TMD extraction update

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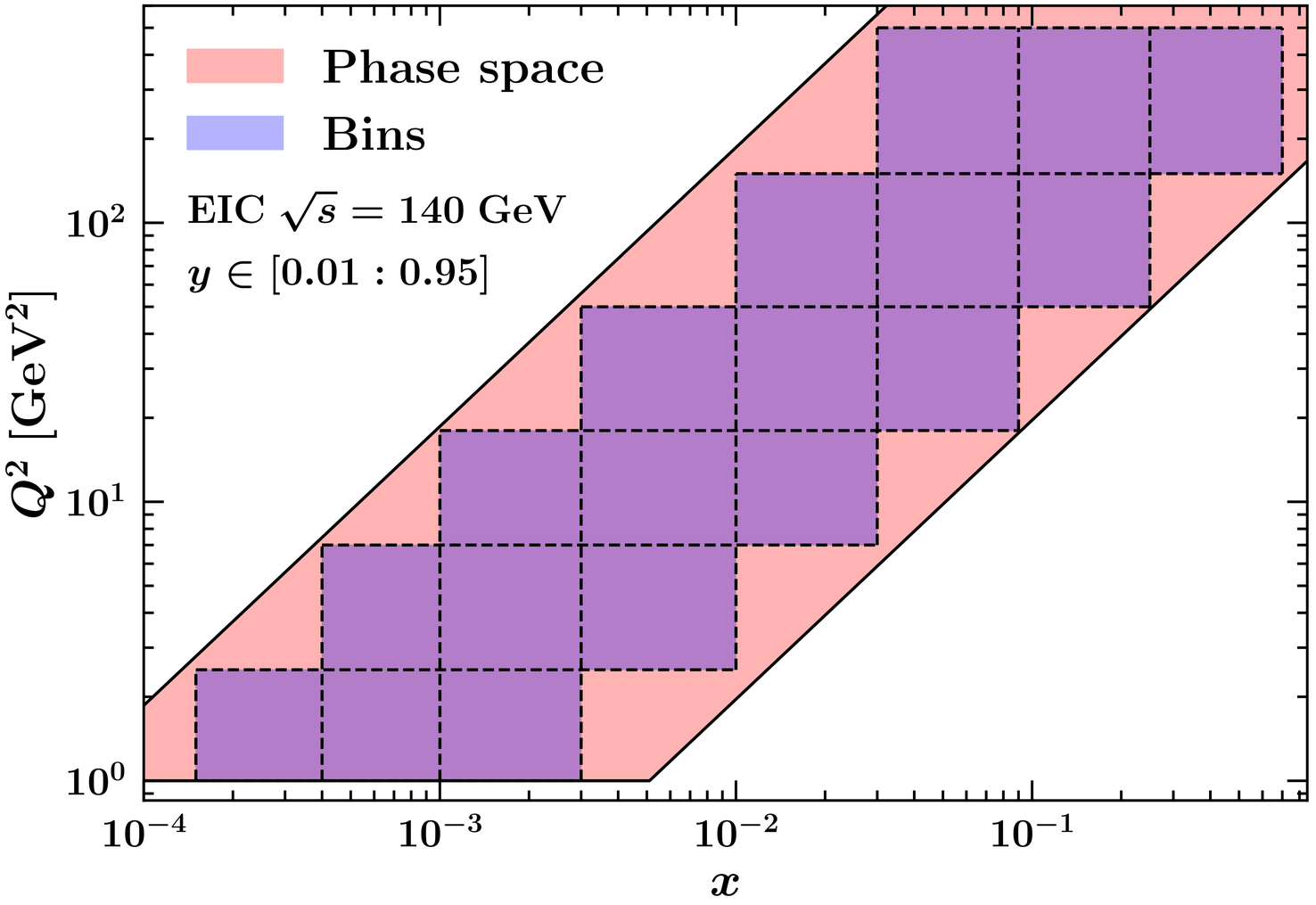
outline

- binning in (x, Q^2, z, q_T) for TMD observables at the EIC
- plot of unpolarized differential cross section in this binning

Chiara Bissolotti

- interpolation grid in (x, $k_\perp$; Q^2) for TMD PDF and (z, $P_\perp$; Q^2) for TMD FF
- plot of unpolarized TMD PDF and TMD FF in these grids
- common format for a library of TMD PDF and TMD FF (TMDlib ?)

binning in (x, Q^2)



Bins have same size to allow recursive integration.
It can be changed on demand..

Arbitrary cuts:

- $x \leq 0.7$
- $Q^2 \leq 500$ GeV^2

binning in (z, q_T)

- finer bins at low $z \geq 0.1$ and wider at large $z \leq 0.8$

- 0.2 [GeV] $\leq q_T \leq Q / 5$ [GeV] in steps of 0.1 [GeV], with $P_{hT} = z\, q_T \geq 0.1$ [GeV]
- but also explore $Q / 5$ [GeV] $\leq q_T \ldots \lesssim Q$ [GeV] ($\Rightarrow P_{hT} > 1$ [GeV])

observable

- unpolarized fully differential cross section

$$\frac{d\sigma}{dx\,dQ\,dz\,dq_T}\quad\left[\frac{\mathrm{pb}}{\mathrm{GeV}^2}\right]$$

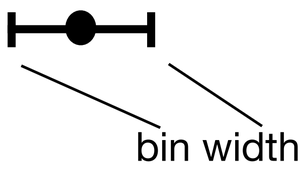
- NangaParbat framework:

