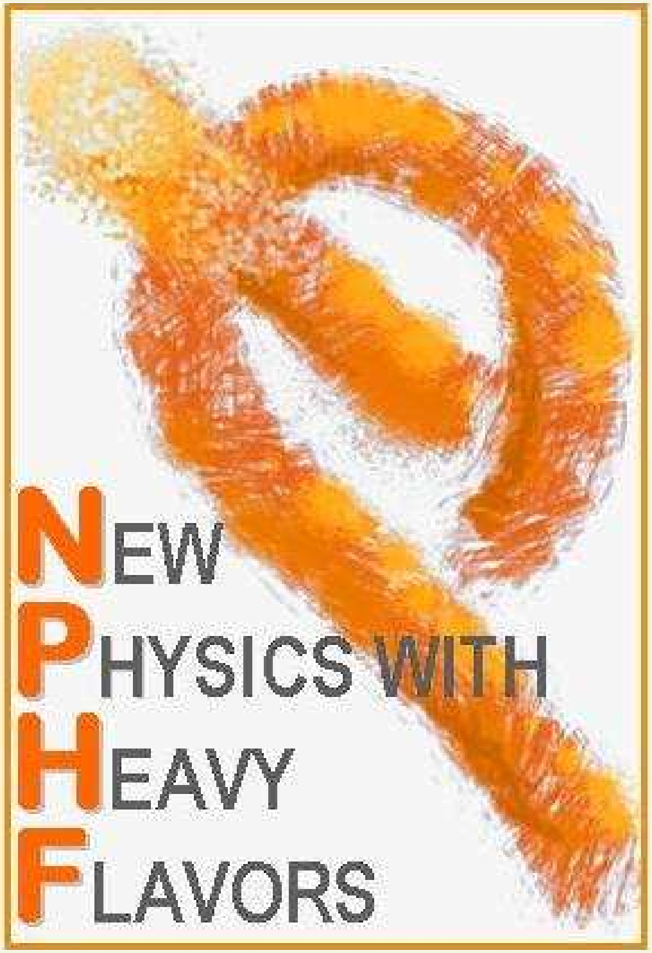


Physics at Super*B*

Alberto Lusiani

INFN and Scuola Normale Superiore
Pisa

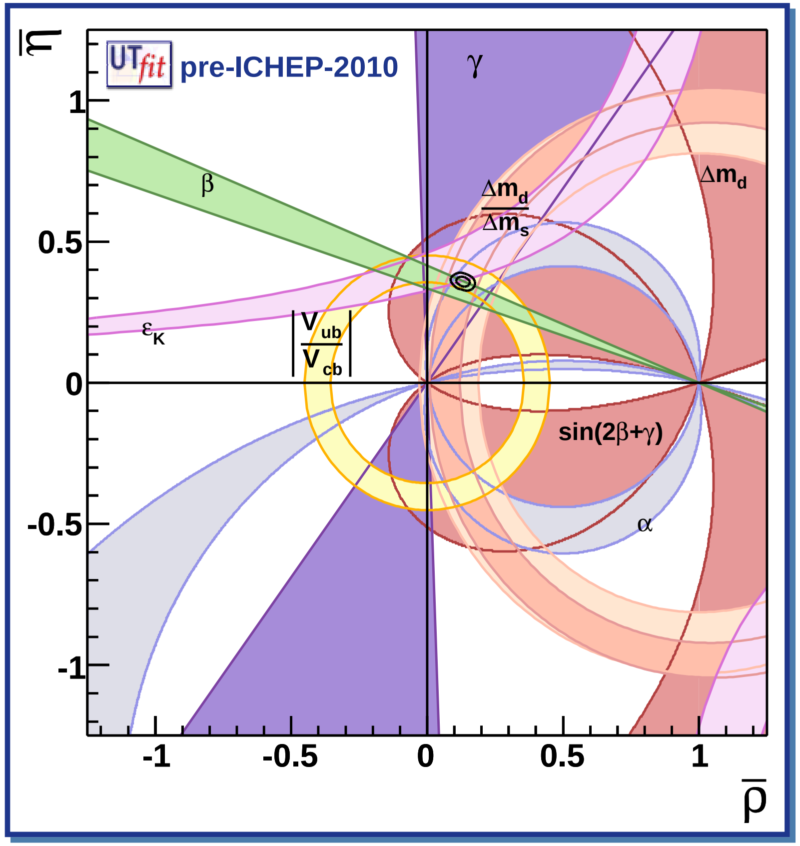
(on behalf of the Super*B* collaboration)

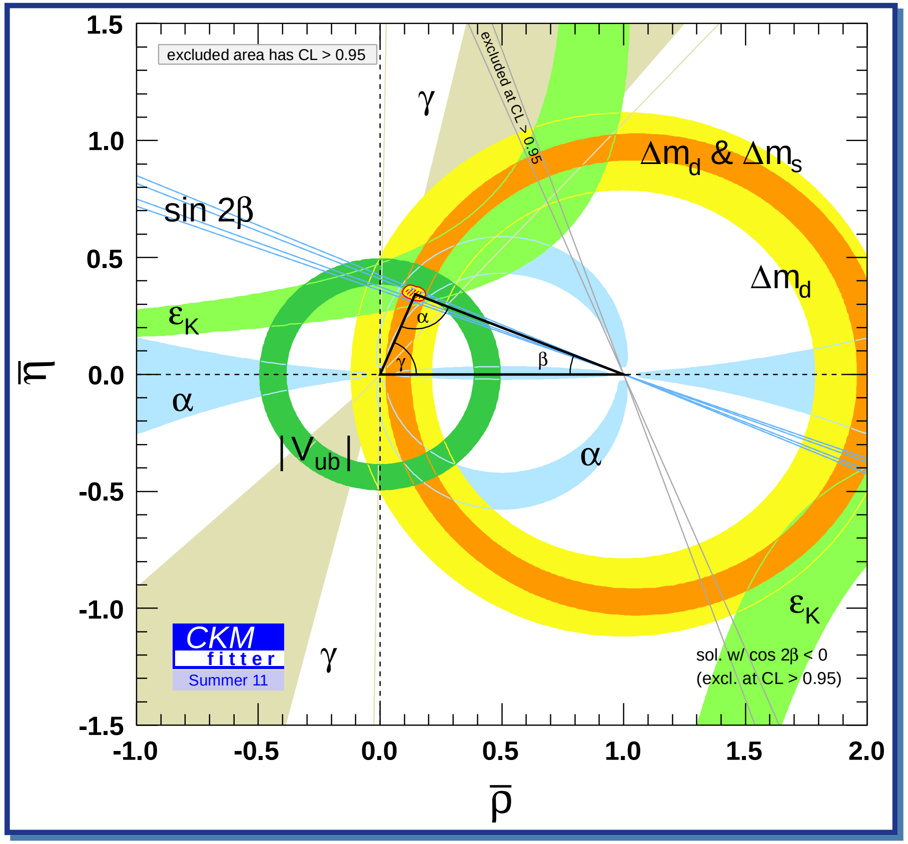
SECOND WORKSHOP ON

FLAVOR PHYSICS IN THE LHC ERA

IFIC, VALENCIA, 16-18 JANUARY 2012

B-factories overconstrained Standard Model & searched for New Physics





- **CKM matrix phase main source of CP violation** (2008 Nobel prize to M.Kobayashi & T.Maskawa)
- no evidence (but perhaps few glimpses) of Physics beyond the Standard Model

The intensity & precision frontier

- energy frontier
  - NP existence & **scale** through effects of **~on-shell processes** with definite energy threshold
- intensity & precision frontier (low-energy)
  - NP existence & **flavour structure** through effects of **off-shell processes**
  - processes very suppressed or even forbidden in the SM
    - FCNC processes ($b \to s\gamma$, $B_{s,d} \to \mu^+\mu^-$, $\mu \to e\gamma$, $\tau \to \mu\gamma$, $K \to \pi\nu\nu$)
    - FCNC & CPV in $B_{s,d}$ and D decay/mixing
    - CPV effects in the electron/neutron EDMs, $d_{e,n}$,...
  - processes predicted with high precision in the SM
    - EW observables like $(g-2)_\mu$
    - Lepton Universality & helicity suppression in $R_M^{e/\mu} = \Gamma(M \to e\nu)/\Gamma(M \to \mu\nu)$ with $M = \pi, K$

Intensity & precision frontier experimental options

- **light leptons & hadrons**
  - e.g. MEG, NA62
  - lower energy, lower cost, very large statistics attainable
  - less variety of processes, no access to heavy-flavour physics
  - smaller size NP effects
- **heavy leptons & hadrons**
  - BES, LHCb, BelleII, **Super*B***
  - higher energy, higher cost, statistics limited by power consumption & cost
  - larger size NP effects
  - larger variety of processes, access also to heavy-flavour physics
    - e^+e^- collisions ⟶ well defined initial state, clean events

NP signals in hadrons and leptons at the intensity frontier

- hadrons
  - NP amplitudes compete with SM amplitudes in forbidden / suppressed / mixing&CPV processes
  - CPV in B mesons ideal because CKM matrix makes it maximal and relatively well calculable
  - in SM, D mixing and CPV are smaller and less precisely predicted
  - theory QCD-related uncertainties
    - important is several cases (D's, $b \to s\gamma$, ϵ_K) (lattice QCD progress dependence)
    - quite small in some cases (CPV in $B \to J/\psi K_S$, $K \to \pi\nu\nu$)
- (charged) leptons
  - (charged) Lepton Flavour Violation
    - clean, mostly QCD-free SM prediction, unambigous NP signal detection
    - NP effects less direct than for hadrons (typically, unknown mass-scale heavy neutrino sector)
    - possibly related to neutrino mixing, esp. θ_{13}
- asymmetric $\Upsilon(4S)$ Super-Flavour-Factories best for most measurements (tau leptons included)
- additional valuable option is running at the charm / tau production threshold

Lattice QCD progress, V.Lubicz, Arcetri, Feb 2010, 1

Cost of the "SuperB" lattice simulation

Simulation parameters

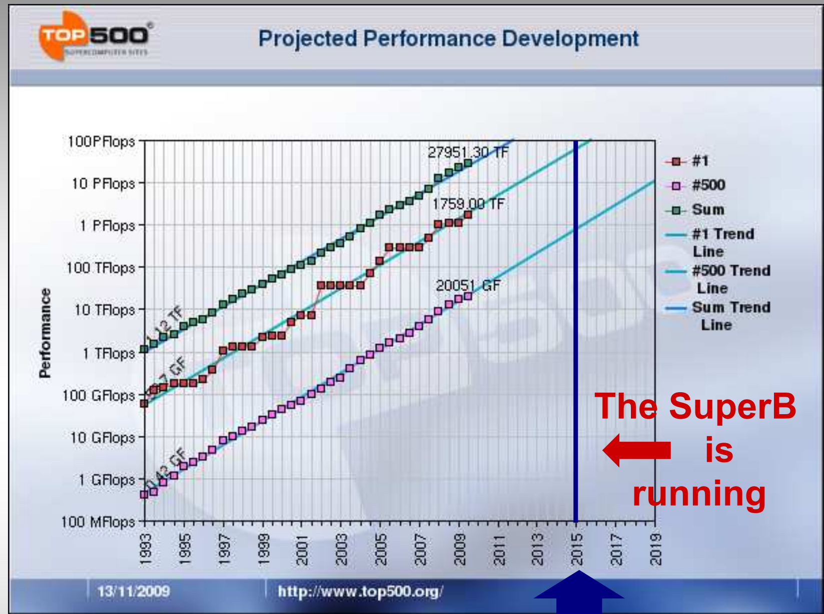
Nconf = 120

a = 0.033 fm
[$1/a$ = 6.0 GeV]

$\hat{m}/m_s$ = 1/12
[M_π = 200 MeV]

L_s = 4.5 fm
[$V = 136^3 \times 270$]

~ 3 PFlop-years



Affordable with 1-10 PFlops available for Lattice QCD in 2015 !

