Electroweak corrections to gauge boson production at large transverse momentum

Anna Kulesza

work in collaboration with J. H. Kühn, S. Pozzorini and M. Schulze

Phys. Lett. B 609 (2005) 277

Nucl. Phys. B727 (2005) 368

JHEP 0603 (2006) 059

hep-ph/0703283

DESY, 22.05.2007

Overview

- Introduction: why are the electroweak corrections important?
- Theoretical status
- $\mathcal{O}(\alpha)$ corrections to gauge boson production
  - What is calculated?
  - Results
- Impact of the EW corrections on transverse momentum distributions at the LHC

Why are electroweak corrections important?

Simple expectation

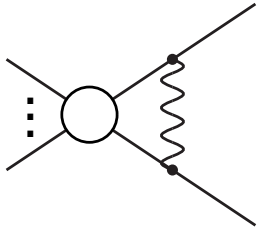
$$\mathcal{O}(\alpha) \quad \sim \quad \mathcal{O}(\alpha_s^2)$$

Why are electroweak corrections important?

Simple expectation

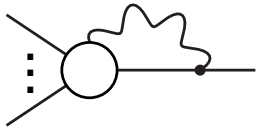
$$\mathcal{O}(\alpha) \quad \sim \quad \mathcal{O}(\alpha_s^2)$$

However



$\longrightarrow$ soft-collinear double logarithms: $\alpha \log^2 \left(\frac{\hat{s}}{M^2}\right)$ LL

EW Sudakov logarithms



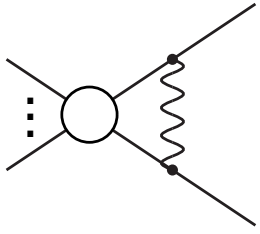
$\longrightarrow$ collinear single logarithms: $\alpha \log \left(\frac{\hat{s}}{M^2}\right)$ NLL

Why are electroweak corrections important?

Simple expectation

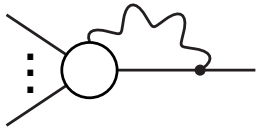
$$\mathcal{O}(\alpha) \quad \sim \quad \mathcal{O}(\alpha_s^2)$$

However



$\longrightarrow$ soft-collinear double logarithms: $\alpha \log^2 \left(\frac{\hat{s}}{M^2}\right)$ LL

EW Sudakov logarithms



$\longrightarrow$ collinear single logarithms: $\alpha \log \left(\frac{\hat{s}}{M^2}\right)$ NLL

$\hat{s} \gg M_W^2$ (accessible at the LHC!)

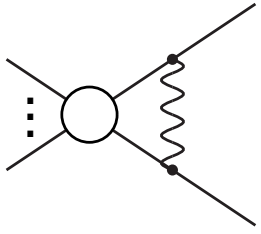
- Sudakov logs dominant

Why are electroweak corrections important?

Simple expectation

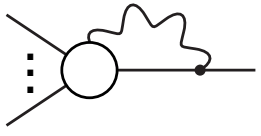
$$\mathcal{O}(\alpha) \quad \sim \quad \mathcal{O}(\alpha_s^2)$$

However



$\rightarrow$ soft-collinear double logarithms: $\alpha \log^2 \left(\frac{\hat{s}}{M^2}\right)$ LL

EW Sudakov logarithms



$\rightarrow$ collinear single logarithms: $\alpha \log \left(\frac{\hat{s}}{M^2}\right)$ NLL

$\hat{s} \gg M_W^2$ (accessible at the LHC!)

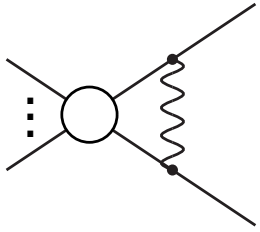
- Sudakov logs dominant
- Typically at $\hat{s} \sim 1$ TeV,
  $\mathcal{O}(10\%) \rightarrow$ NLO EW $\sim$ NLO QCD

Why are electroweak corrections important?

Simple expectation

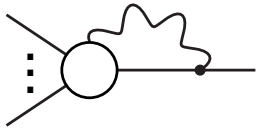
$$\mathcal{O}(\alpha) \quad \sim \quad \mathcal{O}(\alpha_s^2)$$

However



$\rightarrow$ soft-collinear double logarithms: $\alpha \log^2 \left(\frac{\hat{s}}{M^2}\right)$ LL

EW Sudakov logarithms



$\rightarrow$ collinear single logarithms: $\alpha \log \left(\frac{\hat{s}}{M^2}\right)$ NLL

$\hat{s} \gg M_W^2$ (accessible at the LHC!)

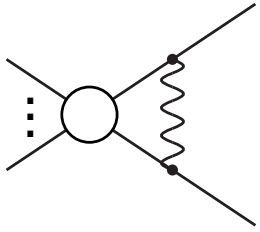
- Sudakov logs dominant
- Typically at $\hat{s} \sim 1$ TeV,
  $\mathcal{O}(10\%) \rightarrow$ NLO EW $\sim$ NLO QCD
- Important for BSM searches, large-x
  PDFs, ...

Why are electroweak corrections important?

Simple expectation

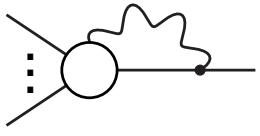
$$\mathcal{O}(\alpha) \quad \sim \quad \mathcal{O}(\alpha_s^2)$$

However



$\rightarrow$ soft-collinear double logarithms: $\alpha \log^2\left(\frac{\hat{s}}{M^2}\right)$ LL

EW Sudakov logarithms



$\rightarrow$ collinear single logarithms: $\alpha \log\left(\frac{\hat{s}}{M^2}\right)$ NLL

$\hat{s} \gg M_W^2$ (accessible at the LHC!)

- Sudakov logs dominant
- Typically at $\hat{s} \sim 1$ TeV, $\mathcal{O}(10\%) \rightarrow$ NLO EW $\sim$ NLO QCD
- Important for BSM searches, large-x PDFs, ...

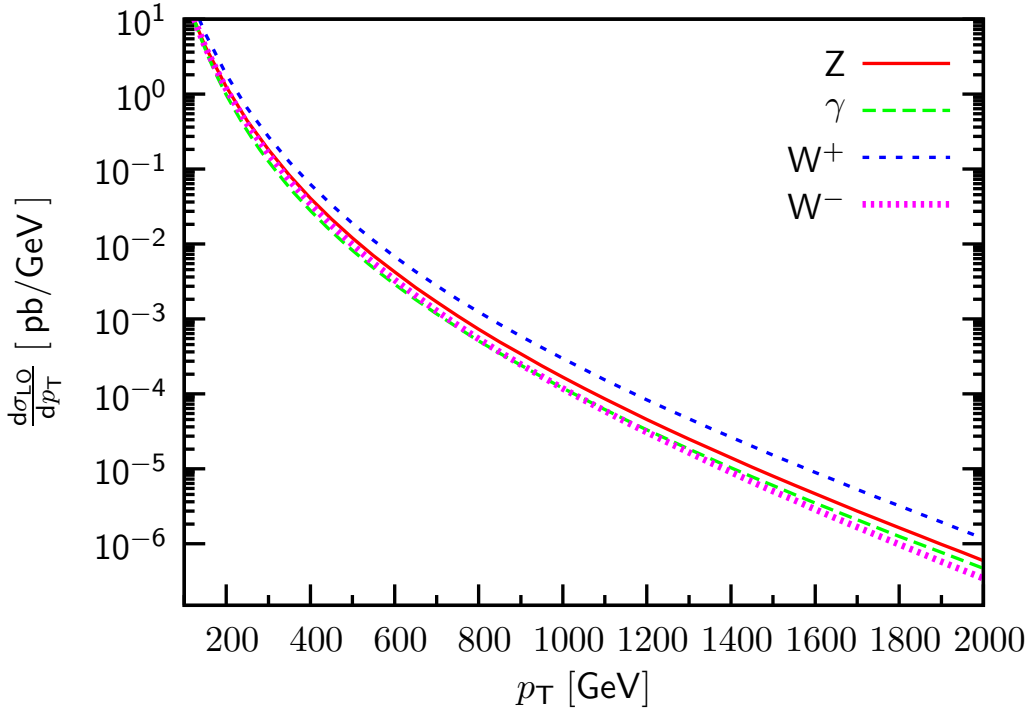
$\hat{s} \sim M_W^2$ (resonant production)

- Sudakov logs negligible
- $\mathcal{O}(1\%) \rightarrow$ NLO EW $\sim$ NNLO QCD
- Important for precision physics (M_W, M_Z, ...)

