Finite top quark mass effects in NNLO Higgs boson production at LHC

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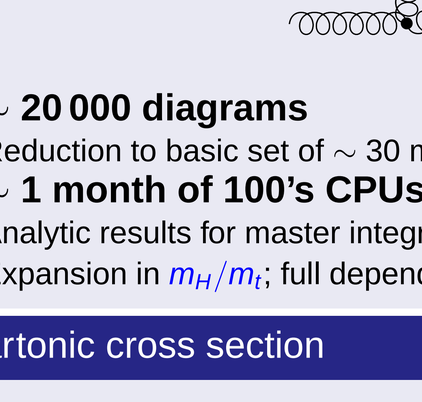
PHYSICS AT THE TERA SCALE Helmholtz Alliance

Introduction

→ LHC at CERN
→ New energy domain
→ New phenomena
→ Higgs boson

Higgs boson production at the LHC: $pp \to H + X$

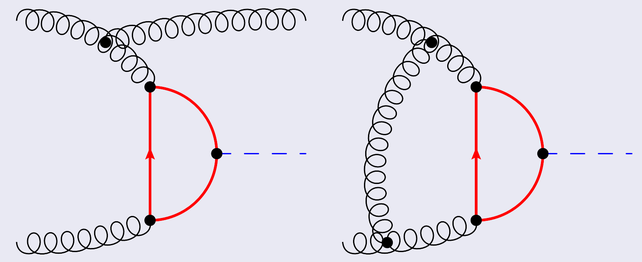


- Most important production channel $gg \to H$ via a top-quark loop
- Complicated since many scales involved
  - ▶ $\sqrt{S_{hadr}}$ up to 14000 GeV
  - ▶ $\sqrt{S_{part}} \sim 100 - 14000$ GeV
  - ▶ Higgs mass $m_H \sim 100 - 300$ GeV
  - ▶ Top-quark mass $m_t \cong 173.1$ GeV

Physical motivation

QCD corrections are quite large:

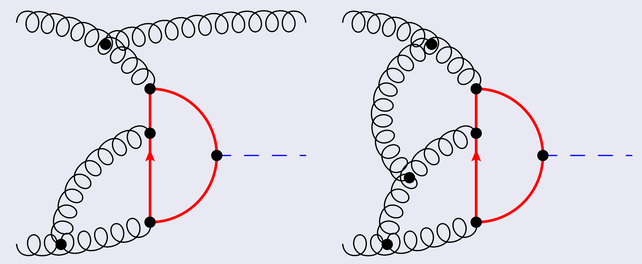
- Next-to-leading order (NLO):



$\sim \mathcal{O}(70\%)$

Known exact for arbitrary scales.

- Next-to-next-to-leading order (NNLO):



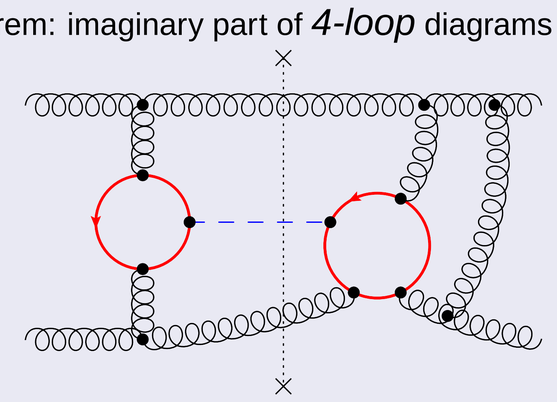
$\sim \mathcal{O}(10\%)$

Until recently, only available in the heavy top limit $m_t \to \infty$.

NNLO cross section with finite Higgs boson mass

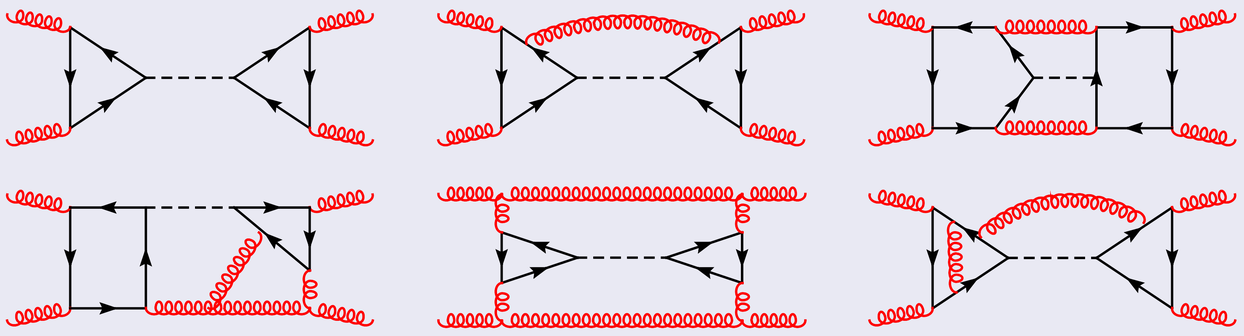
Chain of calculation:

- Use of Optical Theorem: imaginary part of *4-loop* diagrams



- $\sim$ **20 000 diagrams**
- Reduction to basic set of ~ 30 master integrals
- $\sim$ **1 month of 100's CPUs**
- Analytic results for master integrals
- Expansion in m_H/m_t; full dependence on $x = m_H^2/S_{part}$

Sample diagrams for dominant *gg* channel

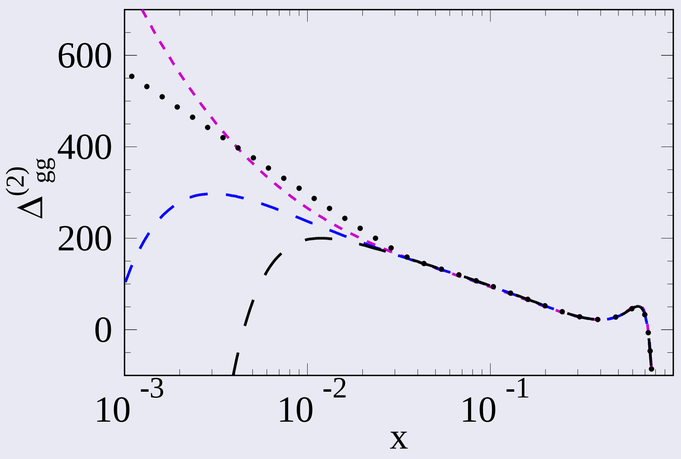


Diagrams for the LO, NLO and NNLO contribution to $gg \to gg$. The appropriate cuts lead to corrections to $gg \to h$. Dashed, curly and solid lines represent Higgs bosons, gluons and top quarks.

Partonic cross section

$$\hat{\sigma}_{gg\to h} = \hat{A}_{\rm LO}\left(\Delta_{gg}^{(0)} + \frac{\alpha_s}{\pi}\,\Delta_{gg}^{(1)} + \left(\frac{\alpha_s}{\pi}\right)^2 \Delta_{gg}^{(2)} + \dots\right),$$

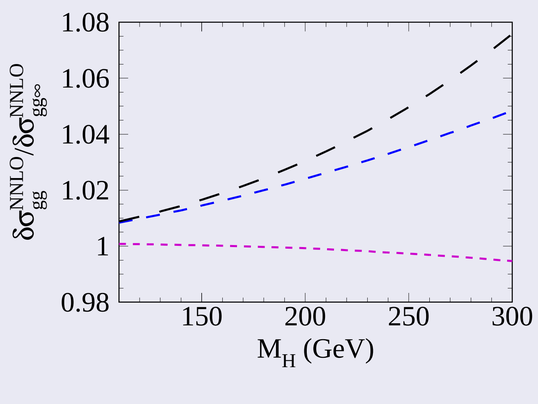
Partonic results for *gg* channel:



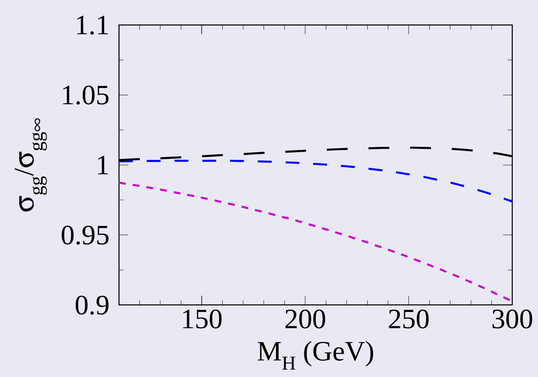
- Lines with longer dashes - higher order terms in m_H/m_t.
- A good convergence of m_H/m_t-series is observed up to the threshold for top quark pair production, i.e., for $x > m_H^2/(4m_t^2)$.
- Proper approximation should be used at $x \to 0$: Match calculated results to asymptotics for small x calculated by Marzani, Ball, Del Duca, Forte, Vicini 08, available only for *gg* channel (dots).

Hadronic cross section

Dominant *gg* channel :



← Ratio of the NNLO hadronic cross section (*gg*-channel) including successive higher orders in $1/m_t$ normalized to the infinite top quark mass result. Computed corrections $\leq 8\%$.



← The prediction of the gluon-induced inclusive Higgs production cross section up to NNLO normalized to the heavy-top limit. Final effect $\leq 1\%$.

Conclusion: the numerical impact of the m_t suppressed terms is below 1%, $\sim$ 10 times smaller than scale uncertainty (not obvious a priori).

Summary

- m_t corrections to Higgs production at NNLO calculated retaining full x dependence
- Expansion around soft limit [R.Harlander and K.Ozeren '08] confirmed
- *Heavy top quark mass approximation* for evaluation of NNLO cross section justified

Publications

- A. Pak, M. Rogal, M. Steinhauser, Phys. Lett. B **679** (2009)
- A. Pak, M. Rogal, M. Steinhauser, arXiv:0911.4622 [hep-ph]