Data Acquisition System for Belle II Electromagnetic Calorimeter
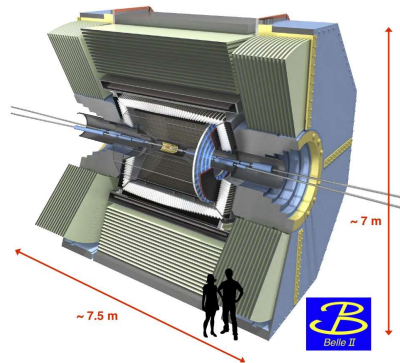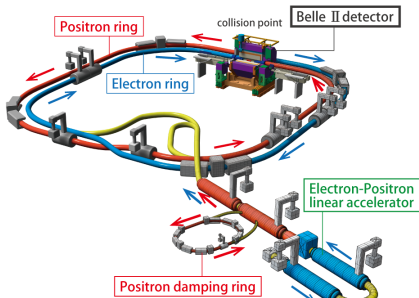
Mikhail Remnev on behalf of the Belle II Calorimeter Group

Budker Institute of Nuclear Physics (BINP)

2020.02.28

- Goals: physics of B- and D-mesons, τ-physics, search for New Physics.
- SuperKEKB — asymmetrical e^+e^- collider, $E_{e^-} = 7$ GeV, $E_{e^+} = 4$ GeV.
- Design luminosity $8 \cdot 10^{35} \mathrm{s}^{-1}\mathrm{cm}^{-2}$, ~ 40 times larger than previous KEKB.
- Electromagnetic calorimeter (ECL) is one of the subsystems of Belle II detector.
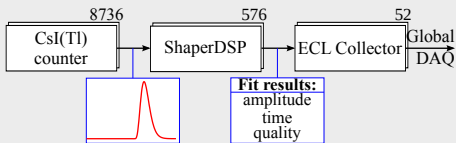

Positron ring

collision point   Belle Ⅱ detector

Electron ring

Electron-Positron
linear accelerator

Positron damping ring

~ 7 m

~ 7.5 m

Belle Ⅱ

Main functions of the calorimeter:

- Measurement of photon energy and directions.
- Providing trigger signal.
- Particle identification.

Data flow from the calorimeter

DAQ parameters

|	
L1 trigger rate at design luminosity	30 kHz
ECL data rate / event (32 bits / channel: amp, time, fit quality)	12 kB
$\sigma E / E$ at $E > 1$ GeV	$\sim 1\%$

Requirements for data acquisition system:

1. Efficient workflow to control and maintain the system.
2. Assurance of data quality.
3. Stability of data taking.

ShaperDSPs and ECL Collectors are complex modules with total configuration consisting of $\sim 10^5$ parameters.
Their configuration is determined and updated in this workflow:
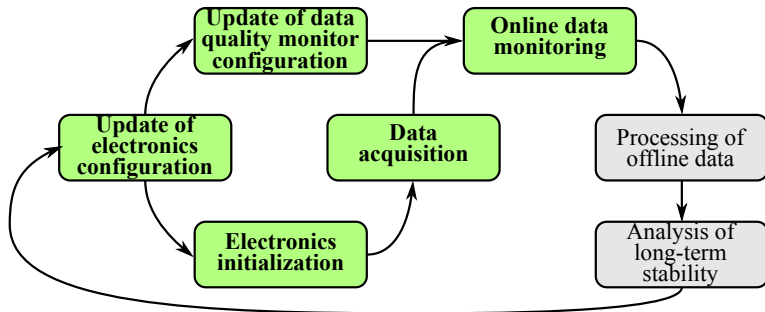
This talk focuses on the following tasks of data acquisition:

1. Management of calorimeter configuration in two databases.
2. Tools to initialize calorimeter electronics.
3. Quality monitoring in firmware and software.
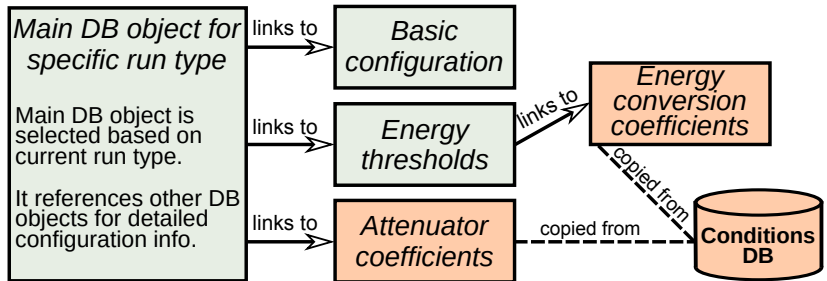4. Procedures to ensure stable data taking in firmware and software.

