B_u B_d B_s D τ ...

Much more than just B physics!

The SuperB Facility

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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

- Baseline Aim: integrate 75 ab^{-1} of data (12ab^{-1}/yr at design lumi).

- Two orders of magnitude larger data set than the current B-factories:
  - i.e. 75 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.
    - Υ(3S) for DM, Light Higgs, LU.

- New concepts in accelerator technology should enable us to meet this target within O(5-6) years of data taking.
  - Accelerator R&D is well underway at Frascati to test these concepts.

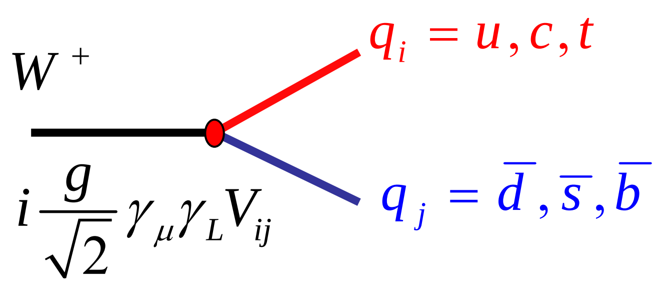
- Timescale: Aim to start taking data 5 years after funding gets approved.

Physics Case – in a Nutshell

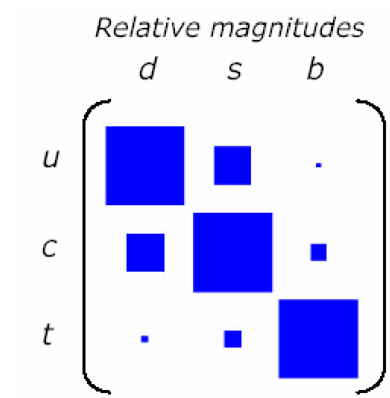
- We expect New Physics (NP) at the TeV scale:
  - Same motivation as the LHC!
- This physics will have some kind of flavour structure:
  - Rich structure: *we have to measure it*!
  - Trivial structure: *we have to confirm*!
- This new physics may, *or may not* help elucidate the matter-antimatter asymmetry 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.
  - Constrain models with light dark matter.

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}^*.

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

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.

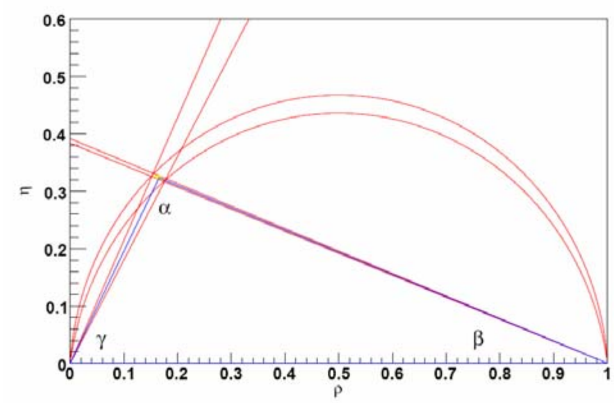
Today's calibration channel is tomorrow's background

Today's calibration channel is tomorrow's background

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 sources of CPV
Signs of heavy new particles
Low mass Higgs
Lepton Flavour Violation
Dark Matter

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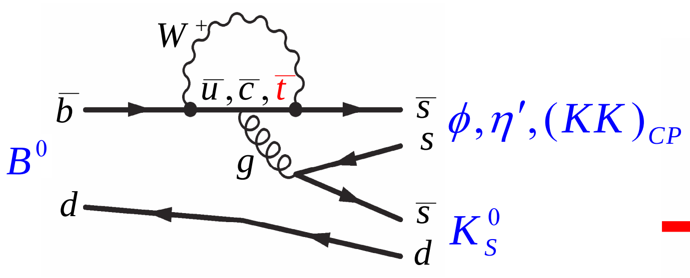
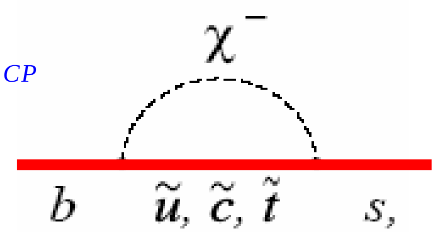
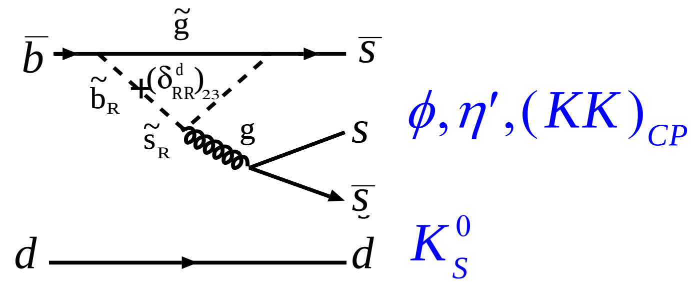
New Physics Search Capability

New Physics in Loops (ΔF=1)

- Rare loop processes can have significant NP contributions.





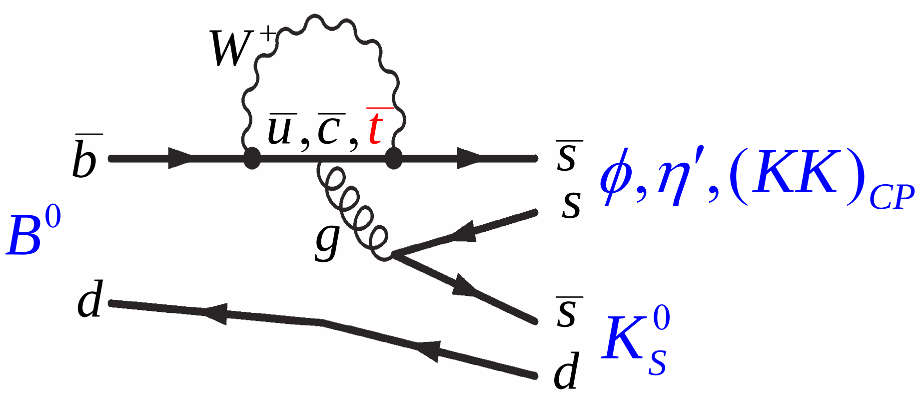


- NP can modify the expected SM amplitudes and asymmetries.
- Want to look in as many different modes (and with as many different observables) as possible.

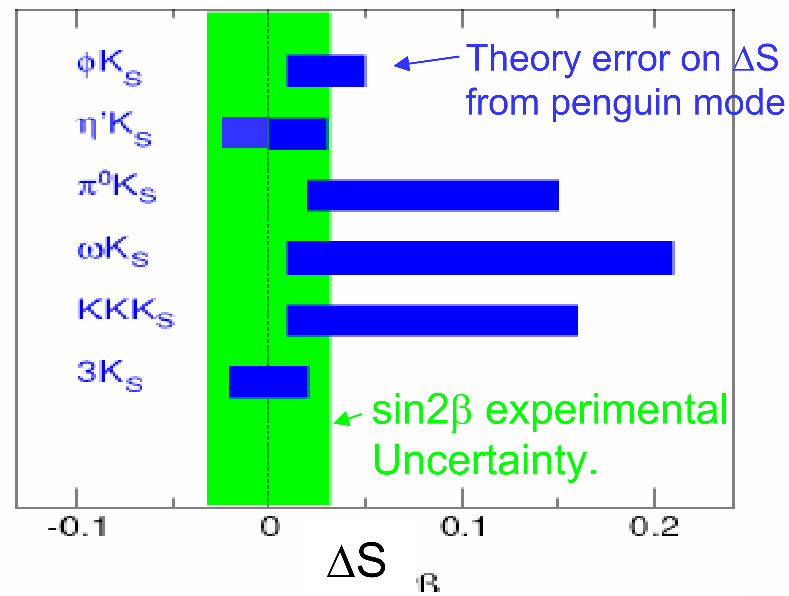
New Physics in Loops ($\Delta F=1$)

- 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
$\sin 2\beta^f_{eff} - \sin 2\beta$



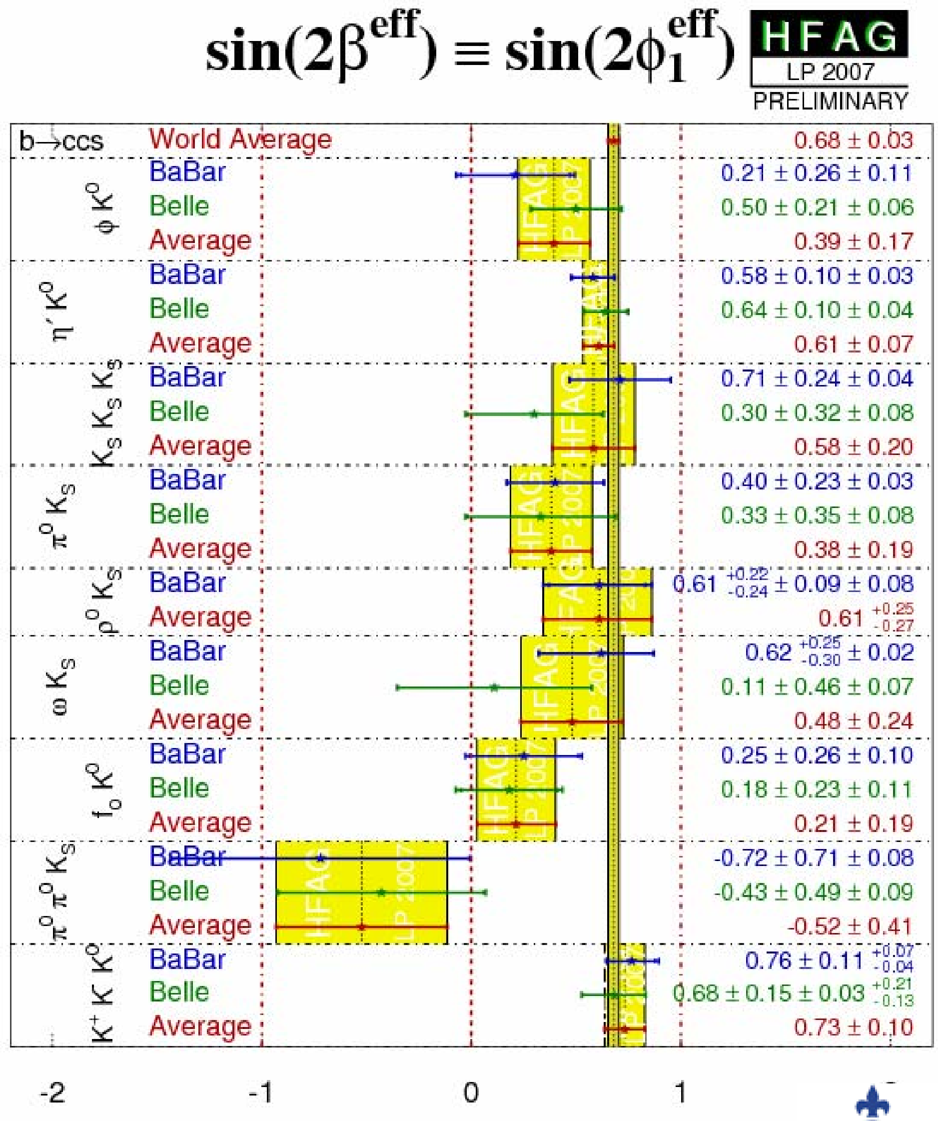
QCDF: (Beneke, PLB620 (2005), 143-150, Cheng et al., PRD72 (2005) 094003 etc.
SCET: (Williamson & Zupan, hep-ph/0601214)
Can estimate ΔS and mostly see a positive shift.

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 $\beta_{eff} > \beta$.

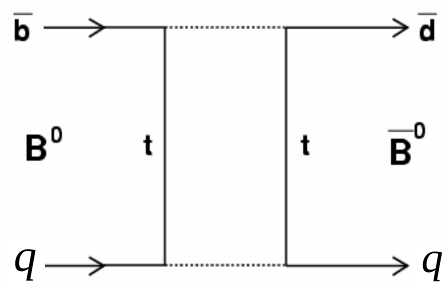
New Physics in Loops (ΔF=1)

- 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).



$$q = d, s$$

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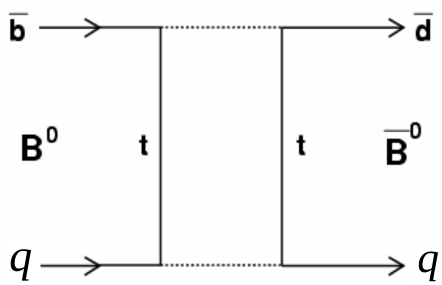


$q = d, s$

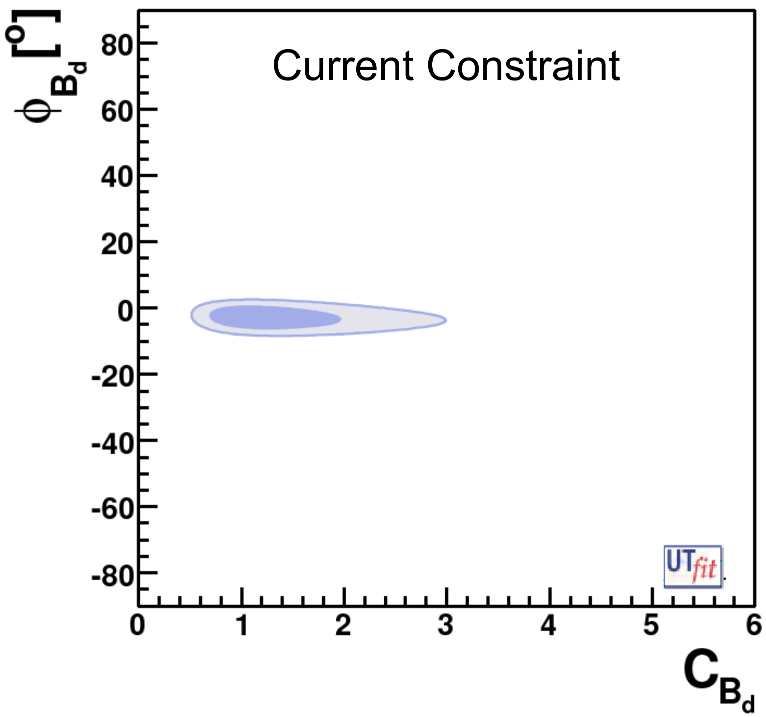
- New physics (NP) can contribute with an amplitude ratio C_q and phase ϕ_q.

