Physics at SuperB

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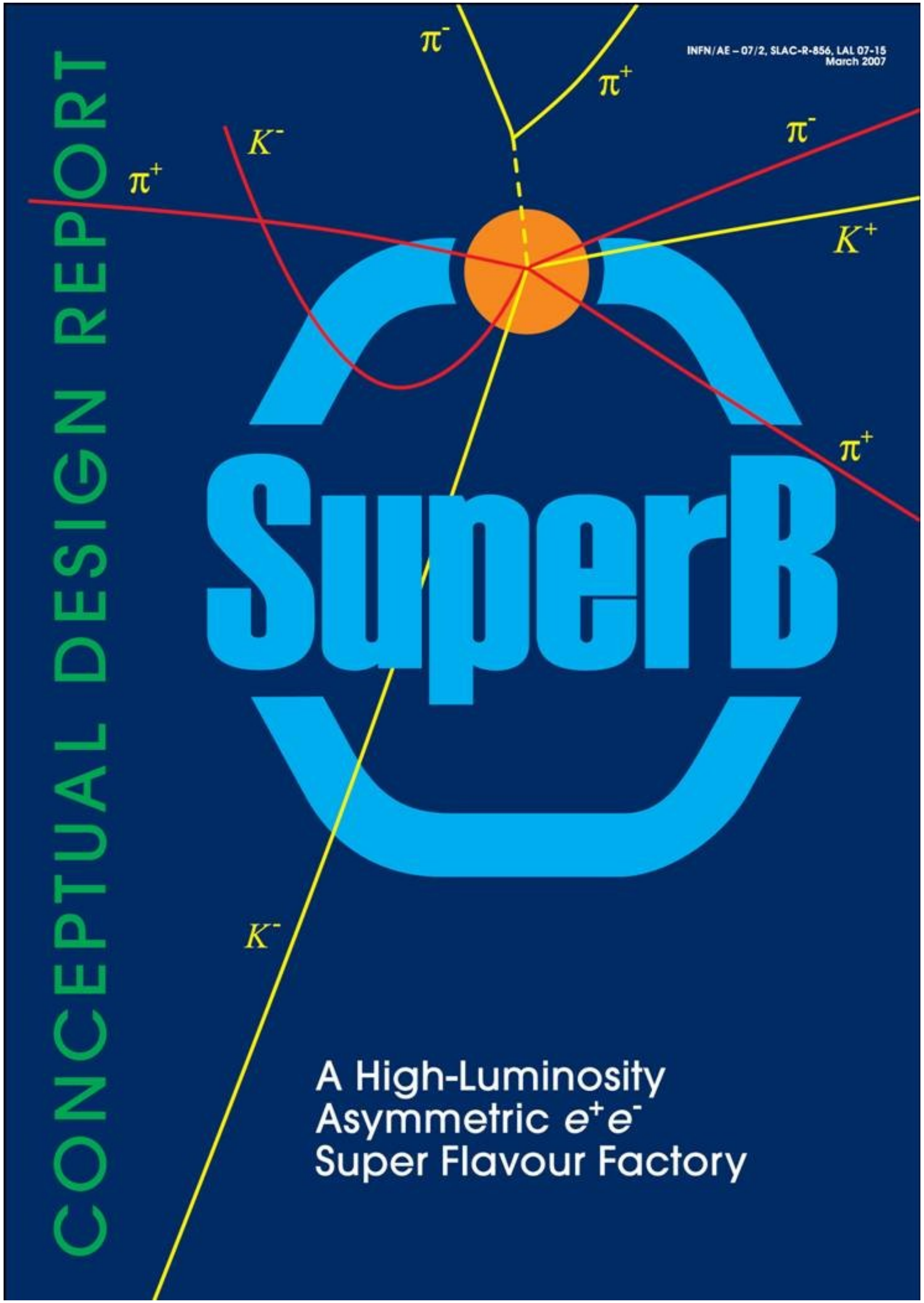


SuperB is

a very high luminosity asymmetric e^+e^- flavour factory

Conceptual design report

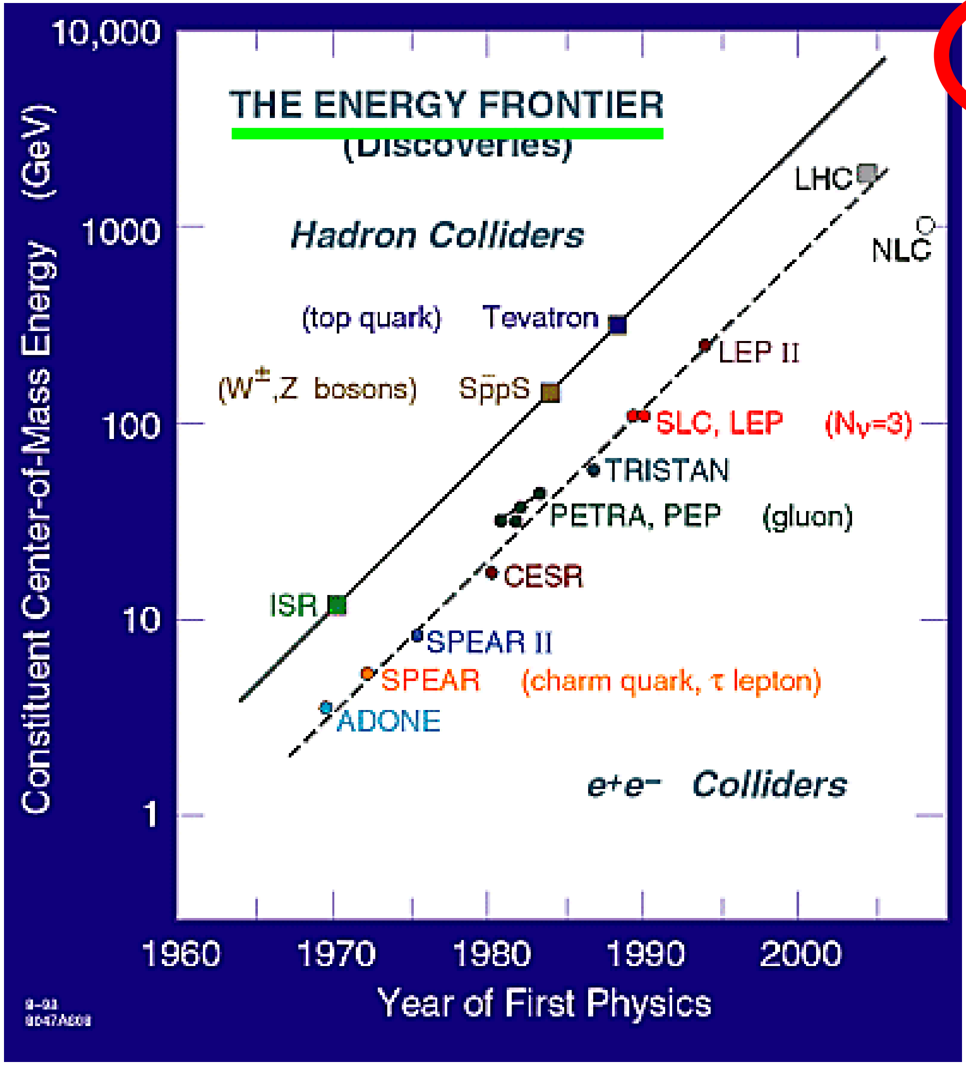
INFN/AE-07/02, SLAC-R-856, LAL 07-15

http://www.pi.infn.it/SuperB

See also

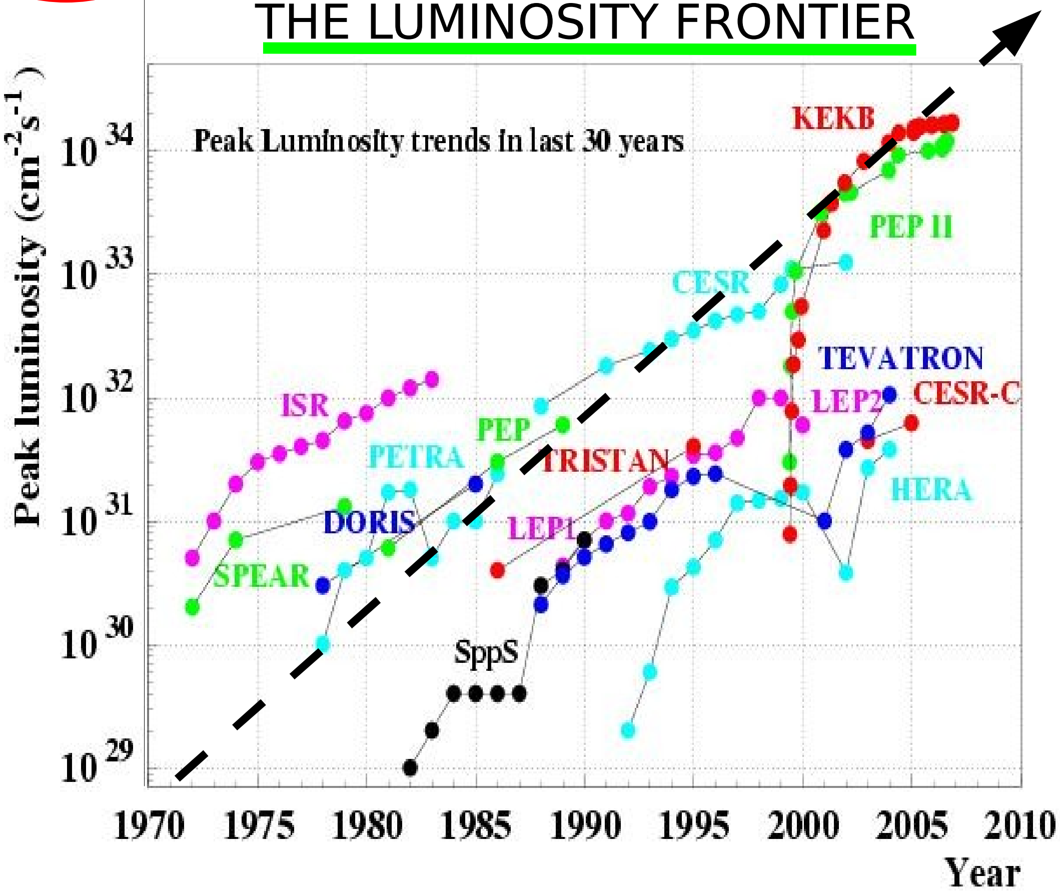
- SuperKEKB Letter of Intent, KEK Report 04-4
- SuperKEKB Physics Working Group, [arXiv:hep-ex/0406071], update in preparation
- J.L.Hewett, D.Hitlin (ed.), SLAC-R-709, [arXiv:hep-ph/0503261]
- Flavour in LHC Era workshops, yellow book in preparation

