Charged Higgs production in association with a W or a top

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- **Charged Higgs production**
- **Higher-order corrections**
- tH^- **production**
- H^-W^+ **production**

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Charged Higgs production

A charged Higgs would be sure sign of new physics

2-Higgs doublet models

LHC has good potential for discovery

I will discuss two production processes
$bg \to tH^-$ **and** $b\bar{b} \to H^- W^+$

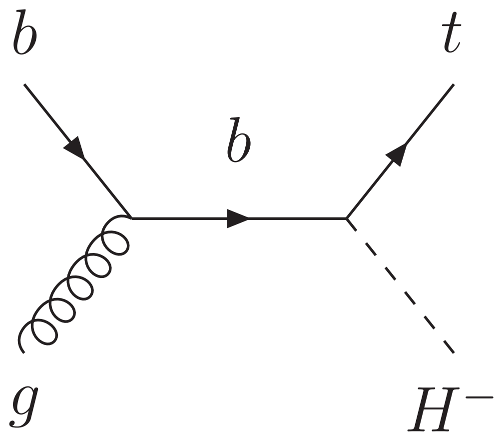
Probe into electroweak and Higgs physics

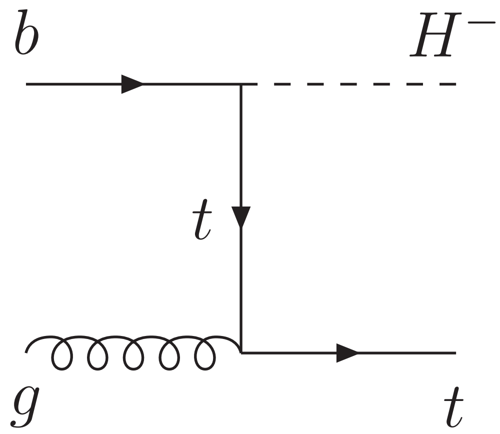
Higher-order corrections are significant

very massive final states

Soft-gluon corrections are important

tH^- production





Top is the heaviest known elementary particle

Decays before hadronization

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** $k \leq 2n - 1$

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

Soft-gluon Resummation

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

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

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

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

Soft function S satisfies the renormalization group equation

$$\left(\mu \frac{\partial}{\partial \mu} + \beta(g_s,\epsilon) \frac{\partial}{\partial g_s}\right) S^{bg \to tH^-} = -2\, S^{bg \to tH^-}\, \Gamma_S^{bg \to tH^-}$$

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**

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

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

Resummed cross section

$$\hat{\sigma}^{bg\to tH^-}_{\rm resummed}(N) = \exp\left[\sum_{i=b,g} E_i(N_i)\right] H^{bg\to tH^-}\left(\alpha_s(\sqrt{s})\right)$$
$$\times S^{bg\to tH^-}\left(\alpha_s\left(\frac{\sqrt{s}}{N'}\right)\right) \exp\left[\int_{\sqrt{s}}^{\sqrt{s}/N'} \frac{d\mu}{\mu}\, 2\,\Gamma_S^{bg\to tH^-}\left(\alpha_s(\mu)\right)\right]$$

The aNNLO soft-gluon corrections are:

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

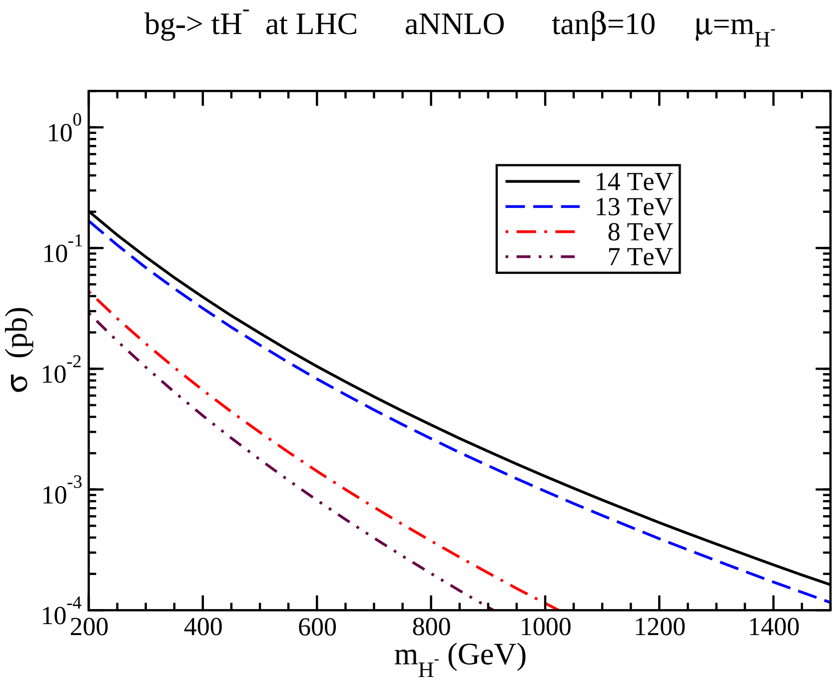
with coefficients $C_3^{(2)} = 2(C_F + C_A)^2$

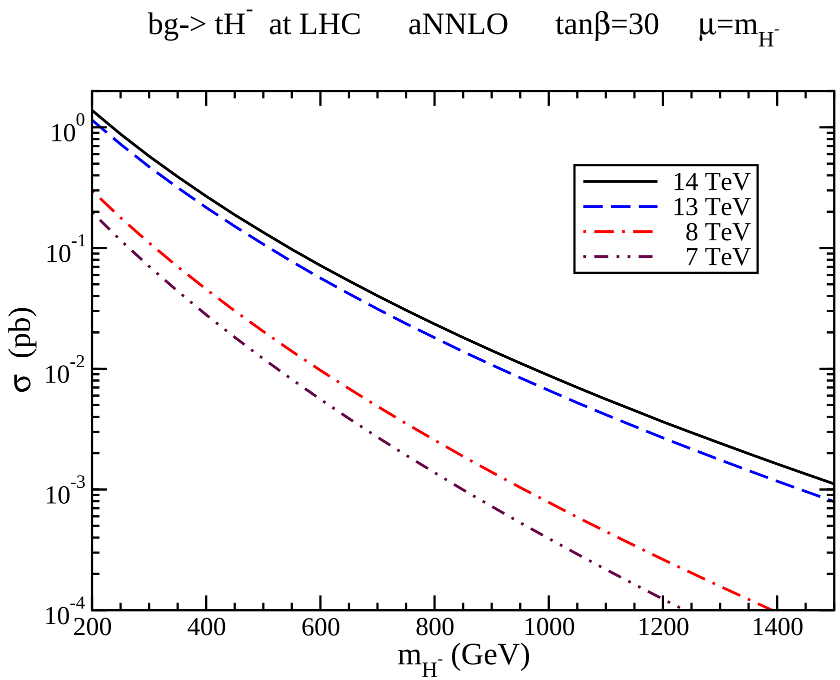
$$C_2^{(2)} = (C_F + C_A)\left\{3C_F\left[2\ln\left(\frac{m_t^2 - t}{m_t\sqrt{s}}\right) - 2\ln\left(\frac{m_H^2 - u}{m_H^2}\right) - 1\right]\right.$$
$$\left. - 3C_A\left[\ln\left(\frac{m_t^2 - t}{m_t^2 - u}\right) + 2\ln\left(\frac{m_H^2 - t}{m_H^2}\right)\right] - 3(C_F + C_A)\ln\left(\frac{\mu_F^2}{s}\right)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

