Lowest order radiative corrections to W-production at hadron colliders

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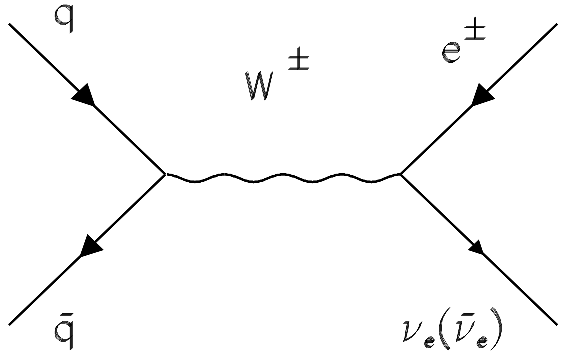

Abstract

The lowest order electroweak radiative corrections to the single W-boson production in hadron-hadron collisions is calculated. The infrared divergence is extracted by the covariant method. The performed numerical analysis of radiative corrections to lepton transverse momentum spectra at LHC kinematics has shown their phenomenological importance.

The set of graphs for the one-loop lowest-order radiative corrections

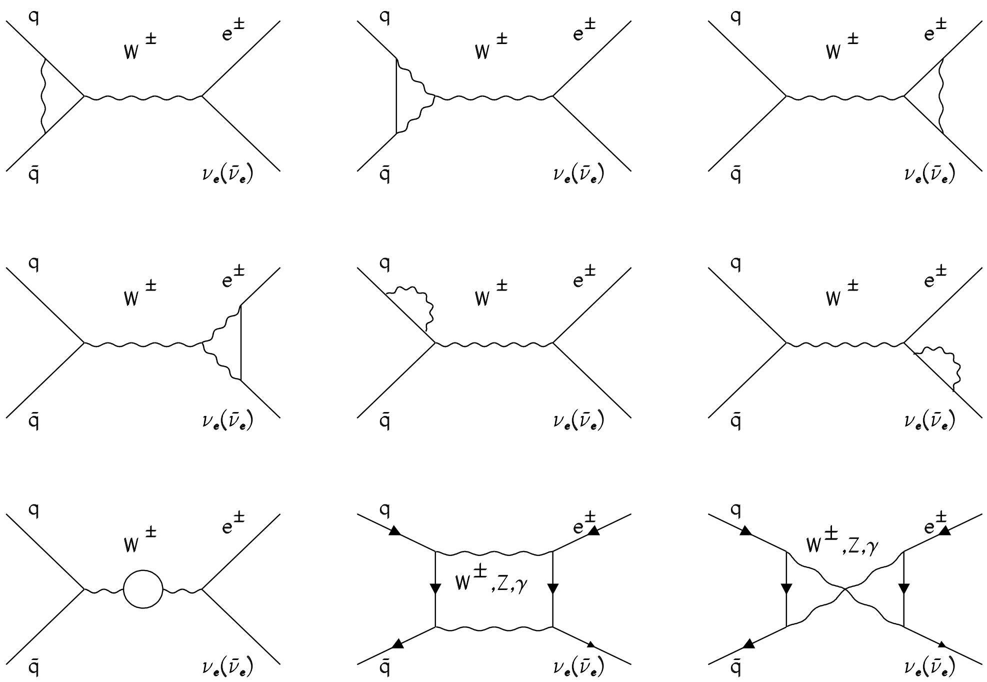

Figure 1: *V-contribution graphs*

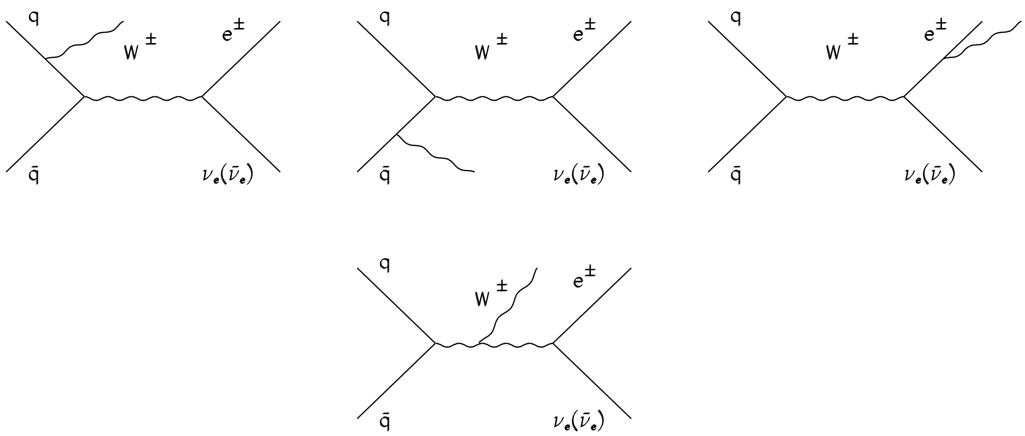

Figure 2: *R-contribution graphs*

The explicit expressions for the one-loop lowest-order radiative corrections

$$\frac{d^2\sigma^{1-loop}}{d\eta dk_T^2} = \sum_{i,i'} \int dx_1 \left(\frac{d^2\sigma_V}{d\eta dk_T^2} + \frac{d^2\sigma_R}{d\eta dk_T^2} \right)$$

1. V-contribution

$$\frac{d\sigma_V}{d\eta dk_T^2} = \frac{\pi\alpha^2 f_i(x_1,Q^2) f_{i'}(x_2,Q^2)|V_{ii'}|^2 \hat{B}_{ii'}}{12 s_w^4 \hat{s}[(\hat{s}-m_W^2)^2 + m_W^2\Gamma_W^2](x_1 S + U)} \delta_V|_{x_2=x_2^0}$$

Here $s_w = \sin\theta_w$ and θ_w is the weak mixing angle, $V_{ii'}$ is KM matrix element, $f_i(x_{1(2)},Q^2)$ is the spin averaged quark densities, $x_2^0 = -x_1 T/(x_1 S + U)$

