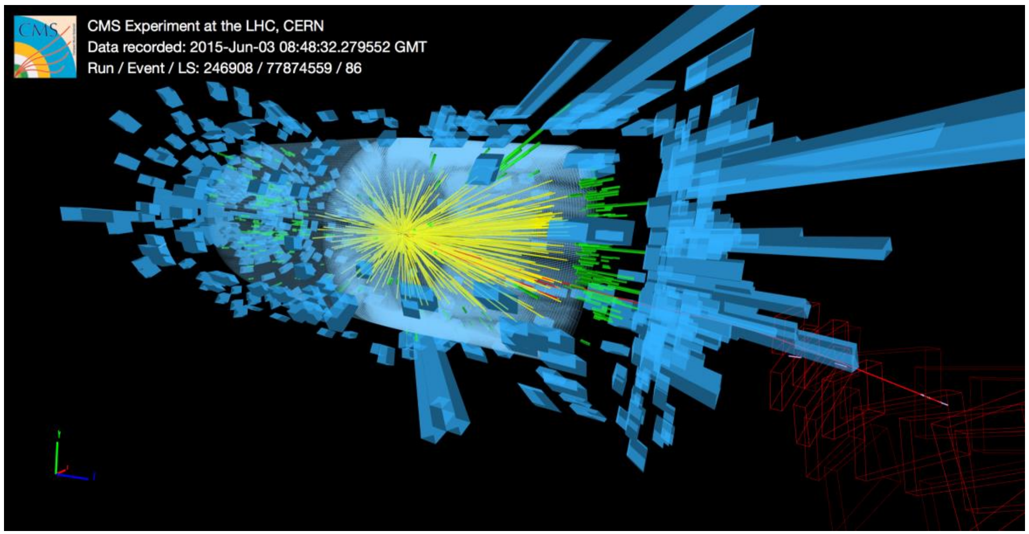
BSM Higgs,
Experimental report

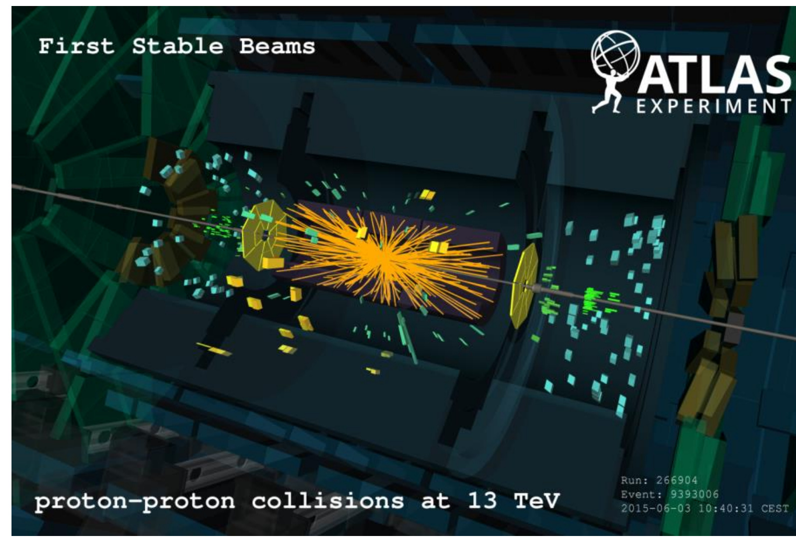
A. Nikitenko, IC

10th June 2015, Les Houches

First pp collision for physics at 13 TeV

June 3, 2015



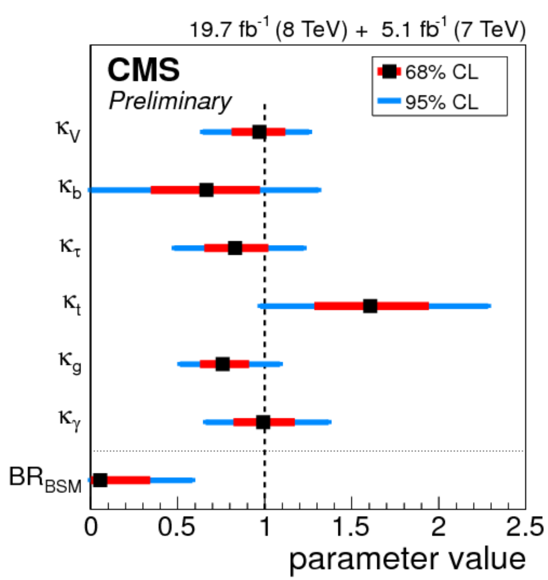


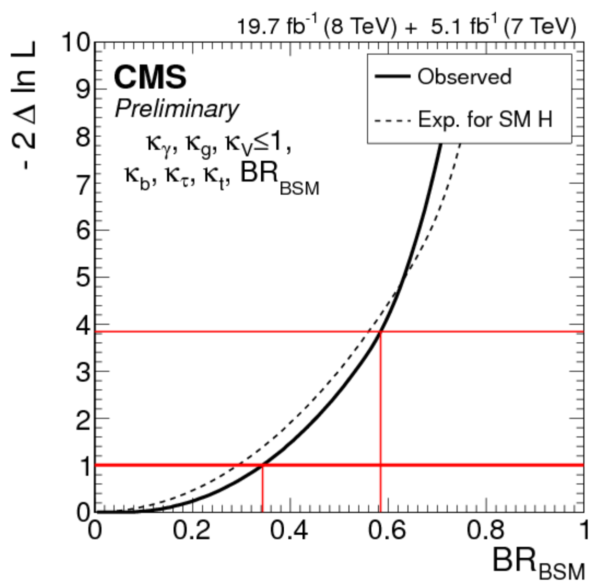
No stone to be left unturned to search for BSM physics with Run II

12 Experimentalists from ATLAS+CMS in Les Houches 2015 for BSM Higgs Session 2

BSM Physics with Higgs bosons

- additional Higgs bosons
- non SM decays of h(125)





$BR_{BSM} < 0.58$ at 95% CL (CMS)

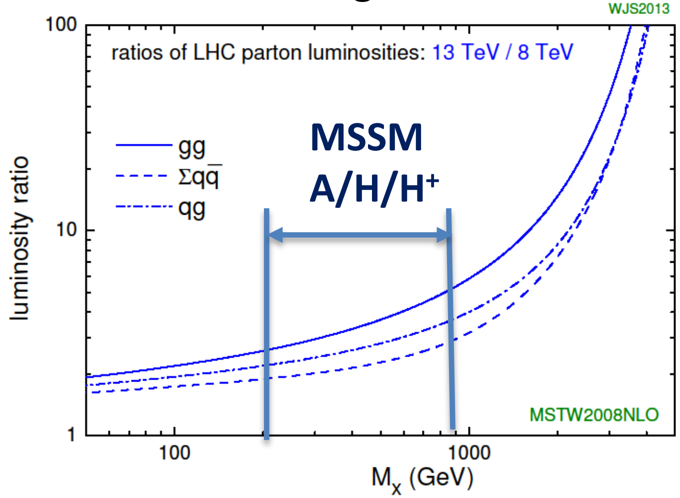
- precise measurements for h(125)
  - EFT, CP properties.

MSSM, 2HDM

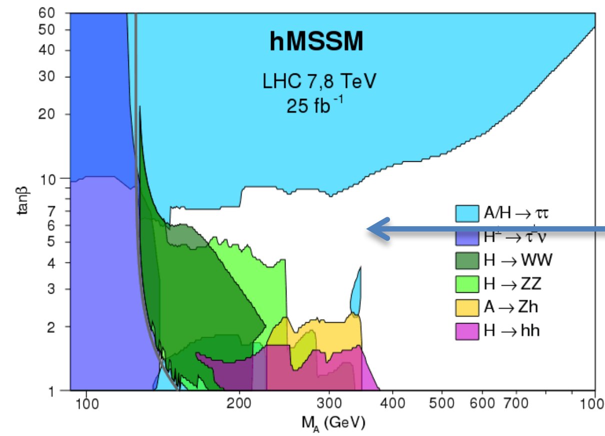
Prospects for 2015-2016

- **No immediate discovery for with first 5-10 fb^{-1} is expected.**
  - with ~ 5-10 fb^{-1} at 13 TeV expect to reach 8 TeV/20 fb^{-1} sensitivity of current 8 TeV analyses and start to explore a new territory

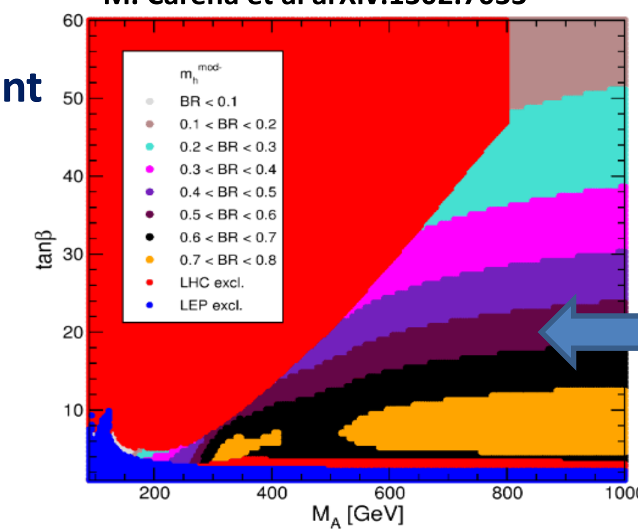
J. Stirling 2013



A. Djouadi et al arXiv:1502.05653



M. Carena et al arXiv:1302.7033



H/A->χχ

Search for heavy A/H->χχ decays could complement direct searches χχ searches:

<u>**Les Houches project:**</u>

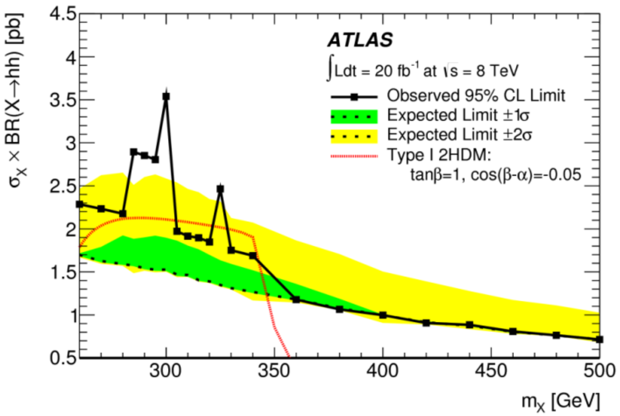
Apyan Aram (CMS), H⁺->χχ

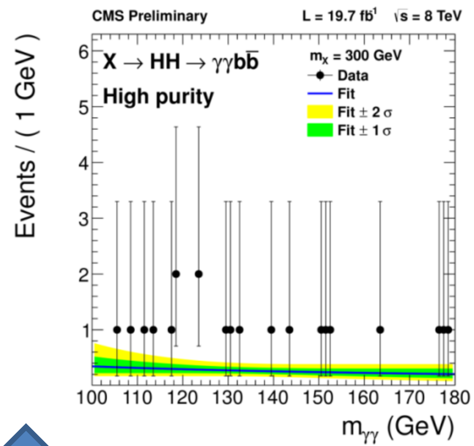
A. Nikitenko (CMS), A/H->χχ

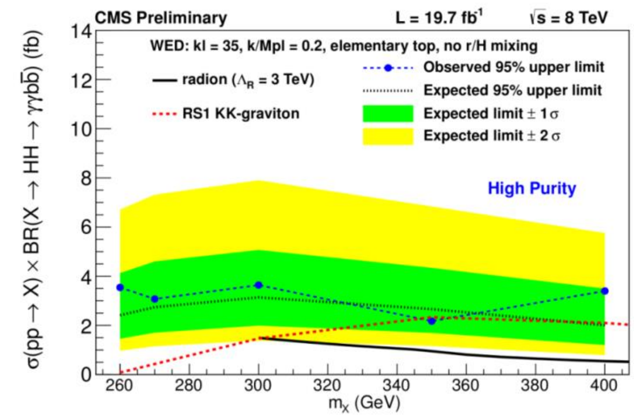
Long pre-LHC data history of these analyses:

F. Moortgat et al, A. Ketevi et. al

(MSSM) H → hh → γγbb, ττbb, bbbb

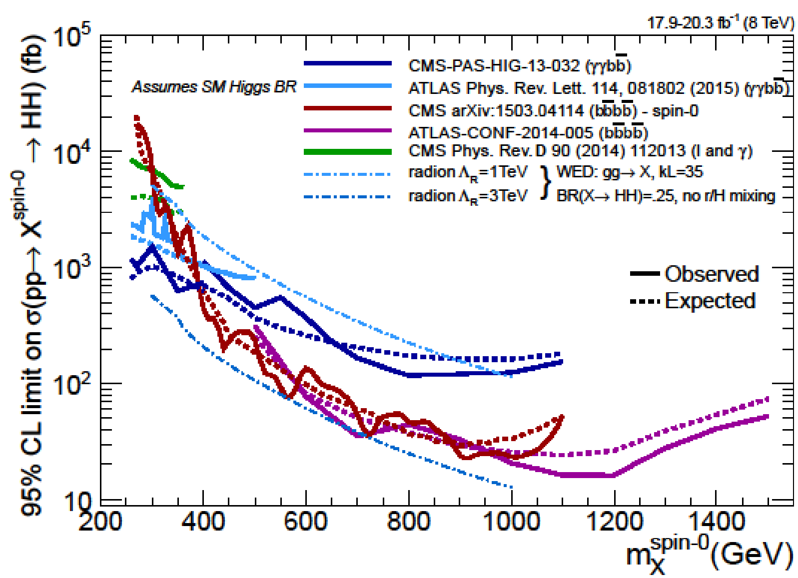






How important is interference with BSM non-resonant di-higgs production ?

