Upgrade of ART23: TMDs fit to SIDIS data

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Workshop on Hadron Structure and Spectroscopy and Correlations in Partonic Hadronic Interactions

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Outline

ART23

8 TMD distributions

quark polarization

Nulceon polarization

N \ q	U	L	T
U	f_1		$h_1^\perp$
L		g_1	$h_{1L}^\perp$
T	$f_{1T}^\perp$	g_{1T}	h_1 $h_{1T}^\perp$

The parametrized forms of the TMD distributions include 8 functions.

In ART23 we extracted the unpolarized distribution (f_1) at N^4LL accuracy.

ART23: model TMDPDF

Using relation between TMDs and PDFs:

$$f_{1,f}(x,b) = \int_x^1 \frac{dy}{y} \sum_{f'} C_{f\to f'}(y, \mathbf{L}, a_s)\, q_{f'}\left(\frac{x}{y}\right) f_{\rm NP}^{f}(x,b)$$

$\rightarrow$ use MSHT20 PDF (NNLO) as boundary condition for TMDPDF.

$$f_{\rm NP}^{f}(x,b) = \frac{1}{\cosh\left(\left(\lambda_1^f(1-x) + \lambda_2^f x\right) b\right)}$$

- flavour dependent ansatz
- $f \in \{u, \overline{u}, d, \overline{d}, sea\}$ $\rightarrow 2 \times 5$ independent parameters

ART23: model Collins Soper kernel

Parametrization of TMD Evolution:

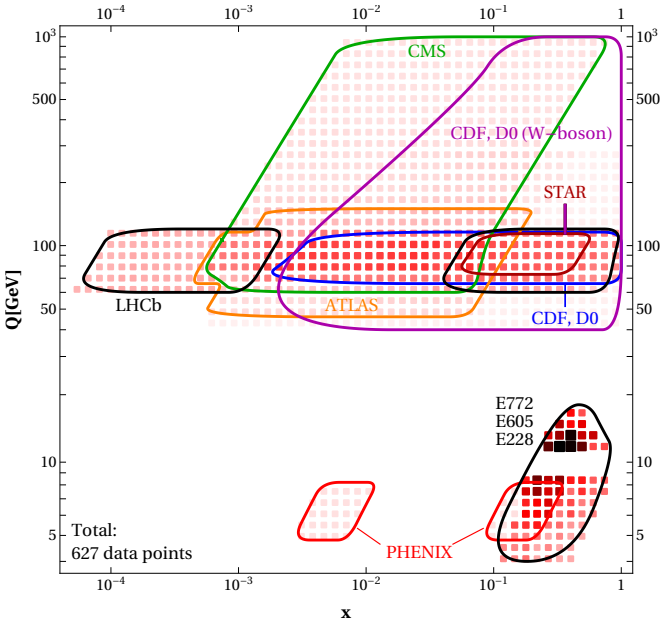
$$\mathcal{D}(b,\mu) = \mathcal{D}_{\text{small-b}}(b^*,\mu^*) + \int_{\mu^*}^{\mu} \frac{d\mu'}{\mu'} \Gamma_{\text{cusp}}(\mu') + \mathcal{D}_{\text{NP}}(b)$$

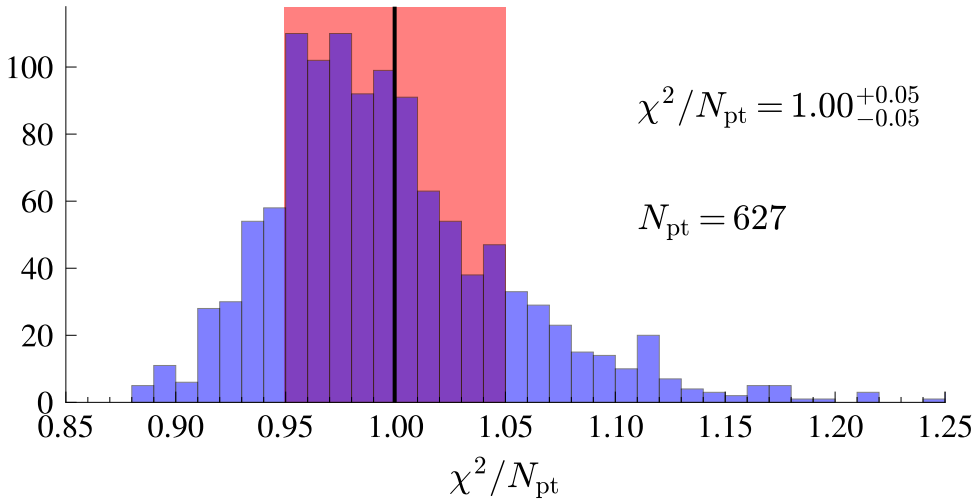
- Ansatz for NP part:

$$\mathcal{D}_{\text{NP}}(b) = c_0\, b b^* + c_1\, b b^* \ln\left(\frac{b^*}{B_{\text{NP}}}\right)$$

- log term brings sensitivity to moderate b region, determined by high energy DY data!
- 3 parameters for TMDPDF scale evolution

ART23 Summary





Features:

- Good fit quality
- conistent uncertainty treatment
- Large kinematic range of datapoints (4–1000 GeV)

New Results: preliminary

model for TMDFF

Using the ART23 settings
Boundary condition:

$$D_{1,f}(z,b) = \frac{1}{z^2}\int_z^1 \frac{dy}{y} y^2 \sum_{f'} C_{f\to f'}(y, \mathbf{L}, a_s)\, d_{1,f'}\left(\frac{z}{y}\right) D^f_{\mathrm{NP}}(x,b)$$

$\rightarrow$ use DSS22 FF (NNLO) for pion and DSS17 (NLO) for kaon FFs in order to describe SIDIS at HERMES (96) and COMPASS (390).

$$D^f_{\mathrm{NP}}(z,b) = \frac{1}{\cosh(\lambda^h b/z)}\left(1+\lambda_h b^2/z^2\right)$$

- distinct parameters for pions / kaons $\rightarrow 2\times 2$ independent parameters

model for TMDPDF

Modifications of ART23 model

- constrain flavour dependent TMDPDF for small-x
- change scale for boundary condition
  increased off-set avoids NP region
- $B_{NP} \to 1.5$ GeV fix