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

- C_q=1, and ϕ_q=0 for the Standard Model (SM).

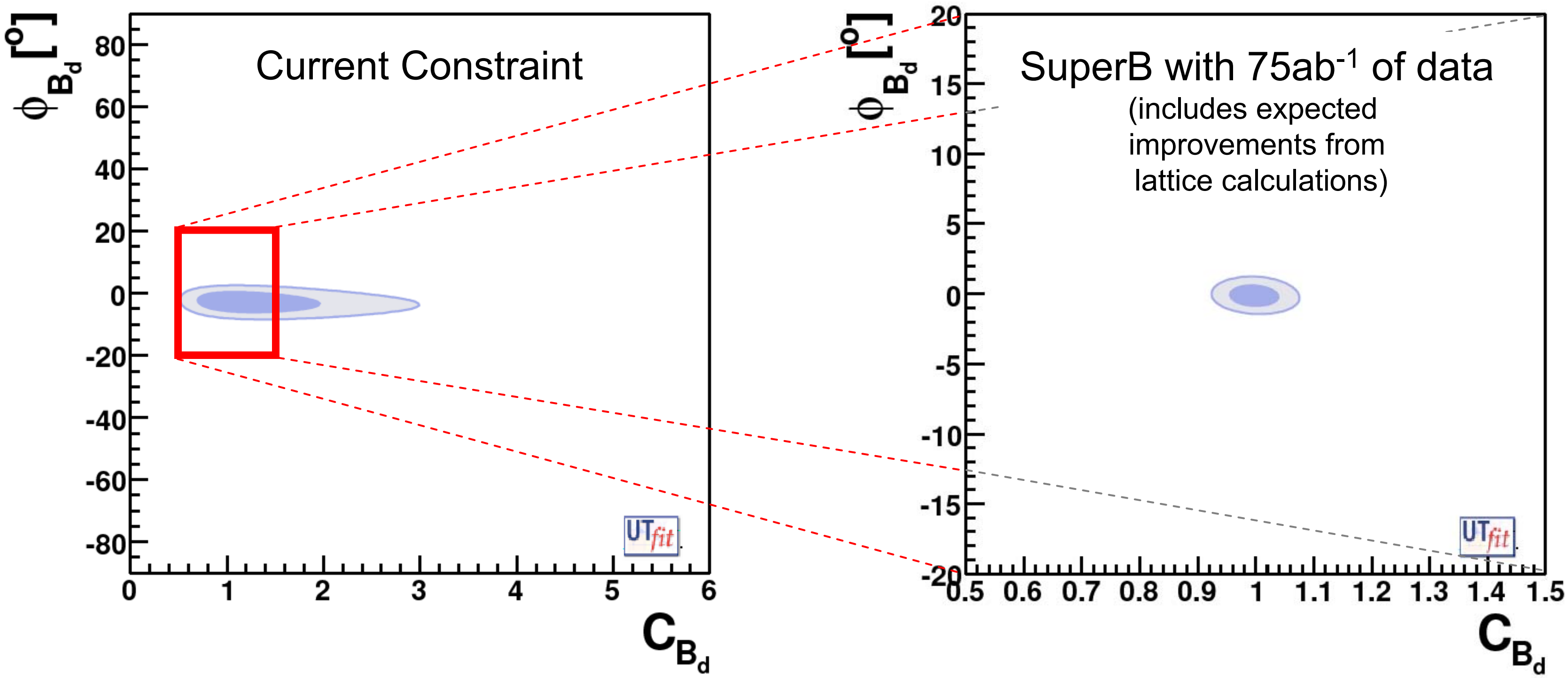
New Physics in ΔF=2 Transitions

- 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 (= $6\Lambda_0$).

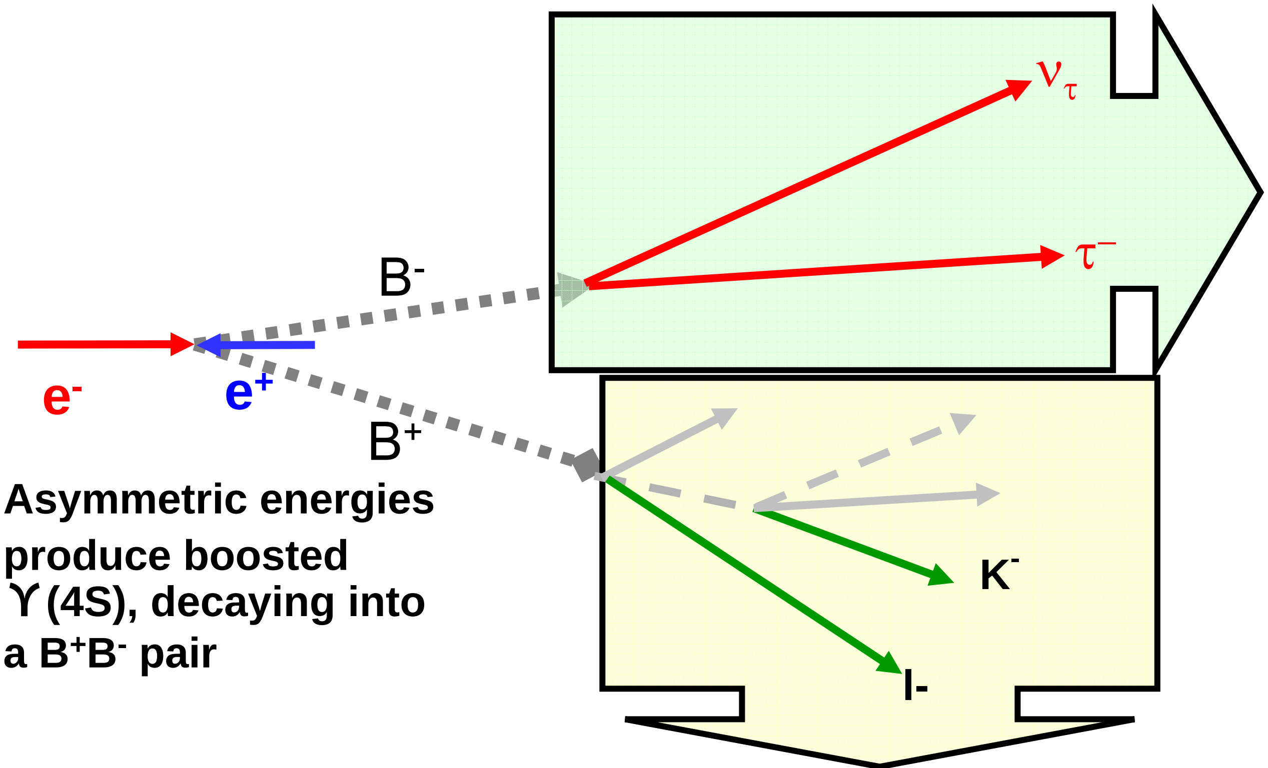
- For loop mediated NP contributions the constraint can be weakened so that $\Lambda \sim$ 700GeV.

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.

$B^+ \to l^+ \nu$



Reconstruct signal via the decay products of the τ lepton from the rest of the event (B_{SIG})

Asymmetric energies produce boosted Υ(4S), decaying into a B^+B^- pair

Fully (Hadronic Tag) or Partially (Semi-leptonic Tag) reconstruct the non-signal B in the event (B_{TAG}).

$\mathcal{B}_{SM} \sim 10^{-4}\,(\tau)$
$\sim 10^{-7}\,(\mu)$

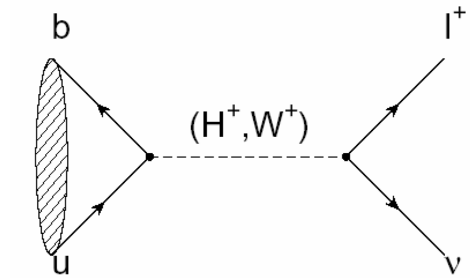
Tag efficiency ~ few per mille.

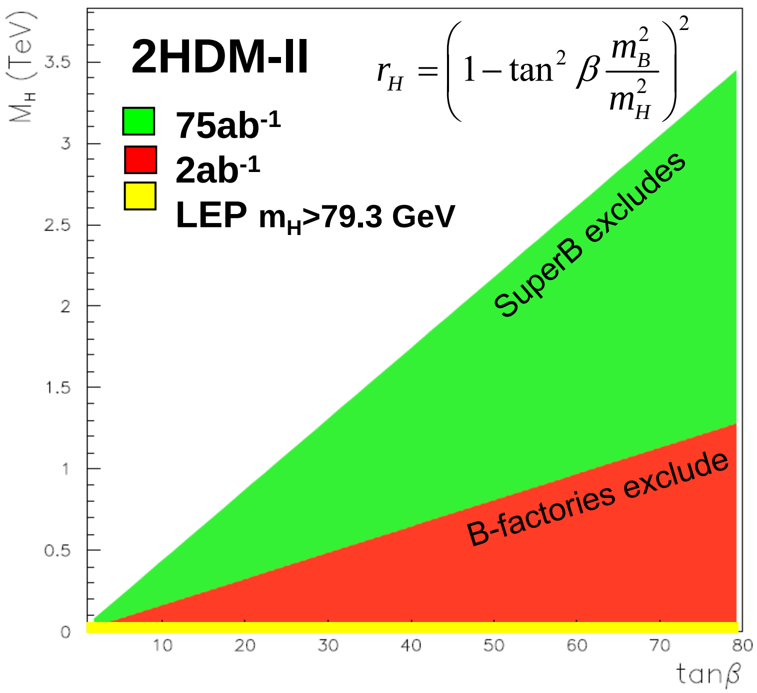
Charm equivalent: $D_s^+ \to \mu^+\nu, \tau^+\nu$

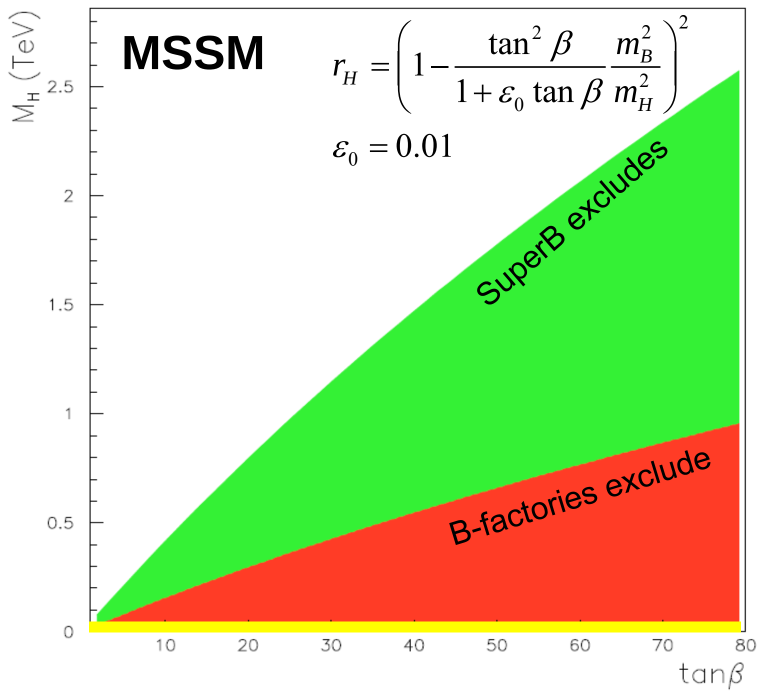
$B \to \tau\nu, \mu\nu$

- Higgs mediated MFV:

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







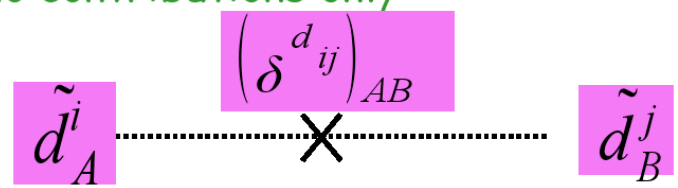
- Multi TeV search capability for large tanβ.

