B Physics Experimental Overview

S. Nishida

KEK

2010 LHC Days in Split

Oct 8, 2010
• Introduction of $e^+e^-$ B factories
• CPV in $b\rightarrow s$ penguins
• $b\rightarrow s\gamma$ and $b\rightarrow s\ell\ell$
• Tauonic B decays
• Future Plan

My talk is focused on B physics from $\Upsilon(4S)$ at $e^+e^-$ B factories.
BaBar & Belle

BaBar (PEP-II) @ SLAC

Belle (KEKB) @ KEK

3km ring

3km Linac

9 GeV e⁻ + 3.1 GeV e⁺

8 GeV e⁻ + 3.5 GeV e⁺

S. Nishida (KEK) Oct. 8, 2010

B Physics Experimental Overview

2010 LHC Days in Split
$e^+e^- \rightarrow \Upsilon(4S) \rightarrow B\bar{B}$ (1.1 nb)

1 fb$^{-1} \sim 10^6$ $B\bar{B}$ @ $\Upsilon(4S)$

Total $\sim 1020$ fb$^{-1}$
Peak $2.11 \times 10^{34}$ cm$^{-2}$ s$^{-1}$

On resonance:
- $\Upsilon(5S)$: 121 fb$^{-1}$
- $\Upsilon(4S)$: 711 fb$^{-1}$
- $\Upsilon(3S)$: 3 fb$^{-1}$
- $\Upsilon(2S)$: 24 fb$^{-1}$
- $\Upsilon(1S)$: 6 fb$^{-1}$

Off resonance, scan:
- $\sim 100$ fb$^{-1}$

Total 550 fb$^{-1}$
Peak $1.21 \times 10^{34}$ cm$^{-2}$ s$^{-1}$

On resonance:
- $\Upsilon(4S)$: 433 fb$^{-1}$
- $\Upsilon(3S)$: 30 fb$^{-1}$
- $\Upsilon(2S)$: 14 fb$^{-1}$

Off resonance:
- $\sim 54$ fb$^{-1}$
The operation of KEKB & Belle has ended on June 30, 2010.
⇒ Start of the upgrade to SuperKEKB & Belle II

KEKB Control Room

Belle Control Room

BaBar (PEP II) ended the operation in 2008.
Measurement of sin2\(\phi_1\)

Golden mode: sin2\(\phi_1\) with \(B^0 \to J/\psi K^0\)

\[
A_{CP}(\Delta t) = \frac{\Gamma(\overline{B}^0(\Delta t) \to f_{CP}) - \Gamma(B^0(\Delta t) \to f_{CP})}{\Gamma(B^0(\Delta t) \to f_{CP}) + \Gamma(\overline{B}^0(\Delta t) \to f_{CP})} = S \sin(\Delta m \Delta t) + A \cos(\Delta m \Delta t)
\]

\(S = -\xi \sin(2\phi_1)\)
\(A = 0\)

Signal Reconstruction:

535M \(\overline{B}B\)

\(B^0 \to J/\psi K_S\)

\(N_{sig} = 7482\)
Purity 97%\n\(CP\) odd

\(B^0 \to J/\psi K_L\)

\(N_{sig} = 6512\)
Purity 59 %\n\(CP\) even
Measurement of $\sin 2\phi_1$

$B^0 \rightarrow J/\psi K^0$

$B^0$ tag

$\bar{B}^0$ tag

$\sum J/\psi K_S$

$J/\psi K_L$

[PRD98, 031802 (2007)]

$535 \text{M } B\bar{B}$

$\sin 2\phi_1 = 0.642 \pm 0.031 \pm 0.017$

$\sin 2\phi_1 = 0.687 \pm 0.028 \pm 0.012$

- Belle will soon provide a new result with the final sample (772M $B\bar{B}$).
  - Reprocessed data (high eff.) + inclusion of all $\psi$ resonances.
  - Effectively ~ twice statistics. Expected $\sin 2\phi_1$ stat. error ~ 0.024.
Unitarity Triangle

Present constraints on UT.

Belle and BaBar confirmed
- CP Violation in the B meson system
- CKM mechanism as a source of the CP Violation.

Next target of B factories is the search and study of New Physics

S. Nishida (KEK)
Oct. 8, 2010
B Physics Experimental Overview

2010 LHC Days in Split
CP Violation in $b \to s$
CP Violation in $b \to s$

$b \to c \left( B \to J/\psi K^0 \right)$

$b \to s \left( B \to \phi K^0, \eta' K^0 \right)$

In the SM,
$$S = -\xi \sin(2\phi_1)$$

for $b \to s$ processes, but possible discrepancy due to non-SM contribution.

- The theoretical uncertainty (within SM) depends on the final states.
- $B \to K^0 K^0 K^0, \phi K^0, \eta' K^0$ are the cleanest modes ($\delta S_{\text{theory}} \sim$ a few %).
New Belle result on $B \rightarrow K^+ K^- K_S$  
[arXiv:1007.3848, accepted by PRD]

- Time dependent Dalitz analysis.
- Measure $\phi_1^{\text{eff}}$ associated with individual intermediate state.
- Multiple solutions; preferred one chosen with external information.

$\phi K_S$:  
$\phi_1^{\text{eff}} = (32.2 \pm 9.0 \pm 2.6 \pm 1.4)^\circ$

$f_0(890)K_S$: $\phi_1^{\text{eff}} = (31.3 \pm 9.0 \pm 3.4 \pm 4.0)^\circ$

$\phi = (21.1 \pm 0.9)^\circ$
**CP Violation in $b \rightarrow s$**

\[ \sin(2\beta_{\text{eff}}) \equiv \sin(2\phi_1) \]

- $\Delta \sin^2 \phi_1$ from $b \rightarrow ccs$ (reference)
- New Belle result
- Now in a good agreement with the SM.
- New CPV effect can be seen with much larger data (note: predicted $\delta \Delta \sin^2 \phi_1 \sim O(\%)$)

### Table: $b \rightarrow ccs$ Results

<table>
<thead>
<tr>
<th>Channel</th>
<th>World Average</th>
<th>$\phi_1^K$</th>
<th>$\Delta \phi_1^K$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b \rightarrow ccs$</td>
<td>$0.67 \pm 0.02$</td>
<td>$0.28 \pm 0.06 \pm 0.03$</td>
<td>$0.90 \pm 0.09 \pm 0.08$</td>
</tr>
<tr>
<td>$b \rightarrow ccs$</td>
<td>$0.58 \pm 0.07$</td>
<td>$0.57 \pm 0.08 \pm 0.02$</td>
<td>$0.64 \pm 0.10 \pm 0.04$</td>
</tr>
<tr>
<td>$b \rightarrow ccs$</td>
<td>$0.59 \pm 0.07$</td>
<td>$0.55 \pm 0.20 \pm 0.03$</td>
<td>$0.67 \pm 0.31 \pm 0.08$</td>
</tr>
<tr>
<td>$b \rightarrow ccs$</td>
<td>$0.55 \pm 0.17$</td>
<td>$0.35 \pm 0.06 \pm 0.03$</td>
<td>$0.35 \pm 0.10 \pm 0.09 \pm 0.10$</td>
</tr>
<tr>
<td>$b \rightarrow ccs$</td>
<td>$0.55 \pm 0.17$</td>
<td>$0.55 \pm 0.20 \pm 0.03$</td>
<td>$0.55 \pm 0.20 \pm 0.03$</td>
</tr>
<tr>
<td>$b \rightarrow ccs$</td>
<td>$0.46 \pm 0.07$</td>
<td>$0.45 \pm 0.24$</td>
<td>$0.45 \pm 0.24$</td>
</tr>
<tr>
<td>$b \rightarrow ccs$</td>
<td>$0.63 \pm 0.16$</td>
<td>$0.60 \pm 0.16 \pm 0.16$</td>
<td>$0.60 \pm 0.16 \pm 0.16$</td>
</tr>
<tr>
<td>$b \rightarrow ccs$</td>
<td>$0.62 \pm 0.13$</td>
<td>$0.62 \pm 0.13$</td>
<td>$0.62 \pm 0.13$</td>
</tr>
<tr>
<td>$b \rightarrow ccs$</td>
<td>$0.82 \pm 0.07$</td>
<td>$0.68 \pm 0.15 \pm 0.03 \pm 0.13$</td>
<td>$0.81 \pm 0.07$</td>
</tr>
</tbody>
</table>