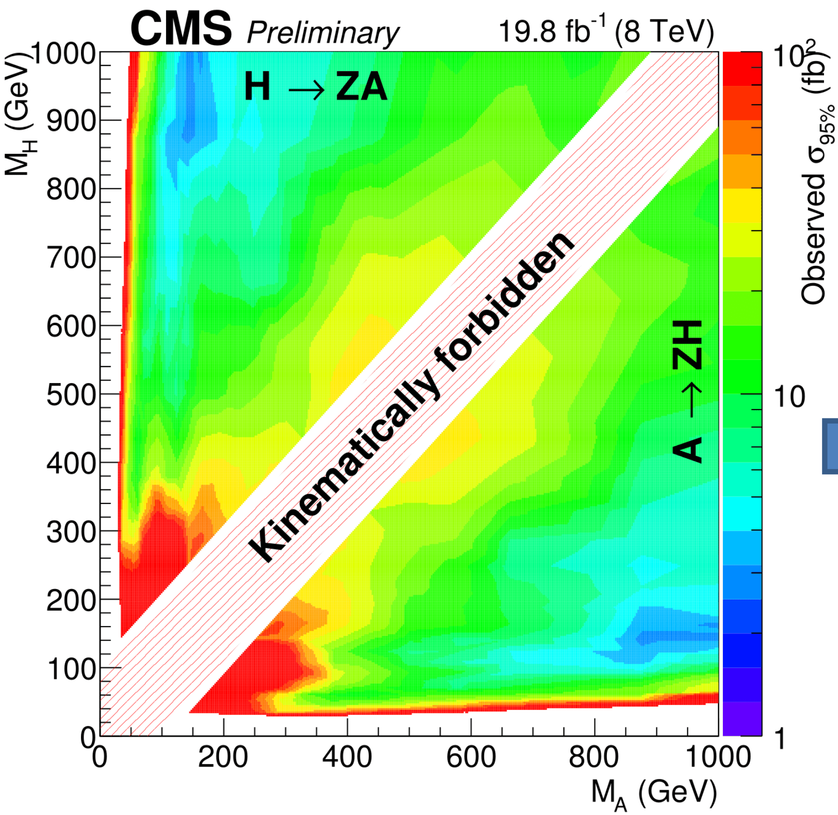
- **Di-Higgs boson production in BSM**:
  - Alexandra Oliveira (CMS)
  - Devdatta Majumder (CMS)
  - Chris Pollard (ATLAS)
    - reconstruction of close by b- jets,…



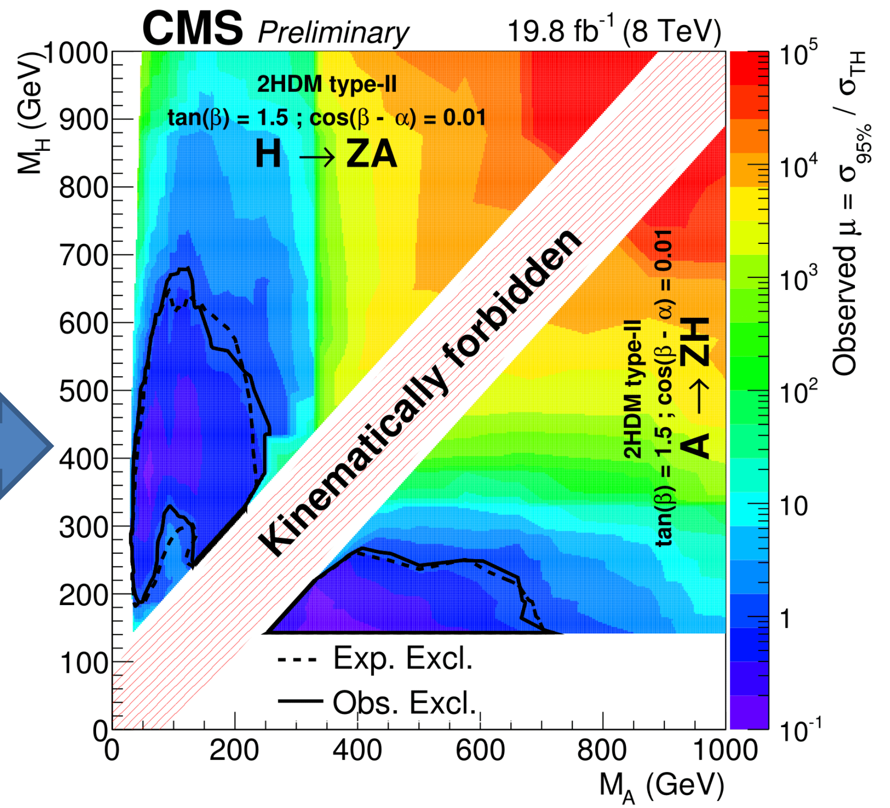
Presentation of limits from heavy Higgs searches in multi-Higgs models

- Example from recent CMS H->ZA, A->ZH analysis (2HDM, m_h=125)

σ x BR observed limit



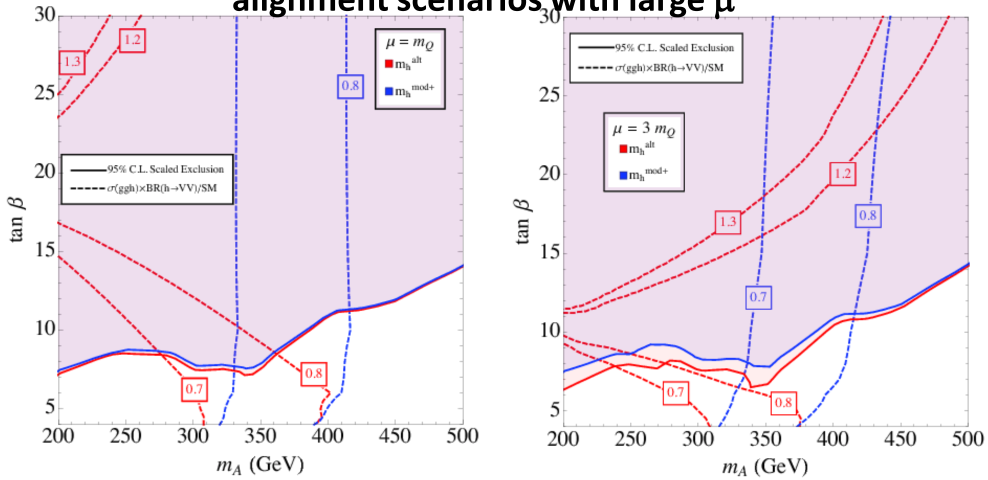
interpretation in 2HDM



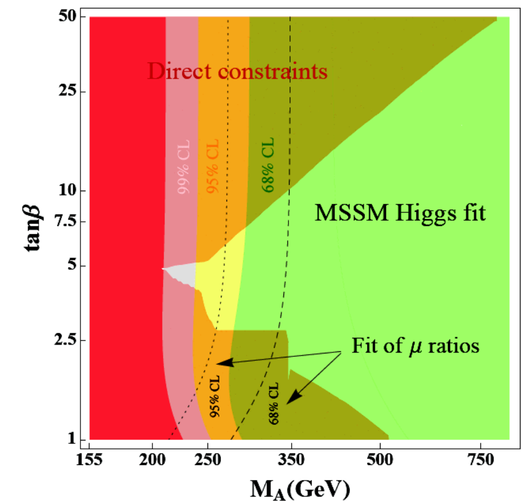
Complementarity between precision measurements of h(125) and direct searches

MSSM

Carena, Haber, Low, Shah, Wagner, arXiv:1410.4969
alignment scenarios with large μ

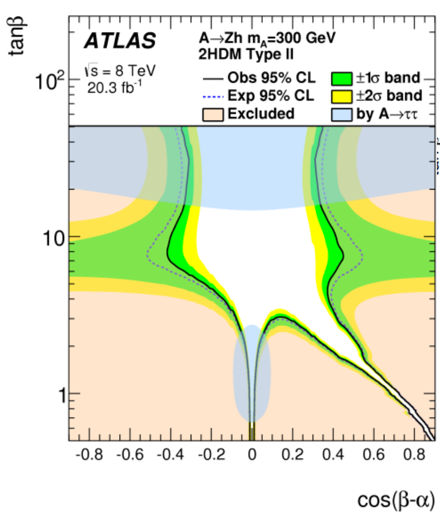


Djouadi et.al. arXiv:1307.5205

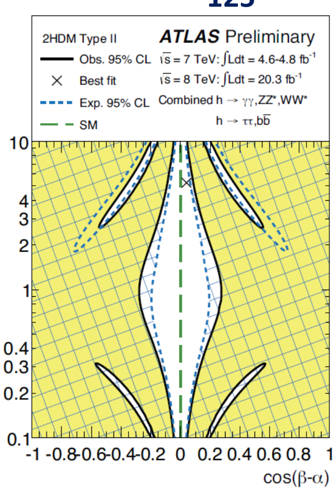


2HDM

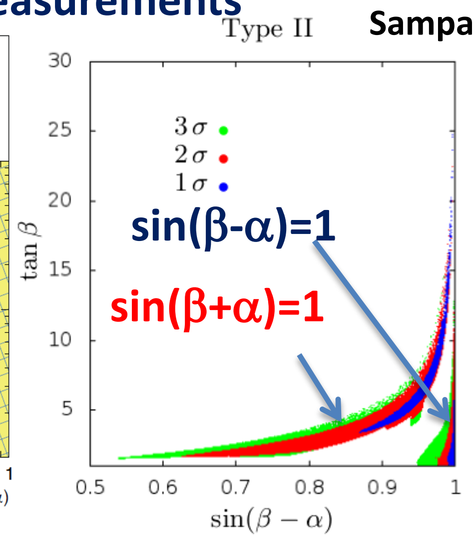
Direct search



h_{125} measurements



Ferreira, Guedes, Gunion, Haber, Sampaio, Santos arXiv:1410.1926



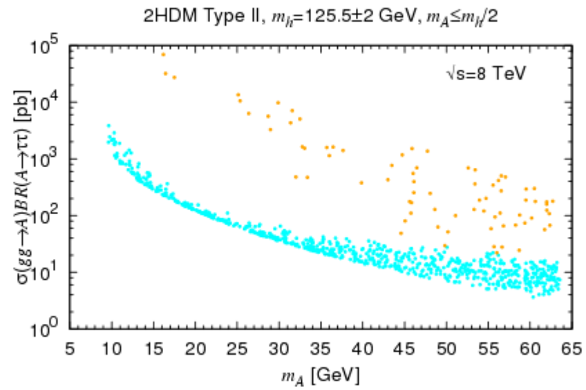
sin(β-α)=1 => SM like limit (alignment)

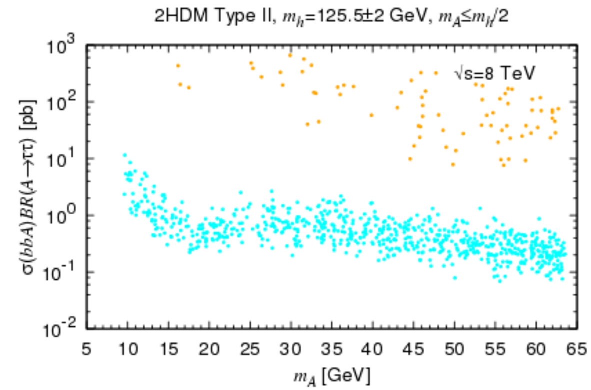
$k_F = k_V = 1$

sin(β+α)=1 => $k_D = -1$ ($k_U = k_V = 1$) "wrong sign" limit; can be excluded with ~ 5 % accuracy on h->γγ measurement

