The Belle II Computing System

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AFAD 2018
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Introduction
The B Factory
Three Frontiers of Particle Physics

- **LHC experiments**
- **Neutrino experiments**
- **Astroparticle experiments**
- particle factories such as Belle (II) and tau-charm factories
Two B Factories from 1999

Belle / KEKB

- CP Violation in the B section confirmed.
- Precision measurement of the CKM matrix. X(3872) and exotic particles.

BABAR / PEP II

- 2008 Nobel Prize, Kobayashi-Maskawa
- 2017 Hoam Prize (Korea), Sookyung Choi
Two B Factories: Current/Next Generation

Belle II Experiment

- B meson pairs at Y(4S)
- High tagging efficiency of B particles
- Direct detection of $\gamma$, $\pi^0$, $K_L$
- Detection of neutrinos as missing energy
# Upgrade from KEK/Belle to SuperKEKB/Belle II

<table>
<thead>
<tr>
<th></th>
<th>KEKB</th>
<th>SuperKEKB</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Luminosity:</strong></td>
<td>$2.1 \times 10^{34}$</td>
<td>$8 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$ (x 40)</td>
</tr>
<tr>
<td><strong>Integrated Luminosity:</strong></td>
<td>$1 \text{ ab}^{-1}$</td>
<td>$50 \text{ ab}^{-1}$ (x 50)</td>
</tr>
<tr>
<td><strong>Runtime:</strong></td>
<td>1998 to 2010</td>
<td>2017 started</td>
</tr>
<tr>
<td><strong>Detector:</strong></td>
<td>Belle</td>
<td>Belle II</td>
</tr>
<tr>
<td><strong>Raw Data:</strong></td>
<td>1 PB</td>
<td>100 PB (projected 2 sets of raw data) (x 100)</td>
</tr>
</tbody>
</table>

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As of 2018.1.29
- 25 countries/regions
- 107 institutions
- ~720 colleagues (40 from South Korea)
- America 17%, Asia 25%, Europe 36%, Japan 17%, Russia 5%
SuperKEKB
Belle II
SuperKEKB Collider

Tokyo

Belle II

electrons
(7GeV)

positrons
(4GeV)
SuperKEKB Construction Finished

- Redesigned the lattice to reduce the emittance
- Replaced beam pipes with TiN-coated beam pipes with antechambers
- New superconducting final focusing magnets near the IP
- Reinforce RF systems for higher beam currents
- Improve monitors and control system
- Upgrade positron capture section
- Low emittance

Nano-Beam scheme
extremely small $\beta_y$
low emittance

$e^+ 3.6A$
$e^- 2.6A$

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Beam Commissioning Phases

• BEAST Phase I in 2016.
  – Simple background measuring detector (diodes, diamonds TPCs, crystals)
  – Only single beam circulated for LER/HER.

• BEAST Phase II in 2018.
  – More precise inner background measuring detector +
  – Full Belle II outer detector
  – Two beams (e+, e–) will collide!

• Belle II Phase III at the end of JFY 2018.
  – The most precise silicon inner detector included.
  – Physics mode with the full Belle II detector.
SuperKEKB/Belle II Schedule

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Courtesy: Takanori Hara @ KEK
The BEAST Phase II Vertex Detector
SuperKEKB/Belle II Luminosity Plan

Goal of Belle II/SuperKEKB

Integrated luminosity (ab⁻¹)

No Vertex Detector

Full Detector

9 months/year
20 days/month

Peak luminosity (cm⁻²s⁻¹)

Calendar Year

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The Belle II Detector

KL and muon detector: 
- Resistive Plate Counter (barrel outer layers)
- Scintillator + WLSF + MPPC (end-caps, inner 2 barrel layers)

EM Calorimeter:
- CsI(Tl), waveform sampling (barrel)
- Pure CsI + waveform sampling (end-caps)

Particle Identification
- Time-of-Propagation counter (barrel)
- Prox. focusing Aerogel RICH (fwd)

Central Drift Chamber
- He(50%):C2H6(50%), small cells, long lever arm, fast electronics

Vertex Detector
- 2 layers DEPFET + 4 layers DSSD

Beryllium beam pipe
- 2cm diameter

Electrons (7GeV)

Positrons (4GeV)

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Installation of Belle II Detectors

May 2016 TOP installed: https://www2.kek.jp/ipns/en/post/2016/05/belle2-top-detector-installation/

Belle II Roll-In April 11, 2017

Photo taken when the detector is just 10 cm from the interaction point. Took 5 hours for the roll-in.

For more photos and news of Belle II,

https://www.facebook.com/belle2collab
The Belle II Computing System
The Basic Computing Model

BNL Data Centre
In Reality, More Details

Distributed Computing

Offline Database (Master)
  BNL (re)process
  mDBT

KEK process
  mDBT

Prompt calibration
Offline calibration

Core services for distributed computing
  DIRAC
  AMG
  FTS

Offline calibration framework (CAF) is being developed with utilizing Data Pipeline Software (Airflow)

Detector
Belle II Detector
Online disk
DAQ unit
DAQ unit
DAQ unit
Online Database
Offline Database
Synchronized database
Under software / DP coordinations
SROOT data transfer
Frontend server:
temporary storage
SROOT → ROOT conversion, merge
DST (calibration) production
DST (ROOT)

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Courtesy: Takanori Hara @ KEK
Network Connectivity

