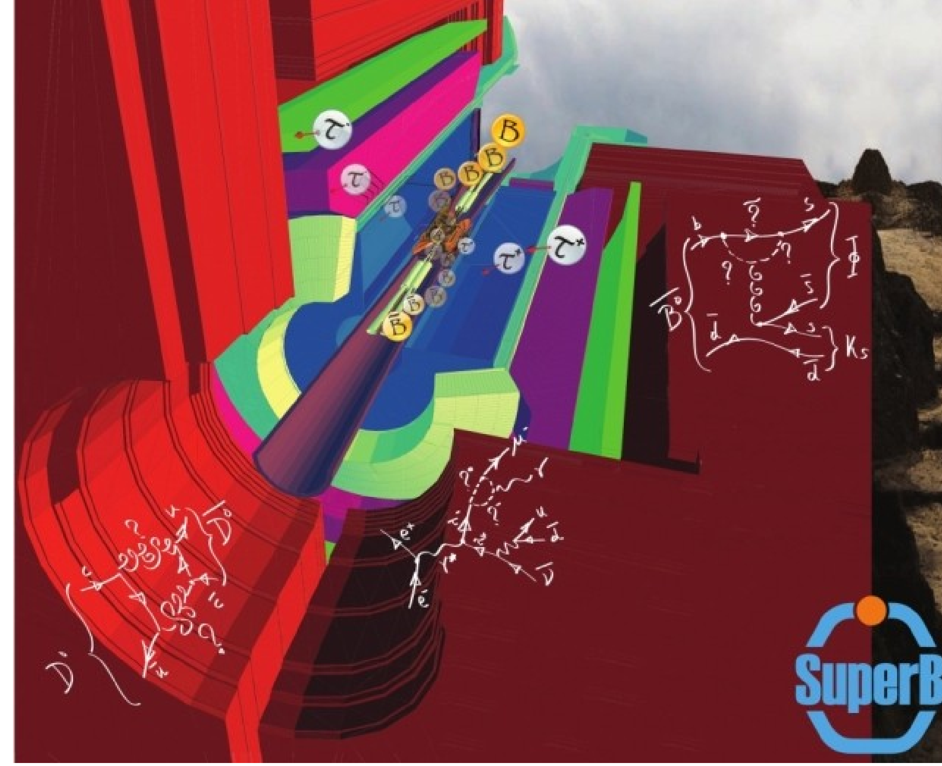
SuperB physics contextualized



Marco Ciuchini

INFN Roma Tre

Implications of LHC results for TeV-scale physics
CERN – 26 March 2012

** the flavor landscape at the time of SuperB

** SuperB confronts other flavor experiments

** the impact of SuperB: illustrative examples

** conclusions and outlook

The SuperB physics case in 1 slide

- 75 ab^{-1} data sample collected at $\Upsilon(4S)$ in 5 years
- can be operated at lower energies (e.g. $\Psi(3770)$)
- the electron beam can be polarized (~80%)

- several NP-sensitive observables in B, D and τ physics not limited by systematic or th. errors
- enough NP-insensitive observables to pin down the SM contribution with the required precision

- access the NP flavor structure at the TeV scale
- unique probe of NP in the multi-TeV region up to hundreds TeV (with caveats of indirect searches)

F.A.Q. on SuperB "physics"

* Which are the SuperB competitors (besides the obvious one) ? What do they compete on ?

* What will be the landscape of flavor physics and the status of NP at the SuperB starting time ?

* What will remain of the SuperB physics program after the completion of today's experiments, both at the energy and intensity fronteers?

and so on…

Answering these FAQs involves several delicate issues, yet it can be attempted once rules are clearly spelled out:

- official schedules are used when available
- preliminary sensitivity studies are trusted (unless they are patently unreasonable)
- some guesswork is inevitably involved
- open issues are present and sometimes crucial

INFN/AE_11/1, LAL-11-200, SLAC-R-14548, MZ-TH/11-25

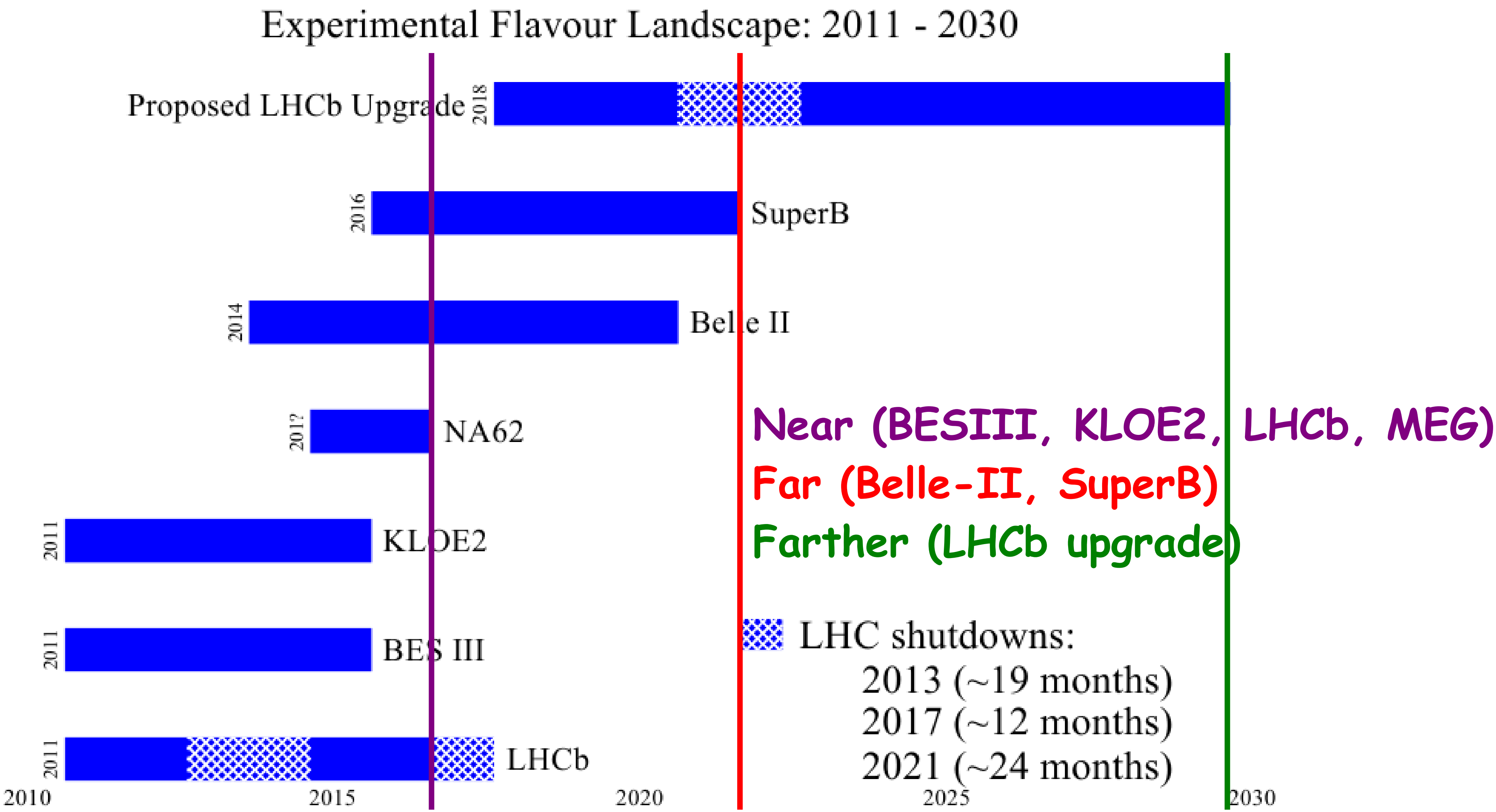
The impact of Super$B$ on flavour physics

July 1, 2011

Abstract

This report provides a succinct summary of the physics programme of Super$B$, and describes that potential in the context of experiments making measurements in flavour physics over the next 10 to 20 years. Detailed comparisons are made with Belle II and LHCb, the other B physics experiments that will run in this decade. SuperB will play a crucial role in defining the landscape of flavour physics over the next 20 years.

The timeline of flavor physics



Dates that matter are when full samples are collected

What SuperB cannot do*

Golden modes of other flavor experiments

Observable	Current value	Experiment	Precision
$\mathrm{BR}(B_s \to \mu\mu)$ $(\times 10^{-9})$	$<$ ~~15~~^{a} 4.5	LHCb	± 1
		LHCb upgrade	± 0.3
$2\beta_s$ from $B_s^0 \to J/\psi\phi$ (rad)	~~0.03 ± 0.19~~^{b} 0.002 0.038	LHCb	0.019
		LHCb upgrade	0.006
S in $B_s \to \phi\gamma$ *		LHCb	0.07
		LHCb upgrade	0.02
$K^+ \to \pi^+\nu\bar{\nu}$ (% BR measurement)	7 events	NA62	100 events (10%)
$K_L^0 \to \pi^0\nu\bar{\nu}$		KOTO	3 events (observe)
$BR(\mu \to e\gamma)$ $(\times 10^{-13})$	$<$ ~~280~~ 240	MEG	< 1
$R_{\mu e}$	$< 7 \times 10^{-12}$	COMET/Mu2E	$< 6 \times 10^{-17}$

* with competitive performances

SuperB physics in tables

arXiv:0709.0451, 0810.1312, 1008.1541

B_d physics @$\Upsilon(4S)$

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 (∗)
$S(K^0_S K^0_S K^0_S)$	0.15	0.02 (∗)
$S(K^0_S \pi^0)$	0.15	0.02 (∗)
$S(\omega K^0_S)$	0.17	0.03 (∗)
$S(f_0 K^0_S)$	0.12	0.02 (∗)
γ $(B \to DK,\, D \to CP$ eigenstates)	$\sim 15^\circ$	2.5°
γ $(B \to DK,\, D \to$ suppressed states)	$\sim 12^\circ$	2.0°
γ $(B \to DK,\, D \to$ multibody states)	$\sim 9^\circ$	1.5°
γ $(B \to DK$, combined)	$\sim 6^\circ$	1–2°
α $(B \to \pi\pi)$	$\sim 16^\circ$	3°
α $(B \to \rho\rho)$	$\sim 7^\circ$	1–2° (∗)
α $(B \to \rho\pi)$	$\sim 12^\circ$	2°
α (combined)	$\sim 6^\circ$	1–2° (∗)
$2\beta + \gamma$ $(D^{(*)\pm}\pi^\mp,\, D^\pm K^0_S \pi^\mp)$	20°	5°
$\lvert V_{cb}\rvert$ (exclusive)	4% (∗)	1.0% (∗)
$\lvert V_{cb}\rvert$ (inclusive)	1% (∗)	0.5% (∗)
$\lvert V_{ub}\rvert$ (exclusive)	8% (∗)	3.0% (∗)
$\lvert V_{ub}\rvert$ (inclusive)	8% (∗)	2.0% (∗)
$BR(B \to \tau\nu)$	20%	4% (†)
$BR(B \to \mu\nu)$	visible	5%
$BR(B \to D\tau\nu)$	10%	2%
$BR(B \to \rho\gamma)$	15%	3% (†)
$BR(B \to \omega\gamma)$	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	0.006 (†)
$S(K^0_S \pi^0 \gamma)$	0.15	0.02 (∗)
$S(\rho^0\gamma)$	possible	0.10
$A_{CP}(B \to K^*\ell\ell)$	7%	1%
$A^{FB}(B \to K^*\ell\ell)s_0$	25%	9%
$A^{FB}(B \to X_s\ell\ell)s_0$	35%	5%
$BR(B \to K\nu\overline{\nu})$	visible	20%
$BR(B \to \pi\nu\bar{\nu})$	–	possible

charm physics

Mode	Observable	B Factories (2 ab^{-1})	Super$B$ (75 ab^{-1})
$D^0 \to K^+K^-$	y_{CP}	2–3×10^{-3}	5×10^{-4}
$D^0 \to K^+\pi^-$	y'_D	2–3×10^{-3}	7×10^{-4}
	x'^2_D	1–2×10^{-4}	3×10^{-5}
$D^0 \to K^0_S\pi^+\pi^-$	y_D	2–3×10^{-3}	5×10^{-4}
	x_D	2–3×10^{-3}	5×10^{-4}
Average	y_D	1–2×10^{-3}	3×10^{-4}
	x_D	2–3×10^{-3}	5×10^{-4}

