Update on resummation for γ, W- and Z-boson production at large p_T

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Introduction: $W/Z/\gamma$ production

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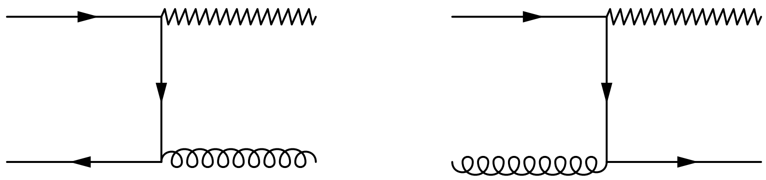

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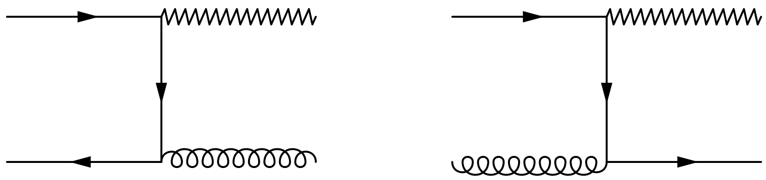

Current work toward obtaining N^{2}LO QCD corrections to the p_T spectrum

NLO is well known, and implemented in numerical integration programs: FEWZ (Melnikov, Petriello'06; Gavin, Li, Petriello, Quackenbush'10), DYNNLO (Catani, Cieri, Ferrera, de Florian, Grazzini'09), QT (Gonsalves), MCFM (Campbell, Ellis, Williams)

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$p_T = p_T^{\rm max}$ limit not relevant phenomenologically: tiny cross section in this region; but threshold-enhanced terms expected to be important away from it: *dynamical threshold enhancement* (effect of rapid falloff of PDFs at large x)

Becher, Neubert, Xu'07; Catani, Mangano, Nason'98; Appell, Sterman, Mackenzie'88

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Hadronic cross section is given by convolution with PDFs

$$d\sigma \propto \sum_{ab} \int dx_1 dx_2 f_a(x_1) f_b(x_2) \left[d\hat{\sigma}_{ab} \right]$$

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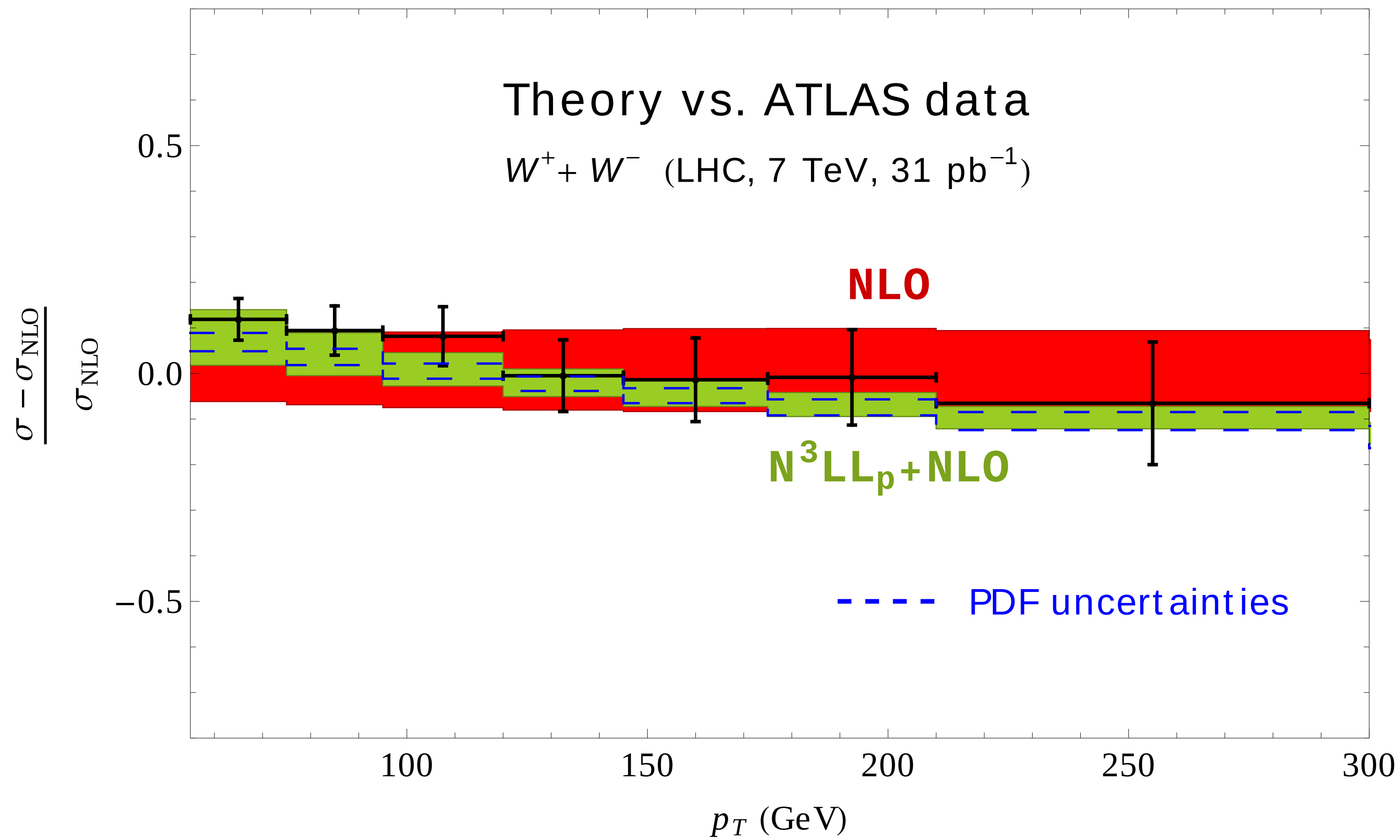

