

Dynamically Solving the μ/B_μ Problem in Gauge Mediated SUSY Breaking

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I. Outlines

- μ/B_μ Problem in Gauge-mediated SUSY Breaking (GMSB)
- A Simple Model to Solve μ/B_μ Problem
- Numerical Analysis
- Gauge Coupling Unification
- Conclusions

II. μ/B_μ Problem in GMSB

A. μ/B_μ Problem and EW Symmetry Breaking

- In the MSSM, we need a term

$$\Delta\mathcal{L} = \int d^2\theta \mu \mathbf{H}_d \mathbf{H}_u + h.c.$$

to give the Higgsinos a mass.

- To stabilize the EW scale, μ and B_μ parameters need to satisfy the minimization conditions of the Higgs potential

$$\mu^2 = -\frac{M_Z^2}{2} + \frac{m_{H_d}^2 - m_{H_u}^2 \tan^2 \beta}{\tan^2 \beta - 1}, \quad \tan \beta = \frac{v_u}{v_d}$$

$$B_\mu = (m_{H_d}^2 + m_{H_u}^2) \frac{\sin 2\beta}{2}$$

- μ/B_μ problem: is there a dynamical way to induce the EW scale values for μ and B_μ ? Particularly in GMSB.

II. μ/B_μ Problem in GMSB

B. Giudice-Masiero Mechanism

- Assume exact PQ symmetry to forbid the bare μ term.
- Introduce higher dimensional operators in Kahler function

$$\Delta\mathcal{L} = \int d^4\theta \mathbf{H}_d \mathbf{H}_u \left(\frac{c_1}{M} \mathbf{X}^\dagger + \frac{c_2}{M^2} \mathbf{X}^\dagger \mathbf{X} \right) + h.c.$$

with $\mathbf{X} = X + \theta^2 F_X$ being a SUSY breaking spurion. Then

$$\mu = \frac{c_1 \langle F_X \rangle}{M}, \quad B_\mu = \frac{c_2 \langle F_X \rangle^2}{M^2}.$$

- Typically, c_1 and c_2 are generated at the same loop level in GMSB, implying

$$B_\mu/\mu \sim \langle F_X \rangle/\Lambda_M \sim 100\text{TeV}.$$

- Different alternatives have been proposed, e.g., effectively generating c_1 and c_2 at different loop levels. But, new dimensional parameters are introduced (G. Giudice et.al.'96,'07)

II. μ/B_μ Problem in GMSB

C. Light Singlet Mechanism

- Assume exact global symmetries (NMSSM, nMSSM) or gauge symmetry (UMSSM) to forbid μ term in MSSM
- Introduce a singlet chiral superfield \mathbf{N} in the observable sector which has the coupling

$$\Delta\mathcal{L} = \int d^2\theta \lambda \mathbf{N} \mathbf{H}_d \mathbf{H}_u + h.c.$$

- The effective μ and B_μ parameters arise as

$$\mu = \lambda v_N, \quad B_\mu = \lambda \langle F_N \rangle + A_\lambda \mu.$$

- As long as N and F_N are stabilized at the EW scale, we will have the correct relationship

$$\frac{B_\mu}{\mu} \sim \frac{\langle F_N \rangle}{v_N} \sim 10^2 - 10^3 \text{GeV}.$$

II. μ/B_μ Problem in GMSB

- Main difficulties: (1) how to generate a negative enough $m_N^2(\Lambda_{EW})$ term in the Higgs potential, to stabilize N to Λ_{EW} ; (2) how to avoid the light $U(1)_R$ axion problem? (M. Dine et. al. '93)
- In the minimal GMSB

$$W = \lambda \mathbf{S} \bar{q} q + \gamma \mathbf{S} \bar{l} l$$

where $(q + l, \bar{q} + \bar{l}) = (3 + 2, \bar{3} + \bar{2})$ are vector-like messengers, and $\mathbf{S} = S + \theta^2 F_S$ is the SUSY breaking spurion, one never gets a negative enough $m_N^2(\Lambda_{EW})$ term, independently of the messenger scale (M. Dine '93; H. Murayama et. al. '99)

