Higgs Mass and other Generic Predictions for Realistic String Vacua

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Higgs Workshop

University of Michigan, Ann Arbor

Based on:

1112.1059 *(Kane, P.K., Lu, Zheng)*

1204.2795 (Acharya, Kane, P.K.)

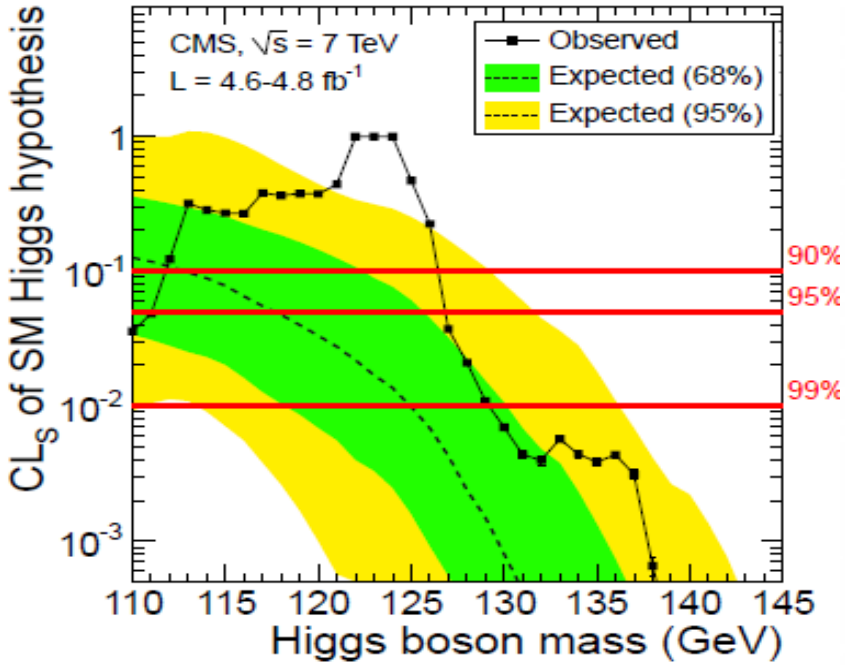
Plan of the Talk

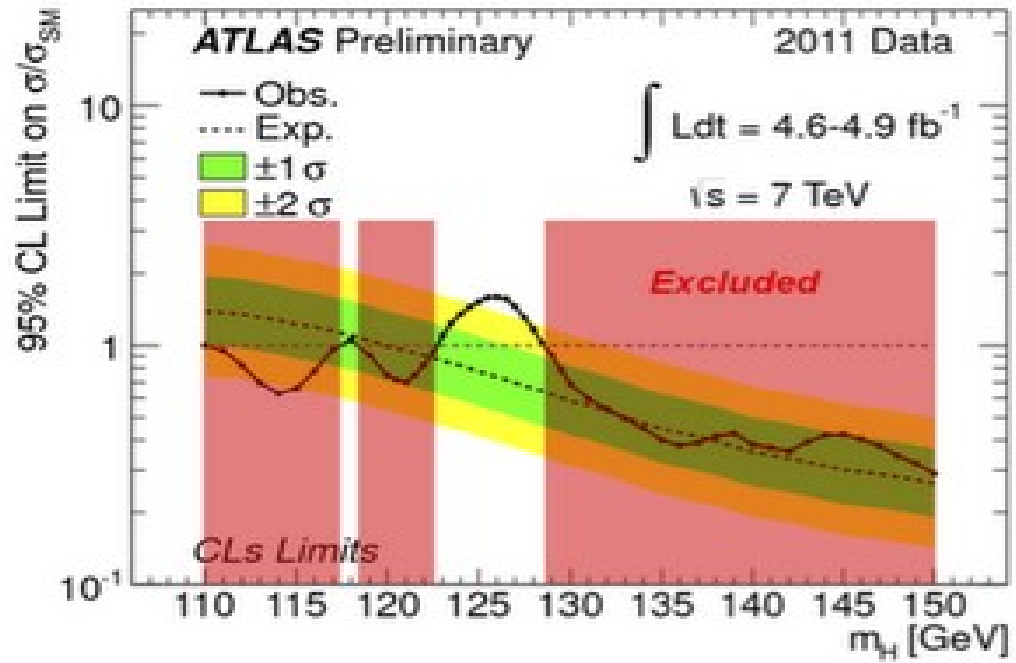
- Introduction & Motivation.
- Summary.
- Details
  - "Model-independent" predictions.
  - Specific Predictions .

    Higgs, BSM physics, DM, Precision

Focus on this, briefly mention others if time.

- Conclusions





Higgs Physics may soon become Experimental Science!

– Until now, only existed in the realm of theory.

- Reason for this meeting
- Generated a lot of interest in the theory community.

Have heard (will hear) many talks trying to make sense of this from the Electroweak scale point of view.

Here, focus on Top-Down Approach
(but include Exp. constraints)

Emphasis laid on solving the “Big Hierarchy” problem

Motivation

The "Big Hierarchy" problem consists of two problems:

– Higgs technical naturalness problem (TeV scale susy keeps Higgs mass stable)

– **Origin of the Electroweak Scale itself – how does it arise from microscopic theory ?**

String Theory

Why is M_{EW} so much smaller than the fundamental scale, the String scale in String theory?

Usually M_{string} close to M_{planck}

Also assume $M_{KK} \sim M_{string}$ (have to be checked self-consistently, dynamically)

- **To solve "Big Hierarchy", have to generate ~ TeV scale SUSY *dynamically*.**

Summary

Study solutions of compactified string/M-theories having the following properties:

1) Supergravity approx. valid 2) Moduli are stabilized.

3) Spontaneously broken SUSY with ~ TeV superpartners .

Within solutions in this class satisfying all current experimental and observational constraints, make predictions for BSM physics:

- Essentially Model-Independent – $m_{3/2} >\sim 30$ TeV ⇒ $\sqrt{F}$ has to be "High"

  Predictions
  - Scalars very heavy – should not be seen at the LHC.
  - Non-thermal cosmological history before BBN.
  - O(1) fraction of DM in the form of axions.

- MSSM matter and gauge

  Spectrum below M_{GUT}

  (w/ R-parity)
  - Compute M_H/M_Z precisely.