Channel	Sensitivity
$D^0 \to e^+e^-$, $D^0 \to \mu^+\mu^-$	1×10^{-8}
$D^0 \to \pi^0 e^+e^-$, $D^0 \to \pi^0\mu^+\mu^-$	2×10^{-8}
$D^0 \to \eta e^+e^-$, $D^0 \to \eta\mu^+\mu^-$	3×10^{-8}
$D^0 \to K^0_s e^+e^-$, $D^0 \to K^0_s\mu^+\mu^-$	3×10^{-8}
$D^+ \to \pi^+ e^+e^-$, $D^+ \to \pi^+\mu^+\mu^-$	1×10^{-8}
$D^0 \to e^\pm\mu^\mp$	1×10^{-8}
$D^+ \to \pi^+ e^\pm\mu^\mp$	1×10^{-8}
$D^0 \to \pi^0 e^\pm\mu^\mp$	2×10^{-8}
$D^0 \to \eta e^\pm\mu^\mp$	3×10^{-8}
$D^0 \to K^0_s e^\pm\mu^\mp$	3×10^{-8}
$D^+ \to \pi^- e^+e^+$, $D^+ \to K^- e^+e^+$	1×10^{-8}
$D^+ \to \pi^-\mu^+\mu^+$, $D^+ \to K^-\mu^+\mu^+$	1×10^{-8}
$D^+ \to \pi^- e^\pm\mu^\mp$, $D^+ \to K^- e^\pm\mu^\mp$	1×10^{-8}

Mode	Observable	$\Upsilon(4S)$ (75 ab^{-1})	$\psi(3770)$ (300 fb^{-1})	LHCb (10 fb^{-1})
$D^0 \to K^+\pi^-$	x'^2	3×10^{-5}		6×10^{-5}
	y'	7×10^{-4}		9×10^{-4}
$D^0 \to K^+K^-$	y_{CP}	5×10^{-4}		5×10^{-4}
$D^0 \to K^0_S\pi^+\pi^-$	x	4.9×10^{-4}		
	y	3.5×10^{-4}		
	$\lvert q/p\rvert$	3×10^{-2}		
	ϕ	2°		
$\psi(3770) \to D^0\overline{D}^0$	x^2		$(1-2) \times 10^{-5}$	
	y		$(1-2) \times 10^{-3}$	
	$\cos\delta$		$(0.01-0.02)$	

τ physics

Process	Sensitivity
$\mathcal{B}(\tau \to \mu\,\gamma)$	2×10^{-9}
$\mathcal{B}(\tau \to e\,\gamma)$	2×10^{-9}
$\mathcal{B}(\tau \to \mu\,\mu\,\mu)$	2×10^{-10}
$\mathcal{B}(\tau \to eee)$	2×10^{-10}
$\mathcal{B}(\tau \to \mu\eta)$	4×10^{-10}
$\mathcal{B}(\tau \to e\eta)$	6×10^{-10}
$\mathcal{B}(\tau \to \ell K^0_s)$	2×10^{-10}

+ τ FC physics (CPV, …)

+ EWP physics

+ Bs physics @$\Upsilon(5S)$

SuperB: a "treasure chest" of new physics-sensitive observables

SuperB "golden channels"

Observable/mode	Current now	LHCb (2017) $5\,\mathrm{fb}^{-1}$	Super$B$ (2021) $75\,\mathrm{ab}^{-1}$	Belle II (2021) $50\,\mathrm{ab}^{-1}$	LHCb upgrade (10 years of running) $50\,\mathrm{fb}^{-1}$	theory now
τ Decays						
$\tau \to \mu\gamma$ ($\times 10^{-9}$)	< 44		< 2.4	< 5.0		
$\tau \to e\gamma$ ($\times 10^{-9}$)	< 33		< 3.0	< 3.7 (est.)		
$\tau \to \ell\ell\ell$ ($\times 10^{-10}$)	$< 150 - 270$	< 244 [a]	$< 2.3 - 8.2$	< 10	< 24 [b]	
$B_{u,d}$ Decays						
$\mathrm{BR}(B \to \tau\nu)$ ($\times 10^{-4}$)	1.64 ± 0.34		0.05	0.04		1.1 ± 0.2
$\mathrm{BR}(B \to \mu\nu)$ ($\times 10^{-6}$)	< 1.0		0.02	0.03		0.47 ± 0.08
$\mathrm{BR}(B \to K^{*+}\nu\overline{\nu})$ ($\times 10^{-6}$)	< 80		1.1	2.0		6.8 ± 1.1
$\mathrm{BR}(B \to K^{+}\nu\overline{\nu})$ ($\times 10^{-6}$)	< 160		0.7	1.6		3.6 ± 0.5
$\mathrm{BR}(B \to X_s\gamma)$ ($\times 10^{-4}$)	3.55 ± 0.26		0.11	0.13	0.23	3.15 ± 0.23
$A_{CP}(B \to X_{(s+d)}\gamma)$	0.060 ± 0.060		0.02	0.02		$\sim 10^{-9}$
$B \to K^*\mu^+\mu^-$ (events)	250[c]	8000	10-15k[d]	7-10k	100,000	-
$\mathrm{BR}(B \to K^*\mu^+\mu^-)$ ($\times 10^{-6}$)	1.15 ± 0.16		0.06	0.07		1.19 ± 0.39
$B \to K^*e^+e^-$ (events)	165	400	10-15k	7-10k	5,000	-
$\mathrm{BR}(B \to K^*e^+e^-)$ ($\times 10^{-6}$)	1.09 ± 0.17		0.05	0.07		1.19 ± 0.39
$A_{FB}(B \to K^*\ell^+\ell^-)$	0.27 ± 0.14[e]	[f]	0.040	0.03		-0.089 ± 0.020
$B \to X_s\ell^+\ell^-$ (events)	280		8,600	7,000		-
$\mathrm{BR}(B \to X_s\ell^+\ell^-)$ ($\times 10^{-6}$)[g]	3.66 ± 0.77[h]		0.08	0.10		1.59 ± 0.11
S in $B \to K^0_S\pi^0\gamma$	-0.15 ± 0.20		0.03	0.03		-0.1 to 0.1
S in $B \to \eta' K^0$	0.59 ± 0.07		0.01	0.02		± 0.015
S in $B \to \phi K^0$	0.56 ± 0.17	0.15	0.02	0.03	0.03	± 0.02
B^0_s Decays						
$\mathrm{BR}(B^0_s \to \gamma\gamma)$ ($\times 10^{-6}$)	< 8.7		0.3	$0.2 - 0.3$		0.4 - 1.0
A^s_{SL} ($\times 10^{-3}$)	-7.87 ± 1.96 [i]	[j]	4.	5. (est.)		0.02 ± 0.01
D Decays						
x	$(0.63 \pm 0.20\%$	0.06%	0.02%	0.04%	0.02%	$\sim 10^{-2}$ [k]
y	$(0.75 \pm 0.12)\%$	0.03%	0.01%	0.03%	0.01%	$\sim 10^{-2}$ (see above).
y_{CP}	$(1.11 \pm 0.22)\%$	0.05%	0.03%	0.05%	0.01%	$\sim 10^{-2}$ (see above).
$\lvert q/p \rvert$	$(0.91 \pm 0.17)\%$	10%	2.7%	3.0%	3%	$\sim 10^{-3}$ (see above).
$\arg\{q/p\}$ ($^\circ$)	-10.2 ± 9.2	5.6	1.4	1.4	2.0	$\sim 10^{-3}$ (see above).
Other processes Decays						
$\sin^2\theta_W$ at $\sqrt{s} = 10.58\,\mathrm{GeV}/c^2$			0.0002	[l]		clean

SuperB golden channels

τ physics

Observable/mode	Current now	LHCb (2017) $5\,\mathrm{fb}^{-1}$	Super$B$ (2021) $75\,\mathrm{ab}^{-1}$	Belle II (2021) $50\,\mathrm{ab}^{-1}$	LHCb upgrade (10 years of running) $50\,\mathrm{fb}^{-1}$	theory now
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$\tau \to e\gamma$ $(\times 10^{-9})$	< 33		< 3.0	< 3.7 (est.)		
$\tau \to \ell\ell\ell$ $(\times 10^{-10})$	$< 150 - 270$	< 244 [a]	$< 2.3 - 8.2$	< 10	< 24 [b]	
$\mathrm{BR}(B \to X_s \ell^+\ell^-)$ $(\times 10^{-6})$[g]	3.66 ± 0.77[h]		0.08	0.10		1.59 ± 0.11
S in $B \to K_S^0 \pi^0 \gamma$	-0.15 ± 0.20		0.03	0.03		-0.1 to 0.1
S in $B \to \eta' K^0$	0.59 ± 0.07		0.01	0.02		± 0.015
S in $B \to \phi K^0$	0.56 ± 0.17	0.15	0.02	0.03	0.03	± 0.02
B_s^0 Decays						
$\mathrm{BR}(B_s^0 \to \gamma\gamma)$ $(\times 10^{-6})$	< 8.7		0.3	$0.2 - 0.3$		0.4 - 1.0
A_{SL}^s $(\times 10^{-3})$	-7.87 ± 1.96 [i]	[j]	4.	5. (est.)		0.02 ± 0.01
D Decays						
x	$(0.63 \pm 0.20\%$	0.06%	0.02%	0.04%	0.02%	$\sim 10^{-2}$ [k]
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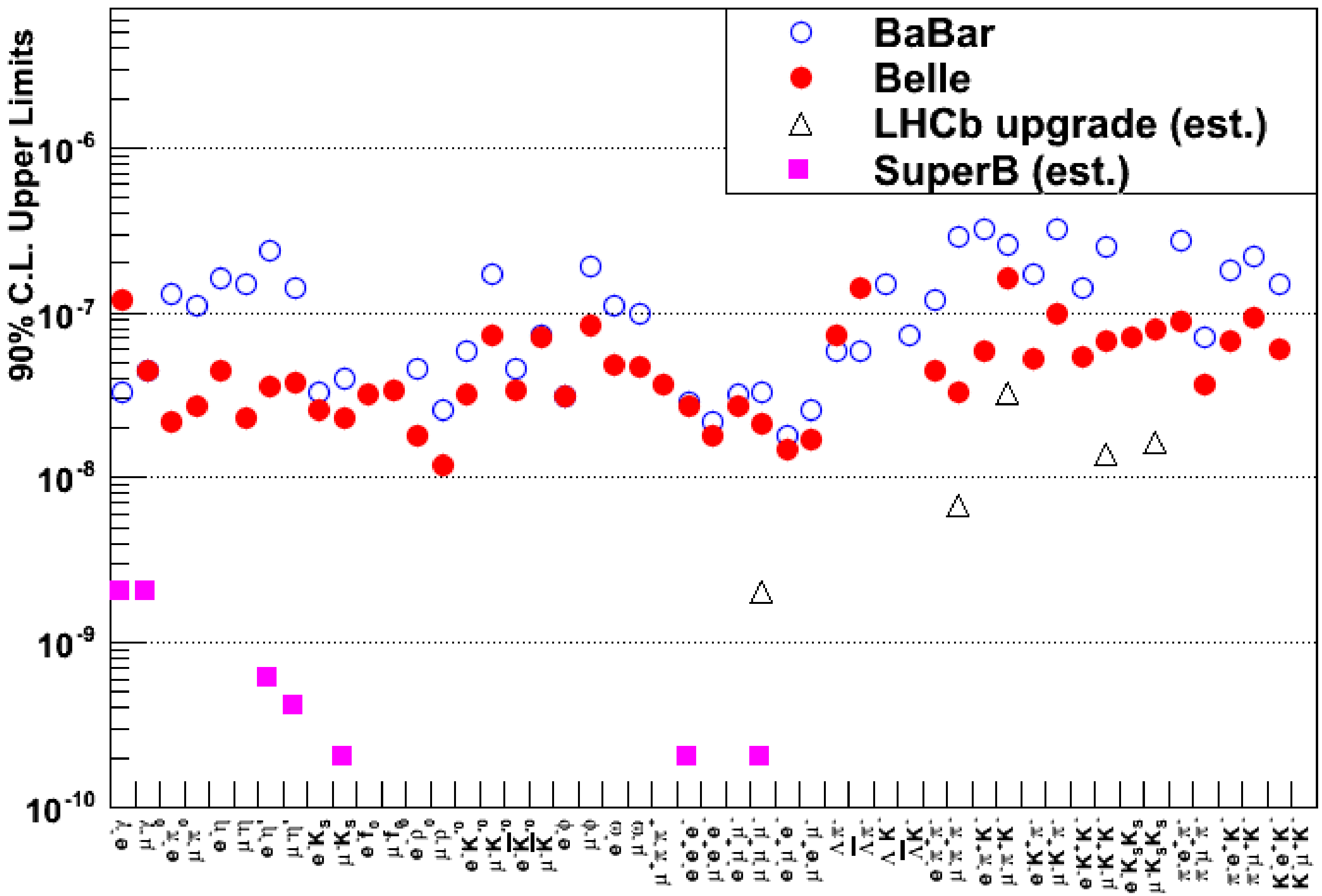
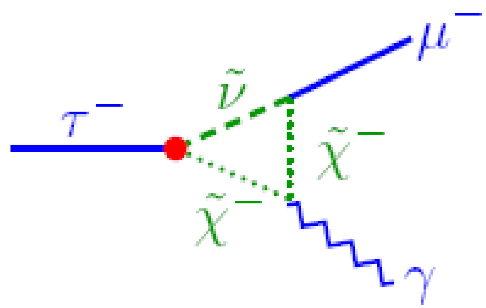
Other processes Decays						
$\sin^2\theta_W$ at $\sqrt{s} = 10.58\,\mathrm{GeV}/c^2$			0.0002	[l]		clean

