Top quark mass effects in Higgs boson pair production at NLO

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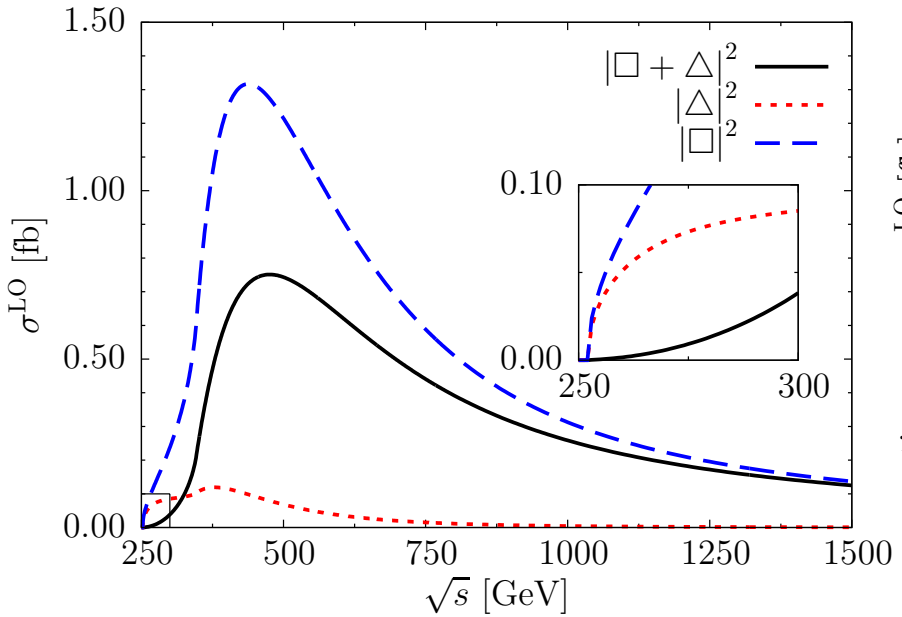
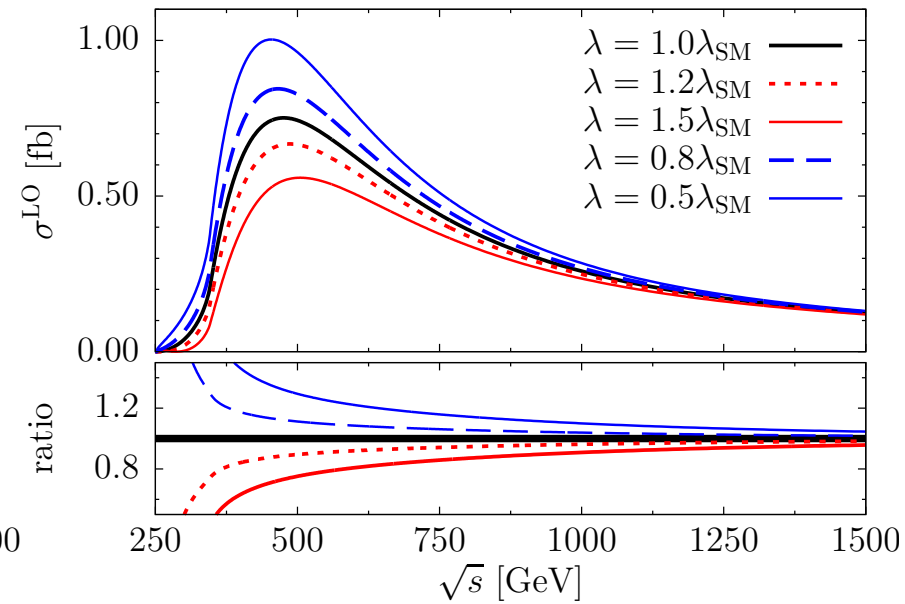
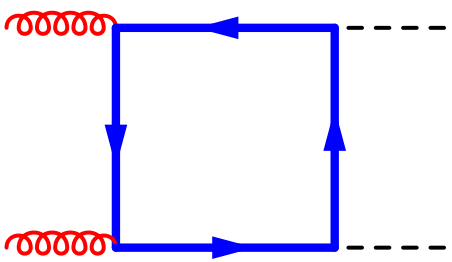
Outline

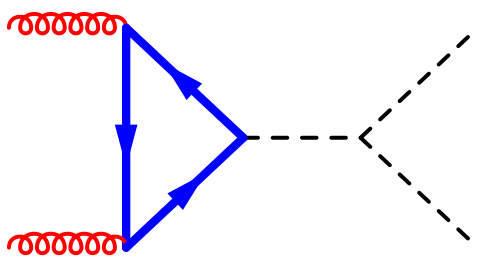
1. our approach: analytic computation of $\sigma(pp \to HH + X)$ up to powers of $(1/m_t^2)^6$ at NLO
2. status quo, results of [JG, Hoff, Melnikov, Steinhauser 2013]
3. recent work, work in progress (preliminary)