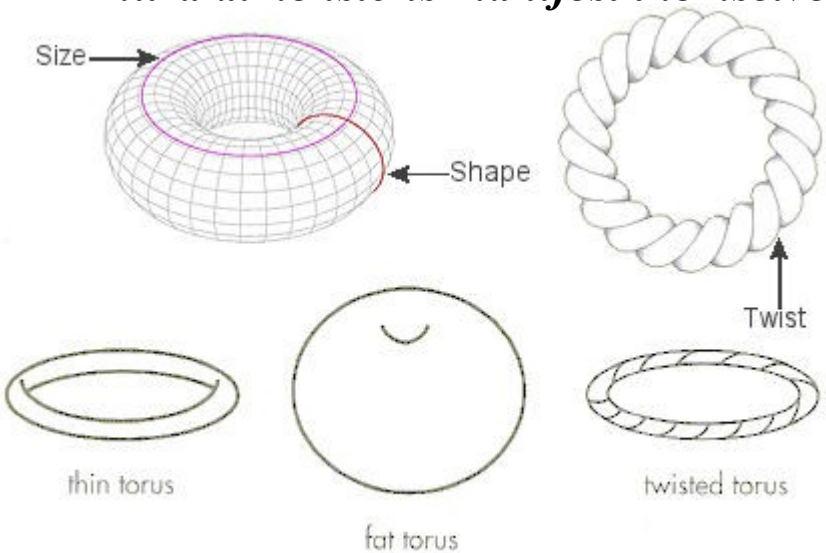
    ⇒ $M_H \sim 125$ GeV for $\tan\beta >\sim 6$.
  - H virtually indistinguishable from SM Higgs.
  - Gluino pair production should be seen.
  - Next gen. DM & EDM experiments should see signal

DETAILS

$M_{KK} >> \sqrt{s}$ (LHC), so

Why is String theory relevant for Particle Physics?

Extra dimensions manifest themselves through presence of "moduli" fields in 4D.



Modes of "X-dim graviton"

Moduli must be "stabilized", & given sufficiently large masses, for two reasons:

1) Satisfy fifth force constraints

2) All low-energy physics couplings determined from their *vevs*. (eg. α_{EM})

Crucial difference between a general EFT and EFT arising from a String compactification – Presence of Moduli

Moduli affect low-energy physics in important ways, indirectly.

- In recent years, significant progress in moduli stabilization in string theory.

Type IIB : /F-Theory

S. Kachru, R. Kallosh, A. D. Linde and S. P. Trivedi, Phys. Rev. D **68**, 046005 (2003) [hep-th/0301240].
F. Denef, M. R. Douglas, B. Florea, A. Grassi and S. Kachru, Adv. Theor. Math. Phys. **9**, 861 (2005) [hep-th/0503124].
V. Balasubramanian, P. Berglund, J. P. Conlon and F. Quevedo, JHEP **0503**, 007 (2005) [arXiv:hep-th/0502058 [hep-th]].
K. Bobkov, V. Braun, P. Kumar and S. Raby, JHEP **1012**, 056 (2010) [arXiv:1003.1982 [hep-th]].

Type IIA :

O. DeWolfe, A. Giryavets, S. Kachru and W. Taylor, JHEP **0507**, 066 (2005) [hep-th/0505160].

J. Shelton, W. Taylor, and B. Wecht, *Nongeometric flux compactifications*, *JHEP* **10** (2005) 085, [hep-th/0508133].

J. Shelton, W. Taylor, and B. Wecht, *Generalized Flux Vacua*, *JHEP* **02** (2007) 095, [hep-th/0607015].

M-theory :

B. S. Acharya, hep-th/0212294.
B. S. Acharya, K. Bobkov, G. Kane, P. Kumar and D. Vaman, Phys. Rev. Lett. **97**, 191601 (2006) [hep-th/0606262].
B. S. Acharya, K. Bobkov, G. L. Kane, P. Kumar and J. Shao, Phys. Rev. D **76**, 126010 (2007) [hep-th/0701034].

Heterotic:

B. Dundee, S. Raby and A. Westphal, Phys. Rev. D **82**, 126002 (2010) [arXiv:1002.1081 [hep-th]].
L. B. Anderson, J. Gray, A. Lukas and B. Ovrut, Phys. Rev. D **83**, 106011 (2011) [arXiv:1102.0011 [hep-th]].

Moduli Stabilization and SUSY breaking entwined

Want moduli stabilization mechanisms which can give rise to ~ TeV scale SUSY.

Hence could give rise to realistic 4D vacua.

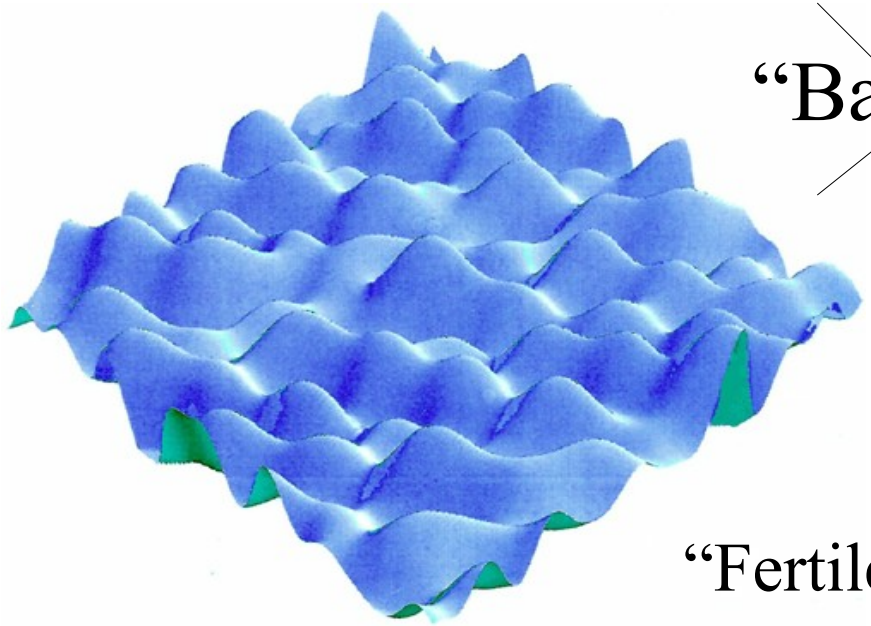
– Of course other kinds of vacua possible, but not interested in those.

PHILOSOPHY

Assuming our Universe is a solution of String Theory,

what "generic" features would one expect for BSM physics?

Throwing Darts on the String Landscape



~~"Barren" Landscape~~

Dartboard

"Fertile" Landscape

SM at low energies

~TeV scale susy, GUT

Dartboard

Look for Generic BSM Features in these Vacua

Getting to the "Fertile" part of the Landscape

Stabilizing Hierarchies and Moduli

Type IIB : *Denef, Douglas, Florea, Grassi, Kachru hep-th/0503124;*
*Bobkov, Braun, **P.K.**, Raby 1003.1982*

M Theory : *Acharya, Bobkov, Kane, **P.K.**, Shao hep-th/0701034;*
Acharya, Bobkov 0810.3285

Basically, realize the old idea of Witten

- Dimensional Transmutation can generate exponentially suppressed scales naturally.

- But now also stabilize moduli

$$m_{3/2} \sim \frac{\Lambda^3}{M_{pl}^2}; \; \Lambda \sim e^{-\frac{2\pi}{\alpha_h b}} M_{pl}.$$

$$\alpha_h^{-1} = \Sigma_i N^i S_i$$

Only dimensionful scale Mpl !

$m_{3/2}$ order parameter of susy breaking (with zero CC).

