MSSM Higgs production at NLO QCD

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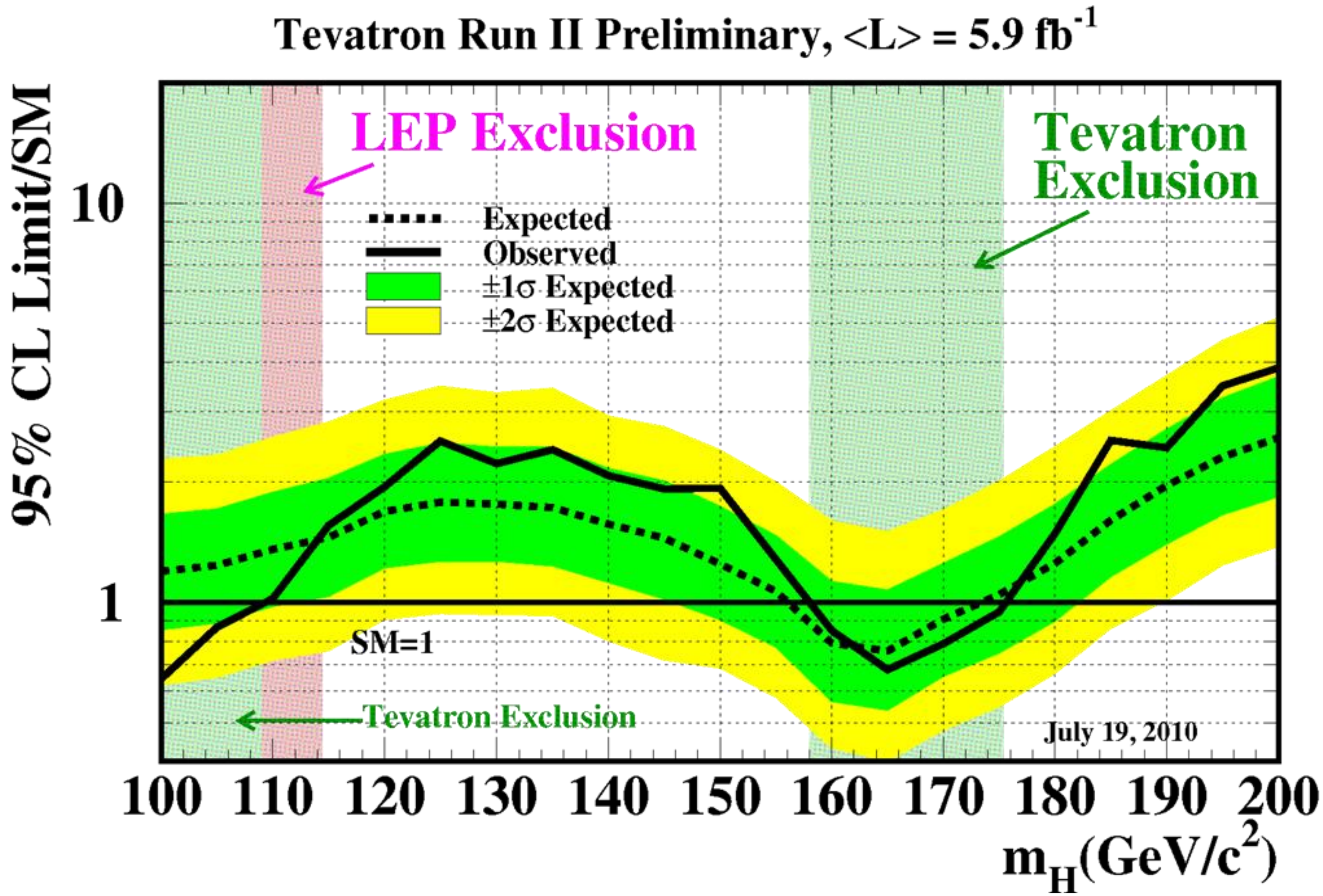
Outline

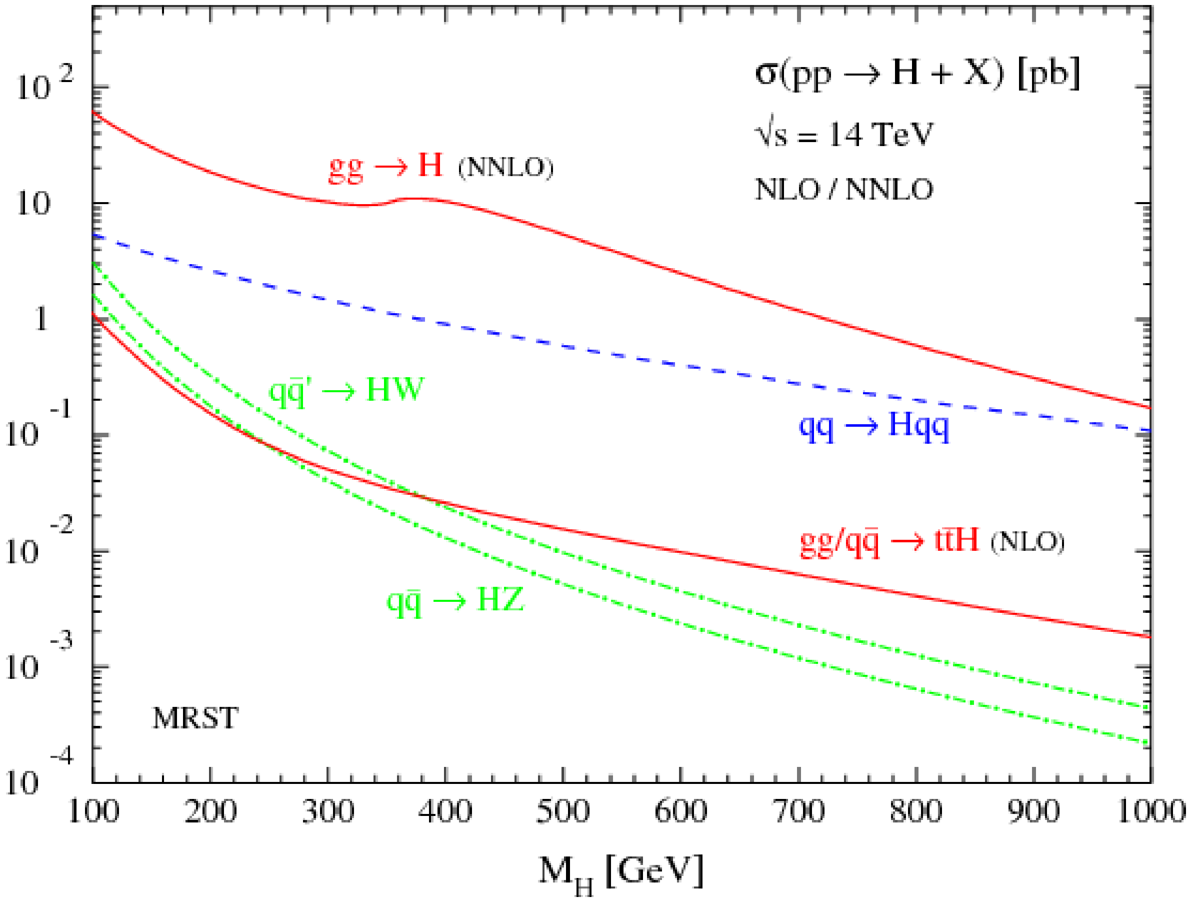
- Higgs production
  - Gluon fusion
  - Effective theory
- Supersymmetry (MSSM)
- Results

