Status of flavor constraints on beyond Standard Model scenarios

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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 searches

- complementary to other searches
- consistency checks with direct observations

New Physics Models

- Two Higgs Doublet Models
- Supersymmetry
- Extra-dimensions
- ...

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Indirect Constraints

Flavor observables

1. Radiative penguin decays
2. Electroweak penguin decays
3. Neutrino modes

Other observables

1. Direct search limits
2. Anomalous magnetic moment of muon $a_\mu = (g-2)/2$
3. Relic density

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- inclusive branching ratio of $B \to X_s\gamma$
- isospin asymmetry of $B \to K^*\gamma$

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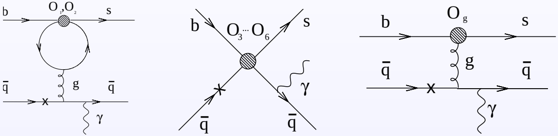
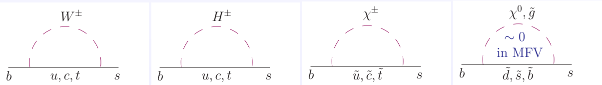
I) Radiative penguin decays

Inclusive branching ratio of $B \to X_s \gamma$



Contributing loops:



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

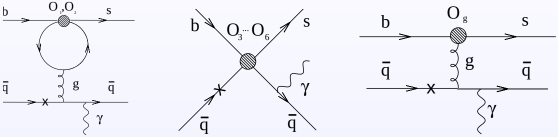
$$\begin{aligned} P(E_0) &= P^{(0)}(\mu_b) + \alpha_s(\mu_b) \left[P_1^{(1)}(\mu_b) + P_2^{(1)}(E_0, \mu_b) \right] \\ &+ \alpha_s^2(\mu_b) \left[P_1^{(2)}(\mu_b) + P_2^{(2)}(E_0,\mu_b) + P_3^{(2)}(E_0,\mu_b) \right] + \mathcal{O}\left(\alpha_s^3(\mu_b)\right) \end{aligned}$$

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

Experimental values (HFAG 2010): $\mathcal{B}[\bar{B} \to X_s\gamma] = (3.55 \pm 0.25) \times 10^{-4}$

I) Radiative penguin decays

Inclusive branching ratio of $B \to X_s\gamma$



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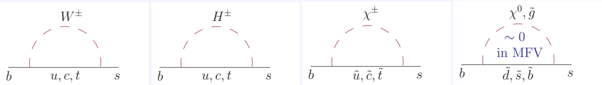

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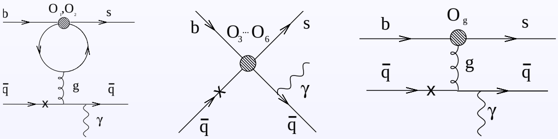

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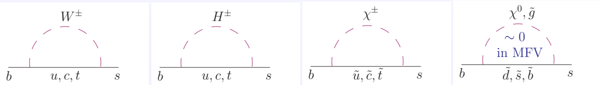

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II) Electroweak penguin decays

- branching ratio of $B_s \to \mu^+\mu^-$
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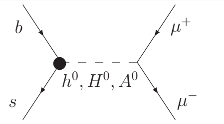
II) Electroweak penguin decays

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: $\mathcal{B}(B_s \to \mu^+\mu^-) < 4.3 \times 10^{-8}$ 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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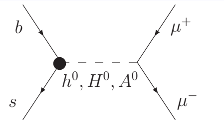

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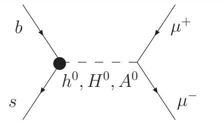

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Flavor observables

III) Neutrino modes

- branching ratio of $B \to \tau\nu$
- branching ratio of $B \to D\tau\nu$
- branching ratios of $D_s \to \tau\nu/\mu\nu$
- branching ratio of $K \to \mu\nu$
- double ratios of leptonic decays

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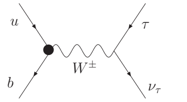
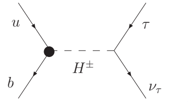
III) Neutrino modes

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

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





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

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

⚠ Large uncertainty from V_{ub} and sensitive to f_B

Also used:

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

III) Neutrino modes

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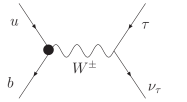

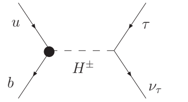

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$$R_{\tau\nu_\tau}^{\mathrm{MSSM}} = \frac{\mathrm{BR}(B_u \to \tau\nu_\tau)_{\mathrm{MSSM}}}{\mathrm{BR}(B_u \to \tau\nu_\tau)_{\mathrm{SM}}} = \left[1 - \left(\frac{m_B^2}{m_{H^+}^2}\right) \frac{\tan^2\beta}{1+\epsilon_0 \tan\beta}\right]^2$$