Crucial Result : For generic moduli Super- & Kahler- potentials,

$$M_{modulus}^{min} = O(1)\, m_{3/2}$$

Explicit examples with more than one moduli satisfy it. Also borne out by general analysis

- Two ways to show this:

I) **General SUGRA result** *Acharya, Kane, Kuflik 1006.3272*

(Denef, Douglas; Scrucca, Gomez-Reino)

– Look at the full scalar mass matrix M^2.
– $M_{min}^2 < \zeta^+ M^2 \zeta$ for any unit vector ζ

Choosing ζ in the sGoldstino direction, can show

$$M_{min}^2 = m_{3/2}^2 (2 + |r|/M_{pl}^2) \quad ; \text{ r = curvature in moduli space}$$

For models in which only one scale present – $m_{3/2}$ (itself, arising from M_{pl})

$$|r|/M_{pl}^2 = O(1) \Rightarrow M_{min} = O(1)\, m_{3/2}$$

II) Even when more than one scale present

can show that for realistic cases which generate Hierarchy

$$M_{min} = O(1)\, m_{3/2}$$

Acharya, Kane, P.K. 1204.2795

P.K. (To appear)

– At least some moduli stabilized by Kahler potential effects

– Geometric Moduli stabilized close to a supersymmetric point.

– Dynamics stabilizing moduli ⟺ Dynamics of supersymmetry breaking.

Due to vanishingly small C.C.

Since generic result for large classes of realistic vacua (with mild assumptions) ⟺ Make general statements about all such vacua.

Generic Predictions

- With rather mild assumptions, essentially : a) Validity of SUGRA approximation.
  b) $H_{inflation} > m_{3/2}$

*(complete set of assumptions carefully explained in the review: **Acharya, Kane, P.K. 1204.2795**)*

– Implies that $M^{min}_{mod} = O(1)\, m_{3/2} >\sim 30$ TeV due to BBN constraints.

– Universe has a "non-thermal" history before BBN.

– $m_{3/2} \simeq \frac{F}{M_{pl}}$ so, $\sqrt{F}$ should be "high", as in gravity mediation.

– Axions form an O(1) abundance of DM. (slightly subtle)

Mechanisms which stabilize many moduli, naturally keep most axions light

One of which can naturally be the QCD axion (solves strong CP with moduli stabilization)

Abundance computed within non-thermal cosmology

$f_a \sim M_{GUT}$ requires only ~ 1-10% tuning

Acharya, Bobkov, P.K. 1004.5138

...continued

- Generically, $m_{scalars}^{SM\text{-}charged} = O(1)\, m_{3/2}$ in general SUGRA.
- Is $m_{scalars}^{SM\text{-}charged} << m_{3/2}$ ("sequestering") possible, in special cases ?
  - To date has not been shown to exist in a viable manner with moduli stabilization
  - M-theory and Type IIA – no pheno. viable sequestering present.
  - Type IIB – Argued that "maybe" present *Kachru, McAllister, Sundrum th/0703105*

    After moduli stabilization, "superpotential de-sequestering"ruins it

    Berg, Marsh, McAllister, Pajer 1012.1858
- So, rather conservative assumption : **NO sequestering** (M_{scalar}, $A = O(1)\, m_{3/2}$)

None of the SM-charged scalars (except the lightest Higgs scalar) should be seen at the LHC !

What about gaugino masses?

- Although scalars heavy, gauginos need not be.

  Suppressed if

  – F-term of modulus determining gauge coupling << Dominant F-term.

  – Happens in M-theory examples as well as many Type IIB examples.

B. S. Acharya, K. Bobkov, G. Kane, P. Kumar and D. Vaman, Phys. Rev. Lett. **97**, 191601 (2006) [hep-th/0606262].
B. S. Acharya, K. Bobkov, G. L. Kane, P. Kumar and J. Shao, Phys. Rev. D **76**, 126010 (2007) [hep-th/0701034].

K. Choi, hep-ph/0511162. K. Choi, A. Falkowski, H. P. Nilles and M. Olechowski, Nucl. Phys. B **718**, 113 (2005) [hep-th/0503216]. M. Endo, M. Yamaguchi and K. Yoshioka, Phys. Rev. D **72**, 015004 (2005) [hep-ph/0504036]. K. Choi, K. S. Jeong and K. -i. Okumura, JHEP **0509**, 039 (2005) [hep-ph/0504037]. A. Falkowski, O. Lebedev and Y. Mambrini, JHEP **0511**, 034 (2005) [hep-ph/0507110]. J. P. Conlon and F. Quevedo, JHEP **0606**, 029 (2006) [hep-th/0605141].

Specific Predictions

Can be relaxed

- Assume matter and gauge spectrum below M_{KK} = MSSM precisely.
  - Motivated by gauge unification and radiative EWSB in MSSM.
  - Explicit constructions exist: *hep-th/0512177; hep-th/0404055; hep-th/0611095....*

Focus on vacua with the following properties:

- M_{scalar}, $A \approx m_{3/2}$, Gaugino masses suppressed.

- μ - both "large "O(m3/2) , & "Small " possible in different vacua

Acharya, Kane, Kuflik, Lu 1102.0556

Giudice, Masiero PLB 206 480, Casas, Munoz ph/9303227
Lee et al 1102.3595

μ generated by string instantons in some constructions, so both "small" and "large" μ possible

Cvetic, Halverson, Richter 0905.3379; Heckman, Vafa 0809.3452

Higgs Mass

(The lightest CP-even neutral scalar - nondecoupling)

PROCEDURE

- Compute soft susy breaking parameters at $M_{KK} \sim M_{GUT}$ in the class of vacua. Find:

  M_a (Gaugino masses) ~ 0.01-0.1 $m_{3/2}$, $A_0/M_0 = O(1)$, $M_0 \approx m_{3/2}$

- tan β should in principle be predictable, but imperfect understanding of μ (Bμ) only allows us to constrain tanβ. However correlation between tanβ and μ

  "Small" μ ⟺ tan β >~ 5 & vice versa

- RGE Evolution – gives rise to radiative EWSB

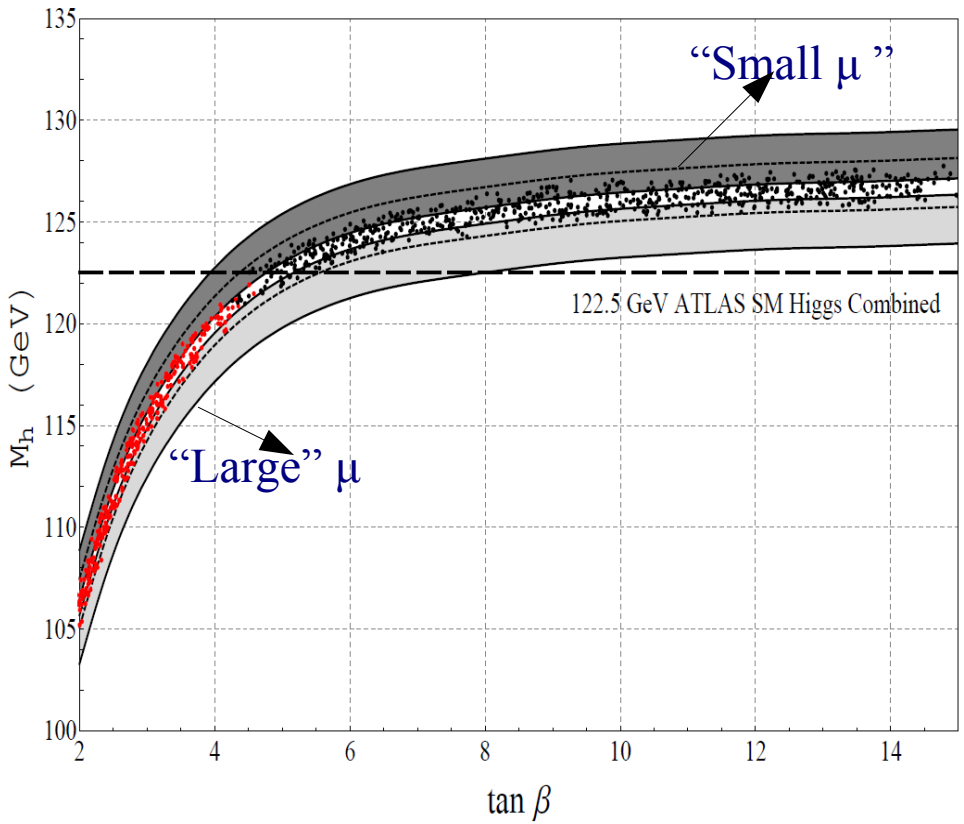
- Match on to EFT with gauginos and scalars at Msusy = √mstop1mstop2 ~ $m_{3/2}$

