Roma, 29 Nov. 2007

On the Higgs sector of the MSSM

Gino Isidori
[*Scuola Normale Superiore - Pisa & INFN - Frascati*]

- The Higgs sector of the SM
- The MSSM
  - A first look to the MSSM Higgs sector
  - Going beyond the tree level: the MFV hypothesis
  - The Higgs sector at large tanβ
- Phenomenological constraints
  - The flavour constraints at large tanβ
- A global fit in the constrained MSSM
- Conclusions

The Higgs sector of the SM

$$\mathscr{L}_{SM} = \mathscr{L}_{\text{gauge}}(A_i, \psi_i) + \mathscr{L}_{\text{Higgs}}(\phi, A_i, \psi_i)$$

- *Natural*
- Experimentally tested with high accuracy
- Stable with respect to quantum corrections

- *Ad hoc*
- Not tested yet with high accuracy
- Not stable with respect to quantum corrections

The origin of all the *problems* of the SM

Experiments provide unambiguous indications that the SM gauge group is spontaneously broken [$SU(2)_L \times U(1)_Y \rightarrow U(1)_Q$]

One elementary $SU(2)_L$ scalar doublet with ϕ^4 potential is the most economical & simple choice to obtain this result, but certainly not the only allowed possibility

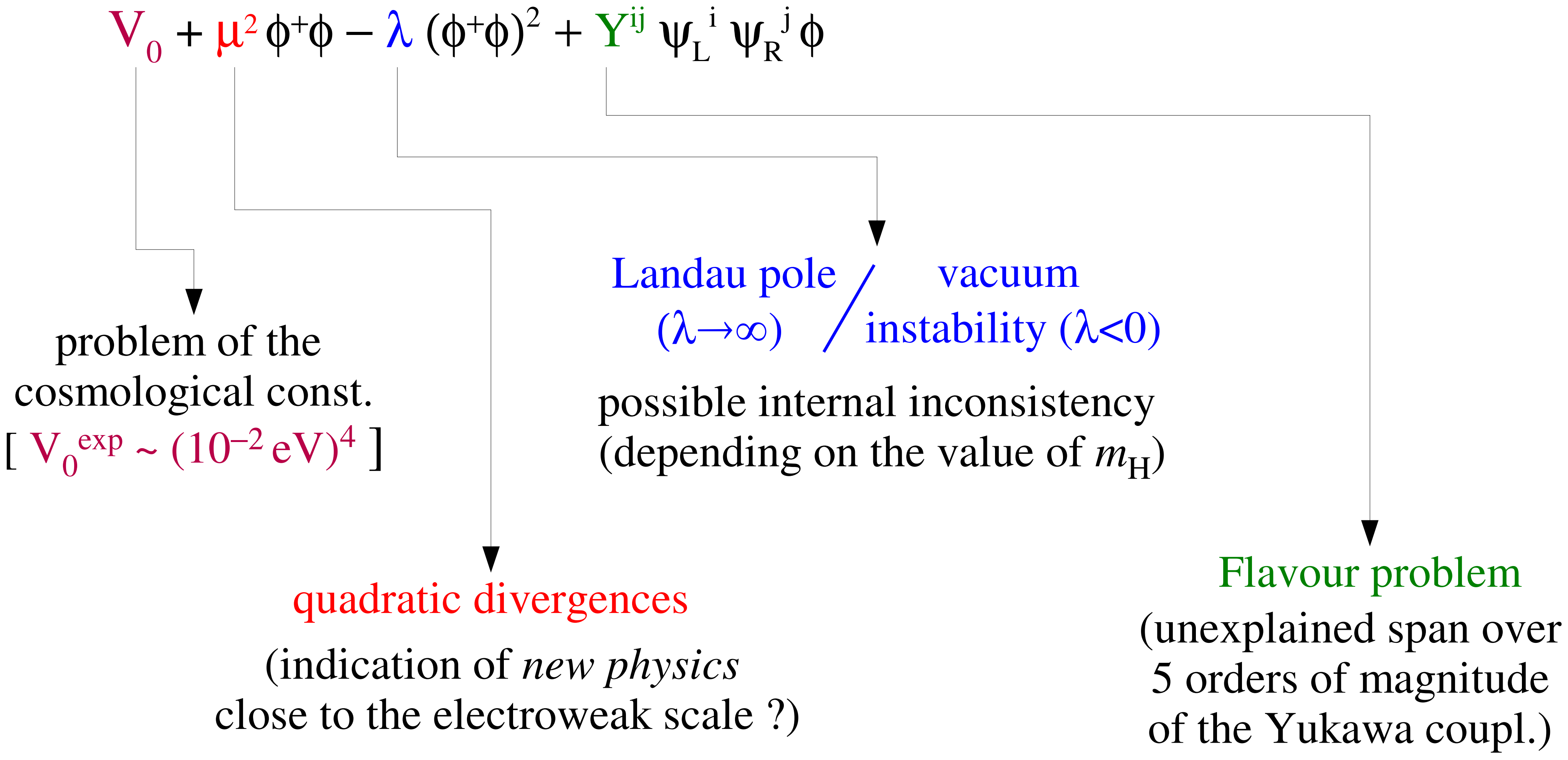
$$\mathscr{L}_{\text{Higgs}}(\phi, A_i, \psi_i) = D_\mu \phi^+ D^\mu \phi + \mu^2 \phi^+ \phi - \lambda (\phi^+ \phi)^2 + Y^{ij} \psi_L^{\,i} \psi_R^{\,j} \phi$$

(1) + 2 + 13 new physical coupl. [⇔ 9 masses + 4 CKM angles (no ν masses)]

V_0

- $\langle \phi \rangle = v = 246$ GeV (⇔ G_F)
- and the still unknown m_H ($m_H = 2\lambda v^2$)

The origin of all the *problems* of the SM :



$$V_0 + \mu^2 \phi^+\phi - \lambda (\phi^+\phi)^2 + Y^{ij} \psi_L^{\,i} \psi_R^{\,j} \phi$$

problem of the
cosmological const.
[$V_0^{\exp} \sim (10^{-2}\,\mathrm{eV})^4$]

quadratic divergences

(indication of *new physics*
close to the electroweak scale ?)

Landau pole ($\lambda \to \infty$) / vacuum instability ($\lambda < 0$)

possible internal inconsistency
(depending on the value of m_H)

Flavour problem

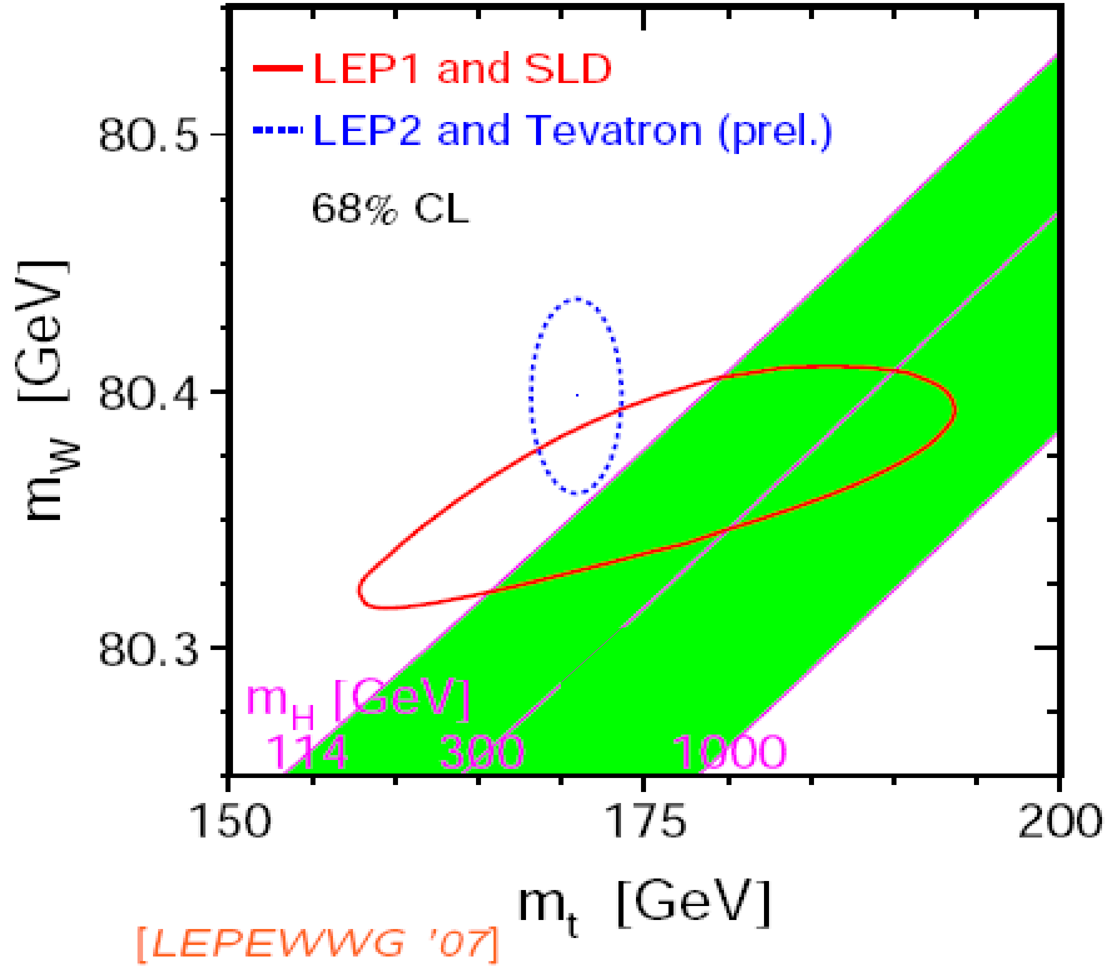
(unexplained span over
5 orders of magnitude
of the Yukawa coupl.)

The most significant (dynamical) information about the Higgs sector is derived, at present, by the electroweak precision tests:

E.g.: $$M_W^2\left(1-\frac{M_W^2}{M_Z^2}\right)=\frac{\pi\,\alpha}{\sqrt{2}\,G_\mu}(1+\Delta r)$$

$$\Delta r(M_H)\sim\log(M_H/M_W)\ \sim 1\%$$

Subleading with respect to gauge and O(m_t) corrections, but non negligible given the present exp. resolution



[LEPEWWG '07]

Results for M_H from other EWPO:

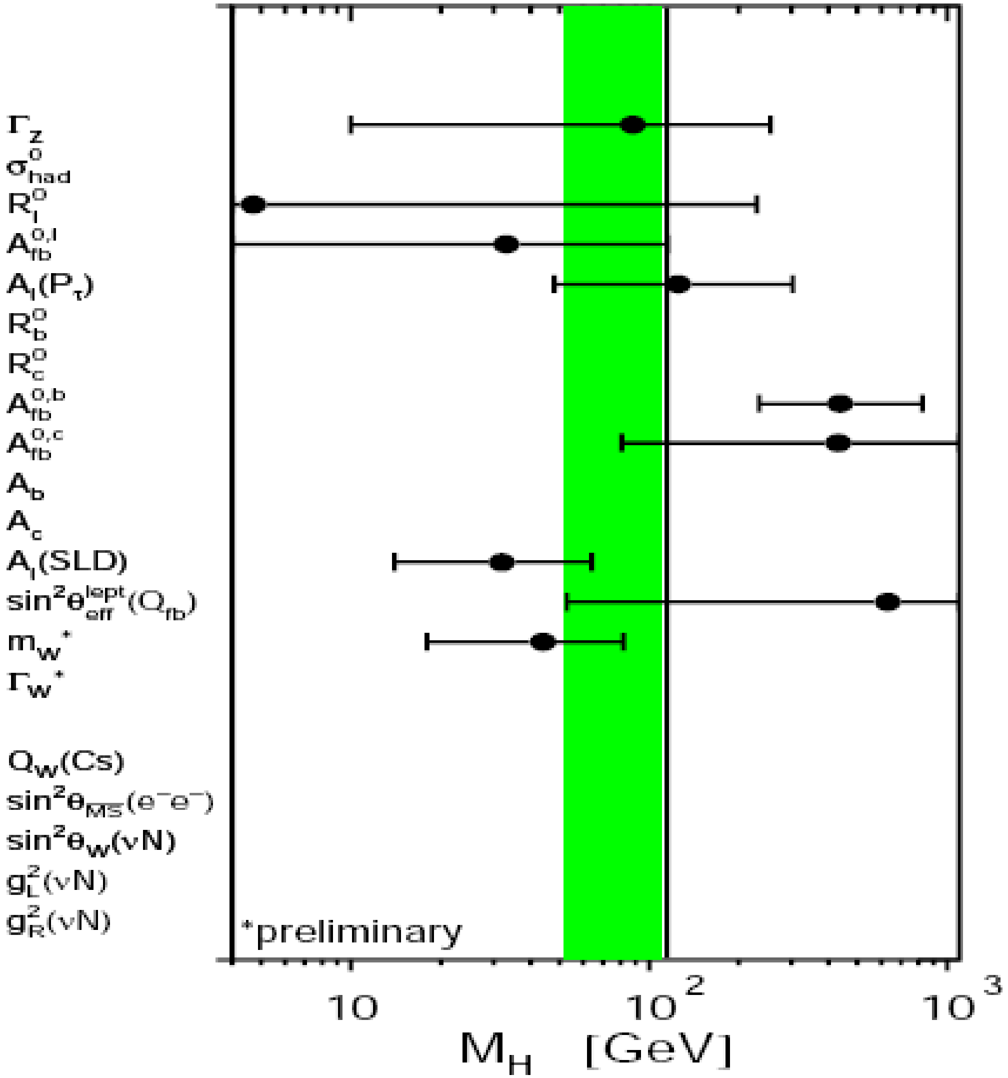
light Higgs preferred by:

M_W, A_l^{LR} (SLD)

heavier Higgs preferred by:

A_b^{FB} (LEP)

