Extraction of transverse momentum distributions from Drell-Yan reaction at N^4LL

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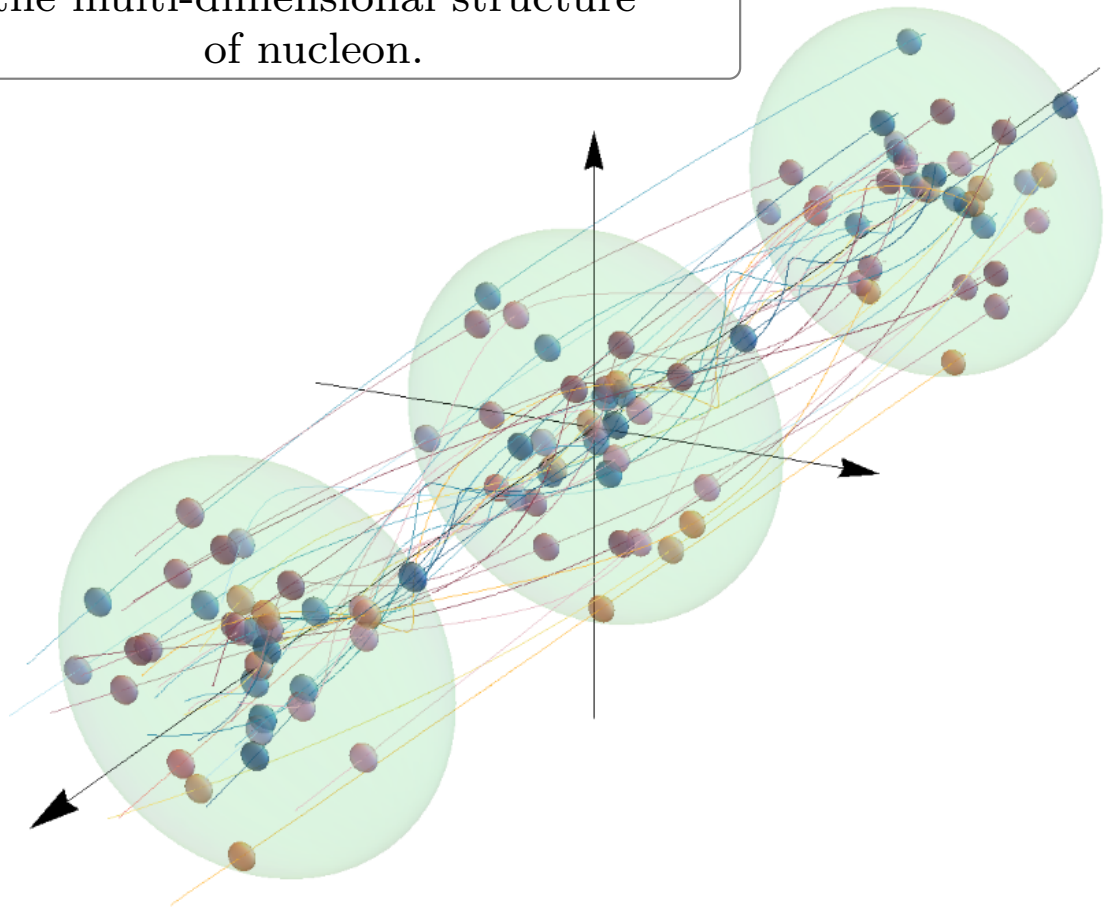
May 10, 2023

Hadron is a 3D object

Nucleon tomography aims to explore the multi-dimensional structure of nucleon.



