WMAP Dark Matter constraints on Yukawa unification with Massive Neutrinos

Pedro Naranjo

University of Patras

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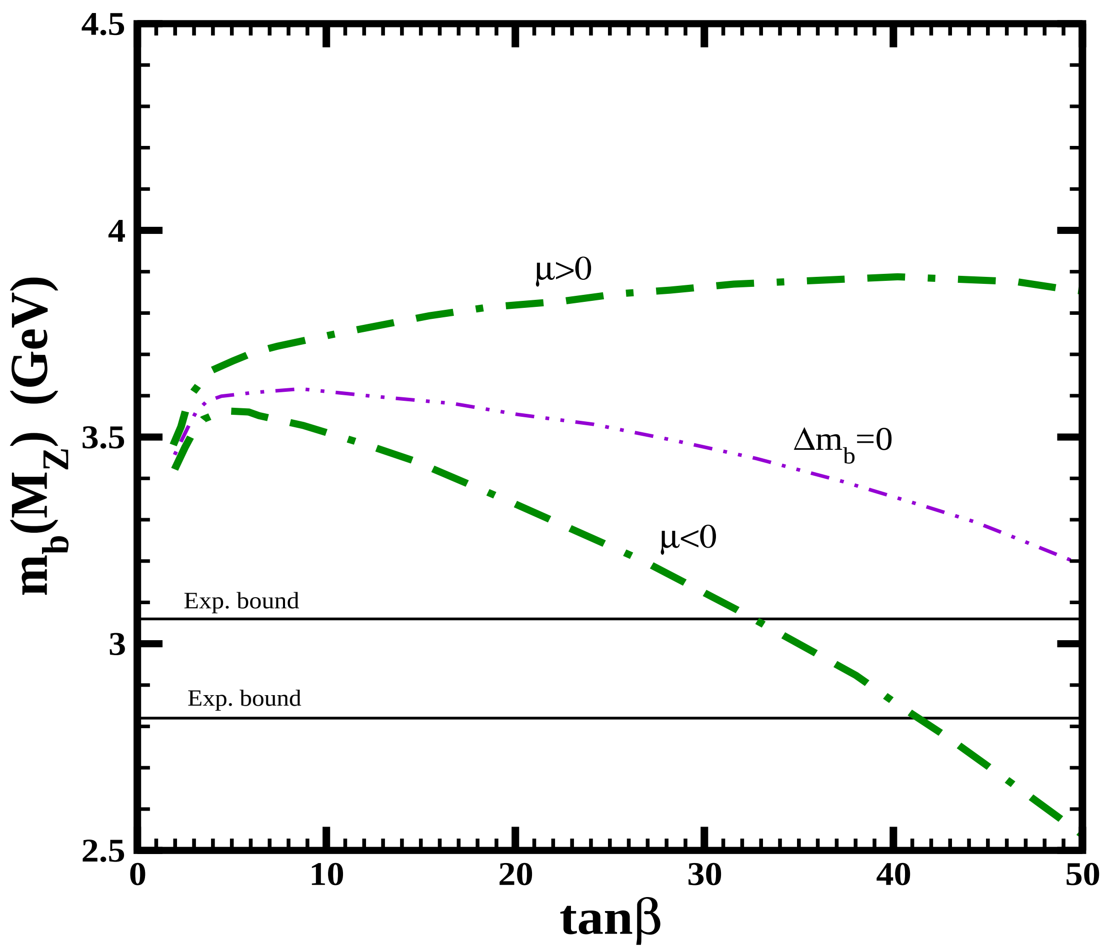
In collaboration with M.E. Gomez, S. Lola and J. Rodriguez-Quintero (hep-ph/0901.4013)

Summary

- SUSY $SU(5)$ and the m_b
- Massive neutrinos
- SUSY $SU(5)$ with massive neutrinos
  1. b mass
  2. Dark Matter
- Conclusions

$b - \tau$ unification and m_b

With no lepton mixing ($m_\nu = 0$)



NEUTRINO FLAVOUR OSCILLATION

- Neutrino data: By now convincing evidence for $m_\nu \neq 0$ and physics beyond SM
- What do we know?

