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

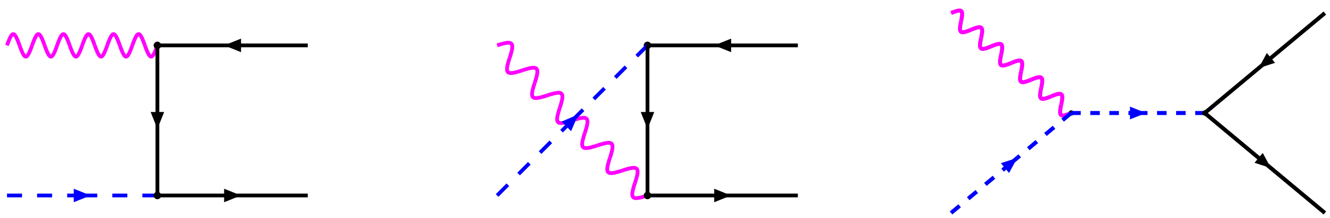
$\Rightarrow$ relevant process:

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

- 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

$\Downarrow$

Analytical calculation important

Born results

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

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

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

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

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

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

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

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

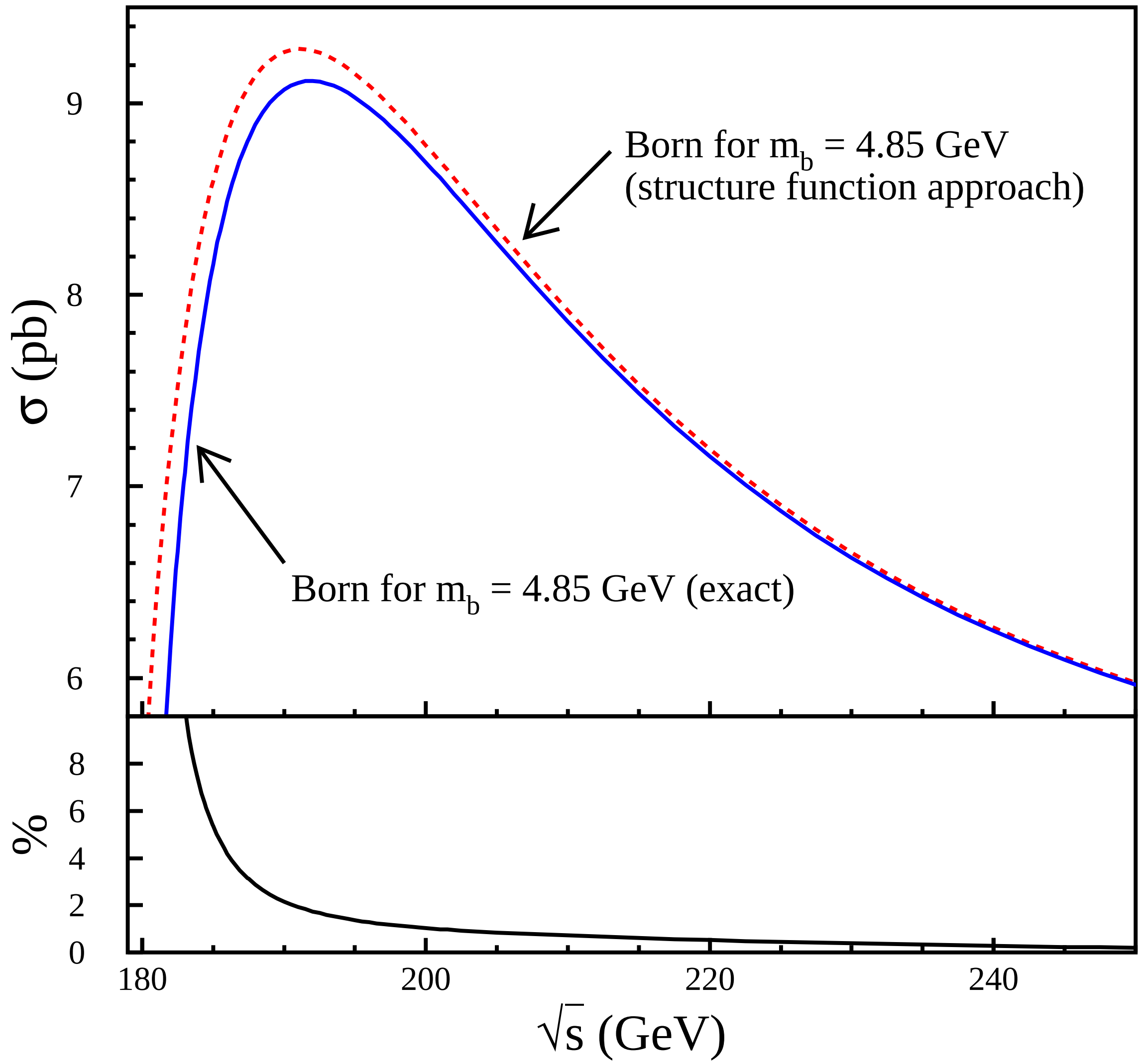
$$\begin{aligned} \sigma &= \int dx\, \Gamma_{\gamma/\gamma}(\mu_F, x) \times \hat{\sigma}(W^+(p_w)\gamma(xp_\gamma) \to t(p_t)\bar{b}(p_b)) \\ &+ \int dx\, \Gamma_{b/\gamma}(\mu_F, x) \times \hat{\sigma}(W^+(p_w)b(xp_\gamma) \to t(p_t)) \end{aligned}$$

