SUSY 2007

SUSY-GUTs, SUSY-Seesaw and the Neutralino Dark Matter

Lorenzo Calibbi
Universidad de Valencia

Karlsruhe, 27/07/2007

SUSY 2007

SUSY-GUTs, SUSY-Seesaw and the Neutralino Dark Matter

Lorenzo Calibbi
Universidad de Valencia

based on L.C., Mambrini, Vempati, arXiv:0704.3518 [hep-ph]

Karlsruhe, 27/07/2007

MSSM neutralinos: $\left(\tilde{B}, \tilde{W}_3, \tilde{H}_d^0, \tilde{H}_u^0\right)$

$$\mathbf{M}_{\widetilde{N}} = \begin{pmatrix} M_1 & 0 & -c_\beta\, s_W\, m_Z & s_\beta\, s_W\, m_Z \\ 0 & M_2 & c_\beta\, c_W\, m_Z & -s_\beta\, c_W\, m_Z \\ -c_\beta\, s_W\, m_Z & c_\beta\, c_W\, m_Z & 0 & -\mu \\ s_\beta\, s_W\, m_Z & -s_\beta\, c_W\, m_Z & -\mu & 0 \end{pmatrix}$$

Lightest eigenvalue: $\tilde{\chi}_1^0 = Z_{11}\tilde{B} + Z_{12}\tilde{W}_3 + Z_{13}\tilde{H}_d^0 + Z_{14}\tilde{H}_u^0$

R-parity makes the LSP stable → candidate for CDM

Relic density (WMAP): $0.087 \lesssim \Omega_{DM} h^2 \lesssim 0.138$

CMSSM and three WMAP "corridors"

CMSSM: $m_0,\ M_{1/2},\ A_0,\ \tan\beta$ $\longrightarrow$ $M_{\rm GUT} \simeq 2\times 10^{16}\ {\rm GeV}$

Mostly "Bino": $\tilde{\chi}_1^0 = Z_{11}\tilde{B} + Z_{12}\tilde{W}_3 + Z_{13}\tilde{H}_d^0 + Z_{14}\tilde{H}_u^0$

Small annihilation cross-section → too large relic density

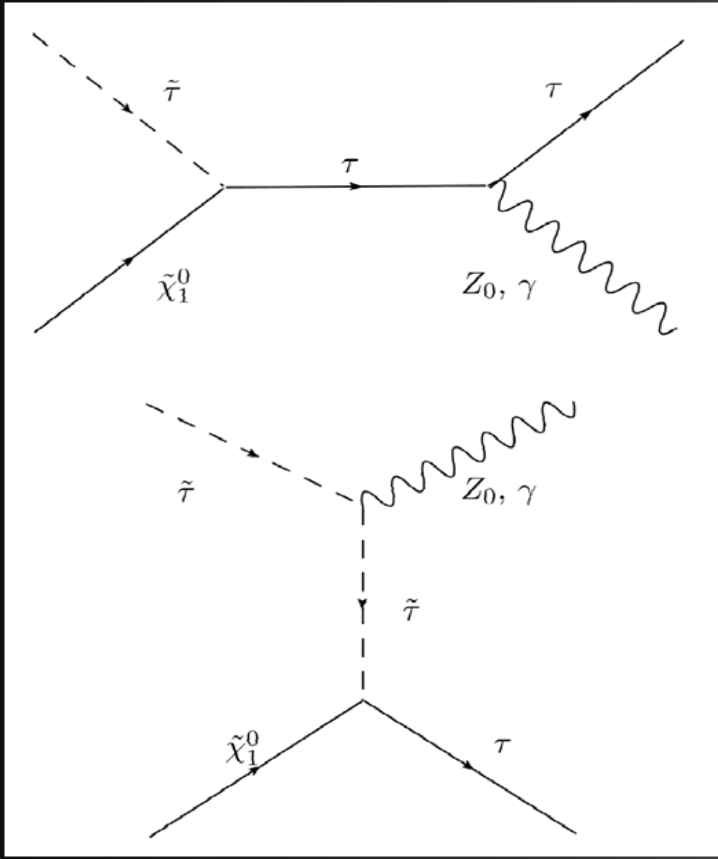
$$0.087 \lesssim \Omega_{DM} h^2 \lesssim 0.138$$

Peculiar conditions to enhance cross-section are needed!

CMSSM and three WMAP "corridors"

CMSSM: $m_0,\ M_{1/2},\ A_0,\ \tan\beta \longrightarrow M_{\rm GUT} \simeq 2\times 10^{16}\ {\rm GeV}$

Mostly "Bino": $\tilde{\chi}_1^0 = Z_{11}\tilde{B} + Z_{12}\tilde{W}_3 + Z_{13}\tilde{H}_d^0 + Z_{14}\tilde{H}_u^0$



Stau coannihilation:

$$\tilde{\chi}_1^0 + \tilde{\tau}_1 \to \tau + Z_0(\gamma)$$

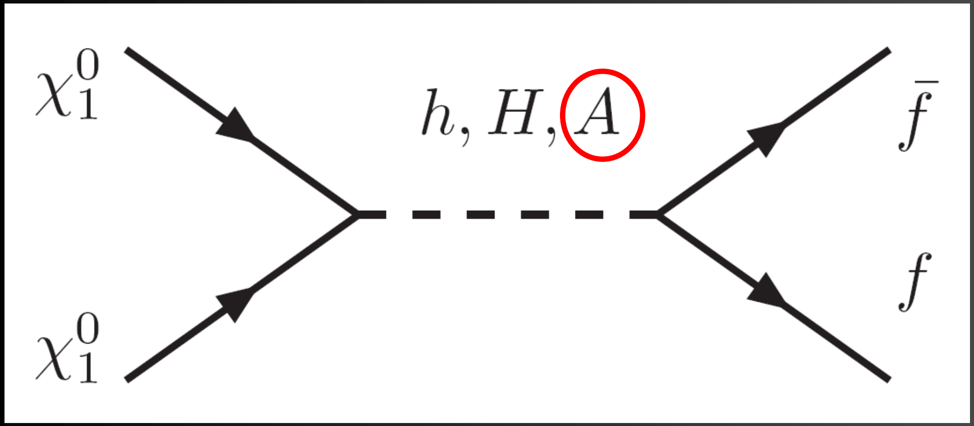
$$m_{\tilde{\chi}_1^0} \simeq m_{\tilde{\tau}_1}$$

→ close to the "stau LSP" region

CMSSM and three WMAP "corridors"

CMSSM: $m_0,\ M_{1/2},\ A_0,\ \tan\beta$ $\longrightarrow$ $M_{\rm GUT} \simeq 2 \times 10^{16}\,\rm GeV$

Mostly "Bino": $\tilde{\chi}_1^0 = Z_{11}\tilde{B} + Z_{12}\tilde{W}_3 + Z_{13}\tilde{H}_d^0 + Z_{14}\tilde{H}_u^0$



A-pole funnel:

$$\tilde{\chi}_1^0 + \tilde{\chi}_1^0 \to f + \bar{f}$$

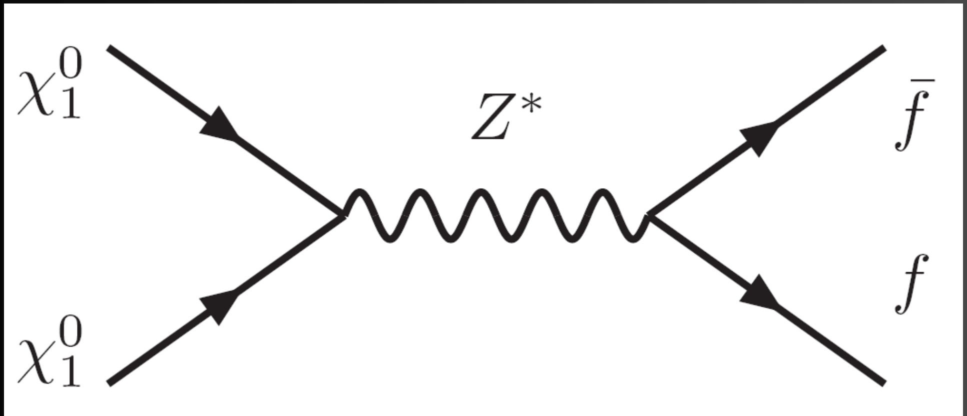
$$2\, m_{\tilde{\chi}_1^0} \simeq m_{A^0}$$

possible for large values of tanβ

CMSSM and three WMAP "corridors"

CMSSM: $m_0,\ M_{1/2},\ A_0,\ \tan\beta$ $\longrightarrow$ $M_{\rm GUT} \simeq 2\times 10^{16}\,{\rm GeV}$

~~Mostly "Bino":~~ $\tilde{\chi}^0_1 = Z_{11}\tilde{B} + Z_{12}\tilde{W}_3 + Z_{13}\tilde{H}^0_d + Z_{14}\tilde{H}^0_u$



Focus point:

$$\tilde{\chi}^0_1 + \tilde{\chi}^0_1 \longrightarrow f + \bar{f}$$

$$\propto \frac{m_f m_\chi}{m_Z^2}\left(-|Z_{13}|^2 + |Z_{14}|^2\right)$$

for small $\mu \rightarrow$ close to the "no EWSB" region ($\mu^2 < 0$)

CMSSM vs. *SU(5)*$_{RN}$

$$W_{\rm MSSM} = Y^u\ Q\ u^c\ h_u + Y^d\ Q\ d^c\ h_d + Y^e\ L\ e^c\ h_d + \mu\ h_u\ h_d$$

$$10 = \begin{pmatrix} 0 & u^c & -u^c & -u & -d \\ -u^c & 0 & u^c & -u & -d \\ u & -u^c & 0 & -u & -d \\ u & u & u & 0 & e^c \\ d & d & d & -e^c & 0 \end{pmatrix}_L \qquad \bar{5} = \begin{pmatrix} d^c \\ d^c \\ d^c \\ e \\ \nu \end{pmatrix}_L$$

$$W_{SU(5)_{RN}} = Y^u\ 10\ 10\ 5_u + Y^d\ 10\ \bar{5}\ \bar{5}_d + Y^\nu\ \bar{5}\ 1\ 5_u + M_R\ 1\ 1 + \mu\ 5_u\ \bar{5}_d$$

