Istituto Nazionale di Fisica Nucleare

UNIVERSITÀ DI PAVIA

Unpolarized TMDs:

latest results

Matteo Cerutti

Previous works

PV17 fit

8059 SIDIS + DY data

NLL Accuracy

Mean variables

$$\chi^2_R = 1.55$$

Bacchetta, Delcarro, Pisano, Radici, Signori, arXiv:1703.10157

Previous works

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Mean variables

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PV19 fit

353 DY data

N3LL Accuracy

Integrated variables

$\chi^2_R = 1.02$

Bacchetta, Bertone, Bissolotti, Bozzi, Delcarro, Piacenza, Radici, arXiv:1912.07550

Goal

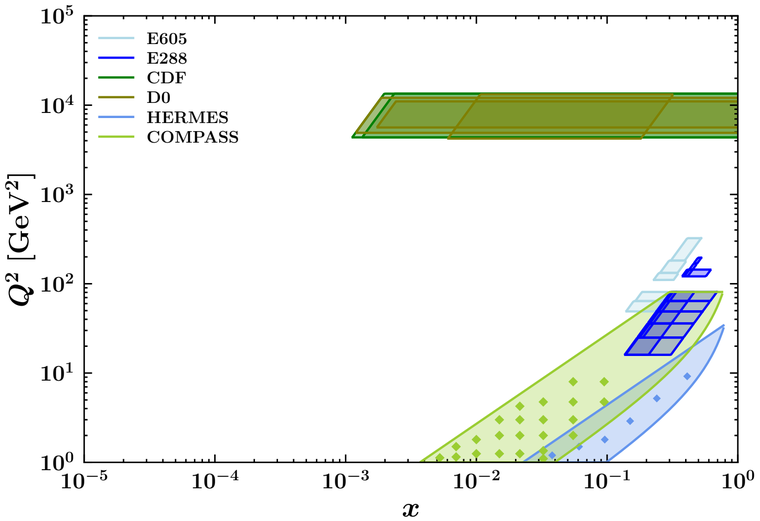
New Global fit:
Simultaneously extraction of unpolarized TMD PDFs and FFs

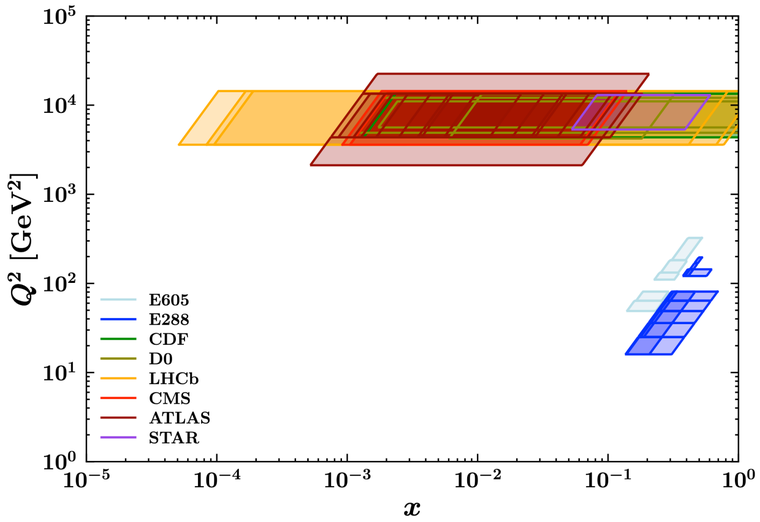
- SIDIS + Drell Yan

Goal

New Global fit

- ✓ SIDIS + Drell Yan





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New Global fit

- ✓ SIDIS + Drell Yan
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New Global fit

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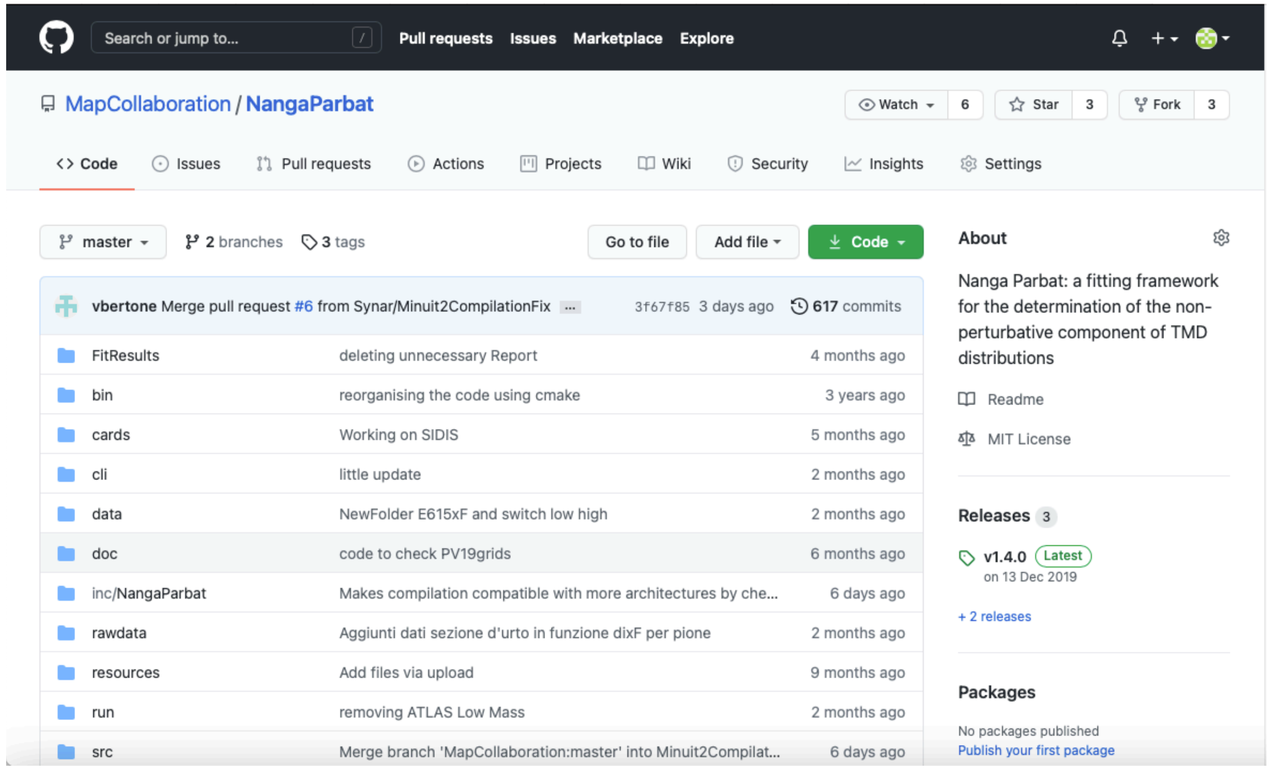


https://github.com/MapCollaboration

Goal

New Global fit

- ✓ SIDIS + Drell Yan
- ✓ Integrated variables
- ○ Up to N2LL/N3LL

Goal

New Global fit

- ✓ SIDIS + Drell Yan
- ✓ Integrated variables
- ○ Up to N2LL/N3LL

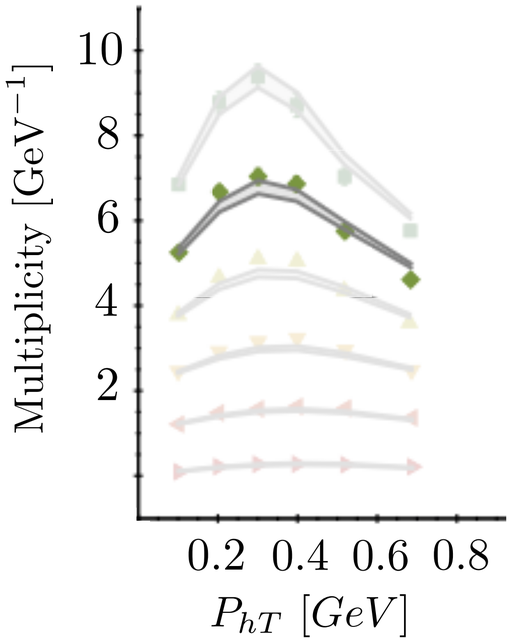
Results at NLL

HERMES multiplicities

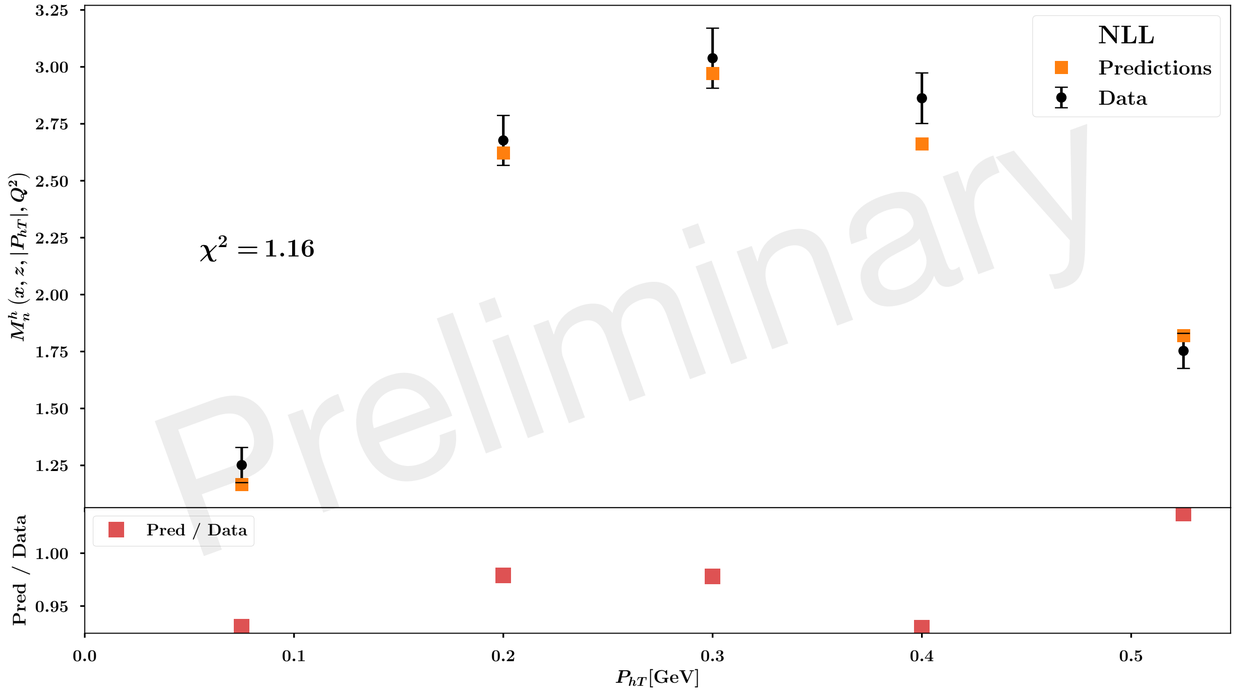
What we expected

$\langle Q^2 \rangle = 2.9\ \mathrm{GeV}^2$

$\langle x \rangle = 0.15$



What we found

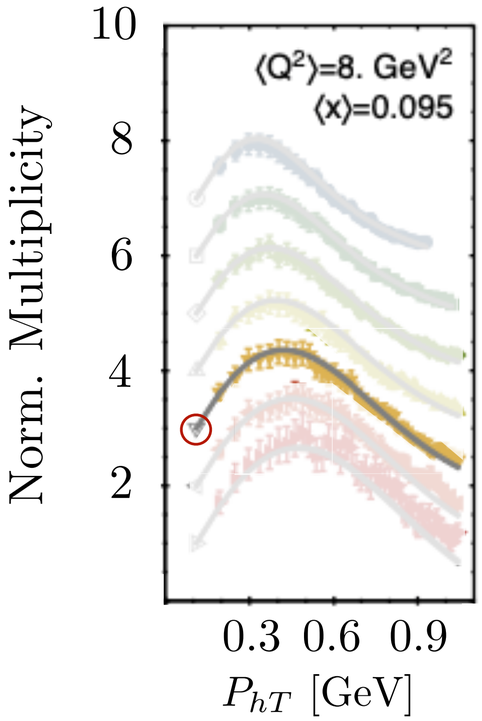


Bacchetta, Delcarro, Pisano, Radici, Signori, arXiv:1703.10157

Results at NLL

COMPASS multiplicities

What we expected



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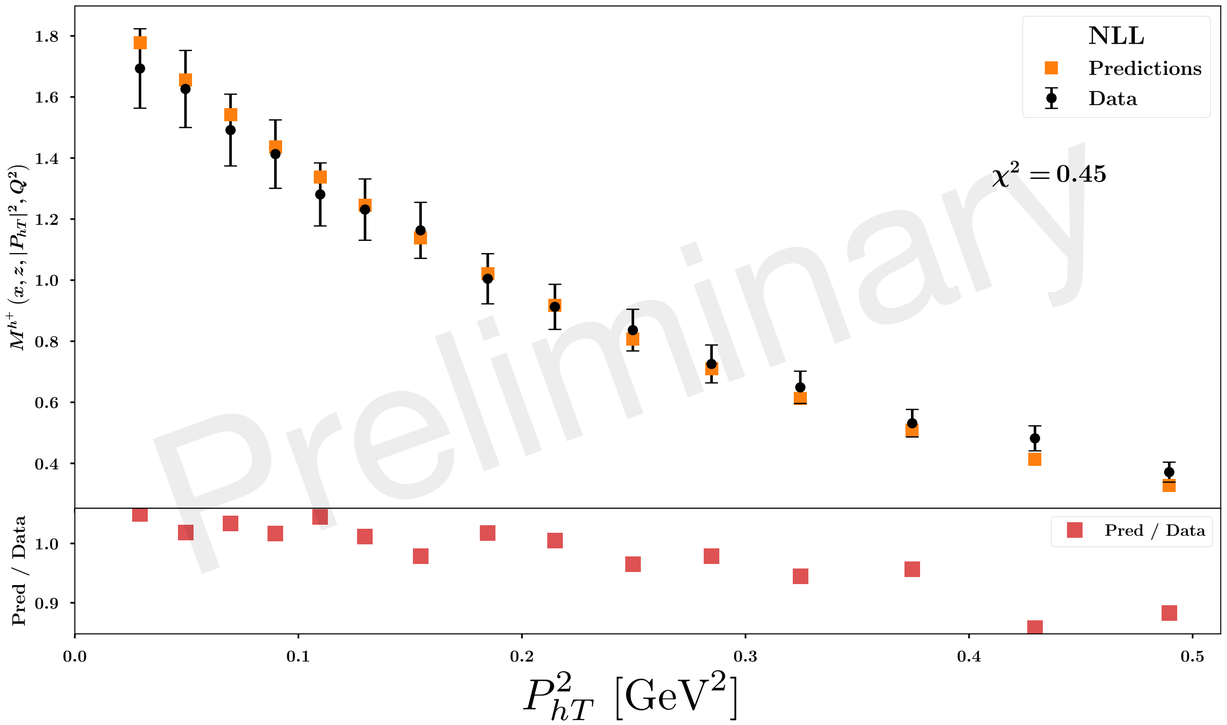


