Benchmarks in Flavour Physics

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Merriam-Webster's Online Dictionary

benchmark

2 entries found for **benchmark**.
To select an entry, click on it.

benchmark[1,noun]
benchmark[2,transitive verb]

Go

Main Entry: **1bench·mark**
Pronunciation: 'bench-"märk
Function: *noun*
1 *usually* **bench mark :** a mark on a permanent object indicating elevation and serving as a reference in topographic surveys and tidal observations
2 a : a point of reference from which measurements may be made **b :** something that serves as a standard by which others may be measured or judged **c :** a standardized problem or test that serves as a basis for evaluation or comparison (as of computer system performance)

??

Google | flavour benchmark | Search | Advanced Search | Preferences

Web — Results **1** - **10** of about **336,000** for **flavour benchmark**. (**0.09** seconds)

MacBook Pro "Santa Rosa" - 3D Gaming
real world speed test results for performance minded Macintosh users.
www.barefeats.com/santarosa.html - 31k - Cached - Similar pages

WG2:B/D/K decays
collider phenomenology with **flavor benchmarks** (studies with Tools at CMS, ATLAS) [20] (Heinemeyer, Polesello, Buchmueller) **...**
flavlhc.kek.jp/cernWS_0507/WG2/WG2.html - 8k - Cached - Similar pages

WG2 chapter for the CERN yellow report:

WG2 Yellow Book planning, updated in the October meeting (pdf)

Instructions on the WG2 chapter for the CERN yellow report

3. New Physics in Benchmark Channels [122]

  - Benchmark channels:
    - **Radiative Penguin Decays** [10] (Gambino, Golutvin)
    - **Electroweak Penguin Decays** [15] (Feldmann, Berryhill)
    - **Neutrino modes** [10] (Grossman, Iijima)
    - **Very rare decays** [12] (Nierste, Smizanska)
    - **UT angles (tree-dominated)** [15] (Soni, Bona, Trabelsi, Wilkinson)
    - **Bs-Bsbar mixing** [10] (Lubicz, van Hunen)
    - **b->s and b->d hadronic transitions** [10] (Ciuchini, Muheim)
    - **Kaon decays** [10] (Buras, Komatsubara)
    - **Charm decays** [20] (Fajfer, Asner)

more or less everything is included

Benchmarks as interesting measurements

Observable	B factories (2 ab^{-1})	Super$B$ (75 ab^{-1})
$\sin(2\beta)$ $(J/\psi\, K^0)$	0.018	0.005 (†)
$\cos(2\beta)$ $(J/\psi\, K^{*0})$	0.30	0.05
$\sin(2\beta)$ (Dh^0)	0.10	0.02
$\cos(2\beta)$ (Dh^0)	0.20	0.04
$S(J/\psi\, \pi^0)$	0.10	0.02
$S(D^+D^-)$	0.20	0.03
$S(\phi K^0)$	0.13	0.02 (∗)
$S(\eta' K^0)$	0.05	0.01 (∗)
$S(K_S K_S K_S)$	0.15	0.02 (∗)
$S(K_S \pi^0)$	0.15	0.02 (∗)
$S(\omega K_S)$	0.17	0.03 (∗)
$S(f_0 K_S)$	0.12	0.02 (∗)
γ ($B \to DK$, $D \to CP$ eigenstates)	$\sim 15^o$	2.5^o
γ ($B \to DK$, $D \to$ suppressed states)	$\sim 12^o$	2.0^o
γ ($B \to DK$, $D \to$ multibody states)	$\sim 9^o$	1.5^o
γ ($B \to DK$, combined)	$\sim 6^o$	1–2^o
α ($B \to \pi\pi$)	$\sim 16^o$	3^o
α ($B \to \rho\rho$)	$\sim 7^o$	1–2^o (∗)
α ($B \to \rho\pi$)	$\sim 12^o$	2^o
α (combined)	$\sim 6^o$	1–2^o (∗)
$2\beta+\gamma$ $(D^{(*)\pm}\pi^\mp,\, D^\pm K_S \pi^\mp)$	20^o	5^o

Observable	B factories (2 ab^{-1})	Super$B$ (75 ab^{-1})
$\lvert V_{cb}\rvert$ (exclusive)	4% (∗)	1.0% (∗)
$\lvert V_{cb}\rvert$ (inclusive)	1% (∗)	0.5% (∗)
$\lvert V_{ub}\rvert$ (exclusive)	8% (∗)	2.0% (∗)
$\lvert V_{ub}\rvert$ (inclusive)	8% (∗)	2.0% (∗)
$\mathcal{B}(B \to \tau\nu)$	20%	4% (†)
$\mathcal{B}(B \to \mu\nu)$	visible	5%
$\mathcal{B}(B \to D\tau\nu)$	10%	2%
$\mathcal{B}(B \to \rho\gamma)$	15%	3% (†)
$\mathcal{B}(B \to \omega\gamma)$	30%	5%
$A_{CP}(B \to K^*\gamma)$	0.007 (†)	0.004 († ∗)
$A_{CP}(B \to \rho\gamma)$	~ 0.20	0.05
$A_{CP}(b \to s\gamma)$	0.012 (†)	0.004 (†)
$A_{CP}(b \to (s+d)\gamma)$	0.03	0.01 (†)
$S(K_S\pi^0\gamma)$	0.15	0.02 (∗)
$S(\rho^0\gamma)$	possible	0.10
$A_{CP}(B \to K^* ll)$	7%	1%
$A^{FB}(B \to K^* ll)s_0$	25%	9%
$A^{FB}(B \to X_s ll)s_0$	35%	5%
$\mathcal{B}(B \to K\nu\bar{\nu})$	visible	20%
$\mathcal{B}(B \to \pi\nu\bar{\nu})$	–	possible

- mostly NP-sensitive measurements
- others needed for precise CKM fit

1st NP model -> observable set #1 \
2nd NP model -> observable set #2 \
⋮ ⋮ ⋮ benchmark set
⋮ ⋮ ⋮ /
nth NP model -> observable set #n /

starting point for attacking the "inverse problem"
(recently popular in high-p_t physics: LHC Olympics)

Flavour physics does not proceed along this way (yet?)

1. **classes of models defined using an EFT approach (ex.: MFV)**
   least predictive in general, (much) more with flavour symmetries
2. **models with generic flavour structure (ex.: MSSM with MI's)**
   more predictive and NP flavour unrestricted within the model
3. **fully-specified models (ex.: mSUGRA, LH with T-parity)**
   very predictive but NP flavour structure strongly restricted

