Why a SuperB Flavour Factory?

Marcello A. Giorgi

INFN & Università di Pisa

9-10 May 2006
Success of BFactories

Original mission

1) Search for CP violation in B meson decays as predicted in Standard Model
2) Measure precisely at this low energy scale enough quantities to impose constraints on the Standard Model parameters

CP in b sector has been established by BaBar and Belle (2001)

TRY to open windows on new Physics beyond Standard Model
More precise CKM measurements, Rare B decays, Charm study, Tau rare decays.
3 ways to CP violation

CPV in decay:

\[
A_{CP,f/\bar{f}} = \frac{\Gamma(i \to f) - \Gamma(i \to \bar{f})}{\Gamma(i \to f) + \Gamma(i \to \bar{f})} = \frac{|A_f^- / A_f|^2 - 1}{|A_f^- / A_f|^2 + 1}
\]

\[|A_f^- / A_f| \neq 1\]

CPV in mixing:

\[
A_{SL}(t) = \frac{d\Gamma/\text{d}t \left( \bar{P}_\text{phys}^0 \to l^+ X \right) - d\Gamma/\text{d}t \left( P_\text{phys}^0 \to l^- X \right)}{d\Gamma/\text{d}t \left( \bar{P}_\text{phys}^0 \to l^+ X \right) + d\Gamma/\text{d}t \left( P_\text{phys}^0 \to l^- X \right)} = \frac{1 - |q/p|^4}{1 + |q/p|^4}
\]

\[|q/p| \neq 1\]

CPV in the interference decay-mixing:

For example: decays to CP eigenstates \( f_{CP} \)

\[
\lambda_f = \frac{q}{p} \frac{\bar{A}_f}{A_f}
\]

\[
A_{f_{\text{CP}}}(t) = \frac{d\Gamma/\text{d}t \left( \bar{P}_\text{phys}^0 \to f_{CP} \right) - d\Gamma/\text{d}t \left( P_\text{phys}^0 \to f_{CP} \right)}{d\Gamma/\text{d}t \left( \bar{P}_\text{phys}^0 \to f_{CP} \right) + d\Gamma/\text{d}t \left( P_\text{phys}^0 \to f_{CP} \right)}
\]

\[\Im(m(\lambda_f)) \neq 0\]
Observables: “direct” CP asymmetry

\[
A_1 = |A_1| \quad i \rightarrow f
\]

\[
A_2 = |A_2| e^{i\delta} e^{i\phi} \quad \delta \rightarrow \delta \quad \text{(CP-conserving)}
\]

\[
\phi \rightarrow -\phi \quad \text{(CP-violating)}
\]

\[
A_{CP,f/\bar{f}} \equiv \frac{\Gamma(i \rightarrow f) - \Gamma(i \rightarrow \bar{f})}{\Gamma(i \rightarrow f) + \Gamma(i \rightarrow \bar{f})} \propto \sin \Phi \sin \delta
\]

Time-integrated “direct” CP asymmetry requires two amplitudes and \( \delta \neq 0 \):

\[
A = A_1 + A_2
\]

\[
\bar{A} = A_1 + \bar{A}_2 \neq A
\]
\( A_{\text{SL}}, |q/p|, \varepsilon_B \) are related (CPV in mixing)

\( A_{\text{SL}} \) observable and CP parameters:

\[
A_{\text{SL}} \equiv \frac{P(B^0 \rightarrow B^0) - P(B^0 \rightarrow \overline{B}^0)}{P(B^0 \rightarrow B^0) + P(B^0 \rightarrow \overline{B}^0)}
\]

\[A_{\text{SL}} = \frac{\Gamma_{Y(4S)\rightarrow l^+ l^+} - \Gamma_{Y(4S)\rightarrow l^- l^-}}{\Gamma_{Y(4S)\rightarrow l^+ l^+} + \Gamma_{Y(4S)\rightarrow l^- l^-}} = \frac{|p/q|^2 - |q/p|^2}{|p/q|^2 + |q/p|^2} = \frac{1 - |q/p|^4}{1 + |q/p|^4} \Rightarrow 4 \text{Re} \varepsilon_B \]

\[
\varepsilon_B = \frac{p - q}{p + q} \Rightarrow \frac{q}{p} = \frac{1 - \varepsilon_B}{1 + \varepsilon_B}
\]

\[
\left| \frac{q}{p} \right| = 4 \sqrt{\frac{1 - A_{\text{SL}}}{1 + A_{\text{SL}}}}
\]

at the B-factories

equivalent to \( \varepsilon_K \) in the K system

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Time dependent rate, flavor mixing and CP, T, CPT

Time dependent rate:
\[ dN \propto \exp(-|\Delta t|/\tau_B) \left( 1 \pm D \left( S \sin(\Delta m \Delta t) - C \cos(\Delta m \Delta t) \right) \right) \otimes R \]

- \( D \) is the mis-tag dilution
- \( R \) is the time resolution

\[ \lambda = \eta_{cp} \frac{q}{p} \frac{\overline{A}_{cp}}{A_{cp}} \]

\[ \frac{q}{p} \neq 1 \implies \text{CP and T Violation in mixing} \]

\[ |\frac{q}{p}| \approx 4\pi \frac{m_e^2}{m_t^2} \sin \beta \approx 5 \times 10^{-4} \]

\[ z = 2 \frac{\delta M - (i/2)\delta \Gamma}{\Delta m - (i/2)\Delta \Gamma} \]

\[ z \neq 0 \implies \text{CP & CPT violation} \]

\[ S = \frac{2 \text{Im} \lambda}{1 + |\lambda|^2} \]

\[ C = \frac{1 - |\lambda|^2}{1 + |\lambda|^2} \]

\[ \lambda_{f_{CP}} = \eta_{f_{CP}} \frac{q}{p} \frac{\overline{A}_{f_{CP}}}{A_{f_{CP}}} \]

\[ \approx e^{-i2\beta} \]

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CPV in Standard Model

\[ V = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} = \begin{pmatrix} 1 - \frac{1}{2} \lambda^2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1 - \frac{1}{2} \lambda^2 & A\lambda^2 \\ A\lambda^3(1 - \rho - i\eta) & -A\lambda^2 & 1 \end{pmatrix} + O(\lambda^4) \]

**CP Violating phase**

\[ d \cdot s^* = 0 \text{ (K system)} \]
\[ s \cdot b^* = 0 \text{ (B_s system)} \]
\[ d \cdot b^* = 0 \text{ (B_d system)} \]

**CKM quark mixing matrix**

**Unitarity**

- **b → uℓν**
- **B → (π, ρ, ω) ℓν**
- **B → D*π, DK, πK, ...**
- **B → j/ψK_s, D*D*, ...**

\[ V_{ud} V_{ud} \]
\[ V_{cd} V_{cd}^* \]

\[ (0, 0) \] to \[ (1, 0) \]

