B_u B_d B_s D τ...

More than just
B physics!

The SuperB Facility

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Edinburgh, 16th November 2007

Conceptual Design Report: arXiv:0709.0451 (hep-ex)
http://www.pi.infn.it/SuperB/

Overview

- Introduction
- New Physics Search Capability
- Accelerator Aspects
- Detector Design
- Summary
- Conclusion

Physics Case

Data Sample

- Aim: integrate 50-100 ab^{-1} of data (12ab^{-1}/yr at design lumi).

- Two orders of magnitude larger data set than the current B-factories:
  - i.e. 55-110 Billion $B\bar{B}$ pairs operating at the Υ(4S).
  - Similar numbers of D mesons and τ leptons.
  - Can run at different $\sqrt{s}$, e.g. Υ(5S) for B_s physics.

- New concepts in accelerator technology should enable us to meet this target within 5 years of data taking.
  - Accelerator R&D is well underway at Frascati to test these concepts.

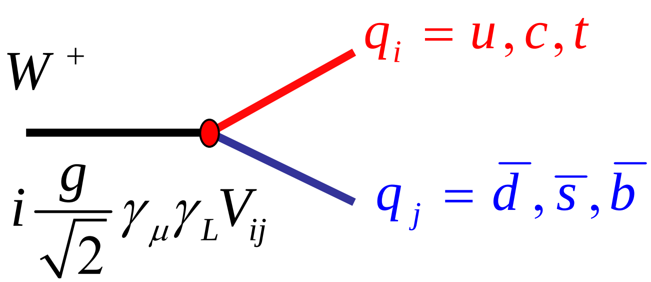
- Timescale: Aim to start taking data 5 years after funding gets approved.

Physics Case – in a Nutshell

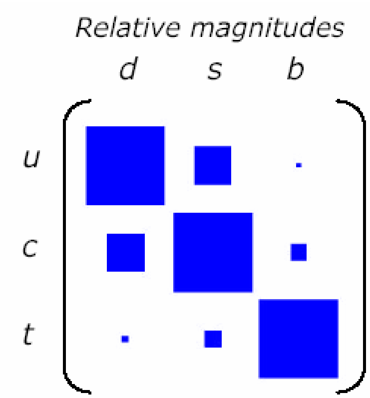
- We expect New Physics (NP) at the TeV scale:
  - Same motivation as the LHC!
- This physics will have some kind of flavour structure:
  - Rich structure: *we have to measure it*!
  - Trivial structure: *we have to confirm*!
- This new physics may, *or may not* help elucidate the matter-antimatter asymmetry problem.
- SuperB can make complementary measurements to the LHC programme:
  - Many rare decay final states are only accessible to SuperB.
  - Sensitive to off-diagonal terms in the squark mixing matrix.
  - Test Lepton Flavour Violation (LFV) in τ decay.
  - Can study CP and CPT violation in τ decay, τ anomalous magnetic moment.
  - Search for CP (and CPT) violation in D decays.

What do we mean by flavour Structure?

- The relation ship between generations of particles (quarks, squarks, leptons).
- Using quarks as an example:



$V =$



- These gauge interactions form a 3x3 unitary matrix called the Cabibbo-Kobayashi-Maskawa CKM matrix.

- The CP conjugate interactions have couplings with factors of V_{ij}^*.

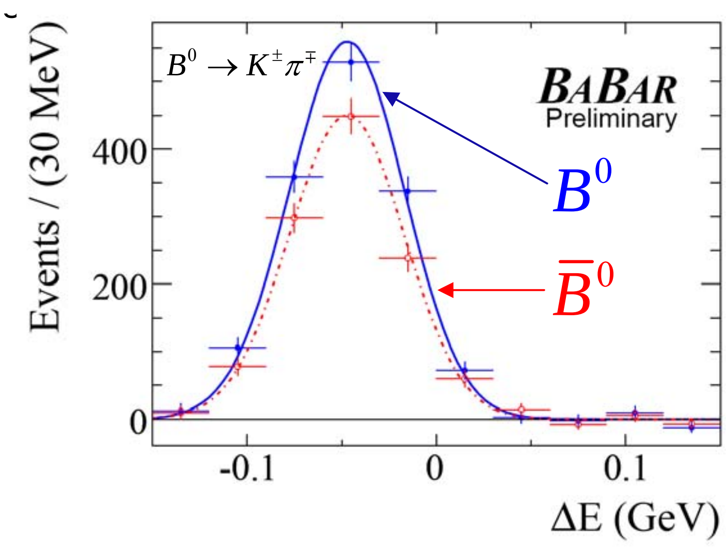
$$V = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

Testing Flavour Structure

- In addition to measuring rates of flavour changing transitions, we can probe flavour structure using asymmetry observables:

$$A = \frac{\bar{N} - N}{\bar{N} + N}$$

  – Integrating over all signal events (e.g. $B^0 \rightarrow K\pi$)



The difference between the blue and red curve indicates direct CP violation in this particular decay.

hep-ex/0607106

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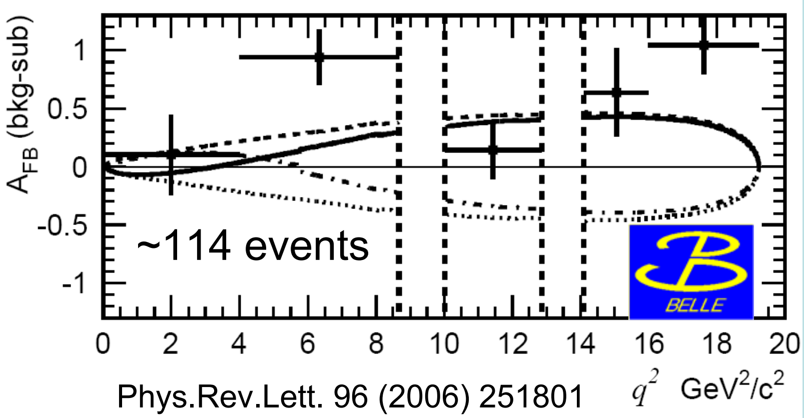
  – As a function of some kinematic variable (e.g. $b \to sll$)

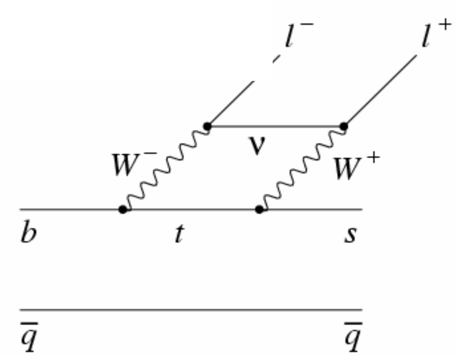


Phys.Rev.Lett. 96 (2006) 251801

The shape and features of the forward backward asymmetry in $B \to K^*ll$ is sensitive to new physics in FCNC.

Solid line = SM prediction
Dotted line = sign flip C_7
Dashed line = sign flip C_9C_{10}
Dot-Dashed line = sign flip both

Super B will probe $K^*e^+e^-$ final state to compliment $K^* \mu^+\mu^-$ from LHCb.



Observables:
f_L, CP asymmetries, A_{FB} and $\mathcal{B}(se^+e^-)/\mathcal{B}(s\mu^+\mu^-)$

Testing Flavour Structure

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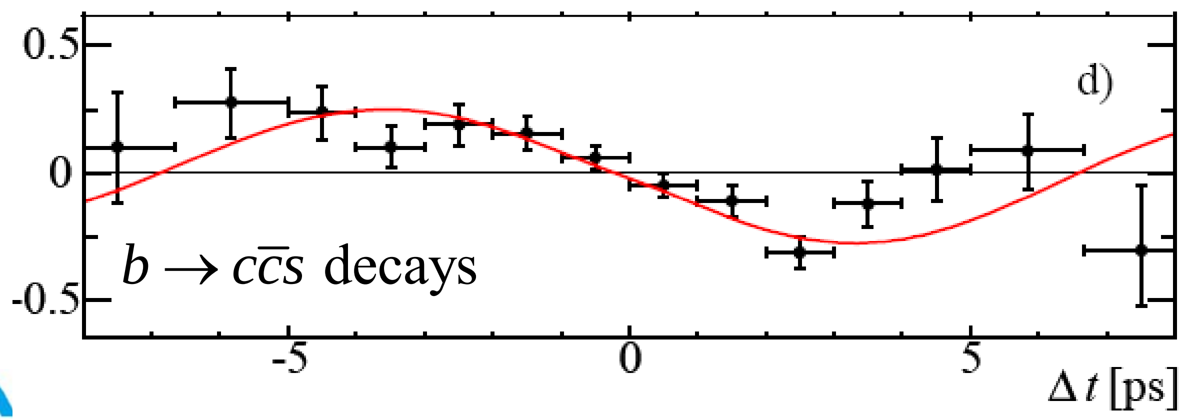
$$A = \frac{\bar{N} - N}{\bar{N} + N}$$

  - Integrating over all signal events (e.g. $B^0 \to K\pi$)
  - As a function of some kinematic variable (e.g. $b \to sll$)
  - As a function of the time difference between a known flavour state decaying, and a tagged flavour state (neutral mesons only) (e.g. $B \to J/\psi K^0_S$).



The sinusoidal oscillation indicates CP violation in this particular decay. Sine and Cosine amplitudes in this plot indicate two different types of CP violation.

Let's put the existing programme into perspective

- The current B factories ***have*** measured the unitarity triangle.
  - Both BaBar and Belle have outperformed expectations:
    - Observed CP violation in the B system, α & β
    - Evidence for oscillations in D system.
    - Measured the characteristics of the unitarity triangle beyond expectations.
    - Discovered a number of low energy hadronic states.
    - And performed a large number of other measurements besides this… with more than 540 publications since 1999.
- The Tevatron has discovered mixing in B_s decays.
- LHCb will start taking data soon, and will overconstrain the Unitarity Triangle.
- So …

… Standard Model tests will have been done to a high precision before a SuperB starts taking data.

Today's calibration channel is tomorrow's background

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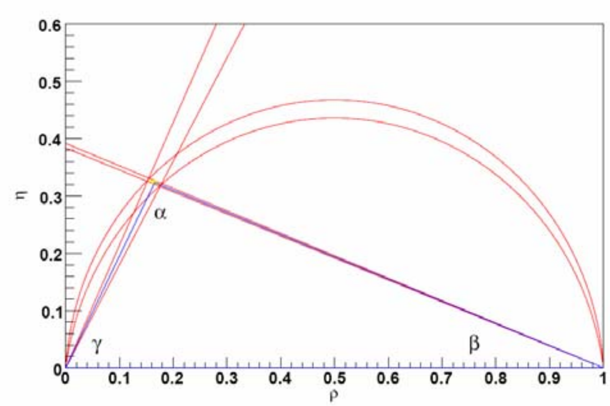
Today's golden channel is tomorrow's calibration mode



- Unitarity Triangle will be well measured before SuperB, and will be precision measurements at SuperB.

- The angles and sides are calibration measurements, required in order to search for NP.

Today's calibration channel is tomorrow's background

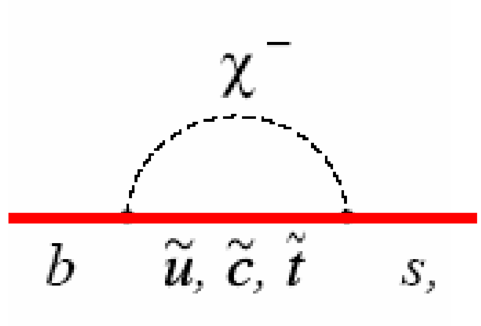
Today's golden channel is tomorrow's calibration mode

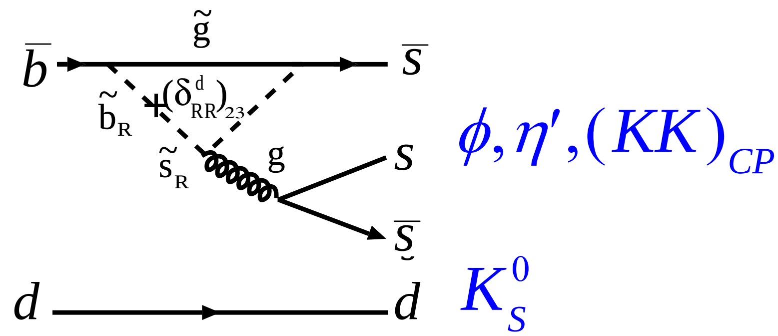
Tomorrow we look for new physics

New Physics Search Capability

New Physics in Loops (ΔF=1)

- Rare loop processes can have significant NP contributions.



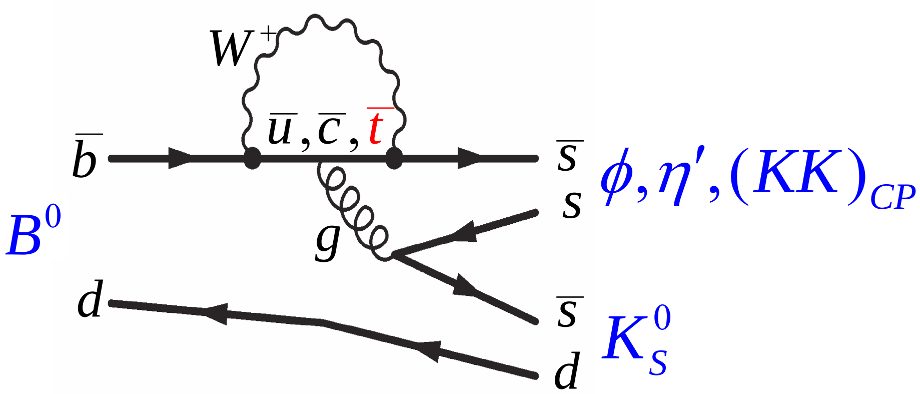


- NP can modify the expected SM amplitudes and asymmetries.
- Want to look in as many different modes (and with as many different observables) as possible.

