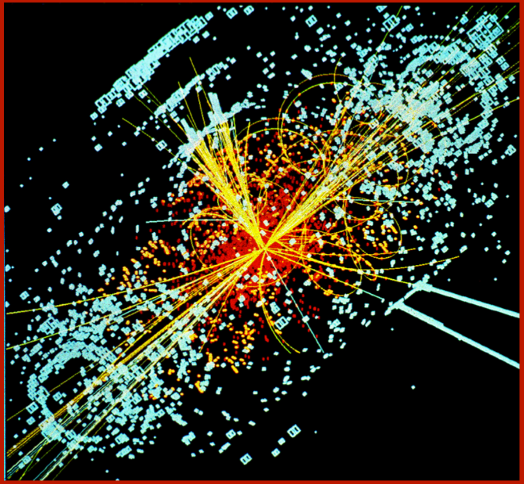


Higgs Pheno Implications of the Aligned NMSSM

Nausheen R. Shah
Wayne State University
Feb 28, 2017

In Collaboration with:
M. Carena, H. Haber, I. Low & C. Wagner arXiv:1510.09137
B. Bhattacharya, M. Carena & C. Wagner, In preparation
S. Baum, K. Freese & B. Shakya arXiv:1703.XXXXX

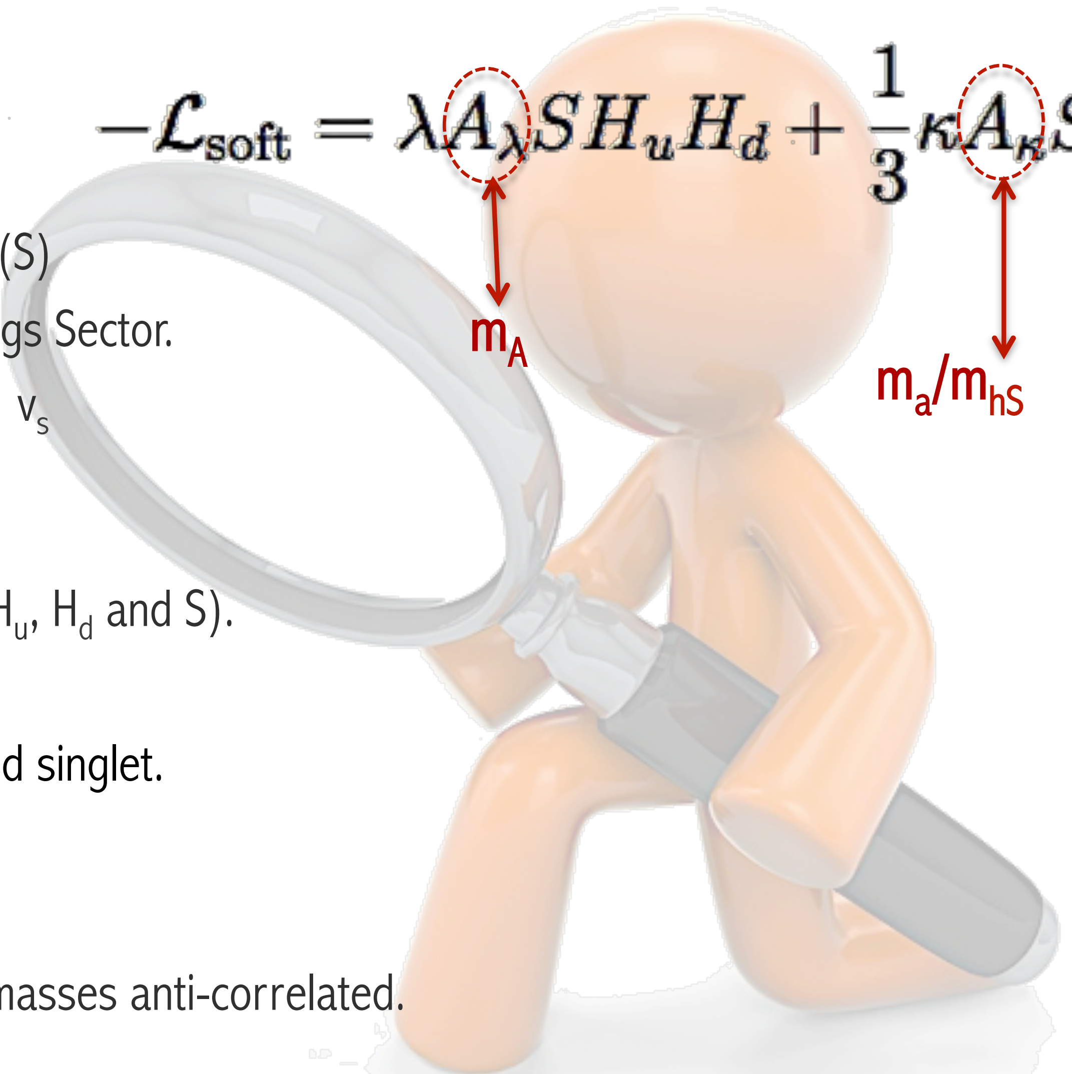
The Higgs Lamp Post: $m_h \sim 125$ GeV + SM-like

No New States at the LHC!!!

Alignment

SUSY → NMSSM

NMSSM Higgs Sector



$$W = \lambda S H_u H_d + \frac{\kappa}{3} S^3 \qquad -\mathcal{L}_{\text{soft}} = \lambda \underset{m_A}{\underset{\updownarrow}{A_\lambda}} S H_u H_d + \frac{1}{3} \kappa \underset{m_a/m_{hS}}{\underset{\updownarrow}{A_\kappa}} S^3$$

- 2 Doublets (H_u, H_d) + Singlet (S)
- Singlet couples only to the Higgs Sector.
- Singlet acquires vev: $\mu = \lambda\ v_s$

- 3 CP-Even Higgses:
  - Mixing between all three (H_u, H_d and S).
- 2 CP-Odd Higgses:
  - Mixtures of “MSSM” m_A and singlet.
- Charged Higgs

- Singlet-like CP-even and odd masses anti-correlated.
- Singlino mass: $2\ \kappa\ \ \mu / \lambda$

Higgs Basis

$$H_{SM} = \sin\beta\Phi_1 + \cos\beta\Phi_2$$

$$H_{NSM} = -\cos\beta\Phi_1 + \sin\beta\Phi_2$$

$$\boxed{\tan\beta = \frac{v_1}{v_2}}$$

$$\langle H_{SM}\rangle = v$$

$$\langle H_{NSM}\rangle = 0$$

- H_{SM} has completely SM-like couplings.
- Mixing between H_{SM} and H_{NSM} , "*cos (β - α)*", gives non-SM behavior of observed h125.

If

cos (β - α) = 0

SM-like HIGGS!!

ALIGNMENT

CP-Even Higgs Bases

- Interaction basis: (H_u, H_d, S)
  - H_u: Couples only to up-type fermions
  - H_d: Couples only to down-type fermions
  - S: Only couples to Higgses

$\langle H_u \rangle = v_u$
$\langle H_d \rangle = v_d$
$t_\beta = v_u/v_d$
$\langle S \rangle = \mu / \lambda$

CP-Even Higgs Bases

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  - H_u: Couples only to up-type fermions
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$$\langle H_u \rangle = v_u$$
$$\langle H_d \rangle = v_d$$
$$t_\beta = v_u/v_d$$
$$\langle S \rangle = \mu / \lambda$$

- "Extended" Higgs basis: (H_{NSM}, H_{SM}, S)
  - H_{NSM}: (down, up, V) = $(y_d\, t_\beta\, ,\, y_u/\, t_\beta\, ,\, 0)$
  - H_{SM}: (down, up, V) = (y_d, y_u, g_{hVV})

$$\langle H_{NSM} \rangle = 0$$
$$\langle H_{SM} \rangle = v$$

- Interaction basis: (H_u, H_d, S)
  - H_u: Couples only to up-type fermions
  - H_d: Couples only to down-type fermions
  - S: Only couples to Higgses

$\langle H_u\rangle = v_u$
$\langle H_d\rangle = v_d$
$t_\beta = v_u/v_d$
$\langle S\rangle = \mu / \lambda$

- "Extended" Higgs basis: (H_{NSM}, H_{SM}, S)
  - H_{NSM}: (down, up, V) = ($y_d\, t_\beta$, y_u/ t_β , 0)
  - H_{SM}: (down, up, V) = (y_d, y_u, g_{hVV})

$\langle H_{NSM}\rangle = 0$
$\langle H_{SM}\rangle = v$

- Mass basis: (H^3, H^2, H^1)
  - $H^i = \kappa^i_{NSM} H_{NSM} + \kappa^i_{SM} H_{SM} + \kappa^i_S S$

CP-Even Higgs Bases

CP-Even Higgs Bases

- Interaction basis: (H_u, H_d, S)
  - H_u: Couples only to up-type fermions
  - H_d: Couples only to down-type fermions
  - S: Only couples to Higgses

$<H_u> = v_u$
$<H_d> = v_d$
$t_\beta = v_u/v_d$
$<S> = \mu / \lambda$

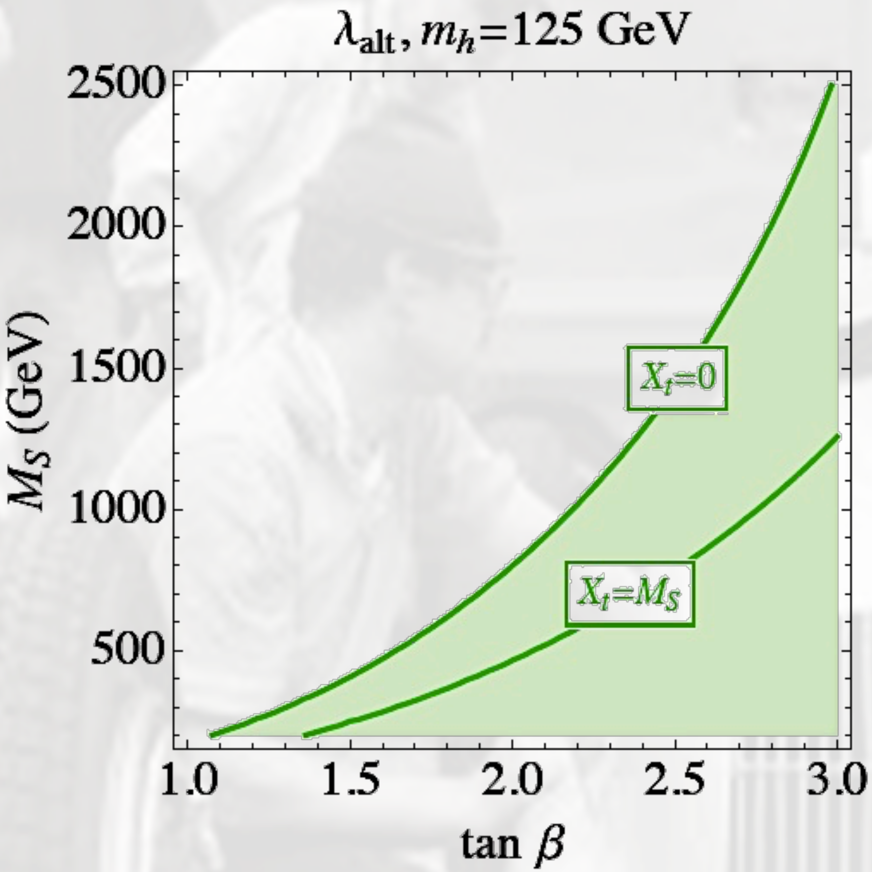
- "Extended" Higgs basis: (H_{NSM}, H_{SM}, S)
  - H_{NSM}: (down, up, V) = $(y_d\, t_\beta\, , y_u/\, t_\beta\, , 0)$
  - H_{SM}: (down, up, V) = (y_d, y_u, g_{hVV})

$<H_{NSM}> = 0$
$<H_{SM}> = v$

- Mass basis: $(H^3, H^2, H^1) \rightarrow (H, h125, hS)$
  - $H^i = \kappa^i_{NSM}\, H_{NSM} + \kappa^i_{SM}\, H_{SM} + \kappa^i_S\, S$

Alignment:
$\kappa^{h125}_{NSM} = 0$
$\kappa^{h125}_{S} = 0$

M. Carena, H. Haber, I. Low, N.R.S., C. Wagner, '15



Alignment (No-Mixing):

$$m_h^2 \simeq \lambda^2 \frac{v^2}{2} \sin^2 2\beta + M_Z^2 \cos^2 2\beta + \Delta_{\tilde{t}}$$

$$\Delta_{\tilde{t}} = -\cos 2\beta (m_h^2 - M_Z^2)$$

Well Known

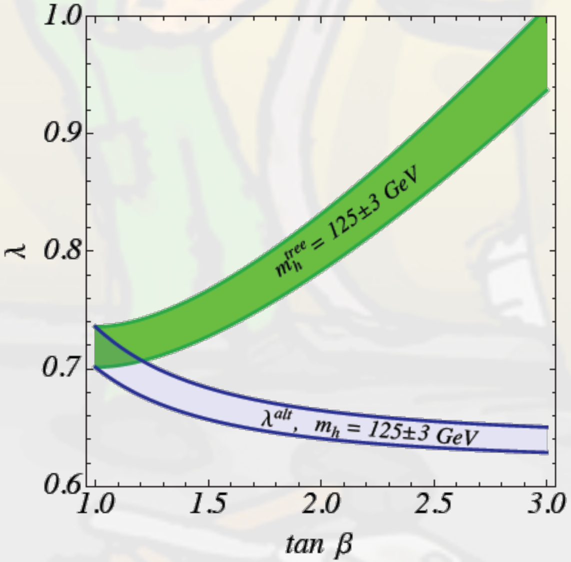
- 125 GeV Higgs
  - Tree-level contribution to Higgs mass from λ .
  - λ ~ 0.65-0.7
- Low tan β
- Light Stops

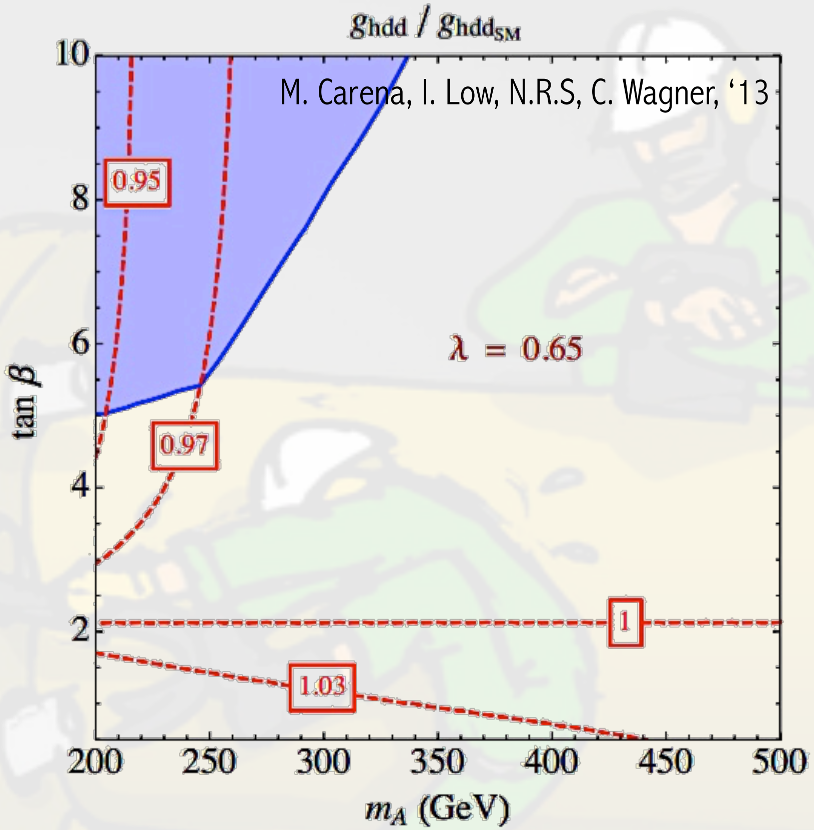
125 GeV Higgs Naturally!

- Perturbative up to GUT scale.
  - $\lambda_{\rm max} \sim 0.7$, $\kappa_{\rm max} \sim \lambda/2$

Not so well known:

- Leads to excellent Alignment (very little mixing with Heavy Higgs) in the m_A- tan β plane.



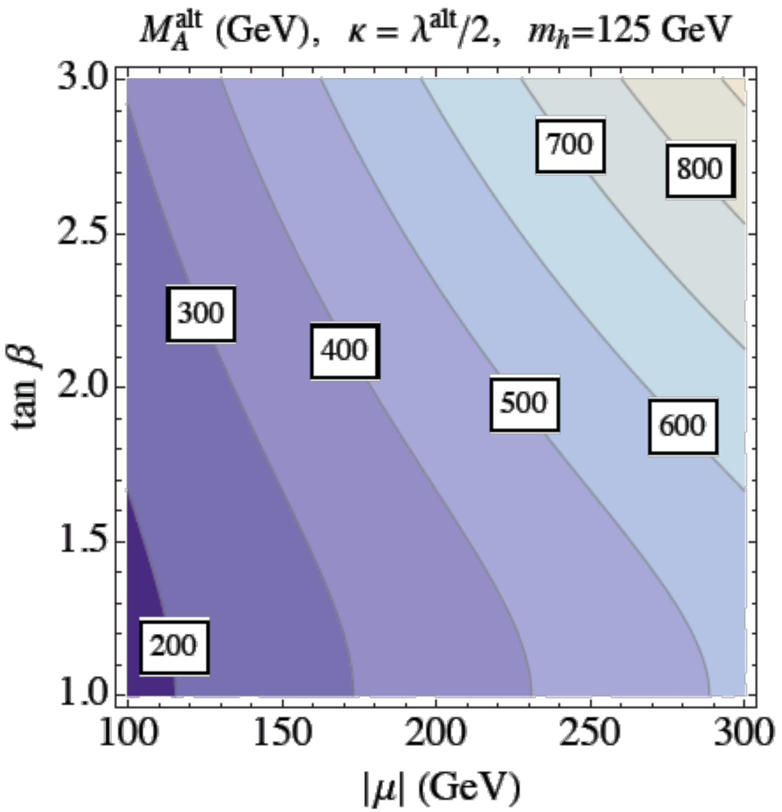


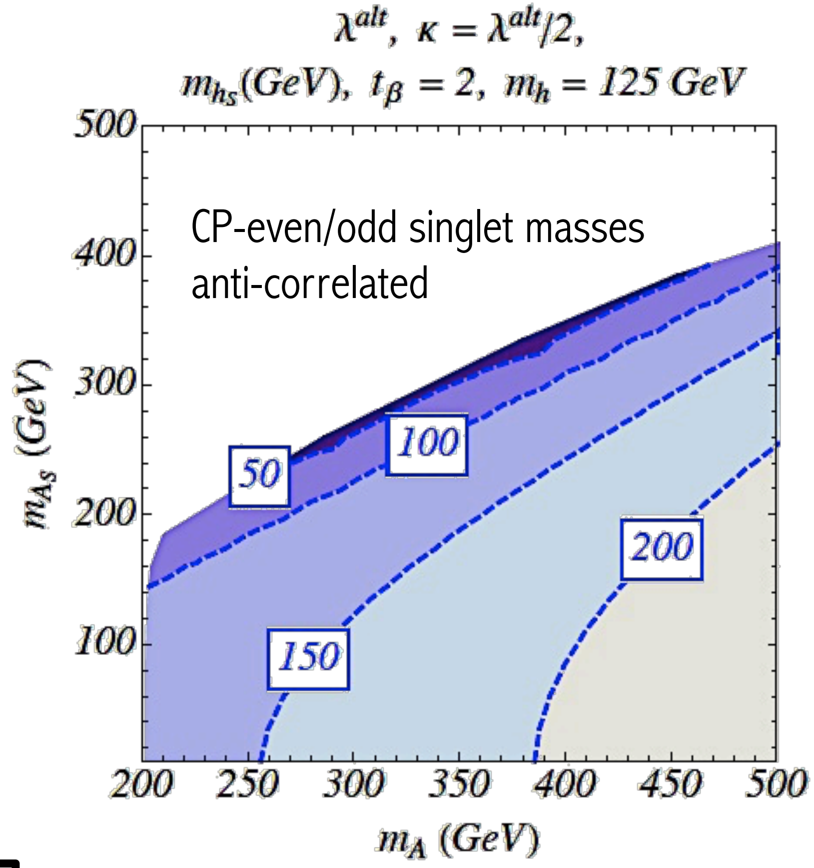
M. Carena, I. Low, N.R.S, C. Wagner, '13

$$\lambda_{\rm alt}^2 = \frac{m_h^2 - M_Z^2 c_{2\beta}}{v^2 s_\beta^2}$$

M. Carena, H. Haber, I. Low, N.R.S., C. Wagner, '15

SM-Like Higgs Naturally!





