SuperKEKB e-cloud mitigation and instrumentation

J.W. Flanagan, KEK
CesrTA Program Advisory Committee Mtg.
2012.9.11
Outline

• SuperKEKB introduction
• Collaborative efforts at CesrTA:
  – E-cloud dynamics studies
  – E-cloud mitigation studies
  – X-ray beam-size monitor development
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SuperKEKB

Mt. Tsukuba

Nikko, Nasu

Super KEKB Rings 3016 m

Belle II

J-Linac

1 km

KEK Site
$e^- 7 \text{ GeV} 2.6 \text{ A}$

SuperKEKB

$e^+ 4 \text{ GeV} 3.6 \text{ A}$

Colliding bunches

Replace short dipoles with longer ones (LER)

Redesign the lattices of both rings to reduce the emittance

New beam pipe & bellows

Low emittance positrons to inject

Damping ring

Low emittance gun

Low emittance electrons to inject

TiN-coated beam pipe with antechambers in LER

Add / modify RF systems for higher beam current

New positron target / capture section

New superconducting final focusing quads near the IP

Belle II

New IR

Positron source

Low emittance electrons to inject

Low emittance positrons to inject

$x \times 40$ Gain in Luminosity

$\text{L} = \frac{\gamma_{\text{e}}}{2e_r} \left(1 + \frac{\sigma_y^{\ast}}{\sigma_x^{\ast}}\right) I_{\text{e}} \left(\frac{\varepsilon_{\text{e}}}{\beta_y^{\ast}} \left(\frac{R_L}{R_y}\right)\right)$
Design Concept of SuperKEKB

- Increase the luminosity by 40 times based on “Nano-Beam” scheme, which was first proposed for SuperB by P. Raimondi.

  - Vertical $\beta$ function at IP: $5.9 \rightarrow 0.27/0.30$ mm ($\times 20$)
  
  - Beam current: $1.7/1.4 \rightarrow 3.6/2.6$ A ($\times 2$)
  
  - Beam-beam parameter: $.09 \rightarrow .09$ ($\times 1$)

  \[
  L = \frac{\gamma_{\pm}}{2er_e} \left( 1 + \frac{\sigma_y^*}{\sigma_x^*} \frac{I_{\pm \xi \pm y}}{R_L} \frac{R_L}{\beta_y^*} \frac{R_y}{R_y} \right) = 8 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}
  \]

  - Beam energy: $3.5/8.0 \rightarrow 4.0/7.0$ GeV

LER : Longer Touschek lifetime and mitigation of emittance growth due to the intra-beam scattering
HER : Lower emittance and lower SR power
## Comparison of Parameters

<table>
<thead>
<tr>
<th></th>
<th>KEKB Design</th>
<th>KEKB Achieved: with crab</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>4.0/7.0</td>
</tr>
<tr>
<td>$\beta_y^*$ (mm)</td>
<td>10/10</td>
<td>5.9/5.9</td>
<td>0.27/0.30</td>
</tr>
<tr>
<td>$\beta_x^*$ (mm)</td>
<td>330/330</td>
<td>1200/1200</td>
<td>32/25</td>
</tr>
<tr>
<td>$\varepsilon_x$ (nm)</td>
<td>18/18</td>
<td>18/24</td>
<td>3.2/5.3</td>
</tr>
<tr>
<td>$\varepsilon_y/\varepsilon_x$ (%)</td>
<td>1</td>
<td>0.85/0.64</td>
<td>0.27/0.24</td>
</tr>
<tr>
<td>$\sigma_y$ ($\mu$m)</td>
<td>1.9</td>
<td>0.94</td>
<td>0.048/0.062</td>
</tr>
<tr>
<td>$\xi_y$</td>
<td>0.052</td>
<td>0.129/0.090</td>
<td>0.09/0.081</td>
</tr>
<tr>
<td>$\sigma_z$ (mm)</td>
<td>4</td>
<td>6 - 7</td>
<td>6/5</td>
</tr>
<tr>
<td>$I_{beam}$ (A)</td>
<td>2.6/1.1</td>
<td>1.64/1.19</td>
<td>3.6/2.6</td>
</tr>
<tr>
<td>$N_{bunches}$</td>
<td>5000</td>
<td>1584</td>
<td>2500</td>
</tr>
<tr>
<td>Luminosity ($10^{34}$ cm$^{-2}$ s$^{-1}$)</td>
<td>1</td>
<td>2.11</td>
<td>80</td>
</tr>
</tbody>
</table>

Y. Ohnishi et al.
SuperKEKB

• Higher beam currents, lower emittance than KEKB mean electron clouds a big issue.

