Panel Discussion
New Higgs States

Moderator:

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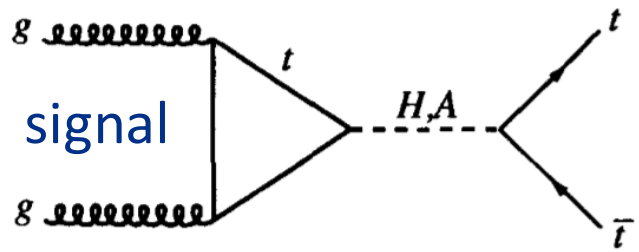
Argonne National Lab

Interference in Higgs States Decaying to Top Quarks

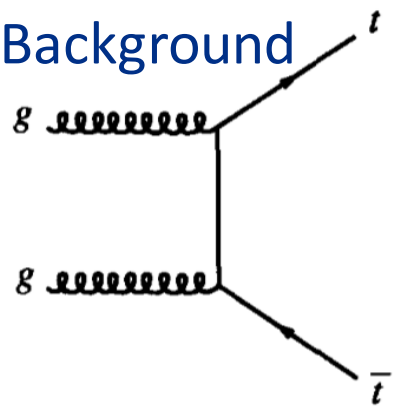
Unfamiliar look of heavy Scalars



signal

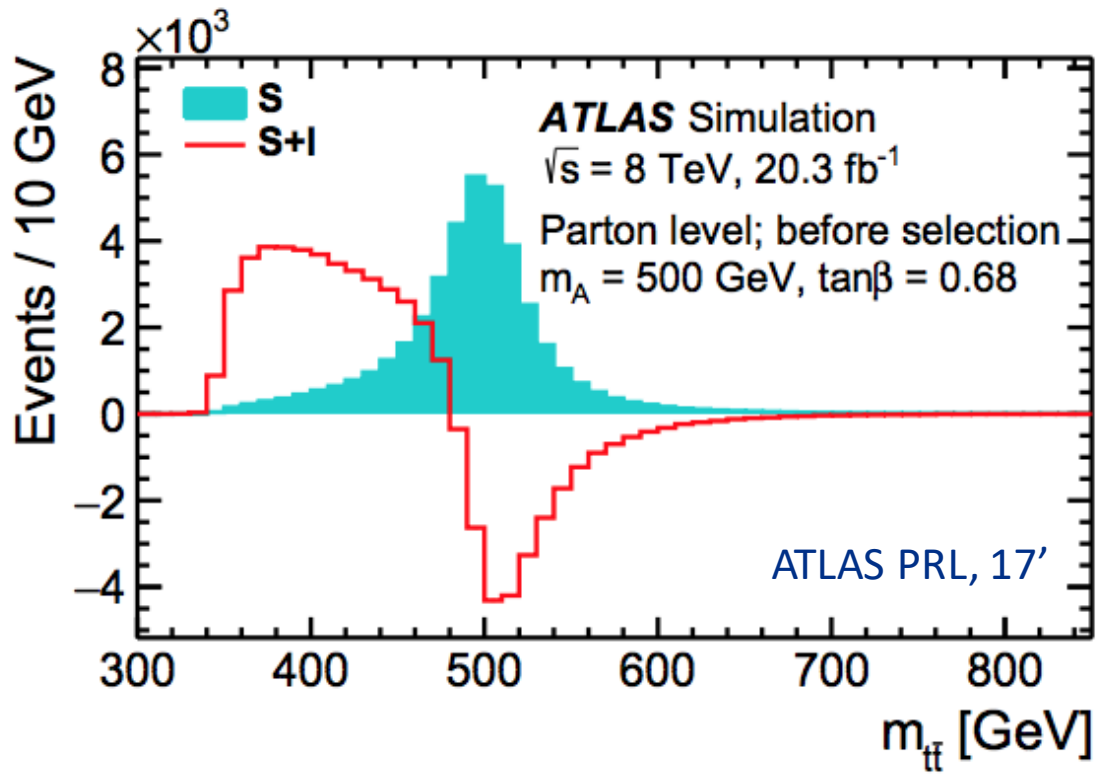
LHC being top factory, the $t\bar{t}$ statistics is very good. $S/\sqrt{B}$ is quite reasonable. However, the challenges lie in the interference effect.

Background



Plus s- and u- channel

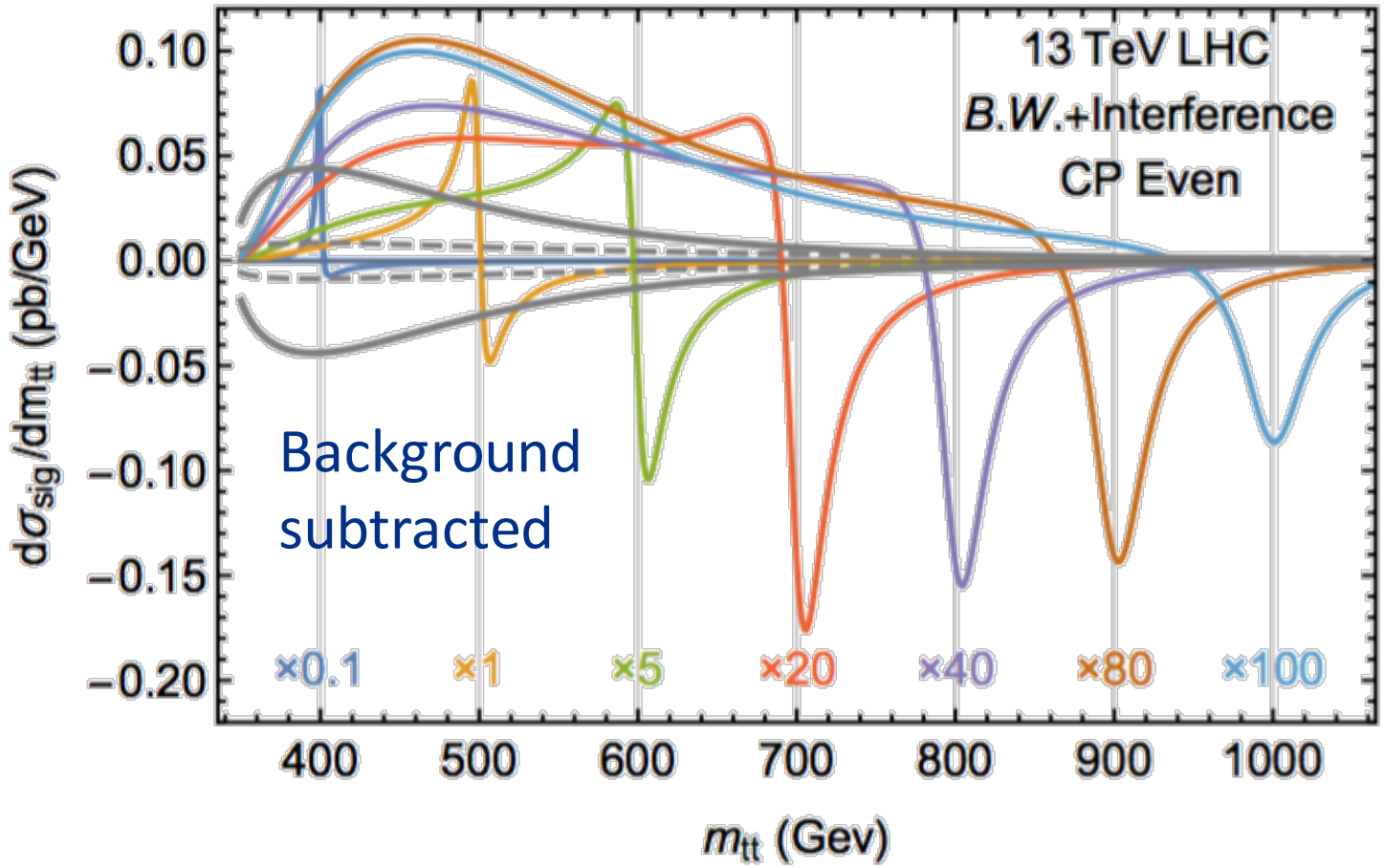
Plus s-channel $q\bar{q} \to t\bar{t}$



D. Dicus, A. Stange, S. Willenbrock, 1991; See also recent work by N. Craig, F. D'Eramo, P. Drapper, S. Thomas, H. Zhang arXiv:1504.04630 and also Jung, Sung, Yoon arXiv:1505.00291, S. Gori, I.-W. Kim, N. Shah, K. Zurek arXiv:1602.02782