Gauge boson production at large p_{T}

- $\hat{s} \gg M_W^2$ region probed in e.g. transverse momentum (p_{T}) distributions at large values of p_{T}

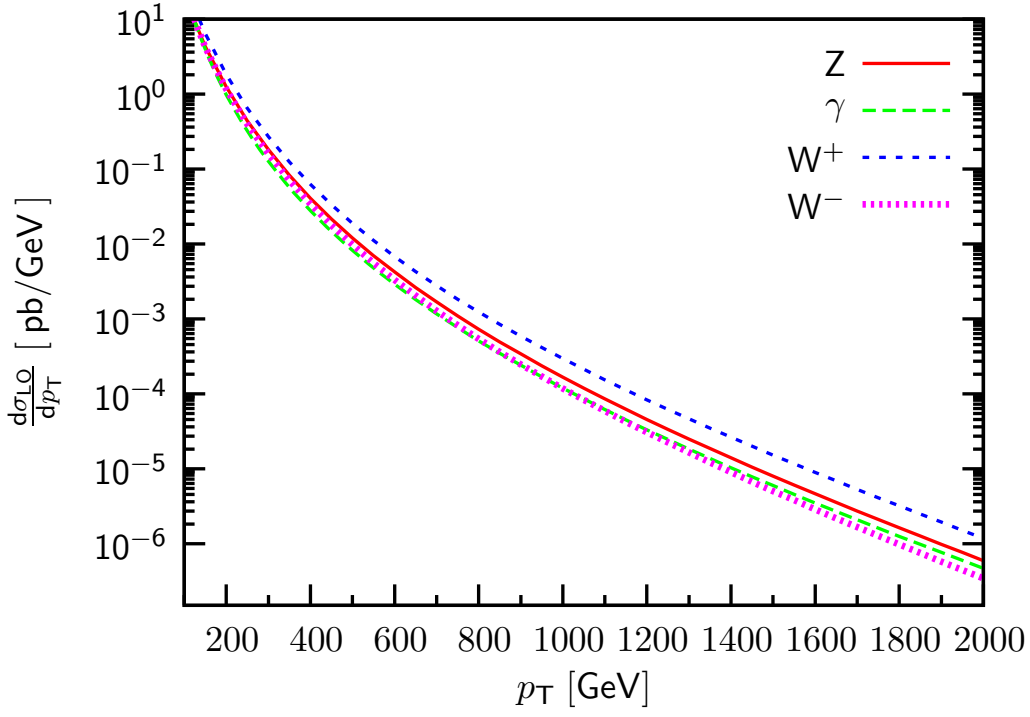
(M_T, E_T, ... distributions)



Gauge boson production at large p_{T}

- $\hat{s} \gg M_W^2$ region probed in e.g. transverse momentum (p_{T}) distributions at large values of p_{T}

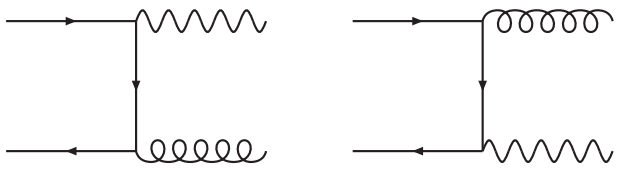
(M_T, E_T, ... distributions)



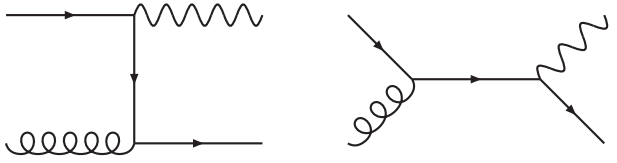
- Large cross sections at LO $\Rightarrow$ good statistics; reducing theoretical error requires calculation of radiative corrections

Gauge boson production at large p_{T}

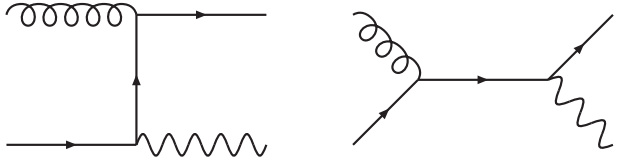
At large p_{T}, LO subprocesses of $\mathcal{O}(\alpha\alpha_s)$



$$\left|\mathcal{M}^{q_i q_j \to V g}\right|^2$$



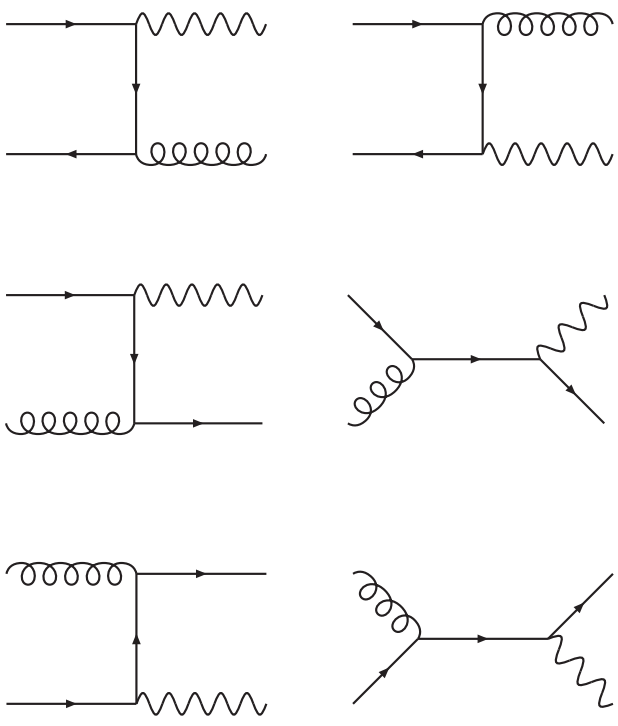
$$\left|\mathcal{M}^{q_i g \to V q_j}\right|^2$$



$$\left|\mathcal{M}^{g q_j \to V q_i}\right|^2$$

Gauge boson production at large p_{T}

At large p_{T}, LO subprocesses of $\mathcal{O}(\alpha\alpha_s)$



$$\left|\mathcal{M}^{q_i q_j \to V g}\right|^2$$

crossing symmetries

$$\left|\mathcal{M}^{q_i g \to V q_j}\right|^2$$

$$\left|\mathcal{M}^{g q_j \to V q_i}\right|^2$$

also true at higher orders

Gauge boson production at large p_{T}

Theoretical status of higher order corrections

- $\mathcal{O}(\alpha_{\mathrm{S}})$ QCD corrections [*Ellis, Martinelli, Petronzio'81*][*Arnold, Reno'89*][*Arnold, Ellis, Reno'89*] [*Gonsalves, Pawłowski, Wai'89*][*Giele, Glover, Kosower'93*][*Melnikov, Petriello'06*]
  - Implementations exist (*DYRAD* [*Giele, Glover, Kosower'93*], *MCFM* [*Campbell, Ellis'02*], *FEWZ* [*Melnikov, Petriello'06*], . . .)