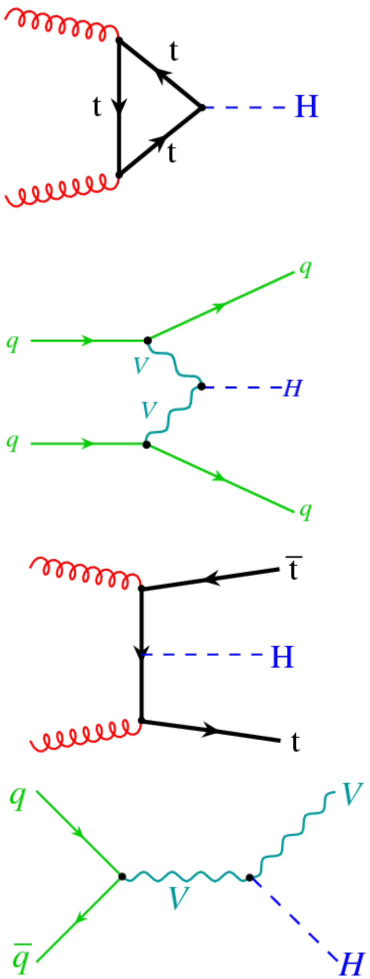
Higgs production

Higgs production

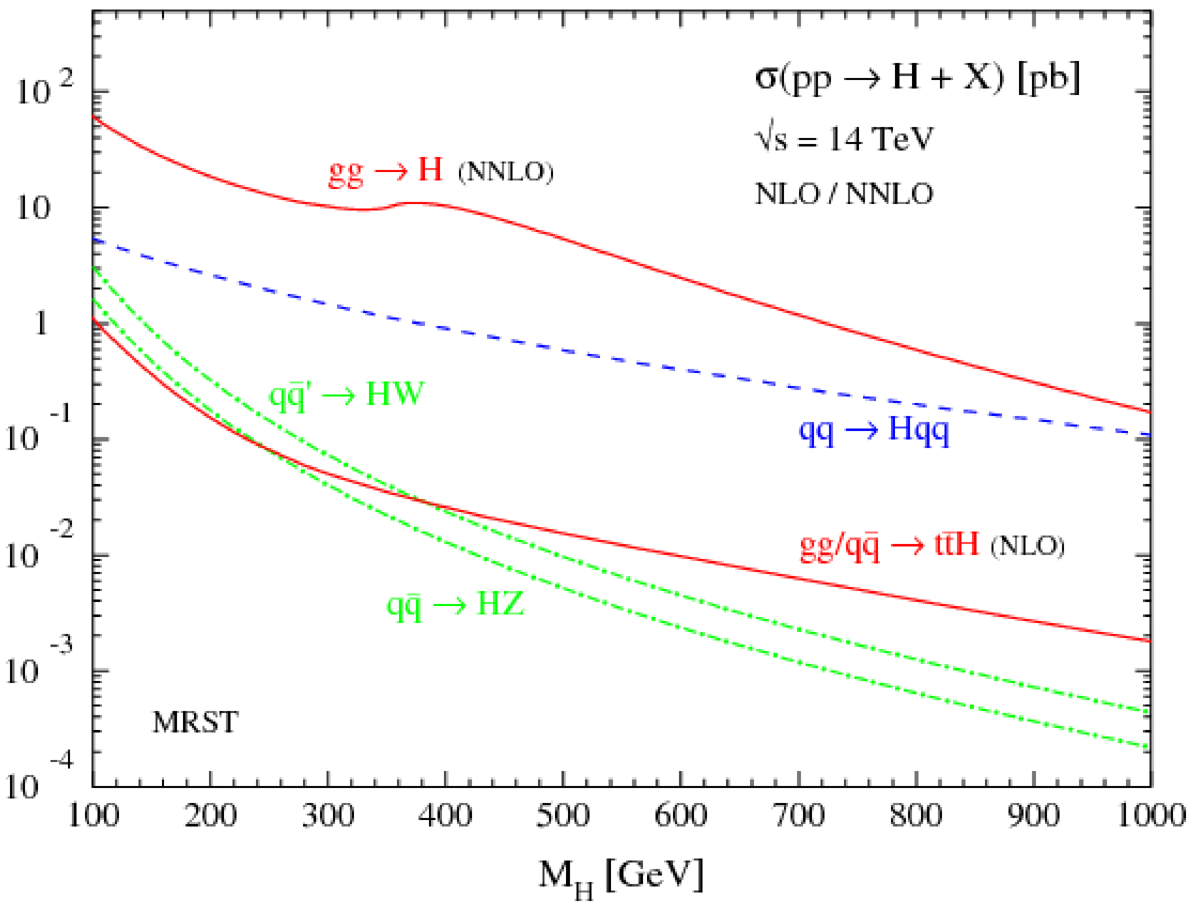


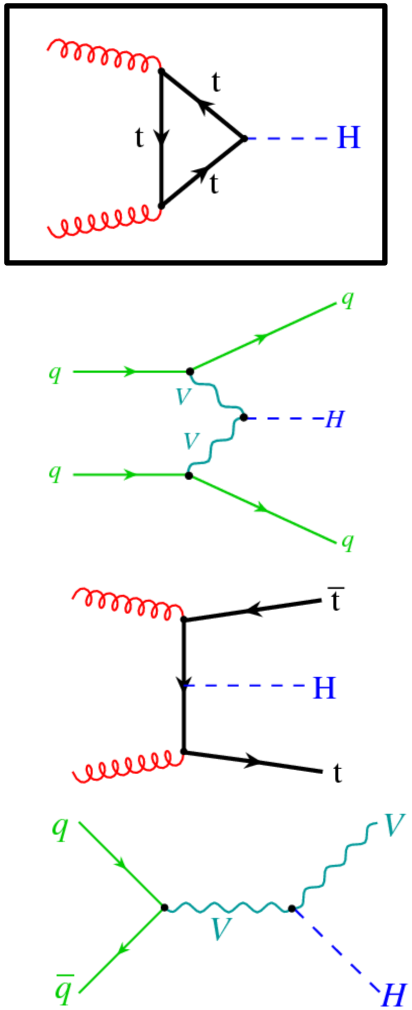
Higgs production





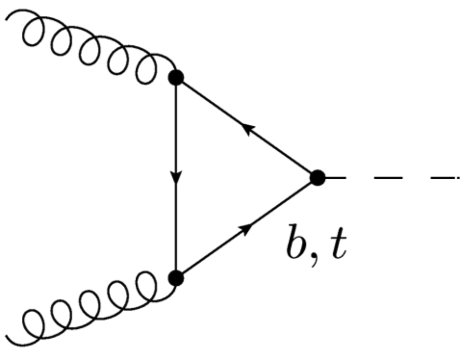
Higgs production





Gluon fusion

leading order
1 loop



$$\sigma_0 = \frac{\alpha_S^2(\mu_R)\, G_F}{288\sqrt{2}\pi} \cdot \left| \sum_q g_q \cdot F(\tau_q) \right|^2$$

$$F(\tau_q) = \frac{3}{2}\tau_q \left[1 + (1 - \tau_q)\, f(\tau_q)\right]$$

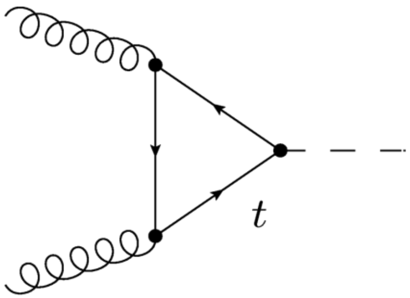
