Prospects of SuperKEKB and Belle-II

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Contents

- Physics case for a Super B factory
- Accelerator upgrade → SuperKEKB
- Detector upgrade → Belle-II
- Summary
B factory main task: measure CP violation in the system of B mesons specifically: various measurements of complex elements of Cabbibo-Kobayashi-Maskawa matrix

CKM matrix is unitary

deviations could signal processes not included in SM

\[
\begin{pmatrix}
V_{ud} & V_{us} & V_{ub} \\
V_{cd} & V_{cs} & V_{cb} \\
V_{td} & V_{ts} & V_{tb}
\end{pmatrix}
= \begin{pmatrix}
1 - \frac{\lambda^2}{2} & \lambda & A\lambda^3(\rho - i\eta) \\
-\lambda & 1 - \frac{\lambda^2}{2} & A\lambda^2 \\
A\lambda^3(1 - \rho - i\eta) & -A\lambda^2 & 1
\end{pmatrix}
\]
CKM: almost a diagonal matrix, but not completely!

CKM: almost real, but not completely!
CP violation in the B system: from the discovery (2001) to a precision measurement (2006)

$\sin^2 \phi_1 = \sin^2 \beta$ from $b \rightarrow c\bar{c}s$

535 M $B\bar{B}$ pairs

$\sin^2 \phi_1 = 0.642 \pm 0.031 \text{ (stat)} \pm 0.017 \text{ (syst)}$
Probability for a b quark to turn into a u quark \( \rightarrow \) determines the length of the side \( V_{ub} \)

CP asymmetry oscillation amplitude

Constraints from measurements of angles and sides of the unitarity triangle

Nobel prize 2008
Also for us a good reason to celebrate...
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., $B \rightarrow \tau \nu$, $D \tau \nu$) by fully reconstructing the other B meson
- Observation of D mixing
- CP violation in $b \rightarrow s$ transitions: probe for new sources if CPV
- Forward-backward asymmetry ($A_{FB}$) in $b \rightarrow s \ell^+ \ell^-$ has become a powerful tool to search for physics beyond SM.
- Observation of new hadrons
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
- $B \rightarrow X_u \ell \nu$, $B \rightarrow K \nu \nu$, $B \rightarrow D\tau\nu, \tau\nu$

Full reconstruction $B \rightarrow D\pi$ etc. (0.1~0.3%)

Offline B meson beam!

Powerful tool for B decays with neutrinos
Event candidate $B^- \rightarrow \tau^- \nu_{\tau}$

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

$$r_H = \frac{BF(B \rightarrow \tau\nu)}{BF(B \rightarrow \tau\nu)_{SM}} = \left(1 - \frac{m_B^2}{m_H^2} \tan^2 \beta \right)^2$$

\[ m_b \tan \beta + m_u \cot \beta \]

\[ m_\tau \tan \beta \]

\[ H^+ \]

$\rightarrow$ limit on charged Higgs mass vs. $\tan \beta$
Why FCNC decays?

Flavour changing neutral current (FCNC) processes (like $b \rightarrow s$, $b \rightarrow d$) are forbidden at the tree level in the Standard Model. Proceed only at low rate via higher-order loop diagrams. Ideal place to search for new physics.
How can New Physics contribute to $b \to s$?

For example in the process:

$$B^0 \to \eta'K^0$$

Ordinary penguin diagram with a $t$ quark in the loop

Diagram with supersymmetric particles
Searching for new physics phases in CP violation measurements in $b \rightarrow s$ decays

Prediction in SM: CP violation parameter

$$\mathcal{B}^0 \rightarrow \eta' K^0$$

$$a_f = - \text{Im}(\lambda_f) \sin(\Delta m t)$$

$$\text{Im}(\lambda_f) = \xi_f \sin 2\phi_1$$

The same value as in the decay $B^0 \rightarrow J/\psi K_S$!

