# Electromagnetic Calorimeter Upgrade for Belle2
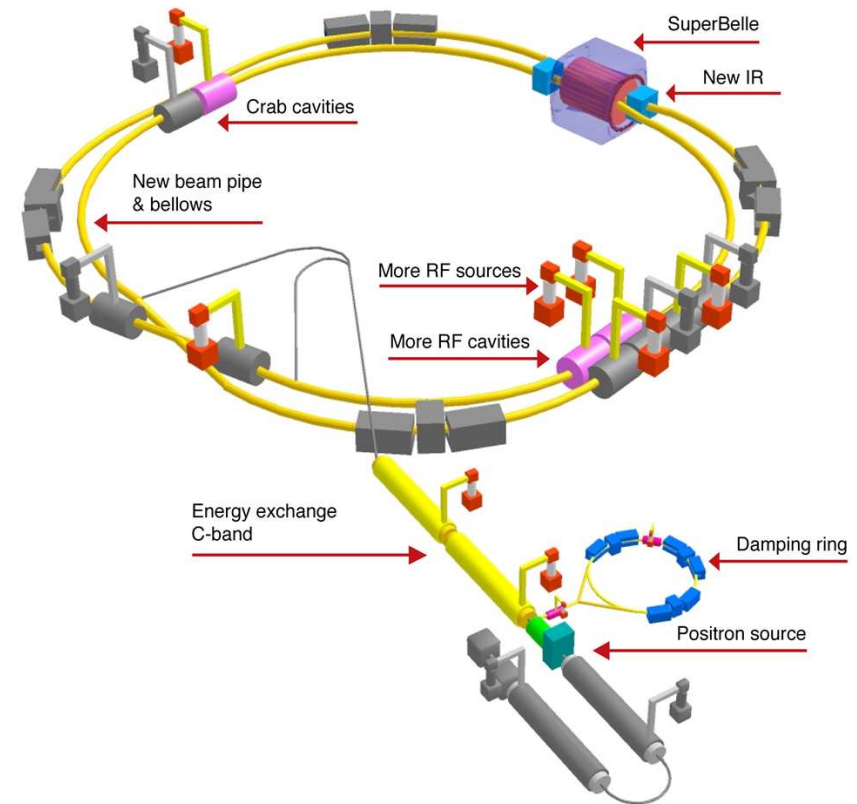
中村 勇 / 高エネルギー研

# SuperKEKB Collider

❏ **Higher Inst. Luminosity (×40 KEKB)**

- Small Beam
  - ◇ 1/20 $\beta_y^*$ (5.9/5.9 $\Rightarrow$ 0.27/0.41 mm)
  - ◇ low emittance beam
- ×2 Higher Current (1.6/1.2 $\Rightarrow$ 3.6/2.6A)
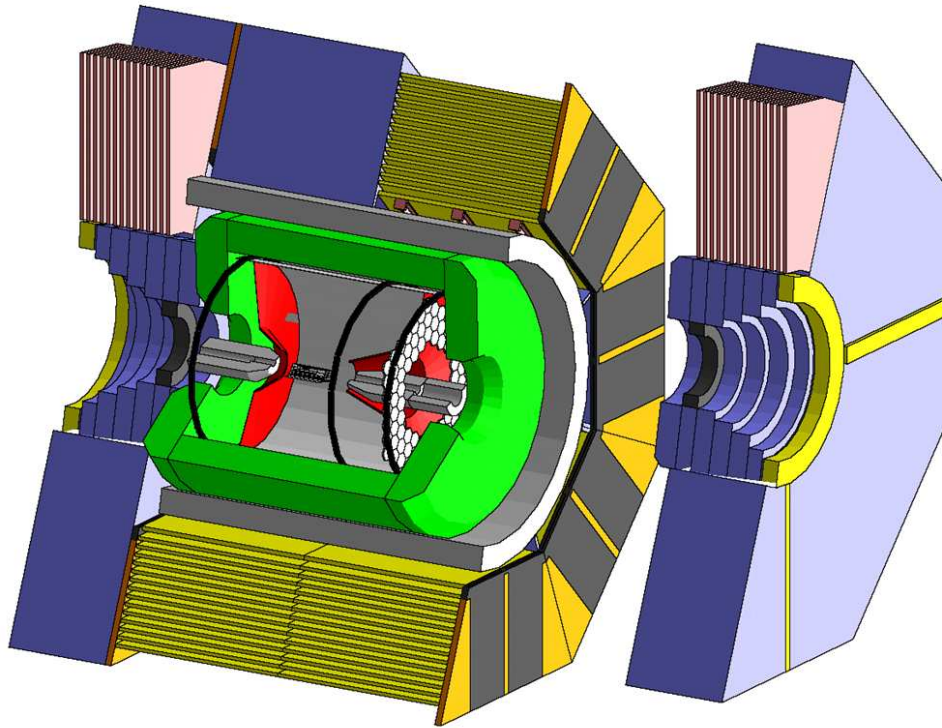  - ◇ 50% more bunches
  - ◇ 50% more bunch current
