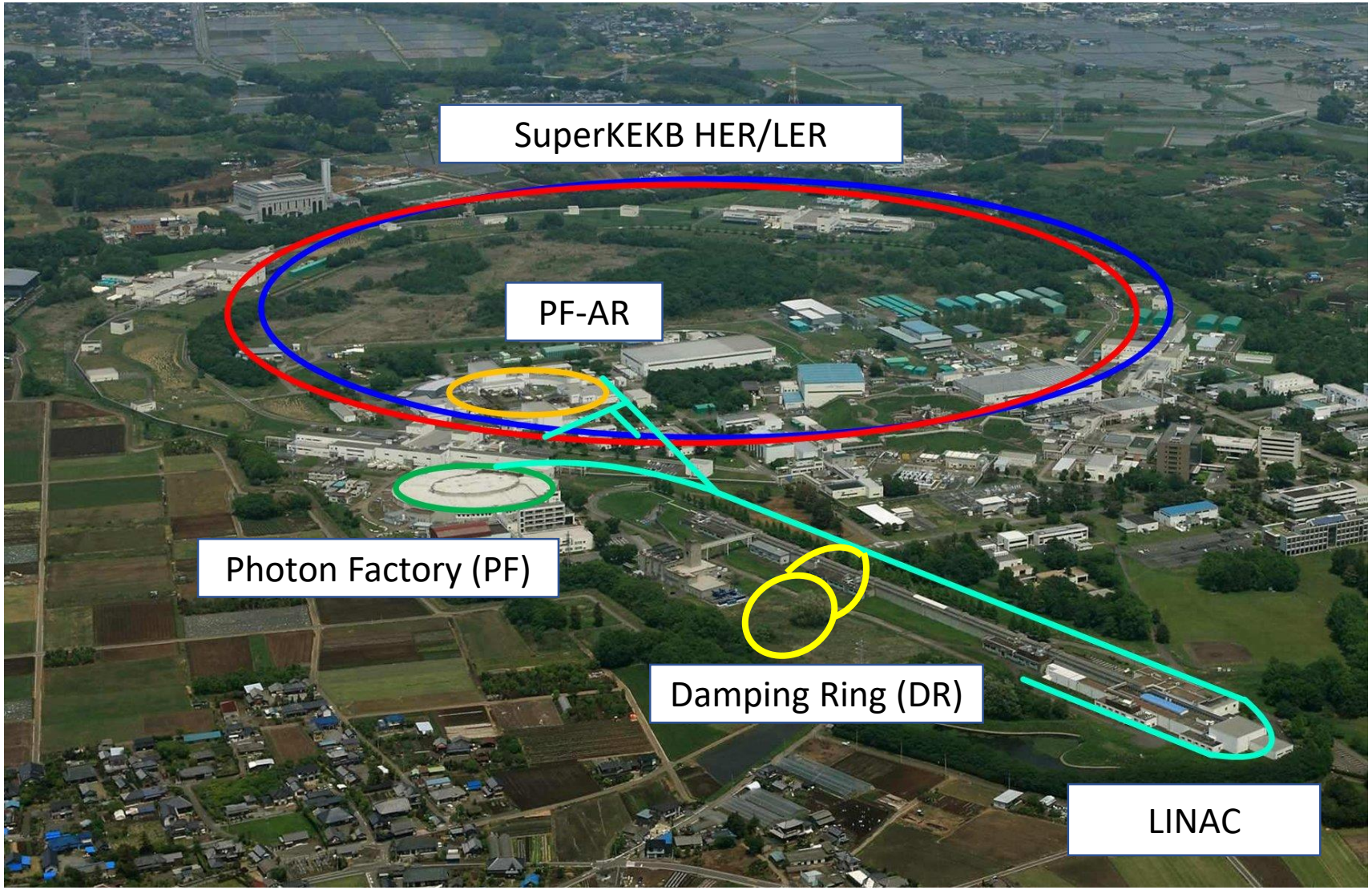
The Fault Diagnosis of Event Timing System in SuperKEKB

D. Wang, K. Furukawa, M. Satoh, H. Kaji, H. Sugimura,
T. Kudou, S. Kusano, Y. Iitsuka
KEK

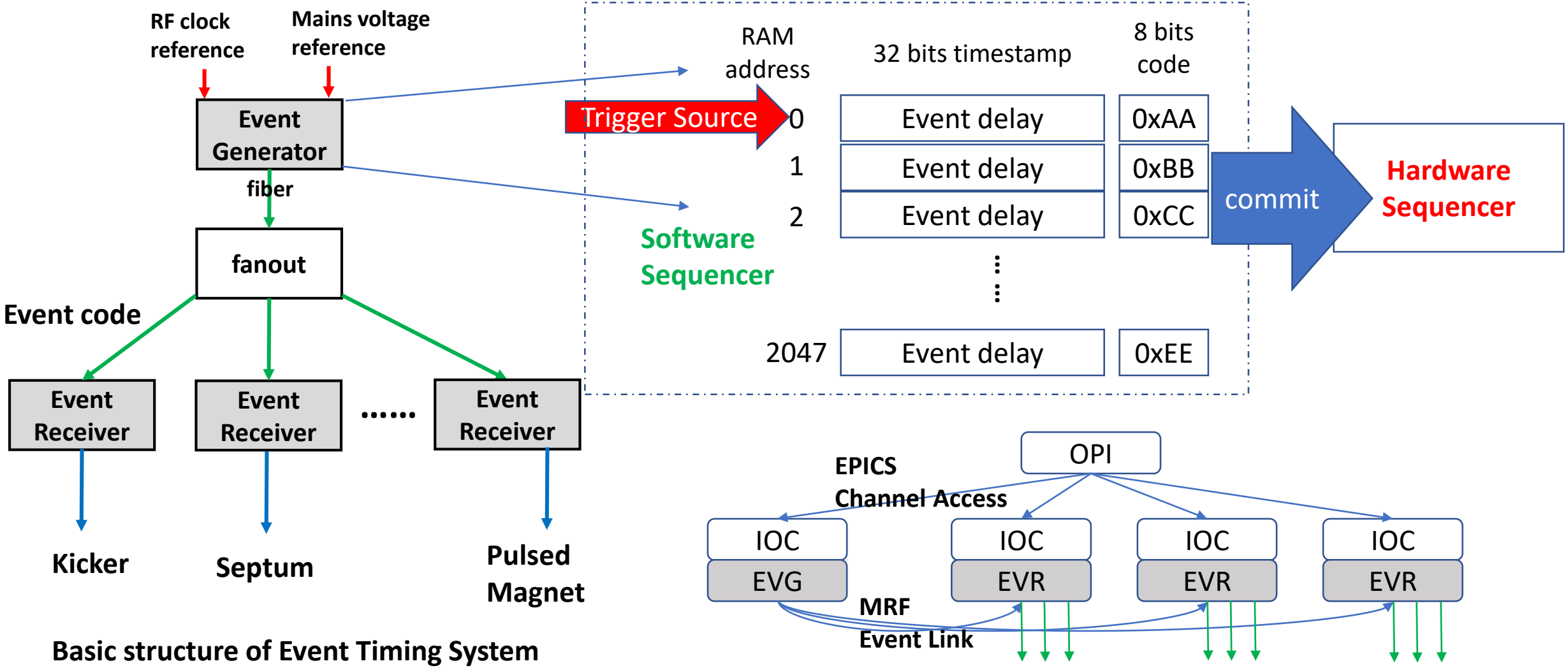
Outline

- Event Timing System in SuperKEKB
- Event Fault Diagnosis System
  - Data Acquisition
  - Data Processing
- Fault Diagnosis
  - Beam Mode Replacement
  - Redundant Beam Mode
- Conclusion and Outlook