- Then compute Quartic (λ_H) in the EFT below Msusy via 2-loop RGEs, taking all relevant LL and finite thresholds into account.

Similar to:

Haber, Hempfling ph/9307201, Carena et al ph/0001002, Giudice, Strumia 1108.6077; Binger ph/0408240; Bernal, Djouadi, Slavich 0705.1496

Higgs Mass Prediction



Higgs mass prediction (at two loops) for three values of $m_{3/2}$ = 25, 50, 100 TeV

Expect: 25 TeV < ~ $m_{3/2}$ <~ 100 TeV

Kane, P.K., Lu, Zheng 1112.1059

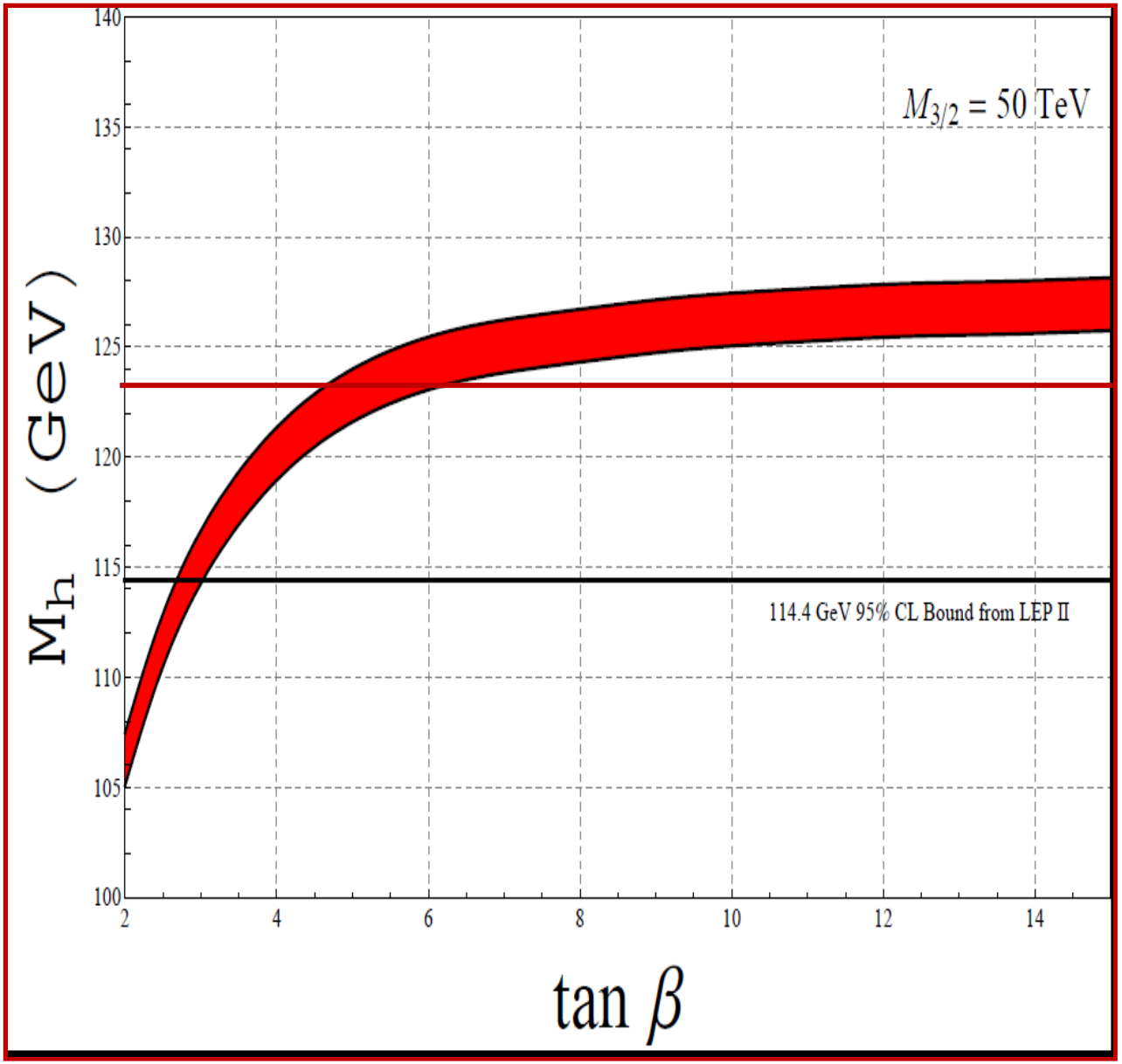
Case	Variation of Input	ΔM_h
"Small" μ	Theoretical	± 0.5
$.05\, m_{3/2} \leq \mu \leq .15\, m_{3/2}$	Theoretical + Experimental	± 1.1
"Large" μ	Theoretical	± 0.5
$0.5\, m_{3/2} \leq \mu \leq 1.5\, m_{3/2}$	Theoretical + Experimental	± 1.25

Uncertainty in the Higgs mass prediction for a given $m_{3/2}$ and tan β

Theoretical	Experimental
$600 \leq m_{\tilde{g}} \leq 1200$	$172.2 \leq m_t \leq 174$ [39]
$0.8\, m_{3/2} \leq A_t \leq 1.5\, m_{3/2}$	$0.1177 \leq \alpha_s^{\overline{MS}}(m_Z) \leq 0.1191$ [40]