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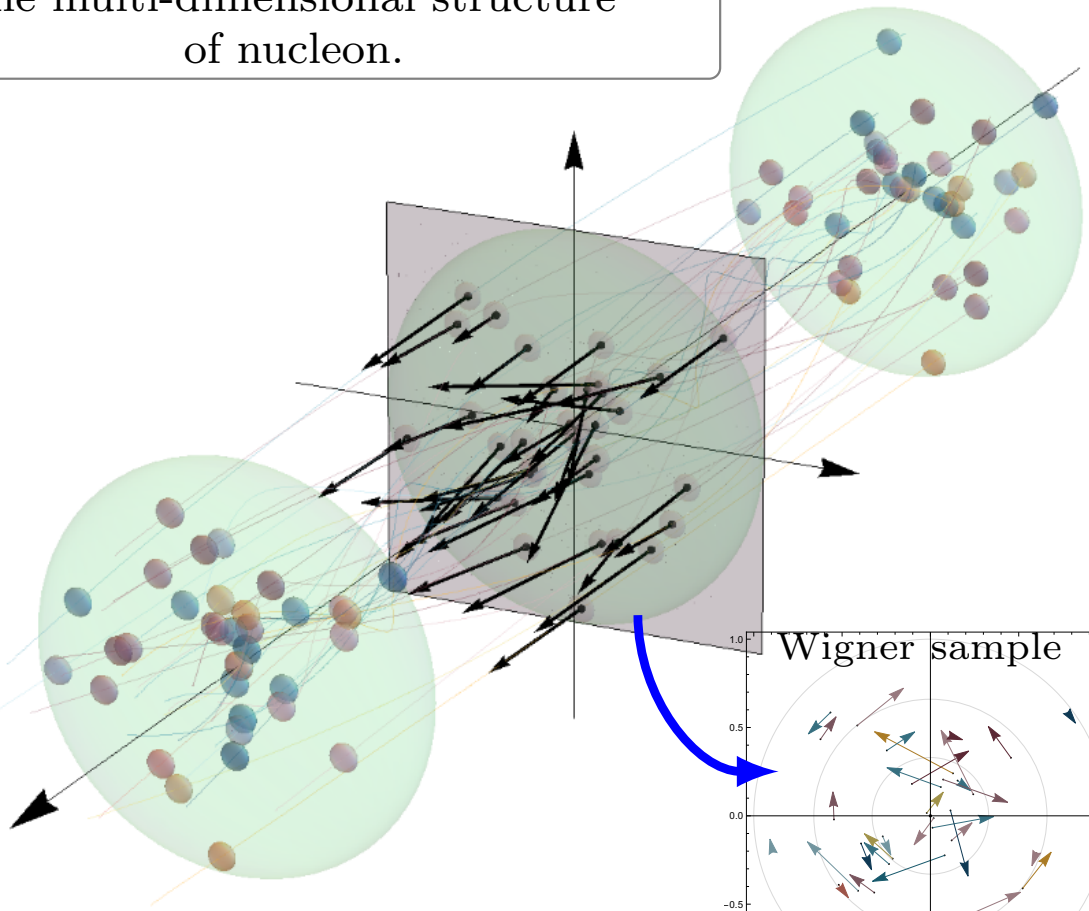
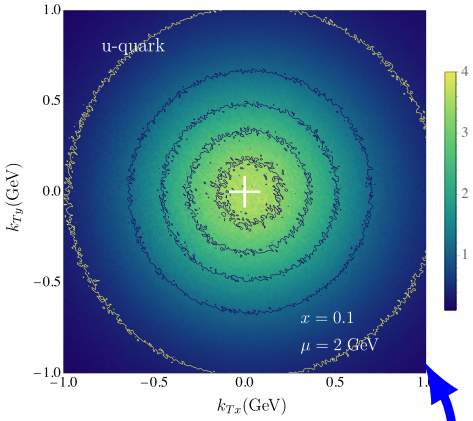
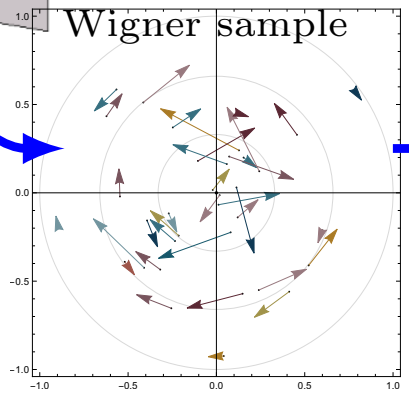
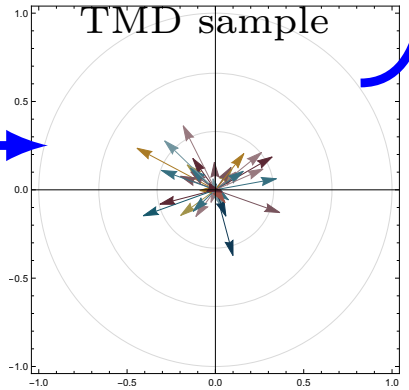


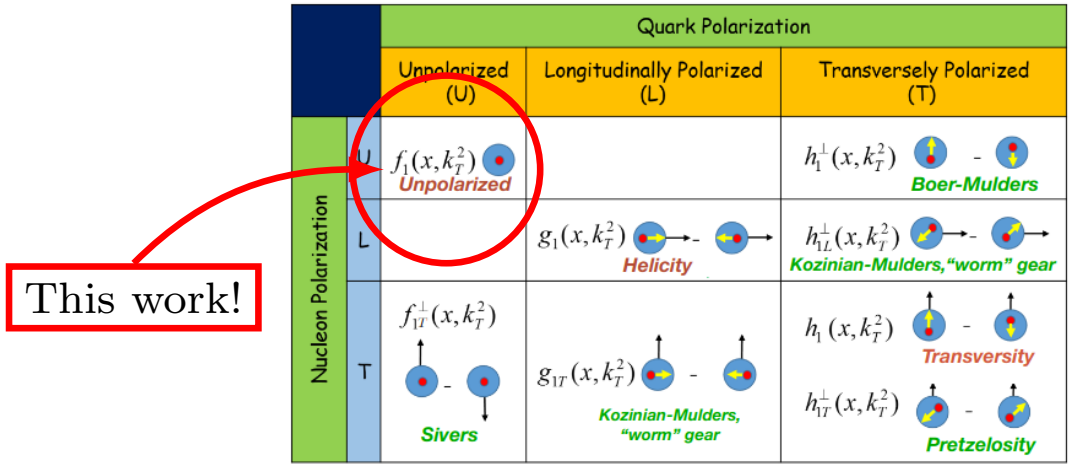
[Bury,Prokudin,AV, PRL 126 (2021)

TMD distribution







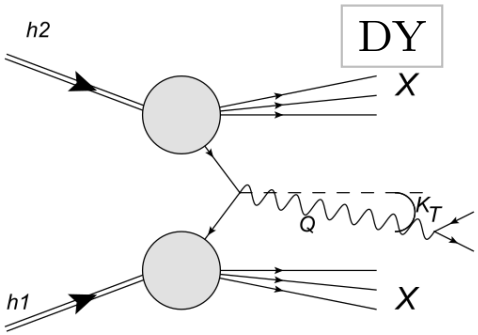


Unpolarized TMD parton distribution function

- Most important TMD distribution (contributes everywhere)
- Previous global extractions:
  - SV19 at N^3LL, with *artemide* [I.Scimemi, AV, 1912.06532]
  - MAP22 at N^3LL, with *NangaParbat* [A.Bacchetta, et al, 2206.07598]
- **Golden process:** Drell-Yan-type reactions

TMD factorization theorem

$$\frac{d\sigma}{dq_T} = \sigma_0 \int \frac{d^2 b}{(2\pi)^2} e^{i(bq_T)} C\left(\frac{Q}{\mu}\right) F(x_1, b; \mu, \zeta) F(x_2, b; \mu, \bar{\zeta})$$



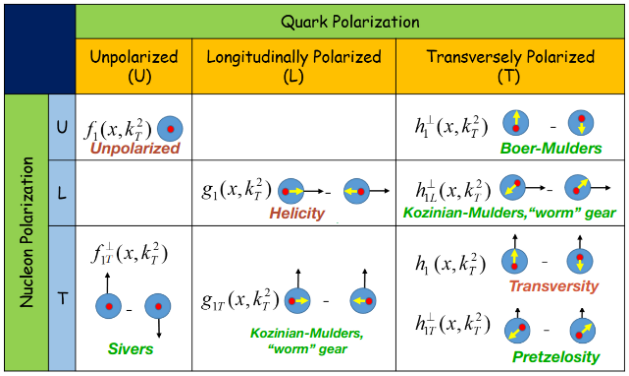
Factorization valid at:

$Q \gg \Lambda \quad Q \gg q_T$

TMD factorization theorem

$$\frac{d\sigma}{dq_T} = \sigma_0 \int \frac{d^2 b}{(2\pi)^2} e^{i(bq_T)} \boxed{C\left(\frac{Q}{\mu}\right)} \boxed{F(x_1, b; \mu, \zeta)} \boxed{F(x_2, b; \mu, \bar{\zeta})}$$

$\boxed{\mathrm{N^4LO}}$



Evolution
$\mathrm{N^4LO}$

TMD factorization theorem

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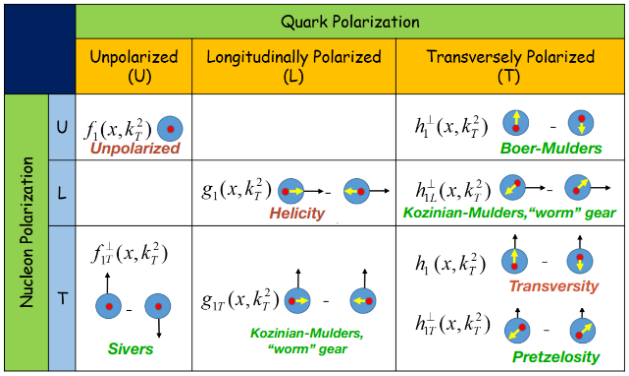
N^{4}LO

N^{3}LO

TMDPDF at small-b

$$\lim_{b\to 0} F_f(x,b) \simeq \int_x^1 \frac{dy}{y} C_{f\leftarrow f;}\left(\frac{x}{y}; \ln(b)\right) q_f(y)$$

(resummation regime)



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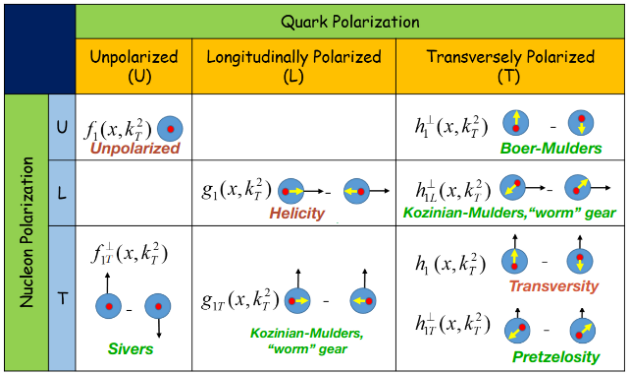
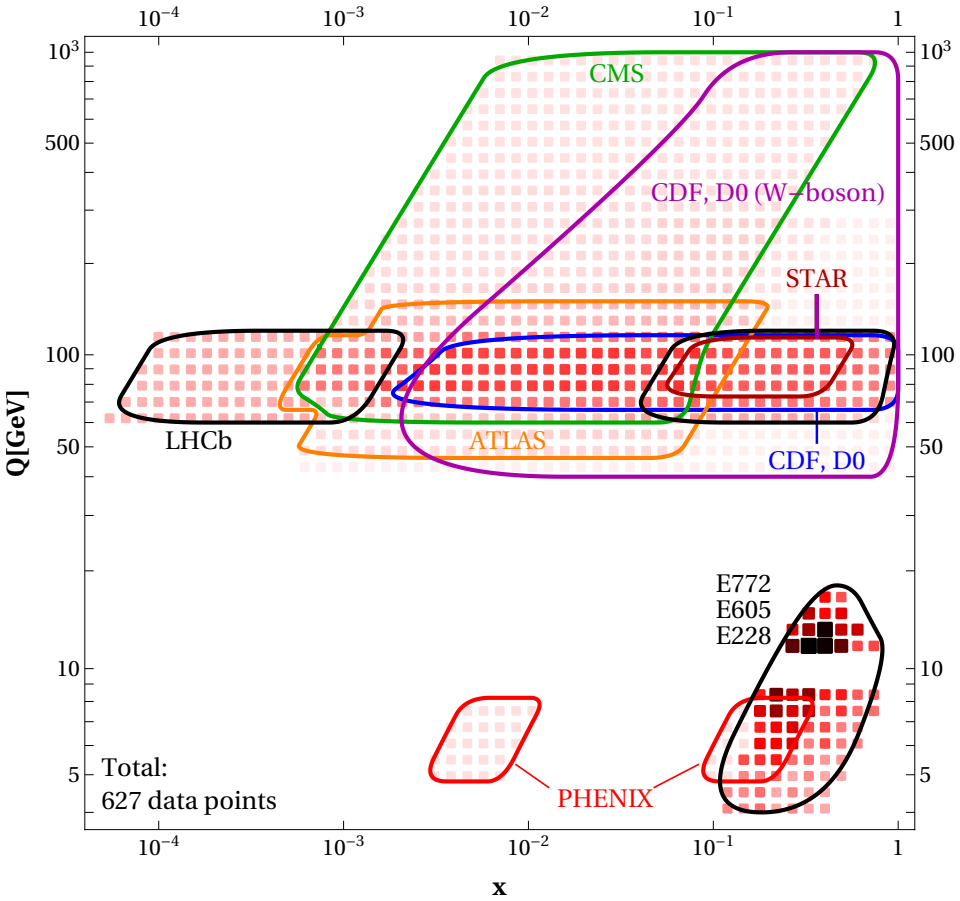


Evolution N^{4}LO

Altogether N^{4}LL
(in resummation nomenclature)