VL @

Lattice QCD progress, V.Lubicz, Arcetri, Feb 2010, 2

V.Lubicz @
Villa Mondragone
Monte Porzio Catone - Italy
13 - 15 November 2006

Hadronic matrix element	Current latt. error (2006)	6 TFlop Year [2009]	60 TFlop Year [2011 LHCb]	1-10 PFlop Year [2015 SuperB]
$f_+^{K\pi}(0)$	0.9% (22% on 1-f_+)	0.7% (17% on 1-f_+)	0.4% (10% on 1-f_+)	**< 0.1% (2.4% on 1-f_+)**
$\hat{B}_K$	11%	5%	3%	**1%**
f_B	14%	3.5 - 4.5%	2.5 - 4.0%	**1 – 1.5%**
$f_{Bs}B_{Bs}^{1/2}$	13%	4 - 5%	3 - 4%	**1 – 1.5%**
ξ	5% (26% on ξ-1)	3% (18% on ξ-1)	1.5 - 2 % (9-12% on ξ-1)	**0.5 – 0.8 % (3-4% on ξ-1)**
$\mathcal{F}_{B\to D/D^*l\nu}$	4% (40% on 1-$\mathcal{F}$)	2% (21% on 1-$\mathcal{F}$)	1.2% (13% on 1-$\mathcal{F}$)	**0.5% (5% on 1-$\mathcal{F}$)**
$f_+^{B\pi}, \ldots$	11%	5.5 - 6.5%	4 - 5%	**2 – 3%**
$T_1^{B\to K^*/\rho}$	13%	----	----	**3 – 4%**

Lattice QCD progress, V.Lubicz, Arcetri, Feb 2010, 3

THE 2009 STATUS REPORT

Hadronic matrix element	Lattice error in 2006	Lattice error in 2009	6 TFlop Year [2009]	60 TFlop Year [2011 LHCb]	1-10 PFlop Year [2015 SuperB]
$f_+^{K\pi}(0)$	0.9%	**0.5%**	0.7%	0.4%	**< 0.1%**
$\hat{B}_K$	11%	**5%**	5%	3%	**1%**
f_B	14%	**5%**	3.5 - 4.5%	2.5 - 4.0%	**1 – 1.5%**
$f_{Bs}B_{Bs}^{1/2}$	13%	**5%**	4 - 5%	3 - 4%	**1 – 1.5%**
ξ	5%	**2%**	3%	1.5 - 2 %	**0.5 – 0.8 %**
$\mathcal{F}_{B\to D/D^*l\nu}$	4%	**2%**	2%	1.2%	**0.5%**
$f_+^{B\pi}$,…	11%	**11%**	5.5 - 6.5%	4 - 5%	**2 – 3%**
$T_1^{B\to K^*/\rho}$	13%	**13%**	----	----	**3 – 4%**

The expected accuracy has been reached! (except for Vub)

Super*B* project features

- **$\Upsilon(4S)$-peak asymmetric energy e^+e^-** Super Flavor Factory
- can also run at the charm threshold by design
- 80% polarized electron beam further defines the already clean initial e^+e^- state
- $\mathbf{L \approx 10^{36}\,cm^{-2}s^{-1}}$ around $\Upsilon(4S)$ peak, $\mathbf{L \approx 10^{35}\,cm^{-2}s^{-1}}$ at tau/charm threshold
  - $\Upsilon(4S)$: **coherent *B* mesons** & time-dep. measurements, charm hadrons, **tau leptons**
  - charm threshold: **coherent *D* mesons** & time-dep. measurements, tau leptons
- Physics program
  - maximize new physics sensitivity and variety of physics measurements
  - precision high statistics measurements & searches on heavy quarks and tau leptons
  - but also precision EW, light new physics searches, ISR measurements, spectroscopy
  - e^+e^- collisions ideal for measurements in almost every energy-accessible topic
- data-taking: **beginning of 2017**
  - plan: 75 ab^{-1} around $\Upsilon(4S)$ (+ continuum), 0.5 ab^{-1} at charm threshold, 1 ab^{-1} at $\Upsilon(5S)$

What Super*B* can do

New Physics (NP) expected beyond Standard Model, perhaps at $\Lambda \sim 1$ TeV

Super*B* can search for NP, in a complementary & competivive way with LHC, MEG and others

case 1 **LHC finds New Physics (therefore determining Λ)**

- Super*B* can study NP flavour structure, but can also be sensitive to larger scales than LHC

case 2 **the NP scale is beyond the LHC reach**

- Super*B* can look for indirect NP signals up to $\Lambda \sim 10$ TeV and more

♦ **Super*B* vs. BelleII**

- competition worked fine for *BABAR* and Belle
- BelleII begins data-taking ~2 years earlier
- Super*B* has **beam polarization**, **charm threshold ability**, **larger design luminosity**,

♦ **LHCb and MEG** partly competitive and partly complementary

- some *B* final states are only measurable by Super*B* (with neutrals or missing momentum)
- Super*B* can test tau LFV, *CPV*, EDM, g–2, can search for light new physics
- Super*B* can do useful measurements on entangled charm mesons decays

Super*B* physics studies initiated in ∼2005

2005 Hewett et al., The Discovery Potential of a Super B factory, **hep-ph/0503261**

2007 Conceptual Design Report, **arXiv:0709.0451 [hep-ex]**

2008 Valencia retreat proceedings, **arXiv:0810.1312 [hep-ex]**

2010 SuperB white paper: Physics, **arXiv:1008.1541 [hep-ex]**

2011 The impact of SuperB on flavour physics, **arXiv:1109.5028v2 [hep-ex]**

Two recent workshops on high intensity frontier measurements

- Workshop on charm physics at threshold (21 - 23, October, 2011, IHEP, China)
  `http://bes3.ihep.ac.cn/conference/threshold2011/index.html`
- Fundamental Physics at the Intensity Frontier (Nov 30-Dec 2, 2011, Rockville, MD USA)
  `http://www.intensityfrontier.org/`

Super*B* golden modes

(indirect searches for NP need 1) good exp. precision & 2) good theory understanding)

$B_{u,d}$ Physics

- $B^+ \to \tau^+\nu$, $B^+ \to \mu^+\nu$, $B^+ \to K^{(*)+}\nu\bar{\nu}$, $b \to s\gamma$, $b \to s\ell\ell$
- precision $\sin 2\beta$ measurements, in particular $B \to \eta' K^0_S, \to K^0_S\pi^0\gamma$

τ Physics

- Lepton flavour violation in tau decays: especially $\tau \to \mu\gamma$ and $\tau \to 3\ell$

Charm Physics

- D^0 mixing parameters and *CP* violation

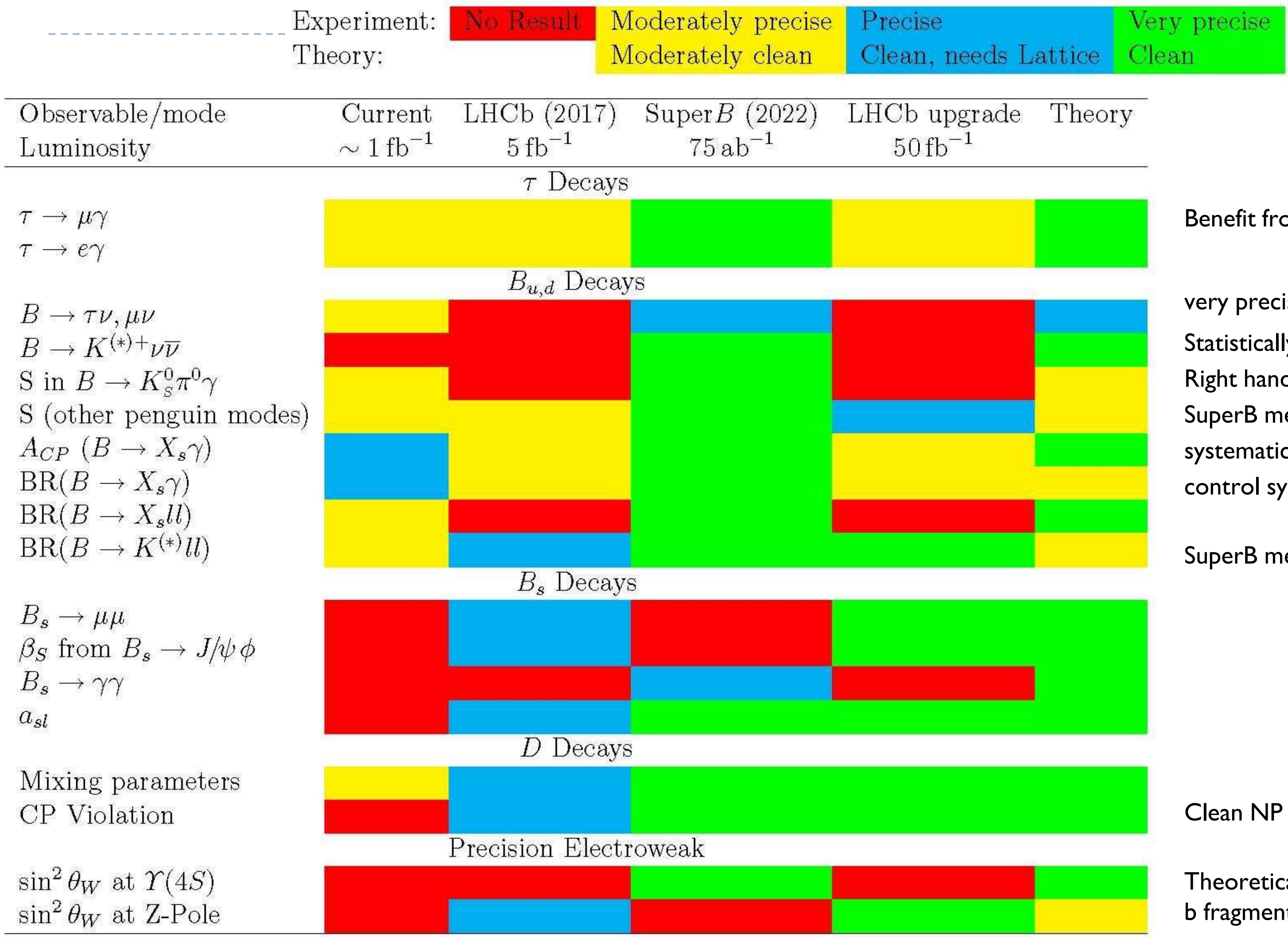
B_s Physics

- Semi-leptonic *CP* asymmetry A^s_{SL}
- $B_s \to \gamma\gamma$

Other Physics

- Precision EW measurement at $\sqrt{s}$ = 10.58 GeV/c^2 with polarized beams
- Direct searches for non-standard light Higgs bosons, Dark Matter and Dark Forces

