

# New constraints on supersymmetric models from B physics

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  - Effective Hamiltonian
  - Isospin Asymmetry
  - Supersymmetric contributions
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# SUSY Constraints

## The most used constraints:

- Collider limits
- Electroweak precision tests
- Cosmological constraints, in particular from WMAP and the relic density
- The anomalous magnetic moment of the muon  $(g - 2)_\mu$

$$\Delta a_\mu \equiv a_\mu^{SUSY} \equiv a_\mu^{exp} - a_\mu^{SM} = (26 \pm 16) \times 10^{-10}$$

- B Physics

# Constraints from B Physics

- $b \rightarrow s\gamma$  transition: very sensitive to new physics
  - forbidden at the tree level in SM and can only be induced via loop diagrams,
  - SM contributions are vanishingly small,
- branching ratios have been extensively used to constrain SUSY parameter space
- Study another observable: isospin asymmetry
  - already measured by BELLE and BABAR
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# Effective Hamiltonian

The idea of  $B \rightarrow X_s \gamma$  decay begins with introducing an effective Hamiltonian:

$$\mathcal{H}_{eff} = -\frac{4G_F}{\sqrt{2}} V_{ts}^* V_{tb} \sum_{i=1}^8 C_i(\mu) O_i(\mu)$$

$$\left\{ \begin{array}{ll} O_1 = (\bar{s}_L \gamma_\mu T^a c_L)(\bar{c}_L \gamma^\mu T^a b_L) & O_2 = (\bar{s}_L \gamma_\mu c_L)(\bar{c}_L \gamma^\mu b_L) \\ O_3 = (\bar{s}_L \gamma_\mu b_L) \sum_q (\bar{q} \gamma^\mu q) & O_4 = (\bar{s}_L \gamma_\mu T^a b_L) \sum_q (\bar{q} \gamma^\mu T^a q) \\ O_5 = (\bar{s}_L \gamma_{\mu_1} \gamma_{\mu_2} \gamma_{\mu_3} b_L) \sum_q (\bar{q} \gamma^{\mu_1} \gamma^{\mu_2} \gamma^{\mu_3} q) & \\ O_6 = (\bar{s}_L \gamma_{\mu_1} \gamma_{\mu_2} \gamma_{\mu_3} T^a b_L) \sum_q (\bar{q} \gamma^{\mu_1} \gamma^{\mu_2} \gamma^{\mu_3} T^a q) & \\ O_7 = \frac{e}{16\pi^2} m_b (\bar{s}_L \sigma^{\mu\nu} b_R) F_{\mu\nu} & O_8 = \frac{g}{16\pi^2} m_b (\bar{s}_L \sigma^{\mu\nu} T^a b_R) G_{\mu\nu}^a \end{array} \right.$$

# Wilson Coefficients

$$C_i^{\text{eff}}(\mu) = C_i^{(0)\text{eff}}(\mu) + \frac{\alpha_s(\mu)}{4\pi} C_i^{(1)\text{eff}}(\mu) + \dots$$

The effective coefficients evolve according to their RGE:

$$\mu \frac{d}{d\mu} C_i^{\text{eff}}(\mu) = C_j^{\text{eff}}(\mu) \gamma_{ji}^{\text{eff}}(\mu)$$

driven by the anomalous dimension matrix  $\hat{\gamma}^{\text{eff}}(\mu)$ :

$$\hat{\gamma}^{\text{eff}}(\mu) = \frac{\alpha_s(\mu)}{4\pi} \hat{\gamma}^{(0)\text{eff}} + \frac{\alpha_s^2(\mu)}{(4\pi)^2} \hat{\gamma}^{(1)\text{eff}} + \dots$$

# Isospin Asymmetry

$$\Delta_{0-} \equiv \frac{\Gamma(\bar{B}^0 \rightarrow \bar{K}^{*0} \gamma) - \Gamma(B^- \rightarrow K^{*-} \gamma)}{\Gamma(\bar{B}^0 \rightarrow \bar{K}^{*0} \gamma) + \Gamma(B^- \rightarrow K^{*-} \gamma)}$$