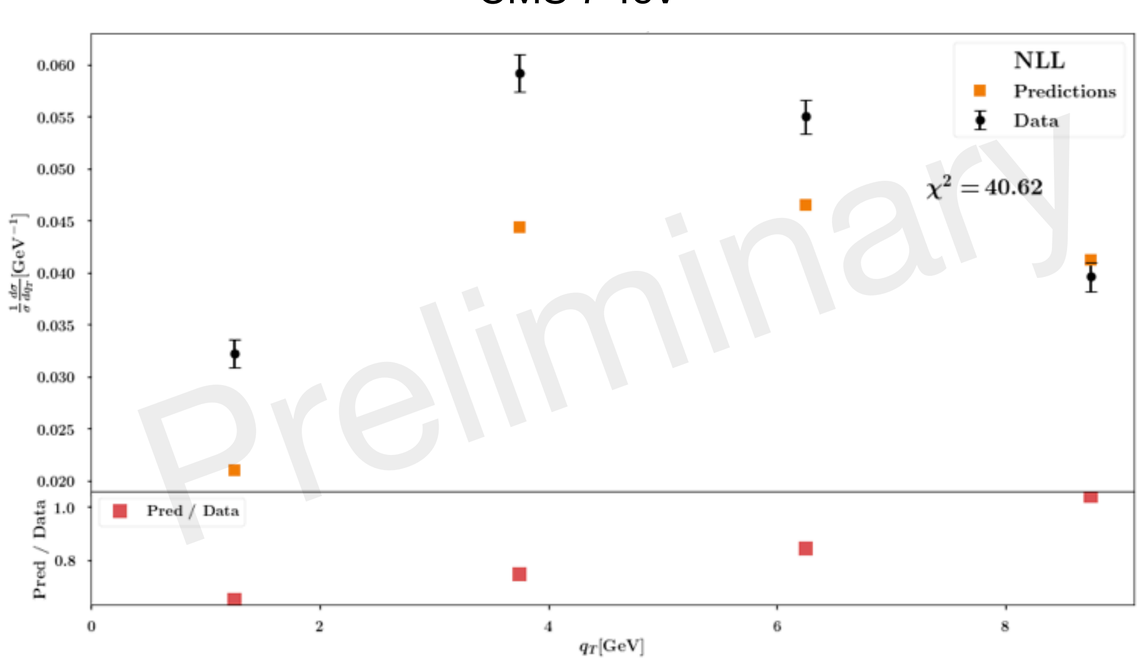
Bacchetta, Delcarro, Pisano, Radici, Signori, arXiv:1703.10157

Results at NLL

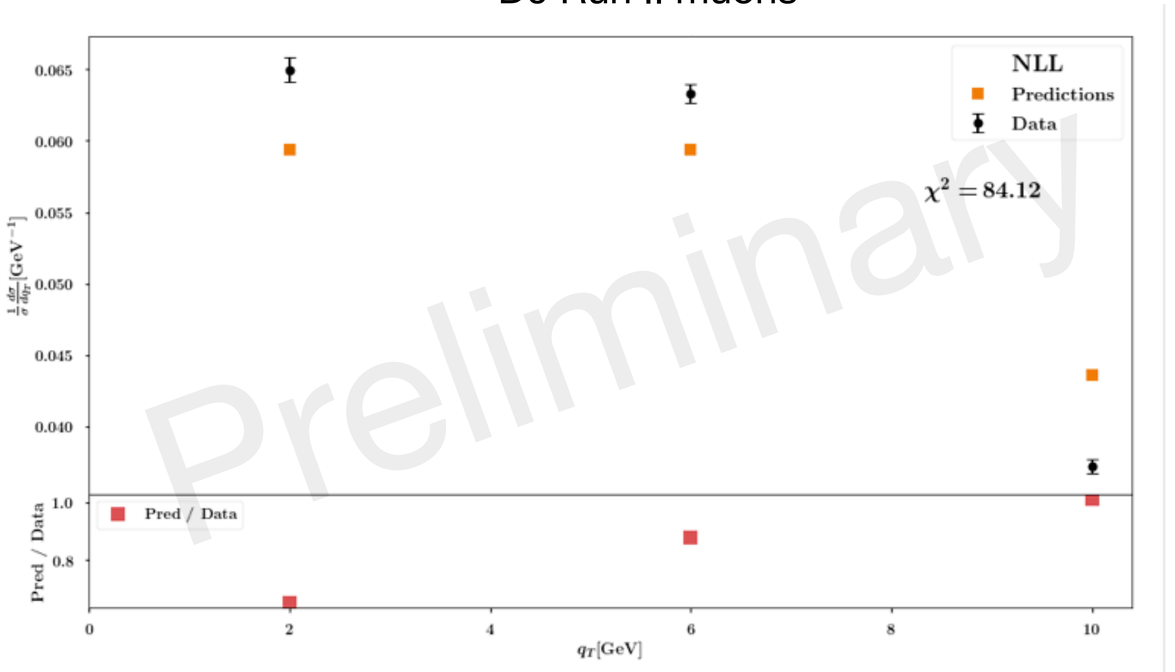
Drell Yan dataset

We need to increase the accuracy

CMS 7 TeV



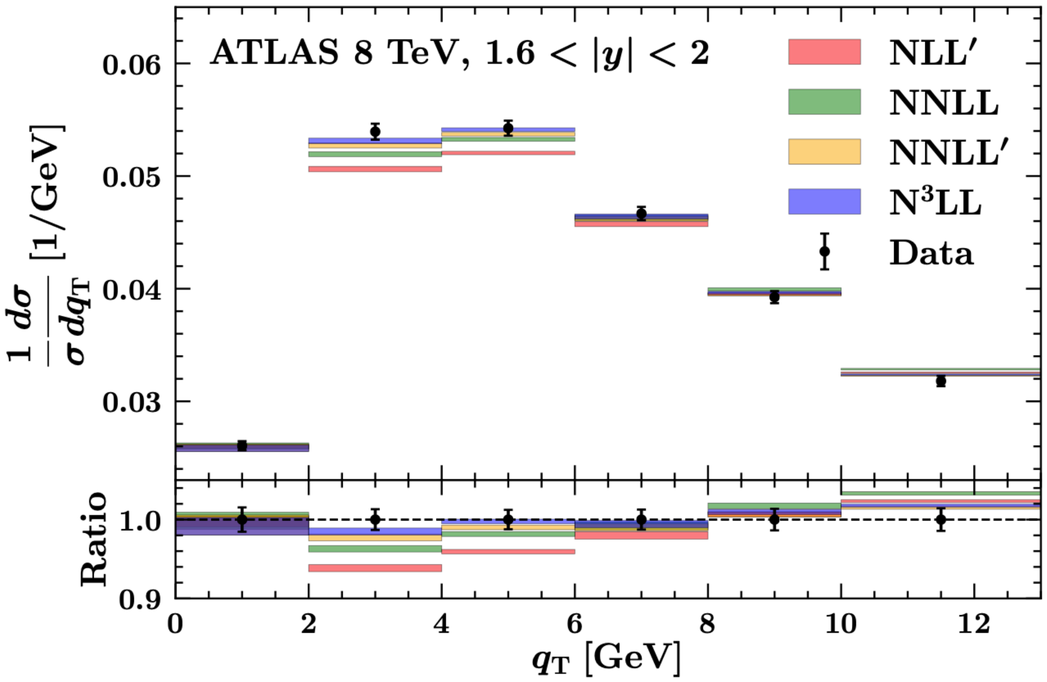
D0 Run II muons



Beyond NLL…

Accuracy at NNLL and N3LL

What we expected

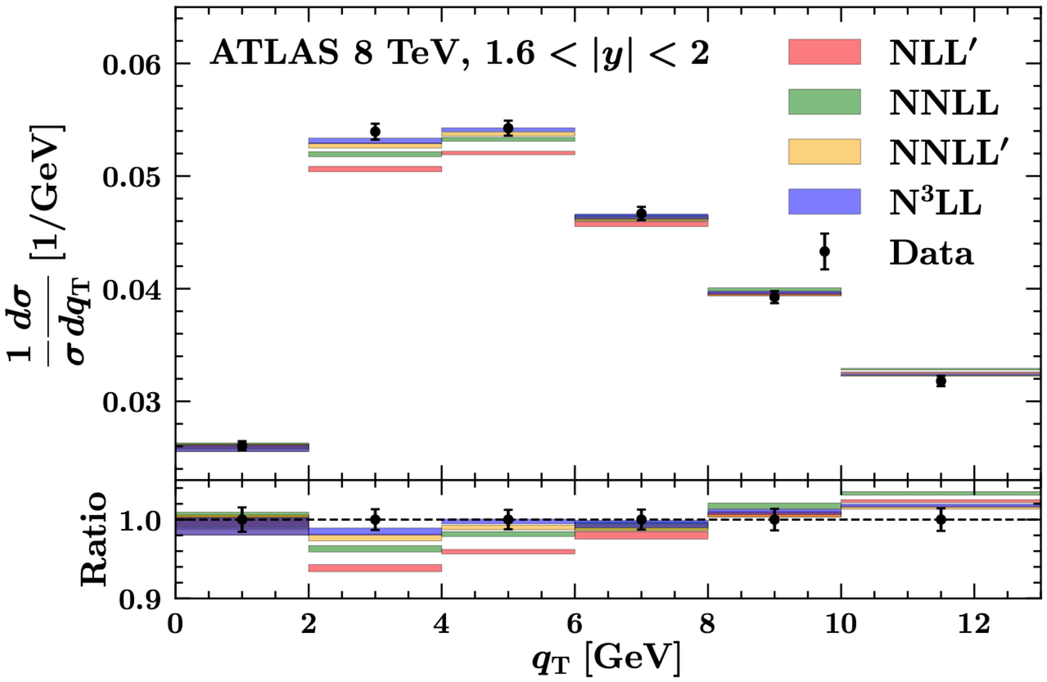


Bacchetta, Bertone, Bissolotti, Bozzi, Delcarro, Piacenza, Radici, arXiv:1912.07550

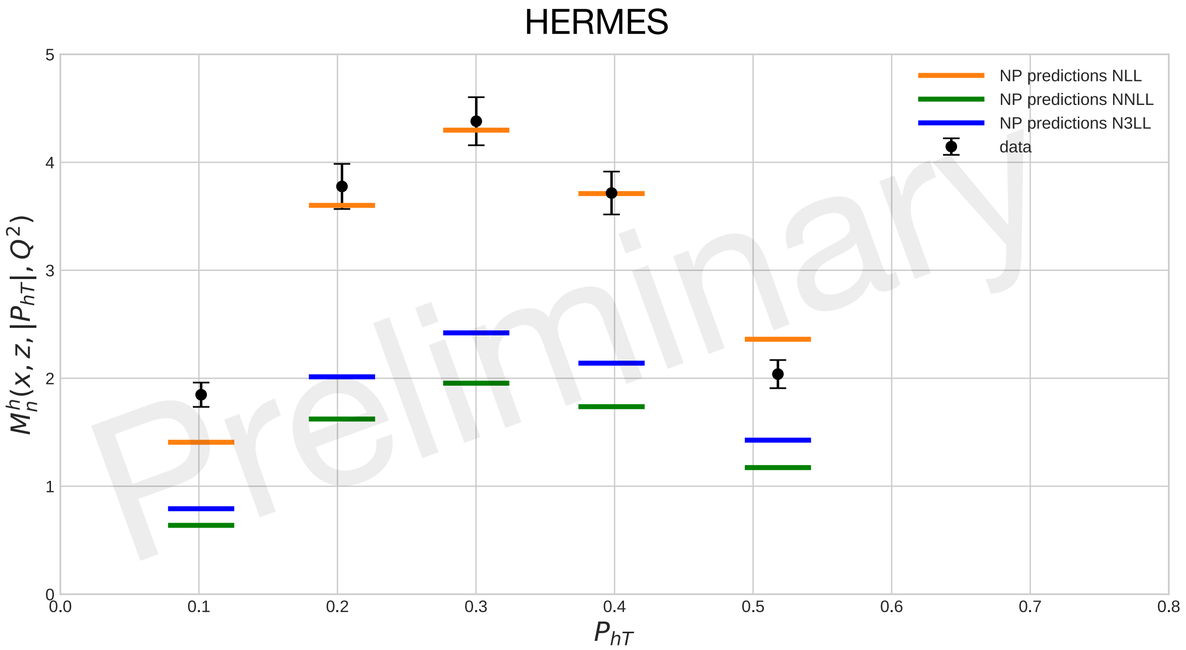
Beyond NLL...

