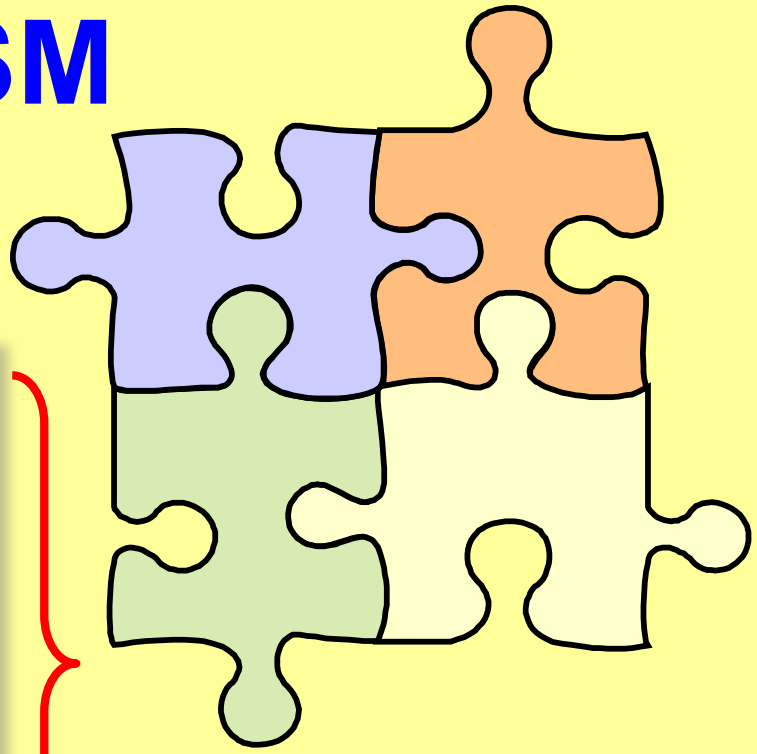
Constrained MSSM



Requirements:

- Unification of the gauge couplings
- Radiative EW Symmetry Breaking
- Heavy quark and lepton masses
- Rare decays (b -> sγ, b->μμ)
- Anomalous magnetic moment of muon
- LSP is neutral
- Amount of the Dark Matter
- Experimental limits from direct search

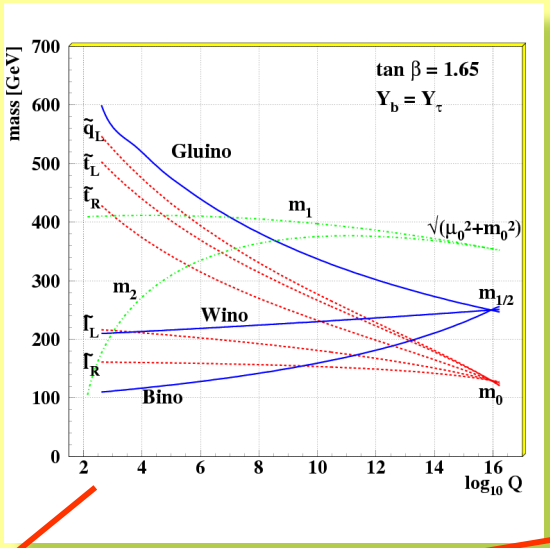
$$A_0, m_0, M_{1/2}, \mu, \tan\beta$$

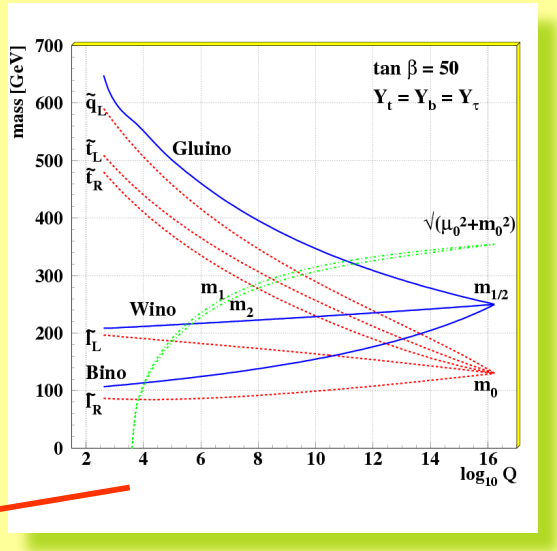
Allowed region
in the parameter
space of the MSSM

$$100\ \text{GeV} \le m_0, M_{1/2}, \mu \le 2\ \text{TeV}$$

$$-3m_0 \le A_0 \le 3m_0,\ 1 \le \tan\beta \le 70$$

Radiative EW Symmetry Breaking





$$\frac{M_Z^2}{2} = -\mu^2 + \frac{m_{H_1}^2 - m_{H_2}^2 \tan^2\beta}{\tan^2\beta - 1}$$

$\Rightarrow$ μ^2 { For given $\tan\beta$ and m_0 and $m_{1/2}$

$$\underbrace{m_{H_1} \sim m_{H_1} \sim m_0}_{\text{Soft SUSY parameters}} \sim 1\ \text{TeV} \Rightarrow \underbrace{\mu \sim 1\ \text{TeV}}_{\text{Hard SUSY parameter}}$$

