Phenomenology of SUSY Gauge-Higgs Unification

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What is Gauge-Higgs Unification ?

4D spin 1 : gauge $\longrightarrow (A_\mu, A_5) \longleftarrow$ 4D spin 0 : Higgs

(see [1])

And with SUSY ?

$$(\Sigma, \lambda_{1,2}, A^M)$$

4D spin 1 : gauge $\searrow$ $\Updownarrow$ $\swarrow$ 4D spin 0 : Higgs

$$(\lambda_1, A^\mu) \qquad (\Sigma + iA^5, \lambda_2)$$

Where SUSY GHU can appear ?

In Orbifold SUSY GUTs

Bottom-up : SUSY GUTs is motivated by couplings unification. The extra dimensions are motivated by GUT problems : doublet-triplet splitting, GUT group breaking, proton decay.

Top-down : SUSY GUT with GHU can naturally come from classes of heterotic strings model.

Natural way to break SUSY ?

With Radion Mediated SUSY breaking (RMSB) [2]

Radion T = field associated to extra dimension fluctuation.

Compactification $\langle T \rangle = R$ implies SUSY breaking :

$\langle F^T \rangle \neq 0$ (radion)

$\langle F^\varphi \rangle \neq 0$ (chiral compensator) with $F^T = -\frac{1}{3W(R)}\frac{\partial W}{\partial T}|_R F^\varphi$

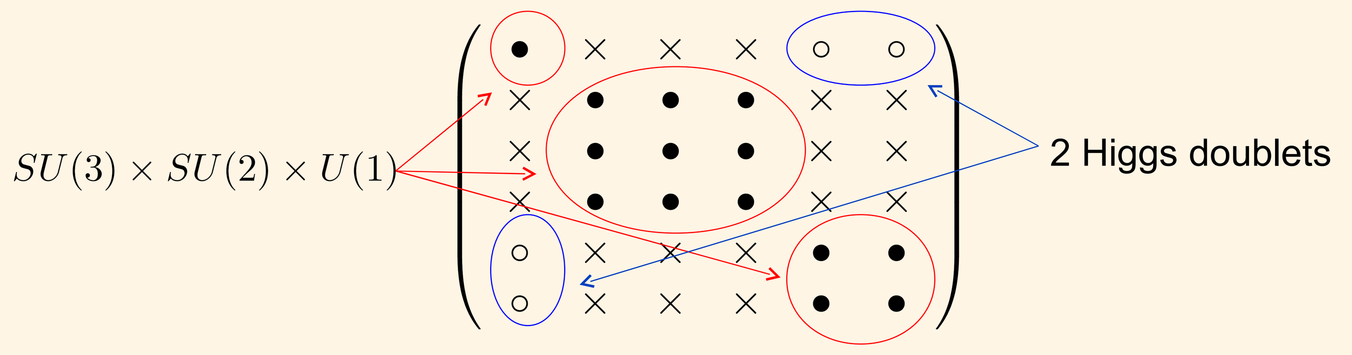
AMSB contributions are generated at one-loop : $\mathcal{O}(F^\varphi/8\pi^2)$

SUSY GUTs with Gauge-Higgs Unification and RMSB generically implies : $\pm B\mu = \mu^2 + m^2_{H_u} = \mu^2 + m^2_{H_d}$ at the SUSY breaking scale.

5D complete realization : Gauge-Higgs sector

We take the 5D SUSY GUT with SU(6) GHU of [3]. The radius T of the 5th dimension stabilized by an unknown mechanism : $\langle T \rangle = R \sim M_{GUT}$

and break the SU(6) adjoint :



In odd number of dimensions, a new term (Chern-Simons) generically appears [5]. It was not taken into account in a previous study [4], whose conclusion was negative, due to no electroweak symmetry breaking. For theory consistency, $c > -1$ and $c = \mathcal{O}(1)$

