Round Table on Future B Factories the Physics Case

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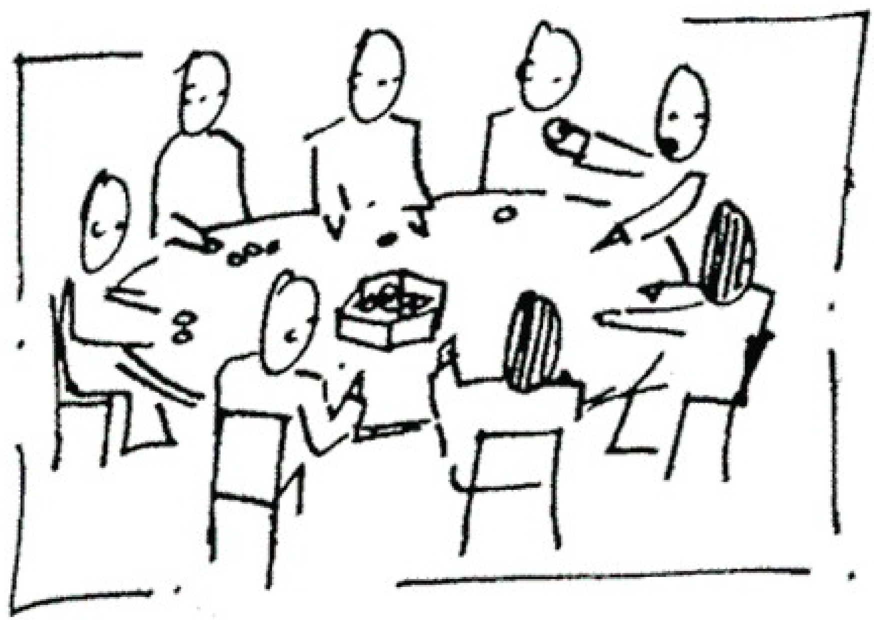
Belle II

Super KEKB Quest for BSM



SuperB

Third Workshop on Theory, Phenomenology and Experiments in Heavy Flavour Physics

July 5-7 2010, Capri, Italy

The physics goal of a Super Flavour Factory: **search for & characterize New Physics**

NP found	NP not found
- determine the FV and CPV couplings of the NP Lagrangian	- look for any deviation from the SM signaling NP in the multi-TeV energy region
- look for the effect of heavier states	

- probe regions of the NP parameter space

Ingredients for a success

- ✔ leap in luminosity
- ✔ a large set of new-physics-sensitive observables related to different flavour sectors (B_d, D, τ, B_s,...) measurable with high accuracy
- ✔ control of the theoretical uncertainties at a level matching the expected experimental precision (in the SM and eventually beyond)

A "treasure chest" of new physics-sensitive observables

theoretical uncertainties

no theory improvements needed	$\beta(J/\psi K)$, $\gamma(DK)$, $\alpha(\pi\pi)$*, $B\to K^{(*)}\nu\nu$ lepton FV and UV, $S(\rho^0\gamma)$ CPV in $B\to X\gamma$, D and τ decays zero of FB asymmetry $B\to X_s l^+l^-$	null tests of the SM or SM already known with the required accuracy
improved lattice QCD	meson mixing, $B\to D(*)l\nu$, $B\to\pi(\rho)l\nu$ $B\to K^*\gamma$, $B\to\rho\gamma$, $B\to l\nu$, $B_s\to\mu\mu$	target error: ~1-2% Feasible (see below)
improved OPE+HQE	$B\to X_{u,c}l\nu$, $B\to X\gamma$	target error: ~1-2% Possibly feasible with SuperB data getting rid of the shape function. Detailed studies required
improved QCDF/SCET or flavour symmetries	S's from TD A_{CP} in $b\to s$ transitions	target error: ~2-3% large and hard to improve uncertainties on small corrections. FS+data can bound the th. error

Theory keeps up...

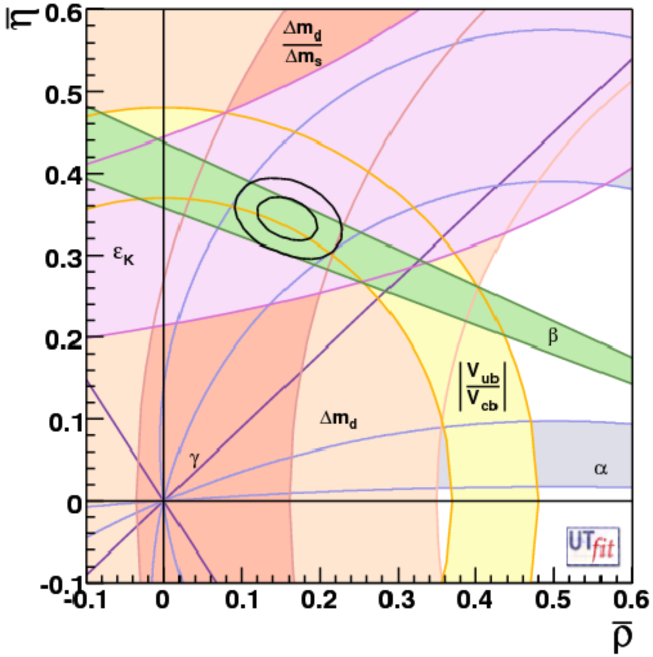
lattice QCD can reach the O(1%) precision goal in time

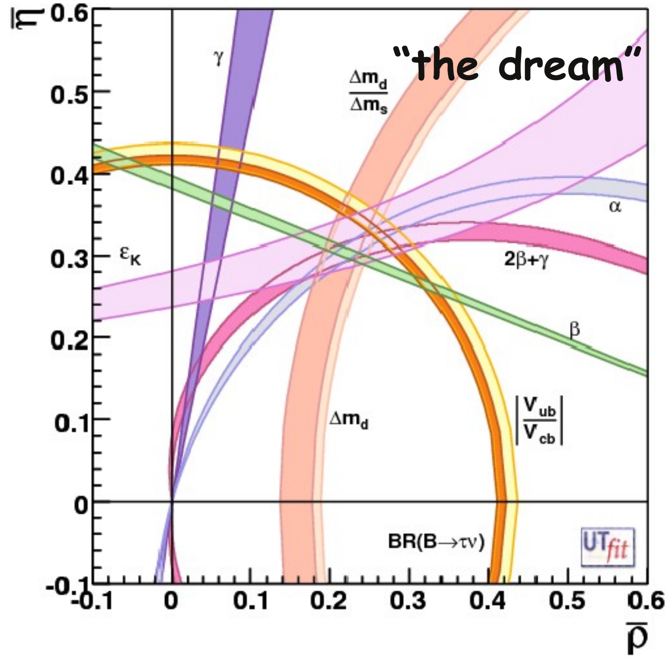
V. Lubicz, SuperB CDR, updated for the physics white paper

