Extraction of TMDs from data (IV)

J. Osvaldo Gonzalez-Hernandez

Outline

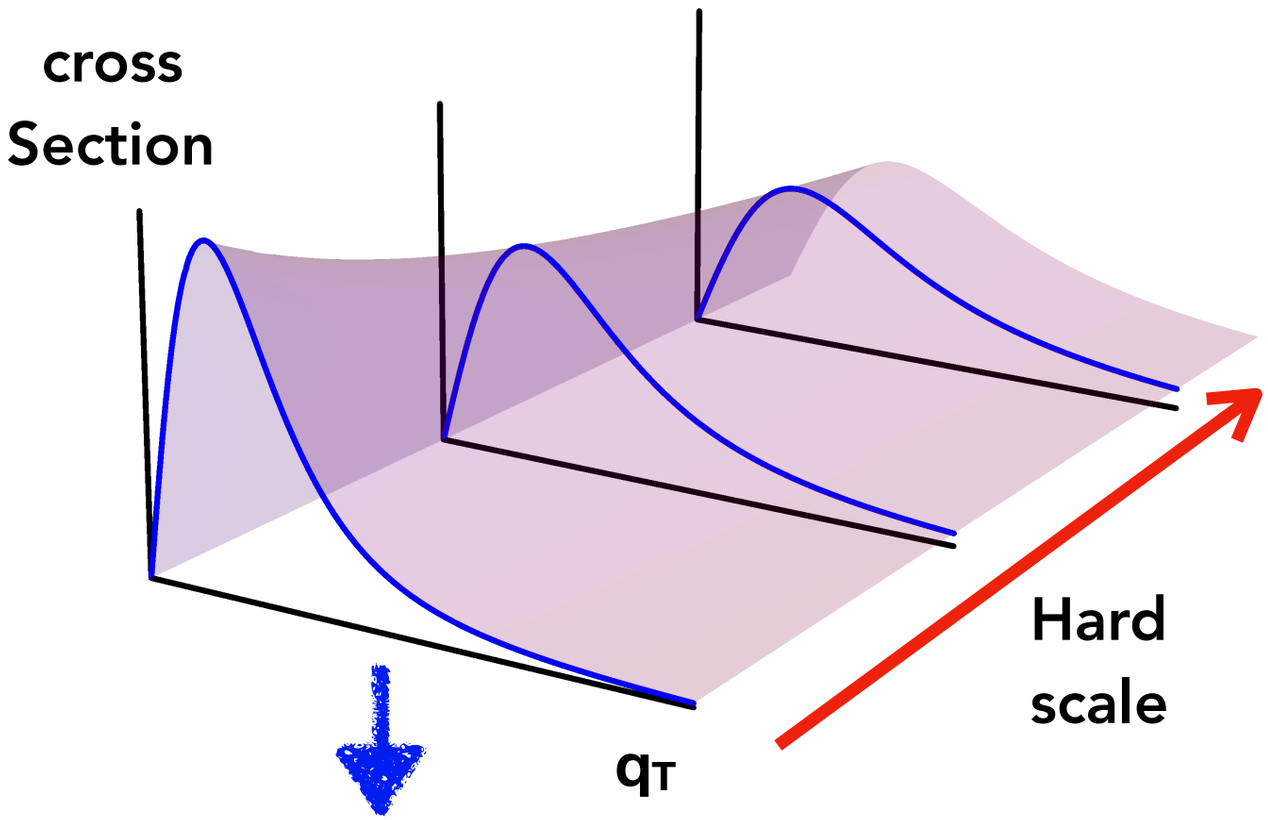
SIDIS

-Parton model picture (ballpark estimates).

-QCD factorization framework (CSS2, challenges)

e+e- annihilation into one hadron (Belle data)

-TMD Fragmentation functions extraction.



Parton model picture
"snapshot" at fixed scale

- **Ballpark estimates (similar kinematics)**
- **Benchmark to assess "data sensitivity"**

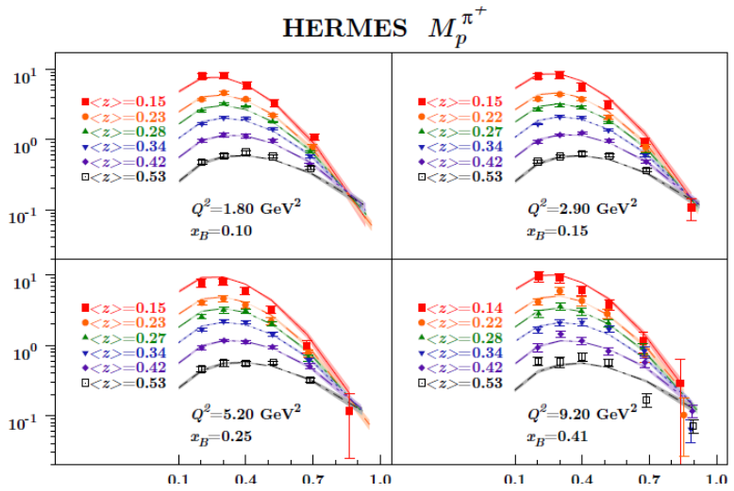
QCD factorization picture,
hard scale evolution.

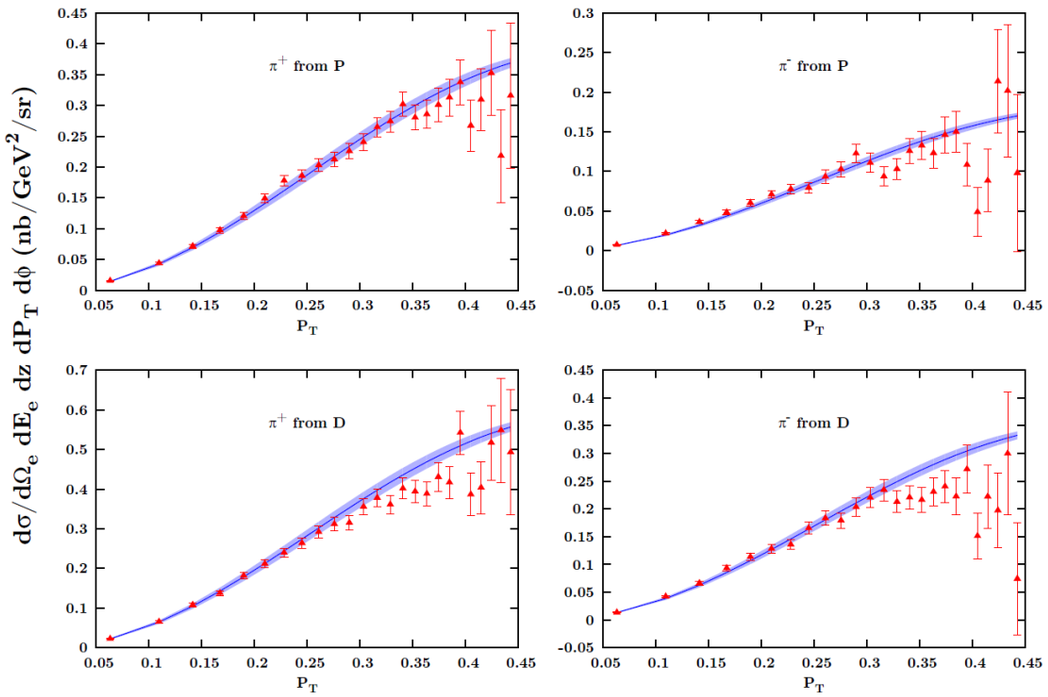
maximal pQCD input
(try to avoid absorbing
effects into model)

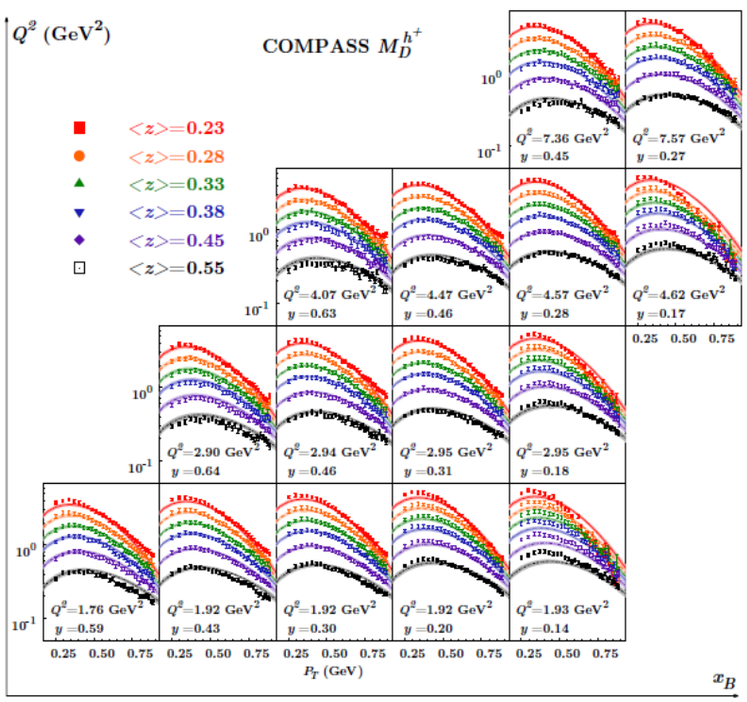
Predictive power
(or even the only way
to do global fits)

Parton model picture (unpolarized observables)

f_1 D_1







Comparison of results to Jlab data
(not a fit, similar kinematics to HERMES)

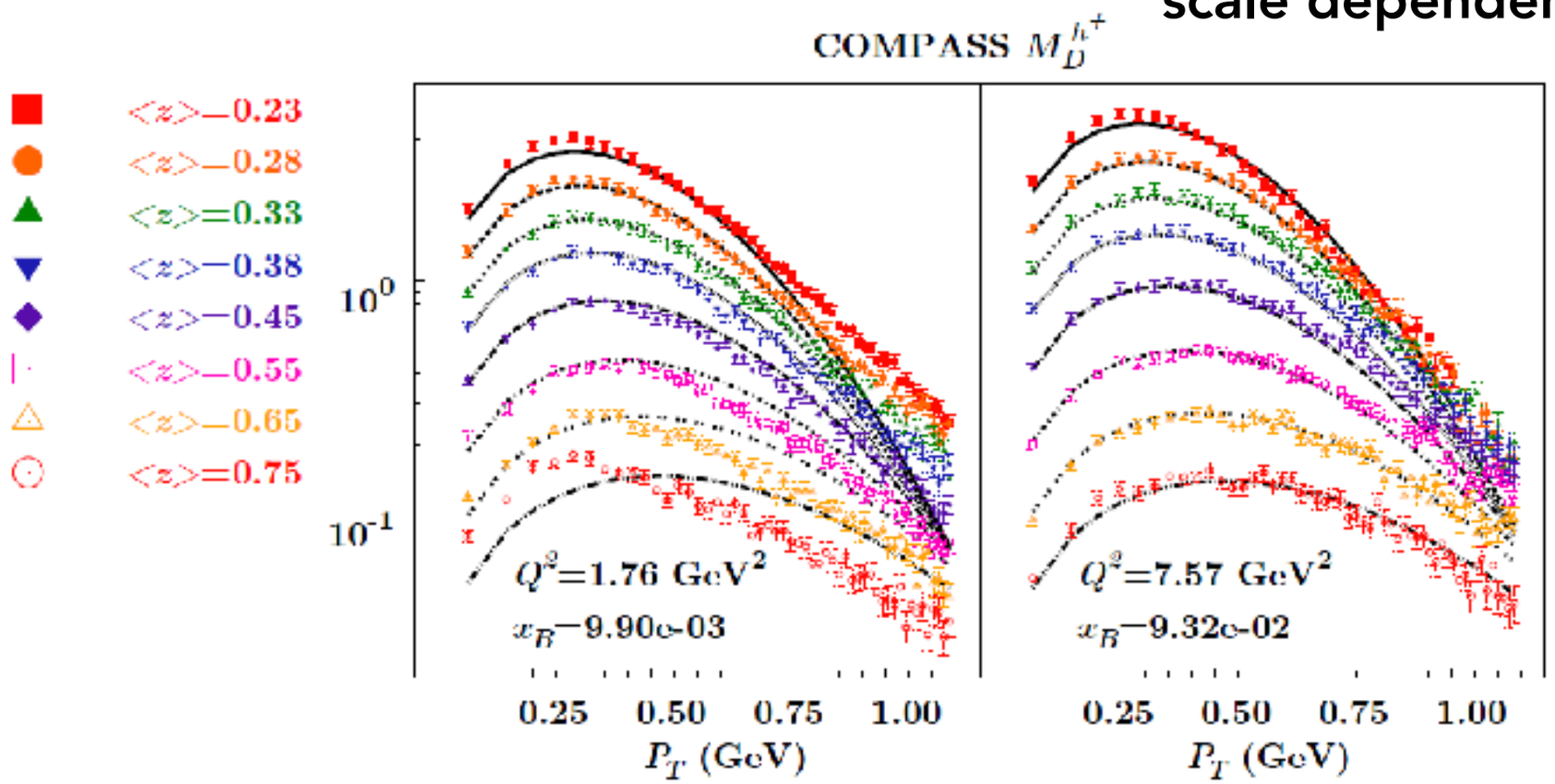
Analysis and extraction

JHEP 1404 (2014) 005 Anselmino, Boglione, Melis, JOGH, Prokudin

Parton model picture (unpolarized observables)

