Differential decay rates of CP even and odd Higgs bosons to massive quarks at NNLO in $\alpha_s$

Long Chen

Max Planck Institute for Physics, Munich, Germany

Higgs Coupling 2018, Tokyo, November 29th

In collaboration with: W. Bernreuther, Z.G. Si

Motivation and Background

- $h \rightarrow b\bar{b}$ is the most probable decay channel of the $h(125)$, and finally observed recently at the LHC (in the $VH$-events)!

  [→talks by D.Schaefer, A.De Wit, G.Zanderighi]

- Many BSM predict heavy scalars and pseudo-scalars coupled to heavy quarks.

  [→talks by R.Santos, J.Steggemann]

- Much work done previously on neutral scalar bosons decay into quarks.

  ▶ **inclusive:**
  known up to $N^4LO$ for CP-even Higgs into massless quarks;
  [Baikov,Chetyrkin,Kuhn,06; Davies,Steinhauser,Wellmann,17; Herzog,Ruijl,Ueda,Vermaseren,Vogt,17]
  NNLO corrections for CP-even/odd Higgs in power expansion of $\frac{m_Q}{m_h}$;
  [Surguladze, 94; Chetyrkin,Kwiatkowski,96; Chetyrkin,Kniehl,Steinhauser,97; Larin,Ritbergen,Vermaseren,95;Harlander,Steinhauser,97; Chetyrkin, Harlander,Steinhauser,97,98]
  . . . . .

  ▶ **differential:**
  CP-even Higgs decay into massless quarks at $NNLO$
  [Anastasiou, Herzog, Lazopoulos, 2012; Duca, Duhr, Somogyi, Tramontano, Trocsanyi, 2015]
Aim of the work

We consider the decay of a neutral Higgs boson $h$ of arbitrary CP to a massive quark antiquark pair at NNLO order in perturbative QCD, i.e. $h \rightarrow Q\bar{Q}X \ (Q = t, b)$, at the fully differential level (using the antenna subtraction method).

- BSM heavy CP-even/odd Higgs boson decay into $t\bar{t}$ pair: inclusive decay width as a function of $m_h$, and $M_{t\bar{t}}$ distributions, etc

- the SM $h(125)$ Higgs boson decay into a massive $b\bar{b}$ pair: inclusive decay width, 2-jet, 3-jet, and 4-jet decay width, and the energy distribution of the leading jet for two-jet events.
UV-renormalization and (antenna) IR subtraction

The **hybrid UV-renormalization** in $pQCD$ with $n_f + 1$ quarks:

- External-fields (and their masses): **on-shell** scheme;
- $\alpha_s$: $\overline{\text{MS}}$-scheme;
- The Yukawa-coupling $y_Q$: $\overline{\text{MS}}$-scheme
UV-renormalization and (antenna) IR subtraction

The hybrid UV-renormalization in $pQCD$ with $n_f + 1$ quarks:

- External-fields (and their masses): on-shell scheme;
- $\alpha_s$: $\overline{\text{MS}}$-scheme;
- The Yukawa-coupling $y_Q$: $\overline{\text{MS}}$-scheme

The general idea of IR-subtraction methods:
insert an identity $0 = \int d\sigma^S - \int d\sigma^S$ into $\sigma_{\text{NLO}} = d\sigma^R + d\sigma^V$.

The $d\sigma^S$ in the antenna subtraction method are constructed according to the universal IR-factorization formulae of color-ordered partial QCD-amplitudes,

Figure: The antenna factorization of a color-ordered partial amplitude (PRD 71, 045016)
Organizations of ingredients for \( h \to Q\bar{Q} + X \) \((Q = t, b)\)

Schematically the NNLO corrections with \textit{antenna} IR subtraction terms:

\[
d\sigma_{\text{NNLO}} = \int d\Phi_4 \left( d\sigma_{\text{RR}}^{\text{NNLO}} - d\sigma_{\text{S}}^{\text{NNLO}} \right) + \int d\Phi_3 \left( d\sigma_{\text{RV}}^{\text{NNLO}} - d\sigma_{\text{T}}^{\text{NNLO}} \right) + \int d\Phi_2 d\sigma_{\text{VV}}^{\text{NNLO}} + \int d\Phi_3 d\sigma_{\text{T}}^{\text{NNLO}} + \int d\Phi_4 d\sigma_{\text{S}}^{\text{NNLO}}
\]

- **RR:** Tree-level double real radiation correction: \( h \to Q\bar{Q}gg \), \( Q\bar{Q}q\bar{q} \) and \( Q\bar{Q}Q\bar{Q} \)

  Implicit IR-singularity removed by \( d\sigma_{\text{S}}^{\text{NNLO}} \).

