Higgs Phenomenology as a Probe of Supersymmetric Grand Unification with the Hosotani Mechanism*

Mitsuru Kakizaki
Department of Physics, University of Toyama, Toyama 930-8555, Japan

In the supersymmetric SU(5) grand unified theory whose gauge symmetry is broken by virtue of the Hosotani mechanism, the huge mass splitting between the colored Higgs triplet and the electroweak Higgs doublet superfields is naturally realized. As a byproduct, the existence of adjoint chiral superfields with masses of the order of the supersymmetry breaking scale is predicted, leading to the Higgs sector that contains an SU(2)_L triplet chiral multiplet with hypercharge zero and a neutral singlet one in addition to the two SU(2)_L doublets of the minimal supersymmetric standard model. We focus on the Higgs sector and investigate to what extent the couplings of the standard model-like Higgs boson and the masses of the additional Higgs bosons deviate from those in the Standard Model and other models due to the new triplet and singlet chiral multiplets. We show that this model can be distinguished using precision measurements of couplings and masses of the Higgs sector particles and serves as a good example of grand unification testable at colliders such as the luminosity up-graded Large Hadron Collider and future electron-positron colliders.

I. INTRODUCTION

In 2012, the ATLAS and CMS collaborations at the CERN Large Hadron Collider (LHC) discovered a new particle whose mass is approximately 125 GeV [2]. Its spin and CP properties as well as its couplings with other particles have been analyzed. So far, no clear evidence that contradicts the properties of the Standard Model (SM) Higgs boson has been found. The SM is now confirmed as a low energy effective theory that successfully explains phenomena below the TeV scale.

The SM, however, bears problems and puzzles that should be solved in a more fundamental theory. These include the hierarchy problem and the charge quantization problem. To keep the mass of the Higgs boson to the electroweak scale, an unnatural huge cancellation between its bare mass squared and quadratically divergent contributions from radiative corrections is required. Although the electric charges of the SM particles can be theoretically arbitrary, they must be fractionally quantized to account for the neutrality of atoms.

It is a natural idea to employ larger symmetries to tackle such problems. Indeed, the above-mentioned problems can be resolved by supersymmetry (SUSY) and grand unification [3, 4]. In supersymmetric extensions of the SM, the quadratically divergent contributions from SM particles to the Higgs boson mass squared are canceled with those from their partner particles, and therefore the hierarchy problem is avoided. Grand Unified Theories (GUTs) give a unified description of the three SM gauge groups and SM fermions. If the gauge group of a GUT is (semi-)simple, the electric charges of the SM particles can be theoretically arbitrary, they must be fractionally quantized to account for the neutrality of atoms.

Although SUSY GUT models contain such appealing features, there are several unattractive points. The typical GUT scale where the three gauge couplings are unified is around 10^{16} GeV in usual SUSY GUTs. According to the decoupling theorem, the effects of the heavy GUT particles are negligible at the TeV scale [5]. One can obtain information on physics realized at the GUT scale only through the relations among the mass and coupling parameters measured at the TeV scale. In addition, an unusually huge mass splitting between the colored Higgs triplets and the electroweak Higgs doublets are assumed to suppress the proton decay rate adequately. Many mechanisms have been proposed to solve this doublet-triplet splitting problem [6-11].

Recently, a SUSY GUT model that predicts the existence of new particles accessible at collider experiments is proposed [12]. In this model, the doublet-triplet mass splitting is naturally realized by supersymmetrizing the Grand Gauge-Higgs Unification (GHU) model [13]. The Supersymmetric Grand Gauge-Higgs Unification (SGGHU) is constructed on an extra dimension whose compactification scale is around 10^{16} GeV, where the GUT gauge symmetry is broken by the Hosotani mechanism [14]. The non-trivial vacuum expectation value (VEV) of the fifth component of one of the gauge fields is responsible for the symmetry breaking. In the SGGHU model, a color octet superfield, an SU(2)_L triplet superfield with hypercharge zero and a neutral

* Talk presented at the International Workshop on Future Linear Colliders (LCWS13), Tokyo, Japan, 11-15 November 2013. This talk is based on the work in collaboration with Shinya Kanemura, Hiroyuki Taniguchi and Toshifumi Yamashita [1].
singlet superfield appear at the TeV scale as a by-product. As compared to the minimal supersymmetric standard model (MSSM), the Higgs sector is extended by the triplet and singlet superfields.

