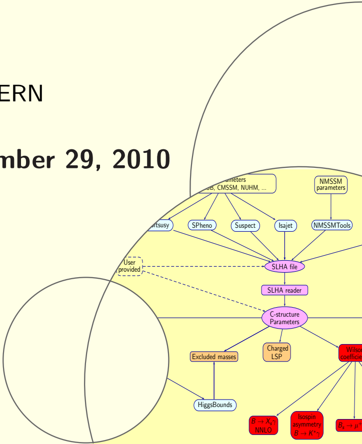
Flavour contraints and SuperIso

Nazila Mahmoudi

LPC Clermont-Ferrand & CERN

cH$^{\pm}$arged 2010 – Uppsala – September 29, 2010



Outline

Motivations

Indirect searches for New Physics

- sensitivity to new physics effects
- complementary to other searches
- probe sectors inaccessible to direct searches
- test quantum structure of the SM at loop level
- constrain parameter spaces of new physics scenarios
- valuable data already available
- promising experimental situation
- consistency checks with direct observations

Indirect Constraints

Flavour observables

1. Radiative penguin decays
2. Electroweak penguin decays
3. Neutrino modes
4. Meson mixings

Other observables

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

Indirect Constraints

Flavour observables

1. Radiative penguin decays
2. Electroweak penguin decays
3. Neutrino modes
4. Meson mixings

Other observables

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

Indirect Constraints

Flavour observables

1. Radiative penguin decays
2. Electroweak penguin decays
3. Neutrino modes
4. Meson mixings

Other observables

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

Indirect Constraints

Flavour observables

1. Radiative penguin decays
2. Electroweak penguin decays
3. Neutrino modes
4. Meson mixings

Other observables

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

Indirect Constraints

Flavour observables

1. Radiative penguin decays
2. Electroweak penguin decays
3. Neutrino modes
4. Meson mixings

Other observables

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

Indirect Constraints

Flavour observables

1. Radiative penguin decays
2. Electroweak penguin decays
3. Neutrino modes
4. Meson mixings

Other observables

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

SuperIso

SuperIso is a public C program

- public C program
- dedicated to the flavour physics observable calculations
- various models implemented
- interfaced to several spectrum calculators
- modular program with a well-defined structure
- SuperIso Relic (with Alex Arbey): extension to the relic density calculation, featuring alternative cosmological scenarios
- complete reference manuals available

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

Models

Standard Model

General Two Higgs Doublet Model

automatic interface with 2HDMC for

- General 2HDM and Types I, II, III, IV

MSSM (with Minimal Flavour Violation)

automatic interfaces with Softsusy, Isajet, Spheno and Suspect available for

- CMSSM, NUHM, AMSB, HC-AMSB, MM-AMSB, GMSB

NMSSM

automatic interface with NMSSMTools available for

- CNMSSM, NNUHM, NGMSB

BMSSM

automatic interface with a modified version of Suspect

Models

Standard Model

General Two Higgs Doublet Model

automatic interface with 2HDMC for

- General 2HDM and Types I, II, III, IV

MSSM (with Minimal Flavour Violation)

automatic interfaces with Softsusy, Isajet, Spheno and Suspect available for

- CMSSM, NUHM, AMSB, HC-AMSB, MM-AMSB, GMSB

NMSSM

automatic interface with NMSSMTools available for

- CNMSSM, NNUHM, NGMSB

BMSSM

automatic interface with a modified version of Suspect

Models

Standard Model

General Two Higgs Doublet Model

automatic interface with 2HDMC for

- General 2HDM and Types I, II, III, IV

MSSM (with Minimal Flavour Violation)

automatic interfaces with Softsusy, Isajet, Spheno and Suspect available for

- CMSSM, NUHM, AMSB, HC-AMSB, MM-AMSB, GMSB

NMSSM

automatic interface with NMSSMTools available for

- CNMSSM, NNUHM, NGMSB

BMSSM

automatic interface with a modified version of Suspect

Models

Standard Model

General Two Higgs Doublet Model

automatic interface with 2HDMC for

- General 2HDM and Types I, II, III, IV

MSSM (with Minimal Flavour Violation)

automatic interfaces with Softsusy, Isajet, Spheno and Suspect available for

- CMSSM, NUHM, AMSB, HC-AMSB, MM-AMSB, GMSB

NMSSM

automatic interface with NMSSMTools available for

- CNMSSM, NNUHM, NGMSB

BMSSM

automatic interface with a modified version of Suspect

Models

Standard Model

General Two Higgs Doublet Model

automatic interface with 2HDMC for

- General 2HDM and Types I, II, III, IV

MSSM (with Minimal Flavour Violation)