Super*B* golden modes compared



Benefit from polarised e⁻ beam

very precise with improved detector

Statistically limited: Angular analysis with >

Right handed currents

SuperB measures many more modes

systematic error is main challenge

control systematic error with data

SuperB measures e mode well, LHCb does

Clean NP search

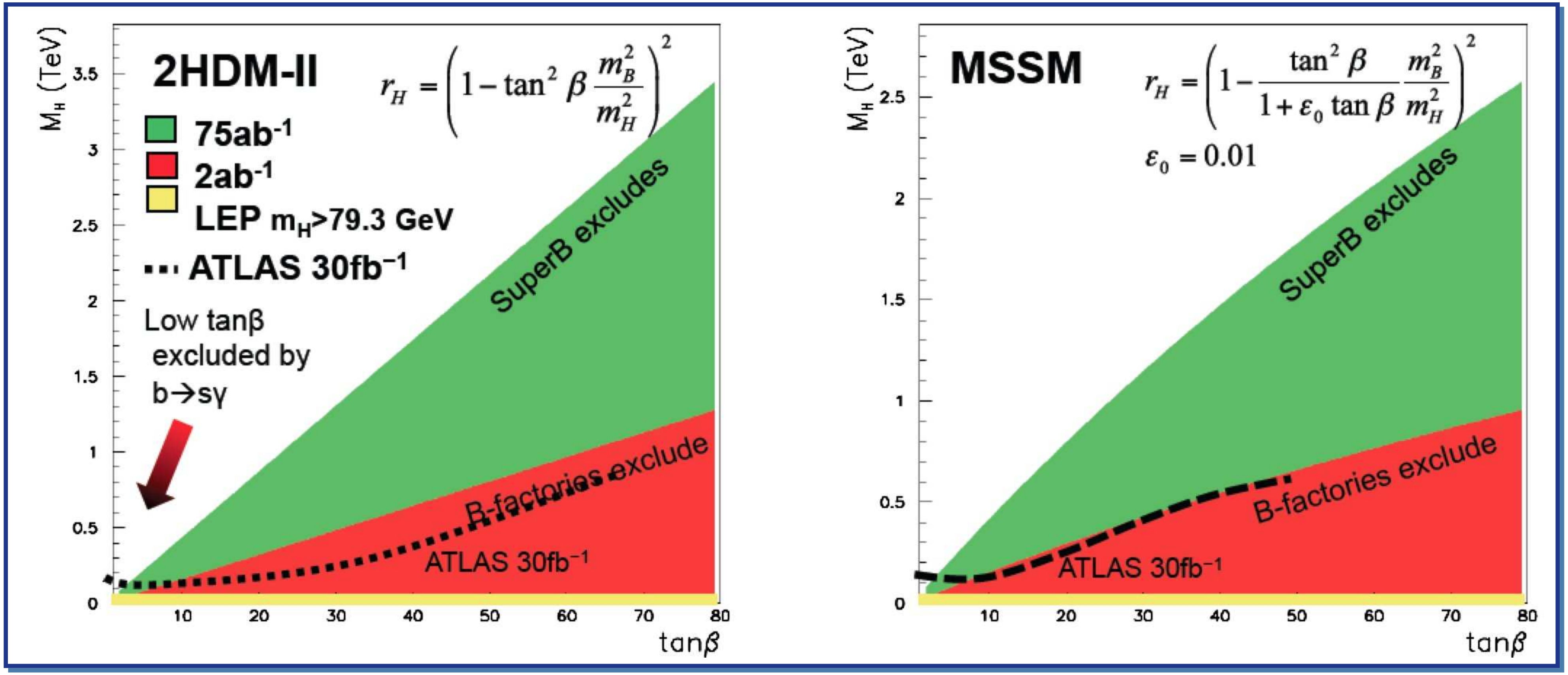
Theoretically clean

b fragmentation limits interpretation

$\mathcal{B}(B \to \tau\nu)$

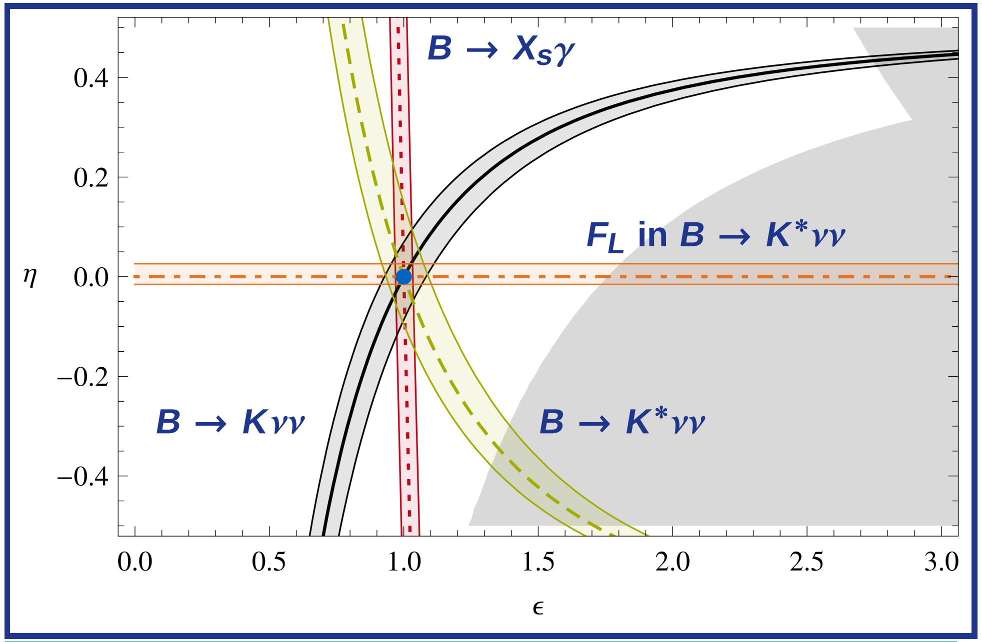
- helicity suppressed, reasonably clean SM prediction
  - within SM, rate proportional to $|V_{ub}|^2$ and f_B^2
- NP charged Higgs interferes negatively, reducing $\mathcal{B}(B \to \tau\nu)$
  - NP effect is larger in $\mathcal{B}(B \to \tau\nu)$ vs. $\mathcal{B}(B \to \mu\nu)$
- non trivial selection and bkg suppression because of neutrinos in final state
- Super*B* offers ideal conditions
  - clean events, hermetic detector, well defined initial state, just 2 *B*s
  - → tag other side with reconstructed *B*
  - → study “extra-energy” distribution with data for bkg subtraction
- 3% measurement of SM prediction possible

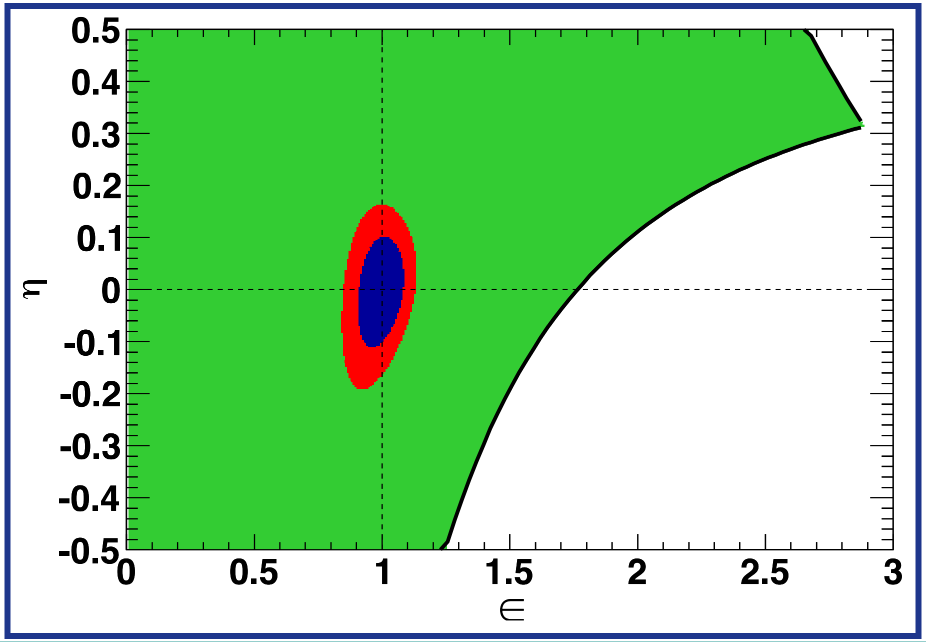
$\mathcal{B}(B \to \tau\nu)$ constrains NP charged Higgs parameters



- $r_H = \mathcal{B}(B \to \tau\nu)/\mathcal{B}_{SM}(B \to \tau\nu)$ exclusion plots assume measurement = SM prediction
- ATLAS exclusion limit for 30 fb^{-1} at 14 TeV computed using arXiv:0901.0512

Constraints on NP from $B \to K^0\nu\nu$, $B \to K^*\nu\nu$, $B \to X_s\gamma$ inclusive





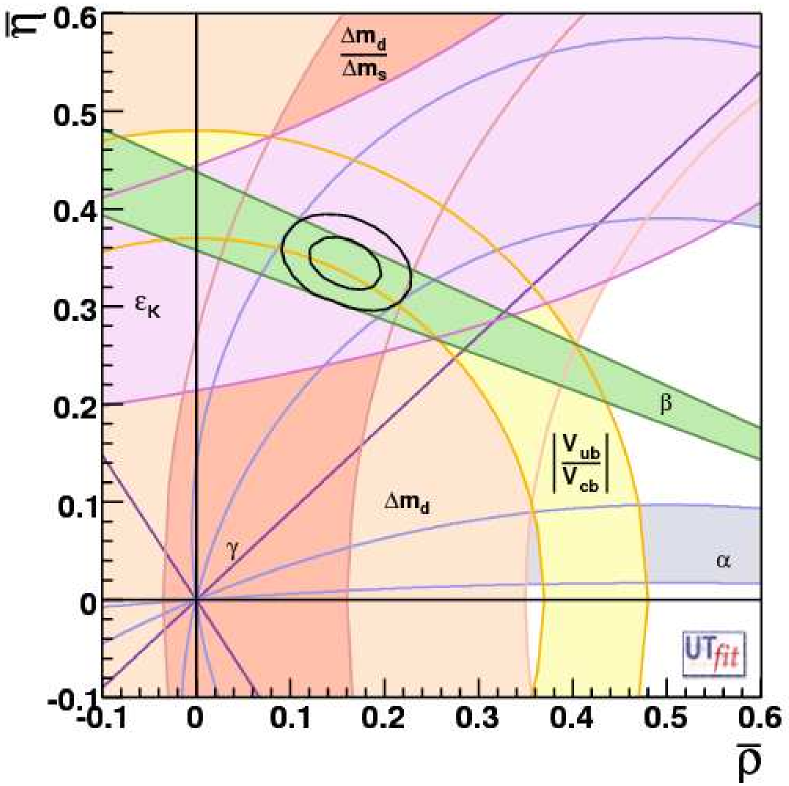
hypothetical future constraints on SM deviations
W.Altmannshofer et al., arXiv:0902.0160 [hep-ph]

present vs. Super$B$ 75 ab^{-1} constraints
(Super$B$ comparison document)