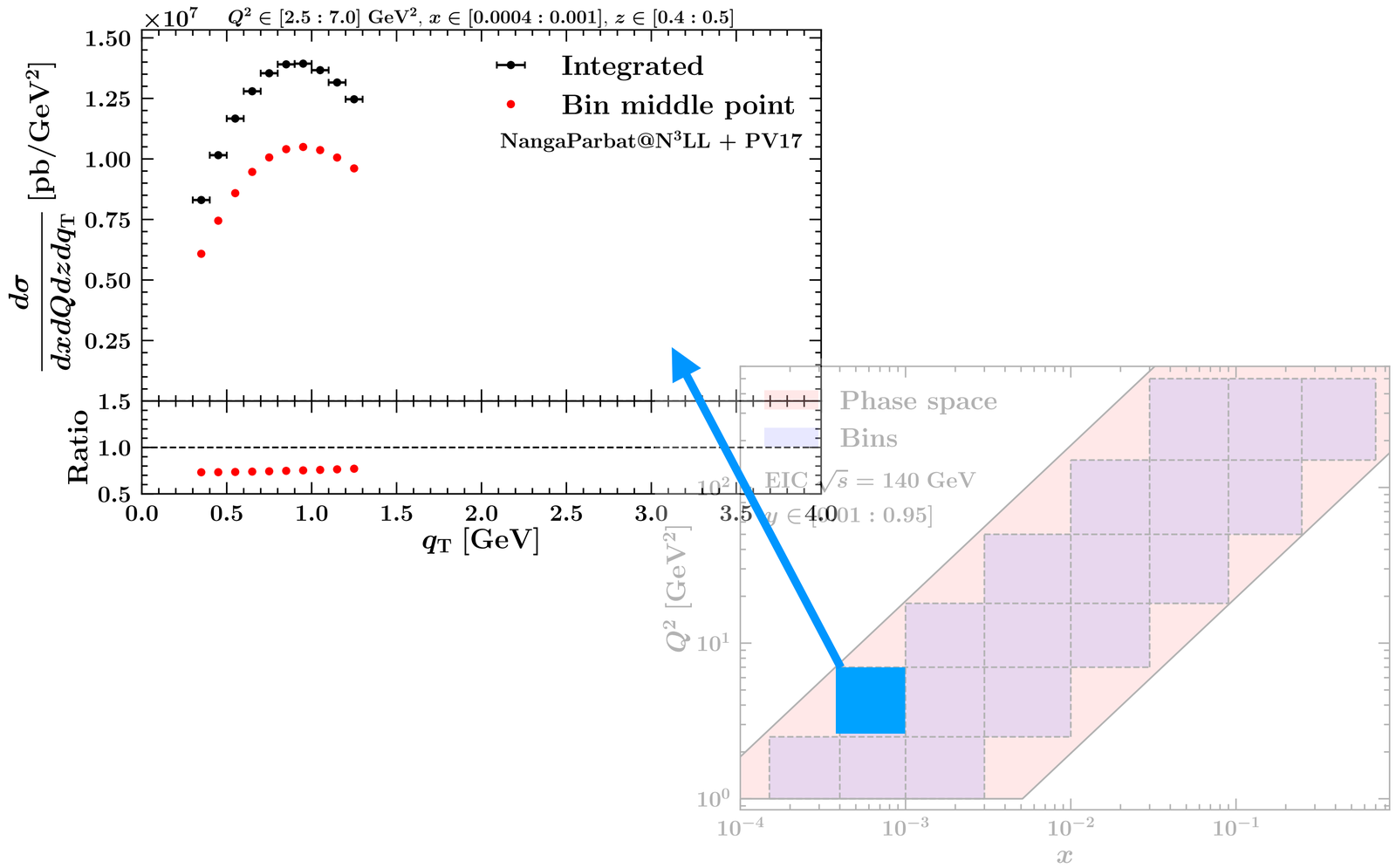
  Bacchetta *et al.*, arXiv:1912.07550

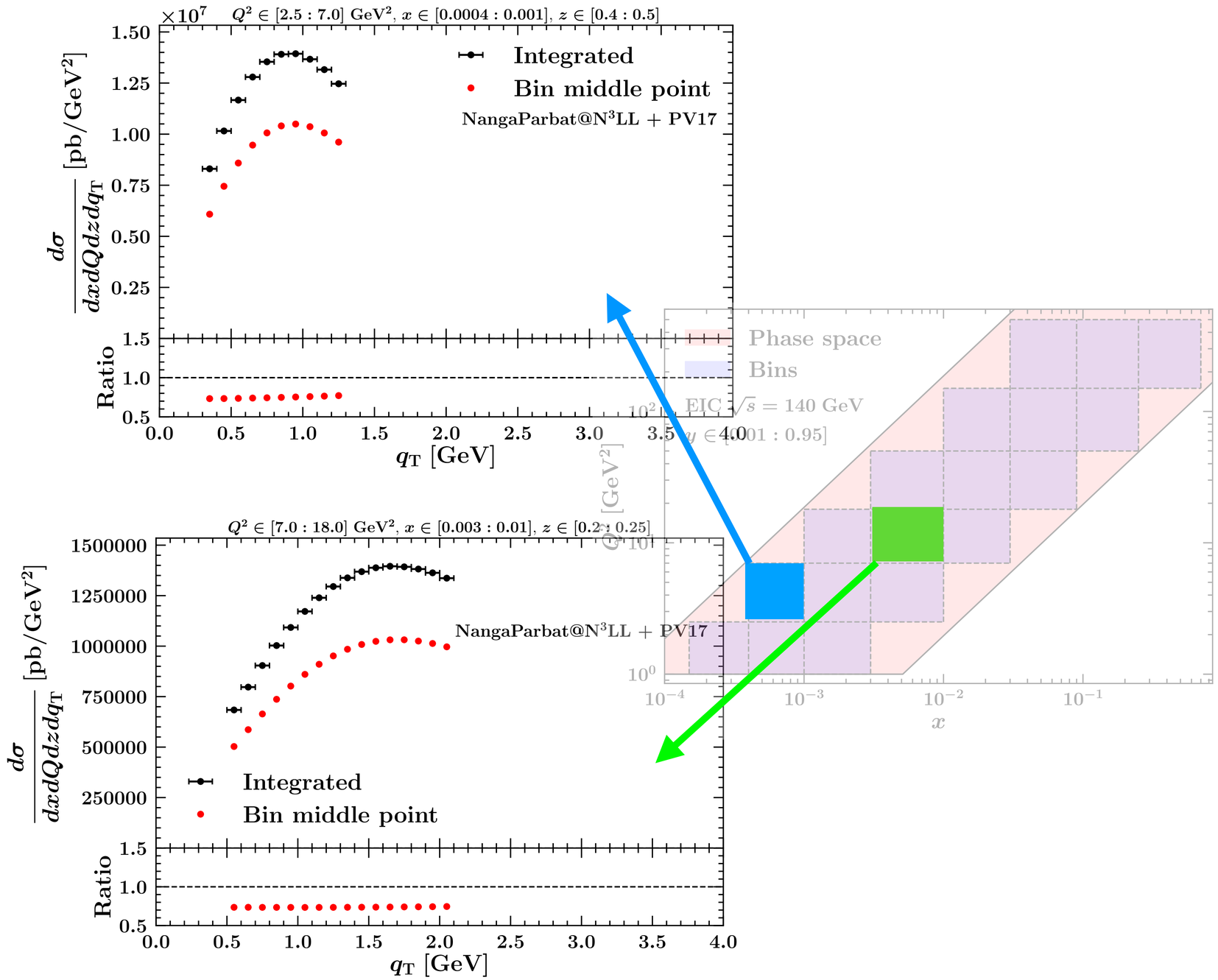
  - resummation at N^{3}LL
  - hard cross section and Wilson coeffs. at NNLO
  - no Y term
  - input TMD PDF and TMD FF from PV17 fit (replica 105)

