

Status of QCD precision predictions for Drell-Yan processes

Adam Kardos

in collaboration with

S. Alekhin, L. Buonocore, A. Huss,
S. Kallweit, S.-O. Moch, F. Petriello,
L. Rottoli, Z. Trócsányi, M. Wiesemann

2023 August 29th



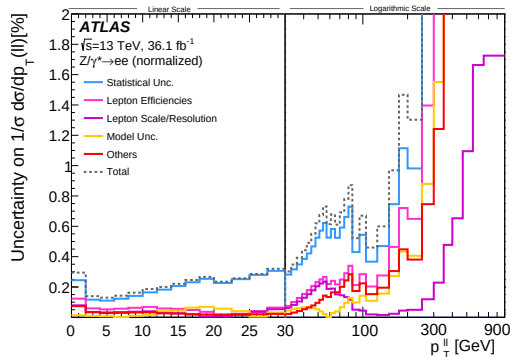
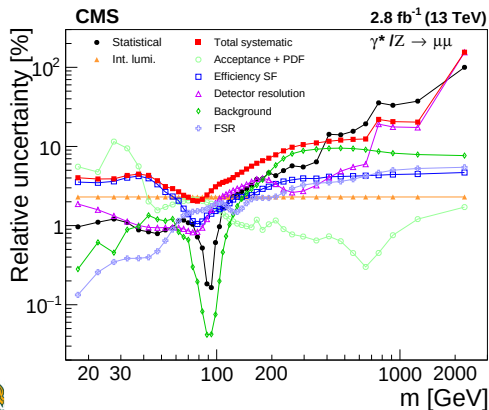
**UNIVERSITY of
DEBRECEN**



Introduction

Motivation:

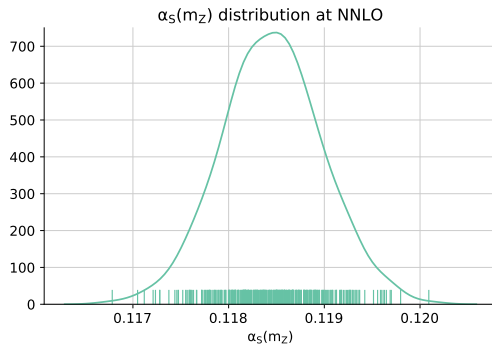
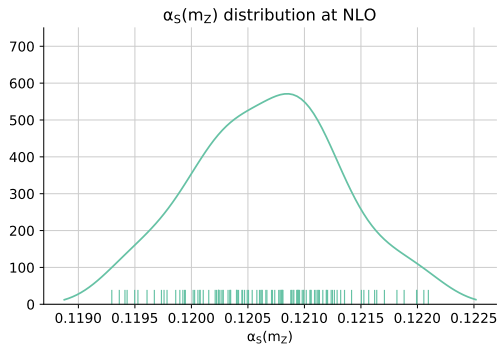
- Exceptional precision in Drell-Yan production!



DEBRECEN

Introduction

- For α_S we need NNLO (more N the better...)