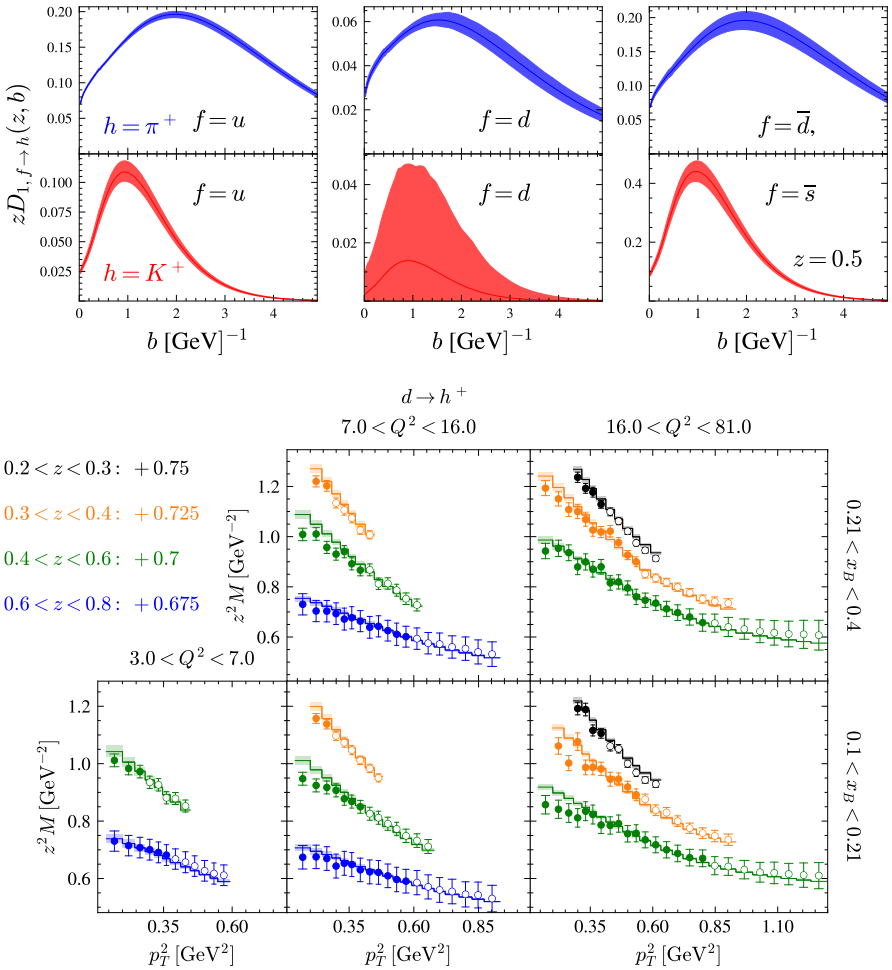
$$f_{1,f}(x,b) = \int_x^1 \frac{dy}{y} \sum_{f'} C_{f\to f'}(y, \mathbf{L}, a_s)\, q_{f'}\left(\frac{x}{y}\right) f^f_{\rm NP}(x,b)$$

$$f^f_{\rm NP}(x,b) = \frac{1}{\cosh\Big(\Big(\lambda^f_1(1-x) + \lambda^f_2 x\Big)\, b\Big)}$$

$$\lambda^u_1 = \lambda^{\overline{u}}_1, \quad \lambda^d_1 = \lambda^{\overline{d}}_1$$

- modification is physically motivated
- great improvement of fit $\chi^2/N_{\rm pt} = 1.7 \to 0.9$ (SIDIS)
- simultaneous improvement of pion-proton DY fit

Results (preliminary) of a *combined* fit



- good result for SIDIS
  $\chi^2/N_{\mathrm{pt}} = 0.93^{+0.10}_{-0.10}$
- good result for combined
  $\boldsymbol{\chi^2/N_{\mathrm{pt}} = 1.07^{+0.06}_{-0.07}}$

Problems (Why the work is not yet published)

SIDIS fit result is “great”
DY fit result is significantly worse than in ART23
Problem

- ART23
  $\chi^2/N_{\text{pt}} = 1.00^{+0.05}_{-0.05}$
- combined fit
  $\chi^2/N_{\text{pt}} = 1.21^{+0.10}_{-0.10}$

- good central fit
- worse: statistical / replica fit (PDF uncertainty progression)
- modifications: scale variation, initial parameters,...

Recapitulation & outlook

What has been done:

- good quality of fit ($\chi^2/N_{\text{pt}} = 1.07^{+0.06}_{-0.07}$)
- additional studies have been done on the result (e.g. PDF uncertainty, PDF choice)

Work in progress:

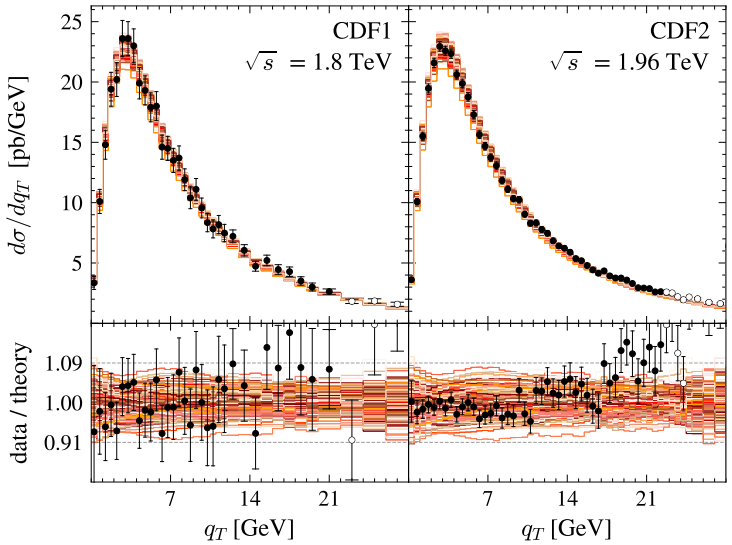
- this.
- a Pion TMDPDF fit

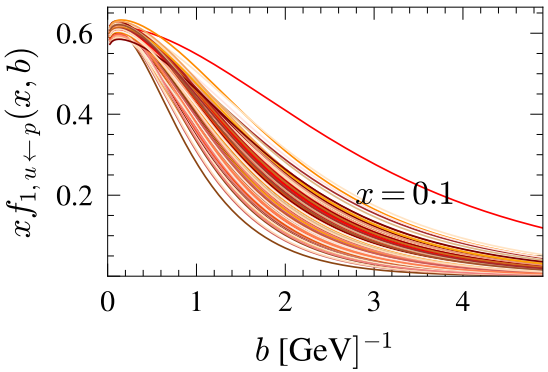
Additional material

Uncertainty processing fit

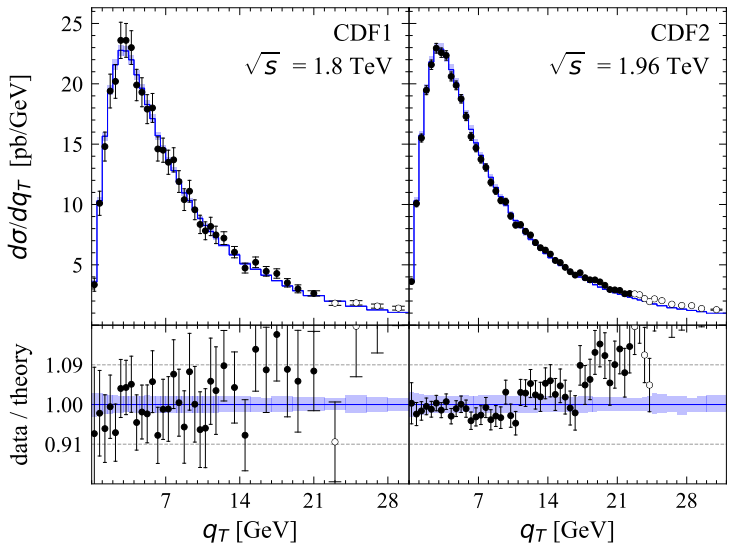
replica of data + replica of PDF $\xrightarrow{\text{fit}}$ TMDPDF replica