Gauge boson production at large p_{T}

Theoretical status of higher order corrections

- $\mathcal{O}(\alpha_{\mathrm{S}})$ QCD corrections [*Ellis, Martinelli, Petronzio'81*][*Arnold, Reno'89*][*Arnold, Ellis, Reno'89*] [*Gonsalves, Pawłowski, Wai'89*][*Giele, Glover, Kosower'93*][*Melnikov, Petriello'06*]
  - Implementations exist (*DYRAD* [*Giele, Glover, Kosower'93*], *MCFM* [*Campbell, Ellis'02*], *FEWZ* [*Melnikov, Petriello'06*], . . .)
  - Note: A MC with matrix element for $pp \to V(\to \dots) + X$ gives a good description only at low p_{T} of V (hard gluon radiation missing)

Gauge boson production at large p_{T}

Theoretical status of higher order corrections

- $\mathcal{O}(\alpha_{\mathrm{S}})$ QCD corrections [*Ellis, Martinelli, Petronzio'81*][*Arnold, Reno'89*][*Arnold, Ellis, Reno'89*] [*Gonsalves, Pawłowski, Wai'89*][*Giele, Glover, Kosower'93*][*Melnikov, Petriello'06*]
  - Implementations exist (*DYRAD* [*Giele, Glover, Kosower'93*], *MCFM* [*Campbell, Ellis'02*], *FEWZ* [*Melnikov, Petriello'06*], . . .)
  - Note: A MC with matrix element for $pp \to V(\to \dots) + X$ gives a good description only at low p_{T} of V (hard gluon radiation missing)
- $\mathcal{O}(\alpha)$ EW corrections to LO $\mathcal{O}(\alpha\alpha_{\mathrm{S}})$ process (no QCD corrections)
  - γ/Z production [*Maina,Moretti, Ross'04*](only numerical results)
  - $\gamma/Z/W^{\pm}$ production [*Kühn, A.K., Pozzorini,Schulze'05-07*](analytic results and numerical predictions)

Gauge boson production at large p_{T}

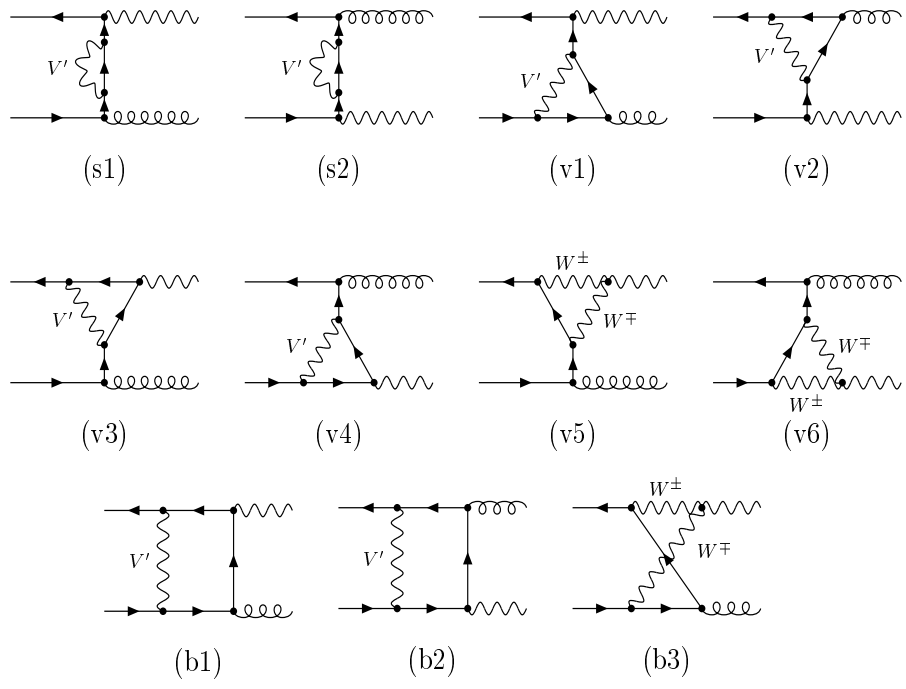
Theoretical status of higher order corrections

- $\mathcal{O}(\alpha_{\mathrm{S}})$ QCD corrections [*Ellis, Martinelli, Petronzio'81*][*Arnold, Reno'89*][*Arnold, Ellis, Reno'89*] [*Gonsalves, Pawłowski, Wai'89*][*Giele, Glover, Kosower'93*][*Melnikov, Petriello'06*]
  - Implementations exist (*DYRAD* [*Giele, Glover, Kosower'93*], *MCFM* [*Campbell, Ellis'02*], *FEWZ* [*Melnikov, Petriello'06*], . . .)
  - Note: A MC with matrix element for $pp \to V(\to \dots) + X$ gives a good description only at low p_{T} of V (hard gluon radiation missing)
- $\mathcal{O}(\alpha)$ EW corrections to LO $\mathcal{O}(\alpha\alpha_{\mathrm{S}})$ process (no QCD corrections)
  - γ/Z production [*Maina,Moretti, Ross'04*](only numerical results)
  - $\gamma/Z/W^{\pm}$ production [*Kühn, A.K., Pozzorini,Schulze'05-07*](analytic results and numerical predictions)
  - Note: EW corrections to $pp \to (V \to \dots)$ known (p_{T} spectra od V decay products) $\to$ implementations (*DK* [*Dittmaier, Krämer,02*], *WGRAD2* [*Baur, Wackeroth'04*], *SANC* [*Arbuzov et al.'06*], *HORACE* [*Carloni Calame et al.'06*])
  - Recently NLO QCD + (NLO EW)$|_{\mathrm{PARTON\ SHOWER}}$ [*HORACE*] $\to$ high p_{T} distributions not reliable

$\mathcal{O}(\alpha)$ corrections to $q_i q_j \to V g$

[Kühn, A.K., Pozzorini, Schulze'05-07]

Z/γ production, $V' = W, Z$

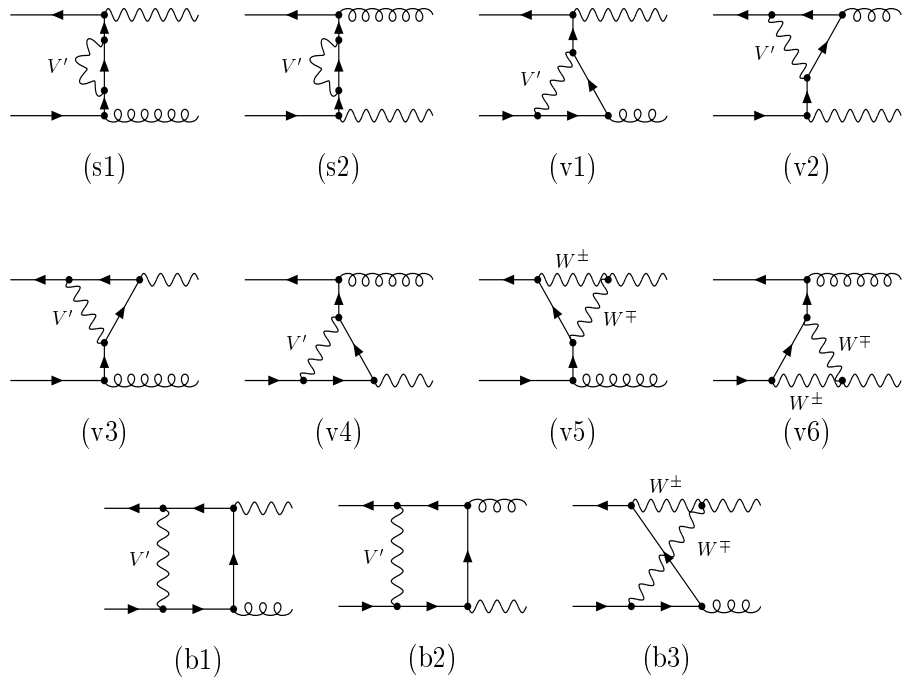


- Loop corrections: IR-finite
- Real corrections: W, Z emission assumed possible to be observed $\to$ not calculated

$\mathcal{O}(\alpha)$ corrections to $q_i q_j \to V g$

[*Kühn, A.K., Pozzorini, Schulze'05-07*]