SUSY CKM

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

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

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



- 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

- Couplings are $\left(\delta_{ij}^{q}\right)_{AB}$

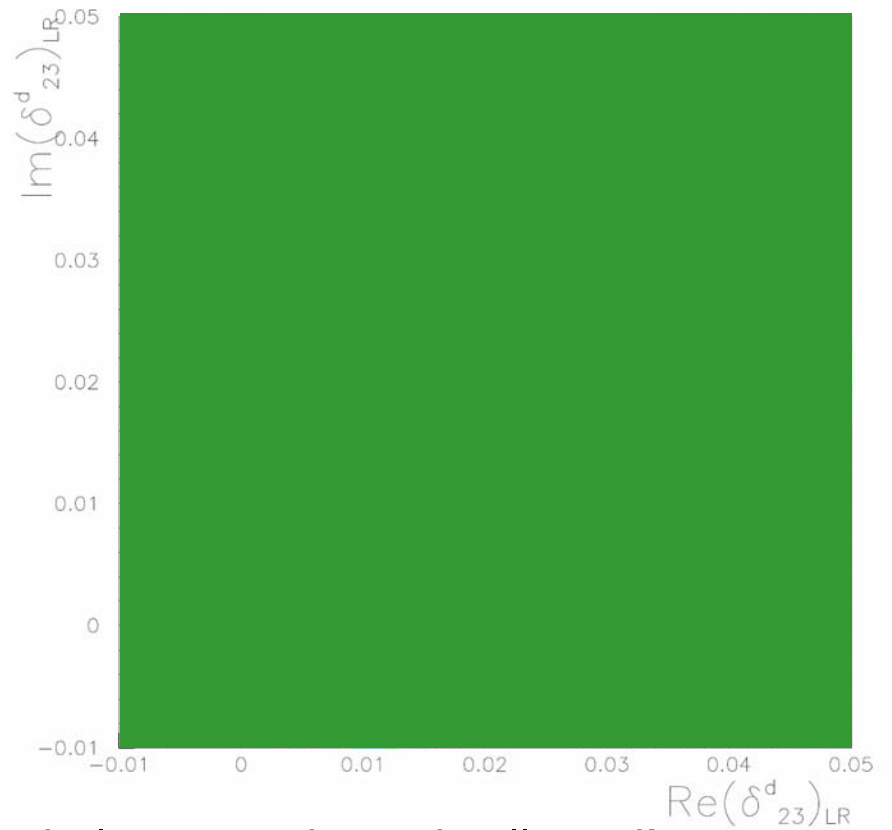
L. Silvestrini (SuperB IV)

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!

SUSY CKM

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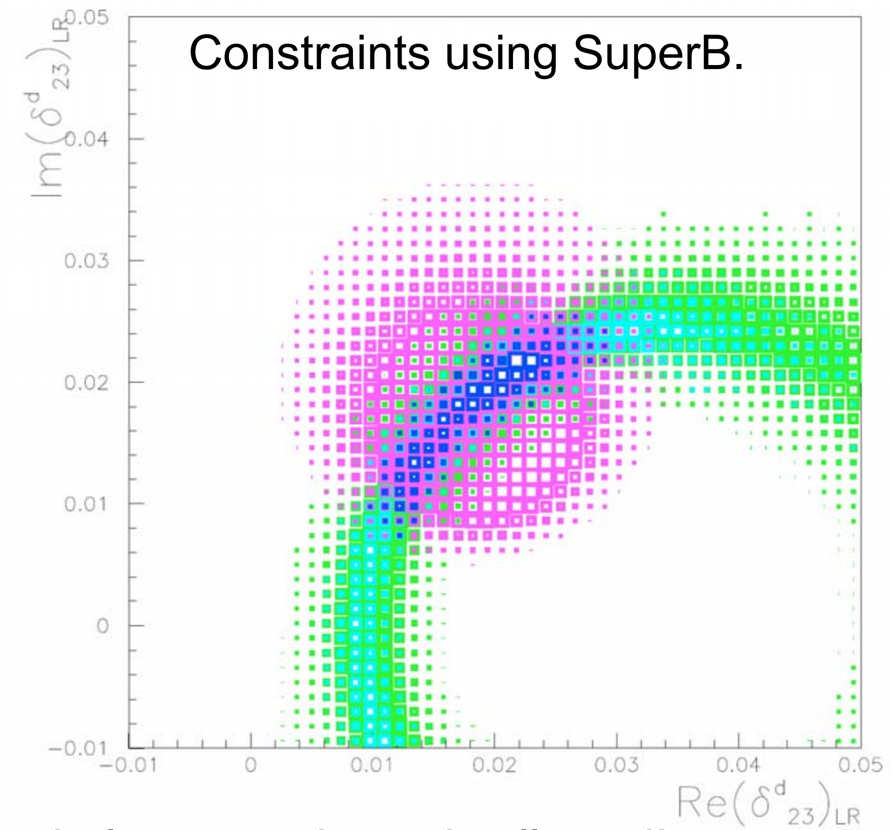

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With current data, the whole range shown is allowed!

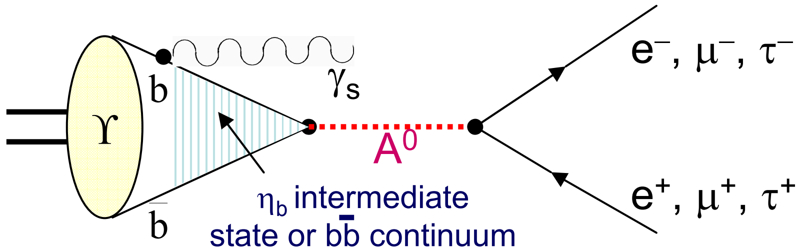
Searching for a Light Higgs or Dark Matter Candidates

LEP data do not exclude the possibility!

For more details see the talks of McElrath and Sanchis at the SuperB retreat in Valencia Jan '08:
http://ific.uv.es/superb/

Searching for a Light Higgs

- Many NP scenarios have a possible light Higgs Boson (e.g. 2HDM).
- Can use $\Upsilon(nS) \to l^+ l^-$ to search for this.
  - Contribution from A^0 would break lepton universality



M. A. Sanchis-Lozano, hep-ph/0510374,
Int. J. Mod. Phys. A19 (2004) 2183

Can expect hundreds of fb^{-1} recorded at the $\Upsilon(3S)$ in SuperB

- NMMSM Model with 7 Higgs Bosons

Physical Higgs bosons: (seven)

2 neutral CP-odd Higgs bosons ($A_{1,2}$)
3 neutral CP-even Higgs bosons ($H_{1,2,3}$)
2 charged Higgs bosons ($H^{\pm}$)

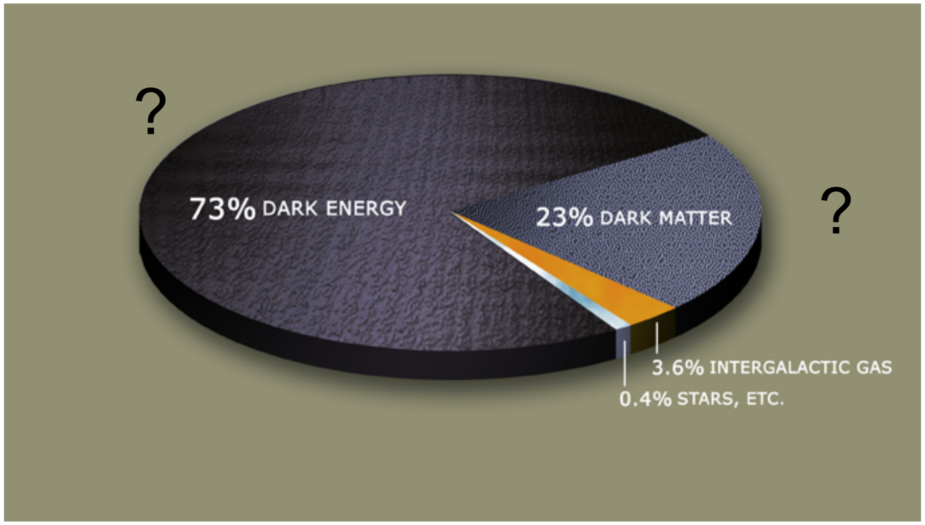
Possible NMMSM Scenario

$A_1 \sim 10$ GeV
$H_1 \sim 100$ GeV (SM-like)
Others ~300 GeV (almost degenerate)

- A_1 could be a light DM candidate.

Gunion, Hooper, McElrath [hep-ph:0509024]
McElrath [hep-ph/0506151], [arXiv:0712.0016]

Searching for Dark Matter

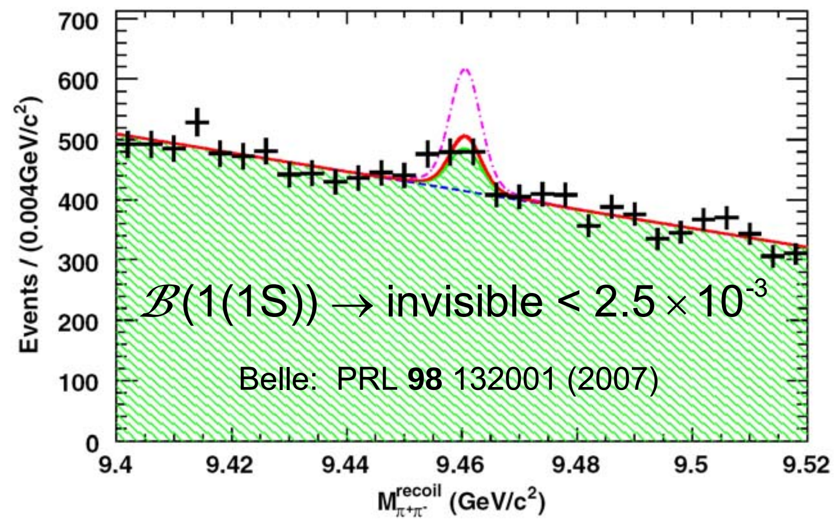


- Possible to search for the effect of DM at the B-factories for most modes:

$$\begin{array}{rl} \Upsilon \rightarrow invisible & J/\Psi \rightarrow invisible \\ \eta \rightarrow invisible & \Upsilon \rightarrow \gamma + invisible \\ B^+ \rightarrow K^+ + invisible & \Upsilon \rightarrow \gamma A_1, A_1 \rightarrow \tau^+\tau^- \\ K^+ \rightarrow \pi^+ + invisible & J/\Psi \rightarrow \gamma A_1 \end{array}$$

hep-ph/0506151, hep-ph/0509024, hep-ph/0401195, hep-ph/0601090, hep-ph/0509024, hep-ex/0403036 ...

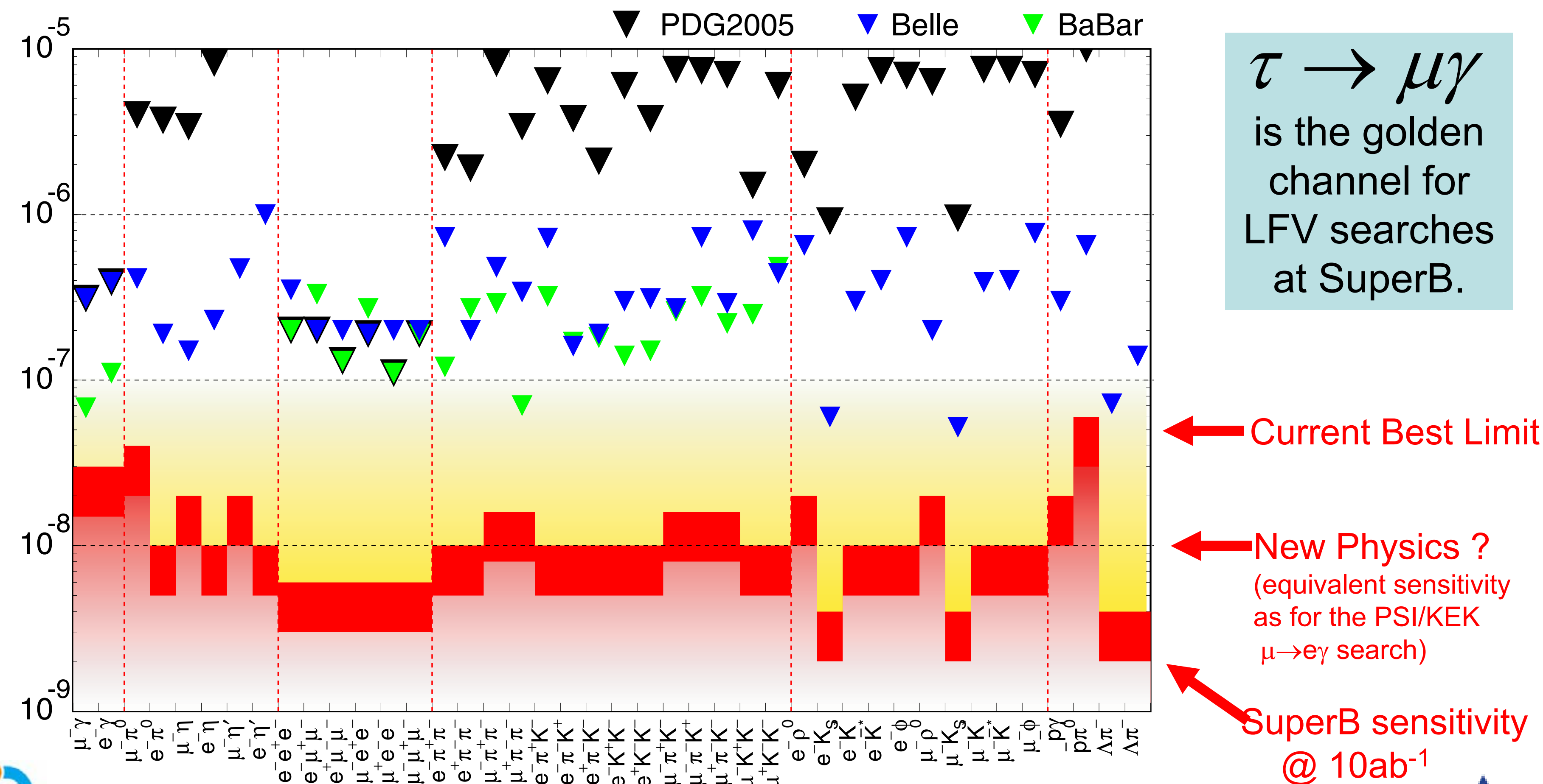
- SM Expectation:
  $\mathcal{B}(\Upsilon(1S) \rightarrow \nu\bar{\nu}) = (9.9 \pm 0.5) \times 10^{-6}$
- NP extension:
  $\mathcal{B}(\Upsilon(1S) \rightarrow \chi\chi)$ up to 6×10^{-3}
- SuperB should be able to provide a precision constraint on this channel.