Atmospheric problem	Solar problem
$\Delta m^2_{atm} = \left(2.6^{+0.4}_{-0.7}\right) \times 10^{-3}$ eV^2 $\sin^2 2\theta_{atm} > 0.90$	$\Delta m^2_{sol} = \left(8.1^{+0.5}_{-0.5}\right) \times 10^{-5}$ eV^2 $\sin^2 2\theta_{sol} = \left(0.86^{+0.05}_{-0.06}\right)$

- Questions:
  1. How do massive neutrinos affect Yukawa unification? Do they alter the predictions for the bottom mass?
  2. What are the implications for DM?

Neutrino mass effects

RGE: $M_{GUT} \rightarrow M_R$

$$16\pi^2 \frac{d}{dt}\lambda_t = \left(6\lambda_t^2 + \lambda_N^2 - G_U\right)\ \lambda_t$$

$$16\pi^2 \frac{d}{dt}\lambda_N = \left(4\lambda_N^2 + 3\lambda_t^2 - G_N\right)\ \lambda_N$$

$$16\pi^2 \frac{d}{dt}\lambda_b = \left(\lambda_t^2 - G_D\right)\ \lambda_b$$

$$16\pi^2 \frac{d}{dt}\lambda_\tau = \left(\lambda_N^2 - G_E\right)\ \lambda_\tau$$

$SU(5)$ GUTs

- SUSY $SU(5)$ RH superpotential

$$\mathcal{W}_X = T^T \lambda_u T H + T^T \lambda_d \bar{F} \bar{H} + \bar{F}^T \lambda_\nu S H + S^T M_R S$$

- With the matter content: $\bar{F}$=5=(D_R^c, L), T=10=(Q,U_R^c,E_R^c).

Yukawa textures in some basis:

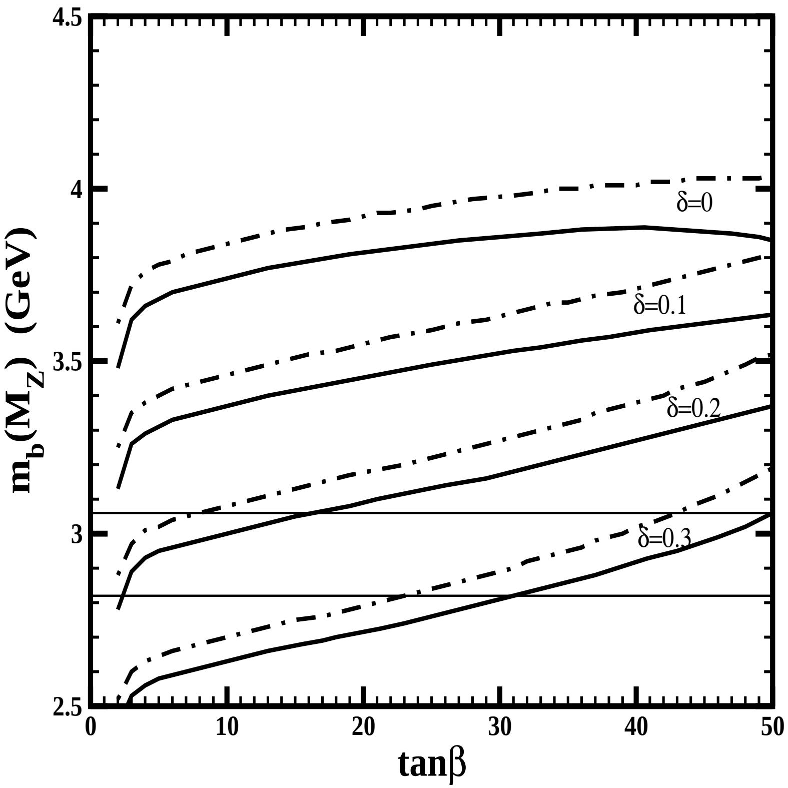
$$m_\ell^0 = m_0 \begin{pmatrix} 0 & x \\ 0 & 1 \end{pmatrix}, \quad m_d^0 = m_0 \begin{pmatrix} 0 & 0 \\ x & 1 \end{pmatrix}$$

