Higgs pair production: EFT and BSM

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Outline

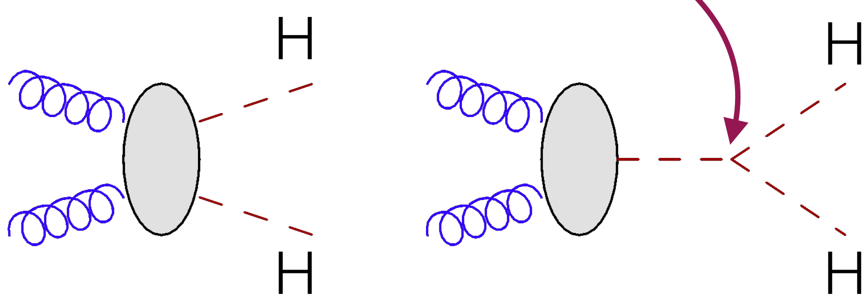
- HH overview
- SMEFT for HH
- HH resonances

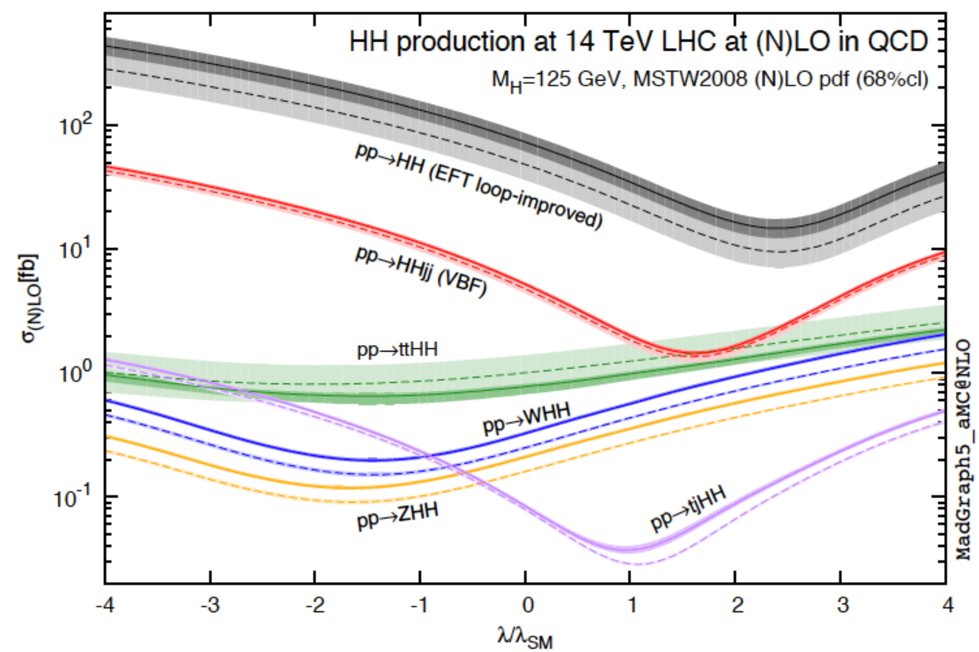
Higgs pair production

The Higgs potential

$$V(H) = \frac{1}{2}M_H^2 H^2 + \lambda_{HHH} v H^3 + \frac{1}{4}\lambda_{HHHH} H^4$$

$$\lambda_{HHH} = \lambda_{HHHH} = \frac{M_H^2}{2v^2}$$

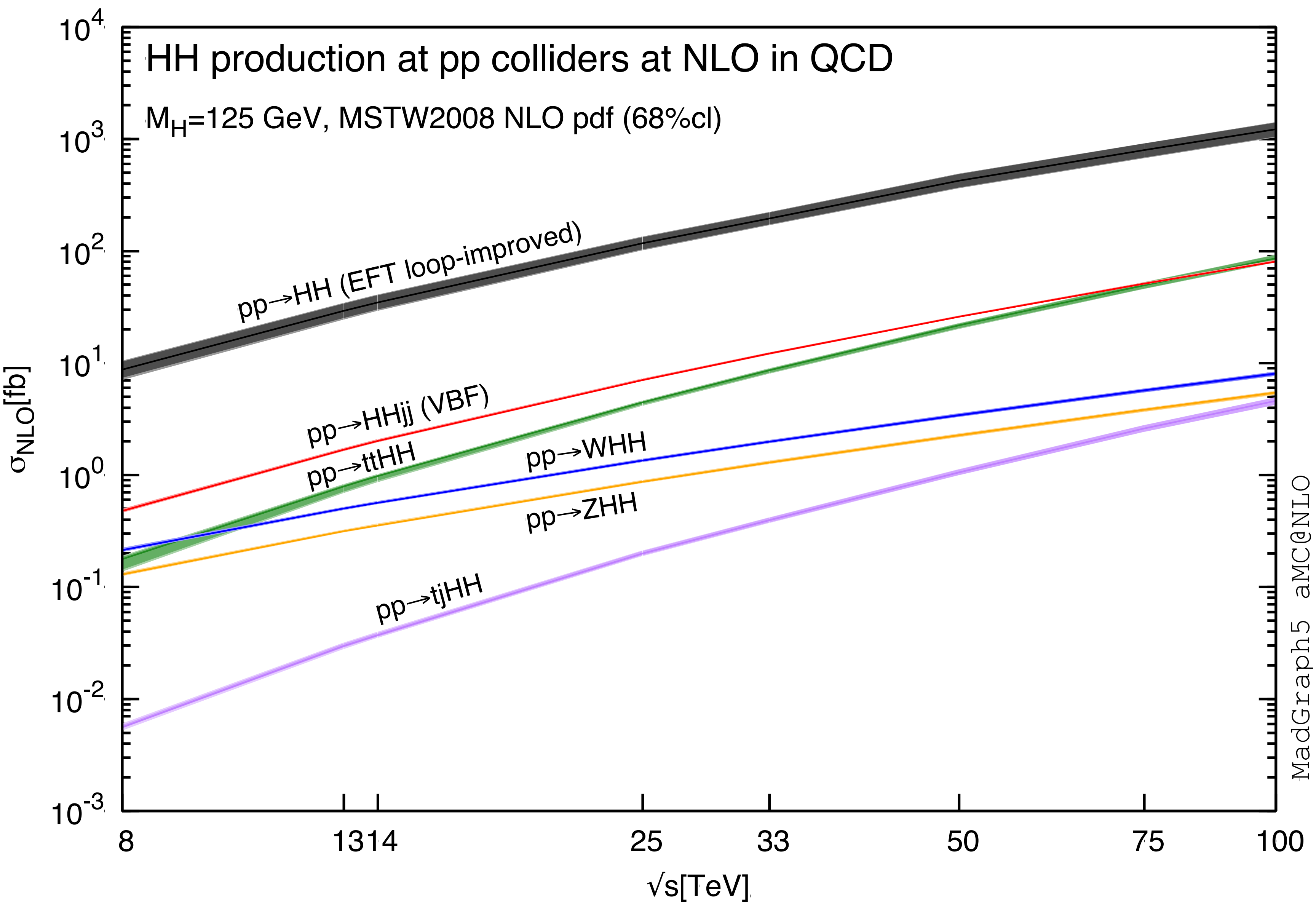




Frederix et al. arxiv:1401.7340

A CHALLENGING PROCESS

Overview of HH in the SM



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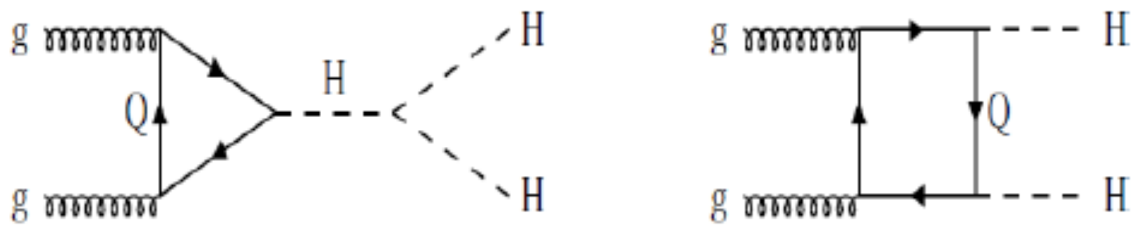
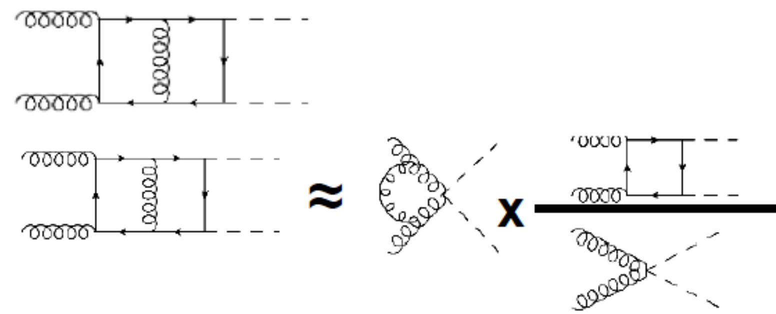
Gluon fusion cross-section



$\sqrt{s}$	13 TeV	14 TeV
NLO [fb]	$27.78^{+13.8\%}_{-12.8\%}$	$32.88^{+13.5\%}_{-12.5\%}$
$\text{NLO}_{\text{FTapprox}}$ [fb]	$28.91^{+15.0\%}_{-13.4\%}$	$34.25^{+14.7\%}_{-13.2\%}$
$\text{NNLO}_{\text{FTapprox}}$ [fb]	$31.05^{+2.2\%}_{-5.0\%}$	$36.69^{+2.1\%}_{-4.9\%}$

Borowka et al 1604.06447, 1608.04798



Born-reweighted loops: $$\mathcal{R}(ij \to HH + X) = \frac{\mathcal{A}^{\text{Born}}_{\text{Full}}(ij \to HH + X)}{\mathcal{A}^{(0)}_{\text{HEFT}}(ij \to HH + X)}$$

Exact double real emission: HH+2 jets

M. Grazzini et al. arXiv:1803.02463

See Gudrun’s and Seraina’s talk for more on the SM cross-section

BSM in HH

HH: a Beyond the SM physics window

Specific models:
Additional particles
Resonances, loop contributions

Model independent:
EFT: Higher dimensional operators

- Non SM Yukawa couplings (1205.5444, 1206.6663)
- Resonances from extra dimensions (1303.6636)
- Vector-like quarks (1009.4670, 1206.6663,1703.10614)
- Light coloured scalars (1207.4496,1504.05596)
- Dimension-6 operators (hep-ph/0609049, 1410.3471, 1502.00539, 1504.06577, 1205.5444, 1704.05700, 1705.05314)
- Higgs Singlet Model (1508.05397)
- 2HDM (1403.1264, 1407.0281,1909.09987)

I. SMEFT for HH

SMEFT

New Interactions of SM particles

$$\mathcal{L}_{\text{Eff}} = \mathcal{L}_{\text{SM}} + \sum_i \frac{C_i^{(6)} O_i^{(6)}}{\Lambda^2} + \mathcal{O}(\Lambda^{-4})$$

