

Beam aborts status

The 23rd KEKB Accelerator Review Committee

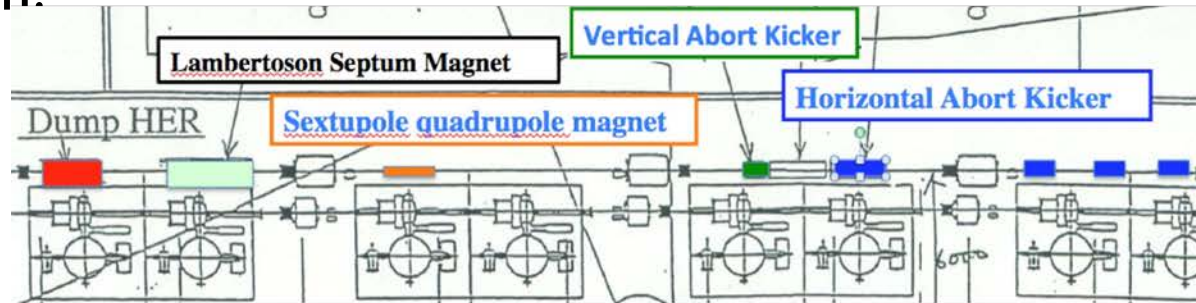
2019/7/8 H.Ikeda

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1. SuperKEKB Abort System

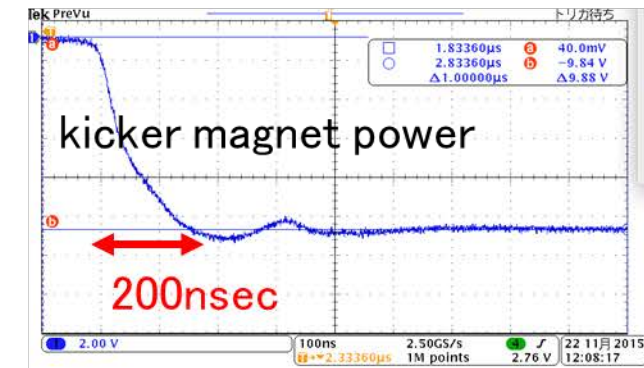
In order to protect the hardware components of the detector and the accelerator against the high beam currents, we installed the controlled abort system.



Dumped beam length : one revolution time ($10\ \mu\text{s}$).

Build-up time of the magnetic field of abort kicker magnet : 200 ns
(empty bucket space).

Synchronization of the kicker timing and the abort gap timing is required for the protection of hardware.

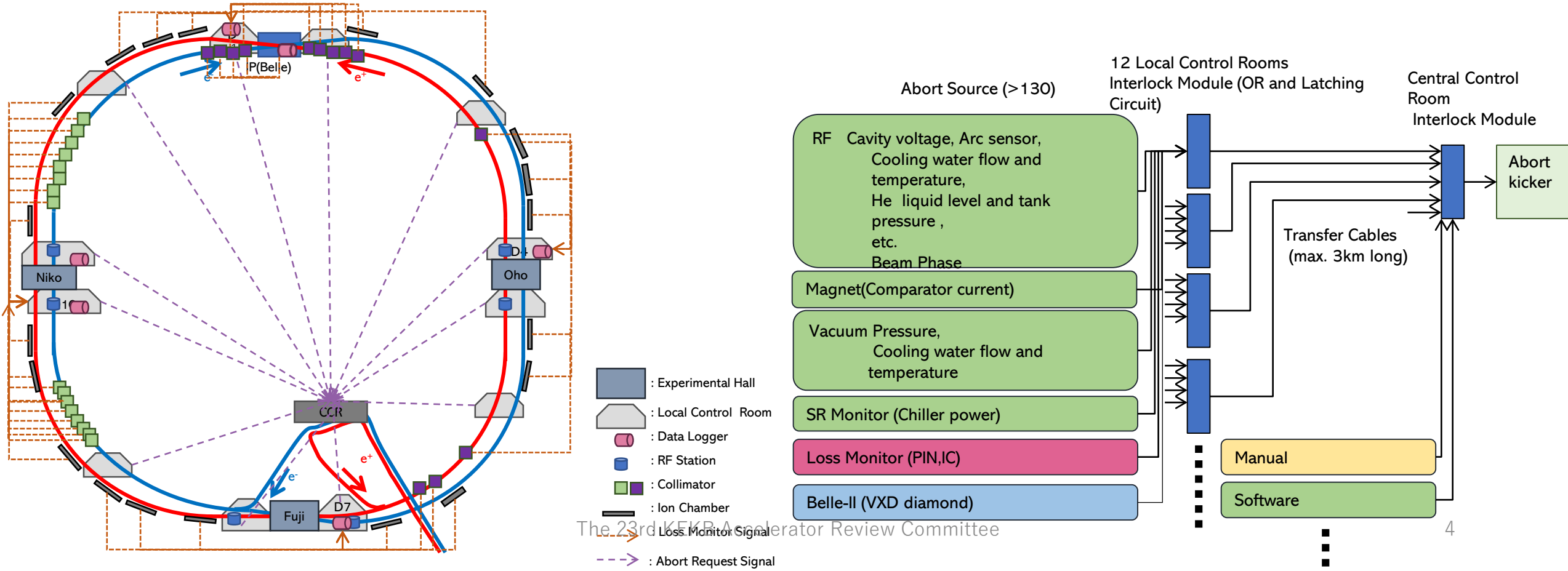


T. Mimashi

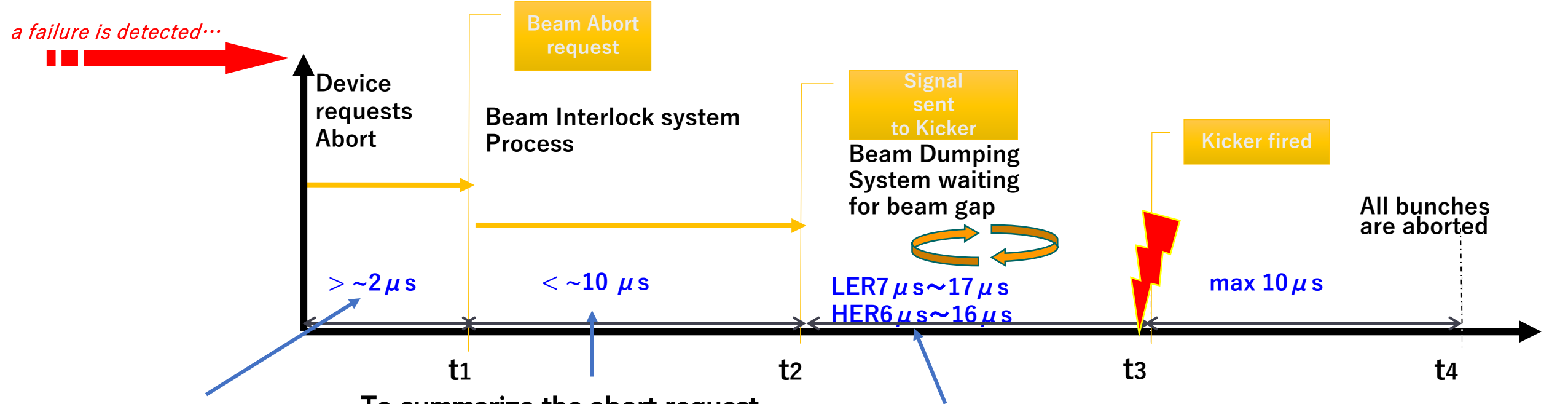
Abort Trigger

The abort request signals from each hardware component are collected in 12 local control rooms (LCRs).

The request signals from LCRs, software abort request signals, and manual abort request signals are collected in the central control room and the abort kicker trigger is sent to the abort kicker.



