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]


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

THE ENERGY FRONTIER (Discoveries)

Hadron Colliders
- (top quark) Tevatron
- (W⁺, Z bosons) SppS
- (Nv=3) LEP II
- SLC, LEP
- PETRA, PEP (gluon)
- TRISTAN
- ISR
- CESR
- SPEAR II (charm quark, τ lepton)
- ADONE

e+e− Colliders

THE LUMINOSITY FRONTIER

Peak Luminosity trends in last 30 years

- KEKB
- PEP II
- TRISTAN
- CESR
- PEP
- LEP
- HERA
- DORIS
- SPEAR
- SppS
- ISR

Year of First Physics

Year
History of the Frontiers

• Signs of new physics seen first in flavour, before confirmation/discovery at the energy frontier
  – suppression of FCNC
    • GIM → discovery of charm
  – CP violation
    • CKM → third generation
• No clear sign of NP in current experiments (though some hints exist)
  ⇒ 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 \((m_\nu/m_W)\)

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

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

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

$$\alpha(B \rightarrow \pi \pi, \rho \pi, \rho \rho) \quad \gamma(B \rightarrow DK) \quad \text{CKM fits}$$

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

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

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

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

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

$$B(\mu \rightarrow e \gamma) \quad B(\mu \rightarrow e^+ e^- e^+) \quad (g-2)_{\mu} \quad \mu \quad \text{EDM}$$

$$B(\tau \rightarrow \mu \gamma) \quad B(\tau \rightarrow e \gamma) \quad B(\tau^+ \rightarrow l^+ l^- l^+) \quad \tau \quad \text{CPV} \quad \tau \quad \text{EDM}$$

$$B(D_{(s)}^{+} \rightarrow l^+ \nu) \quad \chi_D \quad \gamma_D \quad \text{charm \ CPV}$$

... 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

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

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

$$B(\mu \rightarrow e \gamma) \quad B(\mu \rightarrow e^+ e^- e^+) \quad (g-2)_\mu \quad \mu \text{ EDM}$$

$$B(\tau \rightarrow \mu \gamma) \quad B(\tau \rightarrow e \gamma) \quad B(\tau^+ \rightarrow l^+ l^- l^+) \quad \tau \text{ CPV} \quad \tau \text{ EDM}$$

$$B(D_{(s)}^+ \rightarrow l^+ \nu) \quad \mathbf{X_D} \quad \mathbf{Y_D} \quad \text{charm CPV}$$
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?

**LHC new physics discovery?**

**YES**
- Need to measure flavour parameters that cannot be studied at LHC

**NO**
- Need alternative way to search for new physics beyond the LHC scale

SuperB
Couplings and Scales

\[ L = L_{SM} + \sum_{k=1}^{\Lambda} \left( \sum_{i} c_{i}^{k} Q_{i}^{(k+4)} \right) / \Lambda^{k} \]

- New physics effects are governed by:
  - new physics scale \( \Lambda \)
  - effective flavour-violating couplings \( c_{i} \)
    - couplings may have a particular pattern (symmetries)
    - coupling strengths can vary (different interactions)

- If \( \Lambda \) known from LHC, measure \( c_{i} \)
- If \( \Lambda \) not known, measure \( c_{i} / \Lambda \)
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
    
  – 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 $\beta$
    • 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 $\sim$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

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

<table>
<thead>
<tr>
<th>Process</th>
<th>Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>( B(\tau \rightarrow \mu \gamma) )</td>
<td>( 2 \times 10^{-9} )</td>
</tr>
<tr>
<td>( B(\tau \rightarrow e \gamma) )</td>
<td>( 2 \times 10^{-9} )</td>
</tr>
<tr>
<td>( B(\tau \rightarrow \mu \mu \mu) )</td>
<td>( 2 \times 10^{-10} )</td>
</tr>
<tr>
<td>( B(\tau \rightarrow eee) )</td>
<td>( 2 \times 10^{-10} )</td>
</tr>
<tr>
<td>( B(\tau \rightarrow \mu \eta) )</td>
<td>( 4 \times 10^{-10} )</td>
</tr>
<tr>
<td>( B(\tau \rightarrow e \eta) )</td>
<td>( 6 \times 10^{-10} )</td>
</tr>
<tr>
<td>( B(\tau \rightarrow \ell K_S^0) )</td>
<td>( 2 \times 10^{-10} )</td>
</tr>
</tbody>
</table>