τ flavor violation

$\tau \to \mu\gamma, 3\mu$



- negligible BRs in the SM
- BSM can be substantially enhanced



Lepton MFV GUT models

Isidori, 4th SuperB workshop

complementary with MEG

$B(\tau \to \mu\gamma):B(\tau \to e\gamma):B(\mu \to e\gamma) \sim \lambda^{-6}:\lambda^{-4}:1 \sim 10^4:500:1$ ← **LFV from CKM**

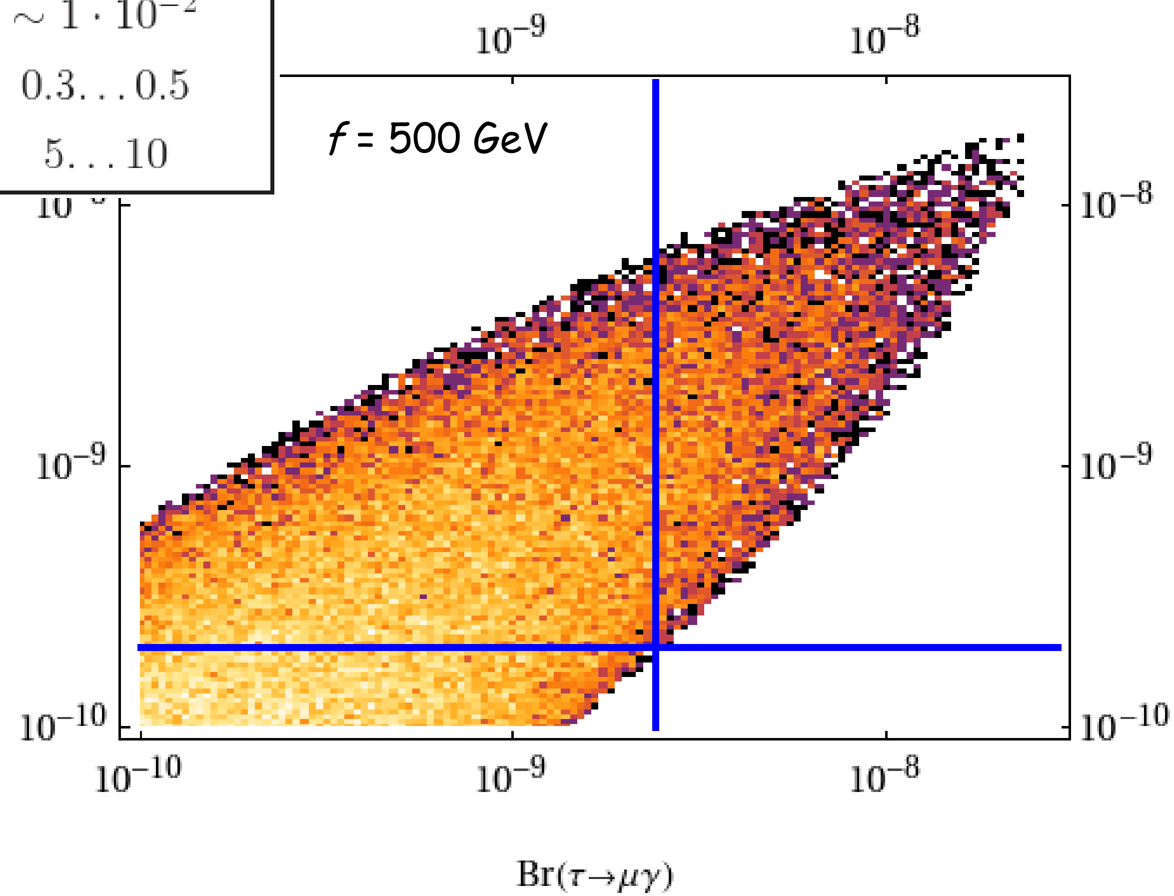
$B(\tau \to \mu\gamma):B(\tau \to e\gamma):B(\mu \to e\gamma) \sim [500\text{–}10]:1:1$ ← **LFV from PMNS**

τFV in the Littlest Higgs model with T-parity

ratio	LHT	MSSM (dipole)	MSSM (Higgs)
$\frac{\mathcal{B}(\tau^- \to e^- e^+ e^-)}{\mathcal{B}(\tau \to e\gamma)}$	$0.4 \ldots 2.3$	$\sim 1 \cdot 10^{-2}$	$\sim 1 \cdot 10^{-2}$
$\frac{\mathcal{B}(\tau^- \to \mu^- \mu^+ \mu^-)}{\mathcal{B}(\tau \to \mu\gamma)}$	$0.4 \ldots 2.3$	$\sim 2 \cdot 10^{-3}$	$0.06 \ldots 0.1$
$\frac{\mathcal{B}(\tau^- \to e^- \mu^+ \mu^-)}{\mathcal{B}(\tau \to e\gamma)}$	$0.3 \ldots 1.6$	$\sim 2 \cdot 10^{-3}$	$0.02 \ldots 0.04$
$\frac{\mathcal{B}(\tau^- \to \mu^- e^+ e^-)}{\mathcal{B}(\tau \to \mu\gamma)}$	$0.3 \ldots 1.6$	$\sim 1 \cdot 10^{-2}$	$\sim 1 \cdot 10^{-2}$
$\frac{\mathcal{B}(\tau^- \to e^- e^+ e^-)}{\mathcal{B}(\tau^- \to e^- \mu^+ \mu^-)}$	$1.3 \ldots 1.7$	~ 5	$0.3 \ldots 0.5$
$\frac{\mathcal{B}(\tau^- \to \mu^- \mu^+ \mu^-)}{\mathcal{B}(\tau^- \to \mu^- e^+ e^-)}$	$1.2 \ldots 1.6$	~ 0.2	$5 \ldots 10$

M. Blanke et al. arXiv:0906.5454

$BR(\tau \to \ell\ell\ell)/BR(\tau \to \ell\gamma)$ is not suppressed by α_e in LHT



LFV is a powerful tool to disentangle LHT and e.g. MSSM

SuperB golden channels
Bd/Bu physics

Observable/mode	Current now	LHCb (2017) 5 fb^{-1}	Super$B$ (2021) 75 ab^{-1}	Belle II (2021) 50 ab^{-1}	LHCb upgrade (10 years of running) 50 fb^{-1}	theory now
			$B_{u,d}$ Decays			
$BR(B \to \tau\nu)$ $(\times 10^{-4})$	1.64 ± 0.34		0.05	0.04		1.1 ± 0.2
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$BR(B \to X_s\gamma)$ $(\times 10^{-4})$	3.55 ± 0.26		0.11	0.13	0.23	3.15 ± 0.23
$A_{CP}(B \to X_{(s+d)}\gamma)$	0.060 ± 0.060		0.02	0.02		$\sim 10^{-6}$
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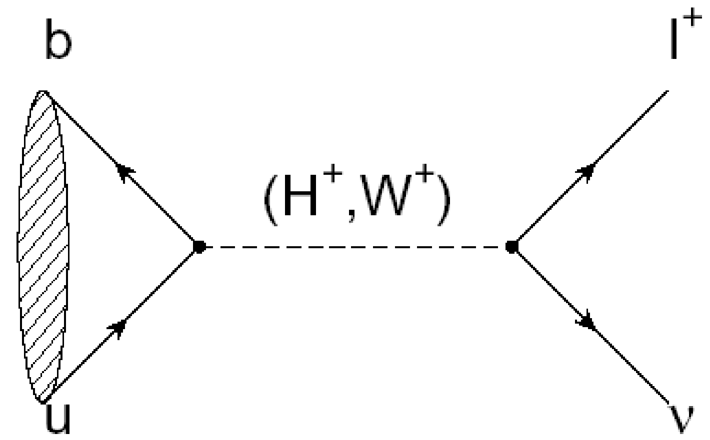
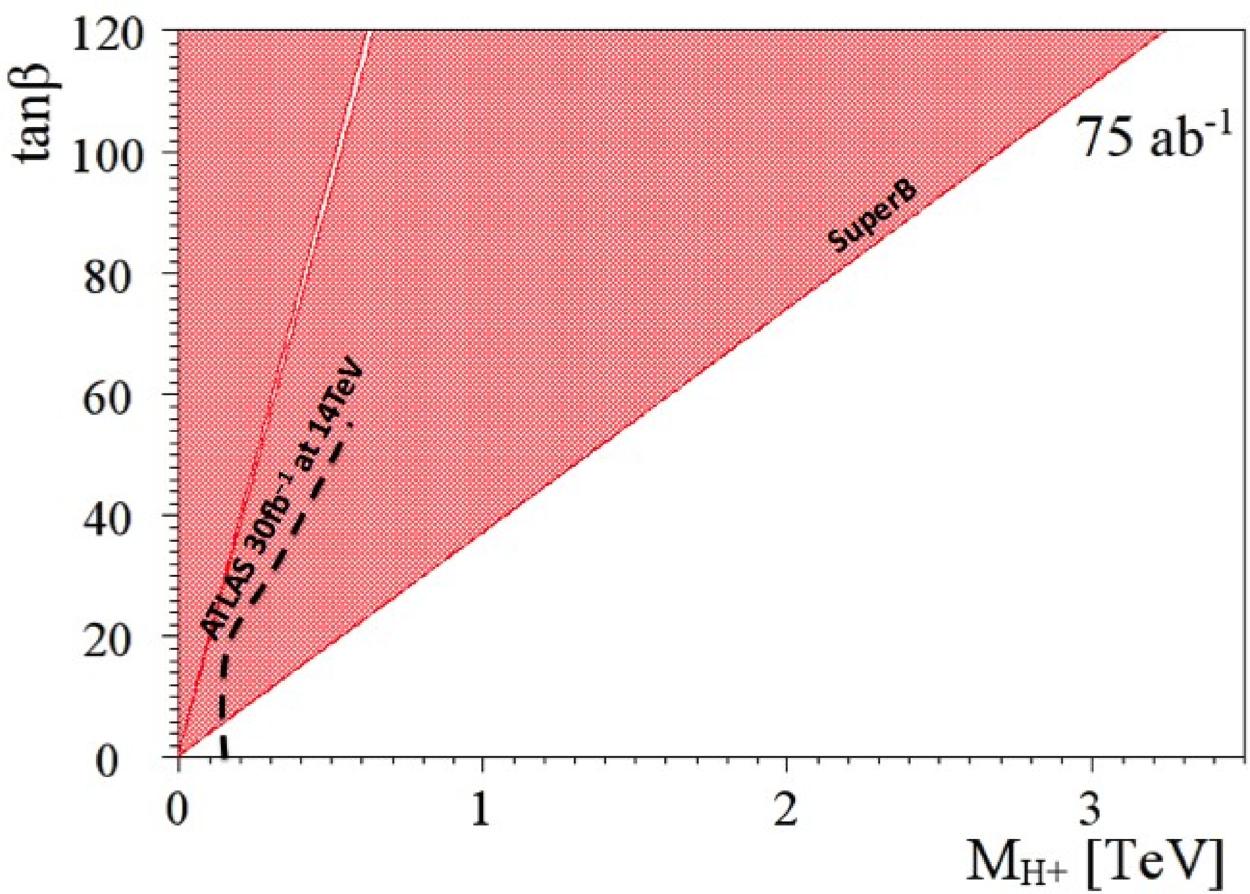
S in $B \to \eta' K^0$	0.59 ± 0.07		0.01	0.02		± 0.015
S in $B \to \phi K^0$	0.56 ± 0.17	0.15	0.02	0.03	0.03	± 0.02

			Other processes Decays			
$\sin^2\theta_W$ at $\sqrt{s} = 10.58\,\mathrm{GeV}/c^2$			0.0002	[l]		clean