Buchmuller, Wyler Nucl.Phys. B268 (1986) 621-653

Grzadkowski et al arxiv:1008.4884

X^3		φ^6 and $\varphi^4 D^2$		$\psi^2\varphi^3$	
Q_G	$f^{ABC} G_\mu^{A\nu} G_\nu^{B\rho} G_\rho^{C\mu}$	Q_φ	$(\varphi^\dagger\varphi)^3$	$Q_{e\varphi}$	$(\varphi^\dagger\varphi)(\bar l_p e_r \varphi)$
$Q_{\widetilde G}$	$f^{ABC} \widetilde G_\mu^{A\nu} G_\nu^{B\rho} G_\rho^{C\mu}$	$Q_{\varphi\Box}$	$(\varphi^\dagger\varphi)\Box(\varphi^\dagger\varphi)$	$Q_{u\varphi}$	$(\varphi^\dagger\varphi)(\bar q_p u_r \widetilde\varphi)$
Q_W	$\varepsilon^{IJK} W_\mu^{I\nu} W_\nu^{J\rho} W_\rho^{K\mu}$	$Q_{\varphi D}$	$\left(\varphi^\dagger D^\mu\varphi\right)^\star \left(\varphi^\dagger D_\mu\varphi\right)$	$Q_{d\varphi}$	$(\varphi^\dagger\varphi)(\bar q_p d_r \varphi)$
$Q_{\widetilde W}$	$\varepsilon^{IJK} \widetilde W_\mu^{I\nu} W_\nu^{J\rho} W_\rho^{K\mu}$				

$X^2\varphi^2$		$\psi^2 X\varphi$		$\psi^2\varphi^2 D$	
$Q_{\varphi G}$	$\varphi^\dagger\varphi\, G^A_{\mu\nu} G^{A\mu\nu}$	Q_{eW}	$(\bar l_p \sigma^{\mu\nu} e_r)\tau^I \varphi W^I_{\mu\nu}$	$Q_{\varphi l}^{(1)}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar l_p \gamma^\mu l_r)$
$Q_{\varphi\widetilde G}$	$\varphi^\dagger\varphi\, \widetilde G^A_{\mu\nu} G^{A\mu\nu}$	Q_{eB}	$(\bar l_p \sigma^{\mu\nu} e_r)\varphi B_{\mu\nu}$	$Q_{\varphi l}^{(3)}$	$(\varphi^\dagger i\overleftrightarrow{D}^I_\mu \varphi)(\bar l_p \tau^I \gamma^\mu l_r)$
$Q_{\varphi W}$	$\varphi^\dagger\varphi\, W^I_{\mu\nu} W^{I\mu\nu}$	Q_{uG}	$(\bar q_p \sigma^{\mu\nu} T^A u_r)\widetilde\varphi\, G^A_{\mu\nu}$	$Q_{\varphi e}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar e_p \gamma^\mu e_r)$
$Q_{\varphi\widetilde W}$	$\varphi^\dagger\varphi\, \widetilde W^I_{\mu\nu} W^{I\mu\nu}$	Q_{uW}	$(\bar q_p \sigma^{\mu\nu} u_r)\tau^I \widetilde\varphi\, W^I_{\mu\nu}$	$Q_{\varphi q}^{(1)}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar q_p \gamma^\mu q_r)$
$Q_{\varphi B}$	$\varphi^\dagger\varphi\, B_{\mu\nu} B^{\mu\nu}$	Q_{uB}	$(\bar q_p \sigma^{\mu\nu} u_r)\widetilde\varphi\, B_{\mu\nu}$	$Q_{\varphi q}^{(3)}$	$(\varphi^\dagger i\overleftrightarrow{D}^I_\mu \varphi)(\bar q_p \tau^I \gamma^\mu q_r)$
$Q_{\varphi\widetilde B}$	$\varphi^\dagger\varphi\, \widetilde B_{\mu\nu} B^{\mu\nu}$	Q_{dG}	$(\bar q_p \sigma^{\mu\nu} T^A d_r)\varphi\, G^A_{\mu\nu}$	$Q_{\varphi u}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar u_p \gamma^\mu u_r)$
$Q_{\varphi WB}$	$\varphi^\dagger\tau^I\varphi\, W^I_{\mu\nu} B^{\mu\nu}$	Q_{dW}	$(\bar q_p \sigma^{\mu\nu} d_r)\tau^I \varphi\, W^I_{\mu\nu}$	$Q_{\varphi d}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar d_p \gamma^\mu d_r)$
$Q_{\varphi\widetilde W B}$	$\varphi^\dagger\tau^I\varphi\, \widetilde W^I_{\mu\nu} B^{\mu\nu}$	Q_{dB}	$(\bar q_p \sigma^{\mu\nu} d_r)\varphi\, B_{\mu\nu}$	$Q_{\varphi ud}$	$i(\widetilde\varphi^\dagger D_\mu \varphi)(\bar u_p \gamma^\mu d_r)$

$(\bar LL)(\bar LL)$		$(\bar RR)(\bar RR)$		$(\bar LL)(\bar RR)$	
Q_{ll}	$(\bar l_p \gamma_\mu l_r)(\bar l_s \gamma^\mu l_t)$	Q_{ee}	$(\bar e_p \gamma_\mu e_r)(\bar e_s \gamma^\mu e_t)$	Q_{le}	$(\bar l_p \gamma_\mu l_r)(\bar e_s \gamma^\mu e_t)$
$Q_{qq}^{(1)}$	$(\bar q_p \gamma_\mu q_r)(\bar q_s \gamma^\mu q_t)$	Q_{uu}	$(\bar u_p \gamma_\mu u_r)(\bar u_s \gamma^\mu u_t)$	Q_{lu}	$(\bar l_p \gamma_\mu l_r)(\bar u_s \gamma^\mu u_t)$
$Q_{qq}^{(3)}$	$(\bar q_p \gamma_\mu \tau^I q_r)(\bar q_s \gamma^\mu \tau^I q_t)$	Q_{dd}	$(\bar d_p \gamma_\mu d_r)(\bar d_s \gamma^\mu d_t)$	Q_{ld}	$(\bar l_p \gamma_\mu l_r)(\bar d_s \gamma^\mu d_t)$
$Q_{lq}^{(1)}$	$(\bar l_p \gamma_\mu l_r)(\bar q_s \gamma^\mu q_t)$	Q_{eu}	$(\bar e_p \gamma_\mu e_r)(\bar u_s \gamma^\mu u_t)$	Q_{qe}	$(\bar q_p \gamma_\mu q_r)(\bar e_s \gamma^\mu e_t)$
$Q_{lq}^{(3)}$	$(\bar l_p \gamma_\mu \tau^I l_r)(\bar q_s \gamma^\mu \tau^I q_t)$	Q_{ed}	$(\bar e_p \gamma_\mu e_r)(\bar d_s \gamma^\mu d_t)$	$Q_{qu}^{(1)}$	$(\bar q_p \gamma_\mu q_r)(\bar u_s \gamma^\mu u_t)$
		$Q_{ud}^{(1)}$	$(\bar u_p \gamma_\mu u_r)(\bar d_s \gamma^\mu d_t)$	$Q_{qu}^{(8)}$	$(\bar q_p \gamma_\mu T^A q_r)(\bar u_s \gamma^\mu T^A u_t)$
		$Q_{ud}^{(8)}$	$(\bar u_p \gamma_\mu T^A u_r)(\bar d_s \gamma^\mu T^A d_t)$	$Q_{qd}^{(1)}$	$(\bar q_p \gamma_\mu q_r)(\bar d_s \gamma^\mu d_t)$
				$Q_{qd}^{(8)}$	$(\bar q_p \gamma_\mu T^A q_r)(\bar d_s \gamma^\mu T^A d_t)$

$(\bar LR)(\bar RL)$ and $(\bar LR)(\bar LR)$		B-violating	
Q_{ledq}	$(\bar l_p^j e_r)(\bar d_s q_t^j)$	Q_{duq}	$\varepsilon^{\alpha\beta\gamma}\varepsilon_{jk}\left[(d_p^\alpha)^T C u_r^\beta\right]\left[(q_s^{\gamma j})^T C l_t^k\right]$
$Q_{quqd}^{(1)}$	$(\bar q_p^j u_r)\varepsilon_{jk}(\bar q_s^k d_t)$	Q_{qqu}	$\varepsilon^{\alpha\beta\gamma}\varepsilon_{jk}\left[(q_p^{\alpha j})^T C q_r^{\beta k}\right]\left[(u_s^\gamma)^T C e_t\right]$
$Q_{quqd}^{(8)}$	$(\bar q_p^j T^A u_r)\varepsilon_{jk}(\bar q_s^k T^A d_t)$	$Q_{qqq}^{(1)}$	$\varepsilon^{\alpha\beta\gamma}\varepsilon_{jk}\varepsilon_{mn}\left[(q_p^{\alpha j})^T C q_r^{\beta k}\right]\left[(q_s^{\gamma m})^T C l_t^n\right]$
$Q_{lequ}^{(1)}$	$(\bar l_p^j e_r)\varepsilon_{jk}(\bar q_s^k u_t)$	$Q_{qqq}^{(3)}$	$\varepsilon^{\alpha\beta\gamma}(\tau^I\varepsilon)_{jk}(\tau^I\varepsilon)_{mn}\left[(q_p^{\alpha j})^T C q_r^{\beta k}\right]\left[(q_s^{\gamma m})^T C l_t^n\right]$
$Q_{lequ}^{(3)}$	$(\bar l_p^j \sigma_{\mu\nu} e_r)\varepsilon_{jk}(\bar q_s^k \sigma^{\mu\nu} u_t)$	Q_{duu}	$\varepsilon^{\alpha\beta\gamma}\left[(d_p^\alpha)^T C u_r^\beta\right]\left[(u_s^\gamma)^T C e_t\right]$

SMEFT assumptions

- No light new physics ($E<\Lambda$)
- Expansion in $1/\Lambda^2$: dimension-6 effects are expected to be dominant over dimension-8 effects etc
- Respects the symmetries of the SM: Higgs is an SU(2) doublet (c.f. EWchL where H is a singlet: see Gudrun's talk)

Which operators enter in HH?

