SuperIso program and flavor data constraints

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Motivations

Searches for New Physics

- direct detection of new physics particles
- nature of Dark Matter
- indirect evidence for new physics

Indirect constraints

- search for new physics effects
- guideline for other searches
- check consistencies with direct observations

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Where to look for?

SUSY models can be divided into two categories:

- R-parity conserving models
- R-parity violating models

R-parity conserving models can also be divided according to how SUSY breaks:

- mSUGRA $\{m_0, m_{1/2}, A_0, \tan\beta, \mathrm{sign}(\mu)\}$
- NUHM {mSUGRA parameters + M_A and μ}
- AMSB $\{m_0, m_{3/2}, \tan\beta, \mathrm{sign}(\mu)\}$
- GMSB $\{\Lambda, M_{\mathrm{mess}}, N_5, c_{\mathrm{grav}}, \tan\beta, \mathrm{sign}(\mu)\}$

In these models, SUSY effects always appear in loops

$\longrightarrow$ difficult to detect unless the SM process is absent or loop-mediated.

$\longrightarrow$ Good places to look for: $B-\bar{B}$ mixing, $b \to s\gamma$, ...

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SUSY Constraints

Observable	Constraint measure
$BR(B_s \to \mu\mu)$	0 ± 0
ΔM_{B_s}	0 ± 0
$\sin^2 \theta_{\rm eff}$	0.007 ± 0
$BR(B \to \tau\nu)$	0.011 ± 0
M_W	0.051 ± 0.001
$BR(b \to s\gamma)$	0.188 ± 0.003
$\Delta_{0-}(b \to s\gamma)$	0.208 ± 0.006
$(g-2)_\mu$	0.390 ± 0.012
$\Omega_{DM} h^2$	0.443 ± 0.006
m_h	0.453 ± 0.053

Molding power of individual observables
for a specific MSSM scenario with $\mu > 0$

Allanach, Dolan and Weber, arXiv:0806.1184

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A public C–program for calculating different observables in supersymmetry

- Automatic calculation in mSUGRA, NUHM, AMSB and GMSB scenarios
- Compatible with the SUSY Les Houches Accord Format (SLHA2)
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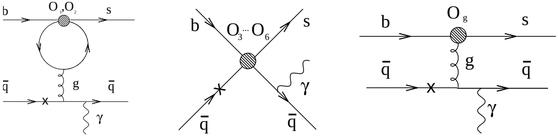
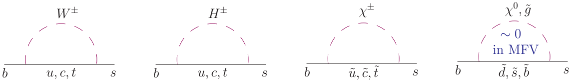
1. Isospin asymmetry of $B \to K^* \gamma$ at NLO



Contributing loops:



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

$$\Delta_{0-} = \mathrm{Re}(b_d - b_u)\;,\; b_q = \frac{12\pi^2 f_B\, Q_q}{m_b\, T_1^{B\to K^*} a_7^c} \left(\frac{f_{K^*}^\perp}{m_b} K_1 + \frac{f_{K^*} m_{K^*}}{6\lambda_B m_B} K_2 \right)$$

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In the Standard Model: $\Delta_{0-} \simeq 8\%$ Kagan and Neubert, Phys. Lett. B539, 227 (2002)

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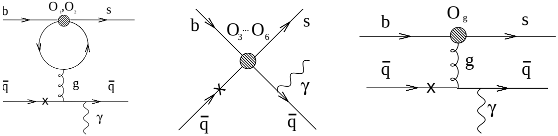

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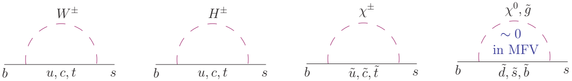

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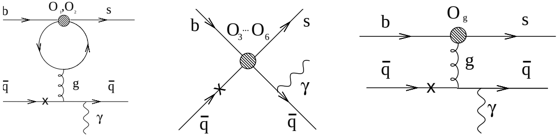

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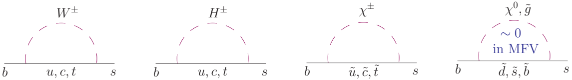

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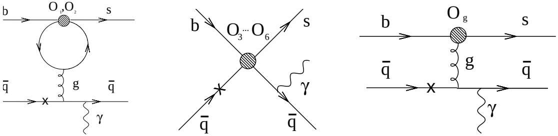

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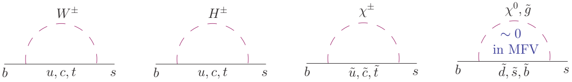

