The SuperKEKB Project

Christoph Schwanda, Vienna
representing the Super KEKB collaboration

SuperB Workshop
LAL, Orsay,
February 15-18, 2009
KEKB Upgrade
• $E_{cm} = 10.58 \text{ GeV } (\text{Y}(4S) \text{ resonance})$
• $L_{peak} = 1.712 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1} (\text{Nov-15, 2006})$
Belle will have $\sim 1/ab$ ($\sim 1$ billion BB events) by the end of data taking in March 2010.
From KEKB to SuperKEKB

Stored currents:
1.7 / 1.4 A (e⁺ / e⁻ KEKB)
→ 9.4 / 4.1 A (SuperKEKB)

Beam-beam parameter:
0.059 (KEKB)
→ >0.24 (SuperKEKB)

Vertical β at IP:
6.5 / 5.9 mm (LER/HER KEKB)
→ 3.0 / 3.0 mm (SuperKEKB)

Increase luminosity from \(1.7 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}\) (KEKB) to \(8 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}\) (SuperKEKB)
SuperKEKB

Electron: \( e^+ \) 4.1 A
Positron: \( e^- \) 9.4 A

\[ L = \frac{\gamma_{\pm}}{2e\varepsilon_0} \left( 1 + \frac{\sigma_y^{\pm}}{\sigma_x^{\pm}} \right) \left( \frac{I_{\pm} \varepsilon_{\pm}}{\beta_y^{\pm}} \right) \left( \frac{R_L}{R_y} \right) \]
<table>
<thead>
<tr>
<th>Cost (oku-yen≈M$)</th>
<th>Effect</th>
<th>Luminosity</th>
</tr>
</thead>
<tbody>
<tr>
<td>New beam pipes</td>
<td>178</td>
<td>Enable high current reduce electron cloud</td>
</tr>
<tr>
<td>New IR</td>
<td>31</td>
<td>Smaller $\beta^*$</td>
</tr>
<tr>
<td>$e^+$ damping ring</td>
<td>40</td>
<td>Reduce emittance of injected $e^+$ beam</td>
</tr>
<tr>
<td>More RF and cooling systems</td>
<td>179</td>
<td>High current</td>
</tr>
<tr>
<td>Crab cavities</td>
<td>15</td>
<td>Higher beam-beam parameter</td>
</tr>
</tbody>
</table>
Finally two crab cavity was installed in KEKB, one for each ring in January 2007.

**HER (e-, 8 GeV)**

**LER (e+, 3.5 GeV)**
Crab Crossing @ KEKB

- Crab Crossing can boost the beam-beam parameter higher than 0.15!  
  K. Ohmi

- Head-on (crab)
  (Strong-strong simulation)

- Crossing angle 22 mrad

- Crab cavities were successfully produced and beam study has started in Feb. 2007.

First proposed by R. B. Palmer in 1988 for linear colliders.
Beams has indeed tilted!

- Observation with Streak Cameras (H. Ikeda et al, FRPMN035)

inside of the rings

outside of the rings

longitudinal

LER

HER

horizontal

The streak camera

In the image, a diagram illustrates the behavior of beams inside and outside the rings, with a focus on longitudinal and horizontal directions. The streak camera is also depicted, highlighting its role in observing these phenomena.
Specific Luminosity

Peak Luminosity with Crab Crossing was 16.5 /nb/s (31 Oct. 2008).

Crab Crossing
- 49 bucket spacing
- The highest vertical beam-beam tune shift was about 0.088.
- Simulation head-on

Crab Crossing
- 3.06 bucket spacing
- Before crab, tune shift was 0.055
- Simulation 22 mrad

A number of measurements indicate effective head-on collision.
- The vertical tune shift became higher than 0.088. Before crab, it was 0.055.
- The specific luminosity / bunch was improved more than the geometrical gain.
- Need more time to achieve the goal (X2 specific luminosity).
Belle upgrade
The Belle detector

- **SC solenoid**: 1.5T
- **CsI(Tl)**: $16X_0$
- **TOF counter**
- **Aerogel Cherenkov cnt.**: $n = 1.015 \sim 1.030$
- **8 GeV $e^-$**
- **3.5 GeV $e^+$**
- **Central Drift Chamber**
  - Small cell +He/C$_2$H$_5$
- **Si vtx. det.**
  - 3(4) lyr. DSSD
- **$\mu / K_L$ detection**
  - 14/15 lyr. RPC+Fe
The upgraded detector must be able to handle (at least) 20x times more beamground.
From Belle to sBelle

• (At least) maintain the current Belle performance in harsh background environment

• Baseline design
  – SuperKEKB Letter of Intent (LoI)
    KEK Report 2004-4
  – sBelle Design Study Report
    KEK Report 2008-7
Baseline design

Particle ID:
- ring imaging Cherenkov devices (TOP in the barrel, ARICH in the forward)

Silicon:
- 2 lyr pixel, 4 lyr DSSD

Drift chamber:
- smaller cell size

Em. calorimeter:
- wave form sampling pure CsI (endcaps)

