Single Top quark production at lepton colliders

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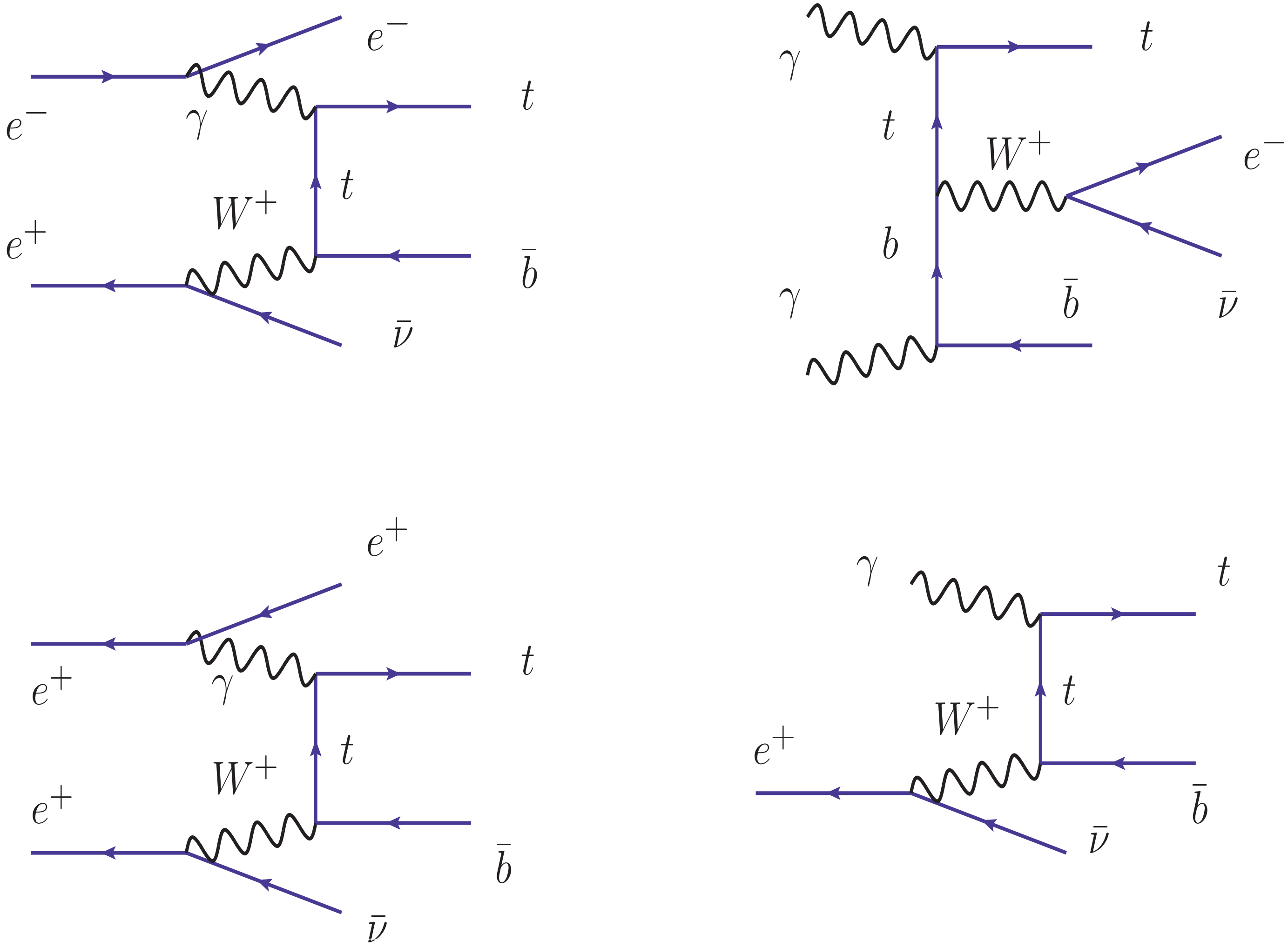
Single Top production

- $V_{tb} = 0{,}88 \pm 0{,}07$ (PDG, 2010).
  $V_{tb} > 0{,}79$ (R. Schwienhorst, D0, DPF-2011, Providence, RI, hep-ex/1109.2826)
  $V_{tb} = 1{,}16 \pm 0{,}22$ (T. Speer, CMS, DPF-2011, Providence, RI, hep-ex/1110.2374)
- V_{tb} up to $1\,\%$ at $e\gamma$.
  E. Boos, M. Dubinin, A. Pukhov, M. Sachwitz and H.J. Schreiber, Eur. Phys. J C**21** (2001) 81. hep-ph/0104279.

