Higgs Bosons in U(1)′ Models with CP violation

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MSSM and U(1)′ Model

SUSY is an attractive extension of the SM that includes:

- the solution of the hierarch and naturalness problem of the SM,
- the unification of the SM gauge couplings at highscale,
- the provision of a Dark Matter (DM) candidate.

The MSSM is the simplest low energy SUSY model

$$SU(3)_C \otimes SU(2)_L \otimes U(1)_Y$$

The MSSM suffers from a naturalness problem due to the presence of the μ parameter

$$\hat{W} = \mu \hat{H}_u . \hat{H}_d + \ldots$$

SUSY models that extend the MSSM gauge structure by an additional Abelian factor U(1)′ generally intend to solve μ problem

The simplest versions (minimal U(1)′ model) contain a singlet field S and a new neutral gauge boson Z′.

After acquiring a VEV, S generates an effective μ parameter $\mu_{eff} = Y_S < S >$.

Its gauge sector and superpotential:

$$SU(3)_C \otimes SU(2)_L \otimes U(1)_Y \otimes U(1)'$$

$$\hat{W} = \underbrace{Y_S \hat{S}}_{\mu_{eff} = Y_S < S >} \hat{H}_u . \hat{H}_d + Y_d \hat{Q} . \hat{H}_d \hat{D} + Y_u \hat{Q} . \hat{H}_u \hat{U} + \ldots$$

The Lagrangian includes new soft supersymmetry breaking terms

$$-L_{soft} = \left(\sum_a M_a \lambda_a \lambda_a + A_S Y_S S H_u . H_d + A_t h_u \tilde{U} \tilde{Q} . H_u + A_b h_d \tilde{D} \tilde{Q} . H_d + \ldots h.c. \right)$$

$$+ m_u^2 |H_u|^2 + m_d^2 |H_d|^2 + m_S^2 |S|^2 + M_{\tilde{Q}}^2 |\tilde{Q}|^2$$

$$+ M_{\tilde{U}}^2 |\tilde{U}|^2 + M_{\tilde{D}}^2 |\tilde{D}|^2 + \ldots$$

$$M_a (a = 1, 1', 2, 3)$$

As we are interested in CP violation, we assume some of the soft breaking terms to be complex

$A_{t,b,S}$, $\langle S \rangle$

The Higgs and Neutralino Sector of the U(1)′

–The Higgs sector at tree level

The effective U(1)′ model inherits two Higgs doublets H_u, H_d from the MSSM, and has an additional singlet field S

$$\langle H_u \rangle = \frac{e^{i\theta_u}}{\sqrt{2}} \begin{pmatrix} \sqrt{2} H_u^+ \\ v_u + \phi_u + i\varphi_u \end{pmatrix}$$

$$\langle H_d \rangle = \frac{e^{i\theta_d}}{\sqrt{2}} \begin{pmatrix} v_d + \phi_d + i\varphi_d \\ \sqrt{2} H_d^- \end{pmatrix}$$

$$\langle S \rangle = \frac{e^{i\theta_s}}{\sqrt{2}} \left(v_S + \phi_S + i\varphi_S \right)$$

The fields in the superpotential are charged under the U(1)′ gauge group

$$\mathcal{Q}_{H_u} + \mathcal{Q}_{H_d} + \mathcal{Q}_S = 0, \qquad \mathcal{Q}_{Q_3} + \mathcal{Q}_{U_3} + \mathcal{Q}_{H_u} = 0, \qquad \mathcal{Q}_{Q_3} + \mathcal{Q}_{D_3} + \mathcal{Q}_{H_d} = 0.$$

The effective μ parameter is generated by the singlet VEV <S> , defined as

$$\mu_{eff} \equiv \underset{\downarrow}{\mu}\, e^{i\theta_s}$$

$$\mu = \frac{Y_S v_S}{\sqrt{2}}$$

(μ is always real)

For the remaining parameters we adopt the convention that the parameters are real, and explicitly attach CP-violating phases

$$\arg(A_t) \equiv \theta_t$$
$$\arg(A_b) \equiv \theta_b$$
$$\arg(S) \equiv \theta_s$$

For the Higgs fields, we assume $\theta_u = \theta_d = 0$ to avoid spontaneous CP breaking in the potential.

