Sparticle and Higgs boson masses from the landscape: dynamical vs. spontaneous SUSY breaking

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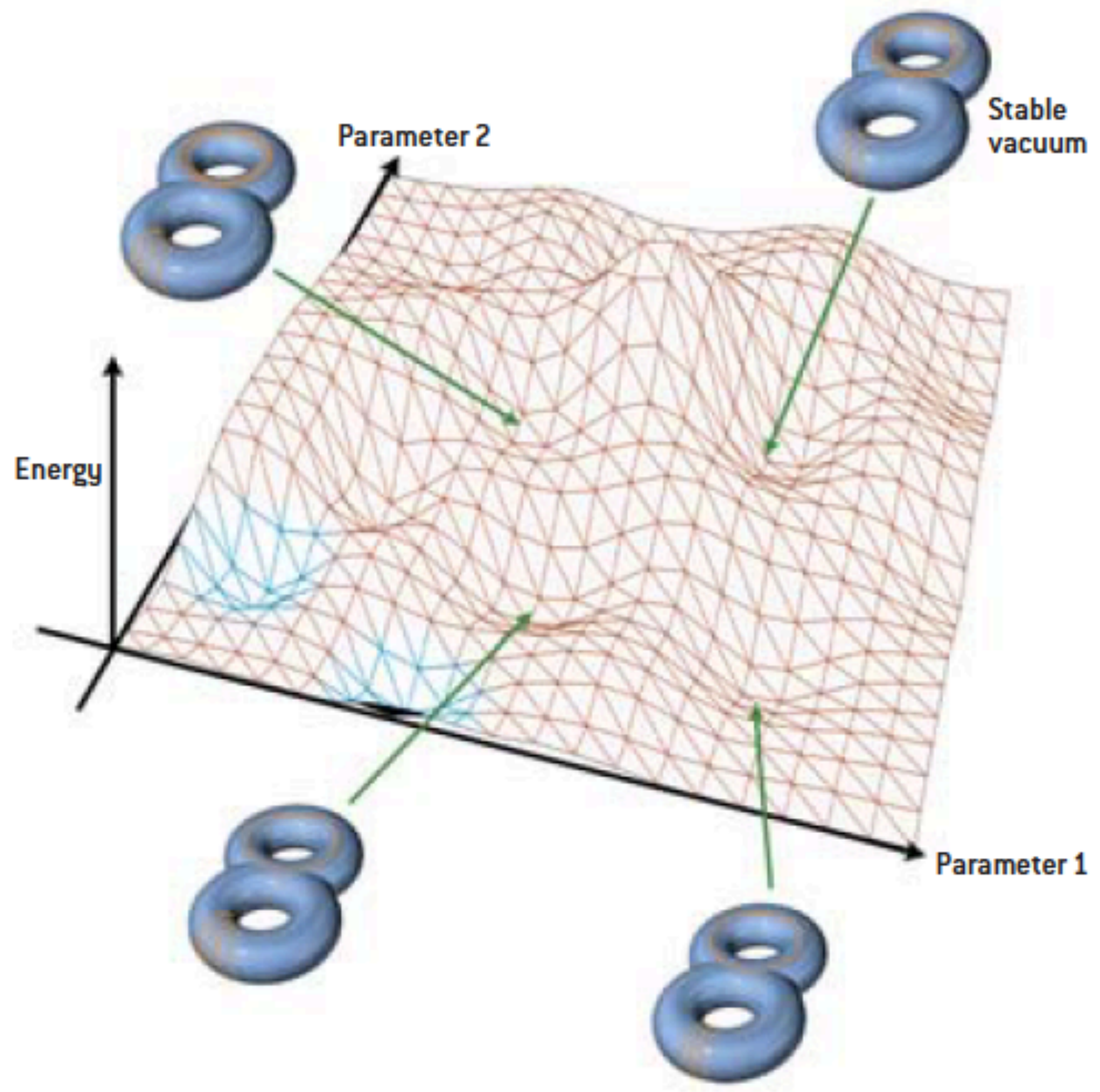
(dedicated to memory of Joe Polchinski)