  Bacchetta *et al.*, JHEP **06** (17) 081
  arXiv:1703.10157

- Legenda of plots:
  - integration over bin width (q_T analytic)
  - computed at bin's middle point




$\times 10^7$ $Q^2 \in [2.5 : 7.0]$ GeV^2, $x \in [0.0004 : 0.001]$, $z \in [0.4 : 0.5]$
Integrated
Bin middle point
NangaParbat@N^{3}LL + PV17
$\frac{d\sigma}{dxdQdzdq_T}$ [pb/GeV^2]
Ratio
q_T [GeV]
Phase space
Bins
EIC $\sqrt{s} = 140$ GeV
$y \in [0.01 : 0.95]$
Q^2 [GeV^2]
x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NangaParbat@N^{3}LL + PV17
Integrated
Bin middle point
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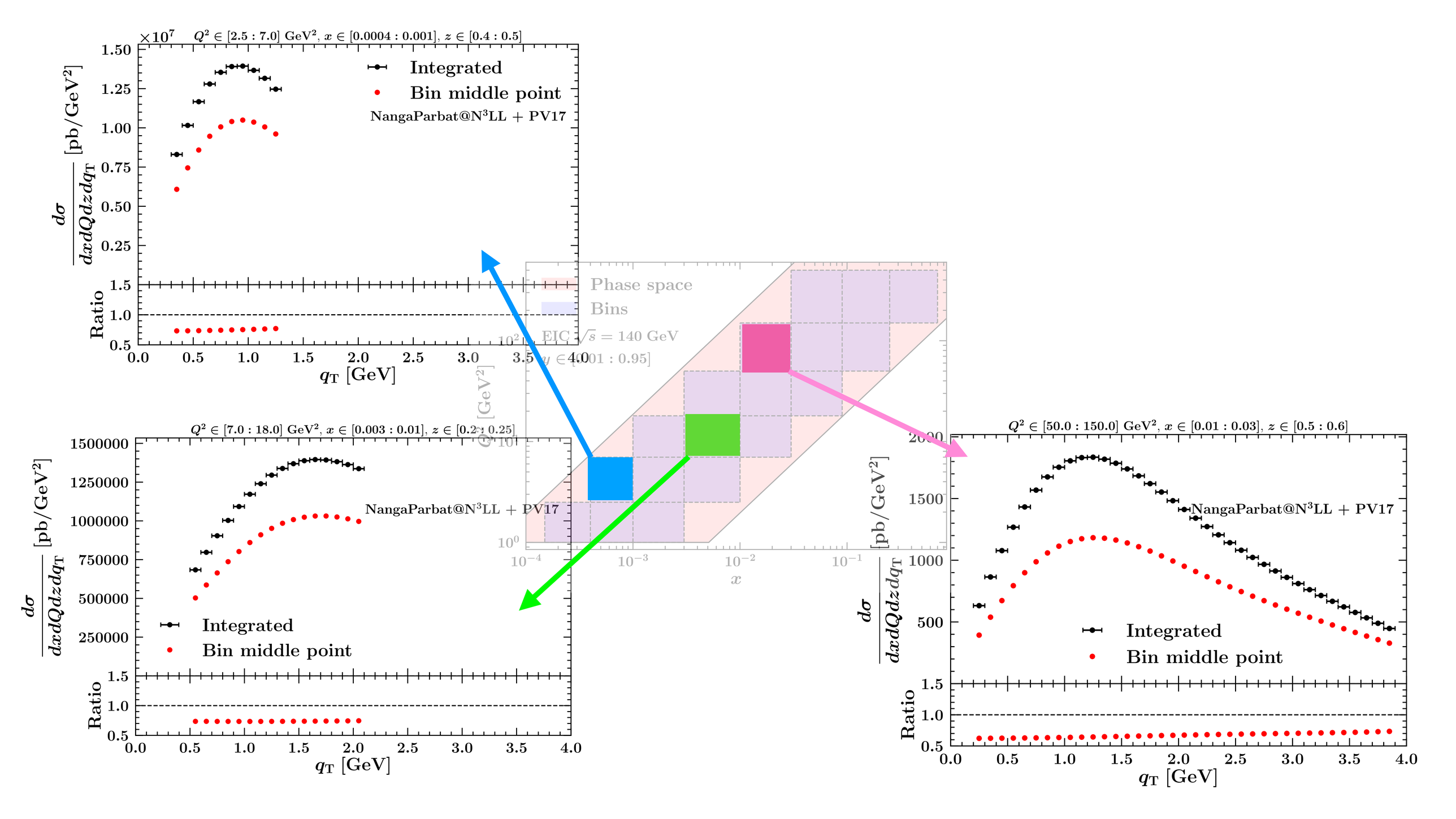
Ratio
q_T [GeV]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Bin middle point
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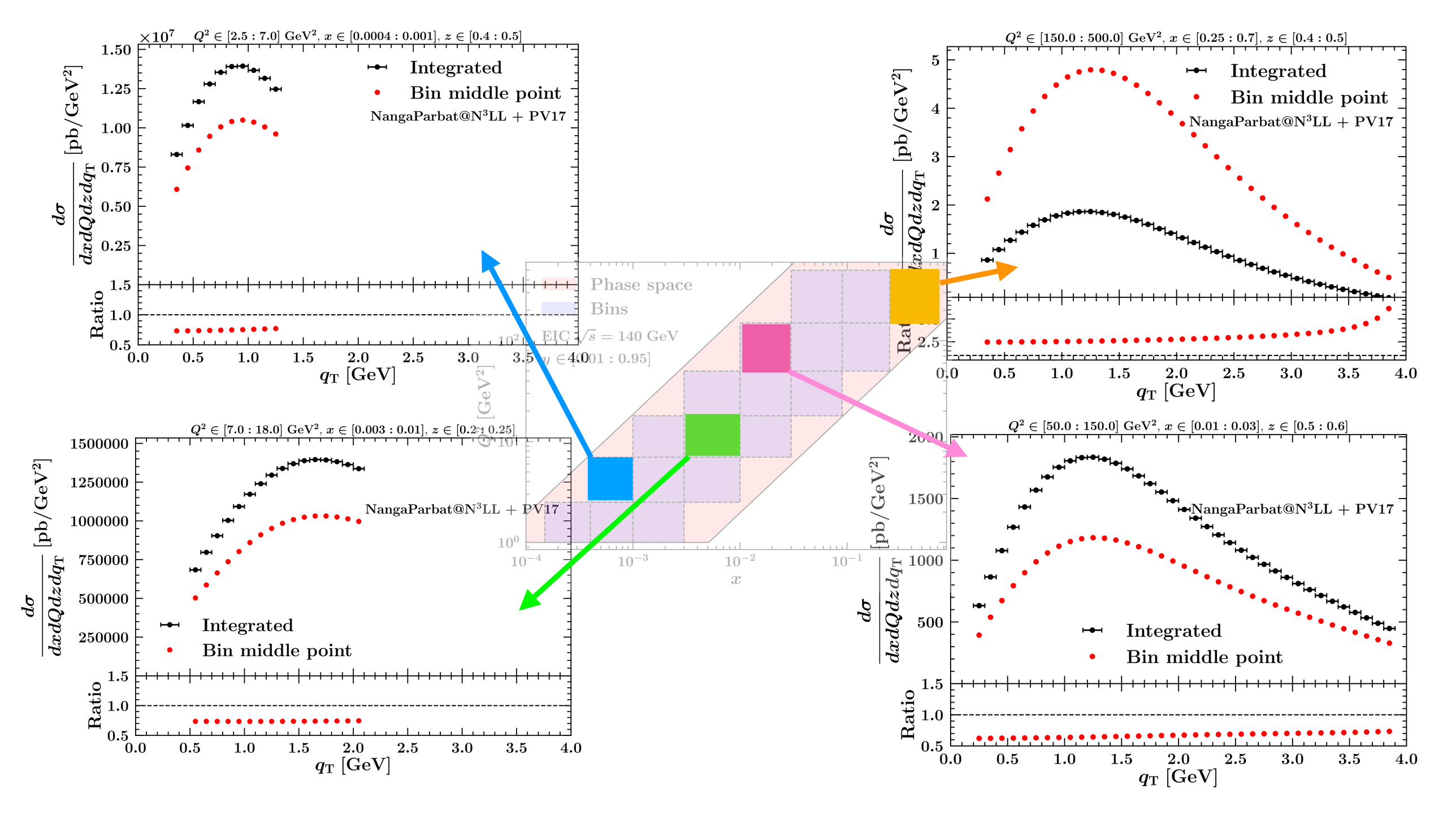
Ratio
q_T [GeV]
$Q^2 \in [50.0 : 150.0]$ GeV^2, $x \in [0.01 : 0.03]$, $z \in [0.5 : 0.6]$
NangaParbat@N^{3}LL + PV17
Integrated
Bin middle point
$\frac{d\sigma}{dxdQdzdq_T}$ [pb/GeV^2]
Ratio
q_T [GeV]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Ratio
q_T [GeV]
$Q^2 \in [150.0 : 500.0]$ GeV^2, $x \in [0.25 : 0.7]$, $z \in [0.4 : 0.5]$
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q_T [GeV]