CP-even/odd singlet masses anti-correlated

$$\boxed{1 - \frac{m_A^2}{4\mu^2} s_{2\beta}^2 - \frac{\kappa}{2\lambda} s_{2\beta} = 0}$$

h125 = H_{SM}

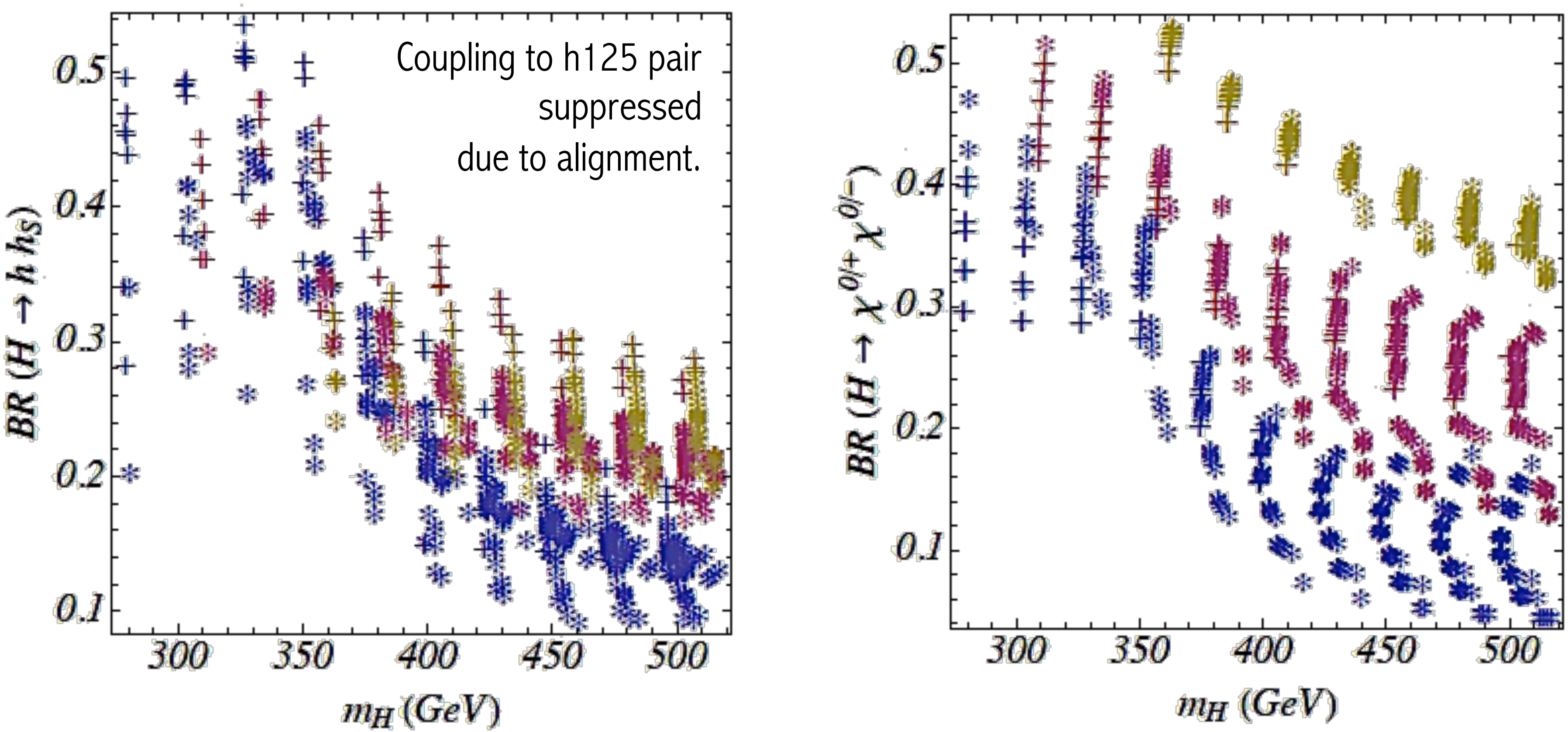
LIGHT SPECTRUM

Singlino: $2\ \kappa\ \ \mu / \lambda \sim < \mu$

Singlet Alignment

M. Carena, H. Haber, I. Low, N.R.S., C. Wagner, '15

- Apart from tt, significant decays into H2+H1 and neutralino/charginos



Coupling to h125 pair suppressed due to alignment.

. tan β =2 . tan β =2.5 . tan β =3

H_3 BR (A_2 BR similar)

M. Carena, H. Haber, I. Low, N.R.S., C. Wagner, ’15

- Light Neutralinos:
  - Relic Density can be obtained via resonances or NMSSM "well-tempered" Neutralinos
  - Generically large direct detection cross-section via h125
  - Need "Blind-spot" cancellations. E.g:

$$\sigma_{SI} \propto \left\{ \left(\frac{2}{t_\beta} - \frac{m_\chi}{\mu}\right) \frac{2\,t_\beta}{m_h^2} + \frac{t_\beta}{m_H^2} + \frac{1}{m_{h_S}^2} \left(2\,S_{h,s} + \frac{\lambda\,v}{\mu}\right) \left[\frac{\lambda\,v}{\mu^2}\,m_\chi + S_{h,s}\left(\frac{2}{t_\beta} - \frac{m_\chi}{\mu}\right) + \frac{\kappa\,\mu}{\lambda^2\,v}\right]\right\}^2 .$$

C. Cheung, M. Papucci, D. Sanford, NRS, K. Zurek, '14

Conditions: $\mu > 0$

$\mu \sim m_\chi\, t\beta/2$ (h125 coupling reduced)

$h_S <$ h125 (need alignment for μ and m_A)

Cosmology?

B. Bhattacharya, M. Carena, NRS & C. Wagner, In preparation

- LSP could be ~O(10 GeV) or ~O(100 GeV)
- h_S < h125
  - Mixing can change total width of h125 – significant mixing still allowed
  - If h_S < h125/2, h125 -> h_S h_S – Exotic decays of h125
  - h_S can have significant production cross-section ~ pb
    - if $h_S > 2\chi$, BR(hS -> χ χ) ~ 100%
    - Otherwise decays with SM-like BR
- For low tan β , m_A can be few hundred GeV
  - Significant decays of both H and A into Higgses and Neutralinos
    - H-> h_S h_S / h_S h125 etc.
    - Note: H -> h125 h125/ WW/ZZ and A -> Z h125 all suppressed by alignment/ decoupling

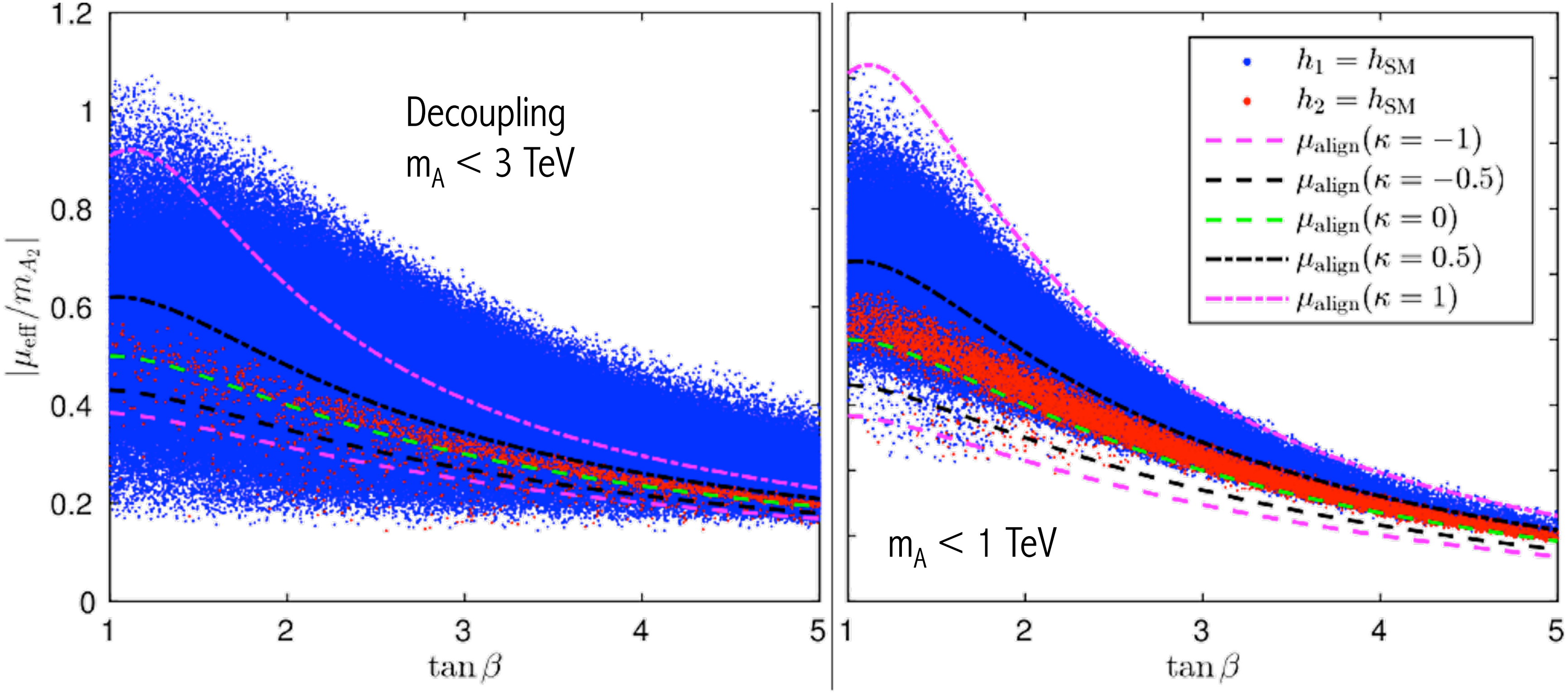
Cosmology Benchmark

- LSP could be stable on detector time-scales but unstable on universe time-scale
- Consider collider phenomenology independent of cosmological constraints
- First question: Alignment with or without decoupling
  - Most interesting LHC phenomenology when all states light (no decoupling)
  - Pursue NMSSM parameter space using “alignment”
  - Pinpoint promising signatures
  - In particular will focus on **mono-Higgs**

Heavy Higgs Pheno

Misalignment?

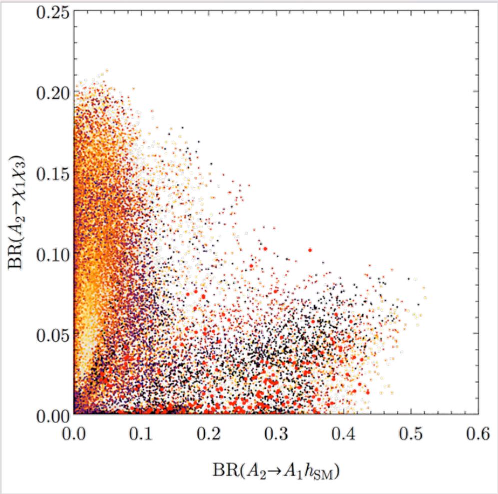
S. Baum, K. Freese, NRS & B. Shakya (preliminary)

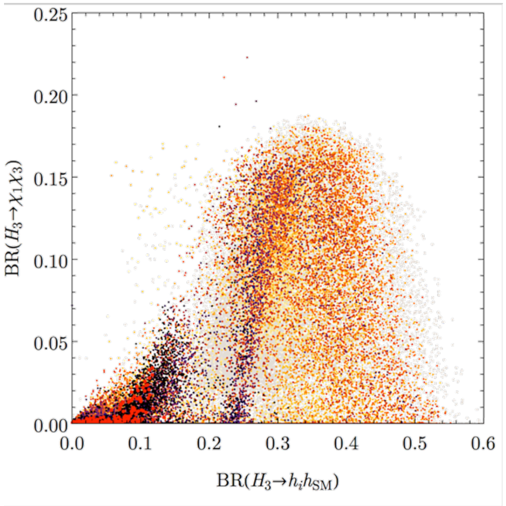


NMSSMTools Scans asking for SM-like h125

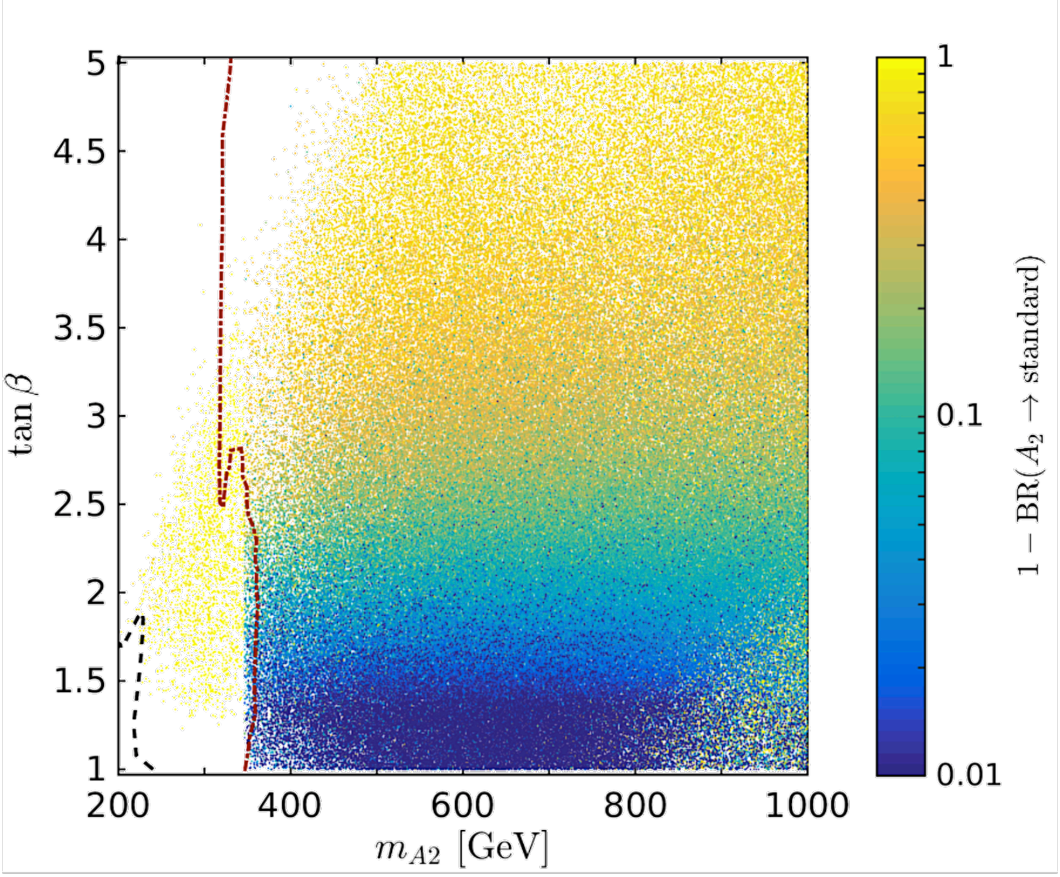
- $m_{A2} \sim m_{H3}$
- Completely "MSSM"-like A_2 has xsec ~ 2 "MSSM"-like H_3
- Mixing with singlets will reduce these xsec
- A_2 can mix significantly with A_1 consistent with alignment conditions
  - Still comparable xsec to H_3
  - Significant BR into non-standards: $\chi_i \chi_1$, A1 h125, h_S Z
- H_3 mixes less with singlet, but enough to also have significant non-standard decays:
  - $\chi_i \chi_1$, h_S h125, A_1 Z

A_2 and H_3





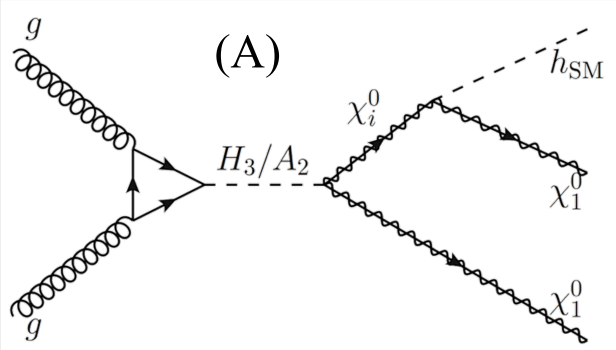
S. Baum, K. Freese, NRS & B. Shakya (preliminary)

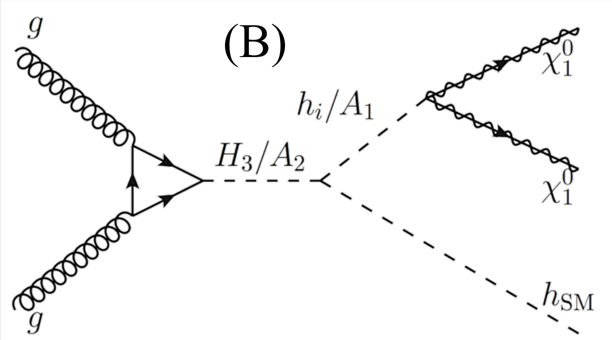


Non-Standard BR

If A_1 or $h_S > 2\chi$, BR($\chi\chi$) large
Otherwise SM-like BR

Mono-Higgs (to $\gamma\ \gamma$)

