Higgs Interferometry in WW/ZZ

Nikolas Kauer
Royal Holloway, University of London (RHUL)

in collaboration with
Claire O'Brien (RHUL) and Eleni Vryonidou (Louvain)

arXiv:1206.4803 in collaboration with Giampiero Passarino

and including results of CMS, MCFM & collaborators and VBFNLO

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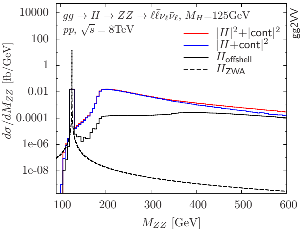
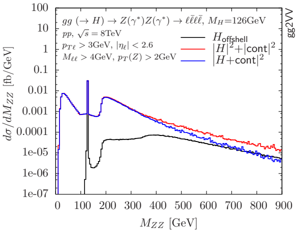
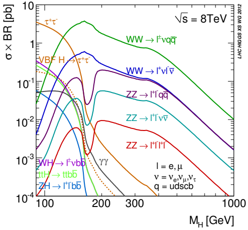
Outline

- $H \to ZZ, WW$ in ggF & VBF: sizeable off-shell Higgs signal contribution with large signal-backg. interference
- $H \to WW/ZZ \to \ell\bar{\nu}_\ell\bar{\ell}\nu_\ell$ and $ZZ \to 4\ell$ interference in ggF
- Interference for $pp \to H \to ZZ$ + jet
- Interference for semileptonic H decay modes in ggF
- Heavy Higgs - light Higgs - background interference
- Summary

$gg \to H \to ZZ, WW$: sizeable off-shell Higgs signal with large signal-background interference



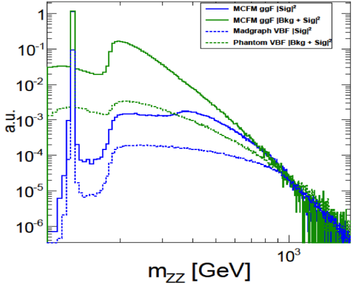


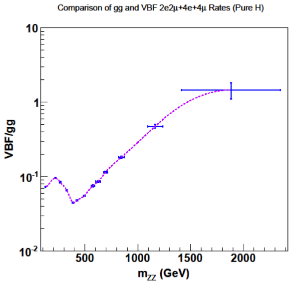


- $gg \to H \to VV \to 4\ell$ and $2\ell 2\nu$ signal-background interference very well studied at LO: Glover, van der Bij (1989); Kao, Dicus (1991); Binoth, Ciccolini, NK, Krämer (2006) (gg2WW); Campbell, Ellis, Williams (2011) (MCFM); NK (2012) (gg2VV); NK, Passarino (2012); Campanario, Li, Rauch, Spira (2012); Bonvini, Caola, Forte, Melnikov, Ridolfi (2013); Caola, Melnikov (2013); NK (2013) (gg2VV); Campbell, Ellis, Williams (2013) (MCFM); Campbell, Ellis, Williams (2014) (MCFM); Campbell, Ellis, Furlan, Röntsch (2014); related interference effects: Bredenstein, Denner, Dittmaier, Weber (2006) (PROPHECY4f); YR3: Denner, Dittmaier, Mück (2013) and Anderson, Bolognesi, Caola, Gao, Gritsan, Martin, Melnikov, Schulze, Tran, Whitbeck, Zhou (2013); Chen, Cheng, Gainer, Korytov, Matchev, Milenovic, Mitselmakher, Park, Rinkevicius, Snowball (2013); Chen, Vega-Morales (2013)
- tools for ggF: MCFM-6.8, gg2VV-3.1.7 (parton-calculators and LO event generators)
- loop technology closing in on NLO calc. (bottleneck: heavy quark loop) Zurich, Karlsruhe, FNAL-RWTH, ...
- gluon-fusion Higgs production and semileptonic decay: Dobrescu, Lykken (2010); Lykken, Martin, Winter (2012); Kao, Sayre (2012); ATLAS arXiv:1206.2443; ATLAS arXiv:1206.6074; CMS PAS HIG-13-008

Sizeable off-shell Higgs signal in vector boson fusion

- similar effect in VBF $H \to VV$ (NK, Passarino): $\mathcal{O}(10\%)$ of Higgs signal is off-shell
  note: no exp. sensitivity to off-shell $H \to VV$ tail in VH and $t\bar{t}H$ channels (see $\sigma_{\text{prod}}(M_H)$)
- total off-shell Higgs signal has $\sim 10\%$ VBF contribution





figures taken from Covarelli's talk at LHC HXSWG workshop (12 Jun 2014)

- tools for VBF: MadGraph5 Alwall et al., Phantom Ballestrero et al., VBFNLO Baglio et al.