Accuracy at NNLL and N3LL

What we expected $Q \sim 100$ GeV



What we get $Q \sim 2$ GeV



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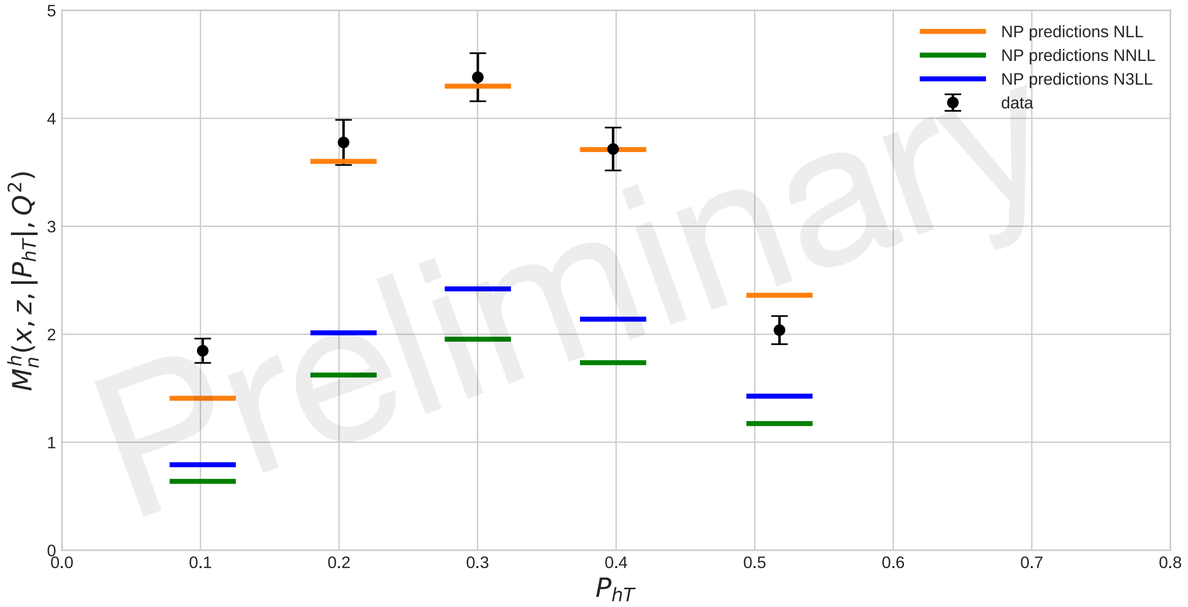
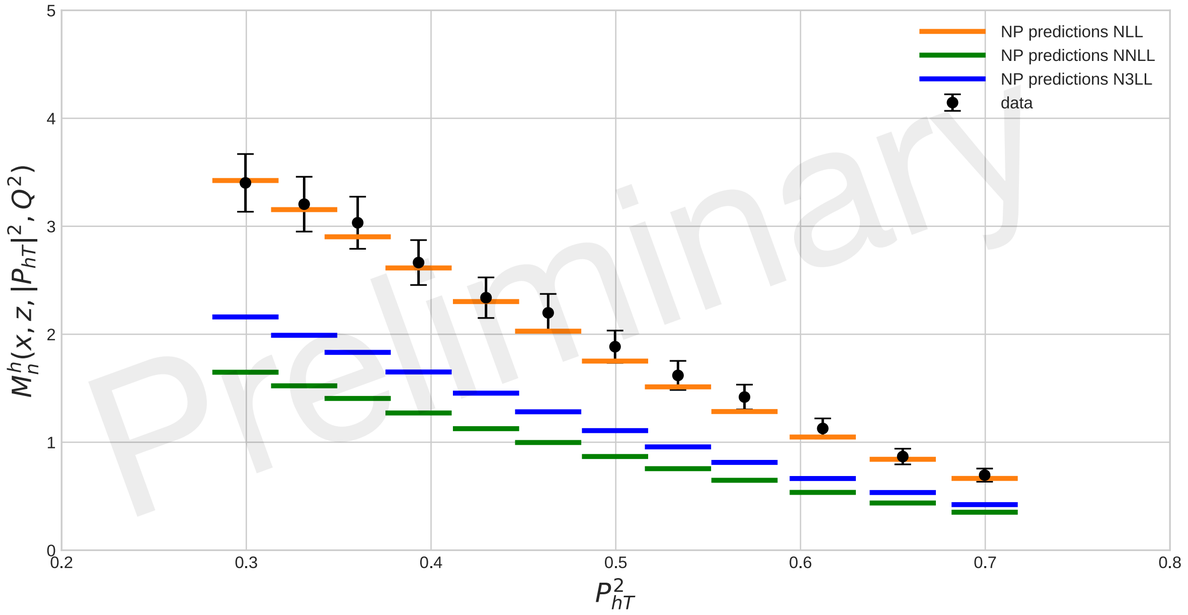
Beyond NLL...

Accuracy at NNLL and N3LL

HERMES multiplicity



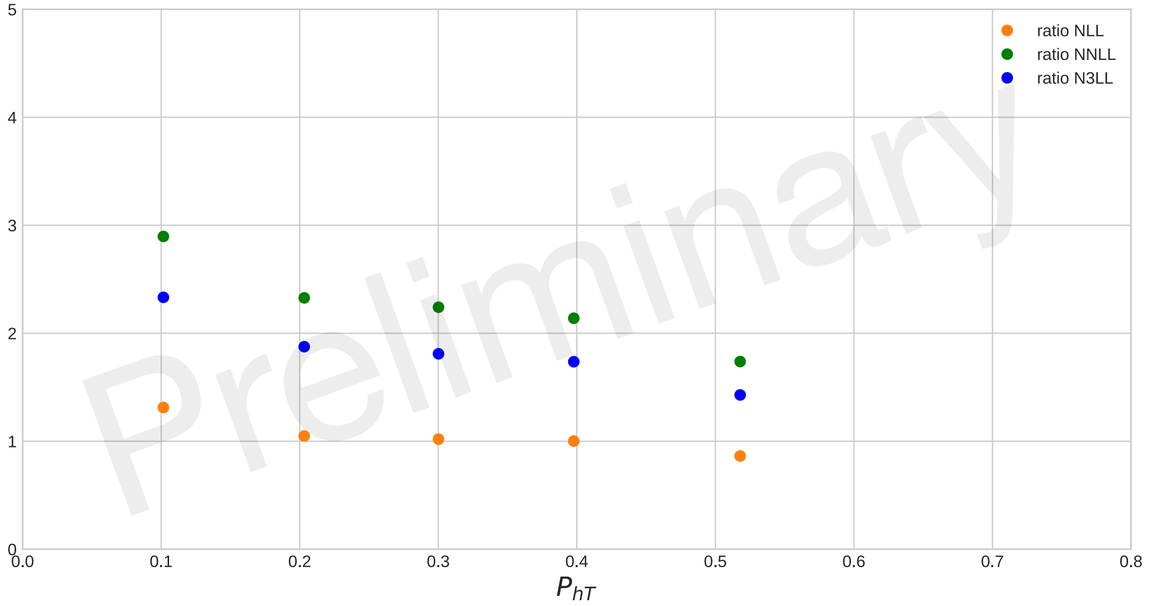
COMPASS multiplicity



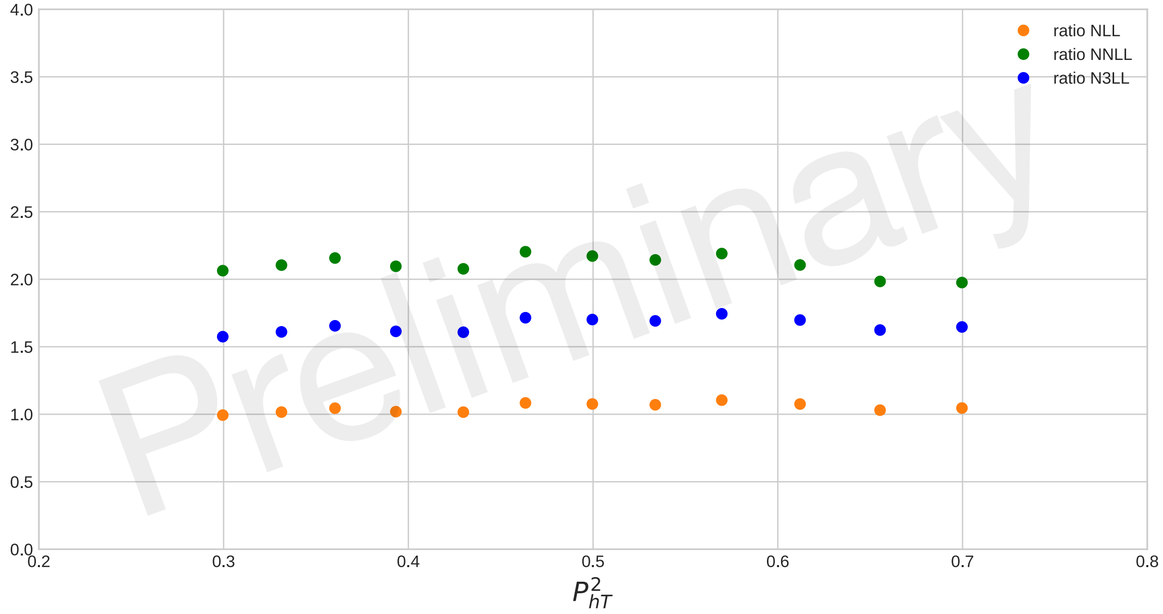
Beyond NLL…

Ratio Data/Predictions

HERMES multiplicity



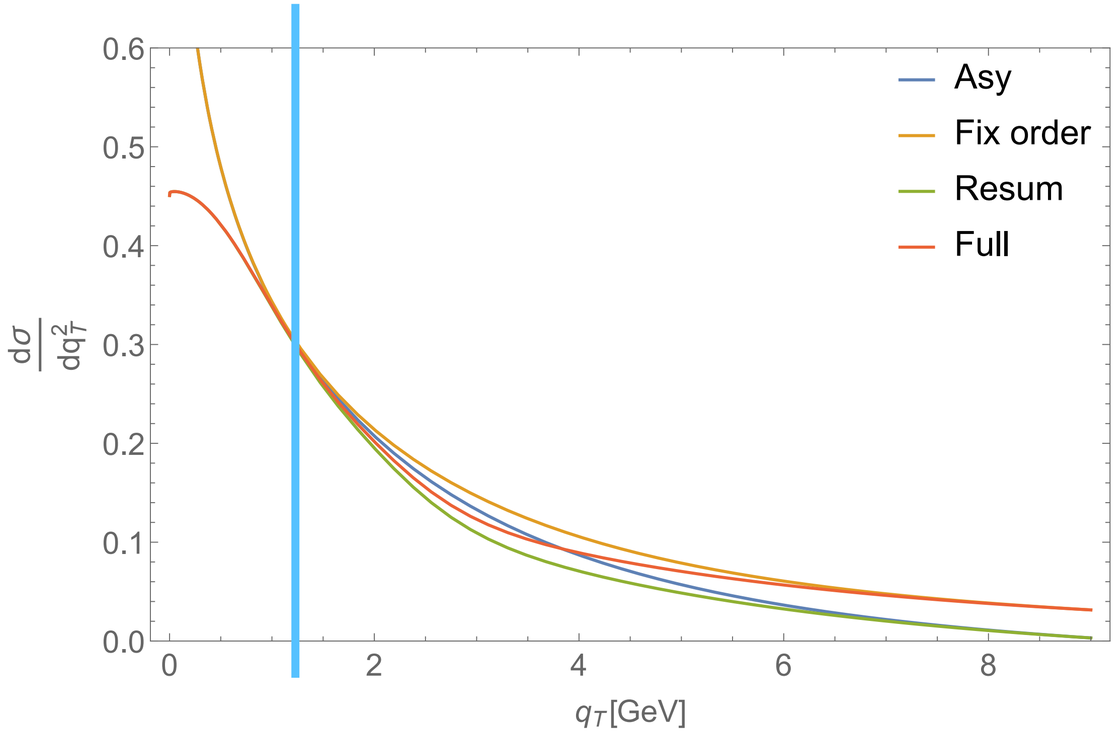
COMPASS multiplicity



Almost constant!

