QCD corrections to single top quark production in electron photon interactions

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Contents:

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Motivation

Single top quark production is important:

- Provides a possibility to measure the CKM-matrix element $|V_{tb}|^2$ directly
- At lepton colliders single top-quark production

$$e^+ \gamma \to t \, \bar{b} \, \bar{\nu}_e$$

- No $t\bar{t}$-background
  $\Rightarrow$ Clean environment to study single top quark production
- Process allows the measurement of $|V_{tb}|^2$ with high accuracy and with an uncertainty of 1% at 2σ level (E. Boos et al. '01)

  $\Rightarrow$ Knowledge of the QCD corrections mandatory

- Large $m_t \Rightarrow$ high energy scale $\Rightarrow$ pert. QCD reliable

  $\Rightarrow$ Test of the SM at high energies $\Rightarrow$ New physics ?

Preliminaries

- Describe process $e^+\gamma \to t\bar{b}\bar{\nu}_e$ through effective W-approximation
  Kane et al. '84; Dawson '85; Lindfors '85; Kunszt, Soper '88; Kauffman '89

- Consider momentum distribution of the W-bosons through structure function $f_{e/W}$

  Structure function distinguishes between longitudinal and transversal polarized W-bosons

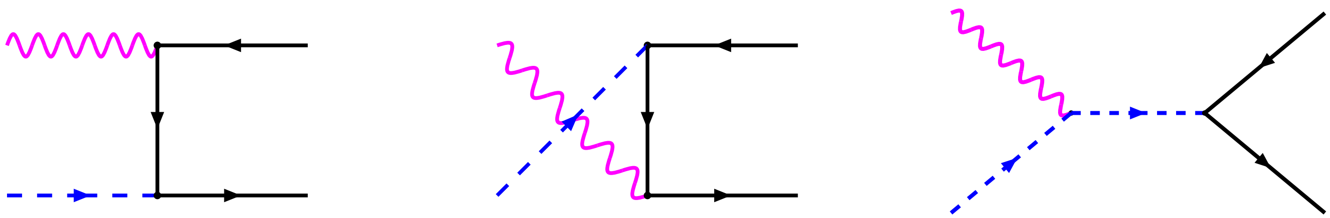
$\Rightarrow$ relevant process:

$$W^+_{\mathrm{l,t}}\,\gamma \longrightarrow t\,\bar{b}$$

- Cross section through convolution:

$$\sigma_{e^+\gamma\to t\bar{b}\bar{\nu}_e} \sim f_{e/W_i} \otimes \sigma_{W_i\,\gamma\to t\bar{b}}$$

Born process



⇒ Trivial calculation!

⇒ In principle it is possible to do it automatically

But:

Structure of logarithmic contributions

⇓

Analytical calculation important

Born results

$$\sigma_{\rm tot}^{T,L} = \frac{1}{9\sqrt{2}} \frac{\alpha\, G_f\, |V_{tb}|^2\, N}{(1-zw)^3} \frac{1}{\mathcal{N}_{T,L}} \left(l_1^{T,L} \ln\left(\frac{1+\beta_b}{1-\beta_b}\right) + l_2^{T,L} \ln\left(\frac{1+\beta_t}{1-\beta_t}\right) + K^{T,L} \right)$$

$$K^L = 2\,\lambda\,(1, z_b, z_t)\,\Big(28\, {z_b}^2 - 9\, z_t + 28\, {z_t}^2 - z_b\,(9 + 56\, z_t) + 2\, zw\,(18\, {z_b}^2 + 41\, z_t + 18\, {z_t}^2 + z_b\,(5 - 36\, z_t)) - {zw}^2\,(-8 + 12\, {z_b}^2 - 3\, z_b\,(1 + 8\, z_t) - 27\, z_t + 12\, {z_t}^2)\Big)$$

$$K^T = 4\, zw\,\lambda\,(1, z_b, z_t)\,\Big(- 24\, {z_b}^2 + 6\, z_b\,(3 + 8\, z_t) - 11 - 12\, z_t - 24\, {z_t}^2 - 2\, zw\,(-9\, {z_b}^2 + 3\, z_b\,(1 + 6\, z_t) + 5 + 15\, z_t - 9\, {z_t}^2) - {zw}^2\,(6\, {z_b}^2 - 12\, z_b\, z_t + 11 - 6\, z_t + 6\, {z_t}^2)\Big)$$

$$l_1^L = 2\,(-10\, {z_b}^3 - 2\, {z_b}^2\,(1 - 11\, z_t) + z_b\,(1 + 4\, z_t - 14\, {z_t}^2) + z_t - 2\, {z_t}^2 + 2\, {z_t}^3 - 2\, zw\,(19\, {z_b}^2 + {z_t}^2 + 4\, z_b\,(1 - 3\, z_t)) + {zw}^2\,(z_t - 7\, z_b))$$

$$l_2^L = 8\,(z_b - 2\, {z_b}^2 + 2\, {z_b}^3 + (1 + 4\, z_b - 8\, {z_b}^2)\, z_t - 2\,(1 - 5\, z_b)\, {z_t}^2 - 4\, {z_t}^3 + zw\,(-2\, {z_b}^2 - 2\,(4 - 9\, z_b)\, z_t - 20\, {z_t}^2) + {zw}^2\,(z_b - 7\, z_t))$$

$$l_1^T = 4\, zw\,\Big(1 + 14\, {z_b}^2 + 2\, z_b\,(1 - 8\, z_t) - 2\, z_t + 2\, {z_t}^2 + 2\, zw\,(7\, z_b - z_t) + {zw}^2\Big)$$

$$l_2^T = 16\, zw\,\Big(1 + 2\, {z_b}^2 - z_b\,(2 + 10\, z_t) + 2\, z_t + 8\, {z_t}^2 - 2\, zw\,(z_b - 4\, z_t) + {zw}^2\Big)$$

$z_i = m_i^2/s,\quad \beta_t = \lambda\,(1, z_b, z_t)\,/(1 + z_t - z_b),$ and $,\beta_b = \lambda\,(1, z_b, z_t)\,/(1 + z_b - z_t)$

Do we need to keep m_b ?

