The Scale of SUSY Breaking, the Higgs Mass and String Theory

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SUSY 2013

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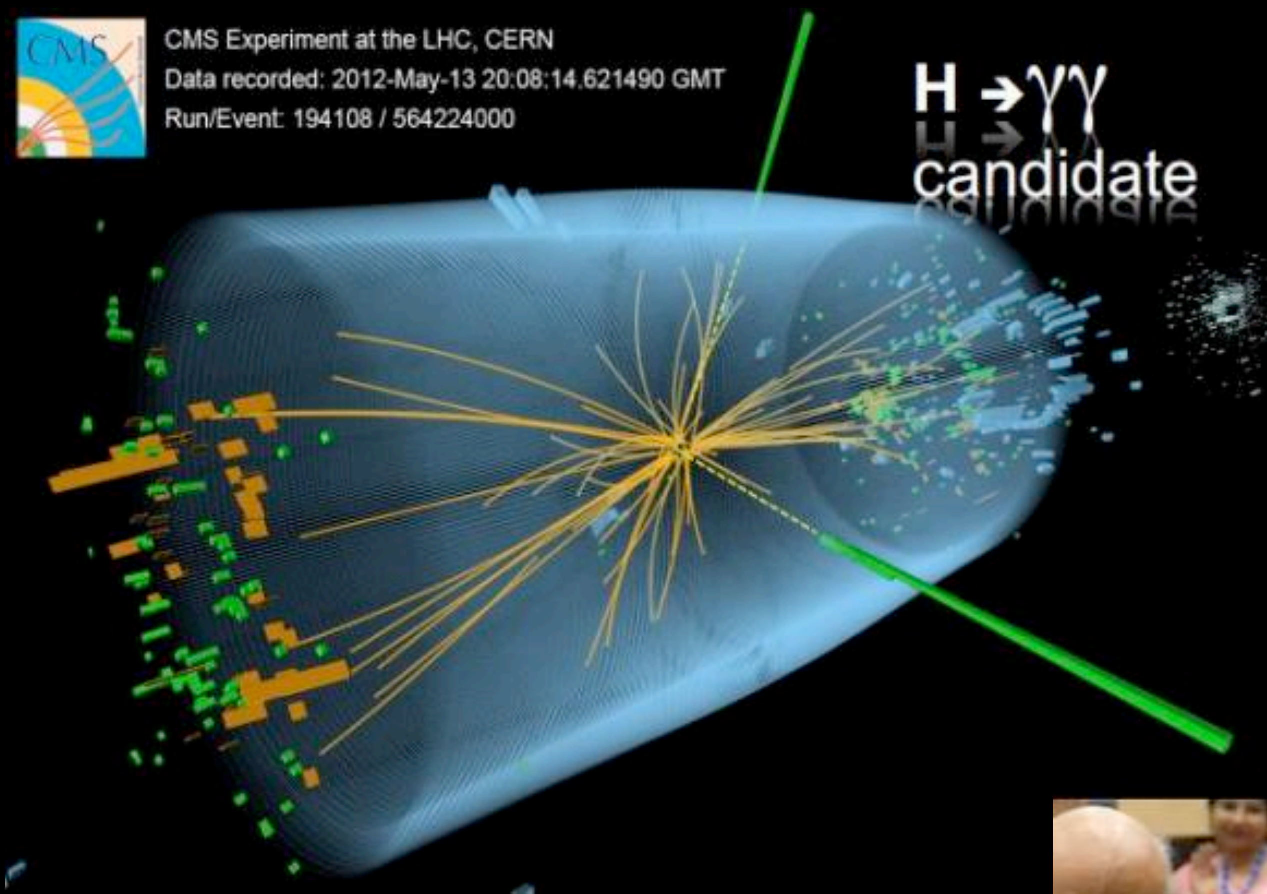
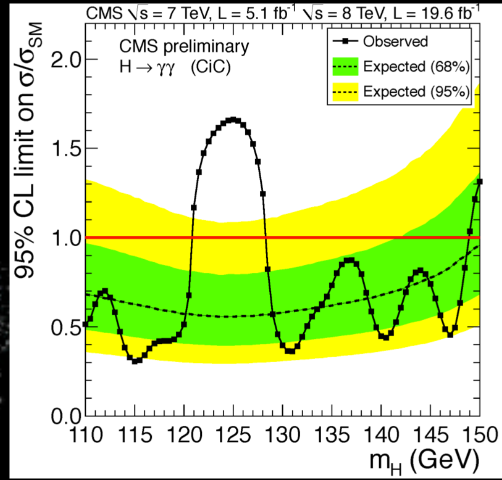

CMS Experiment at the LHC, CERN
Data recorded: 2012-May-13 20:08:14.621490 GMT
Run/Event: 194108 / 564224000
$H \rightarrow \gamma\gamma$
candidate

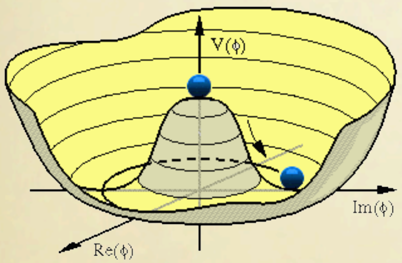

CMS $\sqrt{s}$ = 7 TeV, L = 5.1 fb^{-1} $\sqrt{s}$ = 8 TeV, L = 19.6 fb^{-1}
CMS preliminary
$H \rightarrow \gamma\gamma$ (CiC)
Observed
Expected (68%)
Expected (95%)
95% CL limit on σ/σ_{SM}
0.0
0.5
1.0
1.5
2.0
110 115 120 125 130 135 140 145 150
m_H (GeV)

Happy

- Scalar at 126 GeV looks like the SM Higgs!
- Looks weakly coupled:
  (and elementary)

$$V = \frac{\lambda}{2}|H|^4$$

New fundamental SM parameter measured:



$$\lambda = \frac{m_H^2}{M_W^2}\frac{g_2^2}{4} \simeq 0.27$$

$$(compared\ to\ g_1^2 = 0.11\ ,\ g_2^2 = 0.42)$$

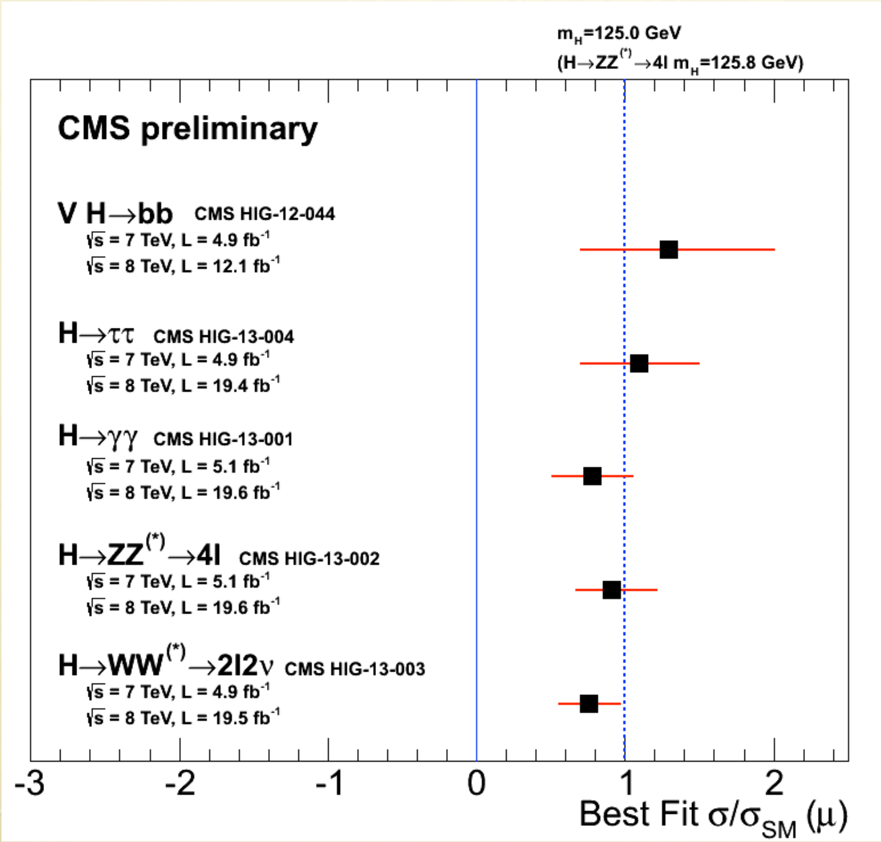
No motivation for compositeness....

$$(No\ more\ than\ for\ W^{\pm}, Z^0 ..\ compositeness)$$

- First elementary scalar ever seen in Physics

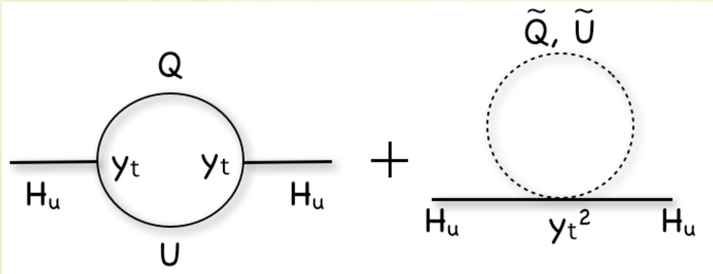
$(Both\ SUSY\ and\ Strings\ predict\ elementary\ scalars\ !)$

- Branching Ratios look also like SM (so far..)

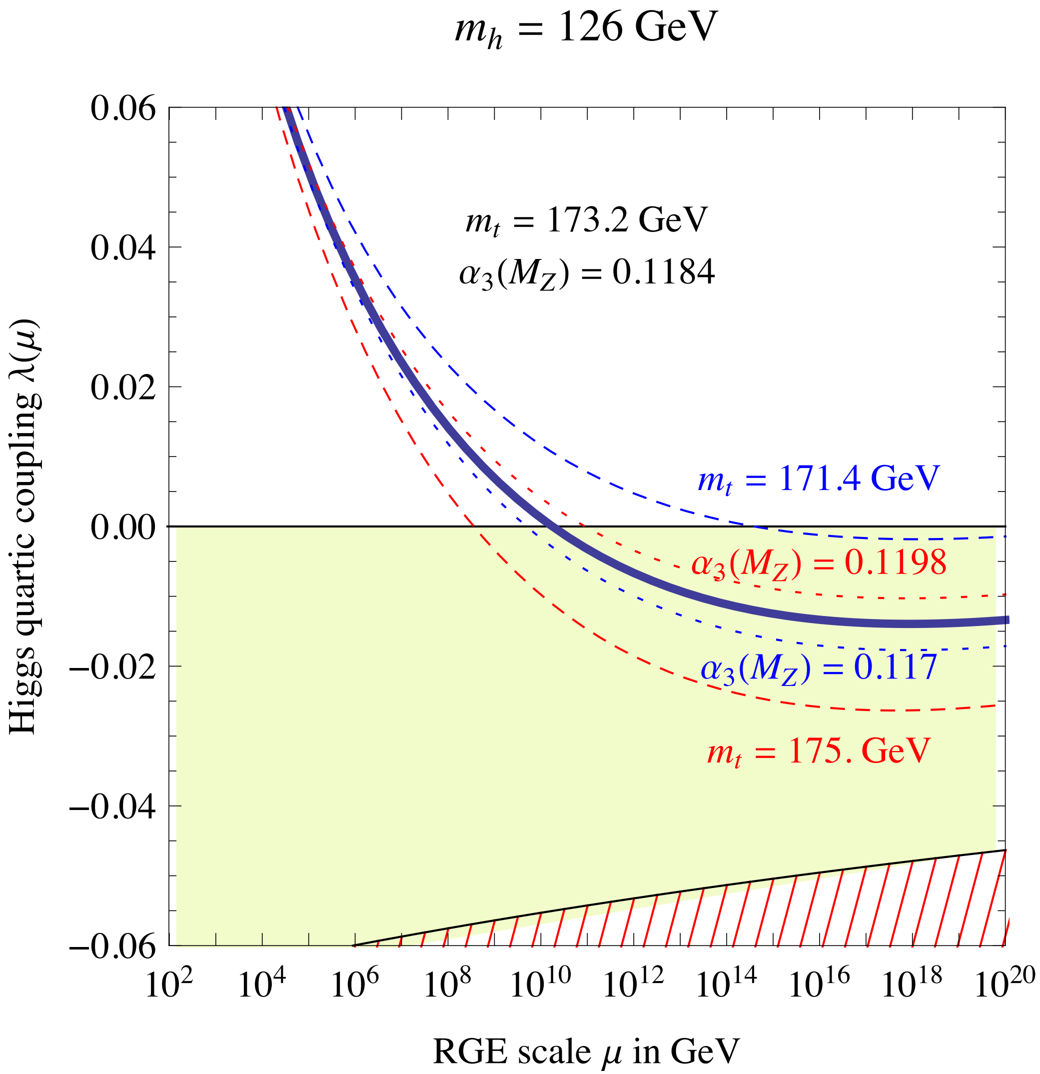


The SM Higgs problems get sharper:

- 1) The gauge hierarchy problem on the nose: the Higgs is there, light and weakly coupled. $Why\ \ m_{Higgs} \ll M_{Planck}$??



- 2) A new 'problem': the `Stability Problem´: the Higgs potential becomes unbounded well below the Planck scale....