* data included for the first time

- ATLAS
  - Z-boson at 8 (y-diff.)
  - **Z-boson at 13 TeV (0.1% prec.!)**
- CMS
  - Z-boson at 7 and 8 TeV
  - Z-boson at 13 TeV (y-diff.)
  - **Z/γ up to $Q = 1000$GeV**
- LHCb
  - Z-boson at 7 and 8 TeV
  - **Z-boson at 13 TeV (y-diff.)**
- **Further more:**
  - Z-boson at Tevatron
  - **W-boson at Tevatron**
  - **Z-boson at RHIC**
  - DY at PHENIX
  - DY at FERMILAB (fix target)

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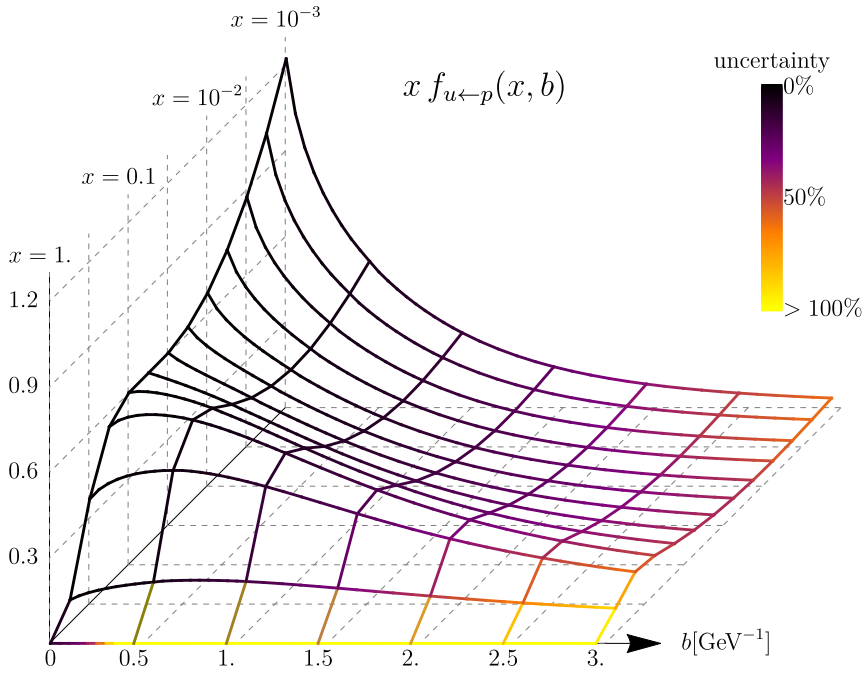
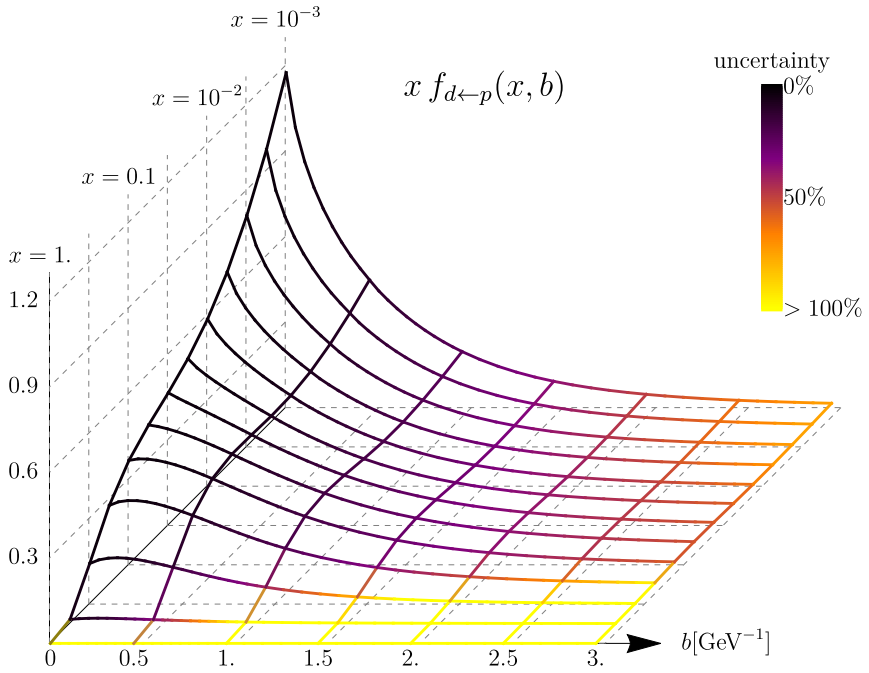
627 data points

