



Higgcision in the Minimal Supersymmetric Standard Model

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arXiv:[hep-ph] 1501.03552

SUSY 2015, 2015.08.25



Outlines



- Introduction
- Higgcision Formalism
- Higgcision Fitting
- Implication on the MSSM spectrum
- Conclusion

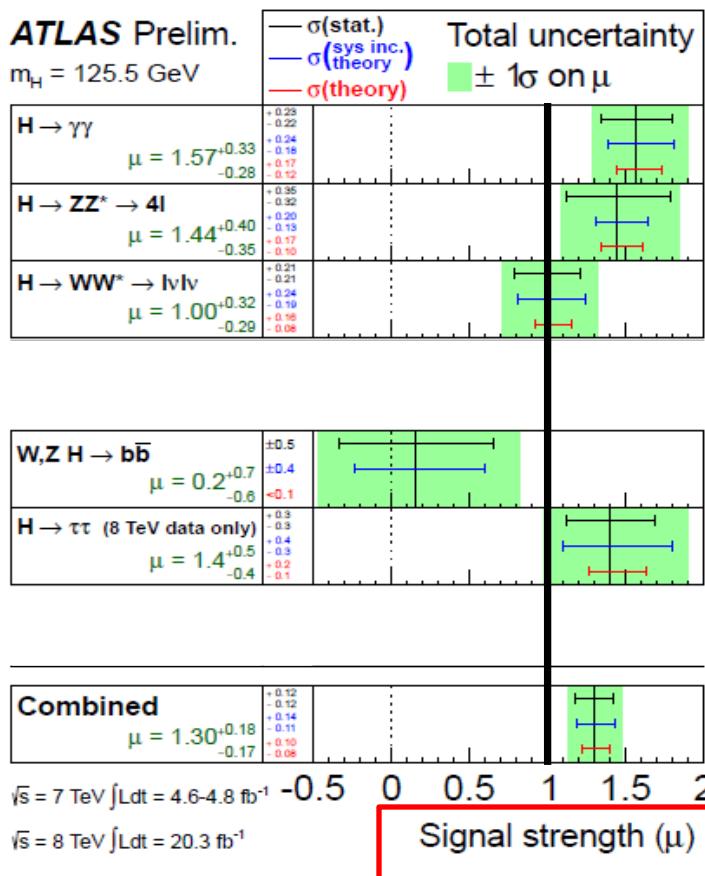


Introduction

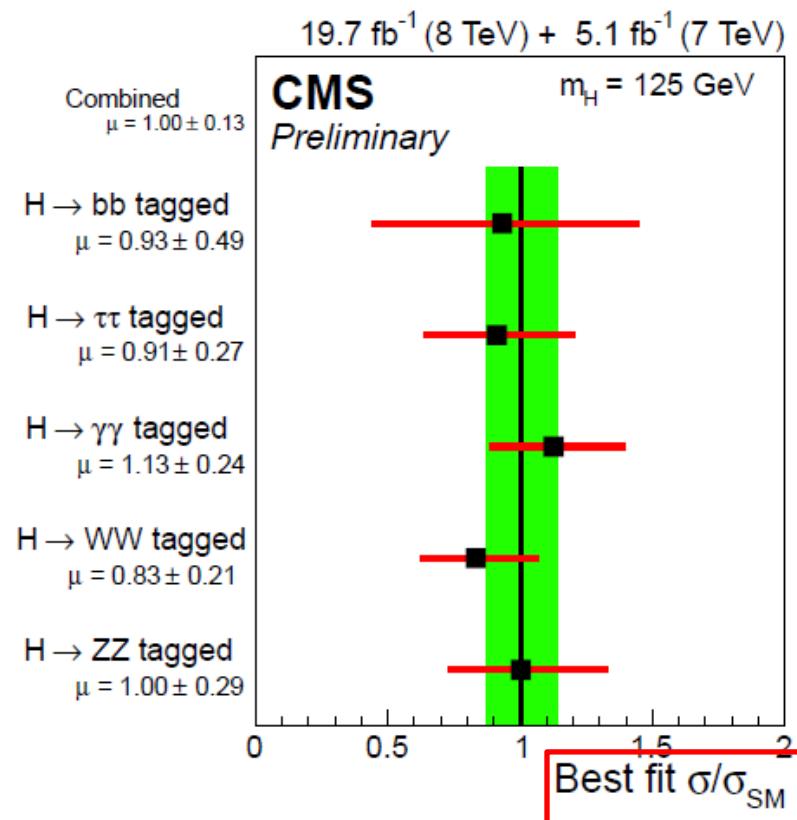
Introduction

- The signal strength data of 125GeV Higgs boson from ICHEP2014 (summer 2014):

ATLAS-CONF-2014-009



CMS PAS HIG-14-009



- New Higgs boson data presented in ICHEP 2014.
- Higgs to diphoton channel:

ATLAS: $1.6 \pm 0.4 \rightarrow 1.17 \pm 0.27$

CMS: $0.78^{+0.28}_{-0.16} \rightarrow 1.12^{+0.37}_{-0.32}$

- ATLAS ZZ* increase from $1.5 \pm 0.4 \rightarrow 1.66^{+0.45}_{-0.38}$.
CMS stays about the same.
- The total $\chi^2_{SM} / \text{d.o.f}$ for SM now is 16.76/29.
 $\text{d.o.f} = \# \text{ of data} - \# \text{ of free parameters for model}$
- P-value of SM is 0.966.

- New Higgs boson data presented in ICHEP 2014.
- Higgs to diphoton channel: SM?

ATLAS: 1.6 ± 1

CMS: 0.78^{+0}_{-0}

- ATLAS ZZ* increase from CMS stays about the same



<http://www.flowcentric.com/>

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- P-value of SM is 0.966.

- MSSM.
- Direct search from LHC. Stop, sbottom > 600GeV
 - The ATLAS Collaboration ,arXiv:1407.0583
 - The CMS Collaborations, arXiv:1503.08037
- EW precision data. W mass
 - CDF and D0 Collaborations ,arXiv:1204.0042
 - P. Bechtle, S. Heinemeyer, O. Stal, T. Stefaniak, G. Weiglein, L. Zeune, arXiv:1211.1955
- Low energy observation: $B \rightarrow X_s \gamma$ (Babar, Belle B-factor, and CLEO) Chargino, charge Higgs,
 $B_s^0 \rightarrow \mu^+ \mu^-$ LHCb stop, sbottom.
 - G. Barenboim, C. Bosch, M.L. Lopez-Ibanez, O. Vives ,arXiv:1307.5973



Higgcision in MSSM: Formalism

- Model independent Higgcision parameters
(CP conserving):

Scalar Yukawa (H-t-t): C_u^S, C_d^S, C_l^S

Gauge coupling (W or Z): C_V

New particle (H^\pm , squarks, stau): $\Delta S^\gamma, \Delta S^g$

Invisible decay (light Higgs, neutrolino): $\Delta\Gamma_{\text{tot}}$

- SM: $C_u^S = C_d^S = C_l^S = 1$

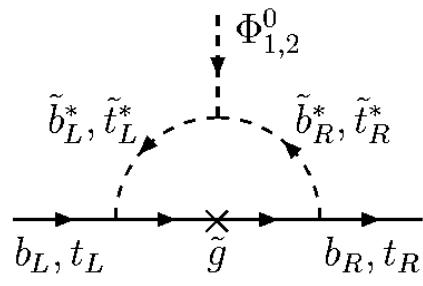
$$C_V = 1$$

$$\Delta S^\gamma = \Delta S^g = \Delta\Gamma_{\text{tot}} = 0$$

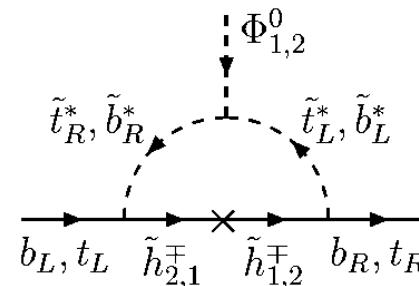
- Higgs sector of MSSM is similar to the Type-II 2HDM.

K. Cheung, J.S. Lee, P.Y. Tseng, JHEP01(2014)085

- Threshold correction to down-type Yukawa coupling:
- From sbottom-gluino diagram and stop-Higgsino diagram:



(a)



(b)

Apostolos Pilaftsis, arXiv:hep-ph/0207277v4

$$C_u^S = O_{\phi_2 i} / \sin \beta$$
$$C_d^S = \left(\frac{O_{\phi_1 i} + \kappa_d O_{\phi_2 i}}{1 + \kappa_d \tan \beta} \right) \frac{1}{\cos \beta}$$
$$C_l^S = O_{\phi_1 i} / \cos \beta$$
$$C_V = \cos \beta \ O_{\phi_1 i} + \sin \beta \ O_{\phi_2 i}$$

- For convenient, we will use :

C_u^S , $\tan \beta$, ΔS^γ , ΔS^g , κ_d , $\Delta \Gamma_{tot}$



Higgcision in MSSM: Fitting

- The fitting categorization:

 $C_u^S, \tan\beta, \Delta S^\gamma, \Delta S^g, \kappa_d, \Delta\Gamma_{tot}$

- CPC.II

- CPC.II.2: $C_u^S, \tan\beta$
- CPC.II.3: $C_u^S, \tan\beta, \kappa_d$
- CPC.II.4: $C_u^S, \tan\beta, \kappa_d, \Delta\Gamma_{tot}$

- CPC.III

- CPC.III.3: $C_u^S, \tan\beta, \Delta S^\gamma$
- CPC.III.4: $C_u^S, \tan\beta, \Delta S^\gamma, \kappa_d$
- CPC.III.5: $C_u^S, \tan\beta, \Delta S^\gamma, \kappa_d, \Delta\Gamma_{tot}$

- CPC.IV

- CPC.IV.4: $C_u^S, \tan\beta, \Delta S^\gamma, \Delta S^g$
- CPC.IV.5: $C_u^S, \tan\beta, \Delta S^\gamma, \Delta S^g, \kappa_d$
- CPC.IV.6: $C_u^S, \tan\beta, \Delta S^\gamma, \Delta S^g, \kappa_d, \Delta\Gamma_{tot}$

- The fitting categorization:

 $C_u^S, \tan\beta, \Delta S^\gamma, \Delta S^g, \kappa_d, \Delta\Gamma_{tot}$

- CPC.II

- CPC.II.2: $C_u^S, \tan\beta$
- CPC.II.3: $C_u^S, \tan\beta, \kappa_d$
- CPC.II.4: $C_u^S, \tan\beta, \kappa_d, \Delta\Gamma_{tot}$

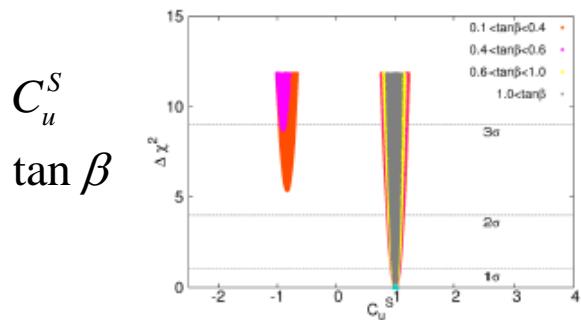
- CPC.III

- CPC.III.3: $C_u^S, \tan\beta, \Delta S^\gamma$
- CPC.III.4: $C_u^S, \tan\beta, \Delta S^\gamma, \kappa_d$
- CPC.III.5: $C_u^S, \tan\beta, \Delta S^\gamma, \kappa_d, \Delta\Gamma_{tot}$

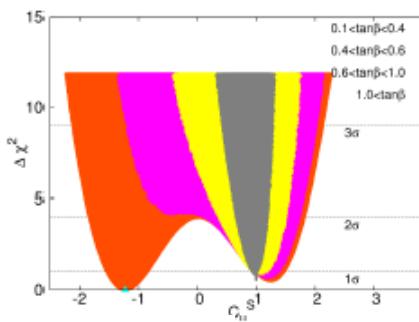
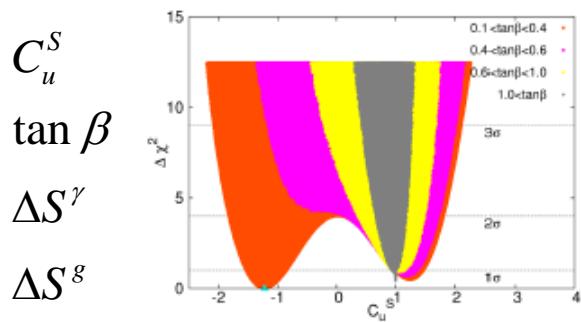
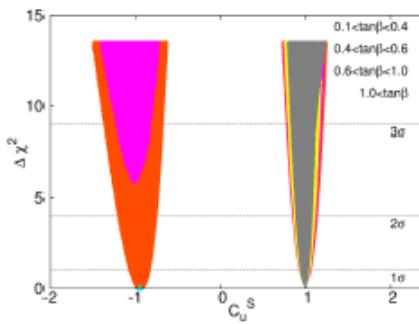
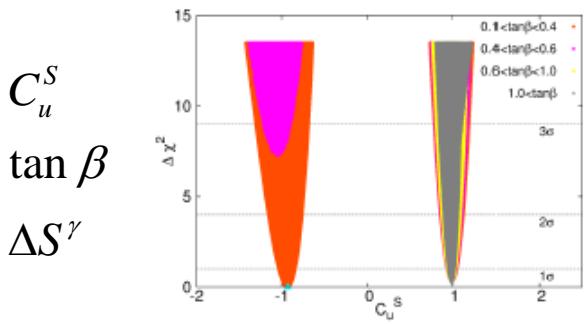
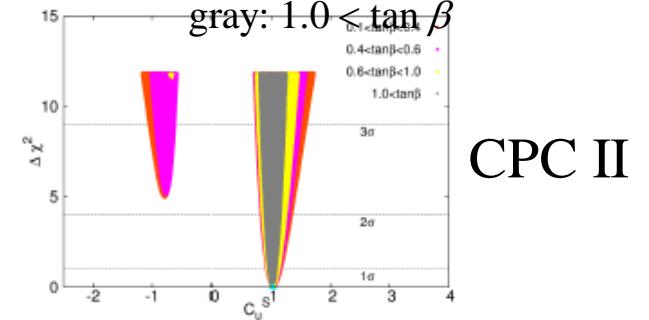
- CPC.IV