M. Carena, ZL,
arXiv:1608.07282, JHEP

Challenges



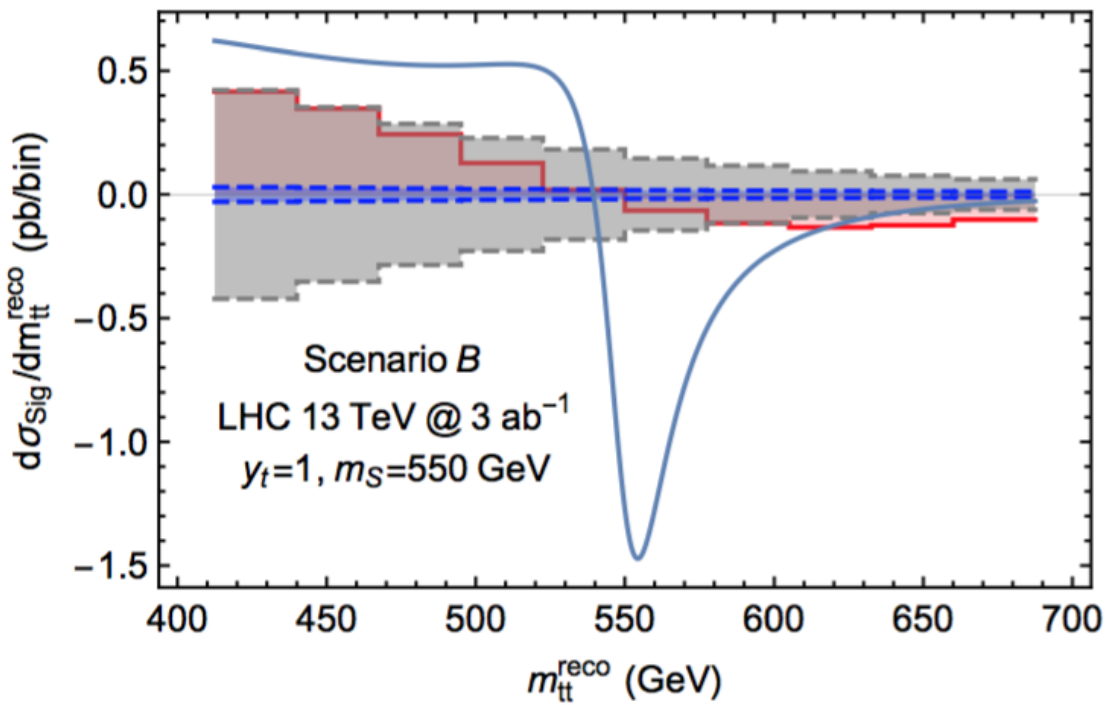
Special line shapes:

a) Bump search not designed/optimized for this, have to modify our current search;

b) Smearing effects erode the structure, making this signal much harder.

LHC perspectives

	$\Delta m_{t\bar{t}}$	Efficiency	Systematic Uncertainty
Scenario A	15%	8%	4% at 30 fb^{-1}, halved at 3 ab^{-1}
Scenario B	8%	5%	4% at 30 fb^{-1}, scaled with $\sqrt{L}$

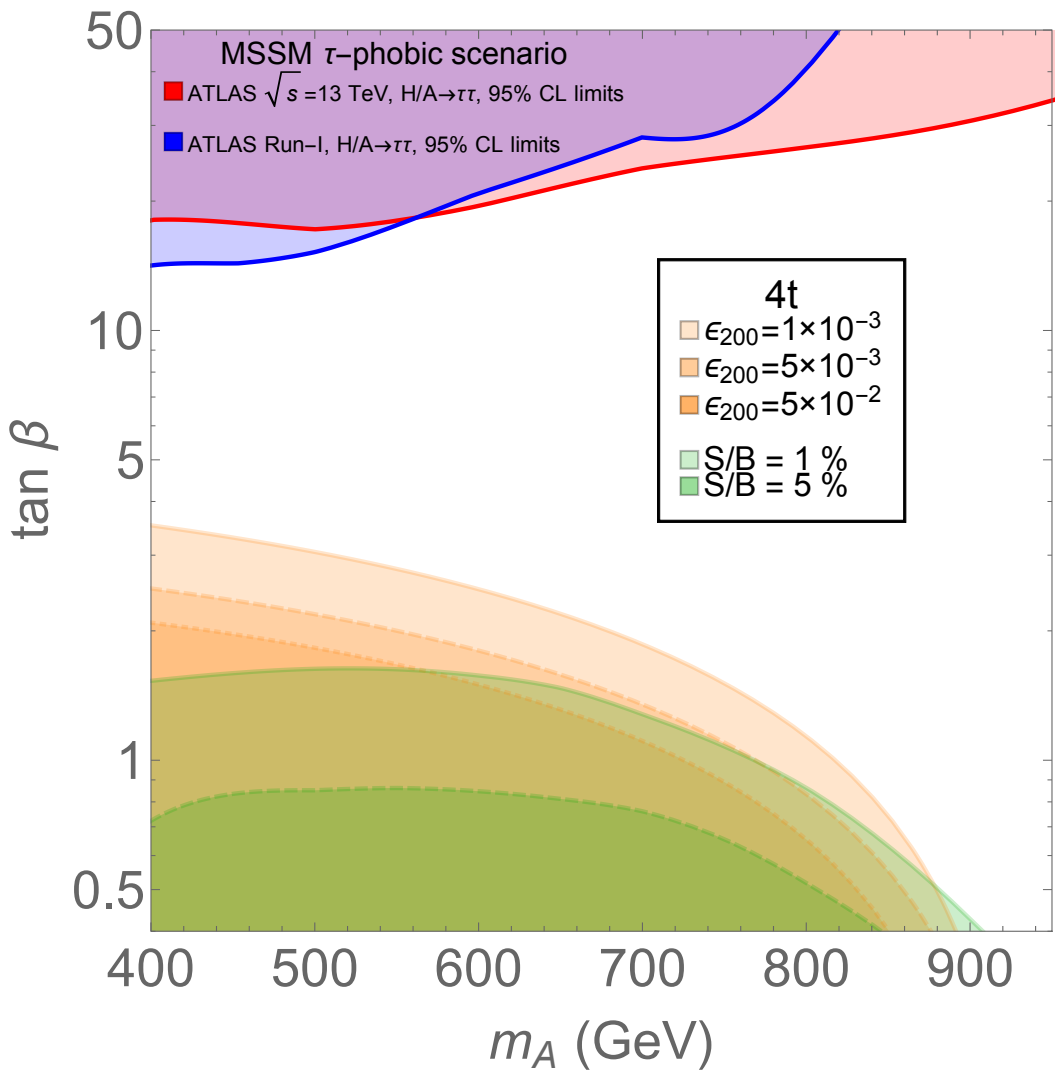


Based on
ATLAS Analysis
(lepton plus jets)

JHEP08 (2015) 148
arXiv:1505.07018

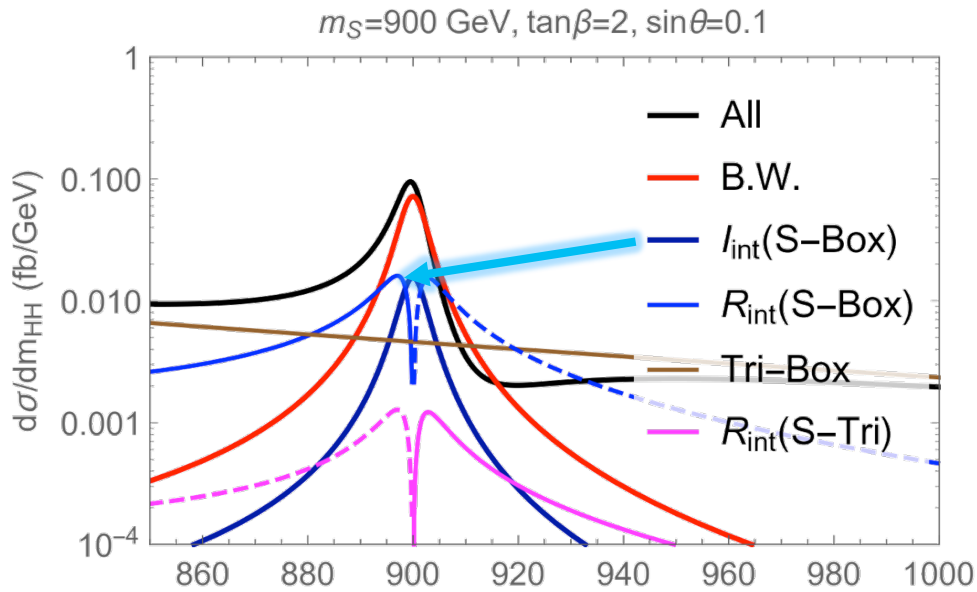
Blue curve, the signal lineshape before mearing;
Red Histogram, the signal after smearing and binning;
Gray and blue histograms, the total and statistical uncertainties;

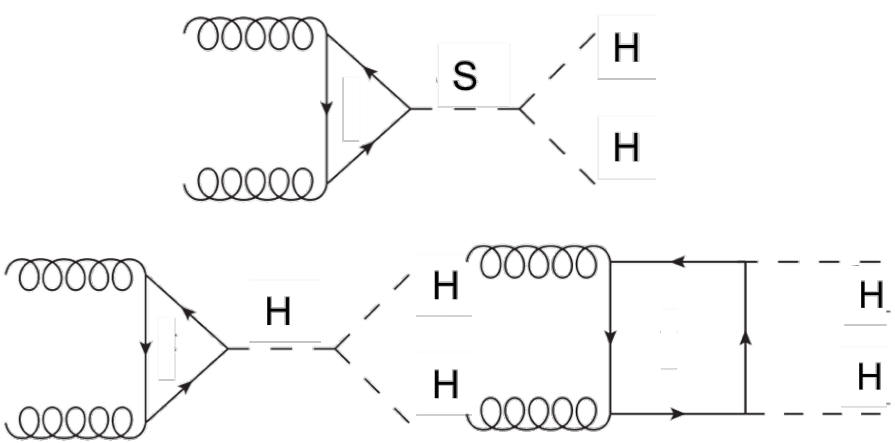
Alternative Production Channel : Associated Production of Higgs with tops