Single Top production

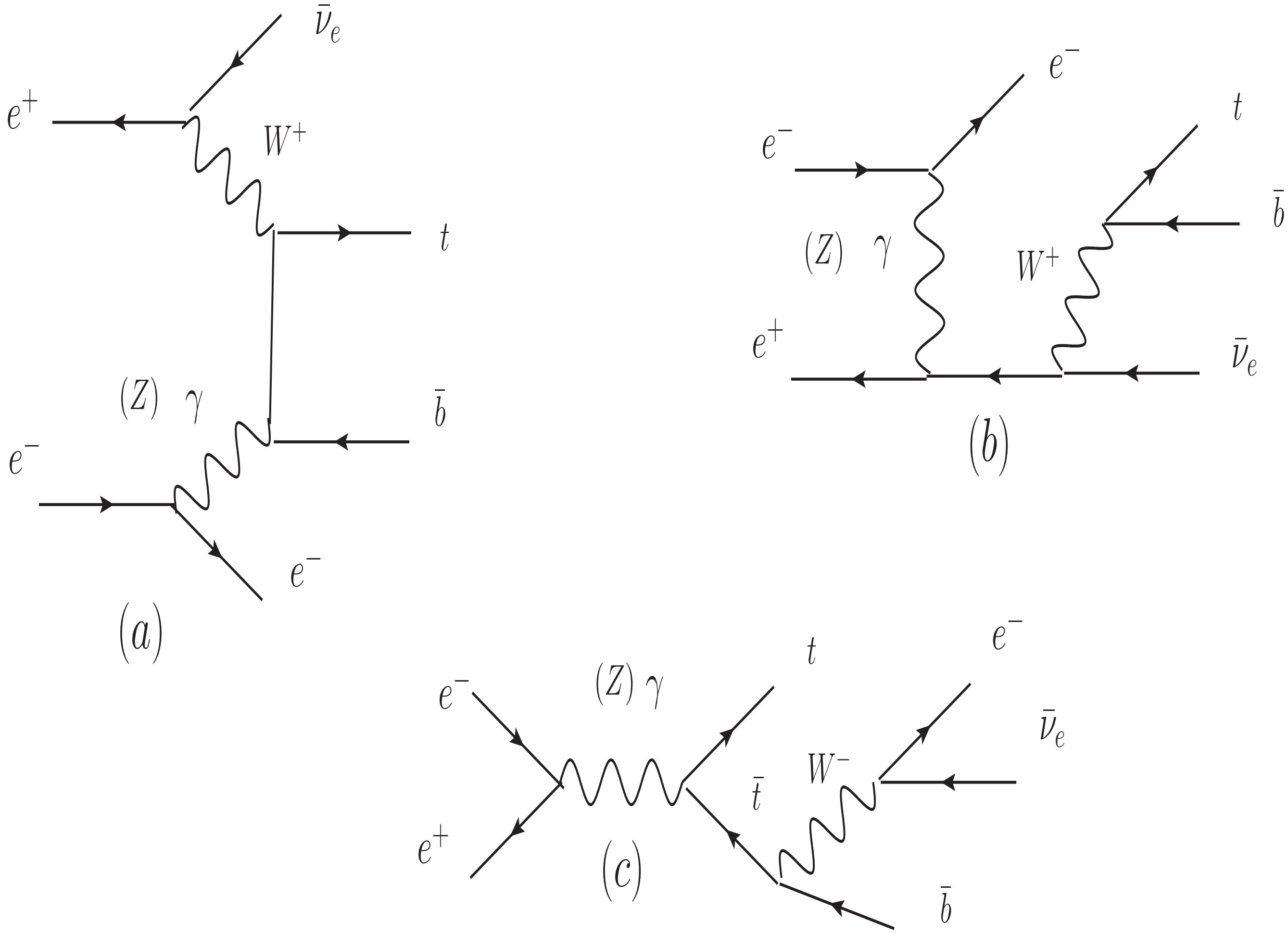


SM single top production cross section

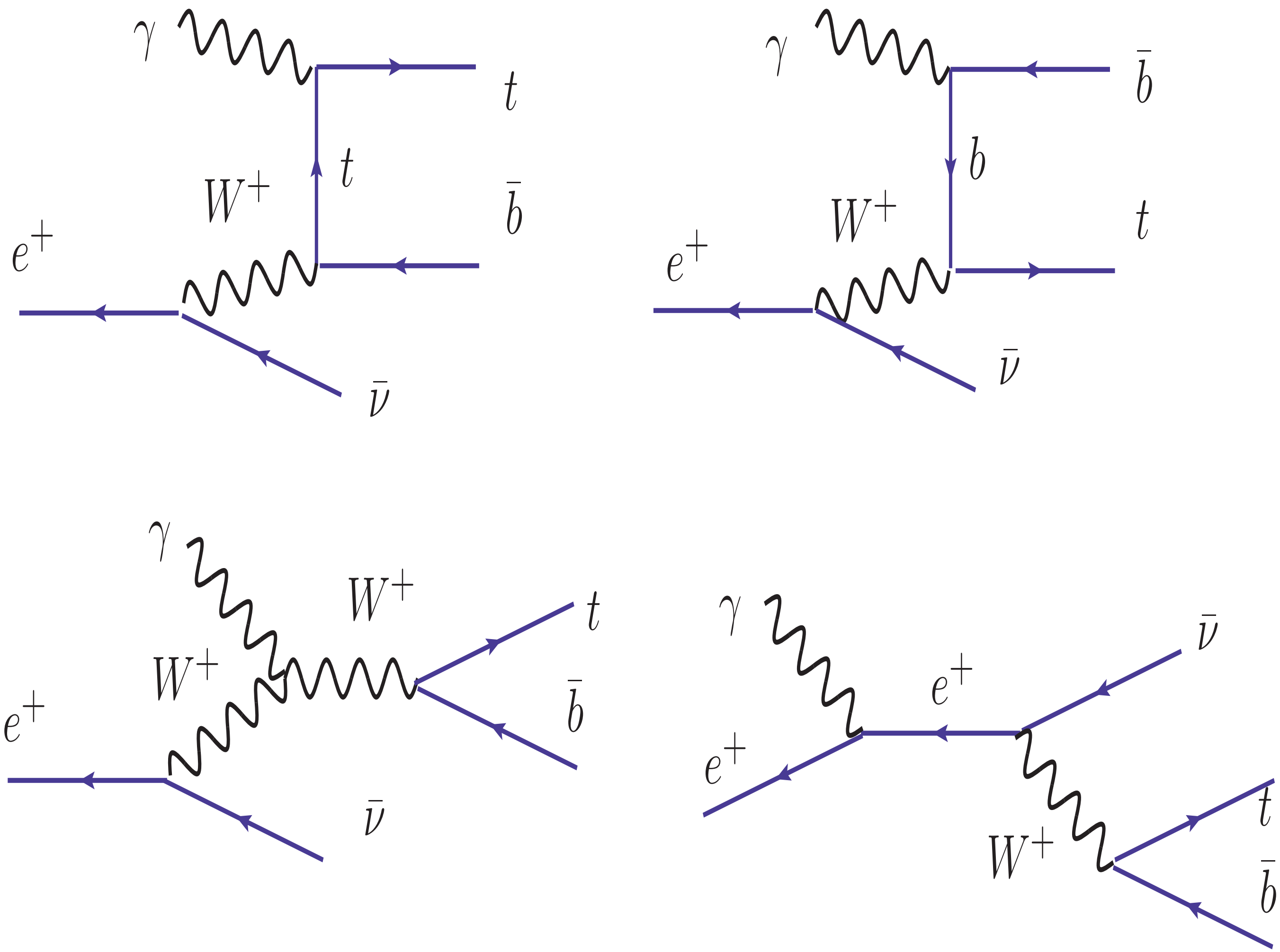
beams	No. of diagrams	$t\bar{t}$?	σ(fb) ($\sqrt{s} = 0{,}5$ TeV)	σ(fb) ($\sqrt{s} = 1{,}0$ TeV)
$e^+ e^-$	20	yes	3.1	6.7
$\gamma\gamma$	21	yes	9.2	18.8
$e\ e$	20	no	1.7	9.1
γe	4	no	30.3	67.6