$$f(\tau) = \begin{cases} \arcsin^2\left(\frac{1}{\sqrt{\tau}}\right), & \tau \geq 1 \\ -\frac{1}{4}\left[\log\frac{1+\sqrt{1-\tau}}{1-\sqrt{1-\tau}} - i\pi\right]^2, & \tau < 1 \end{cases}$$

$$\tau_q = \frac{4m_q^2}{m_h^2}$$

Higher order corrections are difficult to calculate,
but important!

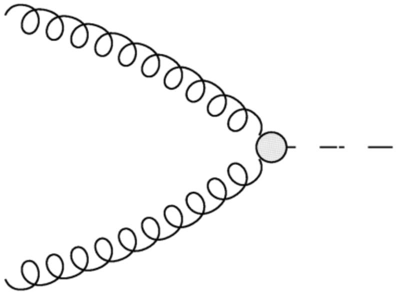
Effective theory

$$\boxed{\mathcal{L}_{\text{eff}} = C_1 \cdot H\, G_{\mu\nu} G^{\mu\nu}}$$



$m_t \gg m_h$

$C_1 \cdot$



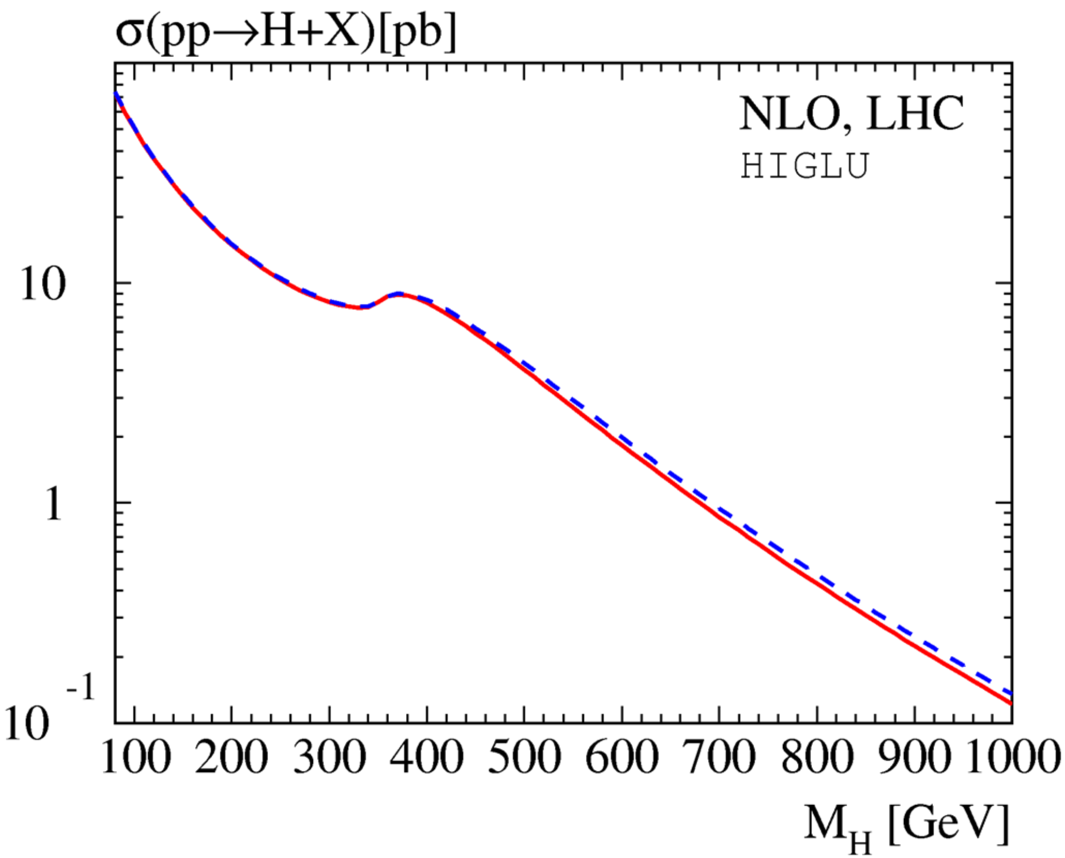
effective vertices:
ggh, gggh etc.

