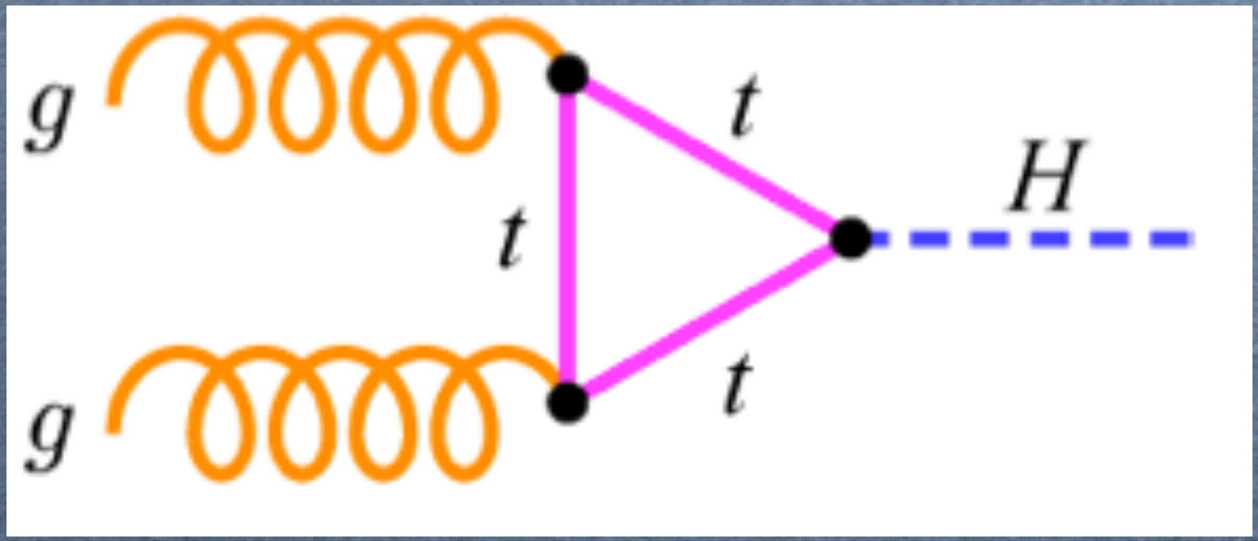
ggF

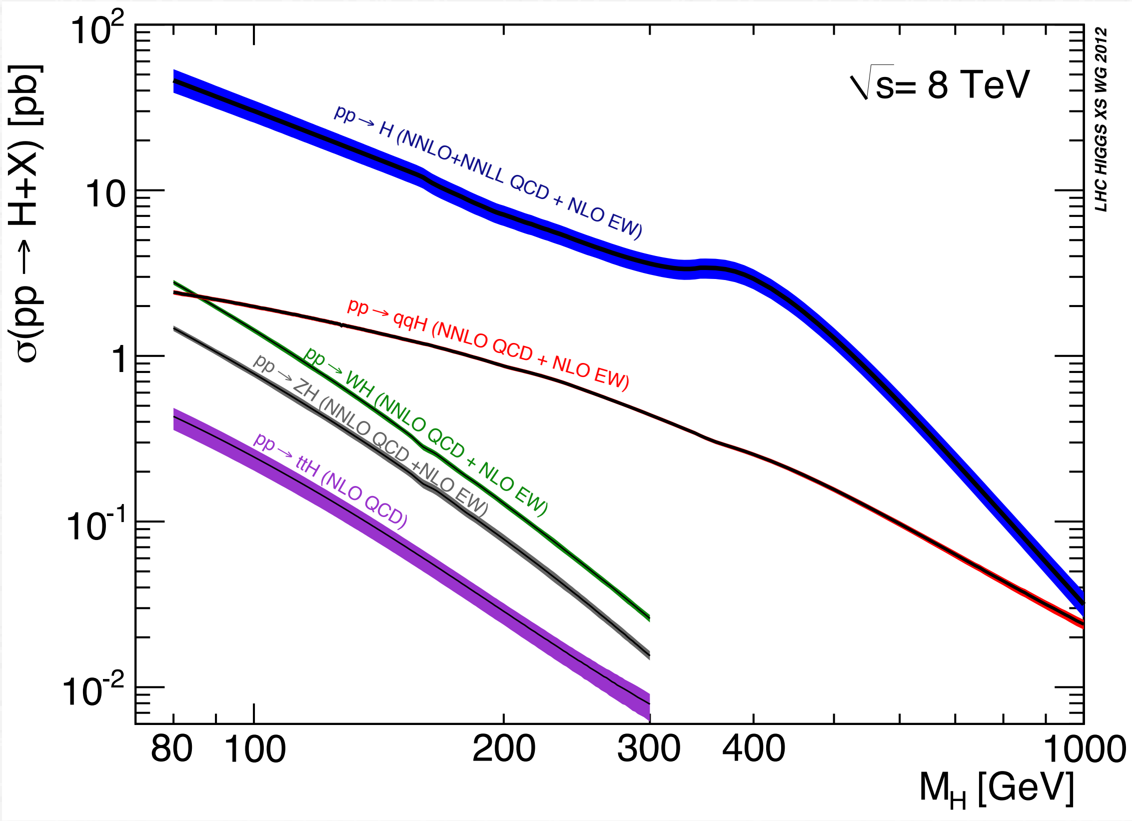


B. Di Micco
Universita' degli Studi di Roma Tre
CERN
for the ggF Higgs XS WG
(D. De Florian, N. Kauer et al.)

Outline

- Cross section values for the ggF process;
- Higgs p_T corrections;
- Finite quark mass effects;
- Off-shell ness and interference
- Background treatment for $\gamma\gamma$ and WW

Higgs production cross section

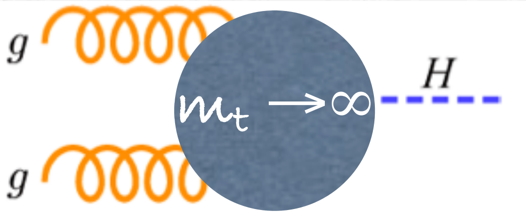


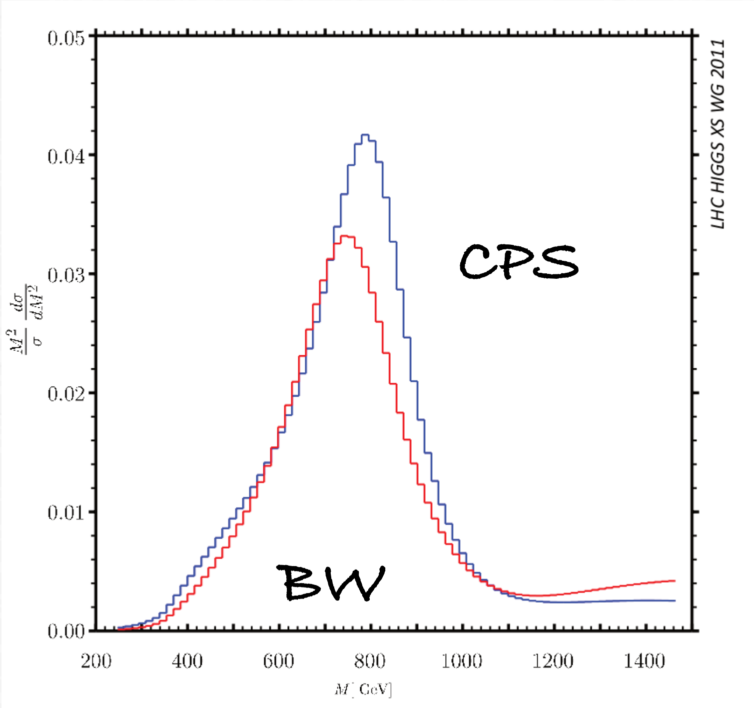
- dFG Evaluated with finite m_t and m_b @NLO + NLL, correction at NNLL +NNLO are computed $m_t \to \infty$.
- Include CPS scheme for the Higgs propagator (no Breit-Wigner neither Zero Width Approximation)
- EW correction applied at NLO

The scale of the calculation is

$$\mu_R = \mu_F = m_H$$

σ (m_H = 125)	scale uncertainty $1/2 < \mu_F, \mu_R < 2$	PDF+α_s (old PDF4LHC)
19.52 pb	**+7.2% -7.8%**	**+7.5 -6.9%**





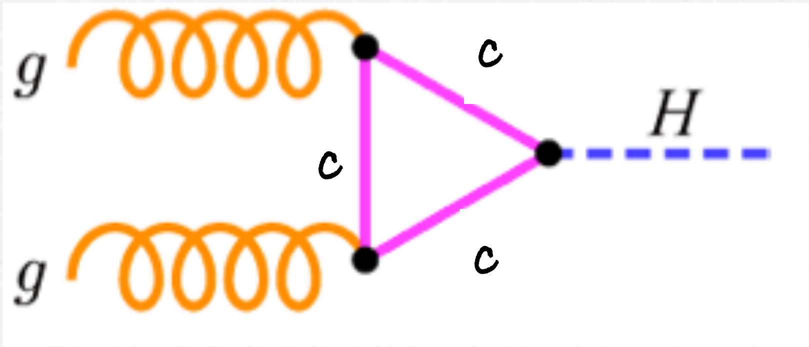
Inclusion of the CPS scheme allowed to reduce the systematics removing comparison with ABPS non resummed calculation that included the finite Higgs width as BW.

ABPS: Anastasiou, Boughezal, Petriello, Stoeckli
dFG: De Florian, Grazzini

Development in the XS calculation.

Up to now only t and b quark finite mass effects were included at NLO+NLL.

Recently it was noticed that charm quark has a sizeble effect.



D. De Florian, M. Grazzini

-2.5% @ 125 GeV @ Borm Level

In the dFG calculation, HQ is treated exactly at NLO+NLL, and $m_t \to \infty$ at NNLO+NNLL

Charm contribution reduces to -1.1% @ NNLO + NNLL

All cross sections will be updated also with new PDFs and uncertainties during the LHC shutdown.

Higgs p_T spectrum.

Big development this year on the Higgs p_T spectrum side.