warning !

- result at **bin's middle point** systematically **smaller**, down to **0.6** x **integrated result**

- for largest Q^2 bin $[150 \leq Q^2 \leq 500]$ result at **bin's middle point** systematically **larger**, up to **2.5-3** x **integrated result**

- possible interplay between missing evolution effects when averaging over large Q^2 bin and behaviour of DGLAP, particularly at large x

TMD library

- for $q_T \ll Q$, cross section / structure functions are convolutions of TMDs

- we propose to release also **interpolation grids for TMDs in a standard format**
  - TMD PDF on a properly tuned grid in $(x, k_\perp; Q)$
  - TMD FF on a properly tuned grid in $(z, P_\perp; Q)$

$$P_{hT} \simeq z\, k_\perp + P_\perp$$

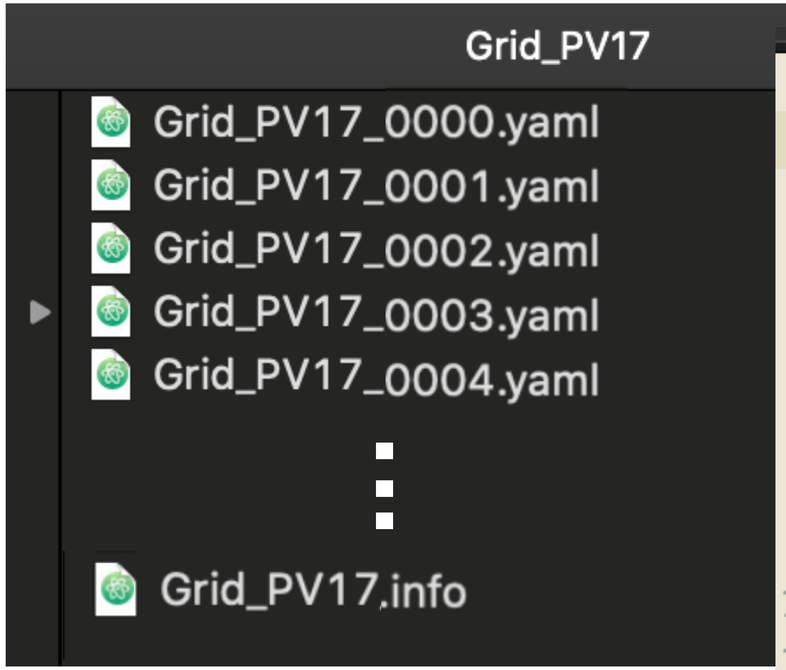
- we provide **interpolation** and **convolution** tools

