Development of Slow Control Package for the Electromagnetic CaLorimeter Trigger System

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Abstract

The Belle II experiment at the SuperKEKB e+e- collider in KEK, Japan does start physics data-taking from early of 2018 with primary physics goal that is to probe the New Physics effect using heavy quark and lepton weak decays. During trigger and DAQ operation upon beam collision, it is important that Belle II detector status have to be monitored in a process of data-taking against an unexpected situation. Slow control system, built in the Control System Studio (CSS) which is a GUI window design tool based on Eclipse, is one of monitoring systems in Belle II operation. Database and archiver servers are connected to slow control system. Experimental parameters are downloaded to Belle II main database server which is based on PostgreSQL. Real-time results are stored in archiver server which is based on EPICS(The Experimental Physics and Industrial Control System) archiver appliances and tomcat which is open-source java servlet container. In this study, we report the development of slow control system for the Belle II electromagnetic calorimeter (ECL) trigger system.

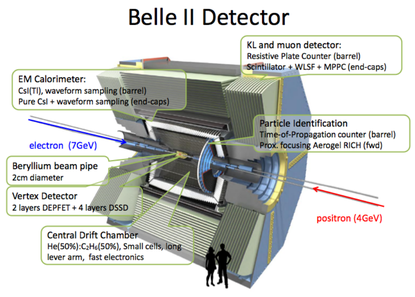
Super KEKB / Belle II & Hardware Trigger System

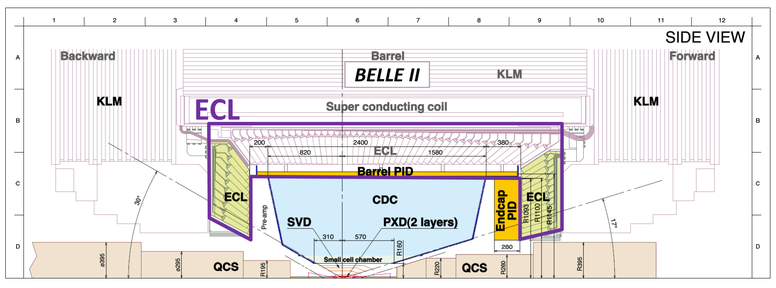
- KEKB / BELLE collected ~1 ab^{-1}, but not enough for the New Physics search.
- The SuperKEKB target instantaneous luminosity is 40x higher than KEKB.
- Anticipated beam background(BG) level in the initial stage of the run is extremely huge and higher than the KEKB.
- Robust and flexible trigger system is indispensable to operate BELLE II against such a BG environment.
- All of Belle II readout and trigger system have been upgraded.

	Belle	Belle II
Data flow	parallel	high-speed serial
Data link	16Mbps	127Mbps
Logic	hard-coded	**FPGA firmware**
Algorithm	2D	3D

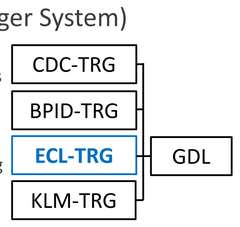
	E(GeV)		β^*y		β^*x		I(A)		L($cm^{-2}s^{-1}$)
	e^+	e^-	e^+	e^-	e^+	e^-	e^+	e^-	-
KEKB	3.5	8.0	5.9	5.9	120	120	1.6	1.2	2.1×10^{34}
SuperKEKB	4.0	7.0	0.27	0.30	3.2	3.5	3.6	2.6	**80×10^{34}**

Belle II Detector



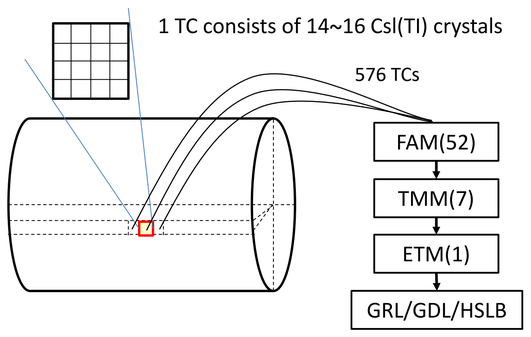


- Trigger requirement
  - TRG efficiency ~100 % for ϒ(4S)
  - Max. TRG rate: 30 kHz at 80 x 10^{34} cm^{-2} s^{-1}
  - Latency < 5 μs
  - Timing precision < 10 ns
  - Min. event separtion: 200 ns
- Sub-Trigger System (Hardware Trigger System)
  - **CDC charged** trigger: Momentum, Position, Charge, and Number of tracks
  - **BPID** trigger: TOP trigger(Barrel PID) Precise timing and hit topology information
  - **ECL neutral** trigger: Total Energy, Isolated Clusters, and Bhabha Counting
  - **KLM** trigger: K_L / μ track information



- GDL & GRL receive sub-trigger information.
  - **Global Decision Logic(GDL)**: Final trigger decision
  - **Global Reconstruction Logic(GRL)**: CDC track & ECL cluster matching
- ECL:
  - 8736 CsI(TI) crystals in total
  - Precise energy measurement