f_1  D_1 

Must resolve scale dependence

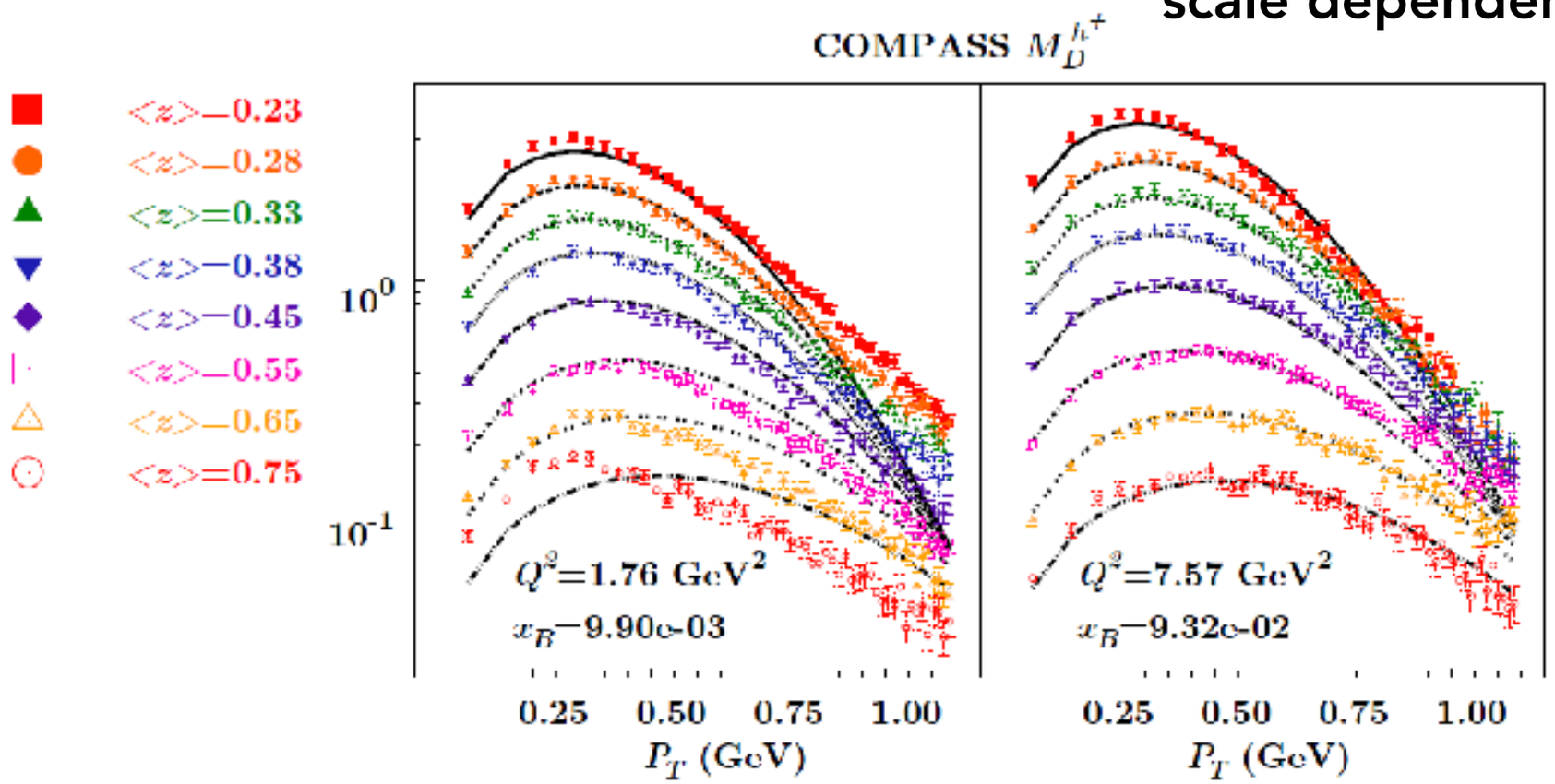


Not so large change in scale (already in trouble)

Parton model picture (unpolarized observables)

f_1  D_1 

Must resolve scale dependence



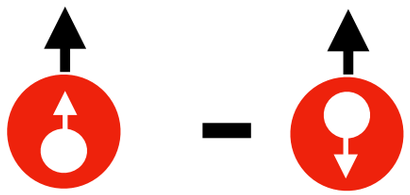
Not so large change in scale (already in trouble)

• • •

EIC

Should not extrapolate these results to EIC energies

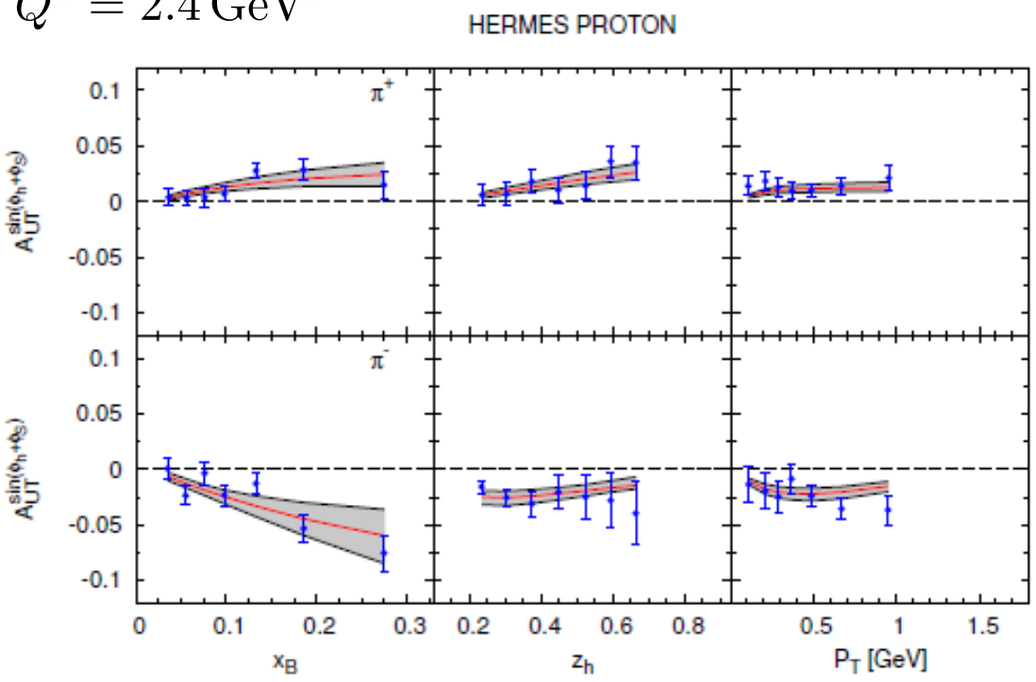
Parton model picture (polarization effects)

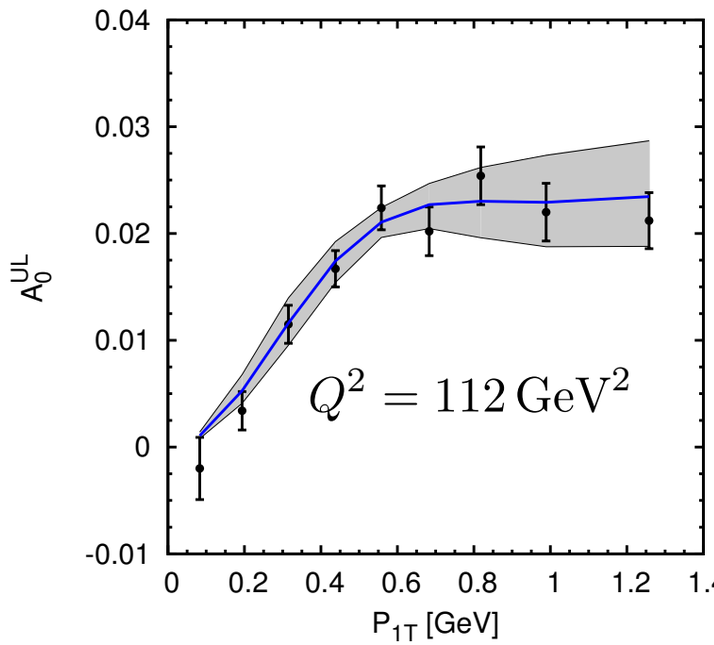
h_1  $H_1^\perp$ 

Transversity

Collins fragmentation function

$Q^2 = 2.4\,\mathrm{GeV}^2$





Analysis and extraction

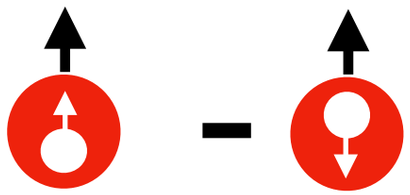
Not so **small** change in scale (already in trouble?)

→ • • • →

EIC

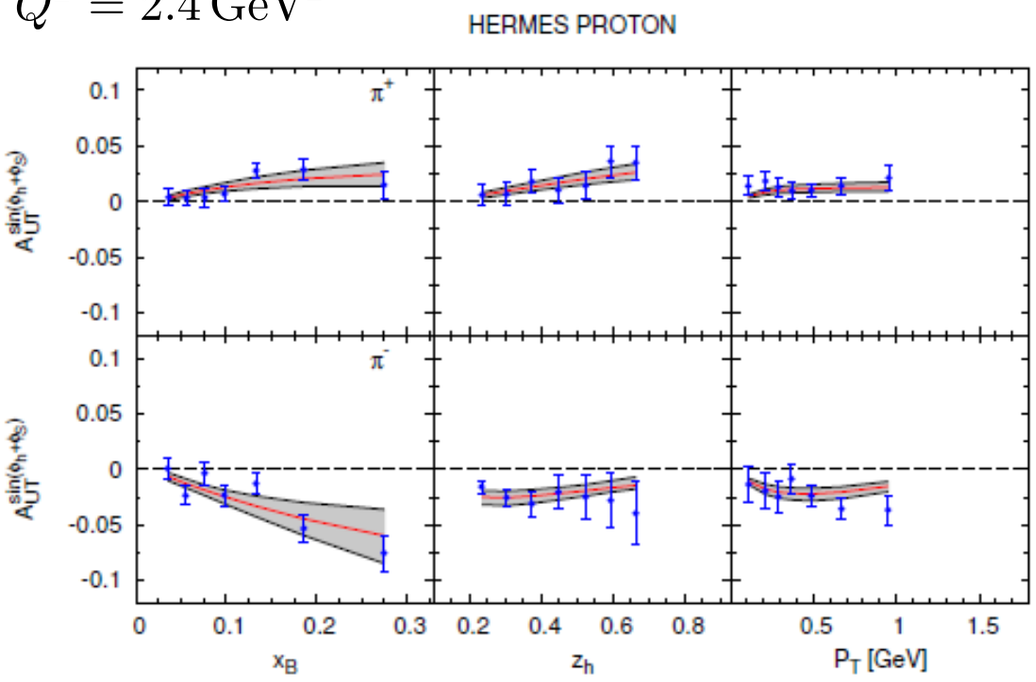
can we see these Effects better?

