Status & Prospects of SuperKEKB & Belle-II

Tagir Aushev (ITEP) for the Belle-II Collaboration
B-factory experiments achievements

- Measurements of CKM matrix elements and angles of the unitarity triangle
- Observation of direct CP violation in B decays
- Measurements of rare decays (e.g., $B \rightarrow \tau \nu$, $D \tau \nu$)
- $b \rightarrow s$ transitions: probe for new sources of CPV and constraints from the $b \rightarrow s \gamma$ branching fraction
- Forward-backward asymmetry in $b \rightarrow sll$ has become a poweRful tool to search for physics beyond SM.
- Observation of new hadrons ($X(3872)$ & etc.)
- Observation of D mixing
- Searches for rare $\tau$ decays

Acknowledgement in Nobel Prize 2008

Presented in details in P.Chang’s talk

8/23/2011
What we started from: KEKB & Belle

Tokyo (40 mins by Tsukuba Exps)

Luminosity at B factories

> 1 ab⁻¹
On resonance:
γ(5S): 121 fb⁻¹
γ(4S): 711 fb⁻¹
γ(3S): 3 fb⁻¹
γ(2S): 24 fb⁻¹
γ(1S): 6 fb⁻¹
Off reson./scan:
~ 100 fb⁻¹

~ 550 fb⁻¹
On resonance:
γ(4S): 433 fb⁻¹
γ(3S): 30 fb⁻¹
γ(2S): 14 fb⁻¹
Off resonance:
~ 54 fb⁻¹
Last KEKB beam abort: June 30, 2010

First physics run on June 2, 1999
Last physics run on June 30, 2010

$L_{\text{peak}} = 2.1 \times 10^{34} \text{/cm}^2\text{/s}$

$L_{\text{int}} > 1 \text{ab}^{-1}$
Deconstructing to start Belle II upgrade

November 2010: extracted SVD

Dec. 9, 2010: Belle Detector Roll-out

Jan. 2011: End-caps, CDC, B-ACC, TOF extraction
Ready for new construction to start…
Why we need to go further?

- Success of B-Factories: confirmation of KM mechanism of CPV
- Standard Model works well in this flavor sector
- Still room for corrections from New Physics at O(10%)
- Hints of NP: tensions between results from B-Factories
- Explore these hints with higher precision

In CKM global fit: 2.4σ discrepancy between direct and indirect measurements of $\sin 2\phi_1 - \text{BR}(B \rightarrow \tau \nu)$
Physics goals of SuperKEKB

- Approach complementary to hadron colliders
  - **LHC**: energy frontier Direct searches NP up to O(1TeV)
  - **SuperKEKB**: rare/precision frontier Search for indirect NP effects
    - up to O(1TeV) if Minimal Flavour Violation assumed
    - up to O(100TeV) if Flavour Violation couplings enhanced

- Observe NP → overconstrain SM and BSM parameters → characterize NP

- New Physics sensitive processes:
  - b → sss penguins
  - B → τν, B → Dτν
  - DCPV in B → Kπ
  - A_{FB} in B → K^{*}l^{+}l^{-}
  - CPV in D decays
  - LFV in τ decays
  (Well described in A. Bevan’s talk for SuperB)
CPV in $b \to s\bar{s}s$ penguin decays

- In SM expected to have similar $\sin 2\phi_1$ as from $B \to J/\psi K_S$
- Current measurements give:

$$\Delta S \equiv \sin 2\phi_1^{B \to K_S} - \sin 2\phi_1^{B \to J/\psi K_S} = 0.22 \pm 0.17$$

- NP particle can contribute to the loop and change $\Delta S$ value

- With Belle-II the error is expected to go down by factor of 10
Puzzling DCPV in $B \to K\pi$

- DCPV from Tree <-> Penguin interference

\[ \Delta A = A_{CP}^{B^0 \to K^+\pi^-} - A_{CP}^{B^+ \to K^+\pi^0} = -0.147 \pm 0.028 \]

- $\Delta A \approx 0$ in SM
- NP (or hadronic effects) can change it
- Model independent sume rule to test SM

\[ A_{CP}^{K^+\pi^-} + A_{CP}^{K^0\pi^+} \frac{B(B^+ \to K^0\pi^+)\tau_{B^0}}{B(B^0 \to K^+\pi^-)\tau_{B^+}} = A_{CP}^{K^+\pi^0} \frac{2B(B^+ \to K^+\pi^0)\tau_{B^0}}{B(B^0 \to K^+\pi^-)\tau_{B^+}} + A_{CP}^{K^0\pi^0} \frac{2B(B^0 \to K^0\pi^0)}{B(B^0 \to K^+\pi^-)} \]
Belle-II & LHCb are complementary
Need $O(100x)$ more data
→ Next generation B-factories