In this talk, we discuss the properties of the SGGHU Higgs sector, and investigate its phenomenological signatures expected at collider experiments. We evaluate the masses and couplings of the Higgs sector particles solving renormalization group equation (RGE) from the GUT scale to the electroweak scale. Our emphasis is that precision measurements of the masses and couplings of the Higgs bosons at the LHC and future electron-positron colliders such as the International Linear Collider (ILC) [15] and the CLIC [16] play an important role in distinguishing particle physics models. The SGGHU model is a good example to show that low-energy collider experiments are capable of testing GUT scale physics.

II. MODEL OF SUPERSYMMETRIC GRAND GAUGE-HIGGS UNIFICATION

Here, we briefly discuss the structure of the Higgs sector of the low energy effective theory of the SGGHU model, which contains an $SU(2)_L$ triplet chiral superfield $\Delta$ and an neutral singlet chiral superfield $S$ as well as the two MSSM Higgs doublets $H_u$ and $H_d$. The superpotential of the SGGHU Higgs sector is given by

$$W = \mu H_u \cdot H_d + \mu_\Delta \text{tr}(\Delta^2) + \frac{\mu_S}{2} S^2 + \lambda_\Delta H_u \cdot \Delta H_d + \lambda_S SH_u \cdot H_d,$$

(1)

where $\Delta = \Delta^a \sigma^a/2$ with $\sigma^a (a = 1, 2, 3)$ being the Pauli matrices. The fact that $S$ and $\Delta$ stem from the gauge supermultiplet leads to the following remarkable features. Although trilinear self-couplings among $S$ and $\Delta$ are not forbidden in the general Higgs superpotential that contains the triplet and singlet superfields, such terms are absent in our model. The newly introduced Higgs couplings $\lambda_\Delta$ and $\lambda_S$ are unified with the SM gauge coupling constants at the GUT scale. Therefore, this model can predict the properties of the Higgs bosons with less ambiguity. The soft SUSY breaking terms in the Higgs potential read

$$V_{\text{soft}} = \bar{m}_{\Delta}^2 |H_d|^2 + \bar{m}_{\Delta}^2 |H_u|^2 + 2 \bar{m}_S^2 \text{tr}(\Delta^2) + \bar{m}_S^2 |S|^2$$

$$+ \left[ B\mu H_u \cdot H_d + \xi S + B_\Delta \mu_\Delta \text{tr}(\Delta^2) + \frac{1}{2} B_{\Delta S} S^2 + \lambda_\Delta A_\Delta H_u \cdot \Delta H_d + \lambda_S A_S S H_u \cdot H_d + \text{h.c.} \right].$$

(2)

The values of the soft parameters at the TeV scale are also determined by solving the RGEs. Due to the top Yukawa contributions to the RGEs, radiative electroweak symmetry breaking occurs. Then, in the Higgs sector, four CP-even, three CP-odd and three charged Higgs bosons appear as physical particles. The VEV of the neutral component of the triplet Higgs boson $v_\Delta$ is obtained from the minimization conditions of the Higgs potential, and must be less than $\approx 10$ GeV to satisfy the ratio parameter constraint. Since this value is sufficiently small compared to $v = 246$ GeV, $v_\Delta$ is neglected in our computation of the Higgs boson masses and couplings.

III. ANALYSIS OF THE RENORMALIZATION GROUP EQUATIONS

Let us turn to discussions about RG evolution of the coupling constants and mass parameters in the SGGHU model. As a consequence of introducing the light adjoint multiplets, the successful gauge coupling unification is disturbed. In our model, by adding extra incomplete $SU(5)$ matter multiplets, the gauge coupling unification can be easily recovered. An successful example for the matter multiplets is a set of two vectorlike pairs of $(\tilde{L}, L)$ ($(1, 2,-1/2)$), one of $(\tilde{U}, U)$ ($(3, 1,-2/3)$) and one of $(\tilde{E}, E)$ ($(1, 1, 1)$), where the numbers in the parentheses are $SU(3)_C, SU(2)_L$ and $U(1)_Y$ quantum numbers, respectively [12]. Fig. I shows the evolution of the Higgs triplet and singlet coupling constants $\lambda_\Delta$ (red line) and $\lambda_S$ (blue), as well as the gauge coupling constants $g_3$, $g_2$ and $g_1$ (green) at the one loop level as a function of the energy scale. The coupling constants are normalized such that $\lambda_S^0 = (2\sqrt{3}/5)\lambda_S$ for the singlet Higgs coupling and $g_1 = (\sqrt{3}/3)g_Y$ for the $U(1)_Y$ gauge coupling. The Higgs trilinear coupling constants at the TeV-scale are

$$\lambda_\Delta = 1.1, \quad \lambda_S = 0.25.$$

(3)

