Higgs cross section at NNLL+NNLO (current recommendation)

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meeting on the ggF inclusive cross section
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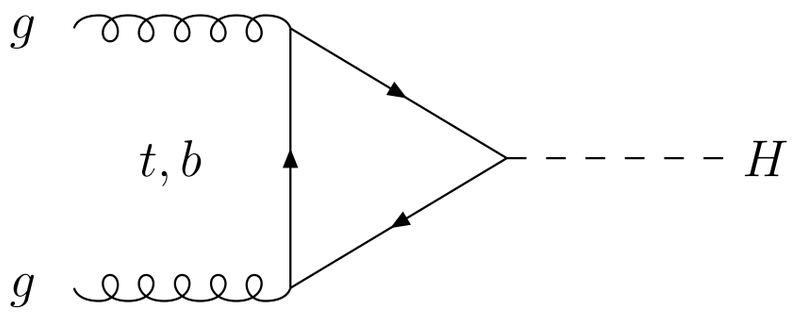
Introduction



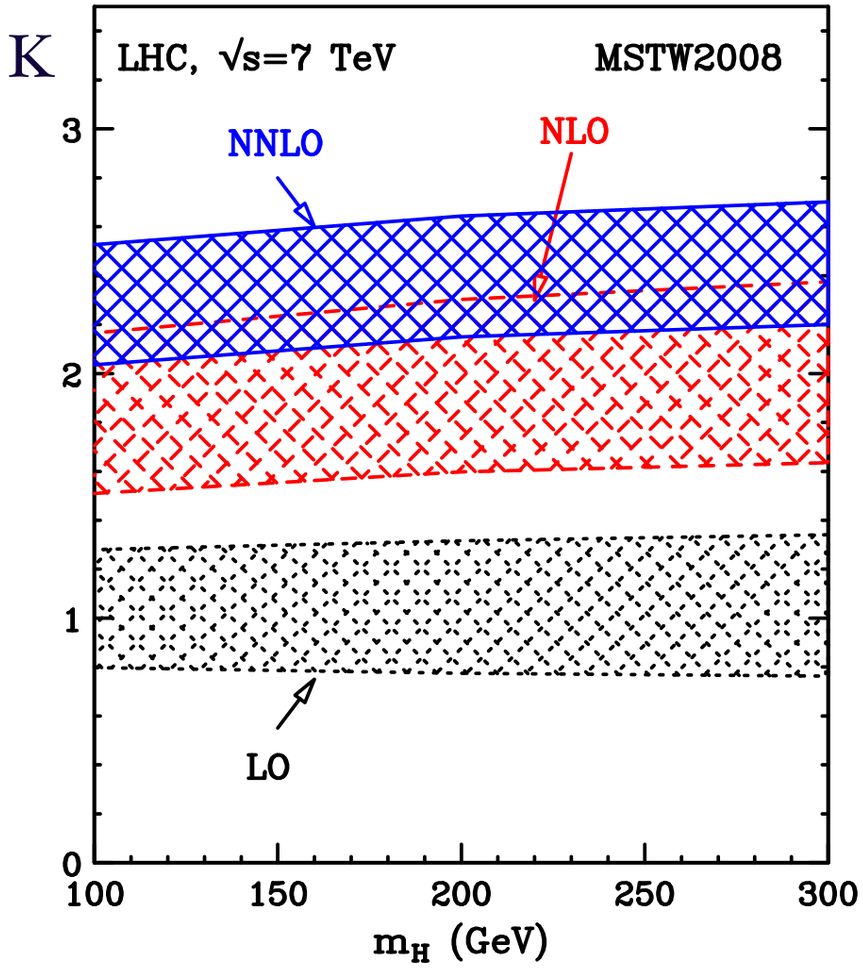
The Higgs coupling is proportional to the quark mass

→ top-loop dominates

$O(\alpha_S^2)$ process already at Born level

QCD corrections to the total rate computed more than 20 years ago and found to be large → O(100 %) effect !

A. Djouadi, D. Graudenz, M. Spira, P. Zerwas (1991)



Next-to-next-to leading order (NNLO) corrections computed in the large-m_{top} limit (+25 % at the LHC, +30 % at the Tevatron)

R.Harlander (2000); S. Catani, D. De Florian, MG (2001)
R.Harlander, W.B. Kilgore (2001,2002)
C. Anastasiou, K. Melnikov (2002)
V. Ravindran, J. Smith, W.L.Van Neerven (2003)

scale uncertainty computed with
$m_H/2 < \mu_F, \mu_R < 2\, m_H$ and $1/2 < \mu_F/\mu_R < 2$

