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Electroweak Corrections to single W production at the LHC: an update

Michael Krämer

(RWTH Aachen)

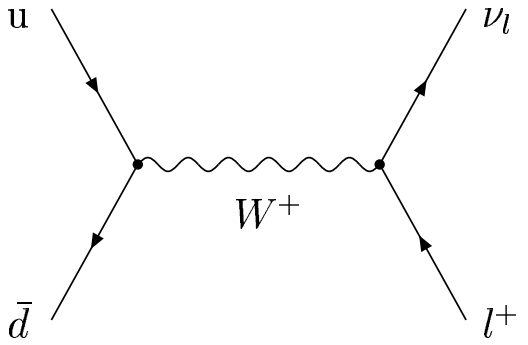
- QED effects in PDFs and photon induced processes
- A tuned comparison of various calculations
- Outlook

work in collaboration with Stefan Dittmaier

Single W-boson production at hadron colliders

- measurement of M_W and Γ_W

$\longrightarrow$ precision test of SM



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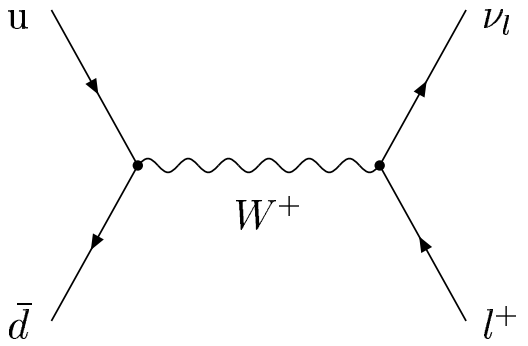
- σ_W as a (parton) luminosity monitor

[Dittmar, Pauss, Zürcher]

e.g. $\delta \dfrac{\sigma(pp \to W^+W^-)}{\sigma(pp \to W^\pm)} \lesssim 1\%$



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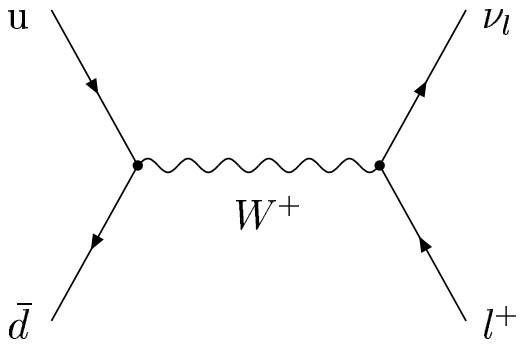

- σ_W as a (parton) luminosity monitor

[Dittmar, Pauss, Zürcher]

e.g. $\delta \dfrac{\sigma(pp \to W^+W^-)}{\sigma(pp \to W^\pm)} \lesssim 1\%$

- Anticipated experimental accuracy:

uncertainty	now	Tevatron Run II	LHC
$\delta \sin^2\theta_{\rm eff}(\times 10^5)$	17	78	14-20
δM_W [MeV]	34	27	15
δm_t [GeV]	5.1	2.7	1.0
$\delta M_H/M_H$ [%] (from all data)	58	35	18

[see e.g. Wackeroth, ESF/IPPP workshop Durham '03]

$\Rightarrow$ Precision calculations required

Single W-boson production at hadron colliders

QCD radiative corrections

— NNLO predictions for total cross section and rapidity distribution

[Hamberg, van Neerven, Matsuura '91; Harlander, Kilg ore '02; Anastasiou, Dixon, Melnikov, Petriello '03]

— soft gluon resummation for transverse momentum distribution [Balazs, Yuan '97]

Single W-boson production at hadron colliders

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Electroweak radiative corrections

– final state photon radiation [Berends, Kleiss '85]

– $\mathcal{O}(\alpha)$ corrections to resonant W production [Hollik, Wackeroth '97; Baur, Keller, Wackeroth '99]

