Plans for future B factories

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Contents

- Physics case for a Super B factory
- SuperKEKB/Belle-II@KEK and SuperB@Frascati
- Accelerators
- Detectors
- Status and prospects of the projects
B factories: CP violation in the B system

CP violation in B system: from the discovery (2001) to a precision measurement (2006)

\[ \frac{\sin 2\phi_1}{\sin 2\beta} \text{ from } b \to ccs \]

**World average 2008:**
\[ \sin 2\phi_1 = 0.681 \pm 0.025 \]

Constraints from measurements of angles and sides of the unitarity triangle → Remarkable agreement
B factories: a success story

- Measurements of CKM matrix elements and angles of the unitarity triangle
- Observation of direct CP violation in B decays
- Measurements of rare decay modes (e.g., $B \to \tau \nu$, $D \tau \nu$)
- $b \to s$ transitions: probe for new sources of CPV and constraints from the $b \to s \gamma$ branching fraction
- Forward-backward asymmetry ($A_{FB}$) in $b \to s l^+ l^-$ has become a powerful tool to search for physics beyond SM.
- Observation of $D$ mixing
- Searches for rare $\tau$ decays
- Observation of new hadrons
Luminosity at B factories

> 1 ab$^{-1}$
On resonance:
Y(5S): 121 fb$^{-1}$
Y(4S): 711 fb$^{-1}$
Y(3S): 3 fb$^{-1}$
Y(2S): 24 fb$^{-1}$
Y(1S): 6 fb$^{-1}$
Off res./scan:
$\sim$ 100 fb$^{-1}$

$\sim$ 550 fb$^{-1}$
On resonance:
Y(4S): 433 fb$^{-1}$
Y(3S): 30 fb$^{-1}$
Y(2S): 14 fb$^{-1}$
Off resonance:
$\sim$ 54 fb$^{-1}$

Fantastic performance much beyond design values!
What next?

B factories $\rightarrow$ is SM with CKM right?

Next generation: Super B factories $\rightarrow$ in which way is the SM wrong?

$\rightarrow$ Need much more data (two orders!) because the SM worked so well until now $\rightarrow$ Super B factory

However: it will be a different world in four years, there will be serious competition from LHCb and BESIII

Still, $e^+e^-$ machines running at (or near) $Y(4s)$ will have considerable advantages in several classes of measurements, and will be complementary in many more
Power of $e^+e^-$, example: Full Reconstruction Method

- Fully reconstruct one of the B’s to
  - Tag B flavor/charge
  - Determine B momentum
  - Exclude decay products of one B from further analysis

Decays of interest
- $B \rightarrow X_u \nu$, $B \rightarrow K \nu \nu$
- $B \rightarrow D \tau \nu$, $\tau \nu$
- $B \rightarrow D \pi$ etc. (0.1~0.3%)

→ Offline B meson beam!

Powerful tool for B decays with neutrinos

Peter Križan, Ljubljana
Event candidate $B^- \rightarrow \tau^- \nu_{\tau}$

\[ B^+ \rightarrow D^0 \pi^+ \]
\[ \quad (\rightarrow K \pi^- \pi^+ \pi^-) \]
\[ B^- \rightarrow \tau (\rightarrow e \nu \bar{\nu}) \nu \]
Charged Higgs limits from $B^{-} \rightarrow \tau^{-} \nu_{\tau}$

$$r_{H} = \frac{BF(B \rightarrow \tau \nu)}{BF(B \rightarrow \tau \nu)_{SM}} = \left(1 - \frac{m_{B}^{2}}{m_{H}^{2}} \tan^{2} \beta \right)^{2}$$

→ limit on charged Higgs mass vs. $\tan \beta$

![Diagram showing limits on charged Higgs mass vs. $\tan \beta$. The left plot shows Belle 4472(6)% BB (68.3%) C.L. and Tevatron Run I Excluded (95%) C.L. with a limit of ~0.5 ab⁻¹. The right plot shows Tevatron Run I Excluded (95%) C.L. with a limit of 50 ab⁻¹.]
Semileptonic decay sensitive to charged Higgs

\[ B \rightarrow D(*)\tau\nu \]

Ratio of \( \tau \) to \( \mu, e \) could be reduced/enhanced significantly

\[ R(D) \equiv \frac{\mathcal{B}(B \rightarrow D\tau\nu)}{\mathcal{B}(B \rightarrow D\ell\nu)} \]

Compared to \( B \rightarrow \tau\nu \)

1. Smaller theoretical uncertainty of \( R(D) \)
   
   For \( B \rightarrow \tau\nu \),
   
   There is \( O(10\%) \) \( f_B \) uncertainty from lattice QCD

2. Large expected \( \text{Br} \)
   
   \[ \mathcal{B}(B^- \rightarrow D^0\tau^\pm\nu_\tau)^{SM} = (0.71 \pm 0.09)\% \]
   
   \[ \mathcal{B}(\bar{B}^0 \rightarrow D^+\tau^-\nu_\tau)^{SM} = (0.66 \pm 0.08)\% \]

