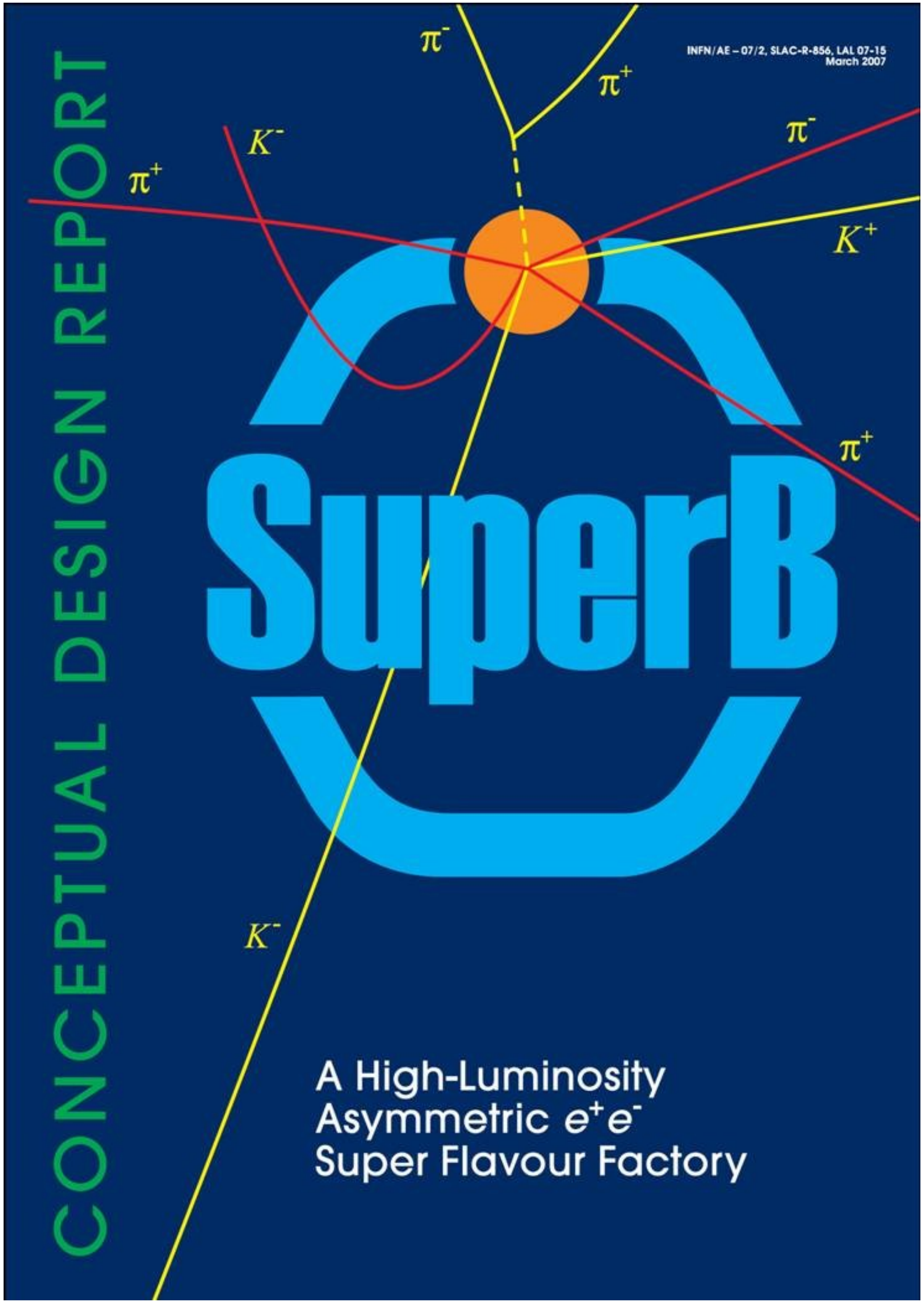
SuperB
A High-Luminosity Asymmetric e^+e^- Super Flavour Factory

Tim Gershon
University of Warwick

Seminar at University of Warwick
14th June 2007



Based on recently completed conceptual design report

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

Available online at:

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

Physics case builds on

SuperKEKB Physics Working Group, [arXiv:hep-ex/0406071]

J.L.Hewett, D.Hitlin (ed.), SLAC-R-709, [arXiv:hep-ph/0503261]

and others ...

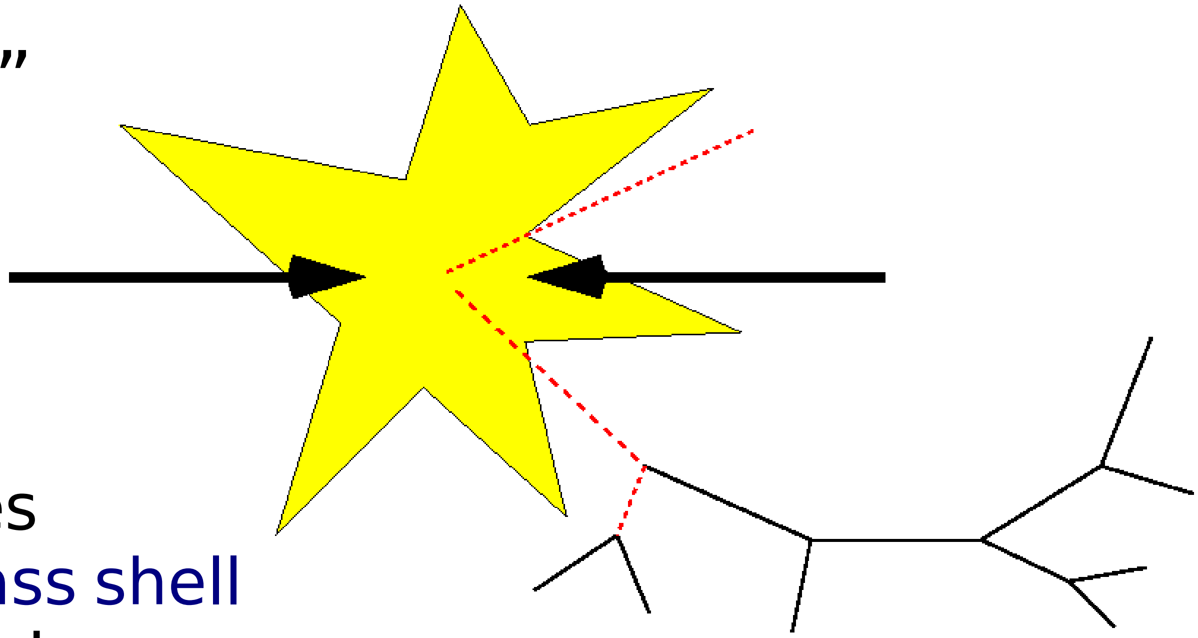
Contents

- Why?
  - Motivation for a Super Flavour Factory in the LHC era
- How?
  - Design of SuperB
- Where? When?

Motivation

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

  1) “relativistic”

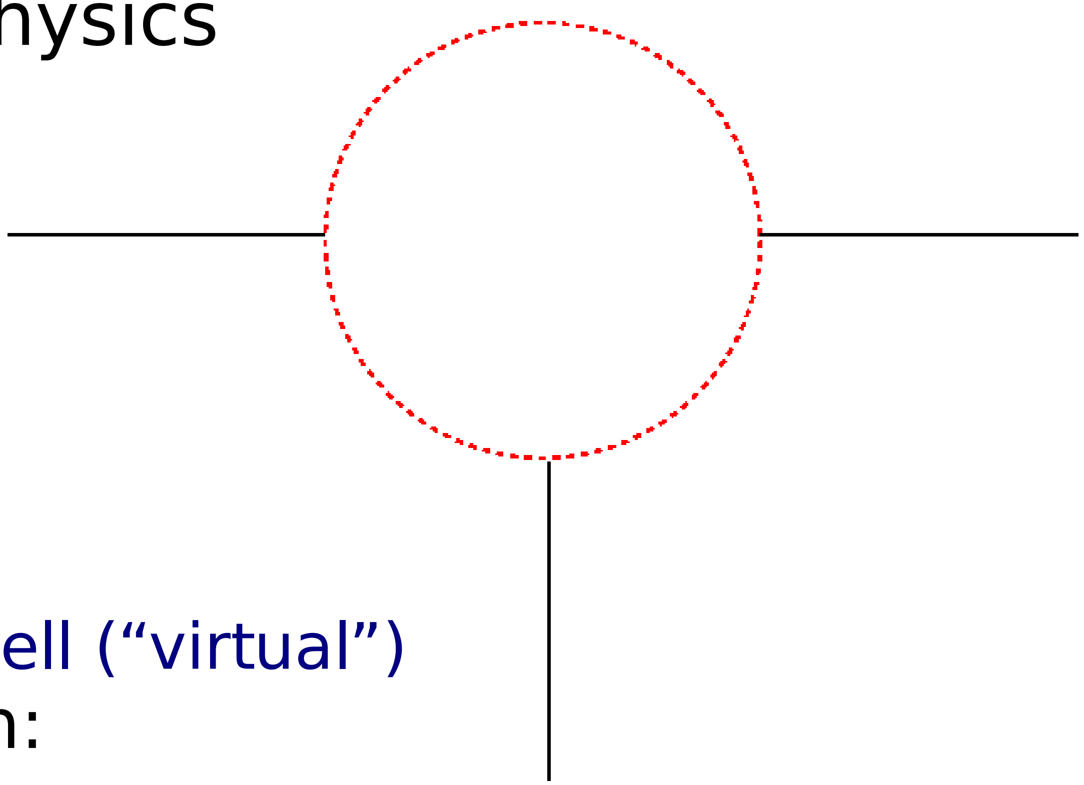


New heavy particles
produced on mass shell
Sensitivity depends on:
available centre-of-mass energy
knowledge of Standard Model backgrounds

Motivation

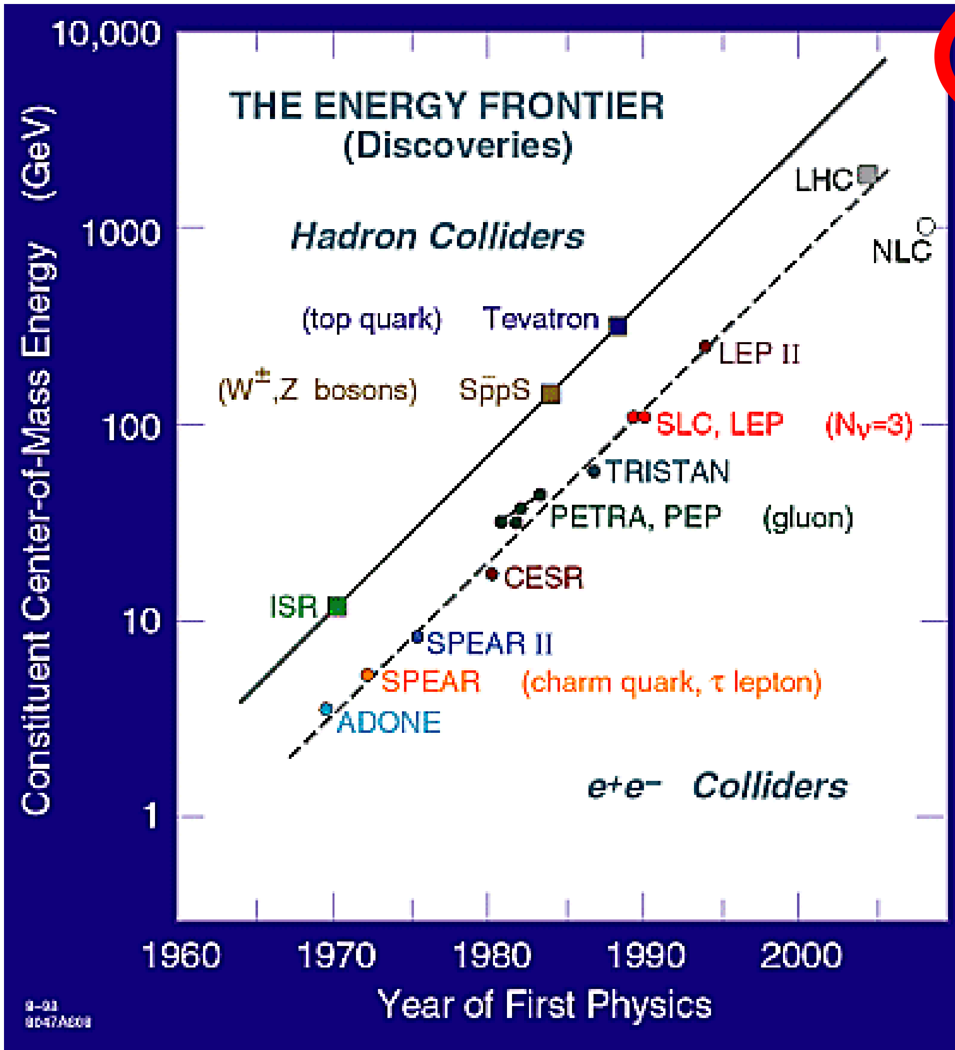
- Major challenge for particle physics in the next decade is to go beyond the Standard Model
- Two paths to new physics