- CPC.IV.4: $C_u^S, \tan\beta, \Delta S^\gamma, \Delta S^g$
- CPC.IV.5: $C_u^S, \tan\beta, \Delta S^\gamma, \Delta S^g, \kappa_d$
- CPC.IV.6: $C_u^S, \tan\beta, \Delta S^\gamma, \Delta S^g, \kappa_d, \Delta\Gamma_{tot}$

Fitting



plots of $C_u^S - \Delta\chi^2$



+ κ_d

+ κ_d , $\Delta\Gamma_{tot}$

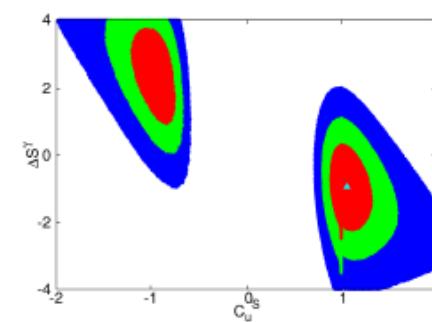
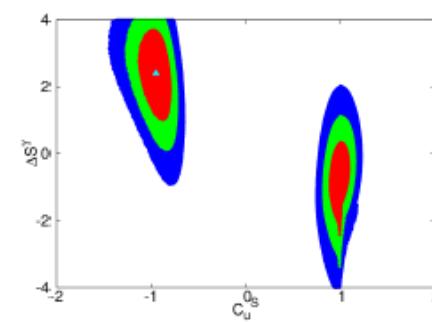
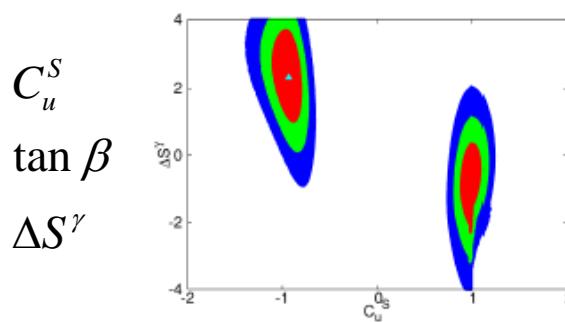
Fitting

C_u^S
 $\tan \beta$

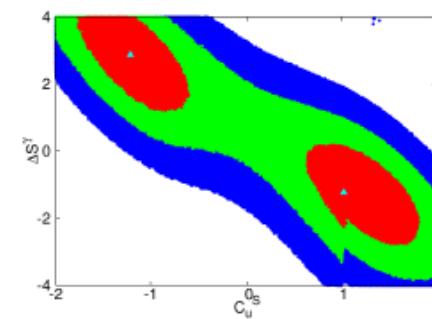
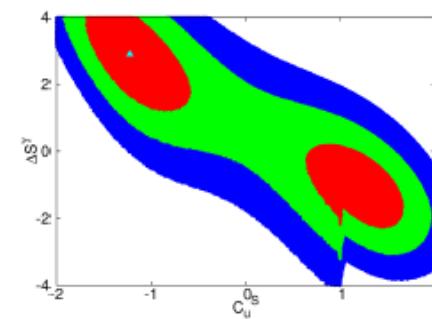
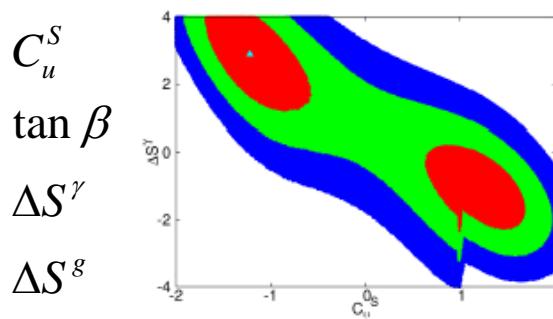
plots of $C_u^S - \Delta S^\gamma$

$\Delta\chi^2 \leq 2.3$ (red 68.3%),
 $\Delta\chi^2 \leq 5.99$ (green 95%),
 $\Delta\chi^2 \leq 11.83$ (blue 99.7%)

CPC II



CPC III



CPC IV

+ κ_d

+ κ_d , $\Delta\Gamma_{tot}$

Fitting

C_u^S
 $\tan \beta$

plots of $C_u^S - \Delta S^\gamma$

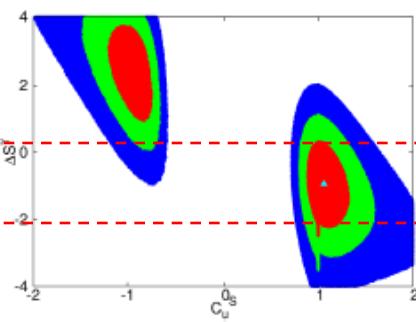
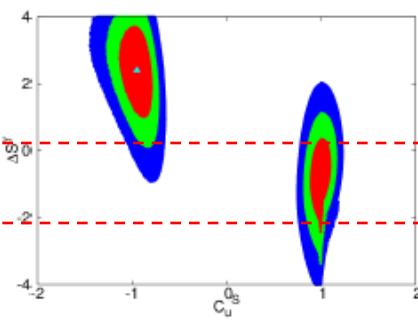
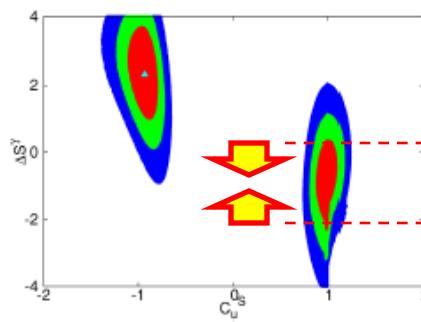
$$S_\text{SM}^\gamma \approx -6.64$$

$$\Delta S^\gamma \approx -1 \pm 1 \Rightarrow 15\%$$

$\Delta\chi^2 \leq 2.3$ (red 68.3%),
 $\Delta\chi^2 \leq 5.99$ (green 95%),
 $\Delta\chi^2 \leq 11.83$ (blue 99.7%)

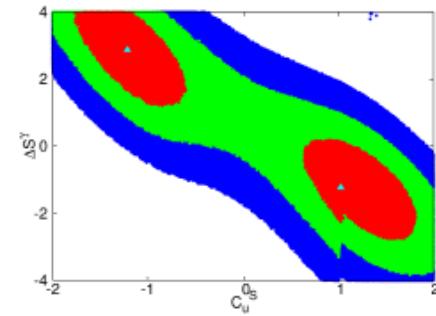
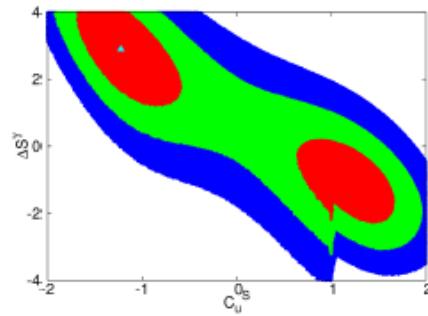
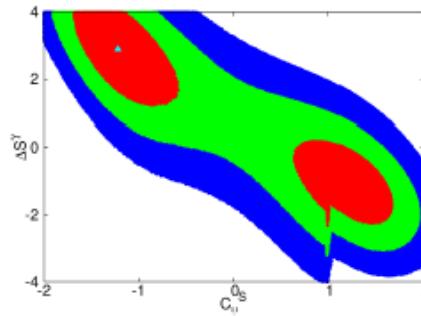
CPC II

C_u^S
 $\tan \beta$
 ΔS^γ



CPC III

C_u^S
 $\tan \beta$
 ΔS^γ
 ΔS^g



CPC IV

+ κ_d

+ κ_d , $\Delta\Gamma_{tot}$



Implications on the MSSM spectrum

$$C_u^S, \tan \beta, \underline{\Delta S^\gamma}, \Delta S^g, \kappa_d, \Delta \Gamma_{tot}$$

- In previous section,
 $\kappa_d, \Delta S^\gamma, \Delta S^g$ are independent variables.
- In this section, one-loop contribution from SUSY particles.

MSSM-1: Charginos only $\tilde{\chi}_1^\pm, \tilde{\chi}_2^\pm$: ΔS^γ

MSSM-2: Scalar taus $\tilde{\tau}_1, \tilde{\tau}_2$: ΔS^γ

MSSM-3: Chargino, scalar tau, sbottom, stop:

$$\kappa_d, \Delta S^\gamma, \Delta S^g$$

- Squarks mass matrix in the $(\tilde{q}_L, \tilde{q}_R)$ basis:

$$\tilde{\mathcal{M}}_q^2 = \begin{pmatrix} M_{\tilde{Q}_3}^2 + m_q^2 + c_{2\beta} M_Z^2 (T_z^q - Q_q s_W^2) & h_q^* v_q (A_q^* - \mu R_q) / \sqrt{2} \\ h_q v_q (A_q - \mu^* R_q) / \sqrt{2} & M_{\tilde{R}_3}^2 + m_q^2 + c_{2\beta} M_Z^2 Q_q s_W^2 \end{pmatrix}$$

- Diagonalized by unitary matrix $U^{b\dagger} \mathcal{M}_b^2 U^b = \text{diag}(m_{b1}^2, m_{b2}^2)$
- Contributions to κ_d , ΔS^γ , ΔS^g :

C_u^S , $\tan \beta$, $A_t = A_b = A_\tau$,
 $M_{L3} = M_{E3}$, $M_{Q3} = M_{U3} = M_{D3}$,
 $M_3 = 1 \text{ TeV}$, $M_A = 300 \text{ GeV}$, $M_2 = \pm \mu$

- The best-fit point: The major contribution to ΔS^γ is from lighter scalar tau.

Fits	χ^2	χ^2/dof	$p\text{-value}$	Best-fit values										
	C_u^S	$\tan \beta$	κ_d	ΔS^γ	ΔS^g	$\Delta \Gamma_{tot}$								
All-SUSY	15.68	0.682	0.869	1.000	16.85	0.002	-0.846	0.001	-					
Best-fit values														
C_v	C_d^S	C_ℓ^S	M_{L_3}	M_{Q_3}	M_2	A_t	$M_{\tilde{\chi}_1^\pm}$	$M_{\tilde{\chi}_2^\pm}$	$M_{\tilde{\tau}_1}$	$M_{\tilde{\tau}_2}$	$M_{\tilde{t}_1}$	$M_{\tilde{t}_2}$	$M_{\tilde{b}_1}$	$M_{\tilde{b}_2}$
1.000	1.040	1.041	220	1732	-1255	-2218	1203	1310	94.5	303	1640	1829	1717	1748