The prehistory (it was jsut in 2011)	Significant deviation between Powheg and NLO+NNLL calculation (HQT) of the Higgs p_T distribution, both ATLAS and CMS reweighted the spectrum to HQT calculation (after hadronisation and underlying event)
But:	HQT didn't include the Heavy Quark mass effects, that were shown to be sizable, the reweighted was performed after hadronisation and UE that can slightly affect the p_T distribution (cancelling their effects).

Beginning of 2012	A new tuning parameter was included in Powheg (hfact) that was able to fix the p_T spectrum at high values Heavy Qaurk mass effects and ElectroWeack corrections were implemented in Powheg (Bagnaschi, Vicini, De Grassi, Slavich) including t,b and c contributions.

Higgs p_T spectrum.

Summer 2012	A complete matching was performed between HNNLO and HQT, providing a NNLO+NNLL calculation of the Higgs p_T spectrum (still no HQ mass effect)

Autumn 2012	For the search at high Higgs masses, the Complex Pole Scheme was implemented in both Standard Powheg and Powheg with HQ mass effect, Electroweak contribution were interpolated up to 2 TeV (big problems in the Higgs line shape were observed before) (E. Bagnaschi, G. De Grassi, A. Vicini, P. Slavich) with help from G. Passarino

Now:

Powheg with tuning to HQT, HQ mass effect corrections and Complex Pole Scheme is available for Higgs boson simulation up to 1 TeV
Default generation for ATLAS

CMS still using 2011 recipe with extra reweighitng to CPS lineshape

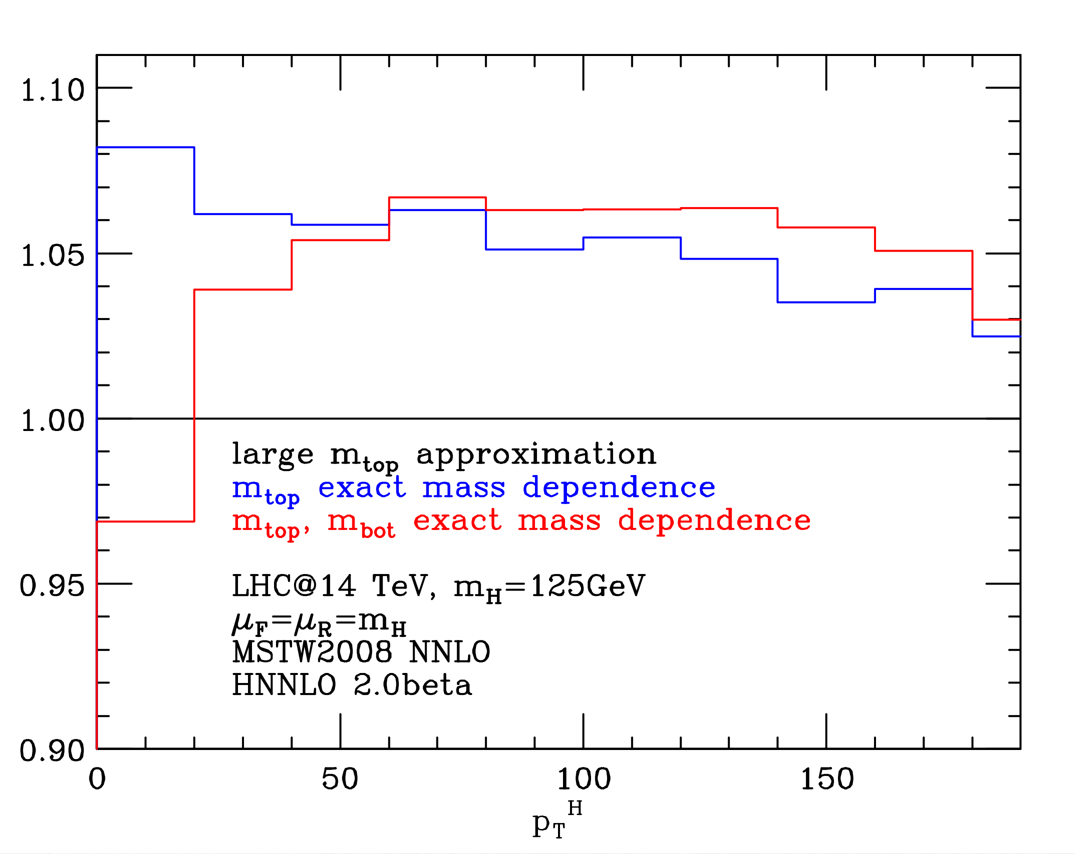
New development in HNNLO 2.0 beta.

Inclusion of Heavy Quark Mass effects on going. Implemented at NLO, will have NNLO correction with $m_t \to \infty$.

Exact dependence on the masses of top and bottom quark known up to NLO

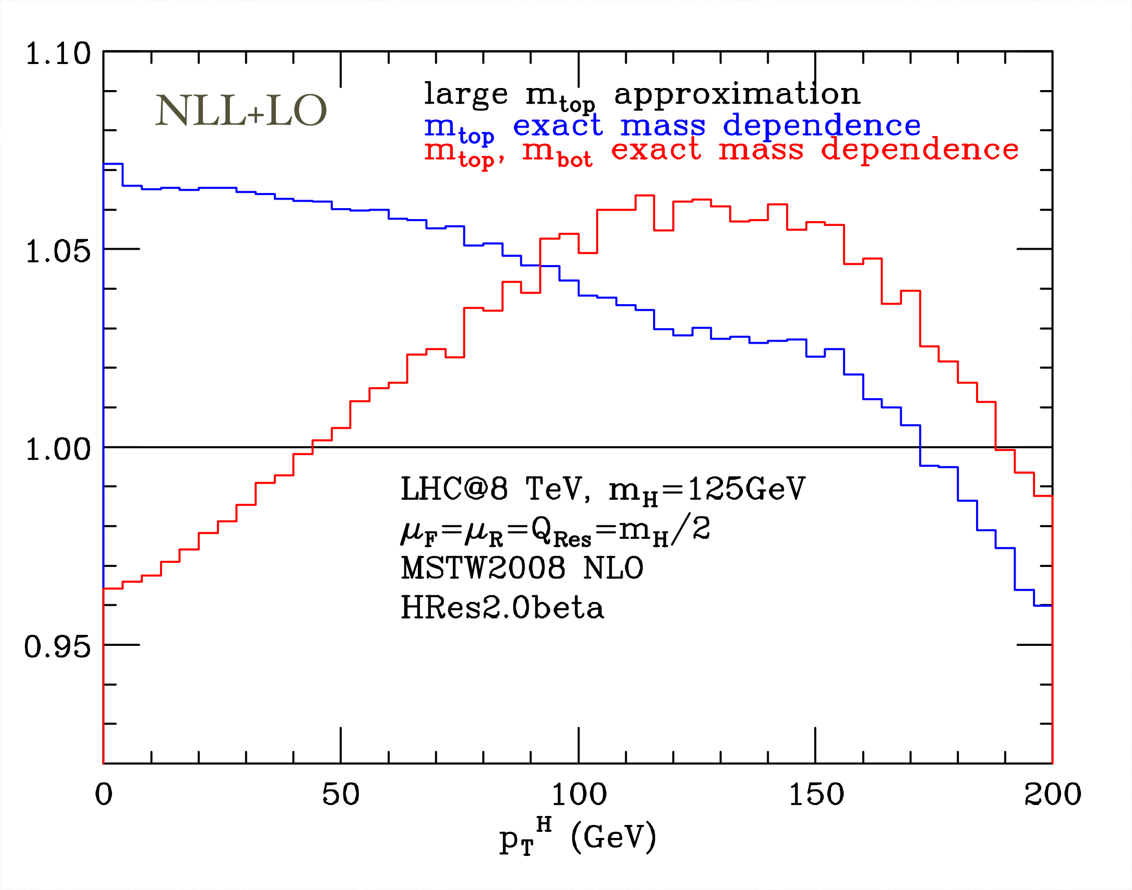
M. Spira et al. (1995)
K. Ellis, Hinchliffe, van del Bij (1988)

Now implemented in NNLO fully exclusive (in number of jets) caluclation.

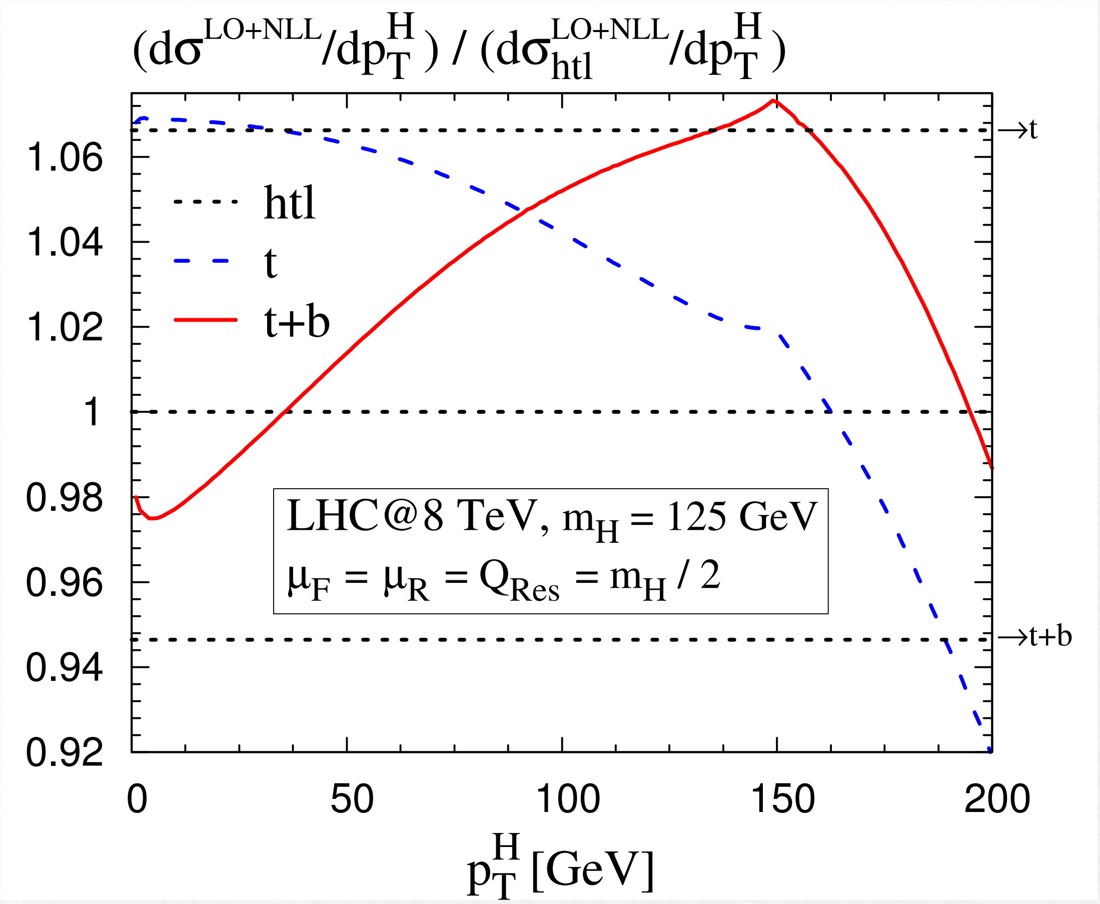


New version of HNNLO is ready to be released.

