Top Mass Effects in Higgs Production at the LHC*

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Bergische Universität Wuppertal

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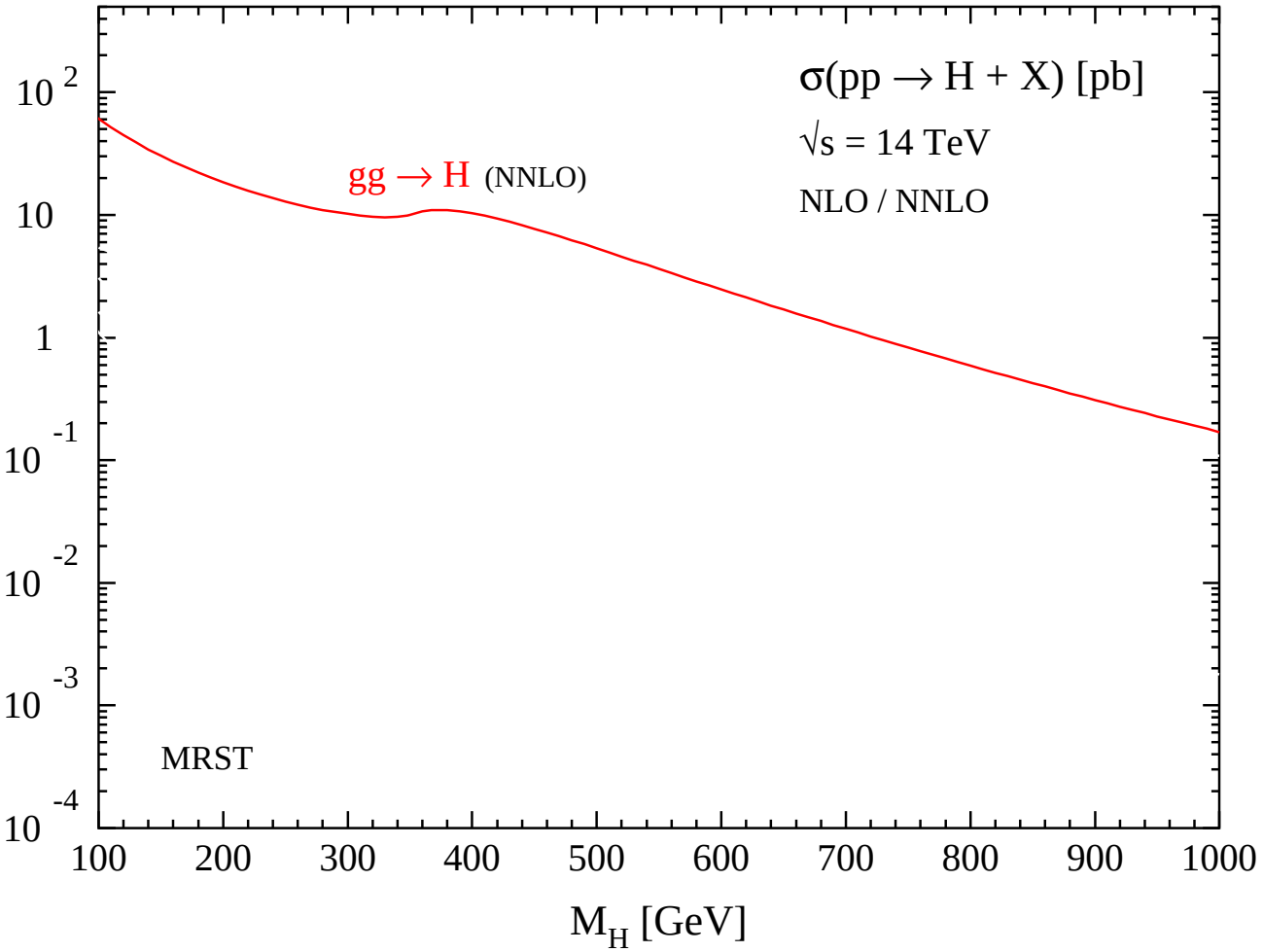
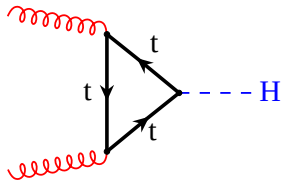
*in collaboration with Kemal Ozeren

arXiv:0907.2997 [Phys. Lett B 679 (2009) 467]
arXiv:0909.3420 [submitted to JHEP]

Higgs cross sections





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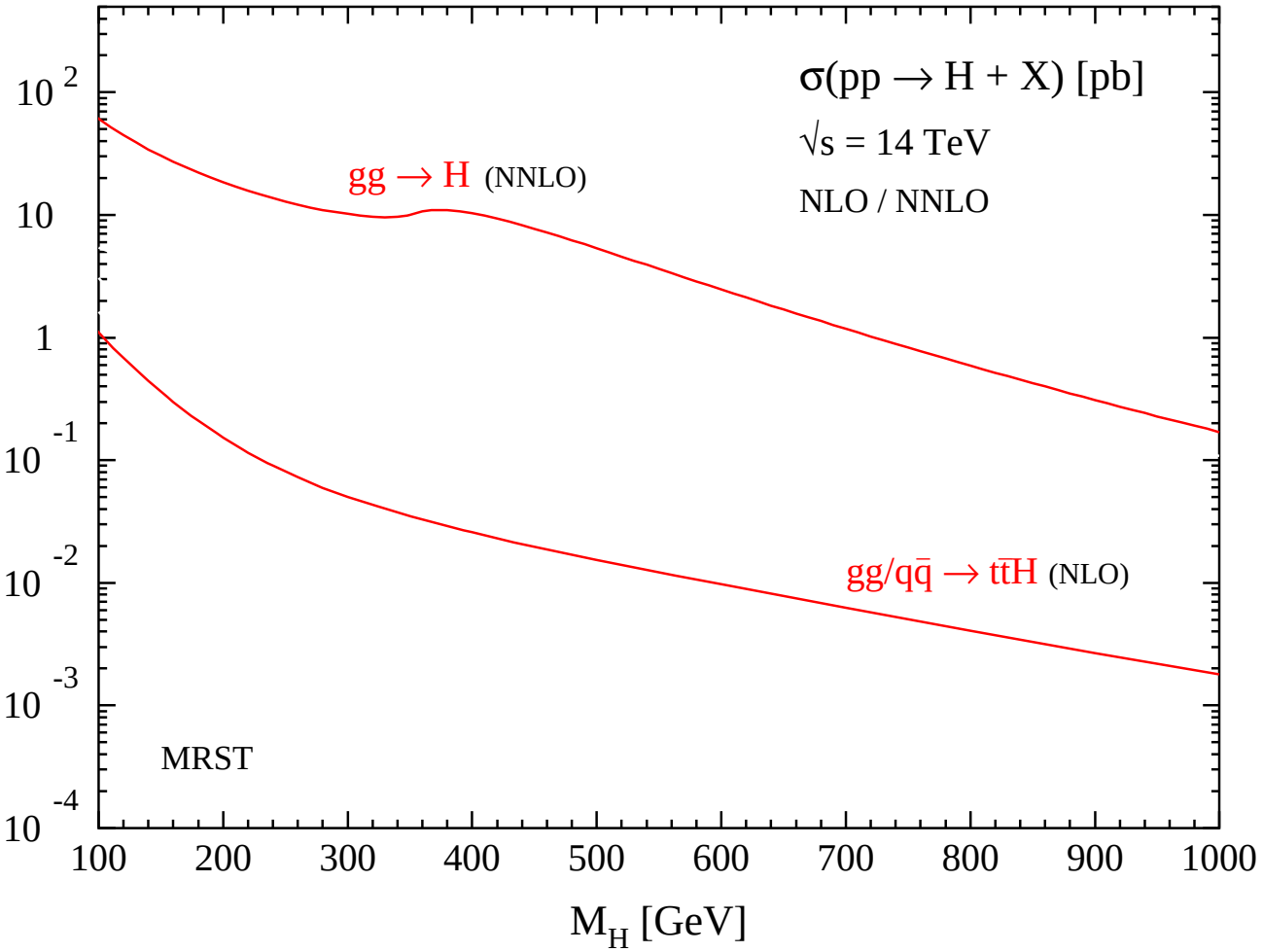

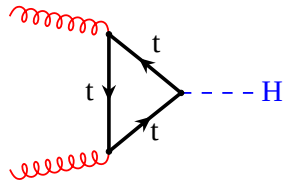

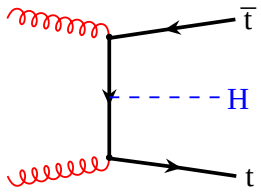

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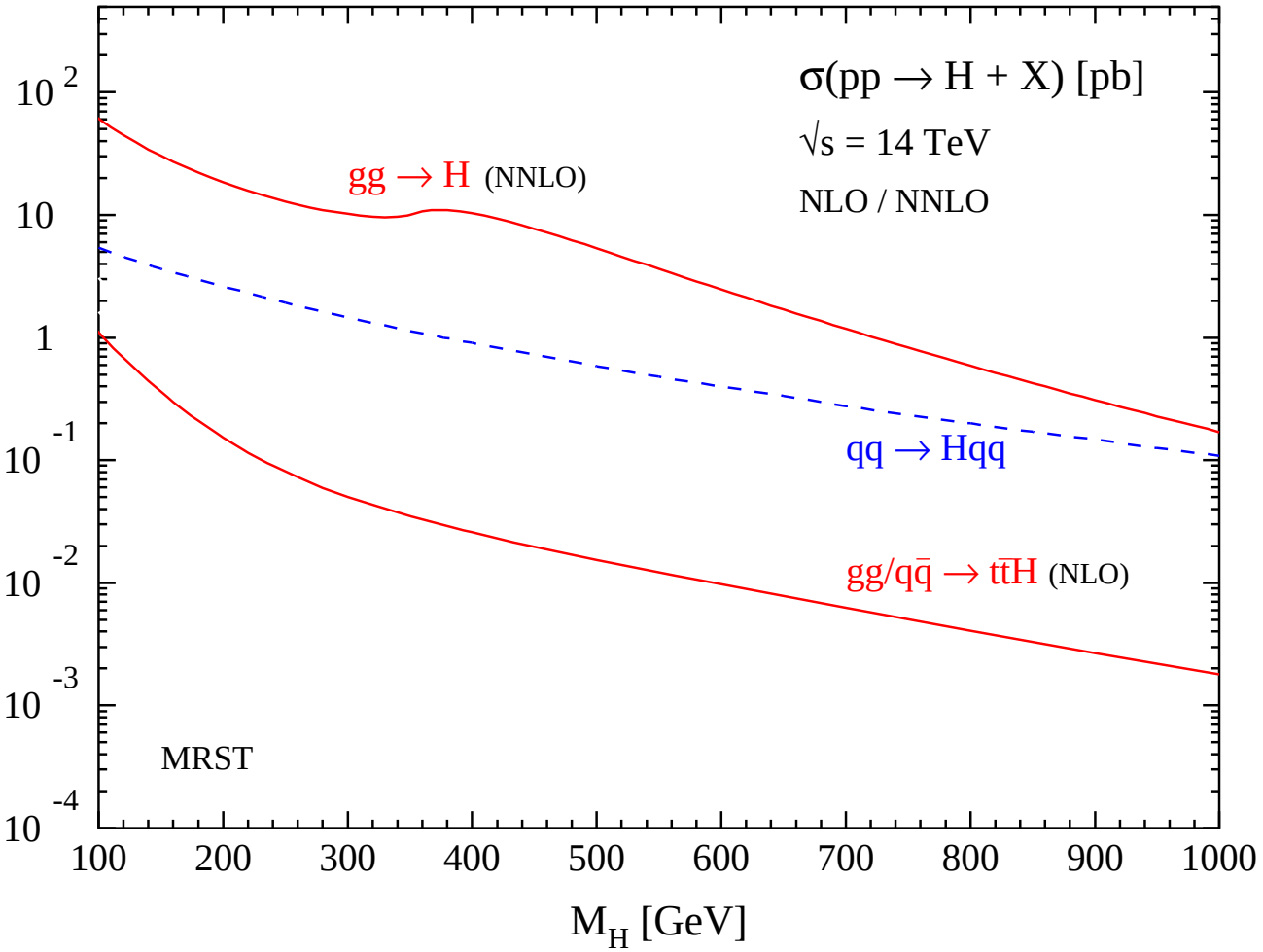

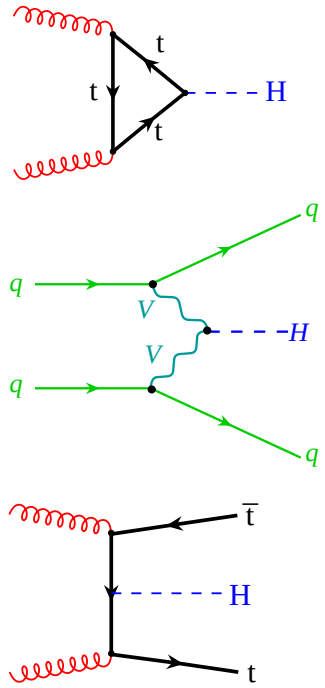

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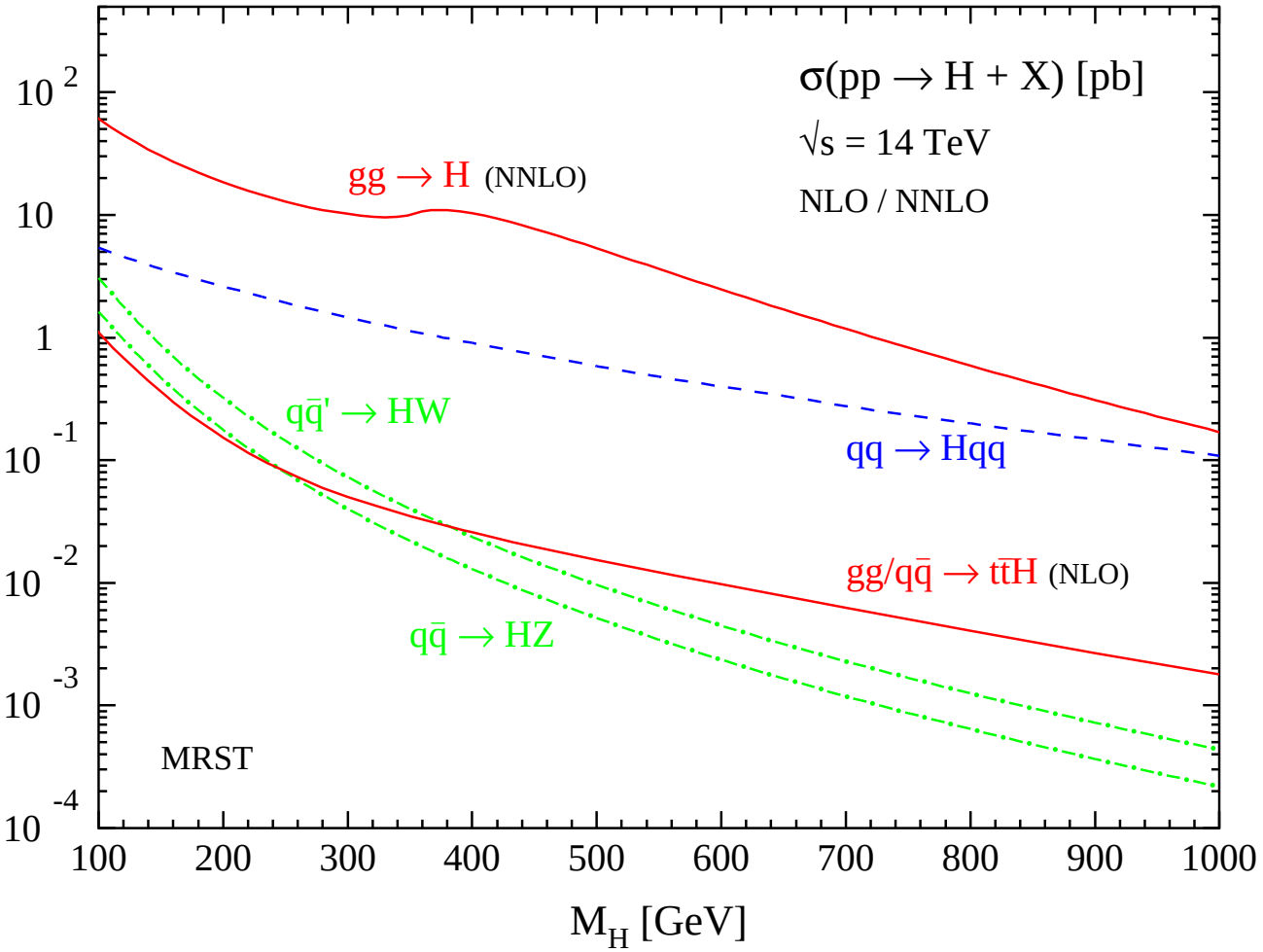
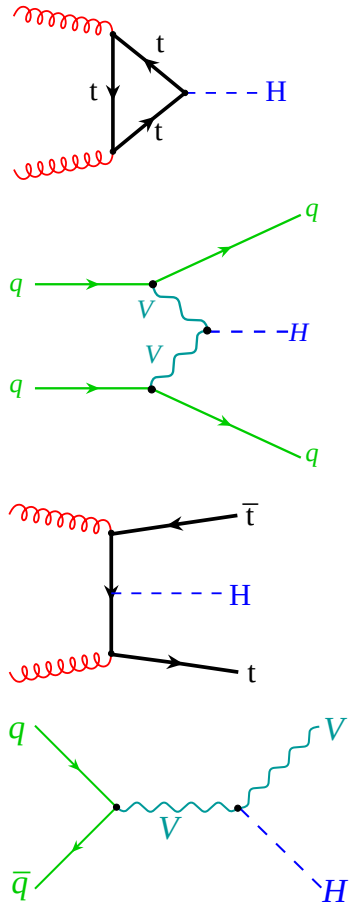
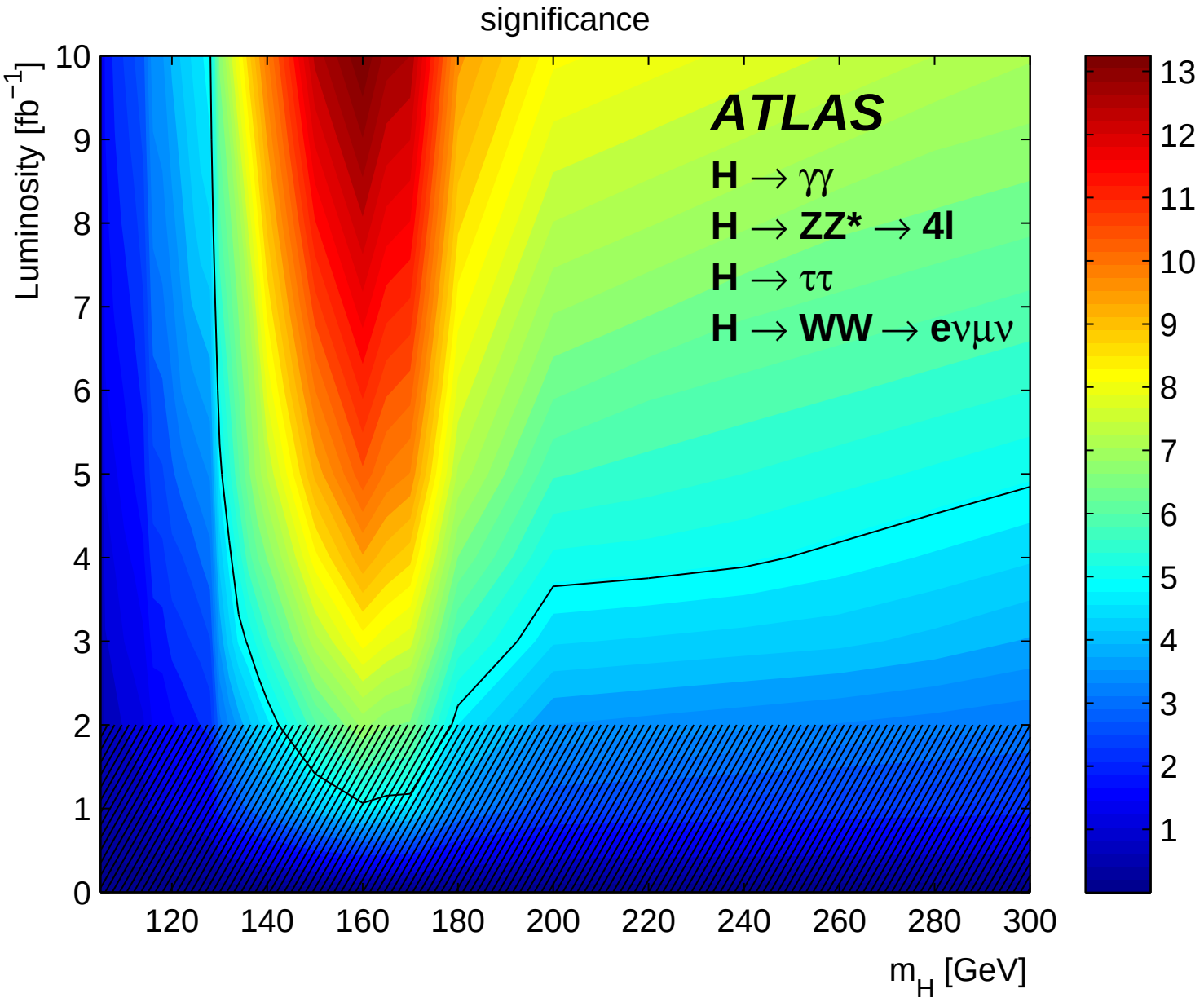
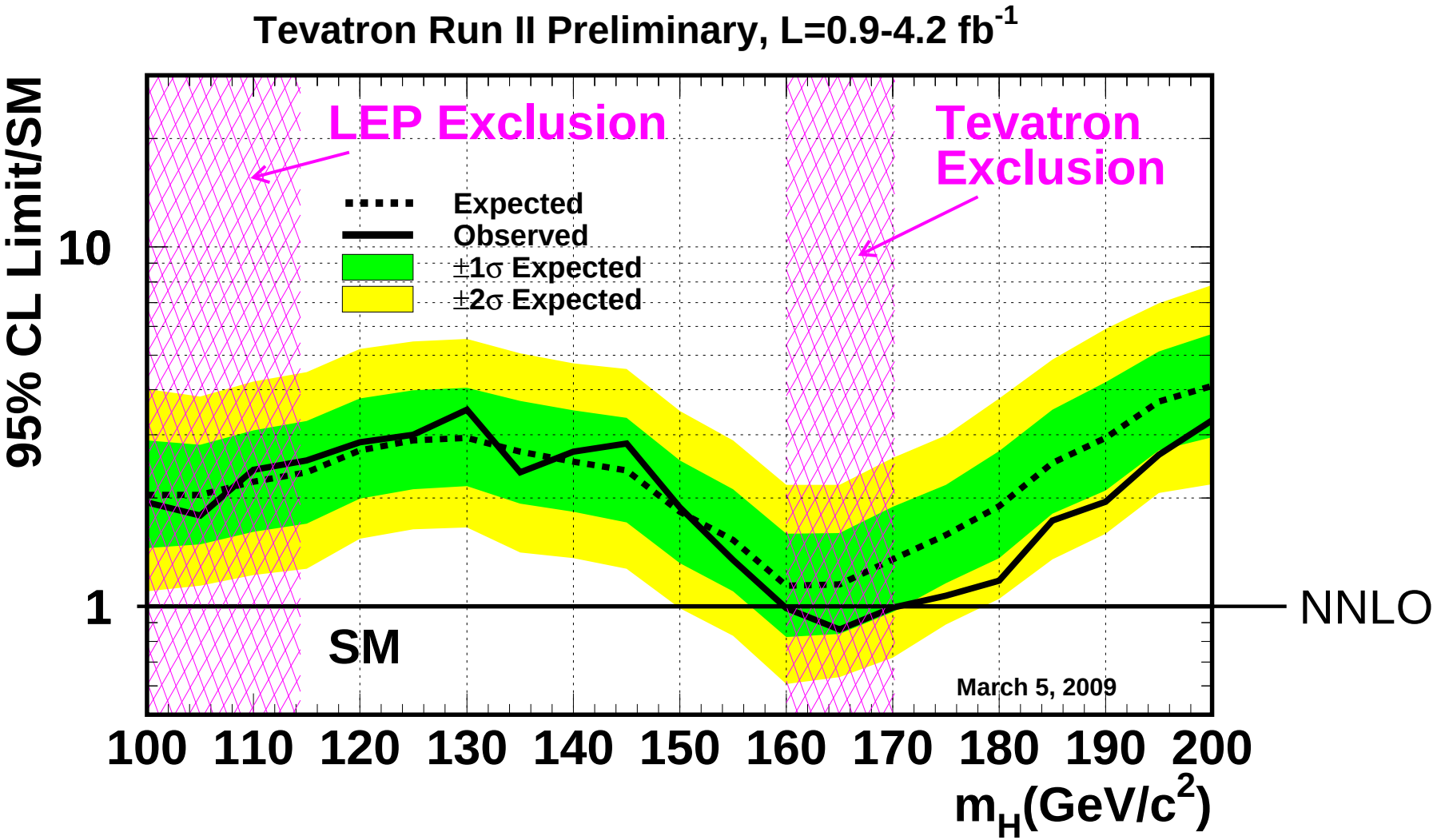




Higgs discovery potential at LHC



Higgs search at the Tevatron



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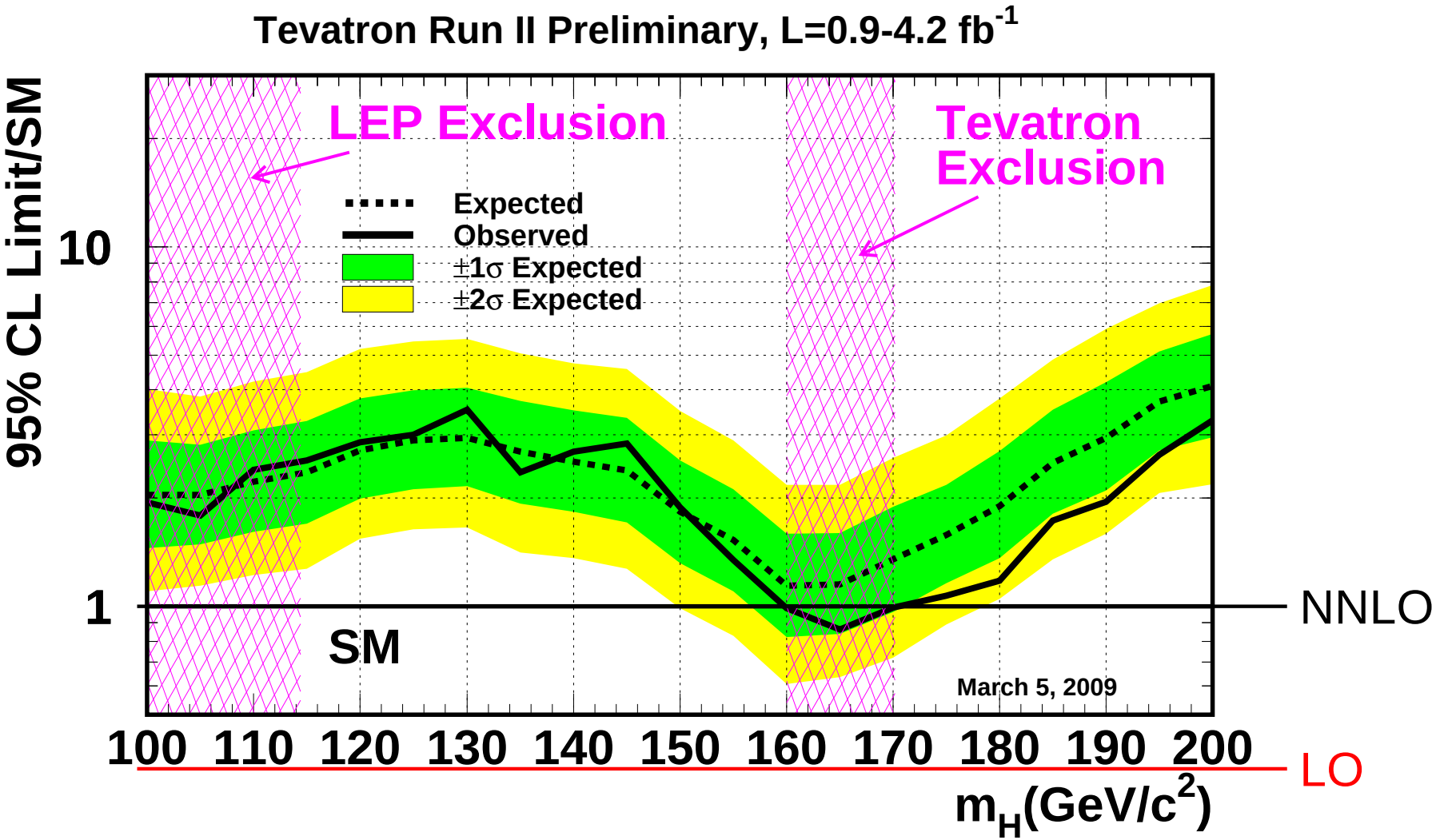

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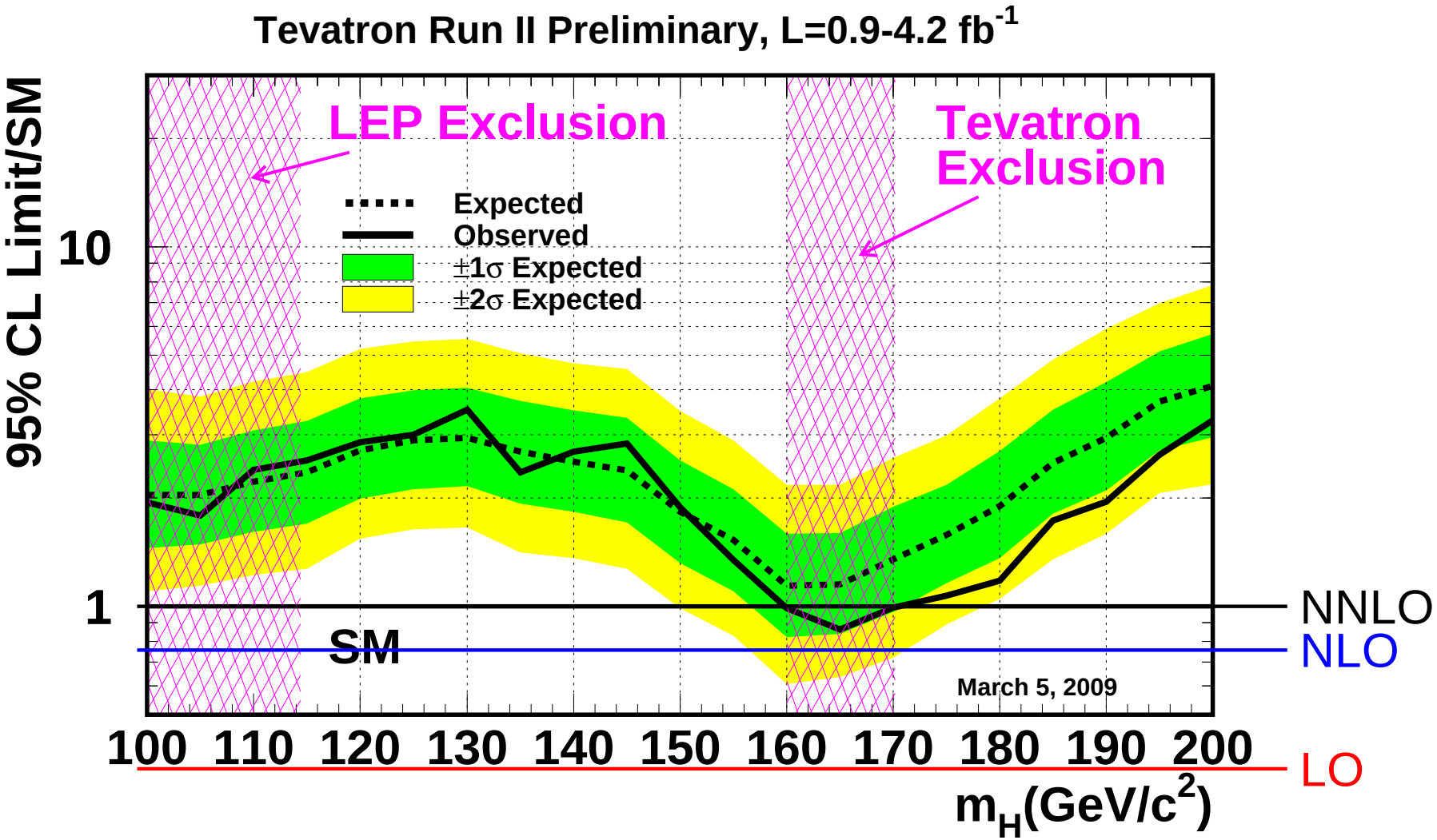

