Precise predictions for Higgs production via gluon fusion in BSM scenarios

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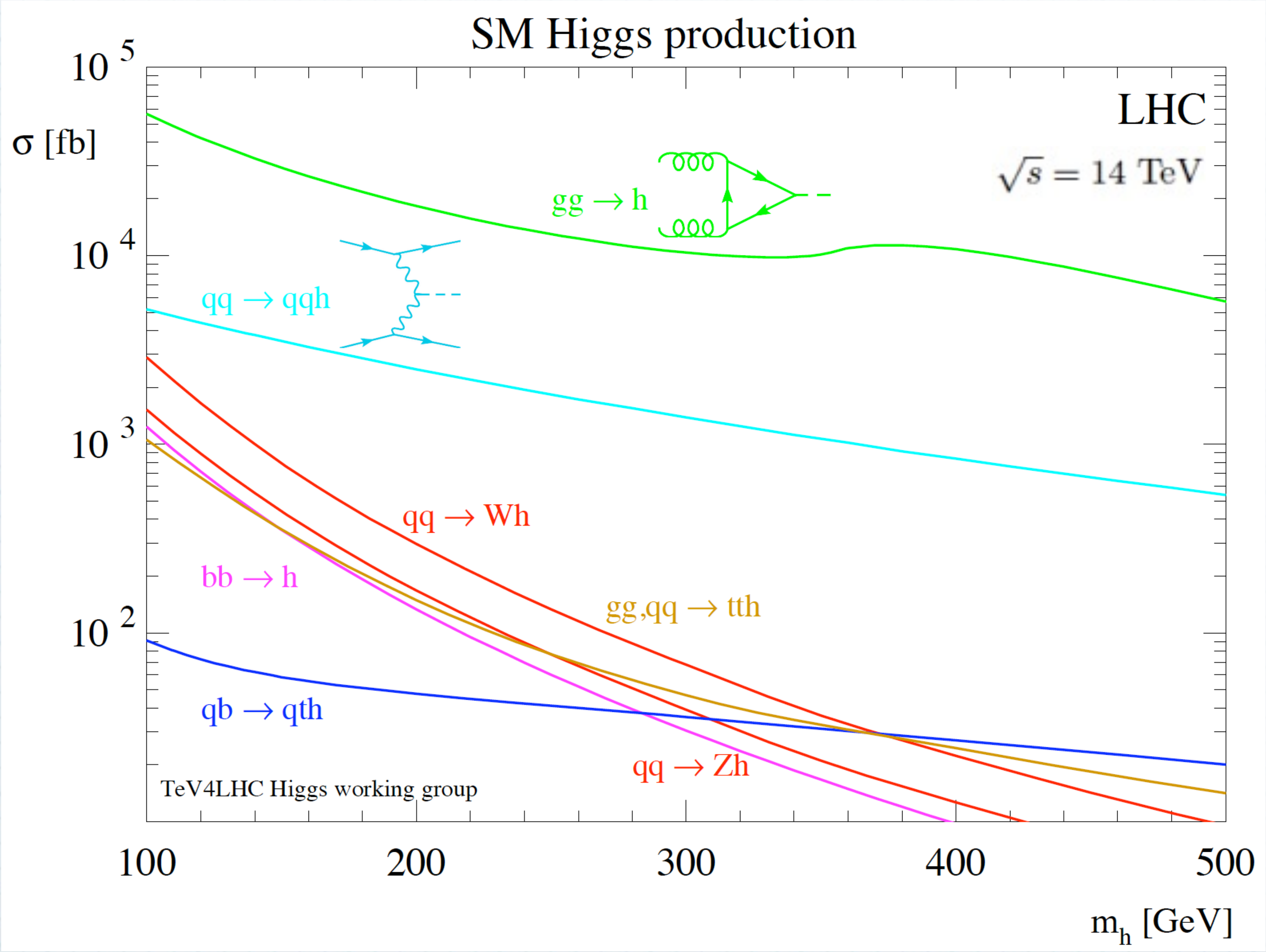
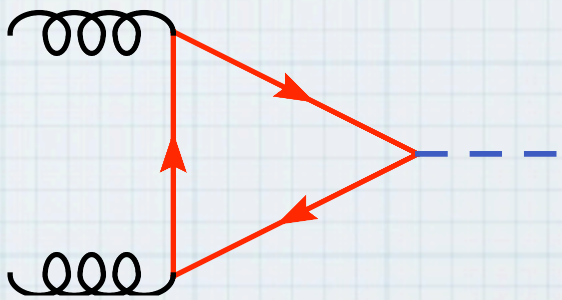
Motivation