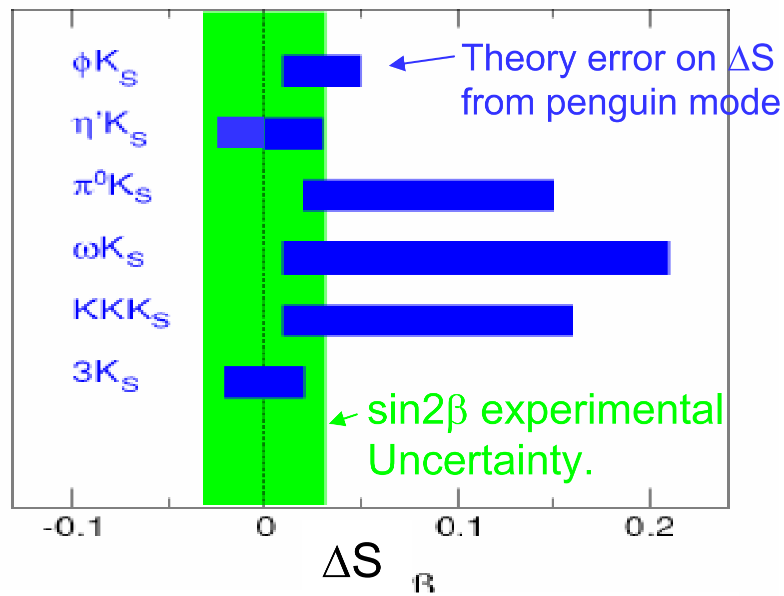
New Physics in Loops ($\Delta F=1$)

- β_{eff} measured in $b \to s$ penguin decays can differ from β in $b \to c\bar{c}s$.

- Small uncertainties come from SM corrections to the decays.
  - $O(0.01)$ on $\sin(2\beta_{eff})$ in $\eta' K^0$ and $3K^0_s$.



some of recent QCDF estimates $\sin 2\beta^f_{eff} - \sin 2\beta$



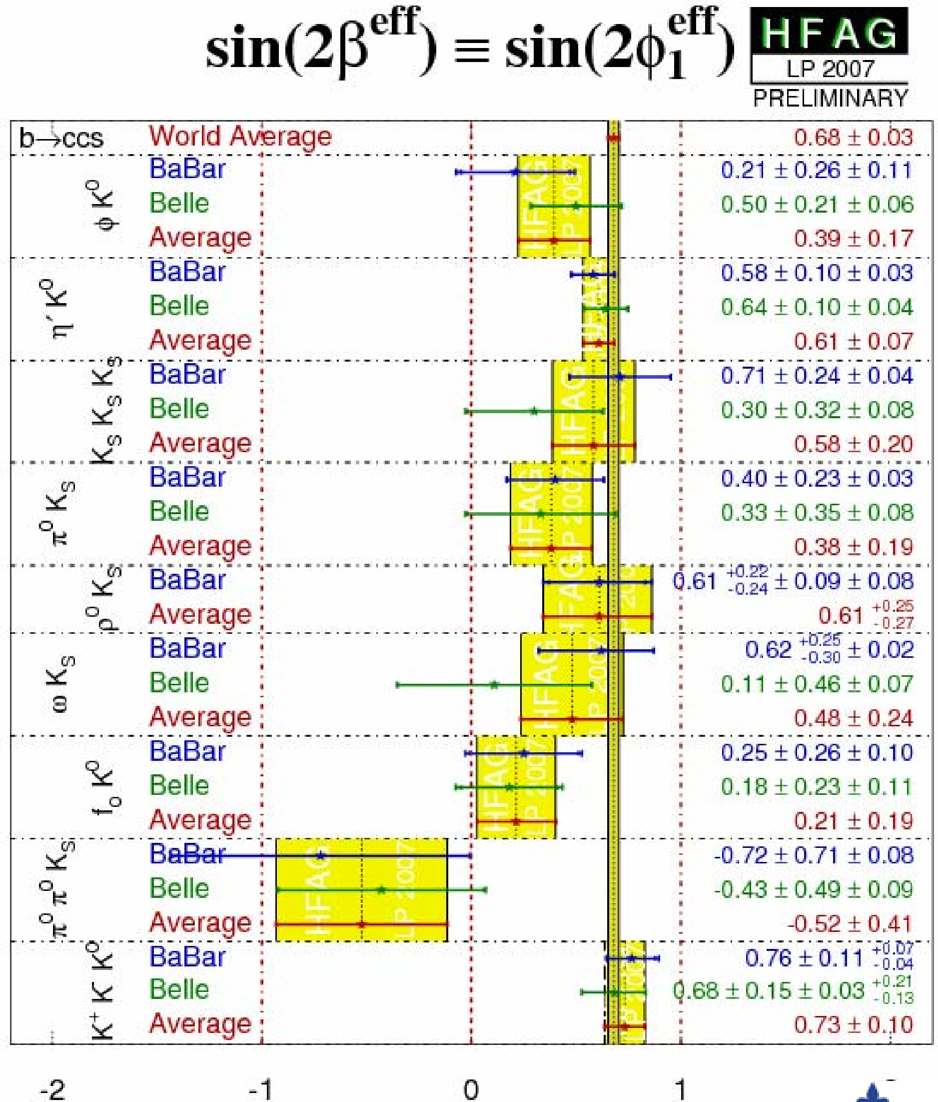
QCDF: (Beneke, PLB620 (2005), 143-150, Cheng et al., PRD72 (2005) 094003 etc.
SCET: (Williamson & Zupan, hep-ph/0601214)
Can estimate ΔS and mostly see a positive shift.

SU(3): Grossman *et al*, PRD68 (2003) 015004; Gronau *et al*, PRD71 (2005) 074019; …).

SM corrections to $b \to s$ penguin decays tend to prefer $\beta_{eff} > \beta$.

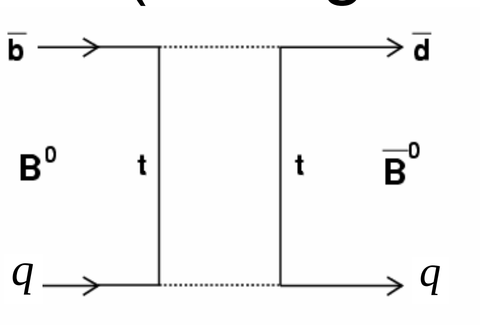
New Physics in Loops ($\Delta F=1$)

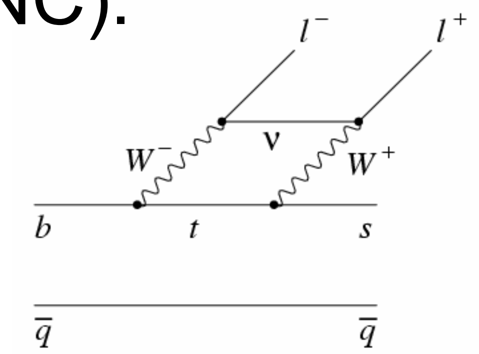
- β_{eff} measured in $b \to s$ penguin decays can differ from β in $b \to c\bar{c}s$.
- Small uncertainties come from SM corrections to the decays.
  - O(0.01) on $\sin(2\beta_{eff})$ in $\eta' K^0$ and $3K^0_s$.
- Large deviations from SM expectation would indicate NP.
  - Discrepancy decreases year by year!
  - Need to perform precision measurements on a mode-by-mode basis!
- SuperB will be able to probe these asymmetries on a mode-by-mode basis to the level of current SM uncertainties (>50ab^{-1}).



New Physics in ΔF=2 Transitions

- ΔF=2 transitions in $B^0_{d,s}\overline{B}^0_{d,s}$ systems are box diagrams (mixing or FCNC).





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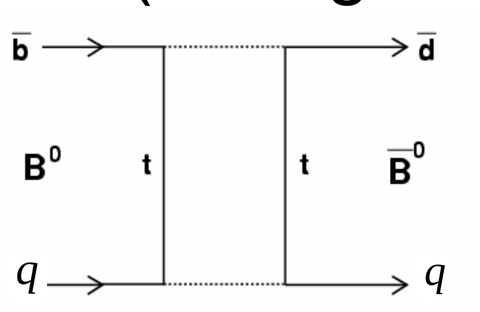
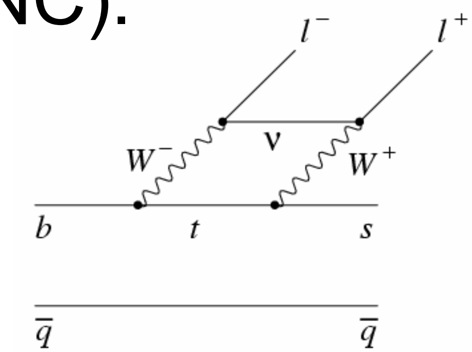




$$q = d, s$$

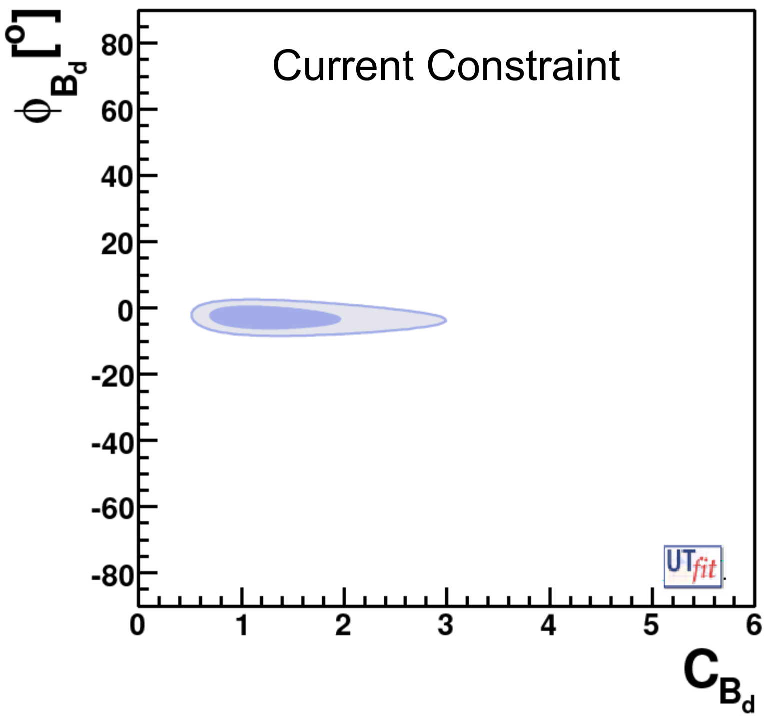
- NP can contribute to these processes.
  – Parameterise with an amplitude ratio C_q and phase ϕ_q.

$$C_q e^{i\phi_q} = \frac{\langle B^0_q \,|\, H_{SM+NP} \,|\, \overline{B}^0_q \rangle}{\langle B^0_q \,|\, H_{SM} \,|\, \overline{B}^0_q \rangle}$$

- C_q=1, and ϕ_q=0 for the SM.

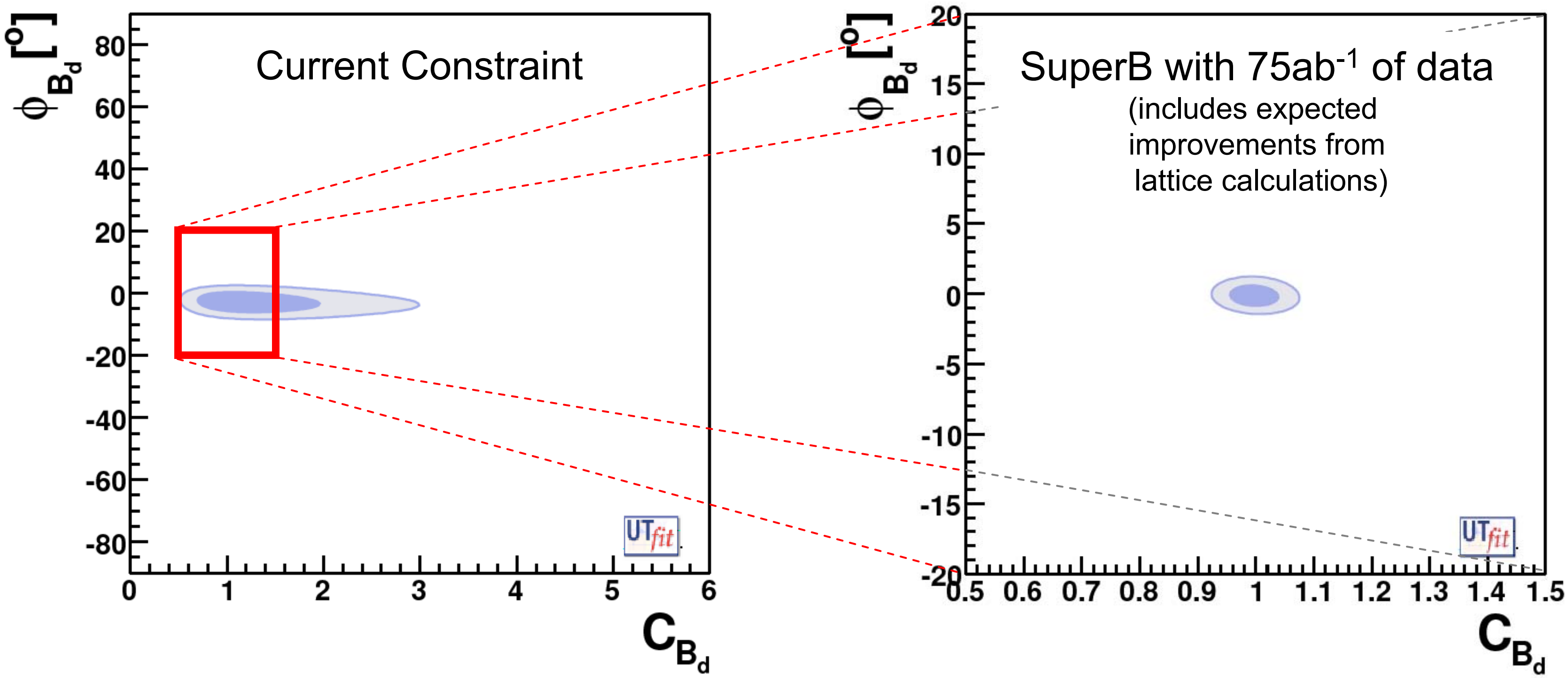
New Physics in ΔF=2 Transitions

- Existing measurements already constrain NP in B_d mixing.