SM (N^4LO): Schröder, Steinhauser (2006)
Chetyrkin, Kühn, Sturm (2006)

MSSM (NLO): Harlander, Steinhauser (2004)
Degrassi, Slavich (2008)
Mühlleitner, Rzehak, Spira (2008)

Effective theory NLO QCD

$$\sigma_{\text{eff}}^{NLO} = \sigma^{LO}(m_t) \cdot \left(\frac{\sigma^{NLO}}{\sigma^{LO}}\right)_{m_t \to \infty}$$



effective theory:

Djouadi, Spira, Zerwas (1991)

Dawson (1991)

exact:

Spira, Djouadi, Graudenz, Zerwas (1995)

Overview

QCD

NNLO (effective theory)

Harlander, Kilgore (2002)
Anastasiou, Melnikov (2002)
Ravindran, Smith, van Neerven (2003)

NNLO $\frac{1}{m_t}$ -terms

Harlander, HM, Marzani, Ozeren (2010)
Pak, Rogal, Steinhauser (2010)

electro-weak

NLO ($\sim$ 5%)

Aglietti, Bonciani, Degrassi, Vincini (2004)
Actis, Passarino, Sturm, Uccirati (2008)

Supersymmetry

The Minimal Supersymmetric Standard Model

SM

- $\begin{matrix} u & c & t \\ d & s & b \\ e & \mu & \tau \\ \nu_e & \nu_\mu & \nu_\tau \end{matrix}$ spin $\frac{1}{2}$
- 1 higgs-boson

  h

MSSM

- $\begin{matrix} \tilde{u} & \tilde{c} & \tilde{t} \\ \tilde{d} & \tilde{s} & \tilde{b} \\ \tilde{e} & \tilde{\mu} & \tilde{\tau} \\ \tilde{\nu}_e & \tilde{\nu}_\mu & \tilde{\nu}_\tau \end{matrix}$ spin 0
- 5 higgs-bosons

  $h, H, A, H^\pm$ + superpartners

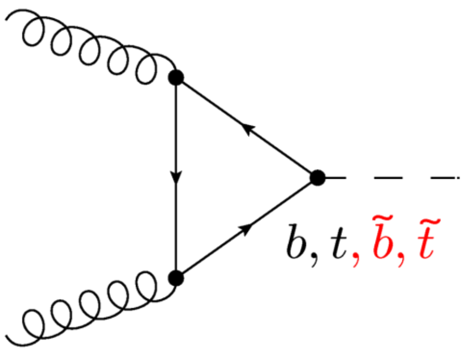
here: only lightest, neutral higgs h

theory prediction: $m_h \lesssim 135$ GeV

Gluon fusion

leading order
1 loop

$$\sigma_0 = \frac{\alpha_S^2(\mu_R)\, G_F}{288\sqrt{2}\pi} \cdot \left| \sum_q g_q \cdot F(\tau_q) + \sum_{\tilde{q}} g_{\tilde{q}} \cdot \tilde{F}(\tau_{\tilde{q}}) \right|^2$$



$$F(\tau_q) = \frac{3}{2}\tau_q \left[1 + (1 - \tau_q)\, f(\tau_q)\right]$$

$$\tilde{F}(\tau_{\tilde{q}}) = -\frac{3}{4}\tau_{\tilde{q}} \left[1 - \tau_{\tilde{q}} f(\tau_{\tilde{q}})\right]$$

$$f(\tau) = \begin{cases} \arcsin^2\left(\frac{1}{\sqrt{\tau}}\right), & \tau \geq 1 \\ -\frac{1}{4}\left[\log\frac{1+\sqrt{1-\tau}}{1-\sqrt{1-\tau}} - i\pi\right]^2, & \tau < 1 \end{cases}$$

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Gluon fusion

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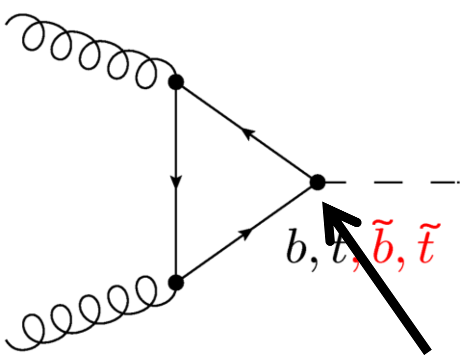

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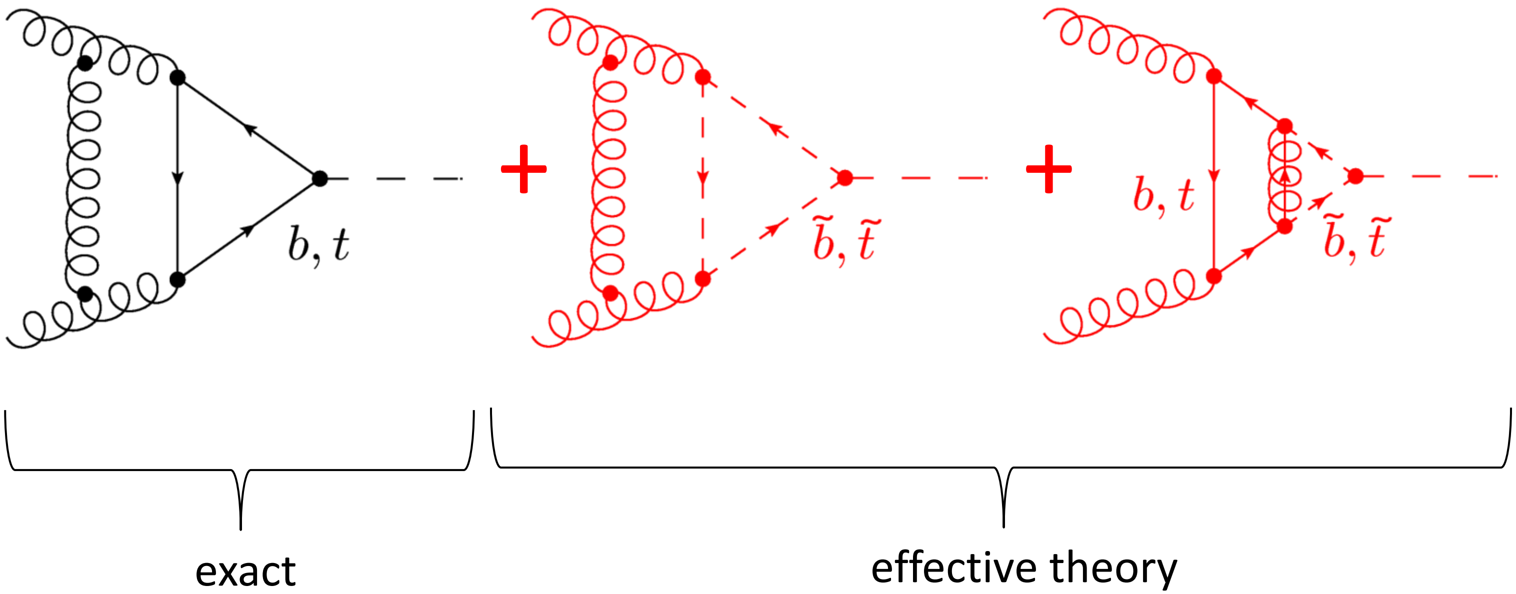
$$g_b, g_{\tilde{b}} \propto \frac{\tan\beta}{\sin\beta}$$