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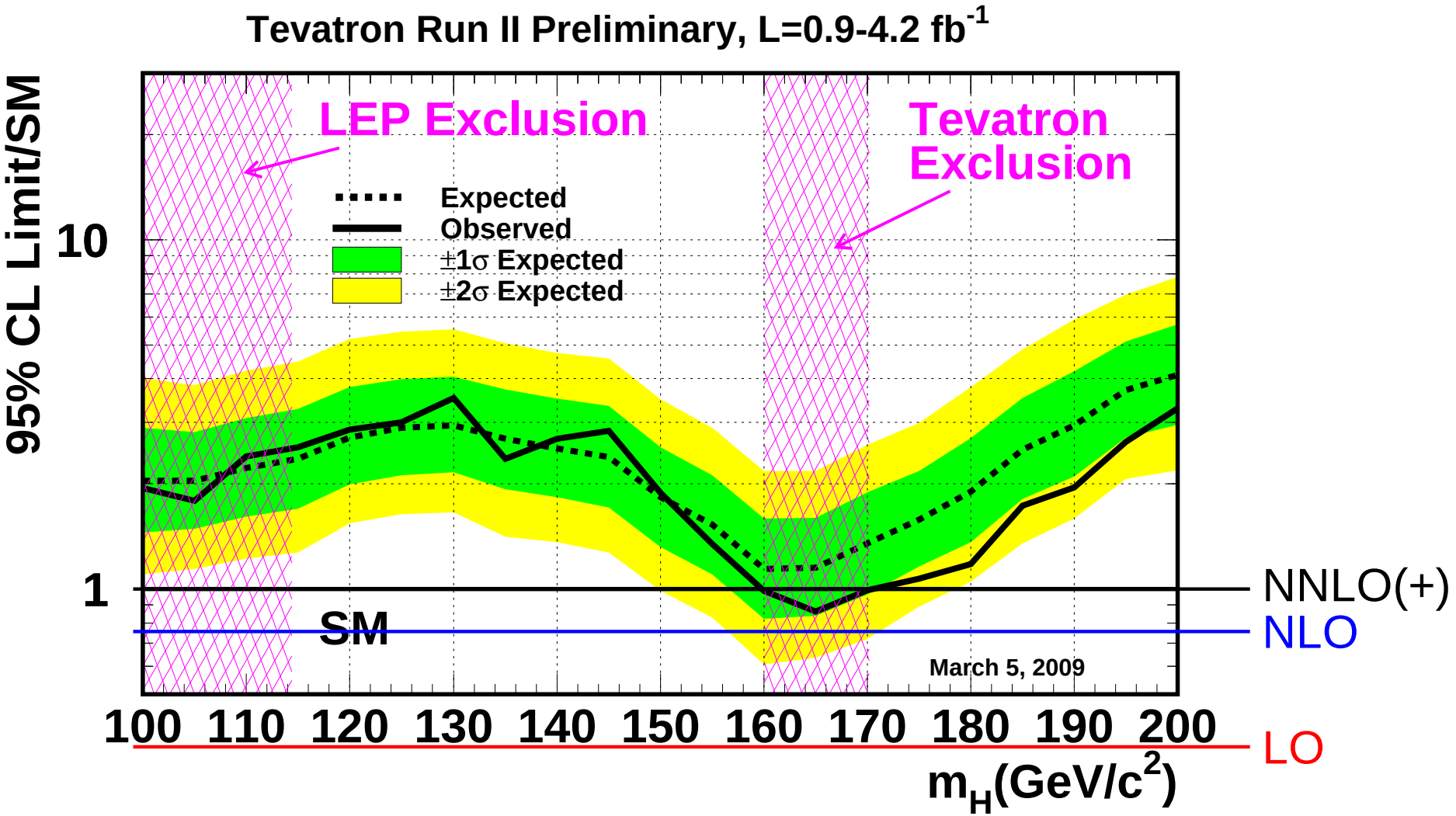

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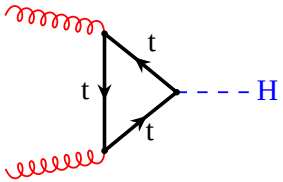

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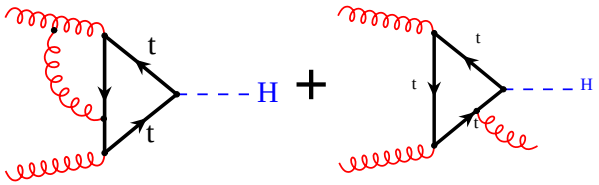

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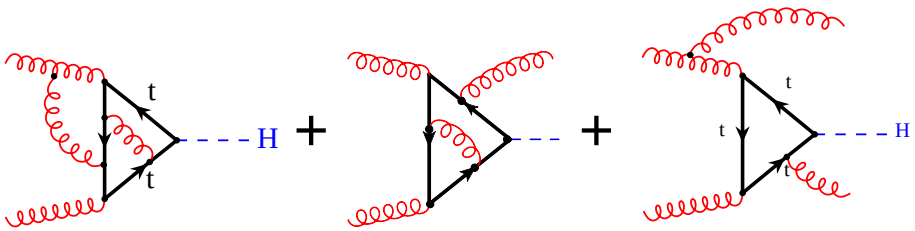

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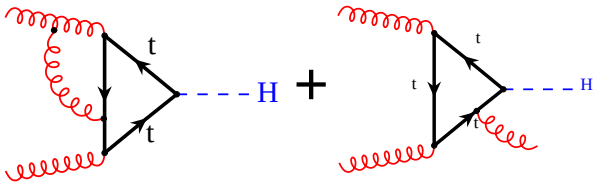

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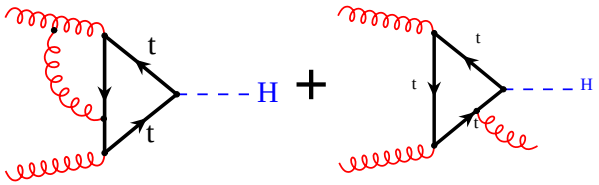

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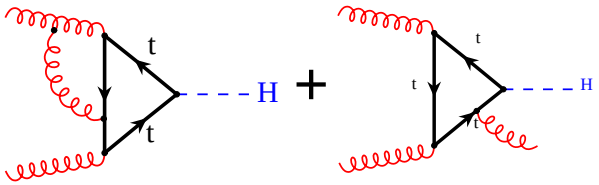

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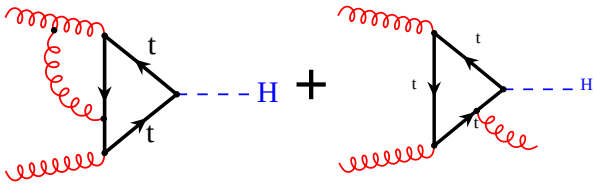

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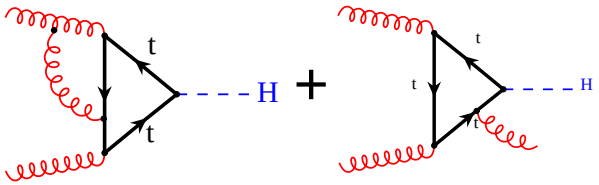

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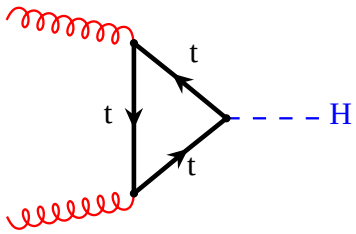

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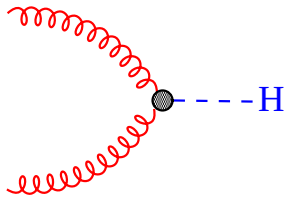

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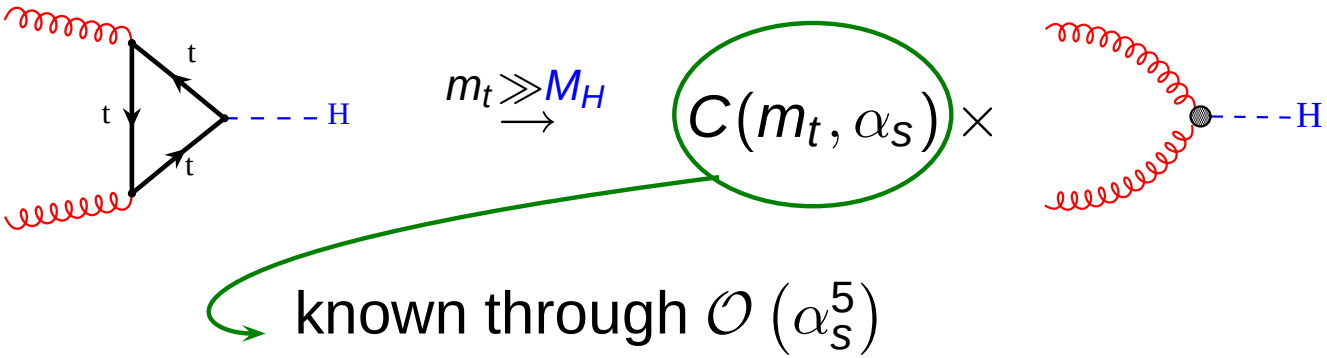

known through $\mathcal{O}\left(\alpha_s^5\right)$

[Schröder, Steinhauser '06]
[Chetyrkin, Kühn, Sturm '06]

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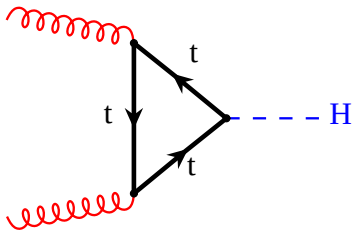

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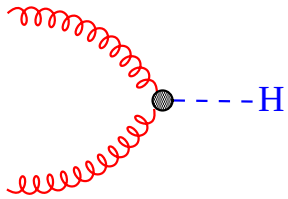

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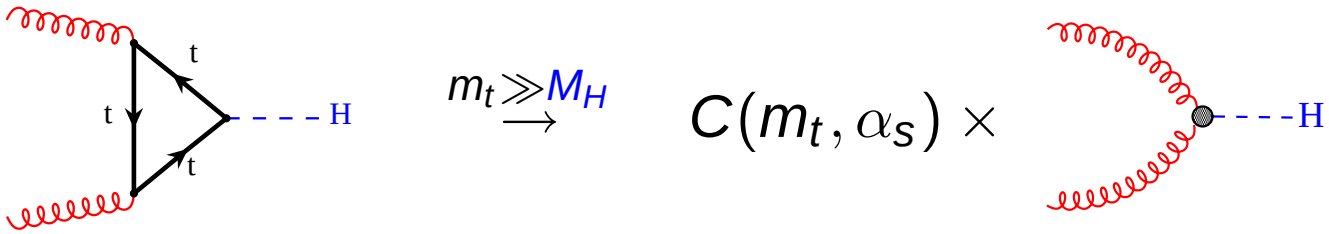

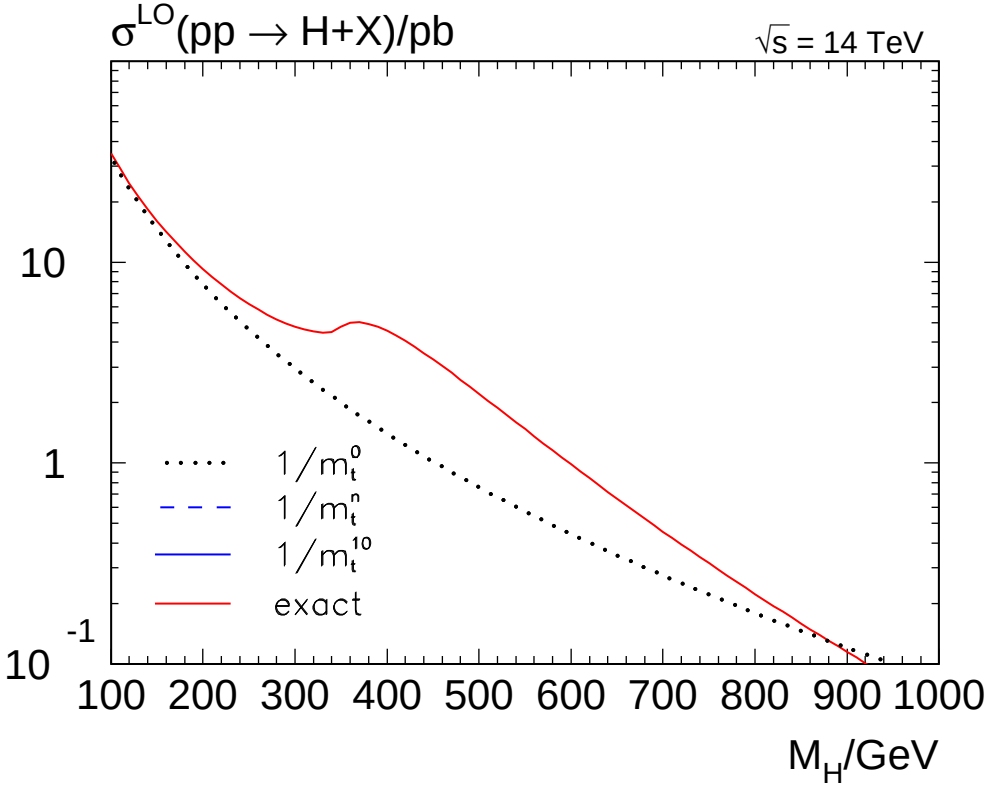

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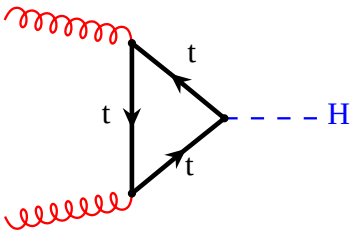

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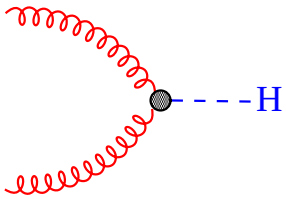

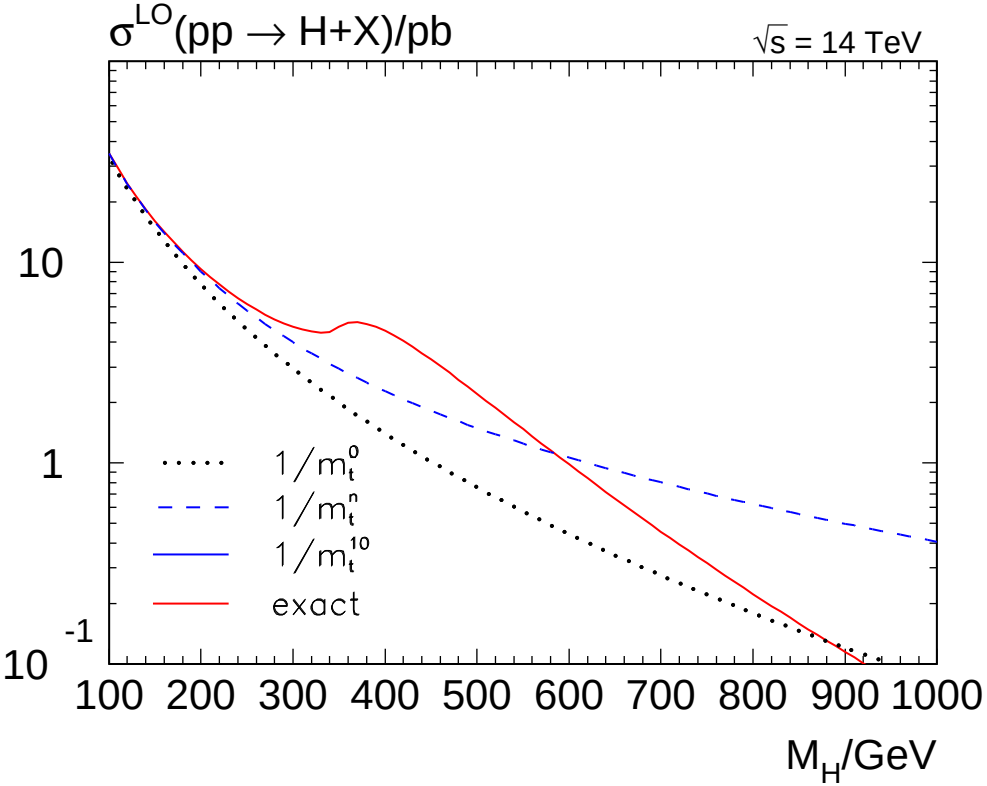

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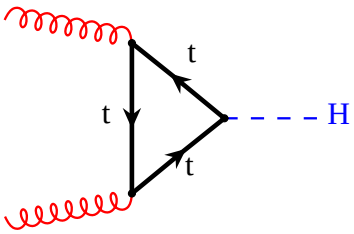

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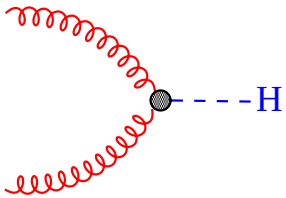

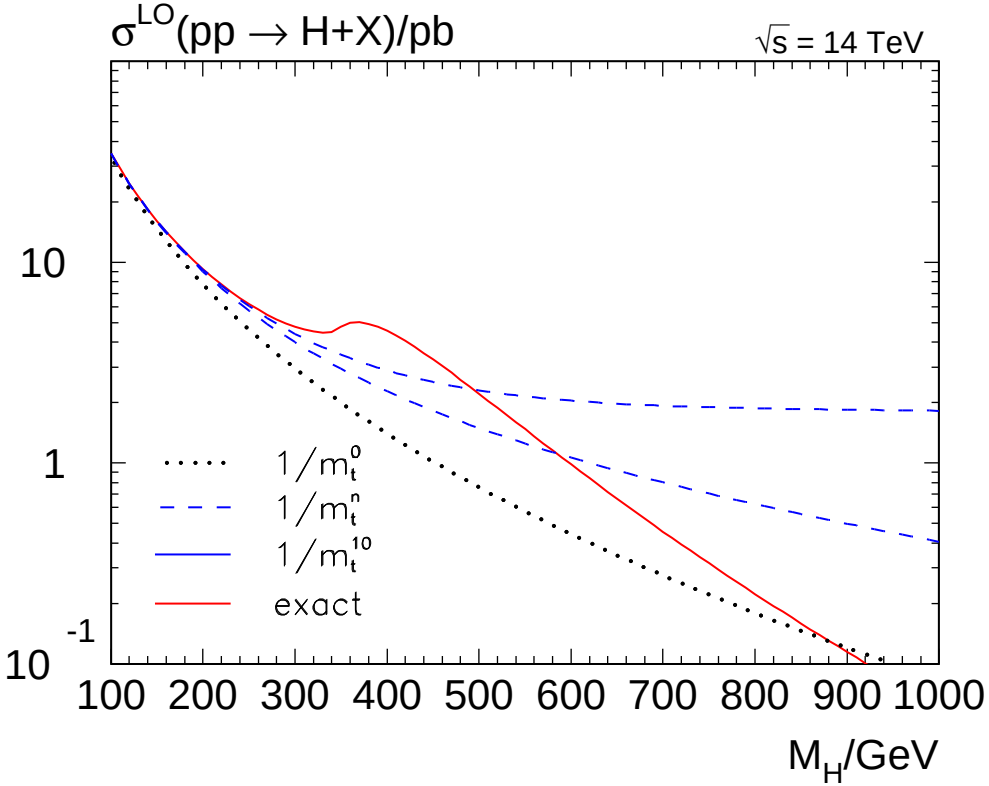

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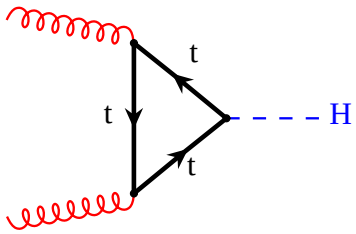

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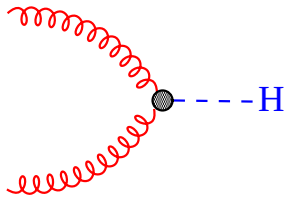

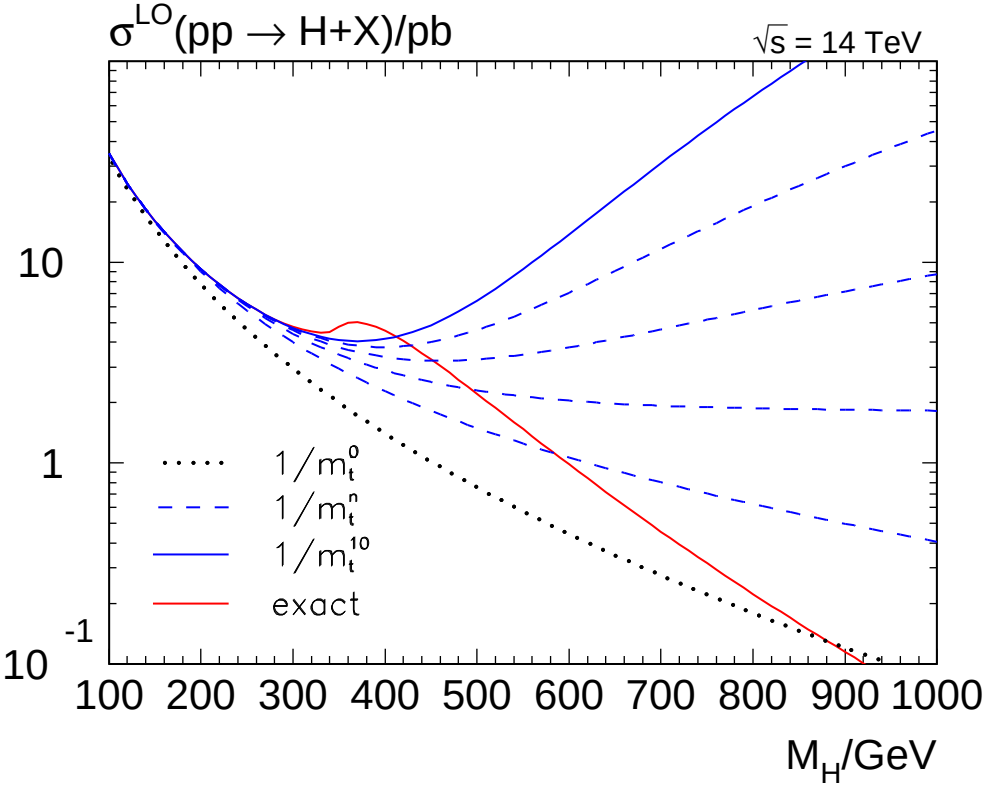

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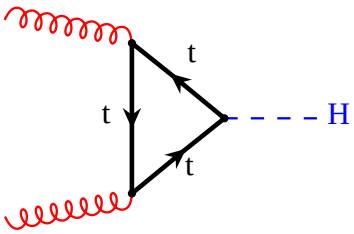

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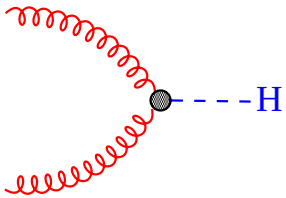

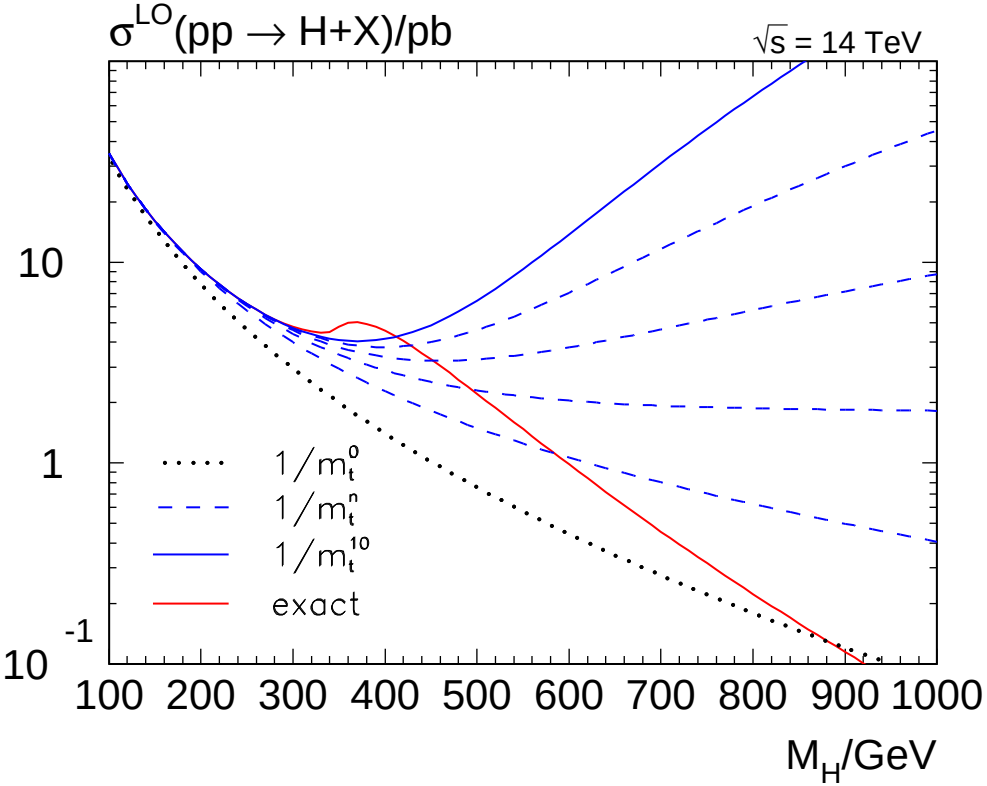

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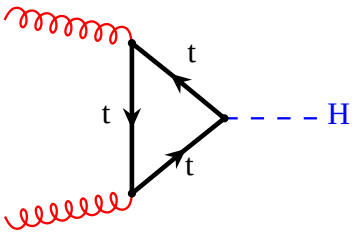

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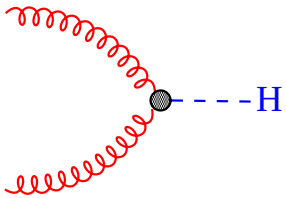

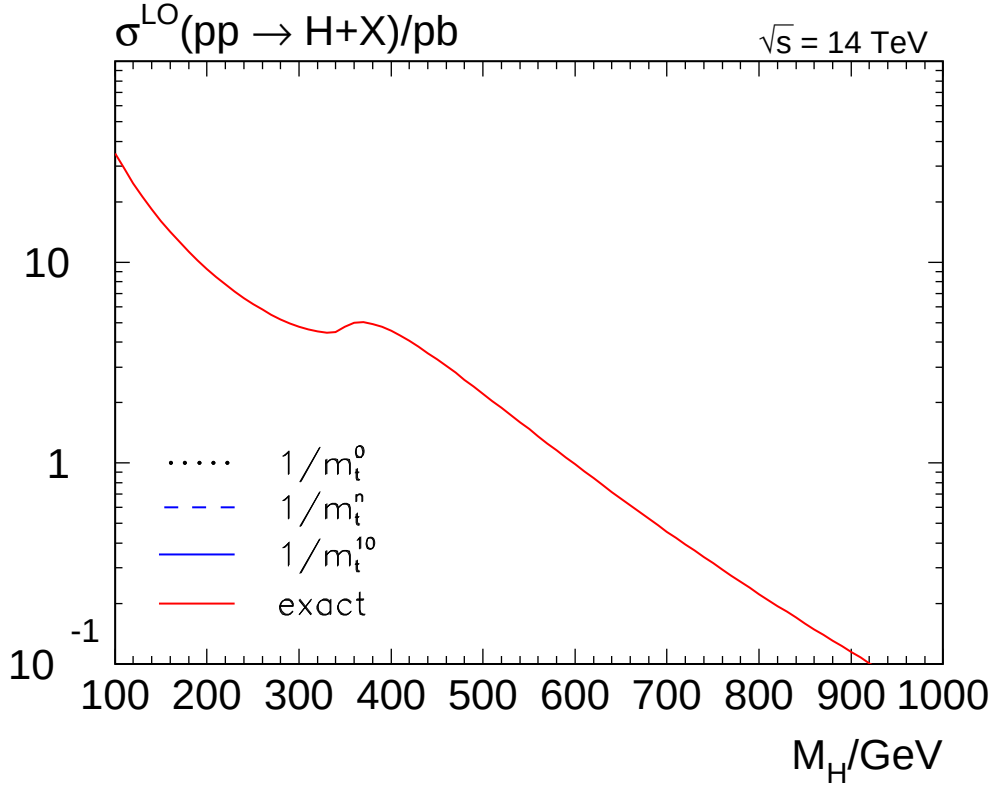

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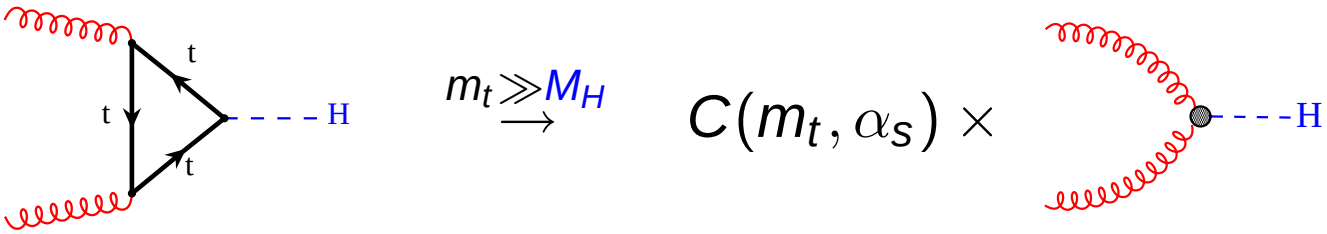

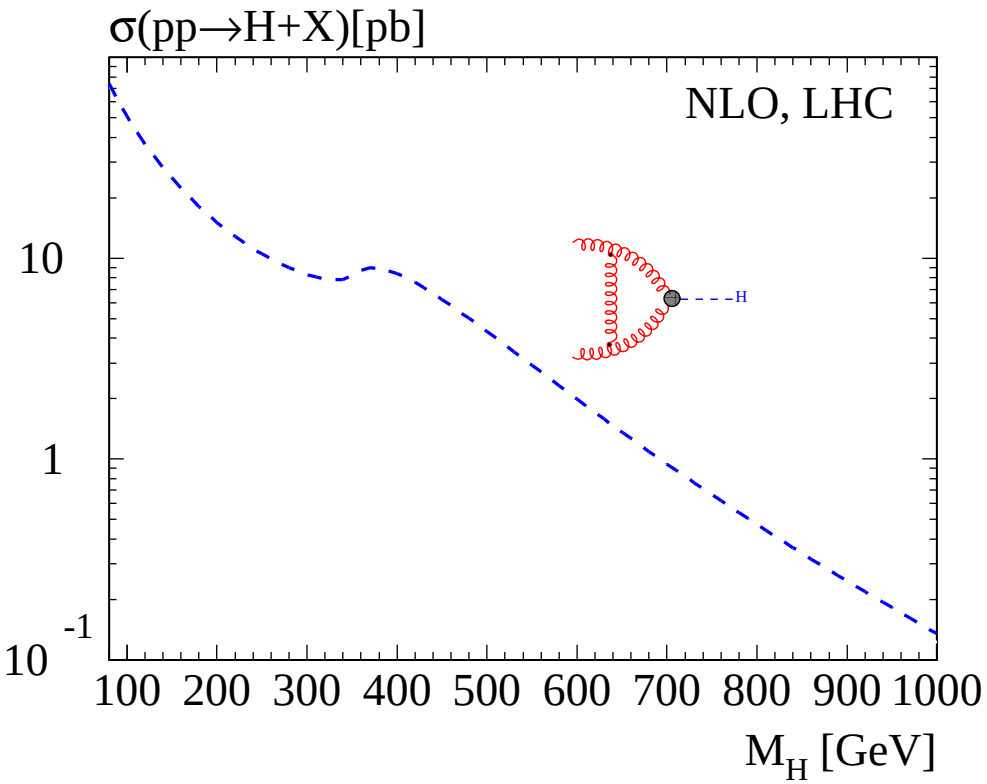

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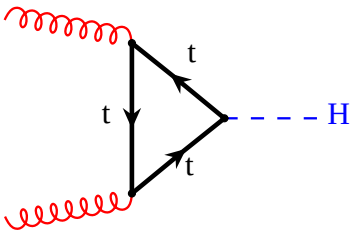

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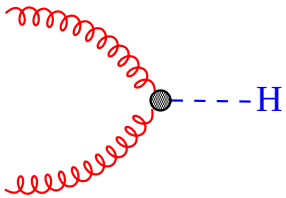

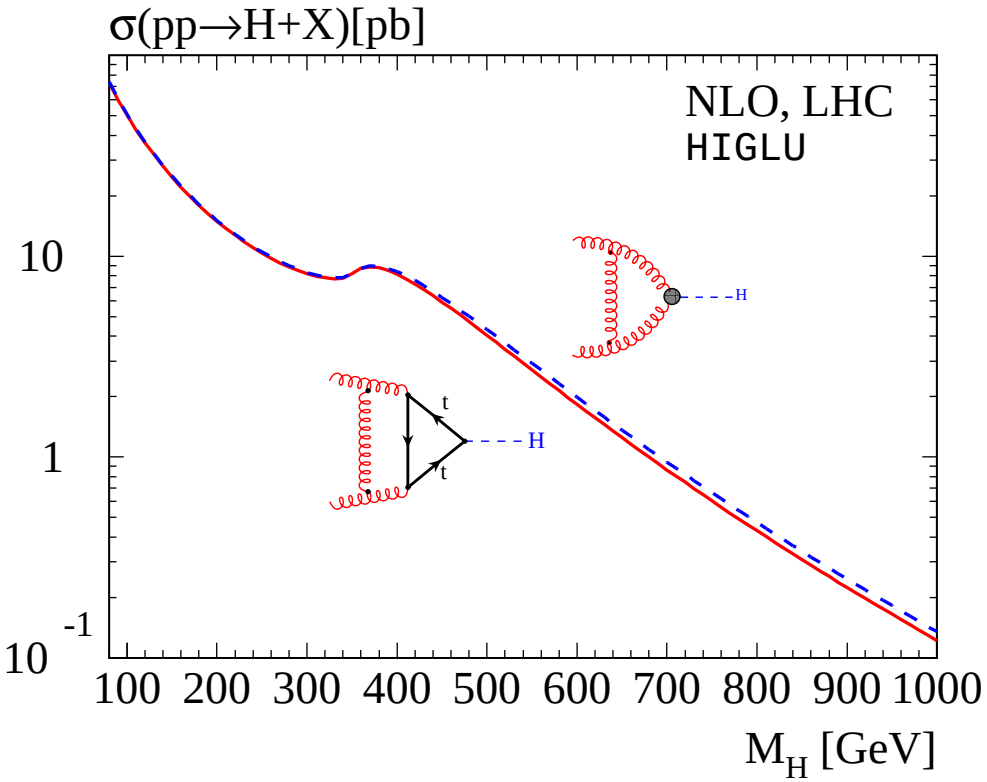

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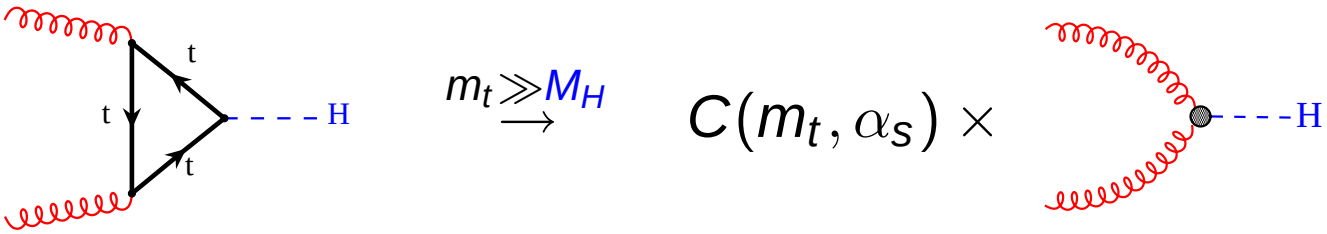
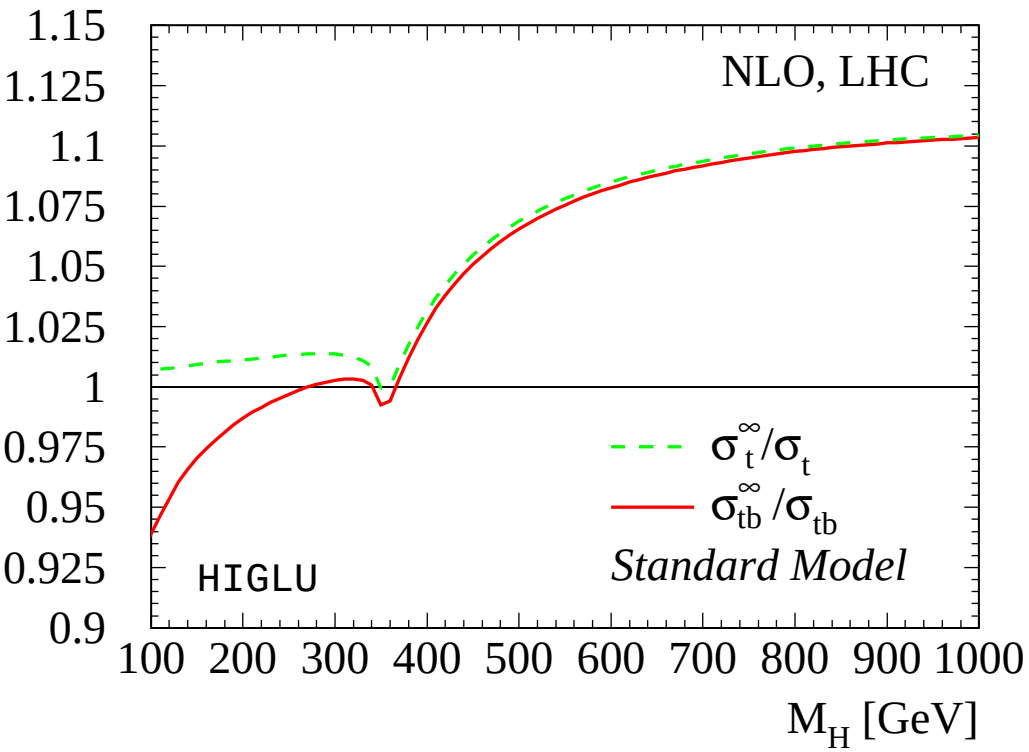
[Dawson '91]
[Graudenz, Spira, Zerwas '91]
[Krämer, Laenen, Spira '96]

Gluon fusion: heavy top limit

- effective theory for $m_t \gg M_H$:





Instead:

$$\sigma_\infty^{\mathrm{HO}} \equiv \sigma^{\mathrm{LO}}(m_t) \left(\frac{\sigma^{\mathrm{HO}}}{\sigma^{\mathrm{LO}}} \right)_{m_t \to \infty}$$

[Dawson '91]
[Graudenz, Spira, Zerwas '91]
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Reason? Still debated!