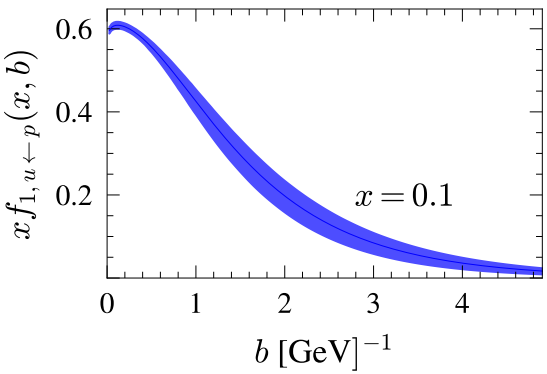
ensemble of replicas





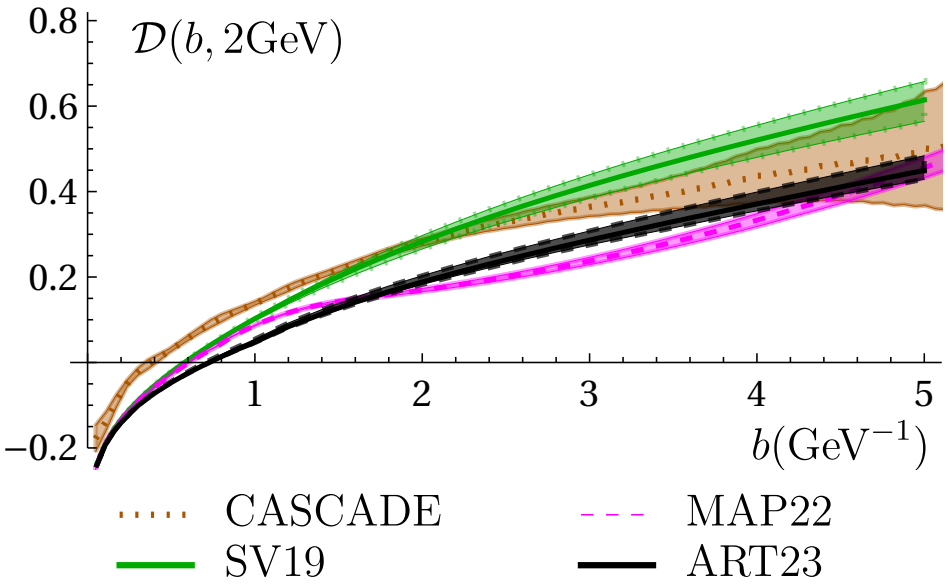
average value and 68% CI



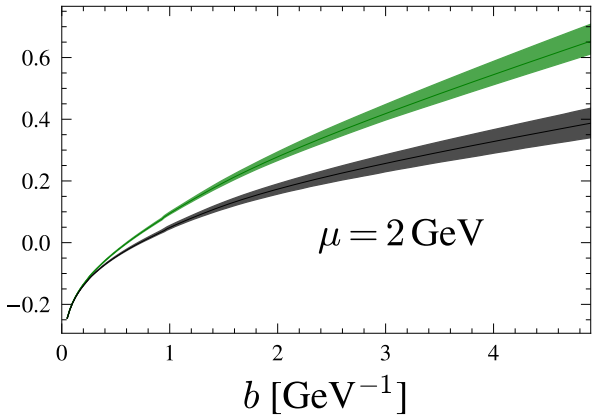


Collins-Soper kernel

ensemble of replicas

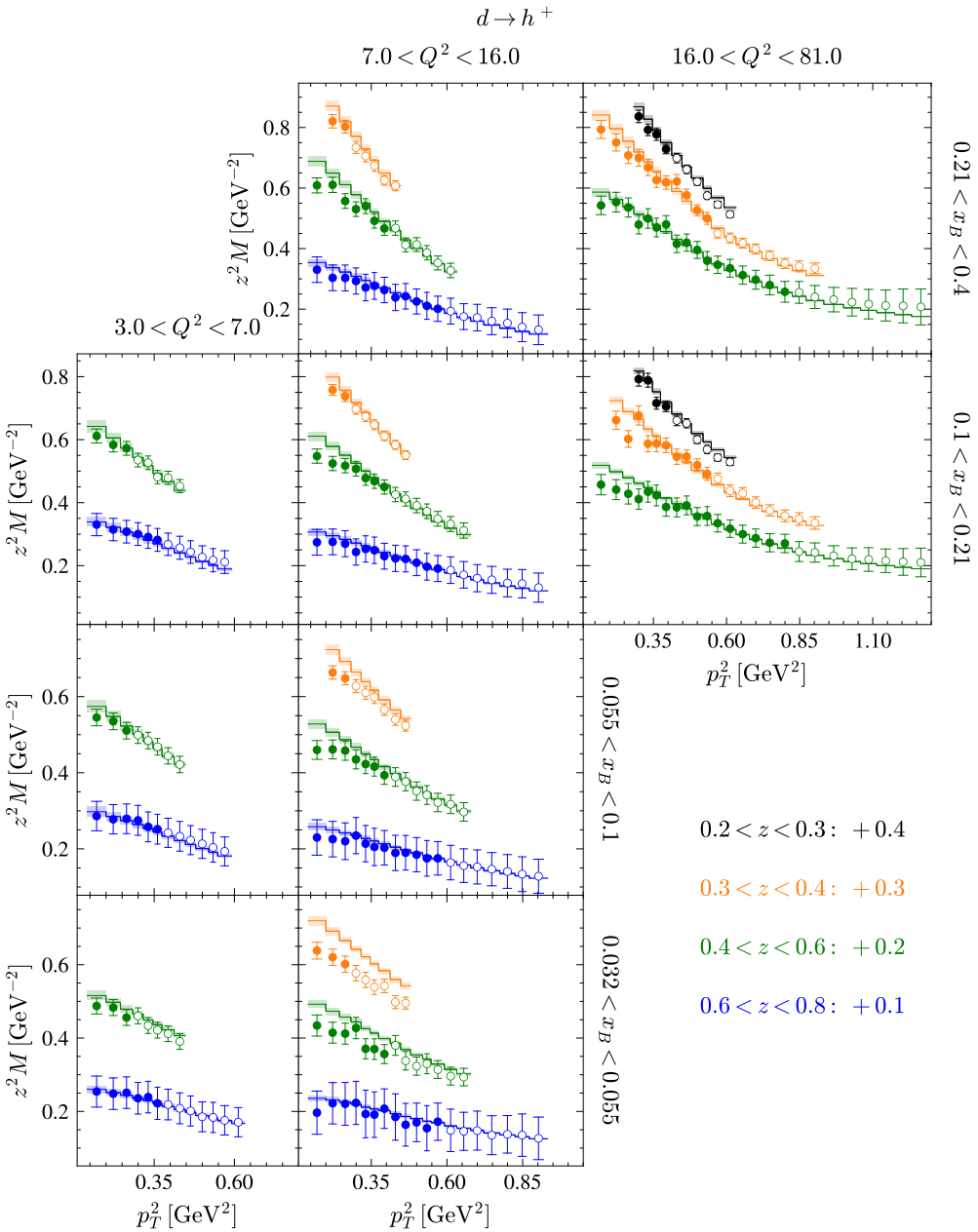


→ ART23: agreement with MAP22



→ now: agreement with SV19
(2019 NNLO fit DY + SIDIS)