Sizeable off-shell Higgs signal in vector boson fusion

CMS-HIG-14-002 *Higgs width constraint from off-shell $H \to ZZ$* includes analysis of VBF contribution (as correction to ggF) Covarelli, Anderson, Sarica

		4ℓ	$2\ell 2\nu$
(a)	Total gg ($\Gamma_H = \Gamma_H^{\mathrm{SM}}$)	1.8 ± 0.3	9.6 ± 1.5
	gg Signal component ($\Gamma_H = \Gamma_H^{\mathrm{SM}}$)	1.3 ± 0.2	4.7 ± 0.6
	gg Background component	2.3 ± 0.4	10.8 ± 1.7
(b)	Total gg ($\Gamma_H = 10 \times \Gamma_H^{\mathrm{SM}}$)	9.9 ± 1.2	39.8 ± 5.2
(c)	Total VBF ($\Gamma_H = \Gamma_H^{\mathrm{SM}}$)	0.23 ± 0.01	0.90 ± 0.05
	VBF signal component ($\Gamma_H = \Gamma_H^{\mathrm{SM}}$)	0.11 ± 0.01	0.32 ± 0.02
	VBF background component	0.35 ± 0.02	1.22 ± 0.07
(d)	Total VBF ($\Gamma_H = 10 \times \Gamma_H^{\mathrm{SM}}$)	0.77 ± 0.04	2.40 ± 0.14
(e)	$q\bar{q}$ background	9.3 ± 0.7	47.6 ± 4.0
(f)	Other backgrounds	0.05 ± 0.02	35.1 ± 4.2
(a+c+e+f)	Total expected ($\Gamma_H = \Gamma_H^{\mathrm{SM}}$)	11.4 ± 0.8	93.2 ± 6.0
(b+d+e+f)	Total expected ($\Gamma_H = 10 \times \Gamma_H^{\mathrm{SM}}$)	20.1 ± 1.4	124.9 ± 7.8
	Observed	11	91

table taken from arXiv:1405.3455

Expected and observed numbers of events in the 4ℓ and $2\ell 2\nu$ channels in gg-enriched regions, defined by $m_{4\ell} \geq 330$ GeV and $\mathcal{D}_{gg} > 0.65$ (4ℓ), and by $m_T > 350$ GeV and $E_T^{\text{miss}} > 100$ GeV ($2\ell 2\nu$). Numbers of expected events are given for a SM Higgs boson ($\Gamma_H = \Gamma_H^{\mathrm{SM}}$) and a Higgs boson width and squared product of the couplings scaled by a factor 10 with respect to their SM values. Total gg and VBF include the negative interferences.

Sizeable off-shell Higgs signal in vector boson fusion

Dedicated VBF study for $H \to ZZ \to 4\ell$ Englert, Spannowsky

VBF selection cuts are applied, which essentially remove ggF contribution:

$$p_T(j) > 20 \text{ GeV}, \ \Delta R(jj) \geq 0.6, \ |y_j| < 4.5,$$
$$\Delta y(jj) \geq 4.5, \ y_{j_1} \times y_{j_2} < 0, \ m(jj) \geq 800 \text{ GeV},$$
$$\Delta R(\ell j) \geq 0.6, \ \text{all } \ell \text{ inside the tagging jets' rapidity gap},$$

and a jet veto: $|y_j^{\text{veto}}| < 2.5, \ p_T^{\text{veto}}(j) > 50 \text{ GeV}, \ \Delta y(j_{\text{veto}} j) > 0.3$

Off-shell signal: σ_H(VBF selection, $m_{4\ell} \geq 130$ GeV, $\ell = e, \mu$) $\simeq 0.04$ fb at 14 TeV

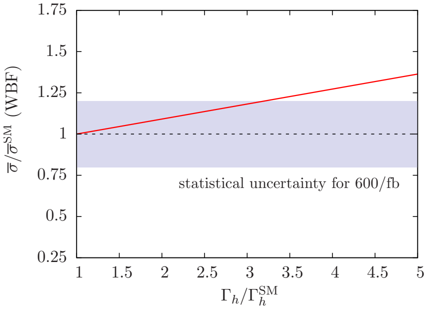


figure taken from arXiv:1405.0285

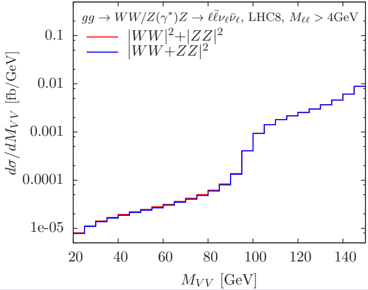
$gg \to H \to WW/ZZ \to \ell\bar{\nu}_\ell\bar{\ell}\nu_\ell$ interference (gg2VV)

Integrated cross sections (SM Higgs)