The soft breaking parameters at the SUSY breaking scale are evaluated by solving the RGEs. Fig. I shows that we have strong gauge couplings at the GUT scale. To satisfy the gluino mass limit [17], the unified gaugino mass at the GUT scale needs to be large. Consequently, soft sfermion and Higgs masses at the SUSY breaking scale are typically multi-TeV. This means that one needs some tuning to have successful radiative electroweak symmetry breaking. In spite of the difficulties, we will show that one can also obtain soft Higgs masses of the order of $\mathcal{O}(100)$ GeV by tuning among the input parameters at the GUT scale.
FIG. 1: Evolution of the Higgs triplet and singlet coupling constants $\lambda_\Delta$ (red line) and $\lambda'_S$ (blue) as well as the gauge coupling constants $g_3$, $g_2$ and $g_1$ (green) at the one loop level as a function of the energy scale.

TABLE I: Benchmark points for the GUT-scale input parameters.

| Case | $\tan \beta$ | $M_{1/2}$ | $\mu_{\Sigma}$ |
|------|--------------|-----------|--------------|
| A    | 3            | 3600 GeV  | -300 GeV     |
| B    | 3            | 3600 GeV  | -300 GeV     |
| C    | 3            | 3600 GeV  | -300 GeV     |

IV. IMPACT ON HIGGS PROPERTIES

First, let us discuss the prediction about the SM-like Higgs boson mass, which is affected by the $SU(2)_L$ triplet and singlet Higgs multiplets. When the soft scalar masses of the triplet and singlet are relatively large, the mass of the SM-like Higgs boson is approximately given by [18, 19]

$$m_h^2 \simeq m_Z^2 \cos^2 \beta + \frac{3m_t^4}{2\pi^2 v^2} \left( \ln \frac{m_t^2}{m_Z^2} + \frac{X_t^2}{m_t^2} \left( 1 - \frac{X_t^2}{12m_t^2} \right) \right) + \frac{1}{8} \lambda_\Delta^2 v^2 \sin^2 2\beta + \frac{1}{2} \lambda_S^2 v^2 \sin^2 2\beta,$$

where $m_Z$ is the Z-boson mass, $m_t$ is the top quark mass, $m_t$ is the averaged stop mass, and $X_t = A_t - \mu \cot \beta$.

In the MSSM, for the SM-like Higgs boson mass to reach 125 GeV using the large stop loop contribution, one needs very large stop masses even in the maximal stop mixing scenario [20]. As in the next-to-MSSM (NMSSM) [21], in our model the SM-like Higgs boson mass is lifted up by the Higgs trilinear couplings with the triplet and singlet superfield, in particular, for small $\tan \beta$ region. In our numerical computation of the masses of the Higgs scalars and superparticle, we have used the public numerical code Suspect [22] after including the contributions from the triplet and singlet Higgs superfields, instead of the approximate formula Eq. (4). Since fine tuning for the GUT-scale input parameters is required, we show results based on some benchmark points that reproduce the correct SM-like Higgs boson mass. Taking theoretical uncertainties into account, we allow the mass range $122 \text{ GeV} < m_h < 129 \text{ GeV}$. We consider the following three typical scenarios:

(A) Mixings between the SM-like Higgs boson and the other Higgs bosons are small.

(B) Mixings between the SM-like Higgs boson and the triplet and singlet Higgs bosons are small.

(C) The triplet and singlet Higgs bosons affect the SM-like Higgs boson couplings.