Where is the problem?

Ideal situation at high Q

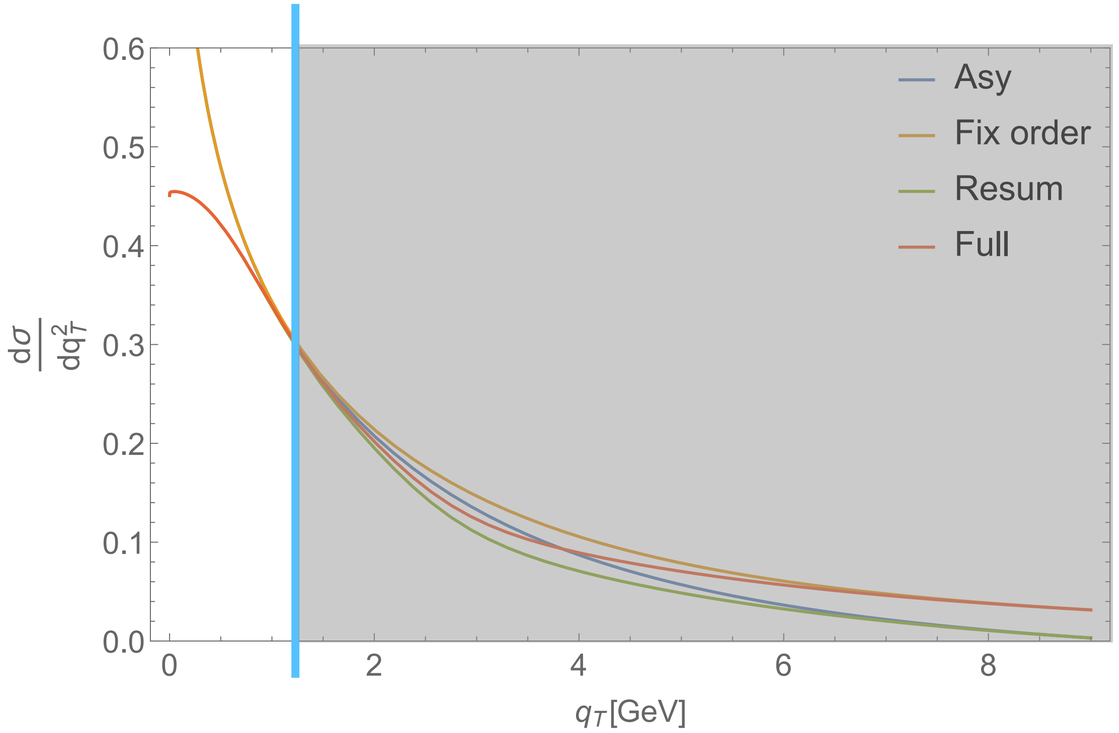


Standard approach

- Resummed contribution is dominant where the Asymptotic term is close to the Fixed Order

Where is the problem?

Ideal situation at high Q



Standard approach

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Where is the problem?

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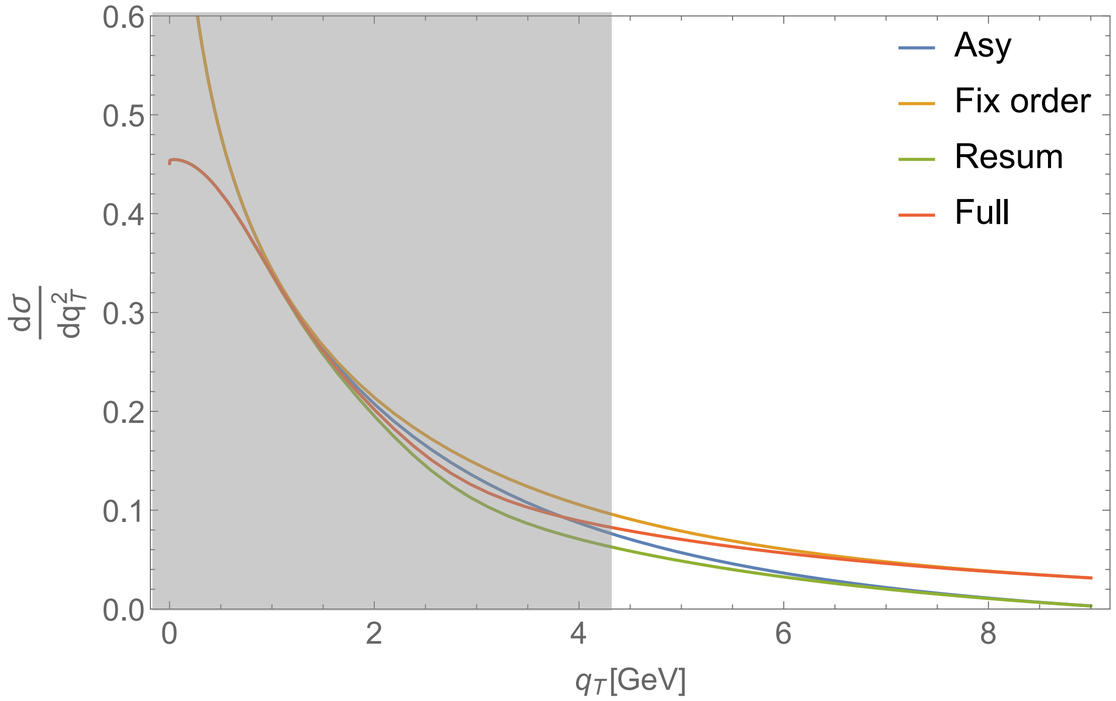
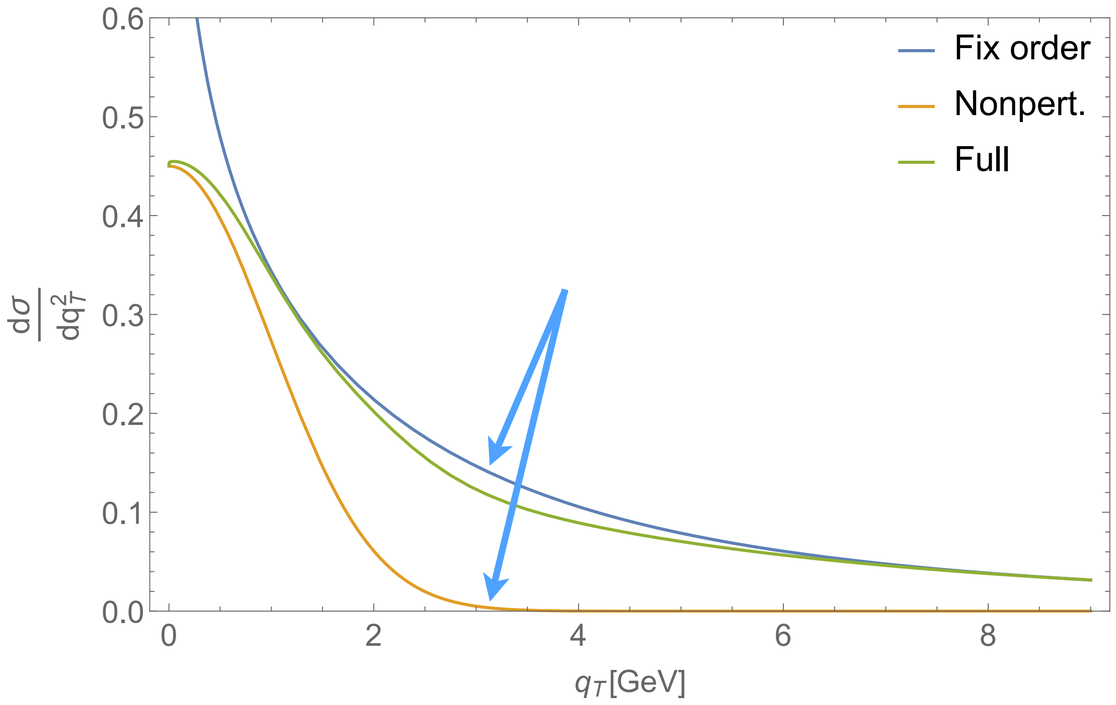


Standard approach

- Resummed contribution is dominant where the Asymptotic term is close to the Fixed Order
- From a certain value of qT the total cross section follows the Fixed Order term

Where is the problem?

Ideal situation at high Q

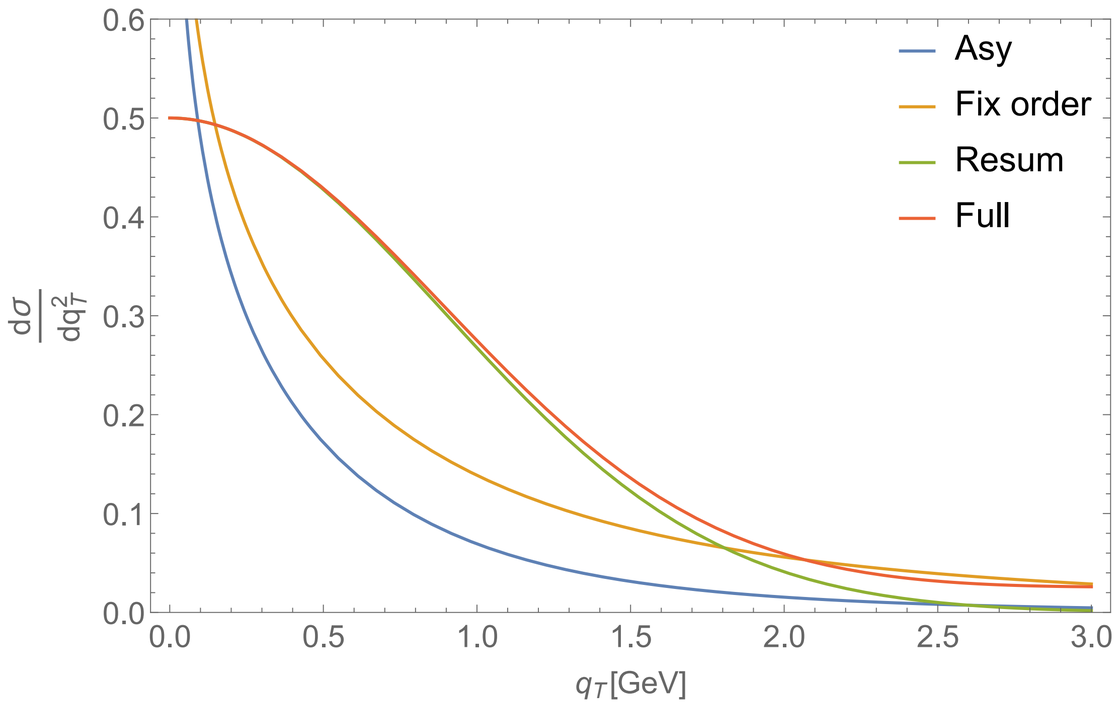


Standard approach

- Collinear result is mostly given by the integral of the Fixed Order
- The Non-Perturbative term is only a small correction

Where is the problem?