	$gg\,(\to H) \to VV \to \ell\bar{\nu}_\ell\bar{\ell}\nu_\ell$, σ [fb], pp, $\sqrt{s} = 8$ TeV, $M_H = 126$ GeV, min. cuts, $\mu_R = \mu_F = M_{\ell\bar{\nu}_\ell\bar{\ell}\nu_\ell}/2$			interference	
VV	H	cont	$\lvert H\text{+cont}\rvert^2$	R_1=(S+B+I)/(S+B)	R_2=(S+I)/S
WW	17.318(4)	16.925(4)	32.803(8)	0.9580(3)	0.9169(6)
ZZ	0.8822(2)	2.1553(6)	2.872(1)	0.9455(4)	0.813(2)
WW/ZZ	17.402(3)	19.084(4)	34.884(7)	0.9561(3)	0.9079(5)
R_3	0.9562(3)	1.0002(3)	0.9778(3)	$\sigma(\lvert WW+ZZ\rvert^2)/\sigma(\lvert WW\rvert^2+\lvert ZZ\rvert^2)$	
R_4	0.9540(3)	1.0002(4)	0.9759(4)	$(\sigma(\lvert WW\rvert^2)+I_{WW/ZZ})/\sigma(\lvert WW\rvert^2)$	
R_6	0.05094(2)	0.12735(5)	0.08756(4)	$\sigma(\lvert ZZ\rvert^2)/\sigma(\lvert WW\rvert^2)$	

minimal cuts: WW/ZZ interference: Higgs signal: ≈5%, gg continuum: negligible

Differential cross sections



$gg \to WW/ZZ$ continuum: M_{VV} distribution

$M_{VV} > 95$ GeV: WW/ZZ interference negligible

$M_{VV} < 95$ GeV: WW/ZZ interference of ≈ 5%

see also: $H \to WW/ZZ \to \ell\bar{\nu}_\ell\bar{\ell}\nu_\ell$ interference at LO & NLO Mück, Bredenstein, Denner, Dittmaier, Weber YR3 arXiv:1307.1347, Sec. 2.2

$gg \to H \to WW/ZZ \to \ell\bar{\nu}_\ell\bar{\ell}\nu_\ell$ interference (gg2VV)

Integrated cross sections (SM Higgs with Higgs search cuts)

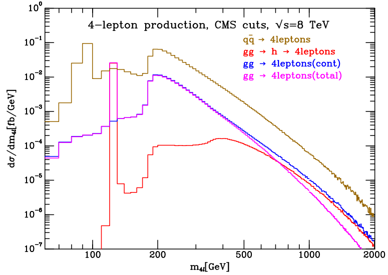
	$gg\ (\to H) \to VV \to \ell\bar{\nu}_\ell\bar{\ell}\nu_\ell$, σ [fb], pp, $\sqrt{s} = 8$ TeV, $M_H = 126$ GeV, Higgs search cuts			interference	
VV	H	cont	$\lvert H\text{+cont}\rvert^2$	R_1	R_2
WW	2.9303(7)	0.7836(4)	3.6649(8)	0.9868(4)	0.9833(4)
ZZ	0.004658(3)	0.002851(2)	0.007494(3)	0.9979(6)	0.9966(9)
WW/ZZ	2.8758(7)	0.7864(4)	3.6131(8)	0.9866(3)	0.9829(4)
R_3	0.9799(4)	0.9999(8)	0.9839(3)		
R_4	0.9798(4)	0.9999(8)	0.9838(3)		
R_6	0.0015898(9)	0.003638(3)	0.002045(1)		

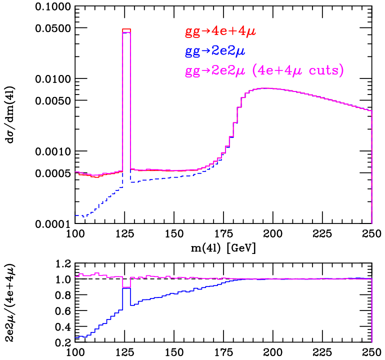
Cuts: $p_{T\ell,\text{1st}} > 25$ GeV, $p_{T\ell,\text{2nd}} > 15$ GeV, $|\eta_\ell| < 2.5$, $\not{p}_T > 45$ GeV, $M_{\ell\bar{\ell}} > 12$ GeV, $|M_{\ell\bar{\ell}} - M_Z| > 15$ GeV, $M_{\ell\bar{\ell}} < 50$ GeV, $\Delta\phi_{\ell\bar{\ell}} < 1.8$, $0.75\,M_H < M_{T1} < M_H$

$$M_{T1} = \sqrt{(M_{T,\ell\bar{\ell}} + \not{p}_T)^2 - (\mathbf{p}_{T,\ell\bar{\ell}} + \not{\mathbf{p}}_T)^2} \quad \text{with} \quad M_{T,\ell\bar{\ell}} = \sqrt{p^2_{T,\ell\bar{\ell}} + M^2_{\ell\bar{\ell}}}$$

NK arXiv:1310.7011

$gg \to H \to ZZ \to 4\ell$ interference (MCFM)