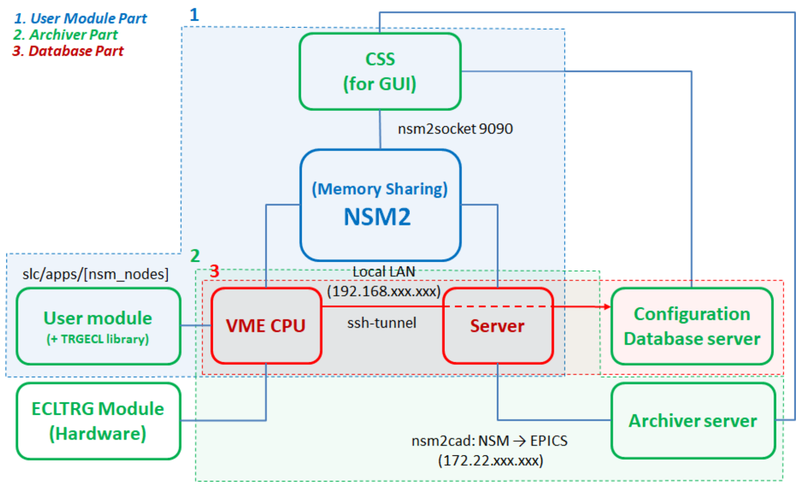
- **ECL Trigger**:
  - Based on 576 Trigger Cells (TC)
    - Physics trigger
    - Bhabha trigger
    - Event timing



FAM	FADC Analysis Module	Kintex 7
• **TC Energy & Timing** decision w/FPGA • Waveform analysis • Apply TC threshold > 100 MeV		
TMM	Trigger Merger Module	Kintex 7
• Merge FAM data and send all TC Energy/Timing to ETM.		
ETM	ECL Trigger Master	Vertex 6
• **Generate trigger** signals on FPGA(Physics & Bhabha trigger). • Send ECL final trigger output to GDL/GRL for global trigger decision, and DAQ system for offline data analysis.		

Slow Control System of ECL Trigger

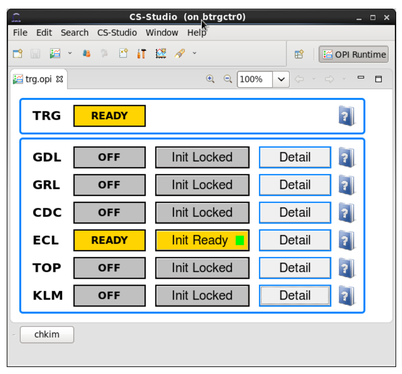
1. User Module Part
2. Archiver Part
3. Database Part



- Updating period is **several seconds**, and this is why the name of the system has "**slow**".
- Accessing to ECLTRG module and archiving outputs from it takes some time(~10^{-1} second) depending on number of them.
- Control, monitor and store data.
- Recognize/handle a simple problem and report a significant one.

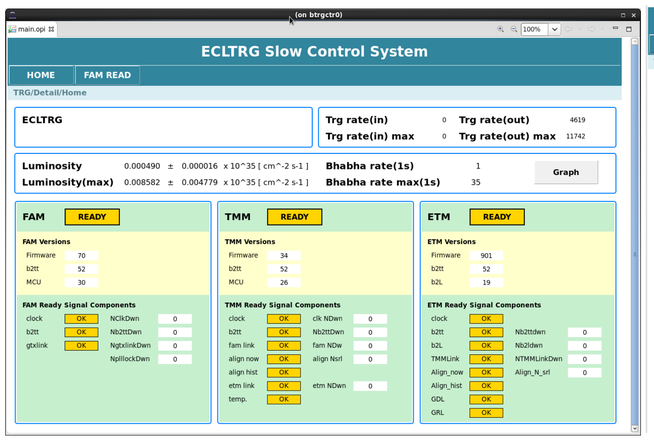
1. User module Part

- **GUI** monitoring module
- ECL Trigger library included



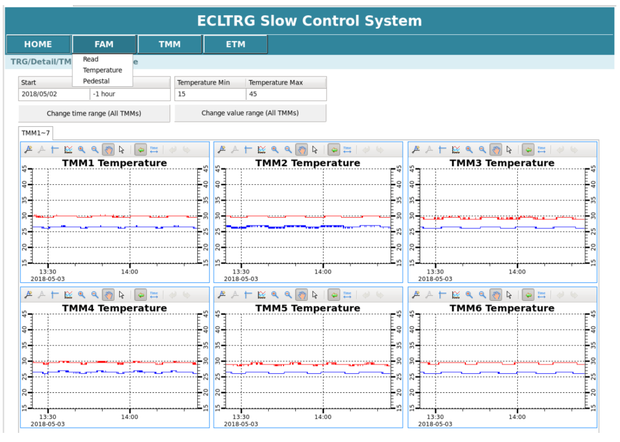
TRGCTR OPI

- **Ready signals** and **initialization** commands of not only ECLTRG but also all sub-trigger should be prepared. Currently, only ECLTRG provides such functions.



