Theoretical results for charged-Higgs production

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- **Charged Higgs production**
- **Higher-order soft-gluon corrections**
- tH^- **production though aN^{3}LO**
- H^-W^+ **production through aN^{3}LO**

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Charged Higgs production

charged Higgs would be a sign of new physics

production processes in 2-Higgs doublet models

LHC has good potential for discovery

I will discuss two production processes

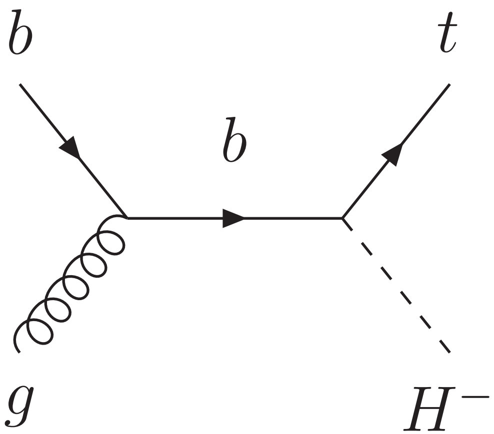
$bg \to tH^-$ **and** $b\bar{b} \to H^- W^+$

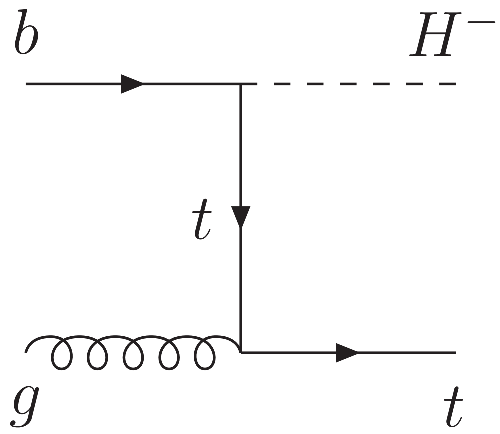
Higher-order corrections are significant

very massive final states

Soft-gluon corrections are important

tH^- production





Born cross section for $bg \to tH^- \propto \alpha\alpha_s(m_b^2 \tan^2\beta + m_t^2 \cot^2\beta)$

$\tan\beta = v_2/v_1$ **ratio of vevs of two Higgs doublets**

Higher-order corrections

$b(p_b) + g(p_g) \longrightarrow t(p_t) + H^-(p_H)$

Define $s = (p_b + p_g)^2$**,** $t = (p_b - p_t)^2$**,** $u = (p_g - p_t)^2$
and $s_4 = s + t + u - m_t^2 - m_H^2$

At partonic threshold $s_4 \to 0$

Soft corrections $\left[\frac{\ln^k(s_4/m_H^2)}{s_4}\right]_+$

For the order α_s^n **corrections** $k \le 2n - 1$

Resum these soft corrections for the double-differential cross section

At NNLL accuracy we need two-loop soft anomalous dimensions

Derive approximate cross sections at NNLO and $\mathbf{N^3LO}$

Soft-gluon Resummation

moments of the partonic cross section with moment variable N:
$\hat{\sigma}(N) = \int (ds_4/s) \, e^{-Ns_4/s} \hat{\sigma}(s_4)$

factorized expression for the cross section in $4-\epsilon$ dimensions

$$\hat{\sigma}^{bg \to tH^-}(N,\epsilon) = \left(\prod_{i=b,g} J_i\left(N,\mu,\epsilon\right) \right) H^{bg \to tH^-}\left(\alpha_s(\mu)\right) \, S^{bg \to tH^-}\left(\frac{m_H}{N\mu}, \alpha_s(\mu)\right)$$

$H^{bg \to tH^-}$ **is hard function and** $S^{bg \to tH^-}$ **is soft function**

Soft anomalous dimension $\Gamma_S^{bg \to tH^-}$ controls the evolution of $S^{bg \to tH^-}$ which results in the exponentiation of logarithms of N

$\Gamma_S^{bg \to tH^-} = (\alpha_s/\pi)\Gamma_S^{(1)} + (\alpha_s/\pi)^2\Gamma_S^{(2)} + \cdots$, **with**

$$\Gamma_S^{(1)} = C_F \left[\ln\left(\frac{m_t^2 - t}{m_t\sqrt{s}}\right) - \frac{1}{2} \right] + \frac{C_A}{2} \ln\left(\frac{m_t^2 - u}{m_t^2 - t}\right)$$

$$\Gamma_S^{(2)} = \left[C_A \left(\frac{67}{36} - \frac{\zeta_2}{2} \right) - \frac{5}{18} n_f \right] \Gamma_S^{(1)} + C_F C_A \frac{(1 - \zeta_3)}{4}$$

aNNLO soft-gluon corrections

$$\frac{d^2\hat{\sigma}^{(2)\, bg \to tH^-}_{\rm aNNLO}}{dt\, du} = F^{bg \to tH^-}_{\rm LO} \frac{\alpha_s^2}{\pi^2} \sum_{k=0}^{3} C_k^{(2)} \left[\frac{\ln^k(s_4/m_H^2)}{s_4}\right]_+$$