COMPASS data description



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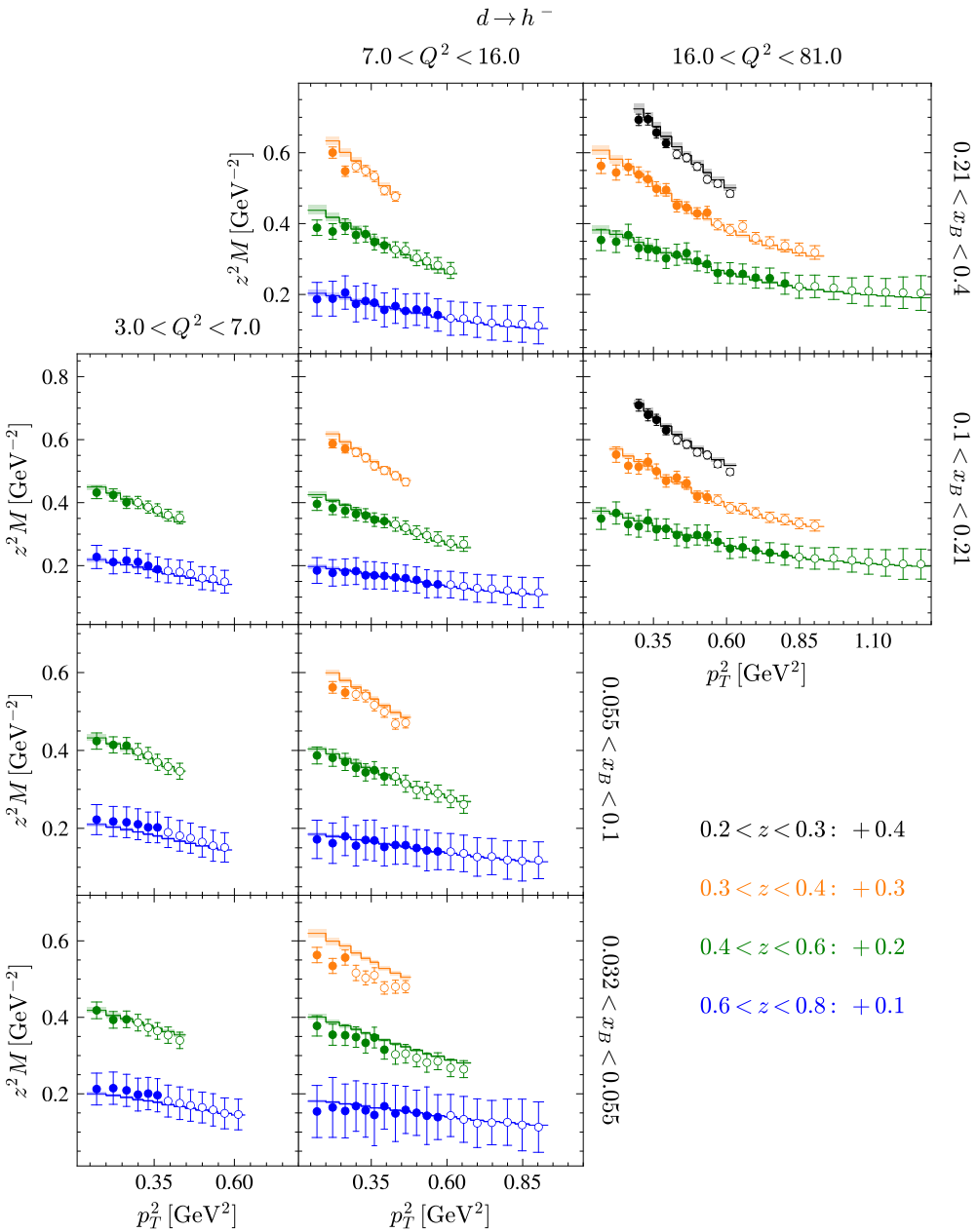
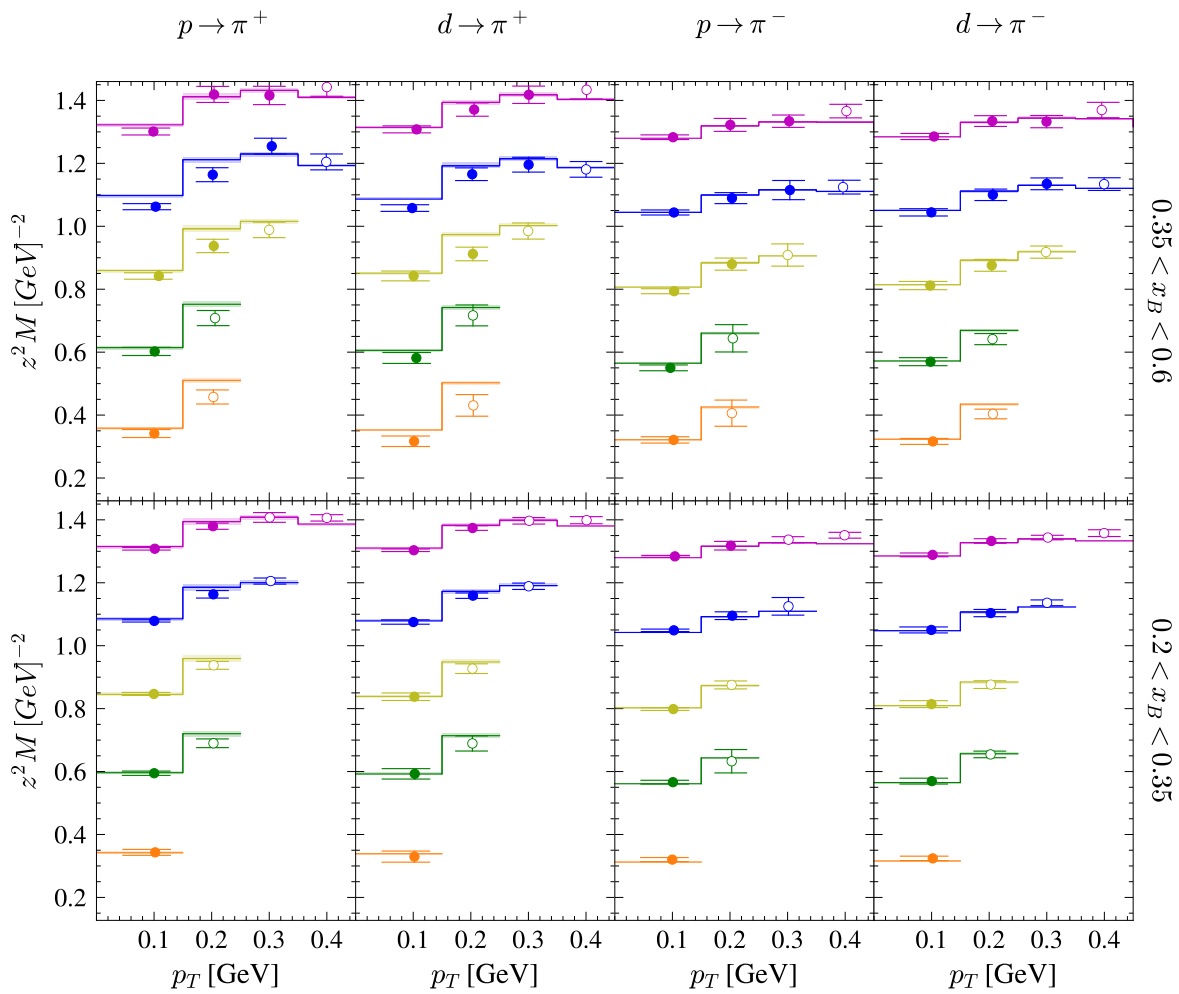


