



Integration of readout of the vertex detector in the Belle II DAQ system

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Belle II experiment

- Next generation B factory experiment starts in 2018
 - Search for New Physics in Flavor sector
 - Upgrade from Belle I for 40 times higher luminosity
- Data Acquisition (DAQ) system is a major upgrade in Belle II
 - L1 Maximum trigger rate : up to 30 kHz
 - Event size without reduction : 1MB/event



PXD gives too huger data than others

33 GB/s

- PXD : 30 GB/s
- 6 others : 3 GB/s in total

A global data acquisition system for Belle II detector was developed

- Online PXD event size reduction
- Unified R/O for other detectors

Belle II Data Acquisition system



Unified Data Acquisition Scheme for Belle II detector

- Fast Timing SWitch (FTSW) for trigger and system clock distribution
- Belle2Link : High speed link board (HSLB) for unified readout except PXD
- Two layers of event builders using commercial network switch and PCs
- High Level Trigger (HLT) PC farms for software trigger decision
- Online data reduction for PXD in FPGA based event processors
- Unified software framework for **slow control**

Belle II Data Acquisition system



Integration to VXD is a challenge in the Belle II DAQ system

- High Level Trigger (HLT) PC farms for software trigger decision
 => Feedback of Regions of Interests (RoIs) in PXD to R/O backend
- Online data reduction for PXD in FPGA based event processors
 => Event size is reduced by a factor of 1/10 before recording
- Unified software application for slow control
 => Complicated system with two different frameworks

Belle II detector construction

Construction of the Belle II detector will be finished in 2017

- The Belle II outer detectors are in commissioning with cosmic rays
 => Talk by S.Yamada
- Phase II (Jan. 2018) : Beam collision for beam commissioning
 - Full system of the outer detectors
 - Partial VXD (4 SVD + 2 PXD) with sensors for beam background
- A beam test for the Belle II VXD was carried out in March 2017

Purpose of the VXD beam test from DAQ viewpoints

- Full data chain of the Belle II DAQ system
 - => Event synchronization between the SVD and PXD
- Stability of the readout electronics
 => High rate performance of Rol feedback with beam
- Demonstration of the slow control scheme
 - => Data taking operation by **non DAQ experts**

Beam test for Belle II VXD

Test at DESY electron test beam facility

- Details by H. Ye
- Setup for Belle II phase II run
- Triggers by plastic scintillator
- Electron beam: 1 3GeV (up to 6GeV)
- Magnet: 0 0.5T
- DAQ system same as Belle II

Performed in March 2017 for a month







Belle II DAQ in the beam test

A minimum copy of the Belle II DAQ system 📫 1/30 scale of full DAQ system

- 2 Flash-ADC readouts for SVD
- Data Handling Hybrids (DHH) for PXD
- 2 FTSWs for SVD and PXD R/O electronics
- 2 COPPER boards with 2 HSLBs
- HLT farm with 3 workers for online tracking
- 2 Online selector nodes (ONSEN) for PXD
- Express reco. : Data quality monitor (DQM)

R. Thalmeie et al, NIM A, Vol 845, 2017, 633-638

D. Levit et al, IEEE TNS, Vol 62, Issue 3, 2015, 1033 - 1039

M. Nakao et al, IEEE TNS, Vol 60, Issue 5, 2013, 3729 - 3734

S. Yamada et al, IEEE TNS, Vol PP, Issue 99, 2017

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Physics 2017 @ Beijing

Readout/DAQ components

Readout equipment was ported to DESY test site

- 2 weeks for setup before beam on
- Located at test area









Control panel in test area



- Physical displays was prepared at the control hut in the beam area
 - => Control was totally taken over to the non DAQ expert shifters
- The GUI was shared in the DESY network
 => DAQ experts helped remotely