Partonic LO cross section $\sigma^{LO}(gg \to HH)$

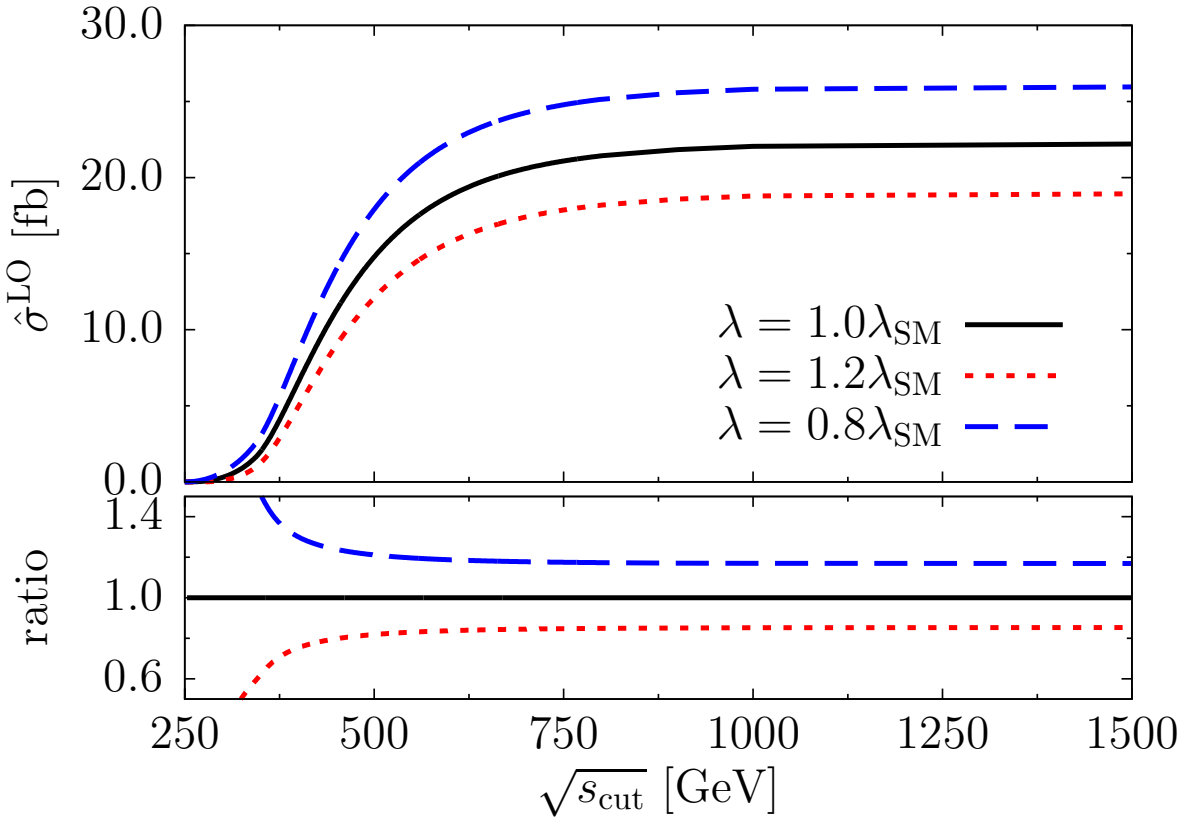








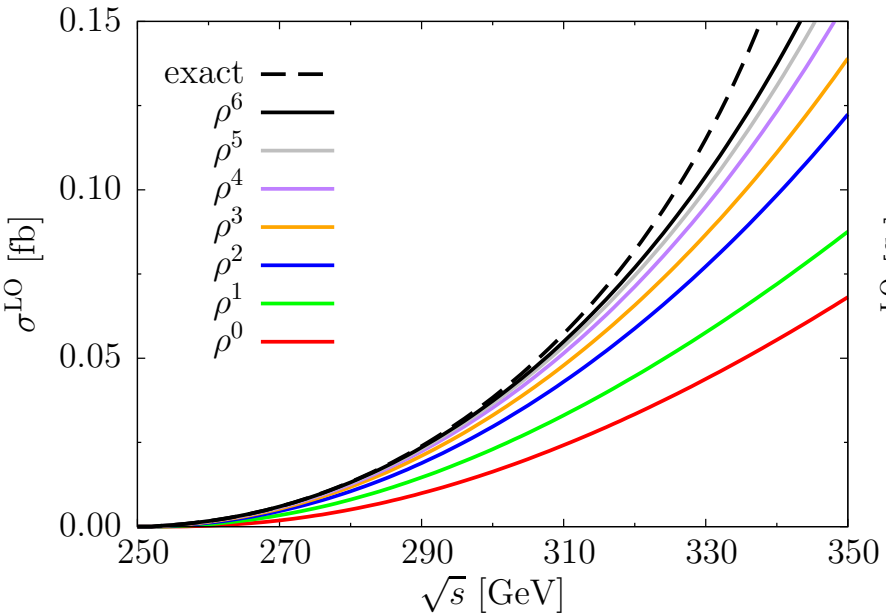
Hadronic LO cross section $\sigma^{LO}(gg \to HH)$

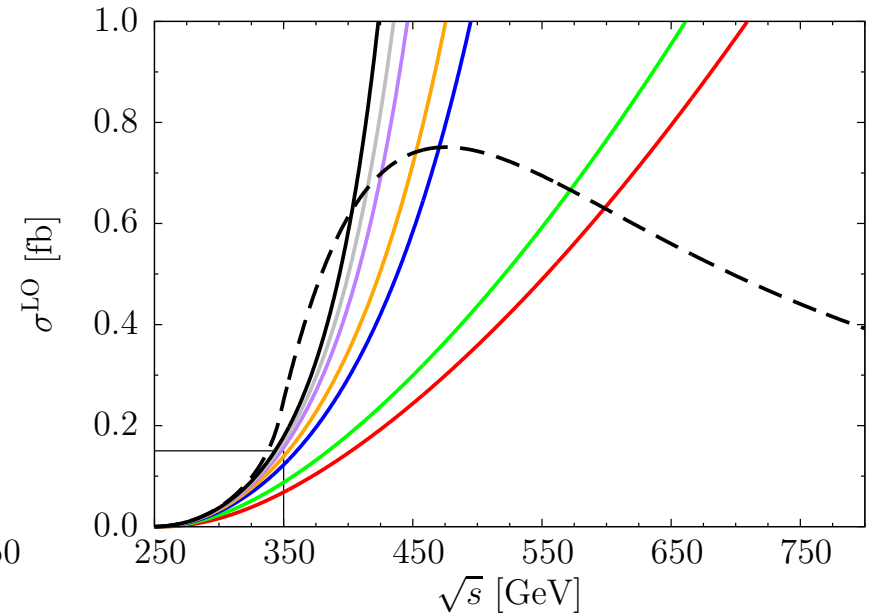


MSTW2008 pdfs $\mu = 2m_H$ at LO: $s = Q^2$

$$\sigma(s_{\rm cut}) = \int_{4m_H^2/s_{\rm had}}^{1} {\rm d}\tau \left(\frac{{\rm d}\mathcal{L}}{{\rm d}\tau}\right) \sigma_{\rm part}(\tau s_{\rm had})\theta(\tau s_{\rm had} - s_{\rm cut})$$

$1/m_t^2$ expansion at LO





scales

$$m_H = 126 \text{ GeV} \qquad \sqrt{s} \geq 2m_H = 252 \text{ GeV}$$

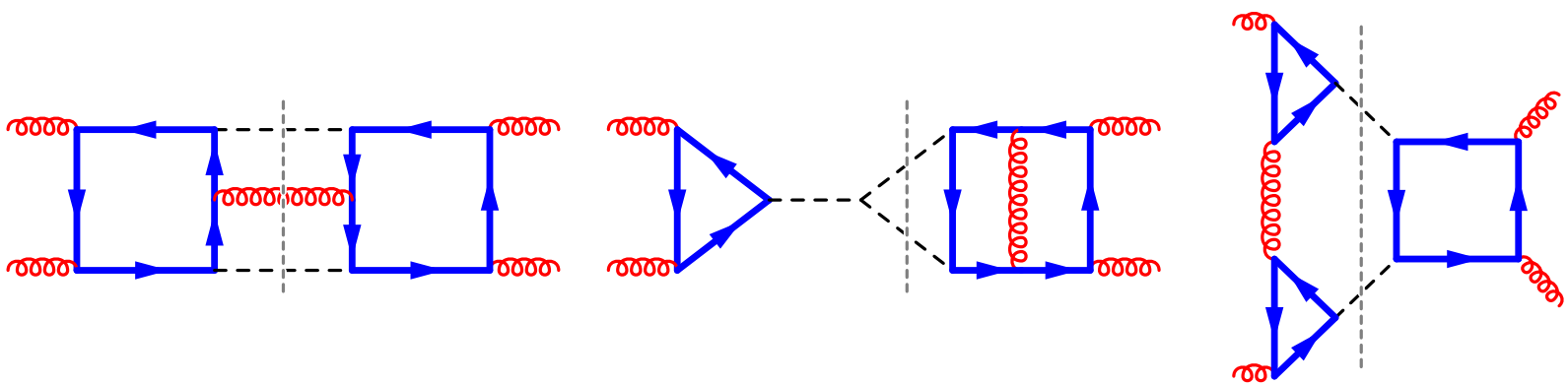
$$m_t = 173 \text{ GeV} \qquad 2m_t = 346 \text{ GeV}$$

$$\rho = \frac{m_H^2}{m_t^2} \approx 0.5$$

NLO computation (asymptotic expansion)

gluon-gluon channel

- virtual corrections
  - $\mathcal{M}(gg \to hh)$ ⇒ analytic results for $\mathrm{d}\sigma_{\mathrm{virt}}$
    126 two loop diagrams
  - cross check: $\mathcal{M}(gg \to gg)$
    1052 four loop diagrams
- real corrections
  - $\mathcal{M}(gg \to gg)$ ⇒ analytic results for σ_{real}
    1530 four loop diagrams