The unification condition

$$\frac{m_b^0}{1+x^2} = \frac{m_\tau^0}{1-x^2} \rightarrow m_b^0 = m_\tau^0 \left(1 - \underbrace{2x^2}_{\delta} + \mathcal{O}(\delta^2) \right)$$

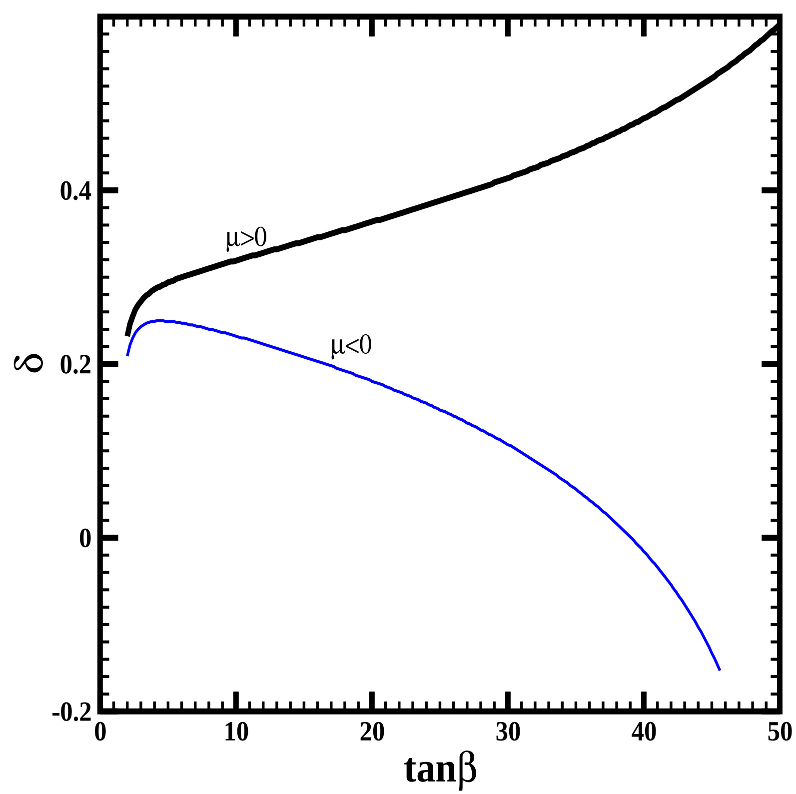
Lepton Mixing Effects

Considering lepton mixing ($\delta \neq 0$), $b - \tau$ unification possible for <u>both</u> signs of μ and a large range of $\tan\beta$



Bottom mass in terms of tanβ for different values of δ.

The value of δ computed for the experimental central value of m_b in terms of $\tan\beta$.



$SU(5)$ RGE effects

The running of the soft terms from a higher scale (M_X) to M_{GUT} induces non universalities on the soft terms :

- $M_x \to M_{GUT}$

$$W_{\mathrm{SU}(5)} \;=\; \frac{1}{4}\, f_u^{ij}\; 10_i\; 10_j\; H + \sqrt{2} f_d^{ij}\; 10_i\; \overline{5}_j\; \overline{H} + f_\nu^{ij}\; 1_i\; \overline{5}_j\; H$$

$$f_u^{ij} = f_u^{\delta},$$

$$f_d^{ij} = V_{CKM}^{*}\, \lambda_d^{\delta}\, V_{KM}^{\dagger}$$

The soft terms (at EW scale) (Calibbi, Mambrini, Vempati JHEP 0709 **081** 2007):