$W^\pm$ production, $V' = W, Z, \gamma$

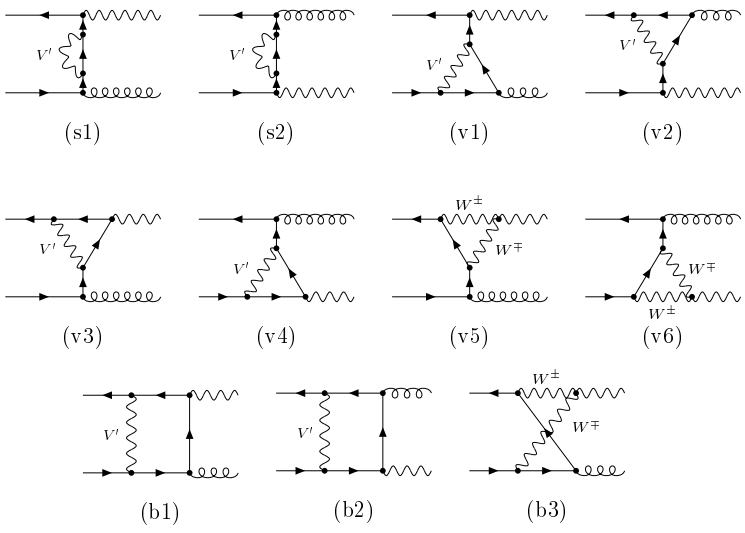


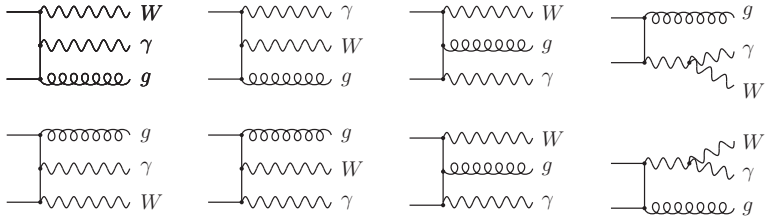
- Loop corrections: IR-singular (photons)

$\mathcal{O}(\alpha)$ corrections to $q_i q_j \to V g$

[*Kühn, A.K., Pozzorini, Schulze'05-07*]

$W^\pm$ production, $V' = W, Z, \gamma$





- Loop corrections: IR-singular (photons)
- Real corrections: W, Z emission assumed possible to be observed $\to$ not calculated
  photon emission IR-singular $\to$ calculated

Results for $\mathcal{O}(\alpha)$ corrections to $q_i q_j \to V g$

[*Kühn, A.K., Pozzorini, Schulze'05-07*]

- Exact results for NLO weak corrections to Z/γ and EW corrections to $W^{\pm}$ production

  $\to$ relatively compact analytic formulae for $\overline{\sum}|\mathcal{M}^{q_i q_j}|^2$

Results for $\mathcal{O}(\alpha)$ corrections to $q_i q_j \to V g$

[*Kühn, A.K., Pozzorini, Schulze'05-07*]

- Exact results for NLO weak corrections to Z/γ and EW corrections to $W^{\pm}$ production

  $\to$ relatively compact analytic formulae for $\overline{\sum}|\mathcal{M}^{q_i q_j}|^2$

- NNLL approximation: high energy limit of the NLO result for $\overline{\sum}|\mathcal{M}^{q_i q_j}|^2$

  $M_W^2/\hat{s} \to 0$ ($\hat{t}/\hat{s}$, $\hat{u}/\hat{s}$ constant)

  terms with $\alpha \ln^2(\frac{\hat{s}}{M_W^2})$, $\alpha \ln(\frac{\hat{s}}{M_W^2})$ and constants

  LL NLL NNLL

  $\to$ extremely compact analytic formulae for NNLL approximation of $\overline{\sum}|\mathcal{M}^{q_i q_j}|^2$

Results for $\mathcal{O}(\alpha)$ corrections to $q_i q_j \to V g$

[*Kühn, A.K., Pozzorini, Schulze'05-07*]

- Exact results for NLO weak corrections to Z/γ and EW corrections to $W^{\pm}$ production

  $\to$ relatively compact analytic formulae for $\overline{\sum}|\mathcal{M}^{q_i q_j}|^2$

- NNLL approximation: high energy limit of the NLO result for $\overline{\sum}|\mathcal{M}^{q_i q_j}|^2$

  $M_W^2/\hat{s} \to 0$ ($\hat{t}/\hat{s}$, $\hat{u}/\hat{s}$ constant)

  terms with $\alpha \ln^2(\frac{\hat{s}}{M_W^2})$, $\alpha \ln(\frac{\hat{s}}{M_W^2})$ and constants

  LL NLL NNLL

  $\to$ extremely compact analytic formulae for NNLL approximation of $\overline{\sum}|\mathcal{M}^{q_i q_j}|^2$

- Dominant (NLL) part of two-loop (NNLO) EW correction

  Exponentiated universal one-loop result [*Denner, Melles, Pozzorini'03*] + general resummation formula [*Melles'02,'03*] $\to$ expansion to $\mathcal{O}(\alpha^2)$

Results for $\mathcal{O}(\alpha)$ corrections to $q_i q_j \to V g$

[*Kühn, A.K., Pozzorini, Schulze'05-07*]

- Exact results for NLO weak corrections to Z/γ and EW corrections to $W^{\pm}$ production

  $\to$ relatively compact analytic formulae for $\overline{\sum}|\mathcal{M}^{q_i q_j}|^2$

- NNLL approximation: high energy limit of the NLO result for $\overline{\sum}|\mathcal{M}^{q_i q_j}|^2$

  $M_W^2/\hat{s} \to 0$ ($\hat{t}/\hat{s}$, $\hat{u}/\hat{s}$ constant)

  terms with $\alpha \ln^2(\frac{\hat{s}}{M_W^2})$, $\alpha \ln(\frac{\hat{s}}{M_W^2})$ and constants

  LL NLL NNLL

  $\to$ extremely compact analytic formulae for NNLL approximation of $\overline{\sum}|\mathcal{M}^{q_i q_j}|^2$

- Dominant (NLL) part of two-loop (NNLO) EW correction

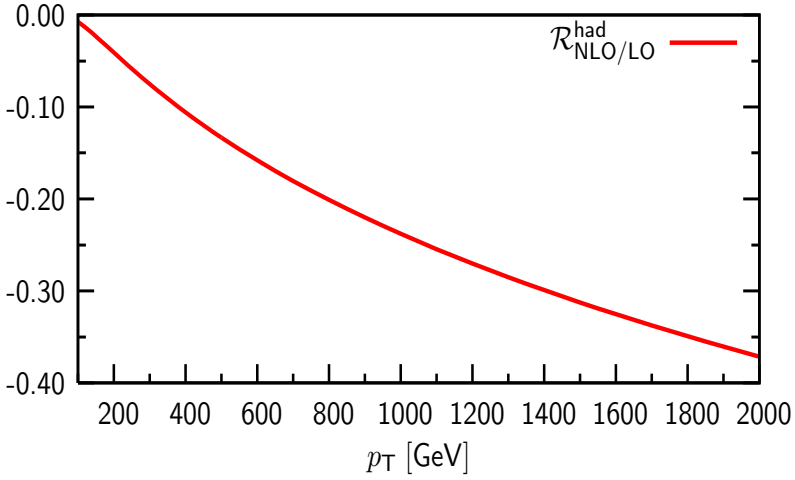
  Factorized corrections

$$\overline{\sum}|\mathcal{M}^{q_i q_j}|^2 = \overline{\sum}|\mathcal{M}^{q_i q_j}_{\rm Born}|^2 \left[\quad 1 \quad + \quad \left(\frac{\alpha}{2\pi}\right) A^{(1)} \quad + \quad \left(\frac{\alpha}{2\pi}\right)^2 A^{(2)} \quad \right]$$

LL + NLL: $\alpha \ln^2(\frac{\hat{s}}{M_W^2})$, $\alpha \ln(\frac{\hat{s}}{M_W^2})$ $\alpha^2 \ln^4(\frac{\hat{s}}{M_W^2})$, $\alpha^2 \ln^3(\frac{\hat{s}}{M_W^2})$

EW corrections to $pp \to Z + 1\,\mathrm{jet}$ at the LHC

$$\mathcal{R}^{had}_{\mathrm{NLO/LO}} = \frac{d\sigma_{\mathrm{NLO}}/dp_T}{d\sigma_{\mathrm{LO}}/dp_T} - 1$$