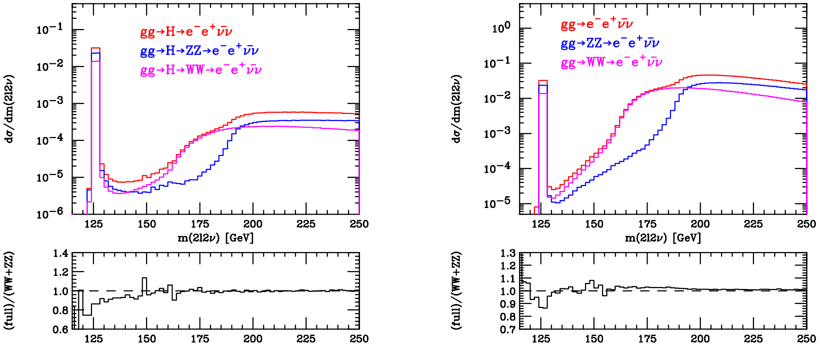




Campbell, R.K. Ellis, Williams figures taken from arXiv:1408.1723

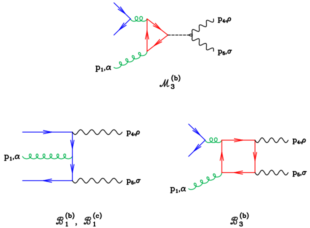
Note: full $ZZ \to 4\ell$ interference effects are also implemented in gg2VV

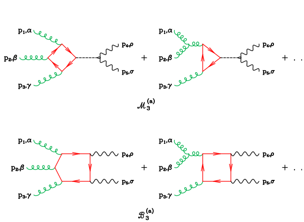
$gg \to H \to WW/ZZ \to \ell\bar{\nu}_\ell\bar{\ell}\nu_\ell$ interference (MCFM)

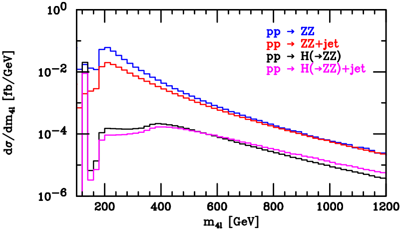


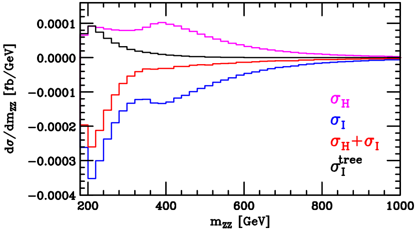
Campbell, R.K. Ellis, Williams figures taken from arXiv:1408.1723

Interference for $pp \to H \to ZZ$ + jet









off-shell Higgs cross sections for ZZ and ZZ+jet comparable ($p_{Tj} > 30$ GeV)

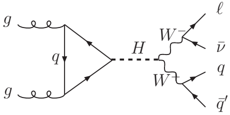
Campbell, R.K. Ellis, Furlan, Röntsch   figures taken from arXiv:1409.1897

Z bosons treated in zero-width approximation (validated for ZZ final state: excellent for $m_{4l} > 300$ GeV)

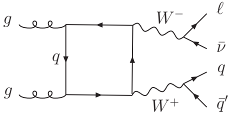
Interference for semileptonic H decay modes in ggF

Charged currents (representative Feynman graphs)

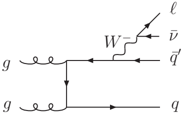
$$gg \to H \to W^-W^+ \to \ell\bar{\nu}q\bar{q}' \quad \text{(and c.c.)}$$



signal



loop background



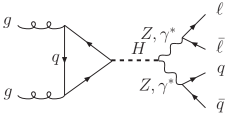
tree background

new feature of signal-background interference: $\mathcal{O}(e^2)$ tree-level graphs contribute

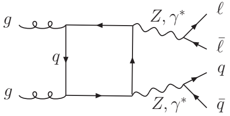
part of $pp \to (W \to \ell\bar{\nu})$+2 jet @ LO and $pp \to W \to \ell\bar{\nu}$ @ NNLO

Similarly: Neutral currents (representative Feynman graphs)

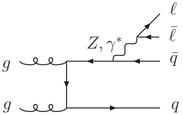
$$gg \to H \to ZZ \to \ell\bar{\ell}q\bar{q}$$



signal



loop background



tree background

tree background part of $pp \to (Z \to \ell\bar{\ell})$+2 jet @ LO and $pp \to Z \to \ell\bar{\ell}$ @ NNLO

Interference for semileptonic H decay modes in ggF

Parton-level signal processes

$$gg \to H \to W^-W^+ \to \ell\bar{\nu}_\ell q_u \bar{q}_d$$
$$gg \to H \to W^+W^- \to \bar{\ell}\nu_\ell \bar{q}_u q_d$$
$$gg \to H \to ZZ \to \ell\bar{\ell} q_u \bar{q}_u$$
$$gg \to H \to ZZ \to \ell\bar{\ell} q_d \bar{q}_d$$

(Note: for crossed processes: t-channel Higgs propagator)

Input parameters and settings

pp, $\sqrt{s} = 8$ TeV, $M_H = 125.5$ GeV, $\mu_R = \mu_F = 0.5\,M_{VV}$, other: default settings of gg2VV-3.1.6