Bousso & Polchinski

- In string theory, only one mass scale: mP~2.4E18 GeV
- Then how do widely disparate mass scales arise, e.g. CC~10^-120 mP^2 or the weak scale m(weak)~100 GeV or QCD scale ~1 GeV?
- CC: Weinberg's anthropic solution: in eternally inflating multiverse, if CC much bigger than measured value, universe would expand so quickly that structure (galaxies) wouldn't form: these 'pocket universe' would not be suitable for evolution of life (structure principle)
- QCD is different: QCD scale arises non-perturbatively (dynamically) from dimensional transmutation: QCD becomes confining at m(proton)~ mP*exp(-8pi*2/g^2) when g^2~1.8

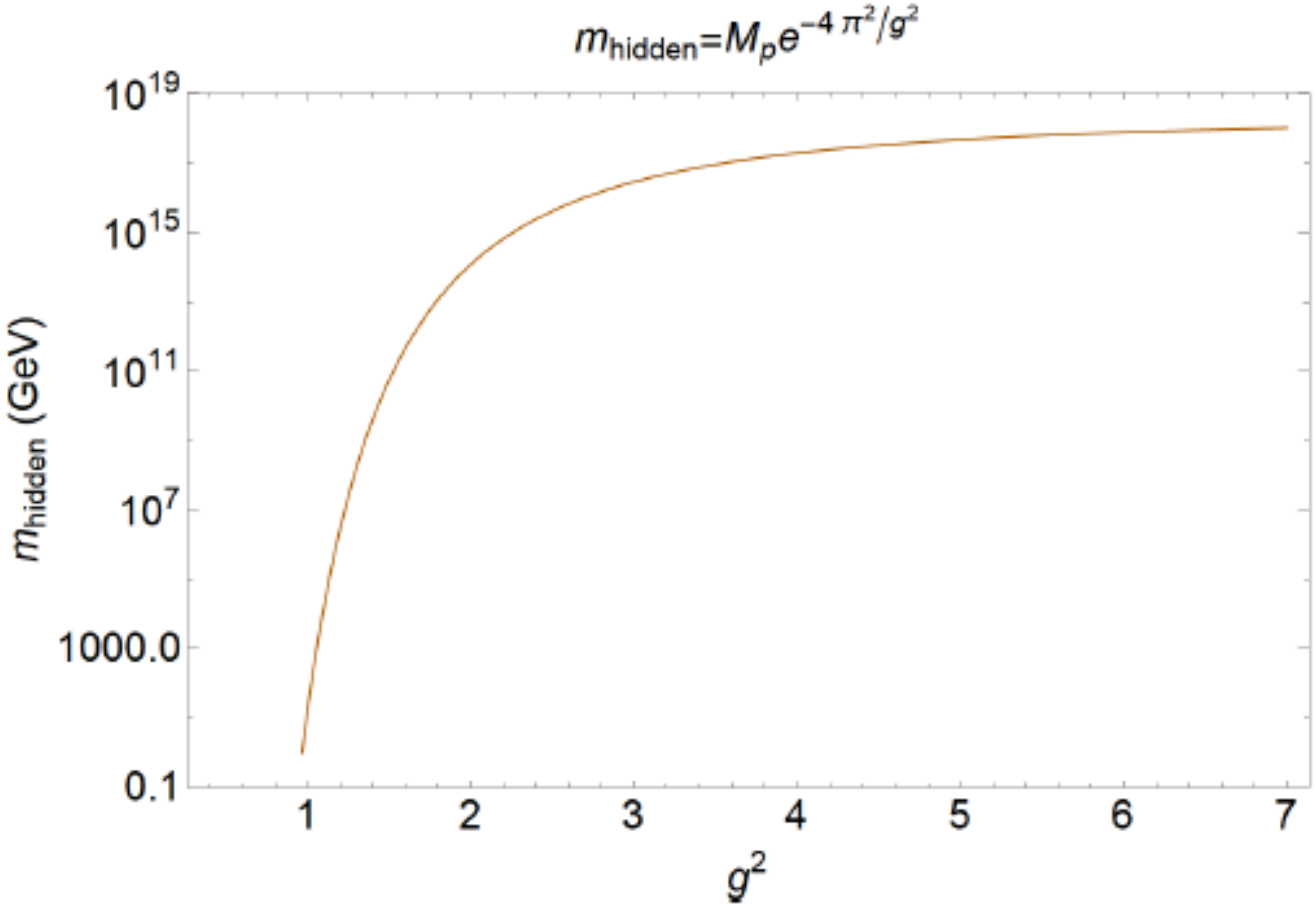
- Weak scale: in SM, quadratic divergences -> m(weak)-> mP: but can (implausibly) tune mu^2 such that m(weak)~100 GeV