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$$\Delta_{0-} = \text{Re}(b_d - b_u).$$

$$b_q = \frac{12\pi^2 f_B Q_q}{m_b T_1^{B \rightarrow K^*} a_7^c} \left( \frac{f_{K^*}^\perp}{m_b} K_1 + \frac{f_{K^*} m_{K^*}}{6\lambda_B m_B} K_2 \right)$$

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$$a_7^c = C_7 + \frac{\alpha_s(\mu) C_F}{4\pi} \left( C_1(\mu) G_1(s_p) + C_8(\mu) G_8 \right) + \frac{\alpha_s(\mu_h) C_F}{4\pi} \left( C_1(\mu_h) H_1(s_p) + C_8(\mu_h) H_8 \right)$$

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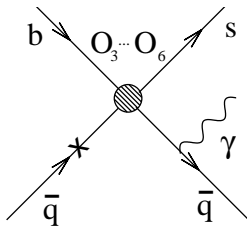
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In the **Standard Model**:  $\Delta_{0-} \simeq 8\%$

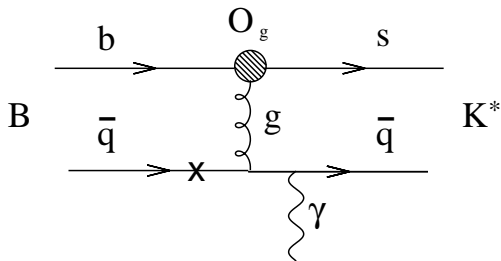
Kagan and Neubert, Phys. Lett. B 539, 227 (2002)

Bosch and Buchalla, Nucl. Phys. B 621, 459 (2002)

# Contribution to Isospin Asymmetry



QCD penguin operators

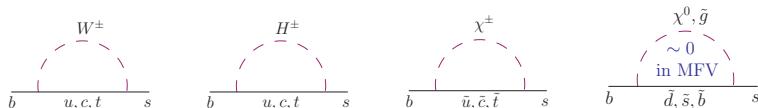


Electro- and chromo-magnetic operators

# Supersymmetric contributions

MSSM with minimal flavor violation (MFV)

↪ no more flavor/CP violation than in SM



Calculation of the coefficients at  $\mu = M_W$ :

$$C_i(\mu) = C_i^{W^\pm}(\mu) + C_i^{H^\pm}(\mu) + C_i^{\chi^\pm}(\mu)$$

Gómez et al. Phys. Rev. D74, 015015 (2006)

Degrassi et al. JHEP 12, 009 (2000)

Ciuchini et al. Nucl. Phys. B 534, 3 (1998)

Ciuchini et al. Nucl. Phys. B 527, 21 (1998)

# SuperIso v1.0

A public C-program for calculating isospin asymmetry of  $B \rightarrow K^* \gamma$  in supersymmetry.

- calculation of isospin asymmetry and inclusive branching ratio,
- automatic calculation in mSUGRA, AMSB and GMSB scenarios,
- compatible with the SUSY Les Houches Accord Format,
- modular program, with a well-defined structure.

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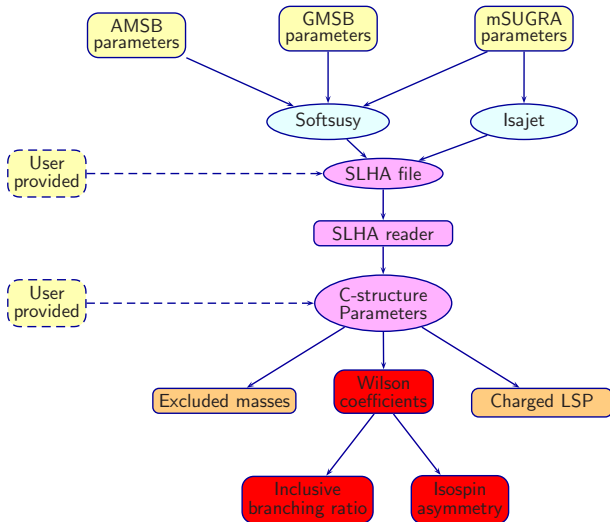
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## SuperIso v1.0