Event Timing System in SKEKB

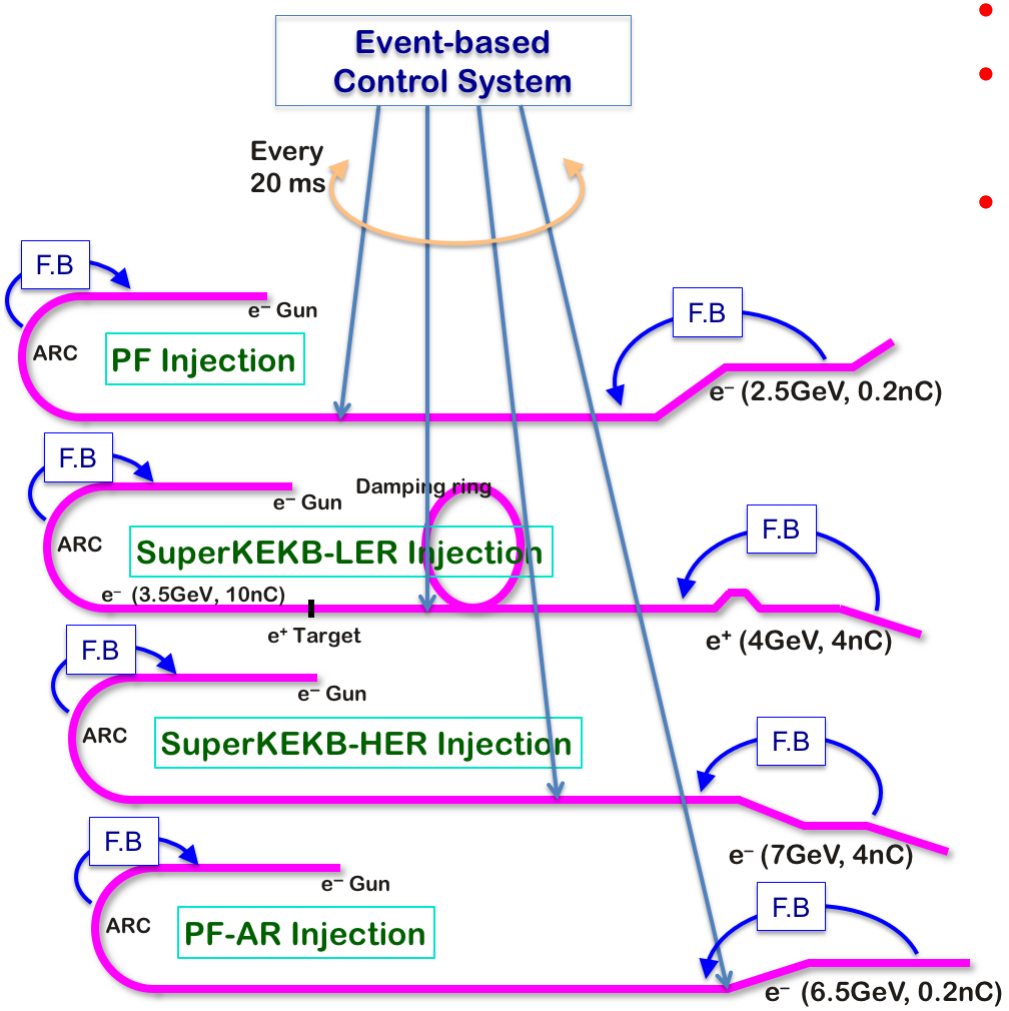


Event Timing System in SKEKB



Basic structure of Event Timing System

Event Timing System in SKEKB

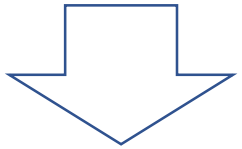


- **Simultaneous injection to 4 rings !**
- **High precision: jitter less than 30 ps for MR, 300/700 ps for PF/PF-AR !**
- **Every pulse synchronized with 50 Hz AC power supply !**

- MRF's series Event Generator and Receivers
  - VME-EVG-230: **4**
  - VME-EVR-230-RF: **50**
  - PXI-EVR-300 : **20**
- 50 Hz beam mode repetition rate
- 114.24 MHz event rate
- **12** kinds of beam mode
- About 120 event codes are defined
- 11 or 12 events every pulse
- EPICS R3.14.12 with mrfioc2 (device support)

Event Timing System in SKEKB

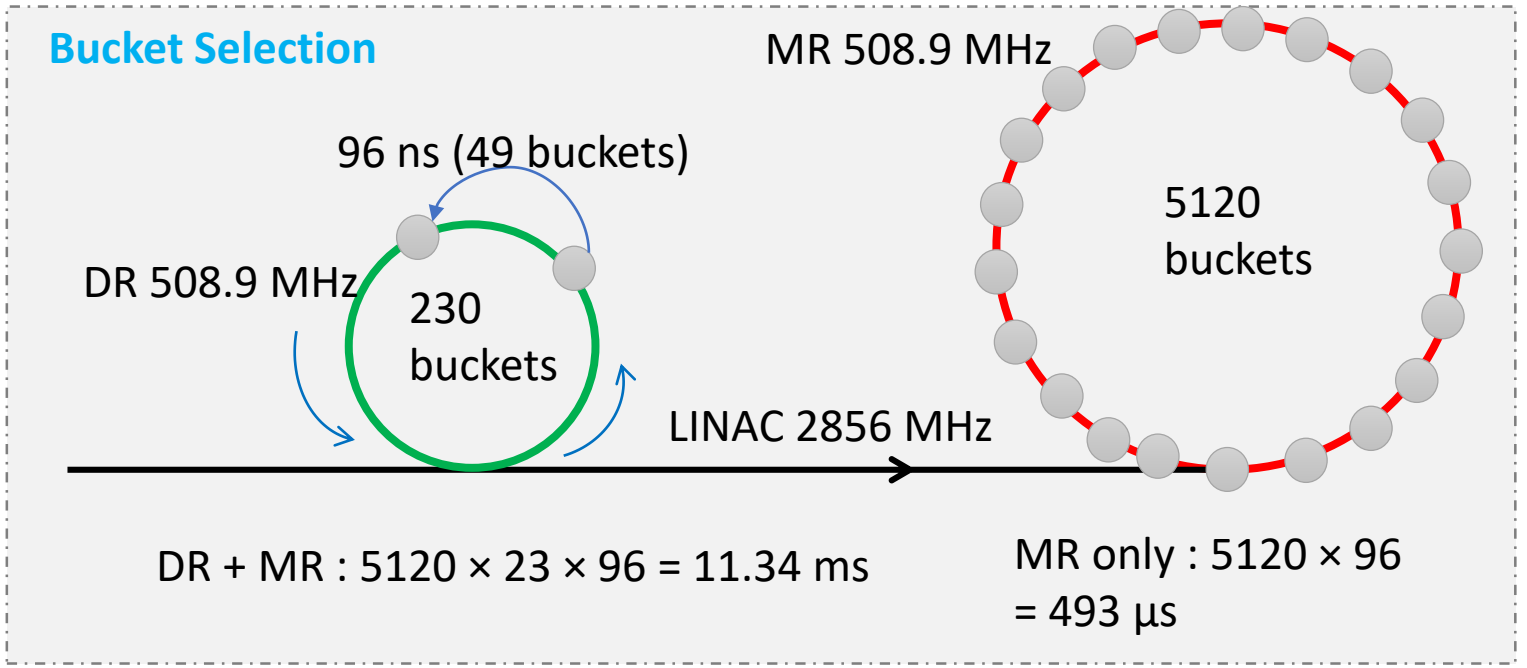
- Common frequency between 2856 MHz and 508.9 MHz is 10.38 MHz (96 ns, 49 buckets duration)
  - Chance of injection timing turns up once per 96ns (49 buckets).
- Requiring two bucket selection timings (injection and extraction at DR, two EVGs are needed)
- The number of combination is 5120 × 23 (least common multiple of DR and MR)
- Can not coincide with AC50 every pulse