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 $\tau \rightarrow \mu \mu \mu$

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

Monte Carlo simulation of $5\sigma$ observation of $\tau \rightarrow \mu \gamma$ at SuperB
Leptonic B Decays
Crucial for MFV models with large tan β (and MSSM)

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

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

<table>
<thead>
<tr>
<th>Observable</th>
<th>$B$ Factories (2 ab$^{-1}$)</th>
<th>SuperB (75 ab)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mathcal{B}(B \rightarrow \tau\nu)$</td>
<td>20%</td>
<td>4% (†)</td>
</tr>
<tr>
<td>$\mathcal{B}(B \rightarrow \mu\nu)$</td>
<td>visible</td>
<td>5%</td>
</tr>
<tr>
<td>$\mathcal{B}(B \rightarrow D\tau\nu)$</td>
<td>10%</td>
<td>2%</td>
</tr>
</tbody>
</table>

$B = B_{SM} \left( 1 - \tan^2 \beta \frac{M_B^2}{M_H^2} \right)$
**Hadronic b → s Penguins**

Current B factory hot topic

\[ \sin(2\beta_{\text{eff}}) \equiv \sin(2\phi_{1\text{eff}}) \]

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<table>
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<th><strong>B Factories (2 ab(^{-1}))</strong></th>
<th><strong>SuperB</strong></th>
</tr>
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<tbody>
<tr>
<td>(S(\phi K^0))</td>
<td>0.13</td>
<td>0.02 (*) [0.030]</td>
</tr>
<tr>
<td>(S(\eta' K^0))</td>
<td>0.05</td>
<td>0.01 (*) [0.020]</td>
</tr>
<tr>
<td>(S(K_S^0 K^0_S K^0_S))</td>
<td>0.15</td>
<td>0.02 (*) [0.037]</td>
</tr>
<tr>
<td>(S(K_S^0 K^0_S))</td>
<td>0.15</td>
<td>0.02 (*) [0.042]</td>
</tr>
<tr>
<td>(S(\omega K^0_S))</td>
<td>0.17</td>
<td>0.03 (*)</td>
</tr>
<tr>
<td>(S(f_0 K^0_S))</td>
<td>0.12</td>
<td>0.02 (*)</td>
</tr>
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</table>

(*) theoretical limited
Correlations Distinguish Models


\[ A_{CP}(b \rightarrow s \gamma) \]

SuperB can reach \(~0.4\%\) precision

\[ S(B^0 \rightarrow K_S \pi^0 \gamma) \]

SuperB can reach \(2\%\) precision

Plots show parameter scans in four different SUSY breaking schemes:
- mSUGRA
- SU(5) + \(\nu_R\) degenerate
- U(2) flavour symmetry
- SU(5) + \(\nu_R\) non-degenerate
## Estimated Sensitivities