Resummation of $\log(\mathbf{m_b^2})$

- Initial state collinear singularity for $m_b = 0$
- In the case of massless b-quarks the singularity is absorbed in stucture functions:

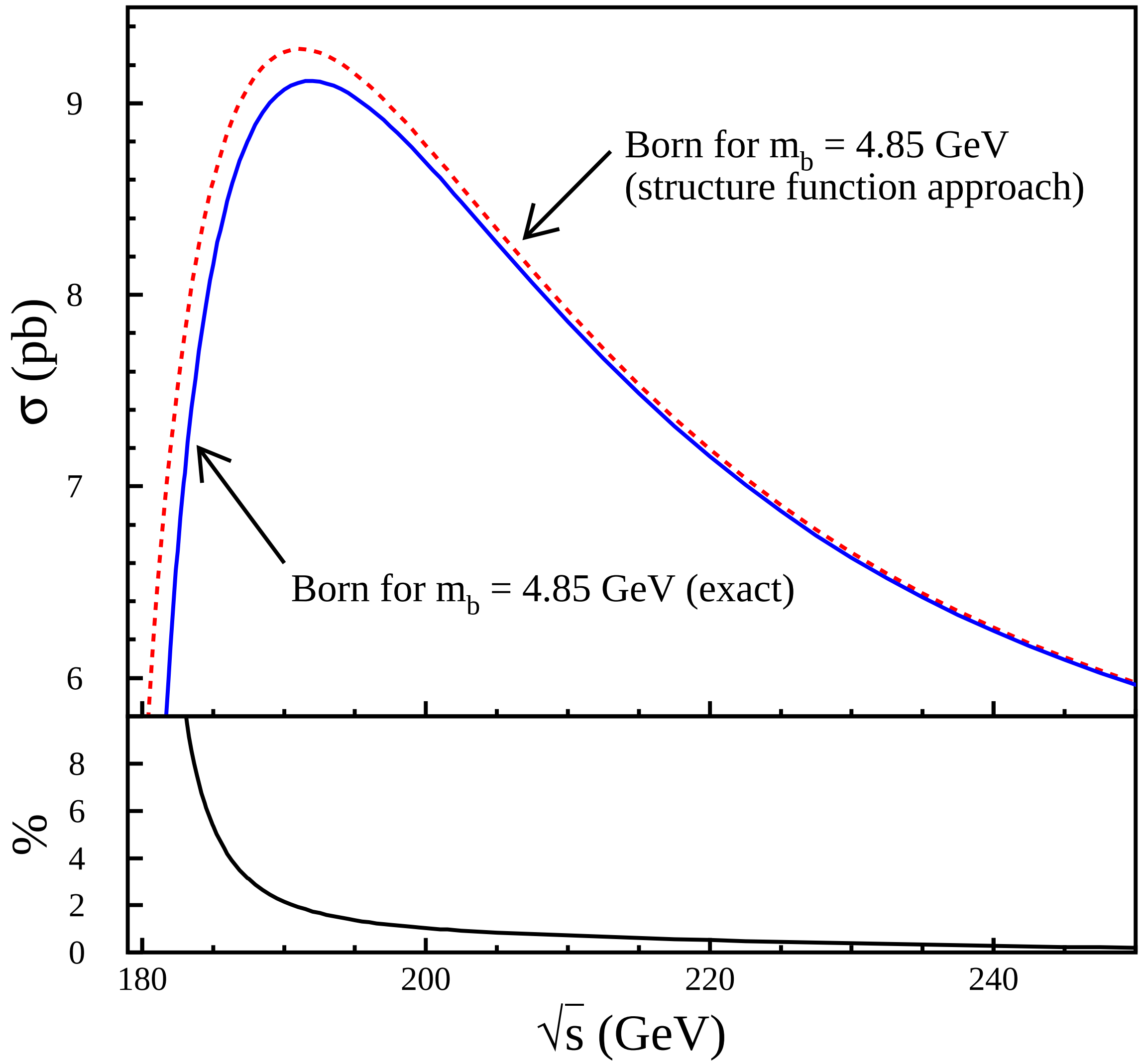
$$\begin{aligned} \sigma &= \int dx\, \Gamma_{\gamma/\gamma}(\mu_F, x) \times \hat{\sigma}(W^+(p_w)\gamma(xp_\gamma) \to t(p_t)\bar{b}(p_b)) \\ &+ \int dx\, \Gamma_{b/\gamma}(\mu_F, x) \times \hat{\sigma}(W^+(p_w)b(xp_\gamma) \to t(p_t)) \end{aligned}$$

- $\hat{\sigma}$: μ_F dependent, $\overline{\text{MS}}$ subtracted cross section
- Matching calculation gives:

$$\begin{aligned} \Gamma_{\gamma/\gamma}(\mu_F, x) &= \delta(1-x) + O(\alpha), \\ \Gamma_{b/\gamma}(\mu_F, x) &= \frac{\alpha}{2\pi} Q_b^2 (x^2 + (1-x)^2) \ln\left(\frac{\mu_F^2}{m_b^2}\right) + O(\alpha^2). \end{aligned}$$

- Resummation of the leading logarithms to all orders through evolution equations à la DGLAP

Fixed order versus structure functions



⇒ Finite b-quark mass is important, affects the location of the threshold

QCD corrections

Calculation of the QCD-corrections consists of 2 parts:

1.) Calculation of the virtual corrections to the process:

$$W^+ \gamma \to t \, \bar{b}$$

2.) Calculation of the real corrections:

$$W^+ \gamma \to t \, \bar{b} \, g$$

Combination of 1.) + 2.) yields finite result

Virtual corrections

Technicalities:

- Dimensional regularisation of the UV-singularities as well as of the IR-singularities (t'Hooft, Veltman; Marciano)
- Passarino-Veltman reduction of the tensor integrals to scalar one loop integrals
- Solution of the scalar integrals through Feynman-parametrisation
- Replacement of the scalar box integrals in $d = 4 - 2\,\varepsilon$ dimensions through:

$$D_0^{d=4-2\,\varepsilon} = \underbrace{a\,D_0^{d+2}}_{\text{IR finite}} + \underbrace{\sum_{i=1}^{4} b_i\,C_0^{i,d}}_{\text{IR divergent}}$$

$\Rightarrow$ algebraic complexity is reduced.

