Super B factory @ KEK
- Super KEKB -

B.G. Cheon
(Hanyang Univ., Seoul)
For the Belle collaboration

- Physics motivation
- Accelerator and Detector
- Project schedule

June 16-21, SUSY08 @ Seoul, Korea
Belle highlights

CPV discovery

Many new resonances

Evidence for $B \rightarrow \tau \nu$

$A_{FB}$ in $B \rightarrow K^* l^+ l^-$

$b \rightarrow d \gamma$ transition

$B \rightarrow D^{*} \tau \nu$

$D^0 - D^0$ mixing

And more …
Why KEK Super B factory?

- Many questions still remain in the SM.
- Something beyond SM should be there.
- Need more data to answer the questions.
  - KEKB/Belle achievement $\sim 0.85 \text{ ab}^{-1}$
  - Initial target $\sim 10 \text{ ab}^{-1}$ (limited funding)
  - Final target $\sim 50 \text{ ab}^{-1}$
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

- ν expts accel, reactor, $g_\mu-2$, $\mu \rightarrow e\gamma$, Project X..
  - ν mass and mixing, CPV, and LFV

- New physics

- Quark sector
  - $\tau$ LFV, $\tau$ CPV
  - Flavor mixing, CPV phases

- Lepton sector

- KEK Super B Factory, LHCb, Rare $K$ expts, BESIII...
Physics at KEK Super B factory

- New source of CP violation
- New source of flavor mixing
- LFV $\tau$ decays
- Precision test of KM scheme
- SUSY breaking mechanism
- Charm physics
  - New resonances, $D^0\overline{D^0}$ mixing...
- Super-high statistics measurements:
  - $\alpha_s$, $\sin^2\theta_W$, etc.
# BSM sensitive measurements

<table>
<thead>
<tr>
<th>Item</th>
<th>Super KEKB</th>
<th>LHCb</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSM CP phase</td>
<td>$t_{CPV}$ in $b \rightarrow s$ penguin ($\phi$ $K_s$, $\eta'$ $K_s$, ...)</td>
<td>$B_s \rightarrow \phi \phi$</td>
</tr>
<tr>
<td>BSM right-handed current</td>
<td>$t_{CPV}$ in $B \rightarrow K^{*} \gamma$</td>
<td>$B_s \rightarrow \phi \gamma$</td>
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<tr>
<td>Charged Higgs</td>
<td>$B \rightarrow \tau \nu$, $B \rightarrow D^{(*)} \tau \nu$</td>
<td>*</td>
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<tr>
<td>Inclusive measurements</td>
<td>$b \rightarrow s\gamma$, $b \rightarrow d\gamma$, $b \rightarrow sll$</td>
<td>*</td>
</tr>
<tr>
<td>$D^0$-$D^{0}$bar Mixing, DCPV</td>
<td>Super-high statistics $D$ decays</td>
<td>O</td>
</tr>
<tr>
<td>Lepton Flavor Violation</td>
<td>Super-high statistics $\tau$ decays</td>
<td>*</td>
</tr>
</tbody>
</table>

* Decay modes including $\gamma / \pi^0 / \nu$ can be accessed only with e+e- machines.

**Flavor physics review talks are waiting for us on Wed. !!!**
One example to find BSM Phases

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

SM: \[ \sin 2\phi_1 = \sin 2\phi_1 \text{ from } B \to J/\psi K^0 \quad (b \to c \bar{c} \ c s) \]

unless there are other, non-SM particles in the loop
BSM effect may enter in $b \rightarrow s$

New physics in loops?