Peak Luminosity Trends ($e^+e^-$ collider)

10^{36}

40 times higher luminosity

SuperKEKB+
SuperB

KEKB
PEP-II


Year

Luminosity

SPEAR DORIS PETRA DAFNE

8/29/2011 Aushev (ITEP), Lomonosov conf.
Colliding bunches

New superconducting/permanent final focusing quads near the IP

Belle II

New beam pipe & bellows

Replace short dipoles with longer ones (LER)

Redesign the lattices of both rings to reduce the emittance

TiN-coated beam pipe with antechambers

Inject low emittance positrons

Damping ring

Add / modify RF systems for higher beam current

Positron source

New positron target/capture section

Low emittance gun

Inject low emittance electrons

\[ L = \frac{\gamma}{2er_e} \left( 1 + \frac{\sigma_y^*}{\sigma_x^*} \right) \left( \frac{\beta_{y}^*}{R_y} \right) \]

x 40 Increase in Luminosity

8/23/2011

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Accelerator upgrade

At SuperKEKB, we increase the luminosity based on "Nano-Beam" scheme (originally proposed for SuperB by P. Raimondi)

\[
L = \frac{y_{\pm}}{2er_e} \left( 1 + \frac{\sigma_y^*}{\sigma_x^*} \right) \left( \frac{L_{\pm}}{\xi_{\pm}} \right) \left( \frac{R_L}{R_y} \right)
\]

- Vertical $\beta$ function at IP: \(5.9 \rightarrow 0.27/0.30 \text{ mm (x20)}\)
- Beam current: \(1.7/1.4 \rightarrow 3.6/2.6 \text{ A (x2)}\)

\[\Rightarrow L = 2 \times 10^{34} \rightarrow 8 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1} \text{ (x40)}\]
Detector upgrade
Detector upgrade

Vertex detector: 4 lyr. Si strip → 2 lyr. pixel (DEPFET) + 4 lyr. Si strip

Parameters are preliminary
Detector upgrade

Vertex detector: 4lyr. Si strip → 2lyr. pixel(DEPFET) + 4lyr. Si strip

Drift chamber for tracking:
Small cells, longer lever arms, faster readout
Deadtime: 1-2 ms → 200 ns
Detector upgrade

**Belle II**

- **Vertex detector:** 4 lyr. Si strip → 2 lyr. pixel(DEPFET) + 4 lyr. Si strip
- **Drift chamber for tracking:** Small cells, longer lever arms, faster readout
- **new PID system:** Cherenkov imaging, very fast readout
Detector upgrade

**Vertex detector:** 4lyr. Si strip → 2lyr. pixel(DEPFET) + 4lyr. Si strip

**Drift chamber for tracking:** Small cells, longer lever arms, faster readout

**Calorimeter:** New readout with wave form sampling -> 7 times smaller BG

**Belle II**

**new PID system:** Cherenkov imaging, very fast readout

Parameters are preliminary
Detector upgrade

**Vertex detector:**
- 4lyr. Si strip
  → 2lyr. pixel(DEPFET) +4lyr. Si strip

**Drift chamber for tracking:**
- Small cells, longer lever arms, faster readout

**Calorimeter:**
- New readout with wave form sampling

**Endcap K_L/muon:**
- RPC → Scintillator + MPPC

**new PID system:**
- Cherenkov imaging, very fast readout

Parameters are preliminary
DEPFET & SVD

Mock-up

Impact parameter resolution $z_0$

$\rho \sin(\theta)_{5/2}$ [GeV/c]

Belle
Belle II

20\,\mu m
10\,\mu m
PID

Aerogel

Hamamatsu HAPD
Q.E. ~33% (recent good ones)
ECL & KLM

The first test module of KLM is assembled this Summer

Basically ready for mass production (minor revisions because we still have time.)
The Belle II Collaboration

more than 300 members from 56 institutes from 15 countries
Luminosity upgrade projection

Integrated Luminosity (ab$^{-1}$)

Peak Luminosity (cm$^{-2}$s$^{-1}$)

Milestone of SuperKEKB

9 month/year
20 days/month

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

Commissioning starts mid of 2014

Shutdown for upgrade


8/23/2011

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Summary

• It was a great era of Belle
  – Many good results were obtained
• Now the preparation for Belle-II experiment is actively ongoing
  – SuperKEKB & Belle-II are constructing now
  – The target is 40 times higher luminosity
• The start of SuperKEKB/Belle-II is in 2014