⇒ keeps SM alive



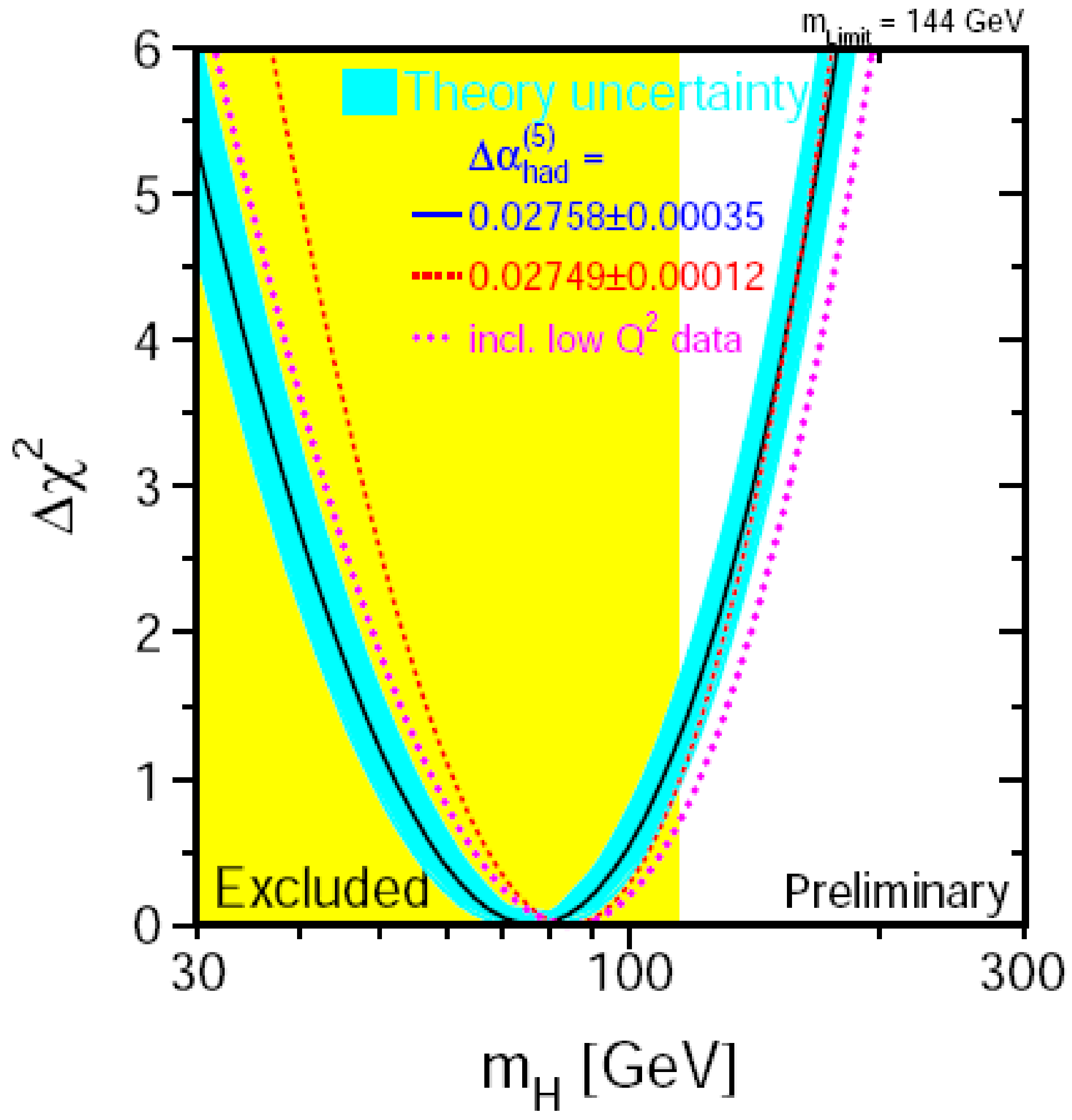
[LEPEWWG '07]

⇒ light Higgs boson preferred

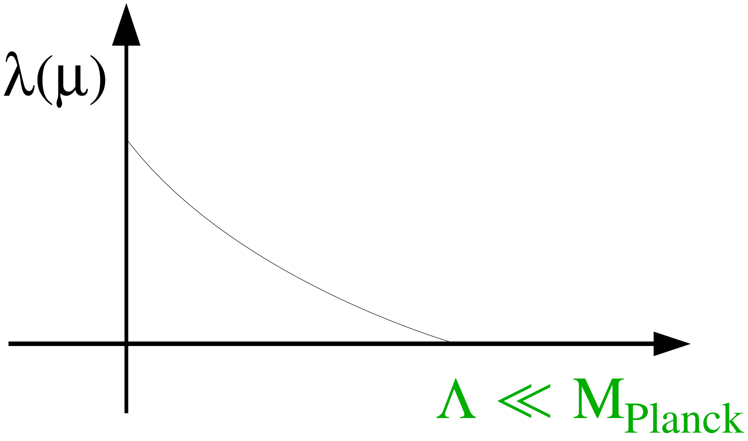
Sven Heinemeyer, Lepton Photon 2007, Daegu, 08/13/2007

Global fit to all EWPO: $M_H = 76^{+33}_{-24}$ GeV [$M_H < 144$ GeV @ 95% CL]

Such a light central value for M_H is slightly in conflict with direct searches (the problem becomes really serious only if the measurement of A_b^{FB} is ignored)



and is (marginally) problematic for vacuum stability:



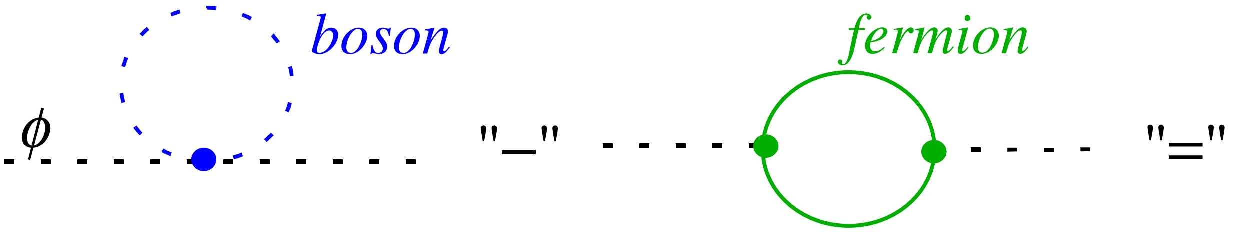
The MSSM

Basic principles of SUperSYmmetry:

$$Q|\text{fermion}\rangle = |\text{boson}\rangle \qquad Q|\text{boson}\rangle = |\text{fermion}\rangle$$

$$\{Q, Q^+\} = P^\mu$$
$$\{Q, Q\} = \{Q^+, Q^+\} = 0$$
$$[Q, P^\mu] = [Q^+, P^\mu] = 0$$

SUSY is very appealing from a pure theoretical point of view (*largest symmetry allowed in a QFT, connection with gravity*) and it has a very appealing phenomenological virtue:



no quadratic divergences
[natural solution for one of the main SM problems]

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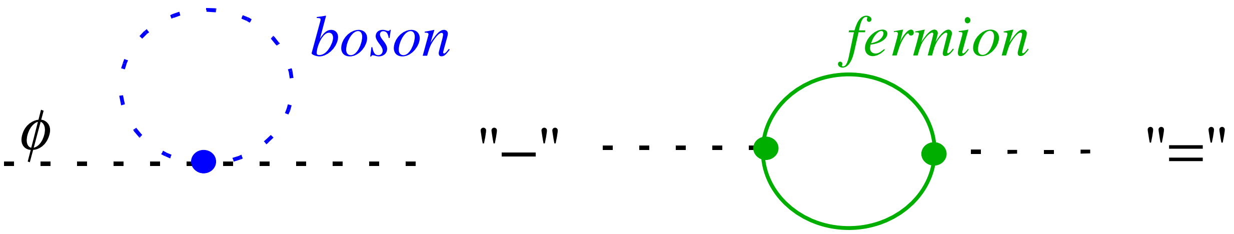

no quadratic divergences
[natural solution for one of the main SM problems]

$$\Delta M^2 \sim \frac{g^2}{16\pi^2}\left[M_b^{\,2} - M_f^{\,2}\right] \Rightarrow$$

SUSY breaking must occur not far from the e.w. scale [= low-energy SUSY]

N.B.: Within low-energy SUSY the existence of a large energy gap between the e.w. scale and the Planck scale is not a technical problem (as in the SM), *but the origin of this hierarchy remains unexplained*

The MSSM

The price to pay for the *stabilization* of the hierarchy problem is non trivial (both in terms of particle content & in terms of free parameters)...

The Minimal Supersymmetric extension of the SM requires more than a doubling of the particle spectrum so far observed:

- scalar partners of the ordinary quarks and leptons [$\tilde{Q}_L$, $\tilde{u}_R$, ...]
- spin-1/2 partners of the ordinary gauge bosons [*gauginos*]
- Two Higgs doublets [H_U , H_D] with their corresponding spin-1/2 partners

The presence of (at least) two Higgs doublets is mandatory: cancellation of triangular gauge anomalies induced by the higgsinos ⊕ analiticity of the superpotential

... but to two very interesting features are obtained as by products:

- gauge coupling unification
- dark matter candidate [Lightest Supersymmetric Particle, assuming R-parity]

✯ *A first look to the MSSM Higgs sector*

In the ideal limit of unbroken SUSY, all the non-gauge interactions of the MSSM are described by a single mass parameter + 3 Yukawa matrices (~SM):

$$W_{\mathrm{MSSM}} = \mu\,\Phi_{\mathrm{U}}\Phi_{\mathrm{D}} \;+\; \text{Yukawa terms}$$

With the inclusion of the (soft) SUSY breaking terms [not fixed a priori by symmetry/theory arguments other than “soft-breaking”] the number of free parameters increase drastically in the squark/slepton sector, while the pure Higgs sector maintains a rather simple structure:

$$\begin{aligned} V^{tree}_{Higgs} = {} & m_1^2\,|H_U|^2 + m_2^2\,|H_D|^2 + B^2\,(H_D H_U + \text{h.c.}) \\ & + \tfrac{1}{8}\,(g_1^2+g_2^2)\,(|H_U|^2-|H_D|^2)^2 + \tfrac{1}{2}\,g_2^2\,|H_D H_U|^2 \end{aligned}$$

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$$+\ \frac{1}{8}\, (g_1^2 + g_2^2)\, (|H_U|^2 - |H_D|^2)^2 \ +\ \frac{1}{2}\, g_2^2\, |H_D H_U|^2$$

3 unknown couplings

$$v^2 = \langle H_U \rangle^2 + \langle H_D \rangle^2 = 246 \text{ GeV}$$

$$M_A, \quad \tan\beta = \langle H_U \rangle / \langle H_D \rangle$$

The Higgs quartic couplings are unambiguously fixed in terms of the gauge couplings [SUSY constraint]

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physical spectrum: $\{h^0, H^0\}$, A^0, $H^\pm$

free param.: M_A (or M_H) & $\tan\beta$

Higgs quartic couplings unambiguously fixed in terms of $g_{1,2}$ → $M_h^{tree} < |\cos(2\beta)|\, M_Z$

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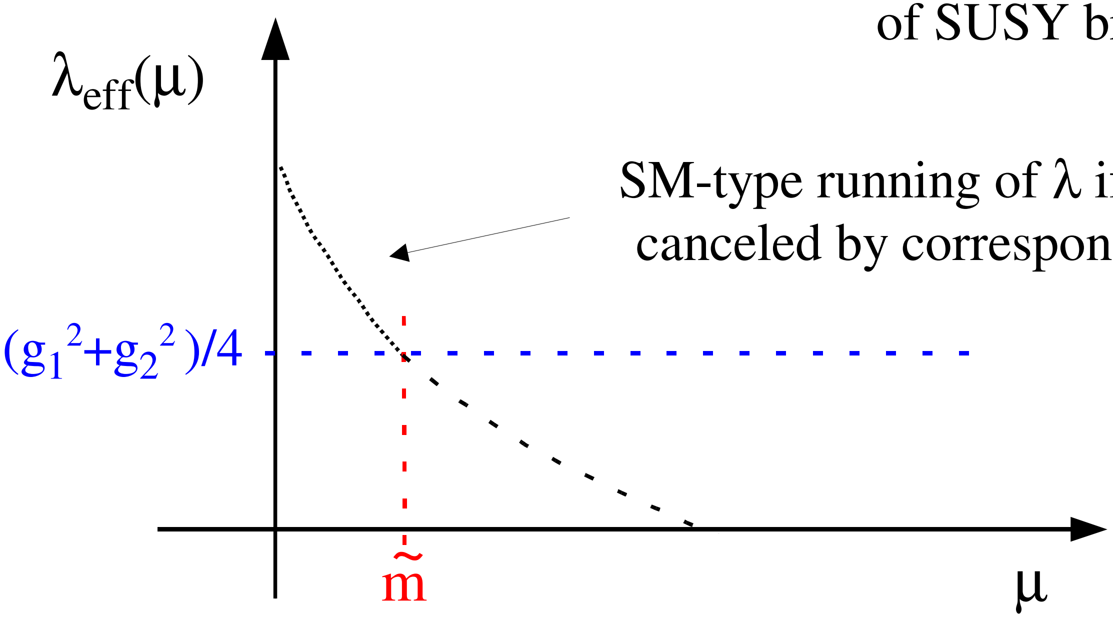
↑

Modified by sizable loop corrections if the scale of SUSY breaking is higher than the e.w. scale



SM-type running of λ if top and Higgs loops are not canceled by corresponding stop and higgsino loops

✯ *Going beyond the tree level: the MFV hypothesis*

In order to estimate quantitatively the impact of radiative corrections in the Higgs sector we need more information about the structure of the soft-breaking terms in the squark sector [⇔ theory assumptions +low-energy data]

The squark soft-breaking sector contains a large number of free parameters. Most of them are related to flavour-symmetry violating couplings, which are severely constrained by data (flavour problem). A simplifying assumption which allow us to circumvent (postpone) this problem is provided by the Minimal Flavour Violation [MFV] hypothesis: *the Yukawa couplings are the only irreducible sources of flavour symmetry breaking*

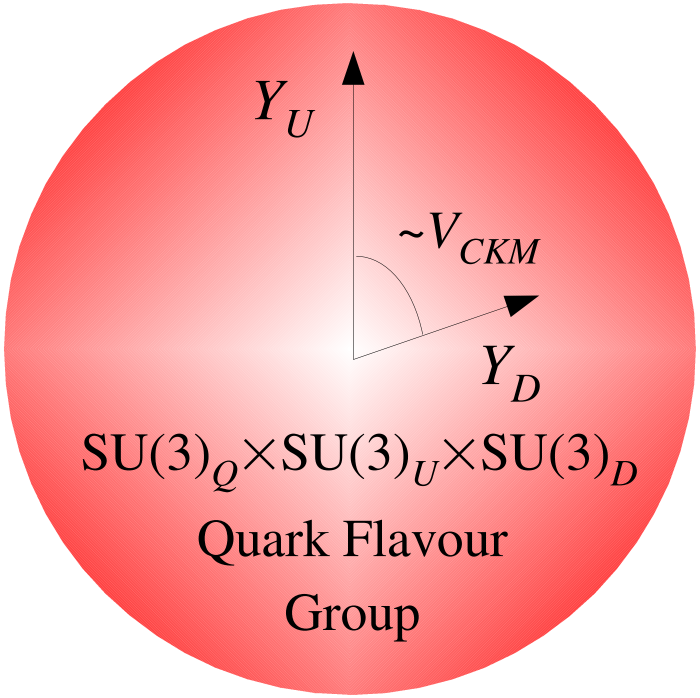
Going beyond the tree level: the MFV hypothesis

The flavour structure of the SM is quite constrained:

- a large global symmetry in the gauge sector
  $U(3)^5 = SU(3)_Q \times SU(3)_U \times SU(3)_D \times \ldots$
- broken only by the Yukawa couplings
  $Y_D \sim \overline{3}_Q \times 3_D \quad Y_U \sim \overline{3}_Q \times 3_U \quad (Y_E \sim \overline{3}_L \times 3_E)$

↓

This specific symmetry + symmetry-breaking pattern is responsible for the suppression of FCNCs, the suppression of CPV, etc...