Exploration of Two Frontiers



10^{36}

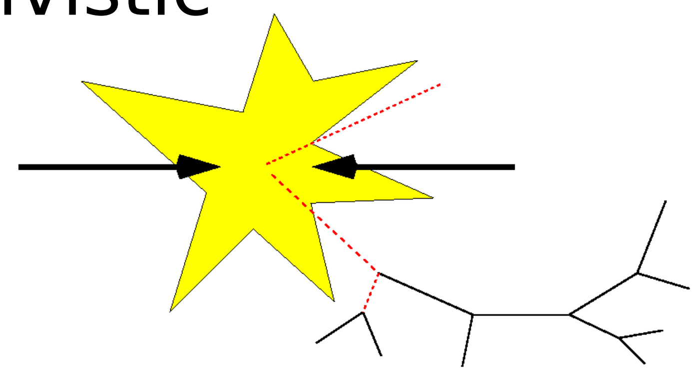
SuperB



Motivation

- Major challenge for particle physics in the next decade is to go beyond the Standard Model

“relativistic”

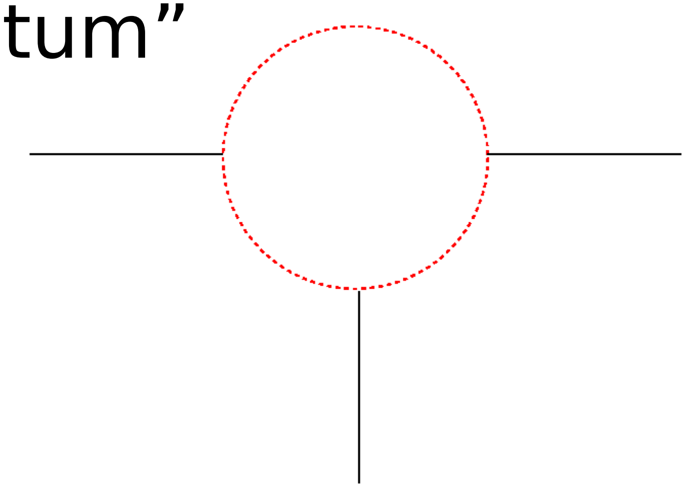


New heavy particles produced on mass shell

Sensitivity depends on:

- available centre-of-mass energy
- knowledge of Standard Model backgrounds

“quantum”



New heavy particles produced off mass shell (“virtual”)

Sensitivity depends on:

- luminosity
- knowledge of Standard Model backgrounds

Flavour Observables Sensitive to New Physics

$$\Delta m_K \quad \epsilon_K \quad \epsilon'/\epsilon_K \quad B(K_L \to \pi^0 \nu \bar{\nu}) \quad B(K^+ \to \pi^+ \nu \bar{\nu}) \quad B(K^+ \to l^+ \nu)$$

$$\Delta m_d \quad A_{SL}(B_d) \quad S(B_d \to J/\psi K_S) \quad S(B_d \to \phi K_S)$$

$$\alpha(B \to \pi\pi, \rho\pi, \rho\rho) \quad \gamma(B \to DK) \quad CKM\ fits$$

$$\Delta m_s \quad A_{SL}(B_s) \quad S(B_s \to J/\psi \phi) \quad S(B_s \to \phi\phi)$$

$$B(b \to s\gamma) \quad A_{CP}(b \to s\gamma) \quad S(B^0 \to K_S \pi^0 \gamma) \quad S(B_s \to \phi\gamma)$$

$$B(b \to d\gamma) \quad A_{CP}(b \to d\gamma) \quad A_{CP}(b \to (d+s)\gamma) \quad S(B^0 \to \rho^0 \gamma)$$

$$B(b \to s l^+ l^-) \quad B(b \to d l^+ l^-) \quad A_{FB}(b \to s l^+ l^-) \quad B(b \to s \nu \bar{\nu})$$

$$B(B_s \to l^+ l^-) \quad B(B_d \to l^+ l^-) \quad B(B^+ \to l^+ \nu)$$

$$B(\mu \to e\gamma) \quad B(\mu \to e^+ e^- e^+) \quad (g-2)_\mu \quad \mu\ EDM$$

$$B(\tau \to \mu\gamma) \quad B(\tau \to e\gamma) \quad B(\tau^+ \to l^+ l^- l^+) \quad \tau\ CPV \quad \tau\ EDM$$

$$B(D^+_{(s)} \to l^+ \nu) \quad x_D \quad y_D \quad charm\ CPV$$

... add your favourite here ...

Good News and Bad News

- Bad news
  - no single “golden mode”
  - (of course, some channels preferred in certain models)
- Good news
  - very many observables sensitive to new physics
  - maximize sensitivity by combining information
  - correlations between results distinguish models

Super Flavour Factory
“treasure chest”
of new physics observables

Will be Studied at SuperB

Δm_K ϵ_K ϵ'/ϵ_K $B(K_L \to \pi^0 \nu \bar{\nu})$ $B(K^+ \to \pi^+ \nu \bar{\nu})$ $B(K^+ \to l^+ \nu)$

Δm_d $A_{SL}(B_d)$ $S(B_d \to J/\psi K_S)$ $S(B_d \to \phi K_S)$

$\alpha(B \to \pi\pi, \rho\pi, \rho\rho)$ $\gamma(B \to DK)$ $CKM\ \ fits$

Δm_s $A_{SL}(B_s)$ $S(B_s \to J/\psi \phi)$ $S(B_s \to \phi\phi)$

$B(b \to s\gamma)$ $A_{CP}(b \to s\gamma)$ $S(B^0 \to K_S \pi^0 \gamma)$ $S(B_s \to \phi\gamma)$

$B(b \to d\gamma)$ $A_{CP}(b \to d\gamma)$ $A_{CP}(b \to (d+s)\gamma)$ $S(B^0 \to \rho^0 \gamma)$

$B(b \to s l^+ l^-)$ $B(b \to d l^+ l^-)$ $A_{FB}(b \to s l^+ l^-)$ $B(b \to s \nu \bar{\nu})$

$B(B_s \to l^+ l^-)$ $B(B_d \to l^+ l^-)$ $B(B^+ \to l^+ \nu)$

$B(\mu \to e\gamma)$ $B(\mu \to e^+ e^- e^+)$ $(g-2)_\mu$ $\mu\ \ EDM$

$B(\tau \to \mu\gamma)$ $B(\tau \to e\gamma)$ $B(\tau^+ \to l^+ l^- l^+)$ $\tau\ \ CPV$ $\tau\ \ EDM$

$B(D^+_{(s)} \to l^+ \nu)$ x_D y_D $charm\ \ CPV$

Super Flavour Factory

- Data taken at Υ(4S) allows studies of B, tau, charm, charmonia, ISR, γγ physics (and more)

- SuperB is designed with flexible running energy
  - charm-tau threshold region
  - other Upsilon resonances – including Υ(5S)

⇒ can study B_s sector, including $\Delta\Gamma_s$ and φ_s (but not Δm_s)

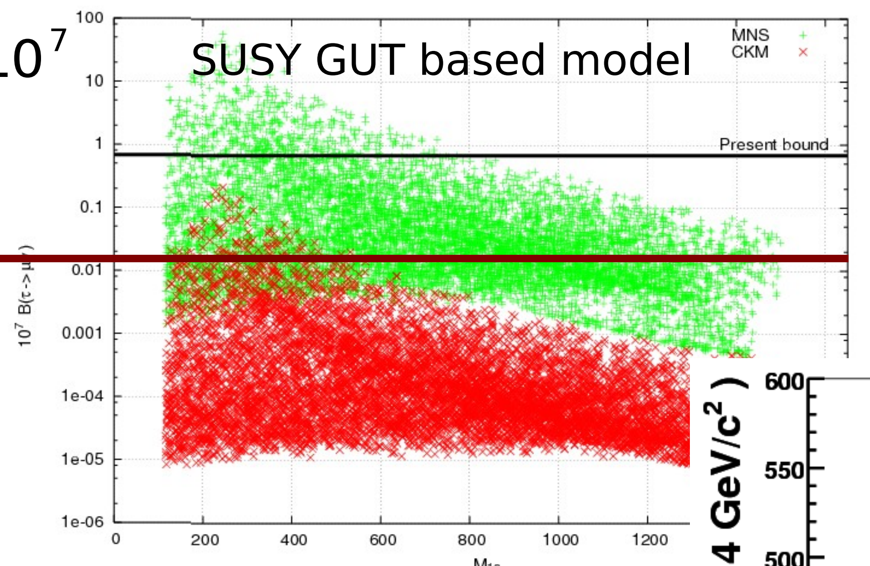
- Considering beam polarization option
  - provides luminosity enhancement
  - significant improvement in sensitivity for τ EDM

see arXiv:0707.1658 and arXiv:0707.2496

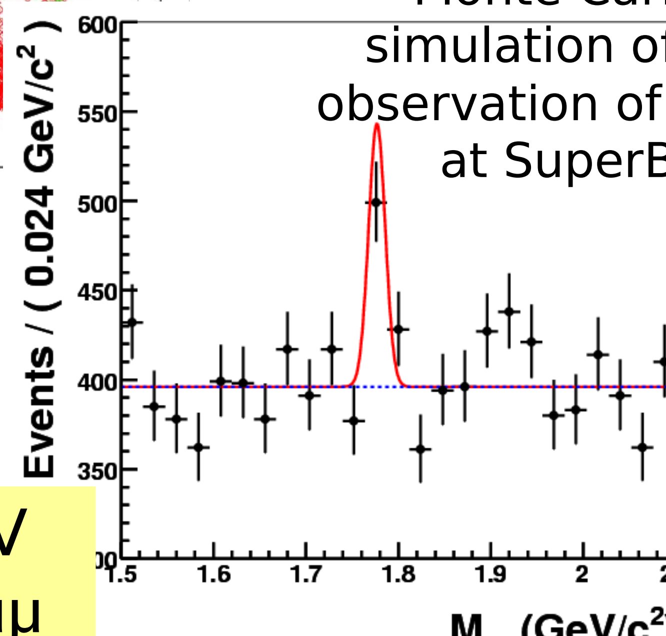
Lepton Flavour Violation

- Observable LFV signals predicted in a wide range of models, including those inspired by Majorana neutrinos

$B(\tau \rightarrow \mu \gamma) \times 10^7$



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



Monte Carlo simulation of 5σ observation of $\tau \rightarrow \mu\gamma$ at SuperB