New Physics in ΔF=2 Transitions

- Existing measurements already constrain NP in B_d mixing.
- SuperB will significantly improve this constraint.



Note that the two plots have very different scales!

Minimal Flavour Violation

- Suppose that there are no new physics flavour couplings (MFV).
  - CP violation comes from the known SM Yukawa couplings.
  - The top quark contribution dominates the SM.
  - NP contribution in ΔB=2 transitions is:

SM Scale ~2.4 TeV

$$\Lambda_0 = Y_t \sin^2\theta_W M_W / \alpha$$

$$\delta S_0 = 4a\left(\frac{\Lambda_0}{\Lambda}\right)^2$$

Real Wilson coefficient $O(1)$

New Physics Scale

  - MFV Includes many NP scenarios i.e. 1HDM/2HDM, MSSM, ADD, RS.
- What is the energy scale that we are sensitive to?

e.g. see hep-ph/0509116 (NMFV), hep-ph/0509219(MFV) and references therein.

Minimal Flavour Violation

- Sensitive to new physics contributions with Λ up to 14 TeV (= $6\Lambda_0$).

- For loop mediated NP contributions the constraint can be weakened so that $\Lambda \sim$ 700GeV.

Worst Case!

- Don't require that the EWSB scale match Λ.

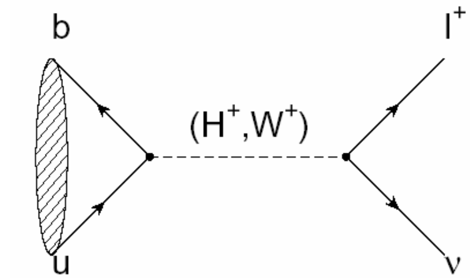
e.g. see hep-ph/0509116 (NMFV), hep-ph/0509219(MFV) and references therein.

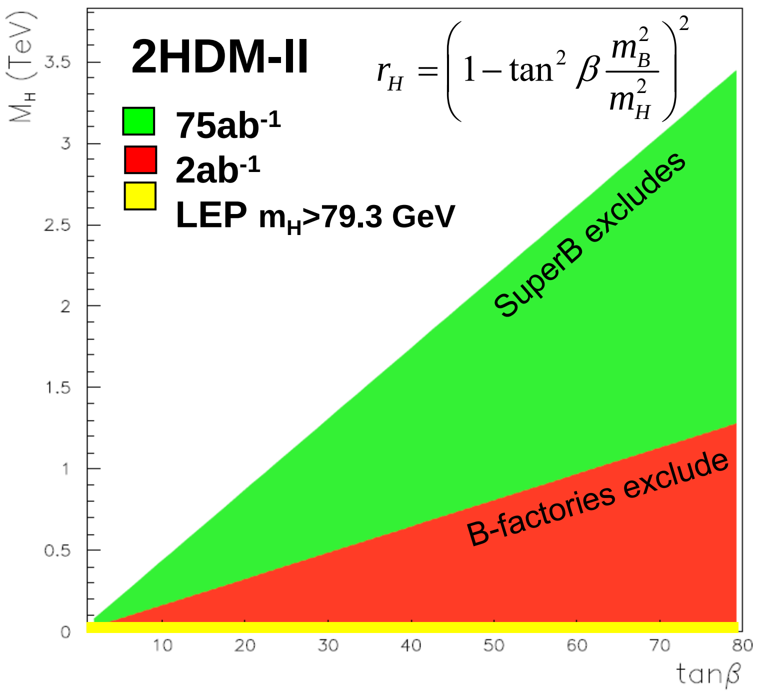
Charm equivalent: $D_s^+ \to \mu^+\nu,\ \tau^+\nu$

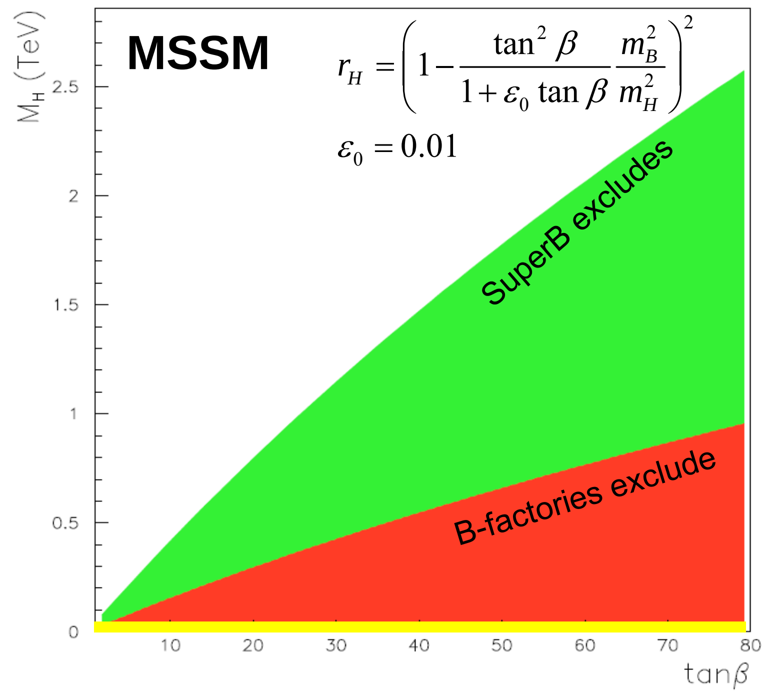
$B \to \tau\nu$

- Higgs mediated MFV:

$$r_H = \frac{\mathcal{B}_{SM+NP}}{\mathcal{B}_{SM}}$$





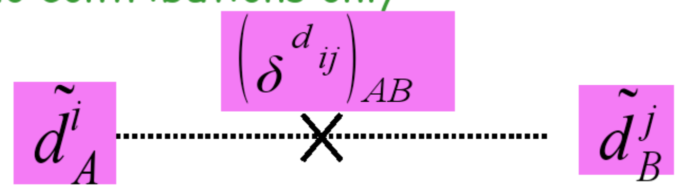


- Multi TeV search capability for large $\tan\beta$.

SUSY CKM

- The SM encodes quark mixing in the CKM matrix, ν mixing with the MSW matrix …. so

Let us now consider a MSSM with generic soft SUSY-breaking terms, but dominant gluino contributions only



- SUSY encodes squark mixing in a Super CKM equivalent of the CKM matrix: V_{SCKM}.
  - Have couplings for LL, LR, RL, RR interactions.

- LHC probes the High Energy Frontier.
  - Measures the diagonal elements of V_{SCKM}.

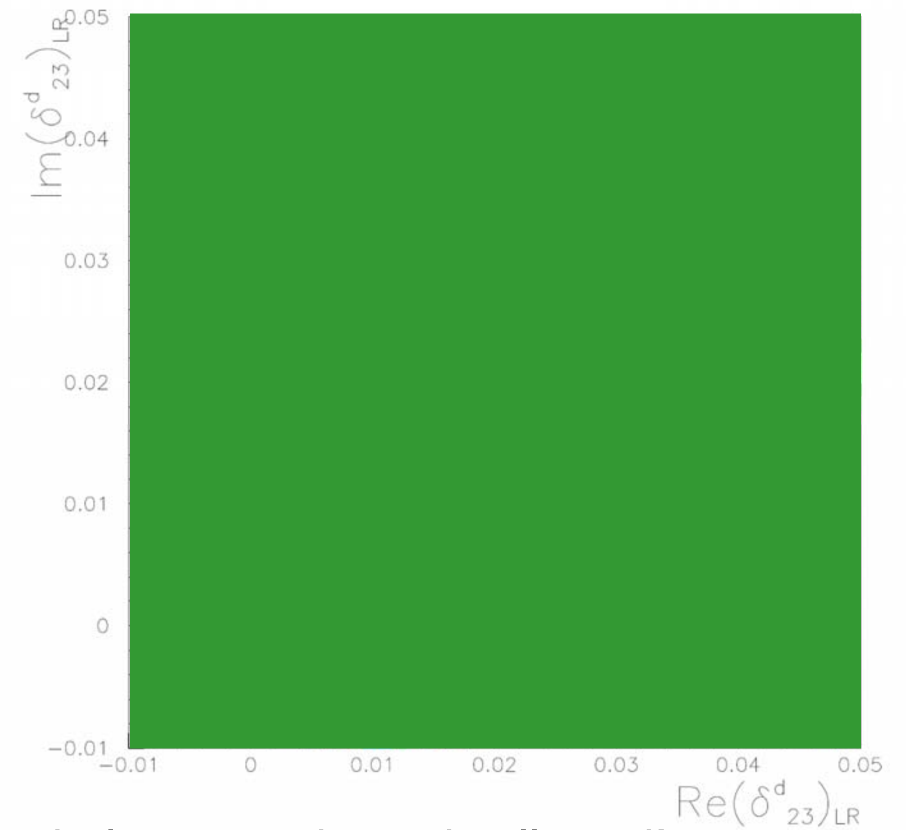
- SuperB probes the Luminosity Frontier.
  - Measures the off-diagonal elements V_{SCKM}.

SUSY CKM

L. Silvestrini (SuperB IV)

- Couplings are $\left(\delta_{ij}^{q}\right)_{AB}$
  where *A*,*B*=*L*,*R*, and *i*,*j* are squark generations.
- e.g. Constrain parameters in V_{SCKM} using:
  - $\mathcal{B}(B \to X_s \gamma)$ [green]
  - $\mathcal{B}(B \to X_s l^+l^-)$ [cyan]
  - $A_{CP}(B \to X_s \gamma)$ [magenta]
  - Combined [blue]

SuperB probes new physics in SUSY larger than 20TeV (and up to 300TeV in some scenarios)



With current data, the whole range shown is allowed!

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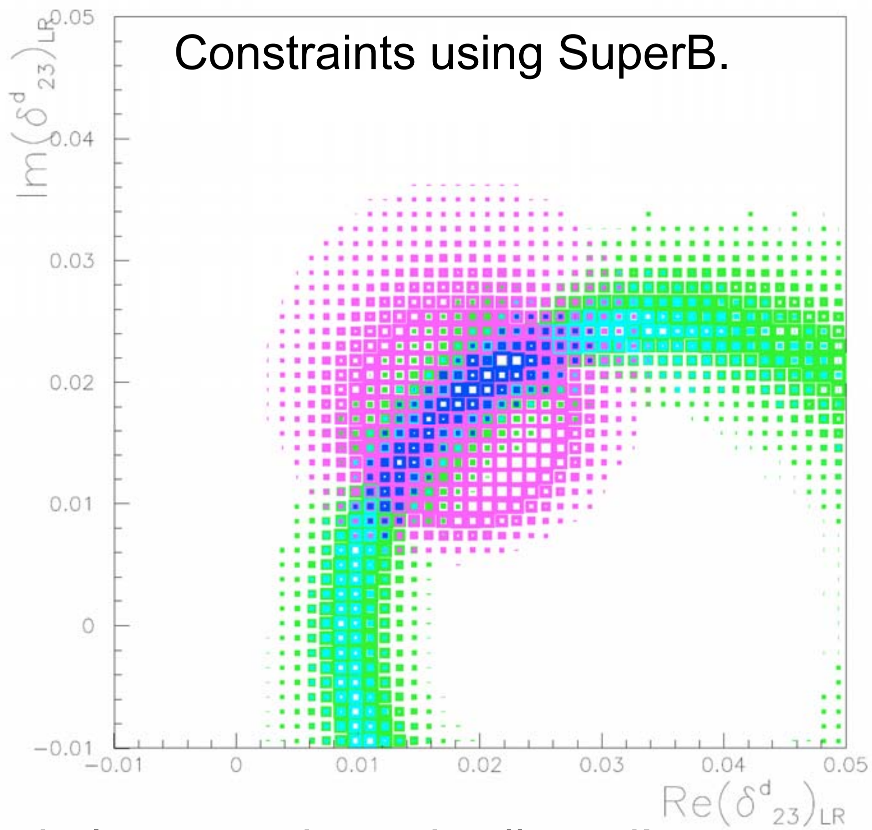