Many new phases are possible in SUSY

Method:
Compare $S(\phi K^0)$ with $S(J/\psi K^0)$

SM prediction:
$\Delta S \equiv S(\phi K^0) - S(J/\psi K^0) \approx 0$

$O(1)$ effect allowed even if SUSY scale is above 2TeV.
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

$$\sin2\phi_1^{\text{eff}} = 0.56 \pm 0.05$$

2.2 $\sigma$ deviation from SM (CL=3%)

<table>
<thead>
<tr>
<th>$b \to c\bar{c}s$</th>
<th>World Average</th>
</tr>
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<tr>
<td></td>
<td>$0.68 \pm 0.03$</td>
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</table>

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<tr>
<th>$b \to c\bar{c}s$</th>
<th>$\phi K^0$</th>
<th>$K_S K_S K_S$</th>
<th>$K^0 K^0 K^0$</th>
<th>$b \to q\bar{q}s$</th>
</tr>
</thead>
<tbody>
<tr>
<td>BaBar</td>
<td>$0.21 \pm 0.26 \pm 0.11$</td>
<td>$0.50 \pm 0.21 \pm 0.06$</td>
<td>$0.58 \pm 0.10 \pm 0.03$</td>
<td>$0.68 \pm 0.15 \pm 0.03$</td>
</tr>
<tr>
<td>Belle</td>
<td>$0.64 \pm 0.10 \pm 0.04$</td>
<td>$0.71 \pm 0.24 \pm 0.04$</td>
<td>$0.30 \pm 0.32 \pm 0.08$</td>
<td>$0.33 \pm 0.35 \pm 0.08$</td>
</tr>
<tr>
<td>BaBar</td>
<td>$0.71 \pm 0.24 \pm 0.04$</td>
<td>$0.40 \pm 0.23 \pm 0.03$</td>
<td>$0.33 \pm 0.35 \pm 0.08$</td>
<td>$0.50 \pm 0.21 \pm 0.06$</td>
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<tr>
<td>Belle</td>
<td>$0.30 \pm 0.32 \pm 0.08$</td>
<td>$0.40 \pm 0.23 \pm 0.03$</td>
<td>$0.61 \pm 0.22 \pm 0.09 \pm 0.08$</td>
<td>$0.58 \pm 0.10 \pm 0.03$</td>
</tr>
<tr>
<td>BaBar</td>
<td>$0.33 \pm 0.35 \pm 0.08$</td>
<td>$0.62 \pm 0.25 \pm 0.02$</td>
<td>$0.11 \pm 0.46 \pm 0.07$</td>
<td>$0.68 \pm 0.15 \pm 0.03$</td>
</tr>
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<td>Belle</td>
<td>$0.11 \pm 0.46 \pm 0.07$</td>
<td>$0.25 \pm 0.26 \pm 0.10$</td>
<td>$0.18 \pm 0.23 \pm 0.11$</td>
<td>$0.76 \pm 0.11 \pm 0.07$</td>
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<tr>
<td>BaBar</td>
<td>$0.25 \pm 0.26 \pm 0.10$</td>
<td>$0.18 \pm 0.23 \pm 0.11$</td>
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<td>$0.18 \pm 0.23 \pm 0.11$</td>
<td>$0.72 \pm 0.71 \pm 0.08$</td>
<td>$0.43 \pm 0.49 \pm 0.08$</td>
<td>$0.76 \pm 0.11 \pm 0.07$</td>
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Theory predicts positive shifts.
Integrated Luminosity

~ 1.4 Billion $B\bar{B}$ pairs

~840/fb (Jun/10/08)

~531/fb (Apr/7/08)

May be time to switch units to ab$^{-1}$

$L_{peak} (KEKB) \approx 1.7 \times 10^{34}$/cm$^2$/sec (design 1.0)
KEKB upgrade
- Super B factory @ KEK -

- Upgrading the existing KEKB collider
- 3 years shutdown from 2009
- Initial target \( \sim 2 \times 10^{35}/\text{cm}^2\text{s} = 10 \times \text{KEKB Luminosity} \)
- Final goal \( \sim 8 \times 10^{35}/\text{cm}^2\text{s} \), Integrated Lum. = 50 ab\(^{-1}\)
- Many components are now being tested.