(arXiv:1206.6115)

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(resummation using traditional approach has now been computed at N^2LL Kidonakis, Gonsalves'12)

New ingredients:

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- (Public) code for N^3LL resummation

  Lorentzen

(Padé approximation $\Gamma_4 = \Gamma_3/(\Gamma_2)^2$ is always used for the four-loop cusp anomalous dimension)

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ew corrections cannot be omitted to have precise prediction for $p_T \gg M_V$

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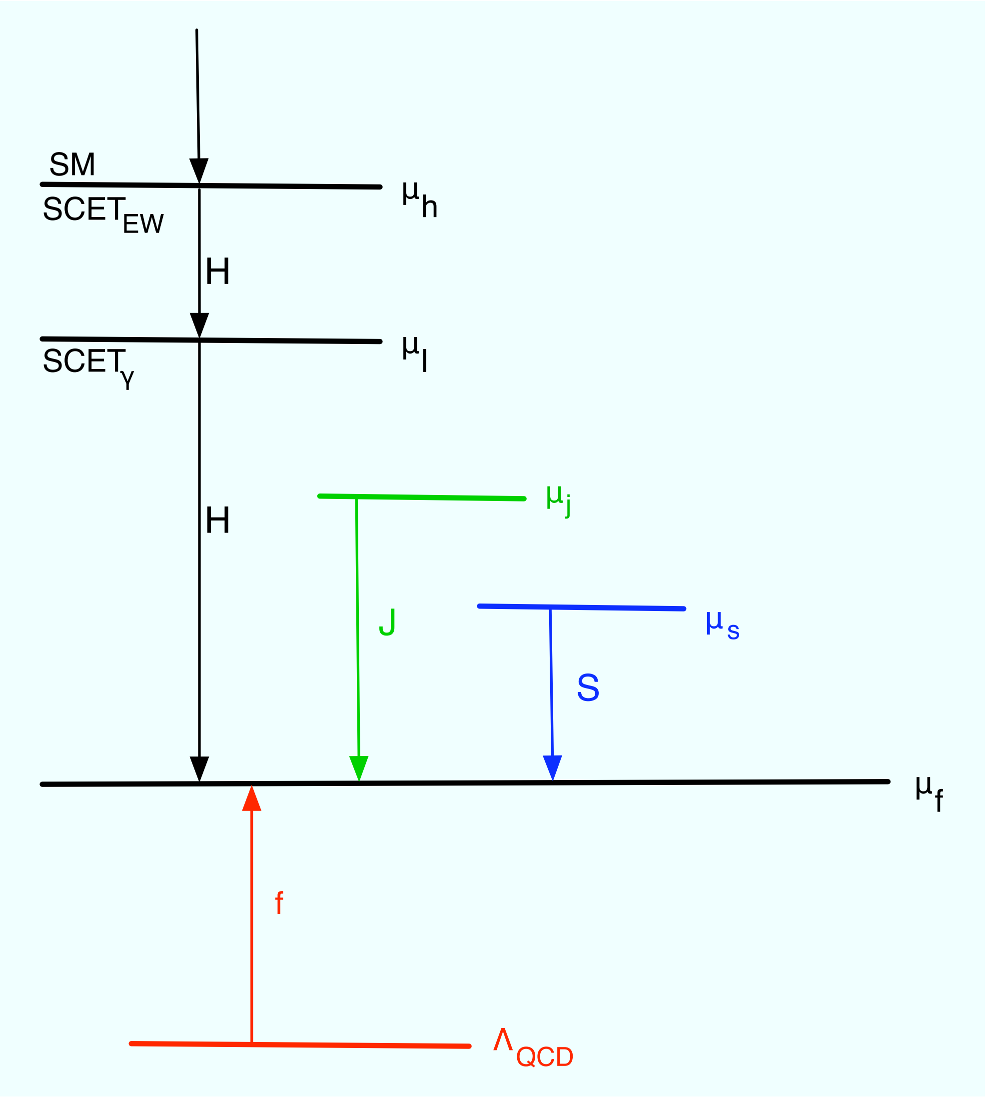
W, Z bosons in SCET$_\gamma$ in terms of (boosted) HQET-like fields.
J and S are defined in SCET$_\gamma$ and contain only photons and gluons