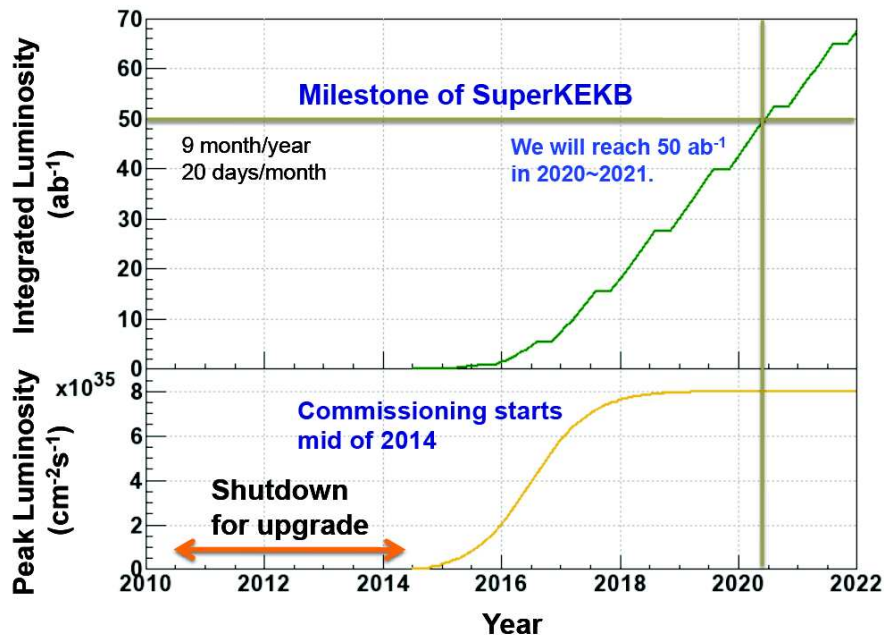
**The SuperKEKB**





❏ Inst. Lumi. $\Rightarrow$ 8 ×$10^{35}$/cm$^2$s or 800/nb/s

❏ Int. Lumi. $\Rightarrow$ 50 ab$^{-1}$

# The Belle2 Detector



**Same or better performance under,**

❏ 10–20× background

- Touschek
- Radiative bhabha

❏ Trigger Rate ~20 kHz

❏ **Vertexing**

- 2 layers DEPFET Pixel ($1cm\phi$ beampipe)
- 4 layers Double Sided Silicon Strip