- **RV:** One-loop correction to \( h \to Q\bar{Q}g \)

  Explicit and implicit IR-singularity removed by \( d\sigma_{\text{T}}^{\text{NNLO}} \).

- **VV:** Two-loop corrections to \( h \to Q\bar{Q} \)

  Explicit IR-poles removed by \( \int d\Phi_3 d\sigma_{\text{T}}^{\text{NNLO}} + \int d\Phi_4 d\sigma_{\text{S}}^{\text{NNLO}} \)
Decay widths in terms of on-shell and $\overline{\text{MS}}$ Yukawa-couplings

The *differential* decay width of a Higgs boson with a generic CP into **unpolarized** $Q\bar{Q}$:

$$d\Gamma^{Q\bar{Q}} = a_Q^2 d\Gamma^{Q\bar{Q}}_S + b_Q^2 d\Gamma^{Q\bar{Q}}_P$$

with the "reduced" Yukawa-couplings $a_Q$ and $b_Q$ as in $-y_Q h [a_Q \bar{Q}Q + b_Q \bar{Q}i\gamma_5 Q]$ (where $y_Q = \frac{m_Q}{\text{vev}}$).

Expanded to order $\alpha_s^2$:

$$d\Gamma^{Q\bar{Q}} = y_Q^2 \left[ d\hat{\Gamma}_0^{Q\bar{Q}} + \frac{\alpha_s(\mu)}{\pi} d\hat{\Gamma}_1^{Q\bar{Q}} + \left( \frac{\alpha_s(\mu)}{\pi} \right)^2 d\hat{\Gamma}_2^{Q\bar{Q}} \right]$$

$$\equiv y_Q^2 d\hat{\Gamma}_0^{Q\bar{Q}} \left[ 1 + \frac{\alpha_s(\mu)}{\pi} d\gamma_1^{Q\bar{Q}} + \left( \frac{\alpha_s(\mu)}{\pi} \right)^2 d\gamma_2^{Q\bar{Q}} \right]$$

$$= y_Q^2 \frac{\alpha_s(\mu)}{\pi} \left[ 1 + \frac{\alpha_s(\mu)}{\pi} \left( 1 + r_1(m_Q, \mu) \right) \left( \frac{\alpha_s(\mu)}{\pi} \right)^2 \left( 1 + r_2(m_Q, \mu) \right) \right]$$

(1)

The on-shell and $\overline{\text{MS}}$ Yukawa-couplings are related by

$$y_Q^2 = \bar{y}_Q^2(\mu) \left[ 1 + r_1(m_Q, \mu) \frac{\alpha_s(\mu)}{\pi} + r_2(m_Q, \mu) \left( \frac{\alpha_s(\mu)}{\pi} \right)^2 \right]$$

$$= \bar{y}_Q^2(\mu) \left[ 1 + r_1(m_Q, \mu) \frac{\alpha_s(\mu)}{\pi} + r_2(m_Q, \mu) \left( \frac{\alpha_s(\mu)}{\pi} \right)^2 \right]$$

(2)

Inserting (2) into (1) and **re-expanding** to order $\alpha_s^2$

$$d\Gamma^{Q\bar{Q}} = \bar{y}_Q^2(\mu) \frac{\alpha_s(\mu)}{\pi} \left[ 1 + \frac{\alpha_s(\mu)}{\pi} \left( d\gamma_1^{Q\bar{Q}} + r_1 \right) + \left( \frac{\alpha_s(\mu)}{\pi} \right)^2 \left( d\gamma_2^{Q\bar{Q}} + r_1 d\gamma_1^{Q\bar{Q}} + r_2 \right) \right].$$
Decays of BSM scalars/pseudo-scalars into $t\bar{t}$: inclusive decay rates

We work in 6-flavor QCD:

**Standard-Model inputs**

\[
\begin{align*}
  m_t^{on} &= 173.34 \text{ GeV}, \text{ corresponding to } m_t(\mu = m_t) = 163.46 \text{ GeV}; \\
  \alpha_s^{(5)}(m_Z) &= 0.118; \quad G_F = 1.166379 \times 10^{-5} \frac{1}{\text{GeV}^2}
\end{align*}
\]
Decays of BSM scalars/pseudo-scalars into $t\bar{t}$: inclusive decay rates

We work in 6-flavor QCD:

<table>
<thead>
<tr>
<th>Standard-Model inputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>$m_t^\text{on} = 173.34\text{ GeV}$, corresponding to $\bar{m}_t(\mu = m_t) = 163.46\text{ GeV}$;</td>
</tr>
<tr>
<td>$\alpha_s^{(5)}(m_Z) = 0.118$; $G_F = 1.166379 \times 10^{-5} \frac{1}{\text{GeV}^2}$</td>
</tr>
</tbody>
</table>

The $t\bar{t}$ inclusive decay widths at NNLO QCD, $\Gamma_{t\bar{t}}^X$ and $\Gamma_{t\bar{t}}^{t\bar{t}}$ ($X = S, P$)

<table>
<thead>
<tr>
<th>$m_h$ [GeV]</th>
<th>$\Gamma_{t\bar{t}}^{t\bar{t}}$ [GeV]</th>
<th>$\Gamma_{t\bar{t}}^S$ [GeV]</th>
<th>$\Gamma_{t\bar{t}}^P$ [GeV]</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>12.529 $^{+0.265}_{-0.314}$</td>
<td>12.955 $^{+0.037}_{-0.046}$</td>
<td>22.392 $^{+0.283}_{-0.411}$</td>
</tr>
<tr>
<td>680</td>
<td>25.007 $^{+0.285}_{-0.408}$</td>
<td>25.647 $^{+0.075}_{-0.101}$</td>
<td>32.188 $^{+0.214}_{-0.397}$</td>
</tr>
</tbody>
</table>

These NNLO QCD results for inclusive $t\bar{t}$-decay widths (exact in $m_t$) agree with the large $m_h$ approximation result (to 4-th order in $(m_t/m_h)^2$) in [Harlander, Steinhauser, 1997].
Decays of BSM scalars/pseudo-scalars into $t\bar{t}$: inclusive decay rates

The decay width into $t\bar{t}$ of scalars/pseudo-scalars at LO, NLO, and NNLO in $\alpha_s$ as a function of $m_h$.

![Graph showing decay widths](image-url)
Decays of BSM scalars/pseudo-scalars into $t\bar{t}$: $m_{t\bar{t}}$ distribution

Distribution $d\Gamma_{X}^{t\bar{t}} / dM_{t\bar{t}}$ of the $t\bar{t}$ invariant mass with $m_{h} = 500$ GeV.
SM $h(125) \rightarrow b\bar{b} + X$: the inclusive decay width

We work in a "5-flavor" QCD:

**Standard-Model inputs**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$m_h$</td>
<td>125.09 GeV</td>
</tr>
<tr>
<td>$m_b(\mu = \bar{m}_b)$</td>
<td>4.18 GeV</td>
</tr>
<tr>
<td>$\alpha_s^{(5)}(m_Z)$</td>
<td>0.118</td>
</tr>
<tr>
<td>$G_F$</td>
<td>$1.166379 \times 10^{-5} \frac{1}{\text{GeV}^2}$</td>
</tr>
</tbody>
</table>

From the 5-flavor QCD two-loop running-mass formula, it reads $m_{b}^{on} = 4.78$ GeV and $\bar{m}_b(\mu = m_h) = 2.80$ GeV, and hence $\bar{y}_b(\mu) = \frac{\bar{m}_b(\mu)}{v_{vev}} = 0.01137$.

