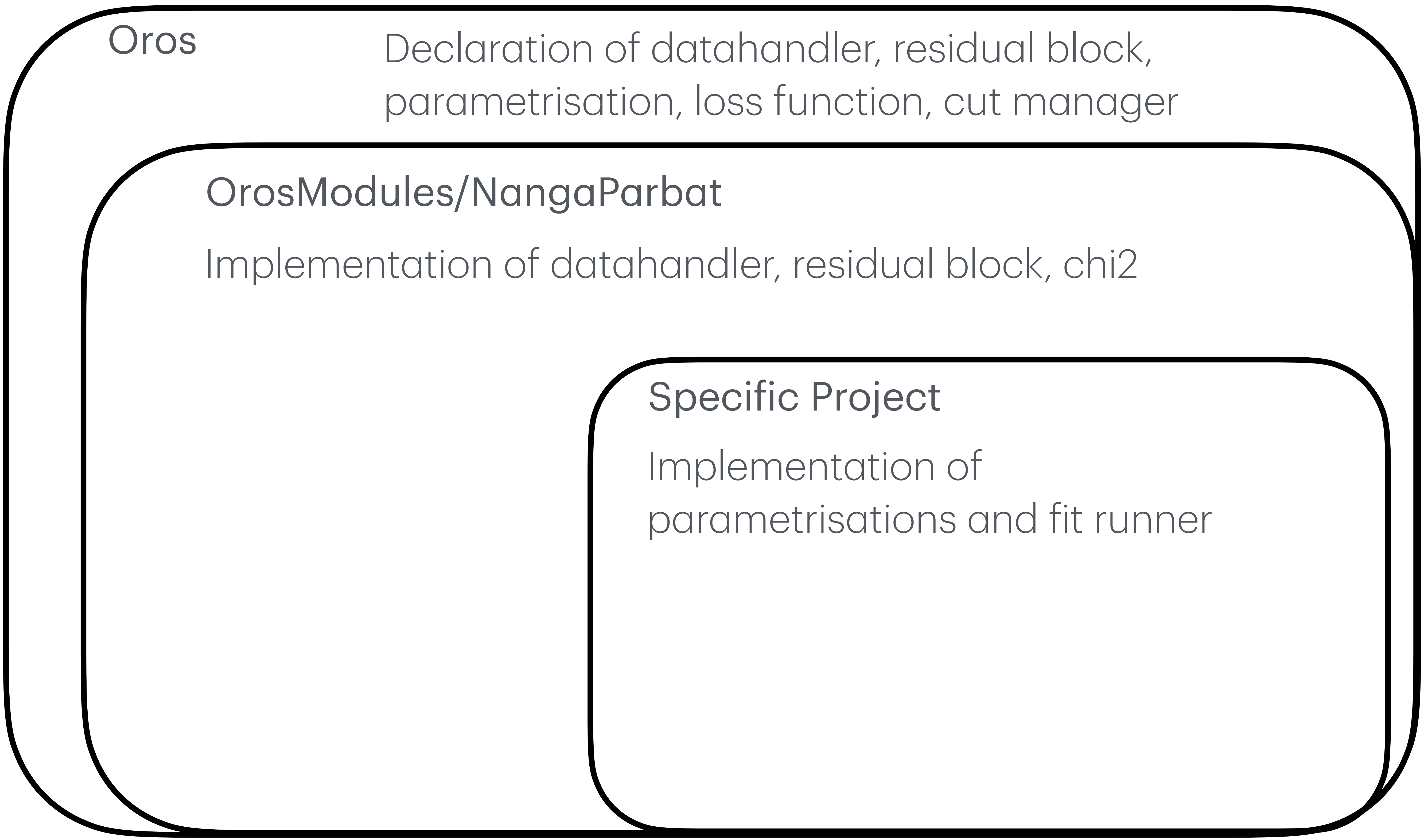
Extension to SIDIS





- NN Global is broader than NN DY-only — **effect of the tensions?**
- Uncertainty bands are smaller than NN DY-only — **constraints from SIDIS**
- But still larger than MAP22 — **more faithful representation of errors**

The Oros chain implemented



First crosscheck: fit DY only

Fit quality

WORK IN PROGRESS ——— $\chi^2/N \sim 1$

Performances

Significant improvement w.r.t NangaParbat-Beta

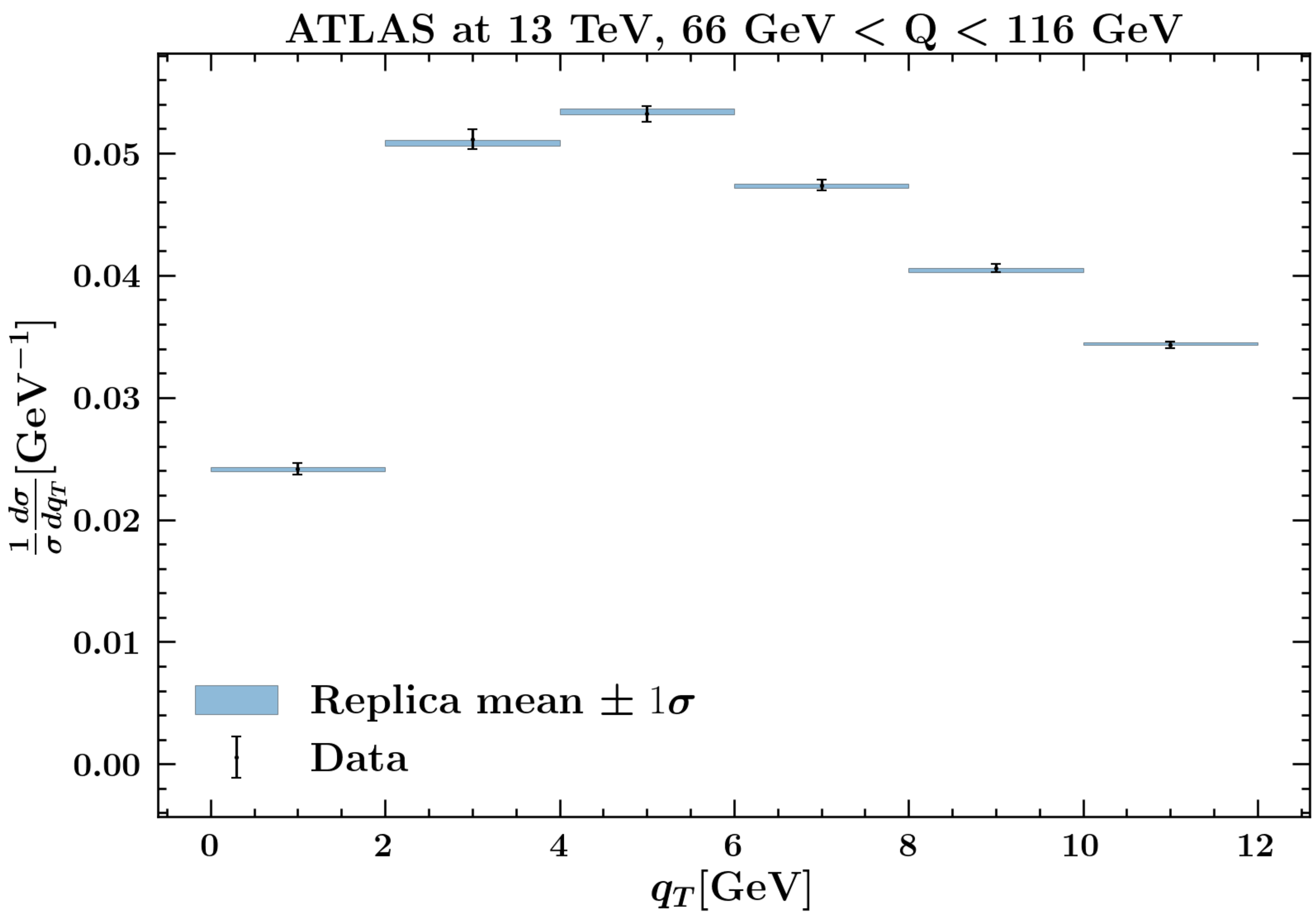
NangaParbat-Beta : **1 fit ~ 1 hour** (no parallelisation)