The tree-level Higgs potential of the effective U(1)′

$$V_{tree} \equiv V_D + V_F + V_{soft}$$

$$V_D = \frac{g^2}{8}(|H_u|^2 - |H_d|^2)^2 + \frac{g_2^2}{2}(|H_u|^2|H_d|^2 - |H_u \cdot H_d|^2) + \frac{g_{Y'}^2}{2}(\mathcal{Q}_u|H_u|^2 + \mathcal{Q}_d|H_d|^2 + \mathcal{Q}_S|S|^2)^2,$$

$$V_F = |Y_S|^2 \left[|H_u \cdot H_d|^2 + |S|^2(|H_u|^2 + |H_d|^2)\right],$$

$$V_{soft} = m_{H_u}^2|H_u|^2 + m_{H_d}^2|H_d|^2 + m_S^2|S|^2 + (A_S Y_S S H_u \cdot H_d + h.c.)$$

$$g^2 \equiv g_2^2 + g_Y^2$$

The spectrum of physical Higgs bosons (CP conserving case):

$$h, H, H', A^0, H^{\pm}$$

In total, the spectrum differs from that of the MSSM by one extra CP-even scalar.

– One-loop Corrections to the Higgs Potential

The tree level potential is insufficient to make precise predictions for masses and mixings.

We use the effective potential approach.

The one-loop corrected potential has two parts

$$V \equiv V_{tree} + \Delta V$$

ΔV : one-loop Coleman-Weinberg potential

We include here the dominant contributions coming from the top and bottom sectors (f=t,b) for both the quarks and scalar quarks.

$$\Delta V = \frac{6}{64\pi^2} \sum_{f=b,t} \left\{ \sum_{k=1,2} (m^2_{\tilde{f}_k})^2 \left[\ln\left(\frac{m^2_{\tilde{f}_k}}{\Lambda^2} \right) - \frac{3}{2} \right] - 2(m^2_f)^2 \left[\ln\left(\frac{m^2_f}{\Lambda^2} \right) - \frac{3}{2} \right] \right\}.$$

The vacuum state is obtained by requiring the vanishing of all tadpoles

The tadpole terms are obtained from

$$\mathcal{T}_i = \left(\frac{\partial V}{\partial \Phi_i}\right)_0, \qquad \Phi_i = \phi_u, \phi_d, \phi_S, \varphi_u, \varphi_d, \varphi_S$$

Since all tadpole terms must vanish, enforcement of $\mathcal{T}_{1,2,3} = 0$ is used to obtain $m_{H_u,H_d,S}$ respectively.

$$m_{H_u}^2 = \frac{A_S Y_S \cos(\theta_\Sigma + \theta_S) v_d v_S}{\sqrt{2} v_u} - \frac{\mathcal{Q}_{H_u}\Pi + Y_S^2(v_d^2 + v_S^2)}{2} + \frac{g^2(v_u^2 - v_d^2)}{8},$$

$$m_{H_d}^2 = \frac{A_S Y_S \cos(\theta_\Sigma + \theta_S) v_u v_S}{\sqrt{2} v_d} - \frac{\mathcal{Q}_{H_d}\Pi + Y_S^2(v_u^2 + v_S^2)}{2} + \frac{g^2(v_u^2 - v_d^2)}{8},$$

$$m_S^2 = \frac{A_S Y_S \cos(\theta_\Sigma + \theta_S) v_d v_u}{\sqrt{2} v_s} - \frac{\mathcal{Q}_S\Pi + Y_S^2(v_d^2 + v_u^2)}{2},$$

$$\Pi = g_{Y'}^2(\mathcal{Q}_{H_d} v_d^2 + \mathcal{Q}_S v_S^2 + \mathcal{Q}_{H_u} v_u^2).$$

– The Higgs mass calculation

The mass-squared matrix of the Higgs scalars (at one loop)

$$\mathcal{M}^2_{ij} = \left(\frac{\partial^2}{\partial \Phi_i \partial \Phi_j} V \right)_0$$

$$\Phi_i = (\phi_i, \varphi_i)$$

Two linearly independent combinations of the pseudoscalar components $\varphi_{u,d,S}$ are the Goldstone bosons G_Z and $G_{Z'}$, leaving one physical pseudoscalar Higgs state A^0, which mixes with the neutral Higgs mass states (CP violation).