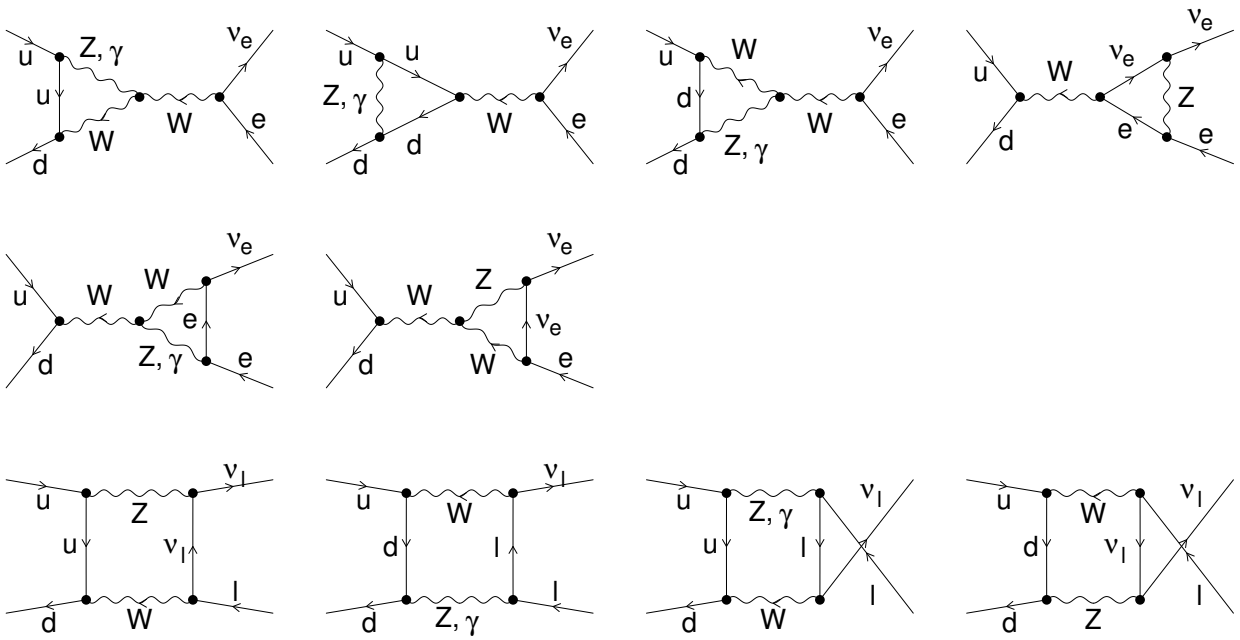
– real two-photon radiation [Baur, Stelzer '00]

– complete $\mathcal{O}(\alpha)$ corrections [Dittmaier, MK '01; Zykunov et al. '01; Baur, Wackeroth '04]

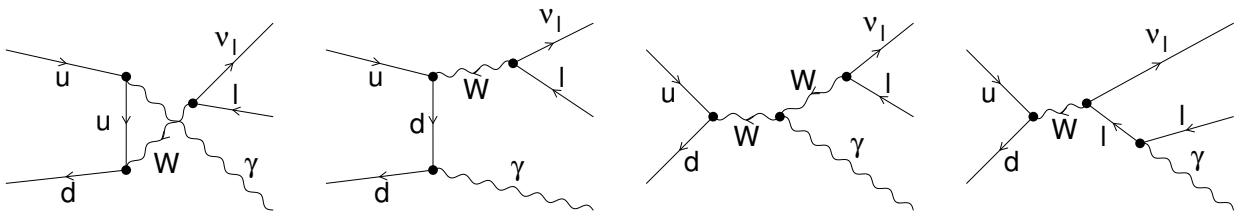
– multiple final state photon radiation [Placzek, Jadach '03; Carloni Calame, Montagna, Nicrosini '03]

Single W-boson production: electroweak corrections

- virtual one-loop corrections

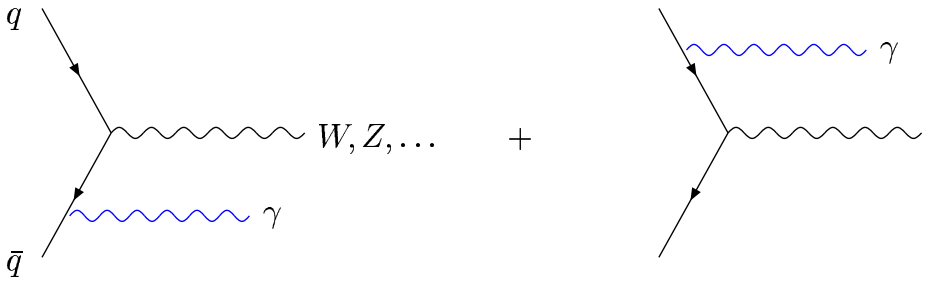


- photon radiation



Single W-boson production: electroweak corrections

- mass singularities



QED initial state collinear singularities are universal $\longrightarrow$ can be absorbed into pdfs

