

New Physics Search

Opportunities in Flavour Physics

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BEAUTY 2005, 10th International Conference on *B* Physics

Assisi (Perugia, Italy), 20-24 June 2005

Opportunities in Flavour Physics

- Introduction
 - QCD \leftrightarrow New Physics
- Exploration of Higher Scales via Rare Decays
 - Inclusive Rare Decays $\bar{B} \rightarrow X_s \gamma$, $\bar{B} \rightarrow X_s l^+ l^-$
 - $K \rightarrow \pi \nu \bar{\nu}$
 - $B \rightarrow \pi \pi$, $B \rightarrow K \pi$
- New physics in CP-violating observables
- Correlation of Collider and Flavour Physics via Squark Mixing

Reviews of Modern Physics 75 (2003) 1159

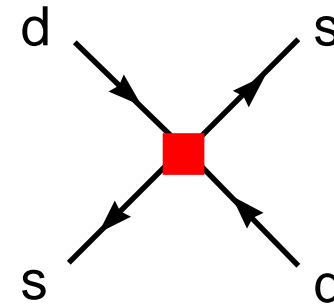
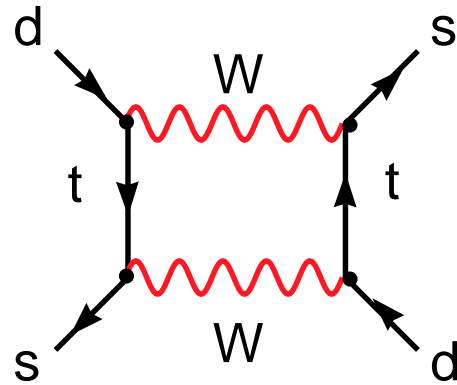
Introduction

- Interplay of LHC and ILC:
Complementarity of discovery and precision machine \Rightarrow LHC/ILC study group
- **However:** ILC will not be built before 2016 (optimistic!)
- **Obvious question:**
What is the role of the flavour factories in this game?
- Experimental 'Roadmap' of flavour physics:
 - **e^+e^- - B -experiments:**
 B factories (Babar,Belle) \geq 1999, CLEO III \geq 2000,
Upgraded or Super B factories \geq 2010
 - **Hadronic B -experiments:**
Tevatron II \geq 2001, LHC (Atlas,CMS,LHCb) \geq 2007, ((B TeV \geq 2009))
 - **Kaon-experiments:**
Kopio,BNL ($K_L \rightarrow \pi^0 \nu \bar{\nu}$), NA 48/3,CERN ($K^+ \rightarrow \pi^+ \nu \bar{\nu}$) \geq 2010
- **Crucial problem in new physics search:**
Separation of new physics effects and hadronic uncertainties

Exploration of higher scales via flavour observables

$$\mathcal{L} = \mathcal{L}_{Gauge} + \mathcal{L}_{Higgs} + \sum_i \frac{c_i^{New}}{\Lambda} \mathcal{O}_i^{(5)} + \dots$$

- SM as effective theory valid up to cut-off-scale Λ
- $K^0 - \bar{K}^0$ -mixing $\mathcal{O}^6 = (\bar{s}d)^2$: $c^{SM}/M_W^2 \times (\bar{s}d)^2 + c^{New}/\Lambda^2 \times (\bar{s}d)^2 \Rightarrow \Lambda > 100 \text{ TeV}$

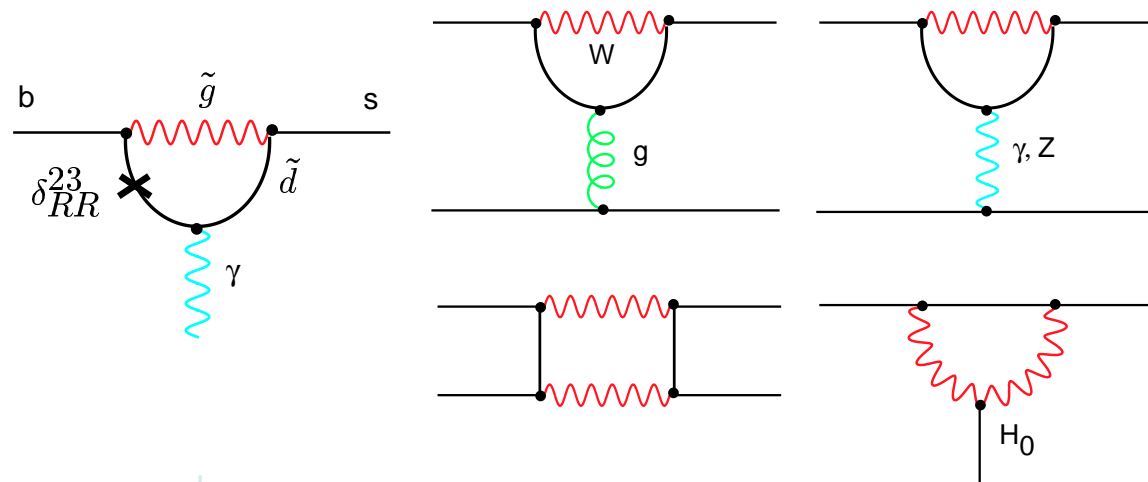


- Natural stabilisation of Higgs boson mass (i.e. supersymmetry) $\Rightarrow \Lambda \sim 1 \text{ TeV}$
(but: little hierarchy problem)
- Expectation: flavour mixing restricted by additional symmetries

Rare decays and CP violating observables allow to analyse flavour symmetry breaking

- Flavourblind elektroweak structure of \mathcal{O}_i :

- connects various (theoretically clean !) observables: $A_{CP}(B_d \rightarrow \Phi K_S) \Leftrightarrow BR(B \rightarrow X_s \gamma)$



- allows for model-independent analysis:

- Flavour part of \mathcal{O}_i :