The EFT approach

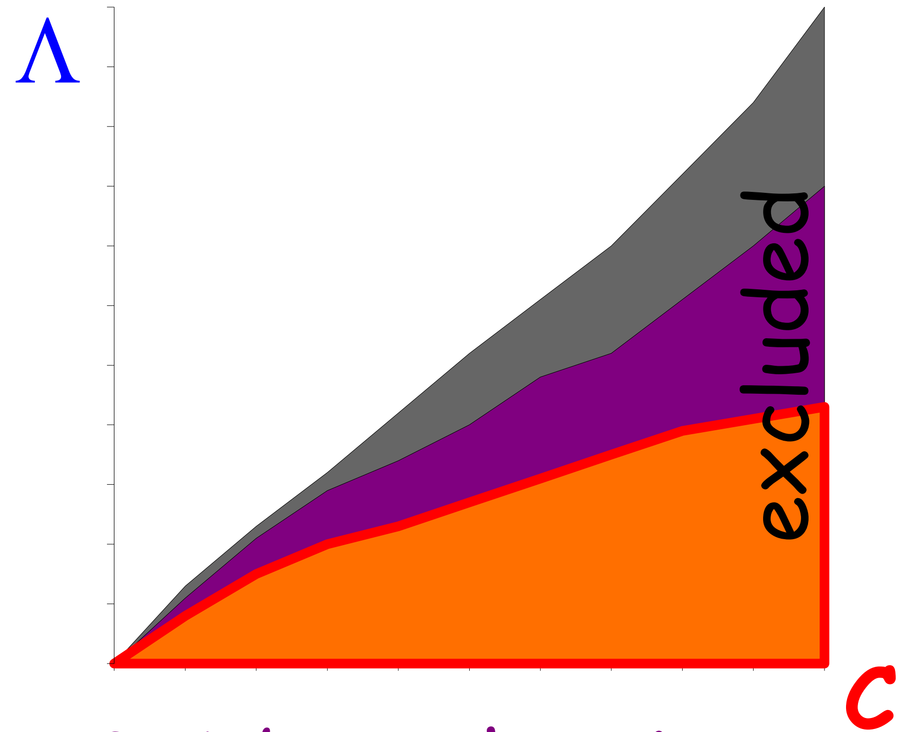
$$\mathcal{L} = \mathcal{L}_{SM} + \sum_{k=1} \left(\sum_i C_i^k \, Q_i^{(k+4)} \right) / \Lambda^k$$

NP effects are governed by:

- a *known* set of local operators $Q_i^{(D)}$
- the value of the new physics scale Λ
- the effective flavour-violating couplings **C's**
  + couplings can follow a given pattern (e.g. dictated by flavour symmetries)
  + couplings can have different strength (e.g. generated by different interactions)

Pictorially :

- exp. constraints give a bound on Λ for any given *C* and vice-versa
- curves correspond to different assumptions



What do we do with such plots? A branch point

- **Λ is not known (beyond the LHC reach)**

  look for indirect NP signals, understand where they may come from, exclude regions in parameter space

- **Λ is known (and <1-2 TeV, thanks LHC!)**

  determine the NP FV couplings C_i, study the flavour structure of NP, look for signal of heavier states

EFT for ΔF=2 transitions

"The simple exercise we all give to our students", A. Masiero

$$H_{eff}^{\Delta F=2} = \sum_{i=1}^{5} C_i(\mu) Q_i(\mu) + \sum_{i=1}^{3} \tilde{C}_i(\mu) \tilde{Q}_i(\mu)$$

$$Q_1 = \bar{q}_L^\alpha \gamma_\mu b_L^\alpha \, \bar{q}_L^\beta \gamma^\mu b_L^\beta \quad \text{(SM)}$$

$$Q_2 = \bar{q}_R^\alpha b_L^\alpha \, \bar{q}_R^\beta b_L^\beta \qquad Q_3 = \bar{q}_R^\alpha b_L^\beta \, \bar{q}_R^\beta b_L^\beta$$

$$Q_4 = \bar{q}_R^\alpha b_L^\alpha \, \bar{q}_L^\beta b_R^\beta \qquad Q_5 = \bar{q}_R^\alpha b_L^\beta \, \bar{q}_L^\beta b_R^\beta$$

$$\tilde{Q}_1 = \bar{q}_R^\alpha \gamma_\mu b_R^\alpha \, \bar{q}_R^\beta \gamma^\mu b_R^\beta$$

$$\tilde{Q}_2 = \bar{q}_L^\alpha b_R^\alpha \, \bar{q}_L^\beta b_R^\beta \qquad \tilde{Q}_3 = \bar{q}_L^\alpha b_R^\beta \, \bar{q}_L^\beta b_R^\beta$$

7 new D=6 operators involving scalar interactions and quarks with different chiralities

H_{eff} can be iteratively recast in terms of $C_i(\Lambda)$

$C_i(\Lambda)$ can be extracted from the data (one by one)

the associated NP scale Λ can be defined as

$$C_i(\Lambda) = \frac{L F_i}{\Lambda^2}$$

strongly interacting NP: $L \sim 1$

weakly interacting NP: $L \sim \alpha_{W,s}^2$

1. MFV at low $\tan\beta$	2. MFV at large $\tan\beta$
- $F_1 = F_{SM} \sim \lambda_t (V_{tq} V_{tb}^*)^2$ - $F_{i\neq 1} = 0$, no NP phases	- $F_1 \sim F_{SM}$, $F_4 \sim F_{SM} \lambda_b \lambda_q / \lambda_t$ - $F_{i\neq 1,4} = 0$, no phases
3. next-to-MFV	**4. generic FV**
- $\lvert F_i \rvert \sim F_{SM}$ - arbitrary NP phases	- $\lvert F_i \rvert \sim 1$ - arbitrary NP phases

UTfit collaboration, in preparation

PRELIMINARY

lower bound on Λ(TeV) from ΔS/B=2 processes

	L~1	L~α_s	L~α_W
MFV	5.5	0.5	0.2
MFV-tanβ	5.1/4.1	0.5/0.4	0.2/0.1
	$M_H > 0.9\ a(\tan\beta)$		
NMFV	62/14	6.2/1.4	2/0.5
generic FV	(2.4/0.2)x10^4	2400/220	800/70

the flavour problem at work

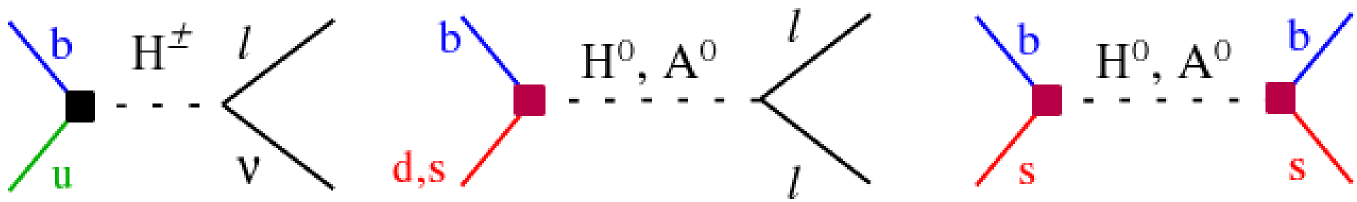
- ΔF=2 chirality-flipping operators are RG enhanced and thus probe larger NP scales
- when scalar operators are present, the NP scale is easily pushed beyond the LHC reach

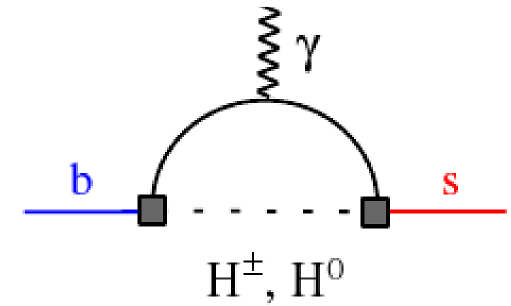
At least NMFV+α_W-loop suppression of ΔF=2 processes required for new flavoured particles detectable at the LHC

