Direct detection rates in well-tempered neutralino models

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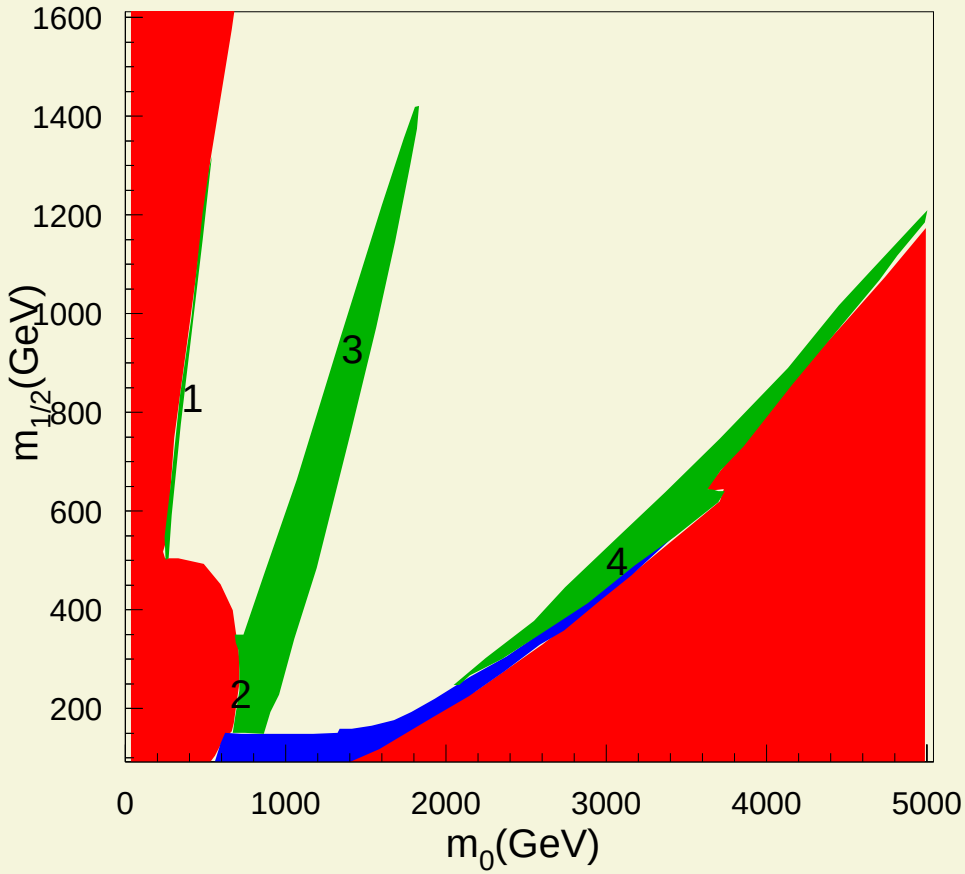
in collaboration with H.Baer, E.-K.Park, X.Tata: JCAP 0701 (2007)