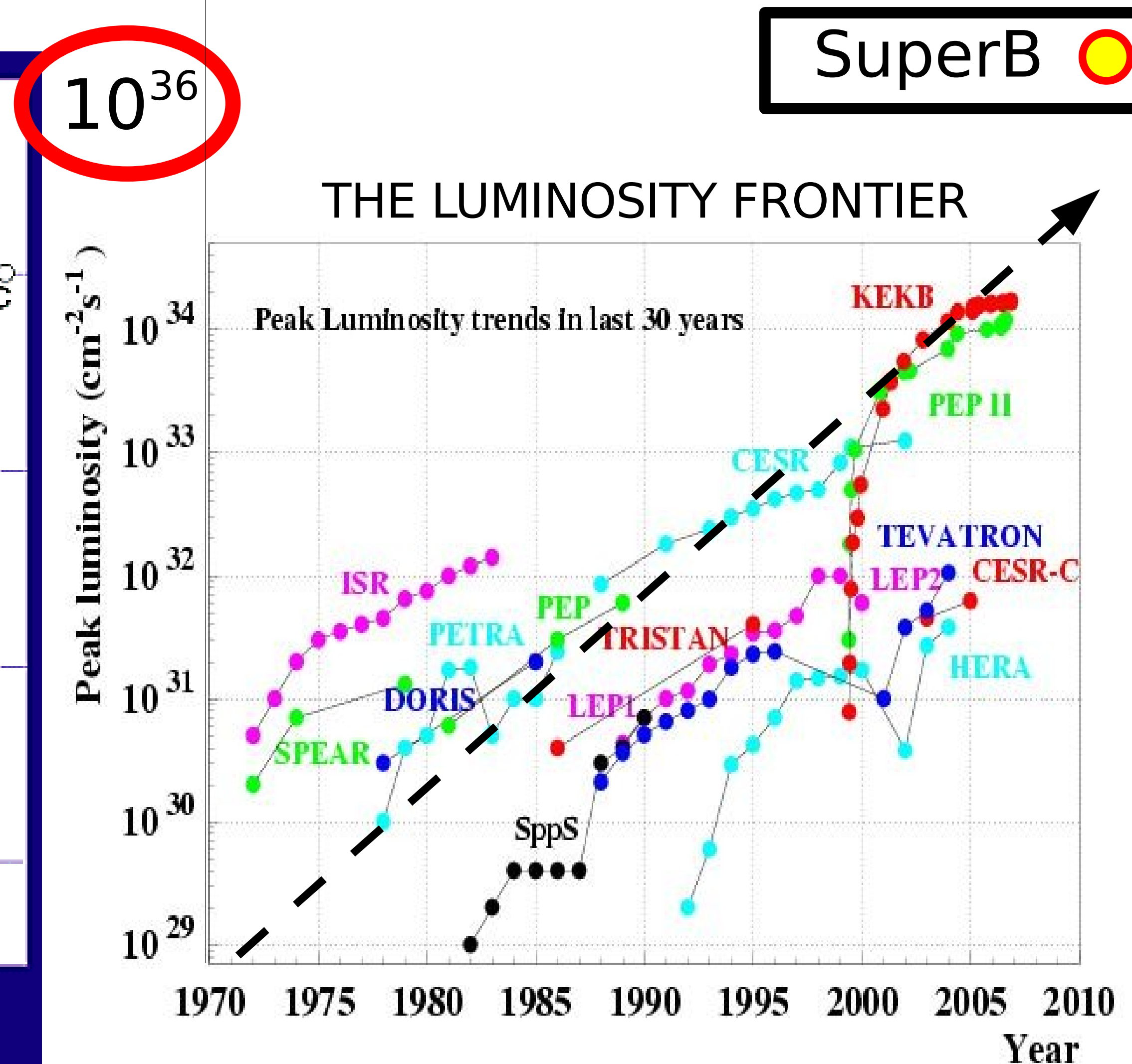
  2) "quantum"



New heavy particles
produced off mass shell ("virtual")
Sensitivity depends on:
luminosity
knowledge of Standard Model backgrounds

A Tale of Two Frontiers





History of the Frontiers

- Signs of new physics seen first in flavour, before confirmation/discovery at the energy frontier
  - suppression of FCNC
    - GIM $\Rightarrow$ discovery of charm
  - CP violation
    - CKM $\Rightarrow$ third generation
- No clear sign of NP in current experiments (though some hints exist)

$\Rightarrow$ a break from history?

Why Flavour?

- Cleanest searches for New Physics where Standard Model rates are well-known and/or small
- Standard Model has
  - quark flavour violation suppressed by mixing angles
  - CP violation similarly suppressed
  - flavour changing neutral currents absent at tree level
  - lepton flavour violation suppressed by (m_ν/m_W)

No *a priori* reason for New Physics to share this pattern

New Physics Sensitive Flavour Observables

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

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

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

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

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

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

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

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

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

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

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

... 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
  - multitude of new physics sensitive observables
  - maximize sensitivity by combining information
  - correlations between results distinguish models

SuperB
“treasure chest”
of new physics sensitive
flavour observables

Will be Studied at SuperB

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

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

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

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

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

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

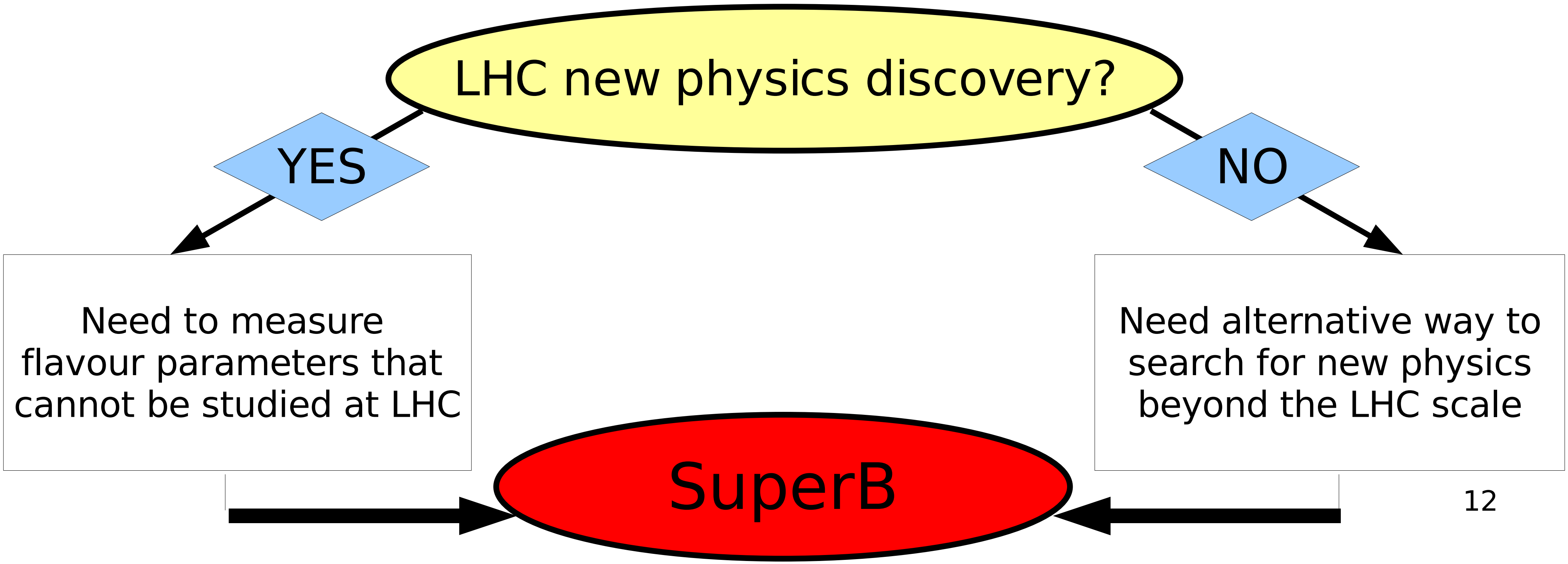
$B(\mu \to e\gamma)$ $B(\mu \to e^+ e^- e^+)$ $(g-2)_\mu$ $\mu \;\; EDM$

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

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

What about LHC?

- Important to note that flavour observables are complementary to those at the energy frontier
  - measure different new physics parameters
  - powerful to distinguish models
- Why not wait for LHC?



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

The Worst Case Scenario

- Can new physics be flavour blind?
  - No, it must couple to Standard Model, which violates flavour
- What is the minimal flavour violation?
  - new physics follows Standard Model pattern of flavour and CP violation

    G. D'Ambrosio, G.F. Giudice, G. Isidori, A. Strumia, NPB 645, 155 (2002)
  - even in this unfavourable scenario SuperB is still sensitive, up to new physics particle masses of 600-1000 GeV

(analysis relies on CKM fits and improvements in lattice calculations)

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)

Better Scenarios

- Move slightly away from the worst case scenario
  - minimal flavour violation with large tan β
    - SuperB sensitive to scales of few TeV
  - next-to-minimal flavour violation
    - SuperB sensitive to scales above 10 TeV
  - generic flavour violation
    - SuperB sensitive to scales up to ~1000 TeV

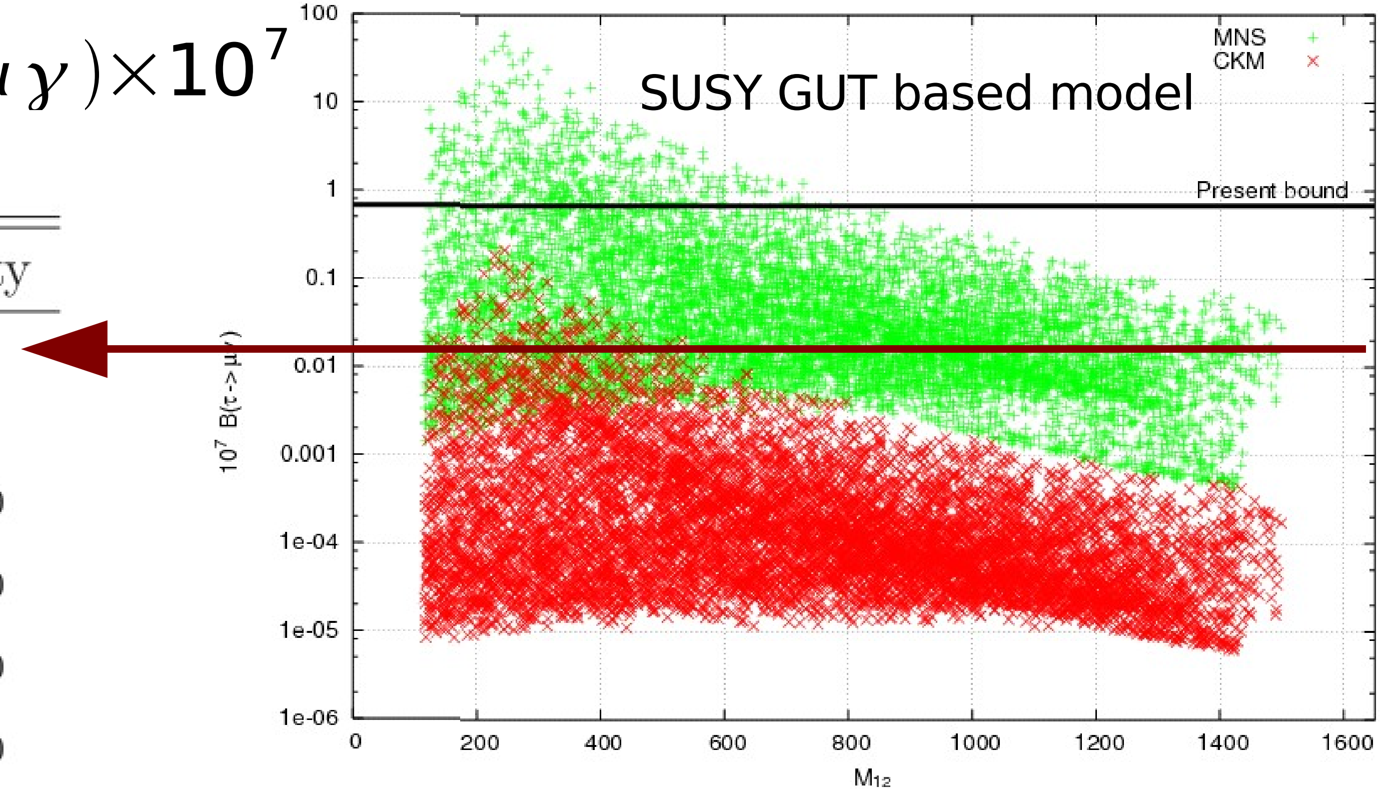
- Look now at a few specific channels

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}



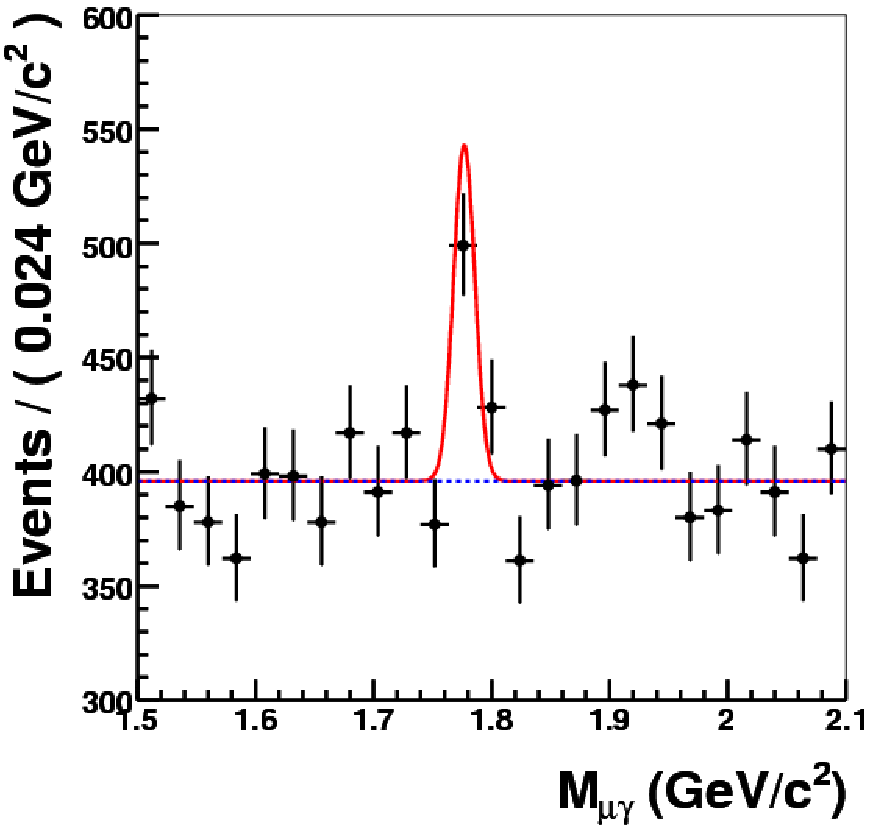
Pattern of LFV signatures distinguish between LHT and SUSY models