$$B_{ii'} = \begin{cases} \hat{u}^2 - \text{ for } q\bar{q} \to l^-\bar{\nu}_l,\ \bar{q}q \to l^+\nu_l\ , \\ \hat{t}^2 - \text{ for } q\bar{q} \to l^+\nu_l,\ \bar{q}q \to l^-\bar{\nu}_l. \end{cases}$$

$\hat{s} = x_1 x_2 S$, $\hat{t} = x_1 T$, $\hat{u} = x_2 U$ **— usual Mandelstam variables**

$$T = -\sqrt{S}|k_T|e^{-\eta},\ U = -\sqrt{S}|k_T|e^{\eta}$$

$\delta_V = \sum_l \delta_V^l$ **– is the sum over all V-contribution graphs.**

Note: $\delta_V = \delta_V^F + \delta_V^{IR}$

2. R-contribution

$$\frac{d\sigma_R}{d\eta dk_T^2} = \frac{d\sigma_R^{IR}}{d\eta dk_T^2} + \frac{d\sigma_R^F}{d\eta dk_T^2}$$

2.1 IR-part

$$\frac{d\sigma_R^{IR}}{d\eta dk_T^2} = -\frac{\alpha}{\pi} f_i(x_1, Q^2)[\Sigma_0 J(t,0) \log \frac{v_m}{\lambda\sqrt{s_0}}$$

$$+ \int\limits_0^{v_m} dv(\Sigma I[F^{IR}] - \Sigma_0 J(t,0)/v)]$$

Here $v = x_2(x_1 S + U)$

$$F^{IR} = \frac{m_l^2}{z^2} + \frac{e_i t}{z z_1} - \frac{e_{i'} u}{z u_1} + \frac{e_i^2 m_i^2}{z_1^2} - \frac{e_i e_{i'} s}{z_1 u_1} + \frac{e_{i'}^2 m_{i'}^2}{u_1^2}$$

$$I[A] = \frac{1}{\pi} \int \frac{d^3 k}{k_0} \delta[(p_1 + p_2 - k_1 - k)^2][A]$$

$$\Sigma_0 = \Sigma|_{x_2 = x_2^0} = \frac{\pi\alpha^2}{12 s_w^4} \frac{|V_{ii'}|^2 \hat{B}_{ii'} f_{i'}(x_2, Q^2)}{\hat{s}[(\hat{s} - m_W^2)^2 + m_W^2 \Gamma_W^2](x_1 S + U)}|_{x_2 = x_2^0}$$

Note that the sum

$$\frac{d\sigma_R^V}{d\eta dk_T^2} + \frac{d\sigma_R^{IR}}{d\eta dk_T^2}$$

is free from the infrared divergence.