$SM : \chi^2 = 16.76, \chi^2 / \text{dof} = 0.578, \text{P-value} = 0.966$

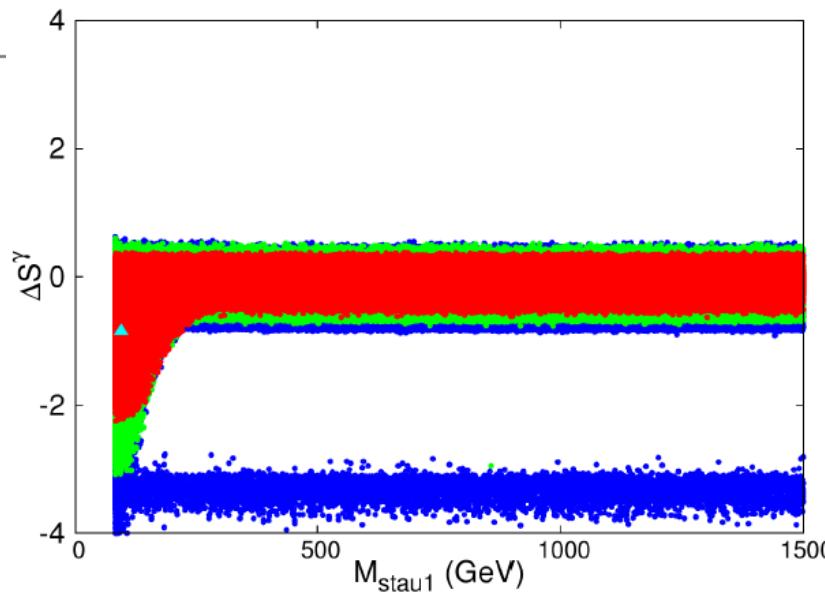
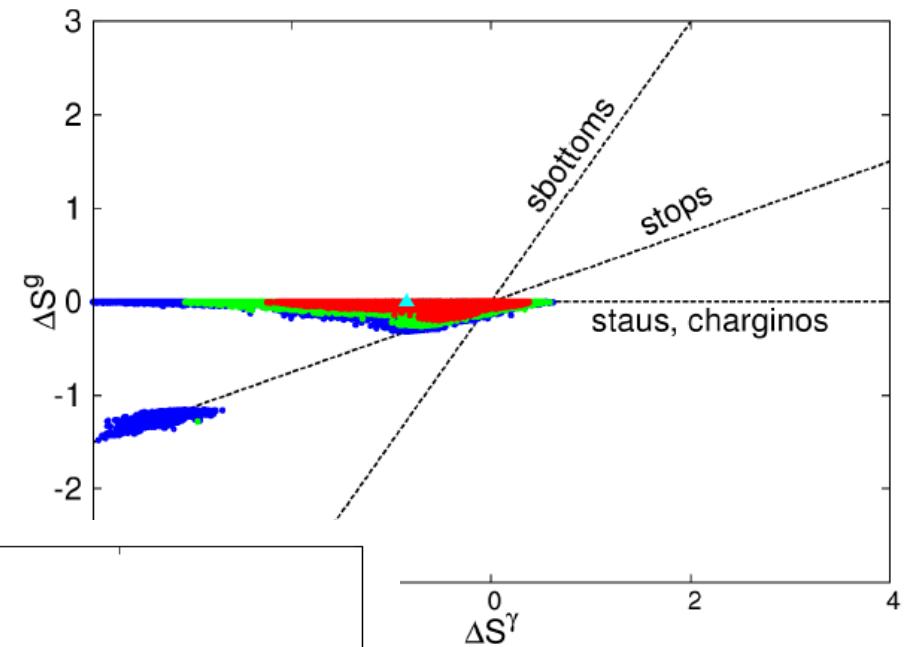
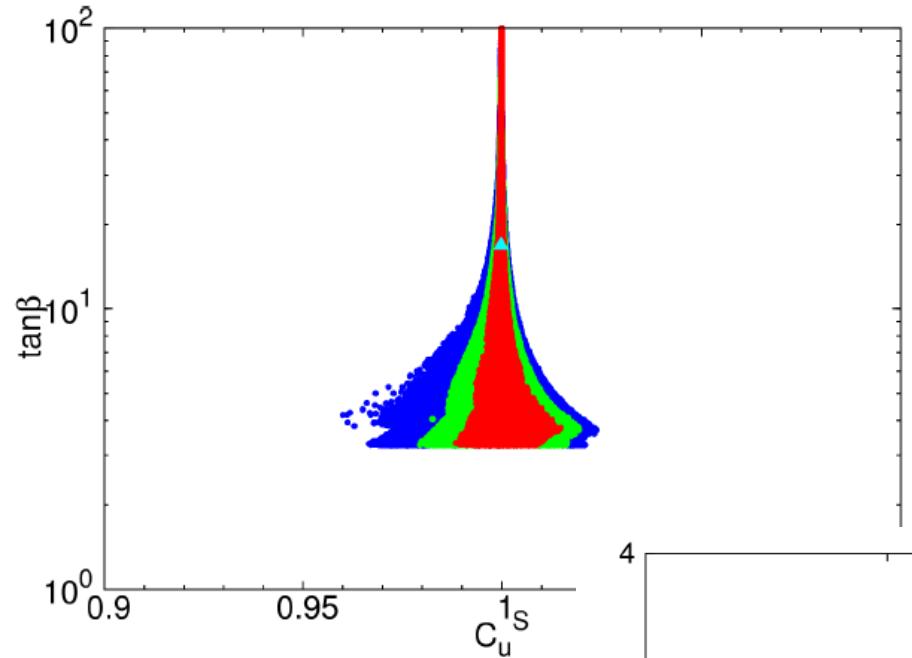
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Best-fit values														
C_v	C_d^S	C_ℓ^S	M_{L_3}	M_{Q_3}	M_2	A_t	$M_{\tilde{\chi}_1^\pm}$	$M_{\tilde{\chi}_2^\pm}$	$M_{\tilde{\tau}_1}$	$M_{\tilde{\tau}_2}$	$M_{\tilde{t}_1}$	$M_{\tilde{t}_2}$	$M_{\tilde{b}_1}$	$M_{\tilde{b}_2}$
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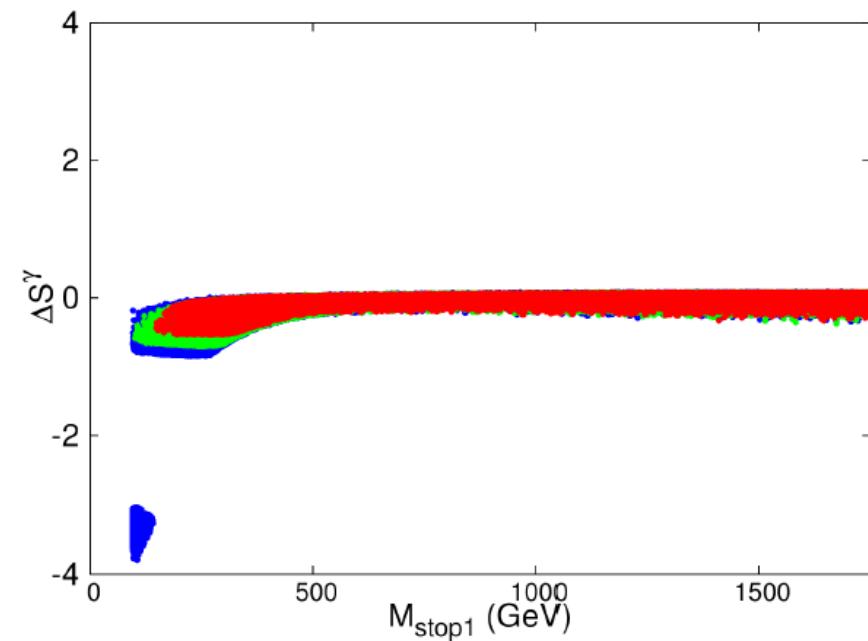
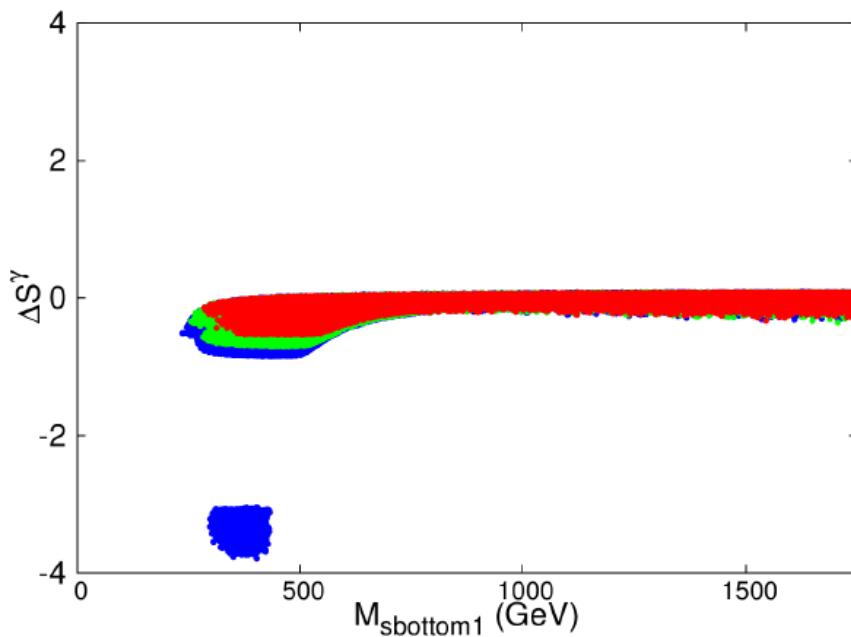
MSSM-3. **chargino, scalar taus, sbottom, stop**



$\Delta\chi^2 \leq 2.3$ (red 68.3%),
 $\Delta\chi^2 \leq 5.99$ (green 95%),
 $\Delta\chi^2 \leq 11.83$ (blue 99.7%)

- Restrict the lighter chargino and scalar tau mass:

$$M_{\tilde{\chi}_1^\pm} > 300 \text{ GeV} \text{ and } M_{\tilde{\tau}_1} > 300 \text{ GeV}$$



- Independent of sbottom and stop mass:

$$|\Delta S^\gamma| \leq 0.6 \text{ at } 68.3\% \Rightarrow \left| \Delta S^\gamma / S_{\text{SM}}^\gamma \right| \leq 0.1$$

$$|\Delta S^\gamma| \leq 0.2 \Rightarrow |\Delta S^\gamma / S_{\text{SM}}^\gamma| \leq 0.03$$

- Lighter chargino and scalar tau mass > 500 GeV.
- Lighter sbottom mass > 600 GeV and stop mass > 650 GeV.



Conclusion

- We have analyzed the relevant parameter space in the MSSM with respect to the most updated Higgs data.

$$C_u^S, \tan \beta, \Delta S^\gamma, \Delta S^g, \kappa_d, \Delta \Gamma_{tot}$$

- $C_u^S, \tan \beta$ determine the tree-level Yukawa and gauge couplings.
- The threshold effect of κ_d is insignificant. The invisible Higgs decay width $\Delta \Gamma_{tot}$ is relatively large.

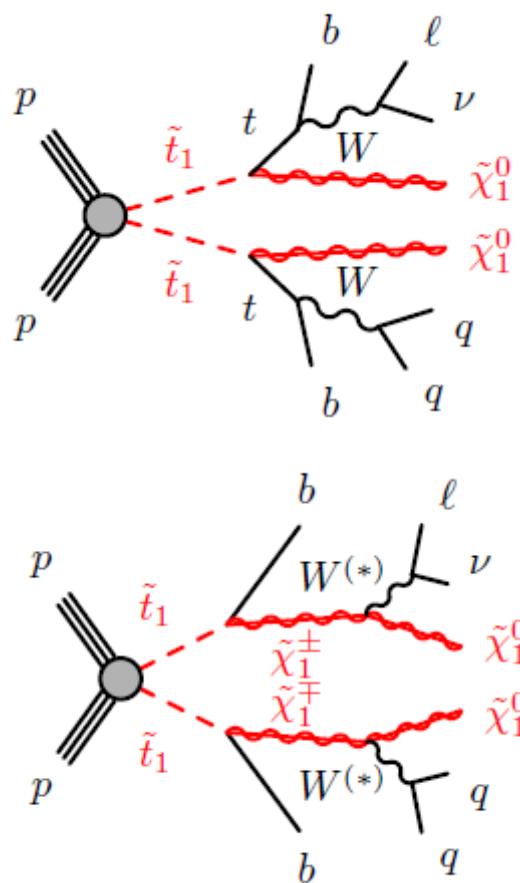
- The SUSY particles have one-loop contribute to ΔS^γ , ΔS^g , κ_d .
- In the squark case, ΔS^γ , ΔS^g are correlated.
- In the **MSSM-3** case, the best-fit point prefer a lighter scalar tau 94.5 GeV.
- The $H\gamma\gamma$ coupling need to be measured down to 10% accuracy to probe chargino and scalar tau \sim 300 GeV.
- Down to 3% accuracy to probe squarks \sim 600 GeV.
Comparable with LHC direct search.

Thank you !