Elias-Miró et al. '12

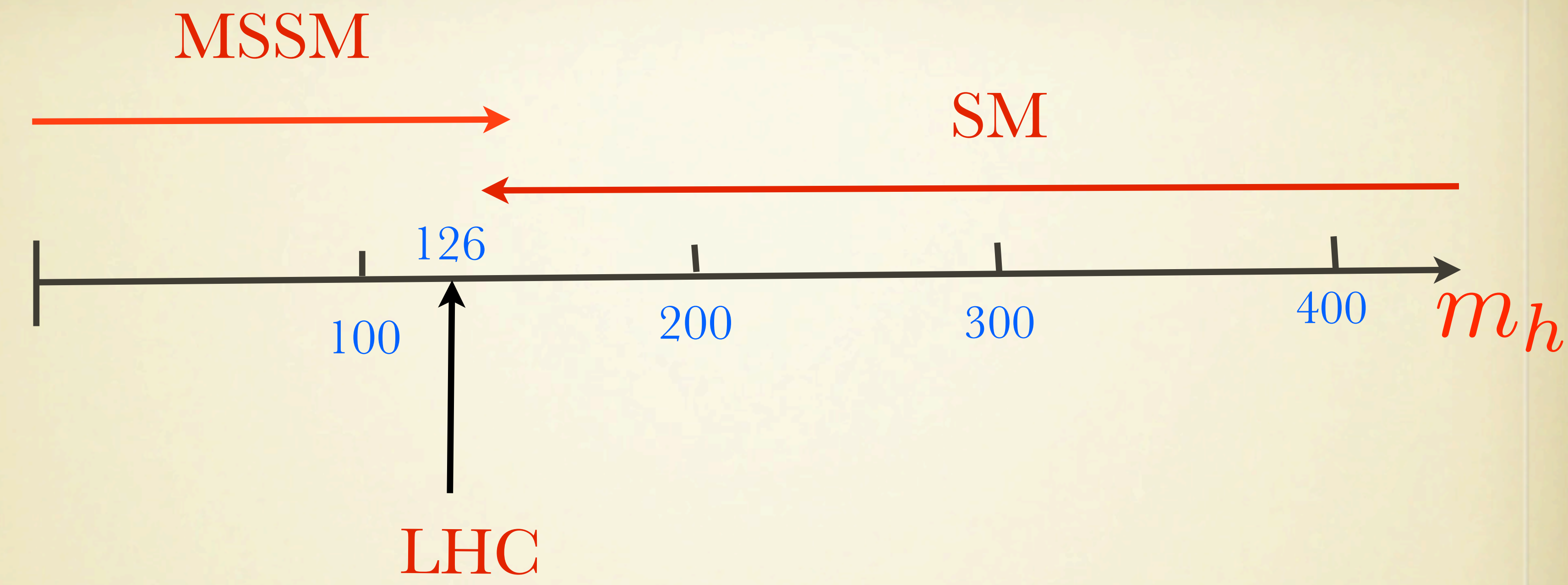
Casas et al. '94; Shaposhnikov, Wetterich '09;
Holthausen et al. '11
Bezrukov et al. '12et al.; Froggatt,Nielsen '96;
Anchordoqui et al.'12

SM

Metastable

$at \simeq 10^{11}\ GeV$

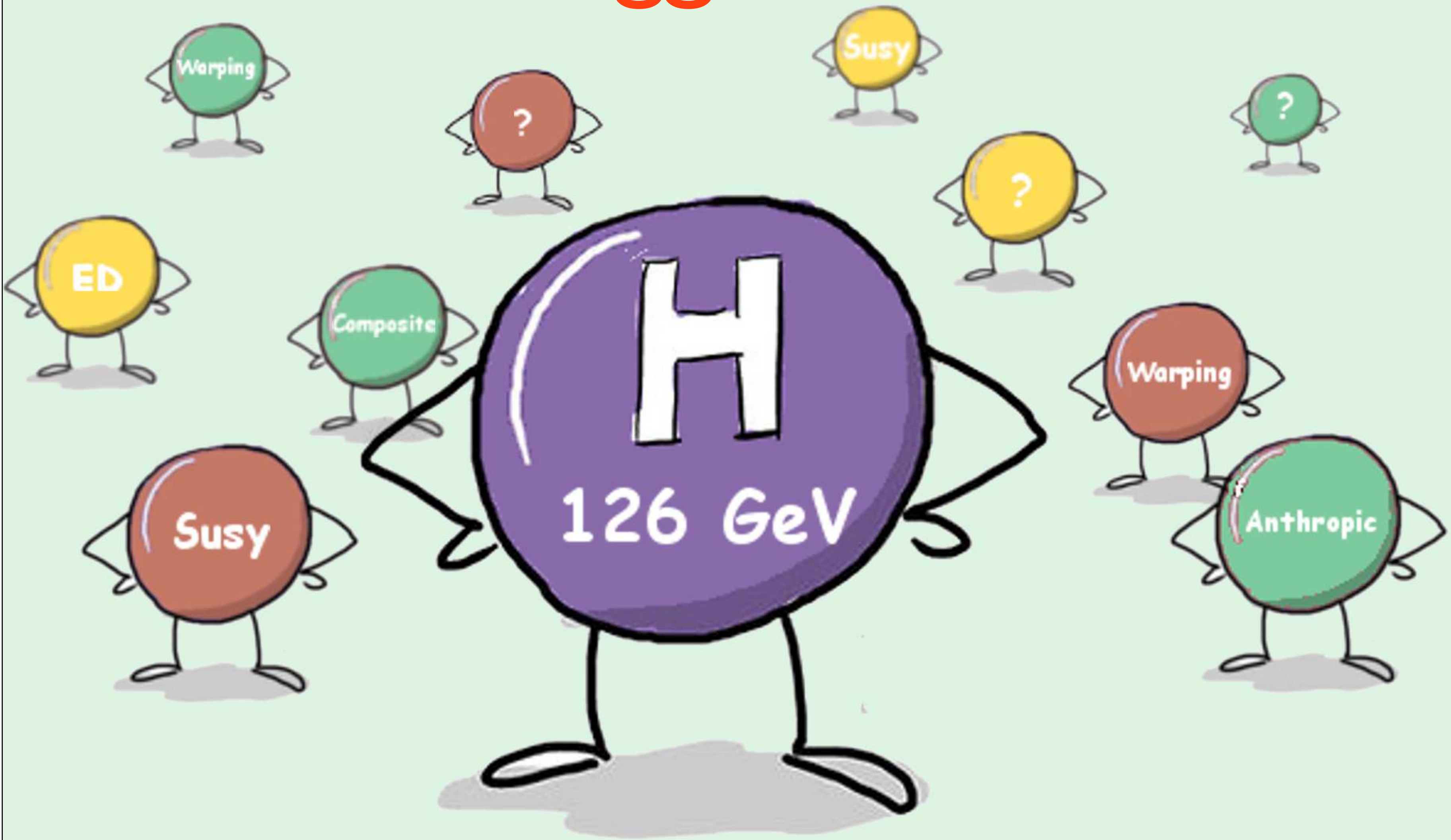
(Not necessarily a problem for a sufficiently long-lived vacuum, but.....)



$$m_h \; = \; 126 \; GeV \; : \;\; a \; borderline \; Higgs$$

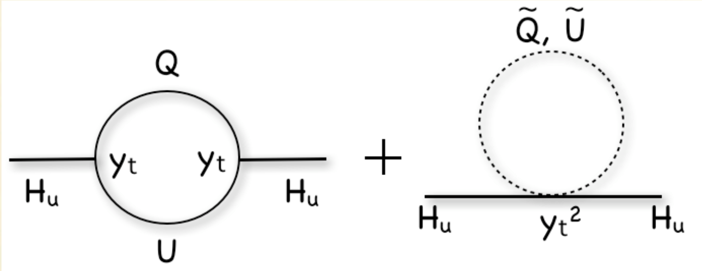
- In the upper region allowed by MSSM
- In the lower region needed for SM stability

The Higgs Puzzle



P. Cámara, adapted from phdcomics.com

Low-energy SUSY?



$= \ 0$

- SUSY predicts $m_h \ \leq \ 130 \ GeV$

In principle 126 GeV Higgs good news for SUSY

However... this value is a bit high....

... and no hints as yet of SUSY particles at LHC!

$$e.g. \ M_{\tilde{g}} = M_{\tilde{q}} \geq \ 1.5 \ TeV \ !$$

(CMSSM)

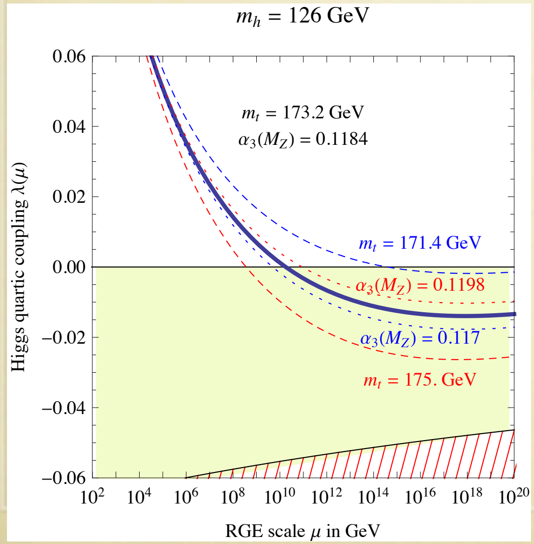

??
Low Energy SUSY
LHC

String Theory Suggests SUSY is present at some scale

- 1) It is a fundamental symmetry of string theory

- 2) To avoid the presence of tachyons in string compactifications

- 3) Additional reason: to stabilize the Higgs potential:



$$V = D^2 + F^2 \geq 0$$

$SUSY\ could\ be\ realised\ at\ a\ scale \gg\ 1\ TeV$

SUSY would be needed NOT to stabilize the hierarchy but to stabilize the SM vacuum

$This\ would\ require\ M_{SS}\ \leq\ 10^{11}\ GeV$

$(before\ \lambda\ becomes\ negative)$

But....what about the hierarchy problem?

String theory provides new avenues:

- The landscape of string vacua may justify an anthropic understanding of the gauge hierarchy via a fine-tuning, in analogy to Weinberg's solution to the c.c. problem

Anthropic: if the Higgs is not light enough, it cannot trigger EW breaking at the right scale and give rise to a sufficiently complex universe so that we can exist...

Agrawal, Barr, Donoghue, Seckel (97, 98); Hogan (99); Tegmark et al (03); Arkani-Hamed, Dimopoulos (04); Giudice, Romanino (04); Dine et al (04); Hall, Nomura (07, 09); Damour, Donoghue (07); Jaffe et al (08), ...

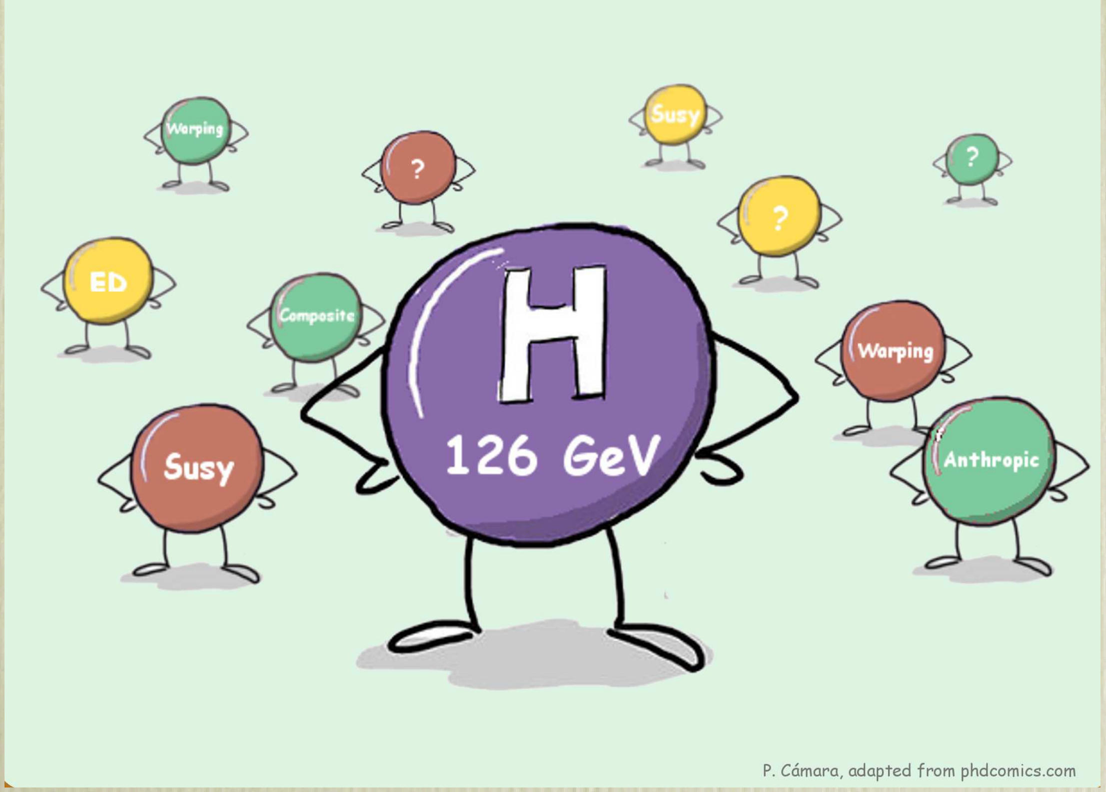
- Assume arbitrarily large SUSY scale

$$M_{SS} \gg 1\ TeV$$

- Assume a light Higgs is fine-tuned (e.g. selected anthropically)

We will see that $m_H \simeq 126\ GeV$ is then a typical value!!