Beam Abort Delays



Hardware dependent

To summarize the abort request on the beam abort system.

Depends on the optical cable length **from the local control room to CCR.**

10 μs for D1, D2(near Belle-II),

2 μs for D7 or D8

Synchronization of the abort request signal with revolution in FPGA. : Max delay=10 μs

Delay to synchronize to the abort gap(fixed delay) : 4.2 μs for LER, 2.8 μs for HER

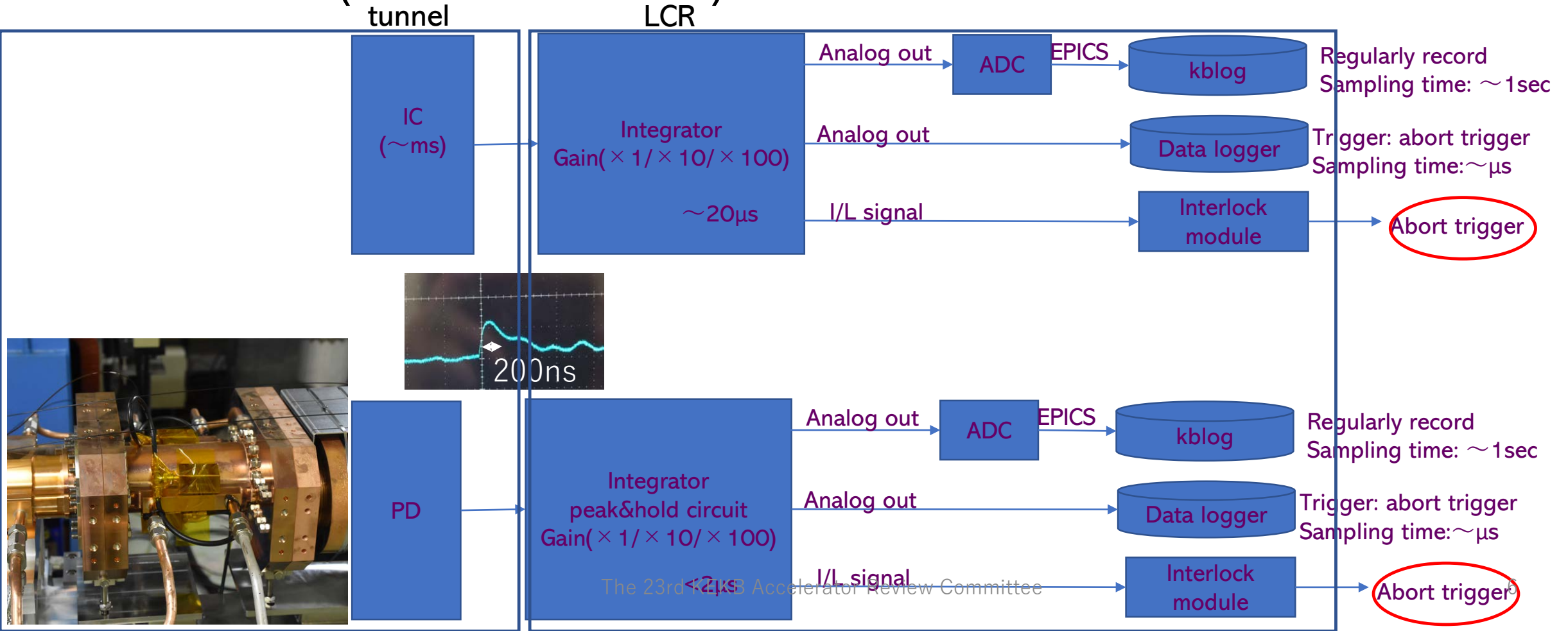
Delay from CCR to kicker (400m) : 2 μs

Thyratron ON :1 μs

Rise time for the kicker : 200ns

Loss Monitor Abort

- Free Air Ion Chamber (20D co-axial cable) : whole ring to cover a wide range in space.
- PIN Photodiode (2.65mm × 2.65mm) : downstream of Collimator and other.

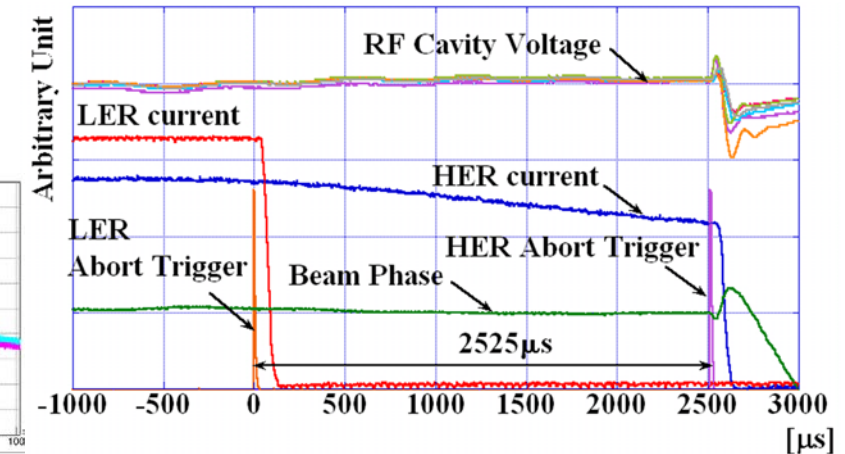
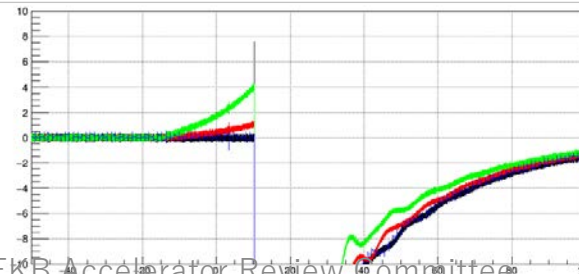
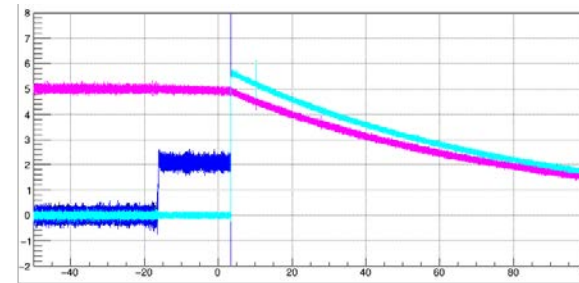
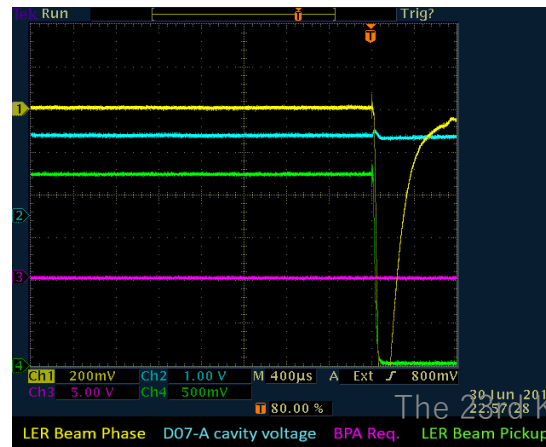


Abort analysis

- Abort Timestamp Log (Control)
 - The order of abort trigger received at LCR is logged.
- Each group prepares the logging system.
 - Abort trigger is input as reference.
 - Monitor (LM, TbT BPM)
 - QCS
 - RF
 - Belle-II