❏ **Tracking**

- smaller cell drift chamber

❏ **PID**

- Time of Propergation Cherenkov
- Aerogel RICH

❏ **Calorimeter**

- Waveform Readout
- Faster Crystal in Endcaps

❏ **Muon and $K_L^0$**

- Scintillator strip + MPPC

# The Belle Calorimeter (1)

❏ **Requirement to the Calorimeter**

- Detection of $\gamma$ and $\pi^0$
- Good Energy Resolution from Low $E$
  - ◇ 10 MeV to 10 GeV
  - ◇ $\sigma$ has linear effect for some physics
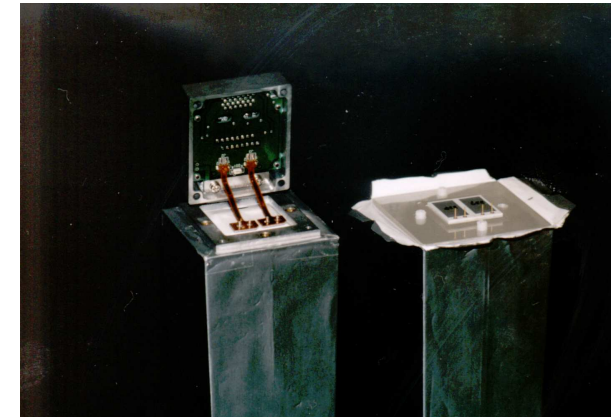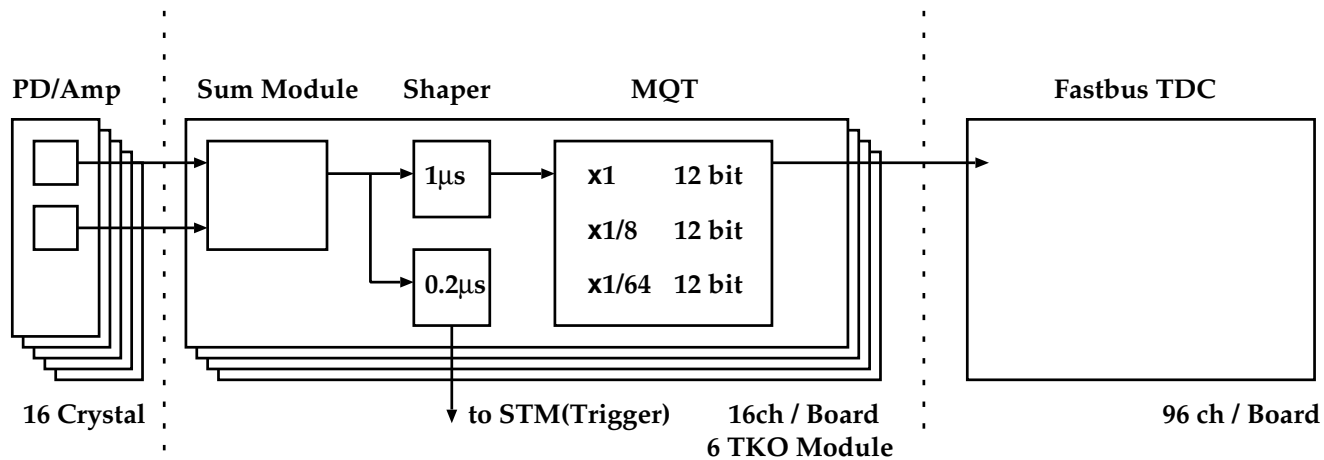- Hermeticity for final state with $\nu$
- Rate resistance

❏ **8736 CsI(Tl) Crystals**

- 5.5×5.5×30 cm$^3$
- 6624(B)+1152(FWD)+960(BWD)
- 12° ↔ 155°
- $\lambda$ =560 nm/$\tau$ =1.3 $\mu$sec (Slow)
- 50000 p.e./MeV (No stochastic term)
- 98 Different Shapes
- Read out by two PIN photodiode (Hamamatsu S2744-08)