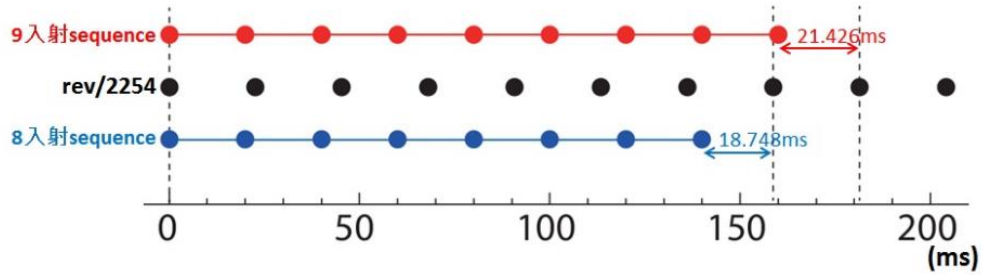


16/18 sequences injection, details are talked in

H. Kaji et al. " BUCKET SELECTION SYSTEM FOR SuperKEKB", PASJ 2015 THP100

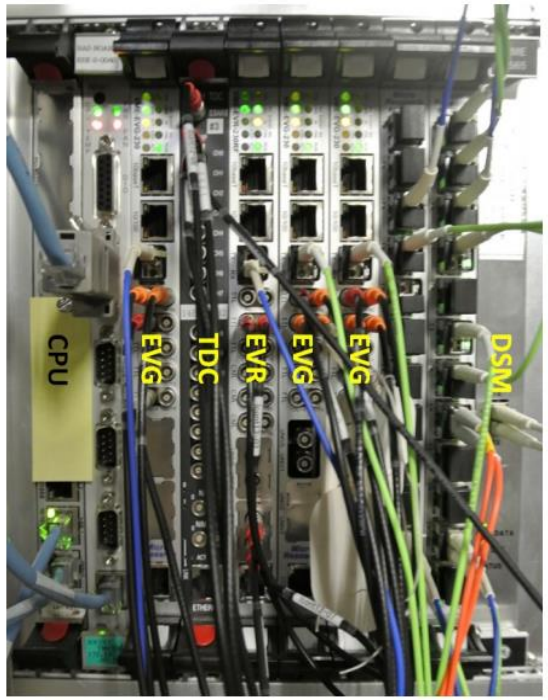
H. Kaji et al. "INSTALLATION AND COMMISSIONING OF NEW EVENT TIMING SYSTEM FOR SuperKEKB", PASJ 2015 FROL15

