Karlsruher Institut für Technologie

Relic Density determination at the LHC

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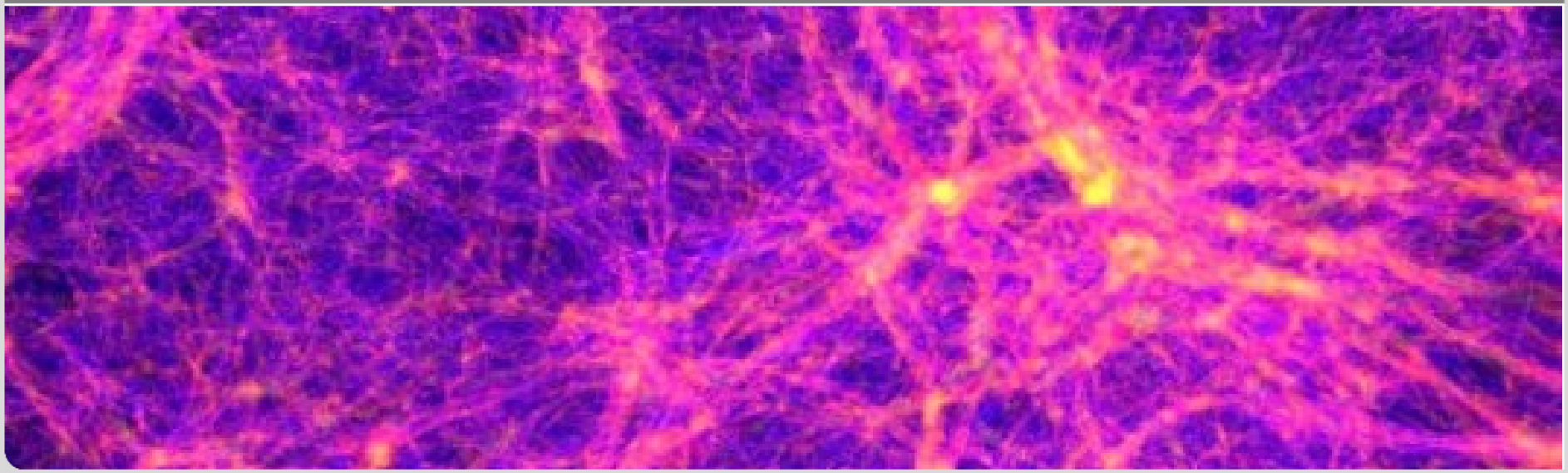
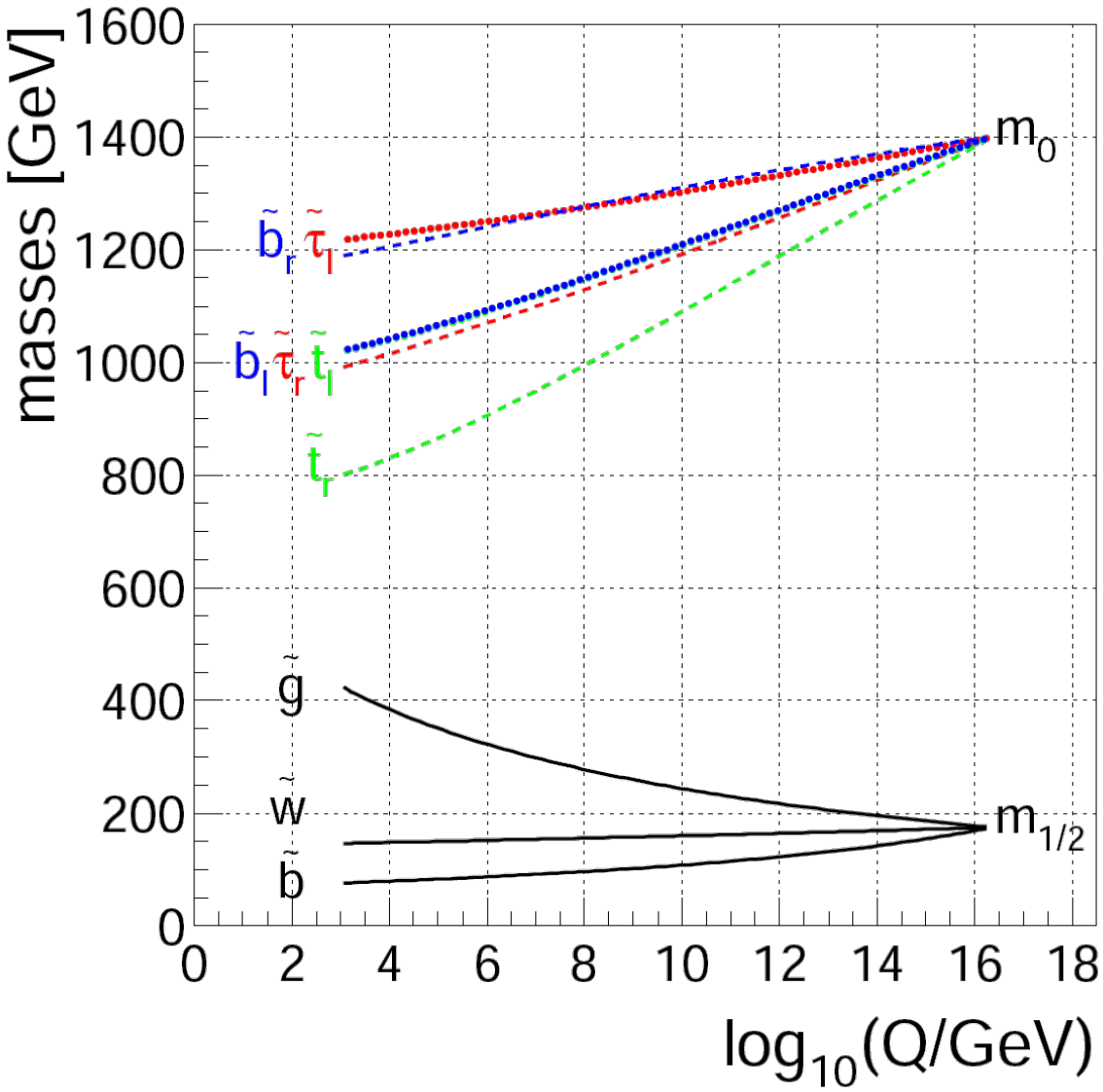


Outline

- Introduction: Assumed model
- Neutralino as dark matter candidate
- Predictions from mSUGRA
- Can one measure Relic Density at the LHC?
- Conclusion

Introduction



- **Unification of SUSY breaking parameters at GUT scale**

  → **5 free parameters:**

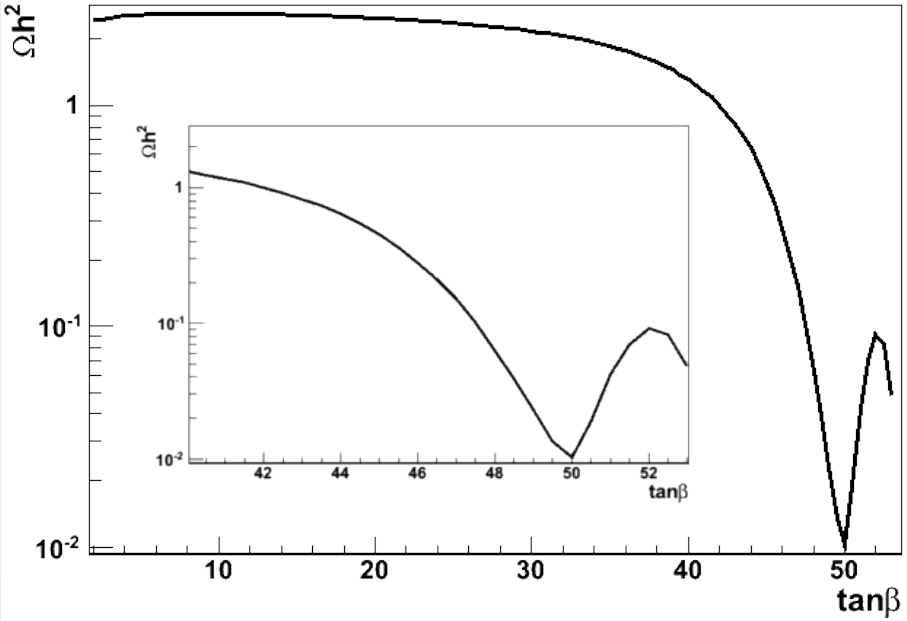
  m_0, $m_{1/2}$, tanβ, A_0, sgn(μ)

