No-scale constraints

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Outline

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The end is (not that) near ?

The LHC just started
Everybody waiting for the results
What's beyond the standard model ?
The chain from experiments to theory is not straightforward

The crime scene

- The MSSM 105 parameters
- phenomenological MSSM 22 parameters
  (no new CP source, no FCNC, 1st gen = 2nd gen)
- mSugra 5 parameters (assuming universality)

$$m_0,\ m_{1/2},\ A_0,\ \tan\beta,\ \mathrm{sgn}(\mu)$$

can we do better ?

The no-scale conditions

$m_0 = 0$ or
$m_0 = A_0 = 0$ or
in the strict no-scale
$B_{GUT} = m_0 = A_0 = 0$

Among possible issues :

- Low Higgs mass
- LSP charged (usually stau)

It might work with non-universal higgs model
we must put back 2 parameters

I'm not a number, I'm a model

Sugra reminder

$$V \sim e^G \left(G^i (G^{-1})_i^{\bar{j}} \; G_{\bar{j}} - 3 \right) + \frac{1}{2} f_{ab} D_a D^a$$

- $W(\phi)$: Superpotential, analytic in ϕ, encode scalar masses and yukawas interactions
- $K(\phi^i, \overline{\phi}^{\bar{j}})$: Kähler function, appears in kinetic terms $K_{i\bar{j}} \partial_\mu \phi^i \partial^\mu \phi^{\bar{j}}$ with $K_{i\bar{j}} = \partial_i \partial_{\bar{j}} K$
- $G(\phi, \overline{\phi}) = K(\phi, \overline{\phi}) + \ln |W(\phi)|^2$
- f_{ab} : gauge kinetic function

Breaking of supersymmetry in a hidden sector No direct interaction

$$W = W_{obs} + W_{hidden}$$

signal of susy breaking : gravitino mass

$$m_{3/2} = \langle e^{G/2} \rangle$$

mSugra

To get breaking

$$V = 0$$

$$\begin{cases} K = \phi^i \overline{\phi}^{\bar{j}} \\ f_{ab} = \delta_{ab} \end{cases}$$

gives for instance $m_0 = m_{3/2}$

SuSy scale fixed by-hand

$$m_{3/2} \propto \frac{M_S^2}{M_p}$$

A naturally vanishing potential

Cremmer, Ferrara, Kounnas and Nanopoulos :
"Naturally Vanishing Cosmological Constant In N=1 Supergravity" 1983

Dynamical solution to $V = 0$

Instead of $K = z^* z$

$$K = 3 \ln(z + z^*)$$

- Symmetry Su(1,1) protecting the potential
- Broken by gravitino mass

One scale to rule them all

$$m_i \propto \mathcal{M}\left(O(1) + O(\alpha)\ln(Q)\right)$$

$$V_{tree} \propto -C\mathcal{M}^4 \ln^2 \frac{\kappa_0 \mathcal{M}^2}{\mu_0^2}$$

Where M is usually the gravitino mass
Ellis, Enqvist, Nanopoulos: *"A very light gravitino in no-scale models "* 1984

Assuming $f_\alpha\beta$ non canonical, link the gravitino to the gauginos

$$f \propto e^{-Az^p}$$

ansatz giving light gravitino

$$m_{3/2} \propto m_{1/2}^{-q(p)}$$

Use gauginos mass as M parameter

Link with higher energy theories

- Witten (1981) : no-scale structure from string theory
- A complete GUT no-scale theory (with unification above the GUT scale): Su(5) $\mathcal{F}$-lipped (Nanopoulos and al.)
- hidden field :

moduli field

$m_0 = 0$
$A_0 = 0$
$B_0 = 0$

dilaton

$m_0 = \frac{1}{\sqrt{3}} m_{\frac{1}{2}}$
$A_0 = -m_{\frac{1}{2}}$
$B_0 = \frac{2}{\sqrt{3}} m_{\frac{1}{2}}$

But specific cases, the coefficients can be slightly different

- We will not do that
- Low-energy approach with phenomenological spectrum $\rightarrow$ find a minimum without assuming its existence