In the basis of scalars $B = \{\phi_u, \phi_d, \phi_S, A^0\}$ the neutral Higgs mass-squared matrix

$$\mathcal{M}^2_{H^0} = \begin{pmatrix} \mathcal{M}^2_{11} & \mathcal{M}^2_{12} & \mathcal{M}^2_{13} & \mathcal{M}^2_{14} \\ \mathcal{M}^2_{12} & \mathcal{M}^2_{22} & \mathcal{M}^2_{23} & \mathcal{M}^2_{24} \\ \mathcal{M}^2_{13} & \mathcal{M}^2_{23} & \mathcal{M}^2_{33} & \mathcal{M}^2_{34} \\ \mathcal{M}^2_{14} & \mathcal{M}^2_{24} & \mathcal{M}^2_{34} & \mathcal{M}^2_{44} \end{pmatrix}.$$

$$\mathcal{O}\mathcal{M}^2_{H^0}\mathcal{O}^{\dagger} = \mathrm{diag}(m^2_{H^0_1}, m^2_{H^0_2}, m^2_{H^0_3}, m^2_{H^0_4})$$

$$m_{H^0_1} < m_{H^0_2} < m_{H^0_3} < m_{H^0_4}.$$

Calculation of masses of the charged Higgs bosons is very similar to the neutral ones

$$\mathcal{M}^2_{H^\pm} = \begin{pmatrix} \mathcal{M}^{2\pm}_{11} & \mathcal{M}^{2\pm}_{12} \\ \mathcal{M}^{2\pm}_{21} & \mathcal{M}^{2\pm}_{22} \end{pmatrix}$$

When CP is not conserved the eigenvalue of this matrix

$$m_{H^\pm}^2 = \frac{\kappa \Delta_b^2 \Delta_t^2}{3v^2 \Sigma_b v_d v_S^2 \Sigma_t v_u} (\Sigma_t (3Y_b^2 v_S^2 (F_b \Sigma_b (\mu A_b (C_b (v_d^4 + v_u^4) + 2S_b v_d^2 v_u^2) - A_b^2 v_d v_u^3 - \mu^2 v_d^3 v_u)$$

$$- \Sigma_b^2 v_d v_u^3 (F_b + G_b - 2) + \Delta_b^2 (G_b - 2) v_d v_u^3) - \Sigma_b (v_d^4 + v_u^4)(8\pi^2 v_d v_u (4\mu^2 - g_2^2 v_S^2) - \mu \chi v_S^2)$$

$$+ 6Y_b^4 \Sigma_b v_d^3 v_S^2 v_u^3 (\ln(\frac{m_b^2}{Q^2}) - 1)) + 3\Sigma_b Y_t^2 v_S^2 (F_t \Sigma_t (\mu A_t (C_t (v_d^4 + v_u^4) + 2v_d^2 S_t v_u^2) - A_t^2 v_d^3 v_u - \mu^2 v_d v_u^3)$$

$$- v_d^3 \Sigma_t^2 v_u (F_t + G_t - 2) + v_d^3 (G_t - 2)\Delta_t^2 v_u) + 6\Sigma_b v_d^3 Y_t^4 v_S^2 \Sigma_t v_u^3 (\ln(\frac{m_t^2}{Q^2}) - 1)).$$

The loop functions

$$G_f = 2 + \ln\left(\frac{m_{\tilde{f}_1}^2}{m_{\tilde{f}_2}^2}\right)\frac{\Sigma_f}{\Delta_f}, \qquad F_f = -2 + \ln\left(\frac{m_{\tilde{f}_1}^2 m_{\tilde{f}_2}^2}{Q^4}\right) - \ln\left(\frac{m_{\tilde{f}_1}^2}{m_{\tilde{f}_2}^2}\right)\frac{\Sigma_f}{\Delta_f},$$

$$\Delta_f = m_{\tilde{f}_2}^2 - m_{\tilde{f}_1}^2 \qquad \Sigma_f = m_{\tilde{f}_2}^2 + m_{\tilde{f}_1}^2 \qquad f = t, b$$

–The neutralino mass matrix in U(1)′

The neutralino sector of the U(1)′ is like the MSSM, but enlarged by a pair of Higgsino and gaugino states ($\widetilde{S}, \widetilde{B}'$)

In the $\{\widetilde{B}, \widetilde{W}^3, \widetilde{H}_d^0, \widetilde{H}_u^0, \widetilde{S}, \widetilde{B}'\}$ basis the mass matrix for the six neutralinos

$$M_{\psi^0} = \begin{pmatrix} M_1 & 0 & -M_Z c_\beta s_W & M_Z s_\beta s_W & 0 & M_K \\ 0 & M_2 & M_Z c_\beta c_W & -M_Z s_\beta c_W & 0 & 0 \\ -M_Z c_\beta s_W & M_Z c_\beta c_W & 0 & -\mu_{eff} & -\mu_\lambda s_\beta & Q_{H_d} M_v c_\beta \\ M_Z s_\beta s_W & -M_Z s_\beta c_W & -\mu_{eff} & 0 & -\mu_\lambda c_\beta & Q_{H_u} M_v s_\beta \\ 0 & 0 & -\mu_\lambda s_\beta & -\mu_\lambda c_\beta & 0 & Q_S M_s \\ M_K & 0 & Q_{H_d} M_v c_\beta & Q_{H_u} M_v s_\beta & Q_S M_s & M_1' \end{pmatrix},$$