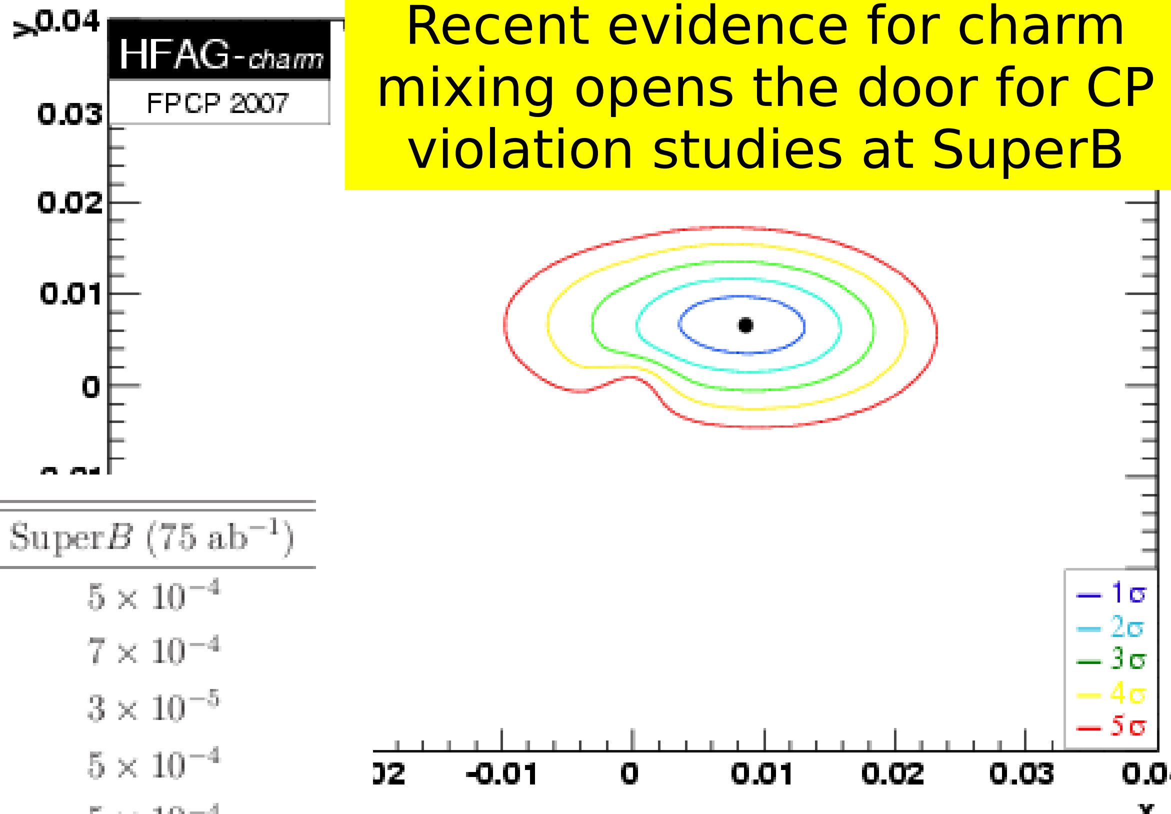
SuperB is *much* more sensitive to LFV than LHC experiments, even for $\tau \rightarrow \mu\mu\mu$

Charm at SuperB

- SuperB *uniquely* can study the full range of charm phenomena

CP violation in charm highly sensitive new physics probe

Recent evidence for charm mixing opens the door for CP violation studies at SuperB



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

Two Scenarios

1) LHC discovers new physics

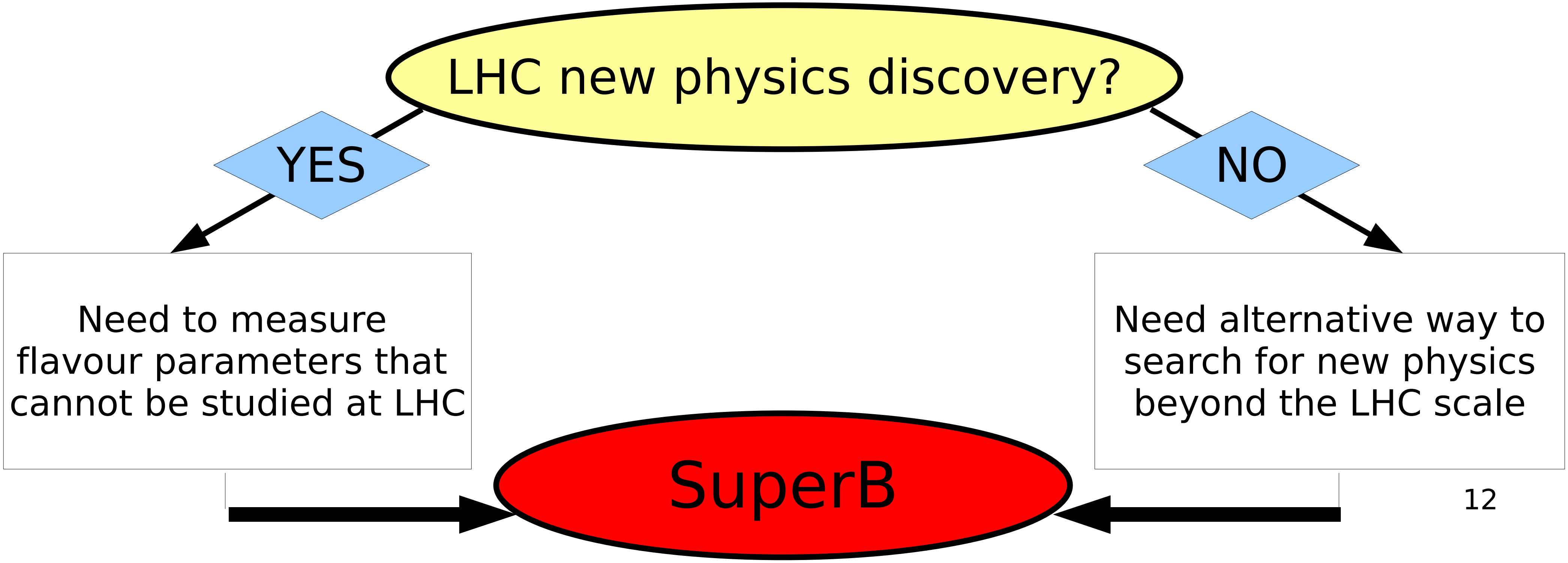
- Can it be flavour blind? (ie. no signals in flavour)
  - No, it must couple to SM, which violates flavour
  - Any TeV scale NP model includes new flavoured particles
- What is the minimal flavour violation? (ie. worst case)
  - NP follows SM pattern of flavour and CP violation
  - SFF detects NP effects for particle masses up to >600 GeV
- What if NP flavour couplings are not suppressed?
  - SFF measures NP flavour couplings and distinguishes models

2) LHC does not discover new physics

- Problem for naturalness?
  - Not really – just an order of magnitude argument
- How to probe higher mass scales?
  - NP models with unsuppressed flavour couplings can reach scales of 10s, 100s or even 1000s of TeV

Interplay of Energy and Luminosity Frontiers

- Important to note that flavour observables are complementary to those at the energy frontier
  - measure different new physics parameters
  - powerful to distinguish models



Estimated Sensitivities

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°

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% (∗)	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%
$\mathcal{B}(B \to K\nu\bar{\nu})$	visible	20%
$\mathcal{B}(B \to \pi\nu\bar{\nu})$	–	possible

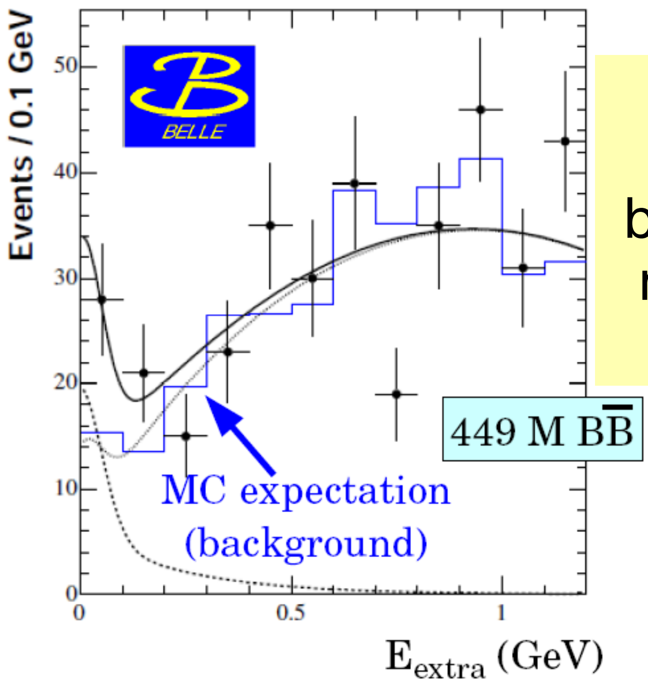
Still only a few measurements systematics (†) or theoretically (*) limited

Leptonic B Decays

Crucial for MFV models with large tan β (and MSSM)

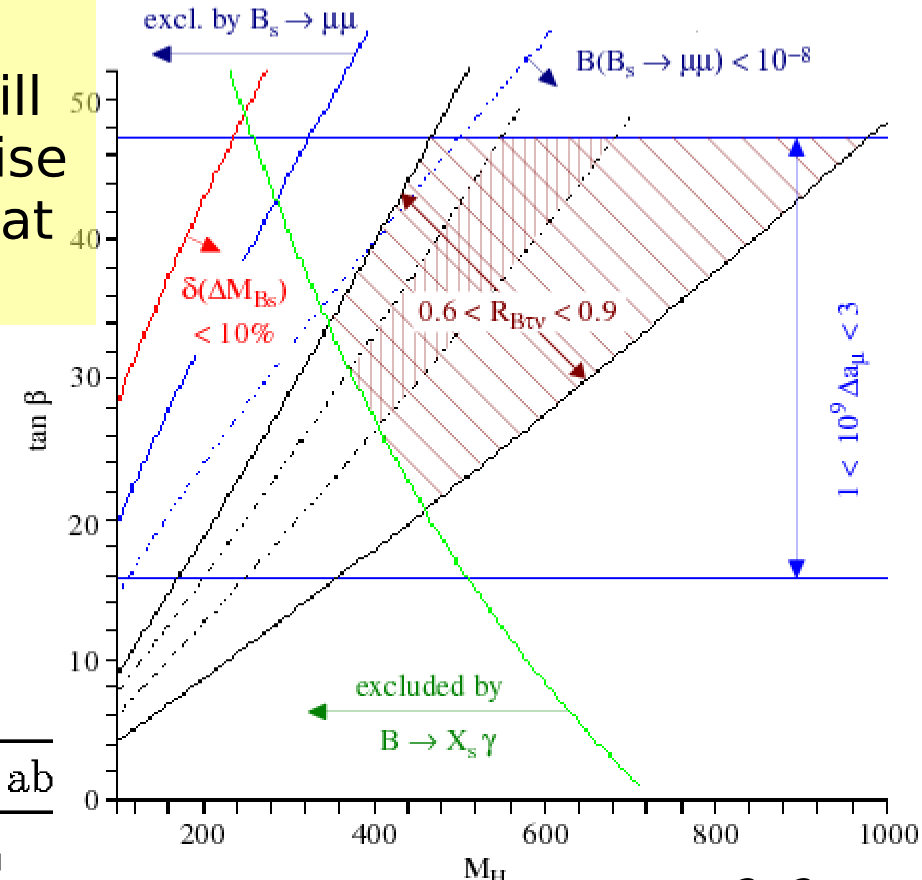
W.-S.Hou, PRD 48, 2342 (1993)
G.Isidori, P.Paradisi, PLB 639, 499 (2006)