E. Boos, M. Dubinin, A. Pukhov, M. Sachwitz and H.J. Schreiber, Eur. Phys. J C**21** (2001) 81. hep-ph/0104279.

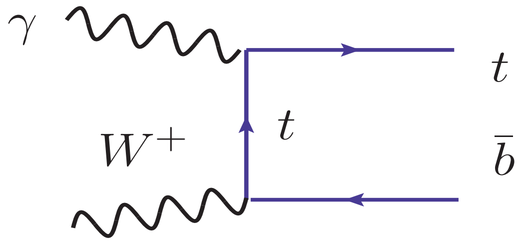
Single Top at the e^+e^- collider

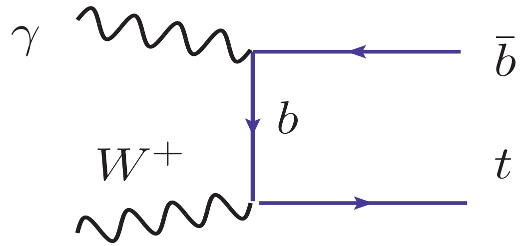


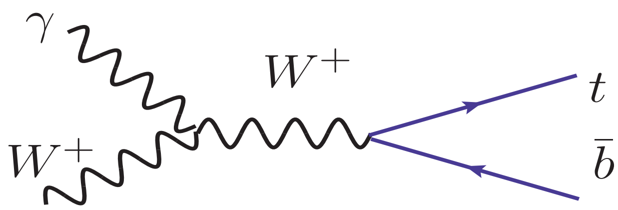
Single Top at the $e^+\gamma$ collider



Single Top and the effective W approximation



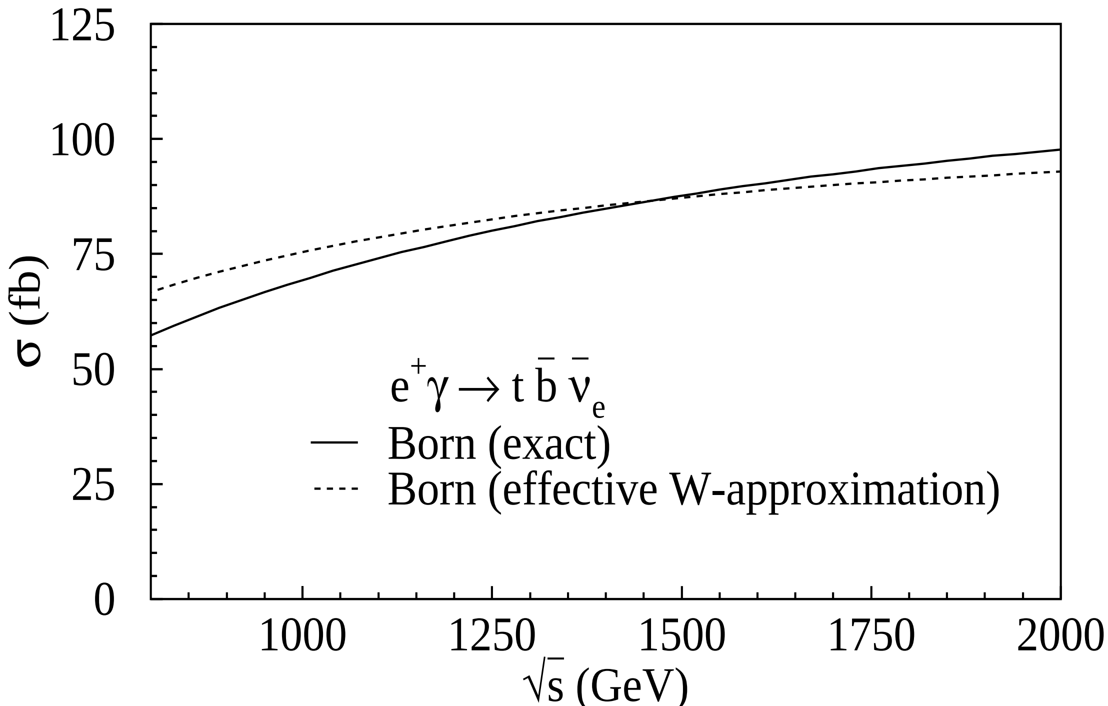




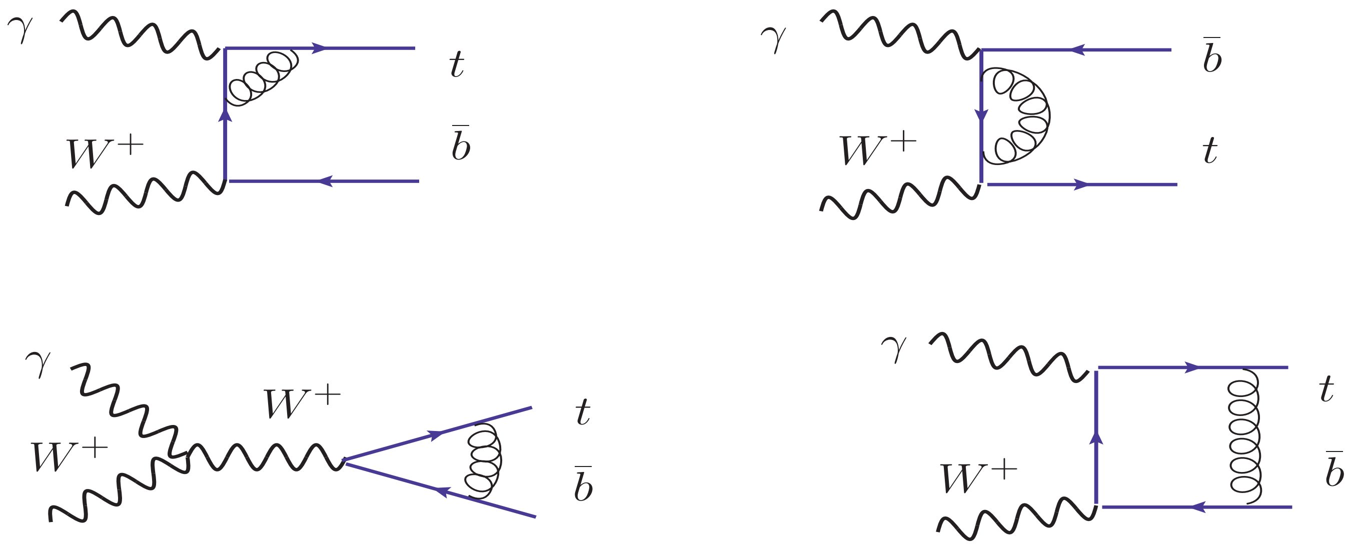
Single Top and the effective W approximation

$$\sigma(e^+\gamma \to t\bar{b}\bar{\nu}_e) = \sum_{W_L, W_T} \int_{x_W^{\min}}^{1} dx_W \, f_{W^+/e^+}(x_W)\, \sigma(W^+\gamma \to t\bar{b})(\hat{s})$$