Effects on the Higgs p_T using Hres 2.0 beta



H. Sargsyan, M. Grazzini



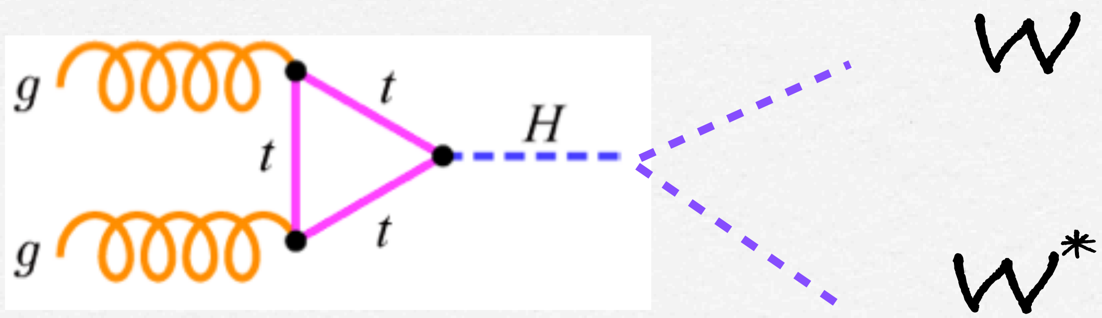
H. Mantler, M. Wiseman (2012)

HQ Mass effect included also in HRES for Higgs p_T determination, results in agreement with recent calculations.

Offshellness and interfernce effects.

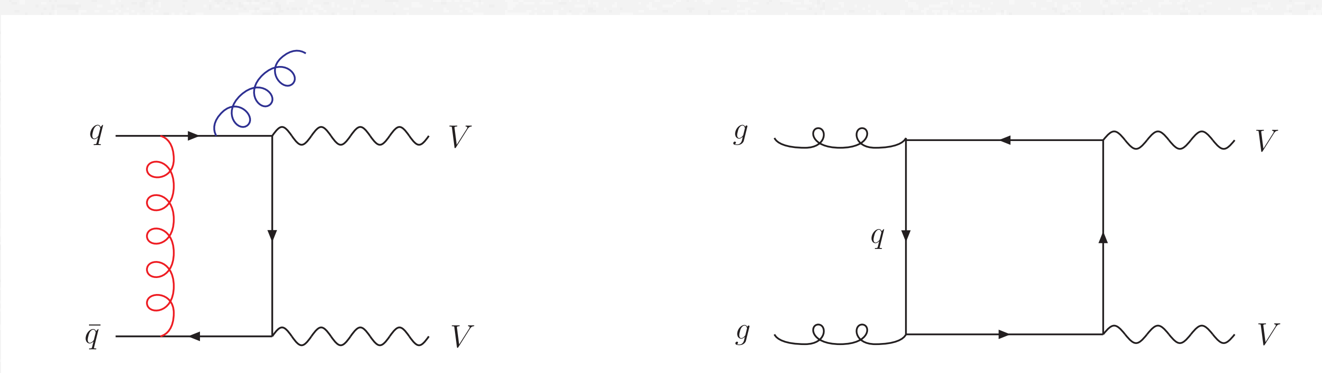
Present Higgs simulation

$pp \to H \to WW^*$ total cross section computed using CPS for the Higgs width, but BR evaluated at $m_H = 125$ GeV



The production yield gets largely enhanced when $m_{WW^*} > 2m_W$

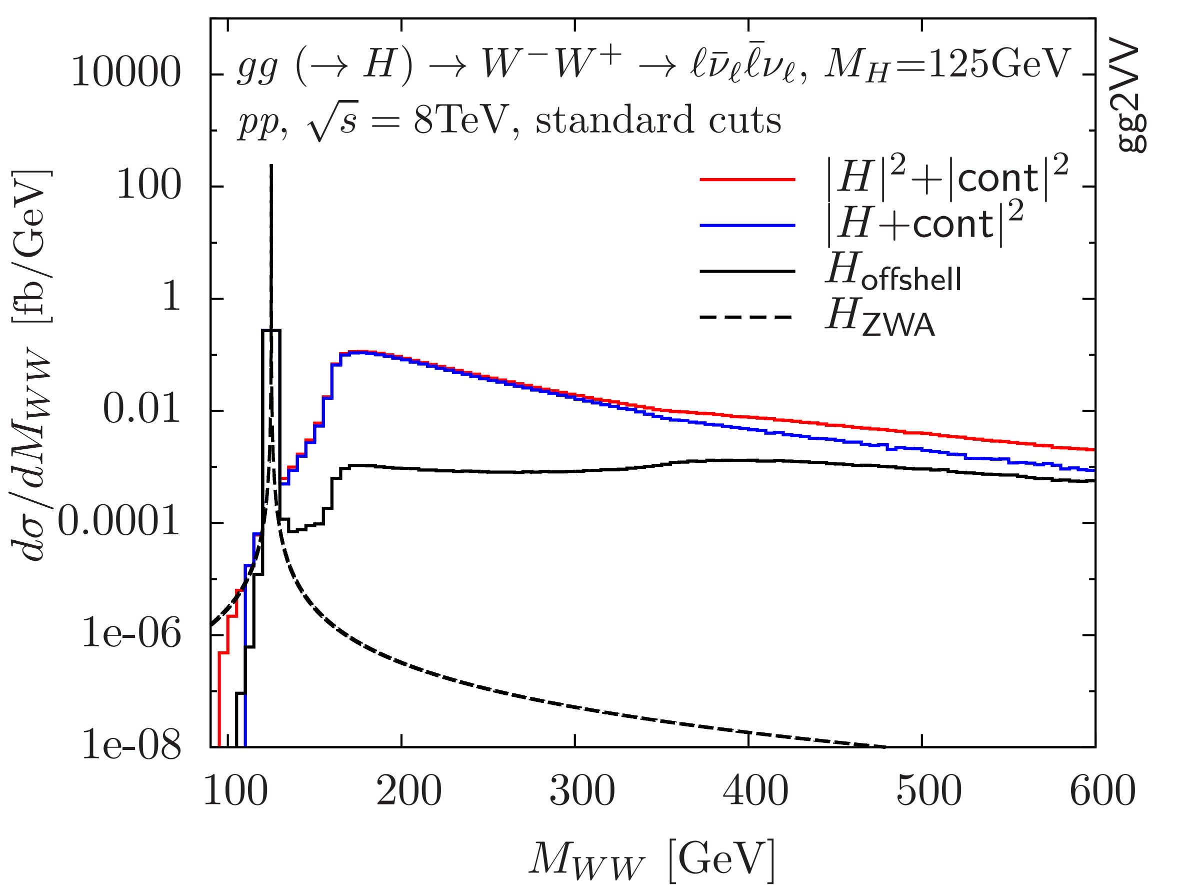
Interference effects become also important at large m_{WW}



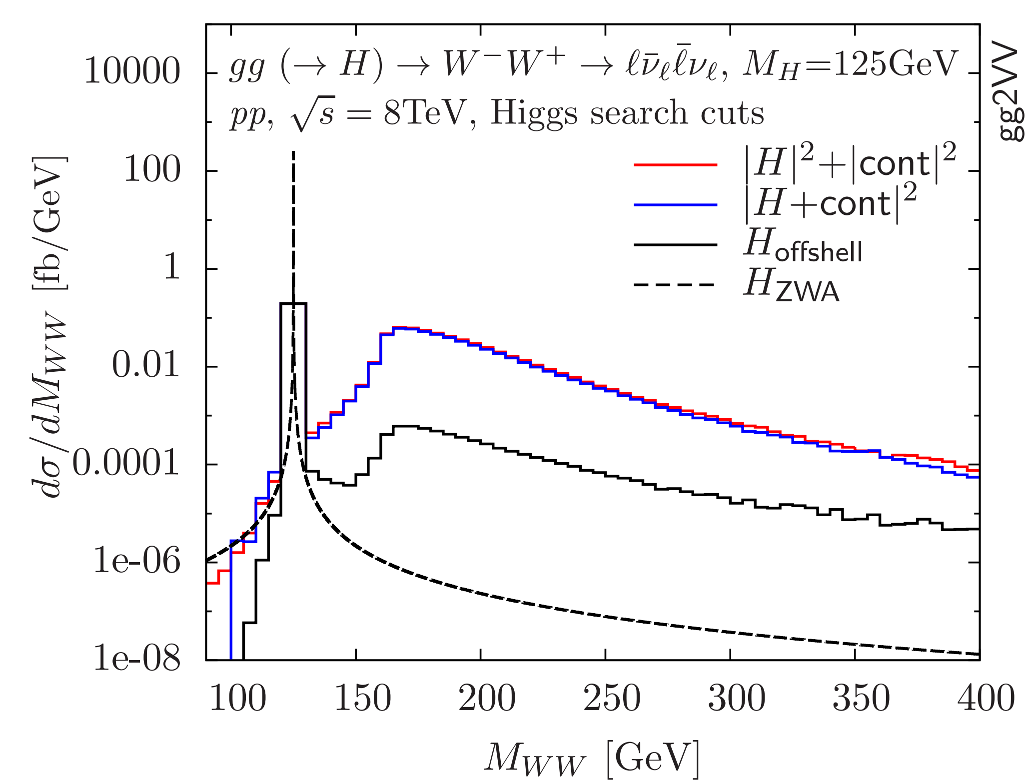
Interference effects now available in several tools:
MCFM, gg2VV, aMC@NLO

N. Kauer

offshellness + interference.