This is only true if there are no other particles in the loop! In general the parameter can assume a different value $\sin 2\phi_1^{\text{eff}}$
Search for NP: $b \rightarrow sqq$

$\sin(2\beta^{\text{eff}}) \equiv \sin(2\phi_1^{\text{eff}})$

<table>
<thead>
<tr>
<th>$b \rightarrow ccs$</th>
<th>World Average</th>
<th>0.68 ± 0.03</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\phi K^0$</td>
<td>BaBar</td>
<td>0.12 ± 0.31 ± 0.10</td>
</tr>
<tr>
<td></td>
<td>Belle</td>
<td>0.50 ± 0.21 ± 0.06</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>0.39 ± 0.18</td>
</tr>
<tr>
<td>$\eta K^0$</td>
<td>BaBar</td>
<td>0.55 ± 0.11 ± 0.02</td>
</tr>
<tr>
<td></td>
<td>Belle</td>
<td>0.64 ± 0.10 ± 0.04</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>0.59 ± 0.08</td>
</tr>
<tr>
<td>$K_S K^0 K_S^*$</td>
<td>BaBar</td>
<td>0.66 ± 0.26 ± 0.08</td>
</tr>
<tr>
<td></td>
<td>Belle</td>
<td>0.30 ± 0.32 ± 0.08</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>0.51 ± 0.21</td>
</tr>
<tr>
<td>$\pi^0 K_S$</td>
<td>BaBar</td>
<td>0.33 ± 0.26 ± 0.04</td>
</tr>
<tr>
<td></td>
<td>Belle</td>
<td>0.33 ± 0.35 ± 0.03</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>0.33 ± 0.21</td>
</tr>
<tr>
<td>$\omega K_S$</td>
<td>BaBar</td>
<td>0.17 ± 0.36 ± 0.53</td>
</tr>
<tr>
<td></td>
<td>Belle</td>
<td>0.13 ± 0.46 ± 0.25</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>0.17 ± 0.25</td>
</tr>
</tbody>
</table>

Gold penguin modes

Hadronic uncertainty $\sim 0.02$

BaBar
Belle
Naïve average

0.26 ± 0.25 ± 0.04
0.67 ± 0.25 ± 0.07
0.45 ± 0.18
0.57 ± 0.08 ± 0.02
0.64 ± 0.10 ± 0.04
0.60 ± 0.07
0.71 ± 0.24 ± 0.04
0.30 ± 0.32 ± 0.08
0.57 ± 0.20

Need much more data to clarify the issue

Peter Križan, Ljubljana
Another FCNC decay: $B \to K^* \ell^+ \ell^-$

$b \to s \ell^+\ell^-$ was first measured in $B \to K \ell^+\ell^-$ by Belle (2001).

Important for further searches for the physics beyond SM

Particularly sensitive: backward-forward asymmetry in $K^* \ell^+\ell^-$

$$A_{FB} \propto \Re \left[ C_{10}^* \left( s C_9^{\text{eff}}(s) + r(s) C_7 \right) \right]$$

$C_i$: Wilson coefficients, abs. value of $C_7$ from $b \to s \gamma$

$s =$ lepton pair mass squared
$A_{FB}(B \rightarrow K^* \ l^+ \ l^-)[q^2]$ at a Super B Factory

- Zero-crossing $q^2$ for $A_{FB}$ will be determined with a 5% error with 50$ab^{-1}$.

Strong competition from LHCb and ATLAS/CMS
D⁰ mixing in K⁺K⁻, π⁺π⁻

Decay time distributions for KK, ππ, Kπ

![Graphs of decay time distributions for KK, ππ, Kπ](image)

Difference of lifetimes visually observable in the ratio of the distributions →

Real fit: \[ y_{CP} = (1.31 \pm 0.32 \pm 0.25) \text{%} \]

An observation of CP violations would be a clear sign of new physics

Peter Križan, Ljubljana
LFV and New Physics

\( \tau \rightarrow l \gamma \)

\( \tilde{\chi}_0 \rightarrow \tau \mu(e) \mu(e) \)

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

\( \text{Br}(\tau \rightarrow \mu \gamma) \equiv 10^{-6} \times \left( \frac{m_L^2}{m_L^2 + m_3^2} \right) \left( \frac{1 \text{TeV}}{m_{\text{SUSY}}} \right)^4 \tan^2 \beta \)

\( \text{Br}(\tau \rightarrow 3l, 3\eta) \)

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

\[ \text{Br}(\tau \rightarrow 3\mu) = 4 \times 10^{-7} \times \left( \frac{m_L^2}{m_L^2 + m_3^2} \right) \left( \frac{\tan \beta}{60} \right)^6 \left( \frac{100 \text{GeV}}{m_A} \right)^4 \]

<table>
<thead>
<tr>
<th>Model</th>
<th>( \text{Br}(\tau \rightarrow \mu \gamma) )</th>
<th>( \text{Br}(\tau \rightarrow 3l, 3\eta) )</th>
</tr>
</thead>
<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>
Precision measurements of $\tau$ decays

LF violating $\tau$ decay?