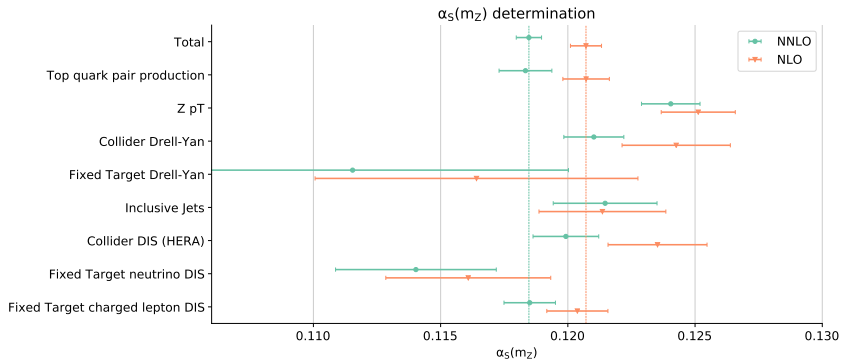
NNPDF, arXiv:1802.03398



UNIVERSITY of
DEBRECEN

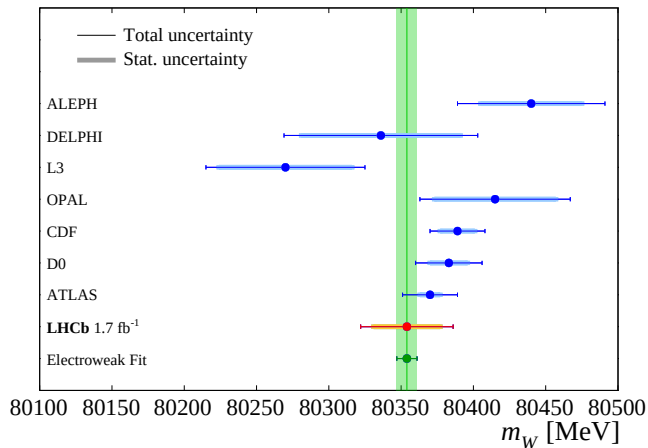
Introduction

- Drell-Yan is an **integral** part of α_S and PDF determination



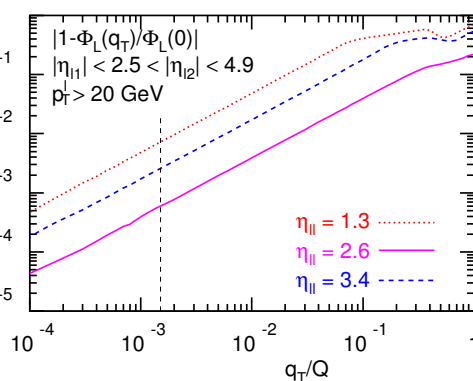
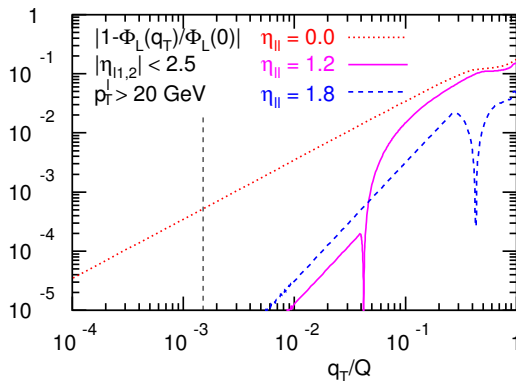
Introduction

- Important in W mass measurements



Previous work

- Linear power corrections in case of cut on lepton $p_{\perp}$ [Ebert et al., 2019.08486]



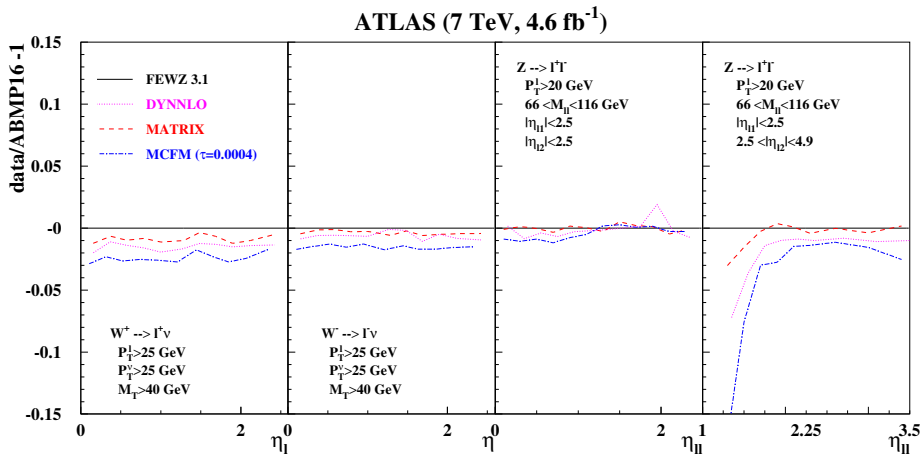
Dashed line: $r_{\text{cut}}^{\text{min}} = 0.15\%$