(LO MRST2001 PDF's, $\mu_F = \mu_R = p_T$)

- $\mathcal{O}(\alpha)$ corrections negative; range from -13% at 500 GeV up to -37 % at 2 TeV

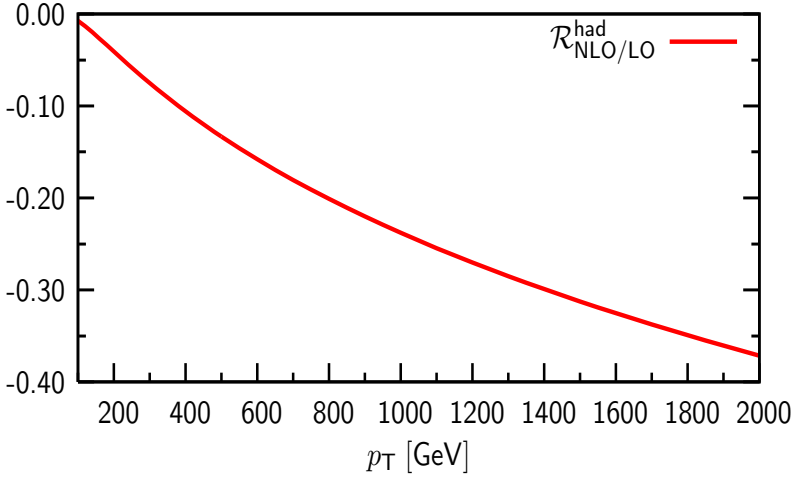
EW corrections to $pp \to Z + 1$ jet at the LHC

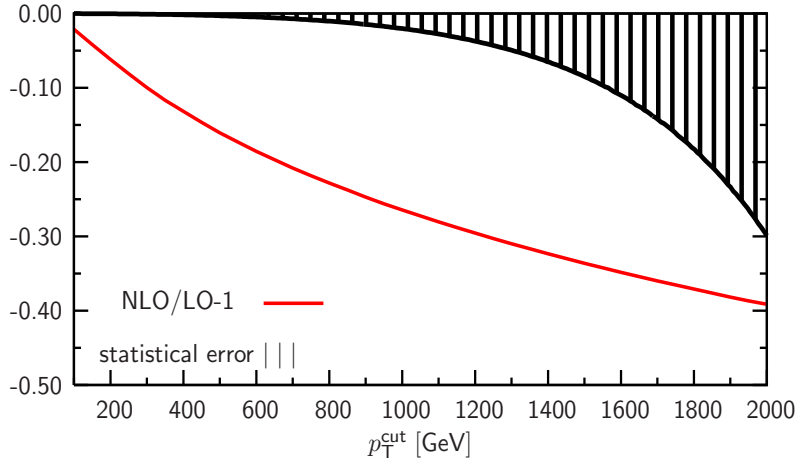
$$\mathcal{R}^{had}_{\mathrm{NLO/LO}} = \frac{d\sigma_{\mathrm{NLO}}/dp_T}{d\sigma_{\mathrm{LO}}/dp_T} - 1$$

Integrated $\Delta\sigma(p_{\mathrm{T}}^{\mathrm{cut}})$ vs. $\Delta\sigma_{\mathrm{stat}} = \frac{\sigma}{\sqrt{N}}$

$N = \mathcal{L} \times \mathrm{BR}(Z \to l,\ \nu_l) \times \sigma_{\mathrm{LO}}$

$\mathrm{BR}(Z \to l,\ \nu_l) = 30.6\%$, $\mathcal{L} = 300$ fb^{-1}





(LO MRST2001 PDF's, $\mu_F = \mu_R = p_T$)

- $\mathcal{O}(\alpha)$ corrections negative; range from -13% at 500 GeV up to -37 % at 2 TeV
- Size of the integrated corrections much bigger than the statistical error!

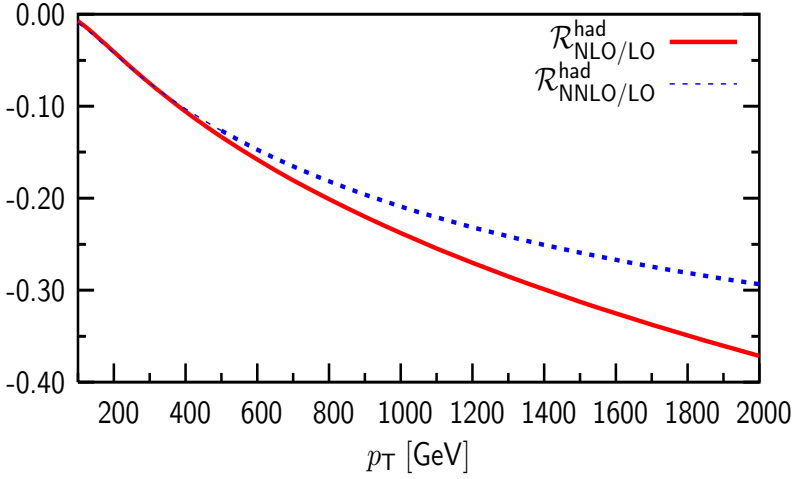
EW corrections to $pp \to Z + 1$ jet at the LHC

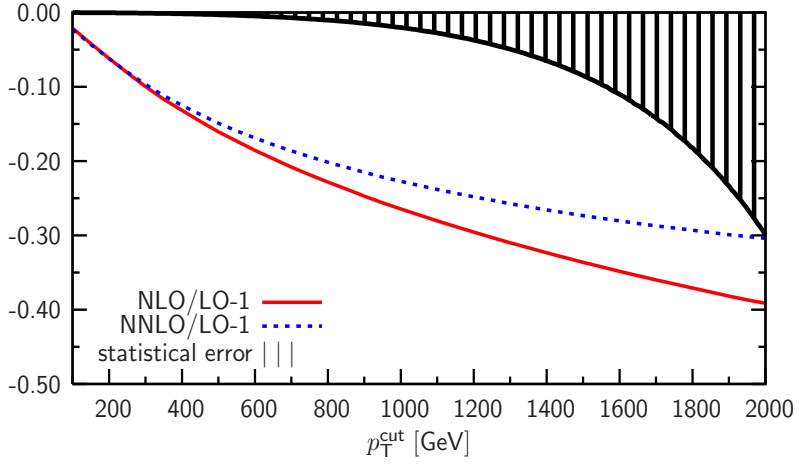
$$\mathcal{R}^{had}_{\mathrm{NNLO/LO}} = \frac{d\sigma_{\mathrm{NNLO}}/dp_T}{d\sigma_{\mathrm{LO}}/dp_T} - 1$$

Integrated $\Delta\sigma(p_{\mathrm{T}}^{\mathrm{cut}})$ vs. $\Delta\sigma_{\mathrm{stat}} = \frac{\sigma}{\sqrt{N}}$

$N = \mathcal{L} \times \mathrm{BR}(Z \to l,\ \nu_l) \times \sigma_{\mathrm{LO}}$