<table>
<thead>
<tr>
<th>Observable</th>
<th>( B \text{ Factories} (2 \text{ ab}^{-1}) )</th>
<th>( \text{Super}B (75 \text{ ab}^{-1}) )</th>
</tr>
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<tbody>
<tr>
<td>( \sin(2\beta) \ (J/\psi K^0) )</td>
<td>0.018</td>
<td>0.005 (†)</td>
</tr>
<tr>
<td>( \cos(2\beta) \ (J/\psi K^{*0}) )</td>
<td>0.30</td>
<td>0.05</td>
</tr>
<tr>
<td>( \sin(2\beta) \ (Dh^0) )</td>
<td>0.10</td>
<td>0.02</td>
</tr>
<tr>
<td>( \cos(2\beta) \ (Dh^0) )</td>
<td>0.20</td>
<td>0.04</td>
</tr>
<tr>
<td>( S(J/\psi\pi^0) )</td>
<td>0.10</td>
<td>0.02</td>
</tr>
<tr>
<td>( S(D^+D^-) )</td>
<td>0.20</td>
<td>0.03</td>
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<td>0.02 (*)</td>
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<tr>
<td>( S(K^0_s\pi^0) )</td>
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<tr>
<td>( \gamma \ (B \to DK, D \to CP \text{ eigenstates}) )</td>
<td>( \sim 15^\circ )</td>
<td>2.5°</td>
</tr>
<tr>
<td>( \gamma \ (B \to DK, D \to \text{suppressed states}) )</td>
<td>( \sim 12^\circ )</td>
<td>2.0°</td>
</tr>
<tr>
<td>( \gamma \ (B \to DK, D \to \text{multibody states}) )</td>
<td>( \sim 9^\circ )</td>
<td>1.5°</td>
</tr>
<tr>
<td>( \gamma \ (B \to DK, \text{combined}) )</td>
<td>( \sim 6^\circ )</td>
<td>1–2°</td>
</tr>
<tr>
<td>( \alpha \ (B \to \pi\pi) )</td>
<td>( \sim 16^\circ )</td>
<td>3°</td>
</tr>
<tr>
<td>( \alpha \ (B \to \rho\rho) )</td>
<td>( \sim 7^\circ )</td>
<td>1–2° (*)</td>
</tr>
<tr>
<td>( \alpha \ (B \to \rho\pi) )</td>
<td>( \sim 12^\circ )</td>
<td>2°</td>
</tr>
<tr>
<td>( \alpha \ (\text{combined}) )</td>
<td>( \sim 6^\circ )</td>
<td>1–2° (*)</td>
</tr>
<tr>
<td>( 2\beta + \gamma \ (D^{(*)}\pm\pi^\mp, D^\pm K^0_s\pi^\mp) )</td>
<td>20°</td>
<td>5°</td>
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<td>10%</td>
<td>2%</td>
</tr>
<tr>
<td>( B(B \to \rho\gamma) )</td>
<td>15%</td>
<td>3% (†)</td>
</tr>
<tr>
<td>( B(B \to \omega\gamma) )</td>
<td>30%</td>
<td>5%</td>
</tr>
<tr>
<td>( A_{CP}(B \to K^{*}\gamma) )</td>
<td>0.007 (†)</td>
<td>0.004 († *)</td>
</tr>
<tr>
<td>( A_{CP}(B \to \rho\gamma) )</td>
<td>( \sim 0.20 )</td>
<td>0.05</td>
</tr>
<tr>
<td>( A_{CP}(b \to s\gamma) )</td>
<td>0.012 (†)</td>
<td>0.004 (†)</td>
</tr>
<tr>
<td>( A_{CP}(B \to (s+d)\gamma) )</td>
<td>0.03</td>
<td>0.006 (†)</td>
</tr>
<tr>
<td>( S(K^0_s\pi^0\gamma) )</td>
<td>0.15</td>
<td>0.02 (*)</td>
</tr>
<tr>
<td>( S(\rho^0\gamma) )</td>
<td>possible</td>
<td>0.10</td>
</tr>
<tr>
<td>( A_{CP}(B \to K^*\ell\ell) )</td>
<td>7%</td>
<td>1%</td>
</tr>
<tr>
<td>( A^{FB}(B \to K^*\ell\ell)s_0 )</td>
<td>25%</td>
<td>9%</td>
</tr>
<tr>
<td>( A^{FB}(B \to X_s\ell\ell)s_0 )</td>
<td>35%</td>
<td>5%</td>
</tr>
<tr>
<td>( B(B \to K\nu\bar{\nu}) )</td>
<td>visible</td>
<td>20%</td>
</tr>
<tr>
<td>( B(B \to \pi\nu\bar{\nu}) )</td>
<td>–</td>
<td>possible</td>
</tr>
</tbody>
</table>

Still only a few measurements systematics (†) or theoretically (*) limited
Physics Beyond the Y(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 $\tau$ 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
Running at the Y(5S)

• Belle & CLEO have demonstrated potential for 
  \(e^+e^- \rightarrow Y(5S) \rightarrow B_s^*(*)B_s^*(*)\)

• Some important channels, such as \(B_s \rightarrow \gamma\gamma\), 
  \(A_{SL}(B_s)\) are unique to SuperB

• Problem: cannot resolve fast \(\Delta m_s\) oscillations
  - retain some sensitivity to \(\varphi_s\), since \(\Delta \Gamma_s \neq 0\)

\[
\Gamma_{\bar{B}_s \rightarrow f}(\Delta t) + \Gamma_{B_s \rightarrow f}(\Delta t) = N e^{-\frac{\Delta \tau}{\tau(B_s)}} \left[ \cosh\left(\frac{\Delta \Gamma_s \Delta t}{2}\right) - \frac{2\text{Re}(\lambda_f)}{1 + |\lambda_f|^2} \sinh\left(\frac{\Delta \Gamma_s \Delta t}{2}\right) \right].
\]

\[
(1.24)
\]

cf. D0 untagged measurement of \(\varphi_s\)
SuperB: How?