2.2 Finite part

$$\frac{d\sigma_R^F}{d\eta dk_T^2} = \int dx_2 f_i(x_1, Q^2) f_{i'}(x_2, Q^2) \frac{d\hat{\Sigma}_R^F}{d\eta dk_T^2}$$

$$\frac{d\Sigma_R^F}{d\eta dk_T^2} = \frac{\alpha^3}{8 s_w^4 s} |V_{ii'}|^2 \int dt_1 dz (v_{ll} + v_{lq} + v_{qq} + v_{lw} + v_{qw} + v_{ww}).$$

The integration over

z, t_1 **— analytically**

x_1, x_2 **— numerically**

The indexes of v correspond to that particle which radiated the photon

l **— final lepton,**

q **— initial quarks,**

w **— W-boson**

Numerical results

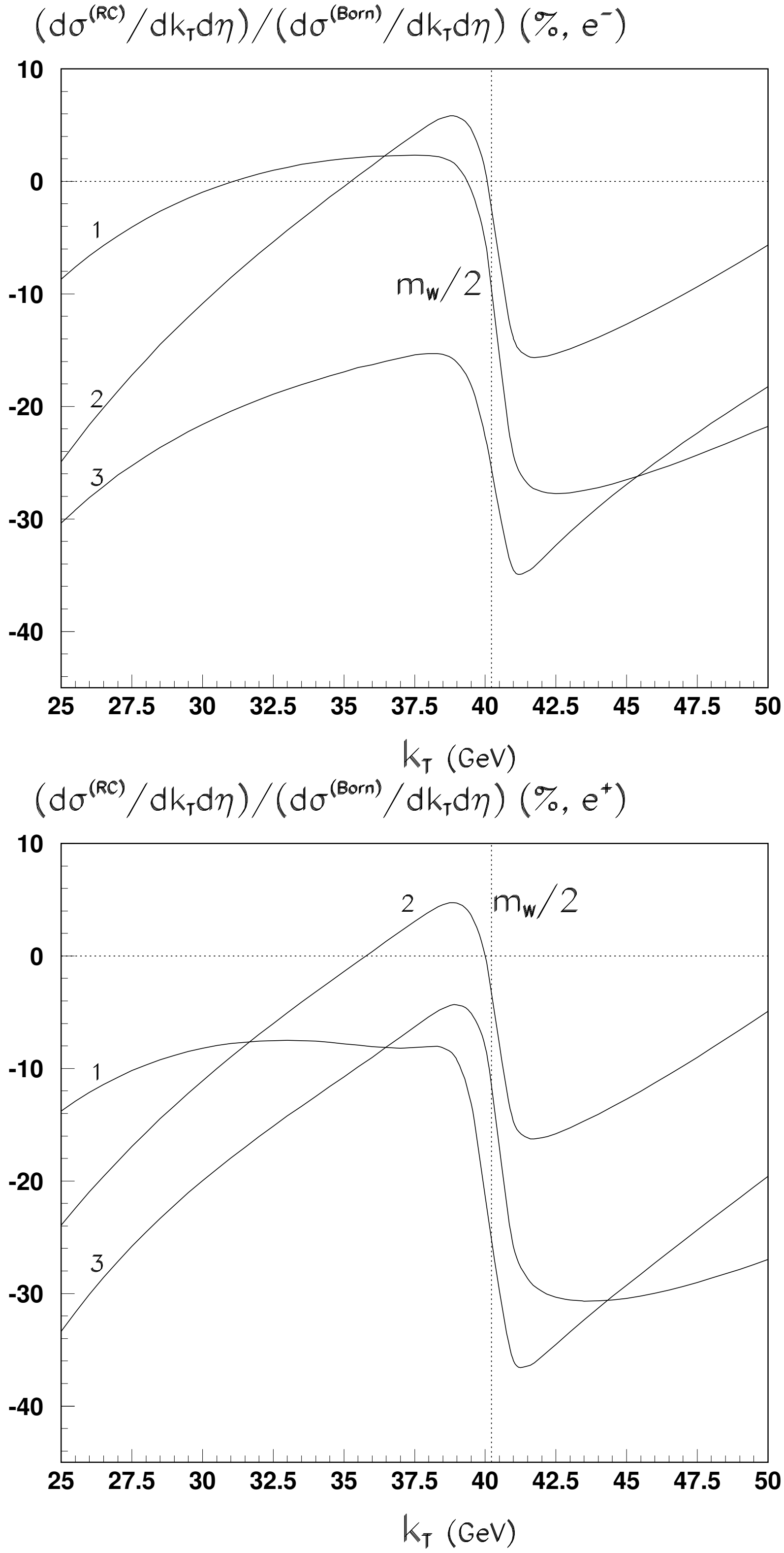

Figure 3: *The $\mathcal{O}(\alpha^3)$ and Born cross section ratio for $pp \to e^{\pm}X$ at $\sqrt{s} = 14$ TeV, (LHC). The numbers $1, 2, 3$, correspond lines with $\eta = -3, 0, 1.3$ respectively.*