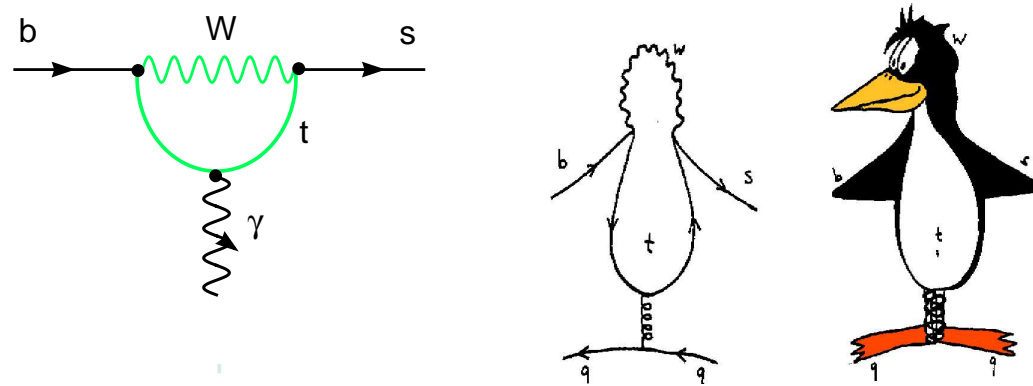
- new flavour structures, i.e. squark-mixing in SUSY

or

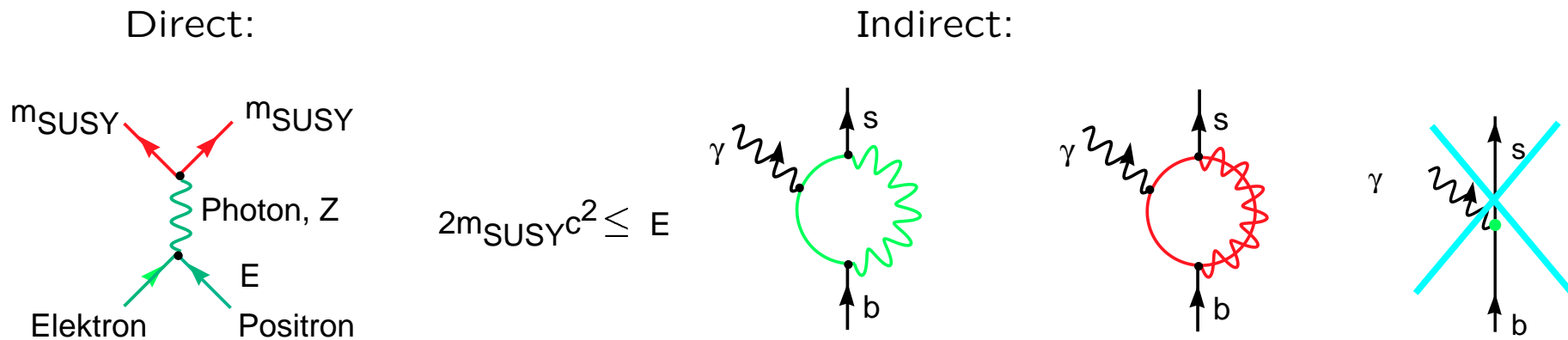
- minimal flavour violation flavour symmetry / CP broken by Yukawa couplings only

* $[b \rightarrow s] \leftrightarrow [b \rightarrow d] \leftrightarrow [s \rightarrow d]$ * RG-invariant definition (d'Ambrosio et al.)

- **Rare B decays** like $b \rightarrow s \gamma$ or $b \rightarrow s \ell^+ \ell^-$ directly probe the SM at the one-loop level.

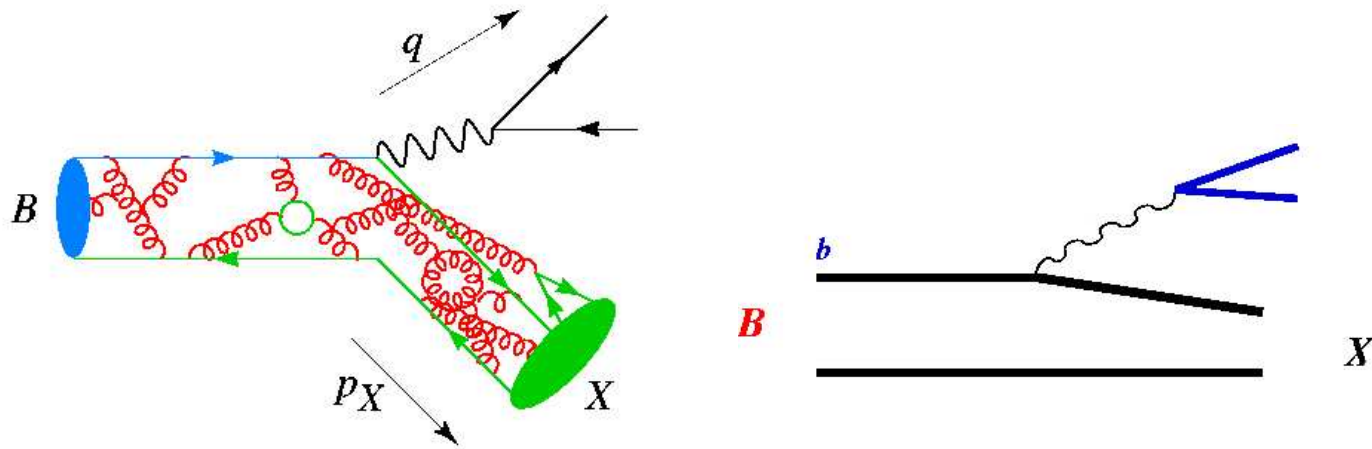


- Search strategies for new degrees of freedom beyond the SM (i.e. for supersymmetry)



- High sensitivity for 'New Physics' (\leftrightarrow elektroweak precision data, 10% \leftrightarrow 0.1%)

This indirect information is analogous to some direct information of a linear collider.



Separation of new physics effects and hadronic uncertainties!

Three strategies:

* focus on inclusive modes:

$$\Gamma(\bar{B} \rightarrow X_s \gamma) \xrightarrow{m_b \rightarrow \infty} \Gamma(b \rightarrow X_s^{\text{parton}} \gamma), \quad \Delta^{\text{nonpert.}} \sim \Lambda_{QCD}^2 / m_b^2$$

No linear term Λ_{QCD}/m_b
(perturbatively calculable contribution dominant)

* focus on ratios of exclusive modes like asymmetries
(hadronic uncertainties partially cancel out)

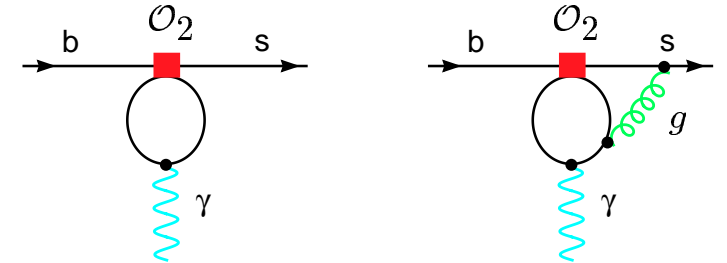
* focus on specific decays like $K \rightarrow \pi \nu \bar{\nu}$
(hadronic matrix elements known from experiment)

Present status of $\bar{B} \rightarrow X_s \gamma$

Problem: renormalization scheme of the charm mass (NNLL) (Gambino, Misiak)

$$m_c^{\text{pole}}/m_b^{\text{pole}} = 0.29 \pm 0.02 \Leftrightarrow m_c^{\overline{\text{MS}}}(\mu)/m_b^{1\text{S}} = 0.23 \pm 0.05$$

\Rightarrow central value $\sim +11\%$



Present NLL Prediction: (Hurth, Lunghi, Porod)

$$BR(\bar{B} \rightarrow X_s \gamma) \times 10^4 = \left(3.79 \left. \begin{array}{c} +0.26 \\ -0.44 \end{array} \right|_{m_c/m_b} \pm 0.02_{\text{CKM}} \pm 0.25_{\text{param}} \pm 0.15_{\text{scale}} \right)$$

NNLL QCD calculation needed for uncertainty $\ll 10\%$! (work in progress !)