Selection cuts

minimal cuts ("min. cuts"): $p_{Tj} > 4$ GeV, for ZZ also: $M_{q\bar{q}} > 4$ GeV, $M_{\ell\bar{\ell}} > 4$ GeV

LHC cuts: minimal cuts & $p_{T\ell} > 20$ GeV, $|\eta_\ell| < 2.5$, $p_{Tj} > 25$ GeV, $|\eta_j| < 4.5$, for WW also: $\not{p}_T > 20$ GeV

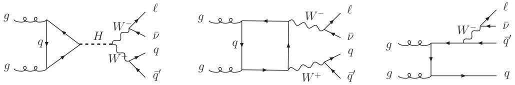
background suppression cuts ("bkg. cuts"): note: here $M_H = 400$ GeV
LHC cuts & $|M_{jj} - M_V| < 5\,\Gamma_V$, $p_{Tj,1st} > 60$ GeV and $p_{Tj,2nd} > 40$ GeV, $|\eta_j| < 2.8$, $\Delta R_{jj} < 1.3$ ATLAS arXiv:1206.6074

no jet clustering, technical cut: $p_{TV} > 1$ GeV to exclude numerical instabilities $\to \approx 0.3\%$ uncertainty on σ

Interference for semileptonic H decay modes in ggF

Integrated results

using standard multi-channel phase space sampling and FeynArts/FormCalc/LoopTools adapted amplitude code, various tests amplitudes validated with independent implementation in MG5-MadLoop, validation of integrated results in progress (Vryonidou)



$$\mathcal{M} = \mathcal{M}_{signal}\ \text{(LO)}\ + \mathcal{M}_{background} = \mathcal{M}_{signal} + \mathcal{M}_{loop} + \mathcal{M}_{tree}$$

Notation for amplitude contributions to cross sections:

$$S \sim |\mathcal{M}_{signal}|^2$$
$$I_{tree} \sim 2\,\mathrm{Re}(\mathcal{M}^*_{signal}\,\mathcal{M}_{tree})$$
$$I_{loop} \sim 2\,\mathrm{Re}(\mathcal{M}^*_{signal}\,\mathcal{M}_{loop})$$
$$I_{full} \sim 2\,\mathrm{Re}(\mathcal{M}^*_{signal}\,\mathcal{M}_{background})$$

$\mathcal{M}_{loop}$ contains all closed quark loop graphs. (NLO EW corrections to I_{tree} not included.)

relative measure for interf. with bkg. i: $$R_i = \frac{\sigma(|\mathcal{M}_{signal}|^2 + 2\,\mathrm{Re}(\mathcal{M}^*_{signal}\mathcal{M}_i))}{\sigma(|\mathcal{M}_{signal}|^2)}$$

Interference for semileptonic H decay modes in ggF

Integrated results

$gg \to H \to W^- W^+ \to \ell \bar{\nu}_\ell q_u \bar{q}_d$ σ [fb], pp, $\sqrt{s} = 8$ TeV		interference			ratio		
cuts	S	I_{tree}	I_{loop}	I_{full}	R_{tree}	R_{loop}	R_{full}
min.	67.3(4)	–2.48(2)	–4.99(5)	–7.42(7)	0.963(7)	0.926(7)	0.890(7)
LHC	1.96(1)	0.269(3)	–2.65(3)	–2.38(2)	1.137(8)	–0.35(1)	–0.21(1)
bkg.	13.29(7)	–0.0062(6)	–1.03(1)	–1.04(1)	1.000(7)	0.922(7)	0.922(7)

$gg \to H \to W^+ W^- \to \bar{\ell} \nu_\ell \bar{q}_u q_d$ σ [fb], pp, $\sqrt{s} = 8$ TeV		interference			ratio		
cuts	S	I_{tree}	I_{loop}	I_{full}	R_{tree}	R_{loop}	R_{full}
min.	67.2(4)	–2.47(2)	–4.99(5)	–7.47(7)	0.963(7)	0.926(7)	0.889(7)
LHC	1.96(1)	0.270(3)	–2.65(3)	–2.38(2)	1.138(8)	–0.35(1)	–0.21(1)
bkg.	13.30(7)	–0.0055(9)	–1.03(1)	–1.04(1)	1.000(7)	0.922(7)	0.922(7)