• Physics case for Super Flavour Factory is compelling

• Luminosity should be above $10^{36}/\text{cm}^2/\text{s}$
  – 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 \(~30 \text{ MW}\)
The Crab Waist

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

<table>
<thead>
<tr>
<th></th>
<th>Cross section</th>
<th>Evt/bunch xing</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiative Bhabha</td>
<td>~340 mbarn (Eγ/Ebeam &gt; 1%)</td>
<td>~680</td>
<td>0.3THz</td>
</tr>
<tr>
<td>e⁺e⁻ pair production</td>
<td>~7.3 mbarn</td>
<td>~15</td>
<td>7GHz</td>
</tr>
<tr>
<td>Elastic Bhabha</td>
<td>O(10⁻⁵) mbarn (Det. acceptance)</td>
<td>~20/Million</td>
<td>10KHz</td>
</tr>
<tr>
<td>γ (4S)</td>
<td>O(10⁻⁶) mbarn</td>
<td>~2/million</td>
<td>1 KHz</td>
</tr>
</tbody>
</table>
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
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 country:
- Australia, 1
- Canada, 7
- France, 21
- Germany, 11
- Israel, 2
- Italy, 137
- Japan, 4
- Norway, 1
- ROC, 3
- Russia, 18
- Slovenia, 5
- Spain, 12
- Switzerland, 4
- UK, 24
- USA, 70

Signatures breakdown by type:
- Experimentalists 75%
- Theorists 13%
- Accelerator physicists 12%

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
CTD includes a cost estimate

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

<table>
<thead>
<tr>
<th></th>
<th>EDIA [my]</th>
<th>Labor [my]</th>
<th>M&amp;S [k€]</th>
<th>Replacement value [k€]</th>
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</thead>
<tbody>
<tr>
<td>Accelerator</td>
<td>452</td>
<td>291</td>
<td>191,166</td>
<td>126,330</td>
</tr>
<tr>
<td>Site</td>
<td>119</td>
<td>138</td>
<td>105,700</td>
<td>0</td>
</tr>
<tr>
<td>Detector</td>
<td>283</td>
<td>156</td>
<td>40,747</td>
<td>46,471</td>
</tr>
</tbody>
</table>

Possible savings from reusing other hardware not yet considered in detail.
### CDR includes a cost estimate

<table>
<thead>
<tr>
<th>WBS</th>
<th>Item</th>
<th>EDIA mm</th>
<th>Labor mm</th>
<th>M&amp;S kEuro</th>
<th>Rep.Val. kEuro</th>
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<td>Magnet and support system</td>
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<tr>
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<td>Vacuum system</td>
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<td>520</td>
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<td>14200</td>
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<td>RF system</td>
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<td>304</td>
<td>22300</td>
<td>60000</td>
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<tr>
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<td>Interaction region</td>
<td>370</td>
<td>478</td>
<td>10950</td>
<td>0</td>
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<tr>
<td>1.6</td>
<td>Controls, Diagnostics, Feedback</td>
<td>963</td>
<td>648</td>
<td>12951</td>
<td>8750</td>
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<td>1.7</td>
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<td>252</td>
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<td>2.0</td>
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<td>Tunnel and Support Buildings</td>
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<td>620</td>
<td>74000</td>
<td>0</td>
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### CDR includes a cost estimate

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<tr>
<td>1</td>
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<td>Tracker (SVT + L0 MAPS)</td>
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<td>348</td>
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<td>1.1.1</td>
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<td>L0 Striplet option</td>
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<td>33</td>
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<td>1.1.3</td>
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<td>DCH</td>
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<td>6728</td>
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<td>DIRC barrel - Pixilated PMTs</td>
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<td>152</td>
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<td>6728</td>
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<td>1.3.2</td>
<td>DIRC barrel - Focusing DIRC</td>
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<td>54</td>
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<td>1545</td>
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<td>1.A</td>
<td>Project Management</td>
<td>720</td>
<td>0</td>
<td>180</td>
<td>0</td>
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</tbody>
</table>