**The Belle Calorimeter**



BELLE CsI ELECTROMAGNETIC CALORIMETER
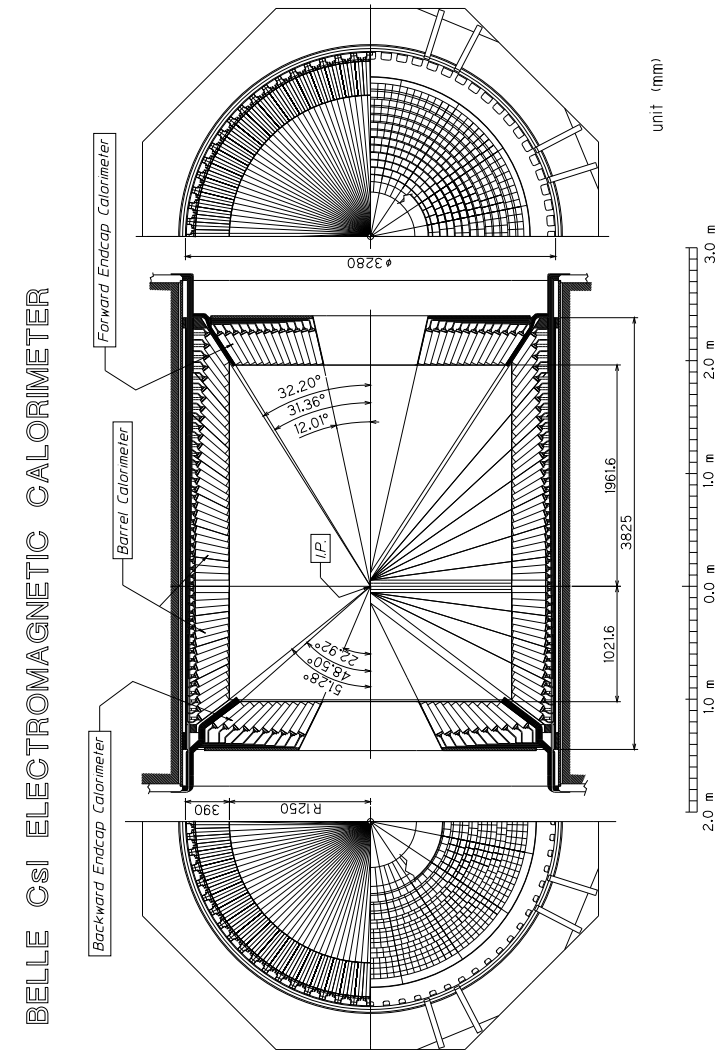
# The Belle Calorimeter (2)



❏ **Readout Electronics**

- Preamplifier (Charge Integration)
- Two Shapers
  - ◇ $1\mu$sec for $E$ measurement, $0.2$ $\mu$sec for Trigger
- $Q \to T$ Translation, LeCroy MQT300A (12 bit×3 ranges)
  - ◇ 16ch/Board (TKO)
- Recorded by FastBus TDC, LeCroy 1877S (16 bit, C.Start)
  - ◇ 96ch/Board (5 Crates), 3 VME Systems
  - ◇ Readout Deadtime ($\sim$ 30 $\mu$sec)
- Energy information Only, no Timing

