Development of the Level-1 Trigger system in the Belle II experiment

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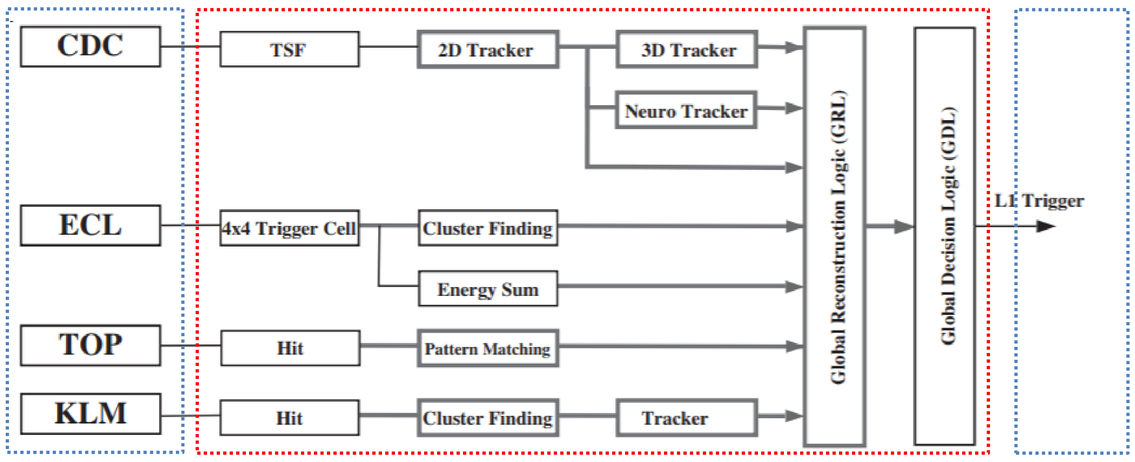
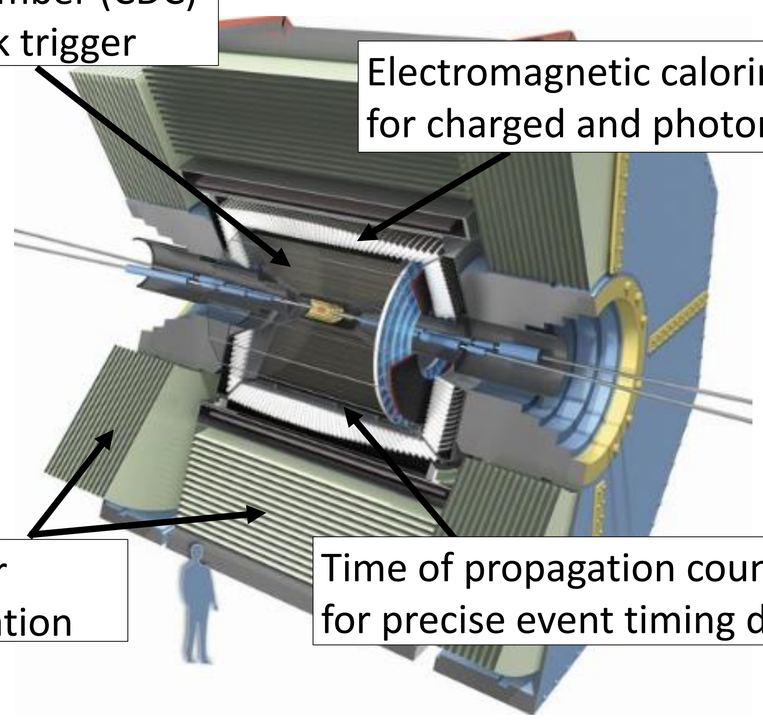
Belle II Level-1 trigger system

-Belle II and superKEKB: high luminosity e+e- collider
-High trigger efficiency for various physics targets: B, D, τ, dark
-Level-1 requirements: 30kHz rate, 4.4μs latency, 10ns event timing resolution



□ board with FPGA
—optical transmission

Belle II detector



Universal Trigger board (UT)

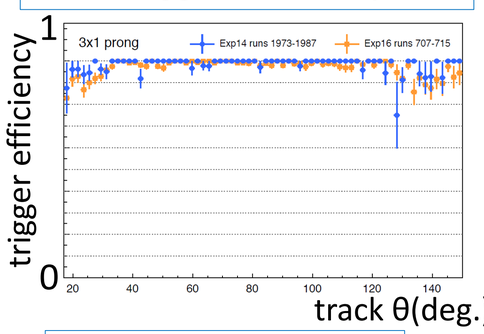
-Universal FPGA board developed for Belle II
-QSFP optical transceiver (GTX,GTH,GTY)
-Register access through VME
-Total ~30boards, common in subtrigger