$\mathrm{BR}(Z \to l,\ \nu_l) = 30.6\%$, $\mathcal{L} = 300$ fb^{-1}

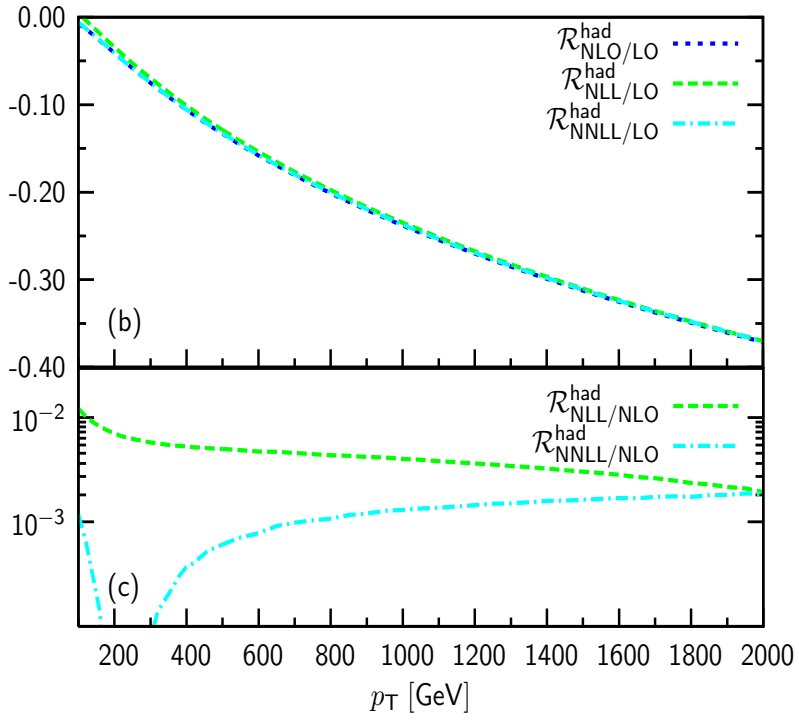




- $\mathcal{O}(\alpha)$ corrections negative; range from -13% at 500 GeV up to -37 % at 2 TeV
- Size of the integrated corrections much bigger than the statistical error!
- 2-loop terms positive, up to 8% contribution (at 2 TeV)
- For large range of p_T values 2-loop effects comparable with statistical error

High-energy approximation of the 1-loop result

Large p_T Z-boson production at the LHC



$$\mathcal{R}^{had}_{\rm NLO/LO} = \frac{d\sigma_{\rm NLO}/dp_T}{d\sigma_{\rm LO}/dp_T} - 1$$

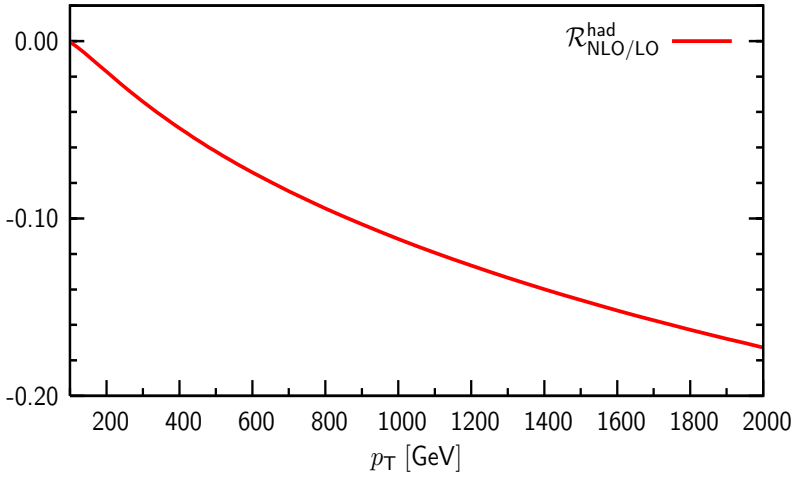
etc.

(LO MRST2001 pdf's, $\mu_F = \mu_R = p_T$)

- NLL approximation: percent (or better) level
  - $\sim$ 1% deviation from NLO at low p_T
  - $\sim$ 0.2% deviation from NLO at $p_T = 2$ TeV
- NNLL approximation: permille level

EW corrections to $pp \to \gamma + 1$ jet at the LHC

$$\mathcal{R}^{had}_{\mathrm{NLO/LO}} = \frac{d\sigma_{\mathrm{NLO}}/dp_T}{d\sigma_{\mathrm{LO}}/dp_T} - 1$$



(LO MRST2001 PDF's, $\mu_F = \mu_R = p_T$)

- $\mathcal{O}(\alpha)$ corrections negative; range from -6% at 500 GeV up to -17 % at 2 TeV

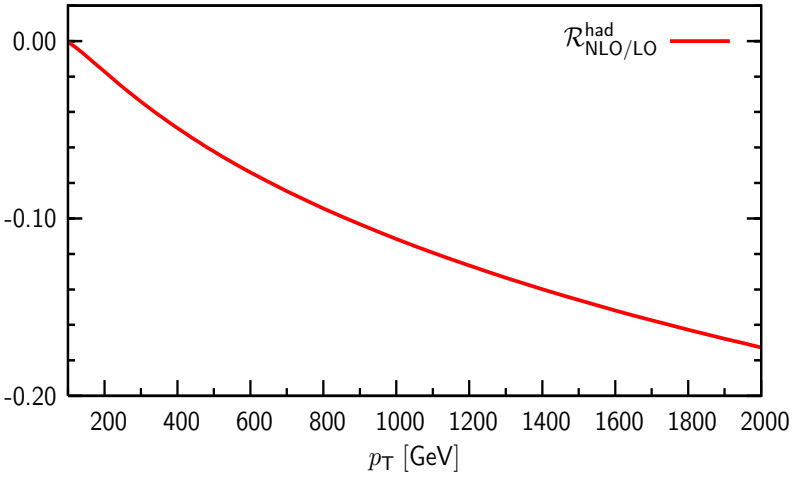
EW corrections to $pp \to \gamma + 1$ jet at the LHC

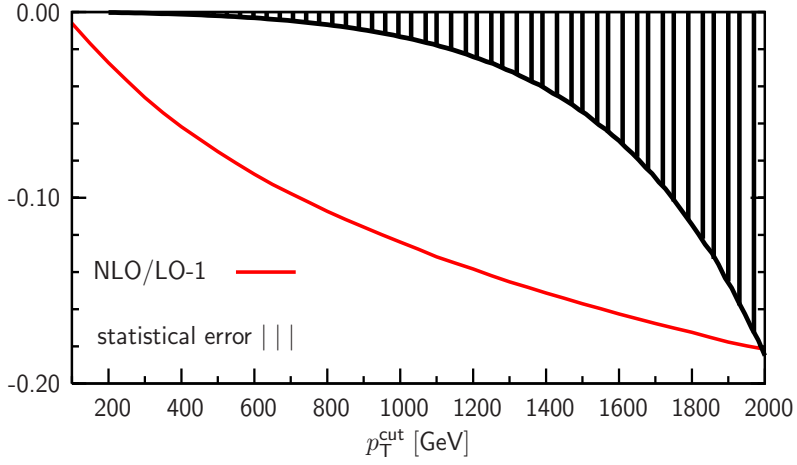
$$\mathcal{R}^{had}_{\mathrm{NLO/LO}} = \frac{d\sigma_{\mathrm{NLO}}/dp_T}{d\sigma_{\mathrm{LO}}/dp_T} - 1$$

Integrated $\Delta\sigma(p_{\mathrm{T}}^{\mathrm{cut}})$ vs. $\Delta\sigma_{\mathrm{stat}} = \frac{\sigma}{\sqrt{N}}$

$N = \mathcal{L} \times \sigma_{\mathrm{LO}}$

$\mathcal{L} = 300$ fb^{-1}





(LO MRST2001 PDF's, $\mu_F = \mu_R = p_T$)

- $\mathcal{O}(\alpha)$ corrections negative; range from -6% at 500 GeV up to -17 % at 2 TeV
- Size of the integrated $\mathcal{O}(\alpha)$ corrections much bigger than the statistical error!