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

tH^- production

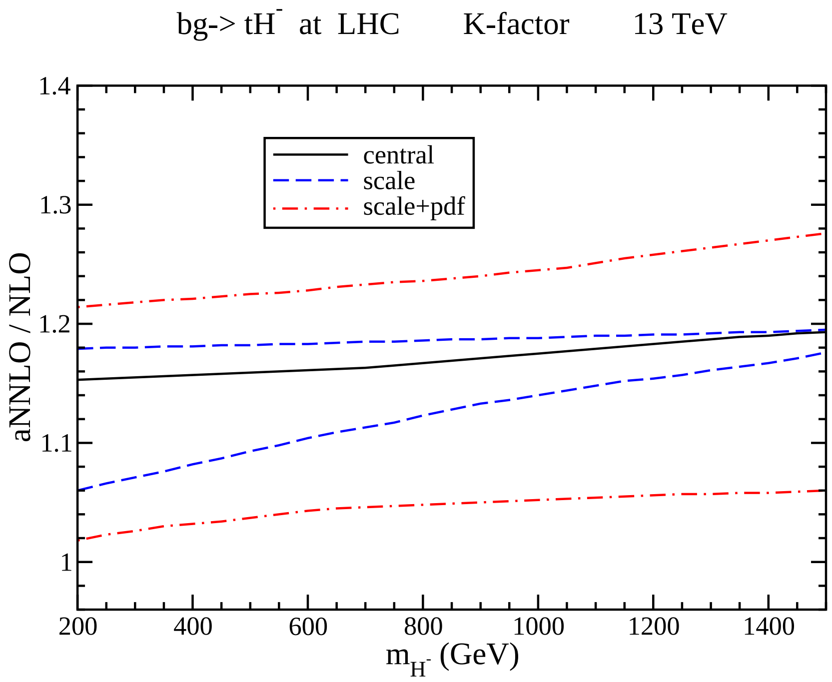
Total cross sections

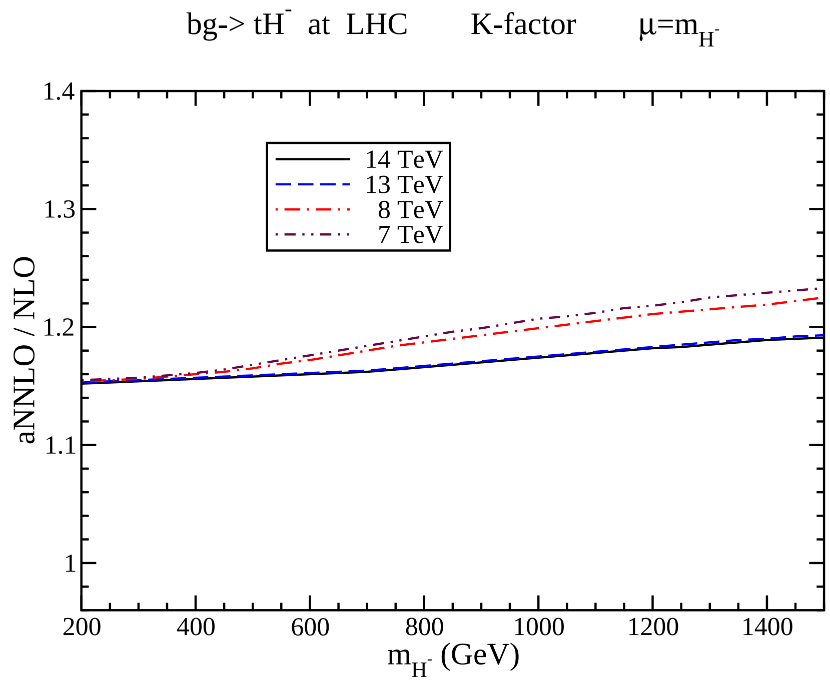




tH^- production

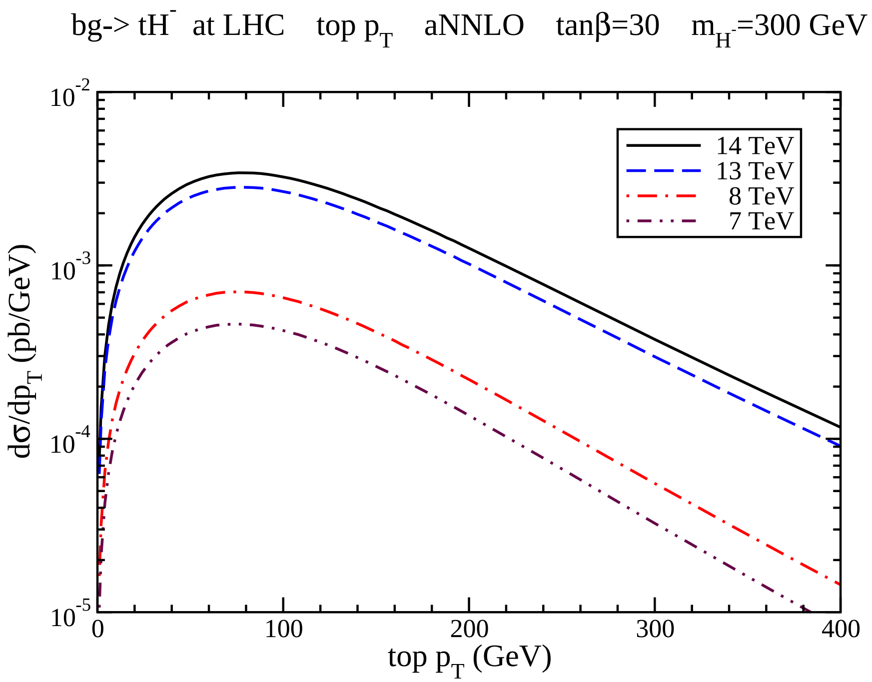
K-factors

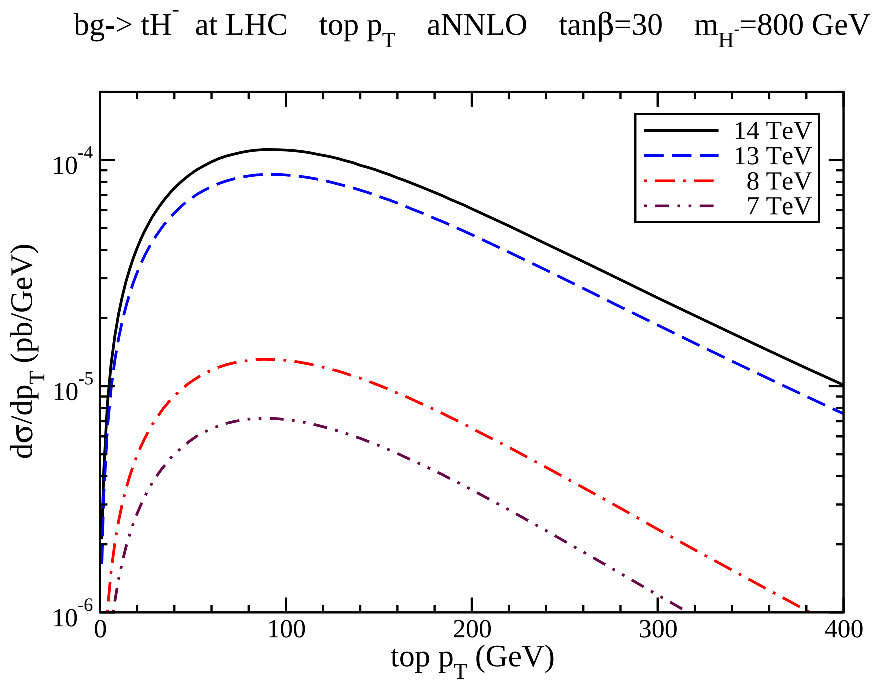




tH^- production

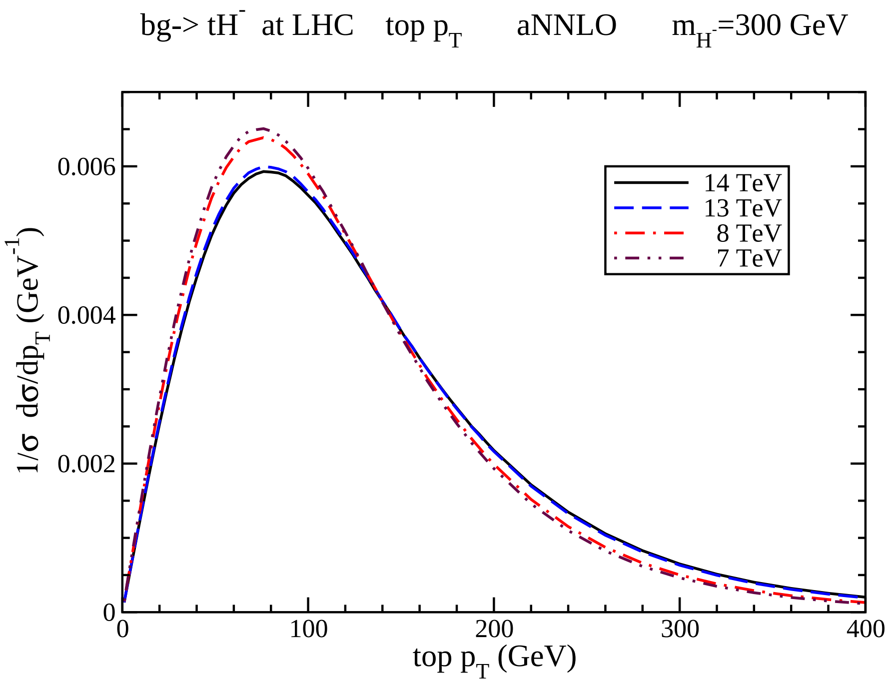
Top p_T distributions

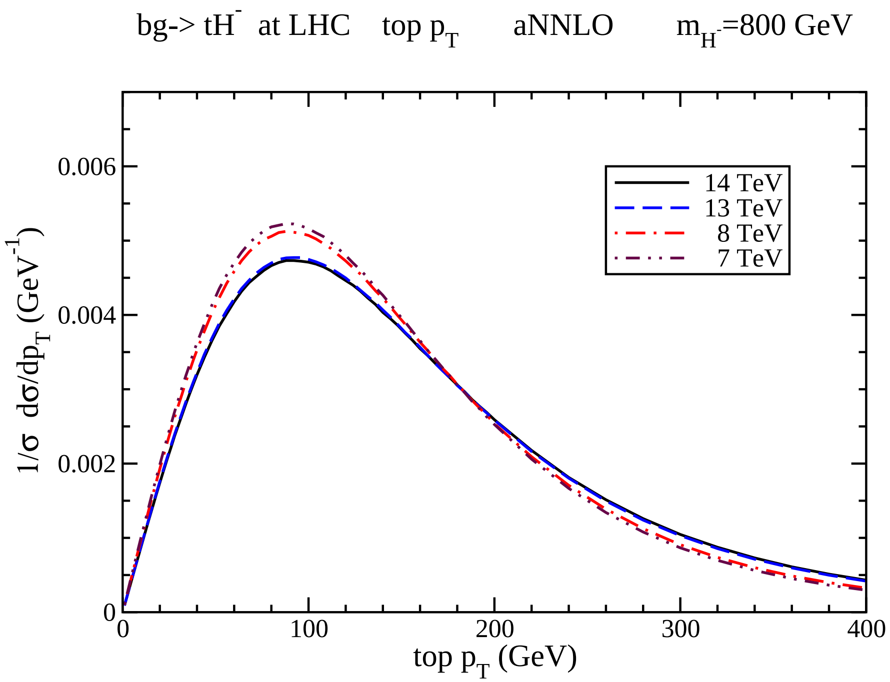




tH^- production