Estimate of the reduction of the scheme dependence at NNLL: $12.4\% \rightarrow 5.1\%$
Asatrian et al. hep-ph/0505068

Experiment:

$$BR(\bar{B} \rightarrow X_s \gamma) = (3.52 \pm 0.30) \times 10^{-4} \quad \text{CLEO, ALEPH, BELLE, BABAR}$$

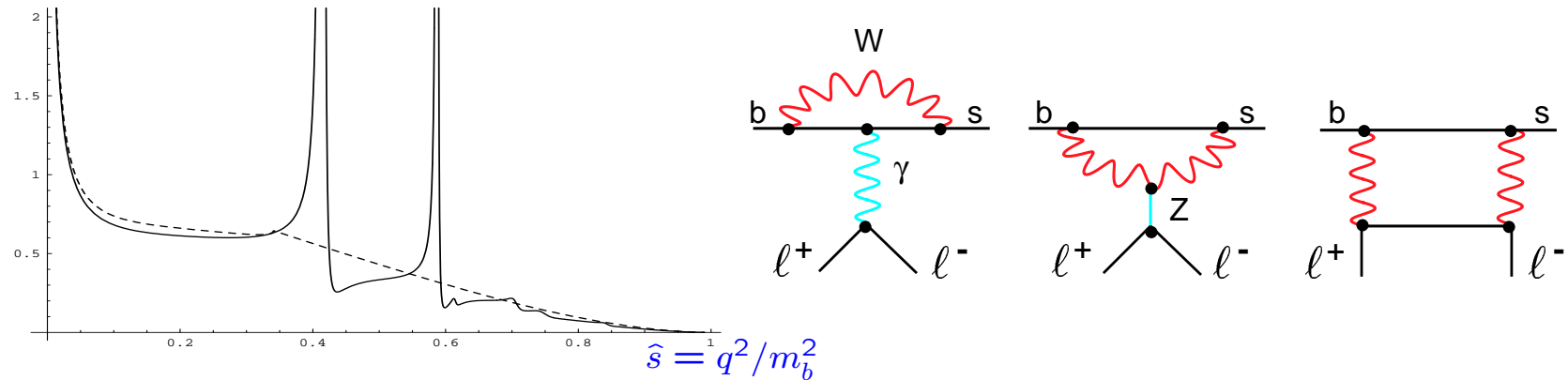
The $\bar{B} \rightarrow X_s \gamma$ data already leads to significant restrictions on the parameter space of various extensions of the SM.

Clearly, this indirect information will be most valuable when the general nature of new physics will be identified in the direct search (LHC).

$\bar{B} \rightarrow X_s l^+ l^-$: Dilepton mass spectrum

- on-shell- $c\bar{c}$ -resonances, cuts necessary : $1\text{GeV}^2 < q^2 < 6\text{GeV}^2$ and $14.4\text{GeV}^2 < q^2$
perturbative contributions dominant

$$\frac{d}{d\hat{s}} BR(\bar{B} \rightarrow X_s l^+ l^-) \times 10^{-5}$$



- Theory NNLL QCD: Ghinculov, Hurth, Isidori, Yao

$$BR(\bar{B} \rightarrow X_s l^+ l^-)_{\text{Cut: } q^2 \in [1\text{GeV}^2, 6\text{GeV}^2]} = (1.63 \pm 0.20) \times 10^{-6}$$

$$BR(\bar{B} \rightarrow X_s l^+ l^-)_{\text{Cut: } q^2 > 14.4\text{GeV}^2} = (4.04 \pm 0.78) \times 10^{-7}$$

NNLL QCD corrections $q^2 \in [1\text{GeV}^2, 6\text{GeV}^2]$

central value: -14% , perturbative error: $13\% \rightarrow 6.5\%$

- Electroweak two-loop corrections: Bobeth, Gambino, Gorbahn, Haisch
 -1.5% shift for $\alpha_{em}(\mu = m_b)$, -8.5% for $\alpha_{em}(\mu = m_W)$

Experimental issues

- Semi-Inclusive Measurements ($m(\ell^+\ell^-) > 0.2\text{GeV}$)

Belle, PRL 90 (2003) 021801 :

$$BR(\bar{B} \rightarrow X_s \ell^+ \ell^-) = (6.1 \pm 1.4(\text{stat}) + 1.4 - 1.1(\text{syst}))10^{-6}$$

Update ICHEP 2004:

$$BR(\bar{B} \rightarrow X_s \ell^+ \ell^-) = (4.11 \pm 0.83(\text{stat}) + 0.74 - 0.70(\text{syst}))10^{-6}$$

Babar, PRL 93 (2004) 081802 :

$$BR(\bar{B} \rightarrow X_s \ell^+ \ell^-) = (5.6 \pm 1.5(\text{stat}) \pm 0.6(\text{syst}) \pm 1.1(\text{mod}))10^{-6}$$

- in agreement with corresponding SM prediction:
 $(4.6 \pm 0.8) \times 10^{-6}$ (Ghinculov, Hurth, Isidori, Yao)
not sensitive yet for NNLL

- semiinclusive: modelling of hadronic mass distribution

- Separate experimental data on two perturbative windows in dilepton mass spectrum desirable (Babar already made first separate measurements with large errors)
- End of Babar and Belle ($1/\text{ab}$): 15% accuracy possible
- LHCb: only semi-inclusive analysis possible without the π_0 modes
- Fully inclusive measurement possible within a Super- B factory