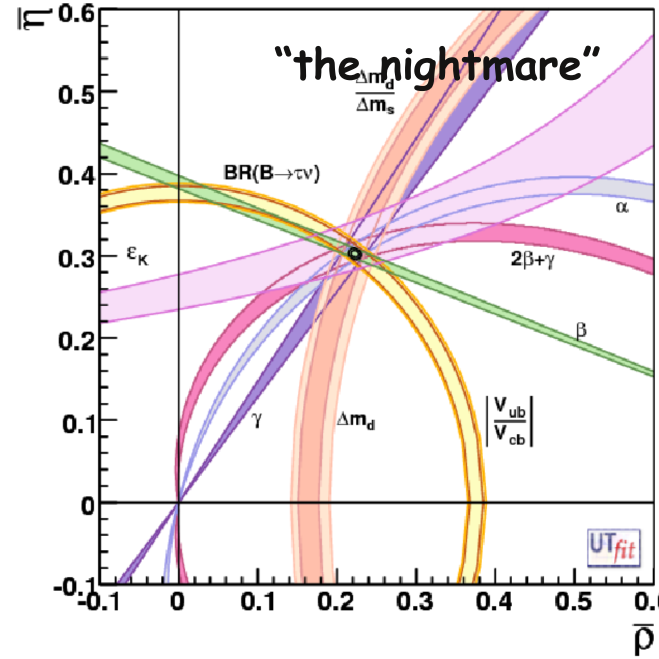
Measurement	Hadronic Parameter	Status End 2006	6 TFlops (Year 2009)	**Status End 2009**	60 TFlops (Year 2011)	1-10 PFlops (Year 2015)
$K \to \pi l \nu$	$f_+^{K\pi}(0)$	0.9 %	0.7 %	0.5 %	0.4 %	$<$ 0.1 %
ε_K	$\hat{B}_K$	11 %	5 %	5 %	3 %	1 %
$B \to l \nu$	f_B	14 %	3.5-4.5 %	5 %	2.5-4.0 %	1.0-1.5 %
Δm_d	$f_{Bs}\sqrt{B_{B_s}}$	13 %	4-5 %	5 %	3-4 %	1-1.5 %
$\Delta m_d / \Delta m_s$	ξ	5 %	3 %	2 %	1.5-2 %	0.5-0.8 %
$B \to D/D^* l \nu$	$\mathscr{F}_{B\to D/D^*}$	4 %	2 %	2 %	1.2 %	0.5 %
$B \to \pi/\rho l \nu$	$f_+^{B\pi}, \ldots$	11 %	5.5-6.5 %	11 %	4-5 %	2-3 %
$B \to K^*/\rho (\gamma, l^+ l^-)$	$T_1^{B\to K^*/\rho}$	13 %	——	13 %	——	3-4 %

CKM matrix at 1%

Today | with 75 ab^{-1} at the $\Upsilon(4S)$





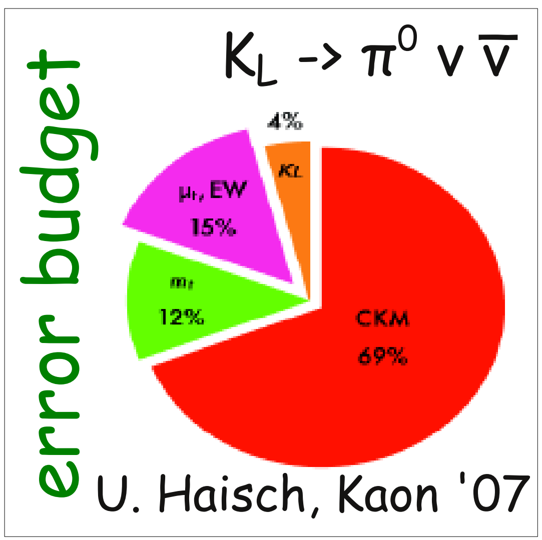


Generalized UT fits:

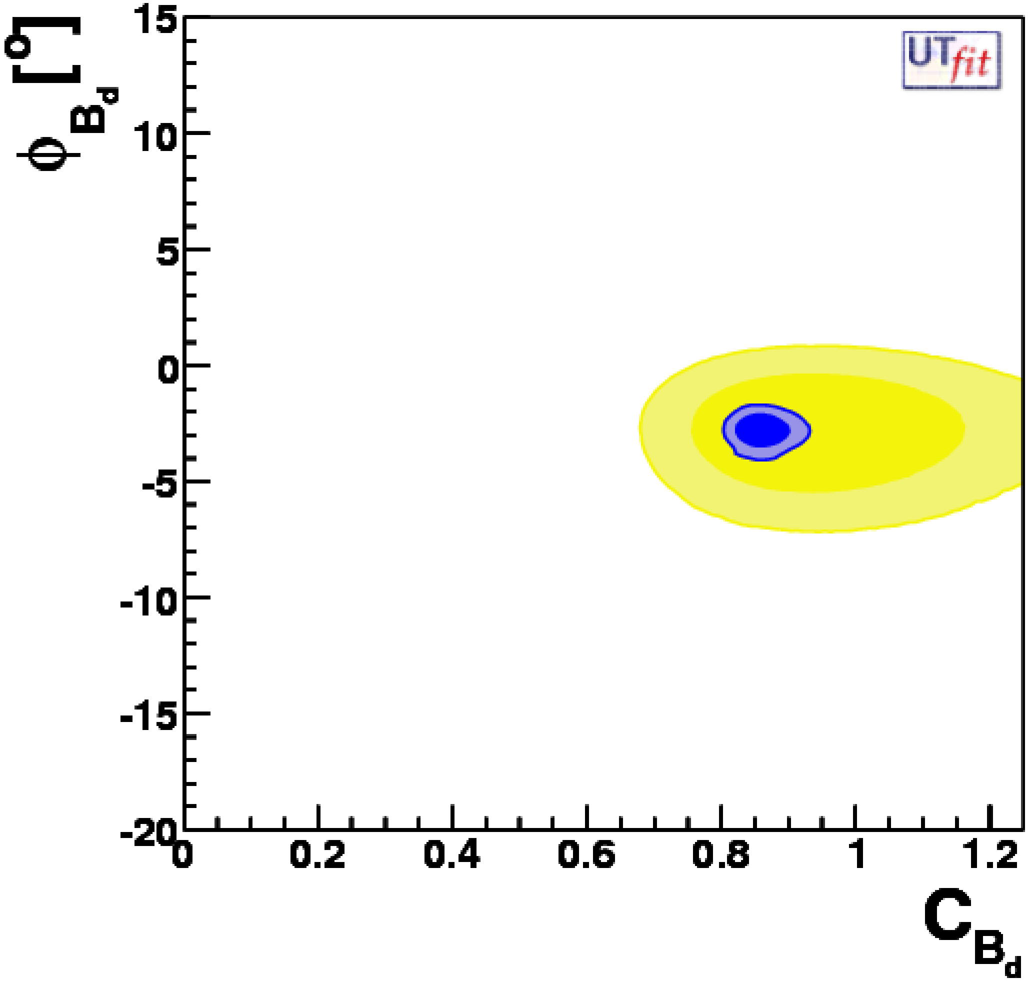
CKM at 1% in the presence of NP!

	today	SuperB
$\bar{\rho}$	0.187±0.056	±0.005
$\bar{\eta}$	0.370±0.036	±0.005

- crucial for many NP searches with flavour (not only in the B sector!)