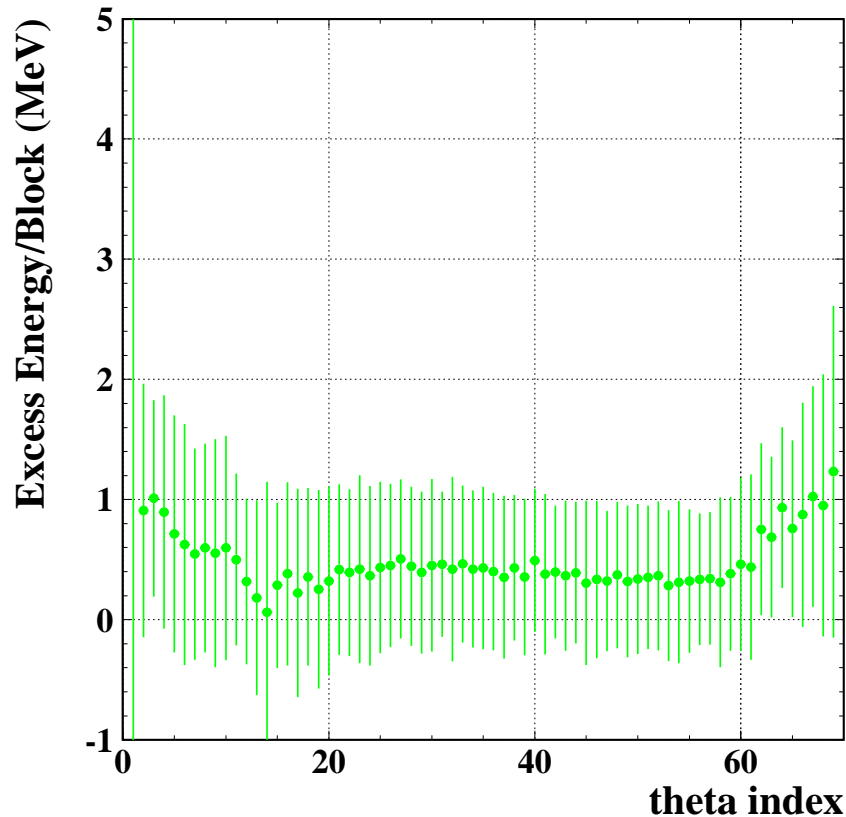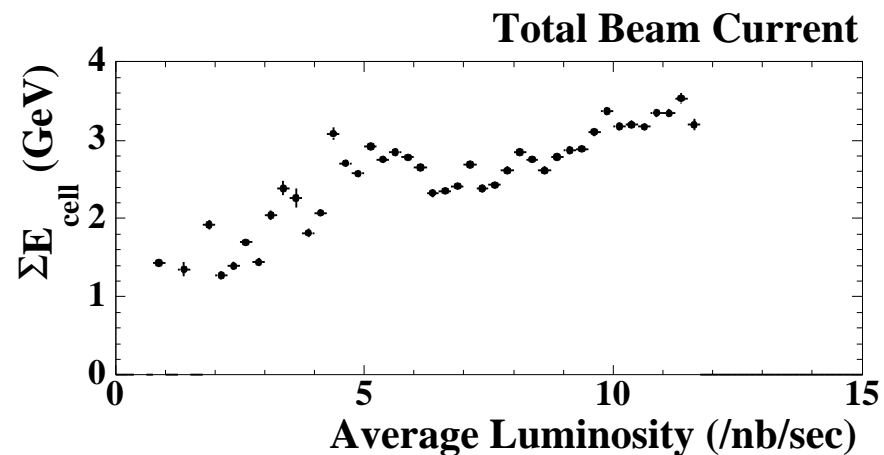# The Belle Calorimeter (3)
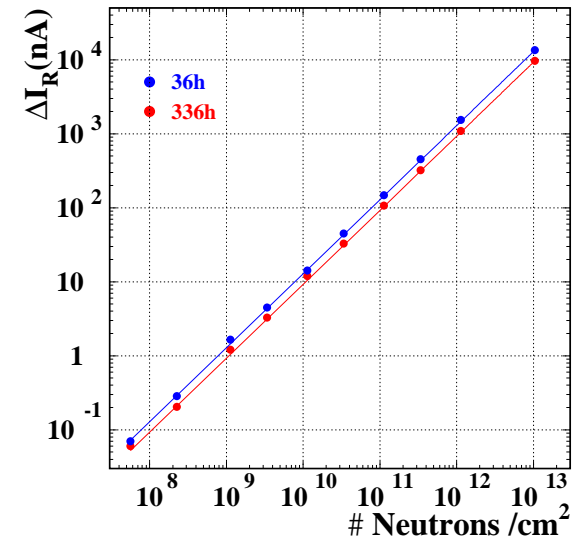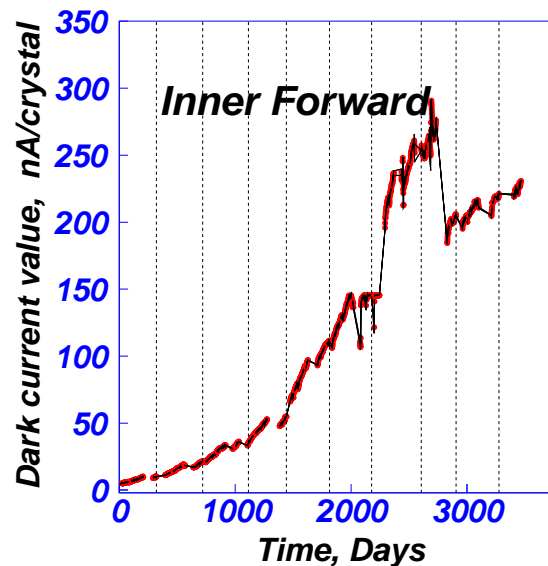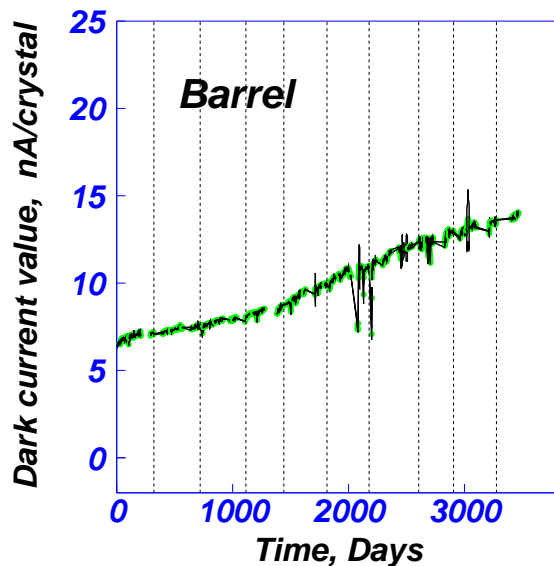