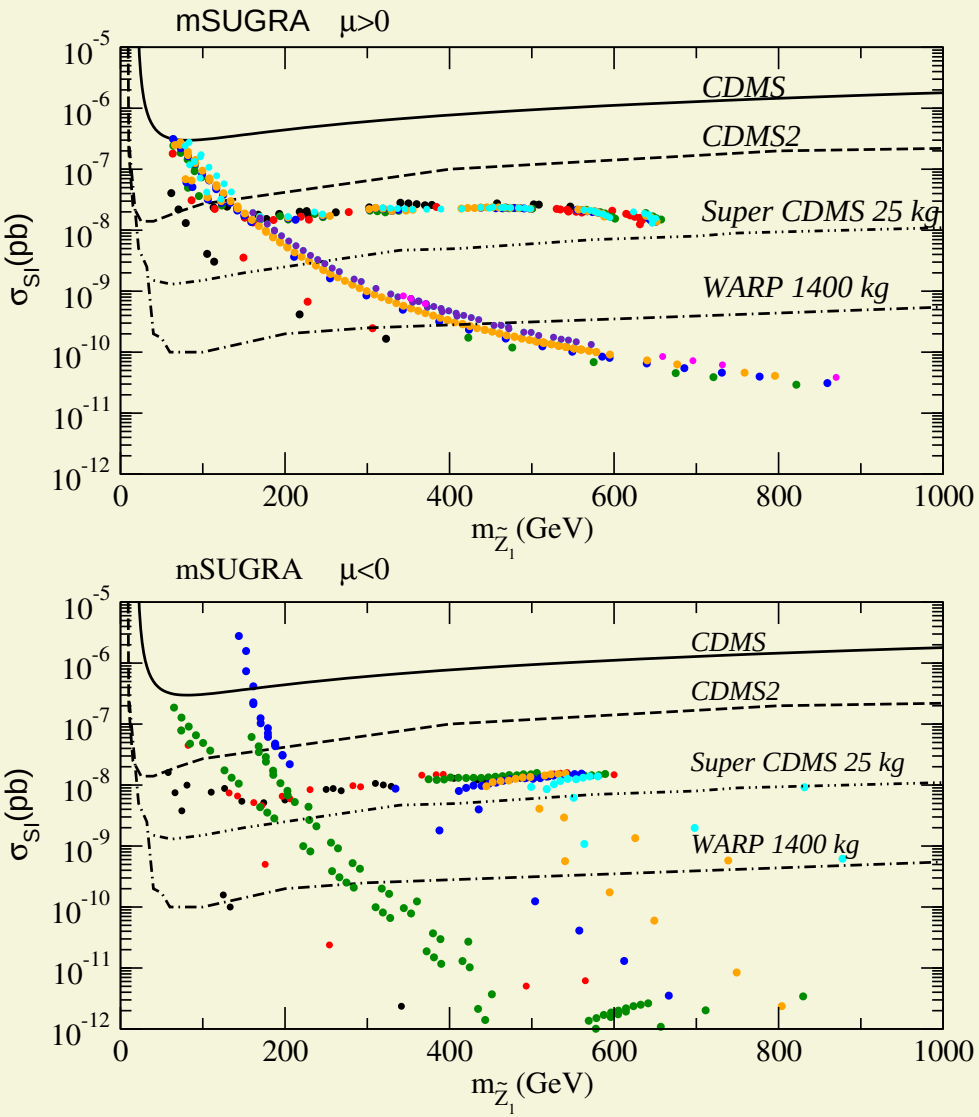
Overview of mSUGRA model

- Parameter space:
  $m_0,\ m_{1/2},\ A_0,\ sign(\mu),\ \tan\beta$
- WMAP allowed regions:
  1. stau co-annihilation ($m_{\widetilde{Z}_1} \simeq m_{\tilde{\tau}_1}$)
  2. bulk region
  3. A-funnel ($2m_{\widetilde{Z}_1} \simeq m_A,\ m_H$)
  4. HB/FP region (small $|\mu|$)
     - ⋆ h corridor ($2m_{\widetilde{Z}_1} \simeq m_h$)
     - ⋆ stop co-annihilation
       ($m_{\widetilde{Z}_1} \simeq m_{\tilde{t}_1}$ for particular A_0)
- $\widetilde{Z}_1$ is almost pure bino
  (mixed bino-higgsino in HB/FP)



Direct detection in mSUGRA

- Scan over $m_0,\ m_{1/2},\ \tan\beta$ (only WMAP-allowed points)
- For both signs of μ
  - Upper branch: HB/FP region
  - Lower branch: coannihilation and A-funnel regions