Upgrading the existing KEKB collider:

- New beam-pipe with antechamber
- Crab cavity
- New IR with crab crossing and smaller \( \beta^* \)
- More RF for higher beam current
- Damping ring for \( e^+ \)
- Ares RF cavity
- e\(^+\) source
- ARES (LER)
- 3.5 GeV \( e^+ \)
- 8 GeV \( e^- \)
- SCC RF(HER)
- 8 GeV \( e^- \)
Three factors to determine the luminosity:

Stored current:
1.7 / 1.4 A (e^+/ e^- KEKB)
→ 9.4 / 4.1 A (SuperKEKB)

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

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

Vertical \( \beta \) at the IP:
6.5/5.9 mm (KEKB)
→ 3.0/3.0 mm (SuperKEKB)
Conservative, robust detector should be handled up to 20 times more background

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

- In contrast to LHCb, superb neutral detection capabilities.
  - e.g. $B \rightarrow K_S \pi^0 \gamma$ can be used to detect right-handed currents.
- Capable of observing rare “missing energy modes”
  - e.g. $B \rightarrow K \nu \bar{\nu}$ with B tags.

Issues:
- Higher background (×20)
  - radiation damage and occupancy
  - fake hits and pile-up noise in the EM
- Higher event rate (×50)
  - higher rate trigger, DAQ and computing
- Required special features
  - low $p \mu$ identification $\leftarrow$ $s_\mu \mu$ recon. eff.
  - hermeticity $\leftarrow$ ν “reconstruction”
Super Belle detector

Possible solution:
- Replace inner layers of the vertex detector with a silicon striplet or pixel detector.
- Replace inner part of the central tracker with a silicon strip detector.
- Better particle identification device (TOP) focusing DIRC (fDIRC).
- Replace endcap calorimeter by pure CsI.
- Faster readout electronics and computing.
  - Replace inner layers of the vertex detector with a silicon striplet or pixel detector.
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New particle identifier with precise Cherenkov device: TOP or fDIRC.

New particle identifier with precise Cherenkov device: TOP or fDIRC.

Faster calorimeter with waveform sampling and pure CsI crystals.

KL/μ detection with scintillator and next generation photon sensors.

Korean group contribution:
- Calorimeter trigger system construction
- CDC Tracker z-trigger system implement
- SVD silicon strip sensor R&D

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 (stripelts or pixels)
2008.01.04
Roadmap of KEK (5 Year Plan)

The future program of KEK will reach a turning point in the years 2009 and 2010. First of all, J-PARC, a high intensity proton accelerator complex, will complete the first phase of construction at Tokai. Material and life science experiments using neutrons and muons will then start as well as particle and nuclear physics experiments including neutrino studies. The KEK B factory is expected to reach the initial target integrated luminosity, 1/ab, by that time. The engineering design report for the international linear collider, the ILC, will be presented up to 2010 by an international collaboration. The community of scientists using the light source facility has also proposed that R&D for an energy recovery linac (ERL) should be carried out as the next generation light source. Finally, it is anticipated that the international experimental program at the LHC, Large Hadron Collider at CERN will announce their first results around 2010.

The purpose of the roadmap is to form a leading research center in the world, by further reinforcing the various research activities at KEK. The plans for J-PARC, the LHC and the light source facility are basically the same as the ones presented in the interim roadmap by Professor Totsuka. However, we are now at the point to decide between early ILC construction and Super-KEKB upgrading the current KEKB, which were mentioned in parallel as an option in the interim report. The roadmap planning committee has proposed to start an early upgrade of KEKB to realize a unique research facility that will enable advanced studies on rare B decays, and to conduct a strong R&D program on superconducting cavities and related topics in order to contribute to the early realization of the ILC. I support the proposal by the committee.
KEK Roadmap

- 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
    - ILC R&D
      - construction
**Tight Schedule for the Super KEKB Collaboration**

Experiment at KEKB

***

KEKB/Belle upgrade

Detector Study Report (March 08)

