The Event Timing Finder for the Central Drift Chamber Level-1 Trigger at the Belle II experiment

Yuki Sue Nagoya University

Bae Hanwook (University of Tokyo), Toru Iijima (Nagoya University), Yoshihito Iwasaki (High Energy Accelerator Research Organization),
Taichiro Koga (High Energy Accelerator Research Organization), Yun-Tsung Lai (IPMU), Hideyuki Nakazawa (National Taiwan University), Kai Lukas Unger (Karlsruhe Institute of Technology)

Belle II Experiment and Level-1 Trigger

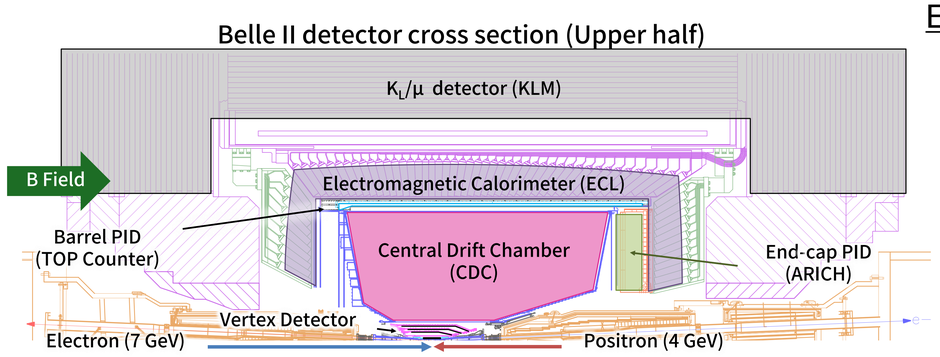
SuperKEKB/Belle II experiment

The SuperKEKB/Belle II experiment aims 30 times peak luminosity of KEKB by higher beam currents and nano-beam scheme to achieve an integrated luminosity of 50 fb^{-1}. The Belle II detector, which consists of several subdetector components, is required to acquire data efficiently under higher background environment.

Belle II Level-1 Trigger System (TRG)

TRG consists of four subdetector triggers and adopts FPGA-based electronics and logics are continuously upgraded.
Requirements to TRG (Excerpt)

- Almost 100% efficiency to interest physics events
- Latency < 4.4 μs
- Precision of event timing decision < 10 ns



Event Timing Decision on Level-1 Trigger

A TRG event timing is determined based on the time information of multiple subdetector triggers, TOP, ECL and CDC, and sent to the Belle II DAQ system.

TOP TRG
It is under development and expected to achieve a resolution of < 5 ns using by Cherenkov photons induced by charged particles.

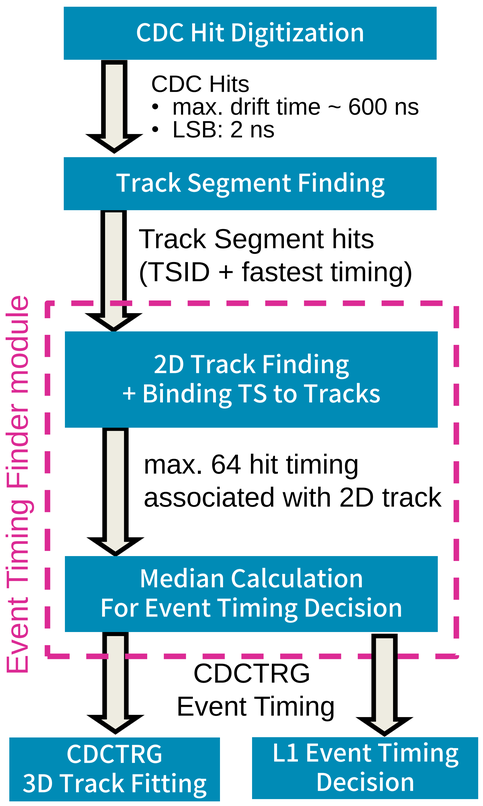
ECL TRG
It is suppling the most of event timing at this moment. The time resolution deteriorates in hadron and low multiplicity events with small energy deposits.

CDC TRG
It detects event timing by finding the earliest hit time (= hit with a short drift distance) among multiple hits induced by charged particles. Background hits is suppressed by reconstructing 2D tracks on FPGA. The accuracy of the event timing of the conventional method is about 20 ns.