$$M_v = g_{Y'} v$$

$$M_s = g_{Y'} v_S.$$

$$\mu_{eff} = Y_S \frac{v_S}{\sqrt{2}} e^{i\theta_s}$$

$$\mu_\lambda = Y_S \frac{v}{\sqrt{2}}$$

$$\mathcal{N}^\dagger M_{\chi^0} \mathcal{N} = \mathrm{diag}(\tilde{m}_{\chi_1^0}, \ldots, \tilde{m}_{\chi_6^0}).$$

Numerical Analysis

In general a $U(1)' \equiv U(1)_{E_6}$ **group is defined**

$$U(1)_{E_6} = \cos\theta_{E_6} U(1)_\chi + \sin\theta_{E_6} U(1)_\psi$$

We distinguish among the different scenario by the values of θ_{E_6}

$\theta_S = \arctan\sqrt{15}/9$ for the secluded $U(1)_S$;

$\theta_I = \arctan\sqrt{\frac{3}{5}}$ for the inert $U(1)_I$

$\theta_\eta = \pi - \arctan\sqrt{\frac{5}{3}}$ for $U(1)_\eta$

$\theta_N = \arctan\sqrt{15}$ for $U(1)_N$

$\theta_\psi = \frac{\pi}{2}$ for $U(1)_\psi$

TABLE II. The benchmark points (in GeV) for the CP-violating (CP-conserving) $U(1)_\eta$, $U(1)_S$, $U(1)_I$, $U(1)_N$, and $U(1)_\psi$ versions of $U(1)'$ models.

Parameters	$U(1)_\eta$	$U(1)_S$	$U(1)_I$	$U(1)_N$	$U(1)_\psi$
θ_s	42(0)	75(0)	60(0)	55(0)	33(0)
$\tan\beta$	1.8(1.7)	1.46(1.42)	1.3(2.5)	1.5(1.8)	1.75(1.75)
$\mu(\lvert\mu_{eff}\rvert)$	360(360)	715(730)	465(461)	292(295)	285(290)
M_1	48(50)	56(59)	57(50)	49(50)	49(51)
M_2	125(130)	115(120)	135(120)	130(170)	140(160)
M_{Q_1}	1000(1000)	1250(850)	750(600)	2000(300)	1000(1000)
M_{Q_2}	1000(1000)	1250(850)	750(600)	2000(300)	1000(1000)
M_{Q_3}	1000(1000)	1250(850)	750(600)	2000(300)	1000(1000)
M_{U_1}	1000(1000)	1250(850)	750(600)	2000(300)	1000(1000)
M_{U_2}	1000(1000)	1250(850)	750(600)	2000(300)	1000(1000)
M_{U_3}	1000(1000)	1250(850)	750(600)	2000(300)	1000(1000)
$\lvert A_t\rvert$	1850(2000)	2200(2500)	2500(1500)	2250(2000)	2000(2000)
$\lvert A_b\rvert$	2000(2000)	2500(2500)	2500(1500)	2500(2000)	2000(2000)

The benchmark points were required to obey those conditions:

- to require the lightest Higgs mass to be very close to 125 GeV (ATLAS, CMS),
- to require the next lightest neutral Higgs boson to have mass $m_{H_2^0} > 600$ GeV,
- to satisfy relic density constraints for the LSP,
- to satisfy constraints from EDMs and CP violation .

Based on the input parameters, we calculate the spectrum of the physical masses of the particles in the model

We also included in this table the relic density of the dark matter for all scenarios.