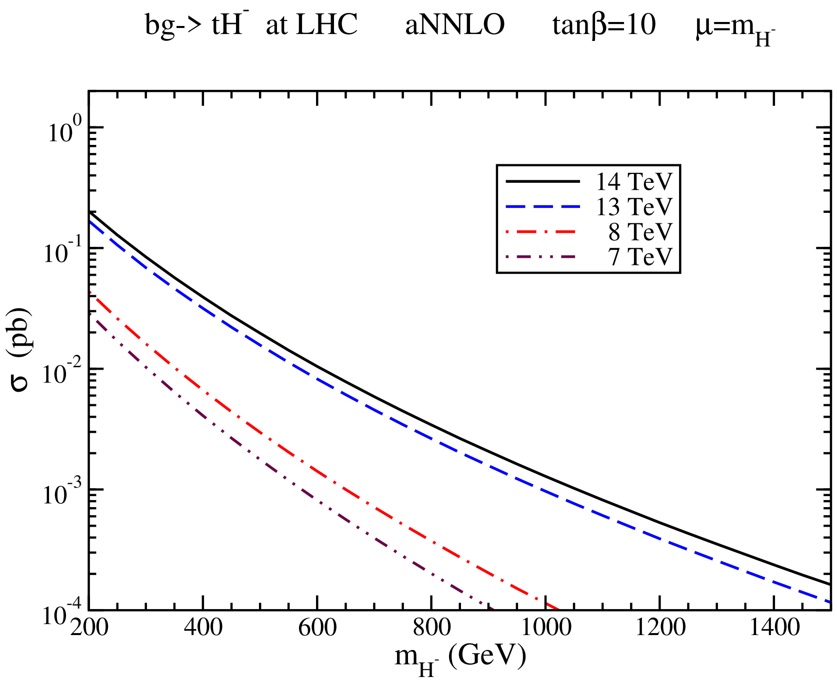
with coefficients $C_3^{(2)} = 2(C_F + C_A)^2$

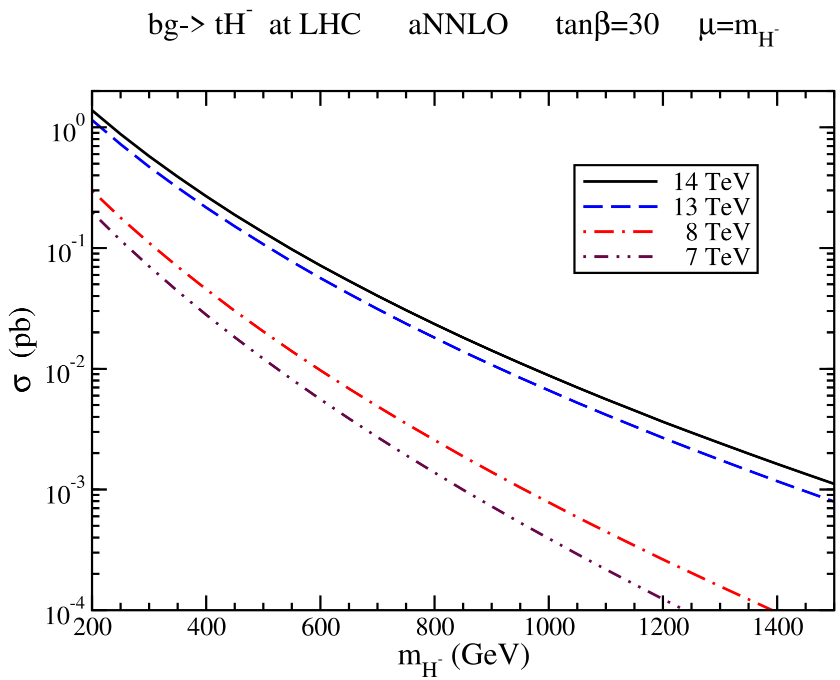
$$C_2^{(2)} = (C_F + C_A) \left\{ 3C_F \left[2\ln\left(\frac{m_t^2 - t}{m_t \sqrt{s}}\right) - 2\ln\left(\frac{m_H^2 - u}{m_H^2}\right) - 1 \right] - 3C_A \left[\ln\left(\frac{m_t^2 - t}{m_t^2 - u}\right) + 2\ln\left(\frac{m_H^2 - t}{m_H^2}\right) \right] - 3(C_F + C_A)\ln\left(\frac{\mu_F^2}{s}\right) - \frac{\beta_0}{2} \right\}$$