MFV NP in $\Delta F=1$ transitions at large $\tan\beta$

Large NP effects from Higgs exchange in elicity-suppressed decays:

(Gino's four musketeers) Isidori, Paradisi, hep-ph/0605012

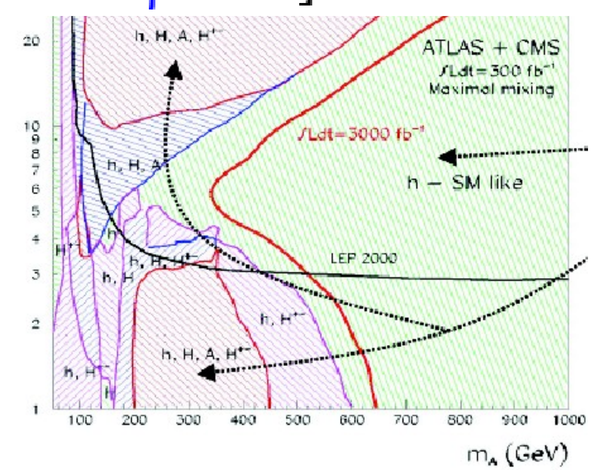




$B^\pm \to l^\pm \nu$	$B_{s,d} \to l^+ l^-$	ΔM_{B_s}	$B \to X_s \gamma$
↓	↓	↓	↓
~(10-50)%	up to 100 ×	~(0-20)%	~(0-50)%
suppression	enhancement	suppression	enhancement

[qualitative general features for $M_H \sim 500$ GeV & $\tan\beta \sim 50$]

- testable pattern of suppression/enhancement
- compatible with present data within errors
- useful to enlarge the region of the MSSM Higgs parameter space accessible at the LHC



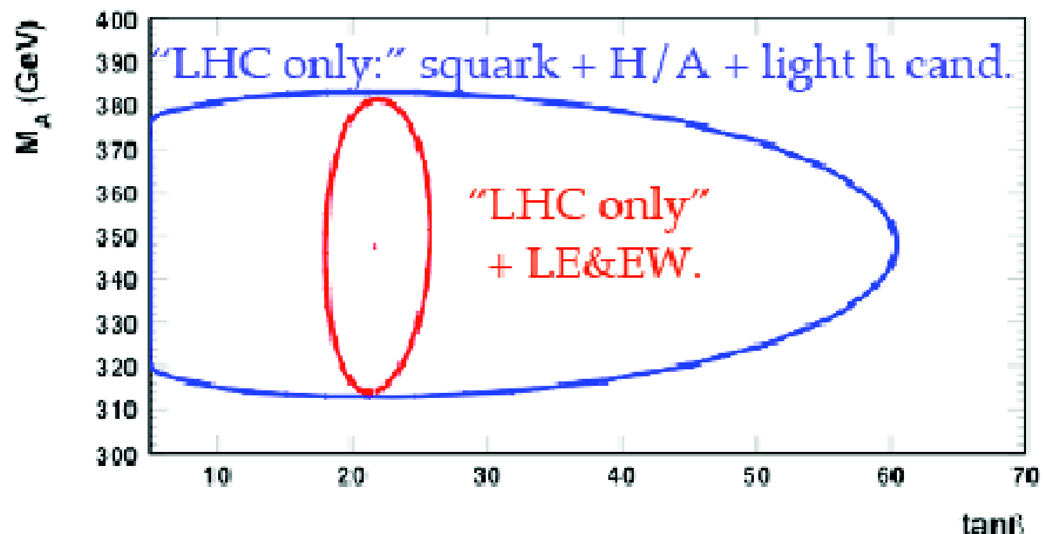
Low-energy (LE) and Electroweak (EW) Constraints

Work started at the LHC Flavour workshop (collaboration from Experimentalist & Theorist)

S.Heinemeyer, G.I., P.Paradisi [TH],
O. Buchmuller, R. Cavanaugh,... [EXP]
work documented in the Yellow Report

A first start: Combine LE and EW calculations in one common code.
New Physics Parameter Space: MSSM

A positive outcome from the CERN workshops:
first concrete example of integration of flavour and high-p_T constraints on the same parameter space showing their complementarity

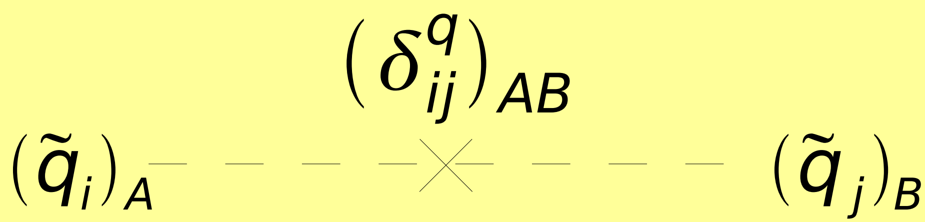


Example: Almost no information on tanβ without external constraints. Note that a direct measurement of tanβ is very difficult at the LHC

MSSM + generic soft SUSY-breaking terms

- only dominant gluino contributions
- mass insertion approximation

All flavour-changing NP effects in the squark propagators



$q = \{u, d\}, \ (A, B) = \{L, R\}$
$(i, j) = \{1,2,3\}$

- NP scale: SUSY masses $\tilde{m} \sim m_{\tilde{g}}$
- FV couplings: $(\delta^q_{ij})_{AB} \equiv \frac{(M^2_{ij})^q_{AB}}{\tilde{m}^2}$ (like CKM for NP)

Precise measurements of FCNC and CP violation can measure the δ's

$\left\|\left(\delta^d_{12}\right)_{LL,RR}\right\|$	$\left\|\left(\delta^d_{12}\right)_{LL=RR}\right\|$	$\left\|\left(\delta^d_{12}\right)_{LR}\right\|$	$\left\|\left(\delta^d_{12}\right)_{RL}\right\|$
$1 \cdot 10^{-2}$	$2 \cdot 10^{-4}$	$5 \cdot 10^{-4}$	$5 \cdot 10^{-4}$

$\left\|\left(\delta^u_{12}\right)_{LL,RR}\right\|$	$\left\|\left(\delta^u_{12}\right)_{LL=RR}\right\|$	$\left\|\left(\delta^u_{12}\right)_{LR}\right\|$	$\left\|\left(\delta^u_{12}\right)_{RL}\right\|$
$4 \cdot 10^{-2}$	$2 \cdot 10^{-3}$	$6 \cdot 10^{-3}$	$6 \cdot 10^{-3}$

$\left\|\left(\delta^d_{13}\right)_{LL,RR}\right\|$	$\left\|\left(\delta^d_{13}\right)_{LL=RR}\right\|$	$\left\|\left(\delta^d_{13}\right)_{LR}\right\|$	$\left\|\left(\delta^d_{13}\right)_{RL}\right\|$
$7 \cdot 10^{-2}$	$5 \cdot 10^{-3}$	$1 \cdot 10^{-2}$	$1 \cdot 10^{-2}$