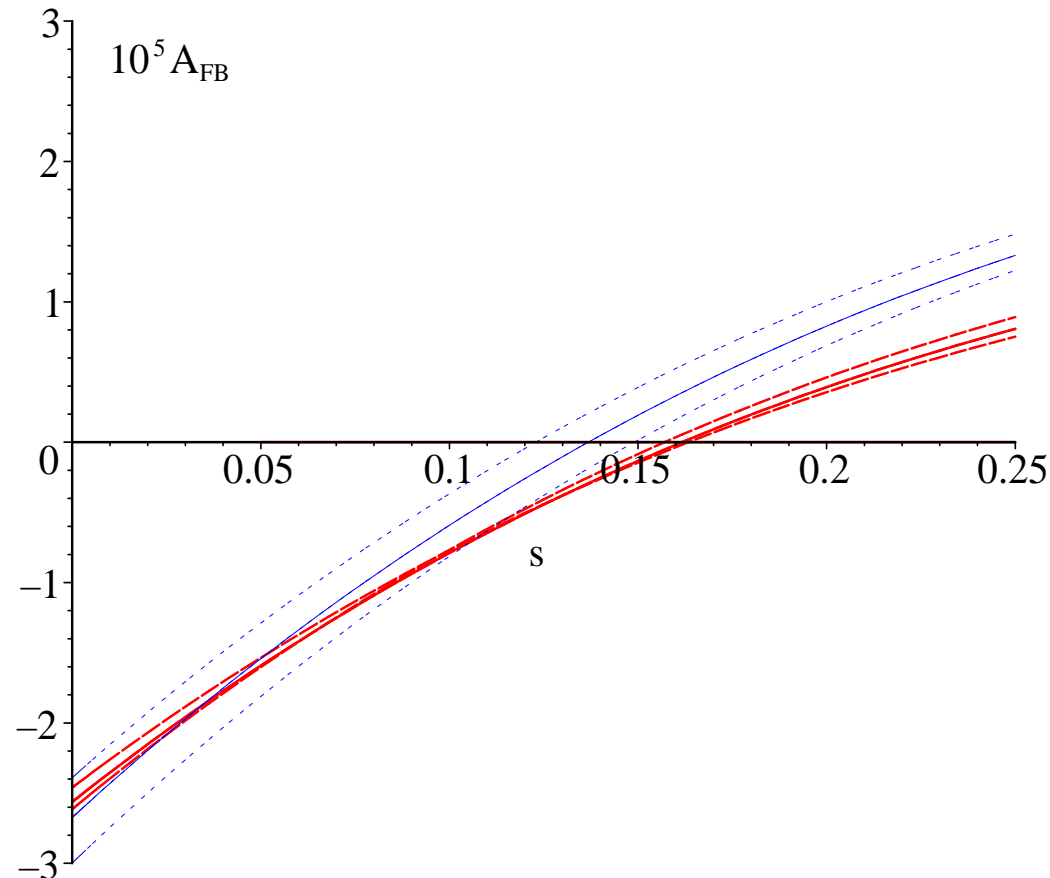
$\bar{B} \rightarrow X_s l^+ l^-$: Forward-backward-charge-asymmetry

Precision test of SM ! $A_{FB} \equiv \frac{1}{\Gamma_{semilep}} \left(\int_0^1 d(\cos \theta) \frac{d^2\Gamma}{dq^2 d\cos \theta} - \int_{-1}^0 d(\cos \theta) \frac{d^2\Gamma}{dq^2 d\cos \theta} \right)$

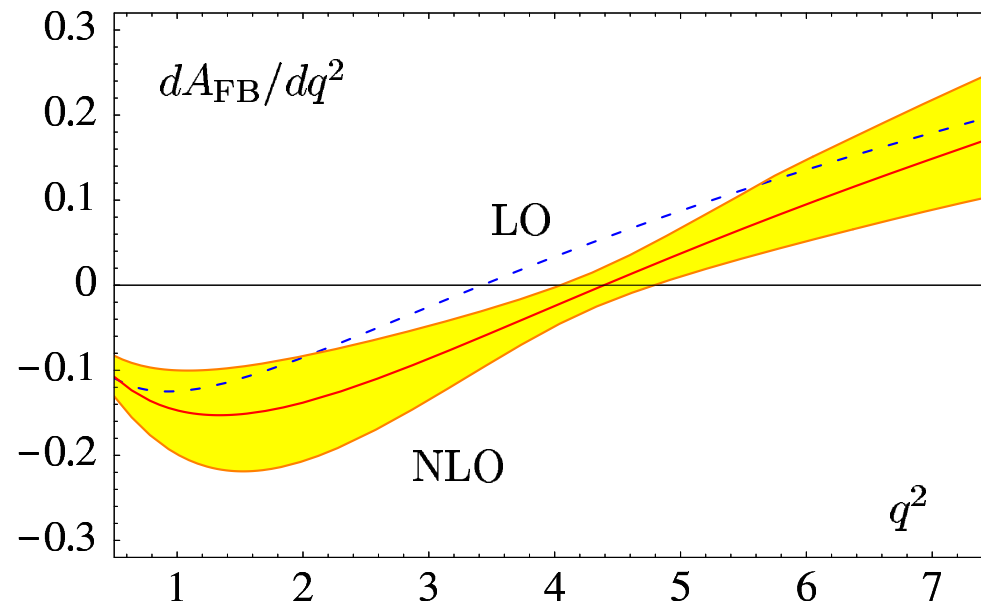
(θ angle between l^+ and B momenta in dilepton CMS)

$$A_{FB}(q_0^2) = 0 \quad \text{for} \quad q_0^2 \sim C_7/C_9$$

NNLL corrections induce large $\sim 16\%$ Shift of the Zero: $q_0^2 = (3.90 \pm 0.25) GeV^2$
(Ghinculov, Hurth, Isidori, Yao) (Asatrian, Bieri, Greub, Hovhannisyan)



FB-charge-asymmetry in $B \rightarrow K^* \ell^+ \ell^-$



- In contrast to the branching ratio the zero of the FBA is almost insensitive to hadronic uncertainties. At LO the zero depends on the short-distance Wilson coefficients only:

$$q_0^2 = q_0^2(C_7, C_9), \quad q_0^2 = (3.4 + 0.6 - 0.5) GeV^2 \quad (LO)$$

- NLO contribution calculated within QCD factorization approach leads to a large shift: Beneke, Feldmann, Seidel

$$q_0^2 = (4.39 + 0.38 - 0.35) GeV^2 \quad (NLO)$$

- Issue of power corrections ($1/m_b$) !
- Theoretical errors in branching ratio: $\Delta BR(B \rightarrow K^* \mu^+ \mu^-) = ({}_{-17}^{+26}, \pm 6, {}_{-4}^{+6}, {}_{+0.4}^{-0.7}, \pm 2)\%$ Ball et al.

conclusions on rare $b \rightarrow s\gamma$ and $b \rightarrow sl^+l^-$ modes

- Model-independent analysis of $b \rightarrow sl^+l^-$ and $b \rightarrow s\gamma$
 - * Global fit to the Wilson coefficients C_7, C_9, C_{10}
⇒ Determines magnitude + sign of these coefficients
 - * In MFV the sign of C_7 is already fixed by $b \rightarrow sl^+l^-$ data [Gambino, Haisch, Misiak](#)
- For new physics search measurements of kinematical distributions are needed (high statistics necessary !):
 - Super-B: 7% accuracy in s_0 possible
 - [Super-B reports of KEK, hep-ph/0406071](#), and of SLAC, [hep-ph/0503261](#).
- Impact of NNLL (NLL) QCD calculations in inclusive modes crucial !
- In exclusive modes issue of $1/m_b$ corrections has to be improved (SCET,...)!

