Status of the KEK Super B Factory

Tom Browder
(University of Hawaii)

Physics Motivation
Accelerator /Detector
Project Schedule

Apologies: Highlights only. Some fairly detailed discussion of the accelerator, which may bore theorists.
**Super B Factory vs current sensitivities**

<table>
<thead>
<tr>
<th>Observable</th>
<th>SFF sensitivity</th>
<th>Current sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sin(2\beta) \ (J/\psi K^0)$</td>
<td>0.005-0.012</td>
<td>0.01</td>
</tr>
<tr>
<td>$\gamma \ (DK)$</td>
<td>1–2°</td>
<td>$\sim 31° \ (\text{CKMFitter})$</td>
</tr>
<tr>
<td>$\alpha \ (\pi\pi, \rho\pi, \rho\rho)$</td>
<td>1–2°</td>
<td>$\sim 15° \ (\text{CKMFitter})$</td>
</tr>
<tr>
<td>$</td>
<td>V_{ub}</td>
<td>(\text{excl})$</td>
</tr>
<tr>
<td>$</td>
<td>V_{ub}</td>
<td>(\text{incl})$</td>
</tr>
<tr>
<td>$\rho$</td>
<td>1.7-3.4%</td>
<td>$\pm 20%$</td>
</tr>
<tr>
<td>$\eta$</td>
<td>0.7-1.7%</td>
<td>$\pm 4.6%$</td>
</tr>
<tr>
<td>$S(\phi K^0)$</td>
<td>0.02-0.03</td>
<td>0.17</td>
</tr>
<tr>
<td>$S(n' K^0)$</td>
<td>0.01-0.02</td>
<td>0.07</td>
</tr>
<tr>
<td>$B(B \rightarrow \tau \nu)$</td>
<td>3–4%</td>
<td>30%</td>
</tr>
<tr>
<td>$B(B \rightarrow \mu \nu)$</td>
<td>5–6%</td>
<td>not measured</td>
</tr>
<tr>
<td>$B(B \rightarrow D \tau \nu)$</td>
<td>2–2.5%</td>
<td>31%</td>
</tr>
<tr>
<td>$B(B \rightarrow \rho \gamma)/B(B \rightarrow K^{*}\gamma)$</td>
<td>3–4%</td>
<td>16%</td>
</tr>
<tr>
<td>$A_{CP}(b \rightarrow s \gamma)$</td>
<td>0.004-0.005</td>
<td>0.037</td>
</tr>
<tr>
<td>$A_{CP}(b \rightarrow s \gamma + d \gamma)$</td>
<td>0.01</td>
<td>0.12</td>
</tr>
<tr>
<td>$S(K_{S}\pi^{0}\gamma)$</td>
<td>0.02-0.03</td>
<td>0.24</td>
</tr>
<tr>
<td>$S(\rho \gamma)$</td>
<td>0.08-0.12</td>
<td>0.67</td>
</tr>
<tr>
<td>$A^{FB}(B \rightarrow K^{+}\ell^{-}\nu)$</td>
<td>4–6%</td>
<td>not measured</td>
</tr>
<tr>
<td>$B(B \rightarrow K^{0}\nu\nu)$</td>
<td>16–20%</td>
<td>not measured</td>
</tr>
<tr>
<td>$B(B \rightarrow s\ell^{+}\ell^{-})_{s0}$</td>
<td>not measured</td>
<td></td>
</tr>
<tr>
<td>$B(B \rightarrow d\ell^{+}\ell^{-})_{s0}$</td>
<td>not measured</td>
<td></td>
</tr>
<tr>
<td>$\phi_D \ (\text{NP phase})$</td>
<td>$\pm(1 - 2)^{\circ}$</td>
<td>$\sim \pm 20^\circ$</td>
</tr>
</tbody>
</table>

(50-75 $ab^{-1}$)

**The Super B Factory is part of a Unified and Unbiased Attack on New Physics**

LHC, ILC

- Higgs boson mass and couplings. New particle searches
- New physics in loops?

New physics

Quark sector:
- $b\rightarrow \phi s$
- $B^0 \rightarrow d\bar{s}$
- $K^0_s \rightarrow d\bar{d}$

Lepton sector:
- $\tau$ LFV, $\tau$ CPV
- Flavor mixing, CPV phases

KEK Super B Factory, LHCb, Rare K expts, BESIII...

$\nu$ expts accel, reactor, $g_\mu-2$, $\mu\rightarrow e\gamma$, Project X...