❏ One dead channel (bias circuit broken)

❏ Light output decreasing 5–10%

❏ Dark current increasing

- • mostly from neutrons
- • ~ $10^{11}$ neutron/cm² fluence
- • 1–4 Gy $\gamma$-ray dose

# The Belle Calorimeter (4)



**Energy/Crystal v θ**

**Energy Deposit in Random Event**

- ❏ Energy deposite in Random Event: 0.5 MeV/Crystal or 3 GeV/ECL

- ❏ "Probably" proportional to Beam current

- ❏ × 3–10 background will be rough estimation

- ❏ Fine segment in time will be necessary

# Upgrade Plan

- ❏ **Expected Situation @ 8×10³⁵**

  - Trigger Rate as high as 20 kHz
  - ×10? Background

- ❏ **Solutions**

  - Pipelined read out
  - Waveform sampling (Timing Info.)
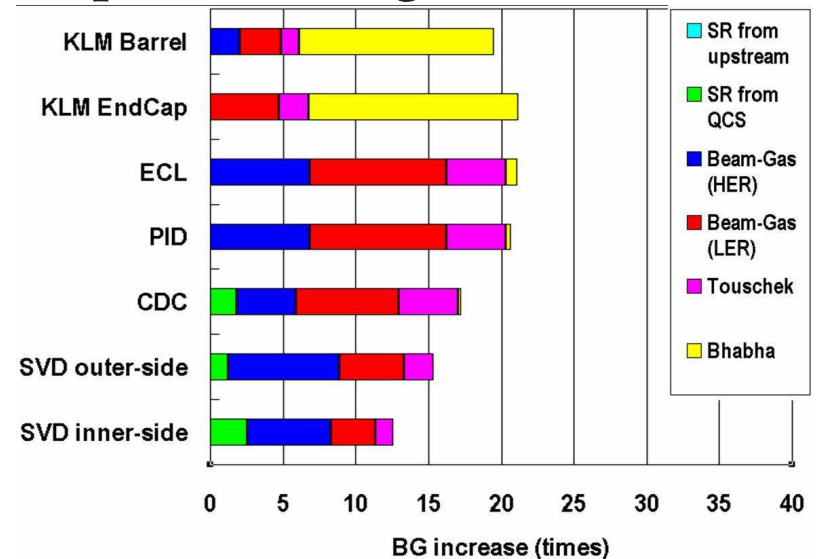  - Faster Crystal

- ❏ **Restrictions**

  - Budget (several 億円, at most)
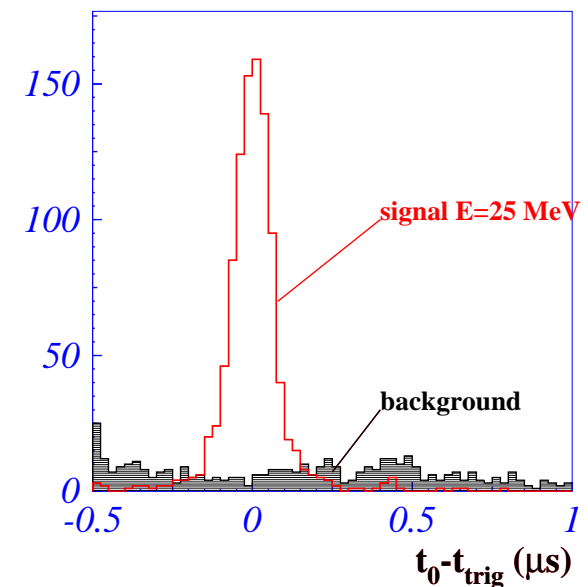  - Human Resources
  - Barrel Replacement Impossible