S. Nishida (KEK)  
Oct. 8, 2010  
B Physics Experimental Overview  
2010 LHC Days in Split
b→sγ and b→sℓℓ
$b \to s\gamma$ and $b \to s\ell\ell$

- $b \to s(d)\gamma$, $b \to s\ell\ell$: FCNC process.
- Electroweak penguin (or box) diagram.
- Sensitive probe of New Physics.
- Limits on B.F. for $b \to s\gamma$ ⇒ constraints on charged Higgs mass.
- Charge asymmetry of $b \to s\gamma$.
  - $A_{CP}(B \to X_s\gamma) = 0.0042^{+0.0017}_{-0.0012}$
  - $A_{CP}(B \to X_s\gamma + X_d\gamma) = 0$
- $b \to s\ell\ell$ is sensitive to $C_7$, $C_9$, $C_{10}$ Wilson Coefficient.
  - $b \to s\gamma$ is sensitive only to $|C_7|$.
  - Sign-flipped $C_7$ is allowed.
- Many observables in $b \to s\ell\ell$
  - Isospin asymmetry
  - Forward backward asymmetry.
BF(B→X_sγ)

b→sγ (B→X_sγ) Branching Fraction

- Most precise results are obtained with fully inclusive method.
  - Subtract the on-resonance photon energy spectrum by the continuum spectrum.
  - Measure at $E_γ>E_γ^{(\text{min})}$. Need extrapolation.
  - Free from the model uncertainty of hadronic system ($X_s$).
  - Generally, has large backgrounds.
  - Lepton tag can be used for background suppression and flavor tagging.

\[
\text{B}(B\rightarrow X_s\gamma; E_\gamma>1.7\text{GeV}) = (3.45 \pm 0.15 \pm 0.40) \times 10^{-4}
\]

\[
\text{B}(B\rightarrow X_s\gamma; E_\gamma>1.6\text{GeV})
\]

\[
= (3.55 \pm 0.24 \pm 0.09) \times 10^{-4}
\]

\[
= (3.15 \pm 0.23) \times 10^{-4}
\]

- 1.2σ difference.
- Constraint on NP: $M(H^+) > 295$ GeV @ 95% C.L.
New BaBar Measurement of CP asymmetry of $b \to s/d\gamma$.

- The flavor of B can be identified by the lepton from the other B.
  - Mistag rate $\omega \sim 13\%$.

$$A_{CP} = \frac{A_{CP}^{\text{meas}}}{1 - 2\omega}$$

<table>
<thead>
<tr>
<th>$\omega \pm 2\sigma$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B^0\bar{B}^0$ oscillation</td>
</tr>
<tr>
<td>$B^0\bar{B}^0:B+B^-$</td>
</tr>
<tr>
<td>Non-direct-semileptonic</td>
</tr>
<tr>
<td>Fake ID</td>
</tr>
<tr>
<td>sum</td>
</tr>
</tbody>
</table>

$N(l^+) = 2623 \pm 158$

$N(l^-) = 2397 \pm 151$

$$A_{CP} = 0.056 \pm 0.060 \pm 0.018$$

(null asymmetry)

[W. Wang @ CKM2010]
Analysis of $B \rightarrow K^{(*)} \ell\ell$ at Belle (similar at BaBar)

- Combine $K$ or $K^*$ (from $K^+\pi^-$, $K_S\pi^+$, $K^+\pi^0$) with $e/\mu$ pair ($l+l^-$).
- Bremsstrahlung photons (20-500MeV, <50mrad) from $e$ recovered
- Dominant background: continuum and semileptonic $B$ decays.
  - Suppress using event shape variables, missing mass etc.
- $J/\psi$ ($\psi'$) veto to remove $B \rightarrow J/\psi X$, $\psi'X$ events ($q^2 = M_{ll}^2$)
  - $8.68 < q^2 < 10.09$, $12.86 < q^2 < 14.18$ for muon pair
  - $8.11 < q^2 < 10.03$, $12.15 < q^2 < 14.11$ for electron pair
- Peaking background from $K^{(*)}\pi\pi$.
- $M_{bc} - M_{K\pi}$ 2d fit for $K^*\ell\ell$, $M_{bc}$ 1d fit for $Kl\ell$.

230 ± 24 events
166 ± 15 events
$B \rightarrow K^{(*)}\ell\ell$

Partial Branching Fraction ($dBF/dq^2$)

New result by CDF (with $4.4 \text{ fb}^{-1}$)

- $K_{s}\ell\ell$
- $K^{*}\ell\ell$
- $K^{*}\mu\mu$

- $K^{\pm}\mu^{\pm}\mu^{\mp}$, $K^{\pm}\pi^{\mp}\mu^{\pm}\mu^{\mp}$ only.

Theory (max. allowed region)

[A. Ali et al. PRD61, 074024 (2000),
A. Ali et al. PRD66, 034002 (2006)]
B → K(*) ℓ⁺ℓ⁻ Branching Fractions

- Total branching fractions of all 3 experiments are consistent with each other and the SM

- Belle updated
  \[ B(B \to X_s ℓ⁺ℓ⁻) \text{ using } 605 \text{ fb}^{-1} \]

  \[ B(B \to X_s ℓ⁺ℓ⁻) = (3.33 \pm 0.8^{+0.19}_{-0.24}) \times 10^{-6} \]

- \textbf{BABAR:}
  \[ B(B \to Kℓ⁺ℓ⁻) = (0.394^{+0.073}_{-0.069} \pm 0.02) \times 10^{-6} \]
  \[ B(B \to K^* ℓ⁺ℓ⁻) = (1.11^{+0.19}_{-0.18} \pm 0.07) \times 10^{-6} \]

- \textbf{Belle:}
  \[ B(B \to Kℓ⁺ℓ⁻) = (0.48^{+0.05}_{-0.04} \pm 0.03) \times 10^{-6} \]
  \[ B(B \to K^* ℓ⁺ℓ⁻) = (1.07^{+0.11}_{-0.10} \pm 0.09) \times 10^{-6} \]

- \textbf{CDF:}
  \[ B(B^± \to K^±μ⁺μ⁻) = (0.38^{+0.05}_{-0.05} \pm 0.03) \times 10^{-6} \]
  \[ B(B^0 \to K^0μ⁺μ⁻) = (1.06^{+0.14}_{-0.14} \pm 0.09) \times 10^{-6} \]

G. Eigen, CKM10 Warwick, 07-09-2010
Asymmetries: smaller theory errors.

Isospin asymmetry \((K^{(*)0}/K^{(*)+})\)

- BaBar found large \(A_{l}\) in low \(q^2\) region \((3.9\sigma)\).
- Belle’s results are consistent with BaBar and SM.

