The Belle II Experiment

Martin Sevior, The University of Melbourne
On behalf of the Belle II Collaboration

7 July 2012
Belle (data taking 1999-2010)

First physics run: 1999
Last physics run 2010
$L_{\text{peak}} = 2.1 \times 10^{34}/\text{cm}^2/\text{s}$  \( L_{\text{tot}} > 1 \text{ab}^{-1} \)

- Exotic resonances in $q \bar{q}$
- $D^0$ mixing
- Electroweak penguin measurements
- Direct CP violation
- Lots of tests of LFV through $\tau$-decays
- Many precision measurements
- Tensions with the Standard Model

\[ \sin 2\phi_1 = 0.667 \pm 0.023(\text{stat}) \pm 0.012(\text{syst}) \]
Rich program of flavour physics to search for New Physics at next generation \(e^+e^\text{-}\text{colliders.}\)

Different models predict different relations for \(\mu\) and \(\tau\) decays

<table>
<thead>
<tr>
<th>model</th>
<th>(\text{Br}(\tau\rightarrow\mu\gamma))</th>
<th>(\text{Br}(\tau\rightarrow\ell\ell\ell))</th>
</tr>
</thead>
<tbody>
<tr>
<td>mSUGRA+seesaw</td>
<td>(10^{-7})</td>
<td>(10^{-9})</td>
</tr>
<tr>
<td>SUSY+SO(10)</td>
<td>(10^{-8})</td>
<td>(10^{-10})</td>
</tr>
<tr>
<td>SM+seesaw</td>
<td>(10^{-9})</td>
<td>(10^{-10})</td>
</tr>
<tr>
<td>Non-Universal (Z')</td>
<td>(10^{-9})</td>
<td>(10^{-8})</td>
</tr>
<tr>
<td>SUSY+Higgs</td>
<td>(10^{-10})</td>
<td>(10^{-7})</td>
</tr>
</tbody>
</table>

Belle II sensitivity for LFV covers predictions of many models

Many of the most interesting processes require:
- High hermeticity for full reconstruction analyses
- Excellent electromagnetic calorimetry
- Excellent PID
- High efficiency tracking
- Excellent vertex resolution

\(\Rightarrow\) Better Detector than Belle in a higher background environment
Upgrade of the world’s highest Luminosity collider by a factor 40

“Nano-Beam” scheme of Pantaleo Raimondi for SuperB

$\gamma_{\pm} \frac{2e r_e}{2} \left( 1 + \frac{\sigma_y^*}{\sigma_x^*} \right) \left( \frac{I_{\pm}^y}{R_L} \right) \left( \frac{R_L}{R_y} \right) = 8 \times 10^{35} \text{cm}^2 \text{s}^{-1}$

Vertical beta function reduction (5.9→0.3 mm) gives x20

Beam Energies 8.0/3.5→7.0/4.0
Increase in LER energy improves lifetime (reduced Touschek scattering)
Decrease in HER energy reduces Synchrotron power requirements

KEKB

(Vertical beam size ~ 60 nm)
SuperKEKB

Replace short dipoles with longer ones (LER)

Larger crossing angle $2\phi = 22$ mrad $\rightarrow$ 83 mrad

Smaller asymmetry $3.5 / 8$ GeV $\rightarrow$ 4 / 7 GeV

New superconducting / permanent final focusing quads near the IP

TiN-coated beam pipe with antechambers

Add / modify RF systems for higher beam current

Redesign the lattices of HER & LER to squeeze the emittance

New positron target / capture section

Low emittance gun

Low emittance electrons to inject

Luminosity increase $x40$
Belle II Detector

New Dead time free readout and high speed computing systems

ECL - Wave sampling + pure CsI crystal (endcap)

PID
TOP + Aerogel-RICH

KL/μ detection
Scintillator + SiPM (endcap)

CDC
Super small cell
Longer lever arm

Vertex Detector
2-lyr. DEPFET pixel + 4-lyr DSSD

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Beam background and it’s mitigation is a major R&D activity at Belle II

- **Loss rate**
  - Touschek LER
  - More horizontal collimators near IP
  - Coulomb HER 40 GHz
  - Coulomb BG found to be dangerous
  - Vertical collimators at small beta_y
  - Extrapolation from machine study

- **Timeline**
  - Sep. '10
  - Dec. '10
  - Mar. '11
  - Jun. '11
  - Sep. '11
  - Dec. '11
  - Now

- **Parameters**
  - 15 GHz
  - 1 GHz
  - 0.2 GHz
  - 0.9 GHz eff
  - RBB LER(e+), RBB HER(e-)

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DEPFET Pixel Detector

IR Beryllium beam pipe
outer radius 12 mm

DEPFET Pixel Detector,
inner r = 14 mm

See next talk by Stefan Rummel
Silicon Strip Detector

Silicon Vertex detector
4 layers DSSD

Improved Ks acceptance

22° 17°
Central Drift Chamber

Connections are very smooth
Accuracy check will be performed in next fiscal year

Wire stringing
Autumn, 2012 - Winter, 2013
Wire stringing place: Fuji B4

Small cell drift chamber

normal cell

10 mm 18 mm
6~8 mm 10~20 mm

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TOP (Barrel PID and Timing)

TOP Detector (Barrel PID)

Prototype MCP for beam test
Aerogel Chernkov (endcap PID)