- There are several kinds of modifications (in the mGMSB framework), but the results are not satisfactory: (M. Dine et. al. '93; G. Giudice et. al. '97,'07; T. Han et.al. '99; P. Langacker et. al. '99)

III. A Simple Model to Solve μ/B_μ Problem

A. The Structure of "General Gauge Mediation"

- Consider a gauge mediation structure

$$W = \zeta \mathbf{S}_q \bar{\mathbf{q}} \mathbf{q} + \gamma \mathbf{S}_I \bar{\mathbf{l}} \mathbf{l},$$

with \mathbf{S}_q and \mathbf{S}_I being SUSY breaking spurions.

- Then we have TWO effective SUSY breaking scales

$$\Lambda_q = \frac{\langle F_q \rangle}{\langle S_q \rangle}, \quad \Lambda_I = \frac{\langle F_I \rangle}{\langle S_I \rangle}.$$

- This extra freedom degree can help implement the light singlet mechanism.

III. A Simple Model to Solve μ/B_μ Problem

B. How General is the "General Gauge Mediation"?

- Such a gauge-mediation structure can naturally arise in many backgrounds.
- For example, assume more than one SUSY breaking spurion in the hidden sector while keeping the messenger sector minimal, then (M. Dine et. al. '07)

$$W = \lambda_i \mathbf{S}_i \bar{\mathbf{q}} \mathbf{q} + \gamma_i \mathbf{S}_i \bar{\mathbf{l}} \mathbf{l},$$

- By redefining

$$\mathbf{S}_q = \lambda_i \mathbf{S}_i, \quad \mathbf{S}_l = \gamma_i \mathbf{S}_i.$$

we have

$$W = \mathbf{S}_q \bar{\mathbf{q}} \mathbf{q} + \mathbf{S}_l \bar{\mathbf{l}} \mathbf{l},$$

which is exactly the structure we are considering.

III. A Simple Model to Solve μ/B_μ Problem

B. Generating Large Negative $m_N^2(\Lambda_{EW})$

- The NMSSM has a superpotential for the Higgs superfields

$$W = \lambda \mathbf{N} \mathbf{H}_d \mathbf{H}_u - \frac{1}{3} \kappa \mathbf{N}^3,$$

- The leading order soft masses at the messenger scale Λ_M are:

$$M_3 = \frac{\alpha_3}{4\pi} \Lambda_q \quad M_2 = \frac{\alpha_2}{4\pi} \Lambda_l \quad M_1 = \frac{\alpha_1}{4\pi} \left[\frac{2}{5} \Lambda_q + \frac{3}{5} \Lambda_l \right]$$

$$m_\phi^2 = 2 \left[C_3^\phi \left(\frac{\alpha_3}{4\pi} \right)^2 \Lambda_q^2 + C_2^\phi \left(\frac{\alpha_2}{4\pi} \right)^2 \Lambda_l^2 + C_1^\phi \left(\frac{\alpha_1}{4\pi} \right)^2 \left(\frac{2}{5} \Lambda_q^2 + \frac{3}{5} \Lambda_l^2 \right) \right]$$

C_i^ϕ s are quadratic Casimir operators of the scalar ϕ .

III. A Simple Model to Solve μ/B_μ Problem

- RGEs (1-loop) of $m_{H_u}^2$ and m_N^2 ($\Lambda_M \rightarrow \Lambda_{EW}$):

$$16\pi^2 \frac{d}{dt} m_{H_u}^2 = 6h_t^2(m_{\tilde{Q}_3}^2 + m_{H_u}^2 + m_t^2 + A_t^2) + 2\lambda^2(m_{H_d}^2 + m_{H_u}^2 + m_N^2 + A_\lambda^2) - 8\left(\frac{1}{4}g_Y^2 M_1^2 + \frac{3}{4}g_2^2 M_2^2\right),$$

$$16\pi^2 \frac{d}{dt} m_N^2 = 4\lambda^2(m_{H_d}^2 + m_{H_u}^2 + m_N^2 + A_\lambda^2) + 4k^2(3m_N^2 + A_k^2).$$