HERMES data description



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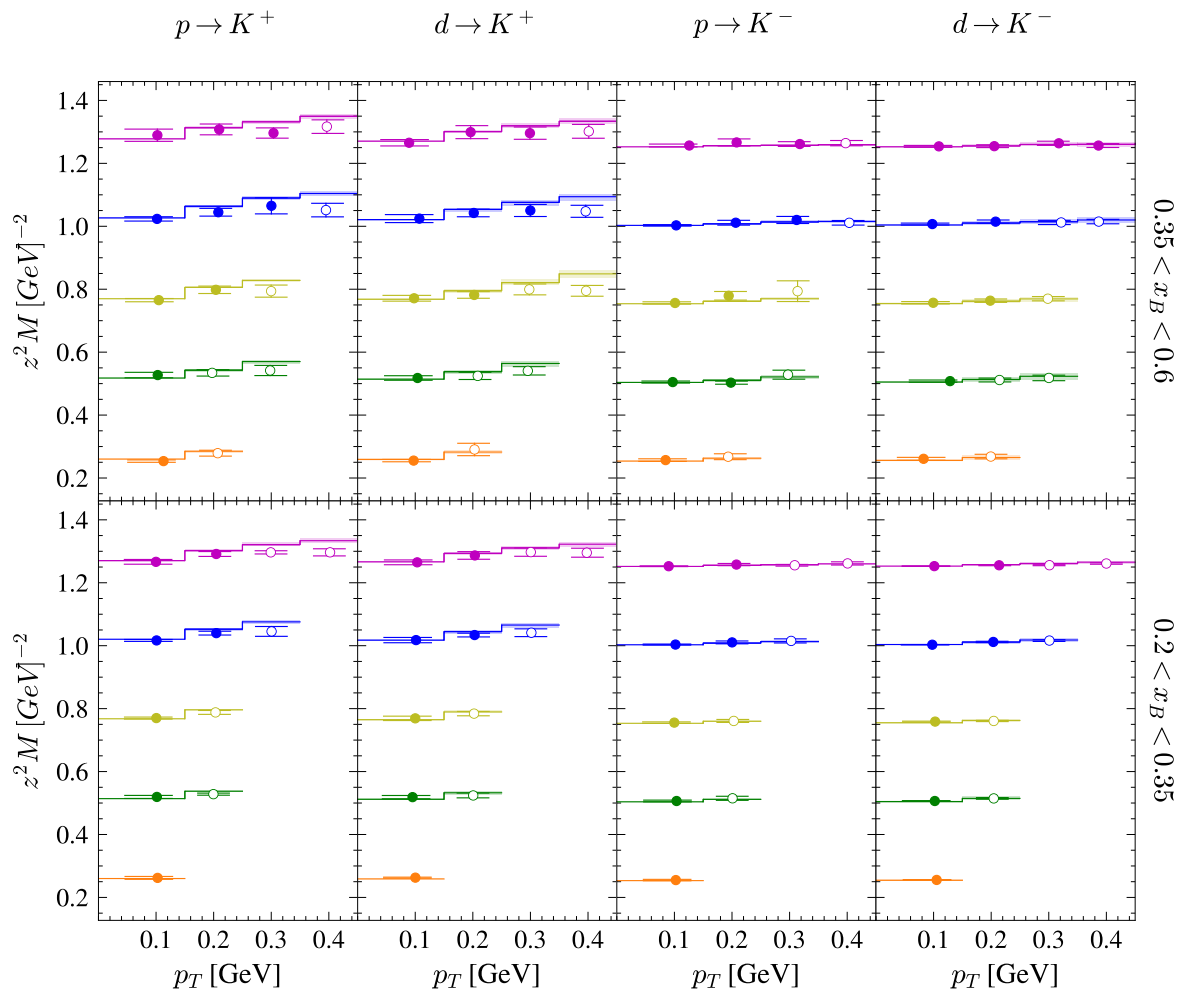
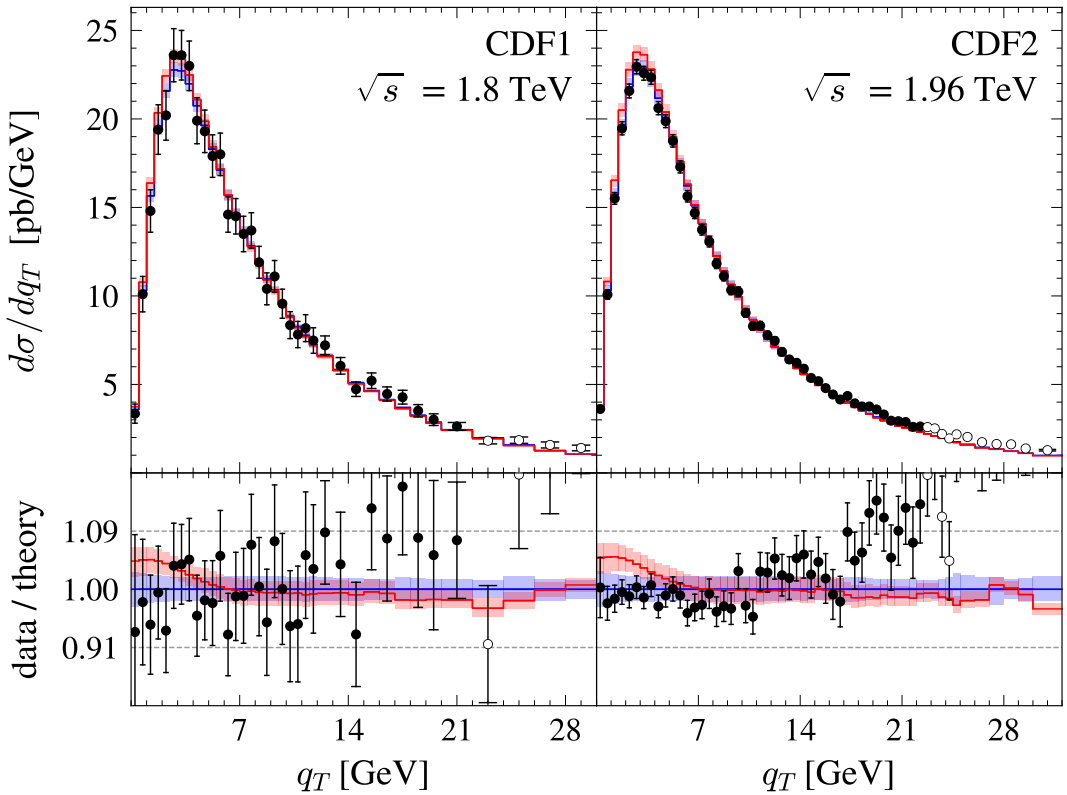
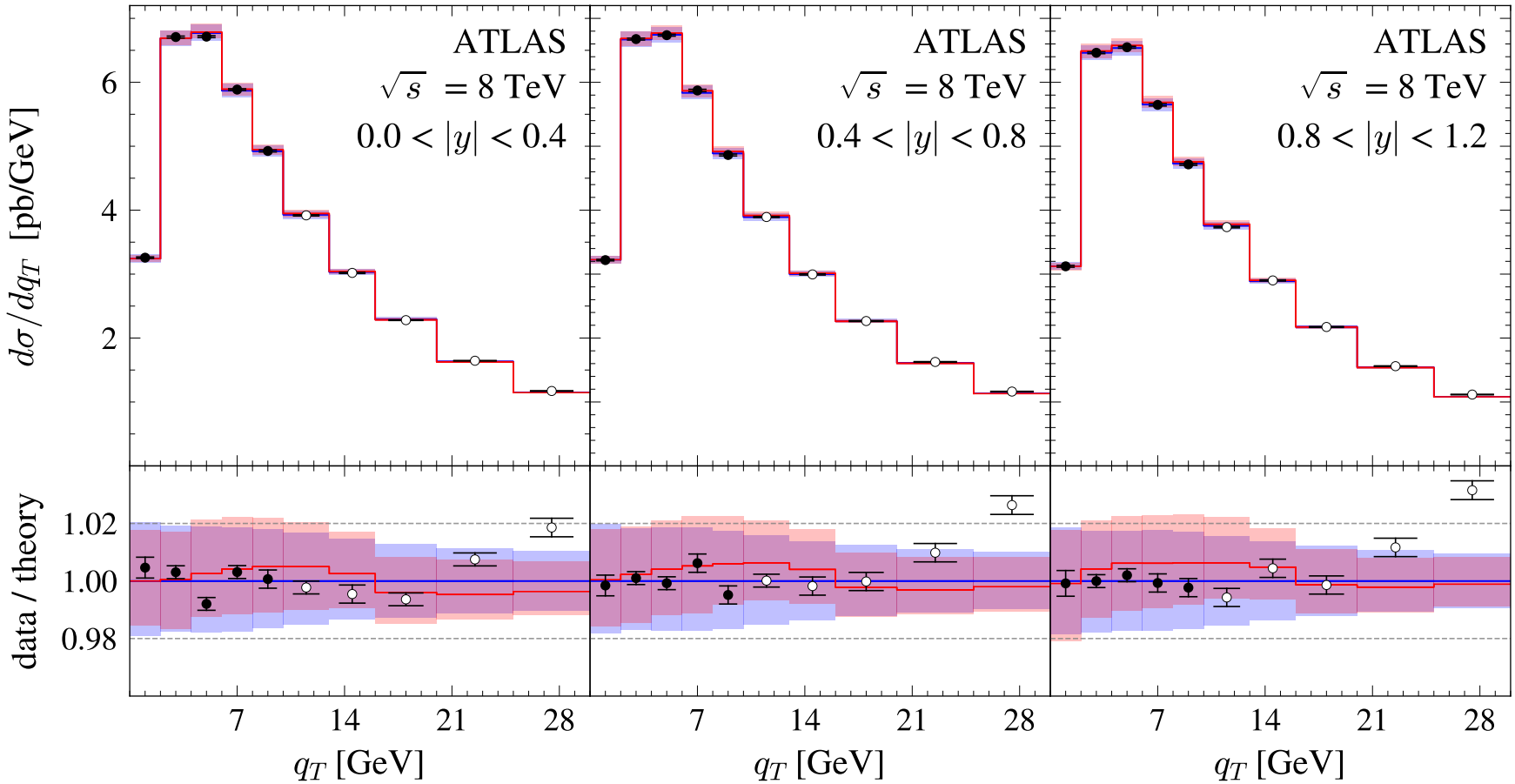