The expressions for $C_1^{(2)}$ and $C_0^{(2)}$ are much longer

tH^- production

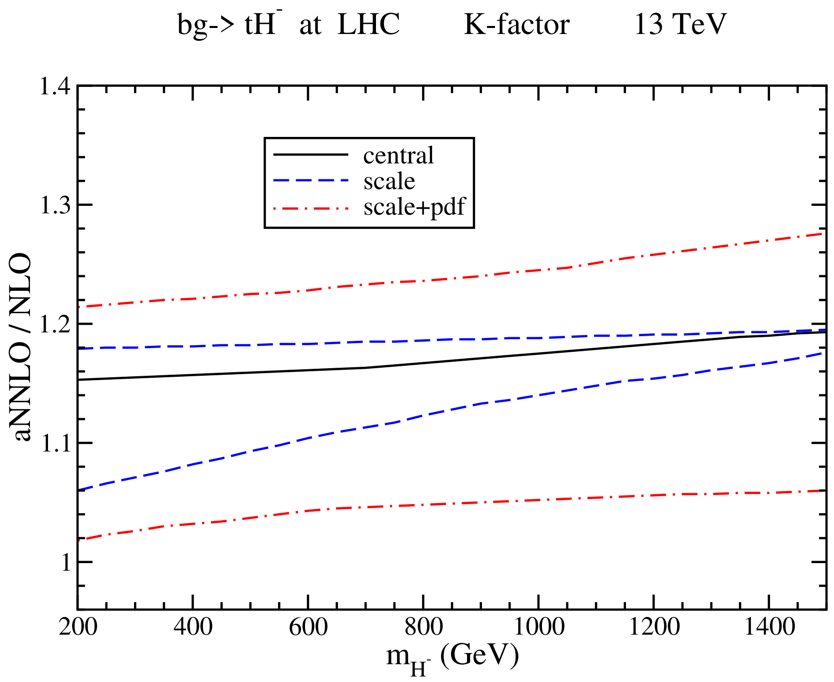
Total cross sections

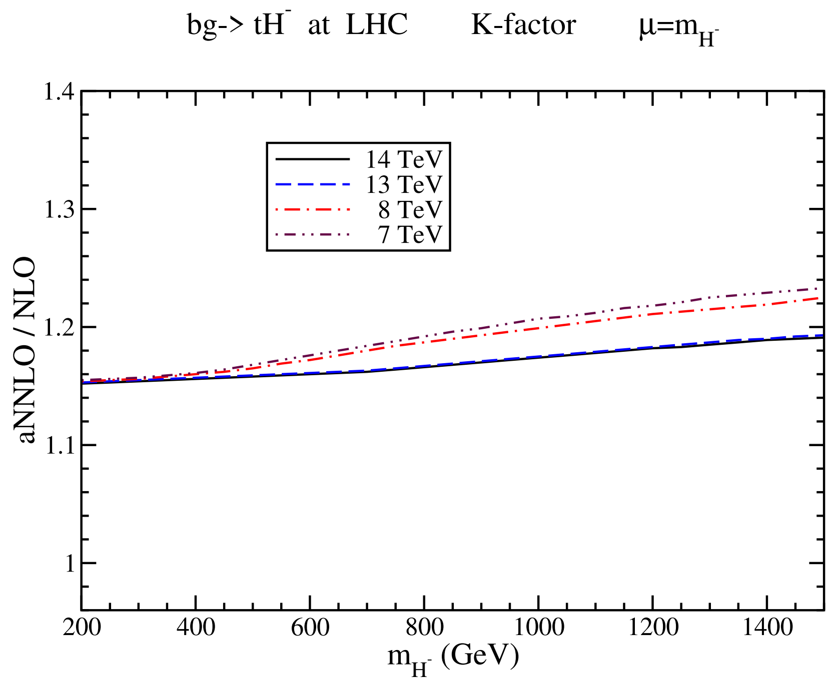




tH^- production

K-factors



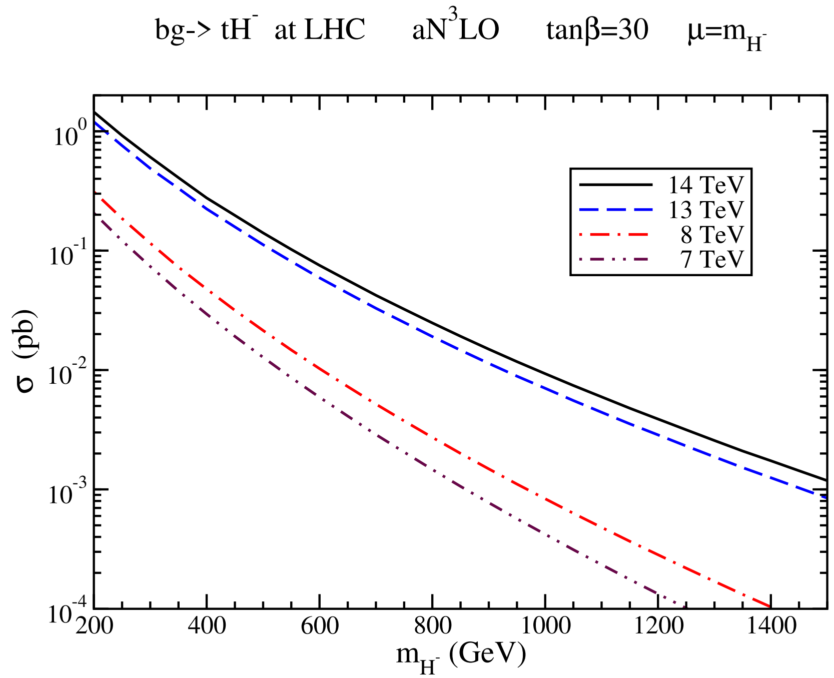


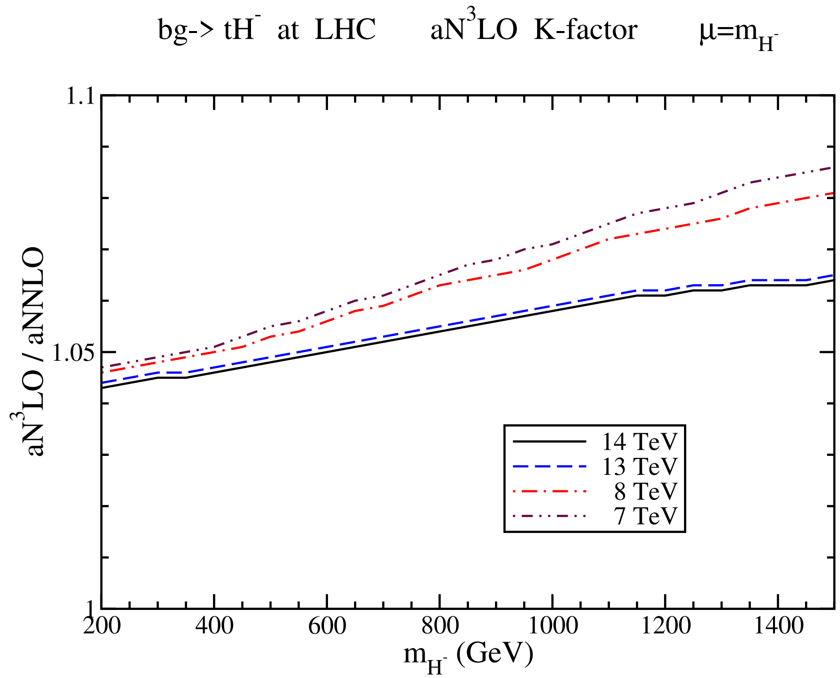
tH^- production

The aN^{3}LO soft-gluon corrections are:

$$\frac{d^2\hat{\sigma}^{(3)\,bg\to tH^-}_{\mathrm{aN^3LO}}}{dt\,du} = F^{bg\to tH^-}_{\mathrm{LO}} \frac{\alpha_s^3}{\pi^3} \sum_{k=0}^{5} C_k^{(3)} \left[\frac{\ln^k(s_4/m_H^2)}{s_4}\right]_+$$