$$g_t, g_{\tilde{t}} \propto \frac{1}{\sin\beta}$$

$$\tau_q = \frac{4m_q^2}{m_h^2}$$

Gluon fusion

NLO virtual corrections

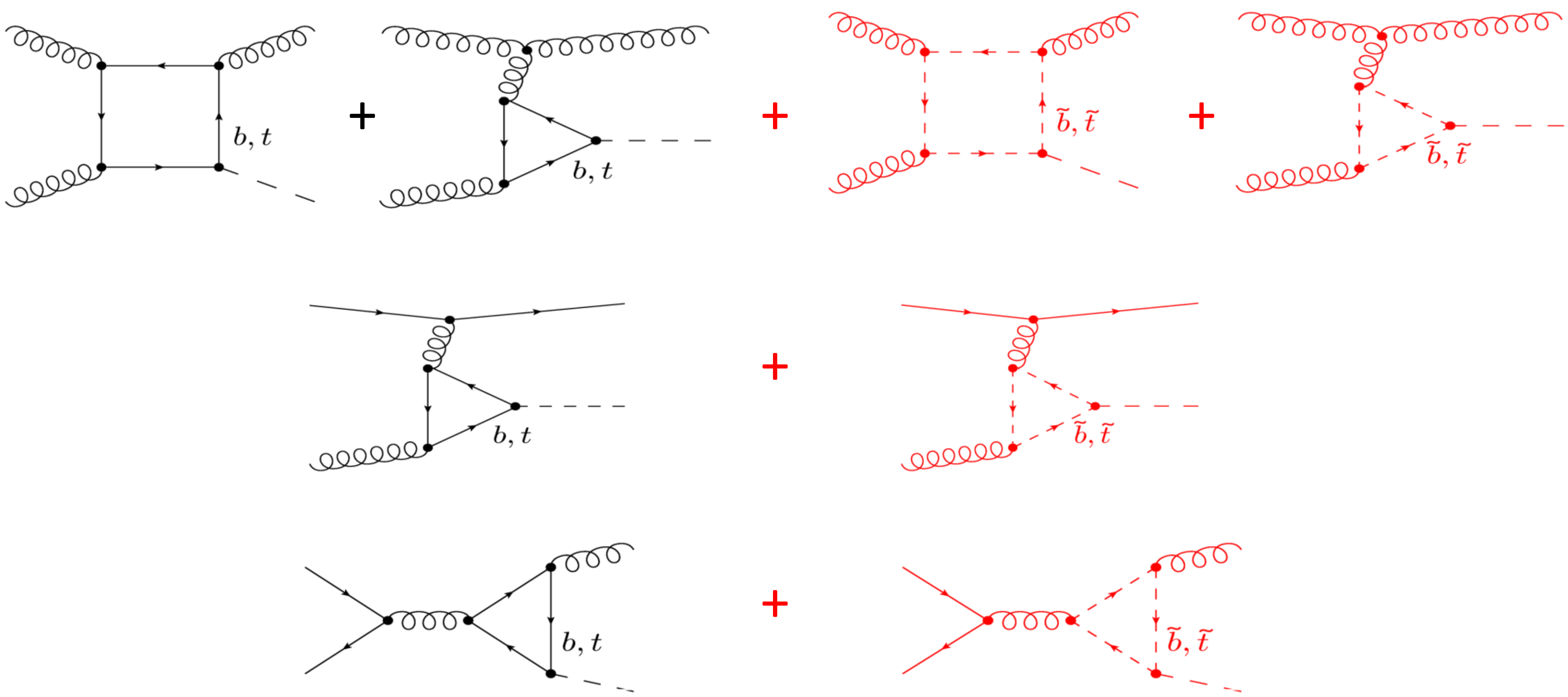


top-sector: $m_t, m_{\tilde{t}_1}, m_{\tilde{t}_2}, m_{\tilde{g}} \gg m_h$

bottom-sector: $m_{\tilde{b}_1} = m_{\tilde{b}_2} = m_{\tilde{g}} = \tilde{M} \gg m_h, m_b$

Gluon fusion

NLO real corrections



Overview

QCD

scalar quarks	Anastasiou, Beerli, Bucherer, Daleo, Kunszt (2007) Aglietti, Bonciani, Degrassi, Vincini (2007) Mühlleitner, Spira (2008)
NLO top/stop (effective theory)	Harlander, Steinhauser (2004) Degrassi, Slavich (2008)
NLO bottom/sbottom (effective theory)	Hofmann (2009) Degrassi, Slavich (2010)
NNLO top/stop (effective theory)	—

electro-weak

—

Results

Parameters of the MSSM

- 105 additional parameters
- define parameters by choosing benchmark scenarios:

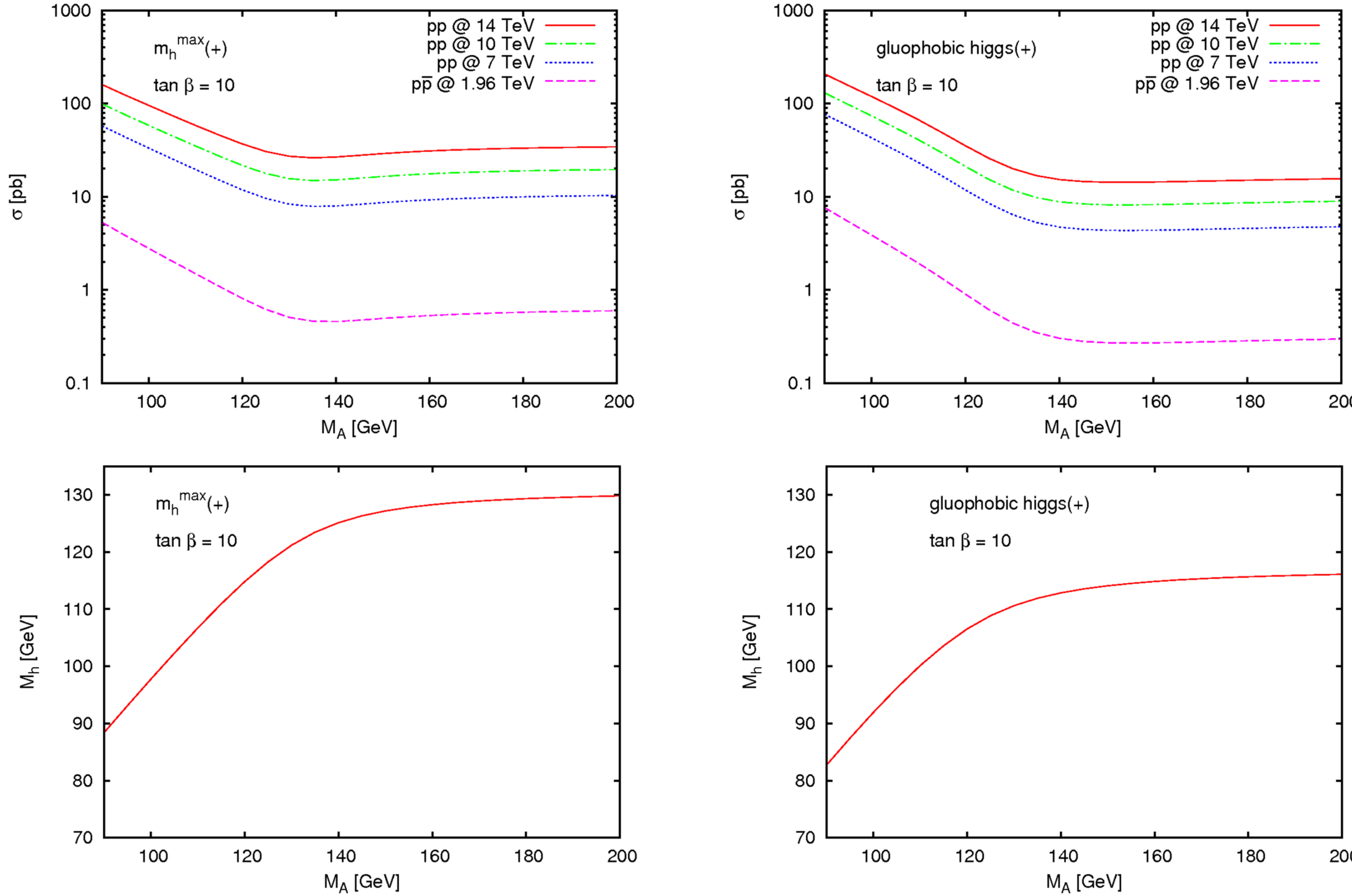
  - $m_h^{max}(\pm)$
  - no-mixing$(\pm)$
  - gluophobic higgs$(\pm)$
  - small $\alpha_{eff}(\pm)$

$$\text{sign}\,(\mu)$$

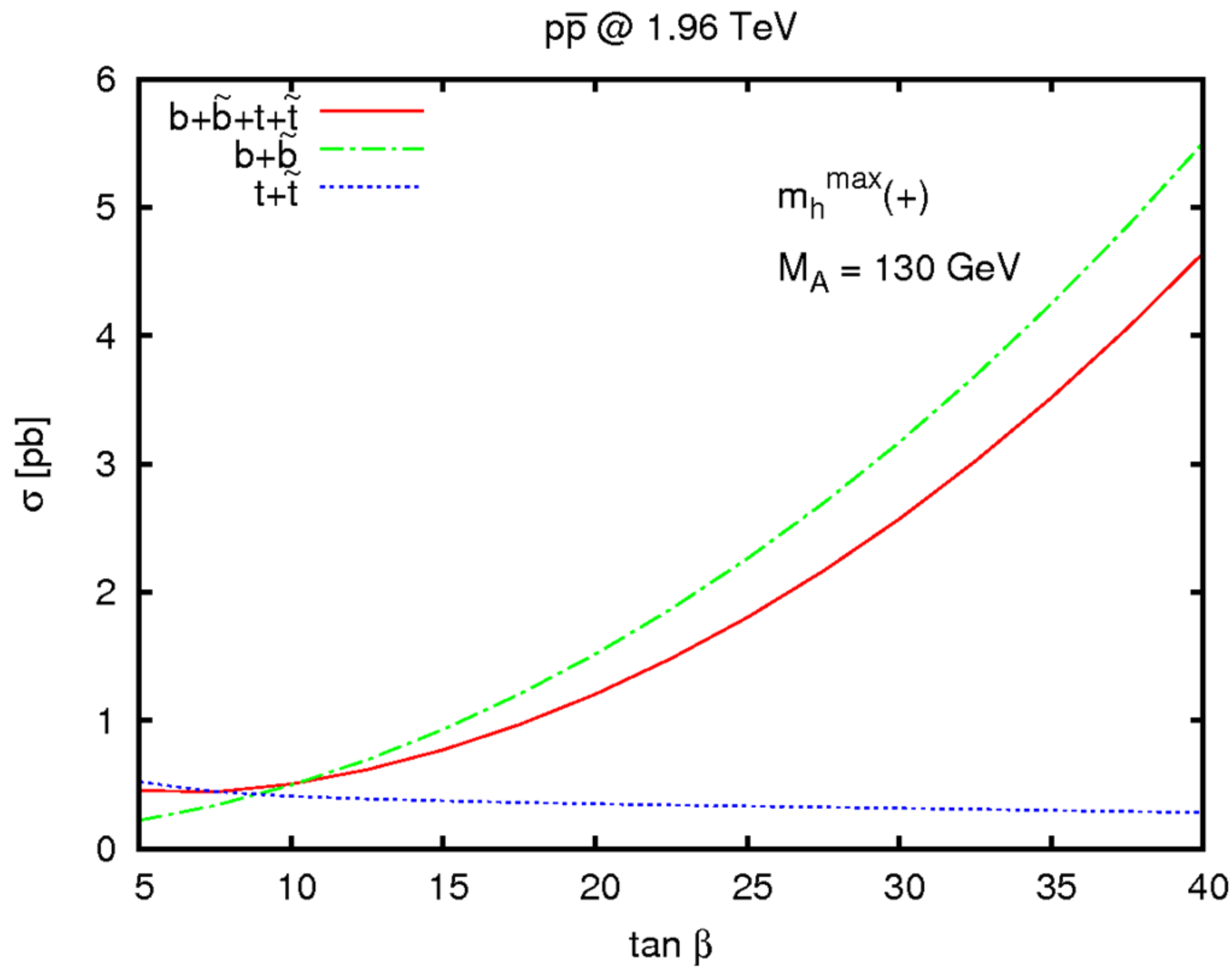
$$0.5 \leq \tan\beta \leq 50$$

$$50\,\text{GeV} \leq M_A \leq 1000\,\text{GeV}$$

Results (Preliminary)