- IR- singularities in three-point integrals (C_0)
- UV- singularities in one-,two-point integrals (A_0, B_0)

Analytic result

As usual:

$$\text{Result} = \sum_{\text{i}} \text{Coefficient}_{\text{i}} \times \text{Scalar-integral}_{\text{i}}$$

Divergent parts:

$$\begin{aligned}\delta|\mathcal{M}_{1,d}|^2\big|_{\mathrm{UV-div.}} &= \frac{\alpha_s}{2\pi}\Gamma(1+\epsilon)C_F\left(\frac{4\pi\mu^2}{m_t m_b}\right)^{\epsilon}\frac{1}{\epsilon}|\mathcal{M}_0|^2 \\ &- 3\,\frac{\alpha_s}{\pi}\Gamma(1+\epsilon)C_F\left(\frac{4\pi\mu^2}{m_t m_b}\right)^{\epsilon}\frac{1}{\epsilon}F(z_w,z_b,z_t) \\ \delta|\mathcal{M}_{1,d}|^2\big|_{\mathrm{IR-div.}} &= \frac{\alpha_s}{\pi}C_F\,(z_b+z_t-1)\,(2\pi\mu)^{2\epsilon}\mathrm{Re}C_0(1,2,3)\;s\sum_{\text{Pol.}}|\mathcal{M}_{0,\mathrm{d}}|^2\end{aligned}$$

the finite parts are a little bit lengthier. . .

Finite part:

$$\sum_{\text{Spins}} M_{fi}^{1-\text{loop}} M_{fi}^{*\,\text{Born,d}}\Big|_{\text{finite}} = \frac{e^4 g_s^2}{2\sin^2\theta_w}\,|V_{tb}|^2\,\big[-8/9\,D_0^6\,(2t_{bg}-t_{tg})\,(-3m_b^4 m_t^2 t_{bg}^2+3t_{bg}^2 m_b^6-2m_b^4 t_{bg}^3+12t_{bg}^3 m_w^4+3m_t^6 t_{bg}^2-4t_{t}$$

$$m_b^6 t_{tg}^2-2m_t^4 t_{bg}^3+m_b^2 t_{tg}^3 t_{bg}+m_t^2 t_{tg}^3 t_{bg}-2m_b^8 t_{bg}+4m_w^8 t_{bg}+12m_w^6 t_{bg}^2+4t_{bg}^4 m_w^2+m_t^2 t_{bg}^4+m_b^2 t_{bg}^4-7m_t^2 t_{bg}^3 m_w^2+4m_b^4 m_t^4 t_{tg}+3$$

$$m_w^2-5m_t^4 t_{tg} t_{bg}^2+2m_b^6 t_{bg} m_w^2+12m_b^4 t_{tg} m_w^4-10m_b^2 m_w^6 t_{bg}+4m_b^4 t_{tg}^2 m_w^2+16t_{tg} t_{bg}^2 m_w^4-10m_t^2 t_{bg} m_w^6-4m_b^2 m_t^6 t_{tg}+2m_t^6 t_{bg} m_w^2+$$

$$m_t^4 t_{bg}+4m_b^2 t_{tg}^2 m_t^4-3m_t^4 t_{tg}^2 t_{bg}+6t_{tg}^2 t_{bg} m_w^4+4m_b^6 t_{tg} m_t^2-18m_t^2 t_{bg}^2 m_w^4+8t_{tg} t_{bg} m_b^6+6m_t^4 t_{bg} m_w^4-8m_b^2 t_{tg}^2 m_w^4+3m_t^4 t_{bg}^2 m_w^2-$$

$$t_{tg}^2 t_{bg}+8t_{tg} t_{bg} m_w^6-7m_b^2 t_{bg}^3 m_w^2+3m_b^2 t_{tg}^2 t_{bg}^2+4t_{tg} t_{bg} m_t^6-5m_b^4 t_{bg}^2 t_{tg}+6m_b^4 t_{bg} m_w^4+3m_b^4 t_{bg}^2 m_w^2-8m_b^2 t_{tg} m_w^6+6t_{tg}^2 t_{bg}^2 m_w^2-1$$

$$m_b^2 t_{tg}+3m_t^2 t_{bg}^3 t_{tg}-3m_t^4 t_{bg}^2 m_b^2-10m_b^2 t_{bg} m_w^2 m_t^4-16m_b^4 t_{tg} m_w^2 m_t^2+10m_t^2 t_{bg}^2 m_w^2 m_b^2-8m_b^2 t_{bg}^2 m_w^2 t_{tg}-3m_b^2 t_{tg}^2 m_w^2 t_{bg}+12m_t^2 t_{tg}$$

$$m_w^4 m_t^2+4m_b^2 t_{tg}^2 m_w^2 m_t^2-12t_{tg} t_{bg} m_w^4 m_t^2+20t_{bg} m_b^2 m_t^2 t_{tg} m_w^2-20t_{tg} t_{bg} m_w^4 m_b^2-8m_t^2 t_{bg}^2 t_{tg} m_w^2-3m_t^2 t_{tg}^2 t_{bg} m_w^2+2m_b^2 m_t^2 t_{tg} t_{bg}^2+$$

$$m_b^4 t_{tg} t_{bg} m_t^2+4m_b^4 t_{tg} t_{bg} m_w^2-10m_b^4 m_t^2 t_{bg} m_w^2)\,(-m_b^2 t_{tg}^2-m_t^2 t_{bg}^2+t_{bg} m_w^2 t_{tg}-m_b^2 t_{tg} t_{bg}-m_t^2 t_{bg} t_{tg}+t_{tg}^2 t_{bg}+t_{bg}^2 t_{tg})/m_w^2/t_{bg}^3/(2m$$

$$m_t^2+t_{tg}+t_{bg})/(-2m_b m_t+m_w^2-m_b^2-m_t^2+t_{tg}+t_{bg})/t_{tg}/(t_{tg}+t_{bg})-2/9\,B_0(1,2)\,(16t_{tg}^6 m_w^{16} m_b^2-56t_{bg}^2 t_{tg}^7 m_w^{12}+135t_{tg}^5 t_{bg}^7 m_t^6-$$

$$m_t^{12} m_w^2-152t_{tg}^6 m_b^6 m_w^{10} m_t^2+m_t^4 t_{tg}^7 m_w^8 t_{bg}^2-3m_t^{10} t_{bg}^2 t_{tg}^8-129t_{bg}^9 m_t^2 t_{tg}^3 m_w^4+12m_t^8 t_{tg}^7 m_b^4 m_w^4-84m_b^{16} t_{tg}^4 m_w^2 t_{bg}^2+15m_t^{12} t_{bg}^2 t_{tg}^7-24$$