Mixing amplitude BSM: $M_{12}^{d} = C_{B_d} e^{2i\phi_{B_d}} |M_{12}^{d,SM}| e^{2i\beta}$



Yellow: today

Blue: future

preliminary, courtesy of M. Bona

phenomenological impact*

*topics selected following the mood and taste of the speaker

MSSM (i): "model-independent"

$M^2_{\tilde{d}} =$

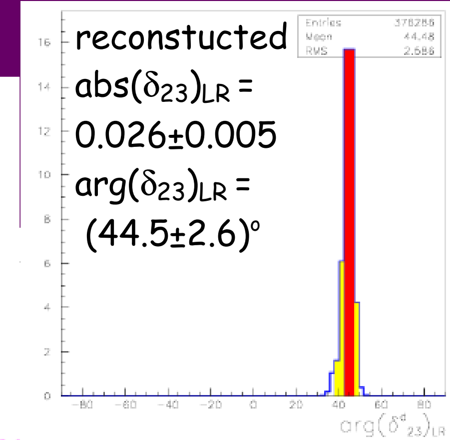
SFF

$$\begin{pmatrix} m^2_{\tilde{d}_L} & m_d(A_d-\mu\tan\beta) & (\Delta^d_{12})_{LL} & (\Delta^d_{12})_{LR} & (\Delta^d_{13})_{LL} & (\Delta^d_{13})_{LR} \\ & m^2_{\tilde{d}_R} & (\Delta^d_{12})_{RL} & (\Delta^d_{12})_{RR} & (\Delta^d_{13})_{RL} & (\Delta^d_{13})_{RR} \\ & & m^2_{\tilde{s}_L} & m_s(A_s-\mu\tan\beta) & (\Delta^d_{23})_{LL} & (\Delta^d_{23})_{LR} \\ & & & m^2_{\tilde{s}_R} & (\Delta^d_{23})_{RL} & (\Delta^d_{23})_{RR} \\ & & & & m^2_{\tilde{b}_L} & m_b(A_b-\mu\tan\beta) \\ & & & & & m^2_{\tilde{b}_R} \end{pmatrix}$$

LHC, ILC - HE frontier

Mass Insertions

$(\delta^d_{ij})_{AB} = (\Delta^d_{ij})_{AB}/m_{\tilde{q}}^2$

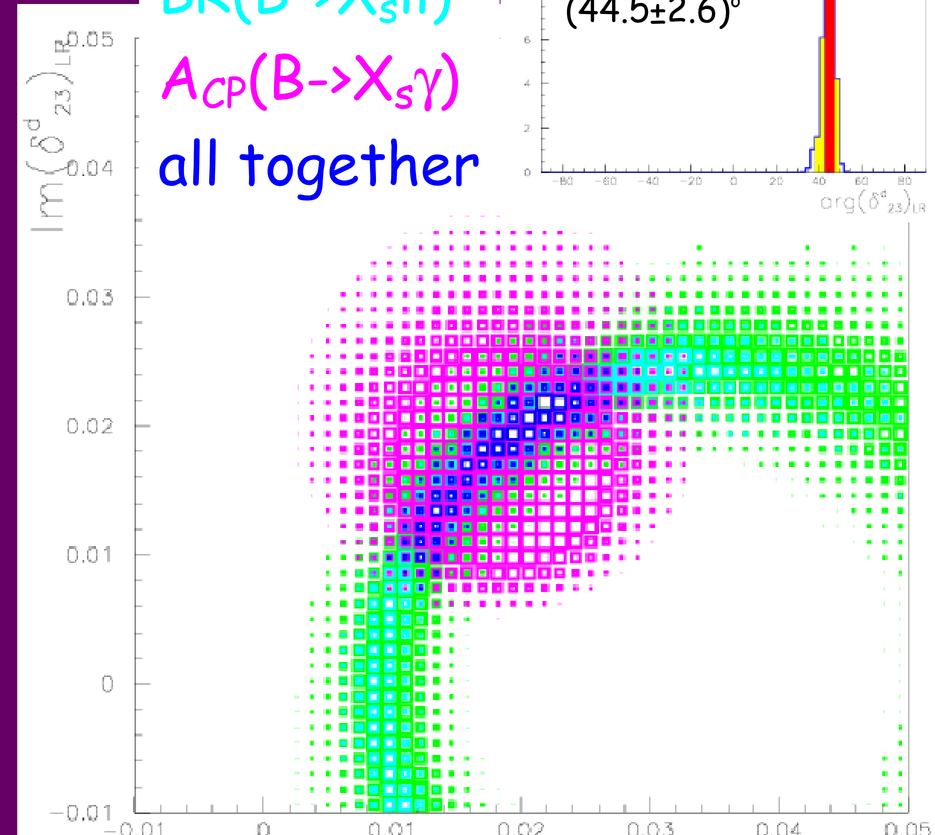


BR(B->$X_s\gamma$)

BR(B->$X_s$ll)

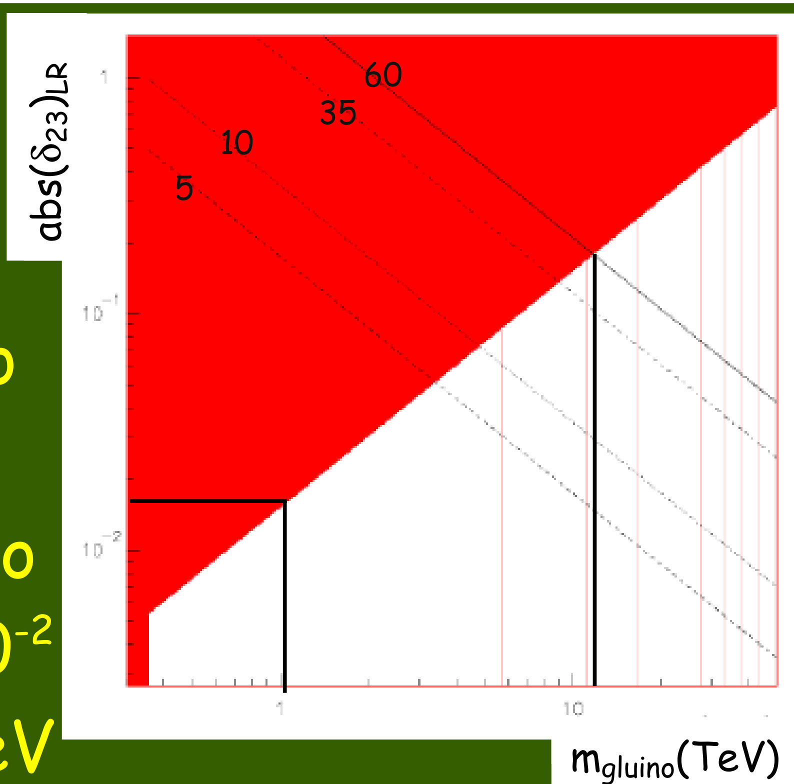
A_{CP}(B->$X_s\gamma$)

all together



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

3σ from 0 sensitivity plot



i) sensit. to $\Lambda<20$ TeV

ii) sensit. to $|(\delta^d_{23})_{LR}|>10^{-2}$ for $\Lambda<1$ TeV

Reconstruction of $(\delta^d_{23})_{LR}=0.028\ e^{i\pi/4}$ for $\Lambda = m_{\tilde{g}} = m_{\tilde{q}} = 1$ TeV

MSSM (ii) : model-dependent studies

W. Altmannshofer et al., 0909.1333

	AC	RVV2	AKM	δLL	FBMSSM
$D^0 - \bar{D}^0$	★★★	★	★	★	★
$S_{\psi\phi}$	★★★	★★★	★★★	★	★
$S_{\phi K_S}$	★★★	★★	★	★★★	★★★
$A_{\rm CP}\,(B \to X_s\gamma)$	★	★	★	★★★	★★★
$A_{7,8}(B \to K^*\mu^+\mu^-)$	★	★	★	★★★	★★★
$A_9(B \to K^*\mu^+\mu^-)$	★	★	★	★	★
$B \to K^{(*)}\nu\bar{\nu}$	★	★	★	★	★
$B_s \to \mu^+\mu^-$	★★★	★★★	★★★	★★★	★★★
$\tau \to \mu\gamma$	★★★	★★★	★	★★★	★★★

