Chargino and Neutralino Mass Parameters at One–Loop Level

W. Öller (ÖAW, Vienna)

Amsterdam, 1–4 April 2003

- On–shell Renormalization
- Chargino & Neutralino Sector
- Parameter Fixing
- Coupling Corrections
- Parameter Analysis
- SU(5) GUT Test
- Conclusions

On–shell Renormalization

$$V = \overline{\psi}_R \underset{\substack{\Uparrow\\ \text{Real(CP–Conservation)}}}{M} \psi_L + \overline{\psi}_L \underset{\Uparrow}{M^\dagger} \psi_R$$

$$f_R = U\psi_R \qquad f_L = V\psi_L \qquad M_D = UMV^T$$

$$V = \overline{f} M_D f = \sum_{i=1}^{n} m_{f_i} \overline{f}_i f_i$$

$$\hat{f}_{L,R} = (1 + \frac{1}{2}\delta Z_{L,R}) f_{L,R}$$
$$\hat{\overline{f}}_{L,R} = \overline{f}_{L,R}(1 + \frac{1}{2}\delta Z^\dagger_{L,R})$$

$$\hat{U} = U + \delta U \quad \hat{V} = V + \delta V \quad \hat{M} = M + \delta M$$

counter term fixing:

$$\delta U = \frac{1}{4}(\delta Z_R - \delta Z_R^T) U$$
$$\delta V = \frac{1}{4}(\delta Z_L - \delta Z_L^T) V$$

$\Rightarrow$ cancel antisymmetric parts of wavefunction corr.

$$\delta M_{ij} = \frac{1}{2} \sum_{l,n} U_{li} V_{nj} \,\mathrm{Re}\left[m_l \Pi^L{}_{nl}(m_l^2) + m_n \Pi^R{}_{ln}(m_n^2) + \Pi^{S,R}{}_{nl}(m_l^2) + \Pi^{S,L}{}_{ln}(m_n^2) \right]$$

$\Rightarrow$ Mass Matrix Counter Term

One–Loop Corrections

$\overline{\text{DR}}$ mass matrix:

$$\hat{M}(Q) \;=\; M + \delta M(Q)$$
$$\hat{M}(Q) \;=:\; \tilde{M} + \delta_C \tilde{M}(Q)$$

⇒ One–Loop Corrections:

$$M = \tilde{M} + \delta_C \tilde{M} - \delta M = \tilde{M} + \Delta M$$

⇒ On–shell Mass Matrix M cannot be written in tree–level form!

Reasons:

- Zero–Elements get finite Corrections
- Parameters and Counter Terms fixed in other Sectors

⇒ Corrections can be important in every Theory with Mass Matrices

Neutralino–Chargino Sector

$\Rightarrow$ **On–shell Renormalization of $\tilde{\chi}^+/\tilde{\chi}^0$–Sector**

[Eberl, Kincel, Majerotto, Yamada 2001]
[Fritzsche, Hollik 2002]

$$\tilde{X} = \begin{pmatrix} M & \sqrt{2} m_W \sin\beta \\ \sqrt{2} m_W \cos\beta & \mu \end{pmatrix}$$

$$\tilde{Y} = \begin{pmatrix} M' & 0 & -m_Z s_W c_\beta & m_Z s_W s_\beta \\ 0 & M & m_Z c_W c_\beta & -m_Z c_W s_\beta \\ -m_Z s_W c_\beta & m_Z c_W c_\beta & 0 & -\mu \\ m_Z s_W s_\beta & -m_Z c_W s_\beta & -\mu & 0 \end{pmatrix}$$

$\Rightarrow$ **Zero Elements get Corrections**

$\Rightarrow$ **m_W, m_Z and $\cos\theta_W$ fixed by Pole Masses**

$\Rightarrow$ **Define $\tan\beta$ in the Higgs Sector**

$\mathrm{Im}\hat{\Pi}_{A^0 Z^0}(m_A^2) = 0$ [e.g. Dabelstein 1995]

$\Rightarrow$ **M, μ and M' fixed in $\tilde{\chi}^+/\tilde{\chi}^0$–Sector**

Parameter Fixing

Fixing M and μ in the Chargino Sector:

$$\begin{aligned} M &\equiv X_{11} \Rightarrow \hat{M} = M + \delta X_{11} \\ \mu &\equiv X_{22} \Rightarrow \hat{\mu} = \mu + \delta X_{22} \end{aligned}$$

$\Rightarrow$ finite shifts in the Neutralino Sector:

$$\begin{aligned} \Delta M &\equiv M^{\tilde{\chi}^+} - M^{\tilde{\chi}^0} = \delta Y_{22} - \delta X_{11} \\ \Delta \mu &\equiv \mu^{\tilde{\chi}^+} - \mu^{\tilde{\chi}^0} = -(\delta Y_{34} + \delta X_{22}) \end{aligned}$$