Results in the heavy-top limit

- NNLO QCD inclusive

  [RH, Kilgore '02], [Anastasiou, Melnikov '02], [Ravindran, Smith, van Neerven '03]

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- NLO p_T, y distributions + resummations

  [de Florian, Grazzini, Kunszt '99], [de Florian, Grazzini '00], [Ravindran, Smith, van Neerven '02], [Glosser, Schmidt '02], [Berger, Qiu '03], [Bozzi, Catani, de Florian, Grazzini '03], [Anastasiou, Dixon, Melnikov '03], [Kulesza, Sterman, Vogelsang '04], [de Florian, Kulesza, Vogelsang '06]

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- NNLO Monte Carlo (partonic)

  [Anastasiou, Melnikov, Petriello '05], [Catani, Grazzini '07]

Test: subleading terms in $1/m_t$

Perform an “honest” expansion:

$$\hat{\sigma}(\hat{s}, m_H, m_t) = \sum_n \left(\frac{m_H^2}{4m_t^2}\right)^n \hat{\sigma}_n(x, \ln m_t, \ln m_H)$$

$$x = m_H^2/\hat{s}$$

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- consider NLO: [Dawson, Kauffman '93]

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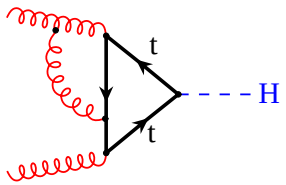

$$\rightarrow \quad \hat{\sigma}_{\text{virt}} \sim \sum_{n \geq 0} \left(\frac{m_H^2}{4 m_t^2} \right)^n c_n \, \delta(1-x)$$

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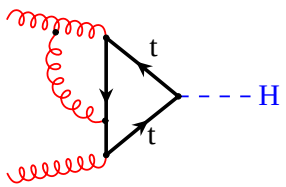

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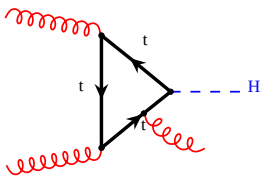

$$\rightarrow \quad \hat{\sigma}_{\text{real}} \sim \sum_{n\geq 0} \left(\frac{m_H^2}{4m_t^2}\right)^n f_n(x)$$

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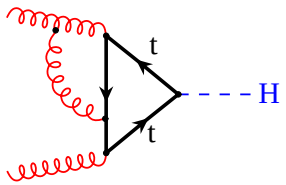

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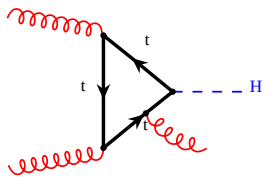

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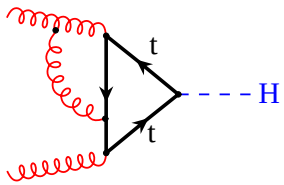

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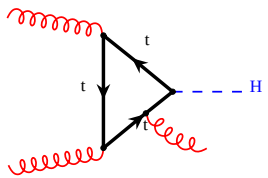

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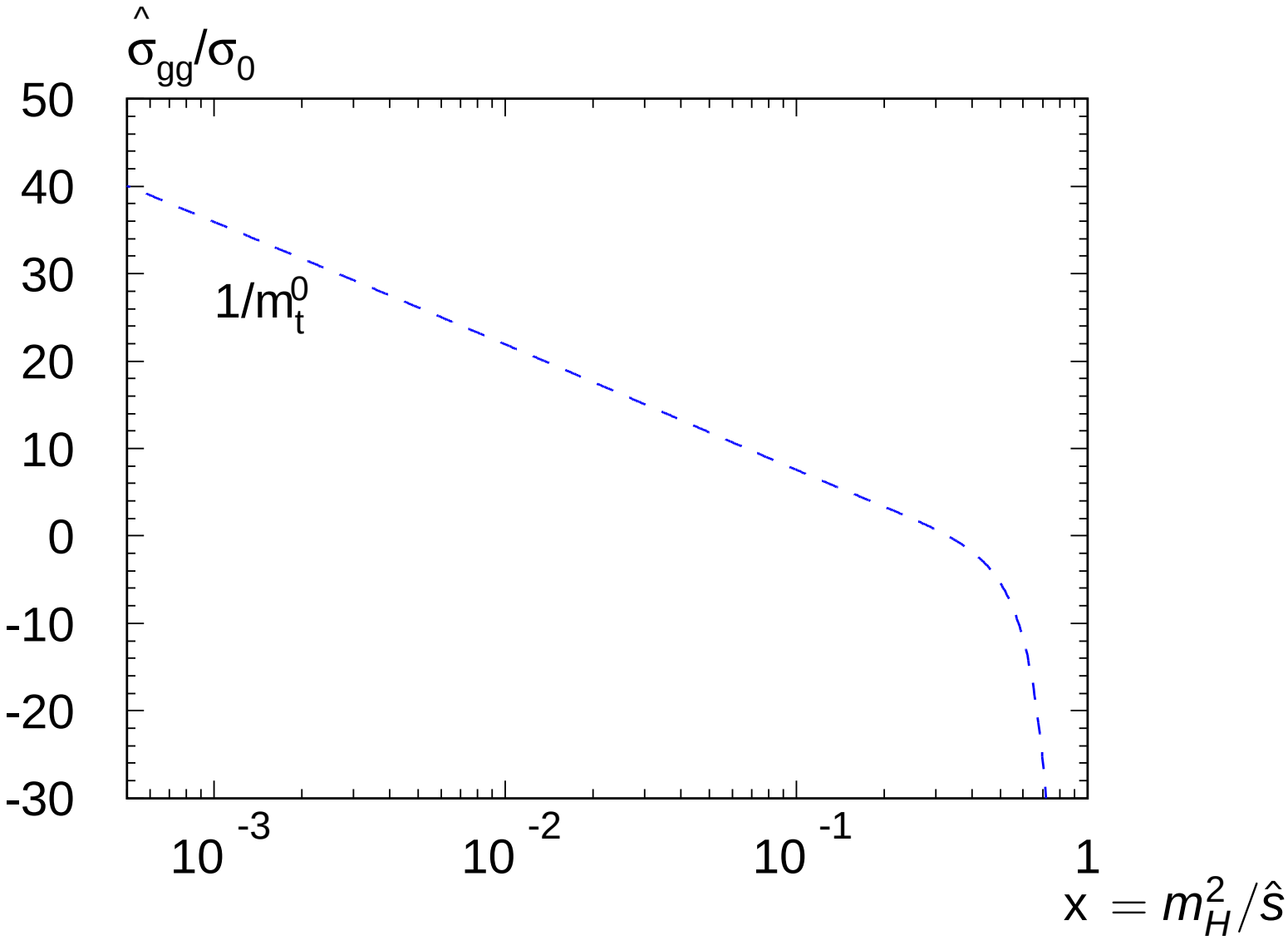
$\Rightarrow \quad f_n(x)$ contains spurious terms $\sim \dfrac{1}{x^n}$

$1/m_t$ expansion at NLO



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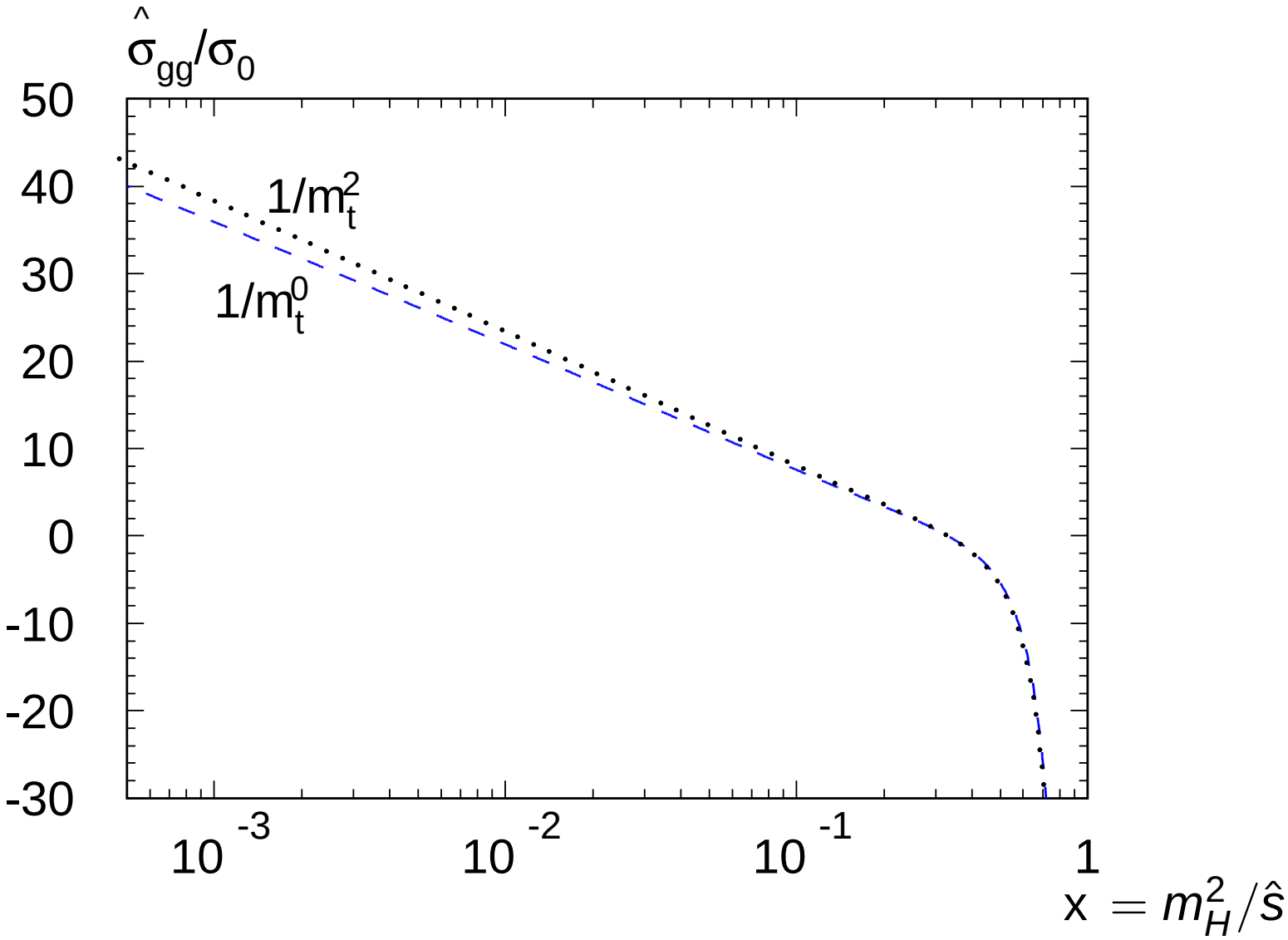

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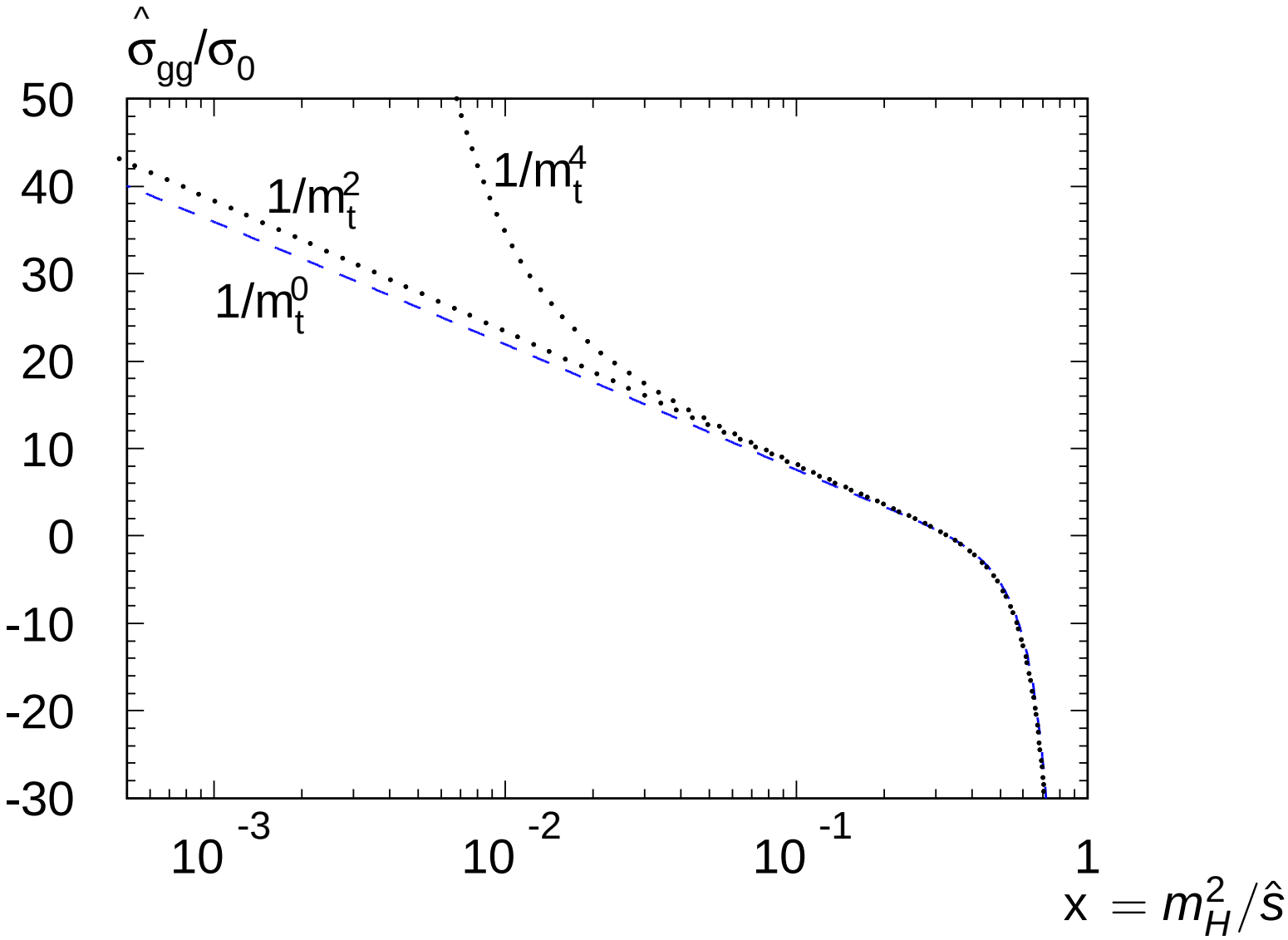

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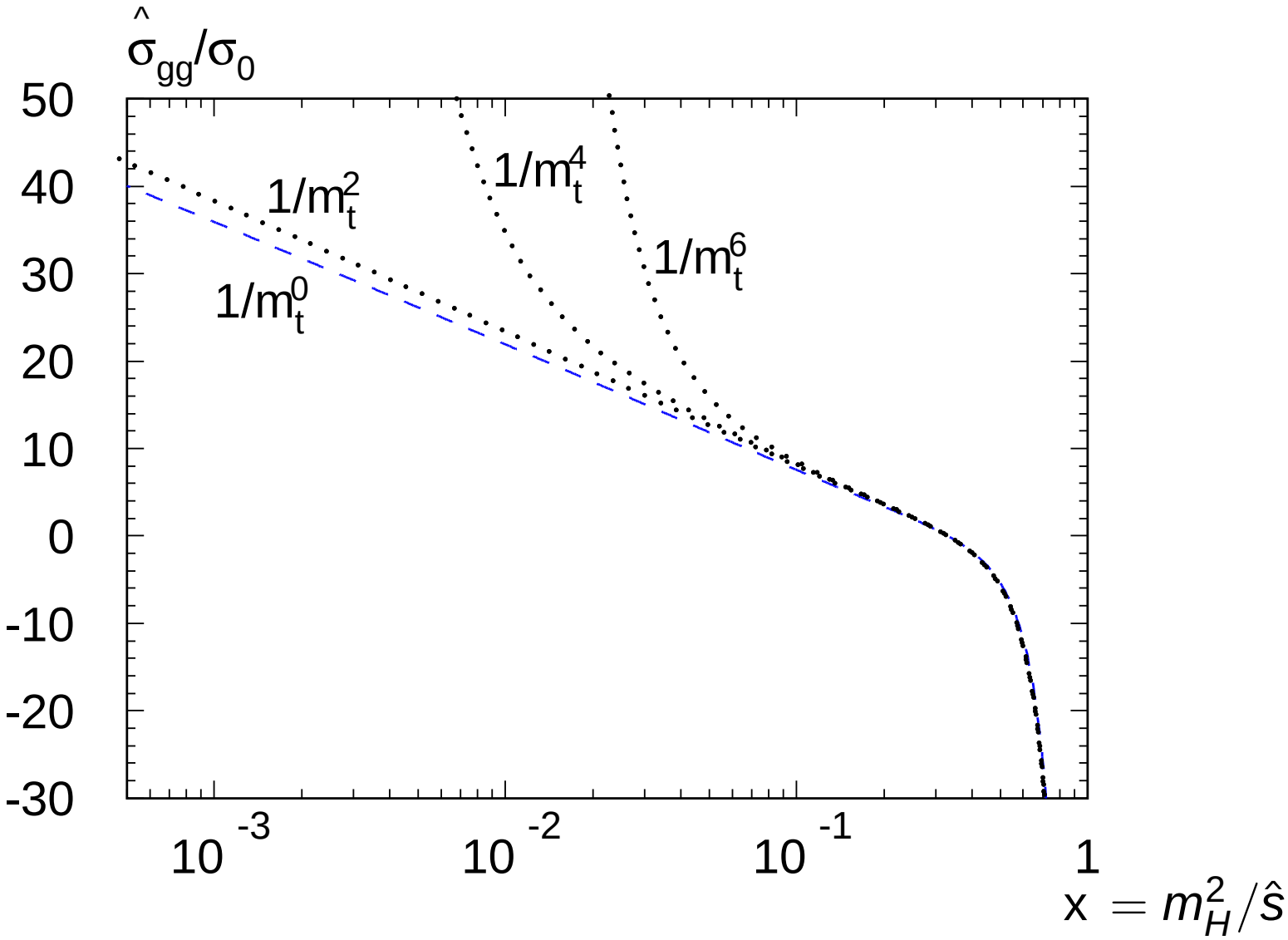

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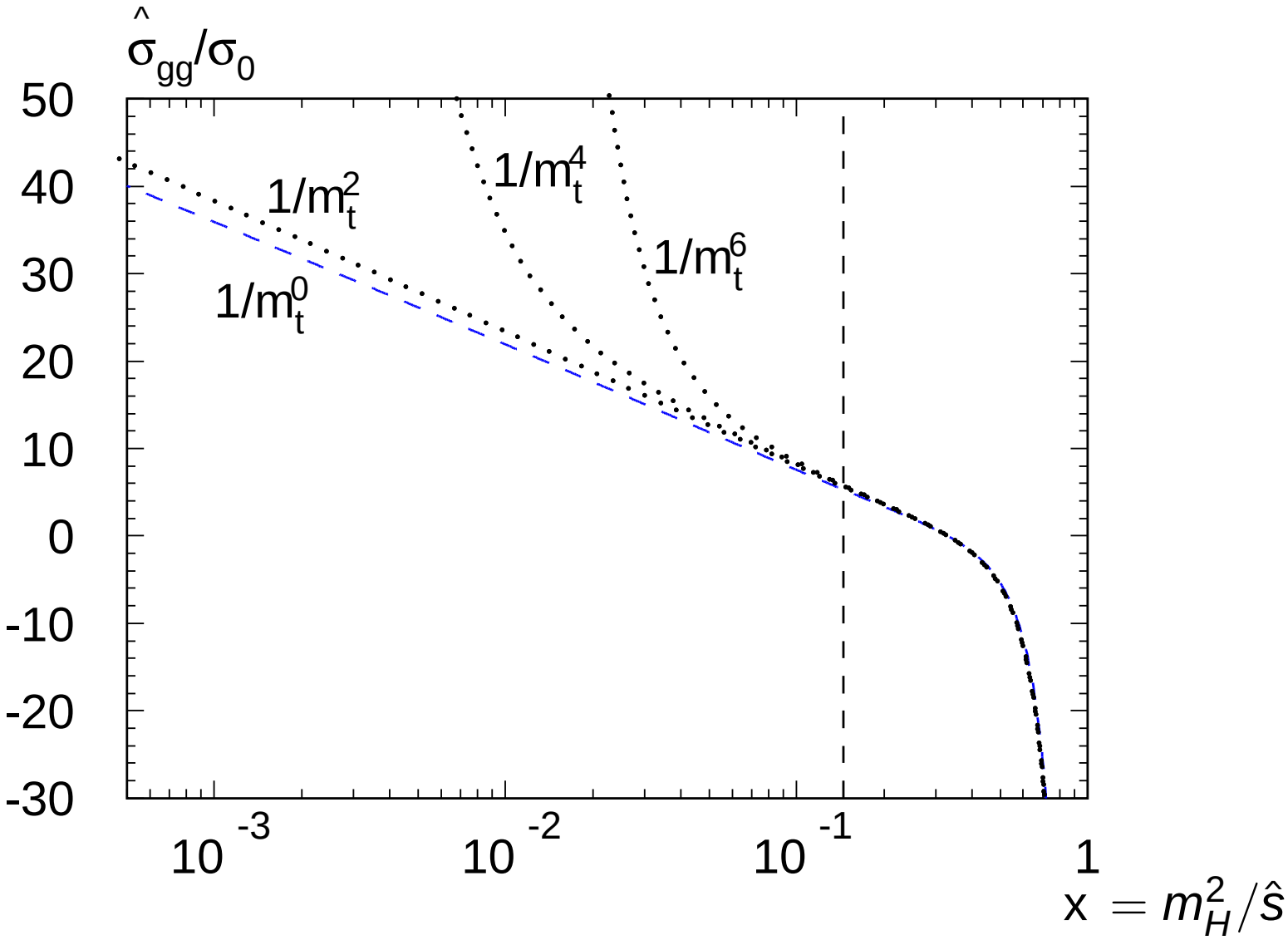

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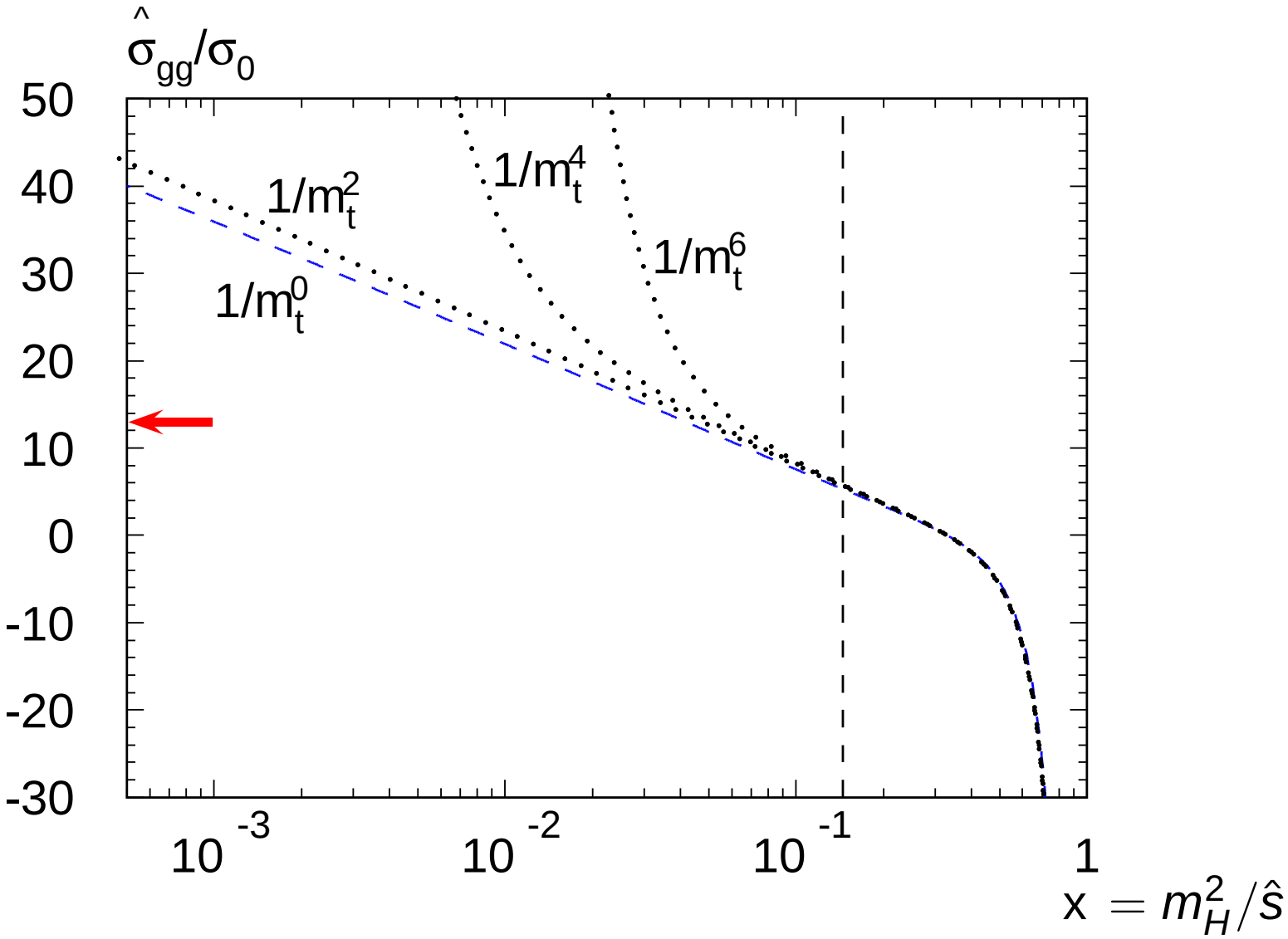

Large-$\hat{s}$ behavior at NLO

- small-x behavior known: $(x = m_H^2/\hat{s})$ [Marzani *et al.* '08]

$$\hat{\sigma}_{gg}^{(1)}(x) \quad \rightarrow \quad -3\,\mathcal{C}^{(1)}(m_H/m_t) + \mathcal{O}(x)\,, \qquad \hat{s} \rightarrow \infty$$

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- combination:

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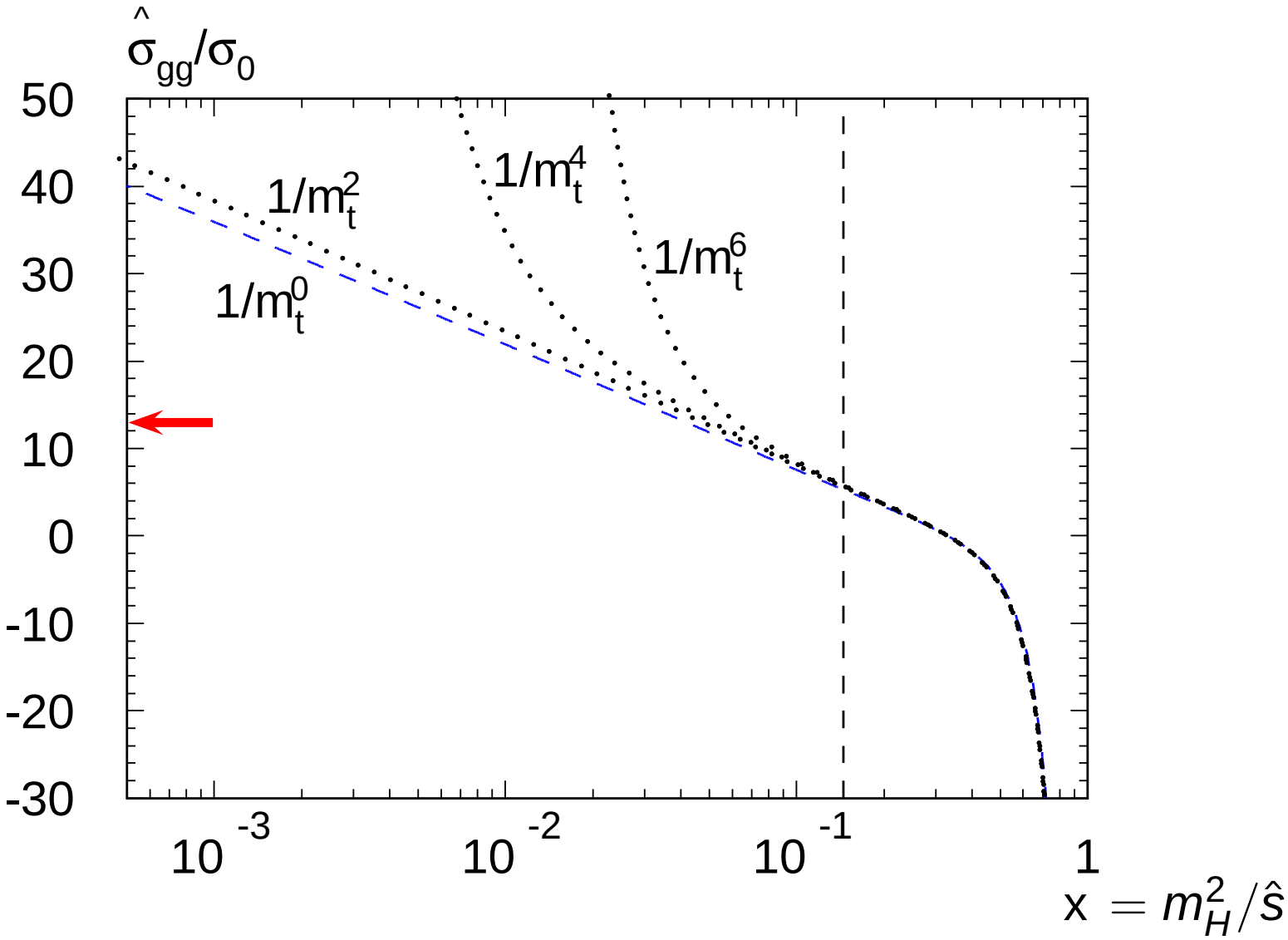
where $\hat{\sigma}_{gg,N}^{(1)}$ is the soft expansion: [RH, Kilgore '02]

$$\hat{\sigma}_{gg,N}^{(1)}(x) = \hat{\sigma}_{\mathrm{s+v}}^{(1)}(x) + \sum_{n\geq 0}^{N}\sum_{k} c_{nk}^{(1)}\,(1-x)^n \ln^k(1-x)$$