SM
SCET_EW
μ_h
H
SCET_γ
μ_l
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μ_j
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S
μ_f
f
Λ_QCD

Counting:

$$\alpha_s \sim a \quad ; \quad L := \log \frac{p_T^2}{M_V^2} \sim \frac{1}{a} \quad ; \quad \alpha_i \sim a^2$$

$(\alpha_i = \alpha_1, \alpha_2, \alpha_{\rm em})$

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$$\log \mathcal{M} \sim \left(\begin{array}{cccc}
\begin{array}{c}\alpha_s L^2 + \alpha_i L^2 \\ \sim \frac{1}{a} + 1\end{array} & \begin{array}{c}\alpha_s L + \alpha_i L \\ \sim 1 + a\end{array} & \begin{array}{c}\alpha_s + \alpha_i \\ \sim a + a^2\end{array} & \\
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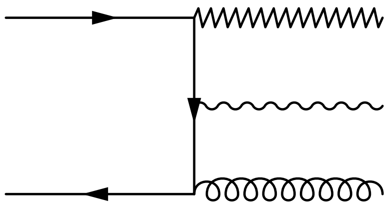
We will consider also the rest of the terms, which involve at least one α_i

Some care is needed to define the observable, since we can have both photon and gluon real radiation.



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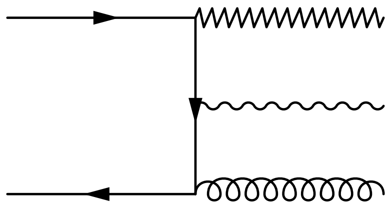

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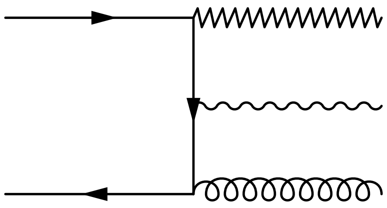

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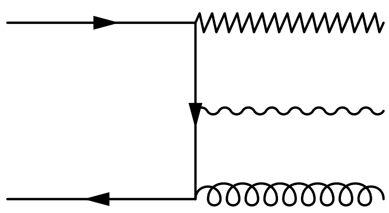

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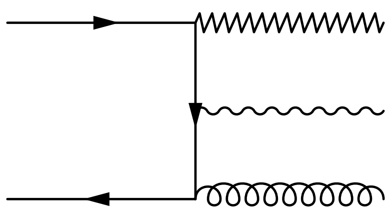

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(the two different approaches only induce small numerical differences on the size of the corrections)

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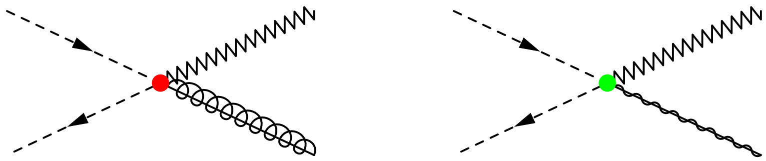

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Can consider them separately at leading power in SCET
-in practice we will just ignore operator (ii)-

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$$\mu_h = \frac{13 p_T + 2 M_V}{12} - \frac{p_T^2}{\sqrt{s}} \quad ; \quad \mu_j = \frac{7 p_T + 2 M_V}{12} \left(1 - 2 \frac{p_T}{\sqrt{s}}\right) \quad ; \quad \mu_s = \frac{\mu_j^2}{\mu_h}$$

