The Fault Diagnosis of Event Timing System in SuperKEKB

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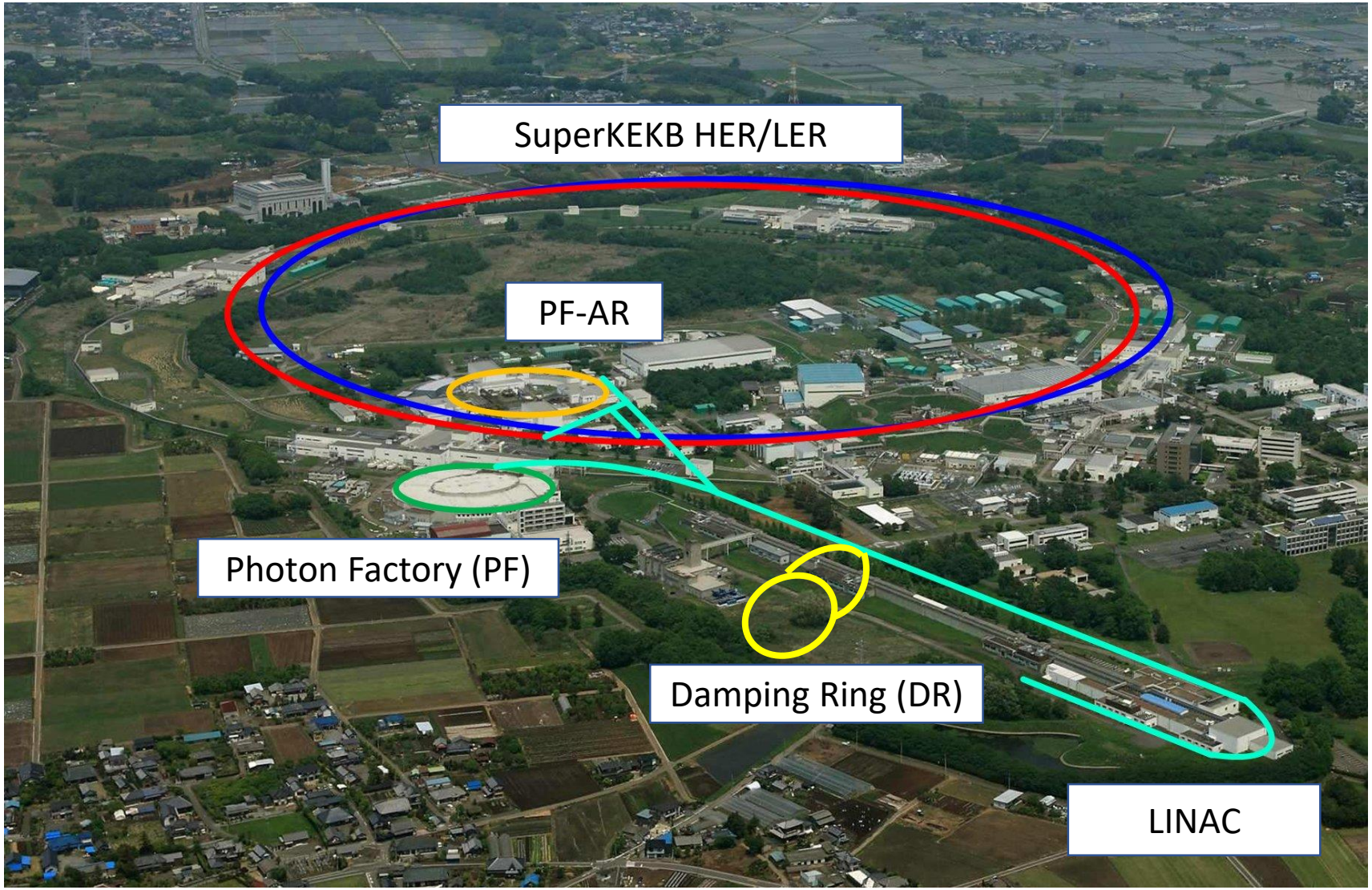
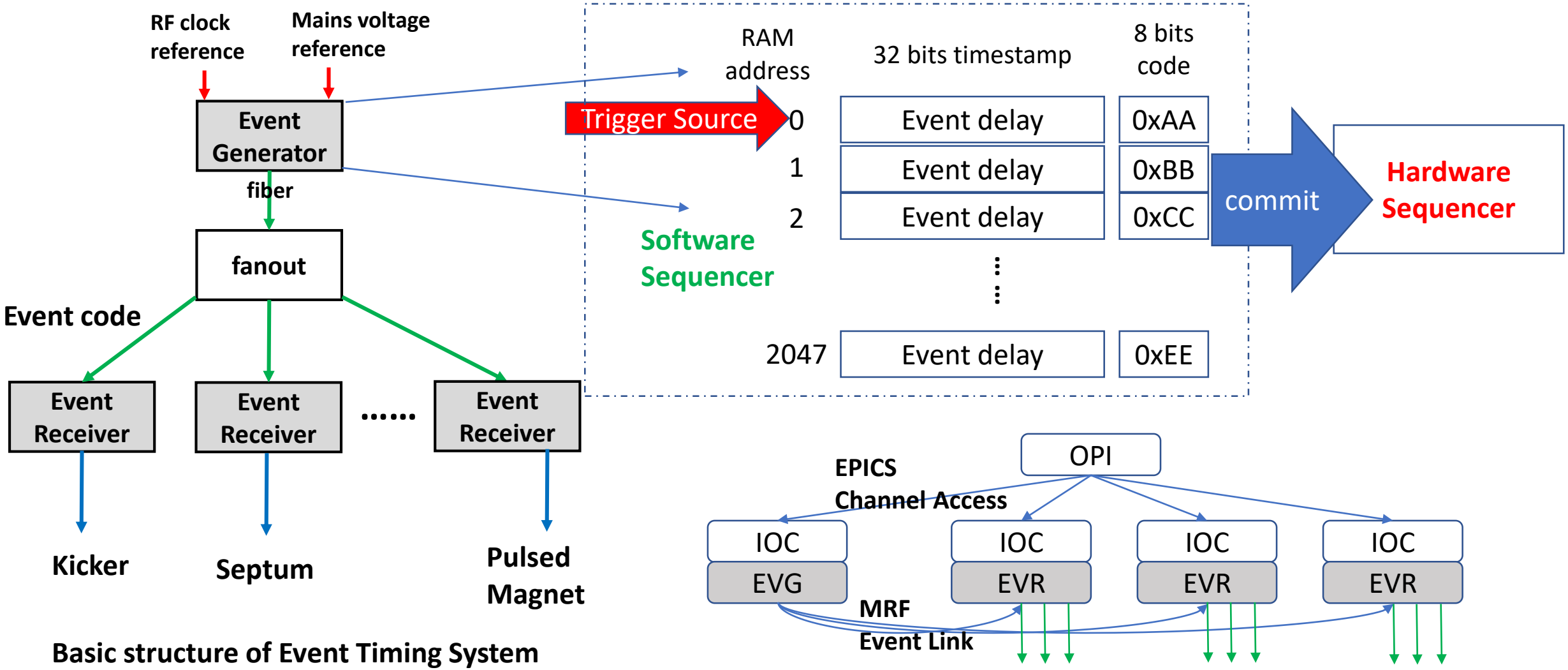
Outline