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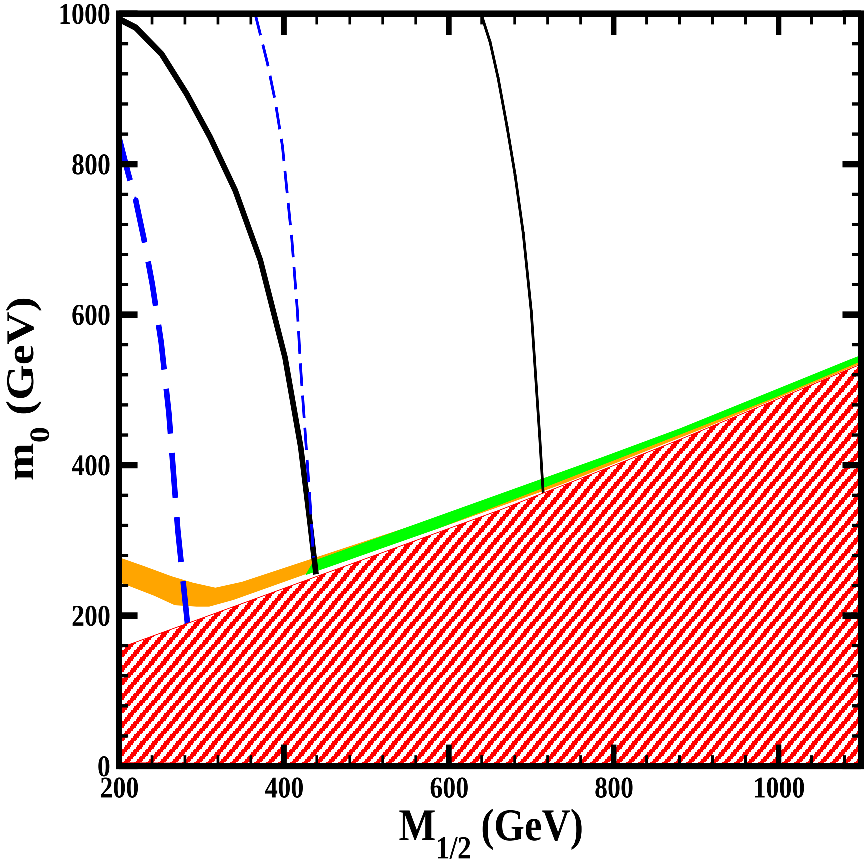
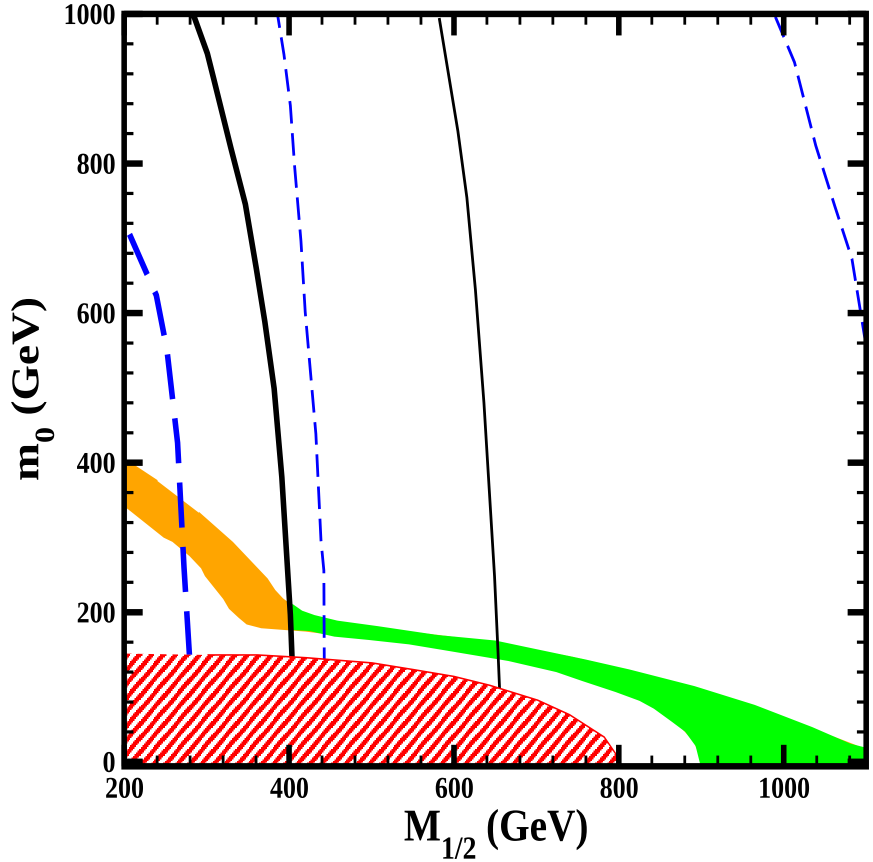
$$m^2_{\tilde{\tau}_{RR}} \simeq (1-\rho_\beta)\, m_0^2 + 0.3 M^2_{1/2}\,, \quad m^2_{\tilde{\tau}_{LR}} \simeq -m_\tau \mu \tan\beta$$

