Off-shell and interference experimental update

Roberto Di Nardo (CERN), Meng Xiao (JHU)
thanks Livia Soffi for the inputs

The 13th Workshop of the LHC Higgs Cross Section Working Group
July 14th, 2017

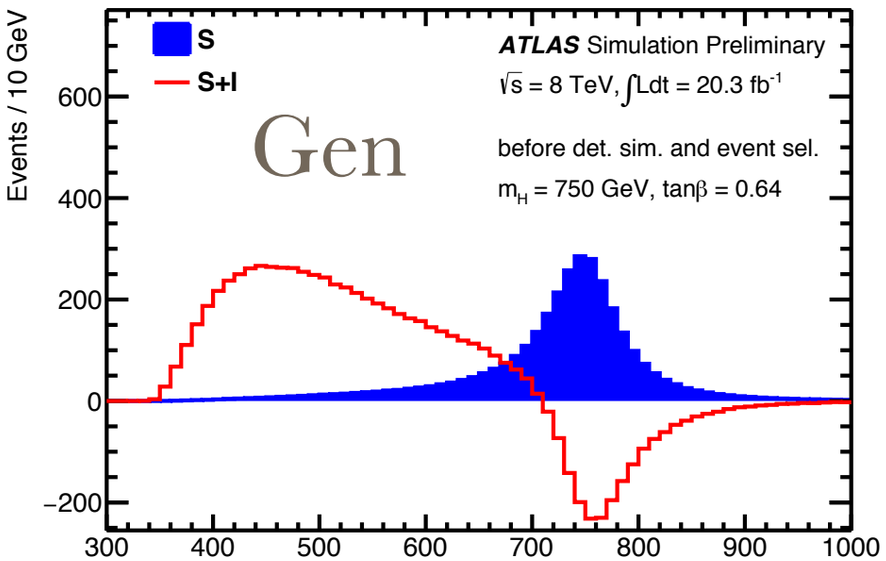
Overview

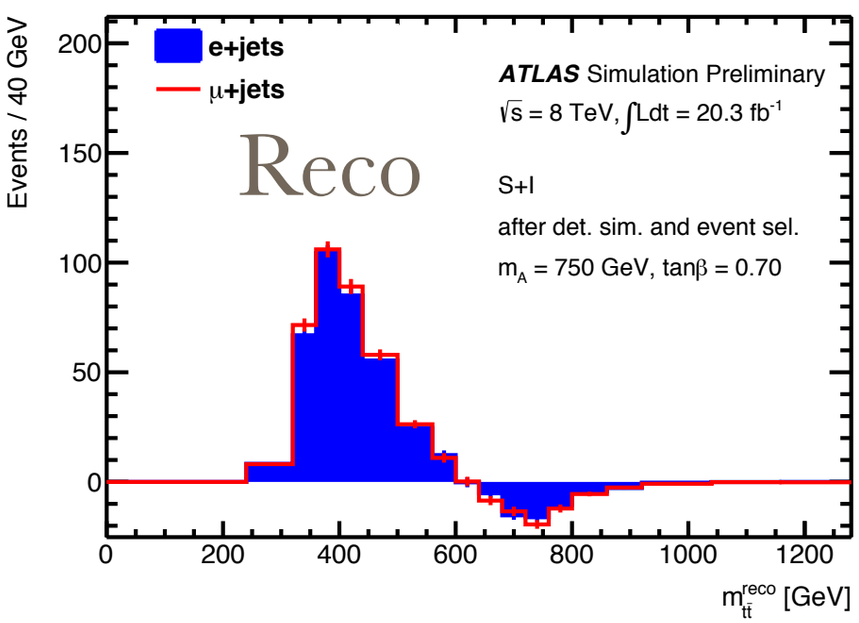
The interference among h, H and bkg: tools and analyses

- heavy resonance search: tt, ZZ, WW
- H width analysis: γγ, ZZ, WW
- off-shell anomalous couplings measurement: ZZ,WW

ATLAS-CONF-2016-073
CERN-EP-2017-134

H/A → tt, resonant search

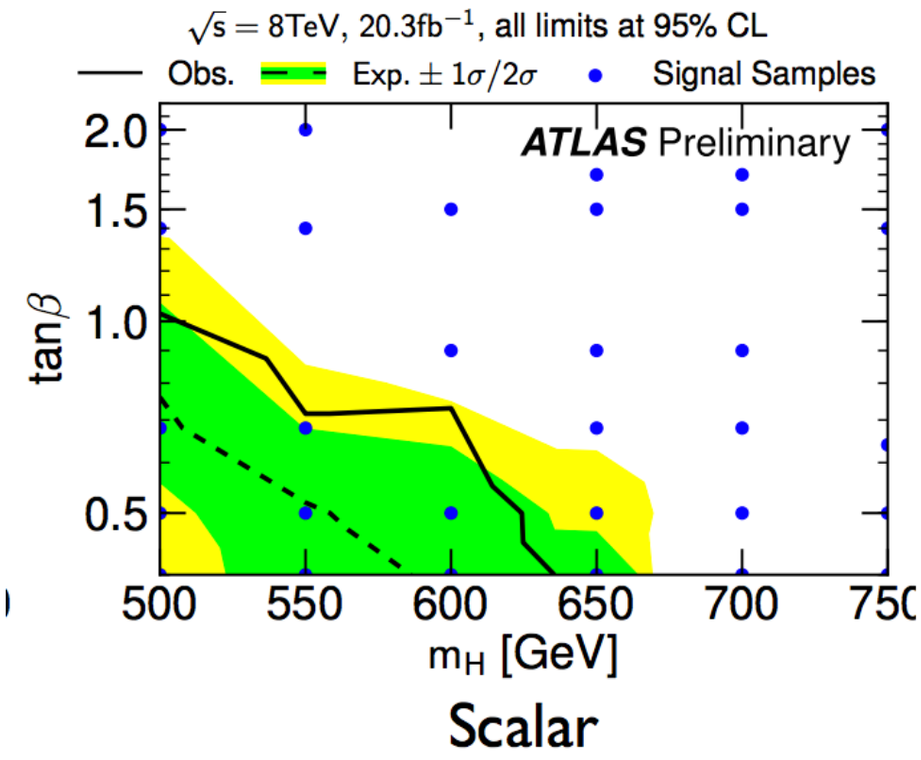




gg→(H/A)→tt interference in 2HDM model

=> signal appear as deficit of events

- aMC@NLO to generate and reweight events



gg→ (H) → tt interference at NLO?