CMSSM vs. *SU(5)*$_{RN}$

$$W_{\rm MSSM} = Y^u\ Q\ u^c\ h_u + Y^d\ Q\ d^c\ h_d + Y^e\ L\ e^c\ h_d + \mu\ h_u\ h_d$$

$$10 = \begin{pmatrix} 0 & u^c & -u^c & -u & -d \\ -u^c & 0 & u^c & -u & -d \\ u & -u^c & 0 & -u & -d \\ u & u & u & 0 & e^c \\ d & d & d & -e^c & 0 \end{pmatrix}_L \qquad \bar{5} = \begin{pmatrix} d^c \\ d^c \\ d^c \\ e \\ \nu \end{pmatrix}_L$$

$$W_{SU(5)_{RN}} = Y^u\ 10\ 10\ 5_u + Y^d\ 10\ \bar{5}\ \bar{5}_d + Y^\nu\ \bar{5}\ 1\ 5_u + M_R\ 1\ 1 + \mu\ 5_u\ \bar{5}_d$$

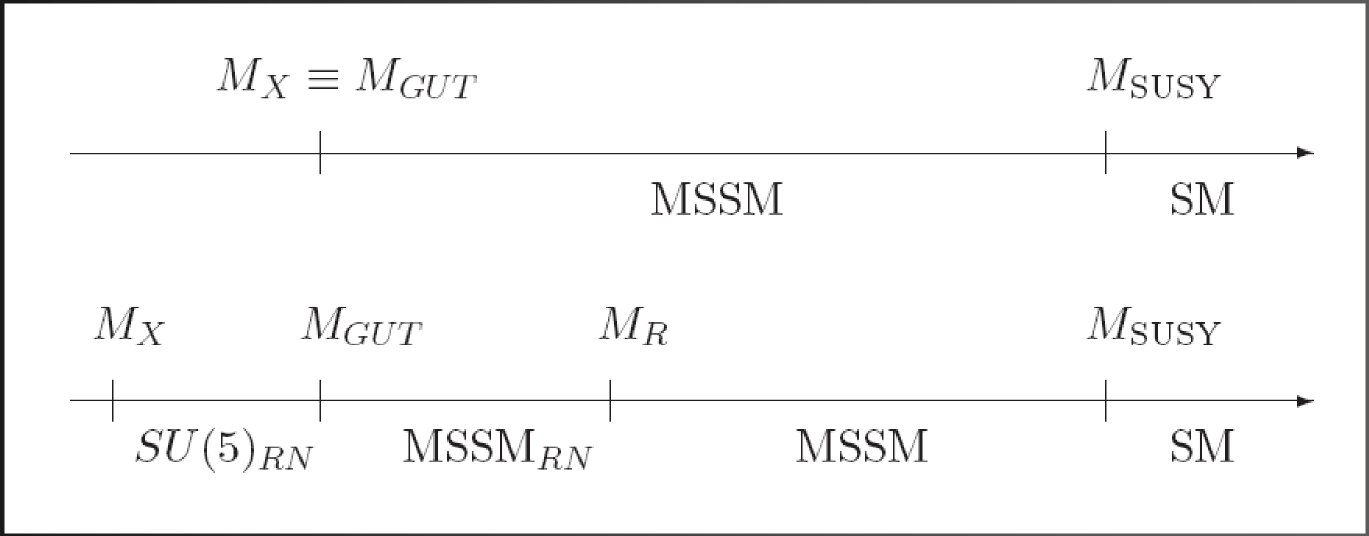
CMSSM vs. $SU(5)_{RN}$

$$W_{\rm MSSM} = Y^u\, Q\, u^c\, h_u + Y^d\, Q\, d^c\, h_d + Y^e\, L\, e^c\, h_d + \mu\, h_u\, h_d$$

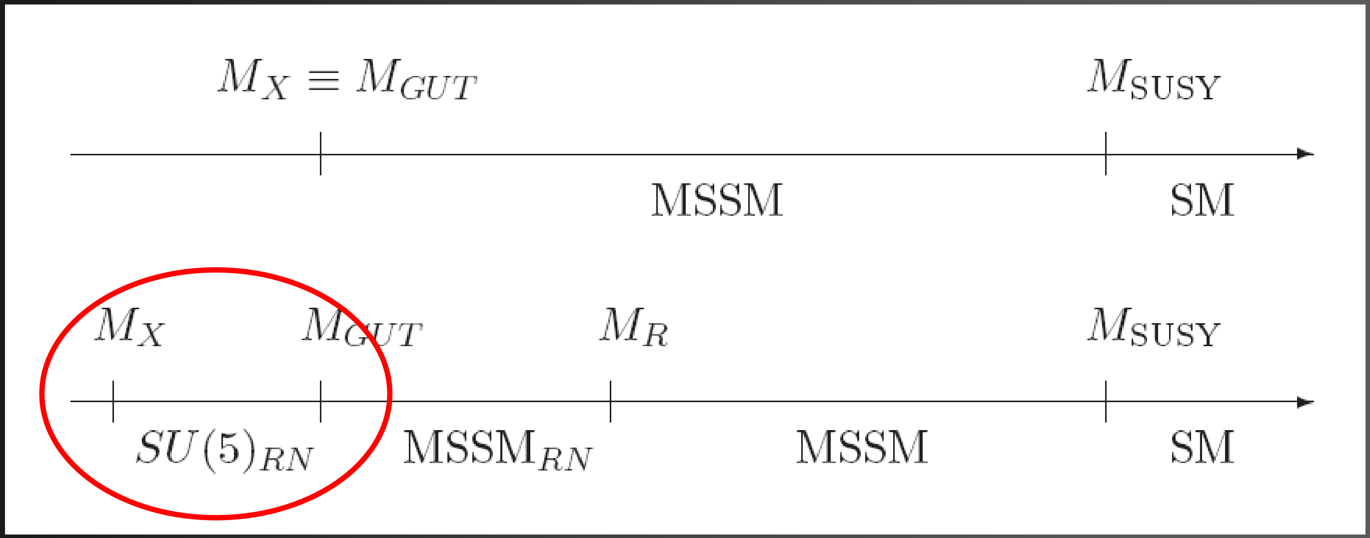
$$10 = \begin{pmatrix} 0 & u^c & -u^c & -u & -d \\ -u^c & 0 & u^c & -u & -d \\ u & -u^c & 0 & -u & -d \\ u & u & u & 0 & e^c \\ d & d & d & -e^c & 0 \end{pmatrix}_L \qquad \bar{5} = \begin{pmatrix} d^c \\ d^c \\ d^c \\ e \\ \nu \end{pmatrix}_L$$

$$W_{SU(5)_{RN}} = Y^u\, 10\, 10\, 5_u + Y^d\, 10\, \bar{5}\, \bar{5}_d + Y^\nu\, \bar{5}\, 1\, 5_u + M_R\, 1\, 1 + \mu\, 5_u\, \bar{5}_d$$