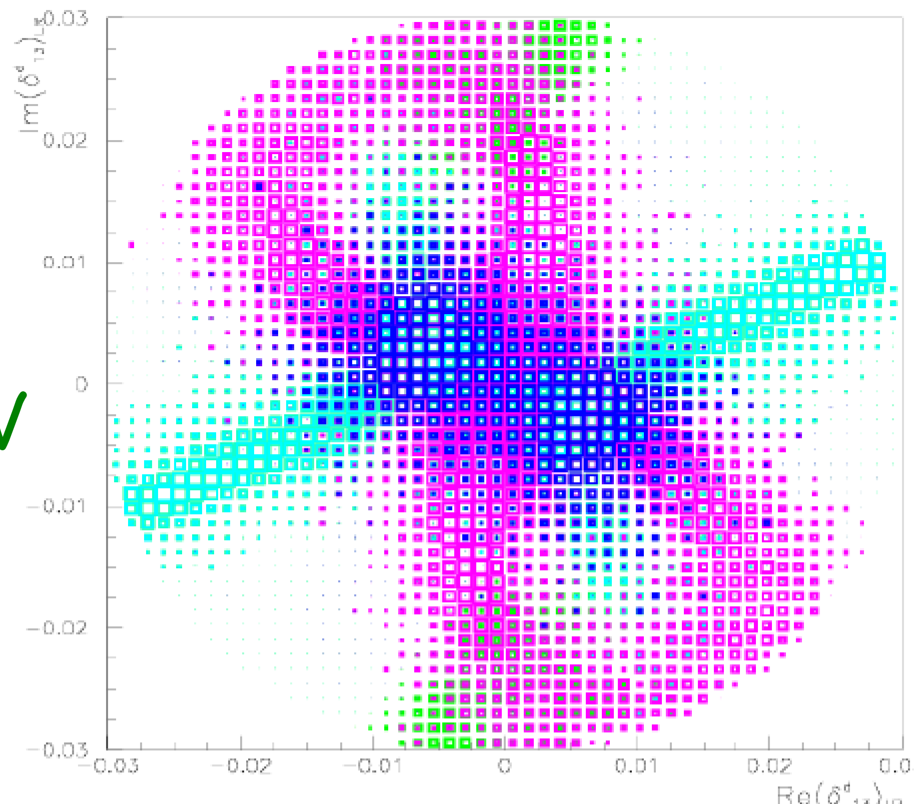
$\left\|\left(\delta^d_{23}\right)_{LL}\right\|$	$\left\|\left(\delta^d_{23}\right)_{RR}\right\|$	$\left\|\left(\delta^d_{23}\right)_{LL=RR}\right\|$	$\left\|\left(\delta^d_{23}\right)_{LR,RL}\right\|$
$2 \cdot 10^{-1}$	$7 \cdot 10^{-1}$	$5 \cdot 10^{-2}$	$5 \cdot 10^{-3}$

Δm_B only

sin 2β only

sin 2β and cos 2β

All constraints

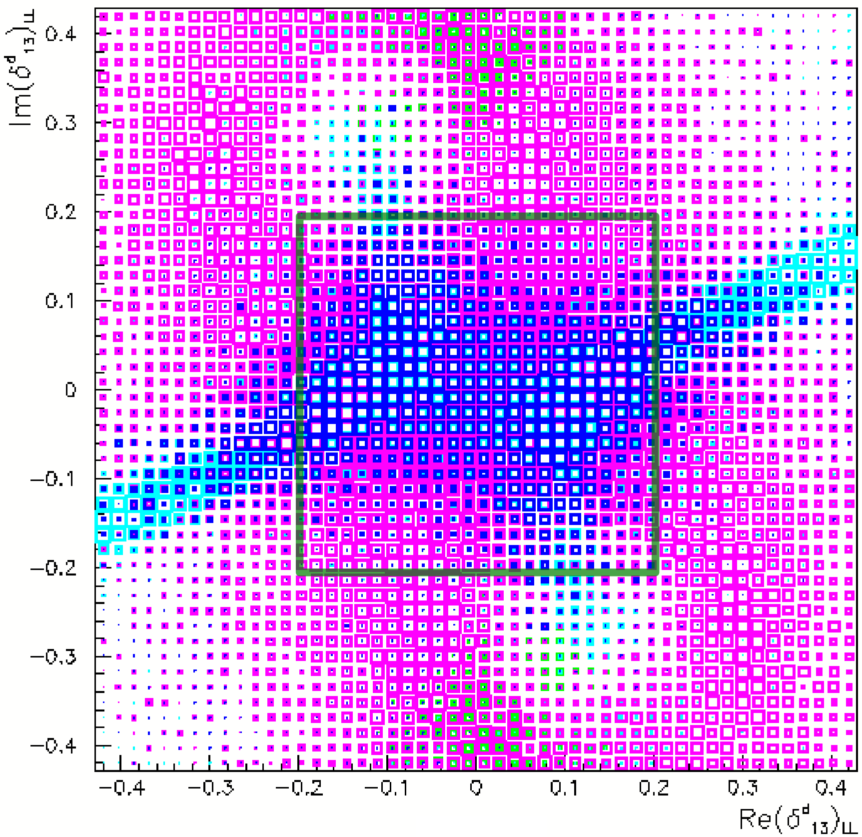


Re $(\delta^d_{13})_{LR,RL}$ vs Im $(\delta^d_{13})_{LR,RL}$

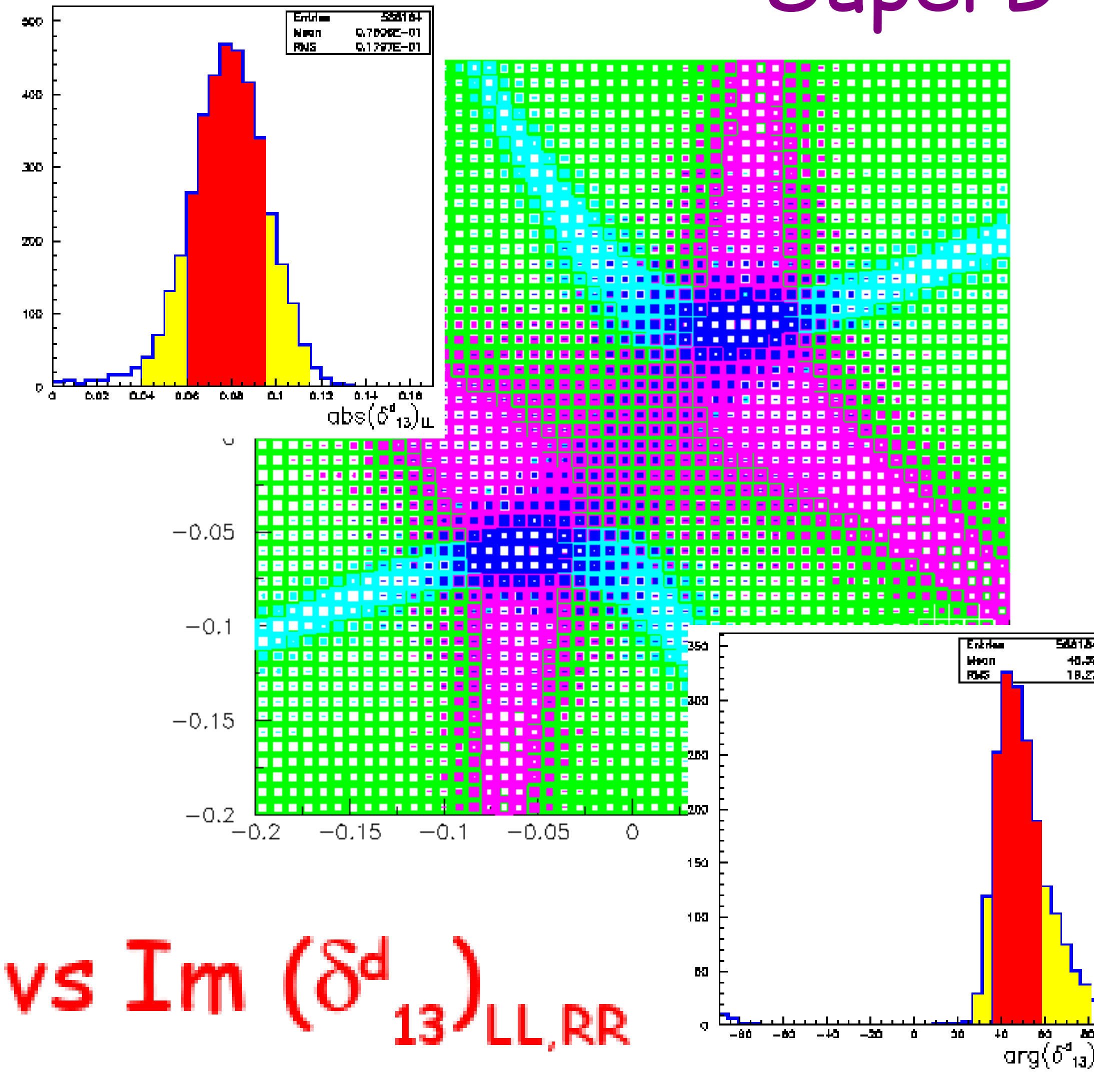
- bounds for $m_{sq}=m_{gl}=-\mu=350$ GeV and $\tan\beta=3$
- bounds scale approximately as ~ m_{SUSY}(GeV)/350