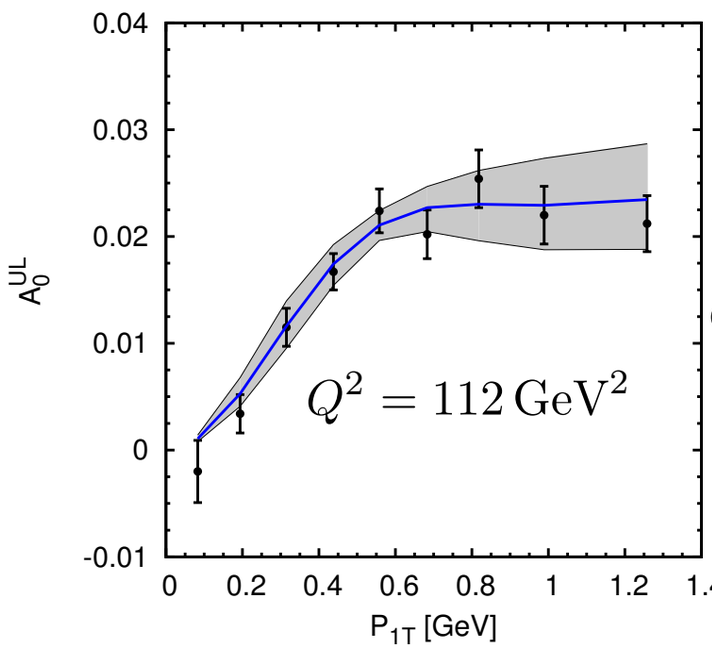
Parton model picture (polarization effects)

h_1  Transversity

$H_1^\perp$  Collins fragmentation function

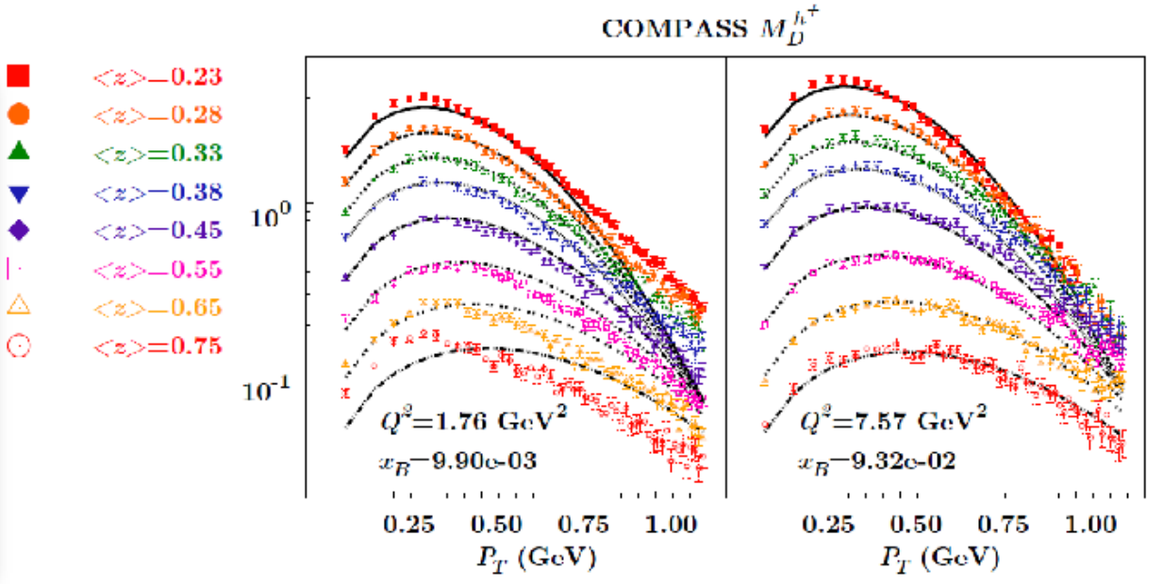
$Q^2 = 2.4\,\mathrm{GeV}^2$





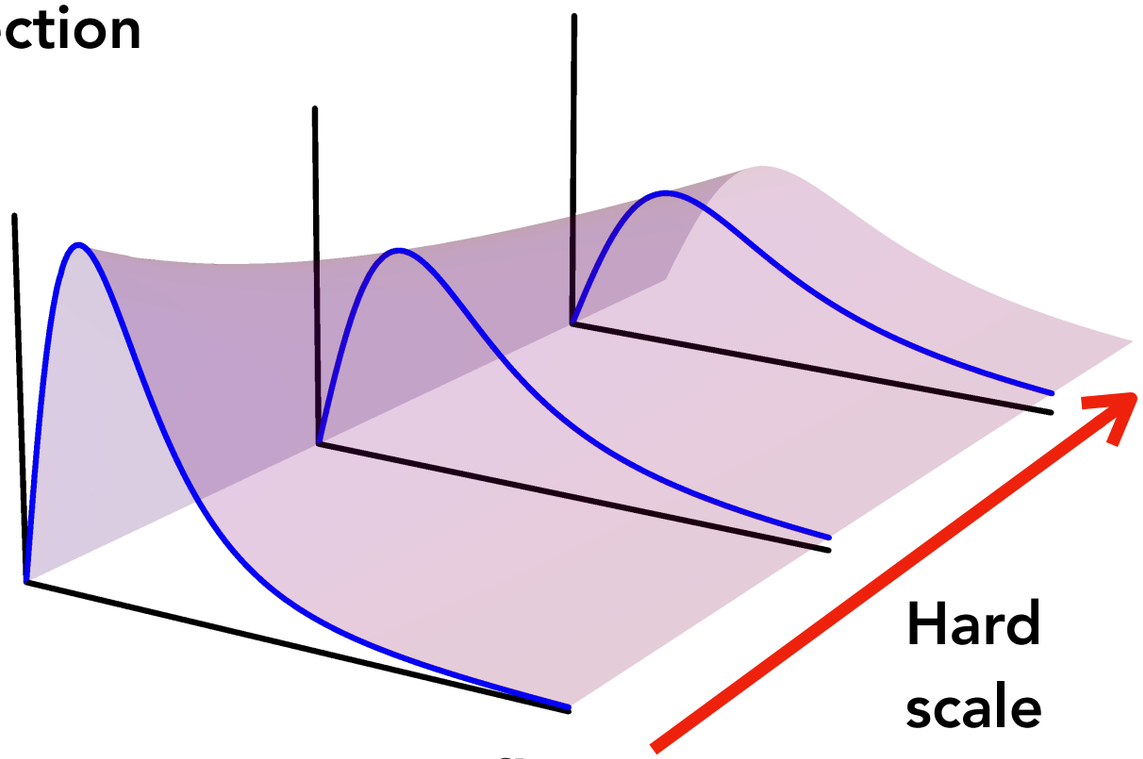
"Indirect" observation of TMD effects

Can the numerators of asymmetries be measured? (uncertainties under control?)



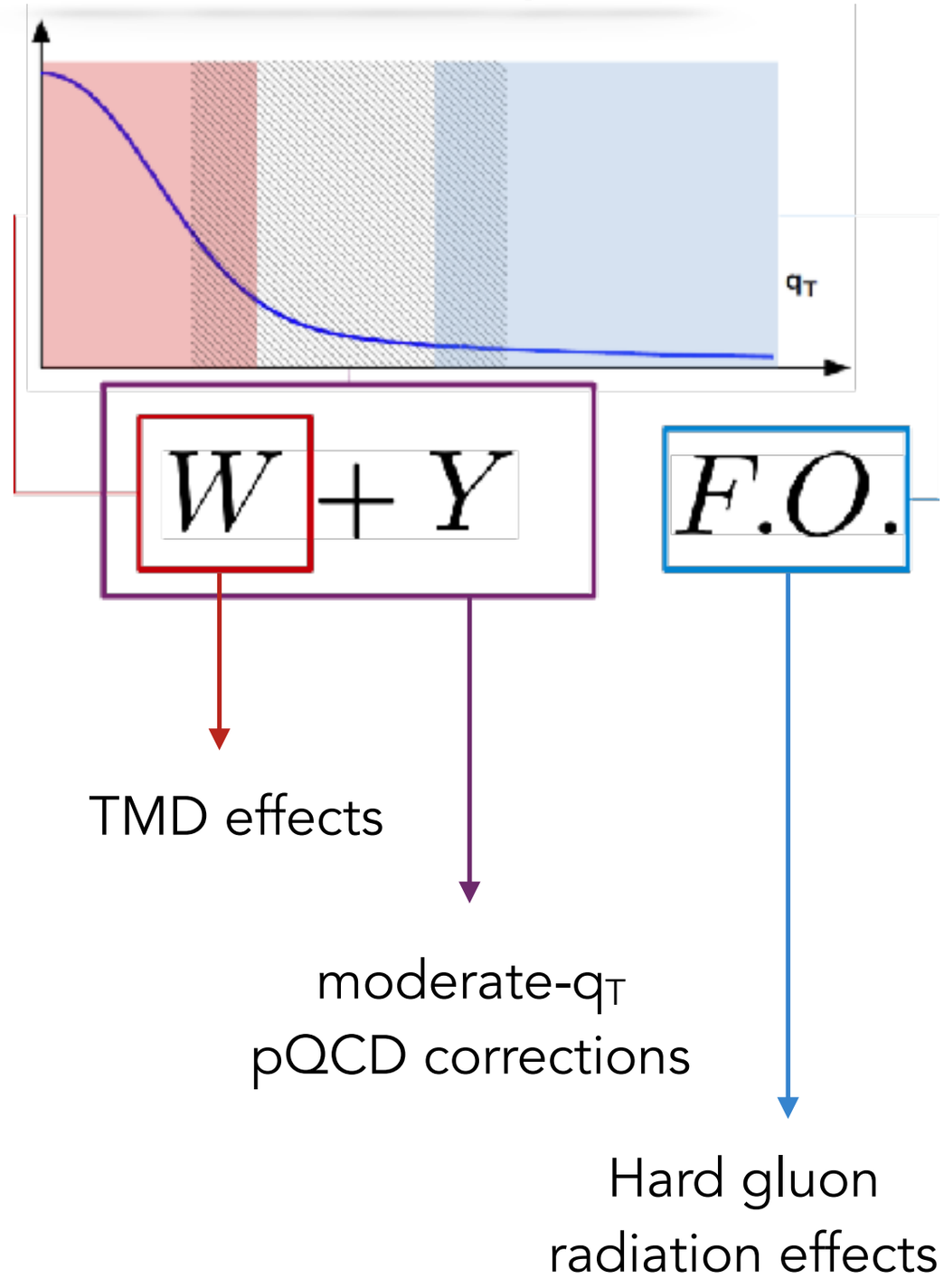
"direct" observation of TMD effects

cross Section

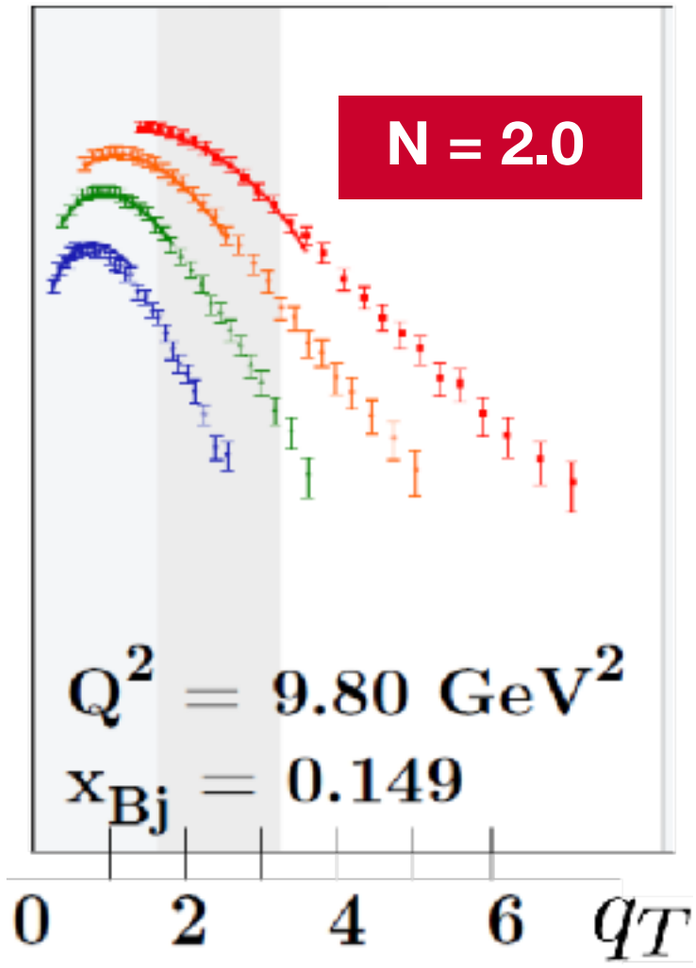


can we smoothly describe all q_T-spectrum?