Dependence on $\hat{s}$ at NLO



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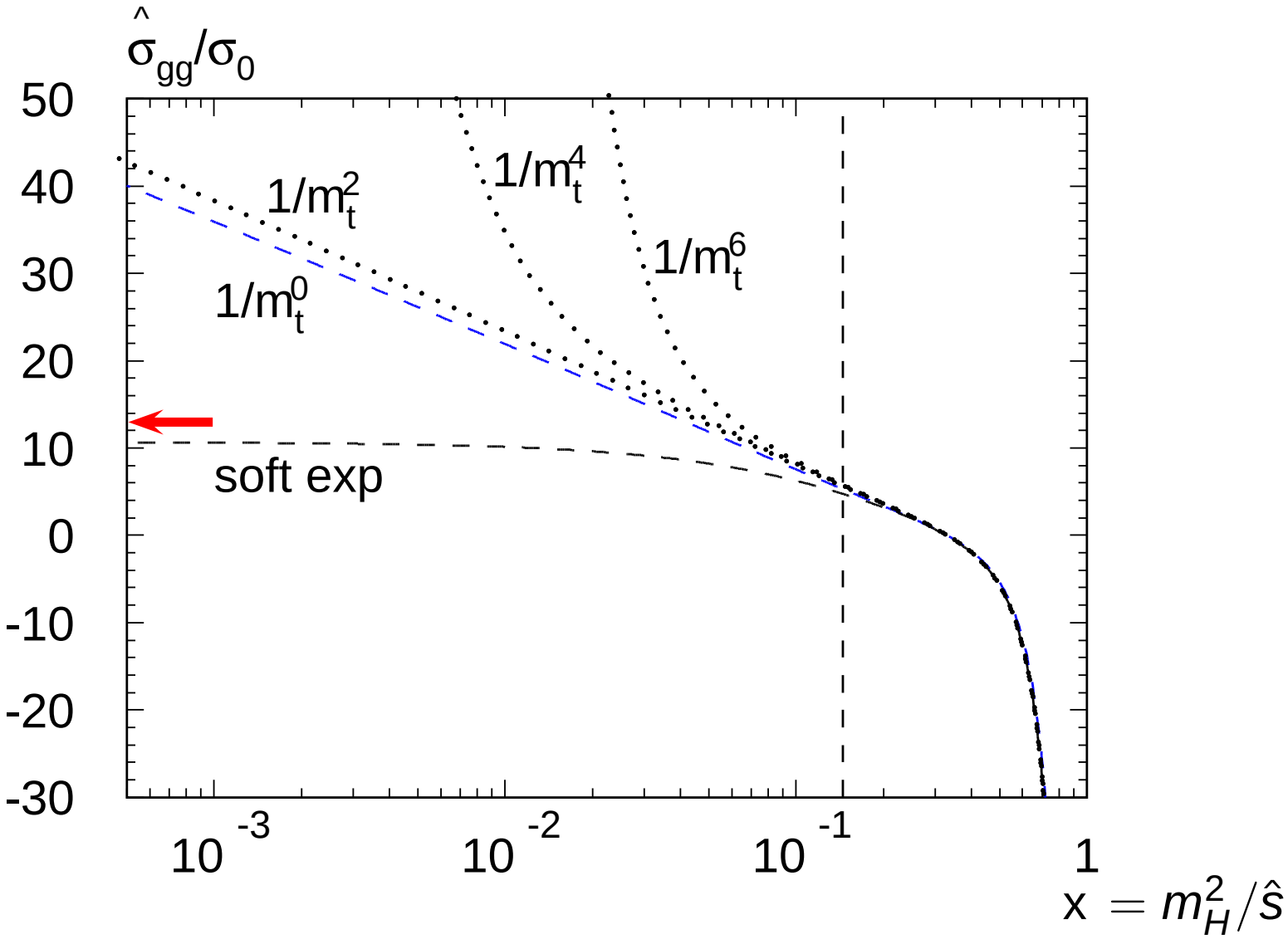

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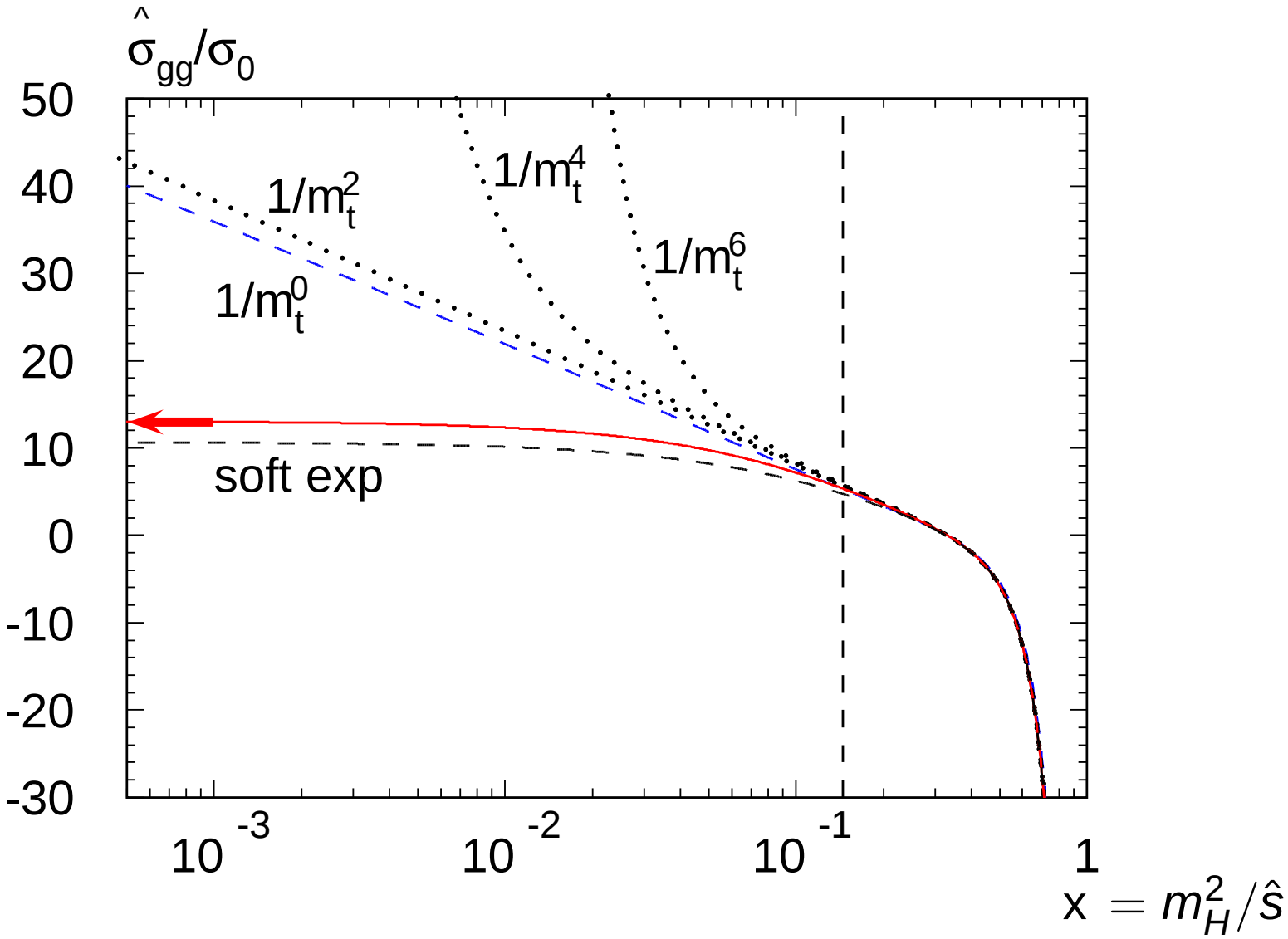

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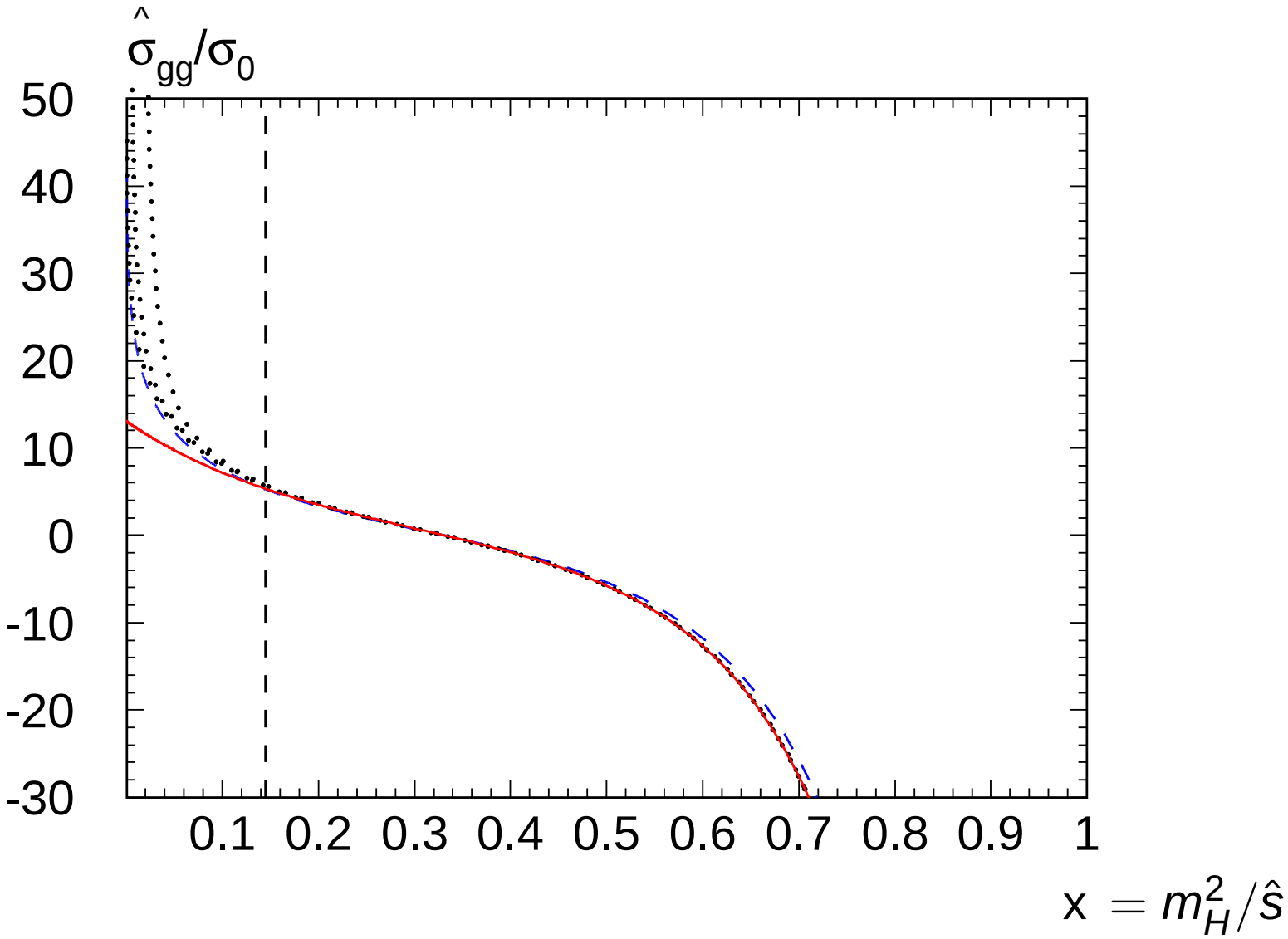

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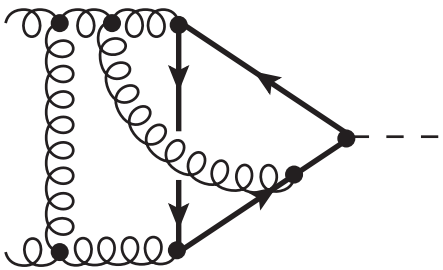

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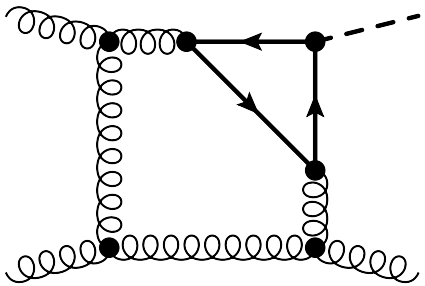

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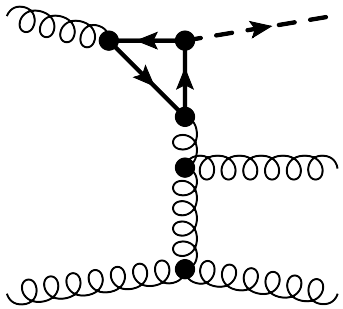

114

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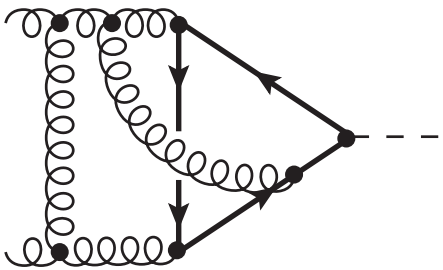

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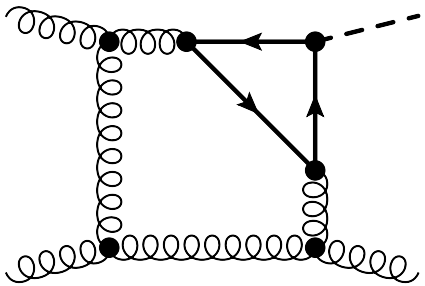

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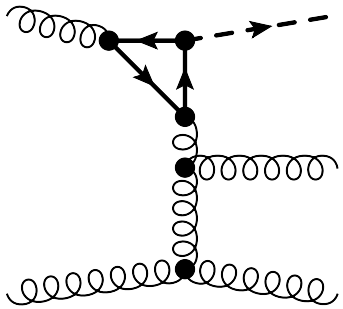
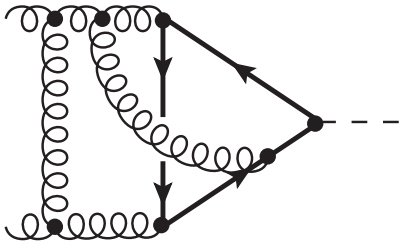


114

$\rightarrow$ calculate by asymptotic expansions

Three-loop virtual



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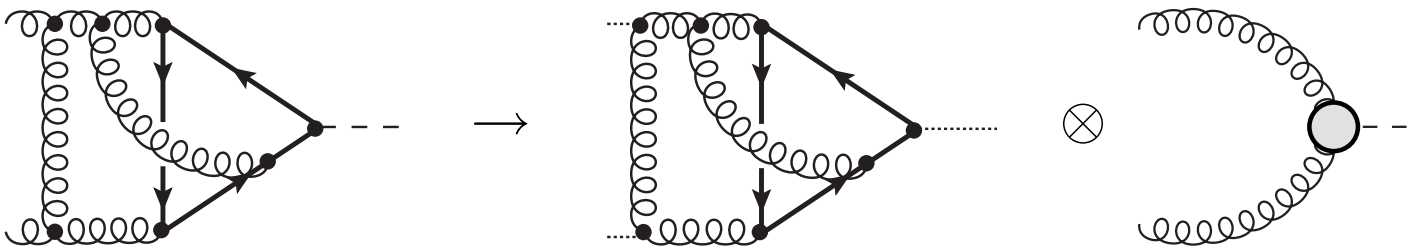

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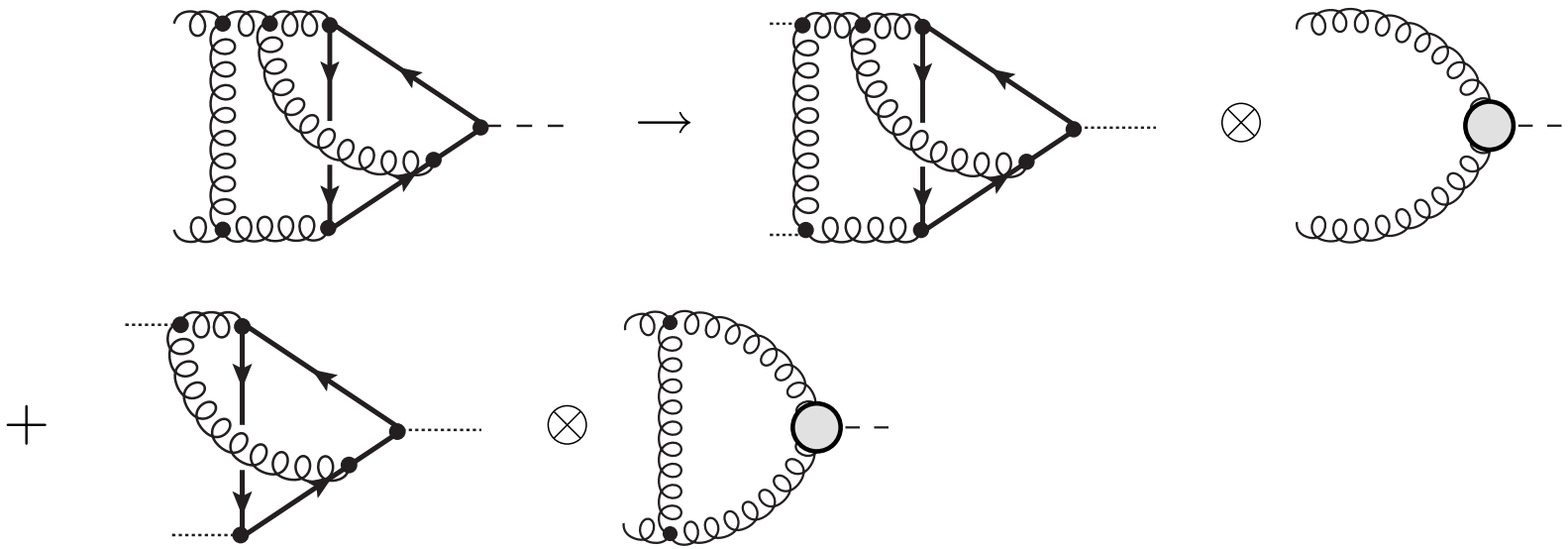

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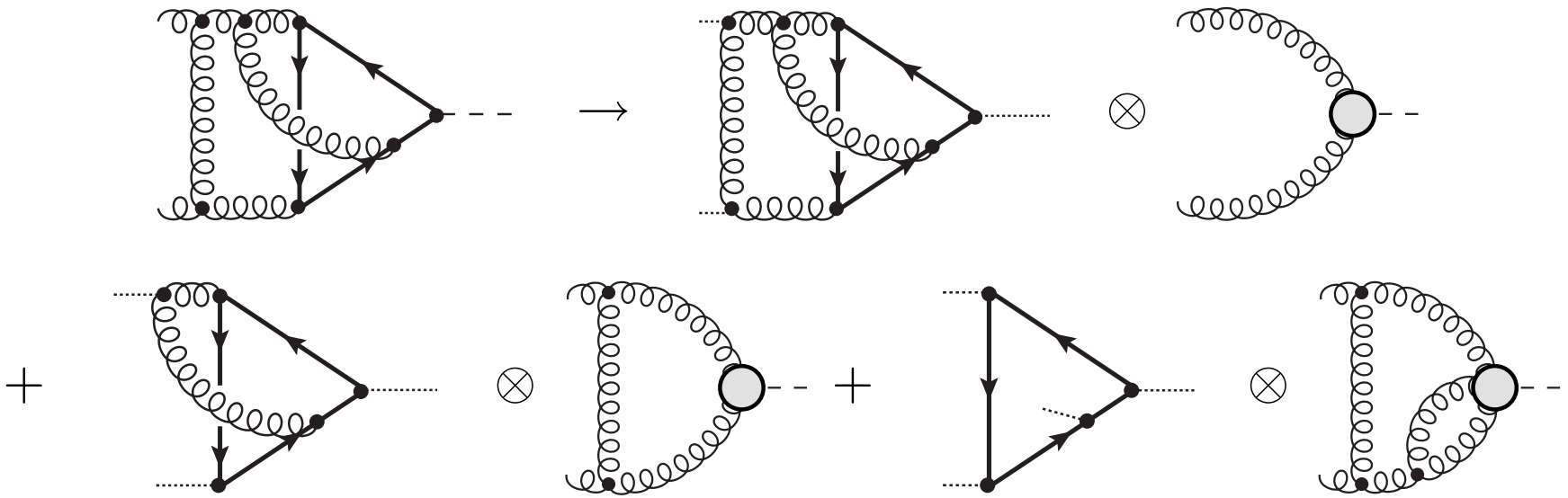

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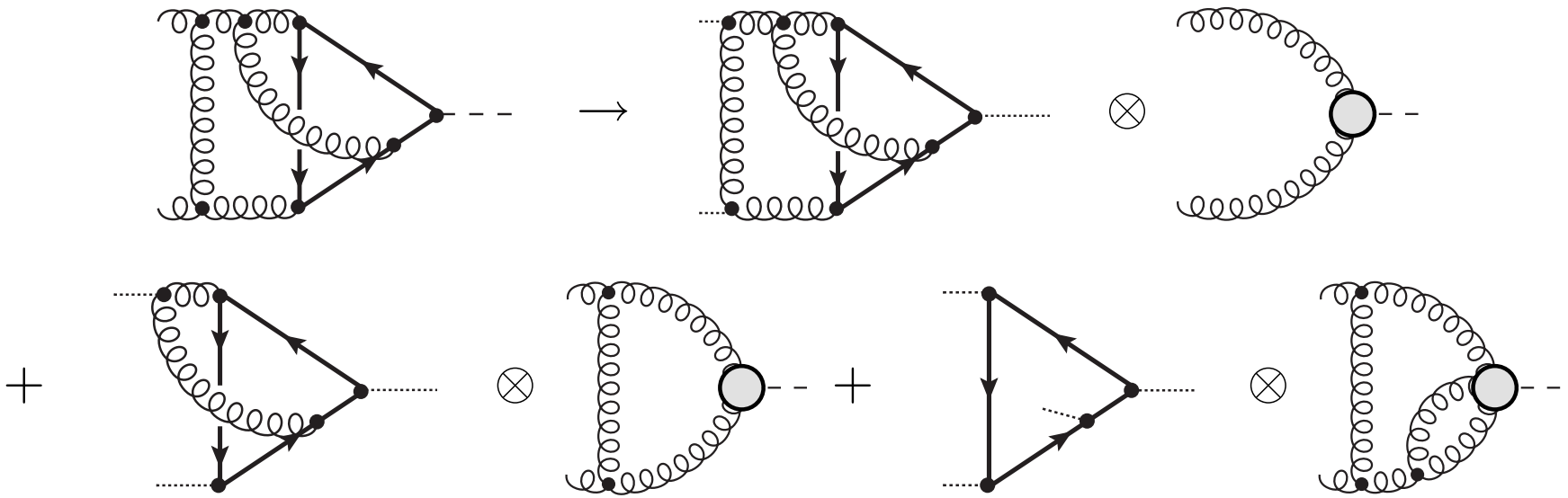

Q2E/EXP [RH, Seidensticker, Steinhauser '99]

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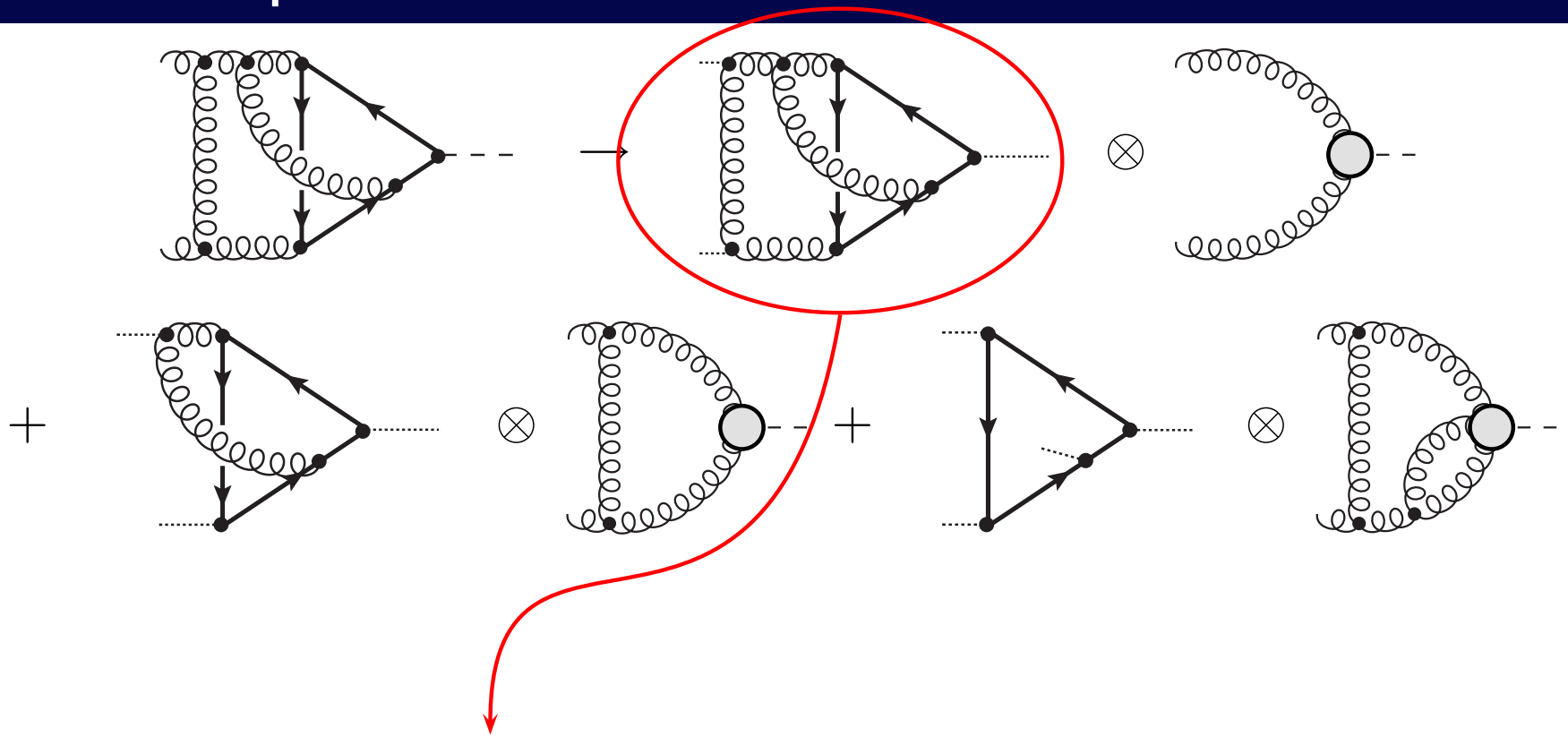
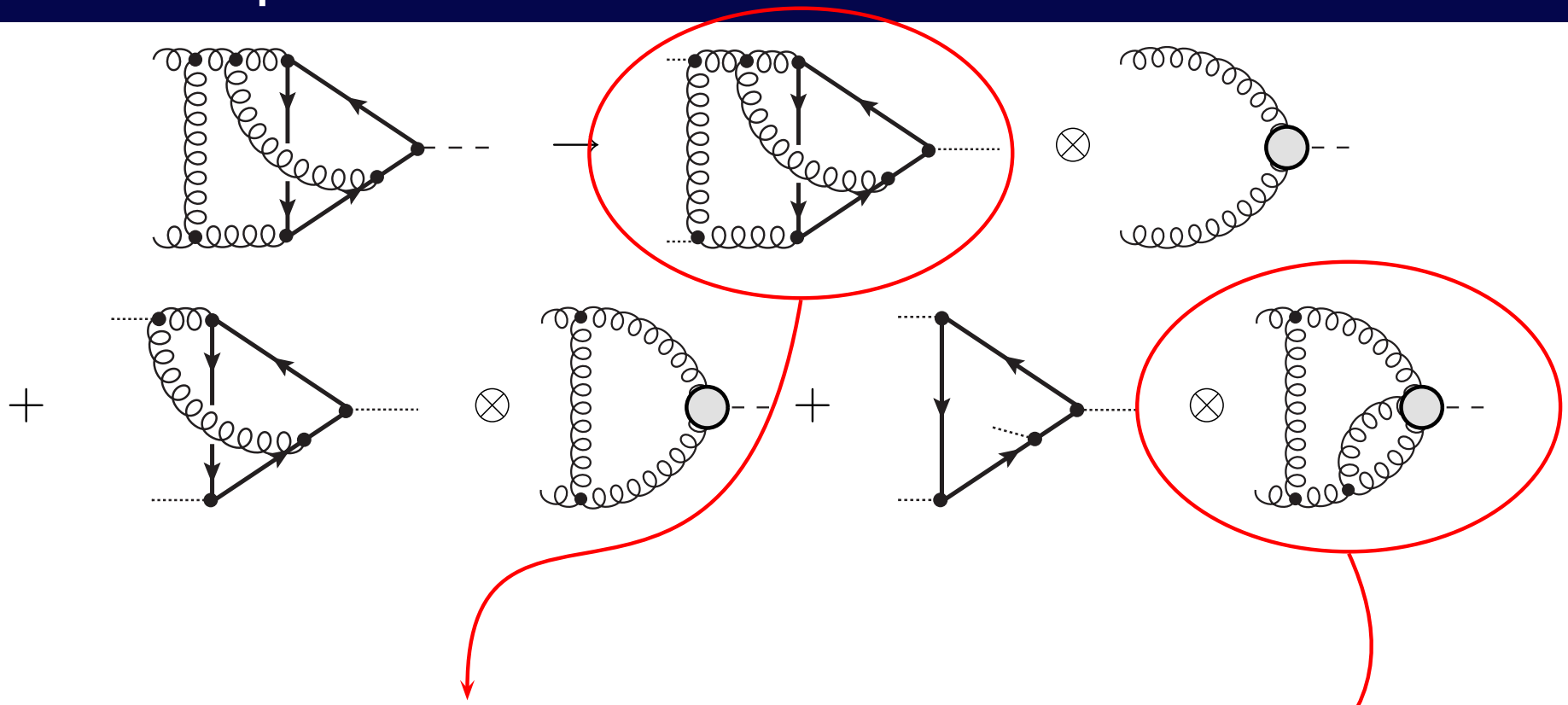


MATAD [Steinhauser '01]

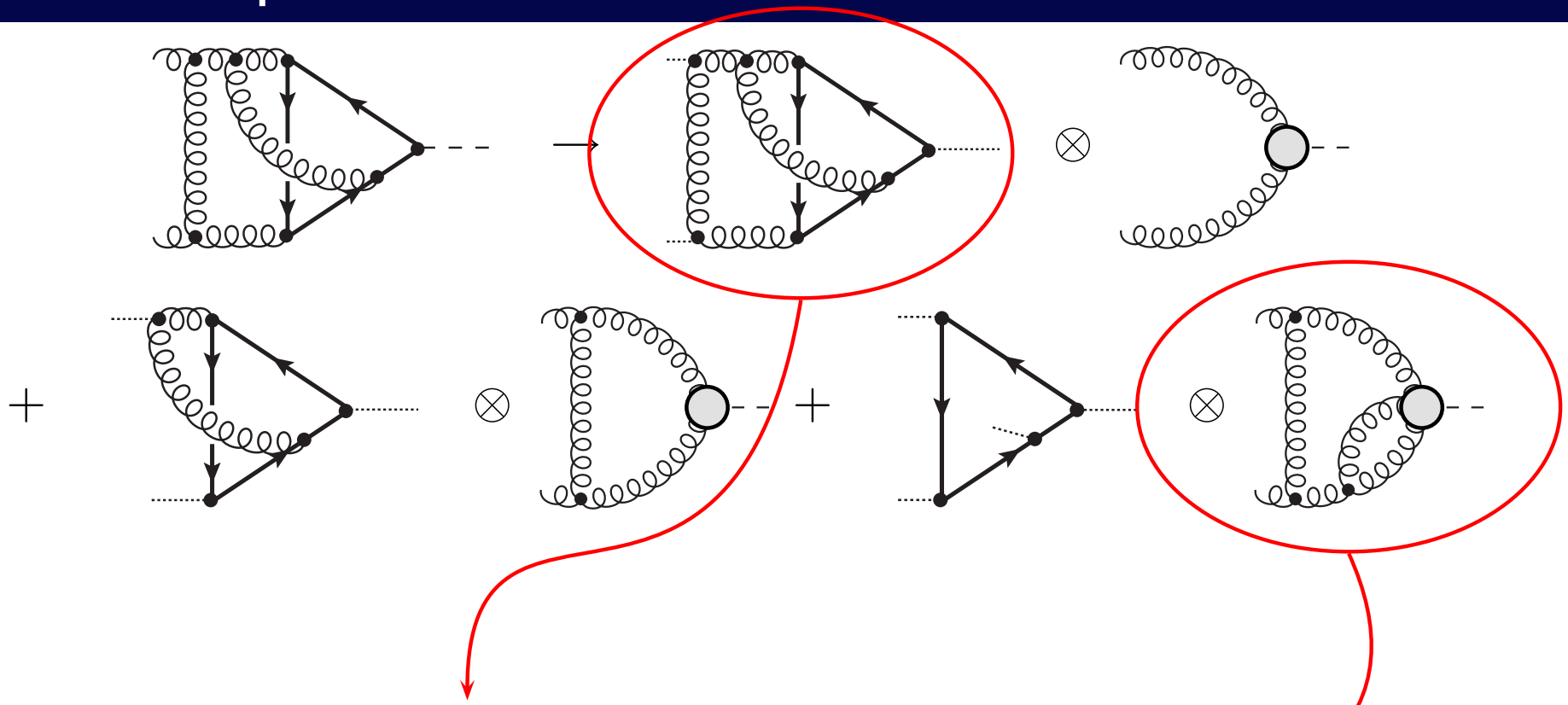
Three-loop virtual



MATAD [Steinhauser '01]