B physics: Rare decays

- Example: $B^{\pm} \to \ell^{\pm} \nu$
  - decay rate modified by charged Higgs exchange





$$r_H = \frac{B_{SM+NP}}{B_{SM}}$$

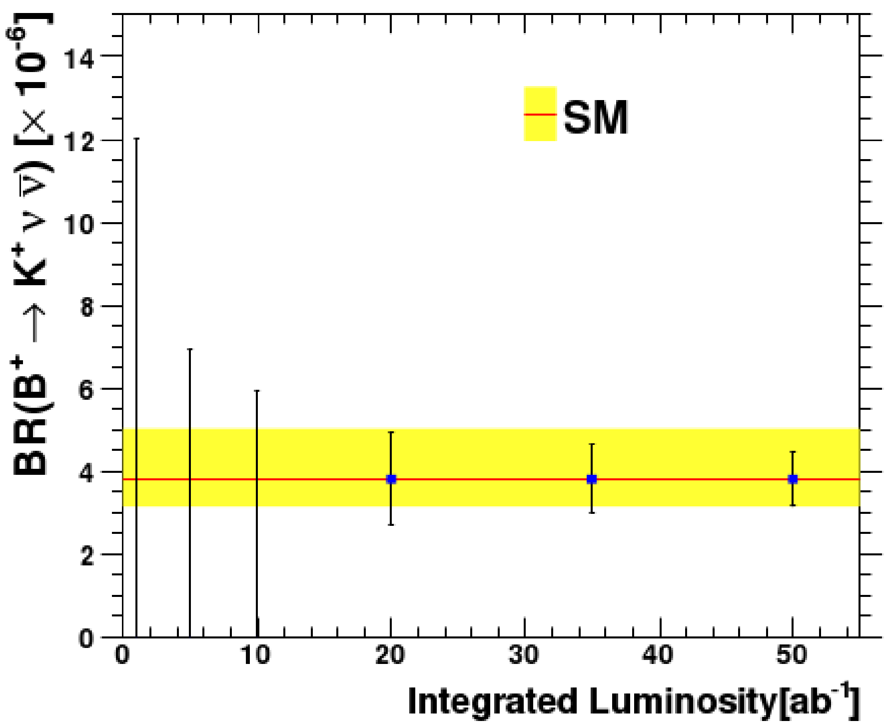
$$r_H = \left(1 - \frac{m_B^2}{m_H^2} \tan^2 \beta\right)$$

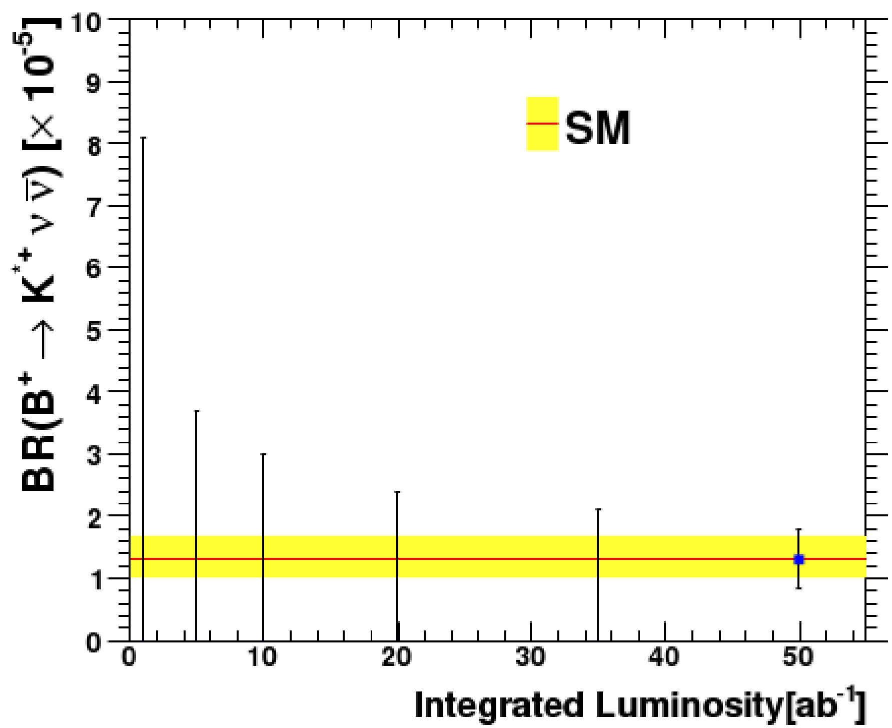
B physics: FCNC

- Example: $B \to K^{(*)}\nu\bar{\nu}$
  - need 75ab^{-1} to observe pseudoscalar and vector modes
  - with more than 75ab^{-1} we could measure polarisation

A SuperB-only problem

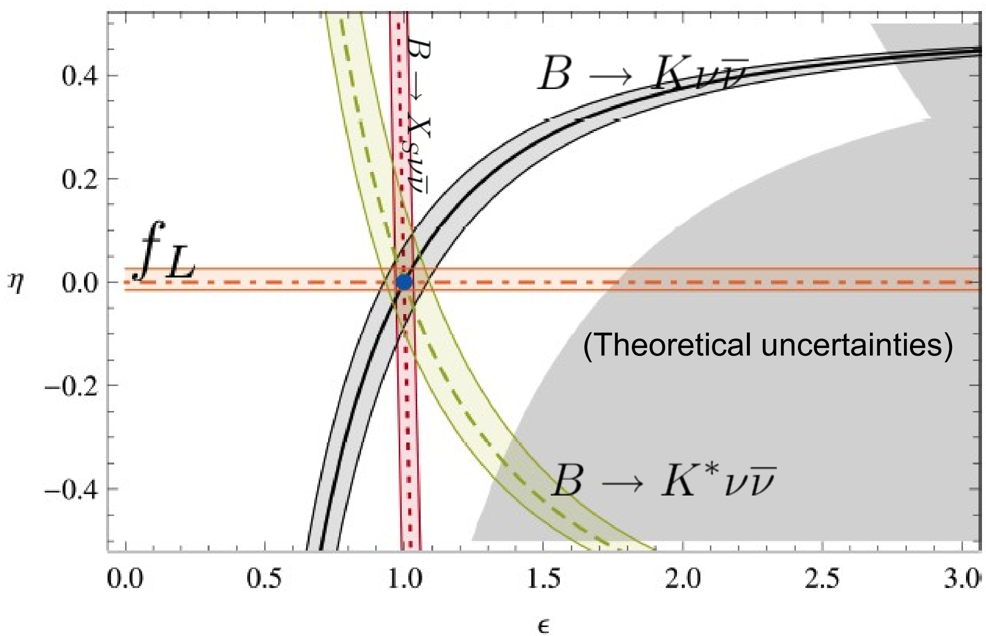
SuperB Workshop VI, arXiv:0810.1312



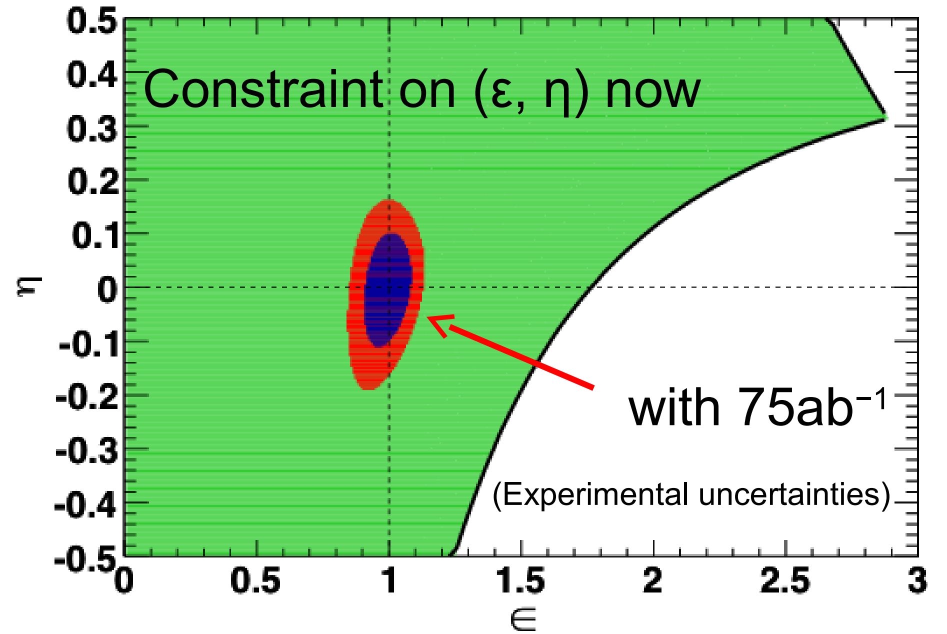


- Model-independent parametrisation

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



Altmannshofer et al, arXiv:0902.0160



- affected by models with Z', RH currents and light scalar particles
- together with b → s γ and b → s ℓℓ, allow to disentangle NP effects in magnetic dipole & Z penguin/box transitions

MSSM: flavour violation in the squark sector

LHCb, SuperB

$$M^2_{\tilde d} \approx \begin{pmatrix} m^2_{\tilde d_L} & m_d(A_d - \mu\tan\beta) & (\Delta^d_{12})_{LL} & (\Delta^d_{12})_{LR} & (\Delta^d_{13})_{LL} & (\Delta^d_{13})_{LR} \\ & m^2_{\tilde d_R} & (\Delta^d_{12})_{RL} & (\Delta^d_{12})_{RR} & (\Delta^d_{13})_{RL} & (\Delta^d_{13})_{RR} \\ & & m^2_{\tilde s_L} & m_s(A_s - \mu\tan\beta) & (\Delta^d_{23})_{LL} & (\Delta^d_{23})_{LR} \\ & & & m^2_{\tilde s_R} & (\Delta^d_{23})_{RL} & (\Delta^d_{23})_{RR} \\ & & & & m^2_{\tilde b_L} & m_b(A_b - \mu\tan\beta) \\ & & & & & m^2_{\tilde b_R} \end{pmatrix}$$