Reach of B factories

Upper limits

B factories
(Belle, BaBar)

2006

1997

CLEO

$\tau \rightarrow \mu \gamma$

$\tau \rightarrow \mu \eta$

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

Theoretical predictions compared to present experimental limits

T.Goto et al., 2007

SU(5)$\Phi\nu_R$, Non-degenerate

$\mu_R = 4 \times 10^{14}$ GeV

$\tan \beta = 30$

$\tau \rightarrow e\gamma$

$\tau \rightarrow \mu\gamma$

$\mu \rightarrow e\gamma$
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 $\tau^\tau$ decays.

• They will help to diagnose (if found) or constraint (if not found) new physics models.

• Even in the worst case scenario (such as MFV), $B \rightarrow \tau \nu$, $D \tau \nu$ 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 TeV scale physics.
• There are many more topics: CPV in charm, new hadrons, ...

• 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

\[ V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \]
Super B factory: an important part of a broad unbiased approach to New Physics

- Super B factory, LHCb, $K$ experiments...
- $\nu$ experiments, $g_\mu - 2$, $\mu \to e\gamma$, etc.
- $\nu$ mass and mixing, CPV, and LFV
- $\tau$ LFV, $\tau$ CPV
- Flavors mixing, CP phases

LHC, ILC

Mass spectrum, interactions

<table>
<thead>
<tr>
<th>Energy frontier</th>
<th>Lepton sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>New physics</td>
<td></td>
</tr>
</tbody>
</table>

Quark sector
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!):
$2.1 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$
The KEKB Performance

Luminosity Records:
- Peak $L = 2.1 \times 10^{34}\ cm^{-2}\ s^{-1}$ (2x the design value)
- Daily $\int L dt = 1.5\ fb^{-1}$ (2.5 x the design value)
- Total $\int L dt \sim 950\ fb^{-1}$ (as of July 2009)

Luminosity of KEKB
Oct. 1999 - June 2009

Peak luminosity in a day (1/nb/s)

1x$10^{34}\ cm^{-2}\ s^{-1}$

Continuous Injection

Crab Crossing

Update: 6/16/2009 8:31:14
The latest improvements in KEKB performance: crab cavity

Installed in the KEKB tunnel (February 2007)

Electron Ring

Positron Ring

22 mrad. crossing

crab crossing
Strategies for Increasing Luminosity

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

$L = \frac{\gamma e^\pm}{2er_e} \left( 1 + \frac{\sigma_y^*}{\sigma_x^*} \right) \left( \frac{I_{e^\pm} \xi_y^{e^\pm}}{\beta_y^*} \right) \left( \frac{R_L}{R_{\xi_y}} \right)$

- Lorentz factor
- Beam current
- Beam size ratio@IP
  1 ~ 2 % (flat beam)
- Vertical beta function@IP
- Nano-Beam Option

Lumi. reduction factor (crossing angle) & Tune shift reduction factor (hour glass effect)
0.8 ~ 1 (short bunch)
Accelerator upgrade strategy

Why did we give up the “high current scheme”?

• To achieve the required luminosity, we had to assume a beam-beam parameter of 0.3 while with Belle we achieved 0.09

• Bunch length could not be reduced to 3mm because of the coherent synchrotron radiation.

• No solution was found for IR design to realize $\beta^*_x=20\text{cm}$.

• Higher operating costs.

→ Adopted the “Nano-beam scheme” as proposed by P. Raimondi and the SuperB group → design is on-going → no showstopper up to now.