$$t_{bg}^9 t_{tg}^2 m_w^8+32m_w^{20} t_{tg}^3 t_{bg}^2-1360t_{tg}^2 t_{bg}^7 m_w^{12}-136m_t^{14} t_{bg}^7 m_w^2+80t_{tg}^6 m_b^{10} m_w^8-16m_t^{10} t_{tg}^7 m_b^2 m_w^4+453t_{bg}^7 m_b^6 m_t^2 t_{tg}^4-496m_b^6 t_{bg}^8 t_{tg}^2 m_w^4$$

$$m_b^2+2652t_{bg}^7 m_t^4 t_{tg}^2 m_w^6 m_b^2-846t_{bg}^7 m_t^2 m_b^4 t_{tg}^4 m_w^2+652t_{tg}^5 t_{bg}^5 m_t^2 m_w^6 m_b^2-532t_{tg} t_{bg}^4 m_t^{12} m_w^2 m_b^6+32t_{tg}^2 t_{bg}^5 m_t^8 m_w^6 m_b^2+978t_{tg}^5 t_{bg}^4 m_t$$

$$t_{bg}^4 m_t^8 m_w^6 m_b^4-349t_{bg}^3 t_{tg}^5 m_t^6 m_w^8-552m_t^{12} t_{bg}^6 m_w^4 t_{tg}-16m_b^{16} t_{tg}^3 m_w^4 t_{bg}^2-578m_t^6 t_{bg}^3 t_{tg}^4 m_w^{10}+202m_t^4 t_{bg}^3 t_{tg}^5 m_w^{10}-111m_t^{12} t_{tg}^2 t_{bg}^5 m_w^4$$

$$m_b^2+440t_{tg}^4 t_{bg}^4 m_t^8 m_w^4 m_b^2+2236t_{tg}^4 t_{bg}^4 m_t^6 m_w^6 m_b^2+9640m_t^4 t_{bg}^6 m_w^6 m_b^6 t_{tg}-1488m_t^8 t_{bg}^5 m_w^6 m_b^6-1440m_t^8 t_{bg}^4 m_w^4 m_b^{10}+224m_t^4 t_{bg}^4 m$$

$$m_w^6 m_b^{10}+288m_t^8 t_{bg}^4 m_w^6 m_b^8+4359t_{tg}^4 m_b^8 t_{bg}^3 m_t^4 m_w^4+560m_t^{10} t_{bg}^7 m_w^4 t_{tg}-3808m_t^{10} t_{bg}^4 m_w^8 t_{tg} m_b^2-2688m_t^{10} t_{bg}^5 m_w^8 t_{tg}-142t_{tg}^6 m_b^8 t_{bg}$$

$$t_{bg}^3 m_w^4 m_t^2-4344m_t^4 t_{bg}^5 m_w^{14} t_{tg}+200m_t^{14} t_{bg}^5 m_w^4 t_{tg}+36t_{tg}^8 m_b^2 t_{bg}^3 m_w^6+7508m_t^4 t_{bg}^4 m_w^{14} t_{tg} m_b^2+8t_{tg}^6 t_{bg}^4 m_w^4 m_b^6-880t_{tg}^6 t_{bg}^5 m_w^2 m_b^4 m_t^2$$

$$t_{tg}-5560m_t^4 t_{bg}^6 m_w^{12} t_{tg}+846t_{bg}^3 t_{tg}^3 m_t^6 m_w^{12}+40t_{tg}^4 m_w^{18} t_{bg}^2+8t_{tg}^7 t_{bg}^6 m_w^4-9m_t^{16} t_{tg}^2 t_{bg}^5+1080t_{bg}^7 m_t^6 m_w^{10}+144t_{tg}^5 t_{bg}^6 m_w^8+16t_{bg}^{11} m$$

$$t_{bg}^8-800m_t^{10} t_{bg}^6 m_w^8+9500m_t^4 t_{bg}^4 m_w^{10} m_b^6 t_{tg}+602t_{tg}^6 t_{bg}^4 m_w^2 m_b^6 m_t^2-3307t_{tg}^3 t_{bg}^4 m_t^{10} m_w^6-1888m_t^6 t_{bg}^4 m_w^8 m_b^6 t_{tg}-936t_{bg}^3 t_{tg}^3 m_t^8 m_w^{10}+$$

$$t_{tg}+1984m_t^8 t_{bg}^6 m_w^8 t_{tg}-90t_{tg}^6 m_b^4 m_t^8 t_{bg}^3-12888m_t^6 t_{bg}^5 m_w^{10} t_{tg} m_b^2+3420m_t^6 t_{bg}^6 m_w^{10} t_{tg}+3440m_t^8 t_{bg}^5 m_w^8 t_{tg} m_b^2-7528m_t^4 t_{bg}^6 m_w^4 m_b^8$$

$$m_w^4-728m_t^{10} t_{bg}^6 m_w^6 t_{tg}+64t_{tg}^5 m_b^{14} m_w^2 t_{bg}^2+573t_{tg}^2 t_{bg}^5 m_t^{10} m_w^4 m_b^2-112m_t^6 t_{tg}^7 m_w^6 t_{bg}^2-8t_{tg}^8 m_b^6 m_w^4 t_{bg}^2-36t_{tg}^8 t_{bg}^3 m_t^4 m_b^4+719m_t^{12} t_{tg}^5 m$$

$$t_{tg}^3 t_{bg}^2+35m_t^8 t_{tg}^5 m_w^8 t_{bg}^2-103m_t^6 t_{tg}^6 m_w^8 t_{bg}^2-176m_t^{14} t_{tg}^3 m_w^6 t_{bg}^2+156m_t^{16} t_{tg}^4 m_w^2 t_{bg}^2+4760m_t^{1}0 t_{bg}^5 m_w^2 m_b^8-252m_t^{14} t_{tg}^3 m_b^4 t_{bg}^2 m_w^2-5$$

$$800m_t^6 t_{bg}^4 m_w^4 m_b^{12}+1184t_{tg}^3 m_b^4 t_{bg}^3 m_w^{14}-72m_t^6 t_{bg}^5 t_{tg}^5 m_b^4+98m_t^6 t_{tg}^6 m_b^2 t_{bg}^3 m_w^4-2m_t^6 t_{tg}^7 m_b^2 t_{bg}^3 m_w^2+188t_{tg}^3 t_{bg}^5 m_t^{12} m_w^2+1580m_t^4 t_{tg}^3$$

$$t_{tg}^4 m_b^2 m_t^6 t_{bg}^3 m_w^8+168m_t^{12} t_{bg}^7 m_w^2 t_{tg}-448m_t^6 t_{bg}^7 m_w^8 t_{tg}+2564m_t^8 t_{tg}^3 t_{bg}^4 m_w^2 m_b^6-3880m_t^8 t_{tg}^3 t_{bg}^5 m_w^2 m_b^4+3156m_t^8 t_{tg}^3 t_{bg}^5 m_w^6-213t_{tg}^4 t$$

$$m_b^6 m_t^8 t_{bg}^2+432m_t^6 t_{bg}^4 t_{tg}^5 m_b^6-308m_t^8 t_{tg}^6 m_b^2 t_{bg}^3 m_w^2-42m_t^6 t_{tg}^7 m_b^6 t_{bg}^2-1017t_{tg}^5 m_b^2 m_t^{10} m_w^4 t_{bg}^2+119t_{tg}^7 m_b^8 m_w^2 m_t^2 t_{bg}^2+560m_w^{16} t_{tg}^3 m_b^4 t$$