- In the ATLAS analysis, k-factor for signal is applied to S+I
- CMS colleagues asked what's the proper k-factor to use?
- arXiv: 1606.04149: full NLO calculation is impossible

$$\sigma_{NLO} = \sigma_{NLO}^{back} + \sigma_{NLO}^{signal} + \sigma_{LO}^{inter}\sqrt{K_S K_B}$$

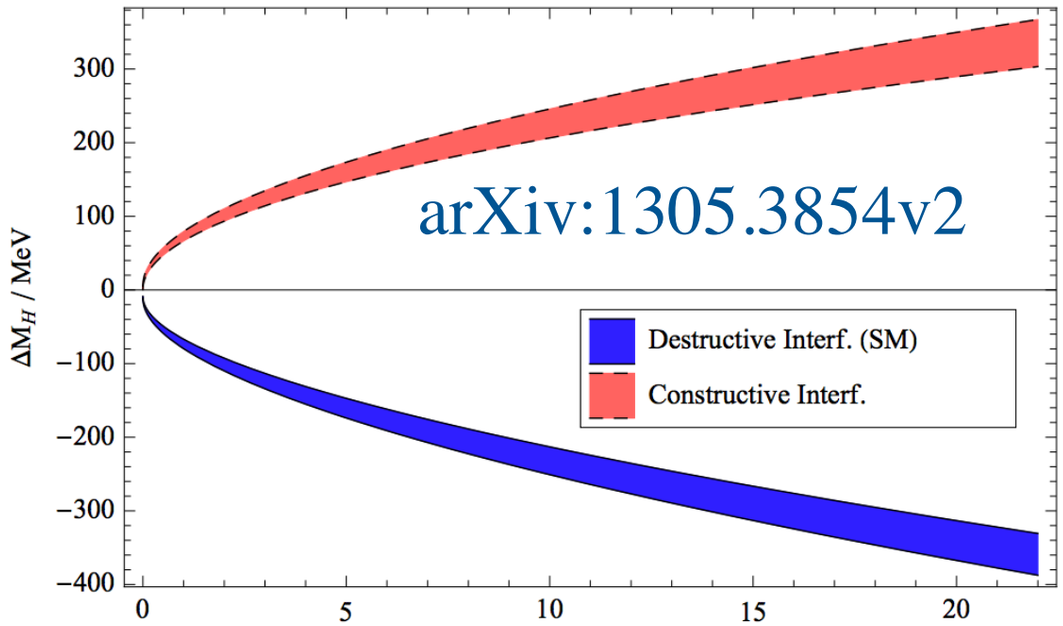
H→ γγ, width measurement

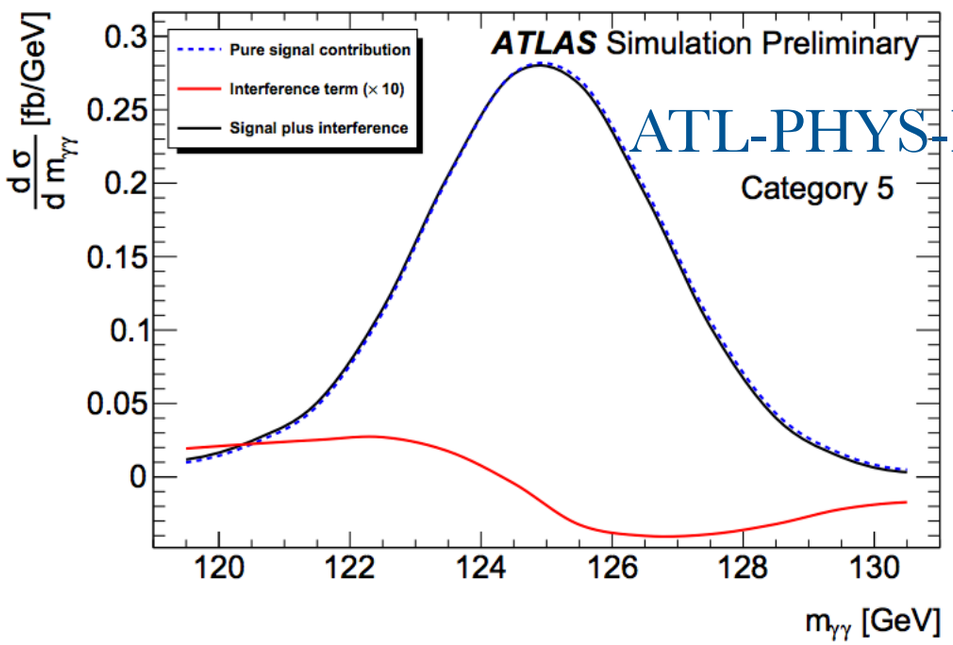
- gg,qg →(H)→ γγ interference at NLO

  => mass shift dependent of Γ_H, p_T

- Use mass shift in different pT region to constrain H width