III) Neutrino modes

Branching ratio of $D_s \to \ell\nu$

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

$$\mathcal{B}(D_s \to \ell\nu) = \frac{G_F^2}{8\pi} |V_{cs}|^2 f_{D_s}^2 m_\ell^2 M_{D_s} \tau_{D_s} \left(1 - \frac{m_\ell^2}{M_{D_s}^2}\right)^2 \times \left[1 + \left(\frac{1}{m_c + m_s}\right)\left(\frac{M_{D_s}}{m_{H^+}}\right)^2 \left(m_c - \frac{m_s \tan^2\beta}{1 + \epsilon_0 \tan\beta}\right)\right]^2 \quad \text{for } \ell = \mu, \tau$$

- Competitive with and complementary to analogous observables
- Dependence on only one lattice QCD quantity
- Interesting if lattice calculations eventually prefer $f_{D_s} < 250$ MeV
- Promising experimental situation (BES-III)

⚠ Sensitive to f_{D_s} and m_s/m_c

III) Neutrino modes

Double ratios of leptonic decays

For example:

$$R = \left(\frac{\mathrm{BR}(B_s \to \mu^+\mu^-)}{\mathrm{BR}(B_u \to \tau\nu)}\right) \Big/ \left(\frac{\mathrm{BR}(D_s \to \tau\nu)}{\mathrm{BR}(D \to \mu\nu)}\right)$$

From the form factor point of view:

$$R \propto \left(\frac{f_{B_s}}{f_B}\right) \Big/ \left(\frac{f_{D_s}}{f_D}\right) \approx 1$$

R has no dependence on the form factors, contrary to each decay taken individually!

- No dependence on lattice quantities
- Interesting for V_{ub} determination
- Interesting for probing new physics
- Promising experimental situation

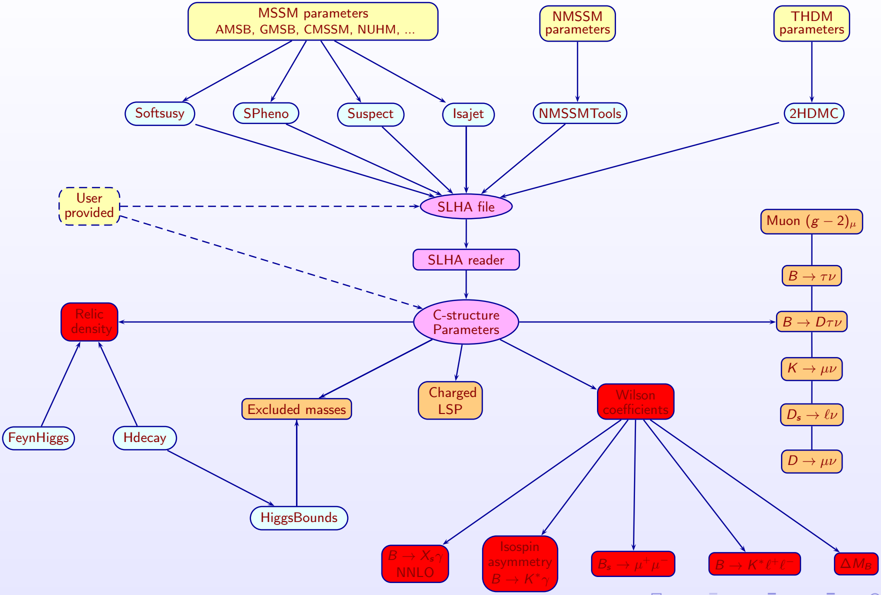
SuperIso

SuperIso is a public C program

- dedicated to the flavor physics observable calculations
- implemented models: SM, THDM, MSSM and NMSSM with MFV
- interfaced to spectrum calculators (2HDMC, SOFTSUSY, ISAJET, SUSPECT, SPHENO, NMSSMTOOLS)
- SuperIso Relic: extension to the relic density calculation, featuring alternative cosmological scenarios

F. Mahmoudi, Comput. Phys. Commun. 178 (2008) 745
F. Mahmoudi, Comput. Phys. Commun. 180 (2009) 1579
F. Mahmoudi, Comput. Phys. Commun. 180 (2009) 1718
A. Arbey & F. Mahmoudi, Comput. Phys. Commun. 181 (2010) 1277