Real situation at low Q



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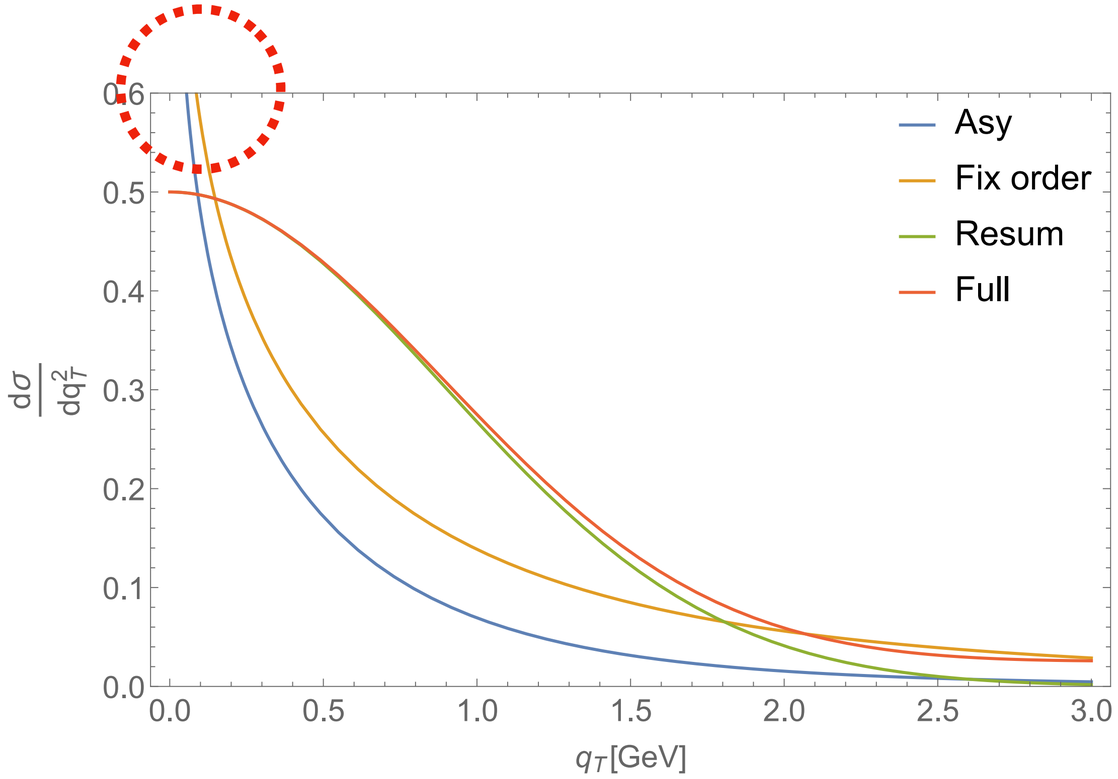
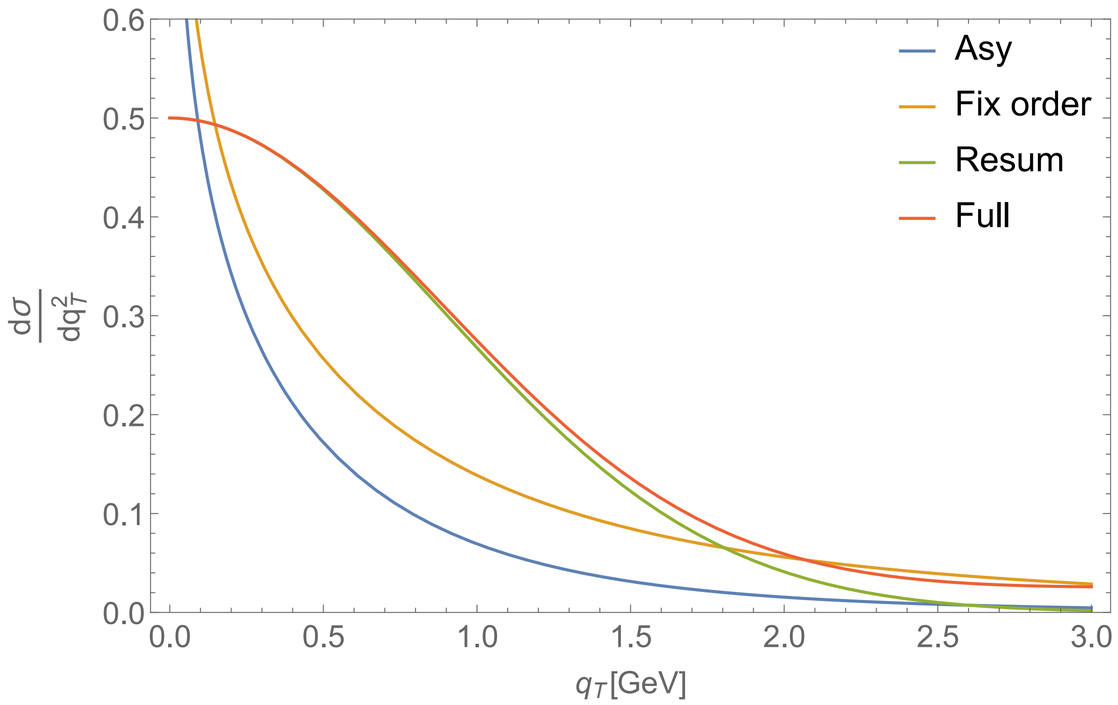


Standard approach

- Resummed contribution is dominant where the Asymptotic term is close to the Fixed Order ⟶ **TMD Region?**

Where is the problem?

Real situation at low Q

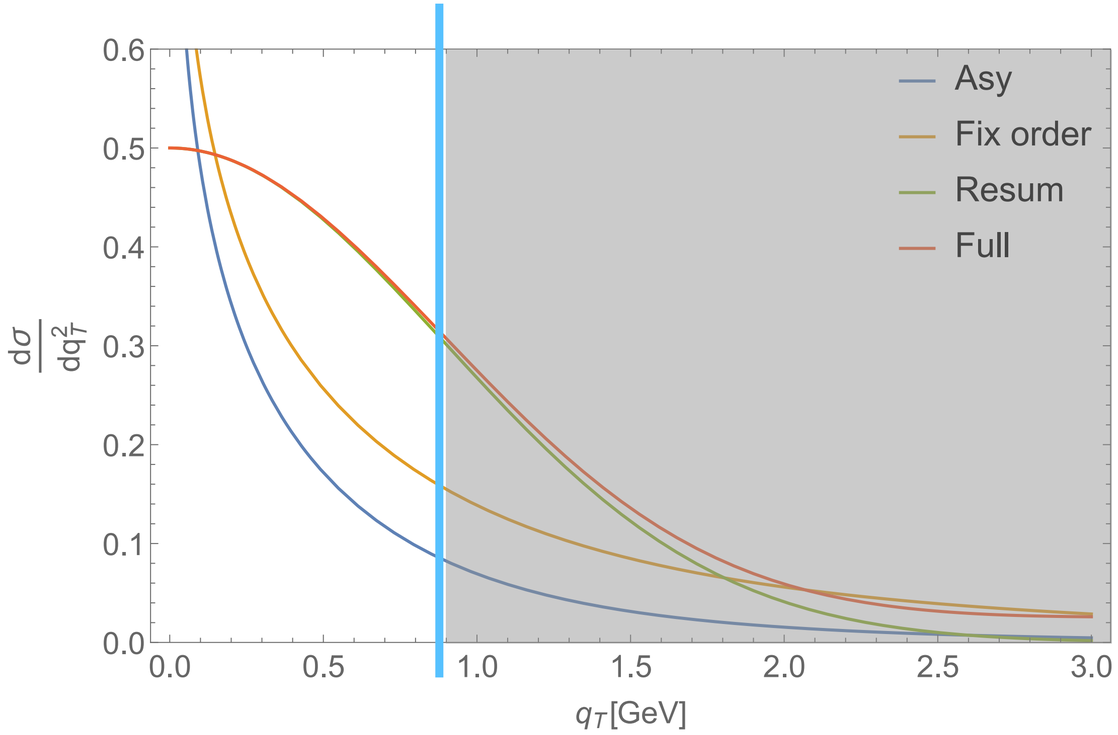


Non-Perturbative approach

- Resummed contribution is dominant where the Asymptotic term is close to the Fixed Order OR the Non-Perturbative contributions dominates

Where is the problem?

Real situation at low Q



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→ **TMD Region**

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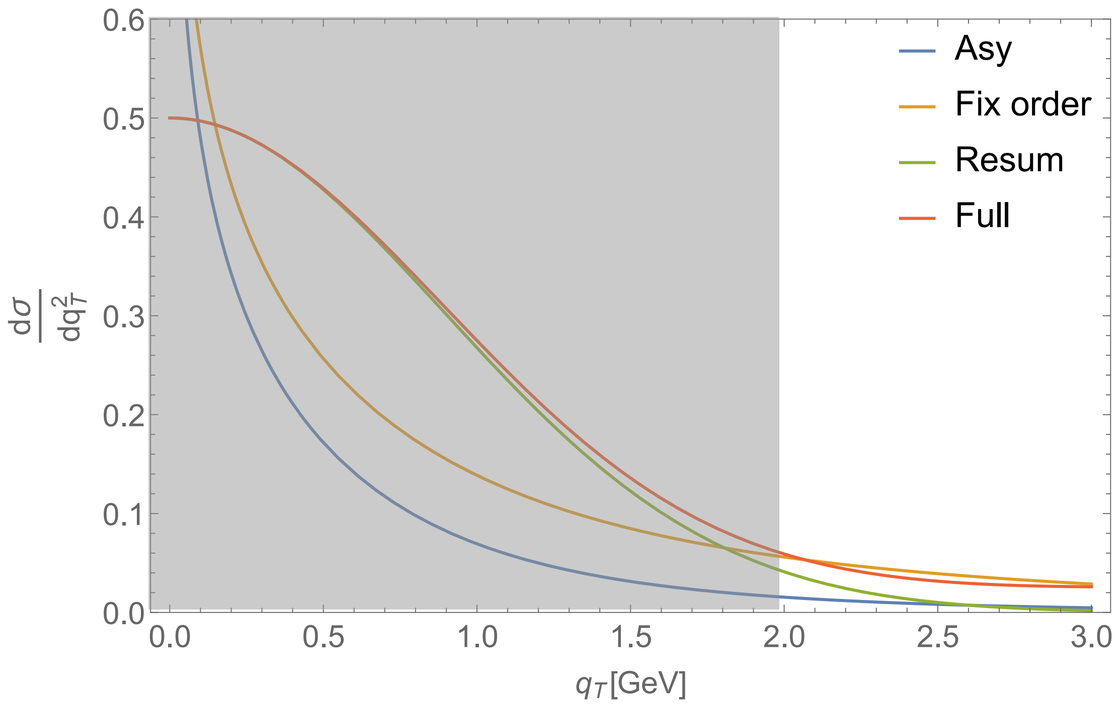

Non-Perturbative approach

- Resummed contribution is dominant where the Asymptotic term is close to the Fixed Order OR the Non-Perturbative contributions dominates

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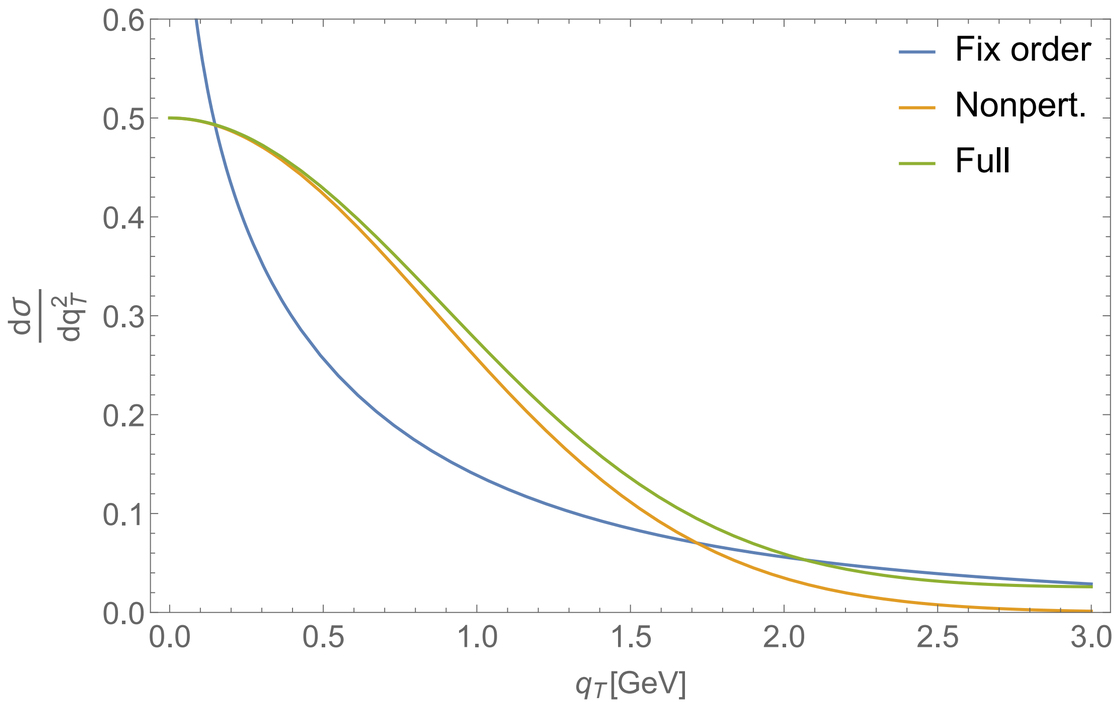
Where is the problem?

Real situation at low Q

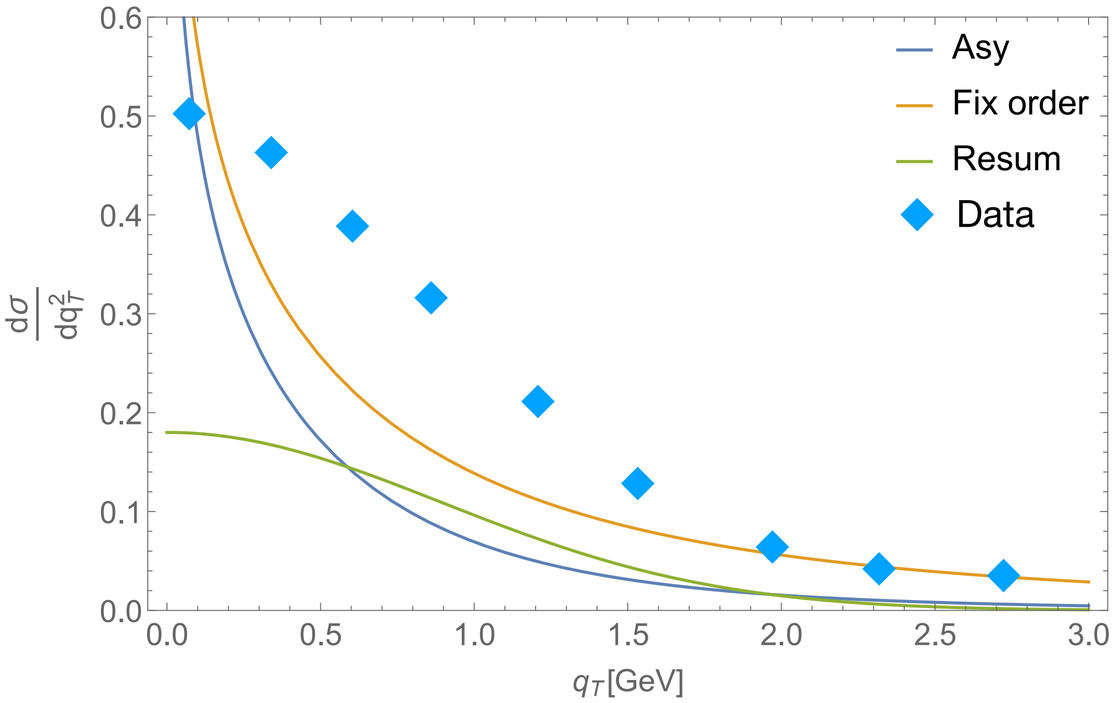


Non-Perturbative approach

- Collinear result is no more mostly given by the integral of the Fixed Order
- The Non-Perturbative term is not only a small correction, but is even larger than the Fixed Order contribution

Where is the problem?