Lepton Flavour Violation

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

M.Roney @ Flavour in the LHC Era Workshop, CERN, March 2007

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



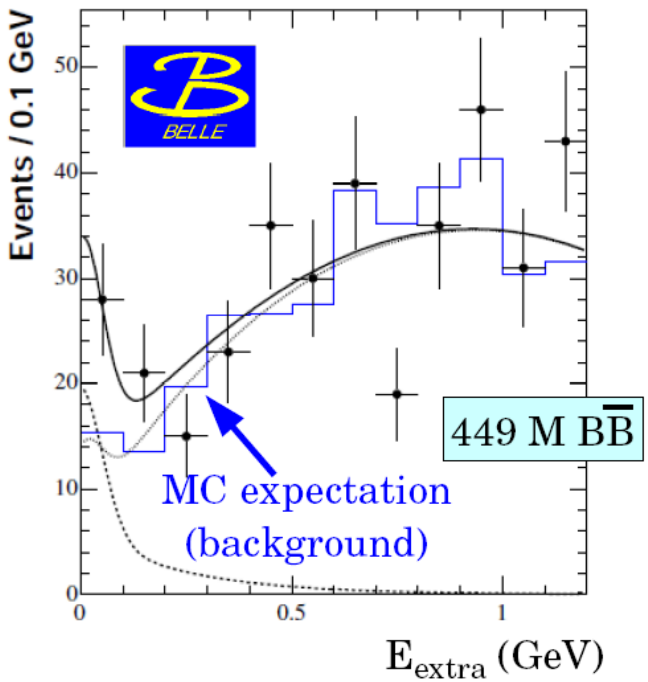
Leptonic B Decays

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

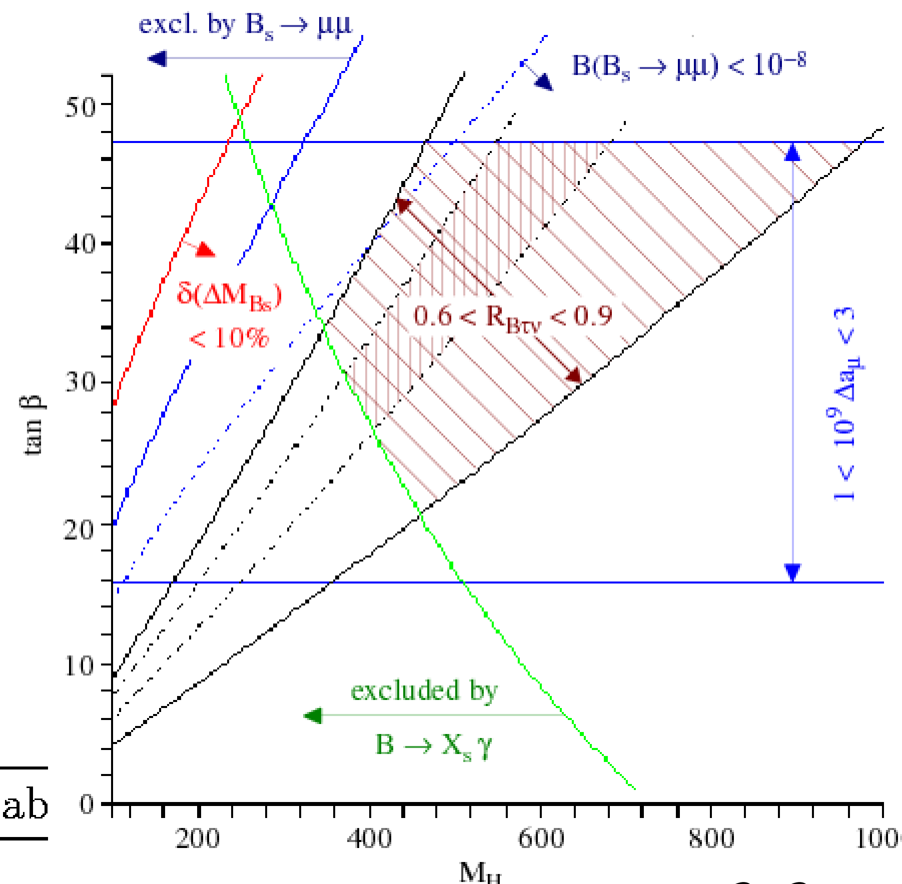
W.-S.Hou, PRD 48, 2342 (1993)

G.Isidori, P.Paradisi, PLB 639, 499 (2006)

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



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

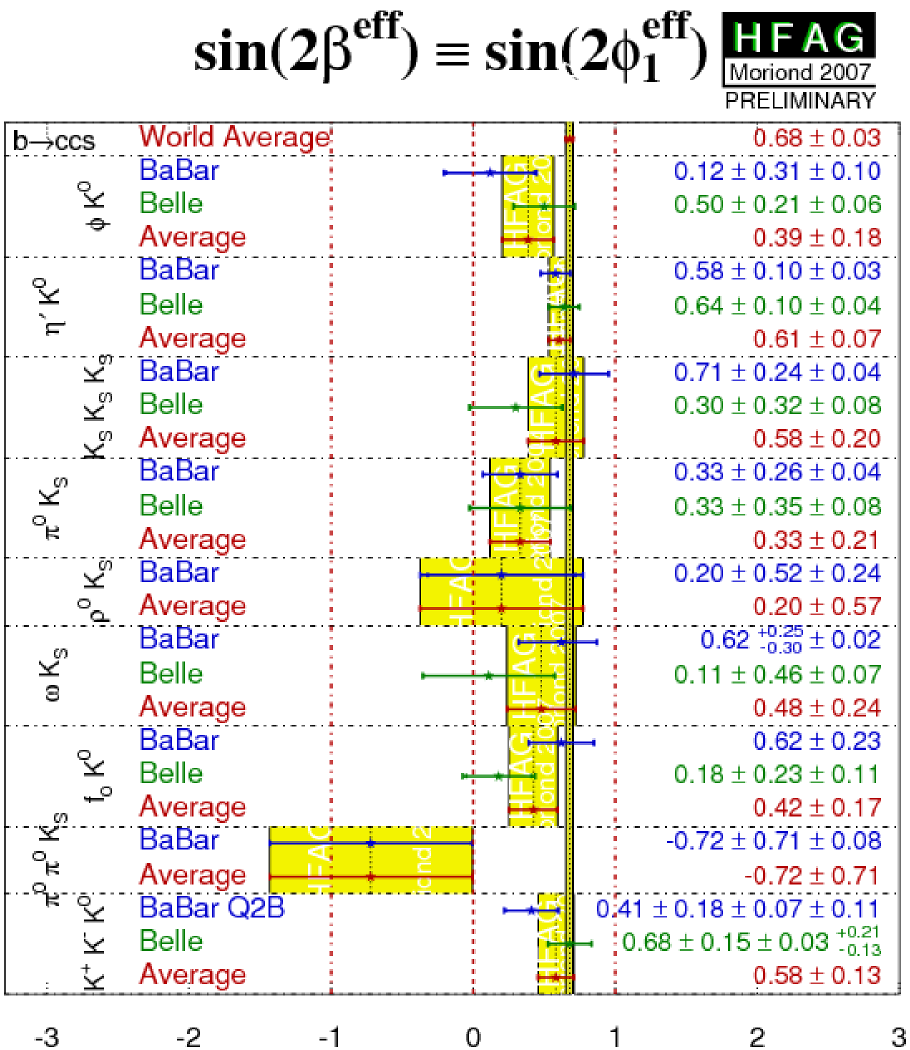


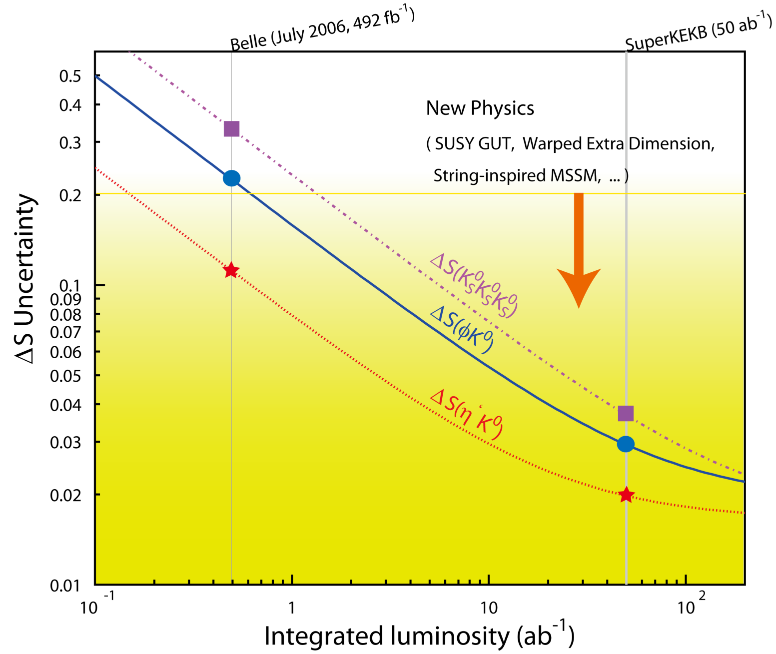
Observable	B Factories (2 ab^{-1})	Super$B$ (75 ab
$\mathcal{B}(B \to \tau\nu)$	20%	4% (†)
$\mathcal{B}(B \to \mu\nu)$	visible	5%
$\mathcal{B}(B \to D\tau\nu)$	10%	2%

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

Hadronic b→s Penguins

Current B factory hot topic





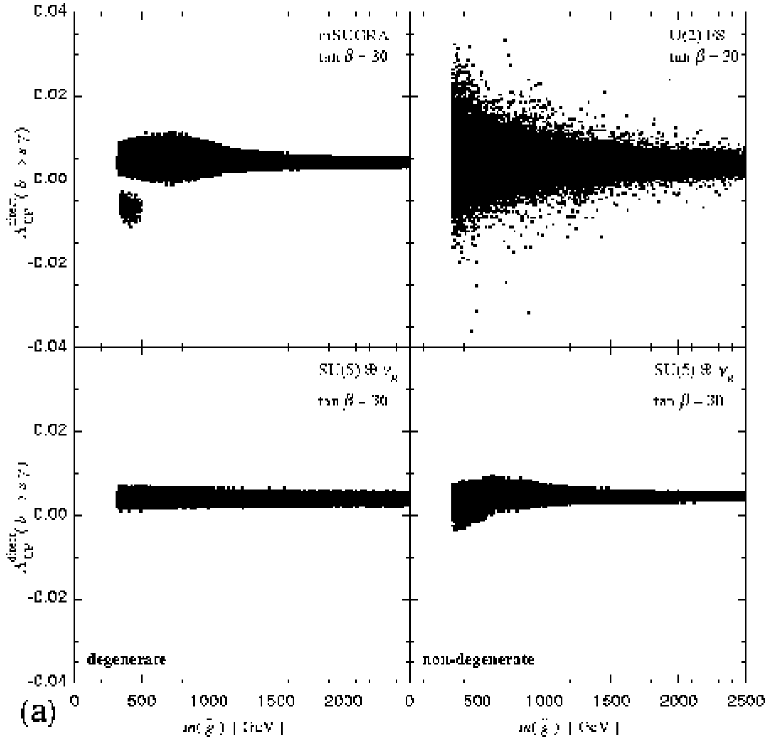
Many channels can be measured with ΔS~(0.01-0.04)

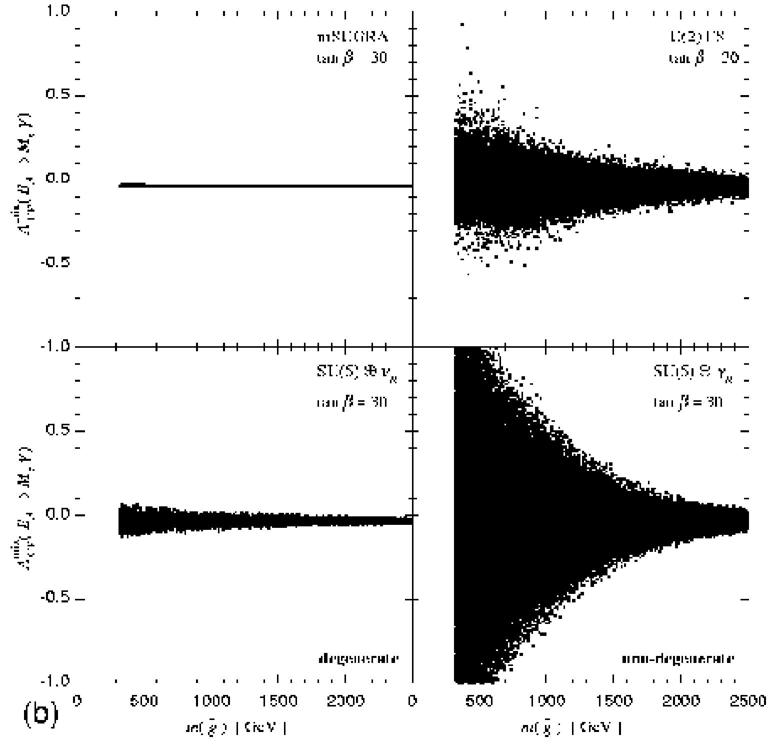
Observable	B Factories (2 ab^{-1})	**SuperB**	
$S(\phi K^0)$	0.13	0.02 (*)	[0.030]
$S(\eta' K^0)$	0.05	0.01 (*)	[0.020]
$S(K^0_S K^0_S K^0_S)$	0.15	0.02 (*)	[0.037]
$S(K^0_S \pi^0)$	0.15	0.02 (*)	[0.042]
$S(\omega K^0_S)$	0.17	0.03 (*)	
$S(f_0 K^0_S)$	0.12	0.02 (*)	

(*) theoretical limited

Correlations Distinguish Models

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





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

SuperB can reach ~0.4% precision $\quad$ SuperB 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

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})
$\|V_{cb}\|$ (exclusive)	4% (∗)	1.0% (∗)
$\|V_{cb}\|$ (inclusive)	1% (∗)	0.5% (∗)
$\|V_{ub}\|$ (exclusive)	8% (∗)	3.0% (∗)
$\|V_{ub}\|$ (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

Physics Beyond the Υ(4S)