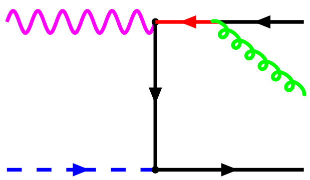
$$m_w^2 m_b^4+888m_t^{14} t_{tg} t_{bg}^5 m_w^2 m_b^2+3856m_t^4 t_{tg}^4 m_b^4 t_{bg}^2 m_w^{10}-2394m_t^4 t_{tg}^4 m_b^2 t_{bg}^3 m_w^{10}-980m_t^{14} t_{tg} t_{bg}^4 m_w^6-346m_t^6 t_{tg}^5 t_{bg}^5 m_w^4+3296m_t^8 t_{tg}^4 t$$

$$t_{bg}^3 m_w^6 m_b^2+224m_t^6 t_{tg}^6 t_{bg}^5 m_w^2+261m_t^{10} t_{tg}^4 t_{bg}^4 m_b^4-34m_t^8 t_{tg}+\ldots$$

$$t_{ij} = 2\,(p_i\cdot p_j)$$

Real corrections

- IR-singularities from phase space integration through soft gluon



Denominator of the propagator:
$-2E_g E_b(1-\beta\cos\theta_{bg})$
$\Rightarrow$ Vanishes for $E_g = 0$

- Factorisation in the limit $p_g \to 0$:

$$\mathcal{M}_0(p_\gamma, p_w, p_t, p_b, p_g) \stackrel{p_g\text{soft}}{\longrightarrow} \mathcal{S}(p_t, p_g, p_b) \times \mathcal{M}_0(p_\gamma, p_w, p_t, p_b)$$

with the eikonal factor

$$\mathcal{S}(p_i, p_s, p_j) = \frac{2\,(p_i \cdot p_j)}{(p_i \cdot p_s)\,(p_j \cdot p_s)} - \frac{(p_i \cdot p_i)}{(p_i \cdot p_s)^2} - \frac{(p_j \cdot p_j)}{(p_j \cdot p_s)^2}.$$

$\Rightarrow$ Consistency check of the amplitudes

- Extraction of the singularities:
  1.) Decomposition of the phase space
  2.) Dipol subtraction method for massive quarks

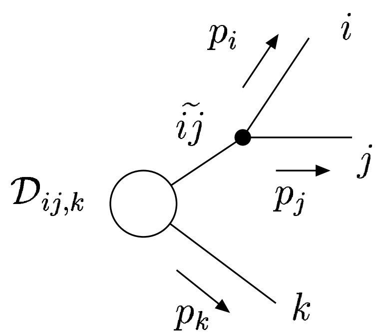
Phaf, Weinzierl '01,
Catani et al. '02

Dipol subtraction method

Basic idea:

$$\sigma^{\mathsf{NLO}} = \int_{m+1} \left[\left(\mathrm{d}\sigma^{\mathrm{R}}\right)_{\epsilon=0} - \left(\mathrm{d}\sigma^{\mathsf{sub}}\right)_{\epsilon=0} \right] + \int_m \left[\mathrm{d}\sigma^{\mathrm{V}} + \int_1 \mathrm{d}\bar{\sigma}^{\mathsf{sub}} \right]_{\epsilon=0}$$

- Construction of $\mathrm{d}\sigma^{\mathsf{sub}}$ — Catani et al. '02



"Dipol"
$(\widetilde{ij}, k)$

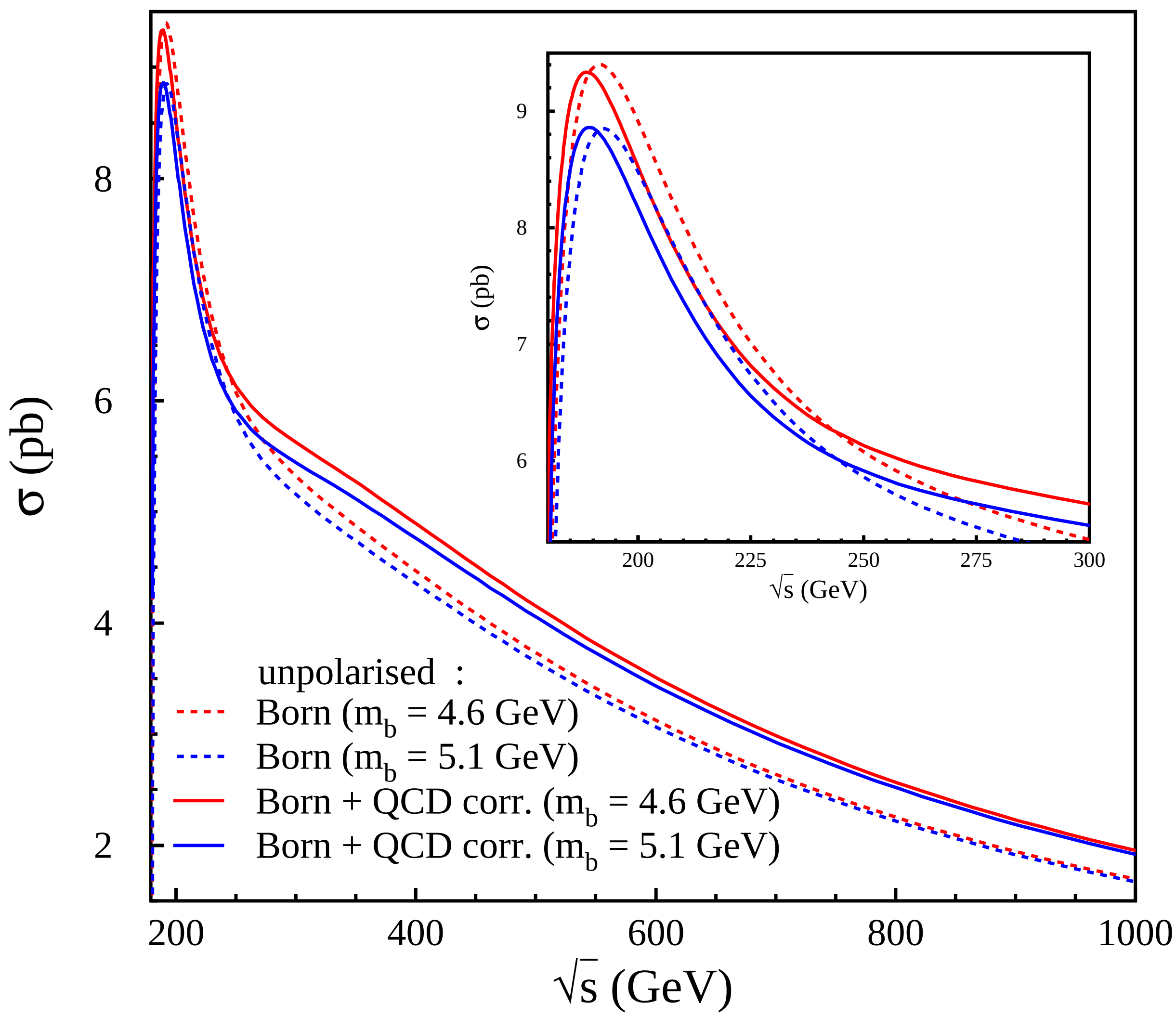
$$\int_{m+1} \mathrm{d}\sigma^{\mathsf{sub}} = \sum_{\mathrm{dipoles}} \int_{m+1} \mathrm{d}\sigma^{\mathsf{LO}} \otimes \mathcal{D}_{\mathrm{ij,k}}$$