$B(B^+ \to \tau^+ \nu)$



$17.2\ ^{+5.3}_{-4.7}$ events

Today's first observation will become a precise measurement at SuperB



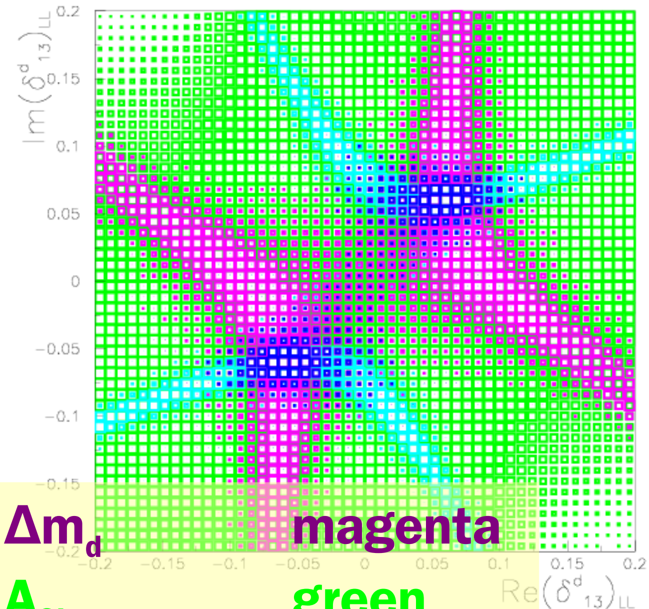
Observable	B Factories (2 ab^{-1})	Super$B$ (75 ab
$\mathcal{B}(B \to \tau\nu)$	20%	4% (†)
$\mathcal{B}(B \to \mu\nu)$	visible	5%
$\mathcal{B}(B \to D\tau\nu)$	10%	2%

see talks in this session

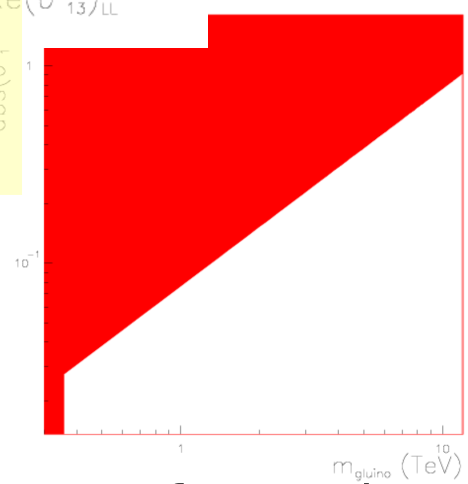
$$B = B_{SM}\left(1 - \tan^2\beta \frac{M_B^2}{M_H^2}\right)^2$$

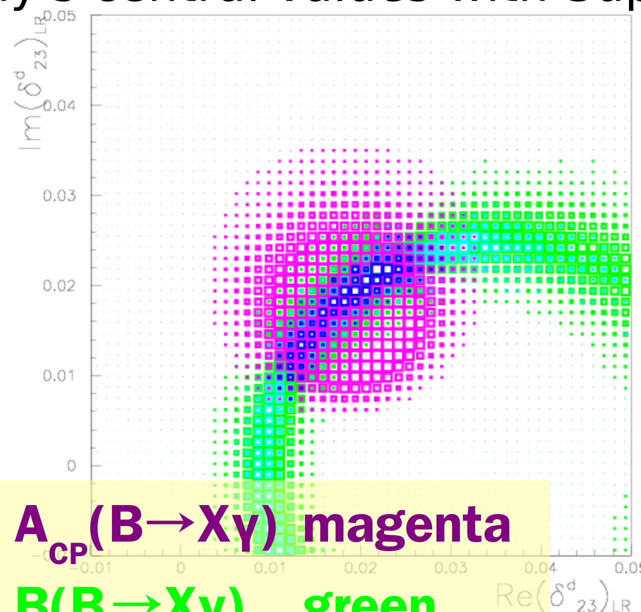
MSSM + Generic Squark Mass Matrices

Today's central values with SuperB precision

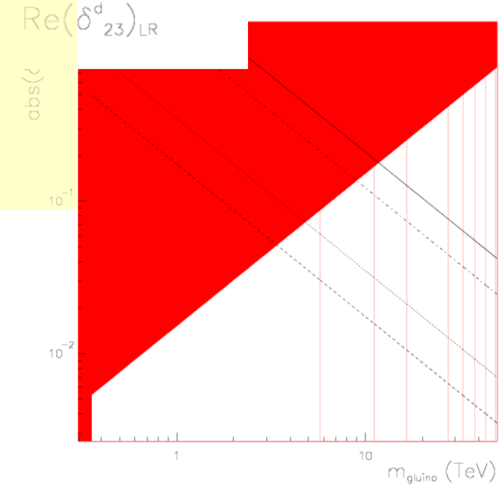


Δm_d	magenta
A_{SL}	green
β	cyan
All	blue





$A_{CP}(B\rightarrow X\gamma)$	magenta
$B(B\rightarrow X\gamma)$	green
$B(B\rightarrow Xl^+l^-)$	cyan
All	blue

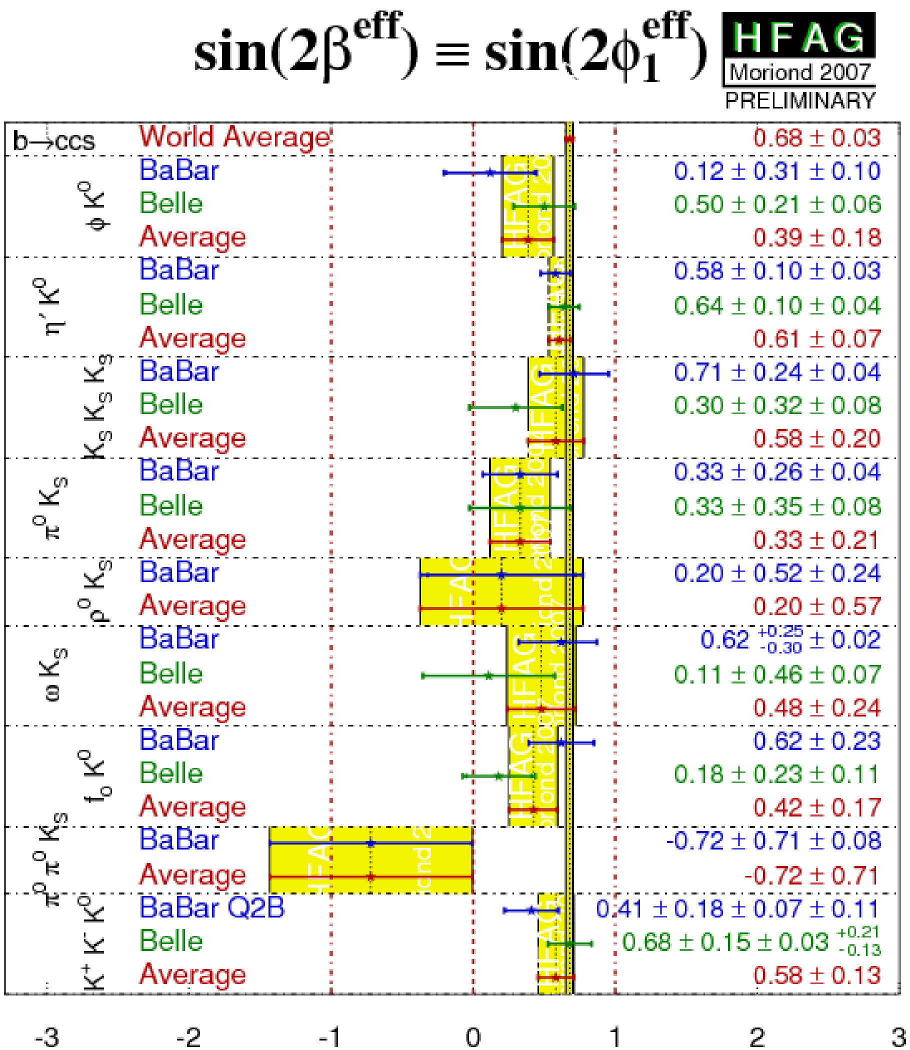


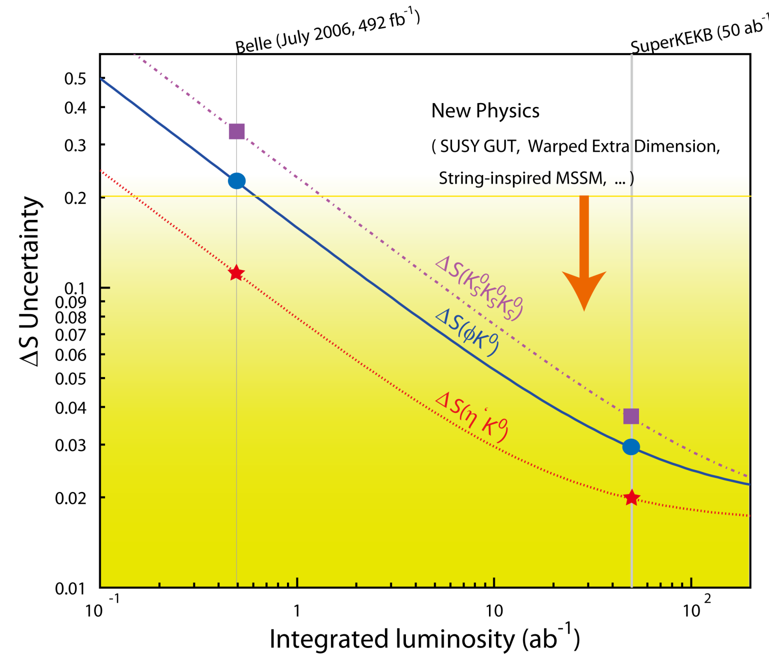
Real vs. imaginary parts of mass-insertion parameters: left $(\delta_{13})_{LL}$; right $(\delta_{23})_{LR}$

Red areas show δ > 3σ from zero with SuperB precision

Hadronic b→s Penguins

Current B factory hot topic





Many channels can be measured with ΔS~(0.01-0.04)