Higgs mass versus SUSY scale



$$Assume\ a\ structure\ of\ scales:$$

$$M_{EW} \ll M_{SS} \ll M_X$$

$$Above\ M_{SS}\ we\ have\ two\ doublets\ H_u, H_d$$

$General\ Higgs\ mass\ terms:$

$$\begin{pmatrix} H_u & , & H_d^* \end{pmatrix} \begin{pmatrix} m_{H_u}^2 & m_3^2 \\ m_3^2 & m_{H_d}^2 \end{pmatrix} \begin{pmatrix} H_u^* \\ H_d \end{pmatrix}$$

Massless eigenstate: $H_{SM} = sin\beta\ H_u - cos\beta\ H_d^*$

Obtained from fine-tuning: $m_3^4 = m_{H_u}^2 m_{H_d}^2$

$$\rightarrow\ tan\beta = \frac{m_{H_d}^2}{m_{H_u}^2}$$

Assumed anthropically tuned

$Then\ there\ is\ SM\ quartic\ potential\ inherited\ from\ MSSM$

Arkani-Hamed, Dimopoulos '04
Hall, Nomura '09

$MSSM\ D-term:$

$SUSY\ predicts\ \lambda(M_{SS}):$

$$V_{SM} \;=\; \underbrace{\frac{1}{8}\left(g_2^2+\frac{3}{5}g_1^2\right) cos^2 2\beta}_{\lambda(M_{SS})} \;\; |H_{SM}|^4$$

$How\ to\ compute\ m_H\ as\ a\ function\ of\ M_{SS}:$

$$V_{SM}(M_{SS}) =$$

$$\underbrace{\frac{1}{8}\left(g_2^2(M_{SS}) + \frac{3}{5}g_1^2(M_{SS})\right) cos^2 2\beta(M_{SS})}_{\lambda(M_{SS})}|H_{SM}|^4$$

$\rightarrow$ $\boxed{need\ to\ compute\ \lambda(M_{SS}):}$

$$1)\ g_{1,2}^2(M_{SS})$$

$$2)\ cos^2 2\beta(M_{SS})$$

1) $One\ computes\ \boxed{g_{1,2}^2(M_{SS})\ using\ the\ 2-loop\ RGE}\ from$ $M_W\ to\ M_{SS}\ scale$ (also $h_t(M_{SS})$)

2) $Compute\ cos^2 2\beta(M_{SS})$:

L.I. and Valenzuela 2013

$Very\ reasonable\ assumption:\ m_{H_u}(M_{GUT}) = m_{H_d}(M_{GUT})$

$and\ computes\ tan\beta(M_{SS}) = |m_{H_u}|/|m_{H_d}|(M_{SS})\ from\ RGE$

$Solving\ the\ RGE\ and\ taking\ CMSSM\ soft\ terms:$

$$m^2_{H_d}(t) = m^2 + \mu^2 q^2(t) + M^2 g(t) \qquad , t = 2log(M_{GUT}/M_{SS})$$
$$m^2_{H_u}(t) = m^2(h(t) - k(t)A^2) + \mu^2 q^2(t) + M^2 e(t) + AmMf(t)$$

$with\ q, g, h, k, e, f\ known\ functions\ of\ h_t\ and\ gauge\ couplings$

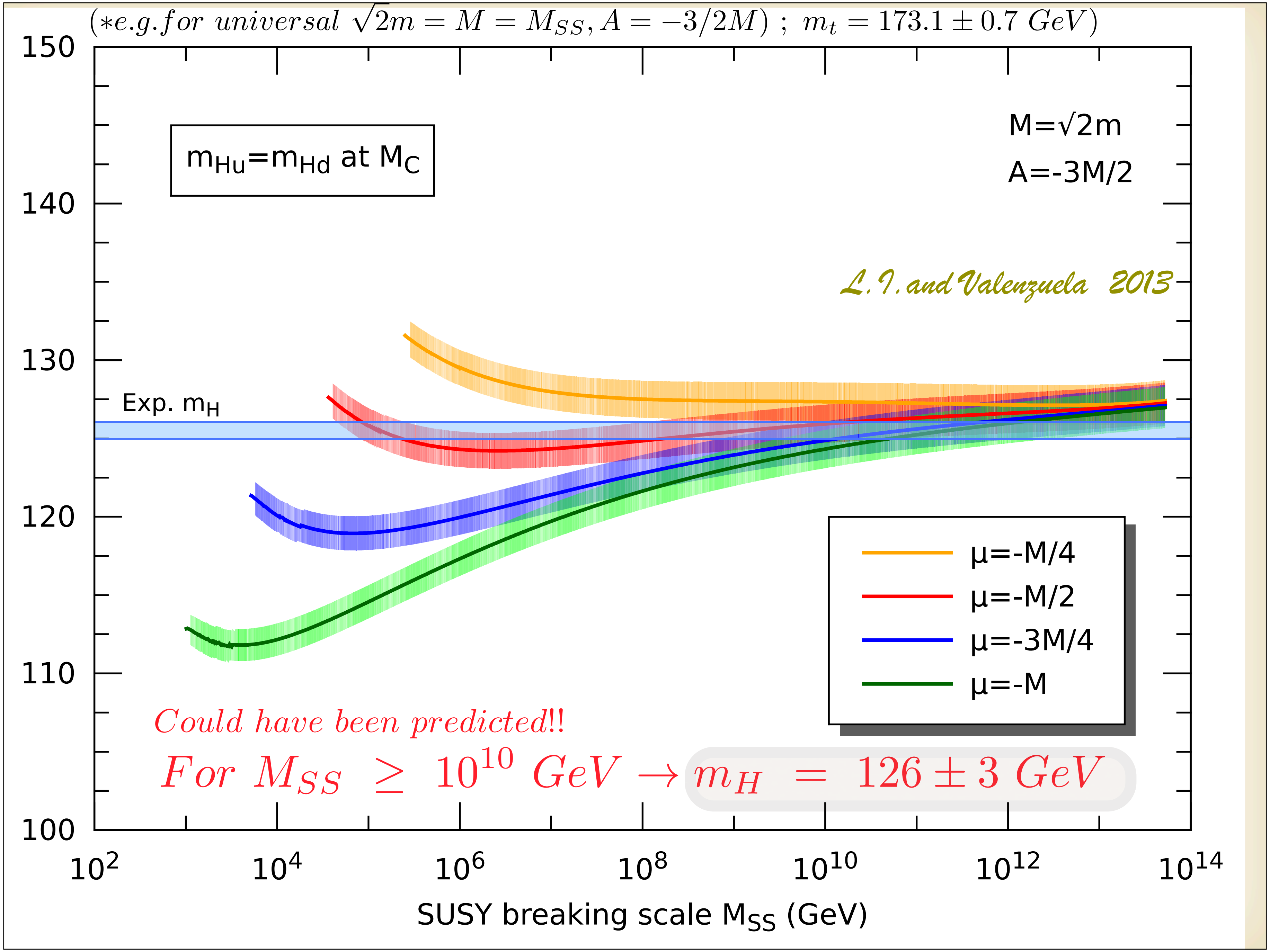
L.I., Muñoz, López 1985

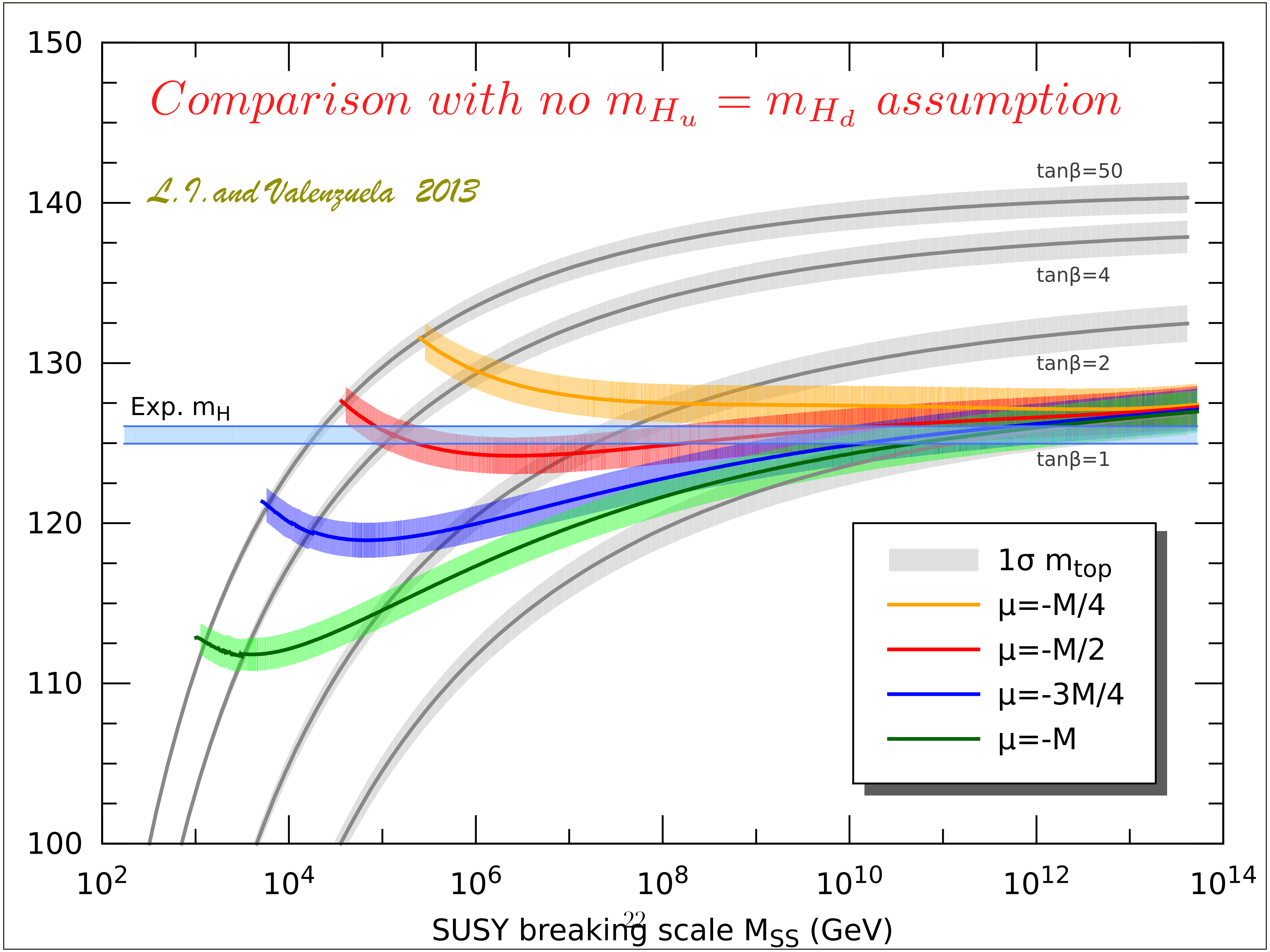
$3)\ Run\ down\ \lambda\ to\ Weak\ Scale:$

$(SUSY\ thresholds\ at\ M_{SS}\ ,\ \delta\lambda(M_{SS})\ ;\ Additional\ EW\ threshold)$

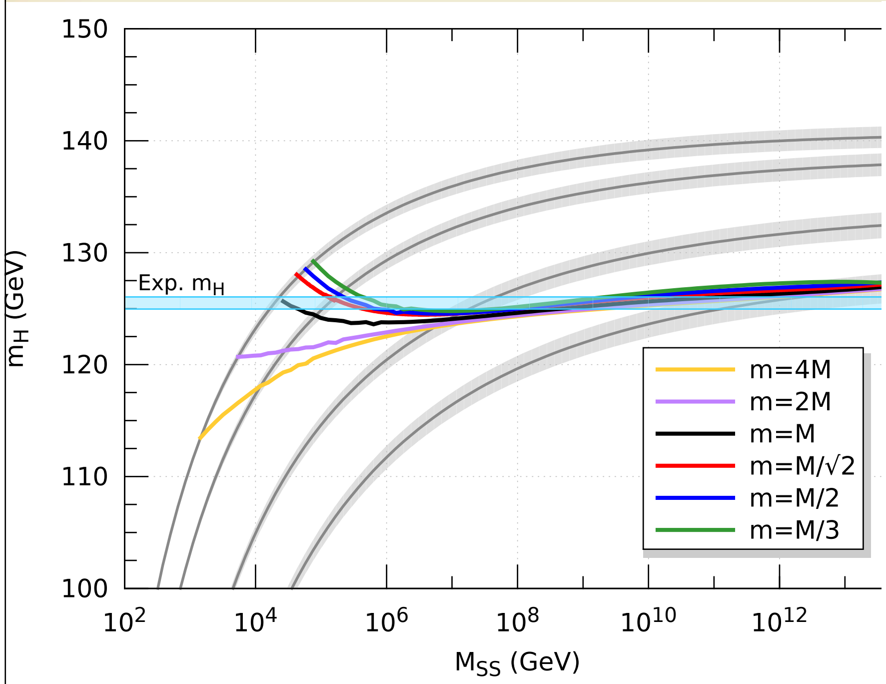
$$\boxed{m_H^2(Q_{EW}) \;=\; \frac{4M_W^2}{g_2^2}\,\lambda(Q_{EW})}$$

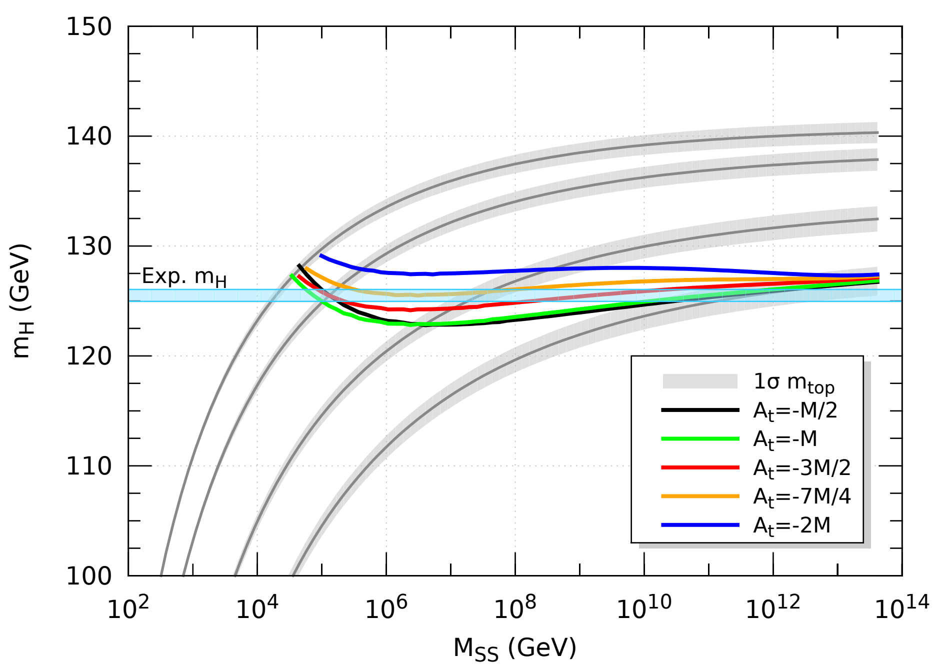
$Weak\ dependence\ on\ gauge\ coupling\ unification$


$(*e.g. for\ universal\ \sqrt{2}m = M = M_{SS}, A = -3/2M)\ ;\ m_t = 173.1 \pm 0.7\ GeV)$
$m_{Hu}=m_{Hd}$ at M_C
M=√2m
A=-3M/2
L.I. and Valenzuela 2013
Exp. m_H
μ=-M/4
μ=-M/2
μ=-3M/4
μ=-M
Could have been predicted!!
$For\ M_{SS} \geq 10^{10}\ GeV \rightarrow m_H = 126 \pm 3\ GeV$
150
140
130
120
110
100
10^2
10^4
10^6
10^8
10^{10}
10^{12}
10^{14}
SUSY breaking scale M_{SS} (GeV)



Comparison with no $m_{H_u} = m_{H_d}$ assumption
L.I. and Valenzuela 2013
tanβ=50
tanβ=4
tanβ=2
tanβ=1
Exp. m_H
1σ m_{top}
μ=-M/4
μ=-M/2
μ=-3M/4
μ=-M
150
140
130
120
110
100
10^2
10^4
10^6
10^8
10^{10}
10^{12}
10^{14}
SUSY breaking scale M_{SS} (GeV)





Similar results for other choices of soft terms

$For\ M_{SS} \leq 10^{10}\ GeV\ more\ model\ dependent$

$Still\ m_H \leq 130\ GeV\ as\ in\ MSSM$

$$m_H \simeq 126\ GeV\ \ suggests\ very\ heavy\ SUSY\ !!$$

But, how heavy is SUSY??

$$M_{SS} \simeq 10^{11}\ GeV\ ?$$

This is the maximum compatible with stable SM...

$$M_{SS} \simeq few\ TeV\ ?$$

This is low energy SUSY, perhaps accesible to LHC...