$\nu$ mass and mixing, CPV, and LEFV
One method to find **New Physics Phases**

**Example:**

\[ V_{ts}: \text{no KM phase} \]

\[
\begin{align*}
V^{*}_{td} & \quad \text{SM: } \sin^2 \phi_1 = \sin^2 \phi_1 \text{ from } B \to J/\psi K^0 \ (b \to c \bar{c} s) \\
\text{unless there are other, non-SM particles in the loop}
\end{align*}
\]
Many new phases are possible in SUSY

\[ \bar{b} \rightarrow \bar{g} \rightarrow \phi \rightarrow \eta' \]

\[ B^0 \rightarrow \bar{d}_R \left( \delta^{d}_{RR} \right) \rightarrow s_R \rightarrow s_R \rightarrow \phi \rightarrow \eta' \]

\[ \bar{B} \rightarrow \bar{g} \rightarrow \phi \rightarrow \eta' \]

\[ d \rightarrow d \]

O(1) effects allowed even if SUSY scale is above 2TeV.
New Kaluza-Klein (K.K) particles are associated with the extra dimension.

(“Tower of states”)

Some may induce new phases and flavor-changing neutral currents.

(Much recent theoretical work to suppress FCNC in extra dimensions)

e.g. K. Agashe, G. Perez, A. Soni, PRD 71, 016002 (2005)

\[
\begin{array}{|c|c|c|c|}
\hline
R_{S_{B_d \to K_{\gamma}}} & S_{B_d \to K_{\gamma}} & S_{B_d \to K_{\gamma}} & S_{B_d \to K_{\gamma}} \\
\hline
O(1) & \sin 2\beta \pm O(1) & Br_{SM}[1 + O(1)] & O(1) \\
\hline
\lambda_c^2 & \sin 2\beta & Br_{SM} & \frac{m_s}{m_b} \left(\sin 2\beta, \lambda_c^2\right) \\
\hline
\end{array}
\]

++CPV in D decay

Model: K.K. Gluon near 3 TeV

Constr. $\varepsilon_K$?
2008: Hints of NP in $b \to s$ Penguins?

$\sin(2\beta_{\text{eff}}) = \sin(2\phi_{1\text{eff}})$

Smaller than $b \to c\bar{c}s$ in 7 of 9 modes

Naïve average of all $b \to s$ modes

$\sin 2\beta_{\text{eff}} = 0.56 \pm 0.05$

2.2 $\sigma$ deviation from SM (CL=3%)
Extrapolation: $B \rightarrow \phi K^0$ at 50/ab with present WA values

This would establish the existence of a NP phase in $b \rightarrow s$

Compelling measurement in a clean mode
Or New Physics might appear like this

NB Constraints from trees and boxes do not agree

This would indicate that there is a NP phase in $b \rightarrow d$

Nishida, 50 ab$^{-1}$
2007 was the year of D" mixing

Measurements by Belle and BaBar (and CDF) demonstrated the existence of D-Dbar mixing
Another new physics phase!

\[ \varphi \sim \frac{2\eta A^2 \lambda^5}{\lambda} \sim O(10^{-3}) \]

CPV in D system negligible in SM

CPV in interf. mix./decay:

\[ \text{Im} \frac{q \bar{A}_f}{p A_f} \equiv (1 + \frac{A_M}{2})e^{i\varphi} \neq 0; \varphi \neq 0 \]

The existence of D mixing (if x is non-zero) allows us to look for another unconstrained new physics phase but this time from up-type quarks. (c.f. CPV in B_\text{s} mixing)

Current sensitivity \( \sim \pm 20^0, 50 \text{ ab}^{-1} \) go below \( 2^0 \)
Perhaps NP will appear in the $\tau$ sector, the heaviest charged lepton.

\[ \tau \rightarrow \mu \gamma \]

\[ \text{BF}(\tau \rightarrow \mu \gamma) \sim 10^{-8} \]

$\tau$ LFV would be an unambiguous signal for NP.
The Accelerator and the Detector

Towards a Super Flavor Factory
KEKB’s Track Record

~ 1.5 Billion $BB$ pairs

~1400/fb!