Fixing M' in the Neutralino Sector:

$$M' \equiv Y_{11} \Rightarrow \hat{M}' = M' + \delta Y_{11}$$

SU(5) GUT Relation for the $\overline{\mathrm{DR}}$ Parameters:

$$\hat{M}' = \frac{5}{3} \tan^2 \hat{\theta}_W \, \hat{M}$$

$\Rightarrow$ On–shell:

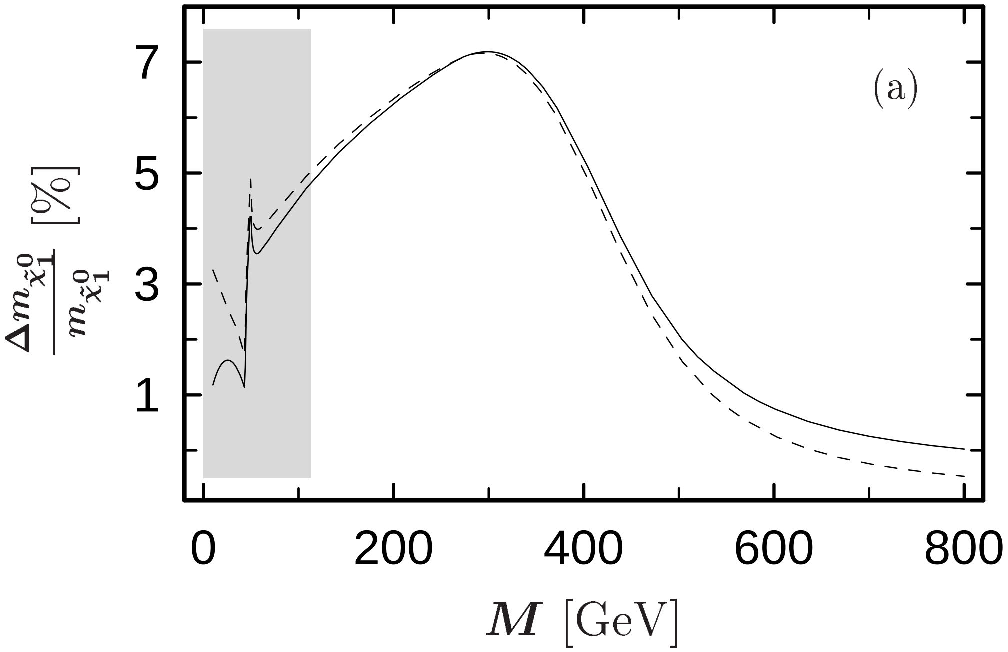
$$M' = \frac{5}{3} \tan^2 \theta_W \, M + \Delta Y_{11}$$

with:

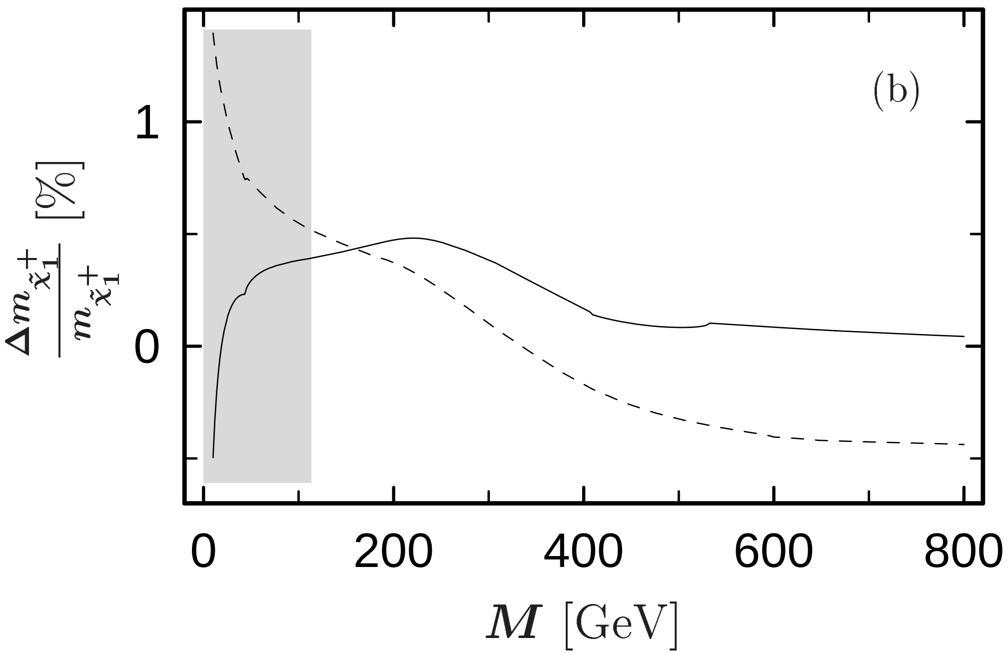
$$\Delta Y_{11} = \left(\frac{2}{\cos^2 \theta_W} \frac{\delta \sin \theta_W}{\sin \theta_W} + \frac{\delta M}{M}\right) Y_{11} - \delta Y_{11}$$