**UNIVERSITY of
DEBRECEN**

Alekhin, AK, Moch & Trócsányi, 2104.02400

Previous work

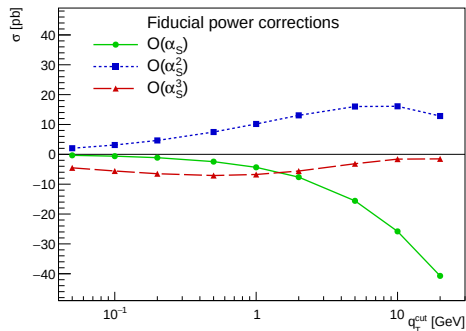


**UNIVERSITY of
DEBRECEN**

Alekhin, AK, Moch & Trócsányi, 2104.02400

Previous work

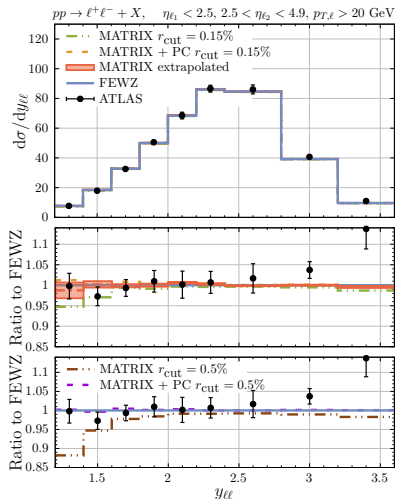
- Observation of large linear PCs ignited further studies:



Camarda et al., 2111.14509



UNIVERSITY of
DEBRECEN

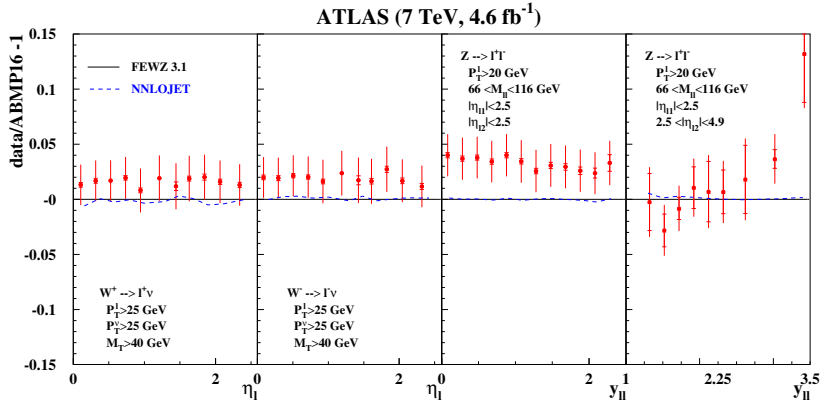


Buonocore et al., 2111.13661

The missing pieces

- In our previous work comparison against NNLOJET and DYTurbo was missing
- Meanwhile linear PCs were introduced to DYTurbo and MATRIX
- FEWZ was the **only** available local subtraction code
- Symmetric cuts can be **problematic** for slicing methods
- How does the perturbative expansion behaves with local subtractions and symmetric cuts?

Comparison between local subtractions

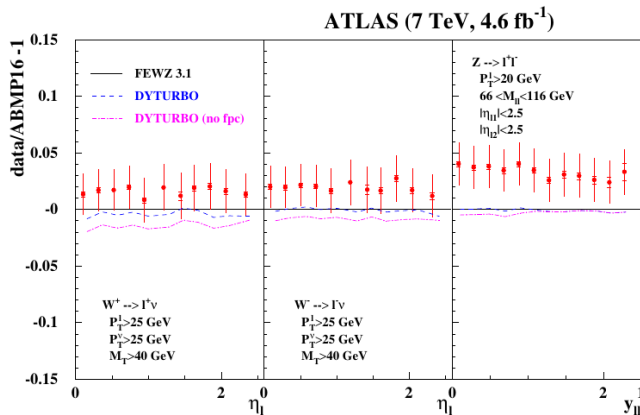


**UNIVERSITY of
DEBRECEN**

- Agreement between local subtractions for W and Z
- They agree even in forward region