Forward-backward asymmetry

- All the three results are consistent with each other and SM-prediction.
- \(C_7\) flipped scenario looks more favoured from \(A_{FB}\) distribution.
B→K*(*)\ell\ell

Future prospects:

• One good benchmark is $q_0^2$ (zero crossing point): theoretically clean.
• Prospects @ LHC-b and super B factories.
  
  LHCb $2 \text{ fb}^{-1}$: 13%
  LHCb $100 \text{ fb}^{-1}$: 2%
  Belle $50 \text{ ab}^{-1}$: 5%

$A_{FB}$

$C_7 = -C_7^{SM}$

$50 \text{ ab}^{-1}$

$q^2 (\text{GeV}^2/\text{c}^2)$

• Inclusive $X_s$ is theoretically more clean: possible only in B factories.
$B \to \tau \nu$ and $B \to D^{(*)} \tau \nu$
• Possible contribution of charged Higgs ($H^+$) in tree level.
• In the SM: $B(B\to \tau \nu) = (1.20 \pm 0.25) \times 10^{-4}$

\[
B(B \to \tau \nu) = \frac{G_F^2 m_B}{8\pi} \frac{m_\tau^2}{m_B^2} (1 - \frac{m_\tau^2}{m_B^2})^2 f_B^2 |V_{ub}|^2 \tau_B
\]

$|V_{ub}| = (4.32 \pm 0.16 \pm 0.29) \times 10^{-3}$

$f_B = 190 \pm 13$ MeV,

However, experimentally very challenging due to more than 1 neutrino in the final state

$B^+ \to \tau^+ \nu_\tau$

$\tau^+ \to e^+ \overline{v}_e \overline{v}_\tau$

$\to \pi^+ \overline{v}_\tau$

---

B meson beam!

Tag one of the B mesons

• Fully reconstruct using hadronic mode.
• Tag with B semi-leptonic decays.

$D \tau \nu$ etc.

Full (0.1~0.3\%) reconstruction $B$ $D \pi$ etc.
$B \rightarrow \tau \nu$

**hadronic tags**

449M $\bar{B}B$

$BF(B \rightarrow \tau \nu) = [1.79^{+0.56}_{-0.49} \text{(stat)}^{+0.46}_{-0.51} \text{(syst)}] \times 10^{-4}$

*first evidence* 3.5$\sigma$


**semileptonic tags**

NEW 657M $\bar{B}B$

$N_{\text{sig}} = 143^{+36}_{-35}$

3.6$\sigma$

**hadronic tags**

NEW, preliminary

468 M $\bar{B}B$

$e$

$\mu$

3.3$\sigma$

$BF(B \rightarrow \tau \nu) = [1.80^{+0.57}_{-0.54} \text{(stat)} \pm 0.26] \times 10^{-4}$

BaBar Collab., arXiv: 1008.0104

$\pi$

$\rho$

$BF(B \rightarrow \tau \nu) = [1.54^{+0.38}_{-0.37} \text{(stat)}^{+0.29}_{-0.31} \text{(syst)}] \times 10^{-4}$

Belle Collab., arXiv: 1006.4201 submitted to PRD-RC

$BF(B \rightarrow \tau \nu) = [1.7 \pm 0.8 \text{(stat)} \pm 0.2] \times 10^{-4}$

BaBar Collab., PRD 81, 051101 (2010)

slide from M. Rozanska @Charged Higgs 2010

24
B → τν

Hadronic tag

Semileptonic tag

SM prediction

HFA (1.64 ± 0.39) × 10^{-4}

Consistent with the SM: (1.20 ± 0.25) × 10^{-4}

Alternative approach is to extract the B.F. from CKM fit (excluding direct meas.).

\[ BF(B \rightarrow τν)_{SM(CKM)} = [0.763^{+0.114}_{-0.061}] × 10^{-4} \]  

(CKMfitter)

\[ BF(B \rightarrow τν)_{SM(UT)} = [0.805 ± 0.071] × 10^{-4} \]  

(UT fit)

Tension!
Limit to charged Higgs mass.

\[
Br(B \to l \nu) = BR_{SM} \times \left(1 - \tan^2 \beta \frac{m_B^2}{m^2_H}\right)^2
\]

(Type II ‘2HDM’)

Unique opportunity to study b-H⁺-u interaction
$B \rightarrow D^{(*)}\tau\nu$

- Similar physics motivation to $B \rightarrow \tau\nu$, but
  - different theoretical uncertainty.
  - Study of $b$-$H^+$-$c$ interaction.
- Similar analysis technique to $B \rightarrow \tau\nu$, but
  - More observables due to kinematical constraints.
  - Two ways of reconstruction: reconstruct tagged $B$ first as $B \rightarrow \tau\nu$; or reconstruct signal first.
  - Simultaneous extractions of multiple modes due to self cross feed.
- Polarization sensitive to the NP.
$B \to D^{(*)}\tau\nu$

$\mathcal{B}(B^+ \to D^*\tau^+\nu_\tau) = (2.12^{+0.28}_{-0.27}(\text{stat}) \pm 0.29(\text{syst}))\%$

8.1$\sigma$

$\mathcal{B}(B^+ \to D^0\tau^+\nu_\tau) = (0.77 \pm 0.22(\text{stat}) \pm 0.12(\text{syst}))\%$

3.5$\sigma$

first evidence
B → D(∗)τν

All measurements are above (but also consistent with) the SM prediction.

Constraint on H⁺
Other Missing Topics

- Measurement of CKM angle $\phi_2$, $\phi_3$.
- Measurement of $|V_{ub}|$ using B semileptonic decay.
- Time dependent CPV of $B \rightarrow K^*\gamma$ (Phonon polarization).
- $B \rightarrow K\pi$ CP Asymmetry ($K\pi$ puzzle).

....

- $\tau$ decays (LFV)
- Charm physics: $D^0$-$\bar{D}^0$ mixing.
- Charmonium spectroscopy (exotic hadrons).

....

- Study of Bs decays by Belle using data at $\Upsilon$(5S).
- Observation of $\eta_b$ by BaBar using data at $\Upsilon$(3S).

....

- $\Delta m_s$, $\Delta \Gamma_s$ from Tevatron.
- Search for $B_s \rightarrow \mu\mu$

....
Super B Factories
Super B Factories

• Although there exist interesting possible hints for the NP at the present B factories, all the results are consistent with the SM.
• NP should exist at the higher energy scale, possibly in TeV region considering the hierarchy problem → LHC will discover it.
• Super B factories can help the identification of the NP, i.e. whether it is SUSY or others, or how SUSY breaking occurs.

