$10^{36}$ ???

20 Apr. 2005
K. Oide (KEK) @ Super B Workshop
- Shutdown for 18-26 months in 2009-2010 for the upgrade.
- 0.9 /ab/month in 2020.

LHCb may produce physics equivalent to 50 /ab in e+e- in some channels within a few years.

Shutdown SuperKEKB may produce physics equivalent to 50 /ab in e+e- in some channels within a few years.

9 /ab/year
3.5 × 10^{35} × 40 weeks

15 /ab/year

Installation of Crab Cavity

We are here.
An example why you need $10^{36}$ ..... (giving a lecture to Buddhas)


\[ B^0 \rightarrow K^{*0} \mu^+\mu^- \]

- Suppressed decay ($\Delta B = 1$ FCNC), $BR \sim 10^{-6}$
- Forward-backward asymmetry in the $\mu\mu$ rest-frame $A_{FB}(s)$ is sensitive probe of new physics [Ali et al]

\[ A_{FB}(s) \]

LHCb: 4400 events/year, $S/B > 0.4$

$A_{FB}(s)$ reconstructed using toy MC
(two years data, background subtracted)
Zero point located to $\pm 0.04$

ATLAS: 2000 events, $S/B = 7$ (30 fb$^{-1}$)
Three factors to determine the luminosity:

- **Stored current:**
  - 1.27/1.7 A (KEKB)
  - → 4.1/9.4 A (SuperKEKB)

- **Beam-beam parameter:**
  - 0.057 (KEKB)
  - → 0.19 (SuperKEKB)

- **Vertical $\beta_v$ at the IP:**
  - 5.2/6.5 mm (KEKB)
  - → 3.0/3.0 mm (SuperKEKB)

Luminosity:
- $0.15 \times 10^{35}$ cm$^{-2}$s$^{-1}$ (KEKB)
- $4 \times 10^{35}$ cm$^{-2}$s$^{-1}$ (SuperKEKB)
# SuperKEKB Machine Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>bare lattice</th>
<th>with beam-beam</th>
<th>unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam current (LER/HER)</td>
<td>I</td>
<td>9.4/4.1</td>
<td>A</td>
</tr>
<tr>
<td>Beam energy (LER/HER)</td>
<td>E</td>
<td>3.5/8.0</td>
<td>GeV</td>
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<tr>
<td>Emittance</td>
<td>$\epsilon_x$</td>
<td>24</td>
<td>128</td>
</tr>
<tr>
<td>Horizontal beta at IP</td>
<td>$\beta_x^*$</td>
<td>20</td>
<td>2.3</td>
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<tr>
<td>Vertical beta at IP</td>
<td>$\beta_y^*$</td>
<td>3</td>
<td>2.4</td>
</tr>
<tr>
<td>Horizontal beam size</td>
<td>$\sigma_x^*$</td>
<td>69</td>
<td></td>
</tr>
<tr>
<td>Vertical beam size</td>
<td>$\sigma_y^*$</td>
<td>0.73</td>
<td>1.23</td>
</tr>
<tr>
<td>Beam size ratio</td>
<td>$r = \sigma_y^<em>/\sigma_x^</em>$</td>
<td>1.1</td>
<td>2.3</td>
</tr>
<tr>
<td>Crossing angle (30 mrad crab crossing)</td>
<td>$\theta_x$</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Luminosity reduction</td>
<td>$R_L$</td>
<td>0.86</td>
<td>0.82</td>
</tr>
<tr>
<td>$\xi_x$ reduction</td>
<td>$R_{\xi_x}$</td>
<td>0.99</td>
<td>0.97</td>
</tr>
<tr>
<td>$\xi_y$ reduction</td>
<td>$R_{\xi_y}$</td>
<td>1.11</td>
<td>1.16</td>
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<tr>
<td>Reduction ratio</td>
<td>$R_L/R_{\xi_y}$</td>
<td>0.78</td>
<td>0.72</td>
</tr>
<tr>
<td>Horizontal beam-beam (estimated with S-S simulation)</td>
<td>$\xi_x$</td>
<td>0.152</td>
<td>0.041</td>
</tr>
<tr>
<td>Vertical beam-beam (estimated with S-S simulation)</td>
<td>$\xi_y$</td>
<td>0.215</td>
<td>0.187</td>
</tr>
<tr>
<td>Luminosity</td>
<td>L</td>
<td>$4.0 \times 10^{35}$</td>
<td>cm$^{-2}$s$^{-1}$</td>
</tr>
</tbody>
</table>
Higher Order Mode Loss (K. Shibata, Y. Suetsugu)

