Higgs to Z $+ \gamma$ at NLO (with full top-mass dependence)

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Next-to-Leading Order QCD and Light-Fermion Corrections to the Decay Width $H \to Z\gamma \to \gamma l^+ l^-$

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Abstract: We present the analytic calculation of the following two sets of contributions at the NLO to the decay width of a Higgs boson into a photon and a leptonic pair: the QCD and the light-fermion corrections. The result is expressed in terms of Generalized Harmonic Polylogarithms of maximun weight 4. ....

Keywords: Higgs decay, Feynman diagrams, Multi-loop calculations.

[*]On leave of absence from Dipartimento di Fisica, Università di Roma "La Sapienza".

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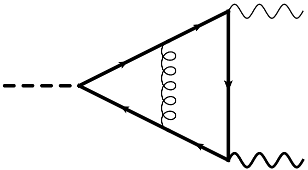
When calculating the cross section we consider $Z \to l\bar{l}$
so this makes it the narrow width approximation of $H \to \gamma l\bar{l}$

The QCD contribution is given by diagrams like



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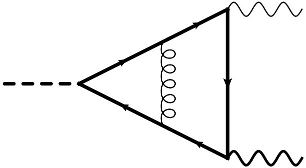
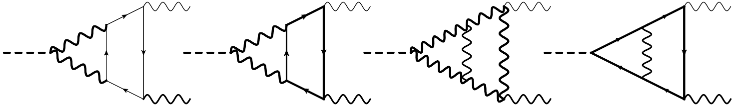
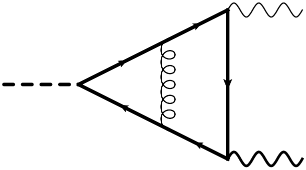
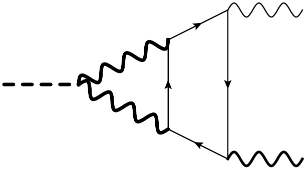


And the 'weak' contributions are given by



(We disregard $Hq\bar{q}$-couplings, internal Hs, etc.)

We will calculate the strong contribution and the massless fermion contribution

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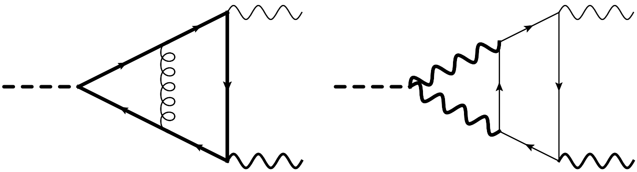
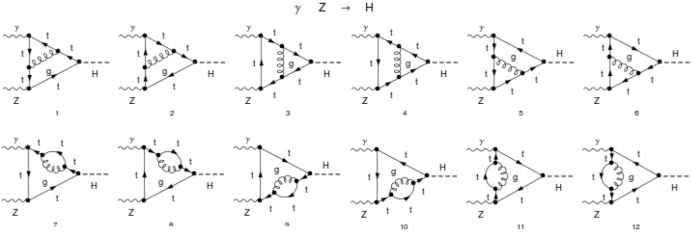


Why the massless fermions?

- It is (presumably) bigger than the other weak contributions due to the number of fermionic flavours.
- It contains no elliptic functions (so the answer is expressable in terms of Goncharov polylogs).

The strong contribution:

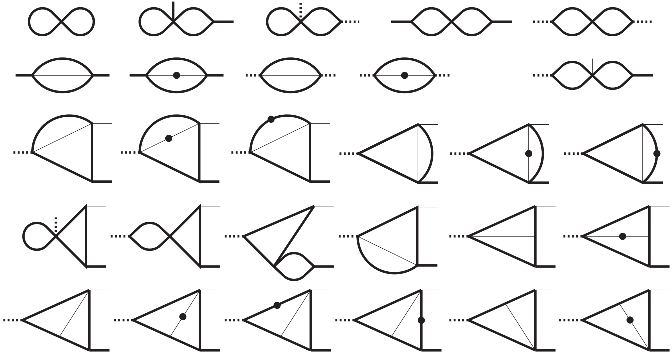
12 Feynman diagrams contribute:



Feynman diagrams are not the bottleneck

Use IBP identities (FIRE5 ArXiv:1408.2372) to reduce all Feynman integrals to master integrals.

There are 28 masters in total:



Find analytical expressions for the masters using differential eqs.

"The Henn Method:" (arXiv:1304.1806)
Find a basis such that

$$\mathrm{d}g(\epsilon, \bar{x}) = \epsilon \mathrm{d}A(\bar{x}) g(\epsilon, \bar{x})$$

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The solution at each order is given by Goncharov polylogs

$$G(a_1, a_2, \ldots, a_n; x) = \int_0^x \frac{\mathrm{d}t}{t - a_1} G(a_2, \ldots, a_n; t)$$

(If A is expressable without roots).