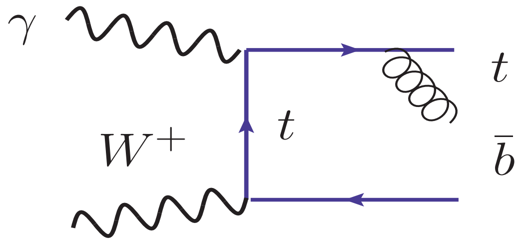
$$x_W^{\min} = \frac{m_W}{E}$$

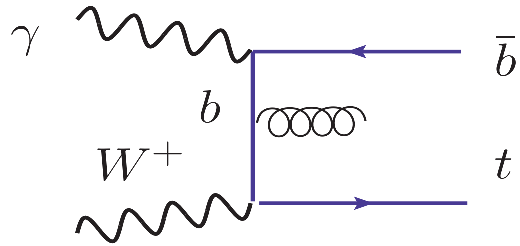


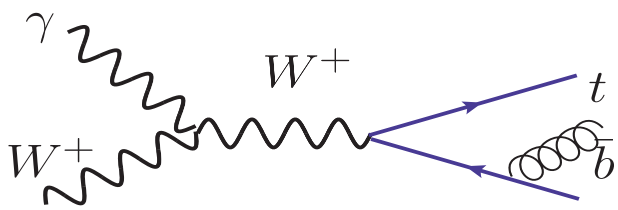
Single Top. The NLO virtual correction



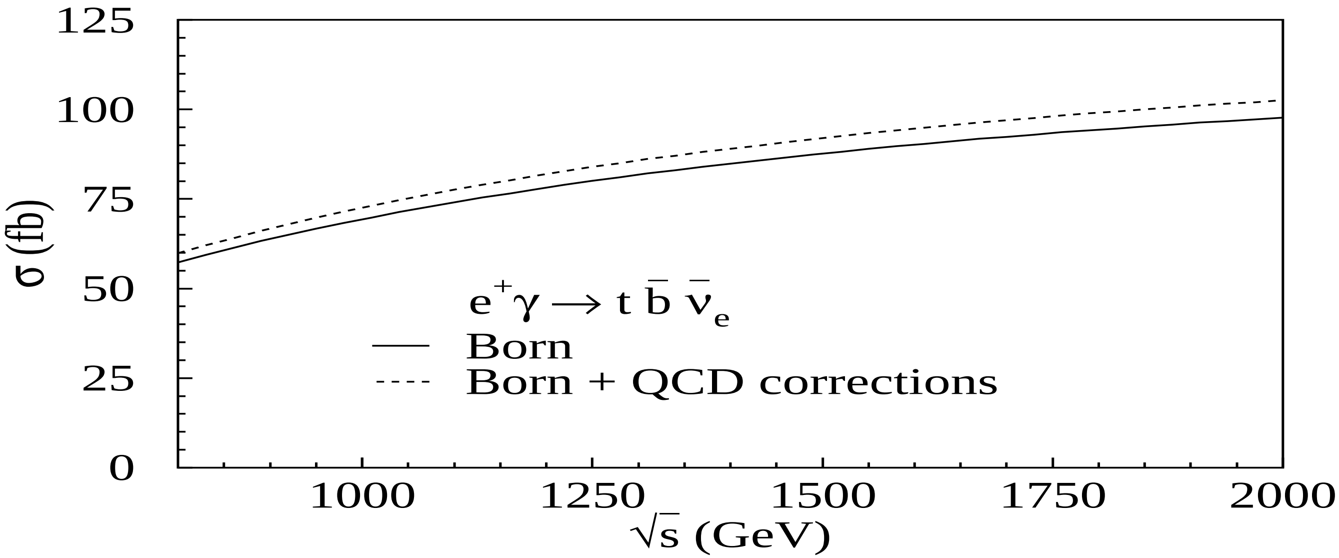
Single Top. The NLO real correction





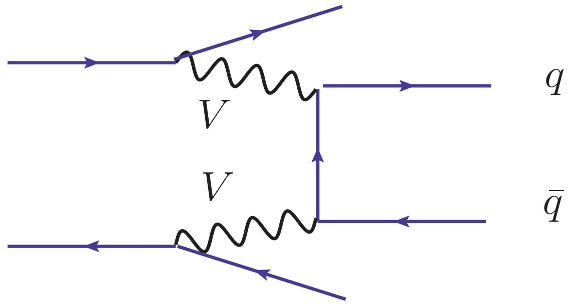


Single Top at NLO



J.H. Kuhn, C. Sturm and P. Uwer, Eur. Phys. J. C**30**, (2003) 169. hep-ph/0303233

The effective W approximation



- $M_V \ll \frac{\sqrt{s}}{2}$.
- $M_V \ll m_q$
- One dominant V polarization.
- $m_V \to 0$ (or $M_V \neq 0$)

S. Dawson, Nucl. Phys. B**249** (1985) 42..

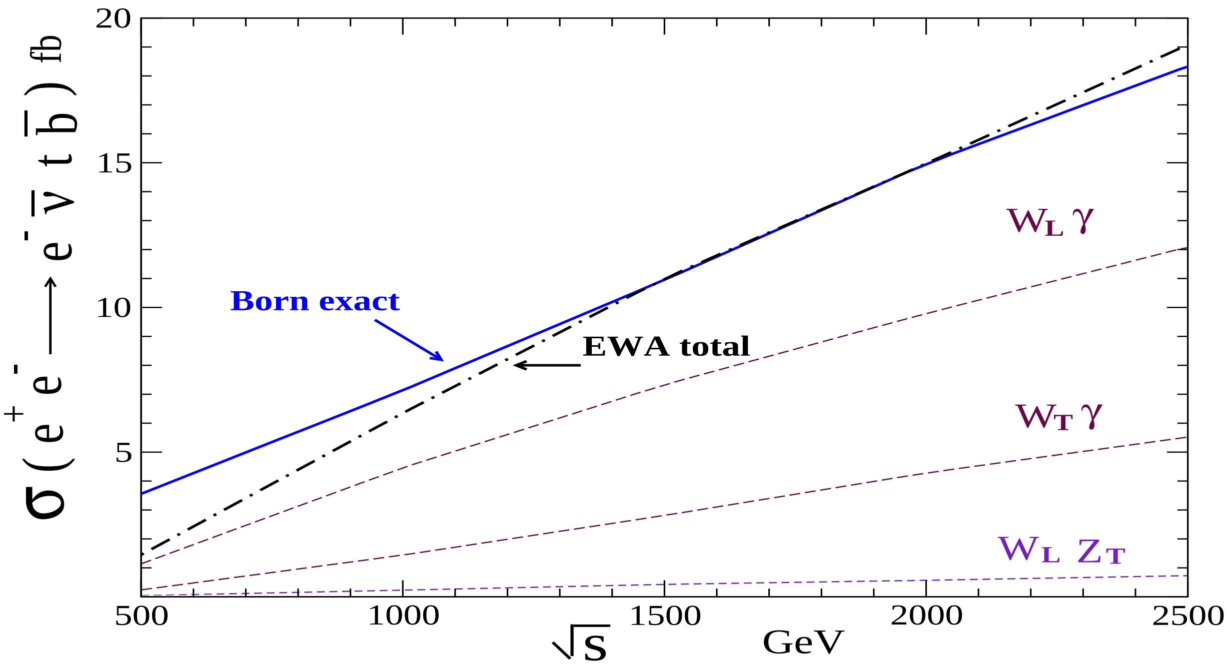
R. Kauffman, PhD. Thesis, SLAC-348 (1989), Phys. Rev. D **41** (1990) 3343.