Bellows - SuperKEKB

- Bellows chamber with a comb-type RF shield
  - Features
    - RF shield: nested comb teeth
      - Length: 10 mm, Width: 1 mm
      - Radial thickness: 10 mm,
    - High thermal strength
    - No radial step on the inner surface
  - Loss Factor (estimated by MAFIA T3)

\[ k(3 \text{ mm}) = 4.1 \times 10^9 \text{ [V/C]} \]

\[ \times 1000 \]

Total: \[ k(3 \text{ mm}) = 4.1 \text{ [V/pC]} \]

\[ P_{\text{HOM}} = 707 \text{ [kW]} \]

\[ k(3\text{mm}) \text{ reduces to } \sim 40 \% \]
Coherent Synchrotron Radiation (T. Agoh)

KEKB

Bunch Length: $\sigma_z = 6\text{mm}$  \Rightarrow  3mm
Bunch Current: $I_b = 1.2\text{mA}$  \Rightarrow  2mA ($\approx 20\text{nC}$)

SuperKEKB

$\Leftarrow$ Energy change by CSR
  for one particle,
  for one bend.

SuperKEKB (red line)
14 times larger $\Delta E$
than KEKB (dotted line)

Square pipe
  $r = 47\text{mm}$
  (half height)
Crab crossing in the near future

- Crab crossing will boost the beam–beam parameter up to 0.19! (Strong–weak simulation)

\[ \text{crossing angle } 22 \text{ mrad} \]

- Superconducting crab cavities are under development, will be installed in KEKB in early 2006.

K. Ohmi & M. Tawada

K. Hosoyama, et al
Can we increase the stored current?

• Bunch current has been already limited by HOM and CSR.
• More bunches are necessary: more RF buckets: 1–1.5 GHz.
• Completely new RF system:
  – Discard all the existing 500 MHz system, which has been developed for 25 years since TRISTAN.
  – Develop klystrons, power supplies, cavities at a new frequency.
  – Superconducting cavity’s HOM absorber will be more than difficult.
  – Feasibility of ARES at higher frequency is unknown.
  – 300 – 500 M$, at least 15 FTE × 5 years. (Where are those people?)
  – In parallel with the operation of the existing system.
• Higher current needs different design of the vacuum system, which requires all magnets to be replaced for larger aperture.
• Is the shorter bunch spacing safe with parasitic collision?
• More electricity (150–200 MW!), additional power stations.
• Bad luminosity/cost.
**ARES Cavity**

- Passive stabilization with huge stored energy.
- Eliminates unnecessary modes by a coupling of 3 cavities.
- Higher order mode dampers and absorbers.
- No need for longitudinal bunch-by-bunch feedback.
- No transverse instability arises from the cavities.

**Superconducting Cavity**

- World’s highest current, 1.3 A.
- Input coupler has been operated up to 380 kW.
- Ferrite HOM absorber working at 12 kW.
ARES upgrade for SuperKEKB

- Larger detuning
  - Change energy ratio: $U_s/U_a = 9 \rightarrow 15$
  - Small modification on the window size of A-cav
  - $-1$ mode growth time: 0.3 ms to 1.6 ms.
  - Then the $-1$ (and $-2$) modes related to the fundamental mode will be suppressed by a FB system in the RF control system.
    (need bunch-by-bunch FB to suppress ARES HOM & $0/\pi$ mode instability)

- Higher HOM power
  - Upgrade of HOM damper

- Higher input RF power
  - 400 kW/cavity $\rightarrow$ 800 kW/cavity
  - R&D of input coupler using new test-stand.