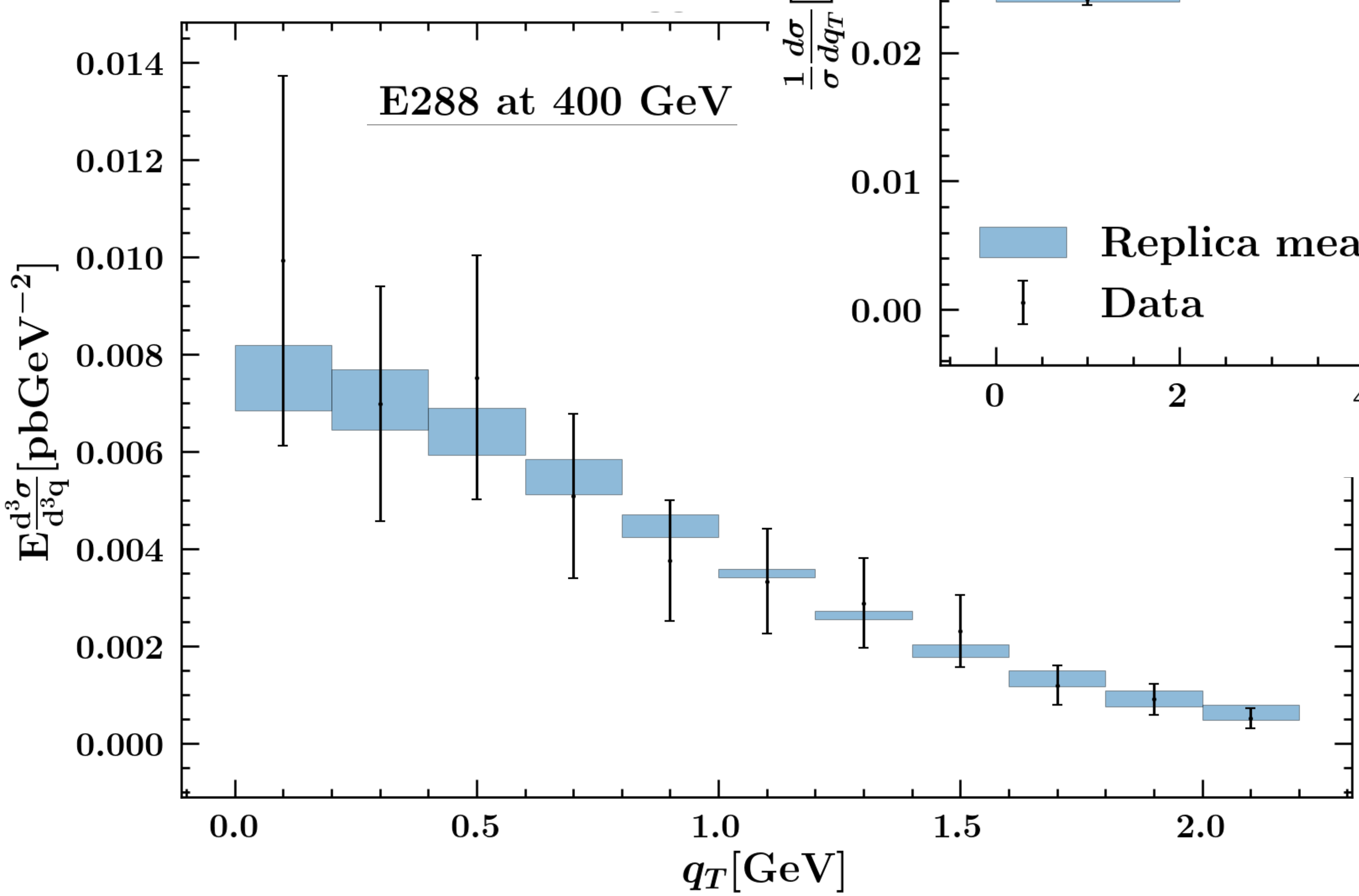
Oros implementation: **1 fit ~ 8 mins**

Running on cluster

First crosscheck: fit DY only

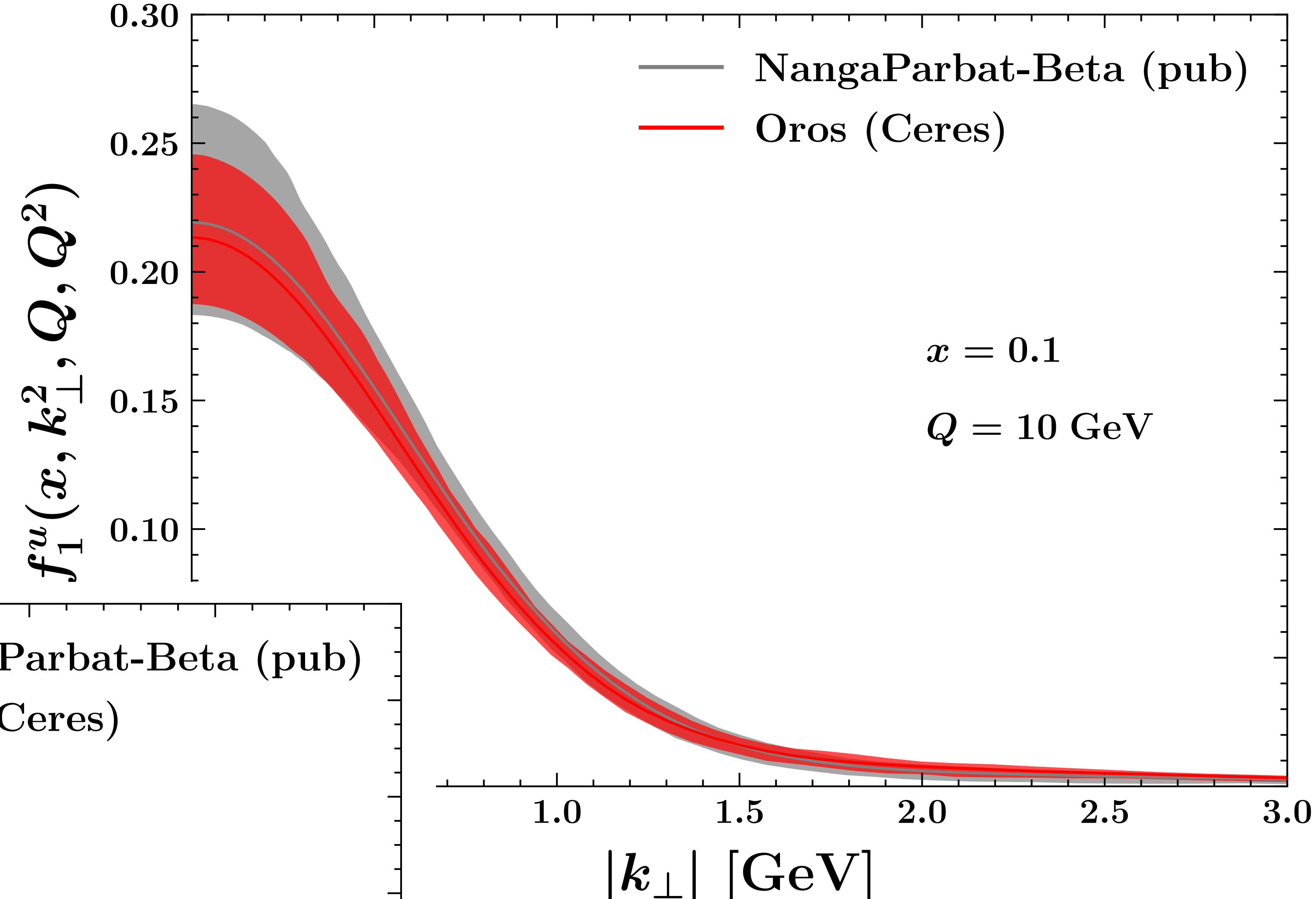
Data/Theory plots

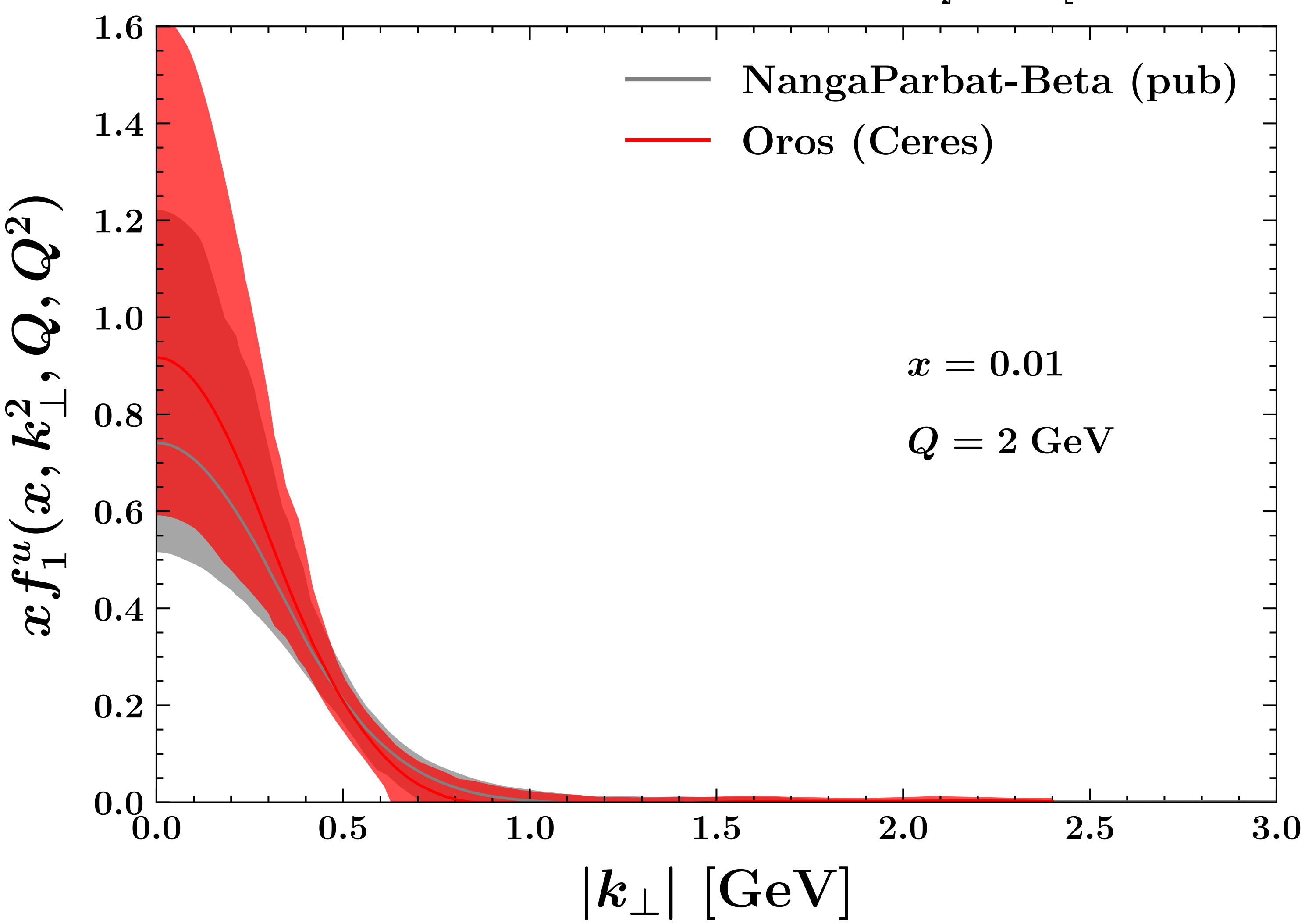




First crosscheck: fit DY only

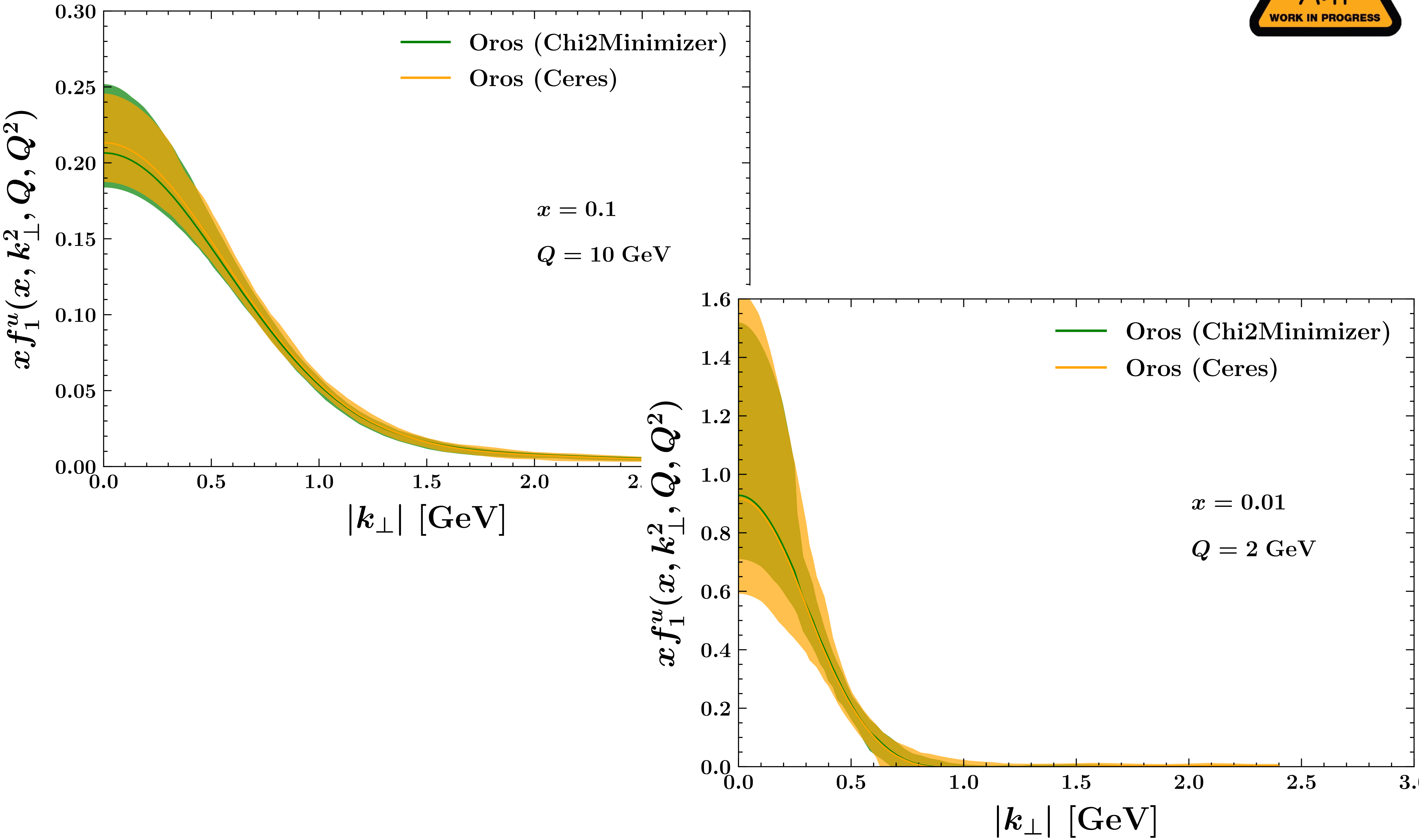
Extracted TMDs





