Prospects and Status of SuperKEKB and Belle II

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(Representing the BELLE(II) Collaborations)
The KEK B factory was a very successful project

\[ \int L > 1 \text{ ab}^{-1} \]
BELLE experiment obtained many exciting results

Final analysis now
Expect more discoveries!

“Last beam abort” ceremony on June 30, 2010
Indirect prediction \( \sin(2\varphi_1) = 0.830^{+0.013}_{-0.034} \)

World Average measurement \( \sin(2\varphi_1) = 0.673 \pm 0.023 \)

a 2.9σ deviation (J. Charles)

Precise measurements of UT are still highly important !!!
Examples of BELLE II Physics Goals

- Measure UT (angles & sides) with much better precision. If new phases contribute to any measurable inconsistency of UT.

- CPV in $b \rightarrow sqq$ vs $b \rightarrow ccs$: Extra new phases in the penguin loop makes CPV parameters different. Typical accuracy in $\Delta S \sigma \approx 0.02-0.03$ for $B \rightarrow K^0 \phi (K^0 \eta')$ with 50ab$^{-1}$

- Search for CPV in radiative decays $B \rightarrow K^{*0}(K^0_s \pi^0) \gamma$ is a test of right-handed current in the penguin loop (CPV $\neq 0$).

- Rare decays $b \rightarrow sg(\gamma)$, $B \rightarrow \tau\nu$. Even Br’s constrain mass of NP

- Electro-weak penguins $b \rightarrow s\mu\mu$, see, $s\nu\nu$: Br’s, $Q^2$-distribution, FB asymmetry are sensitive to NP

- Rare tau decays
- Search for new particles, hadron spectroscopy

- Many more (see A.G. Akeroyd et al., arXiv:1002.5012)

+ New ideas.
SuperKEKB Collider

Approved in 2010

Replace short dipoles with longer ones (LER).

Redesign the lattices of HER & LER to squeeze the emittance.

TiN coated beam pipe with antechambers

Smaller asymmetry 8 / 3.5 GeV → 7 / 4 GeV

Belle II

Add / modify RF systems for higher beam current.

New IP

larger crossing angle 2φ = 22 mrad → 83 mrad for separated final-focus magnets.

"Nano-beam" scheme

σ_x ≈ 10 μm, σ_y ≈ 60 nm

$L = 8 \times 10^{35}$ cm$^{-2}$ s$^{-1}$
Schedule of SuperKEKB

Milestone of SuperKEKB

9 month/year
20 days/month

We will reach 50 ab$^{-1}$ in 2020~2021.

Commissioning starts in the later of 2014.

Shutdown for upgrade

Ground breaking ceremony 08/04/2011

Postponed!
Detector upgrade

- Higher event rate
  - higher rate trigger, DAQ and computing
  - Improve performance
    - try better PID options
    - low p µ identification for b → sµµ efficiency
    - hermeticity → missing E “reconstruction”

Critical issues at $L = 8 \times 10^{35}/\text{cm}^2/\text{sec}$

- Higher background (factor ~20)
  - radiation damage and occupancies
  - fake hits and pile-up noise in the ECL

SC solenoid 1.5T

CsI(Tl) 16$X_0$ → pure CsI (endcap) new electronics

Aerogel Cherenkov counter + TOF counter → “TOP” + Aerogel RICH

$\mu/K_L$ detection
14/15 lyr. RPC+Fe
→ scintillator (endcap)

CDC: Tracking + $dE/dx$
→ small cell + He/C$_2$H$_6$
remove inner lyrs.

New DAQ and computing systems

Si vtx. det. 4 lyr. DSSD
→ 2 DEPFET pixel lyrs.
+ 4 lyr. DSSD
Vertex Detector

10M 50µ x 50(75)µ pixels; 245k strips

\[ \sigma_{z0} \sim 20\mu \]

4lyr. Si strip \( \rightarrow \) 2lyr. pixel (DEPFET) + 4lyr. Si strip

DEPFET detector

Improve decay-time precision and acceptance (Ks's).