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
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 reach already very high luminosity ($\sim 10^{34}\text{ s}^{-1}\text{ cm}^{-2}$). To increase of $\sim$ 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 ($\ldots$) 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

Both cases have the same luminosity,
(2) has longer bunch and smaller $\sigma_x$

With large crossing angle $X$ and $Z$
quantities are swapped: Very important!!!
1) Large Piwinski angle - high $\sigma_z$ and collision angle. (Slight L decrease) ⇒ 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 $\beta_y^*$ (300 $\mu$m) - so little $\sigma_y^*$ (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)
Vertical waist has to be a function of $x$:
Crabbed waist realized with a sextupole in phase with the IP in X and at $\pi/2$ in Y

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

Why? Crabbed waist removes betatron 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 $\pi/2$ in Y

....and slight increase of the luminosity.
• But where is the real gain?

<table>
<thead>
<tr>
<th></th>
<th>PEPII</th>
<th>KEKB</th>
<th>SuperB</th>
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<tbody>
<tr>
<td>current</td>
<td>2.5 A</td>
<td>1.7 A</td>
<td>2.3 A</td>
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<tr>
<td>betay</td>
<td>10 mm</td>
<td>6 mm</td>
<td>0.3 mm</td>
</tr>
<tr>
<td>betax</td>
<td>400 mm</td>
<td>300 mm</td>
<td>20 mm</td>
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<tr>
<td>Emity (sigmay)</td>
<td>23 nm (~100µm)</td>
<td>~ the same (~80µm)</td>
<td>1.6 nm (~6µm)</td>
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<td>y/x coupling</td>
<td>0.5-1 % (~6µm)</td>
<td>0.1 % (~3µm)</td>
<td>0.25 % (0.035µm)</td>
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<td>Bunch length</td>
<td>10 mm</td>
<td>6 mm</td>
<td>6 mm</td>
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<tr>
<td>Tau l/t</td>
<td>16/32 msec</td>
<td>~ the same</td>
<td>16/32 msec</td>
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<tr>
<td>ζy</td>
<td>0.07</td>
<td>0.1</td>
<td>0.16</td>
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<tr>
<td>L</td>
<td>$1.2 \times 10^{34}$</td>
<td>$1.7 \times 10^{34}$</td>
<td>$1 \times 10^{36}$</td>
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<tr>
<td></td>
<td>1</td>
<td>2.4</td>
<td>3.4</td>
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<tr>
<td>------------------------</td>
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<td>Luminosity x 10^{-36}</td>
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<td>Circumference (m)</td>
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<td>Revolution frequency (MHz)</td>
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<td>Momentum spread</td>
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<td>1.0E-03</td>
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<td>Momentum compaction</td>
<td>1.8E-04</td>
<td>3.0E-04</td>
<td>1.8E-04</td>
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<td>Rf Voltage (MV)</td>
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<td>18</td>
<td>7.5</td>
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<td>Energy loss/turn (MeV)</td>
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<td>3.3</td>
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<tr>
<td>Number of bunches</td>
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<td>3466</td>
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<tr>
<td>Particles per bunch x 10^{10}</td>
<td>6.16</td>
<td>3.52</td>
<td>5.34</td>
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<td>Beam current (A)</td>
<td>2.28</td>
<td>1.30</td>
<td>3.95</td>
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<tr>
<td>Beta y^*(mm)</td>
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<td>0.30</td>
<td>0.20</td>
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<td>Beta x^*(mm)</td>
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<td>20</td>
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<td>Emit y (pmr)</td>
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<td>2</td>
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<td>Emit x (nmr)</td>
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<td>Sigma y^*(microns)</td>
<td>0.035</td>
<td>0.035</td>
<td>0.020</td>
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<td>Sigma x^*(microns)</td>
<td>5.657</td>
<td>5.657</td>
<td>4.000</td>
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<td>Bunch length (mm)</td>
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<td>Full Crossing angle (mrad)</td>
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<tr>
<td>Wigglers (#)</td>
<td>4</td>
<td>2</td>
<td>4</td>
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<td>Damping time (trans/long)(ms)</td>
<td>32/16</td>
<td>32/16</td>
<td>25/12.5</td>
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<td>Luminosity lifetime (min)</td>
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<td>5.9</td>
<td>7.4</td>
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<td>Touschek lifetime (min)</td>
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<tr>
<td>Effective beam lifetime (min)</td>
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<td>5.1</td>
<td>2.1</td>
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<tr>
<td>Injection rate pps (100%)</td>
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<td>2.0E+11</td>
<td>1.5E+12</td>
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<tr>
<td>Tune shifts (x/y) (from formula)</td>
<td>0.004/0.17</td>
<td>0.004/0.17</td>
<td>0.007/0.16</td>
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<tr>
<td>RF Power (MW)</td>
<td>17</td>
<td>35</td>
<td>44</td>
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</tbody>
</table>
Table 3-2. Comparison between parameters for the SuperB storage rings and the ILC damping rings.