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Parameter & PEPII & KEKB \\
--- & --- & --- \\
PeakLumi & $10^{33}$ cm$^{-2}$ s$^{-1}$ & 3.0 & 10.0 \\
Ee+(GeV) & 9.0 & 8.0 \\
Ee-(GeV) & 3.1 & 3.5 \\

---

The BaBar Detector

- Superconducting Coil (1.5T)
- Silicon Vertex Tracker (SVT) [5 layers]
- Drift Chamber [40 stereo layers] (DCH)
- CsI(Tl) Calorimeter (EMC) [6580 crystals]
- Instrumented Flux Return (IFR) [Iron interleaved with RPCs]
- Cherenkov Detector (DIRC) [144 quartz bars, 11000 PMTs]

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Belle Detector

- SC solenoid 1.5T
- CsI(Tl) 15X$_0$
- TOF counter 8GeV c$^{-1}$
- Scintillator detector 3-lv DSSD
- Cherenkov detector 14/15 lv RPC + Fe

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Peak Luminosities are now $9 \times 10^{33}$ in PPEPII
And
$14 \times 10^{33}$ in KEKB
The integrated luminosity doubles every 2 years
Observation of CP violation in B meson system

Evidence for direct CP violation in $B \rightarrow K^+\pi^-$

Beginning of $b \rightarrow s$ saga
CP violation in $B \rightarrow \phi K_s, \eta'K_s$ etc.

Observation of CP violation in B meson system

Many new measurements cannot be summarized in one page

Great Success of PEP-II and KEKB

- Integrated luminosity (fb) ~0.8 in total (sum)!
- Peak luminosity $>10^{34}$ cm$^{-2}$s$^{-1}$ in both experiments!
Measuring time-dependent CP asymmetries

\[ \beta \gamma (4S) = 0.55 \]

\[ \Delta z \approx \frac{\Delta z}{\langle \beta \gamma \rangle} \frac{1}{c} \]

\[ \Delta t \text{ is a signed quantity} \]

\[ \sigma_{\Delta t} \sim 1 \text{ ps} \leftrightarrow 170 \text{ } \mu m \]

\[ \tau_B \sim 1.6 \text{ ps} \leftrightarrow 250 \text{ } \mu m \]

Flavor Tagging

Tag vertex reconstruction

Exclusive B Meson and vertex reconstruction

Tagging performance: Q = 30.5%

Start the Clock

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**Vertex and $\Delta t$ Reconstruction**

- **Reconstruct $B_{\text{rec}}$ vertex from**
  - charged $B_{\text{rec}}$ daughters ($\sigma_z(B_{\text{Rec}})=65 \ \mu m$)

- **Determine $B_{\text{Tag}}$ vertex from**
  - charged tracks not belonging to $B_{\text{rec}}$
  - $B_{\text{rec}}$ vertex and momentum
  - beam spot and $\Upsilon(4S)$ momentum

- High efficiency (93%) through inclusion of 1-prong tags
- Average resolution in $\Delta z$ is $180 \ \mu m$ ($\langle|\Delta z|\rangle = \beta \gamma ct = 260 \ \mu m$) corresponding to a $\Delta t$ resolution of 0.6 ps.
- $\Delta t$ resolution function measured from data ($B_{\text{flav}}$ sample)
Hierarchical tagging categories:

- Lepton – charge of lepton
- Kaon – net charge of kaon
- NT1: exploit information from momentum spectrum
- NT2: of charged particles, soft π from D*, unidentified l and K

Large $B_{flav}$ sample provide tagging performance measurement:

<table>
<thead>
<tr>
<th>Tagging category</th>
<th>Efficiency $\varepsilon$ (%)</th>
<th>Mistag fraction $w$ (%)</th>
<th>$B^0/\bar{B}^0$ diff. $\Delta w$ (%)</th>
<th>$Q = \varepsilon(1-2w)^2$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lepton</td>
<td>11.1 ± 0.2</td>
<td>8.6 ± 0.9</td>
<td>0.6 ± 1.5</td>
<td>7.6 ± 0.4</td>
</tr>
<tr>
<td>Kaon</td>
<td>34.7 ± 0.4</td>
<td>18.1 ± 0.7</td>
<td>-0.9 ± 1.1</td>
<td>14.1 ± 0.6</td>
</tr>
<tr>
<td>NT1</td>
<td>7.7 ± 0.2</td>
<td>22.0 ± 1.5</td>
<td>1.4 ± 2.3</td>
<td>2.4 ± 0.3</td>
</tr>
<tr>
<td>NT2</td>
<td>14.0 ± 0.3</td>
<td>37.3 ± 1.3</td>
<td>-4.7 ± 1.9</td>
<td>0.9 ± 0.2</td>
</tr>
<tr>
<td>ALL</td>
<td>67.5 ± 0.5</td>
<td></td>
<td></td>
<td>25.1 ± 0.8</td>
</tr>
</tbody>
</table>

\[ \sigma(\sin 2\beta) \propto \frac{1}{\sqrt{Q}} \]
Two kinematical variables are used in BaBar analyses to select B mesons:

Energy substituted mass

\[ m_{ES} = \sqrt{s/4 - p^*_B} \]

the resolution on \( m_{ES} \) is 2.6 MeV/c^2 and mainly depends on the \( E_{\text{beam}} \) uncertainty.

\[ \Delta E = E^*_B - \sqrt{s}/2 \]

\( \Delta E \) depends on the decay channel (masses of products...), its resolution mainly on tracking.
PHYSICS MENU

- Unitarity Triangle sides measurements
  - From (semi)leptonic decays, inclusive or exclusive
  - $|V_{ub}|$, $|V_{cb}|$, $|V_{td}|$

- UT angles precision measurements
  - $b \rightarrow ccs$ Charmonium $B \rightarrow J/\Psi K_s$, giving $\sin 2\beta$
  - $b \rightarrow sss$ penguin also $\sin 2\beta$ in SM very sensitive to new physics
  - CPV Asymmetries in $B \rightarrow \phi K_s$, $K_s \pi^0$ compared with $\sin 2\beta$.
  - $\alpha$ measurement with $B \rightarrow \pi \pi$ and $\rho \rho$
  - direct CPV
  - $\gamma$ measurement with $B \rightarrow DK$ or similar channels.