Data favors "Small μ" (Black points)
tan β >~ 6

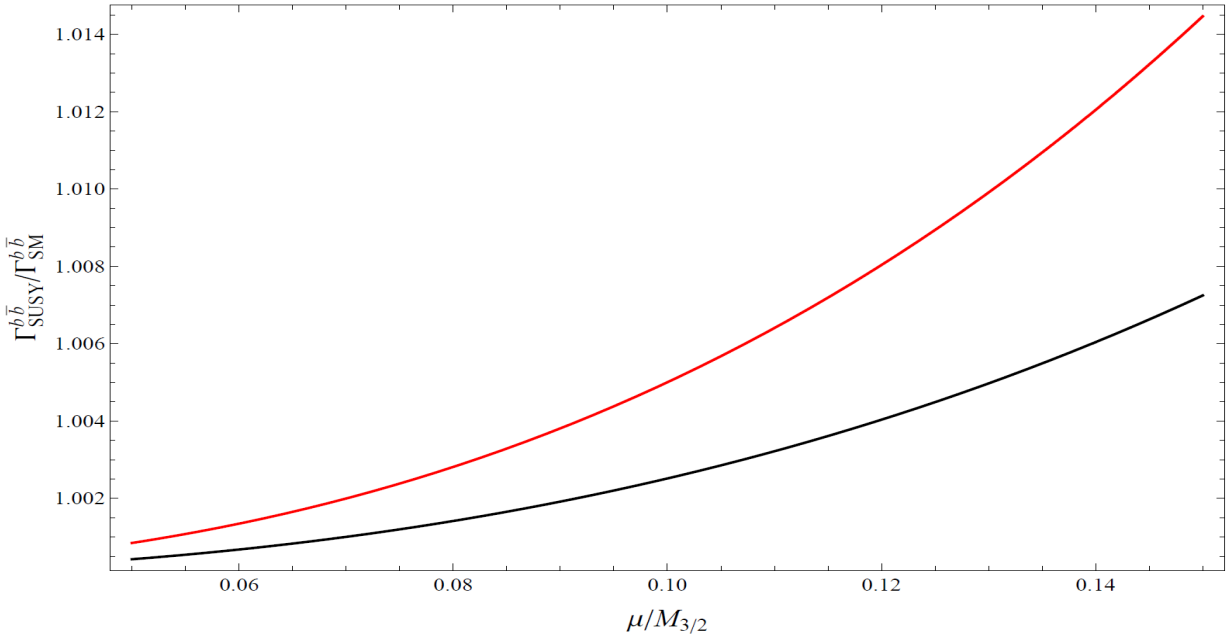
122 GeV <~ M_h < ~ 129 GeV


$M_{3/2}$ = 50 TeV
114.4 GeV 95% CL Bound from LEP II
M_h (GeV)
tan β
140
135
130
125
120
115
110
105
100
2
4
6
8
10
12
14

ATLAS bound

Higgs Properties

- Decoupling Limit → Higgs behaves very similar to the SM Higgs.
- How similar?
  - Production (by gluon fusion) virtually the same since $m_{stop} >> m_{top}$.
  - Decays could be different due to effects from light gauginos and higgsinos.



Tanβ = 20

Tanβ =10

Deviation in h → b bar decay width by at most ~1 % from the SM width.

So, total width hardly changes

$h \longrightarrow \gamma\gamma$ very close to that for SM.

Same for $h \longrightarrow Z\gamma$

$M_{3/2} = 50$ TeV

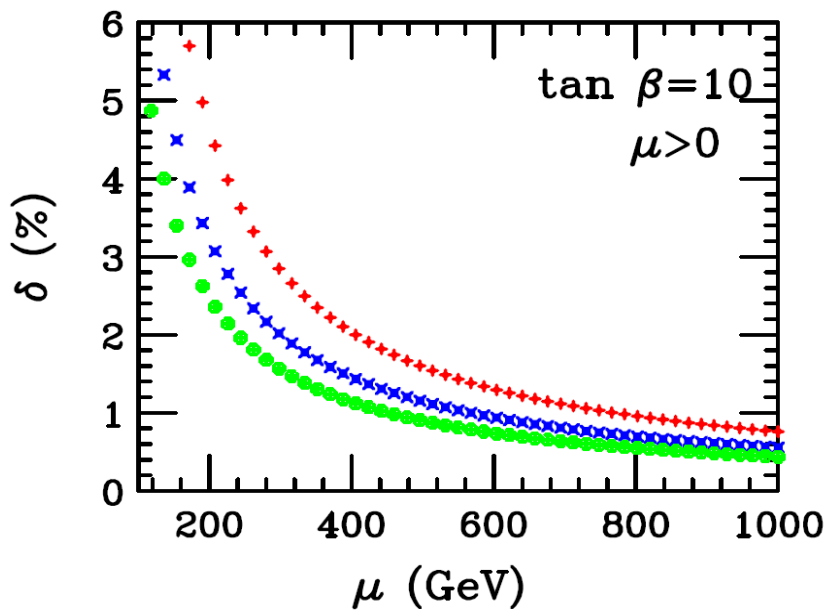
$$\frac{(\Gamma^{\gamma\gamma}_{SUSY} - \Gamma^{\gamma\gamma}_{SM})}{\Gamma^{\gamma\gamma}_{SM}}$$

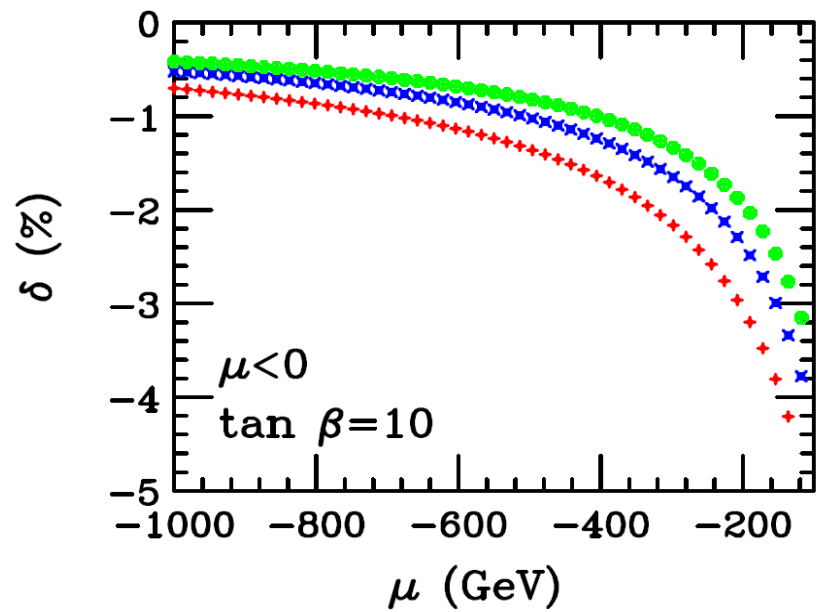
M2 = 200 GeV

M2 = 300 GeV

M2 = 500 GeV

Diaz, Perez hep-ph/0412066





LHC Signatures of the Higgs should be indistinguishable from that of the SM Higgs

Correlated Falsifiable Predictions

- Higgs Mass Result strictly valid only when gauginos are light (<~ TeV)

- So, should see them at the LHC!