$\mathcal{L}_{\text{peak}} (\text{KEKB}) \approx 1.7 \times 10^{34}/\text{cm}^2/\text{sec} \ (\text{design 1.0})$
Three factors determine the luminosity:

\[ L = \frac{I_{\pm}I_{\pm}}{\beta_y^*} \]

- **Stored current:**
  - 1.7 / 1.4 A (e+/e- KEKB)
  - \( \rightarrow 9.4 / 4.1 \) A (Super KEKB)

- **Beam-beam parameter:**
  - 0.059 (KEKB)
  - \( \rightarrow >0.24 \) (SuperKEKB)

- **Vertical \( \beta \) at the IP:**
  - 6.5/5.9 mm (KEKB)
  - \( \rightarrow 3.0/3.0 \) mm (SuperKEKB)

- **Luminosity:**
  - \( 0.17 \times 10^{35} \) cm\(^{-2}\)s\(^{-1} \) (KEKB)
  - \( 8 \times 10^{35} \) cm\(^{-2}\)s\(^{-1} \) (SuperKEKB)

- **Geometrical repipeion factors due to crossing angle and hour-glass effect**

- **Pedagogical slide from Oide**
KEKB Upgrade Plan: A Super-B Factory at KEK

- Asymmetric energy $e^+e^-$ collider at $E_{cm} = m(\Upsilon(4S))$ to be realized by upgrading the existing KEKB collider.
- **Initial target:** $10 \times$ higher luminosity $\cong 2 \times 10^{35}/\text{cm}^2/\text{sec}$ after 3 year shutdown
  $\rightarrow 2 \times 10^9 BB$ and $\tau^+\tau^-$ per yr.
- **Final goal:** $L = 8 \times 10^{35}/\text{cm}^2/\text{sec}$ and $\int L \, dt = 50 \, \text{ab}^{-1}$

Many Super B components are being tested now.
Finite angle crossing and Crabbing
Latest Record with Crab Cavities

Steady progress since fall 2007

$1.61 \times 10^{34}/\text{cm}^2/\text{s}$ (still more expected)

Peak Luminosity 16.097 [nb/sec] @03:10
Integrated Luminosity 1009.20 [pb]
Specific Luminosity in the Crab Era

(Records, dramatic improvement in beam-beam tune shift)

Unsolved mysteries

- $\xi \sim 0.1$
- $\xi \sim 0.055$
- c.f. Crab waist record at DAFNE, $\xi \sim 0.02$
New vacuum chamber successfully tested in KEKB

- Copper beam duct with ante-chamber
  - Copper required to withstand intense SR power

- Features (compared to simple pipe)
  - Low SR power density
  - Few photoelectrons in beam pipe
  - Low beam impedance

Dramatic reduction of photo-electron yield observed.
State of the art RF cavities (both superconducting and normal types are already used in KEKB)

The superconducting cavities will be upgraded to absorb more higher-order mode power, up to 50 kW.
Beam Background (after 1\textsuperscript{st} optimization)

Conservative, robust detector should be handled up to 20 times more background.

Results based on GEANT simulations validated by Belle/KEKB experience.
Features of the Super KEKB detector

In contrast to LHCb, superb neutral detection capabilities.

\[ \text{e.g. } B \rightarrow K_S \pi^0 \gamma \text{ can be used to detect right-handed currents} \]

Capable of observing rare “missing energy modes” such as \( B \rightarrow K \nu \bar{\nu} \)
with B tags. Hermiticity is critical.

Issues:

- Higher background (x 20)
- Radiation damage and occupancy
- Fake hits and pile-up in EM cal
- Higher event rate (x 50)
Super Belle: A detector for SuperKEKB

- Faster calorimeter with waveform sampling and pure CsI (endcap)
- New particle identifier with precise Cherenkov device: (i)TOP or fDIRC.
- KL/$\mu$ detection with scintillator and next generation photon sensors
- Background tolerant super small cell tracking detector
- New dead time free pipelined readout and high speed computing systems
- Si vertex detector with high background tolerance ((1) faster readout then (2)pixels)
Conventional solutions (DSSD Si strips) are on the edge

Stopgap alternatives include faster readout electronics

SuperKEKB luminosity: $L \sim 1.7 \times 10^{34} \rightarrow L \sim 10^{36} \text{ cm}^{-2}\cdot\text{s}^{-1}$

SVD occupancy

Present: layer 1 of SVD

$\sim 10\%$ occupancy / 200 krad yr$^{-1}$

KEKB Upgrade: Super-Belle

$\sim x 20$ expected increase
A more robust long term solution: Super KEKB Pixel Detector

**Significant R+D Issues**

Assume 22.5 $\mu$m pixels and 10 $\mu$sec integration time

Can expect ~ 0.5% occupancy

**(MPI Munich and collaborators)**

DEPFET Test Beam results

![DEPFET concept](image1)

![Hawaii CAD](image2)

![Resolution graph](image3)
Two new particle ID devices, both using Cherenkov light:

Barrel: Time-Of-Propagation (TOP) (baseline), iTOP, focusing DIRC

Endcap: proximity focusing aerogel RICH
**Principle of a TOP counter**

(Measure 1D position and time in a compact detector)

- Linear-array type photon detector
- Quartz radiator
- Linear array PMT (~5mm)
- Time resolution $\sigma \sim 40 ps$

Different propagation lengths $\rightarrow$ propagation times

US groups: Can the performance be improved by imaging (i-TOP or f-DIRC)?