Muons, neutrals:
- scintillator strips (endcaps)
DEPFET pixel layers

- Build by collaboration around MPI Munich (http://www.depfet.org/)
- 2 pixel layers close to beam pipe ($r > 1.3$cm)
- Pixel size 50 $\mu$m x 75 $\mu$m
- Fully depleted sensitive volume
- Row-wise readout
- Sensor thinning (50 $\mu$m)
  S/N $\approx$ 20-40 @ 50 $\mu$m
- Radiation hard
Silicon strip layers

- Front-end chip: APV25 (originally developed for CMS)
- 6 consecutive time samples for hit time reconstruction
- Chip-on-sensor for outer layers (origami module with thinned APV25)
- DSSD manufacturer?
TOP counter for barrel PID

- Cherenkov photons reflected inside quartz radiator
- Cherenkov image reconstructed from one coordinate and precise timing
- Successful test of realistic prototype in June 2009
ARICH for forward PID

- Proximity focussing RICH
- $\pi/K$ separation from 1.5 to 4 GeV/c
- Inside axial magnetic field
- Test at KEK Fuji beamline (2 GeV e-)
  - Cherenkov ring observed
  - 6 p.e./track
  - 13.2 mrad resolution

![Diagram of ARICH setup]

- Aerogel radiator
- $n \approx 1.05$
- Position sensitive device with $B=1.5$ Tesla
- Distance 200mm
Schedule
KEK Roadmap

- **J-PARC**
  - construction
  - experiment + upgrade

- **KEKB**
  - experiment
  - upgrade
  - experiment

- **PF/PF-AR**
  - experiment + upgrade

- **LHC**
  - construction
  - experiment + upgrade

- **R&Ds for Advanced Accelerator and Detector Technology**
  - Detector R&D
  - ERL
  - C-ERL R&D
    - construction
    - test experiment
  - ILC
  - PF-ERL
    - R&D
    - construction
    - experiment
  - ILC R&D

*Host and Site: Yet to be decided*
Summary and conclusions

• We believe that we can build a Super B factory by upgrading the existing KEKB accelerator and Belle detector
• We are now completing the R&D phase and aim at submitting the TDR soon
• There is great interest in our project in the community, and new groups have joined our efforts
• The SuperKEKB collaboration is emerging -- we had our first collaboration meeting Dec. 10-12, 2008 at KEK
• KEK DG has submitted a funding request to MEXT, and we are optimistic about the outcome
Backup
# Machine parameters of SuperKEKB

<table>
<thead>
<tr>
<th>Parameter</th>
<th>LER</th>
<th>HER</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam Energy</td>
<td>E</td>
<td>3.5</td>
<td>8.0 GeV</td>
</tr>
<tr>
<td>Beam current</td>
<td>I</td>
<td>9.4</td>
<td>4.1 A</td>
</tr>
<tr>
<td>Circumference</td>
<td>C</td>
<td>3016</td>
<td>m</td>
</tr>
<tr>
<td>Number of bunches</td>
<td>$n_b$</td>
<td>5018</td>
<td></td>
</tr>
<tr>
<td>Number of particles</td>
<td>N/bunch</td>
<td>11.8</td>
<td>5.1 x10^{10}</td>
</tr>
<tr>
<td>Emittance</td>
<td>$\varepsilon_x$</td>
<td>9</td>
<td>nm</td>
</tr>
<tr>
<td>Emittance ratio</td>
<td>$\varepsilon_y / \varepsilon_x$</td>
<td>0.5</td>
<td>%</td>
</tr>
<tr>
<td>Beta (hor.) at IP</td>
<td>$\beta_x^*$</td>
<td>200</td>
<td>mm</td>
</tr>
<tr>
<td>Beta (ver.) at IP</td>
<td>$\beta_y^*$</td>
<td>3</td>
<td>mm</td>
</tr>
<tr>
<td>Bunch length</td>
<td>$\sigma_z$</td>
<td>3</td>
<td>mm</td>
</tr>
<tr>
<td>Crossing angle</td>
<td>$\theta_x^*$</td>
<td>30 (0 by crab)</td>
<td>mrad</td>
</tr>
<tr>
<td>Beam-Beam (hor.)</td>
<td>$\xi_x$</td>
<td>0.36</td>
<td></td>
</tr>
<tr>
<td>Beam-Beam (ver.)</td>
<td>$\xi_y$</td>
<td>0.43</td>
<td></td>
</tr>
<tr>
<td>RF wall-plug power</td>
<td>$P_{AC}$</td>
<td>65</td>
<td>MW</td>
</tr>
<tr>
<td>Luminosity</td>
<td>L</td>
<td>8.0</td>
<td>x10^{35} cm$^{-2}$s$^{-1}$</td>
</tr>
</tbody>
</table>
Luminosity prospect

50ab$^{-1}$ by 2020

Initial target

$L \approx 2 \times 10^{35}$