### SUSY scenario

<table>
<thead>
<tr>
<th>mSU GRA</th>
<th>MSSM+$\nu_R$</th>
<th>SU(5)+$\nu_R$</th>
<th>U(2) FS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>degenerate</td>
<td>non-degenerate</td>
<td>degenerate</td>
</tr>
<tr>
<td>$A_{CP}(s')$</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>$S(K^*\gamma)$</td>
<td>✓ ✓ ✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$S(\rho\gamma)$</td>
<td>✓ ✓ ✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$S(\phi K_S)$</td>
<td>✓ ✓ ✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$S(B_s\rightarrow J/\psi \phi)$</td>
<td>✓ ✓ ✓</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Observables @ Super B factories or other experiments

<table>
<thead>
<tr>
<th>Observation</th>
<th>MSSM+$\nu_R$</th>
<th>SU(5)+$\nu_R$</th>
<th>U(2) FS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mu\rightarrow e\gamma$</td>
<td>✓ ✓ ✓</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>$\tau\rightarrow e\gamma$</td>
<td>✓ ✓ ✓</td>
<td>?</td>
<td></td>
</tr>
</tbody>
</table>

[based on T.Goto et.al. PRD77, 095010(2008)]
Increase the luminosity by ~2 orders of magnitudes!!

Super KEKB + Super B

Target

Super KEKB
50 ab\(^{-1}\)
8 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}

Super B
75 ab\(^{-1}\)
1 \times 10^{36} \text{ cm}^{-2} \text{ s}^{-1}
Physics with 50(75) ab⁻¹

Two recent publications:

- Physics at Super B Factory (Belle II) arXiv:1002.5012
- SuperB Progress Reports: Physics (SuperB) arXiv:1008.1541

In addition to the topics in this talk,

- Photon polarization of B→K*γ.
- B→K(⁎)νν.
- CPV in D.
- LFV in τ decay.
- …
Nano Beam Scheme

<table>
<thead>
<tr>
<th></th>
<th>KEKB LER</th>
<th>KEKB HER</th>
<th>SuperKEKB LER</th>
<th>SuperKEKB HER</th>
<th>SuperB LER</th>
<th>SuperB HER</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam Energy</td>
<td>3.5</td>
<td>8</td>
<td>4</td>
<td>7</td>
<td>4.18</td>
<td>6.7</td>
<td>GeV</td>
</tr>
<tr>
<td>Half crossing angle</td>
<td>11</td>
<td></td>
<td>41.5</td>
<td></td>
<td>33</td>
<td></td>
<td>mrad</td>
</tr>
<tr>
<td>Beta func. @ IP (x/y)</td>
<td>1200 / 5.9</td>
<td>32 / 0.27</td>
<td>25 / 0.31</td>
<td>26 / 0.253</td>
<td>32 / 0.205</td>
<td></td>
<td>mm</td>
</tr>
<tr>
<td>Beam current</td>
<td>1.64</td>
<td>1.19</td>
<td>3.60</td>
<td>2.60</td>
<td>1.892</td>
<td>2.447</td>
<td>A</td>
</tr>
<tr>
<td>Luminosity [× 10^{34}]</td>
<td>2.1</td>
<td></td>
<td>80</td>
<td></td>
<td>100</td>
<td></td>
<td>cm^{-1}s^{-1}</td>
</tr>
</tbody>
</table>

- Collision with very small spot-size beam.
- Increase beam current (moderately)
- Larger crossing angle.
- Change beam energy to symmetric side (to solve LER short lifetime).
- SuperB has plan to run at $\tau$-charm threshold with $\sim 10^{35}$ cm$^{-1}$s$^{-1}$

[detailed tables are in backup slides]
Upgrade to SuperKEKB

- Colliding bunches
- New beam pipe & bellows
- Belle II
- New IR
- New superconducting /permanent final focusing quads near the IP
- Damping ring
- Positron source
- Add / modify RF systems for higher beam current
- Replace short dipoles with longer ones (LER)
- Redesign the lattices of HER & LER to squeeze the emittance
- TiN-coated beam pipe with antechambers
- Low emittance positrons to inject
- Low emittance electrons to inject
- Low emittance positrons to inject
- Low emittance electrons to inject

To get x40 higher luminosity
SVD: 4 DSSD lyrs → 2 DEPFET lyrs + 4 DSSD lyrs
CDC: small cell, long lever arm
ACC+TOF → TOP+A-RICH
ECL: waveform sampling, pure CsI for end-caps
KLM: RPC → Scintillator +SiPM (end-caps)
SuperKEKB Schedule

SuperKEKB is approved!

- 10 billion yen (~90 million EUR) for machine.
- Continue efforts to obtain additional funds.
- Funds from several non-Japanese agencies.

Milestone of SuperKEKB

- 9 month/year
- 20 days/month
- 50 ab$^{-1}$ in ~2020
- 5 ab$^{-1}$ in 2016

Commissioning starts mid of 2014

- Shutdown for upgrade

S. Nishida (KEK)
Oct. 8, 2010

B Physics Experimental Overview

2010 LHC Days in Split
### Comparison with LHCb

<table>
<thead>
<tr>
<th></th>
<th>Belle</th>
<th>Belle II</th>
<th>Belle II</th>
<th>LHCb</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Delta S(\phi K_S) )</td>
<td>0.22</td>
<td>0.073</td>
<td>0.029</td>
<td>0.14</td>
</tr>
<tr>
<td>( \Delta S(\eta'K_S) )</td>
<td>0.11</td>
<td>0.038</td>
<td>0.020</td>
<td>---</td>
</tr>
<tr>
<td>( \phi_s ) from ( S(J/\psi \phi) )</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>0.01</td>
</tr>
<tr>
<td>( S(K^*\gamma) )</td>
<td>0.36</td>
<td>0.12</td>
<td>0.03</td>
<td>---</td>
</tr>
<tr>
<td>( S(\rho\gamma) )</td>
<td>0.68</td>
<td>0.22</td>
<td>0.08</td>
<td>---</td>
</tr>
<tr>
<td>( \Delta B/B(B \rightarrow \tau \nu) )</td>
<td>3.5(\sigma)</td>
<td>10%</td>
<td>3%</td>
<td>---</td>
</tr>
<tr>
<td>( B_s \rightarrow \mu\mu )</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>5(\sigma) @ 6 fb(^{-1})</td>
</tr>
<tr>
<td>( \tau \rightarrow \mu \gamma ) [(\times 10^{-9})]</td>
<td>&lt;45</td>
<td>&lt;30</td>
<td>&lt;8</td>
<td>---</td>
</tr>
<tr>
<td>( \tau \rightarrow \mu \mu \mu ) [(\times 10^{-9})]</td>
<td>&lt;209</td>
<td>&lt;10</td>
<td>&lt;1</td>
<td>---</td>
</tr>
<tr>
<td>( \phi_2 )</td>
<td>11°</td>
<td>2°</td>
<td>1°</td>
<td>4.5°</td>
</tr>
<tr>
<td>( \phi_3 )</td>
<td>16°</td>
<td>6°</td>
<td>2°</td>
<td>2.4°</td>
</tr>
</tbody>
</table>

**Advantage:**

- **LHCb**
  - Modes where the final states are charged only.
  - \( B_s \)
  - \( B_c, \Lambda_b \)
  - ...