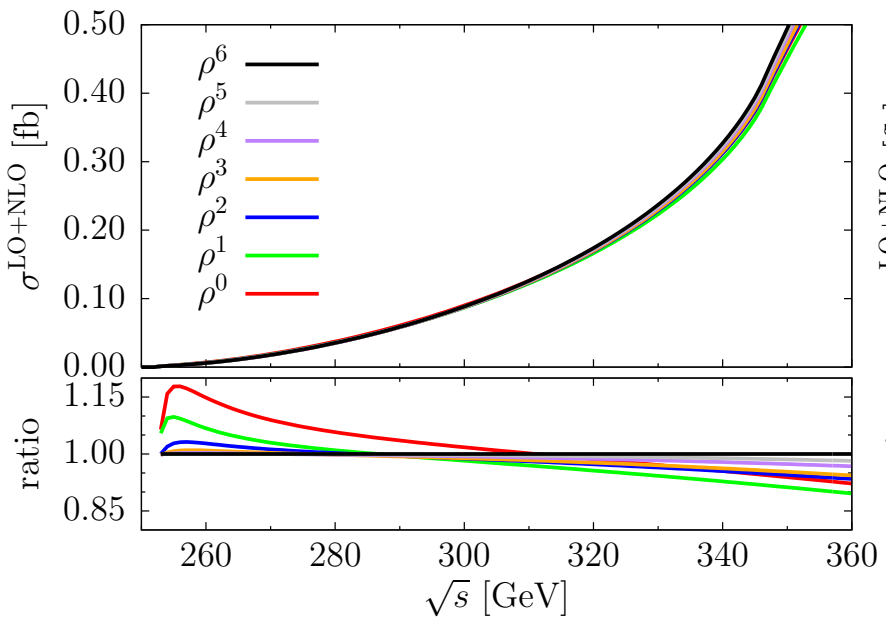


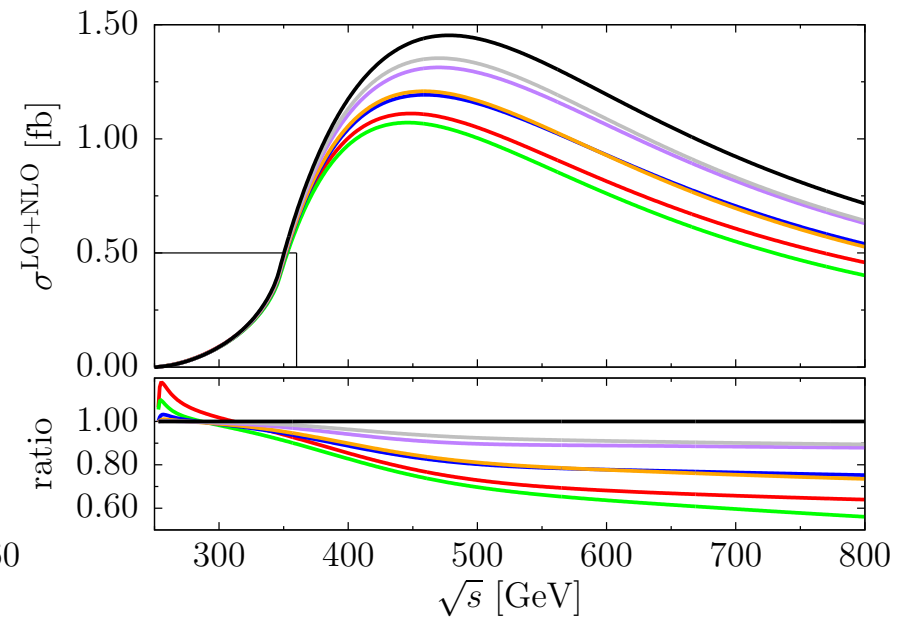
Partonic NLO cross section $\sigma^{LO}(gg \to HH)$

LO factorization for *total* partonic cross section

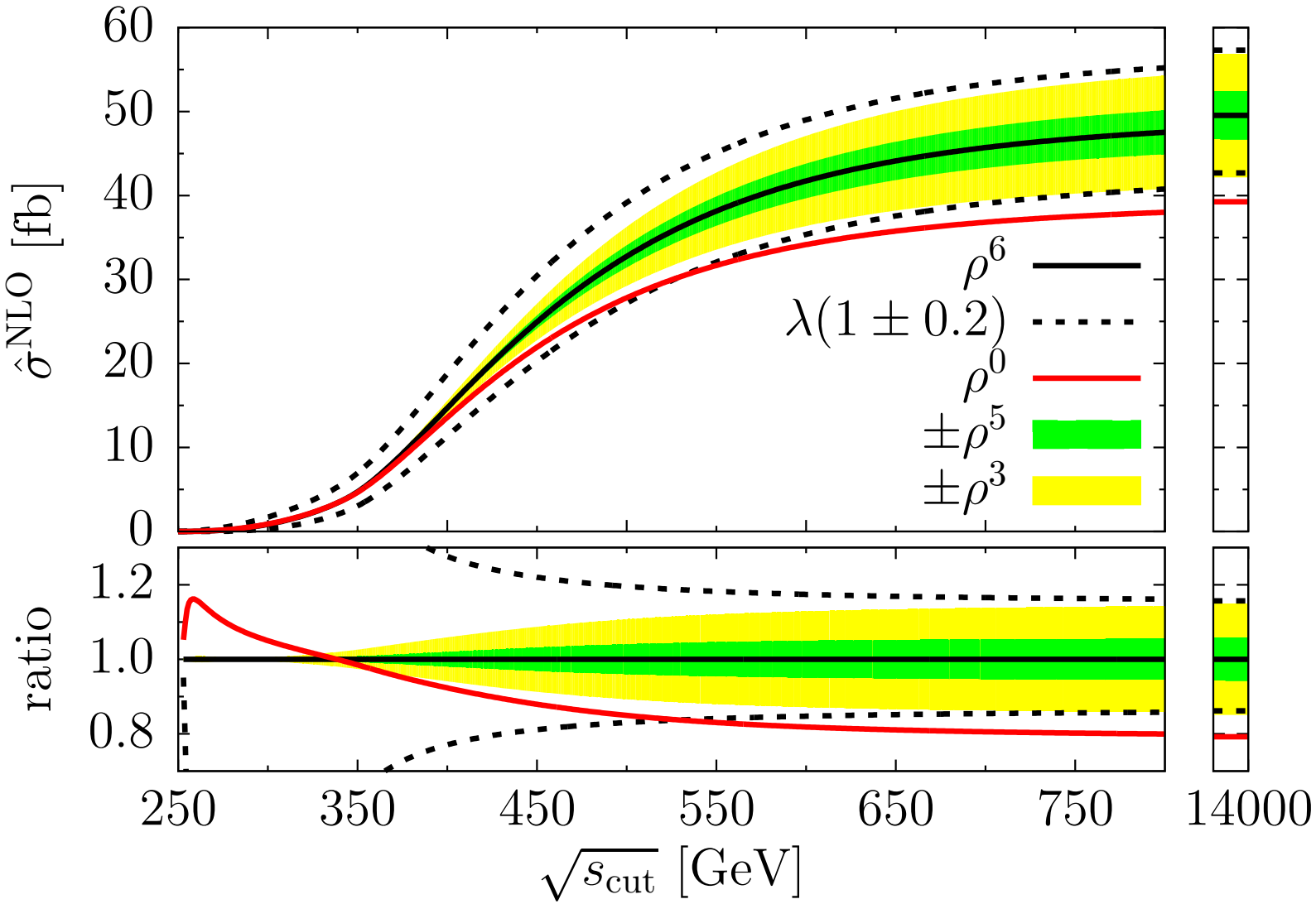
$$\sigma^{\text{NLO}}_{\text{exp}} \to \sigma^{\text{NLO}} := \sigma^{\text{LO}}_{\text{exact}} \frac{\sigma^{\text{NLO}}_{\text{exp}}}{\sigma^{\text{LO}}_{\text{exp}}}$$

$$\sigma = \int_{4m_H^2}^{s} \mathrm{d}Q^2 \; \tilde{\sigma} \qquad\qquad \tilde{\sigma} := \left(\frac{\mathrm{d}\sigma}{\mathrm{d}Q^2} \right)$$





Hadronic NLO cross section $\sigma^{LO}(gg \to HH)$



Factorization of LO cross section

LO factorization for *total* partonic cross section

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$$\sigma = \int_{4m_H^2}^{s} \mathrm{d}Q^2 \; \tilde{\sigma} \qquad\qquad \tilde{\sigma} := \left(\frac{\mathrm{d}\sigma}{\mathrm{d}Q^2} \right)$$

Differential LO factorization (dF)