Standard cuts: $p_{T\ell} > 20$ GeV, $|\eta_\ell| < 2.5$, $\not{p}_T > 30$ GeV, $M_{\ell\ell} > 12$ GeV



Higgs search cuts: $p_{T\ell} > 20$ GeV, $|\eta_\ell| < 2.5$, $\not{p}_T > 30$ GeV, 12 GeV $< M_{\ell\ell} <$ 50 GeV, $\Delta\phi_{\ell\ell} < 1.8$.

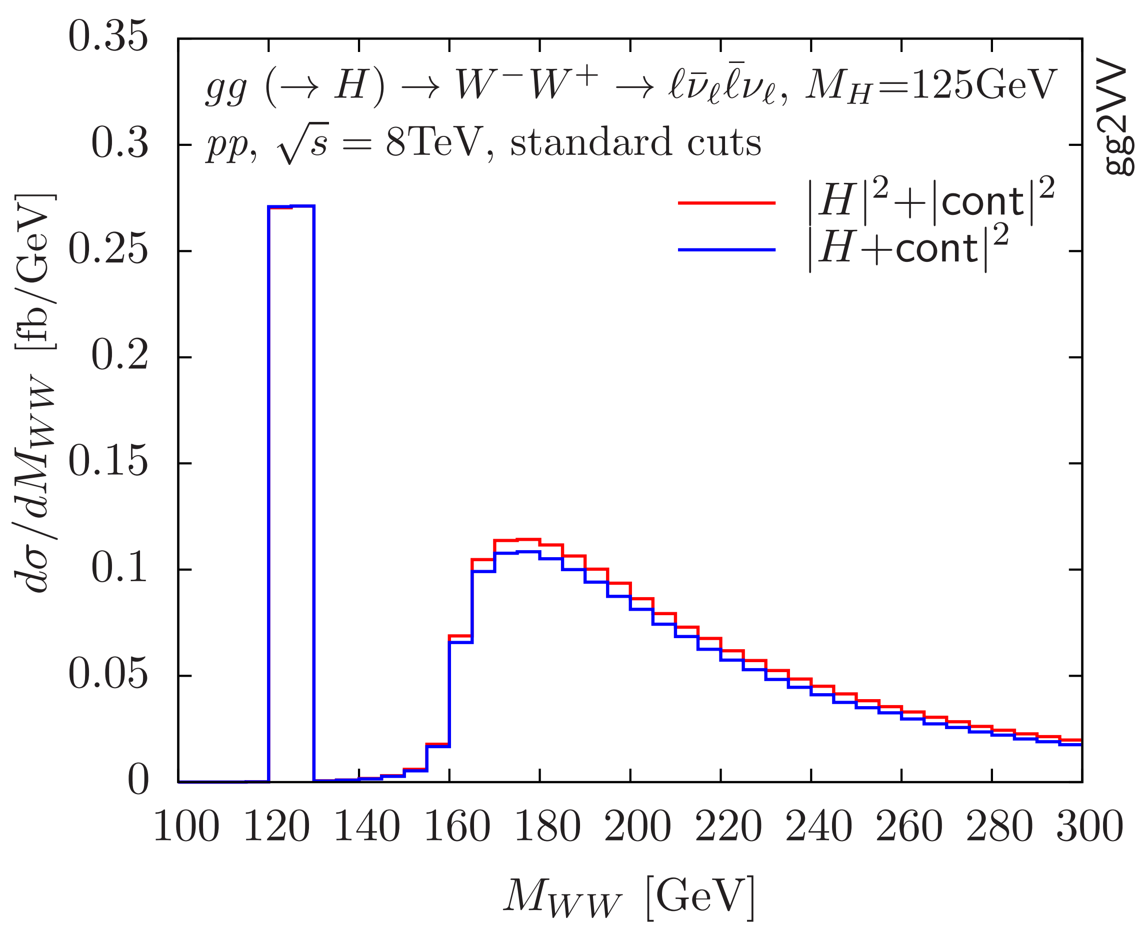
The long high mass tail is enhanced by the lepton p_T cuts but get reduced by the m_{ll} cut applied for the low mass search.

Effect checked with ATLAS cuts: < 2% in the signal region (approximate procedure using an envelop of the high mass samples built using the M_{WW} distribution)

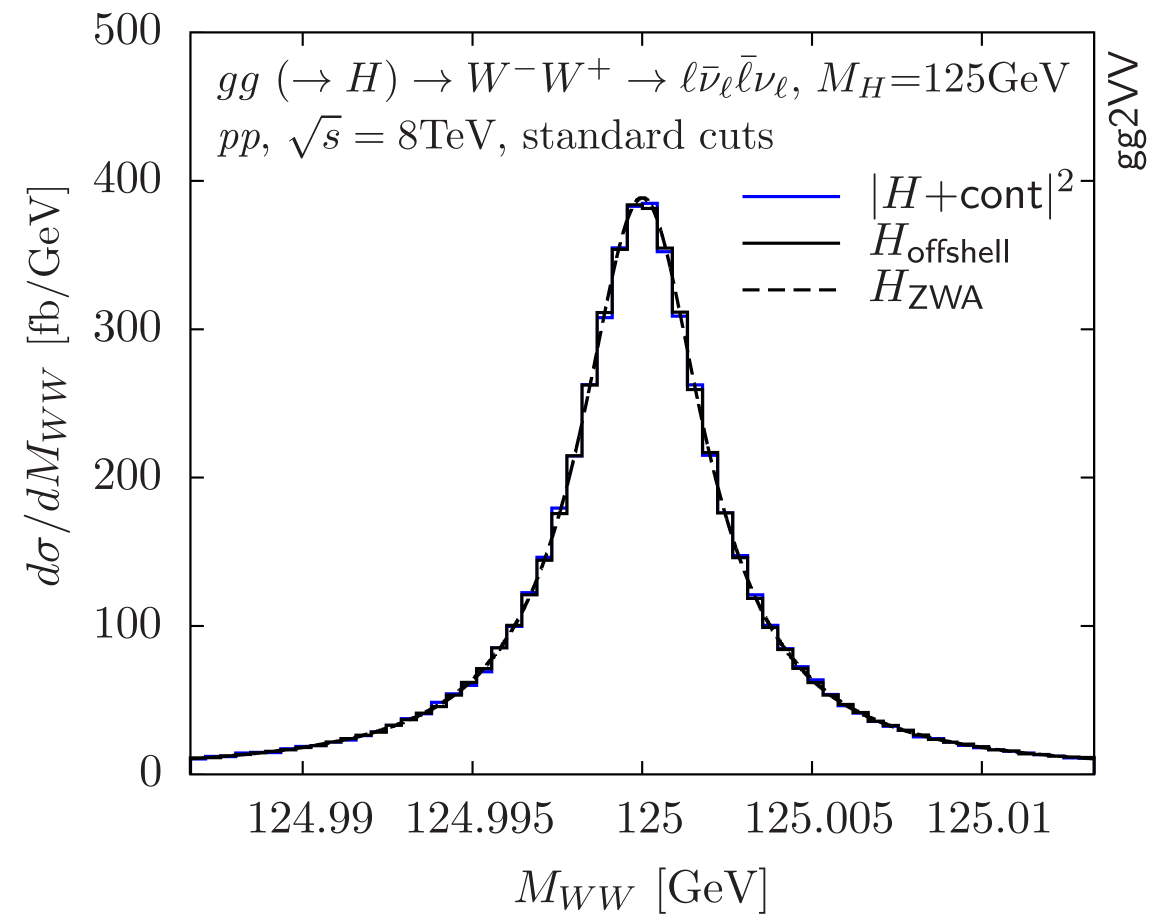
Interference effect.

N. Kauer

The interference effect looks small but not negligible at high m_{WW}.



Standard cuts: $p_{T\ell} > 20$ GeV, $|\eta_\ell| < 2.5$, $\not{p}_T > 30$ GeV, $M_{\ell\ell} > 12$ GeV



Standard cuts: $p_{T\ell} > 20$ GeV, $|\eta_\ell| < 2.5$, $\not{p}_T > 30$ GeV, $M_{\ell\ell} > 12$ GeV

Quantitative estimate of the effect in WW

N. Kauer

	$gg\,(\to H) \to W^-W^+ \to \ell\bar{\nu}_\ell\bar{\ell}'\nu_{\ell'}$						
	σ [fb], pp, $\sqrt{s} = 8$ TeV, $M_H = 125$ GeV				ZWA	interference	
selection cuts	H_{ZWA}	H_{offshell}	cont	$\lvert H_{\text{ofs}}\text{+cont}\rvert^2$	R_0	R_1	R_2
standard cuts	2.707(3)	3.225(3)	10.493(5)	12.241(8)	0.839(2)	0.8923(7)	0.542(3)
Higgs search cuts	1.950(1)	1.980(1)	2.705(2)	4.497(3)	0.9850(7)	0.9599(7)	0.905(2)
$+(0.75 M_H < M_{T1} < M_H)$	1.7726(9)	1.779(1)	0.6443(9)	2.383(2)	0.9966(8)	0.983(1)	0.977(2)
$+(80 \text{ GeV} < M_{T2} < M_H)$	1.7843(9)	1.794(1)	0.955(1)	2.687(3)	0.9944(8)	0.977(1)	0.965(2)

$$R_0 = \sigma_{H,\text{ZWA}}/\sigma_{H,\text{offshell}}$$

$$R_1 = \sigma(|\mathcal{M}_H + \mathcal{M}_{\text{cont}}|^2)/\sigma(|\mathcal{M}_H|^2 + |\mathcal{M}_{\text{cont}}|^2)$$