2019/05/28

RING	MESSAGE	DATE	DELTA
HER	Loss Monitor TSUKUBA B4	2019-05-28 01:32:28.137148700	0.000000000
HER	Loss Monitor D7-3	2019-05-28 01:32:28.137191600	0.000042900
LER	Loss Monitor D7-5	2019-05-28 01:32:28.137911100	0.000762400
HER	Loss Monitor D7-5	2019-05-28 01:32:28.137911300	0.000762600
LER	RF D5-F	2019-05-28 01:32:28.137953400	0.000804700
LER	Loss Monitor D7-1	2019-05-28 01:32:28.137956200	0.000807500
HER	RF D10-C	2019-05-28 01:32:28.140236900	0.003088200
HER	RF D11-C	2019-05-28 01:32:28.140282200	0.003133500
HER	RF D11-D	2019-05-28 01:32:28.140301300	0.003152600
HER	RF D10-D	2019-05-28 01:32:28.140529200	0.003380500
HER	RF D11-A	2019-05-28 01:32:28.140694500	0.003545800
HER	RF D10-B	2019-05-28 01:32:28.140896100	0.003747400
HER	RF D11-B	2019-05-28 01:32:28.141427200	0.004278500
HER	RF D10-A	2019-05-28 01:32:28.145618800	0.008470100
LER	QCS Quench I/L	2019-05-28 01:32:28.150796900	0.013648200
LER	QCS Quench I/L	2019-05-28 01:32:28.150797000	0.013648300
HER	QCS PS OFF I/L	2019-05-28 01:32:28.200838300	0.063689600
HER	Soft Abort	2019-05-28 01:32:28.917360300	0.780211600
LER	Soft Abort	2019-05-28 01:32:28.917385400	0.780236700



2. QCS quench abort @Phase-III

	Day/time	Reason	Ring	Vacuum Spike	1 st Abort trigger
1	5/28 01:32 - 22:20	QC2LE PS trouble	HER	-	LM@D1H5 collimator
2	5/31 19:49 - 22:00	Beam loss	LER	D06_L07 3.98E-7 Pa (B2P_65)	LM@D6V2 collimator
3	6/6 14:53 - 18:19	QC2LE PS trouble	HER	-	Belle2 VXD diamond
4	6/9 22:11 - 6/13 19:01	Beam loss (155mA)	LER	D02_L18 3.64E-5 Pa (D02_V1 collimator) D05_L20 9.64E-8 Pa (between D05 ARES and wiggler) D06_L25 4.86E-7 Pa (D06_V2 collimator) D11_L22 8.35E-7 Pa (NIKKO D11 wiggler)	Belle2 VXD diamond
5	6/27 11:41 - 12:34	Beam loss	LER	D03_L20 1.17E-7 Pa (B2P_96)	Belle2 VXD diamond

Threshold and range of Belle-II VXD diamond abort was changed at 6/5.

Ex1. 5/28 01:32 QCS quench (HER)

- Caused by QCS PS problem.
- The beam loss was detected at D1H5 collimator.
- QCS quench I/L $\sim 13\text{ms}$
- QCS PS OFF I/L $\sim 63\text{ms}$

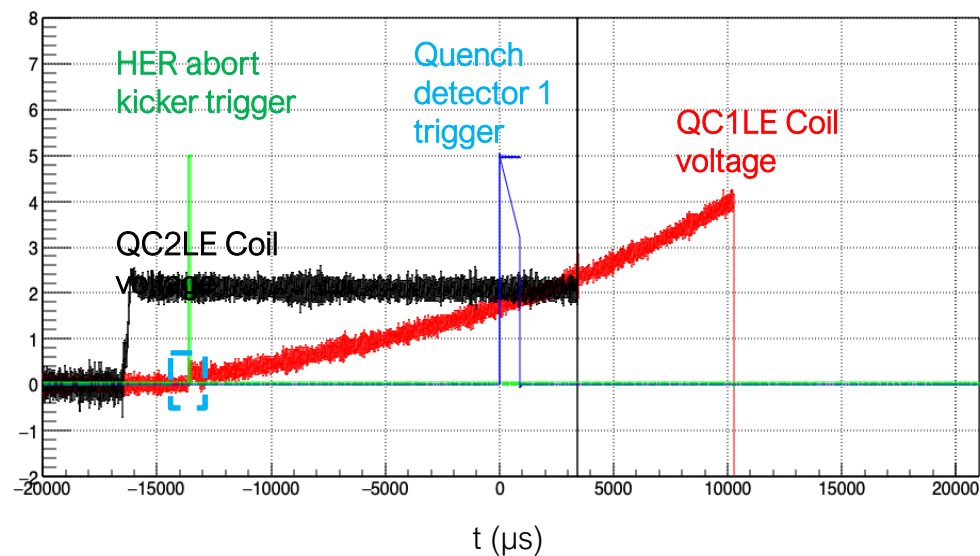
Abort Timestamp Log Viewer

2019/05/28

01:32:28

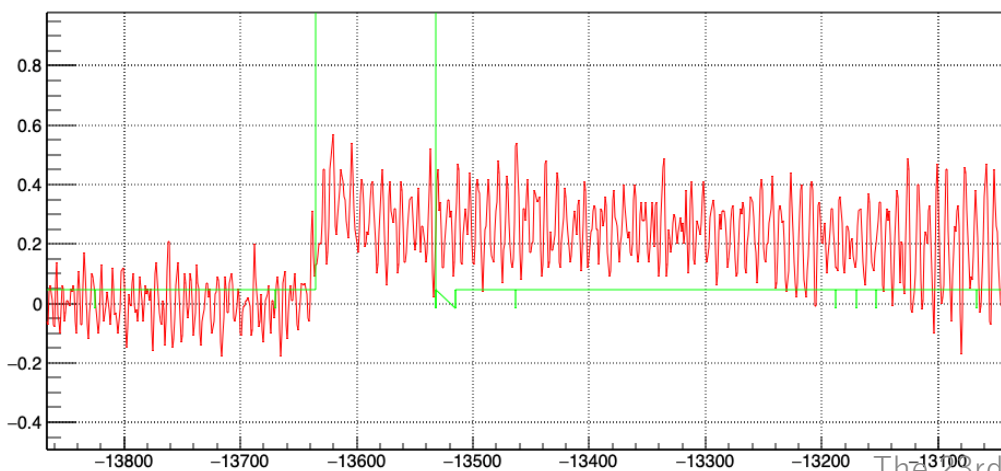
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HER	Soft Abort	2019-05-28 01:32:28.917360300	0.780211600
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- The beam loss occurred at D1H5 collimator several ms after QC2 LE PS problem.

