mSUGRA at the Tevatron and LHC

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OUTLINE

- Tevatron's reach in mSUGRA
- The capabilities of the LHC in mSUGRA
- The LC in mSUGRA and cosmological constraints on the parameter space
- Direct and indirect DM detection reaches in mSUGRA

MSSM has 124 parameters. That leads us to consider more restricted theories, such as

mSUGRA (CMSSM)

- Supersymmetry is broken in the hidden sector, giving rise to a massive gravitino
- SUSY breaking in the hidden sector generates soft SUSY breaking terms in the visible sector
- Model has 5 parameters:
m_0, $m_{1/2}$, A_0, $\tan\beta \equiv \frac{v_u}{v_d}$, $sgn(\mu)$
- The lightest neutralino $\tilde{Z}_1^0$ is an LSP and a good candidate for CDM particle

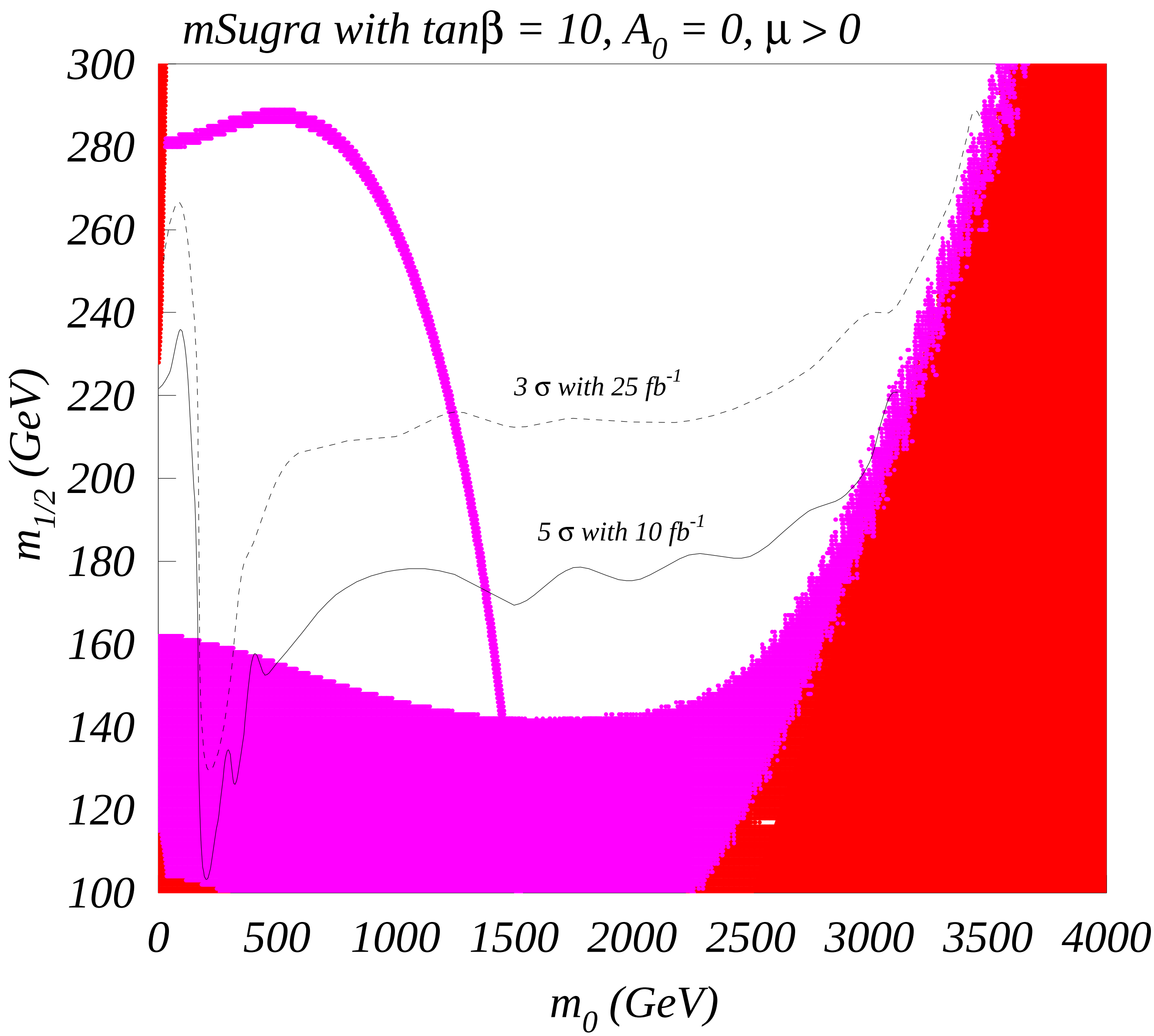
mSUGRA at the Tevatron

If charginos and neutralinos are within Tevatron's reach, then one expects to produce

- $\tilde{W}_1\tilde{Z}_1 \Longrightarrow \tilde{W}_1 \to l\nu\tilde{Z}_1 \Longrightarrow$ 1 lepton + $\not{E}_T$
- $\tilde{W}_1^+\tilde{W}_1^- \Longrightarrow \tilde{W}_1 \to l\nu\tilde{Z}_1 \Longrightarrow$ 2 leptons + $\not{E}_T$
- $\tilde{W}_1\tilde{Z}_2 \Longrightarrow \tilde{W}_1 \to l\nu\tilde{Z}_1, \quad \tilde{Z}_2 \to l\bar{l}\tilde{Z}_1 \Longrightarrow$ 3 leptons + $\not{E}_T$.