=> Slow control was established for shifter

Control hut next to the beam area



DAQ control GUI



DAQ log view panel

| III Message History 🛛 | | | | | | | |
|-----------------------|---------------------|---------|----------|---|--------|--------|--------|
| Start: | -2 hour | | | End: now | mes Fi | lter 😽 | |
| SEQ | CREATETIME | NAME | SEVERITY | TEXT | STATUS | 5 | ^ |
| 33 | 2017-02-27 08:23:02 | ROPC01 | INFO | eb0 : event_no = 2070000 | | | = |
| 34 | 2017-02-27 08:22:56 | STORAGE | DEBUG | eb2rx : event 2060000 | | | |
| 35 | 2017-02-27 08:22:56 | ROPC01 | INFO | eb0 : event_no = 2060000 | | | |
| 36 | 2017-02-27 08:22:49 | STORAGE | DEBUG | eb2rx : event 2050000 | | | |
| 37 | 2017-02-27 08:22:49 | ROPC01 | INFO | eb0 : event_no = 2050000 | | | |
| 38 | 2017-02-27 08:22:47 | STORAGE | INFO | storagerecord : New file /x02/disk01/storage/beam.0003.000256.sroot-8 is opened | | | |
| 39 | 2017-02-27 08:22:47 | STORAGE | INFO | storagerecord : disk : 1 is available | | | |
| 40 | 2017-02-27 08:22:47 | STORAGE | DEBUG | storagerecord : fileid: 8 | | | |
| 41 | 2017-02-27 08:22:47 | STORAGE | DEBUG | storagerecord : db: fileid: 8 | | | |
| 42 | 2017-02-27 08:22:43 | STORAGE | DEBUG | eb2rx : event 2040000 | | | |
| 43 | 2017-02-27 08:22:43 | ROPC01 | INFO | eb0 : event_no = 2040000 | | | |
| 44 | 2017-02-27 08:22:37 | STORAGE | DEBUG | eb2rx : event 2030000 | | | |
| 45 | 2017-02-27 08:22:37 | ROPC01 | INFO | eb0 : event_no = 2030000 | | | |
| 46 | 2017-02-27 08:22:30 | STORAGE | DEBUG | eb2rx : event 2020000 | | | |
| 47 | 2017-02-27 08:22:30 | ROPC01 | INFO | eb0 : event_no = 2020000 | | | |
| 48 | 2017-02-27 08:22:24 | STORAGE | DEBUG | eb2rx : event 2010000 | | | |
| 49 | 2017-02-27 08:22:24 | ROPC01 | INFO | eb0 : event_no = 2010000 | | | |
| 50 | 2017-02-27 08:22:18 | STORAGE | DEBUG | eb2rx : event 2000000 | | | |
| 51 | 2017-02-27 08:22:18 | CPR011 | INFO | basf2 : Event 2000000 Rate 1.57[kHz] Recvd 0.99[MB/s] sent 1.04[MB/s] RunTime 1248.77[s] | | | |
| 52 | 2017-02-27 08:22:18 | CPR010 | INFO | basf2 : Event 2000000 Rate 1.57[kHz] Recvd 0.74[MB/s] sent 0.79[MB/s] RunTime 1248.77[s] | | | |
| 53 | 2017-02-27 08:22:18 | ROPC01 | INFO | eb0 : event_no = 2000000 | | | |
| 54 | 2017-02-27 08:22:18 | ROPC01 | INFO | CPR011 : Event 2000000 Rate 1.57[kHz] Recvd 0.99[MB/s] sent 0.90[MB/s] RunTime 1317.98[s | | | |
| 55 | 2017-02-27 08:22:18 | ROPC01 | INFO | CPR010 : Event 2000000 Rate 1.57[kHz] Recvd 0.74[MB/s] sent 0.65[MB/s] RunTime 1317.98[s | | | |
| 56 | 2017-02-27 08:22:18 | ROPC01 | DEBUG | CPR011 : #### PostRawCOPPER : Eve 001e8480 block 0 finesse 0 B2LCRC16 000064ff calculated CRC16 000 | | | |
| 57 | 2017-02-27 08:22:18 | ROPC01 | DEBUG | CPR010 : #### PostRawCOPPER : Eve 001e8480 block 0 finesse 0 B2LCRC16 00003a65 calculated CRC16 00 | | | |
| 58 | 2017-02-27 08:22:12 | STORAGE | DEBUG | eb2rx : event 1990000 | | | |
| 59 | 2017-02-27 08:22:11 | ROPC01 | INFO | eb0 : event_no = 1990000 | | | |
| 60 | 2017-02-27 08:22:05 | STORAGE | DEBUG | eb2rx : event 1980000 | | | |
| 61 | 2017-02-27 08:22:05 | ROPC01 | INFO | eb0 : event_no = 1980000 | | | |
| 62 | 2017-02-27 08:21:59 | STORAGE | DEBUG | eb2rx : event 1970000 | | | |
| 63 | 2017-02-27 08:21:58 | ROPC01 | INFO | eb0 : event_no = 1970000 | | | |
| 64 | 2017-02-27 08:21:52 | STORAGE | DEBUG | eb2rx : event 1960000 | | | |
| 65 | 2017-02-27 08-21-52 | RODCO1 | INFO | ahn · avant no - 1060000 | | | \sim |