Three successful benchmark points for the GUT-scale input parameters and the resulting TeV-scale parameters obtained after RG evolution are shown in Tab. I and II, respectively.
The couplings between the SM-like Higgs boson and SM particles can be significantly affected by the existence of the new Higgs bosons. In fingerprinting the SM-like Higgs boson couplings, it is useful to define the following scaling factors
\[
\kappa_X = \frac{g_{hXX}}{g_{hXX}^{\text{SM}}},
\]
where \(g_{hXX}\) denotes the coupling with the SM particle \(X\). In Fig. 2, the deviations in the scaling factors \(\kappa_X\) are plotted on the \(\kappa_\gamma-\kappa_b\) plane, the \(\kappa_\gamma-\kappa_b\) plane (\(V = Z, W\)) and the \(\kappa_\gamma-\kappa_b\) plane [27]. The deviations in the three benchmark scenarios (A), (B) and (C) in the SGGHU are shown with green blobs. The MSSM predictions are shown with red lines for \(\tan\beta = 10\) (thick line) and \(\tan\beta = 3\) (dashed), which indicate mixings between the SM-like and singlet-like Higgs bosons of 10%, 20% and 30% from the right to the left. Since the Higgs boson couplings to the down-type quarks and charged leptons are common in our model as in the Type-II two Higgs doublet model, the predicted SGGHU deviations lie on the MSSM and NMSSM lines on the \(\kappa_\gamma-\kappa_b\) plane. At the ILC with \(\sqrt{s} = 500\) GeV, expected accuracies for the scaling factors \(\kappa_Z, \kappa_W, \kappa_b\) and \(\kappa_c\) are 1.0% 1.1% 1.6%, 2.3% and 2.8%, respectively [23]. These plots show that characteristic SGGHU predictions about the Higgs couplings are distinguishable from those of the SM and MSSM by measuring the Higgs boson couplings accurately at the future ILC while it may be difficult to completely distinguish our model from the NMSSM only through the precision measurements. Nevertheless, if the pattern of the Higgs coupling deviations turns out to be close to one of our benchmark points, the possibility of the SGGHU is increased. Independent measurement of \(\tan\beta\) utilizing Higgs boson decay at the ILC [23, 26] will be also useful in distinguishing new physics models. As for the Higgs coupling with the photon and Higgs self-coupling, we obtained 0.94 < \(\kappa_\gamma\) < 1.0 and 0.82 < \(\kappa_b\) < 0.93, respectively, for the above benchmark points. To observe such deviations one needs more precise measurements at the ILC with \(\sqrt{s} = 1\) TeV [28].

Let us mention the masses of the additional MSSM-like Higgs bosons. For relatively large soft scalar masses of the triplet and singlet, the MSSM-like charged Higgs boson mass \(m_{H^\pm}\) is approximately written as
\[
m_{H^\pm}^2 = m_{H^\pm}^2|_{\text{MSSM}}(1 + \delta_{H^\pm})^2 \simeq m_A^2 + m_W^2 + \frac{1}{8}\lambda_\Delta v^2 - \frac{1}{2}\lambda_\lambda v^2,
\]
where \(m_A\) is the MSSM-like CP-odd Higgs boson mass, and \(\delta_{H^\pm}\) parametrizes the deviation of \(m_{H^\pm}\) from the MSSM prediction. The sign difference between the triplet and singlet contributions comes from group theoretical factors. Since \(\lambda_\Delta\) is significantly larger than \(\lambda_s\) due to radiative corrections, the MSSM-like charged Higgs boson mass in our model is larger than the MSSM prediction. Fig. 3 shows the deviation parameter \(\delta_{H^\pm}\) of the MSSM-like charged Higgs boson mass as a function of \(m_A\) for relatively large soft Higgs masses. The black, blue and green lines correspond to triplet contribution, singlet contribution and their sum, respectively. When the MSSM-like Higgs bosons are lighter than 500 GeV, the mass deviation is found to be \(\delta_{H^\pm} \sim O(1)\%\) - \(O(10)\%\) and detectable at the LHC [23].

If the triplet-like and singlet-like Higgs bosons are lighter than 500 GeV, the new Higgs bosons can be directly produced at the ILC and CLIC. As shown in Tab. II, the benchmark point (C) contains such light Higgs bosons. For example, \(\Delta^\pm\) can be probed through the channel \(e^+e^- \rightarrow \Delta^+\Delta^- \rightarrow t\bar{t}b\bar{b}\), which is induced by the mixing between the MSSM-like and triplet-like charged Higgs bosons.