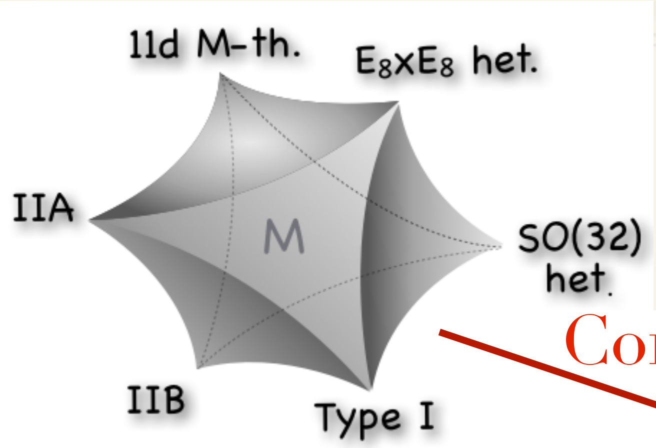
Both are possible....

- 1) An intermediate SUSY breaking scale

$M_{SS} \simeq 10^{10}\ GeV$ is typical in String Compactifications

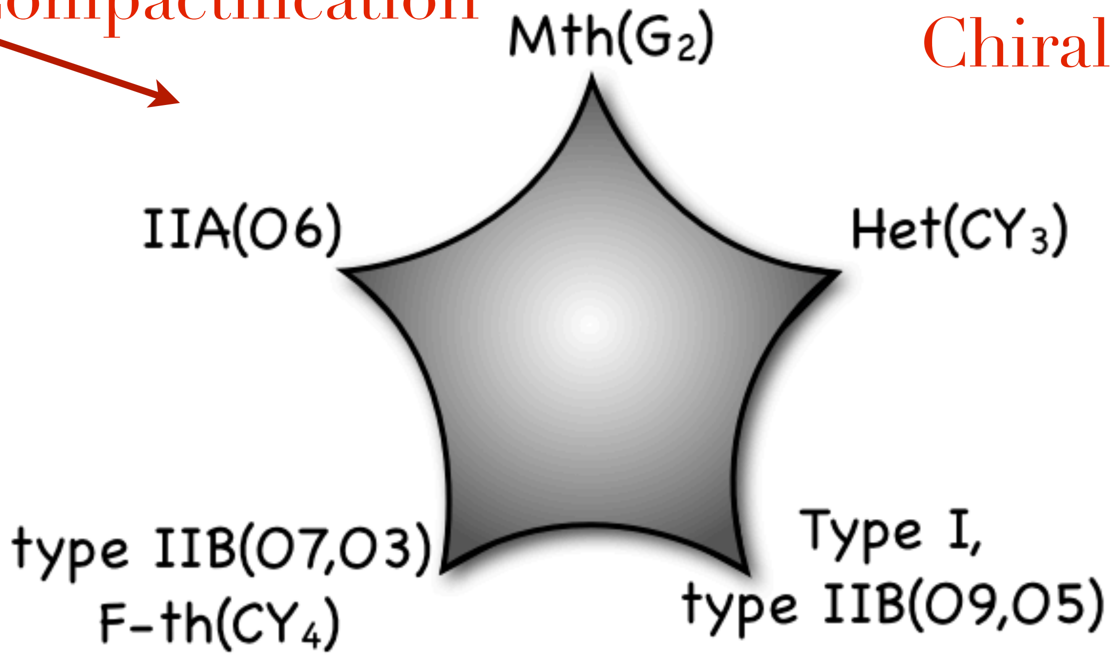
- 2) Low scale SUSY is however not yet excluded and predictive soft masses are obtained in modulus domination both in MSSM and NMSSM, see later

STRINGS



Compactification

Chiral



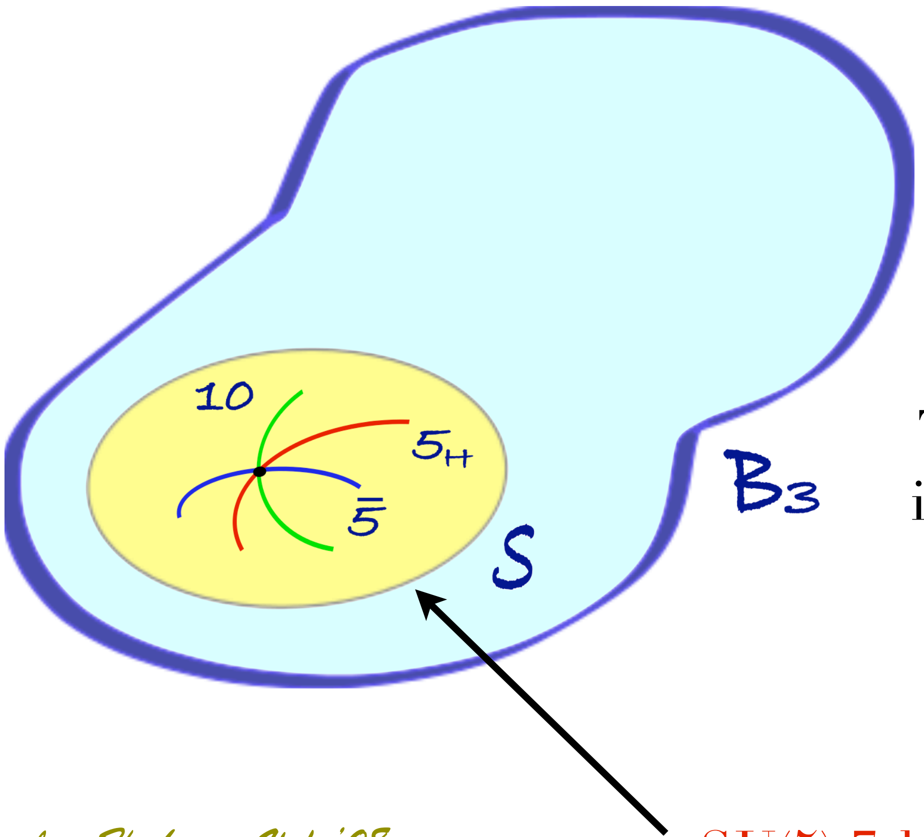
Concentrate on:

F-theory: Combines GUT unification with flux moduli fixing

F-theory SU(5)

Vafa '96

- F-theory may be considered as a non-perturbative version of Type IIB orientifolds. One considers an auxiliary 12-dimensional theory on a complex 4-fold



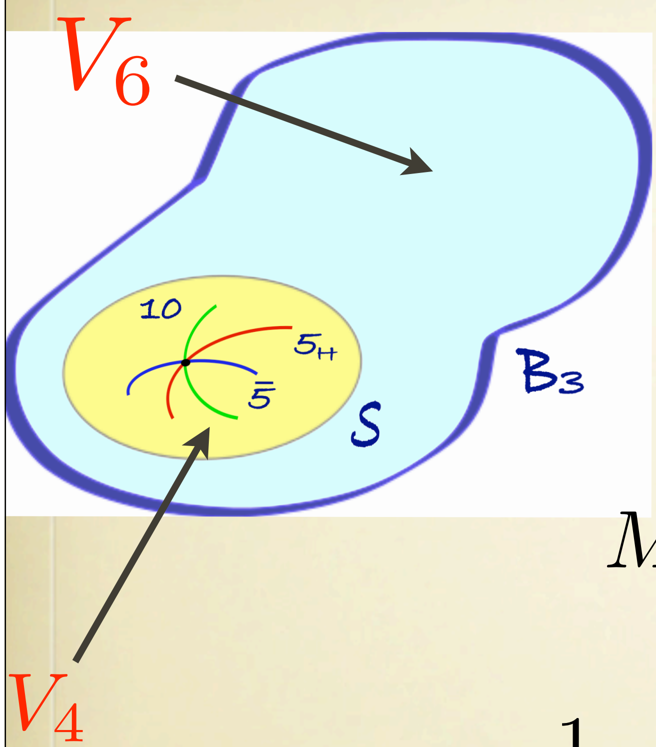
$$X_4 \sim T^2 \times B_3$$

The c.s. modulus of 2-torus is identified with complex dilaton

SU(5) 7-branes wrap a 4-cycle S

Beasley, Heckman, Vafa '08
Donagi & Wijnholt '08

1) Mass Scales (IIB)



$$M_s^2 \;=\; (\alpha')^{-1} \qquad \text{String scale}$$

$$M_p^2 \;=\; \frac{8M_s^8 V_6}{(2\pi)^6 g_s^2} \qquad \text{Planck scale}$$

$$M_c \;=\; \frac{1}{R_c} \;=\; M_s \left(\frac{\alpha_G}{2g_s}\right)^{1/4} \qquad \text{Unification scale}$$

$$where\ \frac{1}{\alpha_G} \;=\; \frac{V_4 M_s^4}{8\pi^4 g_s} \qquad parametrizing\ V_4 = (2\pi R_c)^4$$

$$M_c \;\leq M_s \;\leq M_p$$

$(V_4\ indep.\ from\ V_6)$

2) Important new ingredient:

(no adjoint Higgs!!)
(no Wilson lines!!)

SU(5) Symmetry breaking through hypercharge flux:

Flux along the hypercharge direction:

Beasley, Heckman, Vafa '08
Donagi & Wijnholt '08

$$\int_\Sigma F_Y = integer \qquad \Sigma \; is \; a \; 2-cycle \; in \; S$$

(sort of adjoint Higgsing)

$$(\Sigma \; trivial \; in \; B_3, so \; that \; hypercharge \; remains \; massless)$$

$$F_Y \simeq \frac{1}{R_c^2} = M_c^2$$

$$M_c \; is \; the \; unification \; scale$$

3) Closed String Fluxes: A natural source of SUSY breaking

In Type IIB there are RR and NS 3-form fluxes G_3 inducing SUSY-breaking soft terms of order:

$$M_{SS} \simeq G_3 \simeq \frac{\alpha'}{V_6^{1/2}} \simeq \frac{M_s^2}{M_p}$$

$$(since \int_{3-cycle} G_3 \in integer \rightarrow G_3 \simeq \frac{1}{V_6^{1/2}})$$

$$\longrightarrow \quad M_{SS} \simeq \left(\frac{2g_s}{\alpha_G}\right)^{1/2} \frac{M_c^2}{M_p}$$

Geometrical mean

This is the typical SUSY breaking scale in string theory!

(In the MSSM scenario these fluxes should be suppressed somehow !!)

4) Gauge coupling unification

$$
\begin{aligned}
4\pi f_{SU(3)} &= T \\
4\pi f_{SU(2)} &= T \\
\frac{3}{5} 4\pi f_{U(1)} &= T
\end{aligned}
$$

$T \ is \ local \ Kahler \ modulus \qquad T = \frac{M_s^4 V_4}{8\pi^4 g_s} + i\ \eta$

4) Gauge coupling unification

Hypercharge fluxes induce corrections to SU(5) unification:

Donagi & Wijnholt'08
Blumenhagen'08

$$4\pi f_{SU(3)} = T$$

$$4\pi f_{SU(2)} = T - \frac{1}{2}\tau \int_S (F_Y \wedge F_Y)$$

$$\frac{3}{5} 4\pi f_{U(1)} = T - \frac{1}{2}\tau \int_S \left(\frac{3}{5}(F_Y \wedge F_Y) \right)$$

T *is local Kahler modulus* $\quad T = \dfrac{M_s^4 V_4}{8\pi^4 g_s} + i\,\eta$

$\tau = \frac{1}{g_s} + iC_0$ is the complex dilaton

$(From\ DBI\ action\ = \dfrac{M_s^8}{g_s(2\pi)^3}\int_{D7}\sqrt{det(G+B-2\pi\alpha' F)}\ \simeq\ cte. +\ T\ F^2\ +\ \tau\ < F_Y >^2\ F^2\ +\ ....$