Comparison with DYTurbo

Preliminary:

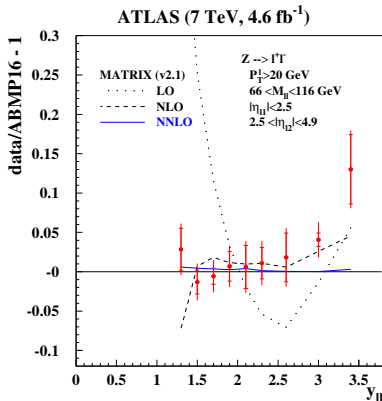


UNIVERSITY of
DEBRECEN

- Agreement with FEWZ if linear PCs are included
- Note: result for forward region is still missing!

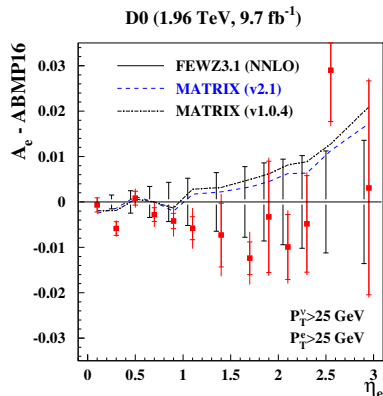
Symmetric cuts

- Symmetric $p_{\perp}$ cuts enhance soft sensitivity [Klasen et al., Harris et al. and Frixione et al.]
- Large logs only partially cancelling
- This challenges slicing methods for these processes
- Including linear PCs help



Symmetric cuts

- There can be observables **tough** for all methods
- ⇒ Electron charge asymmetry (A_e) at TeVatron
- With linear PCs situation improves but even local subtractions have (numerical) challenges
- Observable based on a **difference**



Symmetric cuts

- With local subtractions **region around** symmetric cuts can be analyzed precisely
- **Staggered cuts** are used to mitigate the behavior of symmetric ones:

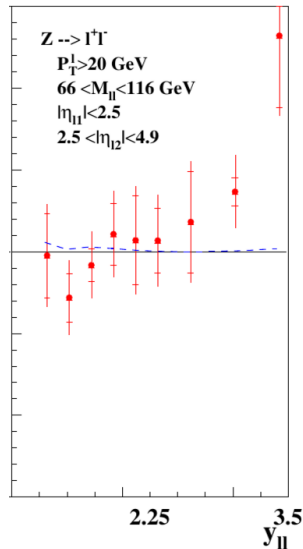
$$p_{\perp}^{\ell_1} \geq p_{\perp, \min} + \Theta(\Delta p_{\perp}) \Delta p_{\perp},$$

$$p_{\perp}^{\ell_2} \geq p_{\perp, \min} + \Theta(-\Delta p_{\perp}) \Delta p_{\perp}$$

- Behavior of perturbative series for $\Delta p_{\perp} \in [-5, 5] \text{ GeV}$

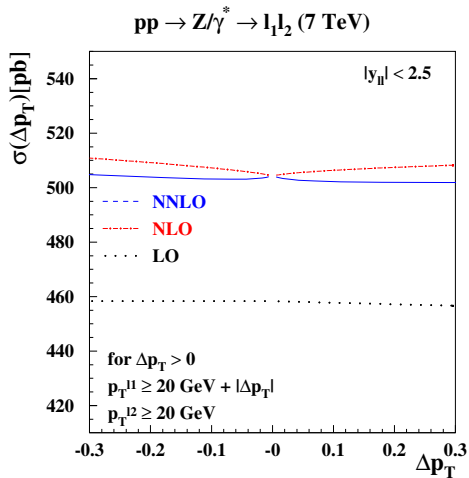
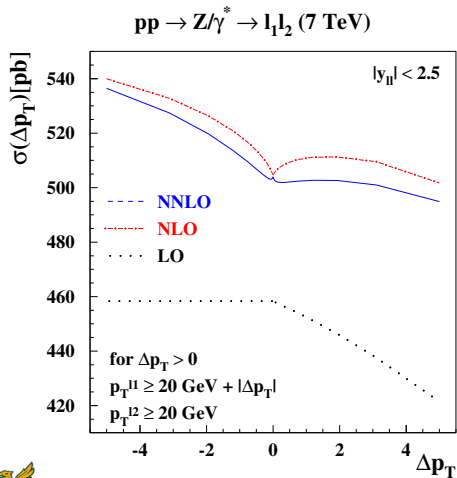