SuperIso


MSSM parameters
AMSB, GMSB, CMSSM, NUHM, ...
NMSSM parameters
THDM parameters
Softsusy
SPheno
Suspect
Isajet
NMSSMTools
2HDMC
User provided
SLHA file
SLHA reader
Muon $(g-2)_\mu$
$B \to \tau\nu$
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$K \to \mu\nu$
$D_s \to \ell\nu$
$D \to \mu\nu$
Relic density
C-structure Parameters
Excluded masses
Charged LSP
Wilson coefficients
FeynHiggs
Hdecay
HiggsBounds
$B \to X_s\gamma$ NNLO
Isospin asymmetry $B \to K^*\gamma$
$B_s \to \mu^+\mu^-$
$B \to K^*\ell^+\ell^-$
ΔM_B

Download

http://superiso.in2p3.fr

SuperIso

By Farvah Nazila Mahmoudi

SuperIso
- Description
- Manual

SuperIso Relic
- Description
- Manual

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- SuperIso Relic
- SuperIso Relic shared

Calculation of flavor physics observables

SuperIso is a program for calculation of flavor physics observables in the Standard Model (SM), general two-Higgs-doublet model (2HDM), minimal supersymmetric Standard Model (MSSM) and next to minimal supersymmetric Standard Model (NMSSM). SuperIso, in addition to the isospin asymmetry of B -> K* gamma, which was the main purpose of the first version, incorporates other flavor observables such as the branching ratio of B -> Xs gamma at NNLO, the branching ratio of Bs -> mu+ mu-, the branching ratio of B -> tau nu, the branching ratio of B -> D tau nu, the branching ratio of K -> mu nu as well as the branching ratios of Ds -> tau nu and Ds -> mu nu. It also computes the muon anomalous magnetic moment (g-2).

For the isospin asymmetry, the program calculates the NLO supersymmetric contributions using the effective Hamiltonian approach and within the QCD factorization method. Isospin asymmetry is a particularly useful observable to constrain supersymmetric parameter spaces.

SuperIso uses a SUSY Les Houches Accord file (SLHA1 or SLHA2) as input, which can be either generated automatically by the program via a call to SOFTSUSY, ISAJET, NMSSMTools or provided by the user. SuperIso can also use the LHA inspired format for the 2HDM generated by 2HDMC.

SuperIso is able to perform the calculations automatically in the SM, in the 2HDM (general 2HDM or types I-IV) and in different supersymmetry breaking scenarios, such as mSUGRA, NUHM, AMSB and GMSB (for MSSM) and CNMSSM, NGMSB and NNUHM (for NMSSM).

For any comment, question or bug report please contact Nazila Mahmoudi.

Manual

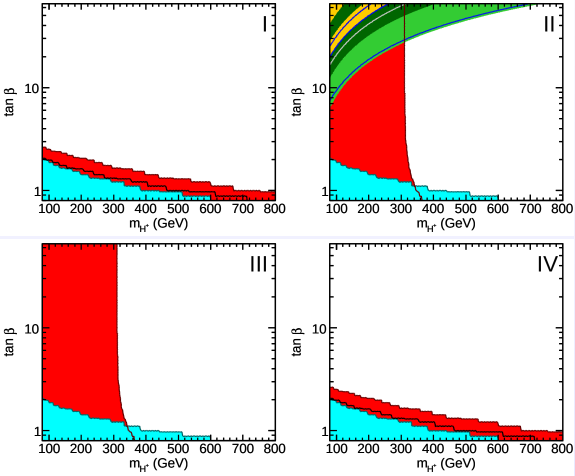
NEW **The latest version of the manual can be found here (10 September 2009).**

For more information:

- F. Mahmoudi, arXiv:0710.3791 [hep-ph], JHEP12 (2007), 026
- M.R. Ahmady and F. Mahmoudi, hep-ph/0608212, Phys. Rev. D75 (2007), 015007
- D. Eriksson, F. Mahmoudi and O. Stål, arXiv:0808.3551 [hep-ph], JHEP11 (2008), 035

THDM

THDM (Types I–IV)

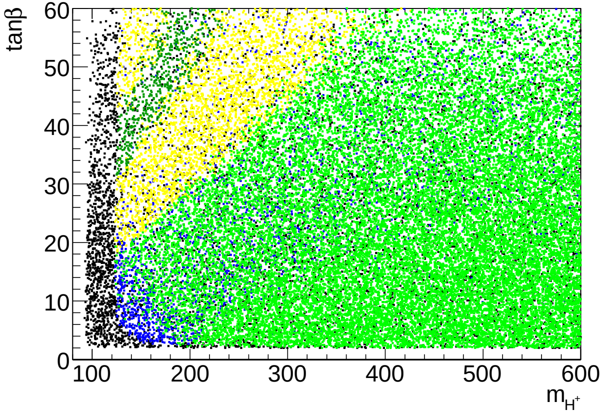


Red: $b \to s\gamma$
Cyan: ΔM_{B_d}
Blue: $B_u \to \tau\nu_\tau$
Yellow: $B \to D\ell\nu_\ell$
Gray: $K \to \mu\nu_\mu$
Green: $D_s \to \tau\nu_\tau$
Dark green: $D_s \to \mu\nu_\mu$