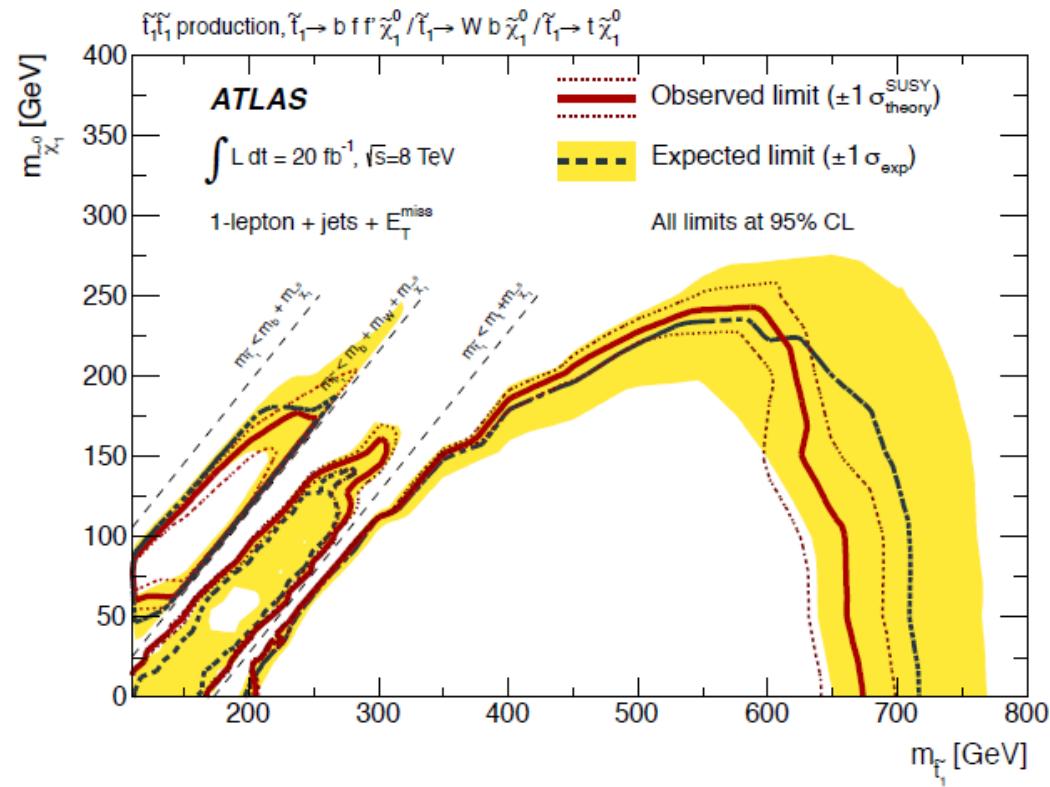
Back up

Introduction

- MSSM.
- Direct search from LHC. Stop, sbottom > 600GeV



The ATLAS Collaboration ,arXiv:1407.0583





Formalism: Higgs sector

- Higgs sector of MSSM is similar to the Type-II 2HDM.
- The mixing between the mass eigenstates $H_{1,2,3}$ and the EW eigenstates ϕ_1, ϕ_2, a is described by an orthogonal matrix $O_{\alpha j}$:

$$(\underbrace{\phi_1, \phi_2}_\text{CP even})_\alpha^T = O_{\alpha j} (H_1, H_2)_j^T$$

CP even

, with mass ordering $M_{H_1} < M_{H_2}$.

- We do not specify which one is the 125 GeV Higgs.

- Effective Yukawa coupling:

$$L_{H\bar{f}f} = - \sum_{f=u,d,l} \frac{gm_f}{2M_W} C_f^S H_i \bar{f} f$$

- Tree level:

$$\tan \beta \equiv v_2 / v_1$$

$$(C_f^S, C_f^P) = (O_{\phi_1 i} / \cos \beta, 0) \quad \text{for } f = (l, d)$$

$$(C_f^S, C_f^P) = (O_{\phi_2 i} / \sin \beta, 0) \quad \text{for } f = u$$

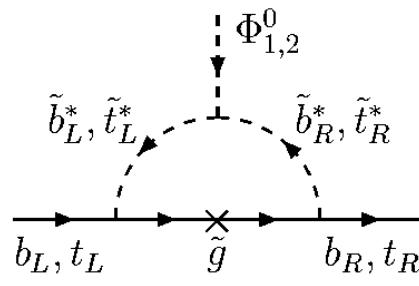
- Include threshold correction and CP conserving, the coupling for down-type quarks:

$$C_d^S = \left(\frac{O_{\phi_1 i} + \kappa_d O_{\phi_2 i}}{1 + \kappa_d \tan \beta} \right) \frac{1}{\cos \beta}$$

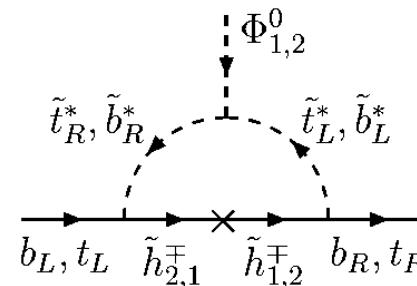
- Threshold correction to down-type Yukawa coupling:

$$h_d = \frac{\sqrt{2}m_d}{v \cos \beta} \frac{1}{1 + \kappa_d \tan \beta}$$

- From sbottom-gluino diagram and stop-Higgsino diagram:



(a)



(b)

Apostolos Pilaftsis, arXiv:hep-ph/0207277v4

- Higgs couplings to massive vector bosons:

$$L_{HVV} = gM_W \left(C_V W_\mu^+ W^{-\mu} + C_V \frac{1}{2c_W^2} Z_\mu Z^\mu \right) H_i$$

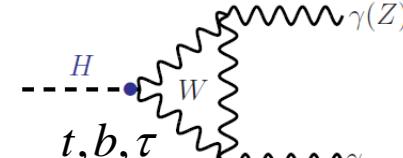
, and

$$C_V = \cos \beta \ O_{\phi_1 i} + \sin \beta \ O_{\phi_2 i}$$

Formalism: gauge bosons

A Djouadi, Phys.Rept.457 (2008)1-216

- $H\gamma\gamma$ coupling:

$$\mathcal{M}_{\gamma\gamma H} = -\frac{\alpha M_H^2}{4\pi v} \left\{ S^\gamma(M_H) \frac{(\epsilon_{1\perp}^* \cdot \epsilon_{2\perp}^*)}{\text{scalar}} - P^\gamma(M_H) \frac{2}{M_H^2} \langle \epsilon_1^* \epsilon_2^* k_1 k_2 \rangle \right\}$$


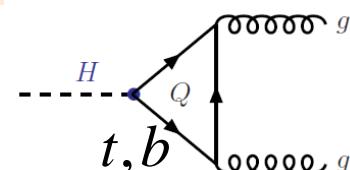
CP even : $S^\gamma \simeq -8.35 C_V + 1.76 C_u^S + (-0.015 + 0.017i) C_d^S + \Delta S^\gamma$

CP odd : $P^\gamma = 0$

- Hgg coupling:

CP even : $S^g \simeq 0.688 C_u^S + (-0.037 + 0.050i) C_d^S + \Delta S^g$

CP odd : $P^g = 0$



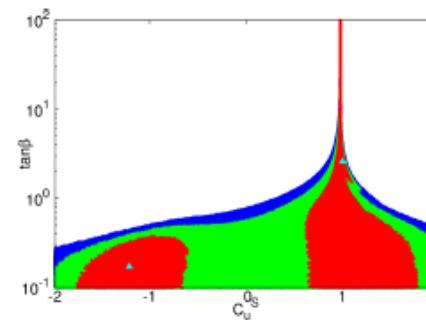
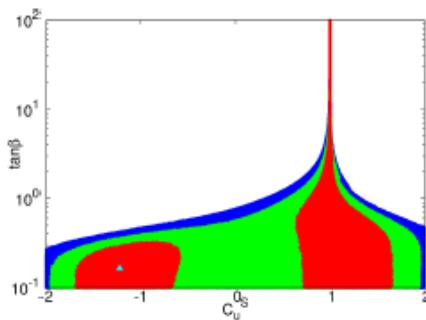
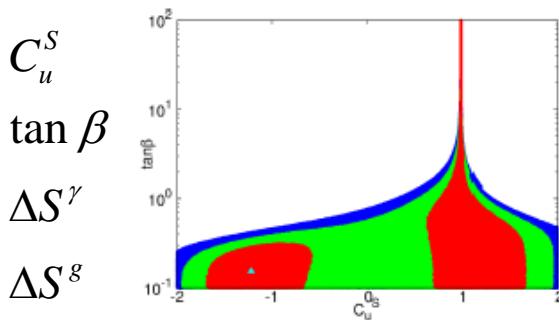
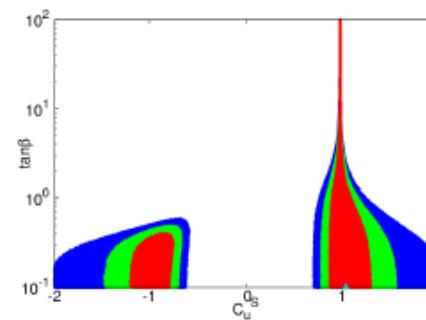
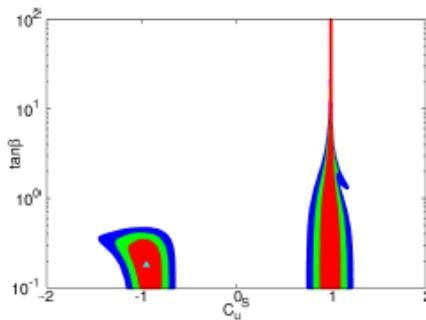
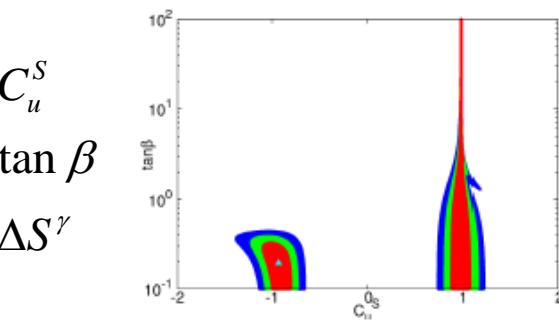
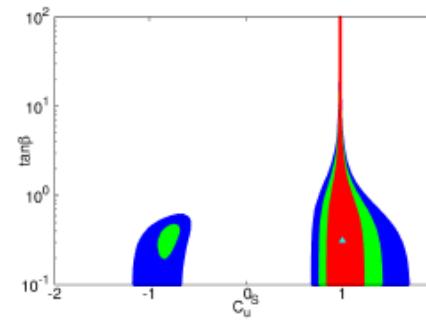
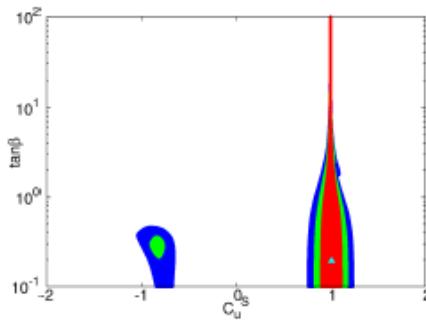
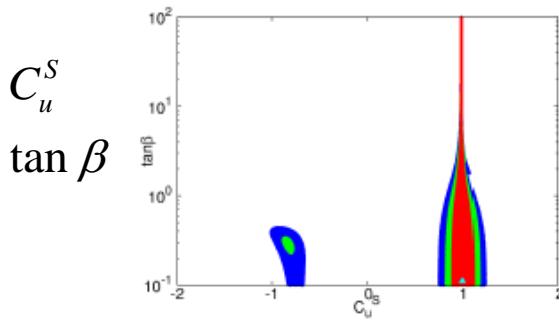
- SM $\chi^2_{SM} / \text{d.o.f}$ is 16.76/29, and P-value is 0.966.

	Fits	χ^2	χ^2/dof	p-value
$C_u^S, \tan \beta$ + κ_d + $\kappa_d, \Delta\Gamma_{tot}$	CPC.II.2	16.74	0.620	0.937
	CPC.II.3	16.74	0.644	0.917
	CPC.II.4	16.72	0.669	0.892
$C_u^S, \tan \beta, \Delta S^\gamma$ + κ_d + $\kappa_d, \Delta\Gamma_{tot}$	CPC.III.3	15.50	0.596	0.947
	CPC.III.4	15.48	0.619	0.929
	CPC.III.5	15.43	0.643	0.907
$C_u^S, \tan \beta, \Delta S^\gamma, \Delta S^g$ + κ_d + $\kappa_d, \Delta\Gamma_{tot}$	CPC.IV.4	14.85	0.594	0.945
	CPC.IV.5	14.83	0.618	0.926
	CPC.IV.6	14.83	0.645	0.901