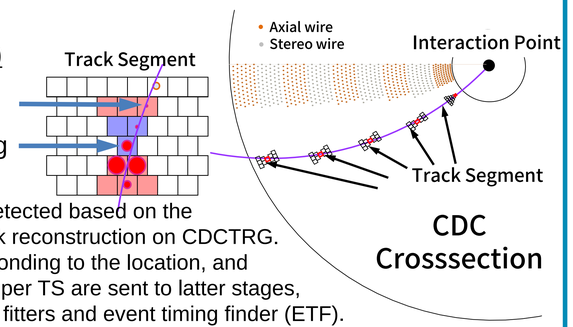
CDC Event Timing Finder Logic

Goal: new CDCTRG module for a timing resolution of 10 ns and higher efficiency for charged track events

Data Flow



Track Segment (TS)



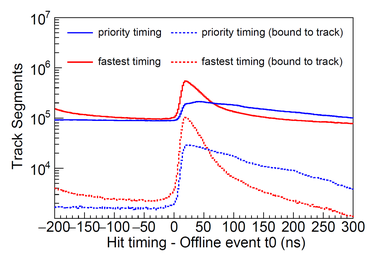
Track Segment (TS) is detected based on the 5-layer hit pattern for track reconstruction on CDCTRG. The TS ID, which corresponding to the location, and one hit timing information per TS are sent to latter stages, 2D track finders, 3D track fitters and event timing finder (ETF).
Hit timing information in a specific layer called "priority timing" (blue line) is used for trigger track reconstruction. Instead, The earliest hit timing in TS called "fastest timing" (red line) is newly implemented and sent to the new ETF logic.

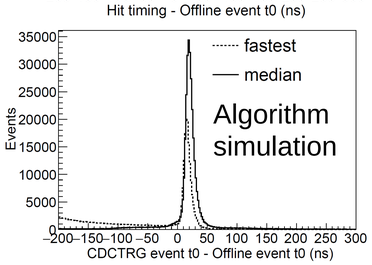
2D Track Finding

There are huge background hits derived from beam background, crosstalk and so on. To reduce these hits, only the TS timing associated with the found 2D track is used in the event timing calculation. The tracks are reconstructed by a 2D Hough transform.

Event Timing Decision

Finally, the event time is determined based on the time information of up to 64 TS. By selecting the median of multiple timings, good time resolution of around 10 ns is achieved while suppressing the effects of residual background hits.

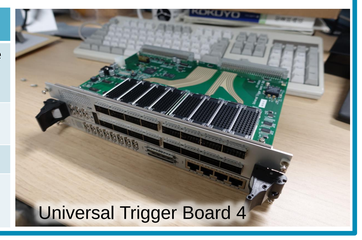




Universal Trigger Board 4

The Universal Trigger board (UT) is a general-purpose FPGA board for TRG. In order to realize more complicated and better performance logic, we developed UT4 as an upgrade from the UT3, which we have been using so far. The ETF logic is implemented in UT4, and other modules are being replaced with UT4 in sequence.

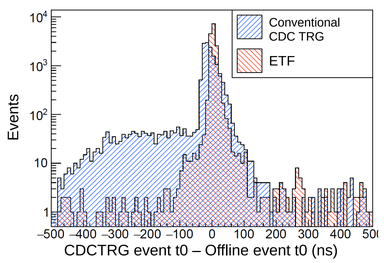
	UT3	UT4
Main FPGA	Virtex 6 VC6VHX 380/565T	Virtex7 UltraScale XCVU 080/160/190
Sub FPGA	-	Artix 7 XC7A15T
Logic gates	382k / 580k	975k / 2027k
Optical bandwidth (Total)	530 Gbps	1300 Gbps


Universal Trigger Board 4

Performance in e^+e^- Collision

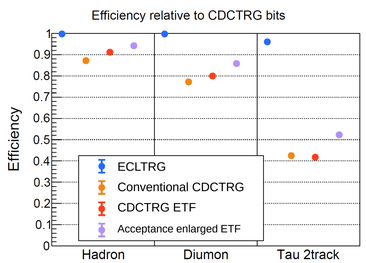
Time resolution

ETF have achieved a time resolution of 10 ns in std. dev., which is about half resolution of existing CDCTRG. In the hadron event with a large number of tracks, a resolution of about 5 ns is achieved.



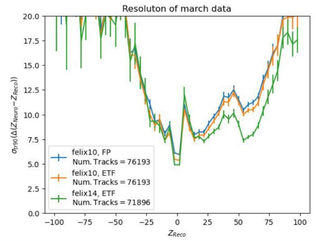
Efficiencies

The efficiencies of event timing for charged-track events are improved from conventional CDCTRG by better time resolution and extended acceptance.



3D track fitting

An ETF event timing improves the vertex resolution of 3D track reconstruction using a Neural Network. This is expected to reduce the L1 TRG rate that is triggered by beam background tracks emitted out of interaction point.



Summary

- A new module for the CDC trigger is developed to improve the event timing resolution on TRG for charged tracks.
- The new logic that introduced the fastest timing and median calculation was implemented to improve the accuracy.
- It was confirmed that the time resolution and efficiency were improved as expected in a beam collision operation.