First crosscheck: fit DY only

Different minimisers (Ceres vs internal minimiser)



Second crosscheck: global fit

Fit quality

WORK IN PROGRESS ——— $\chi^2/N \sim 1$

Performances

Significant improvement w.r.t NangaParbat-Beta

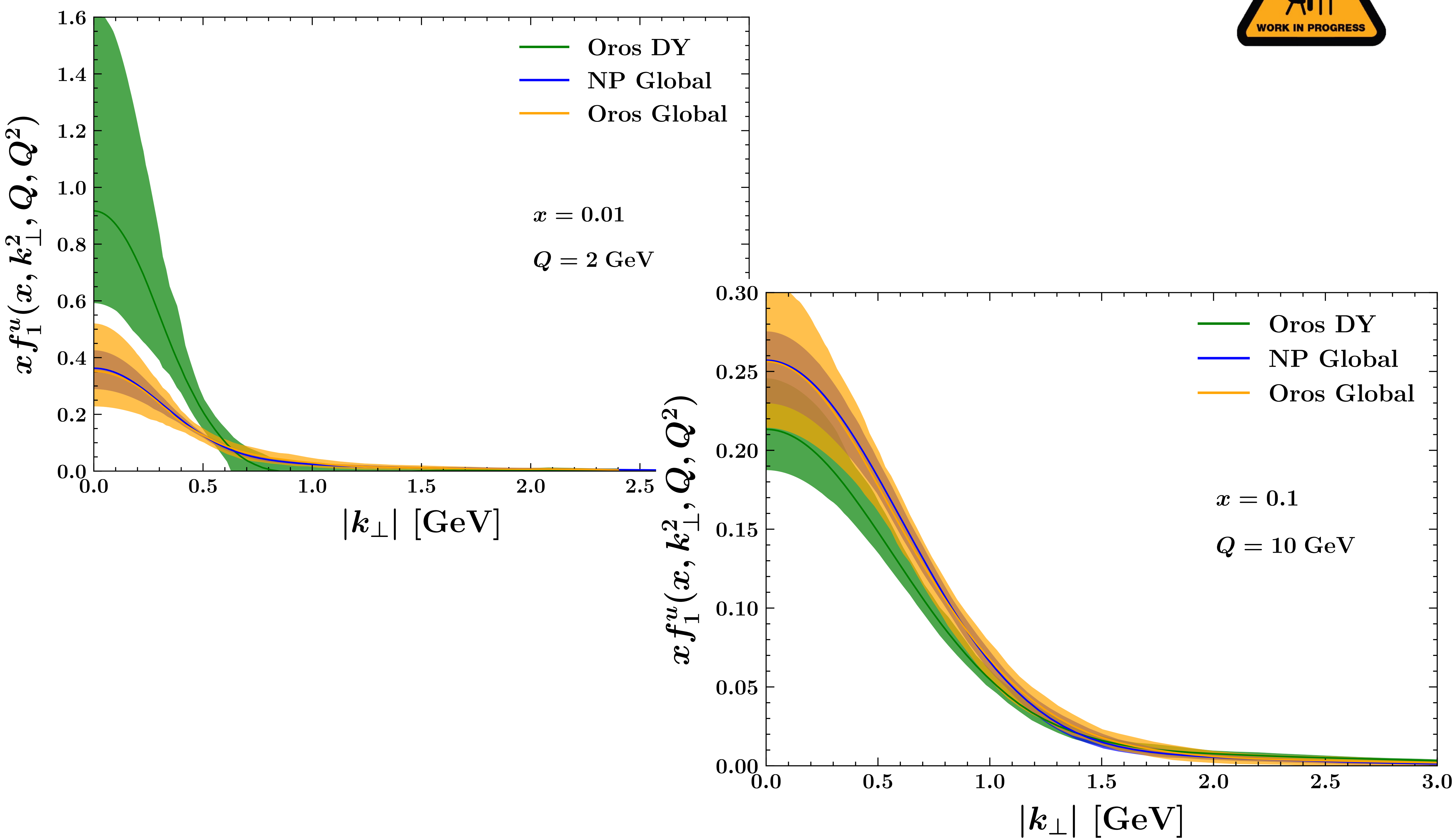
NangaParbat-Beta : **1 fit ~ 5 hours** (no parallelisation)