• DAQ logs are collected to Java Message Server (JMS) => shown on GUI

Online tracking and DQM

Online event display



- Tracking software in HLT created Rols to select hit channels
- DQM software worked in HLT (SVD/ROI) and express reco. (PXD)
- Event display stably fetched event to show reconstructed tracks

Online DQM browsers Correlation of Hit positions in SVD sensors



Hit map on PXD sensor modules



DAQ stability with online tracking



- Trigger input and output rates were monitored and recorded
 - Due to conflicts in memory access in HLT caused back pressure=> Fixed
 - Finally trigger rate got sable at 1.6 kHz with tracking software
- Data taking continued for up to **16 hours** without any error in data
 - Longer enough for run time of Belle II (8 hours)

PXD R/O performance for trigger veto



Further test for PXD-DHH performance with various trigger veto window

- Nominal value : 200 μ s => 140 μ s is the current limit in PXD-DHH
- Various veto windows were tested to see increase of the trigger rate
 - Triggers were more suppressed with beam due to beam bunches
 - Trigger rate increased up to 2.3kHz for Poisson and 2 kHz for beam

Remaining issues toward Phase II run

- Data from PXD-ONSEN was corrupted at run start
 - No error during data taking
 - Several minutes to recover due to firmware re-download
- Trigger rate is not enough due to the trigger veto by PXD-DHH

Reconstructed the test setup for permanent study (PERSY)

- SVD and PXD sensors
- SVD and PXD readouts
- DAQ backend stuff



Debugging firmware is still ongoing using the real setup with sensors

Summary

- Belle II experiment starts in 2018 to search for New Physics
- Data acquisition system is the key component in the Belle II upgrade
 - Common DAQ scheme with data reduction from PXD
- A beam test was carried out as a step of VXD integration in 2017
 - Full DAQ data chain was established with the SVD and PXD
 - Stable operation over 16 hours with RoI feedback from tracking
 - Data taking operation was totally done by non DAQ experts
- The test setup remains in the test site as a permanent debug platform
 - Debugging/Improvement of the PXD R/O firmware are still ongoing
- Phase II run as with beam collision will start in Jan. 2018

PXD readout: Data Handling Hybrid





DHH processor card for DHE/DHC

Dedicated readout system for PXD sensor modules

- Drain Current Digitizer (DCD) : 256 analog input to 8bit ADC : 4 chips on board
- Data Handling Processor (DHP) : zero suppression : 4 chips on board
- Data Handling Hybrid : FPGA (Vertex-6) based event builder
 - DHE (DH Engine) : 4 DHP outputs to 6.25Gbps Aurora link
 - DHC (DH Concentrator) : 5 DHE outputs to multiple ONSENs (5 x 6.25 Gbps)
- 40 DHE / 8 DHC for Full PXD 40 sensor half ladders

PXD backend : ONline SElector Node (ONSEN)



Diagram of the Belle II VXD DAQ for setup at KEK

ONSEN in ATCA crate





ATCA module with Xilinx Vertex-5

- 8 GB DDR-2 memory
- Input: Xilinx Aurora Link from DHH
- Rol: SiTCP from HLT
- Output : SiTCP to Event builder