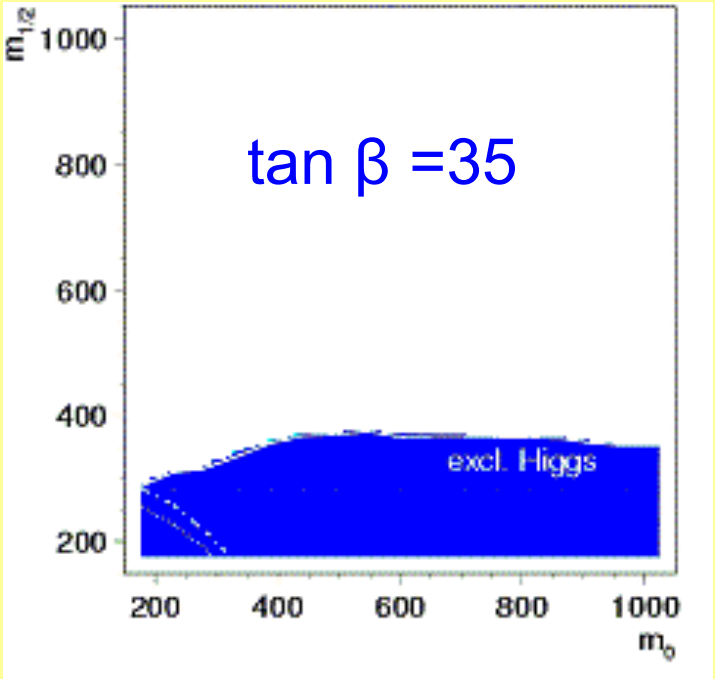
μ - problem

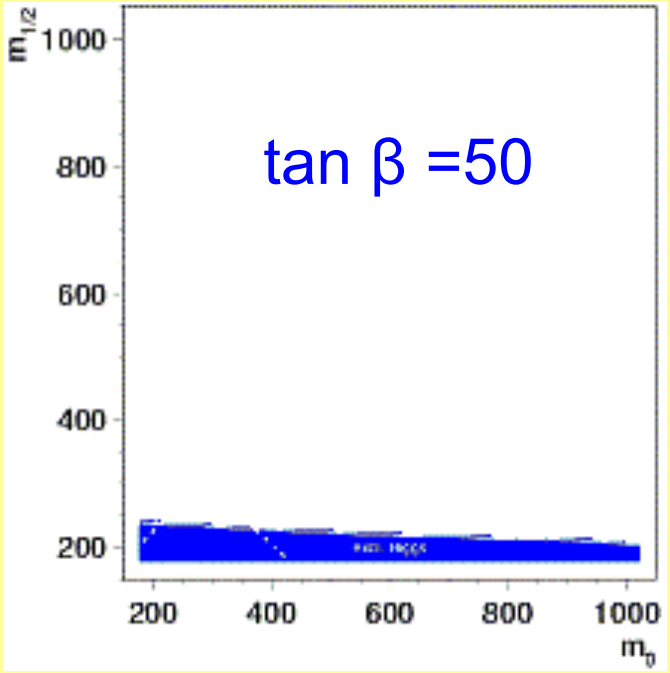
Constrained MSSM (Choice of constraints)

Experimental lower limits on Higgs and superparticle masses

Regions excluded by Higgs experimental limits provided by LEP2

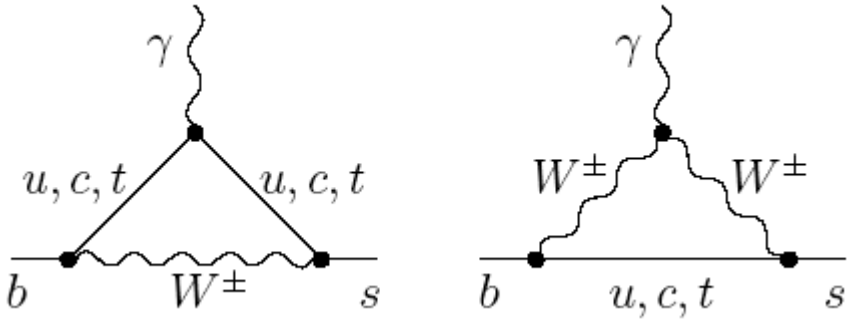
$$m_{Higgs} \geq 114.3 \text{ GeV}$$



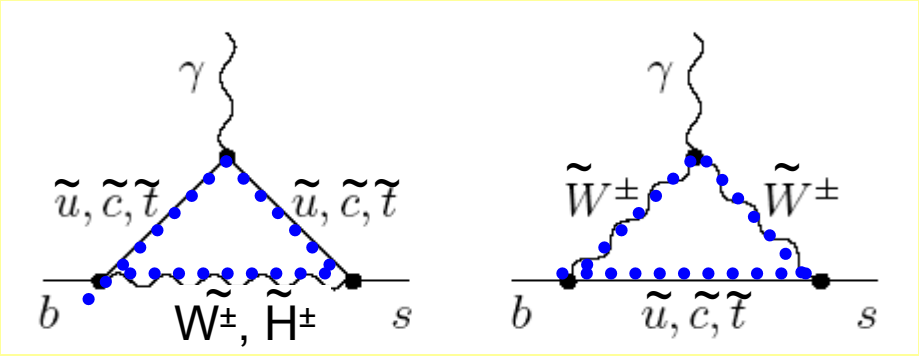


B->s γ decay rate

Standard Model



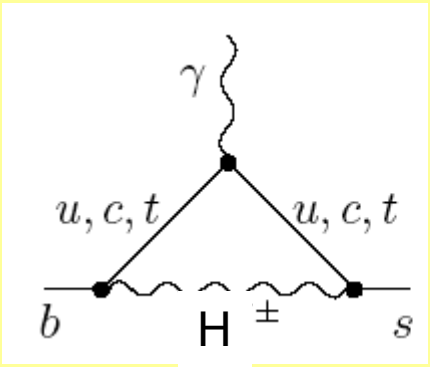
MSSM



SM: $\mathcal{B}(B \to X_s\gamma) = (3.28 \pm 0.33) \times 10^{-4}$.

MSSM

$$\mathcal{BR}(b \to s\gamma)|_{\chi^\pm} \propto \mu A_t \tan\beta f(m_{\tilde{t}_1}, m_{\tilde{t}_2}, m_{\tilde{\chi}^+}) \frac{m_b}{v(1+\Delta m_b)}$$



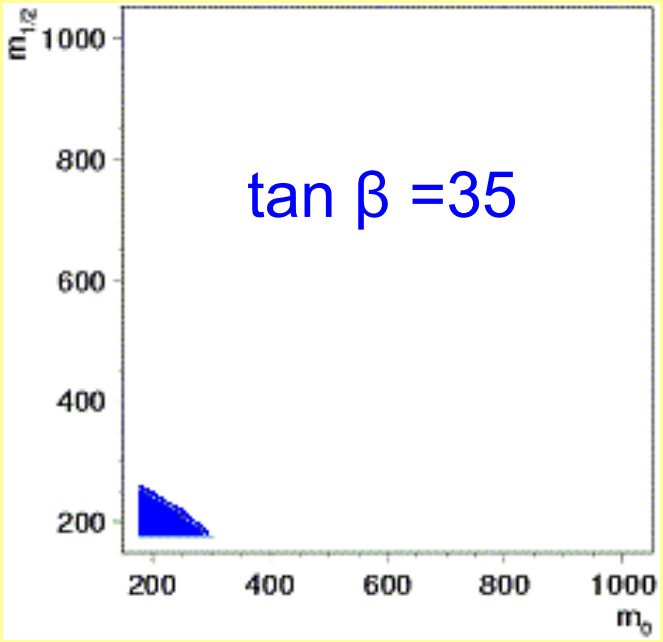
Experiment $B(B \to X_s\gamma) = (3.43 \pm 0.36) \cdot 10^{-4}$