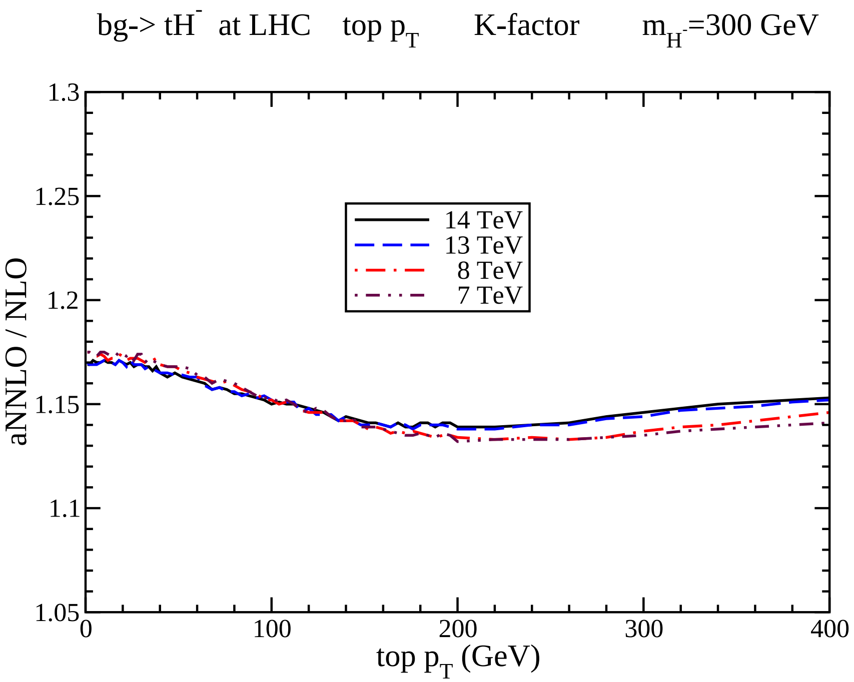
Normalized top p_T distributions

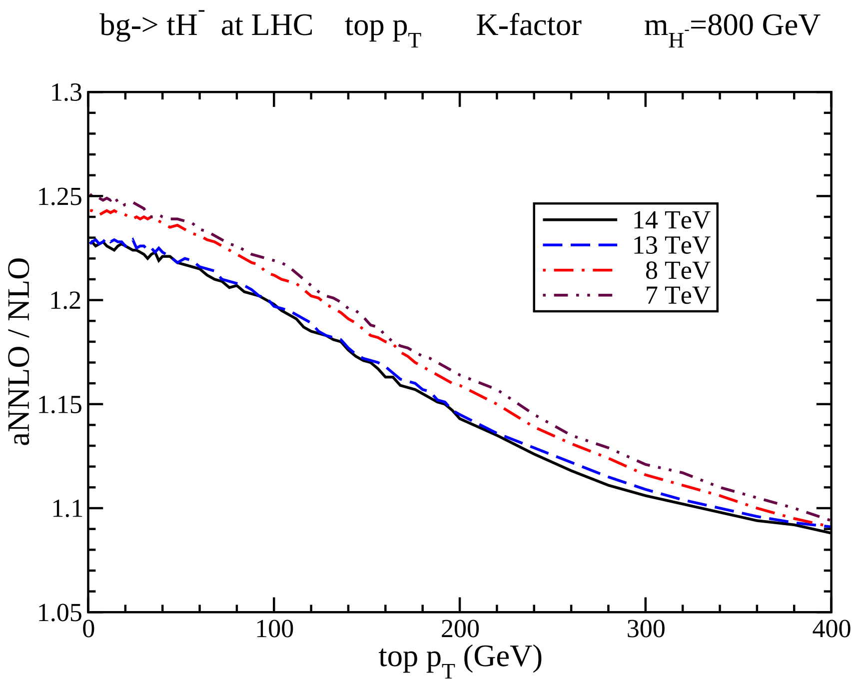




tH^- production

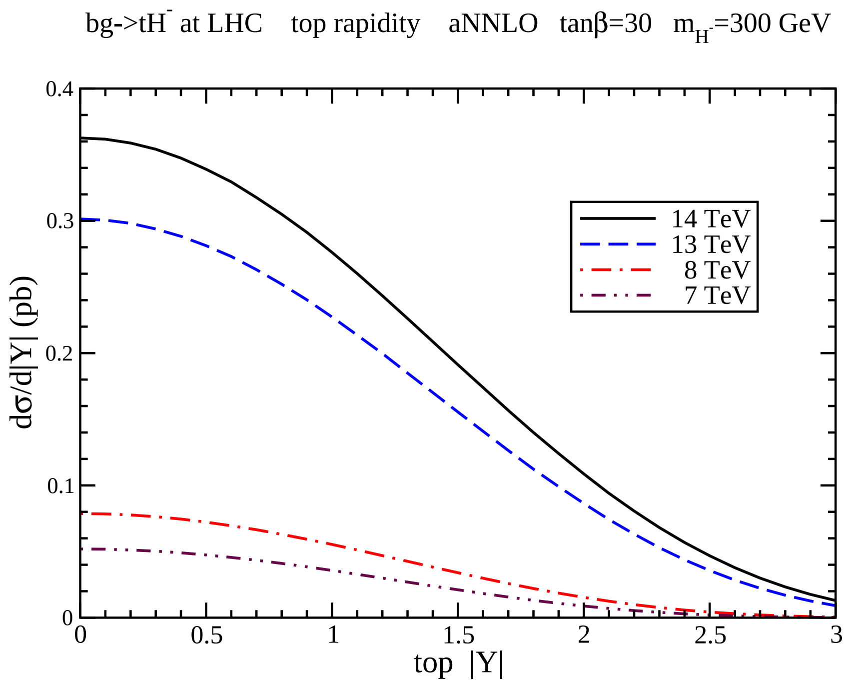
K-factors for top p_T distributions

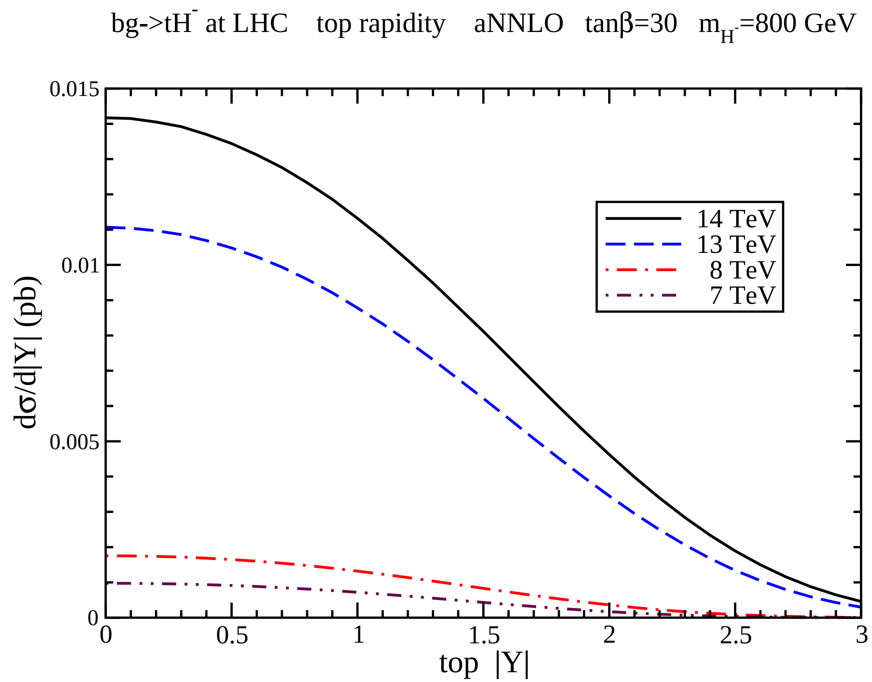




tH^- production

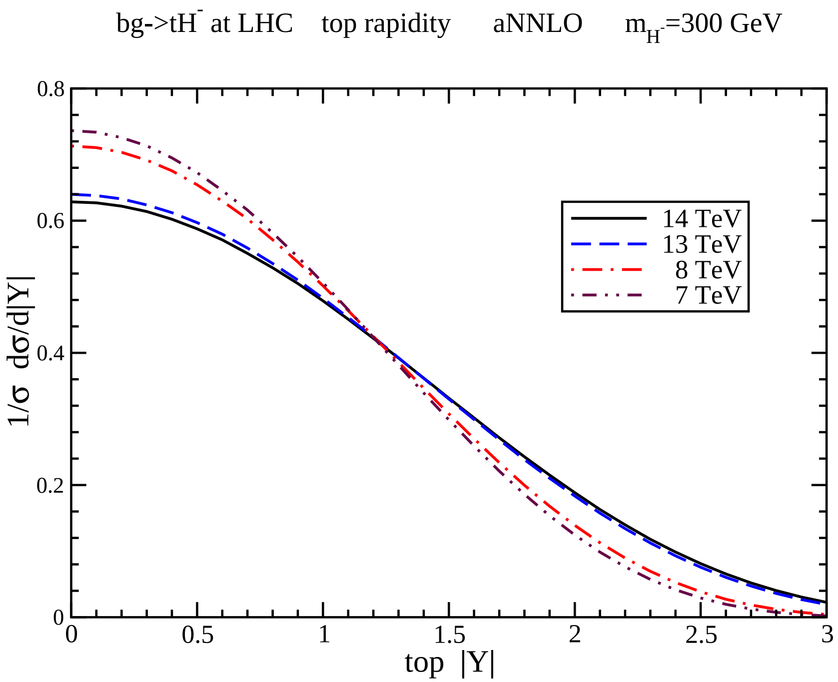
Top rapidity distributions

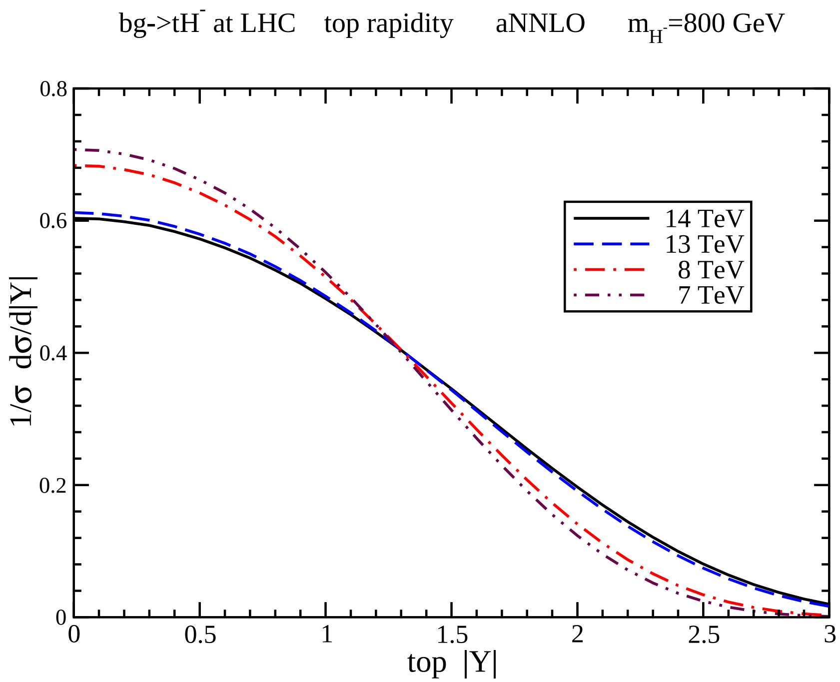




tH^- production