T. Kageyama
**Achievements of KEKB-SC**

**RF power absorbed by HOM dampers at 1.27 A**

- A beam of 1.27 A in 1293 bunches induces the HOM of 14 - 16 kW for each module. ($\sigma_z=7$mm)
- The ratio of SBP / LBP is 7 kW / 9 kW.

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S. Mitsunobu, T. Furuya
Summary

• Present design of SuperKEKB hits fundamental limits in the beam–beam effect and the bunch length (HOM & CSR).

• Higher current is the only way to increase the luminosity.

• Many technical and cost issues are expected with a new RF system.

• We need a completely different collider scheme.....
## Construction schedule of SuperKEKB RF system

---|---|---|---|---|---|---|---|---|---|---|---|---
**KEKB** | KEKB operation | KEKB shut down |
**SuperKEKB** | New buildings | SuperKEKB construction | SuperKEKB commissioning |
---|---|---|---|---|---|---|---|---|---|---|---|---
### Operating stations (cavities)

| D1 | 2 (Crabs) | → | → | → | → |
| D2 | 2 (Crabs) | → | → | → | → |
| D4 | 3 (6A) | → | → | → | 10 (10AH) | → | → | → | → | 14 (14AH) |
| D5 | 3 (6A) | → | 4 (6A) | → | 10 (2AH) | → | 6 (2H+4L) | → | 10 (2H+8L) |
| D7 | 5 (10A) | → | → | → | 10 (10AL) | → | → | → | → |
| D8 | 5 (10A) | → | → | → | 10 (10AL) | → | → | → | → |
| D10 | 4 (4S) | → | → | → | 6 (6SH) | → | 6 (6SH) | → | → | → | → |
| D11 | 4 (4S) | → | 6 (4S+2C) | → | → | → | → | → | → | → | → |
| DR | 1 (1A) | → | → | → | → | → | → | → | → | → | → | → |

**Total number of operating stations**: 24 → 27 → → 49 → 53 → 61

### ARES-AC modify 1 set

<table>
<thead>
<tr>
<th>Design</th>
<th>Prototype</th>
<th>Beam Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fabricate</td>
<td>Install</td>
<td></td>
</tr>
</tbody>
</table>

### ARES-AC modify 20 sets

<table>
<thead>
<tr>
<th>1st S-cav</th>
<th>S-cavity only</th>
<th>Beam pipe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fabricate</td>
<td>Install 4</td>
<td>Install 5</td>
</tr>
<tr>
<td>Move 4</td>
<td>Install 1@DR</td>
<td>Install 3</td>
</tr>
</tbody>
</table>

### ARES new full set

<table>
<thead>
<tr>
<th>4 additional SCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fabricate</td>
</tr>
</tbody>
</table>

### Enlarge beam pipe for existing SCC

<table>
<thead>
<tr>
<th>Beam pipe</th>
</tr>
</thead>
</table>

### Crab RF system @Nikko

<table>
<thead>
<tr>
<th>Construct</th>
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</table>

### Crab RF system @Tsukuba

<table>
<thead>
<tr>
<th>Construct</th>
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</table>

### RF system for Damping Ring

<table>
<thead>
<tr>
<th>Construct</th>
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</thead>
</table>

### Klystron fabrication

| 1 | 3 | 4 | 4 | 5 | 4 | 4 | 3 | 3 | 3 | 3 |

### Power supply for 2 klystrons

| 3 | 3 | 3 | 3 | 2 | 1 | 2 | 2 |

### High-power and cooling system

| 2 | 1 | 8 | 8 | 8 | 2 | 4 | 4 |

### Low-level RF system

| 2 | 1 | 8 | 8 | 8 | 2 | 4 | 4 |

### Reinforce vapor cooling system

| D4 | D7 | D8 | D5 |

### R&Ds

| R&D of HOM damper, Coupler, Control, etc. |

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