ARICH

90%

Focusing configuration:
- ▲ for focusing
- ○ for single layer

Detector configuration

<table>
<thead>
<tr>
<th>Channel</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1ph.</td>
<td>300</td>
</tr>
<tr>
<td>2ph.</td>
<td>250</td>
</tr>
<tr>
<td>3ph.</td>
<td>200</td>
</tr>
<tr>
<td>4ph.</td>
<td>150</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Channel</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>4.075</td>
</tr>
<tr>
<td>P2</td>
<td>0.110</td>
</tr>
<tr>
<td>P3</td>
<td>-0.679E-04</td>
</tr>
<tr>
<td>P4</td>
<td>135.0</td>
</tr>
<tr>
<td>P5</td>
<td>98.03</td>
</tr>
<tr>
<td>P6</td>
<td>17.47</td>
</tr>
<tr>
<td>P7</td>
<td>239.7</td>
</tr>
<tr>
<td>P8</td>
<td>353.6</td>
</tr>
<tr>
<td>P9</td>
<td>26.54</td>
</tr>
<tr>
<td>P10</td>
<td>322.4</td>
</tr>
<tr>
<td>P11</td>
<td>648.8</td>
</tr>
<tr>
<td>P12</td>
<td>24.59</td>
</tr>
<tr>
<td>P13</td>
<td>149.0</td>
</tr>
<tr>
<td>P14</td>
<td>927.0</td>
</tr>
<tr>
<td>P15</td>
<td>26.29</td>
</tr>
<tr>
<td>P16</td>
<td>66.99</td>
</tr>
<tr>
<td>P17</td>
<td>1208.</td>
</tr>
<tr>
<td>P18</td>
<td>27.82</td>
</tr>
<tr>
<td>P19</td>
<td>50.05</td>
</tr>
<tr>
<td>P20</td>
<td>1497.</td>
</tr>
<tr>
<td>P21</td>
<td>42.97</td>
</tr>
</tbody>
</table>

momentum (GeV/c)

$\chi^{2}/ndf = 2112.2/1543$
Electromagnetic Calorimeter

Waveform sampling readout.

Electromagnetic Calorimeter.
CsI(Tl) Barrel
Pure CsI Endcap
$K_L$ – muon detector

Resistive Plate chamber
Readout of barrel layer > 2

Scintillator readout of endcap + inner barrel

K_{L} – muon detector
## DAQ - event rate

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Event Size [kB]</th>
<th>Rate [Hz]</th>
<th>Rate [MB/s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>High rate scenario for Belle II DAQ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Belle II</td>
<td>300</td>
<td>6,000</td>
<td>1,800</td>
</tr>
<tr>
<td>LCG TDR (2005)*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ALICE (HI)</td>
<td>12,500</td>
<td>100</td>
<td>1,250</td>
</tr>
<tr>
<td>ALICE (pp)</td>
<td>1,000</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>ATLAS</td>
<td>1,600</td>
<td>200</td>
<td>320</td>
</tr>
<tr>
<td>CMS</td>
<td>1,500</td>
<td>150</td>
<td>225</td>
</tr>
<tr>
<td>LHCb</td>
<td>25</td>
<td>2,000</td>
<td>50</td>
</tr>
</tbody>
</table>

* The LHC experiments are running at a factor of two or higher event rates
Software/Computing

- New framework with dynamic module loading, parallel processing, python steering, and root I/O
- Full detector simulation with Geant4
- Distributed Computing based on DIRAC
- Can efficiently utilize GRID, Cloud and local resources
Schedule

Will reach 50 ab$^{-1}$ in 2022

Physics run starts end of 2015

Commissioning starts end of JFY 2014

Shutdown for upgrade
International Collaboration

Ground breaking ceremony, November 2011

MoU with German funding agencies

~400 members
65 institutes
from 19 countries

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Progress

13/May/2012

Linac

First Dipole

Quadrapole

3.5GeV

Damping Ring

Collider ring

primary e-

e+

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Conclusions

• SuperKEKB fully funded
  – Approved by Japanese government in December 2010 and by Japanese Diet (parliament) in March 2011
• Belle II detector 50% funded by Japanese government
• Funding in other countries requested or already approved
• MoU signed with German and Slovenian funding agencies

• Exciting and Rich program of Physics for Belle II
• Complementary approach to High Energy Colliders, LHCb
• Look forward to friendly competition from LHCb and SuperB
• Construction well underway.
• First collisions in 2015
• Not too late to join!

Next Open Collaboration meeting – July 22-25 Bad Aibling, Germany
http://indico.mppmu.mpg.de/indico/conferenceDisplay.py?confId=1636
http://belle2.kek.jp/
Physics Impact of PID

![Graphs](image)

Expected $\Delta E$ distribution at 7.5 ab$^{-1}$ for (a) $B^0 \rightarrow \rho^0 \gamma$ with Belle PID configuration (B1+F1), (b) $B^0 \rightarrow \rho^0 \gamma$ with TOP and ARICH (B2+F2), (c) $B^+ \rightarrow \rho^+ \gamma$ with Belle PID configuration (B1+F1), (d) $B^+ \rightarrow \rho^+ \gamma$ with TOP and ARICH (B2+F2).
Backgrounds at Belle II

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Noise

SNR ~ 35
120 GeV π
Normal incidence
Landau fit
g_q ~ 500 pA/e^-

Pedestals

Seed and cluster signal

Entries: 2017
Mean: -5.105
RMS: 30.23

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