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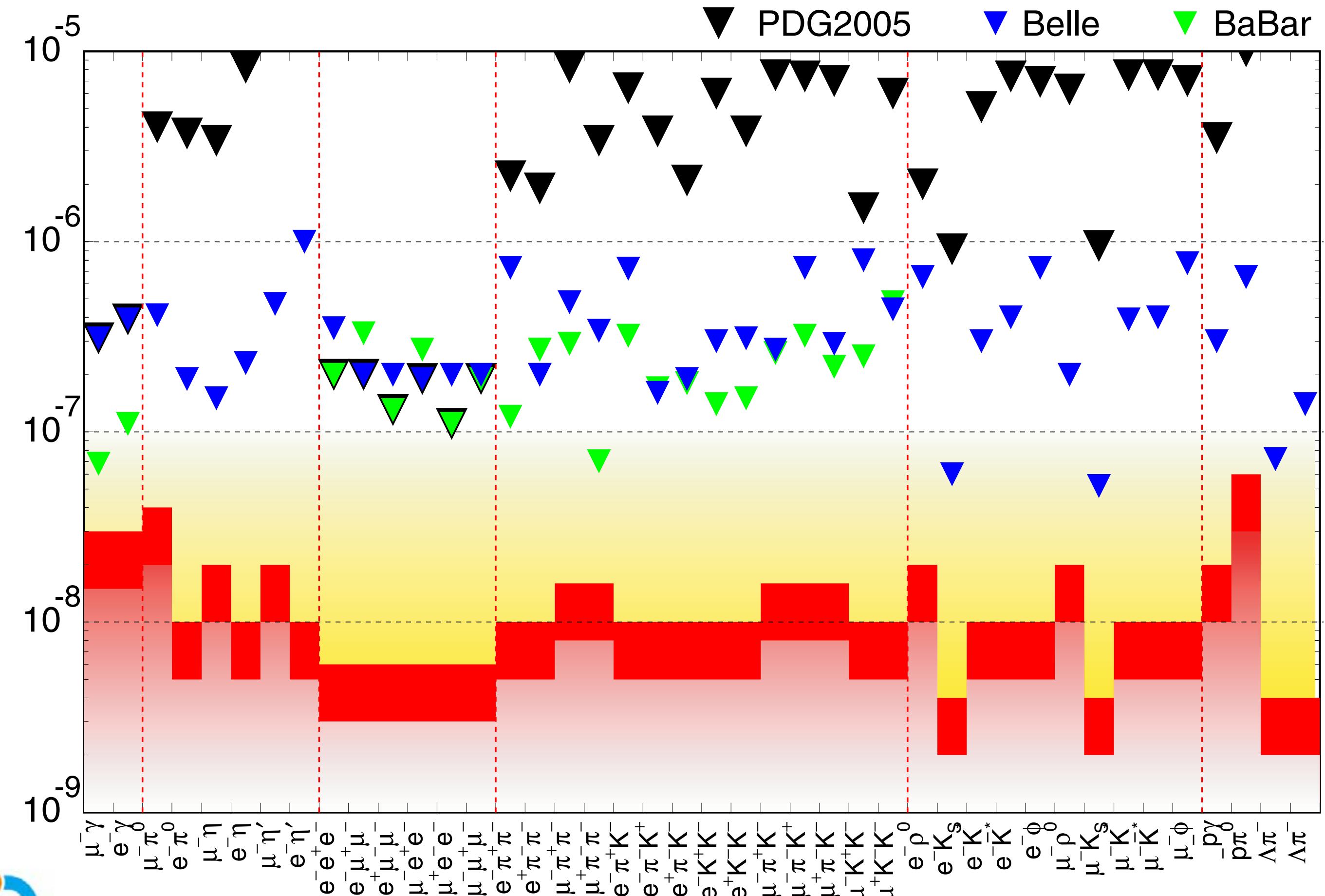
τ Decays

Lepton Flavour Violation

- SUSY breaking at low energies should result in FCNC [e.g. $\tau \to \mu\gamma$, $\mu \to e\gamma$].



$\tau \to \mu\gamma$ is the golden channel for LFV searches at SuperB.

Current Best Limit

New Physics ?
(equivalent sensitivity as for the PSI/KEK $\mu \to e\gamma$ search)

SuperB sensitivity @ $10ab^{-1}$

CP and CPT Violation

- CP Violation.
  - SM decays of the τ have only a single amplitude – so any CP violation signal is an unambiguous sign of NP.
  - e.g. Can have NP contributions from a $H^{\pm}$ in $\tau \to N\pi\nu$, N=3,4.

e.g. see Datta et al., hep-ph/0610162

- CPT Violation.
  - Expect to be able to measure $\dfrac{\tau_{\tau-} - \tau_{\tau+}}{\tau_{\tau-} + \tau_{\tau+}}$ at the level of 10^{-4} (statistical).
  - Current bound is $(0.12 \pm 0.32)\%$.

Nucl. Phys. Proc. Suppl. **144** 105 (2005)

- Polarisation of e^+e^- beams benefits the search for CP and CPT violation in τ decay and the τ anomalous magnetic moment.

e.g. PRD **51** 3172 (1995); arXive:0707.2496 [hep-ph]

Super B factory and Super LHCb:

Sensitivity Comparison ~2020

LHCb 100 fb^{-1} vs Super-B factory 50 ab^{-1}

SuperB numbers from M Hazumi - Flavour in LHC era workshop;
LHCb numbers from Muheim
CDF numbers from Ristori

•LHCb
•Super B

Preliminary

B_s time dependent analysis only accessible to LHCB

Common

No IP, Neutrals, ν, only accessible to SuperB

CDF an important player

- $B_s \to \mu\, \mu$
  - ~ 1-2 10^{-8} con 6 fb-1
- $\Delta\Gamma_s$ e ϕ_s da $B_s \to J/\psi\, \phi$
  - $\sigma(\Delta\Gamma_s)$ 0.04 con 6 fb^{-1} (2σ)
- CP Asymmetry in $B_s \to K\, \pi$
  - 6% con 6 fb-1 (6σ)
- CP Asymmetry in $B_d \to K\, \pi$
  - 1% con 6 fb-1
- World best lifetimes
  - B_s, Λ_b, B_c, Σ_b, new states... ???
- D^0 mixing
  - migliore misura di frequenza?
  - sensibile ad ACP

Decoding the pattern of NP

Table 5-23. *Pattern of deviations from the Standard Model predictions in various models of supersymmetry and extra dimensions. Processes with possible large deviations are indicated. "-" means that the deviation is not expected to be large enough for observation, or not yet studied completely.*

Model	B_d Unitarity	Time-dep. CPV	Rare B decay	Other signals
mSUGRA(moderate $\tan\beta$)	-	-	-	-
mSUGRA(large $\tan\beta$)	B_d mixing	-	$B \to (D)\tau\nu$ $b \to s\ell^+\ell^-$	$B_s \to \mu\mu$ B_s mixing
SUSY GUT with ν_R	-	$B \to \phi K_S$ $B \to K^*\gamma$	-	B_s mixing τ LFV, n EDM
Effective SUSY	B_d mixing	$B \to \phi K_S$	$A_{CP}^{b\to s\gamma}$, $b \to s\ell^+\ell^-$	B_s mixing
KK graviton exchange	-	-	$b \to s\ell^+\ell^-$	-
Split fermions in large extra dimensions	B_d mixing	-	$b \to s\ell^+\ell^-$	$K^0\overline{K}^0$ mixing $D^0\overline{D}^0$ mixing
Bulk fermions in warped extra dimensions	B_d mixing	$B \to \phi K_S$	$b \to s\ell^+\ell^-$	B_s mixing $D^0\overline{D}^0$ mixing
Universal extra dimensioins	-	-	$b \to s\ell^+\ell^-$ $b \to s\gamma$	$K \to \pi\nu\overline{\nu}$

Need to augment matrix with golden D and τ decay studies!

From SLAC-R-709

Decoding the pattern of NP

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SUSY GUT with ν_R	[illegible]	[illegible]	[illegible]	[illegible] mixing τ LFV, n EDM
Effective SU[illegible]	[illegible]	[illegible]	$\rightarrow s\ell^+\ell^-$	B_s mixing
[illegible]	[illegible]	[illegible]	$b \rightarrow s\ell^+\ell^-$	-
[illegible]	[illegible]	-	$b \rightarrow s\ell^+\ell^-$	$K^0\overline{K}^0$ mixing $D^0\overline{D}^0$ mixing
[illegible]ensions	B_d mixing	$B \rightarrow \phi K_S$	$b \rightarrow s\ell^+\ell^-$	B_s mixing $D^0\overline{D}^0$ mixing
[illegible] extra dimensioins	-	-	$b \rightarrow s\ell^+\ell^-$ $b \rightarrow s\gamma$	$K \rightarrow \pi\nu\overline{\nu}$

Need SuperB and LHCb!

Need to augment matrix with golden D and τ decay studies!

Accelerator Aspects

Target Integrated Luminosity

- Why 50-100ab^{-1} of data?
  - Many of these new physics searches become systematically or theoretically limited.
    - e.g. time dependent asymmetry measurements with $b \to s$ penguin decays).
  - This data sample represents two order of magnitude improvement in sensitivity over current experiments.
    - The current B-factories have 1ab^{-1} (combined) on disk/tape.
  - Ensures that if new physics is found (e.g. in LFV) that one can start to perform rudimentary measurements of such phenomena.
    - 10ab^{-1} of data is sufficient to start to constrain models of LFV in τ decays, but need a lot more to ensure competitive results.
  - Will be able to start measuring parameters in V_{SCKM} (if SUSY exists), or constrain Multi TeV energy level NP in your favourite scenario.
    - Strong constraints on NP that complement the LHC direct searches!

How to get increased $\mathcal{L}$

$$\mathcal{L} = \underbrace{\frac{\gamma_{\pm}}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)}_{\text{Lorentz factor, classical } e^{\pm} \text{ radius and ratio of beam sizes}} \underbrace{\left(\frac{I_{\pm}\xi_{\pm y}}{\beta_y^*}\right)}_{\text{Beam current: } I\text{, beam-beam parameter: } \xi\text{, vertical } \beta \text{ function at IP}} \underbrace{\left(\frac{R_L}{R_y}\right)}_{\text{Reduction factor from crossing angle and the hourglass effect}}$$

- Option 1: Brute Force.
  - Increase beam current.
  - Decrease β^*_y.
  - Increase beam-beam effect ξ (reduce bunch length).

(Hard – but possible – to do all of this efficiently)

How to get increased $\mathcal{L}$

$$L = \underbrace{\frac{\gamma_{\pm}}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)}\underbrace{\left(\frac{I_{\pm}\xi_{\pm y}}{\beta_y^*}\right)}\underbrace{\left(\frac{R_L}{R_y}\right)}$$

Lorentz factor,
classical $e^{\pm}$ radius and
ratio of beam sizes

Beam current: I
beam-beam parameter: ξ
vertical β function at IP

Reduction factor from
crossing angle and the
hourglass effect

P. Raimondi's Crab Waist concept.

Test at DAΦNE next Fall !!!

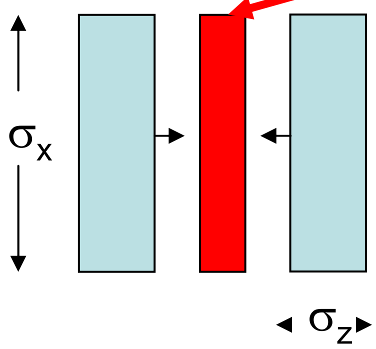
- Option 2: Large Crossing Angle.
  - Have a 15mrad crossing angle of beams.
  - Focus beams at IP (small β^*).
  - Retain longer bunch lengths.
  - Rotate colliding bunches so no geometric loss at IP.
    - Align the focussed parts of bunches that cross each other at the IP. Call this "Crab Crossing/Waist".

Large crossing angle, small x-size

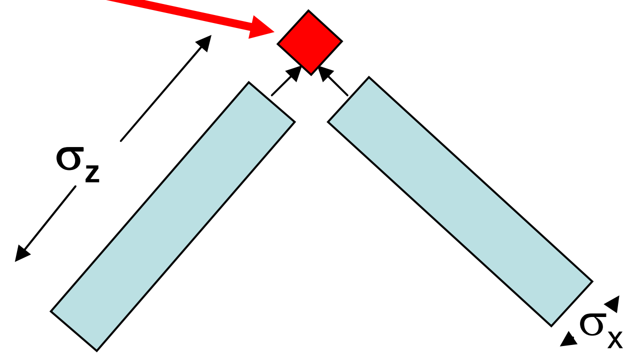
1) Head-on, Short bunches

Overlap region

2) Large crossing angle, long bunches



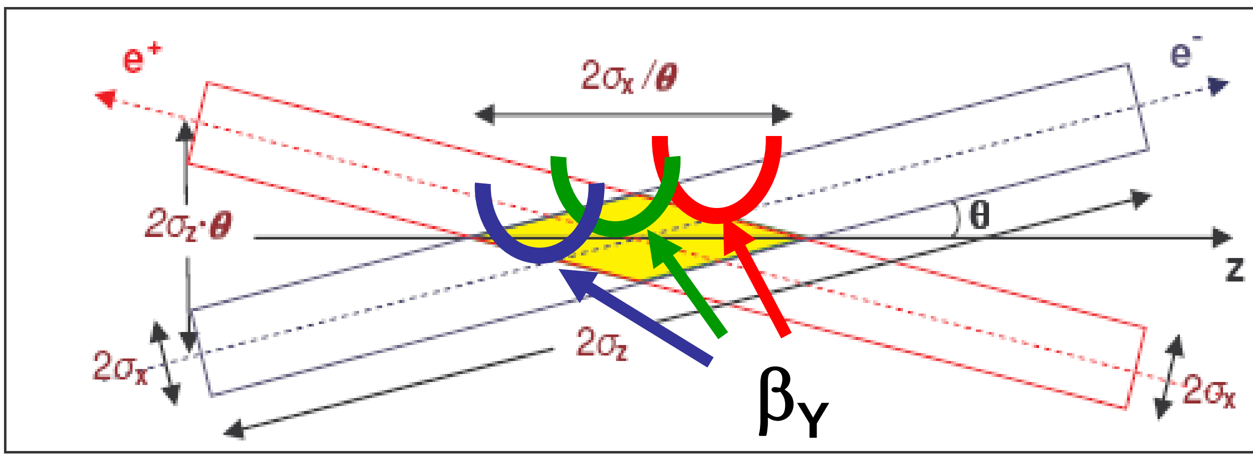
(1) and (2) have same Luminosity, but (2) has longer bunches and smaller σ_x



With large crossing angle the x and z planes are swapped

Large Piwinski angle:

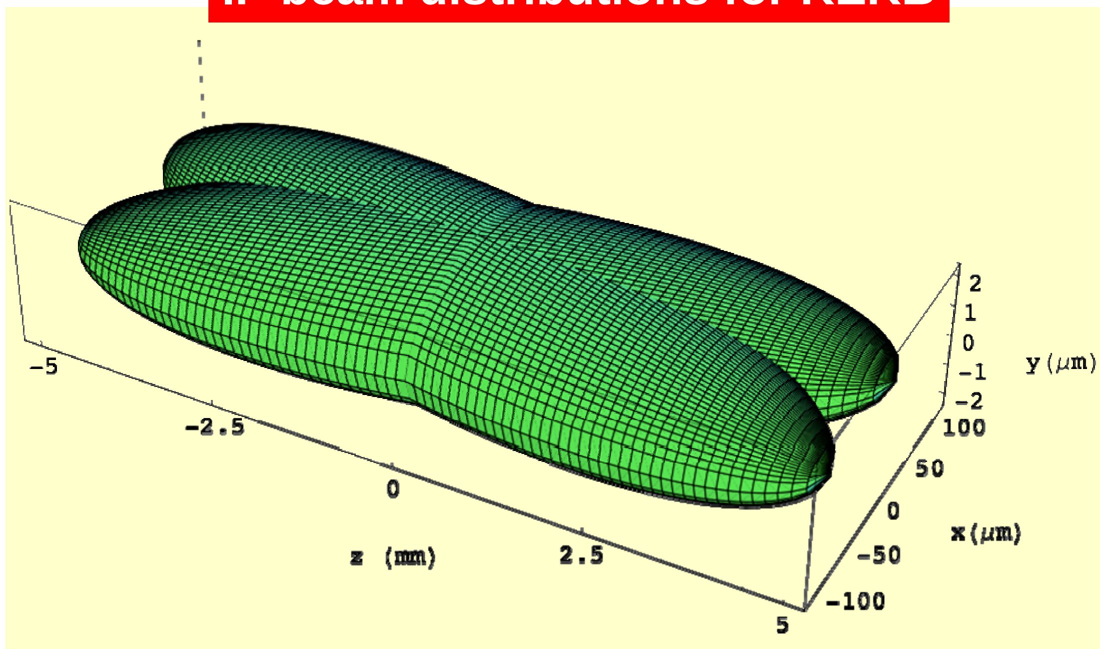
$$\Phi = tg(\theta)\sigma_z/\sigma_x$$

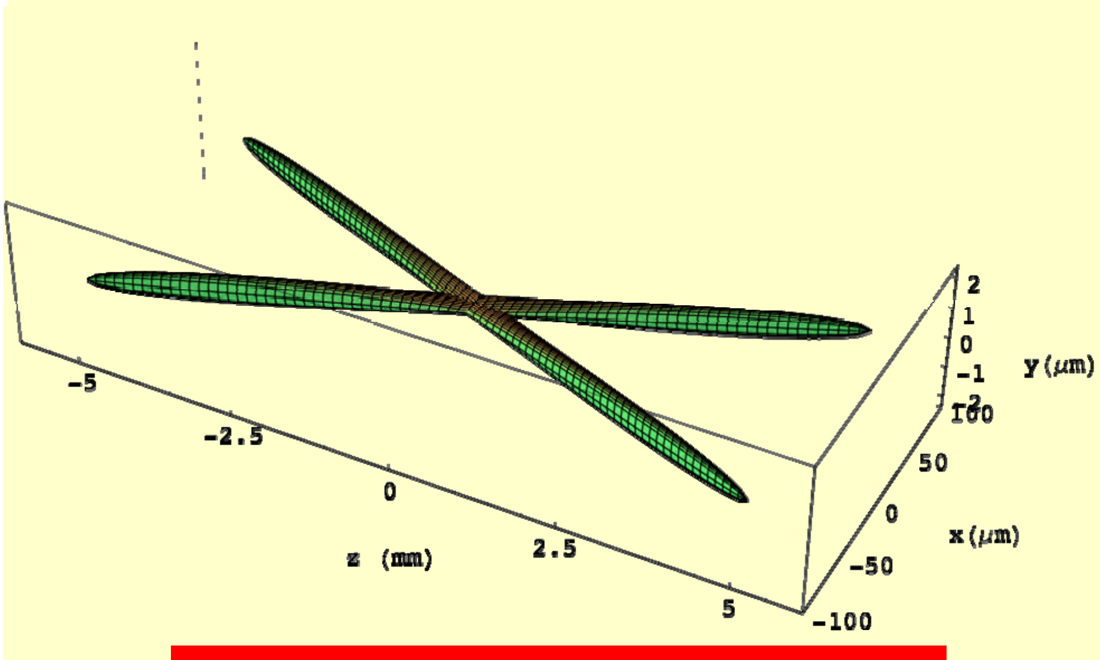


y waist can be moved along z with a sextupole on both sides of IP at proper phase

"Crab Waist"

IP beam distributions for KEKB





IP beam distributions for SuperB

An example...

	KEKB	SuperB
I (A)	1.7	2.
β_y^* (mm)	6	0.3
β_x^* (mm)	300	20
σ_y^* (μm)	3	0.035
σ_x^* (μm)	80	6
σ_z (mm)	6	5
L ($cm^{-2}s^{-1}$)	1.7×10^{34}	$1. \times 10^{36}$

Here is Luminosity gain

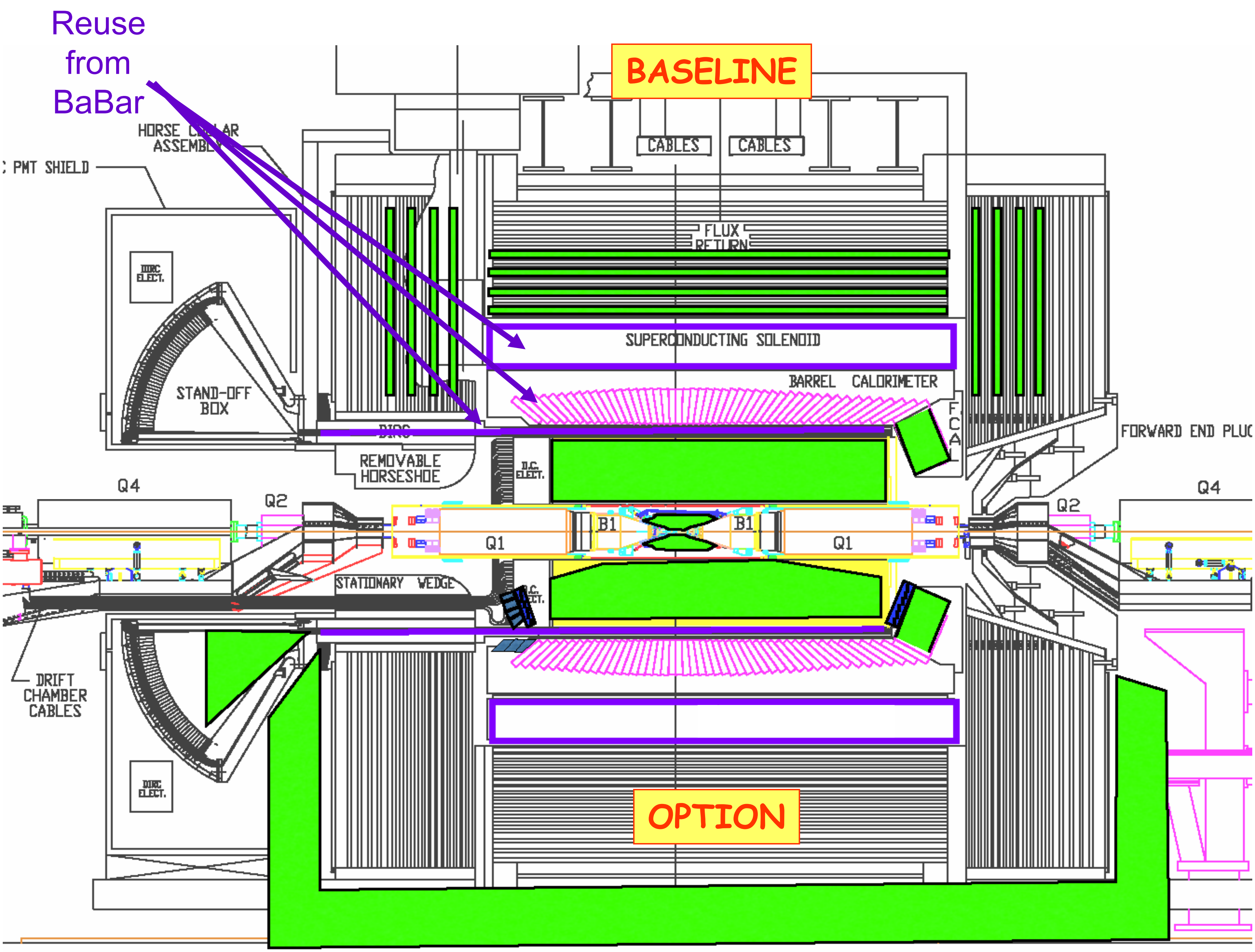
Comparison between machines

	PEPII	KEKB	SuperB
current	2.5 A	1.7 A	2.3 A
β_y	10 mm	6 mm	0.3 mm
β_x	400 mm	300 mm	20 mm
ε_y (σ_y)	23 nm (~100μm)	~ the same (~80μm)	1,6 nm (~6μm)
y/x coupling (σ_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
ζ_y	0.07	0.1	0.16
$\mathcal{L}$	1.2×10^{34}	1.7×10^{34}	1×10^{36}

Detector Design

Requirements

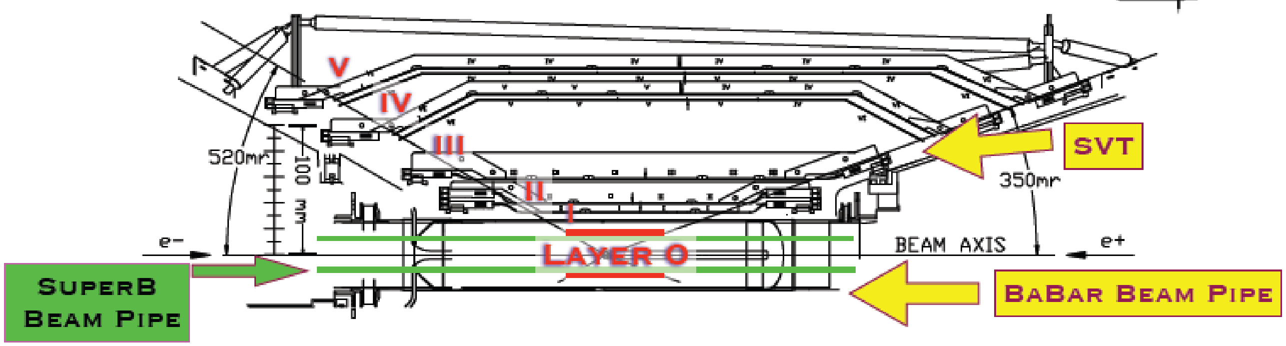
- The B-factory detectors work extremely well.
  - Design of a SuperB detector, essentially means a refinement of the existing detectors.
- SuperB environment will have a higher rate.
  - Some existing detector parts are reusable.
    - CsI Calorimeter barrel.
    - DIRC quartz bars from BaBar. These 3m long bars are required for the particle identification system.
    - Superconducting Solenoid Magnet: creates a 2T magnetic field.
  - Some existing detector parts need to be replaced to cope with the expected rates.
    - Central tracking inside the particle ID system.
    - End Cap of the calorimeter.
    - Instrumented Flux Return (μ, K^0_L detector).
    - Readout electronics.
  - Makes sense to optimise reuse in order to limit the cost of the project.



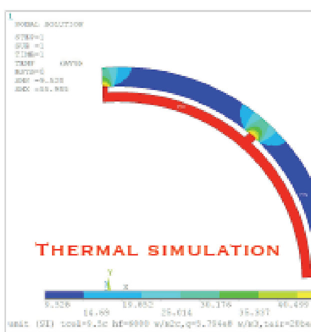
Reuse from BaBar
BASELINE
CABLES
CABLES
FLUX RETURN
HORSE COLLAR ASSEMBLY
PMT SHIELD
DIRC ELECT.
STAND-OFF BOX
SUPERCONDUCTING SOLENOID
BARREL CALORIMETER
FCA
DIRC
REMOVABLE HORSESHOE
D.C. ELECT.
FORWARD END PLUG
Q4
Q2
Q1
B1
B1
Q1
Q2
Q4
STATIONARY WEDGE
DRIFT CHAMBER CABLES
DIRC ELECT.
OPTION

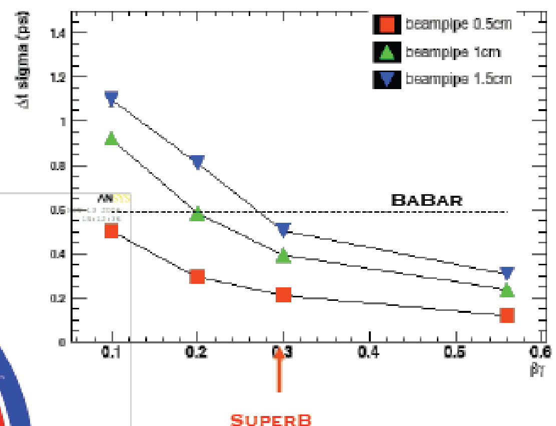
Tracking

Silicon Vertex Tracker



- Baseline: use an SVT similar to the Babar one, complemented by one or two inner layers.
  - Cannot reuse because of radiation damage
- Beam pipe radius is of paramount importance
  - inner radius: 1.0cm,
  - layer0 radius: 1.2cm,
  - thickness: 0.5% X_0





Hadron 07: Frascati, 12 Oct

Eugenio Paoloni

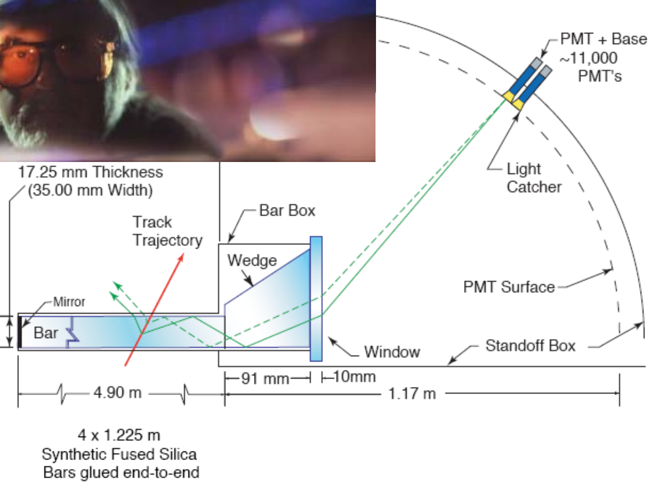
Slide taken from a talk by E. Paoloni @ Hadron 07

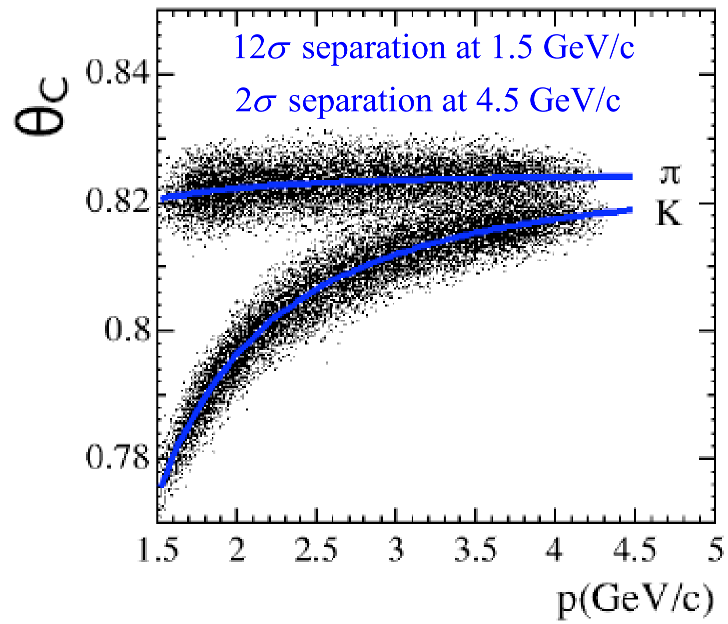
BaBar DCH Design

- Adequate performance.
- Needs to be replaced as the existing detector is aging.