Interference for semileptonic H decay modes in ggF

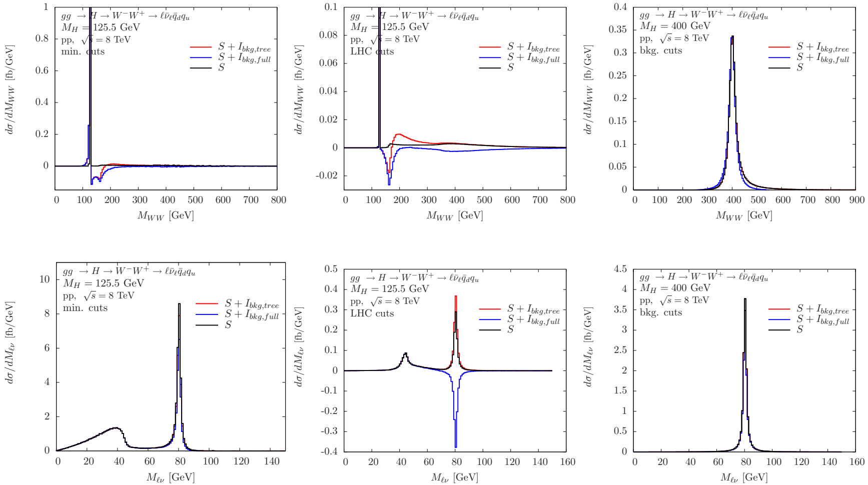
Integrated results

$gg \to H \to ZZ \to \ell\bar{\ell}q_u\bar{q}_u$ σ [fb], pp, $\sqrt{s} = 8$ TeV		interference			ratio		
cuts	S	I_{tree}	I_{loop}	I_{full}	R_{tree}	R_{loop}	R_{full}
min.	1.96(1)	–0.190(4)	–0.343(3)	–0.541(5)	0.903(7)	0.825(7)	0.724(7)
LHC	0.1166(6)	0.017(2)	–0.194(2)	–0.176(6)	1.15(2)	–0.67(2)	–0.51(5)
bkg.	1.342(7)	–0.0012(2)	–0.0882(9)	–0.0892(9)	0.999(7)	0.934(7)	0.934(7)

$gg \to H \to ZZ \to \ell\bar{\ell}q_d\bar{q}_d$ σ [fb], pp, $\sqrt{s} = 8$ TeV		interference			ratio		
cuts	S	I_{tree}	I_{loop}	I_{full}	R_{tree}	R_{loop}	R_{full}
min.	2.51(2)	–0.248(3)	–0.439(6)	–0.680(7)	0.901(7)	0.825(7)	0.729(7)
LHC	0.1497(8)	0.0223(6)	–0.245(5)	–0.227(3)	1.149(9)	–0.64(3)	–0.52(2)
bkg.	1.720(9)	–0.00130(5)	–0.113(1)	–0.114(1)	0.999(7)	0.934(7)	0.934(7)

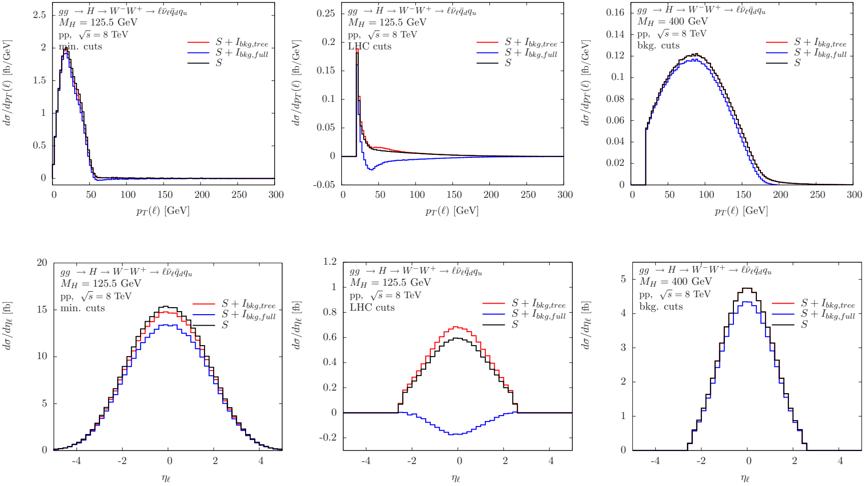
Interference for semileptonic H decay modes in ggF

Differential results



Interference for semileptonic H decay modes in ggF

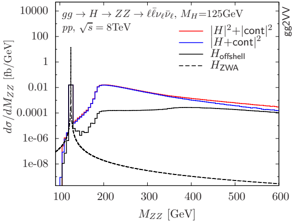
Differential results

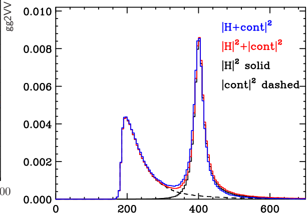


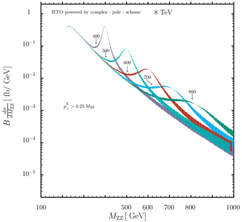
Heavy Higgs - light Higgs - continuum interference

consider a heavy Higgs h_2 (signal) in addition to a light Higgs h_1 at 125 GeV (background)

Two-Higgs model: SM & real EW singlet scalar, as defined in YR3 arXiv:1307.1347, Sec. 13.3







right fig.: G. Passarino (arXiv:1206.3824)

What is the impact of interference with the offshell tail of the 125 GeV Higgs for a heavy Higgs of 300, 600 or 900 GeV?