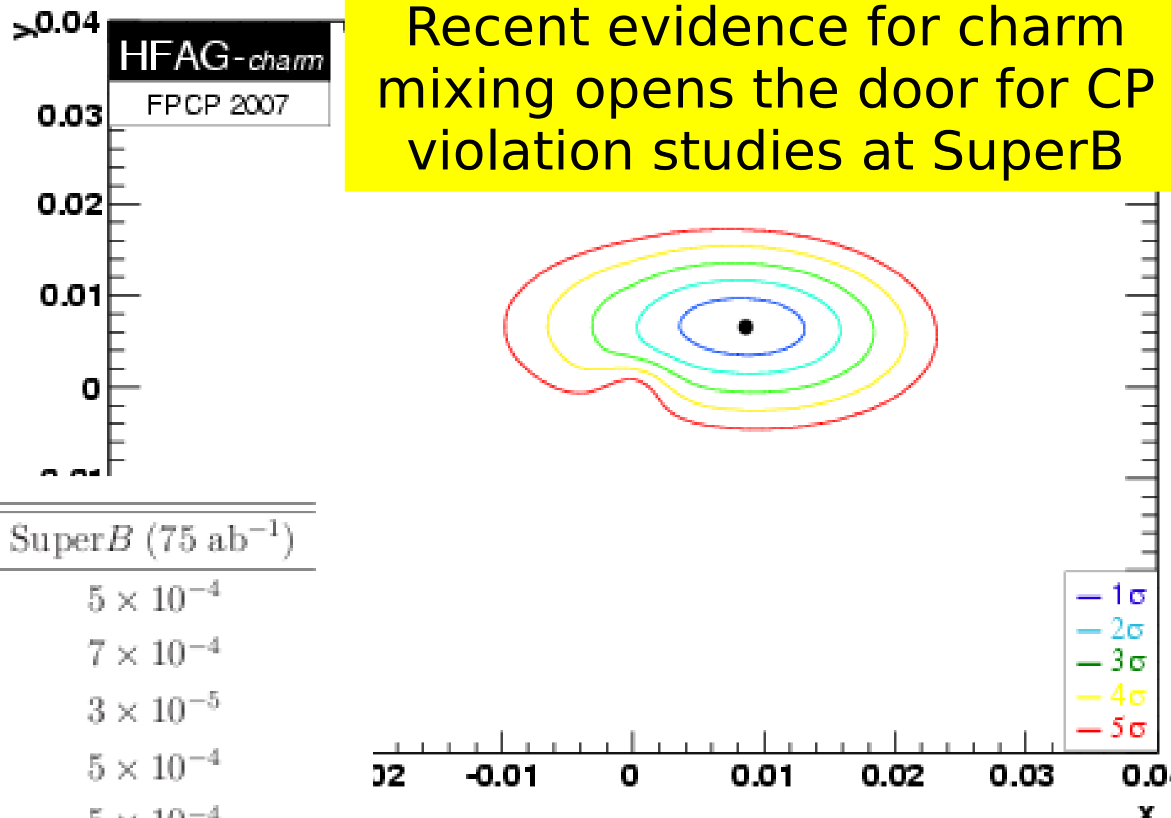
- SuperB is designed with flexible running energy
  - charm-tau threshold region
  - other Upsilon resonances
- Considering beam polarization option
  - provides luminosity enhancement
  - significant improvement in sensitivity for τ EDM

SuperB is really a Super Flavour Factory!

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 ($2\ \mathrm{ab}^{-1}$)	Super$B$ ($75\ \mathrm{ab}^{-1}$)
$D^0 \to K^+K^-$	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}

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 $\Delta\Gamma_s \neq 0$

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

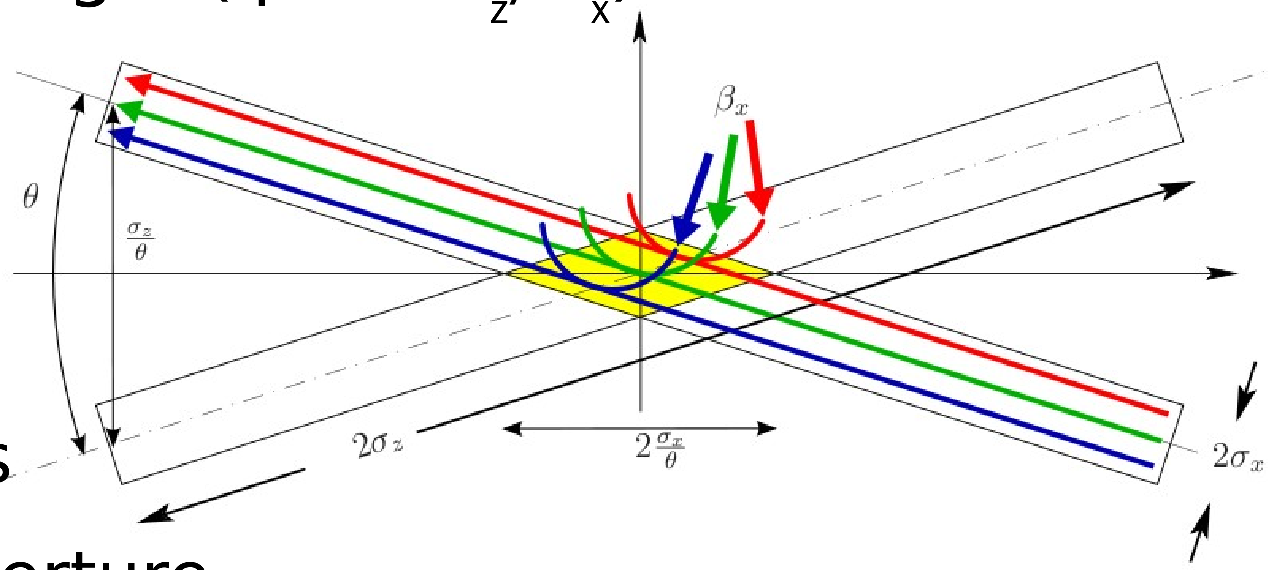
cf. D0 untagged measurement of φ_s

SuperB: How?

- Physics case for Super Flavour Factory is compelling
- Luminosity should be above $10^{36}/cm^2/s$
  - Enables integration of over 10/ab/year
  - Backgrounds and running efficiency should be comparable to current B factories
  - Power consumption should be affordable
- Attempts to upgrade PEP-II and KEKB with high current hit limitations due to beam instabilities, backgrounds and power

A Completely New Idea

- Initially inspired by the ILC damping rings, a new concept for SuperB was born
  - small emittance bunches
  - large Piwinski angle ($\varphi = \theta\, \sigma_z/\sigma_x$)
  - “crab waist”



⇒ High luminosity

⇒ Low currents

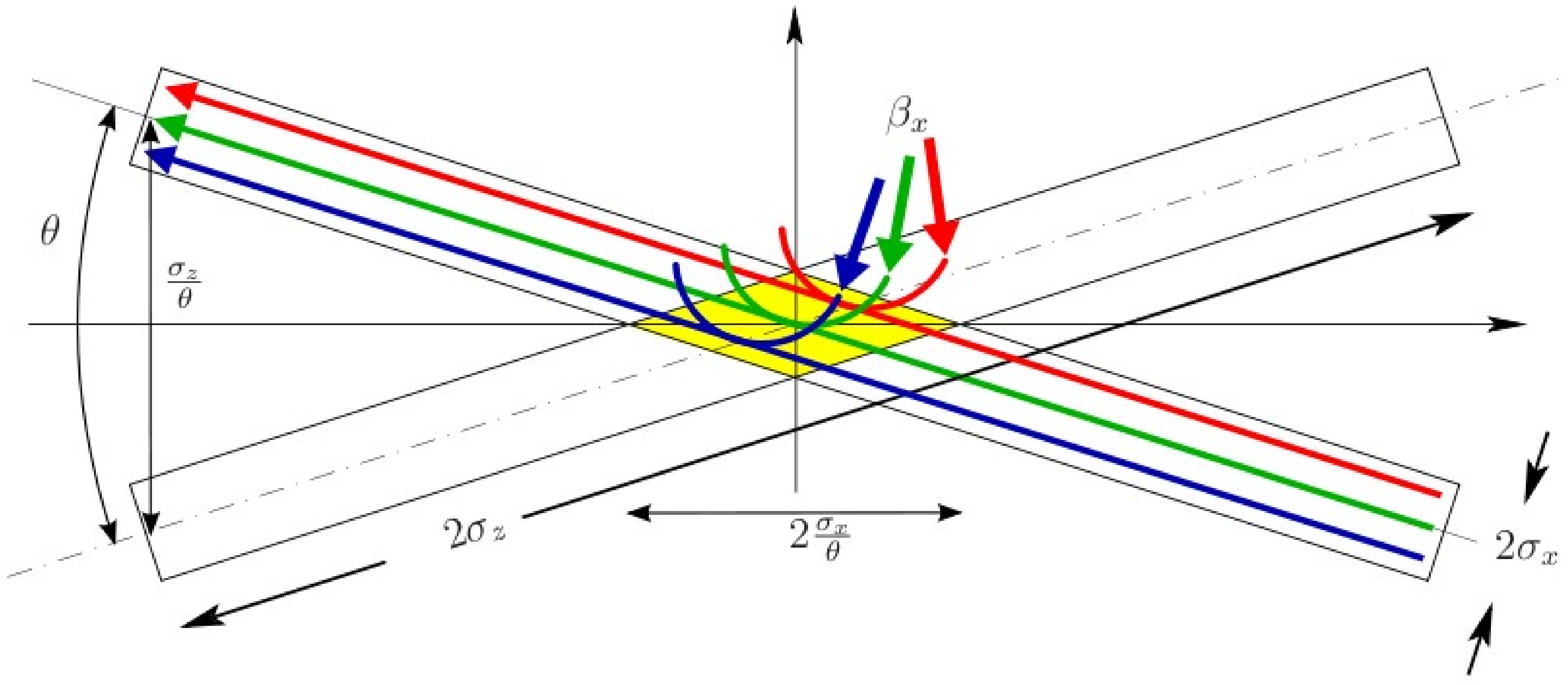
⇒ Small backgrounds

⇒ Stable dynamic aperture

⇒ Wall plug power ~ 30 MW

The Crab Waist

- Maximize overlap of beams even with finite crossing angle
- Achieved through sextupole magnets
- Minimal beam distruption



Breakthrough in Accelerator Technology

- The fledgling crab waist concept has caught on!
  - under consideration for DAPHNE upgrade
  - under consideration for KEKB upgrade
  - proposal for new Novosibirsk tau-charm factory using crab-waist scheme
  - being evaluated at CERN for potential use in LHC upgrade

Good News

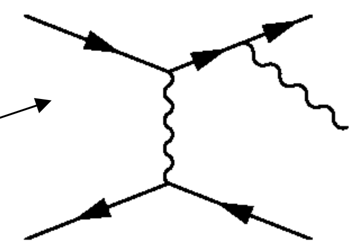
- Although collider scheme is completely new, it can be constructed largely by recycling existing hardware (eg. PEP-II magnets)
- Backgrounds comparable to current B factories, so SuperB detector can be based on BaBar (or Belle)

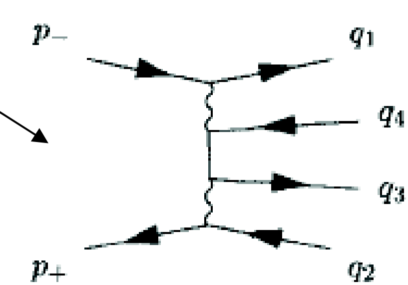
Significant cost savings!

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 ($E\gamma$/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