AC / RVV2,AKM: abelian / non-abelian flavour models

δLL: CKM-like new LH currents + 2↔3 NP CPV phase

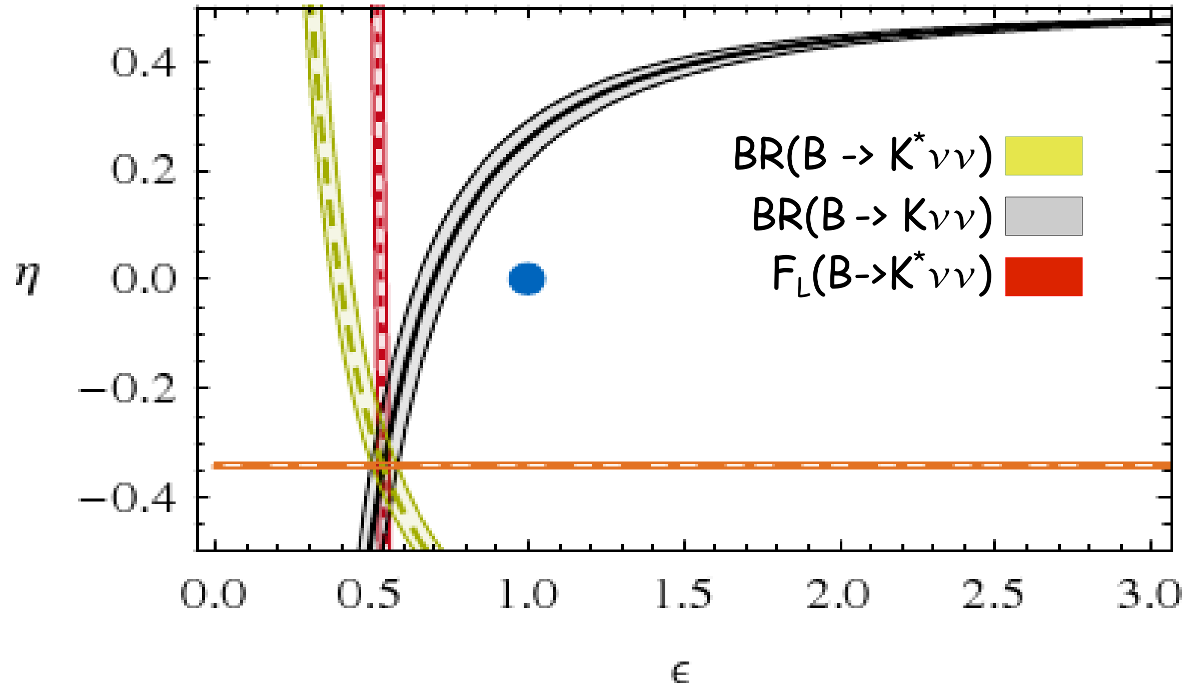
FBMSSM: universal SSB terms + CPV phases

R-H currents in $B \to K^{(*)} \nu\nu$

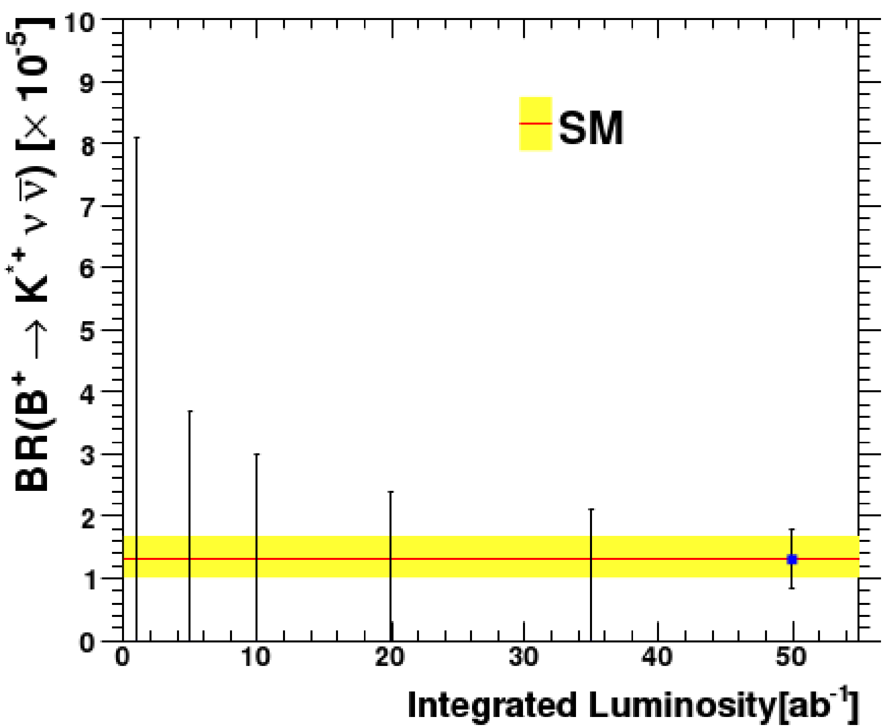
$$\epsilon = \frac{\sqrt{|C_L^\nu|^2 + |C_R^\nu|^2}}{|(C_L^\nu)^{\rm SM}|}$$

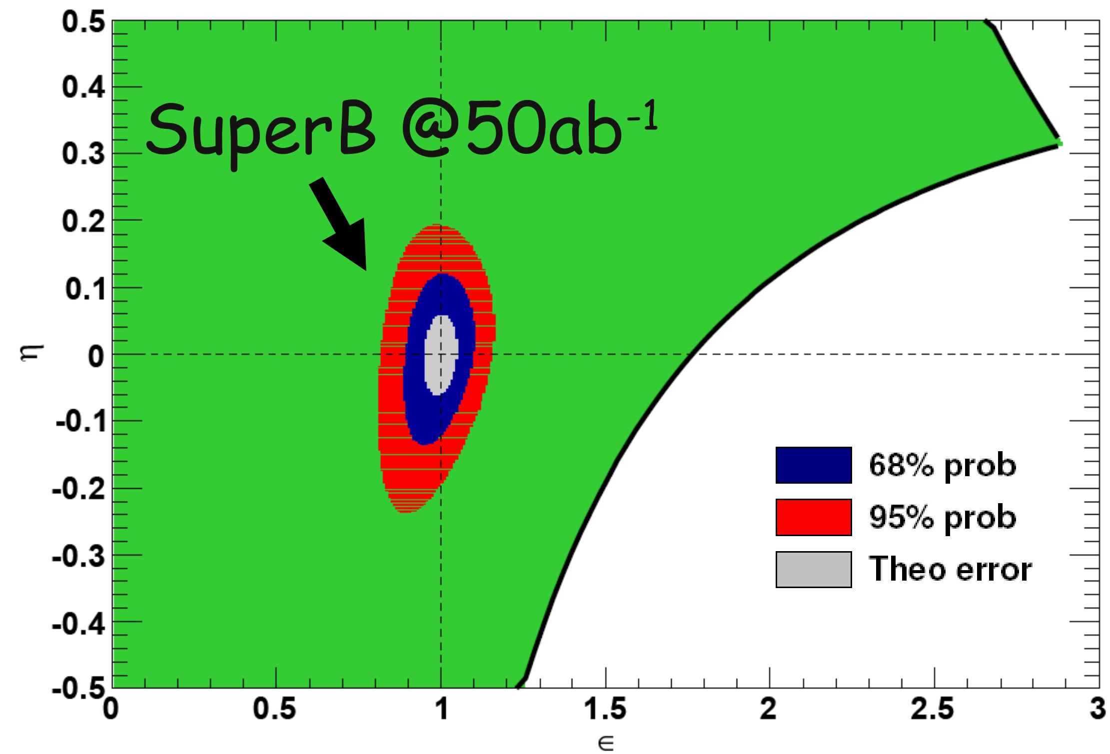
$$\eta = \frac{-{\rm Re}\,(C_L^\nu C_R^{\nu *})}{|C_L^\nu|^2 + |C_R^\nu|^2}$$