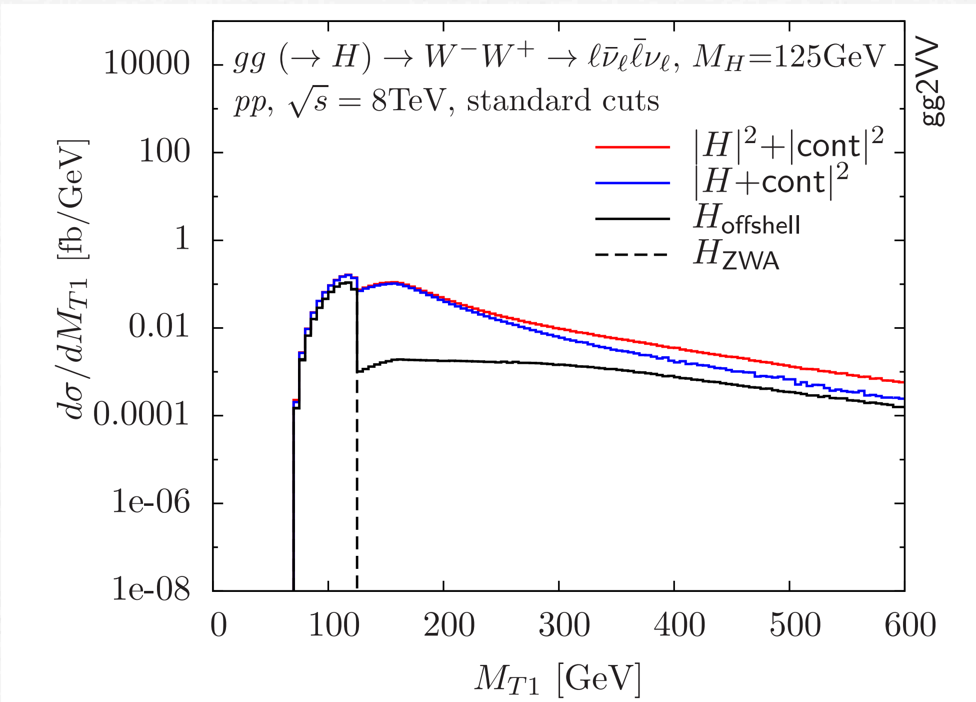
$$R_2 = \sigma(|\mathcal{M}_H|^2 + 2\,\text{Re}(\mathcal{M}_H\mathcal{M}^*_{\text{cont}}))/\sigma(|\mathcal{M}_H|^2)$$

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

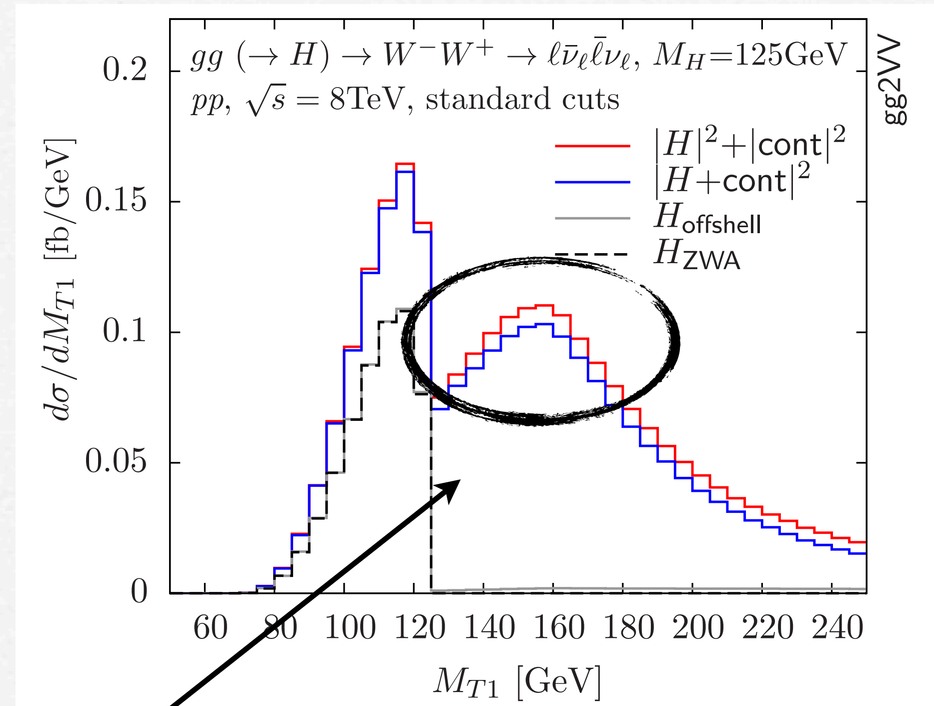
CMS: $M_{T2} = \sqrt{2\,p_{T,\ell\ell}\,\not{p}_T(1 - \cos\Delta\phi_{\ell\ell,\text{miss}})}$ with $\Delta\phi_{\ell\ell,\text{miss}} = \angle(\mathbf{p}_{T,\ell\ell};\ \not{\mathbf{p}}_T)$

The interference effect is sizable if we don't apply low mass Higgs search cuts.
It has a 4% effect on the total background and 2% on the signal yield.

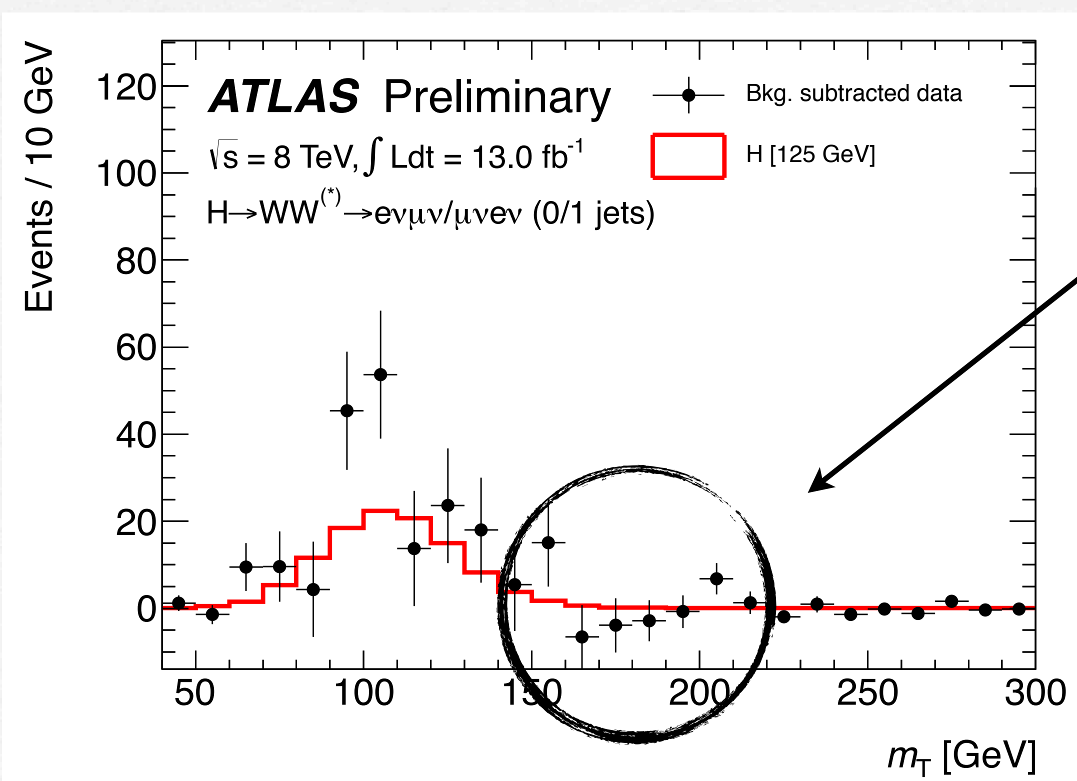
Effect on the m_T distribution



Standard cuts: $p_{T\ell} > 20$ GeV, $|\eta_\ell| < 2.5$, $\not{p}_T > 30$ GeV, $M_{\ell\ell} > 12$ GeV



Standard cuts: $p_{T\ell} > 20$ GeV, $|\eta_\ell| < 2.5$, $\not{p}_T > 30$ GeV, $M_{\ell\ell} > 12$ GeV



?

No interference simulated up to now in ATLAS

gg2VV with LO S,B interferene is under preparation.

Quantitative estimate of the effect in ZZ

$gg \to H \to ZZ \to \ell\bar{\ell}\ell\bar{\ell}$ and $\ell\bar{\ell}\ell'\bar{\ell}'$ at $M_H = 125\,$GeV

	$gg\ (\to H) \to ZZ \to 4\ell$ and $2\ell\,2\ell'$						
	σ [fb], pp, $\sqrt{s} = 8\,$TeV, $M_H = 125\,$GeV				ZWA	interference	
mode	H_{ZWA}	H_{offshell}	cont	$\lvert H_{\text{ofs}}\text{+cont}\rvert^2$	R_0	R_1	R_2
$\ell\bar{\ell}\,\ell\bar{\ell}$	0.0748(2)	0.0747(2)	0.000437(3)	0.0747(6)	1.002(3)	0.994(8)	0.994(8)
$\ell\bar{\ell}\,\ell'\bar{\ell}'$	0.1395(2)	0.1393(2)	0.000583(2)	0.1400(3)	1.002(2)	1.001(2)	1.001(2)

Cross sections for $gg\ (\to H) \to ZZ \to \ell\bar{\ell}\ell\bar{\ell}$ and $\ell\bar{\ell}\ell'\bar{\ell}'$ in pp collisions at $\sqrt{s} = 8\,$TeV for $M_H = 125\,$GeV and $\Gamma_H = 0.004434\,$GeV calculated at LO with gg2VV. The zero-width approximation (ZWA) and off-shell Higgs cross sections, the continuum cross section and the sum of off-shell Higgs and continuum cross sections including interference are given. The accuracy of the ZWA and the impact of off-shell effects are assessed with $R_0 = \sigma_{H,\text{ZWA}}/\sigma_{H,\text{offshell}}$. Interference effects are illustrated through $R_1 = \sigma(|\mathcal{M}_H + \mathcal{M}_{\text{cont}}|^2)/\sigma(|\mathcal{M}_H|^2 + |\mathcal{M}_{\text{cont}}|^2)$ and $R_2 = \sigma(|\mathcal{M}_H|^2 + 2\,\text{Re}(\mathcal{M}_H\mathcal{M}^*_{\text{cont}}))/\sigma(|\mathcal{M}_H|^2)$. γ^* contributions are included in $\mathcal{M}_{\text{cont}}$. Applied cuts: $|M_{ZZ} - M_H| < 1$ **GeV**, $p_{T\ell} > 5\,$GeV, $|\eta_\ell| < 2.5$, $\Delta R_{\ell\ell} > 0.1$, $76\,\text{GeV} < M_{\ell\bar{\ell},12} < 106\,$GeV and $15\,\text{GeV} < M_{\ell\bar{\ell},34} < 115\,$GeV, $M_{\ell\bar{\ell}} > 4\,$GeV. The invariant mass of the same-flavour, opposite-sign lepton pair closest to M_Z is denoted by $M_{\ell\bar{\ell},12}$. $M_{\ell\bar{\ell},34}$ denotes the invariant mass of the remaining lepton pair. Cross sections are given for a single lepton flavour combination. No flavour summation is carried out for charged leptons or neutrinos. The integration error is given in brackets.