1 and 2 lepton signatures have large SM backgrounds. Therefore we adopt the set of cuts SC2 from H. Baer *et al.* for 3 lepton signal:

$p_T(l_1) > 11$, $p_T(l_2) > 7$, $p_T(l_1) > 5$ GeV
$|\eta(l_{1,2/3})| < 1,2$
$ISO_{\Delta R=0.4} < 2$ GeV
$\not{E}_T > 25$ GeV
Z-veto: $m(l\bar{l}) < 81$ GeV
$W^*\gamma^*$-veto: $m(l\bar{l}) > 20$ GeV
$m_T(l, \not{E}_T) < 60$ GeV, $m_T(l, \not{E}_T) > 85$ GeV



The reach of Fermilab Tevatron in the m_0 $vs.$ $m_{1/2}$ parameter plane of the mSUGRA model for $m_t = 175$ GeV. The red (magenta) region is excluded by theoretical (experimental) constraints. The region below the magenta contour has $m_h < 114.1$ GeV, in violation of Higgs mass limits from LEP2.

mSUGRA at the LHC

Production of gluinos, squarks and sleptons leads to cascade decays $\Rightarrow$ expect large E_T^{miss}, multiple jets and/or multiple leptons.

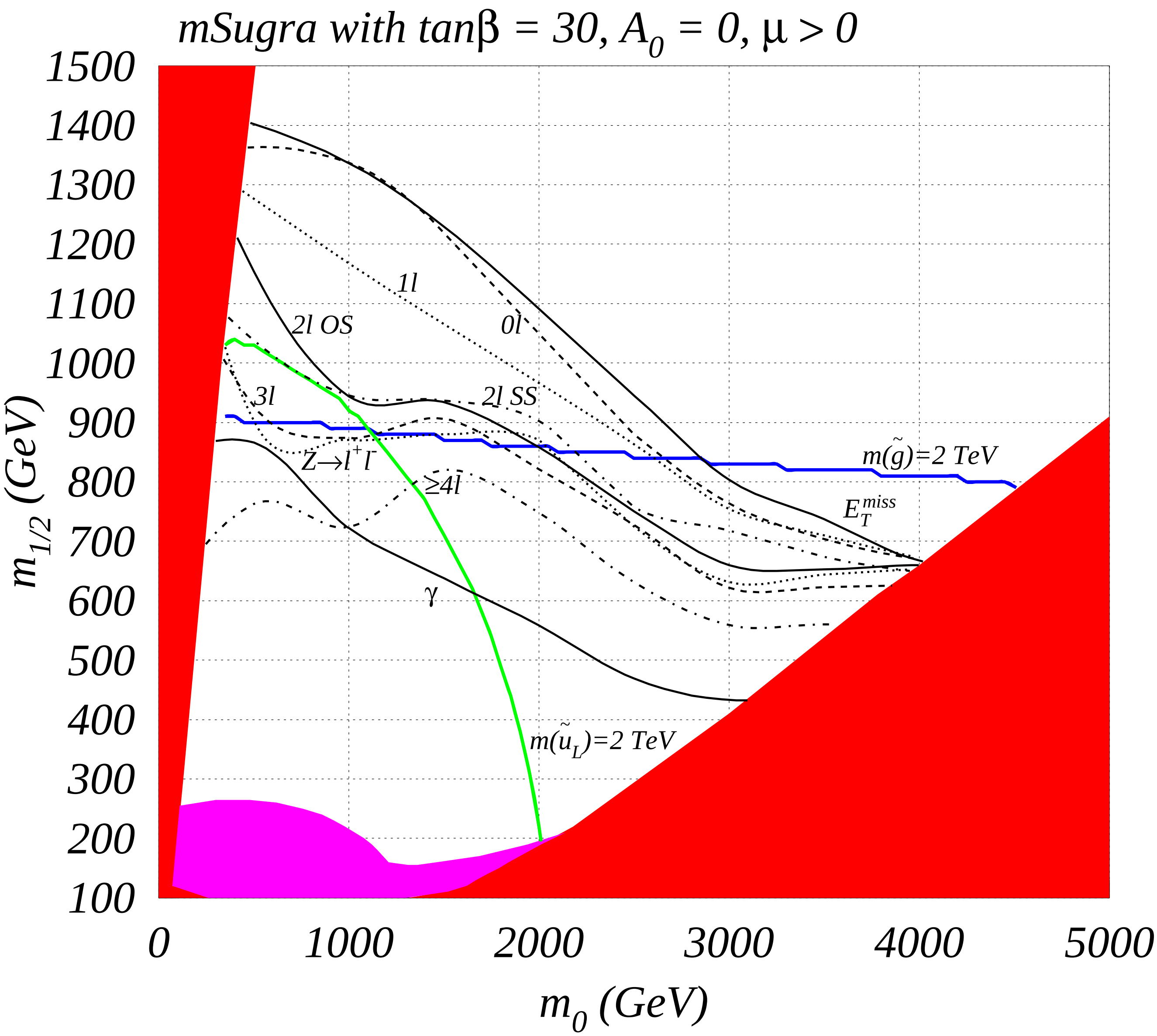
We use CMSJET 4.801 (Abdullin, Khanov, Stepanov) for the CMS detector simulation and ISAJET 7.64 (Baer, Paige, Protopopescu, Tata) for the event generation

Pre-cuts:

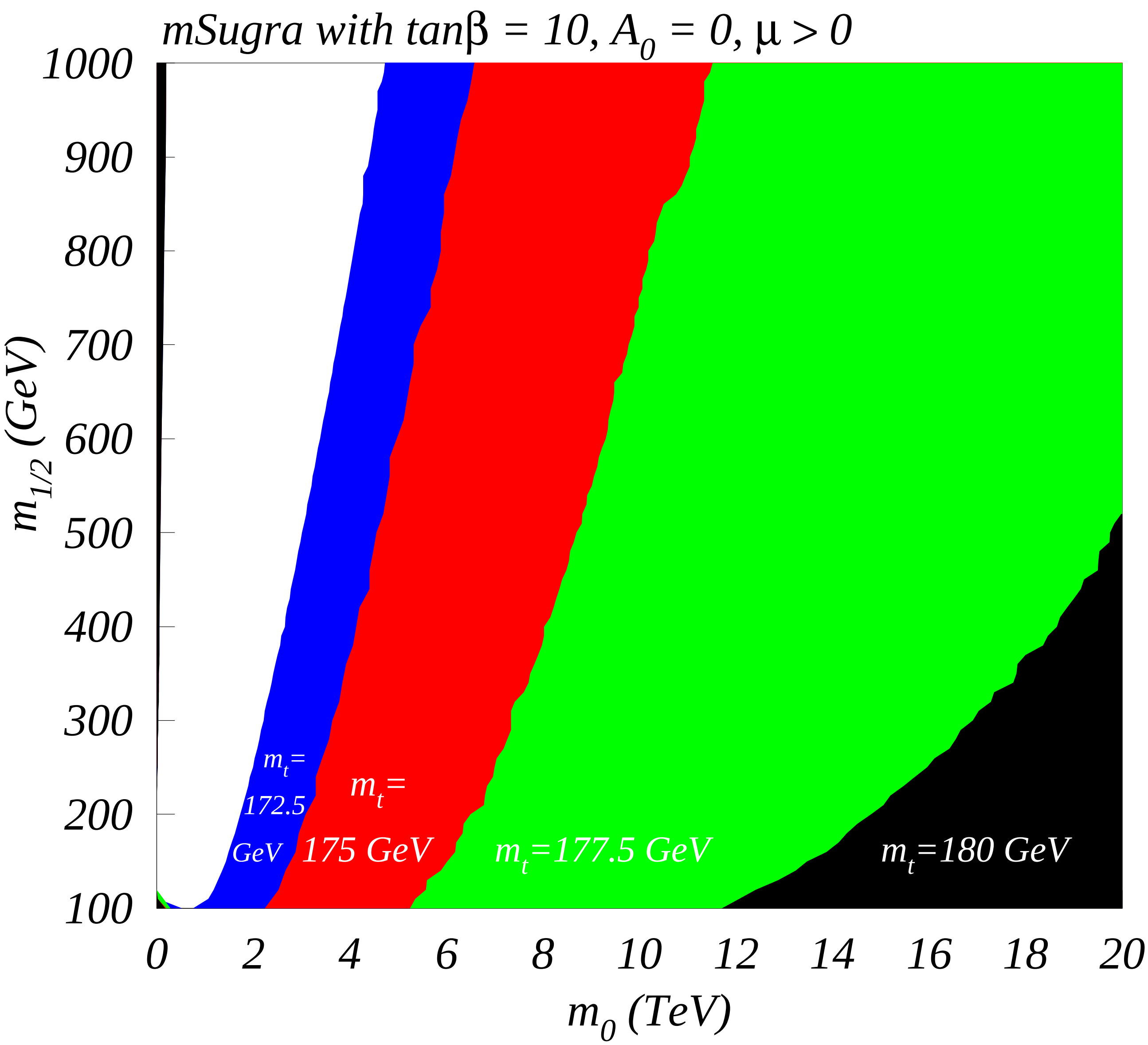
- $E_T^{miss} > 200$ GeV
- at least 2 jets with $p_T^{jet} > 40$ GeV

The cuts are optimized for each point in the mSUGRA parameter space (Abdullin, Charles):

Variable(s)	Values
N_j	2, 3, 4, ..., 10
E_T^{miss}	200, 300, 400, ..., 1400 GeV
E_T^{j1} E_T^{j2}	40, 150, ..., 1000 GeV 40, 80, ..., 500 GeV
$\Delta\phi$ (p_T^l, E_T^{miss})	0, 20 deg.
$Circularity$	0, 0.2
μ isolation	on, off



The reach of CERN LHC, assuming 100 fb^{-1} of integrated luminosity for $m_t = 175$ GeV. The red (magenta) regions are excluded by theoretical (experimental) constraints.
We show the reach in the 0ℓ, 1ℓ, OS, SS, 3ℓ, $\geq 4\ell$, γ and Z channels, as well as in the "inclusive" $\not{E}_T$ channel.