τ Decays

Lepton Flavour Violation

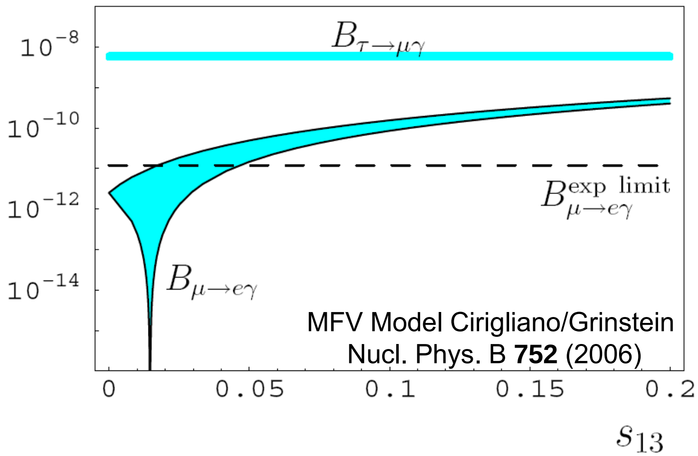
- SUSY breaking at low energies should result in FCNC [e.g. $\tau \rightarrow \mu\gamma$, $\mu \rightarrow e\gamma$].



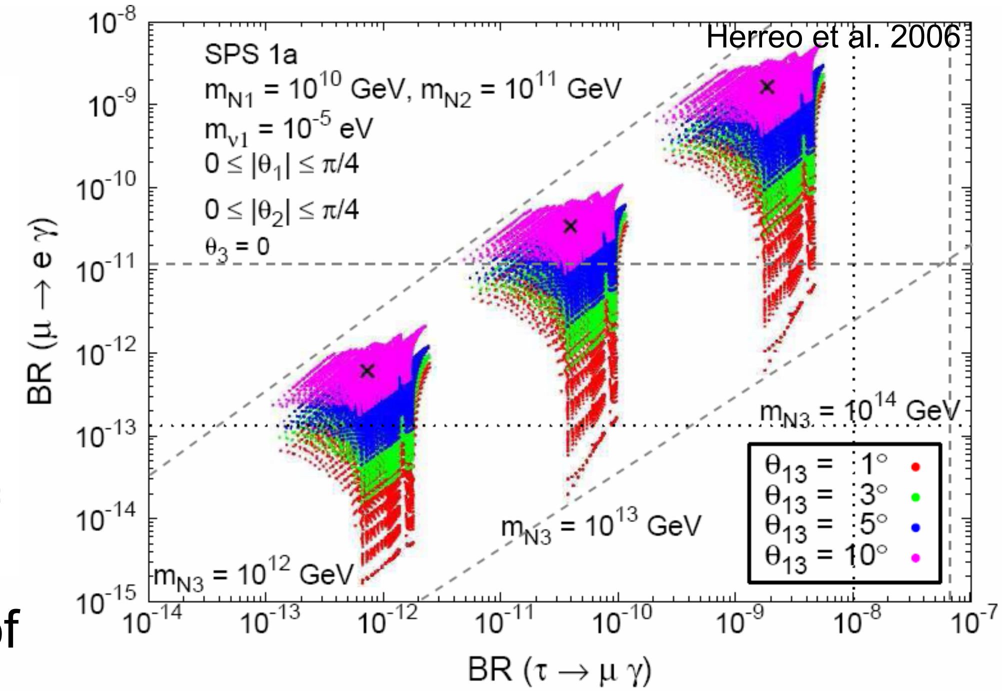
$\tau \rightarrow \mu\gamma$ is the golden channel for LFV searches at SuperB.

$\tau \to \mu\gamma$ / 3leptons

- Comparison of $\mu \to e\gamma$ and $\tau \to \mu\gamma$ rates can distinguish between NP scenarios.



SUSY seasaw = CMSSM + $3\nu_R$ + $\tilde{\nu}$



- Can depend on the value of θ_{13}.

- Best search capability for LFV in $\tau \to$3leptons of any experiment.

$\tau^- \to e^- e^+ e^-$	$2 \cdot 10^{-8}$
$\tau^- \to \mu^- \mu^+ \mu^-$	$3 \cdot 10^{-8}$
$\tau^- \to e^- \mu^+ \mu^-$	$2 \cdot 10^{-8}$
$\tau^- \to \mu^- e^+ e^-$	$2 \cdot 10^{-8}$
$\tau^- \to \mu^- e^+ \mu^-$	$2 \cdot 10^{-14}$
$\tau^- \to e^- \mu^+ e^-$	$2 \cdot 10^{-14}$

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.
  - Can have NP contributions from a $H^{\pm}$ in many modes, and largely experimentally un-explored.

Studies starting in this area

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

- CPT Violation.
  - Expect to be able to measure $\frac{\tau_{\tau-} - \tau_{\tau+}}{\tau_{\tau-} + \tau_{\tau+}}$ 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]

From SLAC-R-709

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 Υ, D and τ decay studies!

From SLAC-R-709

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Model	B_d Unitarity	Time-dep. CPV	Rare B de[illegible]	[illegible]
mSUGRA(moderate $\tan\beta$)	-	-	[illegible]	[illegible]
mSUGRA(large $\tan\beta$)	B_d mixing	[illegible]	[illegible]	[illegible]
SUSY GUT with ν_R	[illegible]	[illegible]	[illegible]	[illegible] mixing τ LFV, n EDM
Effective SUS[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 Υ, D and τ decay studies!

Accelerator Aspects

The numbers presented in this section are baseline.
It could be possible to exceed this by a factor 2-5 maintaining reasonable power consumption.

Target Integrated Luminosity

- Why at least 75ab^{-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 over 1ab^{-1} (combined) on disk/tape.
    - Will record a total of ~1.5ab^{-1}.
  - 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.
    - Need more than this to ensure discovery.
  - 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!
  - Will be able to test for light Higgs/dark matter particles and lepton universality by running at the Y(3S) resonance [hundreds of fb^{-1} from a few months running].

How to get increased $\mathcal{L}$

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

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

- 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 $\mathcal{L}$

$$\mathcal{L} = \frac{\gamma_{\pm}}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_{\pm}\xi_{\pm y}}{\beta_y^*}\right)\left(\frac{\mathcal{R}_{\mathcal{L}}}{\mathcal{R}_y}\right)$$

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.

Testing at DAΦNE NOW !!!

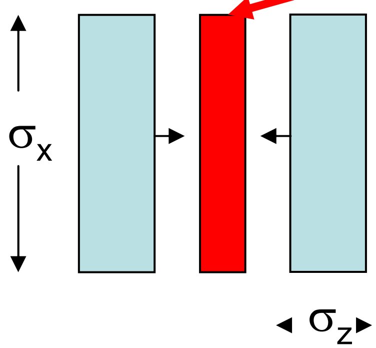
- Option 2: Large Crossing Angle.
  - Have a 15mrad crossing angle of beams.
  - Focus beams at IP (small β^*).
  - Retain longer bunch lengths.
  - Rotate colliding bunches so no geometric loss at IP.
    - Align the focussed parts of bunches that cross each other at the IP. Call this "Crab Crossing/Waist".

Large crossing angle, small x-size

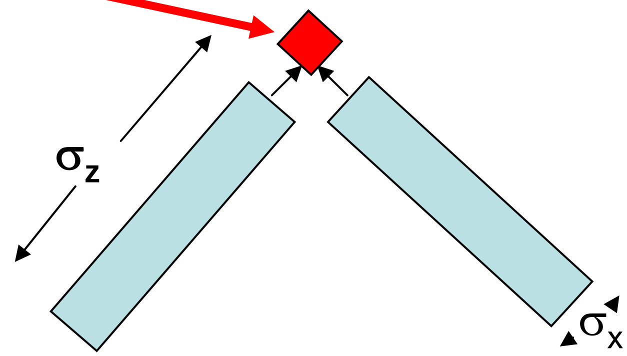
1) Head-on, Short bunches

Overlap region

2) Large crossing angle, long bunches



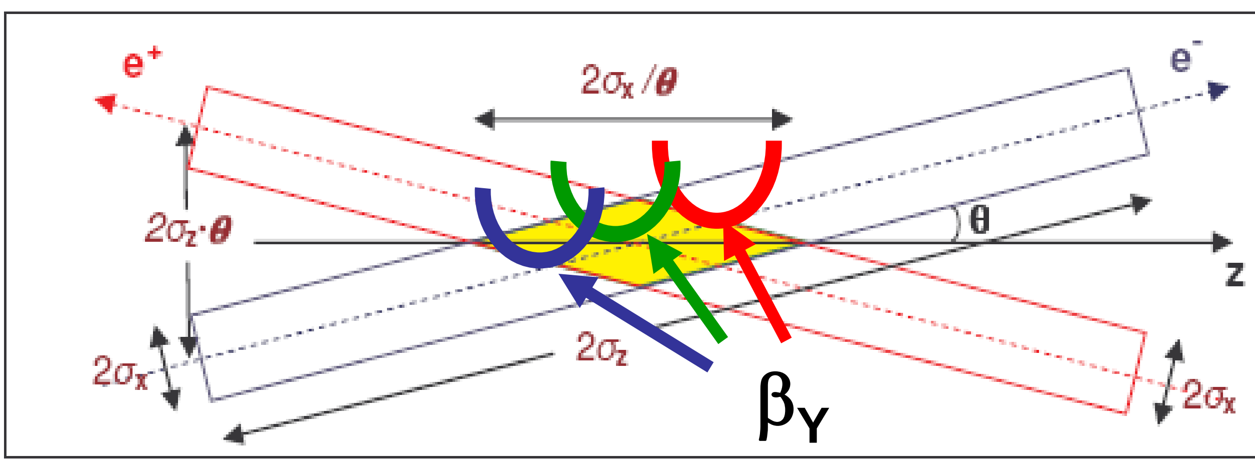
(1) and (2) have same Luminosity, but (2) has longer bunches and smaller σ_x



With large crossing angle the x and z planes are swapped

Large Piwinski angle:

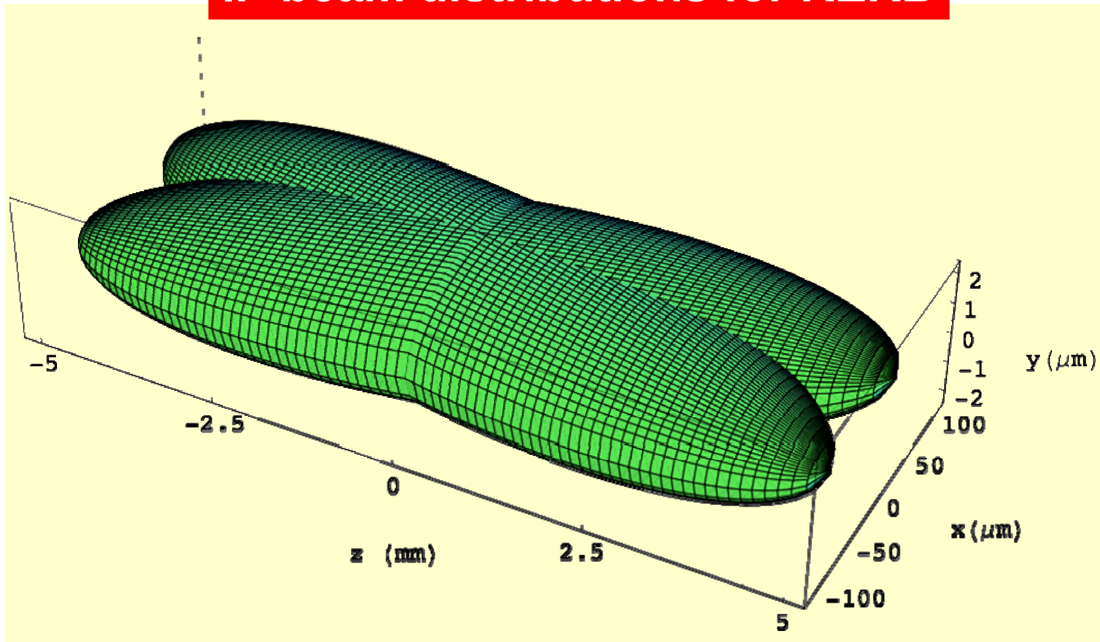
$\Phi = tg(\theta)\sigma_z/\sigma_x$

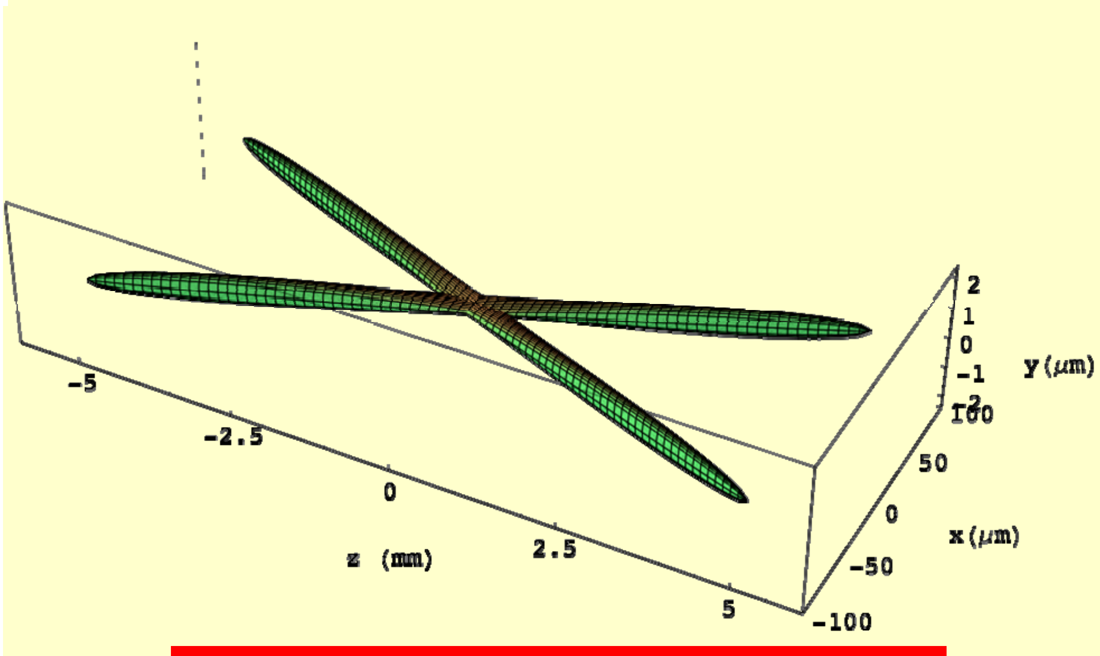


y waist can be moved along z with a sextupole on both sides of IP at proper phase

"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}	$1.\times10^{36}$

Here is Luminosity gain

Comparison between machines

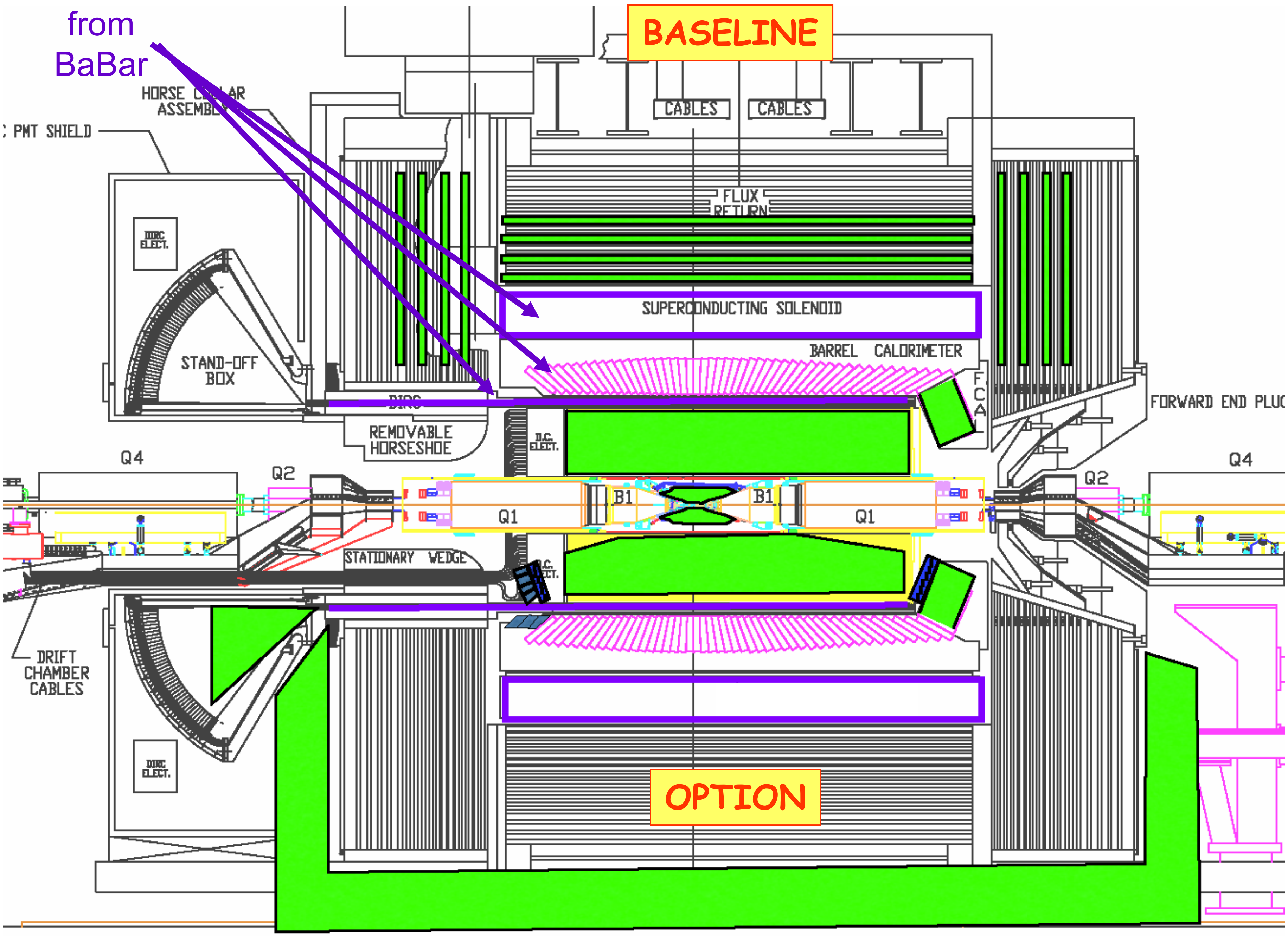
	PEPII	KEKB	SuperB
current	2.5 A	1.7 A	2.3 A
β_y	10 mm	6 mm	0.3 mm
β_x	400 mm	300 mm	20 mm
ε_y (σ_y)	23 nm (~100μm)	~ the same (~80μm)	1,6 nm (~6μm)
y/x coupling (σ_y)	0,5-1 % (~6μm)	0.1 % (~3μm)	0,25 % (0,035μm)
Bunch length	10 mm	6 mm	6 mm
Tau l/t	16/32 msec	~ the same	16/32 msec
ζ_y	0.07	0.1	0.16
$\mathcal{L}$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

Detector Design

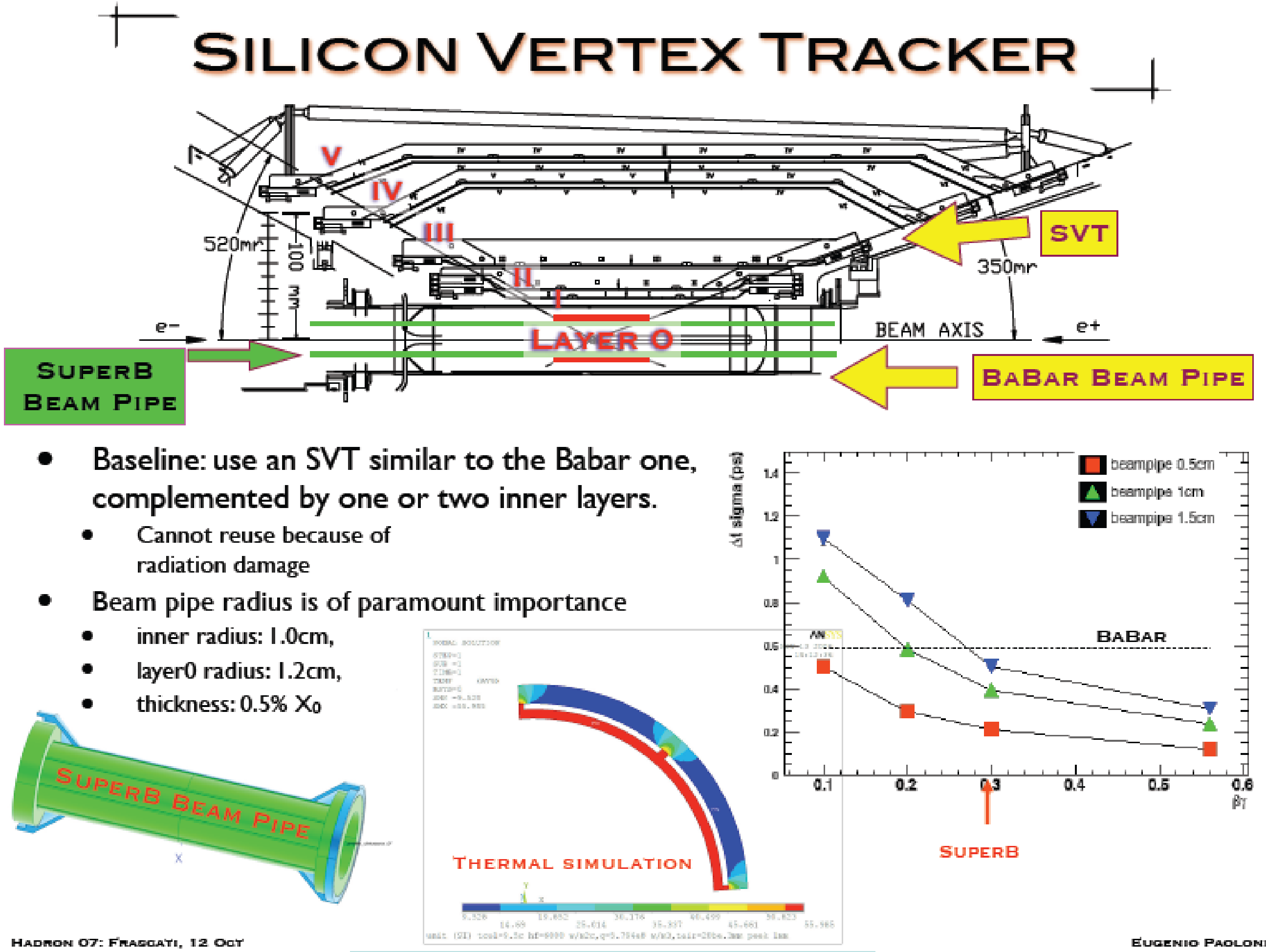
Requirements

- 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

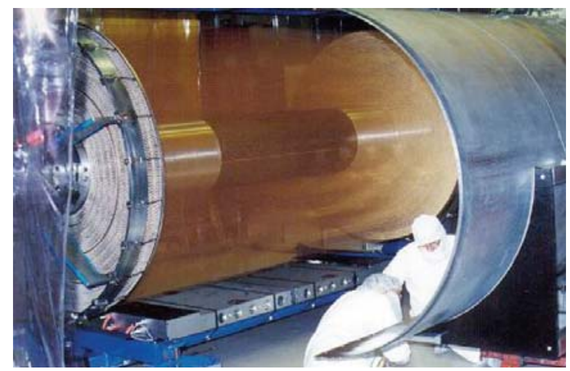


Tracking



BaBar DCH Design

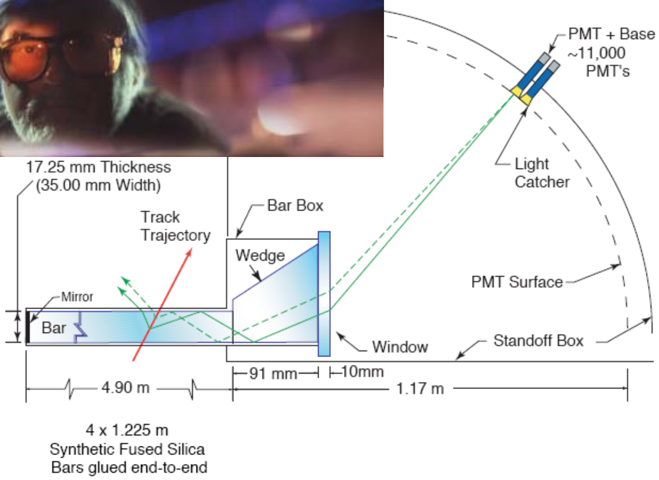
- Adequate performance.
- Needs to be replaced as the existing detector is aging.