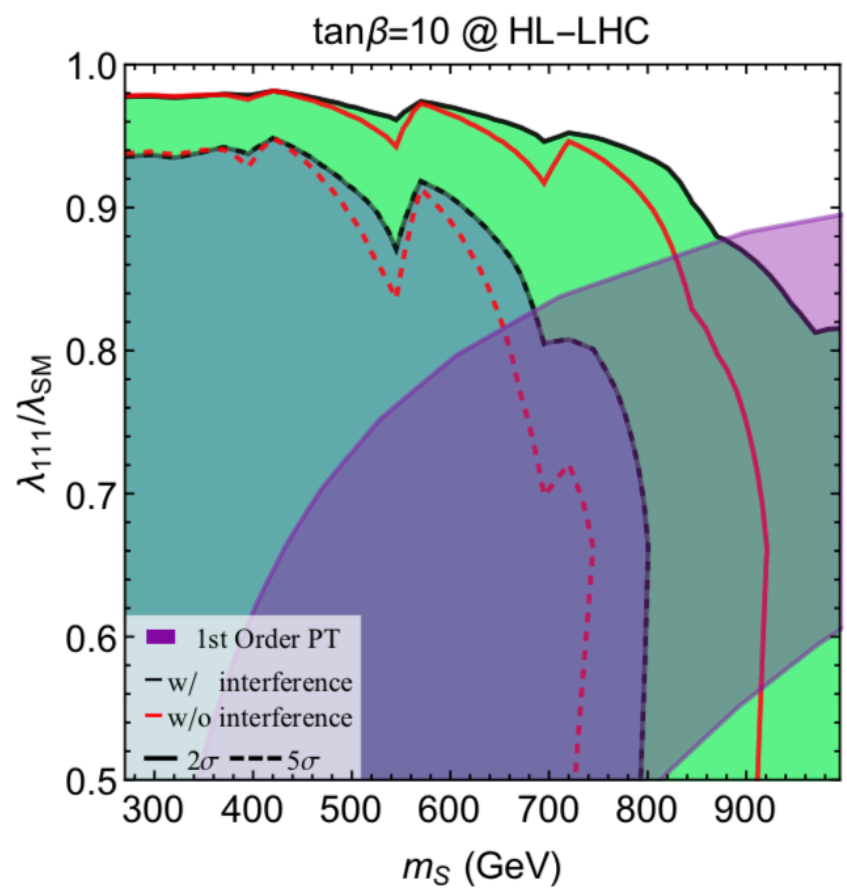


Interference in Resonant Di-Higgs Production Searches

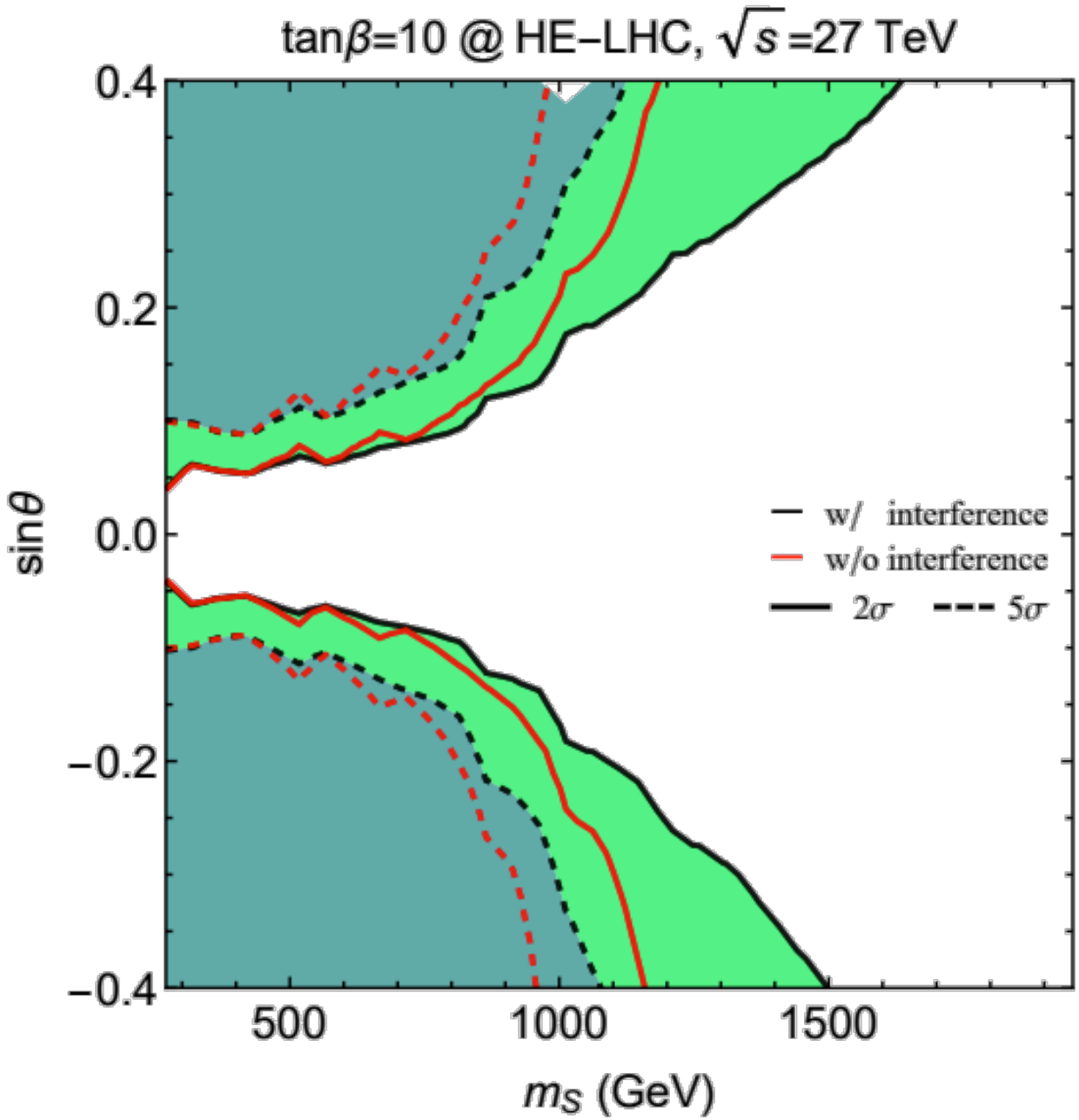
- Study the physics consequences of the novel on-shell and off-shell **interference effect** in this process.
- Correctly taking into account this effect can enhance the signal strength sizably and differential lineshape analysis shows that the inclusion of interference effect will enhance the sensitivity to this model.
- The interference effect is relevant where a **first order electroweak phase transition** is enabled in this model through a simplified EFT analysis.





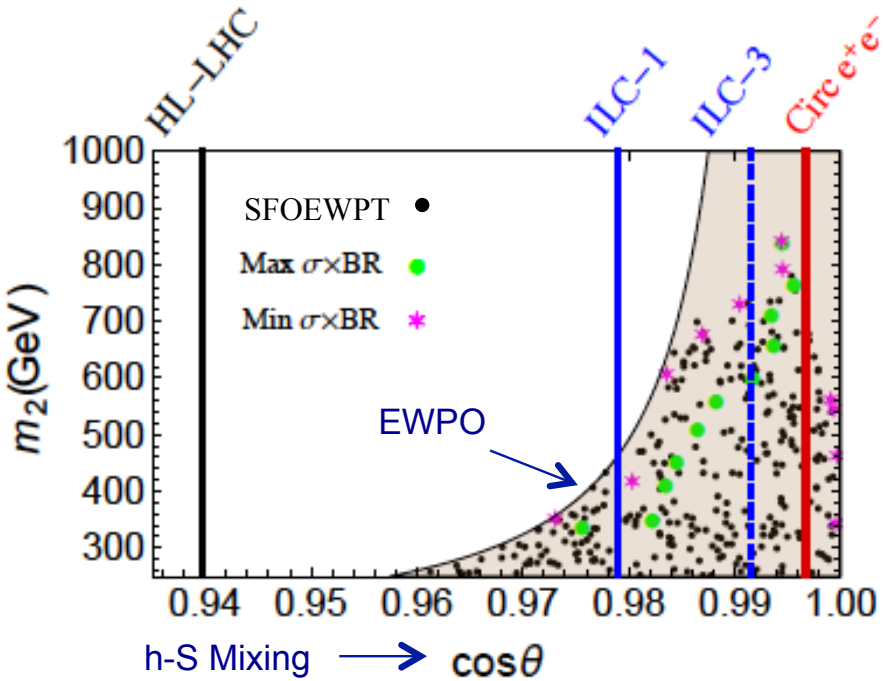


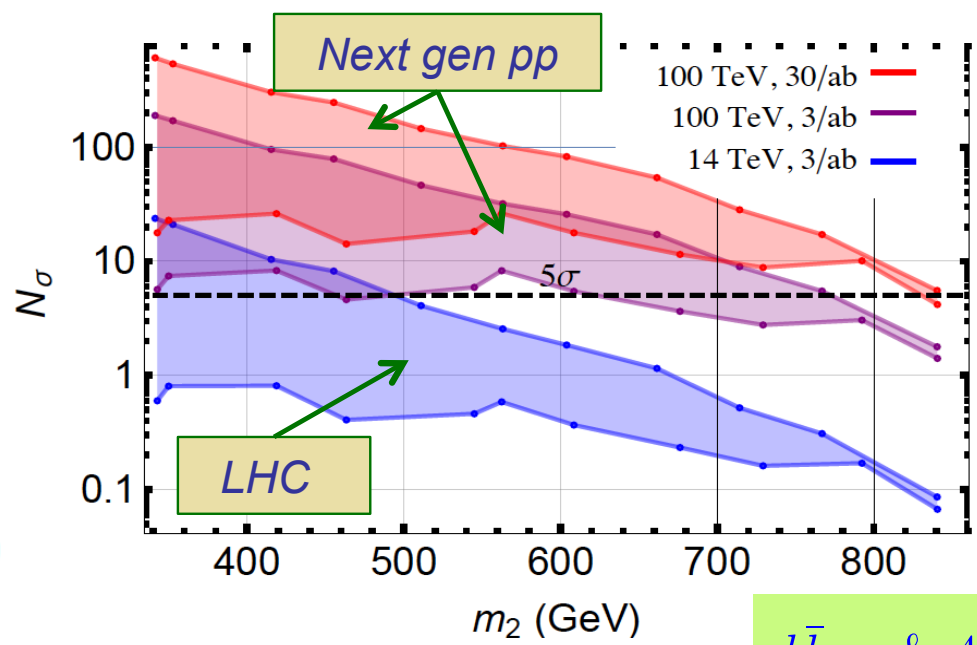
M. Carena, Z. Liu, M. Riembau, [1801.00794]


tanβ=10 @ HE−LHC, √s =27 TeV
0.4
0.2
0.0
−0.2
−0.4
sinθ
500
1000
1500
mS (GeV)
w/ interference
w/o interference
2σ
5σ