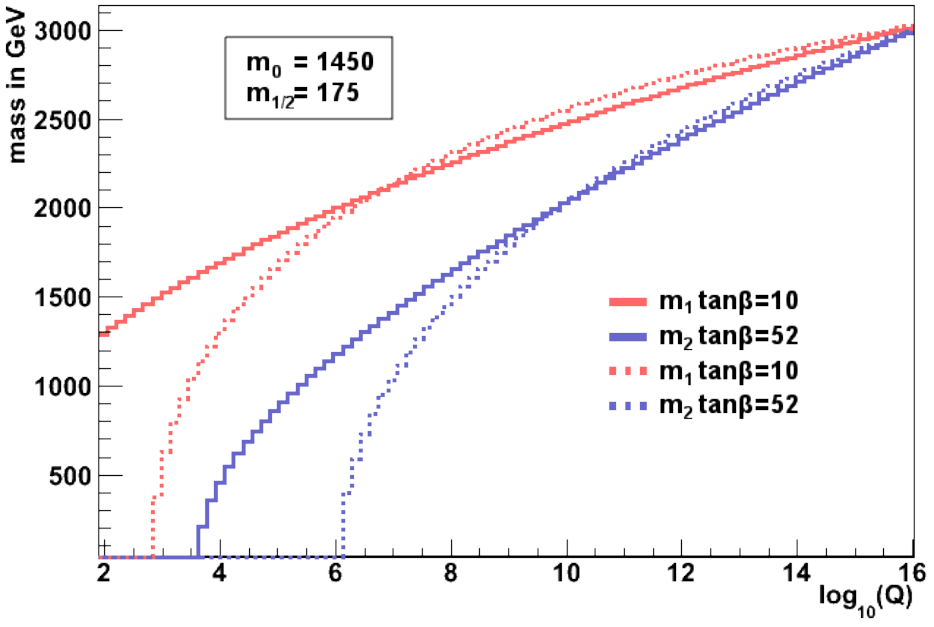
- **R-parity conserved:**
  - R=+1 for SM particles
  - R=-1 for SUSY particles

  → χ_1^0 **stable (LSP):**

  perfect dark matter candidate

Introduction





- **Cold dark matter as thermal relic:**

  $\Omega h^2 = 3.10^{-27}/\langle\sigma v\rangle$

  $= 0.1131 \pm 0.0034$

  → **Strong dependence on tanβ**

- **Tree level:**

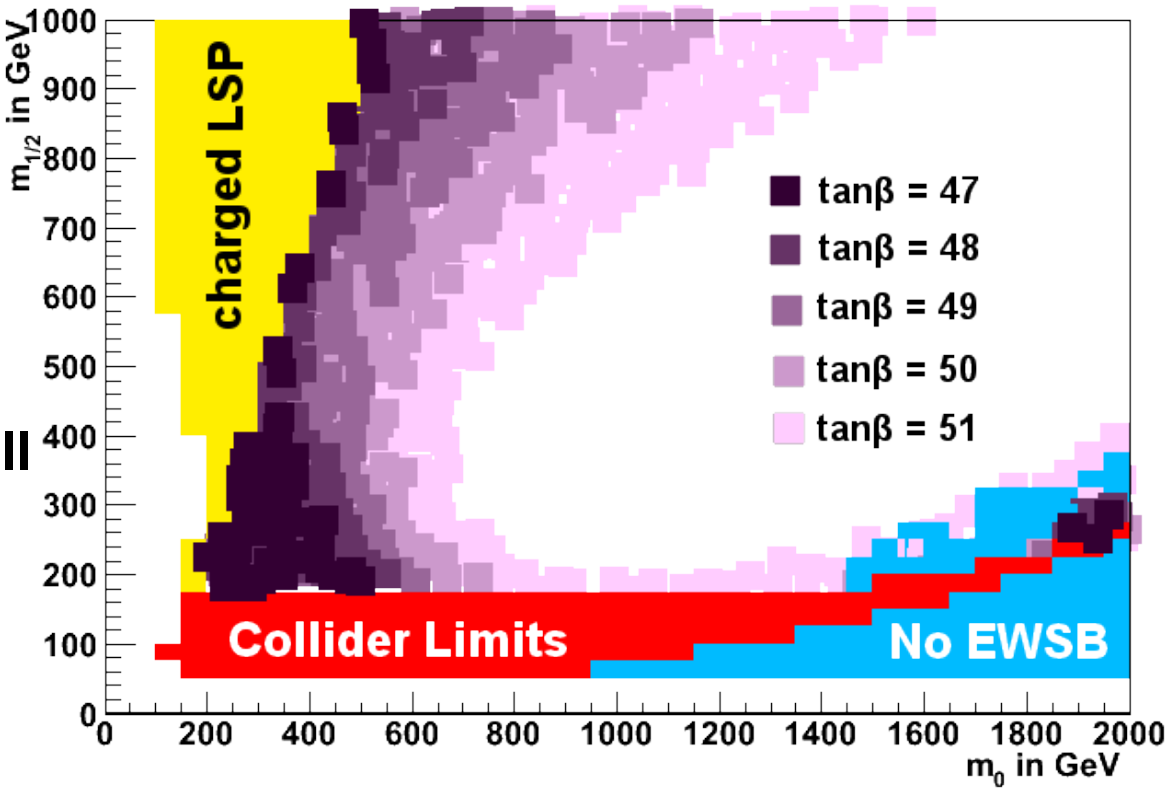
  $m_A^2 = m_1^2 + m_2^2$

- **For large tanβ m_A small**

  → **large contribution to annihilation**

The Neutralino as CDM Candidate

- R-parity conserved
  → LSP annihilates in pairs
- Dark matter consistency (pink-violet) for fixed tanβ only given for small area in $m_0 m_{1/2}$-plane



