Karlsruhe Institute of Technology

Institute for Theoretical Physics

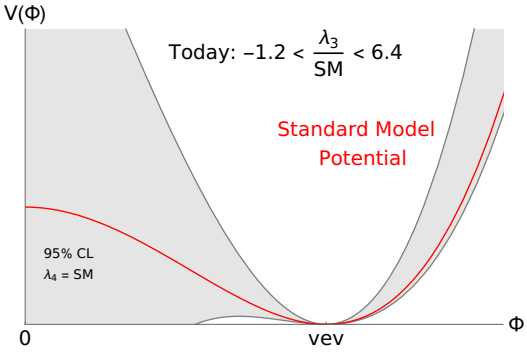
Electroweak Corrections to Higgs Boson Pair Production: The Light Quark Case [2503.16620]

Marco Bonetti, **Philipp Rendler**, William J. Torres Bobadilla | July 21, 2025

Overview

The Trilinear Higgs Coupling

$$\mathcal{L}_{\text{Higgs}} = \frac{1}{2}\left(\partial_\mu H\right)\left(\partial^\mu H\right) + \frac{1}{2}m^2H^2 + \lambda_3 H^3 + \lambda_4 H^4$$



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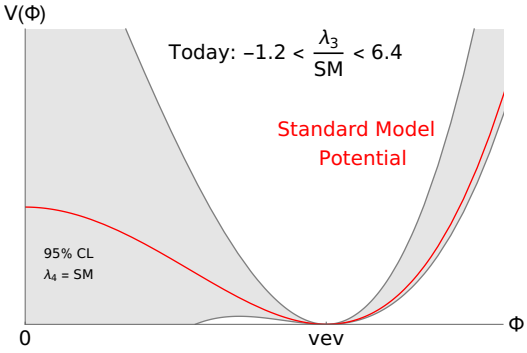

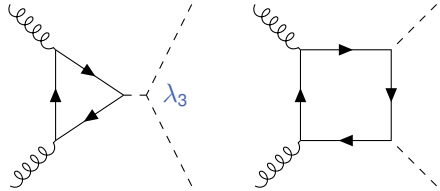

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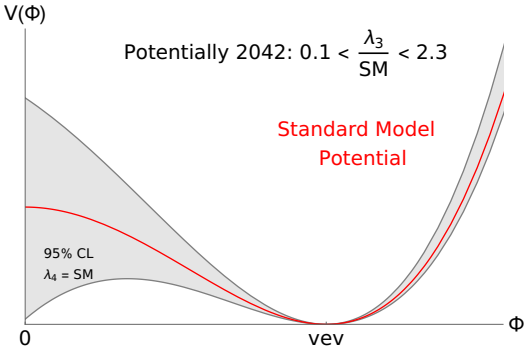
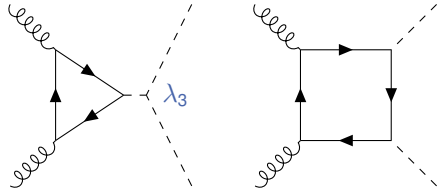
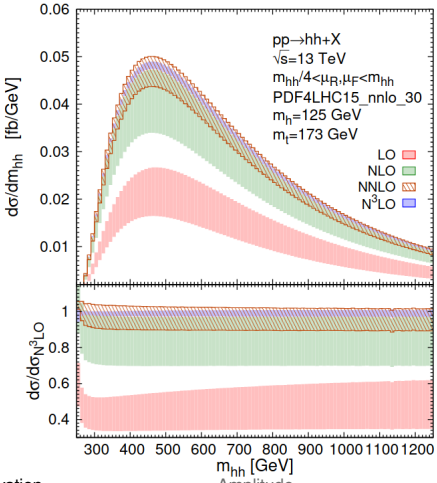




QCD Corrections

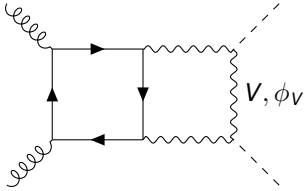


- QCD: N^{3}LO corrections:
  $+60\,\%(\mathrm{NLO}) \rightarrow +30\,\%(\mathrm{NNLO_{HTL}}) \rightarrow +7\,\%(\mathrm{N^3LO_{HTL}})$
- Currently under investigation: [2501.00587]
  Top mass renormalization uncertainty $\mathcal{O}(5\,\%)$