EW Phase Transition: Singlet Scalars

SFOEWPT Benchmarks: Resonant di-Higgs & precision Higgs studies



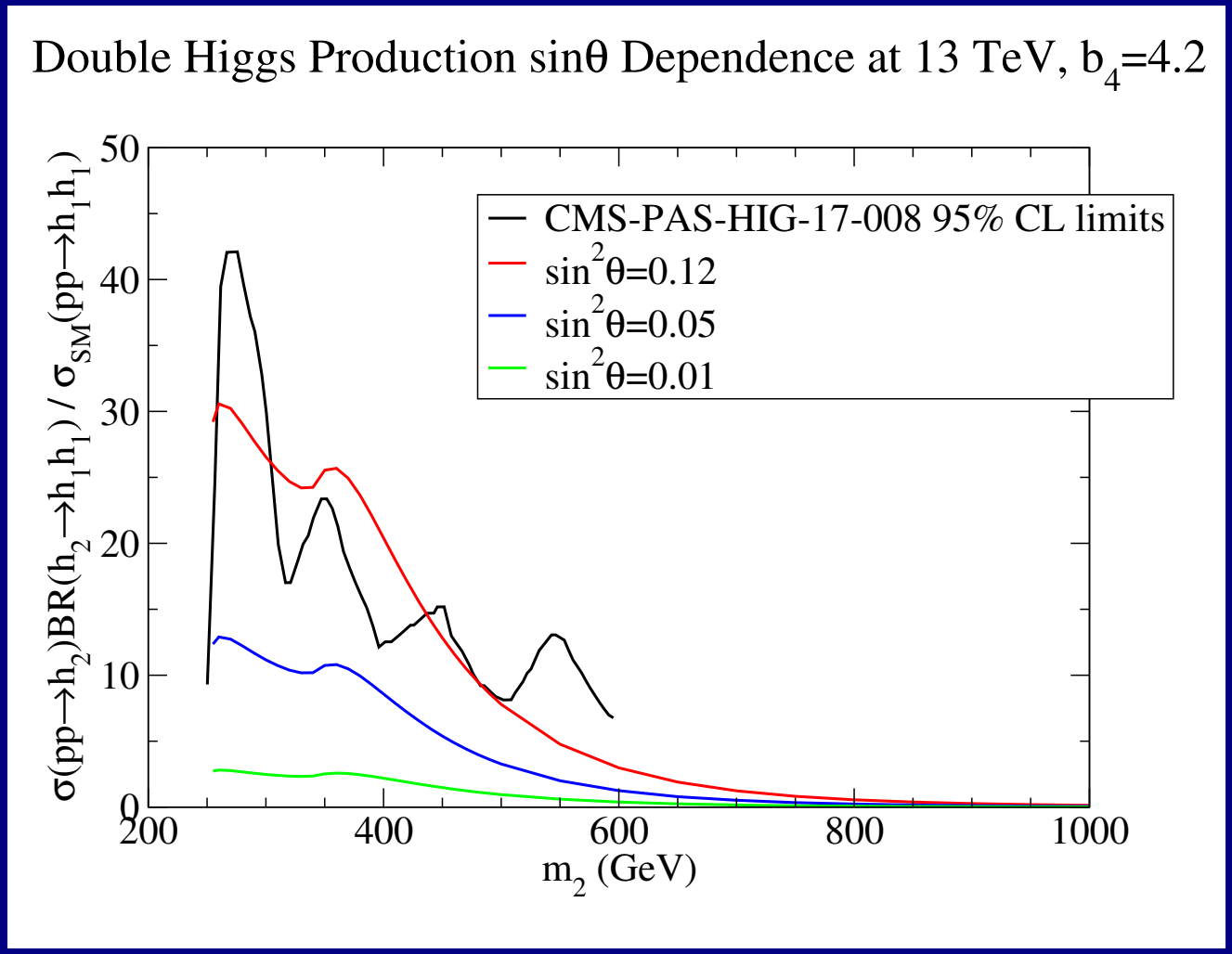


$b\bar{b}\gamma\gamma$ & 4τ

Kotwal, No, R-M, Winslow 1605.06123

See also: Huang et al, 1701.04442

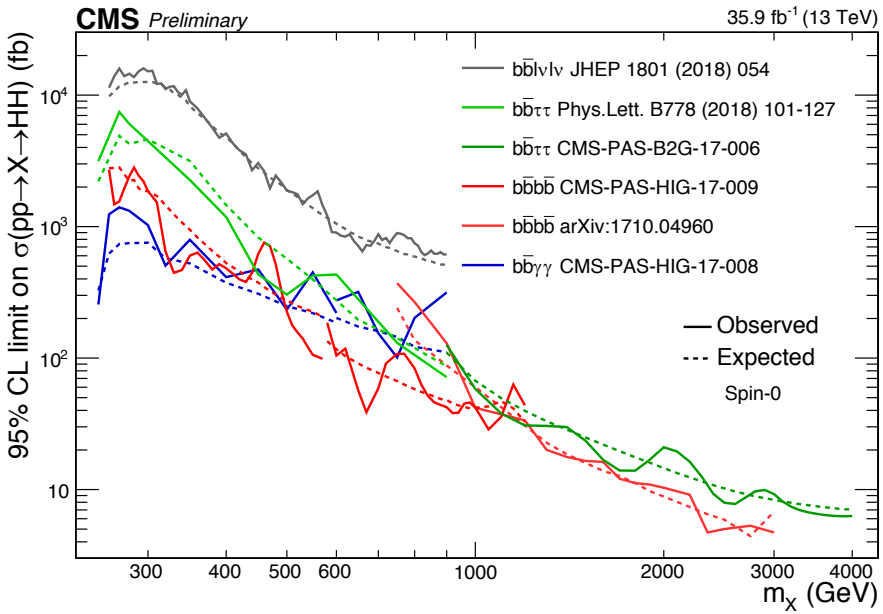
arXiv:1701.08774, Ian M. Lewis, Matthew Sullivan

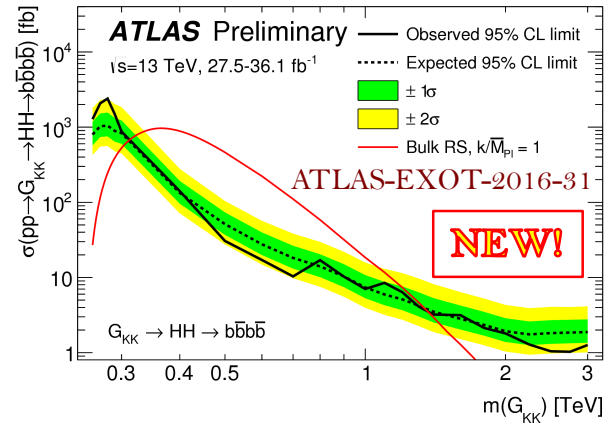


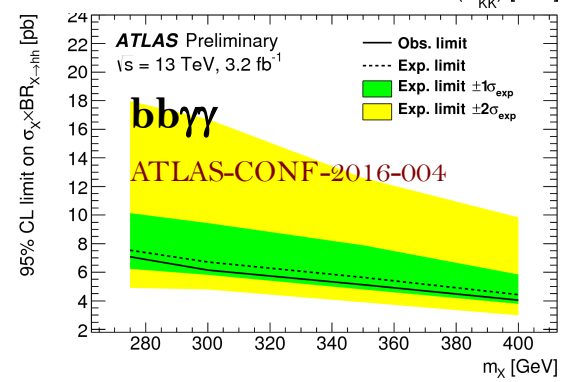
- $\sigma_{SM} = 32.91^{+13.6\%}_{-12.6\%}$ fb, NLO in QCD w/ full top mass effects
- Recent analysis (black) of 13 TeV constrains some regions
- At higher luminosity, θ will become more constrained

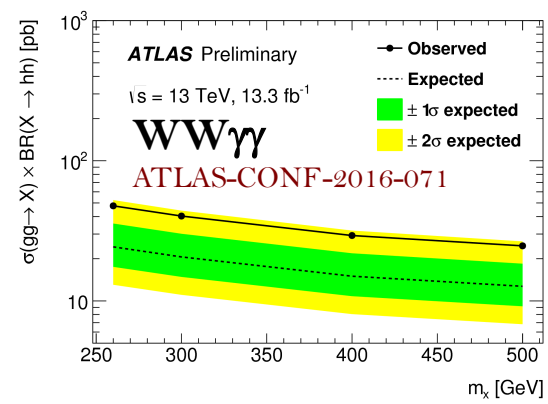
Resonant Summary

Current LHC Status







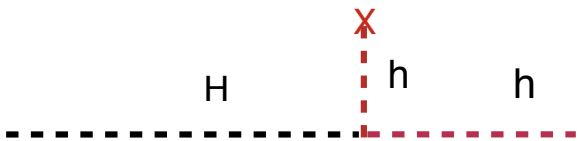


- Limits O(pb) for low mass resonances around 300 GeV
- Limits O(fb) for high mass resonances above a TeV

Decays into Additional light Scalar States Appear even with no Mixing with SM Higgs

(Alignment Limit)