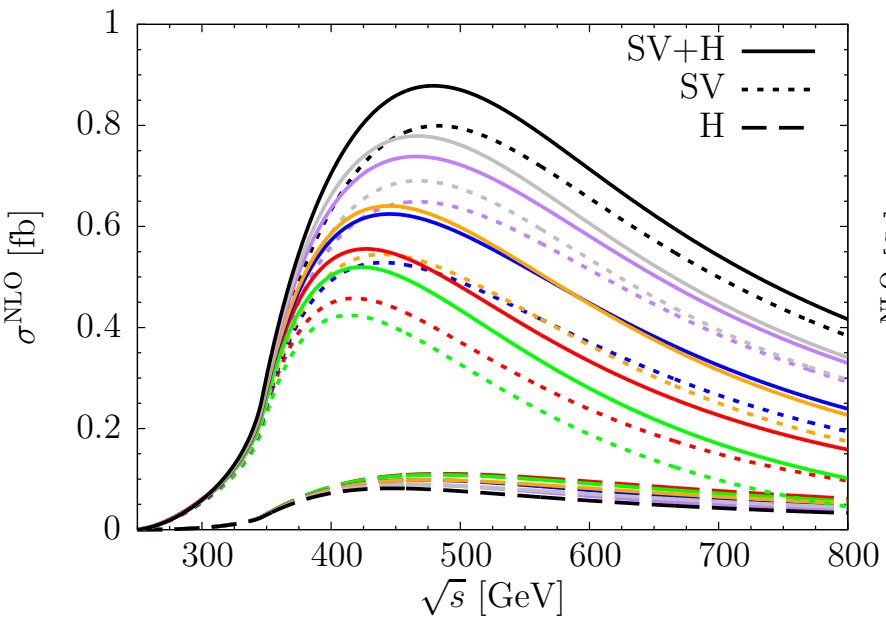
$$\tilde{\sigma}^{\text{NLO}}_{\text{exp}} \to \tilde{\sigma}^{\text{NLO}} := \tilde{\sigma}^{\text{LO}}_{\text{exact}} \frac{\tilde{\sigma}^{\text{NLO}}_{\text{exp}}}{\tilde{\sigma}^{\text{LO}}_{\text{exp}}}$$

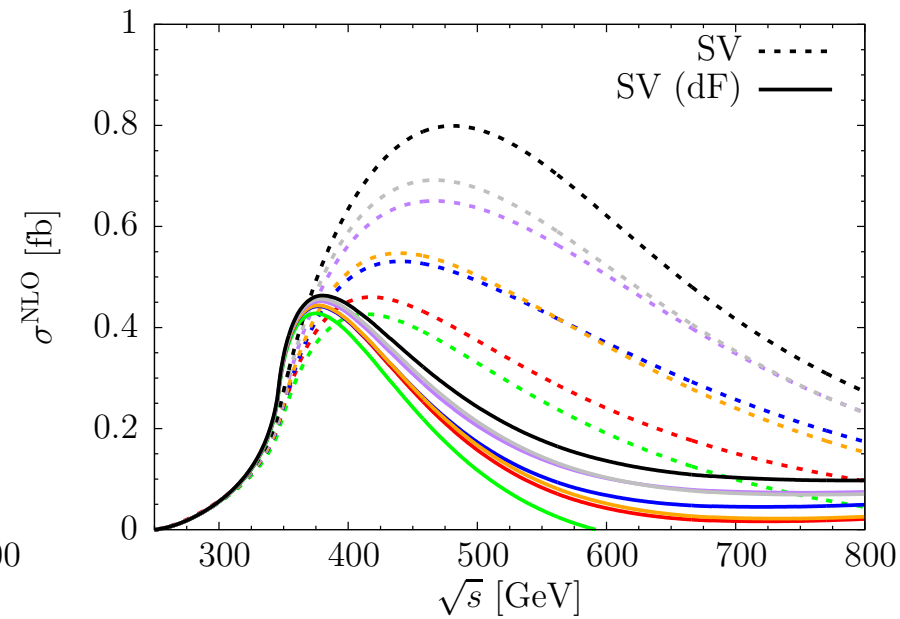
Differential LO factorization (dF)

$$\sigma^{\mathrm{NLO}} = \left(\int \mathrm{d}Q^2 \quad \tilde{\sigma}_V \right) + \sigma_S + \sigma_H$$

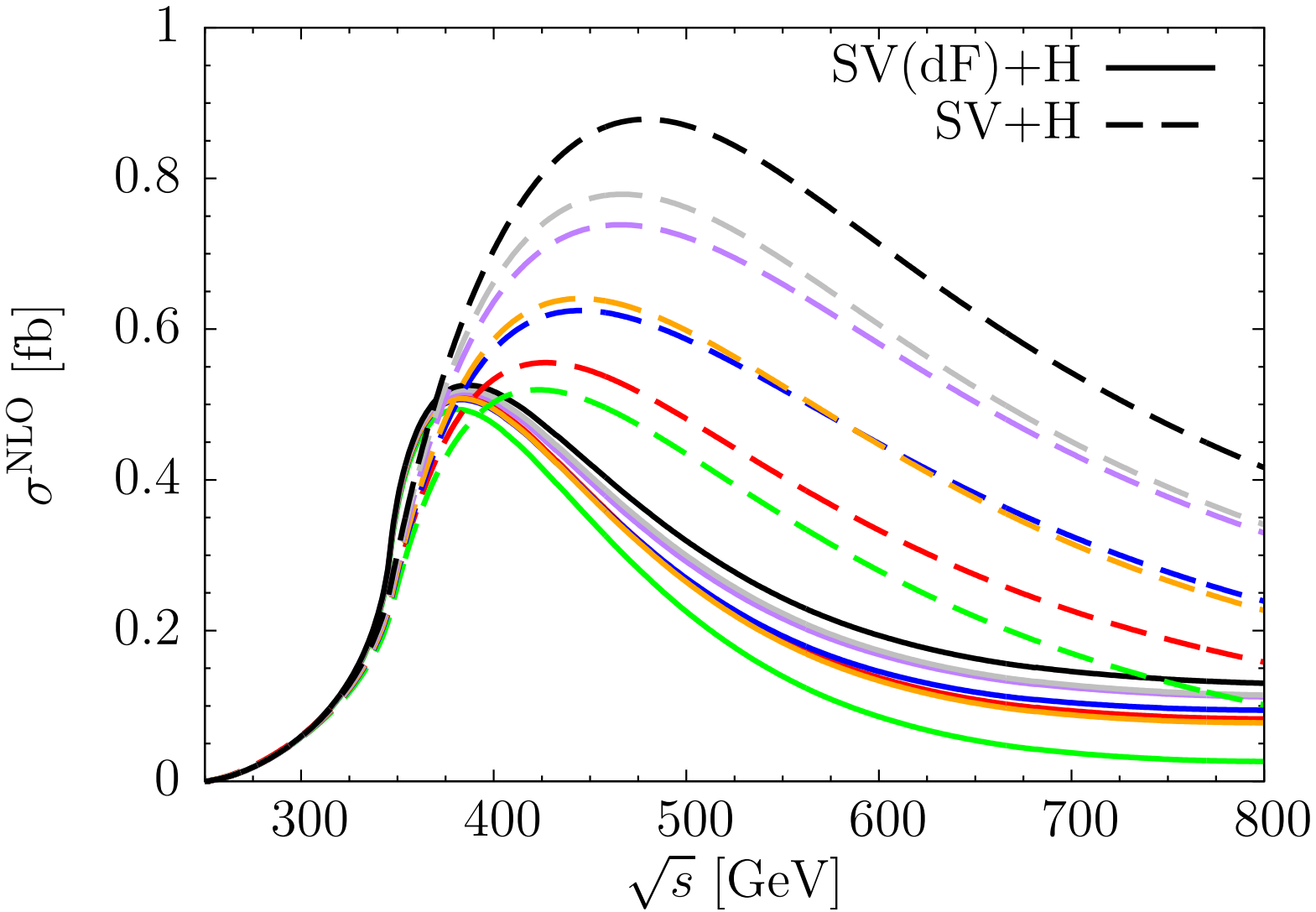
$$\rightarrow \sigma^{\mathrm{NLO}} = \left(\int \mathrm{d}Q^2 \quad \tilde{\sigma}_V + \tilde{\sigma}_S \right) + \sigma_H$$