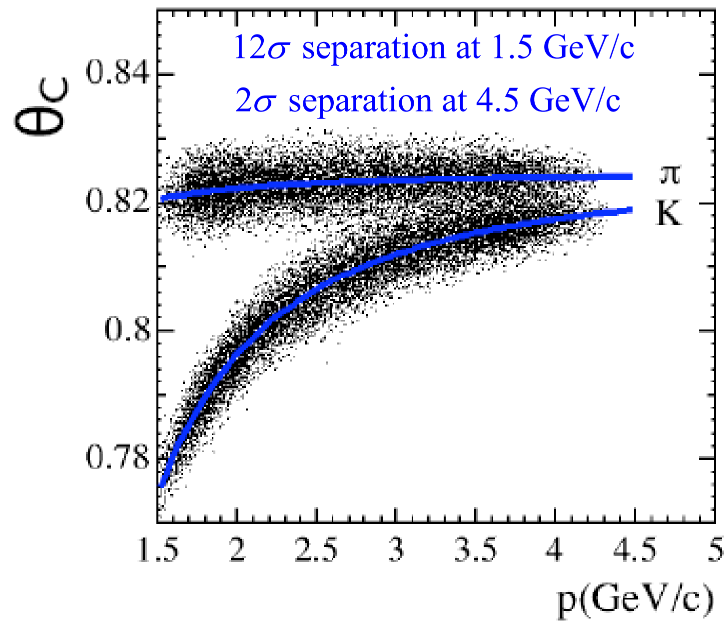


Slide taken from a talk by E. Paoloni @ Hadron 07

Particle ID

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



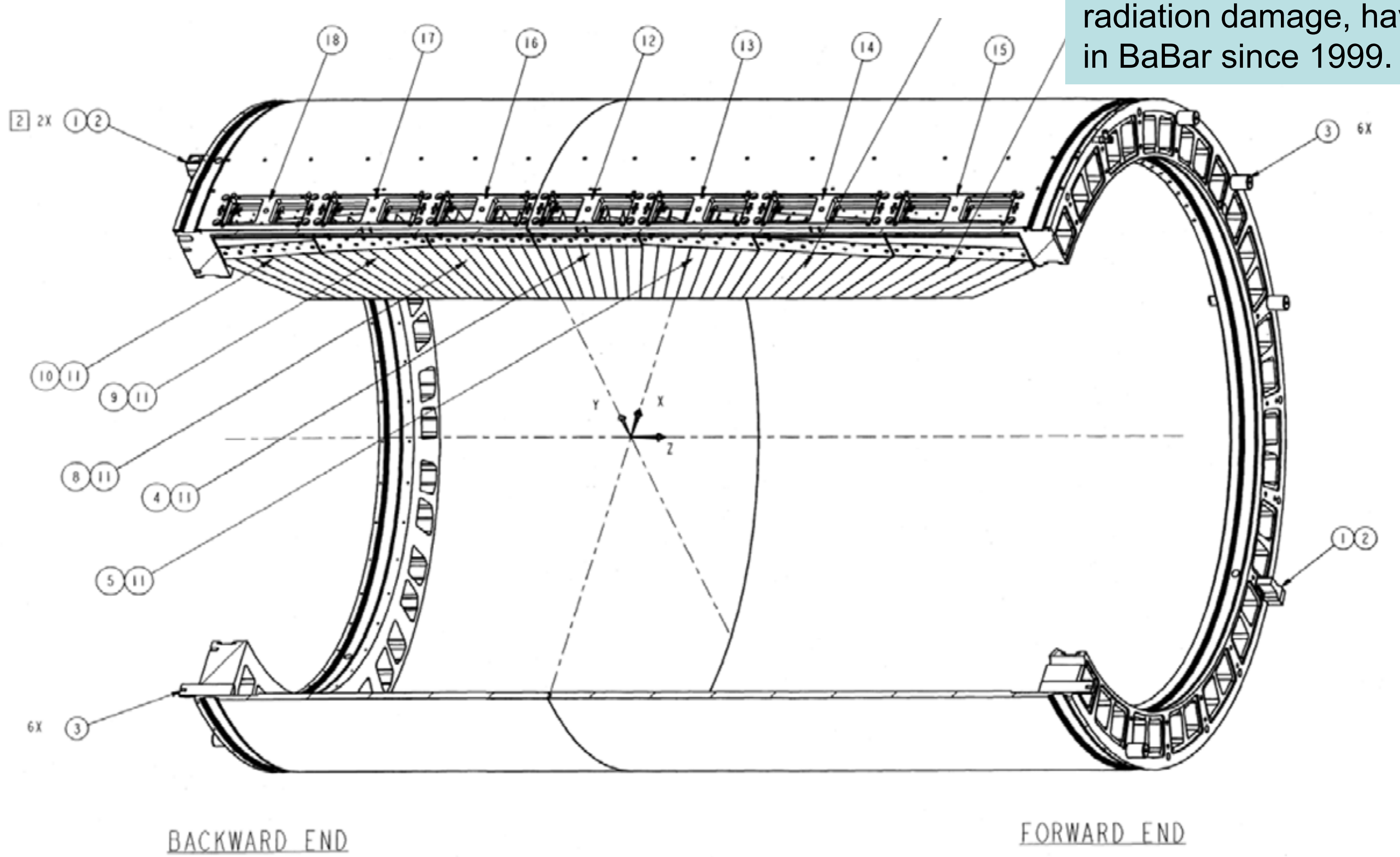


Can benefit from reducing the volume of water between the end of the quartz bars and the photodetectors (PMTs) at SuperB.

Calorimeter Barrel

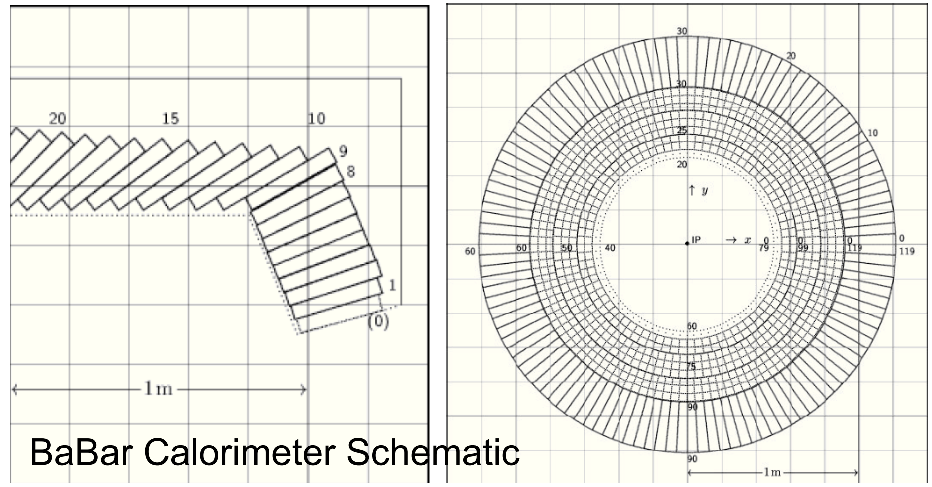
- Calorimeter Barrel is more than sufficient for our needs.

•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.

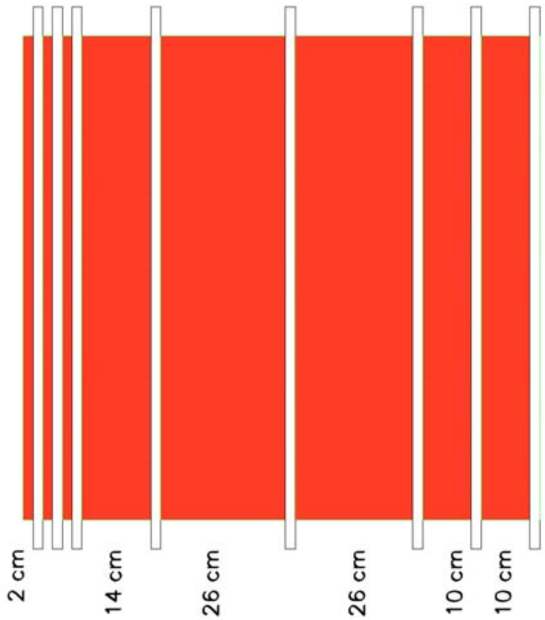


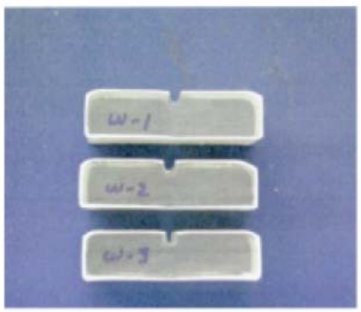
BaBar Calorimeter Schematic

2.5 x 2.5 x 20 cm (18 X_0) Bar

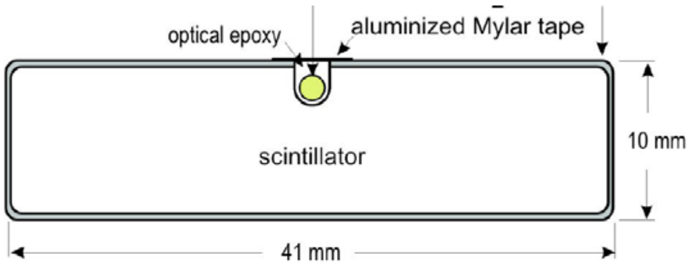
Instrumented Flux Return

- 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.

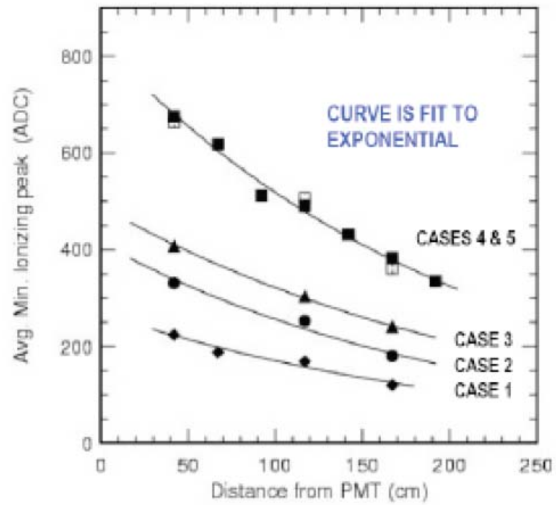




MINOS PRODUCTION BARS SHOWING 4 x 1 cm² CROSS SECTION WITH CO-EXTRUDED TiO_2 AND GROOVE FOR WLS FIBER



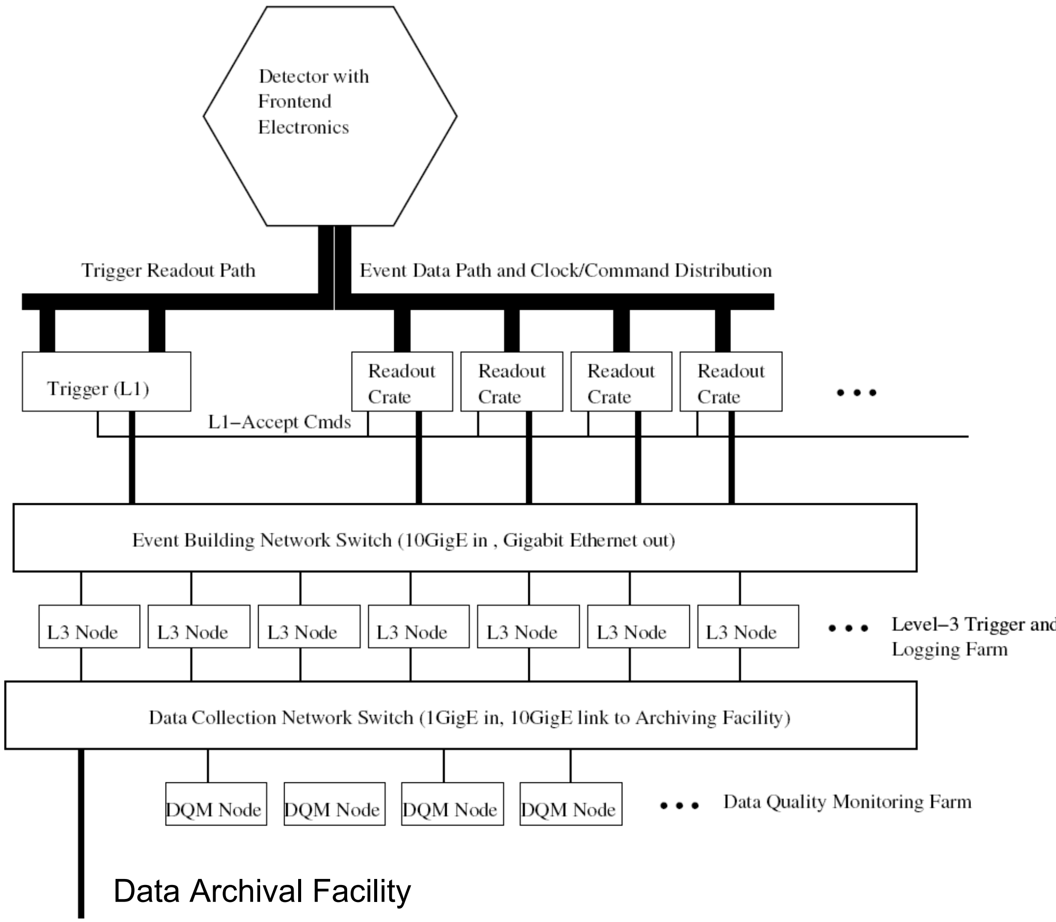
ATTENUATION LENGTH MEASUREMENTS FOR 5 CASES



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?