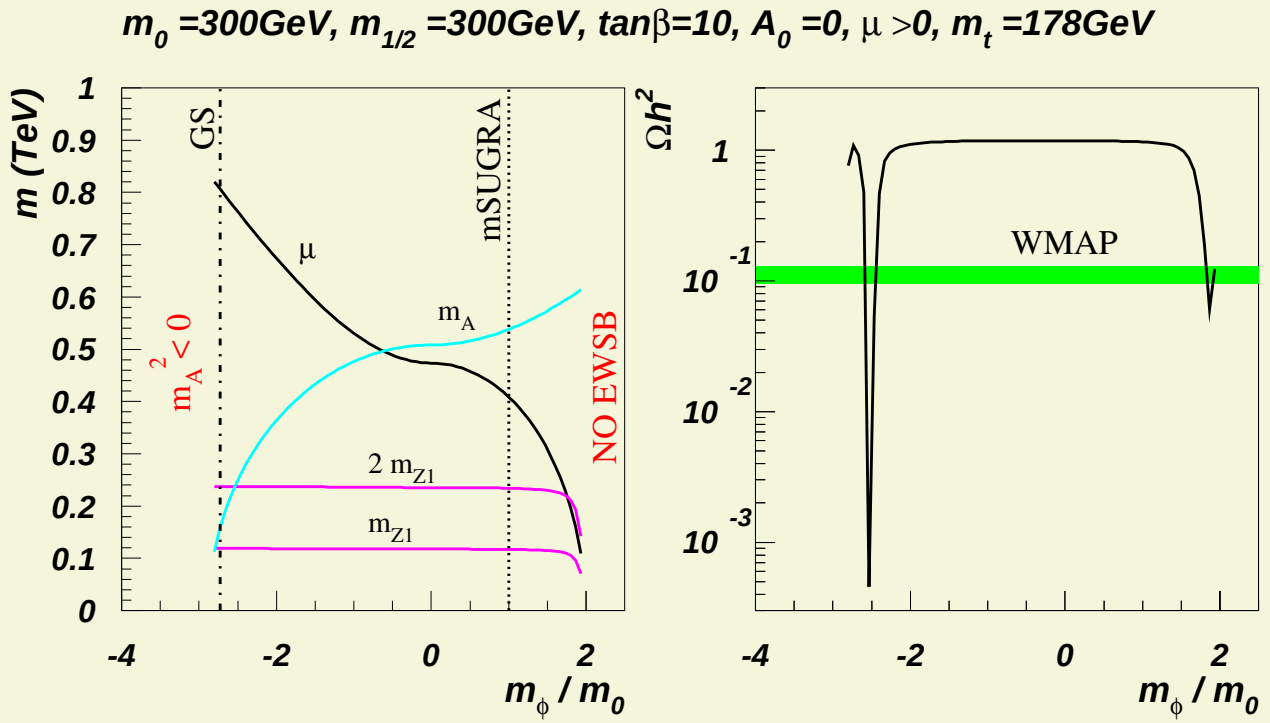


Non-universal SUGRA models

- Generally, mSUGRA has bino-like $\widetilde{Z}_1 \Rightarrow$ too high $\Omega_{\widetilde{Z}_1} h^2$, low DD rates
- Adjusting $\widetilde{Z}_1$ composition can give WMAP relic density - well-tempered neutralino models [*Arkani-Hamed et al.*]
- mSUGRA assumes universal SSB terms at GUT scale
- Non-universal SSB natural in many SUSY CUTs and string models
- Strategy:
  - adopt independent gaugino/Higgs masses at GUT scale
  - scan over $m_0,\ m_{1/2}$
  - adjust one of gaugino/Higgs masses to get $\Omega_{\widetilde{Z}_1} h^2 \sim 0.11$
  - compute DD rate using IsaReS (part of IsaTools package)

Non-universal Higgs model

- $m^2_{H_u} = m^2_{H_d} \equiv m^2_\phi \neq m^2_0$
- Motivated by $SO(10)$ SUSY GUTs where $\hat{H}_{u,d} \in \phi(10)$ while matter $\in \psi(16)$
- Two solutions for relic density:
  $m^2_\phi \gg m^2_0 \Rightarrow$ higgsino DM for any $m_0,\ m_{1/2}$
  $m^2_\phi < 0 \Rightarrow$ A-funnel for any $\tan\beta$, $\widetilde{Z}_1$ is bino-like