[Baikov, Smirnov '00], [RH '00]

Three-loop virtual

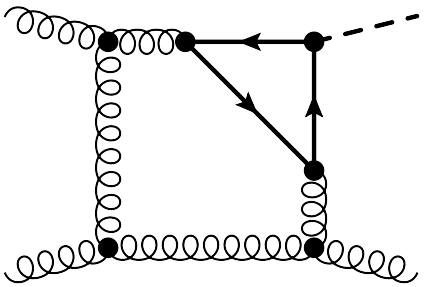


MATAD [Steinhauser ’01]

[Baikov, Smirnov ’00], [RH ’00]

[RH, Ozeren ’09]
[Pak, Rogal, Steinhauser ’09]

Single real radiation



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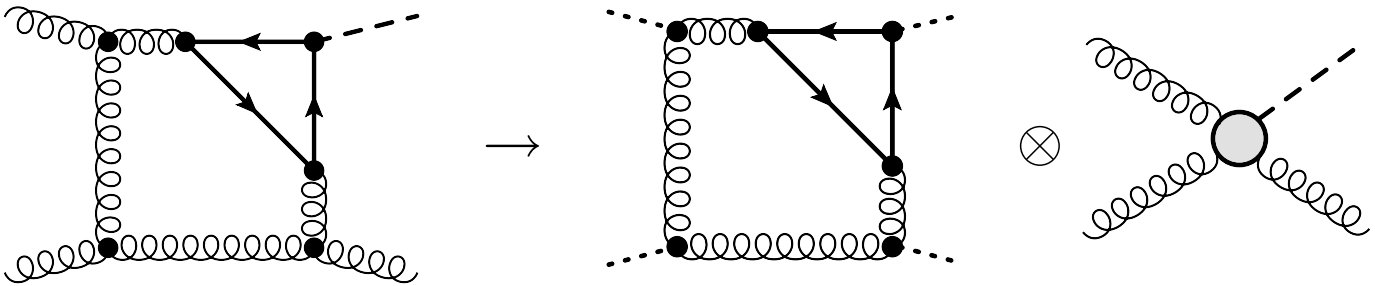

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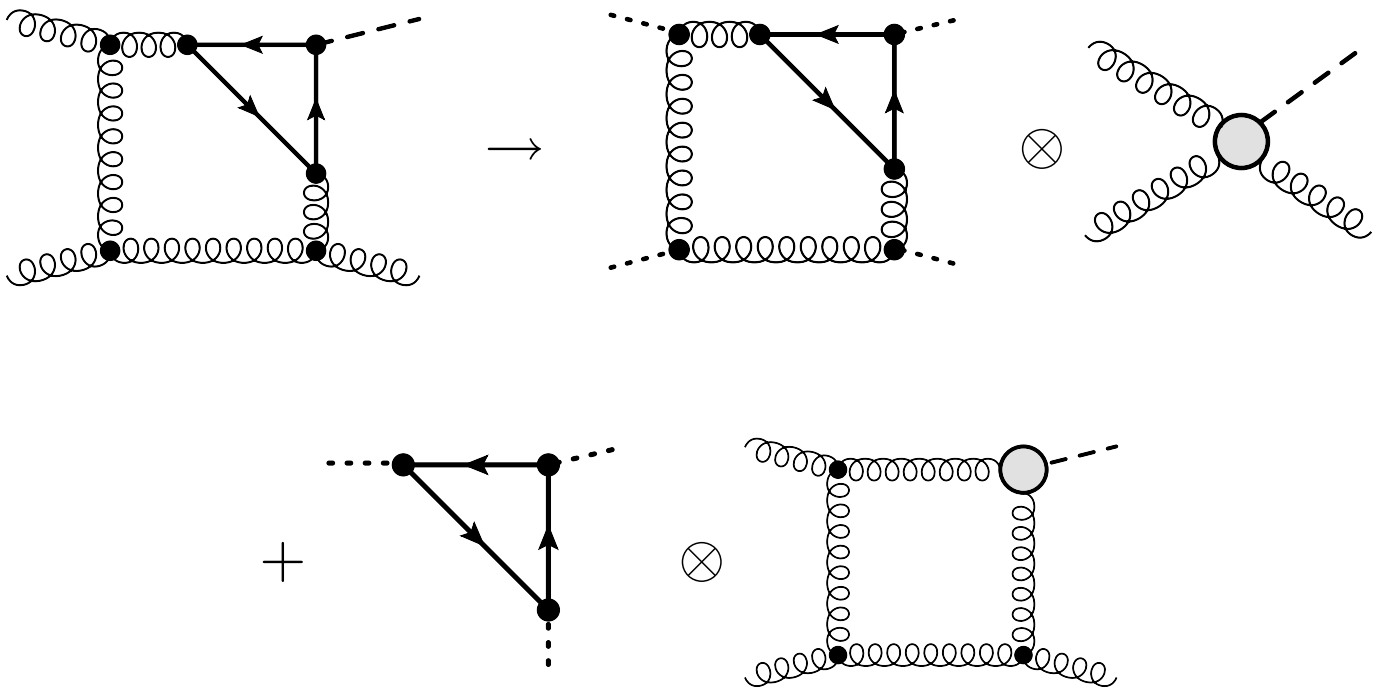

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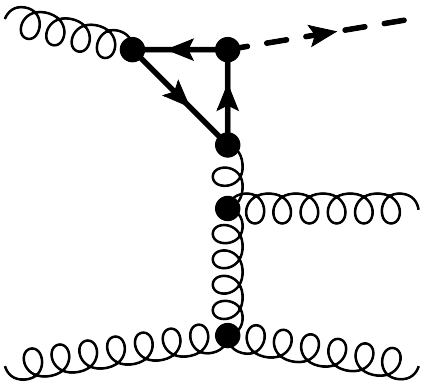

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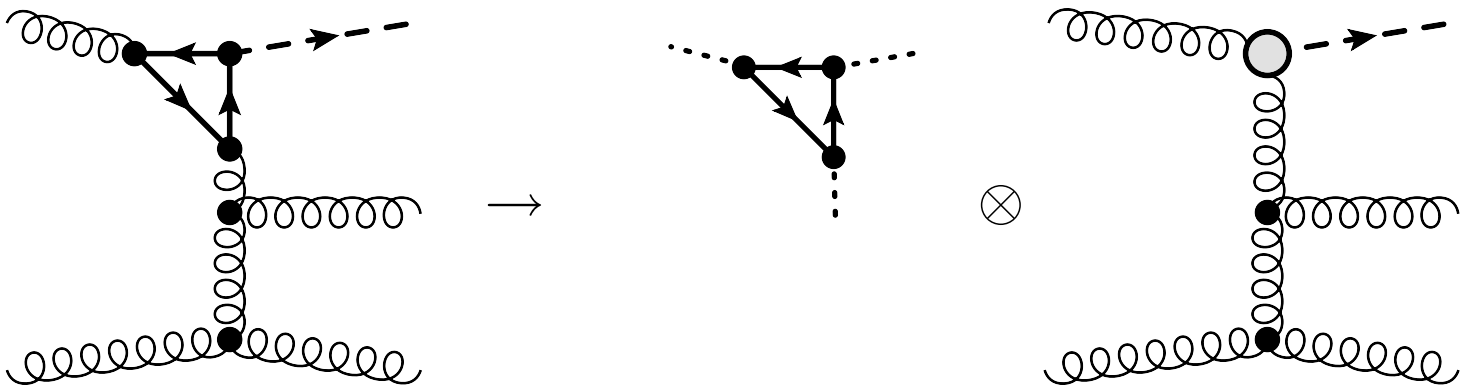

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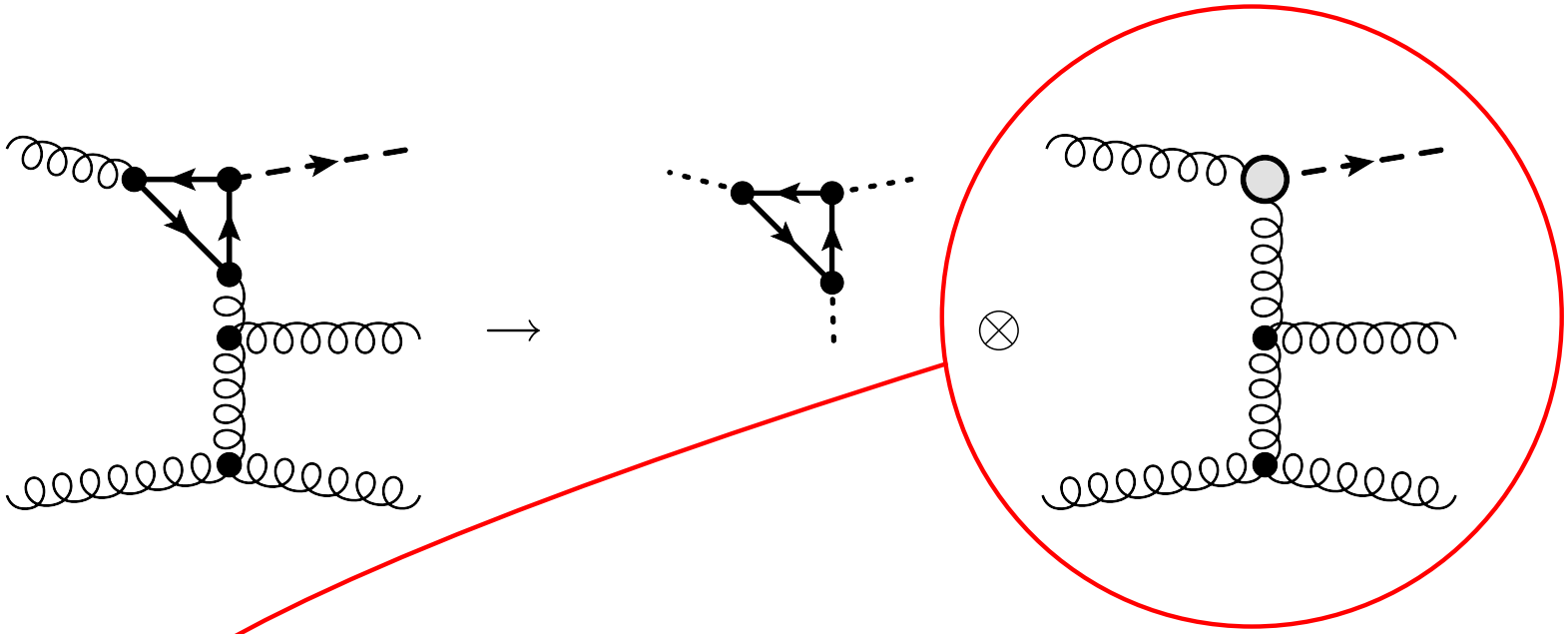
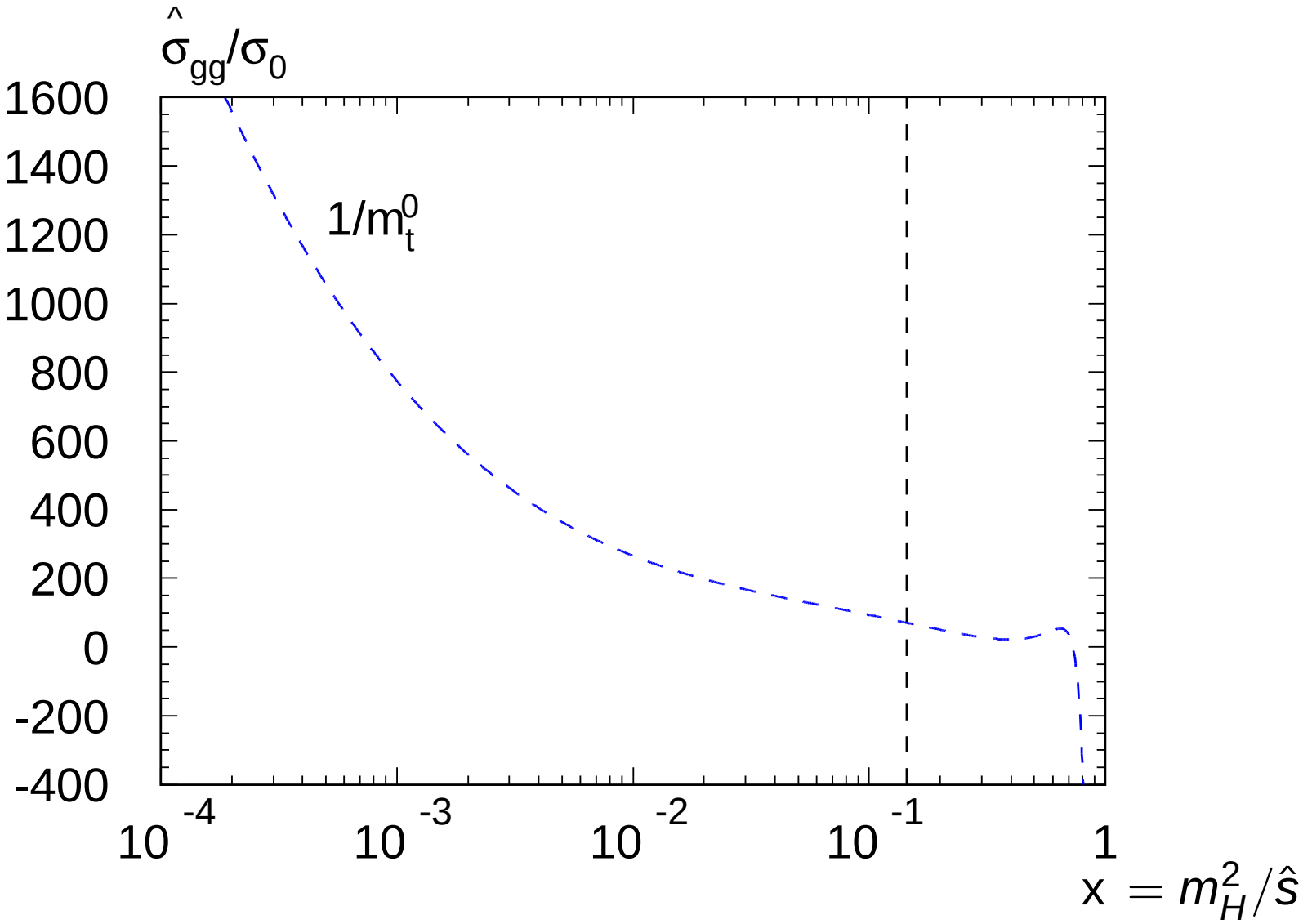


phase space:

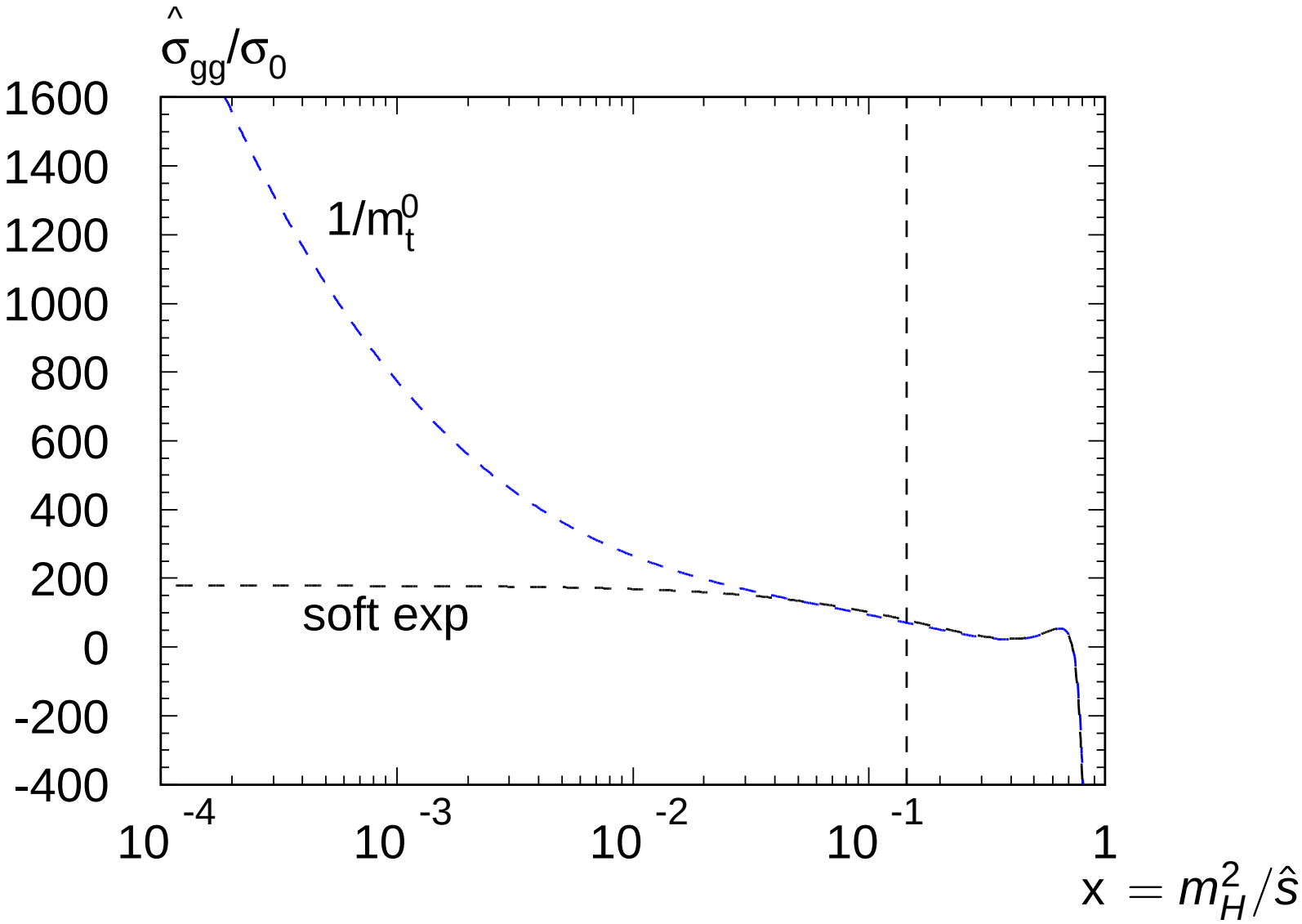
soft expansion [RH, Kilgore '02]

$x = m_H^2/\hat{s} \to 1$

Dependence on $\hat{s}$ at NNLO



Dependence on $\hat{s}$ at NNLO



Large-$\hat{s}$ behavior at NNLO

- small-x behavior known: $(x = m_H^2/\hat{s})$ [Marzani *et al.* '08]

$$\hat{\sigma}_{gg}^{(2)}(x) \quad \rightarrow \quad -9\,C^{(2)}(m_H/m_t)\ln x + c + \mathcal{O}(x)\,, \qquad \hat{s} \rightarrow \infty$$

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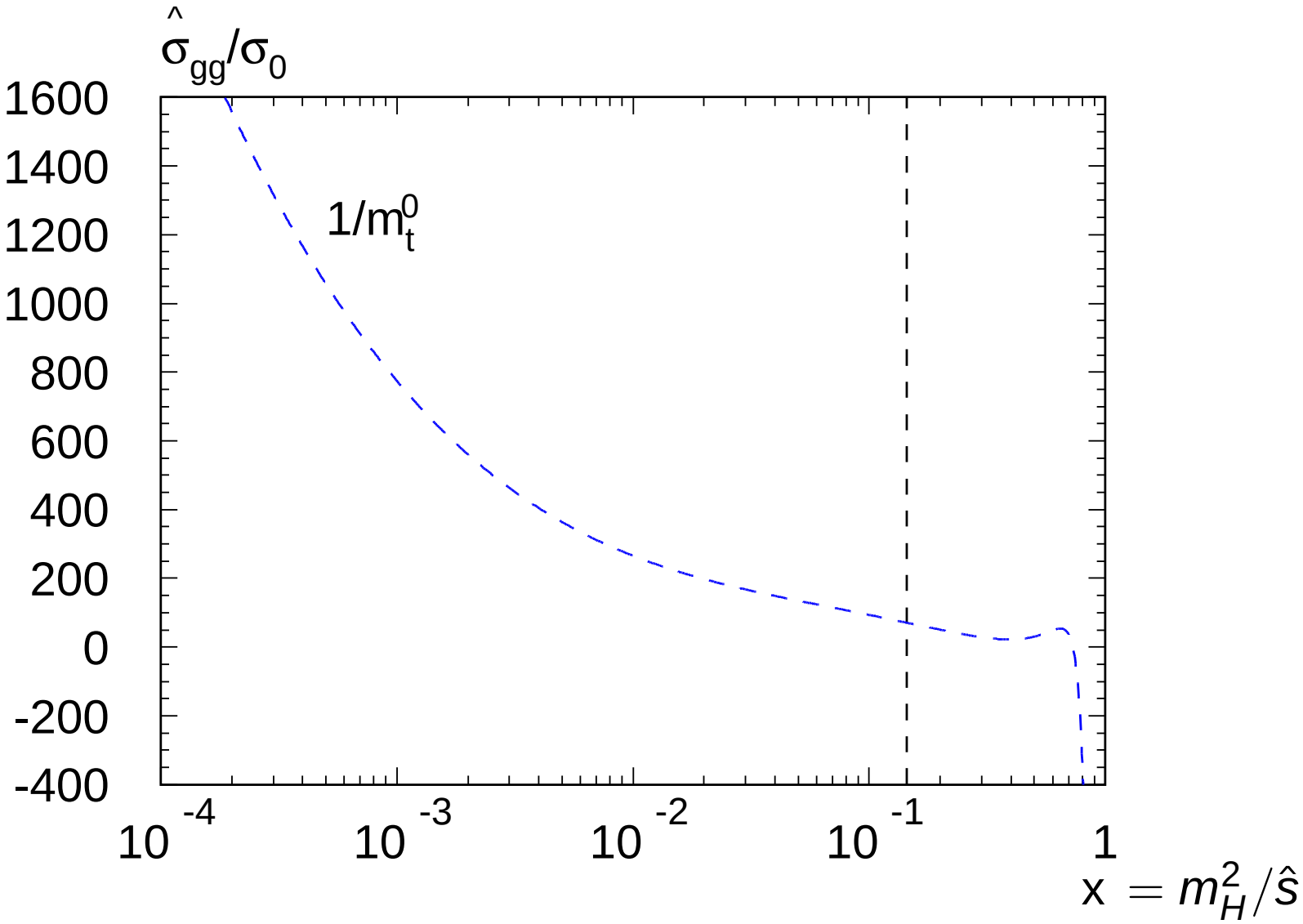

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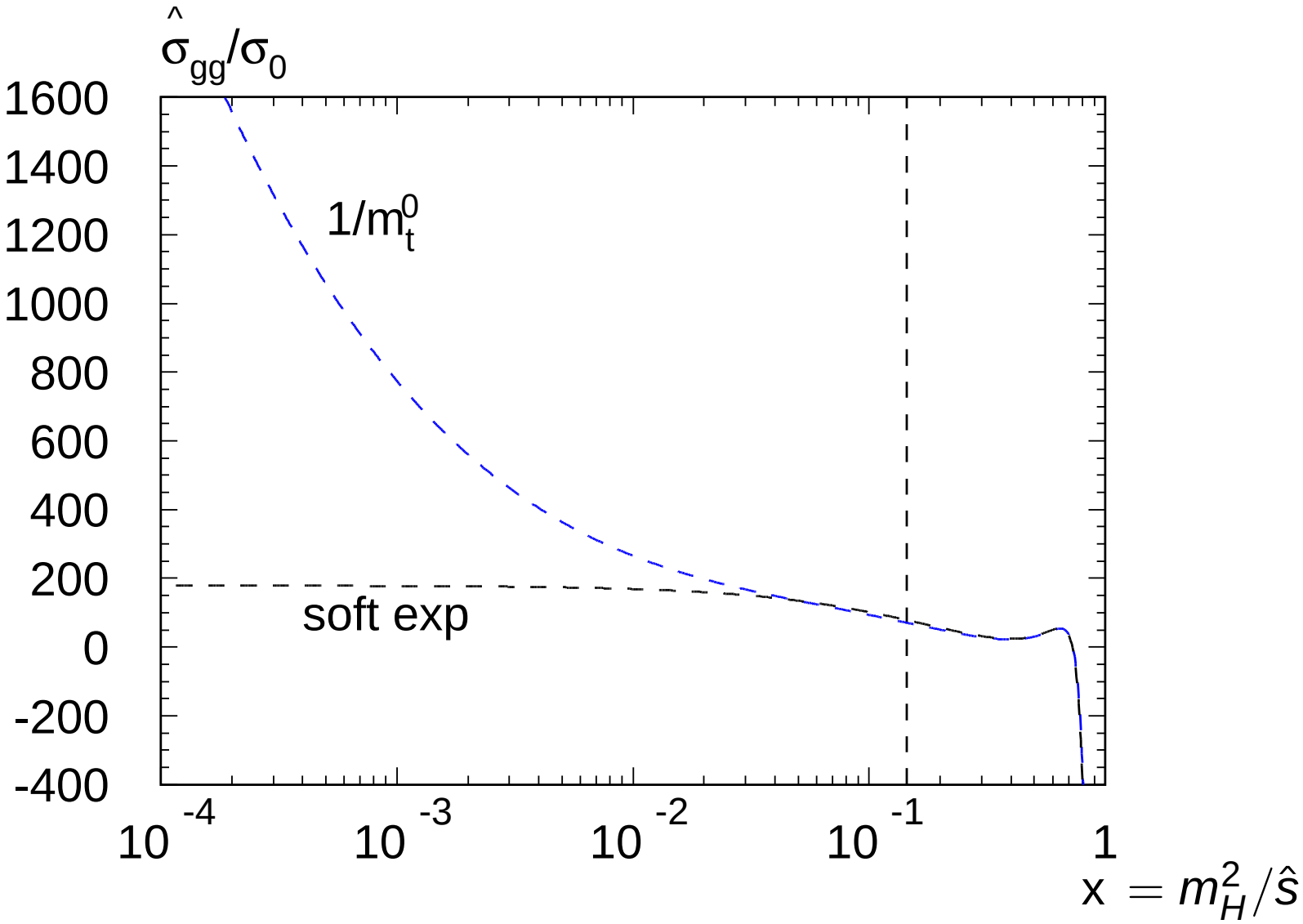

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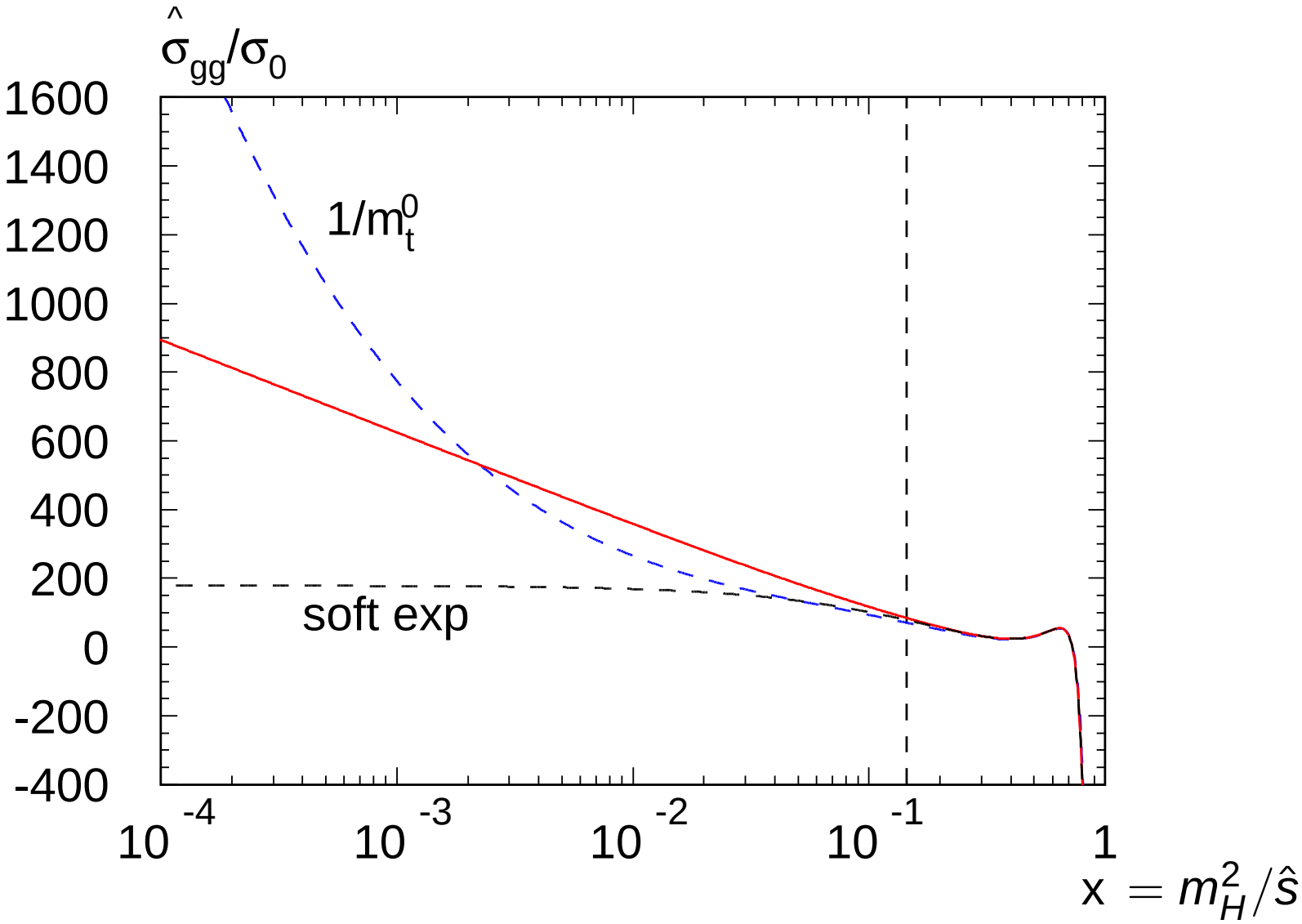

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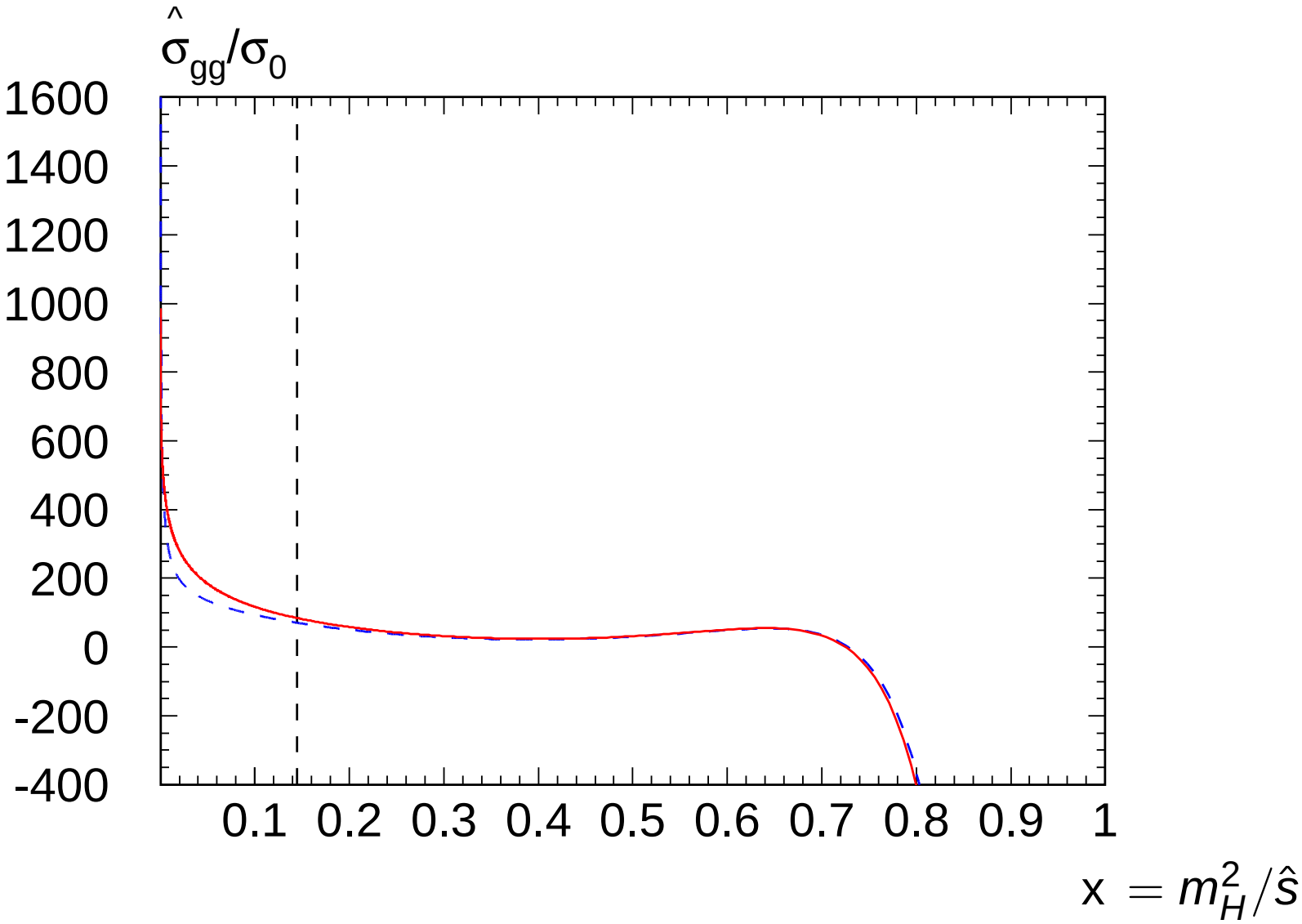
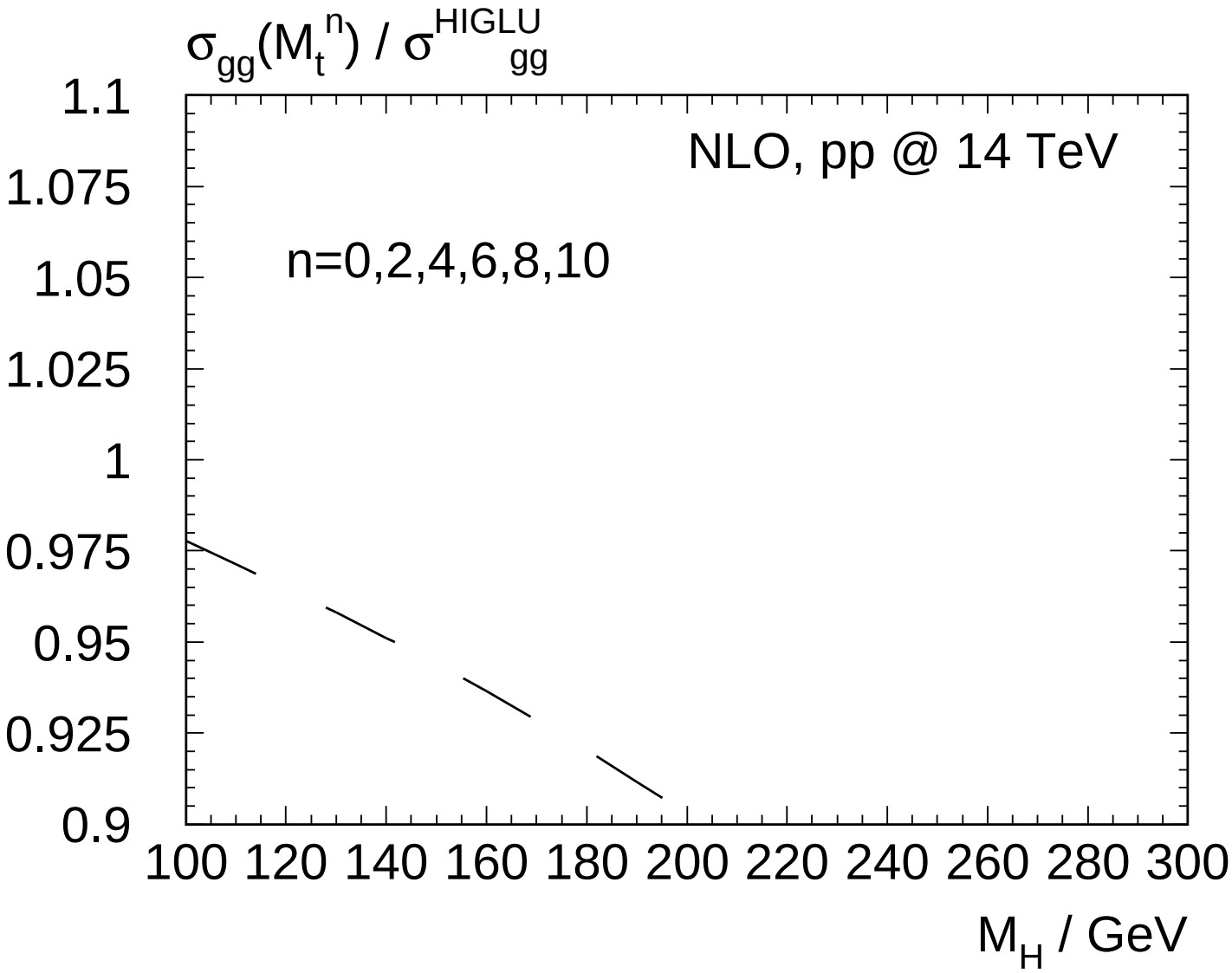