$\Lambda = m_{\tilde{g}} = m_{\tilde{q}} = 1$ TeV

today



SuperB



Re $(\delta^d_{13})_{LL,RR}$ vs Im $(\delta^d_{13})_{LL,RR}$

Δm_B only

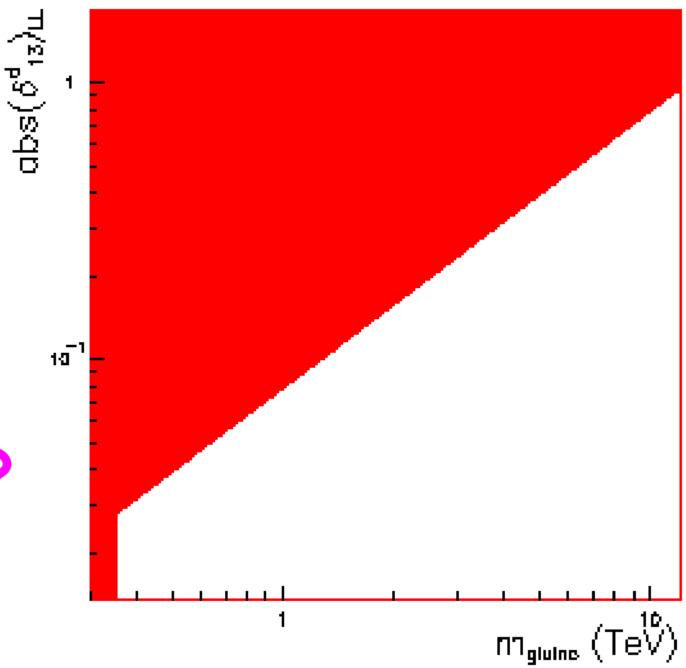
A^d_{SL} only

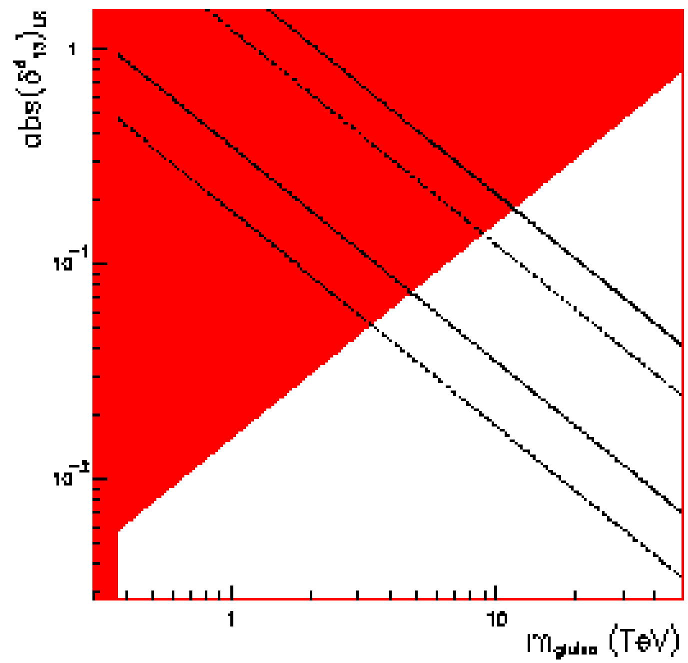
sin 2β and cos 2β

All constraints

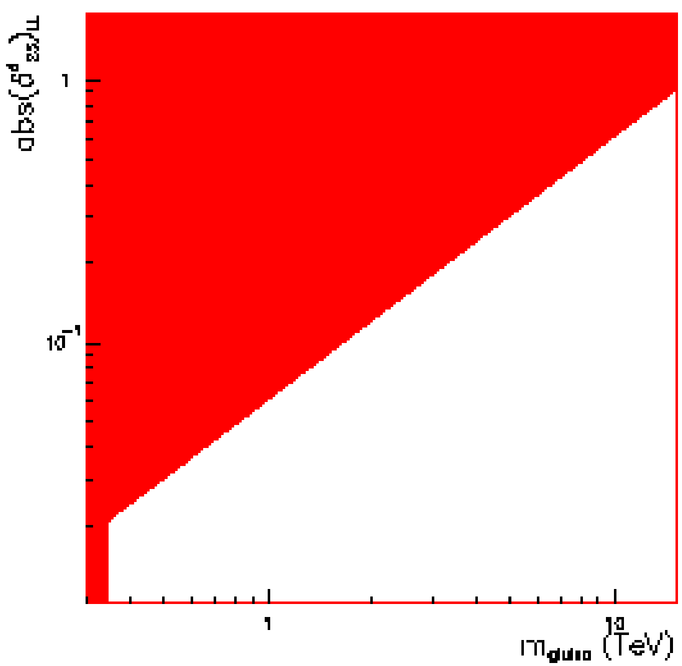
Which is the minimum coupling for which SuperB gives evidence of a non-vanishing δ?