- Weak scale SUSY stabilizes weak scale, but does not explain magnitude

- e.g. for SUGRA breaking, W(Polonyi)=m^2(h+beta) for lone superfield h: gives right answer if m~10^11 GeV and beta~mP (must implausibly put in by hand)

- But maybe instead SUSY breaking dynamical (like QCD): m^2~mP^2*exp(-8pi^2/g_hidden^2)

- e.g. hidden sector gauge group SU(N) becomes confining (gaugino condensation) at : Lambda(GC)~10^13 GeV => m=sqrt(Lambda^3/mP)~10^11 GeV



When g becomes confining ~1-2, then SUSY breaking scale uniformly distributed across the decades of possibilities: then in landscape context, $f_{\rm SUSY}^{\rm DSB} \sim 1/m_{soft}$

see e.g Dine, Gorbatov, Thomas (2008)

In landscape context (used to solve CC problem), expect ~10^500 string vacua (Denef & Douglas)

vacua distributed as:

$$dN_{vac}[m^2_{hidden}, m_{weak}, \Lambda_{cc}] = f_{SUSY} \cdot f_{EWSB} \cdot f_{cc} \cdot dm^2_{hidden}$$

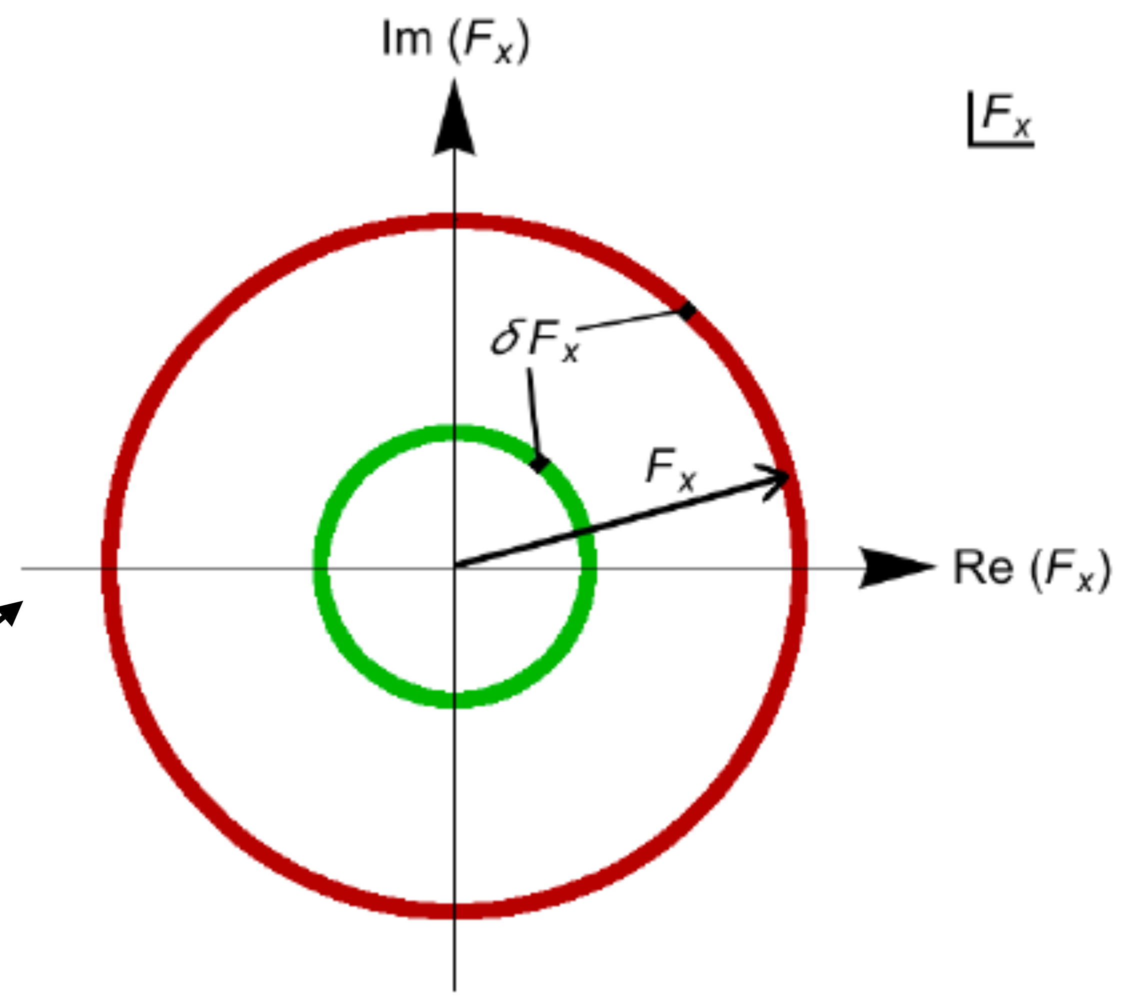
For spontaneous SUSY breaking (mass scale included, perturbative)

$$f^{SSB}_{SUSY} \sim m^n_{soft}$$

where $n = 2n_F + n_D - 1$ and n_F are the number of hidden sector SUSY breaking F-fields and n_D is the number of hidden sector D-breaking fields contributing to the overall SUSY breaking

Thus, in landscape, DSB favors low soft terms while SSB favors large soft terms!