To achieve a luminosity of $8.0\times10^{35}\text{cm}^{-2}\text{s}^{-1}$ (x40 of peak KEKB value),

• Beam current 1.7/1.4 $\rightarrow$ 3.6/2.6 A (x2)

• Beam-beam parameter 0.09 $\rightarrow$ 0.09 (x1)

• Small beta function at IP (x 1/20): horiz.: 1200 $\rightarrow$ 32/25mm / vert.: 5.9 $\rightarrow$ 0.27/0.42mm; beam size 100µm(H) x 2µm(V) $\rightarrow$ 10µm(H) x 59nm(V)

• Crab waist is considered as an option
## Design parameters

<table>
<thead>
<tr>
<th></th>
<th>KEKB Design</th>
<th>KEKB Achieved: with crab</th>
<th>SuperKEKB High-Current</th>
<th>SuperKEKB Nano-Beam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (GeV) (LER/HER)</td>
<td>3.5/8.0</td>
<td>3.5/8.0</td>
<td>3.5/8.0</td>
<td>4.0/7.0</td>
</tr>
<tr>
<td>$\beta_x^*$ (cm)</td>
<td>100/100</td>
<td>120/120</td>
<td>20/20</td>
<td>3.2/2.5</td>
</tr>
<tr>
<td>$\beta_y^*$ (mm)</td>
<td>10/10</td>
<td>5.9/5.9</td>
<td>3/6</td>
<td>0.27/0.42</td>
</tr>
<tr>
<td>$\varepsilon_x$ (nm)</td>
<td>18/18</td>
<td>18/24</td>
<td>24/18</td>
<td>3.2/1.7</td>
</tr>
<tr>
<td>$\sigma_y$ (µm)</td>
<td>1.9</td>
<td>0.94</td>
<td>0.85/0.73</td>
<td>0.059</td>
</tr>
<tr>
<td>$\xi_y$</td>
<td>0.052</td>
<td>0.129/0.090</td>
<td>0.3/0.51</td>
<td>0.09/0.09</td>
</tr>
<tr>
<td>$\sigma_z$ (mm)</td>
<td>4</td>
<td>~ 6</td>
<td>5/3</td>
<td>6/5</td>
</tr>
<tr>
<td>$I_{\text{beam}}$ (A)</td>
<td>2.6/1.1</td>
<td>1.64/1.19</td>
<td>9.4/4.1</td>
<td>3.6/2.6</td>
</tr>
<tr>
<td>$N_{\text{bunches}}$</td>
<td>5000</td>
<td>1584</td>
<td>5000</td>
<td>2500</td>
</tr>
<tr>
<td>Luminosity ($10^{34}$ cm$^{-2}$ s$^{-1}$)</td>
<td>1</td>
<td>2.11</td>
<td>53</td>
<td>80</td>
</tr>
</tbody>
</table>
SuperKEKB

- e- 2.6 A
- e+ 3.6 A

Replace long TRISTAN dipoles with shorter ones (HER)

Redesign the HER arcs to squeeze the emittance

TiN coated beam pipe with antechambers

Damping ring

Low emittance positrons to inject

New beam pipe & bellows

Add / modify RF systems for higher beam current

Positron source

New positron target / capture section

New superconducting / permanent final focusing quads near the IP

Low emittance electrons to inject

Low emittance positrons to inject

\[ L = \frac{\gamma_{\pm}}{2er_e} \left(1 + \frac{\sigma_y^*}{\sigma_x^*}\right) \frac{\beta_y^*}{\beta_y} R_L \]

40x Belle luminosity
Copper beam duct with ante-chambers
- Copper is required to withstand intense SR power

Features (compared to simple pipe):
- Low SR power density
- Less photoelectrons in beam pipe
- Low beam impedance
IR Superconducting magnets: main quads(8), corrector solenoids(2), corrector coils(43)

Preliminary! Under optimisation
- **For the nano-beam option**
  → There are two final-Q magnets in both L / R sides

- **7x4GeV beam energies**
  To solve the problem of dynamic aperture.

- **Crossing angle becomes 83 mrad**
  to put the final-Q magnets closer to the IP

- **The QCS chamber radius is 1cm**
  → to avoid the resonant cavity structure
  →**IP beam-pipe radius should be 1cm**

Detector backgrounds are under study – depend on the new machine parameters. Different in the nano-beam option than for the high current version
Requirements for the Belle II detector

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

- **Higher background (×20)**
  - radiation damage and occupancy
  - fake hits and pile-up noise in the EM
- **Higher event rate (×10)**
  - higher rate trigger, DAQ and computing
- **Require special features**
  - low $p\mu$ identification $\leftrightarrow s\mu\mu$ recon. eff.
  - hermeticity $\leftrightarrow \nu$ “reconstruction”

Possible solution:
- 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.
Belle Upgrade for Super-B

SC solenoid
1.5T

Csl(Tl) 16\(X_0\) → pure CsI (endcap)