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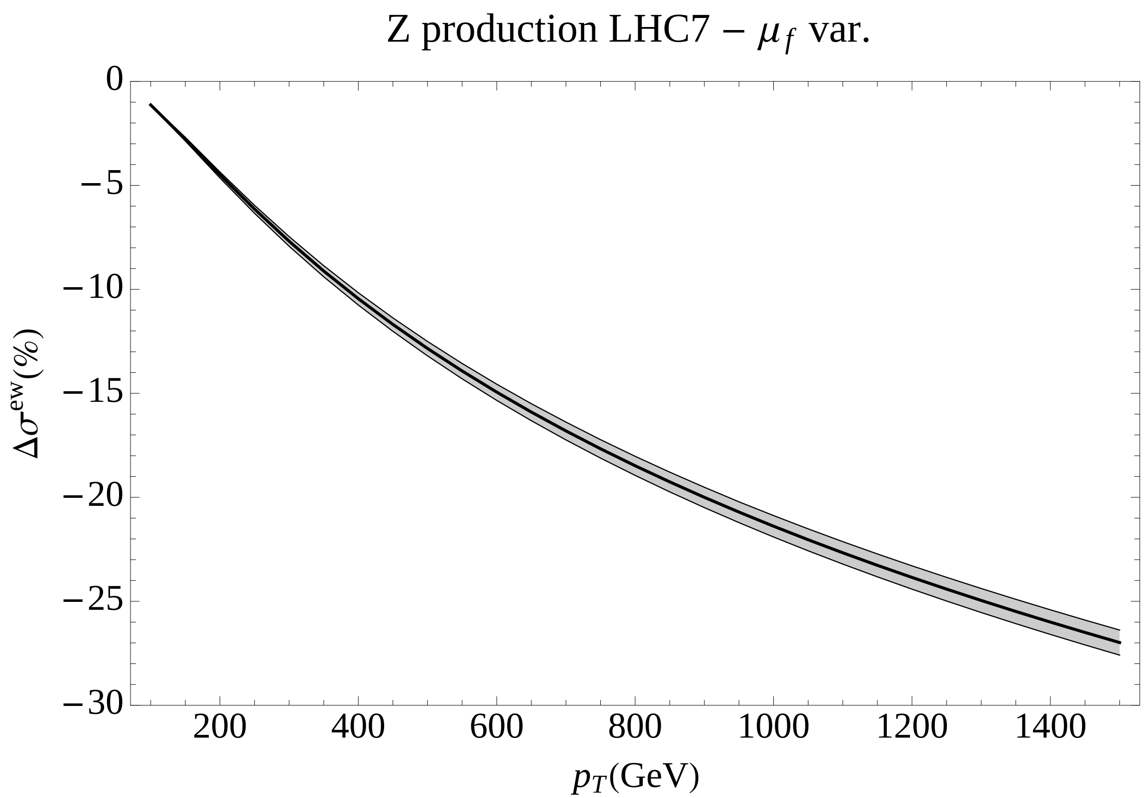
- main part of the ew corrections contained in the hard function
- ew corrections to jet and soft functions are small $\rightarrow$ Consider only leading ew terms in J and S, then ew and strong corrections do not mix. Can set $\mu_j = M_V$ just in ew part