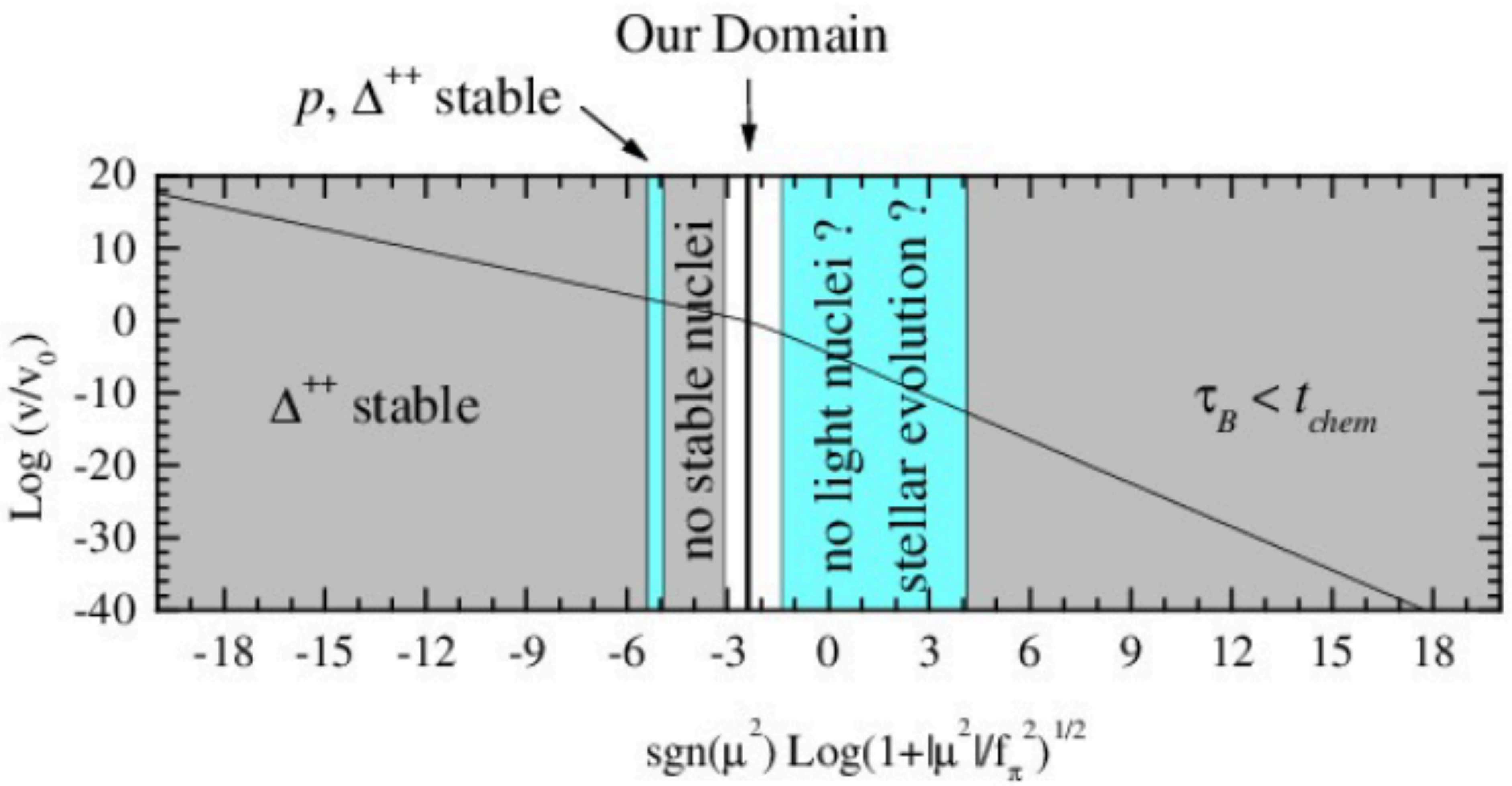
single F term distributed uniformly as complex number



[footnote: f_cc doesn't contribute to SUSY breaking scale determination (Douglas)]

$f_{\rm EWSB}$?

From Agrawal, Barr, Donoghue, Seckel (ABDS, 1998):
if pocket universe value of weak scale too displaced
from measured value in our universe (OU) [factor 2-5],
then complex nuclei and hence atoms will not form:
pocket universe will not sustain life as we know it!



atomic principle

also: veto CCB
and noEWSB minima

can calculate m(weak)
in MSSM

$$(m_Z^{\rm PU})^2/2 = \frac{m_{H_d}^2 + \Sigma_d^d - (m_{H_u}^2 + \Sigma_u^u)\tan^2\beta}{\tan^2\beta - 1} - \mu^2 \simeq -m_{H_u}^2 - \Sigma_u^u - \mu^2$$