The large-m_{top} approximation

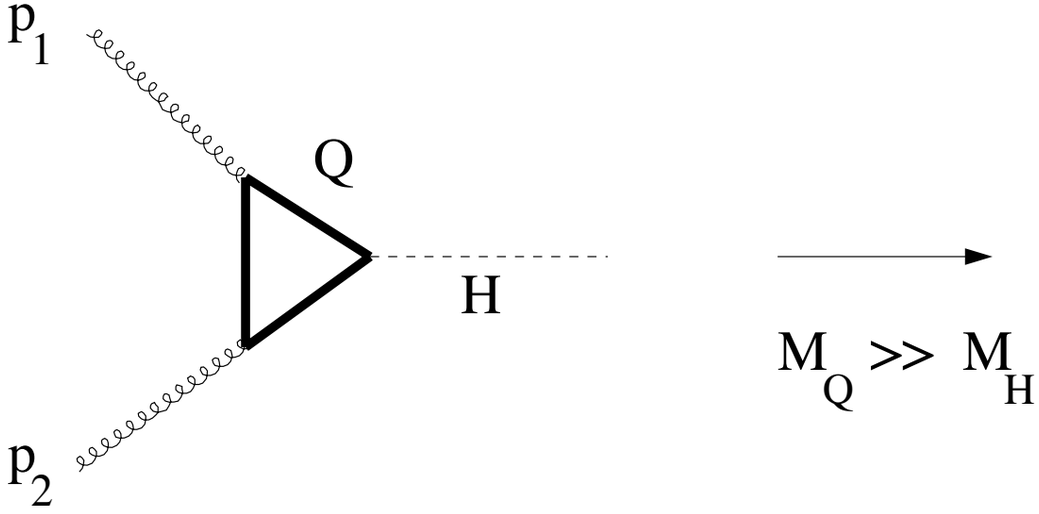
For a light Higgs it is possible to use an effective lagrangian approach obtained when $m_{top} \to \infty$

J.Ellis, M.K.Gaillard, D.V.Nanopoulos (1976)
M.Voloshin, V.Zakharov, M.Shifman (1979)

$$\mathcal{L}_{eff} = -\frac{1}{4}\left[1 - \frac{\alpha_S}{3\pi}\frac{H}{v}(1+\Delta)\right] \mathrm{Tr}\, G_{\mu\nu}G^{\mu\nu}$$

Known to $\mathcal{O}(\alpha_S^3)$

K.G.Chetirkin, M.Steinhauser, B.A.Kniehl (1997)



Effective vertex: one loop less !

Subleading terms in large-m_{top} limit at NNLO have been evaluated

S.Marzani et al. (2008)
R.Harlander et al. (2009,2010)
M.Steinhauser et al. (2009)

→ **The approximation works to better than 0.5 % for $m_H < 300$ GeV**

Soft-gluon resummation

All-order resummation of soft-gluon effects can be used to improve our fixed order perturbative predictions

S. Catani, D. De Florian, P. Nason, MG (2003)

Soft-virtual effects are logarithmically enhanced at $z = m_H^2/\hat{s} \longrightarrow 1$

Steepness of gluon density enhances the relevance of the threshold region

The dominant behaviour can be organized in an all order resummed formula

Resummation works in Mellin space L=ln N

$$\sigma^{\rm res} \sim C(\alpha_{\rm S}) \exp\{L g_1(\alpha_{\rm S} L) + g_2(\alpha_{\rm S} L) + \alpha_{\rm S} g_3(\alpha_{\rm S} L) + ...\}$$

We can perform the resummation up to NNLL+NNLO accuracy

This means that we include the full NNLO result plus all-order resummation of the logarithmically enhanced terms → No information is lost

The current recommendation

D. de Florian, MG (2009,2012)

The current recommendation is based on a NNLL+NNLO calculation

- Start from exact NLO calculation including top, bottom and charm mass effects (charm contributes -2.5 % at LO !)

A. Djouadi, D. Graudenz, M. Spira, P. Zerwas (1991)

- Carry out soft-gluon resummation up to NLL+NLO

- Include NNLL+NNLO top-quark contribution in the large-m_{top} approximation (normalized to exact LO cross section)

- Include EW corrections assuming complete factorisation
- (+5.2% at mh=125 GeV)

U. Aglietti et al. (2004)
G. Degrassi, F. Maltoni (2004)
G. Passarino et al. (2008)

→ **Recommended result by the LHC Higgs XS WG and used as reference theoretical prediction by ATLAS and CMS**

(corresponding results for the Tevatron still used by CDF+D0)

Benchmarking exercise

The ggF convenors suggested to use the following setup for a comparison:

- $\sqrt{s}$=13 TeV m_H=125 GeV m_{top}=172.5 GeV no bottom
- MSTW2008 NNLO with α_S=0.1171 (central value)

Electroweak corrections not included

With this setup our NNLL+NNLO calculation gives:

$\mu_F=\mu_R=m_H$

$$\sigma = 44.64^{+8.1\%}_{-8.7\%}\ \text{pb}$$

$\mu_F=\mu_R=m_H/2$

$$\sigma = 45.91^{+7.3\%}_{-9.2\%}\ \text{pb}$$

The impact of resummation

As is well known the quantitative impact of soft-gluon resummation depends on the collider energy (and on the Higgs mass)

The higher is the collider energy and the lower is the quantitative impact of soft-gluon terms

With the proposed setup we get:

- +6 % from NNLO to NNLL at 13 TeV
- +8% from NNLO to NNLL at 7 TeV
- +14% from NNLO to NNLL at 1.96 TeV

Note that at 13 TeV the resummation effect is within the scale uncertainty of the NNLO calculation

Summary and final thoughts

- The current recommendation for the inclusive ggF cross section is based on a QCD calculation supplemented with EW effects at two-loop order
- The QCD calculation includes the NNLO fixed order result and soft-gluon effects up to NNLL
- This result has been used as reference at the Tevatron and the LHC over a wide range of collider energies
- The impact of soft-gluon resummation decreases as the collider energy increases and at 13(14) TeV soft-gluon effects are small
- As new theoretical information is now available it is important to discuss how to update the recommendation
- At present I do not see evidence of large missing effects which are not taken into account by the current uncertainty
- A significant reduction of the perturbative uncertainty appears difficult to achieve