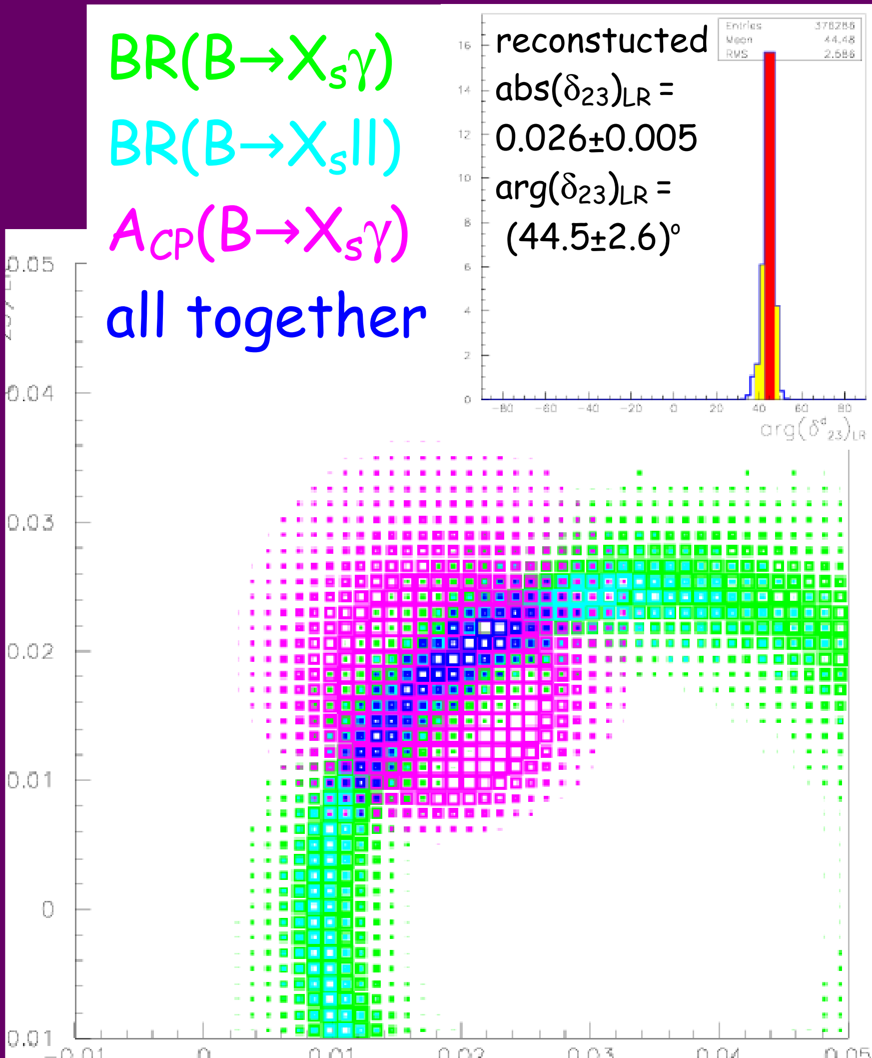
LHC, ILC - HE frontier

and similarly for $M^2_{\tilde u}$

NP scale: $m_{\tilde q}$

FV & CPV couplings: $(\delta^d_{ij})_{AB} = (\Delta^d_{ij})_{AB}/m^2_{\tilde q}$

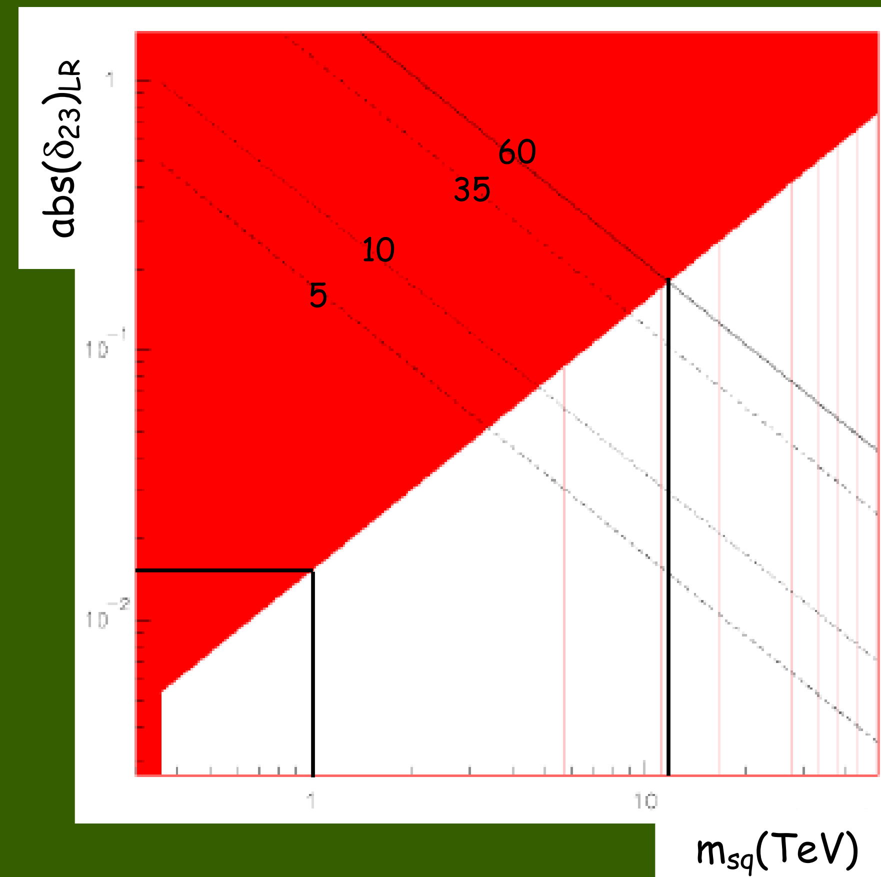
Determination of $(\delta^d_{23})_{LR}$ using SuperB data



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

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

"3σ" sensitivity plot



i) sensitive to $m_{\tilde{q}} < 20$ TeV

ii) sensitive to $|(\delta^d_{23})_{LR}| > 10^{-2}$ for $m_{\tilde{q}} < 1$ TeV

OVERALL SUSY ASSESSMENT

Studying correlations in flavour observables, together with high-p_T info, we can learn about:

- * the SUSY-breaking mechanism
- * the flavour breaking mechanism
- * the underlying presence of a GUT structure
- * the origin of lepton flavour violation

more information in arXiv:1008.1541, arXiv:0909.1333, and arXiv:0810.1312

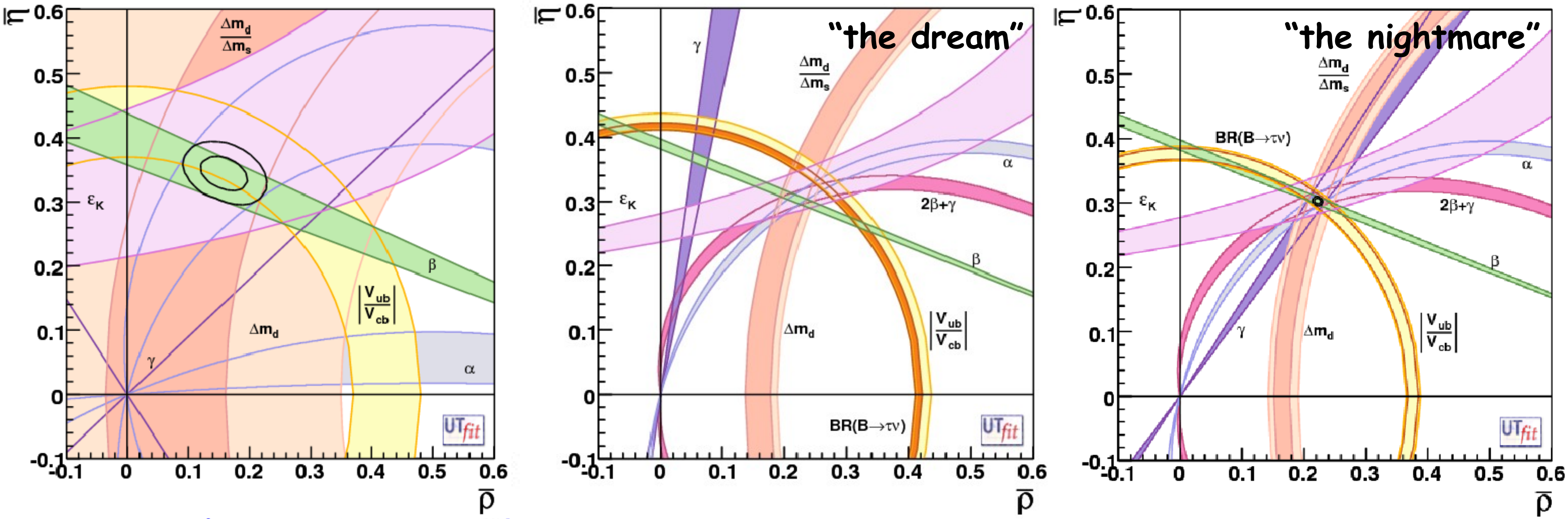
Observable/mode	charged Higgs high $\tan\beta$	MFV NP low $\tan\beta$	non-MFV NP 2-3 sector	NP in Z penguins	Right-handed currents	LHT	SUSY AC	SUSY RVV2	SUSY AKM	SUSY δLL	SUSY FBMSSM	SUSY GUT-CMM
$\tau \to \mu\gamma$							***	***	*	***	***	***
$\tau \to \ell\ell\ell$						***						?
$B \to \tau\nu, \mu\nu$	***(CKM)											
$B \to K^{(*)+}\nu\overline{\nu}$			*	***			*	*	*	*	*	?
S in $B \to K_S^0\pi^0\gamma$			**		***							
S in other penguin modes			***(CKM)		***		***	**	*	***	***	?
$A_{CP}(B \to X_s\gamma)$			***		**		*	*	*	***	***	?
$BR(B \to X_s\gamma)$		*	**		*							**
$BR(B \to X_s\ell\ell)$			**	*	*							?
$B \to K^{(*)}\ell\ell$ (FB Asym)							*	*	*	***	***	?
a_{sl}^s			***			***						***
Charm mixing							***	*	*	*	*	
CPV in Charm	**									***		

Precision CKM measurement at SuperB

Observable/mode	Current now	LHCb (2017)	Super$B$ (2021)	Belle II (2021)	LHCb upgrade (10 years of running)	theory now
		$5\,\text{fb}^{-1}$	$75\,\text{ab}^{-1}$	$50\,\text{ab}^{-1}$	$50\,\text{fb}^{-1}$	
α from $u\overline{u}d$	6.1°	$5^{\circ\,a}$	1°	1°	^{b}	$1-2^\circ$
β from $c\overline{c}s$ (S)	0.9° (0.024)	0.5° (0.008)	0.1° (0.002)	0.3° (0.007)	0.2° (0.003)	clean
S from $B_d \to J/\psi\pi^0$	0.21		0.014	0.021 (est.)		clean
S from $B_s \to J/\psi K^0_S$		?			?	clean
γ from $B \to DK$	11°	$\sim 4^\circ$	1°	1.5°	0.9°	clean
$\|V_{cb}\|$ (inclusive) %	1.7		0.5%	0.6 (est.)		dominant
$\|V_{cb}\|$ (exclusive) %	2.2		1.0%	1.2 (est.)		dominant
$\|V_{ub}\|$ (inclusive) %	4.4		2.0%	3.0		dominant
$\|V_{ub}\|$ (exclusive) %	7.0		3.0%	5.0		dominant

Overture: CKM matrix at 1%

Today | **with SuperB in 2022**



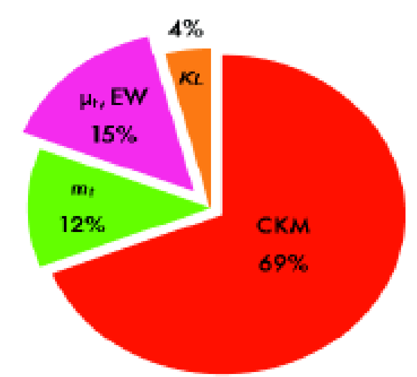
Generalized UT fits:
CKM at 1% in the presence of NP!

	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 at SuperB!)

error budget

$K_L \to \pi^0 \nu \bar\nu$



U. Haisch, Kaon '07

SuperB golden channels
Bs physics

Observable/mode	Current now	LHCb (2017) 5 fb^{-1}	Super$B$ (2021) 75 ab^{-1}	Belle II (2021) 50 ab^{-1}	LHCb upgrade (10 years of running) 50 fb^{-1}	theory now
τ Decays						
$\tau \to \mu\gamma$ ($\times 10^{-9}$)	< 44		< 2.4	< 5.0		
$\tau \to e\gamma$ ($\times 10^{-9}$)	< 33		< 3.0	< 3.7 (est.)		
$\tau \to \ell\ell\ell$ ($\times 10^{-10}$)	$< 150 - 270$	< 244 [a]	$< 2.3 - 8.2$	< 10	< 24 [b]	
$B_{u,d}$ Decays						
BR($B \to \tau\nu$) ($\times 10^{-4}$)	1.64 ± 0.34		0.05	0.04		1.1 ± 0.2
BR($B \to \mu\nu$) ($\times 10^{-6}$)	< 1.0		0.02	0.03		0.47 ± 0.08
BR($B \to X_s\ell^+\ell^-$) ($\times 10^{-6}$)[g]	3.66 ± 0.77[h]		0.08	0.10		1.59 ± 0.11
S in $B \to K_S^0\pi^0\gamma$	-0.15 ± 0.20		0.03	0.03		-0.1 to 0.1
S in $B \to \eta' K^0$	0.59 ± 0.07		0.01	0.02		± 0.015
S in $B \to \phi K^0$	0.56 ± 0.17	0.15	0.02	0.03	0.03	± 0.02
B_s^0 Decays						
BR($B_s^0 \to \gamma\gamma$) ($\times 10^{-6}$)	< 8.7		0.3	$0.2 - 0.3$		0.4 - 1.0
A_{SL}^s ($\times 10^{-3}$)	-7.87 ± 1.96 [i]	[j]	4.	5. (est.)		0.02 ± 0.01
D Decays						
x	$(0.63 \pm 0.20\%$	0.06%	0.02%	0.04%	0.02%	$\sim 10^{-2}$ [k]
y	$(0.75 \pm 0.12)\%$	0.03%	0.01%	0.03%	0.01%	$\sim 10^{-2}$ (see above).
y_{CP}	$(1.11 \pm 0.22)\%$	0.05%	0.03%	0.05%	0.01%	$\sim 10^{-2}$ (see above).
$\lvert q/p \rvert$	$(0.91 \pm 0.17)\%$	10%	2.7%	3.0%	3%	$\sim 10^{-3}$ (see above).
arg$\{q/p\}$ ($^\circ$)	-10.2 ± 9.2	5.6	1.4	1.4	2.0	$\sim 10^{-3}$ (see above).
Other processes Decays						
$\sin^2\theta_W$ at $\sqrt{s} = 10.58\,\mathrm{GeV}/c^2$			0.0002	[l]		clean