Convergence of $1/m_t$ expansion at NLO



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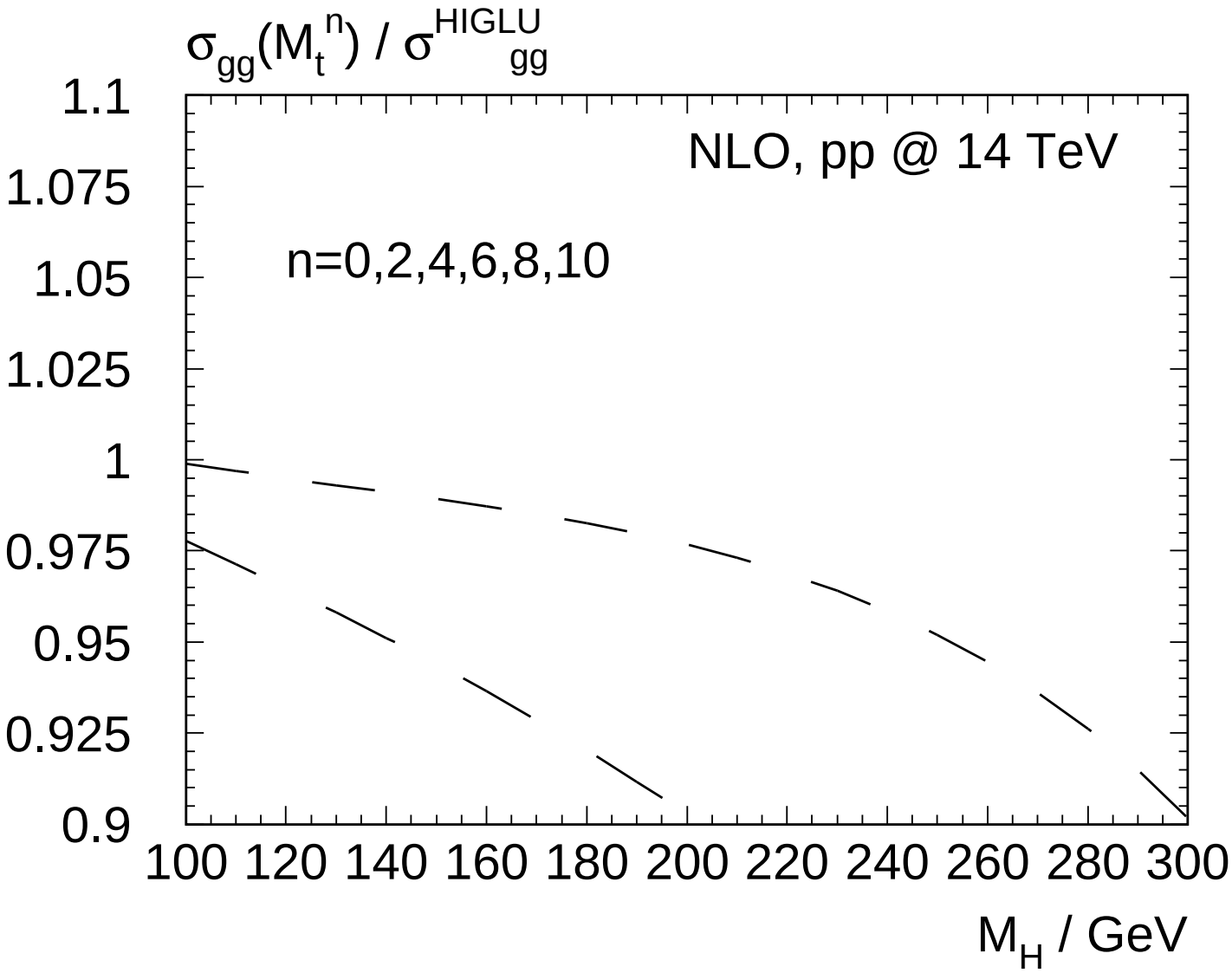

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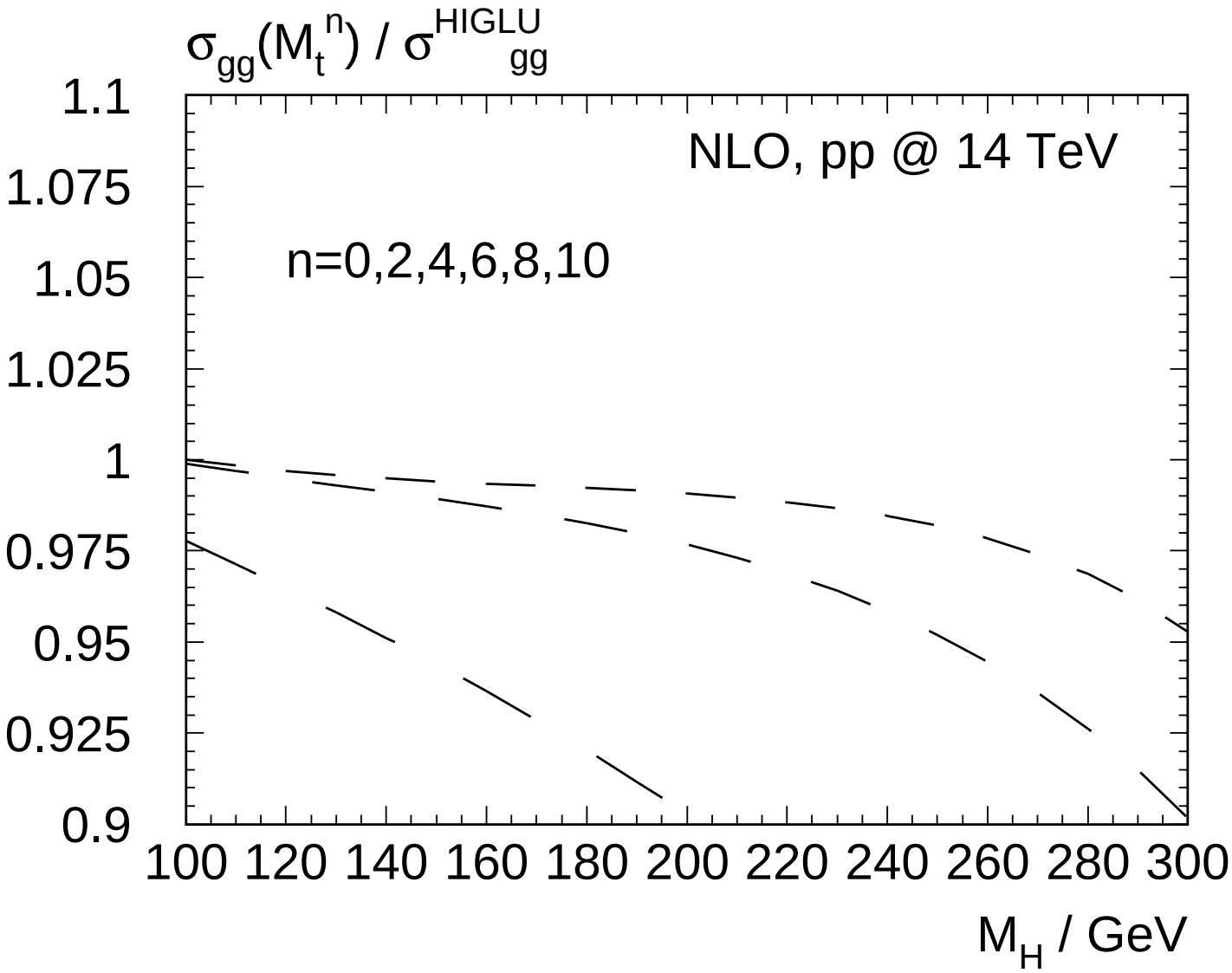

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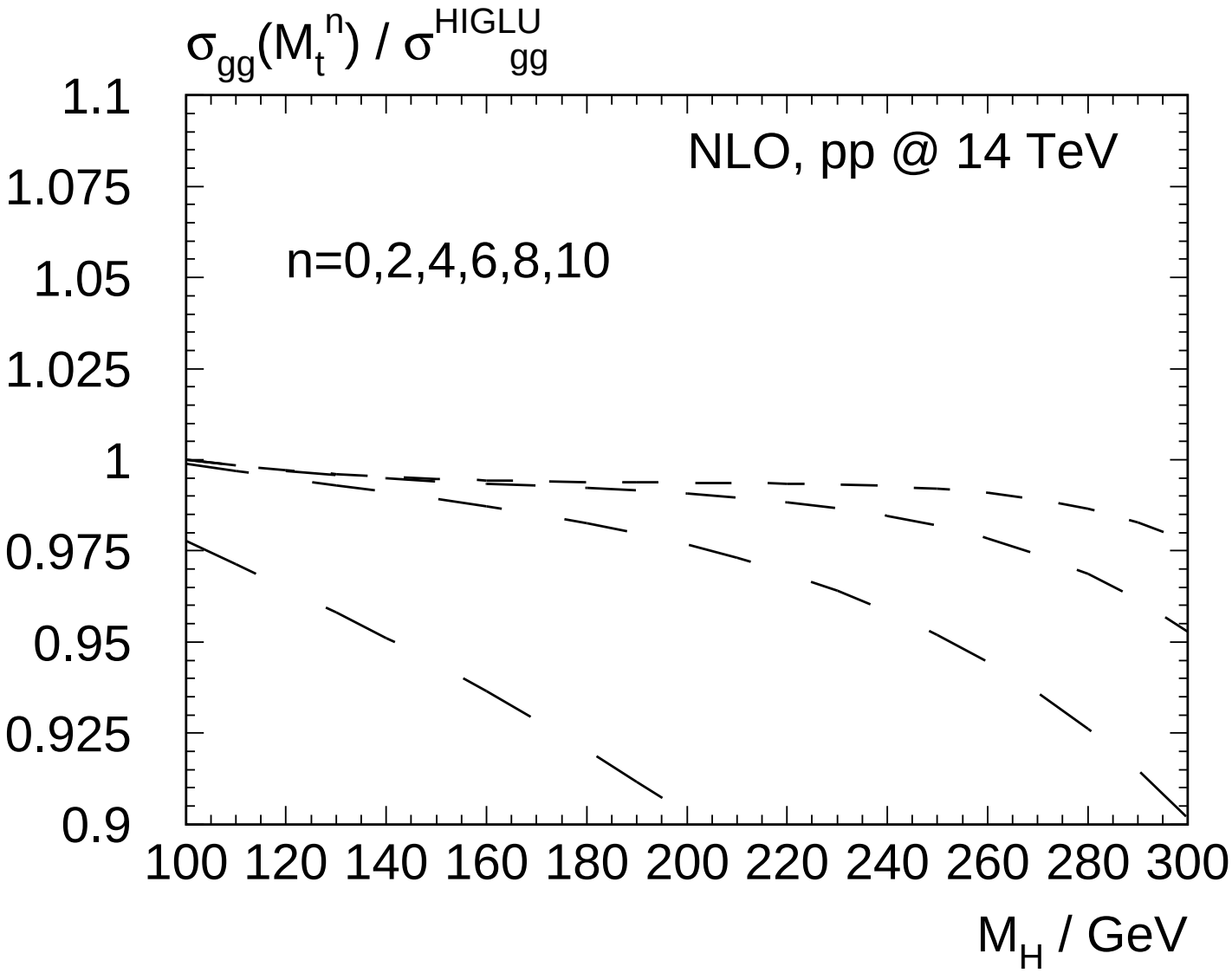

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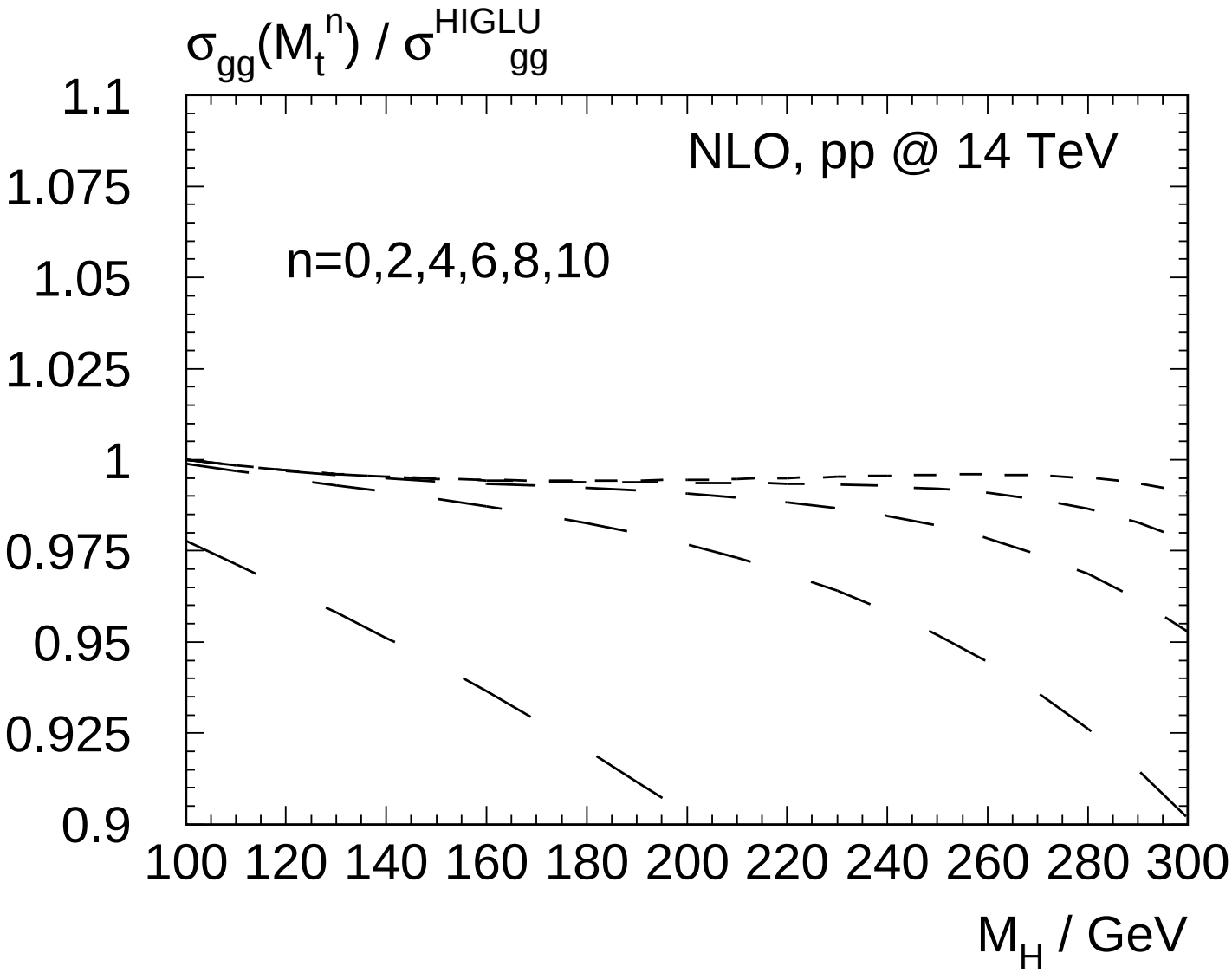

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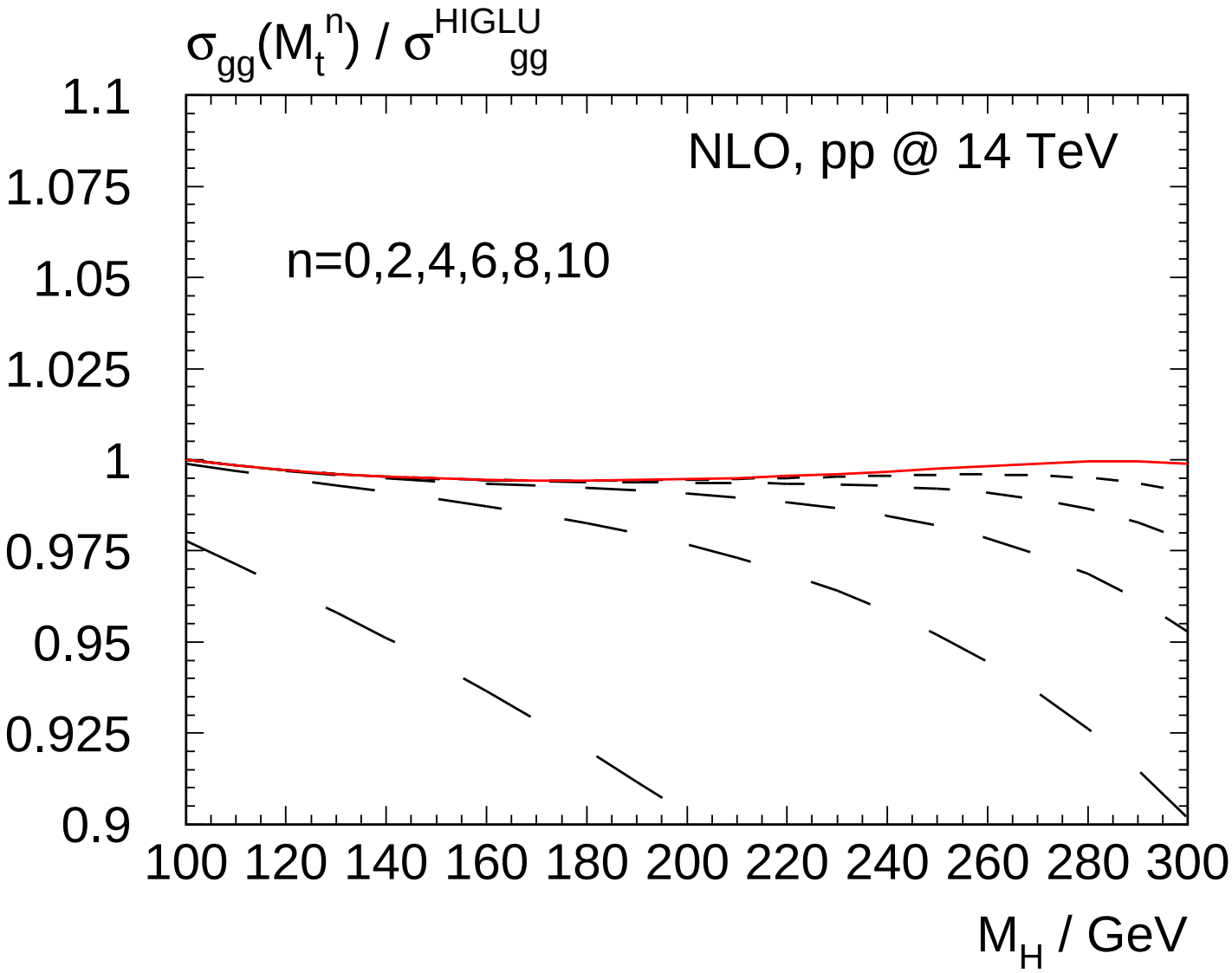


Comparison at NNLO

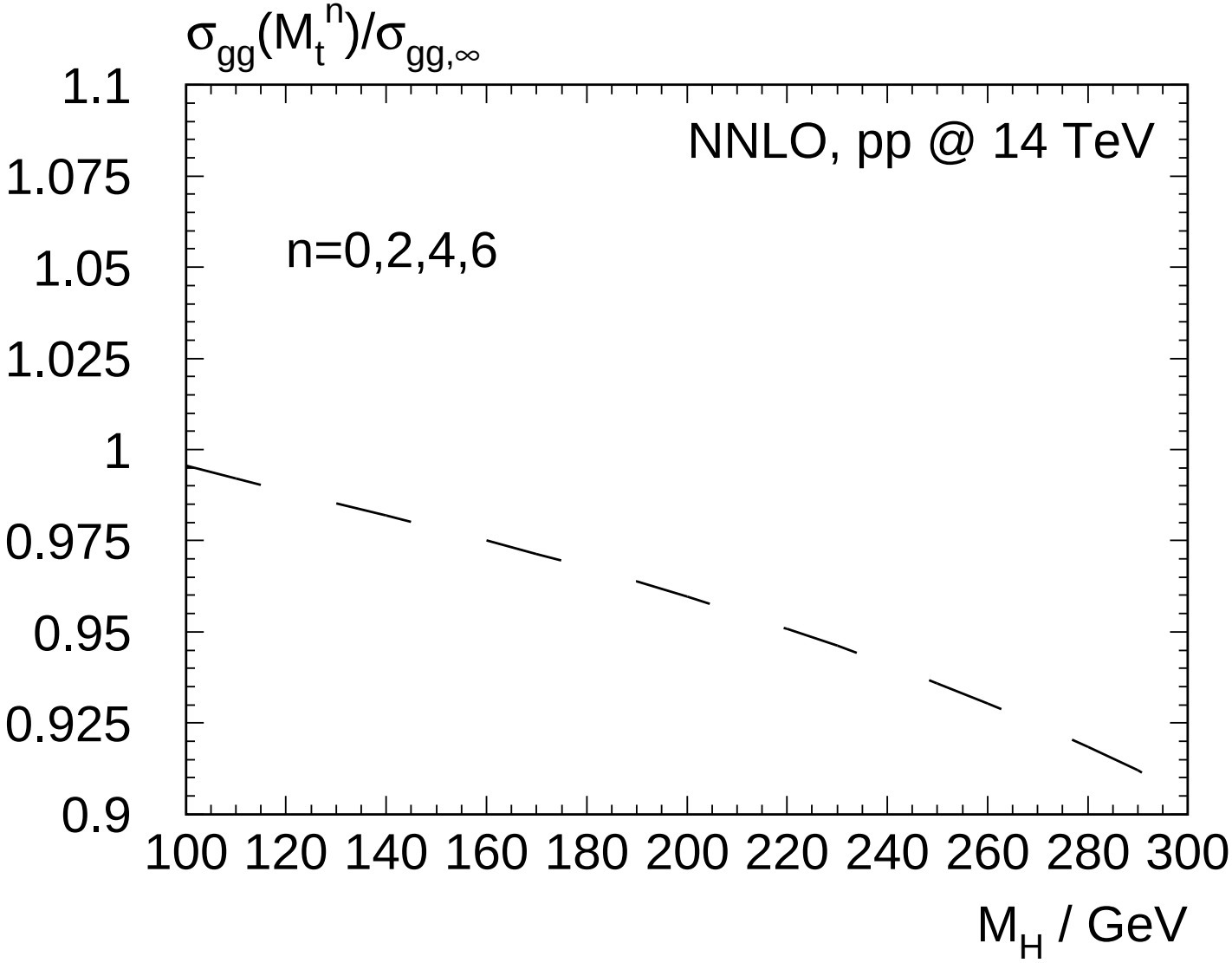
Heavy-top limit:

$$\sigma^{\mathrm{HO}}_{\infty}(s, m_H, m_t) \equiv \sigma^{\mathrm{LO}}(m_t, m_H) \left(\frac{\sigma^{\mathrm{HO}}(s, m_H)}{\sigma^{\mathrm{LO}}} \right)_{m_t \to \infty}$$

Honest expansion:

$$\sigma^{\mathrm{HO}}(s, m_H, m_t) = \sum_n \left(\frac{m_H^2}{4m_t^2} \right)^n \sigma^{\mathrm{HO}}_n(s, m_H)$$

Convergence of $1/m_t$ expansion at NNLO



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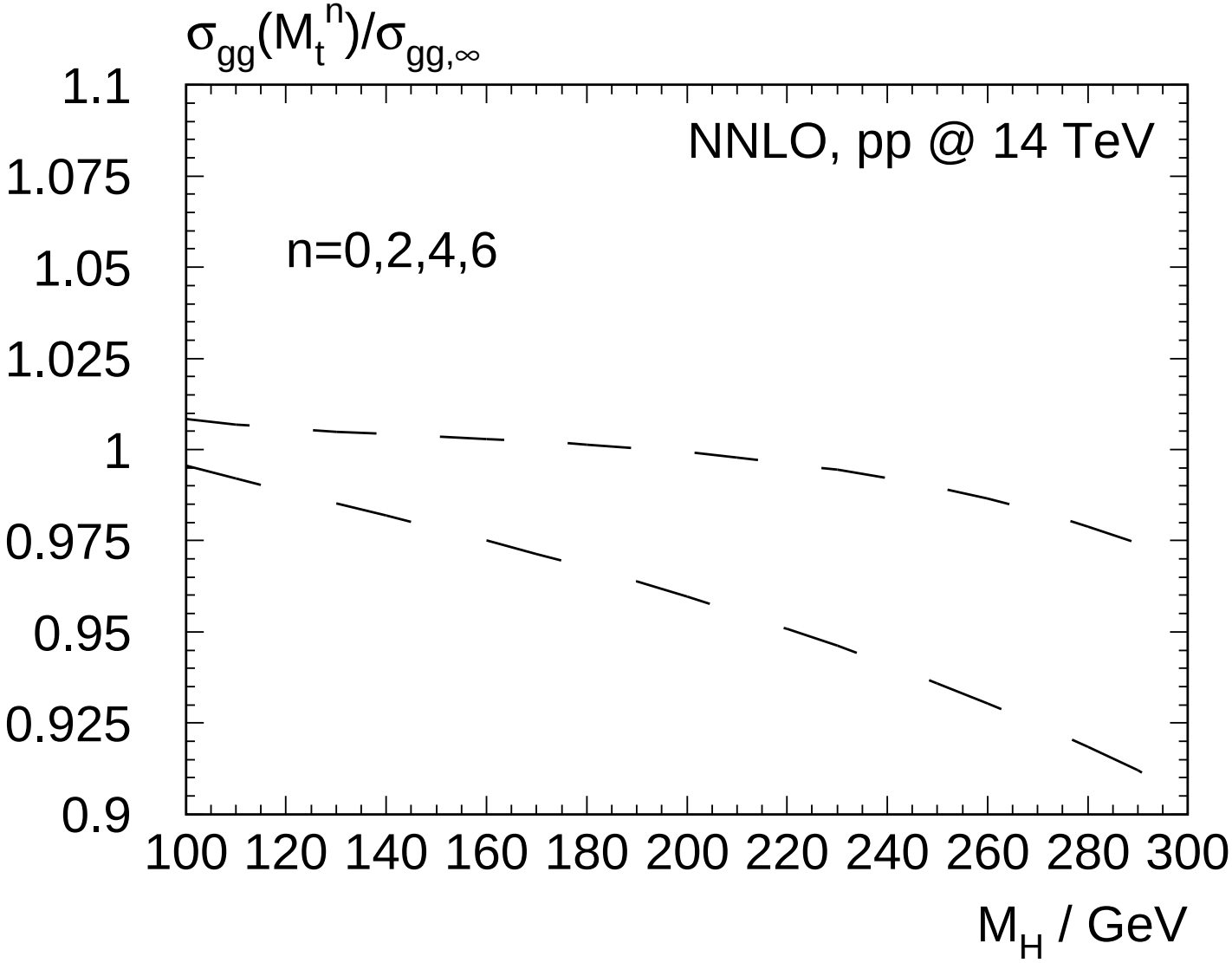

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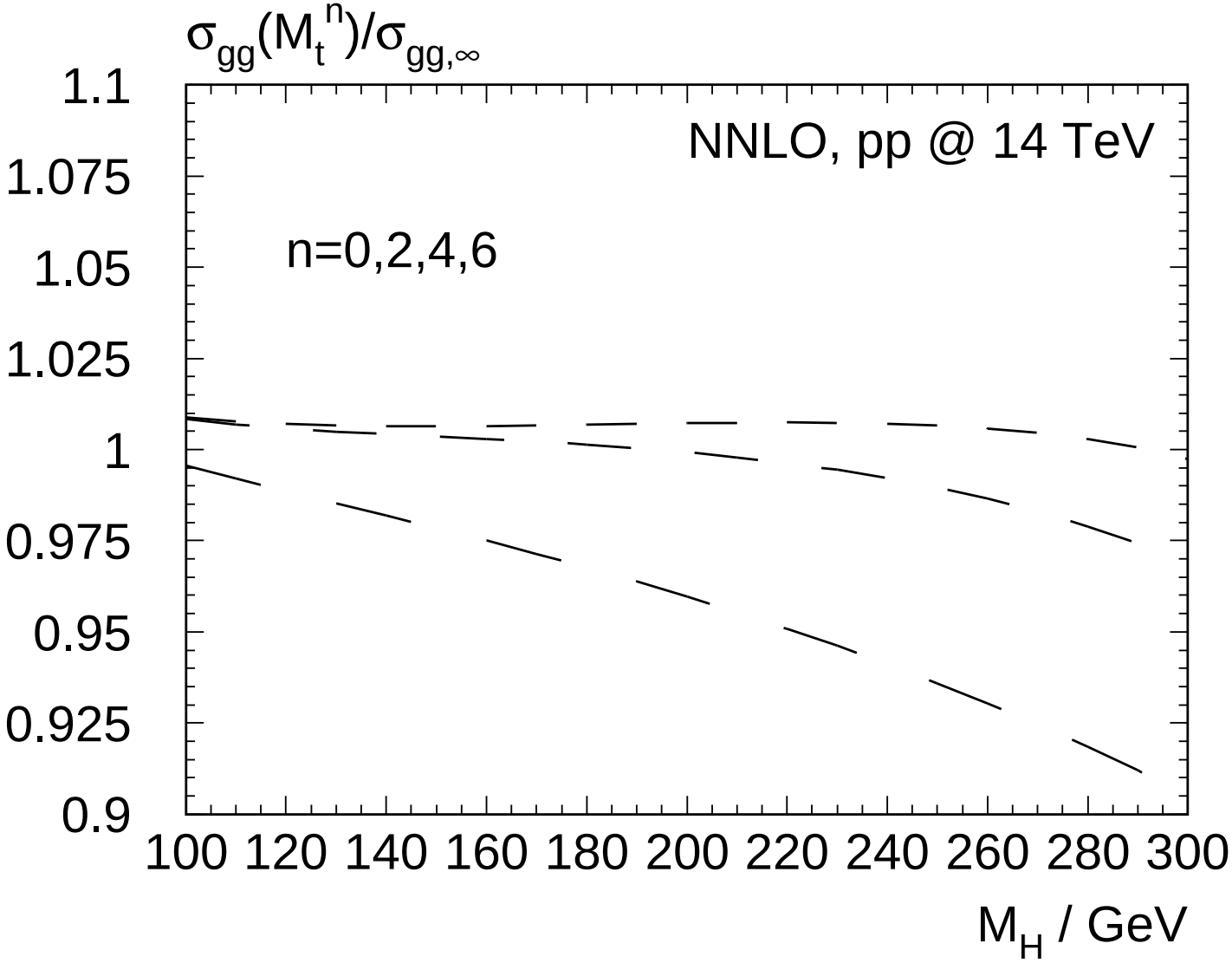