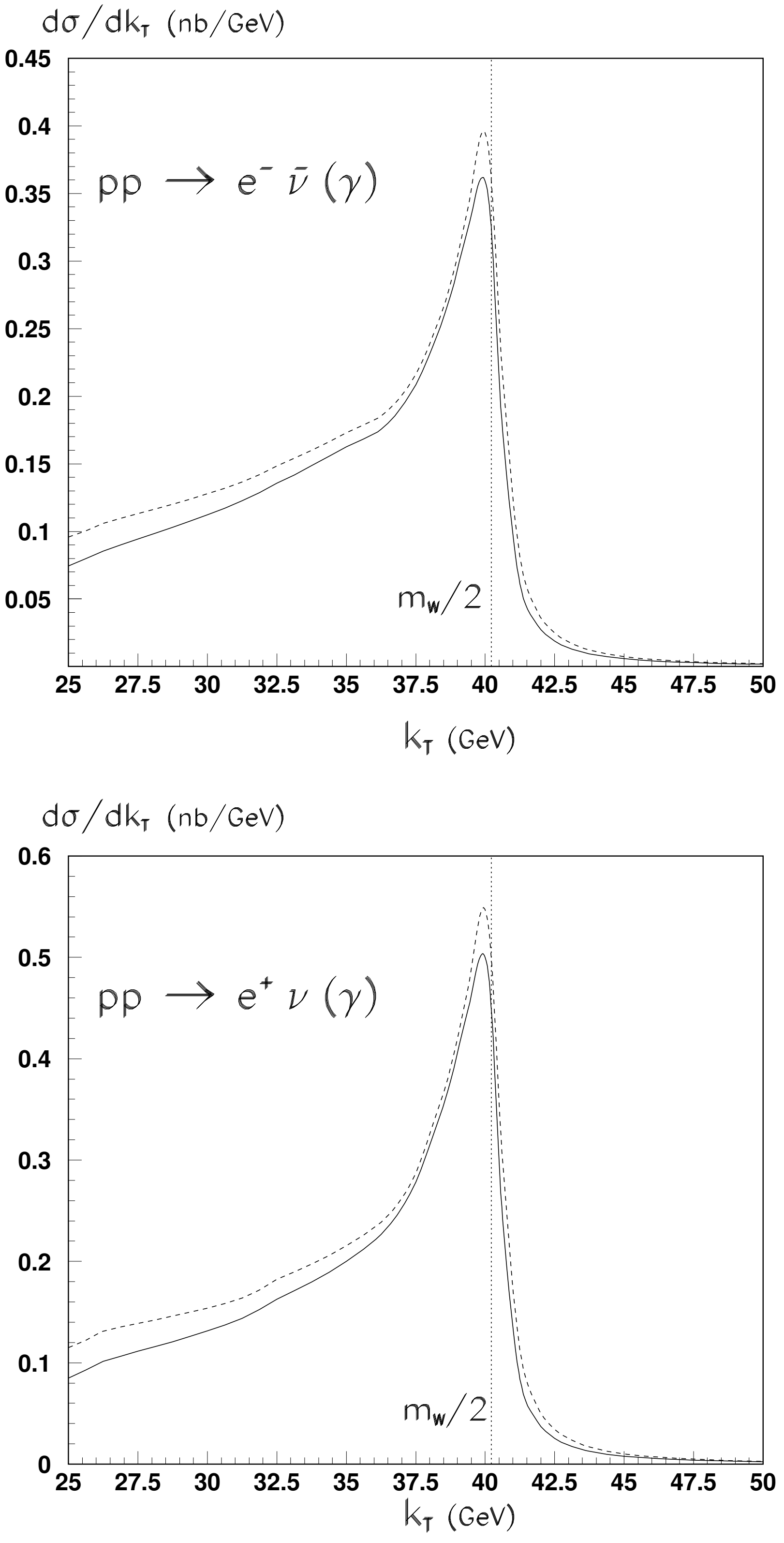

Figure 4: *Differential cross sections for $pp \to e^{\pm}X$ at $\sqrt{s} = 14$ TeV, $|\eta| < 5$ (LHC). The dashed(solid) lines show the distributions for lepton final states at Born level (including $\mathcal{O}(\alpha)$ electroweak corrections).*

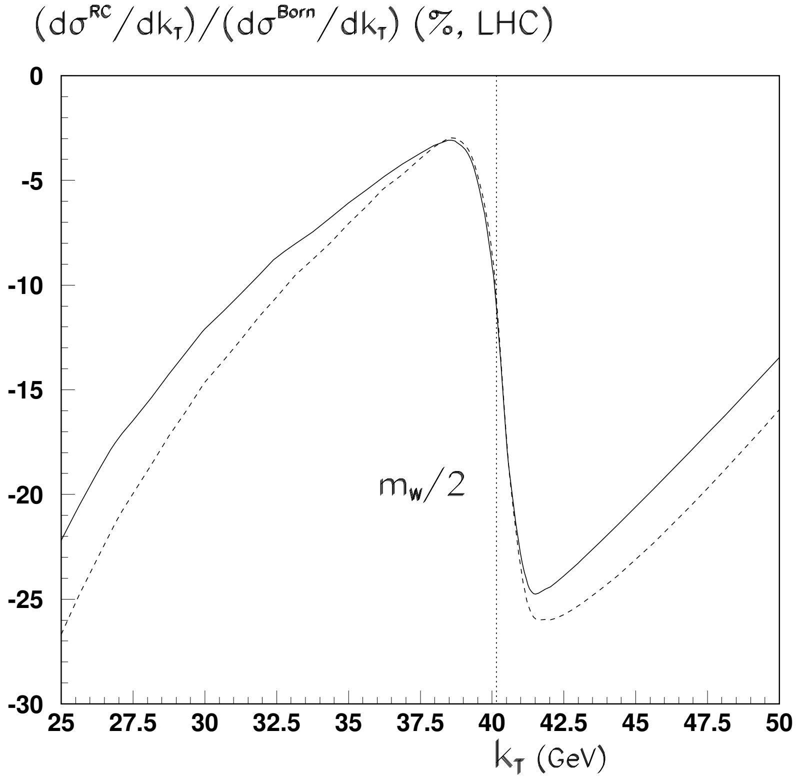

Figure 5: *The $\mathcal{O}(\alpha^3)$ and Born cross section ratio for $e^-\nu(\gamma)$-production (solid lines) and $e^+\nu(\gamma)$-production (dashed lines) whithin LHC kinematics.*

Conclusion

- The explicit expressions for the $\mathcal{O}(\alpha^3)$ EWRC to the single W-production in hadron-hadron collisions which do not depend on any unphysical parameters are obtained.

- The total EWRC decrease the cross section at the peak of the lepton momentum spectrum by about 12% for LHC both for the electron and positron final state.