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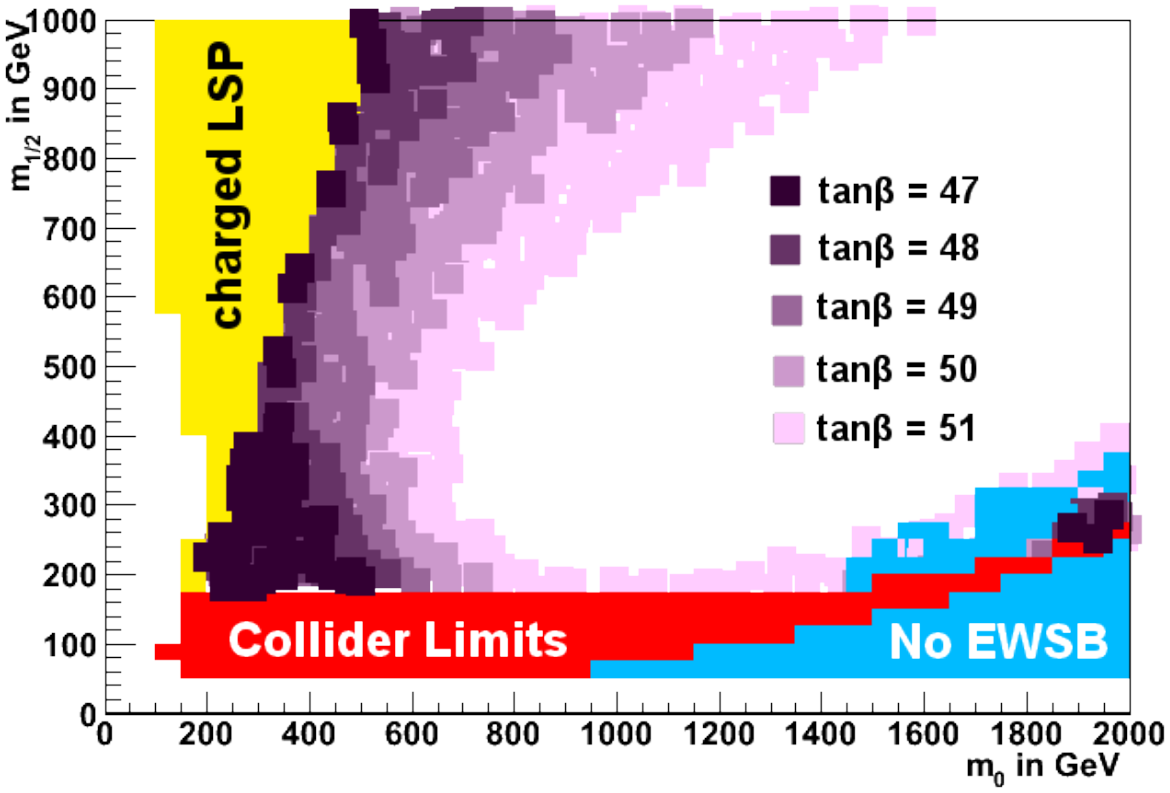

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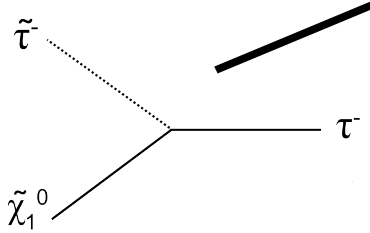

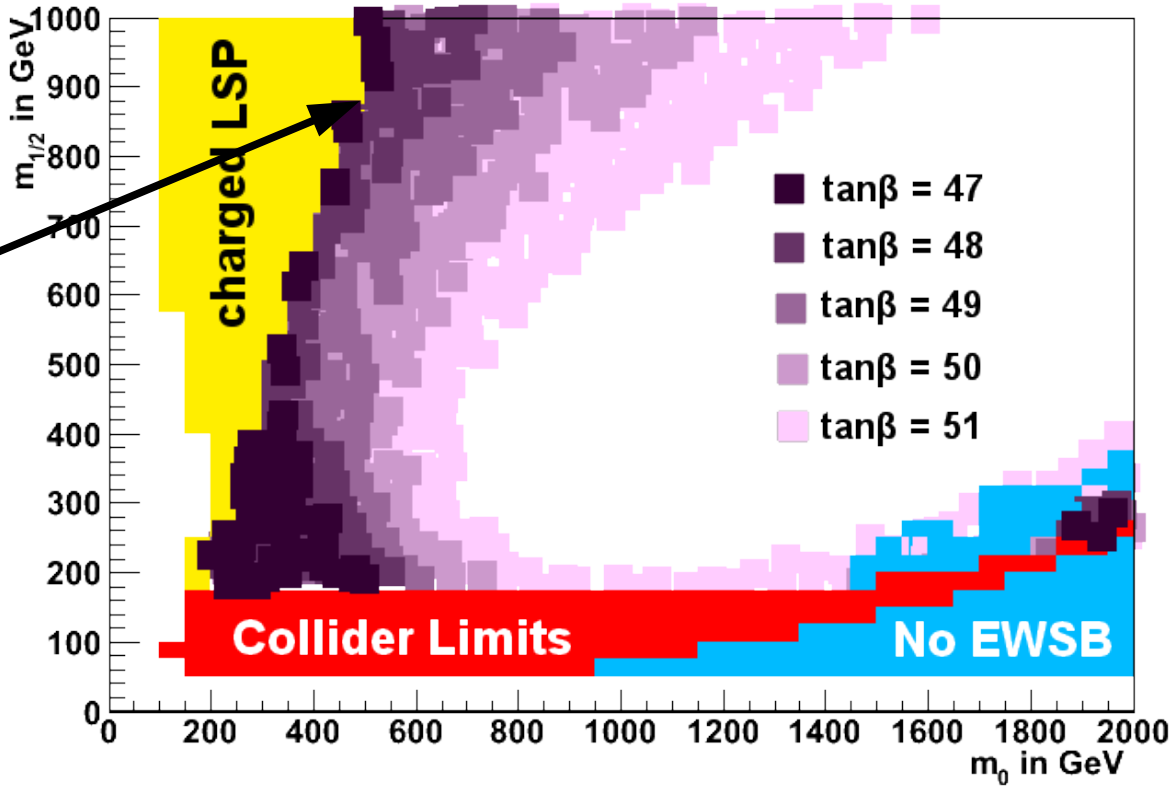

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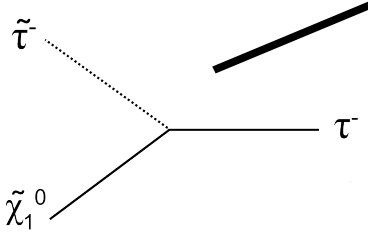