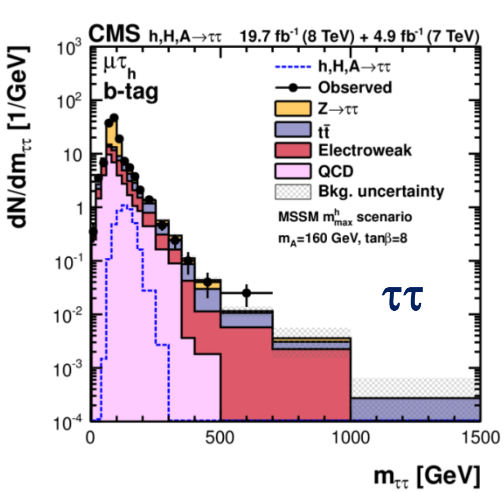
Open a new mass search region for pp->bbϕ and gg->ϕ, ϕ->μμ, ττ analyses

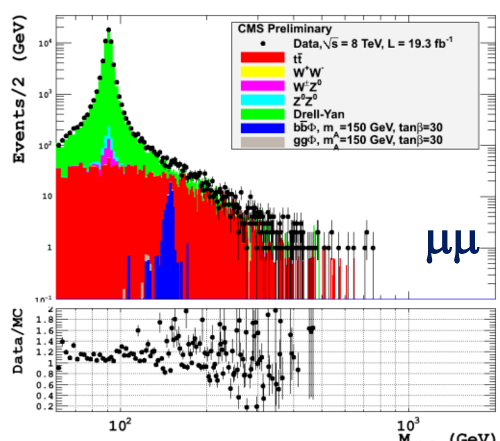
- ~ 20 GeV < m_A < 60 GeV in 2HDM Type II
  - Motivated by Gunion et al. arXiv:1412.3385, arXiv:1405.3584

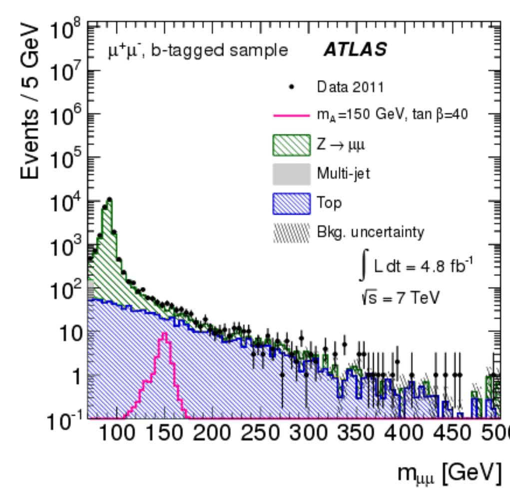




- CMS: re-consider public 8 TeV analyses, bbA, A->μμ, ττ

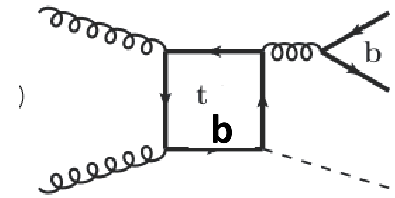


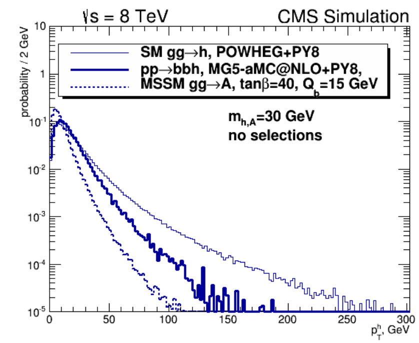


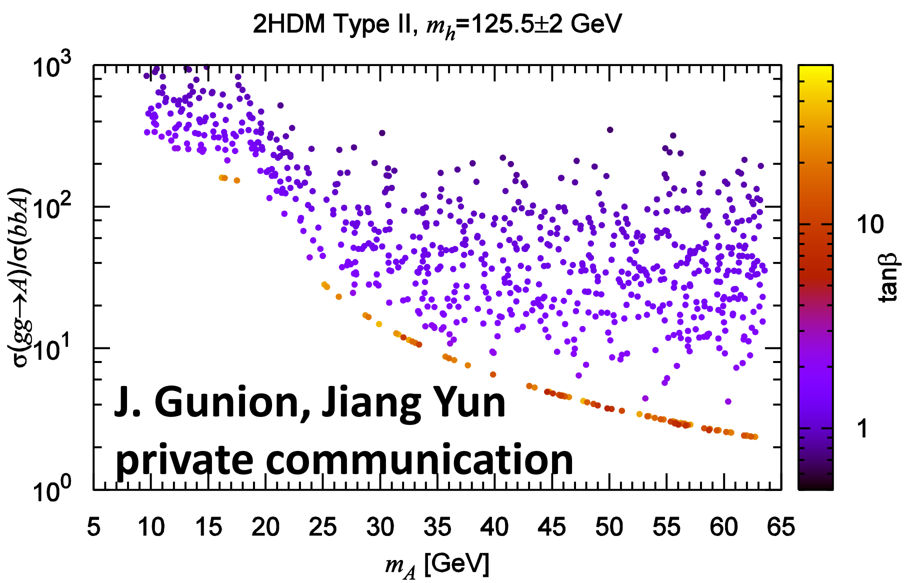


Issue 1

- σ(gg->A) at low m_A can be much bigger than σ(bbA)
  - gg->A contamination in b-tag category can be significant from to two sources:
    - gg->A+gluon
      - gluon->bb
      - gluon is misstaged as b-jet







Brown = wrong sign Yukawa cases:
gg->A/bbA ratio ~ 10 at m_A=30 GeV

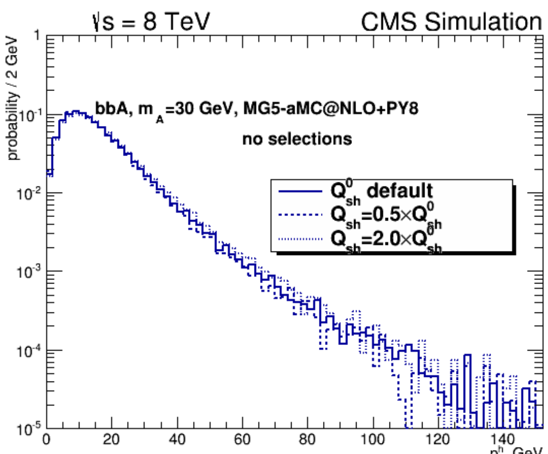
Blue = normal sign Yukawa cases:
gg->A/bbA ratio can be 100 at m_A=30 GeV

Proper generation of gg->h+gluon, gluon->bb is important

Issue 2

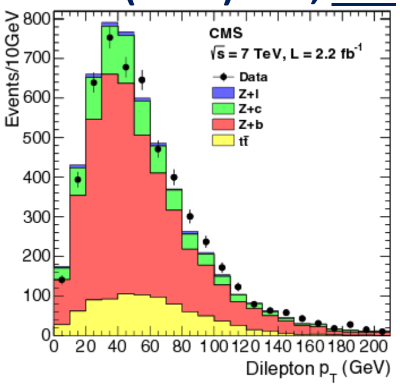
- **Quite large acceptance uncertainty of bbh generation with MG5_aMC@NLO due to Q_{sh}**
  - **Selections applied at particle level:**
    - $p_{T\mu1,2}$ > 25, 5 GeV, $|\eta_{\mu1,2}|$<2.1, 2.4
    - >=1 b-jet p_T > 30 GeV, $|\eta|$<2.4

	shewer scale, Q_{sh} variation		
	0.5	default	2.0
Selection efficiency	2.93x10^{-2}	3.33x10^{-2}	4.14x10^{-2}
Uncert.	-12 %		+24 %

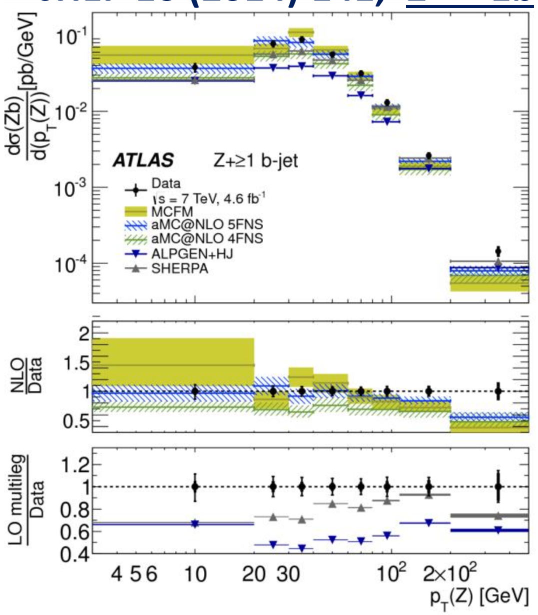


- **bbZ can be used to tune MC settings and use them in h+b**

JHEP 06 (2012) 126, Z+b



JHEP 10 (2014) 141, Z+>=1b



NMSSM, 2HDM+S

S. King, M. Muhlleitner, R. Nevzorov, K. Walz, arXiv:1408.1120

B.1 (Point ID Poi2a)	Decay Rates
$\sigma(ggH_s)$	282.37 fb
$\sigma(ggH_s)\mathrm{BR}(H_s \to WW)$	5.09 fb
$\sigma(ggH_s)\mathrm{BR}(H_s \to A_sA_s)$	274.75 fb
$\sigma(ggH_s)\mathrm{BR}(H_s \to A_sA_s \to bb + bb)$	5.87 fb
$\sigma(ggH_s)\mathrm{BR}(H_s \to A_sA_s \to \gamma\gamma + b\bar{b})$	67.33 fb
$\sigma(ggH_s)\mathrm{BR}(H_s \to A_sA_s \to \gamma\gamma + \gamma\gamma)$	193.22 fb
$\sigma(ggH)$	3.17 pb
$\sigma(ggH)\mathrm{BR}(H \to WW)$	264.73 fb
$\sigma(ggH)\mathrm{BR}(H \to ZZ)$	119.52 fb
$\sigma(ggH)\mathrm{BR}(H \to b\bar{b})$	297.37 fb
$\sigma(ggH)\mathrm{BR}(H \to \tau\tau)$	37.65 fb
$\sigma(ggH)\mathrm{BR}(H \to \tilde{\chi}_1^0\tilde{\chi}_1^0)$	383.33 fb
$\sigma(ggH)\mathrm{BR}(H \to \tilde{\chi}_1^+\tilde{\chi}_1^-)$	403.14 fb
$\sigma(ggH)\mathrm{BR}(H \to hH_s)$	1.609 pb
$\sigma(ggH)\mathrm{BR}(H \to hH_s \to bb + \tau\tau)$	1.44 fb
$\sigma(ggH)\mathrm{BR}(H \to hH_s \to h + A_sA_s \to bb + 4\gamma)$	712.47 fb
$\sigma(ggH)\mathrm{BR}(H \to hH_s \to h + A_sA_s \to \gamma\gamma + 4b)$	248.02 fb
$\sigma(ggH)\mathrm{BR}(H \to hH_s \to h + A_sA_s \to \tau\tau + 4\gamma)$	74.60 fb
$\sigma(ggH)\mathrm{BR}(H \to hH_s \to h + A_sA_s \to \gamma\gamma + 4\tau)$	2.47 fb
$\sigma(ggH)\mathrm{BR}(H \to hH_s \to h + A_sA_s \to 6\gamma)$	2.69 fb
$\sigma(ggH)\mathrm{BR}(H \to hH_s \to h + A_sA_s \to \tau\tau + \gamma\gamma + b\bar{b})$	49.55 fb
$\sigma(ggH)\mathrm{BR}(H \to A_sA_s)$	5.59 fb
$\sigma(ggH)\mathrm{BR}(H \to A_sA_s \to 4\gamma)$	3.93 fb
$\sigma(ggA_s)$	0.08 fb
$\sigma(ggA)$	2.51 pb
$\sigma(ggA)\mathrm{BR}(A \to \tau\tau)$	14.42 fb
$\sigma(ggA)\mathrm{BR}(A \to \tilde{\chi}_1^0\tilde{\chi}_1^0)$	963.87 fb
$\sigma(ggA)\mathrm{BR}(A \to \tilde{\chi}_1^+\tilde{\chi}_1^-)$	273.57 fb
$\sigma(ggA)\mathrm{BR}(A \to H_sA_s)$	525.56 fb
$\sigma(ggA)\mathrm{BR}(A \to H_sA_s \to A_sA_s + A_s \to 6\gamma)$	301.58 fb
$\sigma(ggA)\mathrm{BR}(A \to H_sA_s \to A_sA_s + A_s \to bb + 4\gamma)$	157.64 fb
$\sigma(ggA)\mathrm{BR}(A \to H_sA_s \to A_sA_s + A_s \to 4b + \gamma\gamma)$	27.47 fb
$\sigma(ggA)\mathrm{BR}(A \to H_sA_s \to A_sA_s + A_s \to \tau\tau + 4\gamma)$	14.99 fb
$\sigma(ggA)\mathrm{BR}(A \to H_sA_s \to A_sA_s + A_s \to \tau\tau + bb + \gamma\gamma)$	5.22 fb
$\sigma(ggA)\mathrm{BR}(A \to H_sA_s \to A_sA_s + A_s \to 4\tau + \gamma\gamma)$	0.25 fb
$\sigma(ggA)\mathrm{BR}(A \to hA_s)$	29.96 fb
$\sigma(ggA)\mathrm{BR}(A \to hA_s \to \gamma\gamma + bb)$	16.25 fb
$\sigma(ggA)\mathrm{BR}(A \to hA_s \to \gamma\gamma + \tau\tau)$	1.70 fb
$\sigma(ggA)\mathrm{BR}(A \to hA_s \to b\bar{b} + b\bar{b})$	2.83 fb
$\sigma(ggA)\mathrm{BR}(A \to ZH_s)$	554.38 fb
$\sigma(ggA)\mathrm{BR}(A \to ZH_s \to bb + A_sA_s \to bb + 4\gamma)$	57.36 fb
$\sigma(ggA)\mathrm{BR}(A \to ZH_s \to bb + A_sA_s \to 4b + \gamma\gamma)$	19.99 fb
$\sigma(ggA)\mathrm{BR}(A \to ZH_s \to Z + A_sA_s \to bb + \tau\tau + \gamma\gamma)$	6.35 fb
$\sigma(ggA)\mathrm{BR}(A \to ZH_s \to ll/\tau\tau + A_sA_s \to ll/\tau\tau + 4\gamma)$	12.78 fb
$\sigma(ggA)\mathrm{BR}(A \to ZH_s \to ll/\tau\tau + A_sA_s \to ll\tau\tau/4\tau + \gamma\gamma)$	0.42 fb