ECLTRG OPI

- ECLTRG system consists of FAM, TMM and ETM. This user module shows status of each sub-system such as **version** and **readiness**.



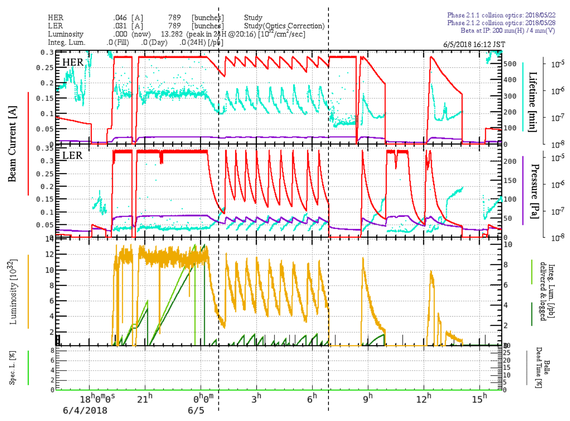
ECLTRG TMM temperature

- Temperature measured by sensor near and far from TMM FPGA.
- TMM temperature data from archiving server are extracted and plotted.
- FAM temperature is also prepared as same style as TMM.

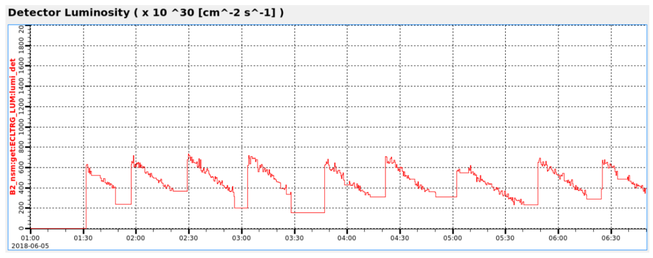
2. Archiver Part

- Based on "EPICS Archiver appliance" and "Apache Tomcat".
- ECLTRG outputs are archived on main archiving server.
- Discussion is required to decide which data should be archived.
- Connection between Archiver and **NSM** through **EPICS** is well established.
- By utilizing CSS data-browser, it is possible to extract data from archiving server and plot on **real-time**.

SUPERKEKB 24-Hour Operation Summary



ECLTRG detector Luminosity



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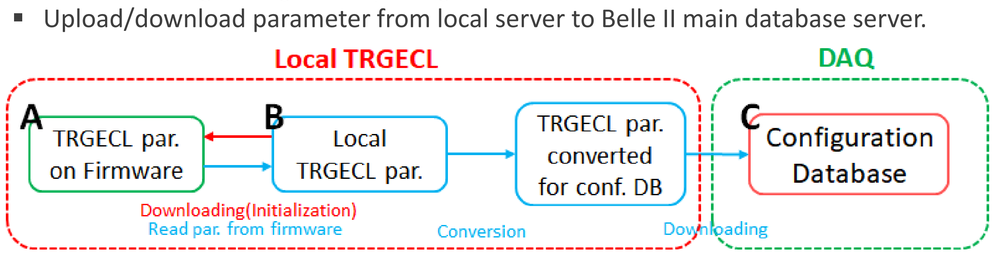
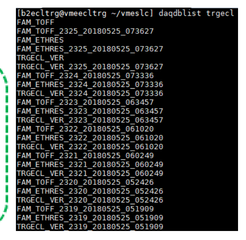
- From above plots, shapes of ECLTRG detector luminosity and SUPERKEKB providing luminosity are **consistent.**
- ECLTRG SLC is not only for **monitoring ECLTRG status**, but also for **SUPERKEKB machine tuning and Beam BKG study**. For such studies, rate of ECLTRG each trigger bit information would be helpful.
- Currently, accelerator luminosity and error of it(2), detector luminosity(1), integrated luminosity(1), averaged hit-rate(4), FAM temperatures(52x2) and TMM temperatures(7x2) are archived.
- Other PVs such as noise(624) and rate of each trigger bit(624) will be also archived.

3. Database Part

- Database using "PostgreSQL" package.
- Upload/download parameter from local server to Belle II main database server.



Schematic of ECLTRG database part



Configuration DB

- When each **run** starts, some of currently applied parameters on hardware such as firmware version(8), fam energy threshold(624) and timing offset(624) are automatically saved on local machine, converted to appropriate format and downloaded to Belle II main database server.
- Other parameters such as pedestal(624) and fitter-CC(303264) will be added.
- Comparing parameters on A, B and C will be added. If all 3 have same value, return 1. Otherwise, 0. This output will be added ECLTRG **ready signal**.

Conclusion

- 1st version of slow control for ECLTRG is prepared.
- ECLTRG initialization, ready signal, version and readiness of each sub-system is included on user module.
- Some ELCTRG parameters are automatically saved on Belle II main database server.
- Several EPICS PVs are archived such as luminosity, averaged hit-rate.
- ECLTRG archived PVs are also helpful to SUPERKEKB developing.