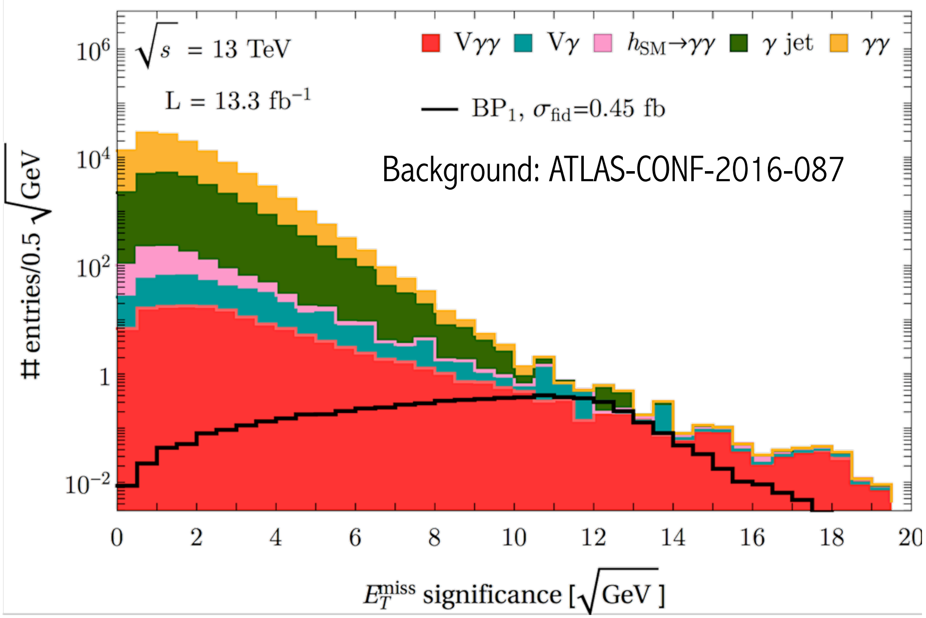




A. Can add up contributions from both H_3 and A_2

B. Expect stronger sensitivity –h125 back-to-back with MET

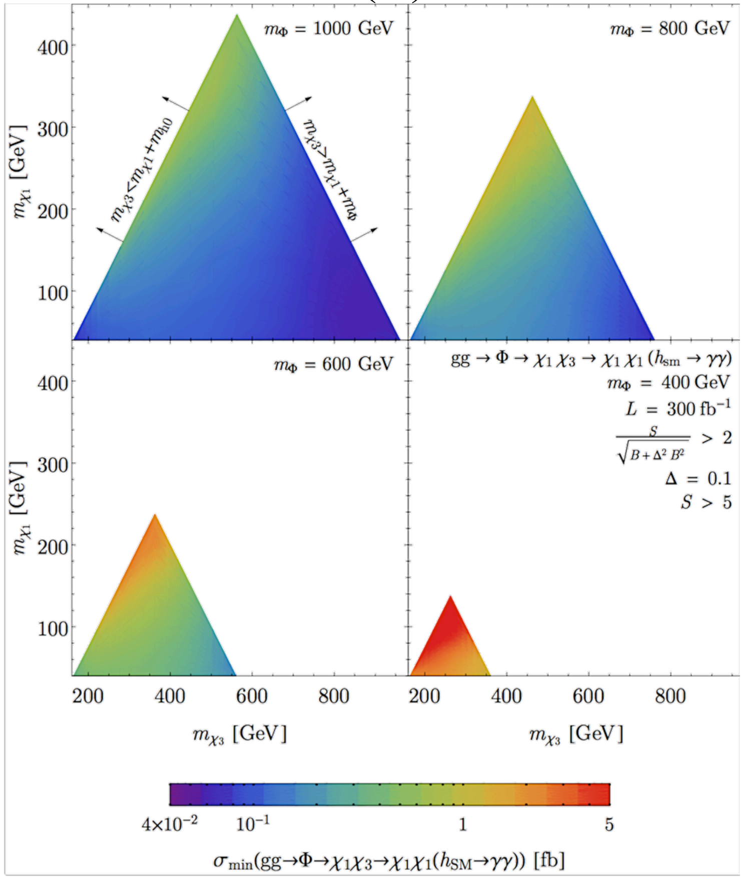
S. Baum, K. Freese, NRS & B. Shakya (preliminary)



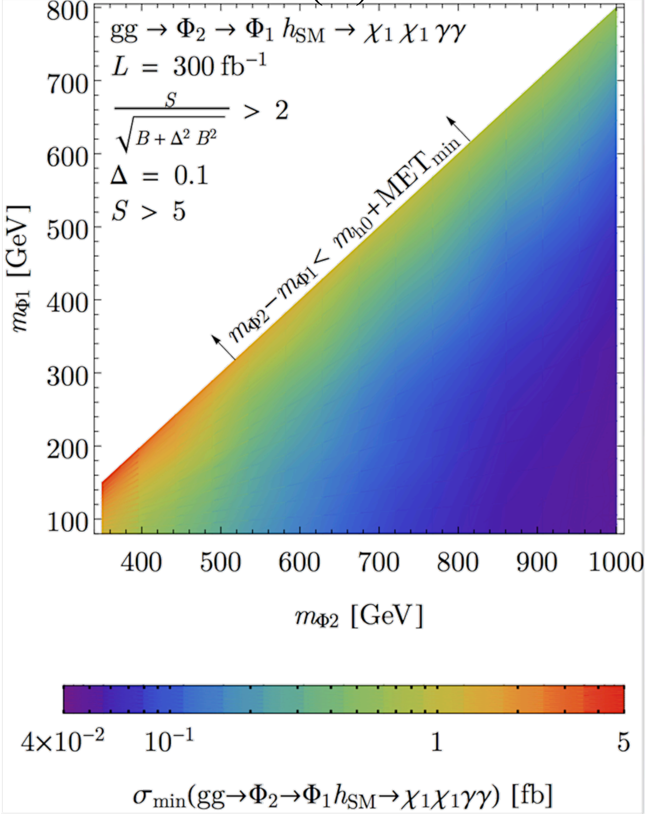
Background: ATLAS-CONF-2016-087

S. Baum, K. Freese, NRS & B. Shakya (preliminary)

(A)



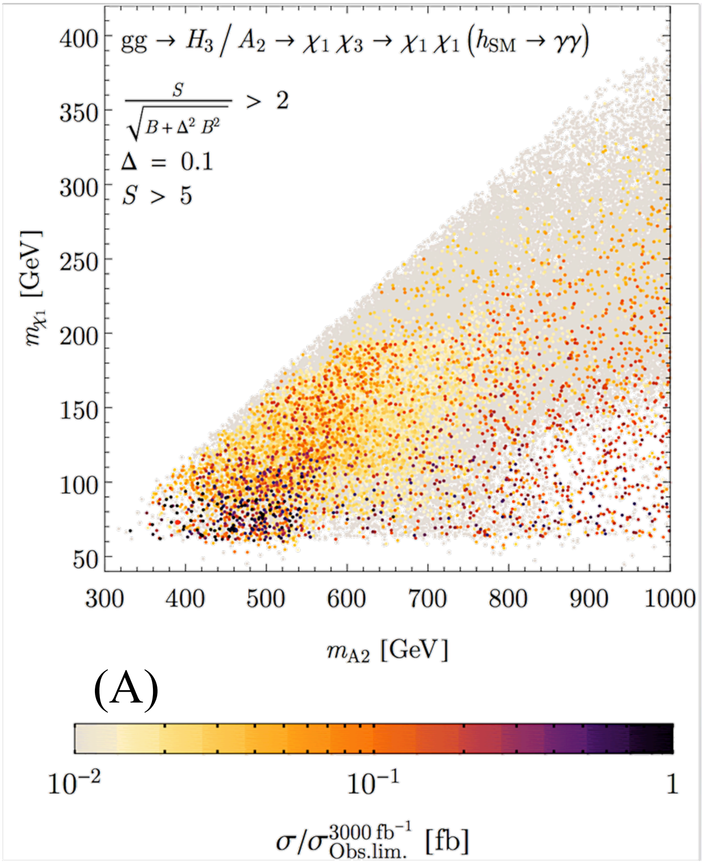
(B)

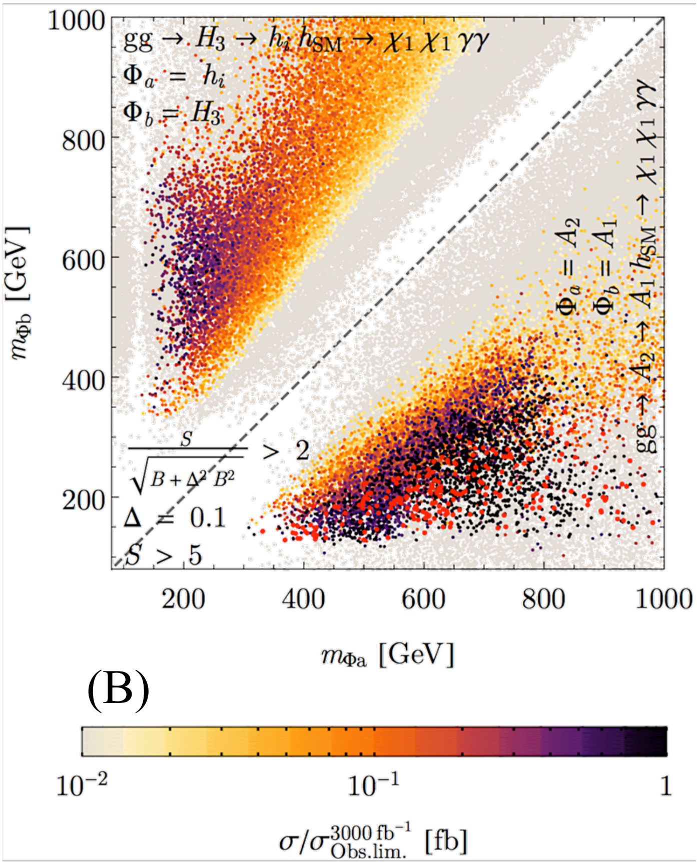


Depending on mass spectrum, can have sensitivity ~sub-fb

Reach?

S. Baum, K. Freese, NRS & B. Shakya (preliminary)



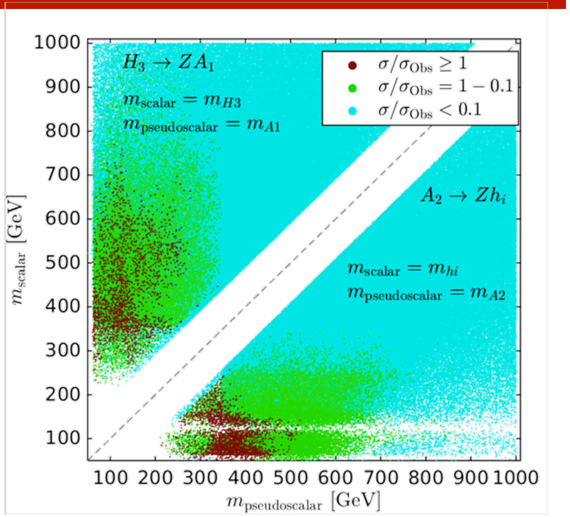


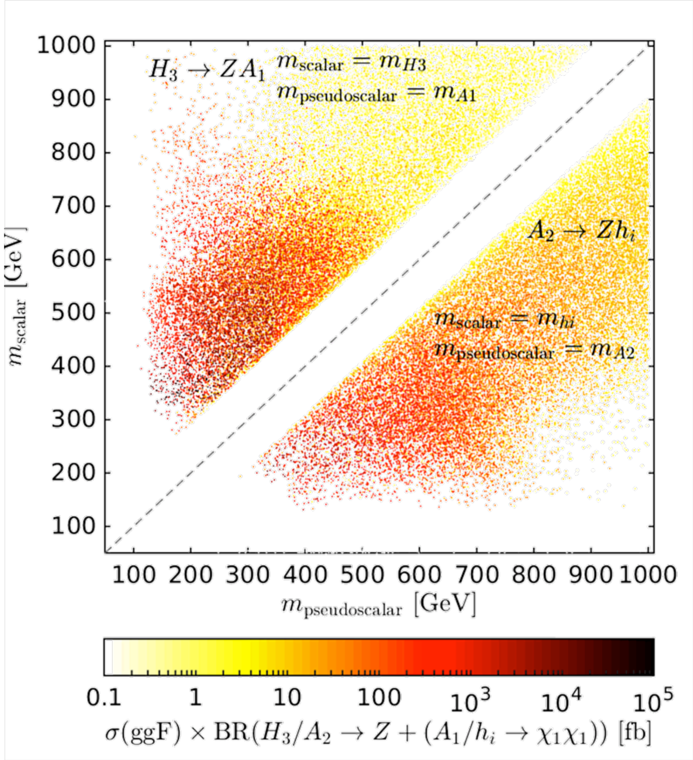
As expected much better reach for channel (B) – even when tt is open

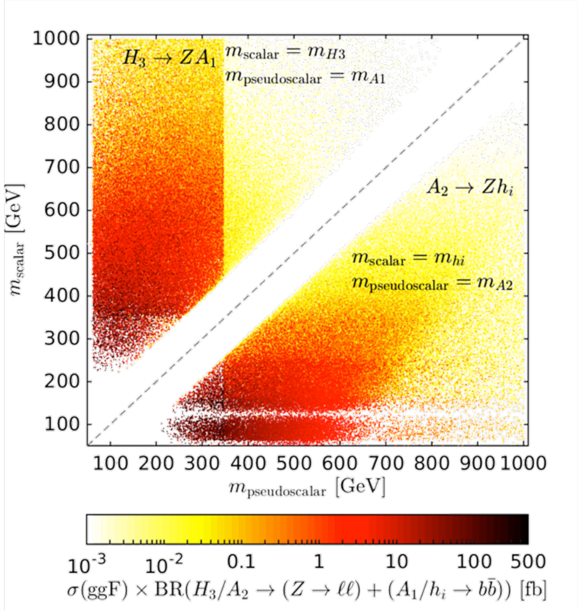
NMSSM

S. Baum, K. Freese, NRS & B. Shakya (preliminary)

- A/H-> Z h_S/a - > Z bb (CMS -- arXiv:1603.02991)
- A/H-> Z h_S/a - > Z $\chi\ \chi$ (mono-Z) (CMS -- arXiv:1701.02042)
- A/H -> h_S/a h125 -> bb $\gamma\ \gamma$, 4b?





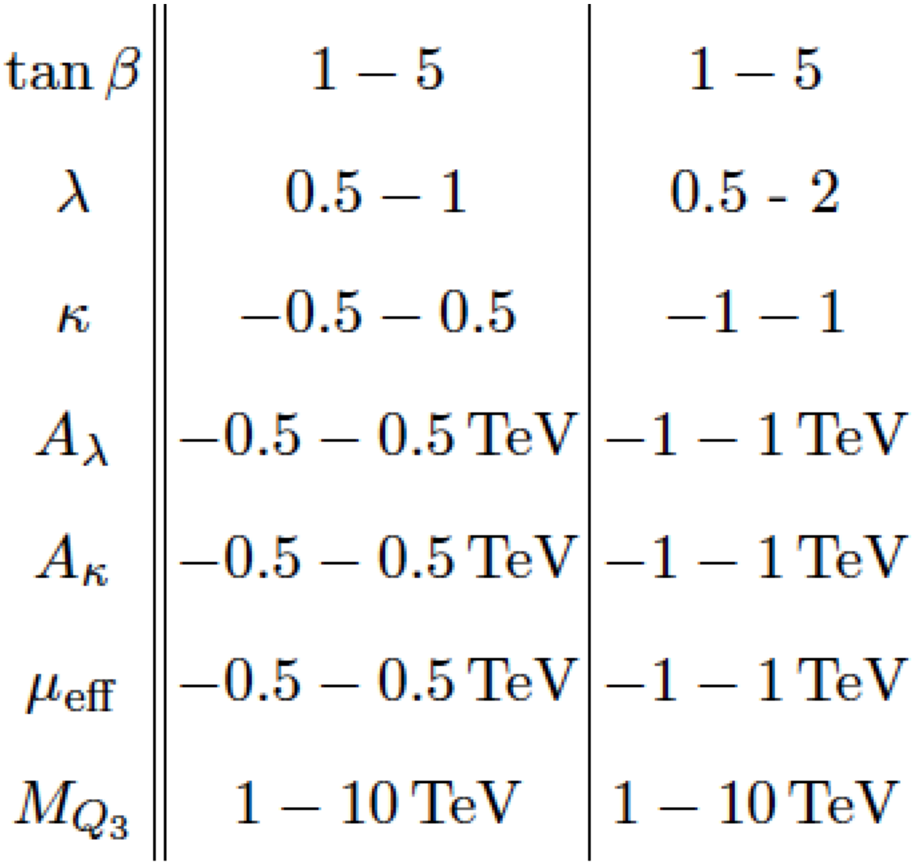


Other Signatures?

Conclusions and Outlook

- **m_h=125 GeV + SM-like**
  - Alignment: Decoupling or Prediction for parameters.
- NMSSM Higgs sector at low tan β .
  - Perturbativity and the requirement of alignment with the singlet
    - light singlets (both CP-even and odd) and singlino + higgsinos (charged and neutral).
    - Consistency with Cosmology provides further guidance
      - singlet scalar lighter than h125 – not decoupled
  - Large BR of non-SM Higgs into singlet like states + neutralinos
    - Mono-Higgs reach studied in detail
    - Complimentary channels:
      - mono-Z
      - 2b 2 γ , 4b?

BACKUP SLIDES



$\tan\beta$	$1-5$	$1-5$
λ	$0.5-1$	0.5 - 2
κ	$-0.5-0.5$	$-1-1$
A_λ	$-0.5-0.5\,\mathrm{TeV}$	$-1-1\,\mathrm{TeV}$
A_κ	$-0.5-0.5\,\mathrm{TeV}$	$-1-1\,\mathrm{TeV}$
μ_{eff}	$-0.5-0.5\,\mathrm{TeV}$	$-1-1\,\mathrm{TeV}$
M_{Q_3}	$1-10\,\mathrm{TeV}$	$1-10\,\mathrm{TeV}$

TABLE I: NMSSM parameter ranges used in `NMSSMTools` scans.

Contamination allowed in h125 ??