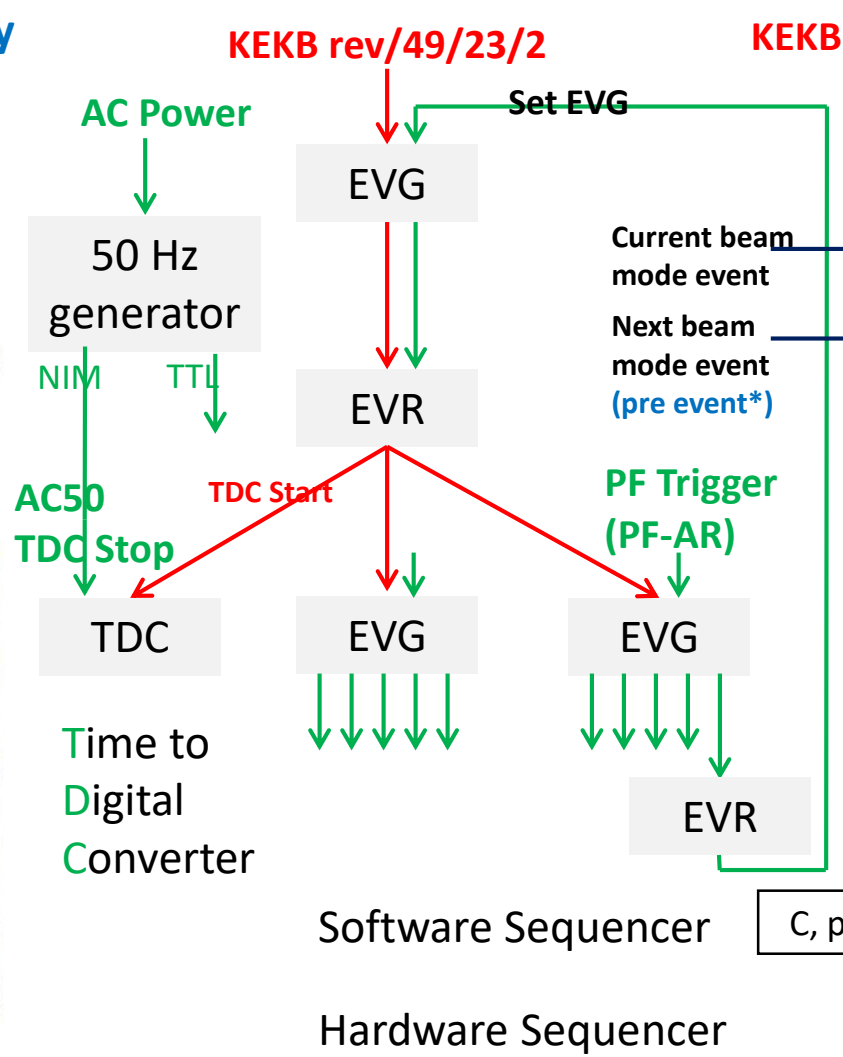


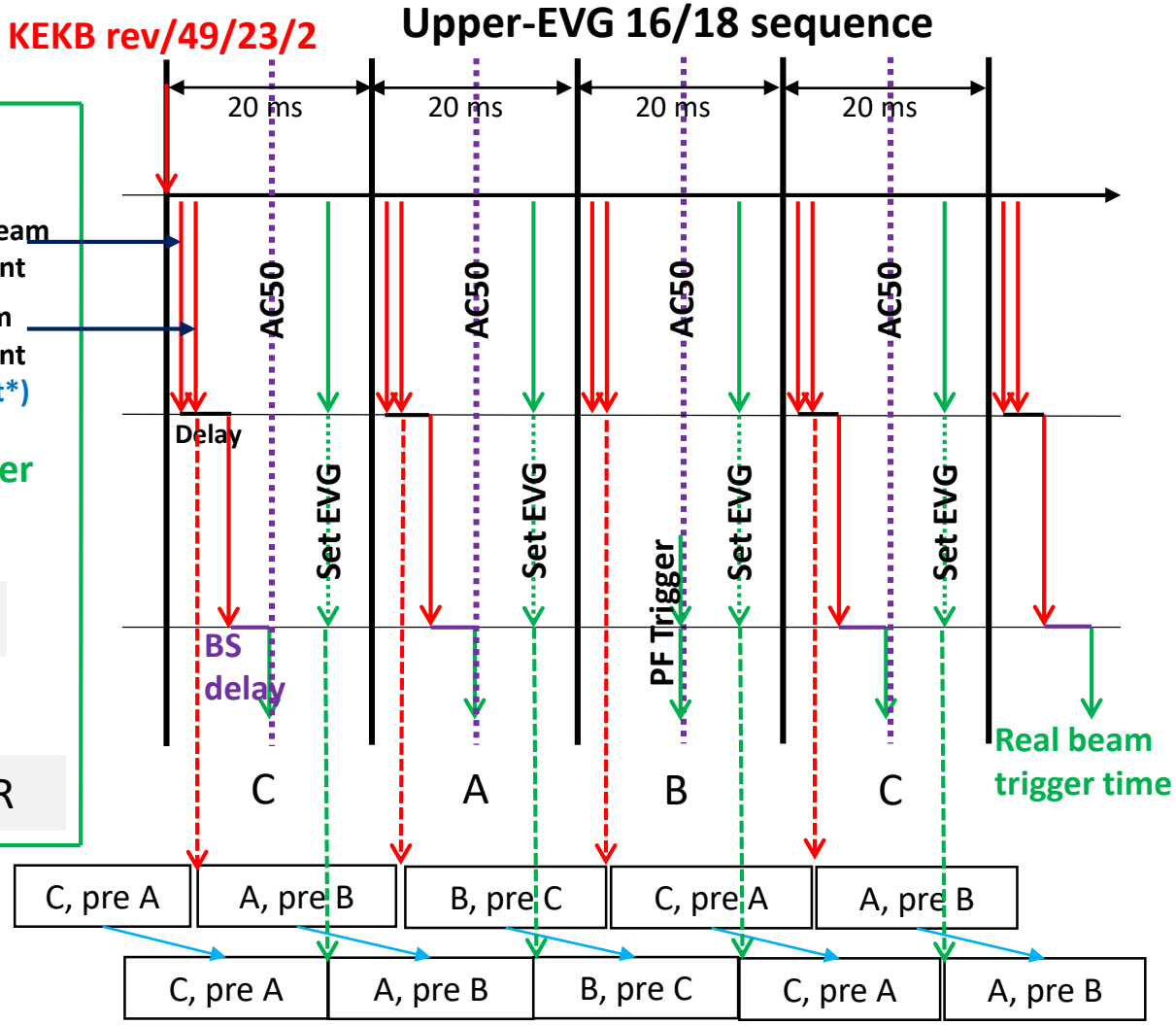


Event Timing System in SKEKB

- *Pre event is necessary because of the kicker charging time





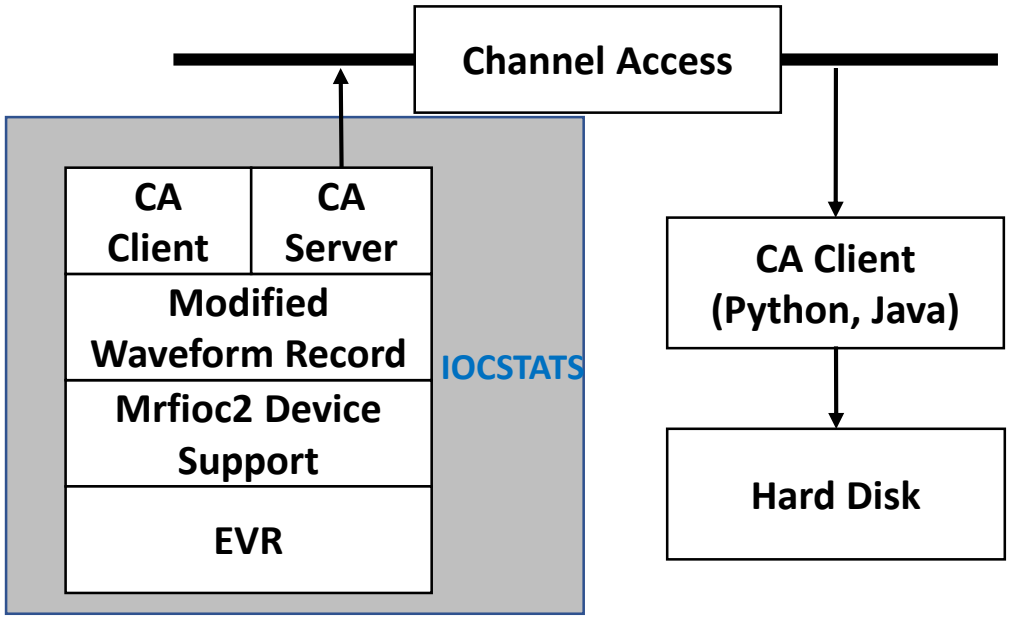


Outline

- Event Timing System in SuperKEKB
- **Event Fault Diagnosis System**
  - **Data Acquisition**
  - **Data Processing**
- Fault Diagnosis
  - Beam Mode Replacement
  - Redundant Beam Mode
- Conclusion and Outlook

Data Acquisition

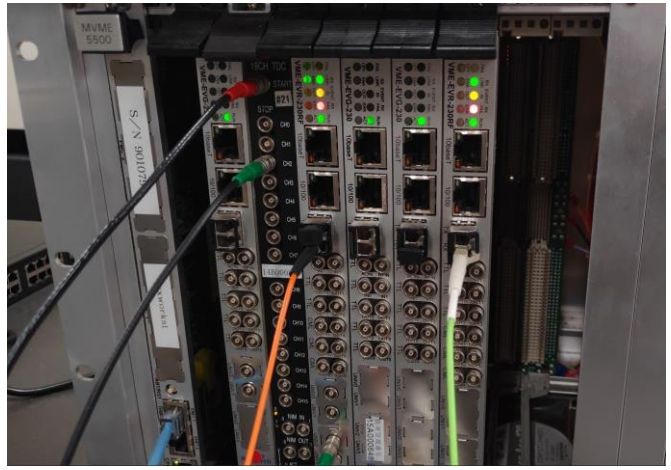
- Requirements:
  - Event code and nanosecond-level timestamp is needed
  - Two EVRs in one VME to monitor two lower-EVGs.
- Obstacles using Channel Access
  - **Some data lost** due to high CPU usage
  - EPICS period Scan task delay in VxWorks IOC is very high
- MVME5500 CPU frequency is 1 GHz, by contrast, the minimal interval between linac event code is 9 ns.
  - VxWorks clock tick is 1000
  - i.e. scan-5 task delay is 4.579 second.