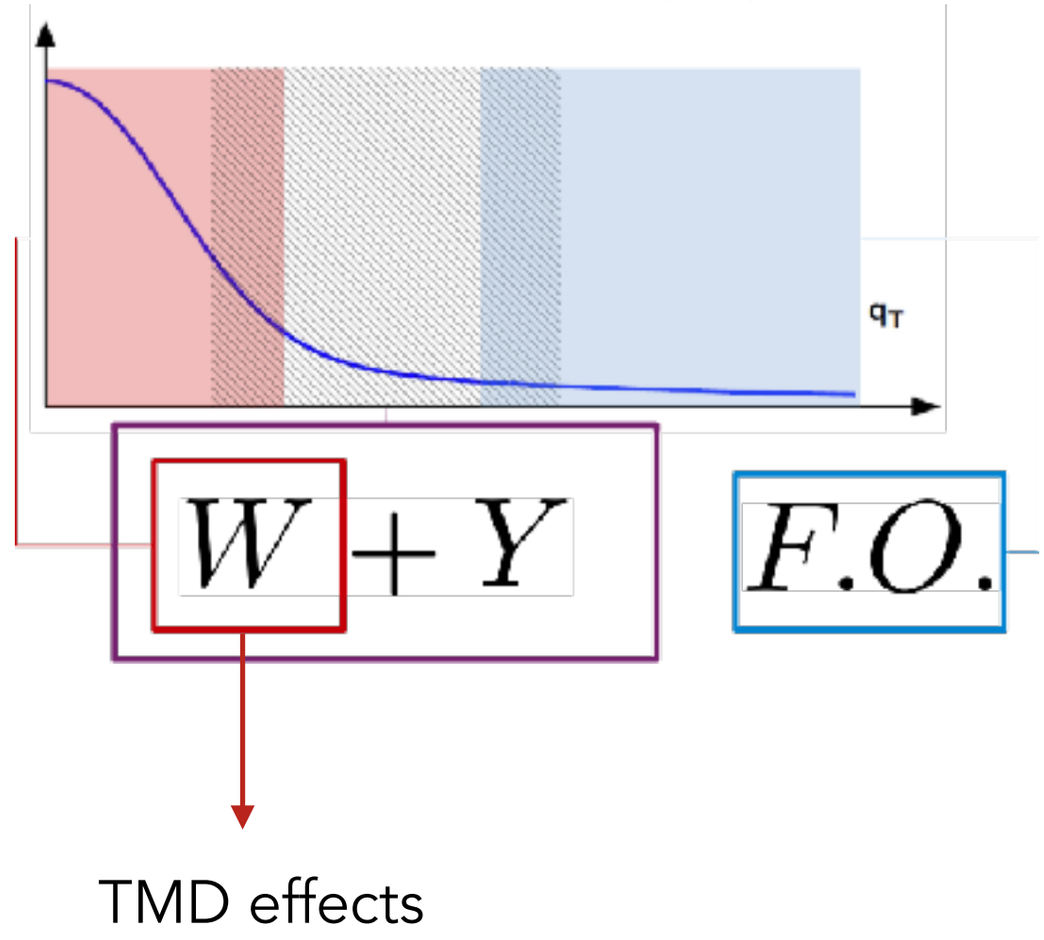
QCD factorization picture



New COMPASS data



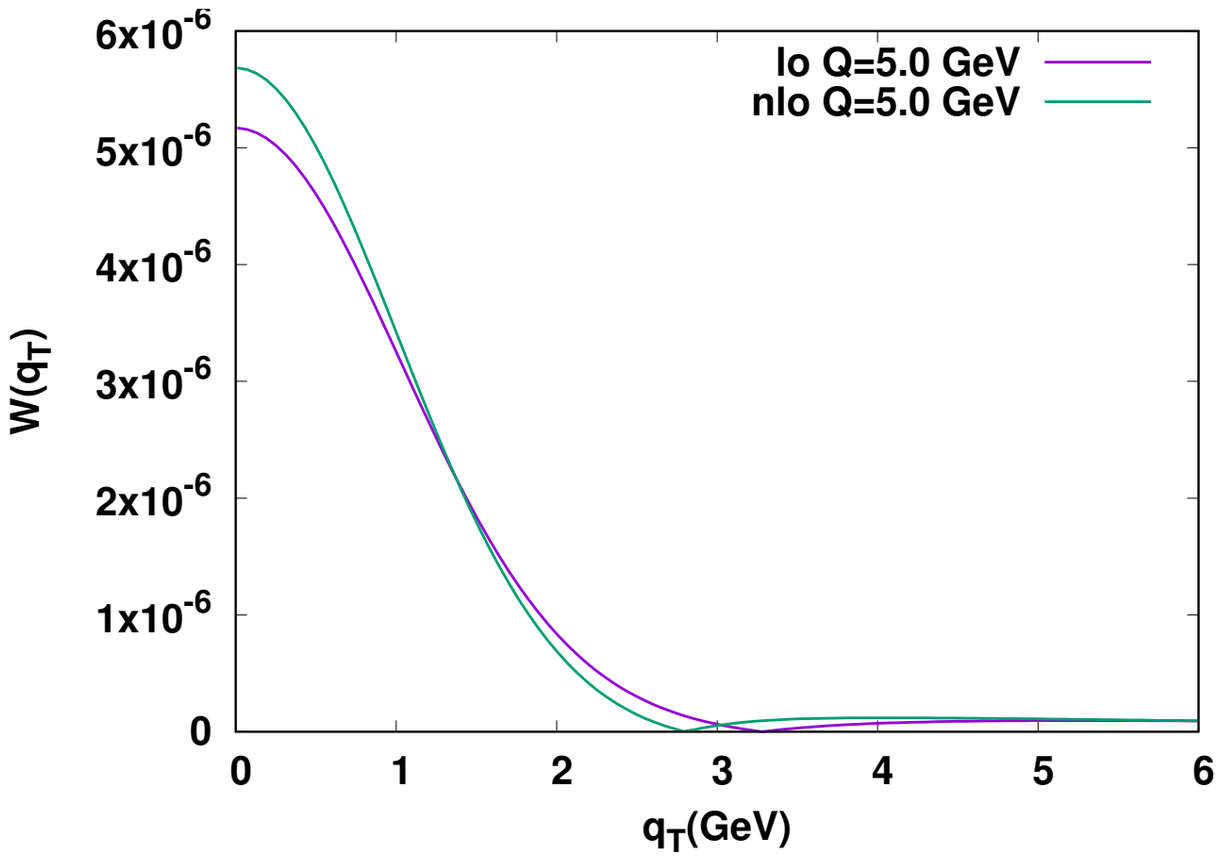
Must smoothly describe all q_T-spectrum



TMD effects

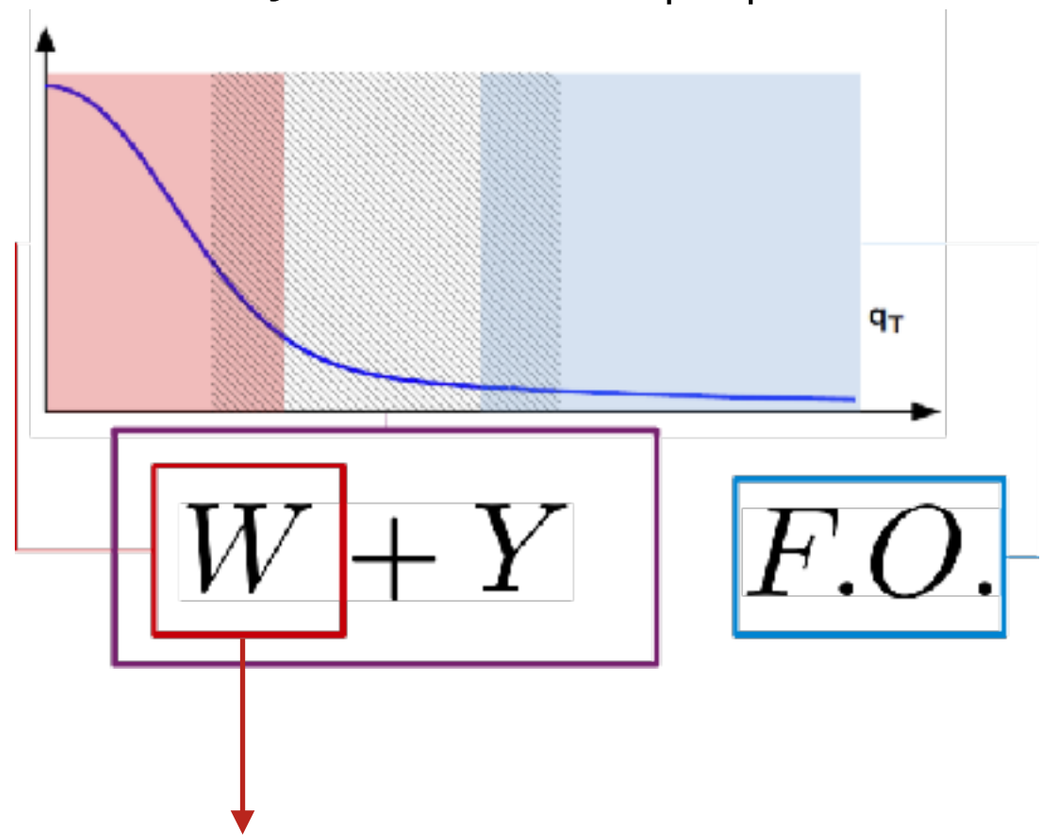
$\mathcal{O}(\alpha_s)$ ingredients known, but hard to describe data at this order