automatic interfaces with Softsusy, Isajet, Spheno and Suspect available for

- CMSSM, NUHM, AMSB, HC-AMSB, MM-AMSB, GMSB

NMSSM

automatic interface with NMSSMTools available for

- CNMSSM, NNUHM, NGMSB

BMSSM

automatic interface with a modified version of Suspect

Flavour Observables

I) Radiative penguin decays

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

II) Electroweak penguin decays

- branching ratio of $B_s \to \mu^+ \mu^-$
- inclusive branching ratio of $B \to X_s \ell^+ \ell^-$
- branching ratio of $B \to K^* \mu^+ \mu^-$

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

IV) Mixings

- B_s, D, K, $\cdots$ meson mixings

Effective Hamiltonian

A multi-scale problem

- electroweak interactions: $MW \approx 80$ GeV
- B meson: $m_b \approx 5$ GeV
- QCD interactions: $\Lambda_{\rm QCD} \approx 0.5$ GeV

$\Rightarrow$ Effective field theory approach:

separation between low and high energies using Operator Product Expansion

- short distance: Wilson coefficients, computed perturbatively
- long distance: local operators

Effective Hamiltonian

$$\mathcal{H}_{eff} = -\frac{4G_F}{\sqrt{2}} V_{\rm CKM} \sum C_i(\mu) O_i(\mu)$$

New physics can show up in new operators or modified Wilson coefficients

$b \longrightarrow s\gamma$ operator set:

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

Wilson Coefficients

Two main steps:

- Calculating $C_i^{eff}(\mu)$ at scale $\mu \sim M_W$ by requiring matching between the effective and full theories

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

- Evolving the $C_i^{eff}(\mu)$ to scale $\mu \sim m_b$ using the RGE:

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

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

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

Flavour observables

I) Radiative penguin decays

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

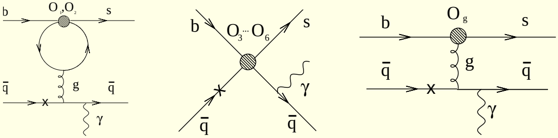
Flavour observables

I) Radiative penguin decays

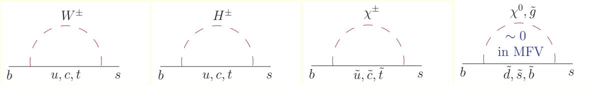
- inclusive branching ratio of $B \to X_s \gamma$
- isospin asymmetry of $B \to K^* \gamma$

I) Radiative penguin decays

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



Contributing loops:



First penguin ever observed!

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

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

M. Misiak & M. Steinhauser, Nucl. Phys. B764 (2007)

I) Radiative penguin decays

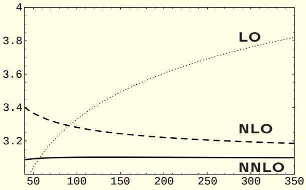
Inclusive branching ratio of $B \to X_s \gamma$

NNLO calculations available for the SM

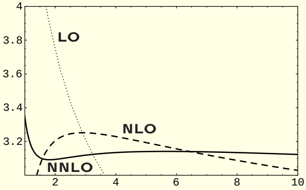
$$\mathcal{B}(\bar{B} \to X_s \gamma)_{E_\gamma > E_0} = \mathcal{B}(\bar{B} \to X_c e \bar{\nu})_{\rm exp} \left| \frac{V_{ts}^* V_{tb}}{V_{cb}} \right|^2 \frac{6\alpha_{\rm em}}{\pi C} \left[P(E_0) + N(E_0) \right]$$

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

Reduced scale dependence:



μ_W-dependence



μ_b-dependence

M. Misiak & M. Steinhauser, Nucl. Phys. B764 (2007)

Flavour observables

II) Electroweak penguin decays

- branching ratio of $B_s \to \mu^+\mu^-$
- forward-backward asymmetry in $B \to X_s\ell^+\ell^-$
- forward-backward asymmetry in $B \to K^*\mu^+\mu^-$