Compare with old result



- ART23 (DY)
- NEW (DY+SIDIS)

Compare with old result



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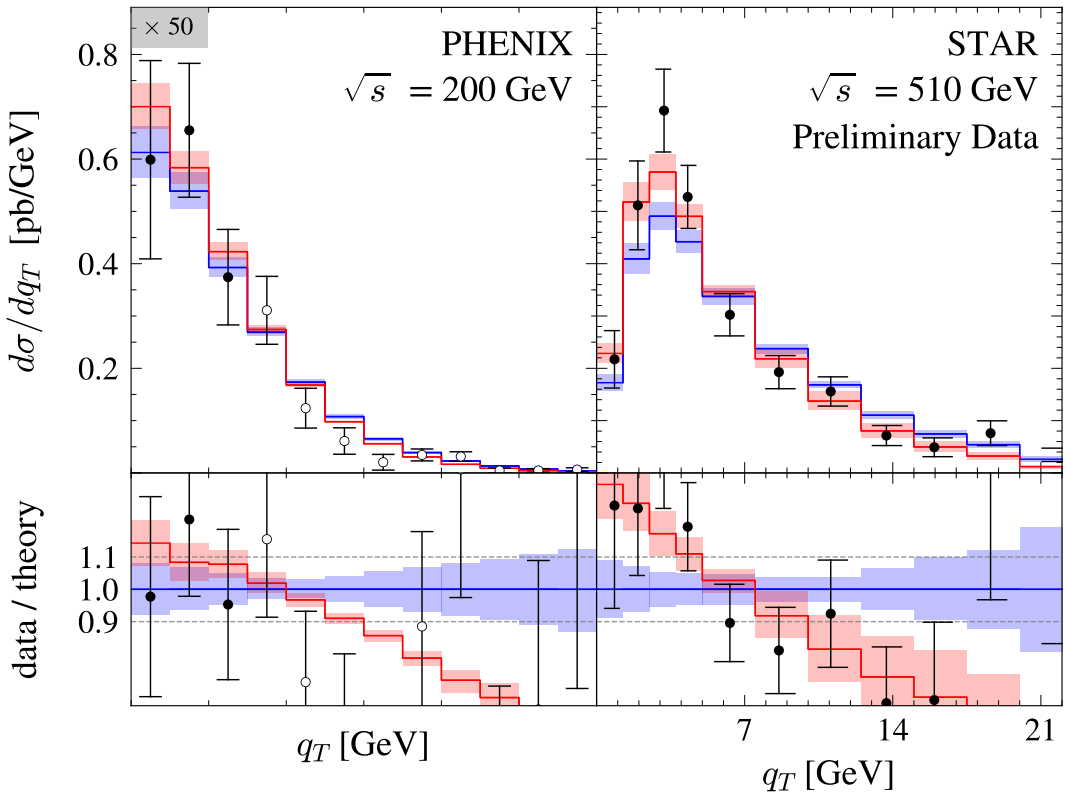

