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How light may the lightest neutralino be?

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1 Motivation

We want to look for a lower bound for the mass of the lightest neutralino $\tilde{\chi}_1^0$ in the Minimal Supersymmetrical Standard Modell (MSSM) without

- GUT relation: $M_1 = \frac{5}{3}\tan^2(\theta_w)M_2$
- Cosmology (supernova, dark matter density)

but with

- Collider bounds (electroweak precision data, reactions at LEP)

Why? The $\tilde{\chi}_1^0$ could have been produced without notice!

2 The neutralino mass matrix

Neutralinos are the SUSY partners of the neutral gauge ($\tilde{B}$, $\tilde{W}^3$) and CP-even Higgs bosons ($\tilde{H}_u$, $\tilde{H}_d$). These states mix, and the mass eigenstates are the eigenvectors of the matrix:

$$M = \begin{pmatrix} M_1 & 0 & -m_Z \sin(\theta_W)\cos(\beta) & m_Z \sin(\theta_W)\sin(\beta) \\ 0 & M_2 & m_Z \cos(\theta_W)\cos(\beta) & -m_Z \cos(\theta_W)\sin(\beta) \\ -m_Z \sin(\theta_W)\cos(\beta) & m_Z \cos(\theta_W)\cos(\beta) & 0 & -\mu \\ m_Z \sin(\theta_W)\sin(\beta) & -m_Z \cos(\theta_W)\sin(\beta) & -\mu & 0 \end{pmatrix}$$

MSSM parameters: M_1, M_2, μ, $\tan\beta$

|eigenvalues| of M = neutralino masses $m_{\chi_i^0}$, $i = 1, \ldots, 4$

3 Constraints on M_2, μ, and M_1

- M_2, μ determine chargino mass:

  LEP II: $m_{\chi_1^+} > 104\,\text{GeV} \Rightarrow M_2, \mu \gtrsim 100\,\text{GeV}$

  yields no bound for $m_{\chi_1^0}$ without GUT relation $M_1 = \frac{5}{3}\tan^2(\theta_w) M_2$

- M_1 can be chosen such that $m_{\chi_1^0} = 0$:

$$\det\left[M(M_1, M_2, \mu, \tan\beta)\right] = 0$$

$$\Rightarrow M_1 = \frac{m_Z^2 M_2 \sin^2\theta_w \sin(2\beta)}{M_2\mu - m_Z^2 \cos^2\theta_w \sin(2\beta)} \approx 0.05\frac{m_Z^2}{\mu} = \mathcal{O}(1\,\text{GeV})$$

$$\Rightarrow M_1 \ll M_2 \quad \Rightarrow \tilde{\chi}_1^0 \ \text{bino}-\text{like} \quad \Rightarrow Z^0 \to \tilde{\chi}_1^0\tilde{\chi}_1^0 \ \text{is suppressed}$$

$$\Rightarrow Z^0 \ \text{invisible width o.k.}$$

4 Experimental constraints on $m_{\chi_1^0}$

Neutralino production at LEP II:

- $e^+e^- \to \chi_1^0\chi_i^0$
- $e^+e^- \to \chi_1^0\chi_1^0\gamma$

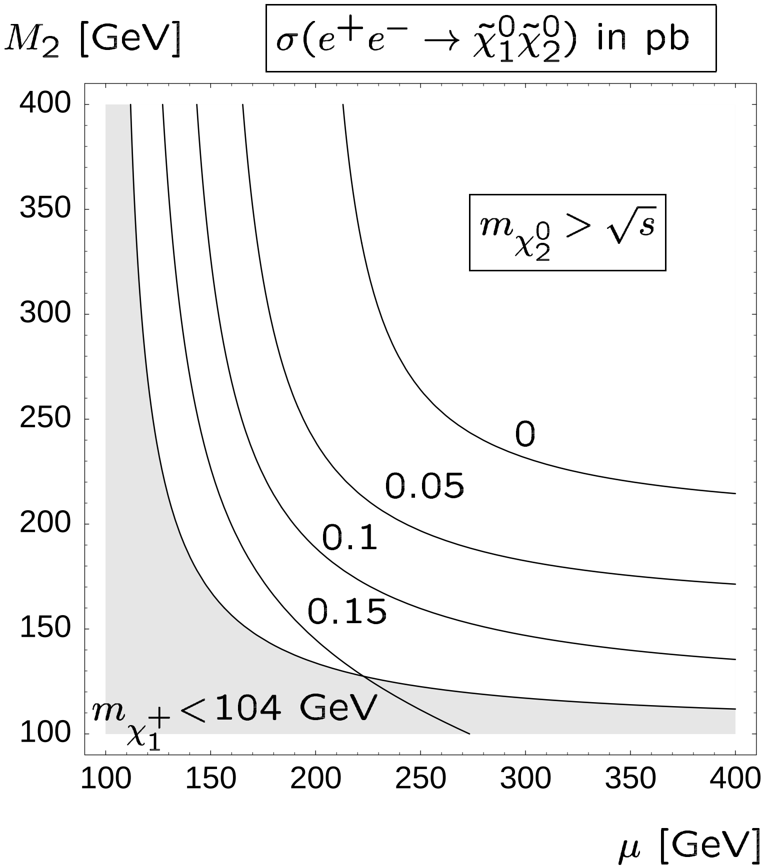
Rare decays and electroweak precision observables:

- $b \to s\gamma$
- $\sin^2(\theta_w)$, M_W, Γ_W
- $(g-2)_\mu$

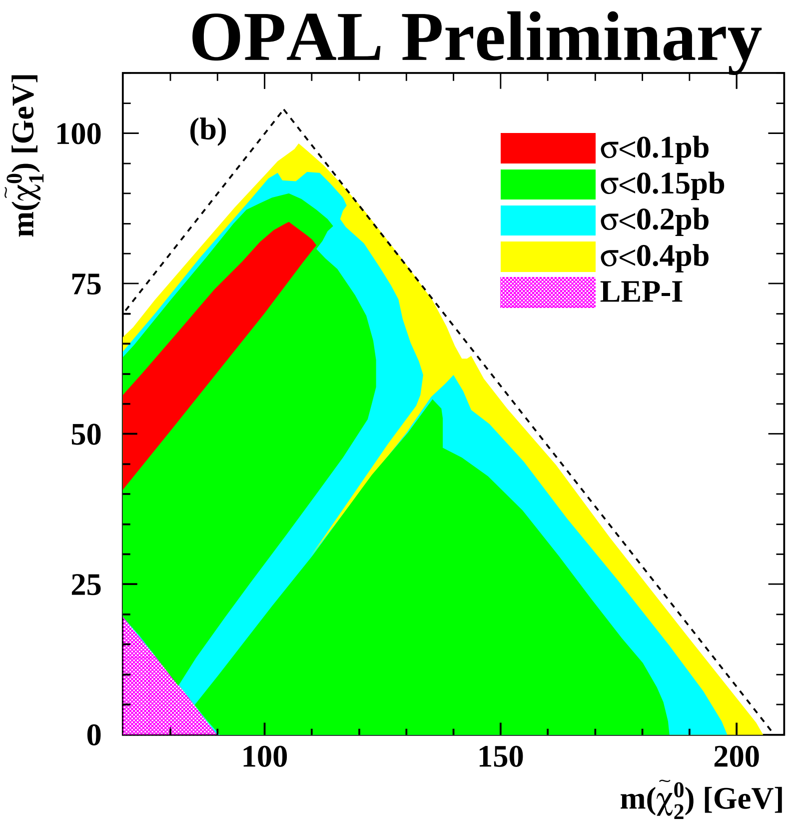
Further reactions (to be looked at)

- $B_s \to \mu^+\mu^-$, . . .