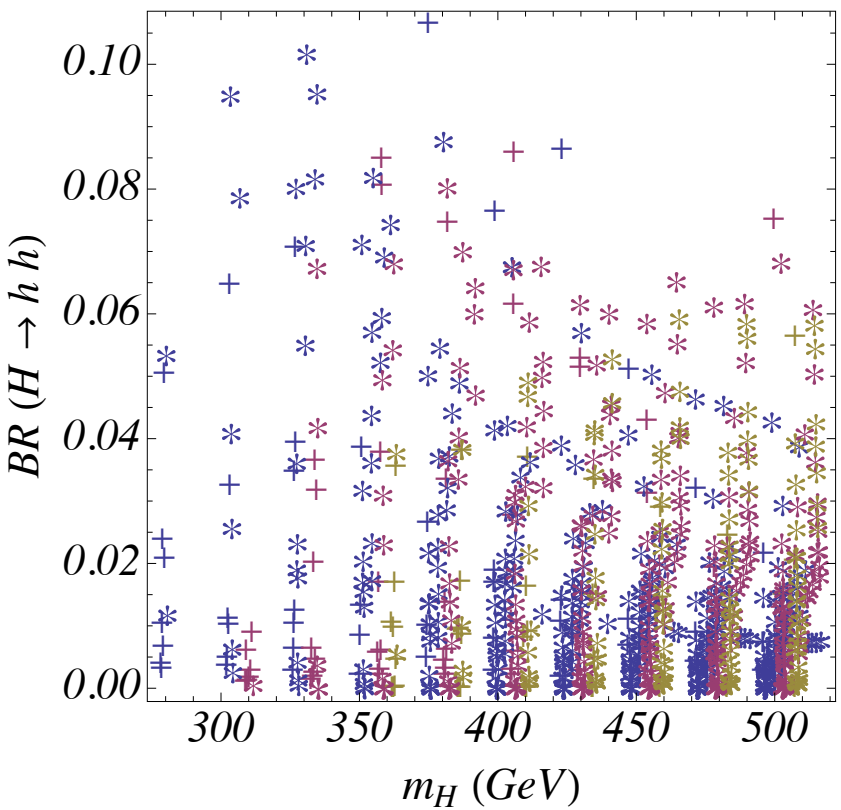
Decays into pairs of SM-like Higgs bosons suppressed by alignment

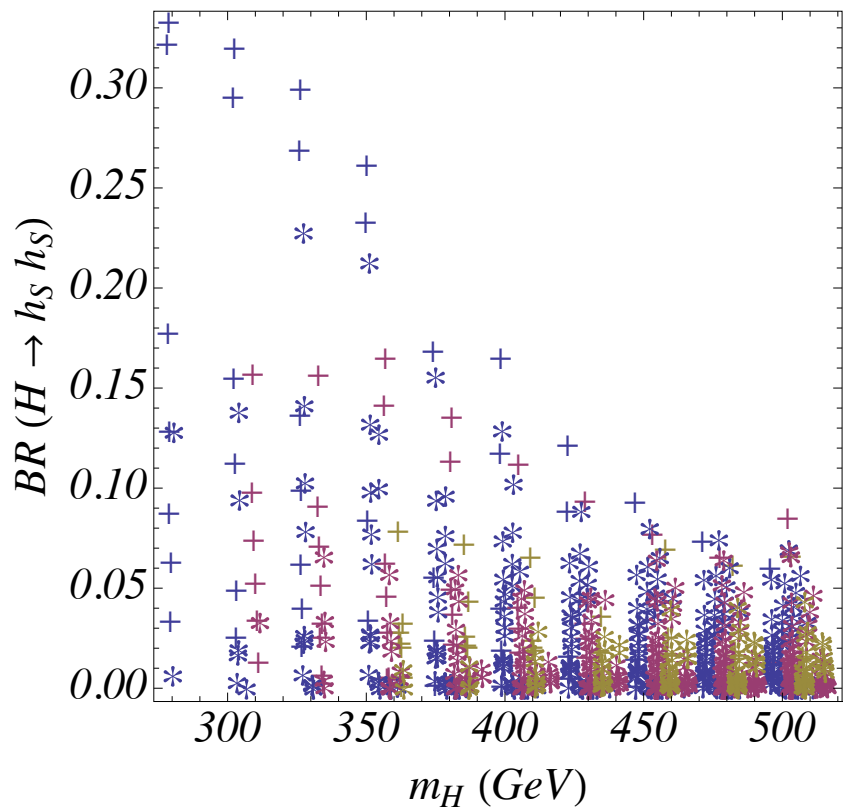


Carena, Haber, Low, Shah, C.W.'15

Crosses : H1 singlet like
Asterix : H2 singlet like

Blue : $\tan\beta = 2$
Red : $\tan\beta = 2.5$
Yellow: $\tan\beta = 3$



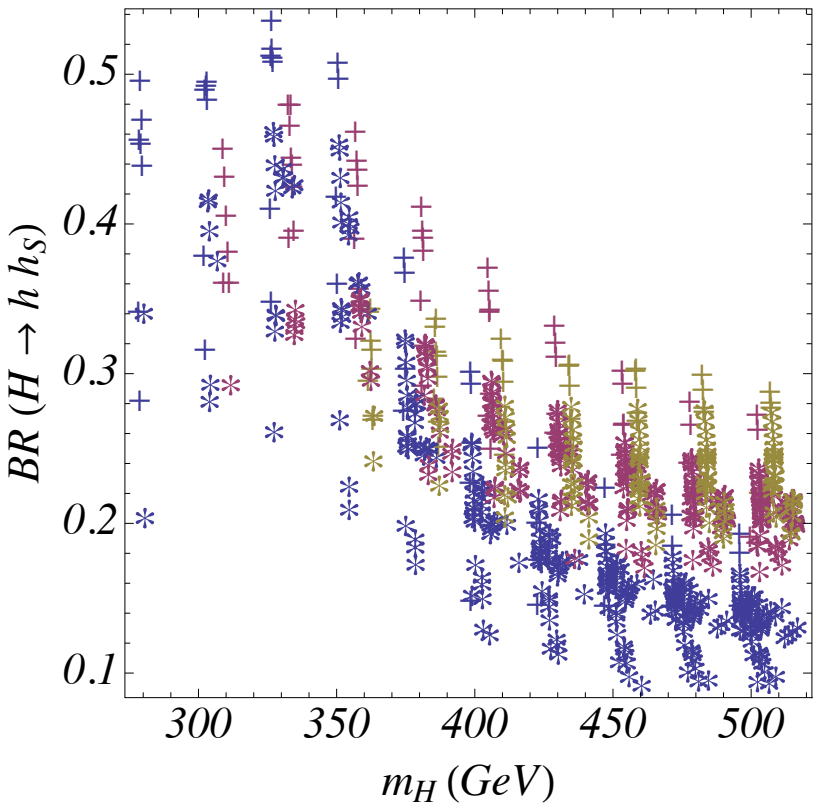


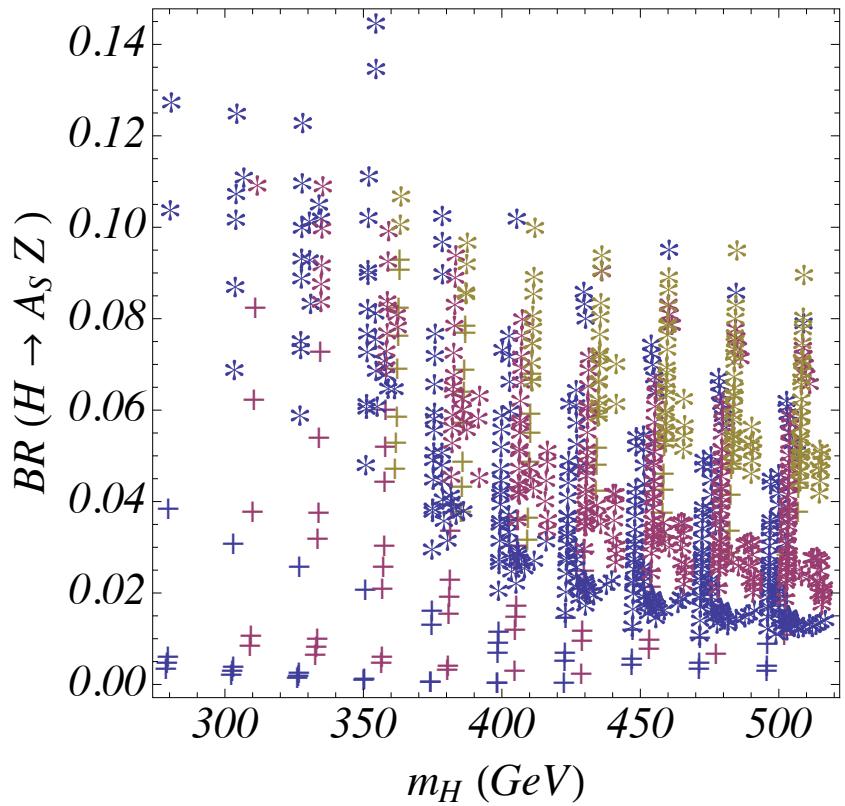
Significant decays of heavier Higgs Bosons into lighter ones and Z's