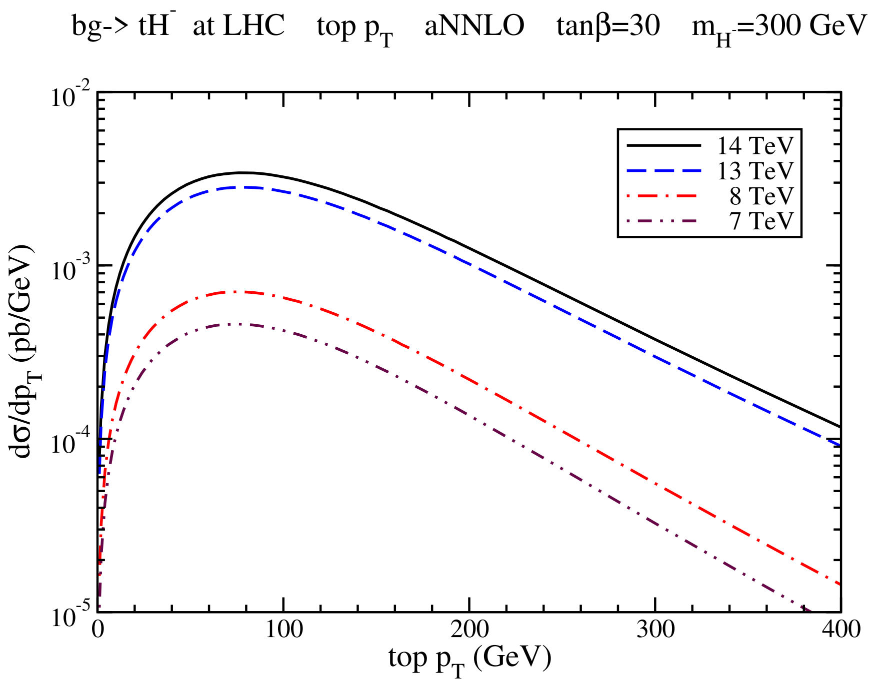
with coefficients $C_3^{(3)} = \frac{1}{2}(C_F + C_A)^3$**, etc.**