- $\hat{\sigma}$: 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:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

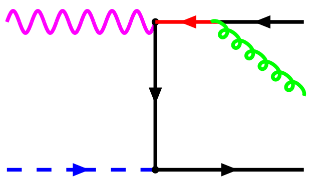
$$m_w^2 m_b^4 + 888 m_t^{14} t_{tg} t_{bg}^5 m_w^2 m_b^2 + 3856 m_t^4 t_{tg}^4 m_b^4 t_{bg}^2 m_w^{10} - 2394 m_t^4 t_{tg}^4 m_b^2 t_{bg}^3 m_w^{10} - 980 m_t^{14} t_{tg} t_{bg}^4 m_w^6 - 346 m_t^6 t_{tg}^5 t_{bg}^5 m_w^4 + 3296 m_t^8 t_{tg}^4 t$$

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

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

Real corrections

- IR-singularities from phase space integration through soft gluon



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

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

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

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

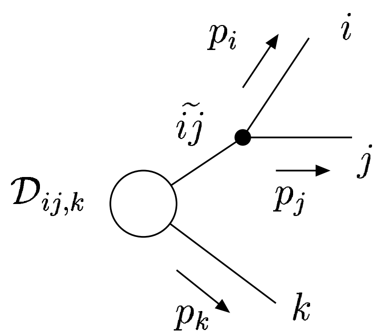
Phaf, Weinzierl '01,
Catani et al. '02

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

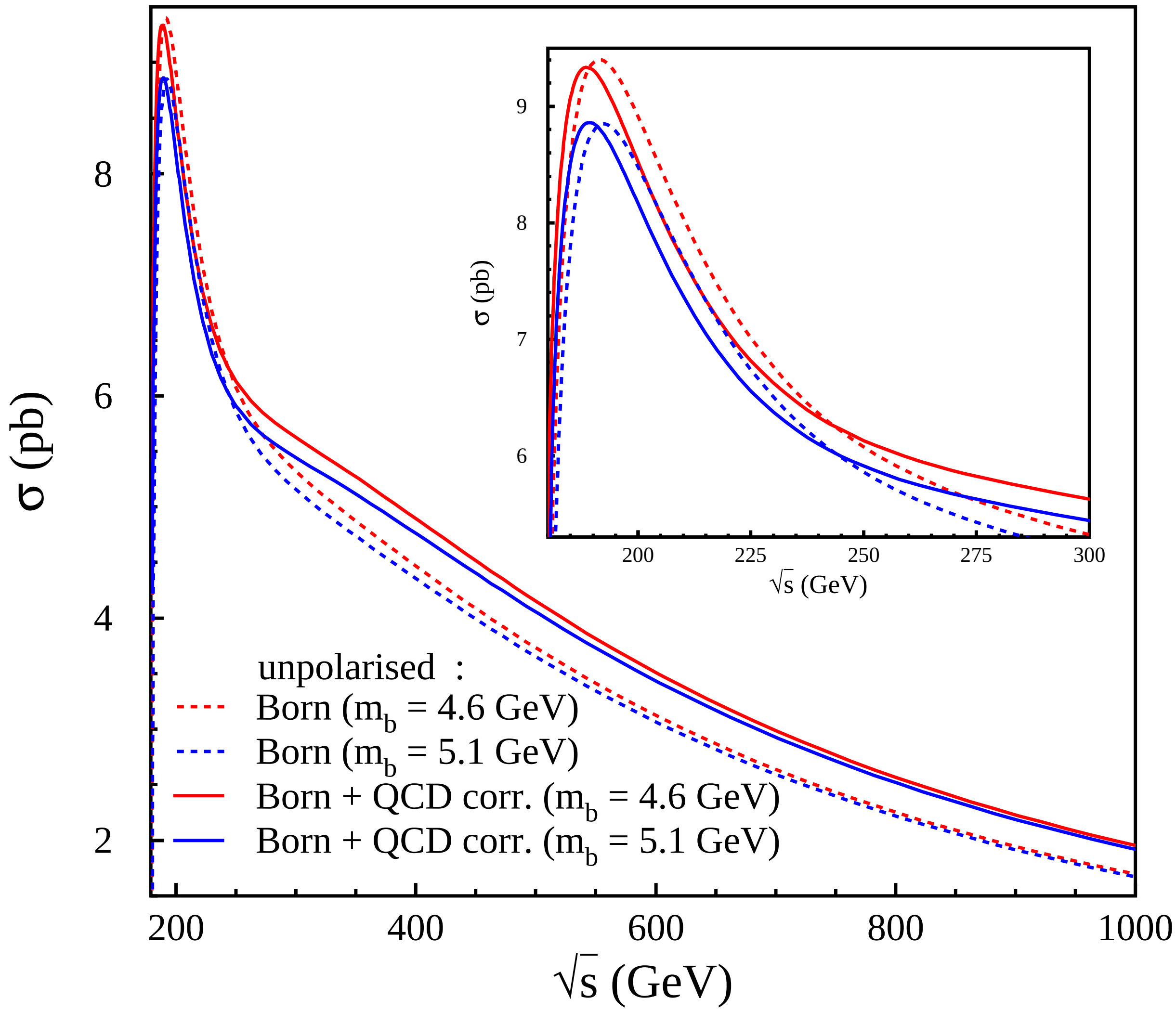
- Coefficients of the scalar one- and two-point integrals checked by UV renormalisation

- Check of the IR divergent integrals and their coefficients through the cancellation with those from Catani et al.

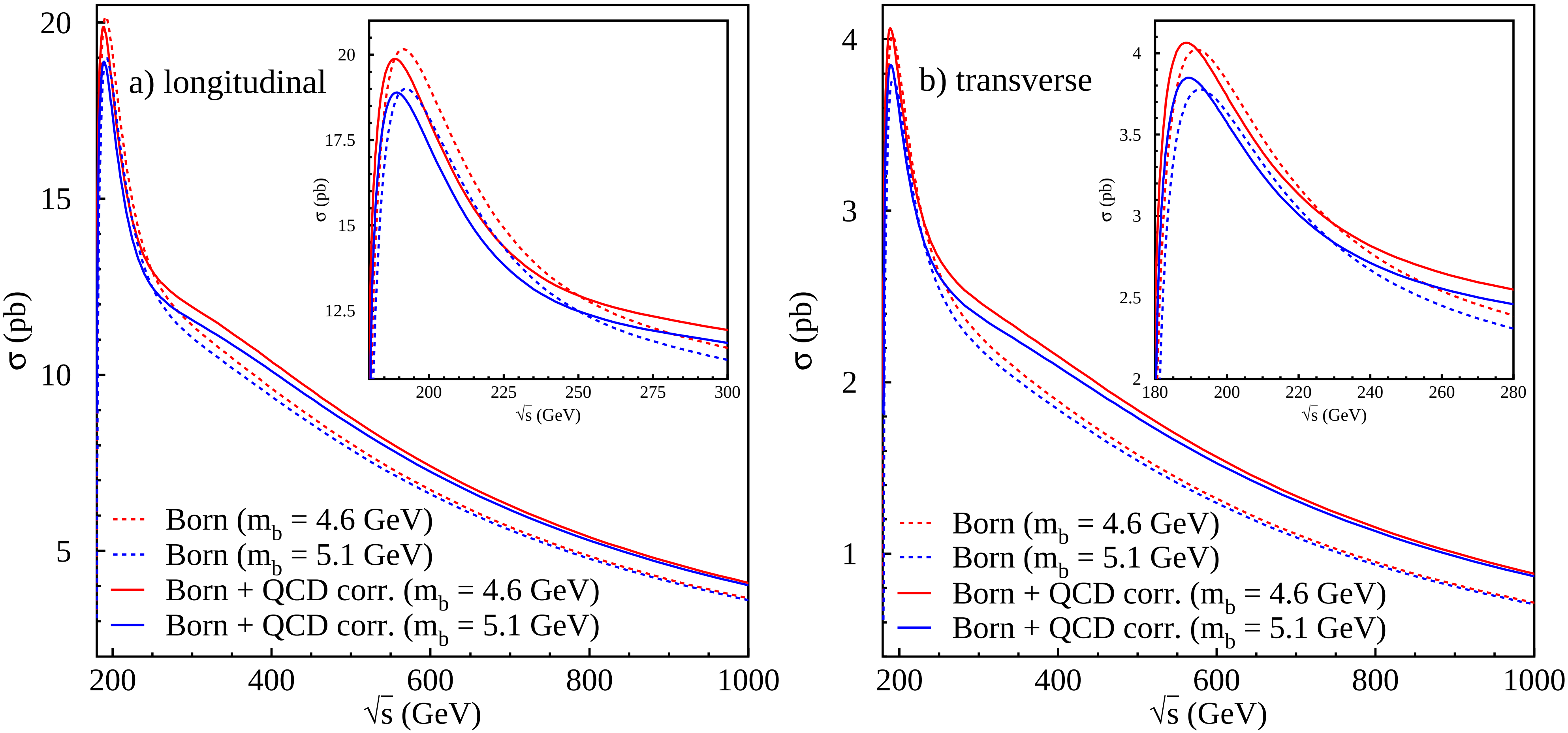
- Factorisation in d dimensions checks the treatment of the γ-matrices in d dimensions