$$S \sim |\mathcal{M}_{h2}|^2$$

$$I_{h1} \sim 2\,\mathrm{Re}(\mathcal{M}^*_{h2}\,\mathcal{M}_{h1})$$

$$I_{bkg} \sim 2\,\mathrm{Re}(\mathcal{M}^*_{h2}\,\mathcal{M}_{bkg})$$

$$I_{full} \sim 2\,\mathrm{Re}(\mathcal{M}^*_{h2}\,(\mathcal{M}_{h1} + \mathcal{M}_{bkg}))$$

Two-Higgs model details: $\theta = \pi/8$ ($\sigma_{h1} \approx \sigma_{H,\mathrm{SM}}$ up to 20%), $\Gamma_{h1} = 4.2577 \cdot 10^{-3}$ GeV for $M_{h1} = 125$ GeV, $\Gamma_{h2} = 1.70204\ (20.7236)\ [69.1805]$ GeV for $M_{h2} = 300\ (600)\ [900]$ GeV

Heavy Higgs - light Higgs - continuum interference

Integrated results

$gg \to h_2 \to W^-W^+ \to \ell\bar{\nu}\bar{\ell}'\nu'$ min. cuts σ [fb], pp, $\sqrt{s} = 8$ TeV		interference			ratio		
M_{h2} [GeV]	S	I_{h1}	I_{bkg}	I_{full}	R_{h1}	R_{bkg}	R_{full}
300	1.4144(6)	0.1173(3)	–0.0453(5)	0.0730(4)	1.0829(7)	0.9679(7)	1.0516(7)
600	0.18744(7)	–0.0558(2)	0.0942(2)	0.03882(7)	0.7025(8)	1.503(1)	1.2071(7)
900	0.017991(7)	–0.03500(3)	0.04957(4)	0.01468(2)	–0.945(2)	3.755(3)	1.816(2)

$gg \to h_2 \to W^-W^+ \to \ell\bar{\nu}\bar{\ell}'\nu'$ min. cuts & $\vert M_{VV} - M_{h2}\vert < \Gamma_{h2}$ σ [fb], pp, $\sqrt{s} = 8$ TeV		interference			ratio		
M_{h2} [GeV]	S	I_{h1}	I_{bkg}	I_{full}	R_{h1}	R_{bkg}	R_{full}
300	0.98(2)	0.00033(4)	0.03431(8)	0.03464(9)	1.00(2)	1.03(2)	1.04(2)
600	0.135(2)	–0.00183(3)	0.01584(4)	0.01401(4)	0.99(2)	1.12(2)	1.10(2)
900	0.01288(2)	–0.001343(5)	0.00432(3)	0.00298(3)	0.896(2)	1.335(3)	1.231(3)

Heavy Higgs - light Higgs - continuum interference

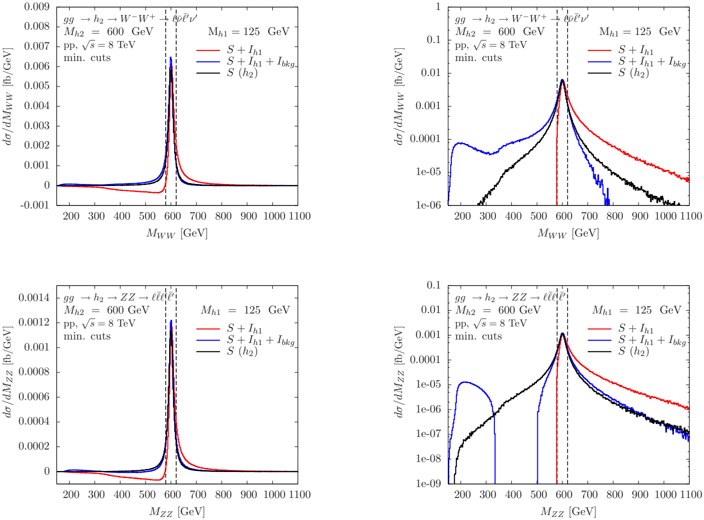
Integrated results

$gg \to h_2 \to ZZ \to \ell\bar{\ell}\ell'\bar{\ell}'$ min. cuts σ [fb], pp, $\sqrt{s} = 8$ TeV		interference			ratio		
M_{h2} [GeV]	S	I_{h1}	I_{bkg}	I_{full}	R_{h1}	R_{bkg}	R_{full}
300	0.12609(5)	0.01187(3)	0.00358(4)	0.01545(5)	1.0941(6)	1.0284(6)	1.1225(7)
600	0.018199(7)	–0.00506(2)	0.00571(2)	0.00064(2)	0.7217(8)	1.3135(9)	1.035(2)
900	0.0017746(7)	–0.003296(4)	0.003403(3)	0.000107(5)	–0.857(3)	2.918(2)	1.060(3)