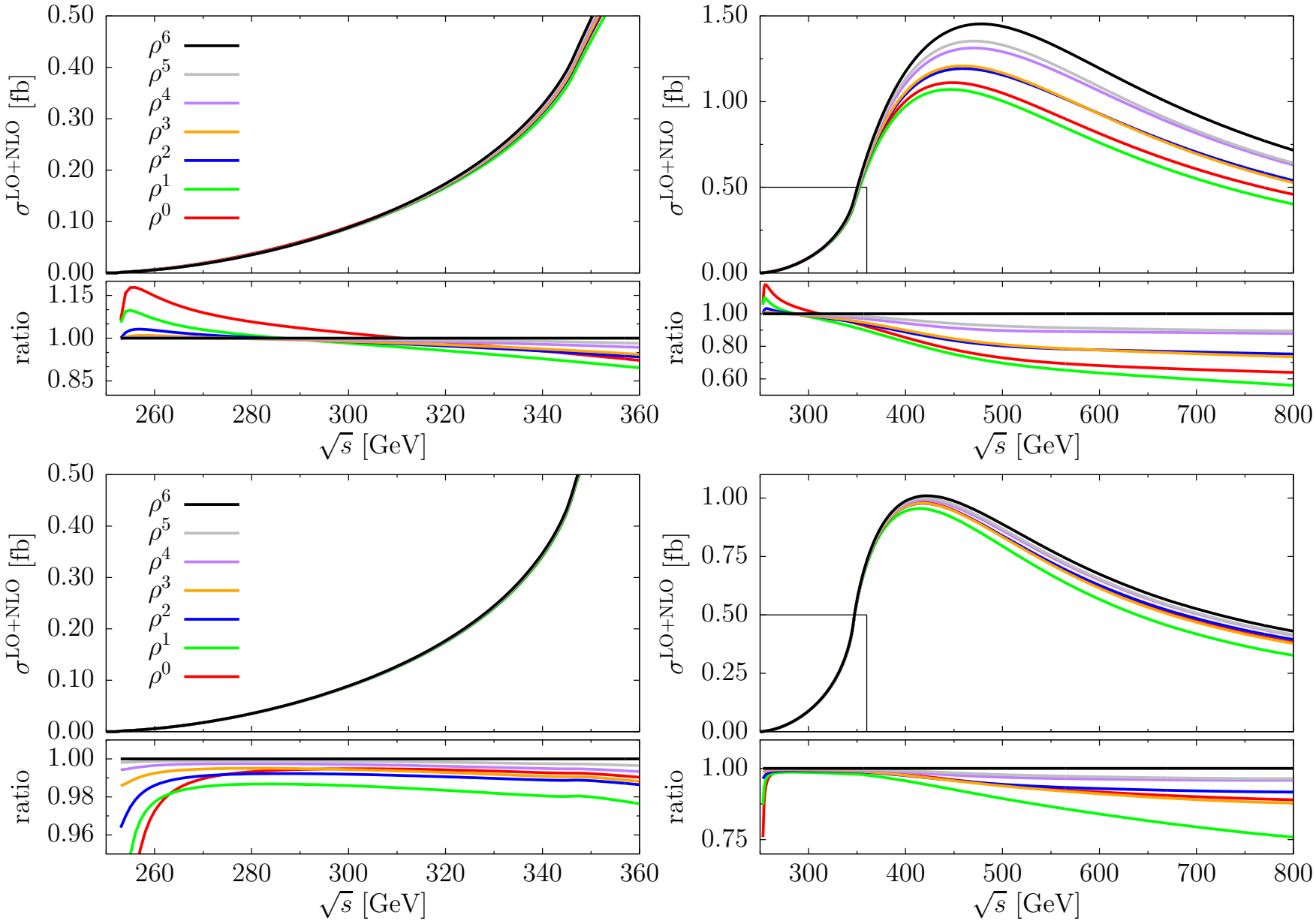
$\tilde{\sigma}_S^{\mathrm{NLO}}, \tilde{\sigma}_{V\mathrm{poles}}^{\mathrm{NLO}} \propto \sigma^{\mathrm{LO}} \Rightarrow \tilde{\sigma}_{\mathrm{SV}}^{\mathrm{NLO}} \propto \sigma^{\mathrm{LO}}$ [de Florian, Mazzitelli 2012]



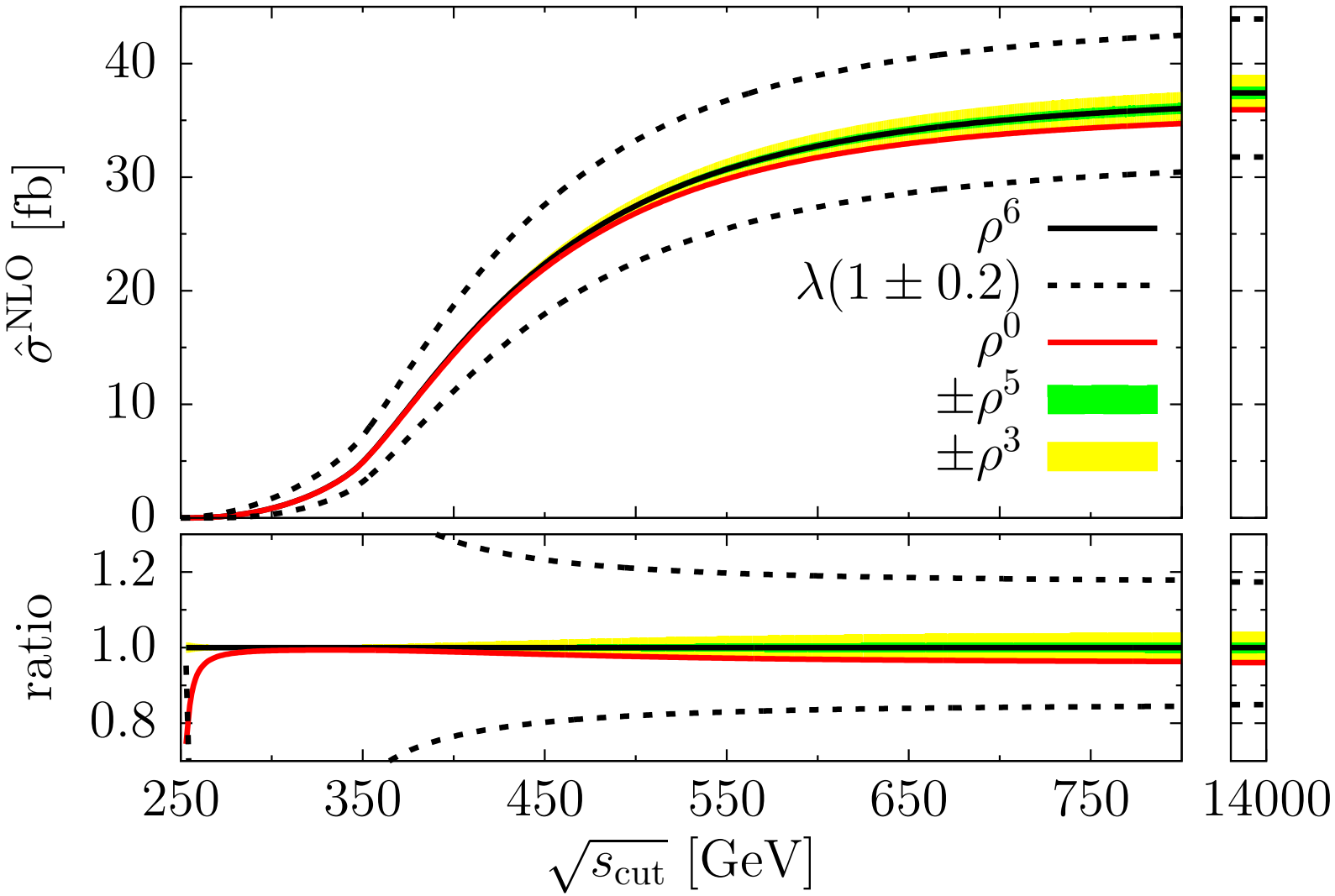


NLO improved




$\sigma^{\mathrm{LO+NLO}}$ [fb]
ratio
$\sqrt{s}$ [GeV]
ρ^6
ρ^5
ρ^4
ρ^3
ρ^2
ρ^1
ρ^0