- Rare decays
  - Exclusive and inclusive $b \rightarrow s\gamma$ BFs, direct asymmetries, photon helicities
  - Exclusive and inclusive $b \rightarrow sl^+l^-$ BFs, $A_{FB}$, CP asymmetries
  - $B$ decays to states with large missing energy, such as $B^{(d,s)} \rightarrow \tau^+\tau^-$, $B \rightarrow K^{(*)}\nu\nu$, $b \rightarrow s\nu\nu$, $B \rightarrow D^{(*)}\tau\nu$, $B \rightarrow X_c\bar{\nu}\nu$, $B \rightarrow \nu\nu$
  - LFV in $\tau \rightarrow \mu\gamma$, $\tau \rightarrow \mu\phi$ and similar channels
Direct CPV

\[ B^0 \rightarrow K^+ \pi^- \]

\textbf{BABAR} \hspace{2cm} \textbf{PRL 93 (2004) 131801}

\[ A_{CP} = -0.133 \pm 0.030 \pm 0.009 \]

\[ 4.2\sigma \]

\textbf{Belle} \hspace{2cm} \textbf{Confirmation at ICHEP04}

\[ B^0 \rightarrow K^+ \pi^- \]

\[ A_{CP} = -0.101 \pm 0.025 \pm 0.005 \]

\[ 3.9\sigma \]

\textbf{Average} \hspace{2cm} \[ A_{CP} = -0.114 \pm 0.020 \]

\[ 3.6\sigma \]

\[ B^+ \rightarrow K^+ \pi^0 \]

\[ A_{CP} = +0.06 \pm 0.06 \pm 0.01 \] \hspace{2cm} \textbf{BABAR}

\[ A_{CP} = +0.04 \pm 0.05 \pm 0.02 \] \hspace{2cm} \textbf{Belle}

\textbf{Average} \hspace{2cm} \[ A_{CP} = +0.049 \pm 0.040 \]

\[ \text{Signal (227M } B\bar{B} \text{ pairs): } 1606 \pm 51 \]

\[ \text{Signal (274M } B\bar{B} \text{ pairs): } 2140 \pm 53 \]

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Experimental status: 
from measurements at LEP, CLEO, BaBar and Belle:

\[
\begin{align*}
\left|\frac{q}{p}\right| &= 1.0013 \pm 0.0067 \\
A_{SL} &= -0.0026 \pm 0.0034 \\
\text{Re} \frac{\epsilon_B}{1 + |\epsilon_B|^2} &= -0.0007 \pm 0.0017
\end{align*}
\]

HFAG, Winter’05 average

Not easy to improve: systematics!

For example, the most recent paper: \textit{BELLE}, hep-ex/0505017:

\[
\begin{align*}
A_{SL} &= (-1.1 \pm 7.9\text{(stat)} \pm 7.0\text{(sys)}) \times 10^{-3}, \\
\left|\frac{q}{p}\right| &= 1.0005 \pm 0.0040\text{(stat)} \pm 0.0035\text{(sys)}, \\
\text{Re}(\epsilon_B) \frac{1 + |\epsilon_B|^2}{1 + |\epsilon_B|^2} &= (-0.3 \pm 2.0\text{(stat)} \pm 1.7\text{(sys)}) \times 10^{-3}
\end{align*}
\]

\textit{BELLE} 2005
(78 + 9) fb^{-1}

< 1/5 of the available data!
New unitarity triangle with new values

**Lp05 new Belle value with 386M**  
$\sin^2 \beta = 0.652 \pm 0.039 \pm 0.020$

$C = -0.010 \pm 0.026 \pm 0.036$

**New average values BaBar Belle**  
$\sin^2 \beta = 0.685 \pm 0.032$

$C = 0.016 \pm 0.046$

$\alpha_{[\text{CKM}]} = (93.1^{+9.6}_{-12.5})^\circ$

$\alpha_{[\text{all}]} = (99^{+12}_{-19})^\circ$

**New value of $\sin^2 \beta$ vs. UT general fit with new $V_{ub}/V_{cb}$ value**

After Lp 05 Preferred solution
Including $\Phi_3/\gamma$ mainly from Dalitz analysis

Deviations from origin indicate $r \neq 0$. Difference between $B^+$ and $B^-$ signifies $\phi_3 \neq 0$ (CPV).

<table>
<thead>
<tr>
<th>Modes</th>
<th>Parameters</th>
<th>$\delta$ (°)</th>
<th>$\phi_3$ (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BaBar</strong></td>
<td>$DK$</td>
<td>$0.118 \pm 0.079 \pm 0.034 \pm 0.036$</td>
<td>$70 \pm 31^{+12}<em>{-10}^{+14}$$^{+15}</em>{-12}$</td>
</tr>
<tr>
<td></td>
<td>$D^*K$</td>
<td>$0.169 \pm 0.096 \pm 0.030$</td>
<td>$296 \pm 41_{-12}^{+14}$</td>
</tr>
<tr>
<td></td>
<td>$D^*K$ combined</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$DK$</td>
<td>$0.21 \pm 0.08 \pm 0.03 \pm 0.04$</td>
<td>$157 \pm 19_{-11}^{+21}$</td>
</tr>
<tr>
<td></td>
<td>$D^*K$</td>
<td>$0.12 \pm 0.16$</td>
<td>$321 \pm 57_{-11}^{+21}$</td>
</tr>
<tr>
<td></td>
<td>$DK^*$</td>
<td>$0.25^{0.17}_{-0.18}$</td>
<td>$358 \pm 35_{-11}^{+21}$</td>
</tr>
<tr>
<td></td>
<td>$DK^*$ combined</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Errors: statistical, detector, systematic. $D \to K\pi\pi$ decays model, non-resonant $DK\pi$.
Hints of NP from UT?

\[ \alpha[\text{all}] = (99^{+12}_{-9})^\circ \]

\[ \alpha[\text{CKM}] = (93.1^{+9.6}_{-12.5})^\circ \]

USE: \( \varepsilon, \Delta m_d, \sin 2\beta, \gamma, \alpha, \cos 2\beta \)

From the general Fit:
- SM at 93% C. L.
- NP at 7% C. L.

L. Silvestrini LP05

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Great success of BaBar and Belle

But great success of CKM

Sides and angles

only angles
\[ \bar{\rho} = 0.193 \pm 0.029 \]
\[ [0.133, 0.248] @ 95\% \text{ Prob.} \]

\[ \bar{\eta} = 0.355 \pm 0.019 \]
\[ [0.318, 0.393] @ 95\% \text{ Prob.} \]
In SM interference between $B$ mixing, $K$ mixing and Penguin $b \rightarrow s\bar{s}s$ or $b \rightarrow s\bar{d}d$ gives the same $e^{-2i\beta}$ as in tree process $b \rightarrow c\bar{c}s$. However loops can also be sensitive to New Physics!

New phases from SUSY?