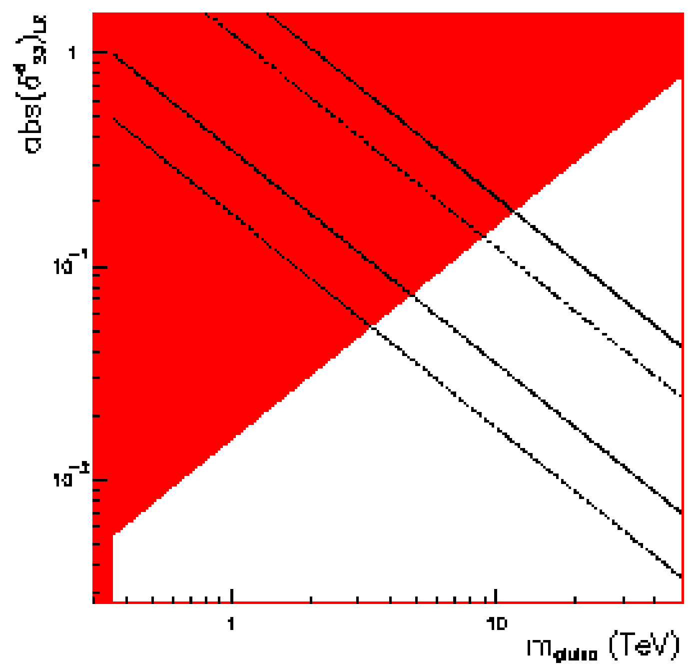
SuperB CDR





In the red regions the δ's reconstructed using SFF constraints are more than 3σ away from 0





FV and CPV in b -> s transitions

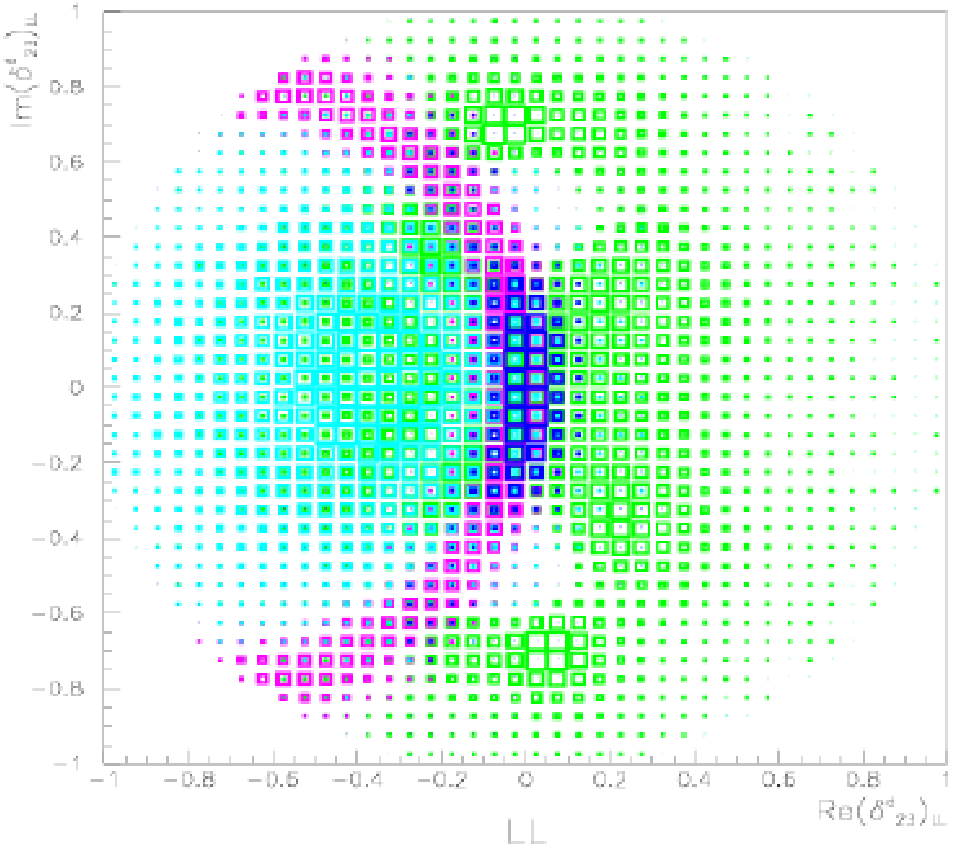
-natural in any flavour models given the strong breaking of family SU(3)

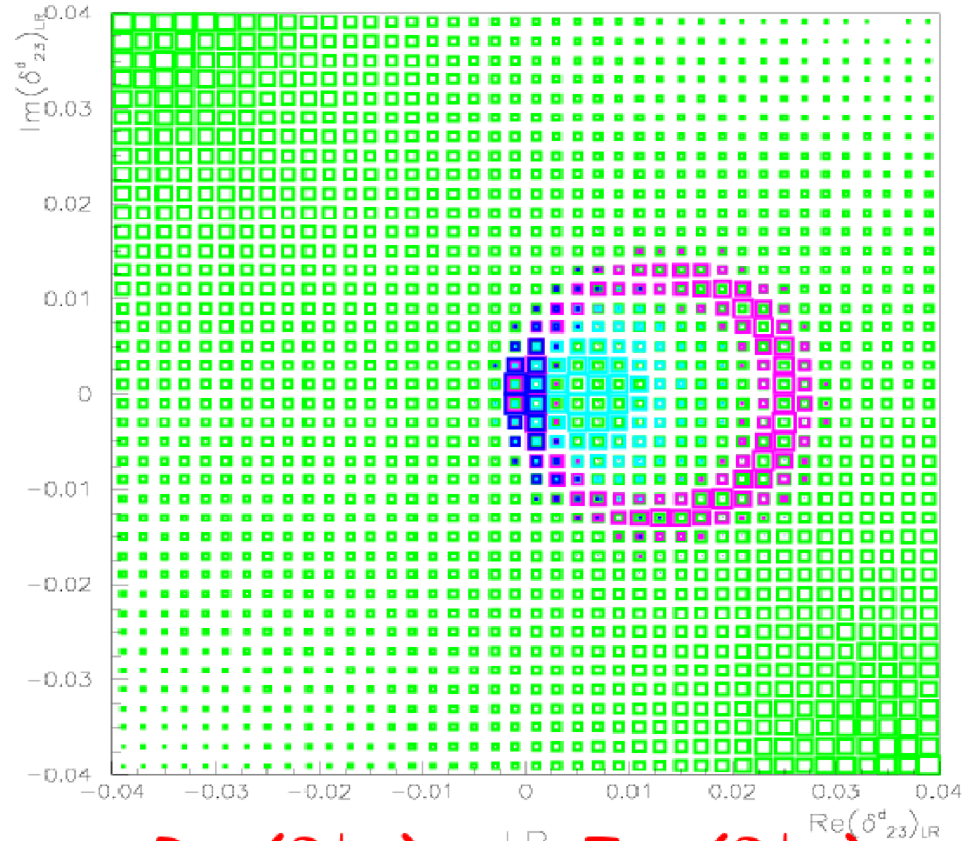
Pomarol, Tommasini; Barbieri, Dvali, Hall; Barbieri, Hall; Barbieri, Hall, Romanino; Berezhiani, Rossi; Masiero, Piai, Romanino, Silvestrini; …

-hinted at by ν's in SUSY-GUTs

Baek, Goto, Okada, Okumura; Moroi; Akama, Kiyo, Komine, Moroi; Chang, Masiero, Murayama; Hisano, Shimizu; Goto, Okada, Shimizu, Shindou, Tanaka; …

-room for deviations from the SM in time-dependent CP asymmetries of b->sqq decays ($\phi K_s, \pi K_s, \ldots$)