5 No LEP bounds on neutralino production $e^+e^- \to \tilde{\chi}^0_1 \tilde{\chi}^0_2$



$\sqrt{s} = 200$ GeV, $M_{\tilde{e}} = 200$ GeV, $\tan\beta = 10$, $m_{\chi^0_1} = 0$ GeV



$\sqrt{s} = 208$ GeV, $CL = 95\%$

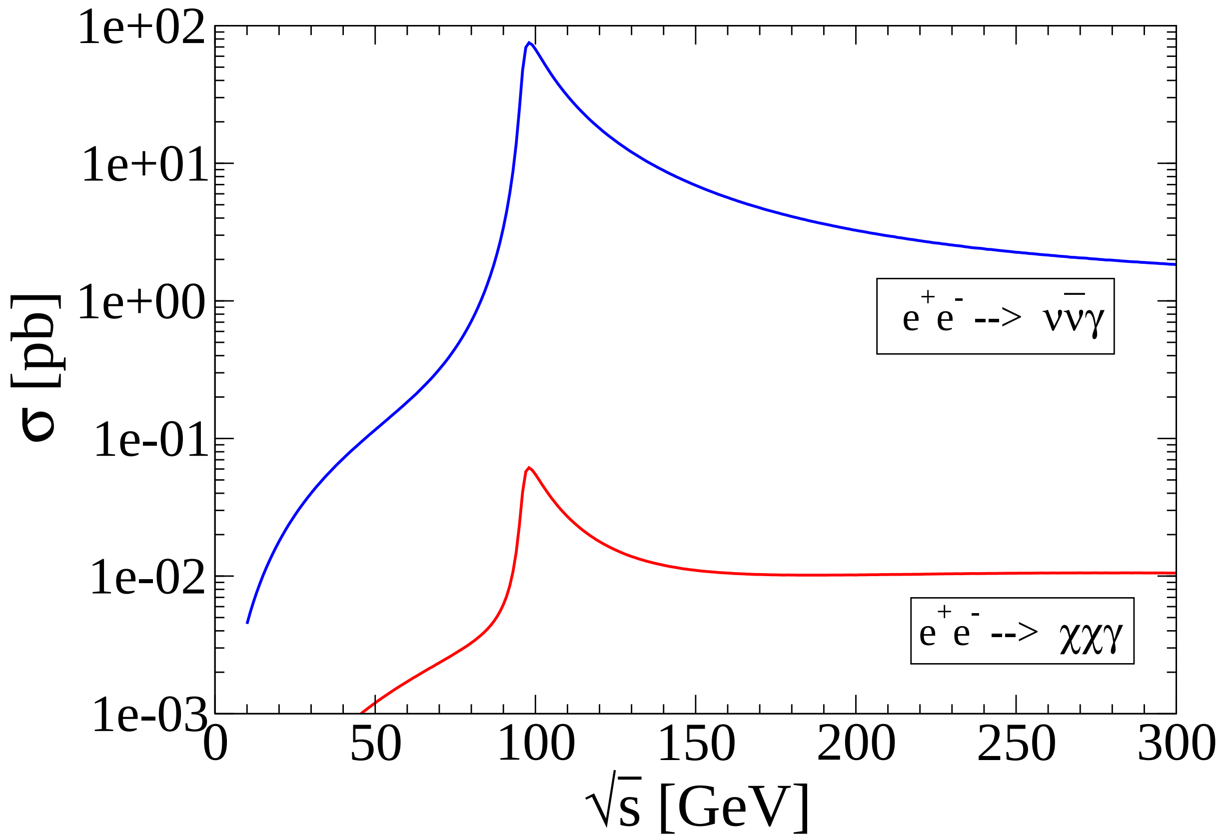
6 And no bound from radiative production $e^+e^- \to \tilde{\chi}_1^0\tilde{\chi}_1^0\gamma$