Oros implementation: **1 fit ~ 25 mins**

Running on PV cluster

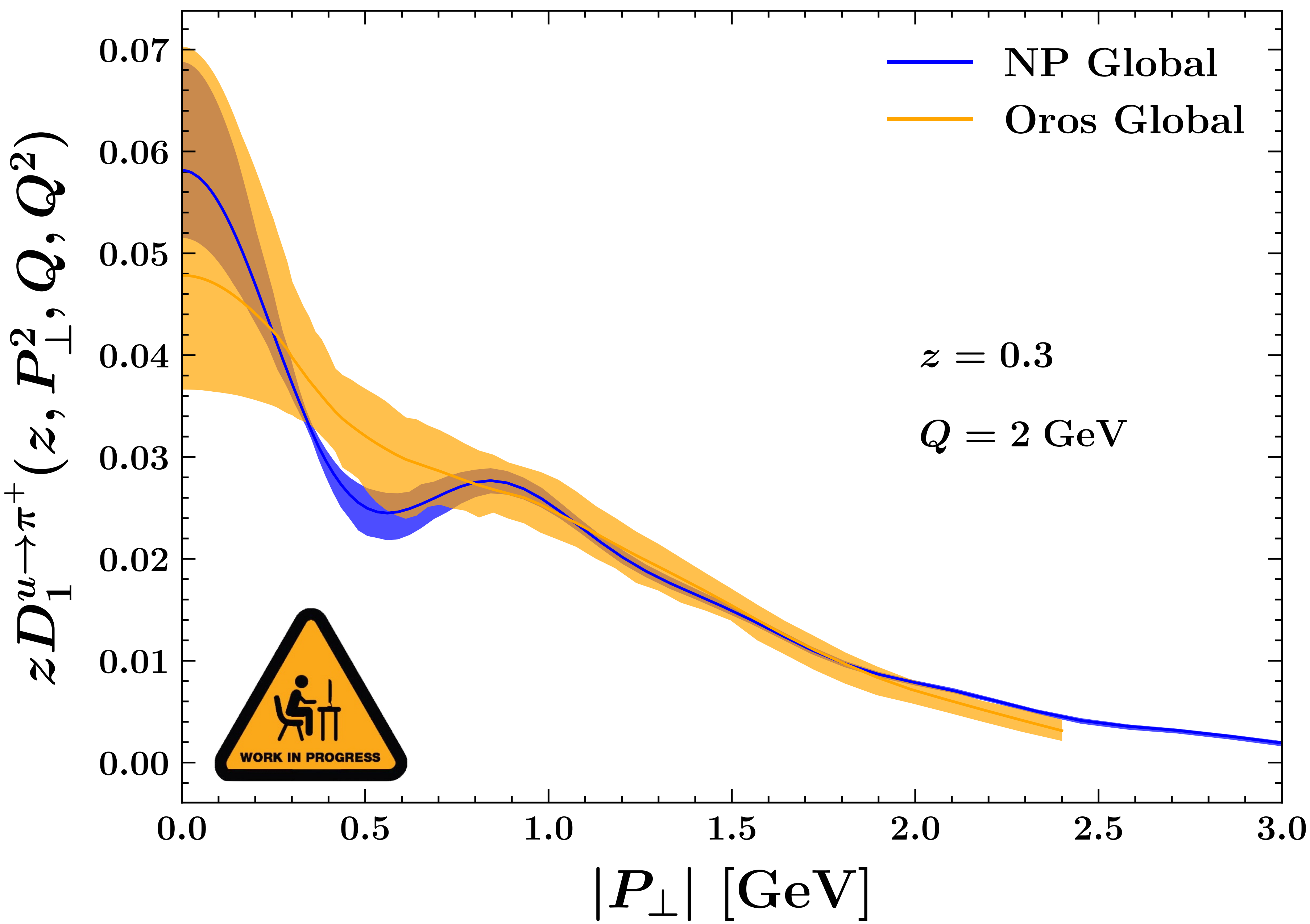
Second crosscheck: global fit

Extracted TMD PDFs



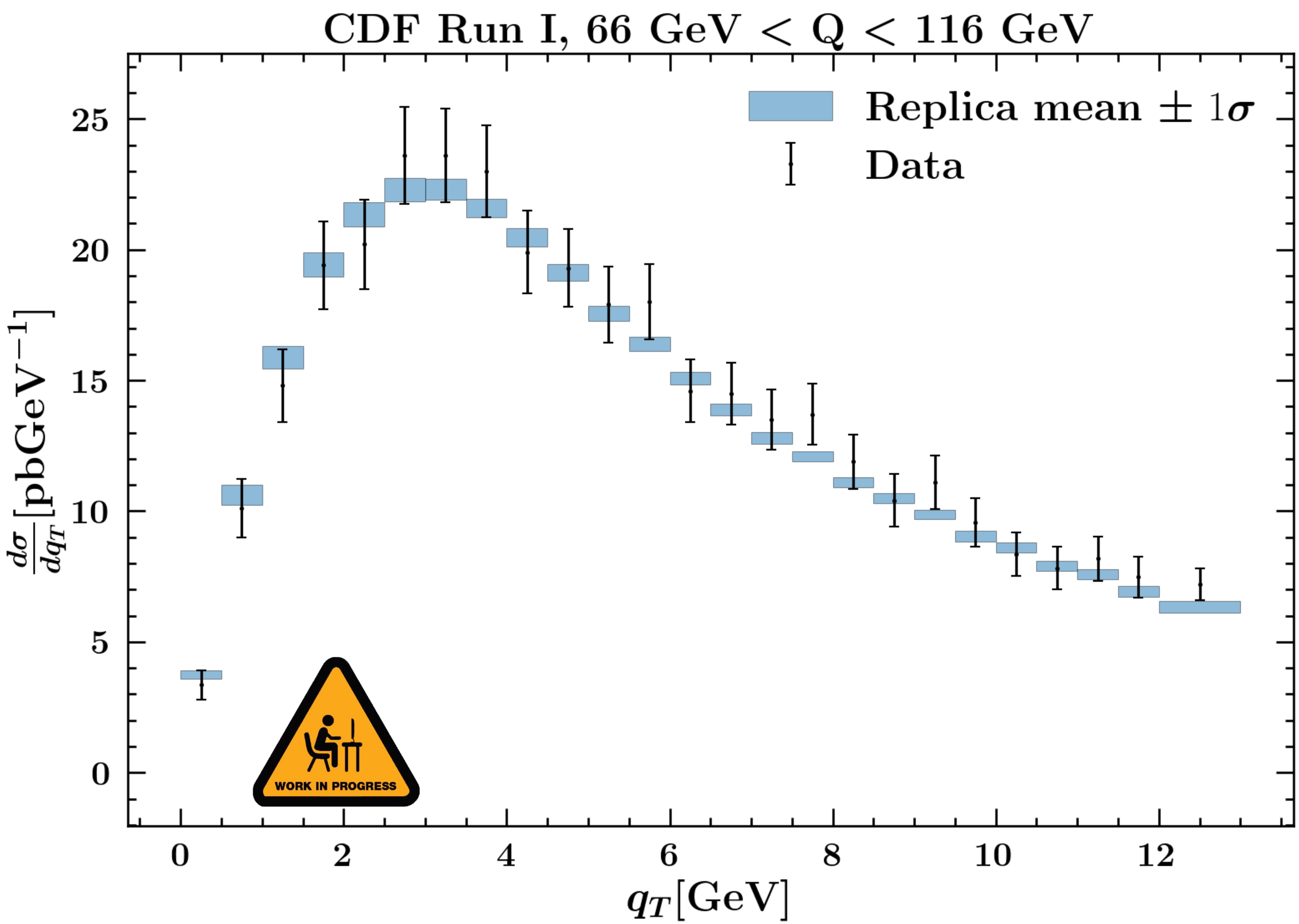
Second crosscheck: global fit

Extracted TMD FFs



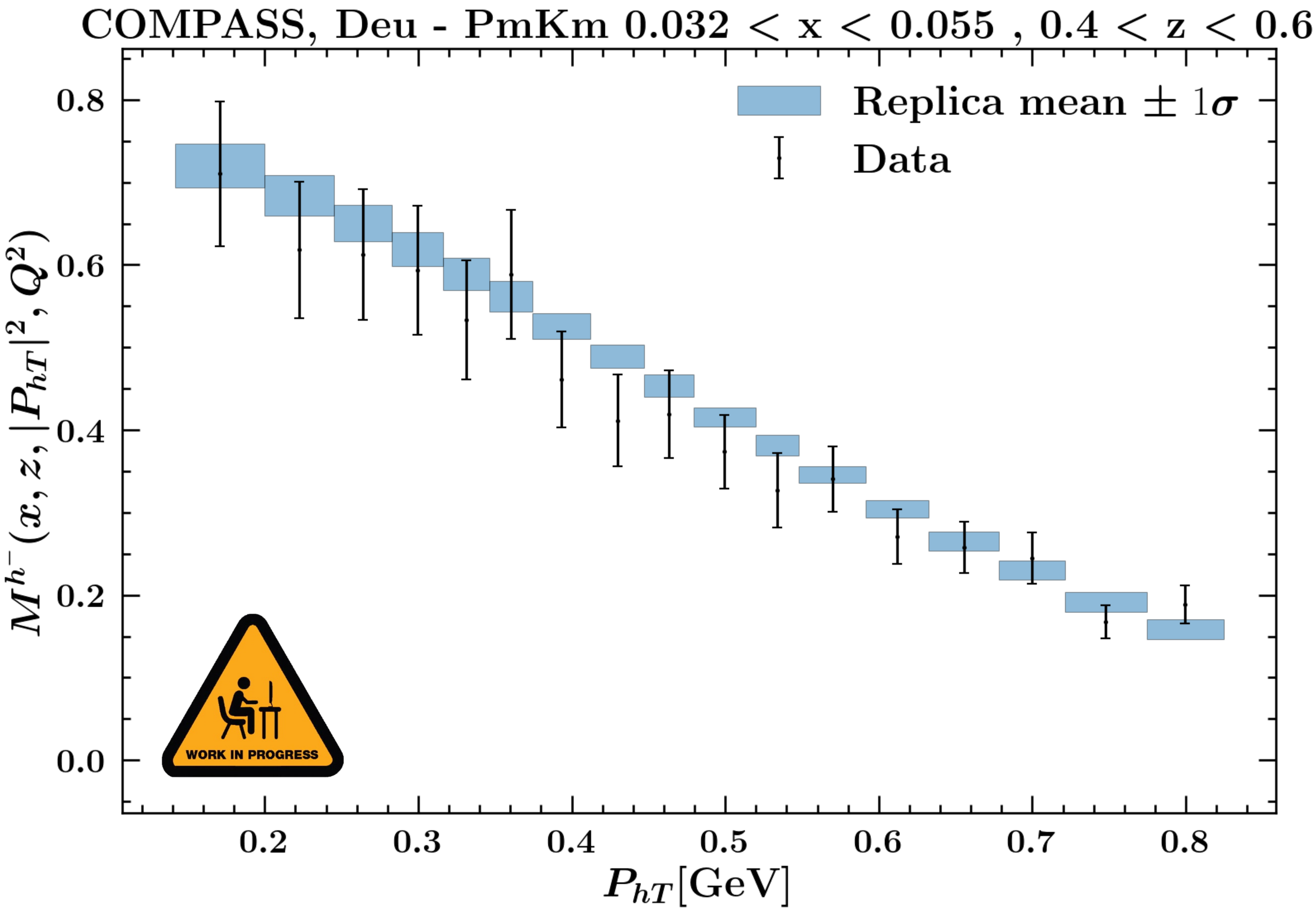
Second crosscheck: global fit

Data/Theory: DY



Second crosscheck: global fit

Data/Theory: SIDIS



Summary&Outlook

- We can extend the NN fit to a **global** NN fit
- Results are promising yet with NangaParbat
- We implemented the fits in the **Oros framework**
- We **benchmarked** the results for DYonly and global fit
- We are ready for extending to **flavour dependence**