- In the minimal GMSB ($\Lambda_I = \Lambda_q$), $m_{H_u}^2$ gets negative quickly due to the top (s)quark contributions, but m_N^2 not. \Rightarrow too small $|m_N^2(\Lambda_{EW})|$.
- In the general GMSB, if $\Lambda_I > \Lambda_q$, the evolution of m_N^2 to a negative value is accelerated, and that of $m_{H_u}^2$ is slowed down. \Rightarrow large negative $m_N^2(\Lambda_{EW})$

III. A Simple Model to Solve μ/B_μ Problem

C. No Light $U(1)_R$ Axion Problem

- The RGE of $m_{H_d}^2$ is given by

$$\frac{d}{dt} m_{H_d}^2 = \frac{2\lambda^2}{16\pi^2} (m_{H_d}^2 + m_{H_u}^2 + m_N^2 + A_\lambda^2) - \frac{2}{16\pi^2} (g_Y^2 M_1^2 + 3g_2^2 M_2^2)$$

Relatively large $\Lambda_I \Rightarrow$ relatively large positive $m_{H_d}^2(\Lambda_{EW})$

- The eigenvector of the light Higgs pseudoscalar is ($v_N \gg v$):

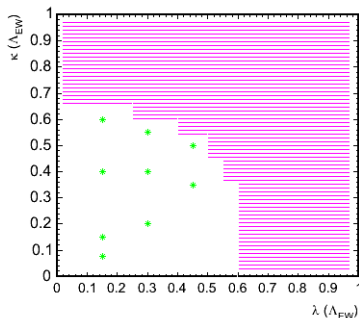
$$\begin{aligned} a_1 &= \cos \theta_A A_{MSSM} + \sin \theta_A A_N, \\ \tan \theta_A &= \frac{v_N}{v \sin 2\beta}, \\ \sin 2\beta &= \frac{2B_\mu}{m_{H_d}^2(\Lambda_{EW}) + m_{H_u}^2(\Lambda_{EW}) + 2\mu^2} \end{aligned}$$

- Large $m_{H_d}^2(\Lambda_{EW}) \Rightarrow$ small $\sin 2\beta$ or large $\tan \beta \Rightarrow \theta_A \approx \pi/2$.
So the light Higgs pseudoscalar is singlet-like.

IV. Numerical Analysis

A. The Strategy

- Low- ($\sim 10^5$ GeV), intermediate- ($\sim 10^{11}$ GeV) and high-scale ($\sim 10^{15}$ GeV) gauge mediations are considered.
- For each case, nine characteristic points are studied, all of them specified by $\lambda(\Lambda_{EW})$ and $\kappa(\Lambda_{EW})$ and located in the perturbative region.



IV. Numerical Analysis

B. Some General Comments

- Four unknown input parameters: $\lambda(\Lambda_{EW})$, $\kappa(\Lambda_{EW})$, the messenger scale Λ_M and $\eta = \Lambda_I/\Lambda_q$
- For all of the 9×3 characteristic points, physical results are obtained by giving proper values to η : 2 – 6
- A relatively large $\tan \beta$: $5 \sim 50$ is favored.
- The composition of singlet in the light $U(1)_R$ axion is larger than $1 - 10^{-4}$
- For large $\tan \beta$ and $v_N \gg v$, $m_{h_1}^2 < M_Z^2$ at the tree-level \Rightarrow heavy stops $\sim \mathcal{O}(TeV) \Rightarrow$ fine tuning of $\mathcal{O}(10^{-3})$ in the low-scale scenario and $\mathcal{O}(10^{-2})$ in the other two scenarios.
- These physical features could be extended into the non-perturbative $\kappa - \lambda$ region as long as these couplings stay perturbative at the messenger scale.