Fitting

$\Delta\chi^2 \leq 2.3$ (red 68.3%),
 $\Delta\chi^2 \leq 5.99$ (green 95%),
 $\Delta\chi^2 \leq 11.83$ (blue 99.7%)

plots of $C_u^S - \tan \beta$



+ κ_d

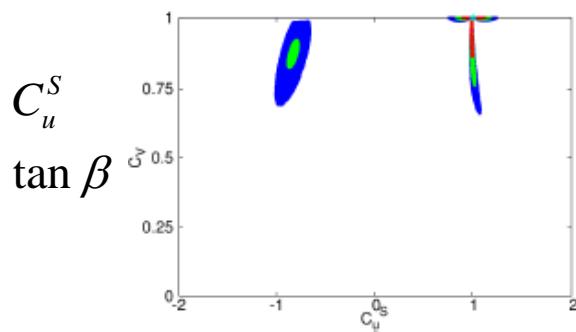
+ κ_d , $\Delta\Gamma_{tot}$

Fitting

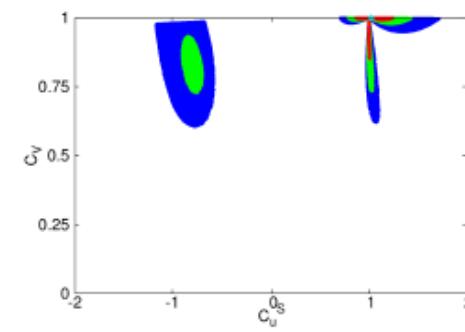
$\Delta\chi^2 \leq 2.3$ (red 68.3%),

$\Delta\chi^2 \leq 5.99$ (green 95%),

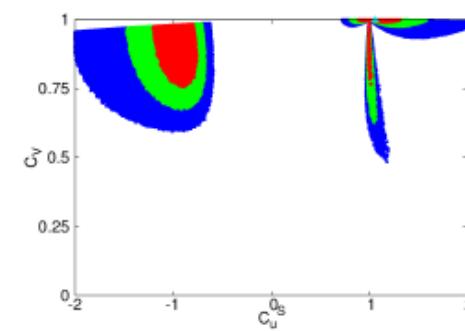
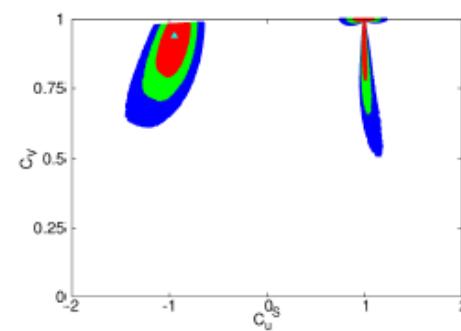
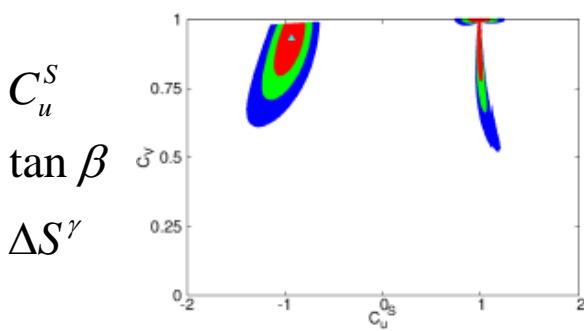
$\Delta\chi^2 \leq 11.83$ (blue 99.7%)



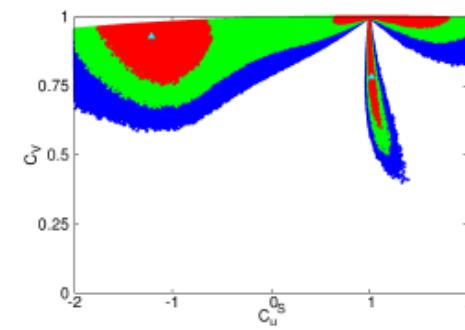
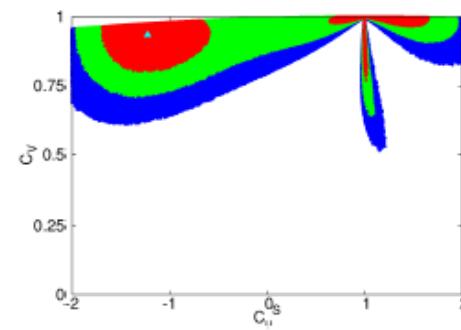
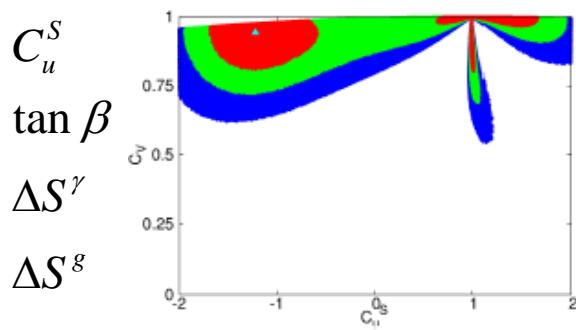
plots of $C_u^S - C_V$



CPC II



CPC III



CPC IV

+ κ_d

+ κ_d , $\Delta\Gamma_{tot}$

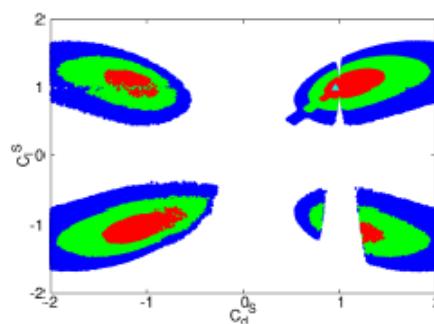
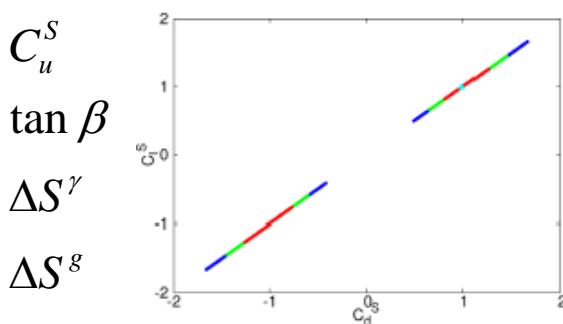
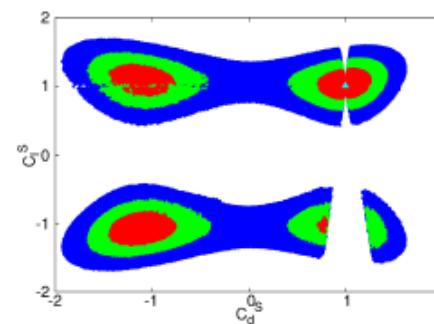
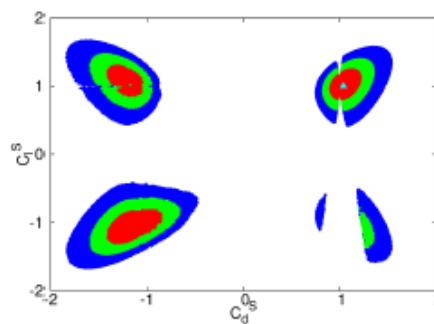
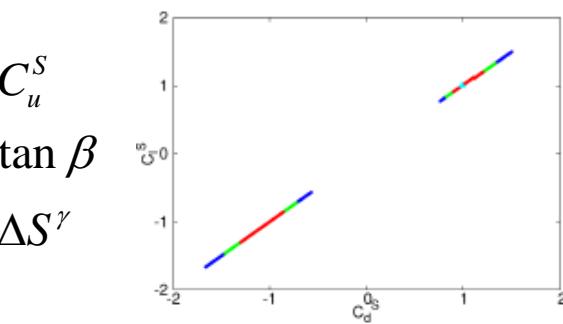
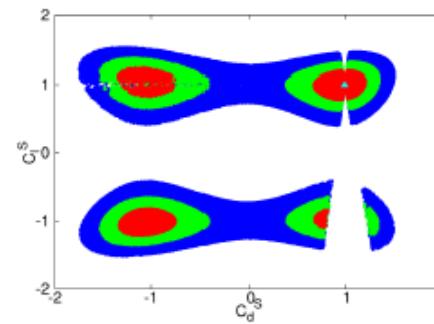
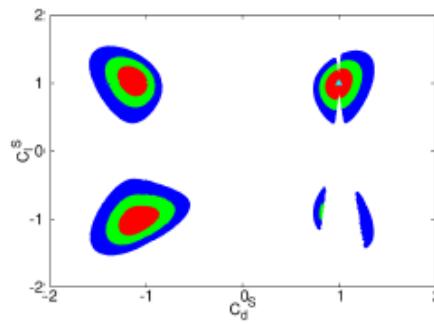
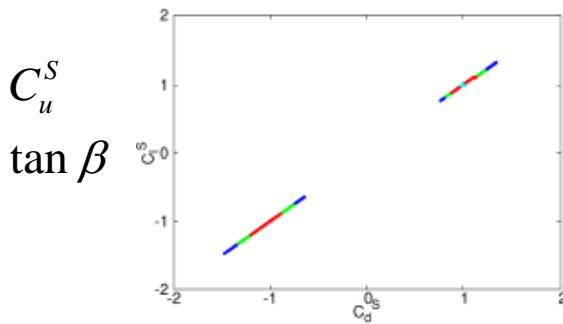
Fitting

$\Delta\chi^2 \leq 2.3$ (red 68.3%),

$\Delta\chi^2 \leq 5.99$ (green 95%),

$\Delta\chi^2 \leq 11.83$ (blue 99.7%)

plots of $C_d^S - C_l^S$



+ κ_d

+ κ_d , $\Delta\Gamma_{tot}$

CPC II

CPC III

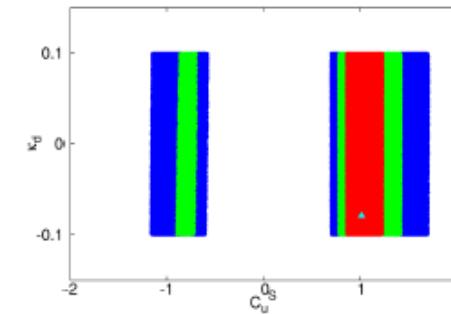
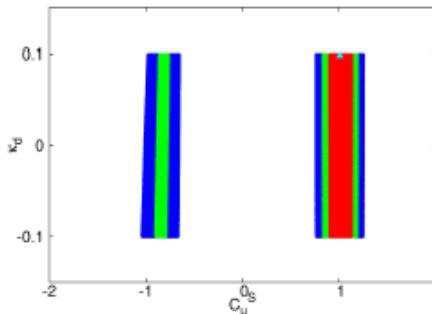
CPC IV

Fitting

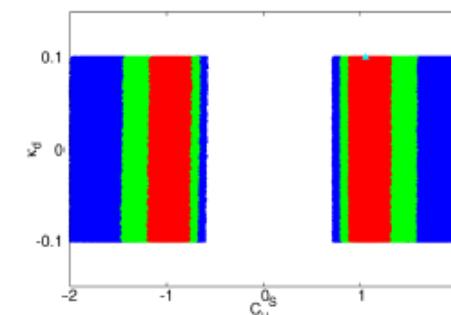
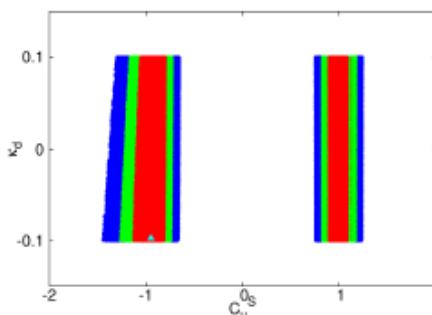
$\Delta\chi^2 \leq 2.3$ (red 68.3%),
 $\Delta\chi^2 \leq 5.99$ (green 95%),
 $\Delta\chi^2 \leq 11.83$ (blue 99.7%)

plots of $C_u^S - \kappa_d$

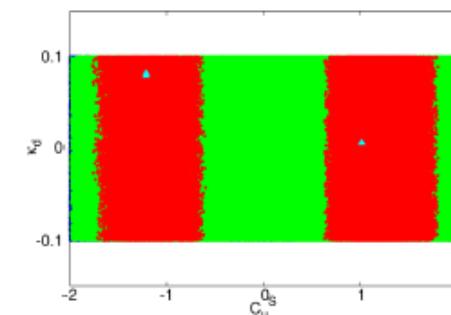
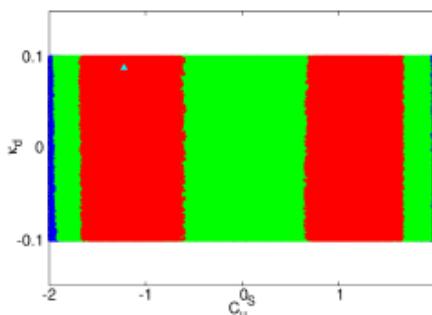
C_u^S
 $\tan \beta$



C_u^S
 $\tan \beta$
 ΔS^γ



C_u^S
 $\tan \beta$
 ΔS^γ
 ΔS^g



+ κ_d

+ $\kappa_d, \Delta\Gamma_{tot}$

CPC II

CPC III

CPC IV

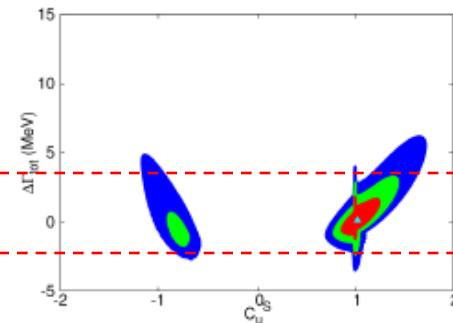
Fitting

$\Delta\chi^2 \leq 2.3$ (red 68.3%),
 $\Delta\chi^2 \leq 5.99$ (green 95%),
 $\Delta\chi^2 \leq 11.83$ (blue 99.7%)

plots of $C_u^S - \Delta\Gamma_{tot}$

C_u^S
 $\tan\beta$

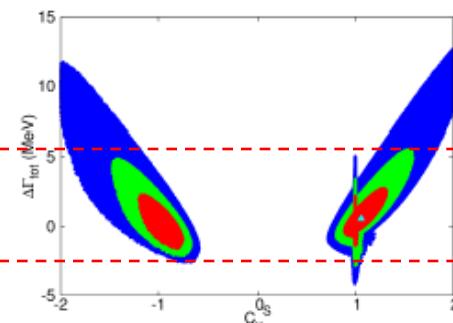
$-2.4 \text{ MeV} < \Delta\Gamma_{tot} < 3.3 \text{ MeV}$