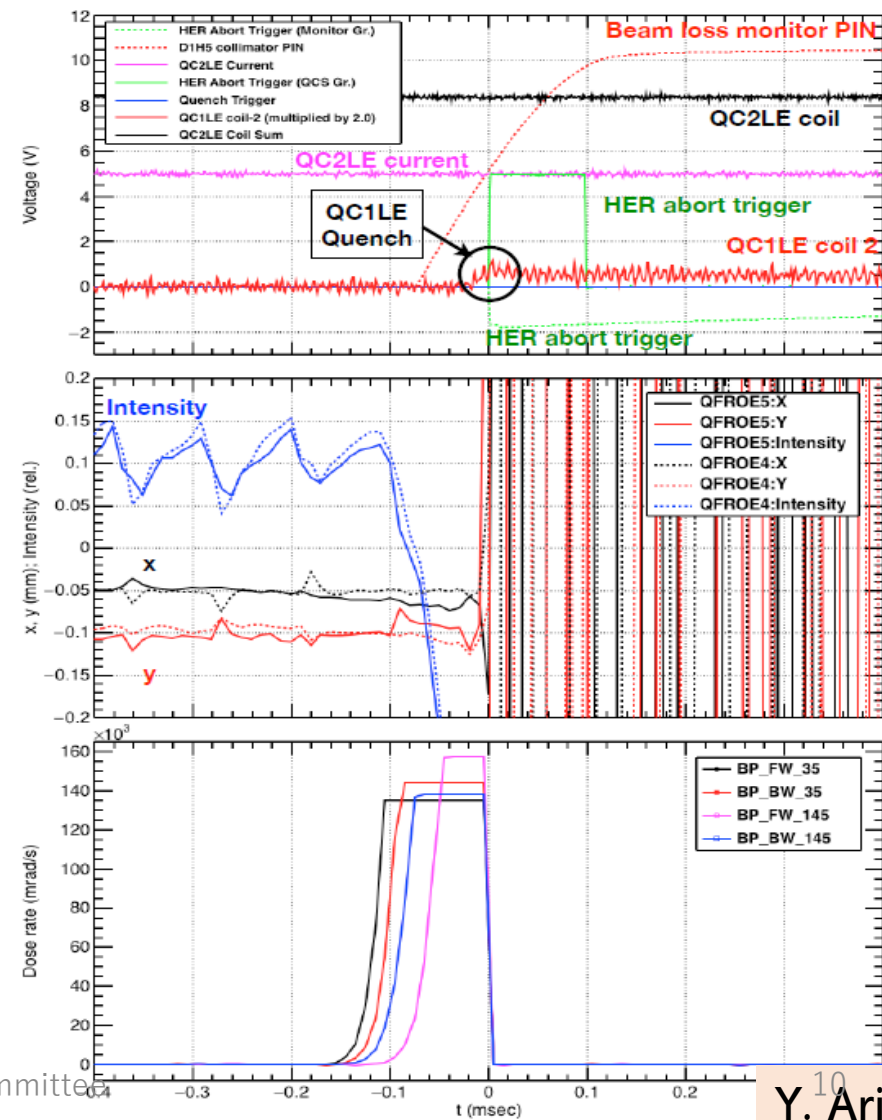


QCS
&
Beam loss monitor

BPM (Libera)



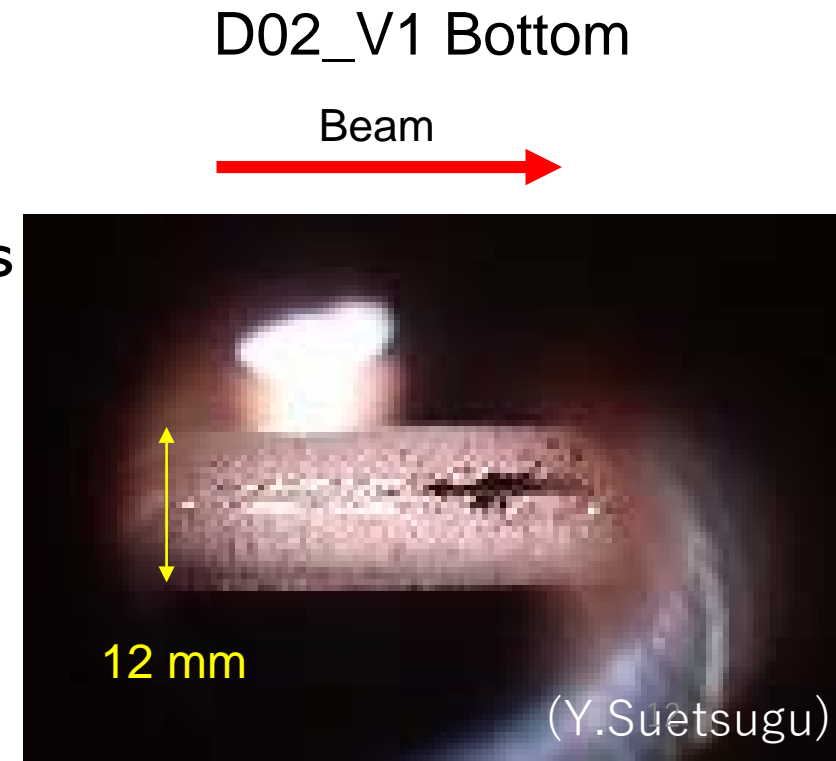
Diamond detector



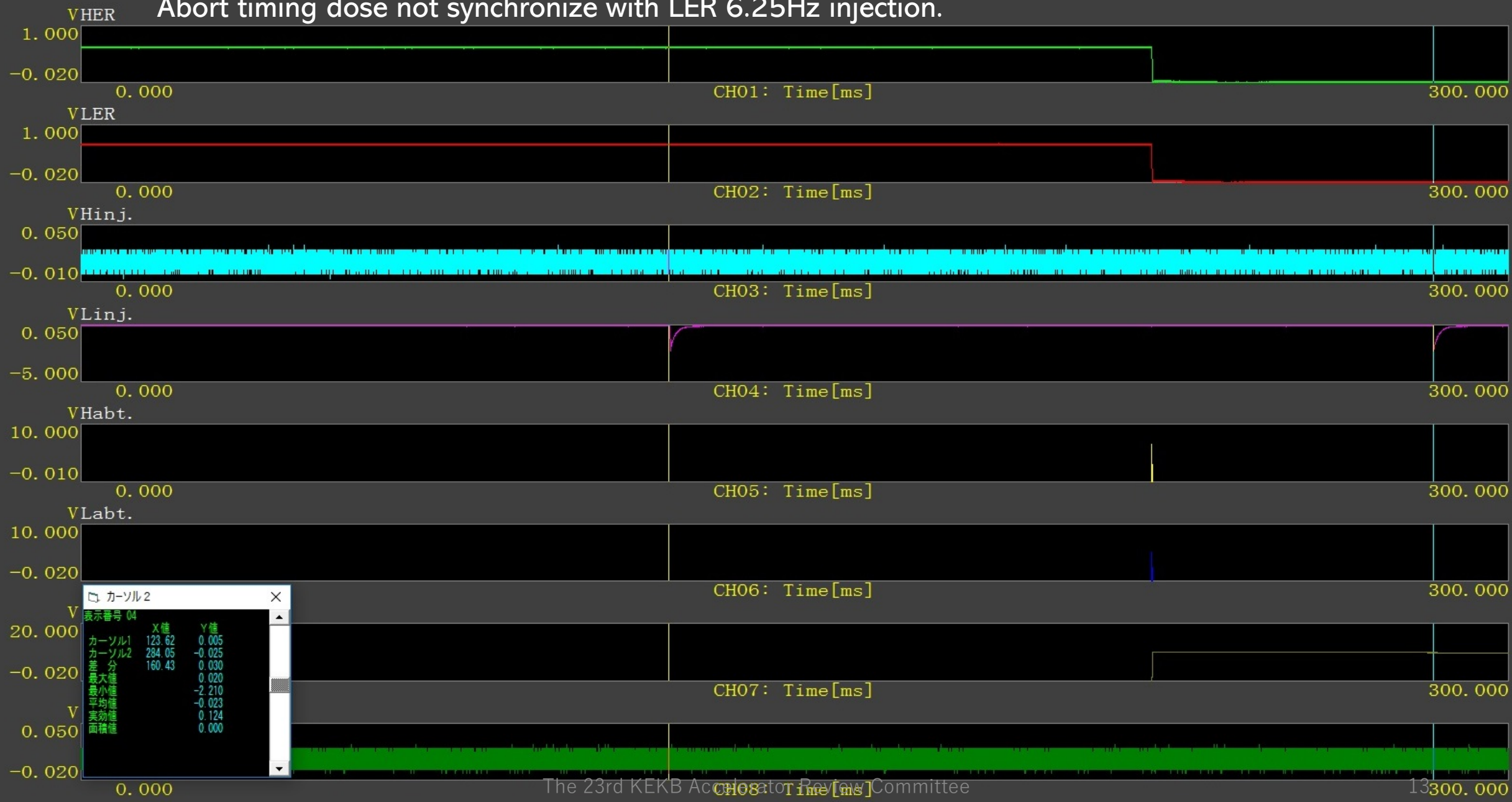
- The beam loss occurred at D1H5 collimator several ms after QC2 LE PS problem.
 - $t_1 \sim 60 \mu s$
 - $t_1 \rightarrow t_2 \sim 10 \mu s$
 - $t_2 \rightarrow t_3 \sim 6 \text{ to } 16 \mu s$
 - $t_3 \rightarrow t_4 \sim 10 \mu s$
 - Sum = $90 \sim 100 \mu s$
- QCS quench I/L $\sim 13 \text{ ms}$ after the LM trigger.
- QCS PS OFF I/L $\sim 63 \text{ ms}$