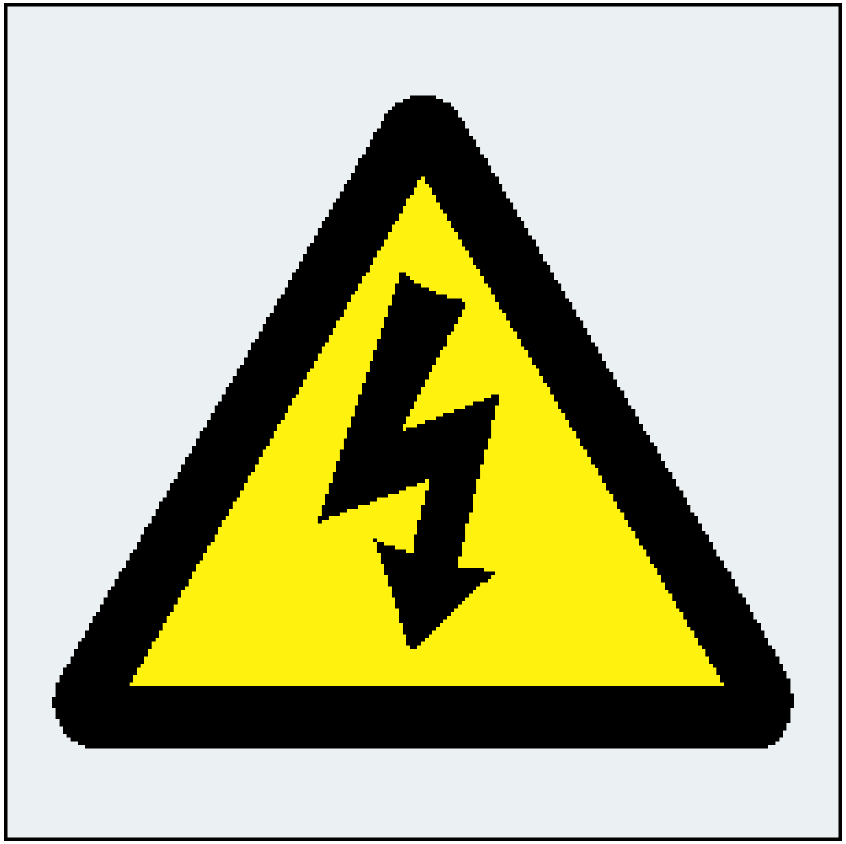
Observable	B Factories (2 ab^{-1})	**SuperB**	
$S(\phi K^0)$	0.13	0.02 (∗)	[0.030]
$S(\eta' K^0)$	0.05	0.01 (∗)	[0.020]
$S(K_s^0 K_s^0 K_s^0)$	0.15	0.02 (∗)	[0.037]
$S(K_s^0 \pi^0)$	0.15	0.02 (∗)	[0.042]
$S(\omega K_s^0)$	0.17	0.03 (∗)	
$S(f_0 K_s^0)$	0.12	0.02 (∗)	

(*) theoretical limited

Summary

- The case for flavour physics in the LHC era is compelling
- SuperB – a high-luminosity asymmetric e^+e^- Super Flavour Factory is the ideal tool
  - significant breakthrough in collider design
- Conceptual Design Report exists
  - clear road ahead to explore the flavour treasure chest by mid-2010s
- See talk by M.Giorgi in EPS-ECFA session for more details of the project

Back Up



Estimated Sensitivities

Observable	Super Flavour Factory sensitivity
$\sin(2\beta)$ $(J/\psi\, K^0)$	0.005–0.012
γ $(B \to D^{(*)}K^{(*)})$	1–2°
α $(B \to \pi\pi, \rho\rho, \rho\pi)$	1–2°
$\|V_{ub}\|$ (exclusive)	3–5%
$\|V_{ub}\|$ (inclusive)	2–6%
$\bar{\rho}$	1.7–3.4%
$\bar{\eta}$	0.7–1.7%
$S(\phi K^0)$	0.02–0.03
$S(\eta' K^0)$	0.01–0.02
$S(K^0_S K^0_S K^0_S)$	0.02–0.04
$\mathcal{B}(B \to \tau\nu)$	3–4%
$\mathcal{B}(B \to \mu\nu)$	5–6%
$\mathcal{B}(B \to D\tau\nu)$	2–2.5%
$\mathcal{B}(B \to \rho\gamma)/\mathcal{B}(B \to K^*\gamma)$	3–4%
$A_{CP}(b \to s\gamma)$	0.004–0.005
$A_{CP}(b \to (s+d)\gamma)$	0.01
$S(K^0_S \pi^0 \gamma)$	0.02–0.03
$S(\rho^0\gamma)$	0.08–0.12
$A^{\rm FB}(B \to X_s \ell^+\ell^-)$ s_0	4–6%
$\mathcal{B}(B \to K\nu\bar{\nu})$	16–20%
$\mathcal{B}(\tau \to \mu\gamma)$	$2\text{–}8 \times 10^{-9}$
$\mathcal{B}(\tau \to \mu\mu\mu)$	$0.2\text{–}1 \times 10^{-9}$
$\mathcal{B}(\tau \to \mu\eta)$	$0.4\text{–}4 \times 10^{-9}$

Range of estimated sensitivities from SuperB CDR and SuperKEKB LoI

A Completely New Accelerator Design

Attempts to upgrade PEP-II and KEKB with high current hit limitations due to beam instabilities, backgrounds and power

⇒ Approach with small emittance bunches (SuperB)

- initially inspired by ILC damping rings
- large Piwinski angle ($\varphi = \theta\, \sigma_z / \sigma_x$)
- "crab waist"

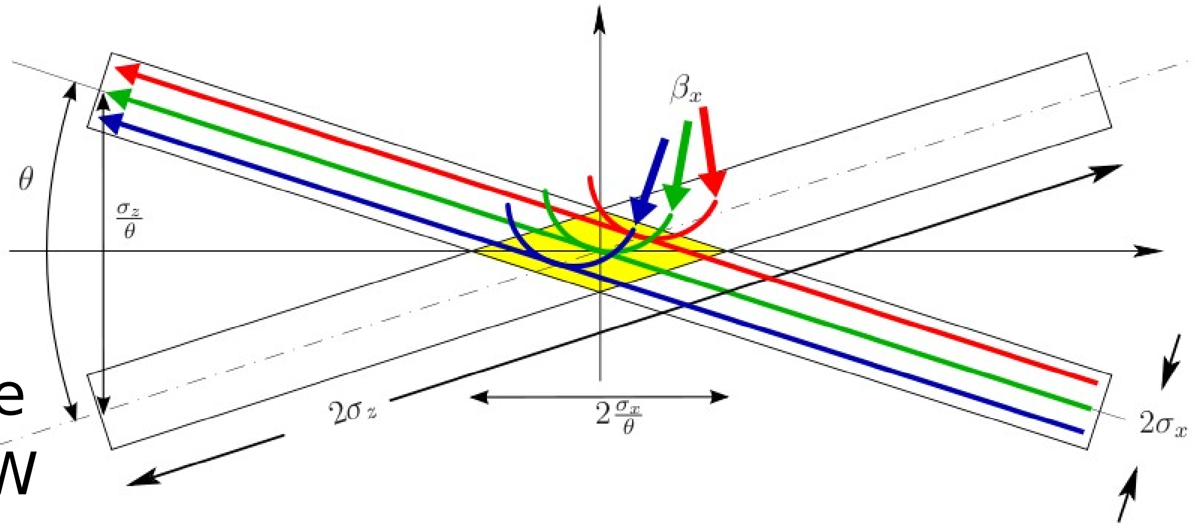
⇒ High luminosity

⇒ Low currents

⇒ Small backgrounds

⇒ Stable dynamic aperture

⇒ Wall plug power ~30 MW



Maximize beam overlap with finite crossing angle

Backgrounds and Detectors

- Backgrounds depend on various factors
  - luminosity
    - radiative BhaBha scattering
    - e^+e^- pair production
  - currents
    - synchrotron radiation
    - beam-gas interaction ← main problem for SuperKEKB: beam backgrounds ~ 20 x today
  - beam size
    - Touschek scattering ← possible problem for SuperB: motivates smaller beam asymmetry (7 GeV on 4 GeV)
    - beam-beam interactions

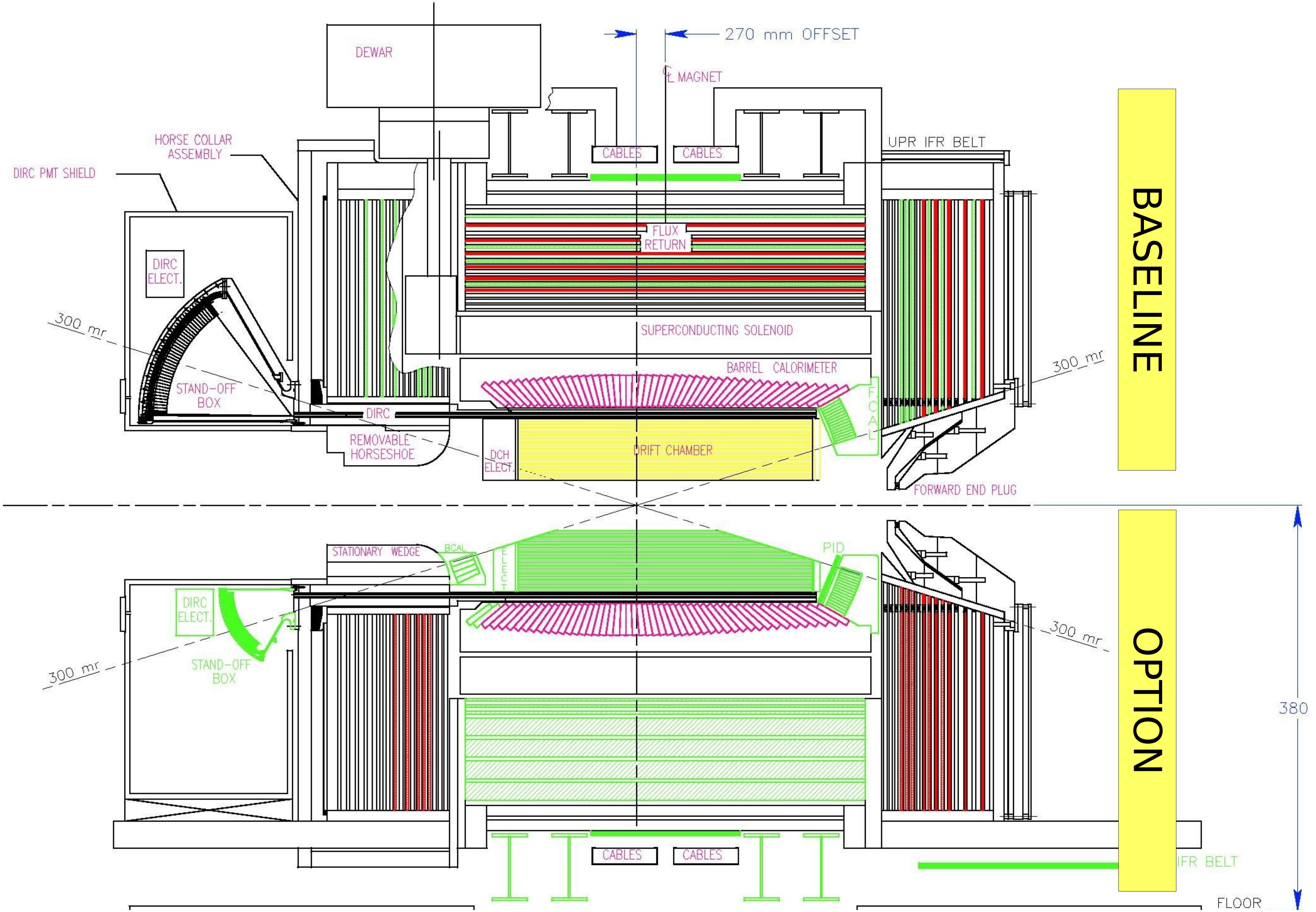
- For either SuperKEKB or SuperB:
  - interaction point design & shielding requires care
  - detector can be based on existing BaBar / Belle