V. Gauge Coupling Unification

- In the MSSM, the $SU(5)$ GUT predicts $\alpha_3(M_Z) = 0.125$ at one-loop level, compared to the experimental value ~ 0.120 . The threshold correction is given by

$$\Delta\alpha_3(M_Z)_{MSSM} \simeq -\frac{19}{28\pi}\alpha_3(M_Z)^2 \ln\left(\frac{|\mu|}{M_Z} \left(\frac{M_2}{M_3}\right)^{3/2}\right)$$

For $\mu \sim \mathcal{O}(10^2 \text{GeV})$, this correction is not negative enough.
(P. Langacker et.al.'93, C. Wagner et.al.'93)

- In our model,

$$\Delta\alpha_3(M_Z) \simeq \alpha_3(M_Z)^2 \left(\frac{9}{14\pi} \ln\left(\frac{\langle S_q \rangle}{\langle S_l \rangle}\right) - \frac{19}{28\pi} \ln\left(\frac{|\mu|}{M_Z} \left(\frac{\eta\alpha_2}{\alpha_3}\right)^{3/2}\right) \right)$$

V. Gauge Coupling Unification

- If $\langle F_I \rangle / \langle F_q \rangle \simeq \eta$, then $\langle S_q \rangle / \langle S_I \rangle \sim 1$ and

$$\Delta_\eta \alpha_3(M_Z) = \Delta \alpha_3(M_Z) - \Delta \alpha_3(M_Z)_{MSSM} \simeq -\frac{57}{56\pi} \alpha_3^2(M_Z) \ln \eta.$$

- If $\langle F_q \rangle \sim \langle F_I \rangle$, then $\langle S_q \rangle / \langle S_I \rangle \simeq \eta$ and

$$\Delta_\eta \alpha_3(M_Z) \simeq -\frac{21}{56\pi} \alpha_3^2(M_Z) \ln \eta.$$

- In both cases, $\Delta_\eta \alpha_3(M_Z) \sim \mathcal{O}(0.001) < 0$, leading to a somewhat better unification prediction than the MSSM limit.

VI. Conclusions

- The light singlet mechanism to solve the μ/B_μ problem in GMSB can be well-implemented in the general gauge-mediation (minimal messenger sector + general hidden sector).
- Good features:
 - Large parameter space are allowed: most perturbative $\kappa - \lambda$ region + all possible messenger scales
 - Better $SU(5)$ GUT prediction for $\mu \sim \mathcal{O}(100\text{GeV})$ which is typical in the general gauge-mediation.
 - Universal structure: no difficulty to extend to other contexts, e.g., mMSSM and UMSSM
- Open question: the little hierarchy of particle spectrum, typical in the mGMSB, is preserved \Rightarrow fine-tuning level 10^{-3} in the low-scale scenario and 10^{-2} in the other two scenarios. Can we resolve or release it?

Thank you!

Table: Parameters of the low-scale general gauge mediation.

Input Parameters				
Pts	$\lambda(\Lambda_{EW})$	$\kappa(\Lambda_{EW})$	Λ_M (GeV)	η
A1	0.15	0.075	2.50×10^5	2.1160
A2	0.15	0.15	5.00×10^5	2.2708
A3	0.15	0.40	5.00×10^6	2.5151
A4	0.15	0.60	2.00×10^7	2.7869
A5	0.30	0.20	2.50×10^5	1.9356
A6	0.30	0.40	2.50×10^5	2.1383
A7	0.30	0.55	5.00×10^5	2.2800
A8	0.45	0.35	2.00×10^6	2.2509
A9	0.45	0.50	2.50×10^5	2.1083