CPC II

C_u^S
 $\tan\beta$
 ΔS^γ

$-2.9 \text{ MeV} < \Delta\Gamma_{tot} < 5.6 \text{ MeV}$



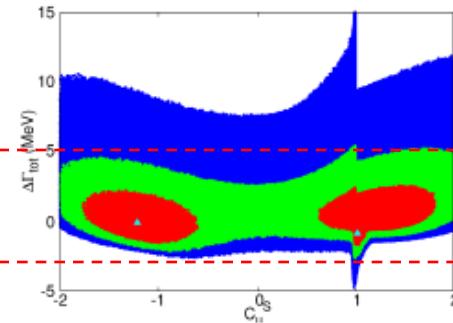
CPC III

C_u^S
 $\tan\beta$
 ΔS^γ
 ΔS^g

$-2.9 \text{ MeV} < \Delta\Gamma_{tot} < 5.6 \text{ MeV}$



$+ \kappa_d$



CPC IV

$+ \kappa_d, \Delta\Gamma_{tot}$

Fitting

C_u^S
 $\tan \beta$

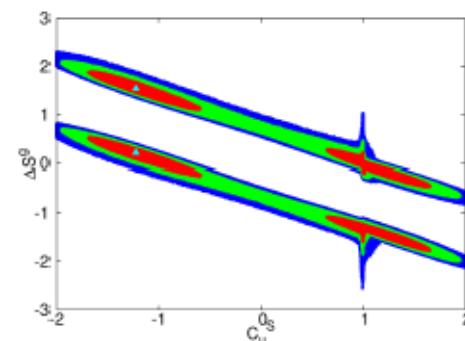
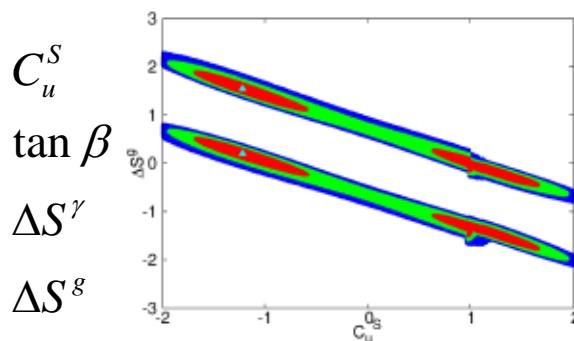
plots of $C_u^S - \Delta S^g$

$\Delta\chi^2 \leq 2.3$ (red 68.3%),
 $\Delta\chi^2 \leq 5.99$ (green 95%),
 $\Delta\chi^2 \leq 11.83$ (blue 99.7%)

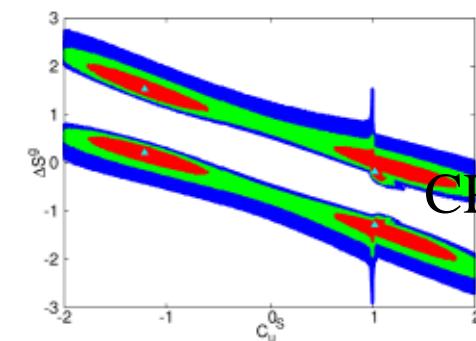
CPC II

C_u^S
 $\tan \beta$
 ΔS^γ

CPC III



+ κ_d



+ κ_d , $\Delta\Gamma_{tot}$

CPC IV

Fitting

C_u^S

$\tan \beta$

C_u^S

$\tan \beta$

ΔS^γ

C_u^S

$\tan \beta$

ΔS^γ

ΔS^g

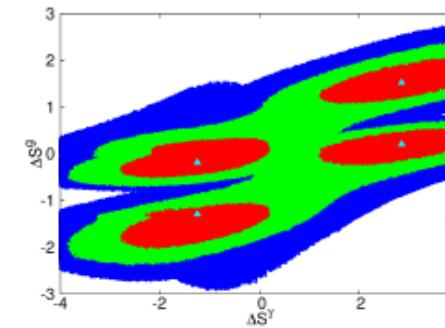
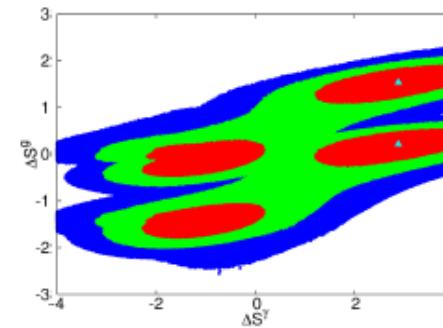
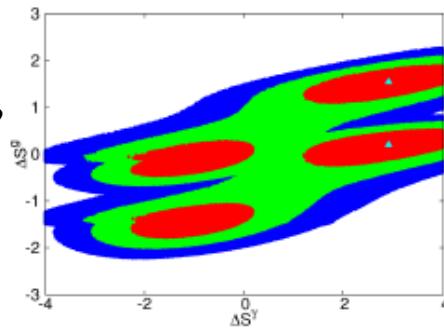
plots of $\Delta S^\gamma - \Delta S^g$

$\Delta\chi^2 \leq 2.3$ (red 68.3%),

$\Delta\chi^2 \leq 5.99$ (green 95%),

$\Delta\chi^2 \leq 11.83$ (blue 99.7%)

CPC II



+ κ_d

+ $\kappa_d, \Delta\Gamma_{tot}$

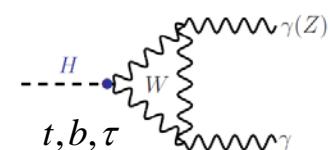
Implications on the MSSM spectrum: C. sbottoms

- Squarks mass matrix in the $(\tilde{q}_L, \tilde{q}_R)$ basis:

$$\tilde{\mathcal{M}}_q^2 = \begin{pmatrix} M_{\tilde{Q}_3}^2 + m_q^2 + c_{2\beta} M_Z^2 (T_z^q - Q_q s_W^2) & h_q^* v_q (A_q^* - \mu R_q) / \sqrt{2} \\ h_q v_q (A_q - \mu^* R_q) / \sqrt{2} & M_{\tilde{R}_3}^2 + m_q^2 + c_{2\beta} M_Z^2 Q_q s_W^2 \end{pmatrix}$$

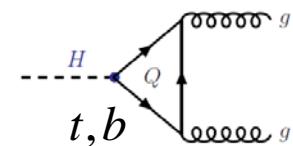
- Diagonalized by unitary matrix $U^{b\dagger} \tilde{\mathcal{M}}_b^2 U^b = \text{diag}(m_{b1}^2, m_{b2}^2)$
- Contributions to κ_d , ΔS^γ , ΔS^g :

$$\Delta S_i^\gamma = \sqrt{2} g \sum_{f=\tilde{\chi}_1^\pm, \tilde{\chi}_2^\pm} g_{H_i \bar{f} f}^S \frac{v}{m_f} F_{sf}(\tau_{if})$$

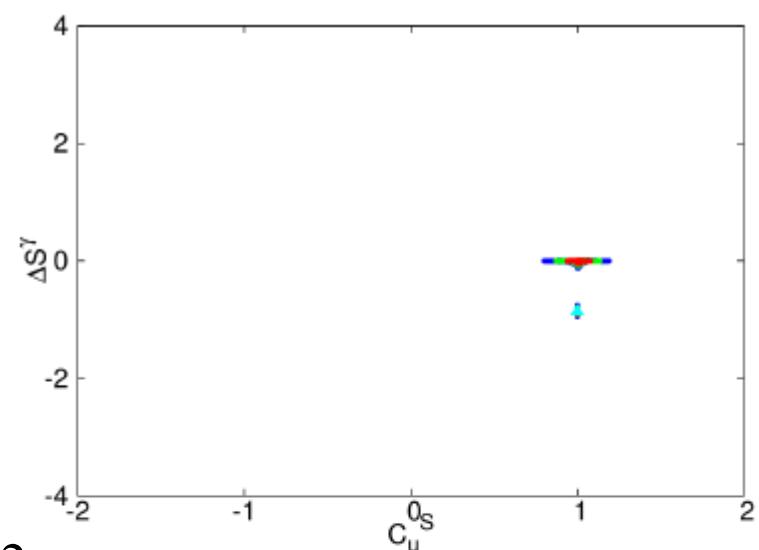
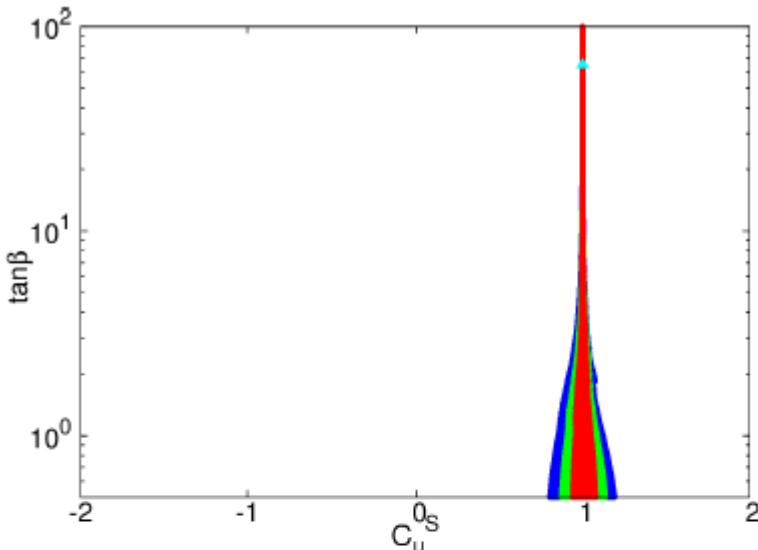


$$- \sum_{\tilde{f}_j = \tilde{t}_1, \tilde{t}_2, \tilde{b}_1, \tilde{b}_2, \tilde{\tau}_1, \tilde{\tau}_2} N_C Q_f^2 g_{H_i \tilde{f}_j^* \tilde{f}_j} \frac{v^2}{2m_{\tilde{f}_j}^2} F_0(\tau_{i\tilde{f}_j}) - g_{H_i H^+ H^-} \frac{v^2}{2M_{H^\pm}^2} F_0(\tau_{iH^\pm}),$$

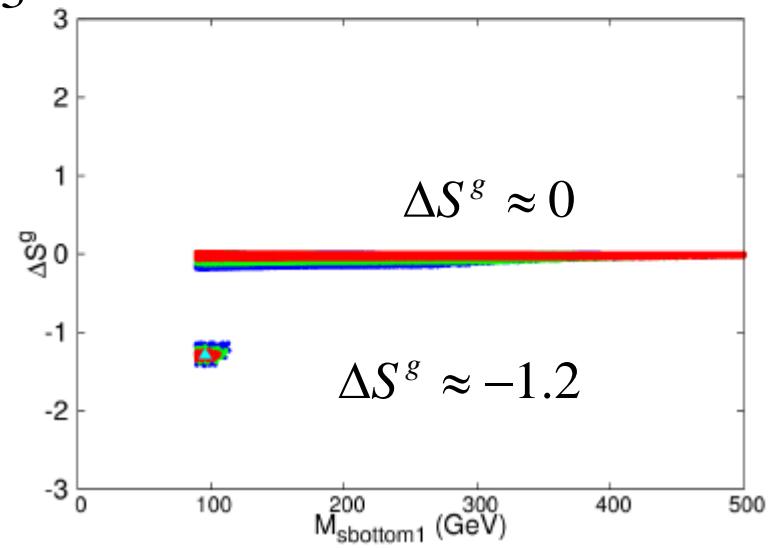
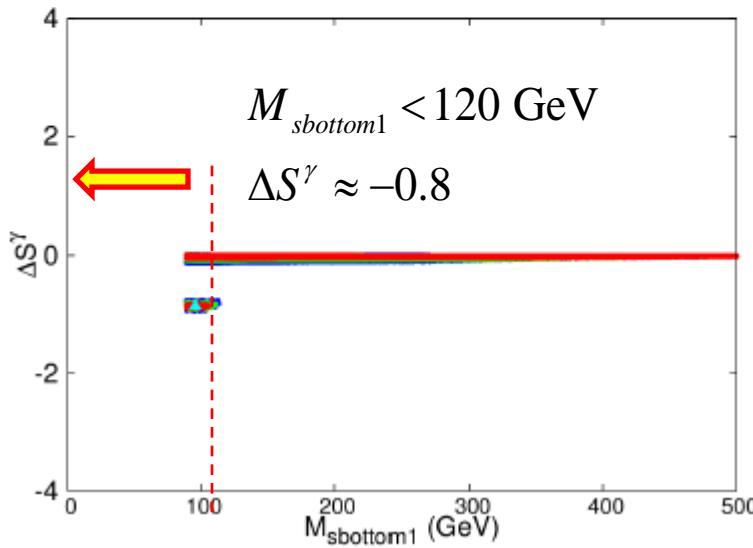
$$\Delta S_i^g = - \sum_{\tilde{f}_j = \tilde{t}_1, \tilde{t}_2, \tilde{b}_1, \tilde{b}_2} g_{H_i \tilde{f}_j^* \tilde{f}_j} \frac{v^2}{4m_{\tilde{f}_j}^2} F_0(\tau_{i\tilde{f}_j})$$



Implications on the MSSM spectrum: C. sbottoms



$$\Delta S^\gamma = \frac{2}{3} \Delta S^g \quad S_{SM}^\gamma \approx -6.59, \quad S_{SM}^g \approx 0.688$$



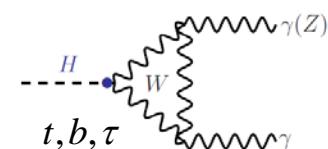
- $-0.1 < \kappa_d < 0.1$ is allowed. No significant impact on the fitting.
- CPC II, $C_u^S \approx 1$ is preferred.
- The 2nd local minimal around $C_u^S \approx -1$ disappears when $\tan \beta > 0.6$.
- Higgcision is sensitive to $H\gamma\gamma$ coupling down to 15% deviation from SM value.

