

# gg2WW/ZZ status report and recent results

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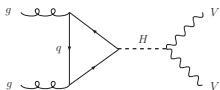
Royal Holloway, University of London

BSM subgroup kickoff meeting

LHC Higgs cross section working group

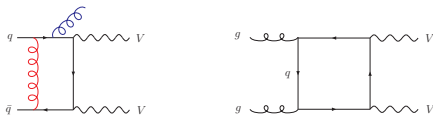
April 30, 2012

# Gluon-fusion Higgs $\rightarrow VV$ and continuum $VV$ production



$gg \rightarrow H \rightarrow VV$  searches Dittmar, Dreiner (1996); Davatz, Giolo-Nicollerat, Zanetti (2006); Mellado, Quayle, Sau Lan Wu (2007); Davatz, Dittmar, Giolo-Nicollerat (2007); Davatz (2007); Quayle (2008); Mellado, Ruan, Zhang (2011)

QCD corrections/shower MCs for  $gg \rightarrow H \rightarrow VV$  searches Cranmer, Mellado, Quayle, Sau Lan Wu (2003); Davatz, Dissertori, Dittmar, Grazzini, Pauss (2004); Davatz, Stöckli, Anastasiou, Dissertori, Dittmar, Melnikov, Petriello (2006); Davatz, Dittmar, Pauss (2006); Grazzini (2006, 2008); Anastasiou, Dissertori, Stöckli (2007); Anastasiou, Dissertori, Stöckli, Webber (2008); Frederix, Grazzini (2008); Anastasiou, Dissertori, Grazzini, Stöckli, Webber (2009)

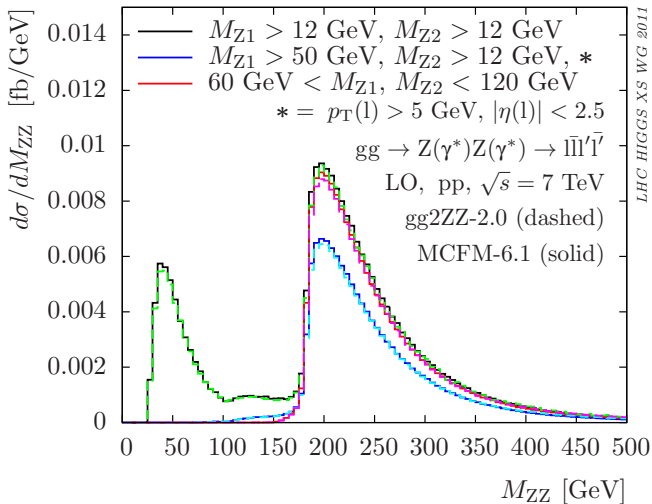


$q\bar{q} \rightarrow VV$  (LO, NLO, decays) Brown, Mikaelian (1979); Stirling, Kleiss, Ellis (1985); Gunion, Kunszt (1986); Muta, Najima, Wakaizumi (1986); Berends, Kleiss, Pittau (1994); Ohnemus (1991); Mele, Nason, Ridolfi (1991); Ohnemus, Owens (1991); Frixione (1993); Ohnemus (1994); Dixon, Kunszt, Signer (1998, 1999); Campbell, Ellis (1999) (MCFM); Campbell, Ellis, Williams (2011) (MCFM); Melia, Nason, Röntsch, Zanderighi (2011) (POWHEG BOX)

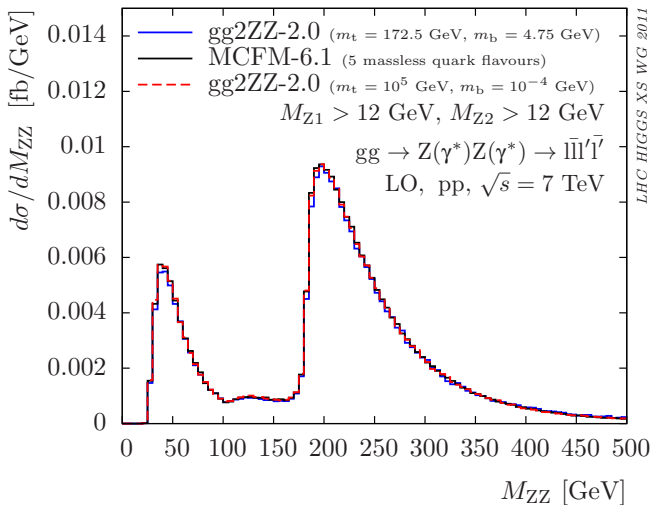
$gg \rightarrow VV$  [loop induced] (LO, decays) Dicus, Kao, Repko (1987); Glover, van der Bij (1989); Kao, Dicus (1991); Matsuura, v.d. Bij (1991); Zecher, Matsuura, v.d. Bij (1994); Dührssen, Jakobs, v.d. Bij, Marquard (2005); Binoth, Ciccolini, NK, Krämer (2005, 2006) (gg2WW); Binoth, NK, Mertsch (2008) (gg2ZZ); Campbell, Ellis, Williams (2011) (MCFM); Frederix, Frixione, Hirschi, Maltoni, Pittau, Torrielli (2011) (aMC@NLO)