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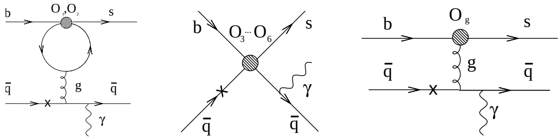

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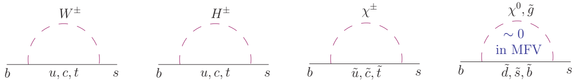

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2. Inclusive branching ratio of $B \to X_s\gamma$ at NNLO

$$\mathcal{B}(\bar{B} \to X_s\gamma)_{E_\gamma > E_0} = \mathcal{B}(\bar{B} \to X_c e\bar{\nu})_{\rm exp} \left|\frac{V_{ts}^* V_{tb}}{V_{cb}}\right|^2 \frac{6\alpha_{\rm em}}{\pi C} [P(E_0) + N(E_0)]$$

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SM prediction: $\mathcal{B}[\bar{B} \to X_s\gamma] = (3.15 \pm 0.23) \times 10^{-4}$

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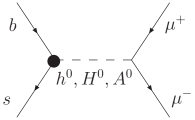
3. Branching ratio of $B_s \to \mu^+\mu^-$

$$\mathcal{B}(B_s \to \mu^+\mu^-) = \frac{G_F^2\alpha^2}{64\pi^3} f_{B_s}^2 \tau_{B_s} M_{B_s}^3 |V_{tb}V_{ts}^*|^2 \sqrt{1 - \frac{4m_\mu^2}{M_{B_s}^2}}$$
$$\times \left\{ \left(1 - \frac{4m_\mu^2}{M_{B_s}^2}\right) M_{B_s}^2 |C_S|^2 + \left| C_P M_{B_s} - 2\, C_A \frac{m_\mu}{M_{B_s}} \right|^2 \right\}$$



Upper limit: $\mathcal{B}(B_s \to \mu^+\mu^-) < 5.8 \times 10^{-8}$ at 95% C.L.

SM predicted value: $\mathcal{B}(B_s \to \mu^+\mu^-)_{SM} \sim 3 \times 10^{-9}$

Interesting in the high $\tan\beta$ regime, where the SUSY contributions can lead to an O(100) enhancement over the SM:

$$\mathcal{B}(B_s \to \mu^+\mu^-)_{MSSM} \sim \frac{m_b^2 m_\mu^2 \tan^6\beta}{M_A^4}$$

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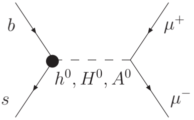
$$\times \left\{ \left(1 - \frac{4m_\mu^2}{M_{B_s}^2}\right) M_{B_s}^2 |C_S|^2 + \left| C_P M_{B_s} - 2\, C_A \frac{m_\mu}{M_{B_s}} \right|^2 \right\}$$



Upper limit: $\mathcal{B}(B_s \to \mu^+\mu^-) < 5.8 \times 10^{-8}$ at 95% C.L.

SM predicted value: $\mathcal{B}(B_s \to \mu^+\mu^-)_{SM} \sim 3 \times 10^{-9}$

Interesting in the high $\tan\beta$ regime, where the SUSY contributions can lead to an O(100) enhancement over the SM:

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SuperIso v2.3: implemented observables

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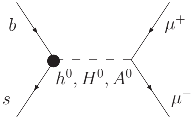

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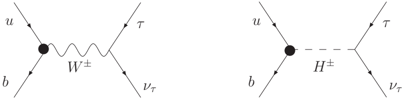
SuperIso v2.3: implemented observables

4. Branching ratio of $B \to \tau\nu$

Tree level process, mediated by W^+ and H^+, higher order corrections from sparticles



$$\mathcal{B}(B \to \tau\nu) = \frac{G_F^2 |V_{ub}|^2}{8\pi} m_\tau^2 f_B^2 m_B \left(1 - \frac{m_\tau^2}{m_B^2}\right)^2 \left|1 - \left(\frac{m_B^2}{m_{H^+}^2}\right) \frac{\tan^2\beta}{1 + \epsilon_0 \tan\beta}\right|^2$$

$$\epsilon_0 = -\frac{2\alpha_s}{3\pi} \frac{\mu}{m_{\tilde{g}}} H_2\left(\frac{m_{\tilde{Q}}^2}{m_{\tilde{g}}{}^2}, \frac{m_{\tilde{D}}^2}{m_{\tilde{g}}{}^2}\right) , \quad H_2(x,y) = \frac{x \ln x}{(1-x)(x-y)} + \frac{y \ln y}{(1-y)(y-x)}$$