$SU(3)_Q \times SU(3)_U \times SU(3)_D$

Quark Flavour Group

One of the most *ugly* parts of the SM Lagrangian which, however, is highly successful from the phenomenological point of view.

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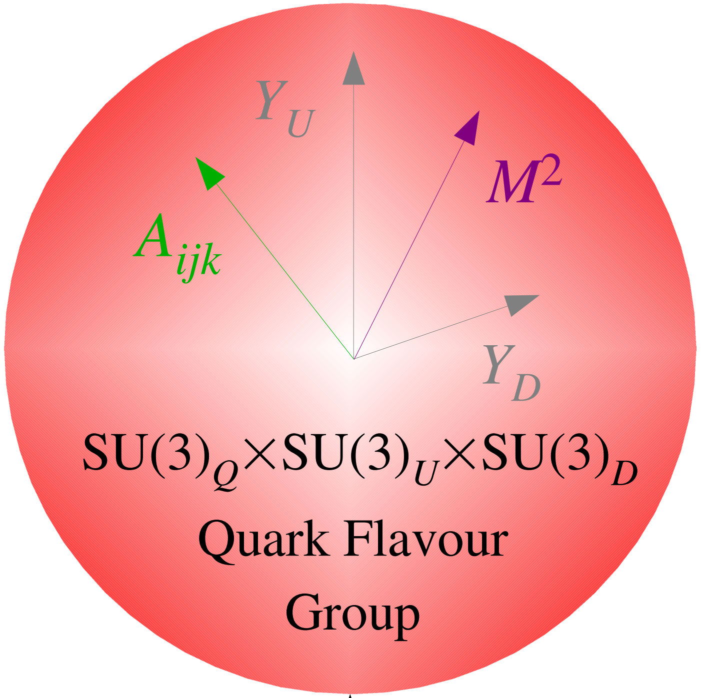


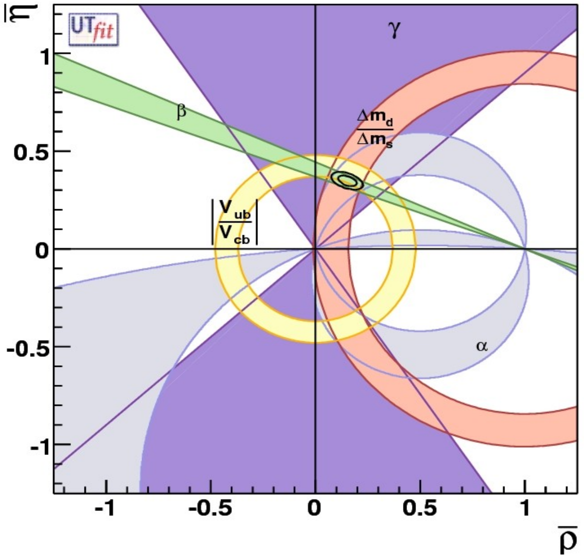
$SU(3)_Q \times SU(3)_U \times SU(3)_D$
Quark Flavour
Group

In principle, the soft breaking terms of the MSSM allow a much reacher symmetry-breaking structure:

$$\mathcal{L}_{soft} \subset (M^2)_{ij} \tilde{Q}_i^+ \tilde{Q}_j + A_{ijk} \tilde{Q}_i^+ \tilde{Q}_j H_k$$

New flavour-breaking terms not necessarily related to the Yukawa couplings

In practice, the absence of deviations form the SM in rare processes and CKM fits implies *severe constraints* on flavour-symmetry breaking terms beyond the SM Yukawas (at last in the quark sector...)

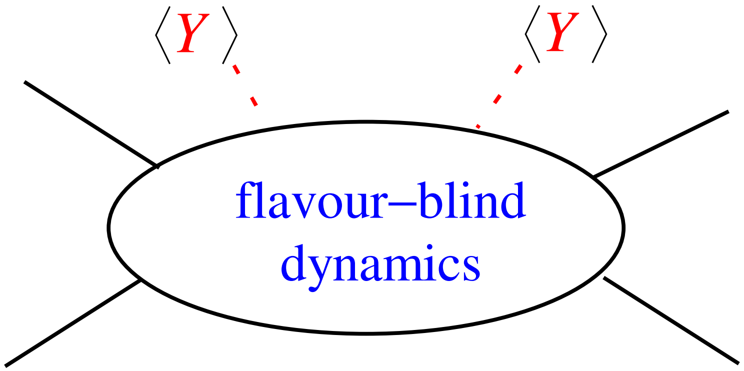


The most natural way out to this problem is the so-called Minimal Flavour Violation [MFV] hypothesis: *the Yukawa couplings are the only irreducible sources of flavour symmetry breaking*

General principle (symmetry + symmetry-breaking structure) which can be formulated for any (TeV-scale) SM extension

Chivukula, Georgi '87

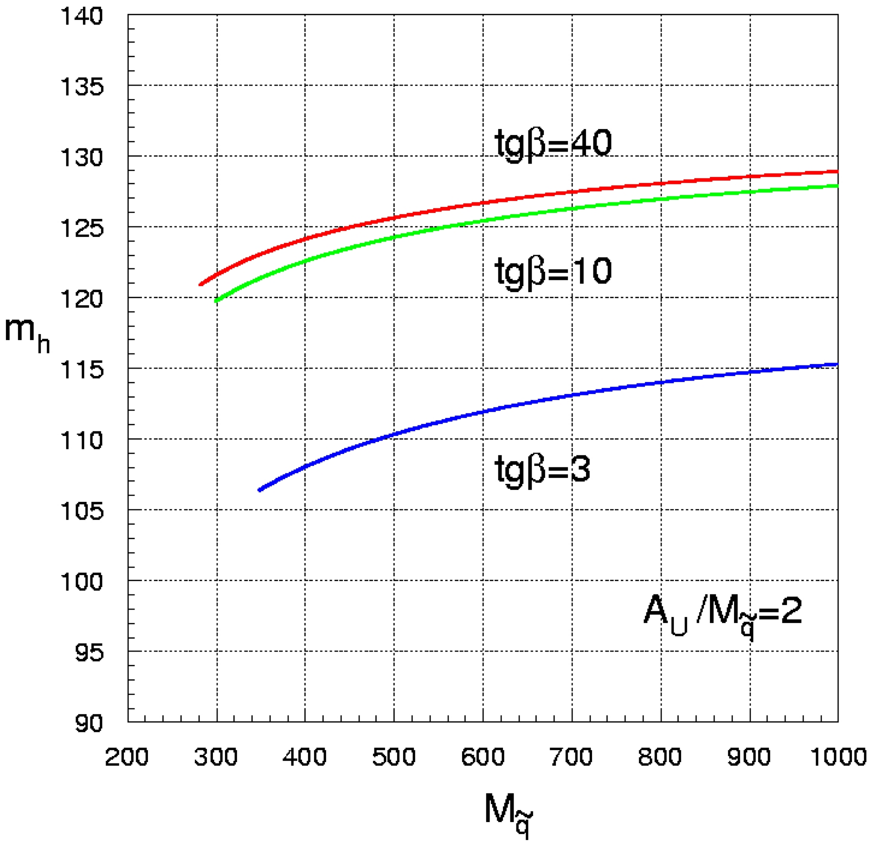
D'Ambrosio, Giudice,
G.I., Strumia '02

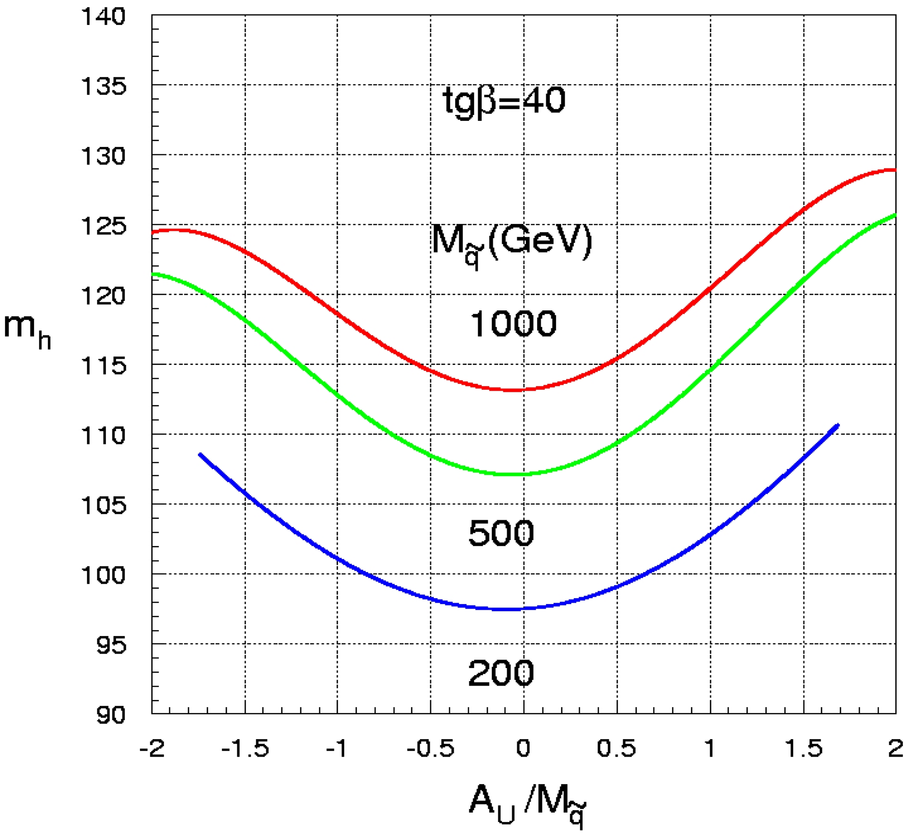

$\langle Y \rangle$ $\langle Y \rangle$

flavour–blind
dynamics

Coming back to the Higgs sector, the key dependence of M_h is from stop masses, A terms and tanβ [large M_h ⇔ large tanβ, m_{stop}, A_t].

Within the MFV hypothesis the values of these parameters can be constrained by various low-energy observables.

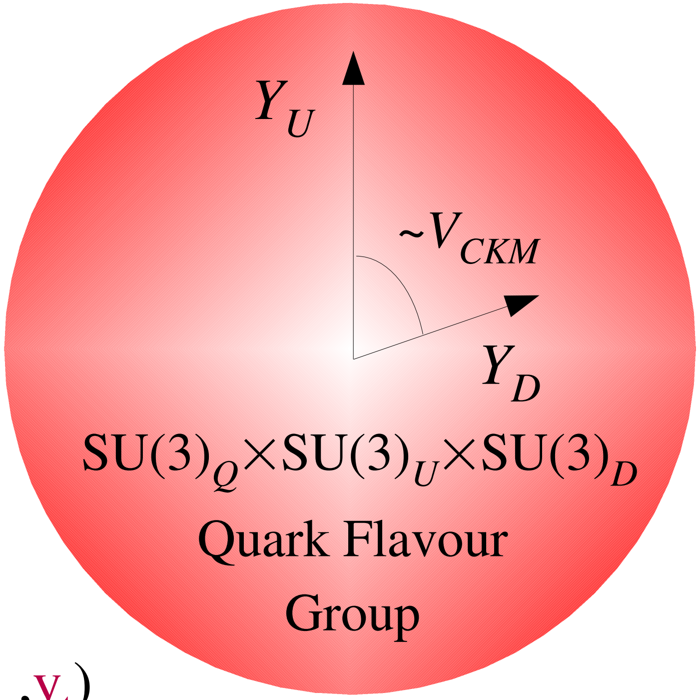




The Higgs sector at large tanβ

With two Higgs doublets and a large ratio of vevs, interesting effects in flavour physics can occur also under the MFV hypothesis

$$\mathscr{L}_{\text{q-Yukawa}} = \bar{Q}_L Y_D D_R H_D + \bar{Q}_L Y_U U_R H_U + \text{h.c.}$$



Y_D & Y_U are still the only irreducible breaking sources of $SU(3)_{Q_L} \times SU(3)_{U_R} \times SU(3)_{D_R}$

→ negligible non-standard effects in the standard CKM fits

$Y_D = \text{diag}(y_d, y_s, y_b)$ $Y_U = (V_{ckm})^+ \times \text{diag}(y_u, y_c, y_t)$

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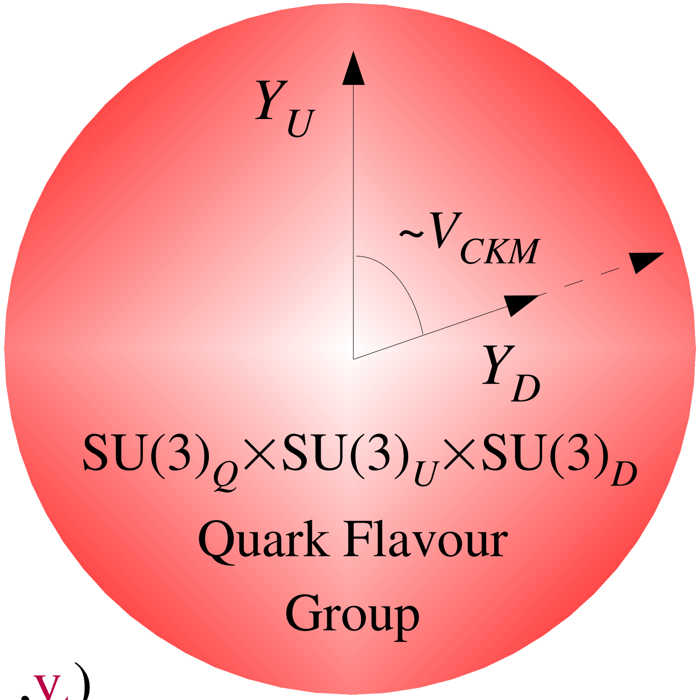

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$$Y_D = \text{diag}(y_d, y_s, y_b) \qquad Y_U = (V_{ckm})^{+} \times \text{diag}(y_u, y_c, y_t)$$

but we are free to change their overall normalization

$$y_u = m_u / \langle H_U \rangle \qquad y_d = m_d / \langle H_D \rangle = \tan\beta \, m_d / \langle H_U \rangle$$

→ sizable phenomenological consequences in helicity-supressed processes if $\tan\beta \gg 1$

N.B.: the *effective* Yukawa interaction of the MSSM can be very different with respect to the non-superymmetric Two-Higgs Doublet Model of type-II, even in the limit of light Higgses & heavy squarks

$$\mathscr{L}_{\text{tree}} = \bar{Q}_L Y_D D_R H_D + \bar{Q}_L Y_U U_R H_U$$

invariant under $\mathrm{U(1)_{PQ}}$ (each Higgs couples only to a specific right-handed field)