Crosses : H1 singlet like
Asterix : H2 singlet like

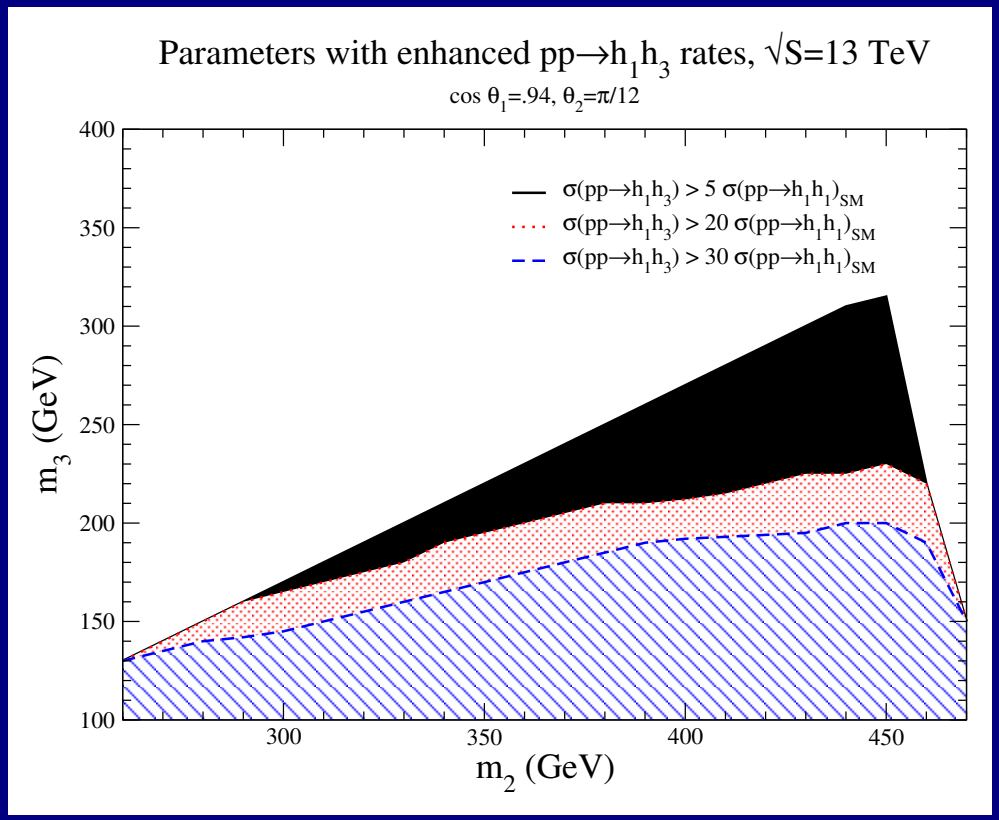
Blue : $\tan\beta = 2$
Red : $\tan\beta = 2.5$
Yellow: $\tan\beta = 3$

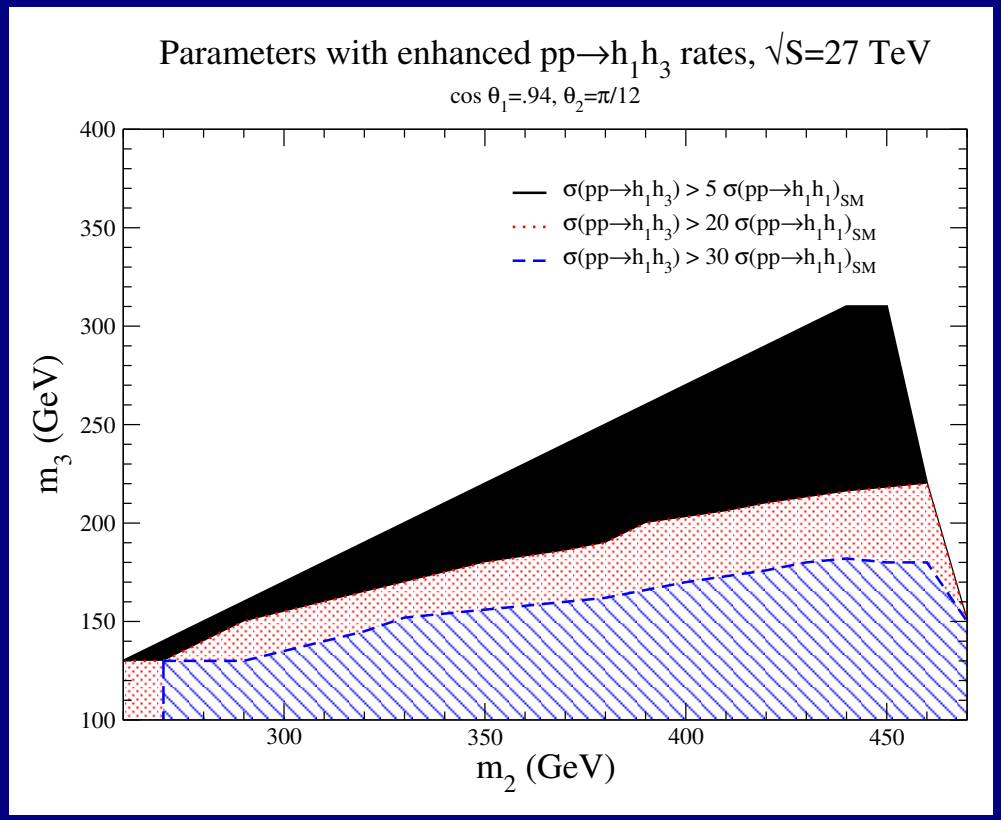
Carena, Haber, Low, Shah, C.W.'15





arXiv:1711.06683, Sally Dawson, Matthew Sullivan

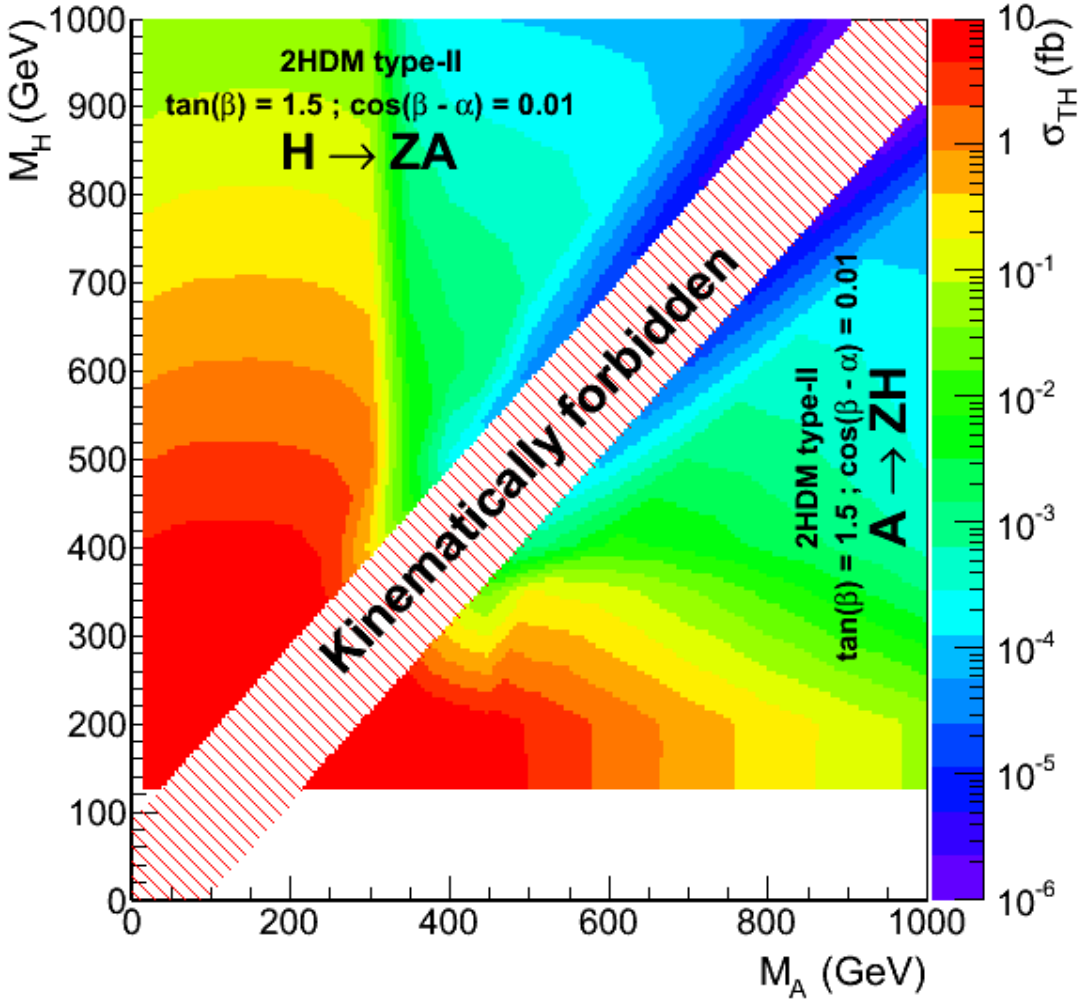




- SM cross section is roughly 13 fb at 13 TeV, roughly 65 fb at 27 TeV
- Energy scaling is roughly the same for all parameter points, about a factor of 5 larger at 27 TeV