We represent our result for inclusive decay width using $\overline{\text{MS}}$ Yukawa-coupling $\bar{y}_b$:

$$\Gamma_{NNLO}^{b\bar{b}} = \Gamma_{LO}^{b\bar{b}} \left[ 1 + g_1 \frac{\alpha_s^{(5)}}{\pi} + g_2 \left( \frac{\alpha_s^{(5)}}{\pi} \right)^2 \right],$$

where

$$\Gamma_{LO}^{b\bar{b}} = \bar{y}_b^2(\mu) \hat{\Gamma}_0^{b\bar{b}}, \quad g_1 = \gamma_1^{b\bar{b}} + r_1, \quad g_2 = \gamma_2^{b\bar{b}} + r_1 \gamma_1^{b\bar{b}} + r_2.$$
**SM $h(125) \to b\bar{b} + X$: the inclusive decay width**

For the QCD-correction coefficients $g_1$, $g_2$ defined in

$$
\Gamma_{NNLO}^{b\bar{b}} = \Gamma_{LO}^{b\bar{b}} \left[ 1 + g_1 \frac{\alpha_s^{(5)}}{\pi} + g_2 \left(\frac{\alpha_s^{(5)}}{\pi}\right)^2 \right],
$$

we obtain

<table>
<thead>
<tr>
<th></th>
<th>$\mu = m_h / 2$</th>
<th>$\mu = m_h$</th>
<th>$\mu = 2m_h$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$g_1$</td>
<td>3.024</td>
<td>5.796</td>
<td>8.569</td>
</tr>
<tr>
<td>$g_2$</td>
<td>3.685</td>
<td>37.371</td>
<td>86.112</td>
</tr>
<tr>
<td>$\Gamma_{LO}^{b\bar{b}}$ [MeV]</td>
<td>2.153</td>
<td>1.910</td>
<td>1.717</td>
</tr>
<tr>
<td>$\Gamma_{NLO}^{b\bar{b}}$ [MeV]</td>
<td>2.413</td>
<td>2.307</td>
<td>2.196</td>
</tr>
<tr>
<td>$\Gamma_{NNLO}^{b\bar{b}}$ [MeV]</td>
<td>2.425</td>
<td>2.399</td>
<td>2.353</td>
</tr>
</tbody>
</table>

The known results for massless $b$ quarks ($\mu = m_h$):

$$
g_1(m_b = 0) = 5.6666 \text{ and } g_2(m_b = 0) = 29.1467
$$

SM $h(125) \rightarrow b\bar{b} + X$: the inclusive decay width

For the QCD-correction coefficients $g_1, g_2$ defined in

$$\Gamma_{NNLO}^{b\bar{b}} = \Gamma_{LO}^{b\bar{b}} \left[ 1 + g_1 \frac{\alpha_s^{(5)}}{\pi} + g_2 \left( \frac{\alpha_s^{(5)}}{\pi} \right)^2 \right],$$

we obtain

<table>
<thead>
<tr>
<th></th>
<th>$\mu = m_h/2$</th>
<th>$\mu = m_h$</th>
<th>$\mu = 2m_h$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$g_1$</td>
<td>3.024</td>
<td>5.796</td>
<td>8.569</td>
</tr>
<tr>
<td>$g_2$</td>
<td>3.685</td>
<td>37.371</td>
<td>86.112</td>
</tr>
<tr>
<td>$\Gamma_{LO}^{b\bar{b}}$ [MeV]</td>
<td>2.153</td>
<td>1.910</td>
<td>1.717</td>
</tr>
<tr>
<td>$\Gamma_{NLO}^{b\bar{b}}$ [MeV]</td>
<td>2.413</td>
<td>2.307</td>
<td>2.196</td>
</tr>
<tr>
<td>$\Gamma_{NNLO}^{b\bar{b}}$ [MeV]</td>
<td>2.425</td>
<td>2.399</td>
<td>2.353</td>
</tr>
</tbody>
</table>

$1 + g_1 \alpha_s + g_2 \alpha_s^2 + \cdots$  total value  components
massive ($\alpha_s^2$)  1.2560  $1 + 0.20789 + 0.04808$
massless ($\alpha_s^4$)  1.2413  $1 + 0.203242 + 0.0374917 + 0.001927 + (-0.001366)$

$n_f = 5, \mu = m_h$  [Baikov, Chetyrkin, Kuhn, 06]

Long Chen (MPI)  NNLO differential decay rates of Higgs  HC 2018  10 / 13
The distribution of the energy of the leading jet in two-jet events is defined w.r.t
\[ x_{\text{max}} = \max(E_{j_1}/m_h, E_{j_2}/m_h) \]
using Durham jet-algorithm with \( y_{\text{cut}} = 0.05 \).