Altmannshofer et al, arXiv:0902.0160



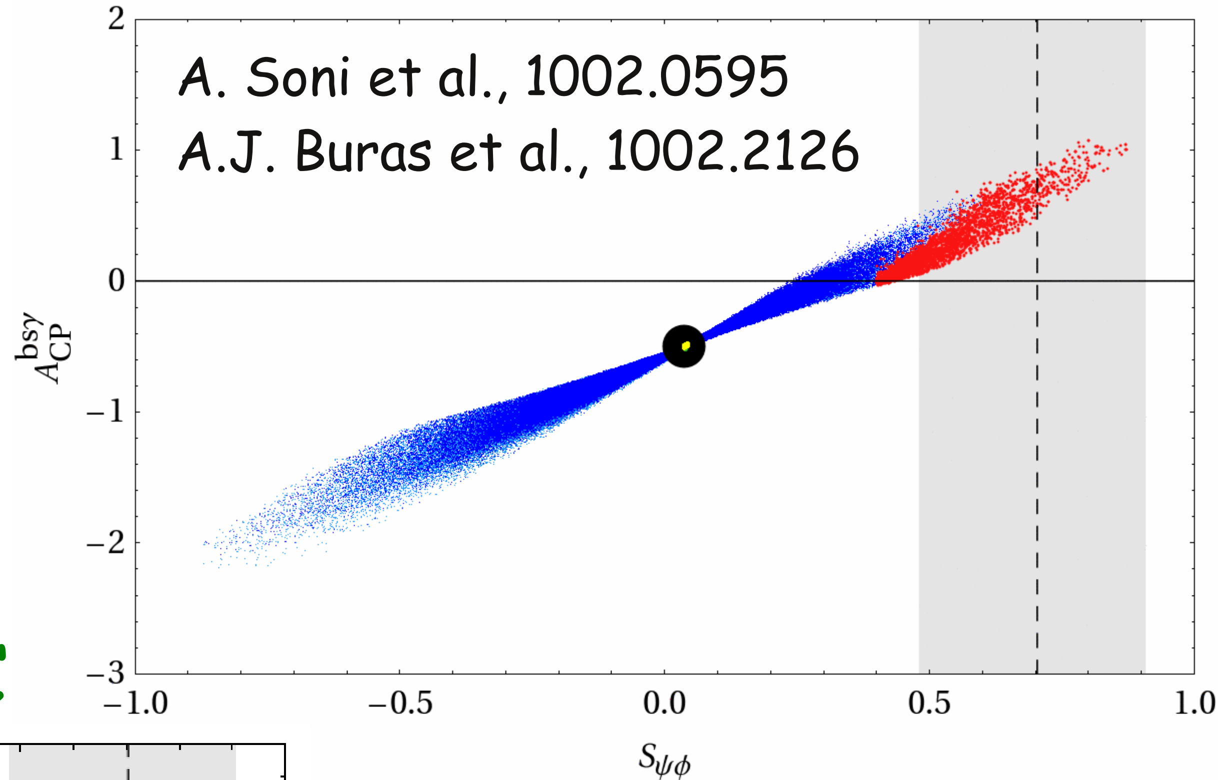
SuperB Workshop VI, arXiv:0810.1312

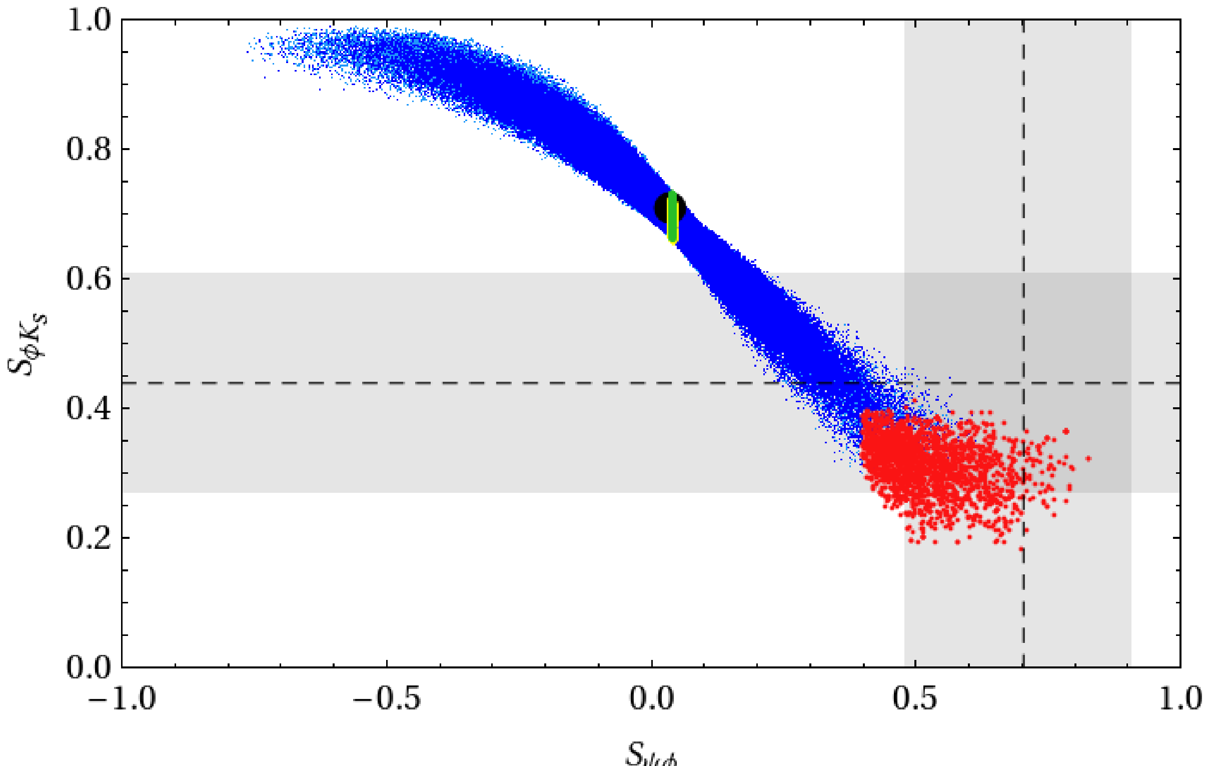




4th generation

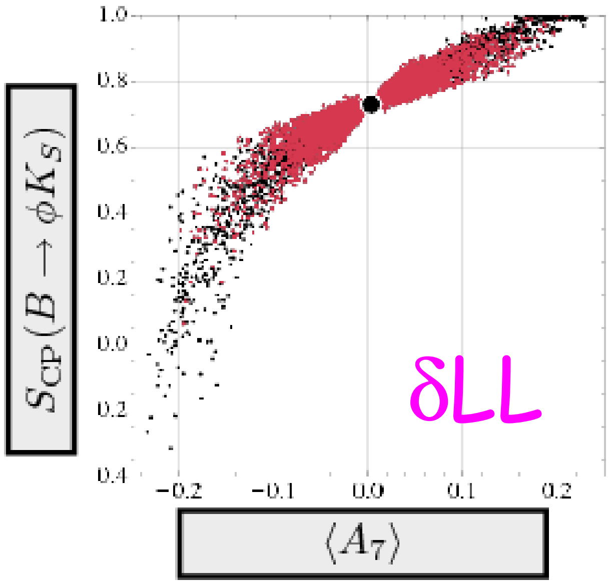
- allows for a heavier Higgs
- allows for large CPV in Bs mixing
- testable at the LHC