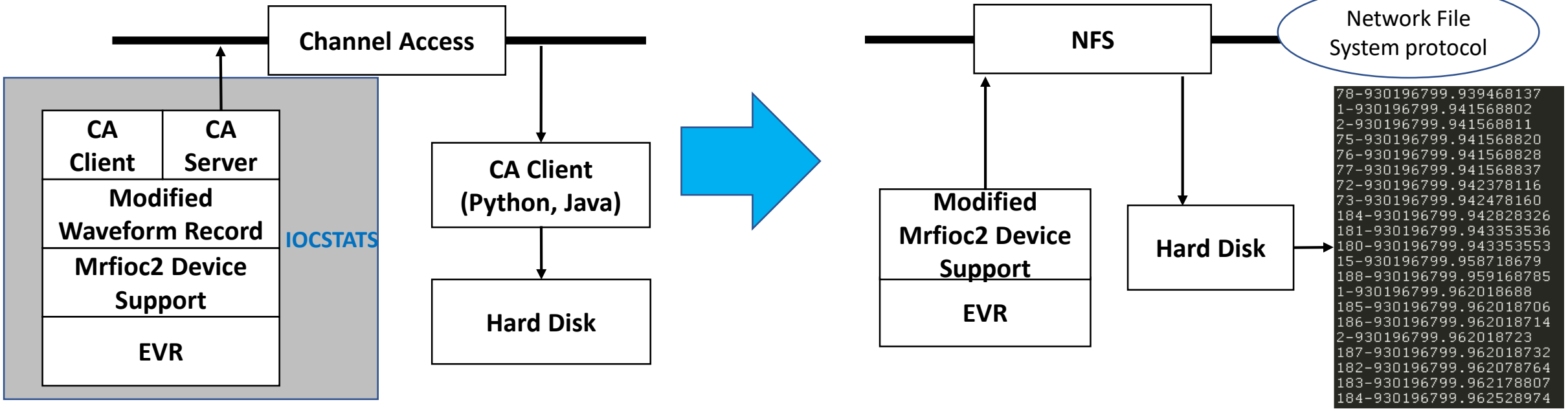


NAME	ENTRY	TID	PRI	STATUS	PC	SP	ERRNO	DELAY
tJobTask	1ce564	4db1d0	0	PEND	24ec6c	4db0f0	0	0
tExcTask	1cd904	302970	0	PEND	24ec6c	302870	0	0
tLogTask	logTask	4de570	0	PEND	24ce28	4de430	0	0
tNbioLog	1cf238	4e1ea0	0	PEND	24ec6c	4e1d80	0	0
tShell0	shellTask	5f7d60	1	PEND	24ec6c	5f7a30	0	0
tShellRem6>	shellTask	614790	1	READY	257338	612990	ad0007	0
ipcom_tick>	261900	5bb410	20	DELAY	25615c	5bb390	0	91
tNet0	ipcomNetTask	4e6fc0	50	READY	24ec6c	4e6eb0	3d0001	0
ipcom_sysl>	17af48	5a2670	50	PEND	24f588	5a24c0	0	0
ipcom_teln>	ipcom_telnet	5dcb70	50	PEND	24ec6c	5dc970	0	0
ipsntps	1bab80	5dfd60	50	PEND+T	24ec6c	5dfbe0	3d0004	519514
ipcom_teln>	ipcom_telnet	1fffda80	50	PEND	24ec6c	1fffd860	0	0
tStdioProx>	18186c	1ffff4b0	50	READY	24ea64	1fffefb0	0	0
tLogin1fff>	181af0	6034c0	50	PEND	24f588	6033f0	0	0
tPortmapd	portmapd	5e3d10	54	PEND	24ec6c	5e3ac0	16	0
EVRFIFO	af4d00	634b60	109	READY	24ce28	634980	0	0
EVRFIFO	af4d00	c00ed0	109	READY	24ce28	c00cf0	0	0
cbHigh	af4d00	74c7b0	128	PEND	24ec6c	74c690	0	0
timerQueue	af4d00	6f73b0	129	PEND	24ec6c	6f7230	3d0004	0
scanOnce	af4d00	7df930	132	PEND	24ec6c	7df800	0	0
scan-0.1	af4d00	80f250	133	PEND+T	24ec6c	80f090	3d0004	28
scan-0.2	af4d00	808730	134	PEND+T	24ec6c	808570	3d0004	128
cbMedium	af4d00	743f80	135	PEND	24ec6c	743e70	0	0
scan-0.5	af4d00	801c10	135	PEND+T	24ec6c	801a50	3d0004	26
scan-1	af4d00	7fb0f0	136	PEND+T	24ec6c	7faf30	3d0004	80
scan-2	af4d00	7f45d0	137	PEND+T	24ec6c	7f4410	3d0004	157
scan-5	af4d00	7edab0	138	PEND+T	24ec6c	7ed8f0	3d0004	4579
scan-10	af4d00	7e6f90	139	PEND+T	24ec6c	7e6dd0	3d0004	9579

Data Acquisition

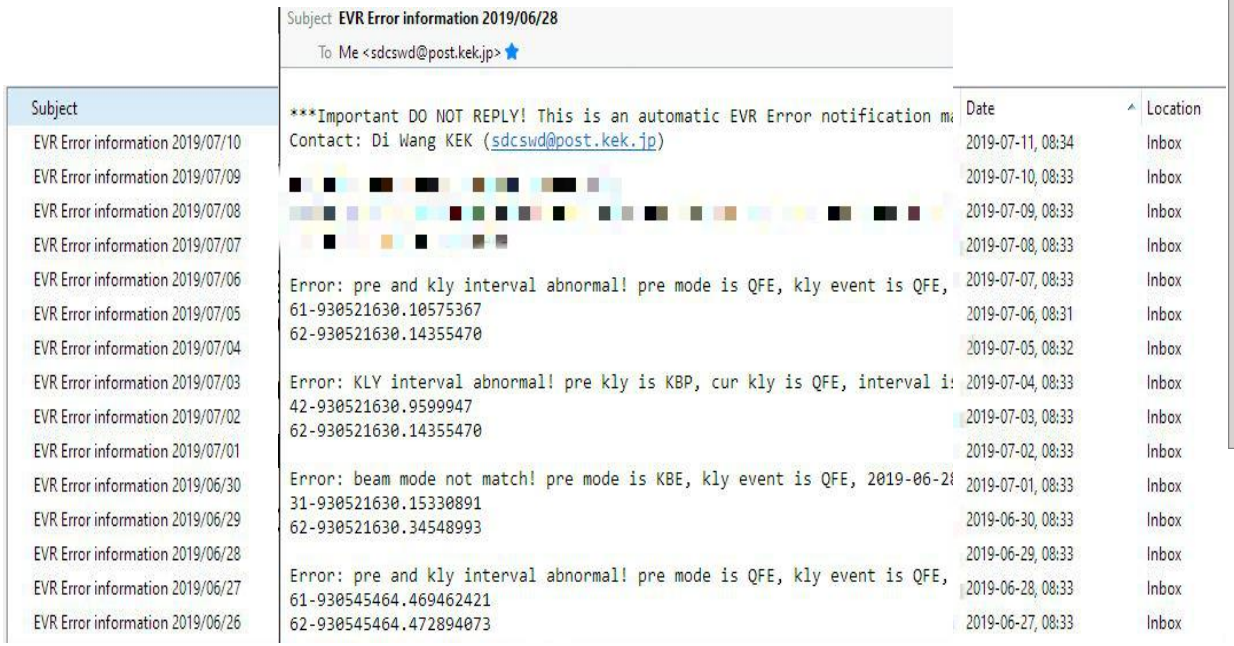
- New approach Implementation:
  - An EPICS thread with a large size ring buffer is created
  - Fetch data and timestamp from EVR FIFO memory
  - Transmit to NFS server using binary format