- **Very reach topologies with cross-sections > ~ 1 fb at 13 TeV !**
- **Need to set up the list of “hottest” and “doable” topologies for Run II**
  - **Ulrich Goerlach (CMS)**
  - **Benoit Courbon (CMS)**
    - Final states with photons
  - **Camilo Carillo (CMS)**
    - Light A/H->γγ (m < 125 GeV)
  - **David Sabes (CMS)**
    - Light scalar bosons in SUSY
  - **Nicolas Chanon (CMS)**
    - Double Higgs

Search for scalar di-photon resonances, m_X=[65-600] GeV

S. King, M. Muhlleitner, R. Nevzorov, K. Walz, arXiv:1408.1120

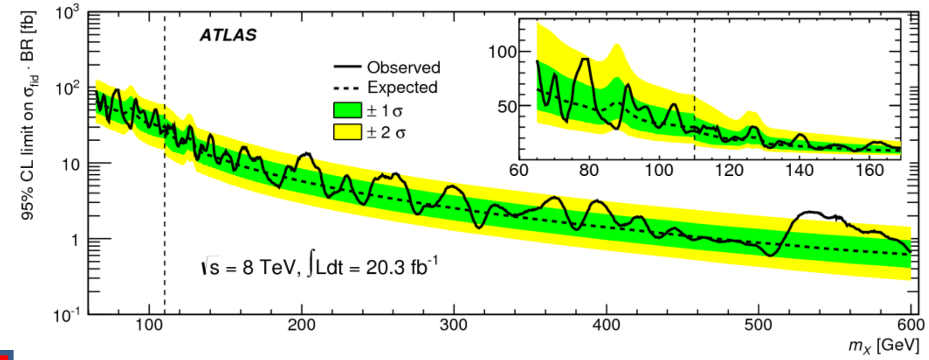
A.1 (Point ID 3877)	Scenario		
$M_{H_1}, M_{H_2}, M_{H_3} = M_{H_s}, M_h, M_H$	90.3 GeV	126.8 GeV	341.3 GeV
$M_{A_1}, M_{A_2} = M_{A_s}, M_A$	118.5 GeV	346.7 GeV	

A.1 (Point ID 3877)	Signal Rates
$\sigma(ggH_s)$	2.37 pb
$\sigma(ggH_s)\mathrm{BR}(H_s \to bb)$	2.04 pb
$\sigma(ggH_s)\mathrm{BR}(H_s \to \tau\tau)$	204.82 fb
$\sigma(ggH_s)\mathrm{BR}(H_s \to \gamma\gamma)$	2.74 fb
$\sigma(ggA_s)$	914.07 fb
$\sigma(ggA_s)\mathrm{BR}(A_s \to bb)$	804.77 fb
$\sigma(ggA_s)\mathrm{BR}(A_s \to \tau\tau)$	84.15 fb
$\sigma(ggA_s)\mathrm{BR}(A_s \to \gamma\gamma)$	0.36 fb

D.2 (Point ID 110)	Scenario		
M_{H_s}, M_h, M_H	112.0 GeV	126.3 GeV	1288.2 GeV
M_{A_s}, M_A	61.5 GeV	1287.4 GeV	

$\sigma(ggH_s)$	17.25 pb
$\sigma(ggH_s)\mathrm{BR}(H_s \to bb)$	14.64 pb
$\sigma(ggH_s)\mathrm{BR}(H_s \to \tau\tau)$	1.50 pb
$\sigma(ggH_s)\mathrm{BR}(H_s \to \gamma\gamma)$	13.93 fb
$\sigma(ggH_s)\mathrm{BR}(H_s \to ZZ)$	23.90 fb
$\sigma(ggH_s)\mathrm{BR}(H_s \to WW)$	401.21 fb
$\sigma(ggH_s)\mathrm{BR}(H_s \to \mu\mu)$	5.33 fb
$\sigma(ggH_s)\mathrm{BR}(H_s \to Z\gamma)$	4.15 fb

Result: limit on σ x BR in fiducial volume



Is it sensitive to SM Higgs Singlet Extension ?

From talk of Tania Robens at SUSY 2014 (see recent updates in arXiv:1501.02234)

What about the "inverse" scenario, ie. $m_H = 125.7\,\mathrm{GeV}$

mainly ruled out by LEP and/ or χ^2 fit from HiggsSignals
however, *still* large number produced due to large $\sigma_{gg\to h}$

m_h[GeV]	$\lvert\sin\alpha\rvert_{\text{min, exp}}$	$\lvert\sin\alpha\rvert_{\text{min, }2\sigma}$	$(\tan\beta)_{\max}$	$\#gg\sim$
110	0.82	0.89	9.2	10^5
100	0.86	−−	10.1	10^5
90	0.91	−−	11.2	10^5
80	0.98	−−	12.6	10^4
70	0.99	−−	14.4	10^4
60	0.98	$\gtrsim 0.99$	16.8	10^4

$\sigma \times \mathrm{BR} = (1-\sin^2\alpha)\sigma_{SM} \times \mathrm{BR}_{SM} < 12.2$ fb at m_h = 100 GeV

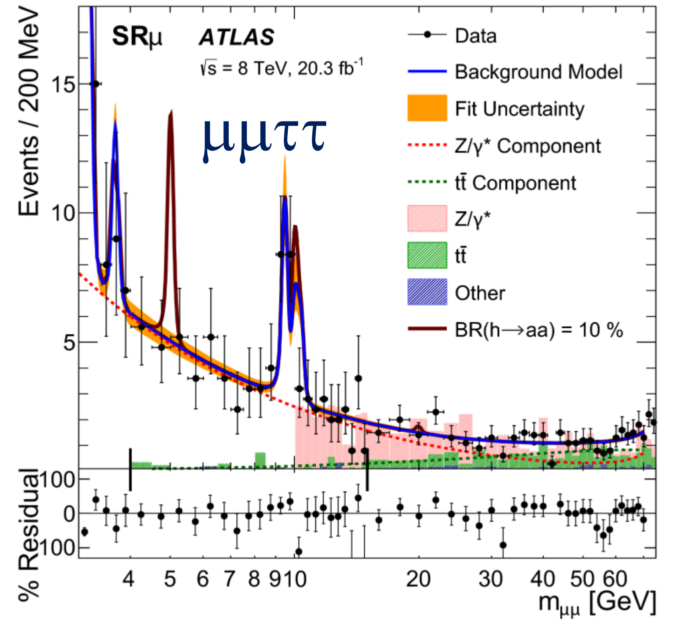
h(125)->$a_1 a_1/h_1 h_1$

S. King, M. Muhlleitner, R. Nevzorov, K. Walz, arXiv:1408.1120

$2m_\tau < m_{a1/h1} < 2m_b$

D.1 (Point ID 5416)	Scenario		
M_{H_s}, M_h, M_H	9.6 GeV	124.2 GeV	793.4 GeV
M_{A_s}, M_A	273.2 GeV	792.2 GeV	
$\lvert S_{H_1 h_s}\rvert^2$, $\lvert P_{A_1 A_s}\rvert^2$	0.98	0.99	

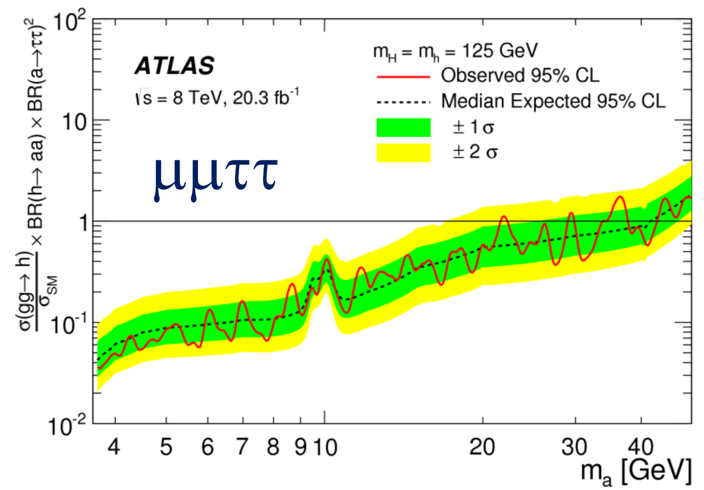
D.1 (Point ID 5416)	Signal Rates
$\sigma(ggh)$	44.28 pb
$\sigma(ggh)\mathrm{BR}(h \to H_s H_s)$	4.22 pb
$\sigma(ggh)\mathrm{BR}(h \to H_s H_s \to \tau\tau + \tau\tau)$	3.58 pb
$\sigma(ggh)\mathrm{BR}(h \to H_s H_s \to \tau\tau + \mu\mu)$	31.64 fb



$2m_b < m_{a1/h1} < 0.5m_{h125}$

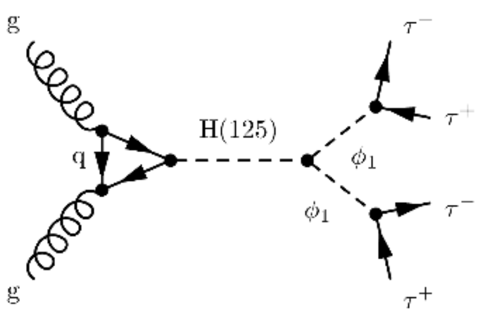
D.2 (Point ID 110)	Scenario		
M_{H_s}, M_h, M_H	112.0 GeV	126.3 GeV	1288.2 GeV
M_{A_s}, M_A	61.5 GeV	1287.4 GeV	