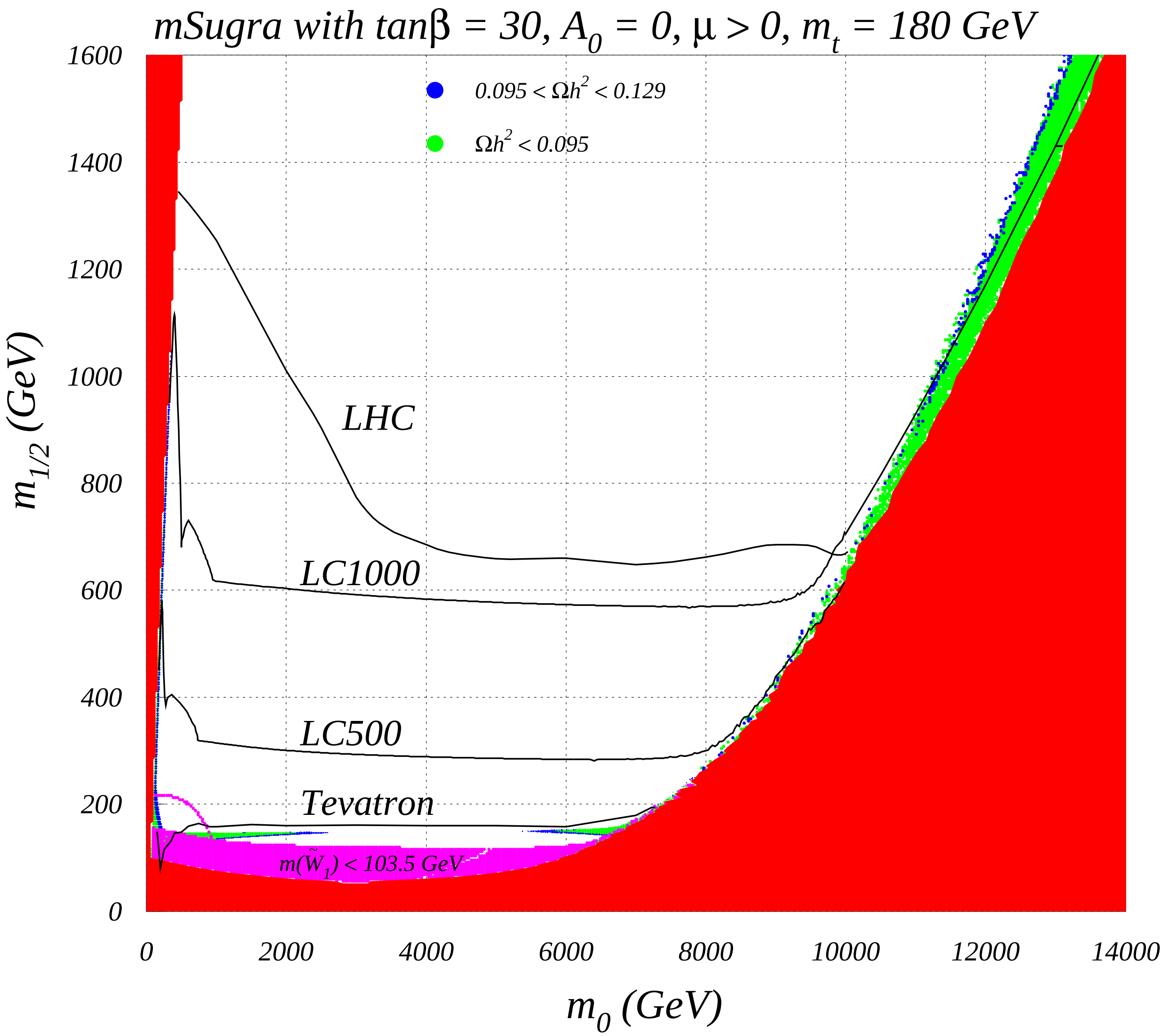


Boundary of the m_0 *vs.* $m_{1/2}$ parameter plane of the mSUGRA model, with $\tan\beta = 10$, $A_0 = 0$ and $\mu > 0$, for $m_t = 172.5$, 175, 177.5 and 180 GeV.

mSUGRA at the LC

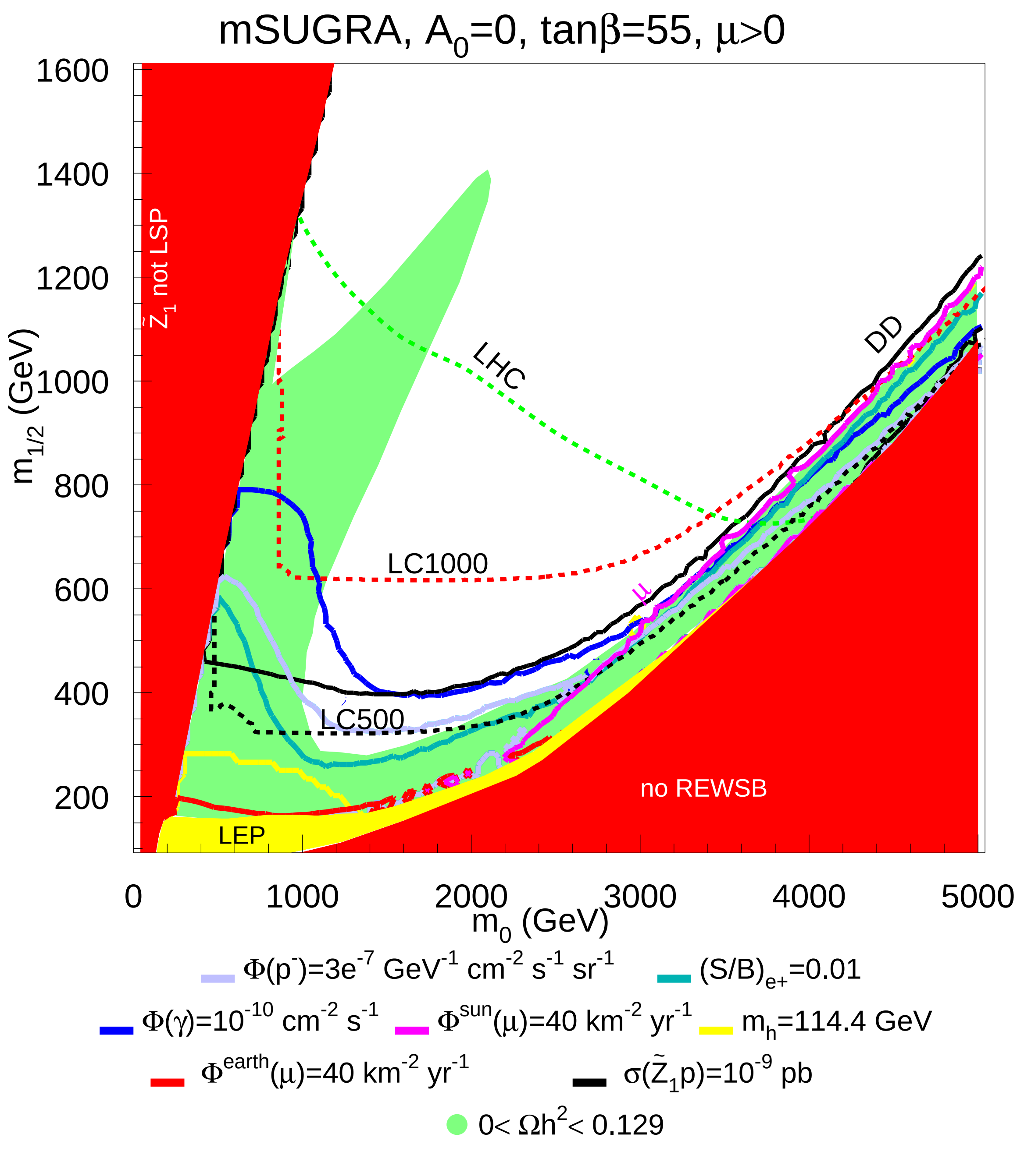
The parameter space can be split into several regions, requiring different cuts:

1. Selectron pair production (2 OS leptons)
2. Stau pair production (2 hadronic 'tau' jets)
3. $\tilde{Z}_1^0 \tilde{Z}_2^0$ production (2 tagged b jets)
4. Chargino pair production (1 lepton + 2 jets)
5. Chargino pair production in the far HB/FP region (1 lepton + 2 jets)



Reach of the Fermilab Tevatron, CERN LHC and a linear collider in the mSUGRA model for $m_t = 180$ GeV.

The red and magenta regions are excluded. The blue region is within the WMAP $\Omega_{\widetilde{Z}_1} h^2$ 2σ limit, while the green region has $\Omega_{\widetilde{Z}_1} h^2$ below the WMAP 2σ limit.



Reaches of direct and indirect DM detection experiments and collider experiments. $m_t = 175$ GeV. The red and yellow regions are excluded. Green region satisfies upper WMAP bound.

Conclusions

- We have explored the capabilities of the Tevatron, LHC and LC in the framework of mSUGRA.

- mSUGRA has a lot of parameter space to hide from the Tevatron. However, Tevatron will let us know what exactly is the available parameter space in mSUGRA by measuring top quark mass with greater precision.

- LHC has a good shot at discovering mSUGRA or ruling out most of the parameter space.

- What LHC still cannot do, LC might be able to.

- The HB/FP area inaccesible to the LHC can also be covered by direct and indirect DM detection experiments.

Do I have 5 minutes remaining?

Is there a problem with mSUGRA?

Only a small portion of mSUGRA parameter space satisfies the WMAP constraint on $\Omega_{\tilde{Z}_1} h^2 = 0.1126 \pm 0.0081$

Other available constraints on the parameter space include:

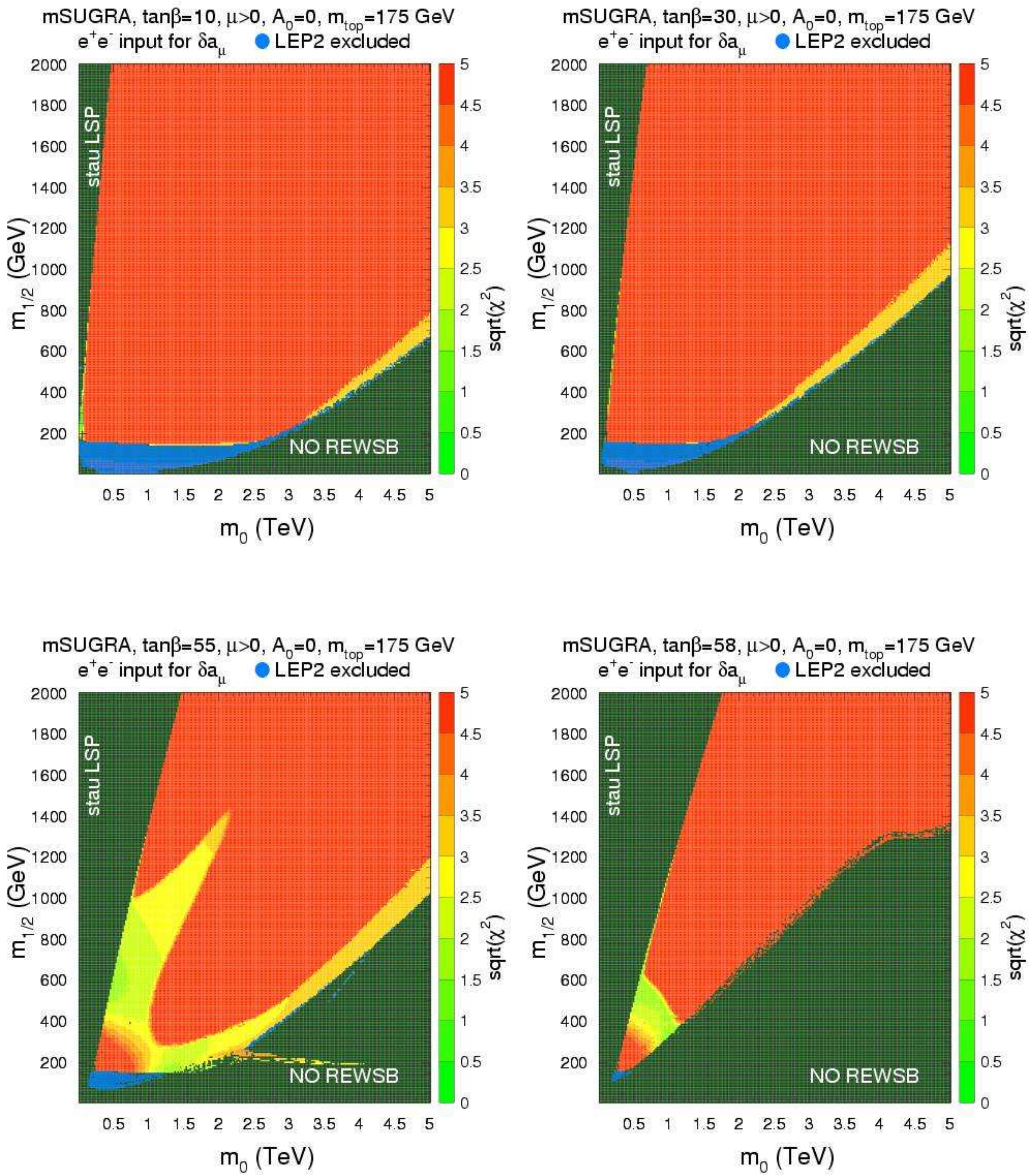
- $(g-2)_\mu$

Deviation from the SM value (Davier *et al.*):
$\Delta a_\mu = (27.1 \pm 9.4) \times 10^{-10}$ ($e^+ e^-$ data)
$\Delta a_\mu = (12.4 \pm 8.3) \times 10^{-10}$ (τ data)

- $b \to s\gamma$

$BF(b \to s\gamma) = (3.25 \pm 0.54) \times 10^{-4}$

Do the χ^2 fit.