3. Differential distributions can be used to discriminate \( W^+ \) and \( H^+ \)

4. Sensitive to different vertex \( B \rightarrow \tau\nu \): \( H-b-u \), \( B \rightarrow D\tau\nu \): \( H-b-c \)

(LHC experiments sensitive to \( H-b-t \))
Exclusion plots for tanβ and H⁺ mass for 5ab⁻¹ and 50ab⁻¹.
\[ \text{BF} \left( B^0 \rightarrow D^*\tau^+\nu_\tau \right) = (2.02^{+0.40}_{-0.37} \text{ (stat)} \pm 0.37 \text{ (syst)} ) \times 10^{-2} \]

**Signal Yield**

\[ N_s = 60^{+12}_{-11} \quad 6.7\sigma \text{ (5.2}\sigma \text{ with syst.)} \]

**First Observation - 2007**

535M BB

**Update at this workshop**

Peter Križan, Ljubljana
$\text{B} \rightarrow \text{K}^{(*)}\nu\nu$

$B \rightarrow K\nu\nu, \quad B \sim 4 \cdot 10^{-6}$
$B \rightarrow K^*\nu\nu, \quad B \sim 6.8 \cdot 10^{-6}$

SM: penguin+box

Look for departure from the expected value $\rightarrow$
information on couplings $C^\nu_R$ and $C^\nu_L$ compared to $(C^\nu_L)^{\text{SM}}$

Again: fully reconstruct one of the B mesons, look for signal (+nothing else) in the rest of the event.

not possible @ LHCb
CP violation in $B \rightarrow K_S \pi^0 \gamma$

CP violation in $B \rightarrow K_S \pi^0 \gamma$ decays:
Search for right-handed currents

$B \rightarrow K^* \gamma, \mathcal{B} \sim 4.0 \cdot 10^{-5}$

$\delta S \sim 0.2$ (present)
$\rightarrow \sim$ a few % at 50 ab$^{-1}$

not possible @ LHCb

Peter Križan, Ljubljana
**LFV and New Physics**

\[ \tau \rightarrow l \gamma \]

- SUSY + Seesaw
- Large LFV \( \text{Br}(\tau \rightarrow \mu \gamma) = O(10^{-7} \sim 9) \)

\[
\text{Br}(\tau \rightarrow \mu \gamma) \equiv 10^{-6} \times \left( \frac{m_L^2}{m_{SUSY}^2} \right) 4 \left( \frac{1 \text{TeV}}{m_{SUSY}} \right)^4 \tan^2 \beta
\]

\[ \tau \rightarrow 3l, l \eta \]

- Neutral Higgs mediated decay.
- Important when \( M_{SUSY} \gg \) EW scale.

\[
\text{Br}(\tau \rightarrow 3 \mu) = 4 \times 10^{-7} \times \left( \frac{m_L^2}{m_{SUSY}^2} \right) \left( \frac{\tan \beta}{60} \right)^6 \left( \frac{100 \text{GeV}}{m_A} \right)^4
\]

<table>
<thead>
<tr>
<th>model</th>
<th>( \text{Br}(\tau \rightarrow \mu \gamma) )</th>
<th>( \text{Br}(\tau \rightarrow 3l) )</th>
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<tbody>
<tr>
<td>mSUGRA + seesaw</td>
<td>( 10^{-7} )</td>
<td>( 10^{-9} )</td>
</tr>
<tr>
<td>SUSY + SO(10)</td>
<td>( 10^{-8} )</td>
<td>( 10^{-10} )</td>
</tr>
<tr>
<td>SM + seesaw</td>
<td>( 10^{-9} )</td>
<td>( 10^{-10} )</td>
</tr>
<tr>
<td>Non-Universal Z'</td>
<td>( 10^{-9} )</td>
<td>( 10^{-8} )</td>
</tr>
<tr>
<td>SUSY + Higgs</td>
<td>( 10^{-10} )</td>
<td>( 10^{-7} )</td>
</tr>
</tbody>
</table>
Rare $\tau$ decays

LF violating $\tau$ decay?