$M_{\tilde{e}} = 200$ GeV

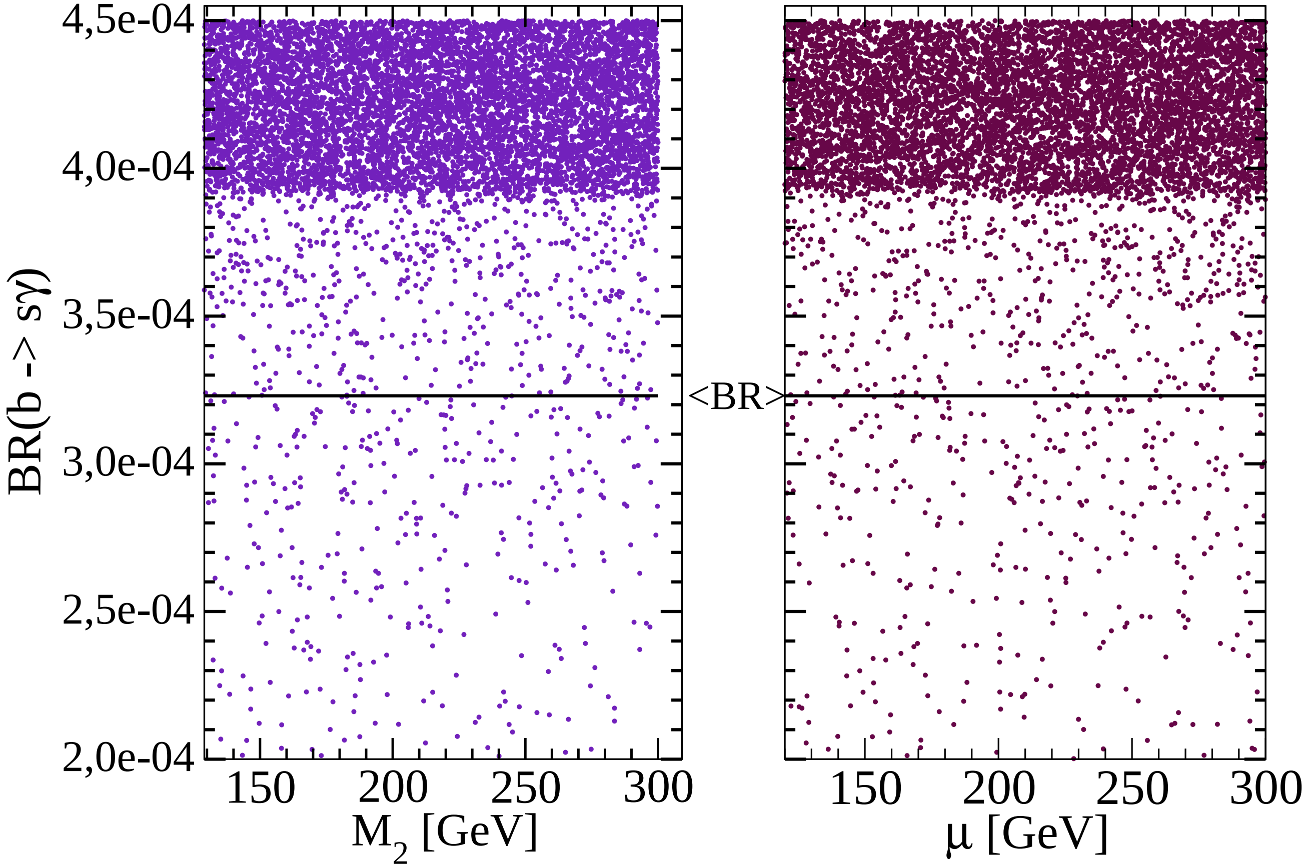
$M_2 = \mu = 200$ GeV

$\tan\beta = 10$

$m_{\chi_1^0} = 0$ GeV



7 No constraints from BR($b \to s\gamma$)



$\tan\beta = 4\ldots20$, $M_0 = 100\ldots1000\,\mathrm{GeV}$, $A_t = 0\ldots5000\,\mathrm{GeV}$, $M_A = 100\ldots1000\,\mathrm{GeV}$

8 Summary

- $M_1 = \frac{m_Z^2 M_2 \sin^2\theta_w \sin(2\beta)}{M_2\mu - m_Z^2 \cos^2\theta_w \sin(2\beta)} \quad \Rightarrow \quad m_{\chi_1^0} = 0\,\mathrm{GeV}$
- no constraints from $e^+e^- \to \tilde{\chi}_1^0 \tilde{\chi}_i^0$
  $e^+e^- \to \tilde{\chi}_1^0 \tilde{\chi}_1^0 \gamma$
- no constraints from $b \to s\gamma$ and from electroweak precision data

$\Rightarrow$ Zero mass neutralino is allowed!

Outlook: study further processes/ more constraints