Detector R&D

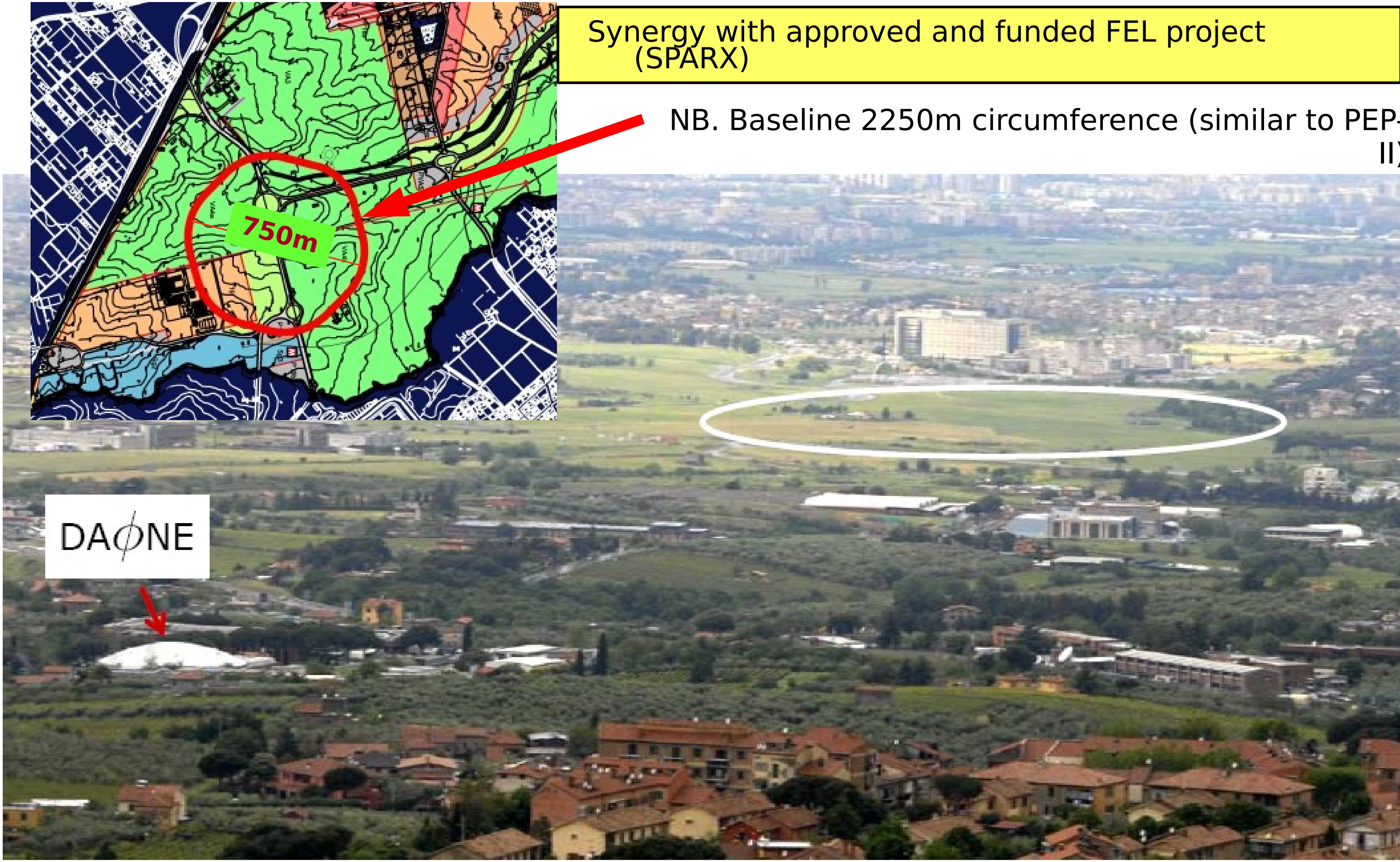
- Detector R&D required for the several subsystems
  - vertex detector
    - first layer close (~1cm) to beam spot
    - use pixels or striplets to cope with occupancy
  - particle identification
    - improved readout for barrel (DIRC)
    - forward PID device (focussing RICH?)
  - calorimeter
    - CsI(Tl) too slow for endcaps → pure CsI? LSO?
  - electronics, trigger, DAQ & offline computing
    - need to deal with high physics trigger rate

improvements in hermeticity important for many measurements

SuperB Detector



Potential SuperB site on the University of Rome Tor Vergata campus



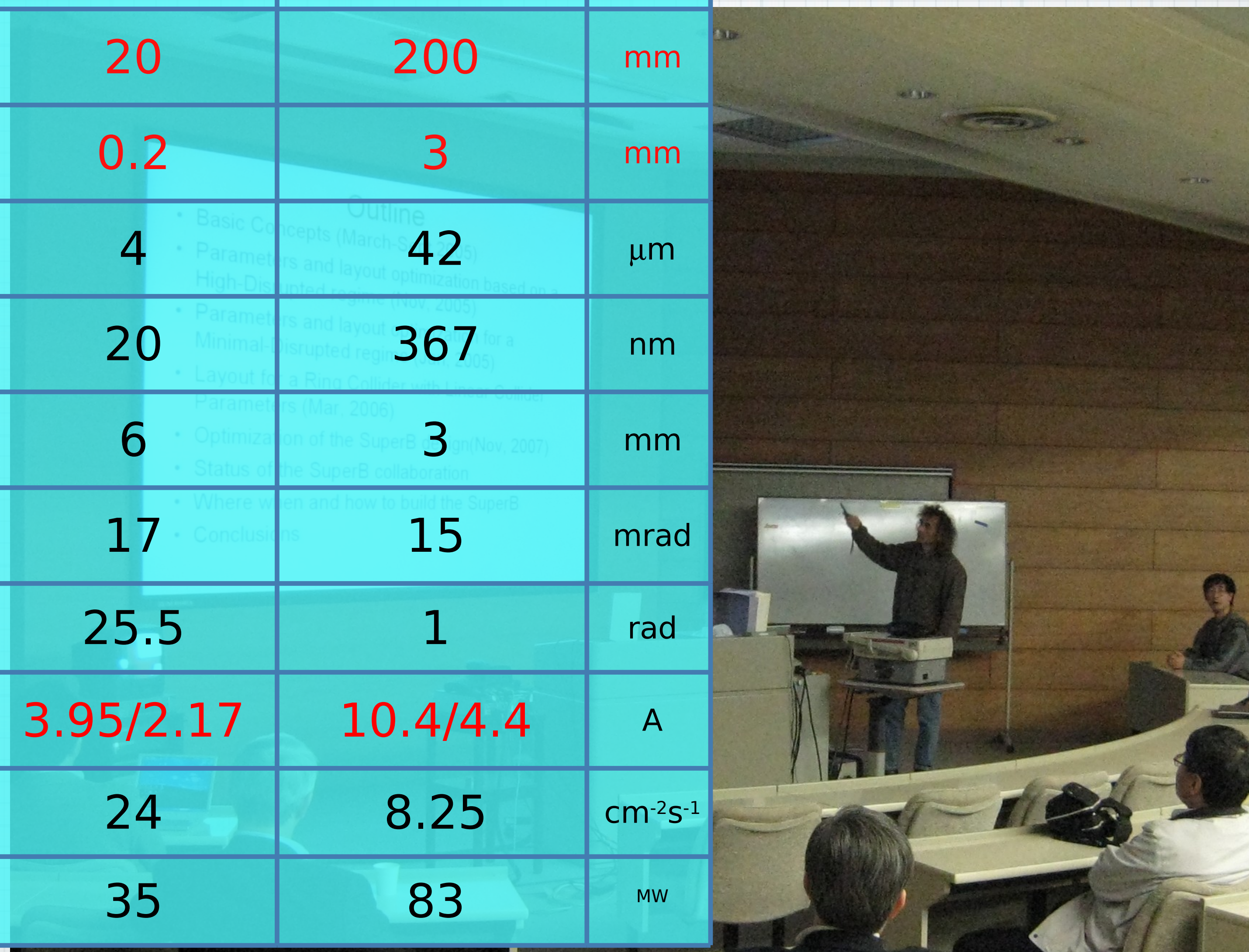
Synergy with approved and funded FEL project (SPARX)

NB. Baseline 2250m circumference (similar to PEP-II)

Comparison between SuperB and SuperKEKB

		SuperB (Upgrade)	SuperKEKB (Low Emittance)	
Emittance	ε_x	0.8	9	nm
Horizontal beta	β_x^*	20	200	mm
Vertical beta	β_y^*	0.2	3	mm
Horizontal beam size	σ_x^*	4	42	μm
Vertical beam size	σ_y^*	20	367	nm
Bunch length	σ_z	6	3	mm
Half crossing angle	ϕ_x	17	15	mrad
Piwinski angle	φ	25.5	1	rad
Current(LER/HER)	I_b	3.95/2.17	10.4/4.4	A
Luminosity ($x10^{35}$)	L	24	8.25	$cm^{-2}s^{-1}$
AC Plug Power	P	35	83	MW

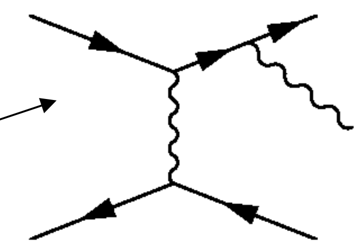
One order magnitude smaller than SuperKEKB

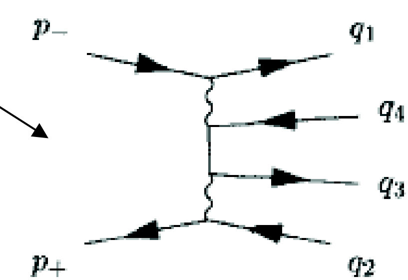


Backgrounds

- Dominated by QED cross section
  - Low currents / high luminosity
    - Beam-gas are not a problem
    - SR fan can be shielded