UNIVERSITY of
DEBRECEN



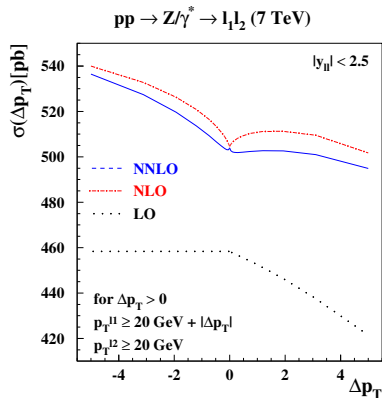
NNLOJET vs. FEWZ

Symmetric cuts



Symmetric cuts

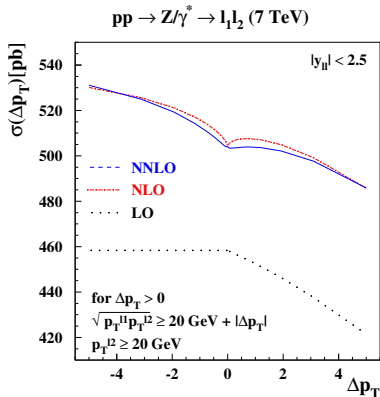
- Symmetric cuts manifest as change of slope at LO
 - Turns into cusp at higher order
 - More terms in perturbative series force it to vanish
- ⇒ Higher order corrections should fill up (partially) the depression



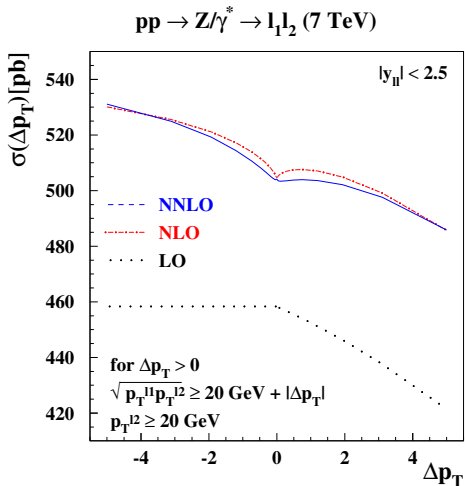
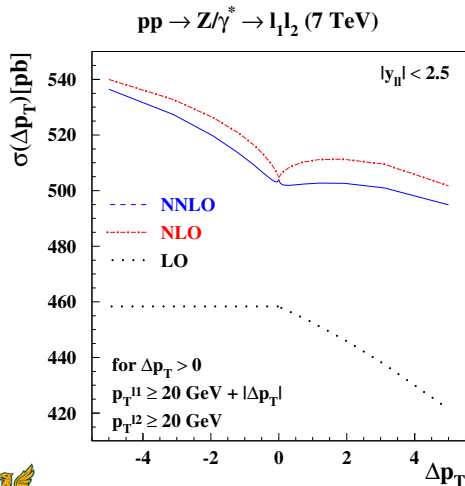
Symmetric cuts

- To change characteristics product cuts were suggested (Salam et al.)