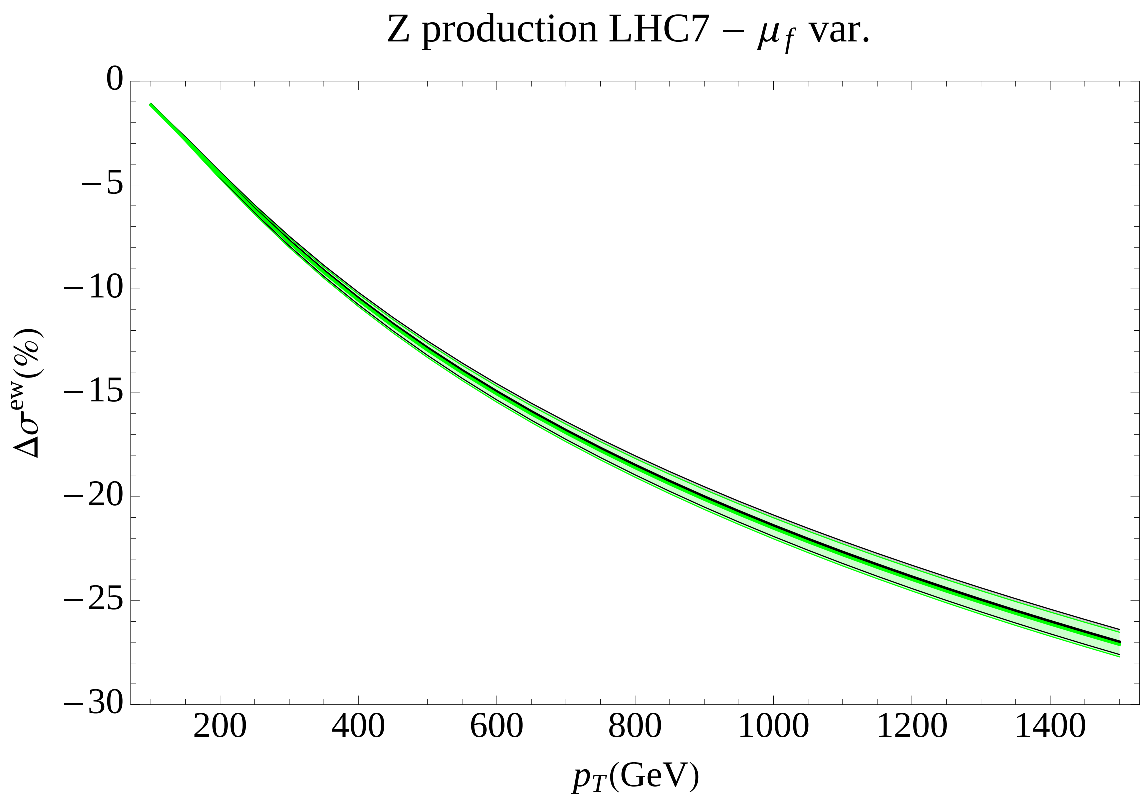


$$\Delta\sigma^{ew} := \frac{\sigma_{ew+QCD} - \sigma_{QCD}}{\sigma_{QCD}}$$

QCD at NLL QCD at N^{2}LL

(scales varied by factor of 2; terms up to order a in the exponent for ew part)

Results



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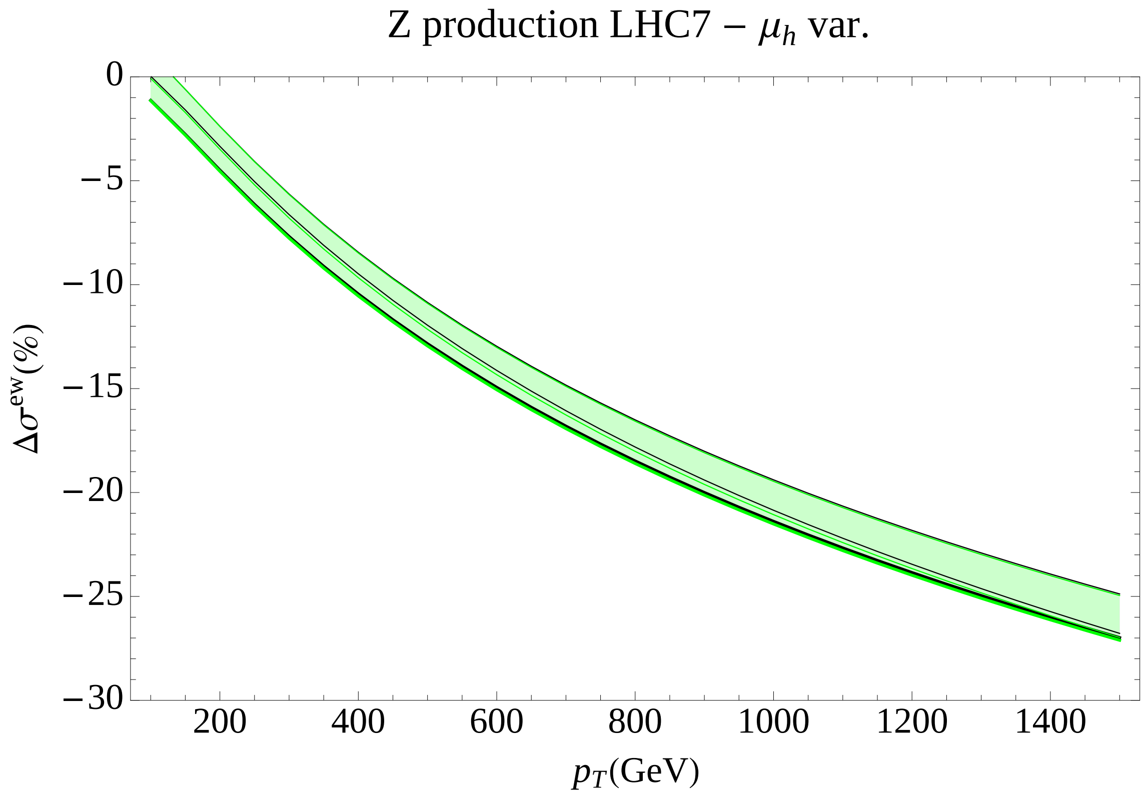