Upper limits

Theoretical predictions compared to present experimental limits

Reach of B factories

Super B factory

Reach of B factories

Super B factories

Peter Križan, Ljubljana
Charm mixing and CP

<table>
<thead>
<tr>
<th>Mode</th>
<th>Observable</th>
<th>$\Upsilon$(4S)</th>
<th>$\psi$(3770)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(2460 ab$^{-1}$)</td>
<td>(3770 ab$^{-1}$)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3770 ab$^{-1}$)</td>
<td>(3770 ab$^{-1}$)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3770 ab$^{-1}$)</td>
<td>(3770 ab$^{-1}$)</td>
</tr>
<tr>
<td>$D^0 \rightarrow K^+\pi^-$</td>
<td>$x^2$</td>
<td>$3 \times 10^{-5}$</td>
<td>$1 \times 10^{-8}$</td>
</tr>
<tr>
<td>$D^0 \rightarrow K^+\pi^-$</td>
<td>$y'\phi$</td>
<td>$7 \times 10^{-4}$</td>
<td>$3 \times 10^{-4}$</td>
</tr>
<tr>
<td>$D^0 \rightarrow K^{0}\pi^+\pi^-$</td>
<td>$x$</td>
<td>$5 \times 10^{-4}$</td>
<td>$3 \times 10^{-4}$</td>
</tr>
<tr>
<td>$D^0 \rightarrow K^{0}\pi^+\pi^-$</td>
<td>$y$</td>
<td>$3.5 \times 10^{-4}$</td>
<td>$3 \times 10^{-4}$</td>
</tr>
<tr>
<td>$</td>
<td>q/p</td>
<td>$</td>
<td>$3 \times 10^{-2}$</td>
</tr>
<tr>
<td>$\phi$</td>
<td>$2^\circ$</td>
<td>$1 \times 10^{-2}$</td>
<td></td>
</tr>
<tr>
<td>$\psi(3770) \rightarrow D^0\overline{D}^0$</td>
<td>$x^2$</td>
<td>$(1-2) \times 10^{-5}$</td>
<td>$(1-2) \times 10^{-5}$</td>
</tr>
<tr>
<td>$\psi(3770) \rightarrow D^0\overline{D}^0$</td>
<td>$y$</td>
<td>$(1-2) \times 10^{-5}$</td>
<td>$(1-2) \times 10^{-5}$</td>
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<tr>
<td>$\cos \delta$</td>
<td></td>
<td>$(0.01-0.02)$</td>
<td>$(0.01-0.02)$</td>
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</table>

Charm FCNC

<table>
<thead>
<tr>
<th>Observable</th>
<th>$\Upsilon$(4S)</th>
<th>$\psi$(3770)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B^0 \rightarrow \pi^+\pi^-$</td>
<td>$7%$</td>
<td>$1%$</td>
</tr>
<tr>
<td>$A^0 \rightarrow \pi^+\pi^-$</td>
<td>$26%$</td>
<td>$5%$</td>
</tr>
<tr>
<td>$D^0 \rightarrow K^0\pi^-\pi^+$</td>
<td>$20%$</td>
<td>possible</td>
</tr>
<tr>
<td>$\gamma(B \rightarrow \pi\pi)$</td>
<td>$3^\circ$</td>
<td>$1^\circ$</td>
</tr>
<tr>
<td>$\gamma(B \rightarrow \rho\rho)$</td>
<td>$7^\circ$</td>
<td>$2^\circ$</td>
</tr>
<tr>
<td>$\gamma(B \rightarrow \rho\pi)$</td>
<td>$12^\circ$</td>
<td>$1^\circ$</td>
</tr>
<tr>
<td>$\gamma(B \rightarrow \pi\pi)$</td>
<td>$20^\circ$</td>
<td>possible</td>
</tr>
<tr>
<td>$\gamma(D_{sL}^0 \rightarrow \pi\pi)$</td>
<td>$20^\circ$</td>
<td>$5^\circ$</td>
</tr>
</tbody>
</table>

B$_s$ Physics @ Y(5S)

<table>
<thead>
<tr>
<th>Observable</th>
<th>Error with 1 ab$^{-1}$</th>
<th>Error with 30 ab$^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta m$</td>
<td>0.16 ps$^{-1}$</td>
<td>0.03 ps$^{-1}$</td>
</tr>
<tr>
<td>$\Gamma$</td>
<td>0.07 ps$^{-1}$</td>
<td>0.01 ps$^{-1}$</td>
</tr>
<tr>
<td>$\beta_s$ from angular analysis</td>
<td>$20^\circ$</td>
<td>$8^\circ$</td>
</tr>
<tr>
<td>$A_{bs}$</td>
<td>0.0006</td>
<td>0.004</td>
</tr>
<tr>
<td>$A_{CP}$</td>
<td>0.004</td>
<td>0.004</td>
</tr>
<tr>
<td>$B(B_s \rightarrow \mu^+\mu^-)$</td>
<td>$&lt; 8 \times 10^{-9}$</td>
<td>$&lt; 8 \times 10^{-9}$</td>
</tr>
<tr>
<td>$</td>
<td>V_{cs}/V_{us}</td>
<td>$</td>
</tr>
<tr>
<td>$B(B_s \rightarrow \gamma\gamma)$</td>
<td>$38^\circ$</td>
<td>$7^\circ$</td>
</tr>
<tr>
<td>$\beta_s$ from $J/\psi\phi$</td>
<td>$10^\circ$</td>
<td>$3^\circ$</td>
</tr>
<tr>
<td>$\beta_s$ from $B_s \rightarrow K^0\pi^0$</td>
<td>$24^\circ$</td>
<td>$11^\circ$</td>
</tr>
</tbody>
</table>