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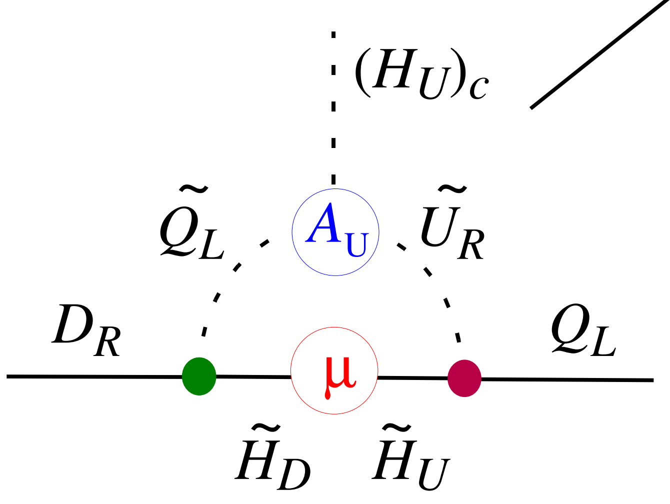
$$\mathscr{L}_{\rm eff} = \bar{Q}_L Y_D D_R H_D + \bar{Q}_L Y_U U_R H_U + \epsilon_1 \bar{Q}_L Y_U Y_U^{+} Y_D D_R (H_U)_c + \ldots$$

...possible large $U(1)_{PQ}$ breaking induced by the μ term



Even if $\epsilon_i \sim (16\pi^2)^{-1}$ these loop corrections are a potential large destabilization of the tree-level Yukawa strucutre:

- $\epsilon_i \times \tan\beta \sim 1$
- dim-4 ops. ⇒ non-decoupling effects

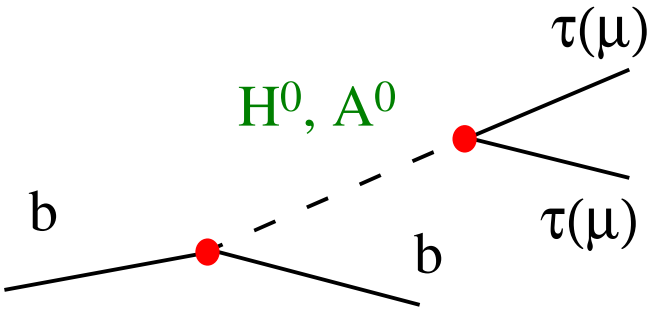
→

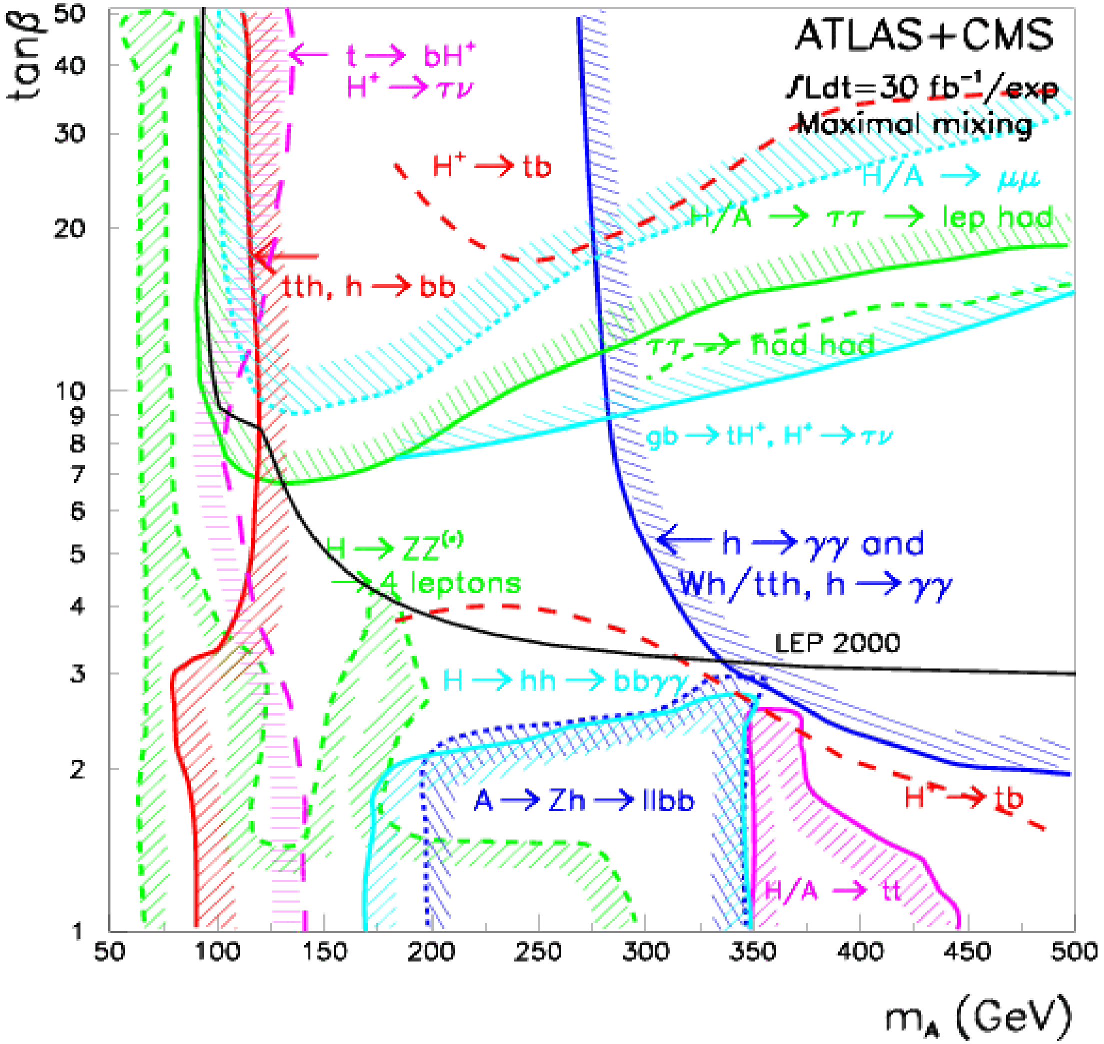
- sizable Higgs-mediated FCNC ampl. in the helicity suppressed $B \to \mu\mu$
- sizable SUSY contribution to $(g-2)_\mu$

The MSSM Higgs sector at large tanβ has also very distinctive signatures at high energies:

- decoupling of H_U (~SM Higgs) and H_D (~ almost degenerate H^0, A^0, $H^\pm$)

- enhanced production of the heavy H^0 & A^0 together with b quarks [$\sigma \sim (\tan\beta)^2$]





- Sizable H^0 & A^0 decays into ττ (and non negligible into μμ) even for high masses

Phenomenological constraints

Waiting for the LHC... at present we only have indirect constraints on the MSSM, which can be divided in three main categories:

EWPO

- Mainly exclusion bounds (e.g.: not possible to improve the A_b^{FB} problem)
- Notable exception provided by: $(g\text{-}2)_\mu$
- Only mild improv. expected in the near future (m_t, M_W)

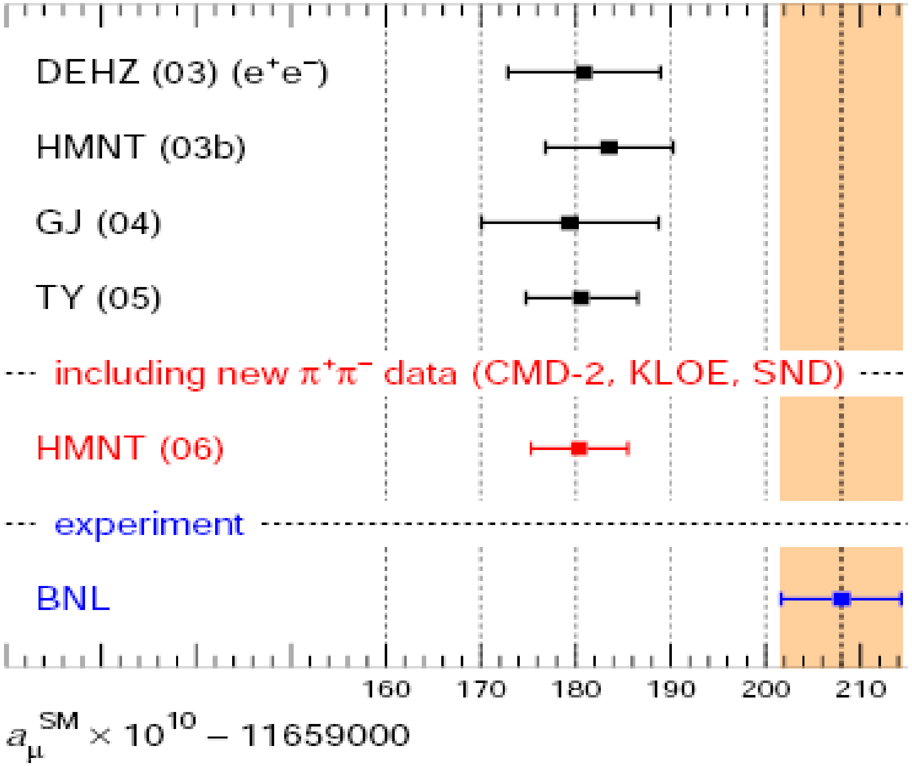
Dark matter

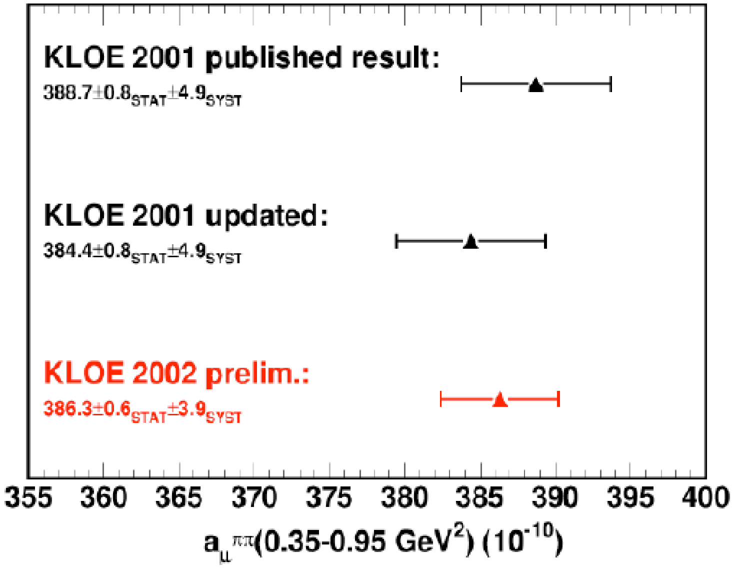
- Clear indication of physics beyond the SM
- Disregarding non-susy explanations it becomes a highly non-trivial constraint
- Improvement possible in the near future (WIMP detection, $\gamma\gamma$ signals,...)

Flavour physics

- Mainly excl. bounds
- Significant improv. possible in the near future ($P \to l\nu$, $B \to \mu\mu$)

On the anomalous magnetic moment of the muon:





$$\Delta a_\mu^{\rm exp} = a_\mu^{\rm exp} - a_\mu^{\rm SM} = (29 \pm 9)10^{-10}$$

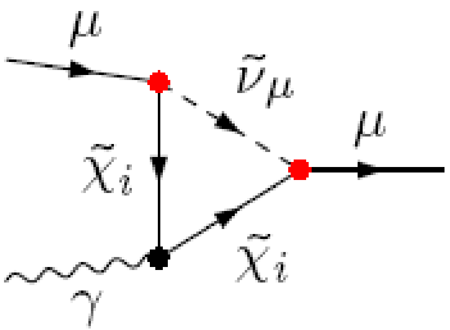
- In the last few years the result for $a_\mu^{\rm SM}$ has become more reliable and the size of the discrepancy has (slightly) increased
- The discrepancy is large compared to $a_\mu^{\rm light\text{-}light}$
- The discrepancy is large compared to $a_\mu^{\rm ew\text{-}SM}$ ($a_\mu^{\rm ew\text{-}SM} \sim 15\times10^{-10}$)

On the anomalous magnetic moment of the muon:

$$\boxed{\Delta a_\mu^{\mathrm{exp}} = a_\mu^{\mathrm{exp}} - a_\mu^{\mathrm{SM}} = (29 \pm 9)10^{-10}}$$

The anomalous magnetic moment is an helicity suppressed observeble ($a_\mu^{\mathrm{SM}} \propto m_\mu$) and SUSYwith moderate/large tanβ provides a natural mechanism to explain this discrepancy:

$$\Delta a_\mu^{\mathrm{SUSY}} \sim \tan\beta \times (m_W/M_{\mathrm{SUSY}})^2 \times (a_\mu^{\mathrm{ew\text{-}SM}}) \times \mathrm{sgn}(\mu)$$



Couplings proportional to the muon Yukawa and not to its mass !!

On the dark-matter constraints:

Two key conditions needed within the MSSM to accommodate the observed dark-matter density ($0.08 < \Omega_{CDM}\, h^2 < 0.12$) are

- A stable and neutral LSP (typically the lightest neutralino)
- With a sufficiently large annihilation cross section into SM particles (not to exceed the upper bound on of Ω_{CDM})

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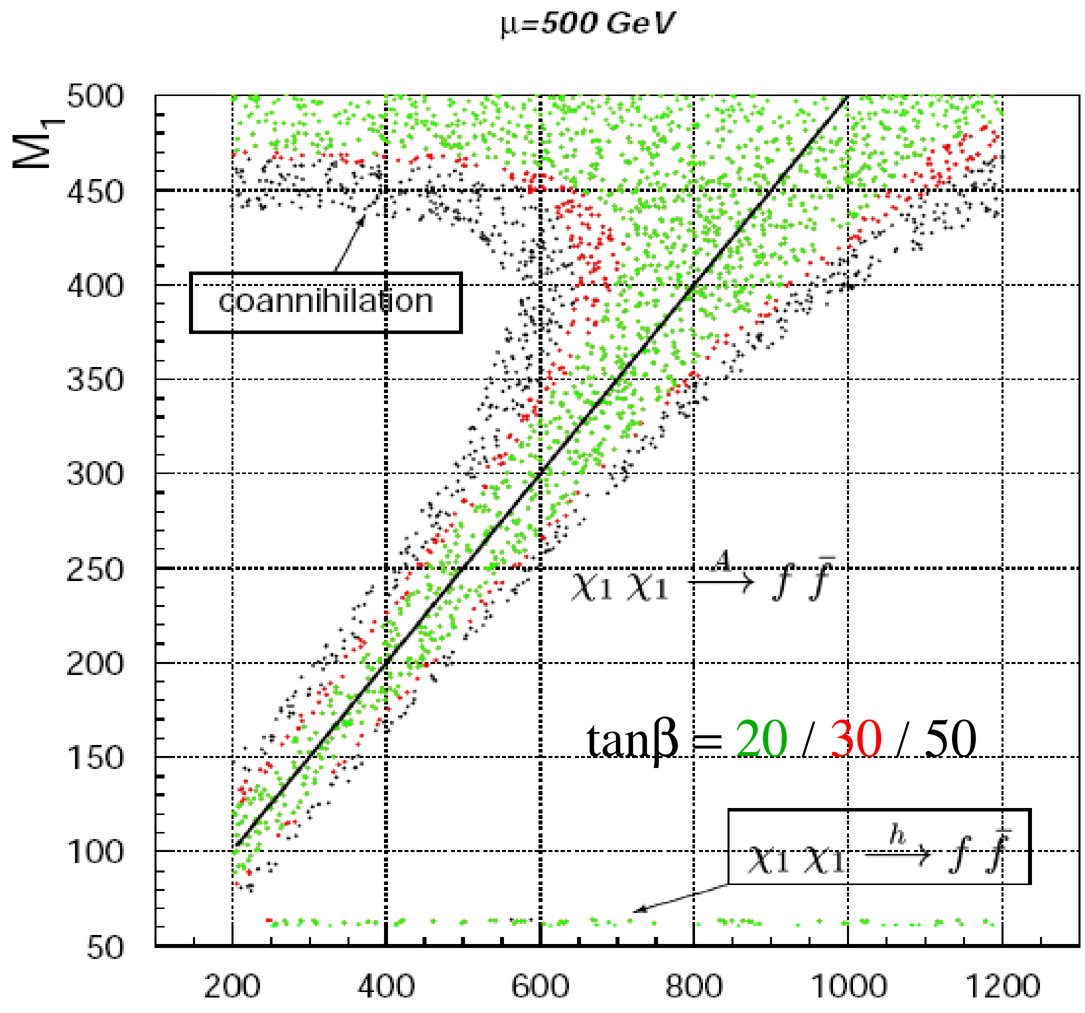
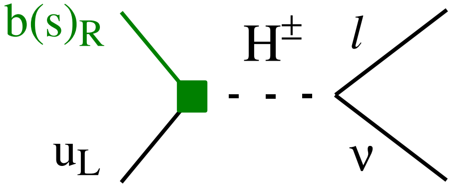
Also in this case large tanβ values induce interesting effects: resonance-enhanced $\chi\chi \to A \to ff$