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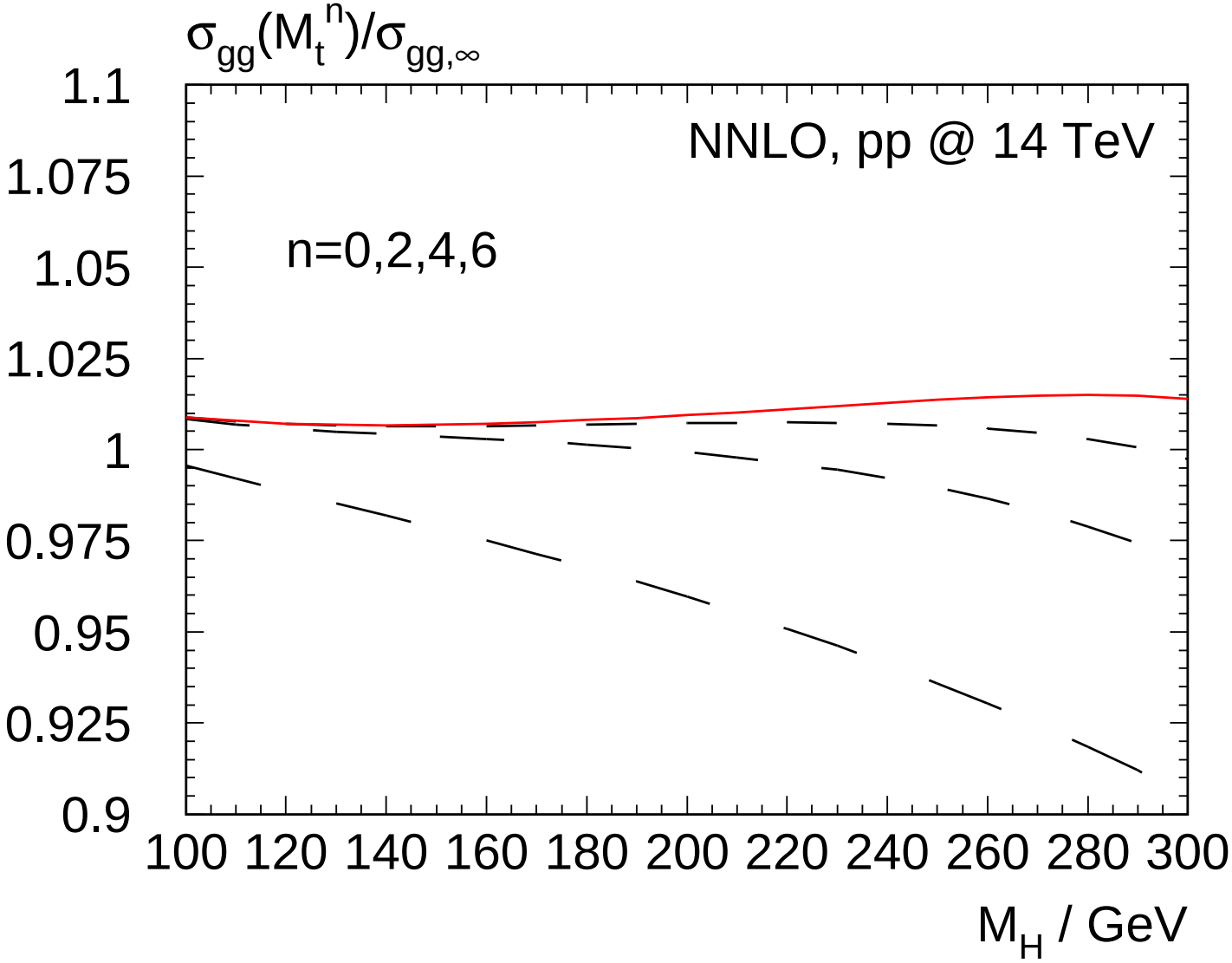

Convergence with N

$$\hat{\sigma}_{gg}^{(1)}(x) \approx \hat{\sigma}_{gg,N}^{(1)}(x) - (1-x)^{N+1}\left[3\,C^{(1)}(m_H/m_t) + \hat{\sigma}_{gg,N}^{(1)}(0)\right]$$

$$\hat{\sigma}_{gg}^{(2)}(x) \approx \hat{\sigma}_{gg,N}^{(2)}(x) - 9\,C^{(2)}(m_H/m_t)\left[\ln x + \sum_{n=1}^{N}\frac{(1-x)^n}{n}\right]$$

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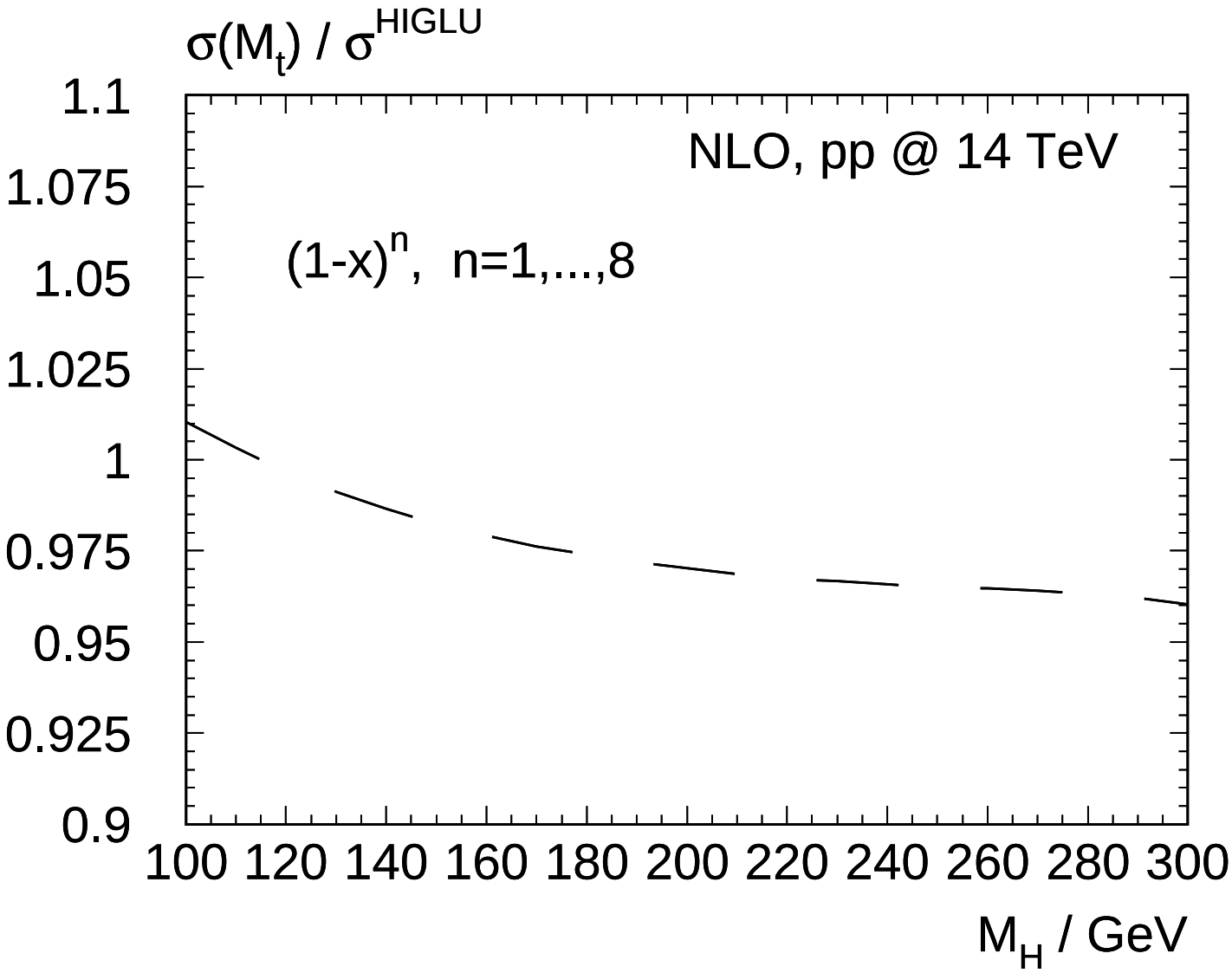
Final result at NLO: $1/m_t$ vs. HIGLU



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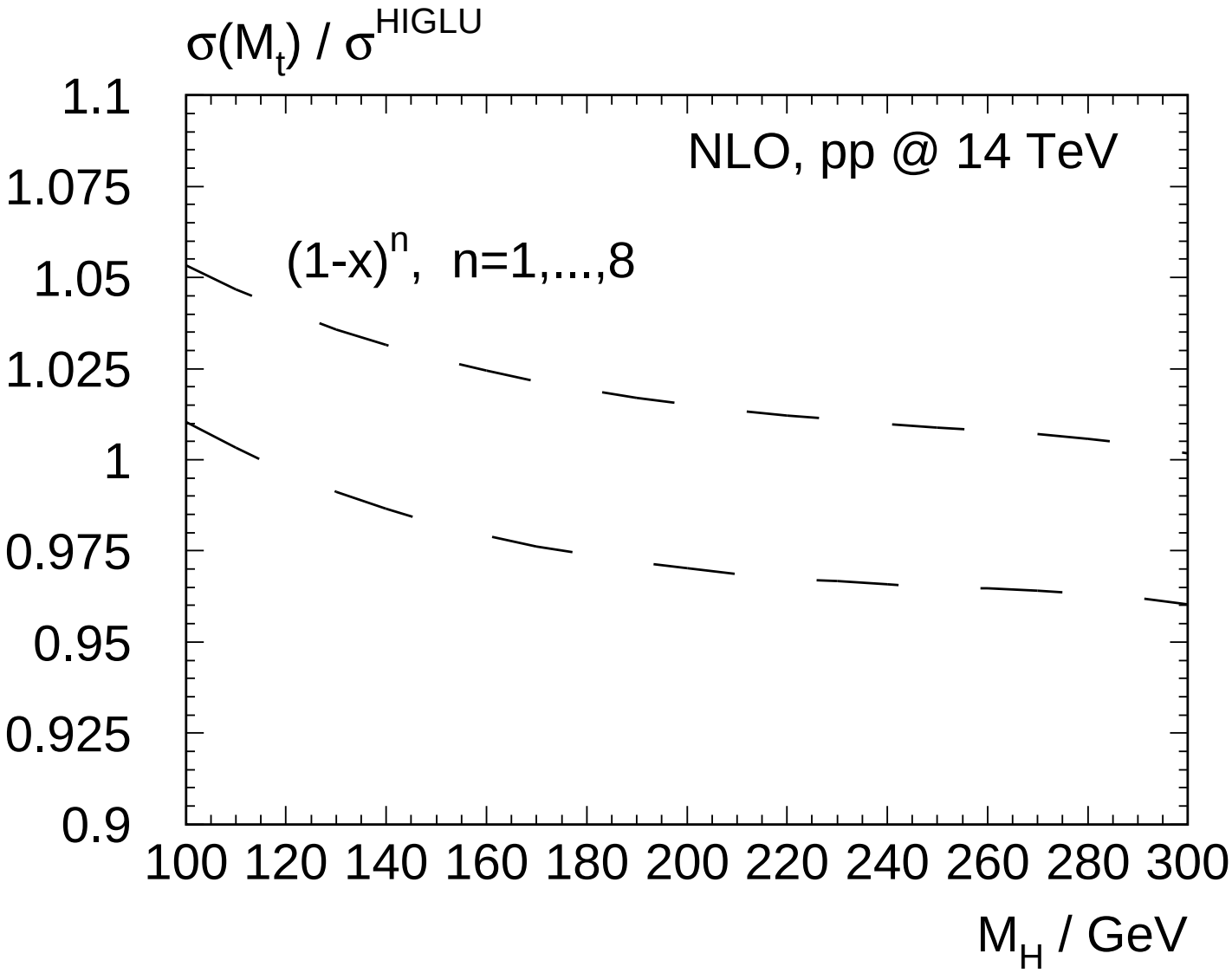

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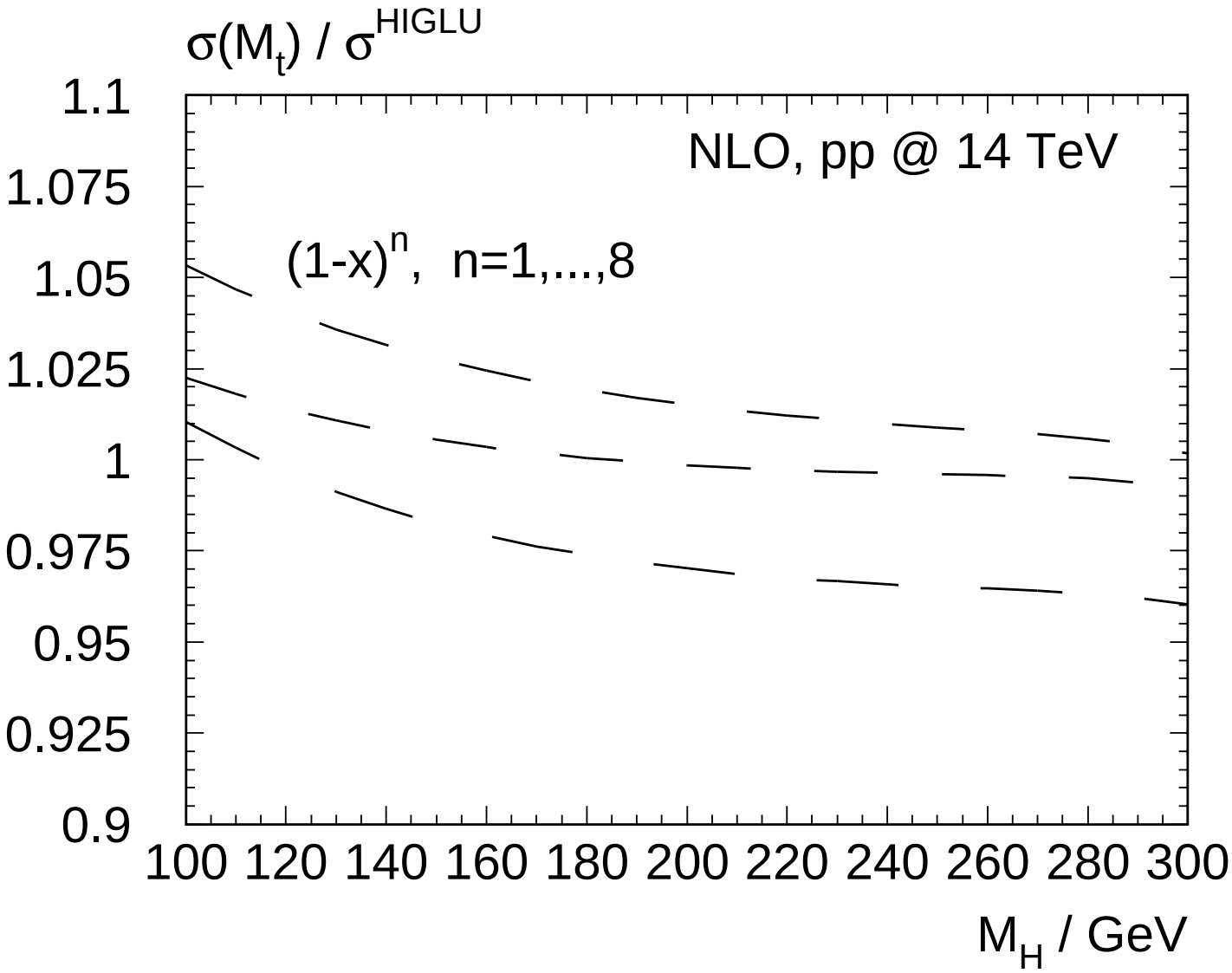

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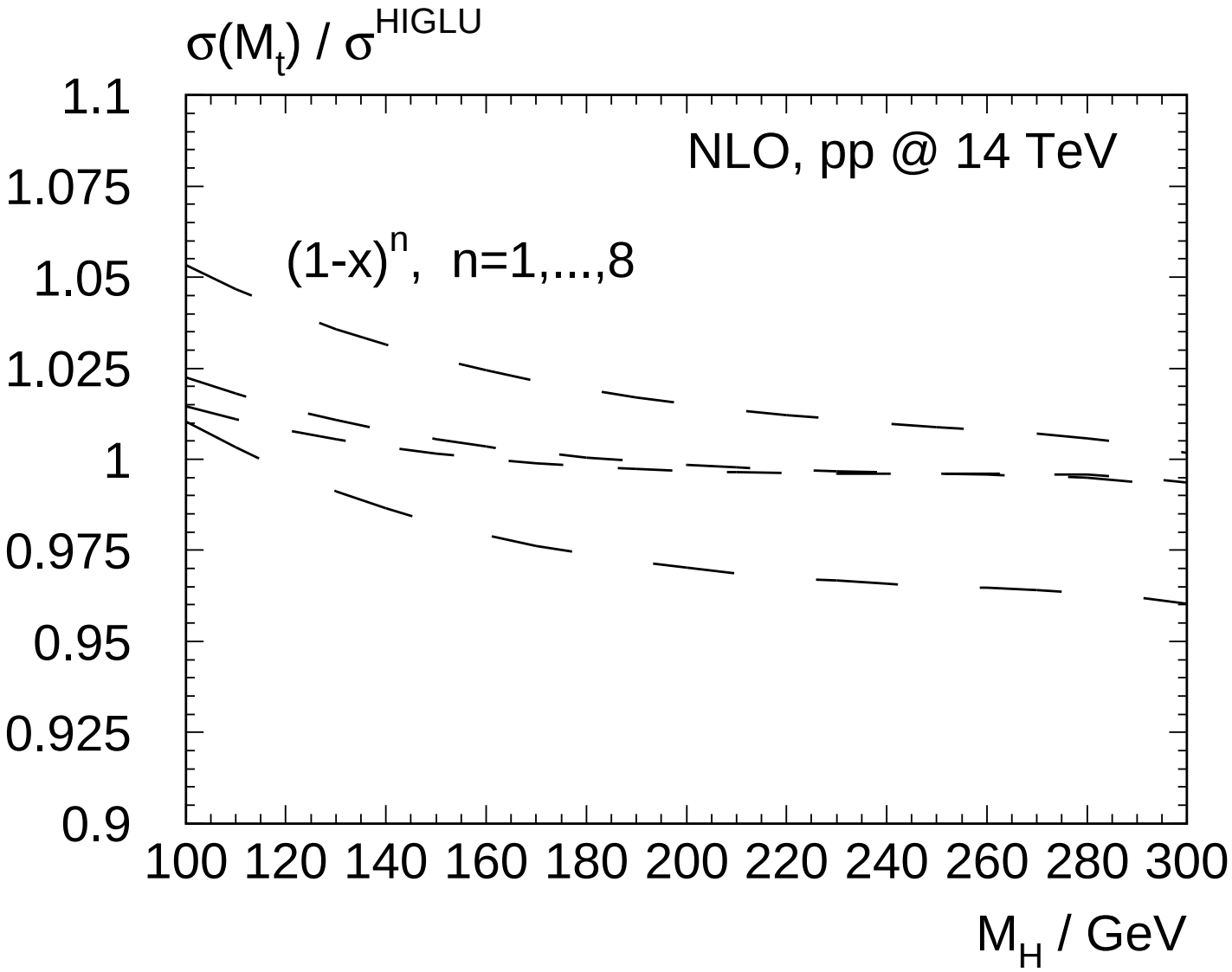

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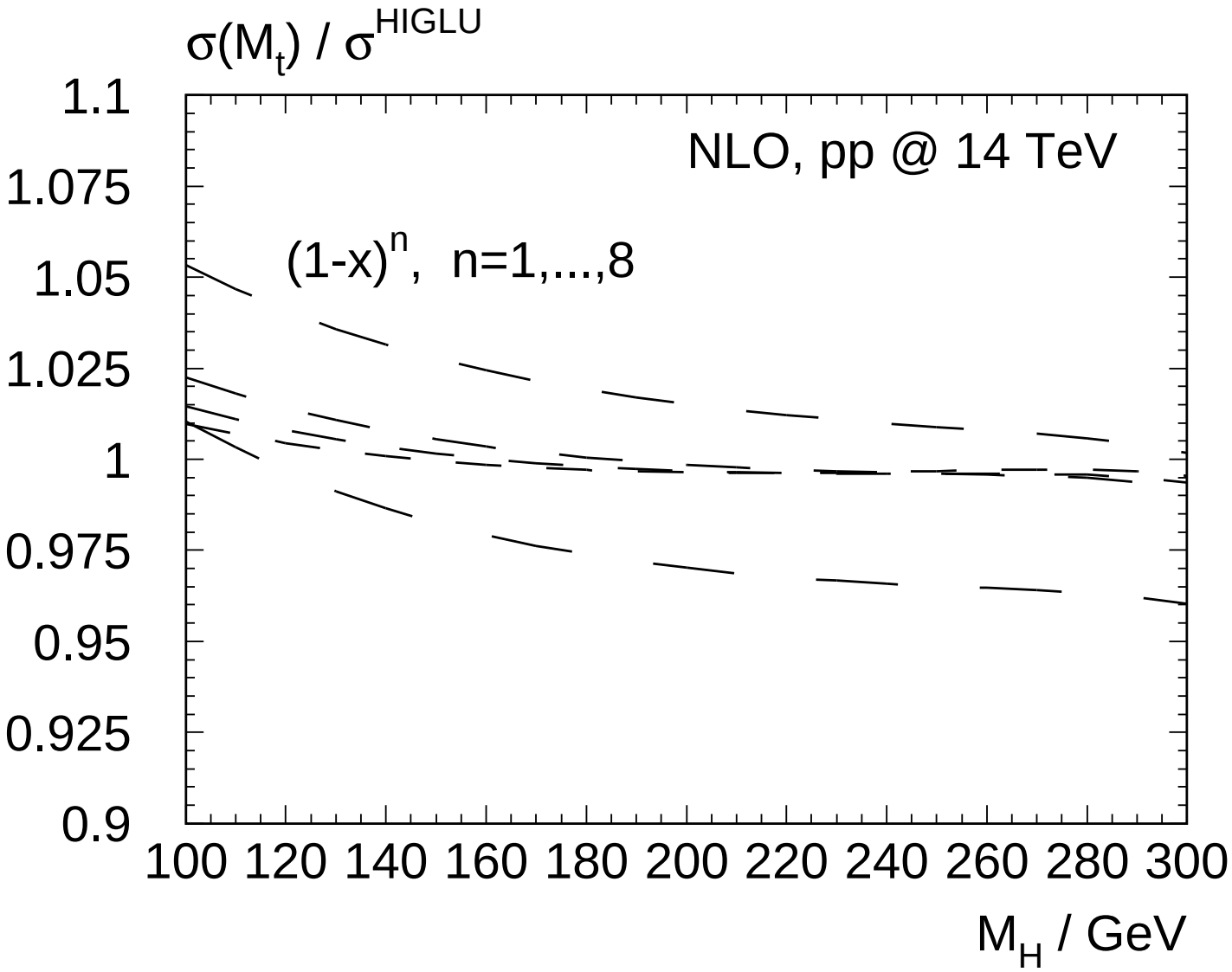

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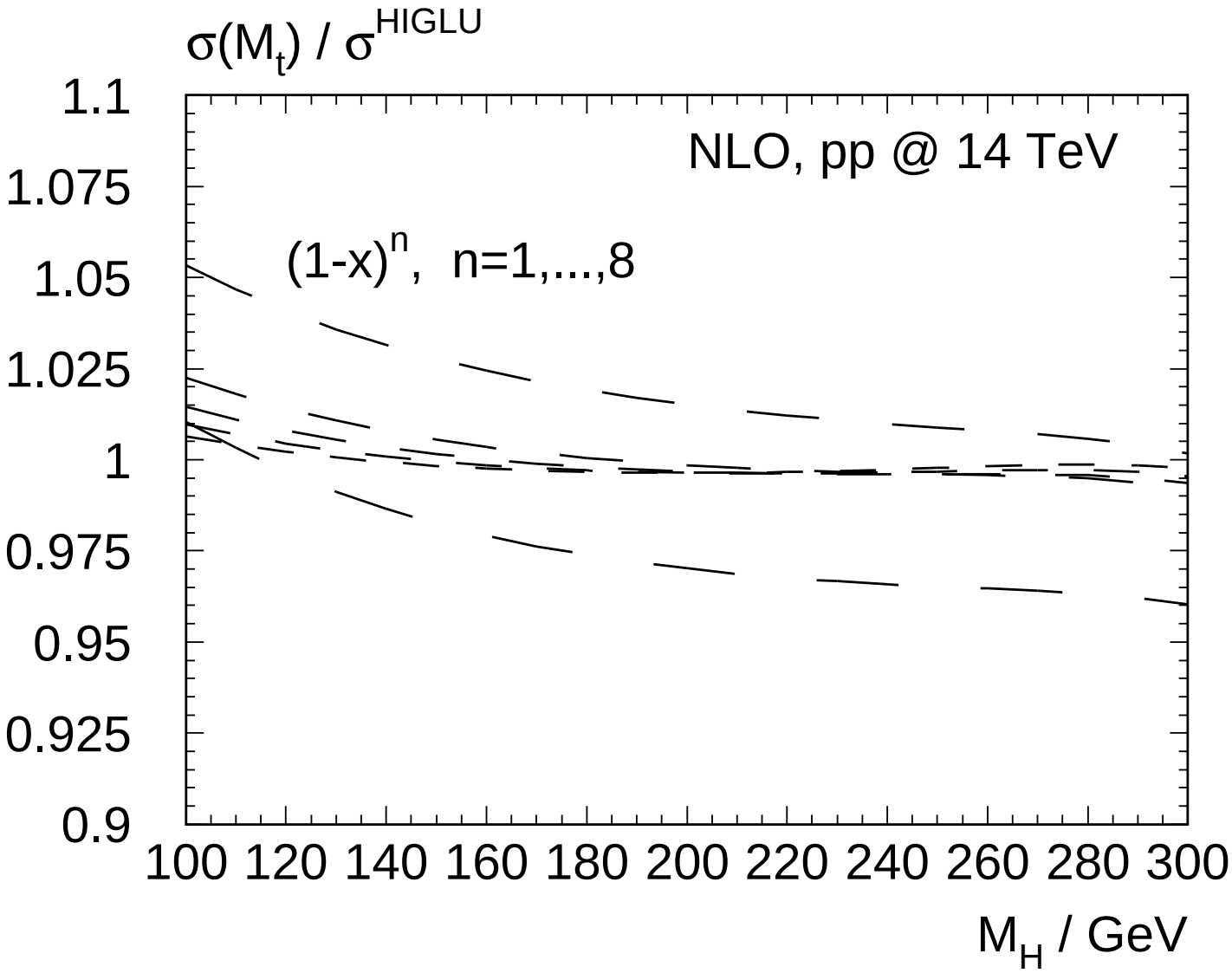

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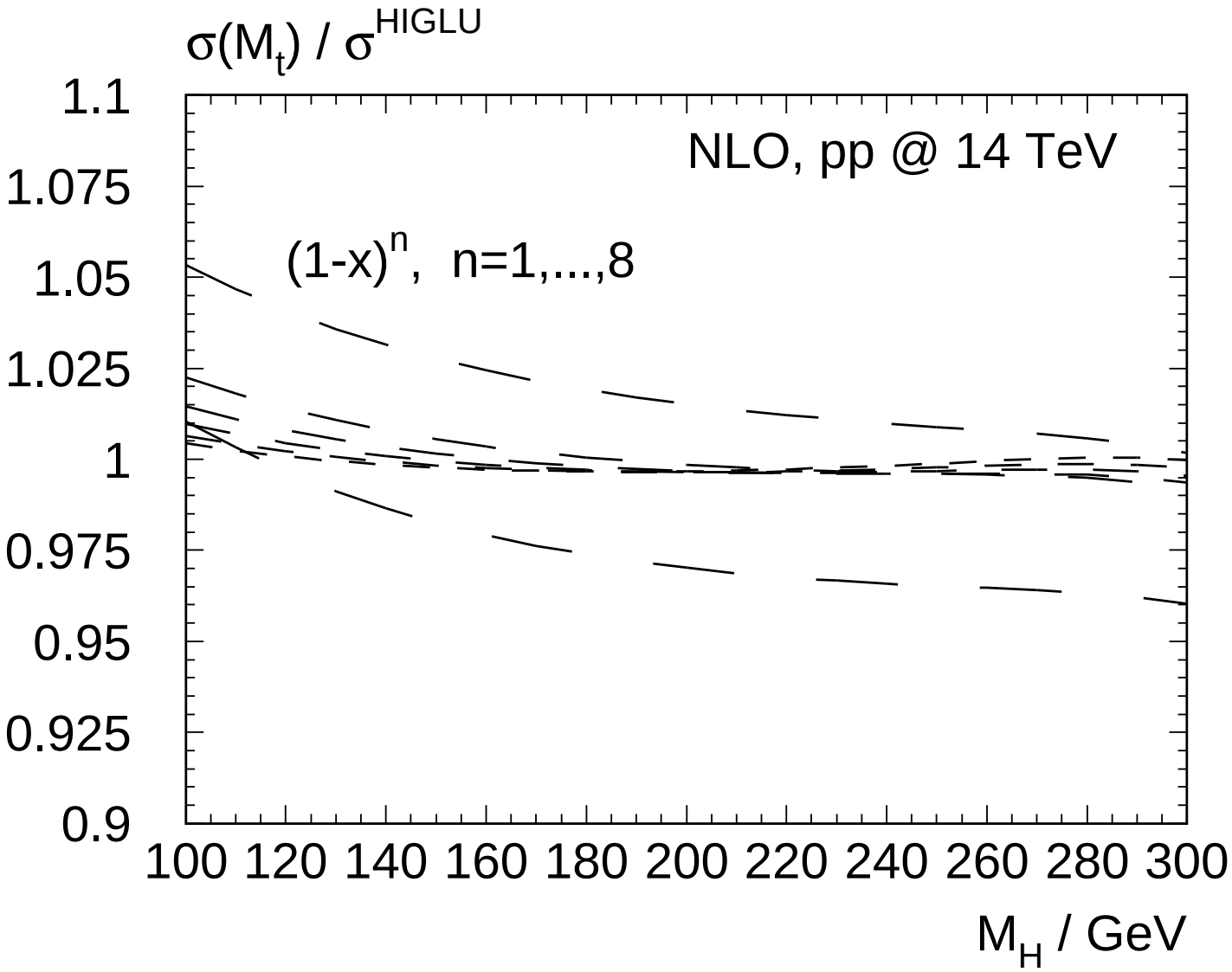

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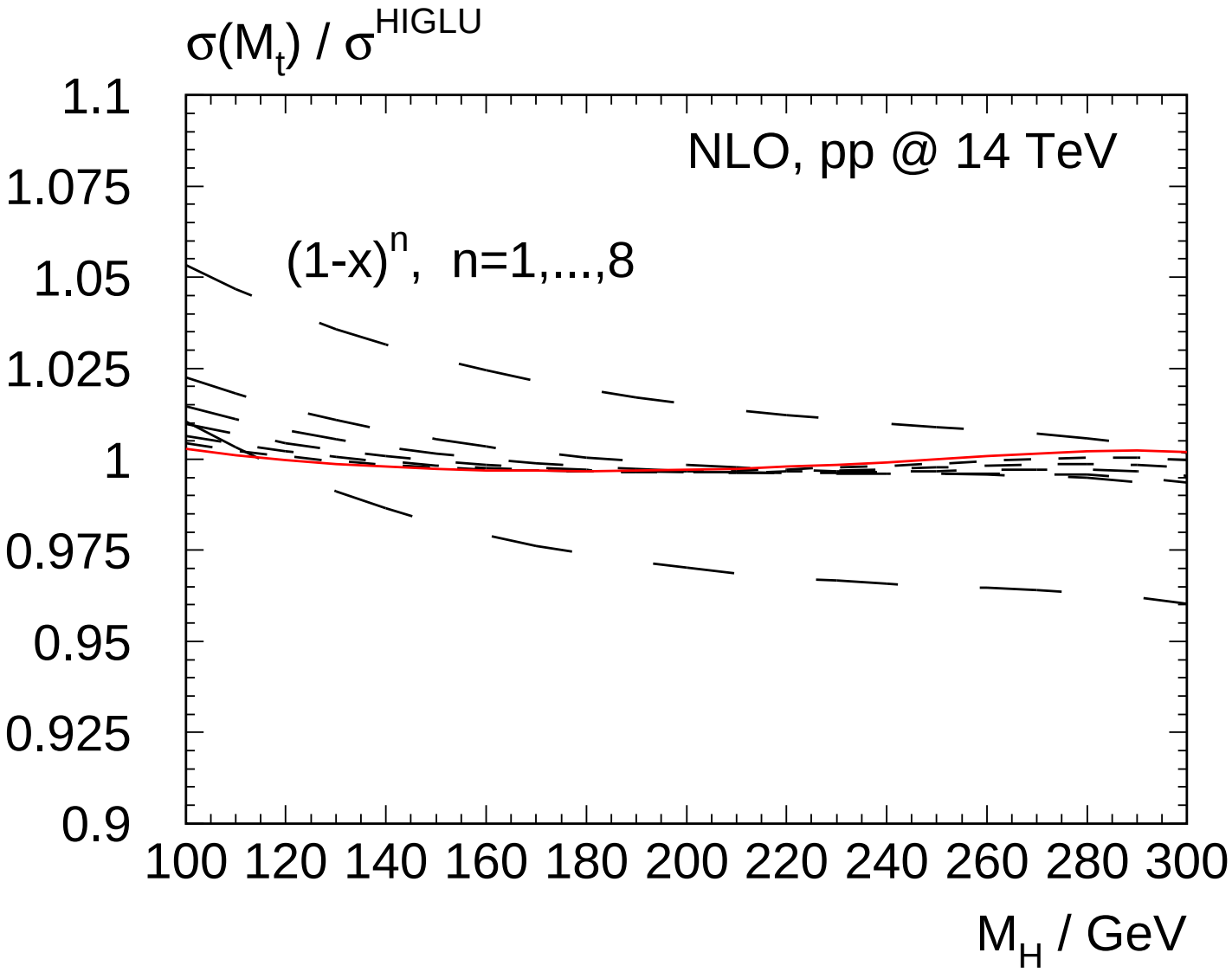