Higgs-continuum  $VV$  interference Glover, van der Bij (1989); Binoth, Ciccolini, NK, Krämer (2006); Campbell, Ellis, Williams (2011); NK (2012)

# $gg \rightarrow ZZ$ : Comparison of gg2ZZ and MCFM



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# Signal-background interference for $M_H = 400$ GeV

$gg (\rightarrow H) \rightarrow W^-W^+ \rightarrow l\bar{\nu}_l\bar{l}'\nu_{l'}$  and  $gg (\rightarrow H) \rightarrow ZZ \rightarrow l\bar{l}l'\bar{l}'$

arXiv:1201.1667

## Settings and cuts

$\mu_R = \mu_F = M_H/2 = 200$  GeV,  $\Gamma_H = 29.16$  GeV (HDECAY)  
MSTW2008LO (68% C.L.), other: LHC Higgs Cross Section WG,  
arXiv:1101.0593 [hep-ph], App. A (with NLO  $\Gamma_V$  and  $G_\mu$  scheme)

### **WW standard cuts:**

$$p_{T\ell} > 20 \text{ GeV}, |\eta_\ell| < 2.5$$

$$p_T^{\ell\bar{\ell}'} > 30 \text{ GeV}, M_{\ell\bar{\ell}'} > 12 \text{ GeV}$$

**WW Higgs search cuts** ( $M_H = 400$  GeV): standard cuts and

$$p_{T\ell\text{min}} > 25 \text{ GeV}, p_{T\ell\text{max}} > 90 \text{ GeV}$$

$$M_{\ell\bar{\ell}'} < 300 \text{ GeV}, \Delta\phi_{\ell\bar{\ell}'} < 175^\circ$$

### **ZZ standard cuts:**

$$p_{T\ell} > 20 \text{ GeV}, |\eta_\ell| < 2.5$$

$$76 \text{ GeV} < M_{\ell\bar{\ell}}, M_{\ell'\bar{\ell}'} < 106 \text{ GeV}$$

**ZZ Higgs search cuts:** standard cuts and

$$|M_{l\bar{l}l'\bar{l}'} - M_H| < \Gamma_H$$

## Sample program output

*WW* standard cuts, LHC, 7 TeV:

$\sigma(|\mathcal{M}_H + \mathcal{M}_{\text{cont}}|^2)$  = 10.5817 MC:  $\pm 0.0063$  ( $\pm 0.059\%$ ) scale( $\times 2$ ):  
-2.5573 (-24%) + 3.6967 (+35%) PDF: -0.2723 (-2.6%) + 0.2382 (+2.3%) fb,  
sym. scale error:  $\pm 28\%$ , sym. PDF error:  $\pm 2.4\%$

$\sigma(|\mathcal{M}_H|^2)$  = 4.3611 MC:  $\pm 0.0021$  ( $\pm 0.048\%$ ) scale( $\times 2$ ): -1.1500 (-26%) +  
1.7227 (+40%) PDF: -0.1318 (-3%) + 0.1261 (+2.9%) fb, sym. scale error:  
 $\pm 31\%$ , sym. PDF error:  $\pm 3\%$

$\sigma(|\mathcal{M}_{\text{cont}}|^2)$  = 6.3506 MC:  $\pm 0.0039$  ( $\pm 0.062\%$ ) scale( $\times 2$ ): -1.4583 (-23%) +  
2.0621 (+32%) PDF: -0.1526 (-2.4%) + 0.1243 (+2%) fb, sym. scale error:  
 $\pm 26\%$ , sym. PDF error:  $\pm 2.2\%$

# Signal-background interference for $M_H = 400$ GeV

## Integrated results

		$\sigma$ [fb], $pp, \sqrt{s} = 7$ TeV, $M_H = 400$ GeV			interference	
process	cuts	$ \mathcal{M}_H ^2$	$ \mathcal{M}_{\text{cont}} ^2$	$ \mathcal{M}_H + \mathcal{M}_{\text{cont}} ^2$	$R_1$	$R_2$
$gg (\rightarrow H) \rightarrow WW$	stand.	4.361(3)	6.351(4)	10.582(7)	0.9879(8)	0.970(2)
$gg (\rightarrow H) \rightarrow WW$	Higgs	2.502(2)	0.633(1)	3.007(3)	0.959(2)	0.949(2)
$gg (\rightarrow H) \rightarrow ZZ$	stand.	0.3654(4)	0.3450(4)	0.7012(8)	0.987(2)	0.975(3)
$gg (\rightarrow H) \rightarrow ZZ$	Higgs	0.2729(3)	0.01085(2)	0.2867(3)	1.010(2)	1.011(2)