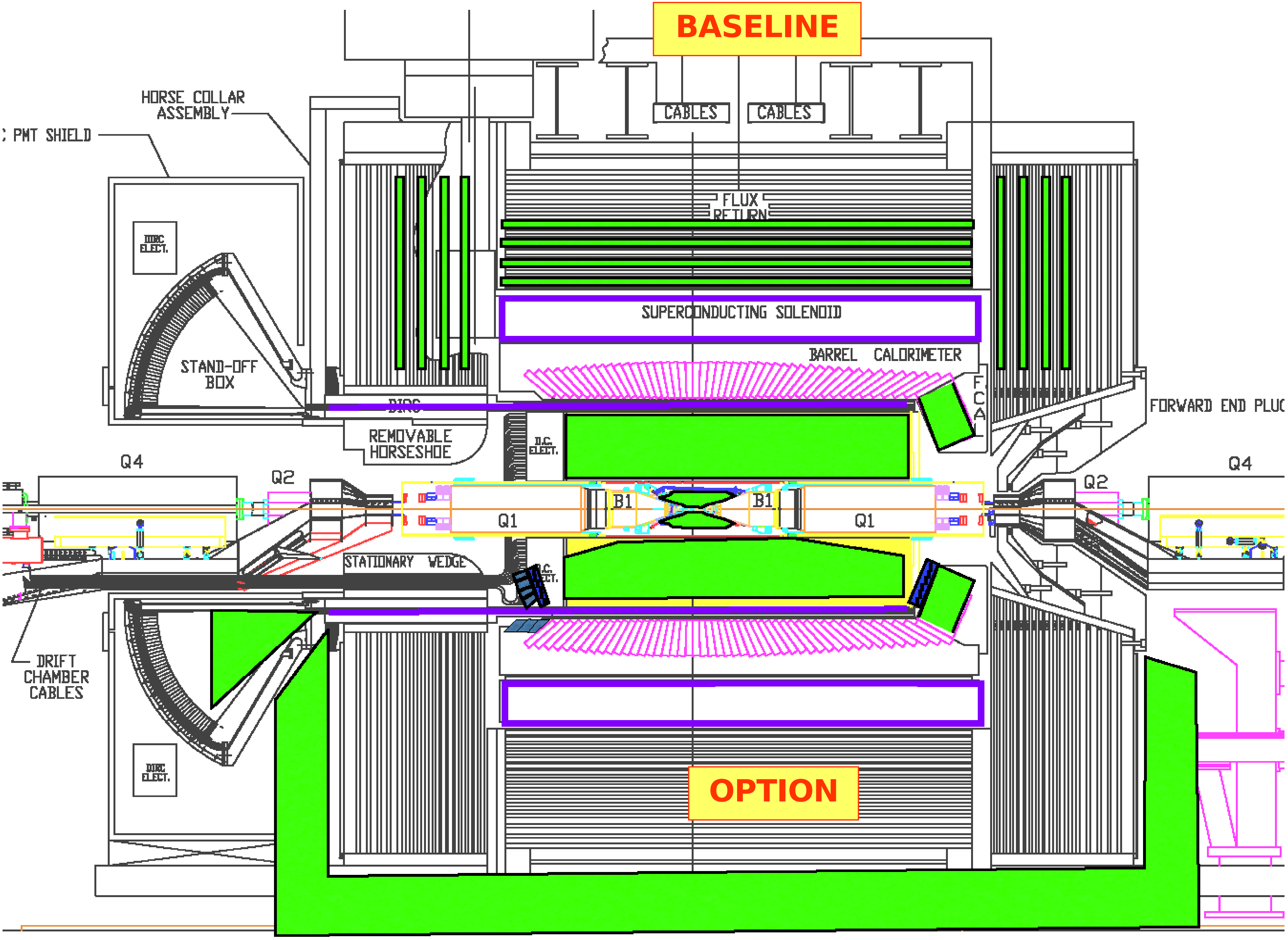


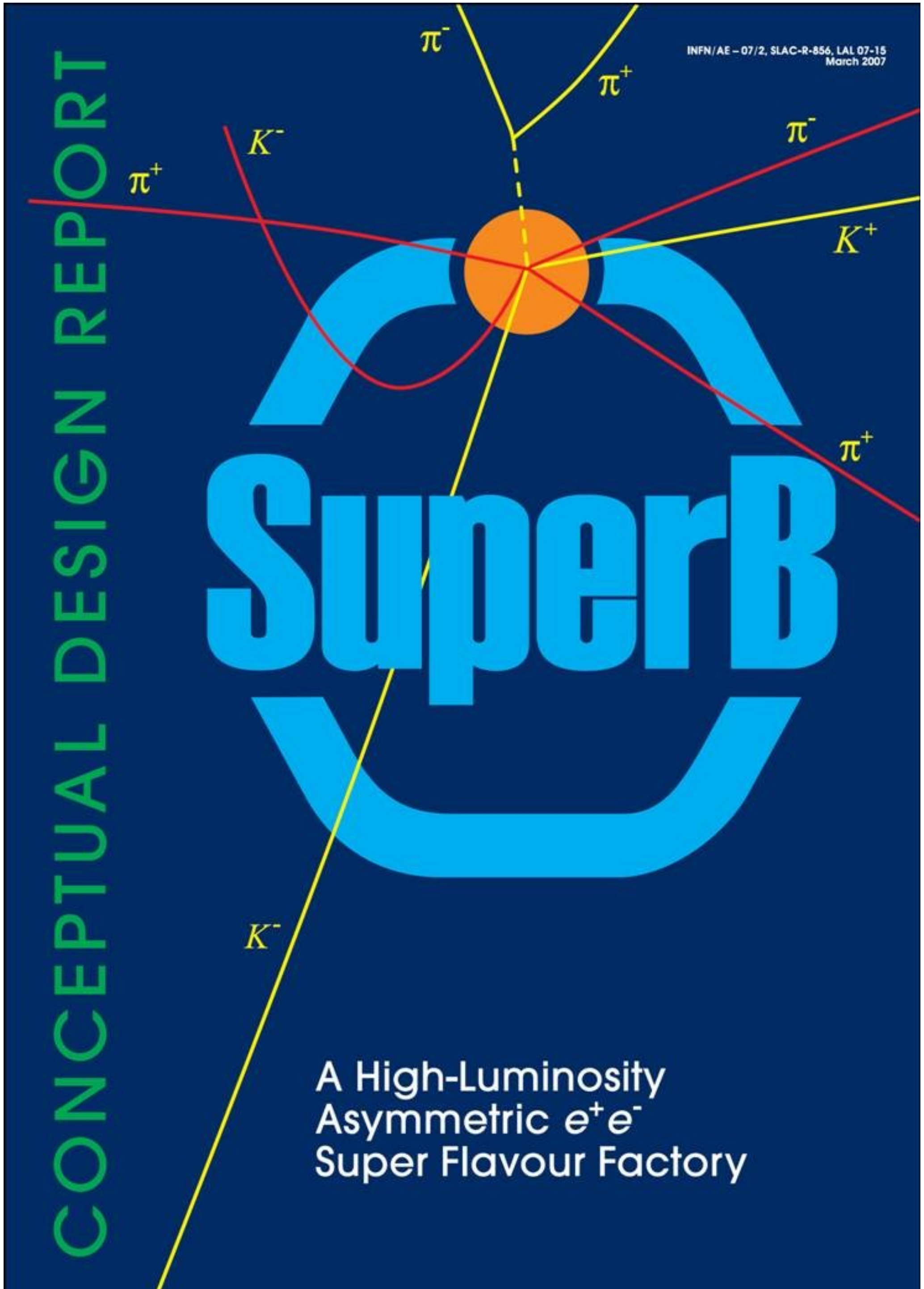
Detector

- Significant R&D necessary to establish final design for SuperB, but baseline consists of
  - vertex detector:
    - pixels mounted on beam pipe (resolution for 7 GeV on 4 GeV collisions improved compared to today)
  - tracking:
    - wire chamber
  - particle identification:
    - barrel PID based on DIRC, with new readout
    - new forward PID device

Detector

- calorimeter:
  - reuse existing barrel CsI(Tl)
  - replace forward endcap with faster crystals (LSO)
  - consider adding backward endcap
- magnet:
  - as now
- muon and KL detection:
  - additional iron in flux return
  - scintillator bar (MINOS style)
- electronics, DAQ and offline computing:
  - upgrades necessary


BASELINE
CABLES
CABLES
HORSE COLLAR ASSEMBLY
PMT SHIELD
DIRC ELECT.
FLUX RETURN
SUPERCONDUCTING SOLENOID
BARREL CALORIMETER
STAND-OFF BOX
FCA
DIRC
FORWARD END PLUG
REMOVABLE HORSESHOE
D.C. ELECT.
Q4
Q2
B1
B1
Q1
Q1
Q2
Q4
STATIONARY WEDGE
DRIFT CHAMBER CABLES
DIRC ELECT.
OPTION



Many more details in the

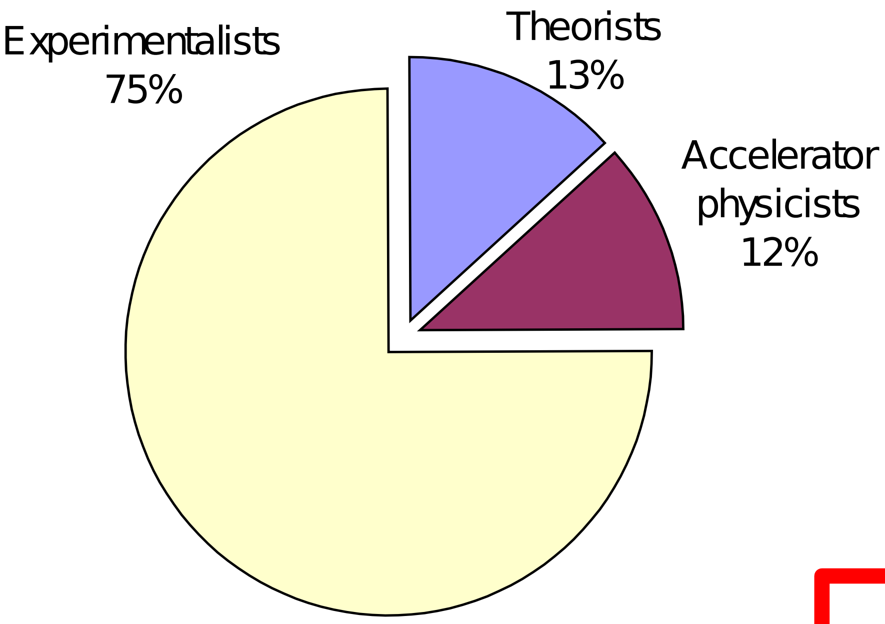
Conceptual Design Report

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

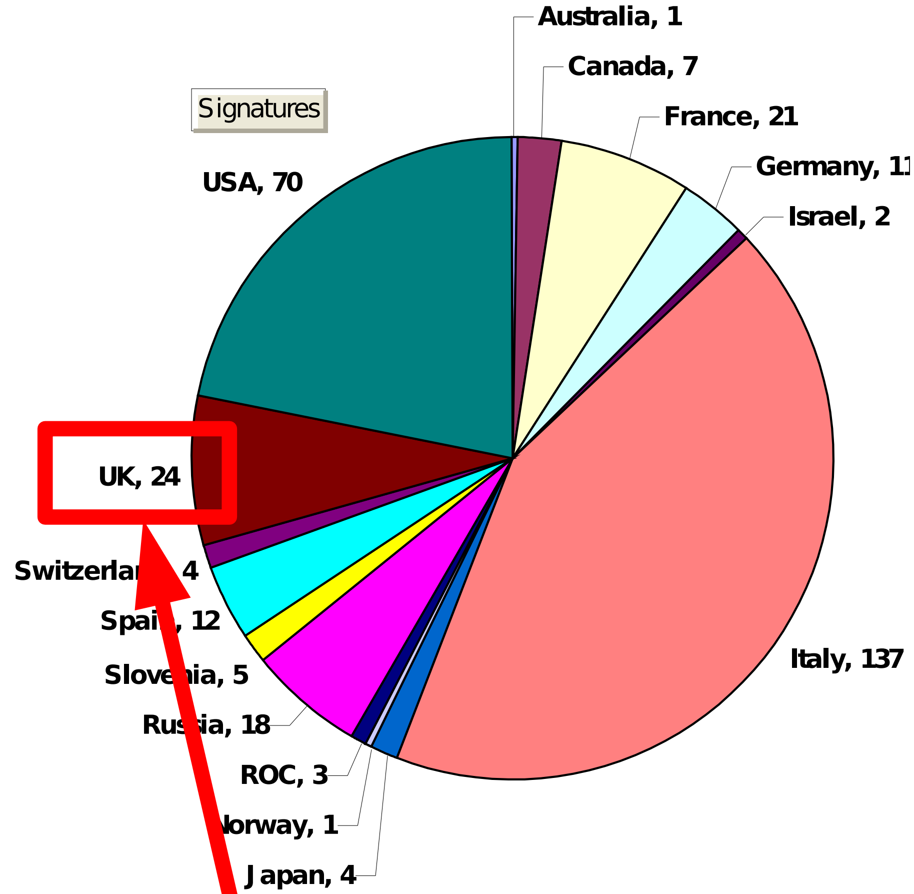
Available online at:

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

- 320 Signatures
- About 85 institutions
- 174 Babar members
- 65 non Babar experimentalists.



Signatures breakdown by type

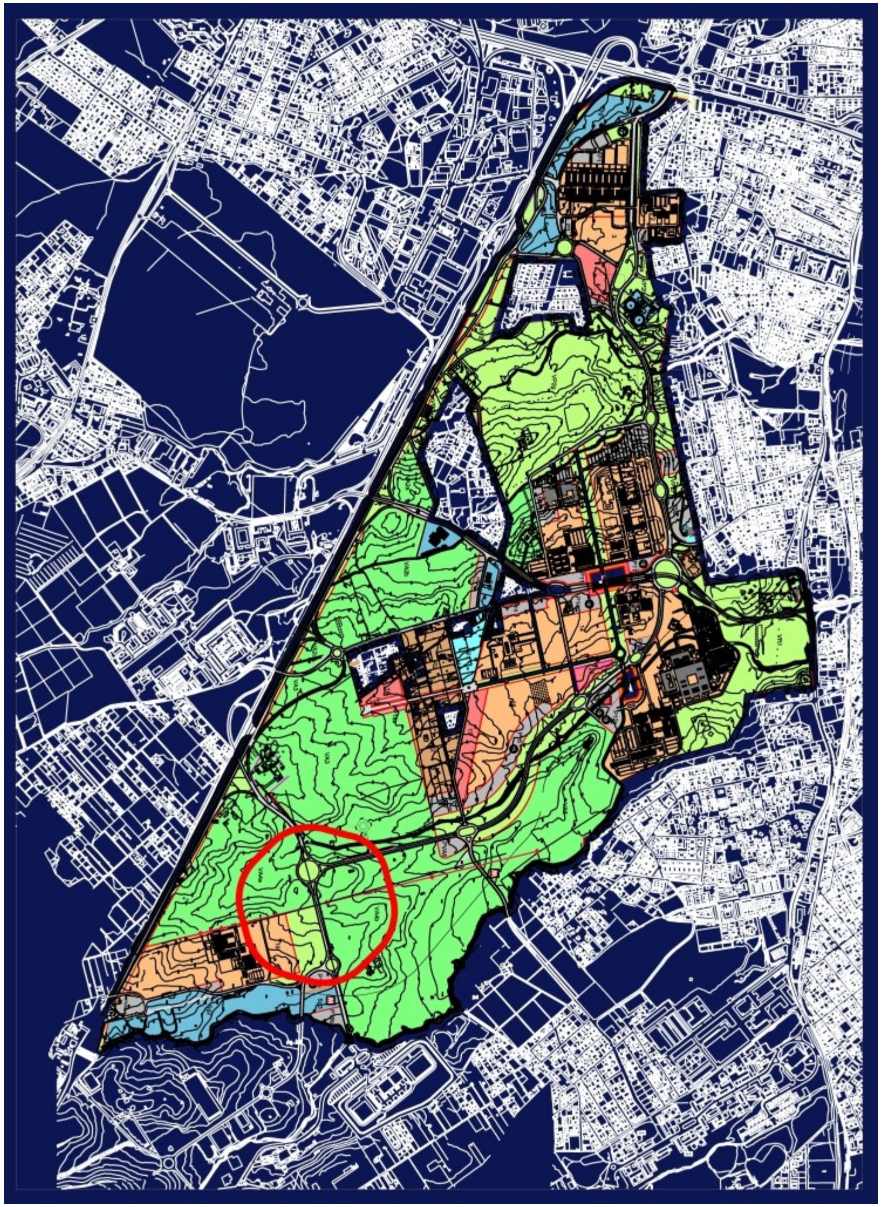


Signatures breakdown by country

UK 3rd biggest block of signatures

Potential SuperB site on the University of Rome Tor Vergata campus

- Literally a “green field” site
- – Synergy with approved and funded FEL project (SPARX)



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

Potential SuperB site on the University of Rome Tor Vergata campus

Photo taken by D.Hitlin from Villa Mondragone

CDR includes a cost estimate

Costs are presented "ILC-style", with replacement value for reusable PEP-II/*BABAR* components

	EDIA [my]	Labor [my]	M&S [k€]	Replacement value [k€]
Accelerator	452	291	191,166	126,330
Site	119	138	105,700	0
Detector	283	156	40,747	46,471

Engineering, Design, Inspection, Acceptance

Materials & Services

Value of reusable items from PEP-II and *BABAR*

Disassembly, crating, refurbishment and shipping costs are included in columns to the left

Costs are in 2007 € inflation adjusted

Possible savings from reusing other hardware not yet considered in detail

CDR includes a cost estimate

WBS	Item	EDIA mm	Labor mm	M\&S kEuro	Rep.Val. kEuro
1	**Accelerator**	**5429**	**3497**	**191166**	**126330**
1.1	Project management	2112	96	1800	0
1.2	Magnet and support system	666	1199	28965	25380
1.3	Vacuum system	620	520	27600	14200
1.4	RF system	272	304	22300	60000
1.5	Interaction region	370	478	10950	0
1.6	Controls, Diagnostics, Feedback	963	648	12951	8750
1.7	Injection and transport systems	426	252	86600	18000

