Computing at the Belle-II experiment

Takanori Hara (KEK)
takanori.hara@kek.jp

For the Belle II distributed computing group
13 April, 2015 @ CHEP2015 in Okinawa
From Belle to Belle II

**Accelerator** KEKB

**Beam Energy (GeV)** $3.5 \times 8$ ($\gamma = 0.425$)

**CM energy** ........, Y(4S), ........

**Luminosity (cm$^2$ s$^{-1}$)** $2.1 \times 10^{34}$

**Total data (ab$^{-1}$)** $1$

- raw data: ~1PB
- mDST data/MC: 0.14/0.6 PB (for one version)

**Computing** one big center @ KEK (non-grid)

**Physics achievements at Belle**

- Bottomed tetra-quark $Z_b$
- $B \to \tau \nu$ decay
- $b \to d \gamma$ transition
- $D^0 \bar{D}^0$ mixing
- Serendipity
- First tetra-quark $X(3872)$
- $B \to Kll$ decay
- Direct CPV in $B \to K\pi\pi$
- CPV in neutral $B$ system
- CPV in $B \to \pi\pi$
- Confirmation of SM

![Graph of $B^0$ and $\bar{B}^0$ events vs $\Delta t$](image)
From Belle to Belle II

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\[\text{Higher intensity}\]
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SuperKEKB
Beam Energy (GeV) \(4 \times 7\) (\(\gamma = 0.28\))
CM energy \(......, Y(4S), ......\)
Luminosity (cm\(^2\) s\(^{-1}\)) \(8 \times 10^{35}\)
Total data (ab\(^{-1}\)) 50

raw data: \(~100\)PB
(another raw data copy outside KEK)

Computing one big center @ KEK (non-grid)

world-wide distributed computing

physics achievements at Belle

Just an Image

Expected achievements at Belle II

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Journey for New physics

Discovery of \(B \to K\nu\nu\)
Precise meas. of D mixing
Discovery of New Subatomic Particles
\(\sin^2\theta_w\) with O(10\(^{-4}\)) precision
Observations with \(Y(5S), Y(3S)\) etc.
Discovery of \(B \to \mu\nu\)
Discovery of \(B \to D\nu\)

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Hardware Resources for Belle II

version estimated in early 2014

uncertainties Performance of accelerator
beam background condition
improvement of software

The yearly profile may change

The total at the last year should stay the same level

Tape (PB) for raw data

Disk space (PB)
LHC resources based on the published pledges

http://wlcg-rebus.cern.ch/apps/pledges/summary/

The real capacities and the usages can be different
## SuperKEKB/Belle II Timeline

**KEK is the hosting institute of the Belle II experiment**

### Calendar Year

<table>
<thead>
<tr>
<th>Year</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
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<tr>
<td>TOP</td>
<td>CDC</td>
<td>ARICH</td>
<td><strong>All modules installed</strong></td>
<td>VXD (SVD + PXD)</td>
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<td>FWD/BWD Endcap</td>
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<tr>
<td>Global Cosmic Ray Run</td>
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<td></td>
<td>Roll-in</td>
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<td>Commissioning detector (Beast2)</td>
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<td>QCS</td>
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<tr>
<td><strong>Phase-1</strong></td>
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<td>KEK Computing System replacement</td>
<td><strong>Phase-2</strong></td>
<td><strong>Phase-3</strong></td>
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<tr>
<td><strong>Computing</strong></td>
<td></td>
<td></td>
<td>Belle II Distributed Computing should be ready (raw data comes but small)</td>
<td>Raw data processing Raw data distribution start</td>
</tr>
<tr>
<td>We are here!</td>
<td></td>
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**KEK Computing System replacement**

- **SuperKEKB/Belle II Timeline**: The timeline outlines the phases and milestones of the experiment, including detector installation, commissioning, and computing system upgrades.

**KEK Computing System replacement**: Indicates the phase of the experiment where the computing system is replaced.

**SuperKEKB/Belle II**: The experiment is hosted by KEK, a joint institute of the University of Tokyo and RIKEN.

**Phase-1**: The initial phase includes detector installation and commissioning.

**Phase-2**: The second phase focuses on roll-in and quality control procedures (QCS).

**Phase-3**: The final phase involves the distributed computing system being ready for processing the large volume of raw data.
23 countries/region  
99 institutes  
634 colleagues

ATLAS, 38 countries, 177 institutes, ~3000 members  
CMS: 42 countries, 182 institutes, 4300 members  
ALICE: 36 countries, 131 institutes, 1200 members  
LHCb: 16 countries, 67 institutes, 1060 members

c.f.