Re $(\delta^d_{23})_{LL}$ vs Im $(\delta^d_{23})_{LL}$

$\tan\beta=3$

Constraint from $b \to s\, ll$

Constraint from $b \to s\, \gamma$

Constraint from C_{Bs}, ϕ_{Bs}

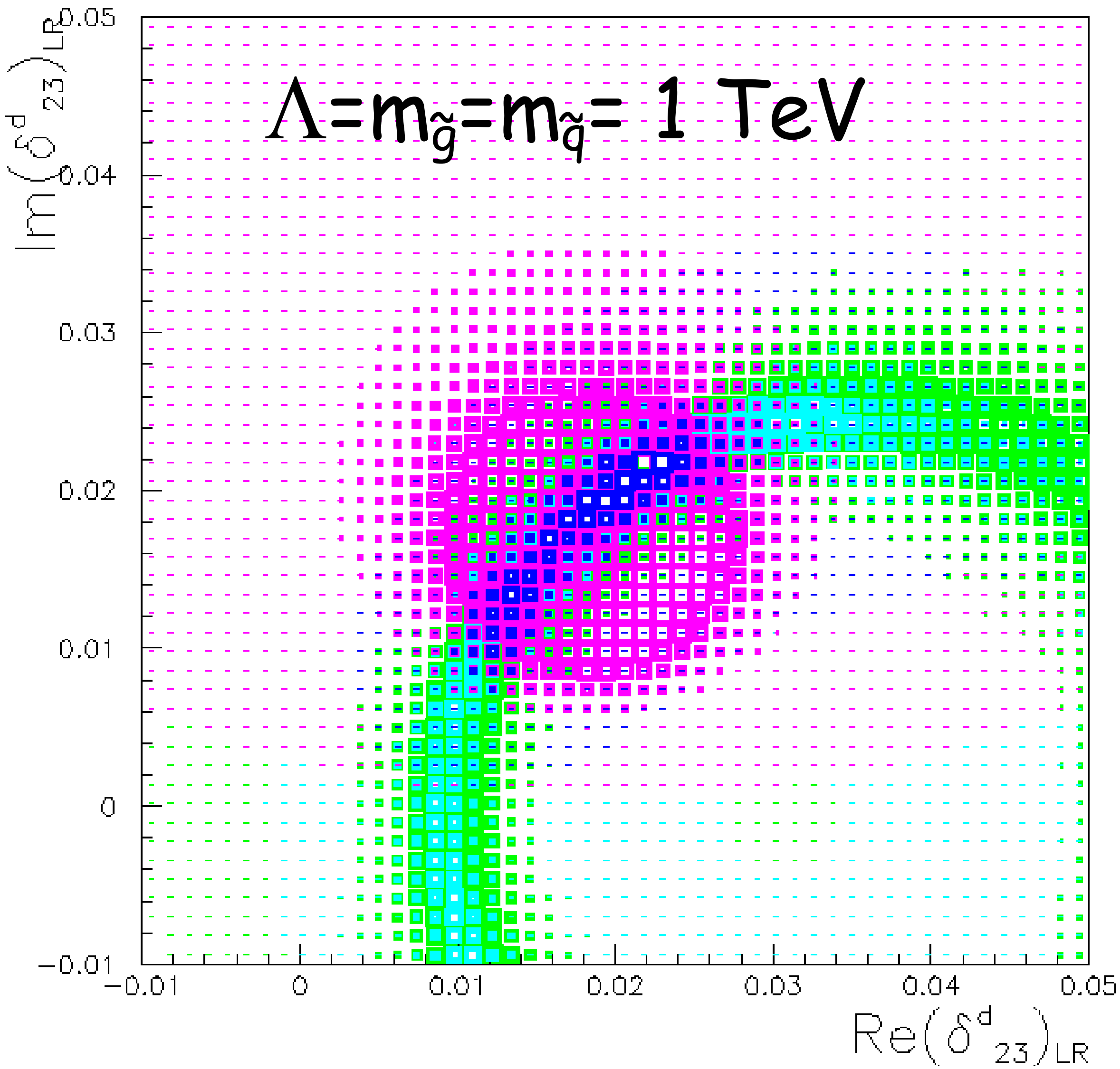
All constraints

Re $(\delta^d_{23})_{LR}$ vs Im $(\delta^d_{23})_{LR}$

LR & RL dominated by BR($b \to s\,\gamma$) & BR($b \to s\, l^+l^-$)