- W describes shape but miss **normalization**



Need to go to order $\mathcal{O}(\alpha_s^2)$

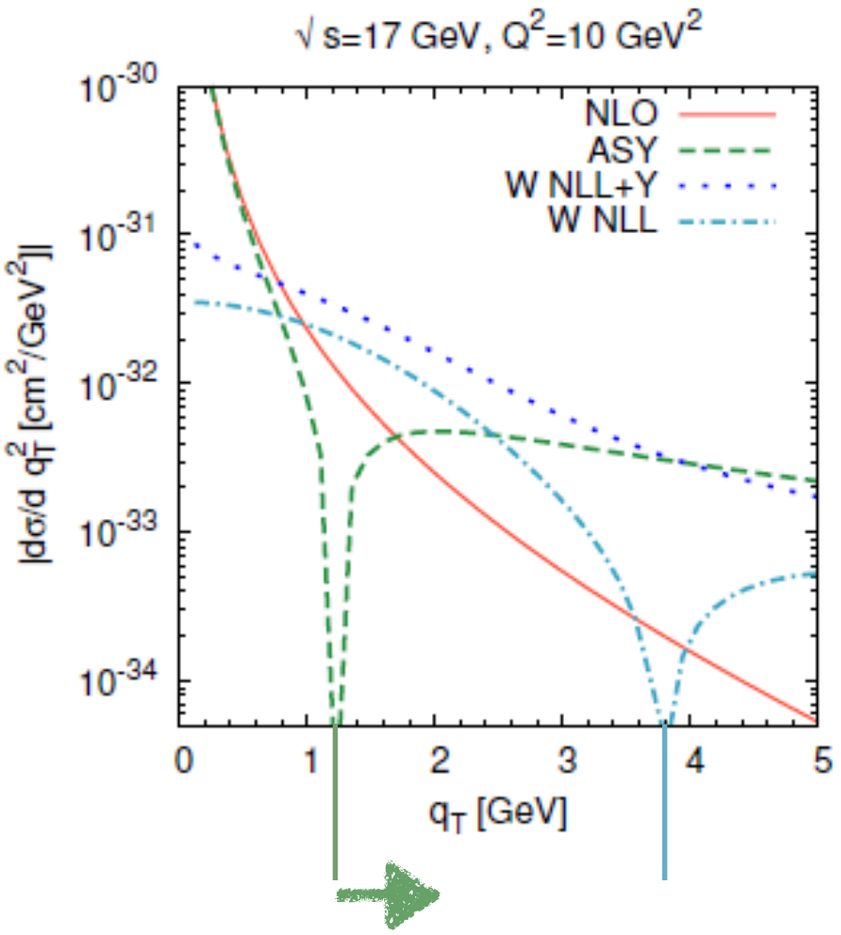
Must smoothly describe all q_T-spectrum



TMD effects

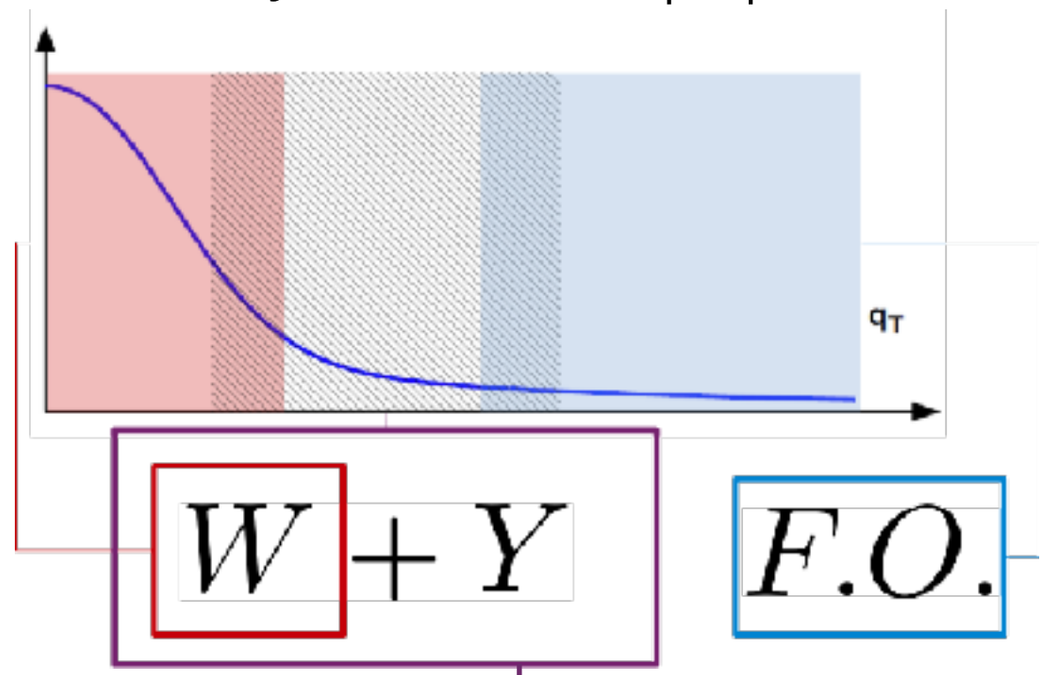
- pQCD pieces of W known, some improvement
  very small q_T, somehow large Q

JHEP 1502 (2015) 095 Boglione, JOGH, Melis, Prokudin



Need node closer to q_T=Q

Must smoothly describe all q_T-spectrum

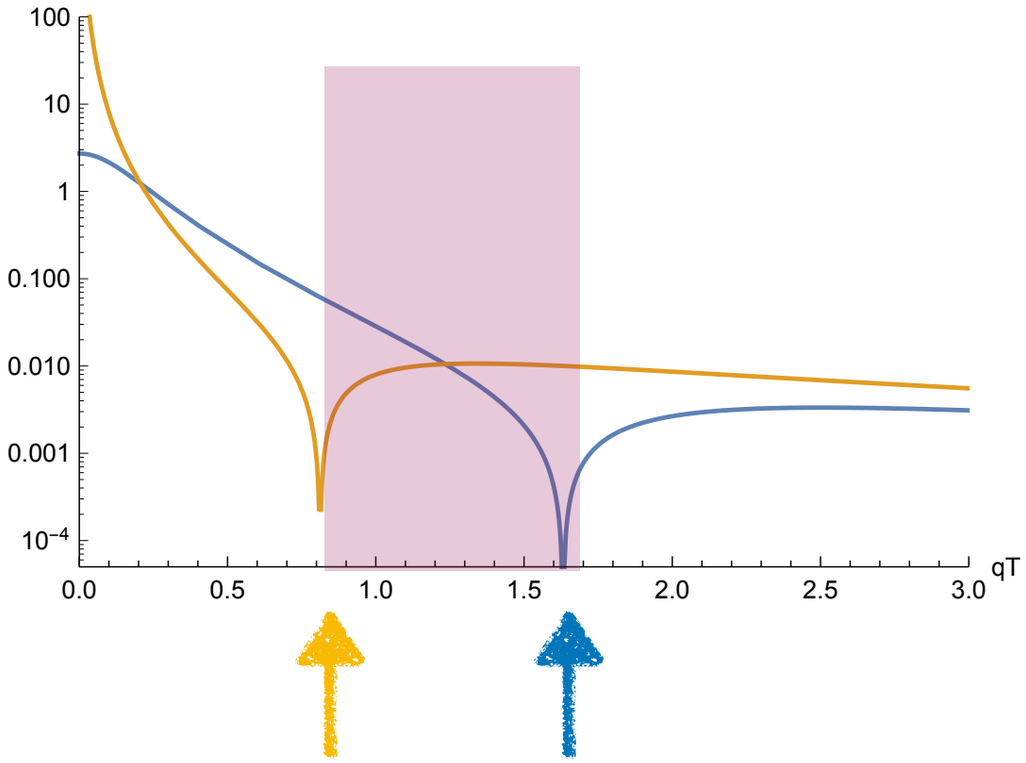


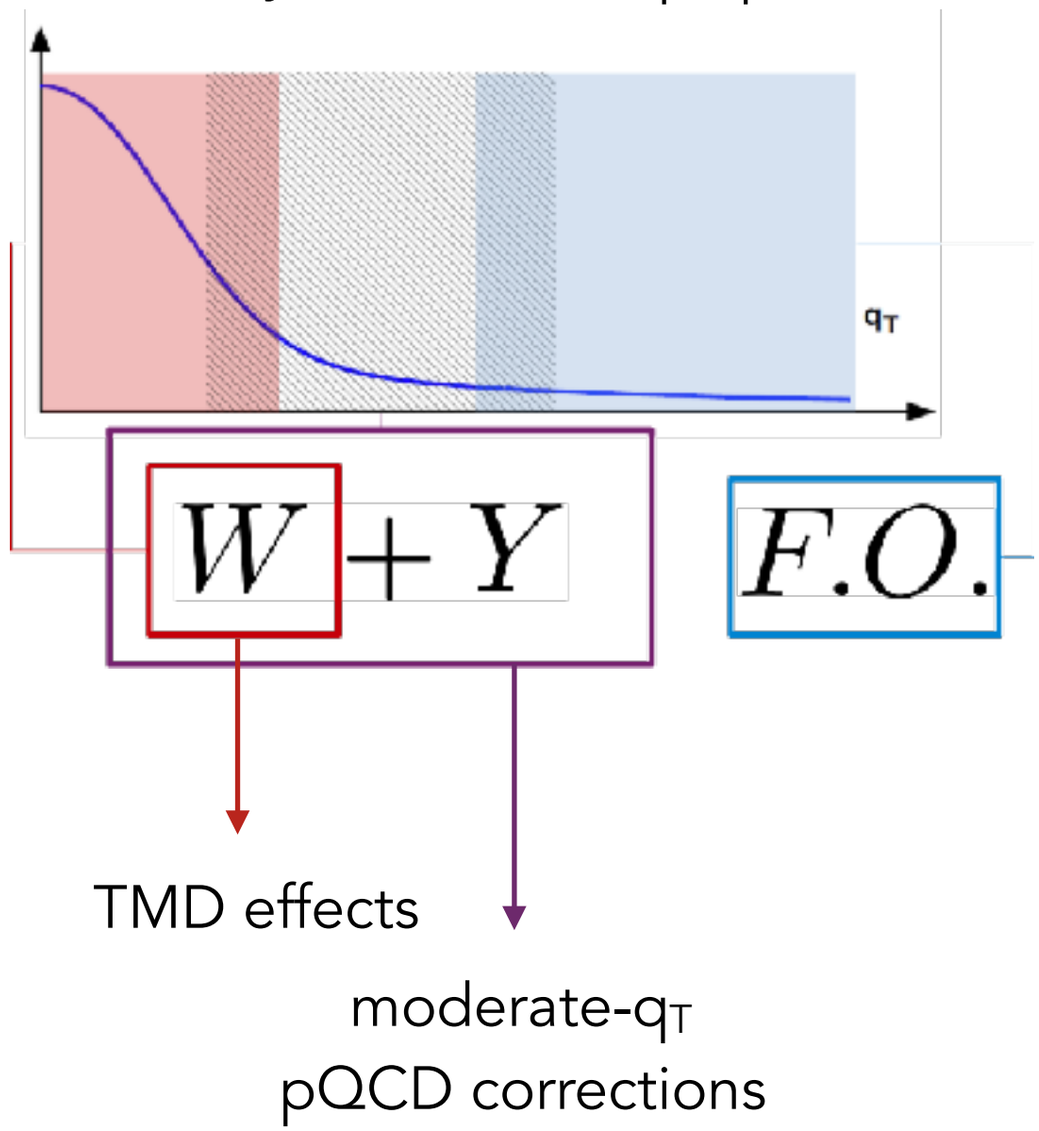
moderate-q_T
pQCD corrections

$\mathcal{O}(\alpha_s)$ ingredients known, but hard to describe data at this order