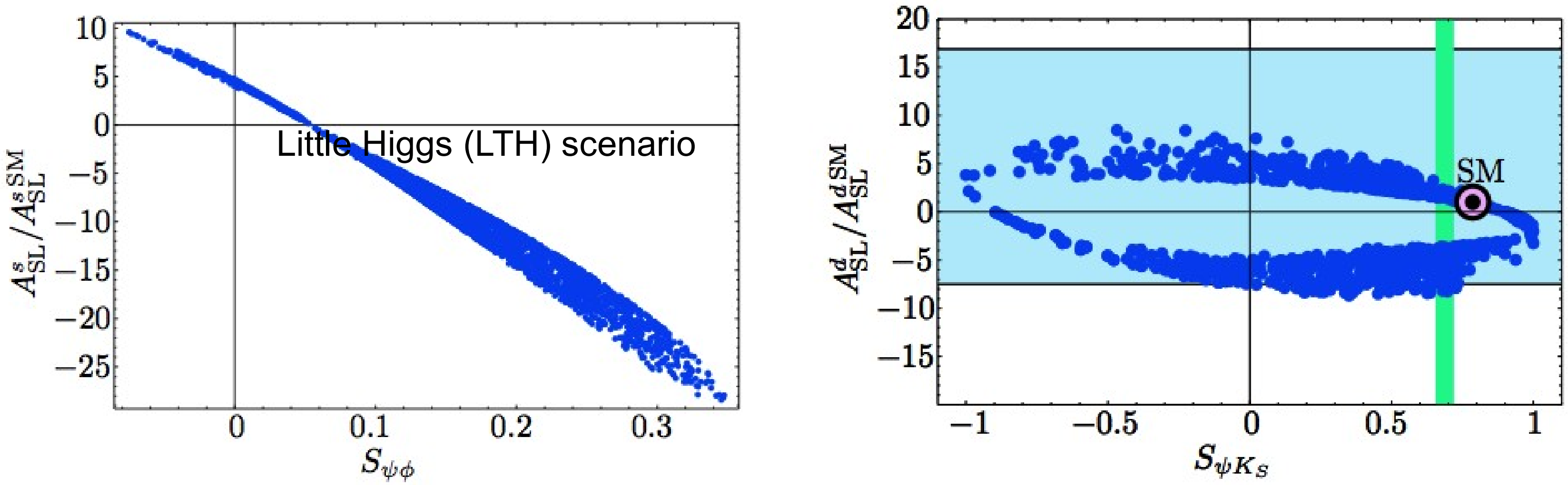
Observable/mode	Current now	LHCb (2017) 5 fb^{-1}	Super$B$ (2021) 75 ab^{-1}	Belle II (2021) 50 ab^{-1}	LHCb upgrade (10 years of running) 50 fb^{-1}	theory now
B_s^0 Decays						
BR($B_s^0 \to \gamma\gamma$) ($\times 10^{-6}$)	< 8.7		0.3	$0.2 - 0.3$		0.4 - 1.0
A_{SL}^s ($\times 10^{-3}$)	-7.87 ± 1.96 [i]	[j]	4.	5. (est.)		0.02 ± 0.01

B_s physics

- can cleanly measure A^s_{SL} using 5S data

$$A^s_{SL} = \frac{\mathcal{B}(B_s \to \overline{B}_s \to X^- \ell^+ \nu_\ell) - \mathcal{B}(\overline{B}_s \to B_s \to X^- \ell^+ \nu_\ell)}{\mathcal{B}(B_s \to \overline{B}_s \to X^- \ell^+ \nu_\ell) + \mathcal{B}(\overline{B}_s \to B_s \to X^- \ell^+ \nu_\ell)} = \frac{1 - |q/p|^4}{1 - |q/p|^4}$$

$$\sigma(A^s_{SL}) \sim 0.004 \text{ with a few } ab^{-1}$$



- SuperB can also study rare decays with many neutral particles, such as Bs → γγ, which can be enhanced by NP
- Normalization for absolute BRs at LHCb(-upgrade)?

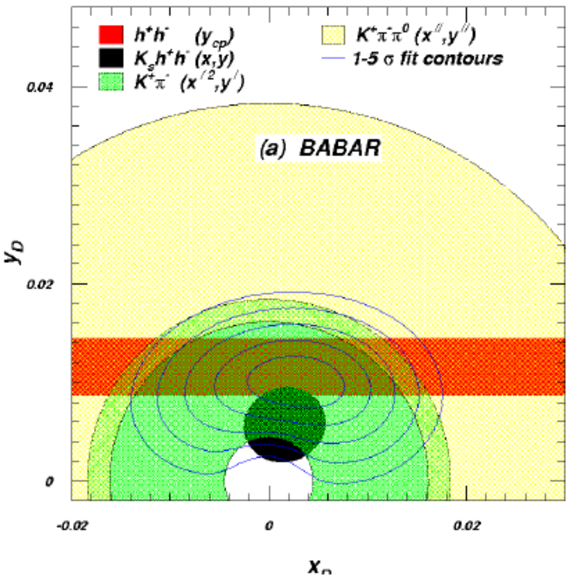
SuperB golden channels
D physics

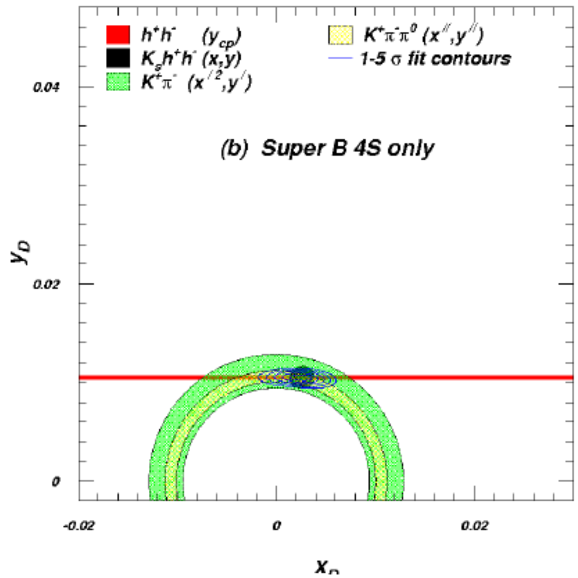
τ Decays						
$\tau \to \mu\gamma$ ($\times 10^{-9}$)	< 44		< 2.4	< 5.0		
$\tau \to e\gamma$ ($\times 10^{-9}$)	< 33		< 3.0	< 3.7 (est.)		
$\tau \to \ell\ell\ell$ ($\times 10^{-10}$)	$< 150 - 270$	< 244 [a]	$< 2.3 - 8.2$	< 10	< 24 [b]	
$B_{u,d}$ Decays						
BR($B \to \tau\nu$) ($\times 10^{-4}$)	1.64 ± 0.34		0.05	0.04		1.1 ± 0.2

Observable/mode	Current now	LHCb (2017) $5\,\text{fb}^{-1}$	Super$B$ (2021) $75\,\text{ab}^{-1}$	Belle II (2021) $50\,\text{ab}^{-1}$	LHCb upgrade (10 years of running) $50\,\text{fb}^{-1}$	theory now
D Decays						
x	$(0.63 \pm 0.20\%$	0.06%	0.02%	0.04%	0.02%	$\sim 10^{-2}$ [k]
y	$(0.75 \pm 0.12)\%$	0.03%	0.01%	0.03%	0.01%	$\sim 10^{-2}$ (see above).
y_{CP}	$(1.11 \pm 0.22)\%$	0.02%	0.03%	0.05%	0.01%	$\sim 10^{-2}$ (see above).
$\|q/p\|$	$(0.91 \pm 0.17)\%$	8.5%	2.7%	3.0%	3%	$\sim 10^{-3}$ (see above).
$\arg\{q/p\}$ ($^\circ$)	-10.2 ± 9.2	4.4	1.4	1.4	2.0	$\sim 10^{-3}$ (see above).

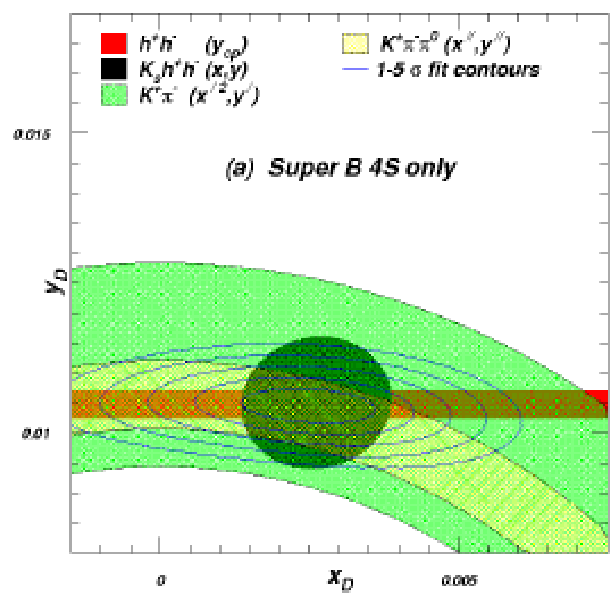
B_s^0 Decays						
BR($B_s^0 \to \gamma\gamma$) ($\times 10^{-6}$)	< 8.7		0.3	$0.2 - 0.3$		0.4 - 1.0
A_{SL}^s ($\times 10^{-3}$)	-7.87 ± 1.96 [i]	[j]	4.	5. (est.)		0.02 ± 0.01
D Decays						
x	$(0.63 \pm 0.20\%$	0.06%	0.02%	0.04%	0.02%	$\sim 10^{-2}$ [k]
y	$(0.75 \pm 0.12)\%$	0.03%	0.01%	0.03%	0.01%	$\sim 10^{-2}$ (see above).
y_{CP}	$(1.11 \pm 0.22)\%$	0.05%	0.03%	0.05%	0.01%	$\sim 10^{-2}$ (see above).
$\|q/p\|$	$(0.91 \pm 0.17)\%$	10%	2.7%	3.0%	3%	$\sim 10^{-3}$ (see above).
$\arg\{q/p\}$ ($^\circ$)	-10.2 ± 9.2	5.6	1.4	1.4	2.0	$\sim 10^{-3}$ (see above).
Other processes Decays						
$\sin^2\theta_W$ at $\sqrt{s} = 10.58\,\text{GeV}/c^2$			0.0002	[l]		clean

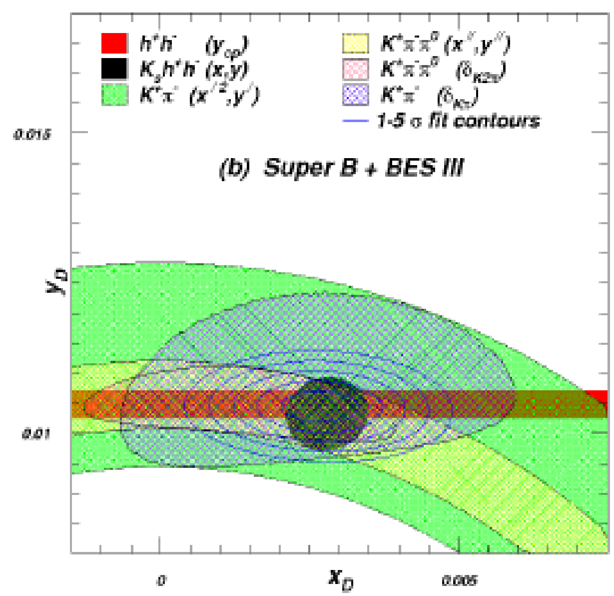
Charm mixing

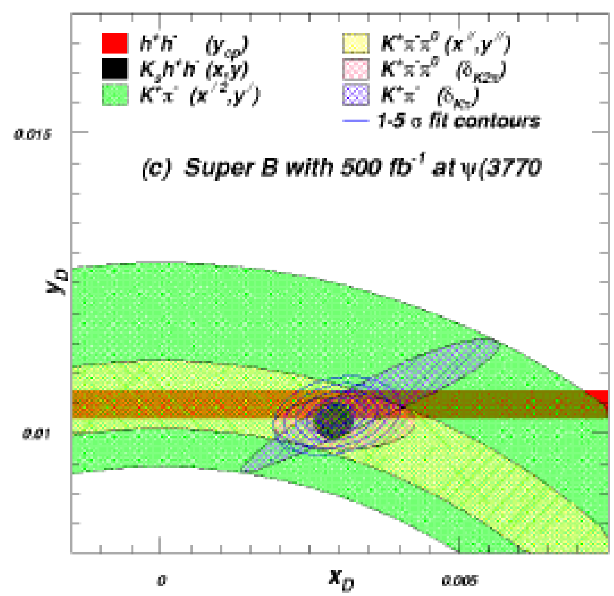




Fit	$x \times 10^3$	$y \times 10^3$	$\delta^{\circ}_{K^+\pi^-}$	$\delta^{\circ}_{K^+\pi^-\pi^0}$
(a)	$3.01^{+3.12}_{-3.39}$	$10.10^{+1.69}_{-1.72}$	$41.3^{+22.0}_{-24.0}$	43.8 ± 26.4
Stat.	(2.76)	(1.36)	(18.8)	(22.4)
(b)	$xxx^{+0.72}_{-0.75}$	$xxx \pm 0.19$	$xxx^{+3.7}_{-3.4}$	$xxx^{+4.6}_{-4.5}$
Stat.	(0.18)	(0.11)	(1.3)	(2.9)
(c)	$xxx \pm 0.42$	$xxx \pm 0.17$	$xxx \pm 2.2$	$xxx^{+3.3}_{-3.4}$
Stat.	(0.18)	(0.11)	(1.3)	(2.7)
(d)	$xxx \pm 0.20$	$xxx \pm 0.12$	$xxx \pm 1.0$	$xxx \pm 1.1$
Stat.	(0.17)	(0.10)	(0.9)	(1.1)