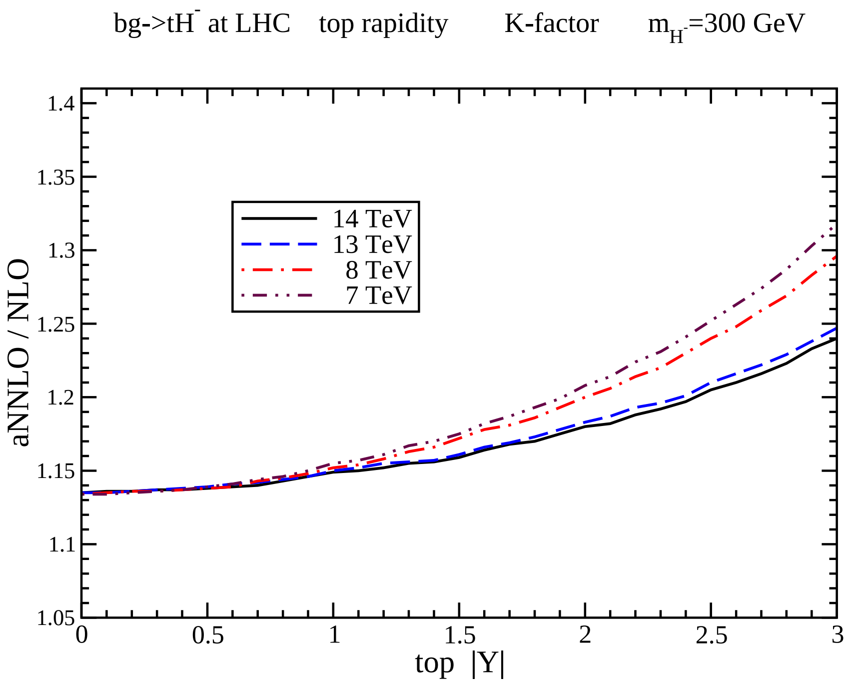
Normalized top rapidity distributions

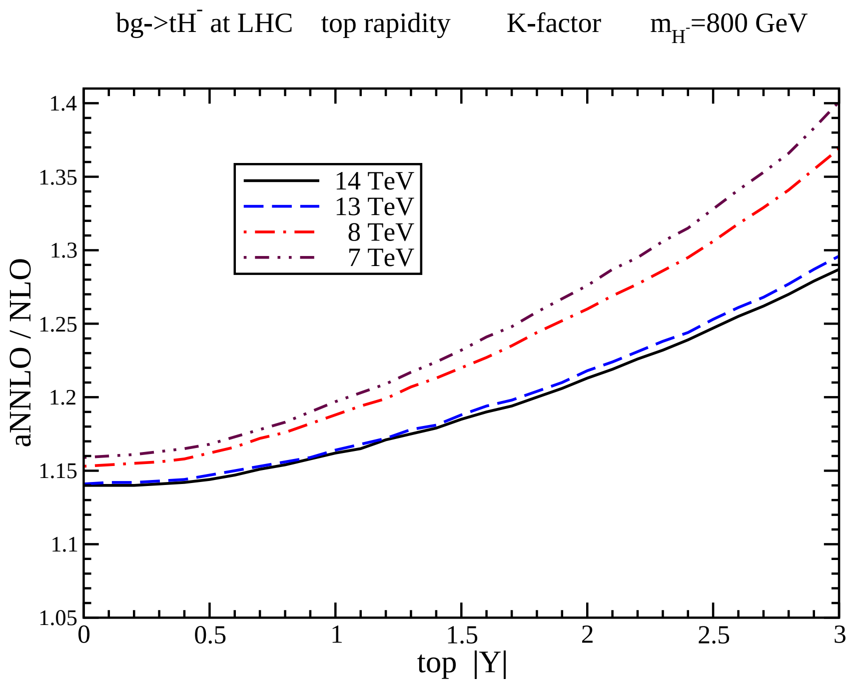




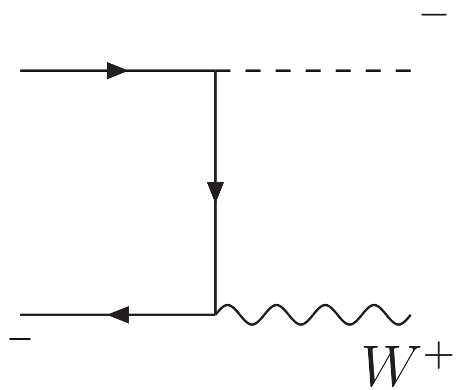
tH^- production

K-factors for top rapidity distributions





H^-W^+ production



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

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 $s_4 \rightarrow 0$

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