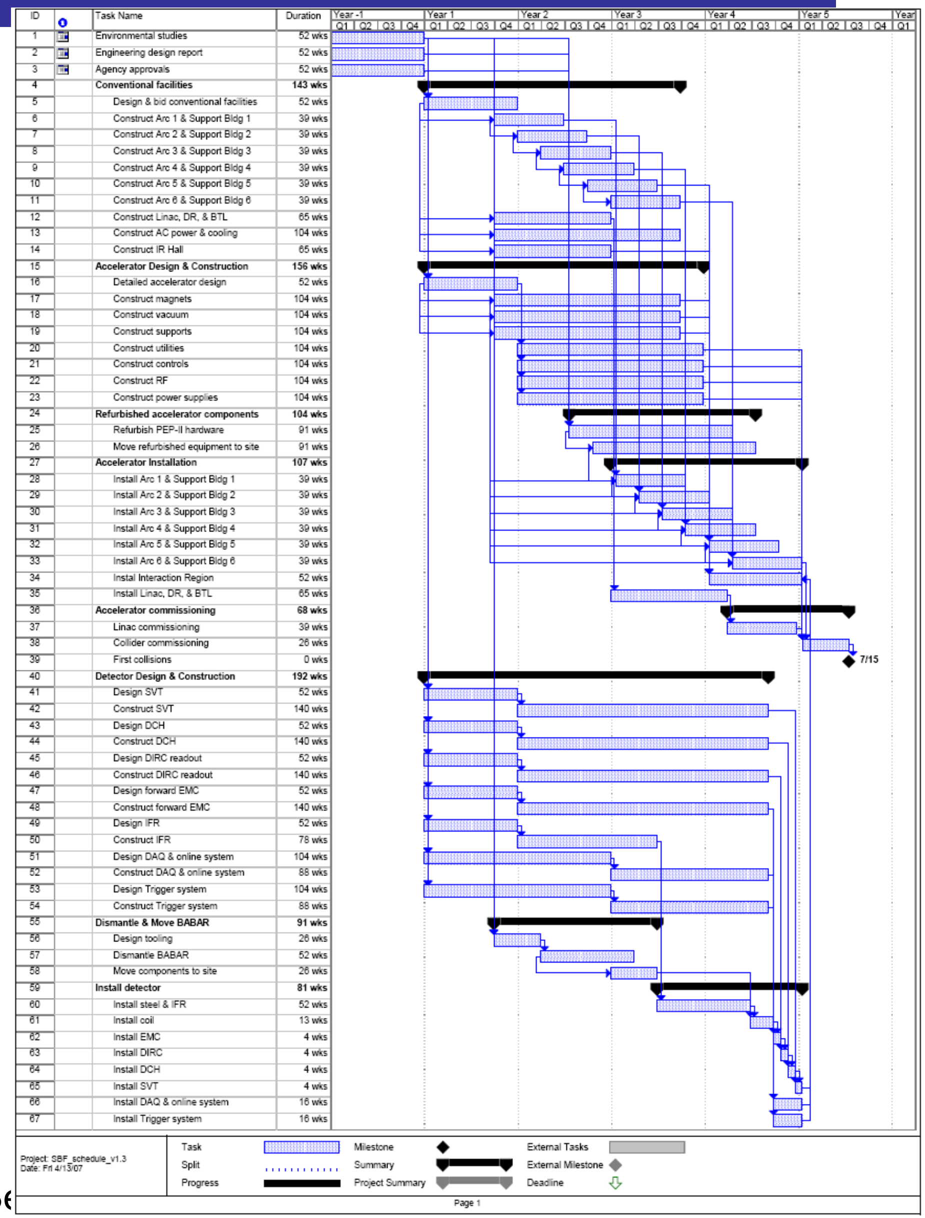


Figure 5-1. *Overall schedule for the construction of the SuperB project.*

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.

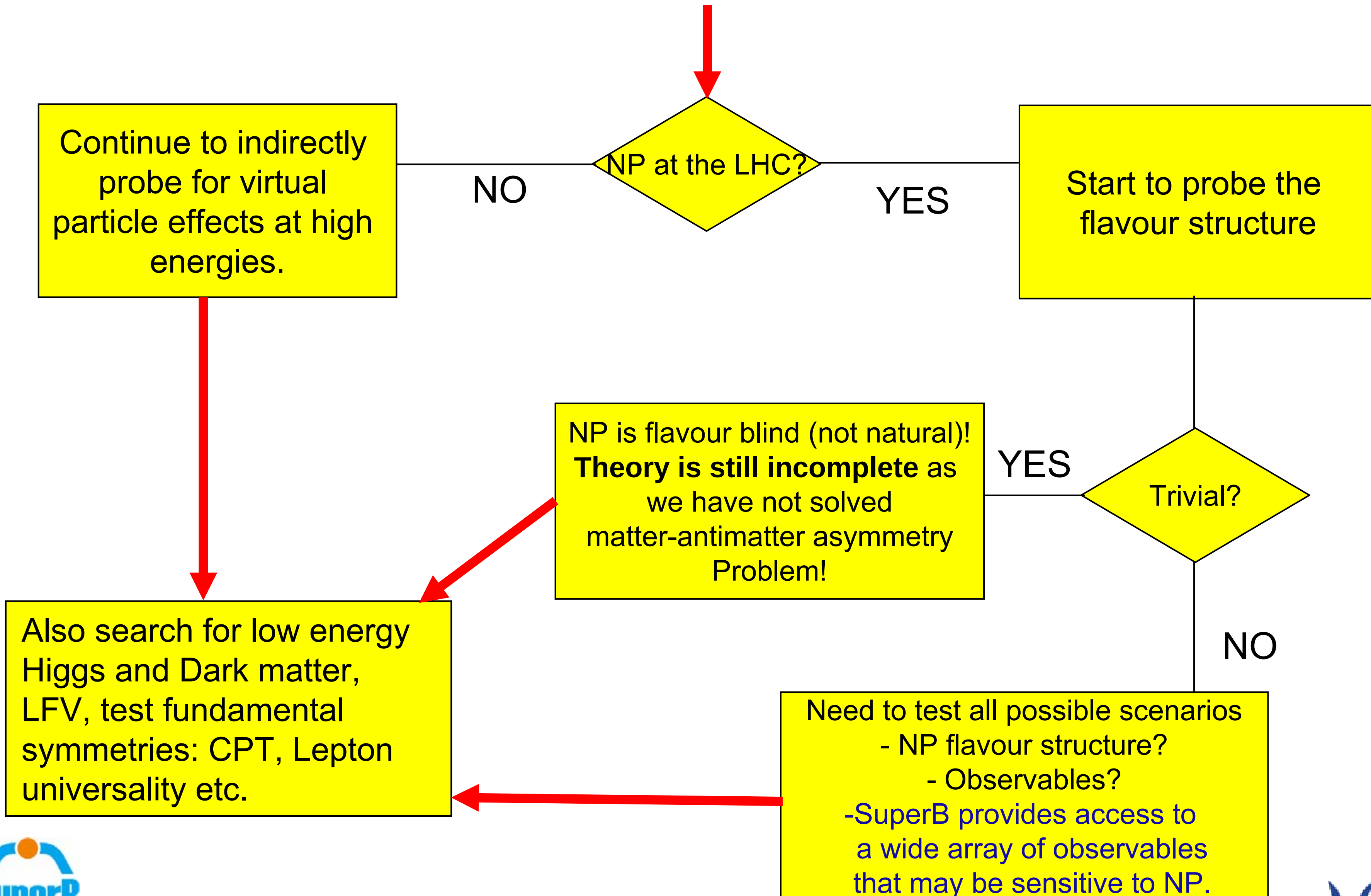
Total = 338M Euro.
= 510M Euro (counting the cost of re-used parts).
⇒ 1/3 of the cost of the project can be saved by re-using parts of BaBar and PEP-II.

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.
- If positive, will discuss the project with ECFA and CERN strategy group.
  - Collaboration will start to form O(May ‘08).
  - R&D will continue for O(2 years).
  - Technical Design Reports finalised O(2 years).
  - Construction T_0 = O(2 years).
- Physics Workshop in Valencia (last week) [Jan ‘08].
- Detector Workshop at SLAC next month [Feb ’08].

Summary

Particle Physics Landscape circa 2015



Conclusion

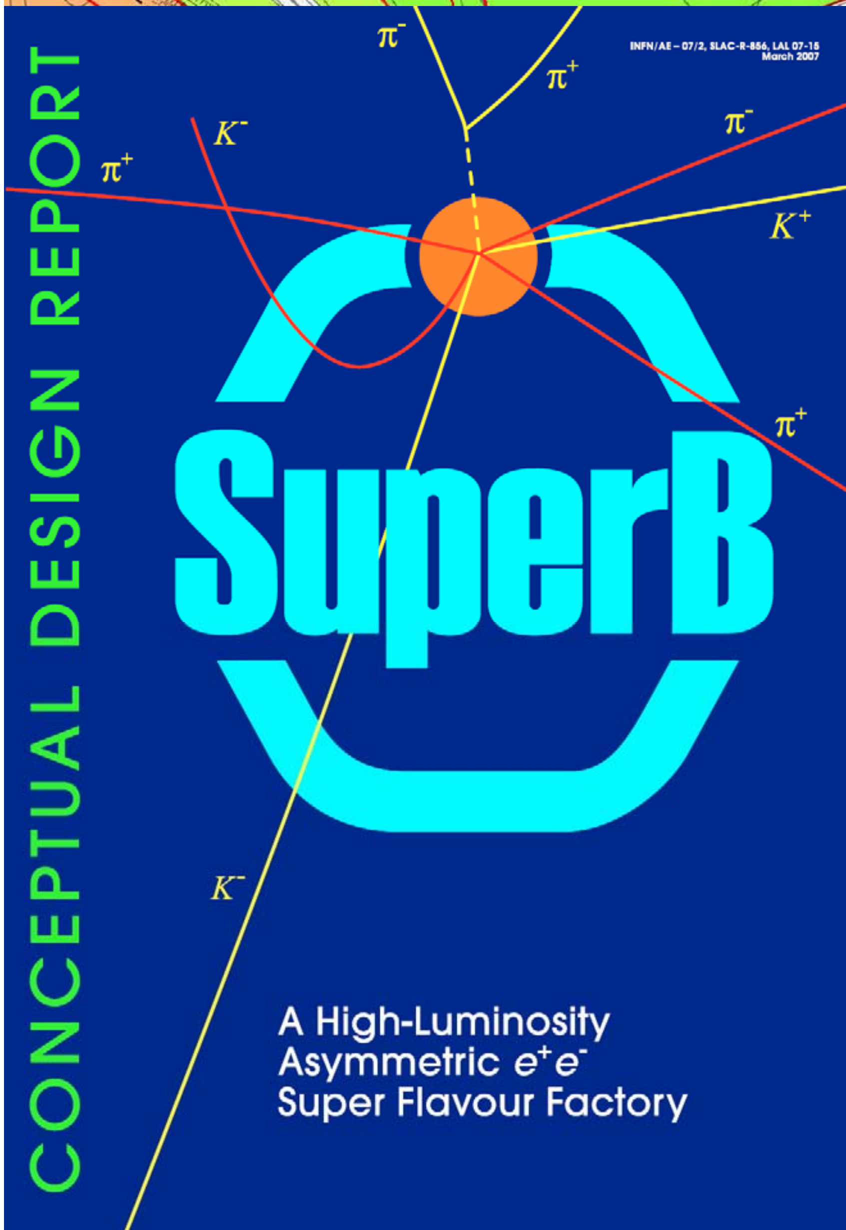
- The SuperB programme has a rich physics case.
  - Much more than I've had time to cover in this seminar!
  - See the 'Physics' section of the SuperB CDR for details.

- 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!
  - CPV in τ decays to be explored!

- Probe:
  - flavour structure of new physics found at the LHC.
  - $\geq O$(TeV) indirect NP search capability using rare decays.
  - Search for low energy NP effects (light H, Dark Matter)
  - Test Fundamental symmetries (Lepton universality, CPT)

- Many important measurements unique to SuperB.

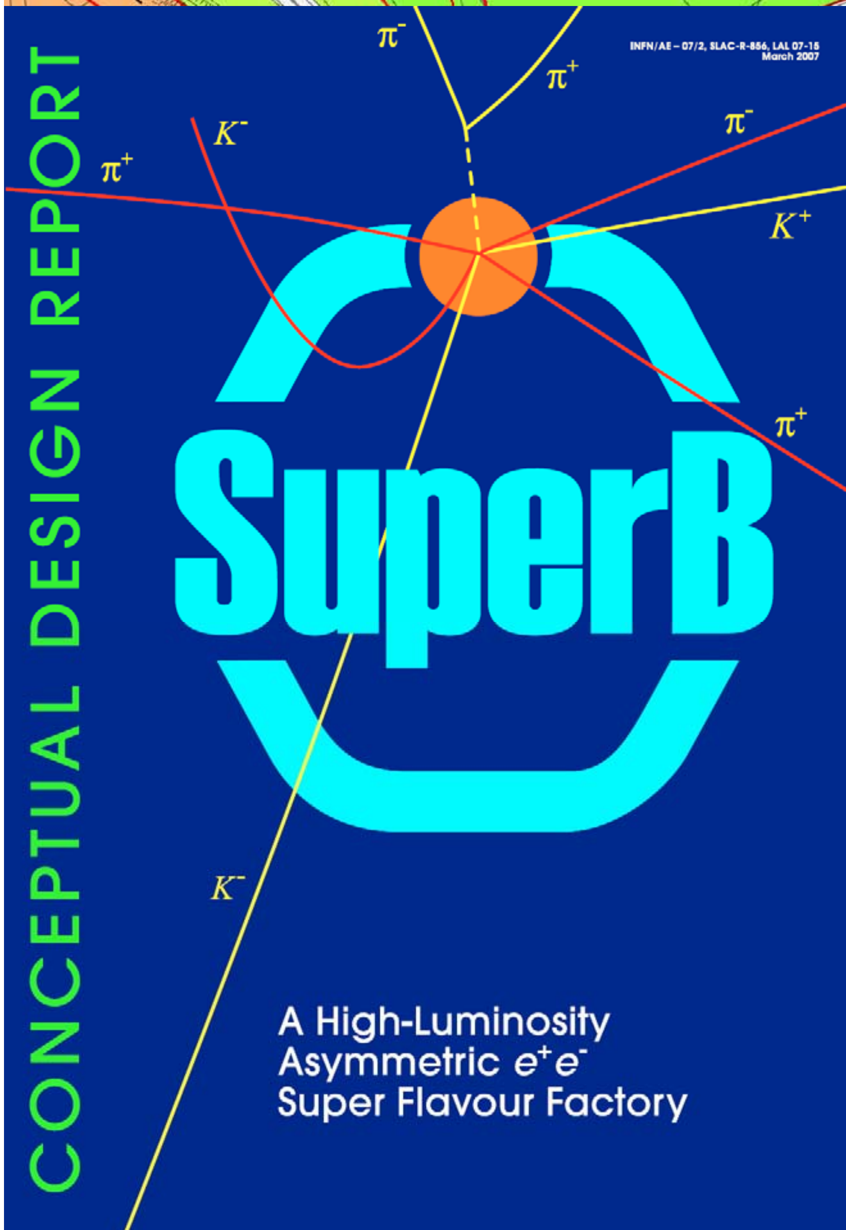
- Complementarity with the LHC high energy frontier and flavour programmes.
  - Need a SuperB to start decoding what new physics scenarios are realistic in the LHC era.