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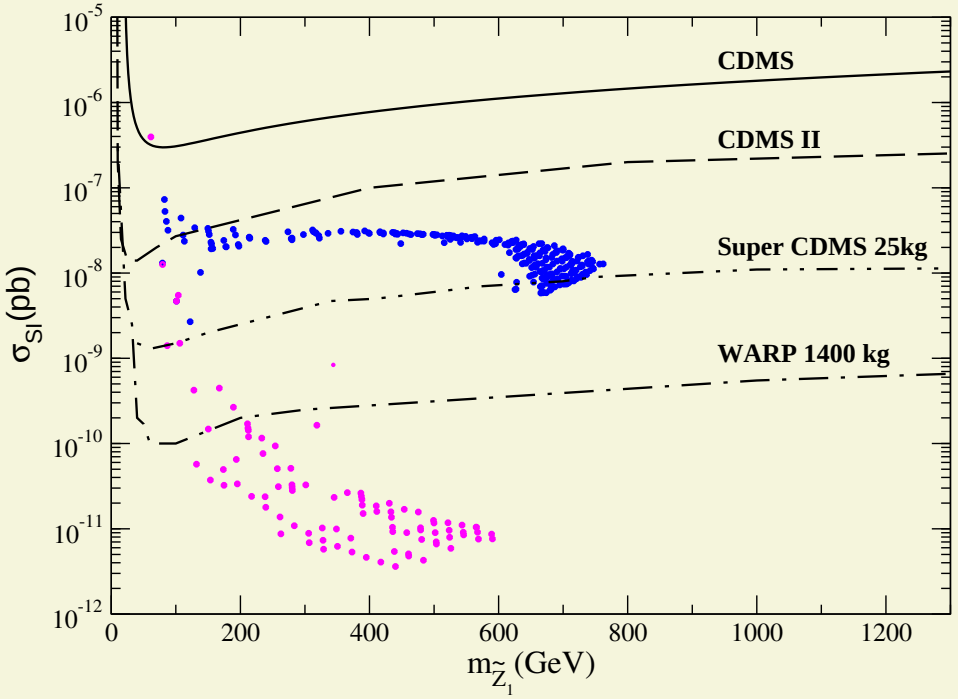
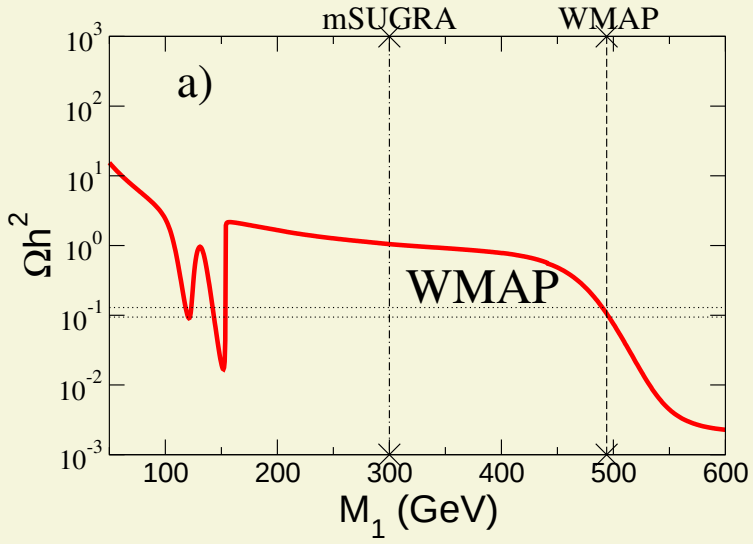
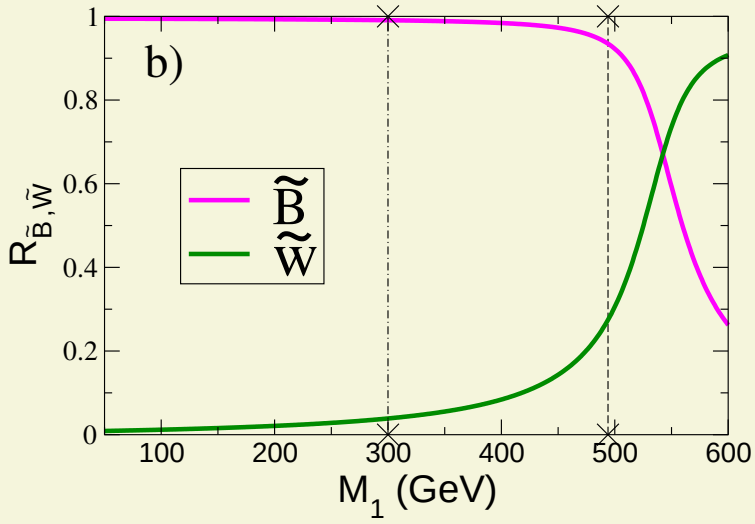