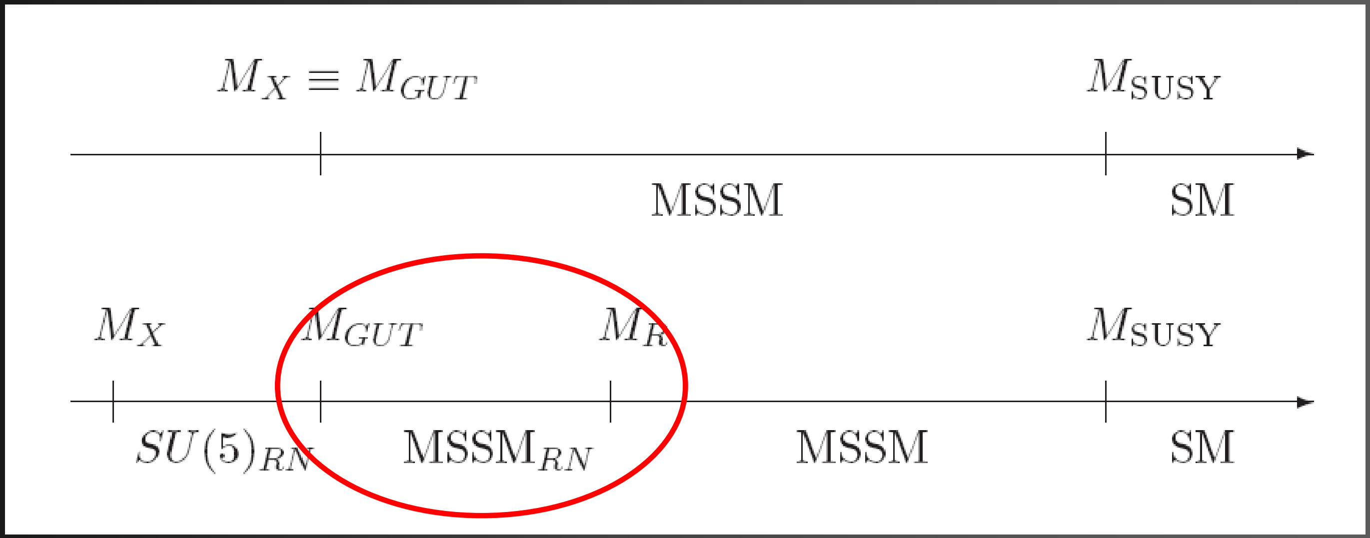
CMSSM vs. $SU(5)_{RN}$



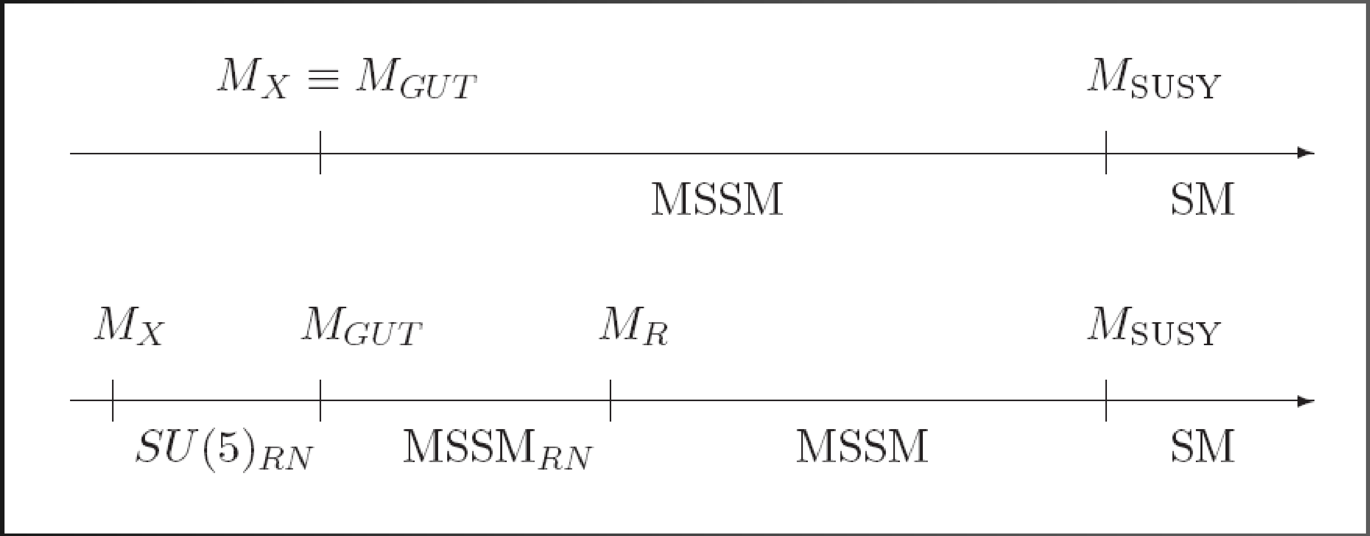
CMSSM vs. $SU(5)_{RN}$

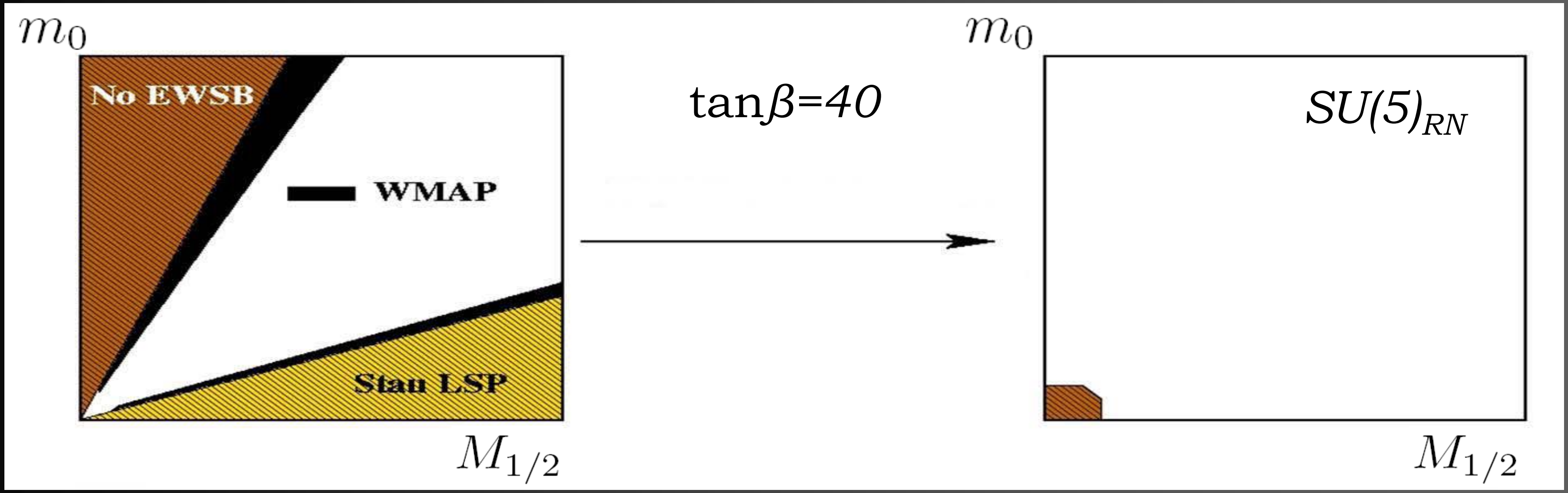


CMSSM vs. $SU(5)_{RN}$



$SU(5)_{RN}$ parameter space

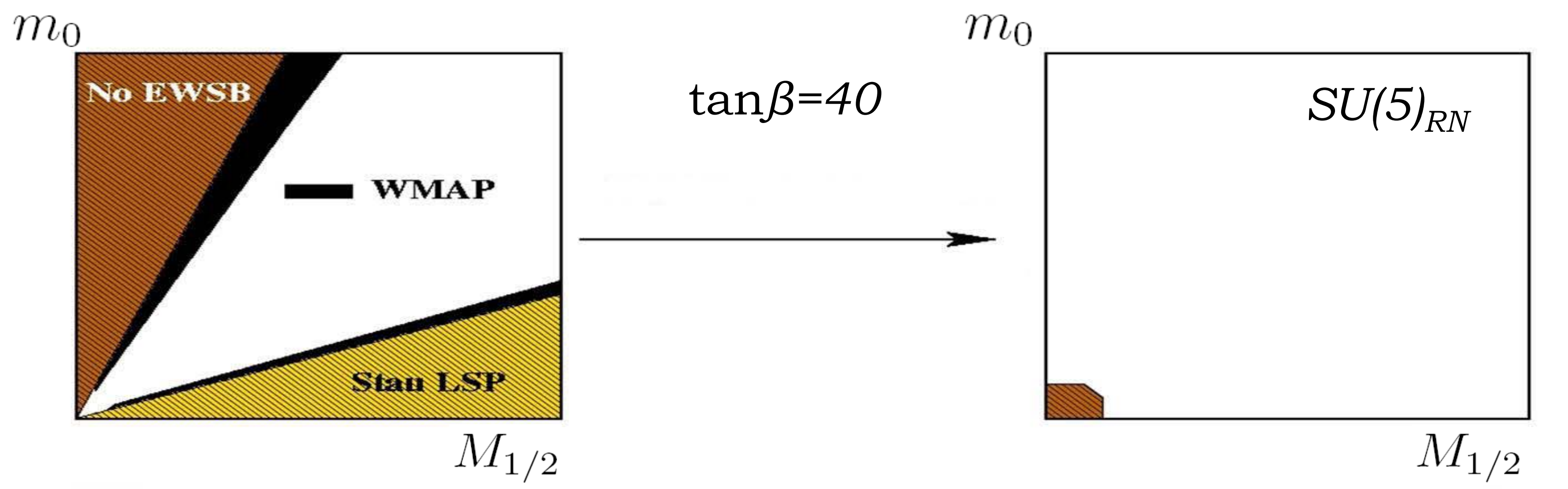




SU(5)$_{RN}$ parameter space

I)

II)

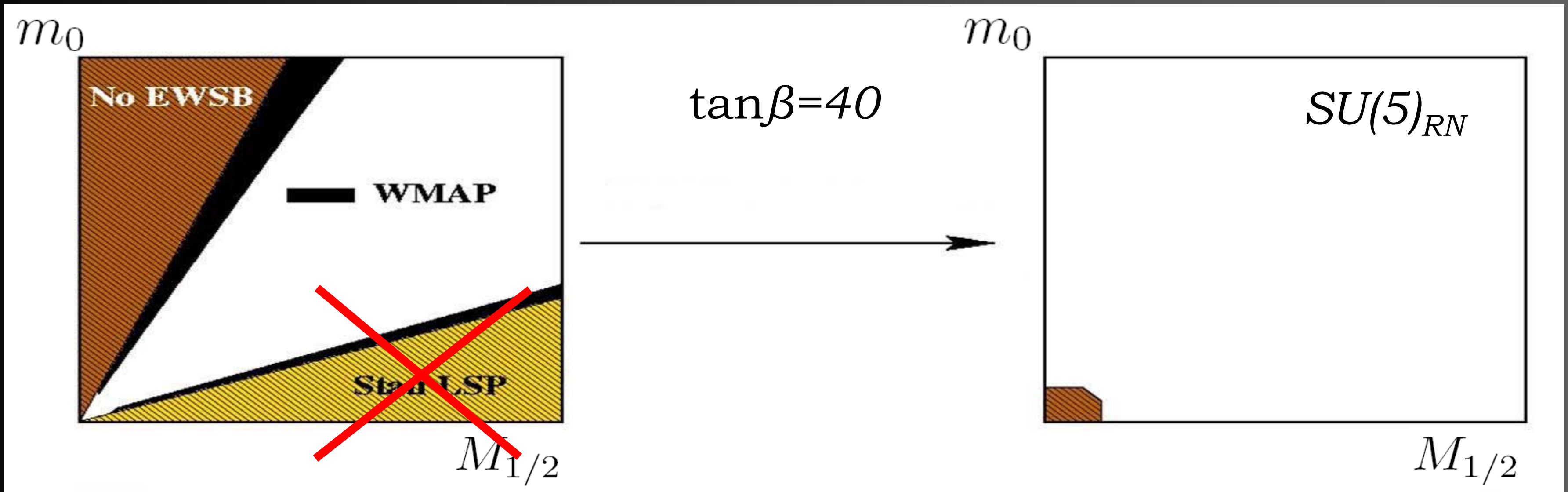


$SU(5)_{RN}$ parameter space

I) $$M_X \longrightarrow M_{\rm GUT} \;\Rightarrow m^2_{\tilde{\tau}_R}(M_{\rm GUT}) \simeq \frac{144}{20\pi}\alpha_5 M^2_{1/2}\ln\left(\frac{M_X}{M_{\rm GUT}}\right) \simeq 0.25\, M^2_{1/2}$$

(right stau mass for $m_0 = 0$)

II)



$SU(5)_{RN}$ parameter space

I)