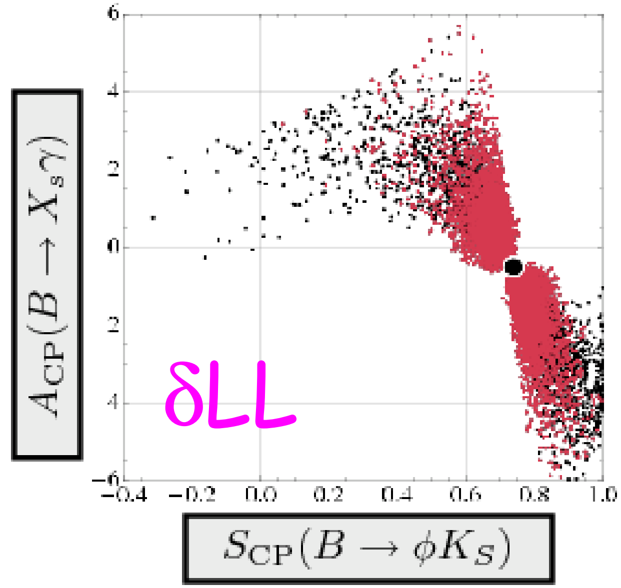


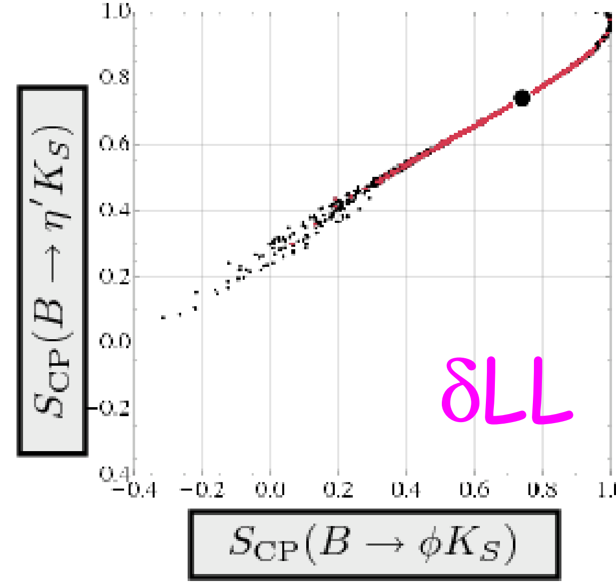


Extremely interesting implications also for the phenomenology of future B factories

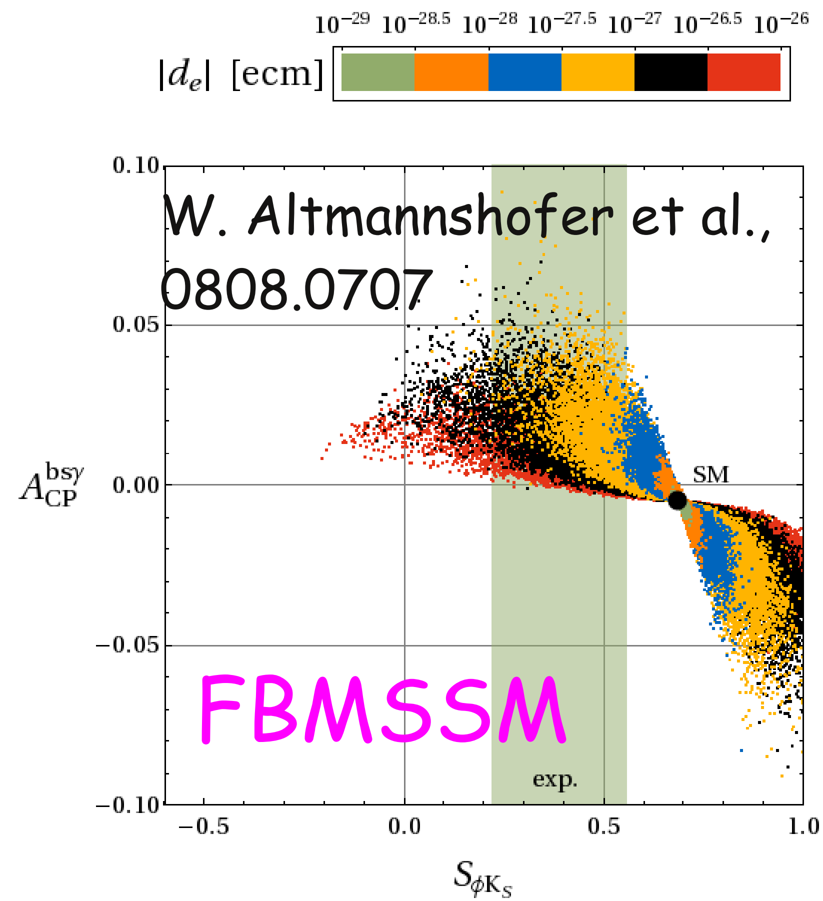
Backup







Correlations between 2+ observables can be used to characterize and possibly identify NP models