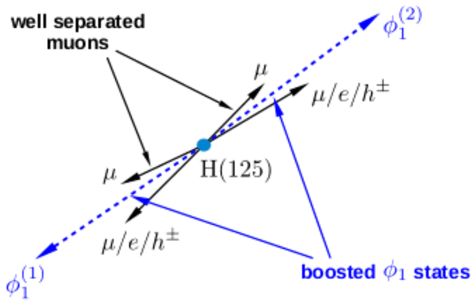
D.2 (Point ID 110)	Signal Rates
$\sigma(ggh)$	27.37 pb
$\sigma(ggh)\mathrm{BR}(h \to A_s A_s)$	1.85 pb
$\sigma(ggh)\mathrm{BR}(h \to A_s A_s \to bb + bb)$	1.55 pb
$\sigma(ggh)\mathrm{BR}(h \to A_s A_s \to bb + \tau\tau)$	276.30 fb
$\sigma(ggh)\mathrm{BR}(h \to A_s A_s \to \tau\tau + \tau\tau)$	12.36 fb
$\sigma(ggh)\mathrm{BR}(h \to A_s A_s \to bb + \gamma\gamma)$	0.34 fb



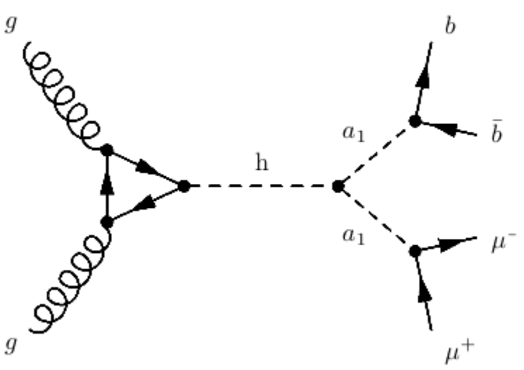
assuming $Br(a\to\mu\mu)+Br(a\to\tau\tau)=1$

- **h(125)->XX analyses in CMS with 8 TeV data:**
  - **inspired, in particular by**
    - **Stefano Moretti et. al, arXiv:0805.3505**
    - **King, Muhlleitner, Nevzorov, Walz arXiv:1211.5074, 1408.1120**
    - **M. Strassier et. al, arXiv:1312.4992: Exotic decays of $_{h125}$**
  - **h(125)->AA->4τ, $2m_{\tau} < m_{A} < 2m_{b}$, approved with 8 TeV**
    - **Paper under preparation (HIG-14-019)**





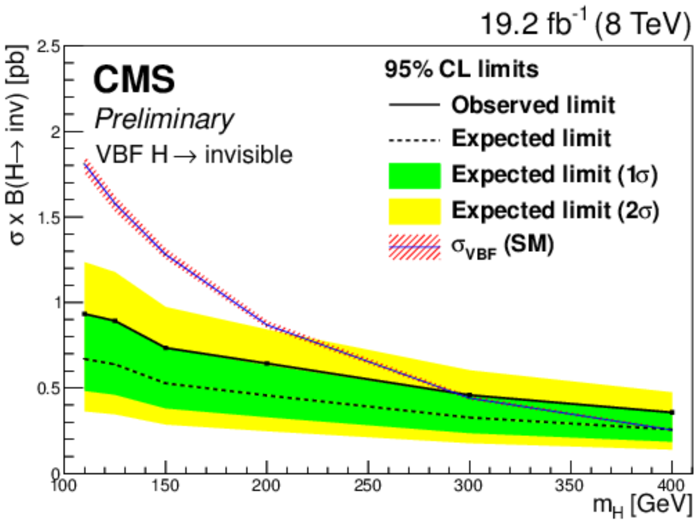
  - **h(125)->AA->μμbb, $2m_{b} < m_{A} < m_{h}/2$ still to be approved; HIG-14-041**



Higgs and DM

Higgs and DM at LHC

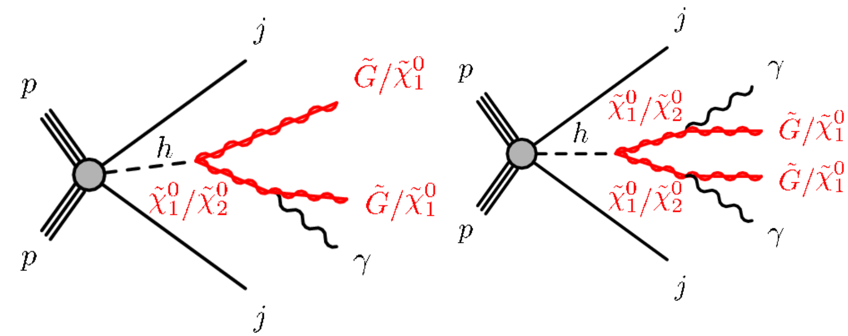
- **Invisible**
  - **Latest ATLAS and CMS results on VBF h->invisible**

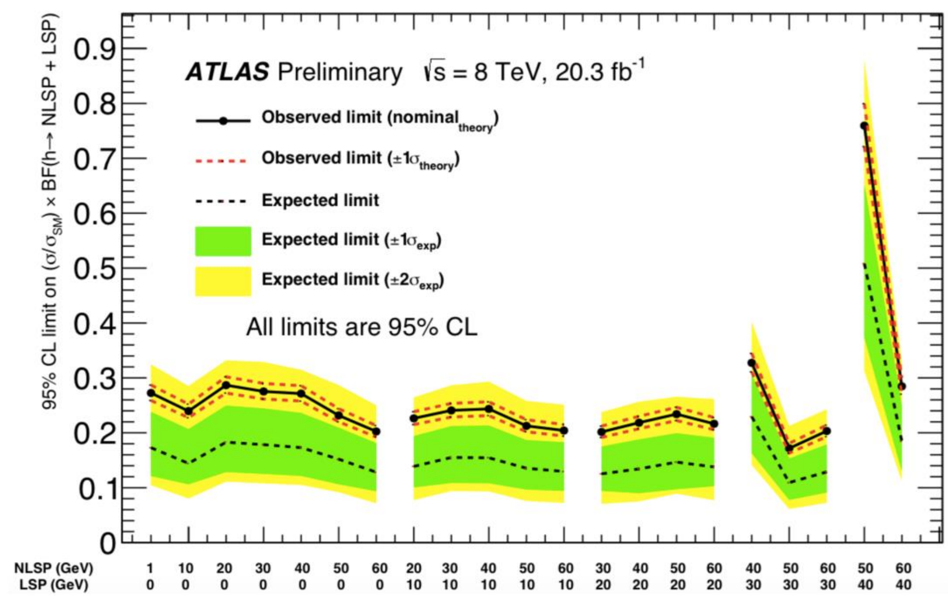


ATLAS analysis
VBF h(125)->invis:
$BR_{obs} < 0.29$
$BR_{exp} < 0.35$

CMS analysis:
VBF h(125)->invis:
$BR_{obs} < 0.57$
$BR_{exp} < 0.40$

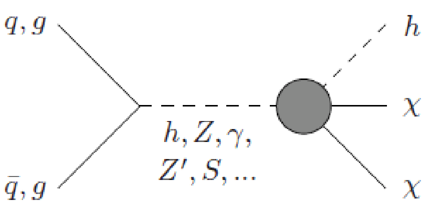
- **Semi-invisible**
  - **ATLAS-CONF-2015-001; GMSB, NMSSM: γ(γγ)+MET from VBF h(125)**

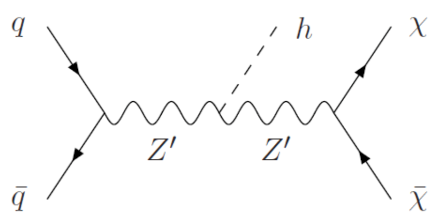




Higgs and DM at LHC

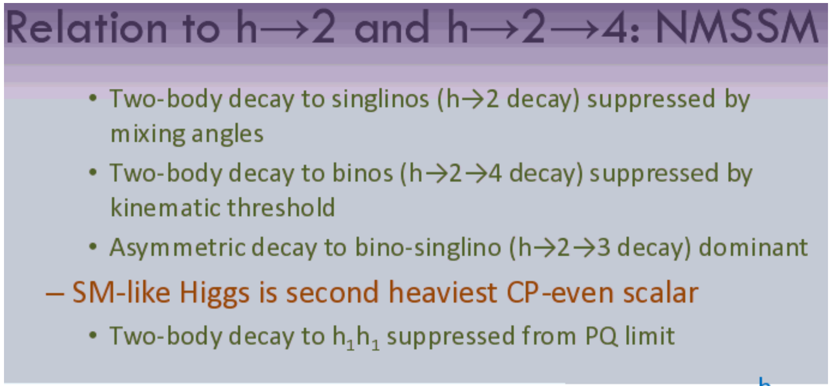
- **Mono-Higgs:**
  - Linda Carpenter et al arXiv:1312.2592





- **Les Houches project:**
  - *Nicola De Filippis*
    - *decays h->4ℓ*

- **Other possibility:**
  - MSSM $h_2(125)$->h_1+MET
    - from Felix Yu talk on LHCHXSWG/WG3 Fermilab meeting May 21, 2015

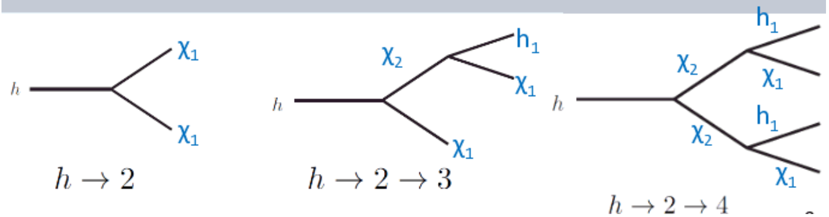


Relation to h→2 and h→2→4: NMSSM

- Two-body decay to singlinos (h→2 decay) suppressed by mixing angles
- Two-body decay to binos (h→2→4 decay) suppressed by kinematic threshold
- Asymmetric decay to bino-singlino (h→2→3 decay) dominant

– SM-like Higgs is second heaviest CP-even scalar

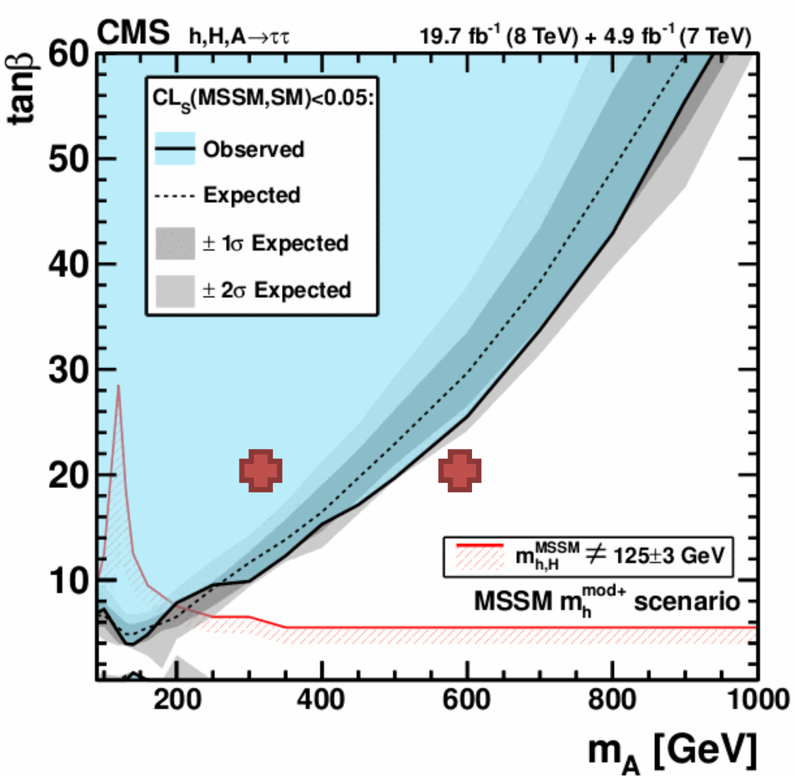
- Two-body decay to h_1h_1 suppressed from PQ limit



Have a good work in Les Houches !