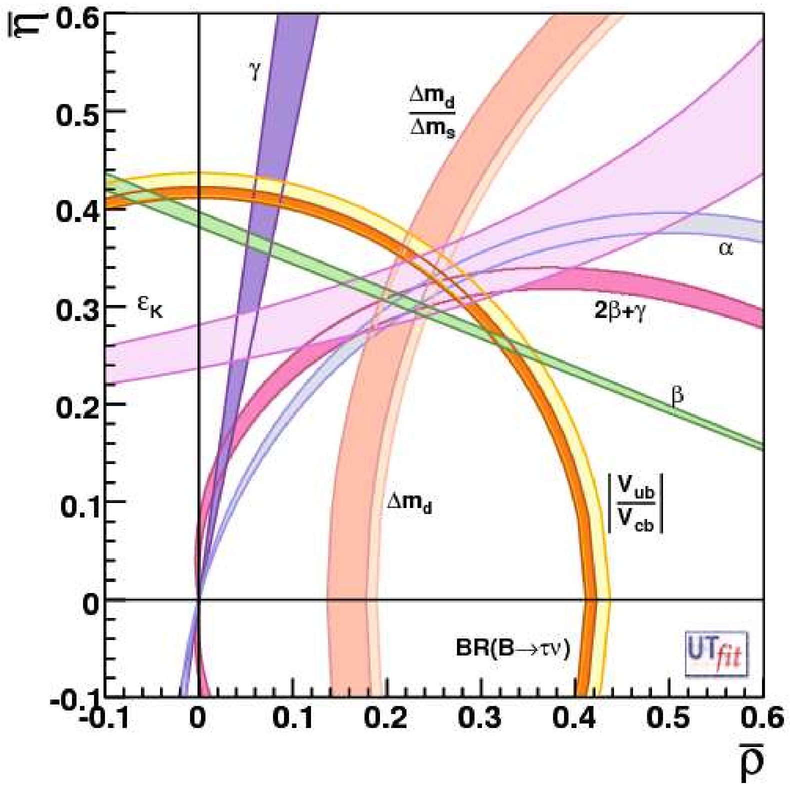
W.Altmannshofer et al., arXiv:0902.0160 [hep-ph]: combining 4 observables provides good test of modified Z-penguin contributions, non-MFV interactions, RH currents, . . .

From ∼10% to ∼1% experimental precision on CKM

CKM fit in 2006



possible fit with Super*B* & improved lattice QCD

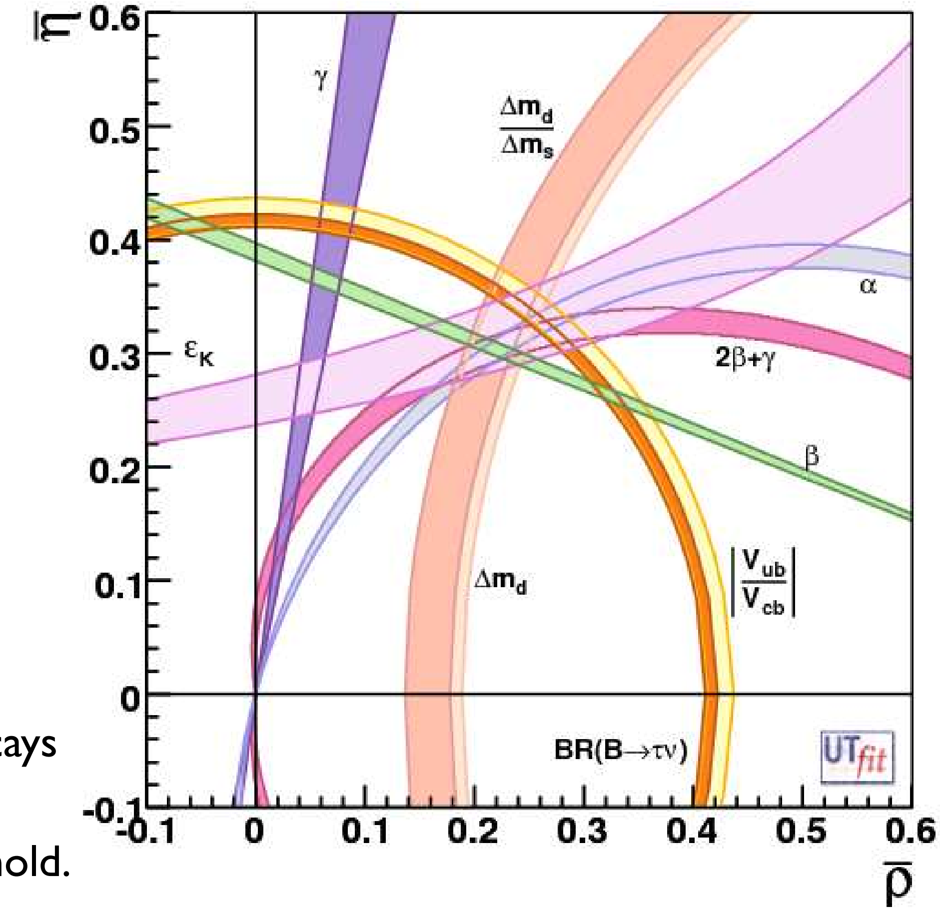


- bands show 95% constraints, 2006 values assumed for the Super*B* fit

From ~10% to ~1% experimental precision on CKM

- Unitarity Triangle Angles
  - σ(α) = 1−2°
  - σ(β) = 0.1°
  - σ(γ) = 1−2°
- CKM Matrix Elements
  - $|V_{ub}|$
    - Inclusive σ = 2%
    - Exclusive σ = 3%
  - $|V_{cb}|$
    - Inclusive σ = 1%
    - Exclusive σ = 1%
  - $|V_{us}|$
    - Can be measured precisely using τ decays
  - $|V_{cd}|$ and $|V_{cs}|$
    - can be measured at/near charm threshold.

The "dream" scenario with 75ab^{-1}



- SuperB Measures the sides and angles of the Unitarity Triangle

Super Flavour Factories can complement LHC in measuring squark matrix

e.g. MSSM: 124 (160 with ν_R) couplings, most are flavour related.

Δ's are related to NP mass scale.

LHCb, SuperB

LHC, ILC - HE frontier

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

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

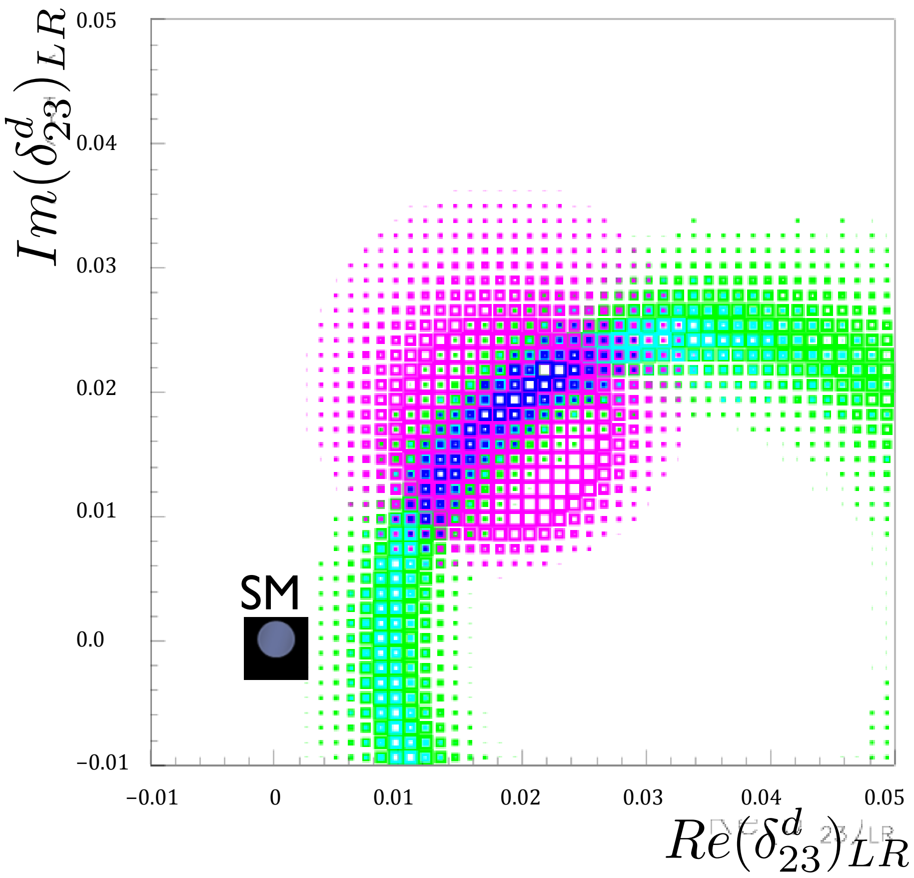
- In many NP scenarios the energy frontier experiments will probe the diagonal elements of mixing matrices.
- Flavour experiments are required to probe off-diagonal ones.

Super Flavour Factories can complement LHC in measuring squark matrix (2)

- e.g. MSSM with generic squark mass matrices.
- Use Mass insertion approximation with $m_{\tilde{q}} \sim m_{\tilde{g}}$ to constrain couplings:

$$(\delta^q_{ij})_{AB} = \frac{(\Delta_{ij})^q_{AB}}{m^2_{\tilde{q}}}$$

- Can constrain the δ^d_{ij}'s using
  - $\mathcal{B}(B \to X_s \gamma)$ (green)
  - $\mathcal{B}(B \to X_s \ell^+ \ell^-)$ (cyan)
  - $\mathcal{A}_{CP}(B \to X_s \gamma)$ (magenta)



e.g. see Hall et al., Nucl. Phys. B **267** 415-432 (1986)
Ciuchini et al., hep-ph/0212397

Super*B* $\Upsilon(4S)$ *B* Physics reach, 1

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°

† exp. syst. limited

∗ theory syst. limited

most measurements with π^0, γ, ν, many K^0's cannot be done at LHCb

SuperB $\Upsilon(4S)$ B Physics reach, 2

Observable	B Factories (2 ab^{-1})	SuperB (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% (∗)	3.0% (∗)
$\lvert V_{ub}\rvert$ (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	0.006 (†)
$S(K^0_S\pi^0\gamma)$	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%
$\mathcal{B}(B \to K\nu\overline{\nu})$	visible	20%
$\mathcal{B}(B \to \pi\nu\overline{\nu})$	–	possible