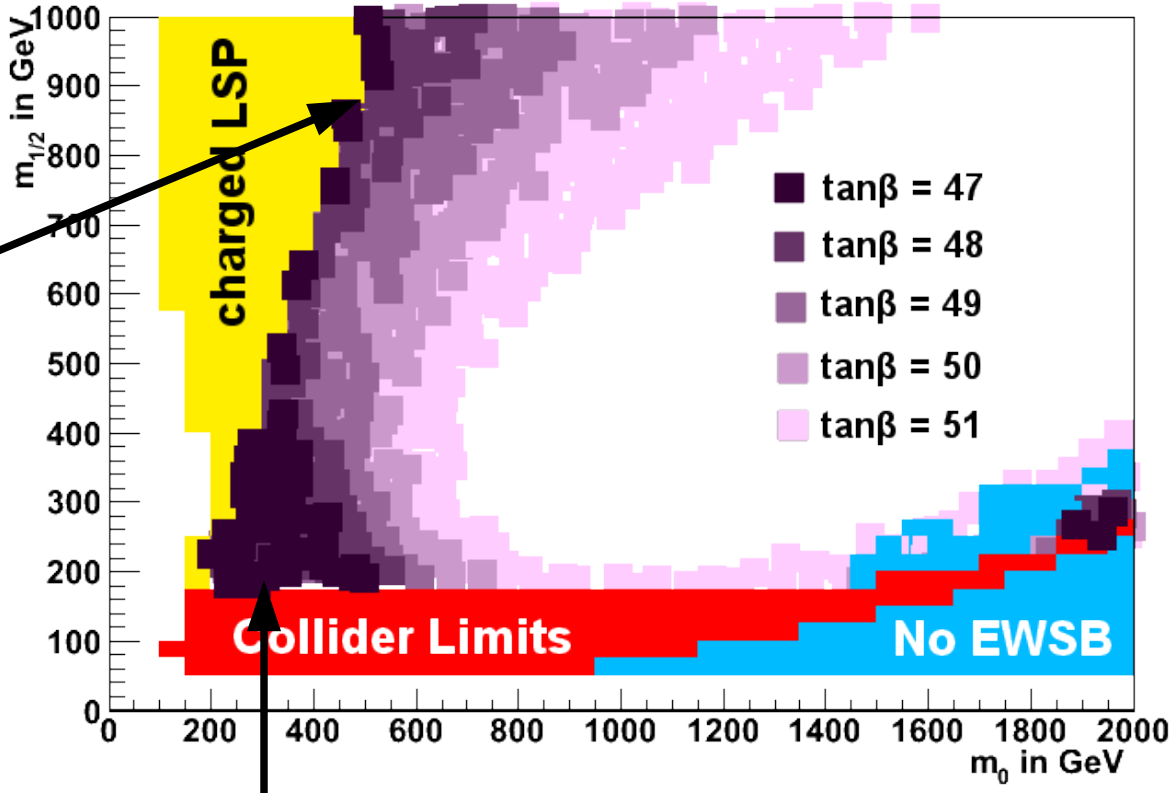

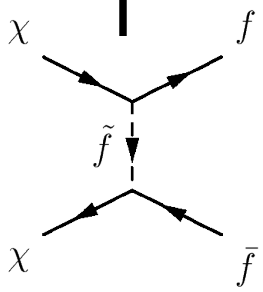

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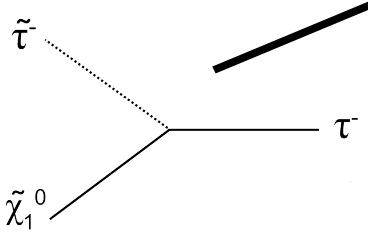

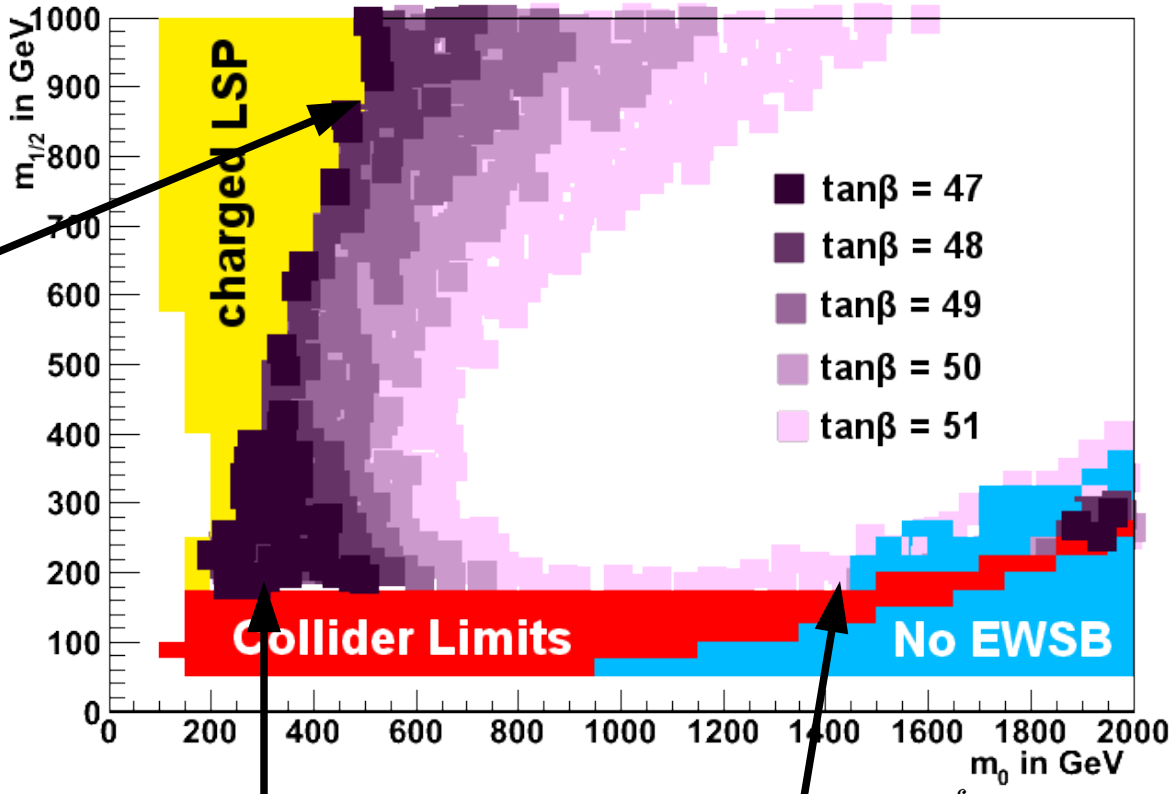

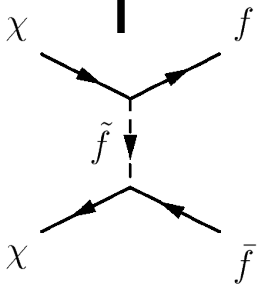

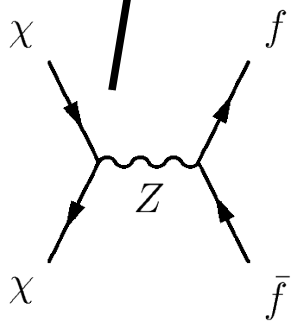

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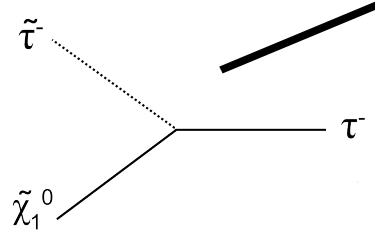