		$\sigma$ [fb], $pp, \sqrt{s} = 14$ TeV, $M_H = 400$ GeV			interference	
process	cuts	$ \mathcal{M}_H ^2$	$ \mathcal{M}_{\text{cont}} ^2$	$ \mathcal{M}_H + \mathcal{M}_{\text{cont}} ^2$	$R_1$	$R_2$
$gg (\rightarrow H) \rightarrow WW$	stand.	23.38(2)	26.47(2)	48.26(4)	0.9680(8)	0.932(2)
$gg (\rightarrow H) \rightarrow WW$	Higgs	13.54(2)	3.201(5)	15.74(2)	0.940(2)	0.926(2)
$gg (\rightarrow H) \rightarrow ZZ$	stand.	1.893(3)	1.417(2)	3.205(5)	0.969(2)	0.945(3)
$gg (\rightarrow H) \rightarrow ZZ$	Higgs	1.377(2)	0.0531(1)	1.445(2)	1.011(2)	1.011(3)

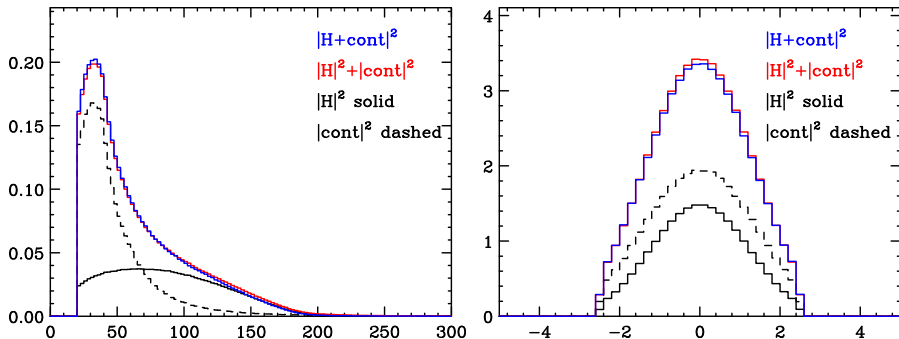
$(S + B)$ -inspired interference measure:  $R_1 = \sigma(|\mathcal{M}_H + \mathcal{M}_{\text{cont}}|^2) / [\sigma(|\mathcal{M}_H|^2) + \sigma(|\mathcal{M}_{\text{cont}}|^2)]$

$(S/B)$ -inspired interference measure:  $R_2 = \sigma(|\mathcal{M}_H|^2 + 2 \text{Re}(\mathcal{M}_H \mathcal{M}_{\text{cont}}^*)) / \sigma(|\mathcal{M}_H|^2)$

# Signal-background interference for $M_H = 400$ GeV

## Differential results

$gg (\rightarrow H) \rightarrow W^- W^+ \rightarrow l \bar{\nu}_l \bar{l}' \nu_{l'}$ , LHC, 7 TeV, standard cuts



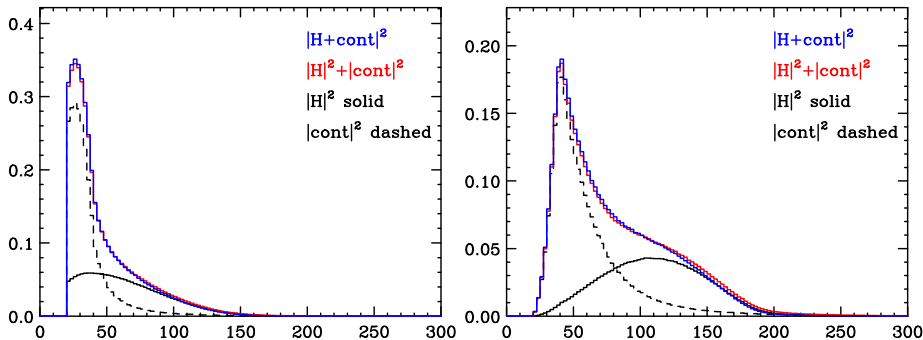
$p_{Tl}$  [GeV] (left) and  $\eta_l$  (right) distributions [fb/[o]]



# Signal-background interference for $M_H = 400$ GeV

## Differential results

$gg (\rightarrow H) \rightarrow W^-W^+ \rightarrow l\bar{\nu}_l\bar{l}'\nu_{l'}$ , LHC, 7 TeV, standard cuts