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

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

Resummed cross section

$$\hat{\sigma}_{\rm res}^{b\bar{b}\to H^- W^+}(N) = \exp\left[\sum_{i=b,\bar{b}} E_i(N_i)\right] H^{b\bar{b}\to H^- W^+}\left(\alpha_s(\sqrt{s})\right)\; S^{b\bar{b}\to H^- W^+}\left(\alpha_s(\sqrt{s}/\tilde{N}')\right)$$

$$\times \exp\left[2\int_{\sqrt{s}}^{\sqrt{s}/\tilde{N}'} \frac{d\mu}{\mu}\, \Gamma_S^{b\bar{b}\to H^- W^+}\left(\alpha_s(\mu)\right)\right]$$

The NNLO collinear and soft-gluon corrections are

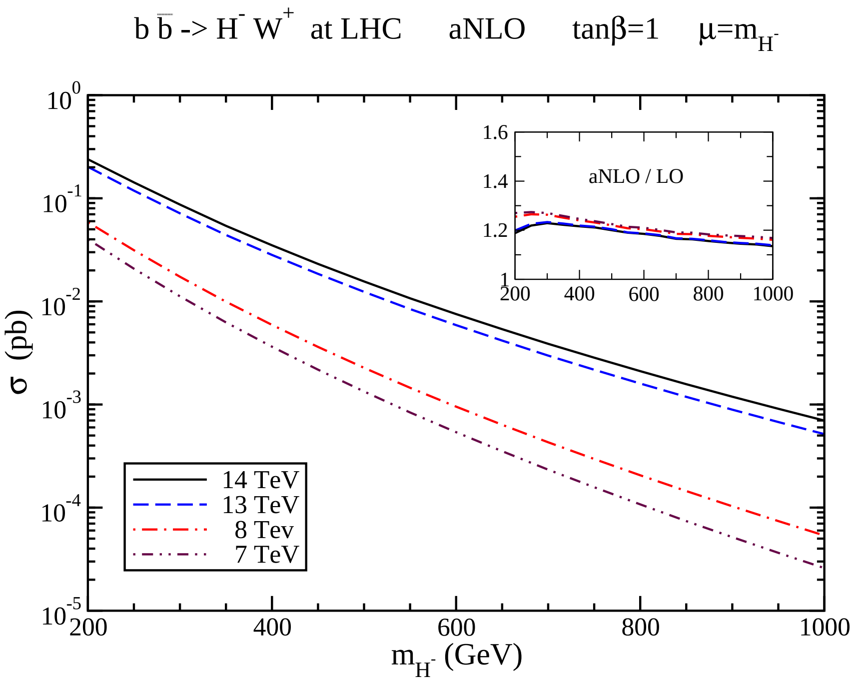
$$\frac{d^2\hat{\sigma}^{(2)\, b\bar{b}\to H^- W^+}_{\rm aNNLO}}{dt\,du} = F_{LO}^{b\bar{b}\to H^- W^+}\frac{\alpha_s^2}{\pi^2}\left\{-C_3^{(2)}\frac{1}{m_H^2}\ln^3\left(\frac{s_4}{m_H^2}\right)+\sum_{k=0}^{3} C_k^{(2)}\left[\frac{\ln^k(s_4/m_H^2)}{s_4}\right]_+\right\}$$

