MSSM Higgs mass, g-2 and LHC

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Introduction

- **The magnetic anomaly momentum of the muon, a signal of new physics?**

- From $e^+e^- \rightarrow$ had data

$$\delta a_\mu = a_\mu^{\mathrm{exp}} - a_\mu^{\mathrm{SM}} = 29{,}5 \pm 8{,}8\ (\mathrm{exp.}) \pm 2\ (\mathrm{theor.}) \times 10^{-10}.$$

There is a more than 3σ discrepancy.

- We will consider the **CMSSM** as a candite of new physics able to provide the missing contribution.

The tree level squared Higgs mass plus the one-loop leading logarithmic contributions is given by,

$$m_h^2 \simeq M_Z^2 \cos^2 2\beta + \frac{3m_t^4}{2\pi^2 v^2}\left[\log\frac{m_{\tilde{t}}^2}{m_t^2} + \frac{X_t^2}{M_S^2}\left(1 - \frac{X_t^2}{12M_S^2}\right)\right] + \cdots$$

where,

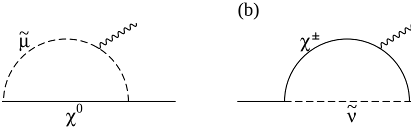
$\tan\beta \equiv \langle H_u\rangle / \langle H_d\rangle$,

m_t is the (running) top mass,

$m_{\tilde{t}}$ is the geometrical average of the stop masses,

$X_t \equiv A_t + \mu\cot\beta$.

The supersymmetric contribution arise mainly from 1-loop diagrams with chargino-sneutrino and neutralino-smuons exchange.



Considering the extreme case

$$M_1 = M_2 = \mu = m_{\tilde{\mu}_L} = m_{\tilde{\mu}_R} = m_{\tilde{\nu}} \equiv M_{\mathrm{SUSY}},$$

then

$$\delta^{\mathrm{SUSY}} a_\mu \propto \frac{m_\mu^2}{M_{\mathrm{SUSY}}^2} \tan\beta.$$

Higgs mass vs a_μ

Intuitively,

Large m_h ($m_h \geq 135$)

$\downarrow$

M_{susy} large

$\downarrow$

Susy decoupled

$\downarrow$

δa_μ^{SUSY} negligible

$\downarrow$

$3{,}3\sigma$ discrepancy with a_μ^{exp}

Higgs mass vs a_μ

How to determine for which m_h the tension stars to be unbearable?

Making a complete scan of the parameter space,

We can conclude if the a_μ^{exp} is unattainable for a given m_h, or if it is attainable, but in an extremely tiny region.

$\Downarrow$

It is possible to quantify the tension between m_h and a_μ.

The posterior probability density function (pdf), $p(p_i^0|\mathrm{data})$, is given by

Bayes Theorem

$$p(\theta_i^0|\mathrm{data}) = \frac{p(\mathrm{data}|\theta_i^0)\, p(\theta_i^0)}{p(\mathrm{data})}$$

where

$p(\mathrm{data}|\theta_i^0)$ is the likelihood,

$p(\theta_i^0)$ is the prior,

$p(\mathrm{data})$ is the evidence.

Bayesian Analysis: The evidence

The evidence measures the global probability of a model,

$$p(\mathrm{data}) = \int \mathrm{d}\theta_1 ... \mathrm{d}\theta_N \ p(\mathrm{data}|\theta_i) \ p(\theta_i)$$

When two different models are used to fit the data, the ratio of their evidences gives a relative probability of these two models.

Bayesian Analysis: The evidence

Separating the data into two subsets

$$\{\text{data}\} = \{\mathscr{D}, D\}$$

D: Data that we assume to be correct (M_z, EW obs, B-Phys, m_h)

$\mathscr{D}$: Data whose compatibility with D we want to test (a_μ).

We construct the probability of measuring certain value of a_μ given M_z, EW obs, B-Phys, m_h

$$p(\mathscr{D}|D) = \frac{p(\mathscr{D}, D)}{p(D)}.$$

Bayesian Analysis: L-test

The consistency of $\mathscr{D}^{obs}$ with respecto to D, can be tested by comparing

$$p\{\mathscr{D}^{obs}|D\} \qquad \text{with} \qquad p\{\mathscr{D}^{max}|D\}.$$

Where $\mathscr{D}^{max}$ is the value of $\mathscr{D}$ that maximaze the evidence.

This gives a measure of the likelihood of the actual data, $\mathscr{D}^{obs}$.

$$\mathscr{L}(\mathscr{D}^{obs}|D) \equiv \frac{p(\mathscr{D}^{\mathrm{obs}}|D)}{p(\mathscr{D}^{\mathrm{max}}|D)} = \frac{p(\mathscr{D}^{\mathrm{obs}}, D)}{p(\mathscr{D}^{\mathrm{max}}, D)}$$

$\mathscr{L}(\mathscr{D}^{obs}|D)$ is analogous to a likelihood ratio in data space.