O$(\lambda^2)$

Purely dimensional estimate

O$(\lambda^2 / \bar{\lambda})$

\~5%}

\~20%
Deviation from SM:
- No theory error: $3.7\,\sigma$
- Naïve theory errors: $2.9\,\sigma$

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- All except $\eta'K^0$ are within $\sim 1\sigma$
- All except $f_0K^0$ have $\Delta S < 0$
PENGUIN contributions

Acp(J/Ψ Ks) - Acp(π0 Ks)  Acp(J/Ψ Ks) - Acp(Φ Ks)

Model independent estimate by Ciuchini, Franco, Masiero, Silvestrini. PRL 79, 978
OTHER CHANNELS for NP (observables in s/d l+ l− decay)

$$A_{cp}(B \rightarrow s l^+ l^-) \quad \text{SM:} \ <0.5\% \ (0.05\% \ \text{for} \ K^* \ l^+ l^-)$$

$$A_{cp}(B \rightarrow d l^+ l^-) \quad \text{SM:} \ \sim(4.4+/4\ )\%$$

$$B(B \rightarrow s\mu^+\mu^-)/B(B \rightarrow se^+e^-) \quad \text{SM:} \ \sim1$$

$$A^{FB}(K^* l^+ l^-): s_0 \text{ (zero crossing)} \quad \text{SM predicts with} \ \sim5\% \ \text{accuracy}$$

$$A^{FB}(K^* l^+ l^-): \text{CP asymmetry} \quad \text{Very small in SM}$$

In dilepton rest frame
$$N_F = \text{when} \ l^+ \ \text{along} \ b \ \text{dir}$$
$$N_B = \text{when} \ l^+ \ \text{opposite} \ b \ \text{dir}$$

$$S_0 \text{ NNLO error} = 5\%$$

$$S_0 = 0.162+/-0.008 \sim C7/C9$$

$$\hat{s} = \left(\frac{m_{l^+l^-}}{m_b}\right)^2$$

In SM: $$A^{CP}_{FB} \sim 0$$

Determination of sign of AFB very important.

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$Kll$, $K^{*}ll$ branching fractions in range predicted by SM + form factors

theory uncertainty > experimental uncertainty

Beyond branching fractions: Asymmetries

$A_{CP}$ consistent with zero

$K_{\mu\mu}$/Kee ratio consistent with unity

Forward-backward angular asymmetry of lepton pair vs. dilepton mass probes relative size, phase of penguin diagrams

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Clean probes of EW scale physics

Branching fractions $\sim 10^{-6}$

Well-established $Kll$, $K^*ll$ signals for B factories ($l = e, \mu$)

$\text{BF} \times 10^6$

$B(\,B \rightarrow K\,\nu\nu\,) < 52$

$B(\,B \rightarrow \pi\nu\nu\,) < 100$

$K\nu\nu$ sensitivity now $< 10 \times \text{SM rate}$

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Recoil Method as pure B beam

Recoil cinematics well known
Recoil flavor and charge is determined
Event closure needed with neutrinos

The final efficiency is \( \sim 0.4\% \) (per \( b\bar{b} \) pair)
\( \Rightarrow \sim 4000 \text{ B/fb}^{-1} \) (at 30\% purity)
\( \Rightarrow 1500 \text{ B}^{0}/\text{fb}^{-1} \)
\( \Rightarrow 2500 \text{ B}^{+}/\text{fb}^{-1} \)
\( > 10^{7} \) recoil Bs in 10ab\(^{-1}\)

You have a single B beam!!
Theoretical uncertainties

<table>
<thead>
<tr>
<th>Measurement (in SM)</th>
<th>Theoretical limit</th>
<th>Present error</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B \rightarrow \psi K_S \ (\beta)$</td>
<td>$\sim 0.2^\circ$</td>
<td>$1.6^\circ$</td>
</tr>
<tr>
<td>$B \rightarrow \phi K_S, \eta^{(i)} K_S, \ldots (\beta)$</td>
<td>$\sim 2^\circ$</td>
<td>$\sim 10^\circ$</td>
</tr>
<tr>
<td>$B \rightarrow \pi \pi, \rho \rho, \rho \pi \ (\alpha)$</td>
<td>$\sim 1^\circ$</td>
<td>$\sim 15^\circ$</td>
</tr>
<tr>
<td>$B \rightarrow D K \ (\gamma)$</td>
<td>$\ll 1^\circ$</td>
<td>$\sim 25^\circ$</td>
</tr>
<tr>
<td>$B_s \rightarrow \psi \phi \ (\beta_s)$</td>
<td>$\sim 0.2^\circ$</td>
<td>—</td>
</tr>
<tr>
<td>$B_s \rightarrow D_s K \ (\gamma - 2\beta_s)$</td>
<td>$\ll 1^\circ$</td>
<td>—</td>
</tr>
<tr>
<td>$</td>
<td>V_{cb}</td>
<td>$</td>
</tr>
<tr>
<td>$</td>
<td>V_{ub}</td>
<td>$</td>
</tr>
<tr>
<td>$B \rightarrow X \ell^+ \ell^-$</td>
<td>$\sim 5%$</td>
<td>$\sim 25%$</td>
</tr>
<tr>
<td>$B \rightarrow K^{(*)} \nu \bar{\nu}$</td>
<td>$\sim 5%$</td>
<td>—</td>
</tr>
</tbody>
</table>
\[ B(\bar{B}^+ \to \tau^+ \nu_\tau) = \frac{G_F^2 m_B}{8\pi} m_\tau^2 \left(1 - \frac{m_\tau^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B \]

- Direct measurement of \( f_B \) (currently only from LQCD)
- \( B(B \to \tau\nu) / \Delta M_{B_d} \) constrains \( |V_{ub}|^2 / |V_{td}|^2 \)

- \( > 2 \nu \) in the event
- Use hadronic or semileptonic tag
- 1 or 3 prong topology
- Can constrain SUSY parameters

\[ B(B \to \tau\nu) < 2.6 \times 10^{-4} @ 90\% \text{ C.L.} \]

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Belle 2006 with 0.414 ab$^{-1}$

Uncertain regions could be clarified by B-Factories
depends on all other SUSY parameters...
Physics case for very high lumi

On the physics case a lot of documents are available they are the result of three years of Physics workshops in Slac, in KEK and Joint meetings in Hawaii.

Three years of Physics Workshops have produced heavy documents. See for example:
The Discovery Potential of a Super B Factory (Slac-R-709)
Letter of Intent for KEK Super B Factory (KEK Report 2004-4)
Physics at Super B Factory (hep-ex/0406071)

At the URL:
www.pi.infn.it/SuperB

you can find documents and links to documents.
The physics case for a Super Flavour Factory is solid if:
The sample of data available in a few years of running can reach $100 \text{ ab}^{-1}$ ($10^{11} \text{ BBbar, tau and charm pairs}$)
The running period is overlapped to LHC. (Results from Super Flavour and LHC are largely complementary).