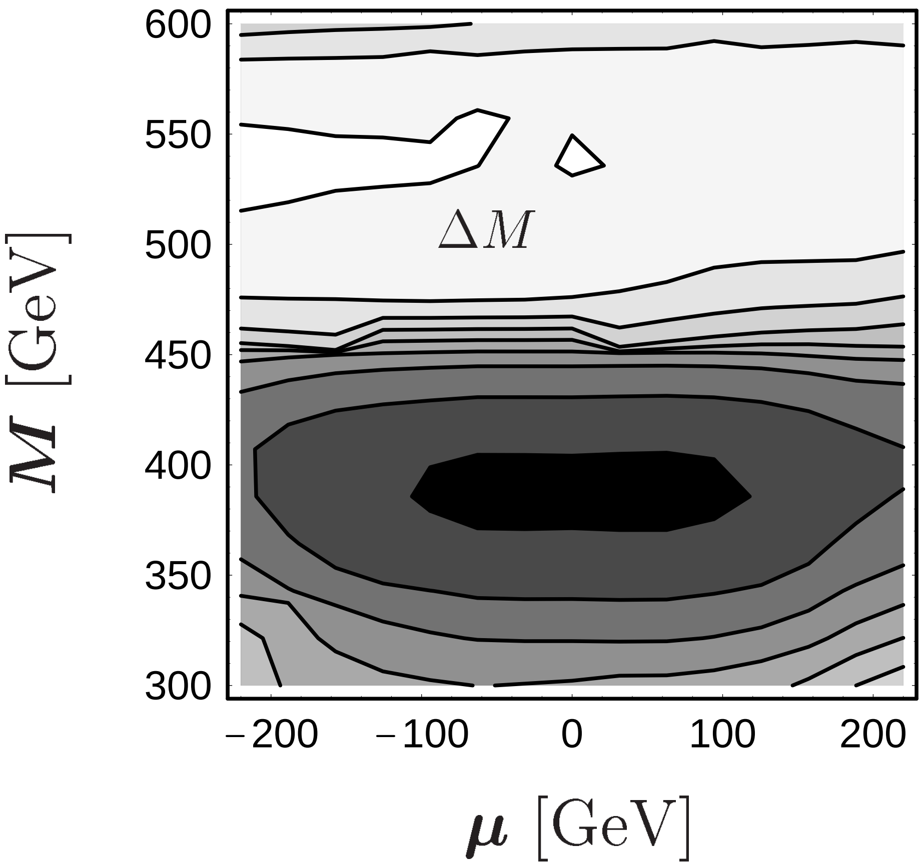
$\Rightarrow$ Correction included if Gauge Unification is explicitly assumed

Mass Corrections

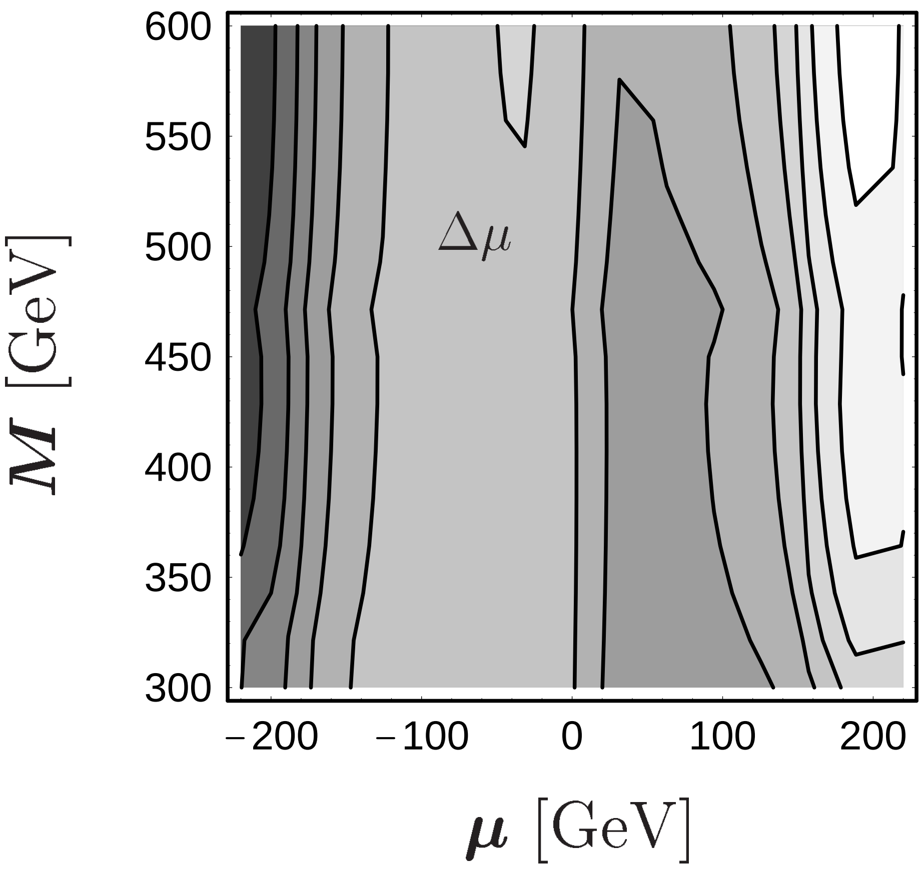


$\{m_{A^0}, \tan\beta, M_{\tilde{Q}_1}, M_{\tilde{Q}}, A, \mu\} = \{500, 40, 300, 300, \text{-}400, \text{-}220\}$ **GeV.**
The grey areas are excluded by the bound $m_{\tilde{\chi}_1^+} \geq 100$ **GeV**