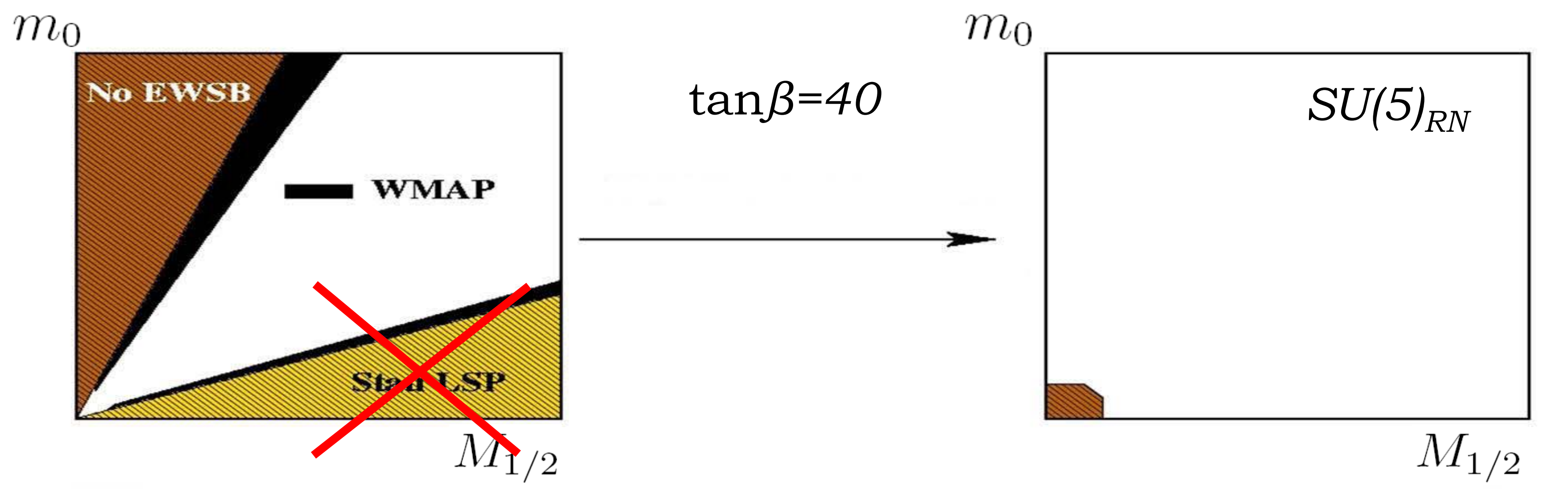
$$M_X \longrightarrow M_{\rm GUT} \;\Rightarrow\; m^2_{\tilde{\tau}_R}(M_{\rm GUT}) \simeq \frac{144}{20\pi}\alpha_5 M^2_{1/2}\ln\left(\frac{M_X}{M_{\rm GUT}}\right) \simeq 0.25\; M^2_{1/2}$$

(right stau mass for $m_0 = 0$)

II)

$$|\mu|^2 = \frac{m^2_{H_d} - m^2_{H_u}\tan^2\beta}{\tan^2\beta - 1} - \frac{1}{2}m^2_Z$$

$$\sin 2\beta = \frac{2B\mu}{m^2_{H_u} + m^2_{H_d} + 2\mu^2},$$



$SU(5)_{RN}$ parameter space

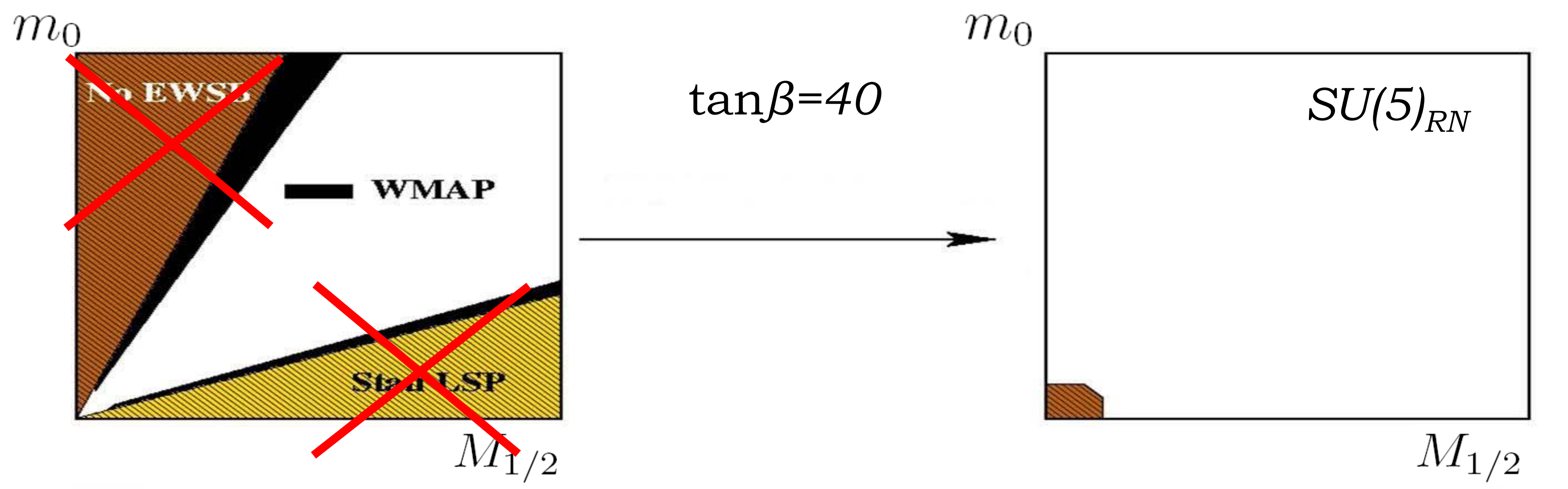
I)

$$M_X \longrightarrow M_{\rm GUT} \;\Rightarrow\; m^2_{\tilde{\tau}_R}(M_{\rm GUT}) \simeq \frac{144}{20\pi}\alpha_5 M^2_{1/2} \ln\left(\frac{M_X}{M_{\rm GUT}}\right) \simeq 0.25\, M^2_{1/2}$$

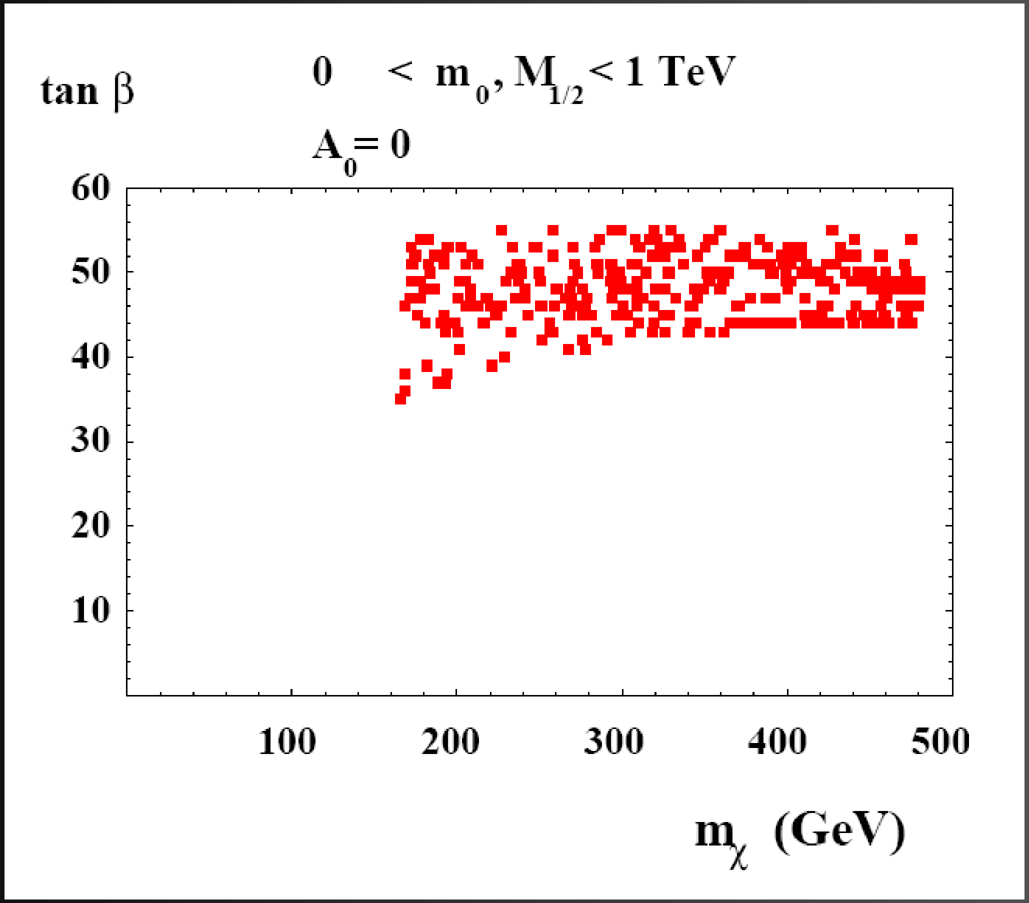
(right stau mass for $m_0 = 0$)

II)

$$(4\pi)^2 \frac{\partial m^2_{H_u}}{\partial \ln(\tilde{\mu}/M_X)} \simeq 6y_t^2(m^2_{H_u} + m^2_{\tilde{U}_3} + m^2_{\tilde{Q}_3} + A_t^2) + 2y_\nu^2(m^2_{H_u} + m^2_{\tilde{N}} + m^2_{\tilde{L}_3} + A_\nu^2)$$