WBS	Item	EDIA mm	Labor mm	M\&S kEuro	Rep.Val. kEuro
2.0	**Site**	**1424**	**1660**	**105700**	**0**
2.1	Site Utilities	820	1040	31700	0
2.2	Tunnel and Support Buildings	604	620	74000	0

CDR includes a cost estimate

WBS	*Item*	*EDIA mm*	*Labor mm*	*M\&S kEuro*	*Rep.Val. kEuro*
1	**SuperB detector**	**3391**	**1873**	**40747**	**46471**
1.0	**Interaction region**	**10**	**4**	**210**	**0**
1.1	**Tracker (SVT + L0 MAPS)**	**248**	**348**	**5615**	**0**
1.1.1	**SVT**	**142**	**317**	**4380**	**0**
1.1.2	***L0 Striplet option***	***23***	***33***	***324***	***0***
1.1.3	**L0 MAPS option**	**106**	**32**	**1235**	**0**
1.2	**DCH**	**113**	**104**	**2862**	**0**
1.3	**PID (DIRC Pixilated PMTs + TOF)**	**110**	**222**	**7953**	**6728**
1.3.1	**DIRC barrel - Pixilated PMTs**	**78**	**152**	**4527**	**6728**
1.3.1	***DIRC barrel - Focusing DIRC***	***92***	***179***	***6959***	***6728***
1.3.2	**Forward TOF**	**32**	**70**	**3426**	**0**
1.4	**EMC**	**136**	**222**	**10095**	**30120**
1.4.1	**Barrel EMC**	**20**	**5**	**171**	**30120**
1.4.2	**Forward EMC**	73	152	6828	0
1.4.3	**Backward EMC**	42	65	3096	0
1.5	**IFR (scintillator)**	**56**	**54**	**1268**	**0**
1.6	**Magnet**	**87**	**47**	**1545**	**9623**
1.7	**Electronics**	**286**	**213**	**5565**	**0**
1.8	**Online computing**	**1272**	**34**	**1624**	**0**
1.9	**Installation and integration**	**353**	**624**	**3830**	**0**
1.A	**Project Management**	**720**	**0**	**180**	**0**

NB. Items in italics (L0 striplet, focusing DIRC) are not included in the baseline

CDR includes a schedule

- Impossible to read here, check the CDR
- Includes site construction, PEP-II & BaBar disassembly, shipping, reassembly, etc.
- Five years from T0 to commissioning

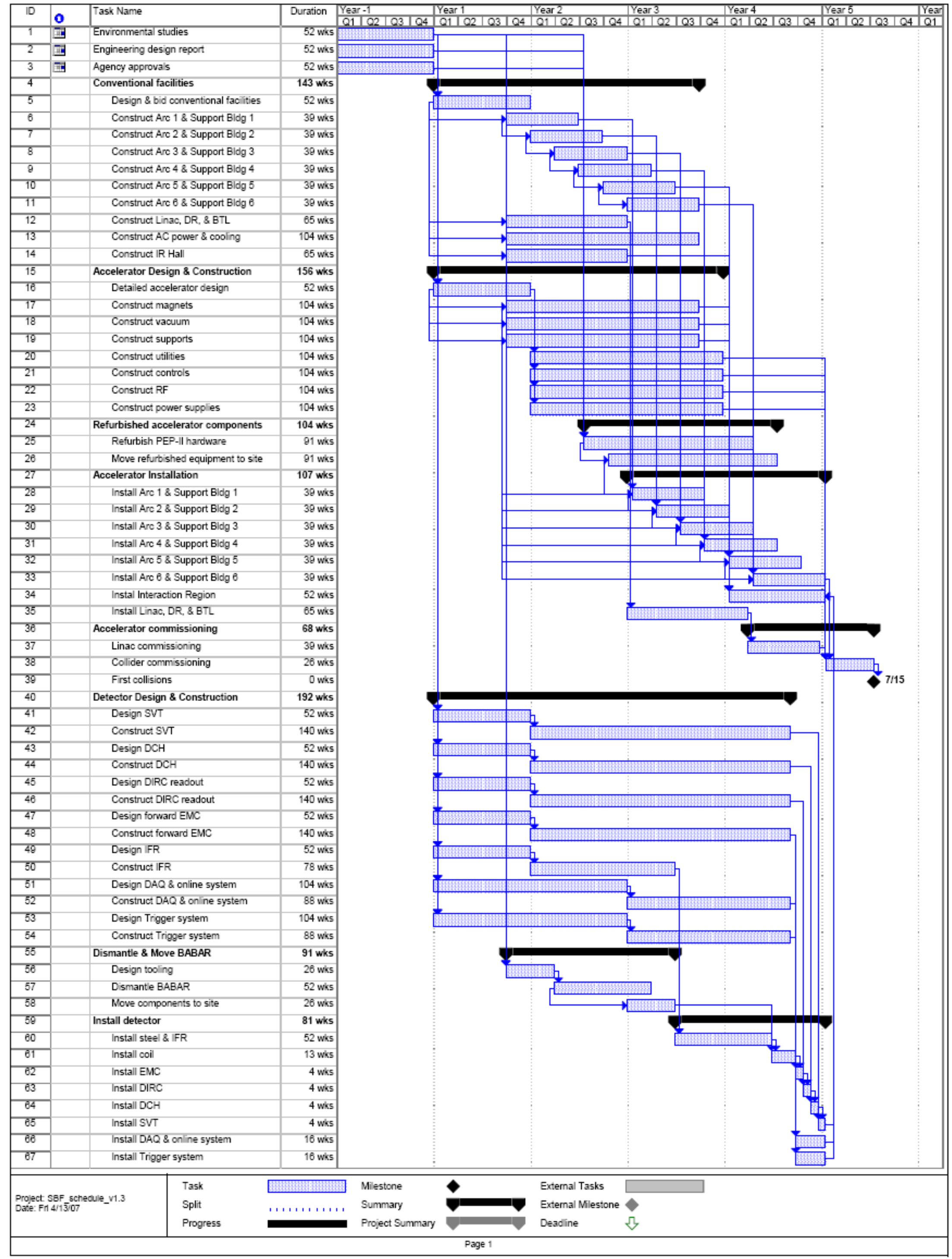


Figure 5-1. *Overall schedule for the construction of the SuperB project.*

What next for the CDR?

- The CDR was officially presented to INFN on 4th May
- Now being read by an international review committee
  - expect interactive review process (ie. discussion between reviewers and authors/editors)
  - final report around end of 2007
- If report is positive, expect approach to INFN to move to next stage (TDR)
- Approval is 2008, data-taking in 2013 is possible!

Summary

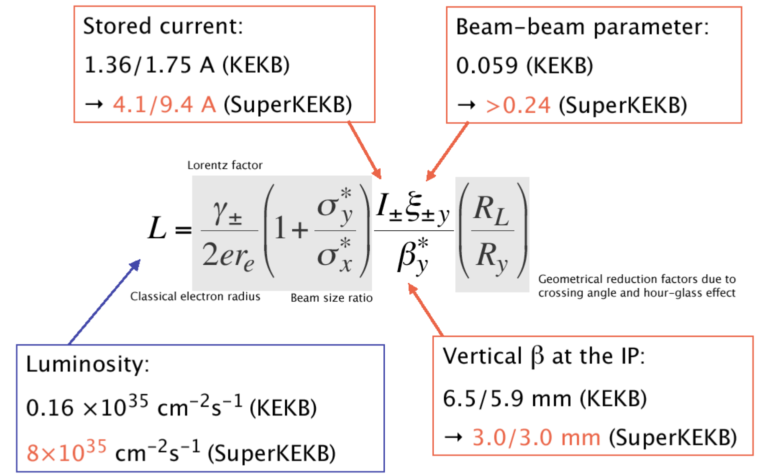
- The case for flavour physics in the LHC era is compelling
- SuperB – a high-luminosity asymmetric e^+e^- Super Flavour Factory is the ideal tool
  - significant breakthrough in collider design
- Conceptual Design Report exists
  - clear road ahead to explore the flavour treasure chest by mid-2010s

Basic concepts

- B-factories reachs already very high luminosity (~10^{34} s^{-1} cm^{-2}). To increase of ~ two orders of magnitude (KeKB-SuperKeKB) it is possible to extrapolate the requirements from the current machines:

Parameters :

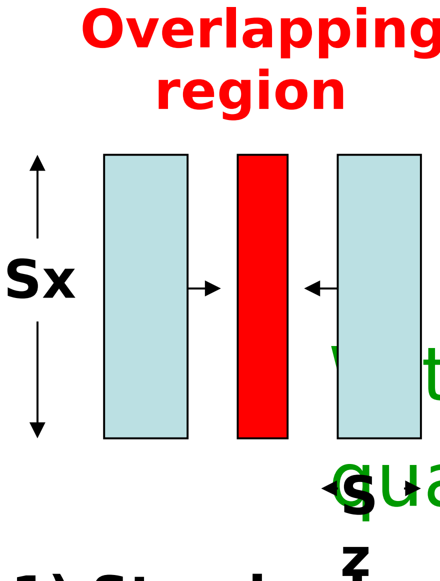
- Higher currents
- Smaller damping time (f(exp1/3))
- Shorter bunches
- Crab collision
- Higher Disruption
- Higher power
- SuperKeKB Proposal is based on these concepts



Increase of plug power ($$$$$..) and hard to operate (high current, short bunches)

look for alternatives keeping constant the luminosity => new IP scheme: Large Piwinsky Angle and CRAB WAIST

Crossing angle concepts

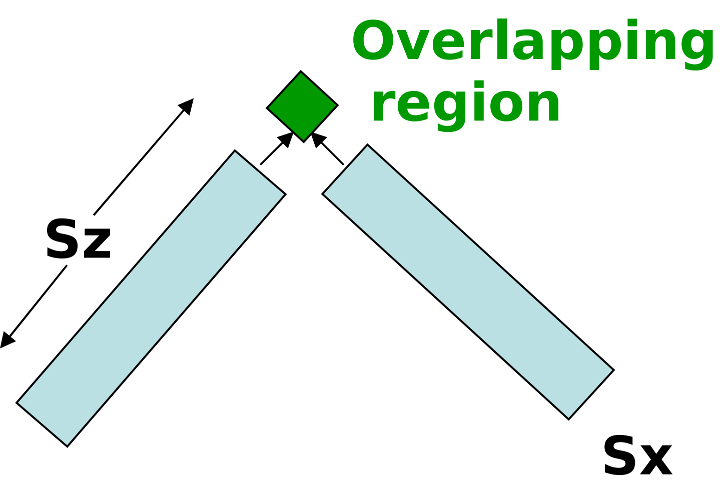


1) Standard short bunches

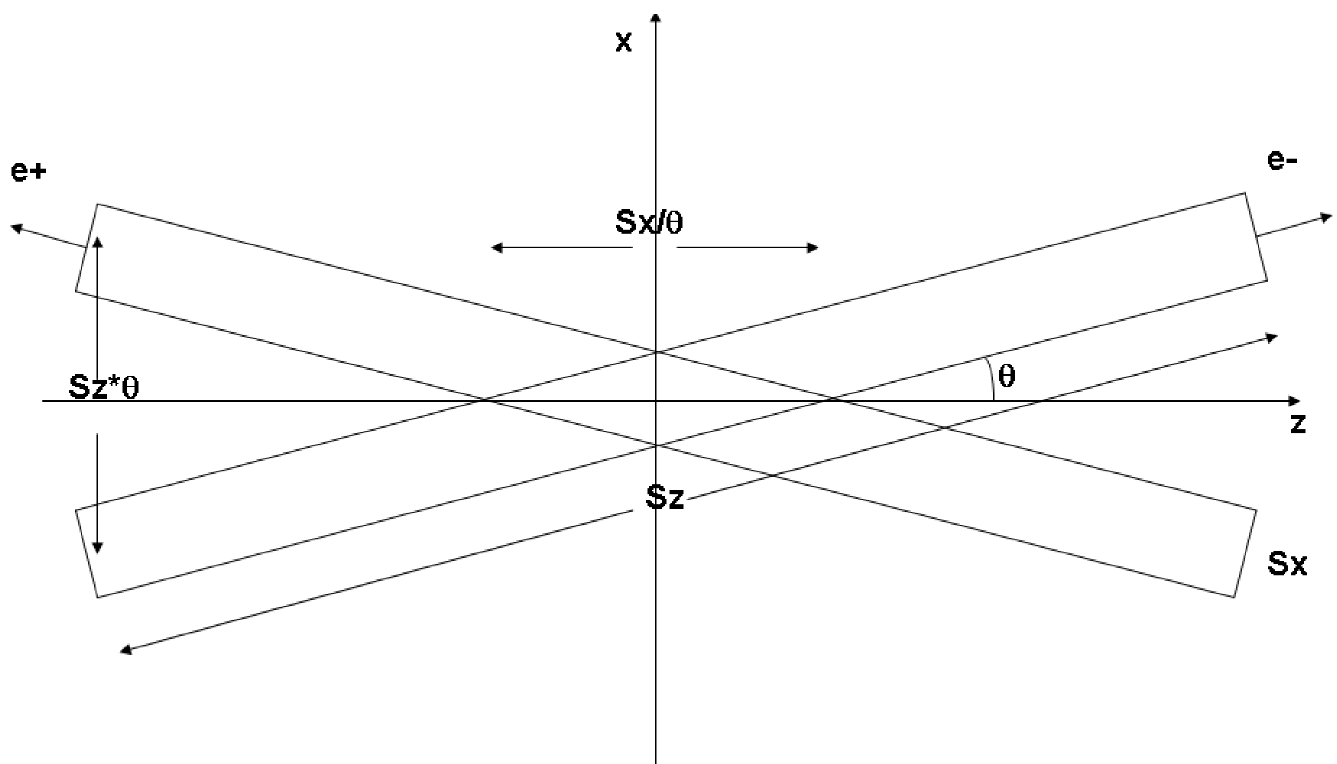
Both cases have the same luminosity,

(2) has longer bunch and smaller σ_x

With large crossing angle X and Z quantities are swapped: Very important!!!