- Events generated by Sherpa

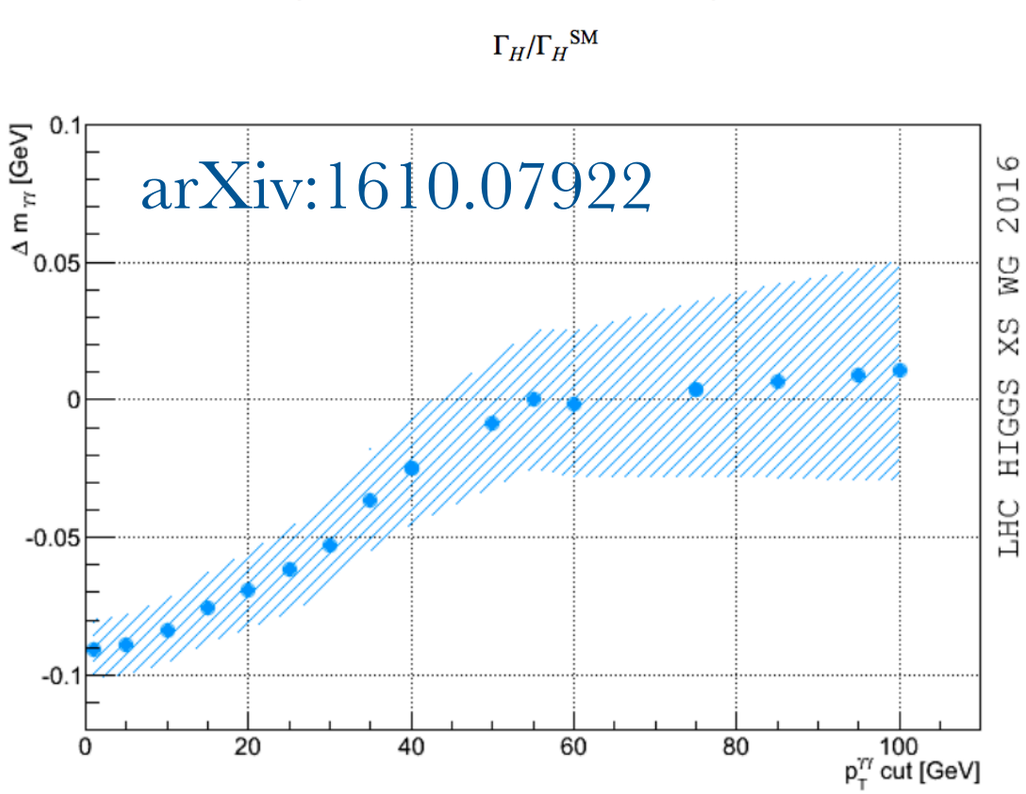




ATL-PHYS-PUB-2016-009

8 TeV:Δm= -35 MeV at Γ=4 MeV

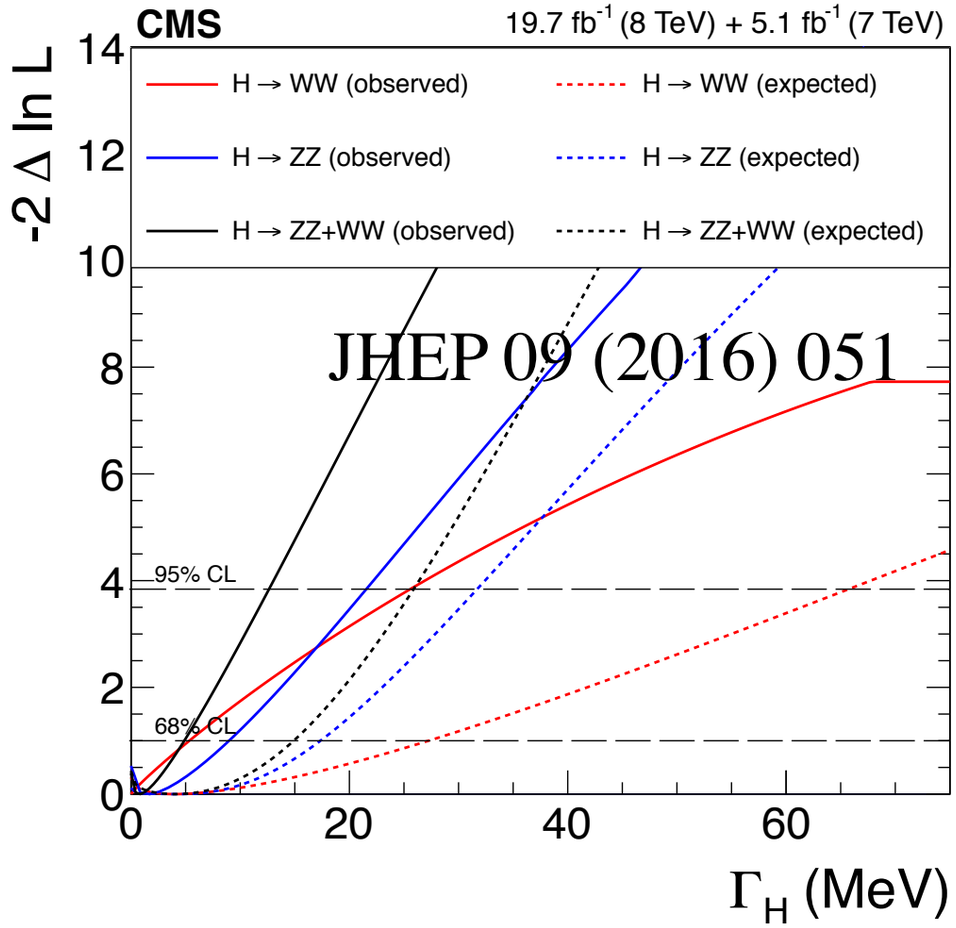
Δm=−313 MeV at Γ=300 MeV



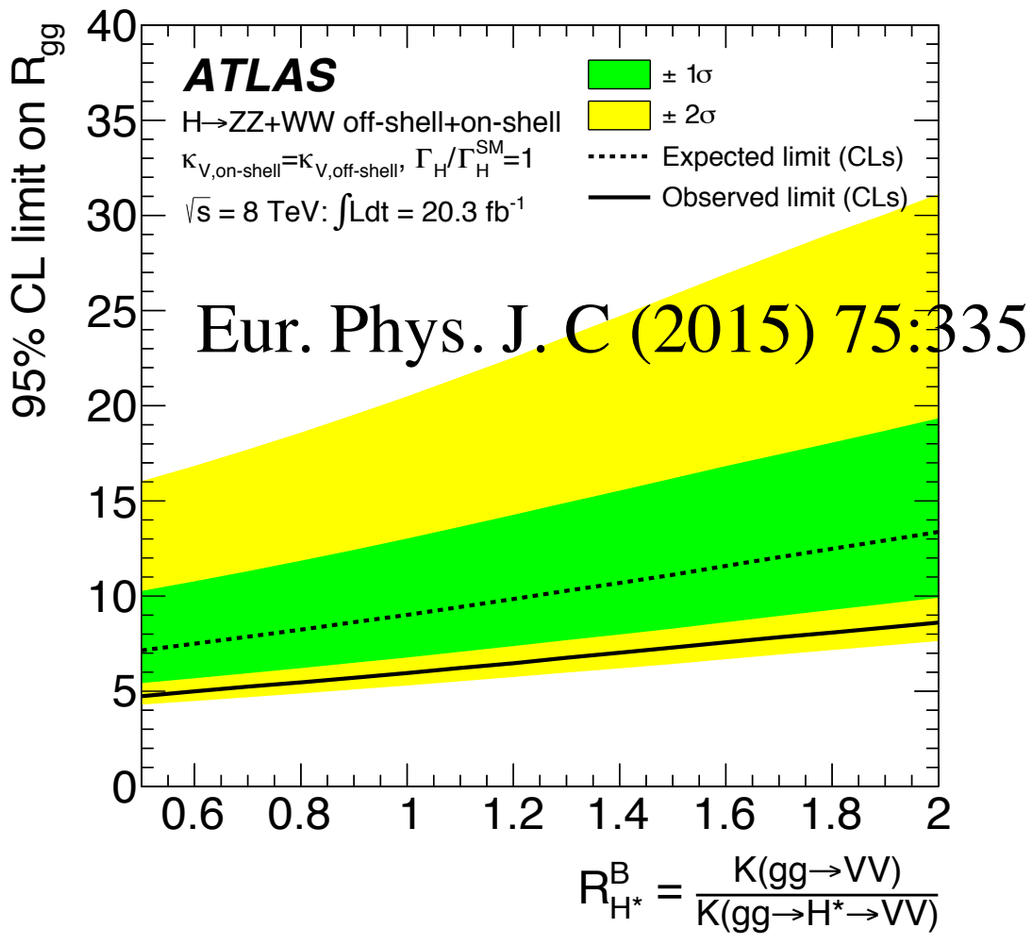
13 TeV:Δm= -89 MeV at Γ=4 MeV

H→ VV (W, Z), width measurement

- Well established Run1 analyses, off-shell/on-shell to constrain the width
- gg/qq→(H)→ VV interference in off-shell region
- Events with interference generated by MCFM, phantom, gg2VV