Corrections modify unification condition to

Blumenhagen '08

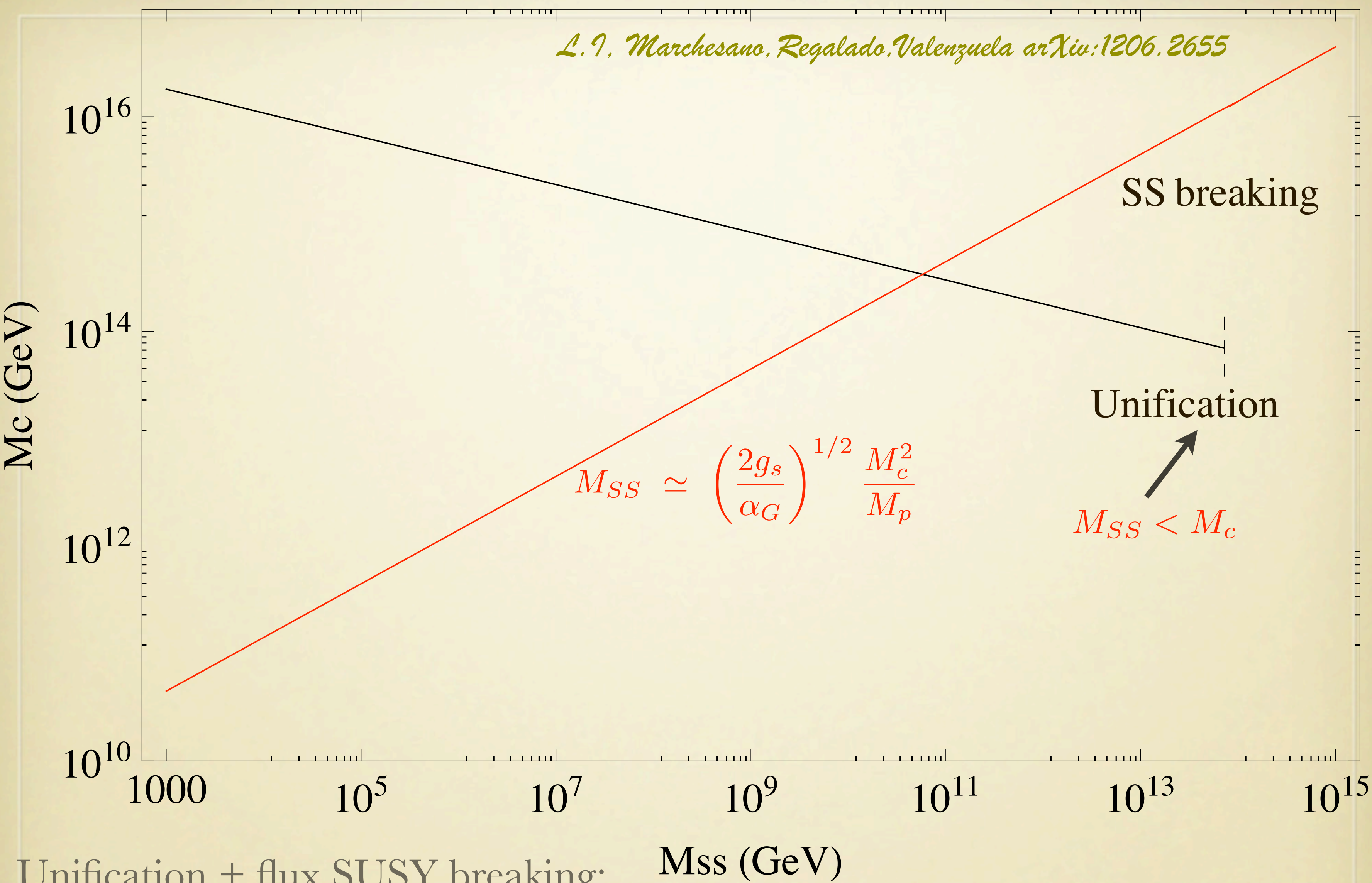
$$\frac{1}{\alpha_1(M_c)} = \frac{1}{\alpha_2(M_c)} + \frac{2}{3\alpha_3(M_c)} \qquad (instead\ of\ (5/3)\alpha_1 = \alpha_2 = \alpha_3)$$

Assume: $M_{EW} < Q < M_{SS} \rightarrow SM$

$$M_{SS} < Q < M_c \rightarrow MSSM$$

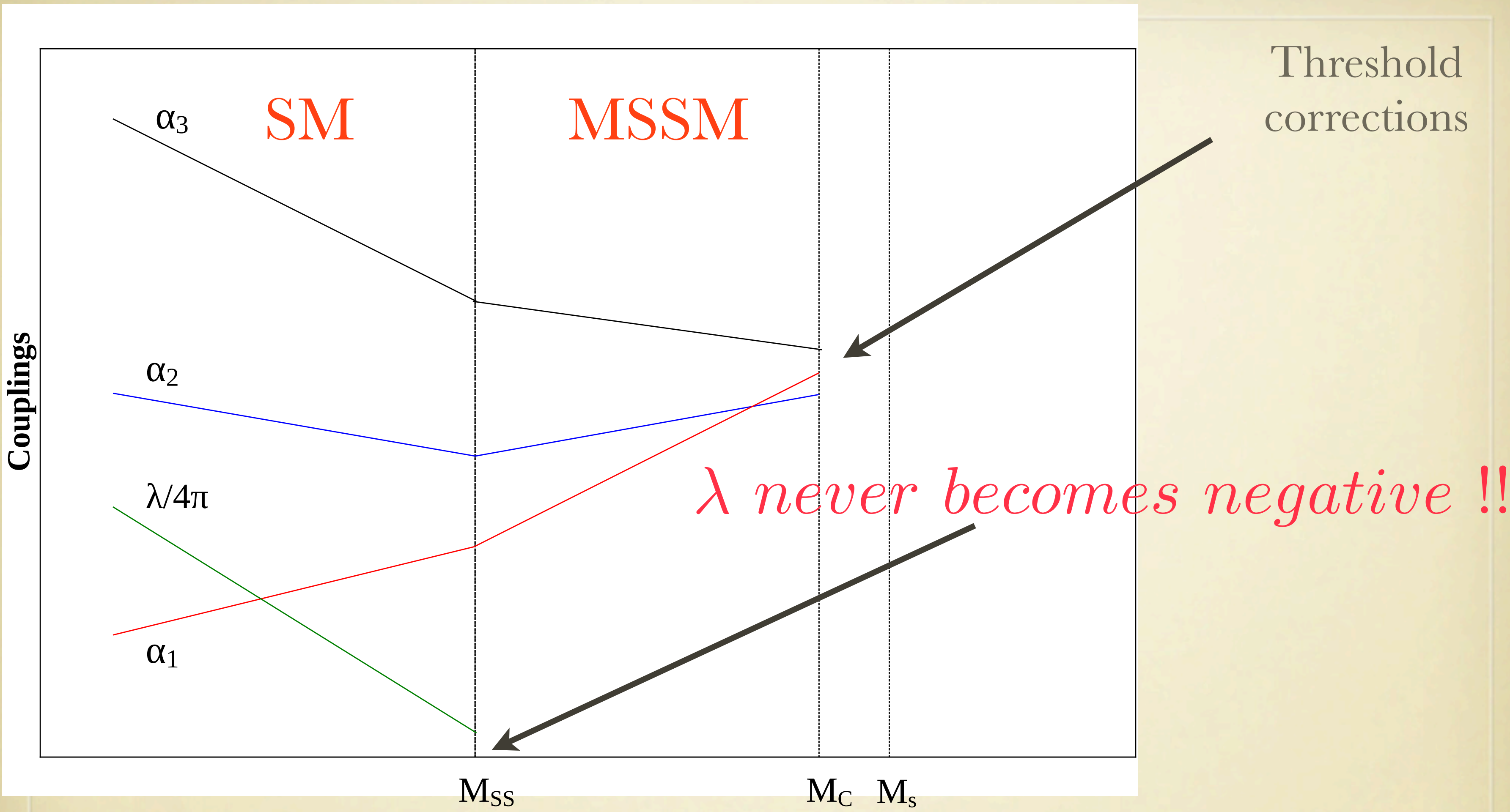
(As in High Scale SUSY breaking Hall, Nomura '09)

(30)



Unification + flux SUSY breaking:

$$M_{SS} \ = \ 2.5 \times 10^{10} \ GeV \ ; \ M_c \ = \ 2.4 \times 10^{14} \ GeV$$



Intermediate Scale SUSY Breaking

$$From\ M_{SS} = 2.5 \times 10^{10}\ GeV\ ;\ M_c = 2.4 \times 10^{14}\ GeV :$$

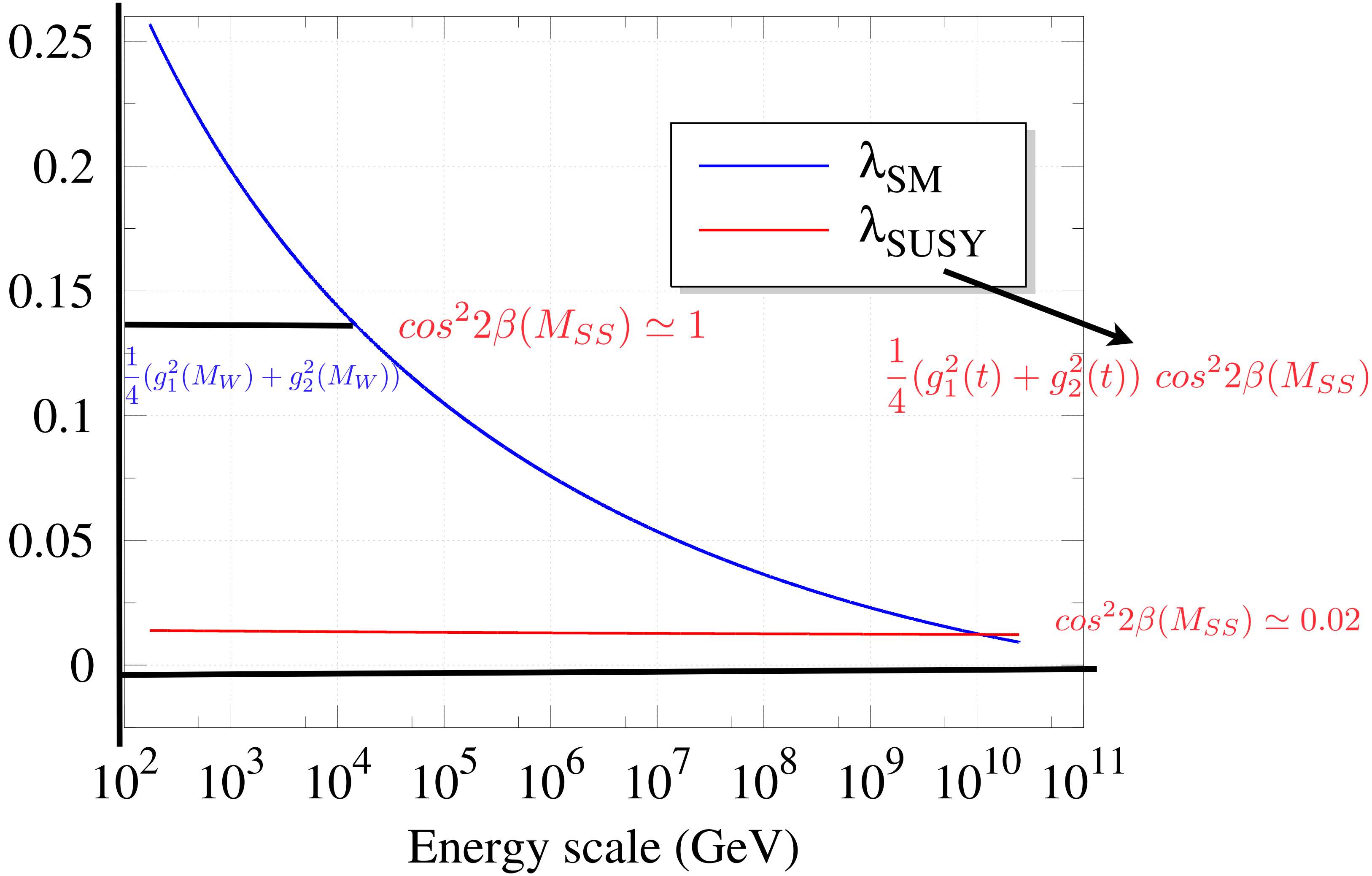
$$\boxed{m_H = 126.1 \pm 1.2\ GeV}$$

$$(*e.g. for\ universal\ \sqrt{2}m = M = M_{SS}, A = -3/2M)\ ;\ m_t = 173.1 \pm 0.7\ GeV)$$

Summary of assumptions:

In the context of IIB/F-theory SU(5) unification, imposing

- Gauge coupling unification (including hypercharge flux corrections)
- Generic closed string flux-induced SUSY-breaking
- Assuming $m_{H_u} = m_{H_d}$ at the compactification scale



0.25
0.2
0.15
0.1
0.05
0
λ_{SM}
λ_{SUSY}
$cos^2 2\beta(M_{SS}) \simeq 1$
$\frac{1}{4}(g_1^2(M_W) + g_2^2(M_W))$
$\frac{1}{4}(g_1^2(t) + g_2^2(t))\ cos^2 2\beta(M_{SS})$
$cos^2 2\beta(M_{SS}) \simeq 0.02$
10^2 10^3 10^4 10^5 10^6 10^7 10^8 10^9 10^{10} 10^{11}
Energy scale (GeV)

1) *Origin of* $m_{H_u}(M_c) = m_{H_d}(M_c)$?

Quite common in string compactifications.

Could also come from shift symmetries *Hebecker, and Weigand '12, '13*

2) *What is Dark matter made of?*

Axions with $F_a \simeq \frac{M_c}{(4\pi)^2} \simeq 10^{12}\ GeV$ *can naturally arise*

see also Niles et al. 2012; Redi, Strumia 2012

3) *Proton decay?* *L.I. Marchesano, Regalado, Valenzuela '12; Camara, Dudas, Palti '11*

Although unification scale somewhat small ($\simeq 3 \times 10^{14}\ GeV$),

decay rate suppressed in F − theory due to w.f. localisation

Hints of an intermediate SUSY scale :

i) Axion dark matter detection in microwave cavity experiments

ii) Proton decay experiments

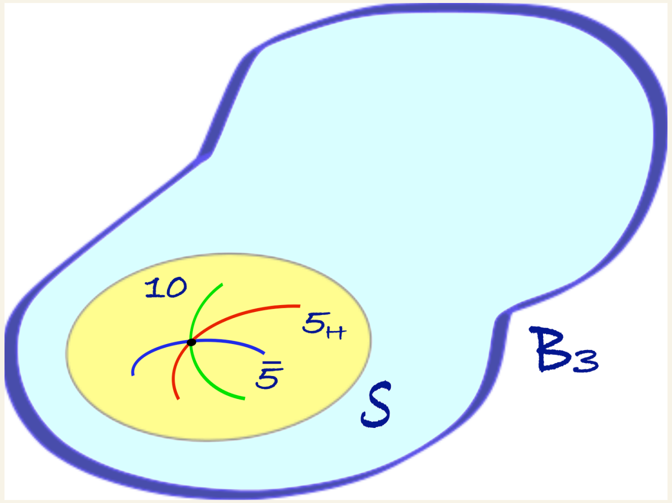
But we should not give up too soon!!