As asked by the president of INFN an international study group has been formed to study the case, to evaluate the solution with time, costs, synergies, footprint of the machine......
# Unitarity Triangle - Sides & Angles

## Unitarity Triangle - Sides

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Goal</th>
<th>3/ab</th>
<th>10/ab</th>
<th>50/ab</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_{ub} ) (inclusive)</td>
<td>syst = 5-6%</td>
<td>2%</td>
<td>1.3%</td>
<td></td>
</tr>
<tr>
<td>( V_{ub} ) (exclusive) ( (\pi,\rho) )</td>
<td>syst = 3%</td>
<td>5.5%</td>
<td>3.2%</td>
<td></td>
</tr>
<tr>
<td>( f_b ) ( B(B \rightarrow \mu \nu) )</td>
<td>SM: ( B \sim 5 \times 10^{-7} )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( F_b B(B \rightarrow \tau \nu) )</td>
<td>SM: ( B \sim 5 \times 10^{-5} )</td>
<td>3.3 ( \sigma )</td>
<td>6 ( \sigma )</td>
<td>13 ( \sigma ) ( f_b ) to ( \sim 10% )</td>
</tr>
<tr>
<td>( V_{td}/V_{ts} (\rho \gamma/K^*\gamma) )</td>
<td>Theory 12%</td>
<td>( \sim 3% )</td>
<td>( \sim 1% )</td>
<td></td>
</tr>
</tbody>
</table>

## Unitarity Triangle - Angles

<table>
<thead>
<tr>
<th>Measurement</th>
<th>( e^+e^- ) Precision</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \alpha (\pi\pi) ) ( (S_{\pi\pi}, B \rightarrow \pi\pi BR's + isospin) )</td>
<td>6.7°</td>
</tr>
<tr>
<td>( \alpha (\rho\pi) ) (Isospin, Dalitz) ( (syst \geq 3°) )</td>
<td>3°</td>
</tr>
<tr>
<td>( \alpha (\rho\rho) ) (penguin, isospin, stat+syst)</td>
<td>2.9°</td>
</tr>
<tr>
<td>( \beta (J/\psi K_S) ) (all modes)</td>
<td>0.3°</td>
</tr>
<tr>
<td>( \gamma (B \rightarrow D^{(*)}K) ) (ADS)</td>
<td>2-3°</td>
</tr>
<tr>
<td>( \gamma (all) )</td>
<td>1.2-2°</td>
</tr>
</tbody>
</table>

Theory: \( \alpha \sim 1° \) \( \beta \sim 0.2° \) \( \gamma \ll 1° \)

---

9-10 May 2006

Marcello A. Giorgi
Universal fit makes only use of quantities independent of NP contributions within MFV
### CP Violation in $b\rightarrow s$ penguins

<table>
<thead>
<tr>
<th>Rare Decays – New Physics – $CPV$ (?)</th>
<th>$e^+e^-$ Precision</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Measurement</strong></td>
<td><strong>Goal</strong></td>
</tr>
<tr>
<td>$S(B^0\rightarrow\phi K_s)$</td>
<td>SM: $&lt;0.25$ (0.05)</td>
</tr>
<tr>
<td>$S(B^0\rightarrow\phi K_S+\phi K_L)$</td>
<td>SM: $&lt;0.25$ (0.05)</td>
</tr>
<tr>
<td>$S(B\rightarrow\eta'K_s)$</td>
<td>SM: $&lt;0.3$ (0.1)</td>
</tr>
<tr>
<td>$S(B\rightarrow K_S\pi^0)$</td>
<td>SM: $&lt;0.2$ (0.15)</td>
</tr>
<tr>
<td>$S(B\rightarrow K_S\pi^0\gamma)$</td>
<td>SM: $&lt;0.1$</td>
</tr>
<tr>
<td>$A_{CP}(b\rightarrow s\gamma)$</td>
<td>SM: $&lt;0.6%$</td>
</tr>
<tr>
<td>$A_{CP}(B\rightarrow K^{*}\gamma)$</td>
<td>SM: $&lt;0.5%$</td>
</tr>
<tr>
<td>$CPV$ in mixing ($</td>
<td>q/p</td>
</tr>
</tbody>
</table>
### b → s l⁺ l⁻ precision measurements

<table>
<thead>
<tr>
<th>New Physics – K(*pow) l⁺ l⁻, s l⁺ l⁻</th>
<th>e⁺ e⁻ Precision</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Measurement</strong></td>
<td><strong>Goal</strong></td>
</tr>
<tr>
<td>B(B → K_{μ⁺μ⁻}) / B(B → K e⁺ e⁻)</td>
<td>SM: 1</td>
</tr>
<tr>
<td>A_{CP}(B → K^{*} l⁺ l⁻) (all)</td>
<td>SM: &lt; 0.05%</td>
</tr>
<tr>
<td>(high mass)</td>
<td></td>
</tr>
<tr>
<td>A_{FB}(B → K^{*} l⁺ l⁻) : \hat{s}_0</td>
<td>SM: ±5%</td>
</tr>
<tr>
<td>A_{FB}(B → s l⁺ l⁻) : \hat{s}_0</td>
<td></td>
</tr>
<tr>
<td>A_{FB} (B → s l⁺ l⁻) : C_{9}, C_{10}</td>
<td></td>
</tr>
</tbody>
</table>
# Rare Decays

<table>
<thead>
<tr>
<th>MEASUREMENT</th>
<th>Goal</th>
<th>3/ab</th>
<th>10/ab</th>
<th>50/ab</th>
<th>100/ab</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B(B \to D^{*} \tau \nu)$</td>
<td>SM: $B$: $8 \times 10^{-3}$</td>
<td>10.2%</td>
<td>5.6%</td>
<td>2.5%</td>
<td></td>
</tr>
<tr>
<td>$B(B \to s \nu \nu)K, K^*$</td>
<td>SM: Theory $\sim 5%$ 1 excl: $4 \times 10^{-6}$</td>
<td>$\sim 1\sigma$</td>
<td>$&gt;3\sigma$</td>
<td>$&gt;4\sigma$</td>
<td>$&gt;5\sigma$</td>
</tr>
<tr>
<td>$B(B \to invisible)$</td>
<td></td>
<td>$&lt;2 \times 10^{-6}$</td>
<td>$&lt;1 \times 10^{-6}$</td>
<td>$&lt;4 \times 10^{-7}$</td>
<td>$&lt;2.5 \times 10^{-7}$</td>
</tr>
<tr>
<td>$B(B_d \to \mu \mu)$</td>
<td>$\sim 8 \times 10^{-11}$</td>
<td>$&lt;3 \times 10^{-8}$</td>
<td>$&lt;1.6 \times 10^{-8}$</td>
<td>$&lt;7 \times 10^{-9}$</td>
<td>$&lt;5 \times 10^{-9}$</td>
</tr>
<tr>
<td>$B(B_d \to \tau \tau)$</td>
<td>$\sim 1 \times 10^{-8}$</td>
<td>$&lt;1 \times 10^{-7}$</td>
<td>$O(10^{-4})$</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>$B(\tau \to \mu \gamma)$ now $&lt; 7 \times 10^{-8}$</td>
<td>?</td>
<td>$&lt;10^{-10}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$B(\tau \to \mu h)$ now $&lt; 10^{-7}$</td>
<td>?</td>
<td>$&lt;10^{-10}$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The LFV limits on $\tau \to \mu \nu$ and $\tau \to \mu \gamma$ scale with the statistics or with the square root of the statistics?