JHEP 09 (2016) 051

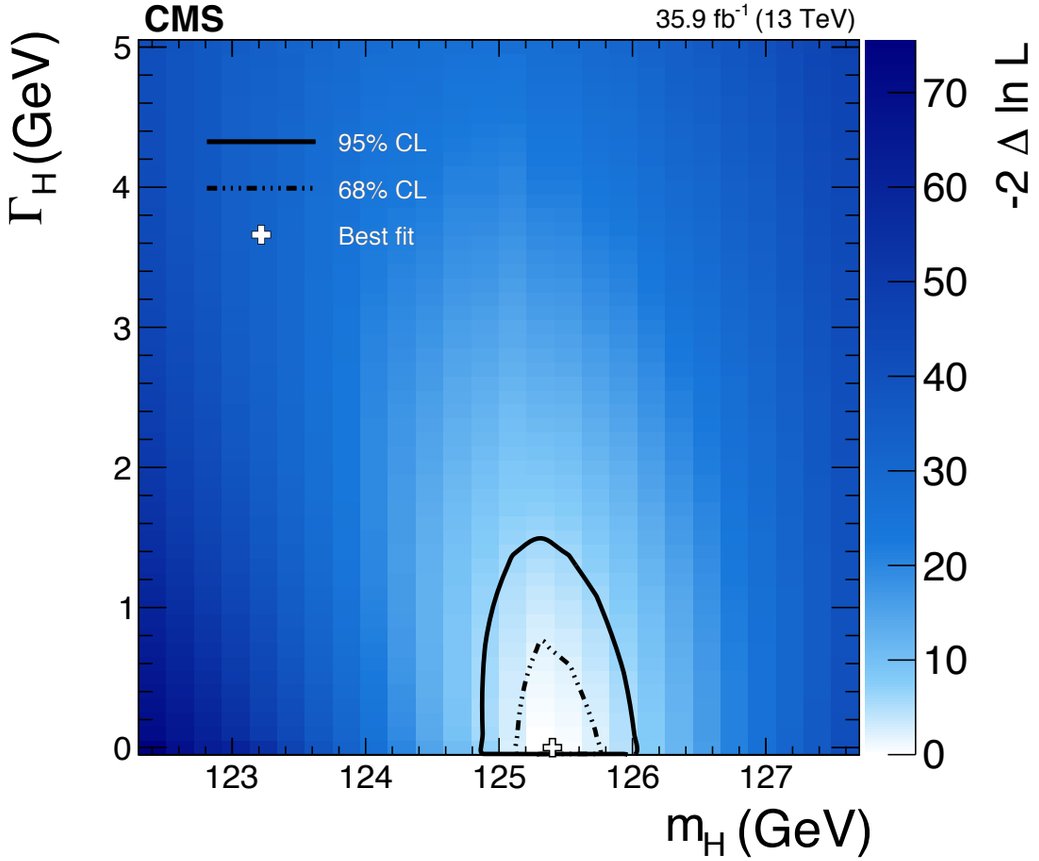


Eur. Phys. J. C (2015) 75:335

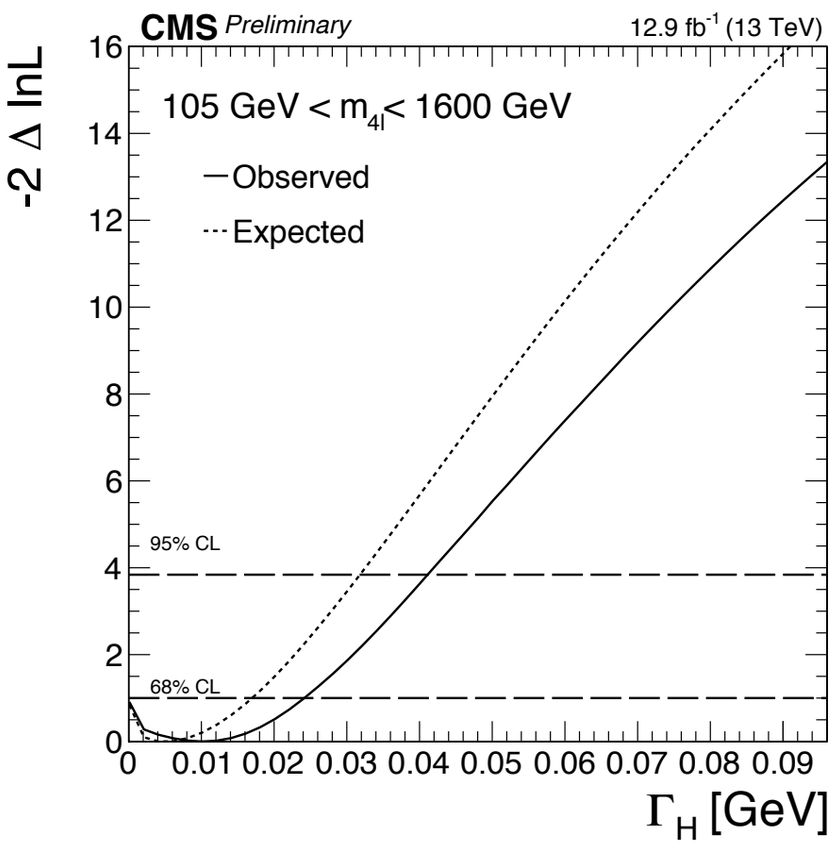
Also lower boundary of Γ_H from lifetime measurement