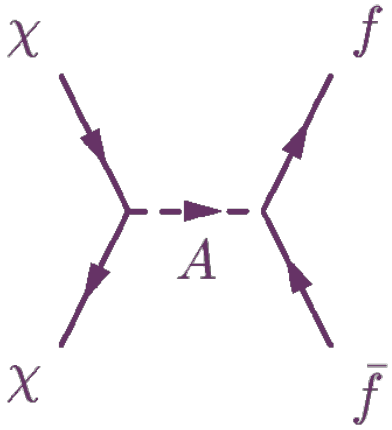

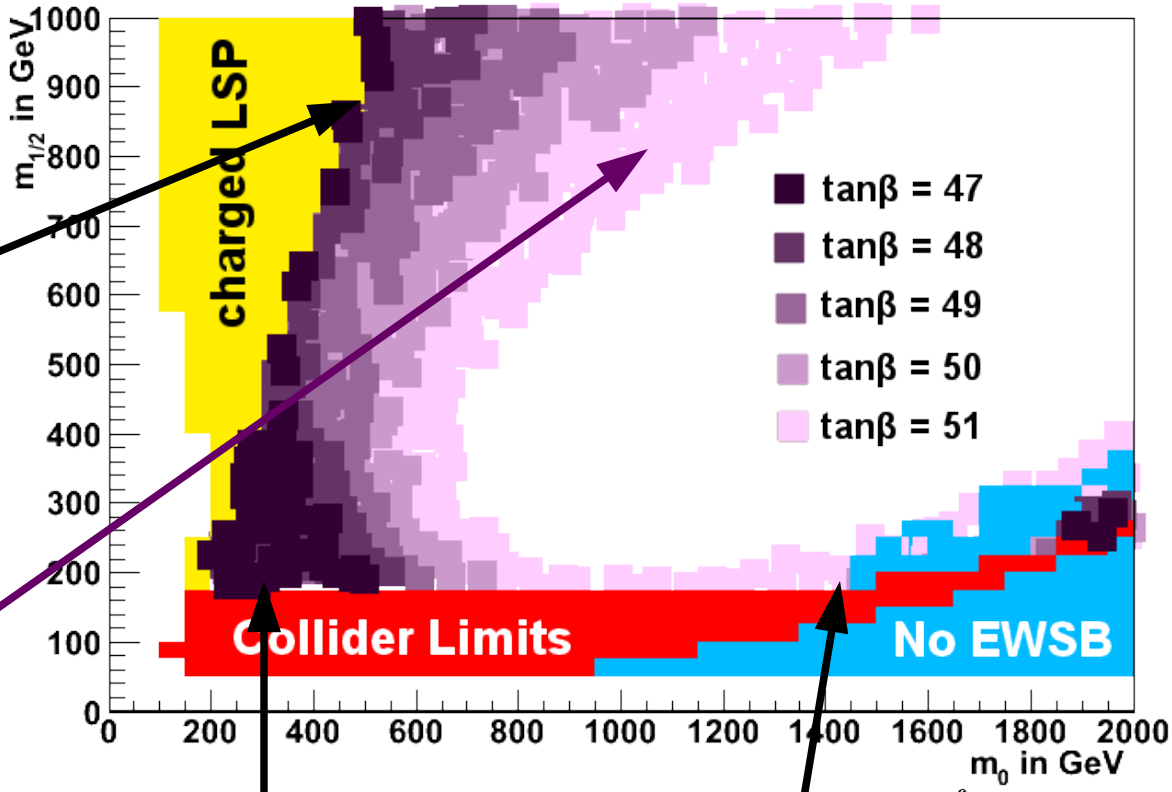

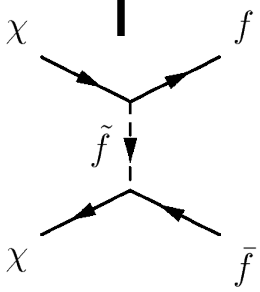

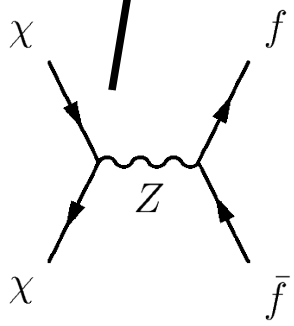

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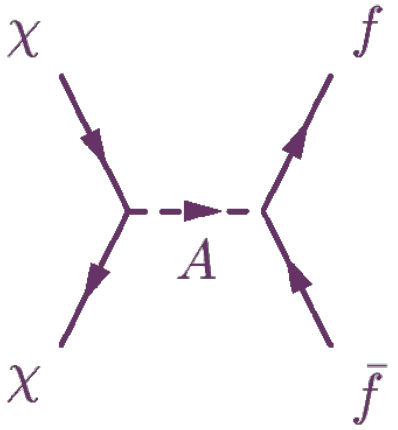
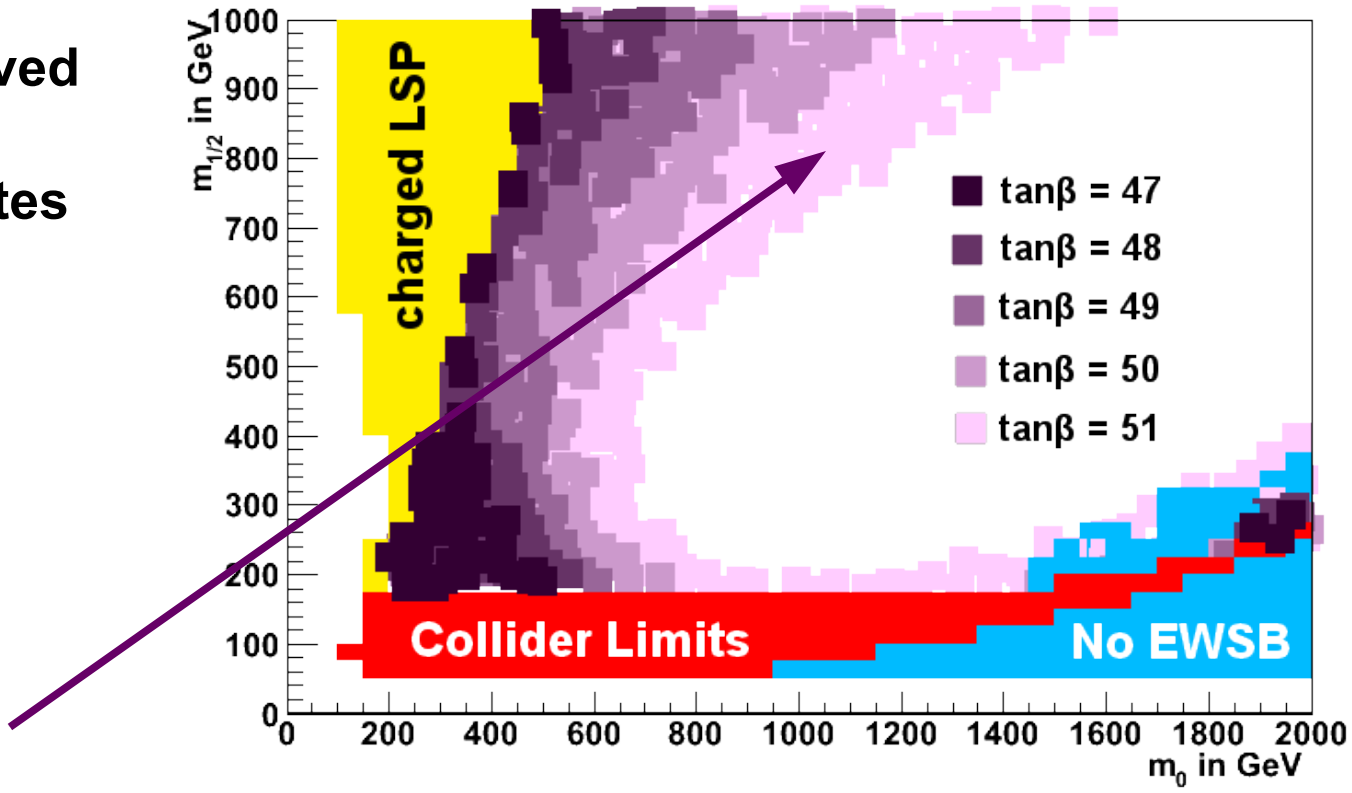