Output Parameters					
Pts	h_t, h_b	Λ_g (GeV)	$\tan\beta$	μ (GeV)	B_μ (GeV ²)
A1	0.949, 0.753	3.90×10^5	43.57	173.8	1.41×10^4
A2	0.948, 0.833	4.52×10^5	48.44	105.1	7.38×10^3
A3	0.948, 0.880	1.37×10^6	51.05	121.8	6.55×10^3
A4	0.948, 0.882	1.34×10^6	52.41	106.0	1.92×10^4
A5	0.949, 0.637	5.46×10^5	36.93	321.8	7.11×10^4
A6	0.948, 0.780	3.95×10^5	45.30	124.2	1.88×10^4
A7	0.948, 0.809	4.38×10^5	46.89	109.9	1.94×10^4
A8	0.950, 0.307	8.68×10^5	17.80	1276.6	1.54×10^6
A9	0.949, 0.533	2.50×10^5	30.87	296.7	1.11×10^5

Table: Mass spectrum of particles and superparticles in the low-scale general gauge mediation.

Particle Masses (TeV)				
Pts	$m_{\bar{g}}$	$m_{\bar{t}_{1,2}}$	$m_{\bar{b}_{1,2}}$	$m_{\bar{\tau}_{1,2}}$
A1	3.44	5.55, 6.36	5.86, 6.35	0.80, 2.84
A2	3.95	6.37, 7.36	6.60, 7.35	0.89, 3.53
A3	11.17	18.63, 22.24	19.08, 22.24	2.27, 11.90
A4	10.98	17.78, 22.18	18.26, 22.18	1.67, 12.98
A5	4.76	7.89, 8.98	8.54, 8.97	1.14, 3.69
A6	3.48	5.62, 6.42	5.89, 6.42	0.80, 2.90
A7	3.83	6.16, 7.14	6.43, 7.14	0.88, 3.43
A8	7.30	12.01, 14.72	14.15, 14.72	2.33, 6.85
A9	3.49	5.63, 6.57	6.23, 6.57	0.92, 2.88

Particle Masses (GeV)				
Pts	$m_{\chi_1^c}$	$m_{\chi_1^0}$	$m_{h_{1,2,3}}$	$m_{a_{1,2}}$
A1	173.4	155.8	118.3, 187.3, 1751.6	15.7, 1751.6
A2	105.0	103.7	136.6, 211.1, 1616.8	20.3, 1616.8
A3	121.7	121.7	152.6, 644.3, 3544.8	71.3, 3544.8
A4	106.0	105.8	152.4, 843.6, 3564.4	98.0, 3564.3
A5	321.4	311.1	117.4, 433.3, 2825.2	53.8, 2825.1
A6	123.9	119.8	133.1, 331.2, 1656.8	43.3, 1656.7
A7	109.7	107.1	137.5, 401.8, 1754.8	54.3, 1754.6
A8	1276.2	1272.4	116.2, 1973.2, 6596.7	337.4, 6596.6
A9	296.1	289.8	121.9, 659.6, 2430.1	96.1, 2429.9

Table: Parameters of the intermediate-scale general gauge mediation.

Input Parameters					
Pts	$\lambda(\Lambda_{EW})$	$\kappa(\Lambda_{EW})$	Λ_M (GeV)	η	
B1	0.15	0.075	1.00×10^{11}	4.180	
B2	0.15	0.15	1.00×10^{11}	4.512	
B3	0.15	0.40	1.00×10^{11}	4.292	
B4	0.15	0.60	1.00×10^{11}	4.126	
B5	0.30	0.20	1.00×10^{11}	3.981	
B6	0.30	0.40	1.00×10^{11}	4.360	
B7	0.30	0.55	1.00×10^{11}	4.620	
B8	0.45	0.35	1.00×10^{11}	4.019	
B9	0.45	0.50	1.00×10^{11}	4.542	