The Analysis

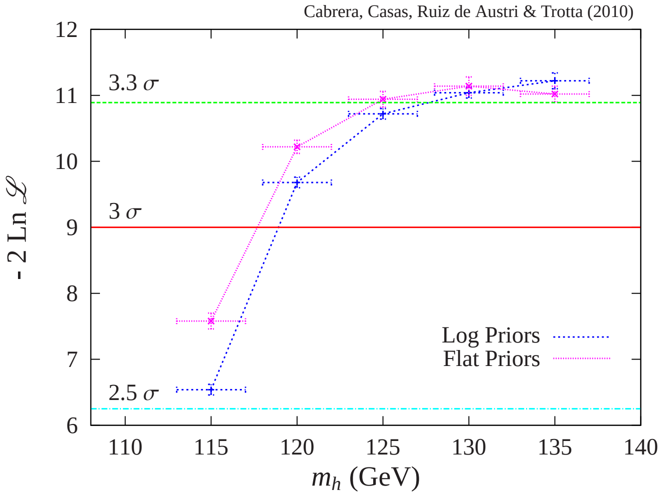
For the numerical calculation we have used MultiNest implemented in `SuperBayes` code.

We calculated the value of $-2\ln\mathscr{L}$ (analogous of χ^2) for different values of Higgs mass,

$$m_h = 115,\ 120,\ 125,\ 130,\ 135.$$

And for two different choices of initial priors, **logarithmic** and **flat priors**.

The Analysis



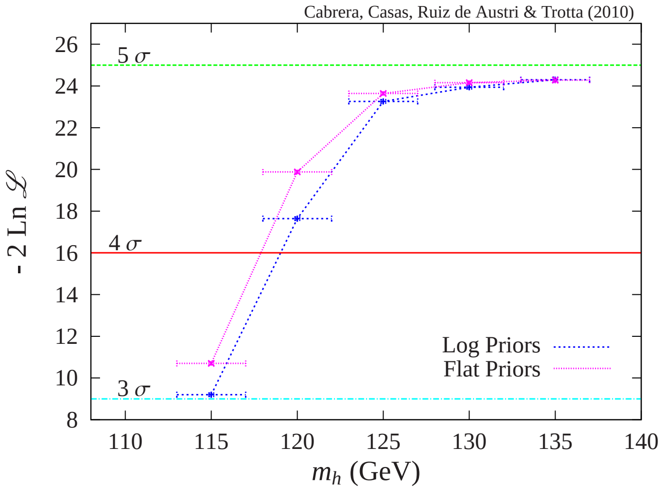
The Analysis

1. The likelihood of a_μ approaches asymptotically the expected $3.3\ \sigma$ discrepancy for large values of m_h.
2. At m_h=125 GeV the maximum level of discrepancy is already achieved.
3. If we require less than 3σ discrepancy, we need $m_h \lesssim 120$.
4. For a larger Higgs mass we should give up either the **CMSSM** model or the computation of a_μ based on $e^+\ e^-$

How our conclusion will change if in the future a_μ becomes more precise?

We performed an exercise, we changed the experimental uncertainty of a_μ^{exp} so that the discrepancy with the **SM** result be 5σ

L-test


Cabrera, Casas, Ruiz de Austri & Trotta (2010)
26
24
22
20
18
16
14
12
10
8
5 σ
4 σ
3 σ
- 2 Ln ℒ
110
115
120
125
130
135
140
m_h (GeV)
Log Priors
Flat Priors

The probability distribution of the **CMSSM** parameters

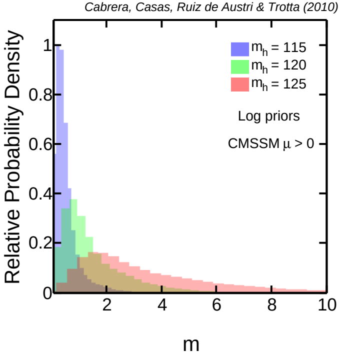
- The location of the peak in the pdf increases with the assumed Higgs mass.
- The model "prefers" to reproduce m_h at the cost of not reproducing a_μ rather than viceversa.
- Note that, for increasing soft masses

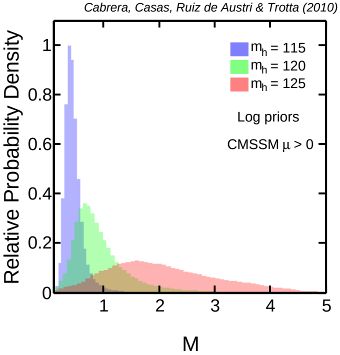
  the discrepancy of $a_\mu \longrightarrow 3.3\ \sigma$,

  but if the soft masses are not large enough,

  the discrepancy of $m_h \longrightarrow$ much more severe.

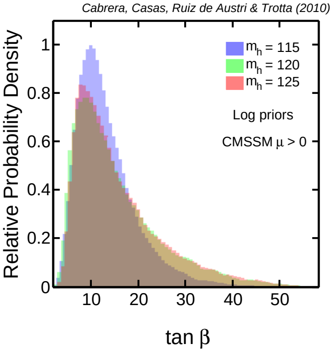
Probability density functions





Probability density functions

- Focus point region.
- Tension between $b \rightarrow s\ \gamma$ and a_μ



Conclusions

- There is a potential tension between $\delta^{SUSY} a_\mu$ and a possibly large Higgs mass.
- If we require less than 3σ level of discrepancy, we need $m_h \lesssim 120$.
- For $m_h \geq 125$ the maximum level of discrepancy is already achieved.
- We have shown how the pdf of m, M, $\tan\beta$ change with increasing m_h