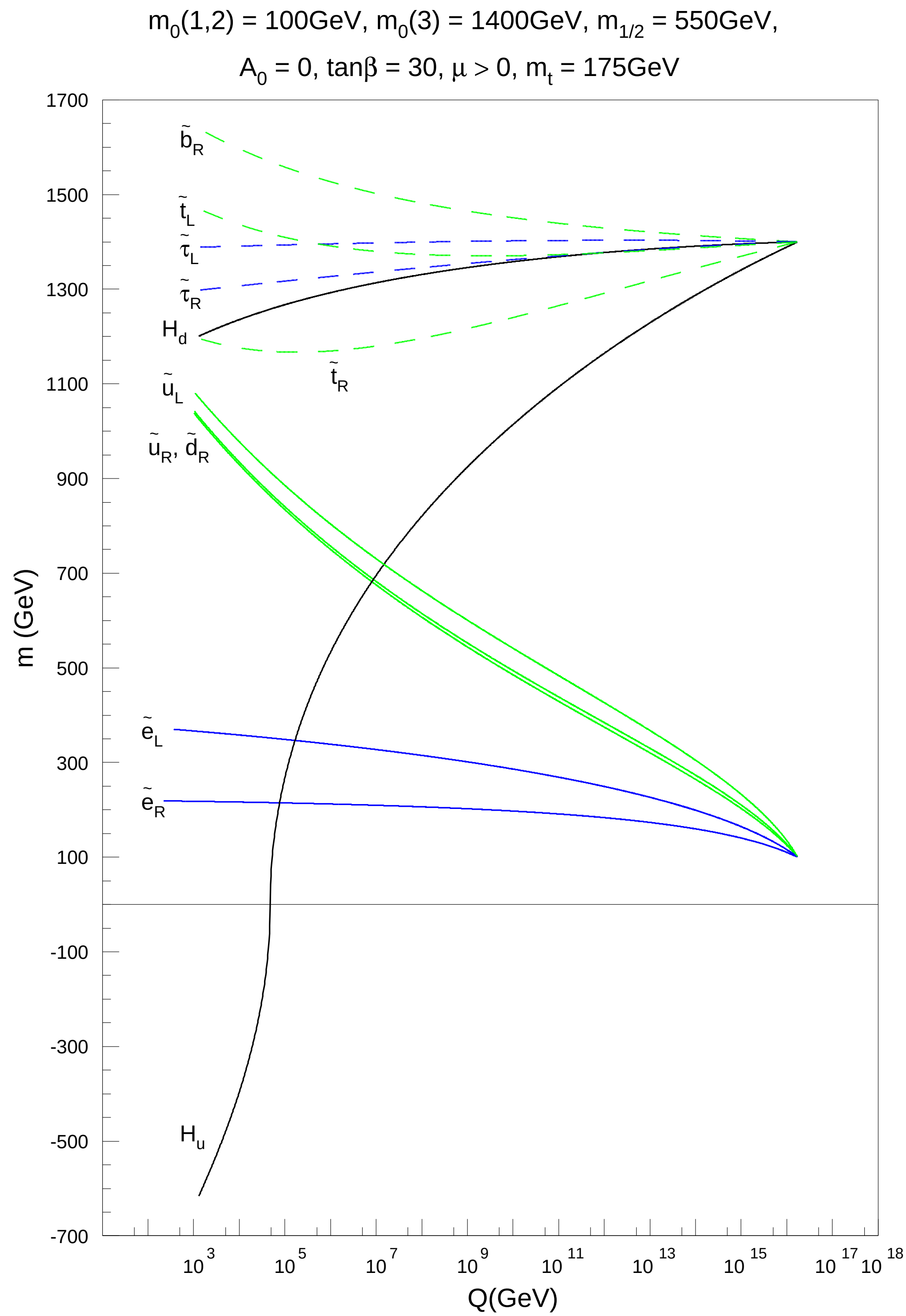


Plot of regions of $\sqrt{\chi^2}$ in the mSUGRA model for $A_0 = 0$, $\mu > 0$, and $\tan\beta = 10,\ 30,\ 55$ and 58.