- Charginos mass matrix in the $(\tilde{W}^-, \tilde{H}^-)$ basis:

$$\mathcal{M}_C = \begin{pmatrix} M_2 & \sqrt{2}M_W c_\beta \\ \sqrt{2}M_W s_\beta & \mu \end{pmatrix}$$

- Diagonalized by $C_R M_C C_L^\dagger = \text{diag}(M_{\chi_1^\pm}, M_{\chi_2^\pm})$
- Contributions to ΔS^γ :

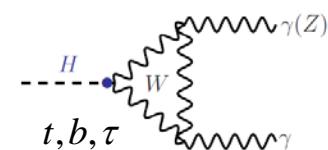
$C_u^S, \tan \beta, M_2, \mu$



- Scalar taus mass matrix in the $(\tilde{\tau}_L, \tilde{\tau}_R)$ basis:

$$\tilde{M}_\tau^2 = \begin{pmatrix} M_{\tilde{L}_3}^2 + m_\tau^2 + c_{2\beta} M_Z^2 (s_W^2 - 1/2) & h_\tau^* v_1 (A_\tau^* - \mu \tan \beta) / \sqrt{2} \\ h_\tau v_1 (A_\tau - \mu^* \tan \beta) / \sqrt{2} & M_{\tilde{E}_3}^2 + m_\tau^2 + c_{2\beta} M_Z^2 s_W^2 \end{pmatrix}$$

- Diagonalized by unitary matrix $U^\tau \tilde{M}_\tau^2 U^\tau = \text{diag}(m_{\tau 1}^2, m_{\tau 2}^2)$
- Contributions to ΔS^γ :



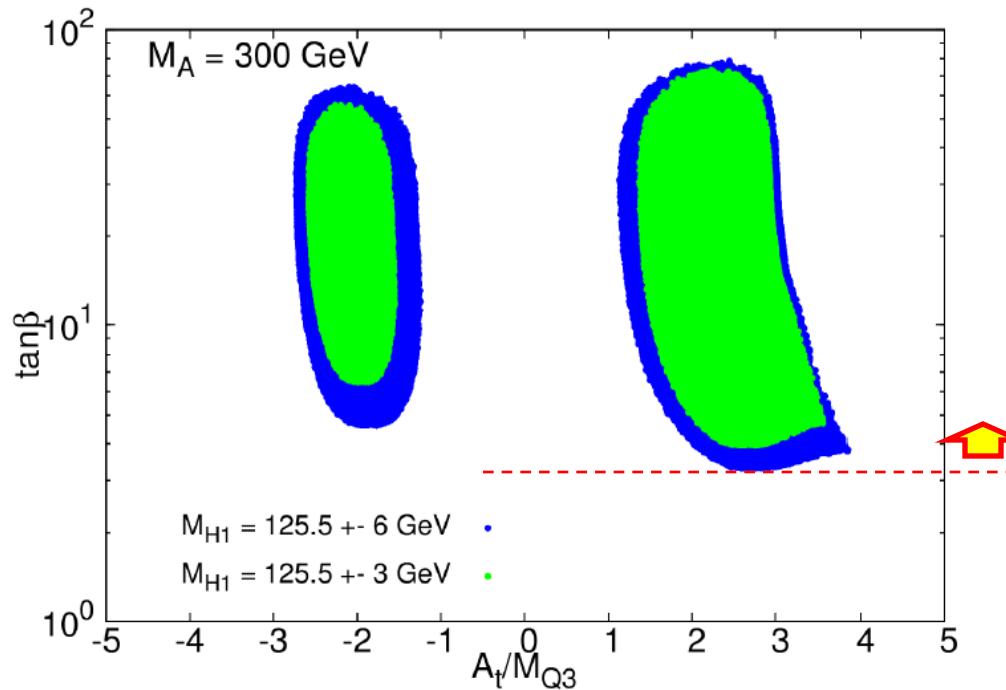
$C_u^S, \tan \beta, A_\tau, \mu, M_{L3} = M_{E3}$

Implications on the MSSM spectrum: D. stops

- The lightest Higgs boson mass: using 2-loop level analytical expression

S. Heinemeyer, W. Hollik, G. Weiglein, hep-ph/9903404

$$m_h^2 = m_h^{2,\text{tree}} + \Delta m_h^{2,\alpha,t/\tilde{t}} + \Delta m_h^{2,\alpha,\text{rest}} + \Delta m_h^{2,\alpha\alpha_s} + \Delta m_h^{2,\alpha^2}$$



$\tan \beta \subset [0.5, 100]$

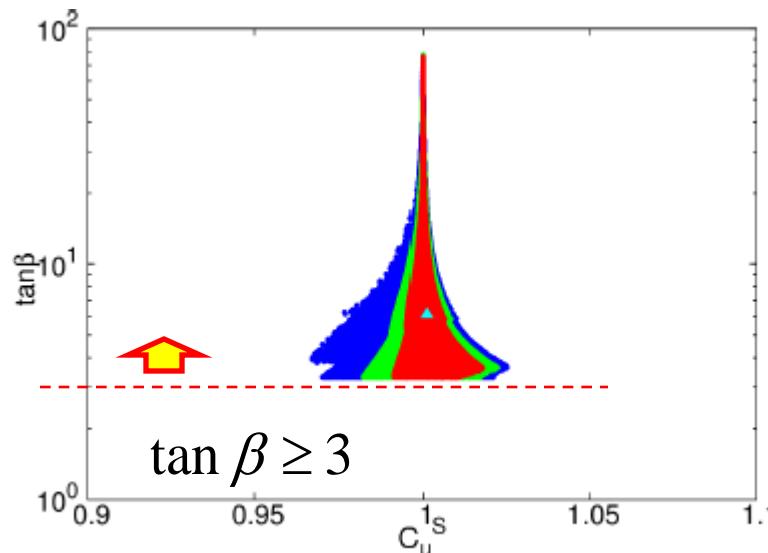
$A_b = A_t \subset [-3 \text{ TeV}, 3 \text{ TeV}]$

$\mu \subset [1 \text{ TeV}, 2 \text{ TeV}]$

$M_{U3} = M_{Q3} \subset [0 \text{ TeV}, 1 \text{ TeV}]$

$M_A = 300 \text{ GeV}$

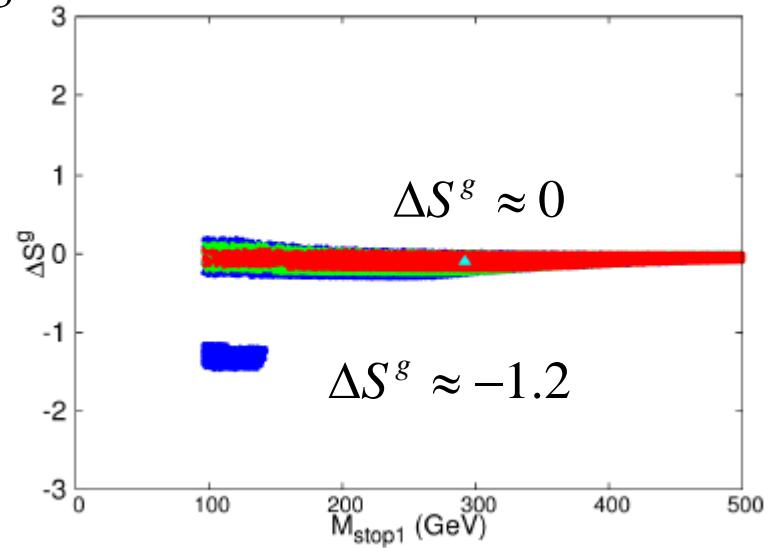
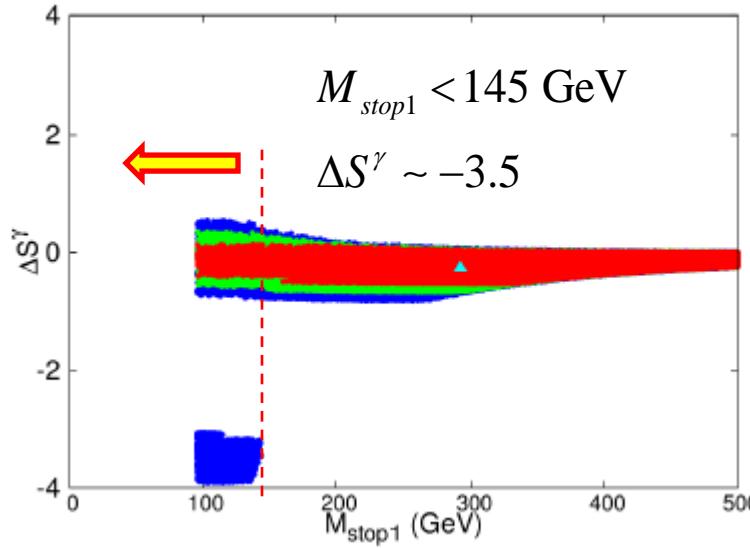
Implications on the MSSM spectrum: D. stops