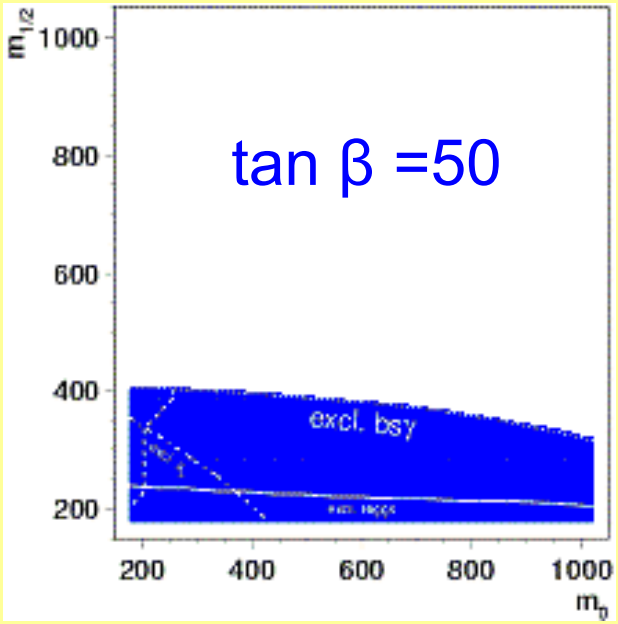
Constrained MSSM (Choice of constraints)

Data on rare processes branching ratios

$$B(B \to X_s\gamma) = (3.43 \pm 0.36) \cdot 10^{-4}$$

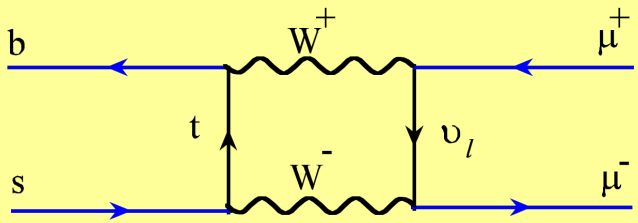
Regions excluded by experimental limits (for large tanβ)