- High degree of automatisation

Results: Total cross section

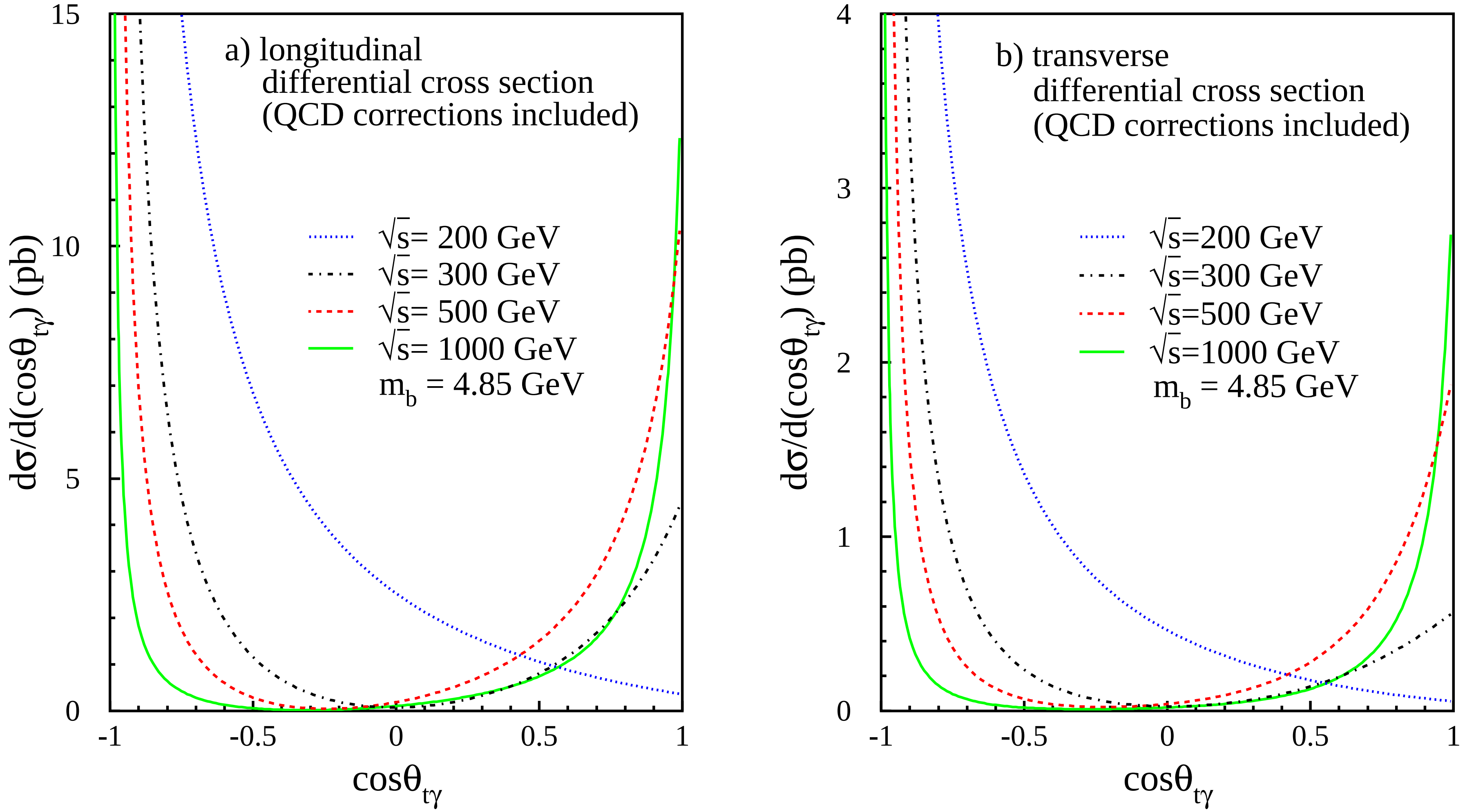


Results



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!