Low energy SUSY
and String
Compactifications

MSSM soft terms from string compactifications

- In string compactifications the auxiliary fields of the moduli are the seed of SUSY breaking in a gravity mediated fashion
- In IIB/F-theory compactifications they are associated to closed string antisymmetric field fluxes *Camara et al. '03; Graña et al. '04*
- Simple assumptions about the structure of an underlying MSSM compactification lead to specific predictions for SUSY-breaking soft terms

Effective action in local intersecting 7-branes



Gauge kinetic function:

$$f \;=\; T$$

Local Kahler Modulus in S
(ReT=Vol(S)=t/2)

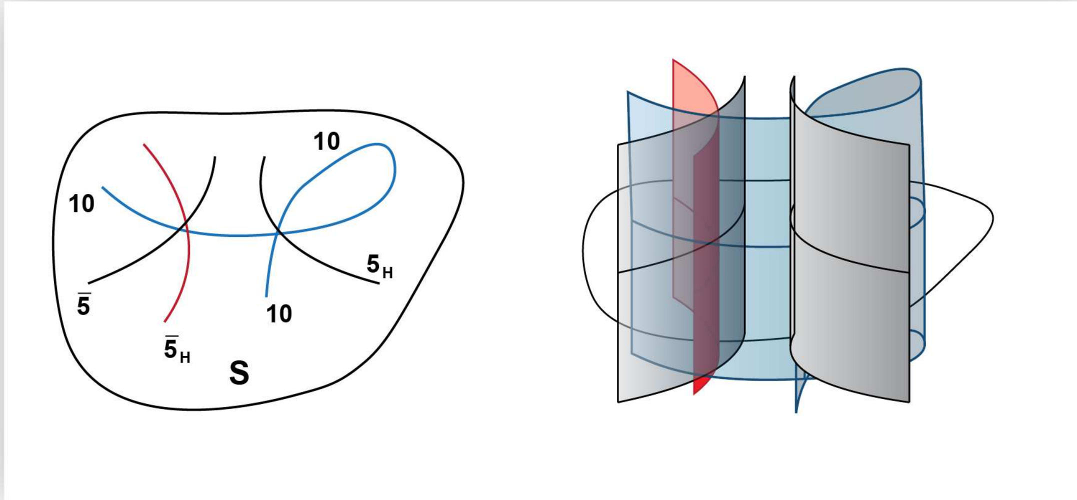
$$\longrightarrow \alpha_{GUT} = t^{-1}$$

Kinetic metric of matter fields:

$$K_\alpha \;=\; \frac{1}{t^{\xi_\alpha}}$$

$$Scaling\ arguments: \xi_\alpha \;=\; 1/2\ for\ intersecting\ 7-branes$$

Conlon, Cremades, Quevedo '07 *Cámara, L.I, Valenzuela '13*



Asumptions:

- MSSM spectrum located at intersection of SU(5) 7-brane with U(1) 7-branes (F-theory matter curves)

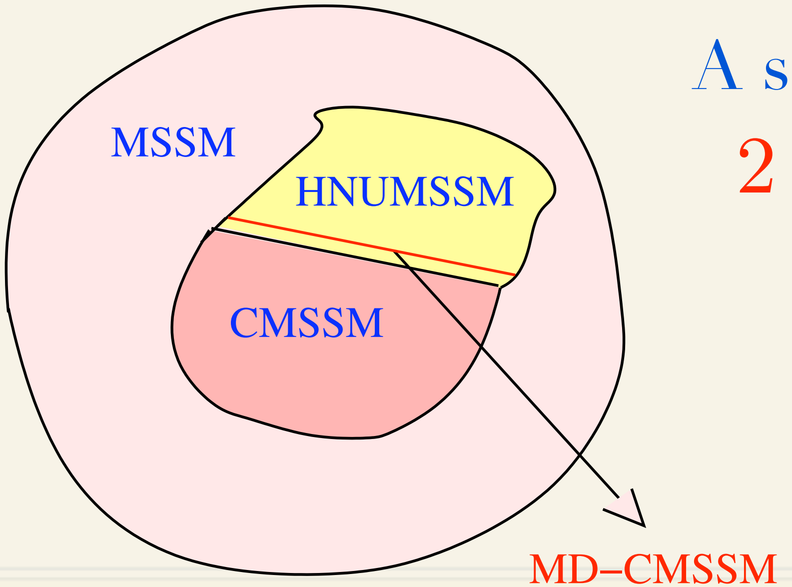
- SUSY breaking induces non vanishing auxiliary field for local Kahler modulus: $F_t \neq 0$

Then one can compute the soft terms as a function of F_t

$$
\begin{aligned}
m_{\tilde{f}}^2 &= \frac{1}{2}|M|^2\,, \\
m_H^2 &= \frac{1}{2}|M|^2(1-\frac{3}{2}\rho_H)\,, \\
A &= -\frac{1}{2}M(3\ -\ \rho_H)\,, \\
B &= -M(1-\rho_H)\,,
\end{aligned}
$$

$(if\ flux\ only\ through\ Higgs)$

$\rho_H \simeq 1/t^{1/2} \simeq \alpha_{GUT}^{1/2} \simeq 0.2$



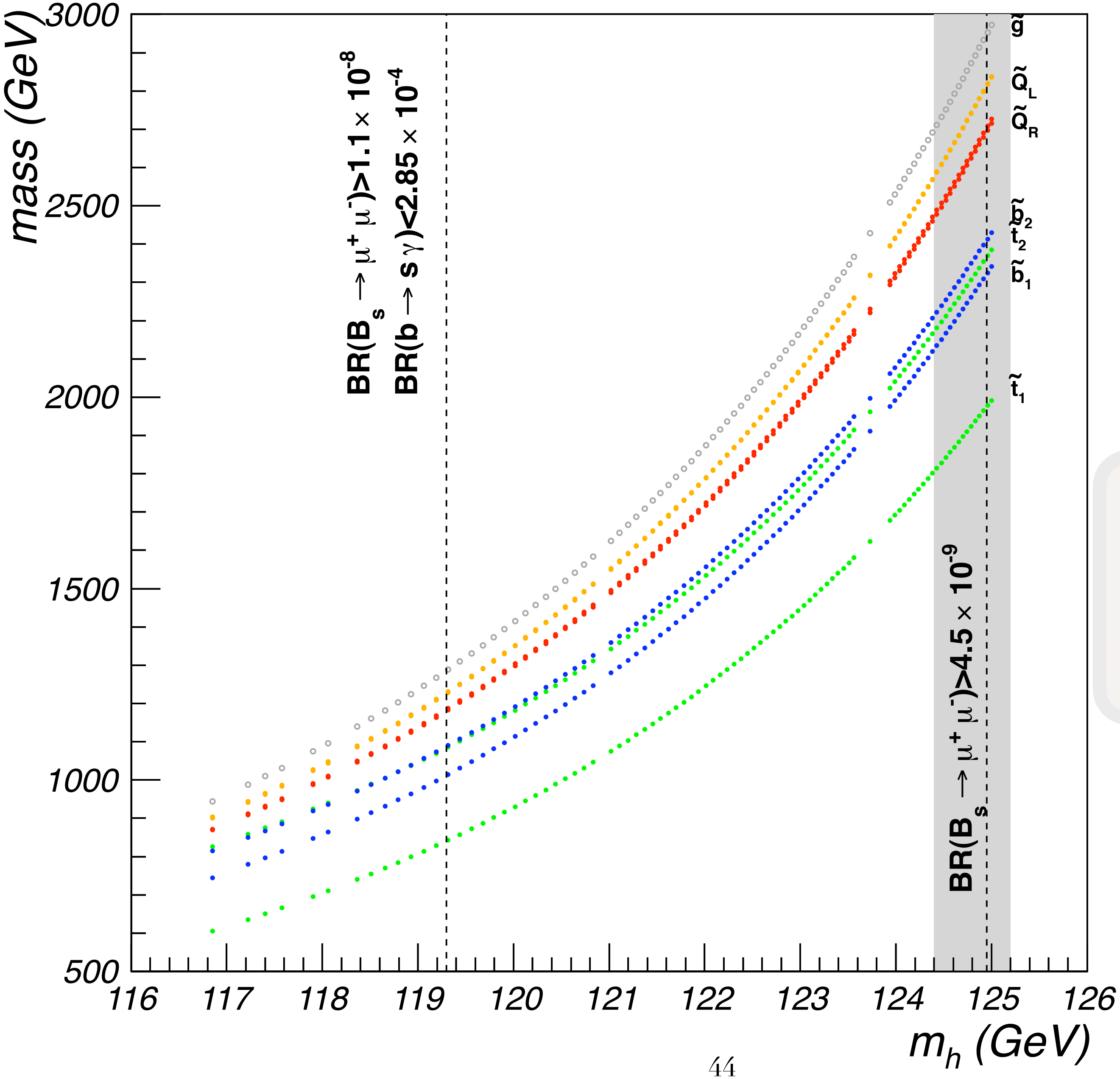
A slight deformation of CMSSM

$2+1\ param:\ M, \mu\ , \rho_H$

$Natural\ large\ A_t\ !$

Aparicio et al '08

Aparicio, Cerdeño, L.I.
arXiv:1202.0822

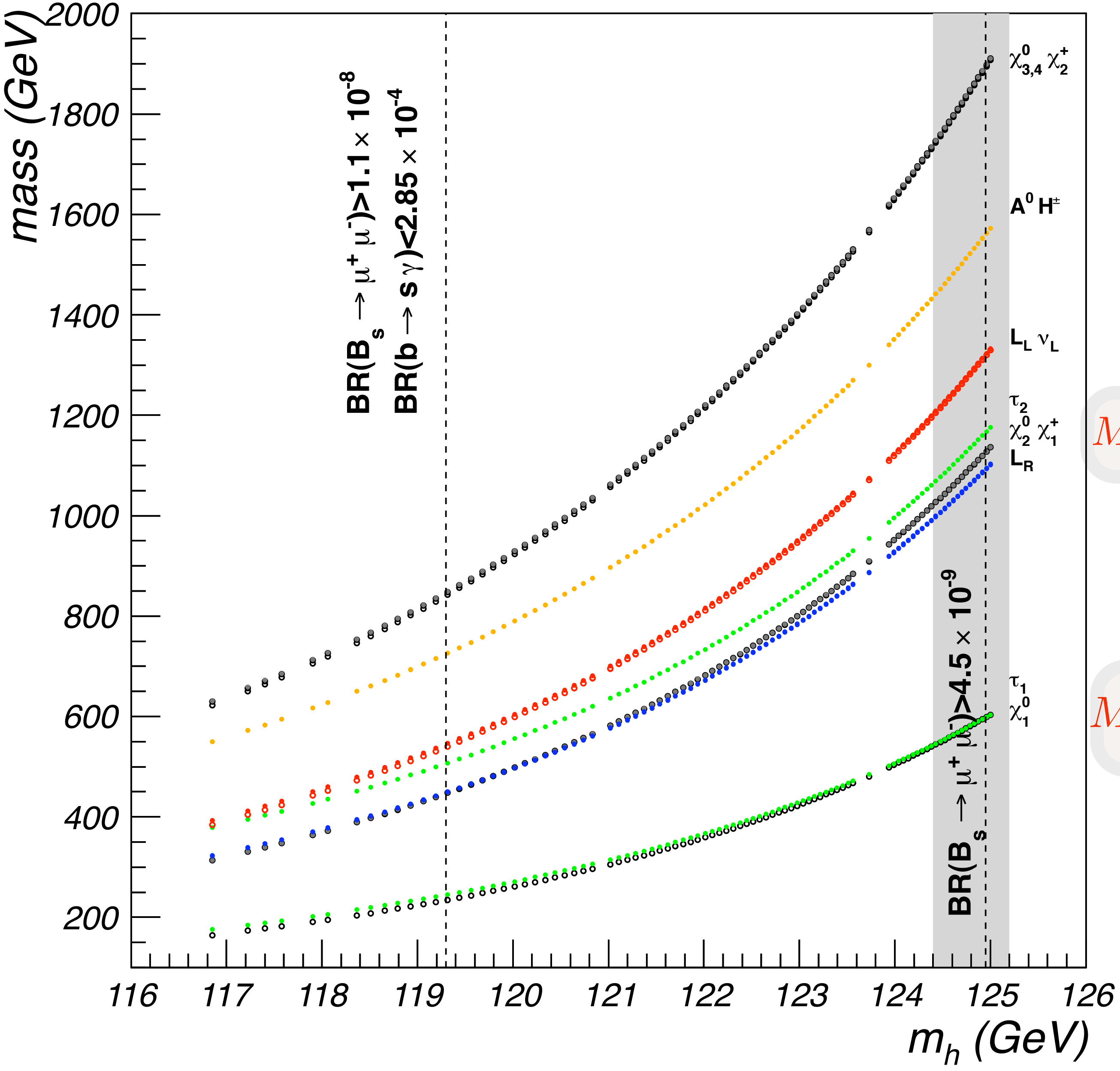


Aparicio, Cerdeño, L.I.
arXiv:1202.0822

$$m_{\tilde{g}} \simeq 3\ TeV$$

$$m_{\tilde{q}} \simeq 2.8\ TeV$$

$$m_{\tilde{t}_1} \simeq 2\ TeV$$



$M_{\chi_1^+}, m_{\tilde{l}_R} \simeq 1100\ GeV$

$M_{\chi_1^0}, m_{\tilde{\tau}_1} \simeq 600\ GeV$

Such soft terms define also a constrained NMSSM

$$W_{\rm NMSSM} \;=\; W_{\rm Yuk} \;+\; \lambda S H_u H_d \;+\; \frac{\kappa}{3} S^3 \;.$$

$$V_{soft}^{S} \;=\; m_{H_u}^2 |H_u|^2 \;+\; m_{H_d}^2 |H_d|^2 \;+\; m_S^2 |S|^2 \;+\; \left(\lambda A_\lambda S H_u H_d \;+\; \frac{\kappa}{3} A_\kappa S^3 \;+\; h.c. \right)$$

Modulus dominance soft terms:

$$\begin{aligned} M &= \frac{F_t}{t} \;, \\ m_H^2 &= \frac{|M|^2}{2}\left(1 - \frac{3}{2}\rho_H\right) \;, \\ m_{\mathbf{5},\mathbf{10}}^2 &= \frac{|M|^2}{2} \;, \\ A &= -\frac{M}{2}(3 - \rho_H) \;. \end{aligned}$$

New:

$$\lambda, \kappa \;\leq\; 0.1$$

$$A_\lambda \simeq \; -M(1 - \rho_H) \;,\; A_\kappa \;\simeq\; m_S^2 \;\simeq 0$$