The case of γγ

Interference in γγ

De Florian

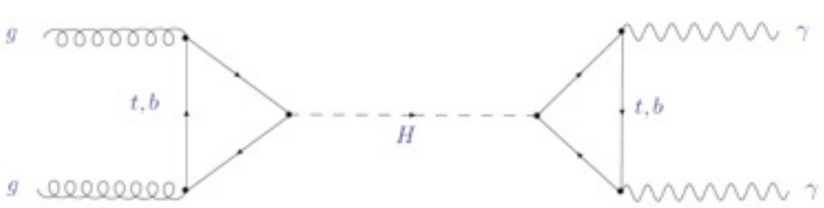
$$\mathcal{A}_{gg\to\gamma\gamma} = \frac{-\mathcal{A}_{gg\to H}\mathcal{A}_{H\to\gamma\gamma}}{\hat{s} - m_H^2 + i m_H \Gamma_H} + \mathcal{A}_{\rm cont}$$

$$\delta\hat{\sigma}_{gg\to H\to\gamma\gamma} = -2(\hat{s} - m_H^2)\frac{\mathrm{Re}\left(\mathcal{A}_{gg\to H}\mathcal{A}_{H\to\gamma\gamma}\mathcal{A}^*_{\rm cont}\right)}{(\hat{s}-m_H^2)^2 + m_H^2\Gamma_H^2} - 2m_H\Gamma_H\frac{\mathrm{Im}\left(\mathcal{A}_{gg\to H}\mathcal{A}_{H\to\gamma\gamma}\mathcal{A}^*_{\rm cont}\right)}{(\hat{s}-m_H^2)^2 + m_H^2\Gamma_H^2}$$

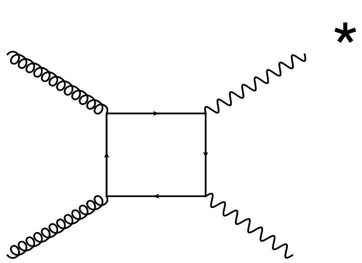
odd ~ vanishes upon integration over s

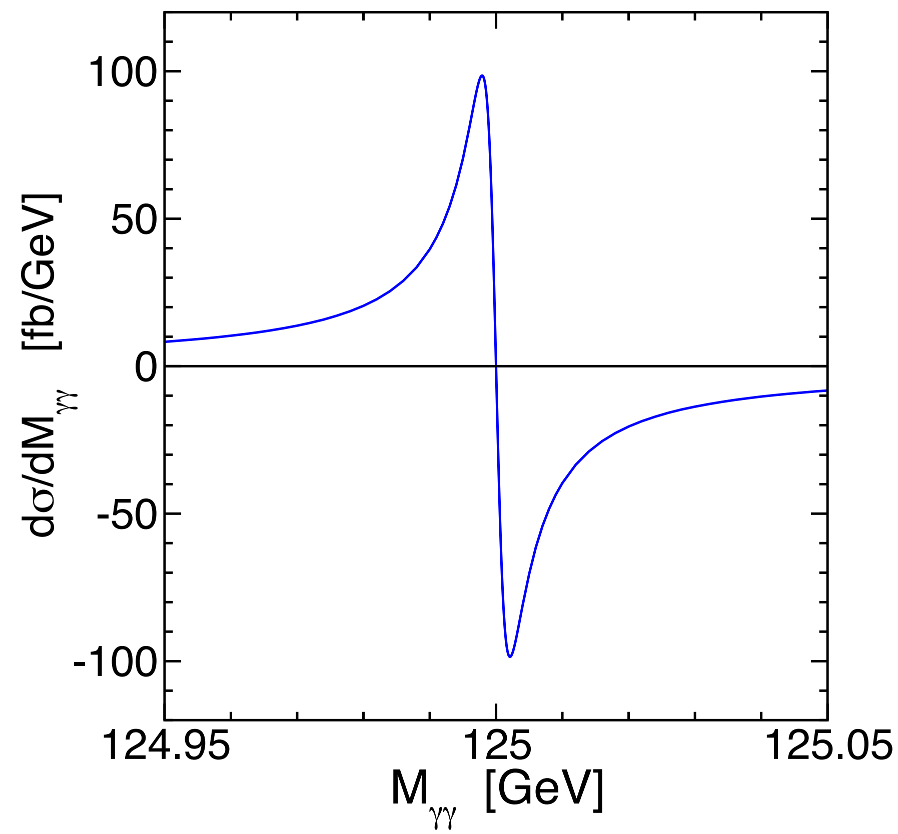
Effect computed by Dixon and Siu
few % for the cross section

S. Martin noticed that
could produce a shift



x

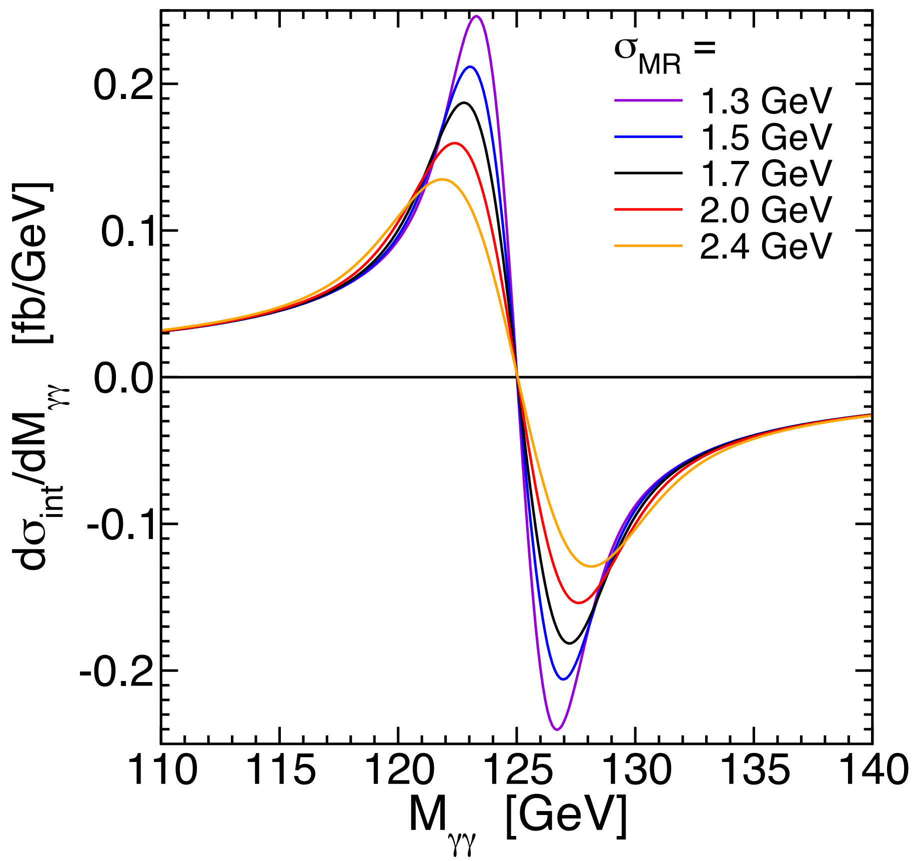




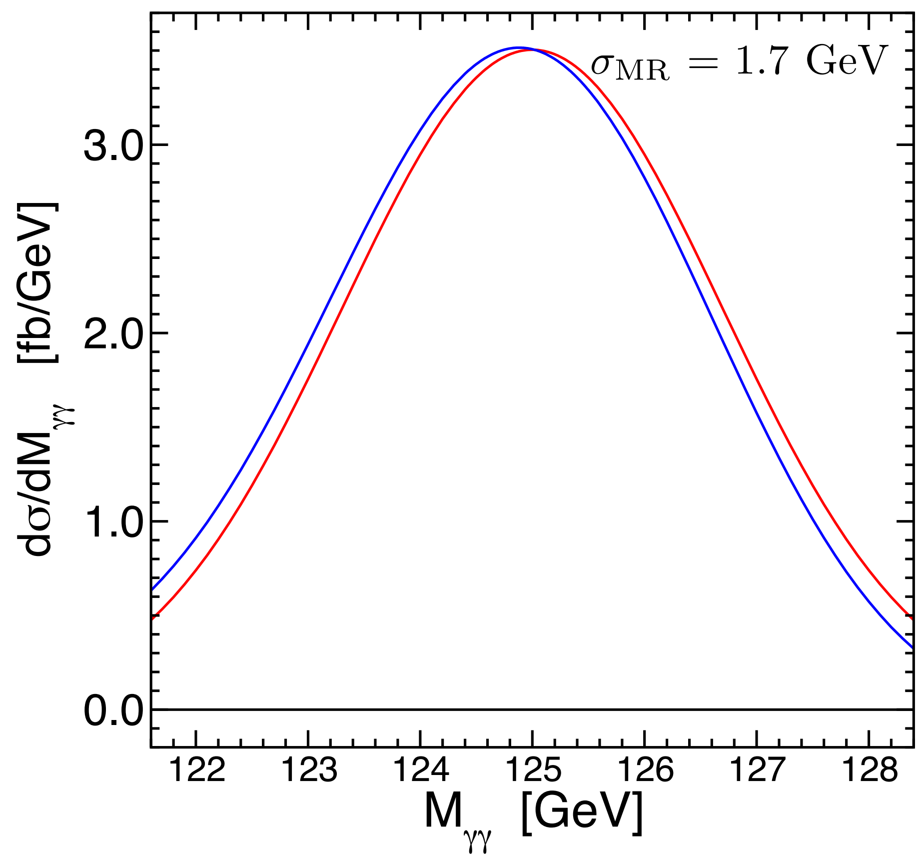
- small asymmetry in the interference
- at this level shift is O(MeV) as expected