- How much “non-standardness” is allowed by h125 measurements??
- $\kappa_{NSM} H_{NSM} + \kappa_{SM} H_{SM} + \kappa_S S$
- Singlet: Only couples to Higgses
- Ratios to SM:
  - $g_{hgg} = (\kappa_{SM} + \kappa_{NSM}/t_\beta)$
  - $g_{hdd} = (\kappa_{SM} - \kappa_{NSM}\, t_\beta)$
  - $g_{hVV} = \kappa_{SM}$
- Significant κ_S OK
- Large κ_{NSM} from sign change of g_{hdd}

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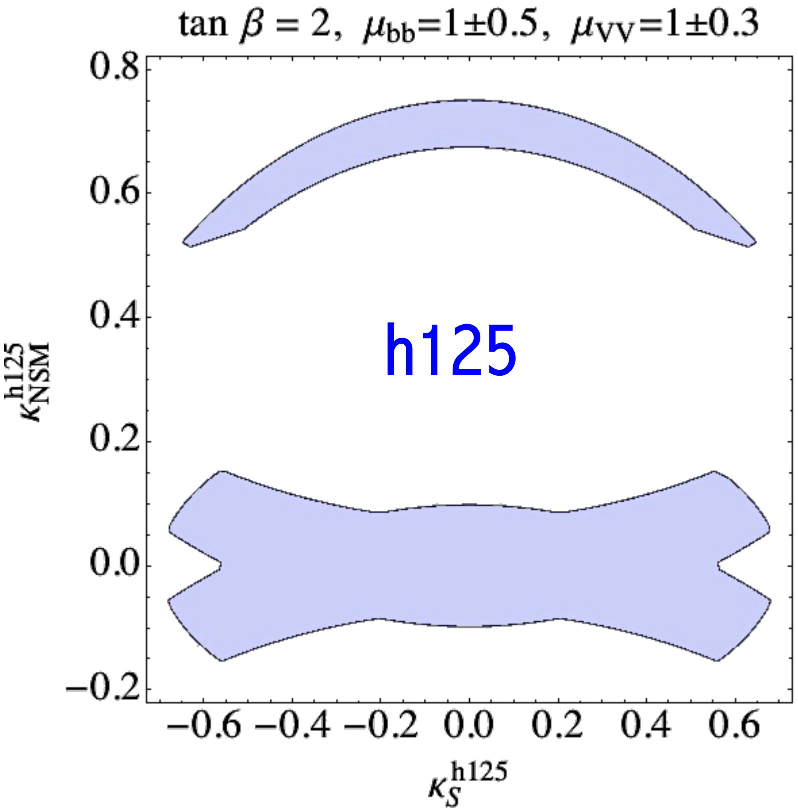
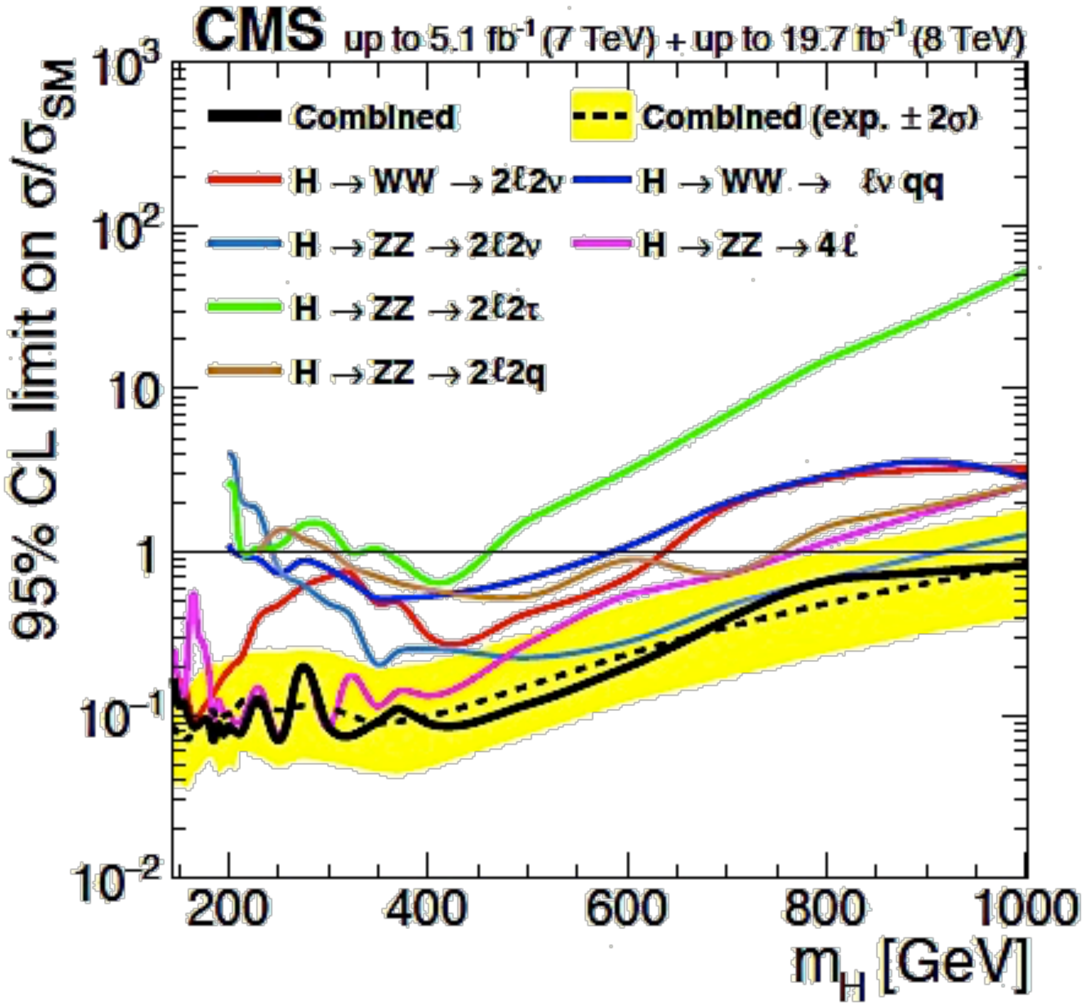


- CMS 1505.03831

- Strong constraints on SM-like Higgs decay to VV ~12-6% SM value for masses 160-500 GeV.



Heavy H to VV ?

- Strong constraints on SM-like Higgs decay to V V ~12-6% SM value for masses 160-500 GeV.

- **Only κ^{i}_{SM} couples to V V**

- What does this imply for SM and NSM components of extra Higgs??
  - 160 GeV < m_{hS} < 350 GeV
  - BR(WW+ZZ) ~1
  - gF production XS impacted.

- With $\kappa^{h125}_{NSM} \sim 0$
  - $\kappa^{hS}_{SM} \sim \kappa^{h125}_{S}$
  - κ^{h125}_{S} smaller than allowed by h125 measurements!

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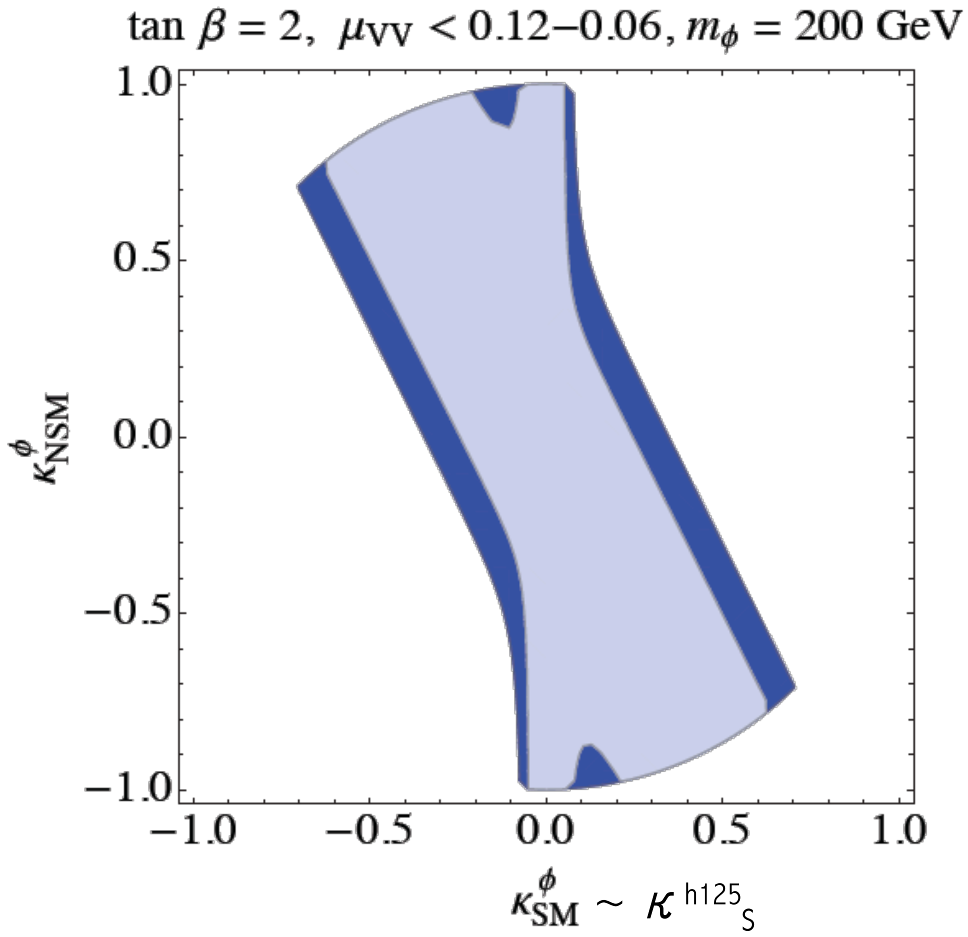


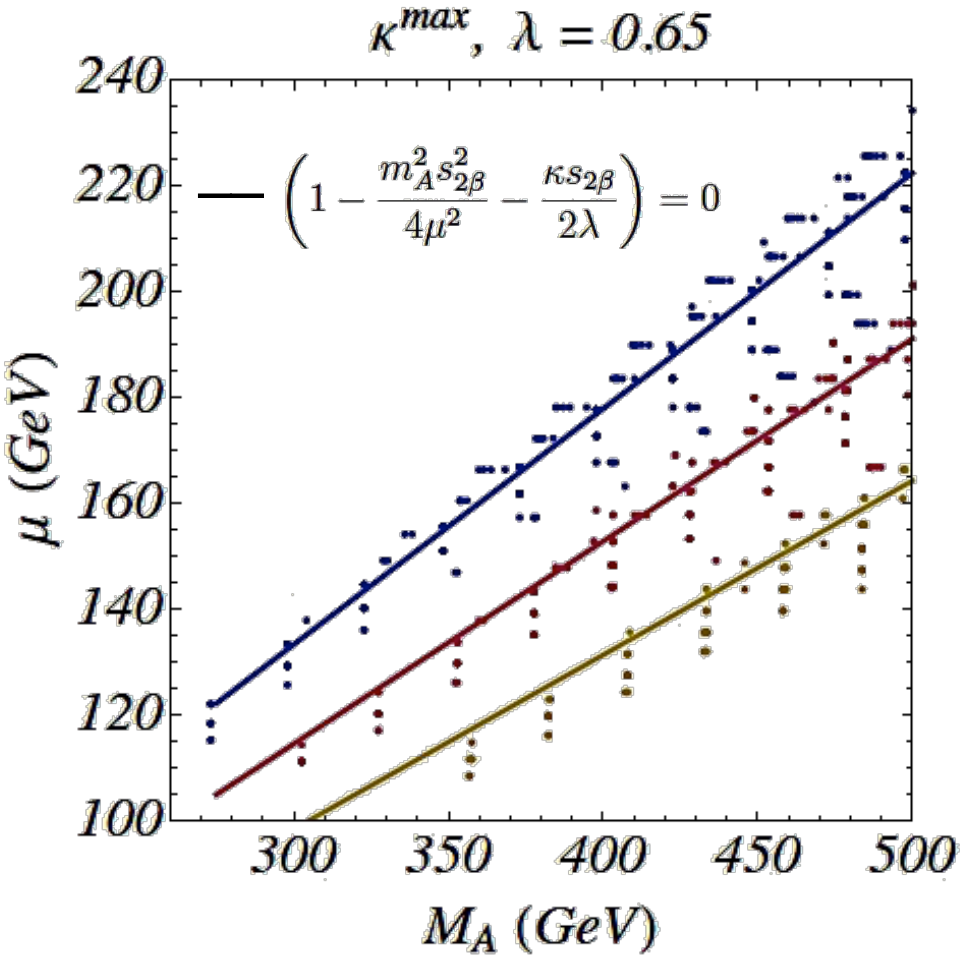
Direct Searches for heavy resonances?

- NMSSMTools + HiggsBounds/Signals
- Allowed “misalignment”

. tan β =2

. tan β =2.5

. tan β =3



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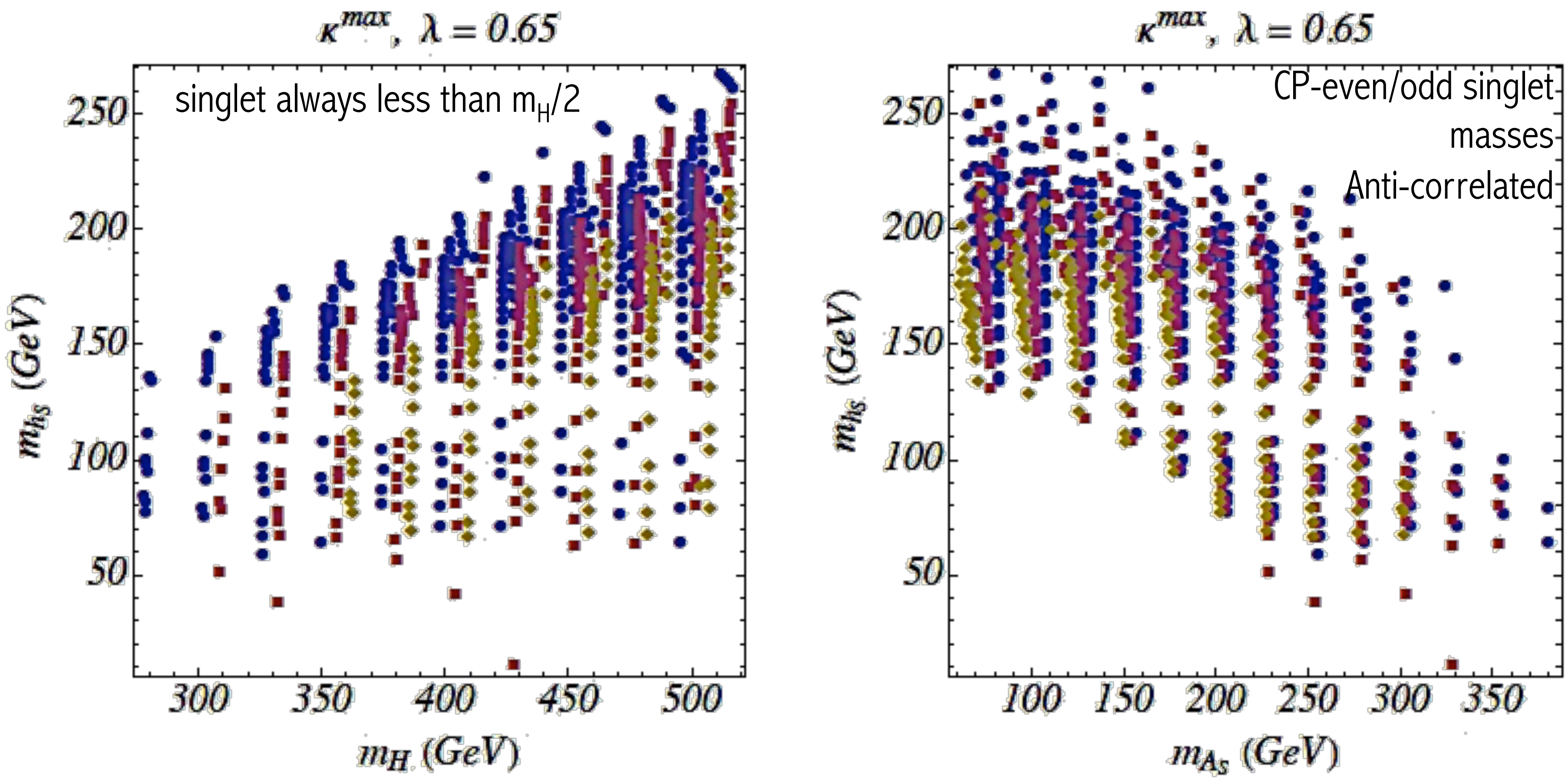
Misalignment

Singlet Spectra

Density of scan not relevant



singlet always less than $m_H/2$

CP-even/odd singlet masses

Anti-correlated

. tan β =2 . tan β =2.5 . tan β =3

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- Decay BR depends on tan β

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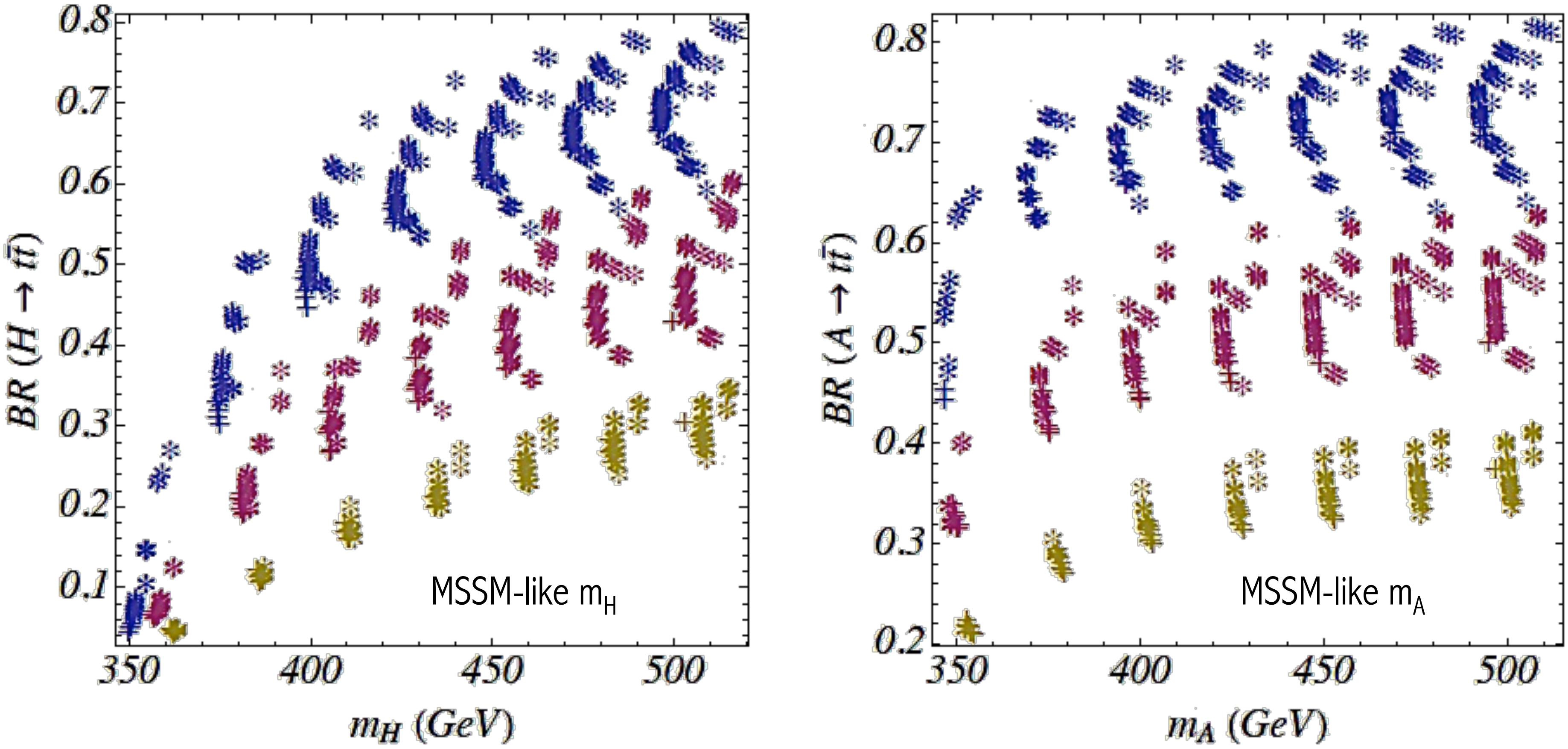
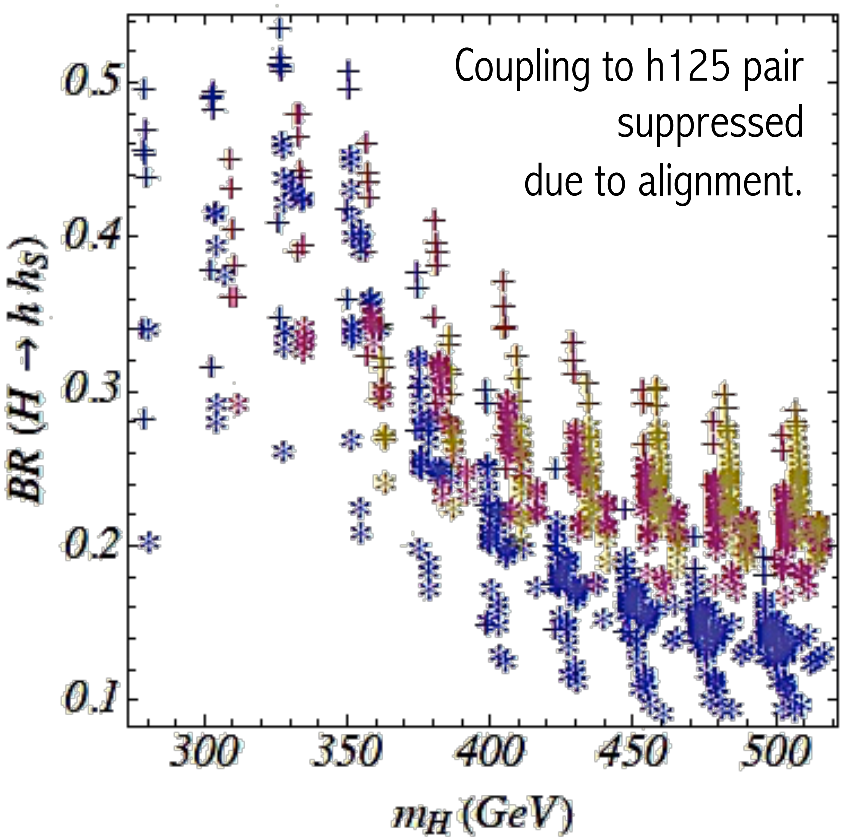