⚠ Large uncertainty from V_{ub}

Also implemented in SuperIso:

$$R_{\tau\nu_\tau}^{\rm MSSM} = \frac{{\rm BR}(B_u \to \tau\nu_\tau)_{\rm MSSM}}{{\rm BR}(B_u \to \tau\nu_\tau)_{\rm SM}} = \left[1 - \left(\frac{m_B^2}{m_{H^+}^2}\right) \frac{\tan^2\beta}{1 + \epsilon_0 \tan\beta}\right]^2$$

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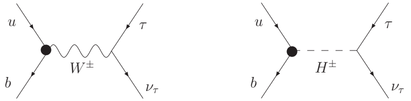

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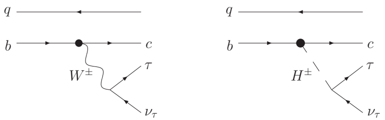
SuperIso v2.3: implemented observables

5. Branching ratio of $B \to D\tau\nu$

Another tree level process:



$$\frac{d\Gamma(B \to D\ell\overline{\nu})}{dw} = \frac{G_F^2 |V_{cb}|^2 m_B^5}{192\pi^3} \rho_V(w) \left[1 - \frac{m_\ell^2}{m_B^2} \left| 1 - \frac{t(w)}{(m_b - m_c)} \frac{m_b}{m_{H^+}^2} \frac{\tan^2\beta}{1+\epsilon_0 \tan\beta} \right|^2 \rho_S(w) \right]$$

$w = v_B \cdot v_D$ ρ_V and ρ_S: vector and scalar Dalitz density contributions

- Depends on V_{cb}, which is known to better precision than V_{ub}
- Larger branching fraction than $B \to \tau\nu$
- Experimentally challenging due to the presence of neutrinos in the final state

Implemented in SuperIso: $\mathcal{B}(B^- \to D^0\tau^-\nu)$ and $\dfrac{\mathcal{B}(B^- \to D^0\tau^-\nu)}{\mathcal{B}(B^- \to D^0 e^-\nu)}$

SuperIso v2.3: implemented observables

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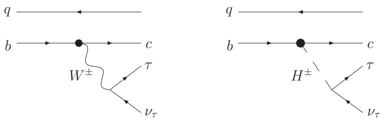

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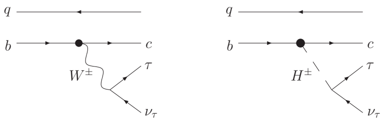

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SuperIso v2.3: implemented observables

6. Branching ratio of $K \to \mu\nu$

Tree level process similar to $B \to \tau\nu$

Two observables are implemented in SuperIso:

$$\frac{\Gamma(K \to \mu\nu)}{\Gamma(\pi \to \mu\nu)} = \left|\frac{V_{us}}{V_{ud}}\right|^2 \frac{f_K^2 m_K}{f_\pi^2 m_\pi} \left(\frac{1 - m_\ell^2/m_K^2}{1 - m_\ell^2/m_\pi^2}\right)^2 \times \left(1 - \frac{m_{K^+}^2}{M_{H^+}^2}\left(1 - \frac{m_d}{m_s}\right) \frac{\tan^2\beta}{1 + \epsilon_0 \tan\beta}\right)^2 (1 + \delta_{\rm em})$$

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Large uncertainty from f_K/f_π

SuperIso v2.3: implemented observables

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SuperIso v2.3: implemented observables

7. Anomalous magnetic moment of muon $a_\mu = (g-2)/2$

Latest measurement on e^+e^- data: $a_\mu^{\rm exp} = (11\,659\,208.0 \pm 6.3) \times 10^{-10}$

Bennett *et al.*, Phys. Rev. D73 (2006)

SM prediction: $a_\mu^{\rm SM} = (11\,659\,178.5 \pm 6.1) \times 10^{-10}$

MSSM contributions:

$$\delta a_\mu^{\rm SUSY} = \delta a_\mu^{\chi^0} + \delta a_\mu^{\chi^\pm} + \delta a_{\mu,\,2\,\rm loop}^{\rm SUSY}$$

Deviation from the SM:

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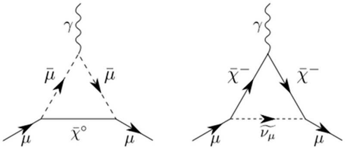

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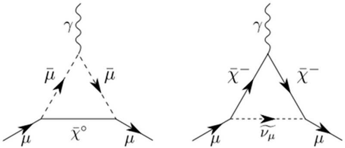