H→ ZZ, mass width

- Run2 CMS analysis
- gg/qq→(H)→ VV interference in both on-shell and off-shell regions
- use mass shape from on-shell and on+off-shell regions to measure the mass and width



arXiv:1706.09936



CMS-PAS-HIG-16-033

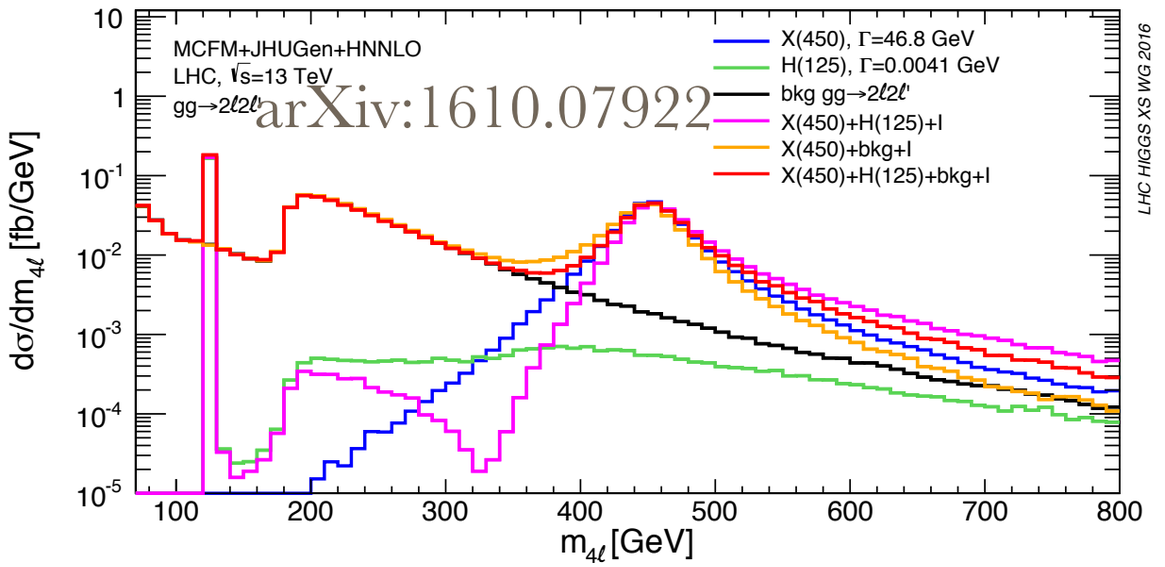
X→ ZZ/WW, resonant search

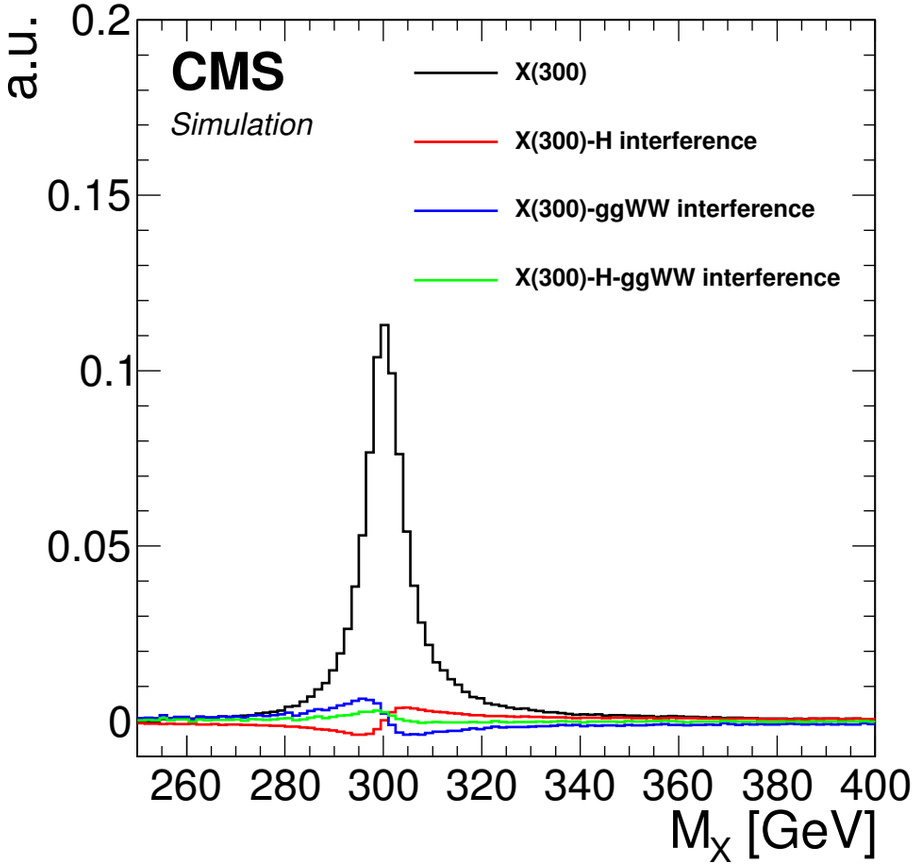
Analysis with X-H-B interferences modeled

ATLAS	L(fb^{-1})	note	CMS	L(fb^{-1})	note
llll+llvv	36.1	ATLAS-CONF-2017-058	llll	12.9	CMS PAS HIG-16-033
llqq+vvqq	36.1	ATLAS-EXOT-2016-29	llvv	2.3	CMS PAS HIG-16-001
lvqq	36.1	ATLAS-CONF-2017-051	llqq	12.9	CMS PAS HIG-16-034
lvlv	13.2	ATLAS-CONF-2016-074	lvlv	2.3	CMS PAS HIG-16-023