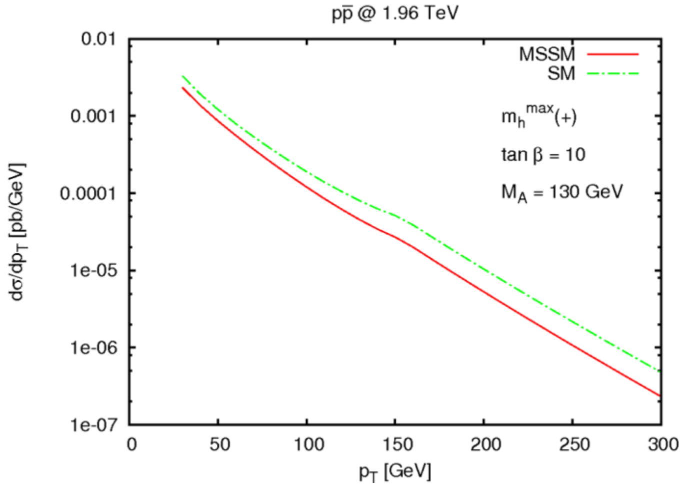


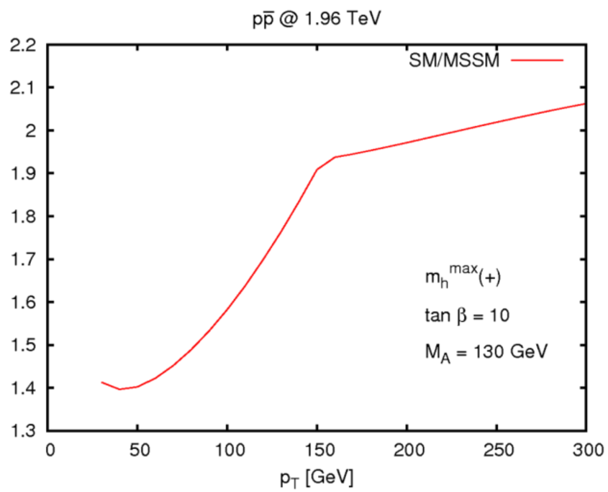
Results (Preliminary)



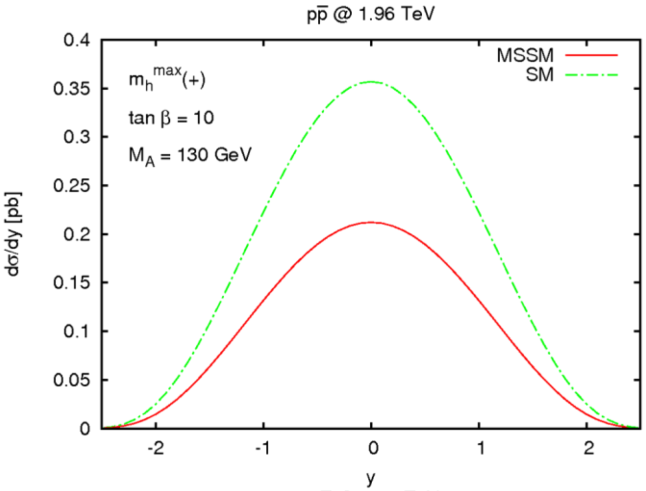
Results (Preliminary)