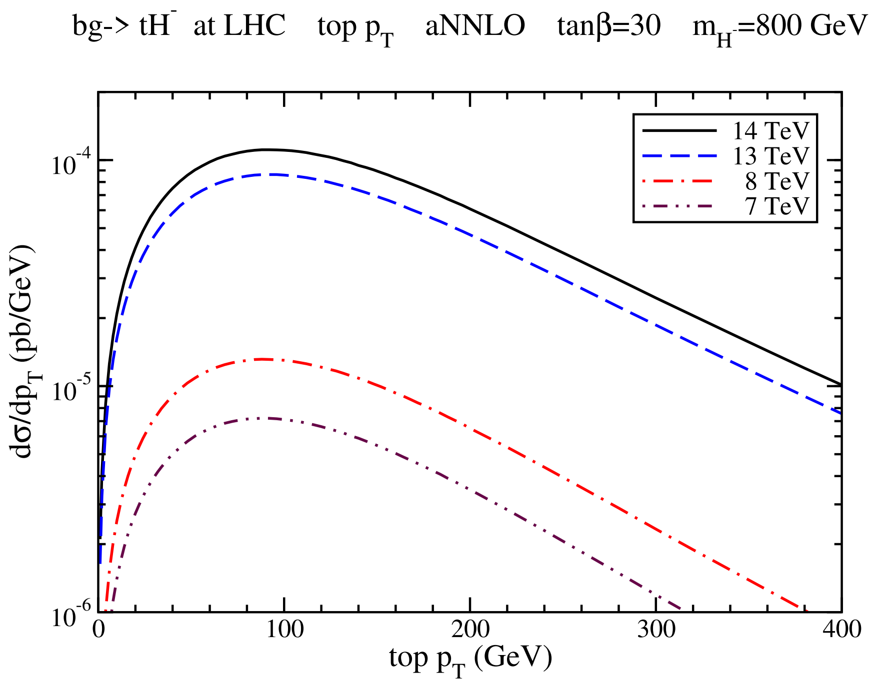




tH^- production

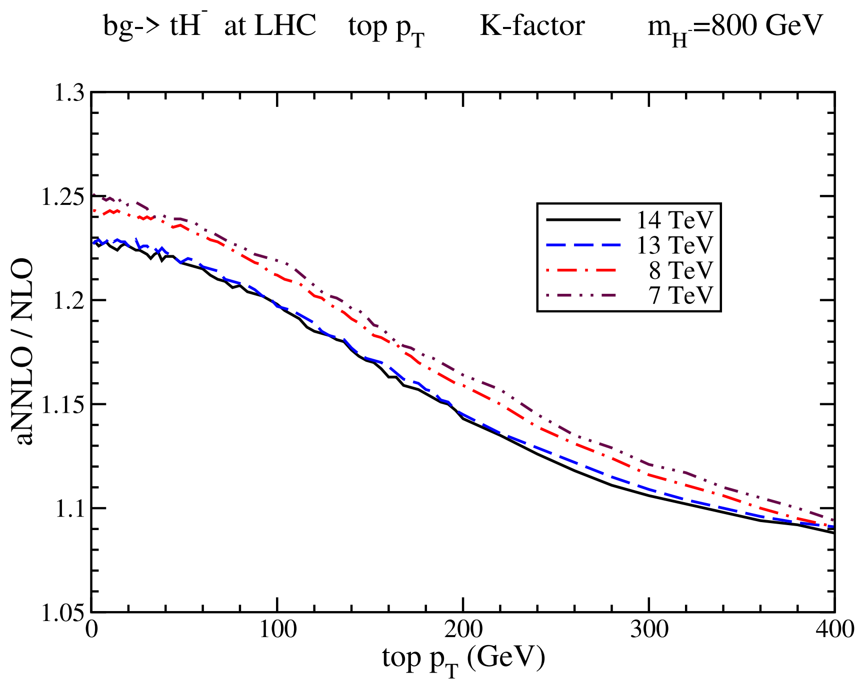
Top-quark p_T distributions

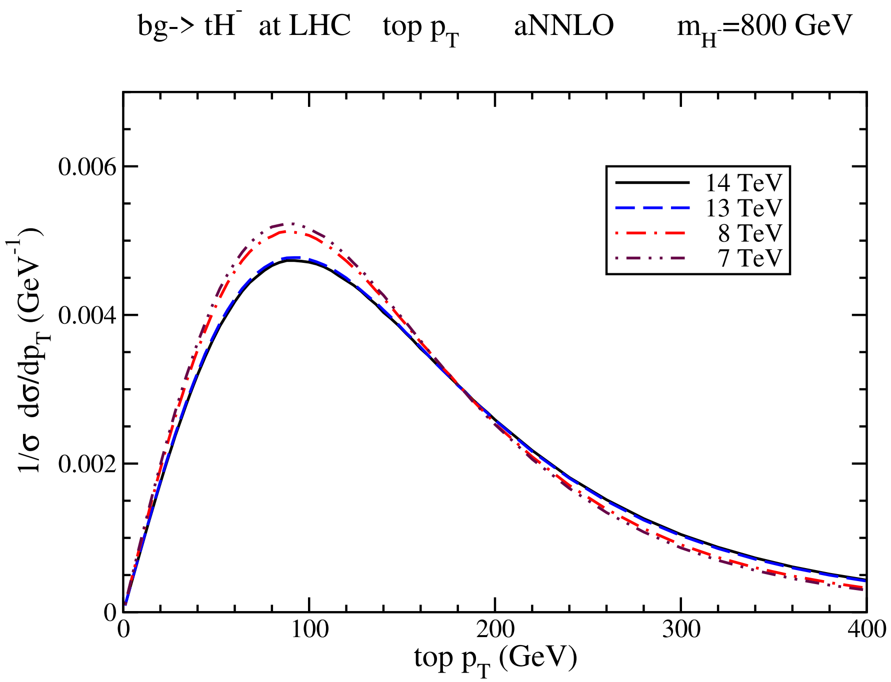




tH^- production

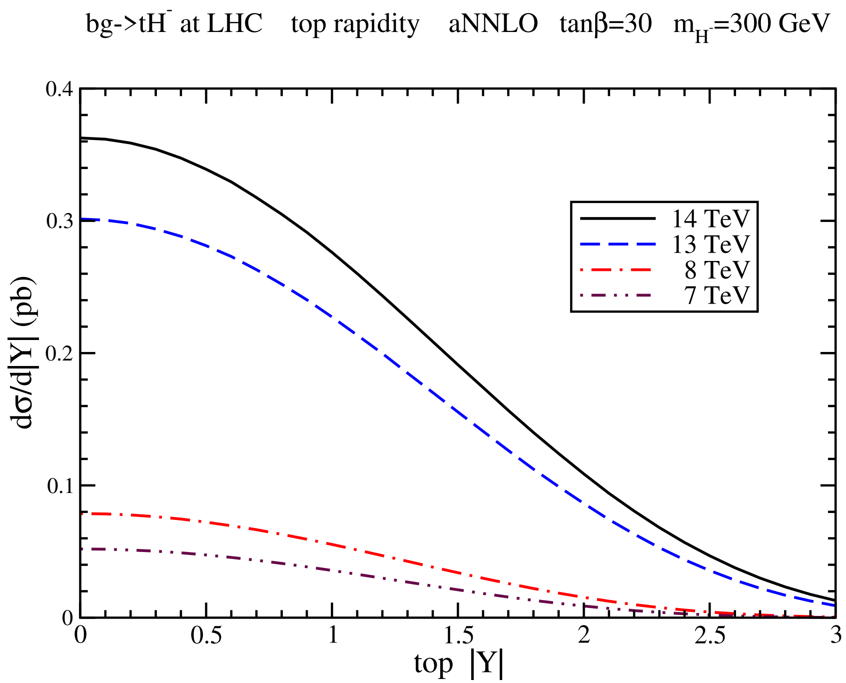
Top-quark p_T distributions

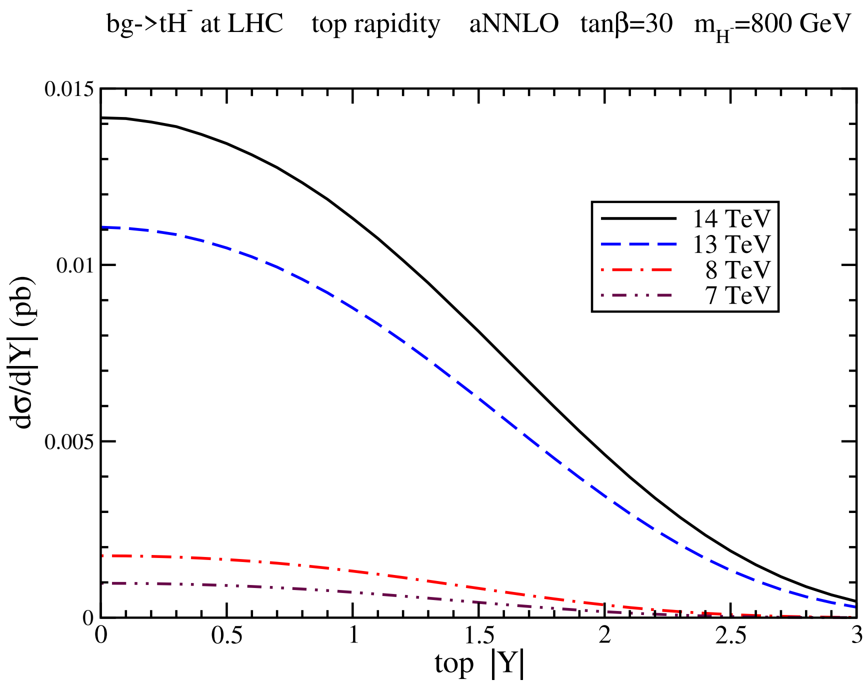




tH^- production

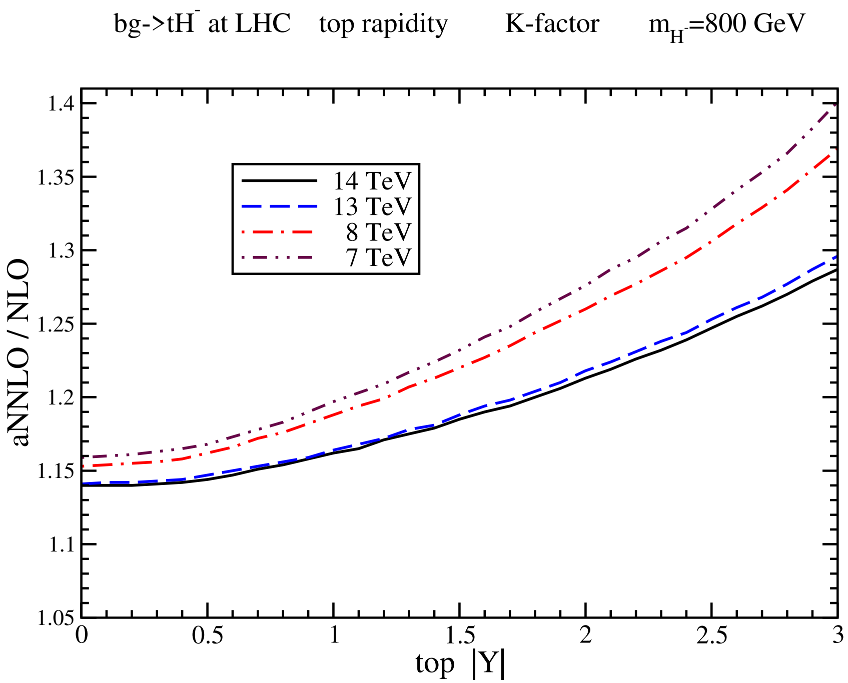