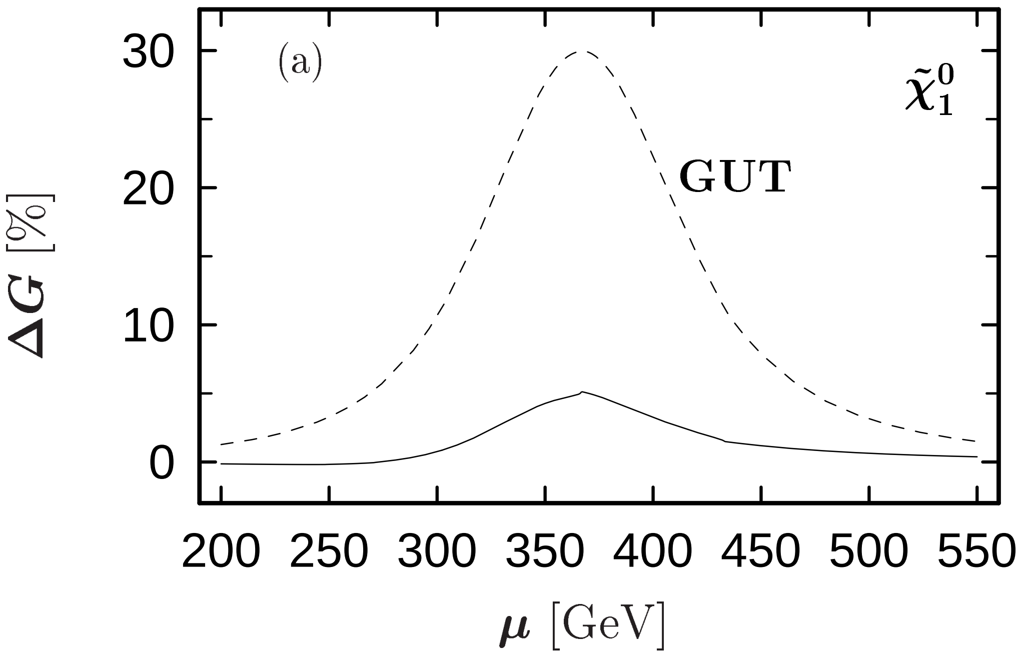


$\{m_{A^0},\, \tan\beta,\, M_{\tilde{Q}_1},\, M_{\tilde{Q}},\, A\} = \{500,\, 7,\, 300,\, 300,\, \text{-}500\}$ **GeV**