Outline

Doing things correctly

How things are done

Input : $\tan\beta$
EWSB $\rightarrow$ μ and B

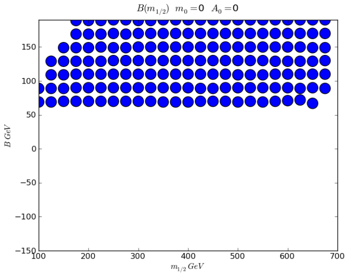
B and μ don't play in the RGE
Not important for the runnings

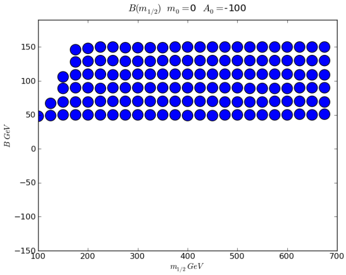
Switching inputs

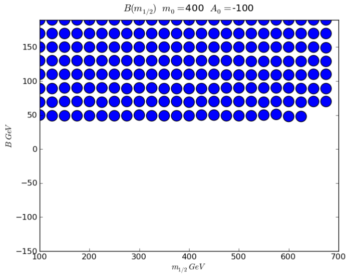
$B \rightarrow \tan\beta$

Pole masses : $\bar{m}_q = y_q v_{u/d}(1 + \delta_{RC})$
changing $\tan\beta$ = changing yukawas

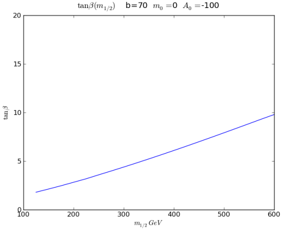
The space we are left with

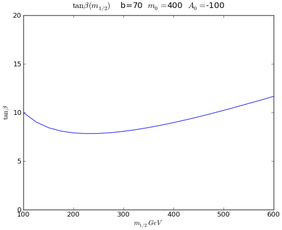


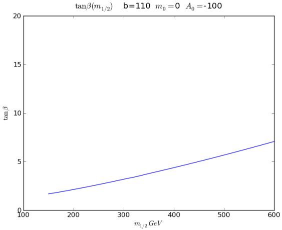


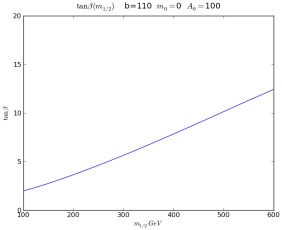


About tan β (and the Higgs)









Knowing how to rise tan β will eventually lead us to a good value for the Higgs mass ($m_{Higgs} \sim 105\,GeV$)

Outline

An updated approach

- Complete determination of minimum (instead of approx. analytical solutions, only valid for low $\tan\beta$)
- top mass :
  1984 : $30\ GeV < m_{top} < 50\ GeV$ today: $m_{top} \sim 172 \simeq GeV$
- Full spectrum for the effective potential (instead of top/stop sector only)
- Trying to improve the dramatic scale dependance of the effective potential

The effective potential

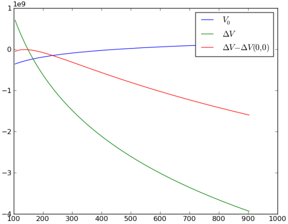
Corrections to the tree level potential:

$$\Delta V = \sum_{particles} \mathrm{Str}\mathcal{M}^4 \left(\ln \frac{\mathcal{M}^2}{Q^2} + \frac{3}{2} \right)$$

Don't include gravitino:

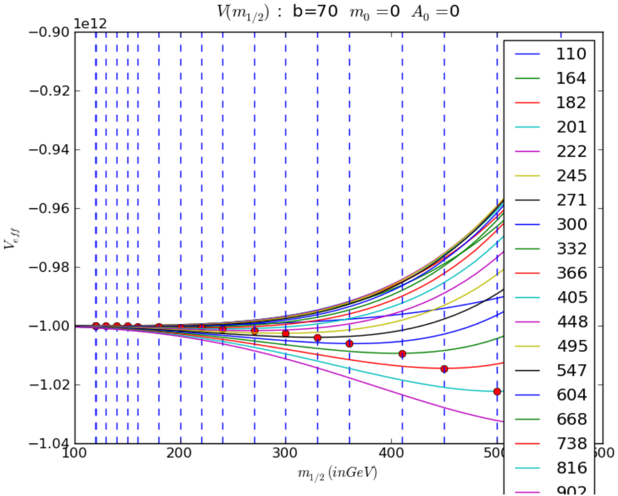
- Mass unknown
- Considering it as LSP, light enough to be neglected

Kelley and al. 1993
The RG-Invariance of the effective potential
substraction of field-independant piece doesn't change the physics, but crucial here



$$\Delta V \rightarrow \Delta V - \ DeltaV(v_u = 0, v_d = 0)$$

The naive scan



How can we trust it?