Intermezzo: There is still some beauty in kaon physics !

- BNL–E787: three events 3/2004 !

$$BR(K^+ \rightarrow \pi^+ \nu \bar{\nu}) = \left(1.47 \begin{array}{c} + 1.3 \\ - 0.9 \end{array}\right) \times 10^{-10}$$

- Present SM theory (in future error **below 5%** possible):

$$BR(K^+ \rightarrow \pi^+ \nu \bar{\nu})_{\text{SM}} = (0.80 \pm 0.11) \times 10^{-10} .$$

What makes the neutrino modes $K \rightarrow \pi \nu \bar{\nu}$ so attractive?

- leading hadronic matrix element is known from K_{l3} decays: $\langle \pi | (\bar{s}d)_{V-A} | K \rangle$
- amplitude dominated by short-distance due to quadratic GIM: $A^q \sim m_q^2 V_{qs} V_{qd}$

Neutrino modes as theoretically clean as inclusive B decays !

\Rightarrow highly sensitive probe for degrees of freedom at higher scales

Proposed experiment at CERN, NA48/3: 'decay in flight'

80 $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ events in about two years of data taking

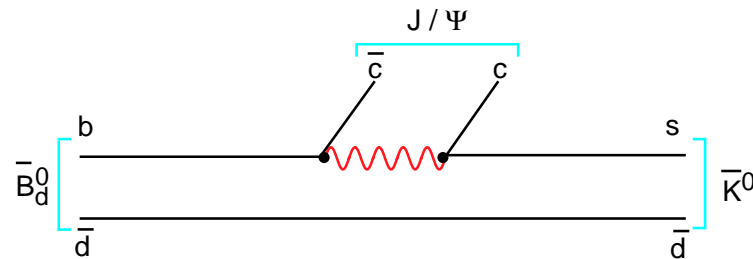
(4×10^{12} kaon decays/SPS year, 10% acceptance, SM)

main background: $K^+ \rightarrow \pi^+ \pi^0$

(γ veto much easier because of high energy kaon beam)

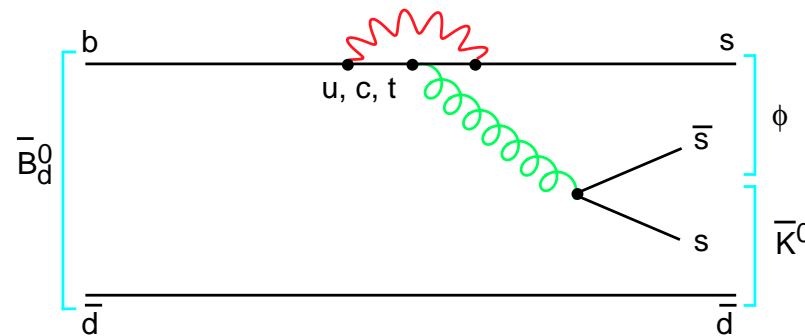
New physics in CP-violating observables ?

- SM is very predictive **only one CP-violating parameter**.
(Kobayashi-Maskawa 1972 !)
- Baryon asymmetry: one needs more sources of CP violation, but **not** necessarily relevant at low energies
- **KM mechanism has passed successfully its first precision test in tree process:**



$$A_{CP}(t) = \frac{\Gamma(\bar{B}^0(t) \rightarrow f) - \Gamma(B^0(t) \rightarrow f)}{\Gamma(\bar{B}^0(t) \rightarrow f) + \Gamma(B^0(t) \rightarrow f)}, \quad A_{CP}(B_d \rightarrow J/\psi K_S) = \sin(2\beta) \sin(\Delta m_B t)$$

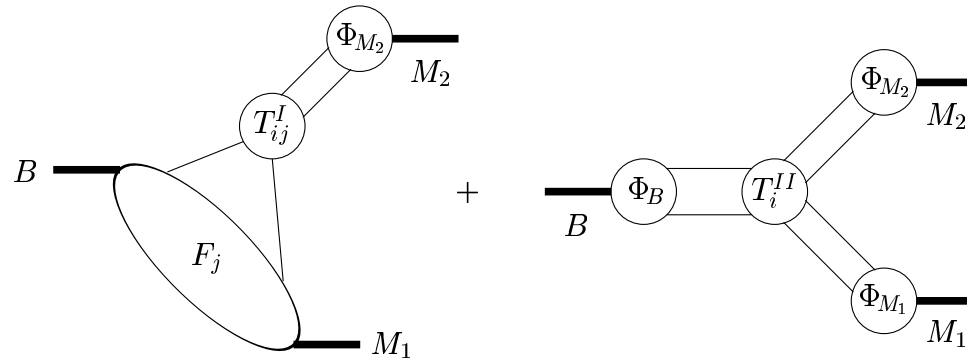
- **Test in $A_{CP}(B_d \rightarrow \Phi K_S)$ is still open Penguin**



Not conclusive yet, various $b \rightarrow s\bar{s}s$ modes have different hadronic uncertainties

Hadronic charmless B decays

- QCD factorization theorems for $B \rightarrow \pi\pi$ and $B \rightarrow K\pi$



$$\langle \pi K | Q_i | B \rangle = F_0^{B \rightarrow \pi} T_{K,i}^I * f_K \Phi_K + F_0^{B \rightarrow K} T_{\pi,i}^I * f_\pi \Phi_\pi + T_i^{II} * f_B \Phi_B * f_K \Phi_K * f_\pi \Phi_\pi + O(1/m_b)$$

- Factorization in B -decays

- Short-distance effects identified + systematically calculable in perturbation theory
- Non-perturbative effects parametrized in terms of a few universal functions (parton distributions, form factors, light-cone distribution amplitudes)
- Hope to achieve necessary accuracy to extract CKM elements
- **Limiting factor: Insufficient information on power-suppressed terms**

- Quantum field theoretical description: SCET (no OPE !) HQET is not applicable to B decays in which some of the outgoing, light particles have momenta of order m_b .