Constraints

$$O_{t\phi} = y_t^3 \left(\phi^\dagger \phi\right) (\bar{Q}t)\, \tilde{\phi}\,,$$ → Inclusive H, Higgs plus jets, ttH

$$O_{\phi G} = y_t^2 \left(\phi^\dagger \phi\right) G^A_{\mu\nu} G^{A\mu\nu}\,,$$ → Inclusive H, Higgs plus jets, ttH

$$O_{tG} = y_t g_s (\bar{Q}\sigma^{\mu\nu} T^A t)\tilde{\phi} G^A_{\mu\nu}$$ → tt, ttH, ttV….

$$O_6 = -\lambda(\phi^\dagger\phi)^3$$ → HH (single Higgs@NLO)

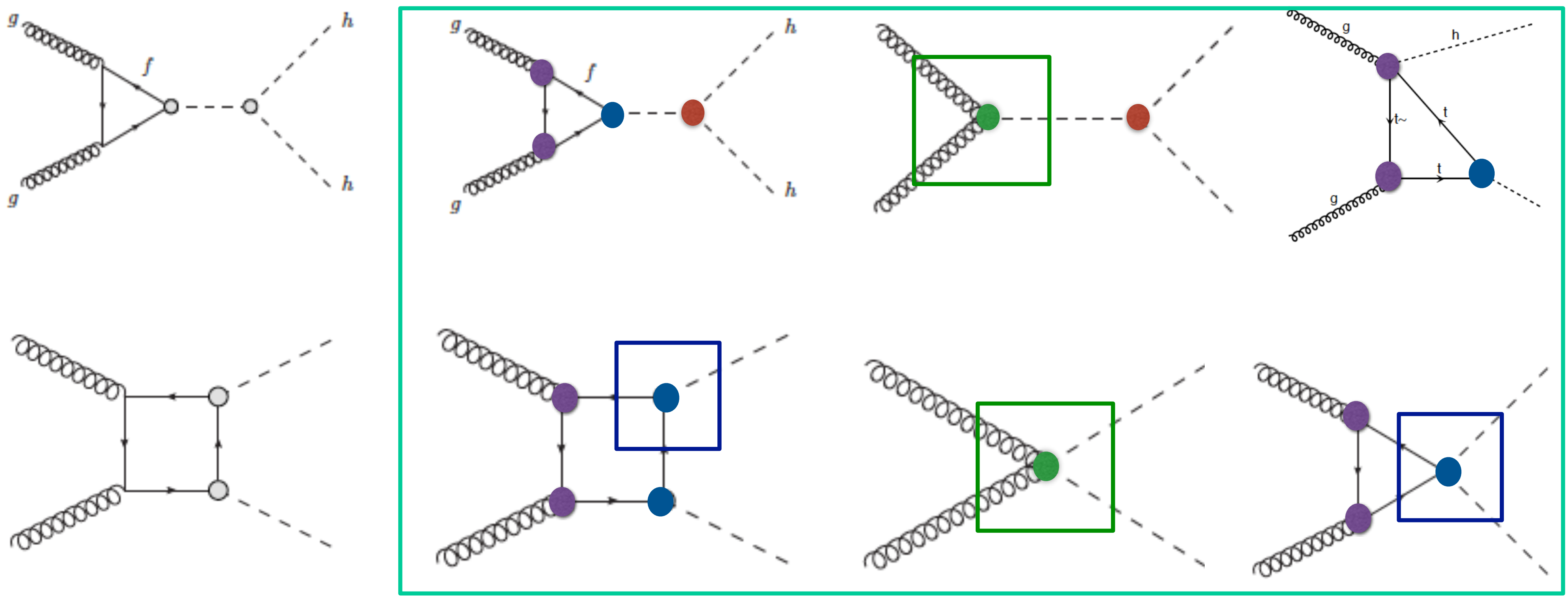
$$O_H = \frac{1}{2}(\partial_\mu(\phi^\dagger\phi))^2$$ → All Higgs couplings H decays, VH, VBF…

All but one operator will receive constraints from another processes (at LO)

SMEFT in HH

SM

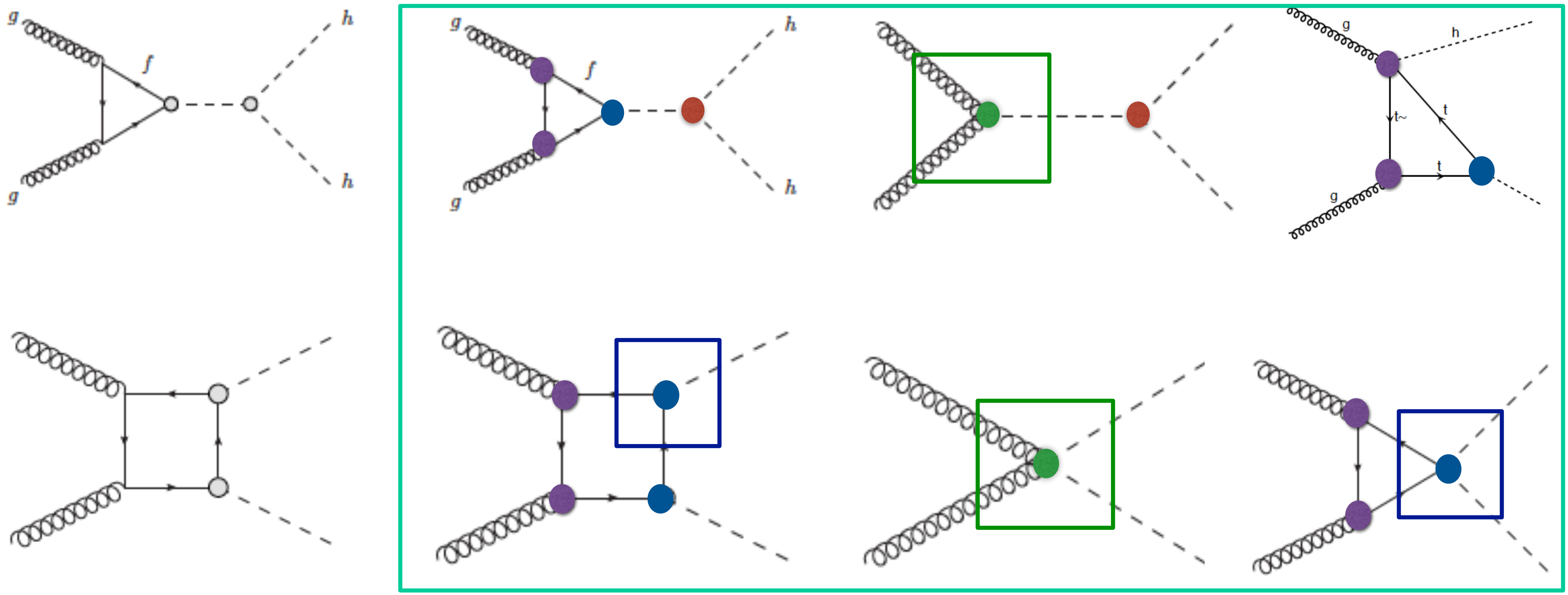
SMEFT



Loop-level Loop-level Tree-level Loop-level

SMEFT in HH

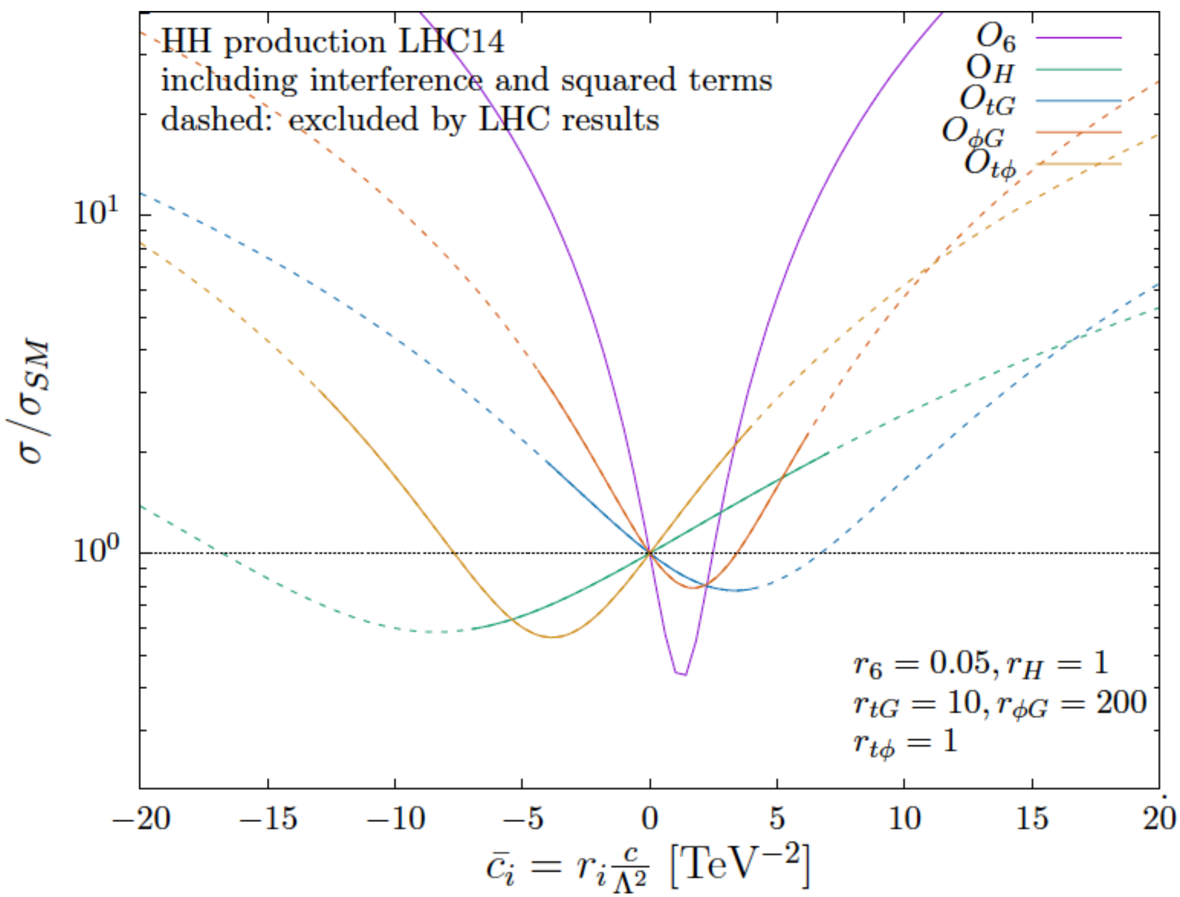
SM SMEFT

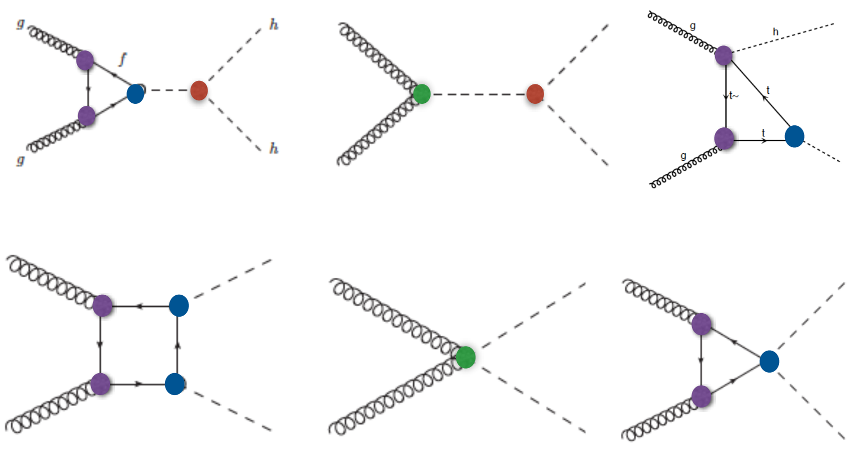


Loop-level Loop-level Tree-level Loop-level

c.f. in EWchL (Buchalla et al arXiv:1806.05162) c_{gghh}-c_{ggh} and c_t-c_{tt} are independent, with c_{gghh}, c_{tt} and c_{hhh} to be determined by HH

How to extract λ_{HHH} from HH?