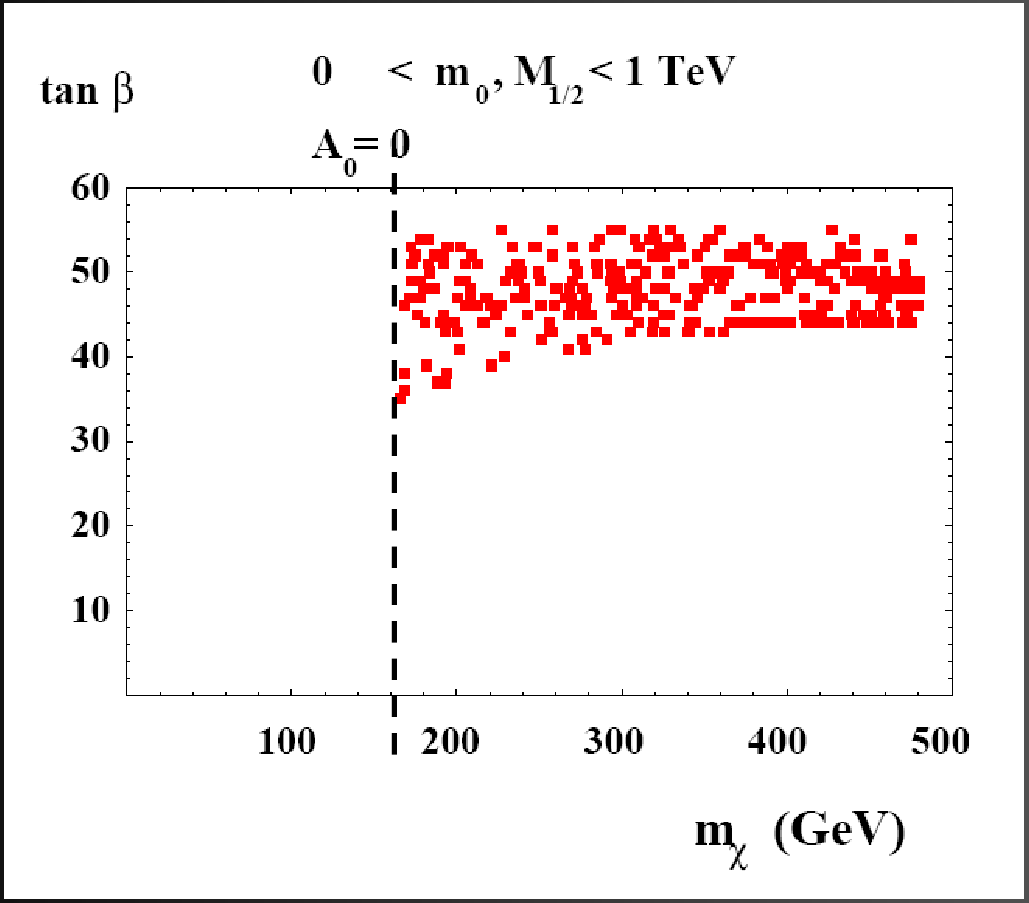


DM phenomenology in $SU(5)_{RN}$



WMAP allowed points

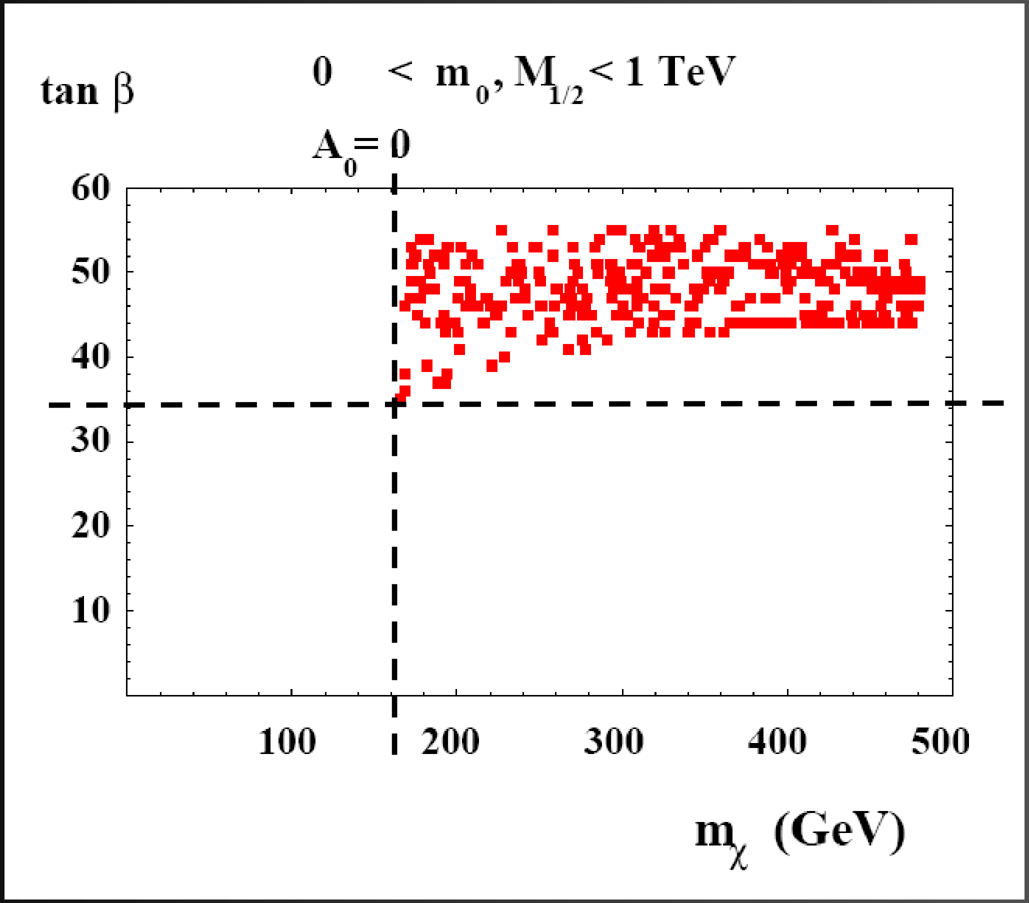
DM phenomenology in *SU(5)*$_{RN}$



WMAP allowed points

$$m_{\tilde{\chi}_1^0} \gtrsim 160\,\mathrm{GeV}$$

DM phenomenology in $SU(5)_{RN}$

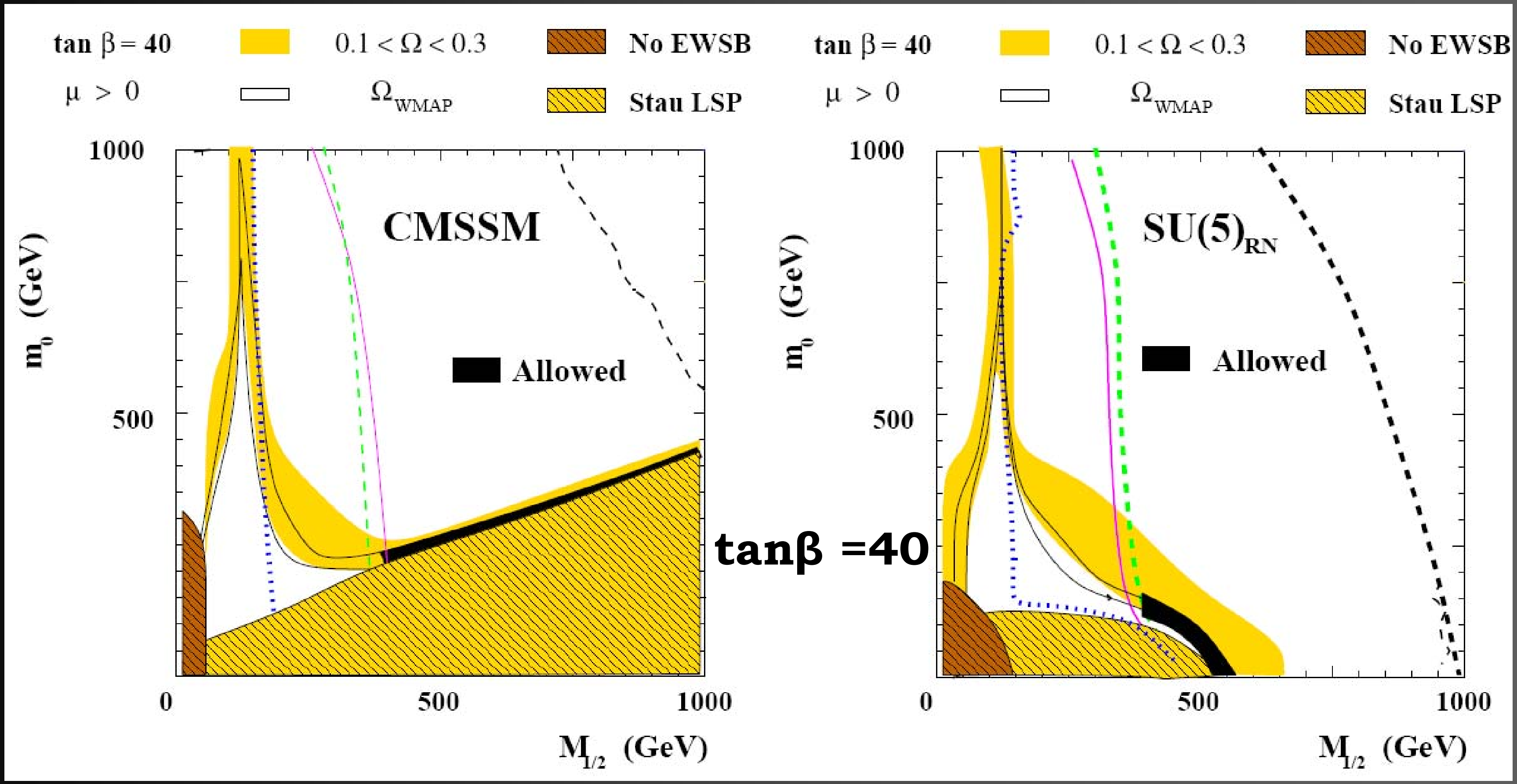


WMAP allowed points

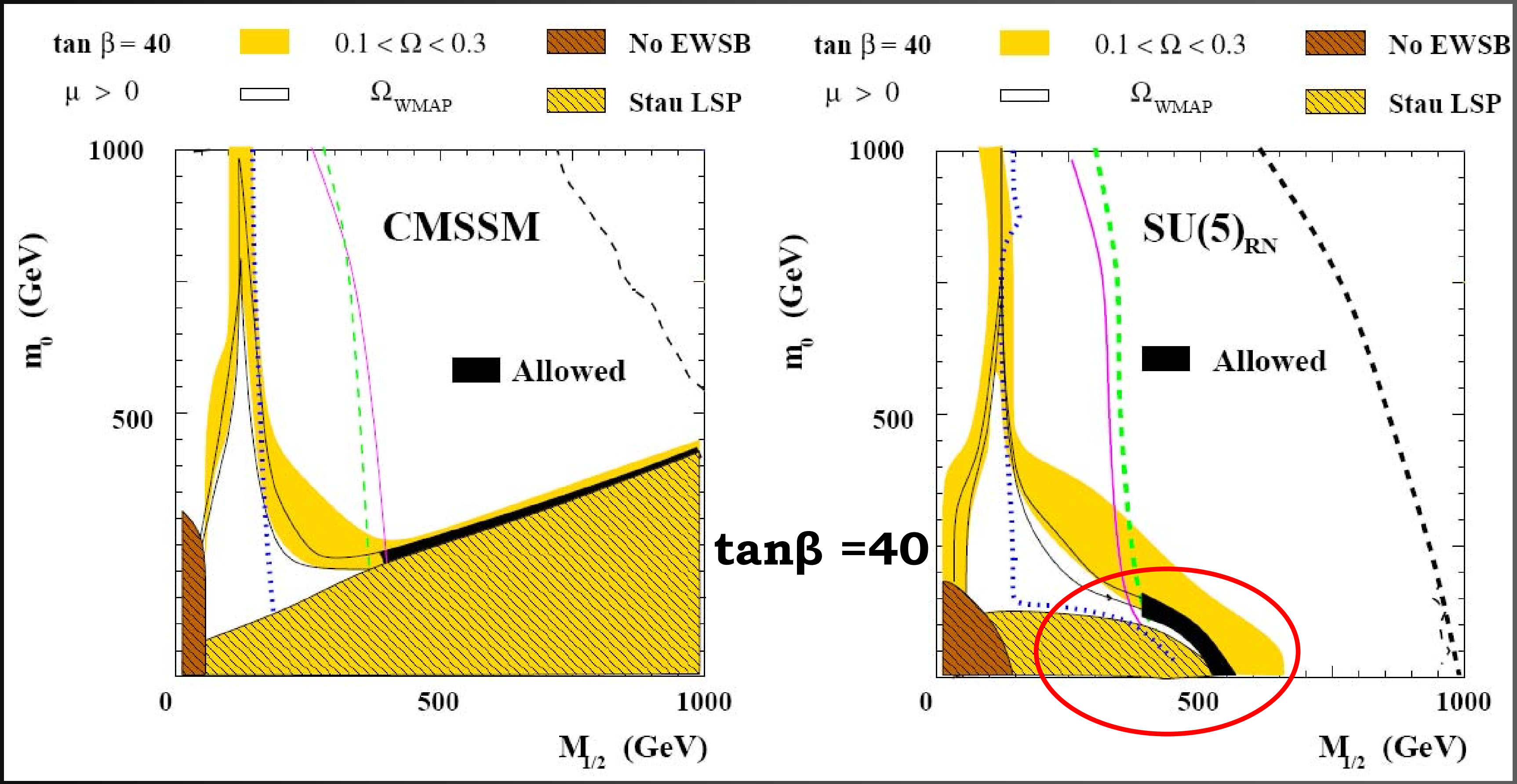
$$\tan\beta \gtrsim 34$$

$$m_{\tilde{\chi}^0_1} \gtrsim 160\,\mathrm{GeV}$$

DM phenomenology in $SU(5)_{RN}$



DM phenomenology in *SU(5)*$_{RN}$

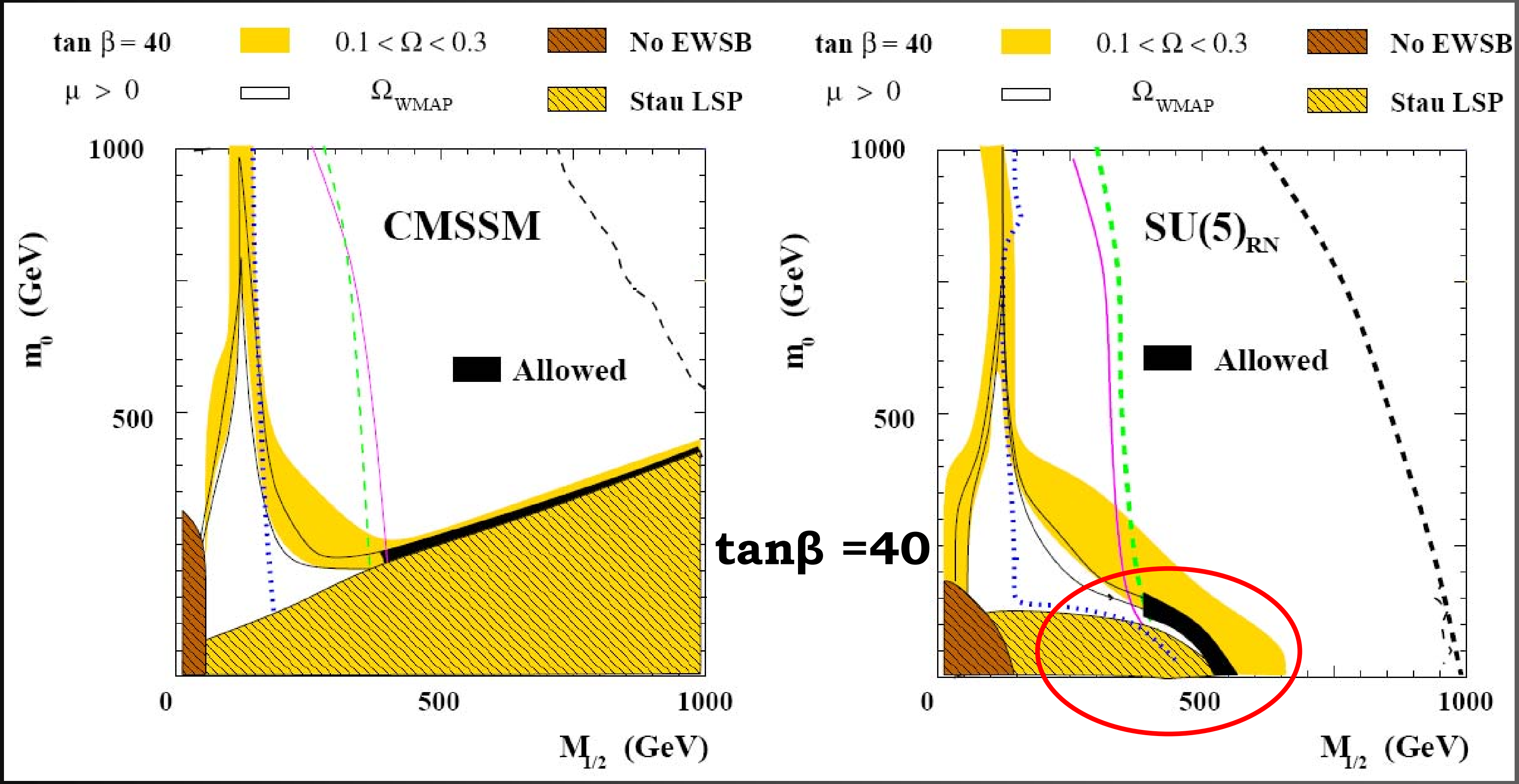


tanβ =40