Including detector resolution. De Florian

• asymmetry in the interference enhanced by gaussian



Interference



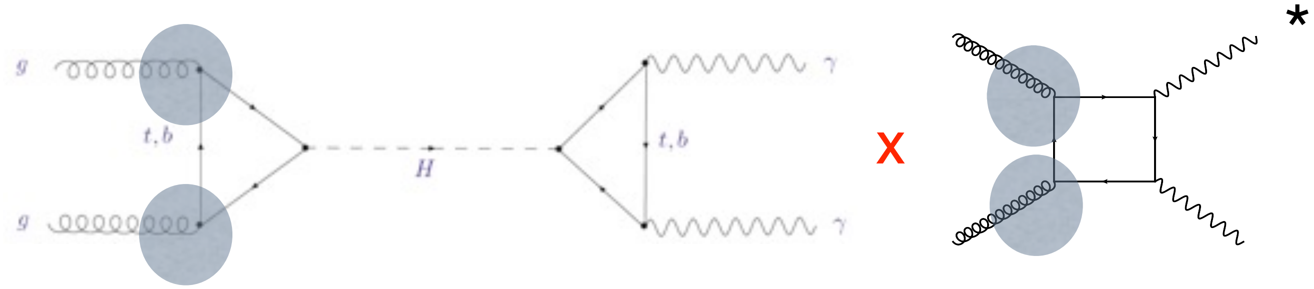
Signal + Interference

• After Gaussian shift is O(100 MeV) towards smaller masses

The background fit could even enhance the effect, being sensitive to both the constructive and the destructive part of the interference.

Further processes could contribute...

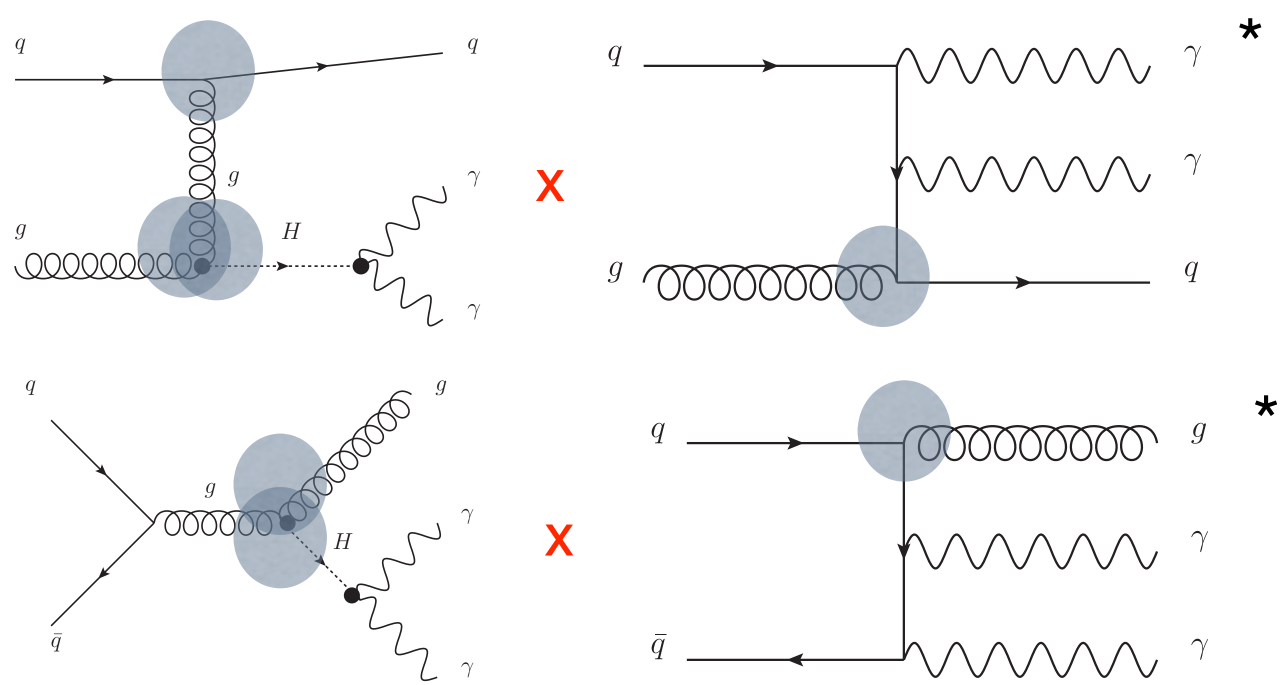
work in progress D.de Florian, N.Fidanza, R.Hernandez, J.Mazzitelli, Y.Rotstein, G.Sborlini



Therefore extra channels can also contribute $q\bar{q}$ and qg

- smaller for the signal but larger for the background
- same order in coupling constant as gg ➡ α_s^2

= $\sqrt{\alpha_s}$

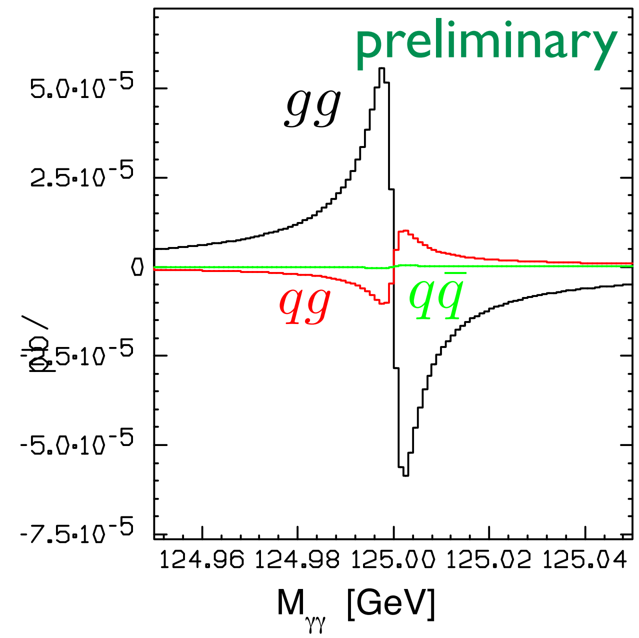


effective ggH vertex

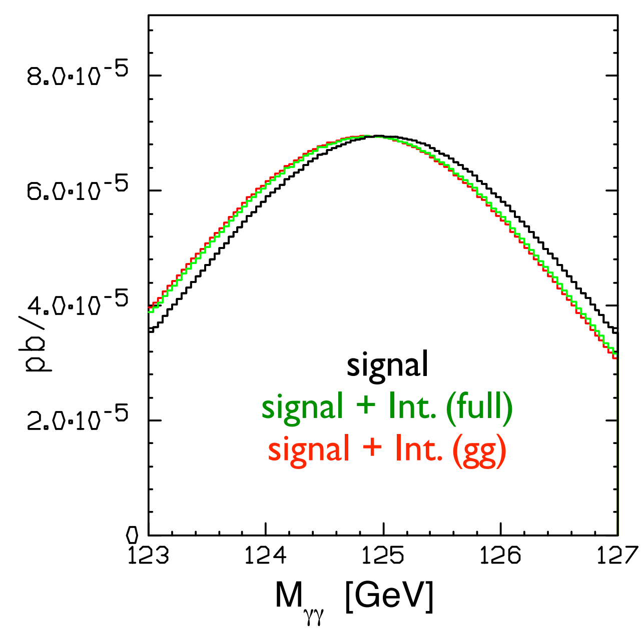
$p_T^\gamma > 40, 30\,\mathrm{GeV}$ isolation with $R = 0.4$ 8 TeV

"Real" interference
from each partonic channel

new channels
with opposite sign to gg
but still small compared to gg



S+I with simple gaussian
effect (1.7 GeV)
need better treatment...