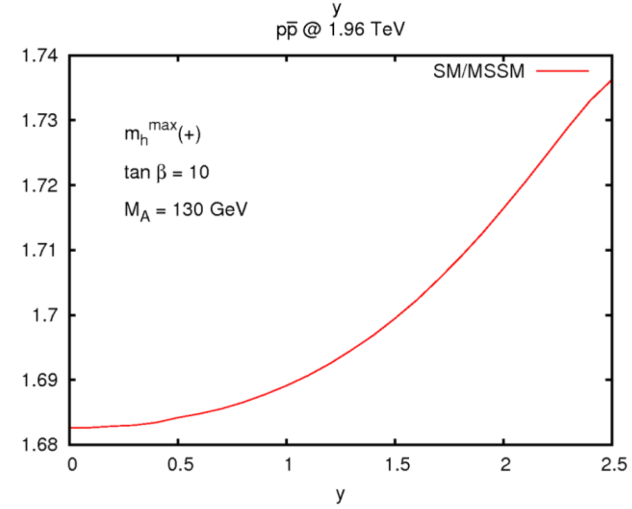
p_T distribution





Rapidity distribution





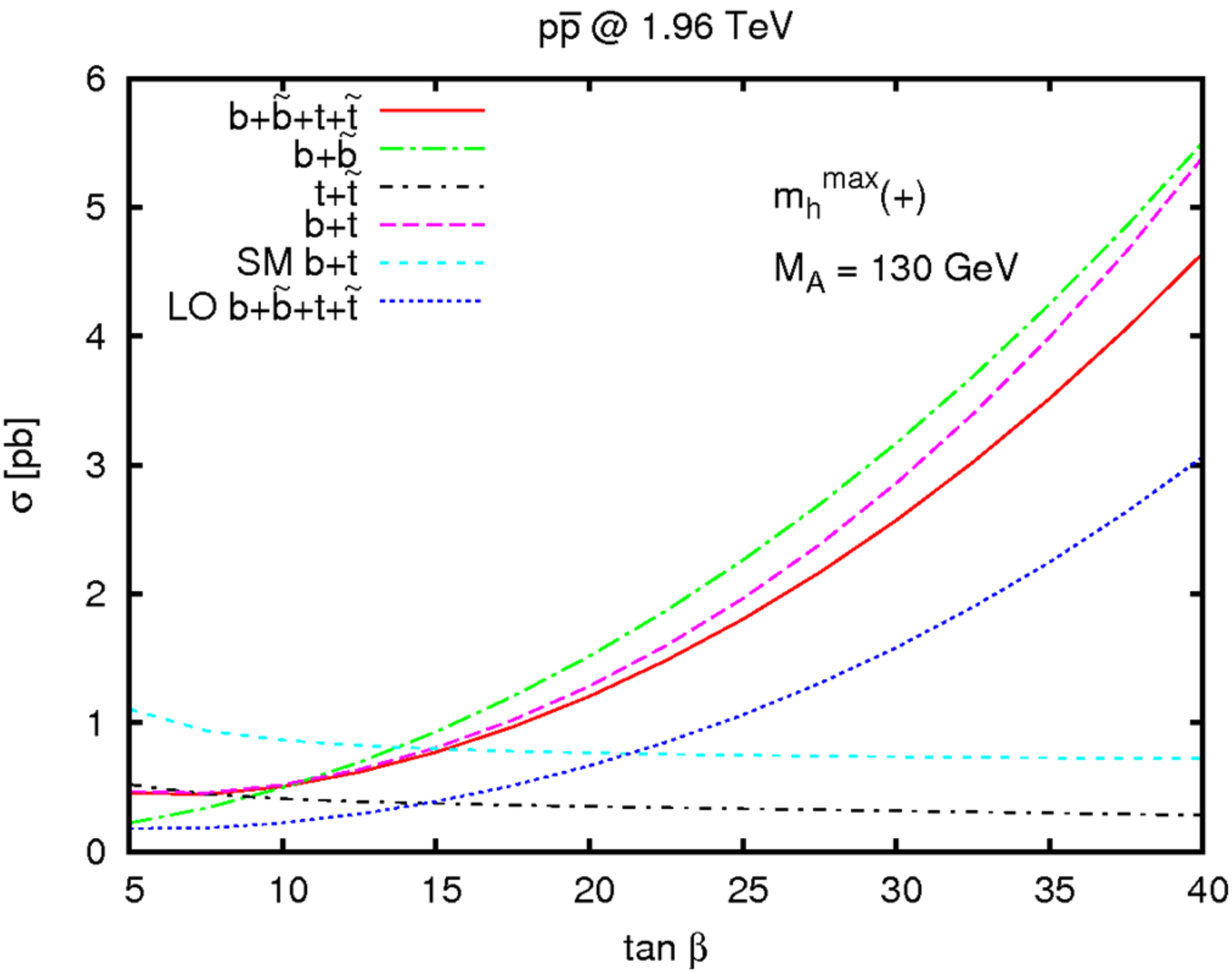
Conclusion

- first complete calculation within the MSSM including the top- and bottom-sector
- p_T- and rapidity distributions

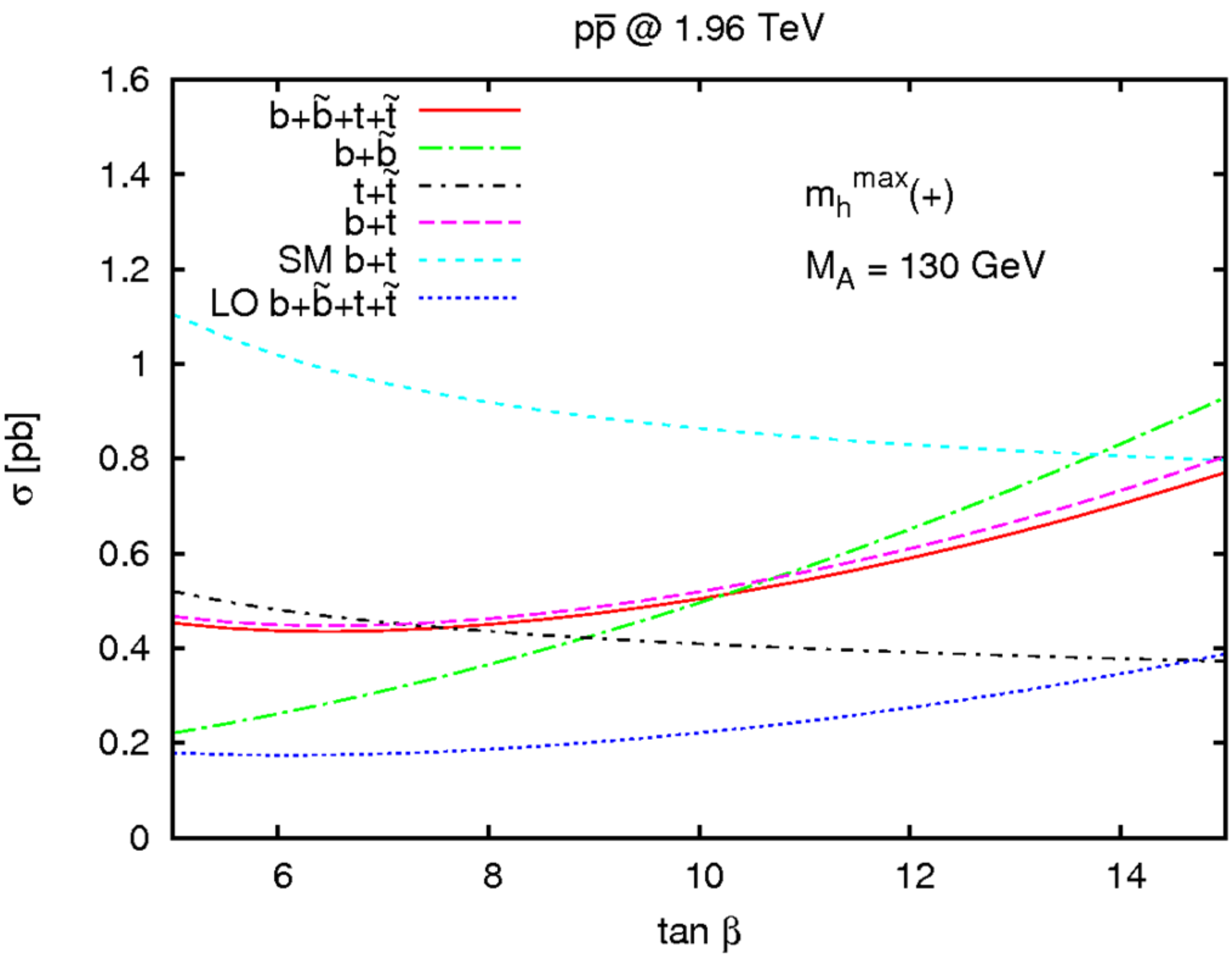
Outlook

- renormalization scheme dependence
- SUSY electro-weak corrections

Results (Preliminary)



Results (Preliminary)



Results (Preliminary)