Other couplings enter in the same process:
top Yukawa, ggh(h) coupling, top-gluon interaction

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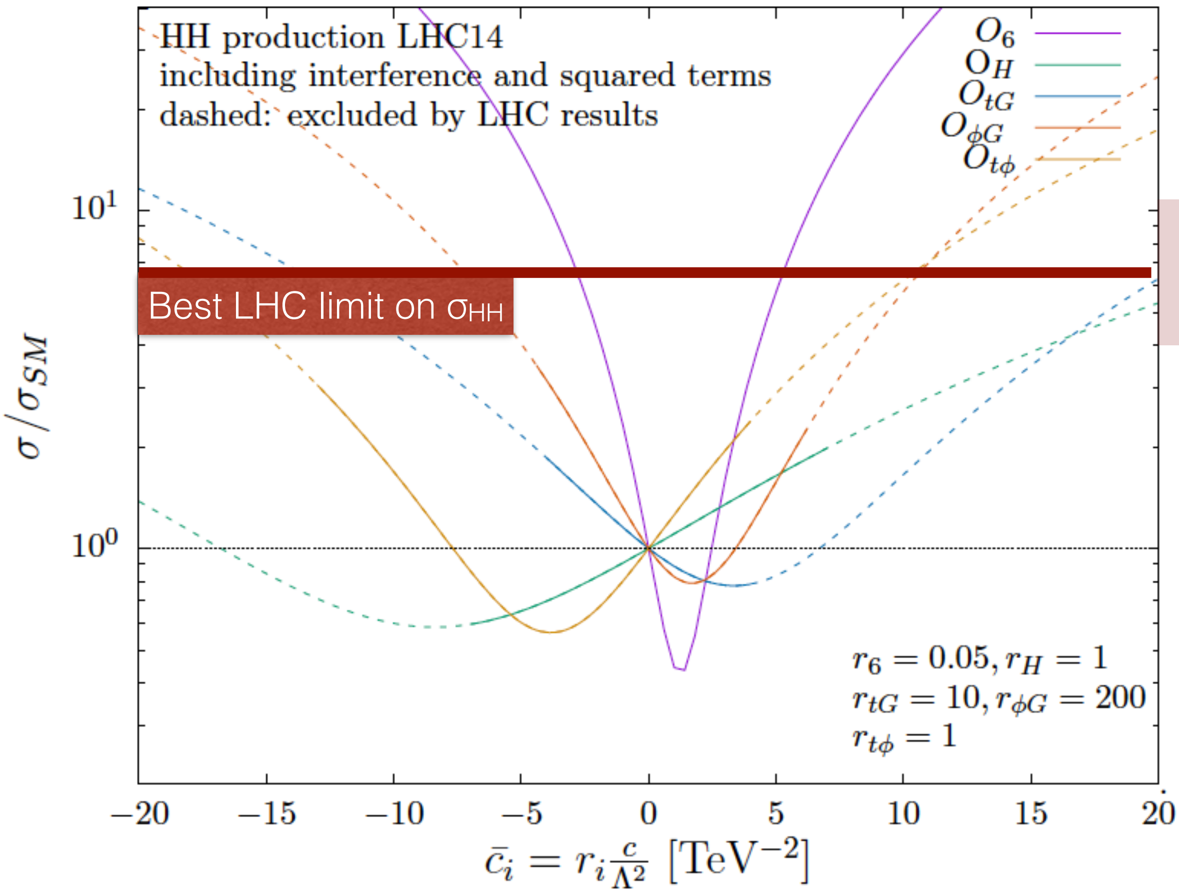

$$O_{t\phi} = y_t^3 \left(\phi^\dagger \phi\right) \left(\bar{Q} t\right) \tilde{\phi} \,,$$

$$O_{\phi G} = y_t^2 \left(\phi^\dagger \phi\right) G^A_{\mu\nu} G^{A\mu\nu} \,,$$

$$O_{tG} = y_t g_s (\bar{Q} \sigma^{\mu\nu} T^A t) \tilde{\phi} G^A_{\mu\nu}$$

$$O_6 = -\lambda (\phi^\dagger \phi)^3$$

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The present
Given the current constraints on σ(HH), σ(H) and the fresh ttH measurement, the Higgs self-coupling can be currently constrained "ignoring" other couplings

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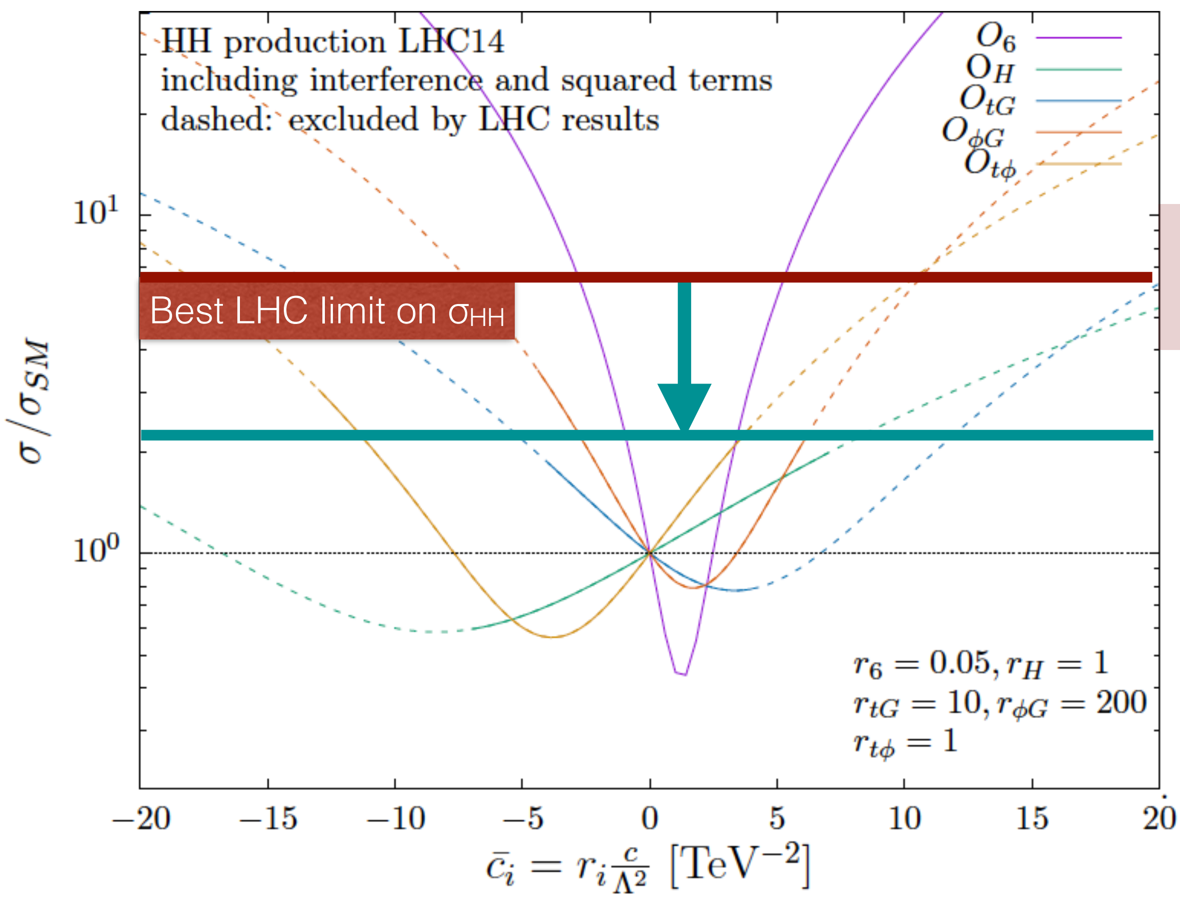

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The future
Precise knowledge of other Wilson coefficients will be needed to bound λ as the bound gets closer to SM
Differential distributions will also be necessary

SMEFT strategy

- Need for SMEFT global analysis including all relevant operators
- Ignoring operators is against the model independent nature of the SMEFT
- Other operators (4/5) will receive constraints from other processes, which can and should be taken into account in a SMEFT analysis of HH

SMEFT in Monte Carlo

SMEFT@NLO:

Based on:

- Warsaw basis
- Degrees of freedom for top operators as in dim6top

Current status:

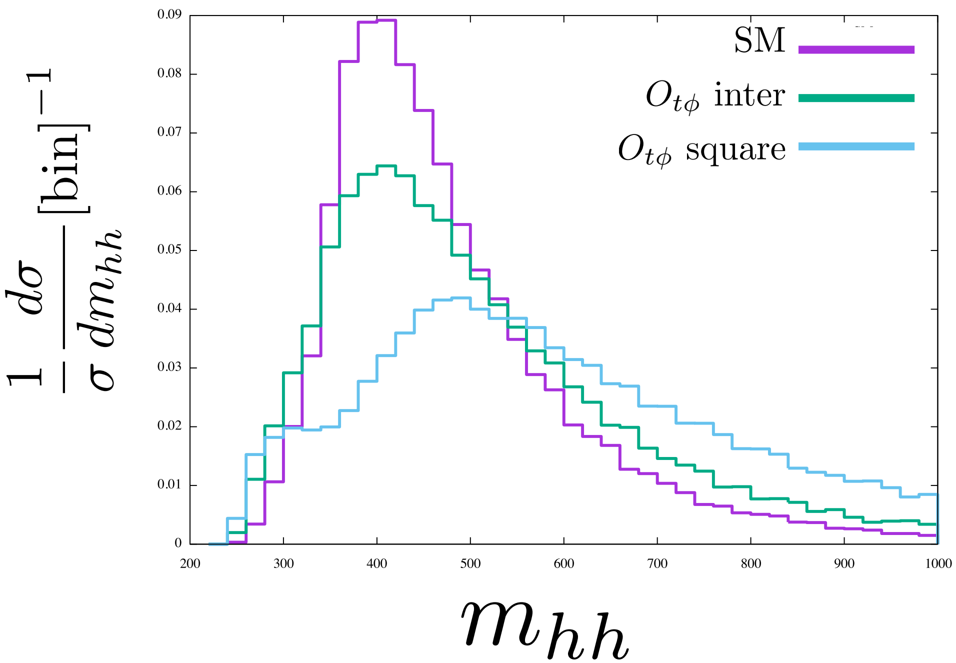
- 73 degrees of freedom (top, Higgs, gauge):
  - CP-conserving
  - Flavour assumption: $U(2)_Q \times U(2)_u \times U(3)_d \times U(3)_L \times U(3)_e$
- Successful validation at LO with dim6top (in turn validated with SMEFTsim)
- 0/2F@NLO operators validated (with previous partial NLO implementations) → **http://feynrules.irmp.ucl.ac.be/wiki/SMEFTatNLO**