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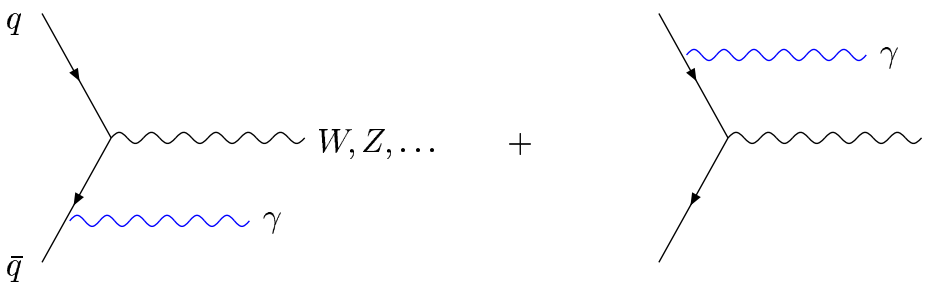


QED initial state collinear singularities are universal $\longrightarrow$ can be absorbed into pdfs

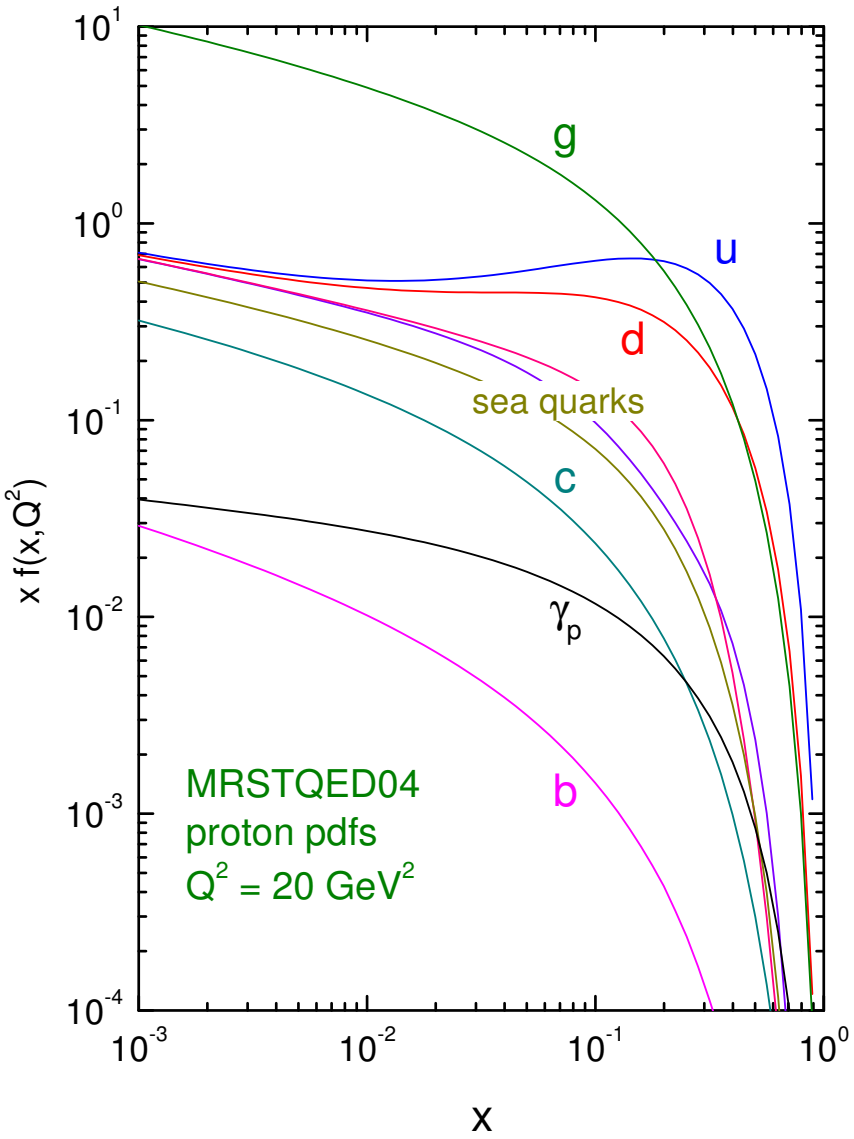
Mass factorization: [Baur, Keller, Wackeroth; Dittmaier, MK, Diener, Dittmaier, Hollik]