Flavour observables

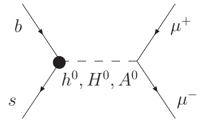
II) Electroweak penguin decays

- branching ratio of $B_s \to \mu^+\mu^-$
- forward-backward asymmetry in $B \to X_s \ell^+\ell^-$
- forward-backward asymmetry in $B \to K^* \mu^+\mu^-$

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.
(CDF public note 9892)

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

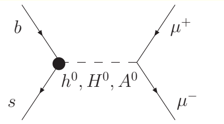
Interesting in the high $\tan\beta$ regime, where the SUSY contributions can lead to an O(100) enhancement over the SM:

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

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.
(CDF public note 9892)

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

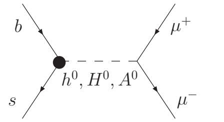
Interesting in the high $\tan\beta$ regime, where the SUSY contributions can lead to an O(100) enhancement over the SM:

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

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. (CDF public note 9892)

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:

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

II) Electroweak penguin decays

Forward-backward asymmetry in $B \to K^* \mu^+ \mu^-$

Interesting observable for NP searches

$$A_{FB}(\hat{s}) = \frac{1}{d\Gamma/d\hat{s}} \left[\int_0^1 d(\cos\theta) \frac{d^2\Gamma}{d\hat{s}d(\cos\theta)} - \int_{-1}^0 d(\cos\theta) \frac{d^2\Gamma}{d\hat{s}d(\cos\theta)} \right]$$

θ: angle between B^0 and μ^+ momenta in the dilepton system center of mass

$\hat{s} = s/M_B^2$, with $s = (p_{\mu^+} + p_{\mu^-})^2$

Effective Hamiltonian:

$$\mathcal{H}_{\rm eff} = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \left(\sum C_i(\mu)\mathcal{O}_i(\mu) + \sum C_{Q_i}(\mu) Q_i(\mu)\right)$$

Important operators:

$$\mathcal{O}_9 = \frac{e^2}{(4\pi)^2}(\bar{s}\gamma^\mu b_L)(\bar{\ell}\gamma_\mu \ell)$$

$$\mathcal{O}_{10} = \frac{e^2}{(4\pi)^2}(\bar{s}\gamma^\mu b_L)(\bar{\ell}\gamma_\mu \gamma_5 \ell)$$

$$Q_1 = \frac{e^2}{16\pi^2}(\bar{s}_L^\alpha b_R^\alpha)(\bar{\ell}\,\ell)$$

$$Q_2 = \frac{e^2}{16\pi^2}(\bar{s}_L^\alpha b_R^\alpha)(\bar{\ell}\gamma_5 \ell)$$

II) Electroweak penguin decays

Forward-backward asymmetry in $B \to K^* \mu^+ \mu^-$

Interesting observable for NP searches

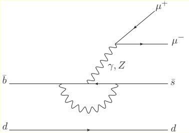
$$A_{FB}(\hat{s}) = \frac{1}{d\Gamma/d\hat{s}} \left[\int_0^1 d(\cos\theta) \frac{d^2\Gamma}{d\hat{s}\, d(\cos\theta)} - \int_{-1}^0 d(\cos\theta) \frac{d^2\Gamma}{d\hat{s}\, d(\cos\theta)} \right]$$

θ: angle between B^0 and μ^+ momenta in the dilepton system center of mass

$\hat{s} = s/M_B^2$, with $s = (p_{\mu^+} + p_{\mu^-})^2$

Effective Hamiltonian:

$$\mathcal{H}_{\rm eff} = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \left(\sum C_i(\mu) \mathcal{O}_i(\mu) + \sum C_{Q_i}(\mu) Q_i(\mu) \right)$$



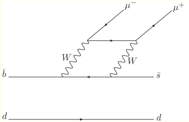
Important operators:

$$\mathcal{O}_9 = \frac{e^2}{(4\pi)^2} (\bar{s}\gamma^\mu b_L)(\bar{\ell}\gamma_\mu \ell)$$

$$\mathcal{O}_{10} = \frac{e^2}{(4\pi)^2} (\bar{s}\gamma^\mu b_L)(\bar{\ell}\gamma_\mu \gamma_5 \ell)$$

$$Q_1 = \frac{e^2}{16\pi^2} (\bar{s}_L^\alpha b_R^\alpha)(\bar{\ell}\,\ell)$$

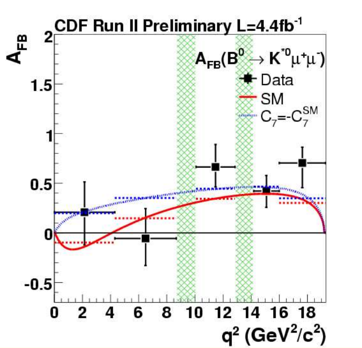
$$Q_2 = \frac{e^2}{16\pi^2} (\bar{s}_L^\alpha b_R^\alpha)(\bar{\ell}\gamma_5 \ell)$$