Mixed wino DM model

- $M_1 > M_2 = M_3 \equiv m_{1/2}$
- $M_1 \simeq M_2$ at weak scale: $\widetilde{Z}_1$ is mixed bino-wino with small higgsino component
- increased $\widetilde{Z}_1\widetilde{Z}_1 \to W^+W^-$ and co-annihilation with wino-like $\widetilde{Z}_2, \widetilde{W}_1$

m_0=300 GeV, $m_{1/2}$=300 GeV, tanβ=10, A_0=0, μ>0, m_t=178 GeV





Mixed wino DM model

- $M_1 > M_2 = M_3 \equiv m_{1/2}$ or $M_2 < M_1 = M_3 \equiv m_{1/2}$
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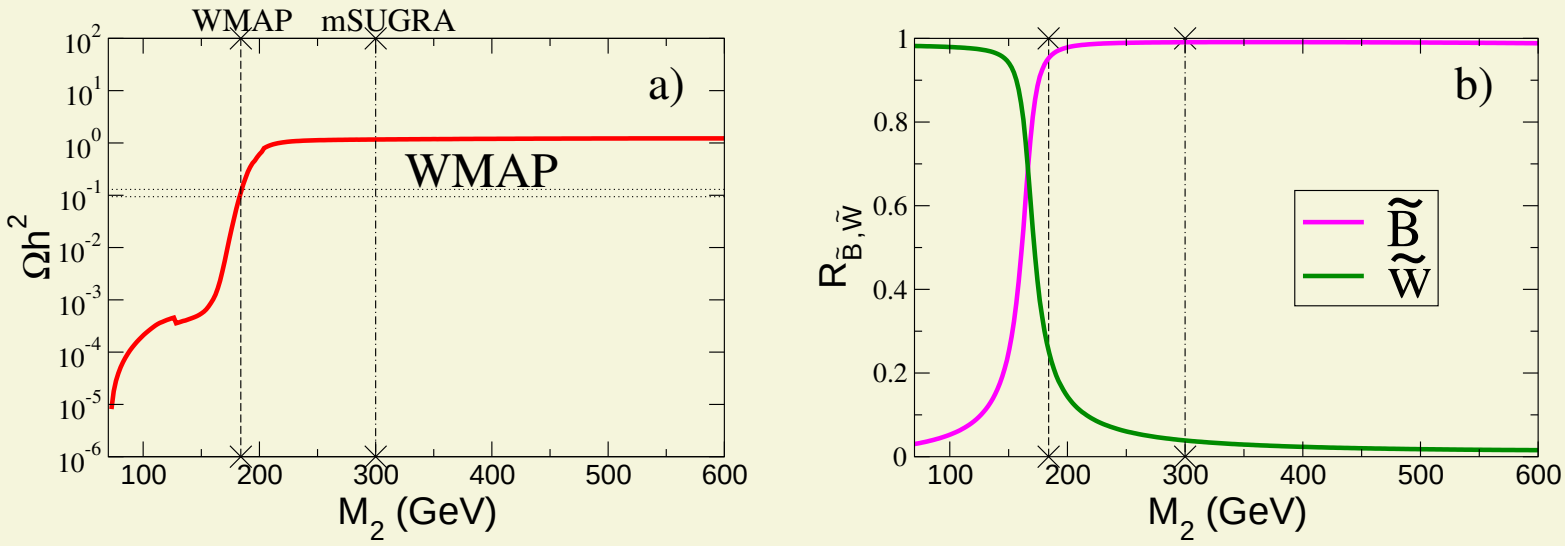