WMAP Dark Matter constraints

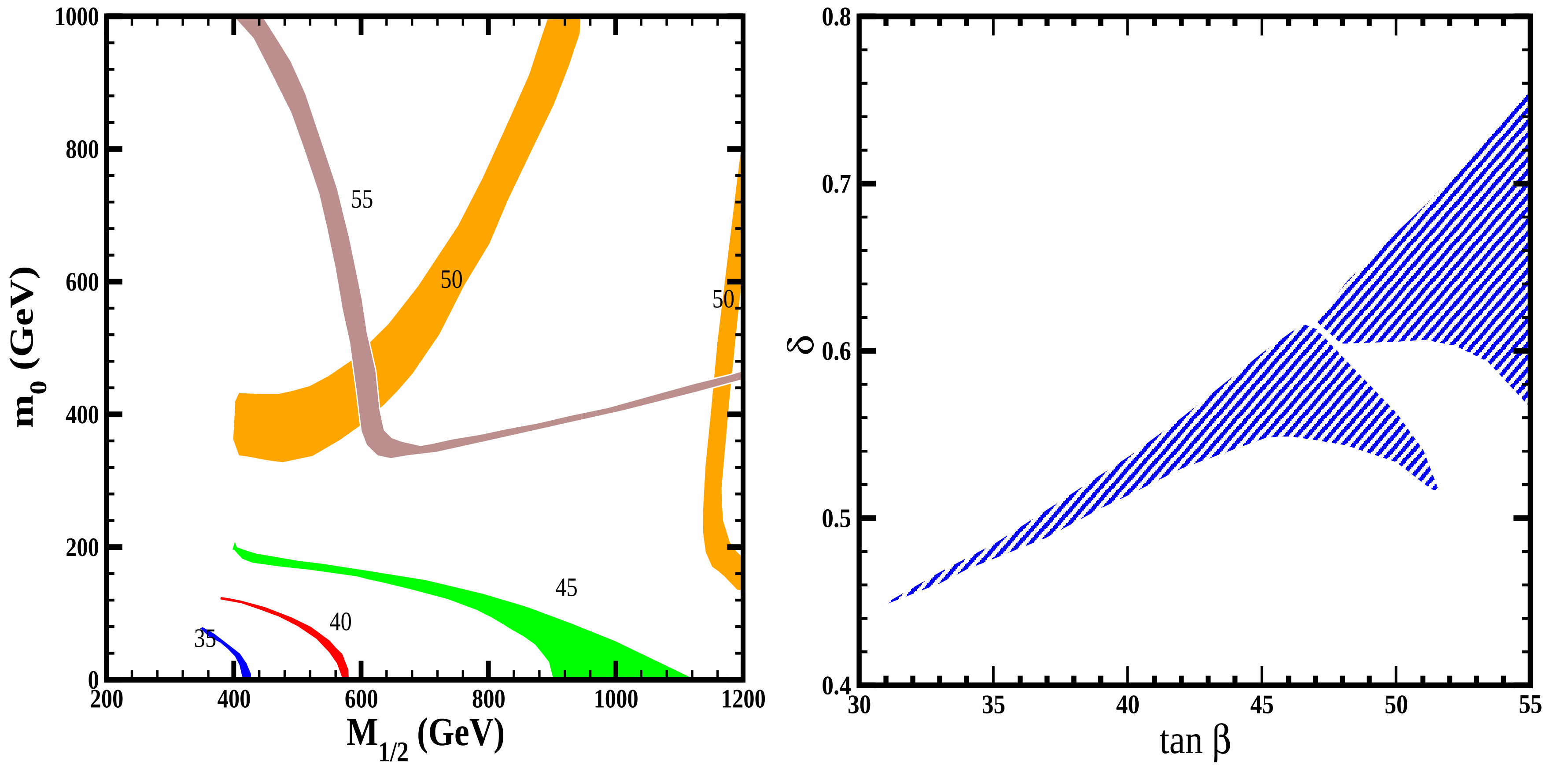
$\mu > 0, \ \tan\beta = 45, \ A_0 = 0$ (central value of m_b)