Similar distributions were presented before for massless \( b \) quarks [Anastasiou, Herzog, Lazopoulos, 2012] (JADE, with \( y_{\text{cut}} = 0.1 \)) and in [Duca, Duhr, Somogyi, Tramontano, Trocsanyi, 2015] (Durham, with \( y_{\text{cut}} = 0.05 \)).
A set up is presented for calculating the fully differential decay width of a scalar and pseudo-scalar to a massive $Q\bar{Q}$ pair at NNLO in $\alpha_s$, which can be used to compute any infrared-safe (differential) observable in these decays.

The set-up is applied to the decays of heavy scalars and pseudo-scalars to $t\bar{t} + X$, and to the decay of the Standard-Model $h(125)$ Higgs boson to massive $b$, $\bar{b}$ quarks. As a check, inclusive decay rates known before are recovered.

We expect that this set up should be useful for having a more precise (and consistent) theoretical description of the $\alpha_s^2$ QCD corrections to the production of the Higgs boson in association with a massive vector boson at LHC, $pp \rightarrow V(W/Z) + H(b\bar{b})$. 
A set up is presented for calculating the fully differential decay width of a scalar and pseudo-scalar to a massive $Q\bar{Q}$ pair at NNLO in $\alpha_s$, which can be used to compute any infrared-safe (differential) observable in these decays.

The set-up is applied to the decays of heavy scalars and pseudo-scalars to $t\bar{t} + X$, and to the decay of the Standard-Model $h(125)$ Higgs boson to massive $b, \bar{b}$ quarks. As a check, inclusive decay rates known before are recovered.

We expect that this set up should be useful for having a more precise (and consistent) theoretical description of the $\alpha_s^2$ QCD corrections to the production of the Higgs boson in association with a massive vector boson at LHC, $pp \rightarrow V(W/Z) + H(b\bar{b})$.

THANK YOU
THE END

THANK YOU
Backup-Slides
Top-Triangle diagrams absent in massless b-quark computations

These amplitudes are ultraviolet- and infrared-finite (directly calculable in 4-dimension).

Figure: The flavor-singlet contributions to \( h \rightarrow Q\bar{Q} \) and \( h \rightarrow Q\bar{Q}g \), where \( Q, Q' = t, b \) and \( h \) denotes a scalar or pseudoscalar Higgs boson. If the quark in a triangle (a) or (b) is taken to be massless then the contribution is zero. Diagrams with reversed fermion flow in the triangles are not shown.

These contributions can not be consistently added in a massless computation at NNLO [Caola, Luisoni, Melnikov, Rontsch, 17].
To lowest order in $\alpha_s$

\[
\hat{\Gamma}_o^{Q\bar{Q}} = N_c \frac{\beta_Q}{8\pi m_h} [a_Q^2 (m_h^2 - 4m_Q^2) + b_Q^2 m_Q^2],
\]

where $\beta_Q = \sqrt{1 - 4m_Q^2 / m_h^2}$ and $N_c$ denotes the number of colors.

\[
\tilde{\Gamma}^{b\bar{b}}_{\text{NNLO}} = \tilde{\Gamma}^{b\bar{b}}_{\text{LO}} \left[ 1 + g_1 \frac{\alpha_s^{(5)}}{\pi} + g_2 \left( \frac{\alpha_s^{(5)}}{\pi} \right)^2 \right],
\]

where

\[
\tilde{\Gamma}^{b\bar{b}}_{\text{LO}} = \bar{y}_b^2(\mu) \hat{\Gamma}_o^{b\bar{b}}, \quad g_1 = \gamma_1^{b\bar{b}} + r_1, \quad g_2 = \gamma_2^{b\bar{b}} + r_1 \gamma_1^{b\bar{b}} + r_2.
\]

<table>
<thead>
<tr>
<th>$y^{\text{MS}}_b$</th>
<th>$\mu = m_h$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$g_1$</td>
<td>5.796</td>
</tr>
<tr>
<td>$g_2$</td>
<td>37.371</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>$\mu = m_h$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$y_b^\text{on-shell}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-9.93, 15.73</td>
</tr>
<tr>
<td></td>
<td>-113.2, 306.7</td>
</tr>
</tbody>
</table>

| $\tilde{\Gamma}^{b\bar{b}}_{\text{LO}} [\text{MeV}]$ | 1.910 |
| $\tilde{\Gamma}^{b\bar{b}}_{\text{NLO}} [\text{MeV}]$ | 2.307 |
| $\tilde{\Gamma}^{b\bar{b}}_{\text{NNLO}} [\text{MeV}]$ | 2.399 |
| $\Gamma^{b\bar{b}}_{\text{LO}} [\text{MeV}]$ | 5.578 |
| $\Gamma^{b\bar{b}}_{\text{NLO}} [\text{MeV}]$ | 3.592 |
| $\Gamma^{b\bar{b}}_{\text{NNLO}} [\text{MeV}]$ | 2.772 |
$h \rightarrow Q\bar{Q}$ decay width with $m_b = 0.5$ GeV