THE END

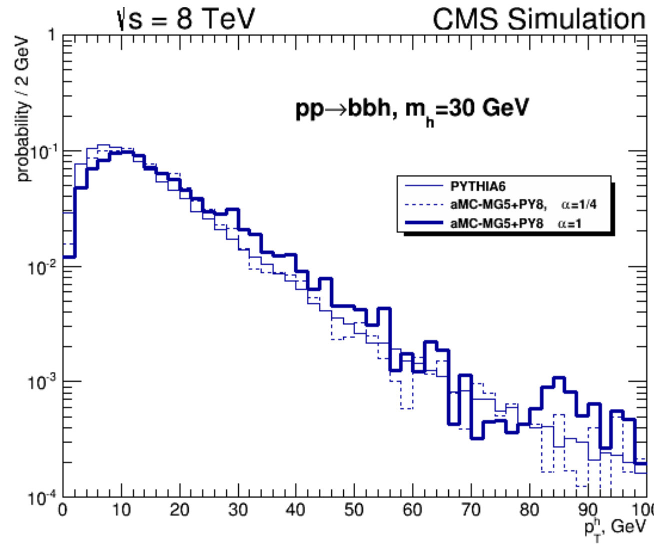
- **Non b-tag category is also dominated by bbH at large m_A**

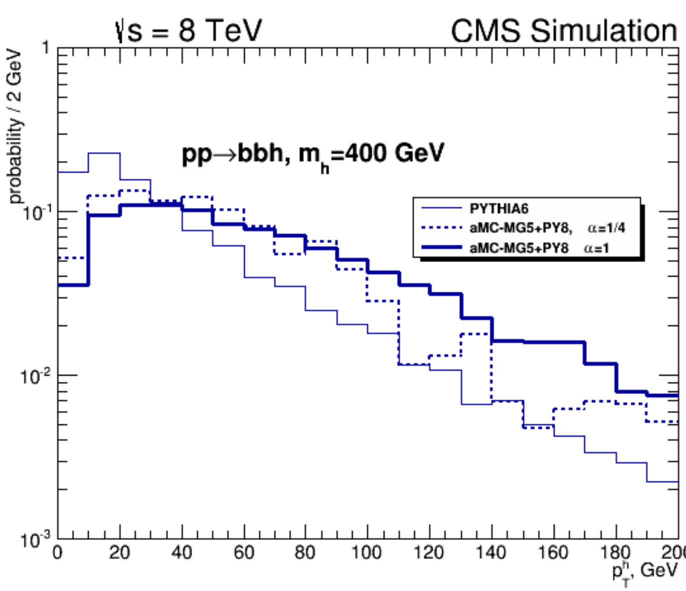


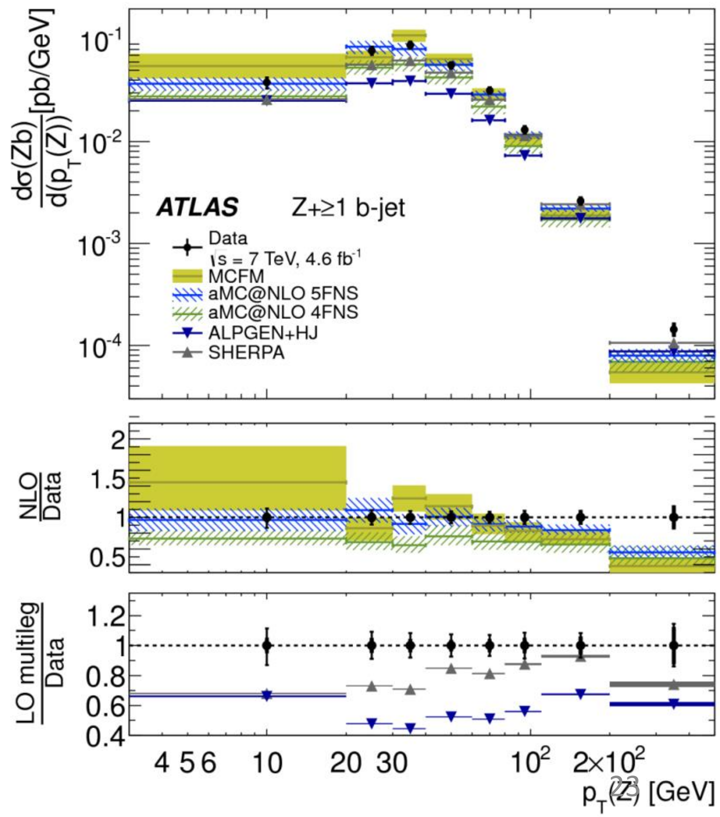
	m_A=300 GeV tanβ = 20	m_A=600 GeV tanβ=20
σ(gg->A+H)/σ(bb->A+H)	0.16	0.08
σ(gg->A+H)/σ(bb->A+H) x $(\varepsilon_{gg\text{->}H}/\varepsilon_{bb\text{->}H})^{exp}$	0.20	0.27

bbH MC

- pp->bbH aMC@NLO vs PY6/8
  - harder Higgs p_T
    - p_T is sensitive to shower scale, Q_{sh} in MG5_aMC@NLO
    - use Z+b data to tune Q_{sh} and apply it to H+b
  - (very) different efficiency of the jet veto
    - change of selection strategy for light pseudoscalar A analysis pp->bbA,A->ττ/μμ







Signal selection efficiencies MG5_aMC@NLO+PY8 vs PY6 for pp->bbA, A->μμ, m_a=30 GeV

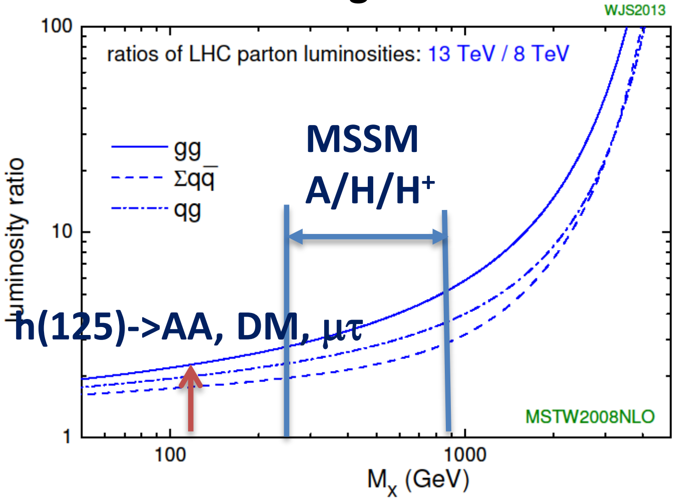
	Selection on muon p_T, GeV |η| < 2.1 for both muons					
	10		15		20	
	NLO+PY8	PY6	NLO+PY8	PY6	NLO+PY8	PY6
Muon selections	0.368	0.379	0.059	0.057	0.013	0.014
>= 1 b-jet after μ's sel. p_T >30 GeV, |η|<2.4	*0.104*	0.106	*0.280*	0.379	*0.558*	0.731
1 b-jet no other jets |η|< 4.7	*0.628*	0.751	*0.643*	0.722	*0.553*	0.640

- **Huge difference in additional jet veto**
  - decided to change a search strategy dropping the jet veto from the selections

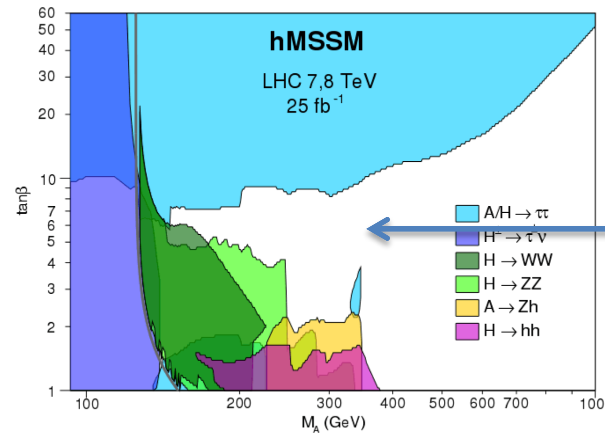
Prospects for 2015-2016

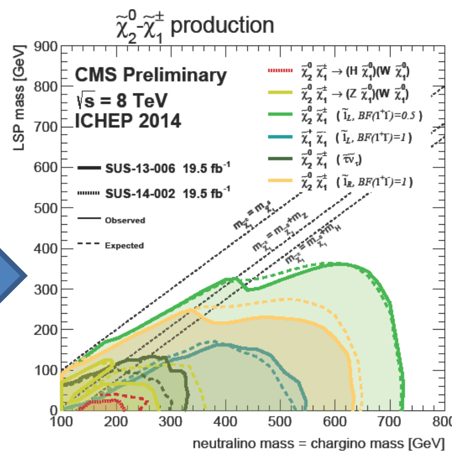
- No immediate discovery for Higgs-Exotics channels with first 5-10 fb^{-1} is expected so far: rare processes, need luminosity
  - with ~ 5-10 fb^{-1} at 13 TeV expect to reach 8 TeV/20 fb^{-1} sensitivity of current 8 TeV analyses and start to explore a new territory

J. Stirling 2013



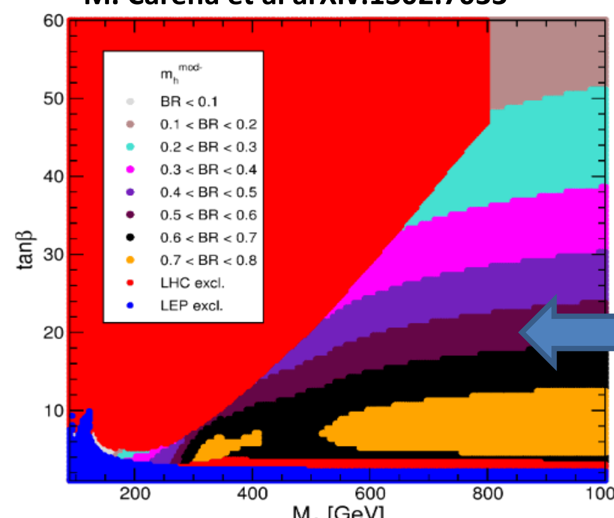
A. Djouadi et al arXiv:1502.05653





Light χ 's are not excluded

M. Carena et al arXiv:1302.7033



H/A->χχ

Benchmarks and tools used so far by ATLAS and CMS for the interpretation in MSSM and 2HDM

- **MSSM benchmark scenarios,** arXiv:1302.7033:

MSSM Higgs Boson Searches at the LHC:
Benchmark Scenarios after the Discovery of a Higgs-like Particle

M. Carena[1,2], S. Heinemeyer[3], O. Stål[4], C.E.M. Wagner[2,5] and G. Weiglein[6]*

  – *tools: XS - HIGLU, SusHi, FeynHiggs; BRs: FeynHiggs+HDECAY*

- **2HDM tools (no benchmark scenarios yet),** arXiv:1312.5571:

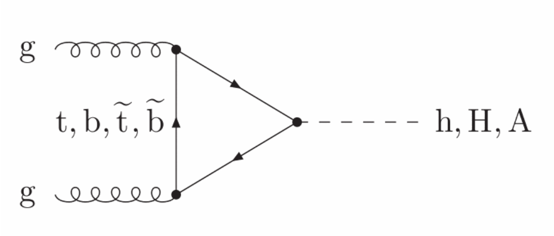
LHC Higgs Cross Section Working Group

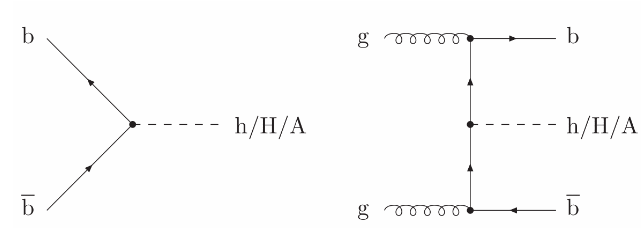
Interim recommendations for the evaluation of Higgs production cross sections and branching ratios at the LHC in the Two-Higgs-Doublet Model

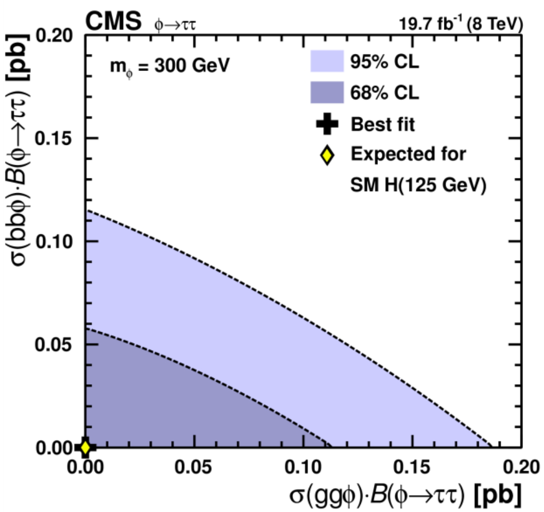
R. Harlander[1], M. Mühlleitner[2], J. Rathsman[3], M. Spira[4], O. Stål[5]