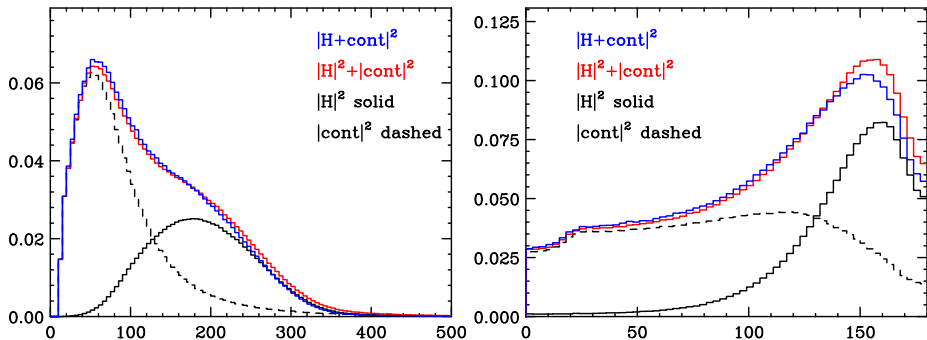


$p_{Tl,min}$  [GeV] (left) and  $p_{Tl,max}$  [GeV] (right) distributions [fb/[o]]

# Signal-background interference for $M_H = 400$ GeV

## Differential results

$gg (\rightarrow H) \rightarrow W^- W^+ \rightarrow l \bar{\nu}_l \bar{l}' \nu_{l'}$ , LHC, 7 TeV, standard cuts

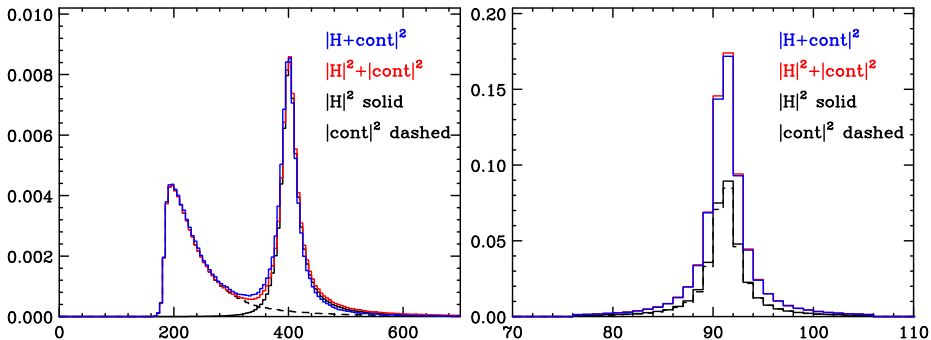


$M_{l\bar{l}}$  [GeV] (left) and  $\Delta\phi_{l\bar{l}}$  [ $^\circ$ ] (right) distributions [fb/[o]]

# Signal-background interference for $M_H = 400$ GeV

## Differential results

$gg (\rightarrow H) \rightarrow ZZ \rightarrow \bar{l}l'\bar{l}'$ , LHC, 7 TeV, standard cuts



$M_{\bar{l}l'l'}$  [GeV] (left) and  $M_{\bar{l}l}$  [GeV] (right) distributions [fb/o]

# gg2WW/ZZ parton-level integrator/event generator status

<http://hepsource.sf.net/programs/>

**gg2WW-3.0 public**  $gg (\rightarrow H) \rightarrow W^- W^+ \rightarrow l\bar{\nu}_l \bar{l}' \nu_{l'}$  in full PS;  $l, l' = e, \mu, \tau$

- event records: massive muon and tau 4-momenta to facilitate decays
- random number generator seed can be set in settings.cpp or specified in text file
- latest parameters/settings (LHC Higgs Cross Section WG and ATLAS MC12) and PDF sets
- works with latest compiler and library versions
- automatic calculation of scale and PDF errors
- simultaneous calculation of cross sections for multiple scale definitions
- alternative FormCalc amplitude implementation
- negative event weights caused by PDFs are now handled

**gg2ZZ-2.0 public**  $gg \rightarrow ZZ \rightarrow \bar{l}l' \bar{l}'$  in full PS;  $l, l' = e, \mu, \tau; l \neq l'$

**WW/ZZ: unweighted event sets in LHEF format for 7 and 8 TeV available as downloads**

**gg2ZZ-3.0 in preparation**  $gg (\rightarrow H) \rightarrow ZZ \rightarrow \bar{l}l' \bar{l}', \bar{l}l\bar{l}, \bar{l}\bar{\nu}_{l'} \bar{\nu}_{l'}, \bar{l}\bar{q}\bar{q}; l, l' = e, \mu, \tau$