SuperB golden channels
EW physics

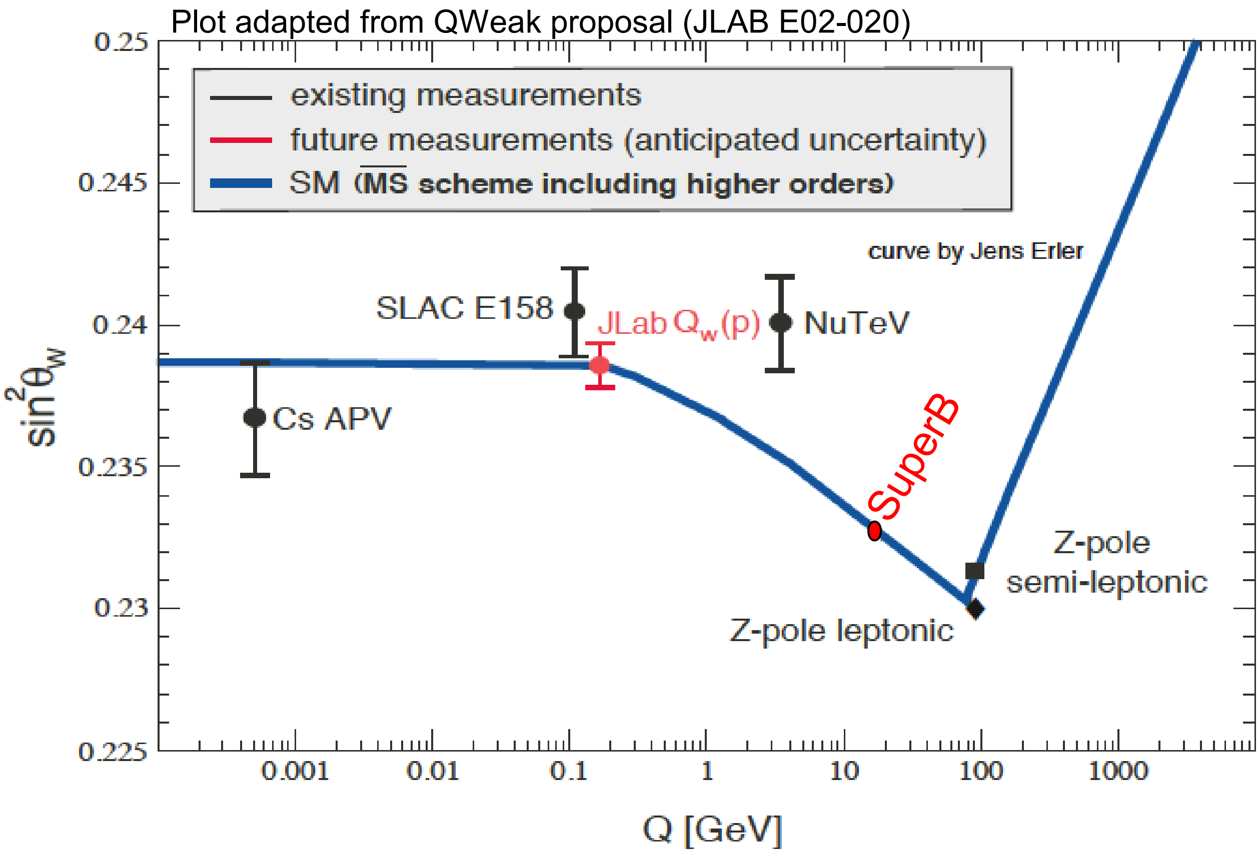
Observable/mode	Current now	LHCb (2017) $5\,\mathrm{fb}^{-1}$	Super$B$ (2021) $75\,\mathrm{ab}^{-1}$	Belle II (2021) $50\,\mathrm{ab}^{-1}$	LHCb upgrade (10 years of running) $50\,\mathrm{fb}^{-1}$	theory now
			τ Decays			
$\tau \to \mu\gamma$ $(\times 10^{-9})$	< 44		< 2.4	< 5.0		
$\tau \to e\gamma$ $(\times 10^{-9})$	< 33		< 3.0	< 3.7 (est.)		
$\tau \to \ell\ell\ell$ $(\times 10^{-10})$	$< 150 - 270$	< 244 [a]	$< 2.3 - 8.2$	< 10	< 24 [b]	
			$B_{u,d}$ Decays			
$\mathrm{BR}(B \to \tau\nu)$ $(\times 10^{-4})$	1.64 ± 0.34		0.05	0.04		1.1 ± 0.2
$\mathrm{BR}(B \to \mu\nu)$ $(\times 10^{-6})$	< 1.0		0.02	0.03		0.47 ± 0.08
$\mathrm{BR}(B \to K^{*+}\nu\overline{\nu})$ $(\times 10^{-6})$	< 80		1.1	2.0		6.8 ± 1.1
$\mathrm{BR}(B \to K^{+}\nu\overline{\nu})$ $(\times 10^{-6})$	< 160		0.7	1.6		3.6 ± 0.5
$\mathrm{BR}(B \to X_s\gamma)$ $(\times 10^{-4})$	3.55 ± 0.26		0.11	0.13	0.23	3.15 ± 0.23
$A_{CP}(B \to X_{(s+d)}\gamma)$	0.060 ± 0.060		0.02	0.02		$\sim 10^{-9}$
$B \to K^*\mu^+\mu^-$ (events)	250[c]	8000	10-15k[d]	7-10k	100,000	-
$\mathrm{BR}(B \to K^*\mu^+\mu^-)$ $(\times 10^{-6})$	1.15 ± 0.16		0.06	0.07		1.19 ± 0.39
$B \to K^*e^+e^-$ (events)	165	400	10-15k	7-10k	5,000	-
$\mathrm{BR}(B \to K^*e^+e^-)$ $(\times 10^{-6})$	1.09 ± 0.17		0.05	0.07		1.19 ± 0.39
$A_{FB}(B \to K^*\ell^+\ell^-)$	0.27 ± 0.14[e]	[f]	0.040	0.03		-0.089 ± 0.020
$B \to X_s\ell^+\ell^-$ (events)	280		8,600	7,000		-
y_{CP}	$(1.11 \pm 0.22)\%$	0.05%	0.03%	0.05%	0.01%	$\sim 10^{-2}$ (see above).
$\lvert q/p\rvert$	$(0.91 \pm 0.17)\%$	10%	2.7%	3.0%	3%	$\sim 10^{-3}$ (see above).
$\arg\{q/p\}$ $(^\circ)$	-10.2 ± 9.2	5.6	1.4	1.4	2.0	$\sim 10^{-3}$ (see above).
			Other processes Decays			
$\sin^2\theta_W$ at $\sqrt{s} = 10.58\,\mathrm{GeV}/c^2$			0.0002	[l]		clean

Other processes Decays

| $\sin^2\theta_W$ at $\sqrt{s} = 10.58\,\mathrm{GeV}/c^2$ | | | 0.0002 | [l] | | clean |

Precision ElectroWeak Test

$\sin^2\theta_W$ can be measured with polarised e^- beam



- measure LR asymmetry in

$$e^+e^- \to b\bar{b}$$
$$e^+e^- \to c\bar{c}$$
$$e^+e^- \to \tau^+\tau^-$$
$$e^+e^- \to \mu^+\mu^-$$

at the $\Upsilon(4S)$ to same precision as SLC at the Z-pole

beam polarization has to be controlled at the percent level

Similar measurements planned/underway at lower energies (QWeak/MESA)

Some Golden Modes

	Red	Yellow	Blue	Green
Experiment:	No Result	Moderately precise	Precise	Very precise
Theory:		Moderately clean	Clean, needs Lattice	Clean

Observable/mode Luminosity	Current $\sim 1\,\mathrm{ab}^{-1}$	LHCb (2017) $5\,\mathrm{fb}^{-1}$	Super$B$ (2022) $75\,\mathrm{ab}^{-1}$	LHCb upgrade $50\,\mathrm{fb}^{-1}$	Theory	
τ Decays						
$\tau \to \mu\gamma$	Yellow	Yellow	Green	Yellow	Green	benefit from polarised e⁻ beam
$\tau \to e\gamma$	Yellow	Yellow	Green	Yellow	Green	
$B_{u,d}$ Decays						
$B \to \tau\nu, \mu\nu$	Yellow	Red	Blue	Red	Blue	very precise with improved detector
$B \to K^{(*)+}\nu\overline{\nu}$	Red	Red	Green	Red	Green	statistically limited: ang. analysis with >$75\mathrm{ab}^{-1}$
S in $B \to K^0_S\pi^0\gamma$	Yellow	Red	Green	Red	Yellow	right handed currents
S (other penguin modes)	Yellow	Yellow	Green	Blue	Yellow	SuperB measures many more modes
A_{CP} ($B \to X_s\gamma$)	Blue	Yellow	Green	Yellow	Green	systematic error is main challenge
BR($B \to X_s\gamma$)	Blue	Yellow	Green	Yellow	Yellow	control systematic error with data
BR($B \to X_s ll$)	Yellow	Red	Green	Red	Green	
BR($B \to K^{(*)} ll$)	Yellow	Blue	Green	Green	Yellow	SuperB measures e mode well, LHCb does μ
B_s Decays						
$B_s \to \mu\mu$	Red	Blue	Red	Green	Green	
β_S from $B_s \to J/\psi\,\phi$	Red	Blue	Red	Green	Green	
$B_s \to \gamma\gamma$	Red	Red	Blue	Red	Green	
a_{sl}	Red	Blue	Green	Green	Green	
D Decays						
Mixing parameters	Yellow	Blue	Green	Green	Green	
CP Violation	Red	Blue	Green	Green	Green	clean NP search
Precision Electroweak						
$\sin^2\theta_W$ at $\Upsilon(4S)$	Red	Red	Green	Red	Green	
$\sin^2\theta_W$ at Z-Pole	Green	Blue	Red	Green	Yellow	b fragmentation limits interpretation at Z pole

Effort to identify golden modes and compare with other experiments

Observable/mode Luminosity	Current $\sim 1\,\mathrm{fb}^{-1}$	LHCb (2017) $5\,\mathrm{fb}^{-1}$	Super$B$ (2022) $75\,\mathrm{ab}^{-1}$	LHCb upgrade $50\,\mathrm{fb}^{-1}$	Theory	
α	Blue	Blue	Green	Blue	Yellow	LHCb can only use ρπ
β from $b \to c\overline{c}s$	Blue	Blue	Green	Green	Green	
$B_d \to J/\psi\pi^0$	Yellow	Red	Green	Red	Green	βtheory error Bd
$B_s \to J/\psi K^0_S$	Red	Yellow	Red	Blue	Green	βtheory error Bs
γ	Yellow	Blue	Green	Green	Green	
$\lvert V_{ub}\rvert$ inclusive	Blue	Yellow	Green	Blue	Blue	need an e+e− environment to do a precision measurement using semi-leptonic B decays.
$\lvert V_{ub}\rvert$ exclusive	Blue	Yellow	Green	Blue	Blue	
$\lvert V_{cb}\rvert$ inclusive	Blue	Yellow	Green	Blue	Blue	
$\lvert V_{cb}\rvert$ exclusive	Blue	Yellow	Green	Blue	Blue	

Conclusions

SuperB will redefine the flavor physics landscape by ~2022, having the best performances on all its golden modes, thanks to its superior luminosity and operation flexibility. The LHCb upgrade will be able to improve only few SuperB results by ~2030

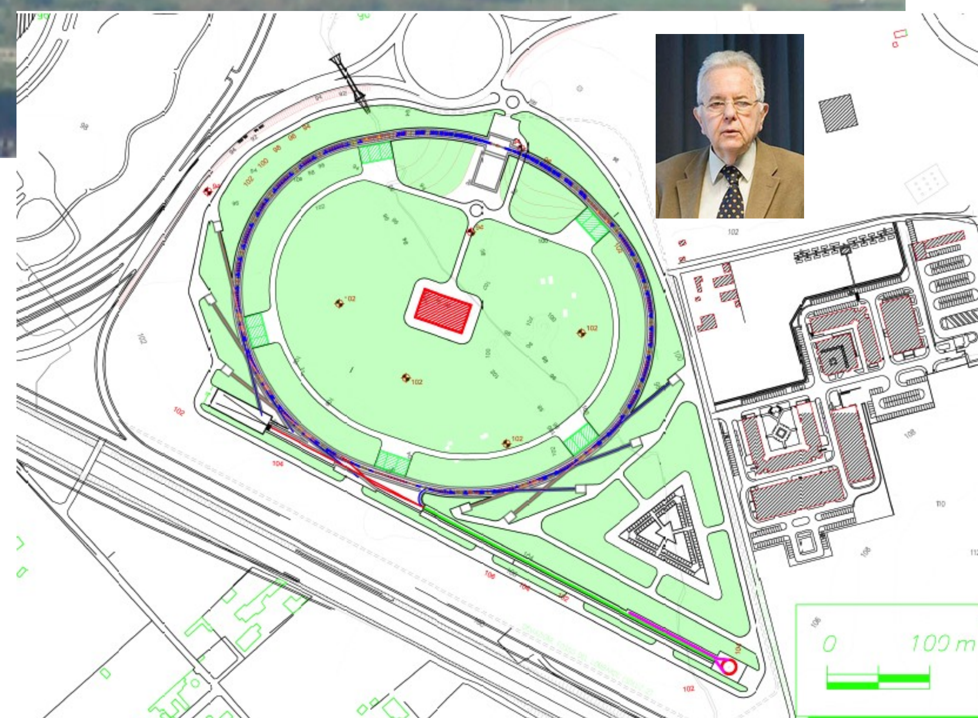
Yet SuperB & LHCb(-upgrade) physics programs are largely complementary. Together with K and μFV experiments, they allow to substantially advance the search for NP FV & CPV in all flavor sectors