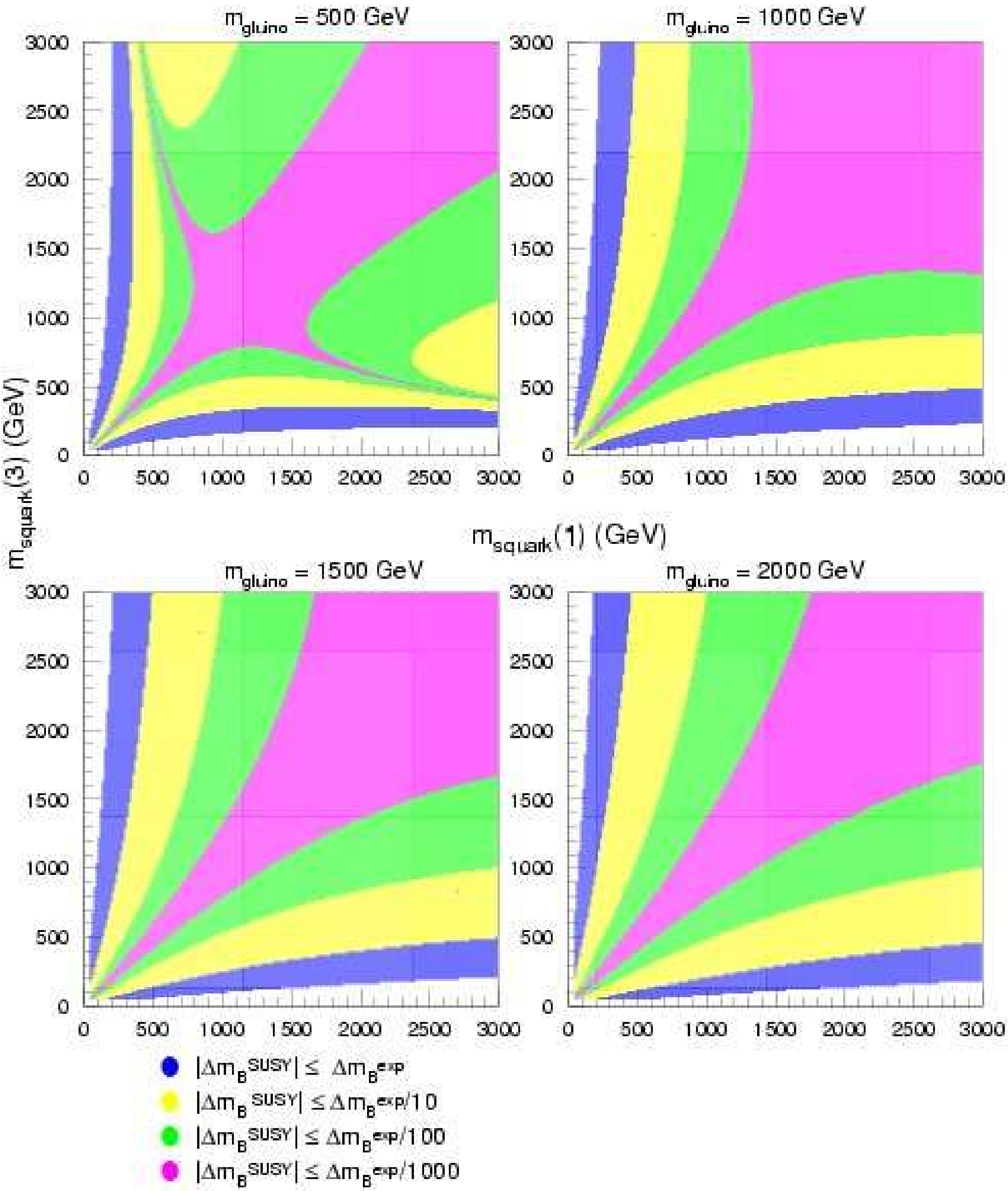
Normal scalar mass hierarchy

• Δa_μ number (using e^+e^- data) favors light sleptons
• $b \to s\gamma$ data prefers heavy squarks (in the multi-TeV range)

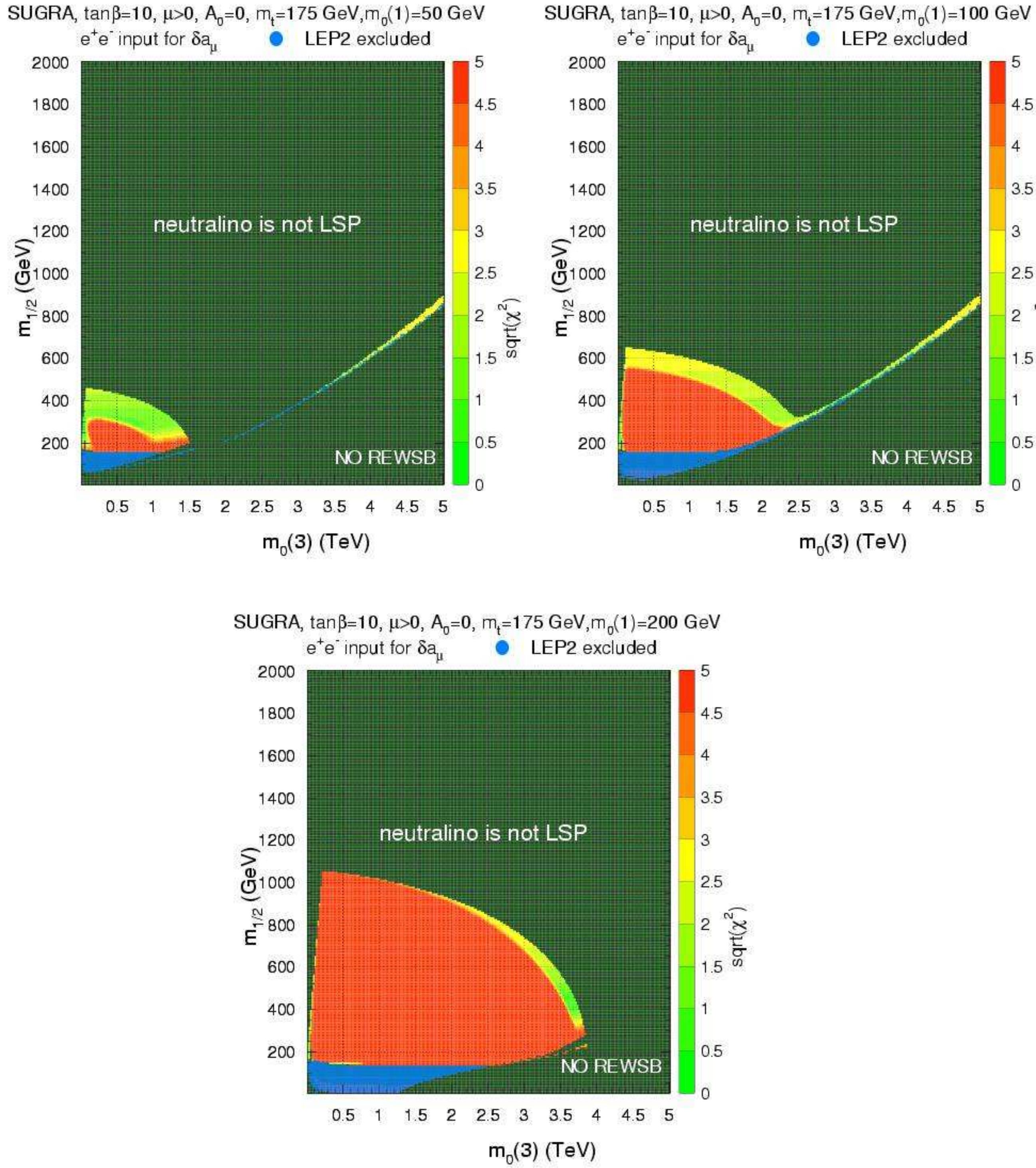
Possible solution: split the third generation scalar masses from the first and second generations at the GUT scale.
$m_0 \longrightarrow m_0(1)$ and $m_0(3)$