Stau coannihilation:

$$m^2_{\tilde{\tau}_1} \simeq m^2_{\tilde{\tau}_{RR}} - m_\tau \, \mu \tan\beta$$

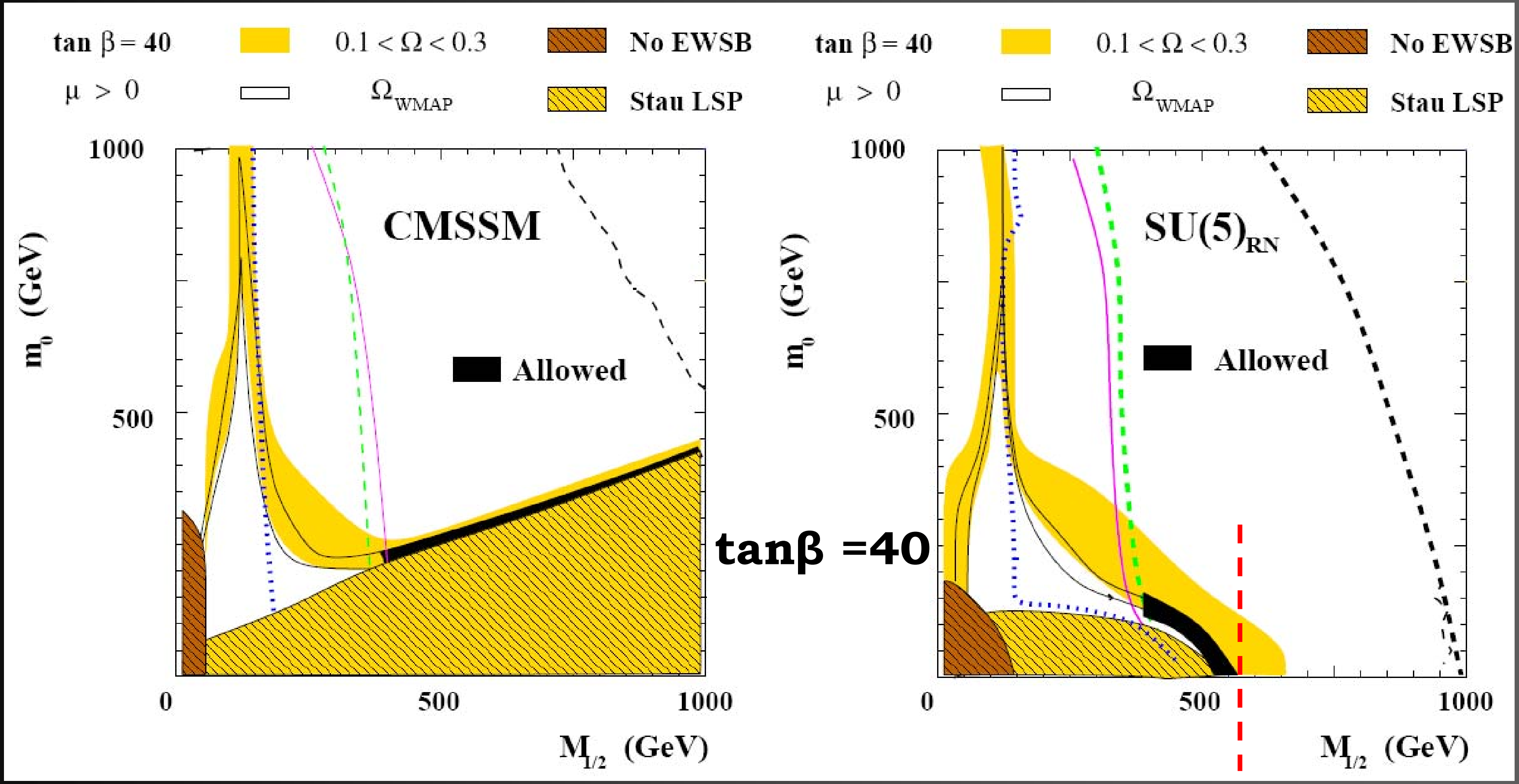
DM phenomenology in *SU(5)$_{RN}$*



Stau coannihilation: $m^2_{\tilde{\tau}_1} \simeq m^2_{\tilde{\tau}_{RR}} - m_\tau \, \mu \tan\beta$

→ lower limit on tanβ $\tan\beta \gtrsim 34$

DM phenomenology in $SU(5)_{RN}$



Stau coannihilation: $m^2_{\tilde{\tau}_1} \simeq m^2_{\tilde{\tau}_{RR}} - m_\tau \, \mu \tan\beta$

→ upper limit on the LSP mass $m_{\tilde{\chi}^0_1} \simeq 240$ GeV $(\tan\beta = 40,\ A_0 = 0)$

The other CMSSM "corridors" ?