Aerogel Cherenkov counter + TOF counter
→ “TOP” + Aerogel RICH

μ / \(K_L\) detection
14/15 lyr. RPC+Fe
→ tile scintillator

New readout and computing systems

Si vtx. det.
4 lyr. DSSD
→ 2 pixel lyrns. + 4 lyr. DSSD

Tracking + \(dE/dx\)
small cell + He/C_2H_6
→ remove inner lyrns.
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
Vertex detector upgrade: PXD+SVD

- Configuration: 4 layers → 6 layers (outer radius = 8cm → 14cm)
  - More robust tracking
  - Higher Ks vertex reconstruction efficiency
- Inner radius: 1.5cm → 1.3cm
  - Better vertex resolution
- Sensors of the two innermost layers L1+L2: DEPFET Pixel sensors → PXD
- Layers 3-6: normal double sided Si detector (DSSD) → SVD
- Strip readout chip: VA1TA → APV25
  - Reduction of occupancy coming from beam background.
  - Pipeline readout to reduce dead time.
Vertex Detector

### Beam Pipe
- DEPFET
  - Layer 1: $r = 1.3\text{cm}$
  - Layer 2: $r = 2.2\text{cm}$

### DSSD
- Layer 3: $r = 3.8\text{cm}$
- Layer 4: $r = 8.0\text{cm}$
- Layer 5: $r = 11.5\text{cm}$
- Layer 6: $r = 14.0\text{cm}$

**Significant improvement in IP resolution!**

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

Less Coulomb scattering

Pixel detector close to the beam pipe
Current system

- Barrel: TOF + ACC
- End cap: ACC

(ACC: Threshold type Aerogel Cherenkov Counter)

Belle-II

- Barrel: **TOP** counter
- End cap: **Aerogel** RICH

(TOP: Time-of-Propagation)

3σ K/π separation

4σ K/π separation up to 4GeV
- Barrel: **TOP counter**
- End cap: **Aerogel RICH**

Expected impact, example $B \rightarrow K^{*0} \gamma$: background reduced from blue (present Belle) to red

→ Up to 80% gain in sensitivity
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 $< \sim 40$ ps
    - Single photon sensitive in 1.5 T
TOP test beam performance: proof-of-principle

Photon detector: Hamamatsu
MCP-PMT 27.5x27.5 mm²

Test beam (2008)  simulation

Beam spot (z = 875mm)

<table>
<thead>
<tr>
<th></th>
<th>TTS (1st peak)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data</td>
<td>76.0±2.0 [ps]</td>
</tr>
<tr>
<td>Simulation</td>
<td>77.7±2.3 [ps]</td>
</tr>
</tbody>
</table>

\[ \sigma_{\text{top}} = \sqrt{\sigma_{\text{MCP-PMT}}^2 + \sigma_{\text{chromatic}}^2} \]
End-cap PID

Proximity focusing RICH with silica aerogel as Cherenkov radiator in a ‘focusing’ configuration

Multi-layer ‘focusing’ radiator, $n \approx 1.05$

Position sensitive PD with $B = 1.5$ Tesla

Readout electronics

x-y view of forward end-cap

Peter Križan, Ljubljana
Excellent HAPD sensors at hand
Q.E. >30% (‘Super-bialkali’)

Proximity focusing RICH:
Beam test performance

Number of photons / track = 14.3
Resolution / photon = 15.2 mrad
Resolution / track = 4.0 mrad

Electron test beam in November 2009
Photon detector for the beam test

Light guides

64 SiPMs

20 mm

Another sensor candidate: SiPMs (G-PAD), easy to handle, but never before used for single photon detection (high dark count rate with single photon pulse height) → use a narrow time window and light concentrators.
Cherenkov ring with SiPMs

First successful use of SiPMs as single photon detectors in a RICH counter!