Above discussions show that new physics models can be distinguished through exhaustive analysis of the masses and couplings of the Higgs sector particles at the LHC and future electron-positron colliders. Even when the additional Higgs bosons are beyond the reach of direct discovery, their effects can be indirectly probed.
by precise measurements of the SM-like Higgs boson couplings and the MSSM Higgs boson masses. A new electron-positron collider is mandatory for exploring the Higgs properties and the underlying theory.

V. SUMMARY

In the SUSY $SU(5)$ GUT model where the Hosotani mechanism is responsible for the $SU(5)$ gauge symmetry breaking, the Higgs sector at the TeV scale contains a Higgs triplet and singlet chiral superfields as well as the

| CP-even | CP-odd | Charged |
|---------|--------|---------|
| 122 GeV | –      | –       |
| 139 GeV | 171 GeV| 204 GeV |
| 370 GeV | 304 GeV| 496 GeV |
| 745 GeV | 497 GeV| 745 GeV |

TAB III: Higgs boson masses for the benchmark point (C).
two MSSM Higgs doublets. We have computed the couplings between the SM-like Higgs boson and SM particles. The deviations of these coupling constants from the corresponding SM predictions are shown to be $\mathcal{O}(1)\%$ when the triplet and singlet Higgs boson masses are smaller than $\simeq 1$ TeV. Such deviations can be measured at future electron-positron colliders. When the masses of the MSSM-like charged Higgs boson and the MSSM-like CP-odd Higgs boson are below $\simeq 500$ GeV, their mass difference is larger than the MSSM prediction by $\mathcal{O}(1)\% - \mathcal{O}(10)\%$, and measurable at the LHC. By combining these observations, we can distinguish our model, MSSM and NMSSM. We emphasise that the supersymmetric grand gauge-Higgs unification model is a good example to show capability of colliders for testing GUT scale physics.

Acknowledgments

The author would like to thank Shinya Kanemura, Hiroyuki Taniguchi and Toshifumi Yamashita for the fruitful collaboration.

[1] M. Kakizaki, S. Kanemura, H. Taniguchi and T. Yamashita, arXiv:1312.7575 [hep-ph].  
[2] G. Aad et al. [ATLAS Collaboration], Phys. Lett. B 716, 1 (2012); S. Chatrchyan et al. [CMS Collaboration], Phys. Lett. B 716, 30 (2012).  
[3] H. Georgi and S. L. Glashow, Phys. Rev. Lett. 32 (1974) 438.  
[4] E. Witten, Nucl. Phys. B 188 (1981) 513; S. Dimopoulos, S. Raby and F. Wilczek, Phys. Rev. D 24 (1981) 1681; S. Dimopoulos and H. Georgi, Nucl. Phys. B 193 (1981) 150; N. Sakai, Z. Phys. C 11 (1981) 153.  
[5] T. Appelquist and J. Carazzone, Phys. Rev. D 11, 2856 (1975).  
[6] S. Dimopoulos and F. Wilczek, NSF-ITP-82-07; M. Srednicki, Nucl. Phys. B 202 (1982) 327; K. S. Babu and S. M. Barr, Phys. Rev. D 48 (1993) 5354; S. M. Barr and S. Raby, Phys. Rev. Lett. 79 (1997) 4748; N. Maekawa, Prog. Theor. Phys. 106 (2001) 401; N. Maekawa and T. Yamashita, Prog. Theor. Phys. 107 (2002) 1201; ibid 110 (2003) 93.  
[7] E. Witten, Phys. Lett. B 105 (1981) 267; D. V. Nanopoulos and K. Tamvakis, Phys. Lett. B 112 (1982) 151; S. Dimopoulos and H. Georgi, Phys. Lett. B 117 (1982) 287; K. Tabata, I. Umemura and K. Yamamoto, Prog. Theor. Phys. 71 (1984) 615; A. Sen, Phys. Lett. B 148 (1984) 65; S. M. Barr, Phys. Rev. D 57 (1998) 190; G. R. Dvali, Phys. Lett. B 324 (1994) 59; N. Maekawa and T. Yamashita, Phys. Rev. D 68 (2003) 055001.  
[8] H. Georgi, Phys. Lett. B 108 (1982) 283; A. Masiero, D. V. Nanopoulos, K. Tamvakis and T. Yanagida, Phys. Lett. B 115 (1982) 380; B. Grinstein, Nucl. Phys. B 206 (1982) 387; S. M. Barr, Phys. Lett. B 112 (1982) 219; I. Antoniadis, J. R. Ellis, J. S. Hagelin and D. V. Nanopoulos, Phys. Lett. B 194 (1987) 231; ibid. B 205 (1988) 459; N. Maekawa and T. Yamashita, Phys. Lett. B 567 (2003) 330.  
[9] K. Inoue, A. Kakuto and H. Takano, Prog. Theor. Phys. 75 (1986) 664; A. A. Anselm and A. A. Johansen, Phys. Lett. B 200 (1988) 331; A. A. Anselm, Sov. Phys. JETP 67 (1988) 663; Z. G. Berezhiani and G. R. Dvali, Bull.
Lebedev Phys. Inst. 5 (1989) 55; Z. Berezhiani, C. Csaki and L. Randall, Nucl. Phys. B 444 (1995) 61; M. Bando and T. Kugo, Prog. Theor. Phys. 109 (2003) 87.