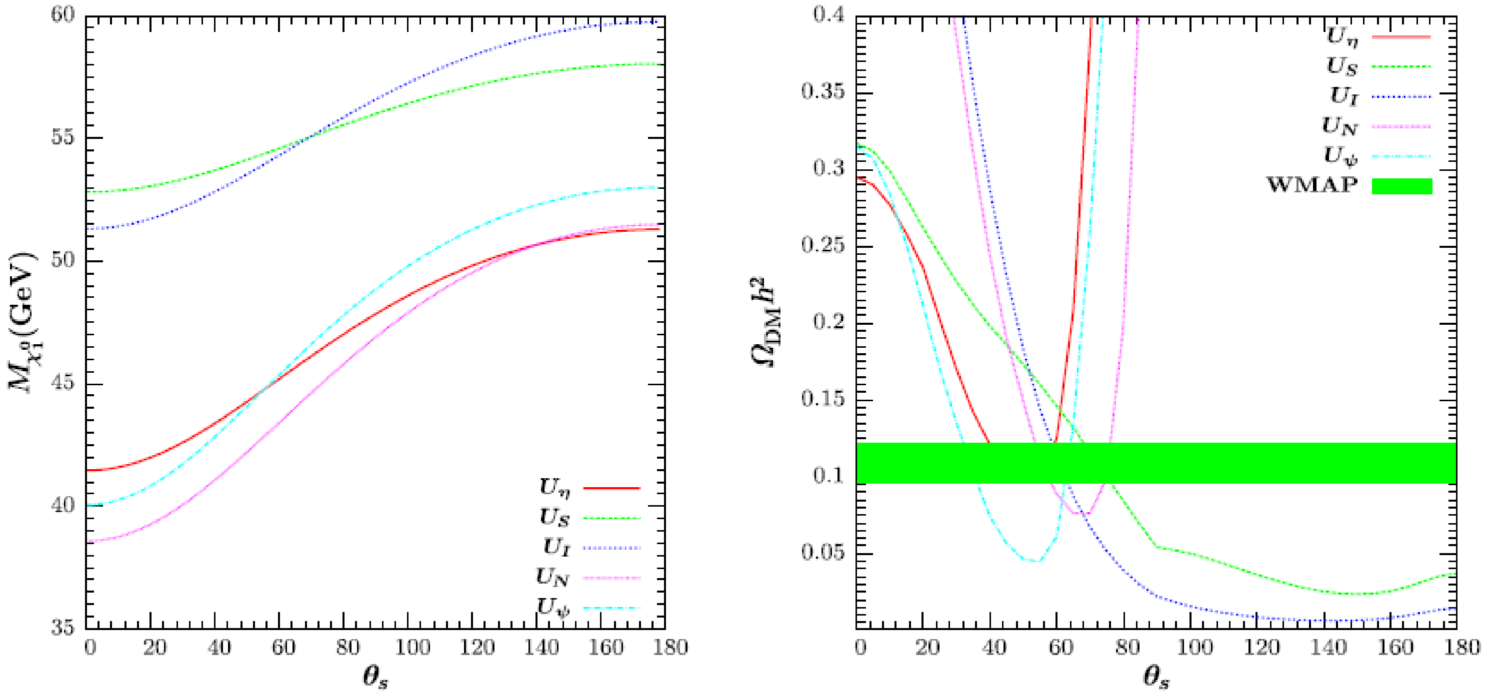
All the numbers are within the WMAP allowed range.

In all of the U(1)′ models under study, the lightest neutralino is mostly bino.

TABLE III. The mass spectra (in GeV) and the relic density Ω_{DM} values for the *CP*-violating (*CP*-conserving) version of the scenarios considered given in Table II for the $U(1)'$ models.