Phenomenological approach to $B \rightarrow \pi\pi$

Feldmann, Hurth

- Use pure QCD-factorization part (\neq BBNS) and general isospin analysis of the non-factorizable part.
- Infer information on nonfactorizable parameters from experimental data by producing random parameters values and calculating the χ^2 -value.
- Nonfactorizable corrections are numerically not negligible
Default scenario in the BBNS approach where all nonfactorizable isospin amplitudes $r_i(I, \Delta I)$ are small is disfavoured by data ! ('so-called $B \rightarrow \pi\pi$ puzzle')
- We also identify model dependence in phenomenological studies due to additional assumptions.
 - **BBNS** Identification/parametrization of dominant $1/m_b$ effects
only simple $1/m_b$ SCET operators considered, not most general parametrization
 - **charming penguins** Dominance of certain flavour topologies in naive quark picture
relation to QCD/SCET unclear
 - **$SU(3)$** Application of approximate flavour symmetries
hadronic errors difficult to estimate

Details:

Standard Isopin Analysis:

$$\begin{aligned}\sqrt{2} \langle \pi^- \pi^0 | H_{\text{eff}} | B^- \rangle &\simeq \lambda_u^{(d)} [3A_u(2, 3/2)] + \lambda_c^{(d)} [3A_c(2, 3/2)] \\ \langle \pi^+ \pi^- | H_{\text{eff}} | \bar{B}^0 \rangle &\simeq \lambda_u^{(d)} [-A_u(0, 1/2) + A_u(2, 3/2)] + \lambda_c^{(d)} [-A_c(0, 1/2) + A_c(2, 3/2)] \\ \sqrt{2} \langle \pi^0 \pi^0 | H_{\text{eff}} | \bar{B}^0 \rangle &\simeq \lambda_u^{(d)} [A_u(0, 1/2) + 2A_u(2, 3/2)] + \lambda_c^{(d)} [A_c(0, 1/2) + 2A_c(2, 3/2)] ,\end{aligned}$$

$\lambda_i^{(q)} = V_{ib} V_{iq}^*$, $A_i(I, \Delta I)$: I denotes the total isospin I of the final state and ΔI the isospin of the operators in the weak effective hamiltonian.

$$A_i(I, \Delta I) = A_i^F(I, \Delta I) + A_i^{NF}(I, \Delta I)$$

- **Factorizable Part:**

A_i^F fixed by QCD factorization with overall normalization: $A_{\pi\pi} = \frac{iG_F}{\sqrt{2}} (m_B^2 - m_\pi^2) F_0^{B \rightarrow \pi}(m_\pi^2) f_\pi$

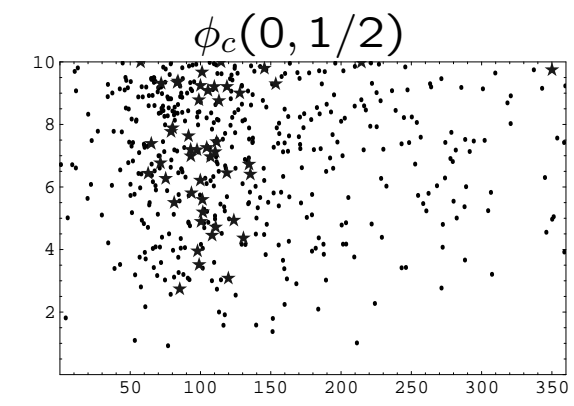
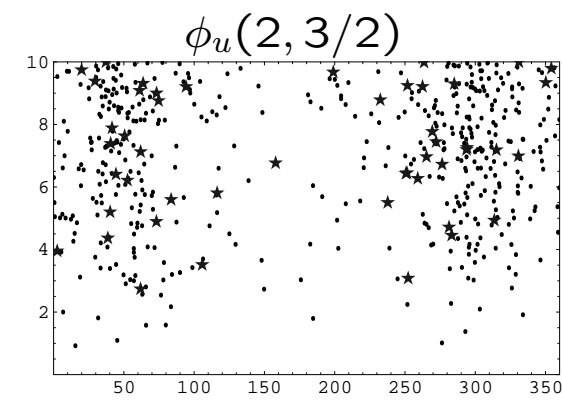
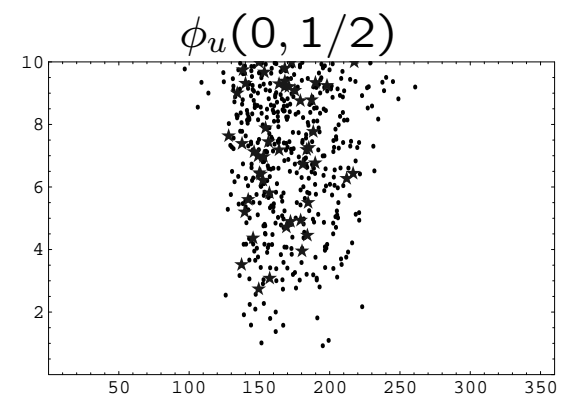
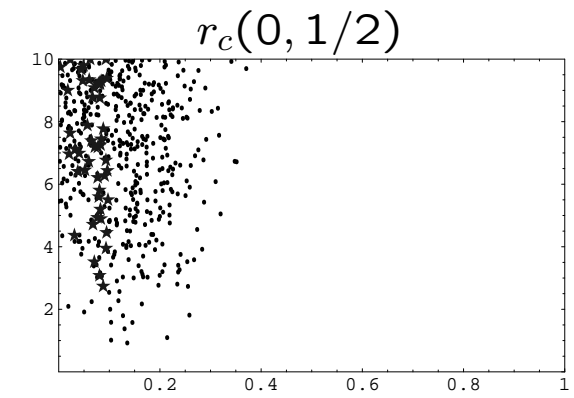
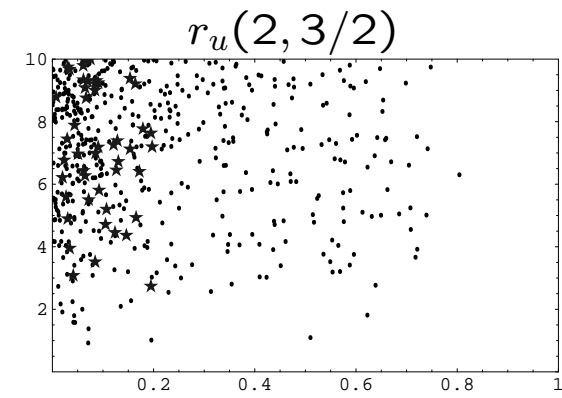
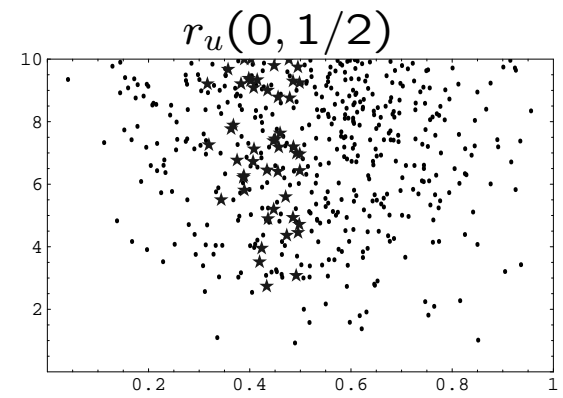
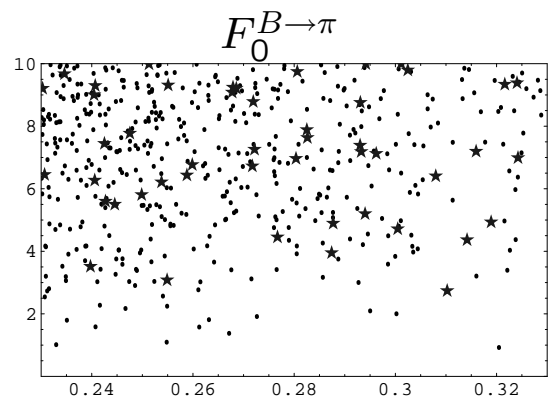
- **Nonfactorizable Part:** $A_i^{NF}(I, \Delta I) := r_i(I, \Delta I) e^{i\phi_i(I, \Delta I)} A_{\pi\pi}$