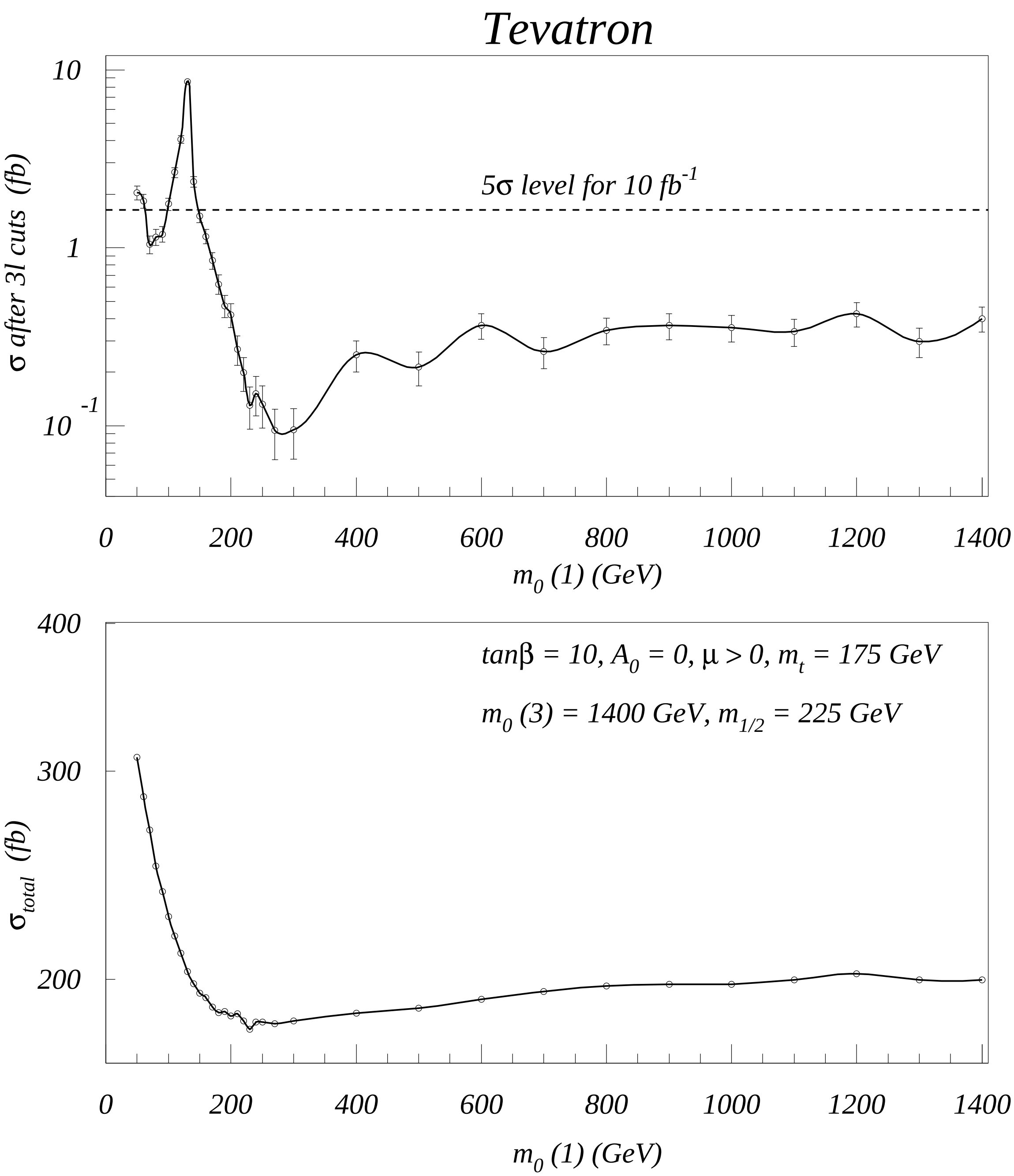
Evolution of soft SUSY breaking masses in the NMH SUGRA model.



Constraints on first and third generation squark masses from Δm_{B_d}.



Plot of regions of $\sqrt{\chi^2}$ in the $m_0(3)$ $vs.m_{1/2}$ plane of the NMH SUGRA model for $m_0(1,2) = 50$, 100 and 200 GeV with $A_0 = 0$, $\mu > 0$, and $\tan\beta = 10$.



Rates for isolated trilepton events at the Fermilab Tevatron $p\bar{p}$ collider, after cuts SC2 from Baer *et al.*(2000).