- 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

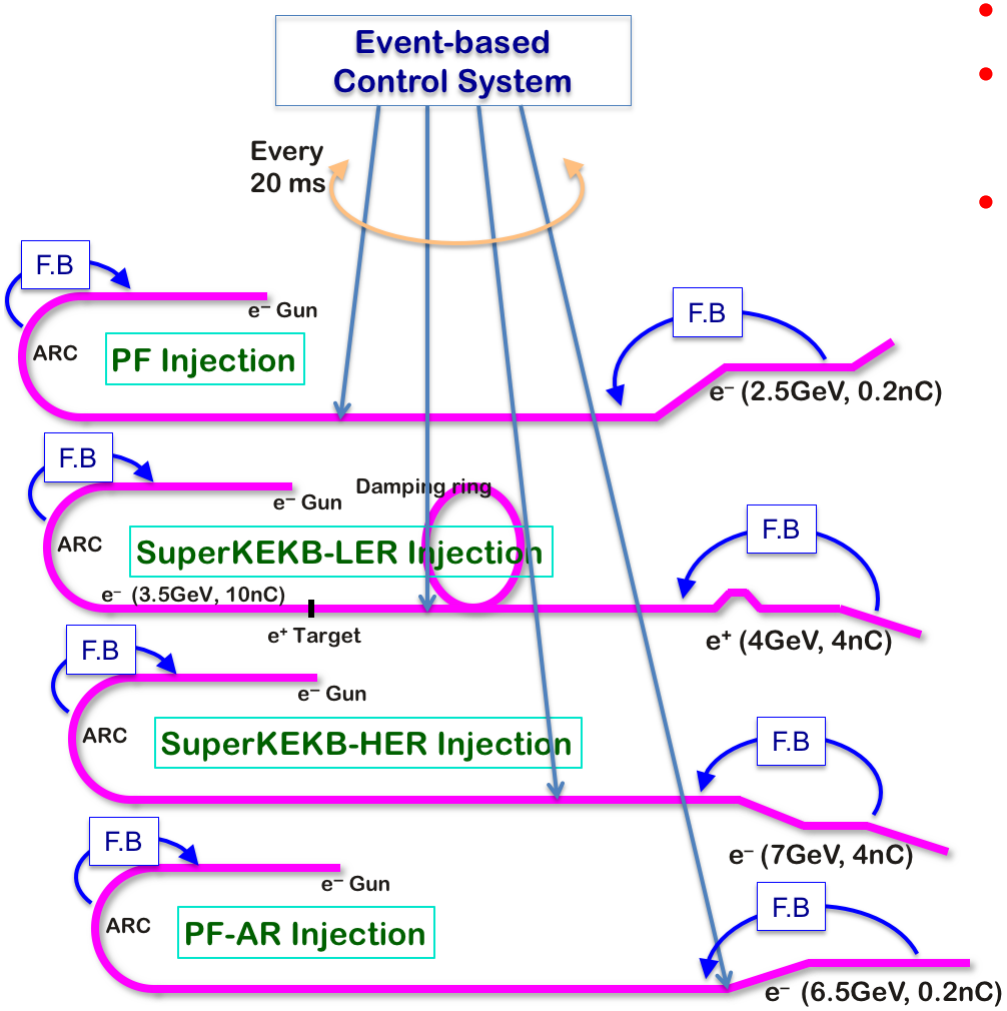


Event Timing System in SKEKB



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)