- grids should be **collected and made public** through a **common library** such as, e.g., TMDlib / TMDplotter

(much like LHAPDF works for collinear PDF / FF)

NangaParbat TMD grids

- format in file**.yaml** ⟶ `key: value`
- **LHAPDF** style: info file and replicas




```yaml
SetDesc: Set produced with NangaParbat + APFEL++
Authors: A. Bacchetta, F. Delcarro, C. Pisano, M. Radici, A. Signori
Reference: arXiv:1703.10157
SetIndex: 000000
TMDType: pdf
CollDist: MMHT2014lo68cl
CollDistMember: 0
Format: TMDlib1
DataVersion: 1
OrderQCD: NLL
Regularisation: bstarmin
NumMembers: 1
ErrorType: Monte Carlo
```

PV17 global fit

… more entries?

NangaParbat TMD grids

- grids in (x, $k_\perp$; Q^2) for **TMD PDF**
- grids**.yaml**

Q ← 41 points

```
Q: [1, 1.11803, 1.22474, 1.4, ..., 178.885, 200]

x: [1e-05, 2e-05, 4e-05, 6e-05, 8e-05, ... , 0.925, 0.95, 0.975, 1]

kToQ: [0.0001, 0.001, 0.0025, ..., 0.9, 1]

TMDs: {-5: [[[-3.33067e-16, 0, -5.55112e-16, -5.55112e-16, 0, -
6.66134e-16, -6.66134e-16, -1.11022e-16, -6.66134e-16, -5.55112e-
16, -5.55112e-16, ...
```

x → 71 points

k_T/Q ← 34 points

TMD map

$x \cdot f_1(x, k_T; Q)$

NangaParbat TMD grids

- grids in (z, $P_\perp$; Q^2) for **TMD FF**
- grids**.yaml**

Q
41 points

```
Q: [1, 1.11803, 1.22474, 1.4, 1.58114, 1.78885, 2, 2.23607, ..., 178.885, 200]

z: [0.01, 0.012, 0.015, 0.017, ..., 0.95, 0.97, 1]

PToQ: [0.0001, 0.001, 0.0025, ... , 0.07, 0.08, 0.09, 0.1, 0.11 ... , 0.9, 1]

TMDs: {-6: [[[6.245e-17, -1.21973e-19, -1.0842e-19, -5.42101e-20, -4.06576e-
20, -4.06576e-20, -2.71051e-20, -8.13152e-20, -8.13152e-20, -9.48677e-20, -
8.13152e-20, -5.42101e-20, -5.42101e-20, -8.13152e-20, -9.48677e-20, -
```