Single Top and the effective W approximation

$$\sigma(e^+e^- \to t\bar{b}\bar{\nu}_e e^-) =$$

$$\sum_{W_L,W_T} \int_{x_W^{\min}}^1 dx_W f_{W^+/e^+}(x_W) \int_0^1 dx_\gamma f_{\gamma/e^-}(x_\gamma)\, \sigma(W^+\gamma \to t\bar{b})(\hat{s}) \; +$$

$$\sum_{W_{L,T},Z_{L,T}} \int_{x_W^{\min}}^1 dx_W f_{W^+/e^+}(x_W) \int_{x_Z^{\min}}^1 dx_Z f_{Z/e^-}(x_Z)\, \sigma(W^+Z \to t\bar{b})(\hat{s})$$



The dipole substraction method

- S. Catani and M.H. Seymour, Phys. Lett. B**378** (1996) 287. [hep-ph/9602277]
- S. Catani and M.H. Seymour, Nuc. Phys. B**485** (1997) 291. [hep-ph/9605323]
- S. Dittmaier, Nuc. Phys. B**565** (2000) 69. [hep-ph/9904440]
- L. Phaf and S. Weinzierl, JHEP **0104** (2001) 006. [hep-ph/0102207]
- S. Catani, S. Dittmaier and Z. Trocsanyi, Phys. Lett. B**500** (2001) 149. [hep-ph/0011222]
- S. Catani, S. Dittmaier, M.H. Seymour and Z. Trocsanyi, Nuc. Phys. B**627** (2002) 189. [hep-ph/0201036]

The dipole substraction method

$$\sigma(W^+\gamma \to t\bar{b}) = \sigma^{LO}(\alpha_s^0) + \sigma^{NLO}(\alpha_s^1)$$

$$\sigma^{NLO} = \sigma^{virtual} + \sigma^{real}$$

$$\rightarrow \ |\mathcal{M}|^2_{Aux} \ \equiv \ D_{gb,t} + D_{gt,b} \qquad\qquad D_{gb,t} = \frac{V_{gb,t}}{2p_g \cdot p_b} |\mathcal{M}_2(\tilde{p}_{gb}, \tilde{p}_t)|^2$$

$$\sigma^{real} - \sigma_A = [flux] \int d\Phi_3(t,b,g) \ \left(|\mathcal{M}_3|^2 - D_{gb,t} - D_{gt,b}\right)$$

$$d\sigma_A = \Sigma_{dipoles} \ d\sigma^{Born} \otimes dV_{dipole}$$

The dipole substraction method

$$\int_3 d\sigma_A = \Sigma_{dipoles} \int_2 d\sigma^{Born} \otimes \int_1 dV_{dipole}$$

$$\equiv \int_2 d\sigma^{Born} \otimes \mathbf{I}$$

$$\sigma^{NLO}(W^+\gamma \to t\bar{b}) =$$

$$\int_{tbg} \left[(d\sigma^R)_{\epsilon=0} - (d\sigma^B \otimes dV_{dipole})_{\epsilon=0} \right] + \int_{tb} [d\sigma^V + d\sigma^B \otimes \mathbf{I}]_{\epsilon=0}$$

The dipole substraction method

$$d\sigma^B \otimes dV_{dipole} \quad = \frac{\langle V_{gt,b}\rangle}{2k_g \cdot k_t}|\mathcal{M}_0(\tilde{k}_{gt}, \tilde{k}_b)|^2 \ + \ \{t \leftrightarrow b\}\,,$$

$$\langle V_{gt,b}\rangle = 8\pi\alpha_s C_F\{\frac{2}{1-\tilde{z}_t(1-y_{gt,b})} - \frac{\tilde{v}_{gt,b}}{v_{gt,b}}[1+\tilde{z}_t + \frac{m_t^2}{k_g \cdot k_t}]\}\,,$$

$$\tilde{z}_t = \frac{k_t \cdot k_b}{(k_t + k_g)\cdot k_b}\,, \qquad y_{gt,b} = 2\frac{k_g \cdot k_t}{s x_{tb}}\,, \qquad \tilde{v}_{gt,b} = \frac{\lambda_{tb}}{x_{tb}}\,,$$

$$v_{gt,b} = \sqrt{(1+a_{gt,b})^2 - a_{gt,b}^2/z_b}\,, \qquad a_{gt,b} = \frac{2z_b}{x_{tb}(1-y_{gt,b})}\,,$$

$$\tilde{k}_b = \frac{x_b}{2}P + \frac{\lambda_{tb}}{\lambda_{gt}}(k_b - \frac{P\cdot k_b}{s}P)\,, \quad \tilde{k}_{gt} = P - \tilde{k}_b\,, \quad P = k_W + k_\gamma\,,$$