$m_{sq}=m_{gl}=-\mu=350$ GeV

δ reconstruction simulated at SuperB



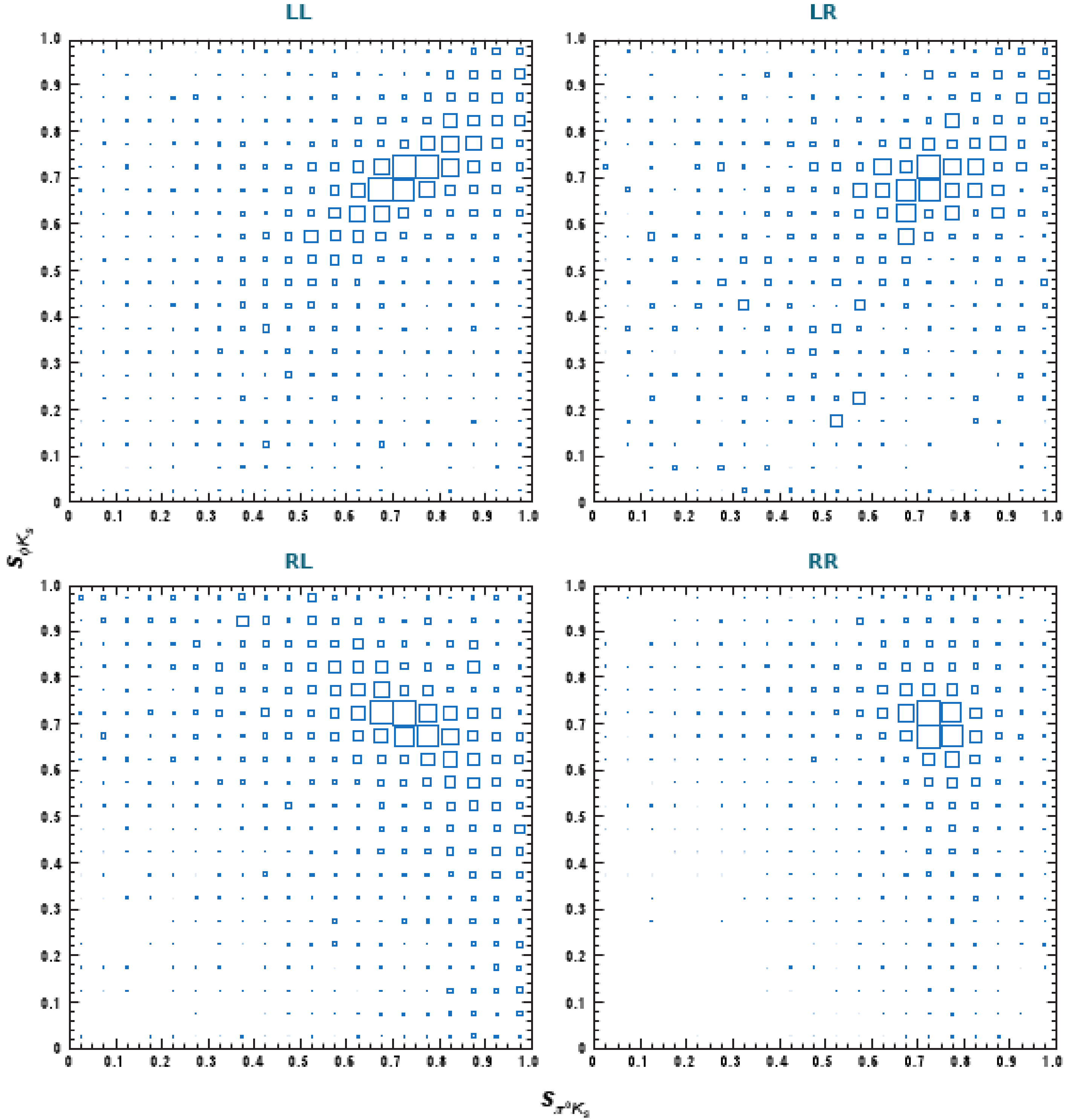
$A_{CP}(B \to X\,\gamma)$ only

$BR(B \to X\,\gamma)$ only

$BR(B \to X\,l^+l^-)$ only

All constraints

Re $(\delta^d_{23})_{LR}$ vs Im $(\delta^d_{23})_{LR}$



Correlation between $S(\phi K_s)$ and $S(\pi^0 K_s)$

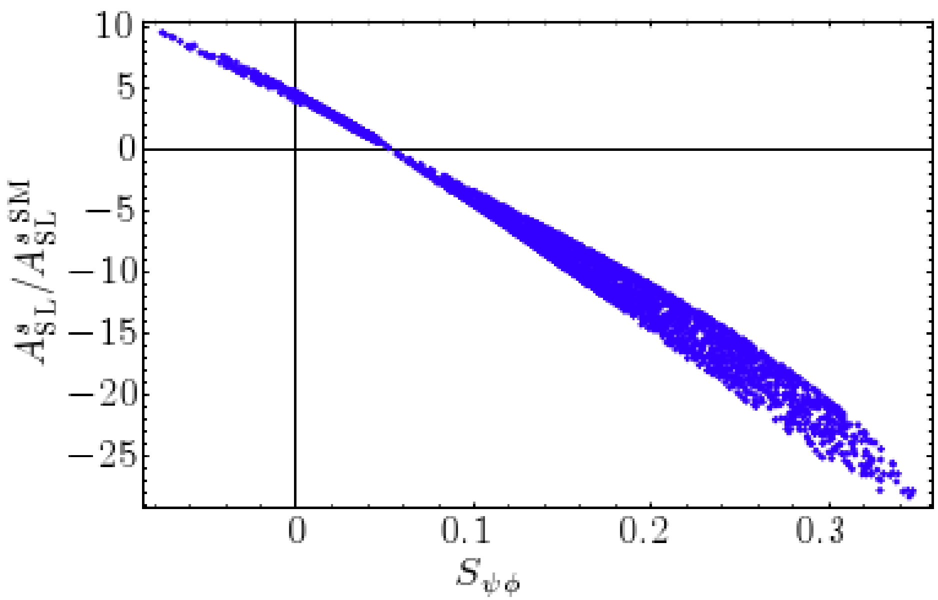
LFV BR ratios can distinguish LHT from SUSY

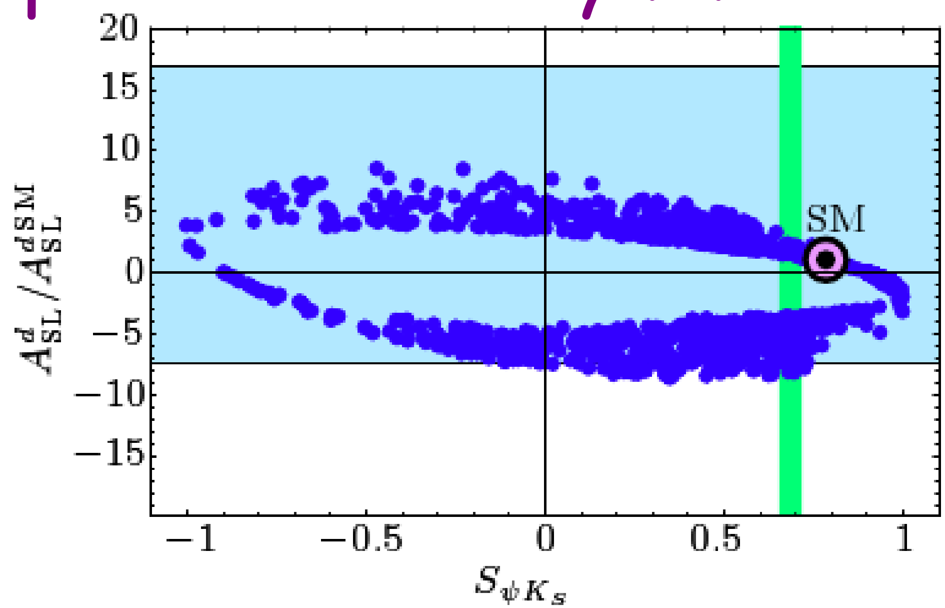
ratio	LHT	MSSM (dipole)	MSSM (Higgs)
$\frac{B(\tau^-\to e^-e^+e^-)}{B(\tau\to e\gamma)}$	$0.4\ldots2.3$	$\sim 1\cdot10^{-2}$	$\sim 1\cdot10^{-2}$
$\frac{B(\tau^-\to \mu^-\mu^+\mu^-)}{B(\tau\to \mu\gamma)}$	$0.4\ldots2.3$	$\sim 2\cdot10^{-3}$	$0.06\ldots0.1$
$\frac{B(\tau^-\to e^-\mu^+\mu^-)}{B(\tau\to e\gamma)}$	$0.3\ldots1.6$	$\sim 2\cdot10^{-3}$	$0.02\ldots0.04$
$\frac{B(\tau^-\to \mu^-e^+e^-)}{B(\tau\to \mu\gamma)}$	$0.3\ldots1.6$	$\sim 1\cdot10^{-2}$	$\sim 1\cdot10^{-2}$
$\frac{B(\tau^-\to e^-e^+e^-)}{B(\tau^-\to e^-\mu^+\mu^-)}$	$1.3\ldots1.7$	~ 5	$0.3\ldots0.5$
$\frac{B(\tau^-\to \mu^-\mu^+\mu^-)}{B(\tau^-\to \mu^-e^+e^-)}$	$1.2\ldots1.6$	~ 0.2	$5\ldots10$

Several peculiar correlations in the littlest Higgs model with T-parity

M. Blanke et al.,
hep-ph/0605214
hep-ph/0702136

correlations of SL and t-dependent CP asymmetries





Conclusions (i)

In indirect searches benchmarks are not needed as long as one looks at low-energy observables: in this case correlations are better studied with EFTs or in models with generic flavour sector

Although flavour physics alone cannot identify the NP model, the determination of the FV and CPV couplings provide unique information on the NP Lagrangian

Conclusions (ii)

First step at the LHC-flavour workshops to implement low- and high-energy constraints on the same MSSMparameter space

Other correlations among low- and high-energy observables still to be explored

For ex.: squark mixing vs squark decays

SUSYfit (?)