Calibration Data Flow and Performance at Belle II

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From $e^+e^-$ collisions to raw data

Asymmetric $e^+e^-$ collider
@ and around the $Y(4S)$ resonance

Belle II Detector

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

- **Beryllium beam pipe:**
  - 2cm diameter

- **Vertex Detector:**
  - 2 layers DEPFET + 4 layers DSSD

- **Central Drift Chamber:**
  - He(50%):C4H6(50%), Small cells, long lever arm, fast electronics

- **KL and muon detector:**
  - Resistive Plate Counter (barrel)
  - Scintillator + WLSF + MPPC (end-caps)

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

**General purpose 4π detector**
From $e^+e^-$ collisions to raw data

**Belle II Detector**
- **KL and muon detector:** Resistive Plate Counter (barrel), Scintillator + WLSF + MIPPC (end-caps)
- **EM Calorimeter:** CsI(Tl), waveform sampling (barrel), Pure CsI + waveform sampling (end-caps)
- **Electron:** 7 GeV
- **Beryllium beam pipe:** 2 cm diameter
- **Vertex Detector:** 2 layers DEPFET + 4 layers DSSD
- **Central Drift Chamber:** He(50%):C2H4(50%), Small cells, long lever arm, fast electronics

**General purpose**
- $4\pi$ detector

**Total integrated luminosity**
- $\mathcal{L} = 424 \text{ fb}^{-1}$

**Belle II Online luminosity**
- Exp: 7-26 - All runs
- Integrated luminosity
  - Recorded Weekly
  - $\int \mathcal{L}_{\text{Recorded}}\,dt = 427.79 \text{[fb}^{-1}]$
Alignment – A brief introduction

Challenges:
Weak modes due to lack of absolute reference → Complementary data samples

Belle II: Global Alignment with Millepede II
Alignment – data samples

hadron event

di-muon event

cosmic ray event (during collisions)
Alignment – Resolution of track parameters

\[ \sigma^2(\tilde{p}) = a^2 + \frac{b^2}{p^2} \]

\[ \tilde{p}_{d0} = p\beta \sin(\theta)^{3/2} \]

\[ \tilde{p}_{z0} = p\beta \sin(\theta)^{5/2} \]

**a**: detector resolution

**b**: material budget affecting multiple scattering

\(\tilde{p}\): pseudo-momentum
ECL reconstruction

Simulated single photon and beam background

signal photon

beam-induced Background cluster

event after clustering and background rejection
ECL calibration

ECL leakage
• Reconstructed energy smaller than true energy through leakage
• Derived from simulated single photon + beam background

Absolute energy
• $ee \rightarrow \gamma\gamma$ or cosmic ray events

Final photon energy
• symmetric $\pi^0$ and $\eta$ candidates
Calibration setup

• Small background rates allow for loose trigger lines
• The high-level trigger does not require precise calibrations
→ Offline calibrations feasible

Advantage:
Calibration of the bucket with the current bucket data instead of the previous bucket data

Disadvantage:
Data “lagging” behind, but prompt calibration done within weeks of data taking
Data Flow

HLT-skimmed raw data produced at KEK (hraw)

~17 TB per loop

register hraw to the Grid

hraw copied to calibration center (BNL)

calibration loop
The calibration loop

1. Local calibrations
2. Pre-tracking/raw-data based calibrations
3. Alignment
4. cDST production
5. Post-tracking/data based calibration
6. Analysis-based calibrations

Calibration skims [hraw] (adaptive prescaling to 9 fb$^{-1}$)

The calibration loop is fully automated and provides physics data within ~2 weeks of data taking
Data Flow

- HLT-skimmed raw data produced at KEK (\textit{hraw})
  - ~17 TB per loop
- \textit{hraw} copied to calibration center (BNL)
- \textit{hraw} deleted
- cDST data produced during the calibration loop
  - ~14 TB per loop
- cDST copied to recalibration center (DESY)
- Calibration loop
  - ~36.2 kHEPSpec06 day
The Belle II calibration procedure

- Prompt loop
- Recalibration loop

Single bucket $\geq 9 \text{ fb}^{-1}$
The Belle II calibration procedure

**Promptly after data taking:**

**prompt calibration @ BNL**

- Minimum luminosity (*) per prompt calibration “bucket”: 9 fb$^{-1}$
- All calibrations included
- Uses hraw as input
- ~one bucket every 2 weeks of data taking
- Ideally already the final calibration

**Before data reprocessing:**

**recalibration @ DESY**

- To update older data with the latest reconstruction software
- Only calibrations with expected improvement
- Uses cDST as input
- ~once/year until 2025, every other year starting from 2025

(*) Data of each individual bucket is adaptively prescaled to correspond to 9 fb$^{-1}$
Summary

• Automation of the Belle II calibration
• Calibrations ready for high precision physics