$$q(x) \quad \to \quad q(x,M^2) - \int_x^1 \frac{dz}{z}\, q\left(\frac{x}{z}, M^2\right)\, \frac{\alpha}{2\pi}\, Q_q^2$$
$$\times \left\{ \ln\left(\frac{M^2}{m_q^2}\right) [P_{ff}(z)]_+ - [P_{ff}(z)\,(2\ln(1-z)+1)]_+ + C(z) \right\}$$

where

$$C(z) = \begin{cases} 0 & \overline{\text{MS}} \\ \left[P_{ff}(z)\left(\ln\left(\frac{1-z}{z}\right) - \frac{3}{4}\right) + \frac{9+5z}{4}\right]_+ & \text{DIS} \end{cases}$$

QED improved parton distributions



→ effect of QED evolution and corrections on quark & gluons pdfs is small [see also Kripfganz, Perlt; Blümlein, Spiesberger, Roth, Weinzierl]

→ dynamic generation of photon parton distribution

→ MRST pdfs are defined in the DIS QED factorization scheme [Diener, Dittmaier, Hollik]

Single W-boson production at the LHC

- for experimental identification require phase space cuts:

  $p_{\mathrm{T},l} > 25$ GeV, $\quad \not{p}_{\mathrm{T}} > 25$ GeV, $\quad |\eta_l| < 1.2$

  assume perfect isolation of photon from charged lepton

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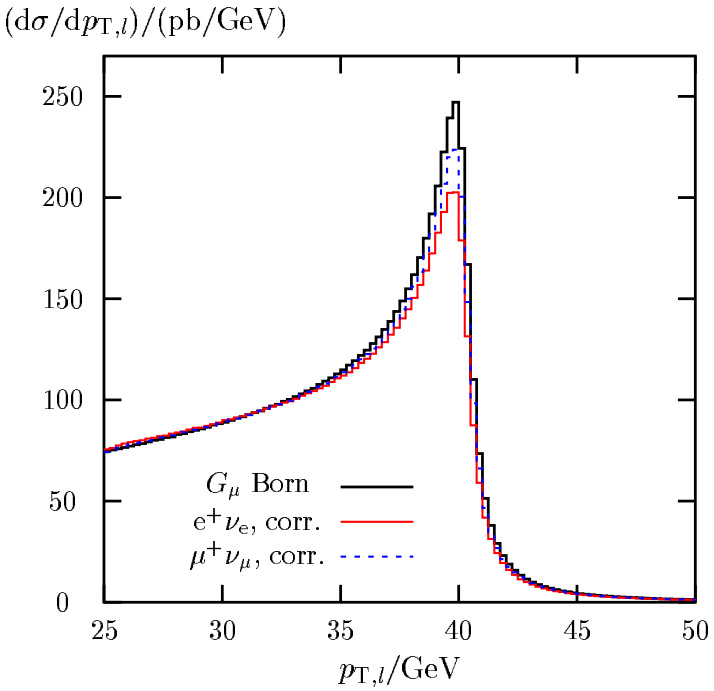
  specifically:

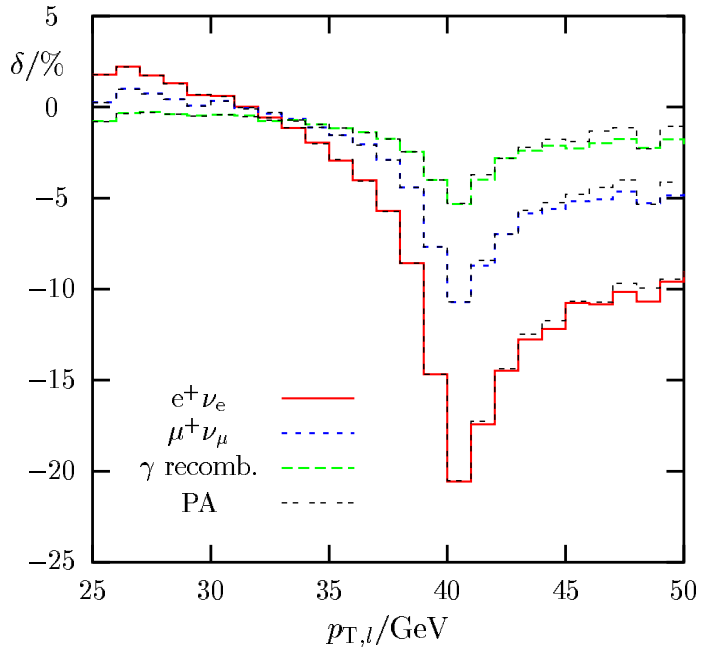
  1. Photons with a rapidity $|\eta_\gamma| > 2.5$, which are close to the beams, are treated as invisible, i.e. they are considered as part of the proton remnant.
  2. If the photon survived the first step, and if the resolution $R_{l\gamma} = \sqrt{(\eta_l - \eta_\gamma)^2 + \phi_{l\gamma}^2}$ is smaller than 0.1 (with $\phi_{l\gamma}$ denoting the angle between lepton and photon in the transverse plane), then the photon is recombined with the charged lepton, i.e. the momenta of the photon and the lepton l are added and associated with the momentum of l, and the photon is discarded.

Single W-boson production at the LHC

- Numerical results: $p_{\mathrm{T},l}$ distribution

[Dittmaier, MK]

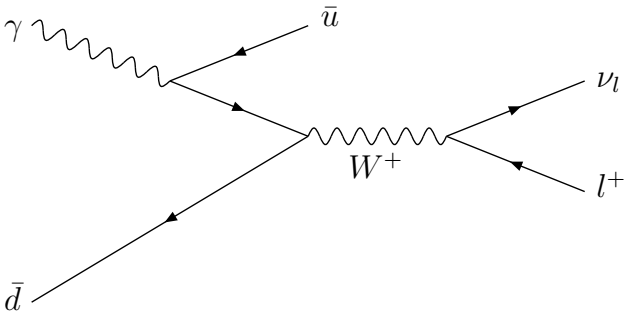


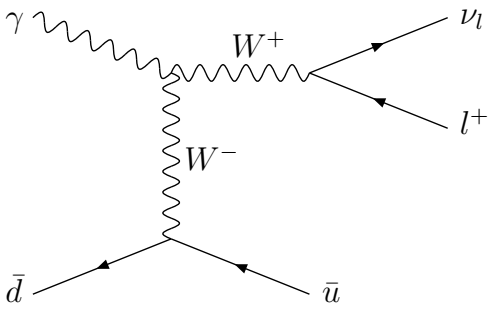


$p_{\mathrm{T},l}/\mathrm{GeV}$	25–∞	50–∞	100–∞	200–∞	500–∞	1000–∞
$\delta_{\mathrm{e}^+\nu_\mathrm{e}}/\%$	$-5.19(1)$	$-8.92(3)$	$-11.47(2)$	$-16.01(2)$	$-26.35(1)$	$-37.92(1)$
$\delta_{\mu^+\nu_\mu}/\%$	$-2.75(1)$	$-4.78(3)$	$-8.19(2)$	$-12.71(2)$	$-22.64(1)$	$-33.54(2)$
$\delta_{\mathrm{rec}}/\%$	$-1.73(1)$	$-2.45(3)$	$-5.91(2)$	$-9.99(2)$	$-18.95(1)$	$-28.60(1)$

Single W-boson production at the LHC

- Numerical results: photon-induced processes [Dittmaier, MK]





Single W-boson production at the LHC

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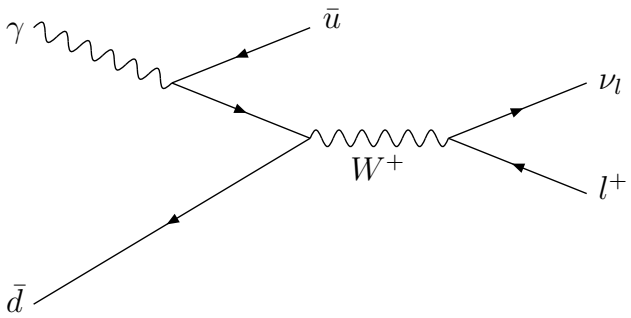