Masses	$U(1)_\eta$	$U(1)_S$	$U(1)_I$	$U(1)_N$	$U(1)_\psi$
$m_{Z'}$	1510(1510)	1507(1539)	1513(1500)	1502(1517)	1513(1540)
$m_{\tilde{\chi}_1^0}$	43(43)	55(55)	54(44)	43(42)	42(42)
$m_{\tilde{\chi}_2^0}$	108(109)	112(110)	125(107)	111(137)	114(128)
$m_{\tilde{\chi}_3^0}$	361(361)	715(730)	464(463)	292(297)	286(292)
$m_{\tilde{\chi}_4^0}$	386(388)	726(742)	485(479)	326(336)	322(331)
$m_{\tilde{\chi}_5^0}$	1487(1489)	1440(1536)	1514(1378)	1505(1498)	1396(1438)
$m_{\tilde{\chi}_6^0}$	1535(1540)	1580(1543)	1521(1711)	1556(1549)	1641(1694)
$m_{\tilde{\chi}_1^\pm}$	107(107)	111(110)	124(106)	108(134)	111(125)
$m_{\tilde{\chi}_2^\pm}$	382(384)	724(740)	481(477)	321(332)	318(326)
$m_{H_1^0}$	125.0(125.0)	125.6(125.0)	125.8(126.0)	125.6(126.0)	125.4(125.0)
$m_{H_2^0}$	743(747)	969(1027)	788(930)	642(688)	665(679)
$m_{H_3^0}$	750(754)	977(1033)	798(933)	652(695)	673(687)
$m_{H_4^0}$	1510(1510)	1508(1539)	1513(1500)	1502(1517)	1513(1540)
$m_{H^\pm}$	572(543)	717(711)	507(802)	418(504)	486(486)
$m_{\tilde{e}_L}$	1341(1341)	1837(1616)	1306(1219)	700(742)	1134(1139)
$m_{\tilde{e}_R}$	1054(1054)	1154(695)	748(598)	513(564)	1133(1137)
$m_{\tilde{\mu}_L}$	1341(1341)	1837(1616)	1306(1219)	700(742)	1134(1139)
$m_{\tilde{\mu}_R}$	1054(1054)	1154(695)	748(598)	513(564)	1133(1137)
$m_{\tilde{\tau}_1}$	1054(1054)	1154(695)	748(598)	513(564)	1133(1137)
$m_{\tilde{\tau}_2}$	1342(1341)	1837(1616)	1306(1219)	700(742)	1135(1139)
$m_{\tilde{\nu}_e}$	1340(1340)	1836(1615)	1306(1217)	699(739)	1133(1137)
$m_{\tilde{\nu}_\mu}$	1340(1340)	1836(1615)	1306(1217)	699(739)	1133(1137)
$m_{\tilde{\nu}_\tau}$	1340(1340)	1836(1615)	1306(1217)	699(739)	1133(1137)
$m_{\tilde{u}_L}$	1054(1054)	879(874)	999(998)	1106(1108)	1133(1137)
$m_{\tilde{u}_R}$	1055(1055)	882(877)	1001(1000)	1107(1109)	1134(1138)
$m_{\tilde{d}_L}$	1056(1055)	880(875)	1000(1001)	1107(1109)	1134(1139)
$m_{\tilde{d}_R}$	1340(1340)	1675(1698)	1463(1457)	1203(1207)	1133(1138)
$m_{\tilde{c}_L}$	1054(1054)	879(874)	999(998)	1106(1108)	1133(1137)
$m_{\tilde{c}_R}$	1055(1055)	882(877)	1001(1000)	1107(1109)	1134(1138)
$m_{\tilde{s}_L}$	1056(1055)	880(875)	1000(1001)	1107(1109)	1134(1139)
$m_{\tilde{s}_R}$	1340(1340)	1675(1698)	1463(1457)	1203(1207)	1133(1138)
$m_{\tilde{t}_1}$	919(911)	659(670)	788(894)	938(968)	994(1002)
$m_{\tilde{t}_2}$	1201(1207)	1085(1070)	1200(1122)	1277(1275)	1281(1283)
$m_{\tilde{b}_1}$	1056(1055)	880(875)	1000(1001)	1107(1109)	1130(1135)
$m_{\tilde{b}_2}$	1340(1340)	1675(1698)	1463(1457)	1203(1207)	1137(1141)
Ω_{DM}	0.114(0.120)	0.100(0.102)	0.113(0.120)	0.111(0.117)	0.117(0.101)

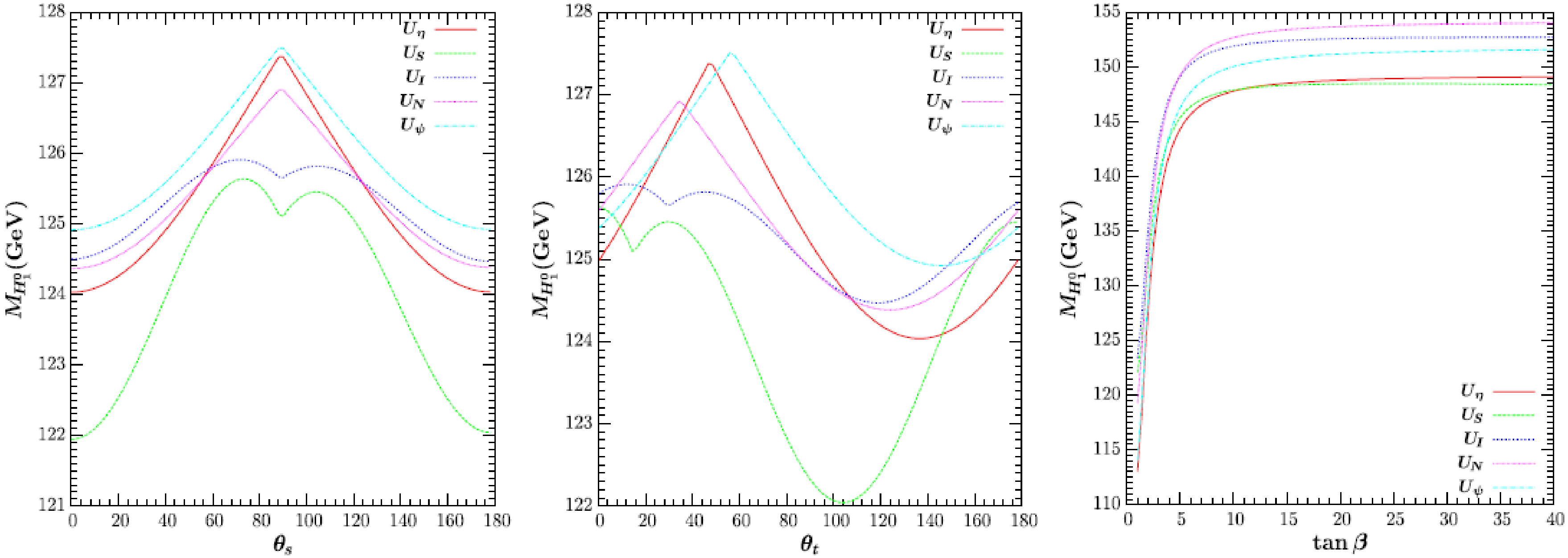
We wish to explore the possibility that Higgs boson decays in a non-SM fashion, in particular, that it can decay significantly invisibly.