The dipole substraction method

$$d\sigma^B \otimes \mathbf{I} = |\mathcal{M}_d(W^+\gamma \to t\bar{b})|^2 \frac{\alpha_s}{2\pi} \frac{1}{\Gamma(1-\epsilon)} \left(\frac{4\pi\mu^2}{s}\right)^\epsilon \, (\mathbf{I}_{gt,b} + \mathbf{I}_{gb,t})$$

$$\mathbf{I}_{gt,b} = C_F[2I^{eik} + I^{coll}_{gt,b}]$$

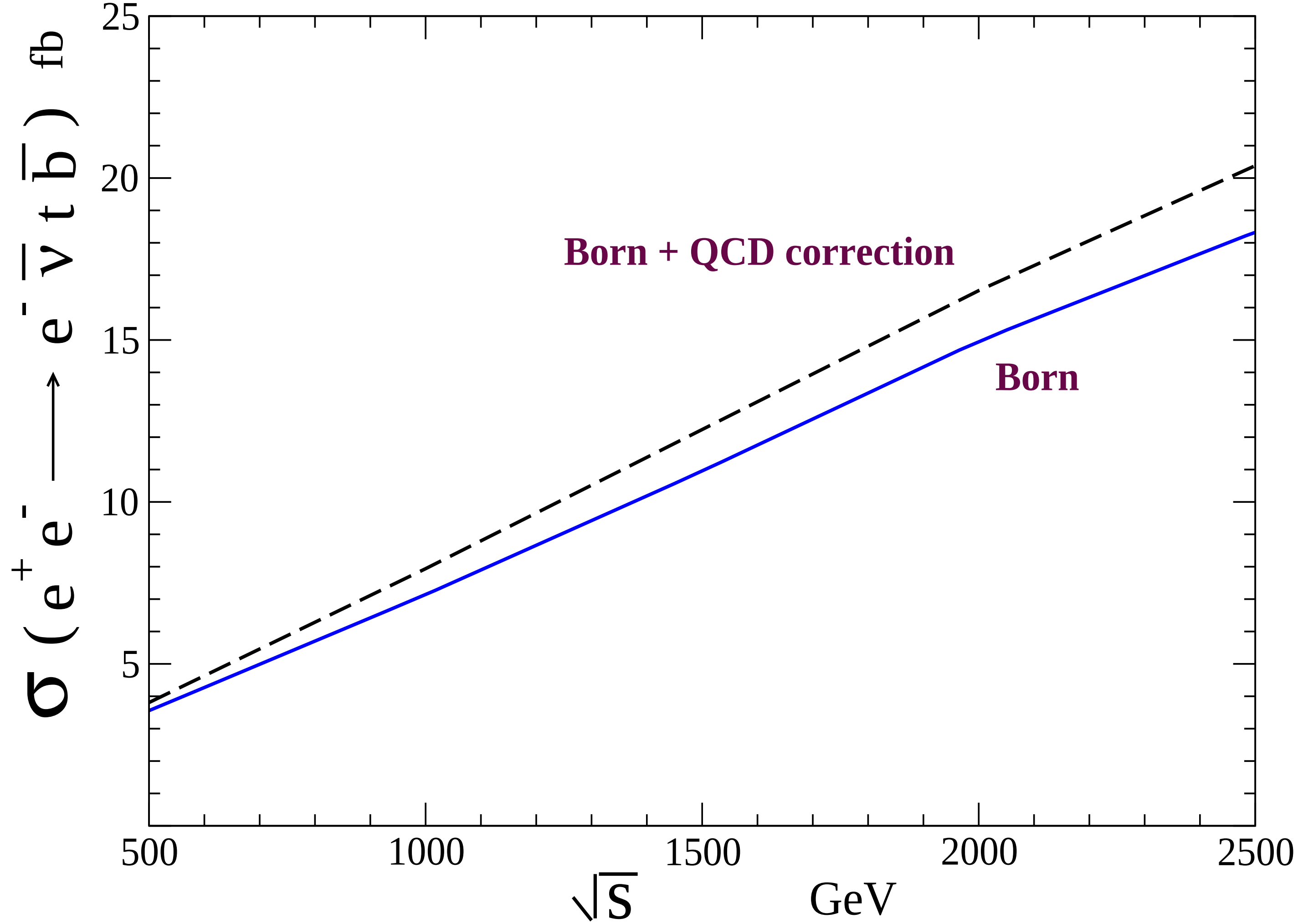
The dipole substraction method

$$I^{eik} = \frac{x_{tb}}{\lambda_{tb}} \{\frac{\ln\rho}{2\epsilon} + \frac{\pi^2}{6} - \ln\rho\ln[1-(\mu_t+\mu_b)^2] - \frac{1}{2}ln^2\rho_t - \frac{1}{2}ln^2\rho_b$$
$$+ 2Li_2(-\rho) - 2Li_2(1-\rho) - \frac{1}{2}Li_2(1-\rho_t^2) - \frac{1}{2}Li_2(1-\rho_b^2)\}$$

$$I_{gt,b}^{coll} = \frac{1}{\epsilon} + 3 + \ln\mu_t + \ln(1-\mu_b) - 2\ln[(1-\mu_b)^2 - z_t] - \frac{\mu_b}{1-\mu_b}$$
$$- \frac{2}{x_{tb}}\left[\mu_b(1-2\mu_b) + z_t\ln\frac{\mu_t}{1-\mu_b}\right]$$