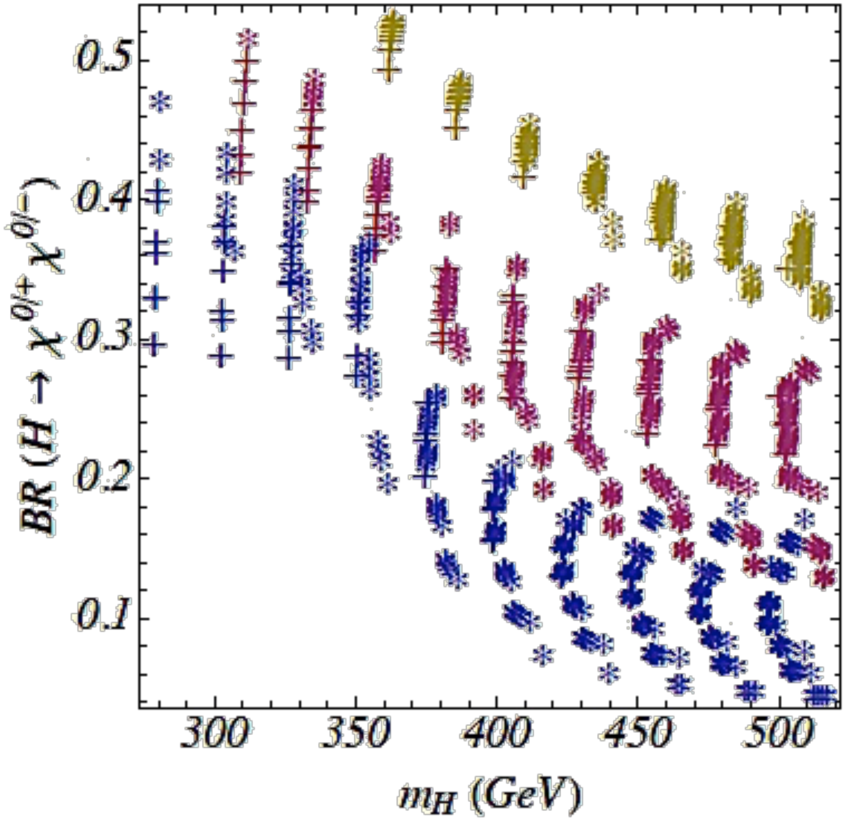
. tan β =2 . tan β =2.5 . tan β =3

MSSM-like A and H decays into tt

- Apart from tt, significant decays into H2+H1 and neutralino/charginos



Coupling to h125 pair suppressed due to alignment.



. tan β =2 . tan β =2.5 . tan β =3

MSSM-like H BR

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MSSM-like A BR

- Into singlet-like H1/H2-Z and inos

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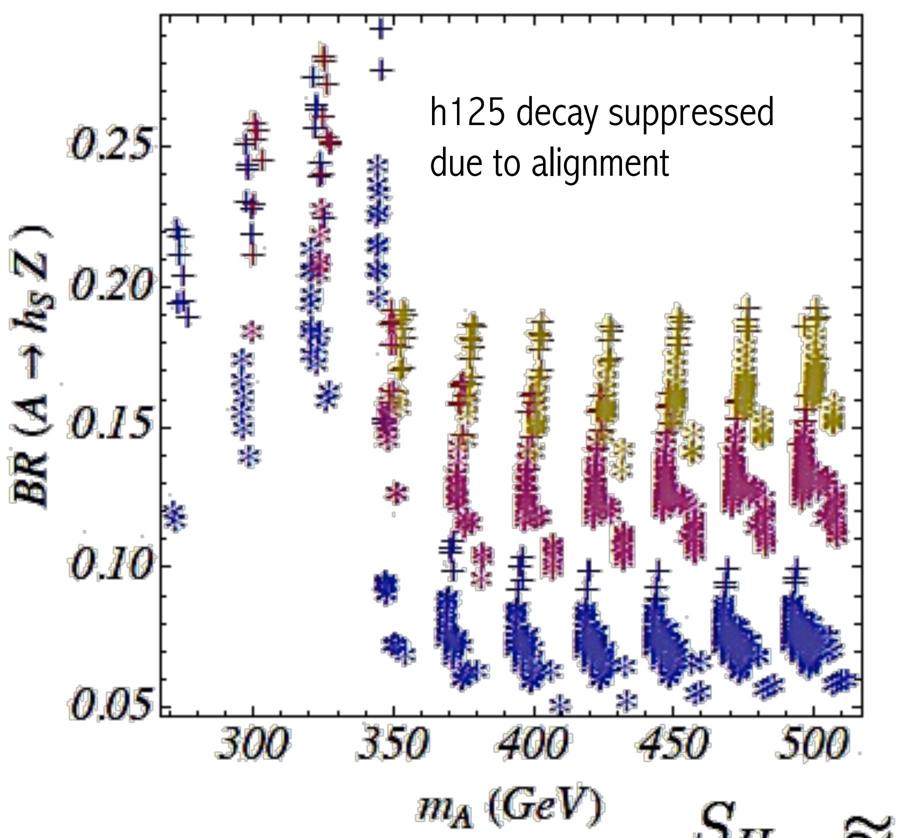
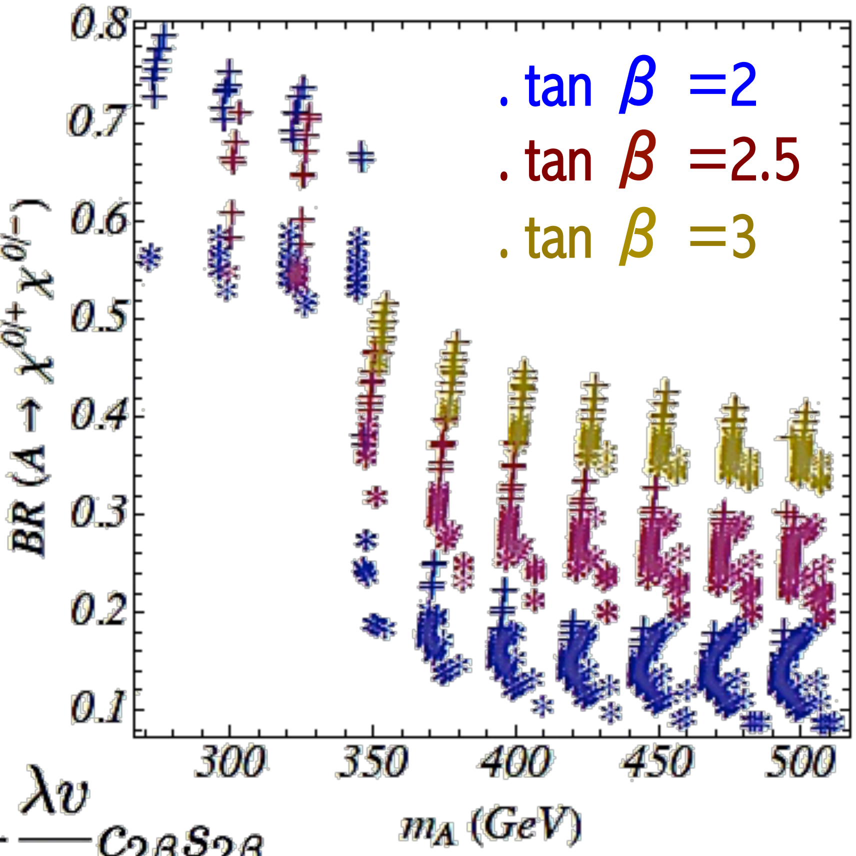
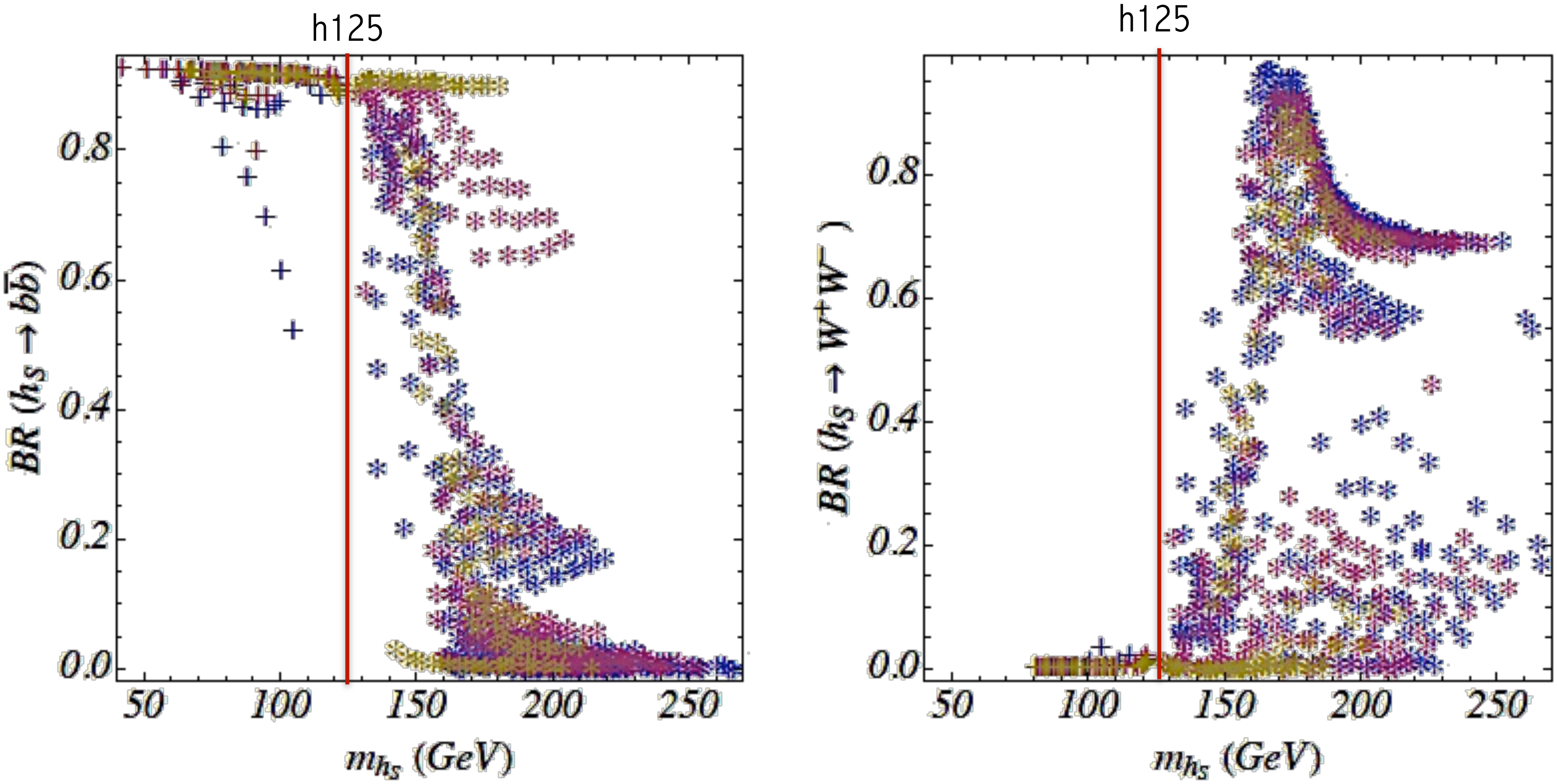


h125 decay suppressed due to alignment



$$S_{H,s} \approx -\frac{\lambda v}{2\mu} c_{2\beta} s_{2\beta}$$

- Singlet mainly decays to bb and WW



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Singlet-like h_S BR

XS factor ~ 4 at 14 TeV compared to 8 TeV

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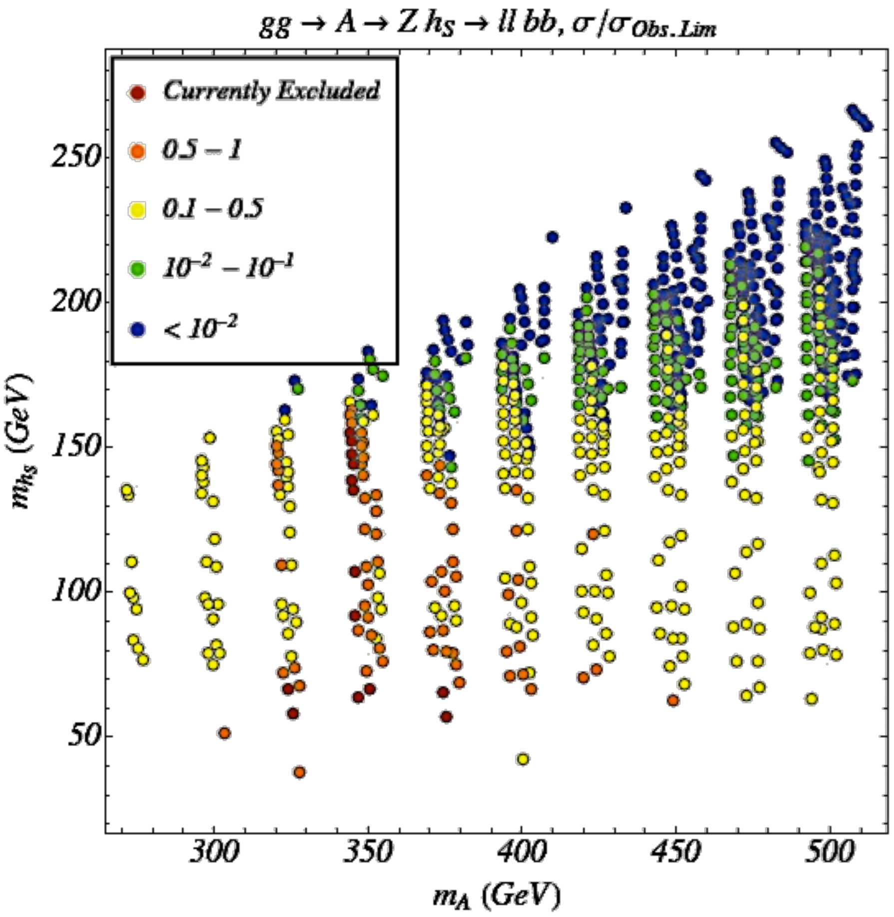
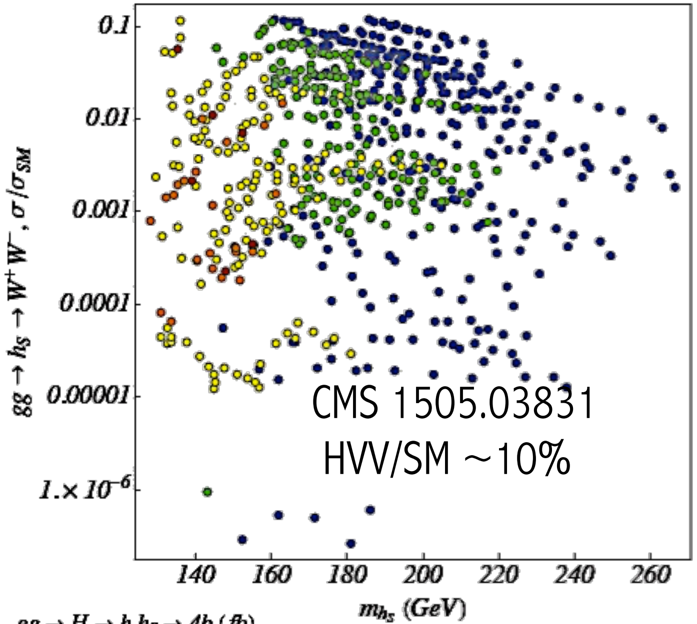
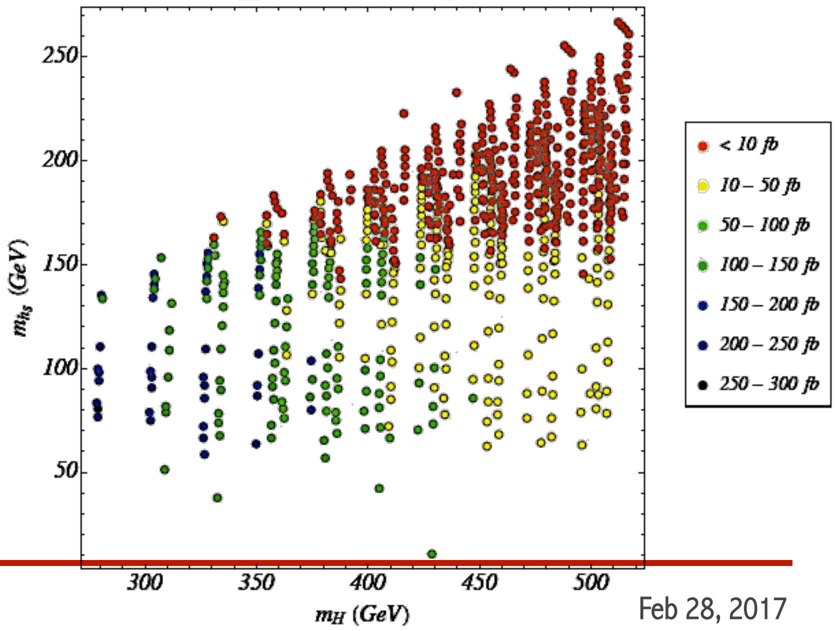
CMS PAS HIG-15-001