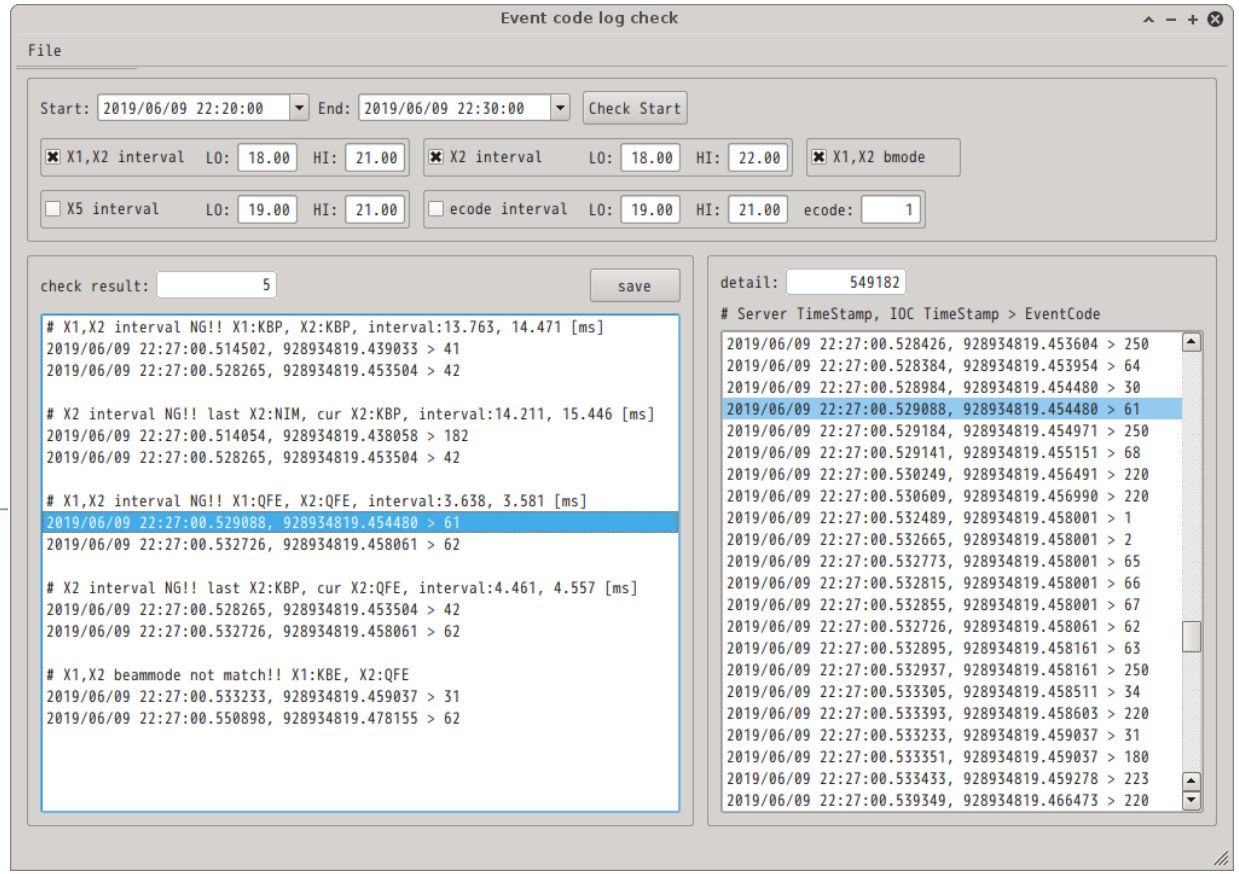




Data Processing

- Using Python script check beam mode interval and event code
- Abnormal data is extracted
- Results are sent by email
- All actions automatically run every day





Optional, manually check detailed data

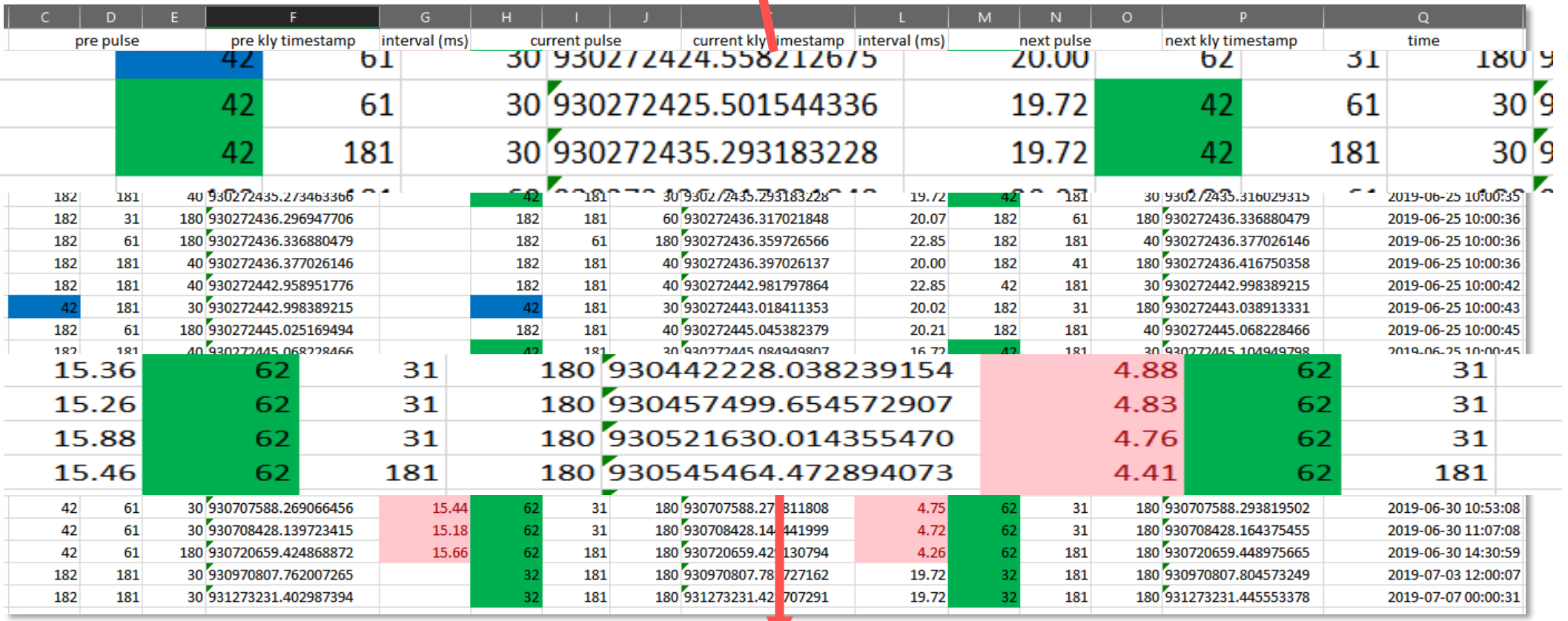
Outline

- Event Timing System in SuperKEKB
- Event Fault Diagnosis System
  - Data Acquisition
  - Data Processing
- **Fault Diagnosis**
  - **Beam Mode Replacement**
  - **Redundant Beam Mode**
- Conclusion and Outlook