Ex4. 6/9 22:21 QCS quench (LER)

- D02V1 collimator head was damaged.
- The beam loss detected at Belle-II VXD diamond at first.
Following times are the delay from diamond trigger.
 - RF D5F arc sensor : $8\mu\text{s}$
 - Loss Monitor D4-3(D6V2 collimator) : $16\mu\text{s}$
 - Loss Monitor D1-1(D2V1,H4,H3 collimator) : $16.5\mu\text{s}$
 - Loss Monitor TSUKUBA B4(D2H4 collimator) : $39.9\mu\text{s}$
 - Loss Monitor D4-1 (D3H1 collimator) : $48.3\mu\text{s}$
- QCS quench I/L : $\sim 16\text{ms}$
- QCS PS OFF I/L : $\sim 49\text{ms}$



Abort timing dose not synchronize with LER 6.25Hz injection.

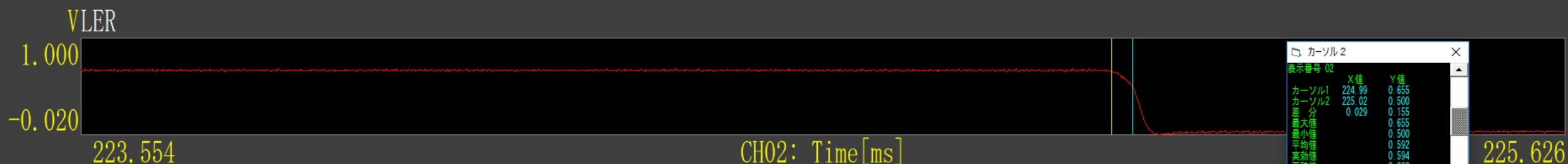


カーソル 2

表示番号 04

	X値	Y値
カーソル1	123.62	0.005
カーソル2	284.05	-0.025
差分	160.43	0.030
最大値		0.020
最小値		-2.210
平均値		-0.023
変動値		0.124
面積値		0.000

It took 30 μ s from starting beam loss to abort.
LER beam was lost about 150mA at that time.



カーソル 2

表示番号	X値	Y値
カーソル1	224.99	0.655
カーソル2	225.02	0.500
差分	0.029	0.155
最大値		0.655
最小値		0.500
平均値		0.592
実効値		0.594
面積値		0.000



Convert_No2_2019-06-09_22-11-10.GBD (No.1)

Convert_No2_2019-06-09_21-28-20.GBD (No.2)

データ再生中

LM signal start at $\sim 30\mu\text{s}$ before from abort trigger ($40\mu\text{s}$ before from beam off).



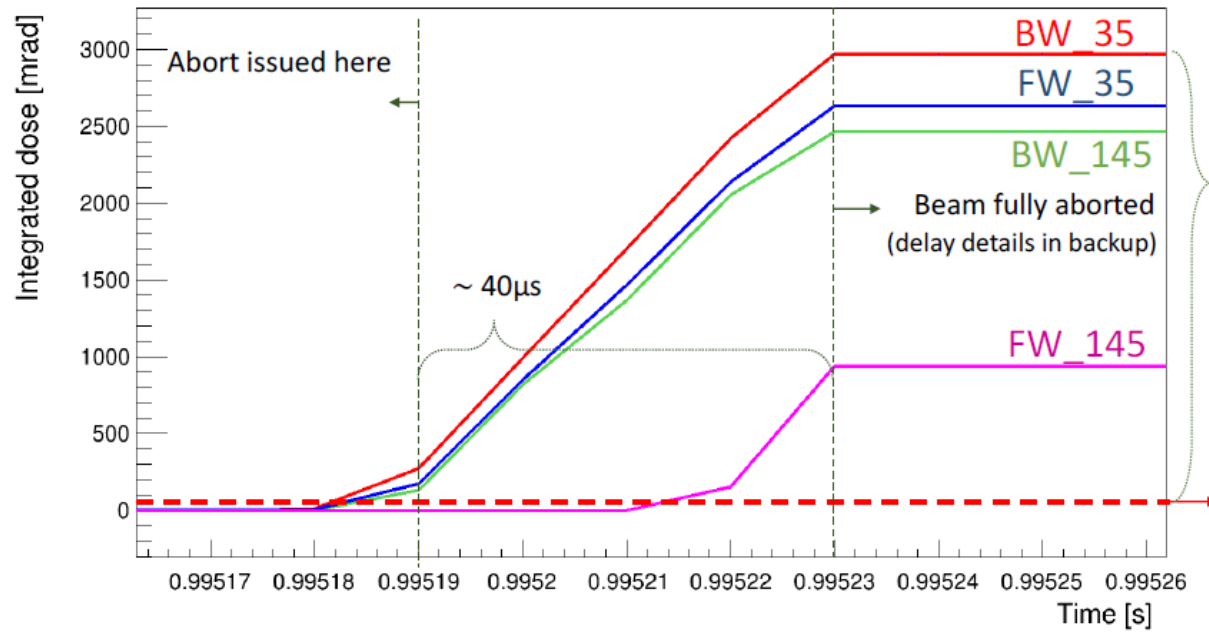
Monitor

CH1-4	+0.004	V
CH2-1	+0.002	V
CH2-2	+0.000	V
CH2-3	+0.005	V
CH2-4	+0.003	V
CH3-1	+0.003	V
CH3-2	-0.002	V
CH3-3	-0.002	V
CH3-4	CH3-4	ON
	+0.184	V
CH4-1	+0.138	V
CH4-2	+0.002	V
CH4-3	+0.003	V
CH4-4	+0.002	V
CH5-1	+0.002	V
CH5-2	+0.001	V
CH5-3	+0.002	V
CH5-4	+0.005	V
CH6-1	-0.002	V
CH6-2	-0.003	V
CH6-3	+0.002	V
CH6-4	+2.213	V
CH7-1	+1.284	V
CH7-2	+1.886	V