If as we have now in Babar the main source of systematic error is the unidentified background with 2 neutrinos and this background is irreducible, the scaling law is the square root?

Can this background kept under control as in $\mu \to e\gamma$?

Can a symmetric machine with very small beam spot (several order of magnitude smaller than in PEPII) and monochromatic taus help in reducing this source of error?
Not only CPV: \( D_s(2317) \rightarrow D^s(1970) \pi^0 \):

\[
\begin{align*}
D^+_s & \rightarrow K^+K^- \pi^+ \\
D^+_s & \rightarrow K^+K^- \pi^+ \pi^0
\end{align*}
\]

CLEO 13.5 fb\(^{-1}\)

BELLE Preliminary 78 fb\(^{-1}\)

9-10 May 2006

Marcello A. Giorgi
More recent: $\Upsilon(4260)$ in $\pi^+\pi^- J/\psi$ Mass Spectrum

- ISR production: $e^+e^- \rightarrow (\gamma) J/\psi \pi^+\pi^-$

$m = 4260 \pm 8$ MeV
$\Gamma = 88 \pm 23$ MeV

$\Upsilon(2S)$ used for cross checks

25% of $\gamma$'s observed

missing mass consistent with $\gamma$: $Y$ data, $Y$ MC, and $\psi(2S)$ data

9-10 May 2006

Marcello A. Giorgi
BABAR has first observed $D_s(2317)$ and BELLE the $X(3872)$ and $Y(3940)$.

Rare states have been accessible to Babar and Belle thanks to the very high statistics collected with a luminosity of about $10^{34}$ cm$^{-2}$ s$^{-1}$.

More states could be accessible with a luminosity $\gg 10^{36}$ cm$^{-2}$ s$^{-1}$. 
What kind of Super B Factory?

- Peak Lumi $>>10^{36}$ cm$^{-2}$ s$^{-1}$ to allow 50/ab in a couple of years
- Running period: overlap with LHC and possibly before ILC
- Asymmetric (at least 7+4 GeV)

Options under evaluation:
Possibility to operate symmetric even at lower energy and with at least one polarised beam for $\tau$ and charm physics.
Still with at least $10^{35}$ cm$^{-2}$ s$^{-1}$. 
Traditional machines

The recipe for high lumi so far is:

- Increase current
- Then increase Background in the detectors
- Increase wall power

Above $5 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$ seems very hard the design of detector with present or near future technology

Wall power jumps soon above hundreds of MW.
Design Peak Lumi $4\div5 \times 10^{35}\text{cm}^{-2}\text{s}^{-1}$
### Some parameters for comparison with hadron expriments

<table>
<thead>
<tr>
<th></th>
<th>P.Lumi ($10^{33}$cm$^{-2}$s$^{-1}$)</th>
<th>$\sigma_{bb}$ ($10^{-33}$)</th>
<th>BB ($10^{7}$/y)</th>
<th>$\sigma_{bb}/\sigma_{qq}$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bfactories</strong></td>
<td>10</td>
<td>1.1</td>
<td>14</td>
<td>0.3</td>
</tr>
<tr>
<td><strong>SuperB</strong></td>
<td>$2 \div 5 \times 1000$</td>
<td>1.1</td>
<td>$3 \div 7 \times 1000$</td>
<td>0.3</td>
</tr>
<tr>
<td><strong>LHC-b</strong></td>
<td>0.15</td>
<td>500000</td>
<td>75x1000</td>
<td>0.005</td>
</tr>
</tbody>
</table>

τ and charm pairs as many as BB in e+e- factories
This was shown by N. Katayama at FCPC a couple of weeks ago

At first glance I’m working on the wrong experiment!

But:
- LHCb ~ 2010
- SuperB ~ 2020
- Some missing LHCb info

Why? 2020 is the design of Super KEKB
Comparison to Super B

- Added some information on several modes
- Scaled LHCb to 10 fb⁻¹ luminosity (~2014) and reordered the measurements
- Symbiosis!
A new scheme:

the “Linear SuperB”
• Basic Idea comes from the ATF2-FF experiment (R&D for ILC)

In the proposed experiment it seems possible to achieve spot sizes at the focal point of about $2\mu m \times 20nm$ at very low energy (1 GeV), out from the damping ring.

• Rescaling at about 10GeV/CM we should get sizes of about $1\mu m \times 10nm$ =>

• Is it worth to explore the potentiality of a Collider based on a scheme similar to the Linear Collider. (P. Raimondi at Hawaii 05 meeting on Super B)
In this simulation
E+=8 GeV
E-=3.5 GeV

Parameter list
for a flat and a round beam case
M. Biagini

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_{rev}$</td>
<td>s$^{-1}$</td>
<td>1.36E+05</td>
</tr>
<tr>
<td>$E^+$</td>
<td>GeV</td>
<td>8</td>
</tr>
<tr>
<td>$E^-$</td>
<td>GeV</td>
<td>3.5</td>
</tr>
<tr>
<td>$v_x$</td>
<td>nm</td>
<td>1.00E-01</td>
</tr>
<tr>
<td>$v_y$</td>
<td>nm</td>
<td>0.0010</td>
</tr>
<tr>
<td>$\beta_x^\pm$</td>
<td>$\mu$m</td>
<td>1.00E+04</td>
</tr>
<tr>
<td>$\beta_y^\pm$</td>
<td>nm</td>
<td>1.00E+05</td>
</tr>
<tr>
<td>$\sigma_t$</td>
<td>nm</td>
<td>1.00E+05</td>
</tr>
<tr>
<td>$\sigma_c$</td>
<td>rad</td>
<td>1.00E+02</td>
</tr>
<tr>
<td>$n_b$</td>
<td></td>
<td>3.50E+03</td>
</tr>
<tr>
<td>$\sigma_x^\pm$</td>
<td>$\mu$m</td>
<td>1.00E+00</td>
</tr>
<tr>
<td>$\sigma_y^\pm$</td>
<td>nm</td>
<td>1.00E+01</td>
</tr>
<tr>
<td>$l^+$</td>
<td>A</td>
<td>3.00E+00</td>
</tr>
<tr>
<td>$l^-$</td>
<td>A</td>
<td>6.00E+00</td>
</tr>
<tr>
<td>$N^+$</td>
<td></td>
<td>3.94E+10</td>
</tr>
<tr>
<td>$N^-$</td>
<td></td>
<td>7.88E+10</td>
</tr>
<tr>
<td>$L_{\infty}$</td>
<td>cm$^{-2}$ s$^{-1}$</td>
<td>1.04E+36</td>
</tr>
<tr>
<td>$\eta$</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>$L_o$</td>
<td>cm$^{-2}$ s$^{-1}$</td>
<td>1.04E+36</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Accelerator</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ATF2</td>
<td>ATF2</td>
<td>ATF2</td>
<td>PEP-II</td>
</tr>
<tr>
<td></td>
<td>crab</td>
<td>crab</td>
<td>round</td>
<td>crab</td>
</tr>
</tbody>
</table>
Horizontal Collision