- **no smooth matching** of small and large q_T regions

Must smoothly describe all q_T-spectrum

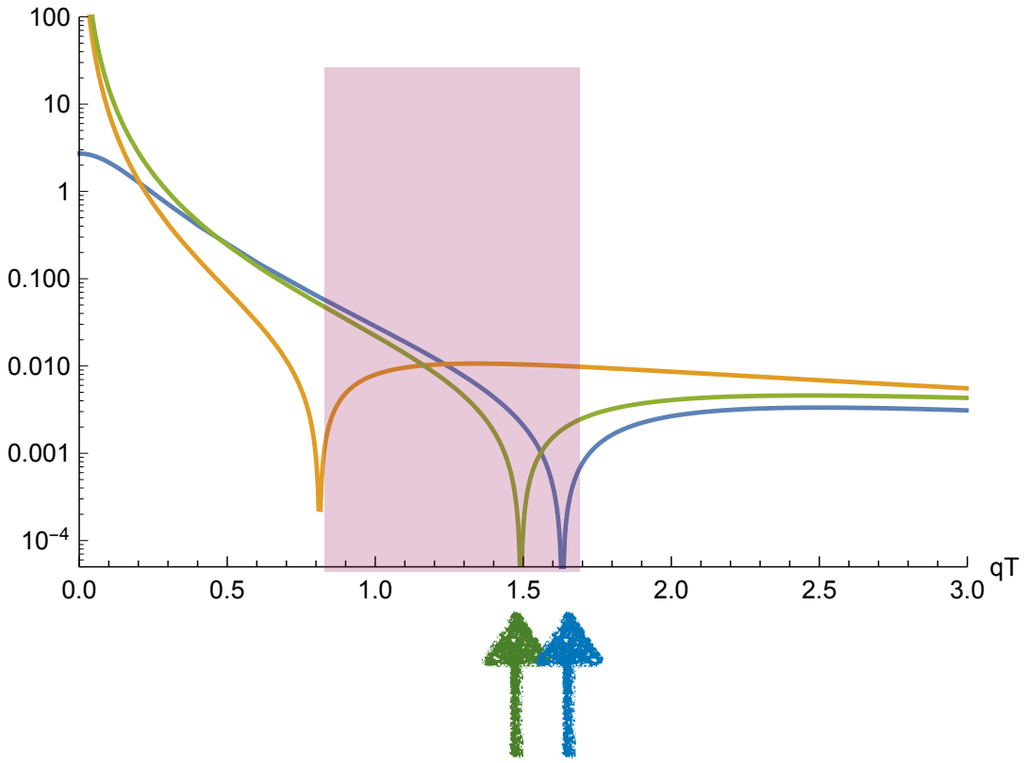




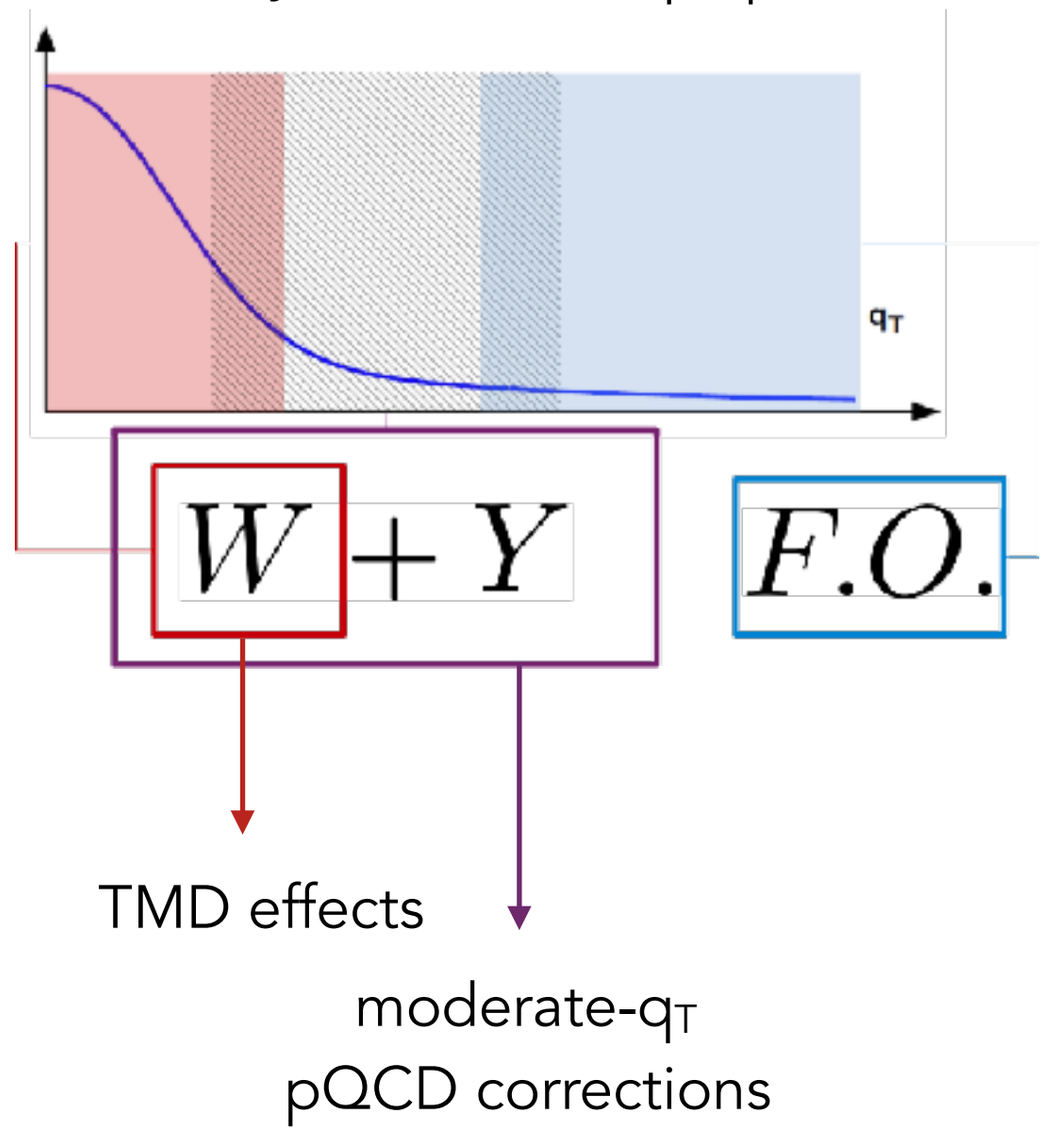
Analysis at order $\mathcal{O}(\alpha_s^2)$:

- Phenomenologically plausible picture (role of model in matching?)

No sharp transitions



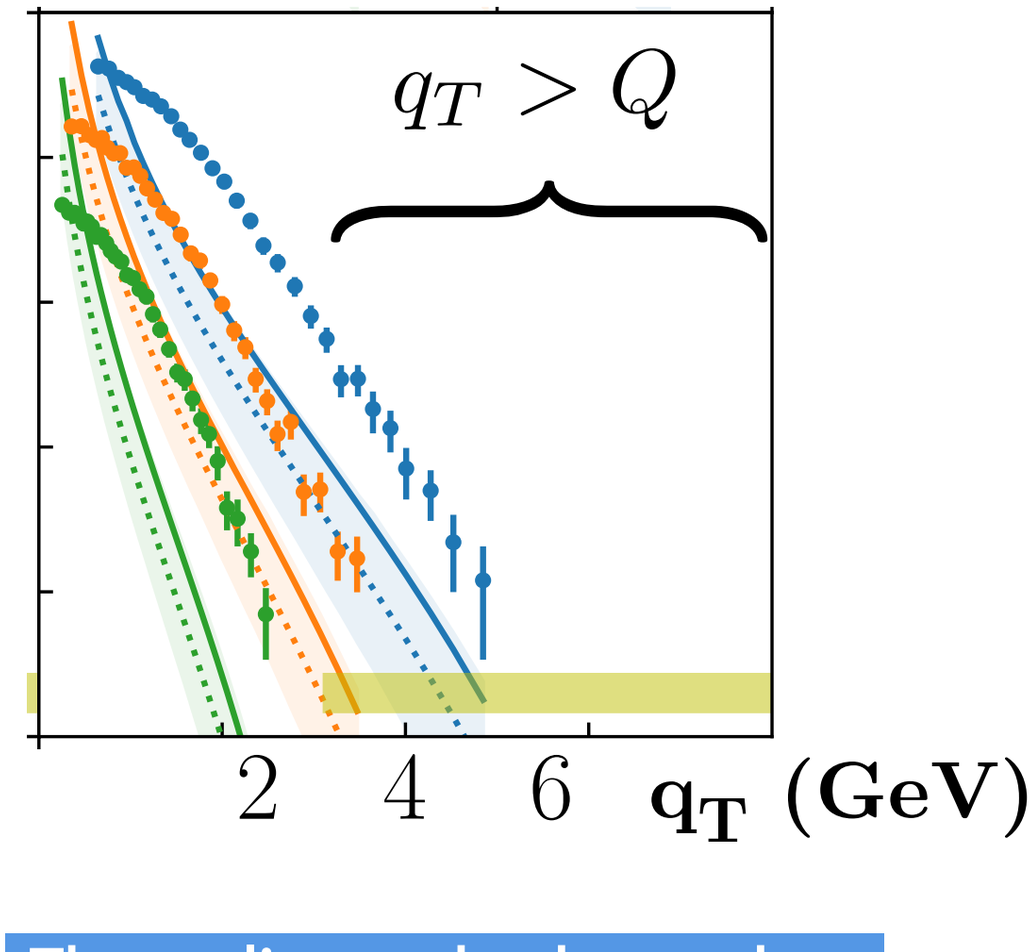
Must smoothly describe all q_T-spectrum



Analysis at order $\mathcal{O}(\alpha_s^2)$:

- Phenomenologically plausible picture (role of model in matching?)
  (need formal developments)
- Analysis of unpolarized SIDIS with maximal pQCD input?

Phys.Rev. D98 (2018) no.11, 114005
JOGH, Rogers, Sato, Wang

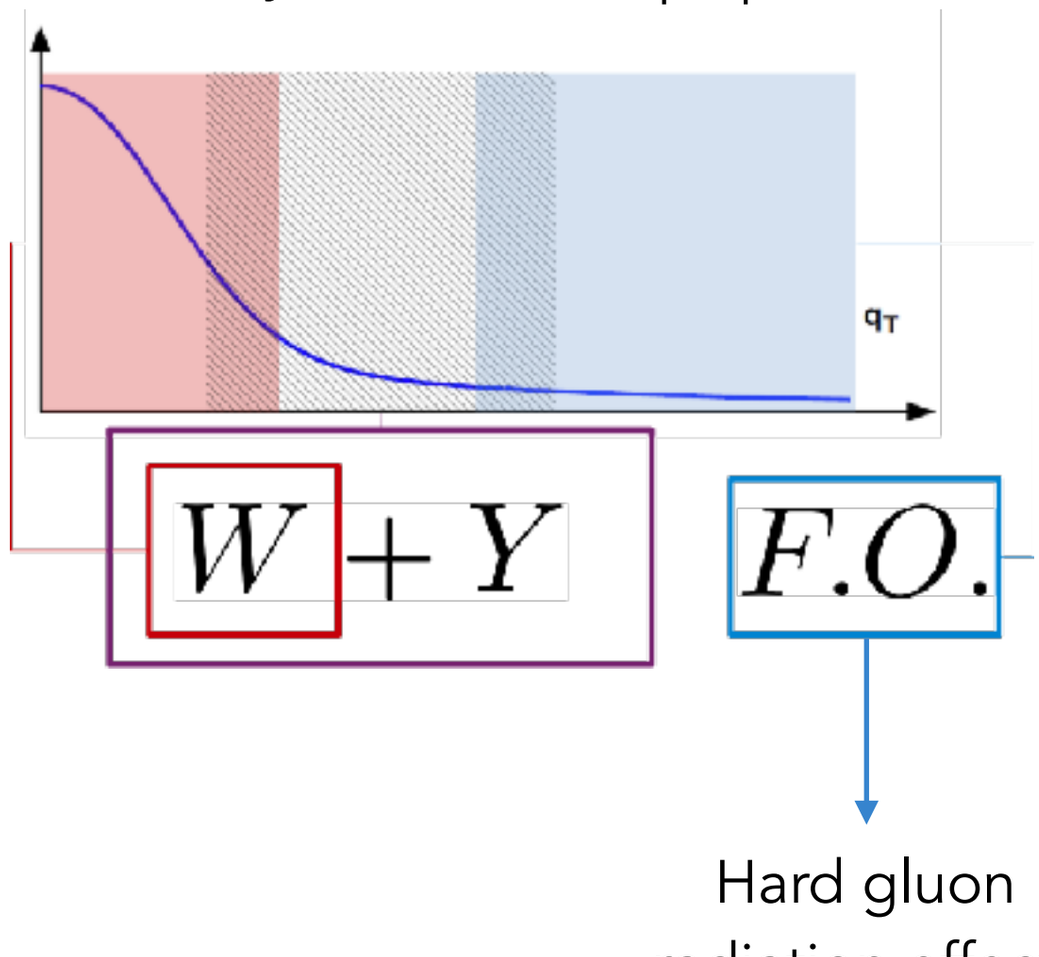


Theory line undershoots data

hard to describe data at $\mathcal{O}(\alpha_s^2)$

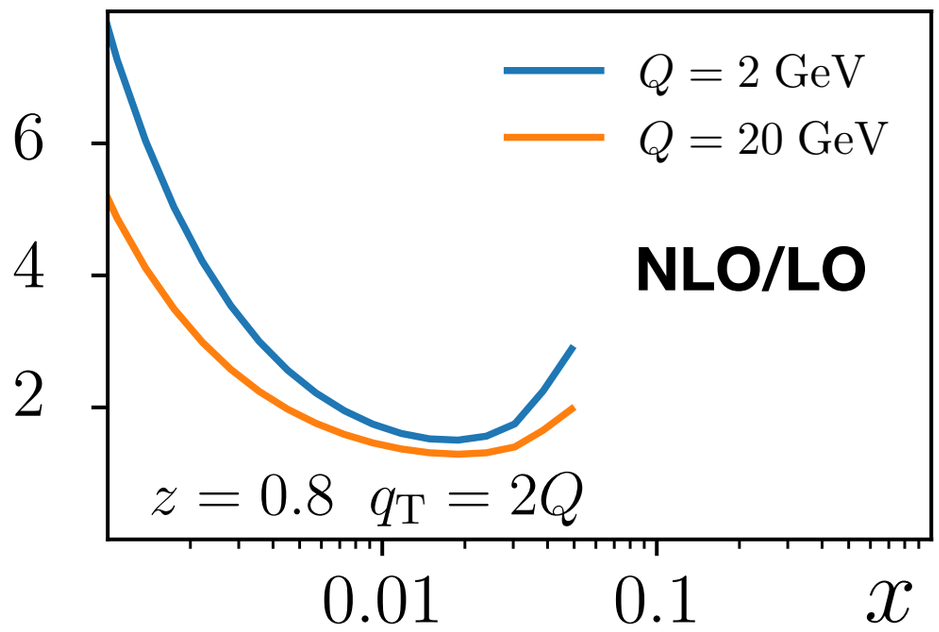
- cannot describe **large q_T behavior**