† exp. syst. limited

∗ theory syst. limited

most measurements with π^0, γ, ν, many K^0's cannot be done at LHCb

Super*B* $\Upsilon(5S)$ B_s Physics reach

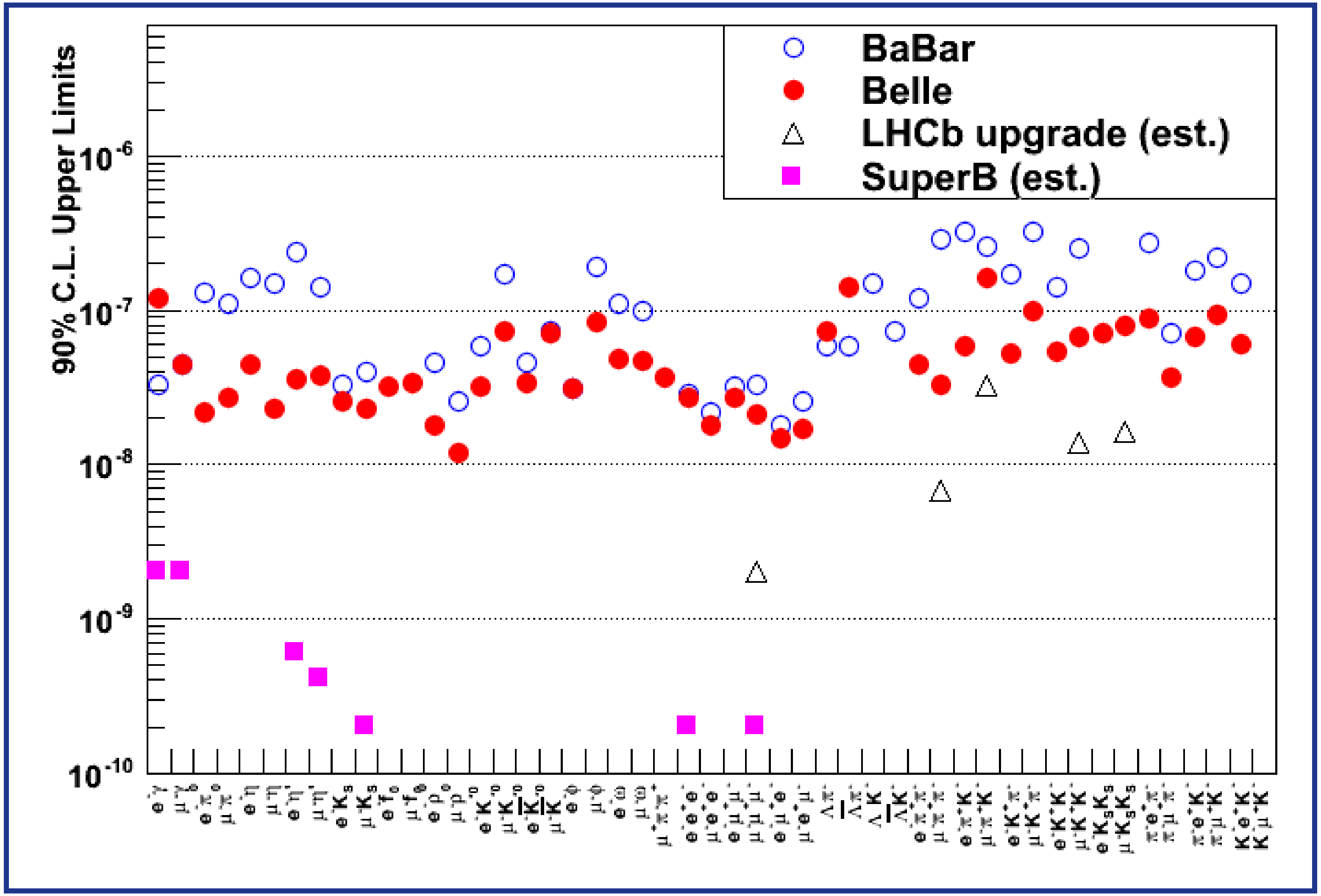
Observable	Error with 1 ab^{-1}	Error with 30 ab^{-1}
$\Delta\Gamma$	0.16 ps^{-1}	0.03 ps^{-1}
Γ	0.07 ps^{-1}	0.01 ps^{-1}
β_s from angular analysis	20°	8°
A_{SL}^s	0.006	0.004
A_{CH}	0.004	0.004
$\mathcal{B}(B_s \to \mu^+\mu^-)$	-	$< 8 \times 10^{-9}$
$\|V_{td}/V_{ts}\|$	0.08	0.017
$\mathcal{B}(B_s \to \gamma\gamma)$	38%	7%
β_s from $J/\psi\phi$	10°	3°
β_s from $B_s \to K^0\overline{K}^0$	24°	11°

- LHCb in general is more competitive for B_s measurements, but there are a few exceptions

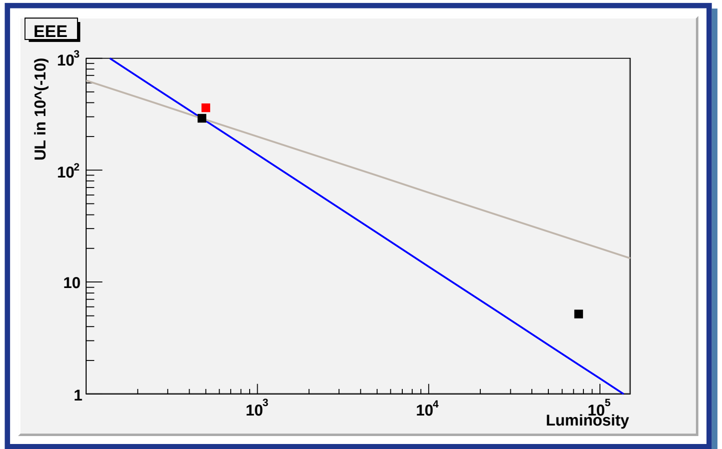
Super*B* Tau Physics NP probes

- Lepton Flavor violation in tau decays
  - many NP models predict tau LFV within Super*B* sensitivity
  - unambiguous NP probe, negligible theory uncertainties
  - Super*B* is complementary with MEG
    ($\mu \to e\gamma$ can be accidentally suppressed, tau measurements are complementary)
  - best channels: $\boldsymbol{\tau \to \mu\gamma, \tau \to 3\ell, \tau \to \mu\rho, \tau \to \mu\eta}$
- Tau *g*–2
  - if MSSM explains today's $\Delta a_\mu \approx 3{\cdot}10^{-9}$ discrepancy ⟶ $\boldsymbol{\Delta a_\tau \approx m_\tau^2/m_\mu^2 \cdot \Delta a_\mu \approx 1{\cdot}10^{-6}}$
  - Super*B* sensitivity is in the range of such prediction
- Tau EDM and CPV
  - Super*B* sensitive to some few NP model CPV effects
  - tau EDM constrained by electron EDM upper limit to a range inaccessible by Super*B*
    anyway, Super*B* can substantially improve the existing limits
- all: **beam polarization improves precision & helps discriminating NP models**

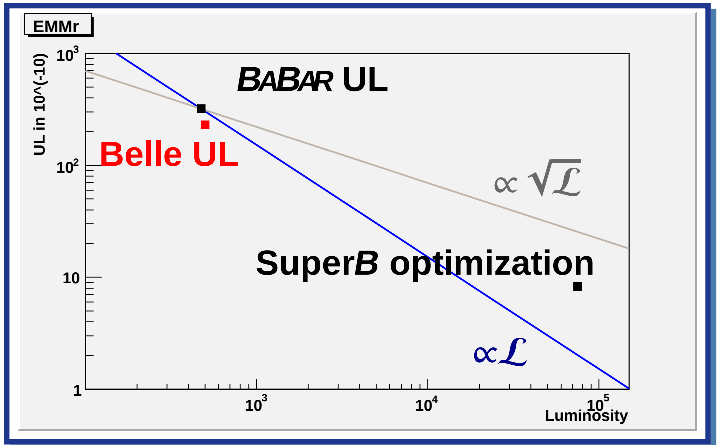
Super*B* 10–100 times more sensitive than *BABAR* to tau LFV modes



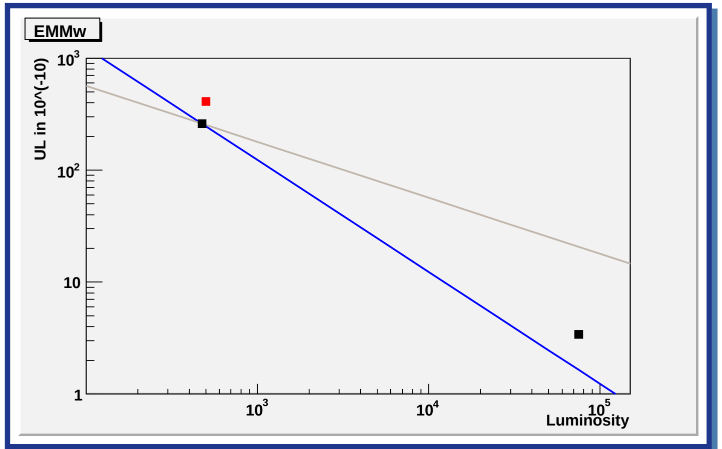
$\tau \to 3\ell$ 90% CM upper limit extrapolations: $\propto\mathcal{L}$ vs. $\propto\sqrt{\mathcal{L}}$ vs. re-optimization