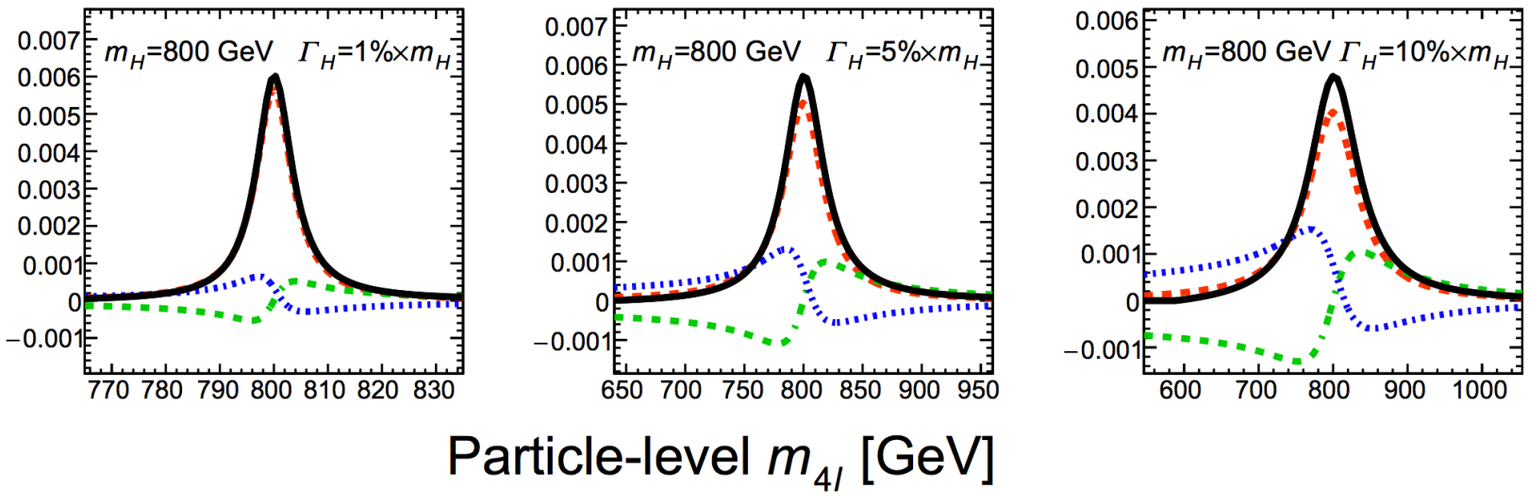
X→ ZZ/WW, resonant search

- gg/qq→(X,H)→ VV interference
- CMS: MCFM+JHUGen, phantom
- ATLAS: MG5, Sherpa, gg2VV

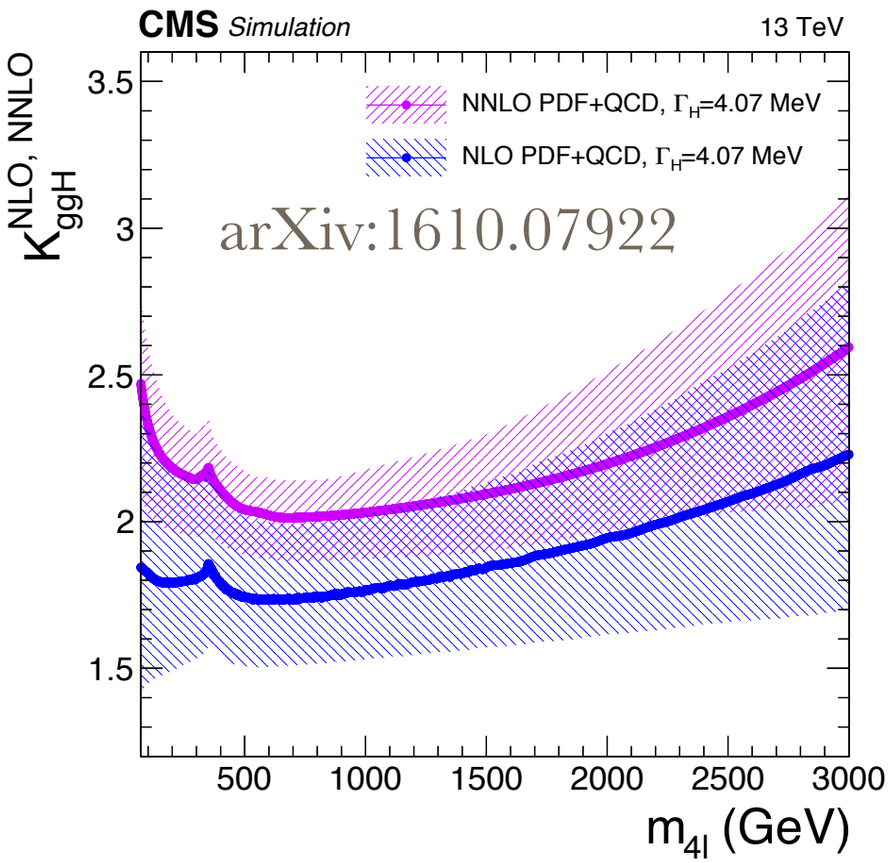




ATLAS-CONF-2017-058



gg→ (H)→ ZZ: higher order corrections



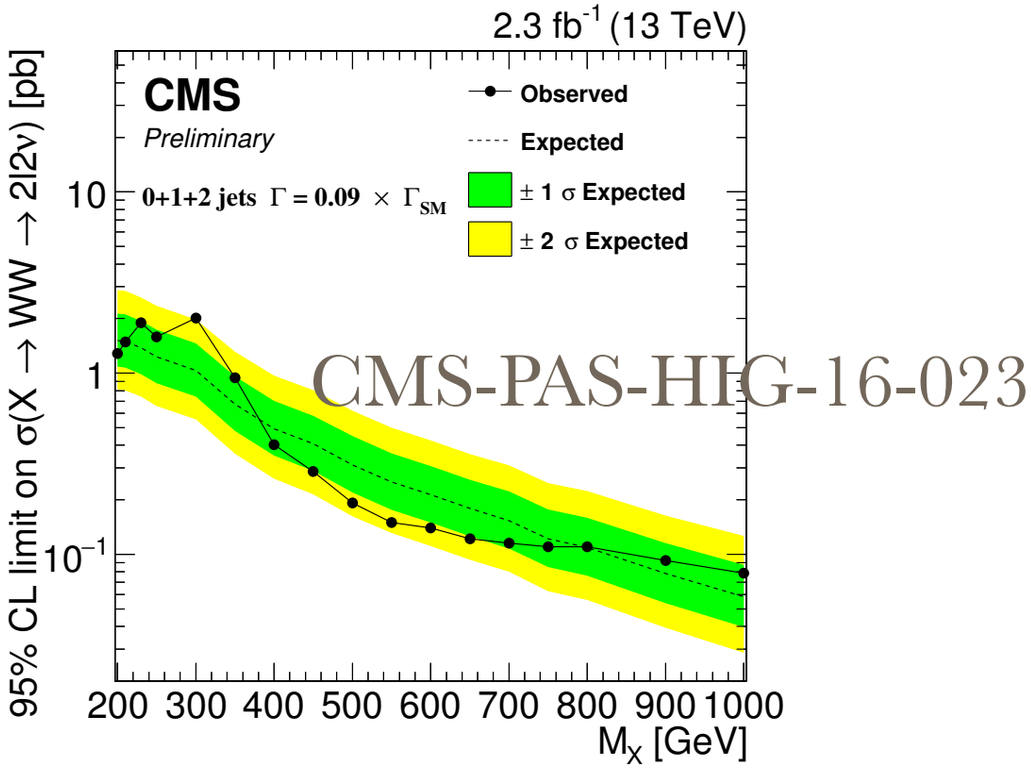
CMS

- NNLO correction for X/H, m_H dependent
  - HNNLO v2, more information see Twiki by U. Sarica
- NLO correction for B and Int(H,B) available: arXiv 1605.04610, arXiv1509.06734, arXiv1511.0861
  - lower order than X/H
  - interference available 150-350 GeV
- Use the above NNLO correction for B, Int, additional 10% uncertainly