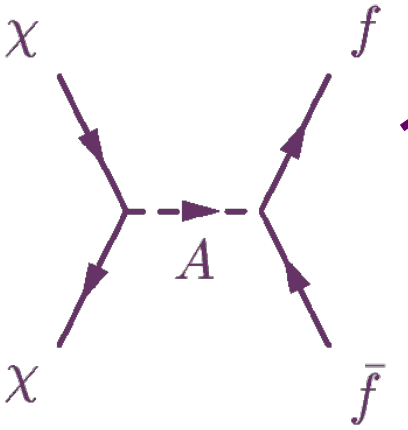
The Neutralino as CDM Candidate

- **R-parity conserved**

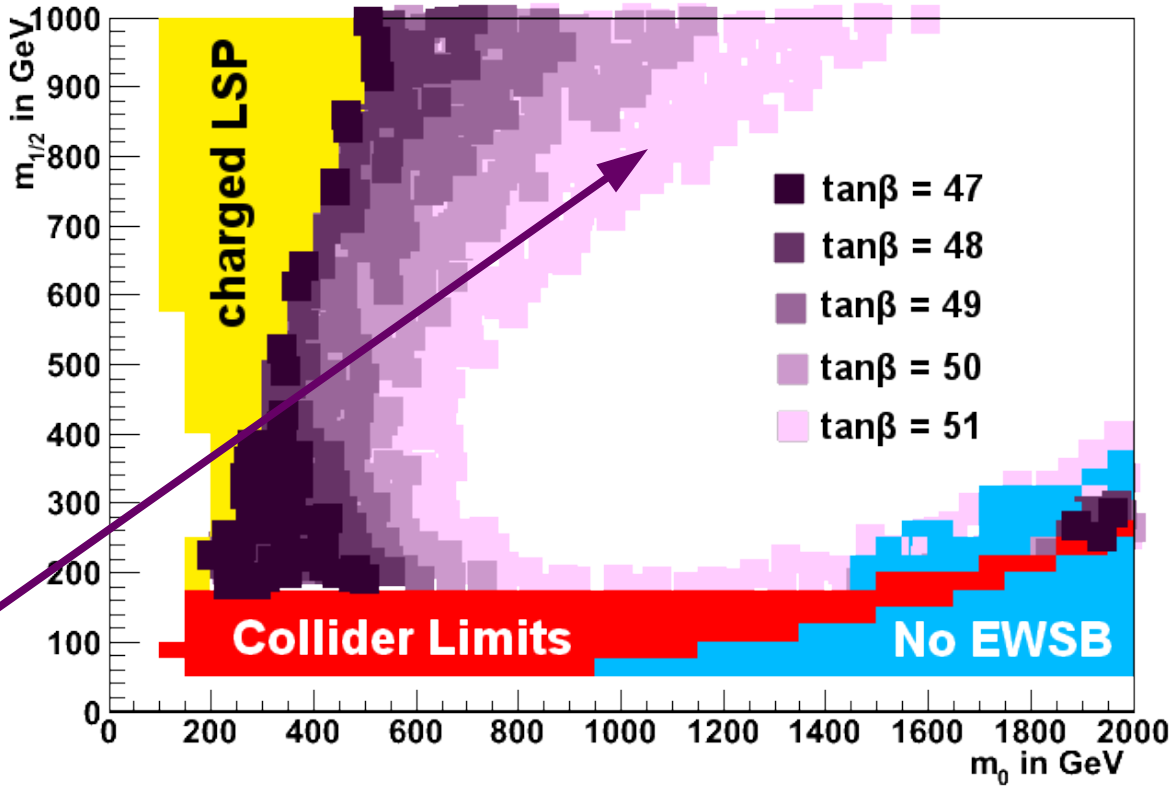
  → **LSP annihilates in pairs**

- **For varying tanβ**

  → **Leading diagram:**

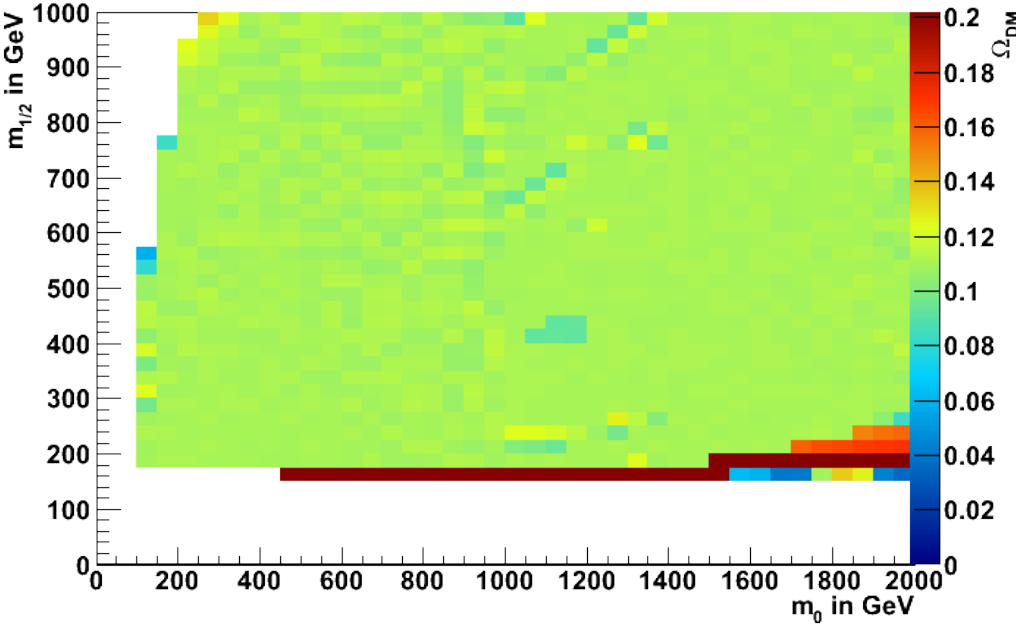


$\propto \tan^2\beta/(4m_\chi^2 - m_A^2)^2$



Find dark matter consistent points for whole $m_0 m_{1/2}$-plane by tuning tanβ

Predictions from mSUGRA

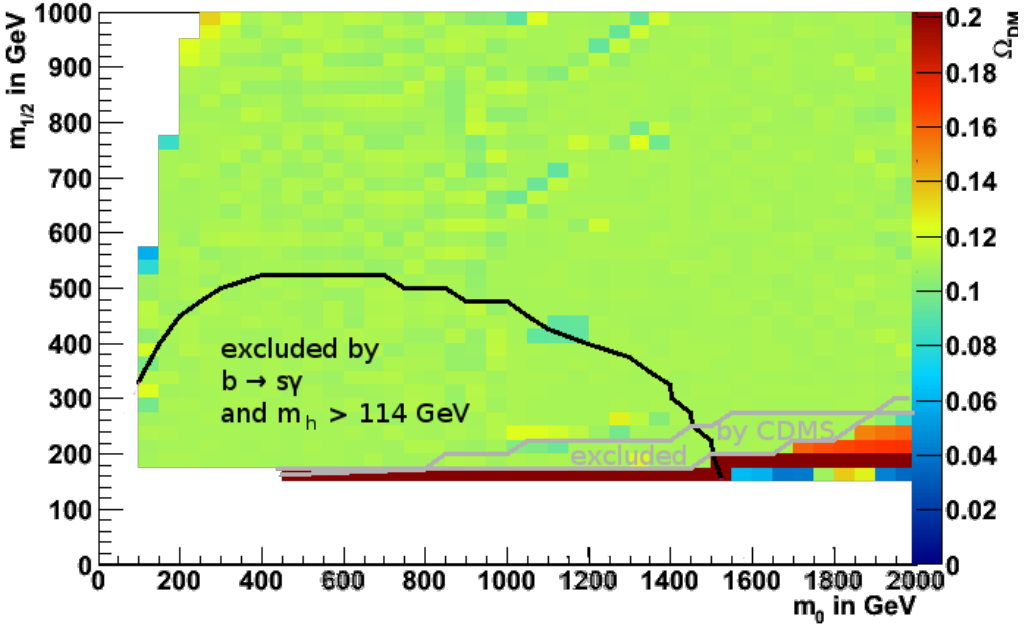


- **Now: Optimize $\tan\beta$ for each point in $m_0 m_{1/2}$ plane**

  → Good relic density solutions for whole parameter space

  → No real constraints from Dark Matter

Predictions from mSUGRA



Real Constraints:

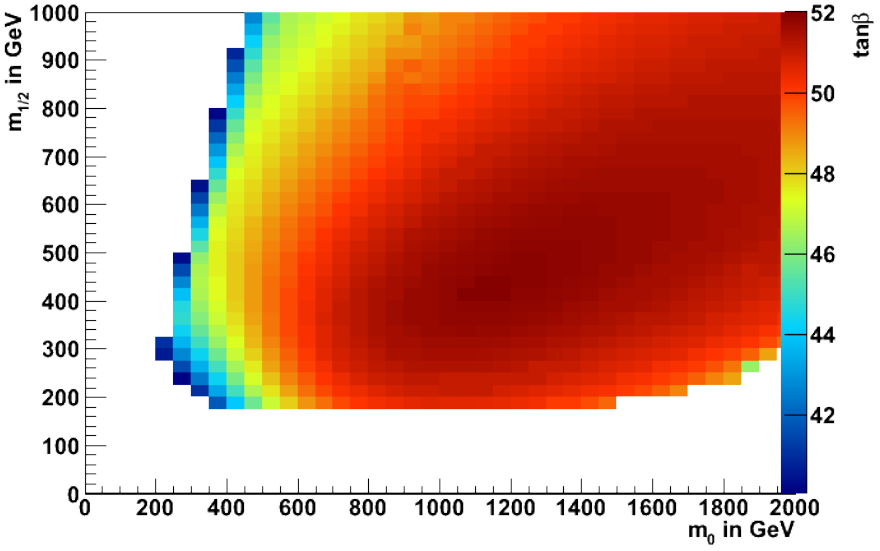
- $Br(b \rightarrow s\gamma) = (3.52 \pm 0.24) \times 10^{-5}$ (HFAG)
- $m_h > 114$ GeV (LEP)
- Exclusion by direct dark matter searches (CDMS)

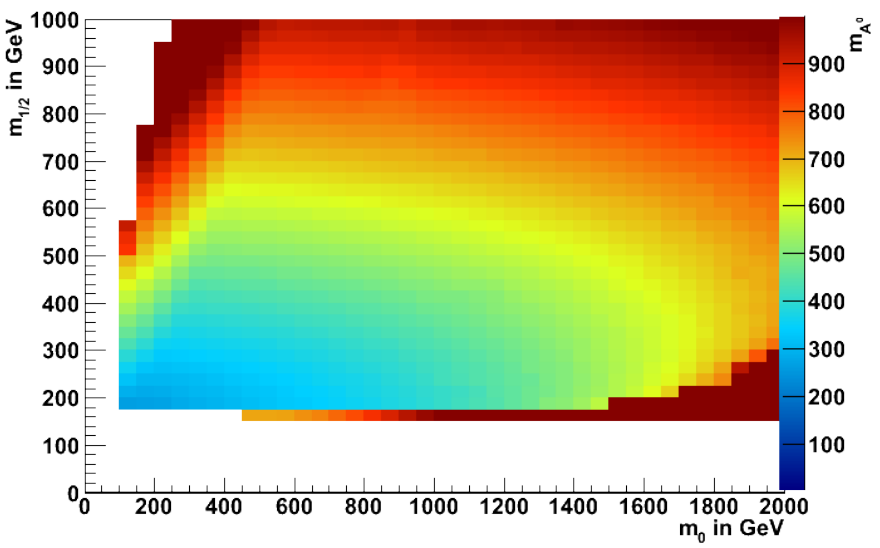
- Now: Optimize $\tan\beta$ for each point in $m_0 m_{1/2}$ plane

  → Good relic density solutions for whole parameter space

  → No real constraints from Dark Matter
- Low $m_{1/2}$ regions excluded by $b \rightarrow s\gamma$ and direct searches

Predictions from mSUGRA



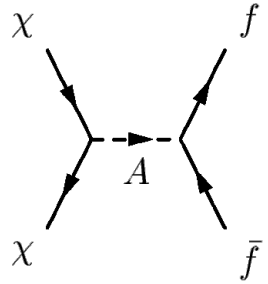


- m_A increasing with increasing $m_{1/2}$
- $m_A/2m_\chi \approx 1.2$ -2.4
- $\tan\beta \approx 50$ prefered

  → Leading annihilation channel via pseudoscalar Higgs

Can one measure Relic Density at the LHC ?

(Tim Hanisch)



$$\Omega h^2 \propto \tan^2\beta/(4m_\chi^2 - m_A^2)^2$$

Expected uncertainties:

- $\tan\beta$ +/- $\Delta \tan\beta$
- m_A +/- Δm_A
- m_χ +/- Δm_χ

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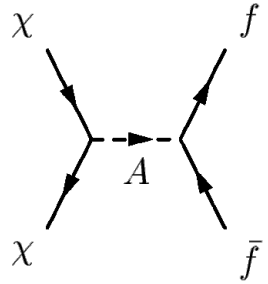

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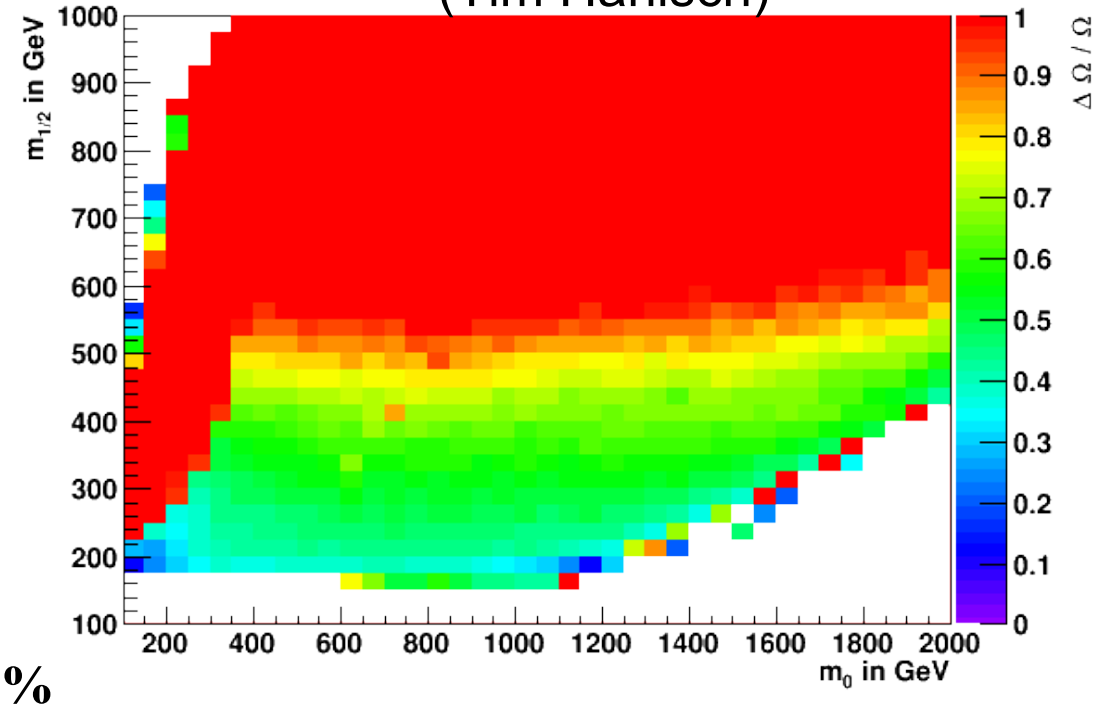