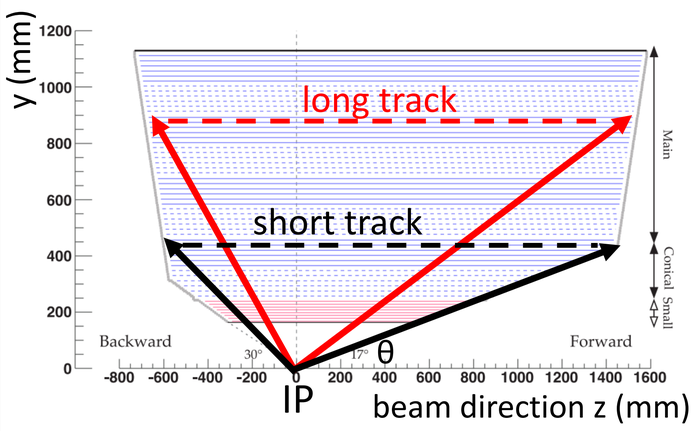
UT	3rd generation	4th generation
FPGA	Xilinx Virtex6 XC6VHX380/565T	Xilinx Virtex Ultrascale XCVU080/160
Logic gate	382k/580k	975k/2026k
IO	GTH 11Gbps × 24lane GTX 6Gbps × 40lane NIM, LVDS, RJ45 JTAG, VME bus	GTY 25Gbps × 32lane GTH 15Gbps × 32lane NIM, LVDS, RJ45 JTAG, VME bus

CDC trigger

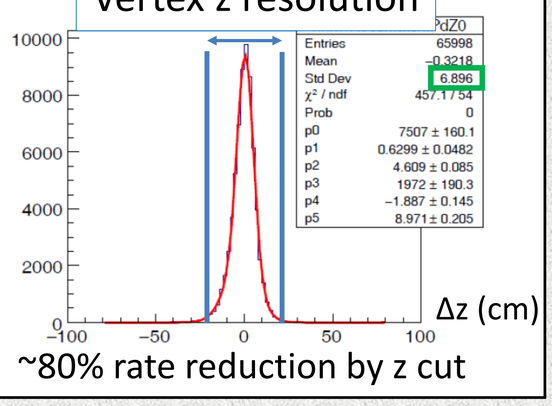
-Trigger charged particle
-Various tracking algorithms
  -Hough transform: long track finding
  -**Neural network**: vertex measurement
  -Pattern matching: short track finding