2) Crossing angle



1) Large Piwinski angle - high σ_z and collision angle. (Slight L decrease)

$\Rightarrow$ allows point (2) & decrease the disruption due to the effective z overlap & minimise parasitic collision. Long bunches are good for the ring stability (CSR, HOM…) but

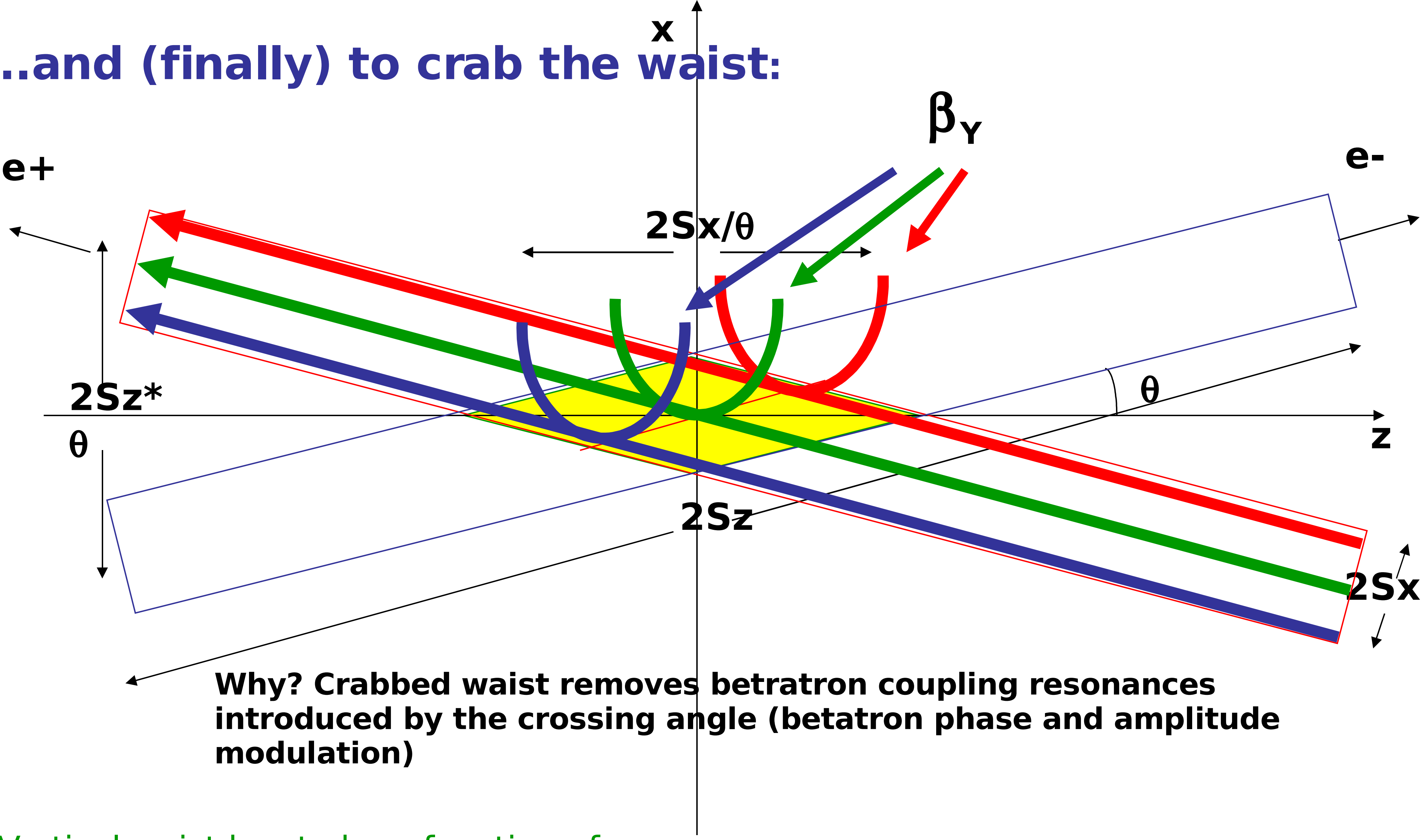
Introduces B-B and S-B resonances (strong coordinates coupling).

2) Extremely short β^*_y (300 μm) - so little σ^*_y (20 nm - High L gain…)

3) Large angle scheme already allows to suppress SB resonances

4) Small horizontal emittance (Horizonatal tune compensated by large Piwinski angle)

....and (finally) to crab the waist:



Why? Crabbed waist removes betratron coupling resonances introduced by the crossing angle (betatron phase and amplitude modulation)

Vertical waist has to be a function of x:

Crabbed waist realized with a sextupole in phase with the IP in X and at π/2 in Y

…….and slight increase of the luminosity.

- But where is the real gain?

	PEPII	KEKB	SuperB
current	2.5 A	1.7 A	2.3 A
betay	10 mm	6 mm	0.3 mm
betax	400 mm	300 mm	20 mm
Emity (sigmay)	23 nm (~100μm)	~ the same (~80μm)	1,6 nm (~6μm)
y/x coupling (sigma y)	0,5-1 % (~6μm)	0.1 % (~3μm)	0,25 % (0,035μm)
Bunch length	10 mm	6 mm	6 mm
Tau l/t	16/32 msec	~ the same	16/32 msec
ζy	0.07	0.1	0.16
L	$1.2\ 10^{34}$	$1.7\ 10^{34}$	$1\ 10^{36}$

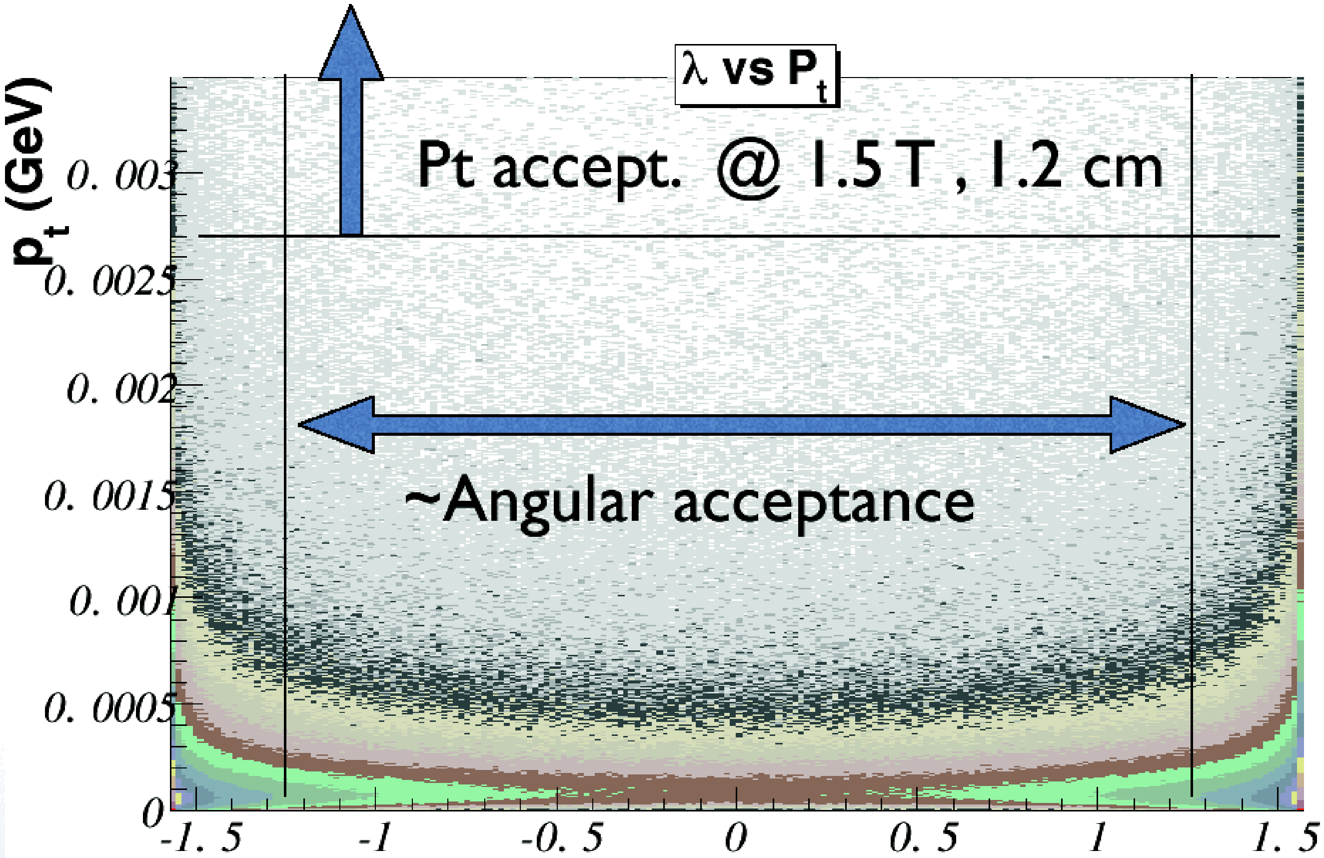
Luminosity x 10^{36}	1		2,4		3,4	
Circumference (m)	2250	2250	2250	2250	2250	2250
Revolution frequency (MHz)	0,13	0,13	0,13	0,13	0,13	0,13
Eff. long. polarization (%)	0	80	0	80	0	80
RF frequency (MHz)	476	476	476	476	476	476
Harmonic number	3570	3570	3570	3570	3570	3570
Momentum spread	8,4E-04	9,0E-04	1,0E-03	1,0E-03	1,0E-03	1,0E-03
Momentum compaction	1,8E-04	3,0E-04	1,8E-04	3,0E-04	1,8E-04	3,0E-04
Rf Voltage (MV)	6	18	6	18	7,5	18
Energy loss/turn (MeV)	1,9	3,3	2,3	4,1	2,3	4,1
Number of bunches	1733	1733	3466	3466	3466	3466
Particles per bunch x10^{10}	6,16	3,52	5,34	2,94	6,16	3,52
Beam current (A)	2,28	1,30	3,95	2,17	4,55	2,60
Beta y* (mm)	0,30	0,30	0,20	0,20	0,20	0,20
Beta x* (mm)	20	20	20	20	20	20
Emit y (pmr)	4	4	2	2	2	2
Emit x (nmr)	1,6	1,6	0,8	0,8	0,8	0,8
Sigma y* (microns)	0,035	0,035	0,020	0,020	0,020	0,020
Sigma x* (microns)	5,657	5,657	4,000	4,000	4,000	4,000
Bunch length (mm)	6	6	6	6	6	6
Full Crossing angle (mrad)	34	34	34	34	34	34
Wigglers (#)	4	2	4	4	4	4
Damping time (trans/long)(ms)	32/16	32/16	25/12.5	25/12.5	25/12.5	25/12.5
Luminosity lifetime (min)	10,4	5,9	7,4	4,1	6,1	3,5
Touschek lifetime (min)	5,5	38	2,9	19	2,3	15
Effective beam lifetime (min)	3,6	5,1	2,1	3,4	1,7	2,8
Injection rate pps (100%)	4,9E+11	2,0E+11	1,5E+12	5,0E+11	2,1E+12	7,2E+11
Tune shifts (x/y) (from formula)	0.004/0.17	0.004/0.17	0.007/0.16	0.007/0.16	0.009/0.2	0.009/0.2
RF Power (MW)	17		35		44	

Table 3-2. *Comparison between parameters for the SuperB storage rings and the ILC damping rings.*

Unit	SuperB LER	SuperB HER	ILC DRs
Beam energy (GeV)	4	7	5
Circumference (m)	2249	2249	6695
Particles per bunch	6.16×10^{10}	3.52×10^{10}	2×10^{10}
Number of bunches	1733	1733	2767
Average current (A)	2.28	1.30	0.40
Horizontal emittance (nm)	1.6	1.6	0.8
Vertical emittance (pm)	4	4	2
Bunch length (mm)	6	6	9
Energy spread (%)	0.084	0.09	0.13
Momentum compaction	1.8×10^{-4}	3.1×10^{-4}	4.2×10^{-4}
Transverse damping time (ms)	32	32	25
RF voltage (MV)	6	18	24
RF frequency (MHz)	476	476	650

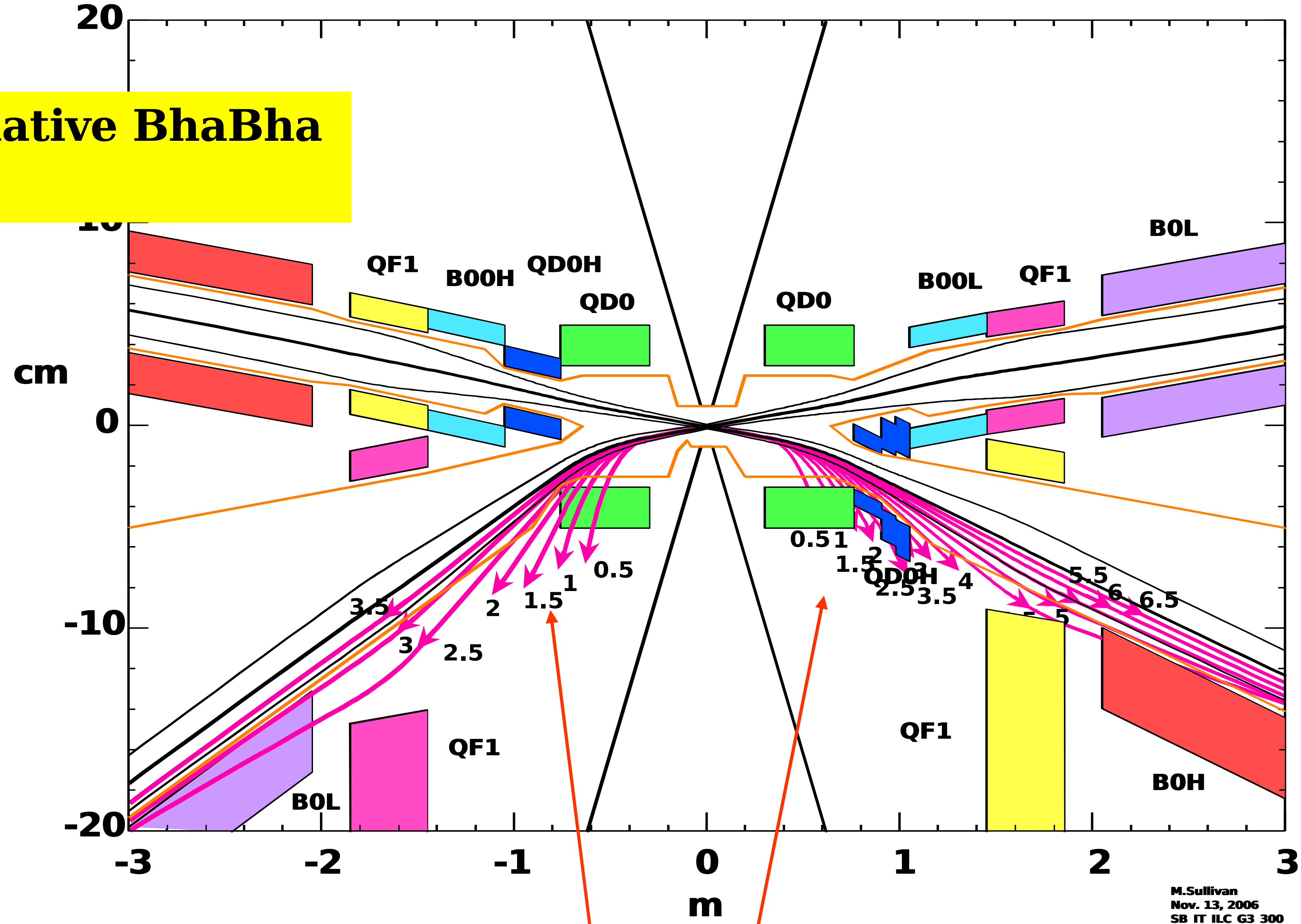
Pair production

- Huge cross section (7.3 mbarn)
- Produced particles have low energy and loop in the magnetic field
- Most particles are outside the detector acceptance