- * **Unconstrained Scenario:**

$$0.23 \leq F_0^{B \rightarrow \pi}(m_\pi^2) \leq 0.33, \quad 0 \leq r_{u,c}(I, \Delta I) \leq 1.0, \quad 0^\circ \leq \phi_{u,c}(I, \Delta I) \leq 360^\circ ,$$

- * **Constrained Scenario:**

$$r_u(0, 1/2) < 0.5 , \quad r_u(2, 3/2) < 0.2 , \quad r_c(0, 1/2) < 0.1$$



dots for unconstrained, stars for constrained scenario.

Is there a R_n -puzzle in $B \rightarrow K\pi$?

CP averaged branching ratios:

$$R = \frac{\tau_{B^+} \text{BR}[B_d^0 \rightarrow \pi^- K^+] + \text{BR}[\bar{B}_d^0 \rightarrow \pi^+ K^-]}{\tau_{B^0} \text{BR}[B_d^+ \rightarrow \pi^+ K^0] + \text{BR}[B_d^- \rightarrow \pi^- \bar{K}^0]} = 0.82 \pm 0.056$$

$$R_n = \frac{1}{2} \frac{\text{BR}[B_d^0 \rightarrow \pi^- K^+] + \text{BR}[\bar{B}_d^0 \rightarrow \pi^+ K^-]}{\text{BR}[B_d^0 \rightarrow \pi^0 K^0] + \text{BR}[\bar{B}_d^0 \rightarrow \pi^0 \bar{K}^0]} = 0.789 \pm 0.075$$

$$R_c = 2 \frac{\text{BR}[B_d^+ \rightarrow \pi^0 K^+] + \text{BR}[B_d^- \rightarrow \pi^0 K^-]}{\text{BR}[B_d^+ \rightarrow \pi^+ K^0] + \text{BR}[B_d^- \rightarrow \pi^- \bar{K}^0]} = 1.004 \pm 0.084$$

- pre-ICHEP04 data:

$$R = 0.91 \pm 0.07, \quad R_n = 0.76 \pm 0.10, \quad R_c = 1.17 \pm 0.12$$

- Approach based on QCD factorization (BBNS)

$$R = 0.91^{+0.13}_{-0.11}, \quad R_n = 1.16^{+0.22}_{-0.19}, \quad R_c = 1.15^{+0.19}_{-0.17}$$

- SM-Fit to $\pi\pi + SU(3)_F$ (Buras et al)

$$R = 0.94^{+0.03}_{-0.03}, \quad R_n = 1.14^{+0.08}_{-0.07}, \quad R_c = 1.11^{+0.06}_{-0.07}$$

(Note: errors reflect only experimental uncertainties of $B \rightarrow \pi\pi$)

Does the R_n puzzle guide us to new physics?

Does the R_n puzzle guide us to new physics?

- large nonfactorizable contributions allow for large $SU(3)_F$ or isospin-violating effects (Feldmann, Hurth) ('so-called $\pi\pi$ puzzle perhaps solves $K\pi$ puzzle')
- radiative corrections to decays with charged particles in the final states may not have been taken into account properly in the experimental analysis ($B^0 \rightarrow \pi^+ K^-$ not yet updated !!)
- possible underestimation of π_0 detection efficiency ($R_n * R_c$)

conclusions on $B \rightarrow \pi\pi$ and $B \rightarrow K\pi$:

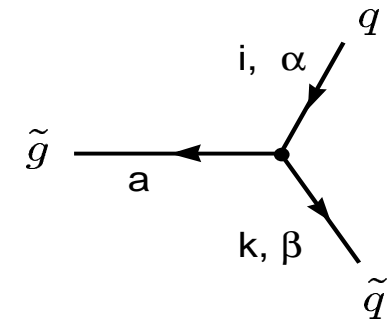
- Use the future data to test various theoretical assumptions on dynamics with the help of a general isospin analysis of the nonfactorizable contributions.
- So-called $\pi\pi$ puzzle perhaps solves $K\pi$ puzzle
- Challenge for theory:

development of non-perturbative methods within SCET:

SCET sum rules De Fazio, Feldmann, Hurth hep-ph/0504088

Correlations between B and collider physics via squark mixing within SUSY

- In the unconstrained MSSM (too many ?) new contributions to flavour violation
 - CKM induced contributions from H^+ , χ^+ exchanges
 - flavour mixing in the sfermion mass matrix
- Gluino-quark-squark coupling: $-ig_s T_{\beta\alpha}^a (\Gamma_{QL}^{ki} P_L - \Gamma_{QR}^{ki} P_R)$
- Possible disalignment of quarks and squarks
 - quark mass matrices are diagonal !
 - squarks are rotated 'parallel' to their fermionic superpartners !
 - in general not mass eigenstates: $\tilde{q}_{L,R} = \Gamma_{QL,R}^+ \tilde{q}_i$



Sfermion mass matrix in uMSSM in $\tilde{q}_{L,R}$ basis:

$$\mathcal{M}_{D/U}^2 = (F/D)_{6 \times 6}^{D/U} + \begin{pmatrix} m_{Q,LL}^2 & m_{D/U,LR}^2 \\ m_{D/U,RL}^2 & m_{(D/U,RR)}^2 \end{pmatrix}$$

from F, D terms

from soft breaking

3×3 diagonal submatrices m_i^2 not diagonal

FCNC are induced by off-diagonal (off-generational) terms in $m_{LL}^2, m_{RR}^2, m_{LR}^2$

- Low energy constraints

- K-physics: ϵ'/ϵ , K^0 - \bar{K}^0 mixing, ...
significantly constrain 1 – 2 and 1 – 3 mixing
- B-physics: $b \rightarrow s\gamma$, ΔM_{B_s} , ...
most important beyond SM contributions: H^+ , $\tilde{\chi}_i^+$, \tilde{g}

- Correlations to Collider Physics (Hurth, Porod)

- squark decays:

$$\begin{aligned}\tilde{u}_i &\rightarrow u_j \tilde{\chi}_k^0, d_j \tilde{\chi}_l^+ \\ \tilde{d}_i &\rightarrow d_j \tilde{\chi}_k^0, u_j \tilde{\chi}_l^-\end{aligned}$$

with $i = 1, \dots, 6$, $j = 1, 2, 3$, $k = 1, \dots, 4$ and $l = 1, 2$.