Output Parameters					
Pts	h_t, h_b	Λ_q (GeV)	$\tan\beta$	μ (GeV)	B_μ (GeV ²)
B1	0.950, 0.331	1.98×10^5	19.11	541.4	3.51×10^5
B2	0.949, 0.550	1.05×10^5	31.88	150.3	4.91×10^4
B3	0.949, 0.780	2.91×10^5	45.17	126.0	6.92×10^4
B4	0.948, 0.832	5.47×10^5	48.15	126.2	9.22×10^4
B5	0.953, 0.183	3.59×10^5	10.57	1406.6	2.22×10^6
B6	0.949, 0.340	1.86×10^5	19.62	384.5	3.33×10^5
B7	0.949, 0.465	1.10×10^5	26.97	163.5	8.23×10^4
B8	0.957, 0.125	4.39×10^5	7.16	2188.5	5.30×10^6
B9	0.953, 0.173	1.76×10^5	10.03	673.5	7.40×10^5

Table: Mass spectrum of particles and superparticles in the intermediate-scale general gauge mediation.

Pts	Particle Masses (TeV)			
	$m_{\tilde{g}}$	$m_{\tilde{t}_{1,2}}$	$m_{\tilde{b}_{1,2}}$	$m_{\tilde{\tau}_{1,2}}$
B1	1.82	1.98, 4.03	3.23, 4.02	0.90, 3.07
B2	1.00	0.98, 2.16	1.56, 2.16	0.32, 1.74
B3	2.61	2.84, 5.58	3.59, 5.58	1.00, 4.49
B4	4.72	5.52, 10.16	6.42, 10.16	2.11, 8.07
B5	3.19	3.69, 7.21	6.04, 7.21	1.75, 5.34
B6	1.72	1.79, 3.86	3.02, 3.85	0.87, 3.01
B7	1.05	1.00, 2.33	1.71, 2.32	0.45, 1.88
B8	3.86	4.42, 8.87	7.44, 8.87	2.20, 6.60
B9	1.63	1.60, 3.76	2.96, 3.75	0.97, 2.98

Pts	Particle Masses (GeV)			
	$m_{\chi_1^c}$	$m_{\chi_1^0}$	$m_{h_{1,2,3}}$	$m_{a_{1,2}}$
B1	540.3	520.5	121.4, 536.5, 2931.9	97.1, 2931.9
B2	149.4	144.7	121.1, 297.6, 1416.9	54.0, 1416.9
B3	125.9	124.4	135.3, 663.8, 2367.7	115.8, 2367.6
B4	126.1	125.4	142.2, 997.6, 3227.7	172.5, 3227.6
B5	1405.5	1342.6	120.6, 1843.4, 5383.5	473.7, 5383.4
B6	383.7	380.6	126.1, 1009.0, 2803.2	192.7, 2136.1
B7	162.6	159.3	122.0, 590.0, 1623.6	150.5, 1623.6
B8	2187.3	1676.5	117.7, 3331.0, 6768.7	1045.5, 6768.5
B9	671.8	658.9	118.6, 1464.2, 2911.0	457.8, 2910.5

Table: Parameters of the high-scale general gauge mediation.

Input Parameters				
Pts	$\lambda(\Lambda_{EW})$	$\kappa(\Lambda_{EW})$	Λ_M (GeV)	η
C1	0.15	0.075	1.00×10^{15}	4.695
C2	0.15	0.15	1.00×10^{15}	4.980
C3	0.15	0.40	1.00×10^{15}	5.060
C4	0.15	0.60	1.00×10^{15}	4.930
C5	0.30	0.20	1.00×10^{15}	4.639
C6	0.30	0.40	1.00×10^{15}	5.110
C7	0.30	0.55	1.00×10^{15}	5.240
C8	0.45	0.35	1.00×10^{15}	4.755
C9	0.45	0.50	1.00×10^{15}	5.560