Gluon TMDs from Higgs production measurements

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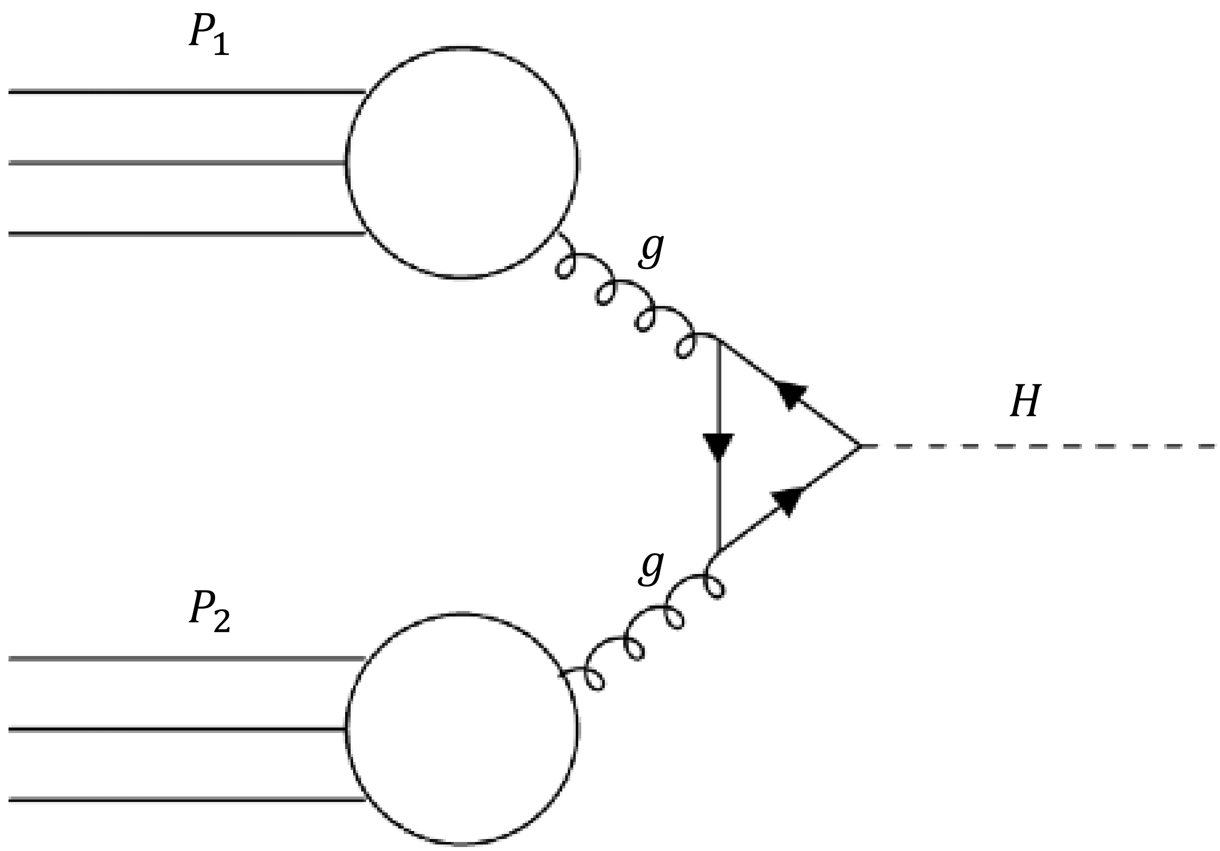
MAP Meeting

Pavia, 29/04/2026

Higgs production



$$H \to \gamma\gamma$$

$$H \to (l^+l^-)(l^+l^-)$$

$$\frac{d\sigma}{dQ\,dy\,dq_T} = \frac{\alpha_S^2(Q)Q^2 G_F \mathcal{P}}{288\pi\sqrt{2}\,\hat{s}} H_{ggH}(Q,\mu) \int \frac{d^2\boldsymbol{b}_T}{(2\pi)^2} e^{ib_T\cdot q_T}$$
$$\times \left[x_1 \tilde{f}_1^g(x_1,\boldsymbol{b}_T;\mu,\zeta_a)\, x_2 \tilde{f}_1^g(x_2,\boldsymbol{b}_T;\mu,\zeta_b) + x_1 \tilde{h}_1^g(x_1,\boldsymbol{b}_T;\mu,\zeta_a)\, x_2 \tilde{h}_1^g(x_2,\boldsymbol{b}_T;\mu,\zeta_b)\right]$$

Unpolarised   Boer-Mulders

Higgs production

Experimental data

Dataset	N_{dat}	Decay channel	$\sqrt{s}$ [GeV]	Ref.
CMS Run II (2017–2018)	7	$H \to \gamma\gamma$	13000	[2]
CMS Run II (2017–2018)	3	$H \to 4\ell$	13000	[3]
CMS Run II (2015–2016)	2	combined	13000	[4]
CMS Run I	2	$H \to \gamma\gamma$	800	[5]
ATLAS Run II (2017–2018)	7	$H \to \gamma\gamma$	13000	[6]
ATLAS Run II (2017–2018)	3	$H \to 4\ell$	13000	[7]
ATLAS Run II (2015–2016)	3	combined	13000	[8]
ATLAS Run I	2	$H \to \gamma\gamma$	800	[9]
ATLAS Run I	1	$H \to 4\ell$	800	[10]
Total	**30**	–	–	–

Phase-space reduction cuts more complicated than standard DY

Slightly large experimental errors ($\mathcal{O}(50\%)$)

Three cuts tested: $q_T/Q < 0.3\,, 0.25\,, 0.2$

Higgs production

Theoretical setup

- N^3LL accuracy
- Collinear PDF set: NNPDF3.1nnlo (pch)
- Narrow width approximation $\delta(Q^2 - M_H^2)$
- Nonperturbative model

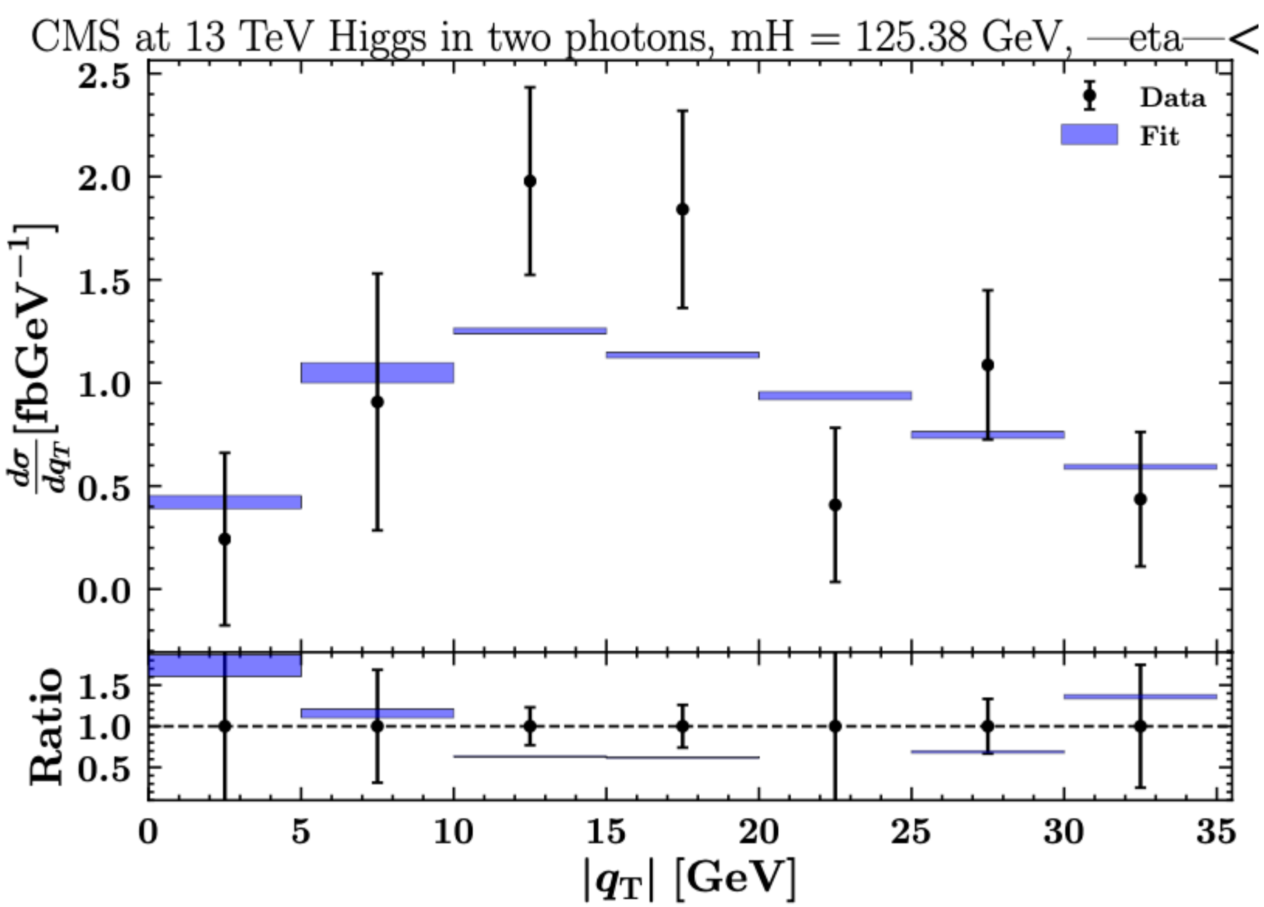
$$f_1^g(b_T) = e^{-g b_T^2/2}$$ (Same for BM)