8 TeV



CMS 1505.03831
HVV/SM ~10%

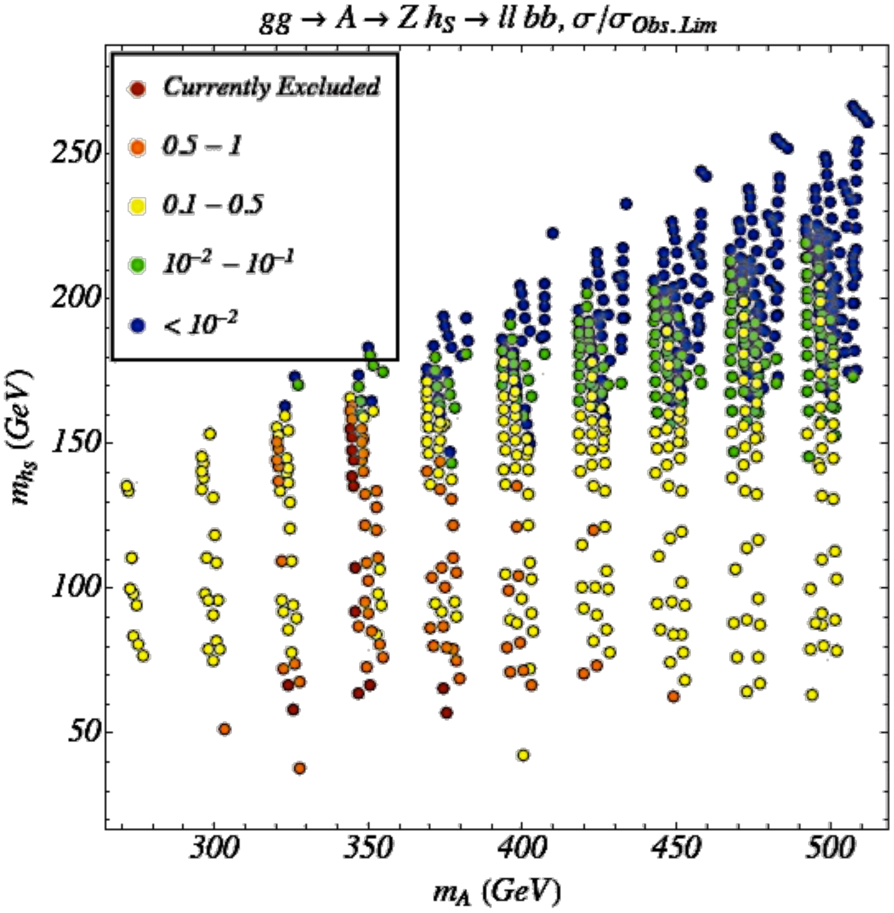


Now & Future

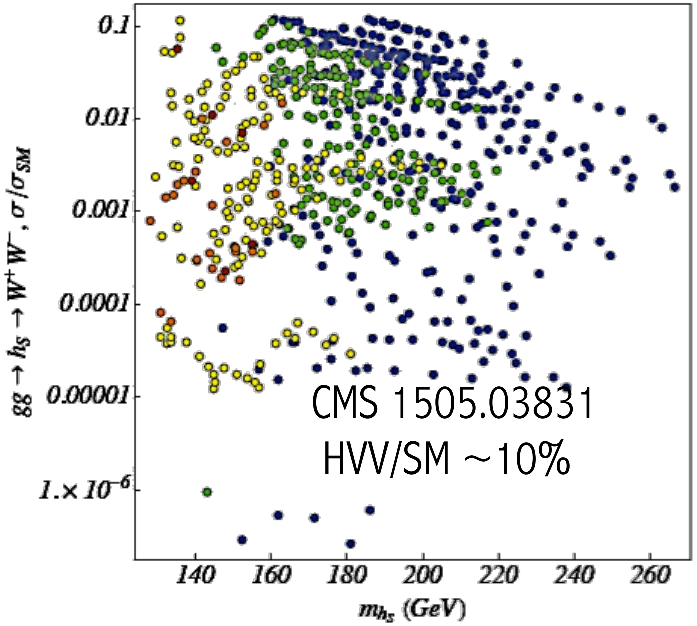
XS factor ~ 4 at 14 TeV compared to 8 TeV

M. Carena, H. Haber, I. Low, N.R.S., C. Wagner, '15

CMS PAS HIG-15-001

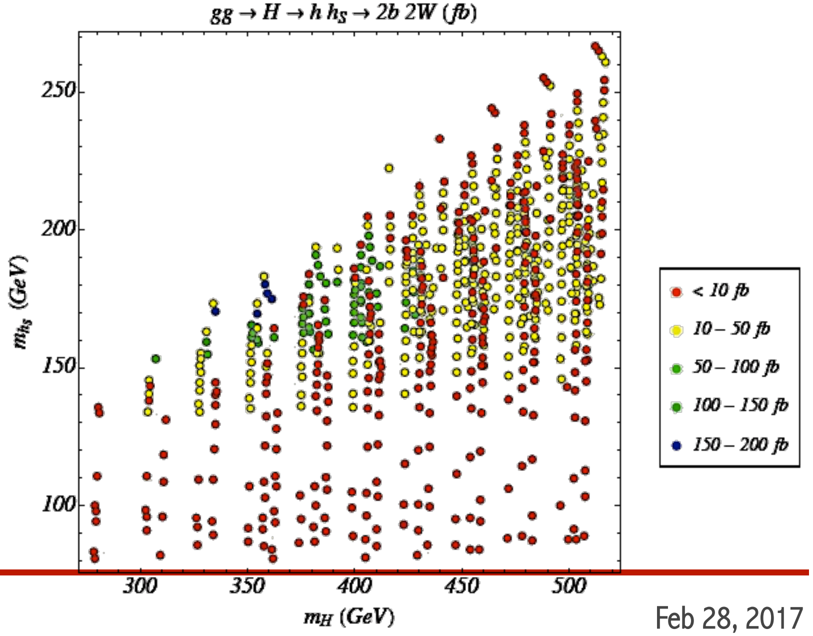


8 TeV



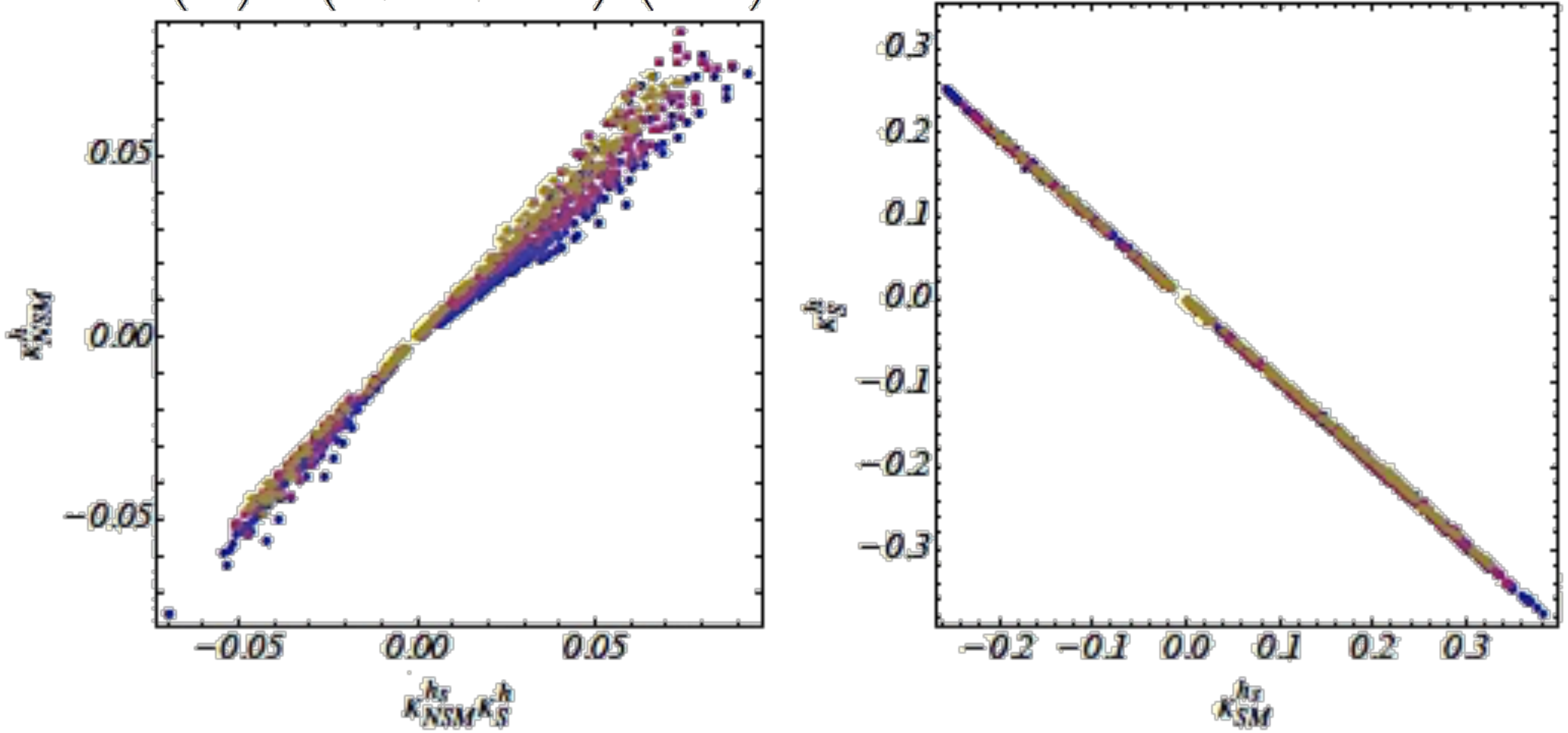
CMS 1505.03831

HVV/SM ~10%



Now & Future

$$\begin{pmatrix} h \\ H \\ h_S \end{pmatrix} \simeq \begin{pmatrix} 1 & -\eta\eta' & \eta' \\ \mathcal{O}(\epsilon) & -1 & -\eta \\ -\eta' & -\eta & 1 \end{pmatrix} \begin{pmatrix} H^{\rm SM} \\ H^{\rm NSM} \\ H^{\rm S} \end{pmatrix}$$



h125 Components

“Extended” Higgs Basis

- Tree-level mass matrix in the (H_{NSM}, H_{SM}, S) basis:

$$\begin{pmatrix} m_A^2 + s_{2\beta}^2\left(m_Z^2 - \frac{1}{2}\lambda^2 v^2\right) & s_{2\beta}c_{2\beta}\left(m_Z^2 - \frac{1}{2}\lambda^2 v^2\right) & -\frac{\lambda v \mu}{\sqrt{2}} c_{2\beta}\left(\frac{m_A^2}{2\mu^2} s_{2\beta} + \frac{\kappa}{\lambda}\right) \\ & c_{2\beta}^2 m_Z^2 + \frac{1}{2}\lambda^2 v^2 s_{2\beta}^2 & \sqrt{2}\lambda v \mu\left(1 - \frac{m_A^2}{4\mu^2} s_{2\beta}^2 - \frac{\kappa}{2\lambda} s_{2\beta}\right) \\ & & \frac{\lambda^2 v^2 s_{2\beta}}{4}\left(\frac{m_A^2 s_{2\beta}}{2\mu^2} - \frac{\kappa}{\lambda}\right) + \frac{\kappa\mu}{\lambda}\left(A_\kappa + \frac{4\kappa\mu}{\lambda}\right) \end{pmatrix}$$

- **Alignment: Mixing between HNSM-SM=0 & SM-S =0**
- Alignment conditions, (+ stop corrections to always obtain h125):

$$\mathcal{M}_S^2(1,2) = \frac{1}{t_\beta}\left[c_{2\beta} m_Z^2 - \mathcal{M}_S^2(2,2) + \lambda^2 v^2 s_\beta^2 + \frac{3 m_t^4 X_t\left(X_t - Y_t\right)}{4\pi^2 v^2 M_S^2}\left(1 - \frac{X_t^2}{6 M_S^2}\right)\right] = 0$$

$$\mathcal{M}_S^2(2,3) = 2\lambda v \mu\left(1 - \frac{m_A^2 s_{2\beta}^2}{4\mu^2} - \frac{\kappa s_{2\beta}}{2\lambda}\right) = 0$$

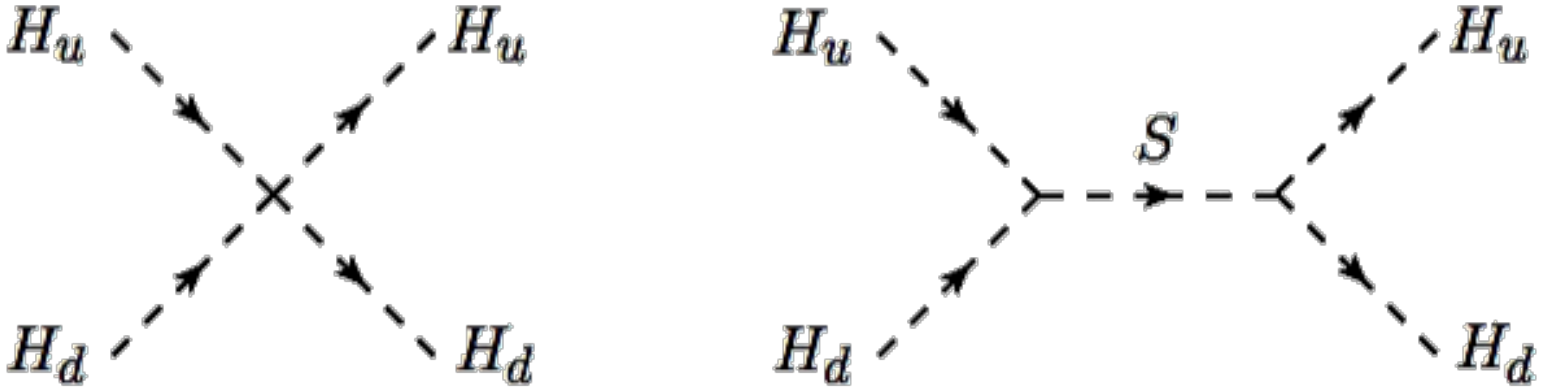
NSM-SM mixing cancels for

$$\lambda_{\text{alt}}^2 = \frac{m_h^2 - M_Z^2 c_{2\beta}}{v^2 s_\beta^2}$$

X. Lu, H. Murayama, J. Ruderman, K. Tobioka '13

$$W \supset \lambda S H_u H_d + \frac{M}{2} S^2 + \mu H_u H_d \qquad V_{\mathrm{soft}} \supset m_S^2 |S|^2$$

$$V \supset |F_S|^2 = |\lambda H_u H_d + M S|^2$$



$$\delta m_h^2 = \lambda^2 v^2 \sin^2 2\beta \left(1 - \frac{M^2}{M^2 + m_S^2}\right)$$

- It is well known that in the NMSSM there are new contributions to the lightest CP-even Higgs mass,

$$W = \lambda S H_u H_d + \frac{\kappa}{3} S^3$$

$$m_h^2 \simeq \lambda^2 \frac{v^2}{2} \sin^2 2\beta + M_Z^2 \cos^2 2\beta + \Delta_{\tilde{t}}$$

- It is perhaps less known that it leads to sizable corrections to the mixing between the MSSM like CP-even states. In the Higgs basis,

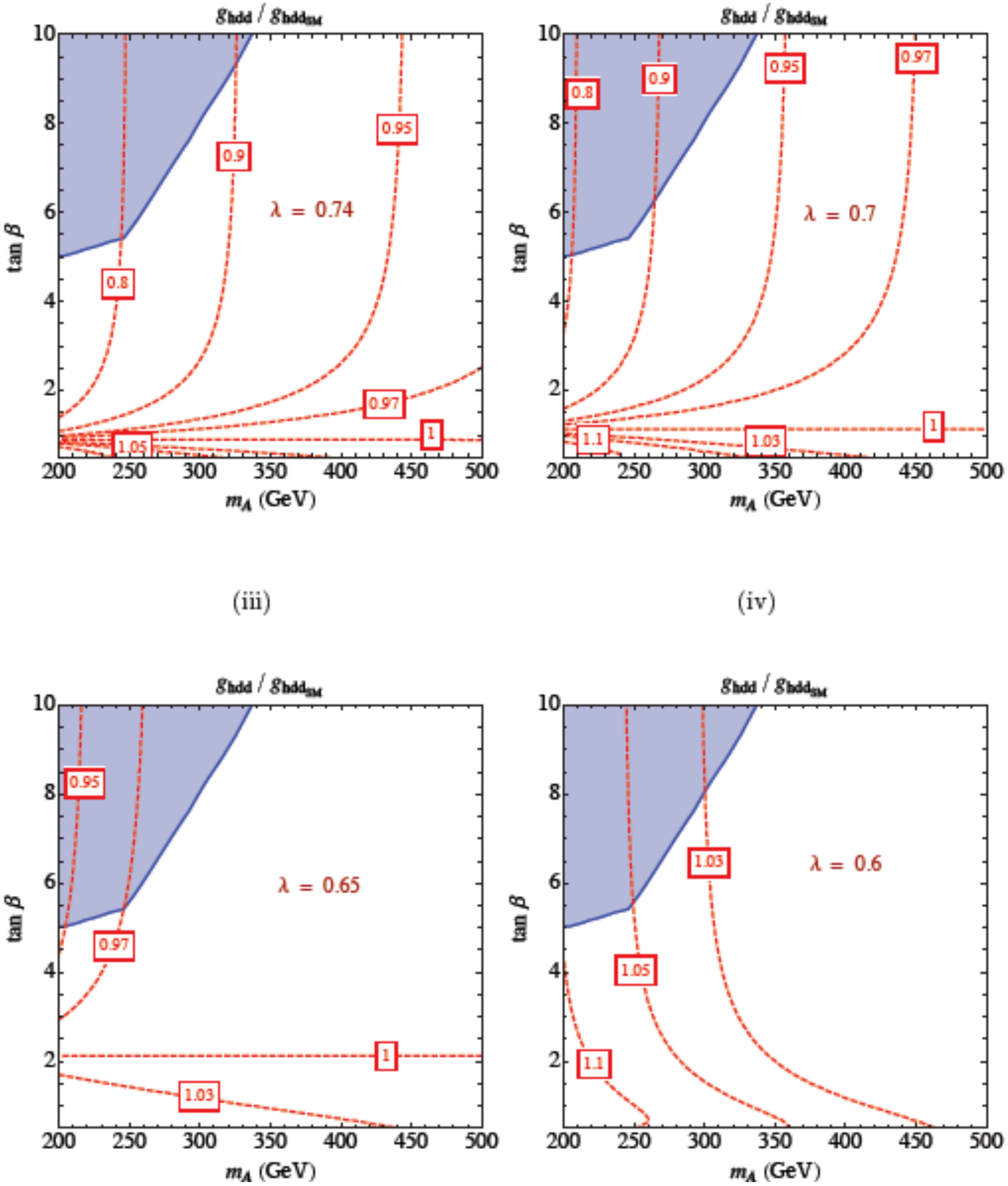
$$M_S^2(1,2) \simeq \frac{1}{\tan\beta} \left(m_h^2 - M_Z^2 \cos 2\beta - \lambda^2 v^2 \sin^2\beta + \delta_{\tilde{t}}\right)$$

- The last term is the one appearing in the MSSM, that are small for moderate mixing and small values of $\tan\beta$

- So, alignment leads to a determination of lambda,

- The values of lambda end up in a very narrow range, between 0.65 and 0.7 for allvalues of tanbeta, that are the values that lead to naturalness with perturbativity up to the GUT scale

$$\lambda^2 = \frac{m_h^2 - M_Z^2 \cos 2\beta}{v^2 \sin^2\beta}$$



(iii) (iv)

M. Carena, I. Low, N.R.S, C. Wagner, '13

It is clear from these plots that the NMSSM does an amazing job in aligning the MSSM-like CP-even sector, provided lambda is of about 0.65