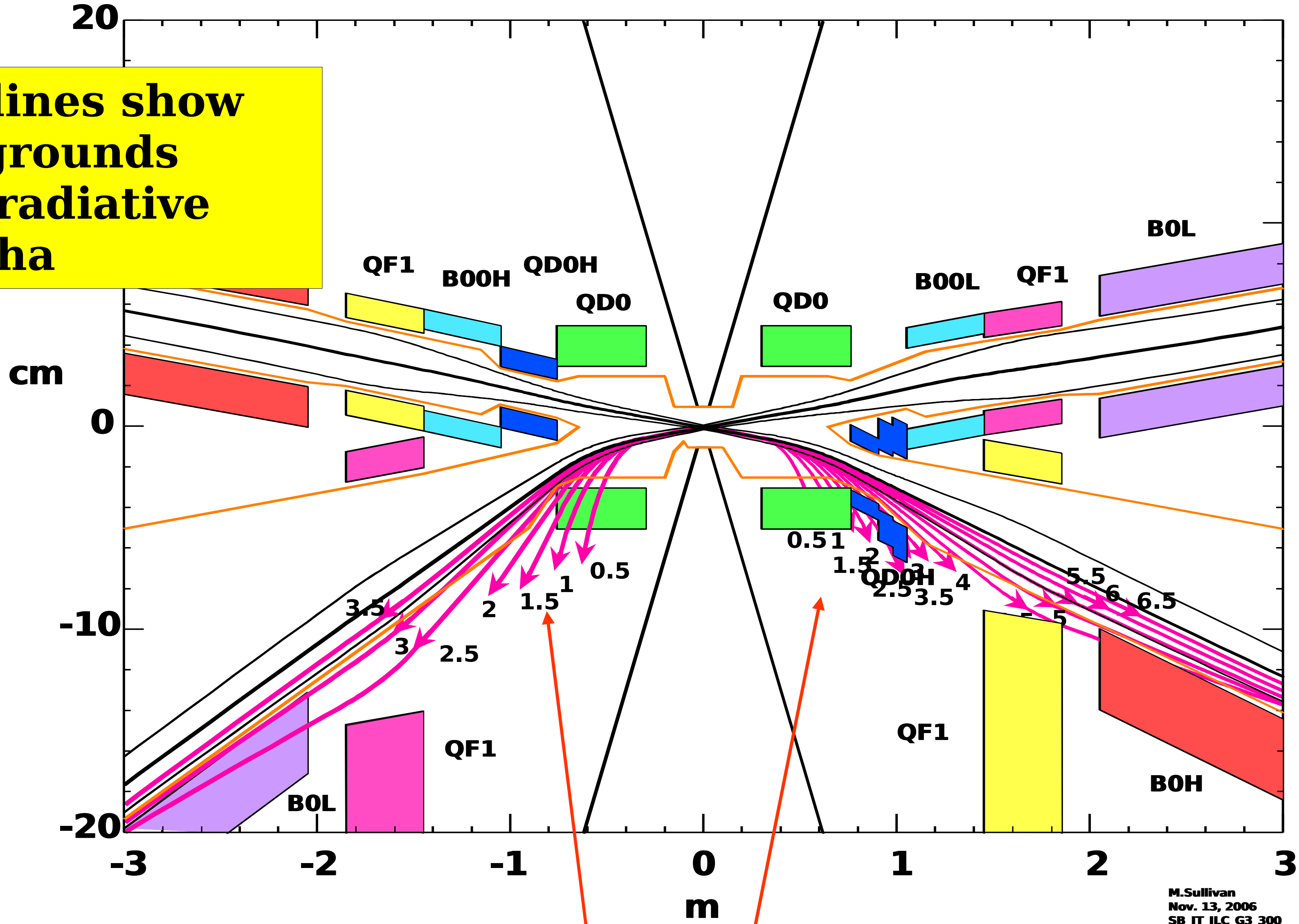
	Cross section	Evt/bunch xing	Rate
Radiative Bhabha	~340 mbarn (Eγ/Ebeam > 1%)	~680	0.3THz
e^+e^- pair production	~7.3 mbarn	~15	7GHz
Elastic Bhabha	$O(10^{-5})$ mbarn (Det. acceptance)	~20/Million	10KHz
$\Upsilon(4S)$	$O(10^{-6})$ mbarn	~2/million	1 KHz





Interaction Region Design

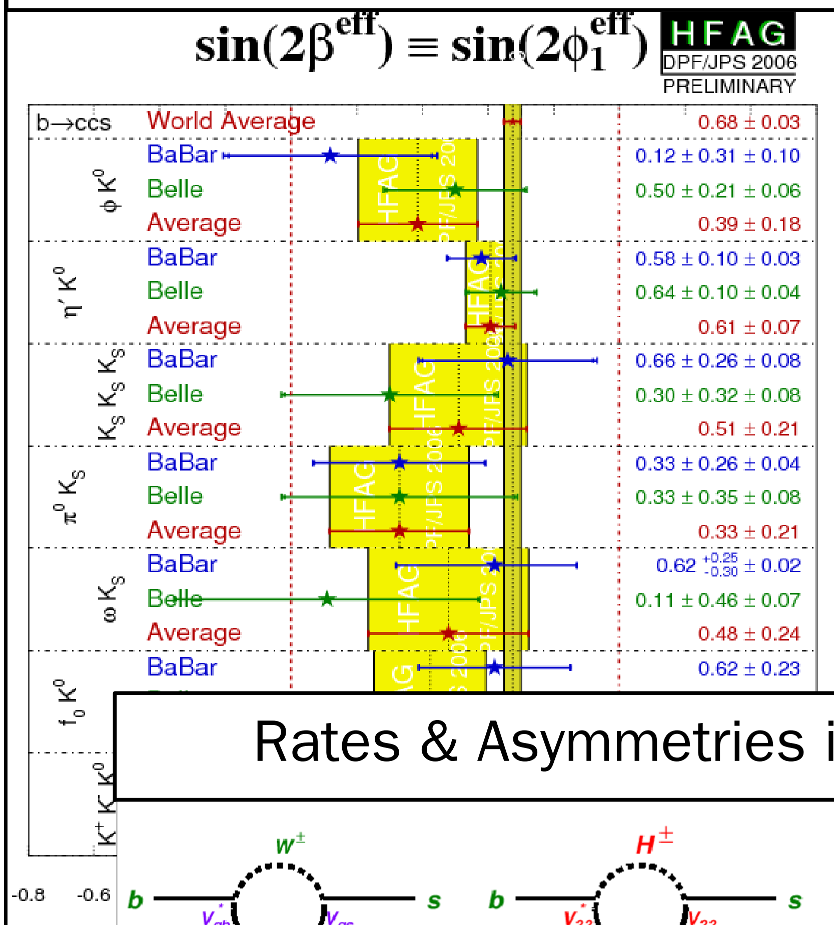
Pink lines show backgrounds from radiative BhaBha



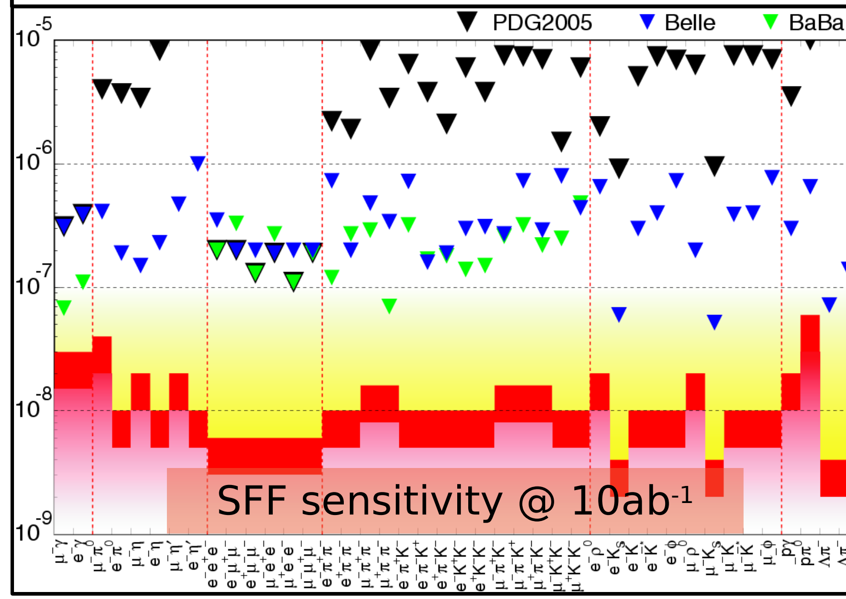
Need serious amount of shielding to prevent the produced shower from reaching the detector.

Some Key Measurements

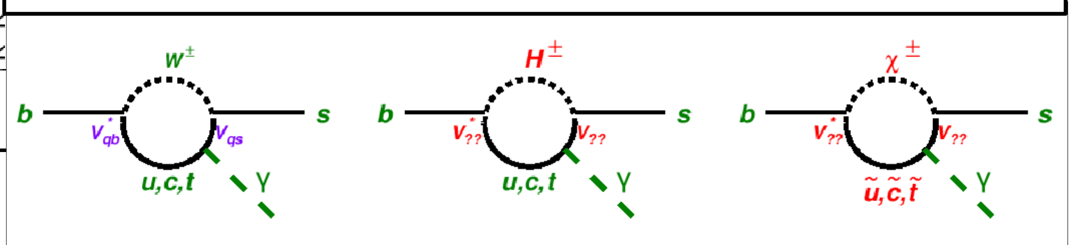
CP Violation in Hadronic b→s



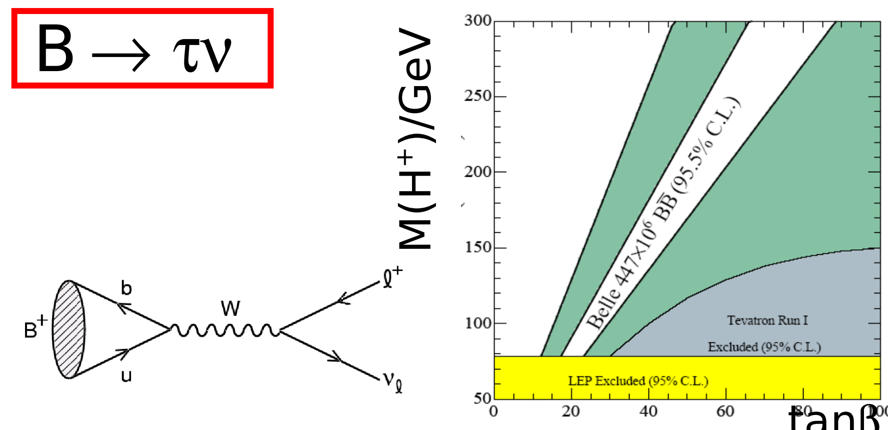
Lepton Flavour Violation in τ Decay



Rates & Asymmetries in b→sγ



B → τν



Couplings and Scales

$$L = L_{SM} + \sum_{k=1} \left(\sum_i c_i^k Q_i^{(k+4)} \right) / \Lambda^k$$

- New physics effects are governed by:
  - new physics scale Λ
  - effective flavour-violating couplings c_i
    - couplings may have a particular pattern (symmetries)
    - coupling strengths can vary (different interactions)

- If Λ known from LHC, measure c_i
- If Λ not known, measure c_i / Λ

MFV Confronts the Data

- Current experimental situation
  - some new physics flavour couplings are small
- Minimal flavour violation
  - all new physics flavour couplings are zero

MFV is a long way from being verified!