Fault Diagnosis

Beam mode repeat

Excerpt of the abnormal

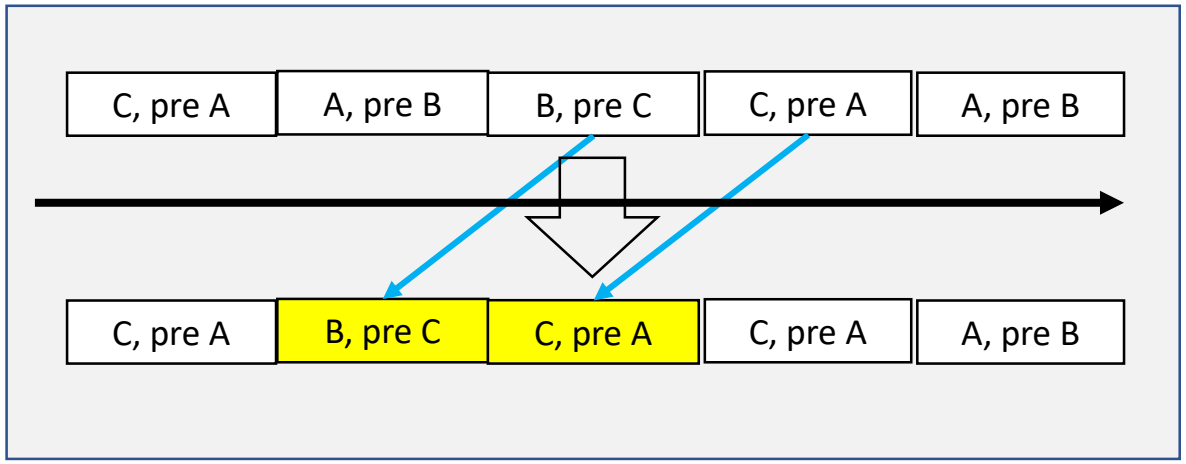


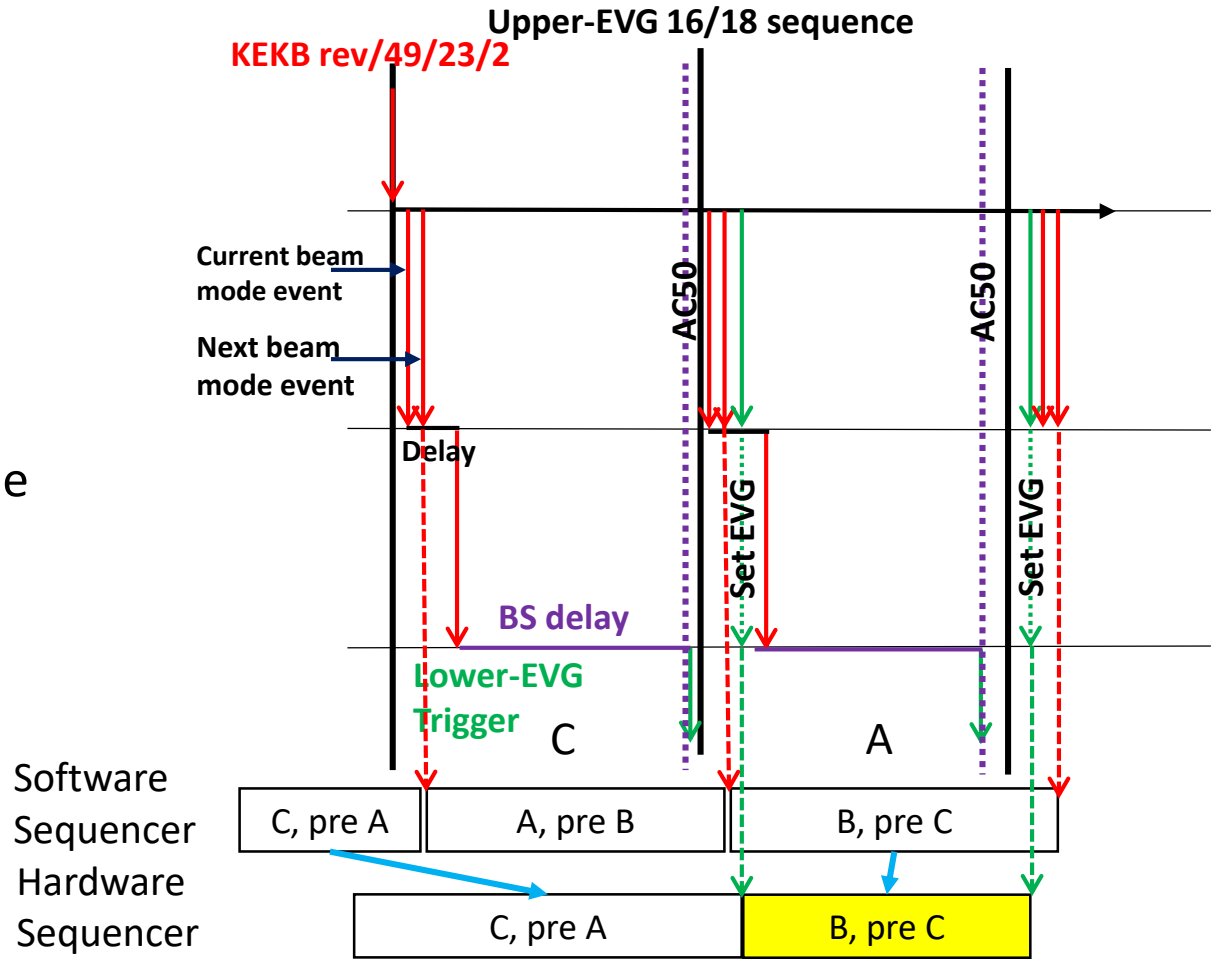
pre pulse			pre kly timestamp	interval (ms)	current pulse			current kly timestamp	interval (ms)	next pulse			next kly timestamp	time
42	61	30	930272424.55821267 5						20.00	62	31	180		
42	61	30	930272425.501544336						19.72	42	61	30		
42	181	30	930272435.293183228						19.72	42	181	30		
182	181	40	930272435.273463366		42	181	30	930272435.293183228	19.72	42	181	30	930272435.316029315	2019-06-25 10:00:35
182	31	180	930272436.296947706		182	181	60	930272436.317021848	20.07	182	61	180	930272436.336880479	2019-06-25 10:00:36
182	61	180	930272436.336880479		182	61	180	930272436.359726566	22.85	182	181	40	930272436.377026146	2019-06-25 10:00:36
182	181	40	930272436.377026146		182	181	40	930272436.397026137	20.00	182	41	180	930272436.416750358	2019-06-25 10:00:36
182	181	40	930272442.958951776		182	181	40	930272442.981797864	22.85	42	181	30	930272442.998389215	2019-06-25 10:00:42
42	181	30	930272442.998389215		42	181	30	930272443.018411353	20.02	182	31	180	930272443.038913331	2019-06-25 10:00:43
182	61	180	930272445.025169494		182	181	40	930272445.045382379	20.21	182	181	40	930272445.068228466	2019-06-25 10:00:45
182	181	40	930272445.068228466		42	181	30	930272445.084949807	16.72	42	181	30	930272445.104949798	2019-06-25 10:00:45
15.36	62	31			180	930442228.038239154			4.88	62	31			
15.26	62	31			180	930457499.654572907			4.83	62	31			
15.88	62	31			180	930521630.014355470			4.76	62	31			
15.46	62	181			180	930545464.472894073			4.41	62	181			
42	61	30	930707588.269066456	15.44	62	31	180	930707588.27 311808	4.75	62	31	180	930707588.293819502	2019-06-30 10:53:08
42	61	30	930708428.139723415	15.18	62	31	180	930708428.14 441999	4.72	62	31	180	930708428.164375455	2019-06-30 11:07:08
42	61	180	930720659.424868872	15.66	62	181	180	930720659.42 130794	4.26	62	181	180	930720659.448975665	2019-06-30 14:30:59
182	181	30	930970807.762007265		32	181	180	930970807.78 727162	19.72	32	181	180	930970807.804573249	2019-07-03 12:00:07
182	181	30	931273231.402987394		32	181	180	931273231.42 707291	19.72	32	181	180	931273231.445553378	2019-07-07 00:00:31