**B factories**

- Modes with \( \gamma, \pi^0 \).
- Modes with \( \nu \).
- \( \tau \) decays.
- \( K_S \) vertex.
Summary

• BaBar/PEP-II and Belle/KEKB discovered the CP violation in B system, and confirmed the CKM mechanism.
  ✓ The data taking finished.
• Focus on the search and study of the NP.
  ✓ CPV in b→s penguins: now consistent with sin2φ₁
  ✓ b→sγ and b→sll: interesting results on A_{FB} for K*ll.
  ✓ Tauonic B decays: limit on charged Higgs mass.
  ✓ And many other results.
• Now it is time to upgrade the B factories to “Super B factories”, which will provide ~2 orders of magnitude higher luminosity.
  ✓ SuperKEKB (with BelleII detector) and SuperB.
• B factories have been leading and will continue to lead the flavour physics, which is complementary to the energy frontier experiments (LHC).
Backup
B Physics Experimental Overview

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Oct. 8, 2010

KEK B-Factory

focusing Q-magnet
Accelerating structures

2010 LHC Days in Split
Unitarity Matrix

CKM matrix is unitary:

\[ V_{ud} V_{ub}^* + V_{cd} V_{cb}^* + V_{td} V_{tb}^* = 0 \]

- This relation becomes a triangle in the complex plane = Unitarity Triangle
- Other triangles tend to be “collapsed”.
- Non-zero \( \phi_1 \) or \( \phi_3 \)
  = Complex phase in the CKM matrix
  = Strong support of KM mechanism.

\[ V = \begin{pmatrix}
V_{ud} & V_{us} & V_{ub} \\
V_{cd} & V_{cs} & V_{cb} \\
V_{td} & V_{ts} & V_{tb}
\end{pmatrix} = \begin{pmatrix}
1 - \lambda^2/2 & \lambda & A \lambda^3(\rho - i\eta) \\
-\lambda & 1 - \lambda^2/2 & A \lambda^2 \\
A \lambda^3(1 - \rho + i\eta) & -A \lambda^2 & 1
\end{pmatrix} \]

- Precise measurement of Unitarity Triangle is one of the main goal of B factory experiments.
- Various B decay modes can be used to measure the angles and sides of the triangle.
The spontaneous broken symmetries that Nambu studied, differ from the broken symmetries described by Makoto Kobayashi and Toshihide Maskawa. These spontaneous occurrences seem to have existed in nature since the very beginning of the universe and came as a complete surprise when they first appeared in particle experiments in 1964. It is only in recent years that scientists have come to fully confirm the explanations that Kobayashi and Maskawa made in 1972. It is for this work that they are now awarded the Nobel Prize in Physics. They explained broken symmetry within the framework of the Standard Model, but required that the Model be extended to three families of quarks. These predicted, hypothetical new quarks have recently appeared in physics experiments. As late as 2001, the two particle detectors BaBar at Stanford, USA and Belle at Tsukuba, Japan, both detected broken symmetries independently of each other. The results were exactly as Kobayashi and Maskawa had predicted almost three decades earlier.
Utilize special kinematics at \( \Upsilon(4S) \)

**Energy difference:**

\[
\Delta E \equiv E_{J/\psi} + E_{K_S} - E_{CM}/2
\]

**Beam-constrained mass:**

\[
M_{bc} = \sqrt{(E_{CM}/2)^2 - (\vec{p}_{J/\psi} + \vec{p}_{K_S})^2}
\]
Asymmetric Collider

- Asymmetric energy to study time-dependent CP Violation (tCPV)
- Measure position instead of time (B lifetime ~1.6ps)

\[ \beta \gamma = 0.425 \text{ (KEKB)} \]
\[ = 0.56 \text{ (PEP-II)} \]

Flavor-tag
(B\(^0\) or \(\bar{B}\(^0\) ?)

Reconstruction
\[ J/\psi(\phi, \eta') \]
\[ f_{CP} \]
\[ K_S \]

Vertexing
\[ t=0 \]
\[ \Delta z \]
\[ \sigma_{\Delta t} \sim 140\text{ps} \]

Asymmetric Collider

\[ \Delta t \sim \Delta z/c\beta \gamma \]

Extract CPV

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Oct. 8, 2010

B Physics Experimental Overview

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Measurement of $\sin(2\phi_1)$

Belle $J/\psi K_L$

$B^0 \rightarrow J/\psi K^0_L$

$q=+1$  

$q=-1$

$\sin(2\beta) = \sin(2\phi_1)$

HAFAG

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Reference</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BaBar</td>
<td>PRD 79 (2009):072009</td>
<td>$0.69 \pm 0.03 \pm 0.01$</td>
</tr>
<tr>
<td>BaBar</td>
<td>PRD 80 (2009):112001</td>
<td>$0.69 \pm 0.52 \pm 0.04 \pm 0.07$</td>
</tr>
<tr>
<td>BaBar</td>
<td>PRD 69 (2004):052001</td>
<td>$1.56 \pm 0.42 \pm 0.21$</td>
</tr>
<tr>
<td>Belle</td>
<td>PRL 98 (2007):031802</td>
<td>$0.64 \pm 0.03 \pm 0.02$</td>
</tr>
<tr>
<td>Belle</td>
<td>PRD 77 (2008):091103(R)</td>
<td>$0.72 \pm 0.09 \pm 0.03$</td>
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<tr>
<td>ALEPH</td>
<td>PLB 492, 259 (2000)</td>
<td>$0.84^{+0.82}_{-1.04} \pm 0.16$</td>
</tr>
<tr>
<td>OPAL</td>
<td>EPJ C5, 379 (1998)</td>
<td>$-3.20^{+2.00}_{-1.00} \pm 0.50$</td>
</tr>
<tr>
<td>CDF</td>
<td>PRD 61, 072005 (2000)</td>
<td>$0.79^{+0.44}_{-0.44}$</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>$0.67 \pm 0.02$</td>
</tr>
<tr>
<td>HFAG</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Oct. 8, 2010  
B Physics Experimental Overview  
2010 LHC Days in Split
Three methods for inclusive analysis for $B \rightarrow X_s \gamma$.

**Fully inclusive**

- Subtract the on-resonance photon energy spectrum by the continuum spectrum.
- Free from the model uncertainty of hadronic system ($X_s$).
- Generally, has large backgrounds.
- Lepton tag is sometimes used for background suppression and flavor tagging.

**Sum of exclusive modes (semi-inclusive; pseudo-reconstruction)**

- Reconstruct hadronic system ($X_s$) as a sum of exclusive modes.
- Signal is cleaner than using the fully inclusive method.
- Model uncertainty of hadronic system; missing modes.
- Separation of $X_s$ and $X_d$.