Present situation at low Q



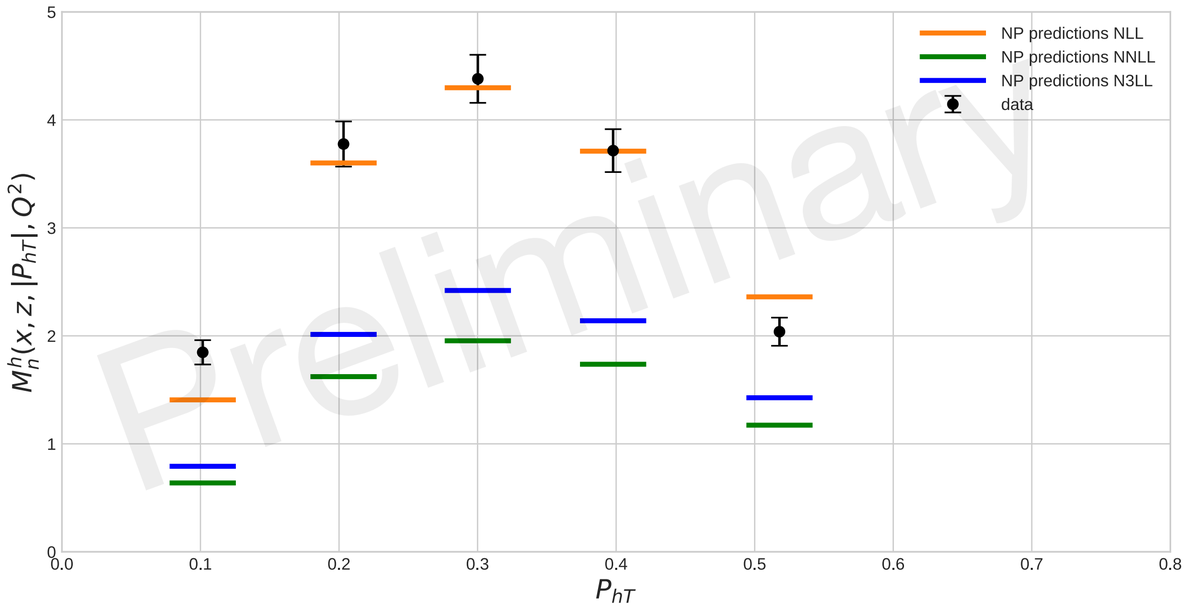
- The Resummed contribution is too small to explain the experimental data
- The Resummed contribution should have been dominant at low Q
- Suppression due to higher order contributions in the Hard Factor

Where is the problem?

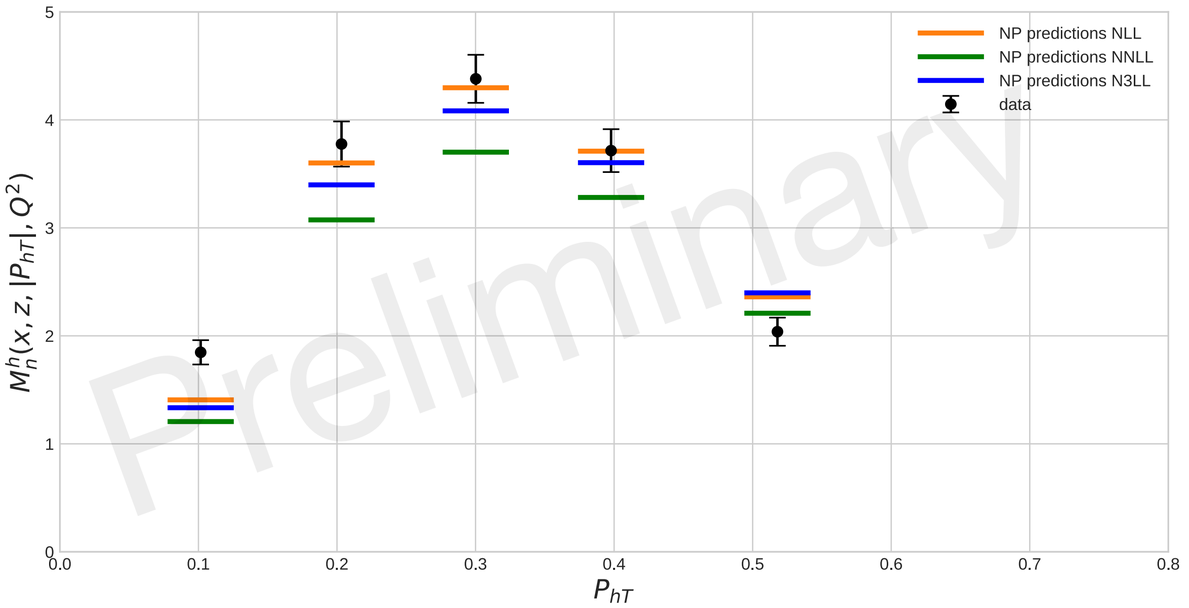
Present situation at low Q

HERMES multiplicity

Full Hard Factor



Hard Factor = 1

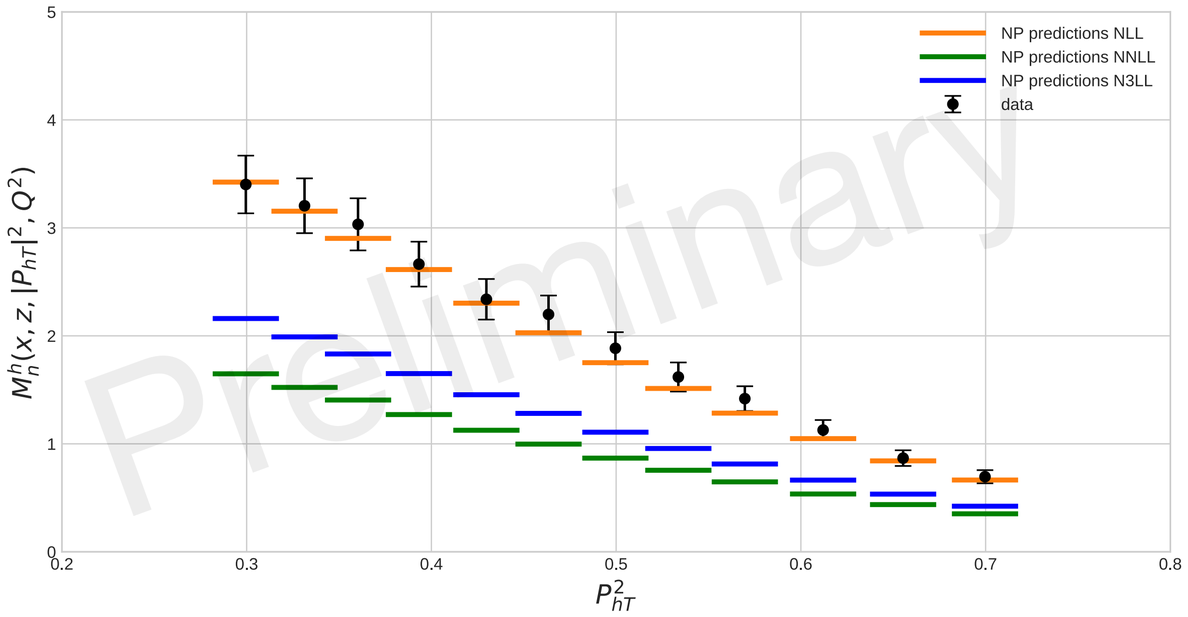


Where is the problem?

Present situation at low Q

COMPASS multiplicity

Full Hard Factor



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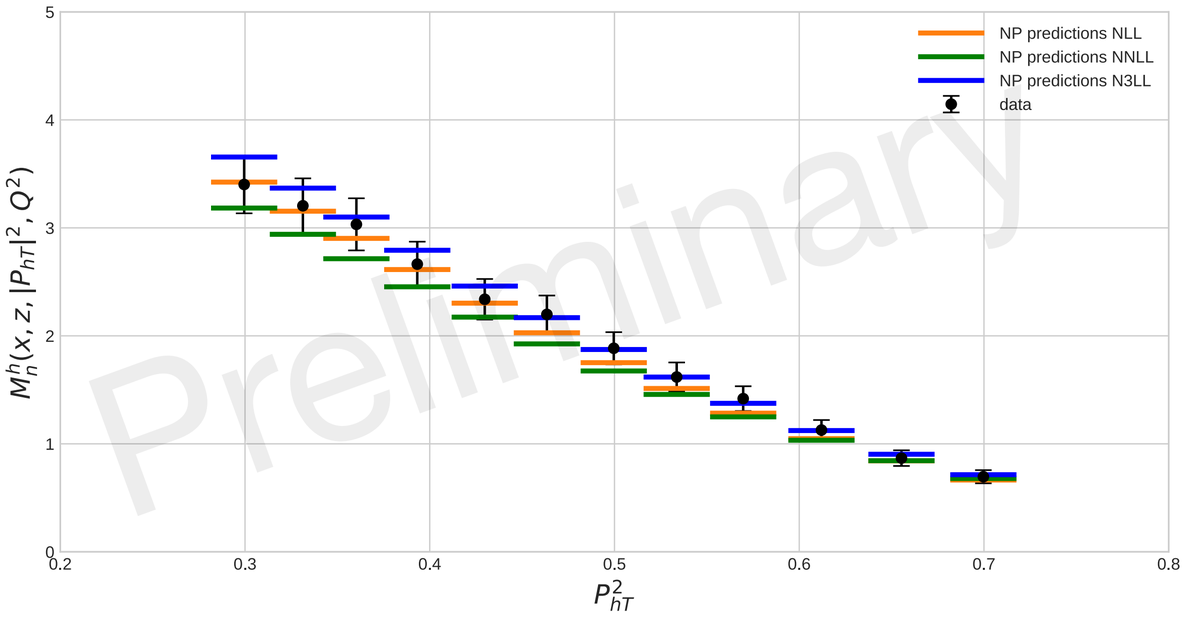

Our possible solution

Introduction of a normalization prefactor that restores the real situation at low Q

$$w(x,z,Q) = \frac{\frac{d\sigma^h}{dx dQ^2 dz}}{\int \mathrm{W} d^2\boldsymbol{q}_T}$$

Proposed by F. Piacenza in his Ph.D. thesis

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$$\left.\frac{d\sigma^h}{dxdQ^2dz}\right|_{O(\alpha_S)} = \sigma_0 \sum_{f,f'} \frac{e_f^2}{z^2}(\delta_{f'f}+\delta_{f'g})\frac{\alpha_S}{\pi}\Big\{\left[D_1^{h/f'}\otimes C_1^{f'f}\otimes f_1^{f/N}\right](x,z,Q) + \frac{1-y}{1+(1-y)^2}\left[D_1^{h/f'}\otimes C_L^{f'f}\otimes f_1^{f/N}\right](x,z,Q)\Big\}$$

$$\int W\Big|_{O(\alpha_S)} = \sigma_0 \sum_{f,f'} \frac{e_f^2}{z^2}(\delta_{f'f}+\delta_{f'g})\frac{\alpha_S}{\pi}\left[D_1^{h/f'}\otimes C_{\mathrm{TMD}}^{f'f}\otimes f_1^{f/N}\right](x,z,Q)$$