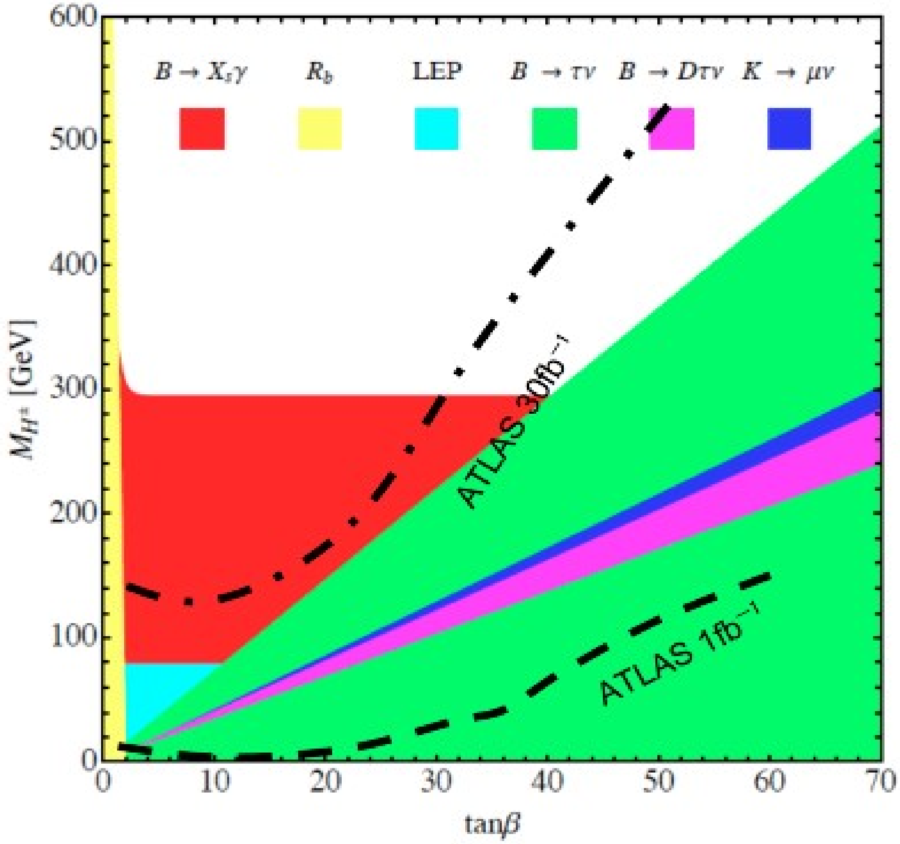


A possible problem of "look-alikes" is much eased thanks to the rich flavour phenomenology

2-Higgs-Doublet Model

* $B \to \tau \nu$ & $B \to D \tau \nu$ on the $\tan\beta$–M_{H^+} plane
* direct searches are not competitive
* strong bounds also from $B_s \to \mu\mu$

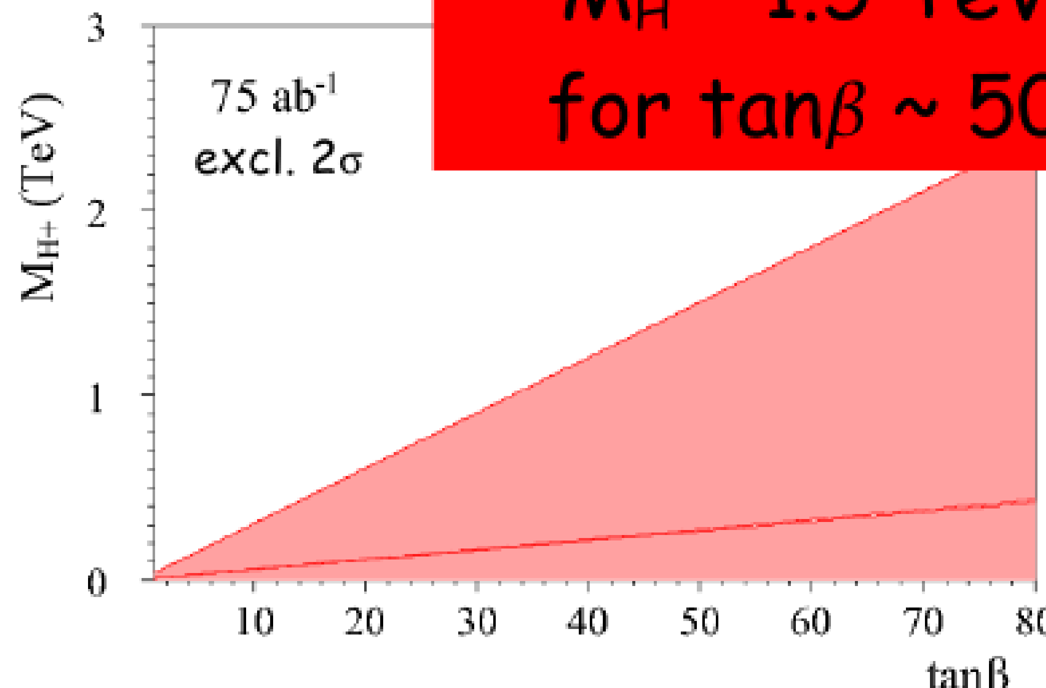
U. Haisch, 0805.2141



SuperB (75/ab)