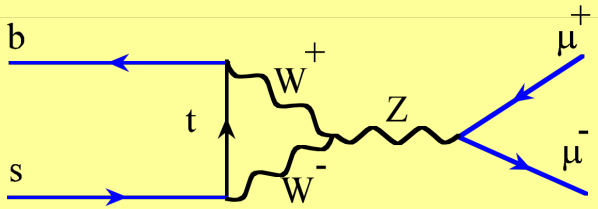




Rare Decay Bs → μ+ μ-

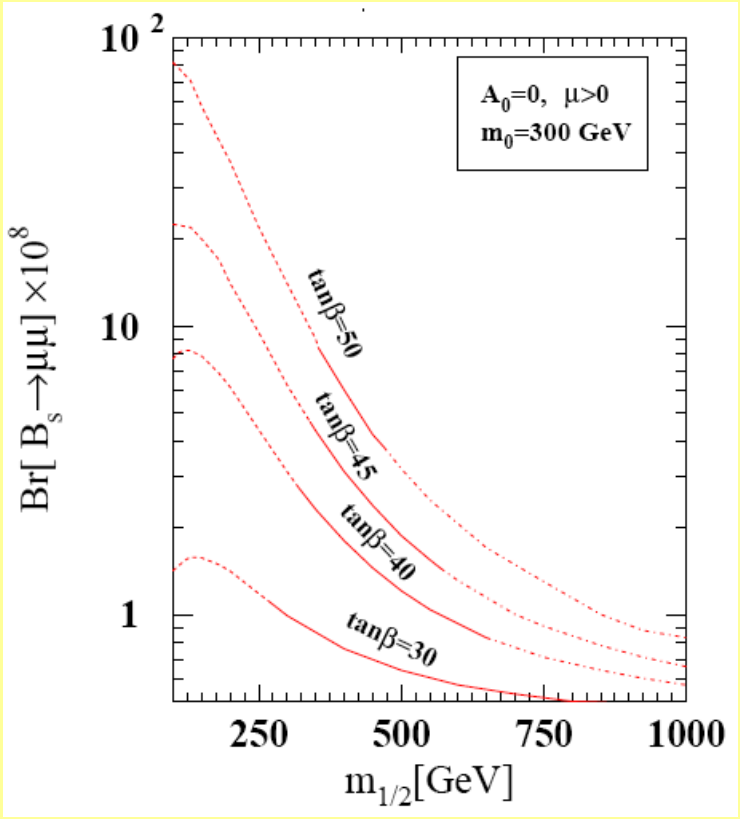
SM



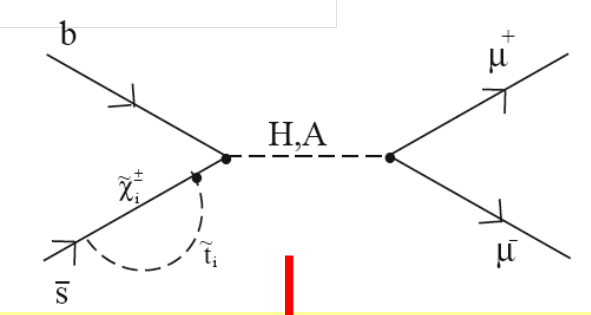


SM: Br=3.5·10^{-9}

Ex: <4.5· 10^{-8}



Main SYSY contribution



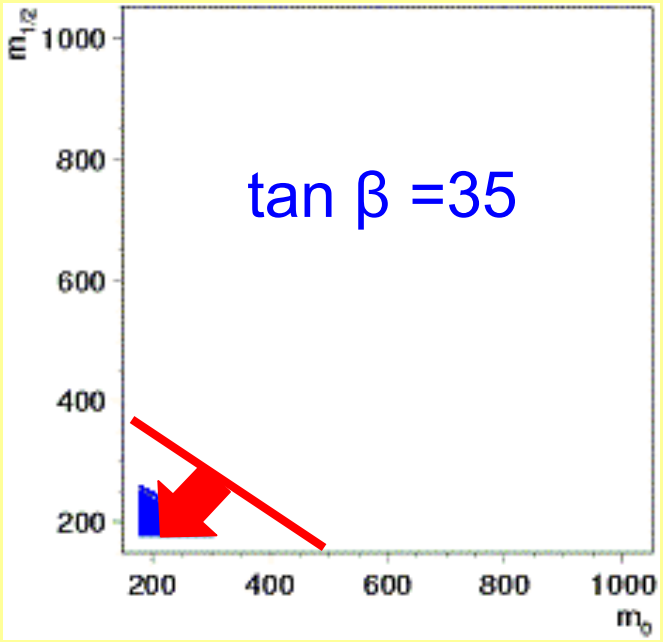
$$Br[B_s \to \mu^+\mu^-] \sim \left| \frac{G_F \alpha}{\sqrt{2}\pi} V_{tb} V_{ts}^* \left(\frac{\tan^3 \beta}{4 \sin^2 \theta_W} \right) \left(\frac{m_b m_\mu m_t \mu}{M_W^2 M_A^2} \right) \frac{\sin 2\theta_{\tilde{t}}}{2} \left(\frac{m_{\tilde{t}_1}^2 \log\left[\frac{m_{\tilde{t}_1}^2}{\mu^2}\right]}{\mu^2 - m_{\tilde{t}_1}^2} - \frac{m_{\tilde{t}_2}^2 \log\left[\frac{m_{\tilde{t}_2}^2}{\mu^2}\right]}{\mu^2 - m_{\tilde{t}_2}^2} \right) \right|^2$$

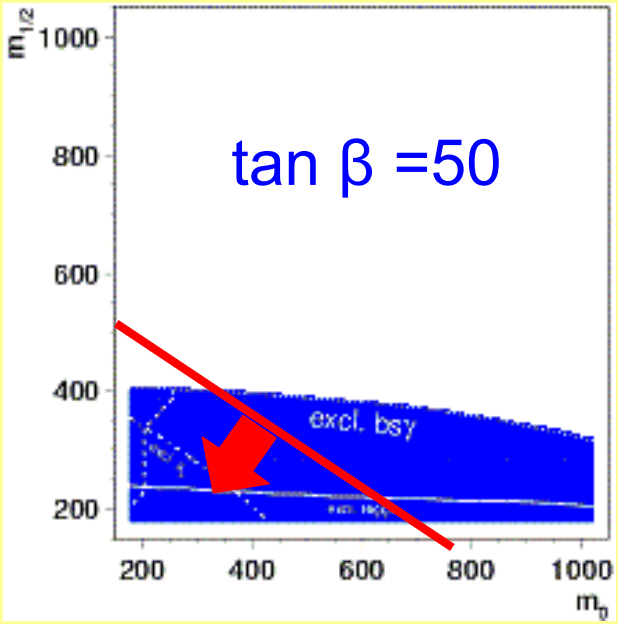
Constrained MSSM (Choice of constraints)

Data on rare processes branching ratios

$$B(Bs \to \mu^+\mu^-) < 3.7 \cdot 10^{-7}$$

Regions excluded by experimental limits (for large tanβ)





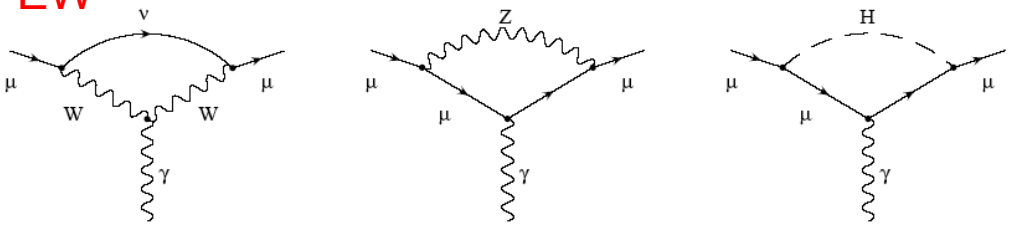
Anomalous magnetic moment

$$a_\mu^{exp} = 11\,659\,202\,(14)(6)\cdot 10^{-10}$$
$$a_\mu^{SM} = 11\,659\,159.6\,(6.7)\cdot 10^{-10}$$

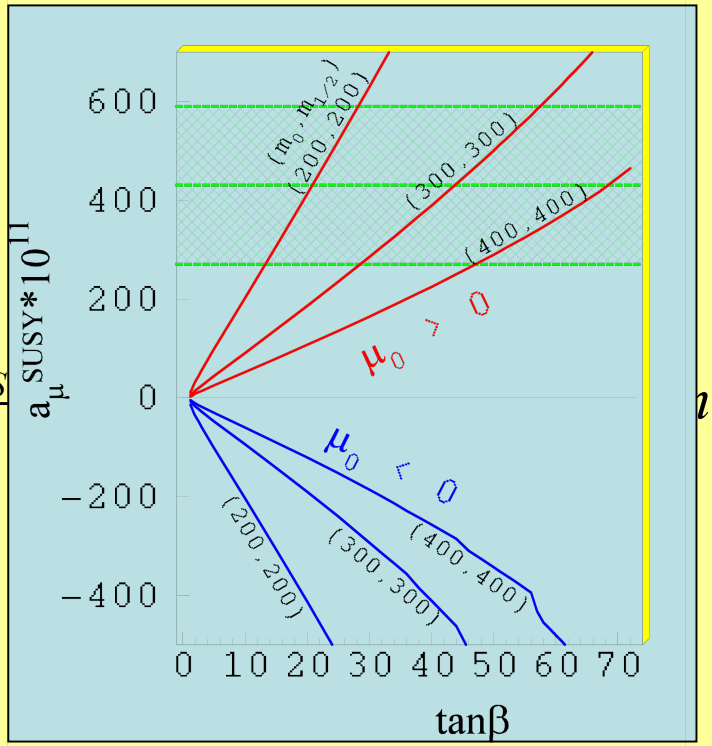
$$a_\mu^{exp} - a_\mu^{SM} = (\ 27\pm10\ )\cdot 10^{-10}$$