Provides $\sim 4\sigma$ π/K separation at 3.5 GeV/c
imaging TOP (iTOP)

Concept: Use best of both TOP (timing) and DIRC and fit in Belle PID envelope

- Use new, compact solid-state photon detectors, new high-density electronics
- Use simultaneous $T, \theta_c$ [measured-predicted] for maximum $K/\pi$ separation
- Keep pixel size comparable to DIRC

Bars compatible (though thinner) with proposed TOP counter
Focusing DIRC Alternative

Cincinnati
End-cap PID (A-RICH)
Test beam results

March 2008 at KEK Fuji electron beam line
$p_e = 2 \text{ GeV/c}$

Clear ring images observed!

$\sigma \sim 12 \text{ mrad}, N_{p.e.} \sim 4$
Scintillator based $K_L/\mu$ for KEK SuperB

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

**Mirror 3M (above groove & at fiber end)**

- Optical glue increase the light yield ~ 1.2-1.4)

**WLS: Kurarai Y11 Ø1.2 mm**

**Diffusion reflector (TiO$_2$)**

**GAPD**

**Strips: polystyrene with 1.5% PTP & 0.01% POPOP**
Funding, Schedule etc.....

Inside blue grotto, Capri
KEK’s 5 year Roadmap

• Official 20 page report released on January 4, 2008 by director A. Suzuki and KEK management

• KEKB’s upgrade to $2 \times 10^{35}$ /cm$^2$/sec in 3+x years is the central element in particle physics. (Funding limited: Final goal is $8 \times 10^{35}$ and an integrated luminosity of 50 ab$^{-1}$)
  – Favorably reviewed by the Roadmap Review Committee (March 9-10).
  • Membership: Young Kee Kim, John Ellis, Rolf Heuer, Andrew Hutton, Jon Rosner, H. Takeda and reviewers from other fields

Super-Belle (and Super KEKB) is an open international project that covers the next two orders of magnitudes at the luminosity frontier. A special opportunity for high impact international collaboration
KEK Roadmap

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<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

- **J-PARC**
  - Construction
  - Experiment + upgrade

- **KEKB**
  - Experiment
  - Upgrade
  - Experiment + upgrade

- **LHC**
  - Construction
  - Experiment + upgrade

- **PF/PF-AR**
  - Experiment + upgrade

- **R&D for Advanced Accelerator and Detector Technology**
  - Detector R&D
  - ERL
    - C-ERL R&D
      - Construction
      - Test experiment
  - PF-ERL
    - R&D
      - Construction
      - Experiment
  - ILC R&D
    - Construction
**Tight Schedule for the Super KEKB Collaboration**

**Possible 6-month shift to the right**
# International Steering Committee for Super KEKB

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>H. Aihara</td>
<td>U Tokyo, Japan</td>
</tr>
<tr>
<td>A. Bondar</td>
<td>BINP, Russia</td>
</tr>
<tr>
<td>T. Browder</td>
<td>U. Hawaii, USA</td>
</tr>
<tr>
<td>P. Chang</td>
<td>NTU, Taiwan</td>
</tr>
<tr>
<td>T. Iijima</td>
<td>Nagoya U, Japan</td>
</tr>
<tr>
<td>P. Krizan (chair)</td>
<td>JSI, Slovenia</td>
</tr>
<tr>
<td>T. Mueller</td>
<td>Karlsruhe, Germany</td>
</tr>
<tr>
<td>H. Palka</td>
<td>Crakow, Poland</td>
</tr>
<tr>
<td>Y. Sakai</td>
<td>KEK, Japan</td>
</tr>
<tr>
<td>M. Sevior</td>
<td>Melbourne, Australia</td>
</tr>
<tr>
<td>C. Schwanda</td>
<td>Vienna, Austria</td>
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<tr>
<td>Y. Ushiroda</td>
<td>KEK, Japan</td>
</tr>
<tr>
<td>E. Won</td>
<td>Korea U, Korea</td>
</tr>
<tr>
<td>M. Yamauchi</td>
<td>KEK, Japan</td>
</tr>
<tr>
<td>C.Z. Yuan</td>
<td>IHEP, China</td>
</tr>
</tbody>
</table>