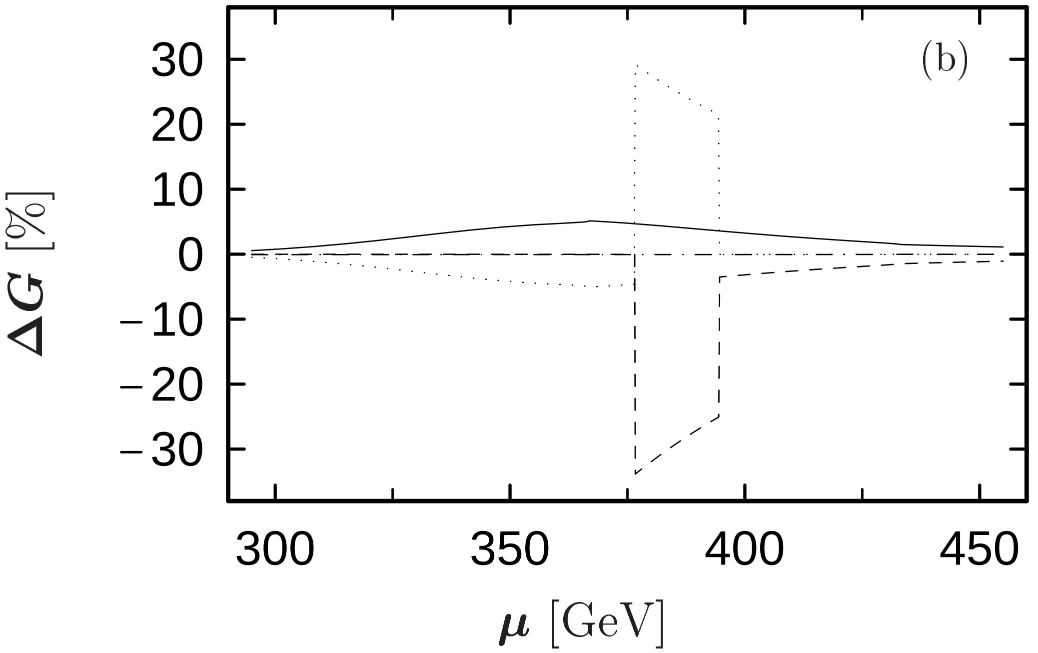


Coupling Corrections

ΔG ... Corrections to the Gaugino Components



$\{m_{A^0},\ \tan\beta,\ M_{\tilde{Q}_1},\ M_{\tilde{Q}},\ A,\ M\} = \{500,\ 20,\ 300,\ 300,\ \text{-}500,\ 700\}$ **GeV**



$\{\tilde{\chi}^0_1,\ \tilde{\chi}^0_2,\ \tilde{\chi}^0_3,\ \tilde{\chi}^0_4\} = \{$**full, dashed, dotted, dash–dotted**$\}$

Parameter Analysis

Physical Input: 2 Chargino Masses
1 Neutralino Mass
$\tan\beta$ from Higgs Sector

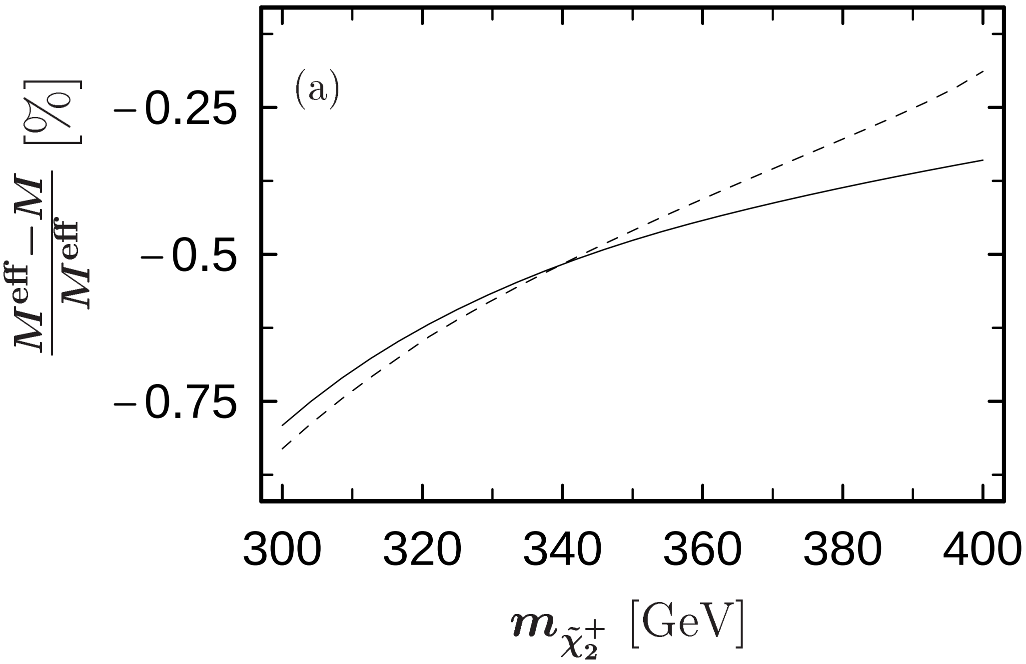
$\Rightarrow$ **effective Parameters M^{eff}, μ^{eff}, M'^{eff}**
derived from tree–level relations

four fold ambiguity $\Rightarrow$ same branch as [Fritzsche, Hollik 2002]

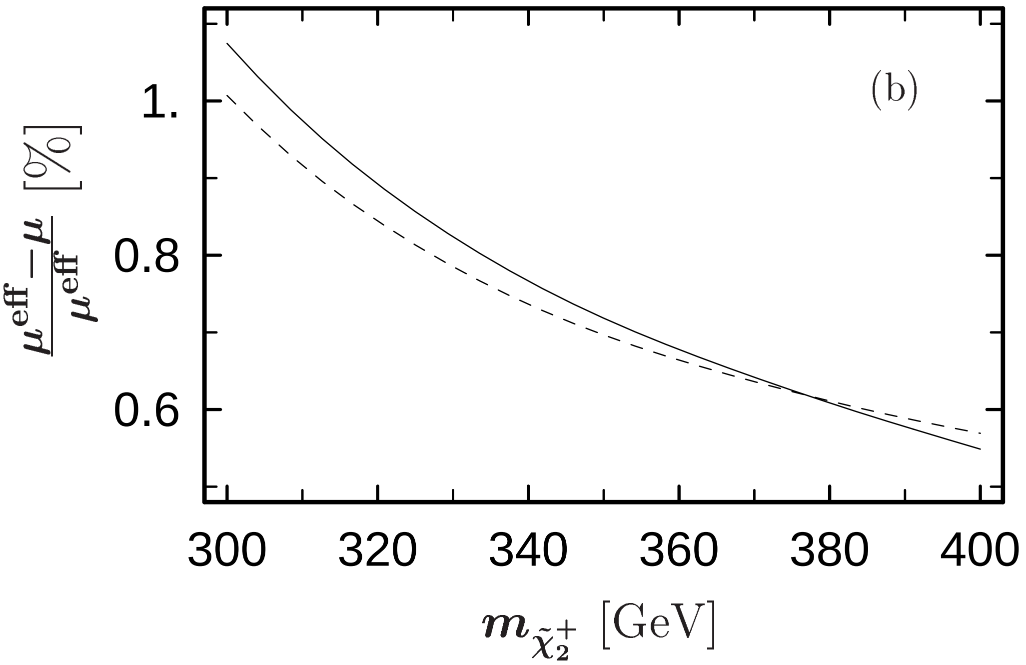
$\Rightarrow$ **calculating On–shell M, μ and M'**