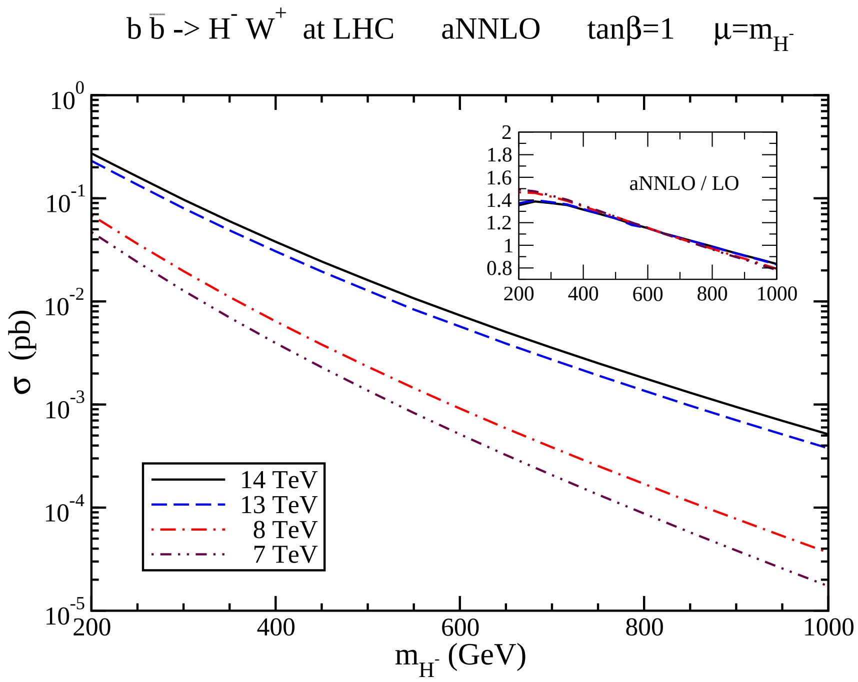
with $C_3^{(2)} = 8C_F^2$

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

H^-W^+ production

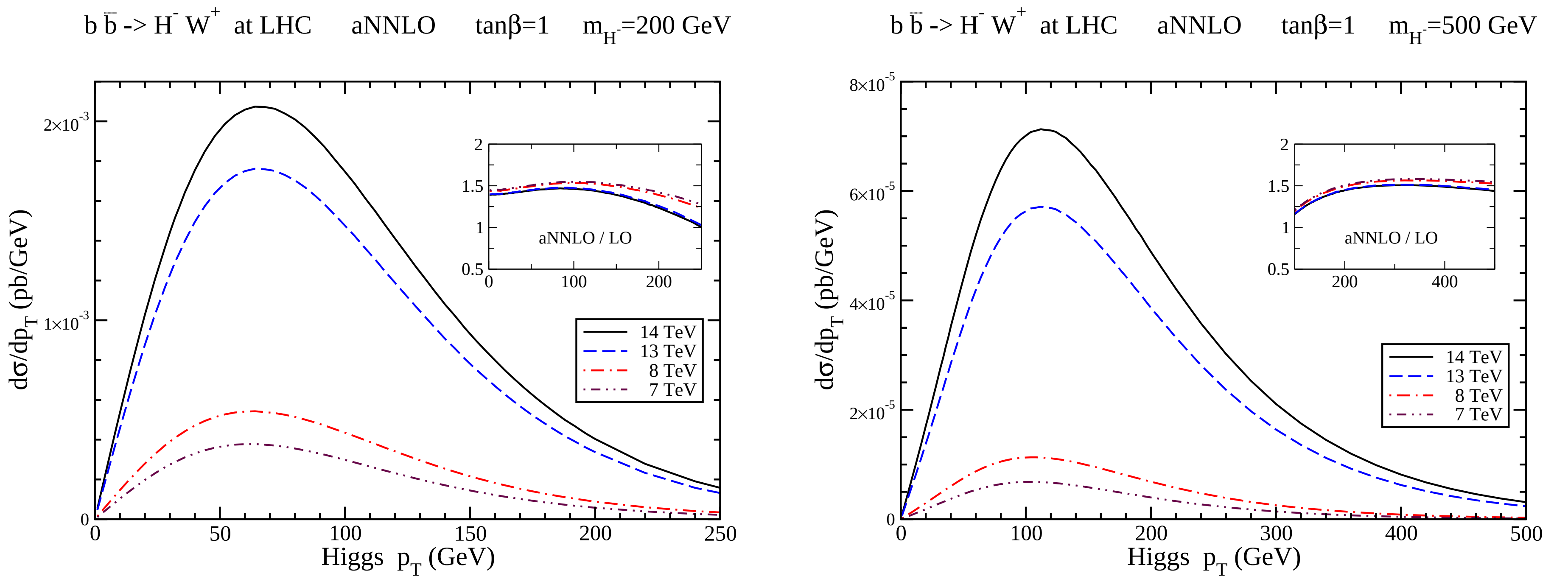
Total cross sections





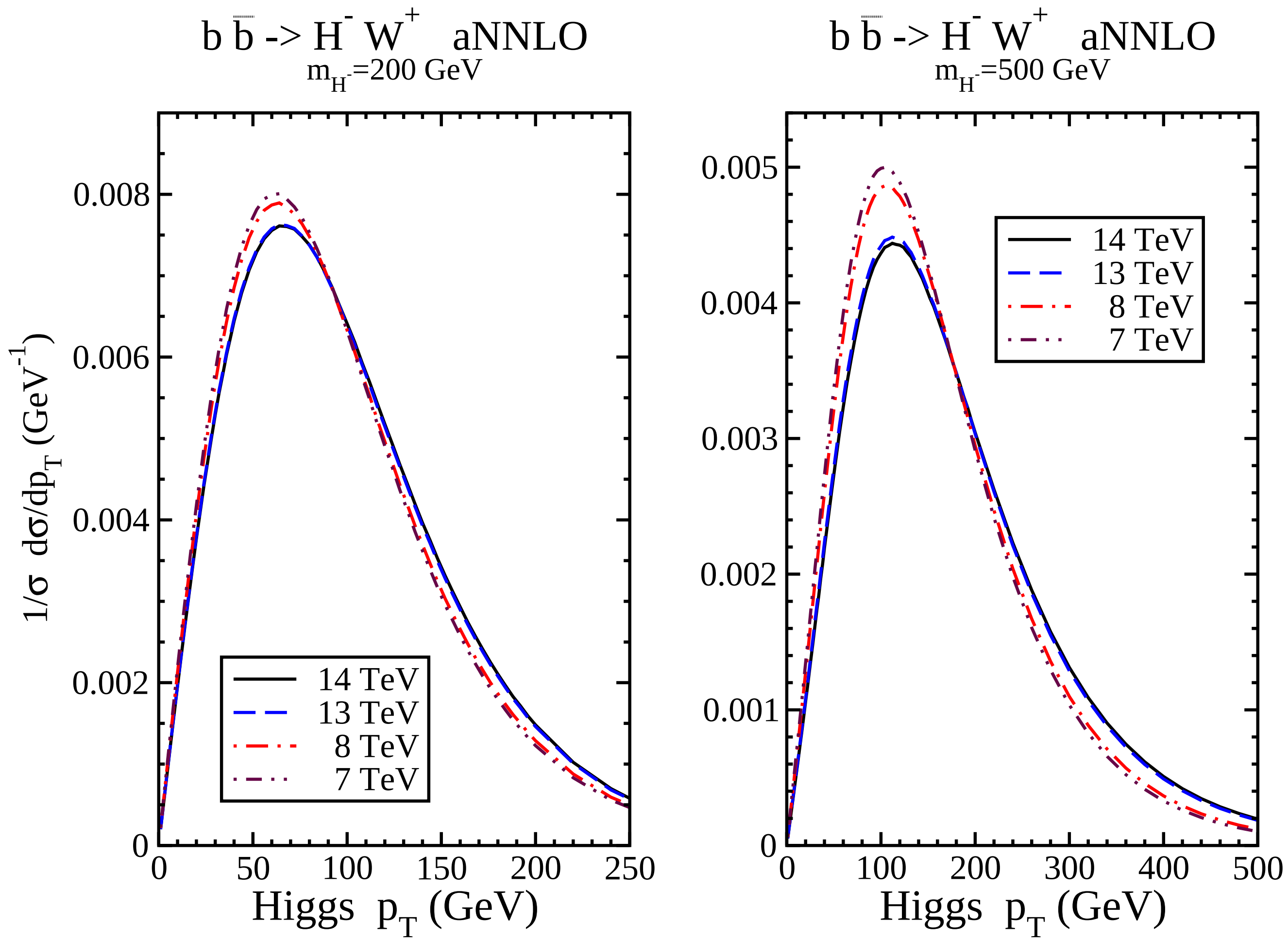
H^-W^+ production

Charged Higgs p_T distributions



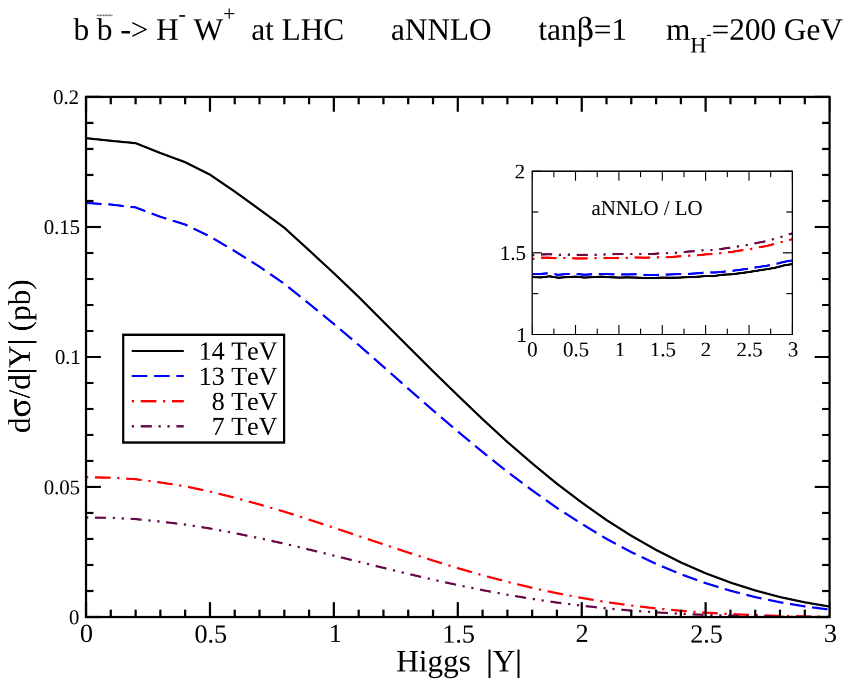
H^-W^+ production

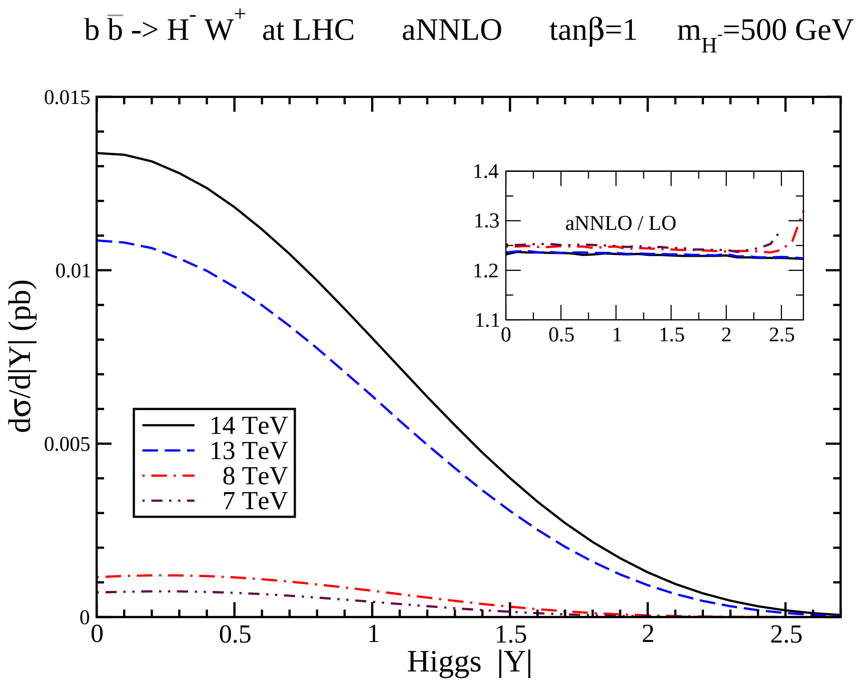