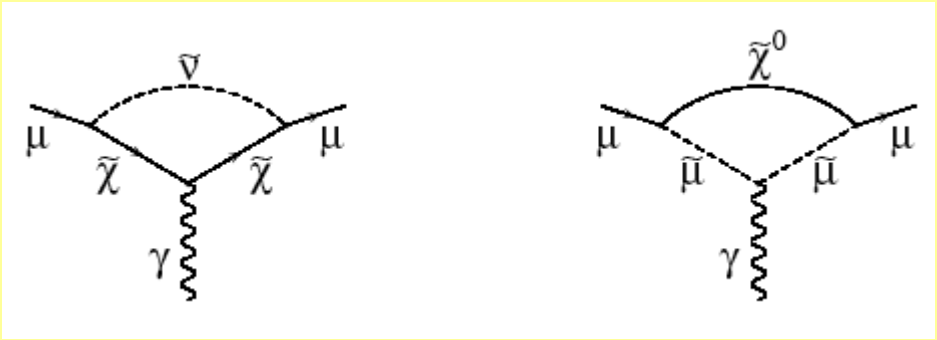
$$\begin{aligned} a_\mu^{QED} &= 11\,658\,470.56\,(0.29)\cdot 10^{-10} \\ a_\mu^{weak} &= 15.1\,(0.4)\cdot 10^{-10} \\ a_\mu^{hadr} &= 673.9\,(6.7)\cdot 10^{-10} \end{aligned}$$

EW



$$|\,a_\mu^{SUSY}\,| \simeq \frac{\alpha(M_Z)}{8\pi Sin^2\theta_W}\frac{m_\mu^2}{M_{SUSY}^2} tan\beta\,(1-\frac{4\alpha}{\pi} log\frac{M_{SUS}}{m_\mu}$$ ...β



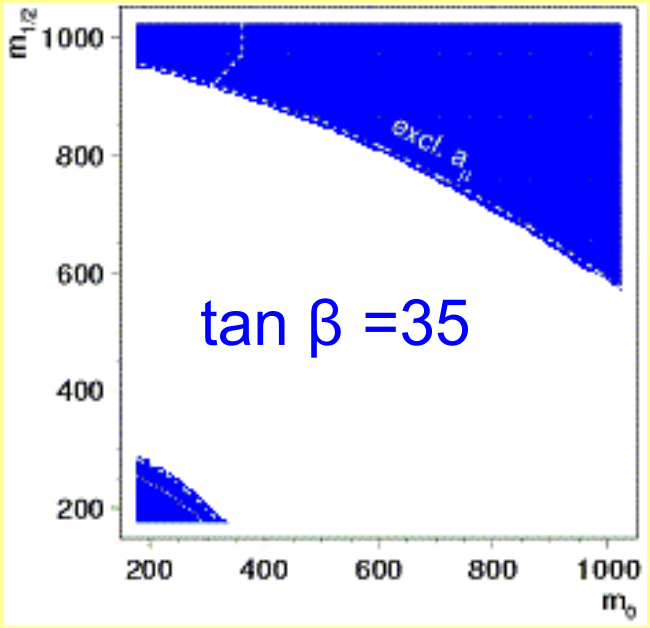


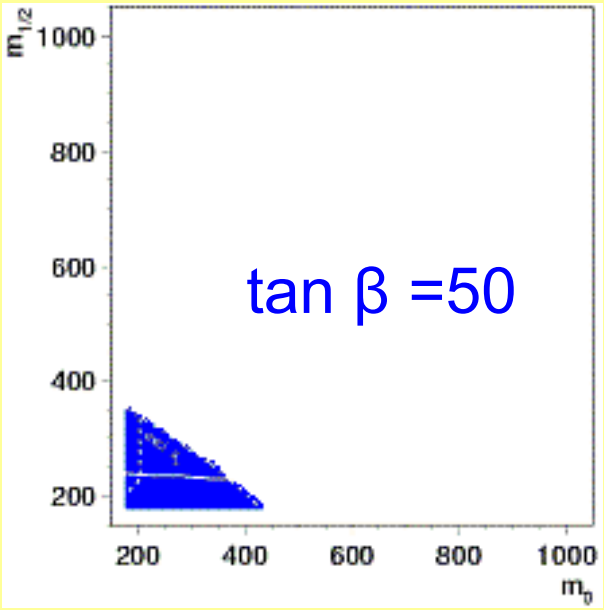
Constrained MSSM (Choice of constraints)

Muon anomalous magnetic moment

$$\Delta a_\mu = a_\mu^{\exp} - a_\mu^{th} = (27 \pm 10) \cdot 10^{-10}$$

Regions excluded by muon amm constraint



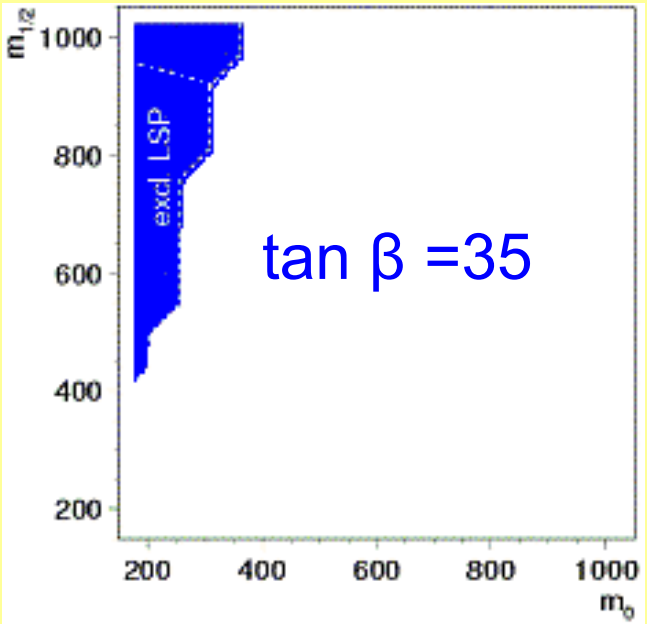


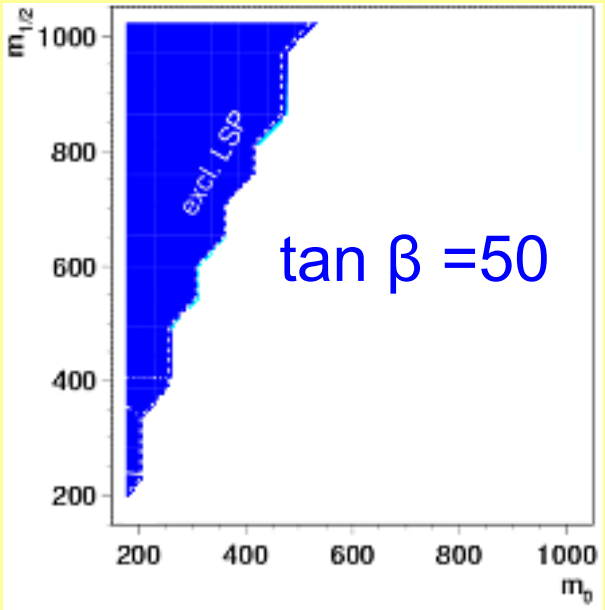
Constrained MSSM (Choice of constraints)

The lightest supersymmetric particle (LSP) is neutral.