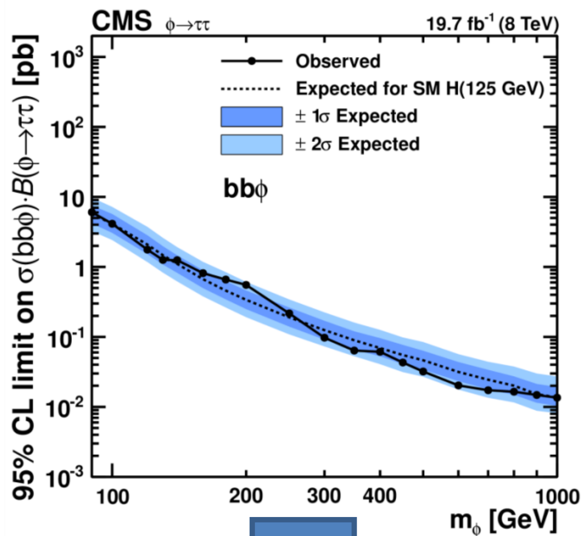
  – *SusHi+FeynHiggs or HIGLU+HDECAY*

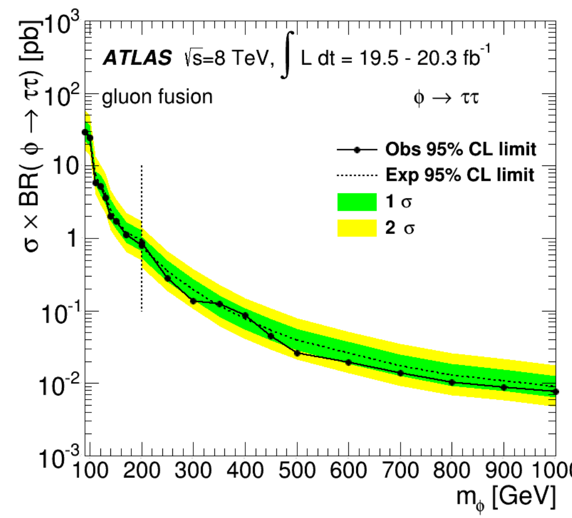
$\phi \to \tau\tau$: "model independent" limits



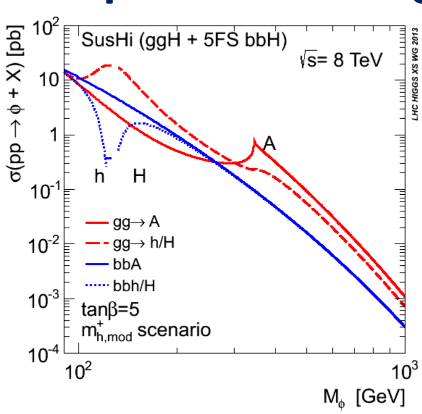


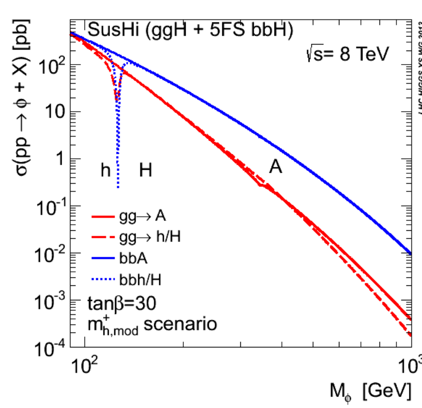




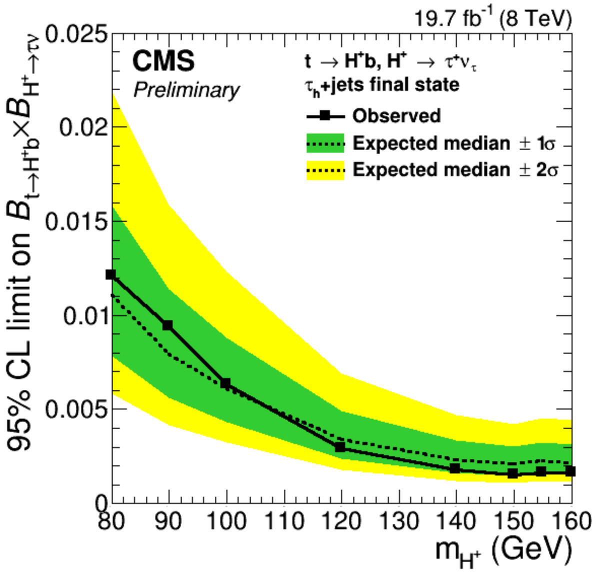


- **Go to MSSM interpretation using inclusive cross section from LHCHXSWG**

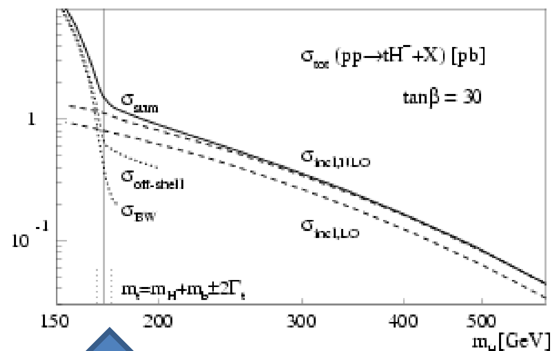


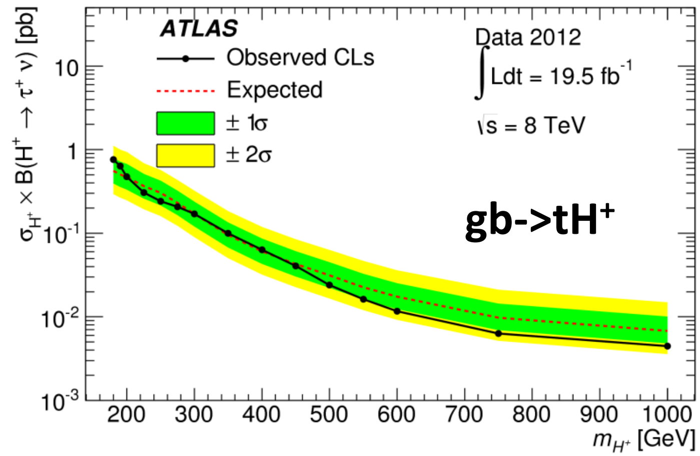


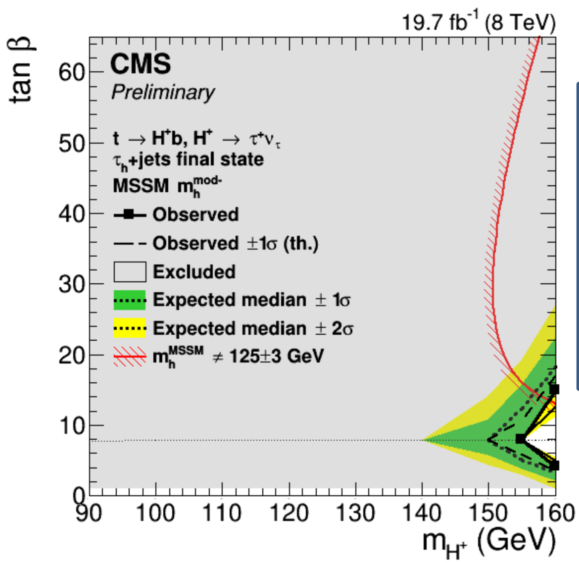
H+->τν: "model independent" limits and MSSM interpretation



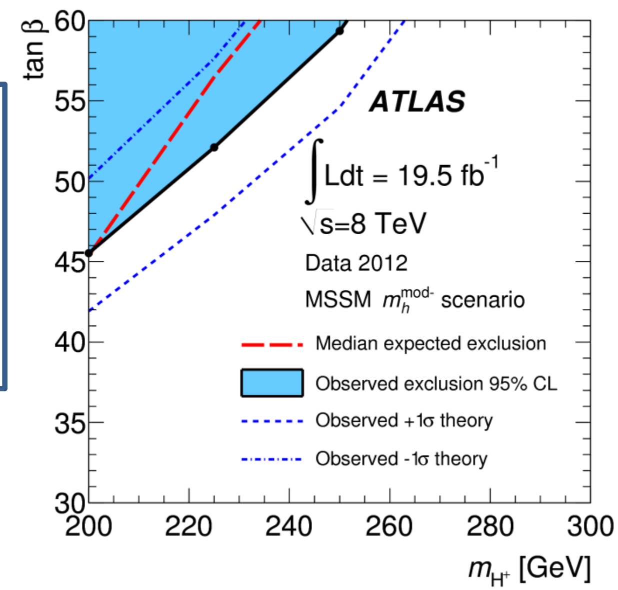
T. Plehn et al., hep-ph/0312286



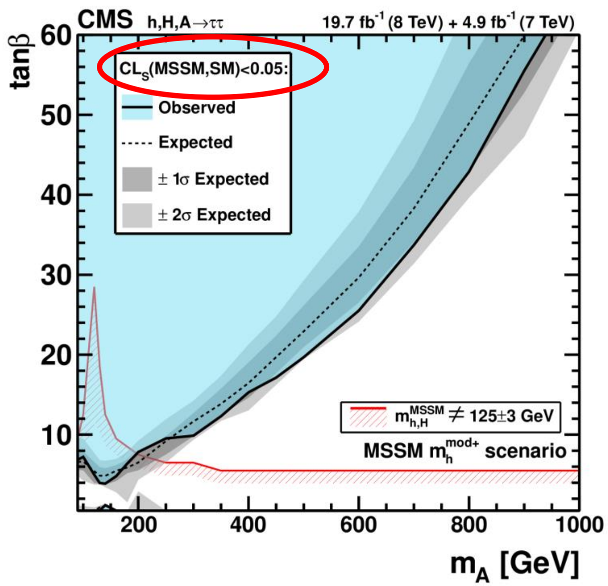




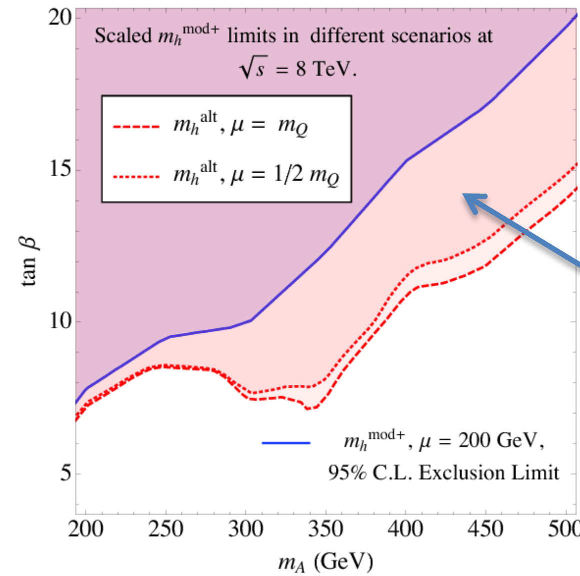
no cross-sections yet available from LHCHXSWG to close the gap m_{H+} [160-200] GeV



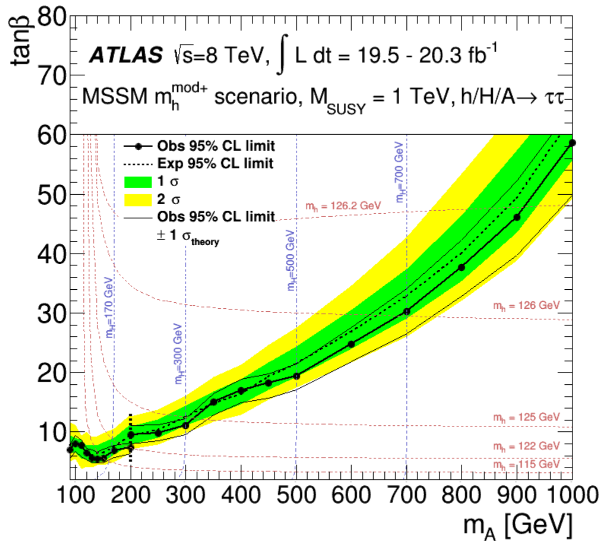
$\phi \to \tau\tau$: interpretation in MSSM benchmark scenarios



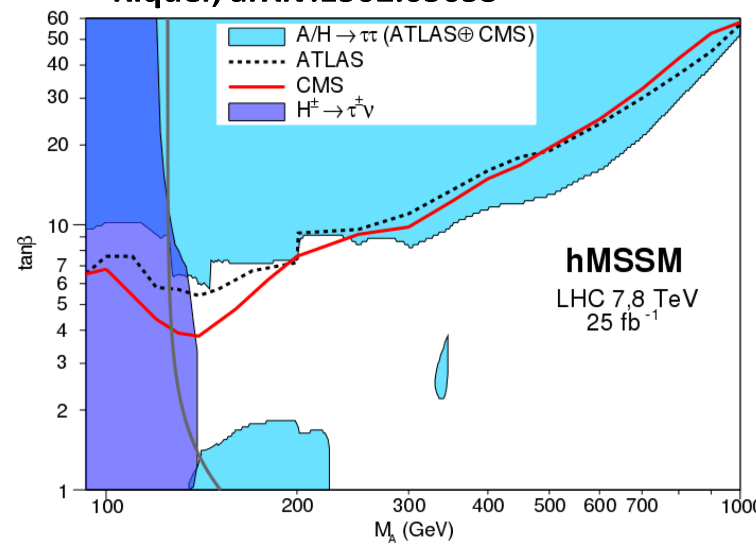
Carena, Haber, Low, Shah, Wagner, arXiv:1410.4969