ATLAS

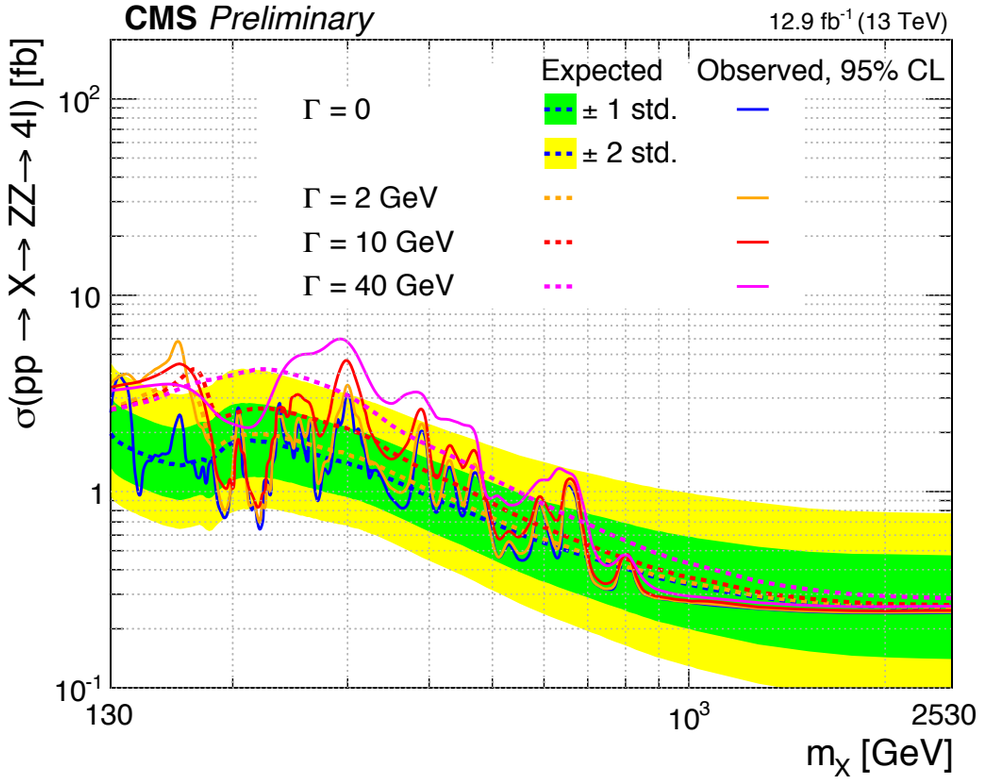
uniform 1.7 k-factor, 60% uncertainty, based on
arXiv: 1509.06734
arXiv: 1605.01380
arXiv: 1503.01274
arXiv: 1504.02388