We have the kinematic variables m_H, m_Z, m_t
but use m_t^2, x, y, such that

$$m_z^2 = -m_t^2 \frac{(1-x)^2}{x} \qquad m_H^2 = -m_t^2 \frac{(1-y)^2}{y}$$

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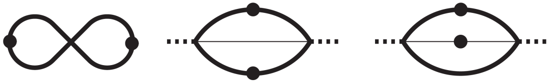
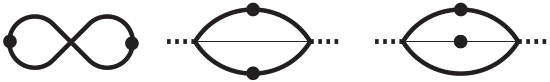
A good boundary point is $m_Z = m_H = 0$
corresponding to $x = y = 1$.

This can be found using 'expansion by subgraphs'.



$$f \propto (m_t^2)^{2\epsilon} \left\{ I_{220} \ , \quad -m_H^2 I_{221} \ , \quad -\sqrt{m_H^4 - 4m_H^2 m_t^2}\left(I_{221} + 2I_{212}\right) \right\}$$



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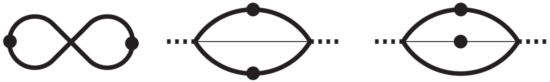
$$A = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 2\log(y-1) - \log(y) & -2\log(y) \\ \log(y) & 3\log(y) & -2\log(y-1) + 4\log(y) - 6\log(y+1) \end{bmatrix}$$



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$$\begin{aligned} f_3 = {} & 0 + G(0,y)\epsilon + \Big(6G(0,-1,y) + 2G(0,1,y) - 6G(0,y)G(-1,y) - 2G(0,y)G(1,y) \\ & + 2G(0,y)^2 - \tfrac{1}{6}\pi^2\Big)\epsilon^2 + \Big(\pi^2 G(-1,y) + \tfrac{1}{3}\pi^2 G(1,y) - 36G(-1,0,-1,y) - 12G(-1,0,1,y) \\ & - 36G(0,-1,-1,y) - 12G(0,-1,1,y) + 24G(0,0,-1,y) + 8G(0,0,1,y) - 12G(0,1,-1,y) \\ & - 4G(0,1,1,y) - 12G(1,0,-1,y) - 4G(1,0,1,y) - 12G(0,y)^2 G(-1,y) - 4G(0,y)^2 G(1,y) \\ & + 36G(0,y)G(-1,-1,y) + 12G(0,y)G(-1,1,y) + 12G(0,y)G(1,-1,y) + 4G(0,y)G(1,1,y) \\ & + \tfrac{5}{3}G(0,y)^3 - \tfrac{2}{3}\pi^2 G(0,y) - 11\zeta_3\Big)\epsilon^3 + \mathcal{O}(\epsilon^4) \end{aligned}$$

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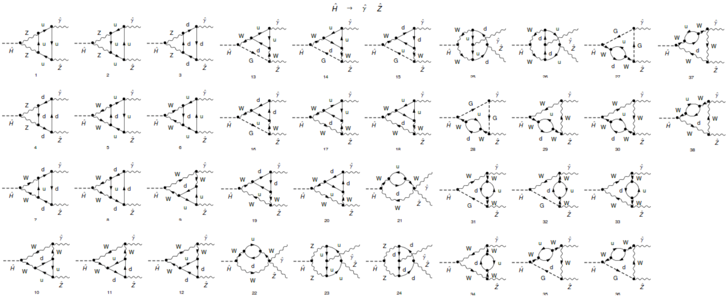
$\approx$ 38 Feynman diagrams (depends on gauge choice):



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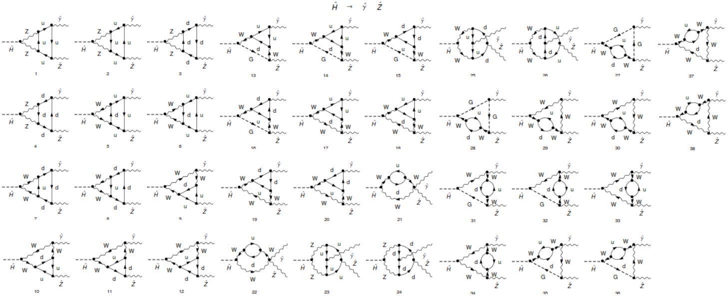

35 master integrals in two families (planar and non-planar).
(Internal W and internal Z can be treated alike)

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But the Ward identity holds

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We need to compare the result with the with the numerical one, and to express it in terms of log and Li_n (and Li_{22}).

Thank you for listening ...

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