• Need to understand:
  – Electron cloud blow-up threshold (dynamics studies).
  – Electron cloud mitigation methods
  – Electron cloud and low-emittance beam diagnostics.

• ➔Studies at CesrTA
Outline

• SuperKEKB introduction

• Collaborative efforts at CesrTA:
  – E-cloud dynamics studies
  – E-cloud mitigation studies
  – X-ray beam-size monitor development
Electron cloud instability

- Single bunch instability
- Coupled bunch instability
Head-tail blow-up at SuperKEKB

- Simulation $\rho_{th}=2.2 \times 10^{11}$ m$^{-3}$ ($\nu_s=0.012$)
- Analytic $\rho_{th}=2.7 \times 10^{11}$ m$^{-3}$.
- Target $\rho_e \sim 1 \times 10^{11}$ m$^{-3}$
- Take care of high $\beta$ section. Effects are enhanced.

$$\int \rho_e \beta_y ds / L = 10^{11} \times 10 \text{ m}^{-2}$$
Fourier power spectrum of BPM data

- LER single beam, 4 trains, 100 bunches per train, 4 rf bucket spacing
- Solenoids off: beam size increased from 60 μm -> 283 μm at 400 mA
- Vertical feedback gain lowered
  - This brings out the vertical tune without external excitation
Beam parameters:
- 2.1 GeV;
- H (V) emittance: 2.6 nm (20 pm);
- bunch length 10.8 mm;
- tunes (H, V, S): (14.57, 9.6, 0.065)

- momentum compaction $6.8 \times 10^{-3}$
- (H,V) chrom = (1.33, 1.155)
- Avg current/bunch = 0.74 mA.
- L-FBK off; H-, V-FBK at 20%
# Parameters

## Table 1: Basic parameters of the positron rings

<table>
<thead>
<tr>
<th>Lattice</th>
<th>KEKB (m)</th>
<th>Cesr-TA (m)</th>
<th>PETRA-III (m)</th>
<th>SuperKEKB (m)</th>
<th>Super B (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circumference</td>
<td>3,016</td>
<td>768</td>
<td>2304</td>
<td>3016</td>
<td>1260</td>
</tr>
<tr>
<td>Energy</td>
<td>3.5</td>
<td>2.5</td>
<td>6</td>
<td>4.0</td>
<td>6.7</td>
</tr>
<tr>
<td>Bunch population</td>
<td>8</td>
<td>2</td>
<td>0.5</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>Beam current</td>
<td>1.7</td>
<td>-</td>
<td>0.1</td>
<td>3.6</td>
<td>1.9</td>
</tr>
<tr>
<td>Emittance</td>
<td>18</td>
<td>2.3</td>
<td>1</td>
<td>3.2</td>
<td>2</td>
</tr>
<tr>
<td>Momentum compaction</td>
<td>0.18</td>
<td>0.023</td>
<td>0.01</td>
<td>0.01</td>
<td>0.005</td>
</tr>
<tr>
<td>Bunch length</td>
<td>6</td>
<td>6.8</td>
<td>12</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>RMS energy spread</td>
<td>0.73</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.64</td>
</tr>
<tr>
<td>Synchrotron tune</td>
<td>0.025</td>
<td>0.067</td>
<td>0.049</td>
<td>0.0256</td>
<td>0.0126</td>
</tr>
<tr>
<td>Damping time</td>
<td>40</td>
<td>56.4</td>
<td>16</td>
<td>43</td>
<td>26</td>
</tr>
</tbody>
</table>