θ_s dependence of the lightest neutralino (LSP) mass and relic density.

The variations of its mass and of the relic density with the other CP-violating phase (θ_t) are negligible.

We present our results for the dependence of the masses on the CP violating phases and $\tan\beta$.



The mass variations with θ_s and θ_t are significant.

Only low values $\tan\beta$ are allowed for all U(1)′ models.

To analyze the decay width of the lightest Higgs boson, we calculate total production cross section in various models for θ_s (with CP) and for $\theta_s = 0$ (no CP).

TABLE IV. Total cross sections (in fb) of associated production channel ($H_1^0 X$) and vector boson fusion production channel ($H_1^0 jj$) (in fb) for the CP-violating (CP-conserving) versions of $U(1)_\eta$, $U(1)_S$, $U(1)_I$, $U(1)_N$, and $U(1)_\psi$ models considered in the paper.

Observables	$U(1)_\eta$	$U(1)_S$	$U(1)_I$	$U(1)_N$	$U(1)_\psi$
$\sigma(pp \to H_1^0 Z)$	639(642)	631(647)	628(610)	628(624)	634(642)
$\sigma(pp \to H_1^0 W^+)$	720(725)	708(725)	705(687)	708(701)	711(720)
$\sigma(pp \to H_1^0 W^-)$	445(447)	437(448)	435(424)	437(433)	439(444)
$\sigma(pp \to H_1^0 jj(VBF))$	4983(4930)	4848(4920)	4861(4840)	4874(4850)	4873(4893)

We do not include here the dominant production mechanism $gg \to H_1^0$ as this mode is plagued by large QCD corrections

We list the dominant branching ratios (in %) for the lightest neutral Higgs in our model and for comparison, in the SM .

TABLE V. Dominant branching ratios (in %) of H_1^0 decay channels for the CP-violating (CP-conserving) version of the $U(1)_\eta$, $U(1)_S$, $U(1)_I$, $U(1)_N$, and $U(1)_\psi$ scenarios considered, and in the SM.

Branching ratio	$U(1)_\eta$	$U(1)_S$	$U(1)_I$	$U(1)_N$	$U(1)_\psi$	SM
$BR(H_1^0 \to \tilde{\chi}_1^0 \tilde{\chi}_1^0)$	36.0(34.0)	8.0(2.6)	20.0(9.0)	49.0(41.0)	54.0(42)	...
$BR(H_1^0 \to b\bar{b})$	48.0(49.0)	70.0(73.0)	60.0(66.0)	38.0(44.0)	36.0(43.0)	60
$BR(H_1^0 \to \tau^- \tau^+)$	2.3(2.4)	3.5(3.6)	3.0(3.3)	1.9(2.2)	1.8(2.2)	6
$BR(H_1^0 \to WW^*)$	7.4(7.2)	10.9(11.1)	9.8(12.0)	6.1(7.5)	5.3(6.6)	21.5