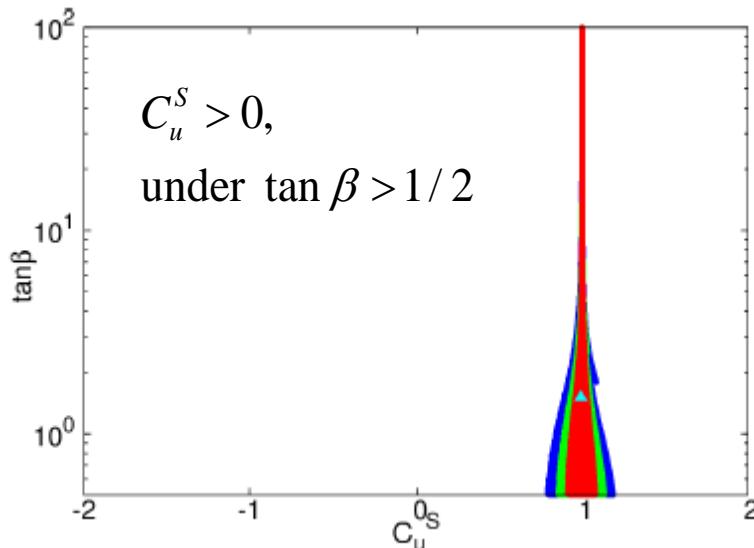
$M_{stop1} > 95.7 \text{ GeV}$

$$\Delta S^\gamma = \frac{8}{3} \Delta S^g$$

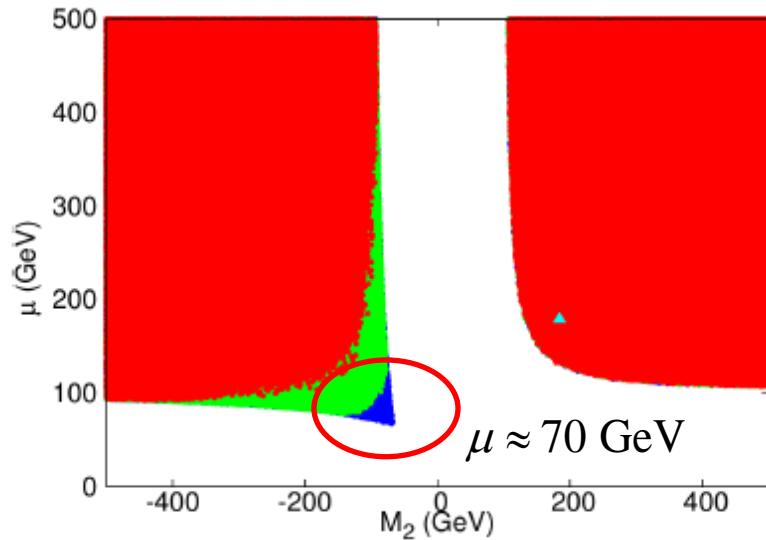
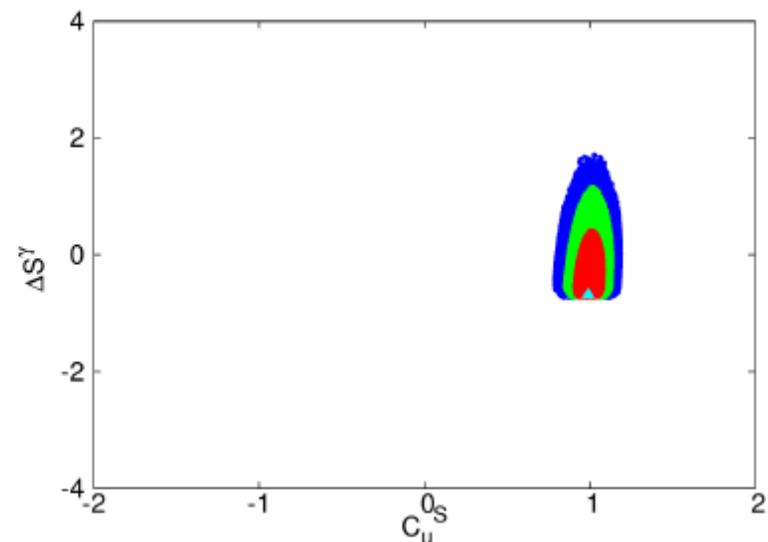
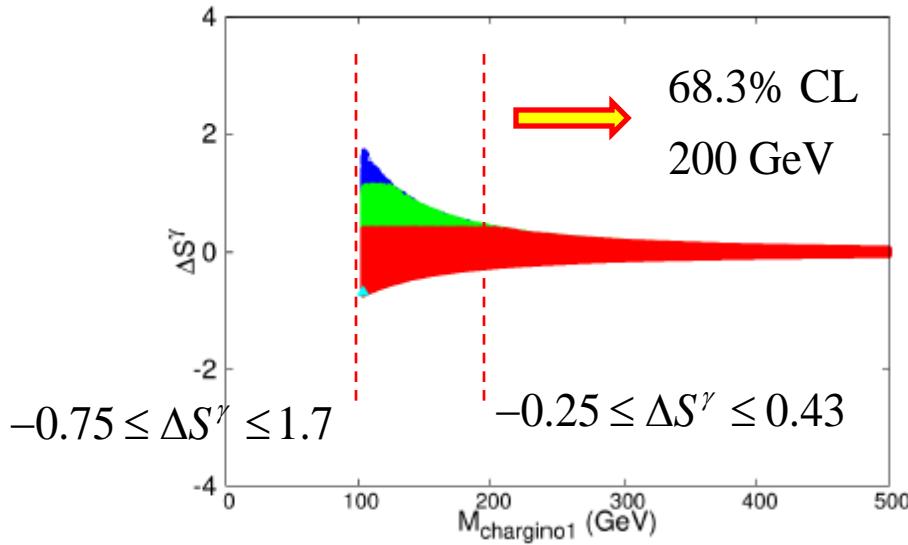
$$S_{SM}^\gamma \simeq -6.59, \quad S_{SM}^g \simeq 0.688$$



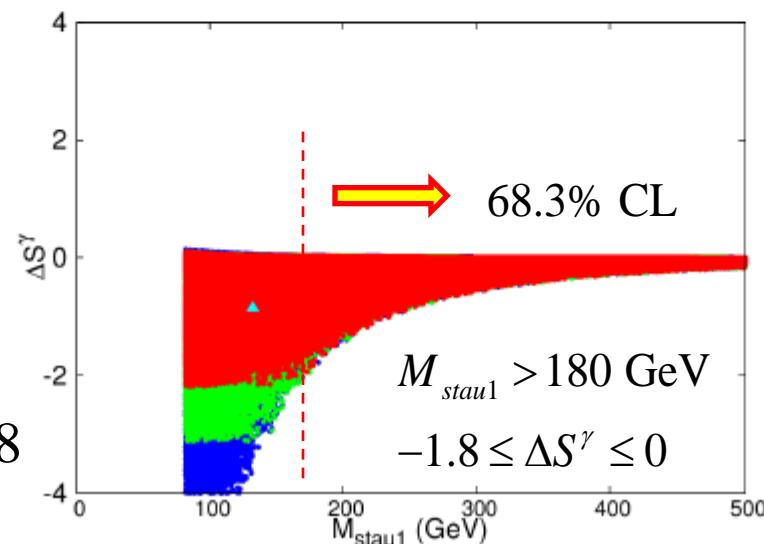
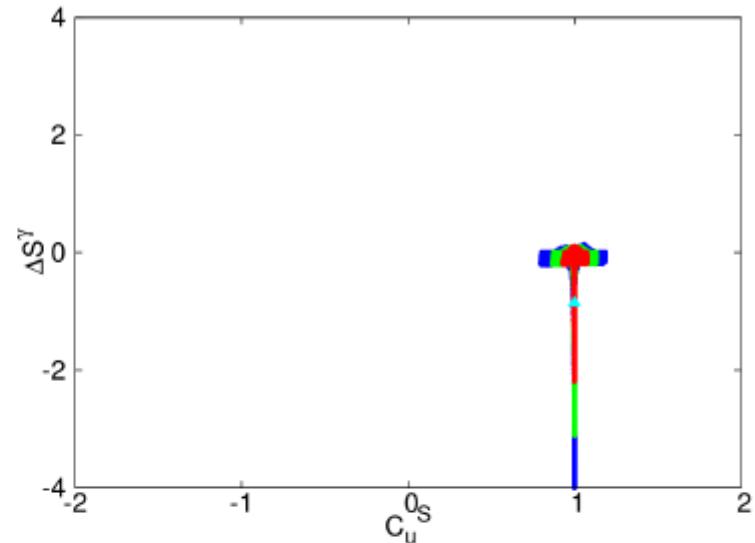
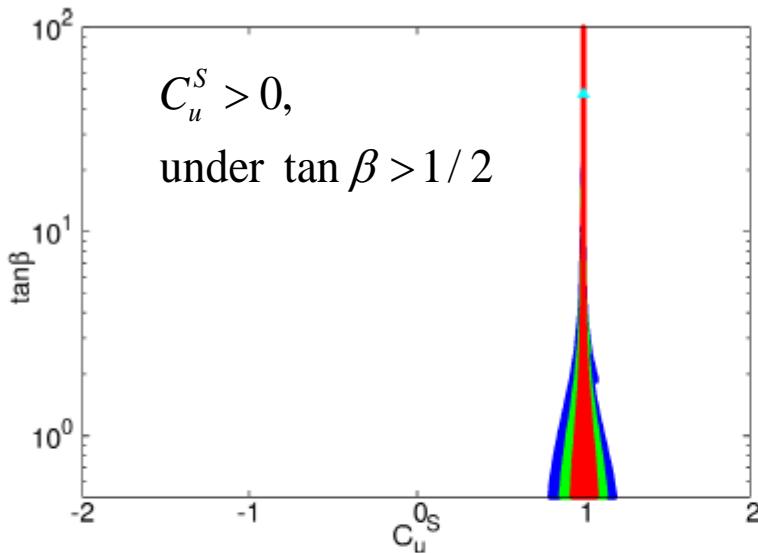
MSSM-1. charginos only



$$S_{SM}^\gamma \simeq -6.59, \quad S_{SM}^g \simeq 0.688$$



MSSM-2. scalar taus



$\Delta \chi^2 \leq 2.3$ (red 68.3%),
 $\Delta \chi^2 \leq 5.99$ (green 95%),
 $\Delta \chi^2 \leq 11.83$ (blue 99.7%)

- The lightest Higgs boson mass: using 2-loop level analytical expression

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$$m_h^2 = m_h^{2,\text{tree}} + \Delta m_h^{2,\alpha,t/\tilde{t}} + \Delta m_h^{2,\alpha,\text{rest}} + \Delta m_h^{2,\alpha\alpha_s} + \Delta m_h^{2,\alpha^2}$$

$$|M_{H1} - 125.5 \text{ GeV}| \leq 6 \text{ GeV} \Rightarrow \tan\beta \geq 3$$

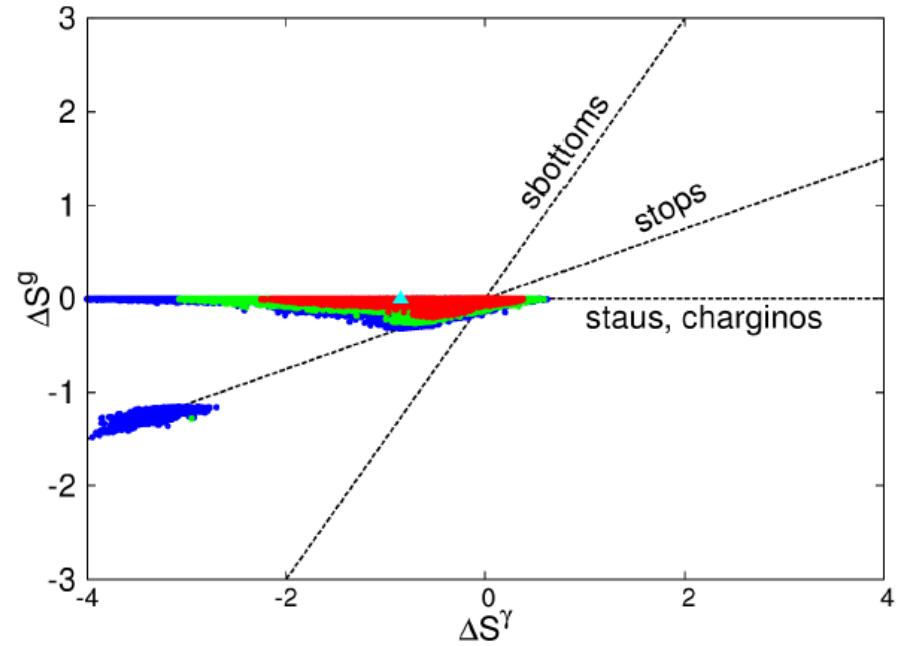
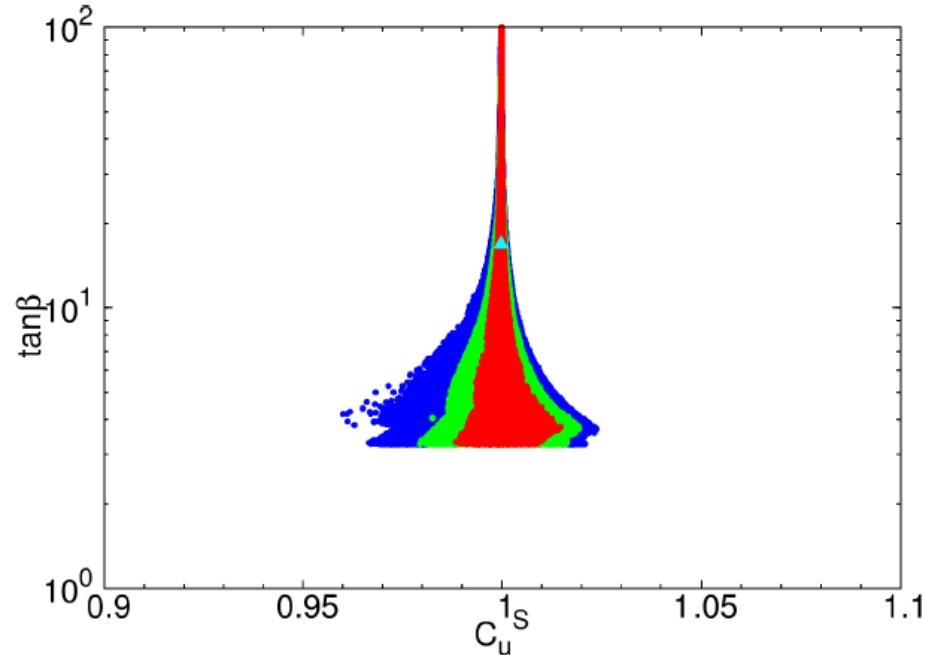
- Sparticle's one-loop contributions to $H\gamma\gamma$ and Hgg couplings:

$$\Delta S^g = 0 \quad \text{charginos, scalar taus}$$

$$\Delta S^\gamma = 2N_C Q_b^2 \Delta S^g = \frac{2}{3} \Delta S^g \quad \text{sbottom}$$

$$\Delta S^\gamma = 2N_C Q_t^2 \Delta S^g = \frac{8}{3} \Delta S^g \quad \text{stop}$$

MSSM-3. **chargino, scalar taus, sbottom, stop**



- The top-Yukawa coupling is very close to SM value:

$$|C_u^S - 1| \leq 0.02$$

$$\begin{aligned}\Delta\chi^2 &\leq 2.3(\text{red } 68.3\%), \\ \Delta\chi^2 &\leq 5.99(\text{green } 95\%), \\ \Delta\chi^2 &\leq 11.83(\text{blue } 99.7\%)\end{aligned}$$