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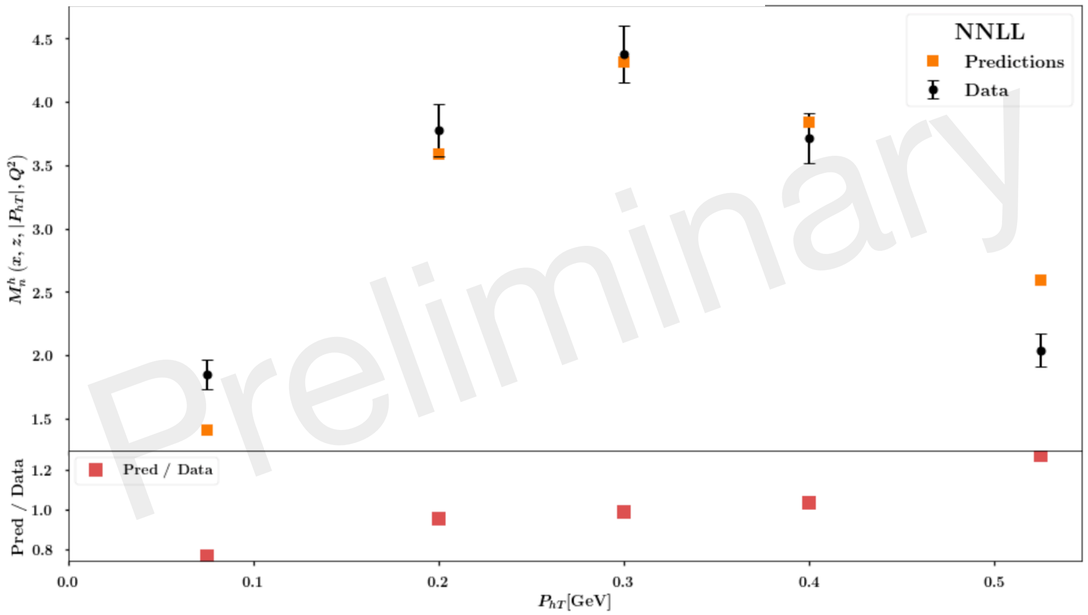
Outcome

Predictions with the inclusion of the normalization prefactors

HERMES multiplicity



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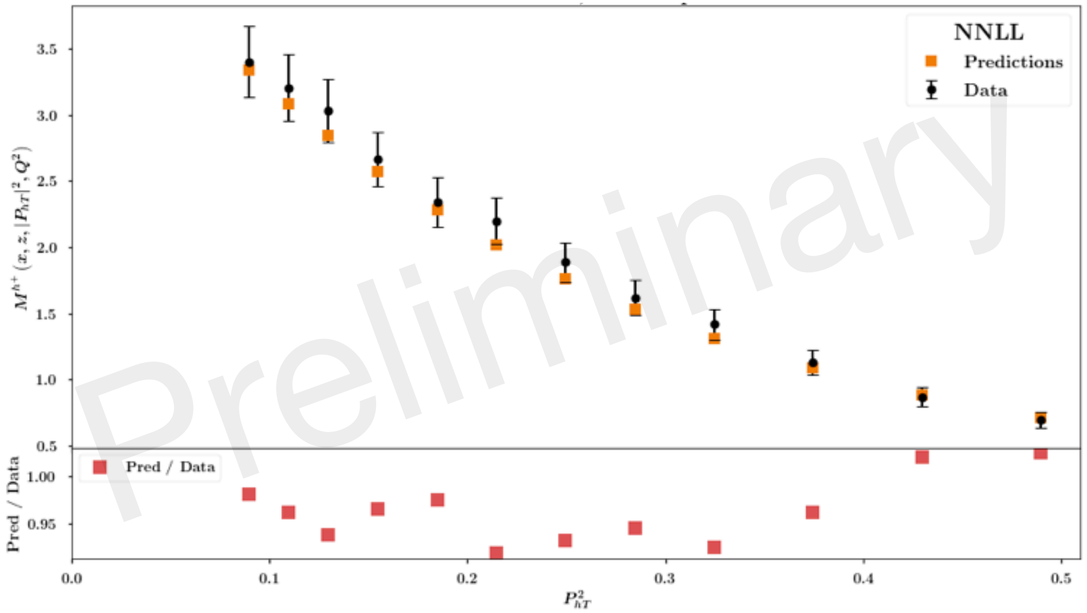
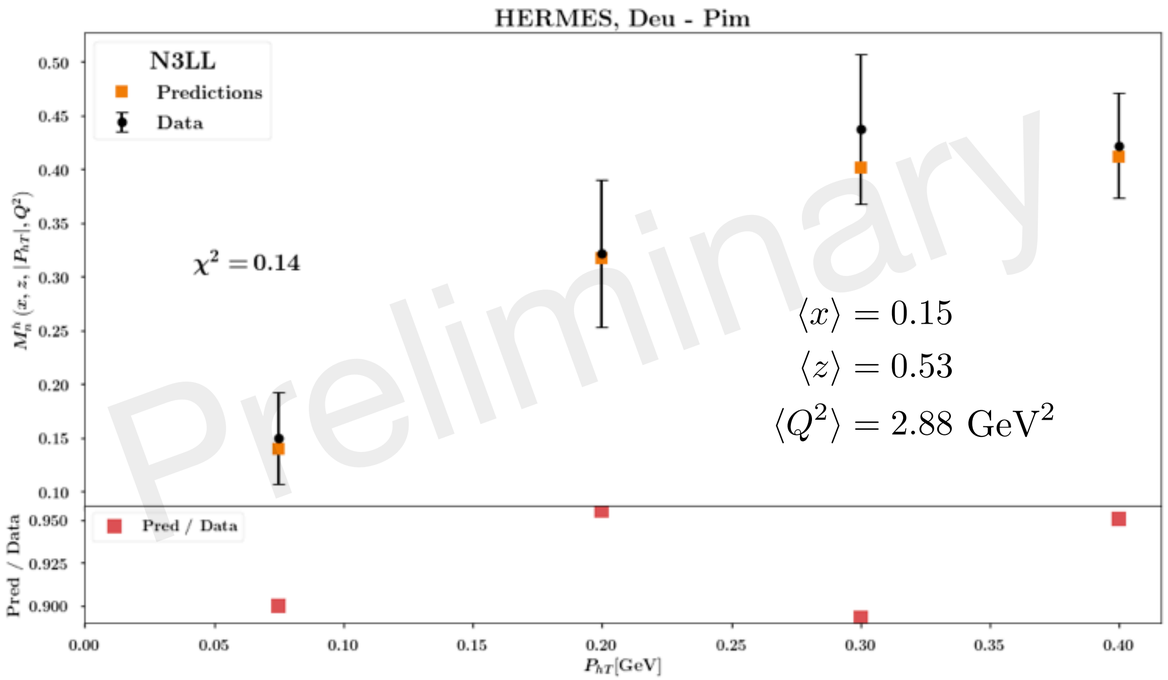
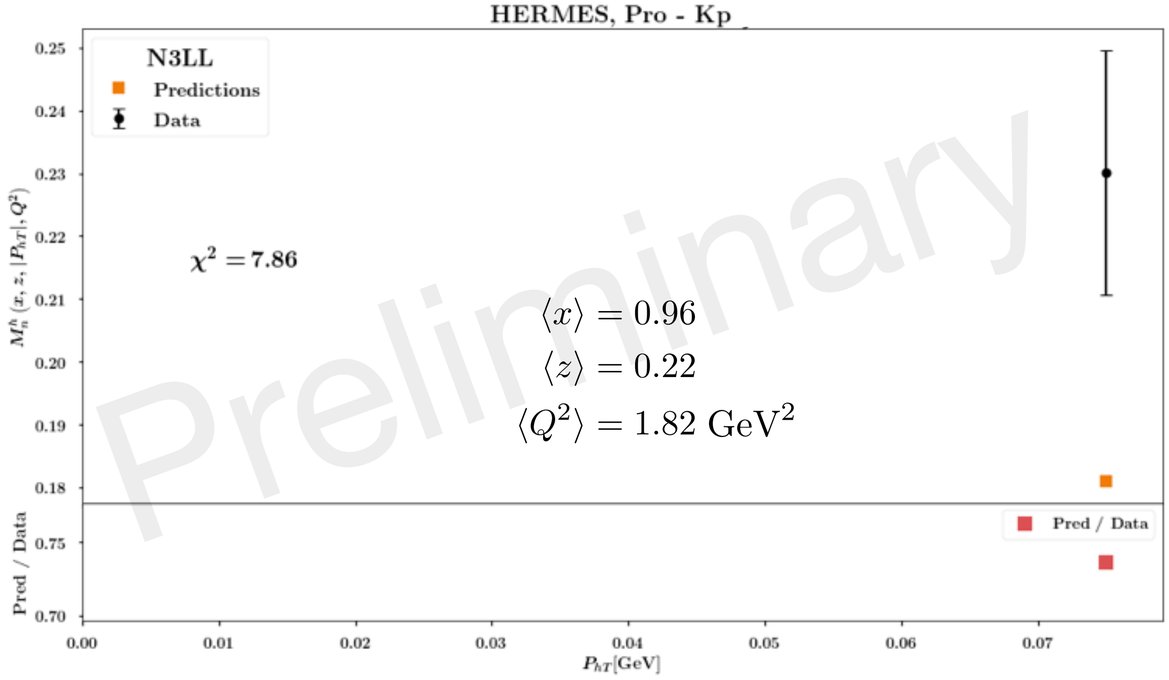


Preliminary results ~ N3LL

Good quality of the fit (with some exceptions)

HERMES multiplicity





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Good quality of the fit (with few exceptions)

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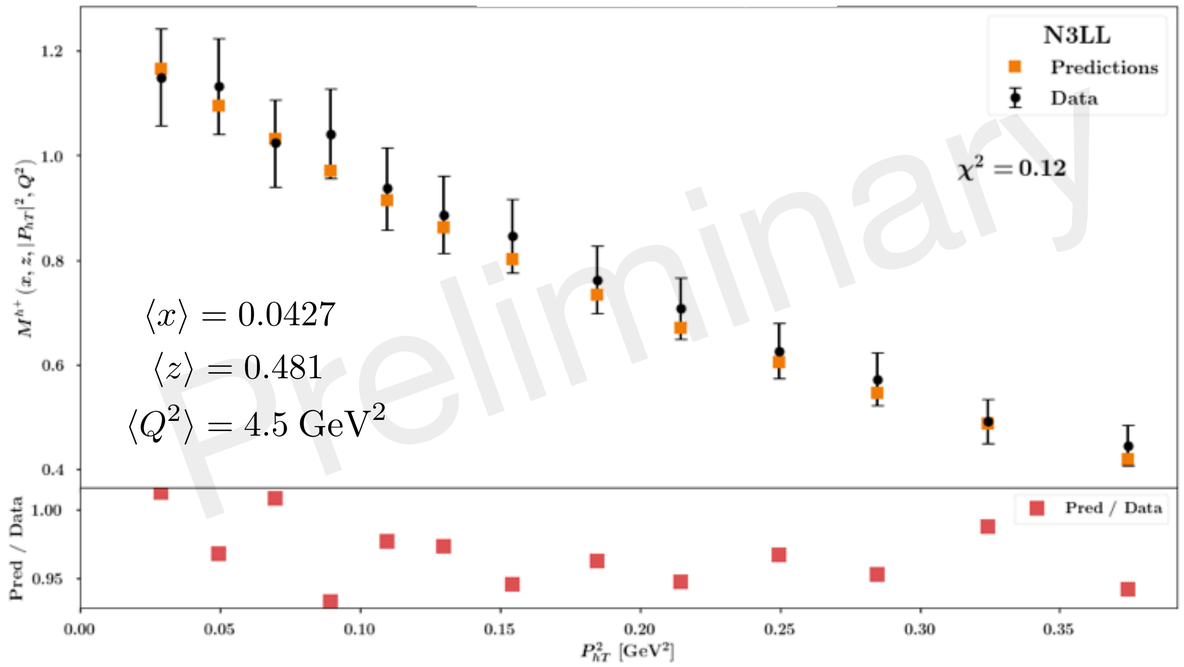