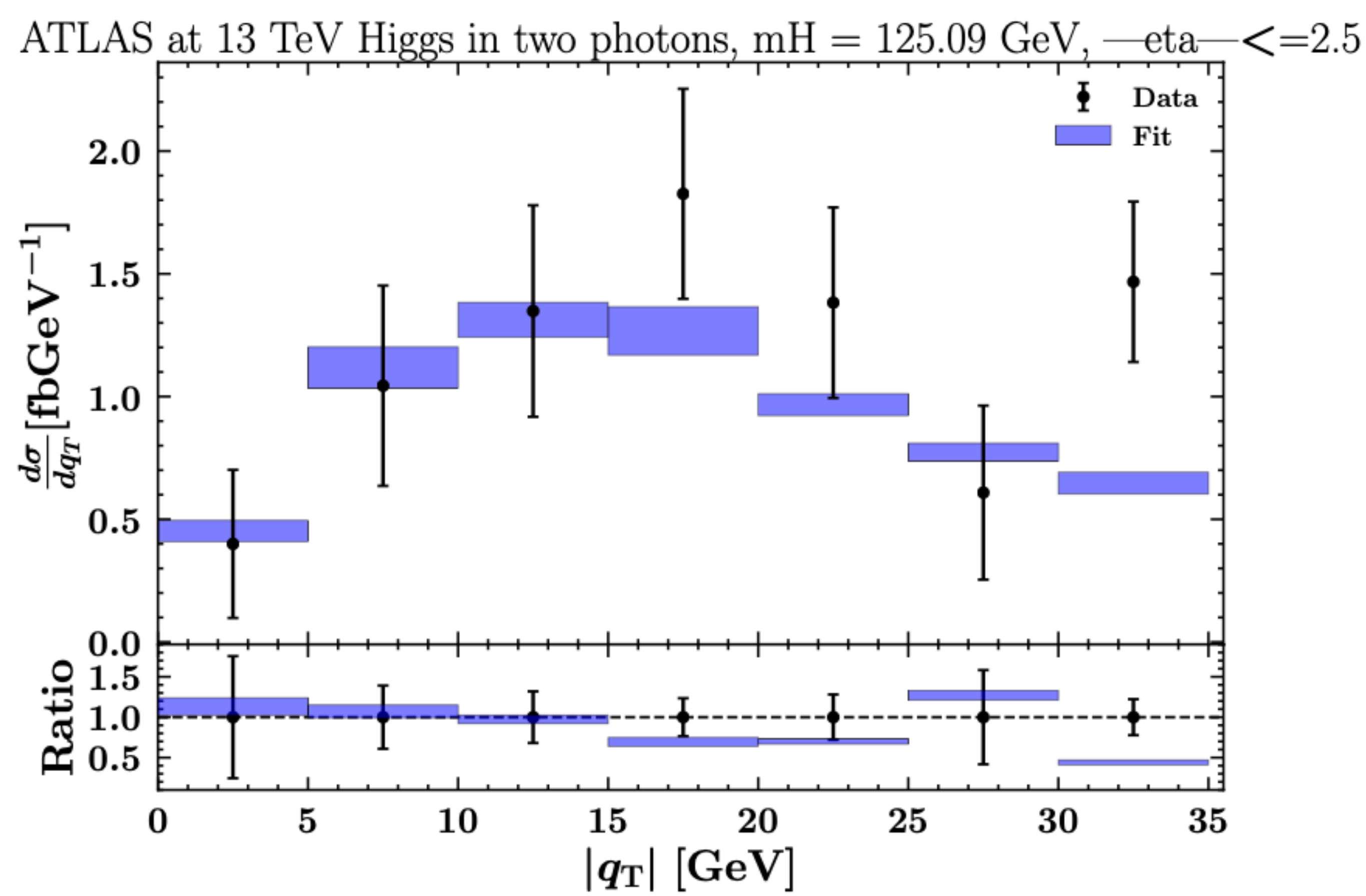
No constraints on g_2^g due to NWA

Higgs production

Fit results

Dataset	N_{dat}	χ^2/N_{dat}	χ^2_D/N_{dat}	$\chi^2_\lambda/N_{\text{dat}}$
CMS Run II $H \to \gamma\gamma$	7	1.15	1.15	–
CMS Run II $H \to 4\ell$	3	1.17	1.17	–
CMS Run II (combined)	2	4.46	4.46	–
CMS Run I $H \to \gamma\gamma$	2	0.26	0.26	–
ATLAS Run II $H \to \gamma\gamma$	7	1.52	1.32	0.20
ATLAS Run II $H \to 4\ell$	3	0.93	0.90	0.03
ATLAS Run II (combined)	3	0.99	0.99	–
ATLAS Run I $H \to \gamma\gamma$	2	3.58	3.50	0.08
ATLAS Run I $H \to 4\ell$	1	0.004	0.004	–
Total	**30**	1.49	1.43	0.06