Aparicio, Cámara, Cerdeño, L.I., Valenzuela
hep-ph/1212.4808

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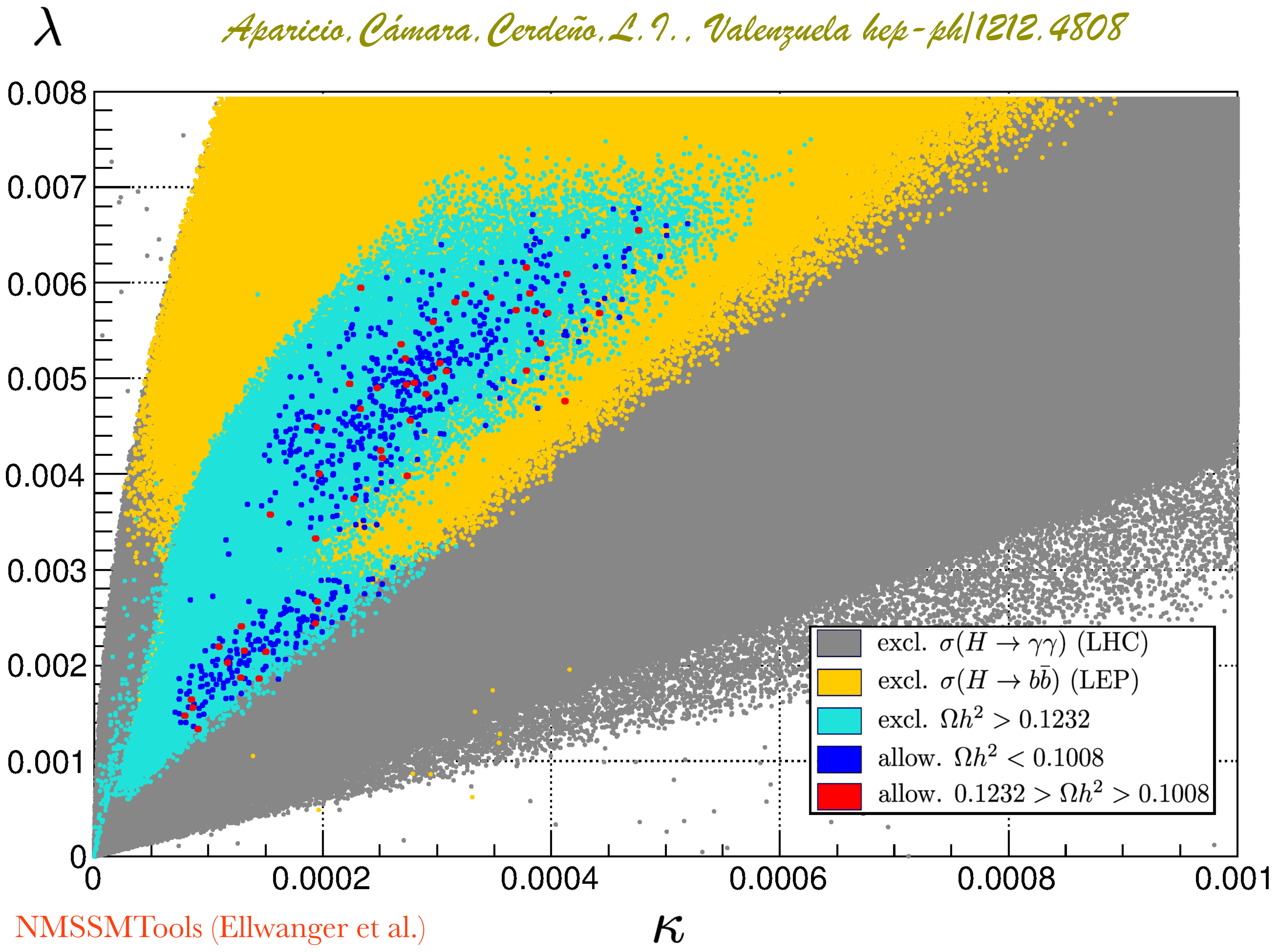
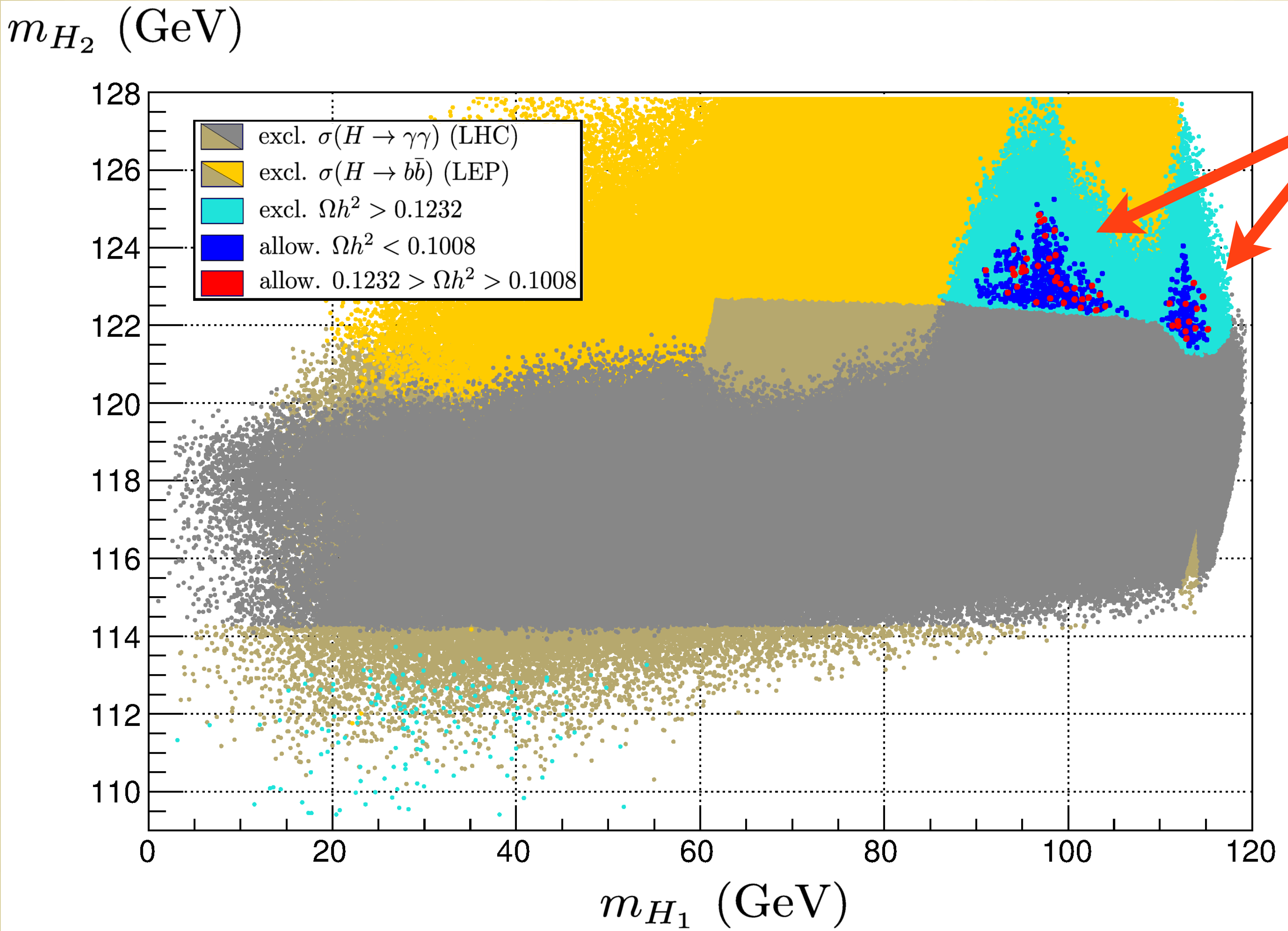


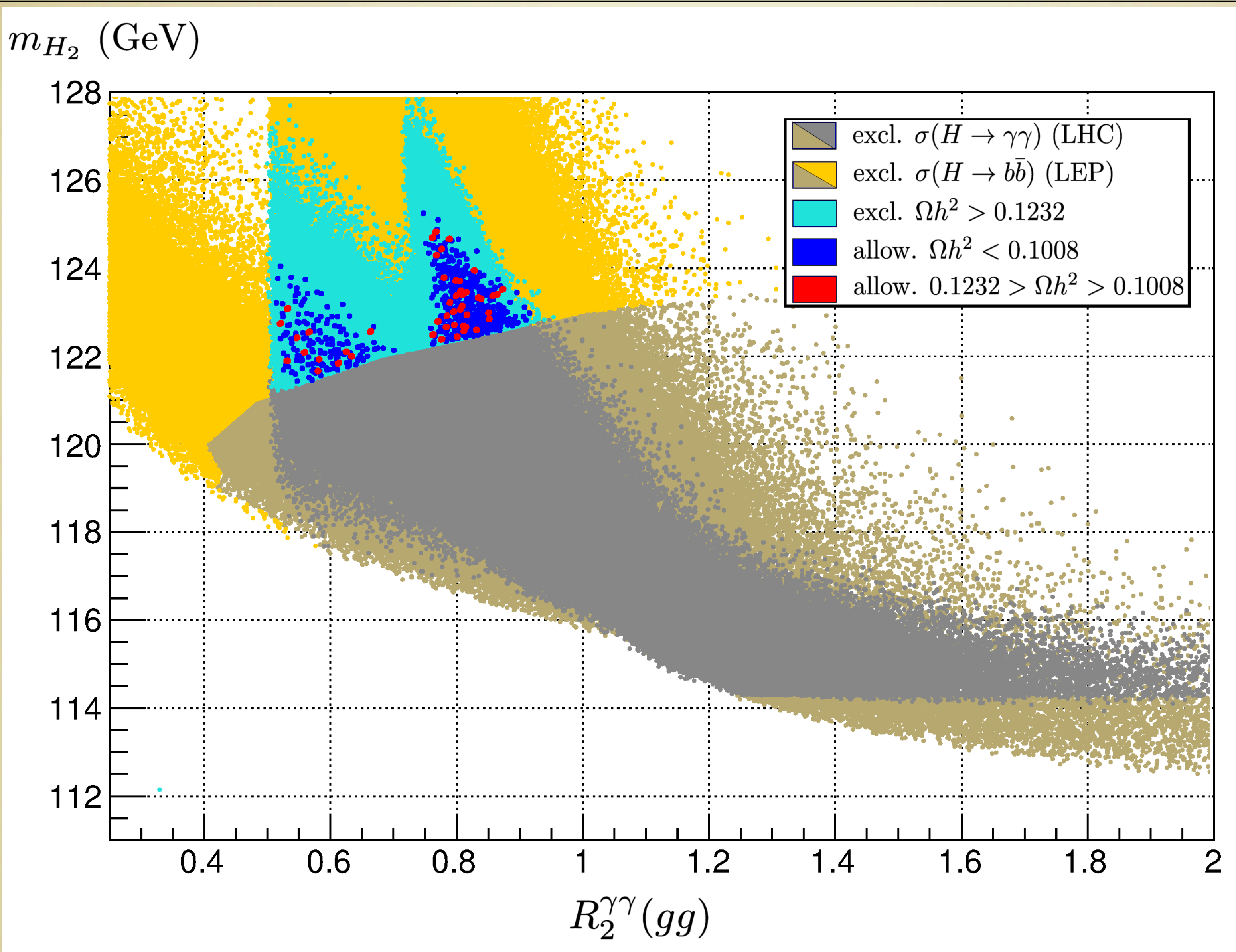
Only small λ, κ viable (consistent w. $F-th$)



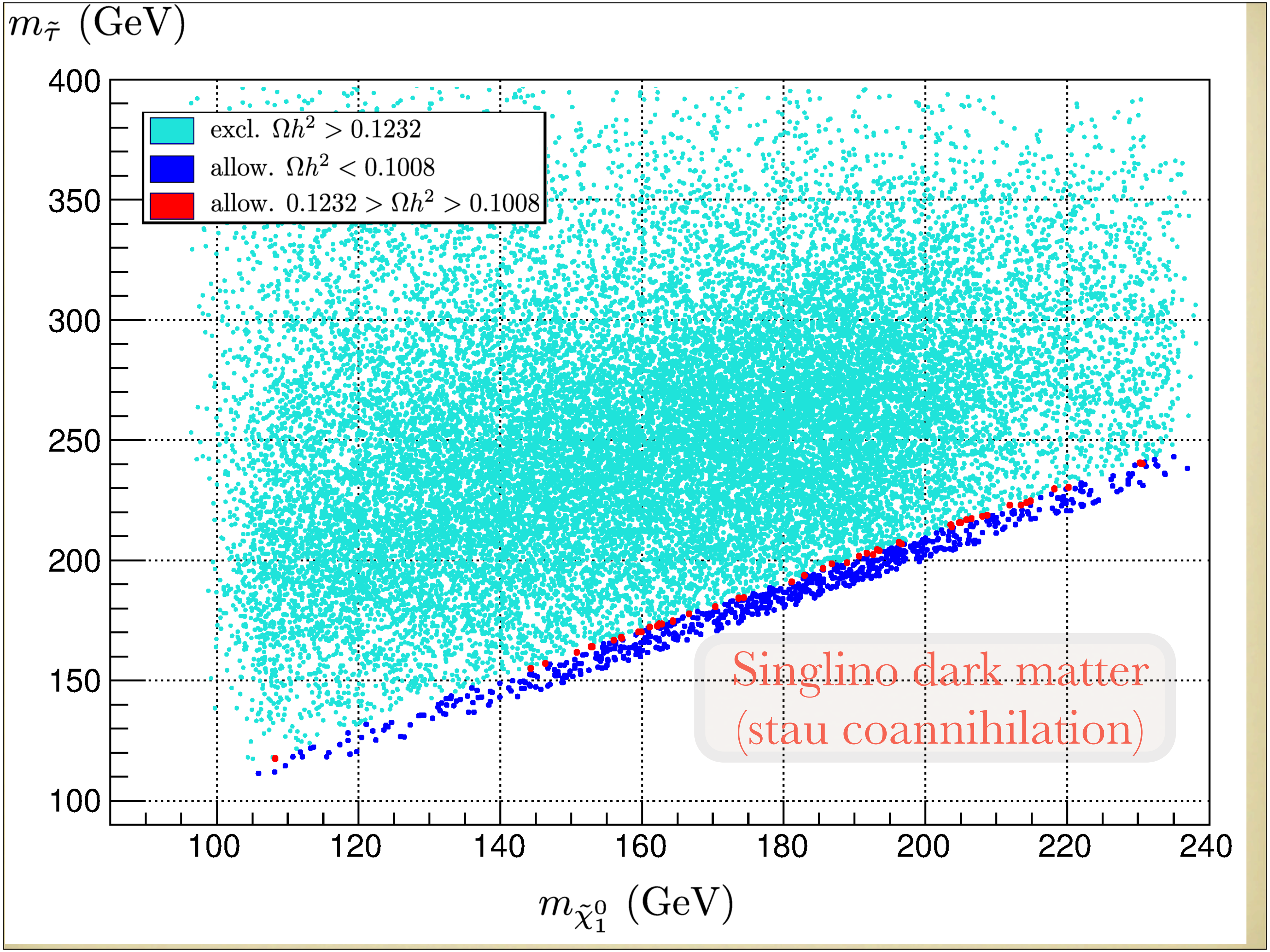
LEP

NMSSMTools (Ellwanger et al.)