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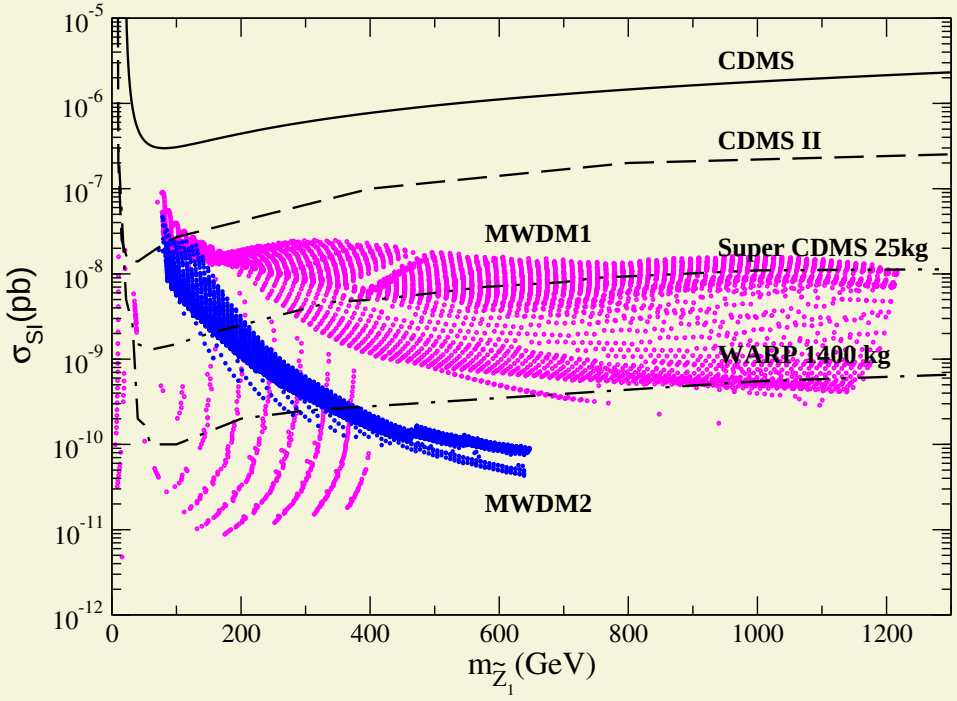
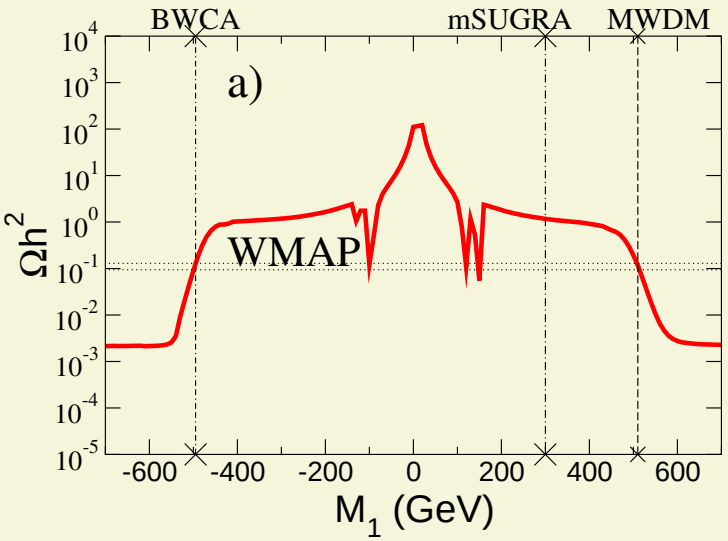
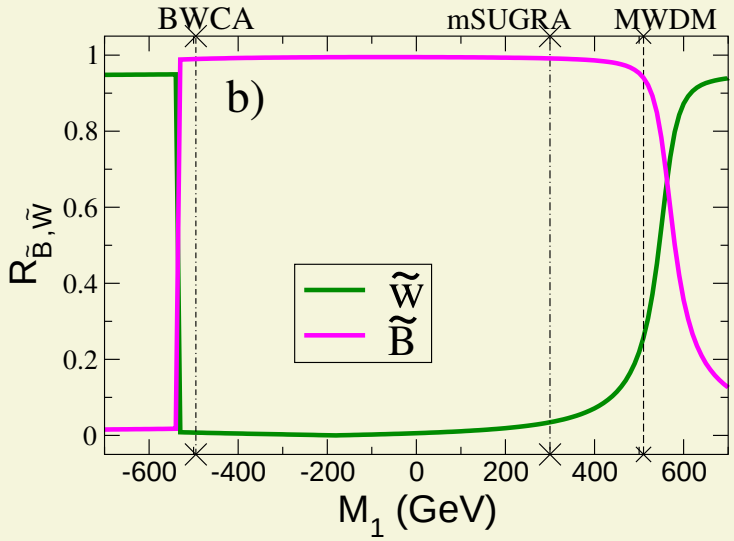