## Table 2: Threshold of the B factories positron rings and others

<table>
<thead>
<tr>
<th>Lattice</th>
<th>KEKB (no sol.)</th>
<th>KEKB (50 G sol.)</th>
<th>Cesr-TA</th>
<th>PETRA-III</th>
<th>SuperKEKB</th>
<th>SuperB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bunch population</td>
<td>$N_+(10^{10})$</td>
<td>3</td>
<td>8</td>
<td>2</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Beam current</td>
<td>$I_+(A)$</td>
<td>0.5</td>
<td>1.7</td>
<td>-</td>
<td>0.1</td>
<td>3.6</td>
</tr>
<tr>
<td>Bunch spacing</td>
<td>$\ell_{sp}(\text{ns})$</td>
<td>8</td>
<td>7</td>
<td>4-14</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Electron frequency</td>
<td>$\omega_e/2\pi(\text{GHz})$</td>
<td>28</td>
<td>40</td>
<td>43</td>
<td>35</td>
<td>150</td>
</tr>
<tr>
<td>Phase angle</td>
<td>$\omega_e\sigma_z/c$</td>
<td>3.6</td>
<td>5.9</td>
<td>11.0</td>
<td>8.8</td>
<td>18.8</td>
</tr>
<tr>
<td>Threshold</td>
<td>$\rho_e (10^{12} \text{ m}^{-3})$</td>
<td>0.63</td>
<td>0.38</td>
<td>1.7</td>
<td>1.2</td>
<td>0.27</td>
</tr>
</tbody>
</table>
Estimation of cloud density and coupled bunch instability

• Ante-chamber, $\delta_{2,\text{max}}=1.2$ without special structure like groove

$\rho_e=2.2\times10^{11}$ m$^{-3}$

• Wake field and growth rate of the coupled bunch instability.

• Suetsugu-san estimates the density based on measurements and is designing the chamber to achieve required density.

Growth time is 40 turns. It should be suppressed at $\rho_e=1\times10^{11}$ m$^{-3}$.

K. Ohmi
Summary

• Threshold of the fast head-tail instability: Theory and simulation agree with measurements at CesrTA and KEKB.
• SuperKEKB prediction should be reliable.
• Head-tail spectrum at KEKB has an upper sideband, with separation $\geq \nu_s$. The head-tail spectrum of Cesr-TA is different from that of KEKB, with a lower sideband at $-\nu_s$.
• Understanding of the head-tail mode is next step.
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Clearing electrode collaboration at CesrTA

• Beam tests of a clearing electrode as a method to mitigate the electron cloud effect was proposed in 2008.
• The clearing electrode suggested is a thin electrode formed by a thermal-spray method, which had been also tested at KEKB.
• The electrode was prepared at KEK and assembled (welded) at LBL.
• Two beam pipes with electrodes for a preliminary test were produced in 2009, and the basic properties, such as the electrical insulation, were investigated at KEK, LBL and Cornell University.
Preliminary test

• Test beam pipes with electrodes
Installation

• A beam pipe with electrode for actual beam test was produced in 2010.
• The beam pipe was installed in a SC wiggler magnet (L0) at CesrTA in April, 2010.
• The beam pipe has an electron monitor (RFA, Retarding Field Analyzer) at the opposite side from the electrode, and the electron population in the beam pipe can be measured just above the electrode.
KEK

- Thermal spray of electrode (Al$_2$O$_3$ and tungsten) on to a half-cut beam pipe
Cornell University

• Assembling of RFA at Cornell
Cornell University

- Wiggler magnet and beam pipe for wiggler magnet (inside view) before experiment

Y. Suetsugu
Experiment

• The experiment was performed in Run #7, 2010.

• The effectiveness of the electrode was compared with that of other mitigation techniques, such as bare copper, TiN coated copper, and grooved copper, under the same beam conditions.

• A significant reduction in electron density by using the electrode was confirmed.
Experimental Result

• The plot shows average collector current density vs beam current. (1x45 e+, 2.1 GeV, 14ns)
• TiN, Grooved, Electrode chamber all in same location at different times.
• Cu, TiN, and grooved chambers all within a factor of two.
• Electrode chamber does significantly better.