  ~g~g followed by decay preferentially to 3rd gen. Quarks via off-shell 3rd gen Squarks

  Acharya, Grajek, Kane, Kuflik, Suruliz, Wang 0901.3367, Kane, Kuflik, Lu, Wang 1101.1963

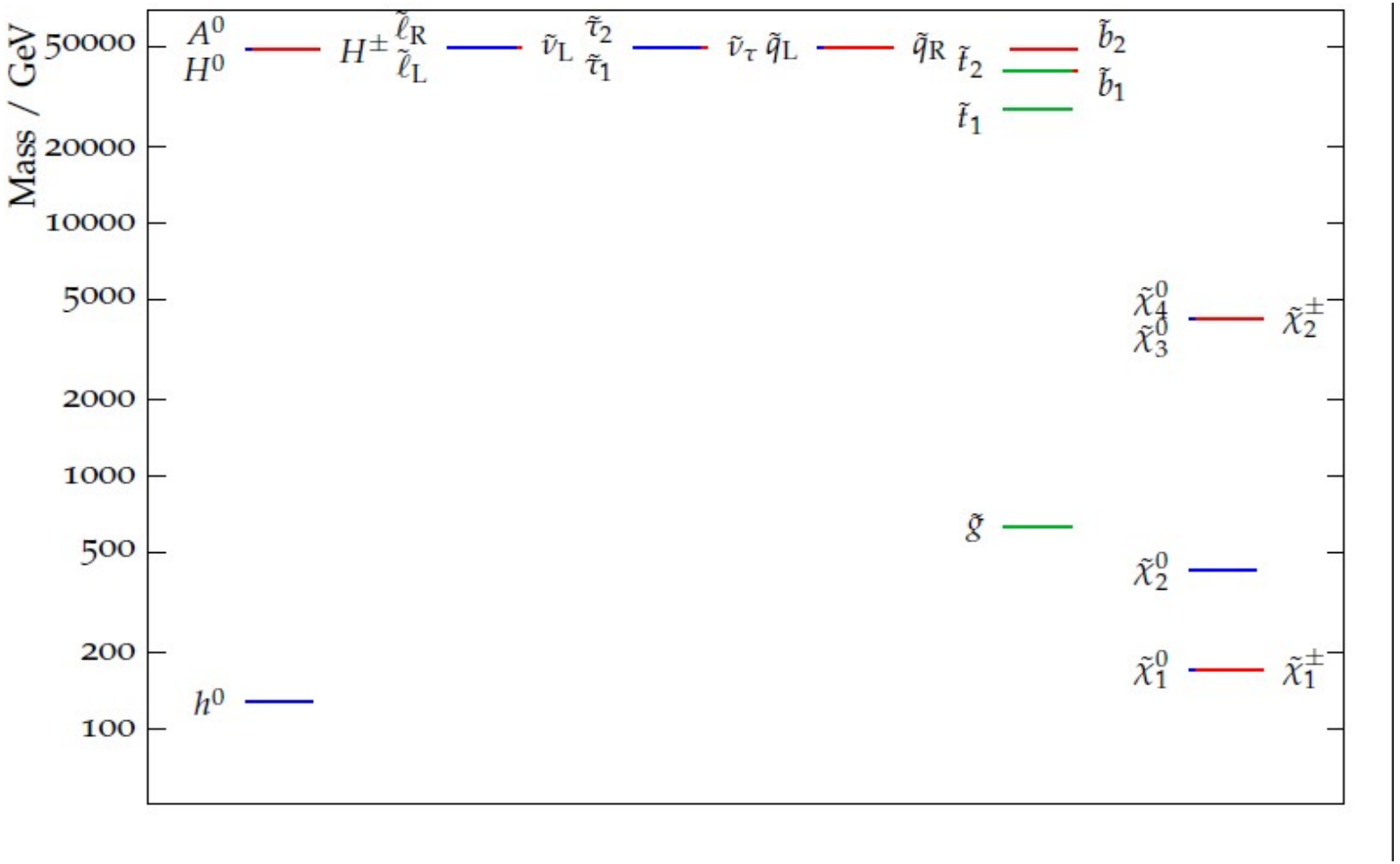
$$\tilde{g} \to tt + \chi, \ \tilde{g} \to bb + \chi, \text{ and } \tilde{g} \to tb + \chi.$$

Recent searches by ATLAS, CMS (saw talks yesterday)

1l+>=1bjets+>=4 jets +Missing ET $\qquad M_{gluino}$ >~ 700-750 GeV

- Should also see disappearing charged tracks from decays of charginos ($\sim W^+ \to \sim W^0$)
- Depending upon the accuracy of M_h measurement, get insight about $m_{3/2}$ and tan β.
  - Use as a consistency check with other measurements.

Typical Spectrum



- **"Dark" Frontier:**

Wino-like LSP DM candidate with EW scale mass.

– Naturally O(1) fraction of DM in LSPs within non-thermal history

Acharya, Kane, P.K., Watson 0908.2430

(Remember, remaining in axions) *Acharya, Bobkov, Kane, P.K., Shao, Watson 0804.0863*

– Indirect-detection → FERMI, AMS 02 should see signals.

– Direct-detection → naturally evade current XENON bounds, but next generation expts should see a signal. (if μ not too large, favored by Higgs mass)

– Axions → Other astrophysical signals (to study)

- **Precision Frontier**:

– EDM measurements improve by few orders of magnitude

Should be able to probe the framework ***Kane, P.K., Shao 0905.2986***
Kadota et al 1107.3105

CONCLUSIONS

In this data-rich era, ultimate scientific metric for the viability of any theory

How does it compare with Experiment?

- We have studied Generic features for BSM physics for compactified string theories giving rise to realistic 4D vacua

(with rather mild assumptions)

– solve the Hierarchy problem.

– consistent with particle and cosmological constraints.

Pragmatic Approach – Many testable predictions.

- **Approach very useful even if results do NOT agree with data.**
  - Depending on the nature of data, could tell us which assumption(s) need to be relaxed?
  - Provide a lot of useful insight about nature of microscopic theory.

An Example

If squarks/sleptons observed at the LHC:

– contradiction with some of the basic assumptions/results of the framework.

- Imply one of the following possibilities:

  a) Moduli Super- and Kahler- Potential non-generic (very special).

  b) $H_{inflation} <\sim m_{3/2}$.

  c) Late period of Thermal Inflation.

  d) Some form of sequestering is realized.

None of these possibilities realized naturally within String constructions yet.

Provide very useful insight about Theory !

- Would be a challenge to realize any one of the above within a string theory framework, consistent with experimental constraints.