M. Giorgi, ICHEP2010
Physics with 50ab\(^{-1}\) / 75ab\(^{-1}\)

→ More during this workshop

→ Two recent publications:
  • Physics at Super B Factory (Belle II authors + guests)
    hep-ex > arXiv:1002.5012
  • SuperB Progress Reports: Physics (SuperB authors + guests)
    hep-ex > arXiv:1008.1541
Physics at a Super B Factory

- There is a good chance to see new phenomena;
  - CPV in B decays from the new physics (non KM).
  - Lepton flavor violations in $\tau$ decays.

- They will help to diagnose (if found) or constrain (if not found) new physics models.

- $B \rightarrow \tau \nu$, $D \tau \nu$ can probe the charged Higgs in large $\tan \beta$ region.

- **Physics motivation is independent of LHC.**
  - If LHC finds NP, precision flavour physics is compulsory.
  - If LHC finds no NP, high statistics $B/\tau$ decays would be a unique way to search for the $>\text{TeV}$ scale physics ($=\text{TeV}$ scale in case of MFV).

There are many more topics: CPV in charm, new hadrons, ...
Super B Factory Motivation 2

- Lessons from history: the top quark
  - Physics of top quark
    - First estimate of mass: BB mixing → ARGUS
    - Direct production, Mass, width etc. → CDF/D0
    - Off-diagonal couplings, phase → BaBar/Belle

- Even before that: prediction of charm quark from the GIM mechanism, and its mass from $K^0$ mixing

Peter Križan, Ljubljana
Need $O(100x)$ more data → Next generation B-factories

Peak Luminosity Trends ($e^+e^-$ collider)

- $10^{36}$
- 40 times higher luminosity
- SuperKEKB + SuperB
- KEKB
- PEP-II

- SPEAR
- DORIS
- PETRA
- CESR
- LEP I
- LEP II
- TRISTAN
- DAΦNE
- BEPC-II

Year

How to do it?
→ upgrade KEKB and Belle
The KEKB Collider & Belle Detector

- e^- (8 GeV) on e^+(3.5 GeV)
  - \( \sqrt{s} \approx m_{\Upsilon(4S)} \)
  - Lorentz boost: \( \beta\gamma = 0.425 \)
- 22 mrad crossing angle
- Operating since 1999

Peak luminosity (WR!):

\[ 2.1 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1} = 2 \times \text{design value} \]

First physics run on June 2, 1999
Last physics run on June 30, 2010
\( L_{\text{peak}} = 2.1 \times 10^{34} / \text{cm}^2 / \text{s} \)
\( L > 1 \text{ab}^{-1} \)
The last beam abort of KEKB on June 30, 2010

→ Can start construction of SuperKEKB and Belle II
Strategies for increasing luminosity

1. Smaller $\beta_y^*$
2. Increase beam currents
3. Increase $\xi_y$

Collision with very small spot-size beams

“Nano-Beam” scheme

Invented by Pantaleo Raimondi for SuperB
## Machine design parameters

<table>
<thead>
<tr>
<th>parameters</th>
<th>KEKB</th>
<th>SuperKEKB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LER</td>
<td>HER</td>
</tr>
<tr>
<td>Beam energy $E_b$</td>
<td>3.5</td>
<td>8</td>
</tr>
<tr>
<td>Half crossing angle $\varphi$</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Horizontal emittance $\varepsilon_x$</td>
<td>18</td>
<td>24</td>
</tr>
<tr>
<td>Emittance ratio $\kappa$</td>
<td>0.88</td>
<td>0.66</td>
</tr>
<tr>
<td>Beta functions at IP $\beta_x^<em>/\beta_y^</em>$</td>
<td>1200/5.9</td>
<td></td>
</tr>
<tr>
<td>Beam currents $I_b$</td>
<td>1.64</td>
<td>1.19</td>
</tr>
<tr>
<td>beam-beam parameter $\xi_y$</td>
<td>0.129</td>
<td>0.090</td>
</tr>
<tr>
<td>Luminosity $L$</td>
<td>$2.1 \times 10^{34}$</td>
<td></td>
</tr>
</tbody>
</table>

- **Small beam size & high current** to increase luminosity
- **Large crossing angle**
- **Change beam energies** to solve the problem of LER short lifetime

M. Iwasaki, ICHEP2010
KEKB to SuperKEKB

Replace short dipoles with longer ones (LER)

Redesign the lattices of HER & LER to squeeze the emittance

TiN-coated beam pipe with antechambers

Add / modify RF systems for higher beam current

New superconducting/permanent final focusing quads near the IP

Positron source

New positron target/capture section

Low emittance gun

Low emittance electrons to inject

To get x40 higher luminosity
How to do it?