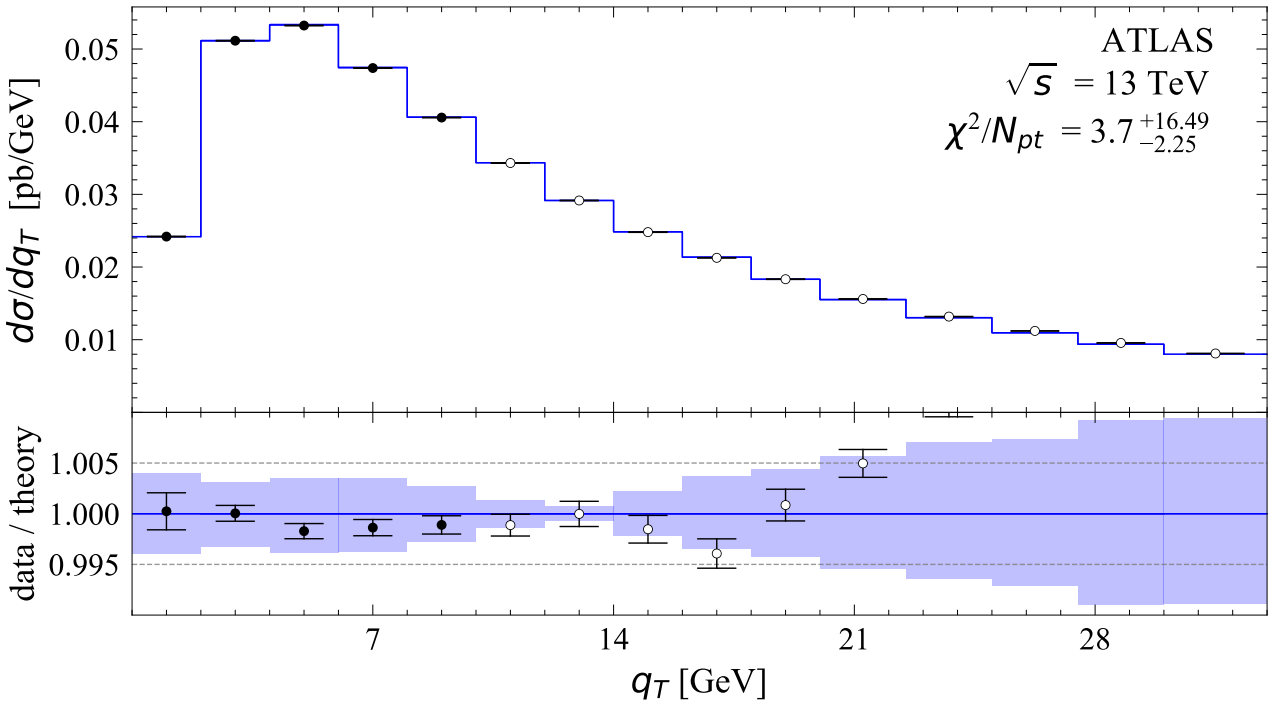
vs. 457 in SV19
vs. 484 in MAP22



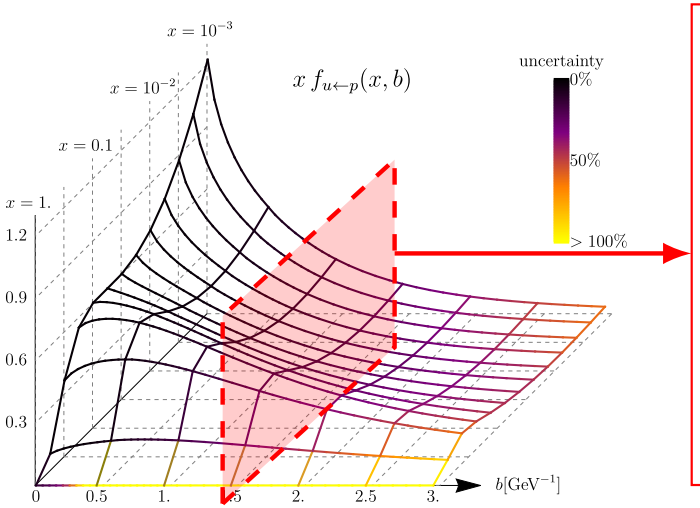


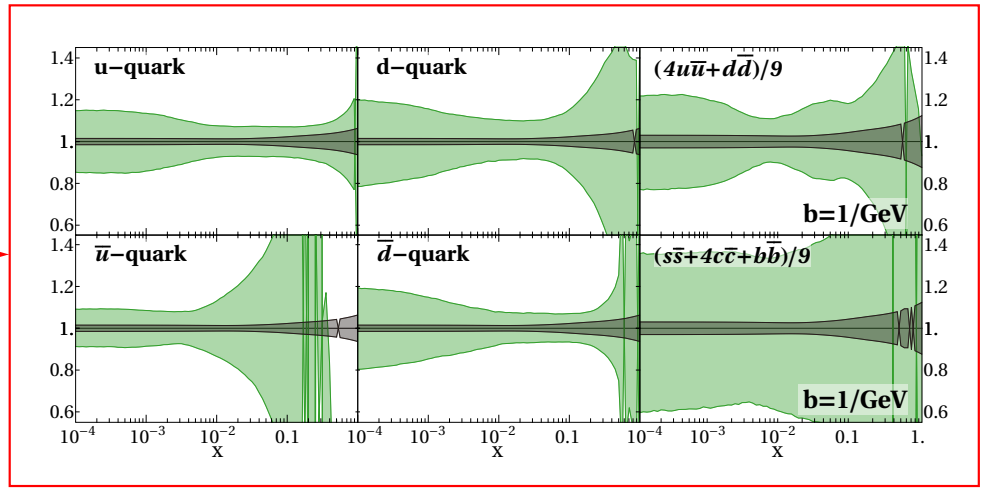
Extra features of analyses:

- Flavor dependent NP-ansatz (first time!)
- New parametrization for Collins-Soper kernel
- Consistent inclusion of the PDF uncertainty (first time!)
- ζ-prescription
- *artemide*