Particle ID

- Detector of Internally Reflected Cherenkov light (DIRC) works extremely well.
- Aim to reuse this principle with state of the art readout.



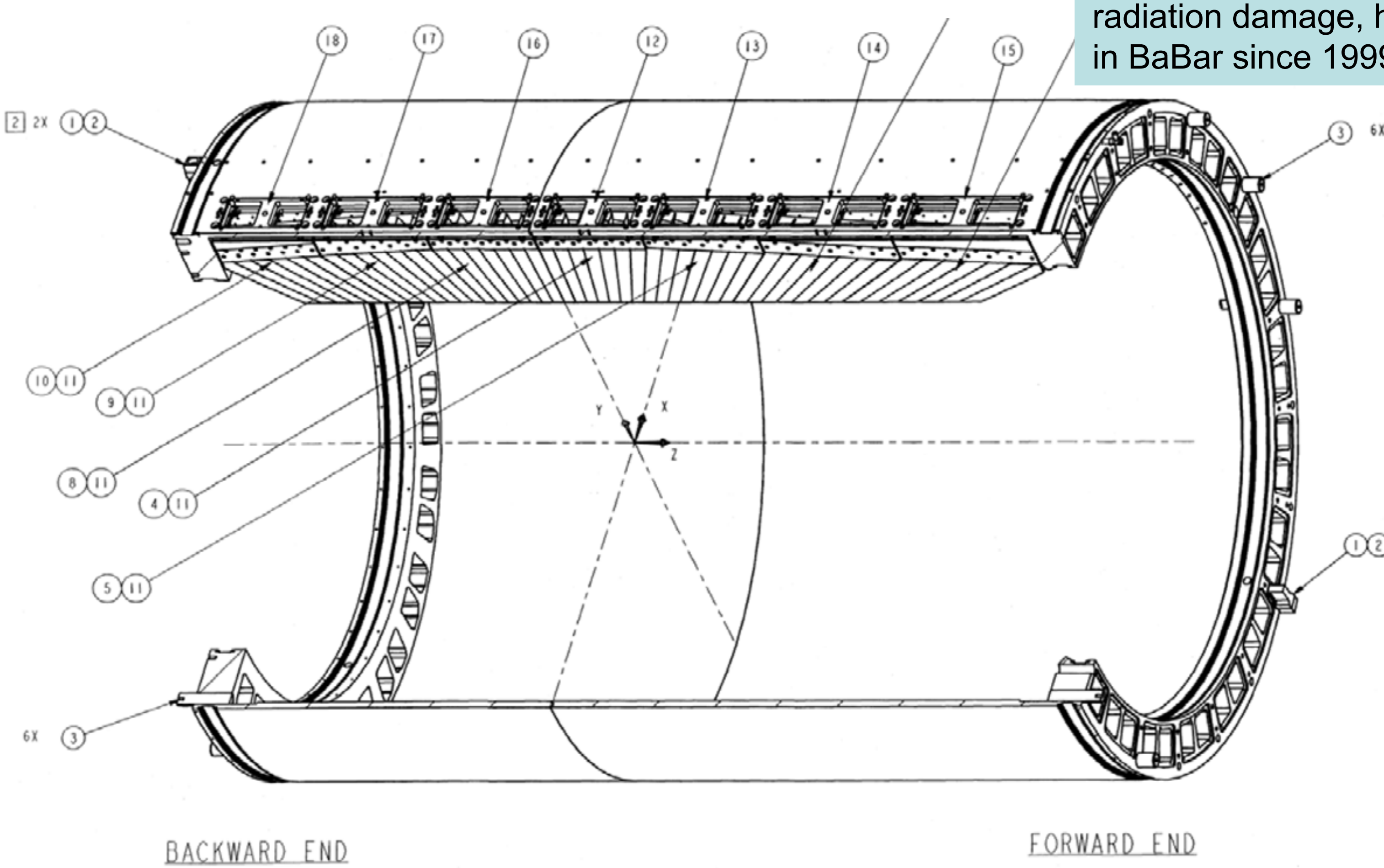


Can benefit from reducing the volume of water between the end of the quartz bars and the photodetectors (PMTs) at SuperB.

Calorimeter Barrel

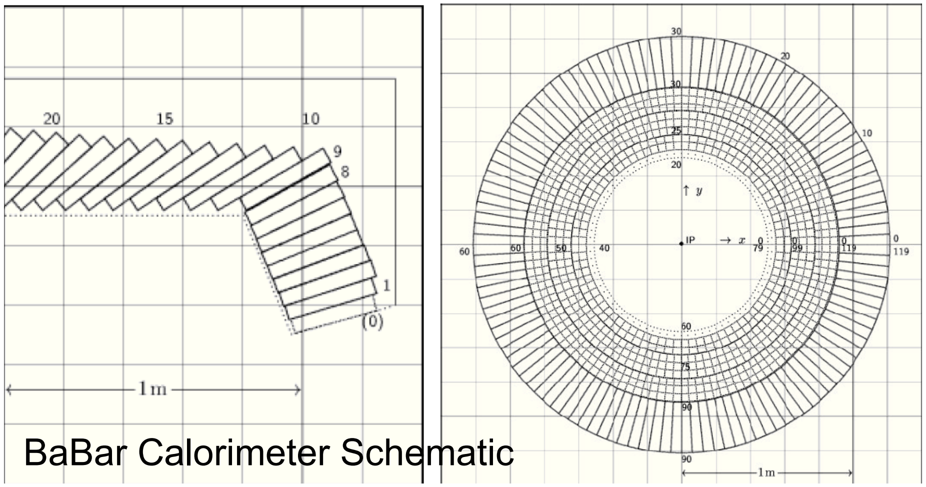
- Calorimeter Barrel is more than sufficient for our needs.

•Fast enough signal output for the expected rates at SuperB
•Not suffering from any signs of radiation damage, having been used in BaBar since 1999.



Calorimeter End-Cap

- BaBar End-Cap doesn't have a fine enough granularity for rates at SuperB.
  - Need a finer segmentation.
  - Similar total X_0.
  - Faster readout electronics.
  - Several candidate materials for End-Cap replacement.
    - LYSO is baseline
      - expensive at the moment (~$40/cc).
      - Aim for $15/cc.
  - Need to integrate into the existing Barrel, and optimise segmentation.
  - R&D underway toward a LYSO Calorimeter test-beam in ~2009.

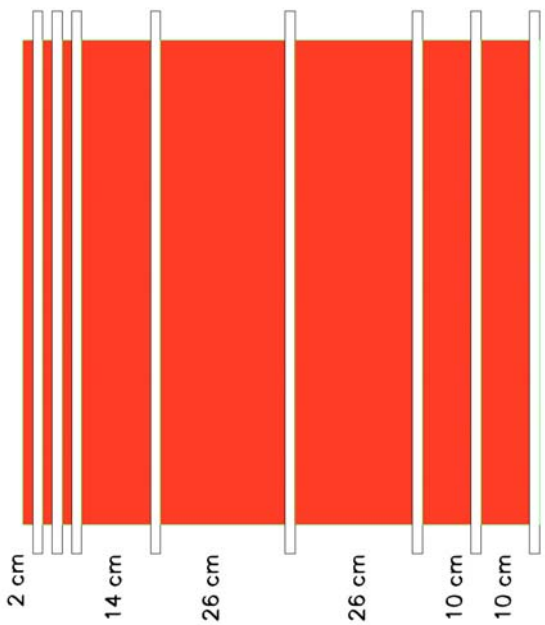


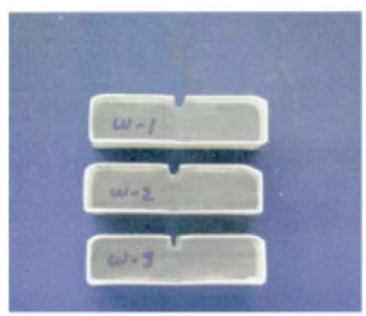
BaBar Calorimeter Schematic

2.5 x 2.5 x 20 cm (18 X_0) Bar

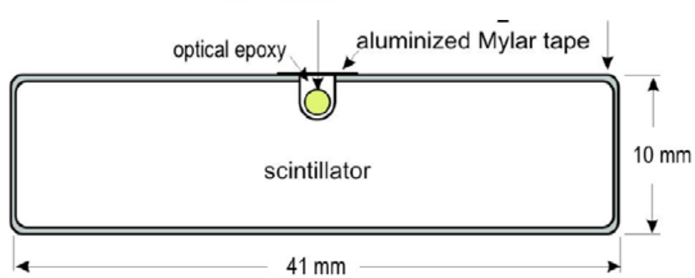
Instrumented Flux Return

- BaBar has 5 radiation lengths of material for μ identification in the flux return.
  - This is not optimal.
  - SuperB will have more iron.
- The segmentation of active regions of the flux return will remain the same as BaBar (3.7cm pitch).
- 7-8 layers of MINOS style scintillator bars.

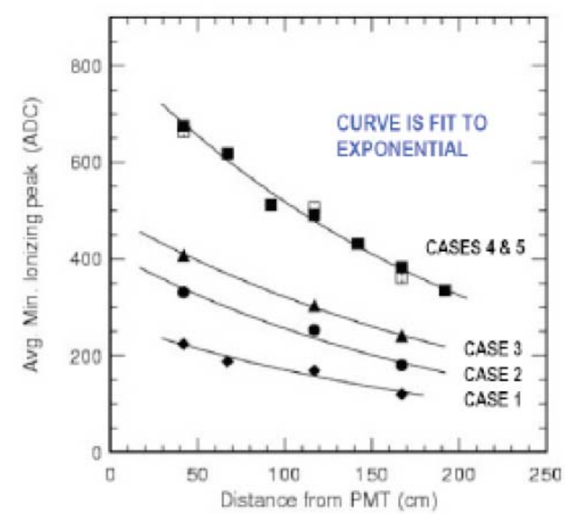




MINOS PRODUCTION BARS SHOWING 4 x 1 cm² CROSS SECTION WITH CO-EXTRUDED TiO_2 AND GROOVE FOR WLS FIBER



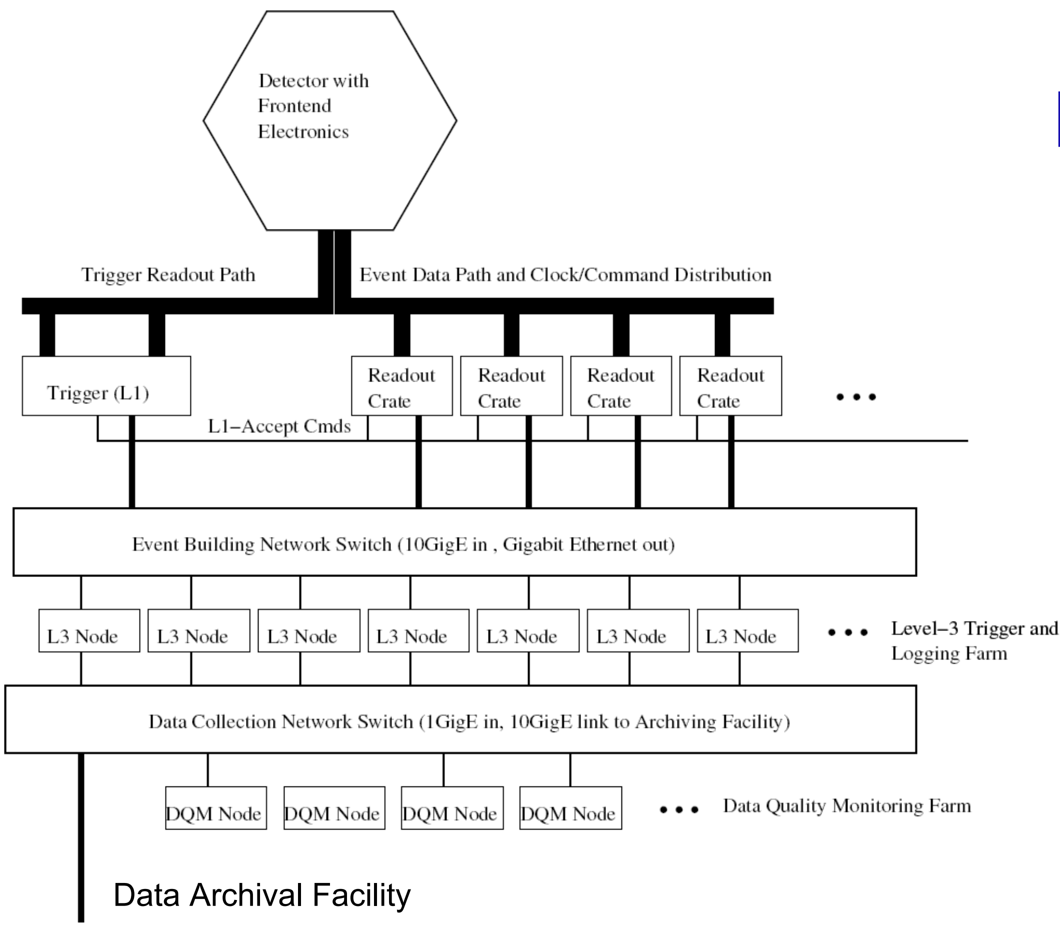
ATTENUATION LENGTH MEASUREMENTS FOR 5 CASES



DAQ

- Modelled on the BaBar Data Acquisition system.