# SuperIso v1.0

Can be downloaded from:

<http://www3.tsl.uu.se/~nazila/superiso/>

Manual:

F. Mahmoudi, arXiv:0710.2067 to appear in Comp. Phys. Comm.

For more information:

M. Ahmady & F. Mahmoudi, Phys. Rev. D75 (2007)

F. Mahmoudi, JHEP 0712, 026 (2007)

# Experimental data

## BABAR

$$\Delta_{0-} = +0.050 \pm 0.045(\text{stat}) \pm 0.028(\text{syst}) \pm 0.024(R^{+/0})$$

Aubert et al. (BABAR Collaboration) Phys. Rev. D72 (2005)

## BELLE

$$\Delta_{0+} = +0.012 \pm 0.044(\text{stat}) \pm 0.026(\text{syst})$$

Nakao et al. (BELLE Collaboration) Phys. Rev. D69 (2004)

Allowed Region:  $-0.018 < \Delta_{0-} < 0.093$

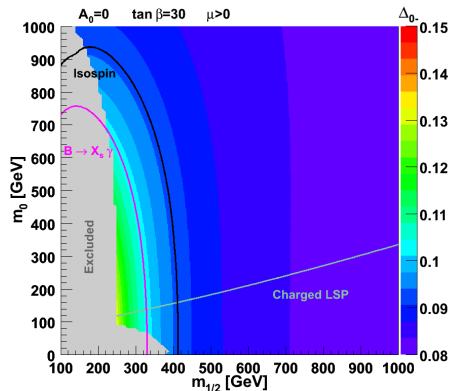
# Experimental limits

Lower bounds on sparticle masses in GeV:

Particle	$h^0$	$\chi_1^0$	$\tilde{l}_R$	$\tilde{\nu}_{e,\mu}$	$\chi_1^\pm$	$\tilde{t}_1$	$\tilde{g}$	$\tilde{b}_1$	$\tilde{\tau}_1$	$\tilde{q}_R$
Lower bound	111	46	88	43.7	67.7	92.6	195	89	81.9	250

Yao et al. J. Phys. G33 (2006)

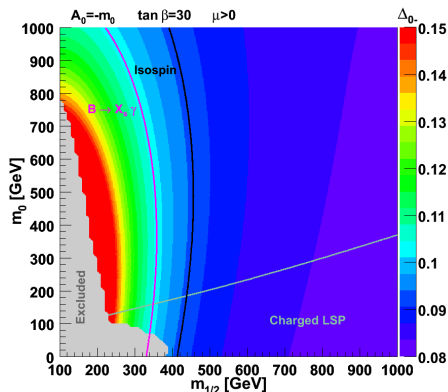
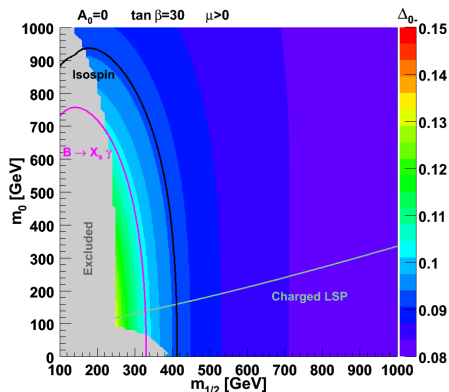
## Results: mSUGRA



$$2.33 \times 10^{-4} < \mathcal{B}(b \rightarrow s\gamma) < 4.15 \times 10^{-4}$$

Ahmady & Mahmoudi, Phys. Rev. D75 (2007)