Expected uncertainties:

- $\tan\beta$ +/- $\Delta \tan\beta$ → 10%
- m_A +/- Δm_A → 3%
- m_χ +/- Δm_χ

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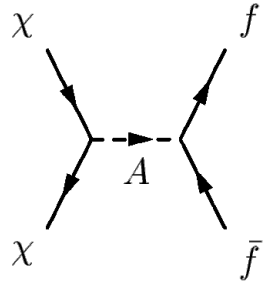

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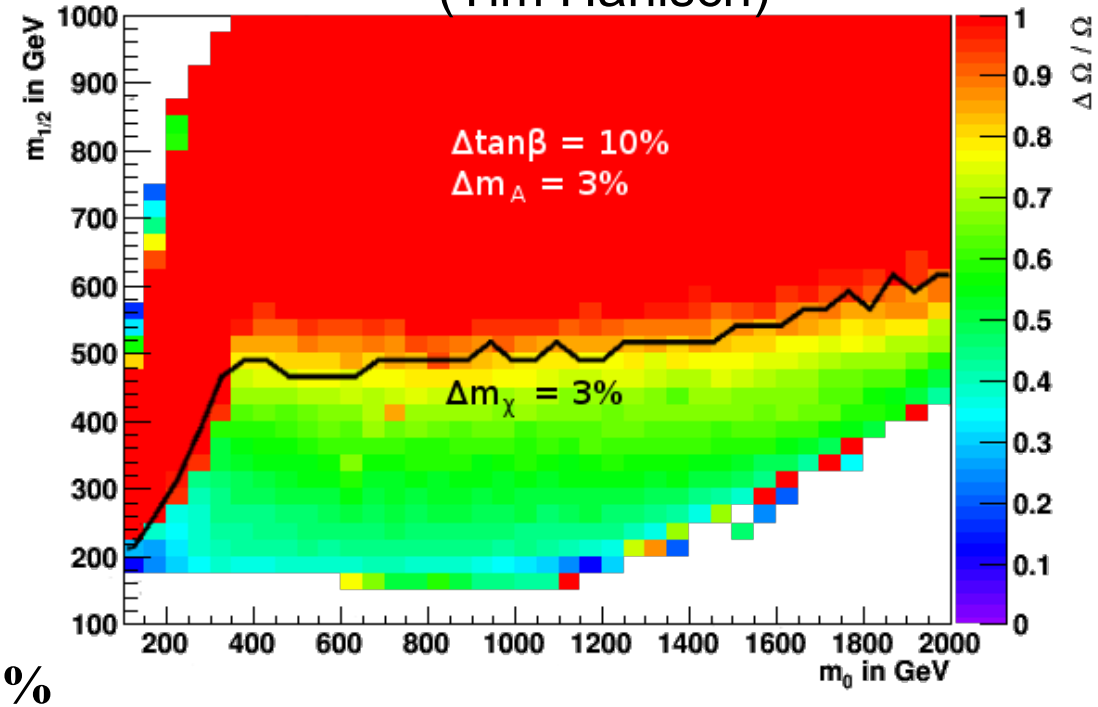


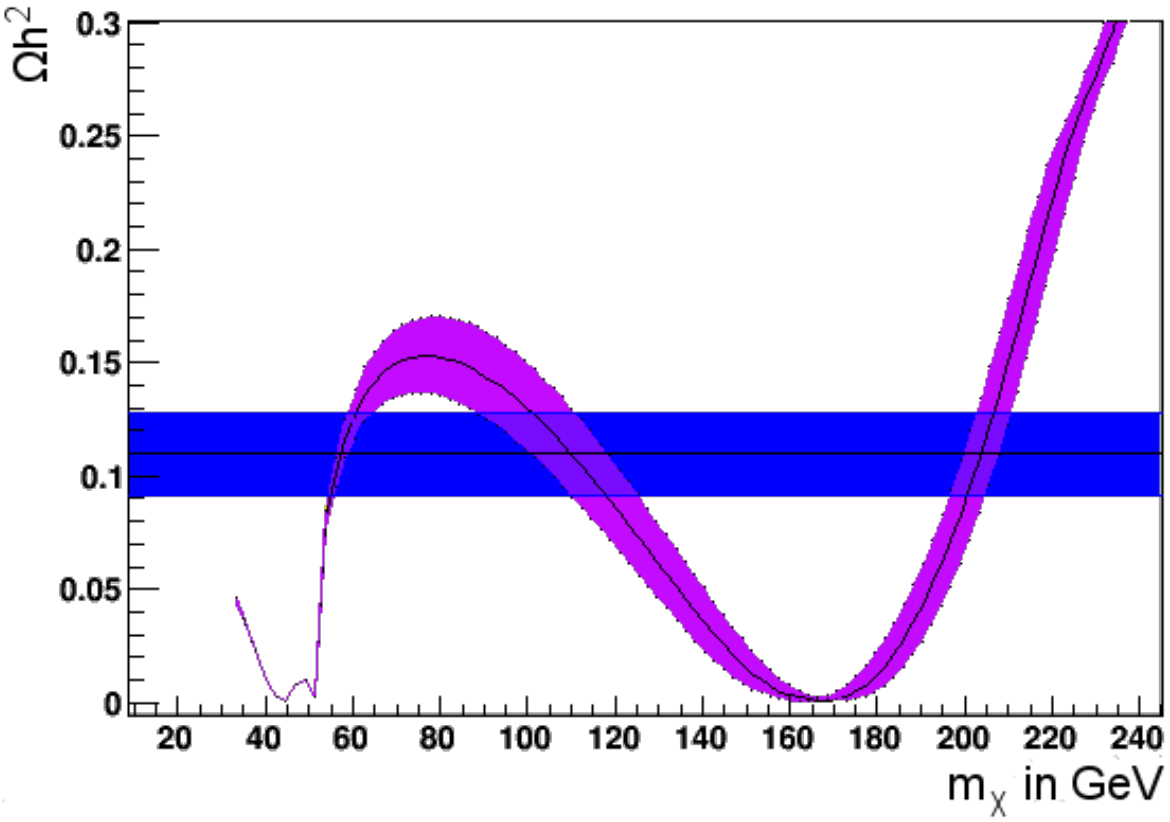
Expected uncertainties:

- $\tan\beta$ +/- $\Delta \tan\beta$ → 10%
- m_A +/- Δm_A → 3%
- m_χ +/- Δm_χ
  - Direct dark matter searches → ?
  - Indirect dark matter searches → ?
  - MET **(e.g. SCUPHY-TH-08006)** → 3%

Alternative: Measurement of m_χ

- **Alternative: Don't try to determine $\Delta\Omega/\Omega$, but determine m_χ from $\Omega = \Omega_{WMAP}$**

  $\rightarrow \Delta m_\chi \approx 10 - 11.5\ \%$



Conclusion

Constraints:

- Relic density doesn't give a constraint on SUSY masses
- Relic density requires $\tan\beta \approx 50$
  ($\rightarrow$ Annihilation via A_0 preferred, see arXiv:1008.2150v1)

Measurement at the LHC:

- Largest uncertainty from m_χ
- m_χ has to be measured more precisely to get accurate relic density from LHC data
- Alternatively, relic density from WMAP can be used to constrain m_χ

Backup: CDMS limit with other form factors

- **Normal:** f_d=0.026 f_u=0.020 f_s=0.02
- **MicrOMEGAs standard:** f_d=0.03302 f_u=0.02348 f_s=0.2594