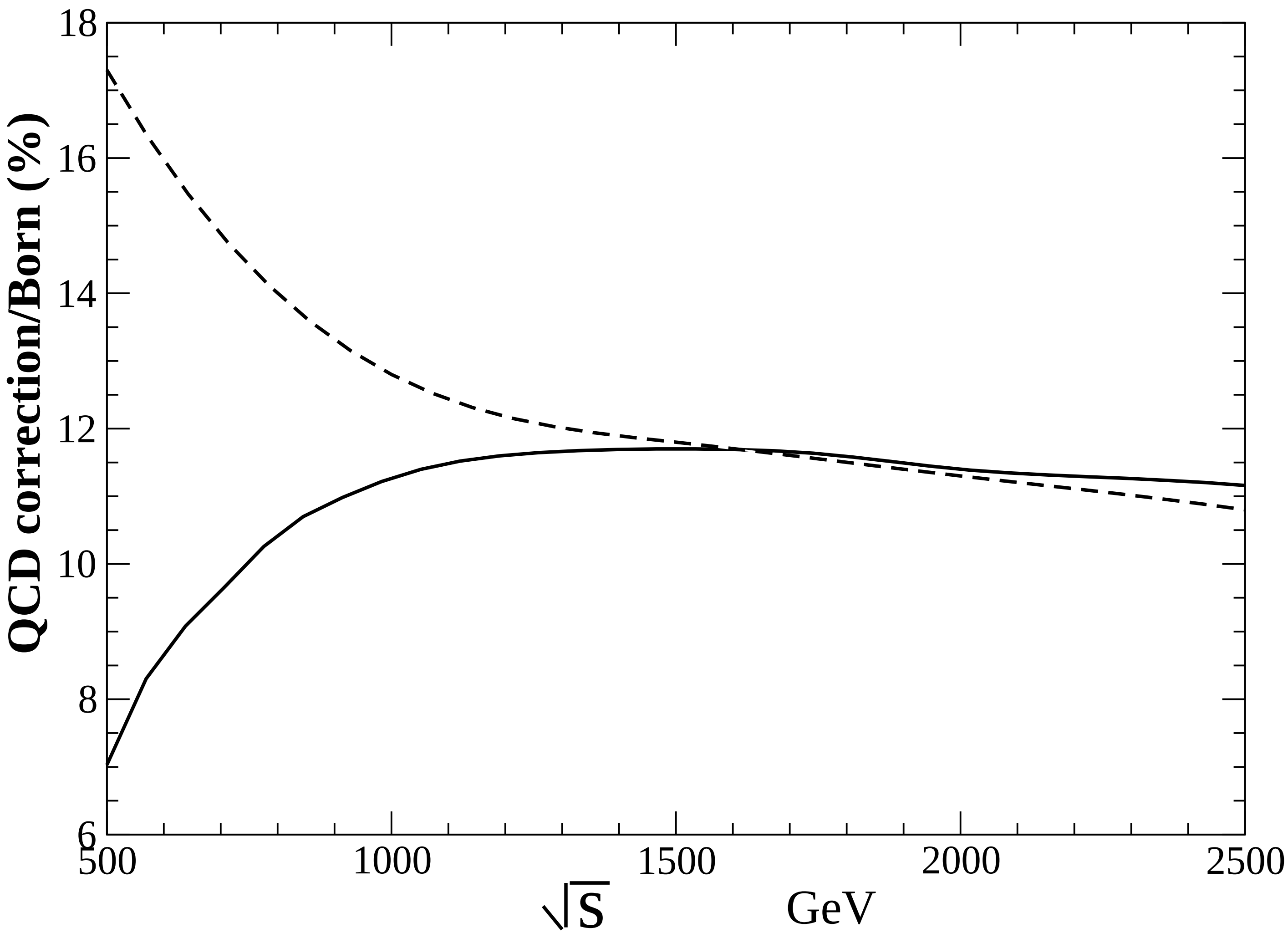
$$\rho^2 = (x_{tb} - \lambda_{tb})/(x_{tb} + \lambda_{tb}),$$
$$\rho_t = (x_{tb} - \lambda_{tb} + 2z_t)/(x_{tb} + \lambda_{tb} + 2z_t),$$
$$\rho_b = \rho_t\{t \leftrightarrow b\}.$$

Single Top at NLO



F. Peñuñuri, F. Larios and Antonio O. Bouzas, Phys. Rev. D**83** (2011) 077501..

Single Top at NLO



Conclusions

- $e^+\gamma \to t\bar{b}\nu$, EWA, NLO correction $5\,\%$.
- $e^+e^- \to t\bar{b}\nu e^-$, EWA, NLO correction $12\,\%$.
- EWA not very reliable for single top. It works better for $t\bar{t}$ than for $t\bar{b}$.