- these decays are governed by the same mixing matrices as the contributions to flavour violating low-energy observables.

Squarks can have large flavourviolating decay modes, compatible with present data from flavour physics.

Strategy

- take SPS1a as starting point:

$$M_0 = 100 \text{ GeV}, M_{1/2} = 250 \text{ GeV}$$

$$A_0 = -100 \text{ GeV}, \tan \beta = 10, \mu > 0$$

\Rightarrow

$$M_2 = 192 \text{ GeV}, \mu = 351 \text{ GeV}$$

$$m_{H^+} = 403 \text{ GeV}, m_{\tilde{g}} = 594 \text{ GeV}, m_{\tilde{t}_1} = 400 \text{ GeV}$$

$$m_{\tilde{t}_2} = 590 \text{ GeV}, m_{\tilde{q}_R} \simeq 550 \text{ GeV}, m_{\tilde{q}_L} \simeq 570 \text{ GeV}$$

(SPheno 2.0)

- vary off-diagonal squark mass entries.
- accept points with $2 \leq 10^4 \text{ BR}(b \rightarrow s\gamma) \leq 4.5$ and $\Delta M_{B_s} \geq 14 \text{ ps}^{-1}$
- For simplicity: real parameters only
- QCD corrections for $b \rightarrow s\gamma$ as given in [Borzumati et al.](#), Phys. Rev. D62, 075005 (2000) and [Besmer et al.](#), Nucl.Phys.B609:359 (2001)
- ΔM_{B_s} , as given in [Baek et al.](#), Phys. Rev. D64, 095001 (2001)

\Rightarrow Typical results:

Branching ratios (in %) of u -type squarks

	$\tilde{\chi}_1^0 c$	$\tilde{\chi}_1^0 t$	$\tilde{\chi}_2^0 c$	$\tilde{\chi}_2^0 t$	$\tilde{\chi}_3^0 c$	$\tilde{\chi}_3^0 t$	$\tilde{\chi}_4^0 c$	$\tilde{\chi}_4^0 t$	$\tilde{\chi}_1^+ s$	$\tilde{\chi}_1^+ b$	$\tilde{\chi}_2^+ s$	$\tilde{\chi}_2^+ b$
\tilde{u}_1	4.7	18	5.2	9.6	6×10^{-3}	0	0.02	0	11.3	46.4	2×10^{-3}	4.7
\tilde{u}_2	19.6	1.1	0.4	17.5	2×10^{-2}	0	6×10^{-2}	0	0.5	57.5	3×10^{-3}	2.9
\tilde{u}_3	7.3	3.7	20	1.4	6×10^{-2}	0	0.6	0	40.3	3.1	1	18.5
\tilde{u}_6	5.7	0.4	11.1	5.3	4×10^{-2}	5.7	0.6	13.2	22.9	13.1	0.6	8.0

Branching ratios (in %) of d -type squarks

	$\tilde{\chi}_1^0 s$	$\tilde{\chi}_1^0 b$	$\tilde{\chi}_2^0 s$	$\tilde{\chi}_2^0 b$	$\tilde{\chi}_3^0 s$	$\tilde{\chi}_3^0 b$	$\tilde{\chi}_4^0 s$	$\tilde{\chi}_4^0 b$	$\tilde{\chi}_1^- b$	$\tilde{\chi}_1^- t$	$\tilde{\chi}_2^- b$	$\tilde{\chi}_2^- t$	$\tilde{u}_1 W^-$
\tilde{d}_1	1.2	5.7	8.4	30.6	2×10^{-2}	1.5	0.2	0.9	16.6	34.1	0.6	0	0
\tilde{d}_2	17.4	5.8	5.1	15.7	7×10^{-2}	7.4	0.3	09.2	9.7	19.7	0.7	0	8.8
\tilde{d}_4	14.7	21.7	11.3	2.2	5×10^{-2}	10.6	0.5	8.4	22.1	3.6	1.2	0	3.4
\tilde{d}_6	1.7	0.5	20.5	6.9	0.1	0.9	1.2	1.3	40.3	10.2	3.4	11.1	1.8

Glauino branching ratios larger than 1%.

Final state	BR [%]	Final state	BR [%]
$\tilde{u}_1 c$	12.9	$\tilde{d}_1 s$	7.2
$\tilde{u}_1 t$	5.7	$\tilde{d}_1 b$	19.8
$\tilde{u}_2 c$	0.4	$\tilde{d}_2 s$	6.1
$\tilde{u}_2 t$	7.6	$\tilde{d}_2 b$	4.7
$\tilde{u}_3 c$	0.6	$\tilde{d}_3 d$	10.0
$\tilde{u}_4 u$	5.5	$\tilde{d}_4 s$	3.5
$\tilde{u}_5 u$	3.0	$\tilde{d}_4 b$	4.9
		$\tilde{d}_5 d$	2.1

conclusions on correlations via squark mixing

- $b \rightarrow s\gamma$ and ΔM_{B_s} (still ?) allow for large mixings between second and third generation squarks, for example \tilde{t}_i, \tilde{c}_i can have large flavour violating decay modes,
- makes life at LHC potentially more interesting and more difficult,
- extra information from ILC or flavour factories needed.

FLAVOUR IN THE ERA OF THE LHC

a Workshop

on the interplay of flavour and collider physics

First meeting: CERN, November 7-11 2005

<http://mlm.home.cern.ch/mlm/FlavLHC.html>

The goal of this Workshop is to outline and document a programme for flavour physics for the next decade, addressing in particular the complementarity and synergy between the LHC and the flavour factories vis a vis the discovery and exploration potential for new physics.

The format of the Workshop will follow the standard CERN experience, with an opening meeting with plenary sessions and with the start of the WG activities, followed by 2-3 meetings of the WG's to take place during the following year, and a final plenary meeting at the end.