Outlook (from Frascati)

The Cabibbo Lab now exists

CABIBBO LAB
Laboratorio Nicola Cabibbo

http://www.cabibbolab.it



Spare Slides

Theory errors keep up

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

V. Lubicz, SuperB CDR, arXiv:0709.0451
updated for the physics white paper
arXiv:1008.1541

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 %
$B \to D/D^* l \nu$	$\mathcal{F}_{B\to D/D^*}$	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 %

no theory improvements needed	$\beta(J/\psi\ K)$, $\gamma(DK)$, $\alpha(\pi\pi)$*, lepton FV and UV, $S(\rho^0\gamma)$ CPV in $B\to X\gamma$, D and τ decays zero of FB asymmetry $B\to X_s l^+ l^-$	NP insensitive or 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

An explicit example: hierarchical soft terms

Nardecchia, Giudice, Romanino, arXiv:0812.3610
Cohen, Kaplan, Nelson, hep-ph/9607394
Dine, Kagan, Samuel, PLB243 (1990)

Sparticles at the EW scale

but for 1st and 2nd generation squarks and sleptons

- no "unnatural" correction to the Higgs mass
- alleviate the flavour problem
- indicate "natural" values for the δ's:

$\hat{\delta}^{LL}_{db} \approx V^*_{td} \sim \mathbf{0.01}$ $\quad \hat{\delta}^{LL}_{sb} \approx V^*_{ts} \sim \mathbf{0.05}$

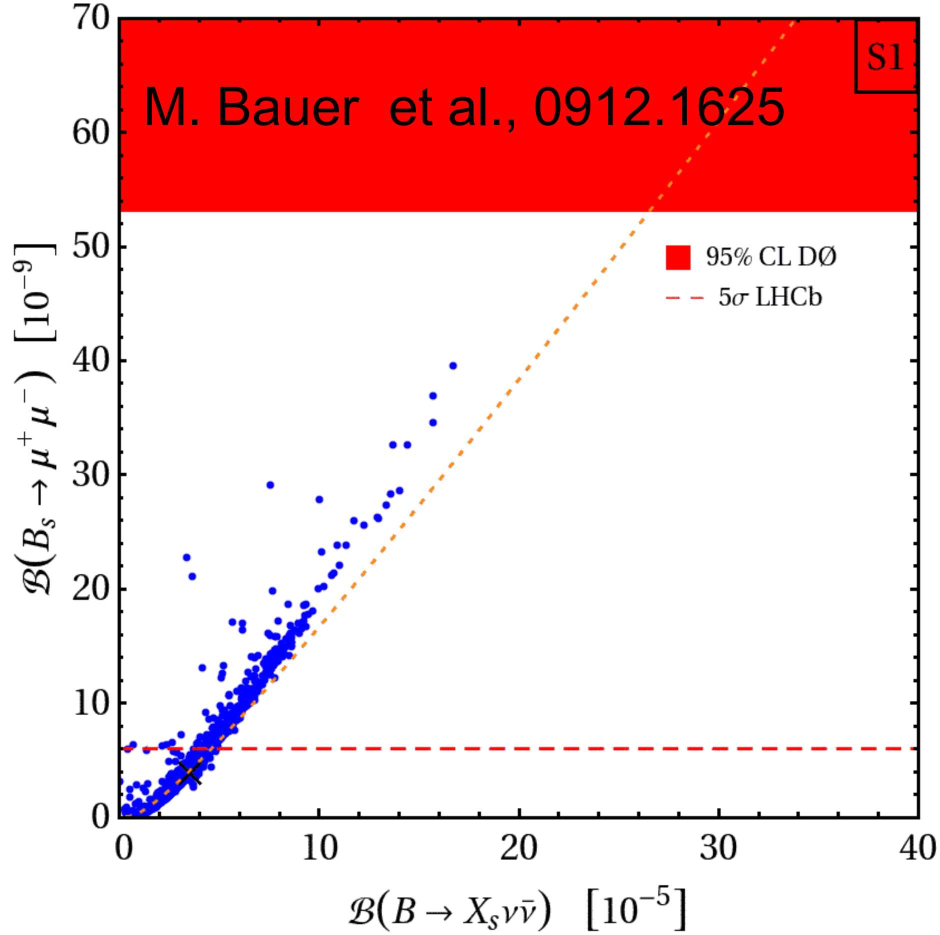
$$\hat{\delta}^{LR}_{i3} \equiv \frac{\mathcal{M}^2_{L3,R3}}{\tilde{m}^2}\hat{\delta}^{LL}_{i3} \qquad i,j = 1,2$$

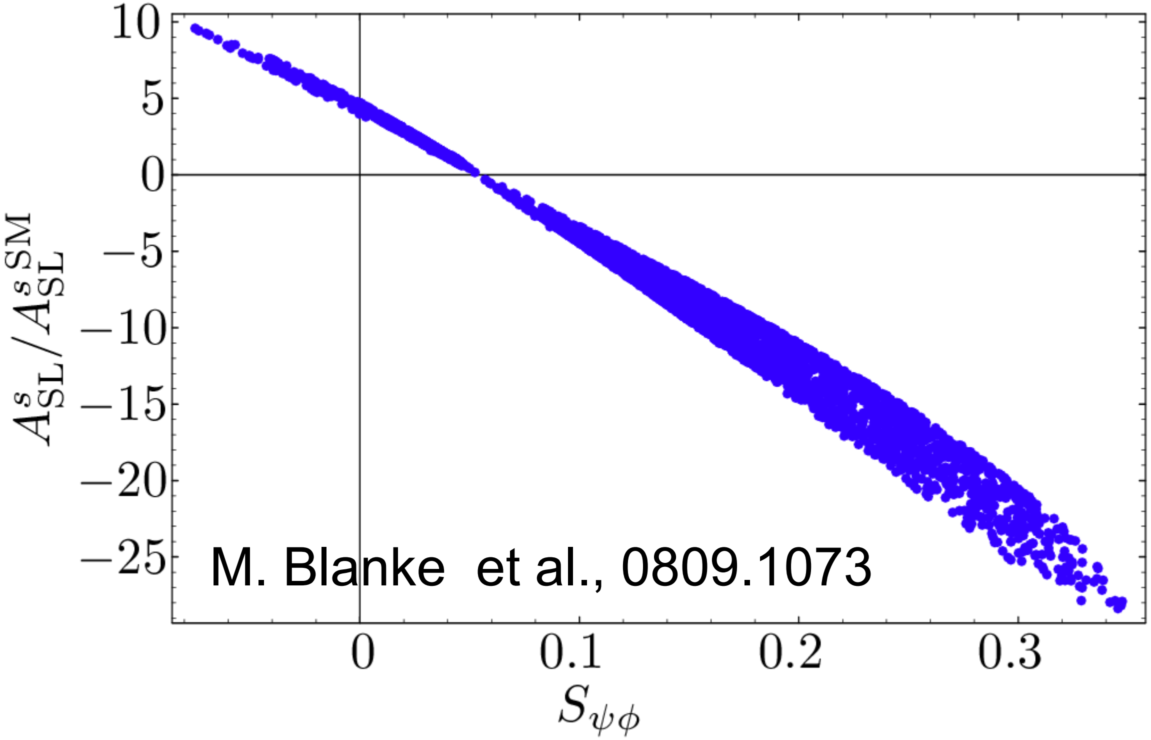
$$\hat{\delta}^{LL}_{ij} \equiv \hat{\delta}^{LL}_{i3}\hat{\delta}^{LL*}_{j3} \qquad \hat{\delta}^{LR}_{ij} \equiv \frac{\mathcal{M}^2_{L3,R3}}{\tilde{m}^2}\hat{\delta}^{LL}_{i3}\hat{\delta}^{RR*}_{j3}$$

these figures are in the ballpark of SuperB sensitivities

R-S models

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





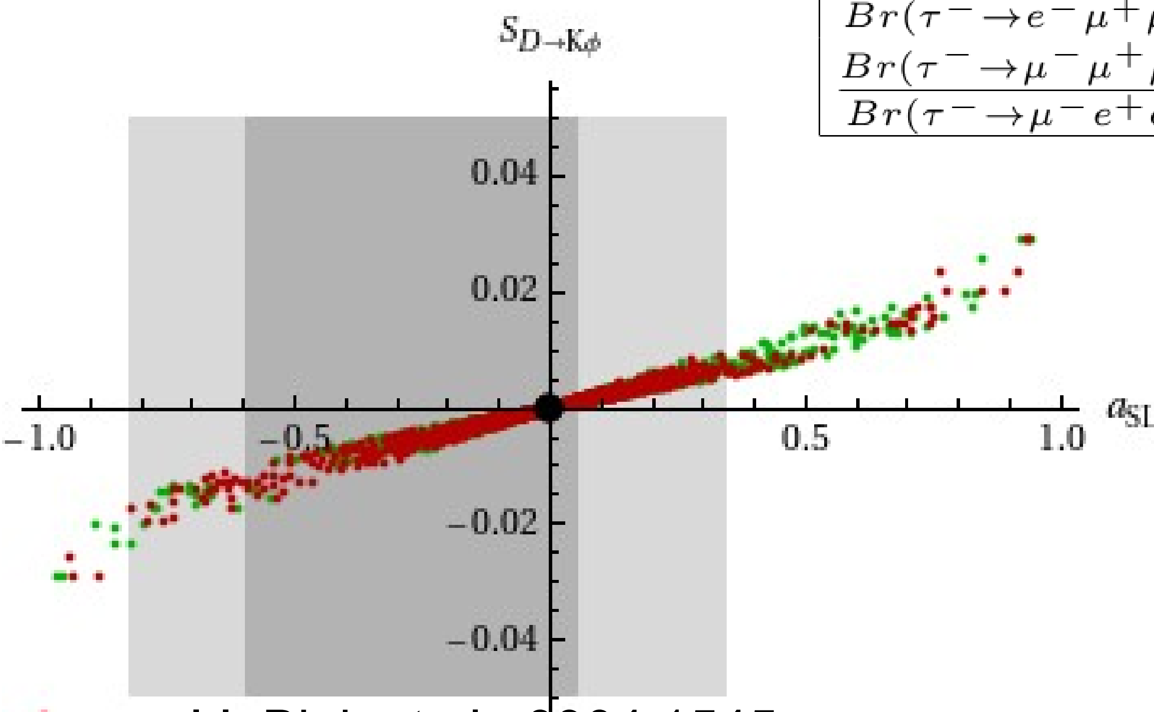
there are R-S models where effects in B(s) are confined to the mixing amplitudes

M. Blanke et al., 0906.5454

LHT model

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

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



I.I. Bigi et al., 0904.1545

Recently: large and correlated CPV effects in D mixing

CPV in charm mixing

Strategy	Decay	$\sigma(\lvert q_D/p_D\rvert) \times 10^2$	$\sigma(\phi_M)^\circ$
HFAG (direct *CPV* allowed):			
Global χ^2 fit	<All modes>	± 18	± 9
Asymmetries a_z:			
x_D	<All modes>	± 1.8	–
y_D	<All modes>	± 1.1	–
y_{CP}	K^+K^-	± 3.8	–
y'	$K^+\pi^-$	± 4.9	–
x'^2	$K^+\pi^-$	± 4.9	–
x''	$K^+\pi^-\pi^0$	± 5.4	–
y''	$K^+\pi^-\pi^0$	± 5.0	–
TDDP (*CPV* allowed):			
Model-dependent	$K_s^0 h^+ h^-$	± 8.4	± 3.3
BES III DP model	$K_s^0 h^+ h^-$	± 3.7	± 1.9
Super$B$ DP model	$K_s^0 h^+ h^-$	± 2.7	± 1.4
SL Asymmetries a_{SL}:			
75 ab^{-1} at $\Upsilon(4S)$	$X\ell\nu_\ell$	± 10	
500 fb^{-1} at $\psi(3770)$	$K\pi$	± 10	
500 fb^{-1} at $\psi(3770)$	$X\ell\nu_\ell$	TBD	

DETECTOR TIMELINE
CARTOON