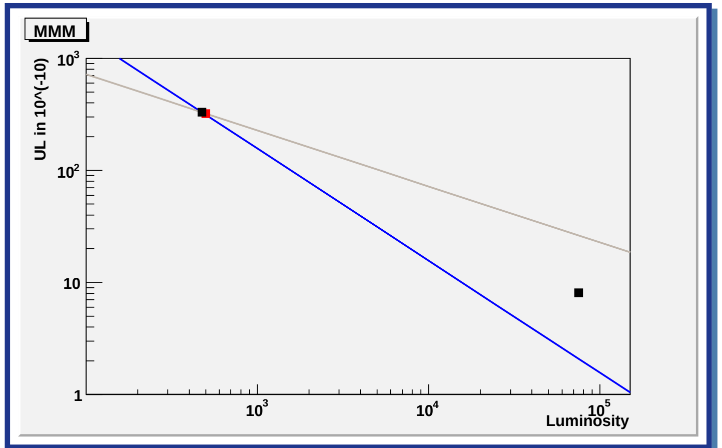
$\tau \to eee$



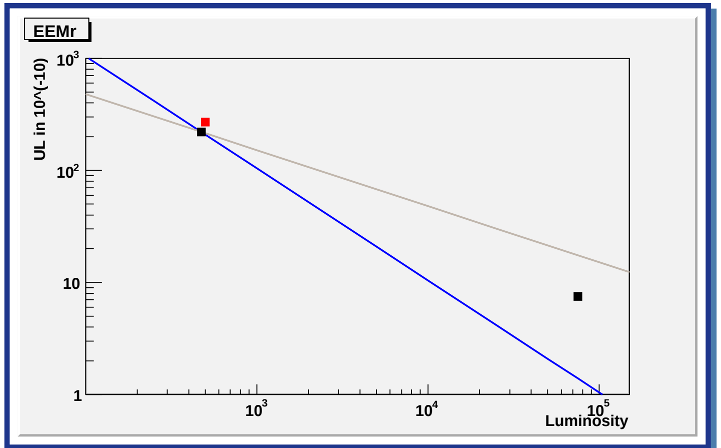
$\tau \to e\mu{+}\mu{-}$



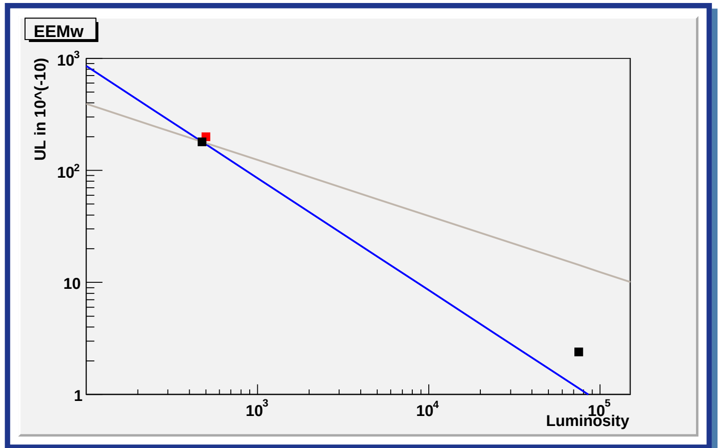
$\tau{-} \to e{+}\mu{-}\mu{-}$



$\tau \to \mu\mu\mu$

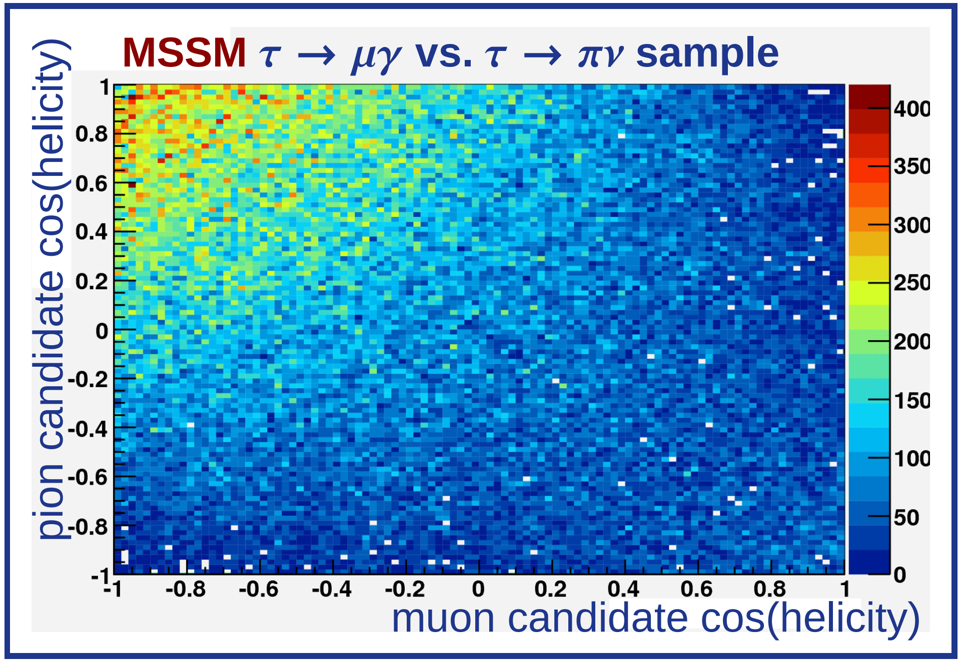


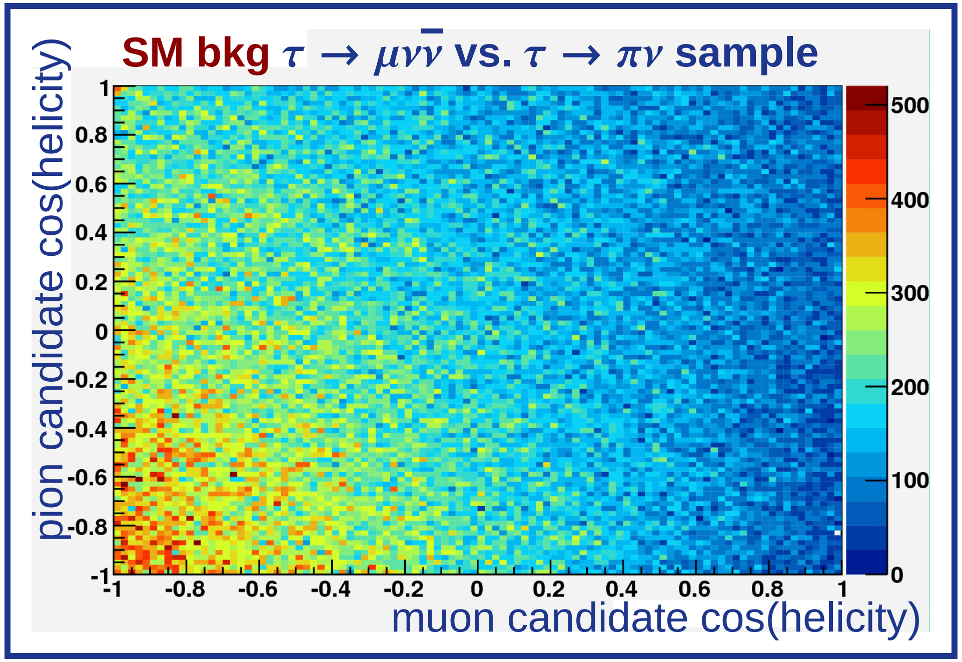
$\tau \to \mu e{+}e{-}$



$\tau{-} \to \mu{+}e{-}e{-}$

Super*B* beam polarization effects on $\tau \to \mu\gamma$ LFV search

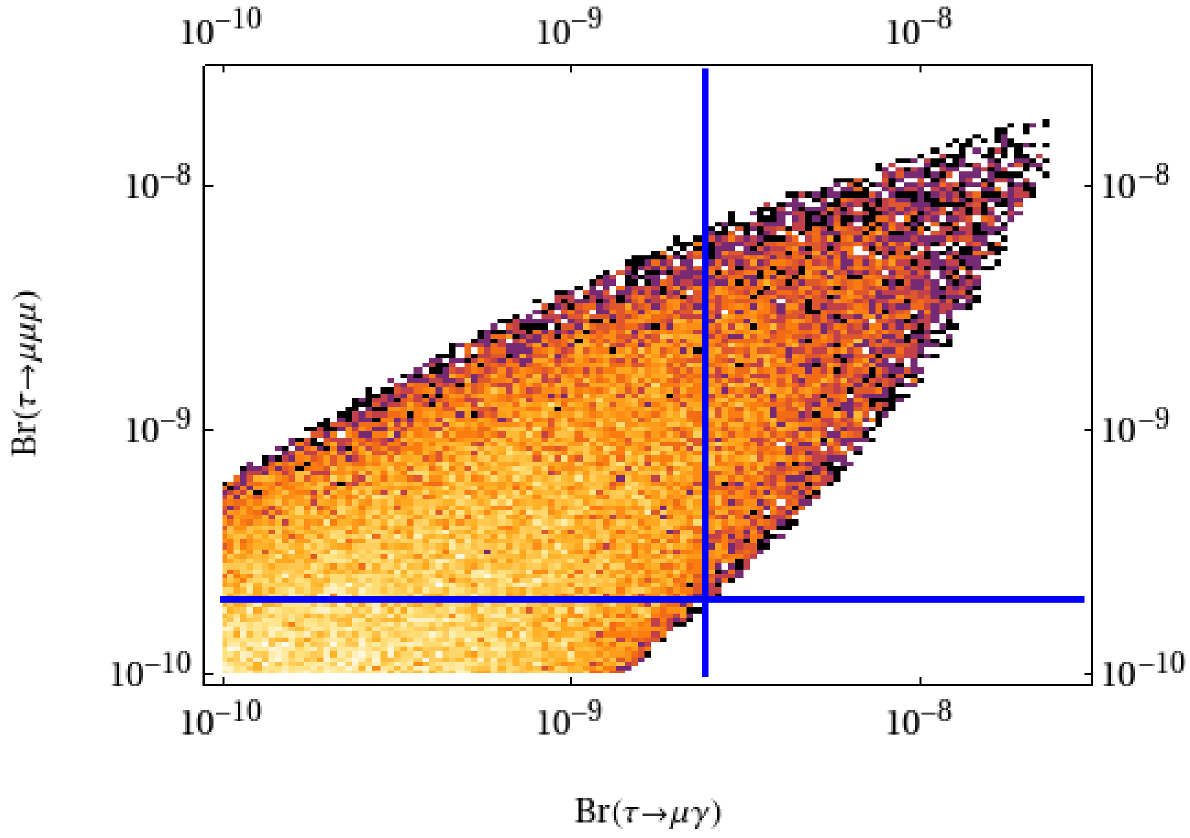




- **signal by specific NP model (MSSM)**
  (implemented in Tauola by S.Banerjee)
- 80% polarized electron beam
- Super*B* fast simulation

- **improve S/N assuming specific NP model**
- **can discriminate between NP models**

Super*B* $\tau \to \ell\gamma$ constraints on LHT model with breaking scale at 500 GeV



- Super*B* reach from arXiv:1109.5028v2 [hep-ex] The impact of SuperB on flavour physics
- NP predictions from M. Blanke et al. arXiv:0906.5454

Tau g–2 at Super*B*

- MSSM can shift muon g–2 by about the presently observed discrepancy $\Delta a_\mu \approx 3{\cdot}10^{-9}$

Δa_μ and Δa_τ for various SPS points						
SPS	1 a	1 b	2	3	4	5
$\Delta a_\mu \times 10^{-9}$	3.1	3.2	1.6	1.4	4.8	1.1
$\Delta a_\tau \times 10^{-6}$	0.9	0.9	0.5	0.4	1.4	0.3
(specific parameters can produce Δa_τ as high as $1{\cdot}10^{-5}$)						

- J.Bernabeu et al., JHEP098P1108 estimate Super*B* $\sigma(a_\tau) = [0.75 - 1.7]{\cdot}10^{-6}$
  - assuming 100% electron beam polarization
  - Super*B* measures $\boldsymbol{a_\tau(q^2)}$ from final state distributions of $e^+e^- \to \tau^+\tau^-$
    - however, Δa_τ from high energy NP contributions is constant for small q^2
  - $\mathrm{Re}\left[a_\tau(q^2)\right]$ measured from τ polar angle distribution or transv. & long. polarization
- considering detector uncertainties and 80% polarization (prelim.) → Super*B* $\sigma(a_\tau) \sim 2.4{\cdot}10^{-6}$

Tau EDM at Super*B*

- $|d_e| < 1.6{\cdot}10^{-27}$ *e* cm at 90% CL, 10.1103/PhysRevLett.88.071805 / PDG10
- most NP models expect linear scaling with lepton mass, $|d_\tau| \propto (m_\tau/m_e)|d_e|$
- Super*B* 2010 Physics White Paper reviews NP models expectations and concludes that:
  $|d_e|$ upper limit → **$|d_\tau^{NP}| < 10^{-22}$ *e* cm**
- Super*B* actually measures **$d_\tau(q^2)$ form factor** from final state distributions of $e^+e^- \to \tau^+\tau^-$
  - however, high energy NP contributions are constant for small q^2
- beam polarization permits measurements based on single tau distributions
- J.Bernabeu et al., arXiv:0707.1658v1 [hep-ph], estimate Super*B* $\sigma(d_\tau) \approx 7.2{\cdot}10^{-20}$ *e* cm
  - 100% electron beam polarization, no uncertainty
  - only $\tau \to \pi\nu$, $\tau \to \rho\nu$, no reconstruction uncertainty
- when considering also detector related uncertainties (prelim.) Super*B* $\sigma(d_\tau) \approx 10{\cdot}10^{-20}$ *e* cm
  (however by combining other tau decay channels one can further improve)
- extrapolating published Belle result **Phys. Lett. B551, 16 (2003), hep-ex/0210066**
  → Super*B* $\sigma(d_\tau) \approx 17\text{–}34{\cdot}10^{-20}$ *e* cm (both real and imaginary parts)
  no beam polarization used, but all tau decay channels combined