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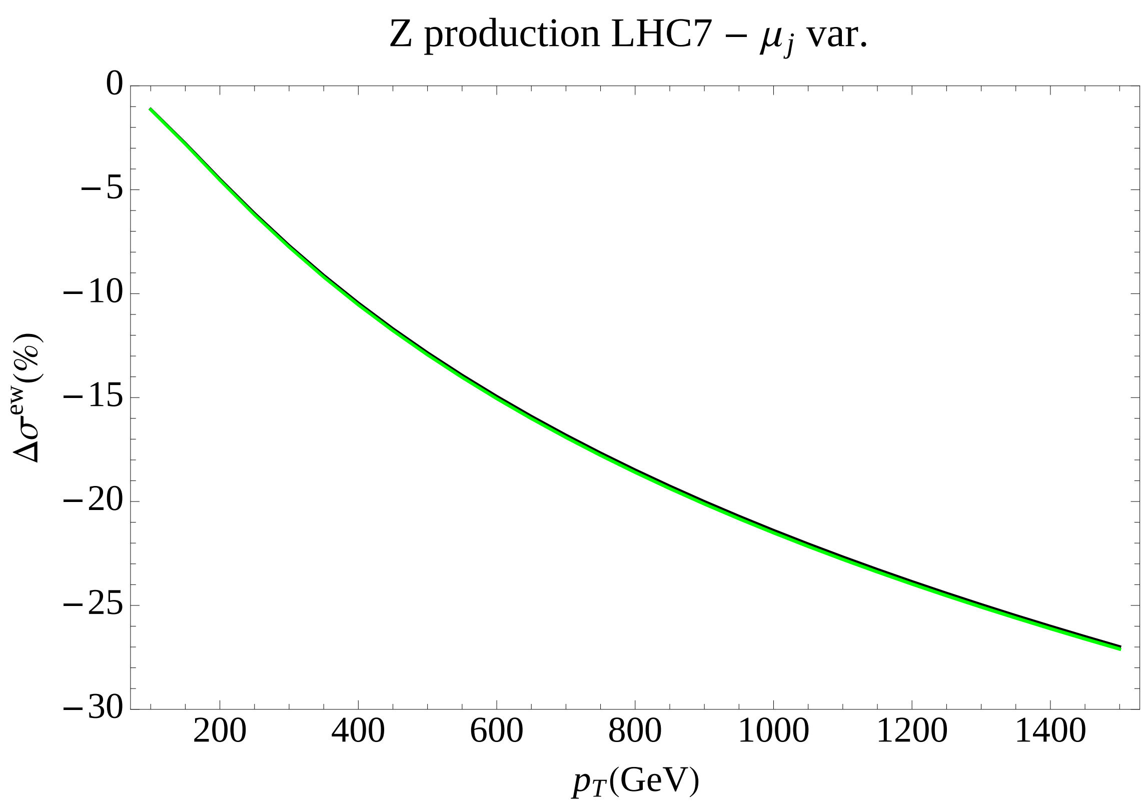