Need to establish correlations between different flavour sectors (B_d,B_s,K)

New Physics Sensitivity in MFV

$$\mathcal{H}_{\rm eff}^{\Delta F=2} = \mathcal{H}_{\rm SM} + \mathcal{H}_{\rm NP} = \left(V_{tq} V_{tq'}^*\right)^2 \left(\frac{S_0(x_t)}{\Lambda_0^2} + \frac{a_{\rm NP}}{\Lambda^2}\right) (\bar{q}' q)_{(V-A)} (\bar{q}' q)_{(V-A)}$$

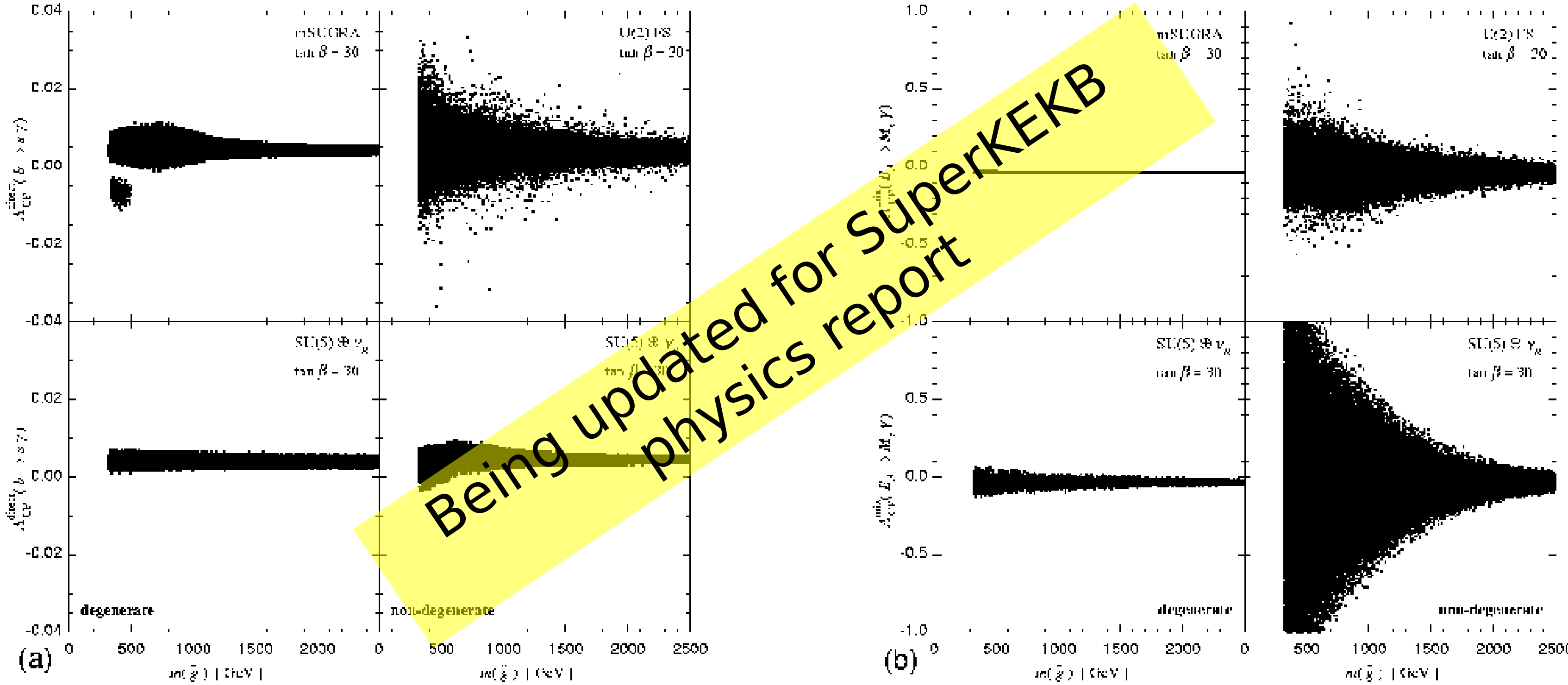
$$S_0(x_t) \rightarrow S_0(x_t) + \delta S_0, \quad |\delta S_0| = O\left(4 \frac{\Lambda_0^2}{\Lambda^2}\right), \quad \Lambda_0 = \frac{\pi Y_t}{\sqrt{2} G_F M_W} \sim 2.4\,\mathrm{TeV}$$

Today	SuperB
Λ(MFV) > 2.3Λ_0 @95C.L. NP masses >200GeV	Λ(MFV) >~6Λ_0 @95C.L. NP masses >600GeV

- analysis relies on CKM fits and improvements in lattice calculations
- only $\Delta F=2$ (mixing) operators considered
- further improvements possible including also $\Delta F=1$ (especially $b\rightarrow s\gamma$)

Correlations Distinguish Models

T.Goto, Y.Okada, Y.Shimizu, T.Shindou, M.Tanaka, PRD 70, 035012 (2004)



$A_{CP}(b \to s \gamma)$ $S(B^0 \to K_S \pi^0 \gamma)$

SFF can reach ~0.4% precision

SFF can reach 2% precision

Plots show parameter scans in four different SUSY breaking schemes:

- mSUGRA
- U(2) flavour symmetry
- SU(5) + ν_R degenerate
- SU(5) + ν_R non-degenerate

Running at the Υ(5S)

- Belle & CLEO have demonstrated potential for $e^+e^- \rightarrow \Upsilon(5S) \rightarrow B_s^{(*)}B_s^{(*)}$
- Some important channels, such as $B_s \rightarrow \gamma\gamma$, $A_{SL}(B_s)$ are unique to SuperB
- Problem: cannot resolve fast Δm_s oscillations
  - retain some sensitivity to φ_s, since $\Delta\Gamma_s \neq 0$

$$\Gamma_{\bar{B}_s\to f}(\Delta t) + \Gamma_{B_s\to f}(\Delta t) = \mathcal{N}\frac{e^{-|\Delta t|/\tau(B_s)}}{2\tau(B_s)}\left[\cosh(\frac{\Delta\Gamma_s\Delta t}{2}) - \frac{2\,\mathrm{Re}\,(\lambda_f)}{1+|\lambda_f|^2}\sinh(\frac{\Delta\Gamma_s\Delta t}{2})\right]. \tag{1.34}$$

cf. D0 untagged measurement of φ_s

Large New Physics Contributions Excluded

Δm_K ϵ_K ϵ'/ϵ_K $B(K_L \to \pi^0 \nu \bar{\nu})$ $B(K^+ \to \pi^+ \nu \bar{\nu})$ $B(K^+ \to l^+ \nu)$

Δm_d $A_{SL}(B_d)$ $S(B_d \to J/\psi K_S)$ $S(B_d \to \phi K_S)$

$\alpha(B \to \pi\pi, \rho\pi, \rho\rho)$ $\gamma(B \to DK)$ CKM $fits$

Δm_s $A_{SL}(B_s)$ $S(B_s \to J/\psi \phi)$ $S(B_s \to \phi\phi)$

$B(b \to s\gamma)$ $A_{CP}(b \to s\gamma)$ $S(B^0 \to K_S \pi^0 \gamma)$ $S(B_s \to \phi\gamma)$

$B(b \to d\gamma)$ $A_{CP}(b \to d\gamma)$ $A_{CP}(b \to (d+s)\gamma)$

$B(b \to s l^+ l^-)$ $B(b \to d l^+ l^-)$ $A_{FB}(b \to s l^+ l^-)$ $B(b \to s \nu \bar{\nu})$

$B(B_s \to l^+ l^-)$ $B(B_d \to l^+ l^-)$ $B(B^+ \to l^+ \nu)$

$B(\mu \to e\gamma)$ $B(\mu \to e^+ e^- e^+)$ $(g-2)_\mu$ μ EDM

$B(\tau \to \mu\gamma)$ $B(\tau \to e\gamma)$ $B(\tau^+ \to l^+ l^- l^+)$ τ CPV τ EDM

$B(D^+_{(s)} \to l^+ \nu)$ x_D y_D $charm$ CPV

Will be Studied at SuperB

Δm_K ϵ_K ϵ' / ϵ_K $B(K_L \to \pi^0 \nu \bar{\nu})$ $B(K^+ \to \pi^+ \nu \bar{\nu})$ $B(K^+ \to l^+ \nu)$

Δm_d $A_{SL}(B_d)$ $S(B_d \to J/\psi K_S)$ $S(B_d \to \phi K_S)$

$\alpha(B \to \pi\pi, \rho\pi, \rho\rho)$ $\gamma(B \to DK)$ CKM $fits$

Δm_s $A_{SL}(B_s)$ $S(B_s \to J/\psi \phi)$ $S(B_s \to \phi\phi)$

$B(b \to s\gamma)$ $A_{CP}(b \to s\gamma)$ $S(B^0 \to K_S \pi^0 \gamma)$ $S(B_s \to \phi\gamma)$

$B(b \to d\gamma)$ $A_{CP}(b \to d\gamma)$ $A_{CP}(b \to (d+s)\gamma)$ $S(B^0 \to \rho^0 \gamma)$

$B(b \to s l^+ l^-)$ $B(b \to d l^+ l^-)$ $A_{FB}(b \to s l^+ l^-)$ $B(b \to s \nu \bar{\nu})$

$B(B_s \to l^+ l^-)$ $B(B_d \to l^+ l^-)$ $B(B^+ \to l^+ \nu)$

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$B(D^+_{(s)} \to l^+ \nu)$ x_D y_D $charm$ CPV

Will be studied at LHCb (+ upgrade)

Δm_K ϵ_K ϵ'/ϵ_K $B(K_L \to \pi^0 \nu \bar{\nu})$ $B(K^+ \to \pi^+ \nu \bar{\nu})$ $B(K^+ \to l^+ \nu)$

Δm_d $A_{SL}(B_d)$ $S(B_d \to J/\psi K_S)$ $S(B_d \to \phi K_S)$

$\alpha(B \to \pi\pi, \rho\pi, \rho\rho)$ $\gamma(B \to DK)$ CKM fits

Δm_s $A_{SL}(B_s)$ $S(B_s \to J/\psi \phi)$ $S(B_s \to \phi\phi)$

$B(b \to s\gamma)$ $A_{CP}(b \to s\gamma)$ $S(B^0 \to K_S \pi^0 \gamma)$ $S(B_s \to \phi\gamma)$

$B(b \to d\gamma)$ $A_{CP}(b \to d\gamma)$ $A_{CP}(b \to (d+s)\gamma)$

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$B(\mu \to e\gamma)$ $B(\mu \to e^+ e^- e^+)$ $(g-2)_\mu$ μ EDM

$B(\tau \to \mu\gamma)$ $B(\tau \to e\gamma)$ $B(\tau^+ \to l^+ l^- l^+)$ τ CPV τ EDM

$B(D^+_{(s)} \to l^+ \nu)$ x_D y_D charm CPV

dashed box = exclusive modes only