We have an IR design coping with main BKG source

Radiative BhaBha



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

Compare to ILC "value estimate"

Costs are presented "ILC-style", with replacement value for reusable PEP-II/*BABAR* components

	EDIA [my]	Labor [my]	M&S [k€]	Replacement value [k€]
Accelerator	452	291	191,166	126,330
Site	119	138	105,700	0
Detector	283	156	40,747	46,471

Totals **337,613 k€** **172,801 k€**

SHARED VALUE = 4.87 Billion ILC VALUE UNITS

SITE-DEPENDENT VALUE = 1.78 Billion ILC VALUE UNITS

TOTAL VALUE = 6.65 Billion ILC VALUE UNITS

(shared + site-dependent)

= 5,519,500 k€

LABOUR = 22 million person-hours = 13,000 person-years

(assuming 1700 person-hours per person-year)

1 ILC VALUE UNIT = 1 US Dollar (2007) = 0.83 Euros = 117 Yen

NB. ILC costs do not include detector, land acquisition, inflation

MORE THAN AN ORDER OF MAGNITUDE DIFFERENCE!

SuperB budget model

- The SuperB budget model still needs to be fully developed. It is based on the following elements (all being negotiated)
  - Italian government ad hoc contribution
  - Regione Lazio contribution
  - INFN regular budget
  - EU contribution
  - In-kind contribution (PEP-II + Babar elements)
  - Partner countries contributions

International Review Committee

- R. Petronzio, President of INFN, has formed an International Review Committee to evaluate SuperB CDR

- The committee members are:

  J. Dainton (chair) [UK]

H. Aihara [Japan]	R. Heuer [Germany]	Y.-K. Kim [US]
A. Masiero [Italy]	J. Siegrist [US]	D. Shulte [CERN]

- First meeting of the committee expected July 2007

- Expect several IRC meetings, some with interactions with primary authors, and a report by end of the year

- Possible further report in Spring 2008 following DaΦNe beam test results

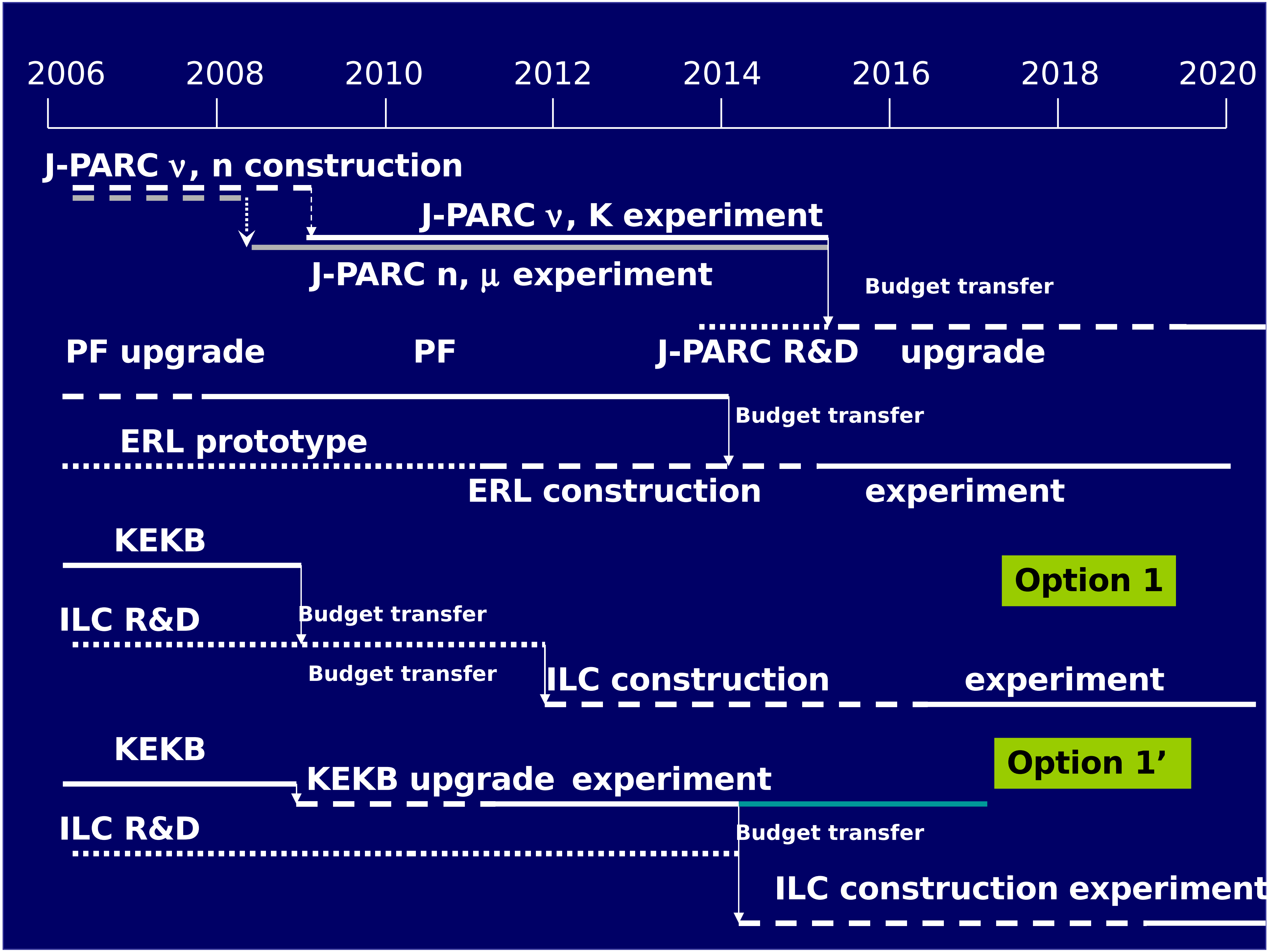
UK signatories

- University of Birmingham (1)
- Brunel University (1)
- ASTeC, Daresbury Laboratory (1)
- IPPP, Durham University (3)
- University of Edinburgh (2)
- Imperial College London (1)
- University of Liverpool (2)
- University of Liverpool and Cockcroft Institute (1)
- Royal Holloway University of London (1)
- Queen Mary University of London (3)
- University of Manchester (2)
- Rutherford Appleton Laboratory (1)
- University of Warwick (5)

24 individuals (~9 non faculty), 13 institutes

News from Japan

- Crab cavities installed and being tested
  - some improvement in specific luminosity seen at low currents
  - now testing with higher currents
- Low emittance scheme under consideration at KEK
  - no stable dynamic aperture found as yet
  - concerns over geological stability
  - intermediate schemes also being considered
- Support for SuperKEKB from
  - Japanese High Energy Physics community (JAHEP)
  - Belle Program Advisory Committee (PAC)
  - statement from KEK director general expected this summer
- No funds available until end of J-PARC construction


2006
2008
2010
2012
2014
2016
2018
2020
J-PARC ν, n construction
J-PARC ν, K experiment
J-PARC n, μ experiment
Budget transfer
PF upgrade
PF
J-PARC R&D
upgrade
Budget transfer
ERL prototype
ERL construction
experiment
KEKB
Option 1
ILC R&D
Budget transfer
Budget transfer
ILC construction
experiment
KEKB
Option 1’
KEKB upgrade
experiment
ILC R&D
Budget transfer
ILC construction experiment

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
Λ(MFV) > 2.3Λ_0 @95C.L.

NP masses >200GeV

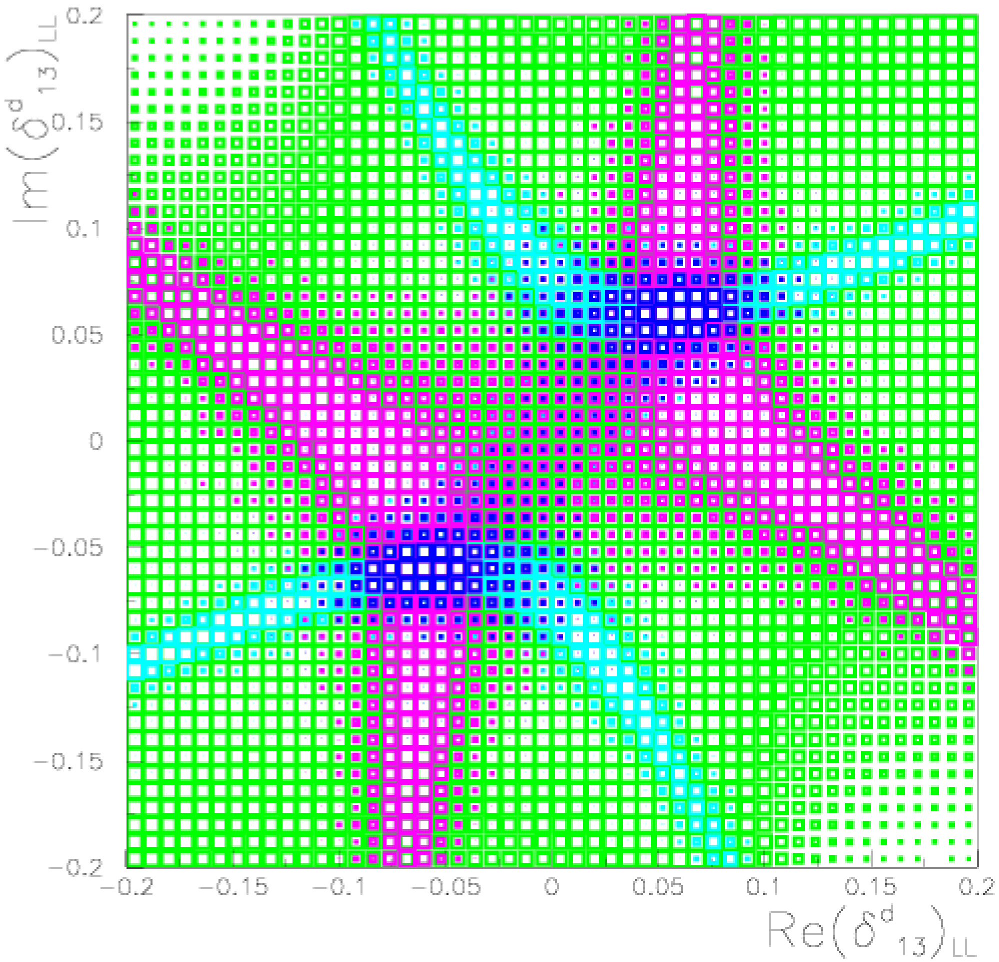
SuperB
Λ(MFV) >~6Λ_0 @95C.L.

NP masses >600GeV

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

MSSM + Generic Squark Mass Matrices

Today's central values with SuperB precision



Δm_d	magenta
A_{SL}	green
β	cyan
All	blue

Real vs. imaginary parts of mass-insertion parameter $(\delta_{13})_{LL}$

	superB	general MSSM	high-scale MFV
$\left\| \left(\delta^d_{13}\right)_{LL} \right\| \ (LL \gg RR)$	$1.8 \cdot 10^{-2} \frac{m_{\tilde{q}}}{(350\mathrm{GeV})}$	1	$\sim 10^{-3} \frac{(350\mathrm{GeV})^2}{m^2_{\tilde{q}}}$
$\left\| \left(\delta^d_{13}\right)_{LL} \right\| \ (LL \sim RR)$	$1.3 \cdot 10^{-3} \frac{m_{\tilde{q}}}{(350\mathrm{GeV})}$	1	$-$
$\left\| \left(\delta^d_{13}\right)_{LR} \right\|$	$3.3 \cdot 10^{-3} \frac{m_{\tilde{q}}}{(350\mathrm{GeV})}$	$\sim 10^{-1} \tan\beta \frac{(350\mathrm{GeV})}{m_{\tilde{q}}}$	$\sim 10^{-4} \tan\beta \frac{(350\mathrm{GeV})^3}{m^3_{\tilde{q}}}$
$\left\| \left(\delta^d_{23}\right)_{LR} \right\|$	$1.0 \cdot 10^{-3} \frac{m_{\tilde{q}}}{(350\mathrm{GeV})}$	$\sim 10^{-1} \tan\beta \frac{(350\mathrm{GeV})}{m_{\tilde{q}}}$	$\sim 10^{-3} \tan\beta \frac{(350\mathrm{GeV})^3}{m^3_{\tilde{q}}}$

we can test scale up to

How to read this table, two examples.

At SuperB we can set a limit on the coupling at $1.8\times10^{-2} \frac{m}{350GeV}$

The natural coupling would be 1

$\delta_{LL}(LL >> RR)$ ⟶ we can test scale up to $\frac{350GeV}{1.8\times10^{-2}} \sim 20TeV$

$\delta_{LL}(LL \sim RR)$ ⟶ we can test scale up to $\frac{350GeV}{1.3\times10^{-3}} \sim 270TeV$

SuperB will probe up to >100 TeV for arbitrary flavour structure!

All these numbers are a factor ~10 better than present bounds

Large New Physics Contributions Excluded

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

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*

$B(D^0 \to l^+ l^-)$ $B(D \to h l^+ l^-)$ $B(D^+_{(s)} \to l^+ \nu)$ x_D y_D

charm CPV