* gluon fusion is the main mechanism for Higgs production at hadron colliders



Motivation

* gluon fusion is the main mechanism for Higgs production at hadron colliders
* it is sensitive to any coloured particle that couples to the Higgs, e.g. the top

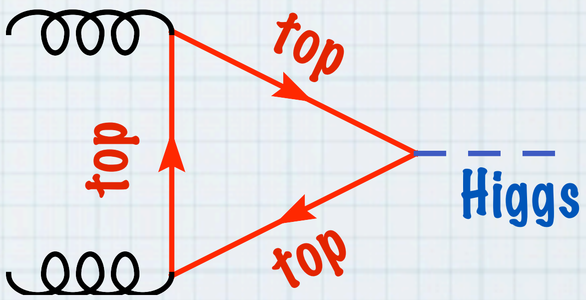


* extensions of the SM require new particles which may contribute to gluon fusion

➡ this channel is very sensitive to new physics effects

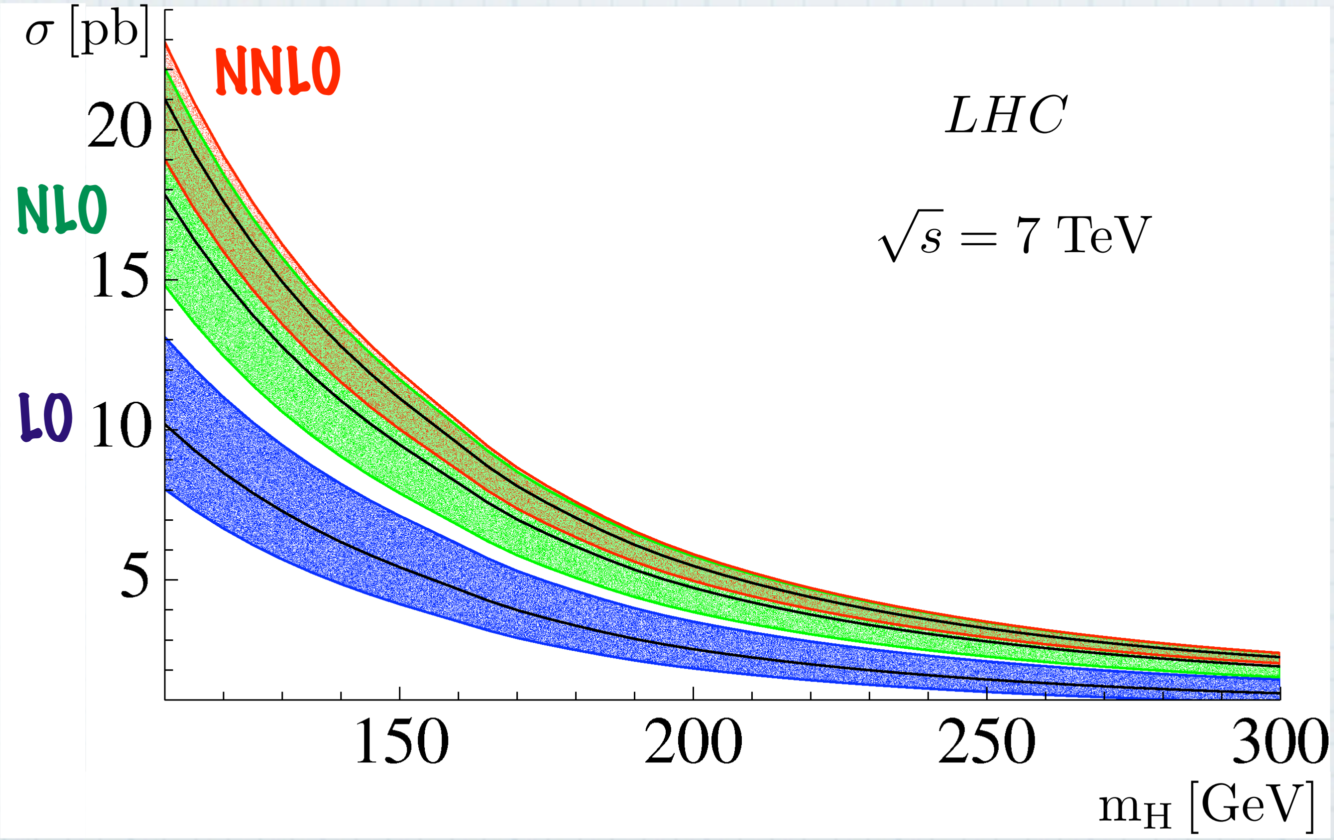
Gluon fusion in the SM

* it is known very precisely...