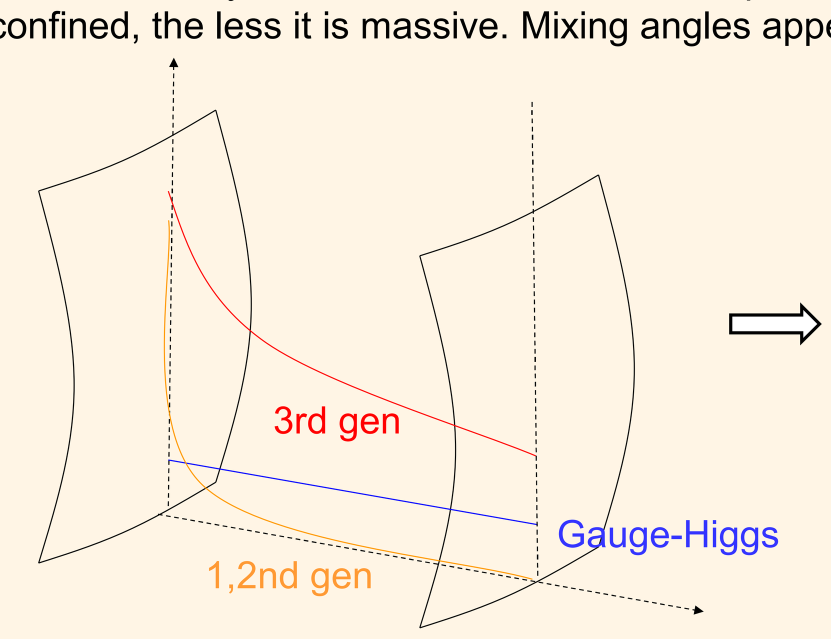
The gauge-Higgs SUSY parameters are generated [6] :

$$\pm B\mu = \mu^2 + m^2_{H_u} = \mu^2 + m^2_{H_d} = (F^\varphi)^2 + 2F^\varphi \frac{F^T}{2R}\frac{1+2c}{1+c} + \frac{(F^T)^2}{(2R)^2}\frac{2c^2}{(1+c)^2}$$

$$M_{1/2} = \frac{F^T}{2R}\frac{1}{1+c} \qquad \mu = F^\varphi - \frac{F^T}{2R}\frac{1+2c}{1+c}$$

5D complete realization : Matter sector

As the gauge and Higgs fields, the matter fields are propagating in the bulk [3]. However they can have a 5D mass term which makes them confined on the branes. The usual 4D yukawas come from the overlap with the Higgs field. The more a field is confined, the less it is massive. Mixing angles appear as new parameters.



$\Longrightarrow$

$$y_t = \sin(\phi_Q)\frac{\pi R M_t}{\sinh \pi R M_t} g_4$$
$$y_b = \cos(\phi_Q)\frac{\pi R M_b}{\sinh \pi R M_b} g_4$$
$$y_\tau = \sin(\phi_L)\frac{\pi R M_\tau}{\sinh \pi R M_\tau} g_4$$
$$\vdots$$

Only bulk matter couples to the SUSY breaking field. Consequently, the soft scalar parameters will qualitatively have the same hierarchy as the yukawas. Roughly, the third generation parameters are large, and the others are negligible.

Spectrum calculation

How to calculate the spectrum of such model ?

The pattern of inputs and constraints is different from other models. Usually, μ and $B\mu$ are computed from the two equation of the Higgs potential minimization :

$$\mu^2 = \frac{1}{2}\tan 2\beta(m^2_{H_u}\tan\beta - m^2_{H_d}\cot\beta - M_Z^2)$$
$$B\mu = \frac{1}{2}\sin 2\beta(m^2_{H_u} + m^2_{H_d} + \mu^2)$$

But in our model, μ ,$B\mu$,$m^2_{H_u}$,$m^2_{H_d}$ are fixed at high scale.