$\Rightarrow$ **One–Loop corrected Masses and Couplings**

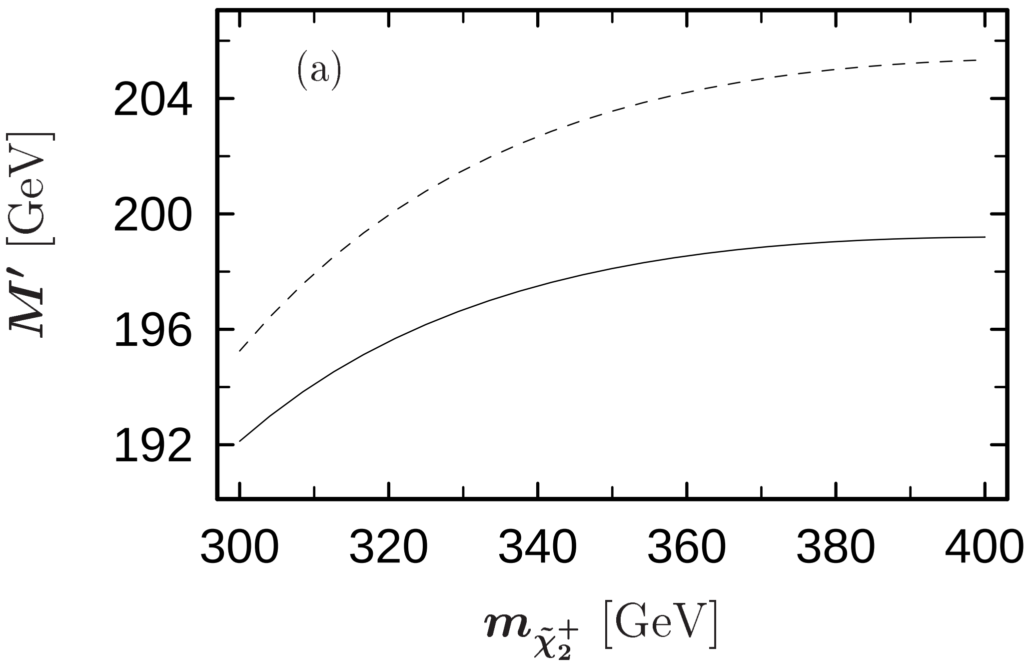
Parameter Analysis



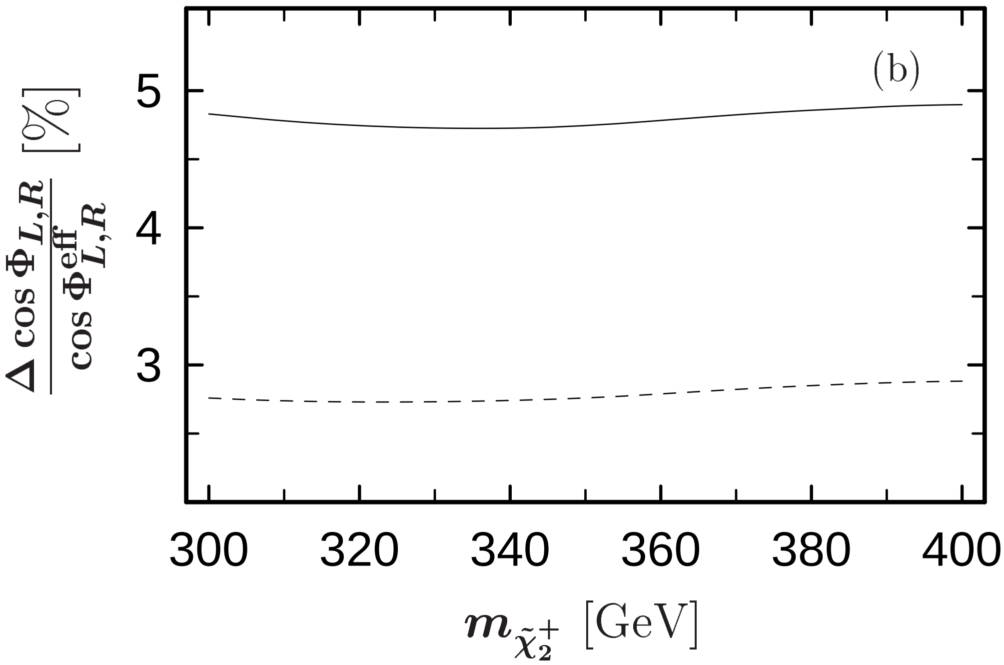
$\boldsymbol{M}$ **and** $\boldsymbol{\mu}$ **fixed in the chargino (full line) and the neutralino (dashed line) sector with** $\{m_{\tilde{\chi}_1^+}, m_{\tilde{\chi}_1^0}, \tan\beta, m_{A^0}, M_{\tilde{Q}_1}, M_{\tilde{Q}}, A\} = \{135, 120, 20, 600, 350, 350, 500\}$ **GeV**