Future plans

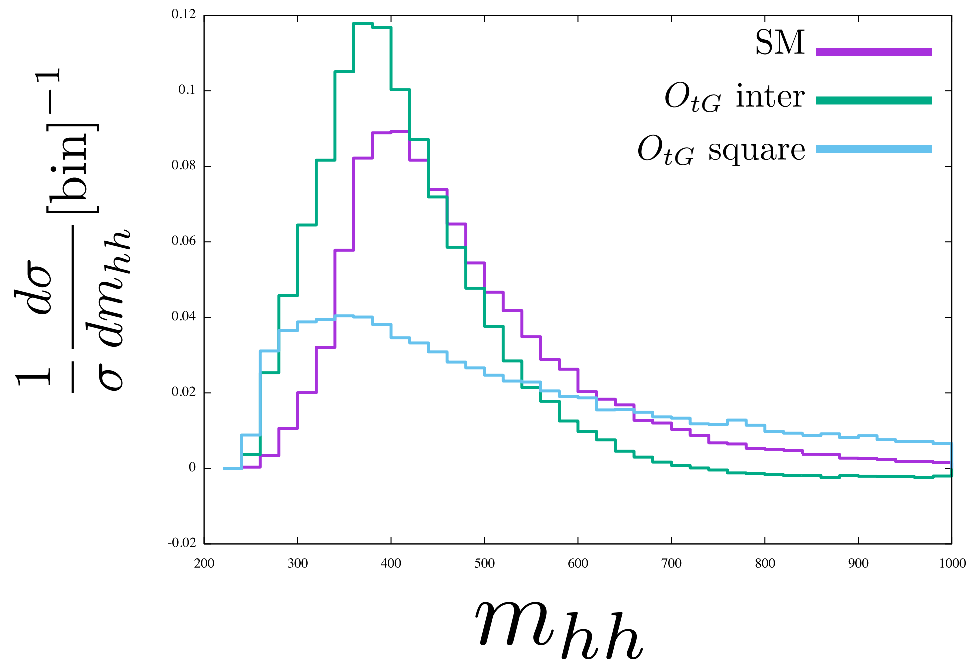
- Full NLO model release (4F@NLO)
- Other flavour assumptions
- CP-violating effects

Work in progress with:
C. Degrande, G. Durieux, F. Maltoni, K. Mimasu, C. Zhang

Results



SM
$O_{t\phi}$ inter
$O_{t\phi}$ square
$\frac{1}{\sigma}\frac{d\sigma}{dm_{hh}}[\text{bin}]^{-1}$
m_{hh}



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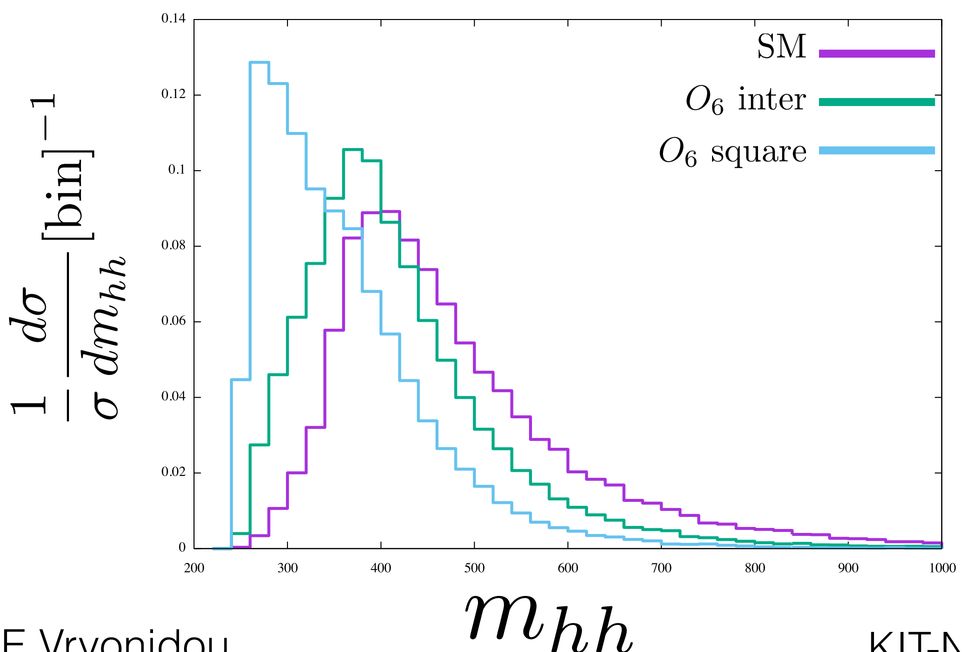

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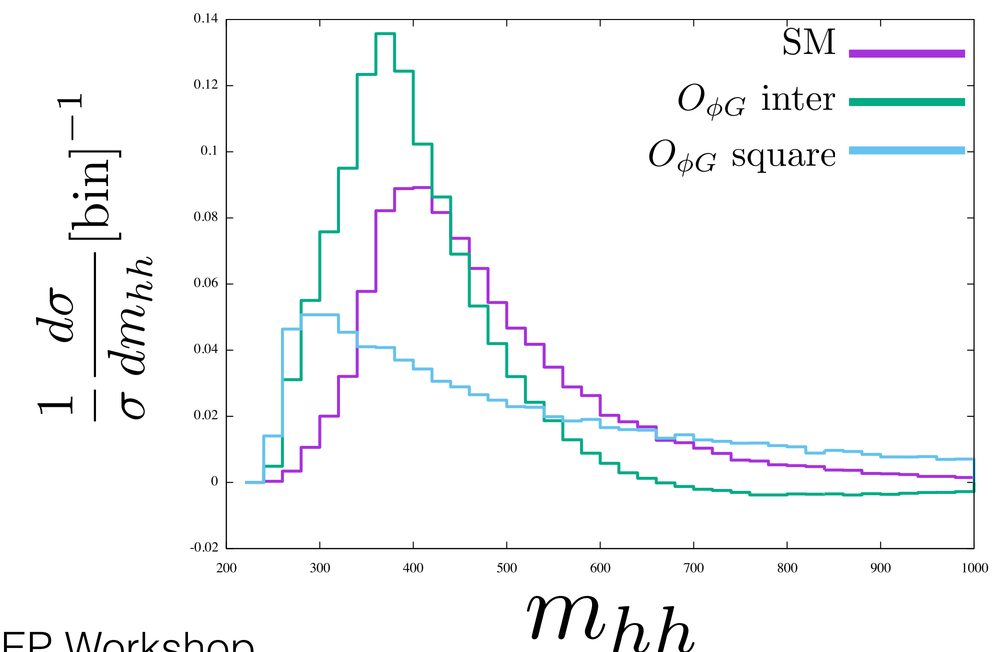

SM
$O_{\phi G}$ inter
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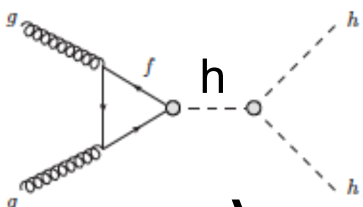
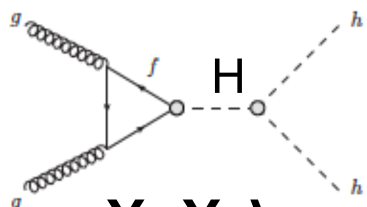
m_{hh}

II. HH resonances

Parameter space for models with extra scalars



y_b, y_t, λ_{hhh}



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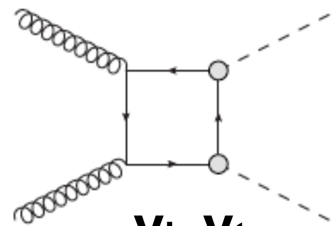

y_b, y_t

In models with extra scalars:

- Parameters of interest for HH:
  - Light and Heavy Higgs Yukawas
  - Trilinear Hhh coupling
  - Trilinear hhh coupling

For a pronounced resonance:

+ Enhanced Heavy Higgs top Yukawa

+ Large trilinear Hhh coupling

+ Relatively Low Mass Heavy Higgs

Is going beyond the NWA approximation needed?

Are heavy Higgs couplings strongly constrained by light Higgs measurements?

Higgs pair production in the 2HDM

2HDM: Additional Higgs doublet

h light CP even
H heavy CP even
A CP odd
H^{+} H^{-} charged

Type-I and Type-II setups
2HDM input:
$\tan\beta$, $\sin\alpha$, m_h, m_H, m_A, m_{H+}, m_{12}^2

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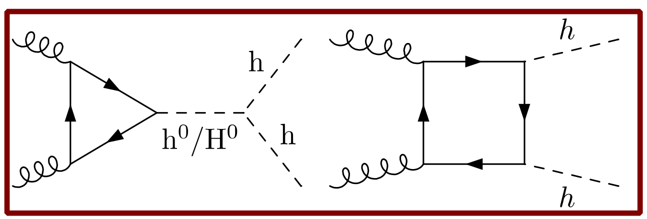
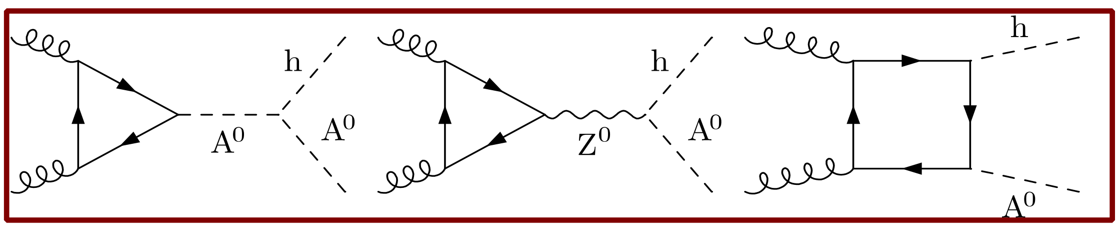
Topologies:





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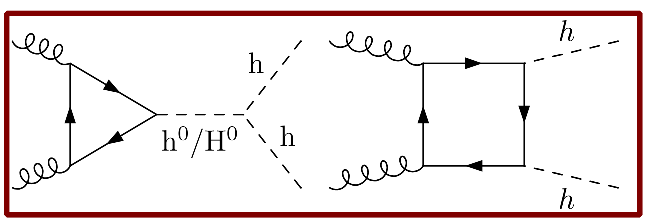
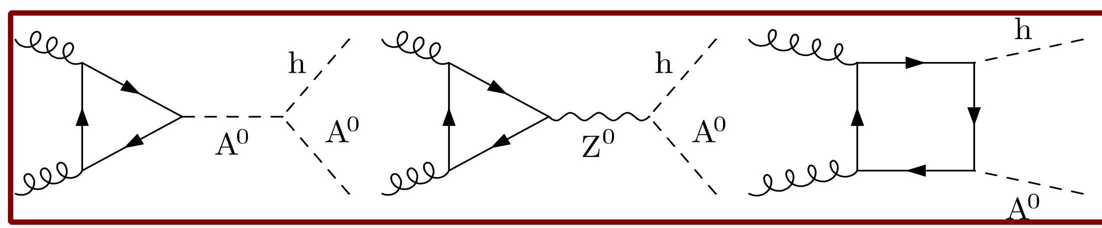
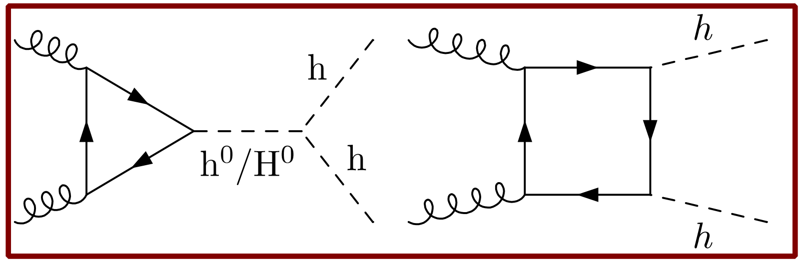




also tree-level qq for hA, HA, H^+H^-

Light Higgs pair production



Relevant couplings:

- Heavy quark Yukawas

$$\boxed{g_{hxx} \equiv g_x^h = \left(1 + \Delta_x^h\right)\ g_x^{\mathrm{SM}}}$$

	Type I	Type II
$1 + \Delta_t^{\mathrm{h}^0}$	$\frac{\cos\alpha}{\sin\beta}$	$\frac{\cos\alpha}{\sin\beta}$
$1 + \Delta_b^{\mathrm{h}^0}$	$\frac{\cos\alpha}{\sin\beta}$	$-\frac{\sin\alpha}{\cos\beta}$
$1 + \Delta_t^{\mathrm{H}^0}$	$\frac{\sin\alpha}{\sin\beta}$	$\frac{\sin\alpha}{\sin\beta}$
$1 + \Delta_b^{\mathrm{H}^0}$	$\frac{\sin\alpha}{\sin\beta}$	$\frac{\cos\alpha}{\cos\beta}$

- Trilinear Higgs couplings

$$\lambda_{\mathrm{h}^0\mathrm{h}^0\mathrm{h}^0} : \quad -\frac{3}{\sin\,2\beta}\left[\frac{4\cos(\alpha+\beta)\cos^2(\beta-\alpha)\,m_{12}^2}{\sin\,2\beta} - m_{\mathrm{h}^0}^2\left(2\cos(\alpha+\beta) + \sin 2\alpha\,\sin(\beta-\alpha)\right)\right]$$

$$\lambda_{\mathrm{h}^0\mathrm{h}^0\mathrm{H}^0} : \quad \frac{\cos(\beta-\alpha)}{\sin\,2\beta}\left[\sin 2\alpha\left(2m_{\mathrm{h}^0}^2 + m_{\mathrm{H}^0}^2\right) - \frac{2m_{12}^2}{\sin\,2\beta}\left(3\sin 2\alpha - \sin\,2\beta\right)\right]$$

2HDM Benchmark selection

Constraints on the 2HDM parameter space:

- Theoretical: Unitarity
  Perturbativity
  Vacuum stability
- Experimental: Electroweak precision tests
  LHC Higgs measurements
  LHC searches for heavy neutral and charged Higgses

decoupling limit $\boxed{\xi = \cos(\beta - \alpha) \ll 1}$

2HDM deviations still possible:

Non-resonant effects:

- enhanced, suppressed or sign-flipped Yukawa couplings
- modified trilinear Higgs couplings

enhancement/suppression/ interference patterns

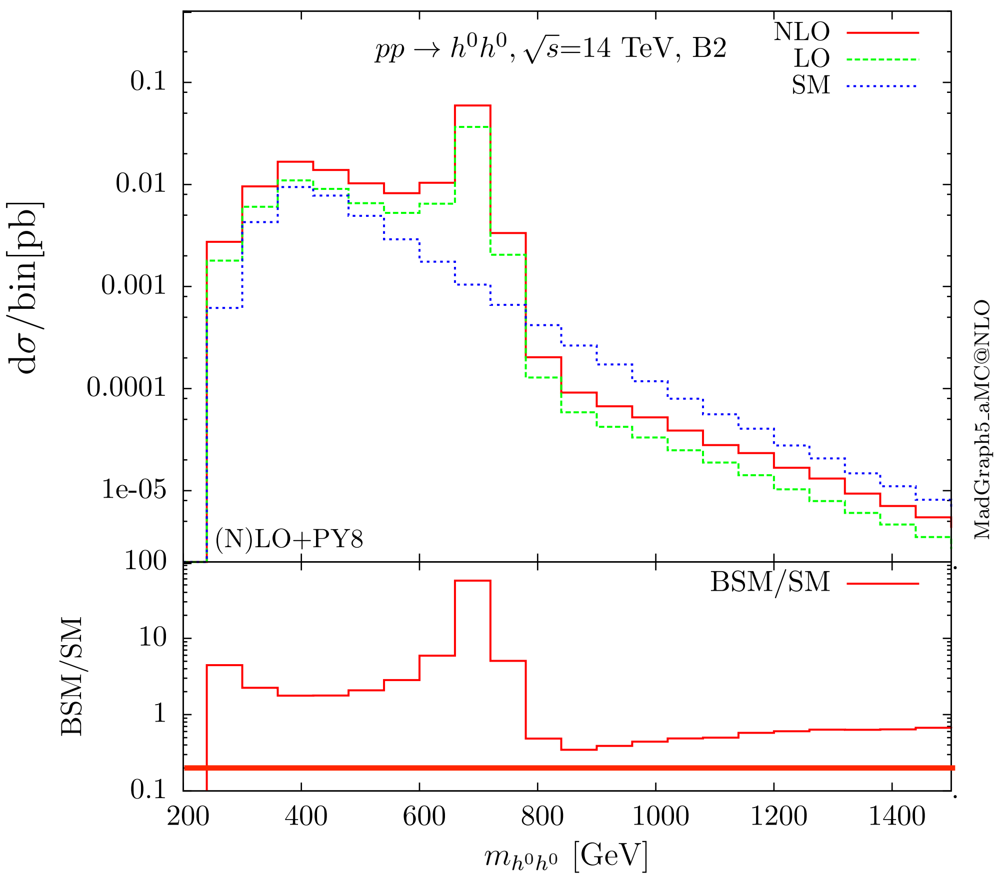
Resonant effects:

- on-shell production of moderately heavy states

significantly enhanced total rates-resonance peaks

Constraints by interfacing public tools:
2HDMC, HIGGSBOUNDS, SUPERISO, HIGGSSIGNALS

Resonant 2HDM scenario: Heavy H



2HDM input: Type-II

	$\tan\beta$	α/π	m_{H^0}	m_{A^0}	$m_{H^\pm}$	m^2_{12}
B2	1.50	-0.2162	700	701	670	180000

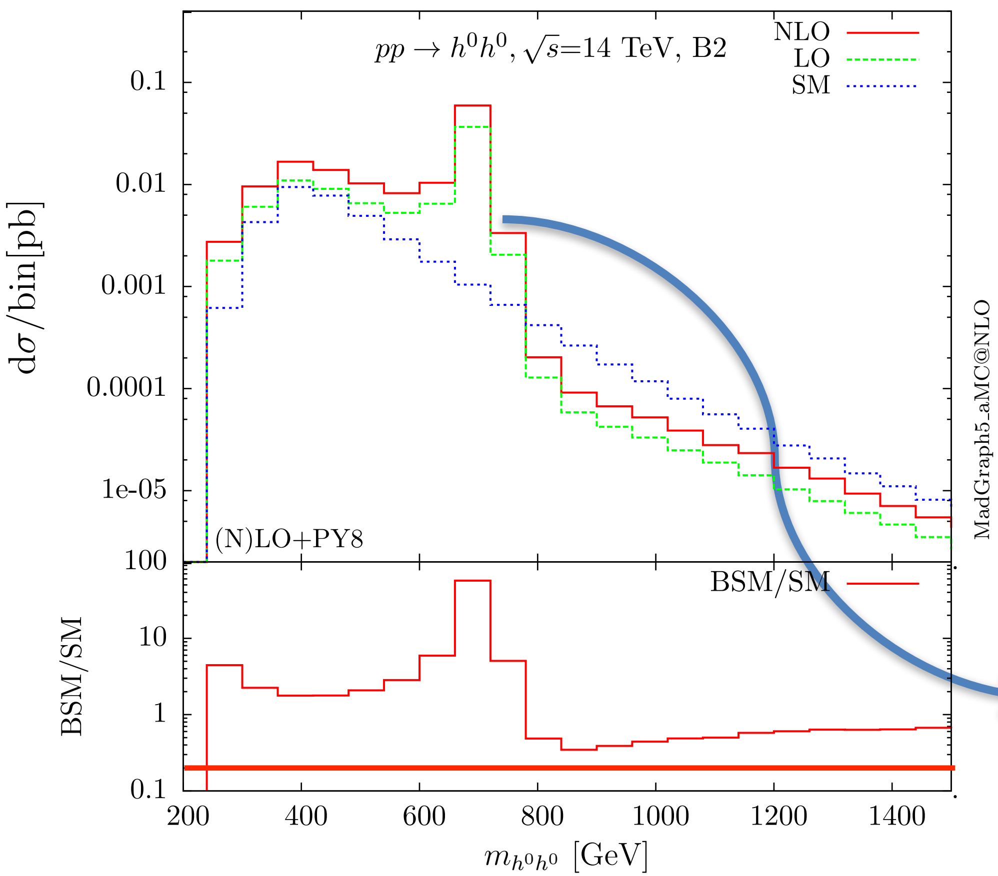
- **Slightly reduced top Yukawa**
- **40% reduction of the hhh coupling**
- **Enhanced Hhh coupling**

- Significant resonant enhancement from H➔hh now at 700 GeV
- Distinctive resonance peak
- Interference patterns before and after the peak, need to go beyond the NWA

σ_{hh}~ 4 times the SM prediction

Hespel, Lopez-Val, EV arXiv:1407.0281

Resonant 2HDM scenario: Heavy H



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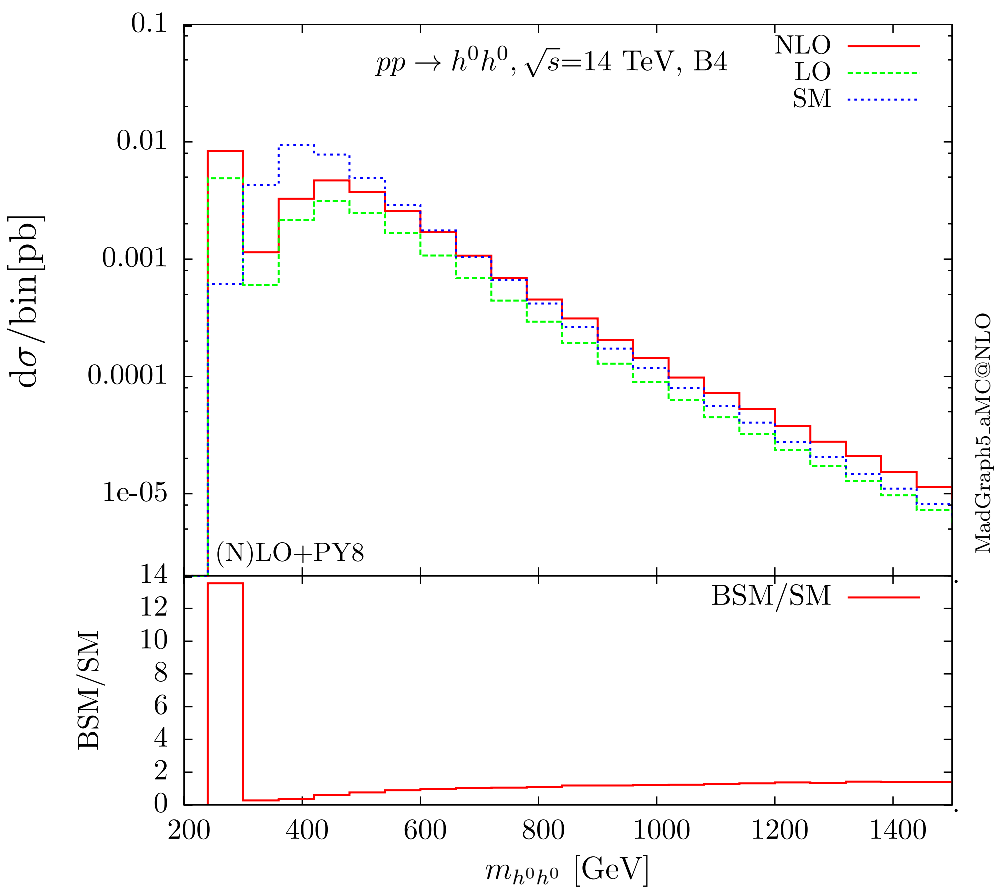
Non-resonant 2HDM scenario