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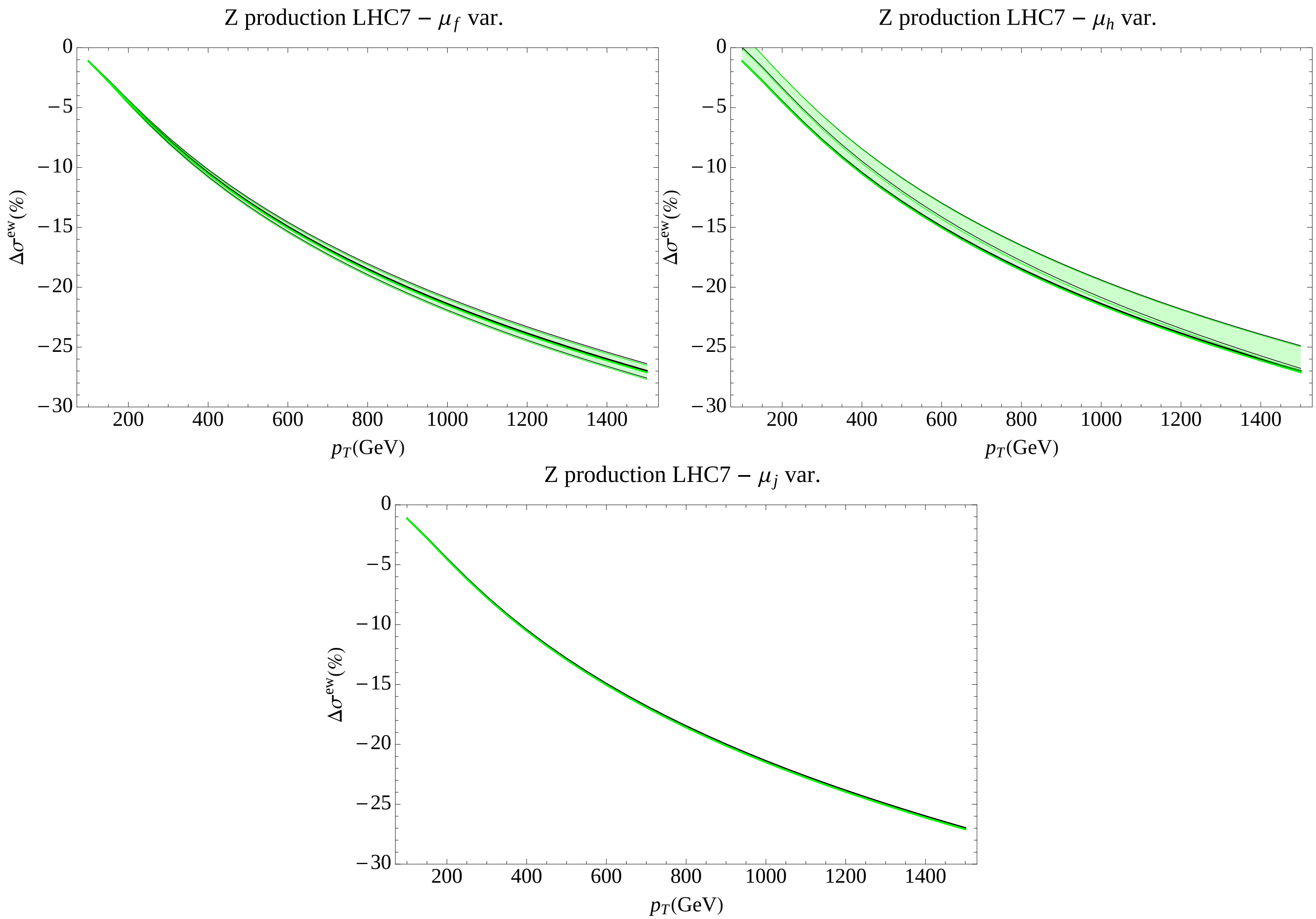
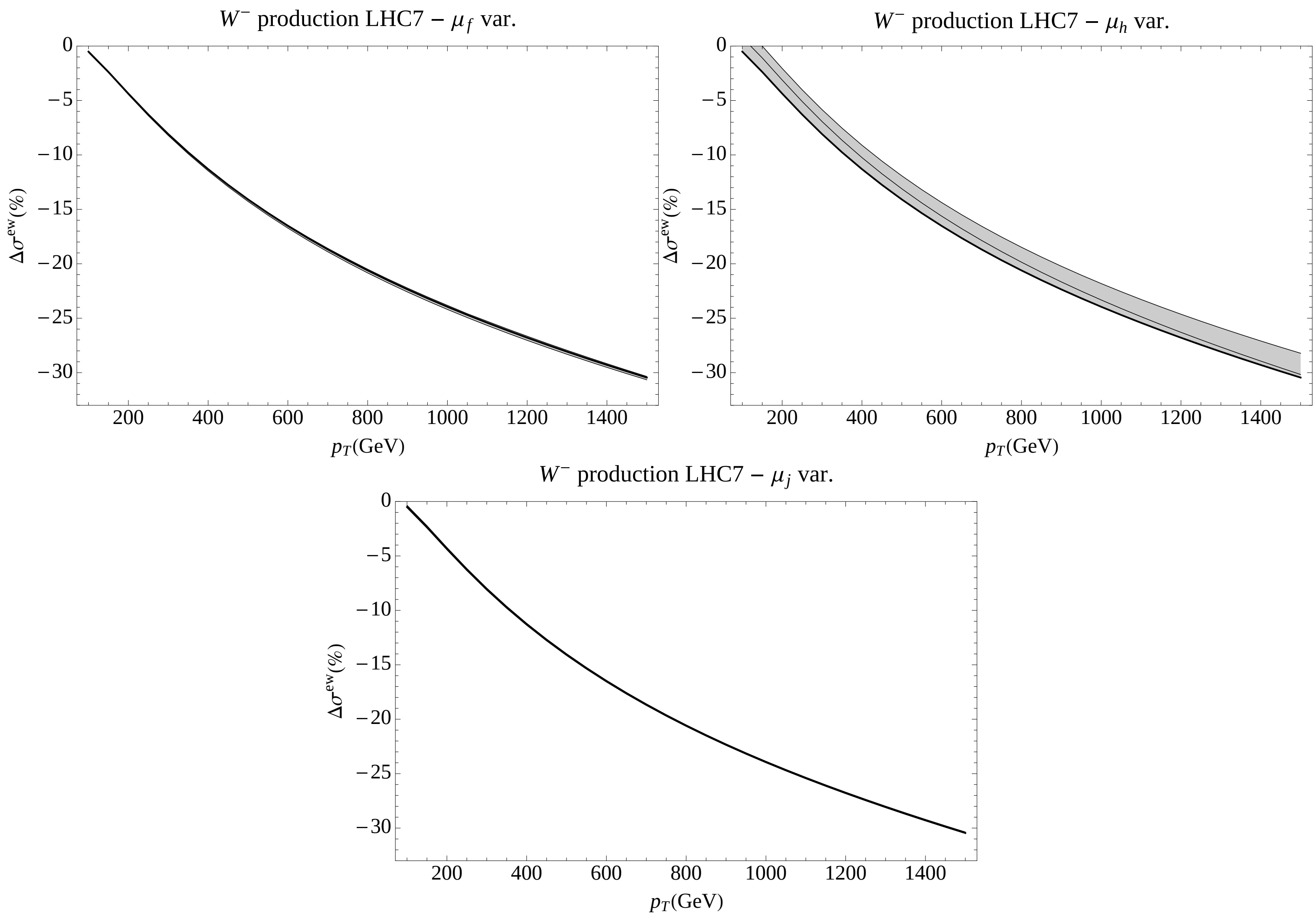