F. Mahmoudi & O. Stål, Phys. Rev. D81, 035016 (2010)

MSSM

NUHM scenario



black: direct constraints

blue: $\mathcal{B}(B \to X_s \gamma)$

yellow: $\mathcal{B}(B \to \tau\nu)$

dark green: $\mathcal{B}(B \to D\tau\nu)$

green: allowed

D. Eriksson, F. Mahmoudi & O. Stål, JHEP 0811 (2008)

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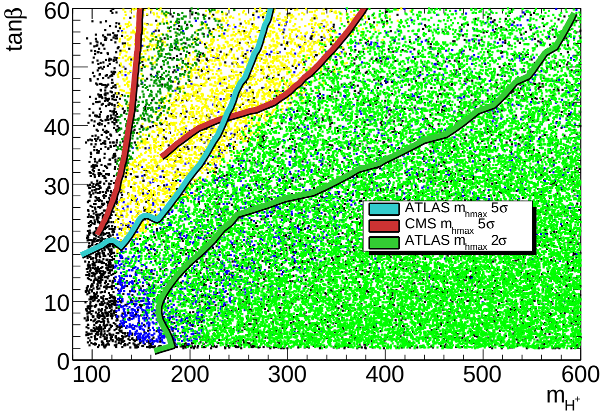

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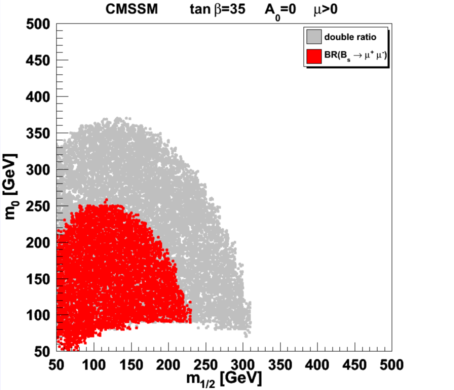
Double ratios

$$R = \left(\frac{\mathrm{BR}(B_s \to \mu^+\mu^-)}{\mathrm{BR}(B_u \to \tau\nu)}\right) \Big/ \left(\frac{\mathrm{BR}(D_s \to \tau\nu)}{\mathrm{BR}(D \to \mu\nu)}\right)$$



$|V_{ub}| = (3.92 \pm 0.46) \times 10^{-4}$ $f_{B_s} = 238.8 \pm 9.5$ MeV (for $B_s \to \mu^+\mu^-$)

A.G. Akeroyd & F. Mahmoudi, arXiv:1007.2757

Flavour Les Houches Accord

The Flavour Les Houches Accord format

Standard format for flavour related quantities, providing:

- A model independent parametrization
- A standalone flavour output in the FLHA format
- Based on the existing SLHA structure
- A clear and well-defined structure for interfacing computational tools of “New Physics” models with low energy flavour calculations
- That will allow different programs to talk and to be interfaced, and users to have a clear and well defined result that can eventually be used for different purposes

For more information

- Wiki page:

http://www.lpthe.jussieu.fr/LesHouches09Wiki/index.php/Flavour_Les_Houches_Accord

- Les Houches write-up: arXiv:1003.1643

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 can be generalized to more new physics scenarios

Ongoing Developments of SuperIso

- Extension to NMFV
- Implementation of other observables

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Backup: General THDM

Charged Higgs boson couplings to fermions:

$$H^+ D\bar{U}: \qquad \frac{ig}{2\sqrt{2}m_W} V_{UD}\left[\lambda^U m_U\left(1-\gamma^5\right) - \lambda^D m_D\left(1+\gamma^5\right)\right]$$

$$H^+ \ell^- \bar{\nu}_\ell: \qquad -\frac{ig}{2\sqrt{2}m_W}\lambda^\ell m_\ell\left(1+\gamma^5\right)$$

THDM types I–IV

- Type I: one Higgs doublet provides masses to all quarks (up and down type quarks) ($\sim$ SM)
- Type II: one Higgs doublet provides masses for up type quarks and the other for down-type quarks ($\sim$ MSSM)
- Type III,IV: different doublets provide masses for down type quarks and charged leptons

Type	λ_U	λ_D	λ_L
I	$\cot\beta$	$\cot\beta$	$\cot\beta$
II	$\cot\beta$	$-\tan\beta$	$-\tan\beta$
III	$\cot\beta$	$-\tan\beta$	$\cot\beta$
IV	$\cot\beta$	$\cot\beta$	$-\tan\beta$