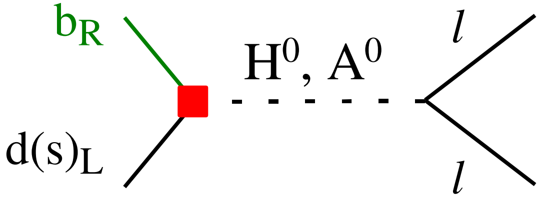
G.I., Mescia, Paradisi, Temes, '07

✭ *The flavour constraints at large tanβ*

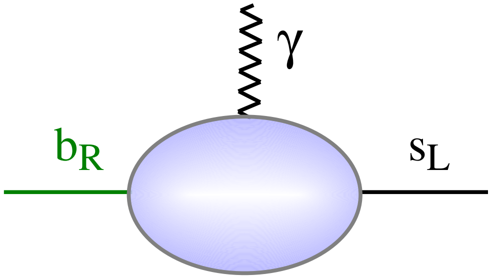
Three most interesting sets of observables:



$P^\pm \rightarrow l^\pm \nu$



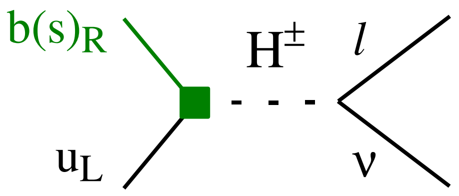
$B_{s,d} \rightarrow l^+ l^-$



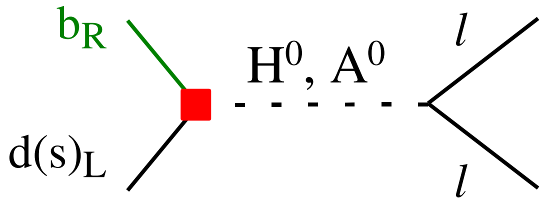
$B \rightarrow X_s \gamma$

The flavour constraints at large tanβ

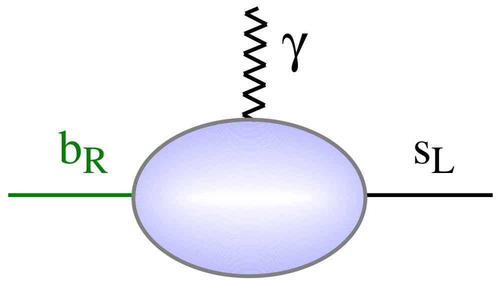
Three most interesting sets of observables:



$P^\pm \to l^\pm \nu$



$B_{s,d} \to l^+ l^-$



$B \to X_s \gamma$

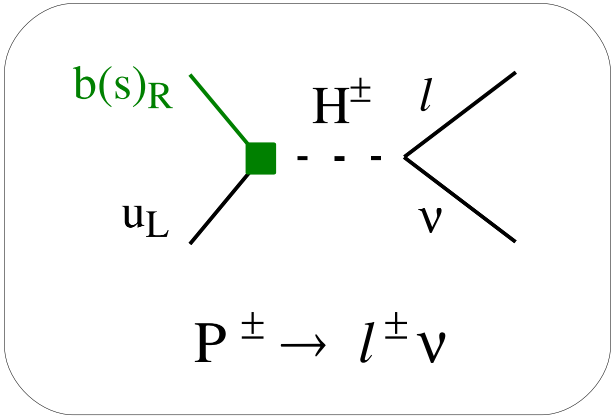
Simplest M_H & tanβ dependence [mild dependence on other parameters]

$$BR = BR_{SM} \times \left(1 - \frac{m_P^2 \tan\beta^2}{M_H^2 (1 + \epsilon_0 \tan\beta)} \right)^2$$

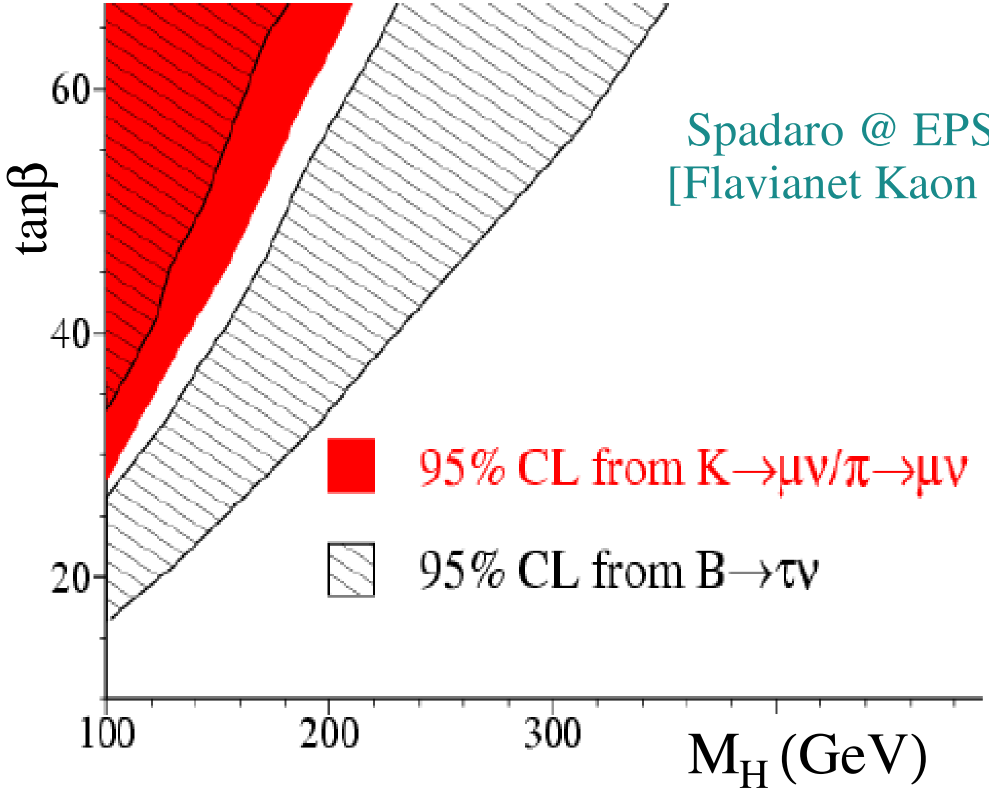
- O(100%)–O(10%) in $B^\pm \to l^\pm \nu$ [most likely $BR_{SUSY} < BR_{SM}$]
- O(1%)–O(0.1%) in $K^\pm \to l^\pm \nu$ [necessarily $BR_{SUSY} < BR_{SM}$]

G. Hou, '93; Ackeroid, Recksiegel, '03
G.I. Paradisi '06

✯ The flavour constraints at large tanβ



$P^\pm \to l^\pm \nu$



Spadaro @ EPS '07
[Flavianet Kaon WG]

$B(B \to \tau\nu) = (1.43 \pm 0.43) \times 10^{-4}$

$[B_{SM} \approx 1\times 10^{-4}]$ [Babar+Belle '07]

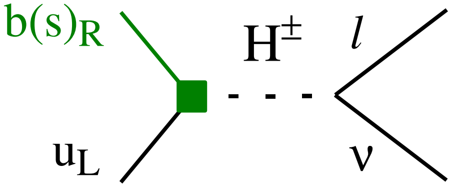
$B(K \to \mu\nu(\gamma)) = (63.66 \pm 0.17)\%$ [KLOE]

+ f_K/f_π @ 0.7% [MILC/UKQCD '07]
+ V_{us} @ 0.5% [KLOE/NA48/KTeV + Theory]

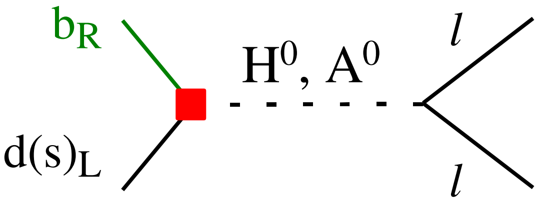
Improving th. and exps. on
$P \to l\,\nu$ can lead to very
valuable infos on M_H & tanβ !

✭ *The flavour constraints at large tanβ*

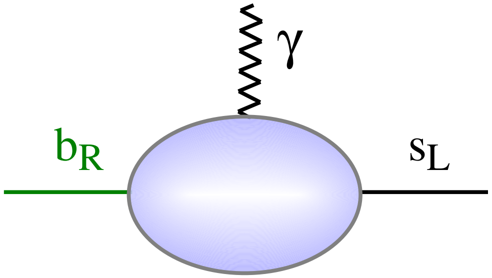
Three most interesting sets of observables:



$P^\pm \to l^\pm \nu$



$B_{s,d} \to l^+ l^-$

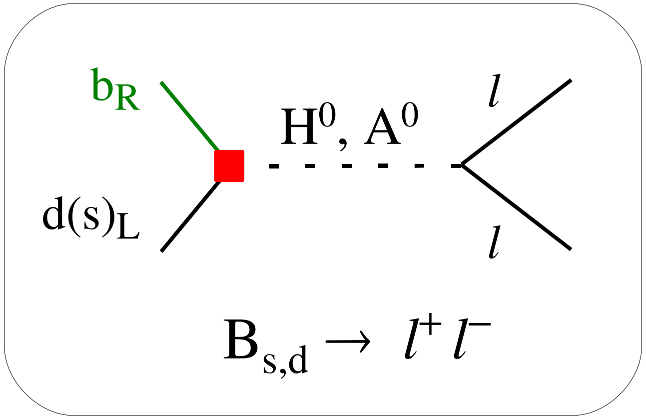


$B \to X_s \gamma$

Crucial dependence on μ and A_U [in addition to M_H & tanβ]

$$A(B\to ll)_H \sim \frac{m_b\, m_l}{M_A{}^2}\,\frac{\mu\, A_U}{\tilde{M}_q{}^2}\,\tan^3\beta$$

Possible large enhancement over the SM
but size (and magnitude) of the effect can change
substantially in different SUSY-breaking scenarios



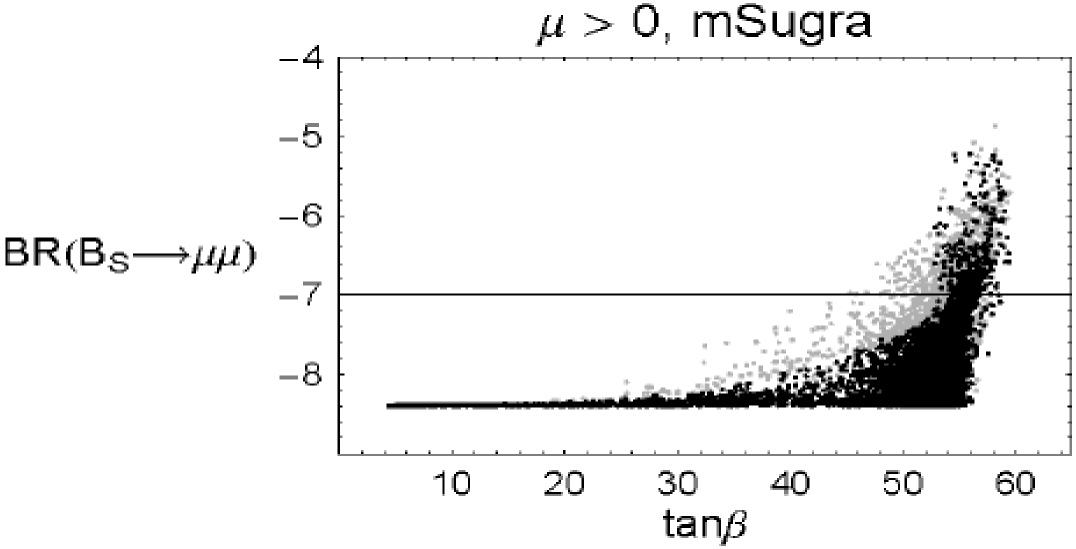
$B_{s,d} \to l^+ l^-$

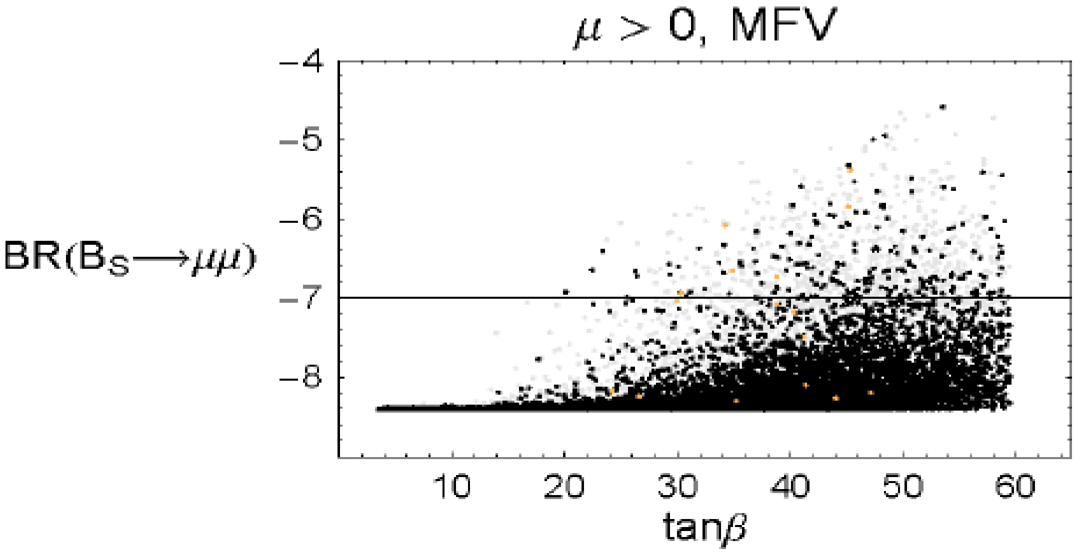
$B(B_s \to \mu\mu) < 5.8 \times 10^{-8}$ (95%CL)