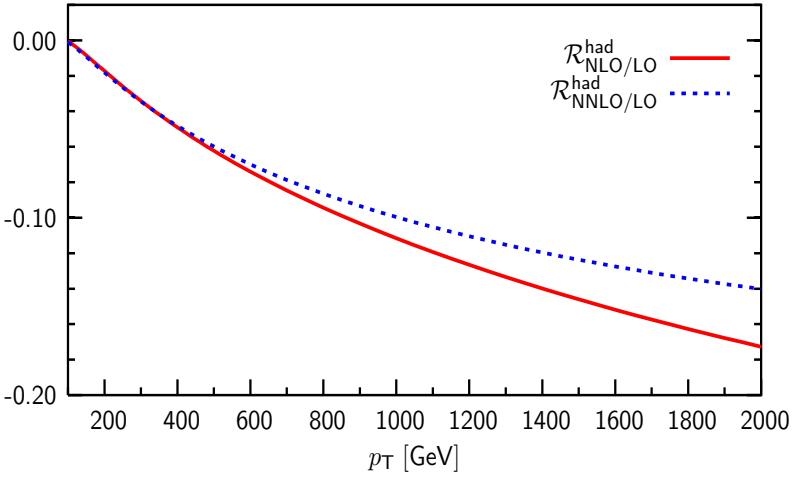
EW corrections to $pp \to \gamma + 1$ jet at the LHC

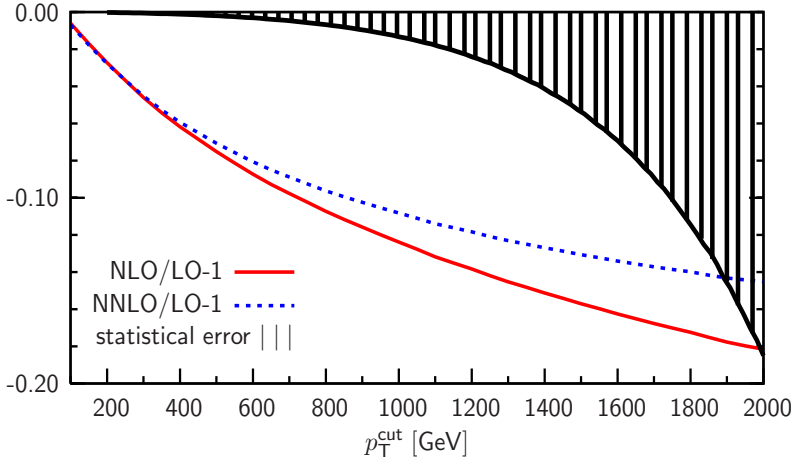
$$\mathcal{R}^{had}_{\mathrm{NNLO/LO}} = \frac{d\sigma_{\mathrm{NNLO}}/dp_T}{d\sigma_{\mathrm{LO}}/dp_T} - 1$$

Integrated $\Delta\sigma(p_{\mathrm{T}}^{\mathrm{cut}})$ vs. $\Delta\sigma_{\mathrm{stat}} = \frac{\sigma}{\sqrt{N}}$

$N = \mathcal{L} \times \sigma_{\mathrm{LO}}$

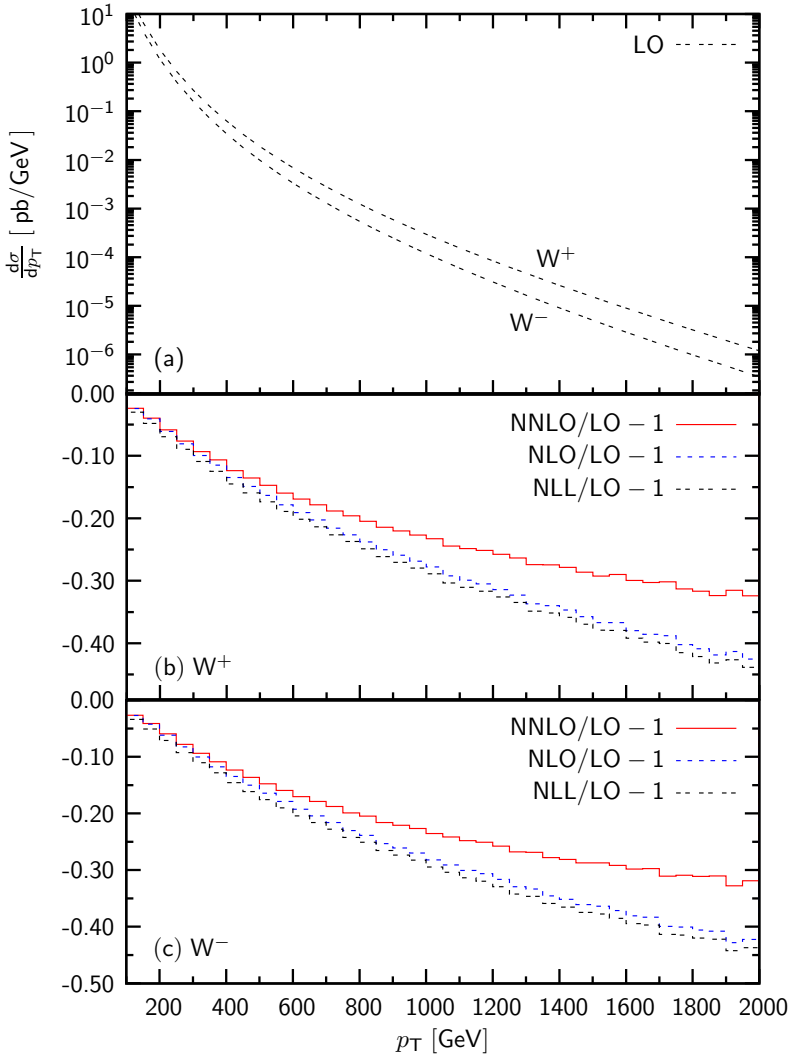
$\mathcal{L} = 300$ fb^{-1}





- $\mathcal{O}(\alpha)$ corrections negative; range from -6% at 500 GeV up to -17 % at 2 TeV
- Size of the integrated $\mathcal{O}(\alpha)$ corrections much bigger than the statistical error!
- 2-loop terms positive, up to 3% contribution (at 2 TeV)
- For large range of p_T values 2-loop effects comparable with statistical error

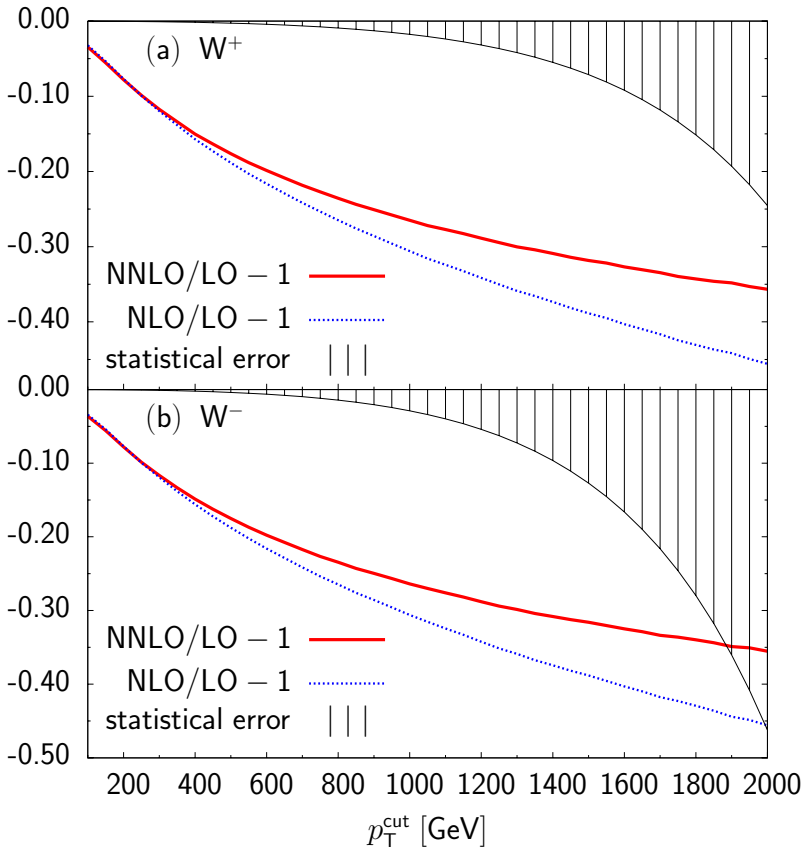
EW corrections to $pp \to W^{\pm} + 1$ jet at the LHC



- $\mathcal{O}(\alpha)$ corrections negative; range from
  -15% at $p_{\mathrm{T}} = 500$ GeV
  up to -42% at $p_{\mathrm{T}} = 2$ TeV
- NLL approximation in good agreement with the full NLO result
- NLL 2-loop terms positive and amount to 2% at $p_{\mathrm{T}} = 500$ GeV and up to 10% at $p_{\mathrm{T}} = 2$ TeV