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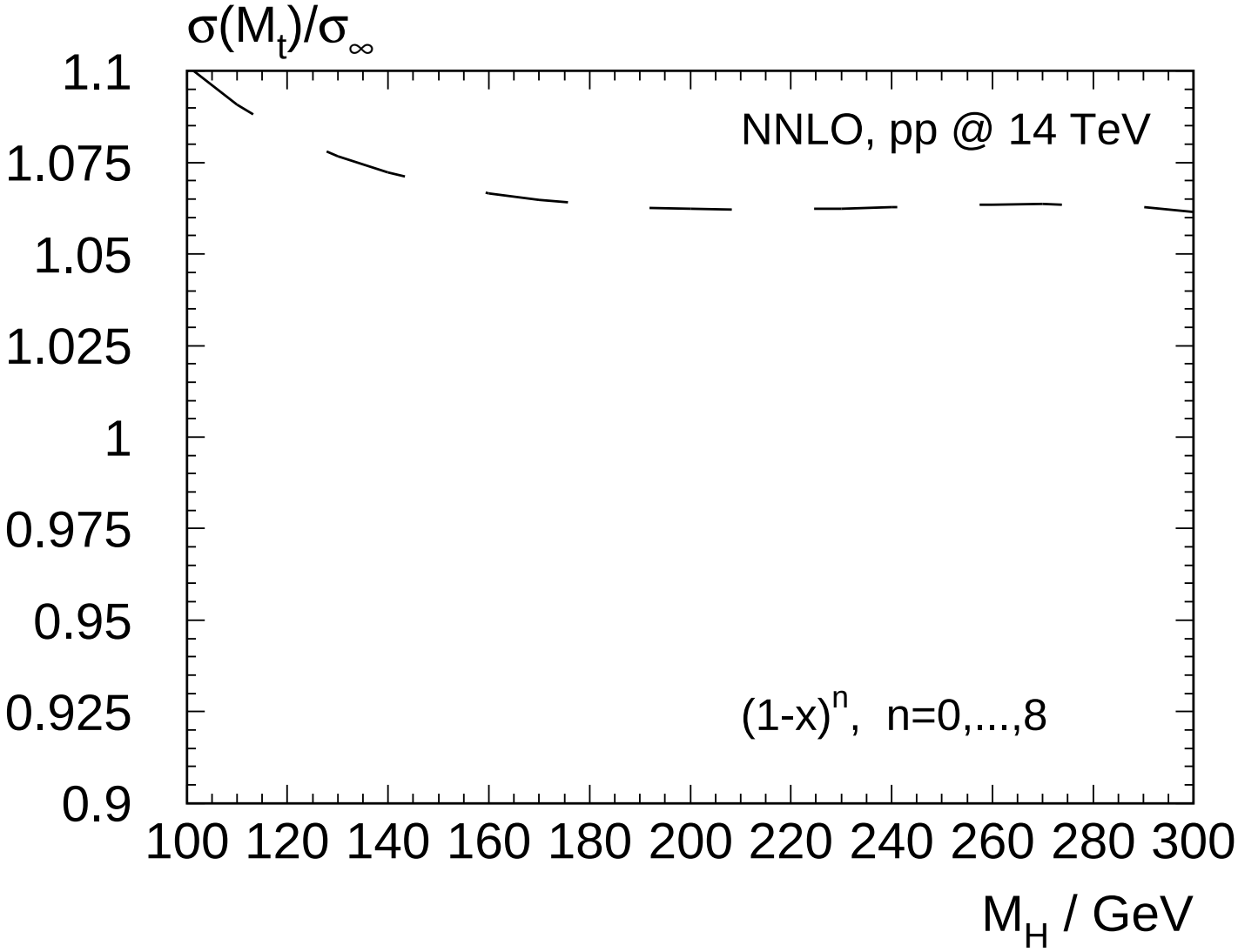

[RH, Ozeren '09]

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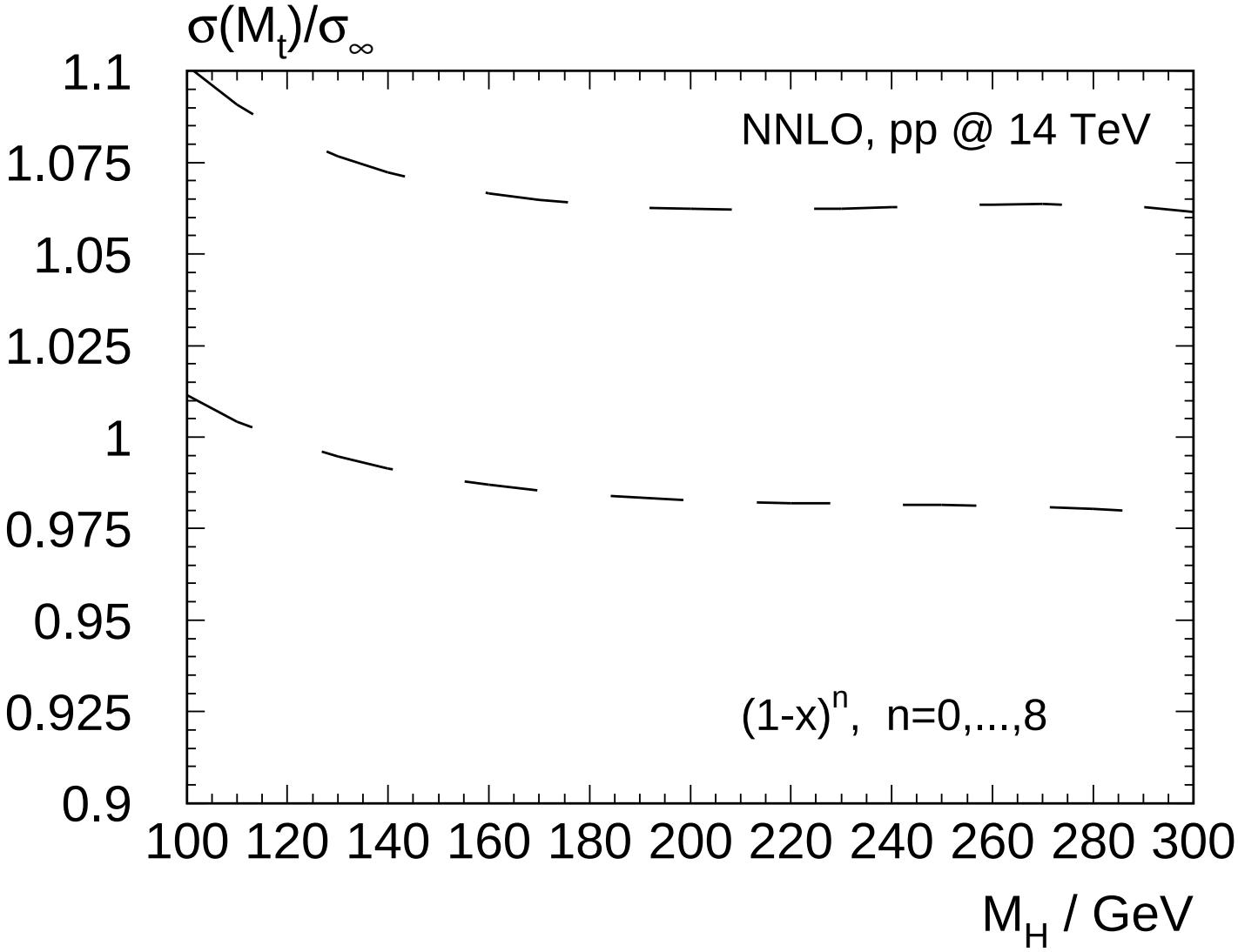

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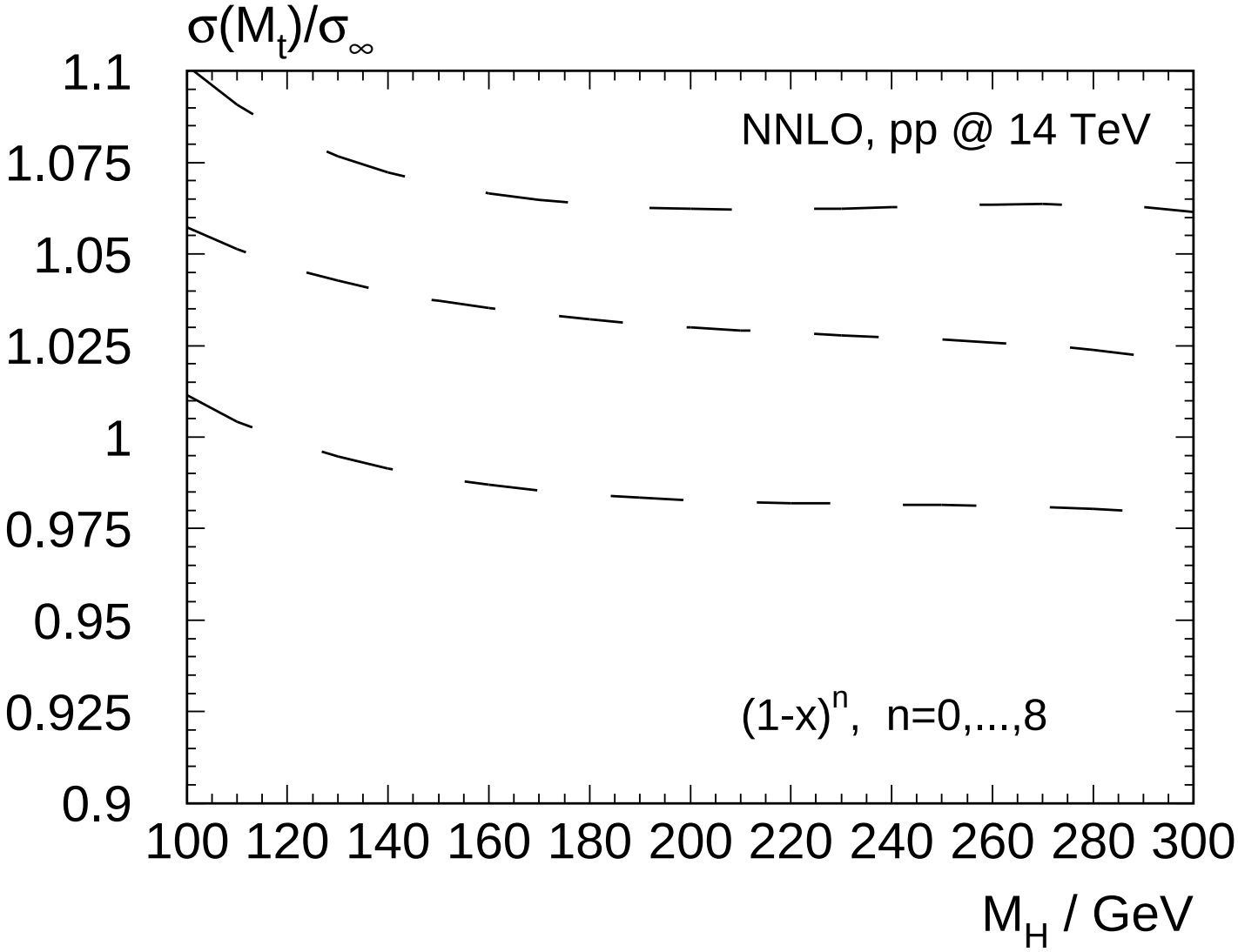

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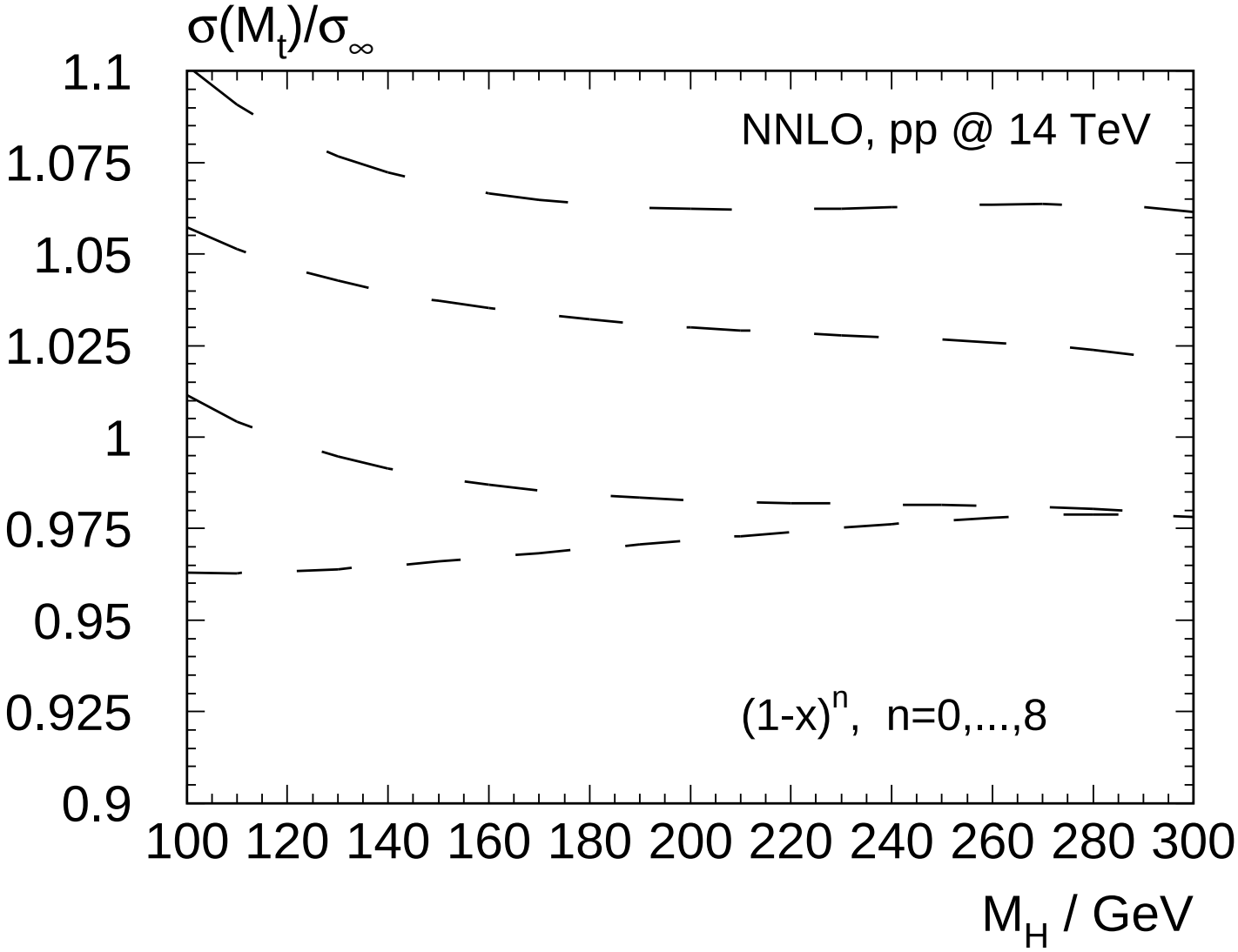

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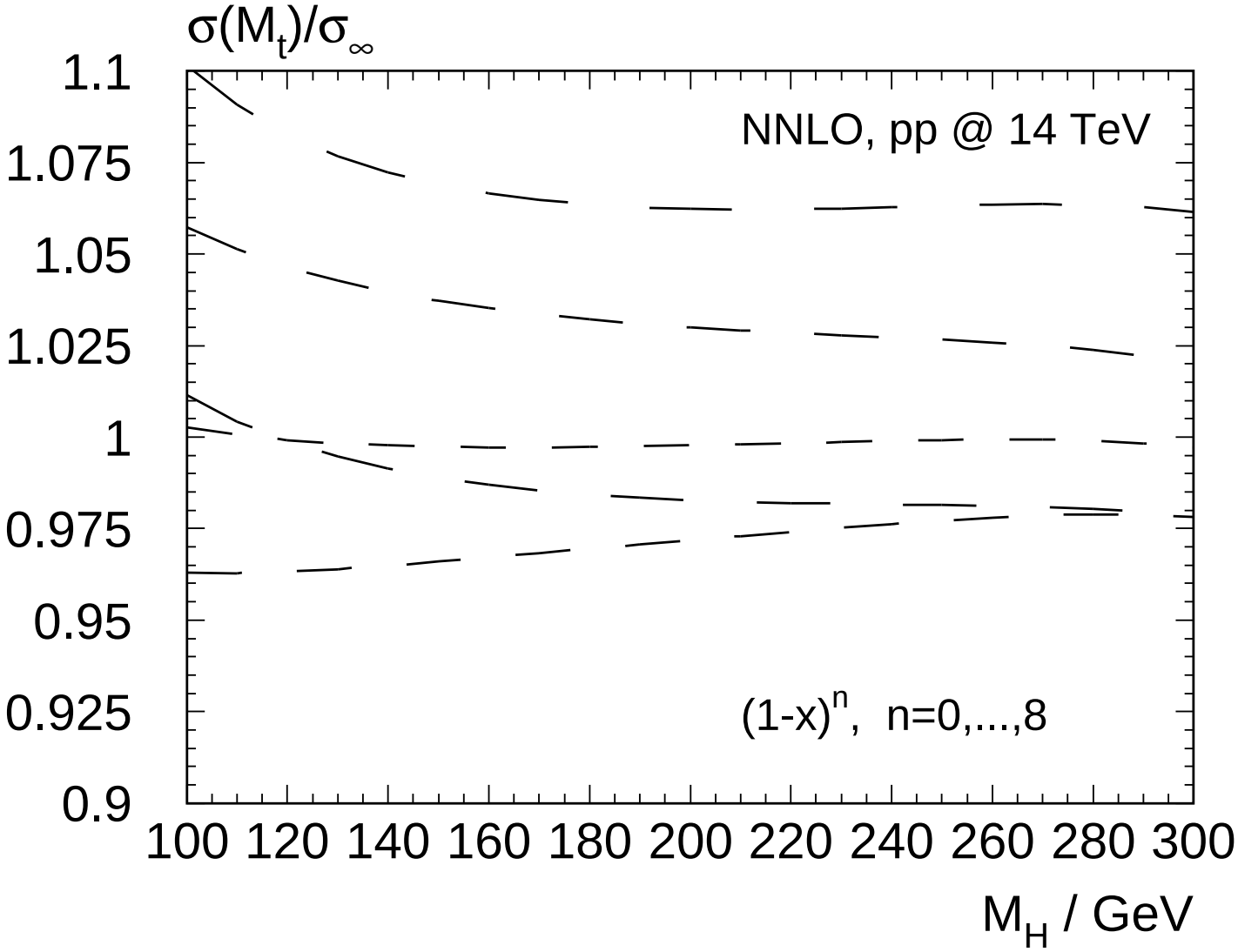

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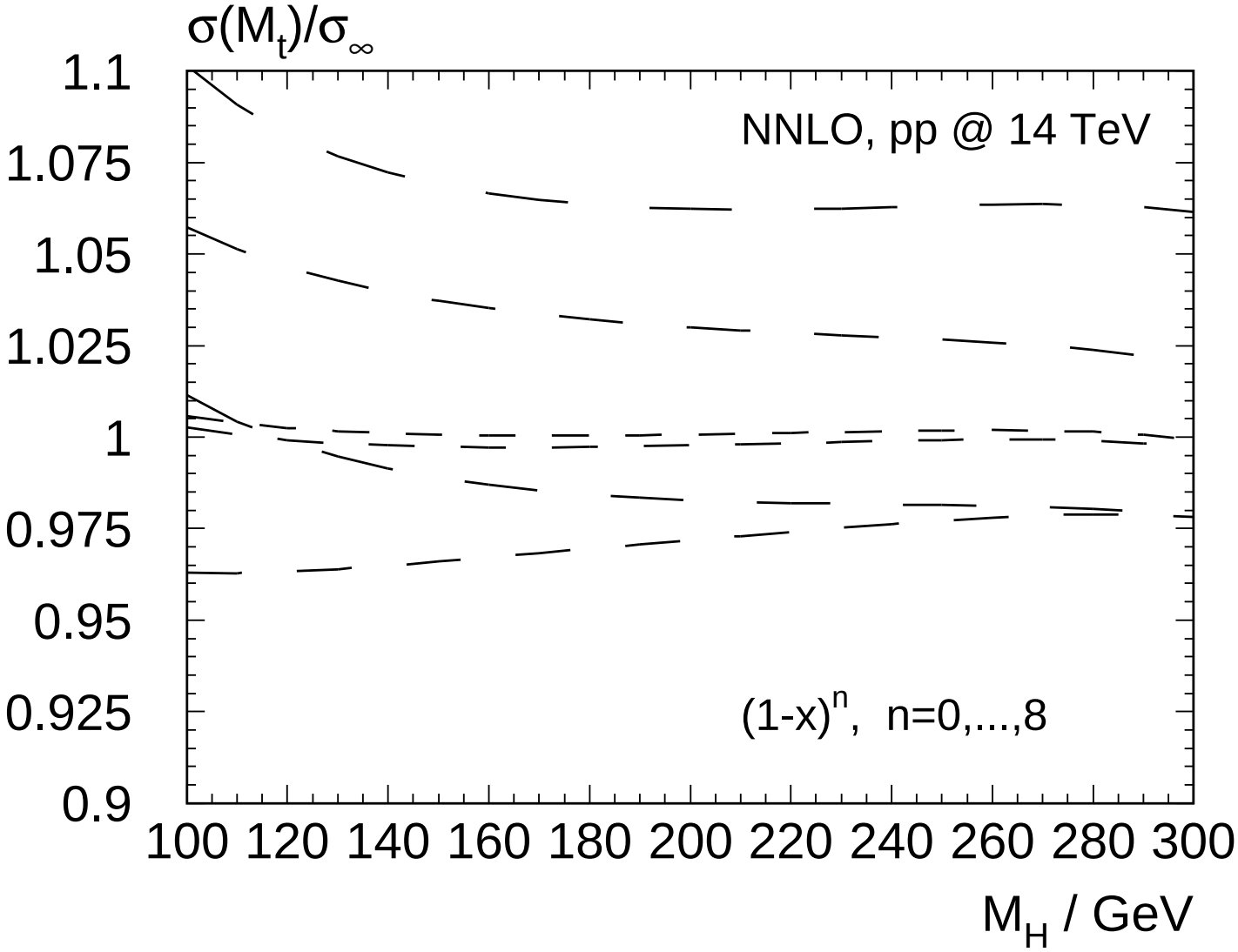

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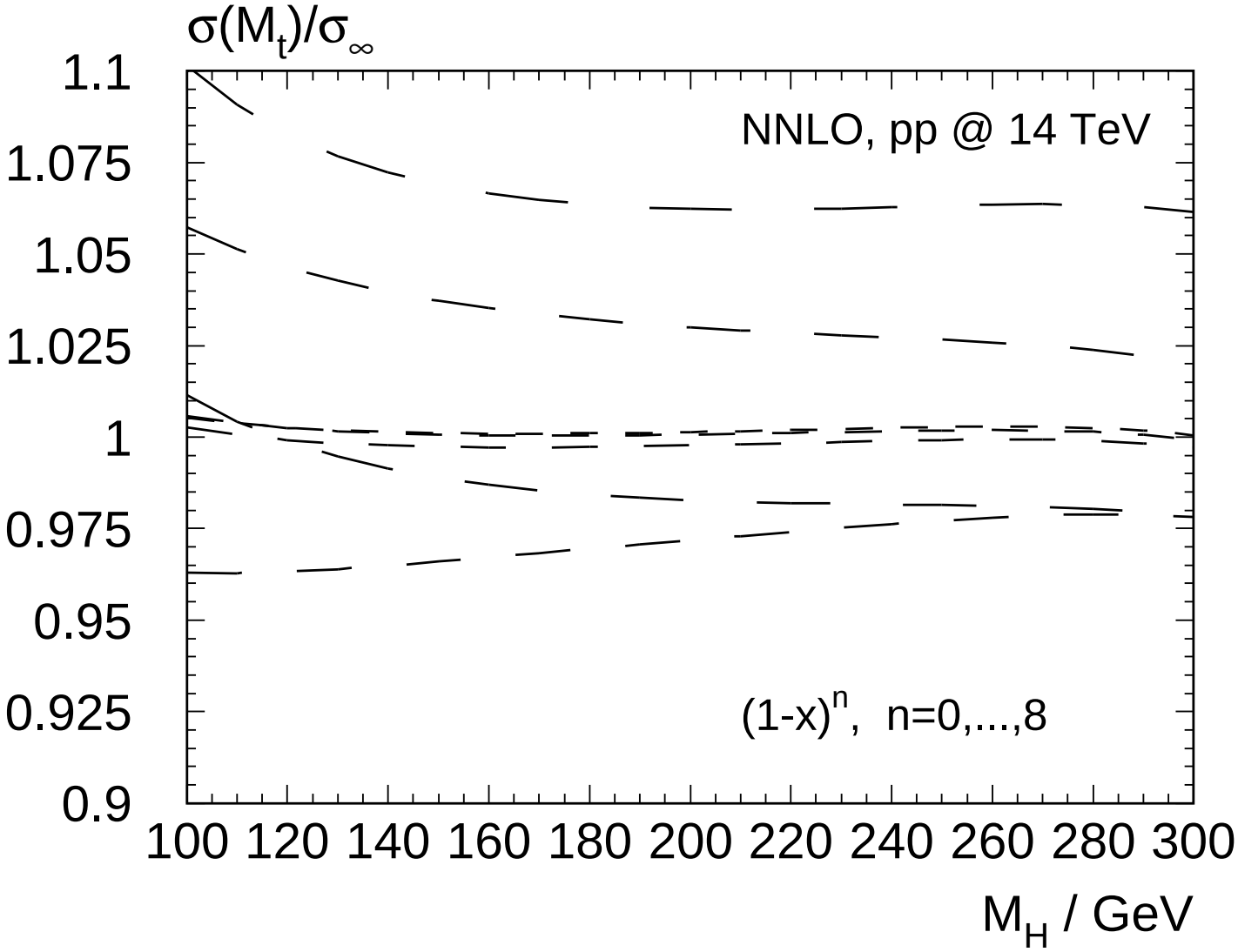

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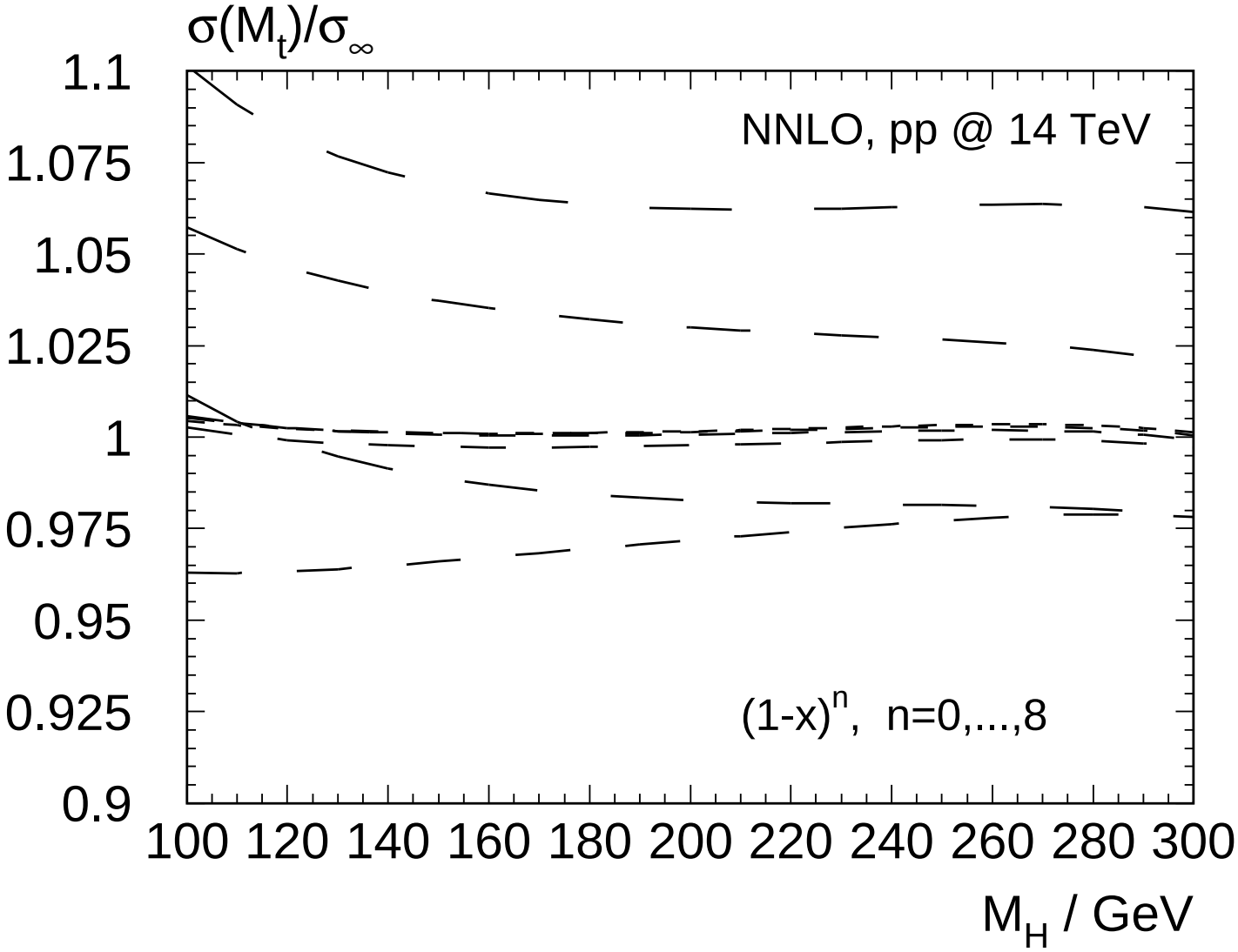

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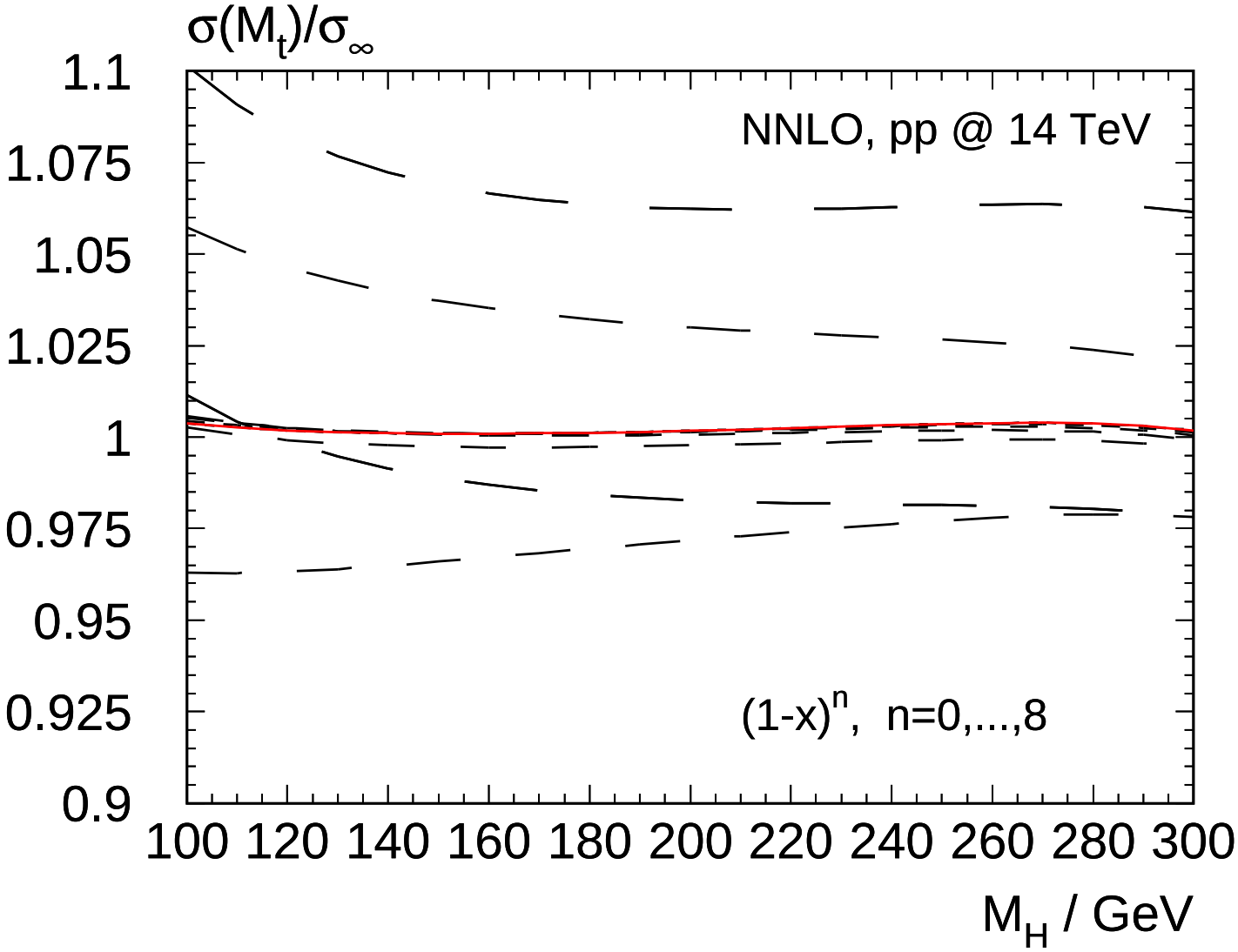

[RH, Ozeren '09]

Conclusions

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- validation of numerous higher order results in gluon fusion
- NNLO differential?
  - more kinematic variables
  - dependence on phase space cuts, etc.