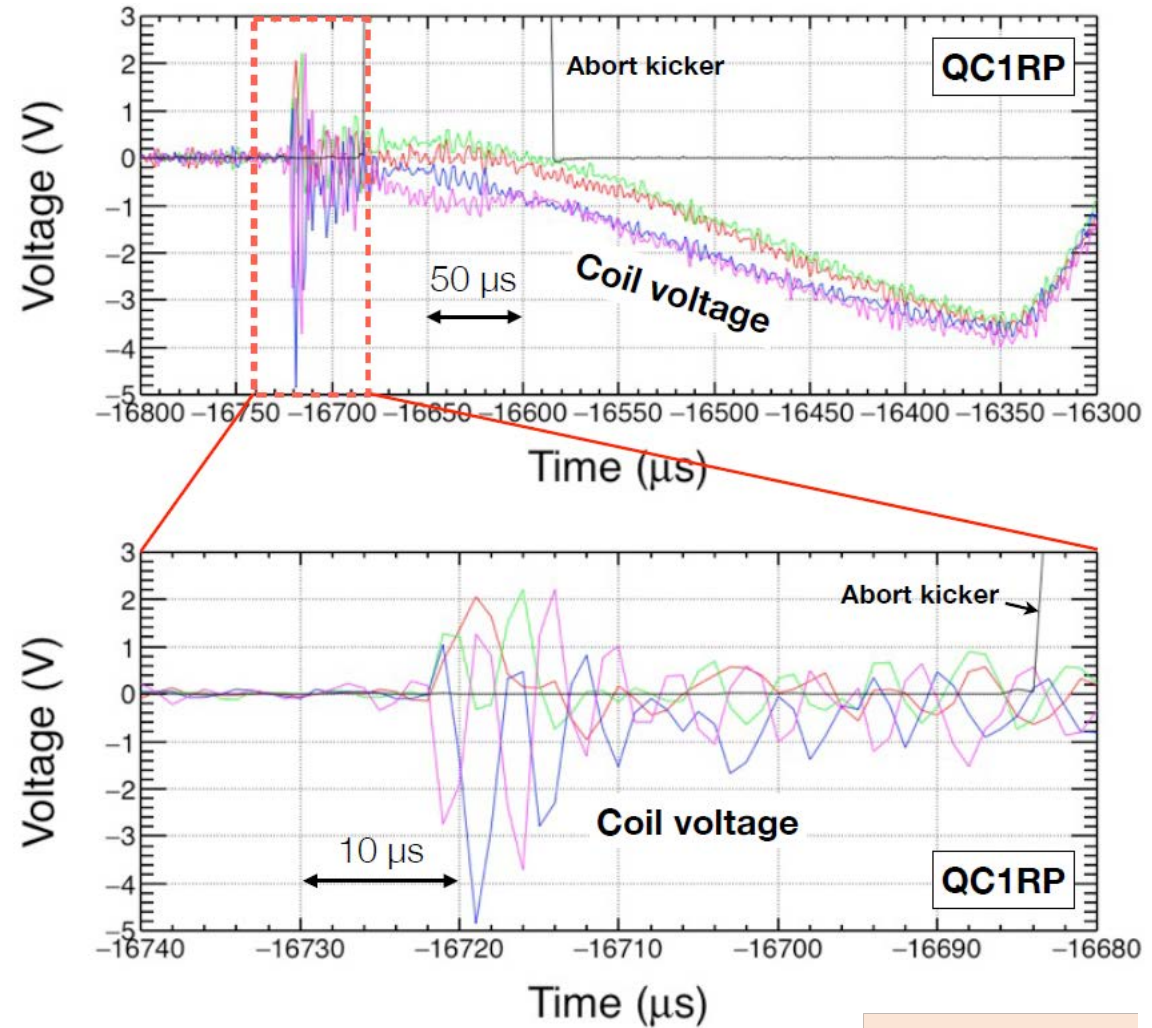
絶対時間

A	2019-06-09 22:11:06 .000 035
B	2019-06-09 22:11:06 .000 005
	0000:00:00.000 030 33333.333333 Hz

- Belle-II beam dose start to increase 50 μ s before beam off.
 - Belle-II abort can be delivered within 10 μ s(sampling time)+700ns.
- Change of QCS voltage started 40 μ s before abort trigger (50 μ s before beam off).

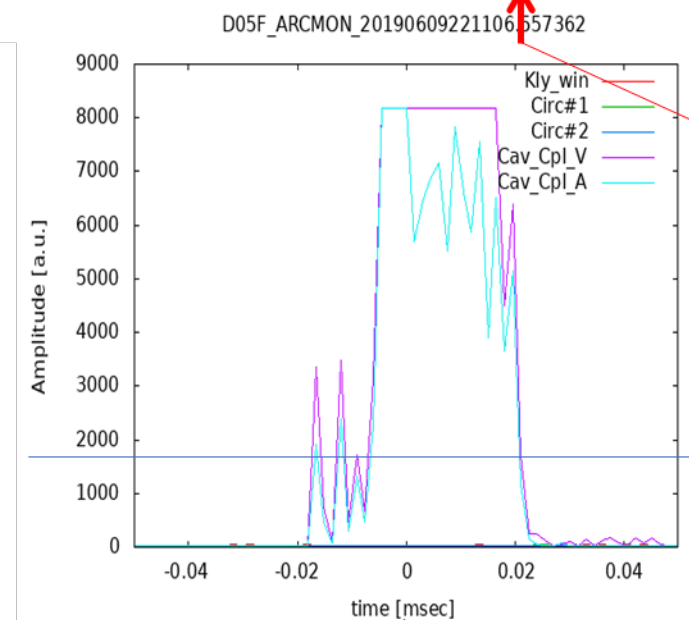
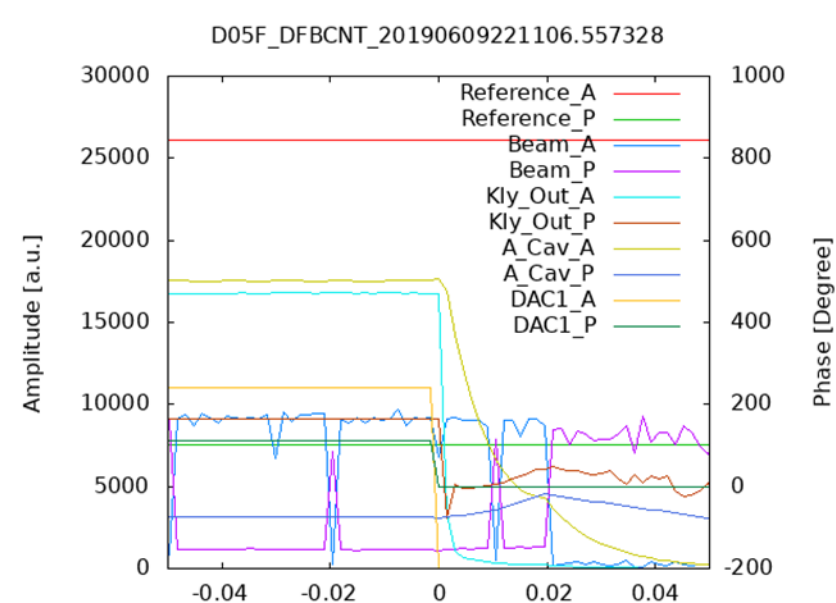
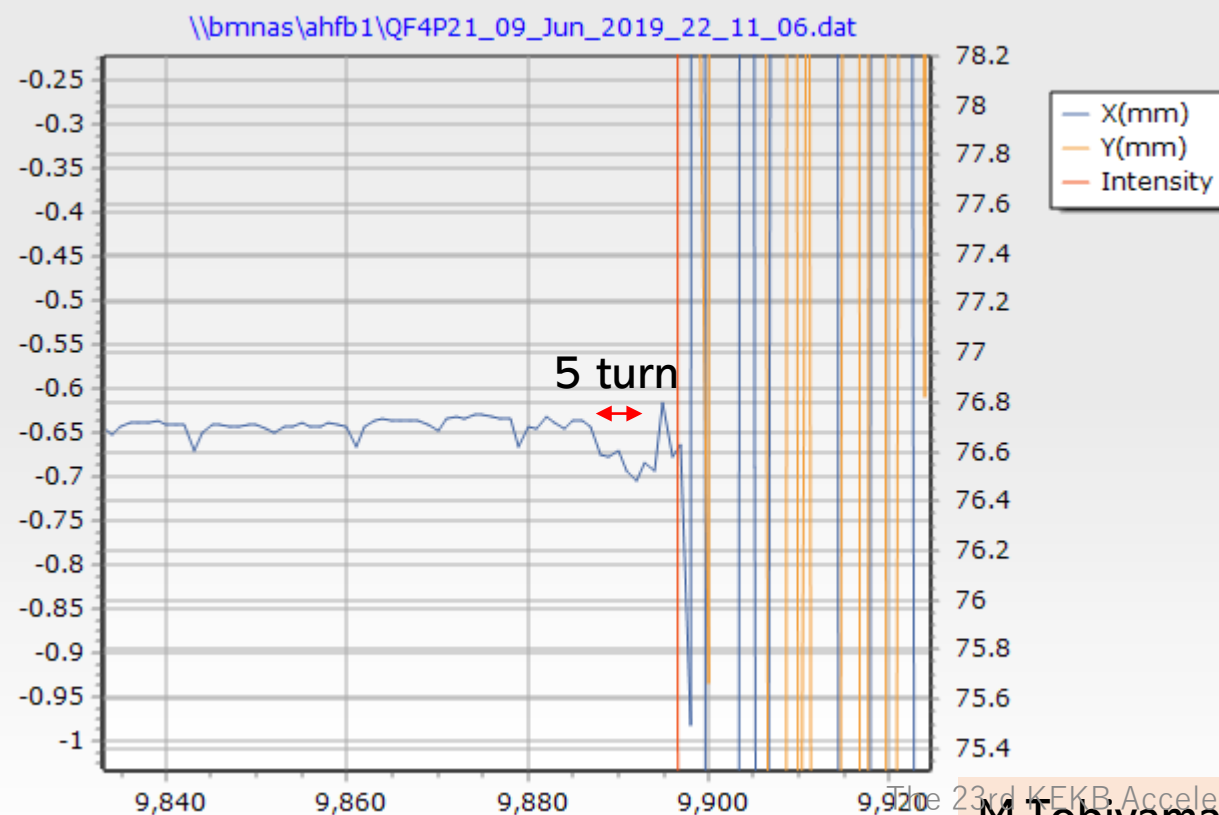