As is the norm with modern experiments, will need tens-hundreds of Pb storage for SuperB.



Cumulative Storage (Pb)	3.9	17.5	47.0	83.4	121.4

Parameter	Year 1	Year 2	Year 3	Year 4	Year 5
Luminosity (ab^{-1})	2	6	12	12	12
Storage (PB)					
Tape	3.1	10.2	22.0	26.2	27.8
Disk	0.83	3.35	7.55	10.2	10.2
CPU (MSpecInt2000)					
Data reconstruction	3.0	8.8	14.7	8.8	0.0
Skimming	2.7	9.4	16.1	12.1	0.0
Monte Carlo	9.5	28.0	46.6	28.0	0.0
Physics analysis	5.1	15.0	30.0	30.0	30.0
Total	20	61	107	79	30

First Year Requirements

Subsequent year increments

Timescale

- Overall schedule dominated by:
  - Site construction.
  - PEP-II/Babar disassembly, transport, and reassembly.
- Possible to reach the commissioning phase after 5 years from T0.
- Physics from circa 2015?

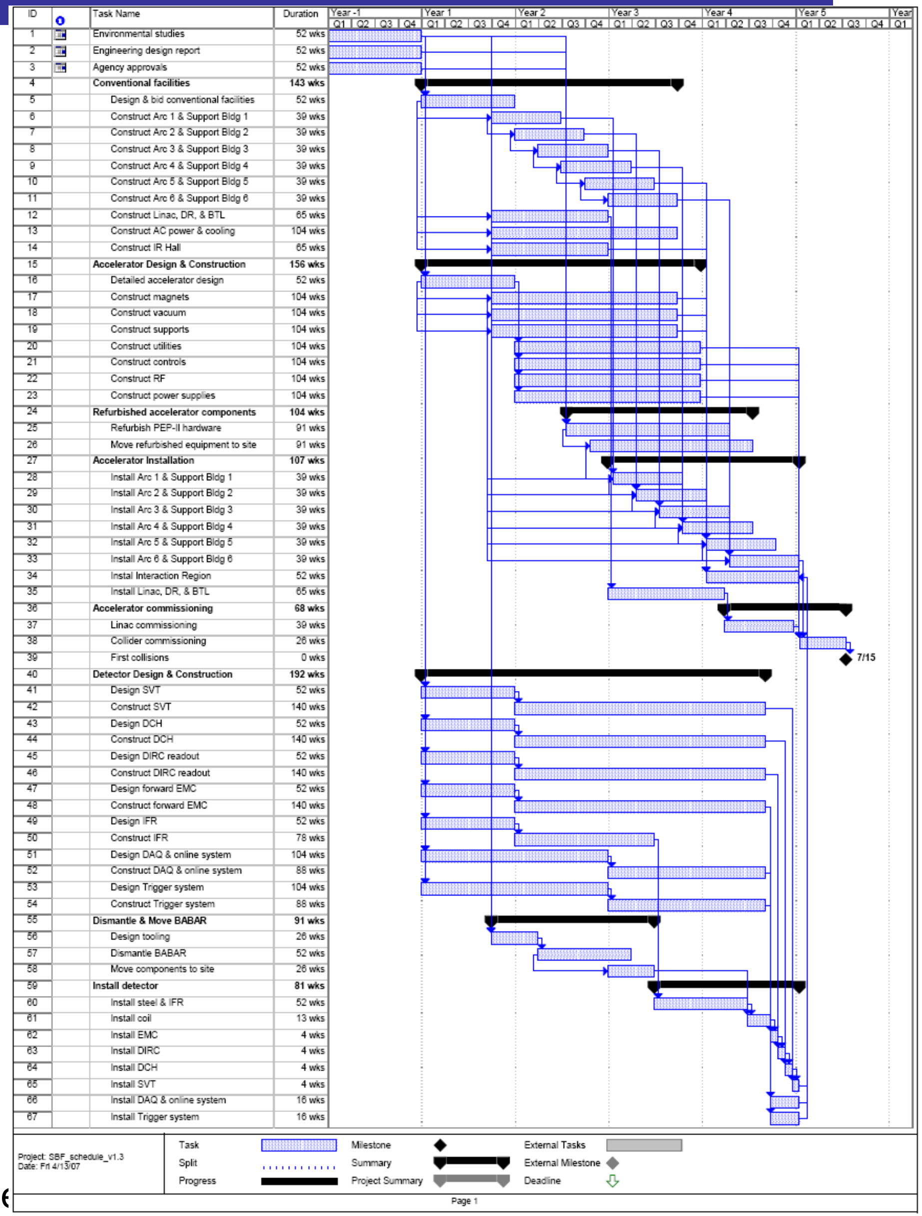


Figure 5-1. *Overall schedule for the construction of the SuperB project.*

Accelerator and site costs

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

Note: site cost estimate not as detailed as other estimates.

Funds needed to build experiment

Replacement value of parts that we can re-use.

Detector cost

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

Note: options in italics are not summed. We chose to sum the options we considered most likely/necessary.

Total = 338M Euro.
= 510M Euro (counting the cost of re-used parts).
⇒ 1/3 of the cost of the project can be saved by re-using parts of BaBar and PEP-II.

Next Steps…

- SuperB Conceptual Design Report compiled (Winter 06/07).
  - Proposed site is the Tor Vergata Campus, Frascati, Italy.
- CDR under INFN funding review by an international committee chaired by John Dainton.
  - Met with committee on 12/13th November at Frascati.
  - Committee will report back to INFN in the 1st quarter of 2008.
  - Physics retreat in Valencia (Jan 08).
- If positive, will discuss the project with ECFA and CERN strategy group.
  - Collaboration will form O(≤1 year).
  - R&D will continue for O(2 years).
  - Technical Design Reports finalised O(2 years).
  - Construction T0 = O(2 years).

Summary

Particle Physics Landscape circa 2015

NP at the LHC?

NO

Continue to indirectly probe for virtual particle effects at high energies.

Same situation as the ILC, but a *significantly* cheaper (and faster) project that might start to shed light on flavour physics at Λ_{NP} > TeV, with Λ_{NP} up to 300 TeV.

YES

Start to probe the flavour structure

Trivial?

YES

NP is flavour blind (not natural)! **Theory is still incomplete** as we have not solved matter-antimatter asymmetry Problem!

NO

Need to test all possible scenarios
- NP flavour structure?
- Observables?
-Need LHCb and SuperB to solve this riddle fully.

Conclusion

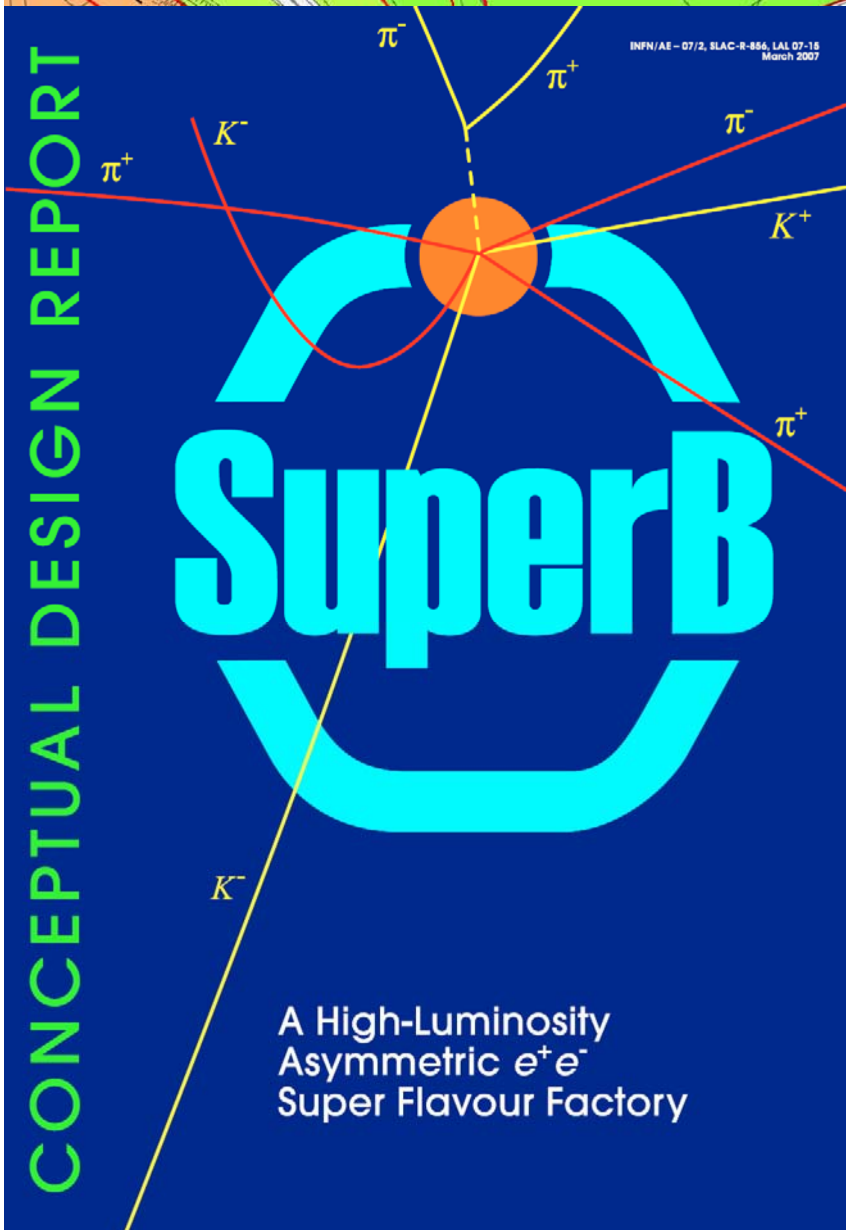
- The SuperB programme has a rich physics case.
  - Much more than I've had time to cover in this seminar!
  - See the 'Physics' section of the SuperB CDR for details.

- Rare decay searches in the worlds largest samples of B, D, τ particles.
  - N.B. the chapter on charm was written before D^0-$\overline{D}^0$ oscillations were discovered. The reach for CPV searches in charm needs to be studied!

- Probe:
  - flavour structure of new physics found at the LHC.
  - $\geq O$(TeV) indirect NP search capability using rare decays.

- Many important measurements unique to SuperB.

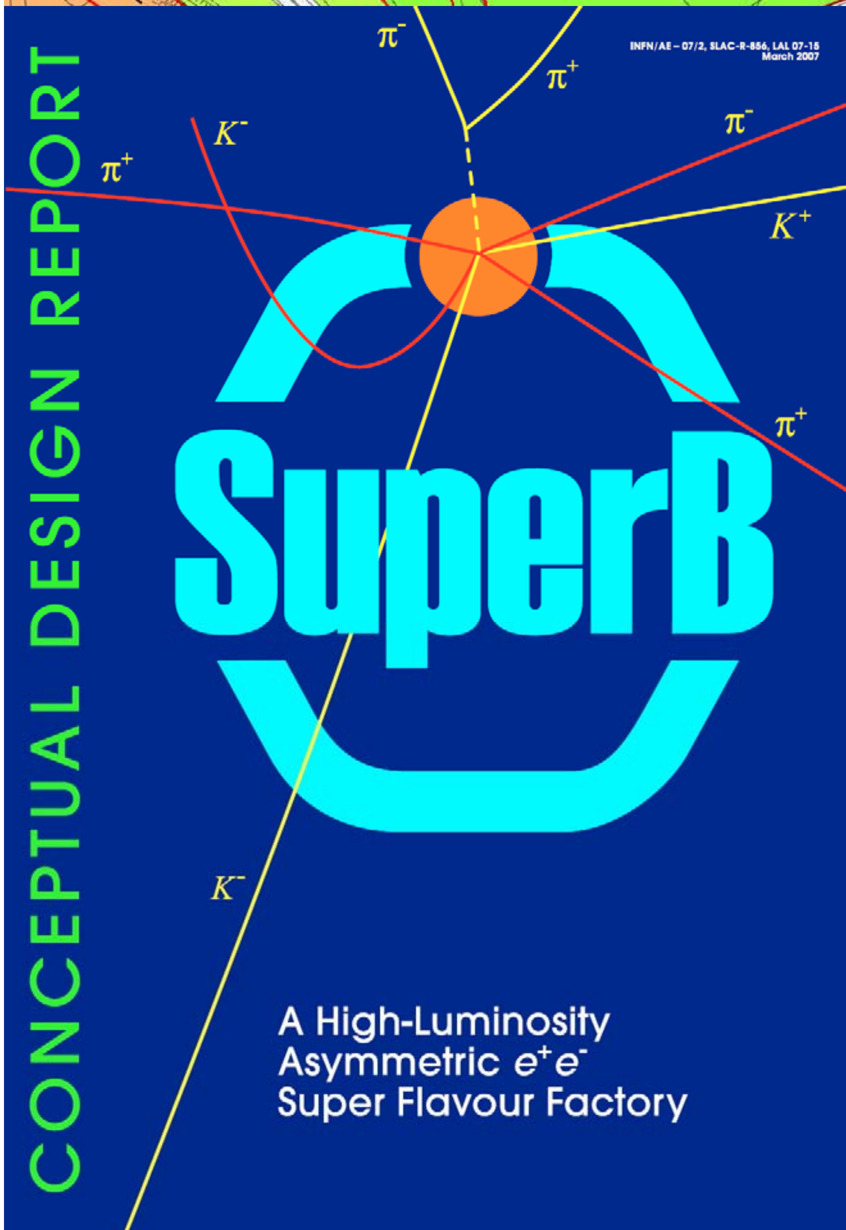
- Complementarity with the LHC high energy frontier and flavour programmes.
  - Need a SuperB to start decoding what new physics scenarios are realistic in the LHC era.