- A-pole funnel

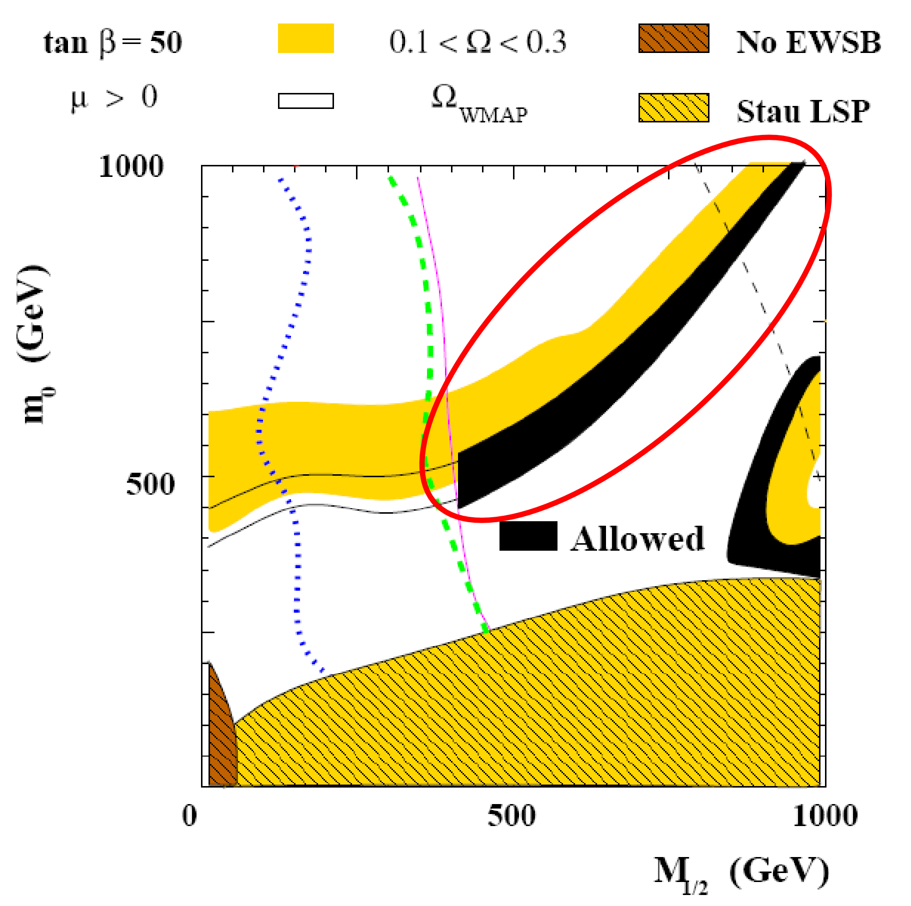
$$\tan\beta \simeq 45 - 50$$

no more upper bound on the LSP mass

- Focus point

not present up to 5 TeV

tanβ =50



The other CMSSM "corridors" ?