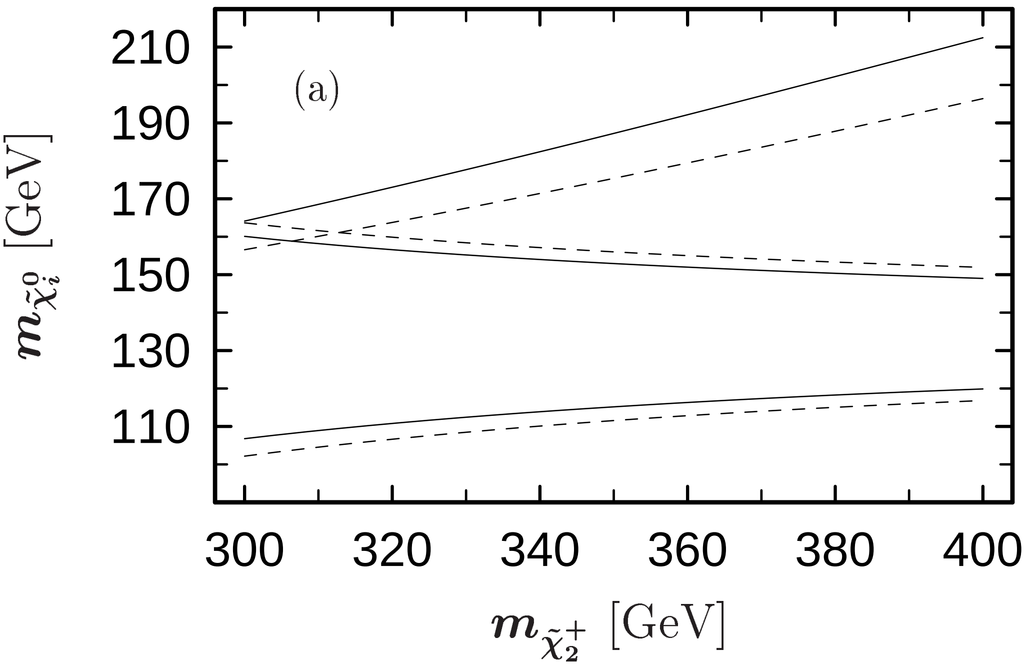
Parameter Analysis



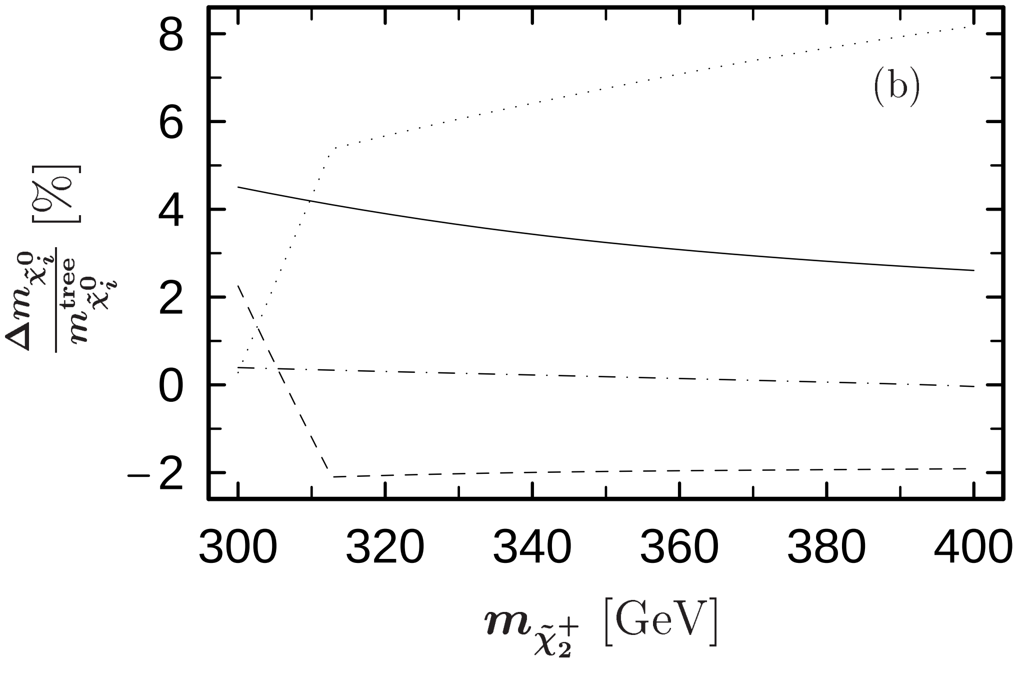
effective (dashed line) and on–shell (full line) M' and the relative corrections to $\cos\Phi_L$ (full line) and $\cos\Phi_R$ (dashed line) $\{m_{\tilde\chi_1^+}, m_{\tilde\chi_1^0}, \tan\beta, m_{A^0}, M_{\tilde Q_1}, M_{\tilde Q}, A\} = \{135, 120, 20, 600, 350, 350, 500\}$ GeV