Normalized charged Higgs p_T distributions



H^-W^+ production

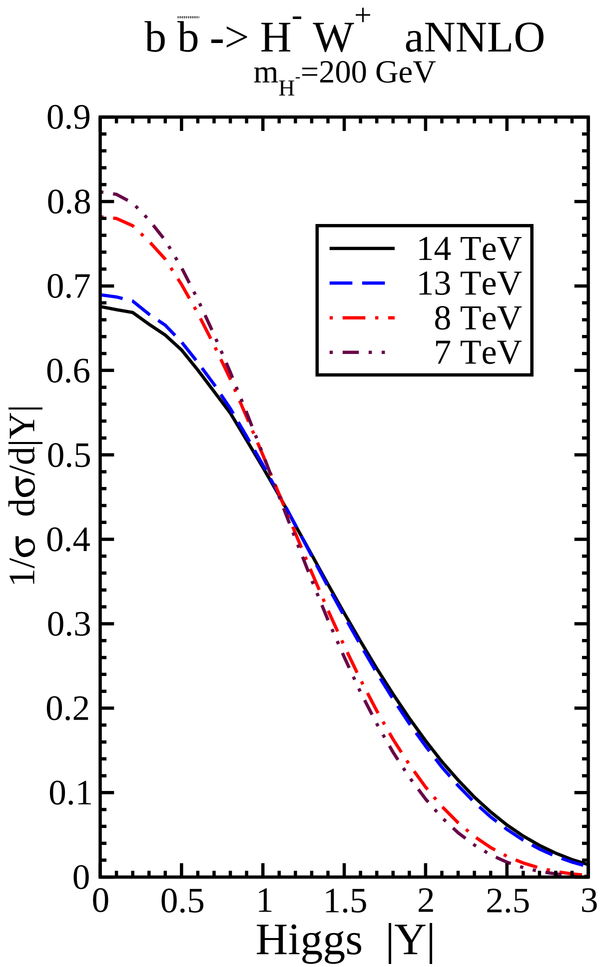
Charged Higgs rapidity distributions

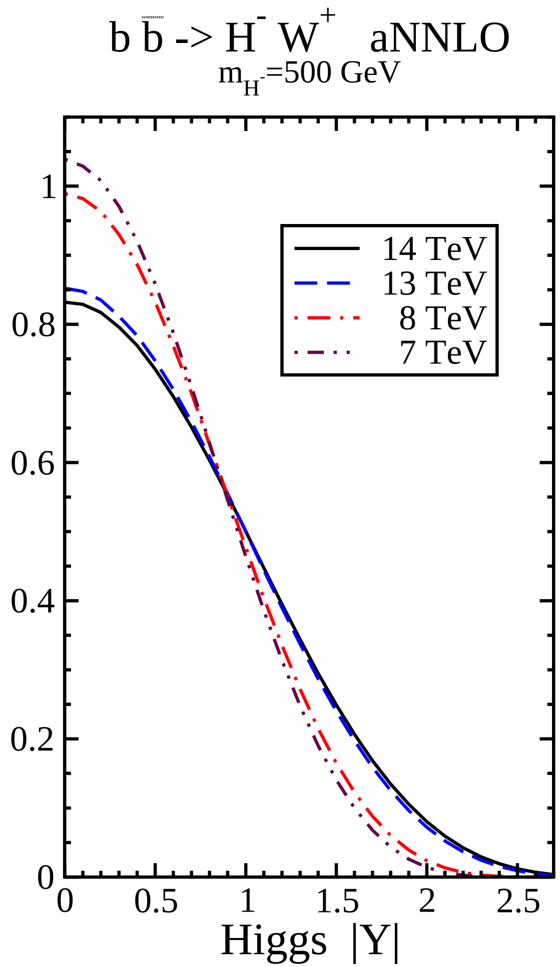




H^-W^+ production

Normalized charged Higgs rapidity distributions





Summary

- **many new results in charged Higgs production**
- **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**