L. Vitale



Y. Arimoto

- Beam orbit (H) moved 0.05mm a few turn before beam off.
- Beam oscillation was not observed before that timing.
- RF arc sensor signal start to change 40μs before beam off.



Beam Dumped

> 1640

RF OFF by Arc IL

- Abort timing does not synchronize with LER 6.25Hz injection.
- It took 30 μ s from starting beam loss to abort trigger.
- LER beam was lost about 150mA at that time.
- Loss monitor, Belle-II diamond and RF arc sensor showed the signal at similar timing.
- Beam orbit started to move at similar timing with beam loss.
- We could not find any beam loss or other behavior.
- Beam loss may be caused by dust since vacuum spike happened at that time.
- Abort delay estimation is consistent with the observation.
 - $t_1 \sim 10\mu$ s (Signal reach to I/L level at 2nd turn.)
 - +8 μ s @ D5F
 - +16 μ s @ D6V2 collimator etc.
 - $t_1 \rightarrow t_2 \sim 10\mu$ s
 - $t_2 \rightarrow t_3 \sim 7 \text{ to } 17\mu$ s
 - $t_3 \rightarrow t_4 \sim 10\mu$ s
 - Sum = 37 \sim 47 μ s

3. Speedup of the abort

1. Minimize t_1 (Detector response time)

① QCS magnet

- Quench detector : Shorter checking time 10ms→2ms for stronger protection of QCS magnet. : (Done)
- QCS PS I/L : Remodel the PS module to take out abort signal directly from FPGA without conventional PLC when there is a failure in a power supply. (start from main magnet)

② Beam loss detection

- Make the threshold of the detectors severe and keep redundancy.
- Loss Monitor : Set lower threshold
 - Use PIN at the place besides collimator.
 - Make the injection veto system for collimator PIN. (from D6V2 as a trial)
- RF D5F arc sensor : Set lower threshold and shorter checking time ($6\mu\text{s}$ →). : Use temporarily.
- Belle : Make shorter sampling time ($10\mu\text{s}$ → $<5\mu\text{s}$)

2. Shorten t_2 - t_1 (Distance from CCR)

- Detect the beam loss by the detector near CCR.
 - D6V2 collimator PIN signal send to D7 in stead of D4.

3. Shorten t_3 - t_2

- Increase the number of abort gap (1→2)
 - Shortened time $< 5\mu\text{s}$

We perform all of these before autumn run.

Ex1. 5/28 01:32 QCS quench (HER)

- The beam loss occurred at D1H5 collimator several ms after QC2 LE PS problem.
 - $t_1 \sim 60\mu\text{s} \rightarrow 2\mu\text{s}$
 - $t_1 \rightarrow t_2 \sim 10\mu\text{s} \rightarrow 5\mu\text{s}$
 - $t_2 \rightarrow t_3 \sim 6 \text{ to } 16 \mu\text{s} \rightarrow 6 \sim 11\mu\text{s}$
 - $t_3 \rightarrow t_4 \sim 10 \mu\text{s}$
 - $\text{Sum} = 90 \sim 100\mu\text{s} \rightarrow 23 \sim 28\mu\text{s}$
- QCS quench I/L $\sim 13\text{ms}$
- QCS PS OFF I/L $\sim 63\text{m} \rightarrow 30 \sim 40\mu\text{s}$ after PS trouble

Ex4. 6/9 22:21 QCS quench (LER)

- The beam loss detected at Belle-II.
 - $t_1 \sim 10 \mu s$ (Signal reach to I/L level at 2nd turn.) $\rightarrow 2 \mu s$
 - $+8 \mu s$ @ D5F $\rightarrow 2 \mu s$
 - $+16 \mu s$ @ D6V2 collimator etc. $\rightarrow 2 \mu s$
 - $t_1 \rightarrow t_2 \sim 10 \mu s \rightarrow 5 \mu s$
 - $t_2 \rightarrow t_3 \sim 7 \text{ to } 17 \mu s \rightarrow 7 \sim 12 \mu s$
 - $t_3 \rightarrow t_4 \sim 10 \mu s$
 - Sum = $37 \sim 47 \mu s \rightarrow 24 \sim 29 \mu s$
- QCS quench I/L $\sim 16 ms \rightarrow 8 ms$
- QCS PS OFF I/L $\sim 49 ms$

Summary

- The abort system of SuperKEKB works well.
- But some sudden beam loss caused QCS quench and gave damage to a collimator and a Belle-II detector before a beam was completely aborted.
- (The beam loss caused by dust ?)
- We improve the abort trigger to abort beam as fast as possible before autumn run.