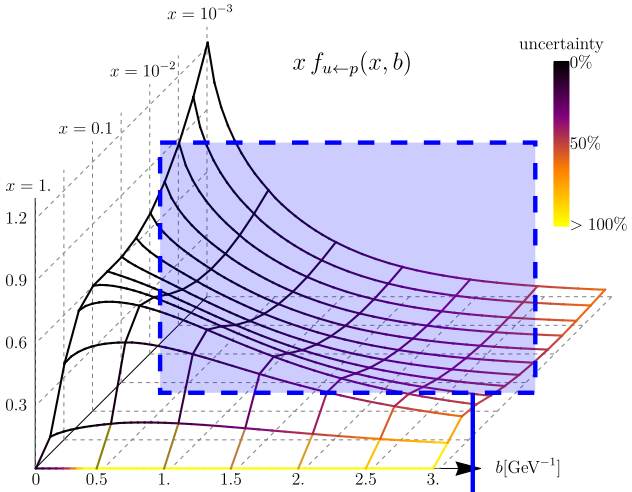


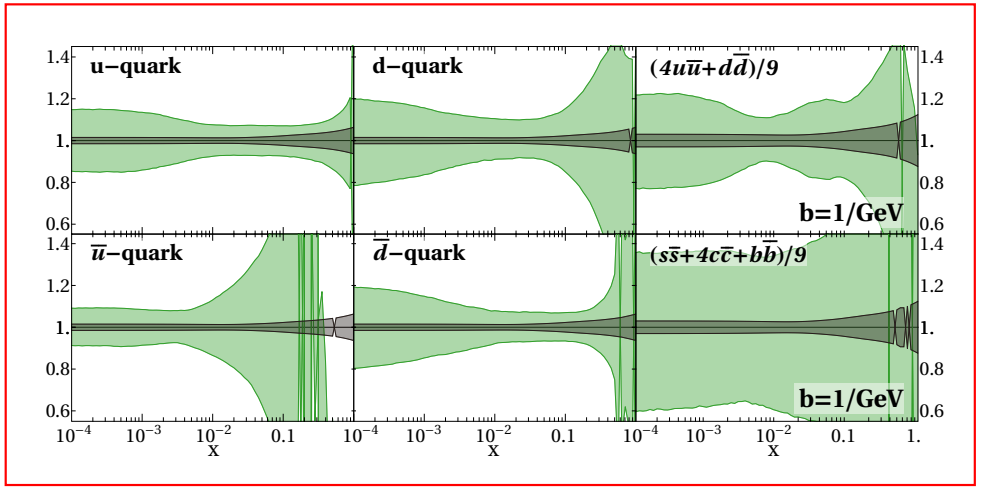
$$\text{TOTAL } (N_{\text{pt}} = 627): \quad \chi^2/N_{\text{pt}} = 0.96^{+0.09}_{-0.01}$$

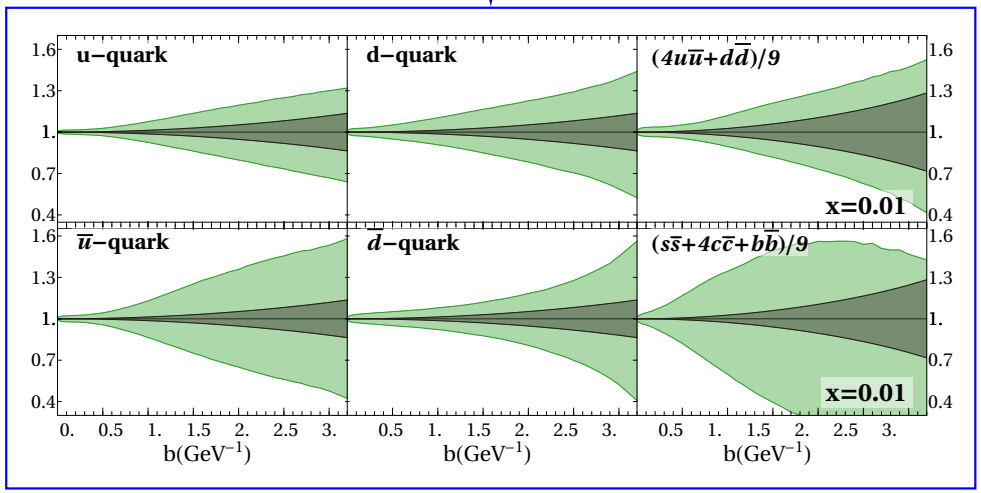




Uncertanty appears
much larger
than in previous fits







Uncertanty appears much larger than in previous fits

Conclusion

New global fit of unpolarized TMDPDF

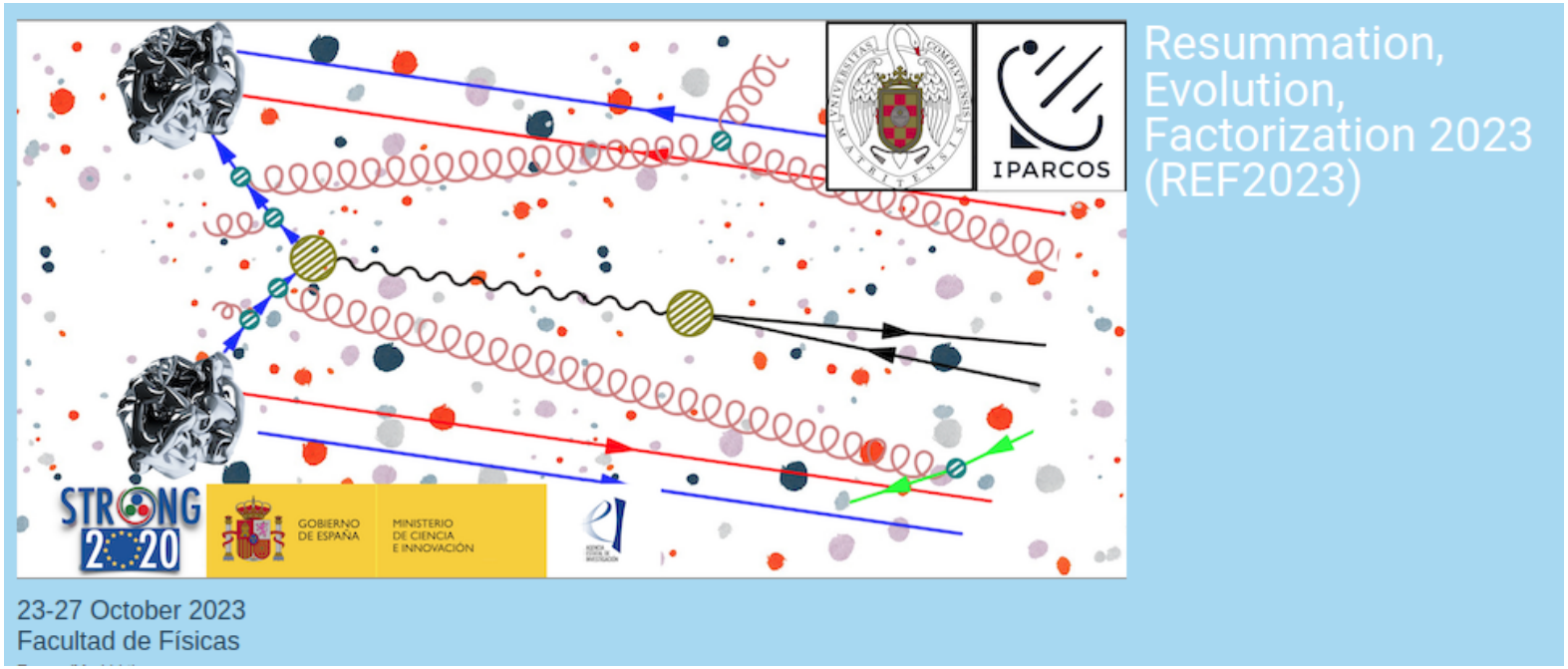
ART23

I.Scimemi, P.M.Zurita, A.Vladimirov (Universidad Complutense de Madrid)
V.Moos (Regensburg University)