z
71 points

$P_\perp/Q$
44 points

TMD map

$z \cdot D_1(z, P_\perp; Q)$

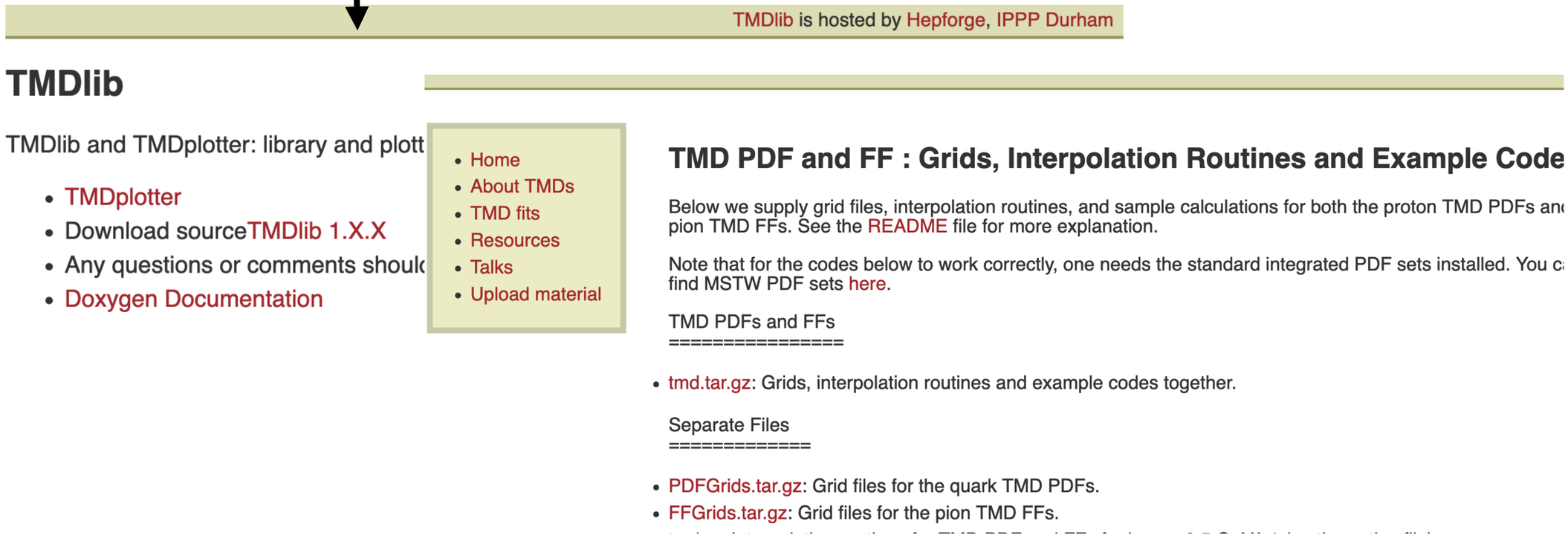
NangaParbat provides an interpolator

APFEL++ based

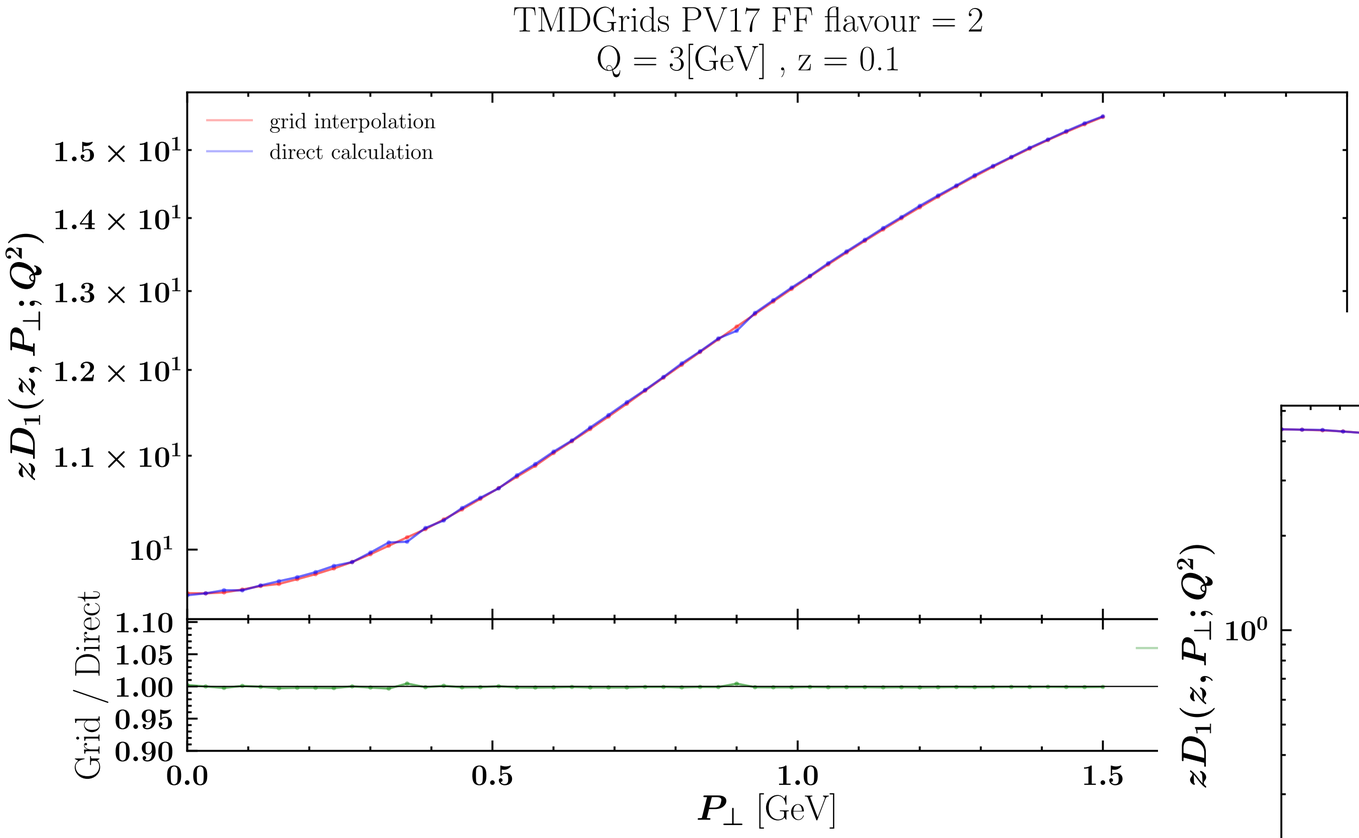
polynomial interpolation

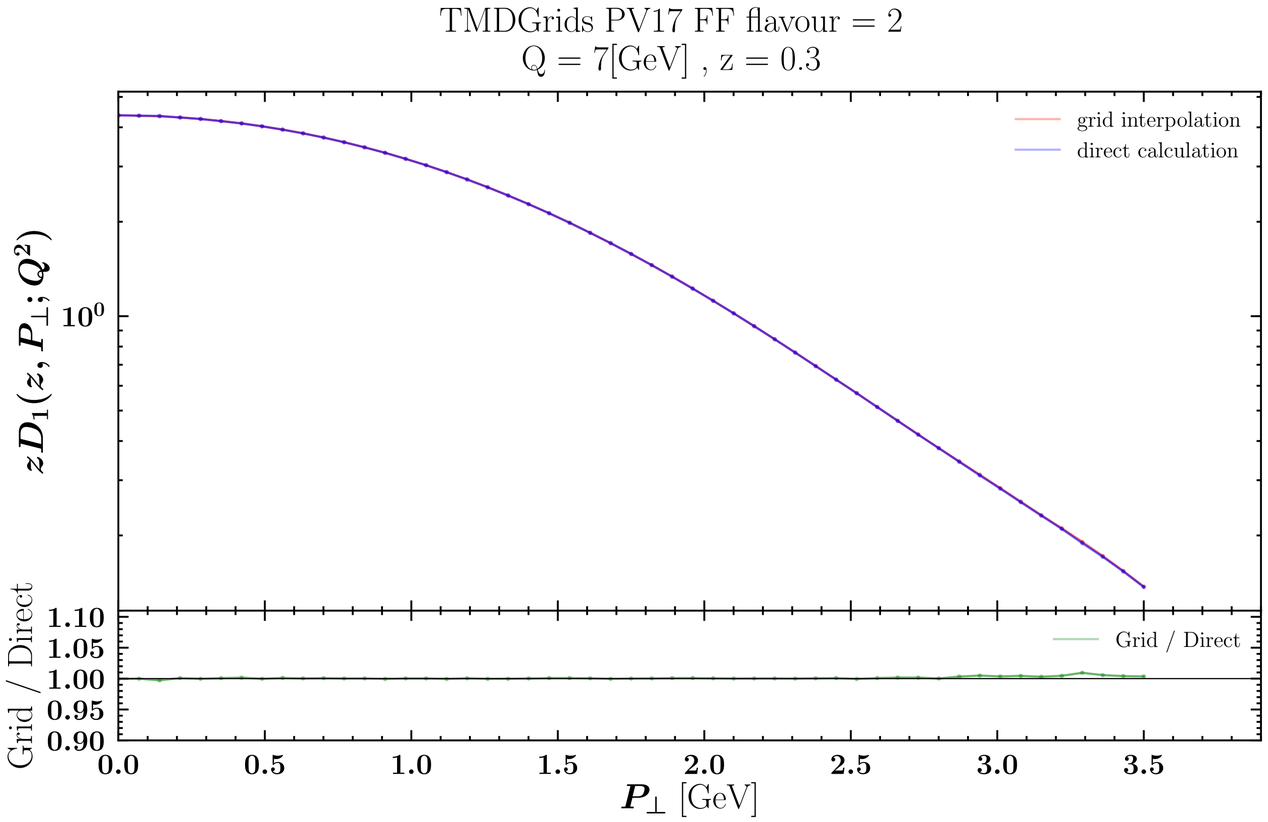
- possibility to choose the degree

to release the grids on

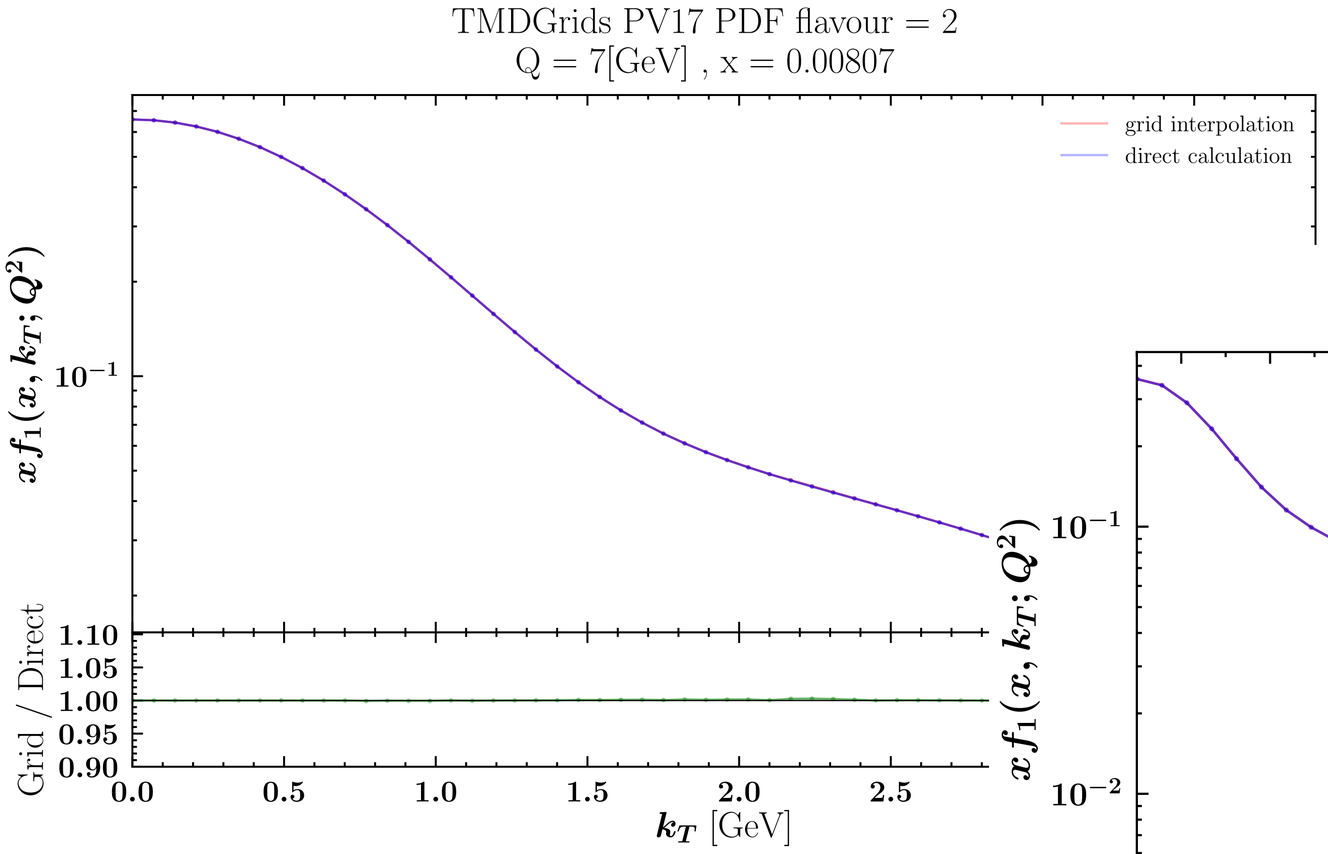