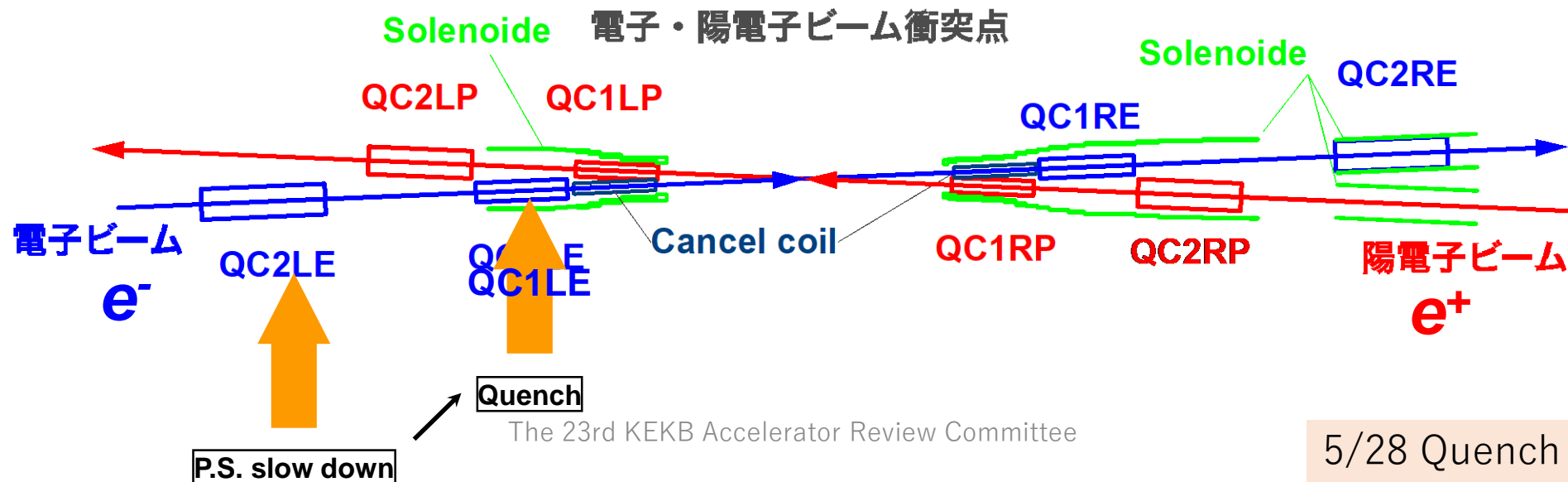
BackUp

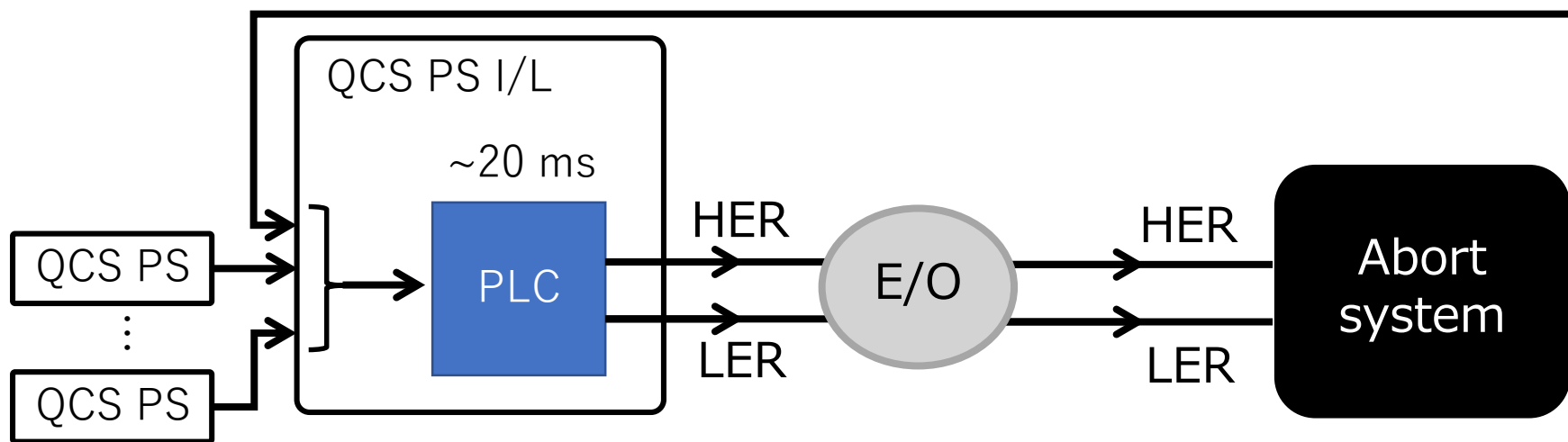
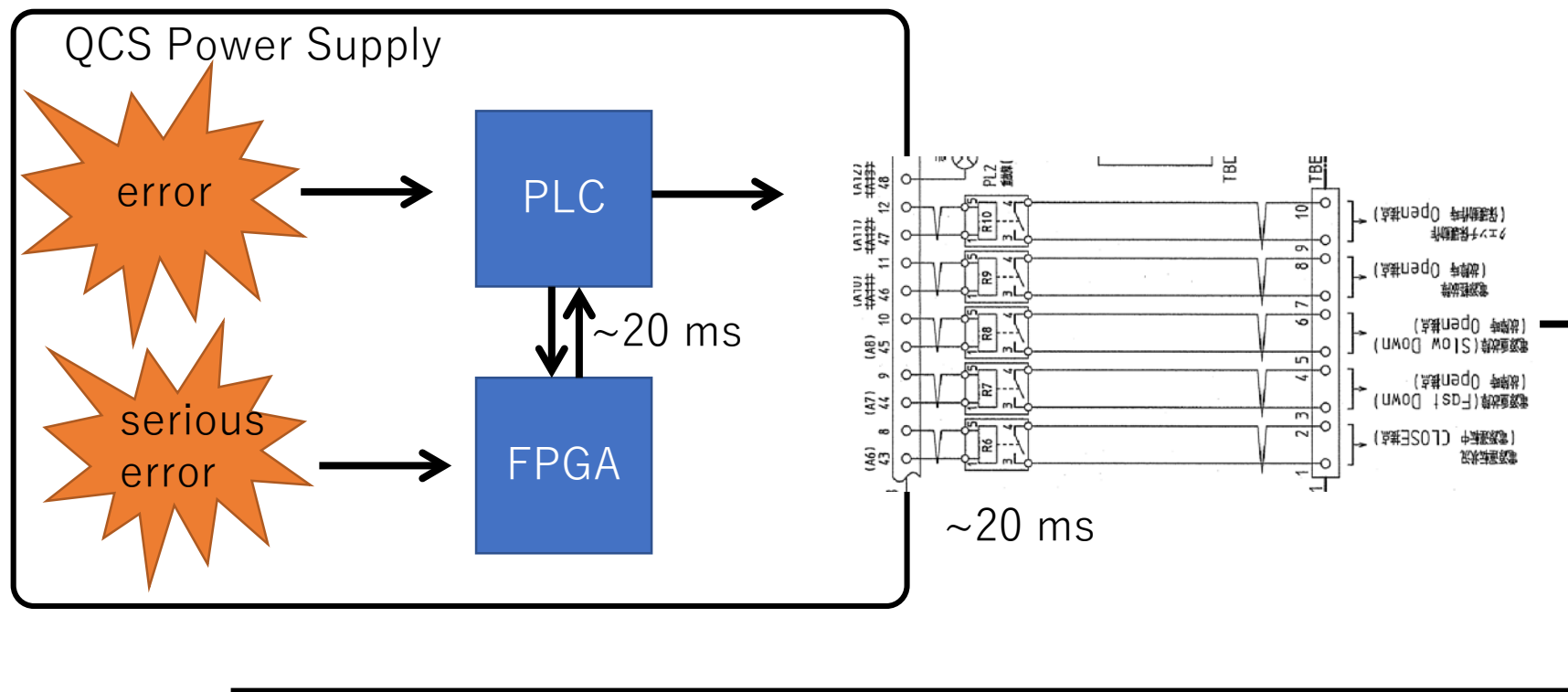
Abort Request

- Hardware
 - Electric signal \rightarrow E/O \rightarrow Abort system (synchronized to revolution)
 - RF, Magnet, Vacuum, Safety, Monitor (Loss monitor), etc.
 - Delay < 3 turns of revolution (see next page)
- Software
 - From many IOCs (not needed instant response)
 - RF, Vacuum, Monitor (Temperature, FB reflection etc), etc
 - Depends on the software processing time (both in local IOC and abort IOC), total time $<$ few seconds.

QCS quench overview (有本氏)

- QC2LE
 - Power supply went to a **slow down** process due to **IPM-abnormality alarm**
- QC1LE
 - Quench was happened.
 - It is deduced that beam hit QC1LE (the beam orbit was changed due to the **slow down** of QC2LE).





time-lag : 40 ~ 60 ms

The 23rd KEKB Accelerator Review Committee

Improvement plan