**Recoil tag (full reconstruction)**

- Fully reconstruct the other side $B$.
- Very low efficiency (<1%), but very clean (continuum bkg becomes negligible).
- Measurement in B frame. Access to flavor information etc.
B→Xsγ

Status of B(B→Xsγ)

<table>
<thead>
<tr>
<th>Mode</th>
<th>B</th>
<th>E_{min}</th>
<th>B(Eγ &gt; E_{min})</th>
<th>B^env (Eγ &gt; 1.6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLEO Inc. [3]</td>
<td>321 ± 43 ± 27^{+18}_{-10}</td>
<td>2.0</td>
<td>306 ± 41 ± 26</td>
<td>327 ± 44 ± 28 ± 6</td>
</tr>
<tr>
<td>Belle Semi.[4]</td>
<td>336 ± 53 ± 42^{+50}_{-54}</td>
<td>2.24</td>
<td>–</td>
<td>369 ± 58 ± 46^{+56}_{-60}</td>
</tr>
<tr>
<td>BABAR Semi.[6]</td>
<td>335 ± 19^{+56}_{-41}+4</td>
<td>1.9</td>
<td>327 ± 18^{+55}_{-40}+4</td>
<td>349 ± 20^{+59}_{-40}+4</td>
</tr>
<tr>
<td>BABAR Inc. [7]</td>
<td>–</td>
<td>1.9</td>
<td>367 ± 29 ± 34 ± 29</td>
<td>390 ± 31 ± 47 ± 4</td>
</tr>
<tr>
<td>BABAR Full [8]</td>
<td>391 ± 91 ± 64</td>
<td>1.9</td>
<td>366 ± 85 ± 60</td>
<td>389 ± 91 ± 64 ± 4</td>
</tr>
<tr>
<td>Belle Inc.[5]</td>
<td>–</td>
<td>1.7</td>
<td>345 ± 15 ± 40</td>
<td>347 ± 15 ± 40 ± 1</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td>355 ± 24 ± 9</td>
<td></td>
</tr>
</tbody>
</table>

c.f.) theory $B(B\to X_s\gamma) = (3.15 \pm 0.23) \times 10^{-4}$
Belle 605 fb$^{-1}$ result

\[ B(B \to X_s \ell^+ \ell^-) = (3.33 \pm 0.80^{+0.19}_{-0.24}) \times 10^{-6} \]

C.f.)

SM (Ali et al): \[ B_{SM} = (4.2 \pm 0.7) \times 10^{-6} \]

C$_7$ sign-flip (Gambino et al): \[ B_{C_7>0} = (8.8 \pm 1.0) \times 10^{-6} \]
B → τν

- 標準模型では W-消滅過程
- SUSYでは荷電ビッグス(H⁺)の寄与

\[ B(B \rightarrow \tau \nu) = B(B \rightarrow \tau \nu)_{SM} \times r_H \]

\[ r_H = \left( 1 - \frac{m_B^2}{m_H^2} \tan^2 \beta \right)^2 \]

\[ B(B \rightarrow \tau \nu) = (1.53 \pm 0.33) \times 10^{-4} \]

\[ \sigma \sim 2\% @ 50 \text{ ab}^{-1} \]

\[ f_B \text{と}|V_{ub}| \text{の誤差を数%まで減らすことが重要（右図はともに2.5%を仮定）} \]

「b-H⁺-u 結合を測定する唯一の手段」

S. Nishida (KEK)
Oct. 8, 2010

B Physics Experimental Overview

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$B \rightarrow K^{(*)} \nu \nu$

$B \rightarrow K \nu \nu, \quad B \sim 4 \cdot 10^{-6}$

$B \rightarrow K^{*} \nu \nu, \quad B \sim 6.8 \cdot 10^{-6}$

SM: penguin+box

Look for departure from the expected value → information on couplings $C_{\nu R}^{\nu}$ and $C_{\nu L}^{\nu}$ compared to $(C_{\nu L}^{\nu})^{SM}$

Again: fully reconstruct one of the B mesons, look for signal (+nothing else) in the rest of the event.
B Physics Experimental Overview

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Oct. 8, 2010

CP Violation in b→s

10-50 ab⁻¹のデータでO(0.01)の精度で測定可能

New Physics
(SUSY GUT, Warped Extra Dimension,
String-inspired MSSM, ...)

SUSYの模型の識別に用いる情報の一つとして有効
Photon Helicity in b→s(d)γ

• 標準模型では、電弱相互作用は左巻きに作用
  ✓ b→s(d)γ 過程からの光子はほぼ左巻き
• 右巻きのカレントは新物理の信号
  ✓ time-dependent CPV が起こる

標準理論では

|S(K*0γ)| < 0.02, S(ρ0γ) ~ 0

ΔS(K*0γ) = 0.027 @ 50 ab⁻¹
ΔS(ρ0γ) = 0.075 @ 50 ab⁻¹

Possible deviation from SM
O(1): Warped extra dim.
O(1): L-R symmetric model
O(0.1): SUSY SU(5)

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Oct. 8, 2010

B Physics Experimental Overview

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τ LFV

・レプトンフレーバーの破れ（LFV）：標準模型では禁止
・多くの新物理モデルでは予言されている
・Bファクトリーでは、大量のτ対が作られる（τファクトリー）。
・τの崩壊：第3世代と第2(1)世代の混合

クォークセクターには新物理の効果があまり現れないモデル

τ → μγ
τ → eγ
μ → eγ
Nano Beam Scheme

Nano-Beam” scheme

Collision with very small spot-size beams

Invented by Pantaleo Raimondi for SuperB

(1) Smaller $\beta_y^*$
(2) Increase beam currents
(3) Increase $\xi_y$
**SuperKEKB**

<table>
<thead>
<tr>
<th>parameters</th>
<th>KEKB</th>
<th></th>
<th>SuperKEKB</th>
<th></th>
<th>units</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LER</td>
<td>HER</td>
<td>LER</td>
<td>HER</td>
<td></td>
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<tr>
<td>Beam energy $E_b$</td>
<td>3.5</td>
<td>8</td>
<td>4</td>
<td>7</td>
<td>GeV</td>
</tr>
<tr>
<td>Half crossing angle $\phi$</td>
<td>11</td>
<td></td>
<td>41.5</td>
<td></td>
<td>mrad</td>
</tr>
<tr>
<td>Horizontal emittance $\varepsilon_x$</td>
<td>18</td>
<td>24</td>
<td>3.2</td>
<td>5.0</td>
<td>nm</td>
</tr>
<tr>
<td>Emittance ratio $\kappa$</td>
<td>0.88</td>
<td>0.66</td>
<td>0.27</td>
<td>0.25</td>
<td>%</td>
</tr>
<tr>
<td>Beta functions at IP $\beta_x/\beta_y$</td>
<td>1200/5.9</td>
<td></td>
<td>32/0.27</td>
<td>25/0.31</td>
<td>mm</td>
</tr>
<tr>
<td>Beam currents $I_b$</td>
<td>1.64</td>
<td>1.19</td>
<td>3.60</td>
<td>2.60</td>
<td>A</td>
</tr>
<tr>
<td>Beam-beam parameter $\xi_y$</td>
<td>0.129</td>
<td>0.090</td>
<td>0.0886</td>
<td>0.0830</td>
<td>cm$^{-2}$s$^{-1}$</td>
</tr>
</tbody>
</table>

- Small beam size & high current to increase luminosity
- Large crossing angle
- Change beam energies to solve the problem of LER short lifetime