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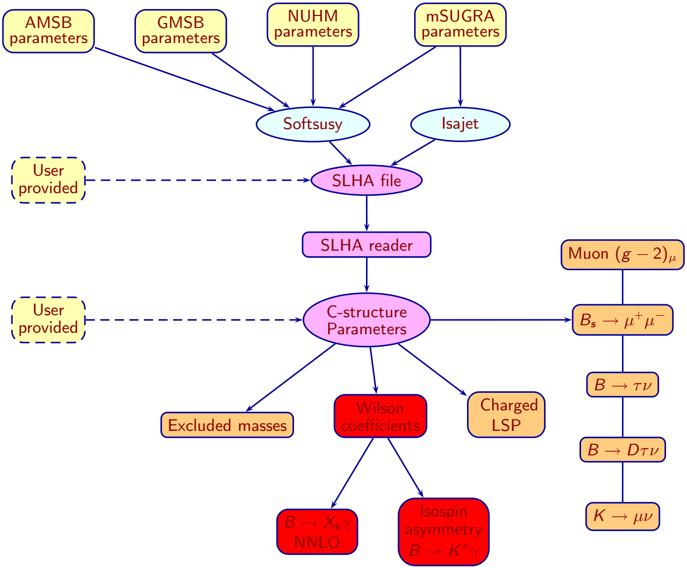
SuperIso v2.3



SuperIso v2.3

Can be downloaded from:

http://www3.tsl.uu.se/∼nazila/superiso/

Manual:

F. Mahmoudi, arXiv:0710.2067, Comput. Phys. Commun. 178, 745 (2008)

F. Mahmoudi, arXiv:0808.3144 [hep-ph]

For more information:

F. Mahmoudi, JHEP 0712, 026 (2007)

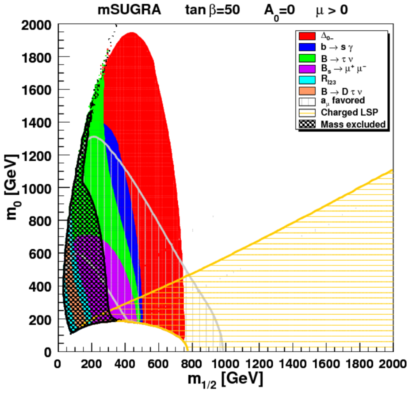
M. Ahmady & F. Mahmoudi, Phys. Rev. D75 (2007)

A. Arbey & F. Mahmoudi, Phys. Lett. B (2008)

D. Eriksson, F. Mahmoudi, O. Stål, arXiv:0808.3551 [hep-ph]

Combined constraints in the MSSM

mSUGRA



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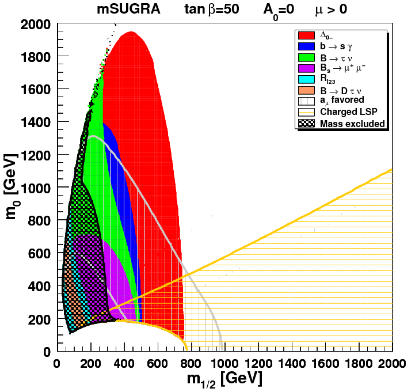
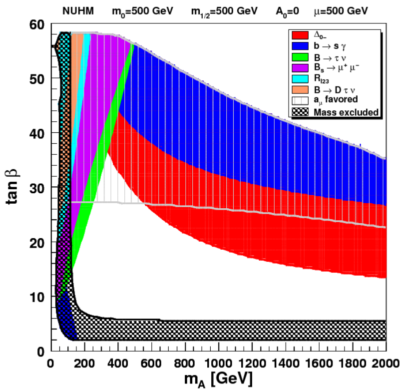


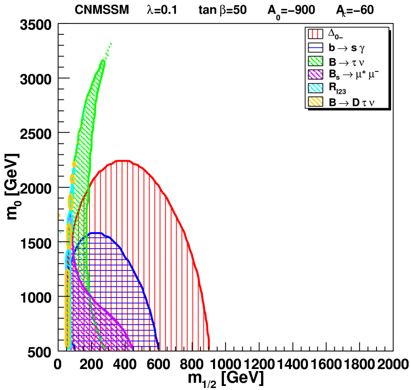
NUHM



F. Mahmoudi, arXiv:0808.3144

Combined constraints in the NMSSM

CNMSSM



F. Mahmoudi, preliminary results

Application to the charged Higgs

$\longrightarrow$ see the next talk by Oscar Stål.

Conclusion

- Indirect constraints and in particular flavor physics are essential to restrict new physics parameters
- That will become even more interesting when combined with LHC data
- This kind of analysis should be generalized to more new physics scenarios

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- Extension to NMSSM
- Implementation of the relic density calculation (with A. Arbey)
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