- SINET5 has direct international lines to USA, Europe, and Asia.
  - USA: 100-Gbps line to Los Angeles, 10-Gbps line to New York, and 10-Gbps backup line
  - Europe: Two 10-Gbps lines to London for small latency
  - Asia: 10-Gbps line to Singapore

**LHCONE routing**
- Sep. 2016
  - GEANT at London (20G)
  - GEANT at NY (10G, backup)
  - ESnet, CANARIE at LA (100G)

- Sep. 29th 2017
  - ASGC, KOREONET, (TEIN at Hong Kong (100G)

International lines will be renewed in April 2019

SINET International Links will be renewed in March 2019 for next period of 3 years.
EU link will be upgraded to 100G
NY link will be upgraded to 100G hopefully
SG link may be upgraded to 100G
Belle II can utilize LHCOPN

BNL is connected via LHCOPN to KIT/CNAF/KISTI

BNL can use LHCONP for Belle II traffic if participating LHC Tier1 sites agree and do not jeopardize LHC operations.

Discussed and decided at the last LHCOPN/ONE meeting on Oct. 2017

This makes the network setup at BNL easier and less costly.

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Courtesy: Takanori Hara @ KEK
## Resource Requirement for Near Future

<table>
<thead>
<tr>
<th>Year</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luminosity (ab⁻¹ / year)</td>
<td>0.21</td>
<td>1.67</td>
<td>4.67</td>
<td>8.60</td>
<td>12.03</td>
</tr>
<tr>
<td>Integrated Luminosity (ab⁻¹)</td>
<td>0.21</td>
<td>1.88</td>
<td>6.64</td>
<td>15.23</td>
<td>27.27</td>
</tr>
</tbody>
</table>

**Note:** Calendar year. Not JFY

<table>
<thead>
<tr>
<th>Year</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total tape (PB)</td>
<td>1.6</td>
<td>6.4</td>
<td>17.3</td>
<td>36.1</td>
<td>62.5</td>
</tr>
<tr>
<td>Total disk (PB)</td>
<td>3.5</td>
<td>13.2</td>
<td>22.3</td>
<td>23.3</td>
<td>43.6</td>
</tr>
<tr>
<td>Total CPU (kHEPSpec)</td>
<td>175</td>
<td>404</td>
<td>431</td>
<td>534</td>
<td>733</td>
</tr>
</tbody>
</table>

January 29, 2018  Courtesy: Fabrizio Bianchi @ INFN and University of Torino
Automated Production System Planned

![Diagram of the automated production system planning process]

- **Project management system**
  - Create a project for:
    - Raw data process
    - Simulation
    - User analysis

- **Fabrication system**
  - Control jobs for:
    - Raw data process
    - Simulation
    - User analysis

- **Distributed data management system (DDM)**
  - Control the data management
    - Bulk replication
    - Bulk deletion

- **Data quality system**
  - Verify that outputs can be used in physics analysis
    - Feedback to production manager (human)

- **Verification system**
  - Verify that tasks are correctly finished
    - Feedback to Fabrication & Distributed data management

- **Monitoring system**
  - Check the jobs/network status
    - Feedback to Fabrication & Distributed data management
    - Sending problematic status to GOCDB

- **Production manager (human)**
  - Define the project for:
    - Raw data process
    - Simulation
    - User analysis

**Locations:**
- KEK
- PNNL
- Nagoya-Niigata
Skim Strategy

uDST files are produced and stored at Belle II Grid

More skim types are in development.
Usage of Belle II Grid System
Usage of Belle II GRID Computing Resources: Number of Jobs by Country

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Courtesy: Jake Bennett @ Carnegie Melone University,
Karim Trabelsi @ KEK
Production on Grid Example: MC9

- No. of MC events: ~ 40 billions (8 billions to be produced)
  - Signal events; ~ 10%
- Size of the final sample: ~ 353 TB
- Size of skimmed files: ~ 78 TB
- Total disk size including intermediate files: ~ 1,350 TB

<table>
<thead>
<tr>
<th>Exp. Phase</th>
<th>Sample Type</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase III</td>
<td>Y(3S) generic</td>
<td>300 fb⁻¹</td>
</tr>
<tr>
<td></td>
<td>Y(4S) generic</td>
<td>4,000 fb⁻¹</td>
</tr>
<tr>
<td></td>
<td>Y(5S) generic</td>
<td>1,000 fb⁻¹</td>
</tr>
<tr>
<td></td>
<td>Y(6S) generic</td>
<td>100 fb⁻¹</td>
</tr>
<tr>
<td></td>
<td>Signal and low multiplicity</td>
<td></td>
</tr>
<tr>
<td>Phase II</td>
<td>Y(4S) generic</td>
<td>50 fb⁻¹</td>
</tr>
<tr>
<td></td>
<td>Signal and low multiplicity</td>
<td></td>
</tr>
</tbody>
</table>
Cosmic Particle July 2017

- Relatively low trigger rate
- ~ 10,000 2GB files.
- ~ 17TB for two months.
Summary

• The Belle II Experiment is preparing for the beam collision events in 2018.

• The Belle II Experiment is ideal for new phenomena and precision physics.
  – Huge amount of computing resources are required.
  – Belle II grid system has been tested by periodic tests of MC production. The system passed the tests.
  – User analysis on the grid has started. Ready for physics.
Extra
Usage of Belle II GRID Computing Resources: Usage of CPU by Job Type

At the end of Nov. 2017