* ... but it required tough calculations

Harlander, Kilgore; Anastasiou, Melnikov; Ravindran, Smith, van Neerven



Gluon fusion in the SM

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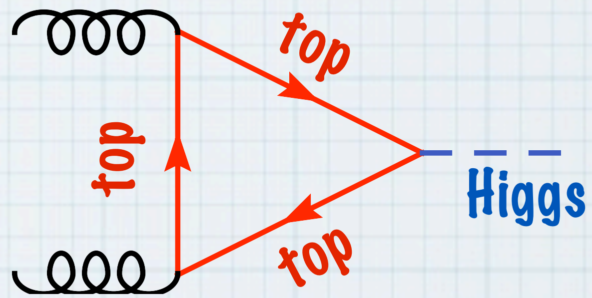
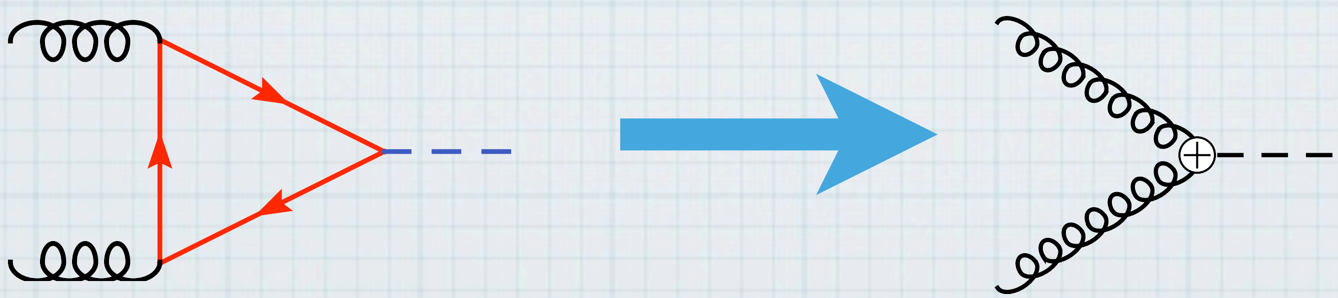


* ... and it required an heavy-quark effective theory (HQET) approach
  ⇨ integrating out the top quark

(Chetyrkin, Kniehl, Steinhauser)



Gluon fusion in BSM

* Only very recent NNLO calculations in some BSM scenarios

  scalar octects (Boughezal, Petriello); fourth generation (Anastasoiu, Boughezal, EF; Anastasoiu, Buehler, EF, Herzog, Lazopoulos); MSSM (Pak, Steinhauser, Zerf)

* The low-energy theory is the same as in SM HQET, but the matching calculation at NNLO is much more complicated:

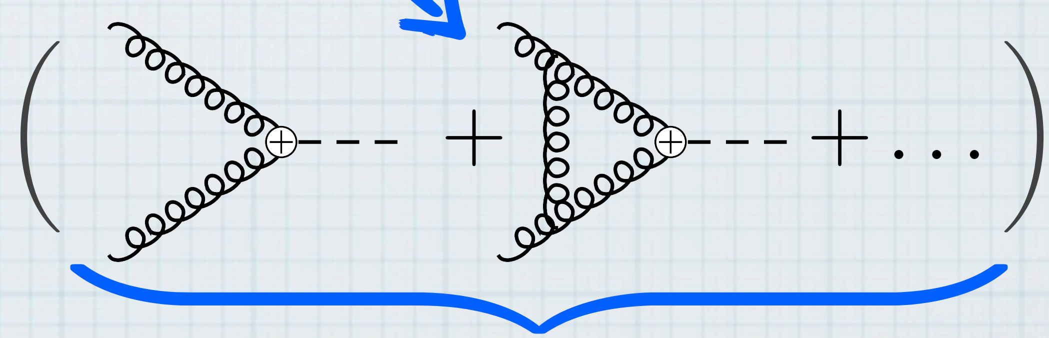
  * number of diagrams (~10^3 - 10^4)
  * renormalization (e.g., new vertices)
  * dependence on multiple mass scales