2HDM input: Type-I

	$\tan\beta$	α/π	m_{H^0}	m_{A^0}	$m_{H^\pm}$	m_{12}^2
B4	1.20	-0.1760	200	500	500	-60000

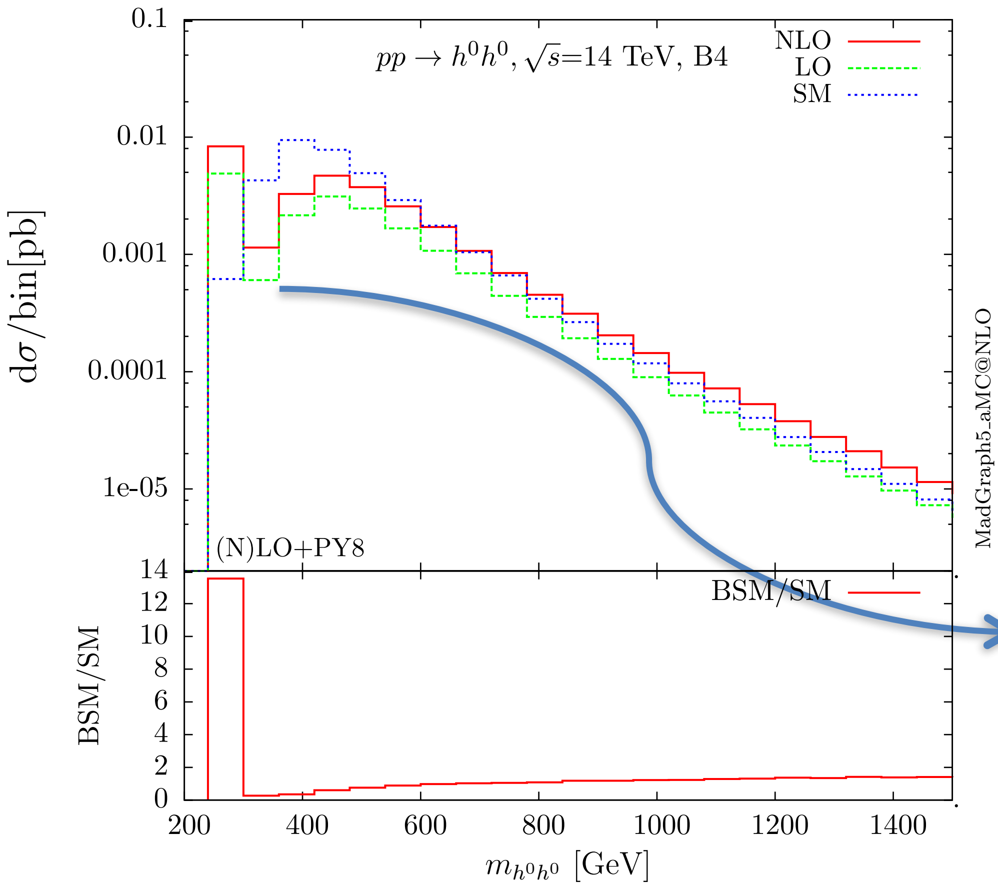
- **Slightly enhanced top Yukawa**
- **Enhaced hhh coupling**
- **Enhanced Hhh coupling**

- Heavy Higgs mass below the hh threshold: No resonant enhancement
- Interference between different contributions leads to a different shape compared to the SM
- Important to study the distributions, not just total rates

σ_{hh}~ 30% reduction of the SM prediction

Hespel, Lopez-Val, EV arXiv:1407.0281

Non-resonant 2HDM scenario



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HH in the Higgs singlet model (1)

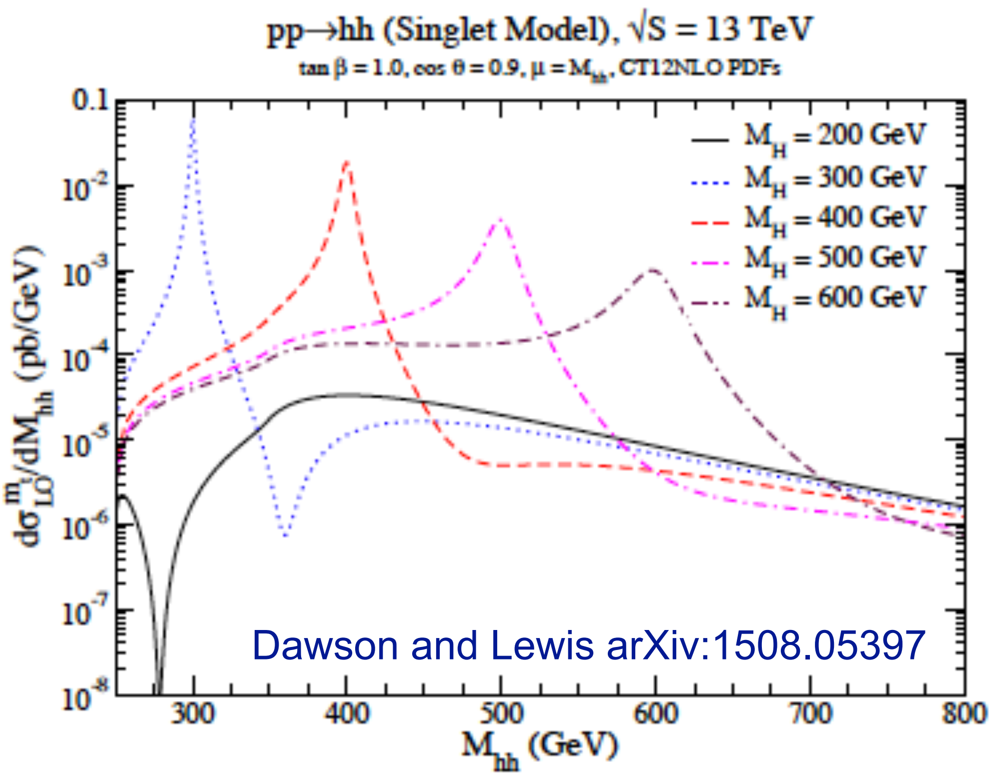
$$\boxed{V = -\mu^2 \Phi^\dagger\Phi - m^2 S^2 + \lambda(\Phi^\dagger\Phi)^2 + \frac{a_2}{2}\Phi^\dagger\Phi S^2 + \frac{b_4}{4}S^4}$$

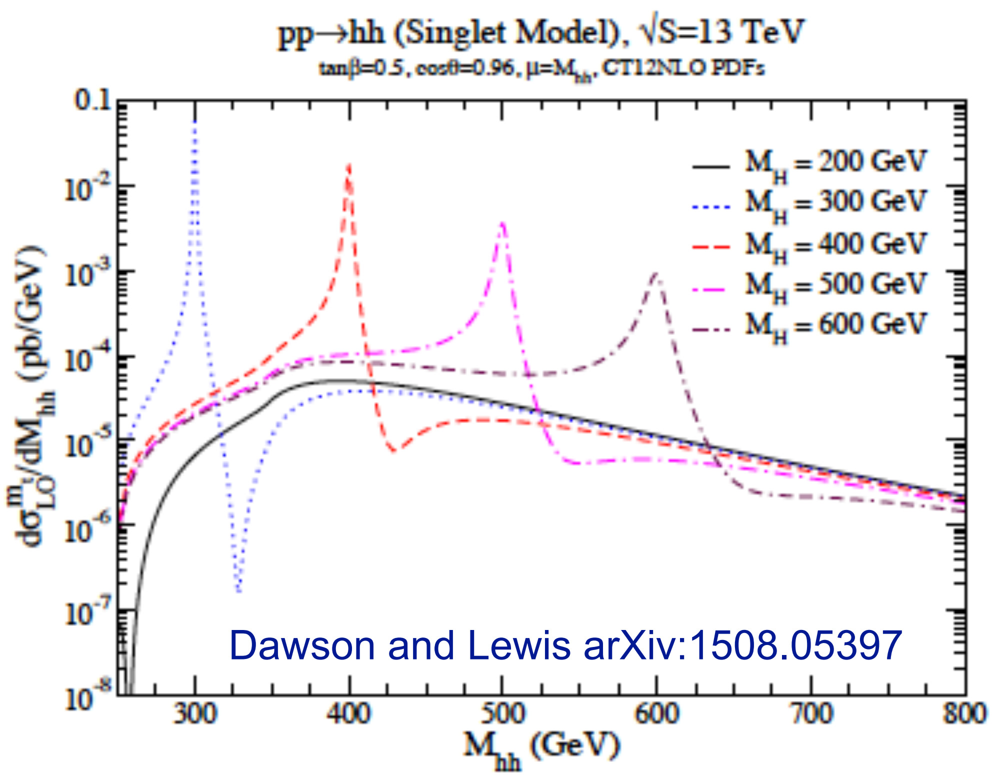
Additional real singlet S

$$\begin{pmatrix} h \\ H \end{pmatrix} = \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} \phi_0 - v \\ s \end{pmatrix}$$

$$m_h = 125\ GeV, M_H, v = 246\ GeV, \tan\beta, \cos\theta$$

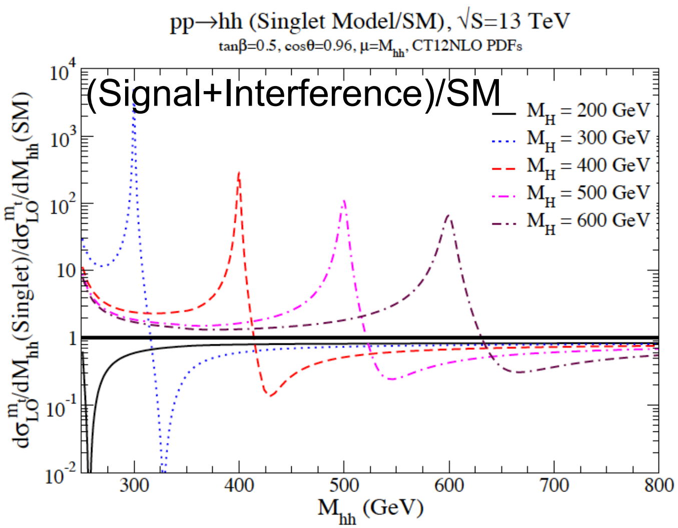
$$\boxed{\Gamma(h \to XX^\dagger) = \cos^2\theta\,\Gamma(h \to XX^\dagger)_{SM}}$$