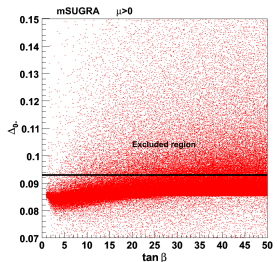
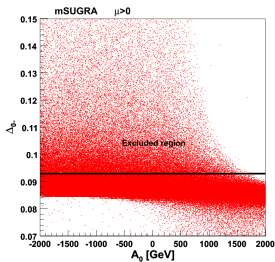
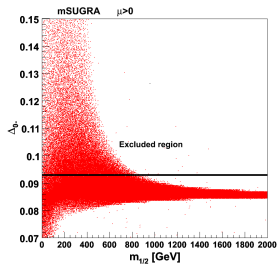
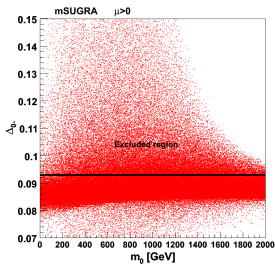
## Results: mSUGRA



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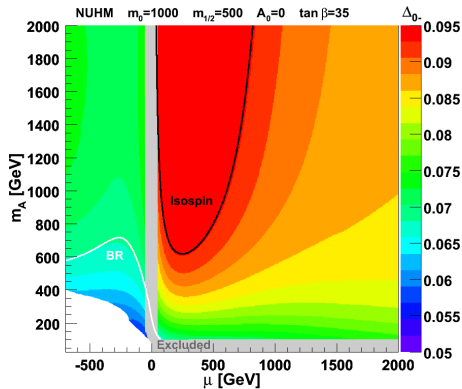
Ahmady & Mahmoudi, Phys. Rev. D75 (2007)

## Results: mSUGRA



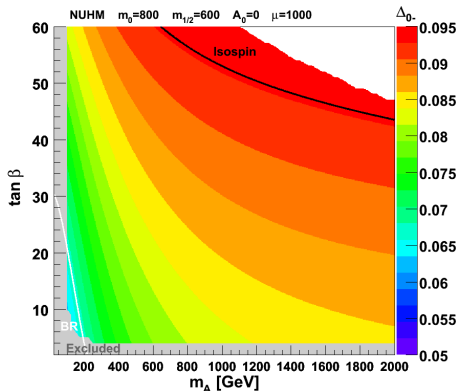
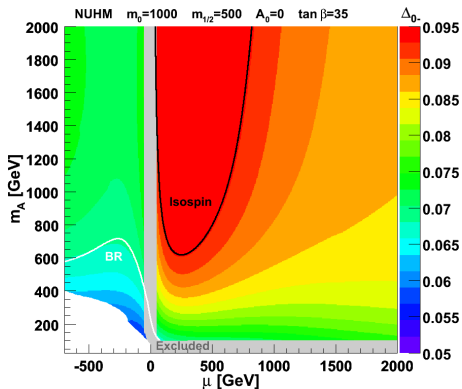
F. Mahmoudi, JHEP 0712, 026 (2007)

## Results: NUHM



F. Mahmoudi, JHEP 0712, 026 (2007)

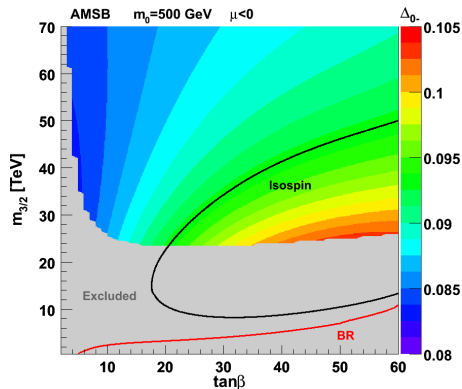
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F. Mahmoudi, JHEP 0712, 026 (2007)