II) Electroweak penguin decays

Forward-backward asymmetry in $B \to K^* \mu^+ \mu^-$

Of particular interest, the position of the zero point: $A_{FB}(\hat{s}_0) = 0$



The value of $\hat{s}_0$ is very robust with respect to hadronic uncertainties

NP can modify the $\hat{s}_0$ value or even suppress the zero point

Flavour 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

Flavour observables

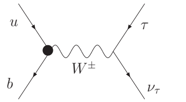
III) Neutrino modes

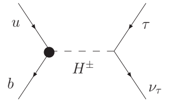
- branching ratio of $B \to \tau\nu$
- branching ratio of $B \to D\tau\nu$
- branching ratios of $D_s \to \tau\nu/\mu\nu$
- branching ratio of $K \to \mu\nu$
- double ratios of leptonic decays

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

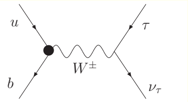
Also used:

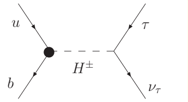
$$R^{\rm MSSM}_{\tau\nu_\tau} = \frac{{\rm BR}(B_u \to \tau\nu_\tau)_{\rm MSSM}}{{\rm BR}(B_u \to \tau\nu_\tau)_{\rm SM}} = \left[1 - \left(\frac{m_B^2}{m_{H^+}^2}\right) \frac{\tan^2\beta}{1+\epsilon_0 \tan\beta}\right]^2$$

III) Neutrino modes

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

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

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

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

- 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:

$$R \propto \left(\frac{f_{B_s}}{f_B} \right)^2 \Big/ \left(\frac{f_{D_s}}{f_D} \right)^2 \approx 1$$

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

Flavour observables

IV) Meson mixings

- $B_{(s)} - \bar{B}_{(s)}$ mixings
- $K - \bar{K}$, $D_{(s)} - \bar{D}_{(s)}$ mixings

Flavour observables

IV) Meson mixings

- $B_{(s)} - \bar{B}_{(s)}$ mixings
- $K - \bar{K}$, $D_{(s)} - \bar{D}_{(s)}$ mixings

IV) Meson mixings

$B_{(s)} - \bar{B}_{(s)}$ mixings

$$\mathcal{H}_{\rm eff} = \frac{G_F^2}{16\pi^2} V_{tq} V_{tq}^* \eta_{B_q} F_{tt}^q \mathcal{O}^{B_q}$$

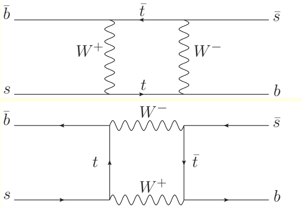
$$\mathcal{O}^{B_q} = \bar{q}\gamma_\mu(1-\gamma_5) b \bar{q}\gamma^\mu(1-\gamma_5) b$$

$$\langle B_q^0 | \mathcal{O}^{B_q} | \bar{B}_q^0 \rangle \propto m_{B_q}^2 f_{B_q}^2 B_{B_q}$$

Mass difference:

$$\Delta M_{B_q} = \frac{G_F^2 M_W^2}{6\pi^2} |V_{tq} V_{tq}^*|^2 M_{B_q} \eta_{B_q} f_{B_q}^2 B_{B_q} |F_{tt}^q|$$

Experimentally: $\Delta M_{B_d} = 0.507 \pm 0.005 \text{ ps}^{-1}$



Interesting to probe Higgs mediated FCNC

Complementary to EW penguins

IV) Meson mixings

$B_{(s)} - \bar{B}_{(s)}$ mixings

$$\mathcal{H}_{\rm eff} = \frac{G_F^2}{16\pi^2} V_{tq} V_{tq}^* \eta_{B_q} F_{tt}^q \mathcal{O}^{B_q}$$