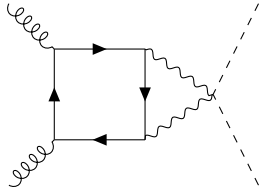
$\Rightarrow$ Electroweak corrections are relevant

[1912.13001]

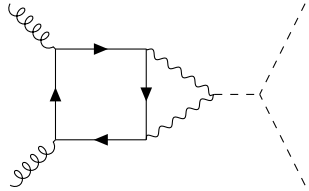
Electroweak Corrections: The Light Quark Case



(a) VVV



(b) VVHH



(c) VVH

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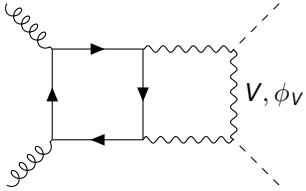

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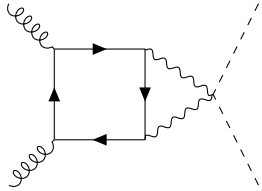

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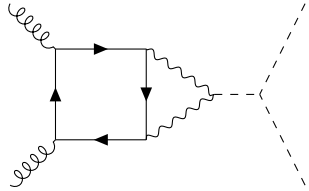
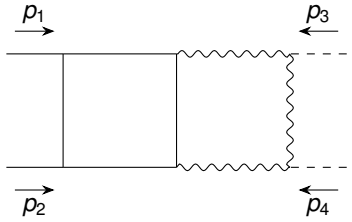


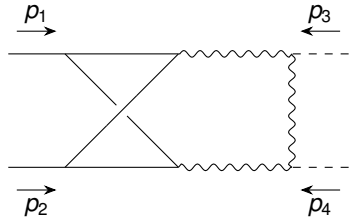
(c) VVH

$$\mathcal{M} \propto \begin{cases} \mathcal{F}^{++} = \mathcal{A}_1 + \mathcal{A}_3 + \frac{3m_H^2}{s-m_H^2}\mathcal{A}_3 \\ \mathcal{F}^{+-} = \mathcal{A}_2 \end{cases}$$

Topologies



Planar topology: 45 master integrals



Non-planar topology: 43 master integrals

Differential Equations

DEs in Canonical Form

$$\mathrm{d}\mathbf{J} = \varepsilon \sum_{i=1}^{77} \mathbb{A}_i \, \mathrm{dlog}(\alpha_i) \, \mathbf{J}$$

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Solution: Chen Iterated Integrals

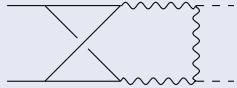
$$\mathbf{J} = \sum_n \varepsilon^n \mathbf{J}^{(n)}$$

$$\mathbf{J}^{(n)} = \int \sum_{i=1}^{77} \mathbb{A}_i \, \mathrm{dlog}(\alpha_i) \, \mathbf{J}^{(n-1)} + \mathbf{C}^{(n)}$$

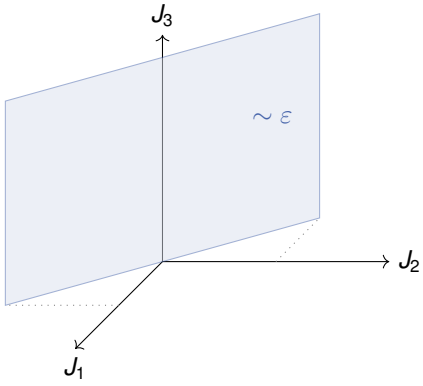
Boundary Conditions

We generate boundary functions with the **large mass expansion** $m_V^2 \to \infty$.

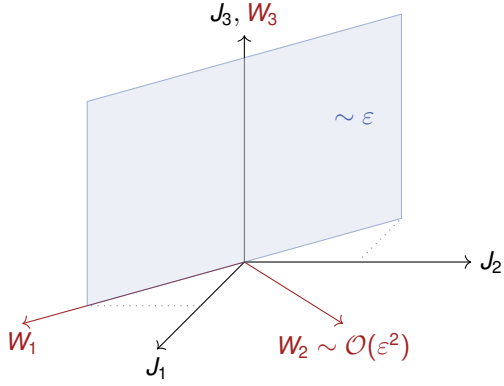
Example: Large Mass Expansion

m_V^6  $\xrightarrow[m_V^2 \to \infty]{}$ m_V^6  $= -\frac{2}{\varepsilon^2} - \frac{10}{\varepsilon} + (-20 - \pi^2) + \mathcal{O}(\varepsilon)$