$gg \to h_2 \to ZZ \to \ell\bar{\ell}\ell'\bar{\ell}'$ min. cuts & $\lvert M_{VV} - M_{h2}\rvert < \Gamma_{h2}$ σ [fb], pp, $\sqrt{s} = 8$ TeV		interference			ratio		
M_{h2} [GeV]	S	I_{h1}	I_{bkg}	I_{full}	R_{h1}	R_{bkg}	R_{full}
300	0.0879(2)	4.0(4)e–05	0.00547(2)	0.00551(2)	1.000(2)	1.062(2)	1.063(2)
600	0.01318(2)	–0.00020(2)	0.001045(7)	0.00084(2)	0.985(3)	1.079(3)	1.064(3)
900	0.001273(2)	–0.000130(2)	0.000373(2)	0.000243(3)	0.898(3)	1.293(3)	1.191(3)

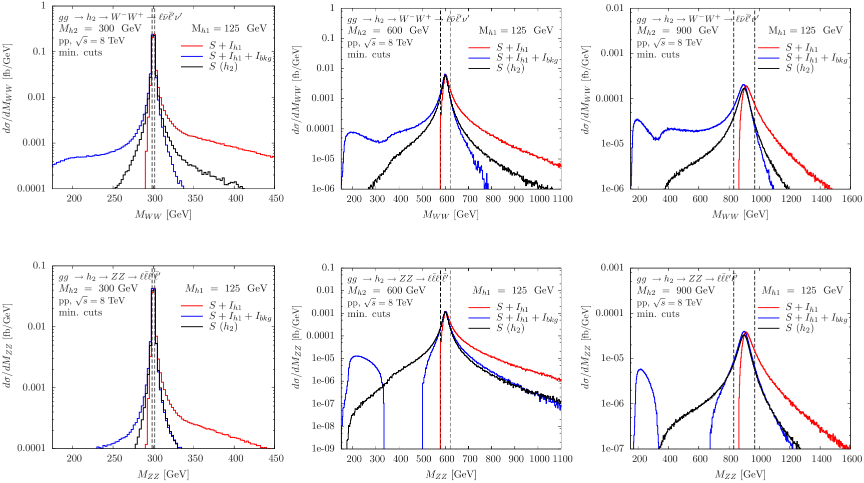
Heavy Higgs - light Higgs - background interference

Differential results



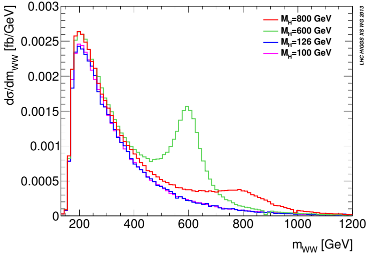
Heavy Higgs - light Higgs - background interference

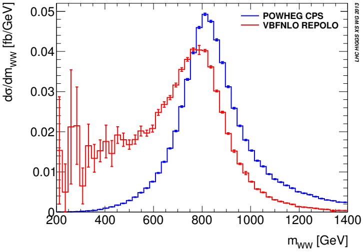
Differential results



Heavy Higgs interference in VBF

similar study for VBF (SM-like light & heavy Higgs)





figures taken from YR3 arXiv:1307.1347, Sec. 12.4

Michael Rauch, Franziska Schissler (VBFNLO)

left: SM Higgs with M_H including continuum background and interference
right: heavy SM Higgs signal only (blue),
blue plus interference with cont. bkg. & light SM Higgs (red)

standard VBF cuts & LHC detector acceptance cuts are applied

$\rightarrow$ Michael Rauch's talk for additional related results

Summary

- $H \to ZZ, WW$ in ggF & VBF: $\mathcal{O}(10\%)$ off-shell Higgs signal contribution with large Higgs(-Higgs)-continuum interference: now taken into account, provides *complementary physics information* ($\to$ Kirill Melnikov's talk and Christoph Englert's talk)
- $gg \to H \to ZZ, WW \to 2\ell 2\ell,\ 4\ell,\ 2\ell 2\nu$: interference studied in great detail, tools & events available (caveat: LO); NLO calculation: very hard, in progress
- First analysis of interference for $pp \to H \to ZZ$ + jet Campbell, R.K. Ellis, Furlan, Röntsch
- Semileptonic channels $gg \to H \to WW \to \ell\nu q q'$ and $gg \to H \to ZZ \to \ell\bar{\ell} q\bar{q}$ contribute to ongoing (heavy) Higgs analyses
- First analysis of interference effects in semileptonic channels, new feature: interfering tree-level background, contribution of tree amplitude to (large) full interference is minor (cf. $pp \to H \to ZZ$ + jet results), and negligible when heavy Higgs search cuts are applied
- First analysis of heavy Higgs - light Higgs interference effects in $gg \to H \to VV$, in general significant compared to Higgs-continuum interference, effective suppression to $< 2\%$ with window cut $M_{h2} \pm \Gamma_{h2}$ on M_{VV} (M_T) for $M_{h2} \lesssim 600$ GeV
- outlook: further phenomenological studies, improved amplitude implementation in gg2VV