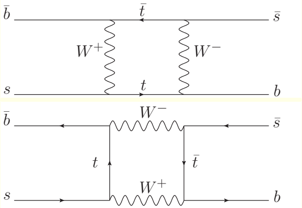
$$\mathcal{O}^{B_q} = \bar{q}\gamma_\mu(1-\gamma_5) b \bar{q}\gamma^\mu(1-\gamma_5) b$$

$$\langle B_q^0 | \mathcal{O}^{B_q} | \bar{B}_q^0 \rangle \propto m_{B_q}^2 f_{B_q}^2 B_{B_q}$$

Mass difference:

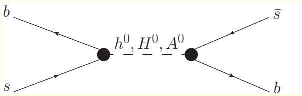
$$\Delta M_{B_q} = \frac{G_F^2 M_W^2}{6\pi^2} |V_{tq} V_{tq}^*|^2 M_{B_q} \eta_{B_q} f_{B_q}^2 B_{B_q} |F_{tt}^q|$$

Experimentally: $\Delta M_{B_d} = 0.507 \pm 0.005$ ps^{-1}



Interesting to probe Higgs mediated FCNC

Complementary to EW penguins



double penguins

IV) Meson mixings

$B_{(s)} - \bar{B}_{(s)}$ mixings

$$\mathcal{H}_{\rm eff} = \frac{G_F^2}{16\pi^2} V_{tq} V_{tq}^* \eta_{B_q} F_{tt}^q \mathcal{O}^{B_q}$$

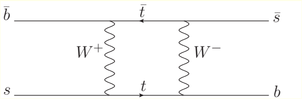
$$\mathcal{O}^{B_q} = \bar{q}\gamma_\mu(1-\gamma_5)b\bar{q}\gamma^\mu(1-\gamma_5)b$$

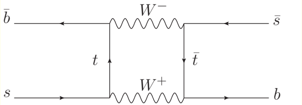
$$\langle B_q^0|\mathcal{O}^{B_q}|\bar{B}_q^0\rangle \propto m_{B_q}^2 f_{B_q}^2 B_{B_q}$$

Mass difference:

$$\Delta M_{B_q} = \frac{G_F^2 M_W^2}{6\pi^2}|V_{tq}V_{tq}^*|^2 M_{B_q}\eta_{B_q} f_{B_q}^2 B_{B_q}|F_{tt}^q|$$

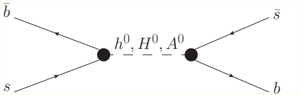
Experimentally: $\Delta M_{B_d} = 0.507 \pm 0.005$ ps^{-1}





Interesting to probe Higgs mediated FCNC

Complementary to EW penguins



double penguins

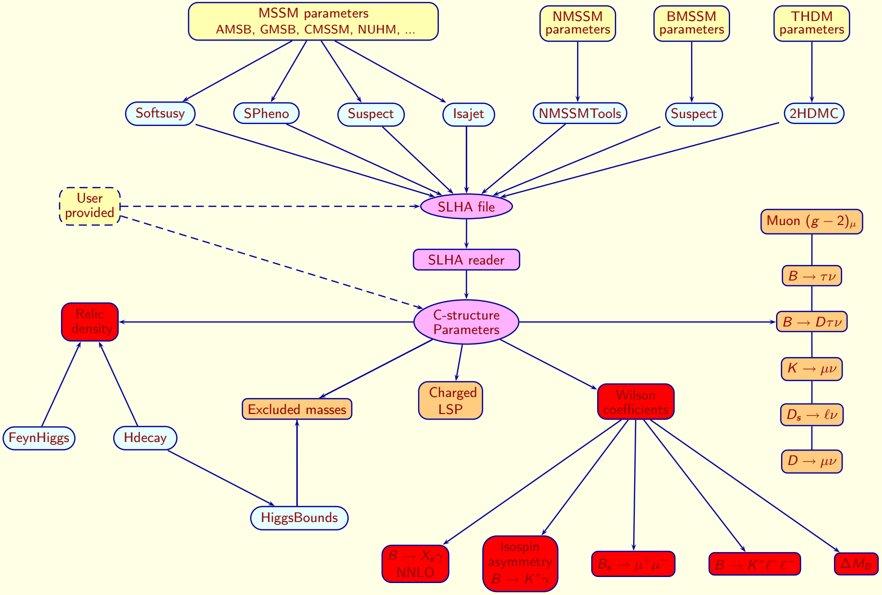
Sensitive to $f_{B_q}^2 B_{B_q}$ and V_{td}