This constraint is a consequence of *R*-parity conservation requirement

Regions excluded by LSP constraint

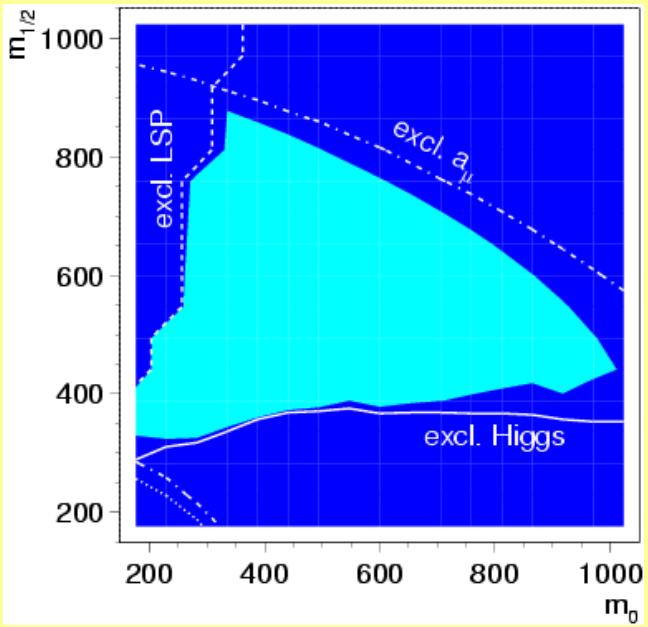




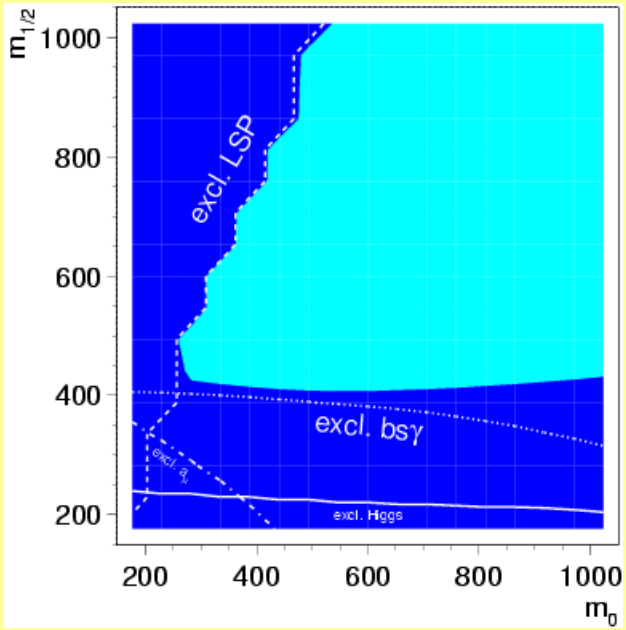
Favoured regions of parameter space

Pre-WMAP allowed regions in the parameter space.