DAQ
DB

Conditions
DB

Database for DAQ configurations

Database for calibration data

Configuration should always be consistent between two databases.

Main DB object for
specific run type

Main DB object is
selected based on
current run type.

It references other DB
objects for detailed
configuration info.

links to

Basic
configuration

links to

Energy
thresholds

links to

Attenuator
coefficients

links to

Energy
conversion
coefficients

copied from

copied from
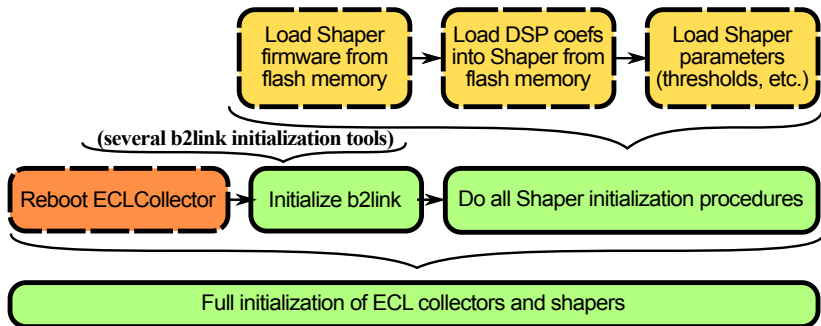
Conditions
DB

Initialization software

- All of low-level initialization software has been combined into a single C++ library.

- This library is now a submodule of slow control repository.
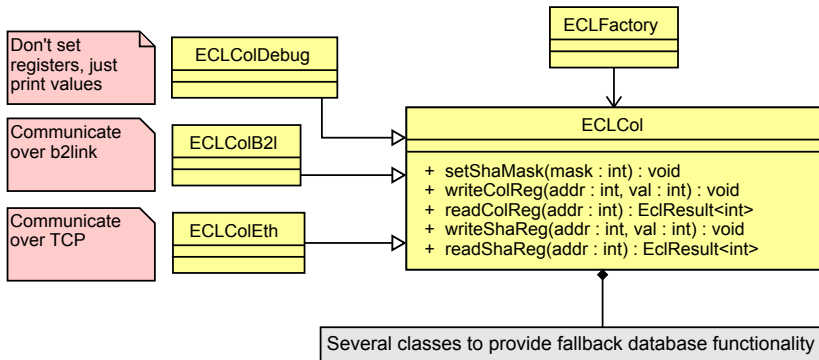
This software library allows to select:

- Initialization protocol (ethernet/b2link).

- Configuration storage (DAQ DB/file)

- Logging target (DAQ DB, file, stdout)

- ECL expert shifters normally use utilities listed in green rectangles.
- ECL initialization tools support custom masking
  - Masks can be set by crate ID, trigger group number and other criteria.
  - Example: `ecl-init-shaper 10-15,20-25`
- Full initialization takes ∼1 minute.
- Initialization procedure is documented in expert manual.

Data quality monitor

Belle II data quality monitor allows to continuously validate the data during the run.
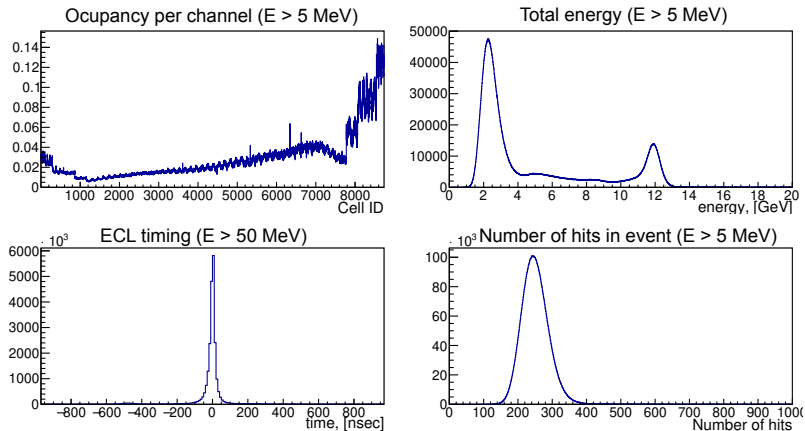
- There are ∼20 histograms that monitor a variety of ECL parameters.
- Small number of these histograms are checked by control room shifters, other histograms are monitored by ECL experts.