A second Higgs with $m_{H_1} \simeq 100$ *GeV*



Slight $R_2^{\gamma\gamma}$ supression rather than enhancement



$m_{\tilde{\tau}}$ (GeV)
400
350
300
250
200
150
100
excl. $\Omega h^2 > 0.1232$
allow. $\Omega h^2 < 0.1008$
allow. $0.1232 > \Omega h^2 > 0.1008$
100
120
140
160
180
200
220
240
$m_{\tilde{\chi}_1^0}$ (GeV)
Singlino dark matter
(stau coannihilation)

Point	$\tilde{g}$	$\tilde{Q}_{R,L}$	$\tilde{t}_{1,2}$	$\tilde{b}_{1,2}$	$\tilde{L}_{R,L}$	$\tilde{\tau}_{1,2}$	$\tilde{\chi}_i^0$	$\tilde{\chi}_i^+$	m_{H_i}	m_{A_i}	m_{H^+}
P_1	1921	1758 1827	1263 1558	1481 1583	684 827	230 719	213 367; 696 1238; 1243	696 1244	103 122.4 1016	321 1016	1019
P_2	1983	1814 1886	1302 1601	1521 1626	708 855	175 735	164 381; 721 1274; 1279	721 1279	98.1 123.4 1036	220 1036	1040
P_3	2716	1989 2069	1434 1749	1673 1778	782 944	199 807	189 423; 800 1394; 1400	800 1400	96.9 124.8 1131	273 1131	1134
P_4	2236	2042 2125	1499 1802	1718 1827	804 971	197 831	186 436; 824 1440; 1444	824 1445	97.4 124.3 1095	266 1094	1098
P_5	2289	2091 2175	1527 1841	1762 1868	825 996	216 851	205 447; 845 1471; 1475	845 1476	97.4 124.7 1148	306 1148	1151
P_6	2585	2358 2455	1728 2064	1986 2095	939 1133	178 955	167 513; 967 1653; 1657	967 1657	98.5 124.4 1274	223 1274	1277
P_7	2663	2428 2528	1809 2134	2046 2161	970 1169	204 990	193 530; 999 1712; 1716	999 1716	93.9 123.4 1227	287 1227	1230
P_8	2769	2525 2629	1862 2207	2127 2238	1011 1219	164 1023	153 554; 1043 1770; 1774	1043 1774	97.9 123.7 1330	192 1329	1332

Table 4: Supersymmetric spectrum and Higgs masses for the set of benchmark points. All the masses are given in GeV.

$$m_{\tilde{g}} \simeq \ 1.9 - 2.8 \ TeV$$

$$m_{\tilde{q}} \simeq \ 1.7 - 2.6 \ TeV$$

$$m_{\tilde{t}_1} \simeq \ 1.2 - 1.9 \ TeV$$

Accesible to LHC(13)!

Conclusions

- We are looking forward to the LHC(8-13) data which may give the final verdict about low energy SUSY!

- If SUSY is found, large classes of SUSY breaking schemes in string compactifications will be tested.

- If no sign of SUSY (or alternative new physics) is seen, a substantial fine-tuning of parameters will be required.

- If that is the case it makes sense to reconsider a fine-tuning solution of the gauge hierarchy based on anthropic arguments: suggests a string landscape

- We have seen that a 126 GeV Higgs is possibly a signature of SUSY......but typically very heavy SUSY

- Even if SUSY is not present at the EW scale, string-theory suggest its presence at some large scale below the string scale for Higgs potential stability.

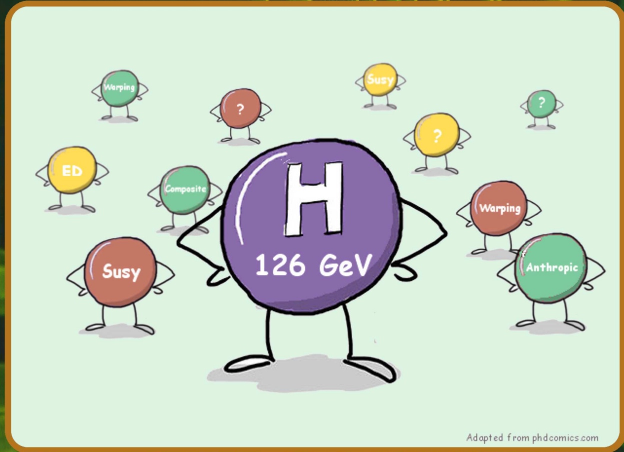
- Improved precision in both Higgs and top quark mass important to confirm SM instability at intermediate scale.

- Otherwise no new physics at LHC: ruled out if large $\gamma\gamma$ rate true.
- Axion detection and proton decay could provide additional information about this possibility. Should also study its cosmological consequences.

Thank you !!

25-27 Sept. 2013

Why $m_H = 126$ GeV?



European Research Council
SPLE Advanced Grant

Instituto de Física Teórica-UAM/CSIC
Madrid, 25-27 September 2013

http://workshops.ift.uam-csic.es/WMH126

Speakers:

B. Allanach (Cambridge U.)
I. Antoniadis (CERN)
G. Belanger (Annecy LAPTH)
M. Dine (UC, Santa Cruz)
M.R. Douglas (Stony Brook & IHES)
E. Dudas (Ecole Polytechnique & Orsay)
G. Dvali (Munich & CERN & New York U.)
U. Ellwanger (Orsay)
J.R. Espinosa (ICREA & IFAE)
A. Falkowski (Orsay)
C. Grojean (ICREA & IFAE)
A. Hebecker (Heidelberg U.)
J. Lykken (Fermilab)
C. Mariotti (CMS & Torino)
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M. Shaposhnikov (ITPP Lausanne)
A. Strumia (Pisa & NICPB Tallinn)
*G. Villadoro (ICTP)**
N. Weiner (New York U.)

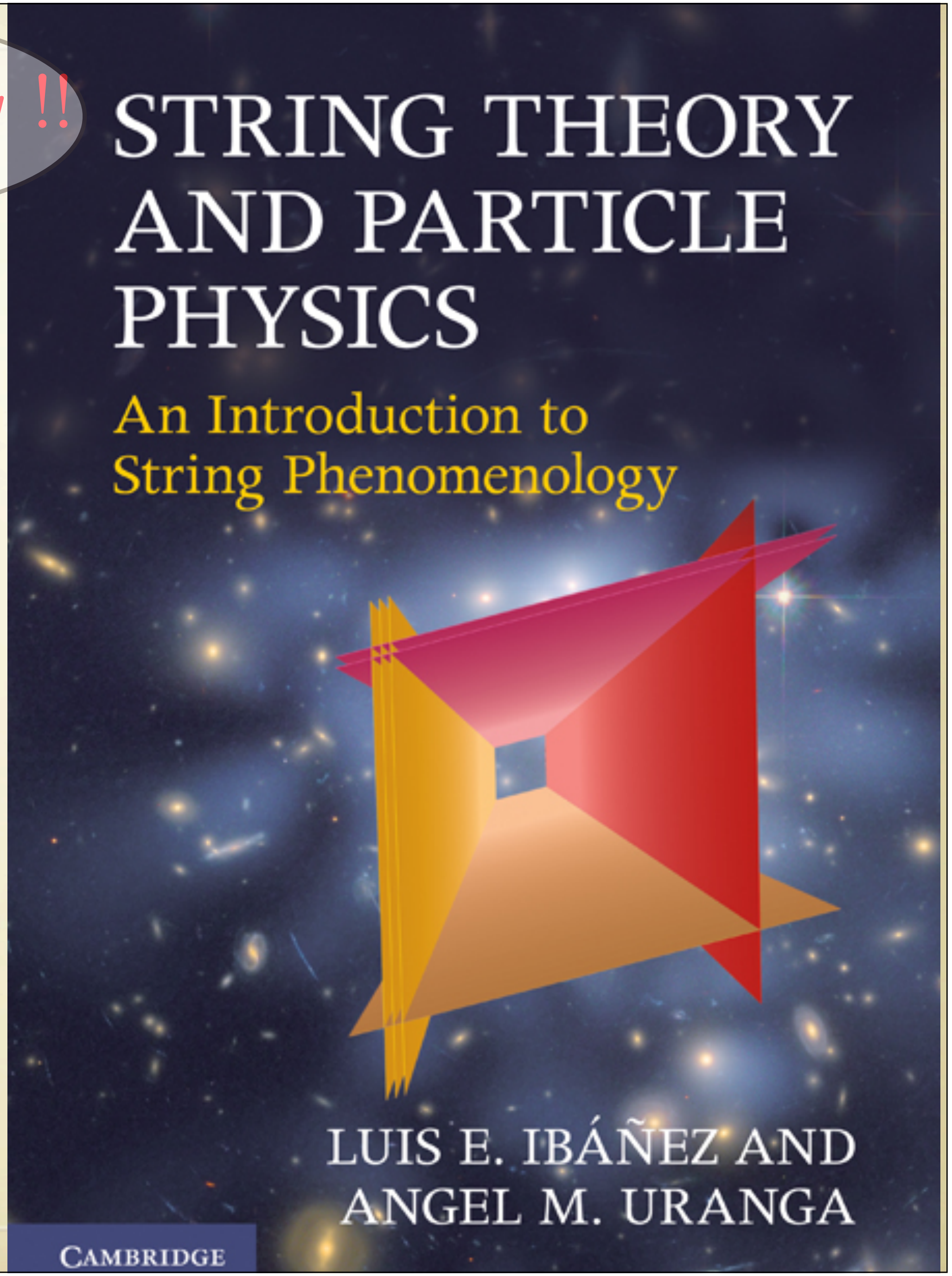
** To be confirmed*

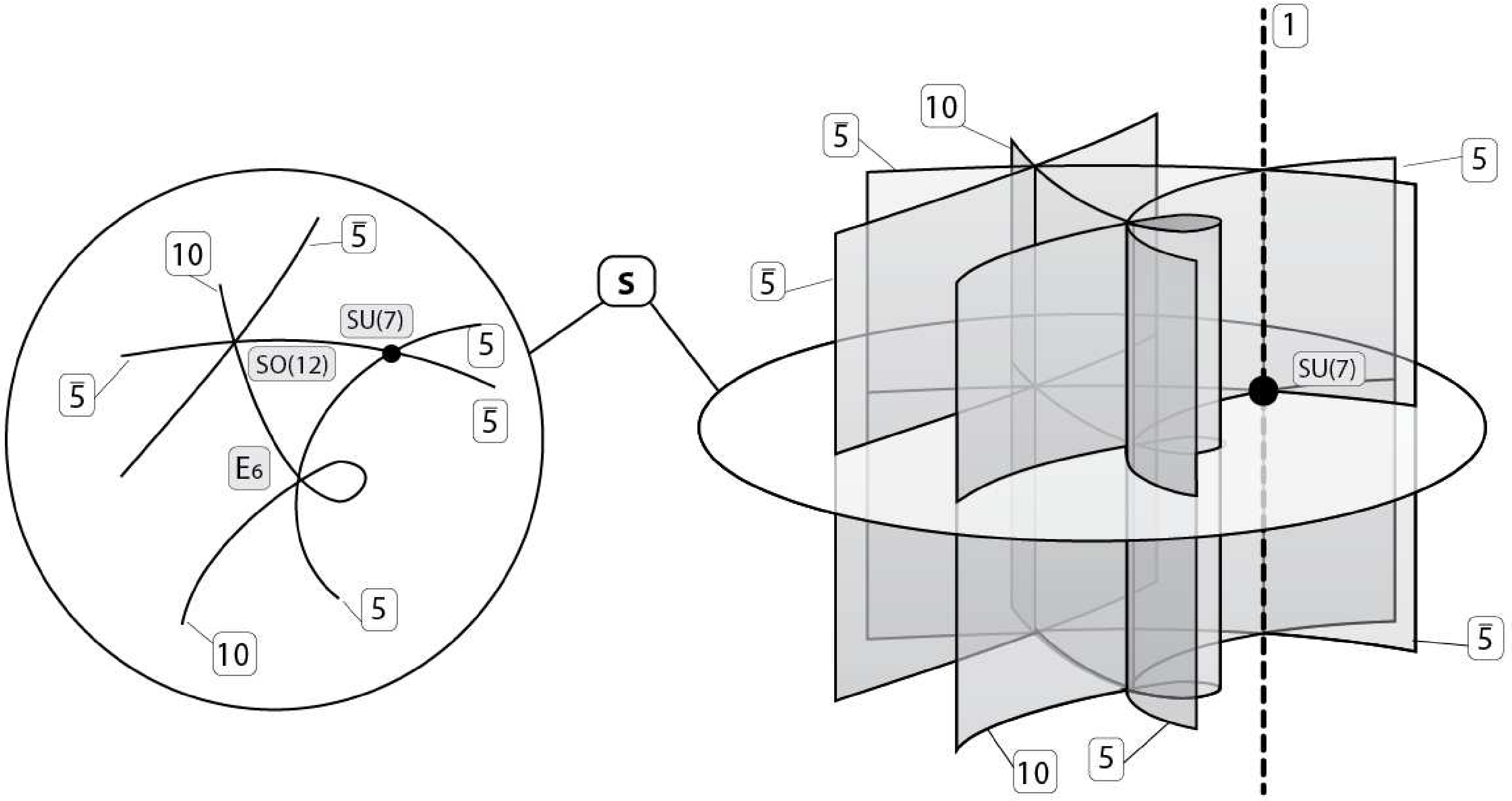
Organisers:

P.G. Cámara (U. Barcelona)
D.G. Cerdeño (IFT UAM/CSIC)
L.E. Ibáñez (IFT UAM/CSIC)

Amazing !!

Sheldon Cooper likes it




10
$\bar{5}$
SU(7)
5
$\bar{5}$
SO(12)
$\bar{5}$
E6
5
10
S
1
10
$\bar{5}$
5
$\bar{5}$
SU(7)
$\bar{5}$
10
5