BWCA model

- $-M_1 \neq m_{1/2}$ or $-M_2 \neq m_{1/2}$
- $-M_1 \simeq M_2$ at weak scale: no mixing between bino and wino, $\widetilde{Z}_1$ is pure bino
- Can only reduce relic density via bino-wino co-annihilation ($m_{\widetilde{Z}_1} \simeq m_{\widetilde{Z}_2} \simeq m_{\widetilde{W}_1}$)

m_0=300 GeV, $m_{1/2}$=300 GeV, tanβ=10, A_0=0, μ>0, m_t=178 GeV





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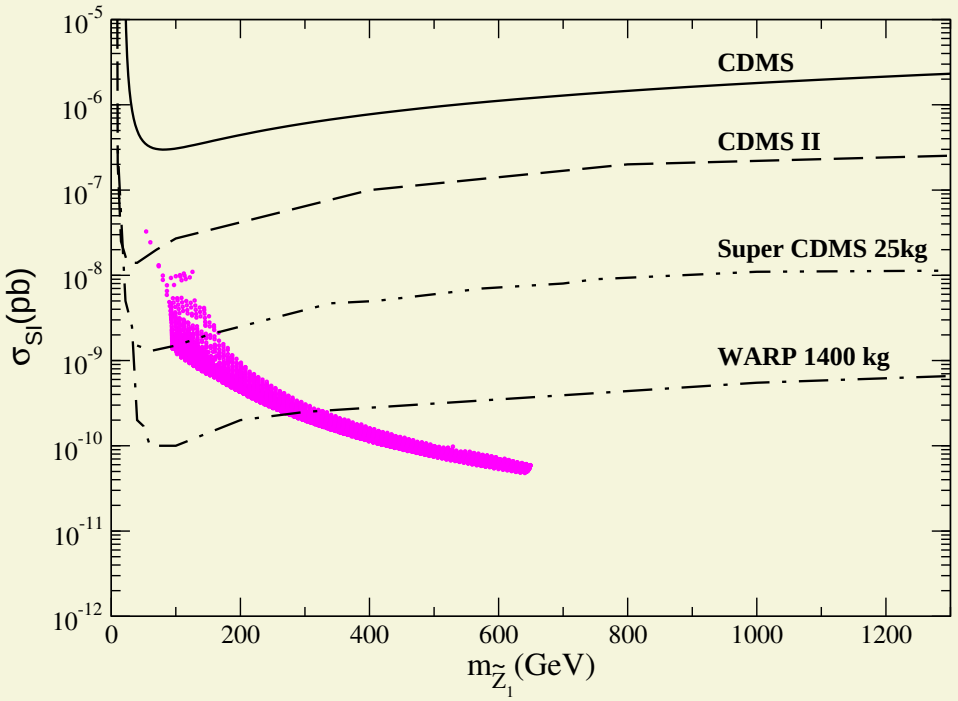
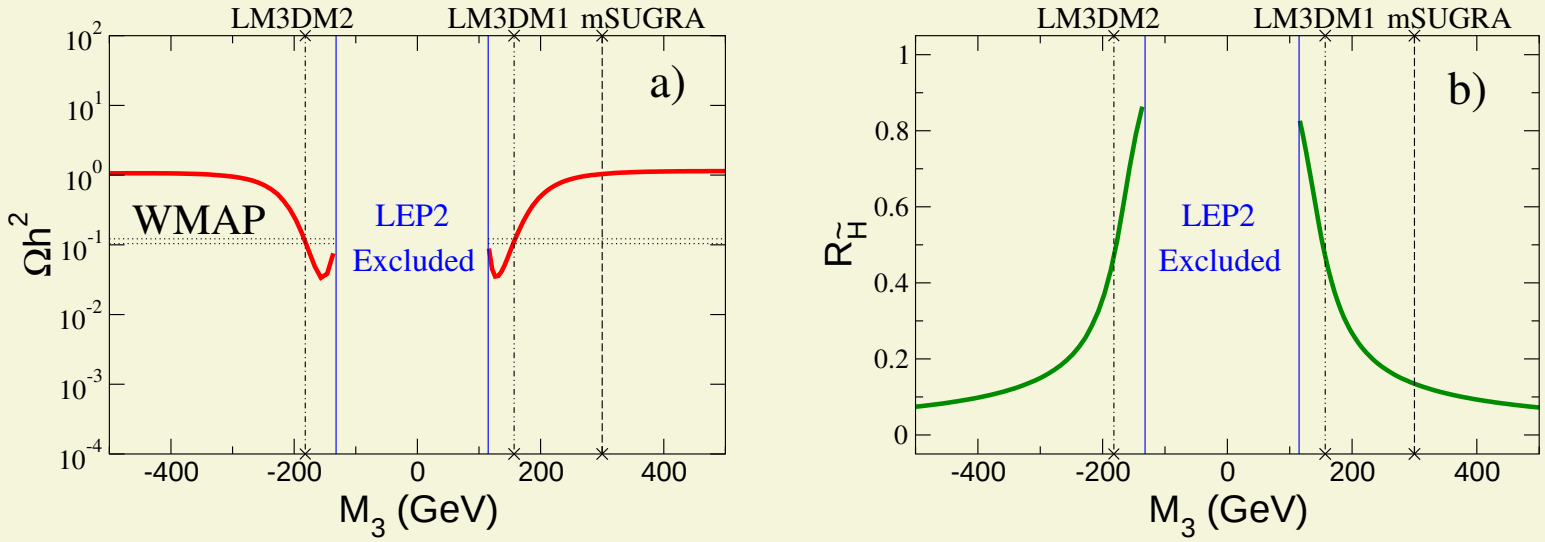