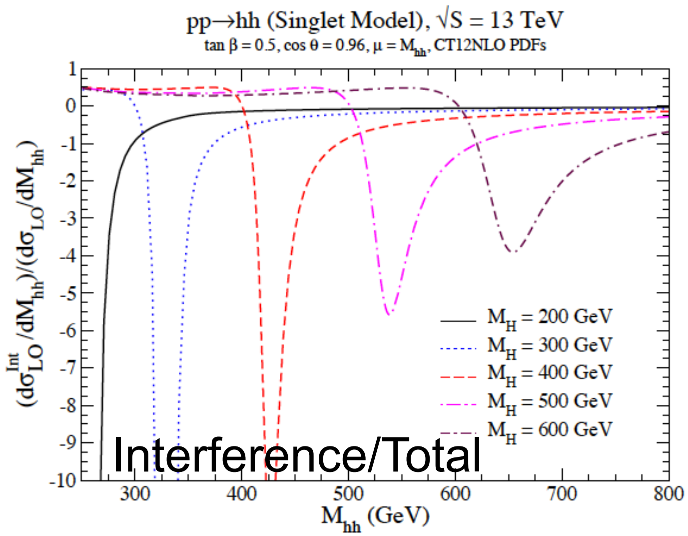




Interesting interference patterns: Peak-dip structures

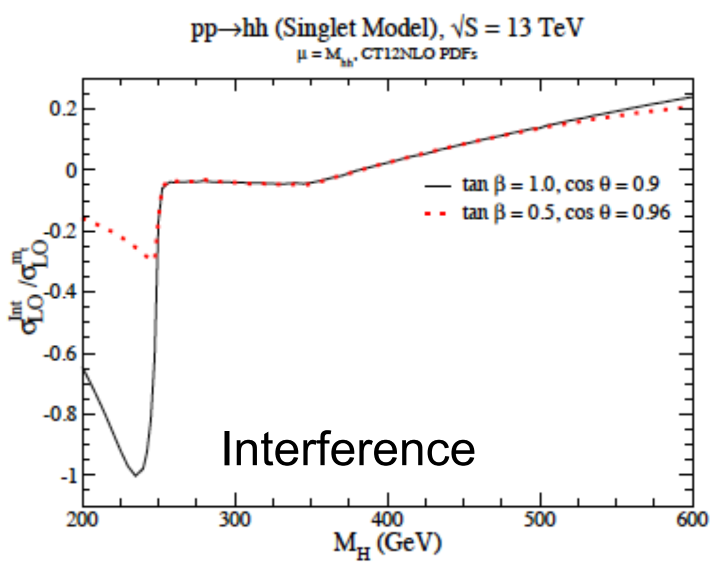
HH in the Higgs singlet model (2)

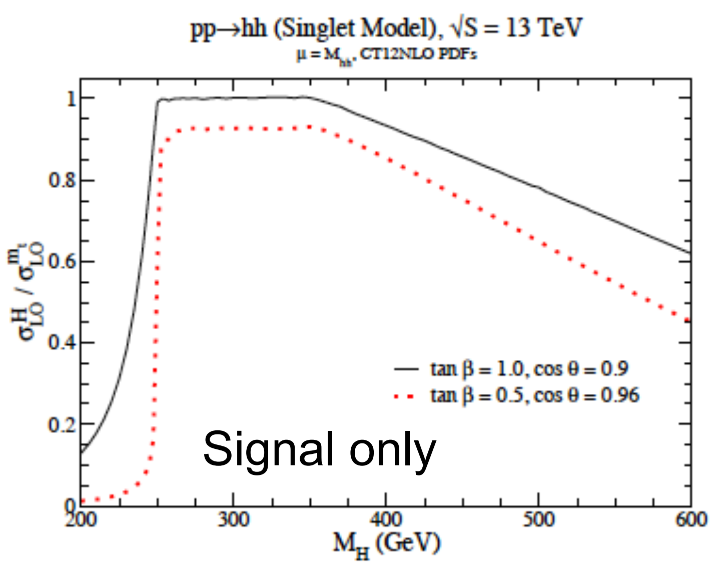




Interference responsible for peak-dip structures-Relative contribution depends on the heavy scalar mass

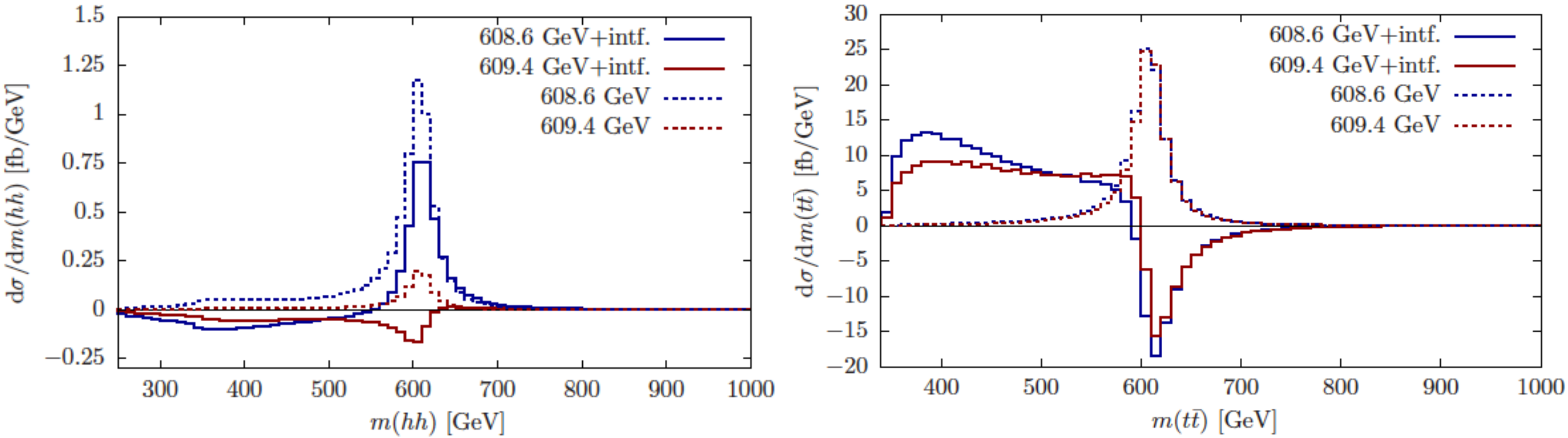
Dawson and Lewis arXiv:1508.05397





Interference also important at the total cross-section level, for low (below $2M_H$) and large H masses

C2HDM: CP-violating 2HDM



Basler, Dawson, Englert, Mühlleitner arXiv:1909.09987

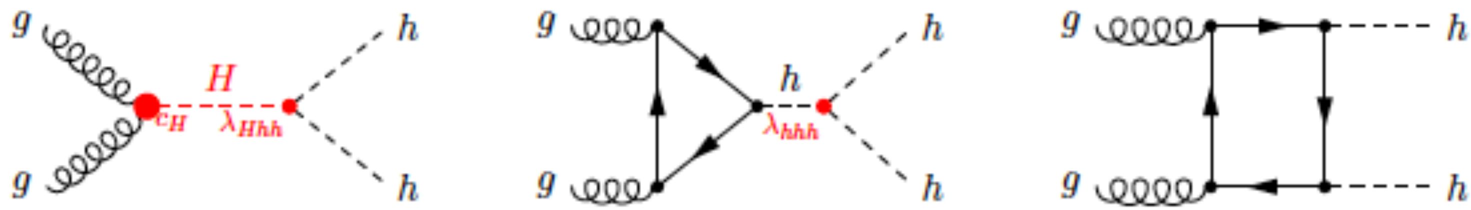
Comparison with top pair production:

- Interference is much more severe in tt
- Dip-like structure in tops
- Breit-Wigner enhancement in HH

Viable scenarios evading LHC constraints exist

When is the interference important?

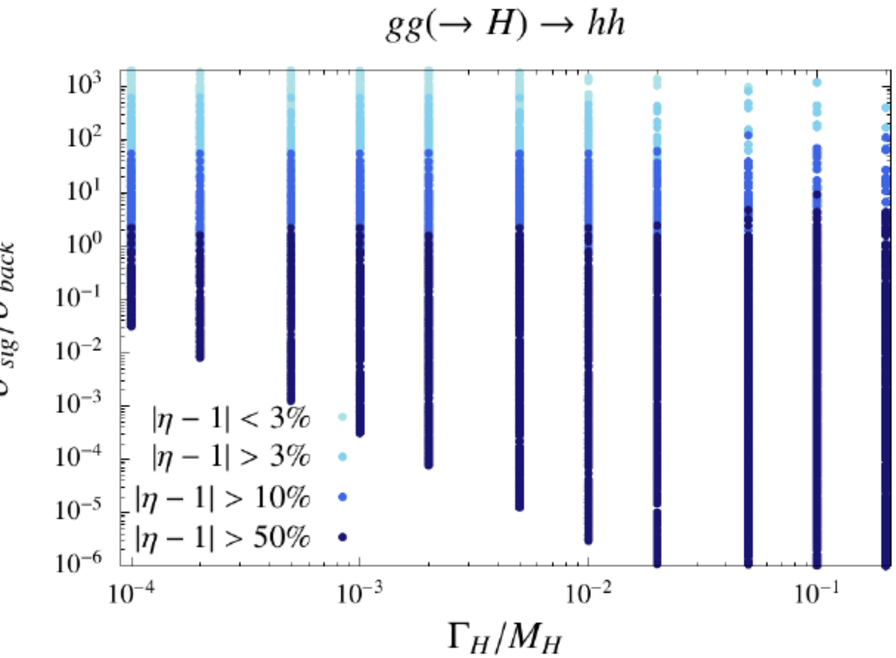
Is Γ/m a good criterion?



Toy Example

$$L \supset \frac{\alpha_s}{12\pi v} c_H \, H G^a_{\mu\nu} G^{a,\mu\nu} \,.$$

$$\eta = \int_{m_\varphi - 10\Gamma_\varphi}^{m_\varphi + 10\Gamma_\varphi} dm_F \left(\frac{d\sigma_S}{dm_F} + \frac{d\sigma_I}{dm_F} \right) \Big/ \int_{m_\varphi - 10\Gamma_\varphi}^{m_\varphi + 10\Gamma_\varphi} dm_F \left(\frac{d\sigma_S}{dm_F} \right)$$



$\sigma_{sig}/\sigma_{back}$ can be a better alternative

Interference can be sizeable and should be taken into account even for large $\sigma_{sig}/\sigma_{back}$

LesHouches proceedings: A. Carvalho et al arXiv:1803.10379

Conclusions-Outlook

- Higgs pair production is a challenging process but also a path to explore beyond the SM physics
- BSM possibilities include models with new states and models with new interactions (EFT)
- New interactions can modify both the rate and distributions
- Models with HH resonances can lead to large deviations from the SM predictions: 1HSM, 2HDM, C2HDM etc
- Studies exploring interference effects are available
- With the increased sensitivity of the experimental analyses, going beyond the NWA becomes necessary

Thanks for your attention...