SU(5) GUT Test



neutralino mass spectrum (a) at one–loop (full) and tree–level (dashed)
$\{m_{\tilde{\chi}_1^+}, \tan\beta, m_{A^0}, M_{\tilde{Q}_1}, M_{\tilde{Q}}, A\} = \{135, 20, 600, 350, 350, 500\}$ **GeV**
$m_{\tilde{\chi}_4^0} \simeq m_{\tilde{\chi}_4^0}^{\text{tree}} \simeq m_{\tilde{\chi}_2^+}$.
$\{\tilde{\chi}_1^0, \tilde{\chi}_2^0, \tilde{\chi}_3^0, \tilde{\chi}_4^0\} = \{$**full, dashed, dotted, dash–dotted**$\}$

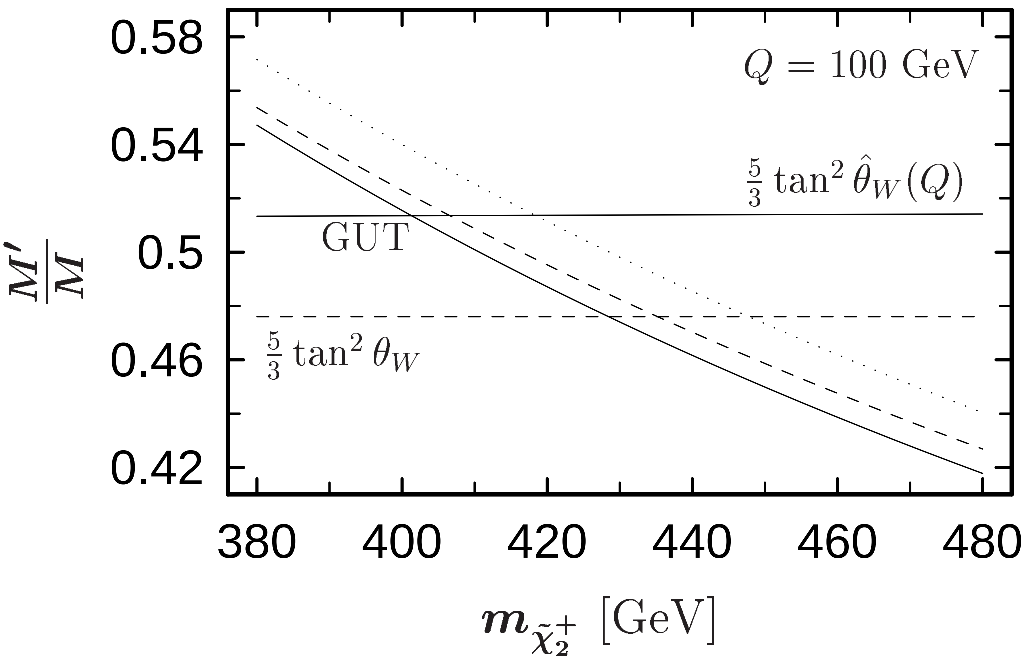


SU(5) GUT Test

$$\hat{M} = \frac{5}{3}\tan^2\hat{\theta}_W\,\hat{M}$$

$$\begin{aligned}\hat{M}'(Q) &= M' + \delta M'(Q)\\ \hat{M}(Q) &= M + \delta M(Q)\\ \tan\hat{\theta}_W &= \tan\theta_W + \delta\tan\theta_W\end{aligned}$$

$\{m_{\tilde{\chi}_1^+},\, m_{\tilde{\chi}_1^0},\, \tan\beta,\, m_{A^0},\, M_{\tilde{Q}_1},\, M_{\tilde{Q}},\, A\} =$
$\{135,\, 120,\, 20,\, 600,\, 350,\, 350,\, 500\}$ GeV



Conclusions

- **On–shell Renormalization of the Neutralino and Chargino Mass Matrices**
- **Numerical Analysis based on a full One–Loop Calculation**
- **Mass and Coupling Corrections**
- **Analysis of the Mass Parameters at One–Loop Level**
- **Tests for an SU(5) GUT Relation**