Final detector design (April 09)

Detector proposals

BNM (January 08)

Pre kick-off meeting (March 08)

2nd open meeting (July 08)

Internal review (inc. PID shootout)

Actions to invite new collaborators

** Possible 6-month shift to the right

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** Tight Schedule for the Super KEKB Collaboration**

- **2007**: 10
- **2008**: 4 7 10
- **2009**: 4 7 10
- **2010**: 4 7 10
- **2011**: 4 7 10
- **2012**: 1 4

- **Experiment at KEKB**
- **KEKB/Belle upgrade**
- **Detector Study Report (March 08)**
- **Final detector design (April 09)**
- **Detector proposals**
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**Possible 6-month shift to the right**
Conclusions

KEKB is moving ahead with a machine and detector designed to discover new sources of flavor mixing and CPV.

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

Super KEKB and LHCb are complementary.

Super KEKB is a special opportunity for high impact international collaboration.
Backup slides
Major Achievements Expected at SuperKEKB: An Image

Projection of KEKB Luminosity

Integrated Luminosity (ab)

Year

- Discovery of Direct CP Violation in $B^0 \to K\pi$ Decays (2005)
- Discovery of CP Violation in Neutral $B$ Meson System (2001)
- Discovery of CP Violation in Charged $B$ Decays
- Discovery of $B \to D_{\tau\nu}$
- Discovery of $B \to \mu\nu$
- Precise meas. of D mixing
- Discovery of New Subatmic Particles
- Discovery of $B \to \phi K$ (for present WA)
- $\sin^2\theta_W$ with $O(10^{-4})$ precision
- Discovery of $B \to K_{\nu\nu}$
- CKM Angle Measurements with 1 degree precision
- New CP-Violating Phase in $b \to s$ with 1 degree precision
- "Discovery" with significance > $5\sigma$
- Observations with $\Upsilon(5S)$, $\Upsilon(3S)$ etc.
Search for new right-handed currents through CP violation

- SM Electroweak: purely left-handed
  
  Almost purely left-handed photon

  $\bar{B}^0 \rightarrow K_s \pi^0$ described with an amplitude for a left-handed photon: $\psi_L$

- New right-handed current $\rightarrow \psi_R$

Interference b/w $\psi_L$ and $\psi_R$ $\rightarrow$ Large CP violation

Atwood-Gronau-Soni 1997
Atwood-Gershon-Hazumi-Soni 2005
Identification of SUSY breaking scenario

Pattern of deviations from the Standard Model

<table>
<thead>
<tr>
<th>SUSY models</th>
<th>Observables</th>
<th>Bd- unitarity</th>
<th>$\varepsilon$</th>
<th>$\Delta m(Bs)$</th>
<th>$B\rightarrow\phi Ks$</th>
<th>$B\rightarrow M_{\gamma}$ indirect CP</th>
<th>$b\rightarrow s_{\gamma} d$ direct CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>mSUGRA</td>
<td></td>
<td>$-$</td>
<td>$-$</td>
<td>$-$</td>
<td>$-$</td>
<td>$-$</td>
<td>$+$</td>
</tr>
<tr>
<td>SU(5)SUSY GUT + $\nu_R$ (degenerate)</td>
<td>$-$</td>
<td>$+$</td>
<td>$+$</td>
<td>$-$</td>
<td>$+$</td>
<td>$-$</td>
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<td>$++$</td>
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<tr>
<td>U(2) Flavor symmetry</td>
<td>$+$</td>
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<td>$+$</td>
<td>$++$</td>
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<td>$++$</td>
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</table>

$++$: Large, $+$: sizable, $-$: small
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 $\sigma \approx 40$ ps

Provides $\sim 4\sigma$ \(\pi/K\) separation at 3.5 GeV/c

Simulation 2GeV/c, $\theta = 90$ deg.

Different propagation lengths $\rightarrow$ propagation times