Top-quark rapidity distributions

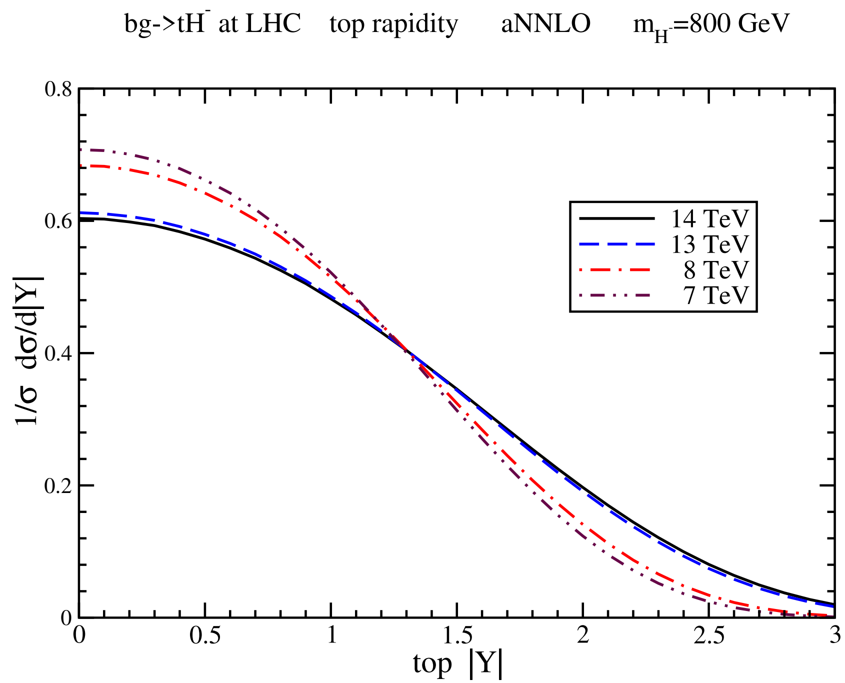




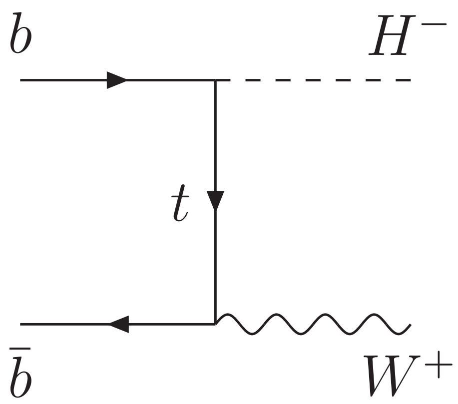
tH^- production

Top-quark rapidity distributions





$H^- W^+$ production



$$b(p_1) + \bar{b}(p_2) \to H^-(p_3) + W^+(p_4)$$

Define $s = (p_1 + p_2)^2$, $t = (p_1 - p_3)^2$, $u = (p_2 - p_3)^2$
and $s_4 = s + t + u - m_H^2 - m_W^2$