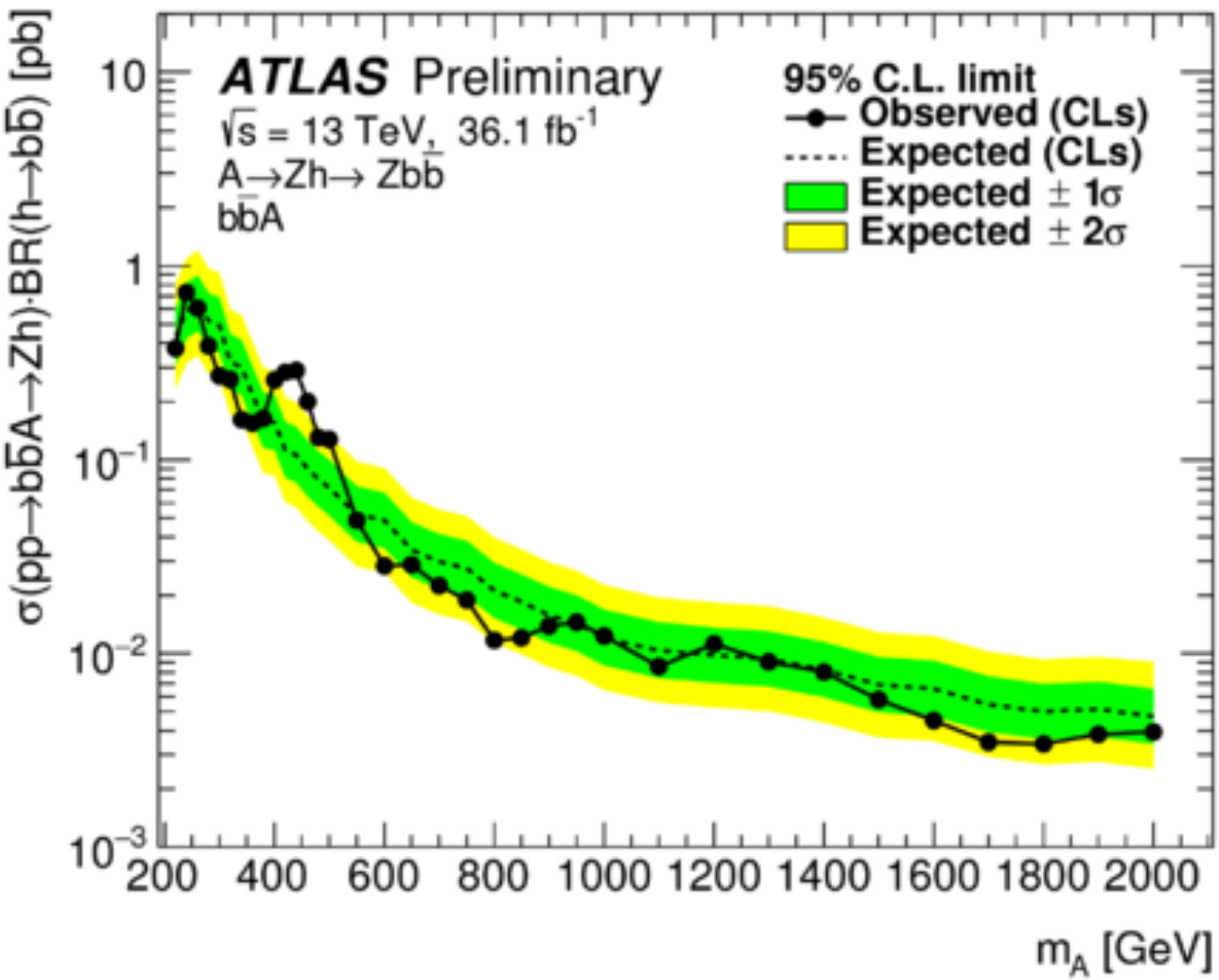
Search for (psudo-)scalars decaying into lighter ones

CMS-PAS-HIG-15-001

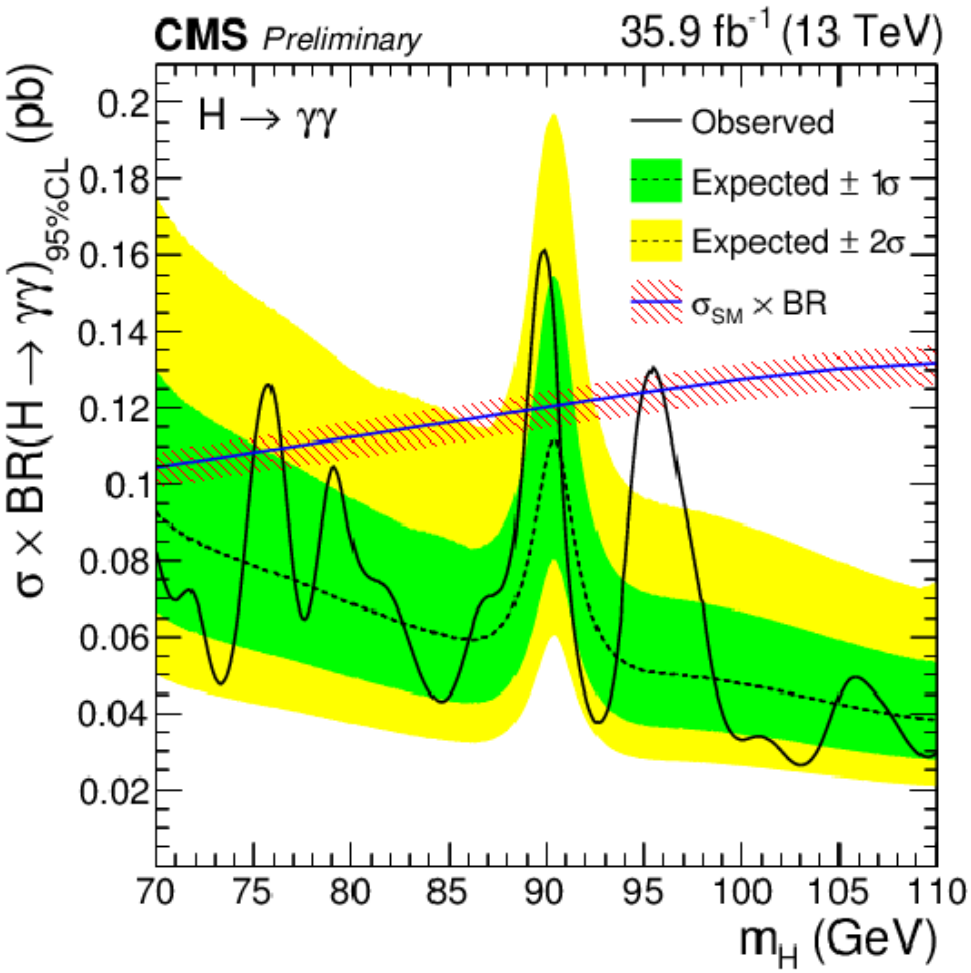


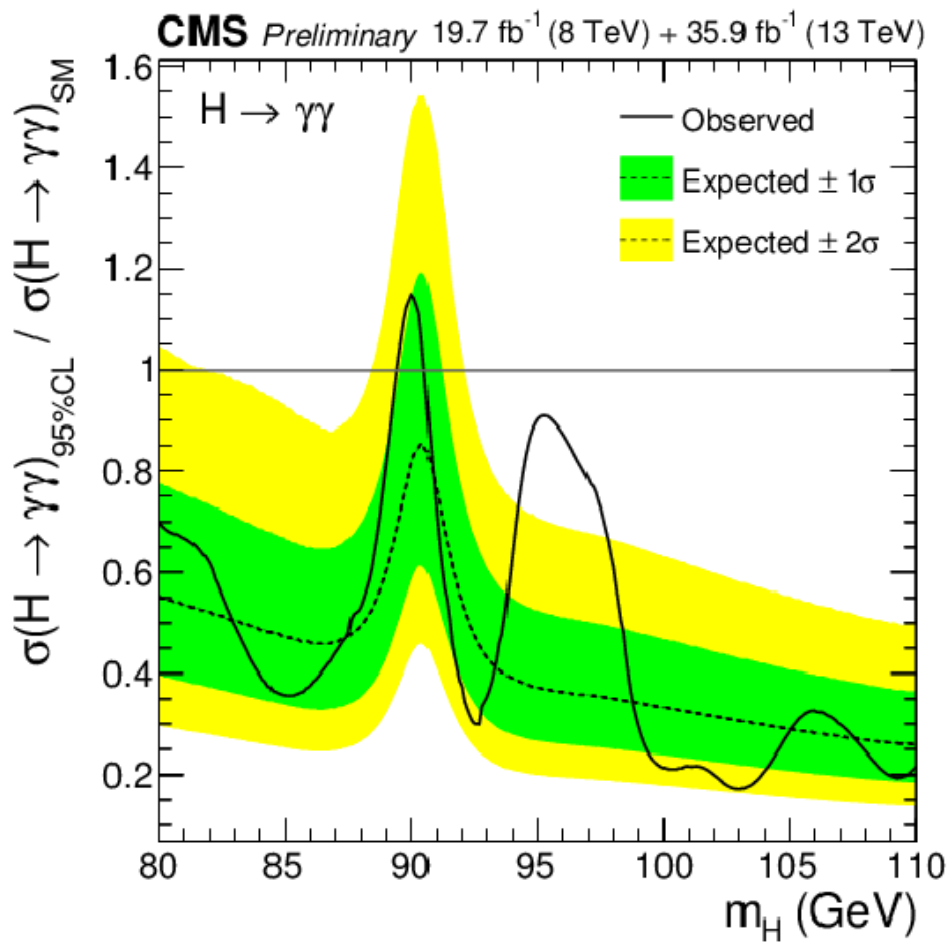
It is relevant to perform similar analyses replacing the gauge bosons by additional Higgs bosons !

Channels with extra gauge Bosons Relevant (ATLAS Excess)



CMS Excess ?