Observables

V) Other observables

- collider mass limits
- muon anomalous magnetic moment $(g-2)_\mu$
- dark matter relic density $\rightarrow$ SuperIso Relic

SuperIso


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

Download
- SuperIso
- 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

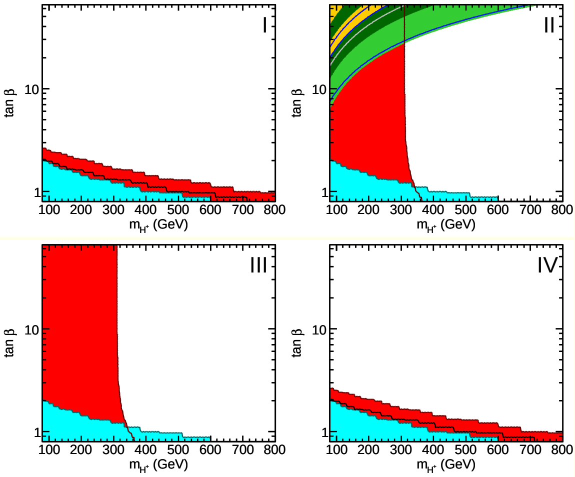
NEW **The latest version of the manual can be found here (10 September 2009).**

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)

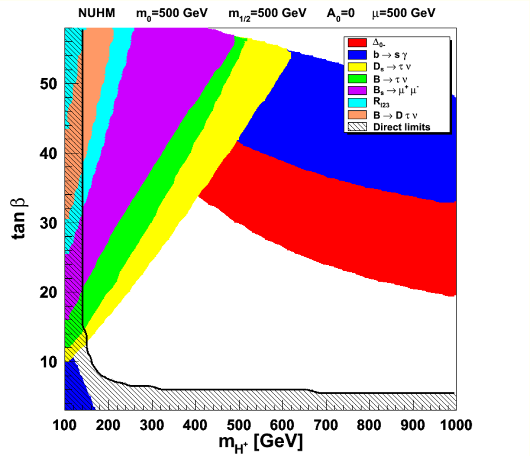


Red: $b \to s\gamma$
Cyan: ΔM_{B_d}
Blue: $B_u \to \tau\nu_\tau$
Yellow: $B \to D\ell\nu_\ell$
Gray: $K \to \mu\nu_\mu$
Green: $D_s \to \tau\nu_\tau$
Dark green: $D_s \to \mu\nu_\mu$

FM, O. Stål, Phys. Rev. D81, 035016 (2010)

MSSM

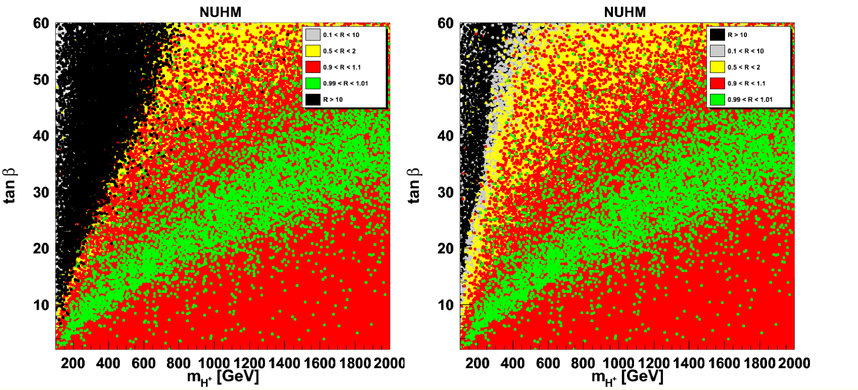
NUHM scenario



MSSM

Double ratios

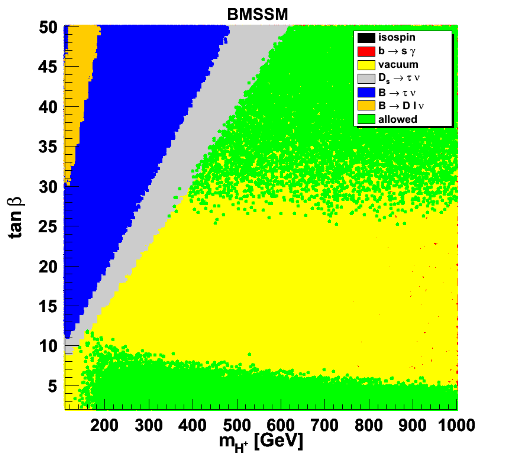
$$R = \left(\frac{\mathrm{BR}(B_s \to \mu^+\mu^-)}{\mathrm{BR}(B_u \to \tau\nu)} \right) \Big/ \left(\frac{\mathrm{BR}(D_s \to \tau\nu)}{\mathrm{BR}(D \to \mu\nu)} \right)$$