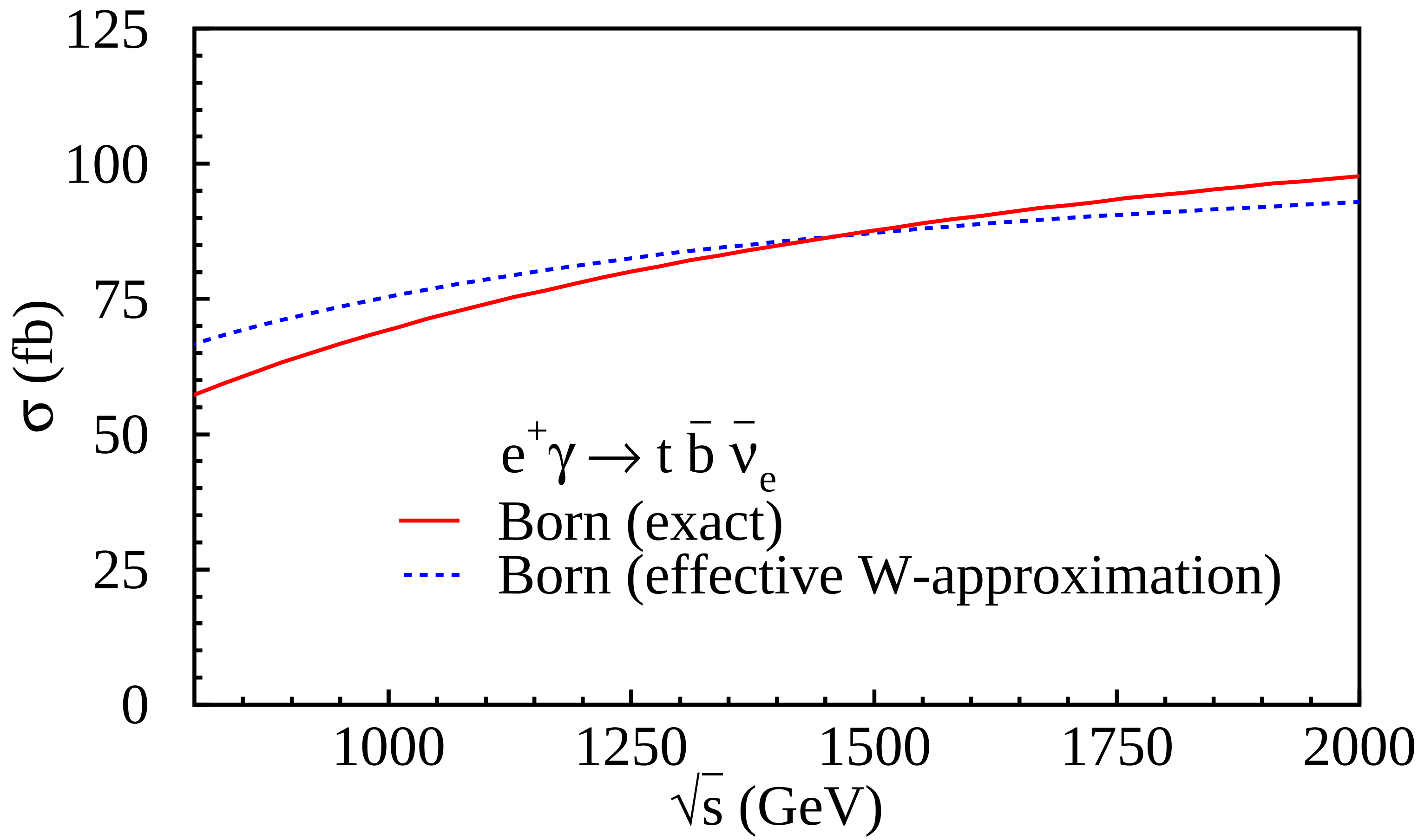
QCD Logarithms

- 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

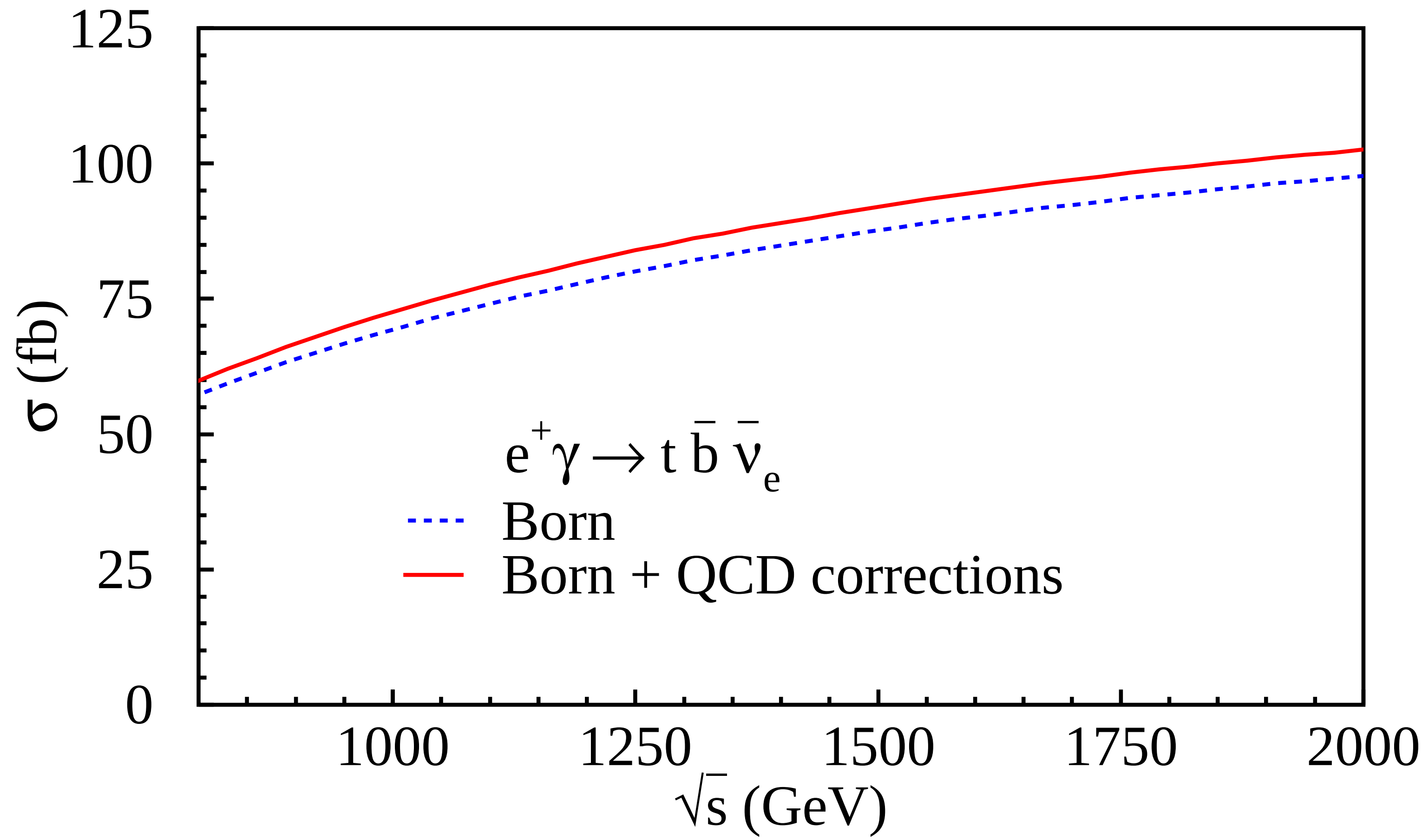


⇒ Quality 10% for $\sqrt{s}$ =900 GeV

$\longrightarrow$ 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 $|V_{tb}|$