→ Construct a new tunnel at LNF Frascati
→ Move magnets from PEP-II
→ Move BaBar, upgrade
Nano-beam collisions with crab waist

Crab waist scheme: successfully tested in the DAΦNE ring

All particles from both beams collide in the minimum $\beta_y$ region, with a net luminosity gain

Without Crab-sextupoles

With Crab-sextupoles

Pantaleo Raimondi
### Parameters for $1 \times 10^{36}$ Lumi (max $4 \times 10^{36}$)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Base Line</th>
<th>Low Emittance</th>
<th>High Current</th>
<th>Tau/Charm (prelim.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LUMINOSITY</strong></td>
<td>cm$^{-2}$ s$^{-1}$</td>
<td>1.00E+36</td>
<td>1.00E+36</td>
<td>1.00E+36</td>
<td>1.00E+36</td>
</tr>
<tr>
<td>Energy</td>
<td>GeV</td>
<td>6.7 4.18</td>
<td>6.7 4.18</td>
<td>6.7 4.18</td>
<td>2.58 1.61</td>
</tr>
<tr>
<td>Circumference</td>
<td>m</td>
<td>1250.4</td>
<td>1258.4</td>
<td>1258.4</td>
<td>1258.4</td>
</tr>
<tr>
<td>X-Angle (full)</td>
<td>mrad</td>
<td>66</td>
<td>66</td>
<td>66</td>
<td>66</td>
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<tr>
<td>Fisunski angle</td>
<td>rad</td>
<td>22.00</td>
<td>10.60</td>
<td>32.36</td>
<td>26.30</td>
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<tr>
<td>$\beta_x$ @ IP</td>
<td>cm</td>
<td>2.6</td>
<td>3.2</td>
<td>2.6</td>
<td>3.2</td>
</tr>
<tr>
<td>$\beta_y$ @ IP</td>
<td>cm</td>
<td>0.0253</td>
<td>0.0205</td>
<td>0.0179</td>
<td>0.0145</td>
</tr>
<tr>
<td>Coupling (full current)</td>
<td>%</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>$\sigma_x$ (without IBS)</td>
<td>nm</td>
<td>1.97</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
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<tr>
<td>$\sigma_y$ (without IBS)</td>
<td>nm</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
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<tr>
<td>$\sigma_x$ @ IP</td>
<td>$\mu$m</td>
<td>5.61</td>
<td>2.5</td>
<td>3.07</td>
<td>10.056</td>
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<td>$\sigma_y$ @ IP</td>
<td>$\mu$m</td>
<td>0.036</td>
<td>0.021</td>
<td>0.021</td>
<td>0.054</td>
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<td>$\gamma_x$</td>
<td></td>
<td>11.433</td>
<td>8.085</td>
<td>15.944</td>
<td>29.732</td>
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<td>$\gamma_y$</td>
<td></td>
<td>0.050</td>
<td>0.030</td>
<td>0.076</td>
<td>0.131</td>
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<tr>
<td>$\sigma_x$ (full current)</td>
<td>mm</td>
<td>4.69</td>
<td>4.29</td>
<td>4.73</td>
<td>4.34</td>
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<tr>
<td>$\sigma_y$ (full current)</td>
<td>mm</td>
<td>5.00</td>
<td>5.00</td>
<td>5.00</td>
<td>5.00</td>
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<tr>
<td>Dcem current</td>
<td>mA</td>
<td>1092</td>
<td>243</td>
<td>1460</td>
<td>1000</td>
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<tr>
<td>Buckets distance</td>
<td>#</td>
<td>2</td>
<td>2</td>
<td>1000</td>
<td>400</td>
</tr>
<tr>
<td>Ion gap</td>
<td>%</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td></td>
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<tr>
<td>RF frequency</td>
<td>Hz</td>
<td>4.76E+08</td>
<td>4.76E+08</td>
<td>4.76E+08</td>
<td>4.76E+08</td>
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<tr>
<td>Number of bunches</td>
<td></td>
<td>970</td>
<td>970</td>
<td>1950</td>
<td>1950</td>
</tr>
<tr>
<td>N. Particle/bunch</td>
<td></td>
<td>5.08E+10</td>
<td>6.56E+10</td>
<td>3.92E+10</td>
<td>5.06E+10</td>
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<tr>
<td>Tune shift $x$</td>
<td></td>
<td>0.0021</td>
<td>0.0033</td>
<td>0.0017</td>
<td>0.0025</td>
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<tr>
<td>Tune shift $y$</td>
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<td>0.0079</td>
<td>0.0091</td>
<td>0.0089</td>
<td>0.0069</td>
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<tr>
<td>Long. damping time</td>
<td>msec</td>
<td>13.4</td>
<td>20.3</td>
<td>13.4</td>
<td>20.3</td>
</tr>
<tr>
<td>Energy Loss/turn</td>
<td>MeV</td>
<td>2.11</td>
<td>0.065</td>
<td>2.11</td>
<td>0.065</td>
</tr>
<tr>
<td>$\sigma_E$ (full current)</td>
<td>dE/E</td>
<td>6.43E-04</td>
<td>7.34E-04</td>
<td>6.43E-04</td>
<td>7.34E-04</td>
</tr>
<tr>
<td>CM $\sigma_E$</td>
<td>dE/E</td>
<td>5.00E-04</td>
<td>5.00E-04</td>
<td>5.00E-04</td>
<td>5.00E-04</td>
</tr>
<tr>
<td>Total lifetime</td>
<td>min</td>
<td>4.23</td>
<td>4.48</td>
<td>3.96</td>
<td>3.00</td>
</tr>
<tr>
<td>Total RF Power</td>
<td>MW</td>
<td>17.08</td>
<td>12.72</td>
<td>30.48</td>
<td>3.11</td>
</tr>
</tbody>
</table>