WMAP Dark Matter constraints

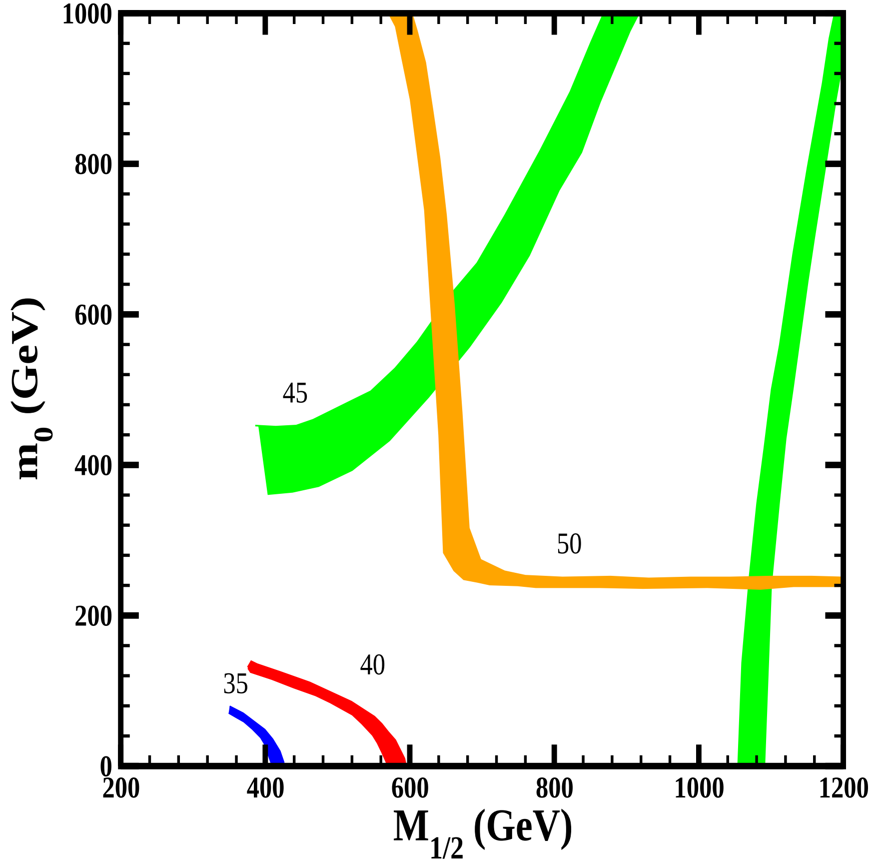
$\mu > 0, \ A_0 = 0$ (central value of m_b)