Choose a specific scale for which we trust the most our potential
Actually described in historical papers, but for easing calculus:

$$Q(m_{1/2}) \text{ such that } \Delta \mathrm{V}|_{\mathrm{Q}} = 0$$

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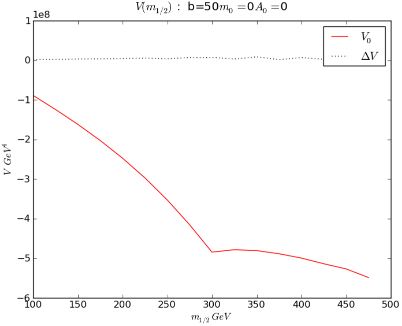
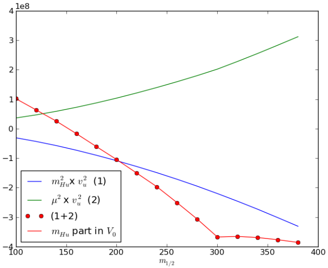


About this "minimum"

It's not really the minimum we were looking for
But gives us a scale-invariant point were the potential "bumps"

$$V_0 = (\mu^2 + m_{H_u}^2)v_u^2 + ...$$



- m_{H_u} term driven by top yukawa
- μ raises because of the radiative corrections

Substraction and cosmological constant

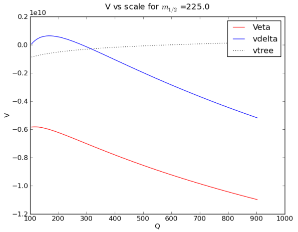
Kounnas, Zwirner, Pavel:
"Toward dynamical determination of parameters in the MSSM" 2004

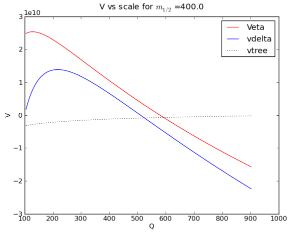
If we want to consider the full potential :

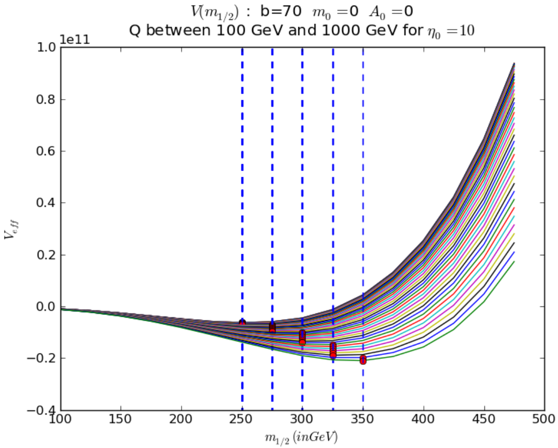
$V \supset \Lambda = \eta m_{1/2}^4$ (cosmological constant like term)

Imposing the RG-invariance gives the following:

$$\begin{cases} \eta_0 = \eta(Q_{GUT}) \\ \frac{d\eta}{dt} = \frac{1}{32\pi}\left[\frac{\mathrm{Str}\mathcal{M}^4}{m_{1/2}^4}\right]_{v_u=v_d=0} \end{cases}$$







Higher stability for some values of η_0
We switched one parameter for another, but this one is not important for the spectrum

It's only the beginning of our journey

Preliminary results and expectations

- We have found a "no-scale" favored region for $m_{1/2}$ around 300 GeV
- Though we didn't consider all the phenomenological constraints, the stability of this prediction make us confident in finding a correct set of parameters
- One real phenomenological issue: the Higgs mass is the main strong constraint on the models (if we assume MSSM)
- With known cosmological constraints on gravitino and a "fixed" value of $m_{1/2}$, we can try to put constraints on gauge function f_{ab}
- With this and the η_0 constraint on the existence of minimum, might give us a way to access higher energy theories (like string inspired supergravity)