(LO MRST2001 PDFs, $\mu_F = \mu_R = p_T$, $p_T^{\min}(\mathrm{jet}) = 100$ GeV)

EW corrections to $pp \to W^{\pm} + 1$ jet at the LHC



Integrated $\Delta\sigma(p_{\mathrm{T}}^{\mathrm{cut}})$ vs. $\Delta\sigma_{\mathrm{stat}} = \frac{\sigma}{\sqrt{N}}$

$N = \mathcal{L} \times \mathrm{BR}(W \to e\nu_e, \mu\nu_\mu) \times \sigma_{\mathrm{LO}}$

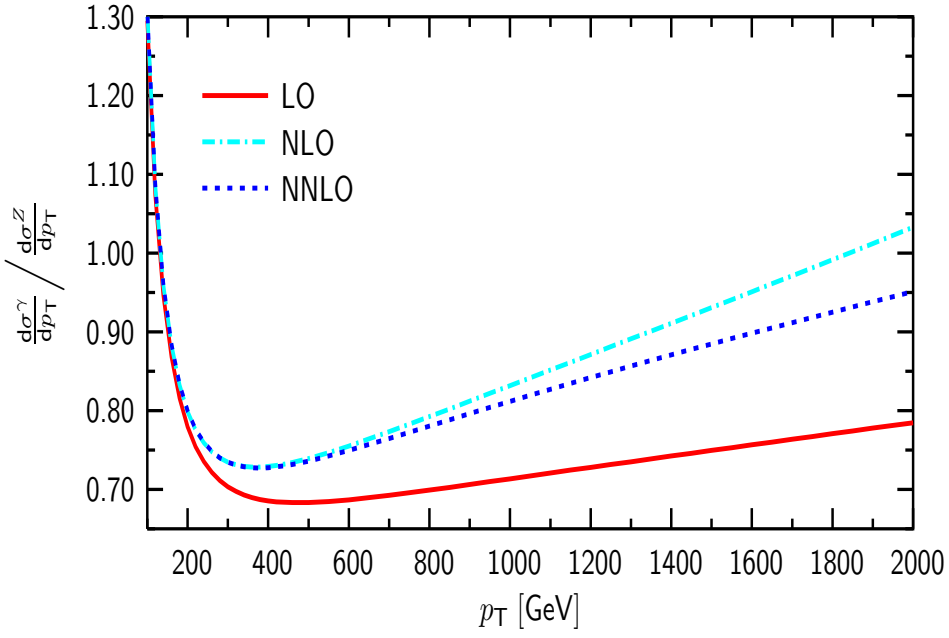
$\mathrm{BR}(W \to e\nu_e, \mu\nu_\mu) = 22.2\%,$

$\mathcal{L} = 300$ fb^{-1}

- Size of the integrated $\mathcal{O}(\alpha)$ corrections much bigger than the statistical error!
- For large range of p_T values 2-loop effects comparable with statistical error

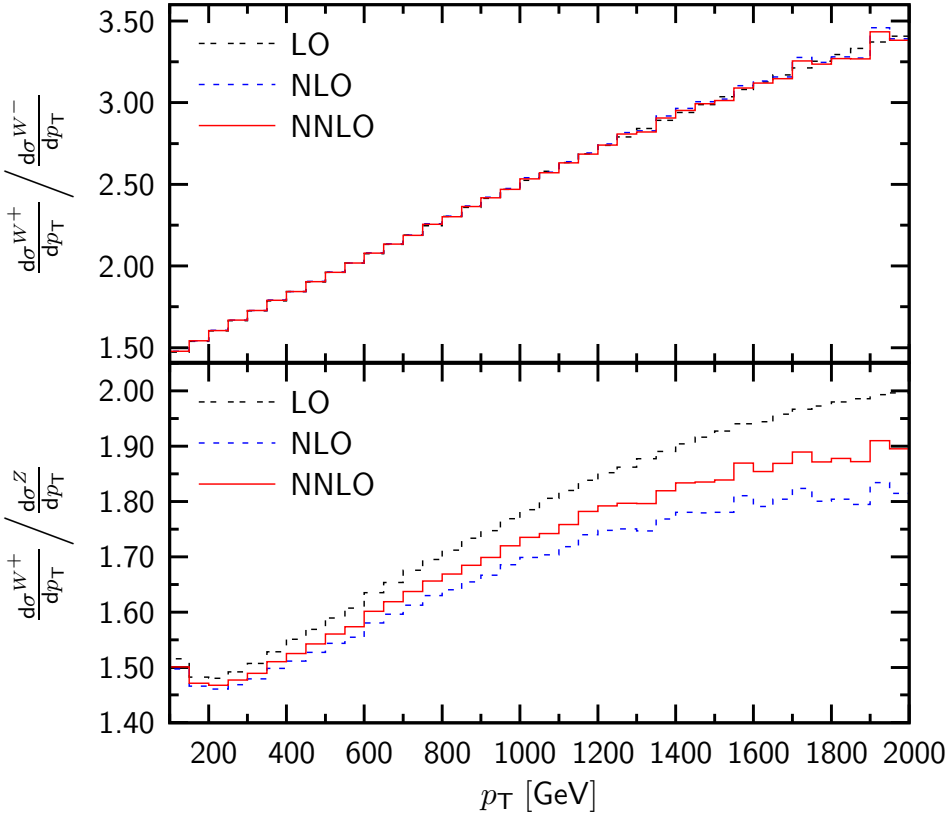
(LO MRST2001 PDFs, $\mu_F = \mu_R = p_T$, $p_T^{\min}(\mathrm{jet}) = 100$ GeV)

Ratio of the p_T distributions: γ to Z



- Cancellation of theoretical uncertainties (PDFs α_S)
- Stability wrt. QCD corrections
- Ratio of the LO distributions: $\frac{d\sigma^\gamma}{dp_T} / \frac{d\sigma^Z}{dp_T} \sim 0.7 - 0.8$
- EW corrections modify the ratio; strongest effect at large p_T
  NLO: $\frac{d\sigma^\gamma}{dp_T} / \frac{d\sigma^Z}{dp_T} \sim 0.75 - 1$, NNLO: $\frac{d\sigma^\gamma}{dp_T} / \frac{d\sigma^Z}{dp_T} \sim 0.75 - 0.95$

Ratio of the p_T distributions: W^+ to W^-, W^+ to Z



- EW corrections to $\frac{d\sigma^{W^+}}{dp_T} / \frac{d\sigma^{W^-}}{dp_T}$ almost identical
- Above 1 TeV, 5-10% corrections to $\frac{d\sigma^{W^+}}{dp_T} / \frac{d\sigma^{Z}}{dp_T}$

Summary

- Analytic results for the p_T distribution of direct photons, Z-bosons and W-bosons
  - Exact $\mathcal{O}(\alpha)$ correction
  - NNLL approximation of the $\mathcal{O}(\alpha)$ correction $\longrightarrow$ excellent approximation
  - Dominant (NLL) part of the 2-loop corrections
- Results are in compact form, ready to implement in a code of your choice
- Conclusion: EW corrections extremely important for the precise knowledge of the production cross sections at large p_T (large logs at TeV scales!)
  - Negative 1-loop corrections of the order of tens of percent at high p_{T} at the LHC
  - Positive 2-loop NLL corrections of the order of several percent at high p_{T} at the LHC $\Rightarrow$ relevant for the analysis!
- Ratio $\frac{d\sigma^{\gamma}}{dp_T} / \frac{d\sigma^{Z}}{dp_T}$ and $\frac{d\sigma^{W^{\pm}}}{dp_T} / \frac{d\sigma^{Z}}{dp_T}$: significant effects due to EW corrections at large p_T
- Relevant issues...
  - Size of the stat. error due to detector and bckg. subtraction at large p_{T}
  - Extent to which real radiation of massive gauge bosons can be seen in the experiment