**Baseline + other 2 options:**
- Lower $y$-emittance
- Higher currents (twice bunches)

**Baseline:**
- Higher emittance due to IBS
- Asymmetric beam currents

**RF power includes SR and HOM**

---

M. Giorgi, ICHEP2010
Interest of running at charm threshold

Decays of $\psi(3770) \rightarrow D^0\bar{D}^0$ produce coherent $(C=-1)$ pairs of $D^0$'s

- 3 months of running will give 500fb$^{-1}$: 50x BES-III

- Precision charm mixing,
- CPT Violation, rare decays, CPV using quantum correlations, decay constants, ...

A. Bevan, Capri Workshop July 2010
Polarized beam helps to reduce irreducible background in tau decays (e.g. $\tau \to \mu \gamma$)

Applying a rectangular cut eff. on signal $\sim$40-45%
bkg retained $\sim$ 10-15%

Sensitivity improves at least by a factor 2.
Equivalent to a factor 4 increase in luminosity.

M. Giorgi, ICHEP2010
Study is in progress on a shorter version, entirely fitting the LNF site.

Polarization is understood and feasible! Parameter flexibility allows $10^{36}$ peak lumi without stressing limits!

No impediment caused by the photon operation is seen so far to prevent design operations of SuperB for HEP.

M. Giorgi, ICHEP2010
Detectors
Requirements for the Belle II detector

Critical issues at $L = 8 \times 10^{35}/\text{cm}^2/\text{sec}$

- **Higher background ($\times 10^{-20}$)**
  - radiation damage and occupancy
  - fake hits and pile-up noise in the EM

- **Higher event rate ($\times 10$)**
  - higher rate trigger, DAQ and computing

- **Require special features**
  - low $p\mu$ identification $\leftrightarrow s\mu\mu$ recon. eff.
  - hermeticity $\leftrightarrow \nu$ “reconstruction”

Solutions:
- Replace inner layers of the vertex detector with a pixel detector.
- Replace inner part of the central tracker with a silicon strip detector.
- Better particle identification device
- Replace endcap calorimeter crystals
- Faster readout electronics and computing system.

Very similar reasoning also for SuperB
Belle II in comparison with Belle

**SVD:** 4 DSSD lys → 2 DEPFET lys + 4 DSSD lys
**CDC:** small cell, long lever arm
**ACC+TOF** → **TOP+A-RICH**
**ECL:** waveform sampling, pure CsI for end-caps
**KLM:** RPC → Scintillator +SiPM (end-caps)

Parameters are preliminary

Y. Ushiroda, ICHEP2010
A prototype ladder using the first 6 inch DSSD from Hamamatsu has been assembled and tested.
Expected performance

Significant improvement in IP resolution!

\[ \sigma = a + \frac{b}{p\beta \sin^\nu \theta} \]

- Less Coulomb scatterings
- Pixel detector close to the beam pipe

**Belle II**

- Significantly improved impact parameter resolution \( \sigma[\mu m] \)
  - \( p\beta \sin(\theta)^{3/2} [GeV/c] \) vs. Resolution [\( \sigma[\mu m] \)]
  - \( p\beta \sin(\theta)^{5/2} [GeV/c] \) vs. Resolution [\( \sigma[\mu m] \)]

**Belle II'**

- Improved B decay point reconstruction with \( K_S \) trajectory
- Larger radial coverage of SVD