Hadronic NLO improved cross section $\sigma^{LO}(gg \to HH)$

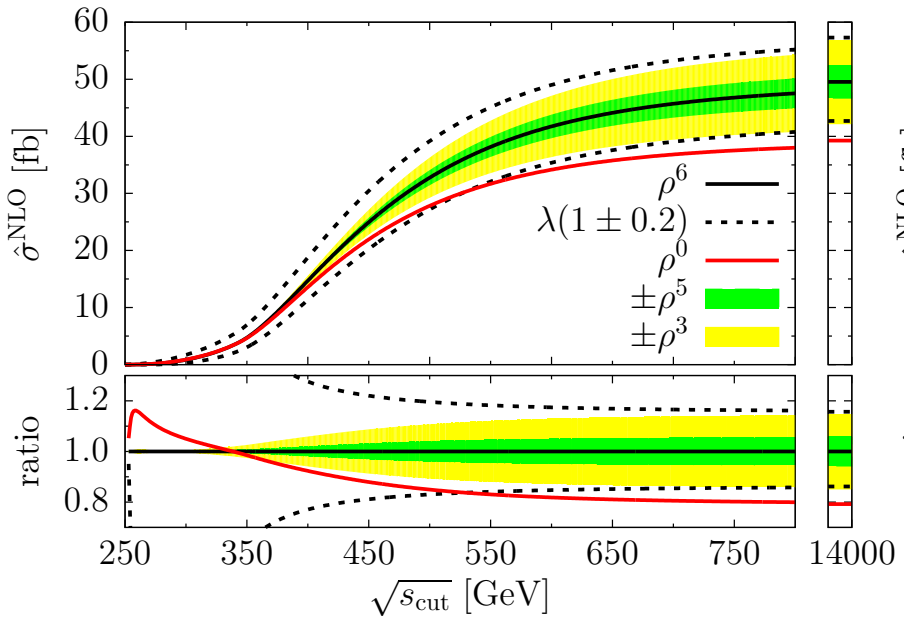


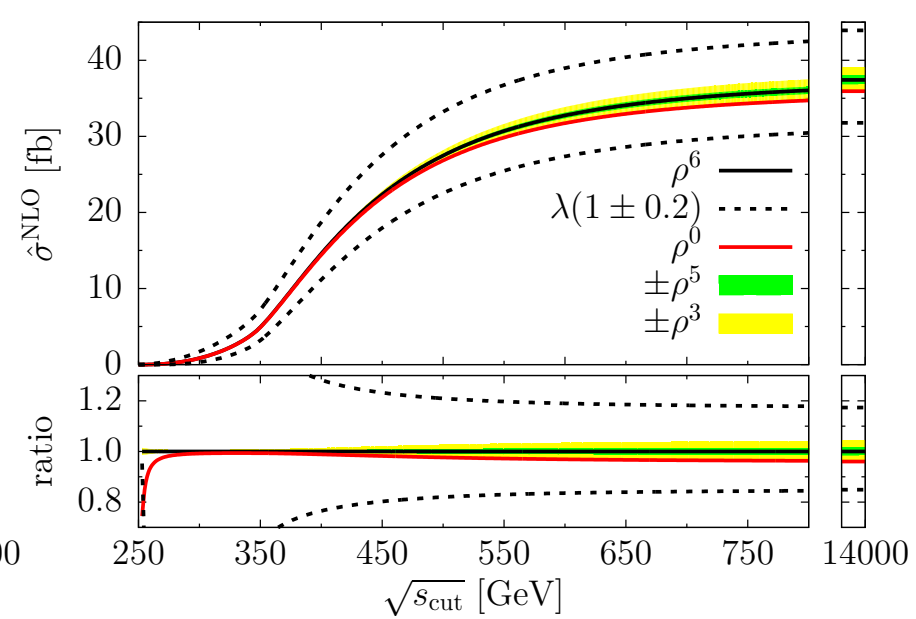
Conclusions and Outlook

- m_t effects at NLO are
  - (previous work) of $\mathcal{O}(10\%)$ for σ_{tot}
    [JG, Hoff, Melnikov, Steinhauser 2013]
  - (recent work, preliminary) of at most $\pm 15\%$ for σ_{tot}
  - smaller for low $s(Q^2)$
- analytic expansion of *exact* NLO cross section below top threshold
  $\Rightarrow$ benchmark for upcoming *exact* computations
- $\Rightarrow$ $m_t \to \infty$ is
  - reasonable starting point at NLO
  - probably sufficient at NNLO
- NNLO ($m_t \to \infty$) already available, another $+20\%$!
  [de Florian, Mazzitelli 2013] [JG, Melnikov, Steinhauser 2014]