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

A.G. Akeroyd, FM, arXiv:1007.2757

BMSSM NUHM-like scenario



N. Bernal, M. Losada, FM, work in progress

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

Flavour Les Houches Accord

Involved people

F. Mahmoudi, S. Heinemeyer, A. Arbey, A. Bharucha, T. Goto, T. Hahn, U. Haisch, S. Kraml, M. Muhlleitner, J. Reuter, P. Skands, P. Slavich

For more information

- Les Houches write-up: arXiv:1003.1643 [hep-ph]
- Official write-up: arXiv:1008.0762 [hep-ph]

Conclusion

- Indirect constraints and in particular flavour 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

- We have learned a lot from flavour physics so far
- But what is still to be discovered is more!

Conclusion

- Indirect constraints and in particular flavour 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

- We have learned a lot from flavour physics so far
- But what is still to be discovered is more!

Conclusion

- Indirect constraints and in particular flavour 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

- We have learned a lot from flavour physics so far
- But what is still to be discovered is more!

Conclusion

- Indirect constraints and in particular flavour 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

- We have learned a lot from flavour physics so far
- But what is still to be discovered is more!

Conclusion

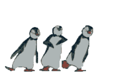
- Indirect constraints and in particular flavour physics are essential to restrict new physics parameters
- That will become even more interesting when combined with LHC data
- This kind of analysis can be generalized to more new physics scenarios

- We have learned a lot from flavour physics so far
- **But what is still to be discovered is more!**

Conclusion

- Indirect constraints and in particular flavour 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

- We have learned a lot from flavour physics so far
- **But what is still to be discovered is more!**



Backup: General THDM

Charged Higgs boson couplings to fermions:

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

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

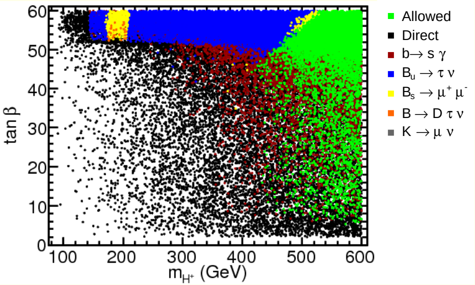
THDM types I–IV

- 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

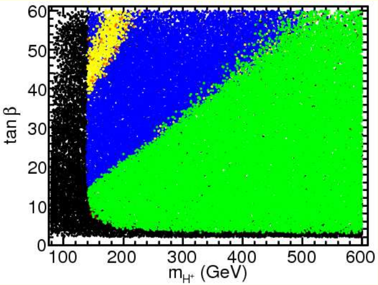
Type	λ_U	λ_D	λ_L
I	$\cot\beta$	$\cot\beta$	$\cot\beta$
II	$\cot\beta$	$-\tan\beta$	$-\tan\beta$
III	$\cot\beta$	$-\tan\beta$	$\cot\beta$
IV	$\cot\beta$	$\cot\beta$	$-\tan\beta$

Combined results

mSUGRA



NUHM

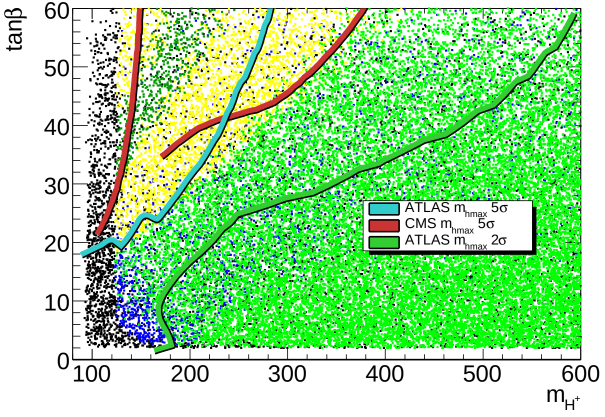


$m_{H^+} \gtrsim 400$ GeV

$m_{H^+} \gtrsim 135$ GeV

D. Eriksson, FM, O. Stål, JHEP 0811 (2008)

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, FM, O. Stål, JHEP 0811 (2008)