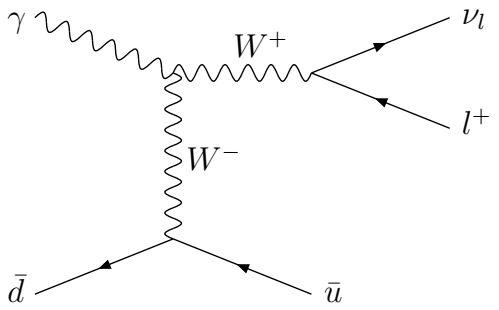

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$\delta_{\mathrm{rec}}/\%$	$-1.73(1)$	$-2.45(3)$	$-5.91(2)$	$-9.99(2)$	$-18.95(1)$	$-28.60(1)$
$\delta_{\gamma q}/\%$	$+0.071(1)$	$+5.24(1)$	$+13.10(1)$	$+16.44(2)$	$+14.30(1)$	$+11.89(1)$

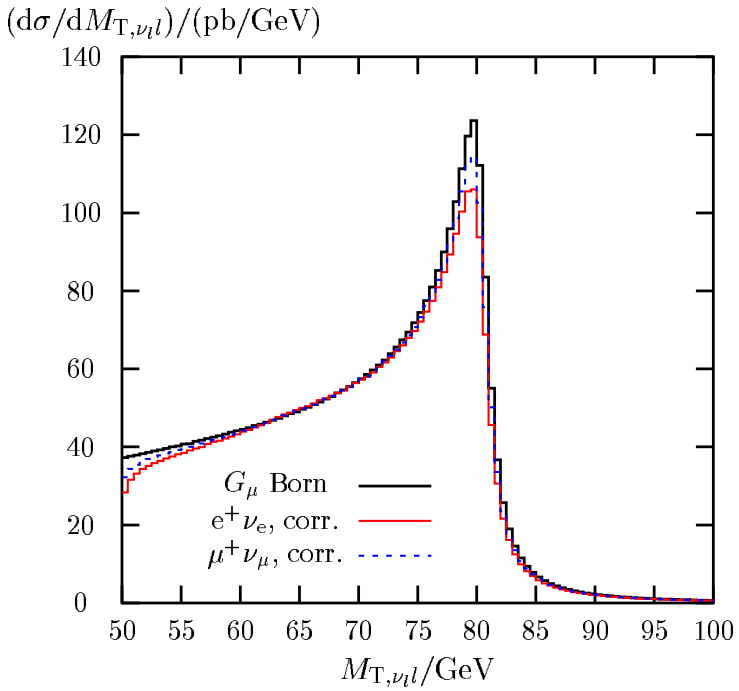
$\longrightarrow$ large corrections due to photon-induced process

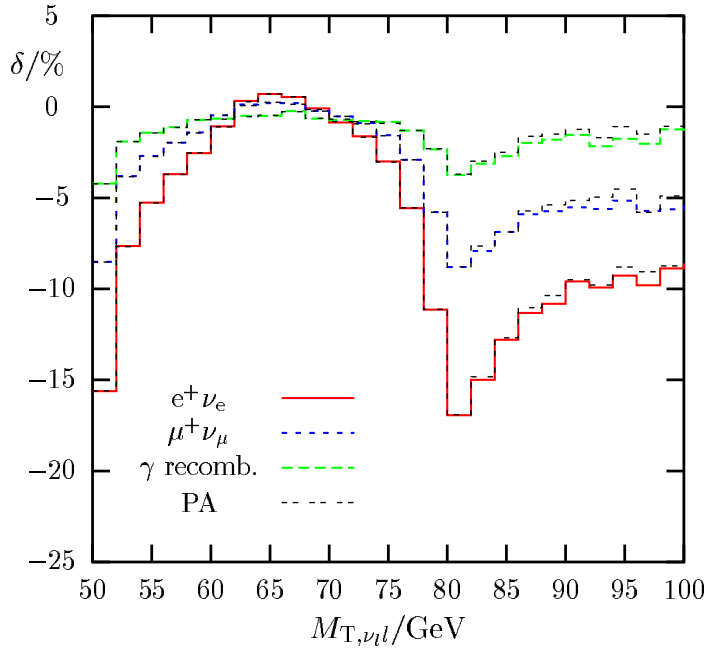
$\longrightarrow$ but: $p_{\mathrm{T},l}$ distribution very sensitive to QCD effects

Single W-boson production at the LHC

- Numerical results: $M_{\mathrm{T},\nu_l l}$ distribution

[Dittmaier, MK]