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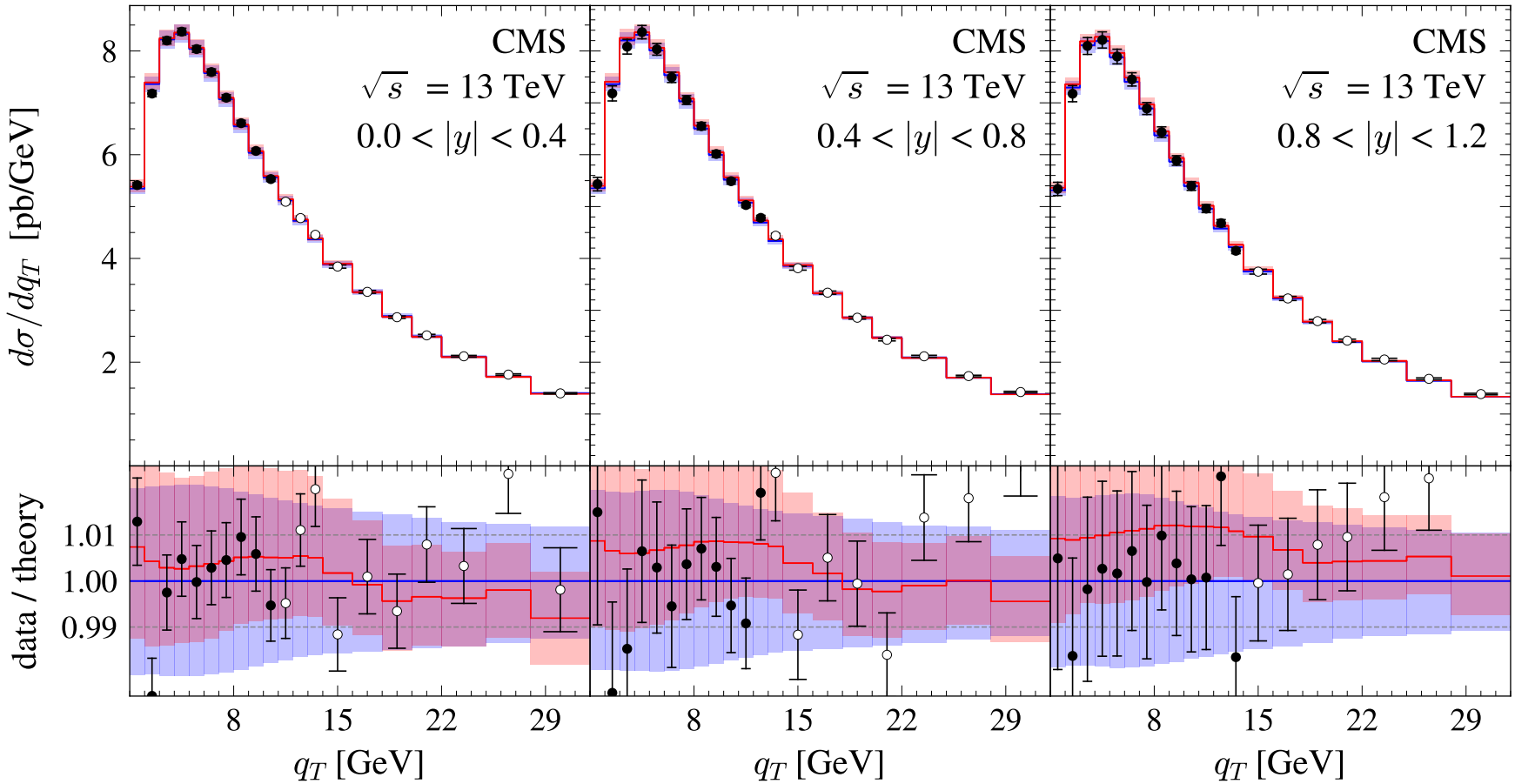

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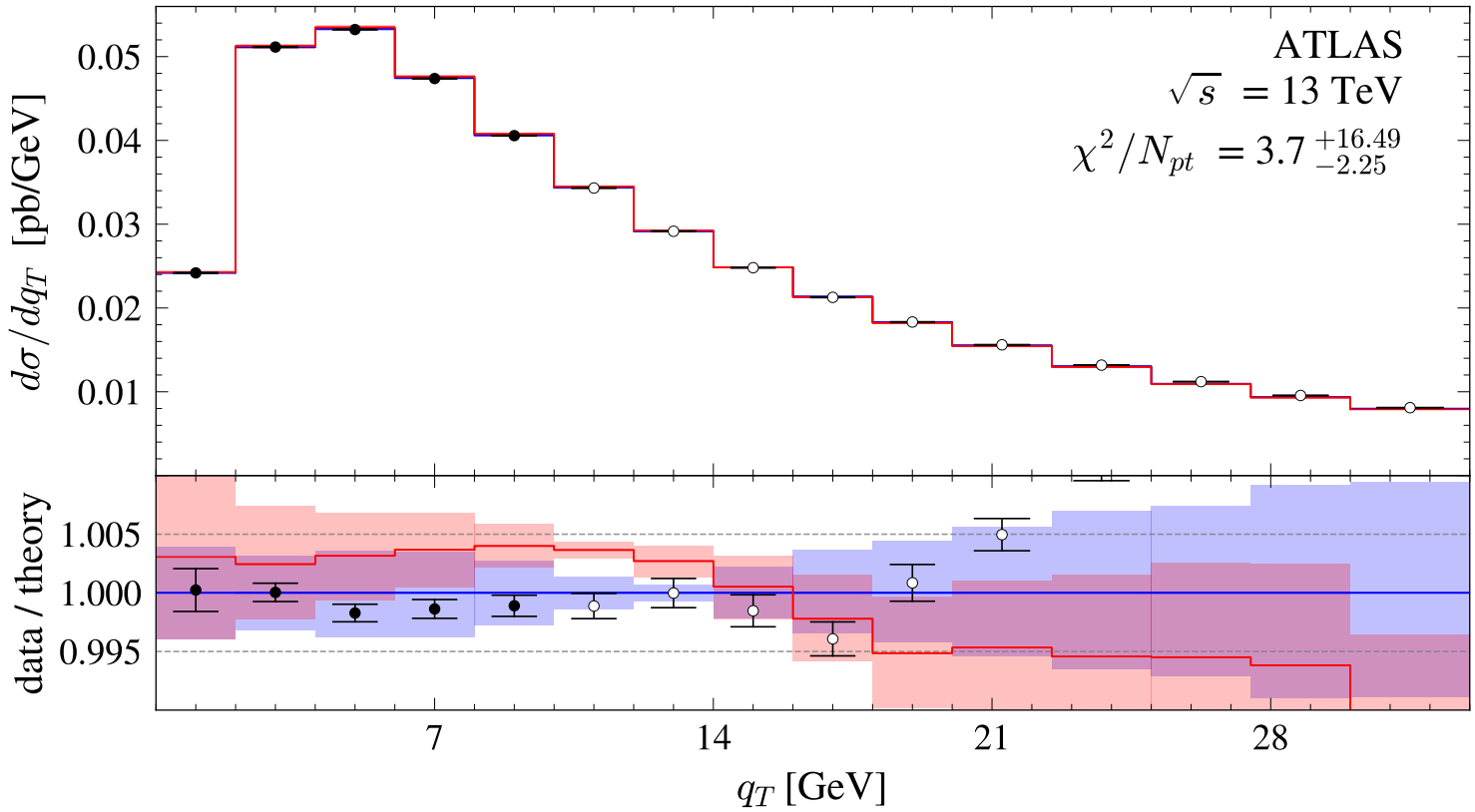

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