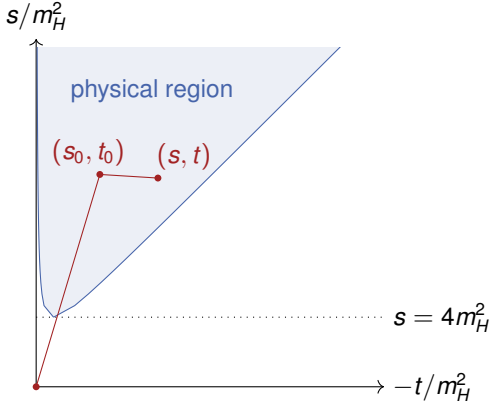
Rotation of Canonical Basis



$\mathbf{J} \longrightarrow \mathbf{W} = R\,\mathbf{J}$



Numerical Evaluation



We decompose the rotated basis into **independent functions**,

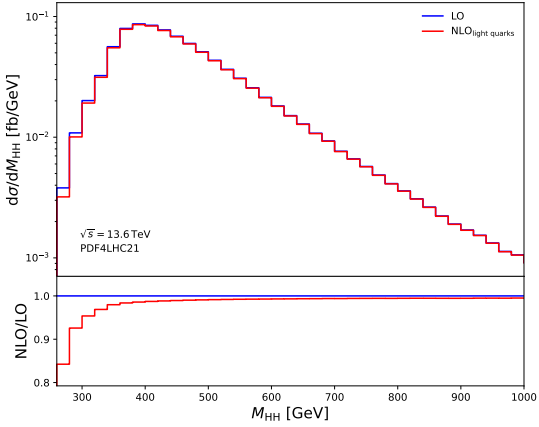
$$W_i(x) = \sum_j \varepsilon^j w_i^{(j)}(x)\,.$$

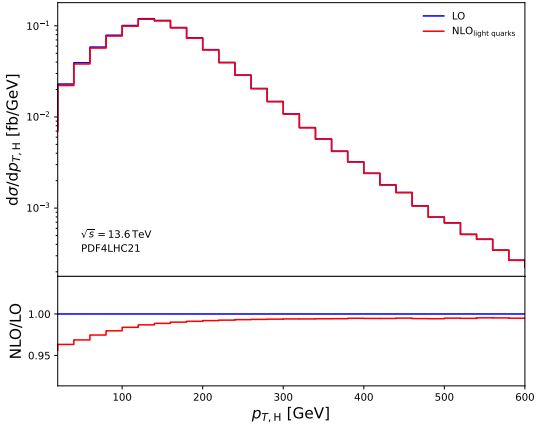
Then, we construct **differential equations**,

$$\mathrm{d}w_i^{(j)} = \sum_k \mathrm{d}\Omega_{i,k}\, w_k^{(j-1)}\,,$$

which we solve with DIFFEXP [2006.05510].

Results


LO
NLO$_{\text{light quarks}}$
$\sqrt{s} = 13.6\,\text{TeV}$
PDF4LHC21
$d\sigma/dM_{HH}$ [fb/GeV]
NLO/LO
M_{HH} [GeV]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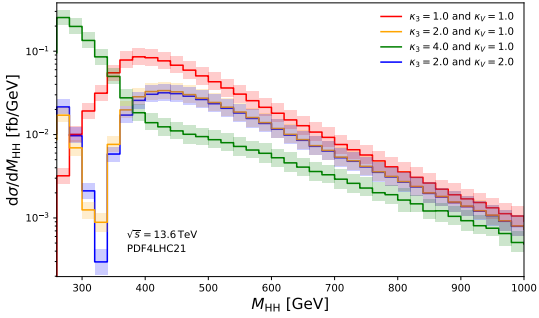
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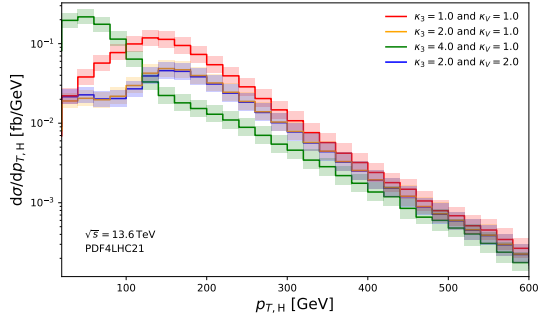
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Future projects:

- The dependence of the form factors on **coupling variations** will be addressed in a dedicated study
- Combination with further EW and QCD corrections
- The integrals and computational framework will be used for **quark-initiated double Higgs production**.

Thank you!