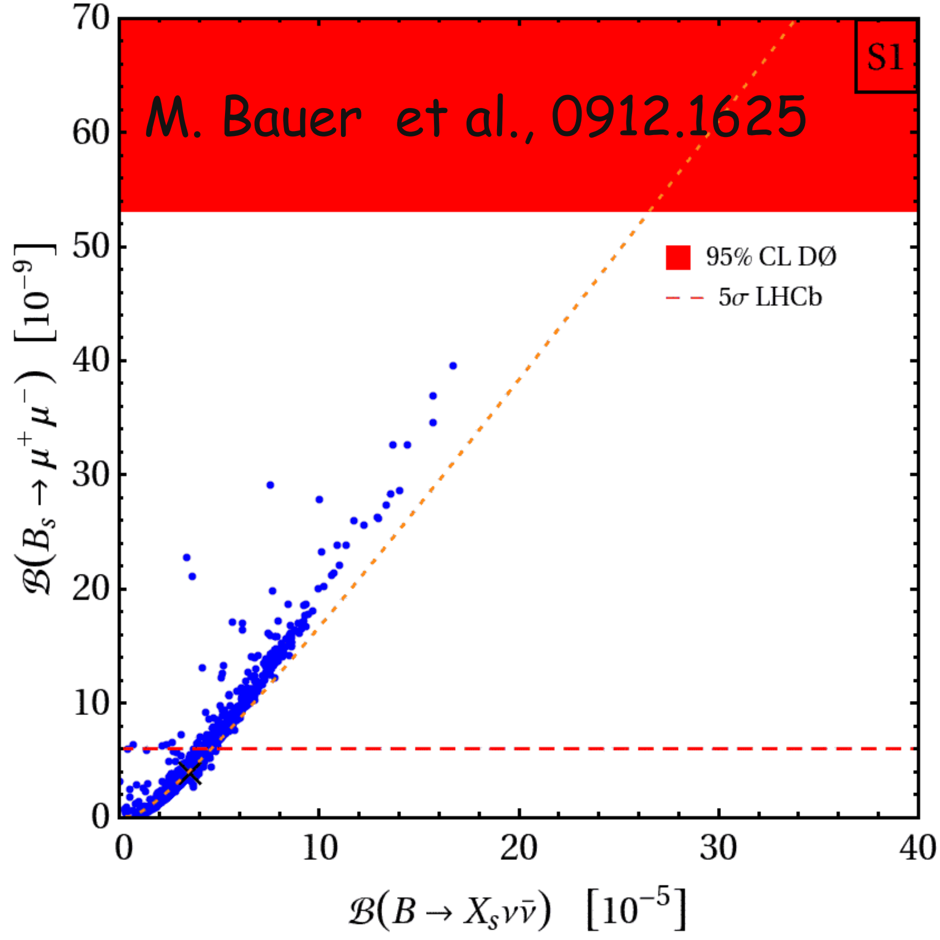
$M_H \sim 1.5$ TeV

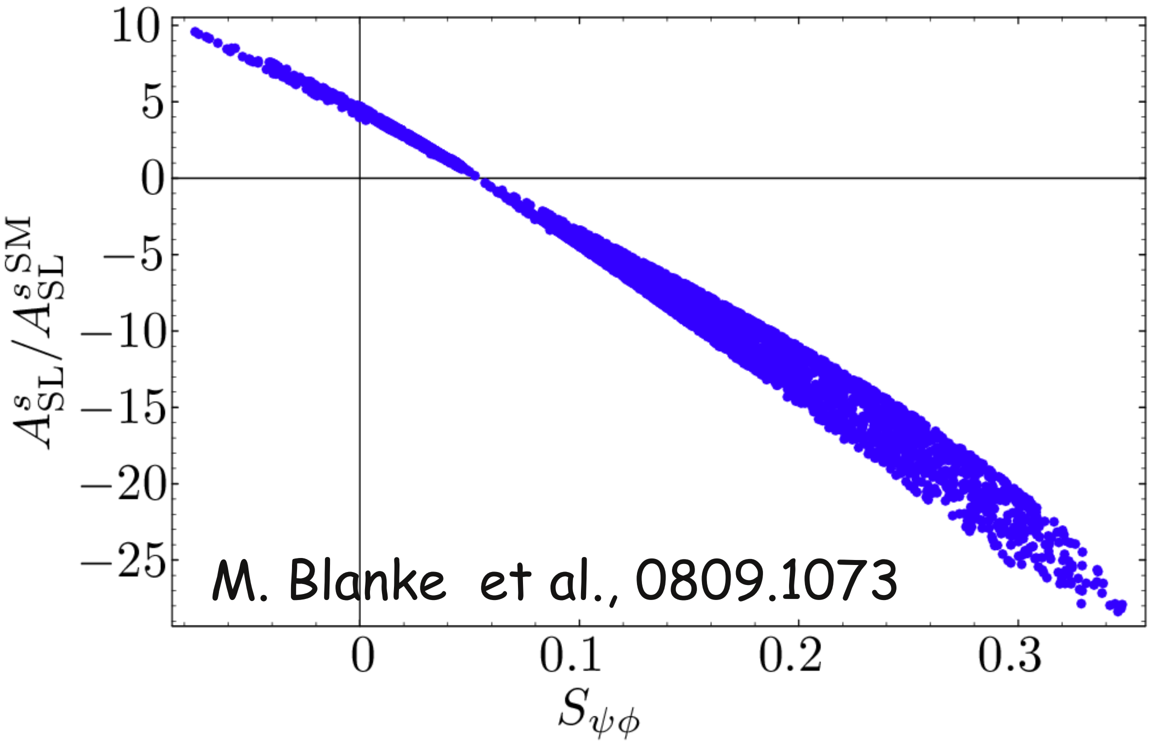
for $\tan\beta \sim 50$



R-S models

- flavour in extra-dim. is severely constrained by ε_K
- large B/Bs effect are still possible





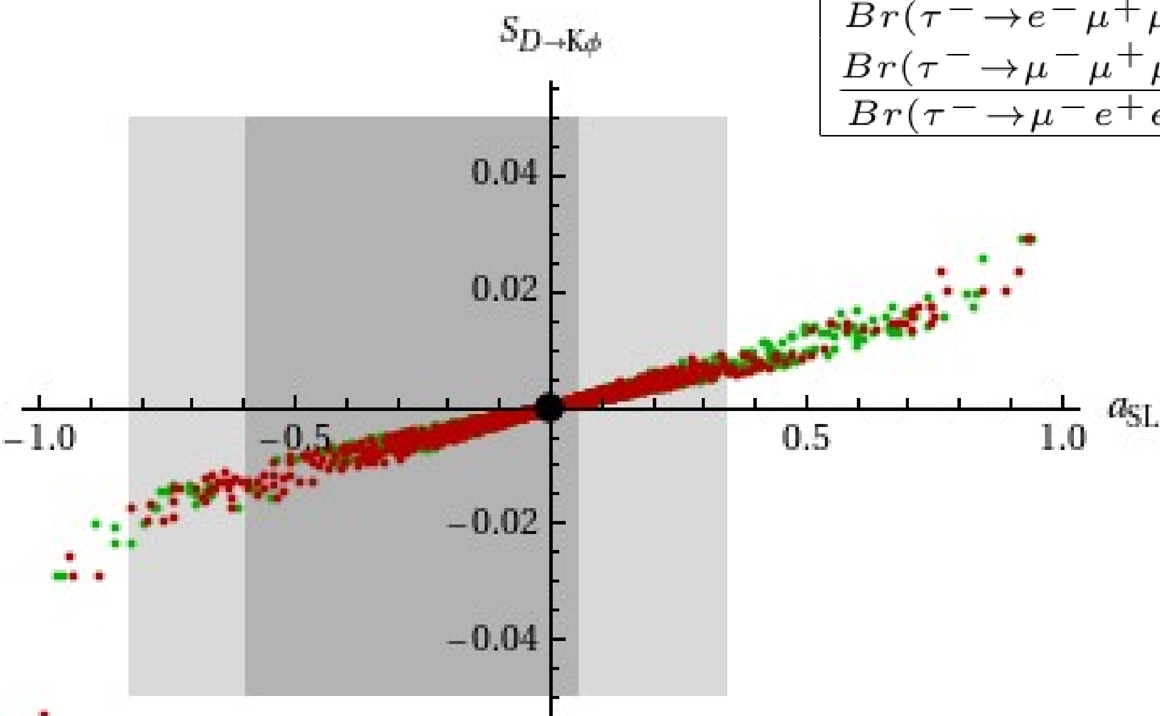
there are R-S models where effects in B(s) are confined to the mixing amplitudes

LHT model

- LFV: $\tau \to \mu\gamma$ vs $\tau \to \ell\ell\ell$
- semileptonic asymmetries

M. Blanke et al., 0906.5454

ratio	LHT	MSSM (dipole)	MSSM (Higgs)
$\frac{Br(\tau^- \to e^- e^+ e^-)}{Br(\tau \to e\gamma)}$	$0.04 \ldots 0.4$	$\sim 1 \cdot 10^{-2}$	$\sim 1 \cdot 10^{-2}$
$\frac{Br(\tau^- \to \mu^- \mu^+ \mu^-)}{Br(\tau \to \mu\gamma)}$	$0.04 \ldots 0.4$	$\sim 2 \cdot 10^{-3}$	$0.06 \ldots 0.1$
$\frac{Br(\tau^- \to e^- \mu^+ \mu^-)}{Br(\tau \to e\gamma)}$	$0.04 \ldots 0.3$	$\sim 2 \cdot 10^{-3}$	$0.02 \ldots 0.04$
$\frac{Br(\tau^- \to \mu^- e^+ e^-)}{Br(\tau \to \mu\gamma)}$	$0.04 \ldots 0.3$	$\sim 1 \cdot 10^{-2}$	$\sim 1 \cdot 10^{-2}$
$\frac{Br(\tau^- \to e^- e^+ e^-)}{Br(\tau^- \to e^- \mu^+ \mu^-)}$	$0.8 \ldots 2.0$	~ 5	$0.3 \ldots 0.5$
$\frac{Br(\tau^- \to \mu^- \mu^+ \mu^-)}{Br(\tau^- \to \mu^- e^+ e^-)}$	$0.7 \ldots 1.6$	~ 0.2	$5 \ldots 10$



I.I. Bigi et al., 0904.1545

Recently: large and correlated CPV effects in D mixing

FC right-handed quark currents

New FC right-handed currents may:

- change the effective γ/g vertex, particularly the magnetic dipole term
  constraints: $b \to s\gamma$, $b \to s\ell\ell$
- change the effective Z vertex (+box)
- introduce a new effective Z' vertex
  constraints: $b \to s\ell\ell$, $b \to s\nu\nu$

Disentangling the different contributions helps identifying the NP model

extreme example: leptofobic Z'