Peter Križan, Ljubljana
Particle Identification Devices

Barrel PID: Time of Propagation Counter (TOP)
- Quartz radiator
- Focusing mirror
- Small expansion block
- Hamamatsu MCP-PMT (measure t, x and y)

Endcap PID: Aerogel RICH (ARICH)
- Aerogel radiator
- Hamamatsu HAPD
- New ASIC

200mm
- Cherenkov photon

Peter Križan, Ljubljana
TOP (Barrel PID)

- Quartz radiator
  - 2.6m$^3$ x 45cm$^W$ x 2cm$^T$
  - Excellent surface accuracy
- MCP-PMT
  - Hamamatsu 16ch MCP-PMT
    - Good TTS (<35ps) & enough lifetime
    - Multialkali photo-cathode → SBA
- Beam test in 2009
  - # of photons consistent
  - Time resolution OK
Aerogel RICH (endcap PID)

Test Beam setup

Aerogel

Hamamatsu HAPD Q.E. ~33% (recent good ones)

Clear Cherenkov image observed

Cherenkov angle distribution

RICH with a novel “focusing” radiator – a two layer radiator

Employ multiple layers with different refractive indices → Cherenkov images from individual layers overlap on the photon detector.

6.6 $\sigma$ $\pi/K$ at 4GeV/c!

Peter Križan, Ljubljana
BEMC Inexpensive Veto device bringing 8-10% sensitivity improvements for $B \rightarrow \tau \nu$. Low momentum PID via TOF? Technical Issues?

IFR Optimized layout. Plan to reuse yoke. Still need to resolve engineering questions.

6Layer SVT L0 Striplets @ 1.6cm if background is acceptable as default. MAPS Option

FPID Physics gains about 5% in $B \rightarrow K(*) \nu \nu$. Somewhat larger gains for higher multiplicities

M. Giorgi, ICHEP2010
### Background Issue: sources

<table>
<thead>
<tr>
<th></th>
<th>Cross section</th>
<th>Evt/bunch xing</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam Strahlung</td>
<td>~340 mbarn (Eγ/Ebeam &gt; 1%)</td>
<td>~850</td>
<td>0.3THz</td>
</tr>
<tr>
<td>e⁺e⁻ pair production</td>
<td>~7.3 mbarn</td>
<td>~18</td>
<td>7GHz</td>
</tr>
<tr>
<td>e⁺e⁻ pair (seen by L0 @ 1.5 cm)</td>
<td>~0.07 mbarn</td>
<td>~0.2</td>
<td>70 MHz</td>
</tr>
<tr>
<td>Elastic Bhabha</td>
<td>O(10⁻⁴) mbarn (Det. acceptance)</td>
<td>~250/Million</td>
<td>100KHz</td>
</tr>
<tr>
<td>Y(4S)</td>
<td>O(10⁻⁶) mbarn</td>
<td>~2.5/Million</td>
<td>1 KHz</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Loss rate</th>
<th>Loss/bunch pass</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Touschek (LER)</td>
<td>4.1kHz / bunch (+/- 2 m from IP)</td>
<td>~3/100</td>
<td>~5 MHz</td>
</tr>
</tbody>
</table>

### Two colliding beams:
- radiative Bhabha → dominant effect on lifetime
- e⁺e⁻ e⁺e⁻ production → important source for SVT layer-0
- synchrotron radiation → strictly connected to IR design

### Single beam:
- Touschek → negligible in BaBar, important in SuperB
- beam-gas
- intra-beam scattering

Collimators, dynamic aperture and energy acceptance optimization solve the problem of Touschek background in LER

M. Giorgi, ICHEP2010
Status of the projects
Belle II Collaboration

13 countries/regions, 54 institutes

300 collaborators, >100 from Europe

Peter Križan, Ljubljana
SuperKEKB/Belle II funding Status

KEKB upgrade has been approved

- 5.8 oku yen (~MUSD) for Damping Ring (FY2010)
- 100 oku yen for machine -- Very Advanced Research Support Program (FY2010-2012)

Continue efforts to obtain additional funds to complete construction as scheduled.

Several non-Japanese funding agencies have already allocated sizable funds for the upgrade.

construction started!
Construction Schedule of SuperKEKB/Belle II

**Linac**
- FY2010: R&D
- FY2011: RF-gun & laser system
- FY2012: Design study
- FY2013: Commissioning at test stand
- FY2014: Construction

**Damping Ring**
- FY2009: Facilities
- FY2010: Tunnel construction
- FY2011: Building construction
- FY2012: Mass Fabrication
- FY2013: Installation
- FY2014: DR commissioning

**Main Ring**
- FY2009: Facilities
- FY2010: Building construction
- FY2011: Mass Fabrication
- FY2012: Installation
- FY2013: MR commissioning