[10] Y. Kawamura, Prog. Theor. Phys. 103, 613 (2000); ibid 105, 691 (2001); ibid 105, 999 (2001); L. J. Hall and Y. Nomura, Phys. Rev. D 64 (2001) 055003; ibid 65 (2002) 125012; ibid 66 (2002) 075004.

[11] M. Kakizaki and M. Yamaguchi, Prog. Theor. Phys. 107, 433 (2002).

[12] T. Yamashita, Phys. Rev. D 84, 115016 (2011).

[13] K. Kojima, K. Takenaga and T. Yamashita, Phys. Rev. D 84 (2011) 051701.

[14] Y. Hosotani, Phys. Lett. B 126, 309 (1983); ibid 129, 193 (1983); Phys. Rev. D 29, 731 (1984); Ann. of Phys. 190, 233 (1989).

[15] J. Brau, (Ed.) et al. [ILC Collaboration], arXiv:0712.1950 [physics.acc-ph]; G. Aarons et al. [ILC Collaboration], arXiv:0709.1893 [hep-ph]; N. Phinney, N. Toge and N. Walker, arXiv:0712.2361 [physics.acc-ph]; T. Bahnke, (Ed.) et al. [ILC Collaboration], arXiv:0712.2356 [physics.ins-det]; H. Baer, et al. "Physics at the International Linear Collider", Physics Chapter of the ILC Detailed Baseline Design Report: http://lcsim.org/papers/DBDPhysics.pdf

[16] E. Accomando et al. [CLIC Physics Working Group Collaboration], hep-ph/0412251

[17] ATLAS Collaboratin, Report No. ATLAS-CONF-2013-047; CMS Collaboration, Report No. CMS-PAS-SUS-13-004.

[18] Y. Okada, M. Yamaguchi and T. Yanagida, Prog. Theor. Phy s. 85, 1 (1991); H. E. Haber and R. Hempfling, Phys. Rev. Lett. 66, 1815 (1991).

[19] J. R. Espinosa and M. Quiros, Phys. Lett. B 279, 92 (1992); Phys. Lett. B 302, 51 (1993); Phys. Rev. Lett. 81, 516 (1998).

[20] For recent analysis, see, for example, L. J. Hall, D. Pinner and J. T. Ruderman, JHEP 1204, 131 (2012); P. Draper, P. Meade, M. Reece and D. Shih, Phys. Rev. D 85, 095007 (2012).

[21] For a review, see, for example, U. Ellwanger, C. Hugonie and A. M. Teixeira, Phys. Rept. 496, 1 (2010).

[22] A. Djouadi, J. -L. Kneur and G. Moulah, Comput. Phys. Commun. 176, 426 (2007).

[23] D. M. Asner, T. Barklow, C. Calancha, K. Fuji, N. Graf, H. E. Haber, A. Ishikawa and S. Kanemura et al., arXiv:1310.0763 [hep-ph].

[24] D. Cavalli et al. [Higgs Working Group Collaboration], hep-ph/0203056

[25] J. F. Gunion, T. Han, J. Jiang and A. Sopczak, Phys. Lett. B 565, 42 (2003).

[26] S. Kanemura, K. Tsumura and H. Yokoya, Phys. Rev. D 88, 055010 (2013).

[27] The plots shown in Fig. 2 are updated from the ones presented at LCWS13.