$M_{\mathrm{T},\nu_l l}/\mathrm{GeV}$	50–∞	100–∞	200–∞	500–∞	1000–∞
$\delta_{\mathrm{rec}}/\%$	$-1.73(1)$	$-3.43(2)$	$-6.52(2)$	$-12.55(1)$	$-19.51(1)$
$\delta_{\gamma q}/\%$	$+0.0567(3)$	$+0.1347(1)$	$+0.2546(1)$	$+0.3333(1)$	$+0.3267(1)$

Single W-boson production at the LHC: a tuned comparison

- HORACE : complete $\mathcal{O}(\alpha)$ corrections or parton shower photon emssion;

  [Carloni Calame, Montagna, Nicrosini, Treccani]

- SANC: complete $\mathcal{O}(\alpha)$ corrections;

  [Andonov, Arbuzov, Bardin, Bondarenko, Christova, Kalinovskaya, Nanava, von Schlippe]

- WGRAD: complete $\mathcal{O}(\alpha)$ corrections;

  [Baur, Keller, Wackeroth]

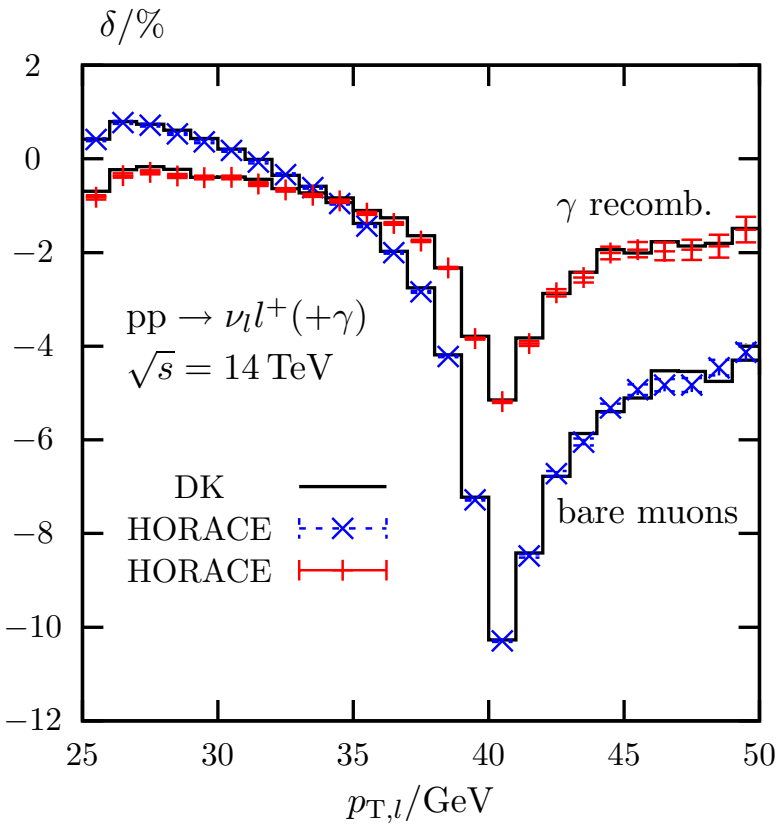
- DITTMAIER-KRÄMER: complete $\mathcal{O}(\alpha)$ corrections, photon induced processes