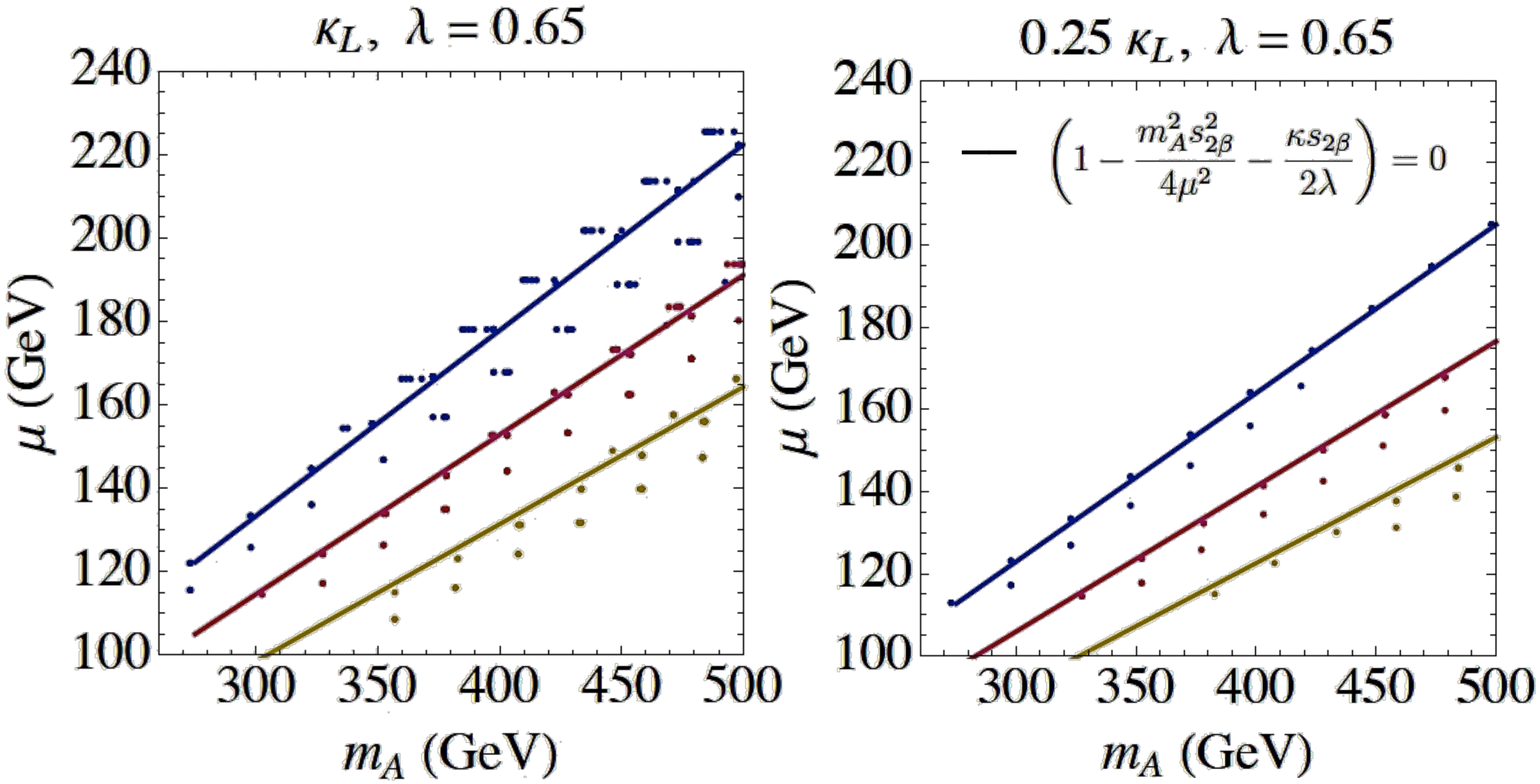
CP-Odd Mass Matrix

- In the (“MSSM m_A”, Singlet) basis:

$$\mathcal{M}_P^2 = \begin{pmatrix} m_A^2 & \frac{\lambda v}{\sqrt{2}} \left(\frac{m_A^2}{2\mu} s_{2\beta} - \frac{3\kappa\mu}{\lambda} \right) \\ & \frac{1}{2}\lambda^2 v^2 s_{2\beta} \left(\frac{m_A^2}{4\mu^2} s_{2\beta} + \frac{3\kappa}{2\lambda} \right) - \frac{3\kappa A_\kappa \mu}{\lambda} \end{pmatrix}$$

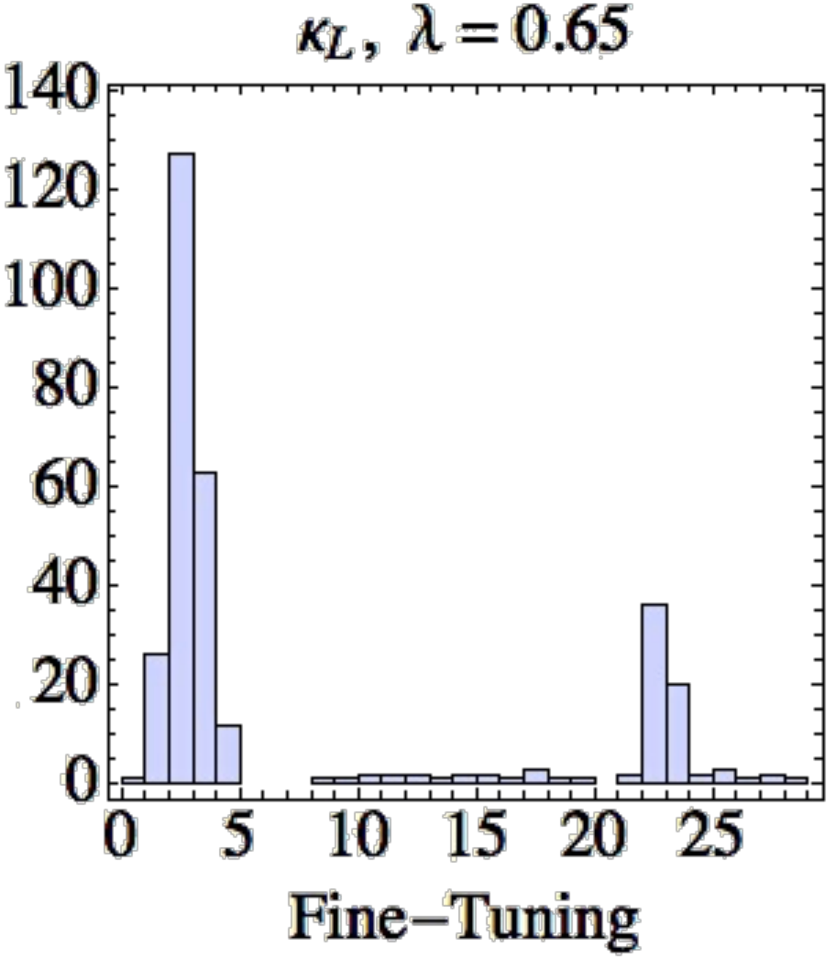
$$m_A^2 = \frac{\mu}{s_\beta c_\beta} \left(A_\lambda + \frac{\kappa\mu}{\lambda} \right).$$

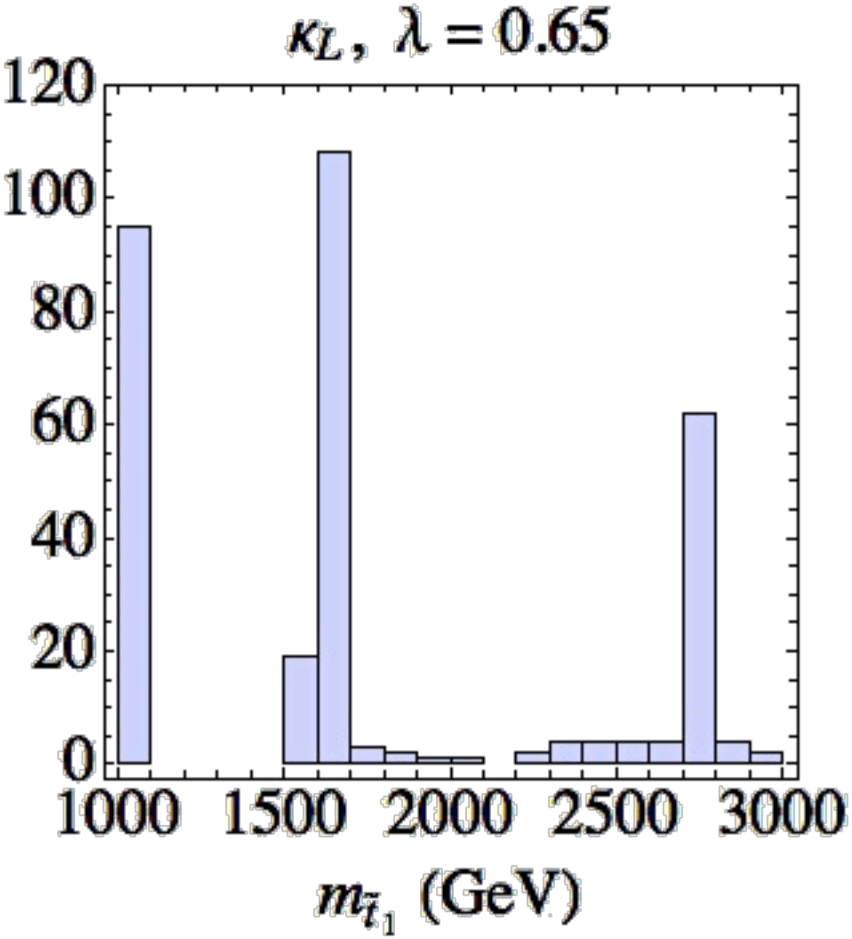
. tan β =2 . tan β =2.5 . tan β =3



Misalignment

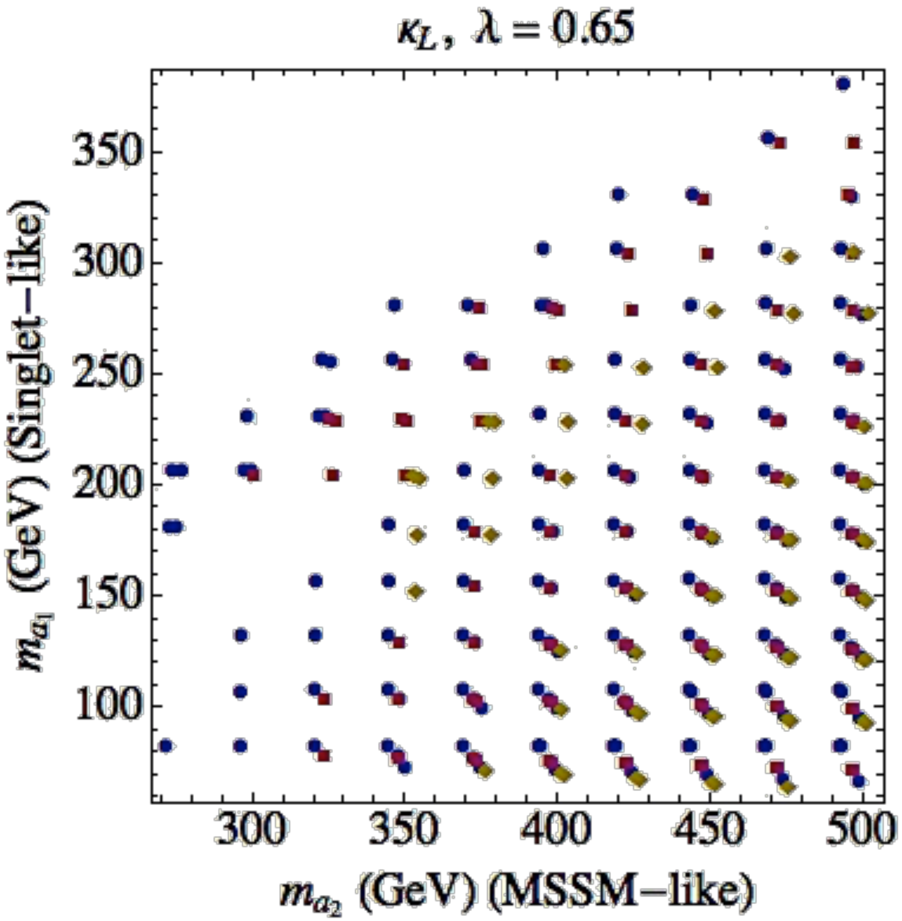
- Larger tan β => Heavier Stops => Larger Fine Tuning

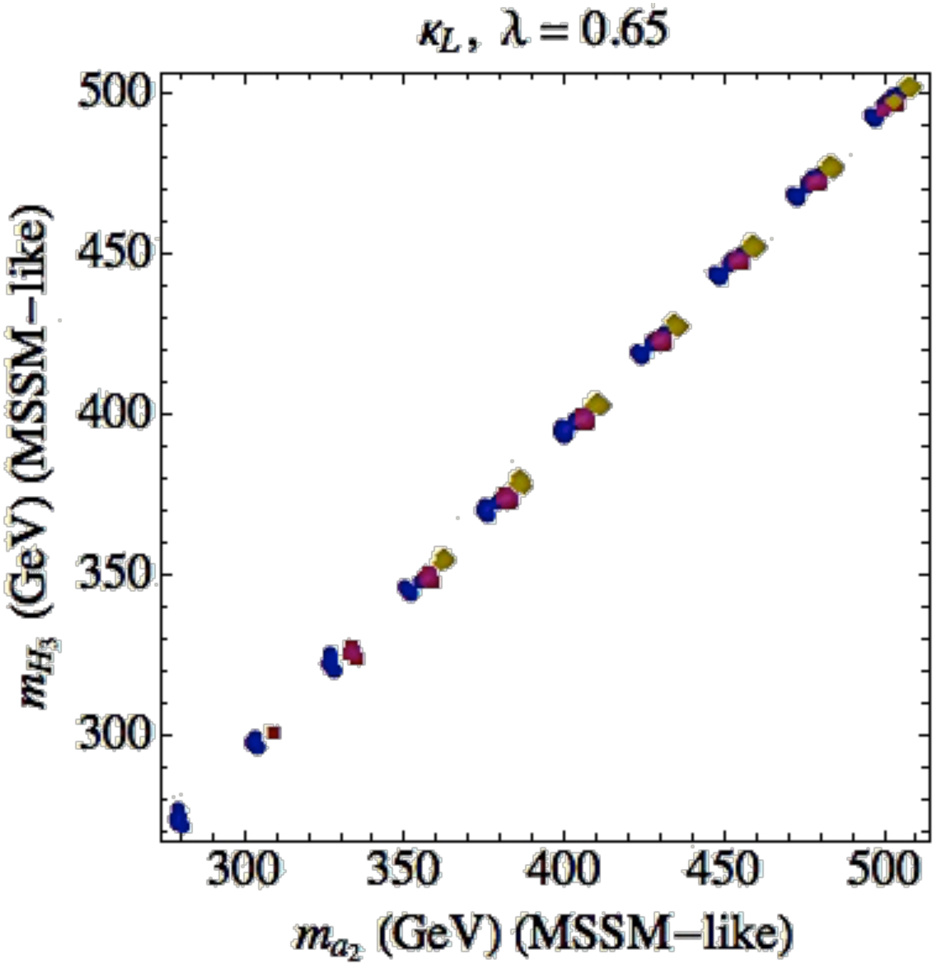




Fine-Tuning (No-mixing in stops)