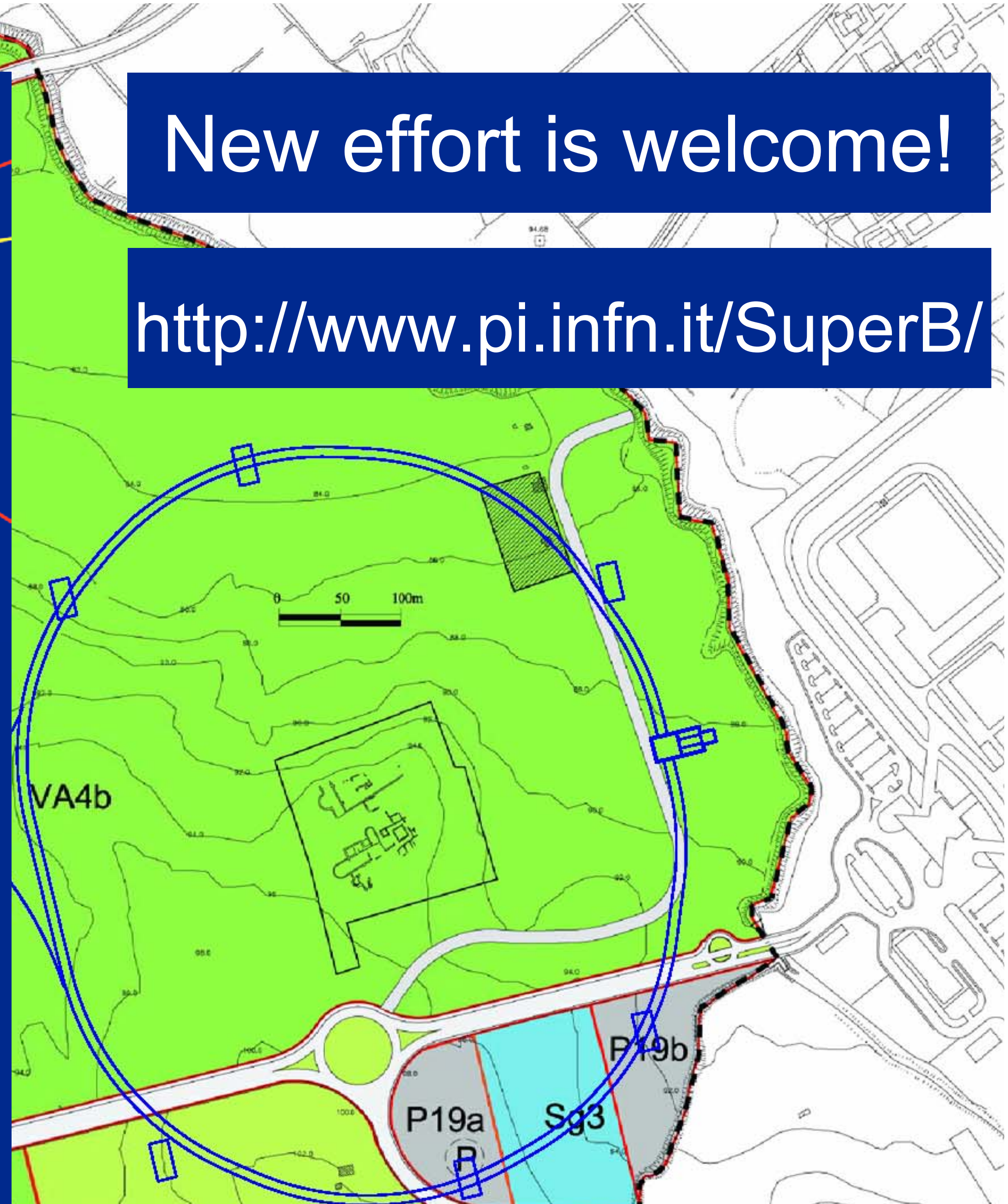


All we need to do is build it!

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

If you would like a copy of the SuperB CDR, please send me an e-mail!
a.j.bevan@qmul.ac.uk





New effort is welcome!

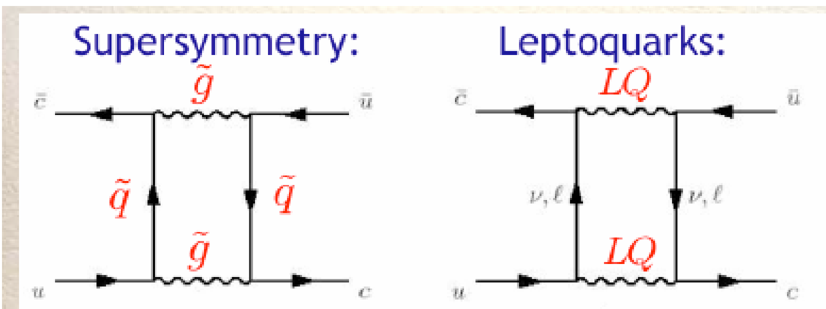
http://www.pi.infn.it/SuperB/

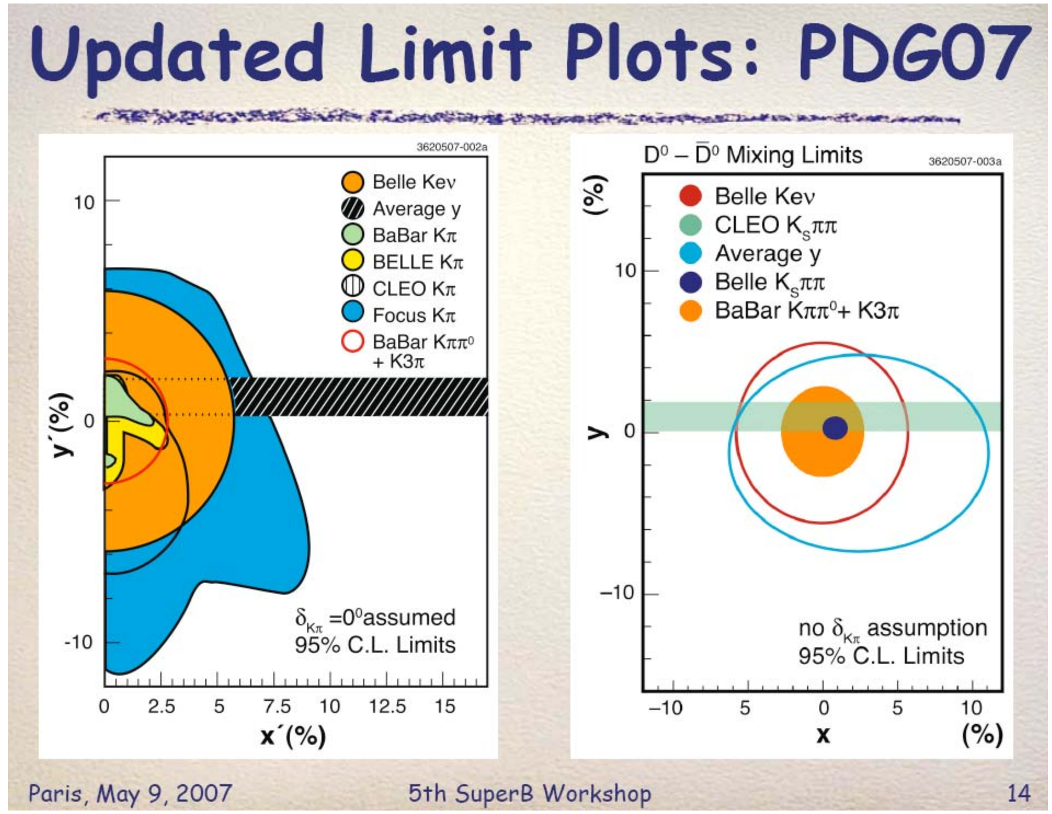
If you would like a copy of the SuperB CDR, please send me an e-mail!
a.j.bevan@qmul.ac.uk

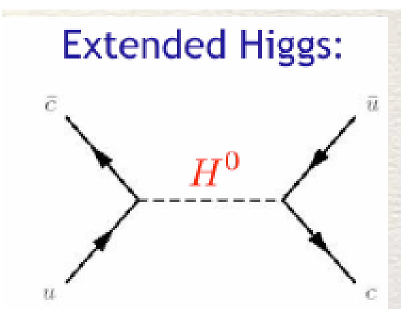
Additional Material

D^0 mixing

- Recent measurements from BaBar and Belle demonstrated B factory capabilities in charm physics
- Possibility to measure CP violation in the charm sector







Projected Sensitivity

Exp't / 1 σ	y_{CP} (10^{-3})	y′ (10^{-3})	x'^2 (10^{-4})	cosδ
B-factories (2ab^{-1})	2-3	2-3	1-2	-
SuperB (50 ab^{-1})	0.5	0.7	0.3	-
LHCb (10 fb^{-1}) Only B->D*	?	0.7	0.7	-
LHCb (100 fb^{-1}) Prompt D*	?	?	?	-
CLEO-c (750 pb^{-1})	10	-	2-3	0.1-0.2
BESIII (20 fb^{-1})	4	-	0.5-1	0.05
SuperB - 4 GeV (0.2 ab^{-1})	1-2	-	‹0.2	‹0.05

Target precision

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 (∗)
$S(K_S^0 K_S^0 K_S^0)$	0.15	0.02 (∗)
$S(K_S^0 \pi^0)$	0.15	0.02 (∗)
$S(\omega K_S^0)$	0.17	0.03 (∗)
$S(f_0 K_S^0)$	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° (∗)
$2\beta + \gamma$ $(D^{(*)\pm}\pi^\mp,\, D^\pm K_S^0 \pi^\mp)$	20°	5°

† Systematics limited

* Theoretically limited.

See Super B workshop V summary talks by

K. George

A. Bondar

A. Bevan

for recent summaries

Super B Workshop V, http://indico.lal.in2p3.fr/conferenceDisplay.py?confId=167

Target precision

† Systematics limited
* Theoretically limited.

Observable	B Factories (2 ab^{-1})	Super$B$ (75 ab^{-1})
$\vert V_{cb}\vert$ (exclusive)	4% (∗)	1.0% (∗)
$\vert V_{cb}\vert$ (inclusive)	1% (∗)	0.5% (∗)
$\vert V_{ub}\vert$ (exclusive)	8% (∗)	3.0% (∗)
$\vert V_{ub}\vert$ (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 († ∗)
$A_{CP}(B \to \rho\gamma)$	$\sim$ 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

The physics programme

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Radiative Decays : $b \to s\ell\ell$ and $b \to d\ell\ell$.

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Written before D mixing was seen. Needs to be updated to reflect this.

Decoding the pattern of NP

Table 5-12. *Pattern of the deviation from the Standard Model predictions for unitarity triangle and rare decays. "√" means that the deviation can be large and "-" means a small deviation. "closed" in the first row of the B_d unitarity means that the unitarity triangle is closed among observables related to B_d, and the second and the third rows show whether deviation is observed from consistency check between the B_d unitarity and ϵ_K and $\Delta m(B_s)/\Delta m(B_d)$, respectively.*

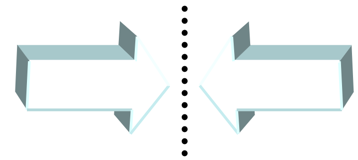
	B_d unitarity			Rare Decays		
	closure	$+\epsilon_K$	$+\Delta m(B_s)$	$A^{\rm mix}_{CP}(B \to \phi K^0_S)$	$A^{\rm mix}_{CP}(B \to M_s \gamma)$	$A^{\rm dir}_{CP}(B \to X_s \gamma)$
mSUGRA	closed	-	-	-	-	-
SU(5) SUSY GUT (degenerate RHN)	closed	√	-	-	-	-
SU(5) SUSY GUT (non-deg. RHN)	closed	-	√	√	√	-
MSSM with U(2)	√	√	√	√	√	√

Table 5-11. *Correlated signatures for an observation of $S_{\phi K}$ much smaller than $S_{\psi K}$, assuming a single SUSY d-squark insertion of the type indicated. The $\pm$ signs represent the sign of the corresponding observable.*

	LL	RR	LR	RL
(δ^d_{23})	$O(1)$	$O(1)$	$O(10^{-2})$	$O(10^{-2})$
SUSY masses	$\lesssim 300$ GeV	$\lesssim 300$ GeV	$\lesssim$ TeV	$\lesssim$ TeV
$C_{\phi K}$	$-$, small	$-$, small	$-$, small	$-$, can be large
$\mathcal{B}(B \to \phi K)$	SM-like	SM-like	varies	varies
$A^{b\to s\gamma}_{\rm CP}$	$+$, few %	SM-like	$+$, $\mathcal{O}(10\%)$	SM-like
Δm_{B_s}	can be large	can be large	SM-like	SM-like

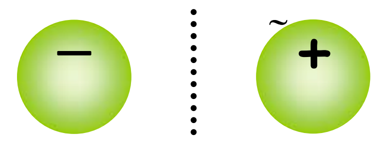
Aside: $\mathcal{P}$, $\mathcal{C}$ and $\mathcal{T}$

- $\mathcal{P}$
  – Mirror reflection, with a rotation of π about an axis perpendicular to the reflection plane.



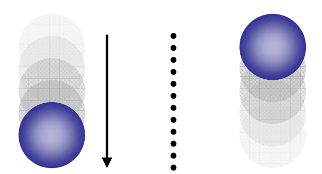
$$\mathbf{r} \to -\mathbf{r}$$
$$\mathbf{p} \to -\mathbf{p}$$
$$\mathbf{L} \to \mathbf{L}$$

- $\mathcal{C}$
  – Change particle to antiparticle.



$$e^- \to e^+$$
$$\gamma \to \gamma$$

- $\mathcal{T}$
  – Reverse the direction of time.



$$t \to -t$$