- Construction of $\mathrm{d}\bar{\sigma}^{\mathsf{sub}}$: $\int_1 \mathrm{d}\bar{\sigma}^{\mathsf{sub}} = \sigma^B \otimes I$

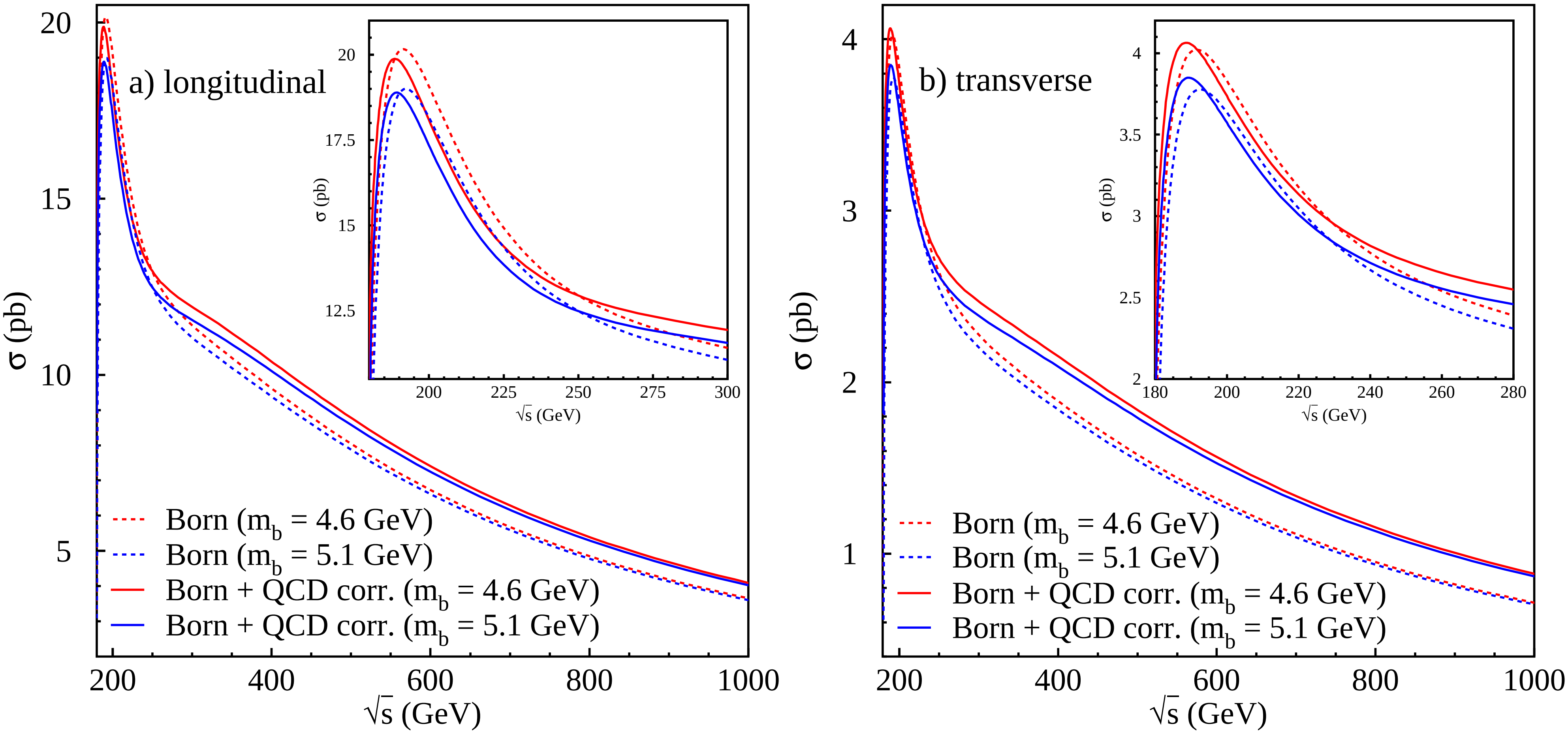
Checks

- Check of the analytical results of the infrared finite scalar integrals with FF Oldenborgh
- D_0-Box checked with the analytic result of Beenakker, Denner
- Coefficients of the scalar one- and two-point integrals checked by UV renormalisation
- Check of the IR divergent integrals and their coefficients through the cancellation with those from Catani et al.
- Factorisation in d dimensions checks the treatment of the γ-matrices in d dimensions
- High degree of automatisation