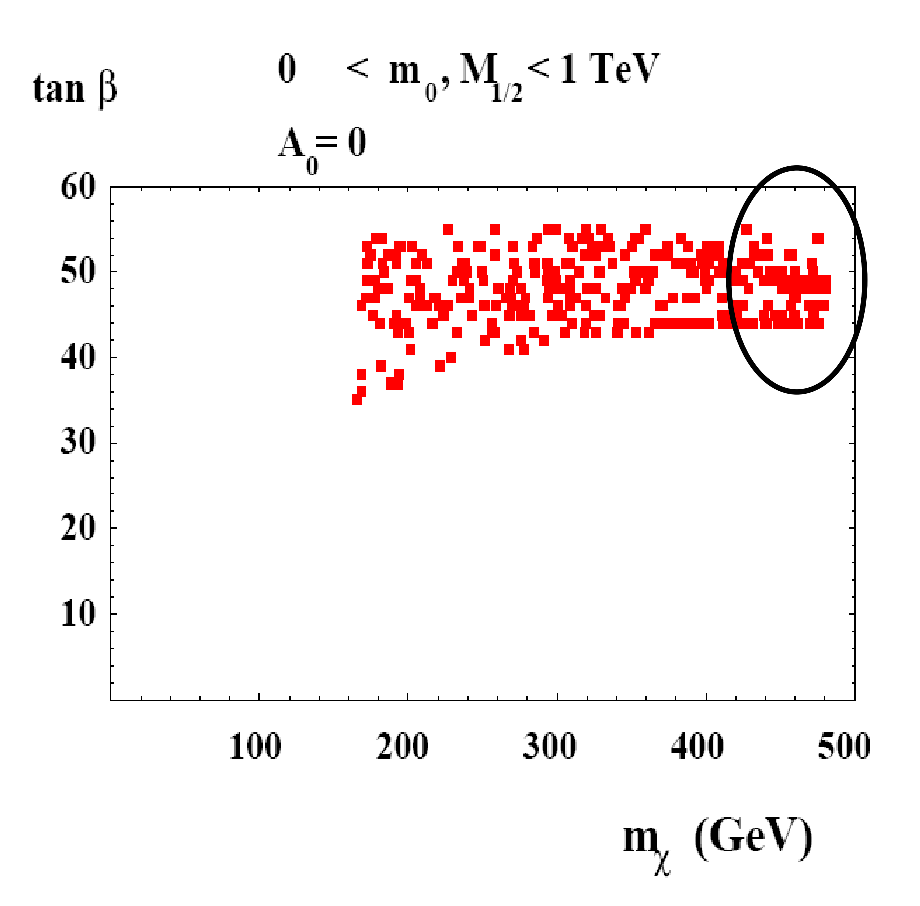
- A-pole funnel

$$\tan\beta \simeq 45 - 50$$

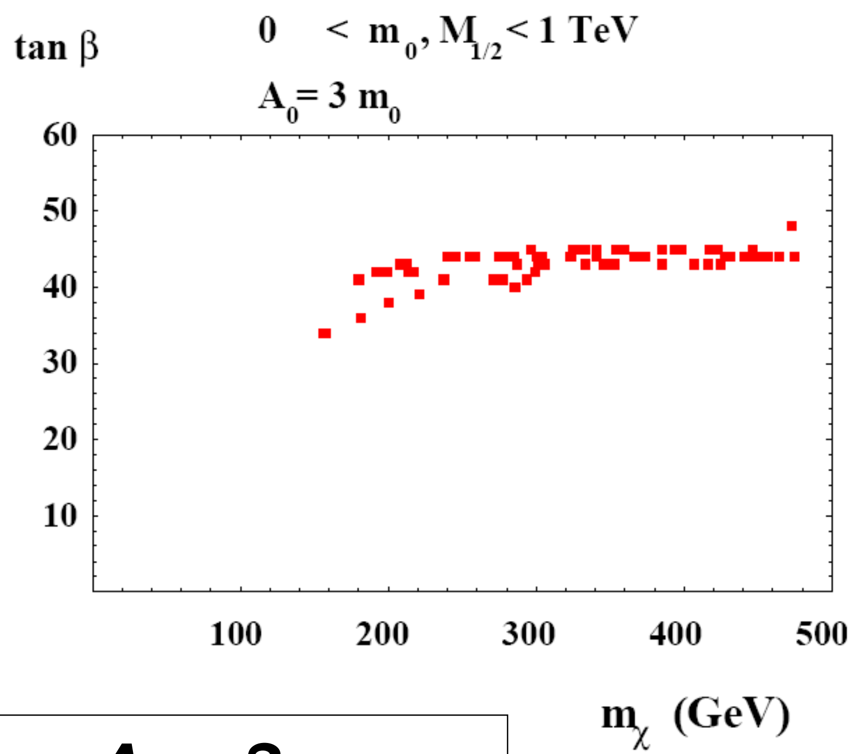
no more upper bound on the LSP mass

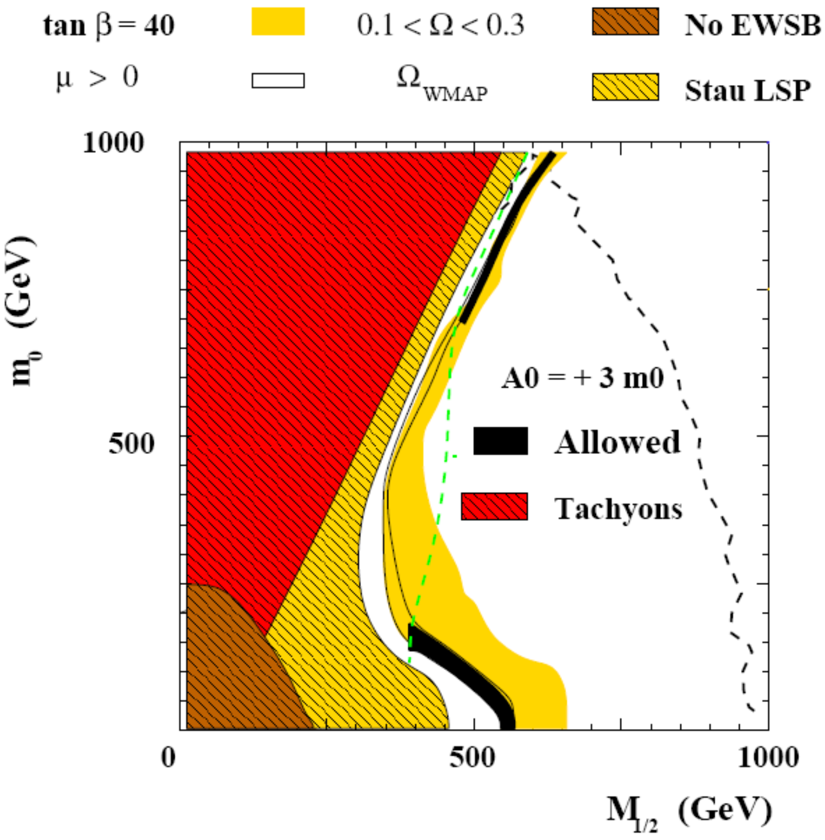
- Focus point

not present up to 5 TeV



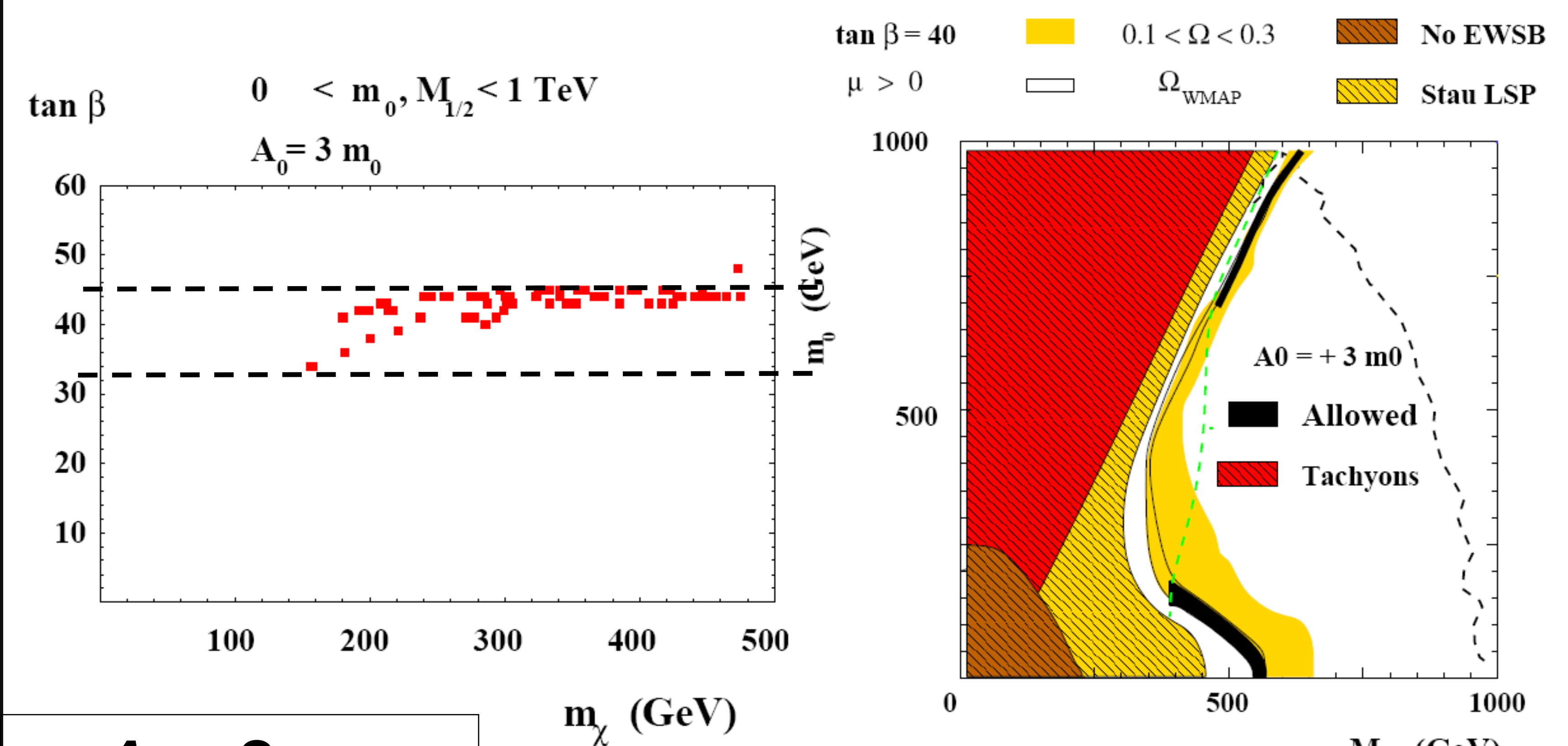
DM phenomenology in $SU(5)_{RN}$





$A_0 = 3\ m_0$

DM phenomenology in $SU(5)_{RN}$



$A_0 = 3\ m_0$

Lower bound: $\tan\beta \gtrsim 34$ such as $A_0 = 0$

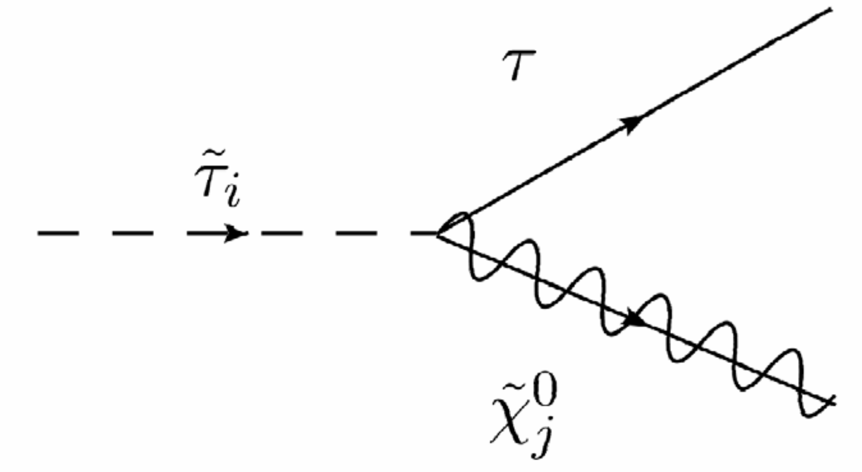
Upper bound: $\tan\beta \lesssim 45$ ⟵ tachyons!

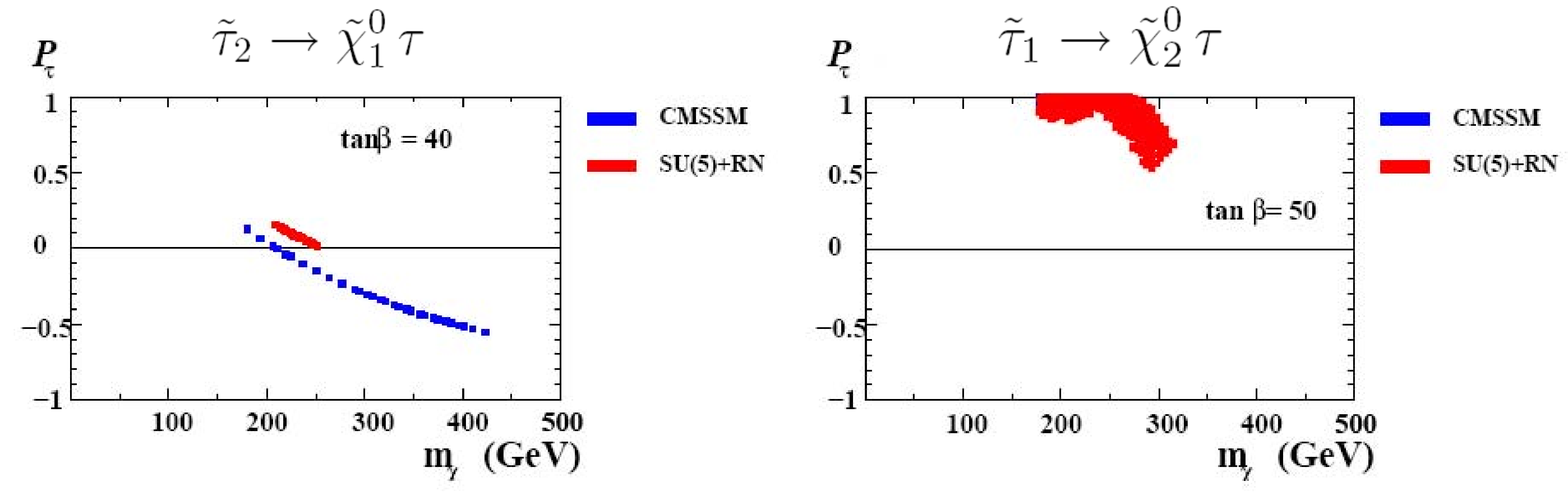
Distinguish $SU(5)_{RN}$ from CMSSM

Tau polarization in stau decays:

$$\mathcal{P}_f = \frac{Br(\tilde{f}_i \to \tilde{\chi}^0_n f_R) - Br(\tilde{f}_i \to \tilde{\chi}^0_n f_L)}{Br(\tilde{f}_i \to \tilde{\chi}^0_n f_R) + Br(\tilde{f}_i \to \tilde{\chi}^0_n f_L)}$$

see e.g. Gajdosik, Godbole, Kraml '04





L.C., Godbole, Mambrini, Vempati in preparation

Conclusions

• In CMSSM, some peculiar relations among parameters are needed to have the correct relic density

• GUT running and/or presence of RH neutrinos can destabilize such relations

• In $SU(5)_{RN}$ relic density requirements put severe constraints on the allowed range of $\tan\beta$ (> 35)

• Coannihilations branch shows a peculiar phenomenology and upper bound on the LSP mass (around 250-350 GeV) in some regions of the parameter space

• A-pole funnel appears for very large $\tan\beta$, while focus point is absent up to 5 TeV