Joseph Calvey
8/9/2010
at ECLOUD10
After experiment

• The thermal sprayed electrode was visually inspected in January, 2011. (By Yulin Li)
• The electrode is in excellent condition.
Results

• Based on the experiment at KEKB and CesrTA:
  – Wiggler chambers for SuperKEKB will use clearing electrodes to suppress electron cloud build-up.
  – In the report of “Recommendation for Mitigations of the Electron Cloud Effect in the ILC Damping Ring” (ECLOUD10), clearing electrodes deposited via thermal spray on copper chambers was recommended for wiggler regions.

Y. Suetsugu
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Beam size measurement at SuperKEKB

- Resolution fundamentally limited by measurement wavelength and opening angle between slits from beam (D/F).
- Max. slit separation determined by beam spread and mechanical considerations.

<table>
<thead>
<tr>
<th>SR Source Bend Parameter</th>
<th>S-LER1 (BSWFRP)</th>
<th>S-HER (BSWOLE)</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\varepsilon_x$</td>
<td>3.20E-09</td>
<td>4.60E-09</td>
<td>m</td>
</tr>
<tr>
<td>$\kappa$</td>
<td>0.27%</td>
<td>0.24%</td>
<td></td>
</tr>
<tr>
<td>$\varepsilon_y$</td>
<td>8.64E-12</td>
<td>1.10E-11</td>
<td>m</td>
</tr>
<tr>
<td>$\beta_y$</td>
<td>29.98</td>
<td>32.49</td>
<td>m</td>
</tr>
<tr>
<td>$\sigma_y$</td>
<td>16.1</td>
<td>18.9</td>
<td>$\mu$m</td>
</tr>
<tr>
<td>Beam Energy</td>
<td>4</td>
<td>7</td>
<td>GeV</td>
</tr>
<tr>
<td>Bend effective length</td>
<td>0.89</td>
<td>2.90</td>
<td>m</td>
</tr>
<tr>
<td>Bend angle</td>
<td>5.04</td>
<td>5.00</td>
<td>mrad</td>
</tr>
<tr>
<td>Bend radius $\rho$</td>
<td>179.0</td>
<td>580.0</td>
<td>m</td>
</tr>
<tr>
<td>Observation wavelength $\lambda$</td>
<td>4.00E-07</td>
<td>4.00E-07</td>
<td>m</td>
</tr>
<tr>
<td>SR Opening angle $\theta_c (\lambda)$</td>
<td>1.0</td>
<td>0.7</td>
<td>mrad</td>
</tr>
<tr>
<td>Slits opening angle D/F</td>
<td>1.2</td>
<td>1.1</td>
<td>mrad</td>
</tr>
<tr>
<td>Max. Visibility (fringe depth) $\gamma_{max}$</td>
<td>95%</td>
<td>95%</td>
<td></td>
</tr>
<tr>
<td>Min. measurable beam size $\sigma_y \text{ min}$</td>
<td>17.3</td>
<td>18.4</td>
<td>$\mu$m</td>
</tr>
</tbody>
</table>

- Vertical beam size measurement is possible with interferometers, though is near the limit of the interferometer resolution.
- Interferometer is also not capable of bunch-by-bunch, turn-by-turn measurements.
- Use x-ray beam size monitors
XRM: LER X-ray beamline (Fuji D8)
XRM: HER X-ray monitor beamline (Oho D4)
XRM: Coded Aperture Imaging

Technique developed by x-ray astronomers using a mask to modulate incoming light. Resulting image must be deconvolved through mask response (including diffraction and spectral width) to reconstruct object. Open aperture of 50% gives high flux throughput for bunch-by-bunch measurements. Heat-sensitive and flux-limiting monochromator not needed.

We need such a wide aperture, wide spectrum technique for shot-by-shot (single bunch, single turn) measurements.

Source distribution:

\[
\begin{bmatrix}
A_\sigma \\
A_\pi
\end{bmatrix} = \frac{\sqrt{3}}{2\pi} \frac{\gamma}{\omega_c} (1 + X^2) (-i) \left[ \frac{K_{2/3}(\eta)}{\sqrt{1 + X^2}} K_{1/3}(\eta) \right],
\]

where

\[
X = \gamma \psi,
\]

\[
\eta = \frac{1}{2} \frac{\omega}{\omega_c} (1 + X^2)^{3/2},
\]