**Belle II Detector**
- FY2009: R&D
- FY2010: Mass Production
- FY2011: Construction
- FY2012: Installation (KLM)
- FY2013: Installation (E-cap)
- FY2014: Installation (Barrel)

Belle roll-out in Dec. 2010
Luminosity upgrade projection

Milestone of SuperKEKB

Plan: reach 50 ab\(^{-1}\) in 2020~2021

9 month/year
20 days/month

5 ab\(^{-1}\) in 2016

Commissioning starts mid of 2014

Shutdown for upgrade

Peter Križan, Ljubljana
Towards green light

- The project is the first “flagship project” of the new national research plan
- The project has been mentioned as a reciprocity condition in a Russian-Italian agreement on ignitor (nuclear fusion)

- A formal commitment with INFN for the project with the declaration of some available budget in the current year is expected.

- This commitment will set the start of the project.

M. Giorgi, ICHEP2010
Comunicato stampa del 26 Aprile 2010 - Muur

Ministero dell'Istruzione, dell'Università e della Ricerca

Estratto da pag. 25

Il Sole 24 ORE

Mer 14/04/2010

Innovazione. Più spazio all'industria

Gelmini aggiorna il piano nazionale

Eugenio Bruno

Un acceleratore di particelle complementare a quello del Cern di Ginevra. Un network dei laboratori di nanotecnologia. Una «fabbrica del futuro» per rilanciare il manifatturiero. Uno studio approfondito nell'epigenetica. Sono alcuni dei «progetti bandiera» che il ministro dell'Istruzione Maristella Gelmini punta a inserire tra le priorità del programma nazionale della ricerca (Pnr) 2010-2012. La lista degli interventi su cui il Muur vuole direttamente le prime ricerche che il Pnr interverranno congiunge 14 voci. Fermo restando che da qui alla sua ufficializzazione potrebbe anche subire delle modifiche, l'unico si presenta estremamente variegato. Alle azioni sulla formazione nel campo del nucleare, sull'affondamento dei rapporti tra invecchiamento Dna e alle mire per l'agroalimentare e i beni culturali - anticipati dal mini- mistero al Sole 24 Ore il 26 marzo - ecco il sovvenzione.

Gli interventi

<table>
<thead>
<tr>
<th>Progetto</th>
<th>Settore</th>
<th>Valore stimato (milioni)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Super B Factory</td>
<td>Fisica</td>
<td>680</td>
</tr>
<tr>
<td>Cosmo - Skymed III generation</td>
<td>Aerospazio</td>
<td>2000</td>
</tr>
<tr>
<td>Epigenetica</td>
<td>N.d.</td>
<td>610</td>
</tr>
<tr>
<td>3N - Network nazionale delle nanotecnologie</td>
<td>Industria</td>
<td>300</td>
</tr>
<tr>
<td>Ritirare - Ricerca it. per il mare</td>
<td>869</td>
<td>795</td>
</tr>
<tr>
<td>Sintonia - Sistema integrato di tele comunicazioni</td>
<td>Industria</td>
<td>671</td>
</tr>
<tr>
<td>Ipi - Invecchiamento e pop. isolato</td>
<td>Agricoltura</td>
<td>100</td>
</tr>
<tr>
<td>Agro Alimentare</td>
<td>63,5</td>
<td>80</td>
</tr>
<tr>
<td>Controllo dei crisi nei sistemi complessi socio-economici</td>
<td>Industria</td>
<td>30</td>
</tr>
<tr>
<td>La fabbrica del futuro</td>
<td></td>
<td>100</td>
</tr>
</tbody>
</table>

M. Giorgi, ICHEP2010
Summary

• B factories have proven to be an excellent tool for flavour physics, with reliable long term operation, constant improvement of the performance, achieving and surpassing design performance

• Major upgrade at KEK in 2010-14 → SuperKEKB+Belle II, L x40, construction started

• SuperB in Frascati: build a new tunnel, reuse (+upgrade) PEP-II and BaBar, waiting for approval

• Physics reach updates available

• Expect a new, exciting era of discoveries, complementary to the LHC
Background composition derived from background study data, which is then scaled by Luminosity, beam current etc.

x10 to x20 as large background as that of 2003 conditions (~worst during Belle running)

Aim for similar or better detector performance even under x20 bkg
Barrel PID: Time of propagation (TOP) counter

- **Cherenkov ring imaging with precise time measurement.**
- Reconstruct angle from two coordinates and the time of propagation of the photon
  - Quartz radiator (2cm)
  - Photon detector (MCP-PMT)
    - Good time resolution ~ 40 ps
    - Single photon sensitivity in 1.5

Peter Križan, Ljubljana
**Barrel:** TOP counter

**End cap:** Aerogel RICH

Expected impact, example B→K*γ: background reduced from blue (present Belle) to red

→ Up to 80% gain in sensitivity

Ljubljana