Results: Total cross section

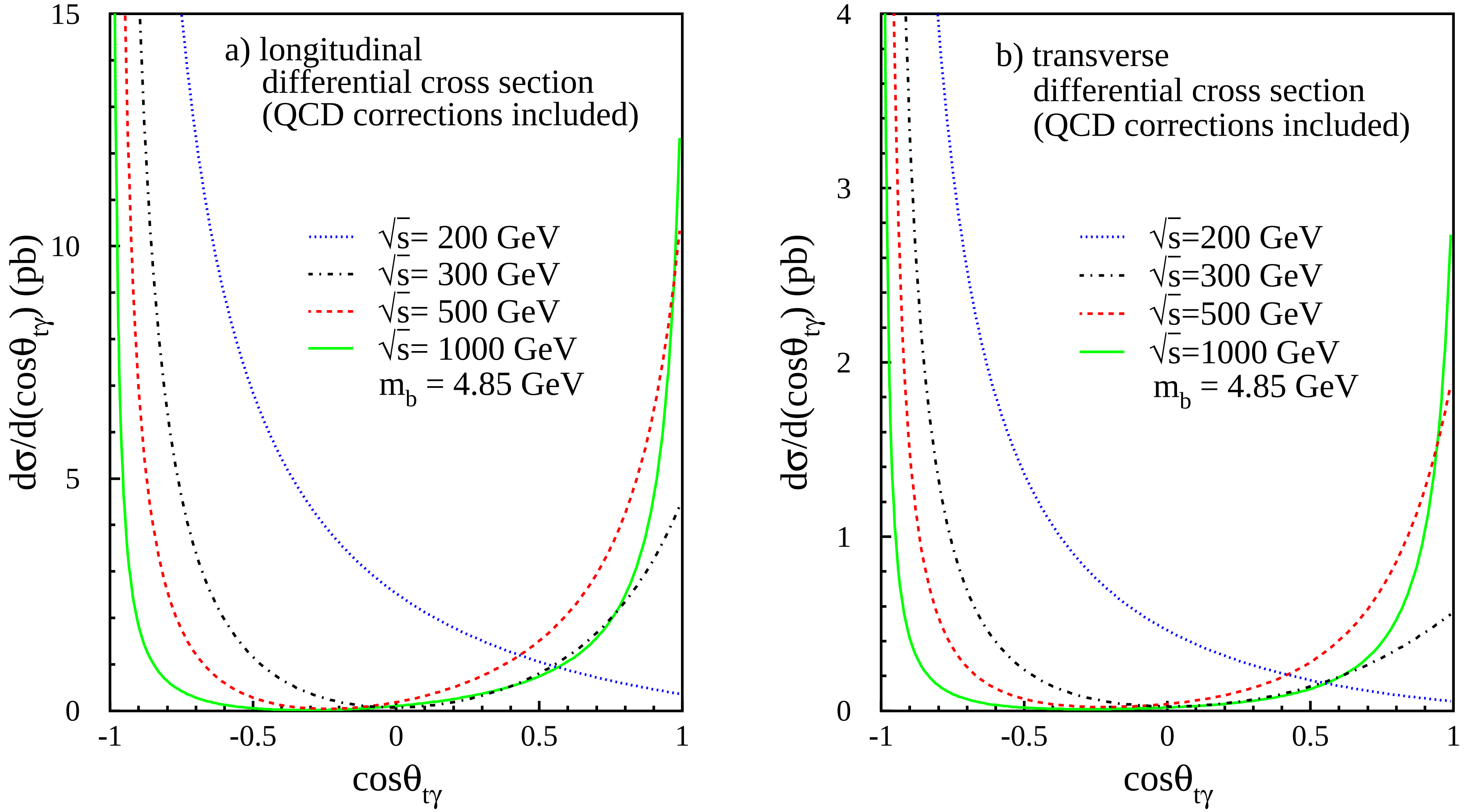


Results



Cross section for longitudinally and transversly polarized W-bososns

Differential cross section



$\Rightarrow$ initial state singularity

Dipol subtraction method allows the calculation of the QCDcorrections for aribtrary observables!