From the Higgs searches tan β >4, from a_μ measurements μ >0

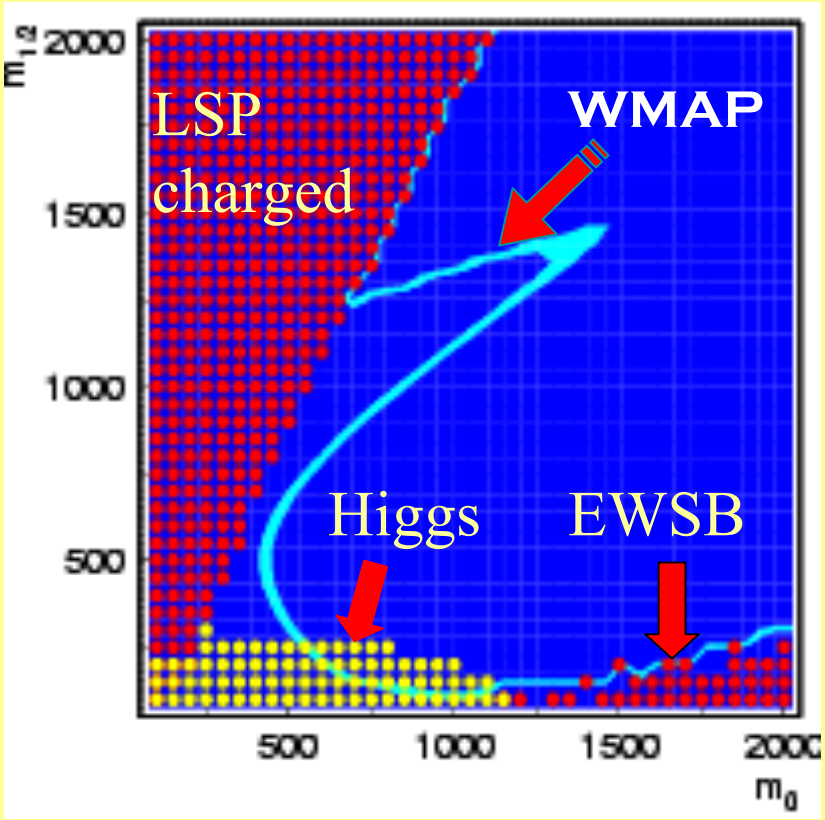


tan β =35



tan β =50

Allowed regions after WMAP



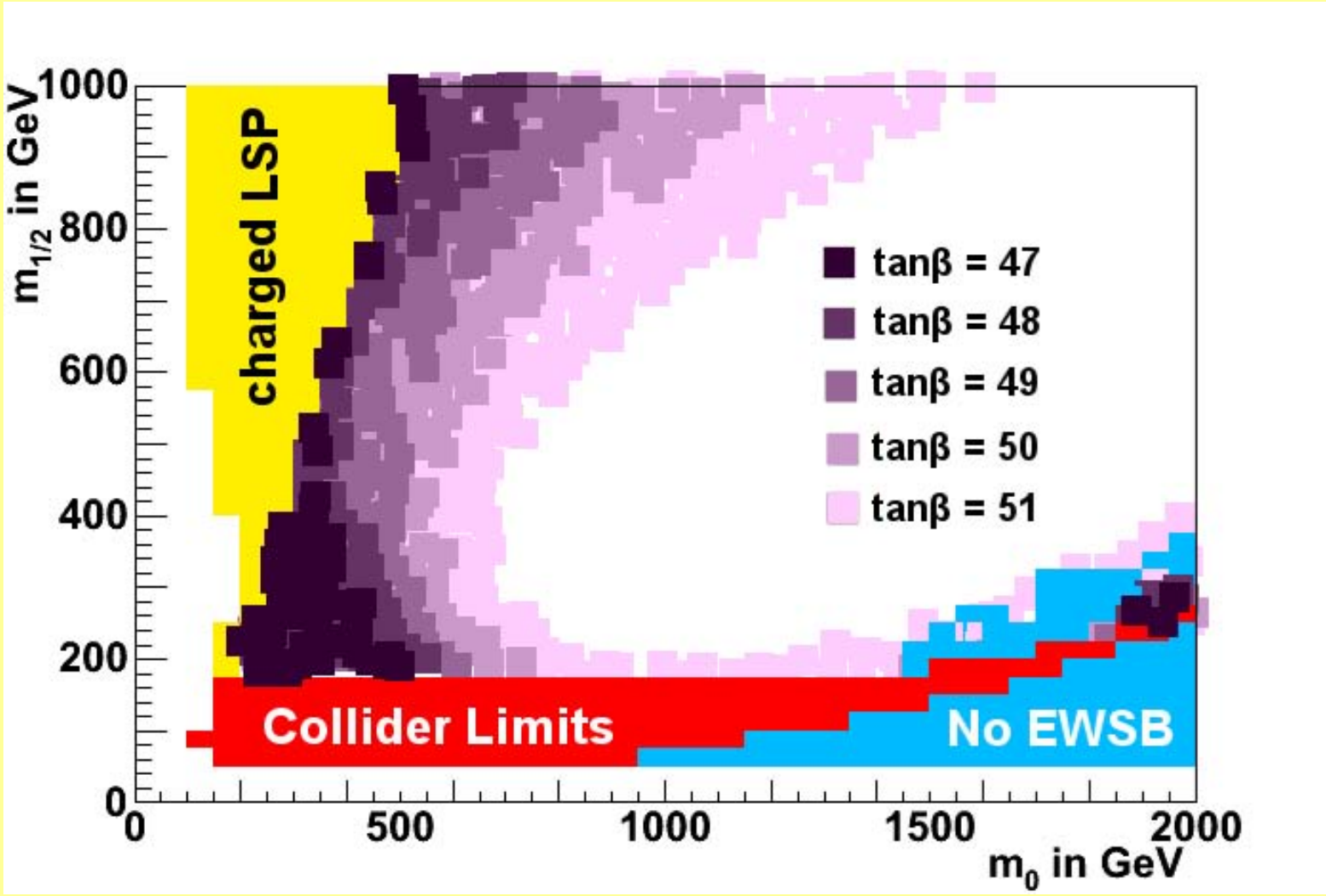
tan β =50

In allowed region one fulfills all the constraints simultaneously and has the suitable amount of the dark matter

Narrow allowed region enables one to predict the particle spectra and the main decay patterns

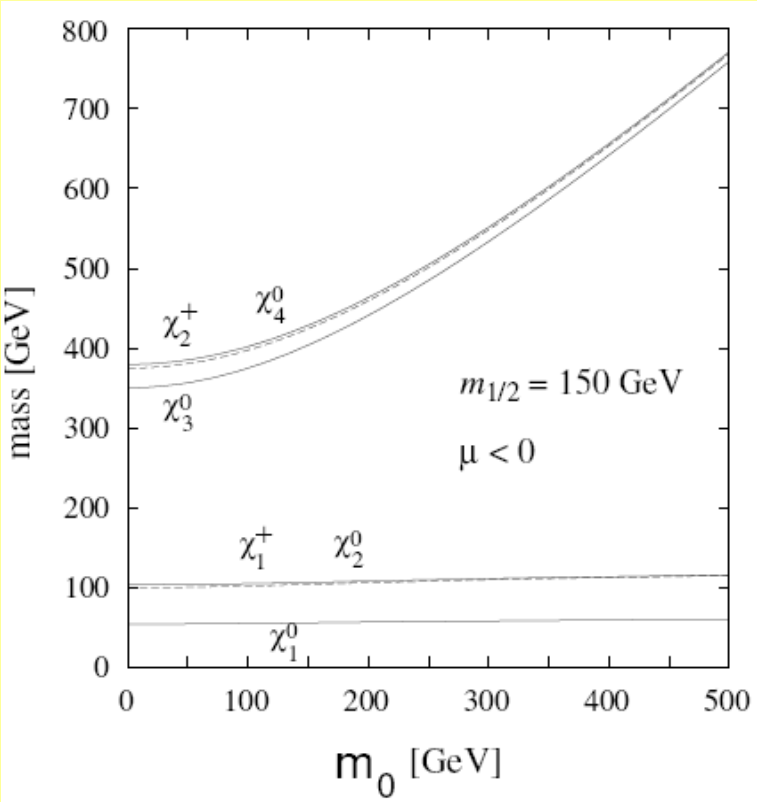
Phenomenology essentially depends on the region of parameter space and has direct influence on the strategy of SUSY searches

Global Fit to data in full Parameter Space

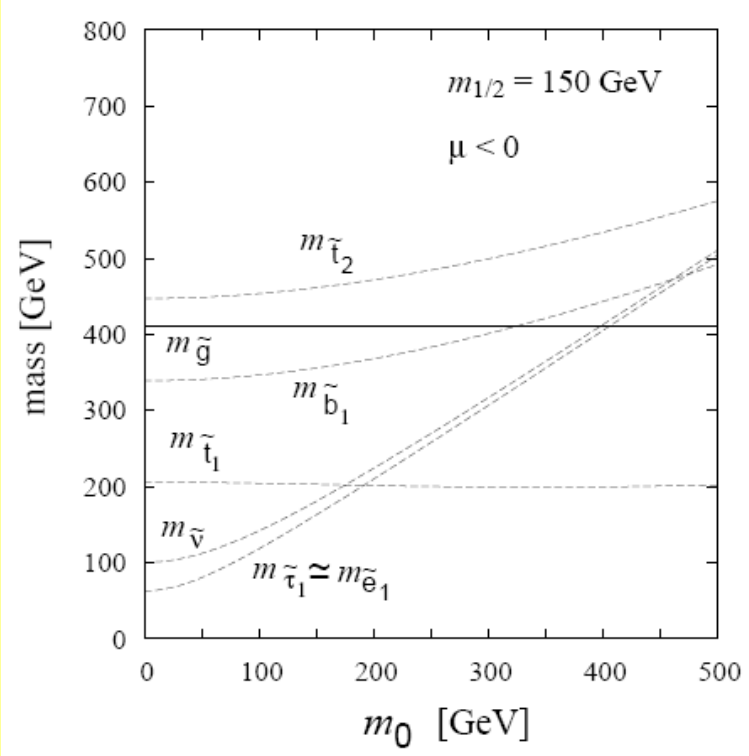


SUSY Masses in MSSM

Gauginos+Higgsinos



Squarks and Sleptons



Mass Spectrum in CMSSM

(Sample)