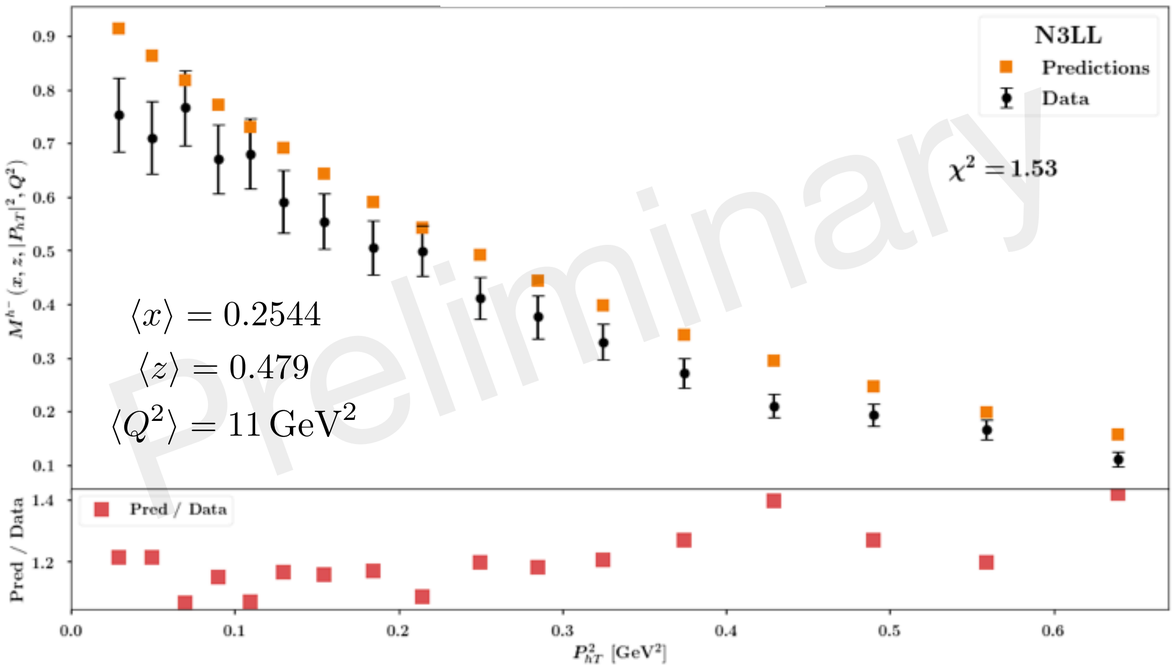

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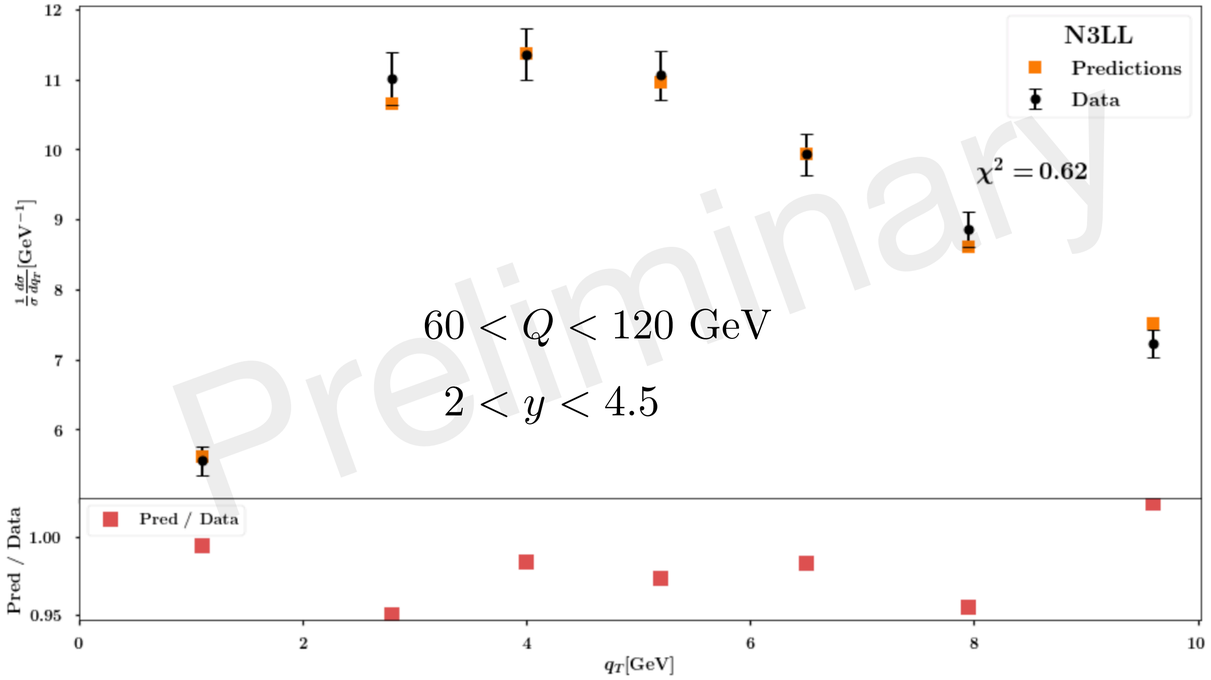
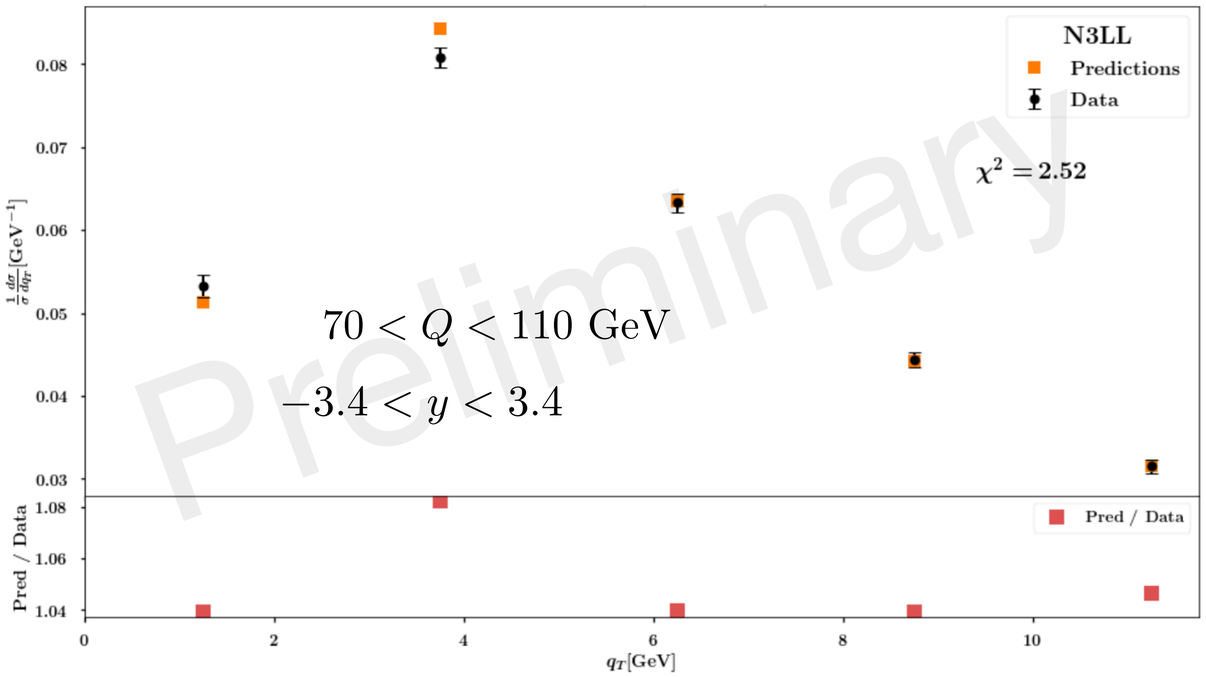
Good quality of the fit (with some exceptions)

Drell-Yan dataset

LHCb 13 TeV



D0 run II

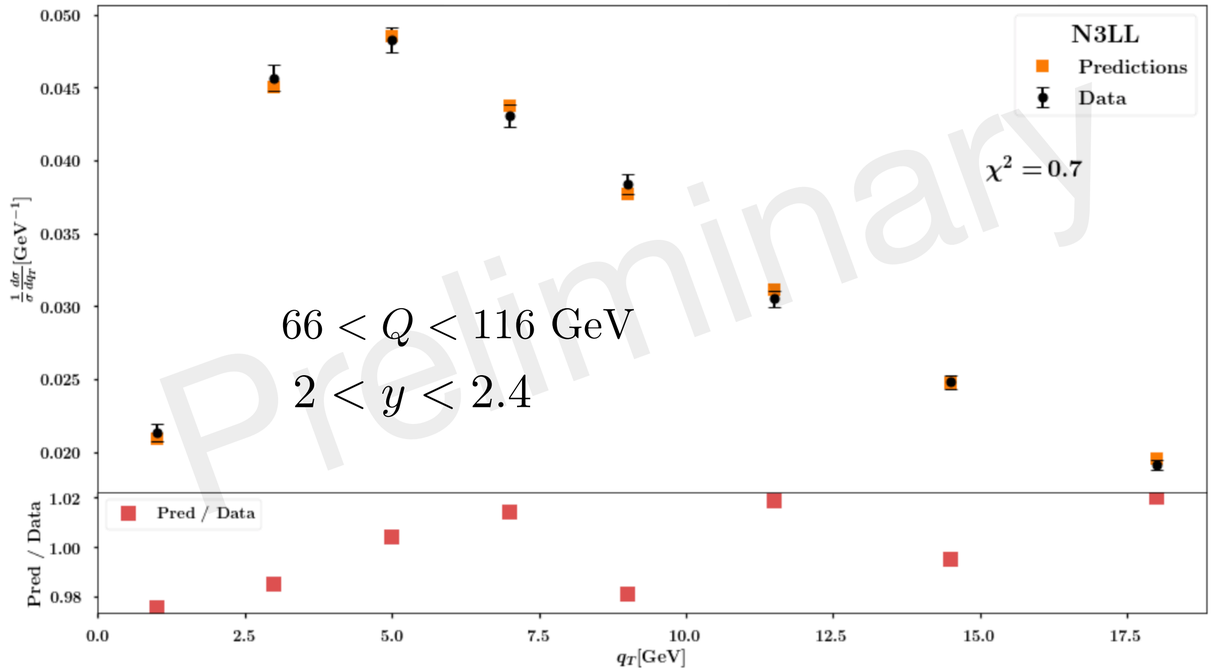


Preliminary results ~ N3LL

Not good description of the ATLAS dataset

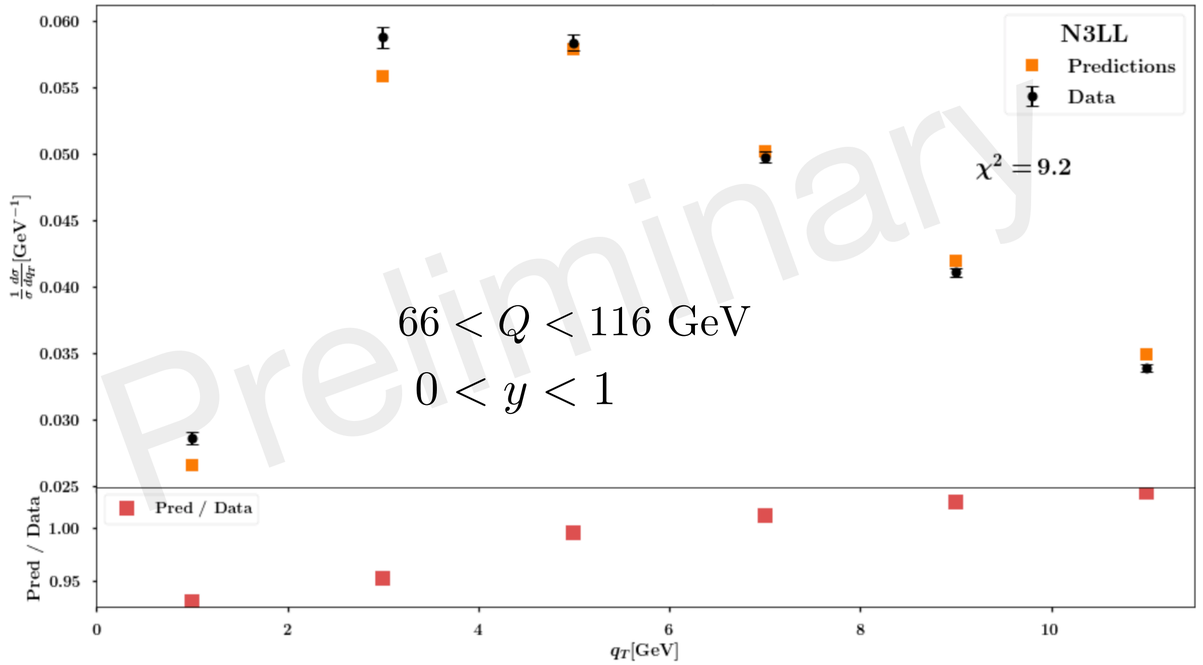
Best described dataset

ATLAS 8 TeV



Worst described dataset

ATLAS 7 TeV



Recap&Conclusions

- We want to perform a global fit of SIDIS and Drell Yan data at the best possible accuracy to simultaneously extract TMD PDFs and FFs
- We checked that the description of the SIDIS dataset is good at NLL, but not for Drell Yan sets
- Going beyond NLL we are able to describe the shape of the SIDIS multiplicities but not the normalization
- We identified the problem in the contribution of the Resummed term, which is suppressed by the higher order corrections in the Hard Factor
- By introducing new normalization coefficients, we are able to properly describe SIDIS data also beyond NLL, but not at all ATLAS data

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Backup slide

Data selection 2017

$Q^2 > 1.4\ \mathrm{GeV}^2$

$0.2 < z < 0.7$

$P_{hT}, q_T < \mathrm{Min}[0.2\ Q, 0.7\ Qz] + 0.5\ \mathrm{GeV}$

Data selection 2019

$q_T < 0.2\ Q$

New global fit

DY $\quad q_T < 0.2\ Q$

SIDIS $\quad P_{hT} < \mathrm{Min}[\mathrm{Min}[0.2\ Q, 0.5\ Qz] + 0.3\ \mathrm{GeV}, Q]$

Backup slide

$$\frac{\mathrm{d}\sigma^X}{\mathrm{d}q_T \mathrm{d}\ldots}(\text{matched}) = W + Y,$$

$$W \equiv \frac{\mathrm{d}\sigma^X}{\mathrm{d}q_T \mathrm{d}\ldots}(\text{TMD}), \qquad (3.29)$$

$$Y \equiv \frac{\mathrm{d}\sigma^X}{\mathrm{d}q_T \mathrm{d}\ldots}(\text{F.O.}) - \frac{\mathrm{d}\sigma^X}{\mathrm{d}q_T \mathrm{d}\ldots}(\text{asy}),$$

Source: F. Piacenza's Ph.D. thesis