Must smoothly describe all q_T-spectrum



Hard gluon
radiation effects

Phys.Rev.D 99 (2019) 9, 094029
Wang, JOGH, Rogers, Sato



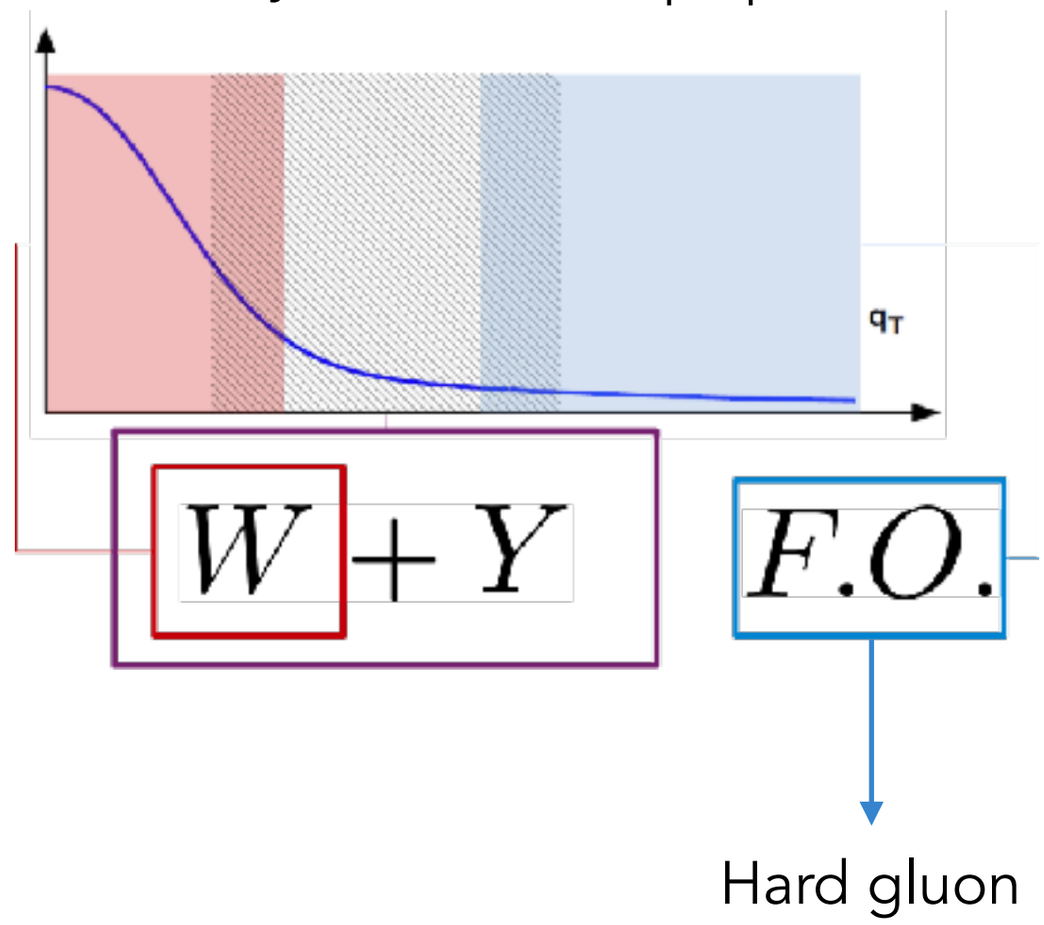
Theory line undershoots data

hard to describe data at $\mathcal{O}(\alpha_s^2)$

- cannot describe **large q_T behavior**

Large-x(z) behavior of collinear functions crucial

Must smoothly describe all q_T-spectrum



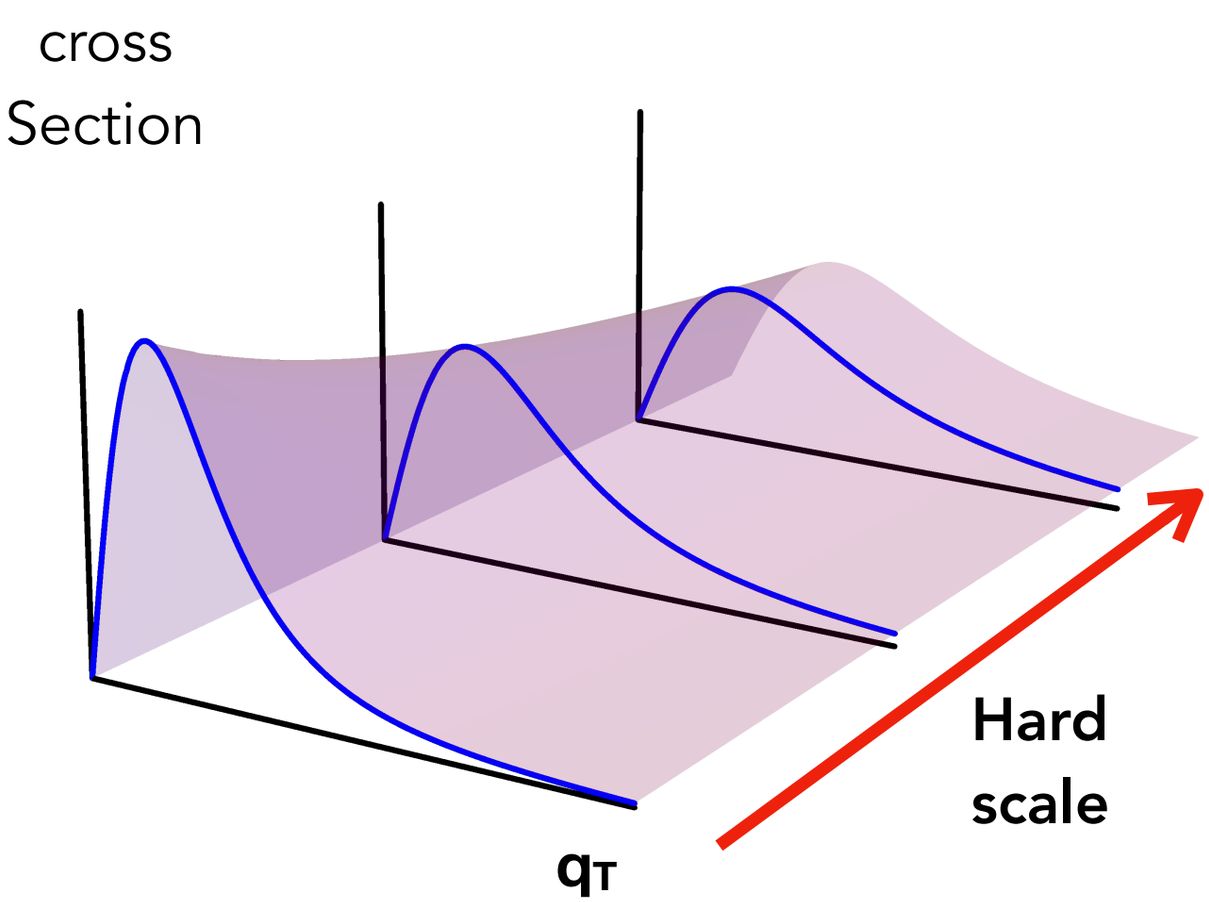
Hard gluon radiation effects

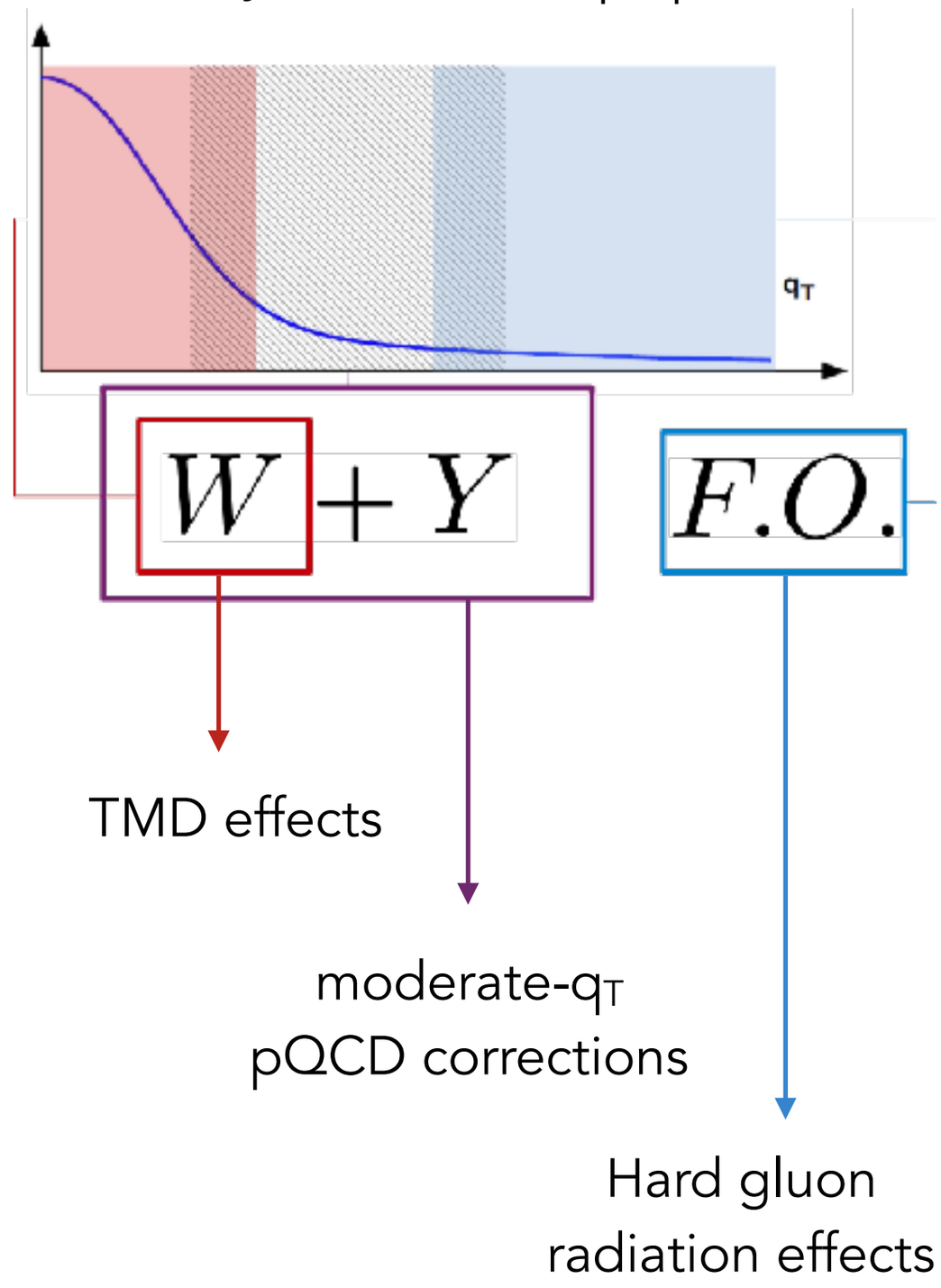
Similar results as in

Phys. Rev. D71, 034013 (2005)

A. Daleo, D. de Florian, and R. Sassot

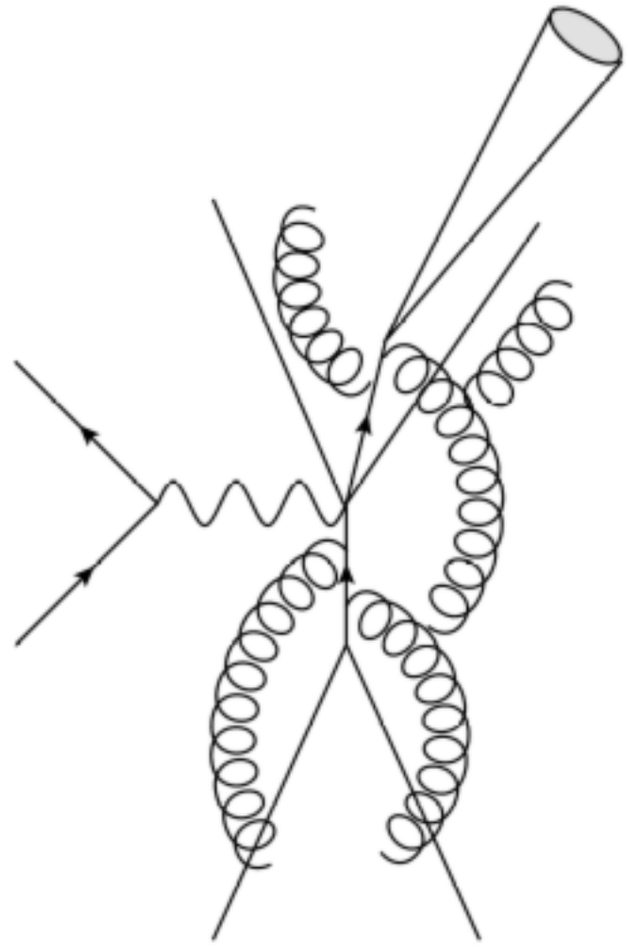
Must smoothly describe all q_T-spectrum





What is the effect of the collinear PDFs and FFs in general?