(to be released within a week)

Features:

- N^4LL perturbative order
- (more) Accurate determination of uncertanties
- Larger data set (mainly due to LHC data)
- *artemide:* https://github.com/VladimirovAlexey/artemide-public



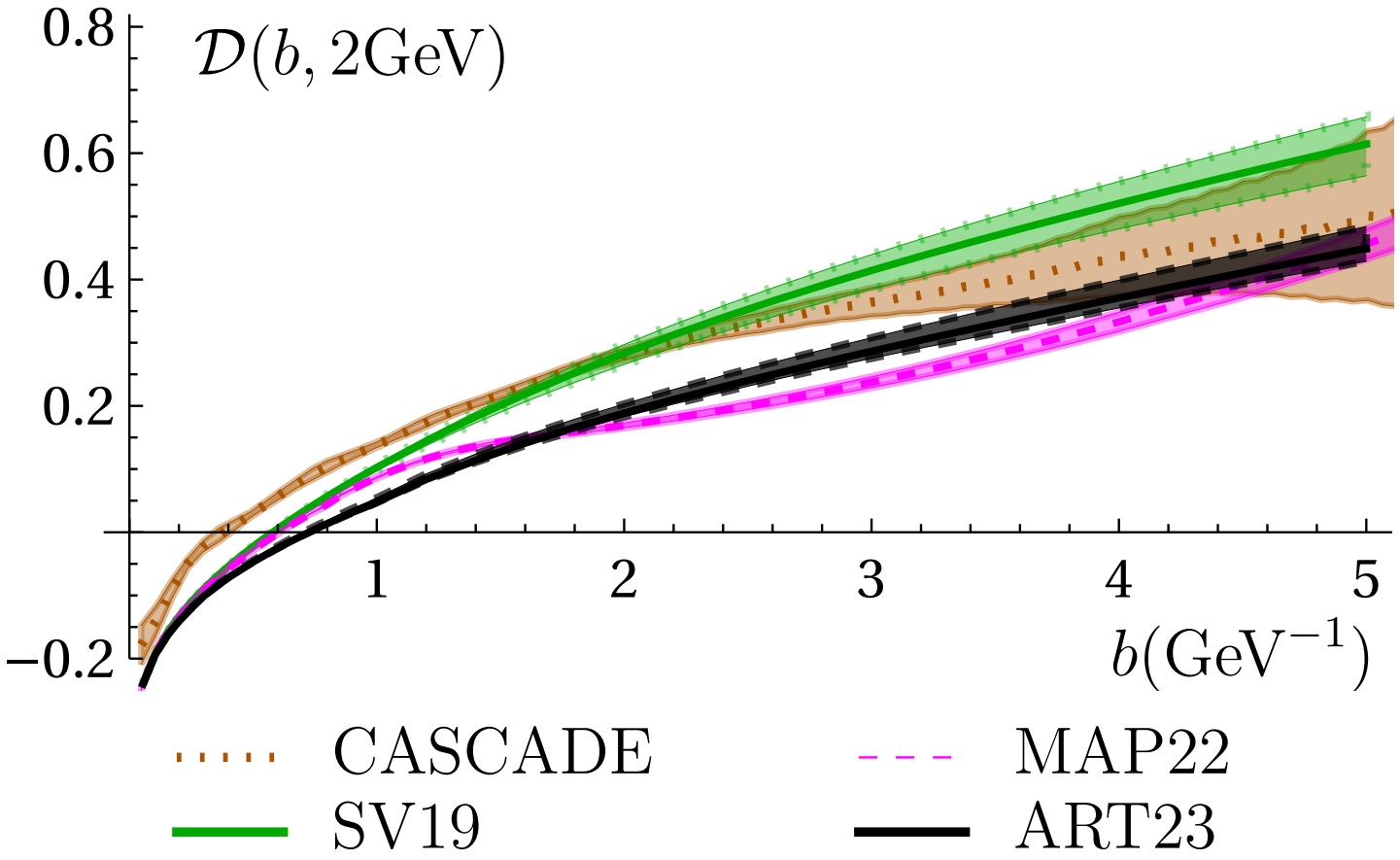
Universidad Complutense de Madrid

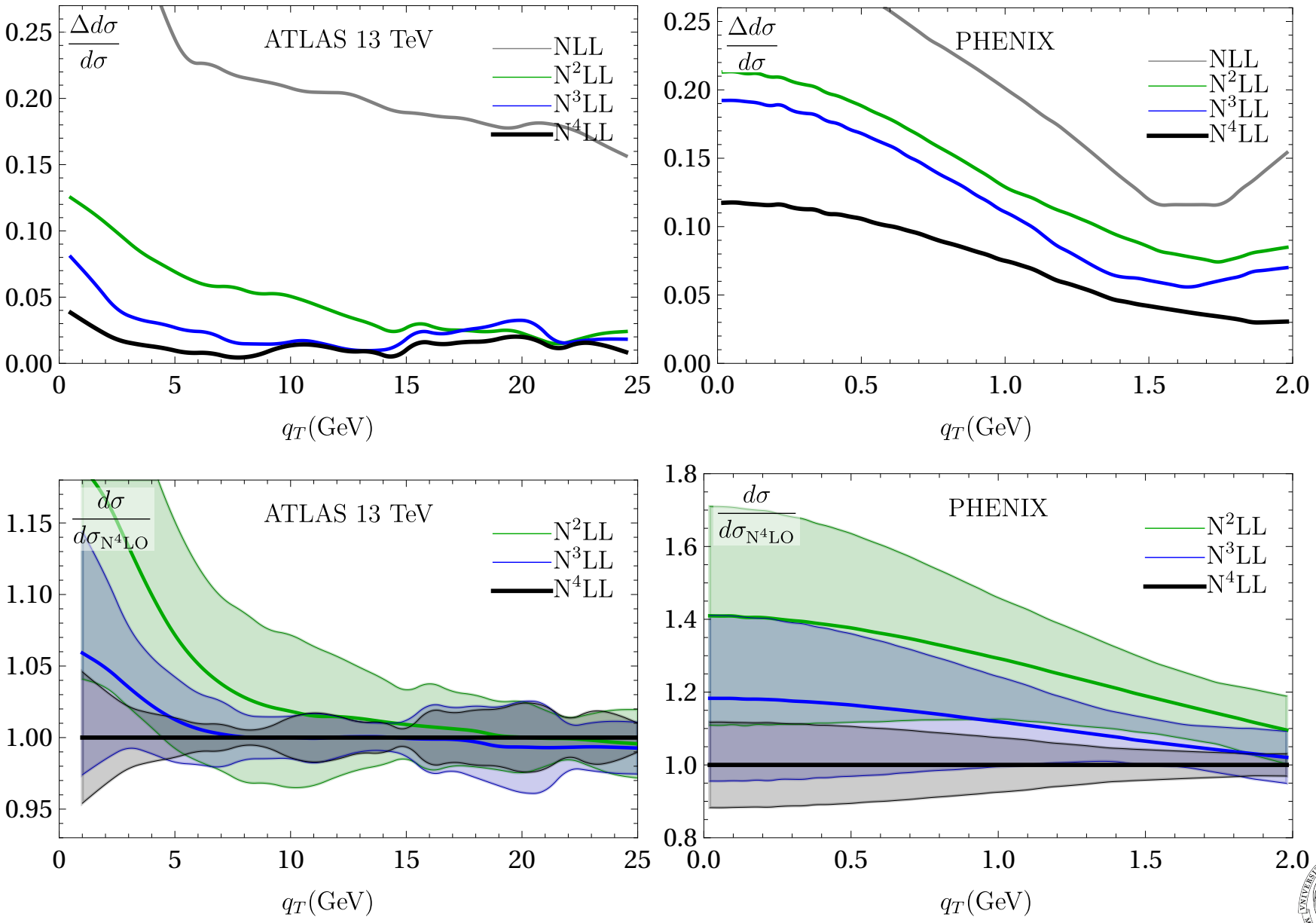
23-27 October 2023

https://indico.fis.ucm.es/event/19/

(registration starts next month)

Backup slides


$\mathcal{D}(b, 2\text{GeV})$
0.8
0.6
0.4
0.2
−0.2
1
2
3
4
5
$b(\text{GeV}^{-1})$
CASCADE
MAP22
SV19
ART23


ATLAS 13 TeV
PHENIX
NLL
N^{2}LL
N^{3}LL
N^{4}LL
$\frac{\Delta d\sigma}{d\sigma}$
$\frac{d\sigma}{d\sigma_{\mathrm{N^4LO}}}$
q_T(GeV)

data set	$N_{\rm pt}$	$\chi^2_D/N_{\rm pt}$	$\chi^2_\lambda/N_{\rm pt}$	$\chi^2/N_{\rm pt}$
CDF (run1)	33	0.51	0.16	$0.67^{+0.05}_{-0.03}$
CDF (run2)	45	1.58	0.11	$1.59^{+0.26}_{-0.14}$
CDF (W-boson)	6	0.33	0.00	$0.33^{+0.01}_{-0.01}$
D0 (run1)	16	0.69	0.00	$0.69^{+0.08}_{-0.03}$