Reps from other nations will be added as new groups join the collaboration.
Steps to start a new project at KEK

KEK = an inter-university research institute corporation

KEK management

Ministry of Education, culture, sports, science and technology

Ministry of Finance

“MEXT (Monbukagakushou)”

“Zaimushou”
Conclusions

KEK is moving ahead with a machine and detector designed to discover new FCNC and new sources of CPV.

The accelerator and detector have a track record of exceeding expectations.

This is a special opportunity for high impact international collaboration.
Backup Slides
The US P5 committee recognizes an off-shore Super B Factory as part of the base HEP program in all but the lowest funding scenario.

**High-sensitivity Measurements**

- The latest developments in accelerator and detector technology make possible promising new scientific opportunities through measurement of rare processes. Incisive experiments, complementary to experiments at the LHC, would probe the Terascale and possibly much higher energies.
- The panel recommends pursuing the muon-to-electron conversion experiment, subject to approval by the Fermilab PAC, under all budget scenarios considered by the panel.
- The intermediate budget scenario would allow in addition pursuing significant participation in one overseas next-generation B factory.
- The more favorable funding scenario, scenario C, would allow for pursuing a program in rare K decay experiments at Fermilab as well.
KEKB RF Power Statistics on Nov. 15, 2006
when the highest peak luminosity $1.71 \times 10^{34}$ cm$^{-2}$ s$^{-1}$ was achieved.

<table>
<thead>
<tr>
<th>Ring</th>
<th>LER</th>
<th>HER</th>
<th>unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam Energy</td>
<td>3.5</td>
<td>8.0</td>
<td>GeV</td>
</tr>
<tr>
<td>Beam Current</td>
<td>1.66</td>
<td>1.34</td>
<td>A</td>
</tr>
<tr>
<td>Total RF Voltage</td>
<td>8.0</td>
<td>15.0</td>
<td>MV</td>
</tr>
<tr>
<td>Radiation Loss</td>
<td>2.55</td>
<td>4.63</td>
<td>MW</td>
</tr>
<tr>
<td>Parasitic Loss</td>
<td>0.55</td>
<td>0.37</td>
<td>MW</td>
</tr>
<tr>
<td>Total Beam Power</td>
<td>3.1</td>
<td>5.0</td>
<td>MW</td>
</tr>
<tr>
<td>Total RF Power</td>
<td>5.4</td>
<td>6.2</td>
<td>MW</td>
</tr>
<tr>
<td>Total AC Plug Power</td>
<td></td>
<td>19</td>
<td>MW</td>
</tr>
</tbody>
</table>

Somewhat lower beam currents and power for same lumi with crab cavities
# RF parameters for SuperKEKB

<table>
<thead>
<tr>
<th>Ring</th>
<th>LER</th>
<th>HER</th>
<th>unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam energy</td>
<td>3.5</td>
<td>8.0</td>
<td>GeV</td>
</tr>
<tr>
<td>Beam current</td>
<td>9.4</td>
<td>4.1</td>
<td>A</td>
</tr>
<tr>
<td>Energy loss /turn</td>
<td>0.84</td>
<td>3.42</td>
<td>MV</td>
</tr>
<tr>
<td>Radiation loss</td>
<td>7.91</td>
<td>14.02</td>
<td>MW</td>
</tr>
<tr>
<td>Total loss factor, assumed</td>
<td>40 ± 5</td>
<td>45 ± 10</td>
<td>V/pC</td>
</tr>
<tr>
<td>Parasitic loss</td>
<td>7.09 ± 0.89</td>
<td>1.52 ± 0.34</td>
<td>MW</td>
</tr>
<tr>
<td>Total beam power</td>
<td>15.0 ± 0.9</td>
<td>15.5 ± 0.3</td>
<td>MW</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cavity type</th>
<th>ARES (modified)</th>
<th>ARES</th>
<th>SCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of cavities (= klystrons)</td>
<td>22~24</td>
<td>18~16</td>
<td>8</td>
</tr>
<tr>
<td>Voltage /cavity</td>
<td>0.5</td>
<td>0.5</td>
<td>1.3</td>
</tr>
<tr>
<td>Beam power /cavity</td>
<td>650</td>
<td>720</td>
<td>460</td>
</tr>
<tr>
<td>Wall loss /cavity</td>
<td>233</td>
<td>150</td>
<td>-</td>
</tr>
<tr>
<td>Detuning frequency</td>
<td>44</td>
<td>31</td>
<td>75</td>
</tr>
<tr>
<td>Klystron power</td>
<td>940</td>
<td>930</td>
<td>490</td>
</tr>
<tr>
<td>Total RF voltage</td>
<td>~11</td>
<td>~18</td>
<td></td>
</tr>
<tr>
<td>Total AC plug power</td>
<td>35</td>
<td>33</td>
<td></td>
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</table>
A recent realistic parameter list