$$e^+e^- \to hX$$



What is the effect of the collinear PDFs and FFs in general?

$$D = D^{\star}\sqrt{M_S}$$

Usual definition TMD FF

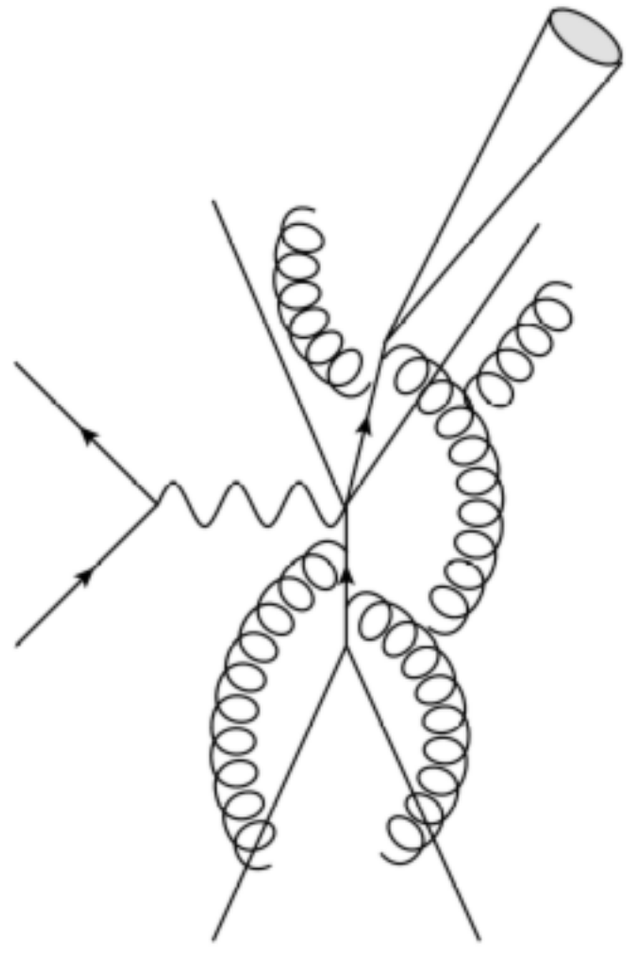
For this process TMD FF

Soft non-perturbative Function

What is the effect of the collinear PDFs and FFs in general?

M. Boglione, A. Simonelli, Eur. Phys. J. C 81 (2021)

$$e^+e^- \to hX$$



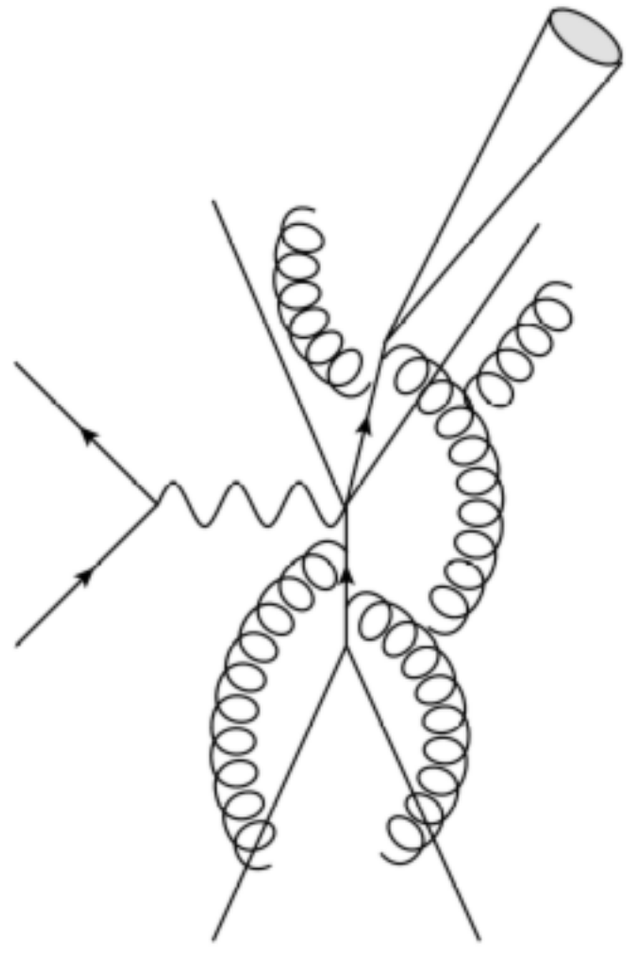
$$\frac{d\sigma}{dP_T} = d\hat{\sigma} \otimes D^{\star}(P_T)$$

$$D = D^{\star}\sqrt{M_S}$$

Same constraints to collinear FF

M. Boglione, A. Simonelli, Eur. Phys. J. C 81 (2021)

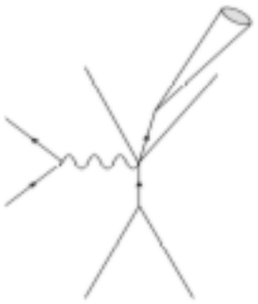
$$e^+e^- \to hX$$



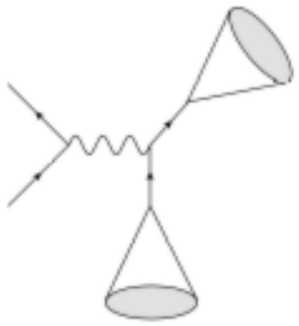
What is the effect of the collinear PDFs and FFs in general?

$$\frac{d\sigma}{dP_T} = d\hat{\sigma} \otimes D^{\star}(P_T)$$

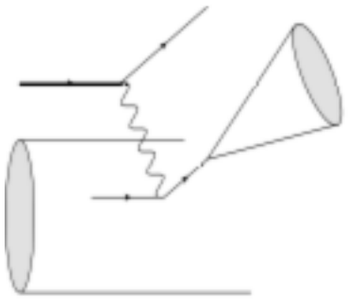
Possible roadmap



1. Extraction of the unpolarized TMD FF, D*, for charged pions from BELLE data (using factorization definition)



2. Two non-perturbative functions:
   D*, known from step 1
   Soft Model M_S, obtained as ratio:

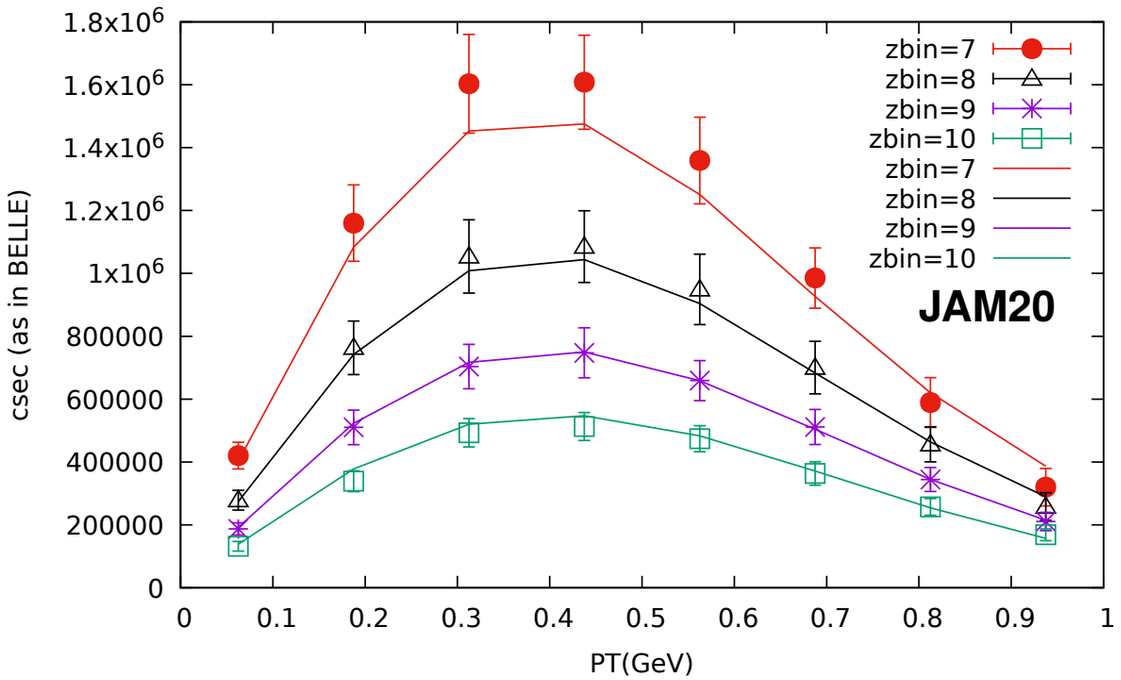


3. SIDIS
   Three non-perturbative functions in the cross section
   D*, known from step 1.
   Soft Model M_S, known from step 2.
   Extraction of the TMD PDF, F* (in the factorization definition, $F^* \neq F$).

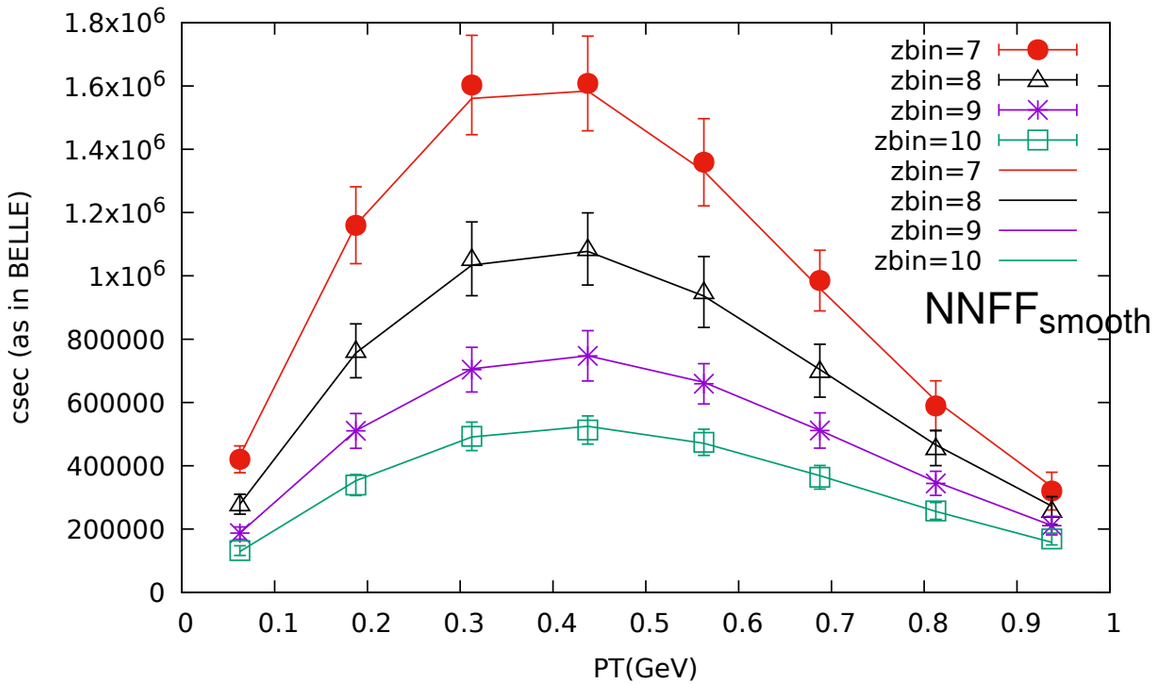
Taken from M. Boglione DIS 2021

Preliminary results

What is the effect of the collinear PDFs and FFs in general?



JAM20 : nice for SIDIS fits



NNFF : nice for this particular analysis

Some tension may happen
In a global fit (must look at errors though)

Final words(outline of open questions)

What is the effect of the collinear PDFs and FFs in general?

Smooth matching in SIDIS

Are power suppressed corrections
Too big?

Thanks