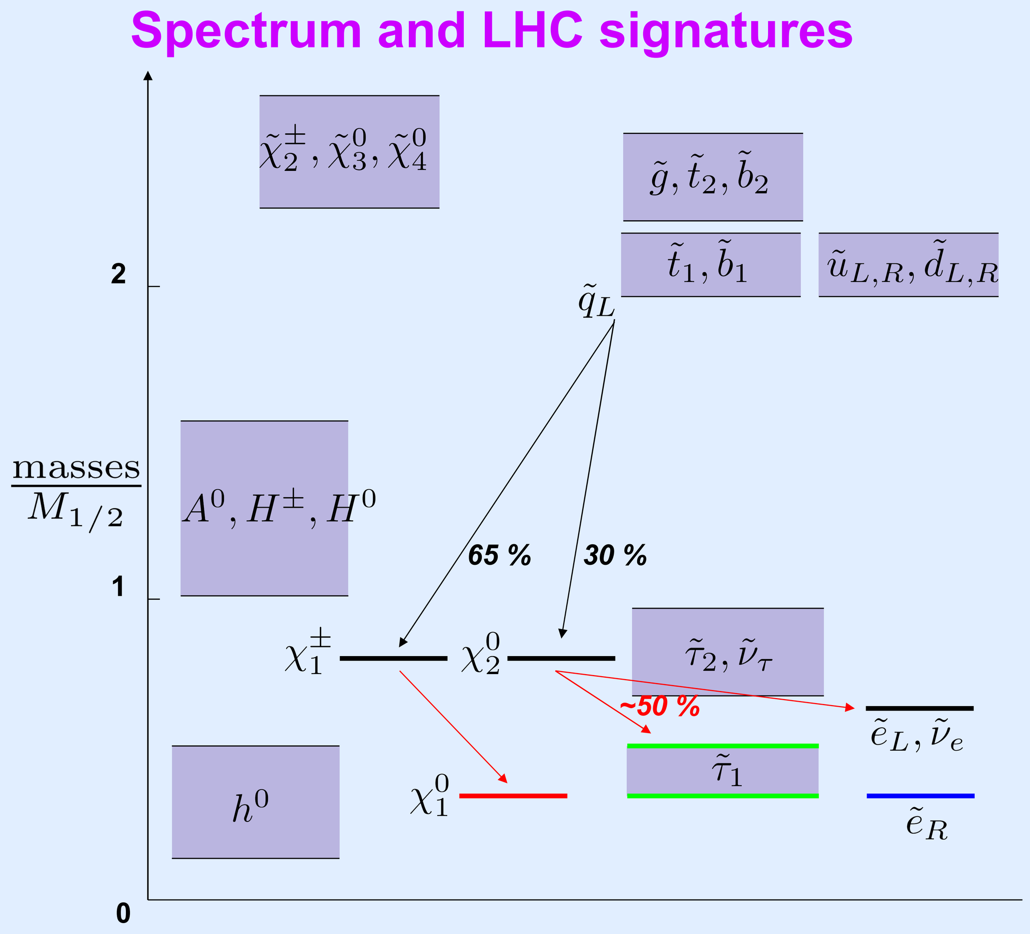
First solution : compute $\tan\beta$ and M_Z at each iteration. But a fixed point algorithm on $\tan\beta$ is unstable. (An alternative is to use a dichotomy algorithm).

Second solution : simply impose $m^2_{H_{d,u}} = B\mu - \mu^2$!

The inputs are then $\tan\beta$, $M_{1/2}$ and soft scalar parameters.

We used SuSpect [7].