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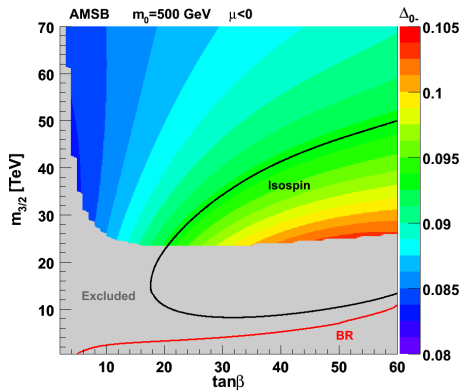
## AMSB



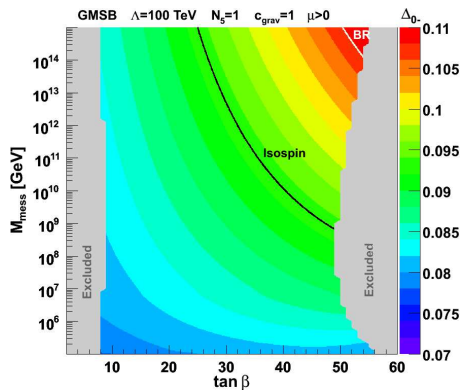
F. Mahmoudi, JHEP 0712, 026 (2007)

## Results

AMSB

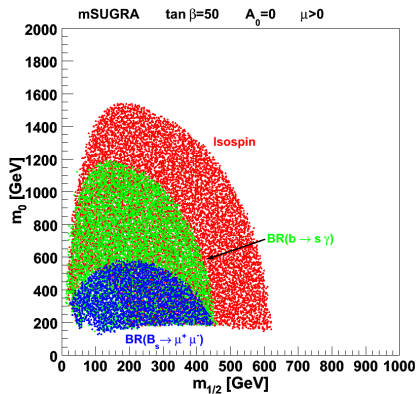


GMSB



F. Mahmoudi, JHEP 0712, 026 (2007)

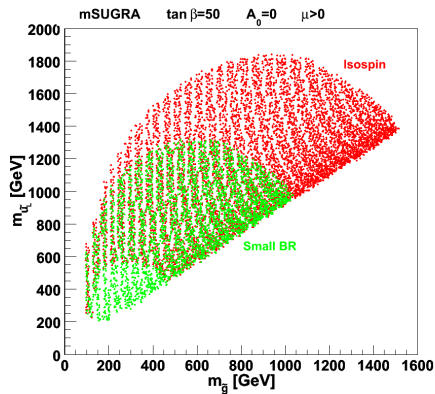
## Results



$$\mathcal{B}(B_s \rightarrow \mu^+ \mu^-) < 0.97 \times 10^{-7}$$

## Results

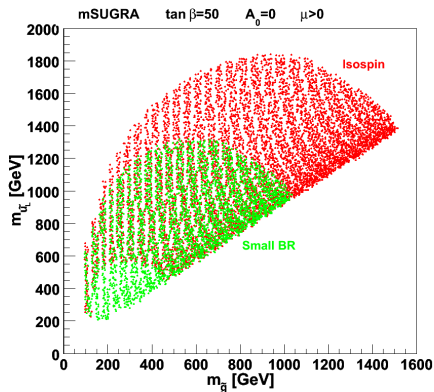
## mSUGRA



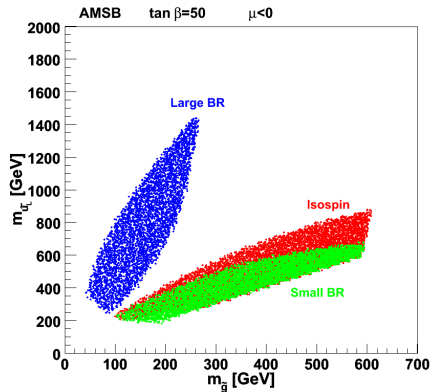
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## Results