At partonic threshold $s_4 \to 0$

Soft corrections $\left[\frac{\ln^k(s_4/m_H^2)}{s_4}\right]_+$

H^-W^+ production

factorized expression for the cross section in $4-\epsilon$ dimensions

$$\hat{\sigma}^{b\bar{b}\to H^-W^+}(N,\epsilon) = \left(\prod_{i=b,\bar{b}} J_i\,(N,\mu,\epsilon)\right) H^{b\bar{b}\to H^-W^+}(\alpha_s(\mu))\; S^{b\bar{b}\to H^-W^+}\left(\frac{m_H}{N\mu},\alpha_s(\mu)\right)$$

The aNNLO collinear and soft-gluon corrections are

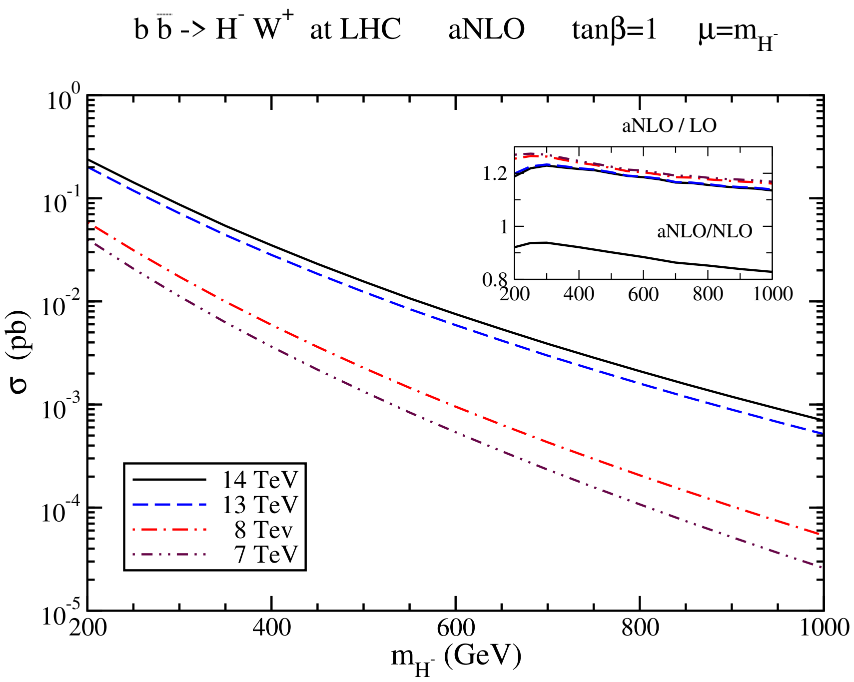
$$\frac{d^2\hat{\sigma}^{(2)\,b\bar{b}\to H^-W^+}_{\rm aNNLO}}{dt\,du} = F^{b\bar{b}\to H^-W^+}_{LO}\,\frac{\alpha_s^2}{\pi^2}\left\{-C_3^{(2)}\frac{1}{m_H^2}\ln^3\left(\frac{s_4}{m_H^2}\right)+\sum_{k=0}^{3}C_k^{(2)}\left[\frac{\ln^k(s_4/m_H^2)}{s_4}\right]_+\right\}$$

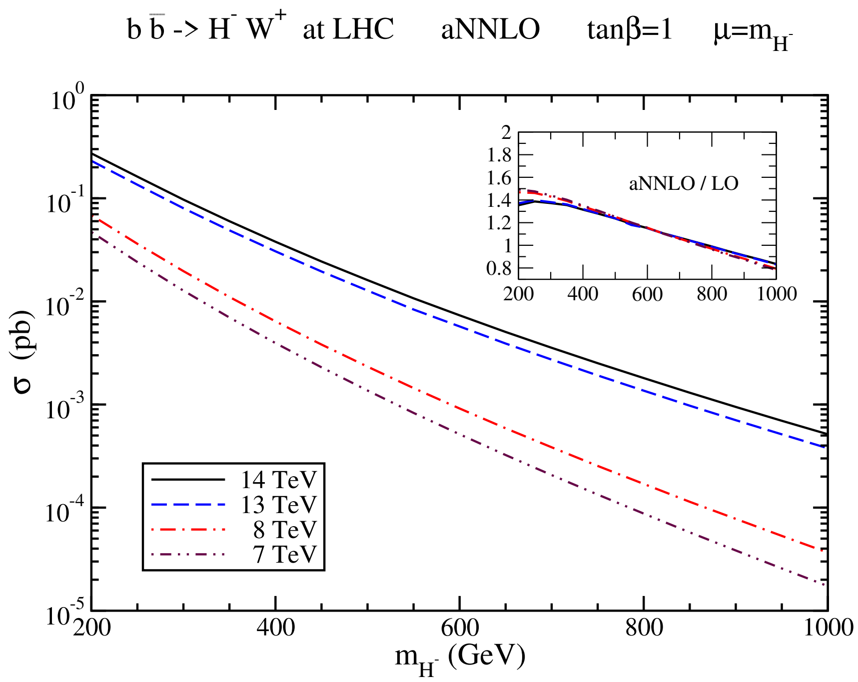
with $C_3^{(2)}=8C_F^2$

$$C_2^{(2)} = -12C_F^2\left(\ln\left(\frac{(t-m_W^2)(u-m_W^2)}{m_H^4}\right)+\ln\left(\frac{\mu_F^2}{s}\right)\right)-\frac{11}{3}C_FC_A+\frac{2}{3}C_Fn_f$$