- ❏ **Decided so far**

  - DAQ part will be upgraded
  - Crystal replacement postponed

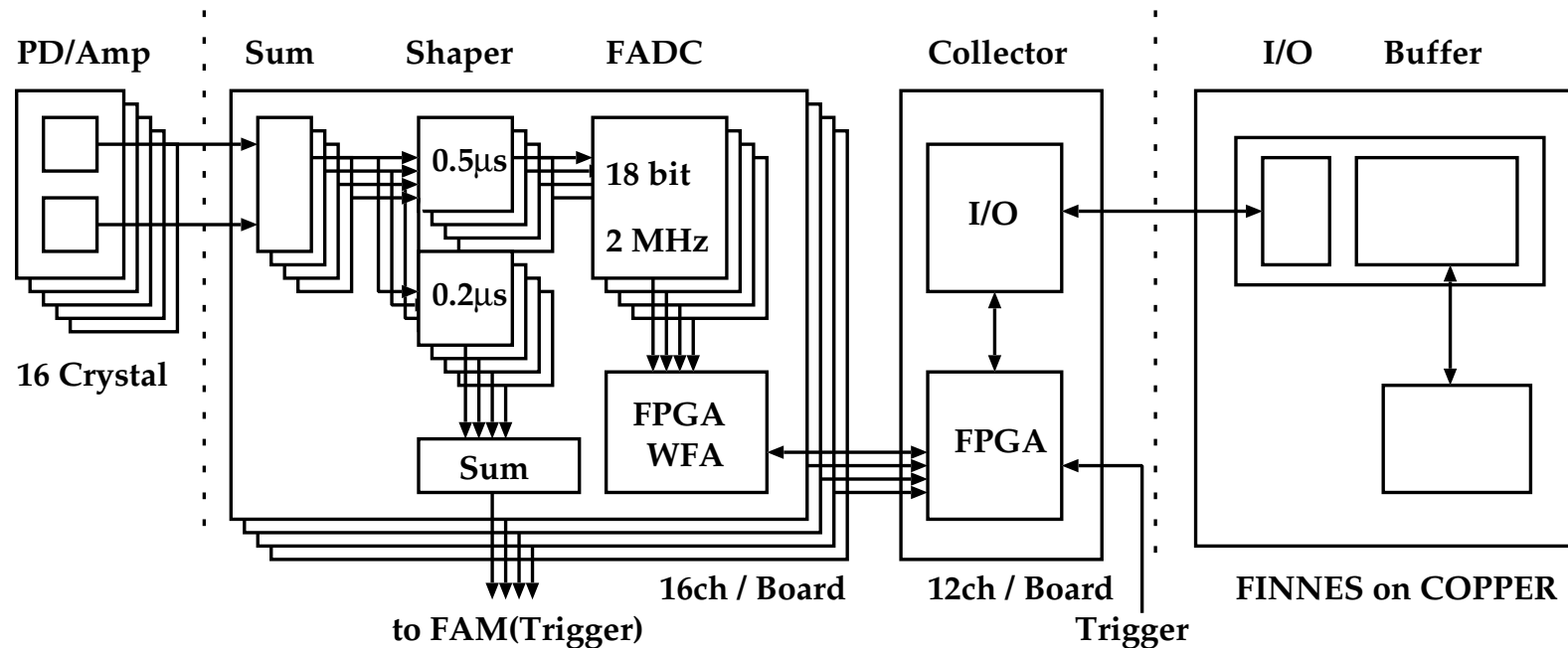## Expected Background Increase



## Simulated Timing Distribution

# ECL Upgrade Plan – DAQ



❏ Faster Shaping Time $1\mu s \to 0.5\mu s$

❏ Waveform Sampling with 18 bit 2MHz ADC

❏ On board FPGA for Waveform fitting

❏ Collector Board to marge data upto 12 Shaper/ADC/DSP board

❏ common I/O Collector $\Leftrightarrow$ FINESSE for Data/Parameter/Firmware transfar