D0 (run2)	13	2.16	0.16	$2.32^{+0.40}_{-0.32}$
D0 (W-boson)	7	2.39	0.00	$2.39^{+0.20}_{-0.18}$
ATLAS (8TeV, $Q \sim M_Z$)	30	1.60	0.49	$2.09^{+1.09}_{-0.35}$
ATLAS (8TeV)	14	1.11	0.11	$1.22^{+0.47}_{-0.21}$
ATLAS (13 TeV)	5	1.94	1.75	$3.70^{+16.5}_{-2.24}$
CMS (7TeV)	8	1.30	0.00	$1.30^{+0.03}_{-0.01}$
CMS (8TeV)	8	0.79	0.00	$0.78^{+0.02}_{-0.01}$
CMS (13 TeV, $Q \sim M_Z$)	64	0.63	0.24	$0.86^{+0.23}_{-0.11}$
CMS (13 TeV, $Q > M_Z$)	33	0.73	0.12	$0.92^{+0.40}_{-0.15}$
LHCb (7 TeV)	10	1.21	0.56	$1.77^{+0.53}_{-0.31}$
LHCb (8 TeV)	9	0.77	0.78	$1.55^{+0.94}_{-0.50}$
LHCb (13 TeV)	49	1.07	0.10	$1.18^{+0.25}_{-0.01}$
PHENIX	3	0.29	0.12	$0.42^{+0.15}_{-0.10}$
STAR	11	1.91	0.28	$2.19^{+0.51}_{-0.31}$
E288 (200)	43	0.31	0.07	$0.38^{+0.12}_{-0.05}$
E288 (300)	53	0.36	0.07	$0.43^{+0.08}_{-0.04}$
E288 (400)	79	0.37	0.05	$0.48^{+0.11}_{-0.03}$
E772	35	0.87	0.21	$1.08^{+0.08}_{-0.05}$
E605	53	0.18	0.21	$0.39^{+0.03}_{-0.00}$
Total	627	0.79	0.17	$0.96^{+0.09}_{-0.01}$