mSUGRA



AMSB



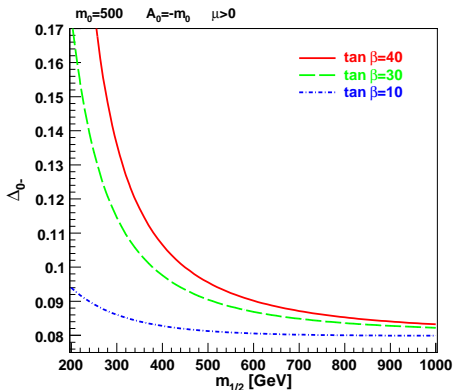
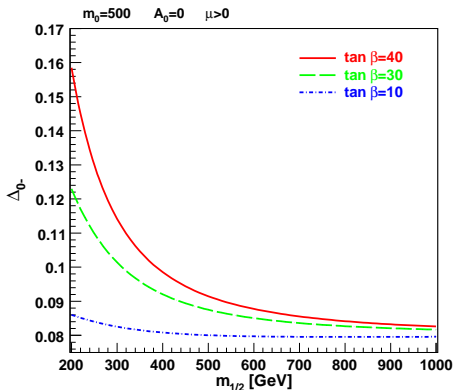
F. Mahmoudi, JHEP 0712, 026 (2007)

# Conclusion

- We can obtain new constraints (new contours) using the Isospin asymmetry
- Very tight constraints on the studied parameter spaces, complementary or even more restrictive than the inclusive branching ratio
- Can be applied to other scenarios
- Isospin asymmetry seems to be an important observable in the precision test of the SM and in constraining new physics parameters

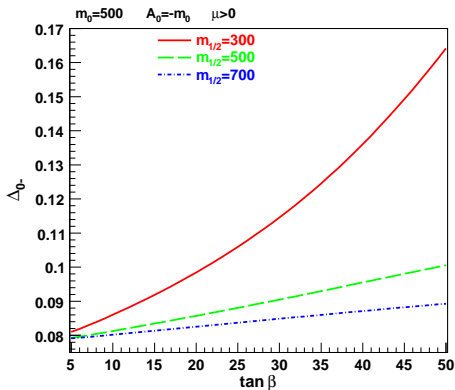
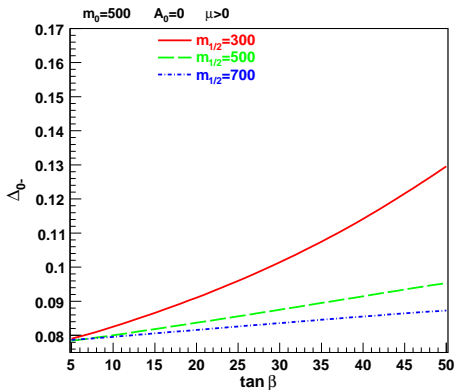
# Backup

# Results: mSUGRA



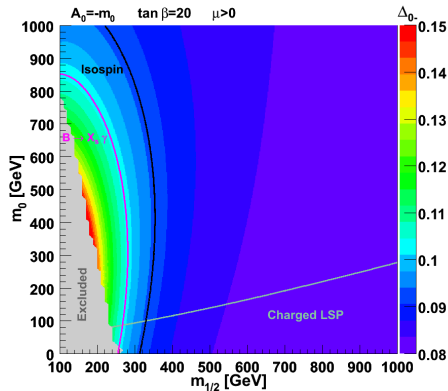
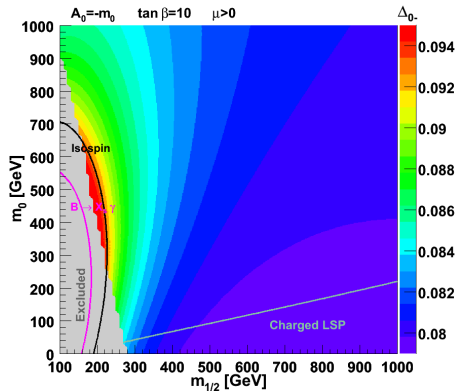
Ahmady & Mahmoudi, Phys. Rev. D75 (2007)