Kirchhoff integral over mask (+ detector response)

\[
A_{\sigma,\pi}(y_d) = \frac{i A_{\sigma,\pi}(\text{source})}{\lambda} \int_{\text{mask}} \frac{\Gamma(y_m)}{r_1 r_2} e^{i 2\pi (r_1 + r_2)} \times \left( \cos \theta_1 + \cos \theta_2 \right) dy_m,
\]

Measured slow-scan detector image (red) at CesarTA, used to validate simulation (blue)

→ Detected pattern:
XRM: Single-shot resolution estimation

• Want to know, what is chance that a beam of a certain size is misfit as one of a different size?
• Tend to be photon statistics limited. (Thus coded aperture.)
• So:
  – Calculate simulated detector images for beams of different sizes
  – “Fit” images pairwise against each other:
    • One image represents true beam size, one the measured beam size
    • Calculate $\chi^2/n$ residuals differences between images:

$$\chi^2 \sim \frac{1}{N-n-1} \sum_{i=1}^{N} \frac{[s'_i - s_i]^2}{\sigma_i^2},$$

• Weighting function for channel $i$:

$$\sigma_i = \sqrt{s_i}.$$

• Value of $\chi^2/n$ that corresponds to a confidence interval of 68% is chosen to represent the 1-s confidence interval
XRM: Coded Aperture tests at CesrTA

Example of turn-by-turn size and position data (one bunch out of train)

Examples of bunch-by-bunch data (electron-cloud blow-up study data)
Single-shot data average for each bunch

Single-shot resolution (simulation + measured spread)
XRM: SuperKEKB x-ray monitor

<table>
<thead>
<tr>
<th>X-ray Source Bend Par.</th>
<th>S-LER (BS2FRP.1)</th>
<th>S-HER (BS2E.82)</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \varepsilon_x )</td>
<td>3.20E-09</td>
<td>4.60E-09</td>
<td>m</td>
</tr>
<tr>
<td>( \kappa )</td>
<td>0.27%</td>
<td>0.24%</td>
<td></td>
</tr>
<tr>
<td>( \varepsilon_y )</td>
<td>8.64E-12</td>
<td>1.10E-11</td>
<td>m</td>
</tr>
<tr>
<td>( \beta_y )</td>
<td>50.0</td>
<td>11.5</td>
<td>m</td>
</tr>
<tr>
<td>( \sigma_y )</td>
<td>20.8</td>
<td>11.3</td>
<td>( \mu \text{m} )</td>
</tr>
<tr>
<td>Beam Energy</td>
<td>4</td>
<td>7</td>
<td>GeV</td>
</tr>
<tr>
<td>Effective length</td>
<td>0.89</td>
<td>5.9</td>
<td>m</td>
</tr>
<tr>
<td>Bend angle</td>
<td>28.0</td>
<td>55.7</td>
<td>mrad</td>
</tr>
<tr>
<td>( \rho )</td>
<td>31.7</td>
<td>105.9</td>
<td>m</td>
</tr>
<tr>
<td>Critical Energy</td>
<td>4.4</td>
<td>7.1</td>
<td>keV</td>
</tr>
</tbody>
</table>

- Mask:
  - 59-element, 10 \( \mu \text{m} \)/element URA
  - High-power design
    - 10 \( \mu \text{m} \) Au mask
    - 625 \( \mu \text{m} \) Si substrate
    - Test at CesrTA
  - Other patterns, materials under study

- Detector:
  - 64-channel, 50 \( \mu \text{m} \)
  - More channels desirable, for background subtraction and to accommodate beam deviations.

**Uniformly Redundant Array (URA) for x-ray imaging to be used at SuperKEKB**

**Simulated detector response for various beam sizes at SuperKEKB LER**
XRM: SuperKEKB estimated single-shot resolutions (SuperKEKB full current)

- **Red points**: using 64-pixel detector of same type as at CesrTA (Fermionics)
- **Green points**: using detector with improved photon detection efficiency at higher x-ray energies (to be developed)
XRM: Mask

• Tests at CesrTA show URA mask gives predicted single-shot resolution.