Results

W production



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- Photon effects on the PDFs not included in the numerical evaluation. Some PDF sets have QED effects, but lower orders for QCD part

Complete N^{3}LL: two-loop hard function

Becher, Bell, Lorentzen, Marti

Two-loop QCD computations needed to extract the hard function H for N^{3}LL accuracy are known

Garland, Gehrmann, Glover, Koukoutsakis, Remiddi'02; Gehrmann, Tancredi'11

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Finite amplitudes: UV renormalized. IR divergences subtracted according to Catani's formula.

Need to add IR div. back and subtract in $\overline{\mathrm{MS}}$ (as needed for H in SCET factorization formula)

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New C++ code to compute the p_T spectrum up to N^{3}LL accuracy.

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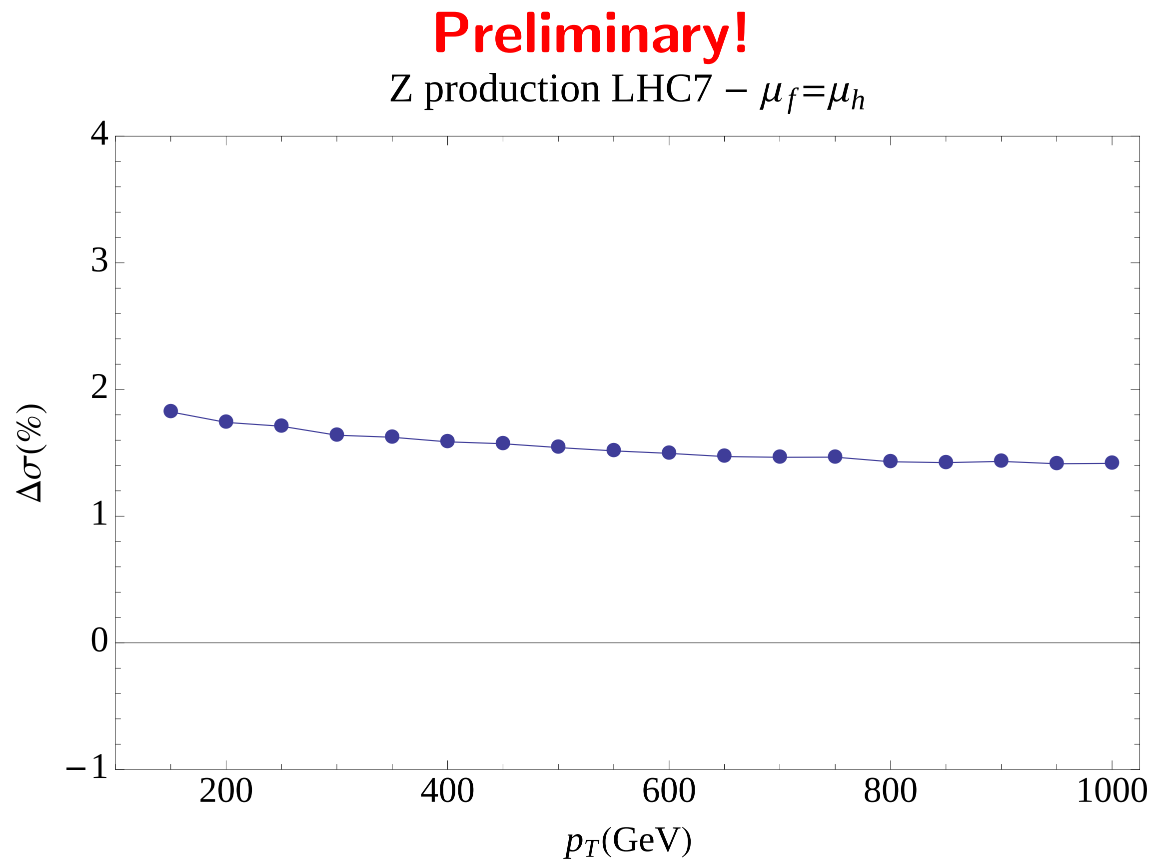
Fully documented, easily configurable input parameters, to be made publicly available in the future

Impact of the 2-loop constant term



$\Delta\sigma$: difference between N^{3}LL and N^{3}LL with 2-loop constant set to 0

($gg \to gV$ channel not implemented yet)

Conclusions and outlook

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- Electroweak-Sudakov effects included
- Complete phenomenological analysis, at N^3LL and with ew effects, and comparisons with LHC data will be presented in the future
  - Higgs production at large p_T will also be presented
    Becher, Schwarz