# Results: mSUGRA



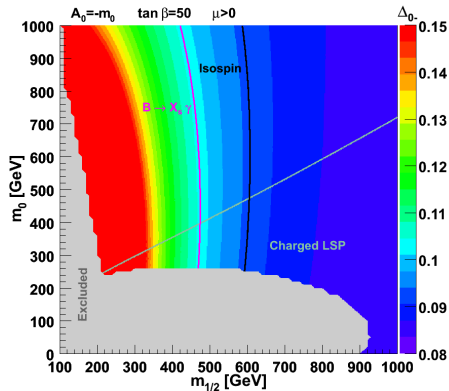
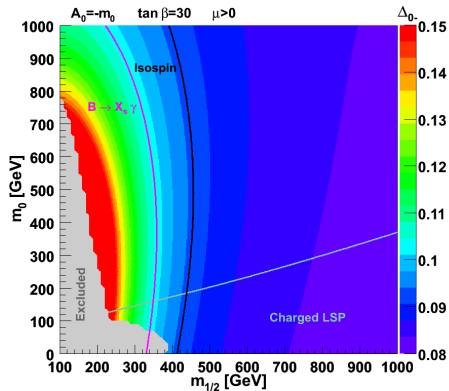
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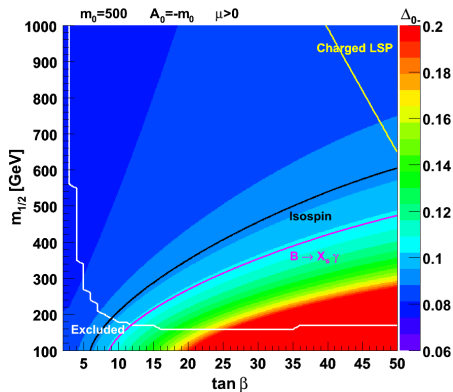
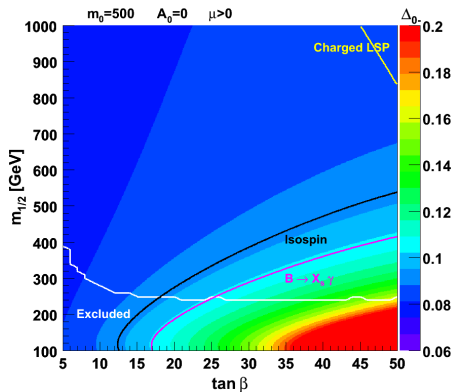
Ahmedy & Mahmoudi, Phys. Rev. D75 (2007)

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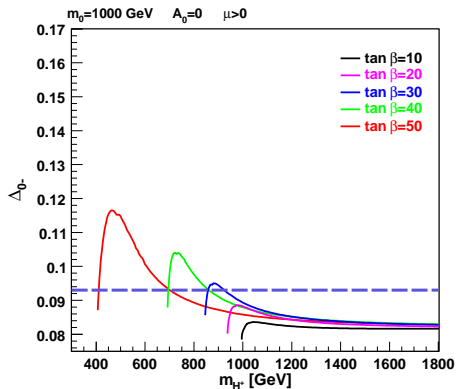
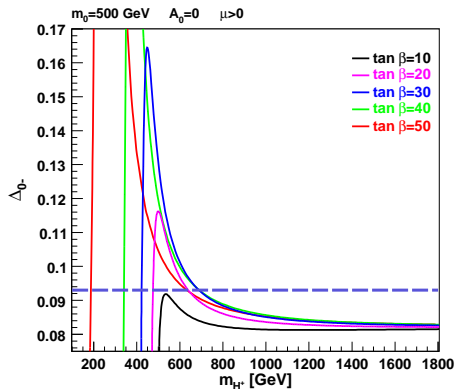
Ahmady & Mahmoudi, Phys. Rev. D75 (2007)