Vertical collision
D. Schulte

Effective horizontal size during collision about 10 times smaller, vertical size 10 times larger
Basic idea

- Instead of being a limitation, Beam-Beam interaction might actually help to increase the luminosity, but more power in DR.
- Need to find a suitable parameters set: stable collisions, reasonable outgoing emittances and energy spread.
- Average current through the detector 10-100 times smaller than in the rings (10-100 mA).
- Experiment looks easy (narrow beam pipe-no Bkgd).
- Damping Rings, even with a parameter set very similar to the ILC ones, have still to handle a lot more current and more radiation from increased damping.
- Energy spread in collision is an issue.
- WALL POWER 1100 MW!!!!!!!
REDUCE POWER and REDUCE $\Delta E$

2 solutions

1) ILC DR+ ILC BC + ILC FF

- Acceleration by ILC SC-cavities not a must anymore but a factor 2 in energy gives a factor 2 reduction in energy spread (and a factor 2 down in beam cooling power in the ring)

- Increased collision rate and reduced beam current gives more luminosity, with an optimum for collisions at every turn

- Possible path: to build the machine with the capability to collide with extraction every 50 turns, and then, while at low bunch charge, have the option of increasing bunch charge or collision rate up to every turn…
Solution 1

ILC ring with ILC FF
ILC compressor
Colliding every 50 turn
Acceleration optional
Crossing angle optional

Compressor
Decompressor

Optional Acceleration and deceleration

FF IP F

ILC ring with ILC FF
ILC Compressor
Colliding every turn
crossing angle optional

Compressor
Decompressor

7+4GeV
2) ILC DR+ ILC FF in DR + crossing angle 25mrad

- Bunch Compressor optional, no acceleration
- Requires virtually no R&D
- Uses all the work done for ILC, 100% synergy with ILC
- Rings and FF layouts virtually done, 3km circumference
- IR extremely simplified
- Currents around 1.5A
- Background should be better than PEP-II and KEKB
- Use of “crabbed waist” new idea
Colliding every turn requires bunch compressor and decompressor in the ring BUT collision with crossing angle doesn’t need beam compression

With large crossing angle X and Z are swapped
Crab waist

Against the unpleasant ‘Long Range Beam Beam’ instead of simply increase the x-ing angle (then reduce the lumi) P.R. applies the travel focus idea in the transverse plane since x and z are swapped.

Vertical waist position in z is a function of x:

\[ Z_{y\text{-waist}}(x) = \frac{x}{\theta} \]

Crabbed waist

All components of the beam collide at a minimum \( \beta_y \)

the geometric luminosity is higher

the bb effects are greatly reduced
Vertical waist has to be a function of $x$:

$Z=0$ for particles at $-\sigma_x$ ($-\sigma_x/2$ at low current)

$Z=\sigma_x/\theta$ for particles at $+\sigma_x$ ($\sigma_x/2$ at low current)
ILC ring with ILC FF
Uncompressed bunches
Colliding every turn
crossing angle=2*25mrad

7+4GeV

3 Km

Marcello A. Giorgi
Flat case, **Collisions in the Ring, Uncompressed Bunches**

- $N_{\text{bunches}}=5000$, **3Km ring**
- Crab focus on in vertical plane
- $X_{\text{crossing\_angle}}=2*25\text{mrad}$
- $\sigma_z=4\text{mm}$, $\sigma_e=5\text{MeV}$, $\sigma_e_{\text{Luminosity}}=7\text{MeV}$
- $\varepsilon_x=0.4\text{nm}$, $\varepsilon_y=0.002\text{nm}$, $\varepsilon_z=4.0\mu\text{m}$
- Collision\_frequency=500MHz
- $L_{\text{multiturn}}=0.8*10^{36}$ (L_{single\_turn}=1.2*10^{36}) with Np=2*10^{10}
- Vertical tune shift as in PEPII! (similar currents but 100 times higher luminosity and 100 times smaller $\beta_y$)

Projected $\sigma_x=\sigma_z*Cross\_angle=100\mu\text{m}$, as in PEPII!

$L=1.6*10^{36}$ with Np=4*10^{10}

Luminosity higher with further simultaneous squeeze of $\beta_x$ and $\beta_y$. 

9-10 May 2006

Marcello A. Giorgi
• Possibly to operate at the $\tau$ with $L=10^{35}$
• To be studied the possibility to run down to $\Phi$
• Total cost about half ILC $e^+\, DRs$ (2 $e^+$ 6km rings in ILC)
• Power around 35MW, to be further optimized (goal 25MW)
• Possible to reuse PEP-II RF system, power supplies, magnets, vacuum pumps, etc., further reducing the overall cost
• Needs standard injector system, probably a C-band 7 GeV linac like in KEKB upgrade (already designed) (around 100Meuro)
Result of simulation (Guinea Pig)

Collisions with uncompressed beams
Crossing angle = 2*25mrad
Relative Emittance growth per collision about $1.5 \times 10^{-3}$

\[
\varepsilon_{\text{after\_collision}} / \varepsilon_{\text{before\_collision}} = 1.0015
\]

9-10 May 2006

Marcello A. Giorgi
SuperB vertical blow-up Ohmi’s weak-strong code

K2 is the strength of the sextupolar nonlinearity introduced to have crab waist
SuperB vertical blow-up Ohmi's weak-strong code
Total Wall Power (66% transfer eff.): 34 MW !!