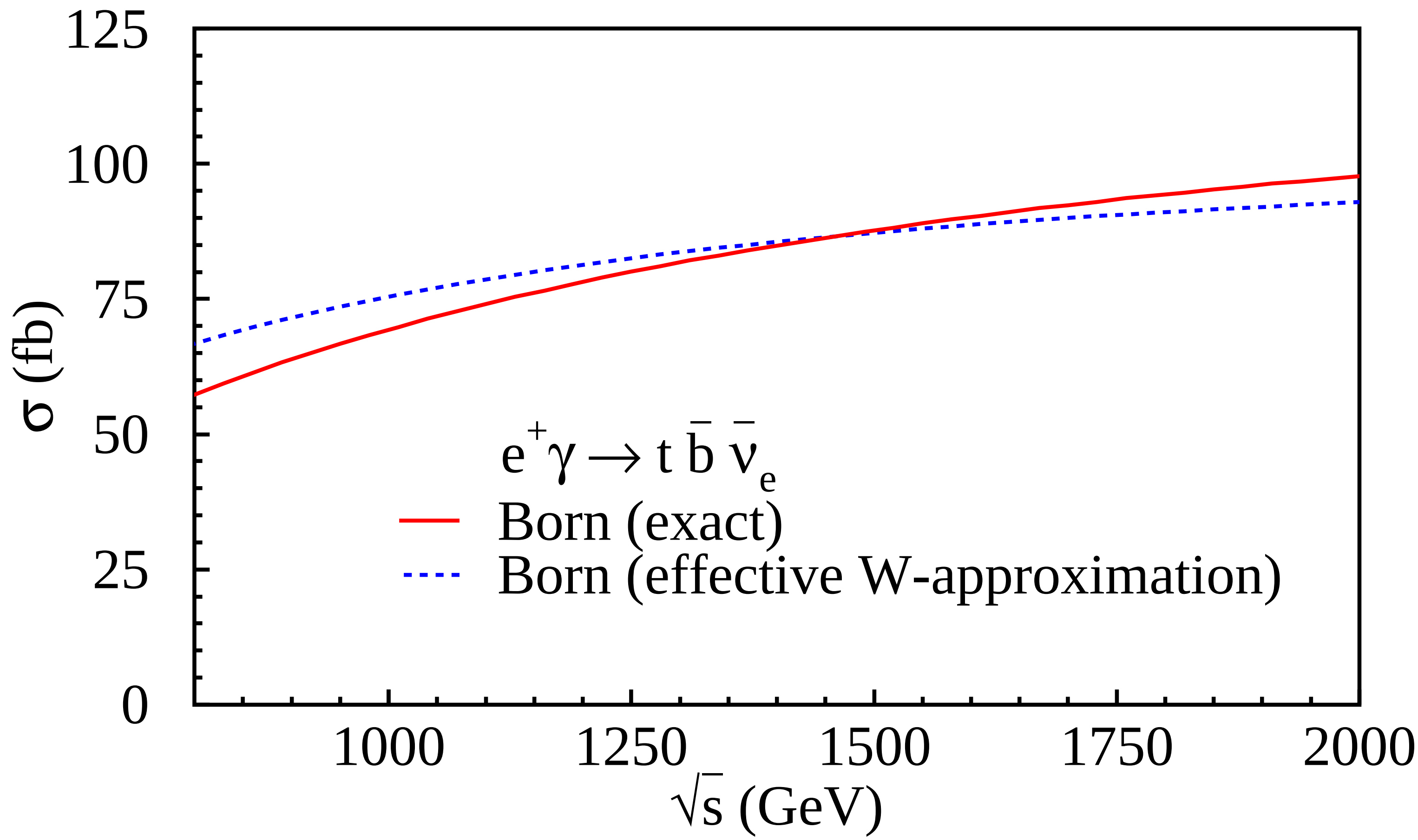
QCD Logarithms

- QCD corrections generate $\alpha_s \times \log(m_b)$ term
- In principle they need to be resummed
  $\Rightarrow$ Same framework like the LO-Resummation

  Ingredients:

  – Mixed evolution
  – QCD corrections to structure functions
- These Logarithms are not expected to be large!

Implementation of the distribution functions

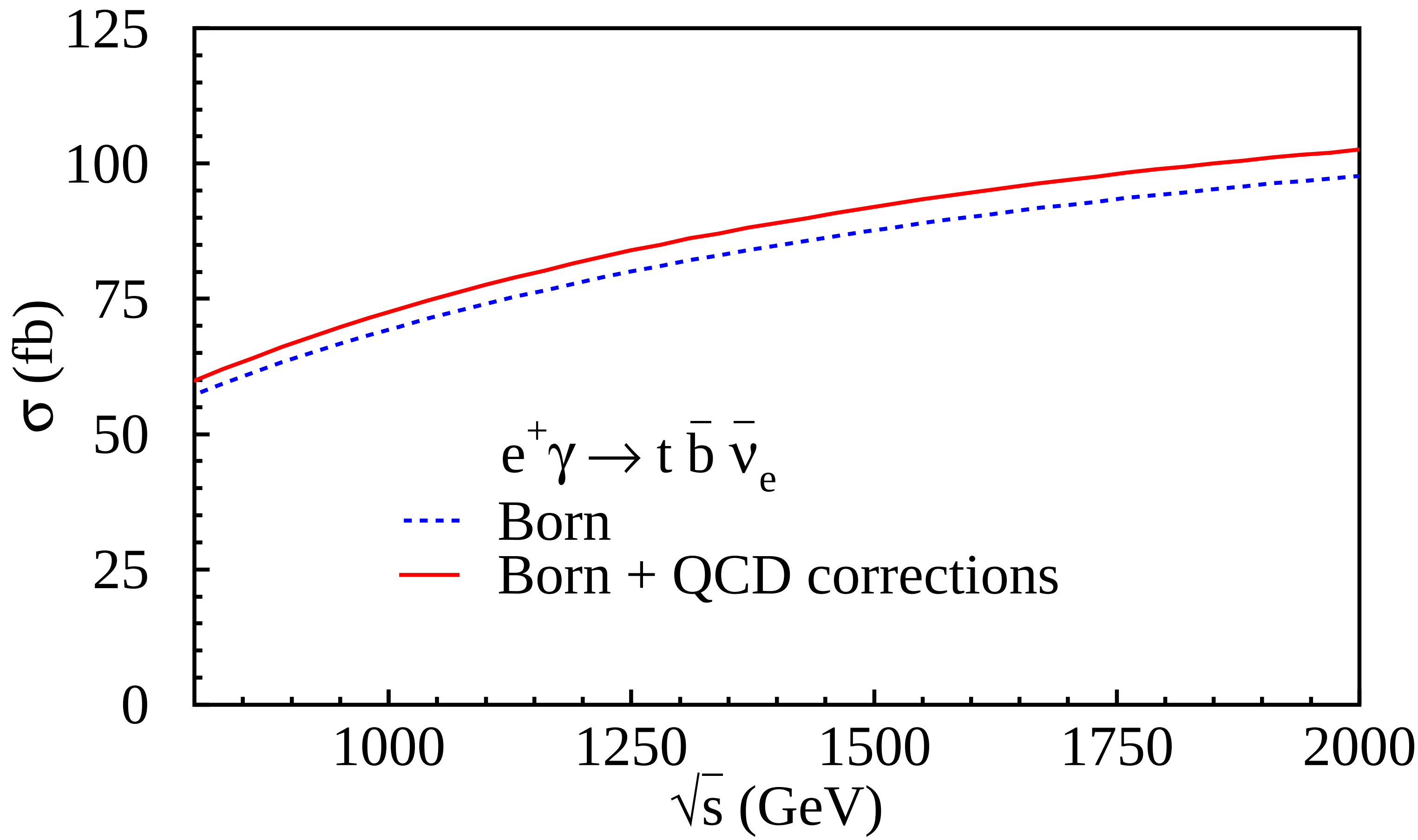


$\Rightarrow$ Quality 10% for $\sqrt{s}$ =900 GeV

$\longrightarrow$ use exact result in LO!

$\longrightarrow$ use W-approximation only for the QCD corrections!

QCD corrections for $e^+\gamma \to t\bar{b}\bar{\nu}$



Conclusions

- Dependence of the b-quark mass of the process $W^+\gamma \to t\bar{b}$ has been studied
  $\to$ b-quark mass effects important in threshold region

- QCD corrections of the process $W^+\gamma \to t\bar{b}$ have been calculated
  $\to$ corrections of the order of 10-20%

- QCD-NLO prediction for $e^+\gamma \to t\bar{b}\bar{\nu}_e$ in the effective W-approximation has been made
  $\to$ QCD corrections are of the order 5%
  $\to$ important for precise measurements of $|V_{tb}|$