for m(weak)^PU<4*m(weak)^OU: then $f_{\rm EWSB} = \Theta(30 - \Delta_{\rm EW})$

Assume fertile patch of landscape
where MSSM is LE-EFT

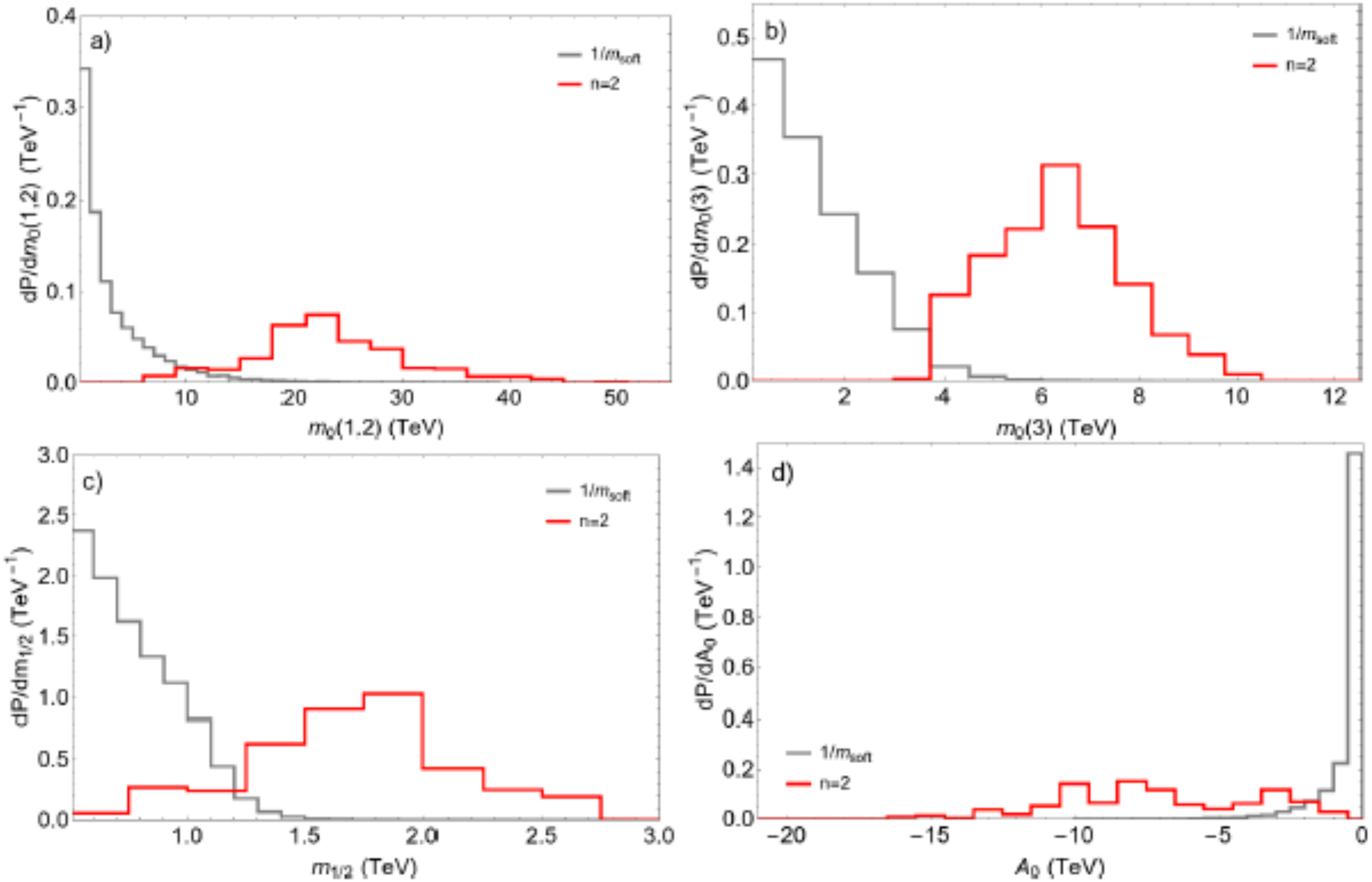
Can scan over parameters in models which allow DEW<30: e.g.

$$m_0(1,2),\ m_0(3),\ m_{1/2},\ A_0,\ \tan\beta,\ \mu,\ m_A \quad \text{(NUHM3)}$$