Results on searches

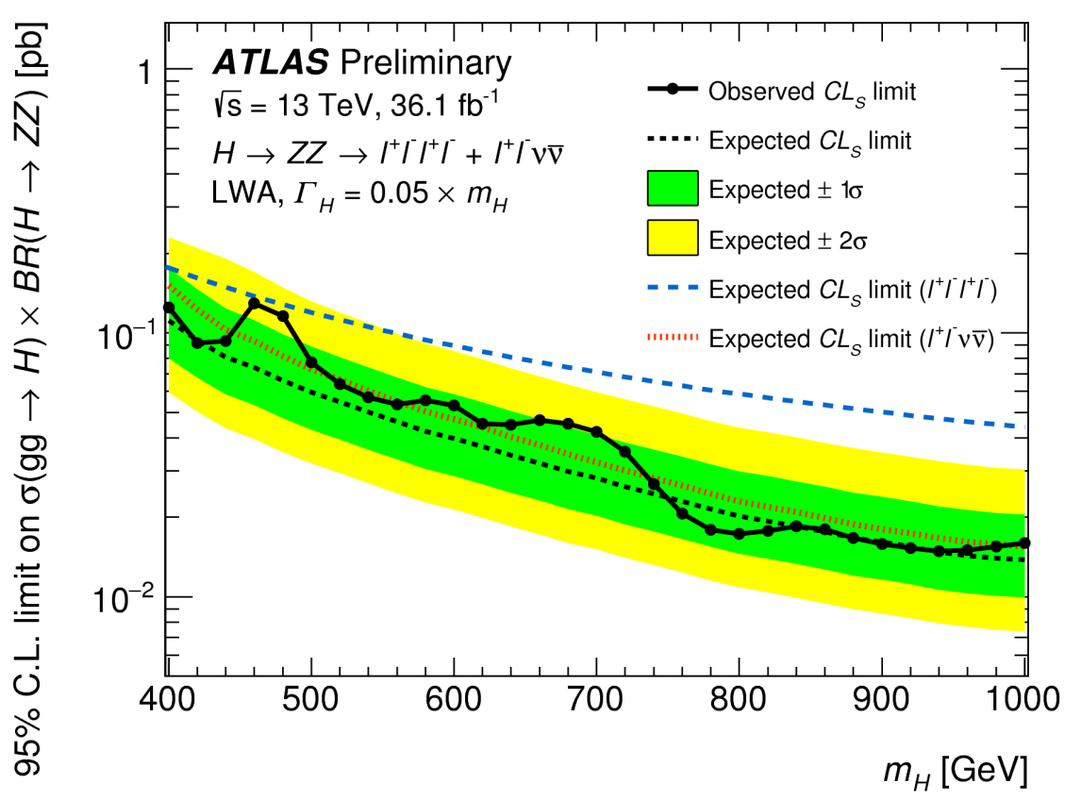


CMS-PAS-HIG-16-023

CMS-PAS-HIG-16-033



ATLAS-CONF-2017-058



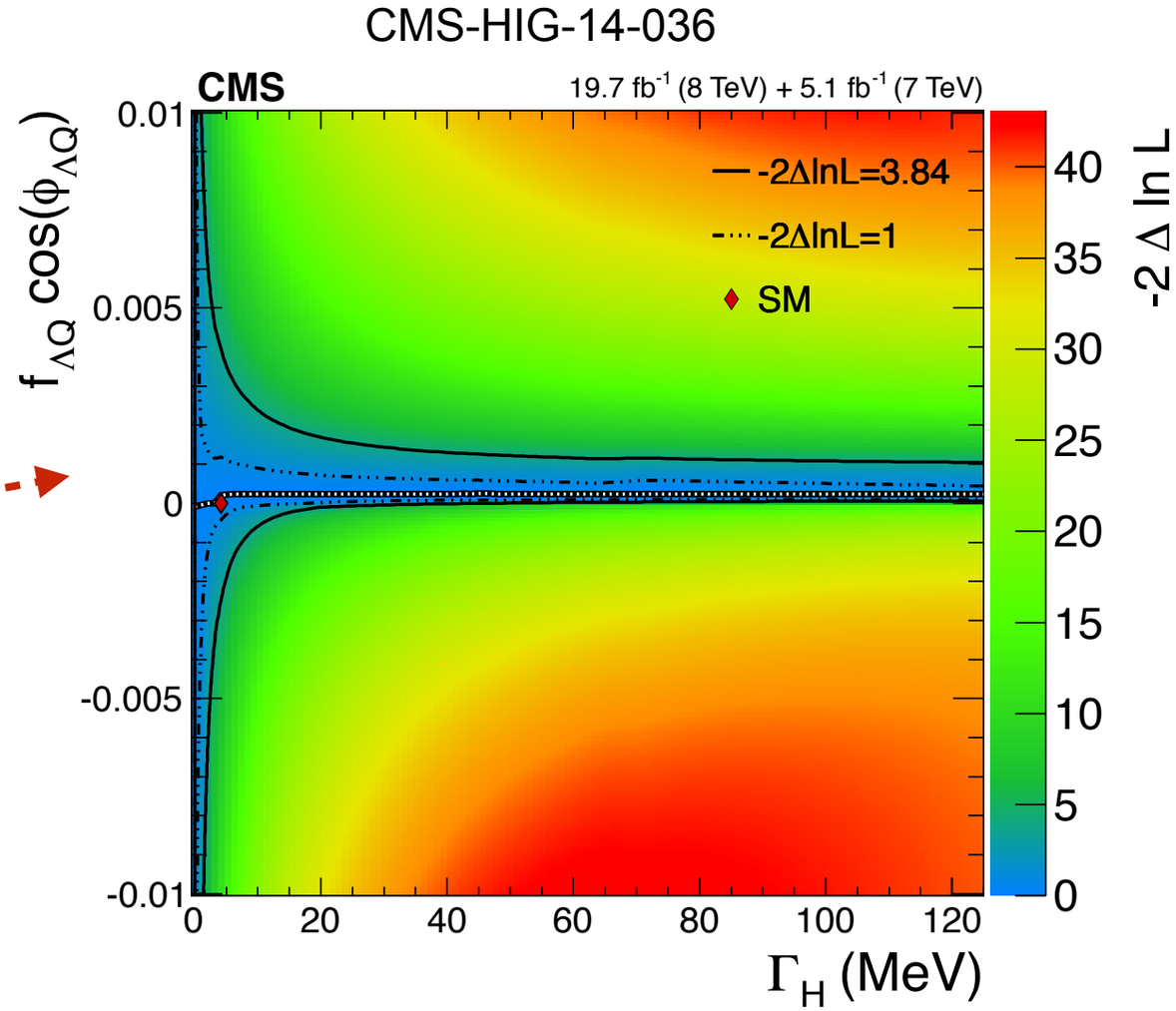
H→ ZZ, anomalous couplings

~10% of H→4ℓ in off-shell, additional $(q_1+q_2)^2$ modeling

view as couplings for given Γ_H or

Γ_H for given variation of couplings

tested $f_{\Lambda Q}$ for given Γ_H

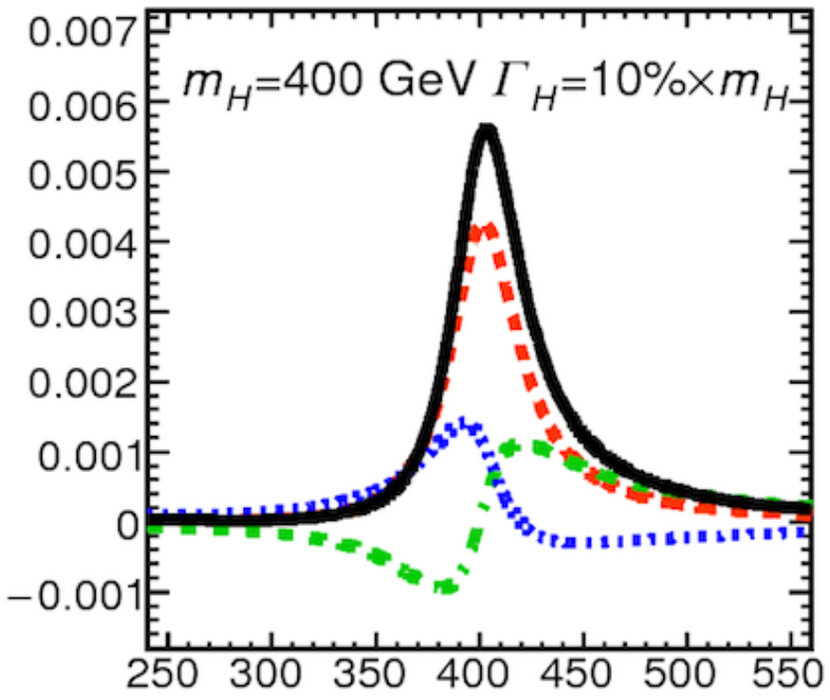


$$A = \frac{1}{v}\left(\left[a_1 - e^{i\phi_{\Lambda Q}}\frac{(q_1+q_2)^2}{(\Lambda_Q)^2} - e^{i\phi_{\Lambda 1}}\frac{q_1^2+q_2^2}{(\Lambda_1)^2}\right] m_V^2 \epsilon_1^* \epsilon_2^* + a_2 f_{\mu\nu}^{*(1)} f^{*(2),\mu\nu} + a_3 f_{\mu\nu}^{*(1)} \tilde{f}^{*(2),\mu\nu}\right)$$

Summary

- Interference effects important and non-negligible in many analyses
  - in additional resonant searches, X-H-bkg change shape and cross-sections
  - can be used to constrain H width
  - non-negligible on mass measurement
  - important for anomalous couplings
  - higher order corrections?

Additional slides


m_H=400 GeV Γ_H=10%×m_H
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
−0.001
250
300
350
400
450
500
550