<table>
<thead>
<tr>
<th>Unit</th>
<th>SuperB LER</th>
<th>SuperB HER</th>
<th>ILC DRs</th>
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<tbody>
<tr>
<td>Beam energy (GeV)</td>
<td>4</td>
<td>7</td>
<td>5</td>
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<tr>
<td>Circumference (m)</td>
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<td>2249</td>
<td>6695</td>
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<td>Particles per bunch</td>
<td>$6.16 \times 10^{10}$</td>
<td>$3.52 \times 10^{10}$</td>
<td>$2 \times 10^{10}$</td>
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<tr>
<td>Number of bunches</td>
<td>1733</td>
<td>1733</td>
<td>2767</td>
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<td>Average current (A)</td>
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<td>Horizontal emittance (nm)</td>
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<td>1.6</td>
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<td>Vertical emittance (pm)</td>
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<td>Bunch length (mm)</td>
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<td>9</td>
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<td>Energy spread (%)</td>
<td>0.084</td>
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<td>Momentum compaction</td>
<td>$1.8 \times 10^{-4}$</td>
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<td>Transverse damping time (ms)</td>
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<td>RF voltage (MV)</td>
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<tr>
<td>RF frequency (MHz)</td>
<td>476</td>
<td>476</td>
<td>650</td>
</tr>
</tbody>
</table>
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

\[ \lambda \text{ vs } P_t \]

Pt accept. @ 1.5 T, 1.2 cm

~Angular acceptance
We have an IR design coping with main BKG source

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

We have an IR design coping with main BKG source

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/BAabar components

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<td>156</td>
<td>40,747</td>
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**Totals**  
337,613 k€  
172,801 k€

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

MORE THAN AN ORDER OF MAGNITUDE DIFFERENCE!

**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)

**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
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
J-PARC $\nu$, n construction

PF upgrade

PF

J-PARC $\nu$, K experiment

J-PARC n, $\mu$ experiment

Budget transfer

ERL prototype

ERL construction

Budget transfer

KEKB

ILC R&D

ILC construction

Budget transfer

Option 1

KEKB

KEKB upgrade

KEKB upgrade experiment

Option 1'

ILC R&D

ILC construction

Upgrade

Experiment
New Physics Sensitivity in MFV

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

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

Today
\[ \Lambda_{\text{(MFV)}} > 2.3 \Lambda_0 \text{ @95C.L.} \]
NP masses >200GeV

SuperB
\[ \Lambda_{\text{(MFV)}} > \sim 6 \Lambda_0 \text{ @95C.L.} \]
NP masses >600GeV

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

Today's central values with SuperB precision

Real vs. imaginary parts of mass-insertion parameter \( \delta_{13}^{\alpha} \)

\( \Delta m_d \) in magenta
\( A_{SL} \) in green
\( \beta \) in cyan
All in blue

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

How to read this table, two examples.

At SuperB we can set a limit on the coupling at

The natural coupling would be 1

\[ \delta_{LL} (LL \gg RR) \rightarrow \text{we can test scale up to} \quad \frac{350\text{GeV}}{1.8 \times 10^{-2}} \sim 20\text{TeV} \]

\[ \delta_{LL} (LL \sim RR) \rightarrow \text{we can test scale up to} \quad \frac{350\text{GeV}}{1.3 \times 10^{-3}} \sim 270\text{TeV} \]

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

All these numbers are a factor \( \sim 10 \) better than present bounds.
Large New Physics Contributions Excluded

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

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

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

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

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

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

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

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

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

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

$B(D^0 \to l^+ l^-), B(D \to h l^+ l^-), B(D_{(s)}^+ \to l^+ \nu), \chi_D, Y_D$

charm CPV