Tau *CPV* at Super*B*

- SM predictions in general very small
  ($\tau^\pm \to K^\pm\pi^0\nu$ *CP* asymmetry $\mathcal{O}(10^{-12})$, D. Delepine et al., PRD 72, 033009 (2005), hep-ph/0503090)
- small SM *CP* asymmetry in $\tau^\pm \to K_S\pi^\pm\nu$ from *CPV* in $K^0\overline{K}^0$
  $3.3{\cdot}10^{-3} \pm 2\%$ relative, I.I.Bigi & A. I. Sanda, PLB 625, 47 (2005), hep-ph/0506037
- most NP models do not induce measurable tau CPV
- R-parity violating SUSY → CPV related asymmetries up to 10%, saturating existing limits
  - sizable asymmetries in $\tau \to K\pi\nu_\tau$, $\tau \to K\eta^{(\prime)}\nu_\tau$, and $\tau \to K\pi\pi\nu_\tau$
- CLEO, PRL 88, 111803 (2002), hep-ex/0111095, 13.3 fb^{-1}, $\tau \to K_S\pi\nu$

  → optimal asymmetry observable $\langle\xi\rangle$ **= (–2.0 ± 1.8)·10^{-3}**
  - data calibration with $\tau \to \pi\pi\pi\nu$
- extrapolating at Super*B*, $\sigma_{\langle\xi\rangle} \approx 2.4{\cdot}10^{-5}$
- beam polarization can help (to be studied)

Super*B* D^0–mixing reach using $\Upsilon(4S)$ data

Super*B* 75 ab^{-1} at $\Upsilon(4S)$

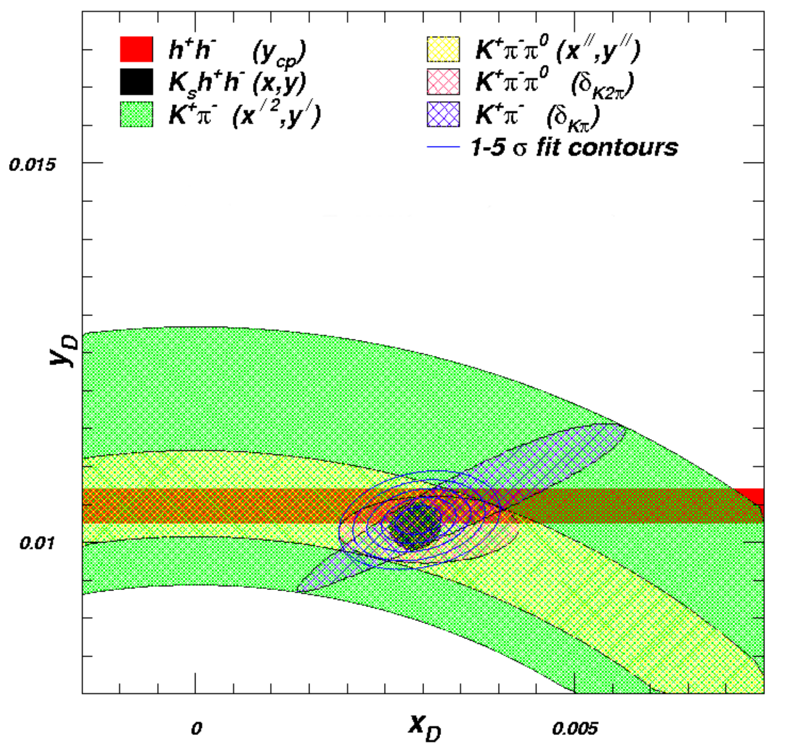
Parameter	$x \times 10^3$	$y \times 10^3$	$\delta_{K\pi}$ (°)	$\delta_{K\pi\pi}$ (°)
σ (stat)	0.18	0.11	1.3	2.7
σ (stat) +(syst)	0.42	0.17	2.2	$^{+3.3}_{-3.4}$

Super*B* 75 ab^{-1} at $\Upsilon(4S)$ with 0.5 ab^{-1} charm threshold run

(measure *D* strong phases on entangled *D*'s at charm threshold)

Parameter	$x \times 10^3$	$y \times 10^3$	$\delta_{K\pi}$ (°)	$\delta_{K\pi\pi}$ (°)
σ (stat)	0.17	0.10	0.9	1.1
σ (stat) +(syst)	0.20	0.12	1.0	1.1

(SuperB white paper: Physics, **arXiv:1008.1541 [hep-ex]**)



D^0 mixing and CPV measurements on entangled *D*'s at charm threshold

M.Rama, Workshop on Charm Physics at threshold, Beijing 21-23 October 2011

- Flavor tag at $D\bar{D}$ threshold provides identical time-dependence than at $\Upsilon(4S)$ using D* tagging, and less events, although in a different environment
- $D\bar{D}$ threshold is unique to provide CP, $K\pi$ and $Ks\pi\pi$ tags
- Variation of Δt resolution and geometrical acceptance vs CM boost was evaluated
- Estimated the impact on physics with 2-body decays
  - Combined fit to all 2-body double-tags allows determination of x, y, arg(q/p), |q/p|
  - Best sensitivity at $\Psi(3770)$ for intermediate boost, $\beta\gamma \approx 0.3$-0.6

Parameter	Sensitivity @ $\Upsilon(4S)$ with time resolution, no mistag. 75 ab^{-1}	Best sensitivity @ $\psi(3770)$ with time resolution ($\beta\gamma$=0.56), no mistag. 0.5 ab^{-1}
x	0.017%	0.11%
y	0.008%	0.05%
Arg(q/p)	0.8 deg	4.8 deg
|q/p|	0.5%	3.7%

Relative effect of flavor mistag similar at $\Psi(3770)$ and $\Upsilon(4S)$

- error per ab^{-1} at $\Upsilon(3770)$ ~ ½ error per ab^{-1} at $\Upsilon(4S)$ (2-body only, no mistag)
- error at $\Psi(3770)$ [0.5ab^{-1}] ~ 6x error at $\Upsilon(4S)$ [75ab^{-1}] (2-body only, no mistag)

Precise EW tests with polarized beams (M.Roney, Super*B* Dec 2011 meeting)

Polarised e- beam yields product of the neutral axial-vector coupling of the electron and vector coupling of the final-state fermion via Z-γ interference:

$$A_{LR} = \frac{4}{\sqrt{2}}\left(\frac{G_F s}{4\pi\alpha Q_f}\right) g_A^e g_V^f \langle Pol \rangle$$

$$\langle Pol \rangle = 0.5\left\{\left(\frac{N_R^{e-} - N_L^{e-}}{N_R^{e-} + N_L^{e-}}\right)_R - \left(\frac{N_R^{e-} - N_L^{e-}}{N_R^{e-} + N_L^{e-}}\right)_L\right\}$$

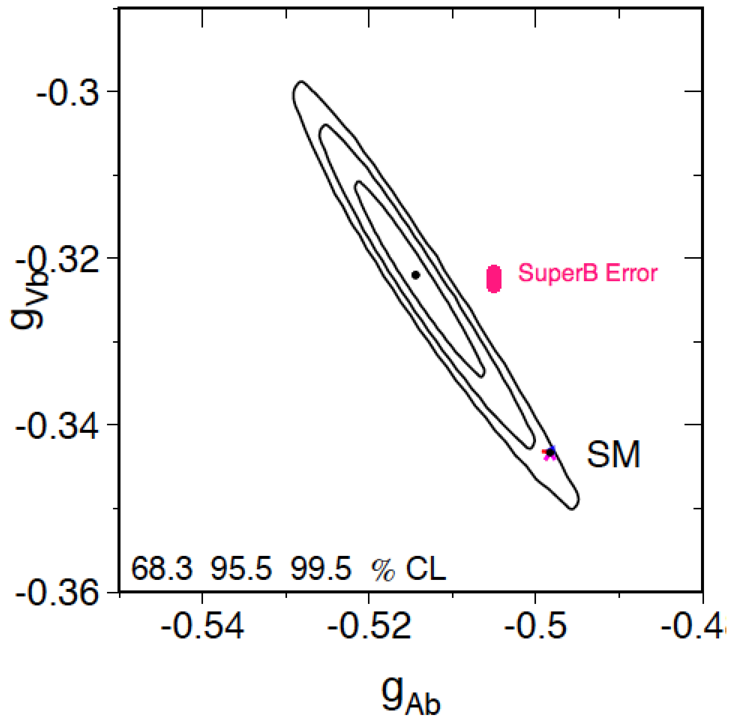
$$g_A^e = T_3^e = 1/2 \qquad g_V^f = T_3^f - 2Q_f \sin^2\theta_W$$

Measure g_{Vb} and test LEP A^b_{FB} anomaly

Measurement of g_V^b

- SM: -0.34372 +0.00049-.00028
- A_{FB}^b: -0.3220±0.0077

- with 0.5% polarization systematic and 0.3% stat error, SuperB can have an error of ±0.0021

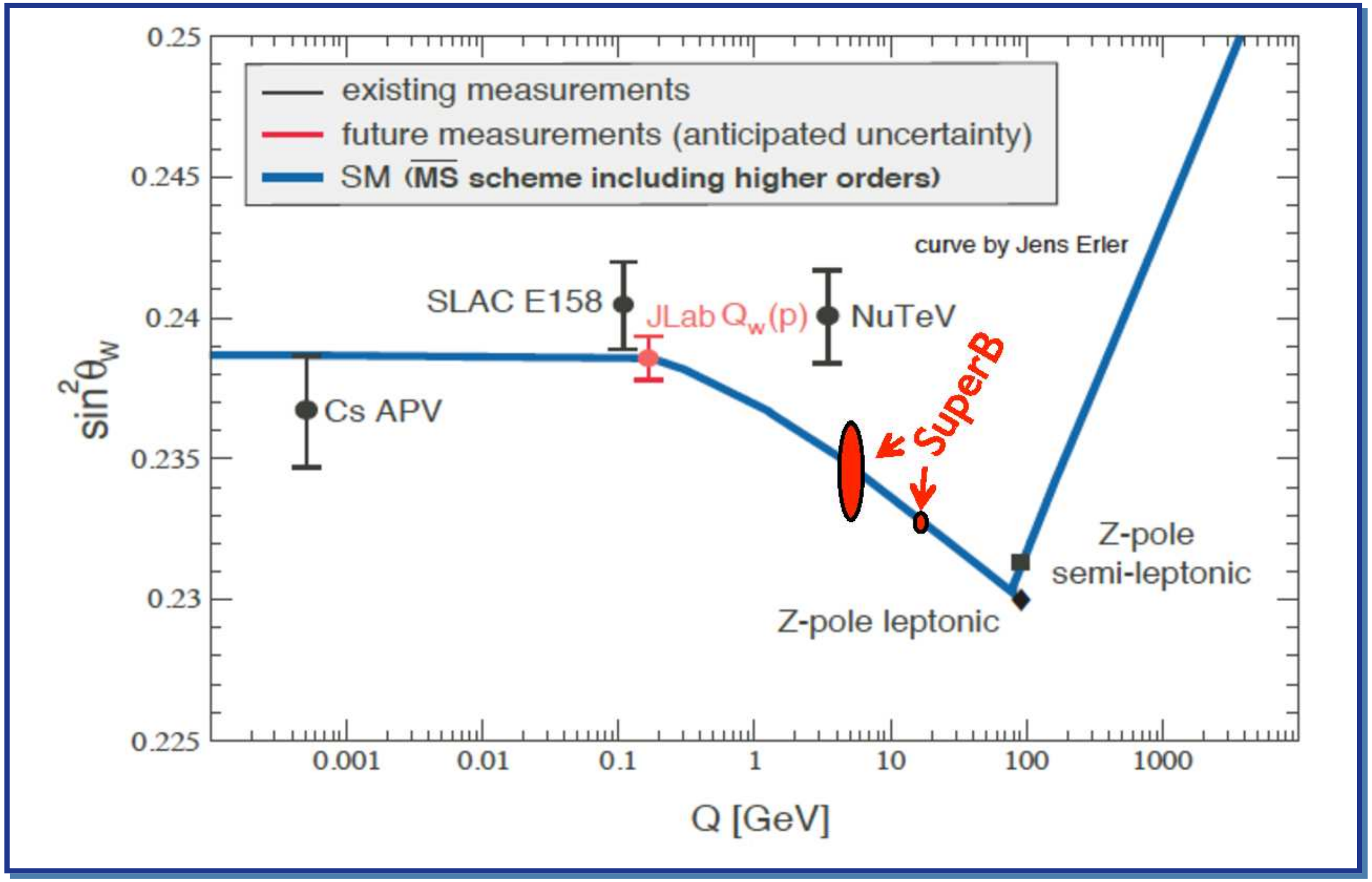


Measure weak charged vector couplings ratios

take ratios of μ,τ,c,b A_{LR} so that of the electron cancels polarisation systematic errors and the electron axial-vector coupling: stat. error dominated