Of course, if data agrees with the predictions from various experiments,

- **Provide great opportunity to learn more about the string vacuum We live in.**

Extra Slides

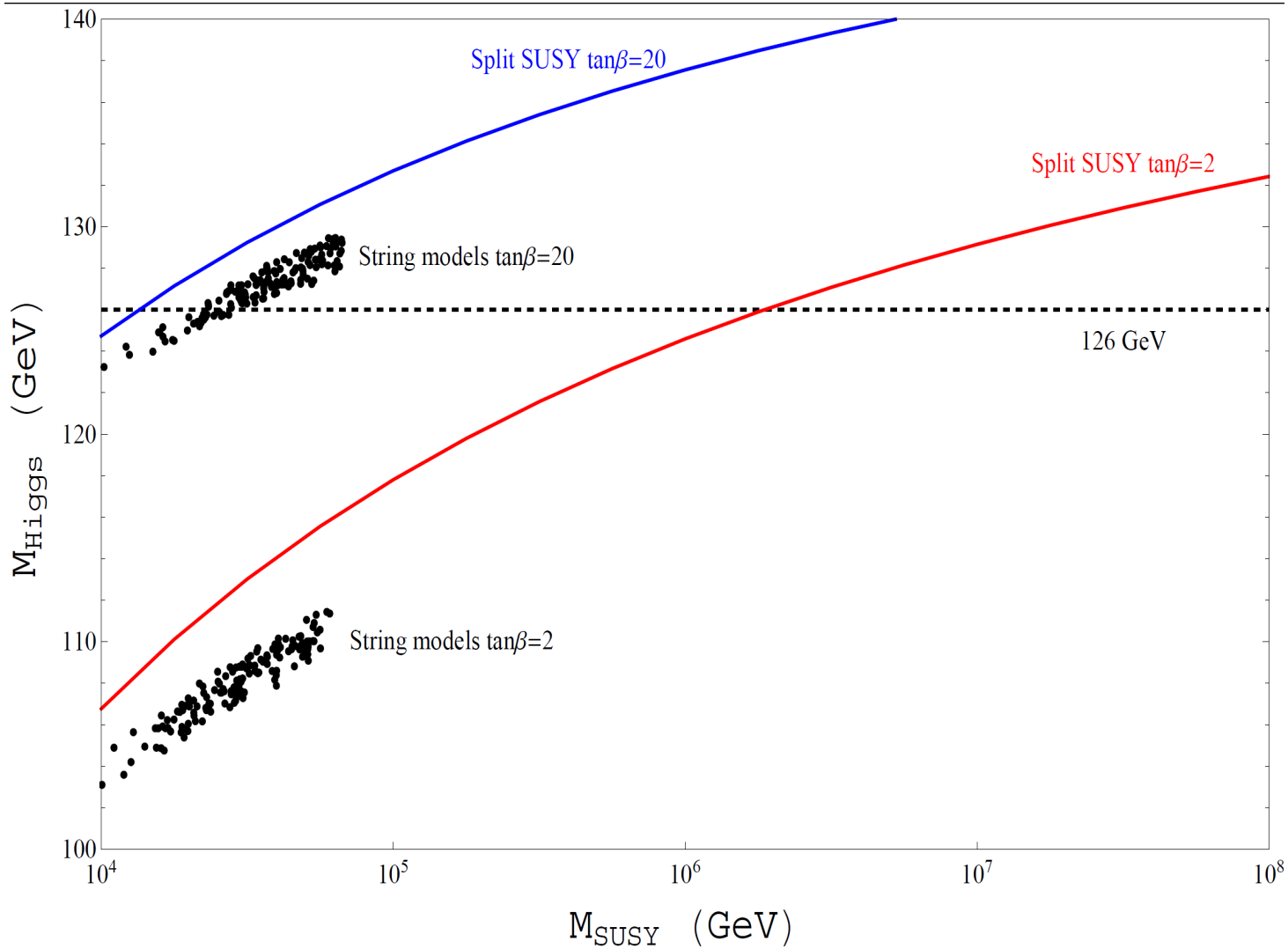
Comparison to Split-SUSY

Top-Down Approach	**Split-SUSY** (anthropic in many cases
• Dynamical solution to Big Hierarchy	Huge fine-tuning *by assumption* for large M_{susy} For smaller M_{susy}, have to explain that scale ($M_h \sim 125$ GeV rules out $M_{susy} > 10^8$ GeV) *Giudice, Strumia 1108.6077*
• EWSB dynamically occurs (Correlation between μ and tanβ)	No EWSB constraint imposed.

Technical

• Only gauginos suppressed, *not* trilinears	Both gauginos and trilinears suppressed.
• Suppression by *Dynamics*	Suppression by *(R)-symmetry*
• Suppression only by 1-2 orders of magnitude	Suppression essentially arbitrary.
• No long-lived gluinos.	Long-lived gluinos – defining feature (at least in original models)

- Higgs mass prediction different in principle for the two cases (even for *same* M_{susy}).



Higgs Mass Comparison

Little Hierarchy/ Fine-Tuning

Notion of Fine-tuning quite subtle

EW Naturalness – Fine-tuning mitigated compared to what is naively expected for such heavy scalars.

From EW point of view, some fine-tuning still remains

But Top-Down Approach → **Another possibility**

The fine-tuning at Low scale may just be "Apparent", caused by "Imperfect understanding" of Microscopic Theory.

If know the theory completely, just compute – no fine-tuning by definition.

Detailed Argument

- EW Naturalness requires

  $|\mu|$, $|m_{Hu}|$ (EW) ~ MZ

$$\frac{1}{2}m_Z^2 = -\mu^2 - \frac{m_{H_u}^2 \tan^2\beta - m_{H_d}^2}{\tan^2\beta - 1} \simeq -\mu^2 - m_{H_u}^2,$$

- For scalar masses >~ 30 TeV, naively have *severe* fine-tuning
- However, not quite true when μ suppressed

$$m_{H_u}^2(t) \simeq f_{M_0}(t)M_0^2 - f_{A_0}(t)A_0^2 + R(t)$$

→ Intersection Point Regime.

- So, natural values $A_0/M_0 \sim 1$ (at M_{GUT})

→ $$m_{H_u}^2 \sim 10^{-2} M_{3/2}^2 \sim \mathcal{O}(\mathrm{TeV}^2)$$

Feldman, Kane, Kuflik, Lu 1105.3765

- So, if $|\mu| \sim 0.1\, m_{3/2}$ → Fine-Tuning Mitigated

possible in string theory constructions, and favored by Higgs mass.