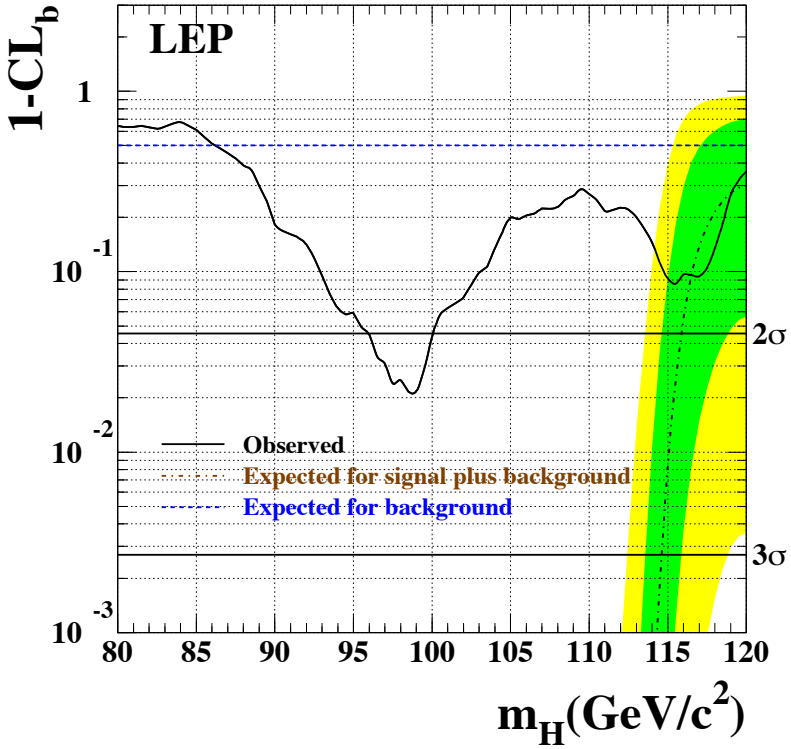

CMS Preliminary
35.9 fb^{-1} (13 TeV)
H → γγ
Observed
Expected ± 1σ
Expected ± 2σ
$\sigma_{SM} \times$ BR
$\sigma \times BR(H \to \gamma\gamma)_{95\%CL}$ (pb)
m_H (GeV)

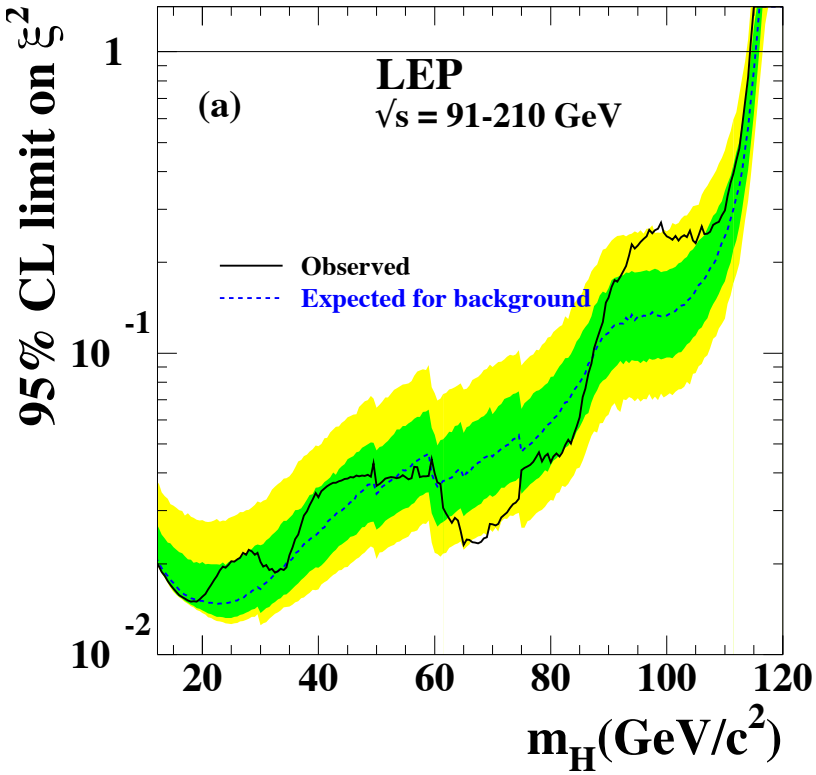

CMS Preliminary 19.7 fb^{-1} (8 TeV) + 35.9 fb^{-1} (13 TeV)
H → γγ
Observed
Expected ± 1σ
Expected ± 2σ
$\sigma(H \to \gamma\gamma)_{95\%CL} / \sigma(H \to \gamma\gamma)_{SM}$
m_H (GeV)

LEP2 Excess

LHWG-2003-011

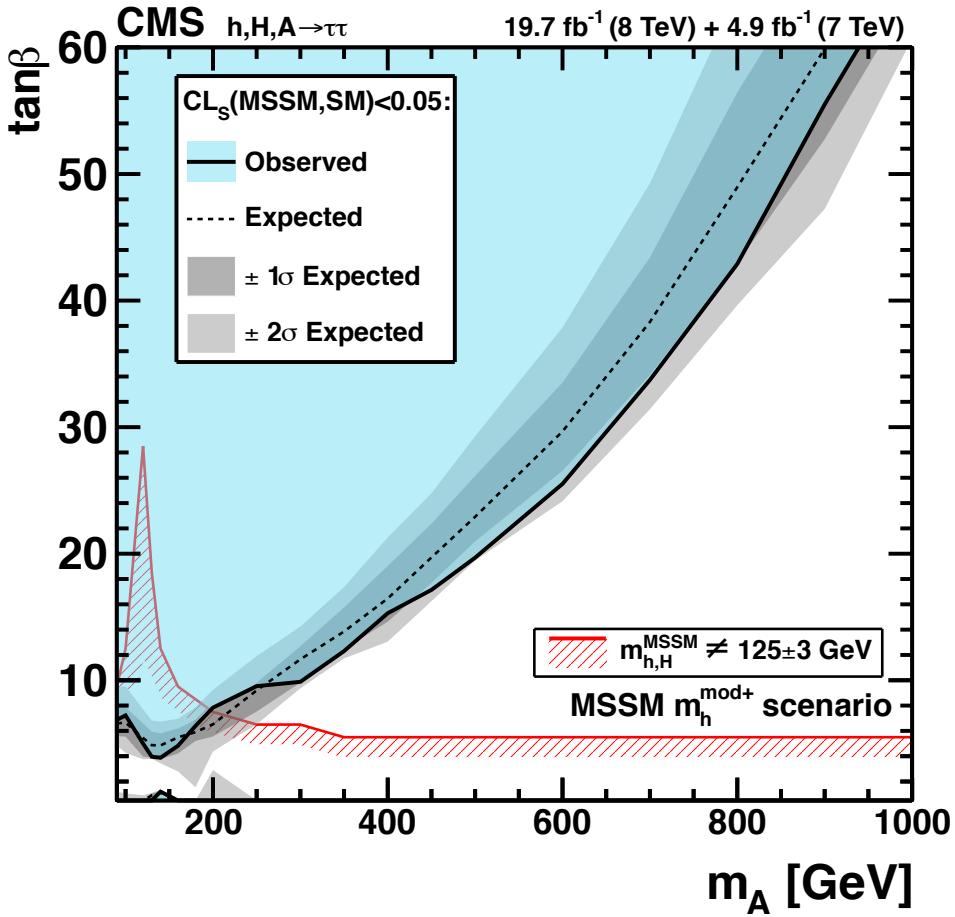
$$\xi^2 = g^2_{ZZh}/g^2_{ZZh_{SM}} \times \frac{\mathrm{BR}(s \to b\bar{b})}{\mathrm{BR}(h^{\mathrm{SM}} \to b\bar{b})}$$

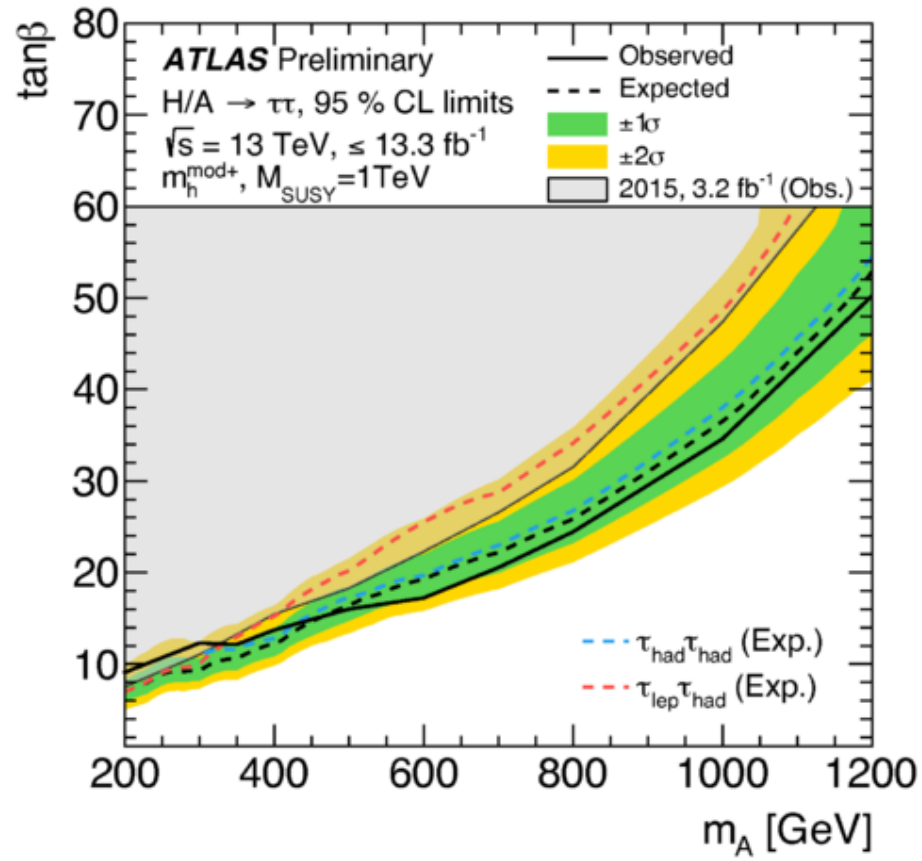




Top and Di-Boson Searches Complementary
to the ones coming from tau and bottom final states

Search for new neutral Higgs bosons





Low values of the new Higgs bosons masses
and large values of tanβ ruled out