$[B_{SM} \sim 3\times10^{-9}]$

non-official CDF+D0 combined limit [EPS '07]

Significant constraint
but a good fraction of the
parameter sapce is still allowed

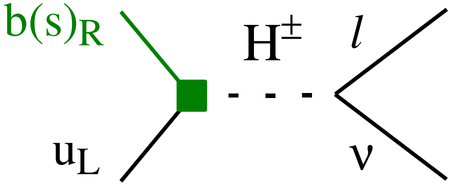




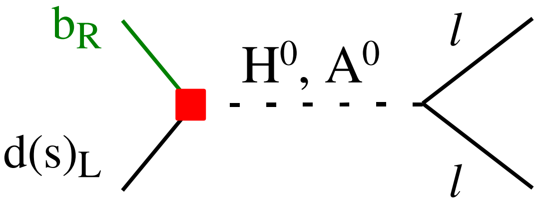
Lunghi, Porod, Vives '06

The flavour constraints at large tanβ

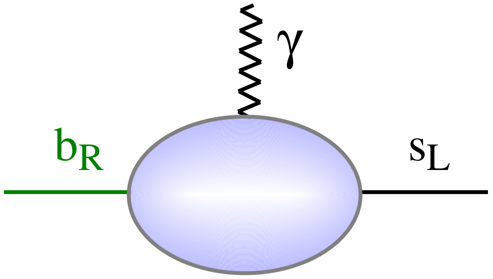
Three most interesting sets of observables:



$P^\pm \to l^\pm \nu$



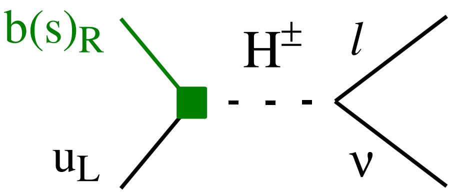
$B_{s,d} \to l^+ l^-$



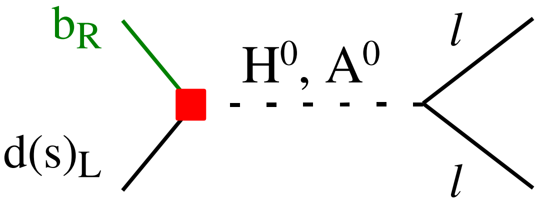
$B \to X_s \gamma$

The flavour constraints at large tanβ

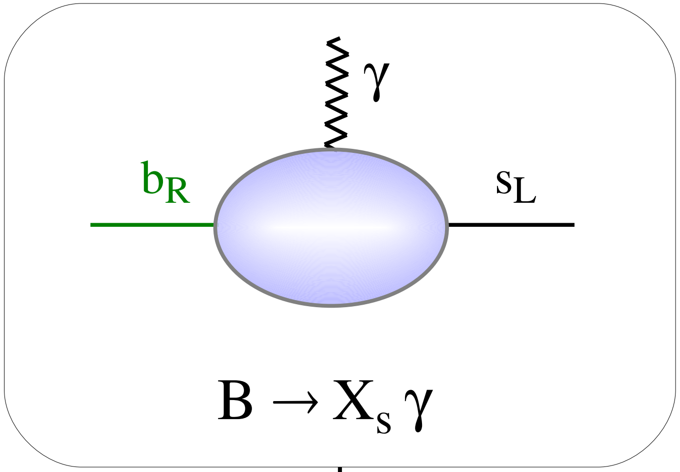
Three most interesting sets of observables:



$P^{\pm} \to l^{\pm}\nu$

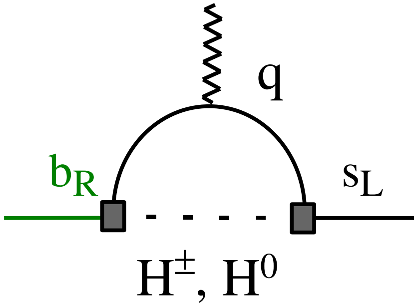


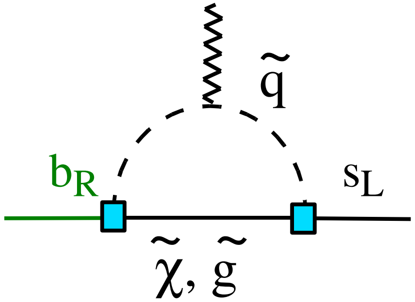
$B_{s,d} \to l^{+} l^{-}$



$B \to X_s\,\gamma$

Most complicated observable with several, naturally competitive, contributions:





- positive
- decreasing with tanβ

- sign ~ sgn(μ,A)
- increasing with tanβ

One of the most significant constraint of the MSSM:

$$B(B \to X_s\gamma)^{\mathrm{exp}} = (3.55 \pm 0.26)\times 10^{-4}$$

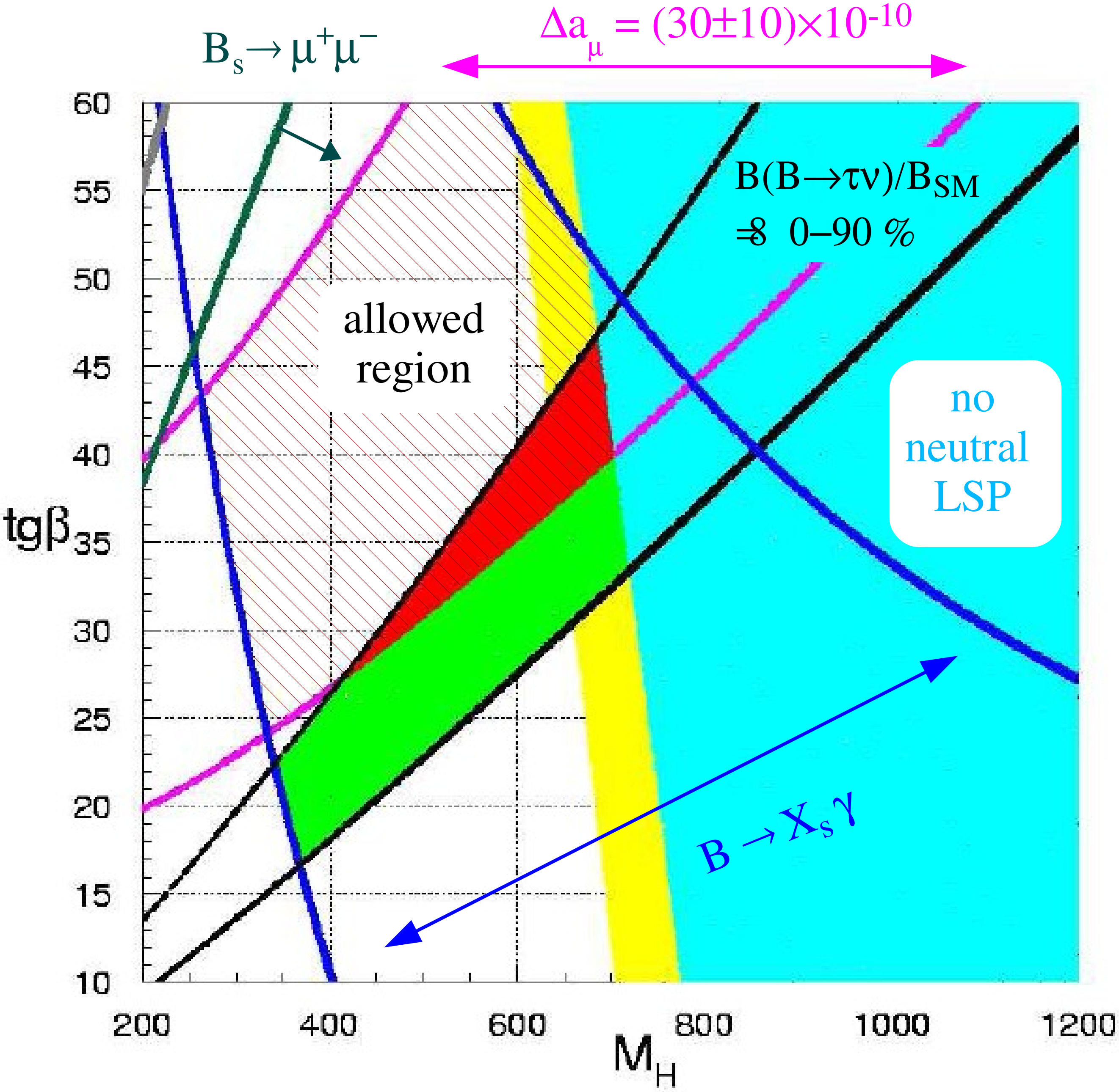
[HFAG '06]

$$B(B \to X_s\gamma)^{\mathrm{SM}} = (3.15 \pm 0.23)\times 10^{-4}$$

[Misiak et al. '06]

E.g.: combined constraints assuming heavy squarks:

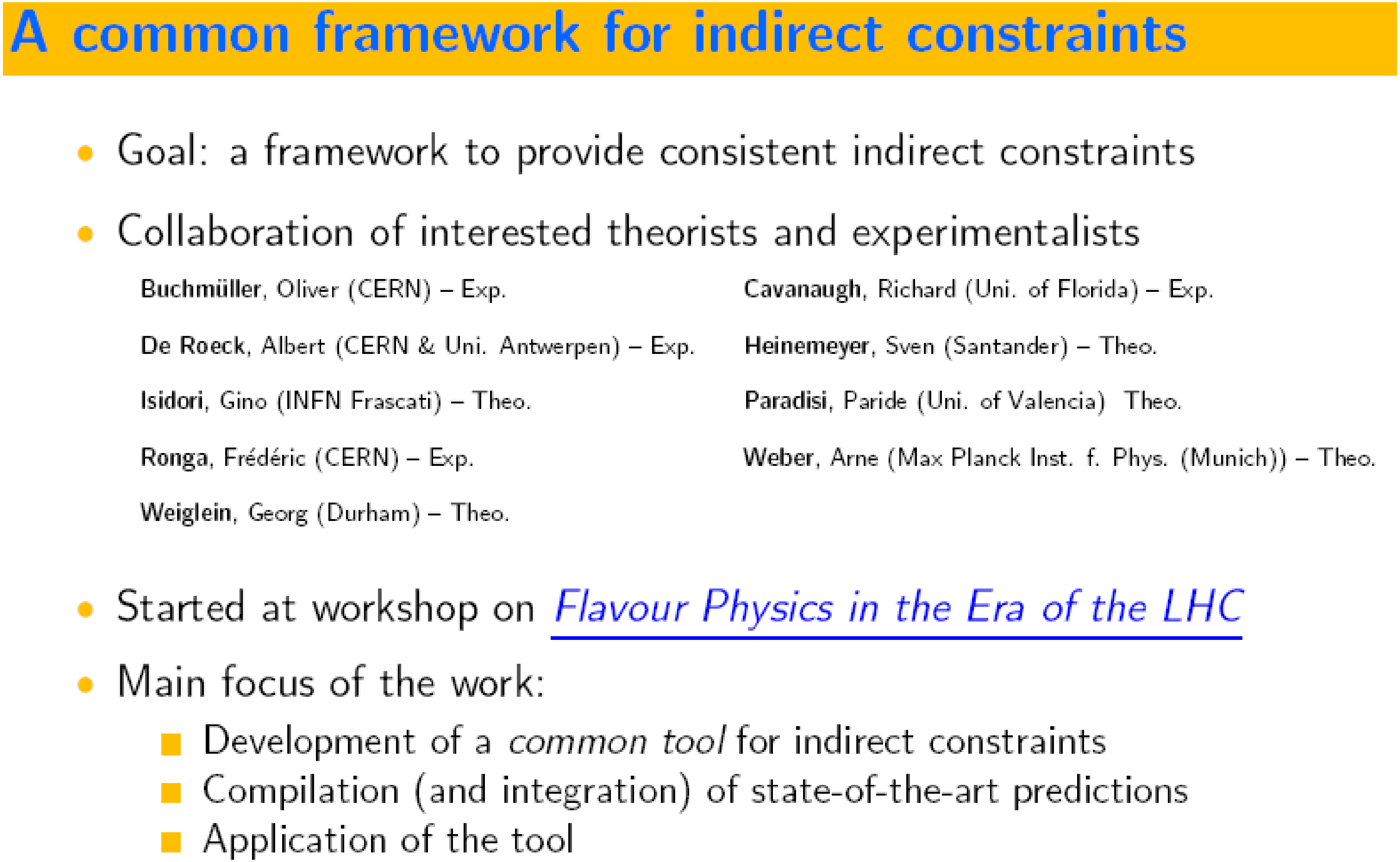
Flavour physics
+ $(g\text{-}2)_\mu$
+ dark matter
(A-funnel region)



$M_{sq} = 1.5$ TeV $M_{sl} = 0.5$ TeV
$A_u = -1.0$ TeV $\mu = 0.5$ TeV

G.I., Mescia, Paradisi, Temes, '07

A global fit in the constrained MSSM



A common framework for indirect constraints

- Goal: a framework to provide consistent indirect constraints
- Collaboration of interested theorists and experimentalists

  Buchmüller, Oliver (CERN) – Exp.

  De Roeck, Albert (CERN & Uni. Antwerpen) – Exp.

  Isidori, Gino (INFN Frascati) – Theo.

  Ronga, Frédéric (CERN) – Exp.

  Weiglein, Georg (Durham) – Theo.

  Cavanaugh, Richard (Uni. of Florida) – Exp.

  Heinemeyer, Sven (Santander) – Theo.

  Paradisi, Paride (Uni. of Valencia) Theo.

  Weber, Arne (Max Planck Inst. f. Phys. (Munich)) – Theo.