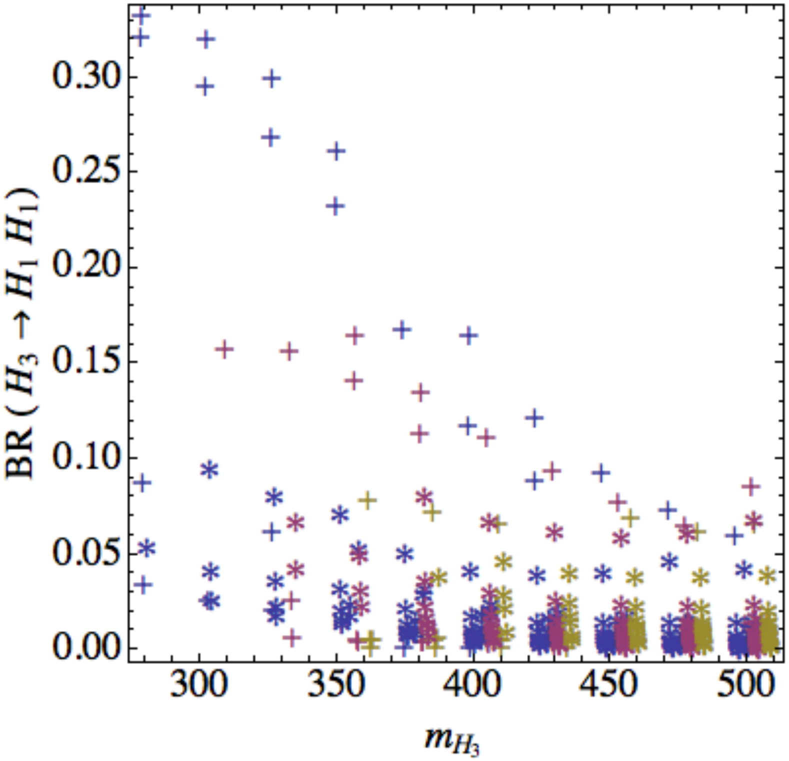
- CP-even vs. Odd

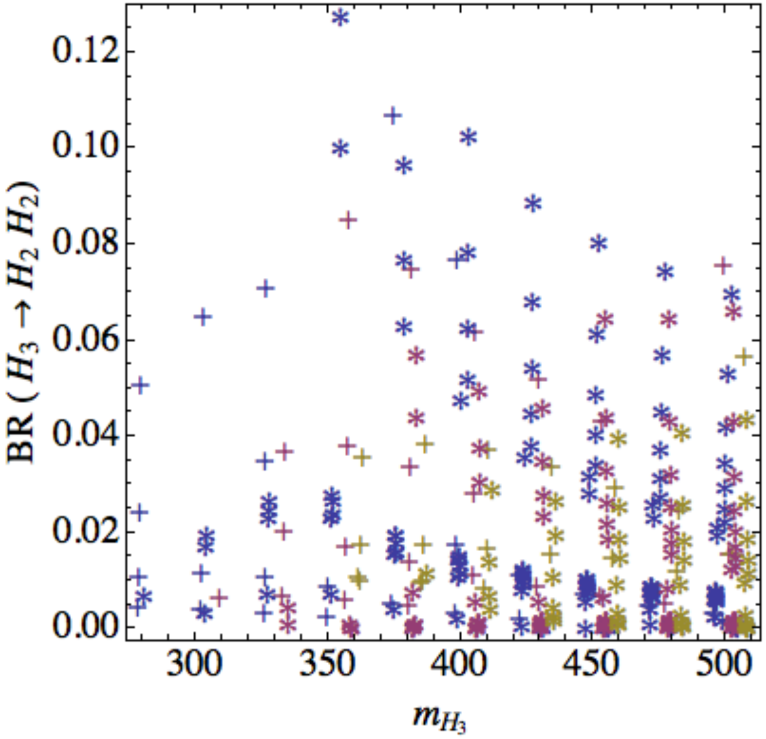




Higgs Spectra

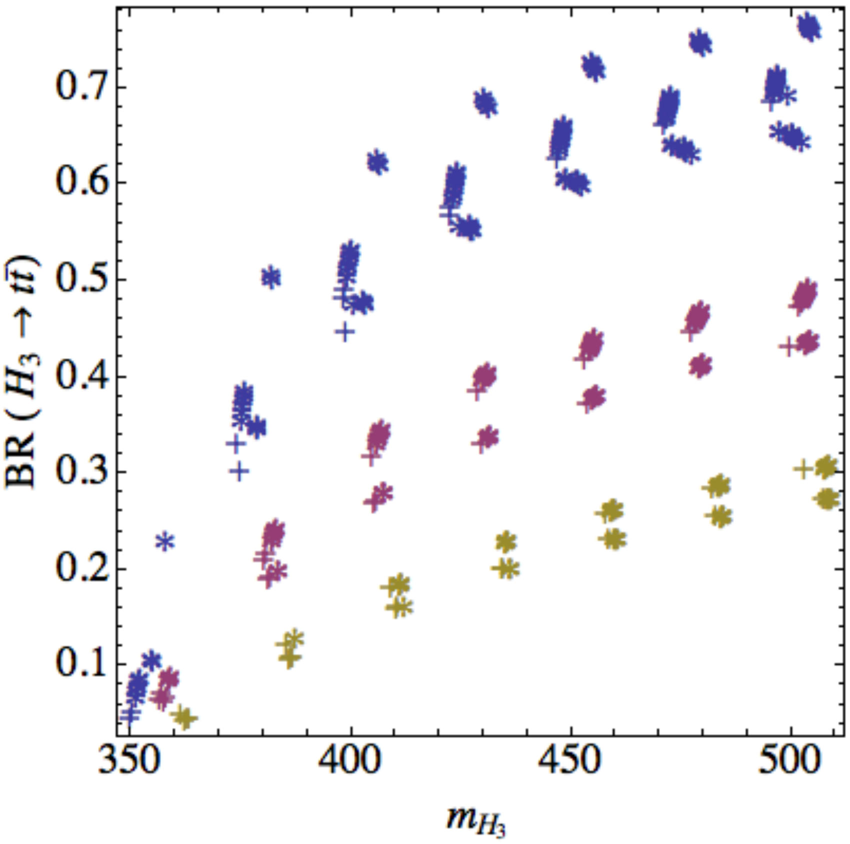
- H1 H1 /H2 H2

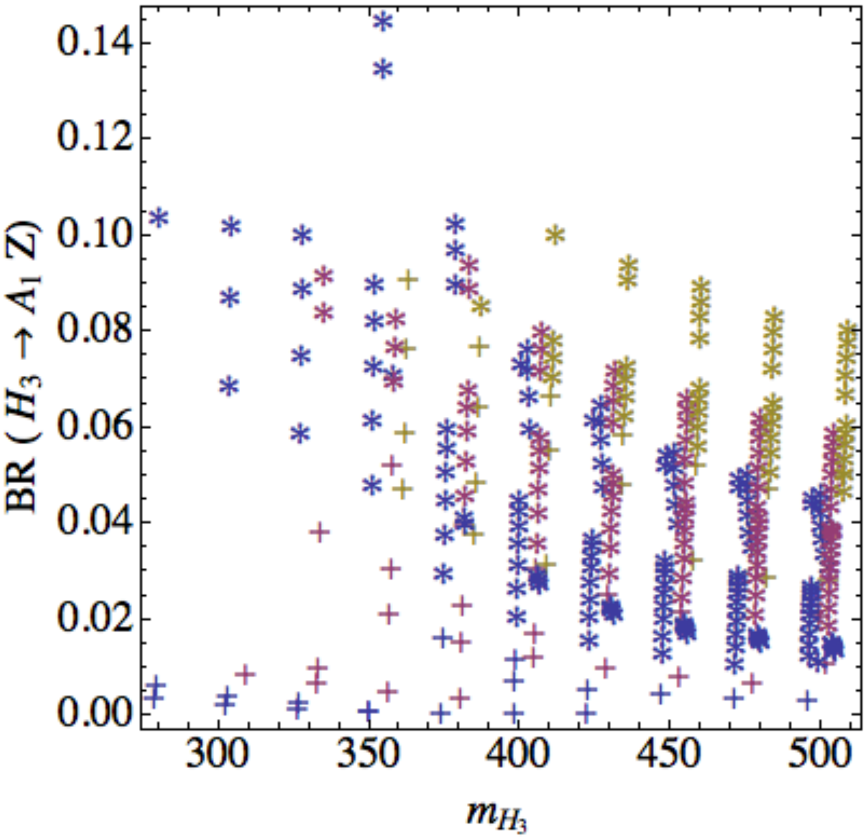




H3 BR

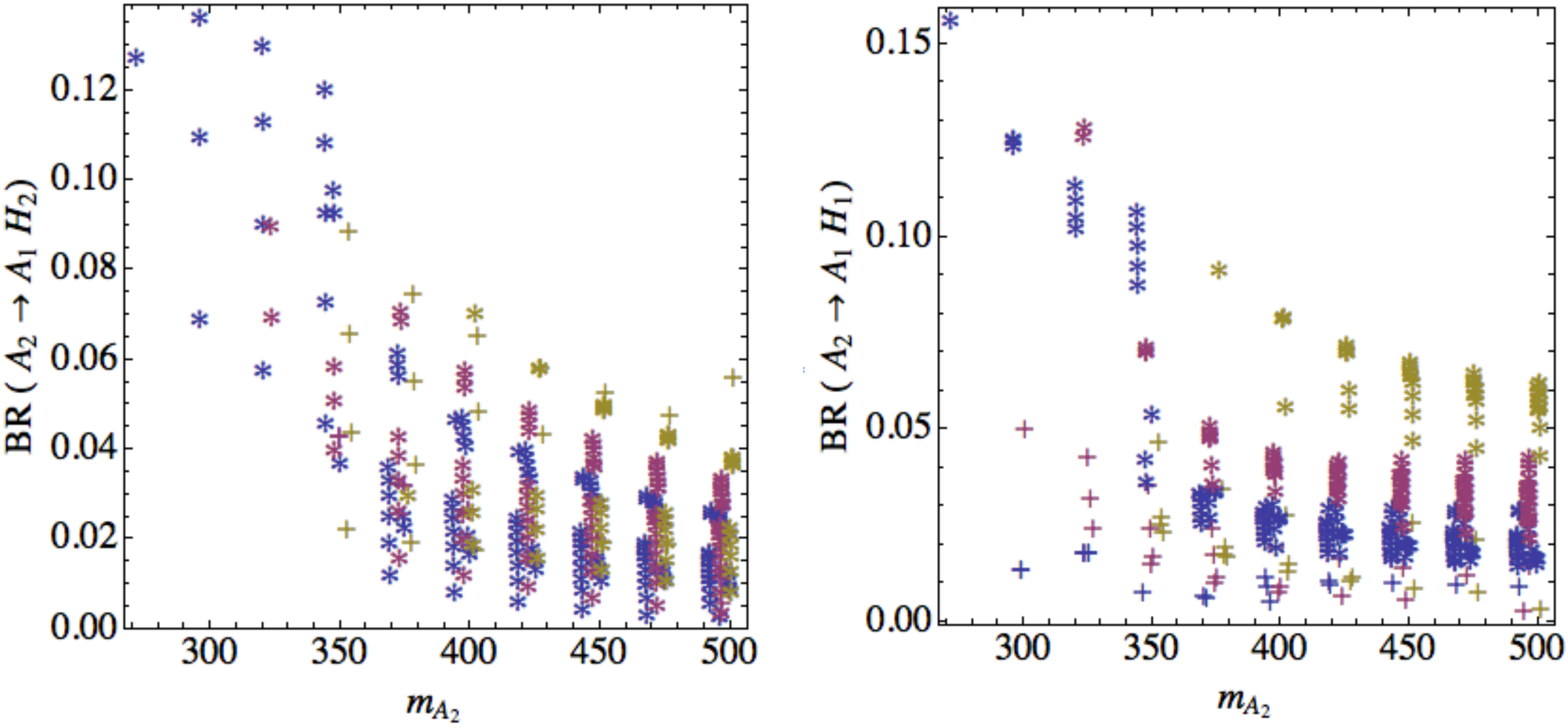
- tt + a Z


BR ($H_3 \to t\bar{t}$)
0.1
0.2
0.3
0.4
0.5
0.6
0.7
350
400
450
500
m_{H_3}


BR ($H_3 \to A_1 Z$)
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
300
350
400
450
500
m_{H_3}

BR H3

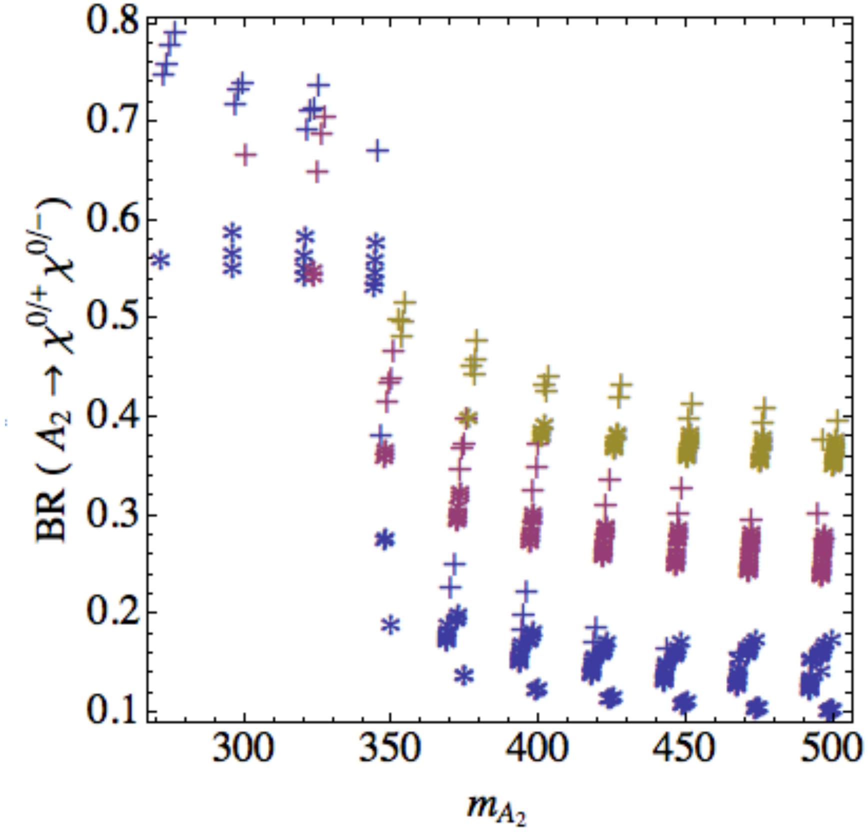
- A1 H1 / A1 H2

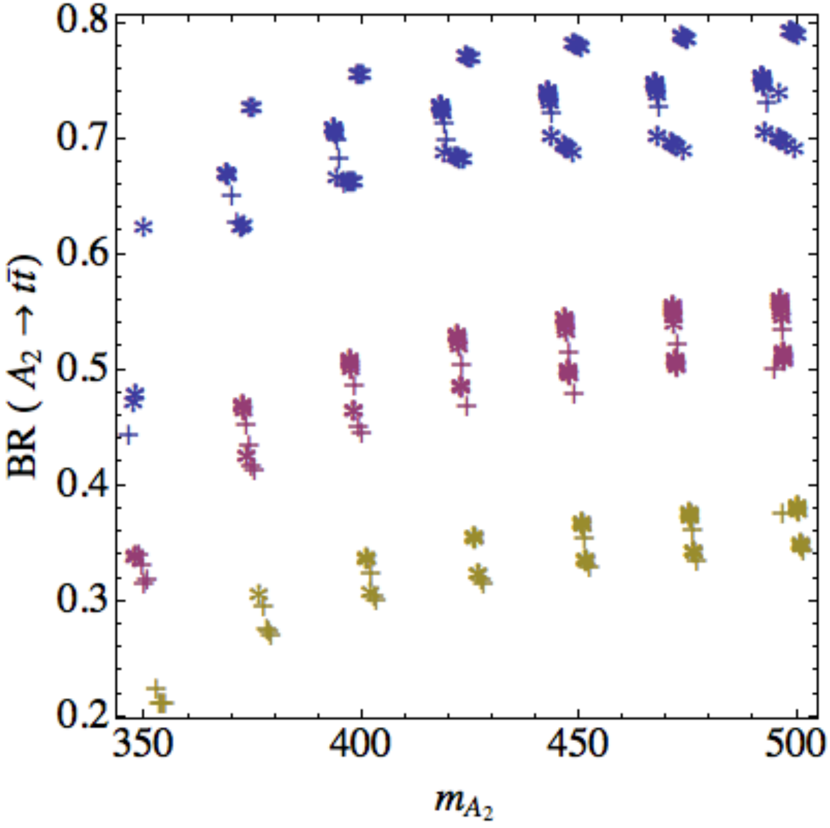


A2 BR

A2 BR

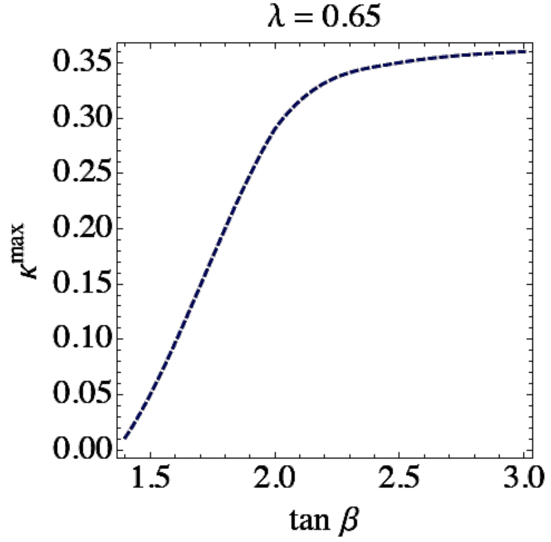
- tt + chargino/neutralinos

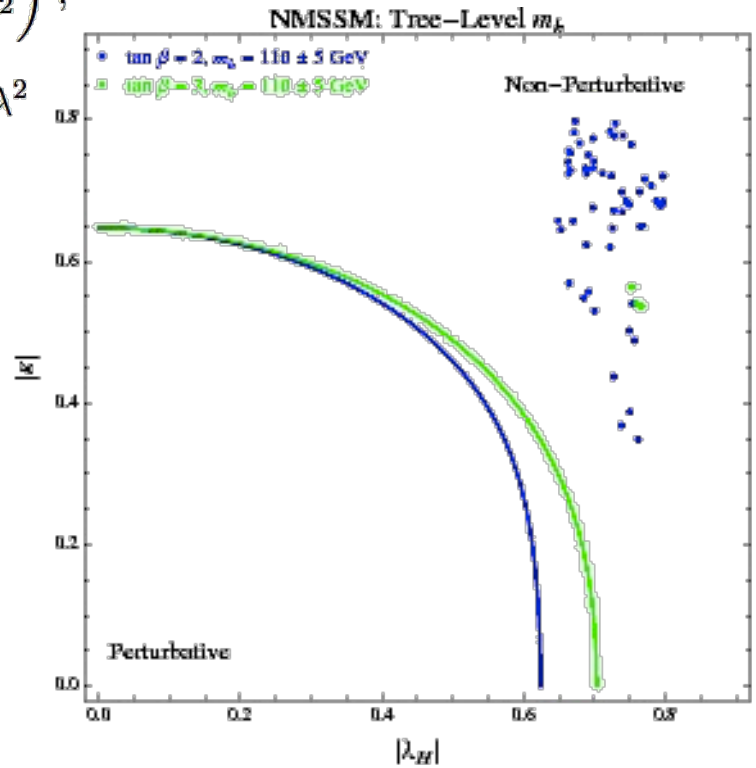




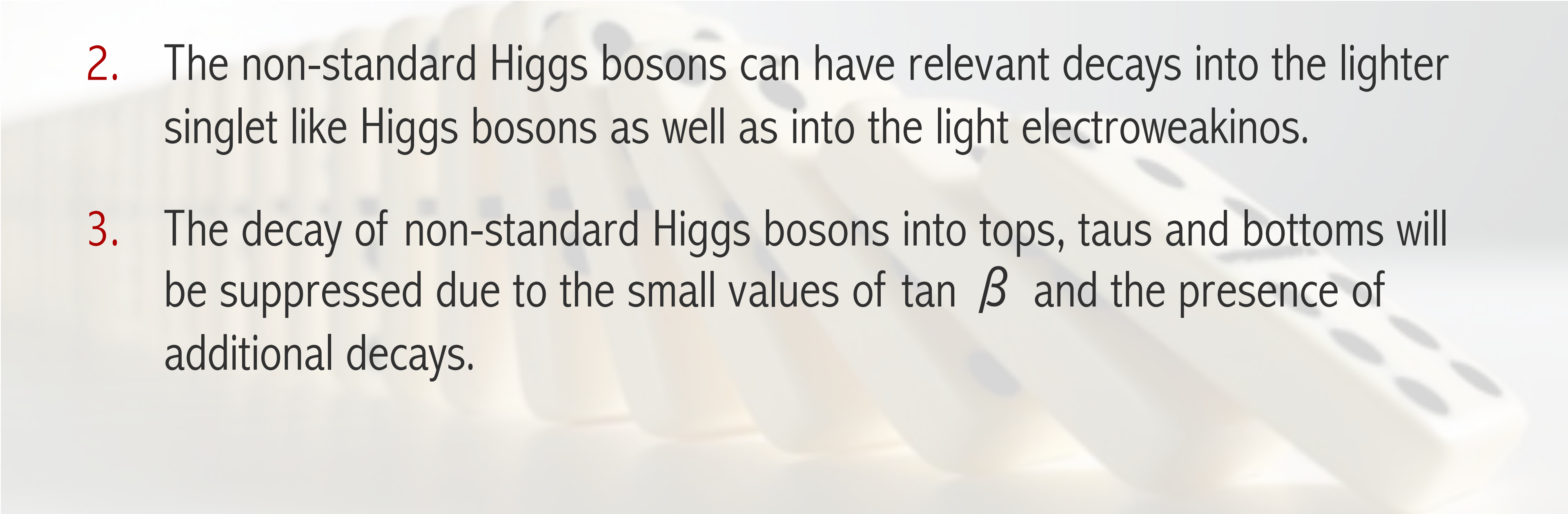
RGE

$$
\begin{aligned}
16\pi^2 \frac{d\lambda^2}{dt} &= \lambda^2\Big(3h_t^2 + 3h_b^2 + h_\tau^2 + 4\lambda^2 + 2\kappa^2 - g_1^2 - 3g_2^2\Big) \\
&+ \frac{\lambda^2}{16\pi^2}\Big(-10\lambda^4 - 9h_t^4 - 9h_b^4 - 3h_\tau^4 - 8\kappa^4 - 9\lambda^2 h_t^2 - 9\lambda^2 h_b^2 \\
&- 3\lambda^2 h_\tau^2 - 12\lambda^2\kappa^2 - 6h_t^2 h_b^2 + 2g_1^2\lambda^2 + \frac{4}{3}g_1^2 h_t^2 - \frac{2}{3}g_1^2 h_b^2 + 2g_1^2 h_\tau^2 \\
&+ 6g_2^2\lambda^2 + 16g_3^2 h_t^2 + 16g_3^2 h_b^2 + \frac{23}{2}g_1^4 + \frac{15}{2}g_2^4 + 3g_1^2 g_2^2\Big), \\
16\pi^2 \frac{d\kappa^2}{dt} &= \kappa^2\Big(6\lambda^2 + 6\kappa^2\Big) + \frac{\kappa^2}{16\pi^2}\Big(-24\kappa^4 - 12\lambda^4 - 24\kappa^2\lambda^2 \\
&- 18h_t^2\lambda^2 - 18h_b^2\lambda^2 - 6h_\tau^2\lambda^2 + 6g_1^2\lambda^2 + 18g_2^2\lambda^2\Big).
\end{aligned}
$$





Phenomenological Consequences



1. The gluon fusion production cross section of the would be heavy MSSM states (**A** and **H**) is enhanced due to the top Yukawa contributions at low tan β , and can be of the order of a few *pb*.
2. The non-standard Higgs bosons can have relevant decays into the lighter singlet like Higgs bosons as well as into the light electroweakinos.
3. The decay of non-standard Higgs bosons into tops, taus and bottoms will be suppressed due to the small values of tan β and the presence of additional decays.