- $m_0(1,2)$: $0.1 - 60$ TeV,
- $m_0(3)$: $0.1 - 20$ TeV,
- $m_{1/2}$: $0.5 - 10$ TeV,
- A_0 : $-50 -\ 0$ TeV,
- m_A : $0.3 - 10$ TeV,

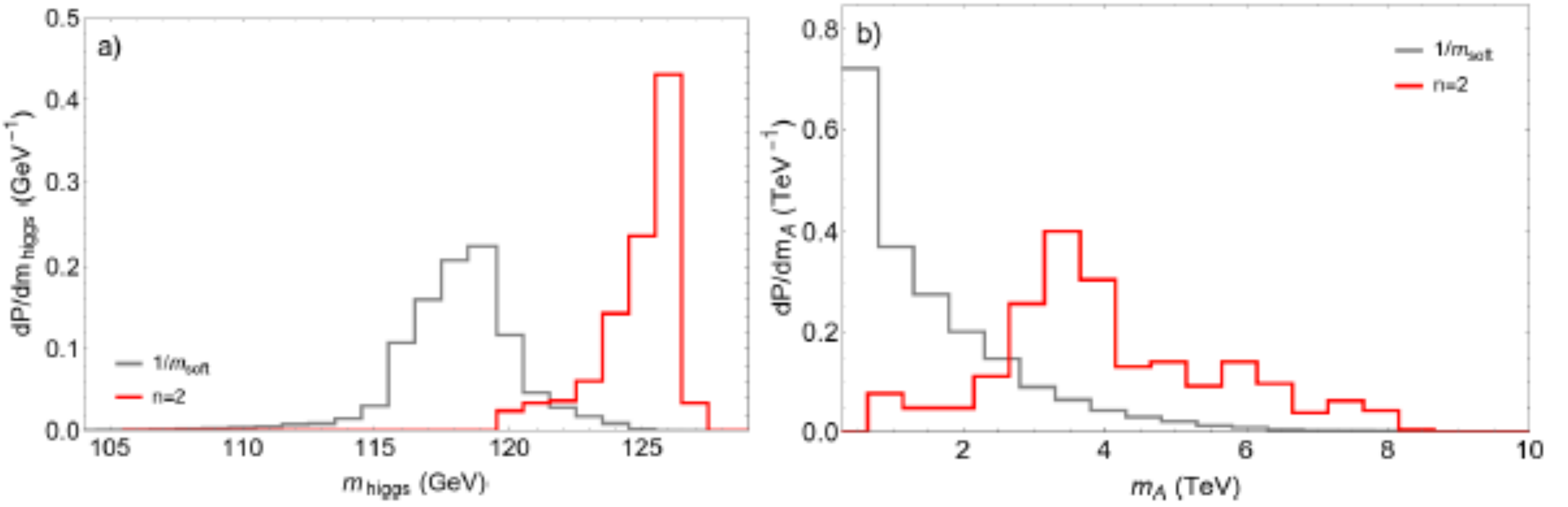
with $\mu = 150$ GeV while $\tan\beta : 3 - 60$

upper limits set beyond
anthropic upper limits:
lower limits set
to compare against
previous scans, but can be lower yet