- Started at workshop on *Flavour Physics in the Era of the LHC*
- Main focus of the work:
  - Development of a *common tool* for indirect constraints
  - Compilation (and integration) of state-of-the-art predictions
  - Application of the tool

A global fit in the constrained MSSM

Given the limited number of positive constraints, we started from the global analysis of a simplified scenario (even simpler than MSSM with MFV): the CMSSM (also known as mSUGRA):

⇒ Scenario characterized by

$$m_0,\ m_{1/2},\ A_0,\ \tan\beta,\ \mathrm{sign}\,\mu$$

m_0 : universal scalar mass parameter

$m_{1/2}$: universal gaugino mass parameter

A_0 : universal trilinear coupling

at the GUT scale

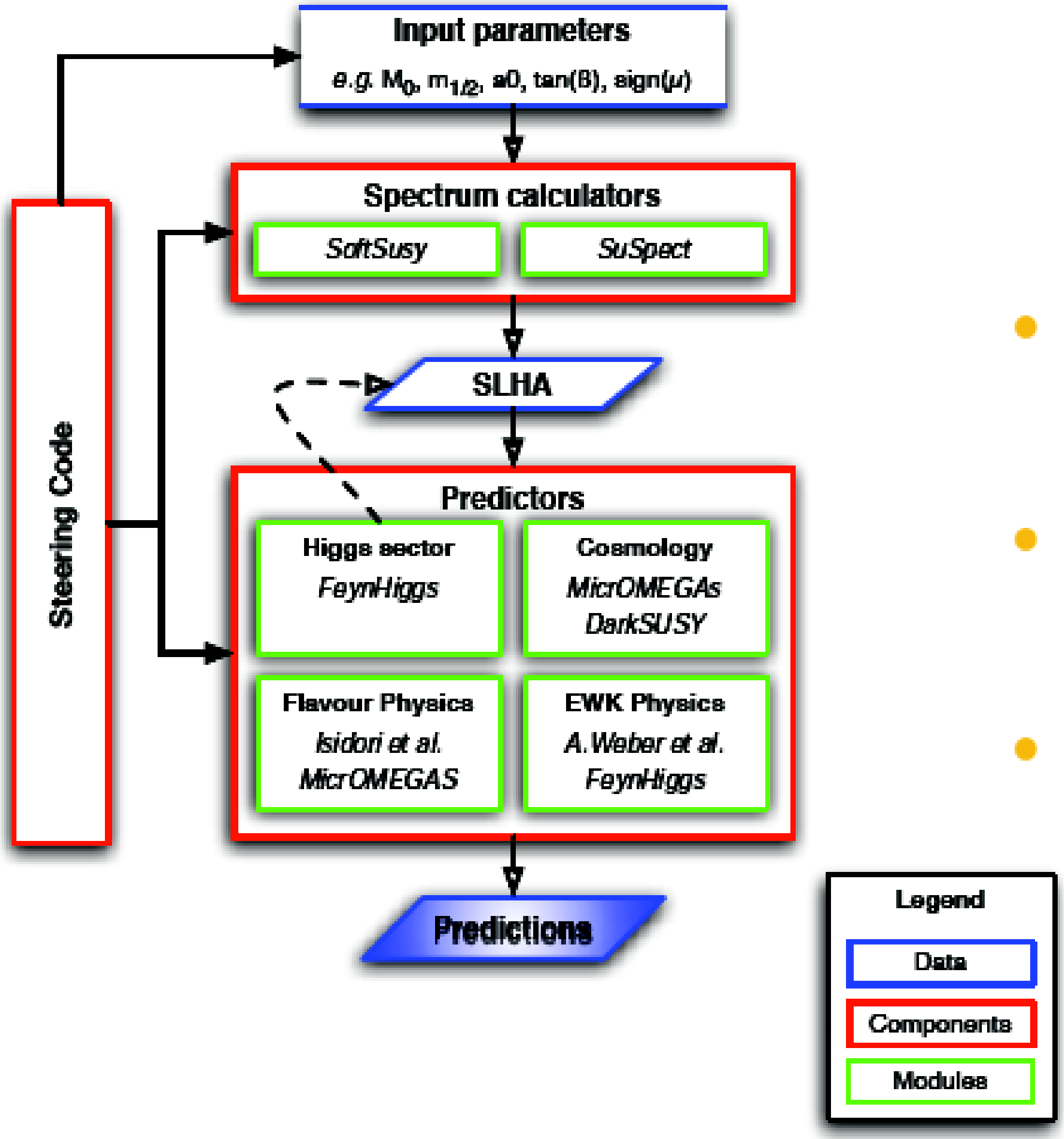
$\tan\beta$: ratio of Higgs vacuum expectation values

$\mathrm{sign}(\mu)$: sign of supersymmetric Higgs parameter

⇒ particle spectra from renormalization group running to weak scale

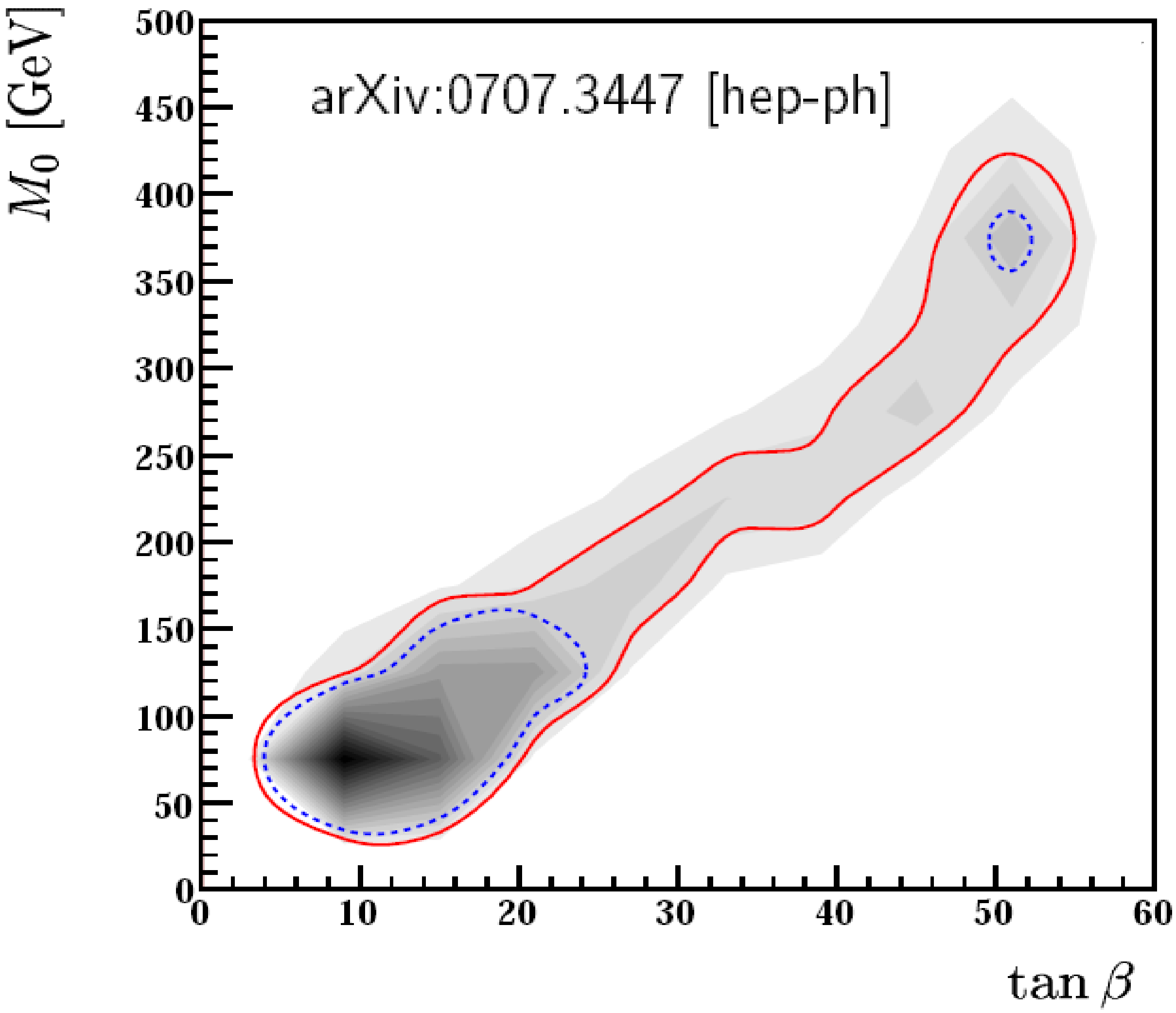
Lightest SUSY particle (LSP) is the lightest neutralino

Flow-chart: general overview



- Consistency
  Ensured using SLHA interface
- Flexibility
  Add/remove predictions
- Modularity
  Compare various calculations

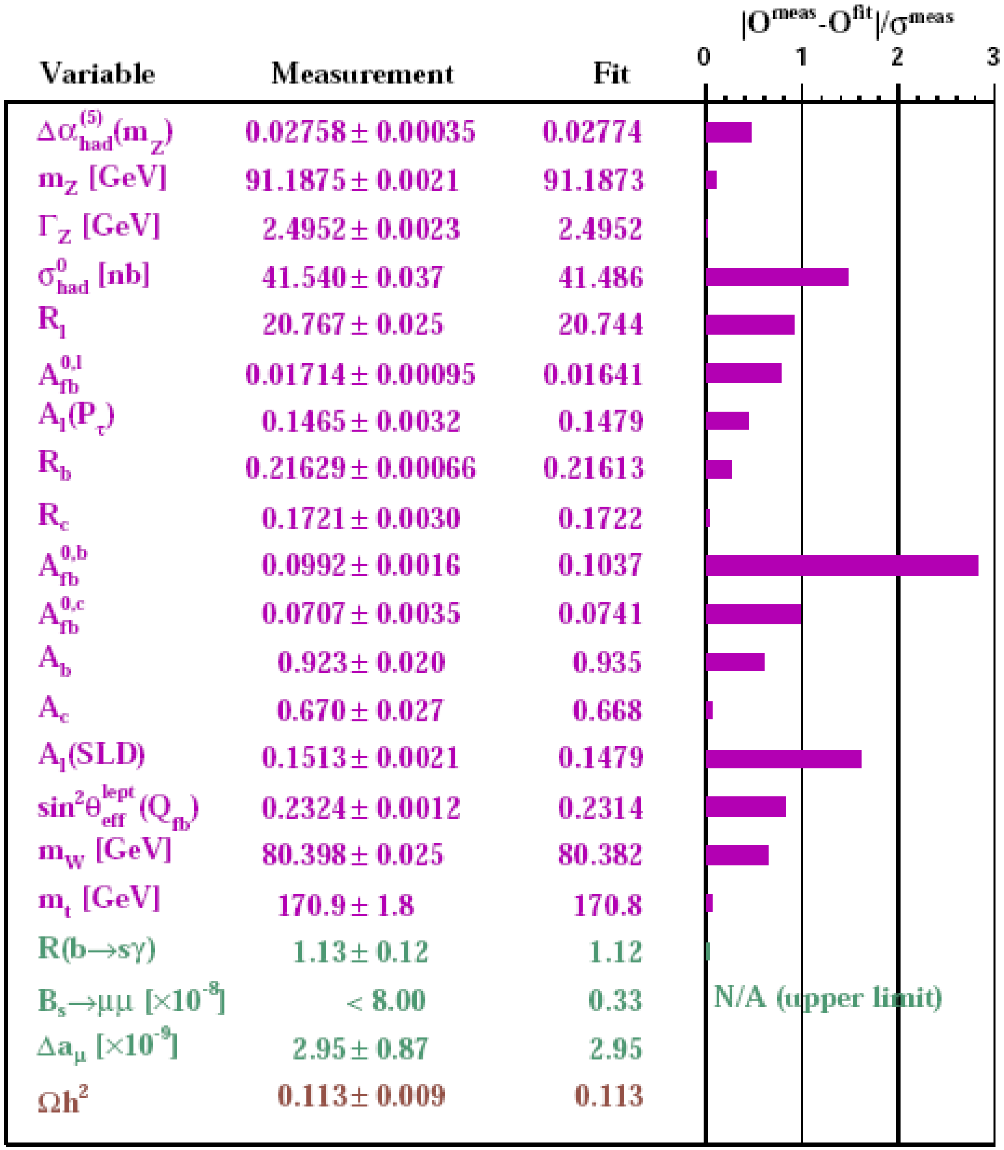
- Multi-parameter χ^2 fit
- fitting for all CMSSM parameters: M_0, $M_{1/2}$, A_0, $\tan\beta$;
- including relevant SM uncertainties (*e.g.* m_{top});



- overall preferred minimum at low $\tan\beta$, low squark mass;
- less preferred region at high $\tan\beta$, higher squark mass;
- consistent with previous studies.

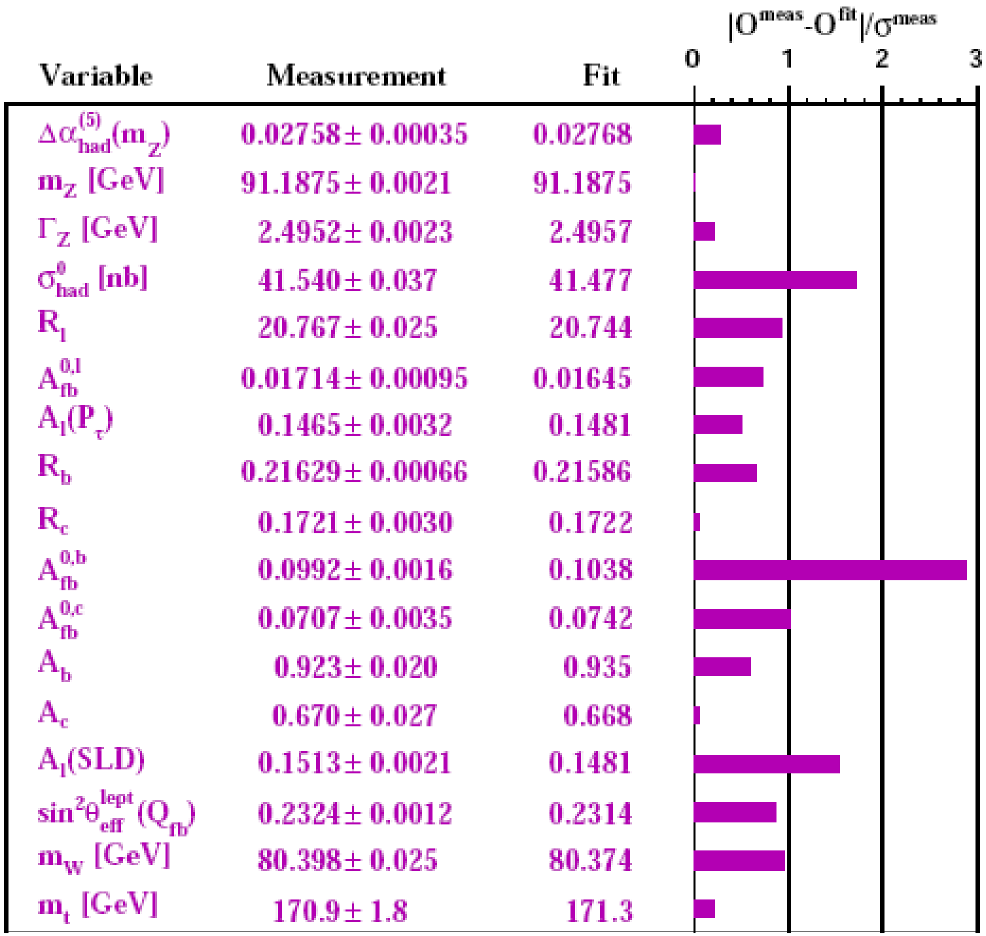
Key roles played by
$(g\text{-}2)_\mu$, Ω_{CDM} & $B \to X_s \gamma$