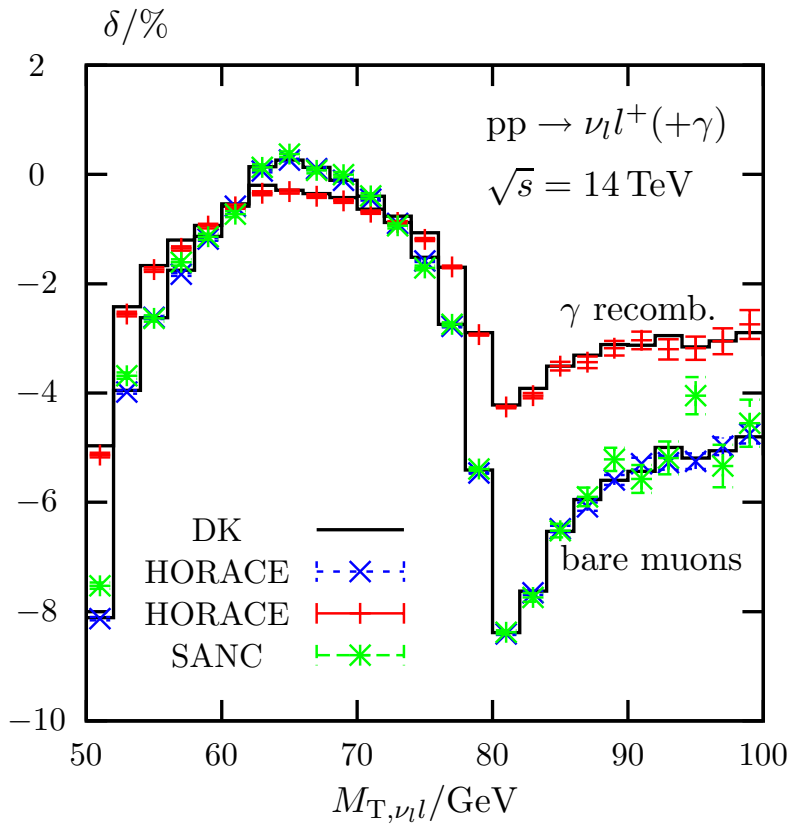
Single W-boson production at the LHC: a tuned comparison

$\mathrm{pp} \to \nu_l l^+(+\gamma)$ at $\sqrt{s} = 14\,\mathrm{TeV}$

$p_{\mathrm{T},l}/\mathrm{GeV}$	25–∞	50–∞	100–∞	200–∞	500–∞	1000–∞
$\delta_{\mathrm{e}^+\nu_\mathrm{e}}/\%$						
DK	$-5.19(1)$	$-8.92(3)$	$-11.47(2)$	$-16.01(2)$	$-26.35(1)$	$-37.92(1)$
HORACE	$-5.23(1)$	$-8.98(1)$	$-11.49(1)$	$-16.03(1)$	$-26.36(1)$	$-37.92(2)$
WGRAD	$-5.10(1)$	$-8.55(5)$	$-11.32(1)$	$-15.91(2)$	$-26.1(1)$	$-38.2(2)$
$\delta_{\mu^+\nu_\mu}/\%$						
DK	$-2.75(1)$	$-4.78(3)$	$-8.19(2)$	$-12.71(2)$	$-22.64(1)$	$-33.54(2)$
HORACE	$-2.79(1)$	$-4.84(1)$	$-8.21(1)$	$-12.73(1)$	$-22.65(1)$	$-33.57(1)$
SANC	$-2.80(1)$	$-4.82(2)$	$-8.17(2)$	$-12.67(2)$	$-22.63(2)$	$-33.50(2)$
WGRAD	$-2.69(1)$	$-4.53(1)$	$-8.12(1)$	$-12.68(1)$	$-22.62(2)$	
$\delta_{\mathrm{recomb}}/\%$						
DK	$-1.73(1)$	$-2.45(3)$	$-5.91(2)$	$-9.99(2)$	$-18.95(1)$	$-28.60(1)$
HORACE	$-1.77(1)$	$-2.51(1)$	$-5.94(1)$	$-10.02(1)$	$-18.96(1)$	$-28.65(1)$
SANC	$-1.89(1)$	$-2.56(1)$	$-5.97(1)$	$-10.02(1)$	$-18.96(1)$	$-28.61(1)$
WGRAD	$-1.71(1)$	$-2.32(1)$	$-5.94(1)$	$-10.11(2)$	$-19.08(3)$	

Single W-boson production at the LHC: a tuned comparison





Single W-boson production at the LHC: outlook

- tuned comparison to be continued and extended

  further improve level of agreement; investigate more distributions; study Z-production

- need summation of multiple-photon emission

  [Placzek, Jadach; Carloni Calame, Montagna, Nicrosini, Treccani]

  $\longrightarrow$ combination of full $\mathcal{O}(\alpha)$ calculation and multiple photon emission

- summation of Sudakov-logarithms

  [Beenakker et al.; Kühn, Penin; Denner, Pozzorini,...]

- EW calculations for W, Z production in association with jets

  [Maina, Moretti, Ross; Kühn, Kulesza, Pozzorini, Schulze; Hollik, Meier; Accomando, Denner, Meier]

- need to combine strong and electroweak higher-order effects [Cao, Yuan]