Large μ: no H->χχ decays



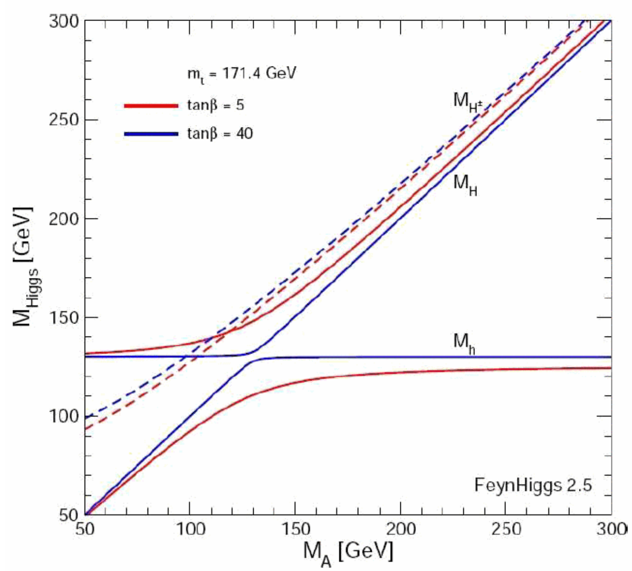
Djouadi, Maiani, Polosa, Quevillon, Riquer, arXiv:1502.05653

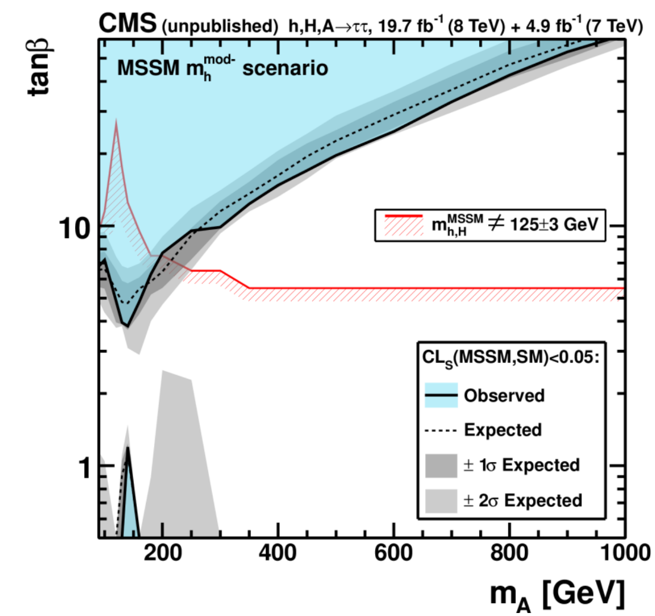


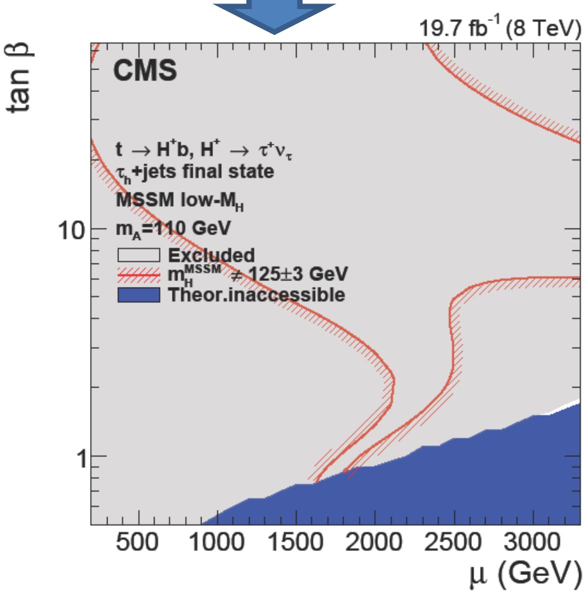
What MSSM Higgs boson is discovered h or H ?

low m_H scenario

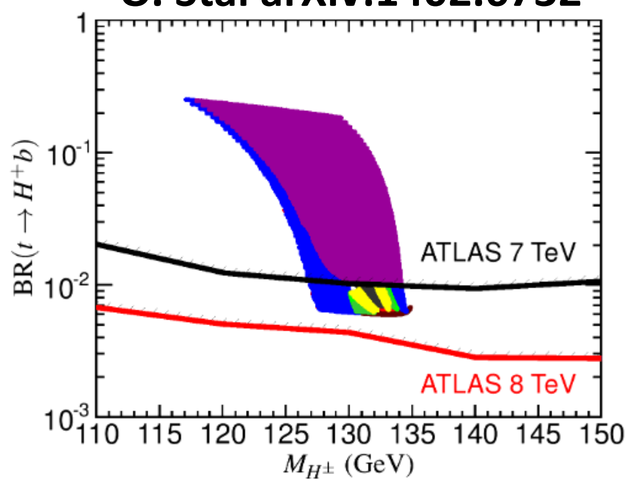
$$m_t = 173.2 \text{ GeV},$$
$$M_A = 110 \text{ GeV},$$
$$M_{\text{SUSY}} = 1500 \text{ GeV},$$
$$M_2 = 200 \text{ GeV},$$
$$X_t^{\text{OS}} = 2.45\, M_{\text{SUSY}} \text{ (FD}$$
$$X_t^{\overline{\text{MS}}} = 2.9\, M_{\text{SUSY}} \text{ (RG c}$$
$$A_b = A_\tau = A_t,$$
$$m_{\tilde{g}} = 1500 \text{ GeV},$$
$$M_{\tilde{l}_3} = 1000 \text{ GeV} .$$

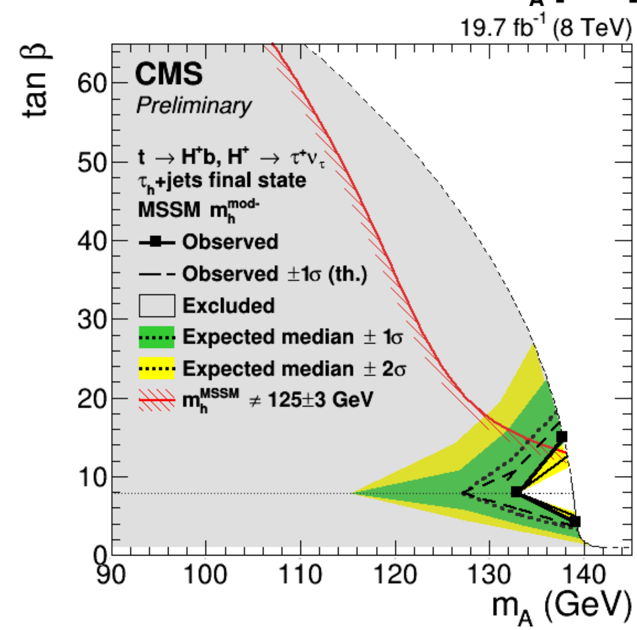






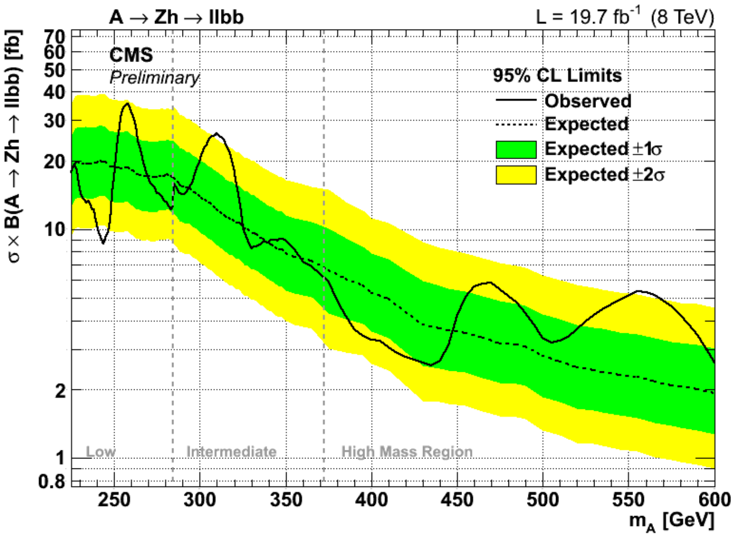
O. Stal arXiv:1402.6732

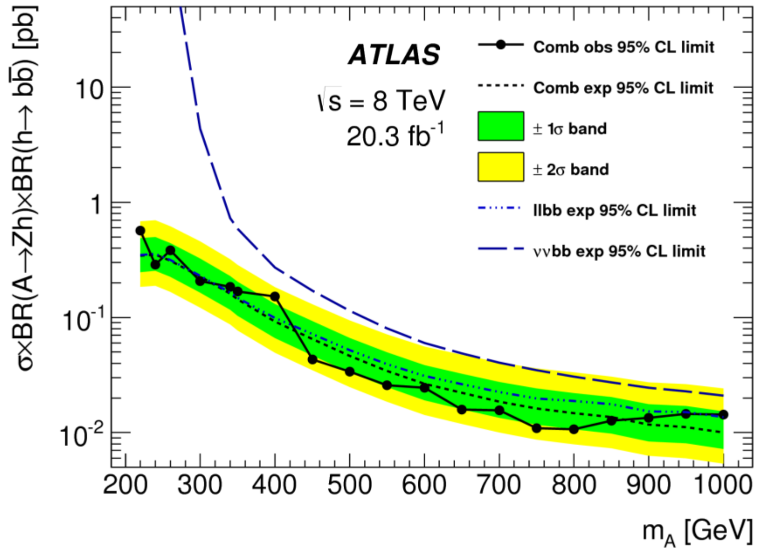




It is the little Higgs boson, h !

A->Zh: the σ x BR limits





- **so far 2HDM interpretation is done in the "physics basis," CP-conserving with input: m_h, m_H, m_A, m_{H+}, α, $\tan\beta$, m_{12}**
  - **additional parameters $\lambda_6,\lambda_7=0$ as result of Z_2 symmetry (H_1->H_1, H_2->-H_2) and m_{12} is taken as in MSSM: $m_A^2=m_{12}^2/(\sin\beta\cos\beta)-\lambda_5 v^2$ with $\lambda_5=0$ as in MSSM**

$$V_{2\mathrm{HDM}} = m_{11}^2|\Phi_1|^2 + m_{22}^2|\Phi_2|^2 - \left[m_{12}^2\Phi_1^\dagger\Phi_2 + \mathrm{h.c.}\right] + \frac{1}{2}\lambda_1|\Phi_1|^4 + \frac{1}{2}\lambda_2|\Phi_2|^4 + \lambda_3|\Phi_1|^2|\Phi_2|^2 + \lambda_4\left(\Phi_1^\dagger\Phi_2\right)\left(\Phi_2^\dagger\Phi_1\right) + \left\{\frac{1}{2}\lambda_5\left(\Phi_1^\dagger\Phi_2\right)^2 + \left[\lambda_6\left(\Phi_1^\dagger\Phi_1\right) + \lambda_7\left(\Phi_2^\dagger\Phi_2\right)\right]\left(\Phi_1^\dagger\Phi_2\right) + \mathrm{h.c.}\right\}$$

MSSM: inclusive cross-sections

- **New for 13 TeV analyses** (S. Liebler, talk on 9th LHCHXSWG workshop Jan 2015):
  - bbϕ: add $y_t y_b$ interference term
  - gg->ϕ: change scale (μ_F/μ_R from m_ϕ to $0.5m_\phi$) and uncertainty
  - PDF+α_S uncertainty as function of m_ϕ (not for every SUSY point)
  - 13/14 TeV root files for Run I benchmark scenarios (Carena et al. 13)
  - Santander matched xs for pp->H^+tb; new scale setting for 5FS

arXiv:1409.5615

Improved cross-section predictions for heavy charged Higgs boson production at the LHC

Martin Flechl[1,2], Richard Klees[3], Michael Krämer[3,4], Michael Spira[5], and Maria Ubiali[6,7]