Abnormal PF beam mode interval

Beam Mode Replacement

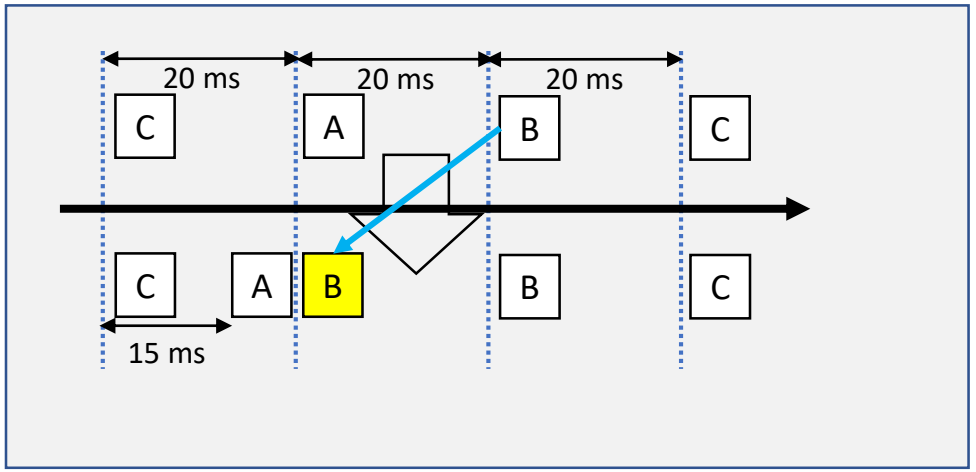
- AC50 comes very late
  - AC power fluctuation
  - Alternating during 16/18 sequences injection
- Bucket Selection delay increases
- ‘Set EVG’ signal comes late than pre event
- Current beam mode is replaced by the next beam mode
- Happened 15 times during 2-weeks operation in June

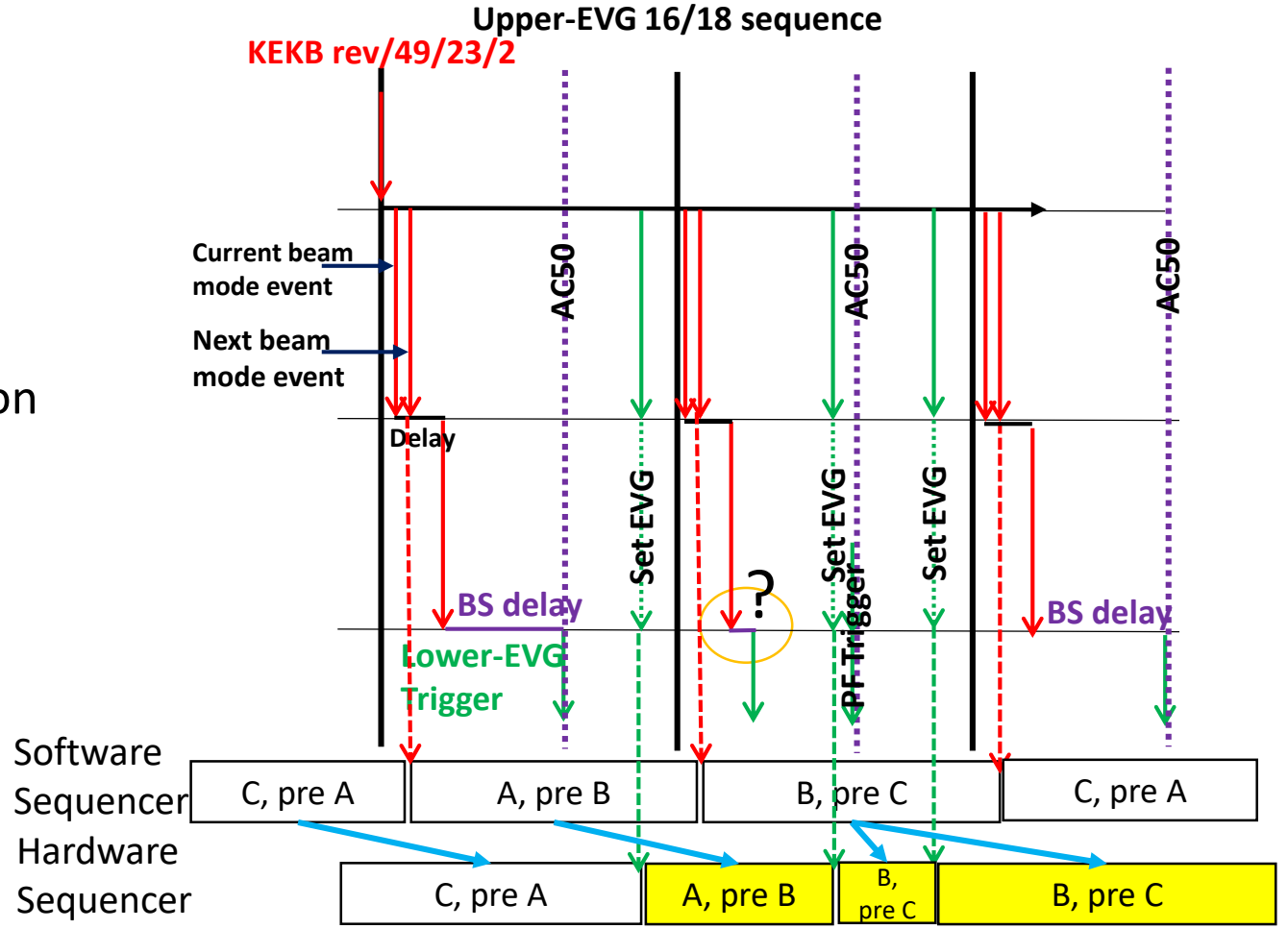




Redundant Beam Mode

- Abnormal value of the calculation of bucket selection of positron in DR and MR
- A positron beam mode comes about 5 ms earlier than normal
- Sequencer trigger source changed
- PF Trigger signal is later than ‘Set EVG’
- Happened 10 times during 2-weeks operation in June





Outline

- Event Timing System in SuperKEKB
- Event Fault Diagnosis System
  - Data Acquisition
  - Data Processing
- Fault Diagnosis
  - Beam Mode Replacement
  - Redundant Beam Mode
- **Conclusion and Outlook**

Conclusion and Outlook

- Solution of beam mode replacement:
  - Upgrade the 50 Hz generator module
  - Decrease reference interval of AC50 (Already done)
- Solution of redundant beam mode:
  - Temporarily separate the positron beam mode and PF mode
  - Figure out the reason of abnormal bucket selection delay
- Much more data required to diagnose the bucket selection program
- Near future: On-line alarm system
- Furthermost, a fault prediction system based on time series forecasting models or deep learning

- Di. Wang (Ph. D Candidate)
- sdcswd@post.kek.jp
- KEK Linac