The QCD-correction coefficients $g_1$, $g_2$ are defined in

$$\Gamma_{NNLO}^{b\bar{b}} = \Gamma_{LO}^{b\bar{b}} \left[ 1 + g_1 \frac{\alpha_s^{(5)}}{\pi} + g_2 \left( \frac{\alpha_s^{(5)}}{\pi} \right)^2 \right].$$

The known results for massless $b$ quarks ($\mu = m_h$):

$$g_1(m_b = 0) = 5.6666 \text{ and } g_2(m_b = 0) = 29.1467$$


We cannot perform the limit $m_b \rightarrow 0$ analytically. Therefore we choose a value for $m_b = 0.5$ GeV that is very small compared to $m_h (\approx \frac{1}{250})$, and excluding the top-quark triangle loop diagrams (which contributes $g_{2t} = 6.898$, not sensitive to $m_b$), we obtain

$$g_1(m_b = 0.5 \text{GeV}) = 5.6685, \text{ and } g_2(m_b = 0.5 \text{GeV}) = 29.187.$$
Decays of BSM scalars/pseudo-scalars into $t\bar{t}$: the $x_t$ distribution

The normalized top-quark energy $x_t = 2E_t/m_h$ (in the rest frame of the Higgs boson) $d\Gamma_{t\bar{t}/X}/dx_t$ for a scalar/pseudo-scalar Higgs boson at LO, NLO, and NNLO QCD.
The $n$-jet rates can be represented, in analogy to the inclusive decay width, to order $\alpha_s^2$ as follows:

$$\Gamma_{2\text{jet}}^{b\bar{b}} = \Gamma_{LO}^{b\bar{b}} \left[ 1 + g_1(2\text{ jet}) \frac{\alpha_s(5)}{\pi} + g_2(2\text{ jet}) \left( \frac{\alpha_s(5)}{\pi} \right)^2 \right],$$  \hspace{1cm} (4)$$

$$\Gamma_{3\text{jet}}^{b\bar{b}} = \Gamma_{LO}^{b\bar{b}} \left[ g_1(3\text{ jet}) \frac{\alpha_s(5)}{\pi} + g_2(3\text{ jet}) \left( \frac{\alpha_s(5)}{\pi} \right)^2 \right],$$ \hspace{1cm} (5)$$

$$\Gamma_{4\text{jet}}^{b\bar{b}} = \Gamma_{LO}^{b\bar{b}} \times g_2(4\text{ jet}) \left( \frac{\alpha_s(5)}{\pi} \right)^2$$ \hspace{1cm} (6)$$

**Table:** The coefficients $g_i(n\text{ jet})$ defined above and computed with the Durham algorithm using $y_{\text{cut}} = 0.01$ and $y_{\text{cut}} = 0.05$ for three renormalization scales $\mu$.

<table>
<thead>
<tr>
<th></th>
<th>$y_{\text{cut}} = 0.01$</th>
<th>$y_{\text{cut}} = 0.05$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mu = m_h/2$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$g_1(2\text{ jet})$</td>
<td>$-5.055$</td>
<td>$0.291$</td>
</tr>
<tr>
<td>$g_2(2\text{ jet})$</td>
<td>$-56.351$</td>
<td>$0.291$</td>
</tr>
<tr>
<td>$g_1(3\text{ jet})$</td>
<td>$8.079$</td>
<td>$2.733$</td>
</tr>
<tr>
<td>$g_2(3\text{ jet})$</td>
<td>$36.873$</td>
<td>$2.733$</td>
</tr>
<tr>
<td>$g_2(4\text{ jet})$</td>
<td>$23.163$</td>
<td>$2.733$</td>
</tr>
</tbody>
</table>