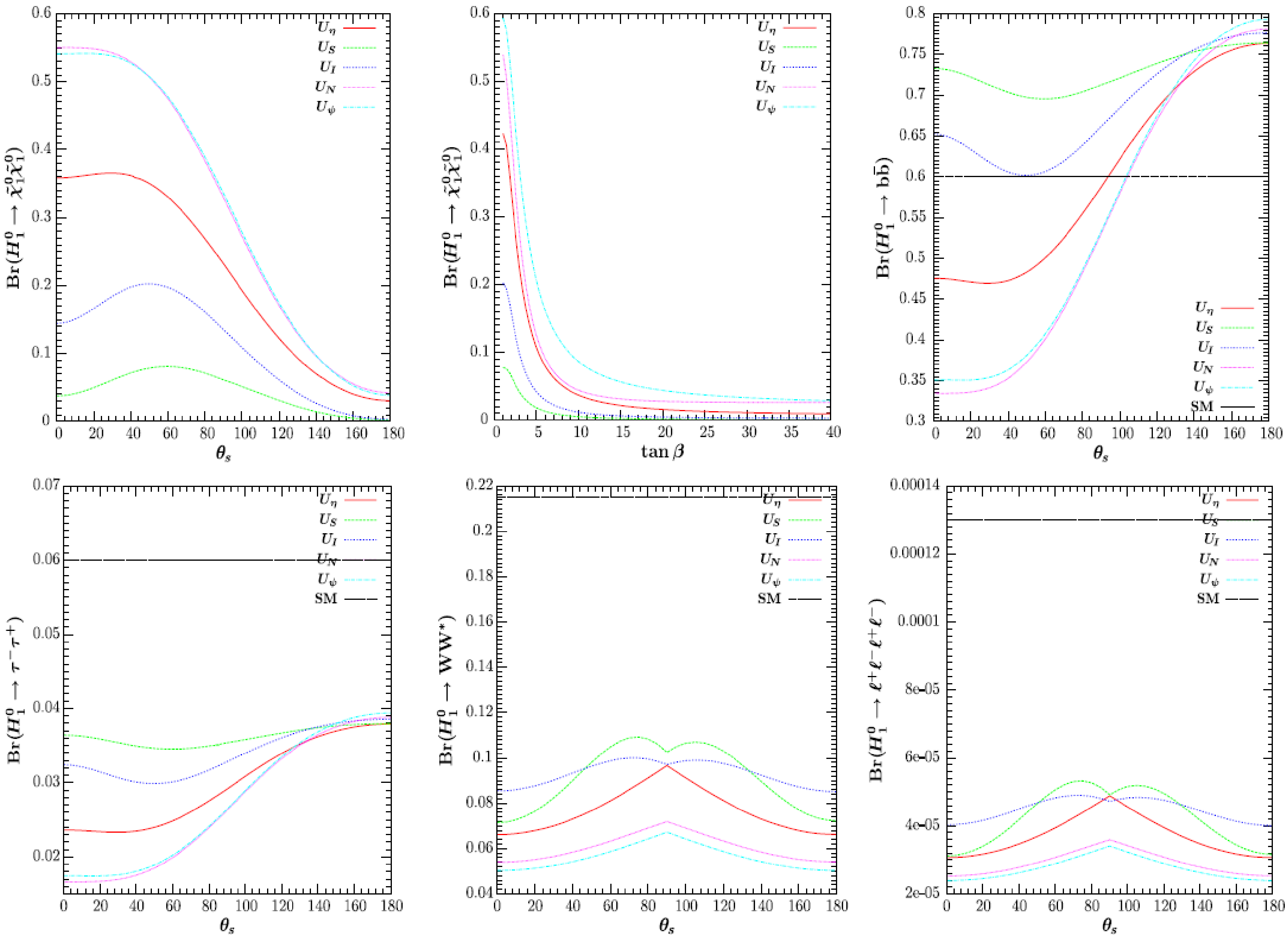
The decay into the invisible mode can reach over 50 %.

In $U(1)_S$ and $U(1)_I$ models $Br(H_1^0 \to b\bar{b})$ is larger with respect to the SM value .

A general feature of all these models is the strong suppression of the $H_1^0 \to WW^*$ and $H_1^0 \to \tau^- \tau^+$ modes.

The branching ratios are phase (θ_s) dependent.

The variation of the branching ratios of the lightest Higgs boson with the CP violating phase θ_s and $\tan\beta$.



Summary and Conclusions

- Our analysis has two goals: One is to analyze effects of CP violation on Higgs masses and decays, the other is look for differences among each of the U(1)′ models.

- The recent discovery of a Higgs-like boson at the LHC does not preclude the possibility of beyond the Standard Model (BSM) physics.

- In addition to the SM modes, the BSM Higgs boson can decay invisibly.

- We find that Higgs phenomenology in U(1)′ model is significantly affected by the CP phases, especially θ_s yields distinct signatures.

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Thanks