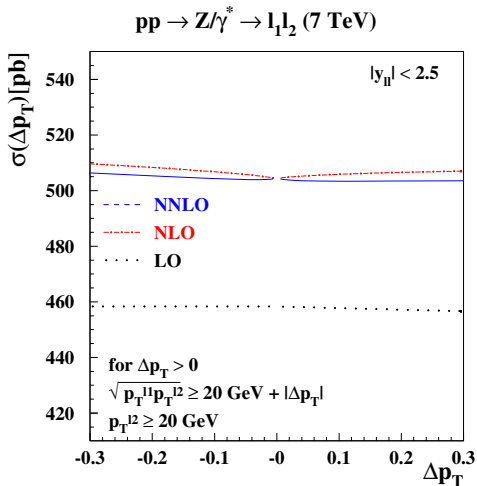
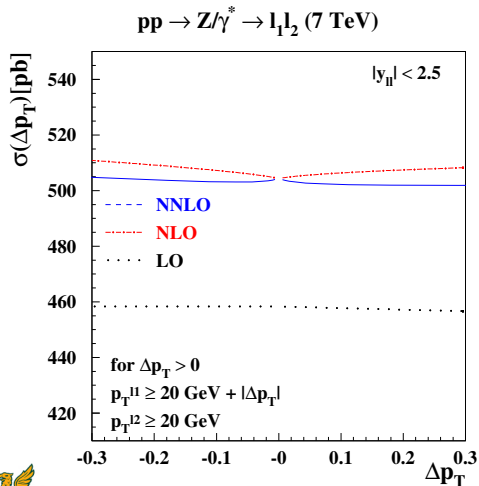
$$\sqrt{p_{\perp}^{\ell_1} p_{\perp}^{\ell_2}} \geq p_{\perp, \min} + \Theta(\Delta p_{\perp}) \Delta p_{\perp},$$
$$p_{\perp}^{\ell_2} \geq p_{\perp, \min} + \Theta(-\Delta p_{\perp}) \Delta p_{\perp}$$



Comparison of cutting schemes

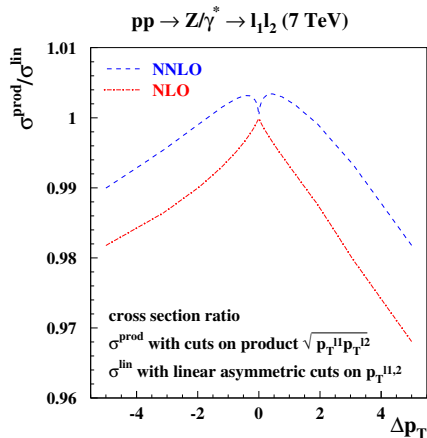
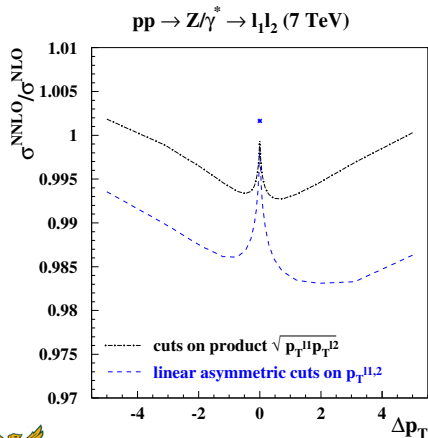


Comparison of cutting schemes



Comparison of cutting schemes

K factor and Ratios of cross sections:



UNIVERSITY of
DEBRECEN

Comparison of cutting schemes

- With product cuts the characteristics **improves**
 - Improvement by factor of 2 – 3
 - Behavior is **not** removed
- ⇒ Improvement is **not significant** enough to worth redo the experimental analysis



Summary

- Several methods are available for Drell-Yan processes for NNLO QCD predictions
 - Included linear power corrections enhanced the applicability of slicing methods for DY
 - For the first time high-accuracy comparison is done between local subtractions (FEWZ and NNLOJET) for DY
- ⇒ Found complete agreement
- Symmetric cuts spoil the perturbative expansion and needs higher orders
 - Product cuts are not a solution to the problem of symmetric cuts



Thank you for your attention!