Asia: ~43%  
N. America: ~17%  
Europe: ~40%

Japan: 139  
Korea: 37  
Taiwan: 25  
India: 25  
China: 18  
Australia: 22

Germany: 89  
Italy: 62  
Russia: 40  
Slovenia: 17  
Austria: 14  
Poland: 11  
Czech rep.: 8

as of April 4, 2015

others: < 8 colleagues / country
Belle II resources / infrastructure overlap with WLCG

- KIT, CNAF, CESNET, SIGNET, HEPHY, UA-ISMA, ULAKBIM, CYFRONET, ..... (GRID Middlewares)
- BINP, NSU, universities in Japan, Korea
- Belle II resources / infrastructure overlap with WLCG
- Clusters w/o middleware: GE, TORQUE, LSF, ...
- Direct submission
- Academic clouds: Melbourne cc1
  - Seen as a traditional CREAM CE site
  - Installed in each cloud site
- Commercial clouds: Academic clouds
  - PNNL HPC
  - UVic
  - HTCondor Cloud Scheduler
  - Dynamic Torque
  - CREAM CE
- HTCondor VM Manager
- Open Science Grid
Interoperability with DIRAC

KIT, CNAF, CESNET, SiGNET, HEPHY, UA-ISMA, ULAKBIM, CYFRONET, ...,

GRID Middlewares

Open Science Grid

Clusters w/o middleware
GE, TORQUE, LSF,...

Direct submission
BINP, NSU, many universities in Japan

Distributed Infrastructure with Remote Agent Control
(Originally developed for LHCb)

Belle II

VMDIRAC

A part of DIRAC

KEK

VMDIRAC

SiteDirector

SLURM SiteDirector

SSH tunnel or DIRAC SiteDirector

HTCondor/Cloud Scheduler

HTCondor VM Manager

Academic clouds

Commercial clouds, Amazon EC2, etc

• Provided as a DIRAC plugin
• Need additional installation
• Multiple cloud sites allowed
• Handle each cloud as a site
• No modification in cloud site

Clouds

Cracow

cloud site

cloud site

cloud site

Academic clouds

Melbourne

nec tar

• Seen as a traditional CREAM CE site
• Installed in each cloud site

UVic

PNNL

HPC

Clusters w/o middleware

Direct submission

BINP, NSU, many universities in Japan
Belle II Distributed Computing system

cvmfs is used for software distribution

DIRAC main servers @ KEK

VOMS @ KEK

AMGA + LFC: has been working well

recent improvement

Studies with DFC vs AMGA+LFC: not yet a stage to tell their scalabilities

FTS3: getting integrated

DIRAC servers for test/development purpose at PNNL (USA), Cracow (Poland), etc.
Data flow diagram

Data
- processed @ "raw data center"
- Online disk (Sequential root)
  - raw data in root: merge
- Offline storage (Sequential root)
  - 300kB / event

MC
- produced on the world-wide distributed computing

Event generation
Detector simulation
Digitization
Reconstruction
- ~4 sec/event
- No intermediate stage is saved

Reconstruction
- mDST: reconstruction level info., μDST : mDST + particle level info., index: collection of pointers to events

User distributed analysis
- "Conceptual" index
- "another possibility" μDST

"coordinated" group skimming
- group official skim: mDST, μDST, index

User distributed analysis
- mDST
  - less disk requirement
  - more chaotic network access
- μDST
  - more disk requirements
  - less network requirements
Operation at larger scale

15 countries/regions
Australia, Austria, Canada, Czeck R., Germany, Italy, Japan, Korea, Poland, Russia, Slovenia, Taiwan, Turkey, Ukraine, USA

31 sites
GRID, Cloud, local cluster is available
more than 3ab⁻¹ data produced in 2014

However, still a factor of x10 below requirements for full Belle II luminosity
It is not sufficient for our operation.
  e.g. pilot status

➔ We are developing our own monitoring system with web interface.