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/

UK Signatories from:

Birmingham University
Brunel University
Edinburgh University
Imperial College London
IPPP Durham
Liverpool University [HEP + Accel.]
Manchester University
Queen Mary University of London
Royal Holloway University of London
Rutherford Appleton Laboratory
Warwick University

[Over 300 names in all]

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

Additional Material

Super B factory and Super LHCb:

Sensitivity Comparison ~2020

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

•LHCb
•Super B

Preliminary

B_s time dependent analysis only accessible to LHCB

Common

No IP, Neutrals, ν, only accessible to SuperB

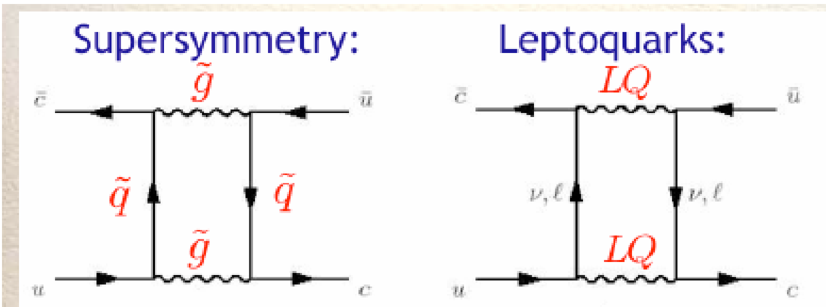
SuperB numbers from M Hazumi - Flavour in LHC era workshop;
LHCb numbers from Muheim
CDF numbers from Ristori

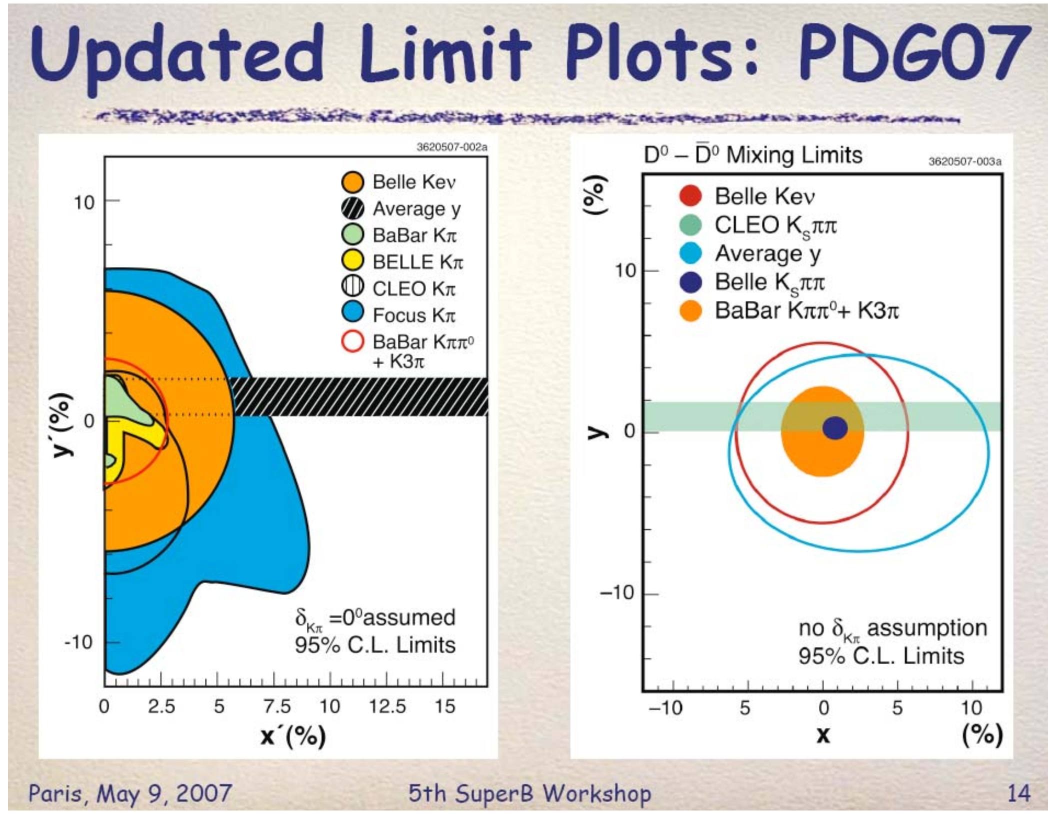
Tevatron is an important Player over the next few years.

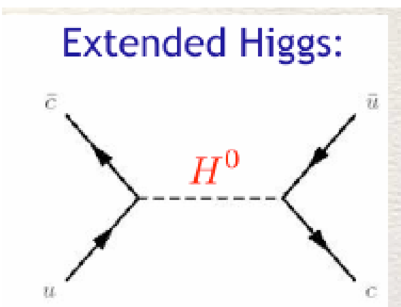
Can compare on common B physics topics
Both experiments have complimentary programmes beyond this.

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

† Systematics limited
* Theoretically limited.

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°

See Super B workshop V summary talks by

K. George (time-dependent S / β measurements)

A. Bondar (γ measurements)

A. Bevan (α measurements)

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})
$\|V_{cb}\|$ (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

The physics programme

The physics programme

The physics programme

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

From SLAC-R-709

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.*

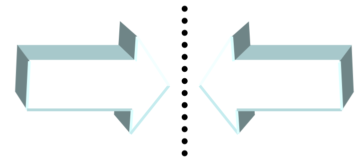
	B_d unitarity			Rare Decays		
	closure	$+\epsilon_K$	$+\Delta m(B_s)$	$A_{CP}^{\text{mix}}(B \to \phi K_S^0)$	$A_{CP}^{\text{mix}}(B \to M_s \gamma)$	$A_{CP}^{\text{dir}}(B \to X_s \gamma)$
mSUGRA	closed	-	-	-	-	-
SU(5) SUSY GUT (degenerate RHN)	closed	√	-	-	-	-
SU(5) SUSY GUT (non-deg. RHN)	closed	-	√	√	√	-
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 ± signs represent the sign of the corresponding observable.*

	LL	RR	LR	RL
(δ_{23}^d)	$O(1)$	$O(1)$	$O(10^{-2})$	$O(10^{-2})$
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
$A_{CP}^{b \to s\gamma}$	+, few %	SM-like	+, $\mathcal{O}(10\%)$	SM-like
Δm_{B_s}	can be large	can be large	SM-like	SM-like

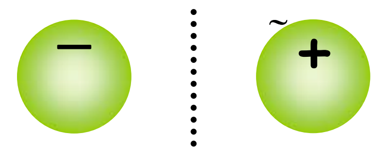
Aside: $\mathcal{P}$, $\mathcal{C}$ and $\mathcal{T}$

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



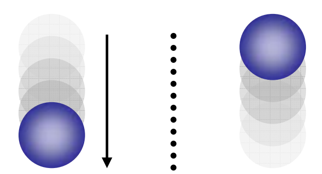
$$\mathbf{r} \rightarrow -\mathbf{r}$$
$$\mathbf{p} \rightarrow -\mathbf{p}$$
$$\mathbf{L} \rightarrow \mathbf{L}$$

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



$$e^- \rightarrow e^+$$
$$\gamma \rightarrow \gamma$$

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



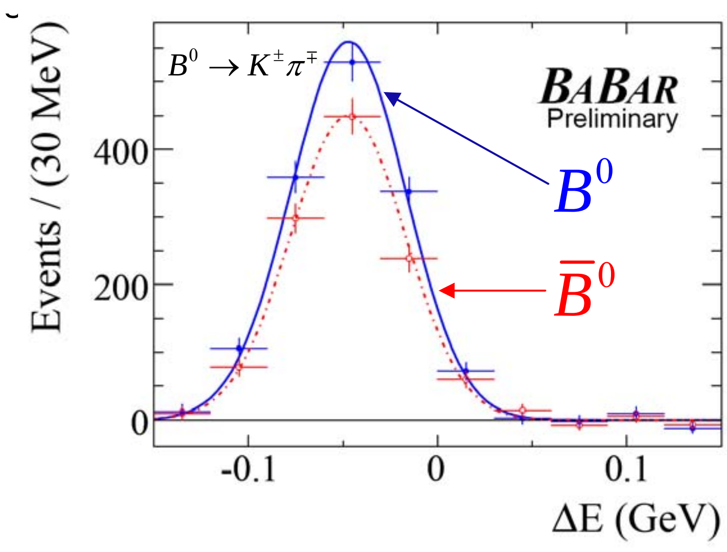
$$t \rightarrow -t$$

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. $B^0 \to K\pi$)



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

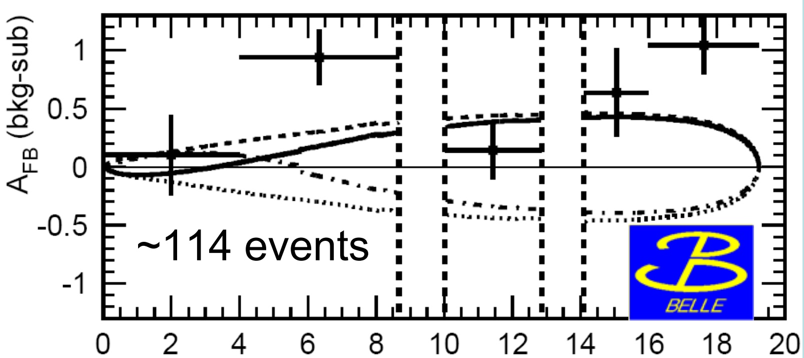
hep-ex/0607106

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. $B^0 \to K\pi$)
  – As a function of some kinematic variable (e.g. $b \to sll$)

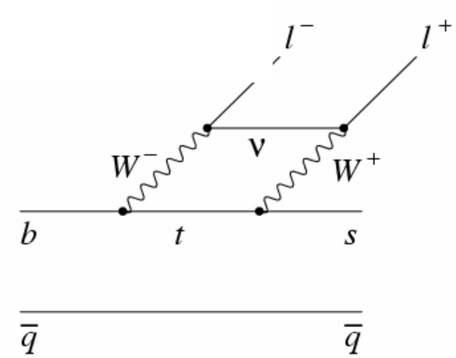


Phys.Rev.Lett. 96 (2006) 251801 q^2 GeV^2/c^2

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 $C_9 C_{10}$
Dot-Dashed line = sign flip both

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



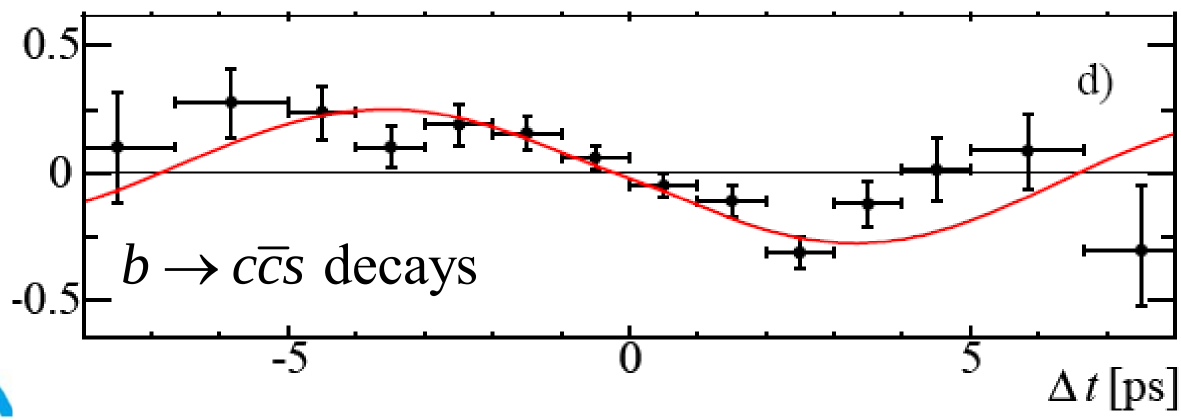
Observables:
f_L, CP asymmetries, A_{FB} and $\mathcal{B}(se^+e^-)/\mathcal{B}(s\mu^+\mu^-)$

Testing Flavour Structure

- 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. $B^0 \to K\pi$)
  – 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.