Separating new physics

* we can construct an effective theory that contains only the light degrees of freedom of the Standard Model
  - ➡ particles that are heavier than half the Higgs mass are integrated out
    ⇨ obtain an effective gluon-gluon-Higgs vertex

$$\mathcal{L}_{eff} = -\frac{\alpha_s}{4v} C\, H G^a_{\mu\nu} G^{a\mu\nu}$$

$$\underbrace{\left(C_0 + \left(\frac{\alpha_s}{\pi}\right) C_1 + \left(\frac{\alpha_s}{\pi}\right)^2 C_2 + \dots\right)}_{\text{depends on the specific model}}$$



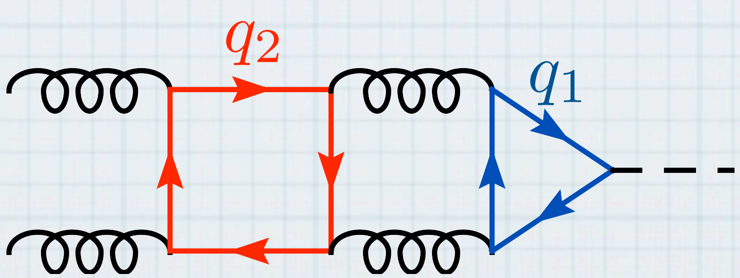
light-flavour QCD only!

Four-generation SM

(Anastasoiu, Boughezal, EF; Anastasoiu, Buehler, EF, Herzog, Lazopoulos)

* we have the tools to compute the Higgs production cross section via gluon fusion at the same level of accuracy as in the SM