2-way monitoring

• Active way
  Submit test job, test SE access, check port access
• Passive way
  Keep statistics on the result of pilot jobs, Analyze log of pilot jobs

Visualize monitoring result on the web page.
  (enable to check it easily, anywhere)
Check basic requirements for each site by test jobs. (libraries, free disk space, etc)

Check pilot status as well as processing time, heartbeat time and so on.

We can quickly find many kinds of problems by our monitoring system now.
As a next step, more sophisticated system is being developed:
  more precise diagnosis, automated notification, etc.

→ made the MC production shift easier
Distributed Computing in future

BelleDIRAC

Production Manager
Fabrication System
gb2 client tools

Data Manager
Distribution System
Web portal

End Users

BelleDIRAC

“Prototype” worked
More development

Grid Services for Belle II

CVMFS

CVM

AMGA

RMS

DMS

Sites

Cloud I/F

Cloud site

Cluster

Cluster

DIRAC slave

SE

Xrootd Server

To be considered

To be developed

To be integrated

local I/O
remote I/O

cloud site
Belle II Computing Model

1. **Detector**
   - Raw data storage and (re)process

2. **Raw Data Center**
   - KEK Data Center (100%)
   - India Data Center (10%)
   - Korea Data Center (10%)

3. **Regional Data Center**
   - Asia
   - North America
     - PNNL Data Center (30%)
   - Europe
     - Germany Data Center (20%)
     - Italy Data Center (20%)
     - Canada Data Center (10%)

4. **MC production site**
   - GRID site
   - Cloud site
   - Computer cluster site

5. **Local resource**
   - User analysis (Ntuple level)

Start year 4 (raw data part)
mDST (data) is copied in Asia, Europe, and USA.

For the MC data seems to be natural to be the similar structure

- better network? in each region
- completeness of the dataset in each region
- easier maintenance?

unbalance of resources
data copy between three regions

main center: KEK (Japan)
  - KISTI (Korea)
  - NTU (Taiwan)
  - Melbourne U. (Australia)
  - IHEP (China)
  - TIFR (India)
  - many Japanese Univ.
  - thai, vietnam, malaysia, ...

main center: GridKa/DESY (Germany), CNAF (Italy)
  - SiGNET (Slovenia)
  - CYFRONET/CC1 (Poland)
  - BINP (Russia)
  - HEPHY (Austria)
  - CESNET (Czech rep.)
  - ISMA (Ukraine)
  - INFN Napoli/Pisa/Frascati /Legnaro/Torino (Italy)
  - ULAKBIM (Turkey)
    - : spain, saudi arabia

main center: PNNL
  - U.Vic. /Mcgill (Canada)
  - VPI, Hawaii, ...
  - many US univ.
    - : mexico
Trans-Pacific data challenge

reached 1000MB/s transfer between PNNL and KEK

eth1 10 GB SuperFast Ethernet (4hour)

Summer 2015 Goal
Summer 2014 Goal

Trans-Pacific data challenge

reached 1000MB/s transfer between PNNL and KEK
Trans-Atlantic data challenge

US side

Dedicated 10G link between PNNL SE and ESNet
10G best-effort Label Switched Path in ESNet backbone

Test was done in May/June 2014

Network providers setup the VLAN

Local network providers and sites coordinated final configurations

Sites must configure hardware interface to match destinations

Europe side

"traceroute" was used to confirm the routing to each SE

"iperf" was used to do initial network transfer rate test

FTS3 server at GridKa was used to schedule data transfers

Vincenzo Capone, Aleksandr Kurbatov, Mian Usman

M. Schram (PNNL)

Chin Guok

Thomas Schmid, Hubert Weibel Marco Marletta

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Results using FTS3 server

Trans-Atlantic data challenge

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Chin Guok

M. Schram (PNNL)

Thomas Schmid, Hubert Weibel

Marco Marletta
The network requirements for Belle II are similar to the LHC experiments. Most Regional Data Centers are already part of LHCONE → LHCONE has been extended to include Belle II

Jason Zurawski, Joe Metzger (Mar. 23, 2015)
http://www.es.net/assets/pubs_presos/20150323-OSG-ATLASCMS-Zurawski-v2.pdf
steering file is written in python
Belle II Analysis Software Framework