NIM A594 (2008) 13
Calorimeter (ECL) Upgrade

- Increase of dark current due to neutron flux
- Fake clusters & pile-up noise

**Barrel:**
- 0.5μs shaping + 2MHz w.f. sampling.

**Endcap:**
- Rad. hard crystals with short decay time (e.g. pure CsI) + photopentodes
- 30ns shaping + 43MHz w.f. sampling

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Peter Križan, Ljubljana
KLM upgrade in the endcaps

Scintillator-based KLM (endcap)

- Two independent (x and y) layers in one superlayer made of orthogonal strips with WLS read out
- Photo-detector = avalanche photodiode in Geiger mode (SiPM)
- ~120 strips in one 90º sector (max L=280cm, w=25mm)
- ~30000 read out channels
- Geometrical acceptance > 99%

Mirror 3M (above groove & at fiber end)

Optical glue increase the light yield ~ 1.2-1.4)

**WLS**: Kurarai Y11 ∅1.2 mm

**Diffusion reflector** (TiO$_2$)  **Strips**: polystyrene with 1.5% PTP & 0.01% POPOP

Iron plate

Aluminium frame

GAPD x-strip plane

y-strip plane
Near-term plan
- Detector proposals (by Dec. 2009)
- Decisions on technology choices (Barrel PID configuration/photon detector, ECL endcap crystals and photosensors)
- TDR by March 2010
Belle-II Collaboration

2004.06: LoI for SuperKEKB
2008.01: KEK Roadmap → identified as high priority project at KEK
2008.12: New collaboration (Belle-II) officially formed

- 13 countries/region, 43 institutes, ~300 members

Separate group/organization from Belle

- Executive Board (Chair: H. Aihara)
  - Spokesperson: P. Križan
  - Project manager: M. Yamauchi

- Institutional Board (Chair: L. Piilonen)

- Physics coordinator: B. Golob
- Technical coordinator: Y. Ushiroda
- Software /computing coordinators: T. Hara / T. Kuhr

2009.11: 4th Open Collaboration Meeting

3rd collab. meeting 7-9 July 2009
European groups of Belle-II

- Austria: HEPHY (Vienna)
- Czech republic: Charles University in Prague
- Germany: U. Bonn, KIT Karlsruhe, MPI Munich, U. Giessen
- Poland: INP Krakow
- Russia: ITEP (Moscow), BINP (Novosibirsk),

Sizeable fraction of the collaboration: in total 100 collaborators out of 287!
Project plans

Long term plan:
• 3 year shut-down for upgrade of the accelerator and detector
• Start machine operation in 2013

Final goal: $L \sim 8 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$

3 year shutdown for upgrade

by ~2020
• SuperKEKB and Belle-II are priorities of KEK

• The Japanese government has allocated 32 oku-yen (32 M$) for upgrade R&D in FY 2009, as a part of its economic stimulus package. This is considered as a very important sign in Japan.

• KEK has submitted to the Ministry of education, science, and technology (MEXT) a budget request for FY 2010 and beyond for 350 M$ for the construction of SuperKEKB. MEXT submitted a request for the upgrade budget to the Ministry of finance.

• Japanese government is currently reviewing all major projects. The decision is expected by the end of this year.

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

- B factories have proven to be an excellent tool for flavour physics, with reliable long term operation, constant improvement of the performance.
- Major upgrade at KEK in 2010-13 → Super B factory, L x40
- Essentially a new project, all components have to be replaced, options to be frozen in the next few months
- The project has a strong European participation (about 1/3!)
- A physics reach update is being prepared – to be made public soon
- Expect a new, exciting era of discoveries, complementary to LHC
Additional slides
# Design parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>LER</th>
<th>HER</th>
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<tbody>
<tr>
<td>Emittance</td>
<td>$\varepsilon_x$</td>
<td>3.2</td>
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<tr>
<td>Coupling</td>
<td>$\varepsilon_y / \varepsilon_x$</td>
<td>0.40</td>
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<tr>
<td>Beta Function at IP</td>
<td>$\beta_x^* / \beta_y^*$</td>
<td>32 / 0.27</td>
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<tr>
<td>Beam Size</td>
<td>$\sigma_x^* / \sigma_y^*$</td>
<td>10.1 / 0.059</td>
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<td>Bunch Length</td>
<td>$\sigma_z$</td>
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<td>Half Crossing Angle</td>
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<td>Beam Energy</td>
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<tr>
<td>Beam Current</td>
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<tr>
<td>Number of Bunches</td>
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<td>Energy Loss / turn</td>
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<tr>
<td>Total Cavity Voltage</td>
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<td>Energy Spread</td>
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<td>Synchrotron Tune</td>
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<td>Momentum Compaction</td>
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<td>Beam-Beam Parameter</td>
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<tr>
<td>Luminosity</td>
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