Track trigger efficiency for τ



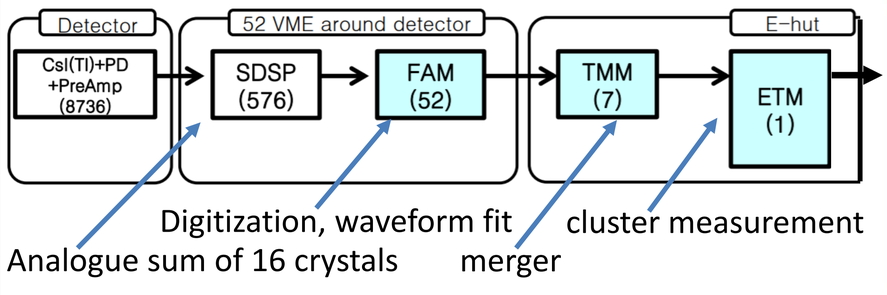


Vertex z resolution

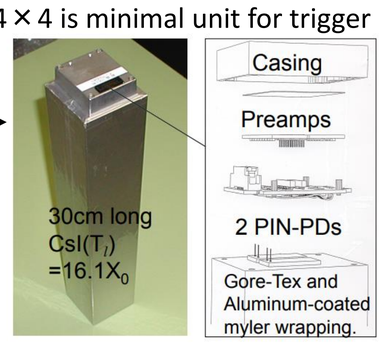


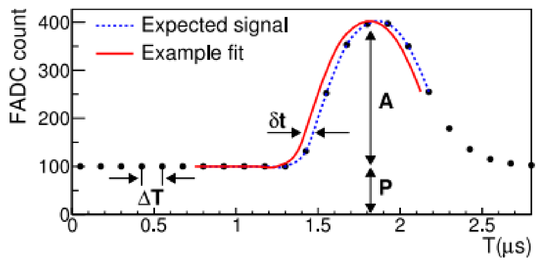
~80% rate reduction by z cut

ECL trigger

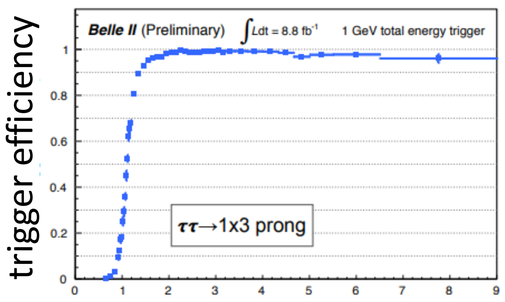


total 8736 crystal
4 × 4 is minimal unit for trigger





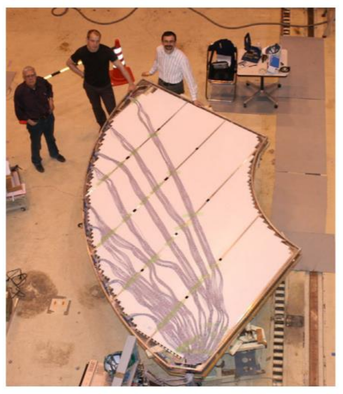
energy trigger efficiency for τ

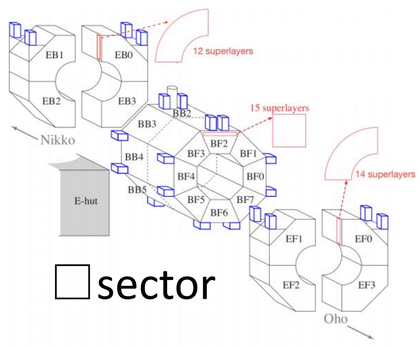


-Measure energy and cluster
-Digitization with waveform fit
-Clustering nearby crystals

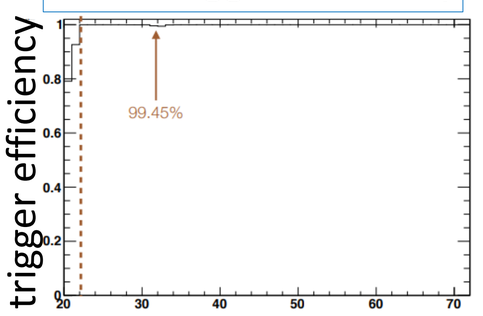
KLM trigger

Frontend → MUX → Count #hits → back to back judgement





Muon trigger efficiency

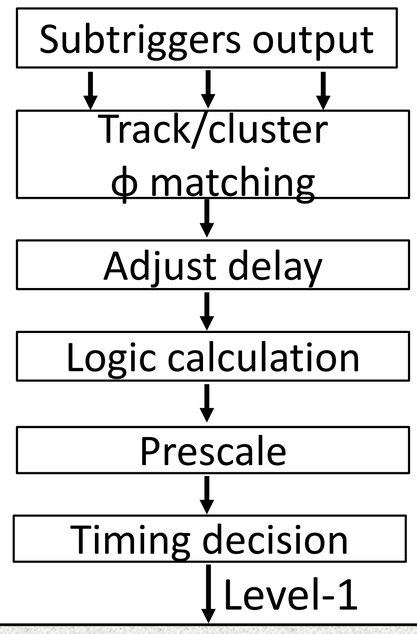


-Sandwich structure of Iron and scintillator/RPC
-Detect muon by counting #hits in each sector (>4hits required)
-Matching with CDC and ECL on GRL for single muon trigger

GRL/GDL and Trigger conditions

-GRL/GDL: combine all subtriggers information and decide Level-1 trigger
-Trigger conditions: 100% efficiency for BB pair. Special conditions for τ and dark physics.

Physics target	Main trigger conditions	Raw rate (KHz) Luminosity=1.5 × 10^{34}/cm^2/s
B physics	CDC three long track	0.13
	CDC two full track Δϕ>90deg.	0.19
	ECL four clusters	0.11
	ECL total energy>1GeV	0.56
τ physics	KLM single muon with ECL/CDC matching	0.13
	CDC single long track with p > 0.7GeV/c	0.44
	CDC two long/short tracks Δϕ>90deg.	0.36
	ECL three clusters, one of them E>0.3GeV	0.50
Dark physics	CDC two full track Δϕ>30deg	0.22
	ECL only one cluster E>0.5GeV at barrel	0.40
	ECL two clusters back to back	0.20
Total Level-1	OR of all conditions	2.5



Summary

-Belle II Level-1 trigger system has been developed for taking various physics events

-Trigger rate, efficiency and latency satisfy their requirements

-Next step is to upgrade the Level-1 system for the incoming higher luminosity and background