Fitted SUSY Parameters

Symbol	Low tan β	High tan β
tan β	1.71	52.2
m_0	200	1500
$m_{1/2}$	500	170
μ(0)	1084	558
A(0)	0	0
$1/\alpha_{GUT}$	24.8	24.8
M_{GUT}	$1.6 \cdot 10^{16}$	$1.6 \cdot 10^{16}$

SUSY Masses in GeV

Symbol	Low tan β	High tan β
$\tilde{\chi}_1^0(\tilde{B}), \tilde{\chi}_2^0(\tilde{W}^3)$	214, 413	64, 113
$\tilde{\chi}_3^0(\tilde{H}_1), \tilde{\chi}_4^0(\tilde{H}_2)$	1028, 1016	194, 229
$\tilde{\chi}_1^{\pm}(\tilde{W}^{\pm}), \tilde{\chi}_2^{\pm}(\tilde{H}^{\pm})$	413, 1026	110, 130
$\tilde{g}$	1155	516
$\tilde{e}_L, \tilde{e}_R$	303, 270	1497, 1499
$\tilde{\nu}_L$	290	1495
$\tilde{q}_L, \tilde{q}_R$	1028, 936	1519, 1523
$\tilde{\tau}_1, \tilde{\tau}_2$	279, 403	1305, 1288
$\tilde{b}_1, \tilde{b}_2$	953, 1010	1309, 1152
$\tilde{t}_1, \tilde{t}_2$	727, 1017	906, 1046
h, H	95 1344	115 372
A, $H^{\pm}$	1340, 1344	372, 383

The Lightest Superparticle

		property	signature
• Gravity mediation	LSP = $\tilde{\chi}_1^0$	stable	jets/leptons $+\not{E}_T$
• Gauge mediation	LSP = $\tilde{G}$	stable	$\not{E}_T$
	NLSP = $\tilde{\chi}_1^0$	$\tilde{\chi}_1^0 \to \gamma\tilde{G}, h\tilde{G}, Z\tilde{G}$	photons/jets $+\not{E}_T$
	NLSP = $\tilde{l}_R$	$\tilde{l}_R \to \tau\tilde{G}$	lepton $+\not{E}_T$
• Anomaly mediation	LSP = $\tilde{\chi}_1^0$	stable	lepton $+\not{E}_T$
	LSP = $\tilde{\nu}_L$	stable	

• R-parity violation — LSP is unstable ® SM particles

• Modern limit — $M_{LSP} \geq 40$ GeV

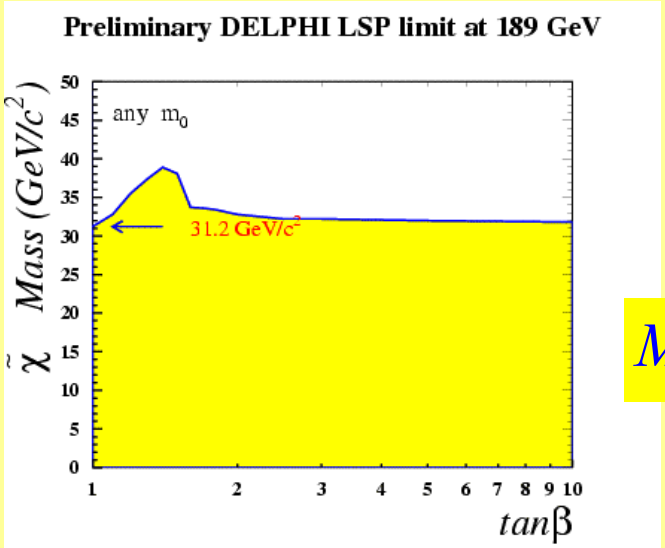
Rare decays
Neutrinoless double β decay

SUSY Dark Matter

Neutralino = SUSY candidate for the cold Dark Matter
Neutralino = the Lightest Superparticle (LSP) = WIMP

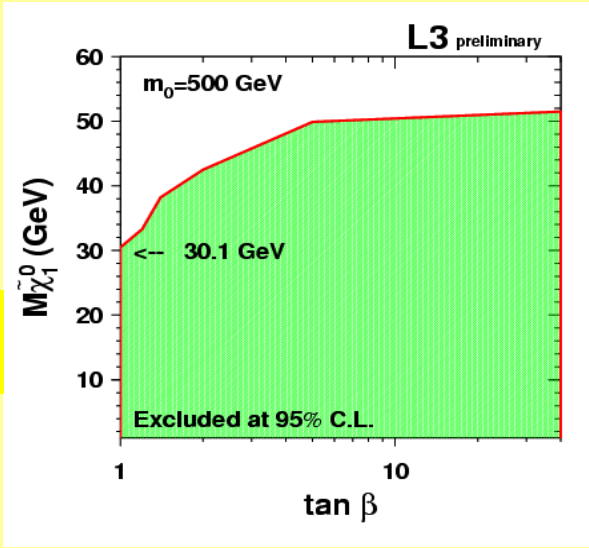
$$\tilde{\chi}^0 = N_1\tilde{\gamma} + N_2\tilde{z} + N_3\tilde{H}_1^0 + N_4\tilde{H}_2^0$$

photino zino higgsino higgsino



$$M_\chi^{exp} \geq 40 \text{ GeV}$$

$$M_\chi^{theor} = 40 \div 400 \text{ GeV}$$



$$R = (-1)^{3(B-L)+2S}$$

$$R_p = +1,\ R_{\not p} = -1$$

- **Superparticles are created in pairs**
- **The lightest superparticle is stable**