H^-W^+ production

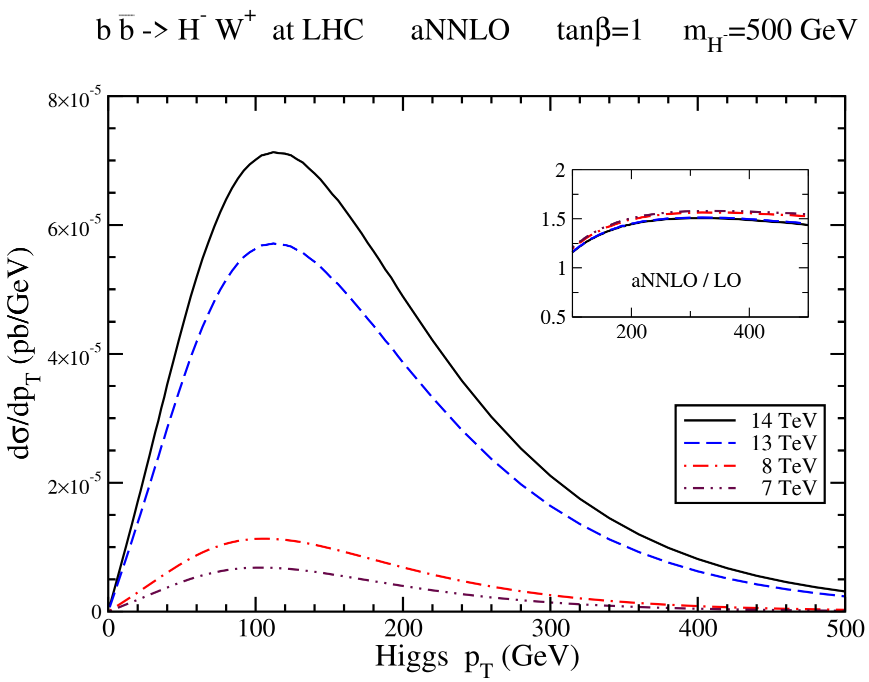
Total cross sections

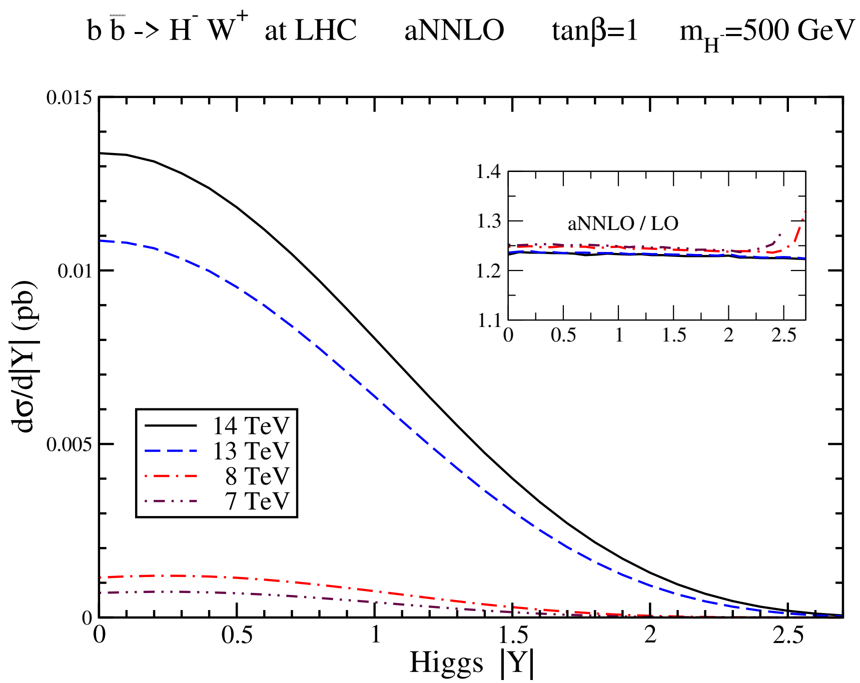




H^-W^+ production

Charged-Higgs p_T and rapidity distributions





$H^- W^+$ production

The aN^{3}LO collinear and soft-gluon corrections are

$$\frac{d^2\hat{\sigma}^{(3)\, b\bar{b}\to H^- W^+}_{\rm aN^3LO}}{dt\, du} = F^{b\bar{b}\to H^- W^+}_{LO} \frac{\alpha_s^3}{\pi^3} \left\{ -C_5^{(3)} \frac{1}{m_H^2} \ln^5\left(\frac{s_4}{m_H^2}\right) + \sum_{k=0}^{5} C_k^{(3)} \left[\frac{\ln^k(s_4/m_H^2)}{s_4}\right]_+ \right\}$$

with $C_5^{(3)} = 8 C_F^3$**, etc.**

aN^{3}LO corrections are small but have big uncertainties

Summary

- **new results in charged Higgs production with a top or W**
- **soft-gluon corrections at aNNLO and aN^{3}LO**
- **total cross sections for tH^- production**
- **top-quark p_T and rapidity distributions in tH^- production**
- **total cross sections for H^-W^+ production**
- **charged-Higgs p_T and rapidity distributions in H^-W^+ production**
- **higher-order corrections are very significant**