<table>
<thead>
<tr>
<th></th>
<th>LER 4 GeV</th>
<th>HER 7 GeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>C (m)</td>
<td>3006.</td>
<td>3006.</td>
</tr>
<tr>
<td>$B_w$ (T)</td>
<td>1.6</td>
<td>1.6</td>
</tr>
<tr>
<td>$L_{bend}$ (m)</td>
<td>5.6</td>
<td>11.2</td>
</tr>
<tr>
<td>$B_{bend}$ (T)</td>
<td>0.078</td>
<td>0.136</td>
</tr>
<tr>
<td>$U_0$ (MeV/turn)</td>
<td>4.6</td>
<td>7.8</td>
</tr>
<tr>
<td>N. wigg. cells</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>$\tau_x$ (ms)</td>
<td>17.5</td>
<td>18.</td>
</tr>
<tr>
<td>$\tau_s$ (ms)</td>
<td>8.8</td>
<td>9.</td>
</tr>
<tr>
<td>$\varepsilon_x$ (nm)</td>
<td>0.54</td>
<td>0.54</td>
</tr>
<tr>
<td>$\sigma_E$</td>
<td>1.1x10^{-3}</td>
<td>1.45x10^{-3}</td>
</tr>
<tr>
<td>$I_{beam}$ (A)</td>
<td>2.5</td>
<td>1.4</td>
</tr>
<tr>
<td>$P_{beam}$ (MW)</td>
<td>11.5</td>
<td>10.9</td>
</tr>
</tbody>
</table>

9-10 May 2006

Marcello A. Giorgi

0.5x10^{-3} cm $\sigma_E$=0.9x10^{-3}
PLANS: (Possible test in 2007) DAΦNE (M. Zobov, LNF)

- Hirata's BBC code simulation (weak-strong, strong beam stays gaussian, weak beam has double crossing angle)
- \(N_p = 2.65 \times 10^{10}\), 110 bunches
- \(I_b = 13\) mA (present working current)
- \(\sigma_x = 300\ \mu m, \sigma_y = 3\ \mu m\)
- \(\beta_x = 0.3\) m, \(\beta_y = 6.5\) mm
- \(\sigma_z = 25\) mm (present electron bunch length)
- \(\theta = 2\times25\) mrad
- \(Y_{IP} = y + 0.4/(\theta \times x \times y')\) crabbed waist shift
- \(L_0 = 2.33 \times 10^{24}\) (geometrical)
- \(L(110\) bunches, 1.43A) = 7.7 \times 10^{32}\)
- \(L_{equil} = 6 \times 10^{32}\)

Factor 3 above design lumi!
Beam Pipe Radius

- Small beam pipe radius possible because of small beam size
  - Studied impact of boost on vertex separation (B→ππ)
  - Beampipe hypothesis (no cooling)
    - 5um Au shield to protect from soft photons
    - 0.5cm → 200um Be and 5um hit resolution (0.21% X0)
    - 0.5cm → 300um Be and 10um hit resolution (0.24% X0)
    - 0.5cm → 500um Be and 10um hit resolution (0.29% X0)
  - Rest of tracking is Babar

7+4GeV
Boost βγ= .28
Instead of 0.56
Beam Pipe Thickness

- With 1.5A beam currents the beam pipe will require cooling.
  - Beampipe design is being developed
  - Study effect of beampipe thickness

- Assume boost=0.28
- B→ππ decay
- 10um hit resolution
- → 1cm beampipe should allow good performance even with βγ=0.28

7+4GeV
Boost βγ=.28
Instead of 0.56

9-10 May 2006
Energy (Under Study)

- Is it interesting to run at different energies?
  - \( Y(5s) \): not an issue for the machine
  - Oscillation of \( B_s \) rapid for TD analysis

- Required resolution very hard to obtain
- Still it might be possible to measure \( \gamma \) through time-integrated measurement branching fractions
  - \( B_s \rightarrow D\phi \)
  - \( B_s \rightarrow K^{+}\pi^{+}\pi^{0} \)

\[ \sigma(\Delta t) \]

\[ \beta_{\gamma} \]

\[ \sigma_{\Delta t} = 0.16 \text{ ps} \]

Renga/Pierini
Energy II (Under Study)

- Is it interesting to run at the $\tau\tau$ threshold or at the $\psi(3770)$?
  - Luminosity will be around $10^{35}$
  - Still more than at tau-charm factories
  - Studies going to on on physics case
    - Absolute D branching fractions, rare decays
    - Form factors
    - Unitarity tests with charm
    - D mixing? Use coherence of initial state
    - CP violation

- Boosted operation
  - Is there something to be gained to run at low energy with boost?
  - It might be possible to separate (a little bit) the D vertices

---

9-10 May 2006

Marcello A. Giorgi
Detector comments

Detectors don’t require a major R&D
Background should be lower than in Babar, even with a smaller radius beam pipe. (from 3cm to 1.cm). Simulations are currently run.
Must be more hermetic than Babar and Belle.
PID in forward/backward
By reducing Lorentz boost higher resolution vertex is needed (MAPS?)
Silicon Vertex Tracker

• **Vertexing**
  - Two monolithic active pixel layers glued on beam pipe
    • Since active region is only ~10um, silicon can be thinned down to ~50um.
    • Good resolution O(5um).
    • Good aspect ratio for small radius (compared to strips)
    • Improves pattern recognition robustness and safety against background
    • needs R&D: feasibility of MAPS, overlaps, cables, cooling

• Quite a bit of R&D going on on MAPS
ST 0.13um triple well technology
Single pixels tested with source
Full signal processing chain

- **SLIM chip**
  (Babar collabor.)

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[Diagram of the SLIM chip circuitry]

<table>
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<tr>
<th>Pre</th>
<th>Shaper</th>
<th>Disc</th>
<th>Latch</th>
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- **Analog section**
  - NMOS, p-well, n-well, p^- epitaxial layer

- **Logic section**
  - SFF, logic gates

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<tr>
<td>1000</td>
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<tr>
<td>2000</td>
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</table>

- **Threshold**
  - 80 mV

- **Noise only**
  (no source)

- **55Fe X-rays**
  - μ=105 mV
  - σ=12 mV

- **90Sr electrons**
  - Saturation due to low energy particle.

- **Charge sharing**

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- **Threshold**
  - 55Fe X-rays

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Marcello A. Giorgi 75

**MAPS R&D II**
Focusing Aerogel-RICH to cover front/back

- New imaging technique by introducing multiple radiators

Increase Cherenkov photons without losing single angle resolution due to emission point uncertainty

Take full advantage of controllable index of aerogel
INFN Roadmap Report

SuperB: a linear high-luminosity B Factory


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2Universita di Pisa, Dipartimento di Fisica, Scuola Normale Superiore and INFN, I-56127 Pisa, Italy
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4Ecole Polytechnique, LLL, F-91128 Palaiseau, France
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11University of Edinburgh, Edinburgh EH9 3JZ, United Kingdom
12Laboratoire de l’Accélérateur Linéaire, F-91898 Orsay, France

Abstract

This paper is based on the outcome of the activity that has taken place during the recent workshop on “SuperB in Italy” held in Frascati on November 11-12, 2005. The workshop was opened by a theoretical introduction of Marco Cinchini and was structured in two working sessions. One focused on the machine and the other on the detector and experimental issues.
An international Study Group was set up coordinated by a steering committee with the aim of preparing a document (CDR) by the end of 2006. Next 2 workshops:

- 14-17 June 06 in SLAC
- October 06 in Rome.

M.A.G. coordinator

Members: 1 Canada, 2 France, 2 Germany, 2 Italy, 2 Russia, 2 Spain, 2 UK, 4 US.

Activity is documented in

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

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

9-10 May 2006