**Input module**

- Geometry initialization
- Event Generator

**Data Store**

**Output module**

- Detector simulation, Digitization,
  Reconstruction (track finding/fitting, $\pi^0/\gamma$ clustering)
- Particle identification

**Ring Buffer**

**multi-process feature**

not optimized for HT yet

**steering file is written in python**
Software update/improvement

CPU time for simulation [HEPSpec06*s]

EvtMetaGen
EvtMetaInfo
EvtGenInput
Gearbox
Geometry
FullSim
MixBkg
PXDDigitizer
PXDClusterizer
SVDDigitizer
SVDClusterizer
CDDigitizer
TOPDigitizer
ARICHDigitizer
ECLDigitizer
BKLMDigitizer
EKLMDigitizer

100 HS06 * s/event → ~40 HS06 *s/event
Coordinated group skimming

From experience of Belle

▷ Many users cannot use resources effectively in skimming process
  ─ iterate the skimming with different selection

▷ Not so many users pay attention
  whether or not the submitted jobs successfully finished
  ─ consideration of exp/run-dependences, log file check, ...

▷ Users’ interests can be easily concentrated on certain datasets
  in particular, the early stage of the experiment
  ─ data taken under good accelerator/detector condition
  ─ new datasets (new exp#/run#)
    → same input but many different outputs

▷ Usually, it takes too much time to carry out the skimming process
  and to finish by users

Job failure rate ↓
“coordinated” group skimming must make the physics analysis faster.
MC in early 2014: no “Production System”

2.5 M jobs: manually submitted by the shifters

→ some mistakes  e.g. same job submitted twice
    wrong destination SE...

MC in late 2014: with “Prototype Production System”

4.7 M jobs: controls by a single person

“Full Production System” yet to be developed
Belle II time line

SuperKEKB accelerator commissioning (phase1) starts in early 2016
Phase2 (w/o VXD) starts in 2017
   → Belle II Distributed Computing should be ready
Phase3 (w/ Full detector) starts in 2018
   → raw data distribution starts

MC mass production & Data transfer challenge
the basic concept of the Belle II computing model was proven
but still we have many things to do (e.g. Data distribution, user distributed analysis, etc.)

Efforts to utilize the limited hardware resources AMAP
are on-going toward the physics run.
multicore jobs (memory size ↓)
Tuning/Optimization of software (memory size ↓, shorter CPU time)
Coordinated group skimming (less human-error)
Production system
### Software

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<th>Track/Poster</th>
<th>Date</th>
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<td>Oliver FROST</td>
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<td>Marko BRACKO</td>
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<td>Marko STARIC</td>
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<td>Thomas HAUTH</td>
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<td>Alignment and calibration of Belle II tracking detectors</td>
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<td>Hideki MIYAKE</td>
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<td>Randy SOBIE</td>
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<td>Yuji KATO</td>
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<td>Job monitoring on DIRAC for Belle II distributed computing</td>
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<td>Chia-Ling HSU</td>
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<td>The Belle II analysis on Grid</td>
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<td>Rafal Zbigniew GRZYMKOWSKI</td>
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<td>Belle II public and private clouds management in VMDIRAC system.</td>
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<td>Kiyoshi HAYASAKA</td>
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<td>Improvement of AMGA Python Client Library for the Belle II Experiment</td>
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<td>Geun Chul PARK</td>
<td>Poster B</td>
<td>313</td>
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<tr>
<td>Directory Search Performance Optimization of AMGA for the Belle II Experiment</td>
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</tbody>
</table>
DAQ + physics trigger
ARDA Metadata Grid Application
   — Metadata server for GRID environment

   (EMI product)

Metadata: data of data
LFN, run range, software version...

LFC (LCG (LHC Computing Grid) File Catalog)
PFN (Physical File Name) a specification of the physical location of a file
   e.g. srm://kek2-se01.cc.kek.jp:8444/grid/belle/MC/signal/...
   c.f. URL http://belle2.kek.jp/join.html
LFN (Logical File Name) = a site-independent file name
e.g. /grid/belle/MC/signal/...
GUID (Globally Unique Identifier)
...

LFN is only common data between LFC and AMGA

AMGA (ARDA Metadata Grid Application)
ARDA (A Realisation of Distributed Analysis for LHC)

AMGA API
   gBasf2

LFC API

API: application interface