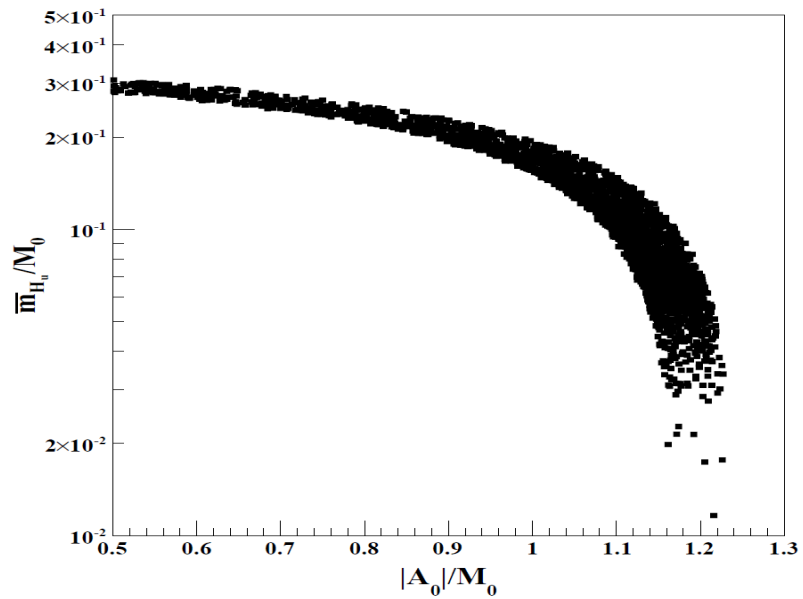
Possibility of No-fine-tuning

- **If for some underlying reason (which we don't know yet)**

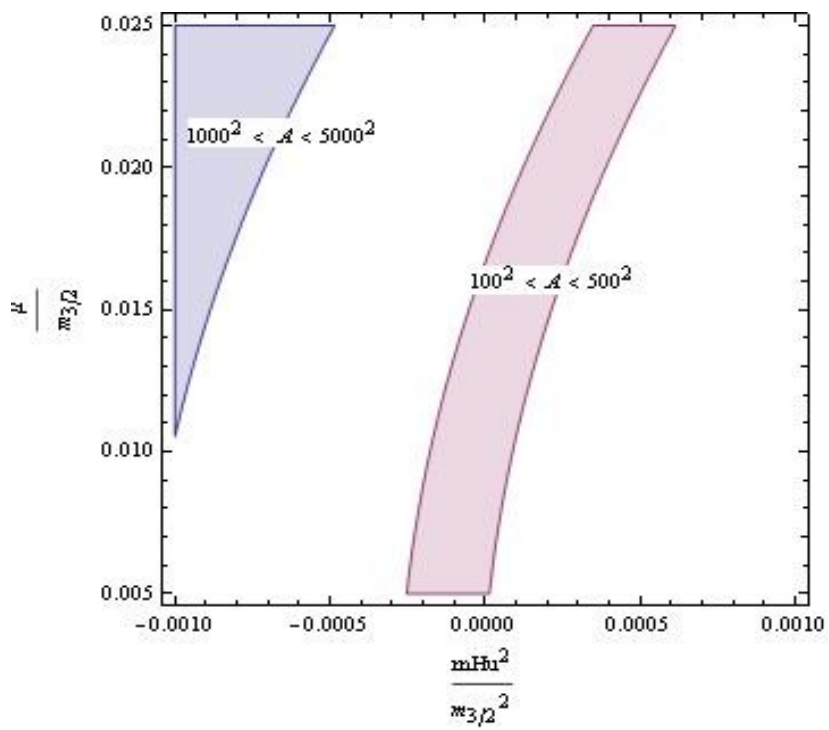
  a) A_0/M_0 close to 1.2,

  b) $\mu \sim 3 * 10^{-2}\, m_{3/2}$

  $\longrightarrow$ $|m_{Hu}|^2(EW) \sim 10^{-2}\, m_{3/2}^{\;2}$



- Region Plot for $M_Z^{\;2}$



$$m_h^2 = 2v^2[\lambda(Q) + \delta_\lambda(Q) + \tilde{\delta}_\lambda(Q)], \qquad m_t = \frac{g_t(Q)v}{1 + \delta_t(Q) + \tilde{\delta}_t(Q)}, \tag{19}$$

where $v = 2^{-3/4}G_{\rm F}^{-1/2} = 174.1\,{\rm GeV}$ is extracted from the Fermi constant for muon decay, $G_{\rm F}$. Here δ_λ [11] and δ_t [12] are the well-known corrections due to SM particles

$$\delta_\lambda = -\frac{\lambda G_{\rm F} M_Z^2}{8\pi^2\sqrt{2}}(\xi F_1 + F_0 + F_3/\xi) \approx 0.0075\lambda \tag{20}$$

$$\delta_t = \delta_t^{\rm QCD} + \delta_t^{\rm EW} \approx -0.0602 - 0.0002 \tag{21}$$

$$\delta_t^{\rm QCD}(m_t) = -\frac{4}{3\pi}\alpha_3(m_t) - 2.64\alpha_3^2(m_t) - 0.92\alpha_3^3(m_t) \tag{22}$$

Higher order corrections to δ_λ may add an uncertainty of ~1 GeV

$$+3g_t^4\left[2X_tF(\frac{m_Q}{m_U}) - \frac{X_t^2}{6}G(\frac{m_Q}{m_U})\right] + \frac{3}{4}X_tg_t^2\left[g_2^2H_2(\frac{m_Q}{m_U}) + \frac{3}{5}g_1^2H_1(\frac{m_Q}{m_U})\right]\cos 2\beta$$

$$\mu^2 = -M_Z^2/2 + \frac{\bar{m}_{H_d}^2 - \bar{m}_{H_u}^2 \tan^2\beta}{\tan^2\beta - 1} \qquad \tan\beta \approx \bar{m}_{H_d}^2/B\mu.$$

$$B\mu = \frac{1}{2}\sin 2\beta(\bar{m}_{H_u}^2 + \bar{m}_{H_d}^2 + 2\mu^2)\ ,$$

$$m_{H_u}^2 \sim 10^{-2} M_{3/2}^2 \sim \mathcal{O}(\mathrm{TeV}^2)$$

In[2]:=
```
Solve[
 {(2 * (-μ^2 + mHd^2/(tanβ^2 - 1.) - mHu2 tanβ^2/(tanβ^2 - 1.)) /. {mHd → m32, mHu2 → a m32^2, μ → b m32, B → c m32} /.
    {c → 1.7, a → 0.01}) == 9.3 * 10^-6 m32^2,
  (2 tanβ/(1 + tanβ^2) + 2 B μ/(mHd^2 + mHu2 + 2 μ^2) /. {mHd → m32, mHu2 → a m32^2, μ → b m32, B → c m32} /.
    {c → 1.7, a → 0.01}) == 0}, {tanβ, b}, Reals]
```

Solve::ratnz : Solve was unable to solve the system with inexact coefficients. The answer was obtained by solving a corresponding exact system and numericizing the result. ≫

Out[2]=
```
{{tanβ → -8.09516, b → 0.0730525}, {tanβ → -1.23503, b → 1.36918},
 {tanβ → 1.23503, b → -1.36918}, {tanβ → 8.09516, b → -0.0730525}}
```

Flavor

- Well known that without any underlying structure, gravity mediation

  ⇒ too large predictions for Flavor observables.

- But flavor is a really ill-understood problem – even the origin of fermion masses and mixings not known.

- Additional structures in the underlying theory could be naturally present.

  Find that quasi-degenerate and heavy scalars ~ 30 TeV consistent with all flavor bounds *Kadota et al 1107.3105*

  Quasi-degenerate scalars could arise from ;

  a) Flavor symmetries present in many string constructions.

  b) Moduli dynamics and mediation of susy breaking could provide further suppression.

- Focus on b) in the following, but should be aware that a) could provide further suppression.

- In non-canonical basis: $$m^2_{\bar{\alpha}\beta} = m^2_{3/2}\tilde{K}_{\bar{\alpha}\beta} - \Gamma_{\bar{\alpha}\beta}$$

- Using homogeneity properties of moduli space, show
  Acharya, Bobkov 0810.3285

$$\Gamma_{\bar{\alpha}\beta} \propto \tilde{K}_{\bar{\alpha}\beta} + \text{ higher order corrections}$$

corrections assumed to be small – not derived, but expected to be true if SUGRA approx. is valid

- Then, going to the canonical basis, find $$\hat{m}^2_{\bar{\alpha}\beta} \simeq m^2_{3/2}\,\delta_{\bar{\alpha}\beta}$$

Giudice, Strumia