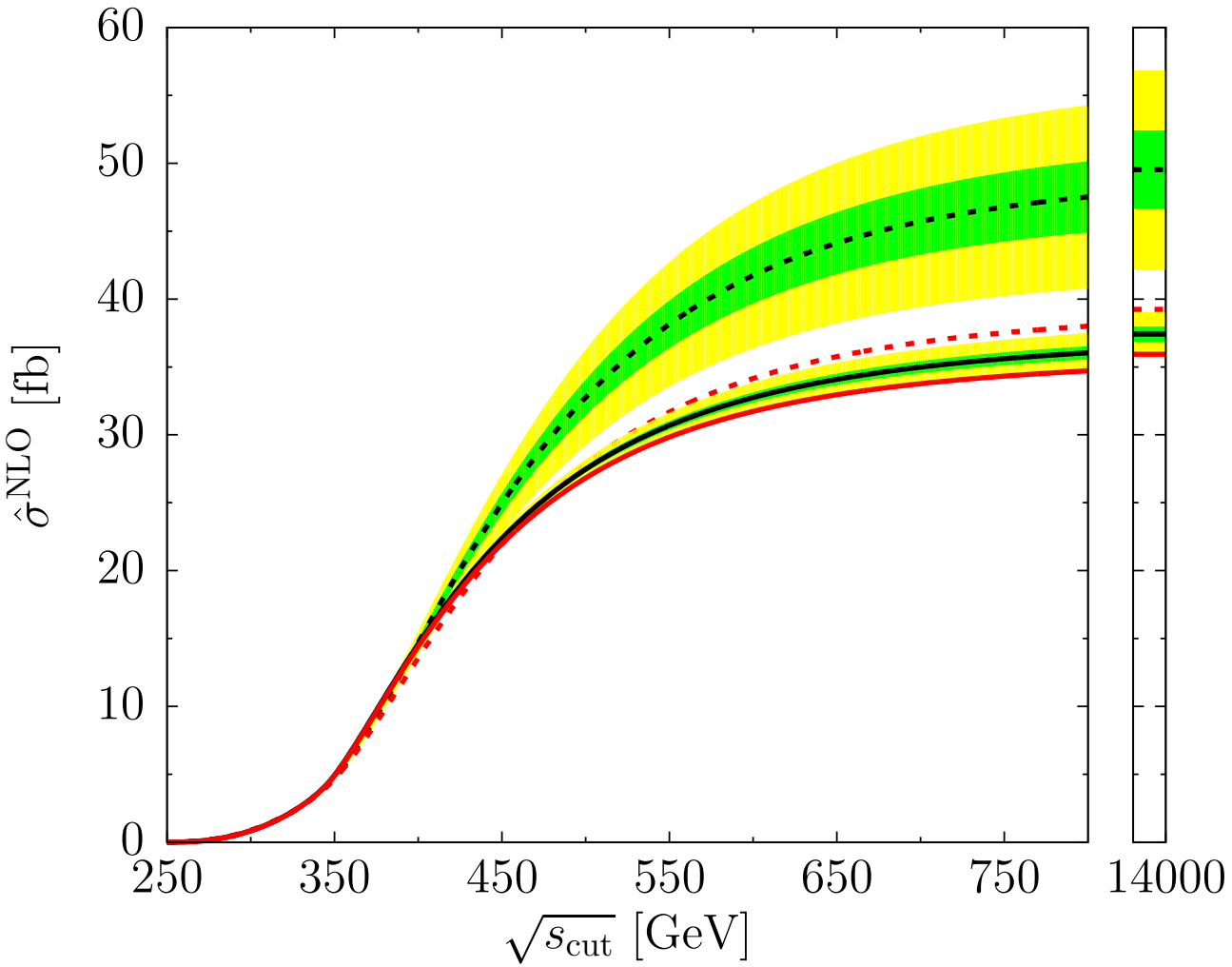
backup

Hadronic NLO improved cross section $\sigma^{LO}(gg \to HH)$

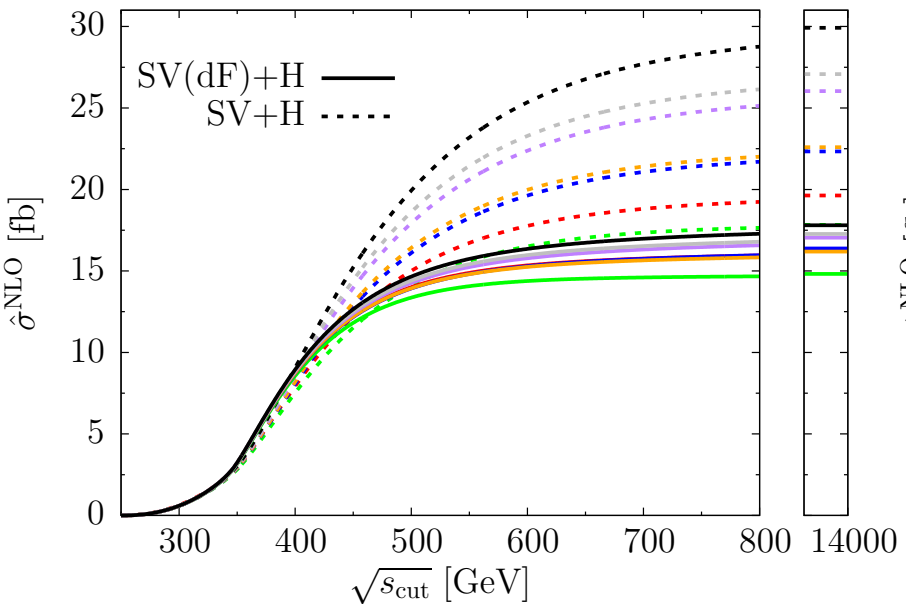


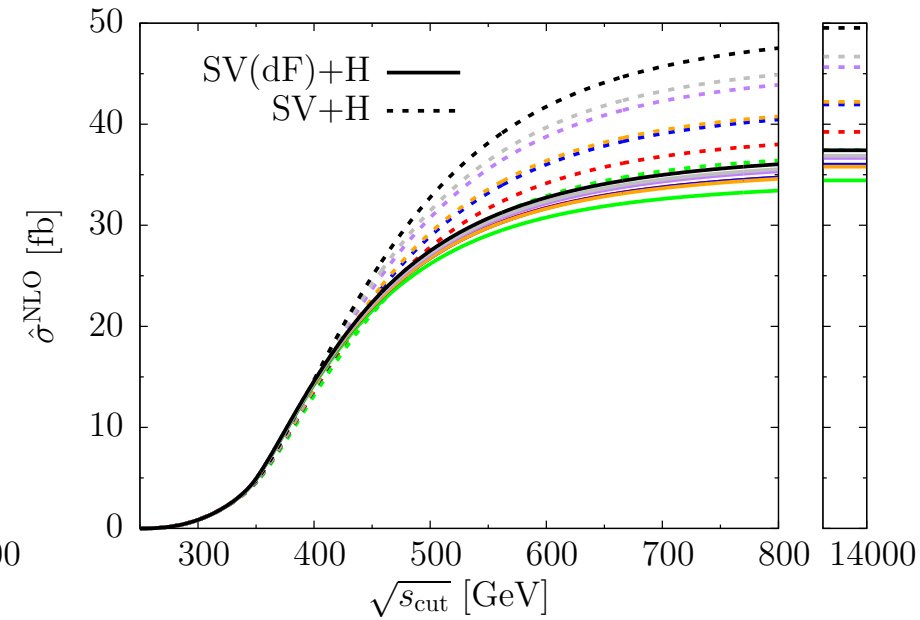


Hadronic NLO... both

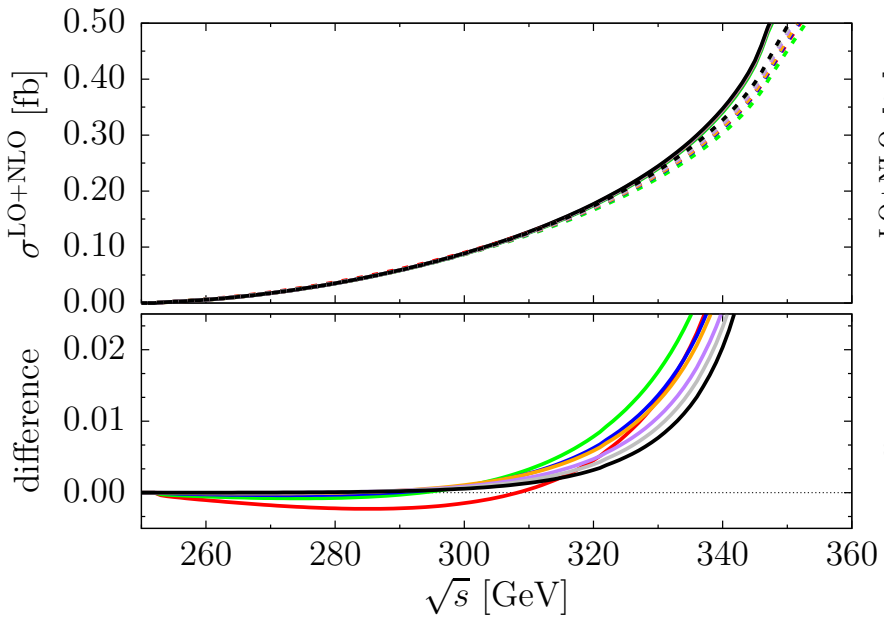