❏ Factor ~7 reduction of background

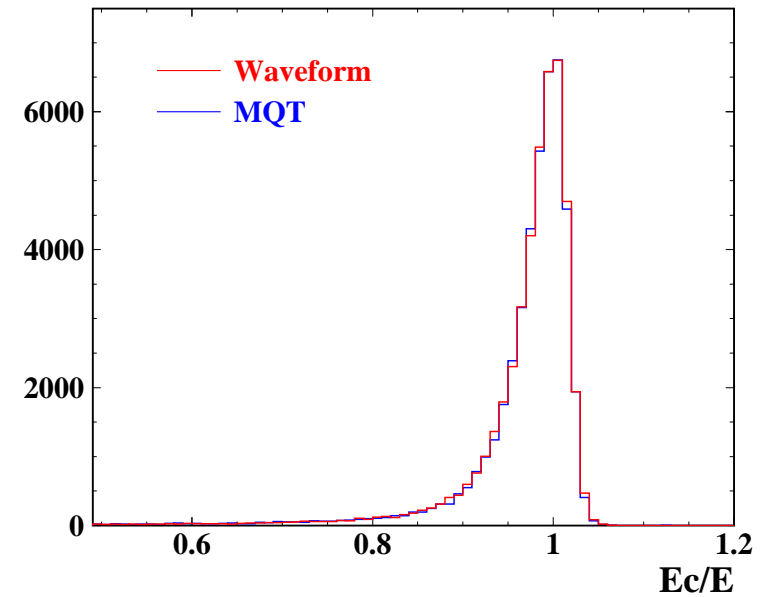# Status – TKO –

❏ was build when TKO was the option

- production by 豊伸電子
- WF part is the same as VME version
- Trigger part same as OLD shaper

❏ WFA done in the backend

❏ Eight set of boards installed in BWD

- Test with real experiment

❏ Real data taking from Summer 2009

- Energy resolution as good as MQT board
- Timing analysis on going

**TKO Shaper Prototype**



**Energy Reconstructed**

# Status – VME –

❏ VME readout board

- 2nd prototype delivered (Sep.2009)
- WFA done in FPGA on board
- Analog sum for Trigger signal
- connection to Collector/FINESS implemented

❏ Collector Board

- 1st prototype delivered (Dec.2009)
- recieve signal from upto 12 boards
- can generate calibration signal
- temporary FiberIO Implemented

❏ Boards being tested

**VME Shaper Prototype**



**Collector Prototype**
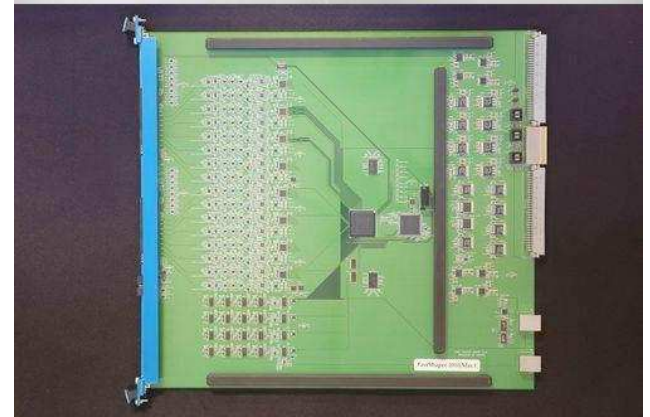
# Faster Crystal

❏ **Not approved yet**

- Crystals too expensive
- less background at the beginning
- more simulation required
- Continue R&D

❏ **Baseline is CsI(Pure) + Phototube**

- 2112 CsI(Pure) crystals with same geometry
- $\tau = \mathcal{O}(10)$ ns, $\lambda = 310$ nm, ~1/10 L.O.
- 2" short PMT (Hamamatsu)
- Fast Shaping (30 ns)
- 3×12bit FADC/42MHz sampling

❏ **Other Options**

- CsI(Pure) + APD
- BSO + APD
- PWO2 + APD

# 纏め

❏ **SuperKEKB/Belle2**

- 800/nb/s (40×KEKB)
- 50 /ab (50×KEKB)
- ~ 10× background
- Trigger Rate ~ 20 kHz
- Same or Better detector performance in Higer background

❏ **ECL DAQ upgrade**

- Waveform Analysis (0.5 $\mu$s)
- Pipelined Readout
- Factor 7 Improvement

❏ **Crystals R&D**

- CsI(Pure) + Phototube + WFA (30 ns) promissing
- Other Crystals (BSO, PWO2) in progless

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