• High-power mask testing started in Fall, 2011
  – Thick Si mask installed at CesrTA for high-power testing.
    • CesrTA at 5.3 GeV can duplicate power load expected at SuperKEKB
    • SuperKEKB full current power load test successful!
      – Big thanks to folks at Cornell for their assistance and efforts.
    • Plan to test at ~20% higher power load
  – Diamond substrate mask also fabricated and installed at CesrTA, and ready to be tested.
Summary

• Collaborative studies done at CesrTA have been very helpful in the design of SuperKEKB.
  – Electron cloud blow-up threshold studies
  – Cloud mitigation methods
  – Low-emittance beam diagnostics
• Further studies will still be valuable:
  – Understanding better the electron-cloud blow-up mechanism (dominant instability mode under different conditions).
    • Dec?
  – X-ray beam size monitor development (high-power component testing, in particular).
    • This Fall for Si, plus future for diamond?
    • Low-emittance high-energy studies?
• CesrTA has proven to be a very useful test bed for effective collaborative studies.
Spares
Synrad 3D?
<table>
<thead>
<tr>
<th></th>
<th>LER</th>
<th>HER</th>
<th>unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2011/July/20</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(E)</td>
<td>4.000</td>
<td>7.007</td>
<td>GeV</td>
</tr>
<tr>
<td>(I)</td>
<td>3.6</td>
<td>2.6</td>
<td>A</td>
</tr>
<tr>
<td><strong>Number of bunches</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2,500</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Bunch Current</strong></td>
<td>1.44</td>
<td>1.04</td>
<td>mA</td>
</tr>
<tr>
<td><strong>Circumference</strong></td>
<td>3,016.315</td>
<td></td>
<td>m</td>
</tr>
<tr>
<td><strong>(\varepsilon_x/\varepsilon_y)</strong></td>
<td>3.2(1.9)/8.64(2.8)</td>
<td>4.6(4.4)/11.5(1.5)</td>
<td>nm/pm</td>
</tr>
<tr>
<td><strong>Coupling</strong></td>
<td>0.27</td>
<td>0.28</td>
<td></td>
</tr>
<tr>
<td><strong>(\beta_x^<em>/\beta_y^</em>)</strong></td>
<td>32/0.27</td>
<td>25/0.30</td>
<td>mm</td>
</tr>
<tr>
<td><strong>Crossing angle</strong></td>
<td>83</td>
<td></td>
<td>mrad</td>
</tr>
<tr>
<td><strong>(\alpha_p)</strong></td>
<td>3.25\times10^{-4}</td>
<td>4.55\times10^{-4}</td>
<td></td>
</tr>
<tr>
<td><strong>(\sigma_\delta)</strong></td>
<td>8.08(7.73)\times10^{-4}</td>
<td>6.37(6.31)\times10^{-4}</td>
<td></td>
</tr>
<tr>
<td><strong>(V_c)</strong></td>
<td>9.4</td>
<td>15.0</td>
<td>MV</td>
</tr>
<tr>
<td><strong>(\sigma_z)</strong></td>
<td>6.0(5.0)</td>
<td>5(4.9)</td>
<td>mm</td>
</tr>
<tr>
<td><strong>(v_s)</strong></td>
<td>-0.0247</td>
<td>-0.0280</td>
<td></td>
</tr>
<tr>
<td><strong>(v_x/v_y)</strong></td>
<td>44.53/44.57</td>
<td>45.53/43.57</td>
<td></td>
</tr>
<tr>
<td><strong>(U_0)</strong></td>
<td>1.87</td>
<td>2.43</td>
<td>MeV</td>
</tr>
<tr>
<td><strong>(\tau_x,\tau_y/\tau_s)</strong></td>
<td>43.1/21.6</td>
<td>58.0/29.0</td>
<td>msec</td>
</tr>
<tr>
<td><strong>(\xi_x/\xi_y)</strong></td>
<td>0.0028/0.0881</td>
<td>0.0012/0.0807</td>
<td></td>
</tr>
<tr>
<td><strong>Luminosity</strong></td>
<td>8\times10^{35}</td>
<td></td>
<td>cm^{-2}s^{-1}</td>
</tr>
</tbody>
</table>


SuperKEKB luminosity projection

We will reach 50 ab$^{-1}$ in 2021.

Commissioning starts in early 2015.

Shutdown for upgrade

Goal of Belle II/SuperKEKB