Low $|M_3|$ DM model

- $|M_3| < M_1 = M_2 \equiv m_{1/2}$
- lower $|M_3| \rightarrow$ low $m_{\tilde{g}}, m_{\tilde{q}} \rightarrow$ low $\mu \rightarrow$ mixed bino-higgsino $\widetilde{Z}_1$
- called "compressed SUSY" in related scenario by S.P.Martin

m_0=300 GeV, $m_{1/2}$=300 GeV, tanβ=10, A_0=0, μ>0, m_t=175 GeV



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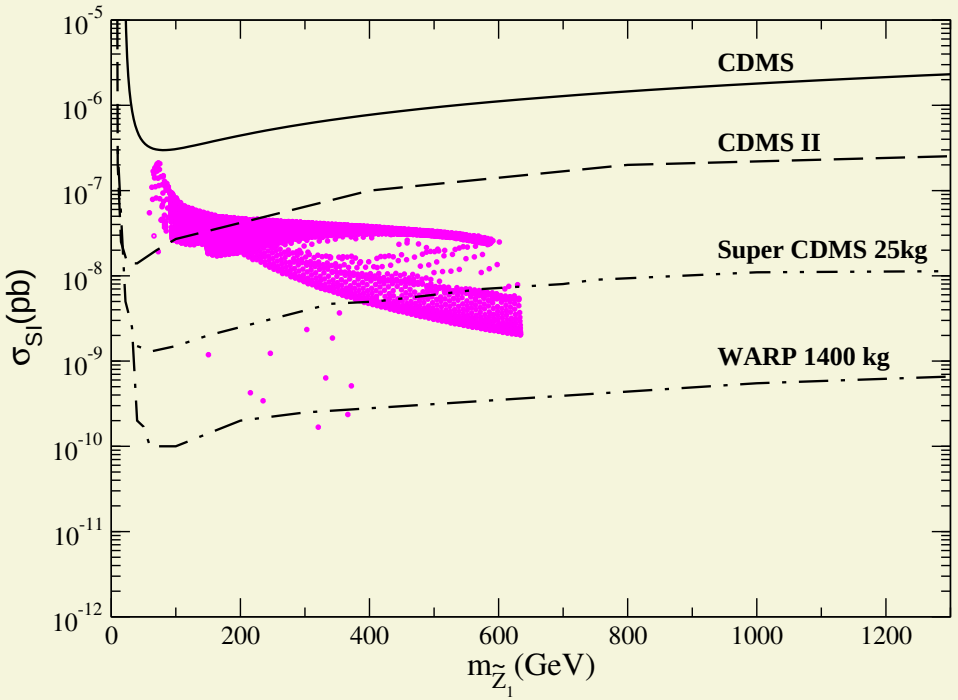

Conlusions

- Universal models (such as mSUGRA) generally predict too high relic density and low DD rates
- Well-tempered $\widetilde{Z}_1$ models where $\widetilde{Z}_1$ composition is adjusted (NUHM1, MWDM1, LM3DM) yield detectable $\sigma(\widetilde{Z}_1 p) \sim 10^{-8}$ pb
- Well-tempered $\widetilde{Z}_1$ models where sparticle masses adjusted instead (NUHM1 with $m_\phi^2 < 0$, MWDM2, BWCA) offer no enhancement of DD rates