* "complication": at NNLO we have diagrams containing two different heavy quarks

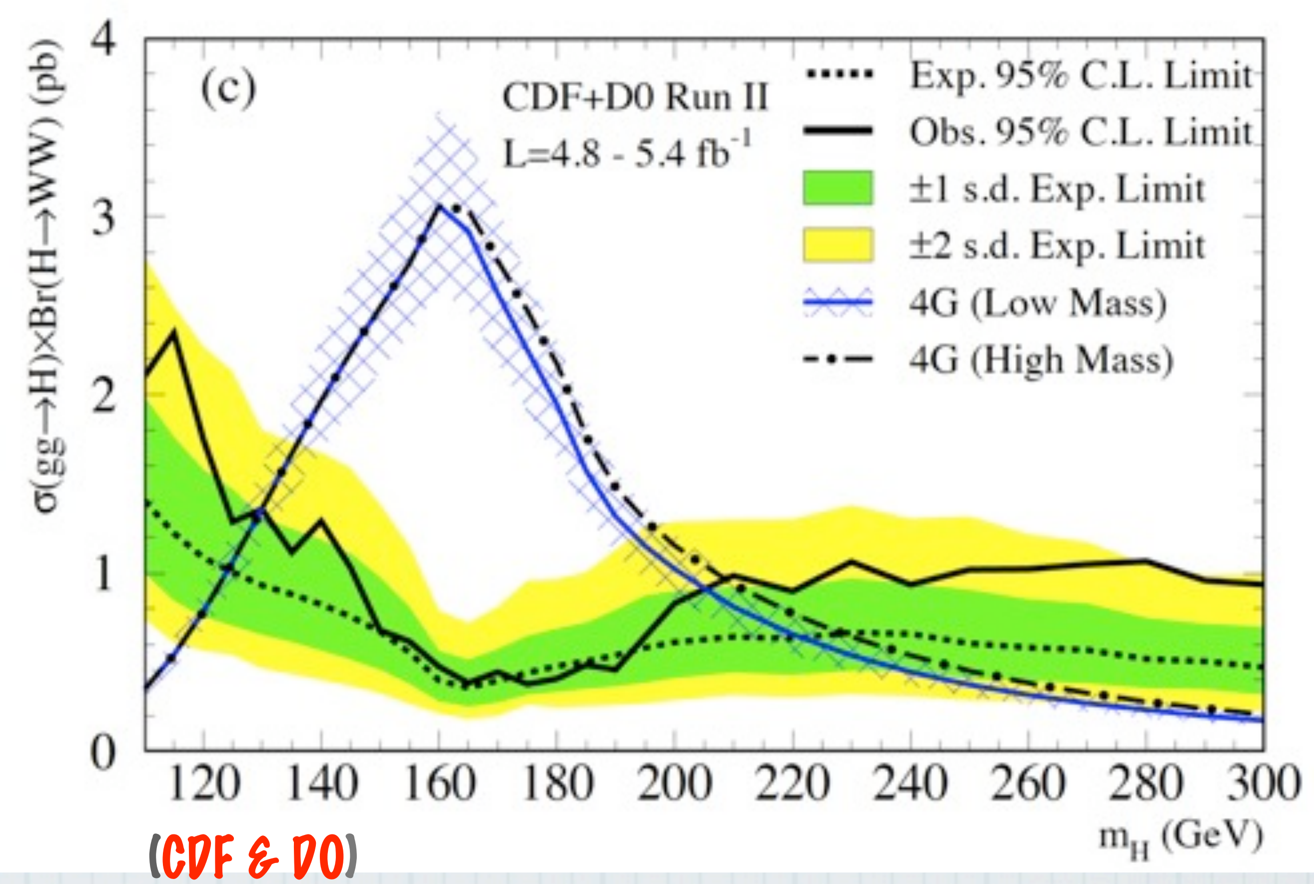


➡ integrals with up to two, different, massive propagators

Four-generation SM

(Anastasoiu, Boughezal, EF; Anastasoiu, Buehler, EF, Herzog, Lazopoulos)

* the NNLO cross section is 10-15% higher than the NLO cross section
* the theoretical error decreases from 20-30% at NLO to 10% at NNLO
* these results can be used by the experimental collaborations to put accurate constraints on the mass of the Higgs boson in a four-generation SM



(CDF & D0)

Composite Higgs models

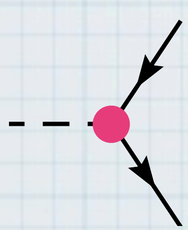
Gerogi, Kaplan; Contino, Nomura, Pomarol;
Agashe, Contino, Pomarol; Contino, Da Rold, Pomarol

* class of models that address the hierarchy problem
* there is a new, strongly interacting sector responsible for EWSB
* quarks get their masses through mixing with composite fermions of the new sector
  - ➡ heavy quarks are largely "composite", so they couple more with the Higgs boson than light quarks
  - ➡ couplings to the Higgs boson are reduced with respect to the Standard Model
  - ➡ we have new heavy quarks that couple to the Higgs boson

} does the Higgs prodction cross section decrease or increase?

Higgs production

* we can compute the Higgs production cross section through NNLO
* differences with the Standard Model calculation:
  - ➡ two different mass scales can appear together at NNLO
  - ➡ Higgs-quark vertex:



$$\cancel{\frac{m_q}{v}} \longrightarrow Y_q$$

- we need to understand how this vertex renormalizes

Higgs production

* confirm the 30-35% LO suppression (Falkowski) with respect to the Standard Model through NNLO
  - for $m_h = 120\,\mathrm{GeV}$,

    $$\sigma_{SM} = 17.6\,\mathrm{pb}$$

    while σ_{CH} is in the range $5.7 - 6.4\,\mathrm{pb}$
* as in the SM, the scale variation error reduces from ${}^{+30\%}_{-22\%}$ at LO to ${}^{+(6\div7)\%}_{-(8\div9)\%}$ at NNLO

Higgs production

* K-factors are slightly larger than in the Standard Model

LHC, 7 TeV	SM	CHM
$\frac{\sigma_{tbew}^{NLO}}{\sigma_{tb}^{LO}}$	+ 84%	+ 90 - 92%
$\frac{\sigma_{tbew}^{NNLO}}{\sigma_{tb}^{LO}}$	+ 116%	+ 121 - 125%

* bottom-quark and two-loop electroweak corrections are more important than in the Standard Model

	SM	CHM
$\frac{\sigma_{tb}^{LO} - \sigma_{t}^{LO}}{\sigma_{t}^{LO}}$	- 7%	- 10%
$\frac{\sigma_{tbew}^{NLO} - \sigma_{tb}^{NLO}}{\sigma_{tb}^{NLO}}$	+ 5%	+ 7%

Conclusions

* the Higgs boson is likely to come with some new physics
* many viable BSM theories exist, and many need to introduce new, coloured particles
* they can significantly affect the gluon-fusion cross section
* we adopt an effective theory approach to disentangle new physics from light-flavour QCD
* we have automatised the matching procedure for BSM models through NNLO
* examples of applications: four-generation Standard Model, composite Higgs model