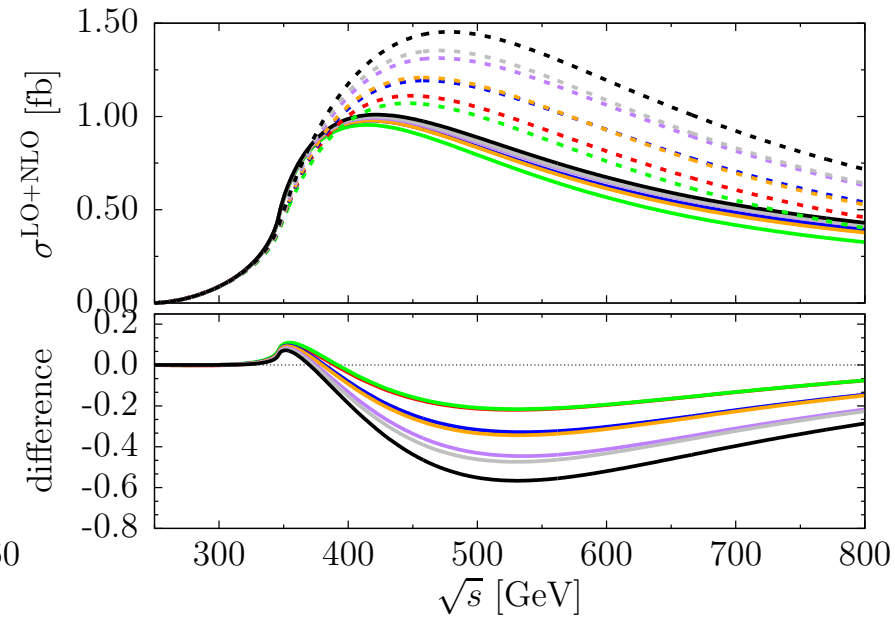
NLO hadronic



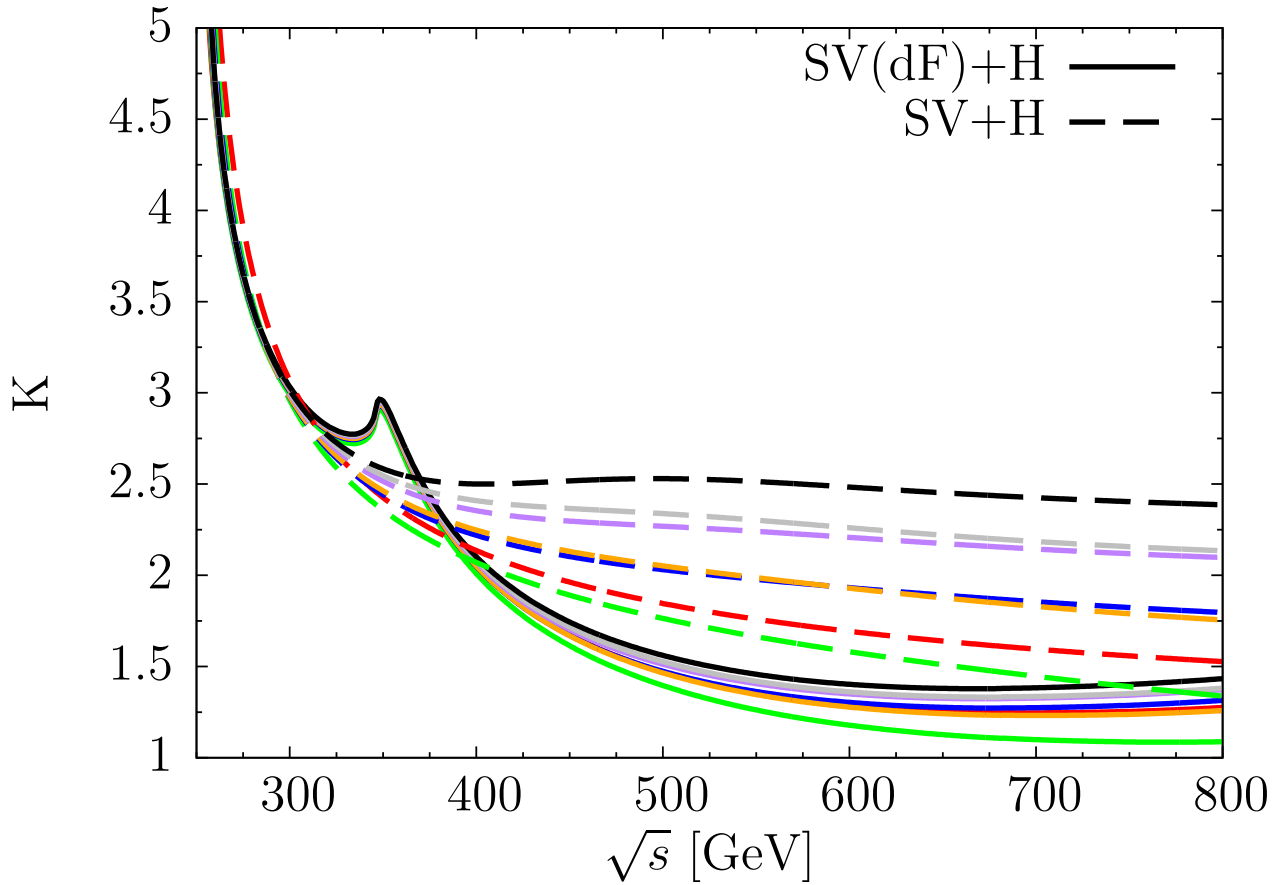


NLO-LO partonic

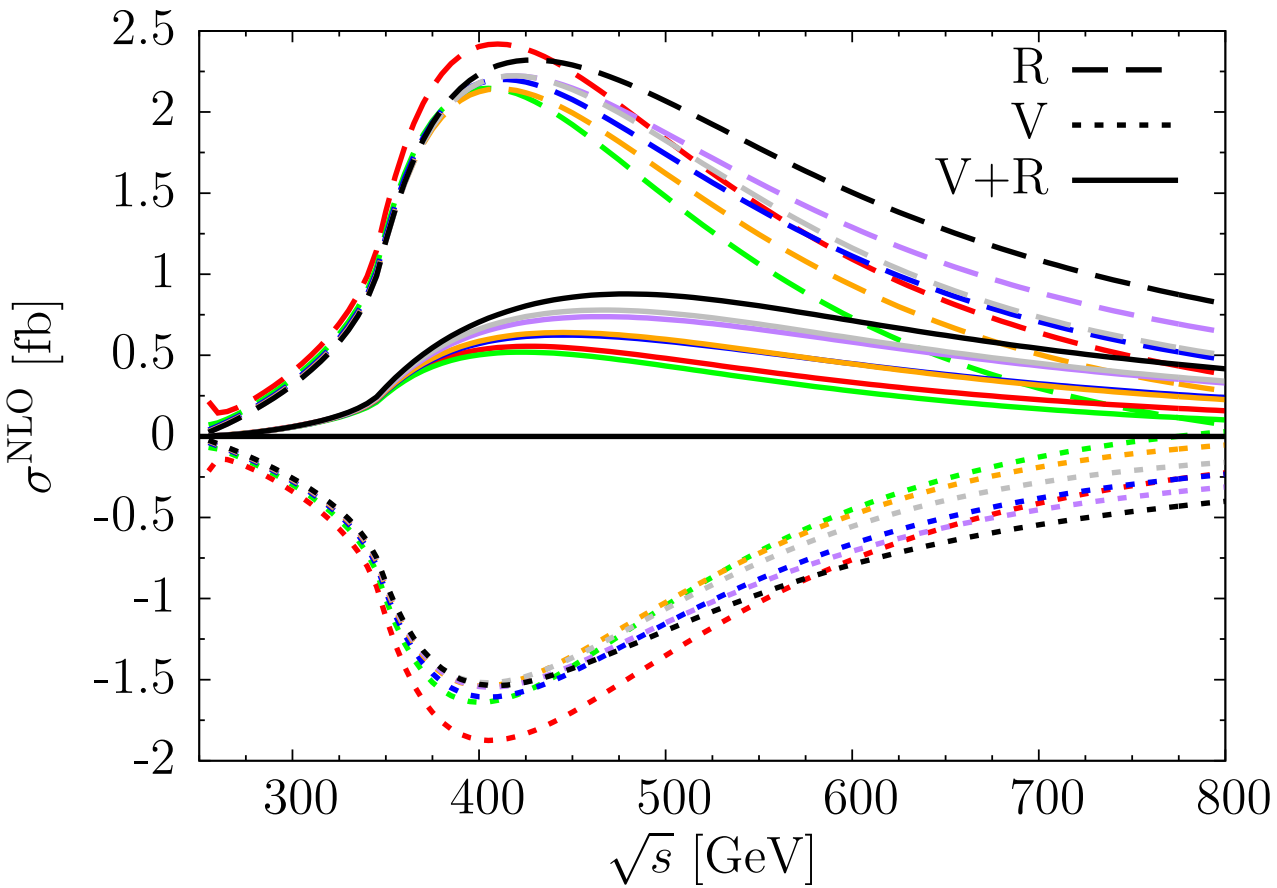




Partonic K-factor



virtual - real



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