Spectrum and LHC signatures

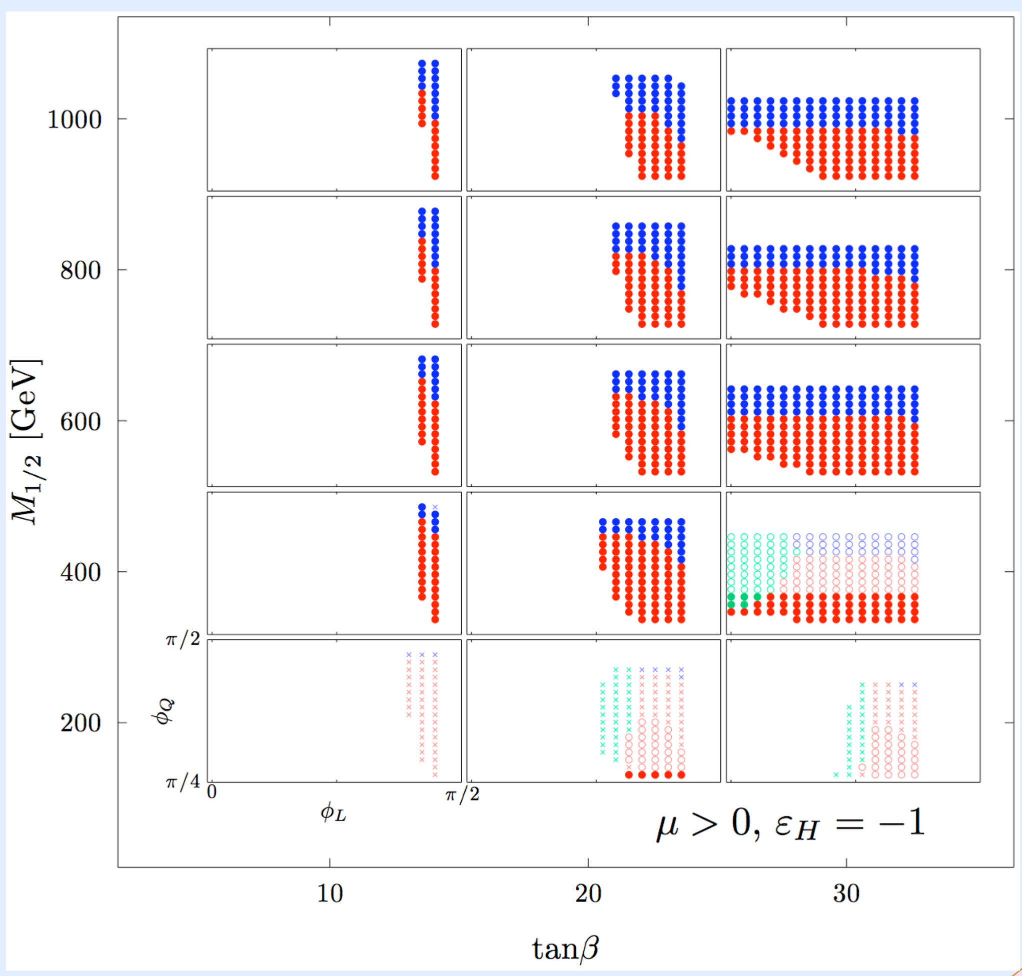


The χ_2^0 is still heavier than the $\tilde e_L$ and the $\tilde\tau_1$. So the SFOS dilepton channel is still open.

Scans and constraints

In the complete realization, we scan over $\tan\beta$, $M_{1/2}$, and the two mixing angles ϕ_Q and ϕ_L . The spectrum is constrained with theoretical consistency (EWSB, no CCB, no tachyons), and with experiment. We use the mass bounds from LEP, the constraints from B-physics (2σ), and verify the agreement with relic density measurement from WMAP (3σ) [8-11].