M. Iwasaki, ICHEP2010

S. Nishida (KEK)  
Oct. 8, 2010  
B Physics Experimental Overview  
2010 LHC Days in Split  
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### Parameters for $1 \times 10^{36}$ Lumi (max $4 \times 10^{36}$)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Base Line HER (e+)</th>
<th>Base Line LER (e-)</th>
<th>Low Emittance HER (e+)</th>
<th>Low Emittance LER (e-)</th>
<th>High Current HER (e+)</th>
<th>High Current LER (e-)</th>
<th>Tau/Charm (prelim.) HER (e+)</th>
<th>Tau/Charm (prelim.) LER (e-)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LUMINOSITY</strong></td>
<td>cm$^{-2}$s$^{-1}$</td>
<td>$1.00 \times 10^{36}$</td>
<td>$1.00 \times 10^{36}$</td>
<td>$1.00 \times 10^{36}$</td>
<td>$1.00 \times 10^{36}$</td>
<td>$1.00 \times 10^{36}$</td>
<td>$1.00 \times 10^{36}$</td>
<td>$1.00 \times 10^{36}$</td>
<td>$1.00 \times 10^{36}$</td>
</tr>
<tr>
<td>Energy</td>
<td>GeV</td>
<td>6.7</td>
<td>4.18</td>
<td>6.7</td>
<td>4.18</td>
<td>6.7</td>
<td>4.18</td>
<td>2.58</td>
<td>1.61</td>
</tr>
<tr>
<td>Circumference</td>
<td>m</td>
<td>1258.4</td>
<td>1258.4</td>
<td>1258.4</td>
<td>1258.4</td>
<td>1258.4</td>
<td>1258.4</td>
<td>1258.4</td>
<td>1258.4</td>
</tr>
<tr>
<td>X-Angle (full)</td>
<td>mrad</td>
<td>66</td>
<td>66</td>
<td>66</td>
<td>66</td>
<td>66</td>
<td>66</td>
<td>66</td>
<td>66</td>
</tr>
<tr>
<td>Fwinski (full)</td>
<td>rad</td>
<td>22.88</td>
<td>18.60</td>
<td>32.36</td>
<td>26.30</td>
<td>14.43</td>
<td>11.74</td>
<td>8.80</td>
<td>7.15</td>
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<tr>
<td>$\beta_x$ @ IP</td>
<td>cm</td>
<td>2.6</td>
<td>3.2</td>
<td>2.6</td>
<td>3.2</td>
<td>5.06</td>
<td>6.22</td>
<td>6.76</td>
<td>8.32</td>
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<tr>
<td>$\beta_y$ @ IP</td>
<td>cm</td>
<td>0.0253</td>
<td>0.0205</td>
<td>0.0179</td>
<td>0.0145</td>
<td>0.0292</td>
<td>0.0237</td>
<td>0.0650</td>
<td>0.0533</td>
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<tr>
<td>Coupling (full current)</td>
<td>%</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
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<tr>
<td>$\sigma_x$ (without IBS)</td>
<td>mm</td>
<td>1.97</td>
<td>1.82</td>
<td>1.00</td>
<td>0.91</td>
<td>1.97</td>
<td>1.82</td>
<td>1.97</td>
<td>1.82</td>
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<tr>
<td>$\sigma_y$ (with IBS)</td>
<td>mm</td>
<td>2.00</td>
<td>2.46</td>
<td>1.00</td>
<td>1.12</td>
<td>2.00</td>
<td>2.46</td>
<td>5.20</td>
<td>6.4</td>
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<tr>
<td>$\sigma_y$</td>
<td>pm</td>
<td>5</td>
<td>6.15</td>
<td>2.5</td>
<td>3.075</td>
<td>10</td>
<td>12.3</td>
<td>13</td>
<td>16</td>
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<tr>
<td>$\sigma_y$ @ IP</td>
<td>mm</td>
<td>7.211</td>
<td>8.872</td>
<td>5.099</td>
<td>6.274</td>
<td>10.060</td>
<td>12.370</td>
<td>18.749</td>
<td>23.076</td>
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<tr>
<td>$\sigma_y$ @ IP</td>
<td>pm</td>
<td>0.036</td>
<td>0.036</td>
<td>0.021</td>
<td>0.021</td>
<td>0.054</td>
<td>0.054</td>
<td>0.092</td>
<td>0.092</td>
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<tr>
<td>$\Sigma_x$</td>
<td>mm</td>
<td>11.433</td>
<td>8.085</td>
<td>15.944</td>
<td>29.732</td>
<td>15.944</td>
<td>29.732</td>
<td>15.944</td>
<td>29.732</td>
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<tr>
<td>$\Sigma_y$</td>
<td>mm</td>
<td>0.050</td>
<td>0.030</td>
<td>0.076</td>
<td>0.131</td>
<td>0.076</td>
<td>0.131</td>
<td>0.076</td>
<td>0.131</td>
</tr>
<tr>
<td>$\sigma_L$ (0 current)</td>
<td>mm</td>
<td>4.69</td>
<td>4.29</td>
<td>4.73</td>
<td>4.34</td>
<td>4.03</td>
<td>3.65</td>
<td>4.75</td>
<td>4.36</td>
</tr>
<tr>
<td>$\sigma_L$ (full current)</td>
<td>mm</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4.4</td>
<td>4.4</td>
<td>5</td>
<td>5</td>
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<tr>
<td>Beam current</td>
<td>mA</td>
<td>1892</td>
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<td>N. Particle/bunch</td>
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<td>13.4</td>
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<td>$\sigma_E$ (full current)</td>
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<td>7.34E+04</td>
<td>6.43E+04</td>
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<td>12.72</td>
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<td>3.11</td>
<td>30.48</td>
<td>3.11</td>
<td>30.48</td>
<td>3.11</td>
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</table>

**Baseline + other 2 options:**
- Lower $\gamma$-emittance
- Higher currents (twice bunches)

**Baseline:**
- Higher emittance due to IBS
- Asymmetric beam currents

**RF power includes SR and HOM**

M. Giorgi, ICHEP2010
Interest of running @ threshold

500/fb at $\psi(3770)$

Decays of $\psi(3770) \rightarrow D^0\bar{D}^0$ produce coherent ($C=-1$) pairs of $D^0$'s. Quantum correlations in their subsequent decays allow measurements of strong phases

- Required for improved measurement of CKM $\gamma$
- Also required for $D^0$ mixing studies

- Dalitz plot model uncertainty shrinks
- Information on overall strong phase is added

Uncertainty in $x_D$ improves more than that of $y_D$
Polarized beam helps to reduce irreducible background in tau decays

Sensitivity improves at least by a factor 2.
Equivalent to a factor 4 increase in luminosity.

M. Giorgi, ICHEP2010
No impediment caused by the photon operation is seen so far to prevent design operations of SuperB for HEP.

M. Giorgi, ICHEP2010
SuperB Detector (with options)

IFR Optimized layout. Plan to reuse yoke. Still need to resolve engineering questions.

BEMC Inexpensive Veto device bringing 8-10% sensitivity improvements for $B \to \tau \nu$. Low momentum PID via TOF? Technical Issues?