<table>
<thead>
<tr>
<th>Parameter</th>
<th>LER</th>
<th>HER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>$E$</td>
<td>3.5</td>
</tr>
<tr>
<td>Current</td>
<td>$I_b$</td>
<td>9.4</td>
</tr>
<tr>
<td>#particles/bunch</td>
<td>$N$</td>
<td>1.18x10^{11}</td>
</tr>
<tr>
<td>#bunches</td>
<td>$n_b$</td>
<td></td>
</tr>
<tr>
<td>Emittance</td>
<td>$\varepsilon_x$</td>
<td>12</td>
</tr>
<tr>
<td>Coupling</td>
<td>$\varepsilon_y/\varepsilon_x$</td>
<td>0.5</td>
</tr>
<tr>
<td>Beta at IP</td>
<td>$\beta_x^*$</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>$\beta_y^*$</td>
<td>3</td>
</tr>
<tr>
<td>Bunch length (0A)</td>
<td>$\sigma_z$</td>
<td>3</td>
</tr>
<tr>
<td>Crossing angle</td>
<td>$\theta_x$</td>
<td>30→0 (crab crossing)</td>
</tr>
<tr>
<td>Bean-beam</td>
<td>$\xi_x$</td>
<td>0.272</td>
</tr>
<tr>
<td></td>
<td>$\xi_y$</td>
<td>0.295</td>
</tr>
<tr>
<td>Luminosity reduction</td>
<td>$R_L$</td>
<td>0.86</td>
</tr>
<tr>
<td>Beam-beam reduction</td>
<td>$R_{\xi_x}$</td>
<td>0.98</td>
</tr>
<tr>
<td></td>
<td>$R_{\xi_y}$</td>
<td>1.11</td>
</tr>
<tr>
<td>Luminosity</td>
<td>$L$</td>
<td>5.5x10^{35}</td>
</tr>
</tbody>
</table>

Slide from Y. Ohnishi
Zoom in: iTOP

44 rows x 92 columns to planar array = 4048 channels
2 ends x 16 bars = 129,536 readout channels

i-TOP is better than TOP
Compatibility with Italian option

LER arc cell

H. Koiso

Preliminary

\[ \varepsilon_x = 6.8 \text{ nm} \]

\[ \varepsilon_x = 2.2 \text{ nm} \]

- The arc cell lattice of the KEKB LER (left) can be modified to the low-emittance version (right), by weakening the magnetic field of the dipoles.
- No need for changing other components, beam pipes, geometry.
- The interaction region must be rebuilt.
- The HER’s emittance is not reduced, but unequal emittance may be OK.
### Costs & Effects

<table>
<thead>
<tr>
<th>Item</th>
<th>Object</th>
<th>Oku-yen = 1.0 M$</th>
<th>Luminosity</th>
</tr>
</thead>
<tbody>
<tr>
<td>New beam pipes</td>
<td>Enable high current</td>
<td>178 (incl. BPM, magnets, etc.)</td>
<td>x1.5</td>
</tr>
<tr>
<td>New IR</td>
<td>Small $\beta^*$</td>
<td>31</td>
<td>x2</td>
</tr>
<tr>
<td>$e^+$ Damping Ring</td>
<td>Allow injection with small increase $e^+$ capture</td>
<td>40 incl. linac upgrade</td>
<td>if not, x0.75</td>
</tr>
<tr>
<td>More RF and cooling systems</td>
<td>High current</td>
<td>179 (incl. facilities)</td>
<td>x3</td>
</tr>
<tr>
<td>Crab Cavities</td>
<td>Higher beam-beam param.</td>
<td>15</td>
<td>x2 - x4</td>
</tr>
</tbody>
</table>

Items are interrelated.

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K. Olde, KEKB Roadmap