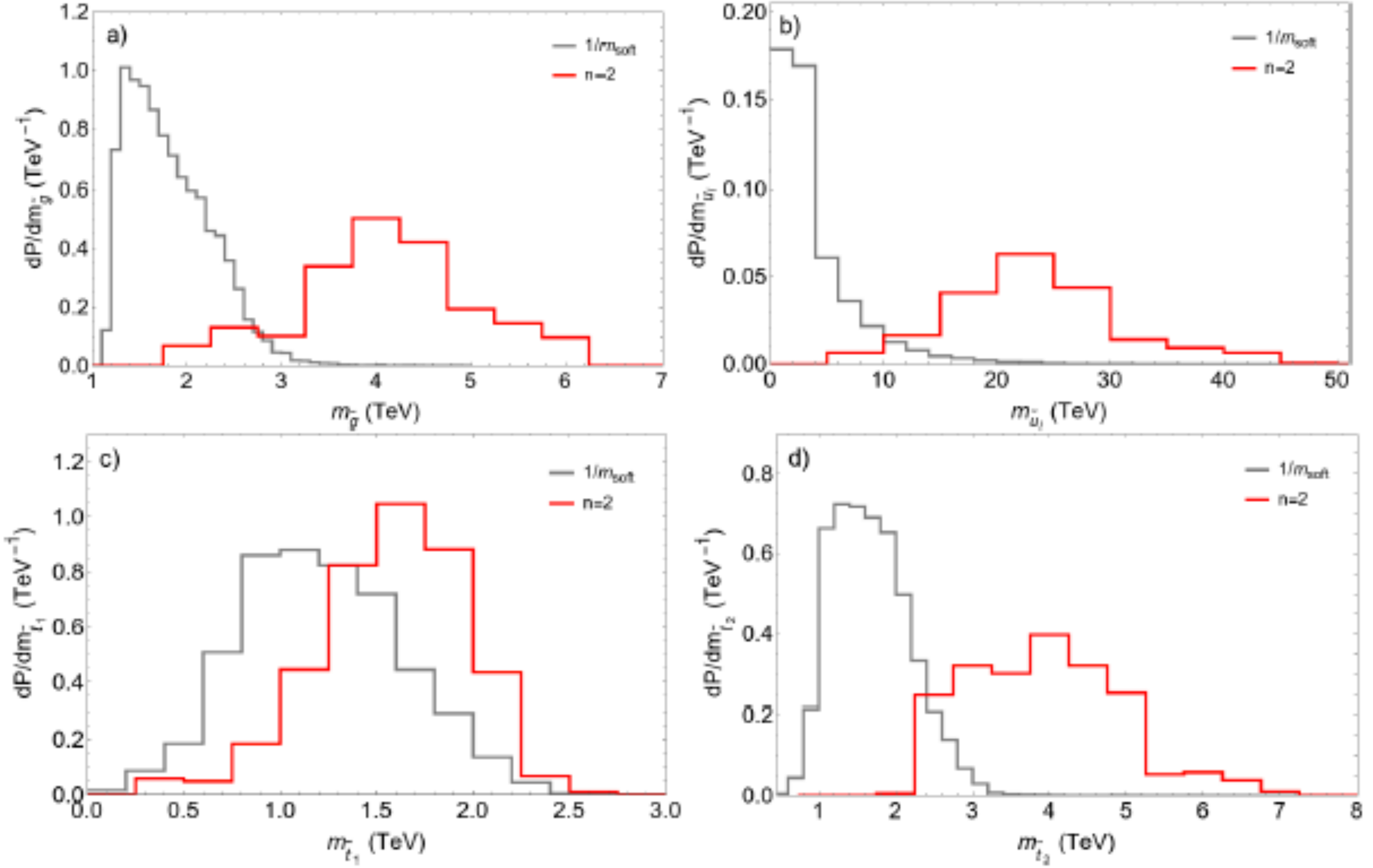
n=2 from
KKLT stabilization;
see Broeckel et al.

as expected, DSB (gray) prefers small soft terms
while SSB (red) prefers large



Higgs masses: DSB=> m(h)<<125 GeV while SSB prefers m(h)~125 GeV

DSB => highly mixed Higgs while SSB prefers decoupled Higgs



DSB => sparticles masses below LHC limits;

SSB prefers => sparticles masses above LHC limits!

[smaller lower scan limits make matters worse for DSB]

Conclusions:

- DSB beautiful theory:
- DSB might explain exponential suppression of weak scale
- DSB predicts m(h)<<125 GeV and excluded sparticles
- SSB in landscape: m(h)~125 GeV and sparticles > LHC limits
- then, exponential suppression of weak scale arises as does the CC: weak scale as big as possible such that atomic principle (existence of atoms) still holds