6Layer SVT L0 Striplets @ 1.6cm if background is acceptable as default. MAPS Option

FPID Physics gains about 5% in $B \to K(*)\nu\nu$. Somewhat larger gains for higher multiplicities

M. Giorgi, ICHEP2010
Towards green light

- The project is the first “flagship project” of the new national research plan.
- The project has been mentioned as a reciprocity condition in a Russian-Italian agreement on ignitor (nuclear fusion).

- A formal commitment with INFN for the project with the declaration of some available budget in the current year is expected.
- This commitment will set the start of the project.

M. Giorgi, ICHEP2010
### Construction Schedule of SuperKEKB/Belle II

**Jun. 24, 2010**

<table>
<thead>
<tr>
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<td>e+ new matching &amp; L-band acc.</td>
<td>R&amp;D</td>
<td>Construction</td>
<td>e+ beam commissioning</td>
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<td>Commissioning at test stand</td>
<td>move to A1</td>
<td>e- beam commissioning</td>
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<td>Building construction</td>
<td>DR commissioning</td>
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<td>Installation</td>
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<td>Installation (E-cap)</td>
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<td></td>
<td>Installation (Barrel)</td>
<td>Cosmic Ray Test</td>
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</table>

**Belle roll-out in Dec. 2010**
SuperKEKB: Major items for upgrade

- **New Ante-chamber beam pipes**
  Mitigation techniques for suppression of the electron cloud.

- **New IR design**
  New superconducting/permanent magnets around IP.
  Optimization of the compensation solenoid.
  Local chromaticity correction sections for both rings.

- **New low emittance optics for both $e^+e^-$ rings**
  Replace dipoles & change the wiggler layout for positron ring

- **New low emittance beam injections**
  New damping ring and target for positrons / New RF gun for electrons

- **Higher beam currents**
  Add / modify the RF systems

- **Precise beam diagnostics and tunings**
  More precise magnet setting ⇔ power supplies.

M. Iwasaki, ICHEP2010
Charmonium spectroscopy

Potential models, energy splitting

Energy splitting: singlet and triplet.

\[
\begin{align*}
2S & \quad 1^- & \Psi' & \eta'_c \\
1P & \quad L=1 & 1^+ & h_c & 2^+ & \chi_{c2} \\
1S & \quad L=0 & 1^- & J/\Psi & 0^+ & \chi_{c0} & \eta_c
\end{align*}
\]

Potential models predict masses of conventional states with fixed quantum numbers.

Generally, accuracy of mass predictions should not exceed few tens of MeV/c^2.
$X(3872) \rightarrow J/\psi \pi^+\pi^-$ decay

First observed by Belle in $B^+ \rightarrow K^+(J/\psi\pi^+\pi^-)$. Then confirmed by CDF, DO and BaBar.

- **Belle**:
  - 304 M $B^+$'s
  - $\psi'$
  - $X(3872)$
  - PRL 91 (2003) 262001

- **CDF**:
  - 220 pb$^{-1}$
  - $X(3872)$
  - PRL 93 (2004) 072001

- **DØ**:
  - 230 pb$^{-1}$
  - $X(3872)$
  - PRL 93 (2004) 162002

- **BaBar**:
  - $455M B^+$'s
  - $X(3872)$
  - PRD 77 (2008) 111101
Interpretations of \(X(3872)\) and \(X(4260)\) are unclear. Most popular for \(X(3872)\) is molecular interpretation \((X(3872) \rightarrow J/\psi \gamma \text{ branching fraction is small for } 1^{++} \chi_c^1)\).
Conventional and unconventional mesons

1. Conventional quark–antiquark mesons ($q\bar{q}$).

2. Glueballs ($gg$, $ggg$). Lightest glueballs $J^{PC} = 0^{++}$ and $2^{++}$.

3. Hybrid mesons ($q\bar{q}g$). Ground states $J^{PC} = 0^{-+}$, $1^{-+}$, $1^{--}$, $2^{-+}$.

4. Tetraquarks ($q\bar{q}qq$). Large binding energy. Non-$qq$ flavor?

5. Molecular states ($qq\bar{q}\bar{q}$). Small binding energy. Deuteron-like.

6. Mixture of these states. Small admixture of exotic state.

Exotic states can be separated using information on masses, widths, quantum numbers, production and decay modes (rates).

Theoretical calculations, potential models, lattice calculations.
Experimental results on $X(3872)$

1. Bound state scenario supported by: $\frac{BR(X \rightarrow D^0\bar{D}^{*0})}{BR(X \rightarrow J/\psi \pi \pi)} \approx 10$

2. CDF angular analysis: $J^{PC}=1^{++}, 2^{+}$ favored

3. Large isospin violation: $\frac{BR(X \rightarrow J/\psi \pi^+\pi^-\pi^0)}{BR(X \rightarrow J/\psi \pi^+\pi^-)} = 1.0 \pm 0.4 \pm 0.3$

4. Radiative decays are important to test molecular interpretation. E. S. Swanson, Phys. Rept. 429, 243 (2006): $\frac{BR(X \rightarrow \gamma \psi)}{BR(X \rightarrow \gamma J/\psi)} < 0.01$ for molecular

Belle, 256 fb$^{-1}$ (hep-ex/0505037)

$\frac{BR(B^+ \rightarrow X(3872)K^+) \times BR(X \rightarrow \gamma J/\psi)}{(1.8 \pm 0.6 \pm 0.1) \times 10^{-5}}$

BaBar (2009)

$\frac{BR(X \rightarrow \gamma \psi)}{BR(X \rightarrow \gamma J/\psi)} = 3.5 \pm 1.4$

$X(3872) \rightarrow \gamma J/\psi$

$3.6\sigma$

$X(3872) \rightarrow \gamma \psi'$

$3.5\sigma$

The BaBar result seems to be serious problem for molecular interpretation.
Belle results on radiative $X(3872)$ decays

Belle preliminary, ICHEP10

$772 \times 10^6$ $B\overline{B}$ pairs

$X(3872) \rightarrow \gamma J/\psi$

$B^+ \rightarrow X(3872)K^+$

$B^0 \rightarrow X(3872)K_s^0$

$\psi' \rightarrow e^+e^-\mu^+\mu^-$

$M(\rightarrow \gamma J/\psi J/\psi')$

$X(3872)K_s^0$

$BR(B^+ \rightarrow X(3872)K^+) \times BR(X \rightarrow \gamma J/\psi) = (1.78 \pm 0.46 \pm 0.12) \times 10^{-6}$

$BR(B^0 \rightarrow X(3872)K^0) \times BR(X \rightarrow \gamma J/\psi) < 2.4 \times 10^{-6} @ 90\% CL$

$BR(B^+ \rightarrow X(3872)K^+) \times BR(X \rightarrow \psi' \gamma) < 3.4 \times 10^{-6} @ 90\% CL.$

$BR(B^0 \rightarrow X(3872)K^0) \times BR(X \rightarrow \psi' \gamma) < 6.6 \times 10^{-6} @ 90\% CL.$

$BR(X \rightarrow \psi' \gamma) < 2.1 @ 90\% CL$

No $X \rightarrow \psi' \gamma$ signal was observed by Belle. Upper limit is smaller than BaBar ratio. However uncertainties are too large to conclude.