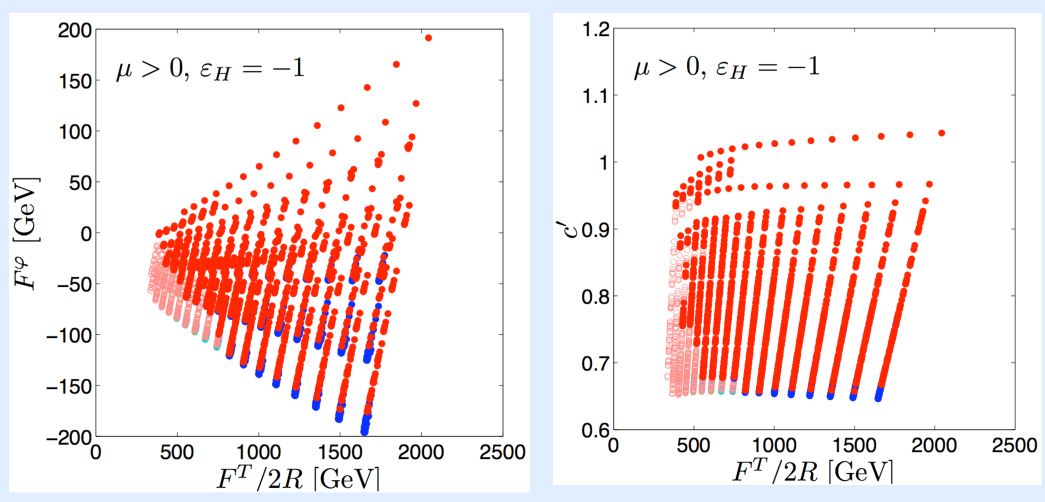
$$\mathrm{Br}(B_s \to \mu^+\mu^-) < 5.8 \times 10^{-8}$$
$$2.85 < \mathrm{Br}(B_s \to s\gamma) \times 10^4 < 4.25$$
$$0.0913 < \Omega h^2 < 0.1285$$



[1] GHU Review : 0704.0833
[2] Chacko, Luty '00 hep-ph/0008103
[3] G. Burdman and Y. Nomura, '03, hep-ph/0210257
[4] K. w. Choi *et al*, 2004, [hep-ph/0312178
[5] CS Review : 0805.1778
[6] A. Hebecker, J. March-Russell and R. Ziegler, arXiv:0801.4101
[7] Suspect (Kneur *et al*) 2007,[arXiv:hep-ph/0211331],
[8] http://lepsusy.web.cern.ch/lepsusy/
[9 CDF 0712.1708 hep-ex
[10] HFAG hep-ex/0603003
[11] WMAP 0803.0586 astro-ph

Check of assumptions

By computing the fundamental parameters, we can check the hypothesis : the AMSB contributions are negligible, and the Chern-Simons coefficient is still non-zero, and of order one.

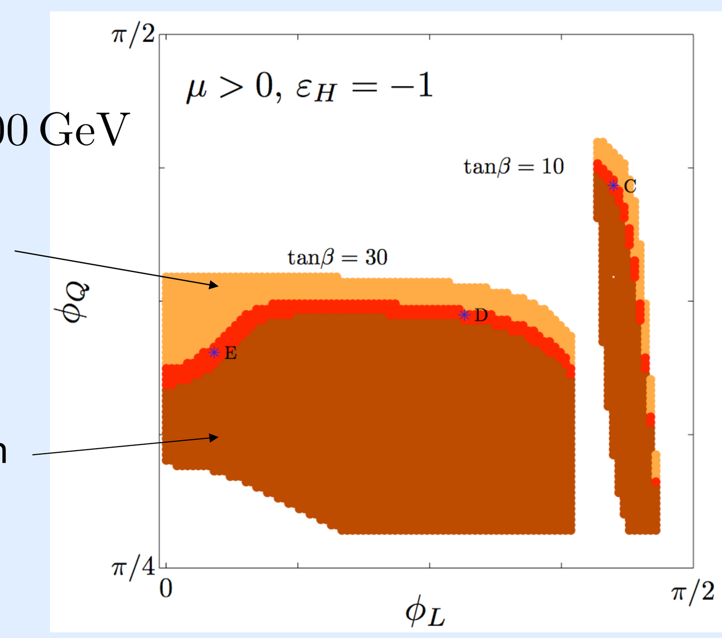


Relic density

For $M_{1/2} = 500\,\mathrm{GeV}$

Not enough

Too much



To sum up, we show that SUSY GHU with RMSB is theoretically viable, and we obtain fully realistic models specifying the matter sector. We modified a spectrum cacultor to compute the physical spectrum. The SFOS dilepton is a generic signature of our 5D model.

However, it should be difficult to discriminate this class of models from general SUGRA and HENS with the LHC.