CMSSM



Variable	Measurement	Fit	$\vert O^{meas}-O^{fit}\vert/\sigma^{meas}$
$\Delta\alpha^{(5)}_{had}(m_Z)$	0.02758 ± 0.00035	0.02774	
m_Z [GeV]	91.1875 ± 0.0021	91.1873	
Γ_Z [GeV]	2.4952 ± 0.0023	2.4952	
σ^0_{had} [nb]	41.540 ± 0.037	41.486	
R_l	20.767 ± 0.025	20.744	
$A^{0,l}_{fb}$	0.01714 ± 0.00095	0.01641	
$A_l(P_\tau)$	0.1465 ± 0.0032	0.1479	
R_b	0.21629 ± 0.00066	0.21613	
R_c	0.1721 ± 0.0030	0.1722	
$A^{0,b}_{fb}$	0.0992 ± 0.0016	0.1037	
$A^{0,c}_{fb}$	0.0707 ± 0.0035	0.0741	
A_b	0.923 ± 0.020	0.935	
A_c	0.670 ± 0.027	0.668	
A_l(SLD)	0.1513 ± 0.0021	0.1479	
$\sin^2\theta^{lept}_{eff}(Q_{fb})$	0.2324 ± 0.0012	0.2314	
m_W [GeV]	80.398 ± 0.025	80.382	
m_t [GeV]	170.9 ± 1.8	170.8	
$R(b\to s\gamma)$	1.13 ± 0.12	1.12	
$B_s\to\mu\mu$ [$\times 10^{-8}$]	< 8.00	0.33	N/A (upper limit)
Δa_μ [$\times 10^{-9}$]	2.95 ± 0.87	2.95	
Ωh^2	0.113 ± 0.009	0.113	

SM



Variable	Measurement	Fit	$\vert O^{meas}-O^{fit}\vert/\sigma^{meas}$
$\Delta\alpha^{(5)}_{had}(m_Z)$	0.02758 ± 0.00035	0.02768	
m_Z [GeV]	91.1875 ± 0.0021	91.1875	
Γ_Z [GeV]	2.4952 ± 0.0023	2.4957	
σ^0_{had} [nb]	41.540 ± 0.037	41.477	
R_l	20.767 ± 0.025	20.744	
$A^{0,l}_{fb}$	0.01714 ± 0.00095	0.01645	
$A_l(P_\tau)$	0.1465 ± 0.0032	0.1481	
R_b	0.21629 ± 0.00066	0.21586	
R_c	0.1721 ± 0.0030	0.1722	
$A^{0,b}_{fb}$	0.0992 ± 0.0016	0.1038	
$A^{0,c}_{fb}$	0.0707 ± 0.0035	0.0742	
A_b	0.923 ± 0.020	0.935	
A_c	0.670 ± 0.027	0.668	
A_l(SLD)	0.1513 ± 0.0021	0.1481	
$\sin^2\theta^{lept}_{eff}(Q_{fb})$	0.2324 ± 0.0012	0.2314	
m_W [GeV]	80.398 ± 0.025	80.374	
m_t [GeV]	170.9 ± 1.8	171.3	

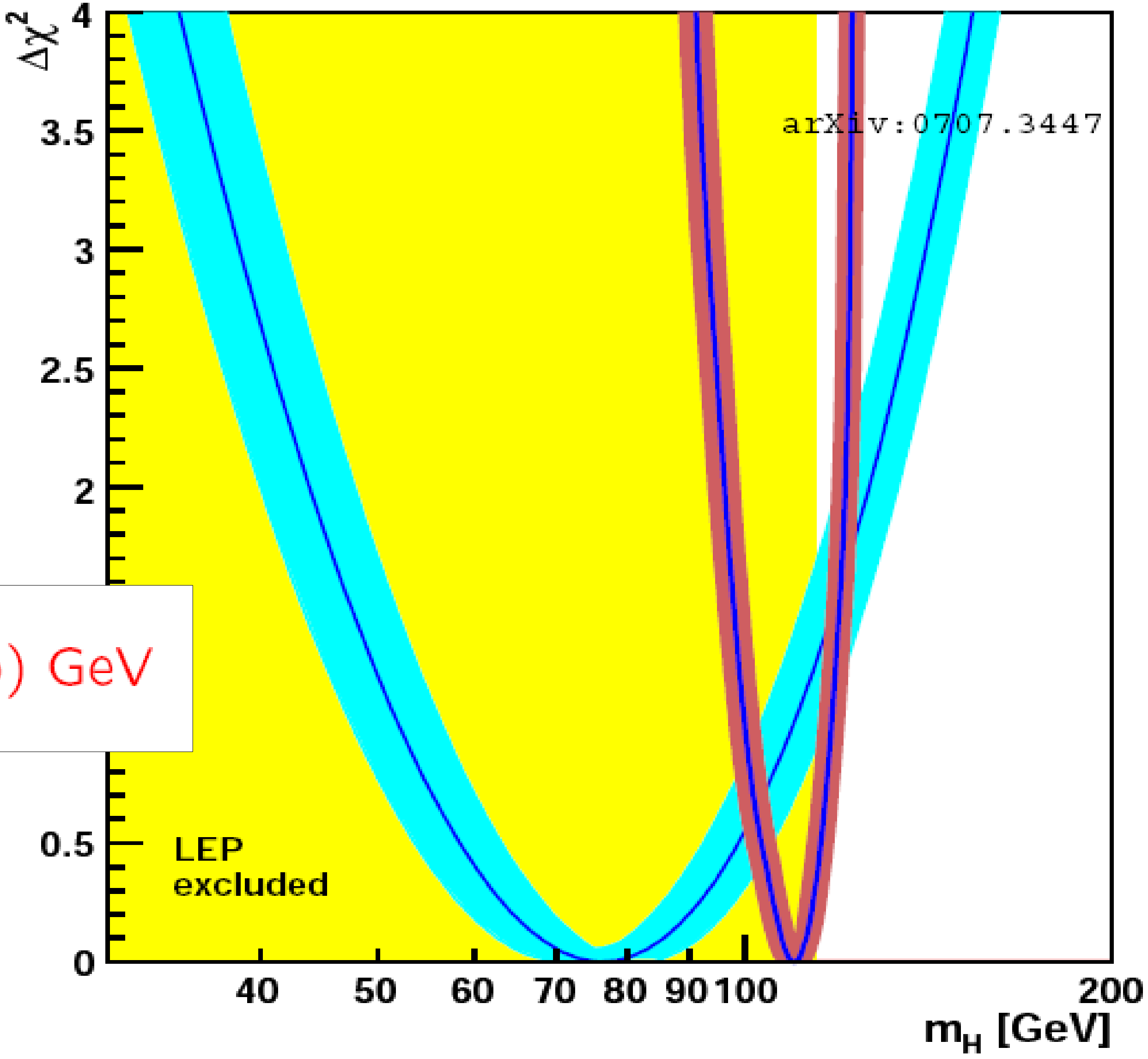
(same number
of d.o.f)

Probabilities from the χ^2 analysis: 24% / 20% 12% / 15% incl. / excl. M_h

Despite its simplicity,
the CMSSM is in (slightly)
better shape with respect
to the SM:

Prediction of the CMSSM fit
<u>without</u> using the LEP limit:

$$M_h = 110^{+8}_{-10}\,(\mathrm{exp}) \pm 3(\mathrm{theo})\ \mathrm{GeV}$$

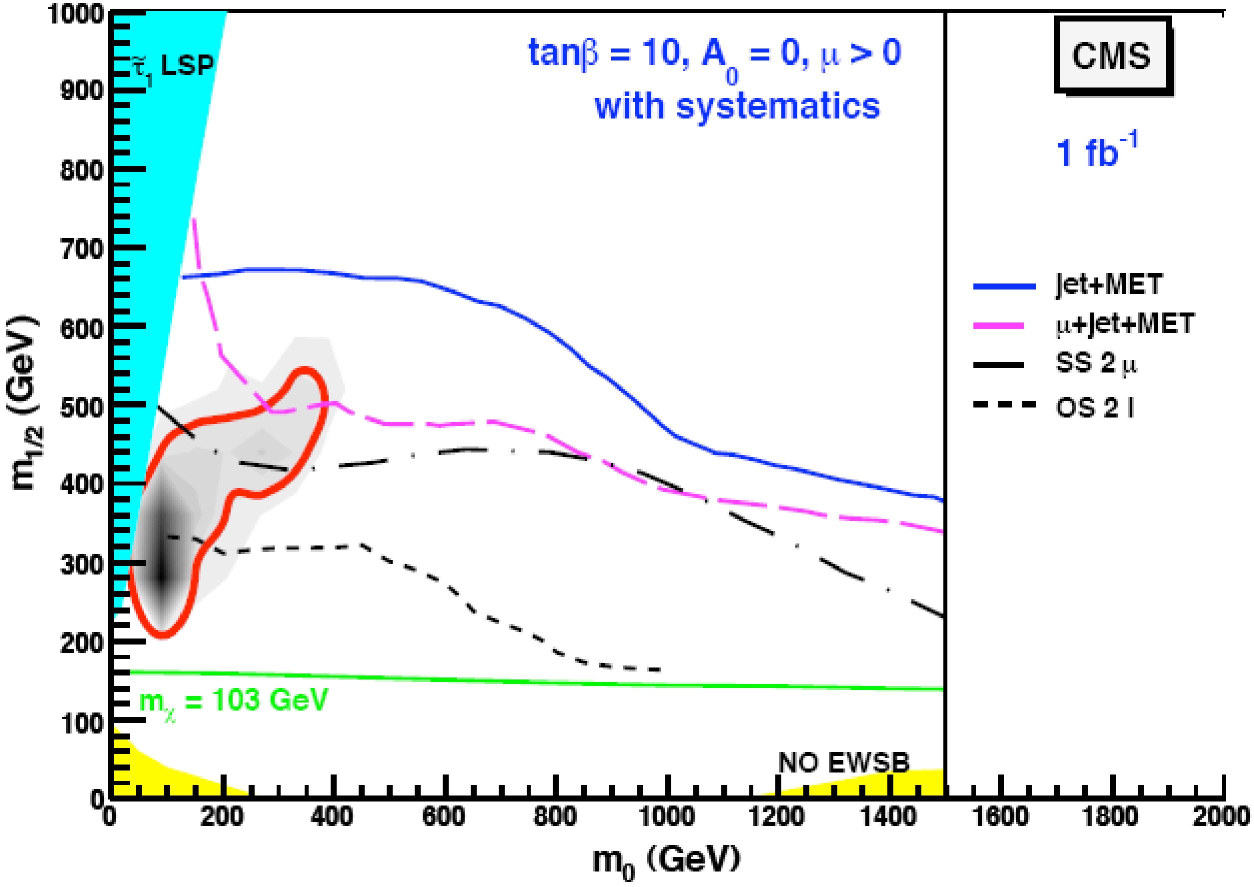


The central value moves up to ~ 120 GeV if we restrict the attention to the large tanβ solution (the second minimum of the fit)

Such a light Higgs will not be easy for the LHC...

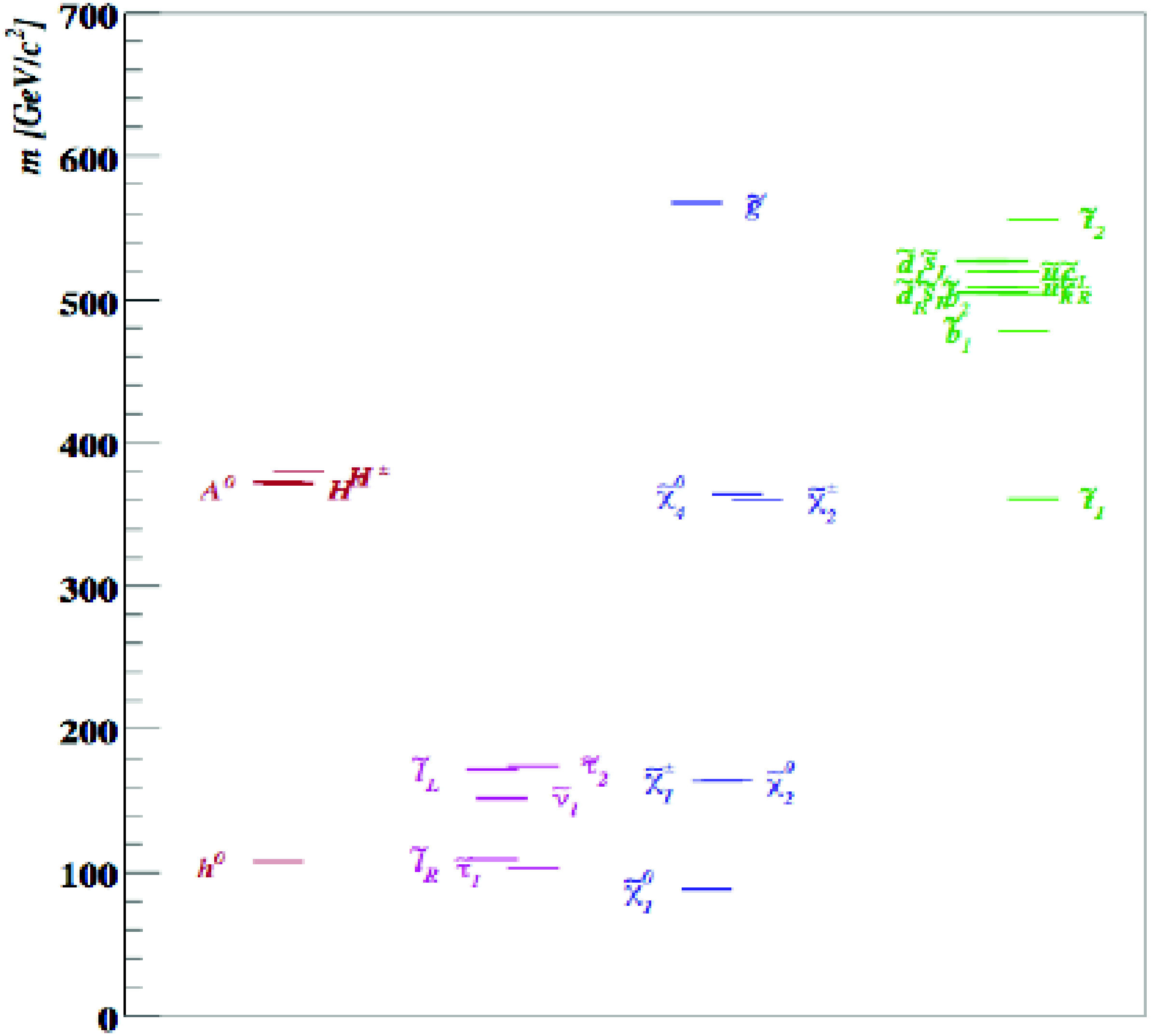
...but if this scenario is correct we should expect clear SUSY signals:

CMS early discovery reach for 1 fb^{-1} (ATLAS similar)



- 5σ discovery reach
- 95% contour (arXiv:0707.3447)

"best CMSSM Fit"



M0	M12	A0	tb
49.2	232.3	-122.4	6.9

Ma=372 GeV; mu=336 GeV; mh=111 GeV

Conclusions

- The MSSM is in good shape !
  Even within its most constrained form, it gives a good fit to present data and solves various phenomenological problems of the SM

- Indirect constraints plays a key role in determining the structure of the model (and will continue to be very relevant also in the LHC era)

- In the CMSSM the preferred region of the parameter space indicates a light Higgs just above the LEP exclusion bound,and light charginos and neutralinos well within the LHC reach

- Work in progress to understand how solid is this conclusion in more general versions of the model (the large $\tan\beta$ region seems particularly favored in scenarios where the universality assumption between squarks, sleptons and Higgs soft-breaking terms is relaxed)