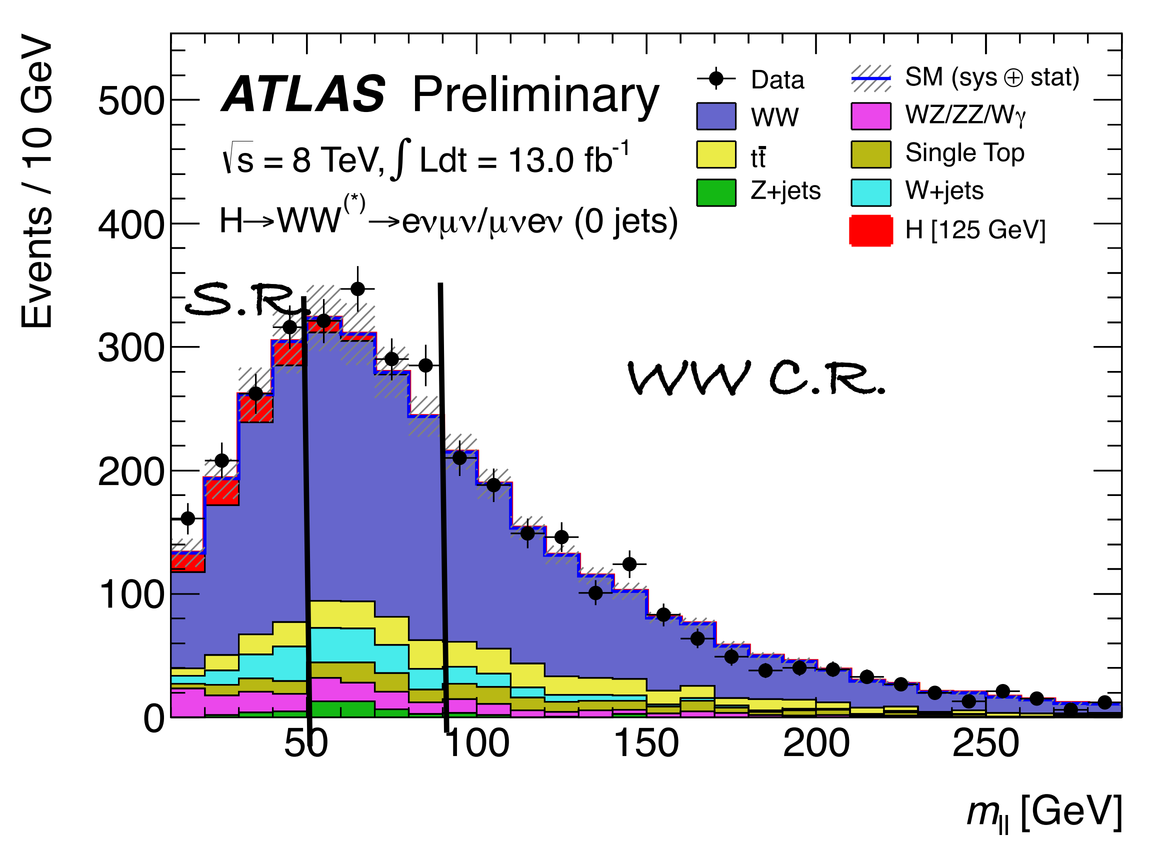
work in progress
D.de Florian, N.Fidanza, R.Hernandez,
J.Mazzitelli, Y.Rotstein, G.Sborlini

Extra contributions look small.

Effect of the background fit must be included plus better simulated detector effects.

WW normalisation in H→WW

WW normalisation.



The SM WW background is the dominant one for the H→WW search.

Due to cuts of number of jets, we cannot have reliable estimates from MC.

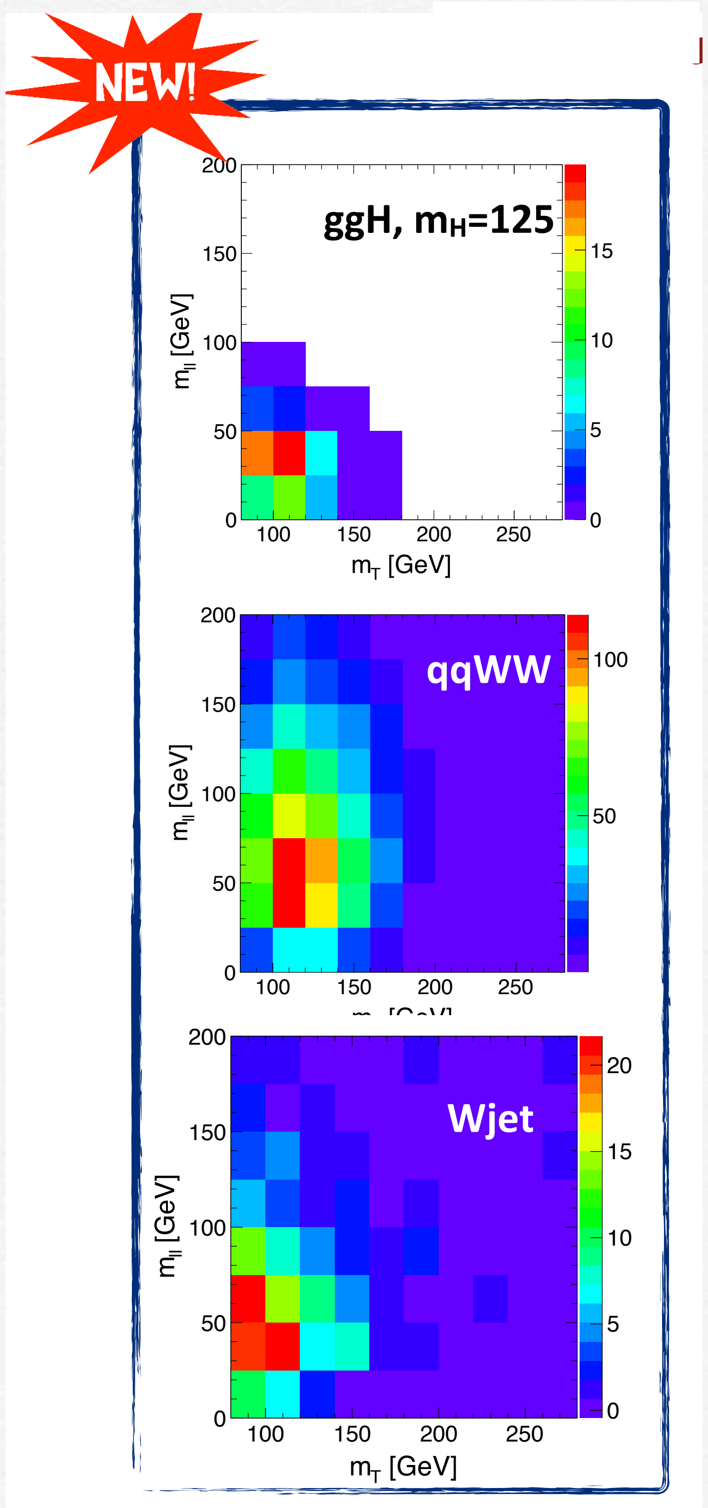
Estimated from data in the high m_{ll} region, both from ATLAS and CMS before HCP.

m_{ll} shape uncertainty have been parametrised as single numbers given by α = SR/CR. Sizable theoretical uncertainties were quoted in YR2.

	scale	PDFs	modelling
α^{0j}_{WW}	2.5%	3.7%	3.5%
α^{1j}_{WW}	4%	2.9%	3.5 %
α^{0j}_{WW}, α^{1j}_{WW} correlation		1	

ATLAS added an extra 4.5% uncertainty due to Parton Shower studies, comparing Powheg+Pythia to Powheg+Herwig.

CMS m_{ll}-m_T fit.



- CMS found that using the full shape information improves a lot the performances of the analysis

expected/observed significance		
8 TeV cut-based	8 TeV shape-based	7+8 TeV shape-based
2.4/1.7	3.7/2.9	4.1/3.1
best fit value		
8 TeV cut-based	8 TeV shape-based	7+8 TeV shape-based
0.80 ± 0.45	0.77 ± 0.28	0.74 ± 0.25

~50% improvement

- The reported systematics sources are: scale variation, MADGRAPH-MC@NLO difference.

No α parametrisation is possible, one would need an NxN bin by bin full covariance matrix, with scale, pdf and modelling uncertainties.

Usually shape systematics are implemented as morphing of a single surface, in the sense that some assumption is done on the bin by bin correlation (the assumption is made by the interpolating model).

In this case, large overconstraining of systematic can be observed (i.e. we assume to be able to measure scale and modelling using the WW enriched region of the fit), if this is the case the post-fit nuissance parameters should distribute as a gaussian with $\sigma << 1$.

CMS m_{ll}-m_T fit.

Work to be done.

The m_{ll} shape fit looks powerful enough to justify more work from the LHC XS WG to put it on solid theoretical ground.

Overconstrainig of modelling and pdf uncertainties could be reasonable (we have large WW statistics, so data are sensitive to systematic mismodelling, and can be probably parametrised as surface morphing if the correlation is properly reproduced by the model).

Scale uncertainties should be probably not overconstrained (we don't know what is the shape of the missing higher order corrections, or some hypothesis on this effect must be done)

From μ to a measurement

We had long discussions in the past on how to sum errors.
In the exclusion phase both ATLAS and CMS have put the theoretical error inside the fit.
So they get profiled and always added in quadrature.

The question now is: how much is different the total production yield from the expected one?
Is it still useful to put the error on the predicted cross section in the measurement?

Fractional uncertainties on $\mu = \sigma/\sigma_{SM}$
(ATLAS H→WW)

Source	Upward uncertainty (%)	Downward uncertainty (%)
Statistical uncertainty	+23	-22
Signal yield ($\sigma \cdot \mathcal{B}$)	+14	-9
Signal acceptance	+9	-6
WW normalisation, theory	+20	-20
Other backgrounds, theory	+9	-9
W+jets fake rate	+11	-12
Experimental + bkg subtraction	+14	-11
MC statistics	+8	-8
Total uncertainty	+41	-38

contains signal cross section and Br

$$\mu = 1.48^{+0.35}_{-0.33}\,(\text{stat})^{+0.41}_{-0.36}\,(\text{syst theor})\,^{+0.28}_{-0.27}\,(\text{syst exp}) \pm 0.05\,(\text{lumi})$$

contains just Bkg and signal acceptance

$$\sigma(pp \to H) \cdot \mathcal{B}(H \to WW)_{m_H = 125\ \text{GeV}} = 7.0\,^{+1.7}_{-1.6}\,(\text{stat})\,^{+1.7}_{-1.6}\,(\text{syst theor})\,^{+1.3}_{-1.3}\,(\text{syst exp}) \pm 0.3\,(\text{lumi})\ \text{pb}$$

$$\sigma^{\text{SM}}(pp \to H) \cdot \mathcal{B}^{\text{SM}}(H \to WW)_{m_H = 125\ \text{GeV}} = 4.77^{+0.64}_{-0.64}(\text{cross section})^{+0.20}_{-0.20}(\text{branching fraction})\ \text{pb}\,.$$

Error on cross section and BR treated as the provider requires.

Conclusions

- A lot of work was done for Higgs hunting;
- A lot new work needs to be done to eat it...

Understanding interference effects on the mass, Higgs p_T, observing off-shell production, provide results in a more theoretical friendly approach, define prescription for more perfonmant background estimation methods.

How much time do we have to write all of this?