# Results: mSUGRA



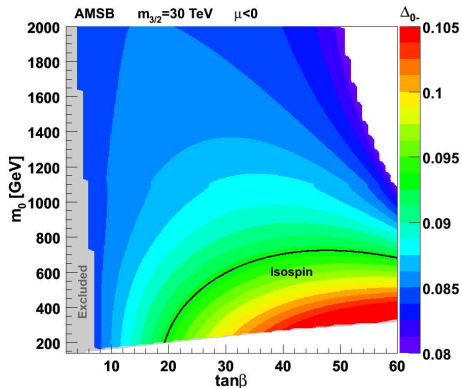
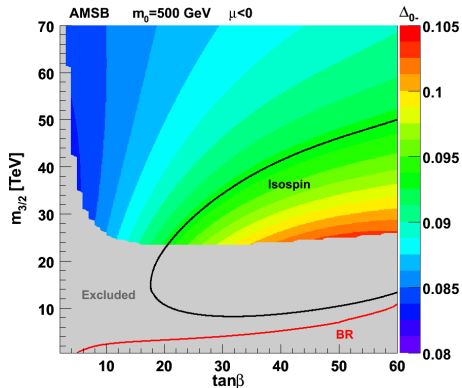
Ahmady & Mahmoudi, Phys. Rev. D75 (2007)

# Results: mSUGRA



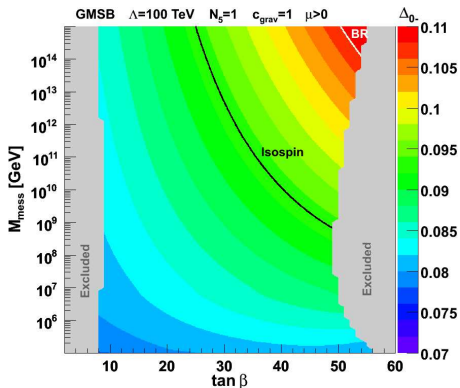
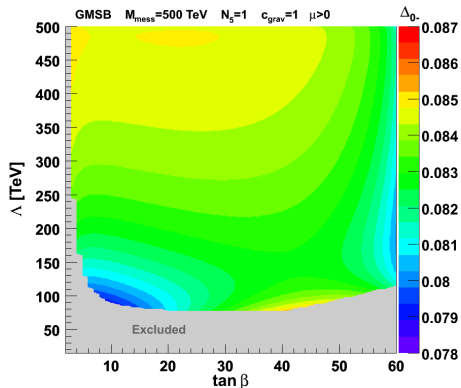
F. Mahmoudi, JHEP 0712, 026 (2007)

# Results: AMSB



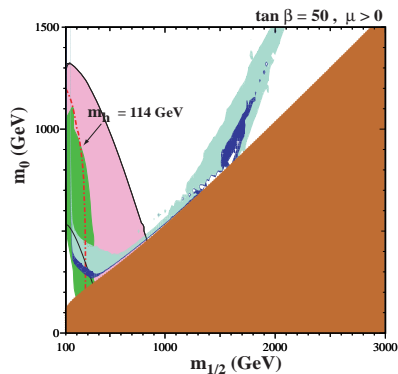
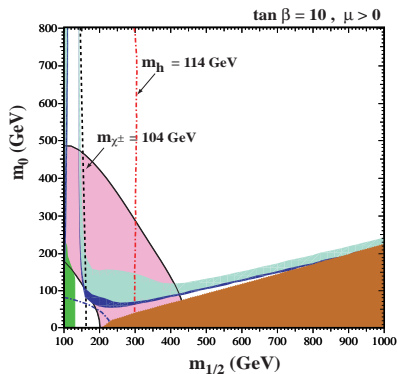
F. Mahmoudi, JHEP 0712, 026 (2007)

# Results: GMSB



F. Mahmoudi, JHEP 0712, 026 (2007)

# Constraining the parameters



Ellis *et al.*, Phys. Lett. B565, 176 (2003)