Data quality monitor

Besides amplitude and time, waveform data is saved for all high-amplitude events and small fraction of low-amplitude events to monitor electronics.
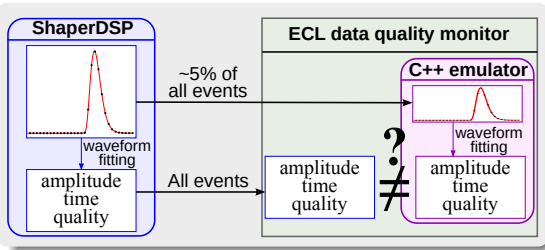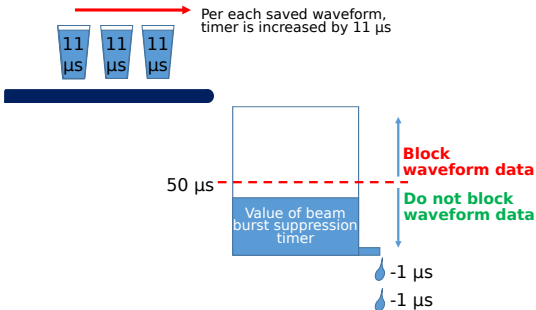

If ShaperDSP and emulator return different fit results, data is corrupted.

- Data quality monitor continuosly checks that fit results are consistent between ShaperDSP and emulator.
- In case of a problem, ECL expert is automatically notified.

Emulator used in data quality monitor has been extensively tested, checked on run data and compared with results from ModelSim FPGA simulation.

Beam burst suppression algorithm

- Normally, only amplitude, time and fit quality are saved in each event.
- For PID purposes we save waveforms for hits with $E > 50$ MeV.
- Beam burst $\Rightarrow$ thousands of waveforms $\Rightarrow$ interruptions in data taking.
- To avoid buffer overflow, special algorithm is implemented.

Per each saved waveform, timer is increased by 11 μs

11 μs   11 μs   11 μs

50 μs

Value of beam burst suppression timer

Block waveform data

Do not block waveform data

-1 μs
-1 μs

- Each waveform increases beam burst suppression timer by 11 μs.
- When timer passes the threshold of 50 μs, waveforms are no longer saved until timer is below 50 μs again.

This algorithm, along with parallel processing and efficient packing of the data, allows ECL electronics to stably work with up to 30 kHz input trigger rate.
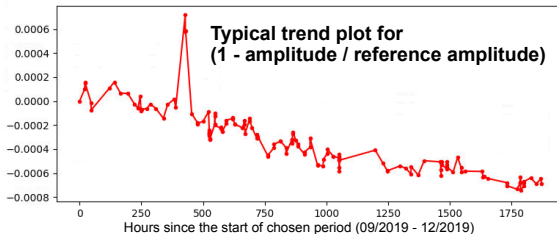
Testpulse calibration

- To get stability of electronics with accuracy better than 1%, we need calibration procedure.
- To calibrate amplitude and time properties of the electronics, daily test-pulse is used.
- For calibration data taking we use standard GUI of Belle II experiment:

ECL-specific additions:
- Data is logged into sqlite DB and then used in study of long-time stability.
- All ECLCollectors are monitored for configuration consistency.
- Shell-based program to process and visualize test calibration data has been prepared:

Typical trend plot for
(1 - amplitude / reference amplitude)

Hours since the start of chosen period (09/2019 - 12/2019)

Monitoring of data-taking stability

- Group of on-site and remote ECL expert shifters monitor the status of ECL data acquisition to provide stable operation and quick fixes in case of problems.
- Several automated tools are used in shifter work:
  - ▶ Simple email notification daemon has been prepared to monitor multiple data quality histograms and condition of ECL-related servers.
  - ▶ Initialization software has been developed to accommodate expected use cases.
- Information on the firmware and software of ECL DAQ has been documented and available for ECL expert shifters.

Conclusion

- Calorimeter data acquisition system provides operation at 30 kHz input trigger rate.
- DAQ working stably since the start of data taking for Belle II experiment at April 2018.
- Software to control ECL DAQ system has been developed and ensures continued stability of the system.
  - ▶ Configuration management.
  - ▶ Initialization.
  - ▶ Quality monitoring.

- Many thanks to ECL expert shifters: their work and feedback ensure efficient operation of ECL DAQ.