	SM (Mh=125GeV)	LEP	SuperB error
g_V^μ / g_V^τ	1	0.997 +/- 0.068	~2% from tau stats
g_V^c / g_V^{lepton}	5.223 +/-	-4.991 +/- 0.074	~1% muon stats +/-0.05
g_V^b / g_V^{lepton}	9.357 +/-	8.58+/- 0.16	~1% from mu stats +/- 0.08

Measure sin θ_W energy evolution with A_{LR} for μ, τ, charm and *b*



- plot adapted by A.Bevan from QWeak proposal (JLAB E02-020)
- precition not yet evaluated at charm threshold

Sensitivity of Super*B* to specific NP models

list of NP models, full description in

- W.Altmannshofer, A.J.Buras, S.Gori, P.Paradisi, D.M.Straub, Anatomy and Phenomenology of FCNC and CPV Effects in SUSY Theories, arXiv:0909.1333 [hep-ph]
- arXiv:1109.5028v2 [hep-ex] The impact of SuperB on flavour physics

AC	(SUSY) abelian model by Agashe and Carone based on a U(1) flavour symmetry
RVV2	(SUSY) non-abelian model by Ross, Velasco-Sevilla and Vives
AKM	(SUSY) non-abelian model by Antusch, King and Malinsky
δLL	(SUSY) purely left-handed currents with CKM-like mixing angles
FBMSSM	flavour-blind MSSM
GUT-CMM	SUSY GUT
SSU(5)	SUSY GUT SU(5)
LHT	Littlest Higgs with T-parity
RS	Randall-Sundrum

Sensitivity of flavour golden modes to specific NP models

	Observable/mode	H^+ high $\tan\beta$	MFV	non-MFV	NP Z penguins	Right-handed currents	LTH	SUSY AC	SUSY RVV2	SUSY AKM	SUSY δLL	SUSY FBMSSM
✓	$\tau \to \mu\gamma$							★★★	★★★	★	★★★	★★★
✓	$\tau \to \ell\ell\ell$						★★★					
✓	$B \to \tau\nu, \mu\nu$	★★★(CKM)										
✓	$B \to K^{(*)+}\nu\overline{\nu}$			★	★★★			★	★	★	★	★
✓	S in $B \to K^0_S\pi^0\gamma$					★★★						
✓	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)							★	★	★	★★★	★★★
	$B_s \to \mu\mu$							★★★	★★★	★★★	★★★	★★★
	β_s from $B_s \to J/\psi\phi$							★★★	★★★	★★★	★	★
✓	a_{sl}						★★★					
✓	Charm mixing							★★★	★	★	★	★
✓	CPV in Charm	★★									★★★	

✓ = SuperB can measure this

More information on the golden matrix can be found in arXiv:1008.1541, arXiv:0909.1333, and arXiv:0810.1312.

Super*B* reach compared (1), Isidori/Nir/Perez, Ann.Rev.Nucl.Part.Sci. 60, 355 (2010)

Observable	SM prediction	Theory error	Present result	Future error	Future Facility
$\|V_{us}\|$ $[K \to \pi \ell \nu]$	input	$0.5\% \to 0.1\%_{Latt}$	0.2246 ± 0.0012	0.1%	K factory
$\|V_{cb}\|$ $[B \to X_c \ell \nu]$	input	1%	$(41.54 \pm 0.73) \times 10^{-3}$	1%	Super*B* $50\,\text{ab}^{-1}$
$\|V_{ub}\|$ $[B \to \pi \ell \nu]$	input	$10\% \to 5\%_{Latt}$	$(3.38 \pm 0.36) \times 10^{-3}$	4%	Super*B* $50\,\text{ab}^{-1}$
γ $[B \to DK]$	input	$< 1^\circ$	$(70^{+27}_{-30})^\circ$	3°	LHCb
$S_{B_d \to \psi K}$	$\sin(2\beta)$	$\lesssim 0.01$	0.671 ± 0.023	0.01	LHCb
$S_{B_s \to \psi \phi}$	0.036	$\lesssim 0.01$	$0.81^{+0.12}_{-0.32}$	0.01	LHCb
$S_{B_d \to \phi K}$	$\sin(2\beta)$	$\lesssim 0.05$	0.44 ± 0.18	0.1	LHCb
$S_{B_s \to \phi \phi}$	0.036	$\lesssim 0.05$	—	0.05	LHCb
$S_{B_d \to K^* \gamma}$	few × 0.01	0.01	-0.16 ± 0.22	0.03	Super*B* $50\,\text{ab}^{-1}$
$S_{B_s \to \phi \gamma}$	few × 0.01	0.01	—	0.05	LHCb
A^d_{SL}	-5×10^{-4}	10^{-4}	$-(5.8 \pm 3.4) \times 10^{-3}$	10^{-3}	LHCb
A^s_{SL}	2×10^{-5}	$< 10^{-5}$	$(1.6 \pm 8.5) \times 10^{-3}$	10^{-3}	LHCb

Super*B* reach compared (2), Isidori/Nir/Perez, Ann.Rev.Nucl.Part.Sci. 60, 355 (2010)

Observable	SM prediction	Theory error	Present result	Future error	Future Facility
$A_{CP}(b \to s\gamma)$	< 0.01	< 0.01	-0.012 ± 0.028	0.005	Super*B* $50\,\mathrm{ab}^{-1}$
$\mathcal{B}(B \to \tau\nu)$	1×10^{-4}	$20\% \to 5\%_{Latt}$	$(1.73 \pm 0.35) \times 10^{-4}$	5%	Super*B* $50\,\mathrm{ab}^{-1}$
$\mathcal{B}(B \to \mu\nu)$	4×10^{-7}	$20\% \to 5\%_{Latt}$	$< 1.3 \times 10^{-6}$	6%	Super*B* $50\,\mathrm{ab}^{-1}$
$\mathcal{B}(B_s \to \mu^+\mu^-)$	3×10^{-9}	$20\% \to 5\%_{Latt}$	$< 5 \times 10^{-8}$	10%	LHCb
$\mathcal{B}(B_d \to \mu^+\mu^-)$	1×10^{-10}	$20\% \to 5\%_{Latt}$	$< 1.5 \times 10^{-8}$	[?]	LHCb
$A_{FB}(B \to K^*\mu^+\mu^-)_{q_0^2}$	0	0.05	(0.2 ± 0.2)	0.05	LHCb
$B \to K\nu\bar{\nu}$	4×10^{-6}	$20\% \to 10\%_{Latt}$	$< 1.4 \times 10^{-5}$	20%	Super*B* $50\,\mathrm{ab}^{-1}$
$\lvert q/p \rvert_{D-mixing}$	1	$< 10^{-3}$	$(0.86^{+0.18}_{-0.15})$	0.03	Super*B* $50\,\mathrm{ab}^{-1}$
ϕ_D	0	$< 10^{-3}$	$(9.6^{+8.3}_{-9.5})^\circ$	2°	Super*B* $50\,\mathrm{ab}^{-1}$
$\mathcal{B}(K^+ \to \pi^+\nu\bar{\nu})$	8.5×10^{-11}	8%	$(1.73^{+1.15}_{-1.05}) \times 10^{-10}$	10%	*K* factory
$\mathcal{B}(K_L \to \pi^0\nu\bar{\nu})$	2.6×10^{-11}	10%	$< 2.6 \times 10^{-8}$	[?]	*K* factory
$R^{(e/\mu)}(K \to \pi\ell\nu)$	2.477×10^{-5}	0.04%	$(2.498 \pm 0.014) \times 10^{-5}$	0.1%	*K* factory
$\mathcal{B}(t \to c\,Z, \gamma)$	$\mathcal{O}(10^{-13})$	$\mathcal{O}(10^{-13})$	$< 0.6 \times 10^{-2}$	$\mathcal{O}(10^{-5})$	LHC ($100\,\mathrm{fb}^{-1}$)

Super*B* vs. LHCb for 5 NP models (P.Paradisi, Super*B* meeting, Dec 2011)

	SSU(5)	AC	RVV2	AKM	δLL	FBMSSM	
$S_{\phi K_S}$	★★★	★★★	●●	■	★★★	★★★	SuperB
$A_{CP}(B \to X_s\gamma)$	■	■	■	■	★★★	★★★	
$B \to K^{(*)}\nu\bar{\nu}$	■	■	■	■	■	■	
$\tau \to \mu\gamma$	★★★	★★★	★★★	■	★★★	★★★	
$D^0 - \bar{D}^0$	■	★★★	■	■	■	■	SuperB
$A_{7,8}(B \to K^*\mu^+\mu^-)$	■	■	■	■	★★★	★★★	vs.
$A_9(B \to K^*\mu^+\mu^-)$	■	■	■	■	■	■	LHCb
$S_{\psi\phi}$	★★★	★★★	★★★	★★★	■	■	LHCb
$B_s \to \mu^+\mu^-$	★★★	★★★	★★★	★★★	★★★	★★★	
ϵ_K	★★★	■	★★★	★★★	■	■	
$K^+ \to \pi^+\nu\bar{\nu}$	■	■	■	■	■	■	
$K_L \to \pi^0\nu\bar{\nu}$	■	■	■	■	■	■	
$\mu \to e\gamma$	★★★	★★★	★★★	★★★	★★★	★★★	
$\mu + N \to e + N$	★★★	★★★	★★★	★★★	★★★	★★★	
d_n	★★★	★★★	★★★	★★★	●●	★★★	
d_e	★★★	★★★	★★★	●●	■	★★★	
$(g-2)_\mu$	★★★	★★★	★★★	●●	★★★	★★★	

elaboration using information in W.Altmannshofer, A.J.Buras, S.Gori, P.Paradisi, D.M.Straub, Anatomy and Phenomenology of FCNC and CPV Effects in SUSY Theories, arXiv:0909.1333 [hep-ph]

Conclusion

Super*B* can search for new physics effects in a competitive and complementary way with the currently operated and planned facilities. Super*B* is designed for maximum versatility and includes beam polarization and the ability of running both around the $\Upsilon(4S)$ peak and at the charm treshold. Its features make it uniquely suited for a large range of new physics searches and precision tests of the standard model.