Belle II

Belle

DSSD ladder

Interaction Point

Hybrid

20.0mm

43.5mm

88.0mm

20.0mm

43.5mm

88.0mm
New Particle Identification System

Barrel PID: Time of Propagation Counter (TOP)
- Quartz radiator
- Small expansion block
- Hamamatsu MCP-PMT (measure t, x and y)

Endcap PID: Aerogel RICH (ARICH)
- Aerogel radiator
  - n~1.05
- Hamamatsu HAPD + new ASIC

Completely different from PID at Belle, with better K/π separation, more tolerance for BG, and less material.

20 p.e., 40 ps resolution

K/π separation for B→ργ:
- 0.5% fake rate, eff.>99%

K/π separation at 4 GeV:
- 1% fake rate; eff.>96%
Hamamatsu HAPD peak Q.E. $\sim$33\% (‘Super Bialkali’)

Aerogel

Test Beam setup
New endcap KLM - scintillator strips with WLS Fiber and MPPC readout

- 75 strips (4 cm width)/sector
- 2 orthogonal sectors/gap
- 16800 strips for F&B endcap KLM
- Efficiency for MIP > 99%, threshold 7.5pix

Cosmics spectra

X strips

Y strips
Charged Higgs in $B$ decays

leptonic
- $B \to \tau \nu_{\tau}$

semileptonic
- $B \to D^{(*)} \tau \nu_{\tau}$

inclusive radiative
- $B \to X_s \gamma$

$B \to D^{0} \tau \nu_{\tau}$

$B \to X_s \gamma$

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

$M_{\text{Miss}}^2 (\text{GeV}^2)$
Examples of Constraints – Type II 2HDM

Limits on H$^+$ are dominated by indirect measurements
M.Rozanska, Charged Higgs 2010

B$\rightarrow$D$\tau$ν$\tau$ more sensitive here

J.Kamenik
CKM2010
Conservatively assuming SM value for BR's

Belle II is sensitive to a wide range of Higgs masses and tan β

Present data - indication of inconsistency
Will become dramatic with 50ab⁻¹ if central value does not change

Conservatively assuming SM value for BR's
LFV and New Physics

Intriguing cluster of events in MEG experiment consistent with large $\text{Br}(\mu \rightarrow e\gamma)$

Different models predict different relations for $\mu$ and $\tau$ decays

- SUSY + Seasaw
- Bkg. $e^+e^- \rightarrow \gamma\tau^+\tau^-$
  - $\text{UL} \sim 1/\sqrt{L}$
- Higgs mediated decays
  - Important for MSUSY$\gg$EW scale
  - Bkg. free. $\text{UL} \sim 1/L$

In several models discovery is just around the corner
Belle II sensitivity for LFV covers predictions of many models

<table>
<thead>
<tr>
<th>Model</th>
<th>$\text{Br}(\tau \to \mu \gamma)$</th>
<th>$\text{Br}(\tau \to lll)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>mSUGRA+seesaw</td>
<td>$10^{-7}$</td>
<td>$10^{-9}$</td>
</tr>
<tr>
<td>SUSY+SO(10)</td>
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<td>$10^{-10}$</td>
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<tr>
<td>SM+seesaw</td>
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<td>$10^{-10}$</td>
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<tr>
<td>Non-Universal $Z'$</td>
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<td>$10^{-8}$</td>
</tr>
<tr>
<td>SUSY+Higgs</td>
<td>$10^{-10}$</td>
<td>$10^{-7}$</td>
</tr>
</tbody>
</table>
Construction of SuperKEKB/Belle II started

Luminosity goals: $L = 8 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$; $50 \text{ ab}^{-1}$ by 2020-2021

Exciting physics program

Upgraded detector capable to reach the physics goals
B factory provides much better constraints on $H^\pm$ than LHC with 30fb$^{-1}$ and 14TeV

2HDM(II) U.Haisch arXiv:0805.2141