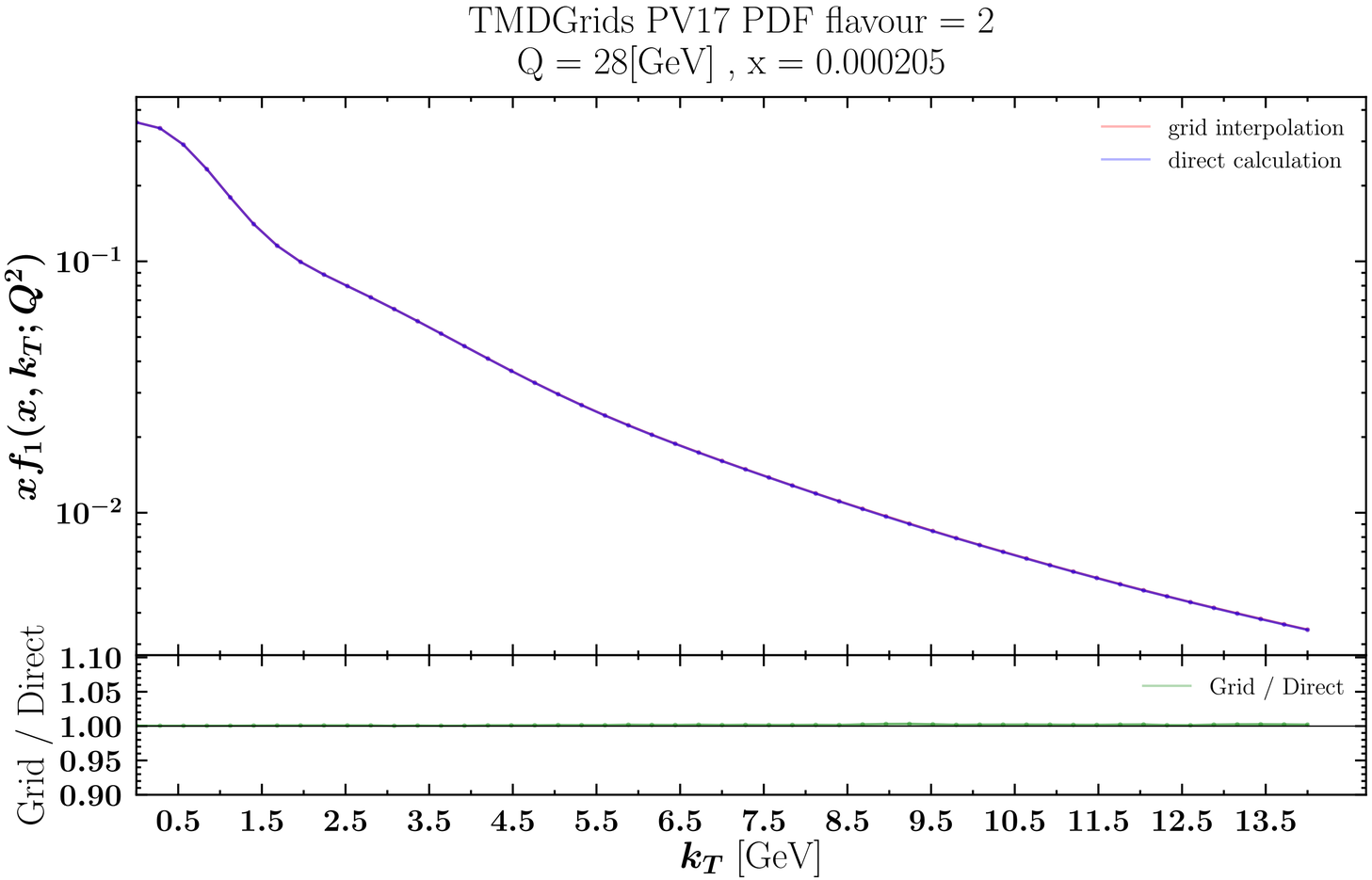
TMD FF grids : interpolation



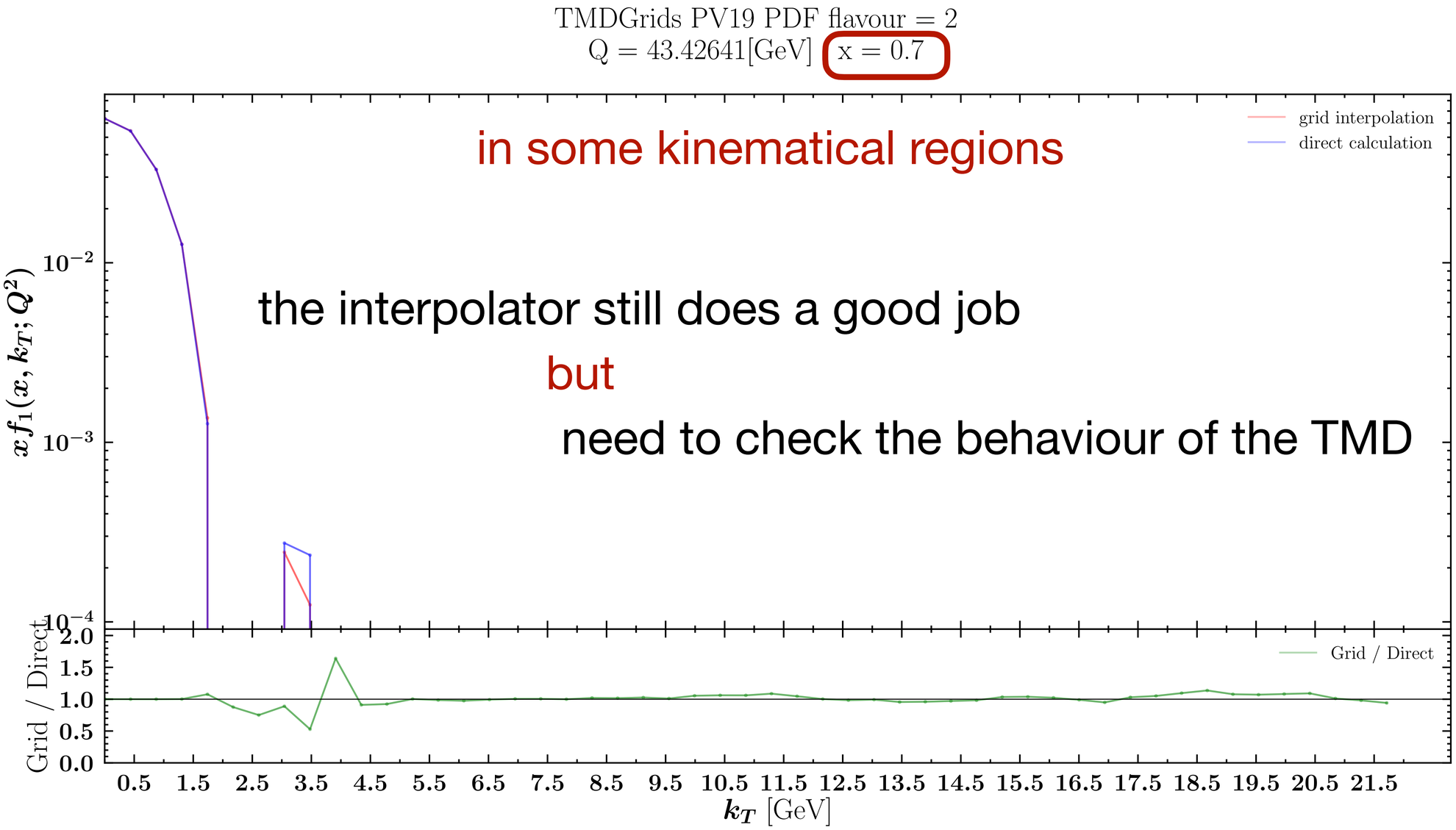


TMD PDF grids: interpolation





TMD Grids: caveat



Nanga Parbat: a TMD fitting framework

Nanga Parbat is a fitting framework aimed at the determination of the non-perturbative component of TMD distributions.

Download

You can obtain NangaParbat directly from the github repository:

https://github.com/vbertone/NangaParbat/releases

reliable grids and interpolator for unpolarized TMD PDFs and TMD FFs

- we propose to release **interpolation grids for TMDs in a standard format**
- grids should be **collected and made public** through a **common library** such as, e.g., TMDlib / TMDplotter