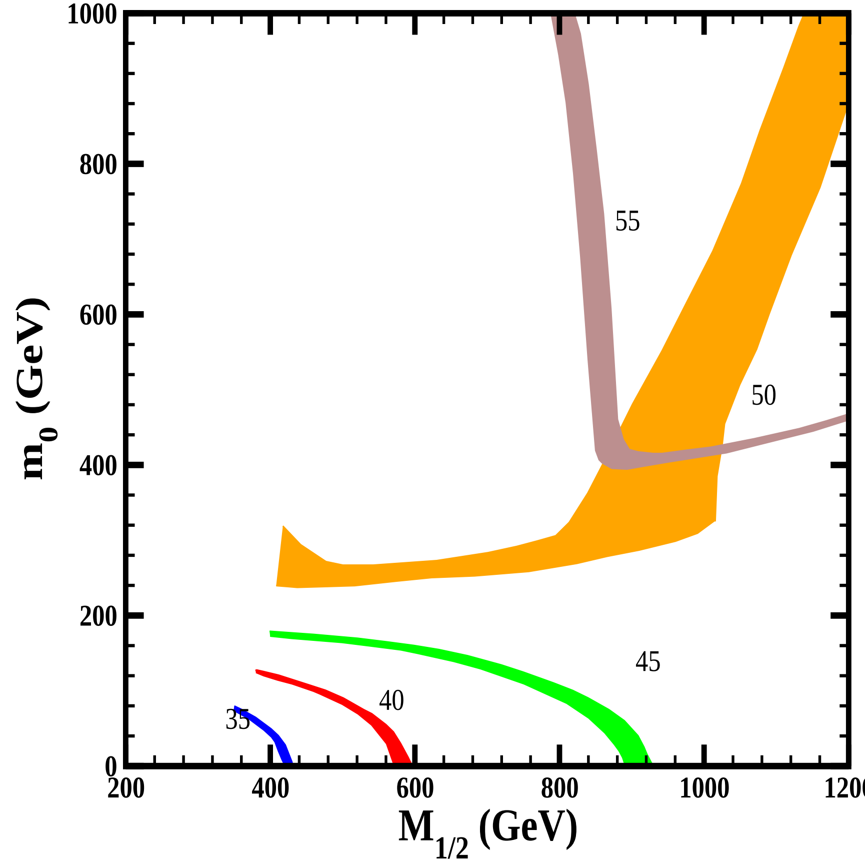


WMAP Dark Matter constraints

$\mu > 0, \ A_0 = 0$

upper value of $m_b(M_Z)$ | lower value of $m_b(M_Z)$

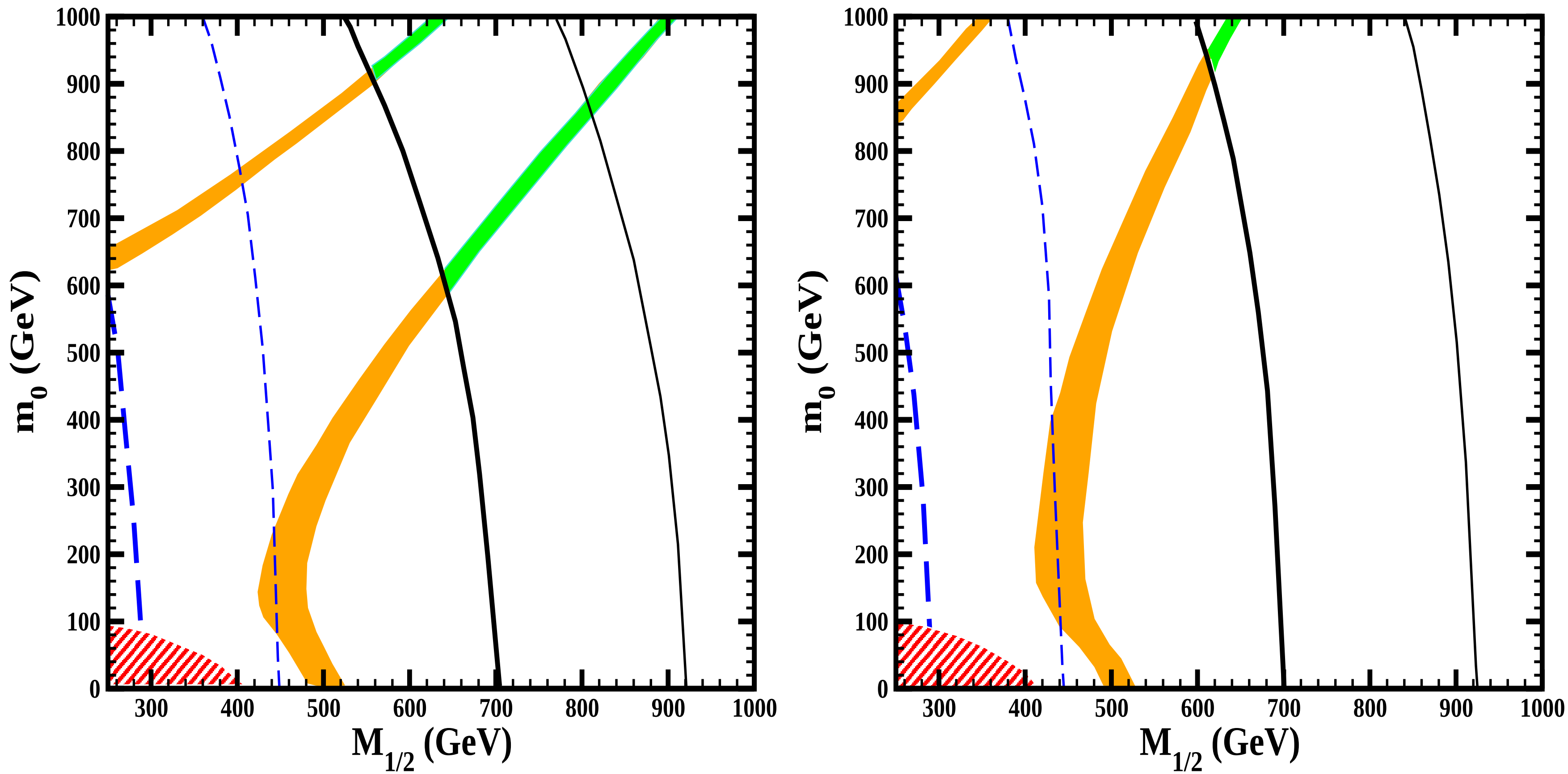




WMAP Dark Matter constraints

$\mu < 0, \ \tan\beta = 40, \ A_0 = 0$

$M_N = 10^{13}$ GeV $\qquad M_N = 6 \times 10^{14}$ GeV



Conclusions

- To explain neutrino data we need large lepton mixing, which also affects Yukawa unification
- The assumption of a sizeable 2-3 flavour mixing in the charged lepton sector
  1. allows unification for $\mu > 0$
  2. enhances the allowed range of $\tan\beta$ where $\lambda_b - \lambda_\tau$ unification is possible
- Using Yukawa textures in $SU(5)$, compatible with neutrino data, we study the WMAP favoured parameter space
  1. *Large* charged lepton mixing only allows $b - \tau$ unification for $\mu > 0$