Output Parameters					
Pts	h_t, h_b	Λ_q (GeV)	$\tan\beta$	μ (GeV)	B_μ (GeV ²)
C1	0.951, 0.220	1.98×10^5	12.63	792.6	8.99×10^5
C2	0.949, 0.391	1.37×10^5	22.64	285.4	2.23×10^5
C3	0.948, 0.702	1.79×10^5	40.79	122.3	8.75×10^4
C4	0.948, 0.794	3.23×10^5	46.05	112.8	1.03×10^5
C5	0.958, 0.124	2.56×10^5	7.10	1524.2	2.87×10^6
C6	0.951, 0.233	1.58×10^5	13.47	492.5	6.20×10^5
C7	0.949, 0.342	1.47×10^5	19.86	306.8	3.38×10^5
C8	0.967, 0.087	4.49×10^5	4.99	3406.1	1.35×10^7
C9	0.958, 0.123	1.54×10^5	7.09	891.2	1.39×10^6

Table: Mass spectrum of particles and superparticles in the high-scale general gauge mediation.

	Particle Masses (TeV)			
Pts	$m_{\tilde{g}}$	$m_{\tilde{t}_{1,2}}$	$m_{\tilde{b}_{1,2}}$	$m_{\tilde{\tau}_{1,2}}$
C1	1.80	1.17, 4.37	3.33, 4.37	1.18, 3.68
C2	1.27	0.61, 3.07	2.15, 3.06	0.68, 2.67
C3	1.63	0.68, 3.82	2.08, 3.81	0.89, 3.43
C4	2.84	1.54, 6.61	3.14, 6.61	2.08, 5.95
C5	2.29	1.48, 5.62	4.37, 5.61	1.59, 4.71
C6	1.46	0.52, 3.65	2.64, 3.65	1.00, 3.19
C7	1.36	0.31, 3.41	2.36, 3.40	0.84, 3.02
C8	3.90	2.07, 9.98	7.71, 9.98	2.89, 8.48
C9	1.43	0.71, 3.76	2.64, 3.76	1.14, 3.40

	Particle Masses (GeV)			
Pts	$m_{\chi_1^c}$	$m_{\chi_1^0}$	$m_{h_{1,2,3}}$	$m_{a_{1,2}}$
C1	791.3	768.6	120.7, 777.4, 3665.7	194.8, 3665.7
C2	284.6	280.6	122.2, 559.6, 2443.0	139.6, 2442.9
C3	122.1	119.9	126.8, 639.4, 2207.5	155.3, 2207.4
C4	112.7	111.6	134.2, 878.8, 2792.8	211.2, 2792.7
C5	1522.3	1101.0	116.6, 1972.0, 4872.1	698.9, 4871.9
C6	491.3	486.7	121.2, 1274.9, 3068.7	446.3, 3068.4
C7	306.0	303.1	120.4, 1086.4, 2765.9	376.0, 2765.6
C8	3404.4	1981.1	120.1, 5084.2, 8909.4	2193.7, 8909.2
C9	889.0	771.4	117.2, 1884.6, 3306.1	806.7, 3305.3

Table: Composition of the light Higgs bosons ($\leq 115\text{GeV}$).

Composition of Light Higgs Bosons (LHB)				
Pts	LHBs	$\text{Im}(H_d)$	$\text{Im}(H_u)$	$\text{Im}(N)$
A1	a_1	-1.2×10^{-3}	-8.8×10^{-4}	0.999999
A2	a_1	-2.0×10^{-3}	-1.1×10^{-5}	0.999998
A3	a_1	-2.2×10^{-3}	9.4×10^{-4}	0.999997
A4	a_1	-2.1×10^{-3}	-7.5×10^{-5}	0.999998
A5	a_1	-2.0×10^{-4}	3.3×10^{-5}	> 0.9999995
A6	a_1	1.3×10^{-4}	-1.7×10^{-6}	> 0.9999995
A7	a_1	1.1×10^{-4}	6.1×10^{-5}	> 0.9999995
A9	a_1	4.6×10^{-3}	1.2×10^{-4}	0.999989
B1	a_1	-7.0×10^{-5}	-1.0×10^{-5}	> 0.9999995
B2	a_1	3.8×10^{-4}	1.7×10^{-5}	> 0.9999995