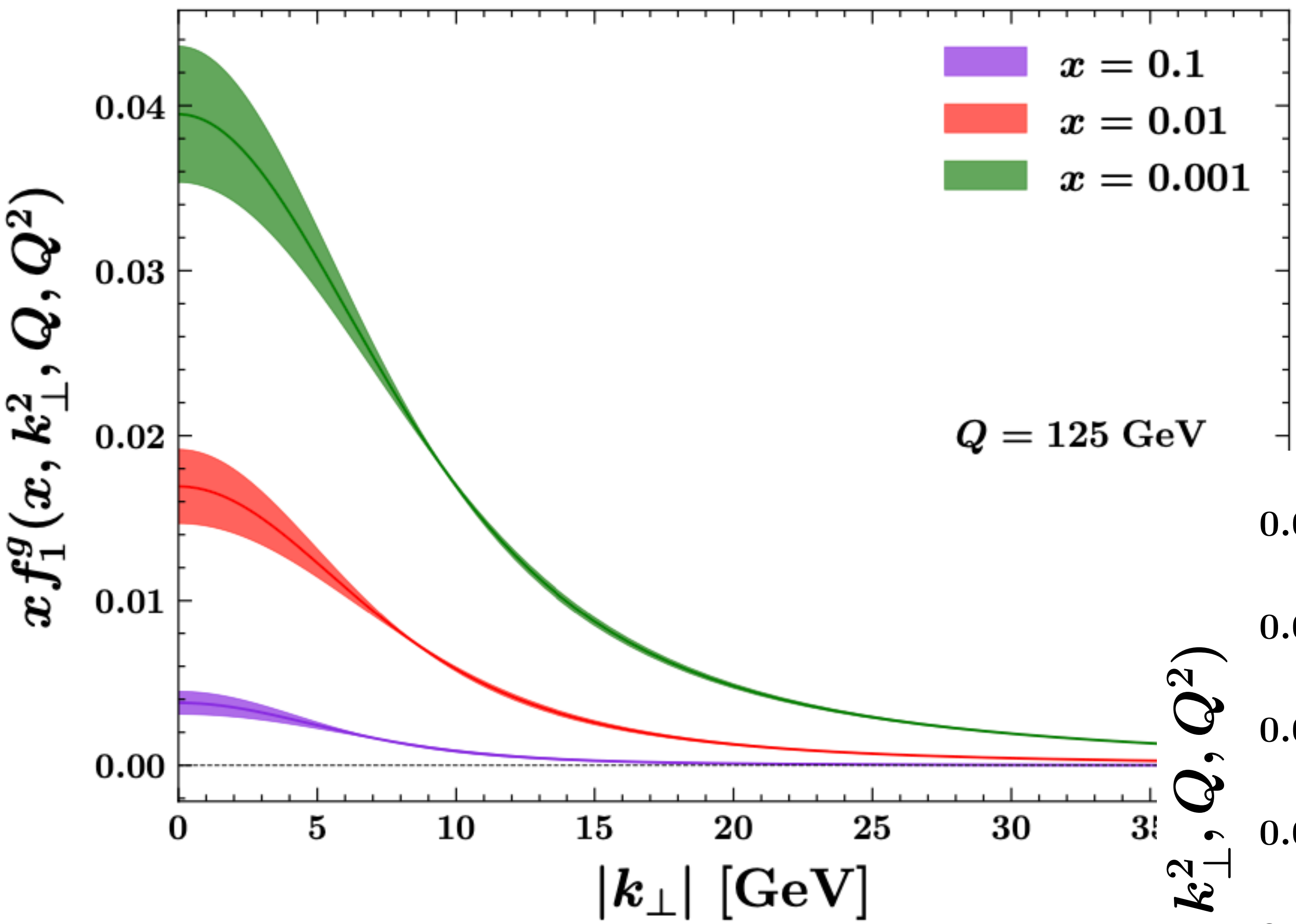


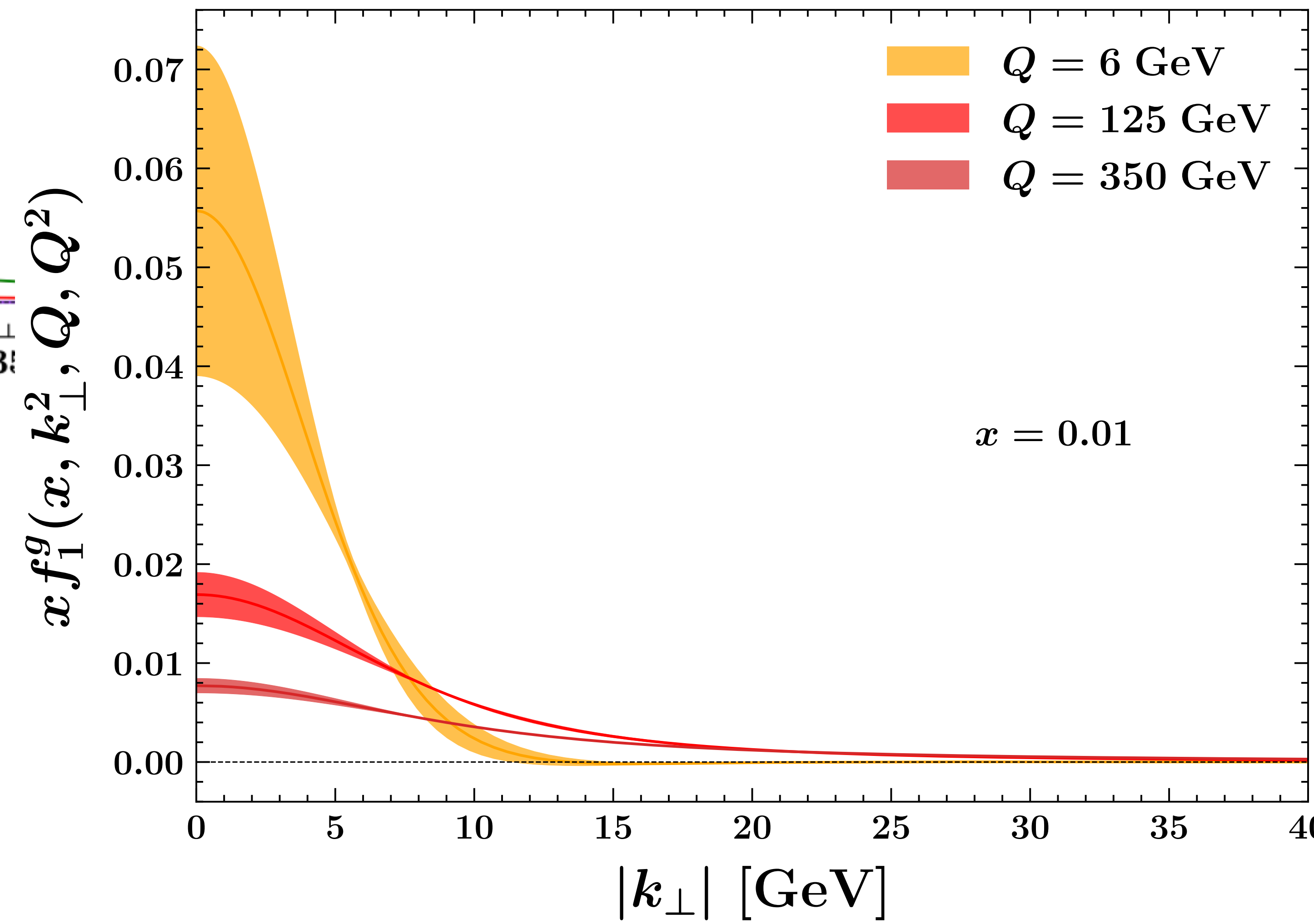


Higgs production

Extracted TMDs

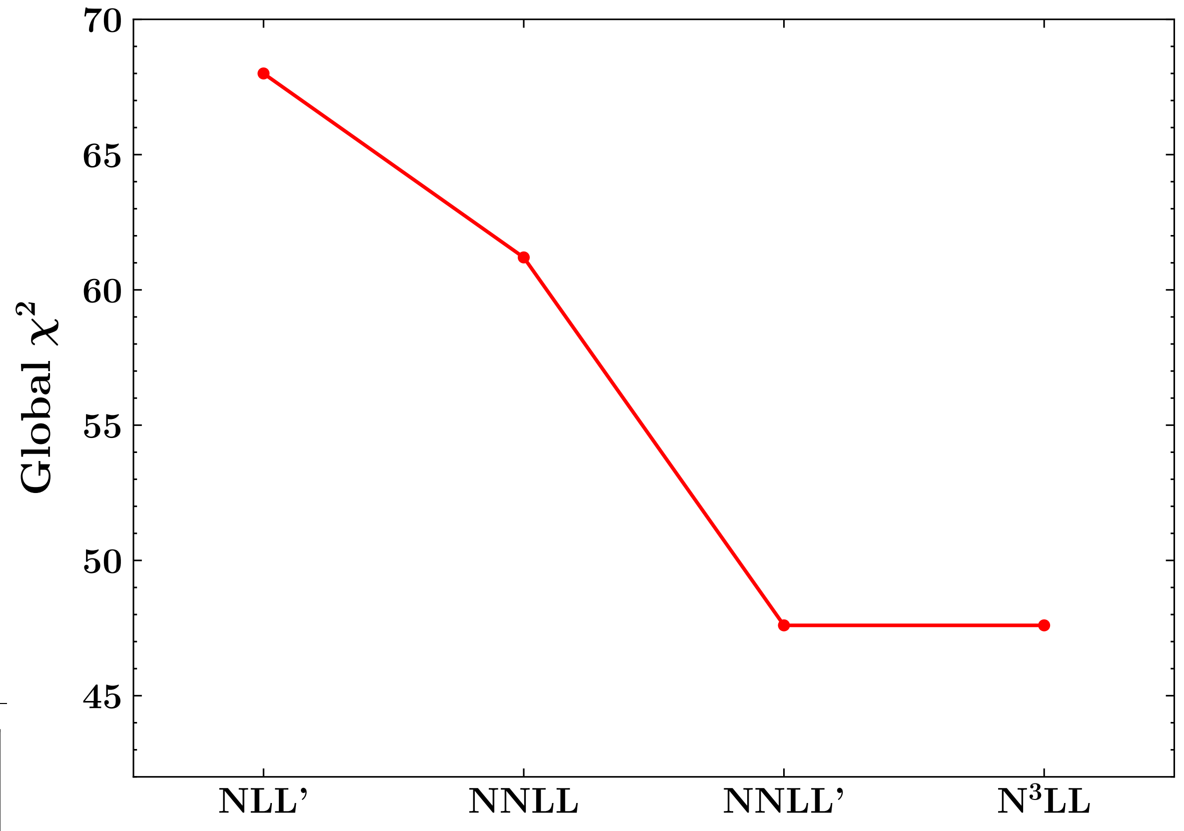
$$g_1 = 14.4 \pm 5.1\, GeV^2$$

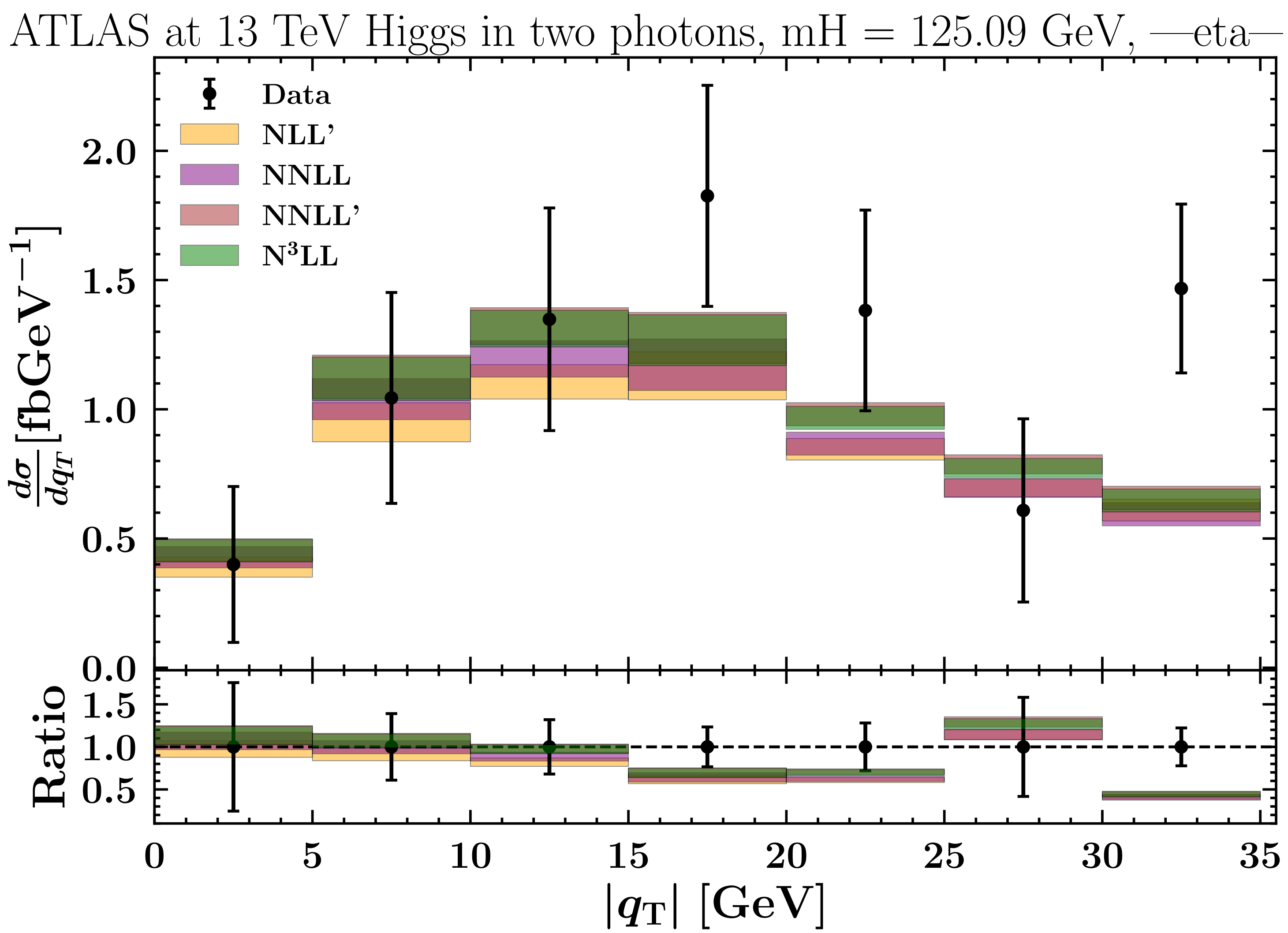




Higgs production

Perturbative convergence





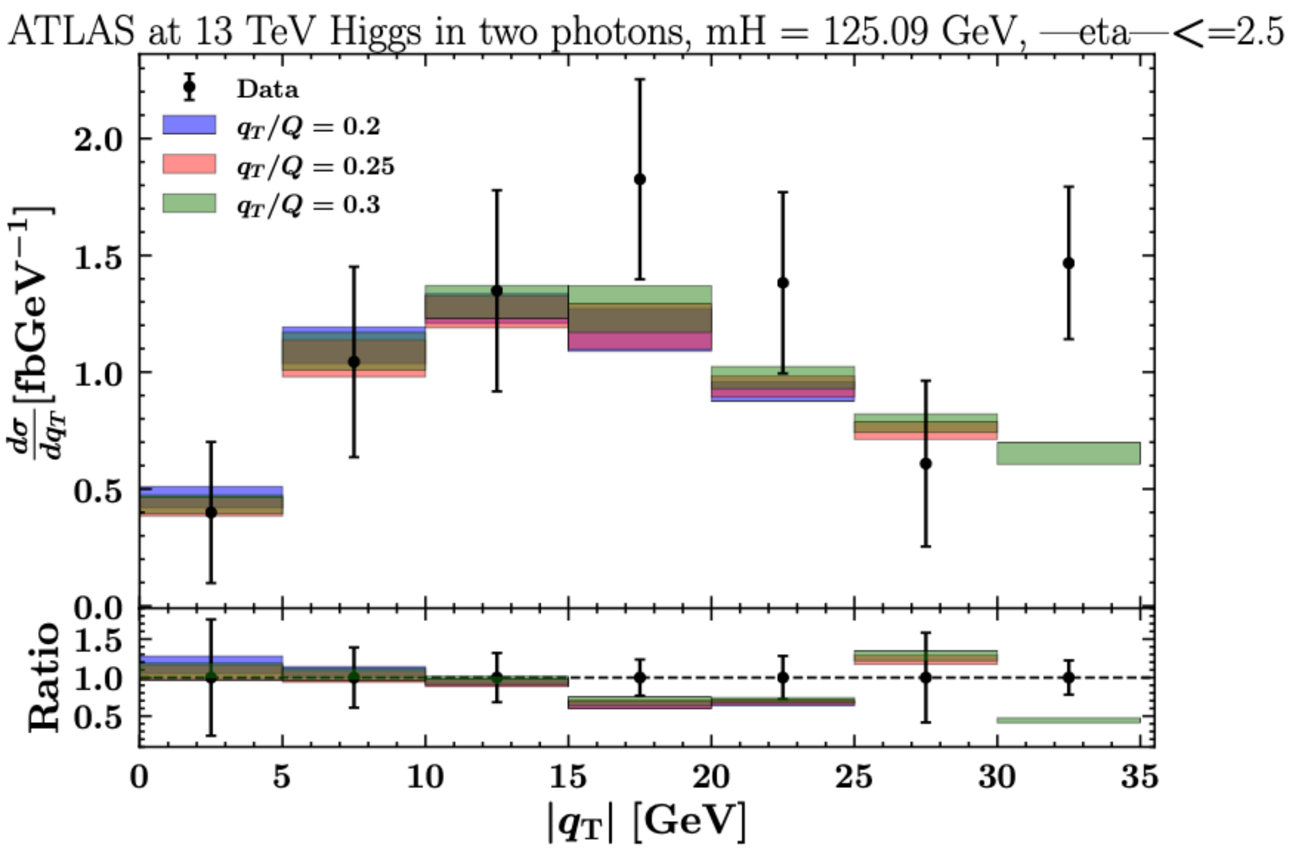
Effect mostly on the region of the peak

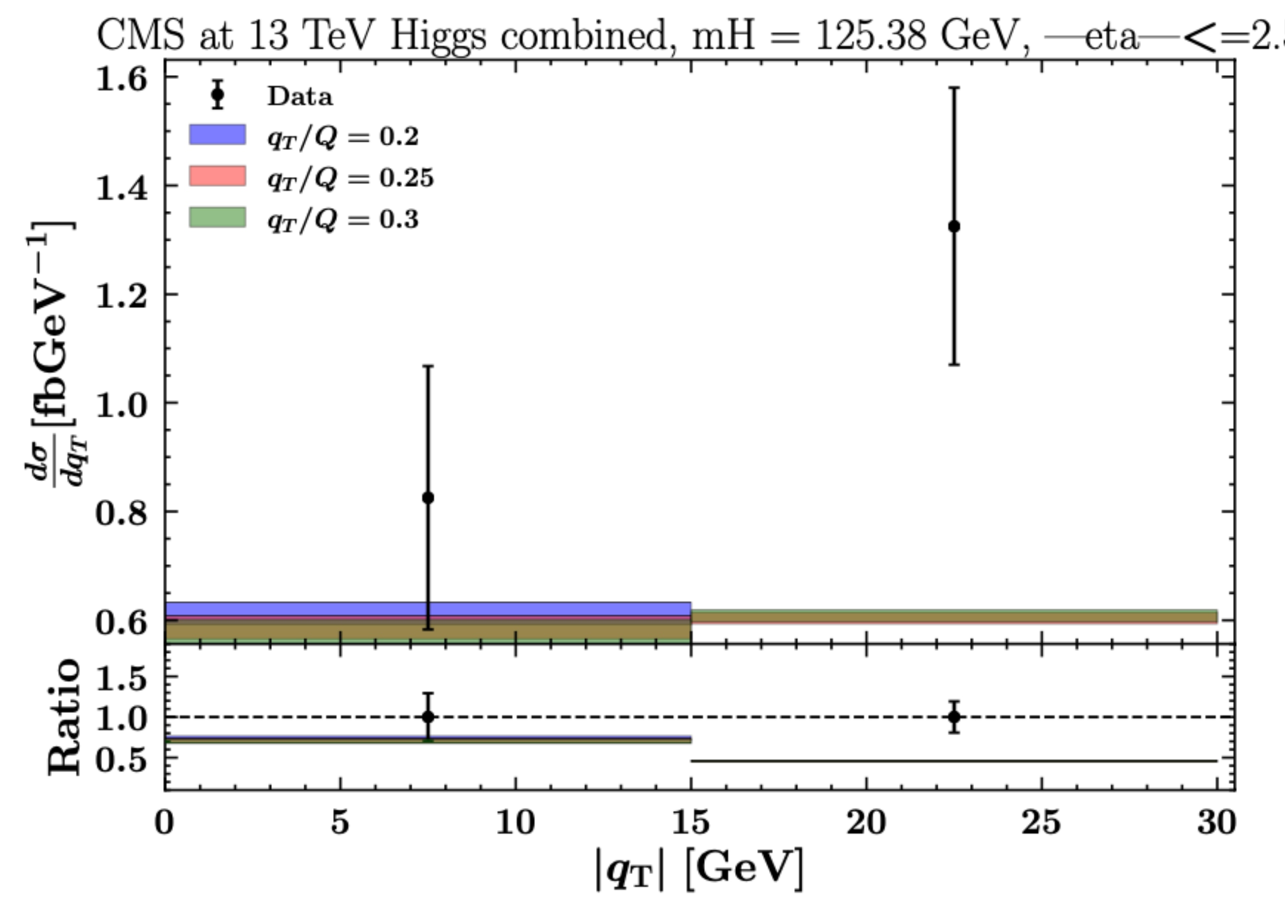
(consistent with findings in PV19)

Higgs production

Dependence on cut q_T/Q

Cut	N_{dat}	χ^2/N_{dat}	$g_1\,[\text{GeV}^2]$
$q_T/Q < 0.2$	20	1.08	7.1 ± 4.3
$q_T/Q < 0.25$	28	1.35	12.6 ± 4.7
$\boldsymbol{q_T/Q < 0.3}$	**30**	**1.49**	$\boldsymbol{14.4 \pm 5.1}$





Slight reduction of the chi2 -> removal of statistical fluctuations

Reduction of the extracted parameter but still compatible

Summary&Outlook

- We performed the first extraction of gluon TMDs from H production
- We used a very simple model due to the scarcity of data
- The quality of the fit is reasonable
- We tested the convergence of the perturbative series
- We tested the stability of the results on the q_T/Q cut

$$g_1 = 2\left(g' - \frac{C_A}{C_F} g_2^2 \log Q^2\right)$$

Non parametric bootstrap
from 200 replicas

Bootstrap from joint fit
lattice+experiment