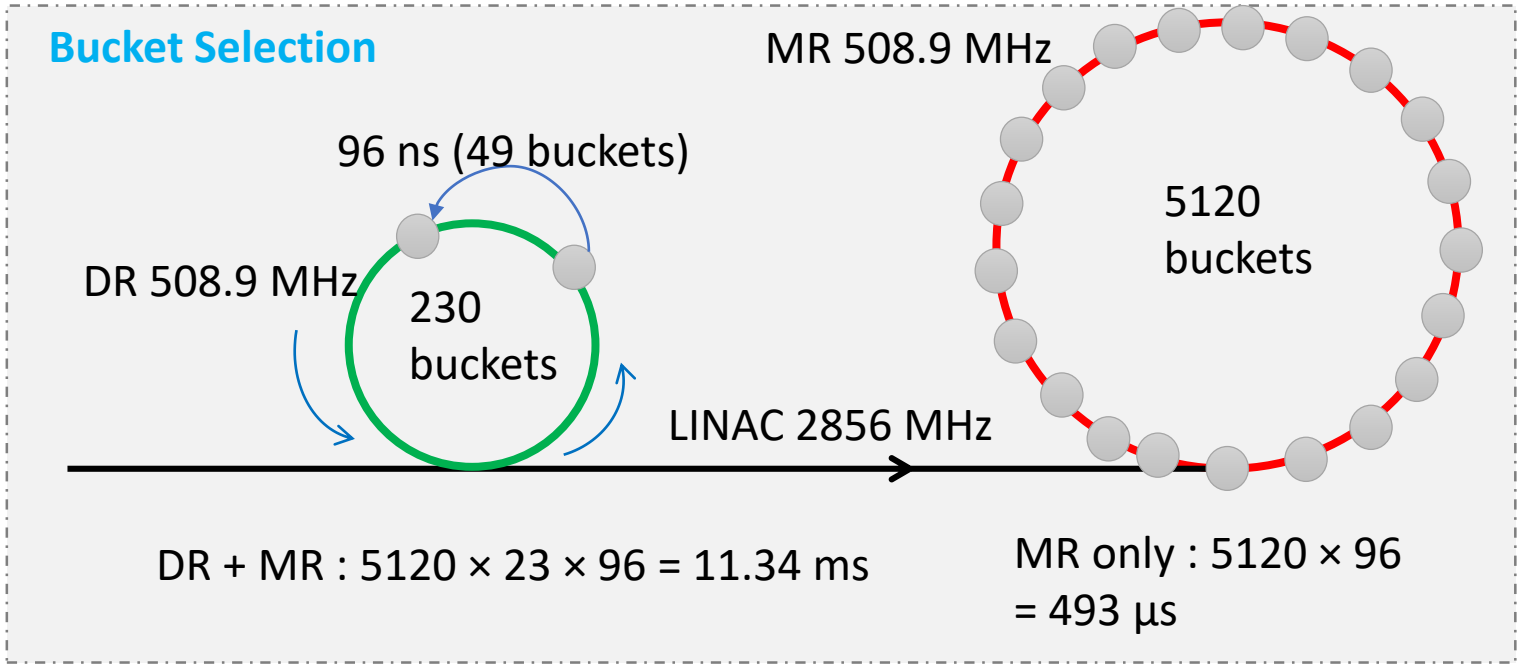
Event Timing System in SKEKB

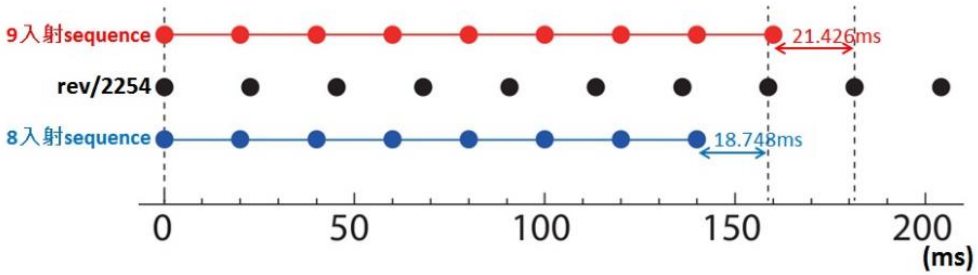
- Common frequency between 2856 MHz and 508.9 MHz is 10.38 MHz (96 ns, 49 buckets duration)
  - Chance of injection timing turns up once per 96ns (49 buckets).
- Requiring two bucket selection timings (injection and extraction at DR, two EVGs are needed)
- The number of combination is 5120 × 23 (least 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

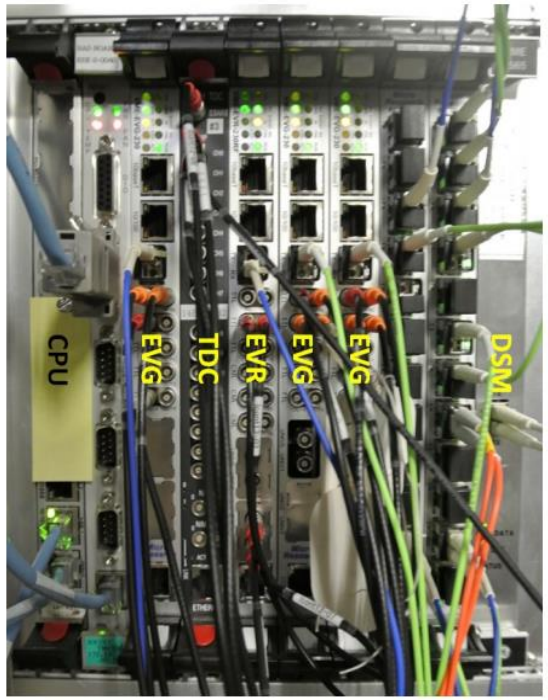
H. Kaji et al. "INSTALLATION AND COMMISSIONING OF NEW EVENT TIMING SYSTEM FOR SuperKEKB", PASJ 2015 FROL15





Event Timing System in SKEKB

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



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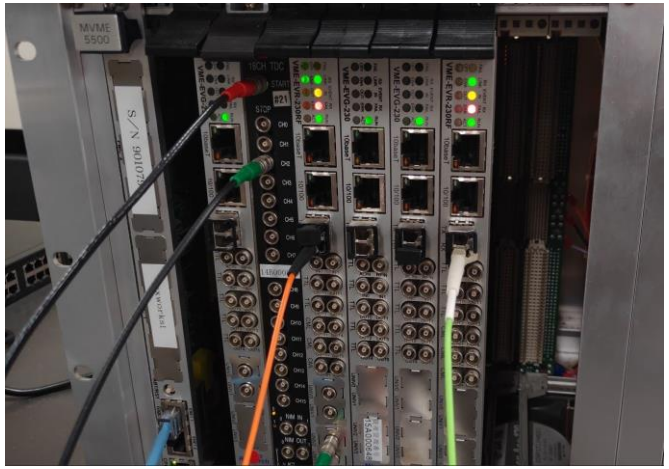
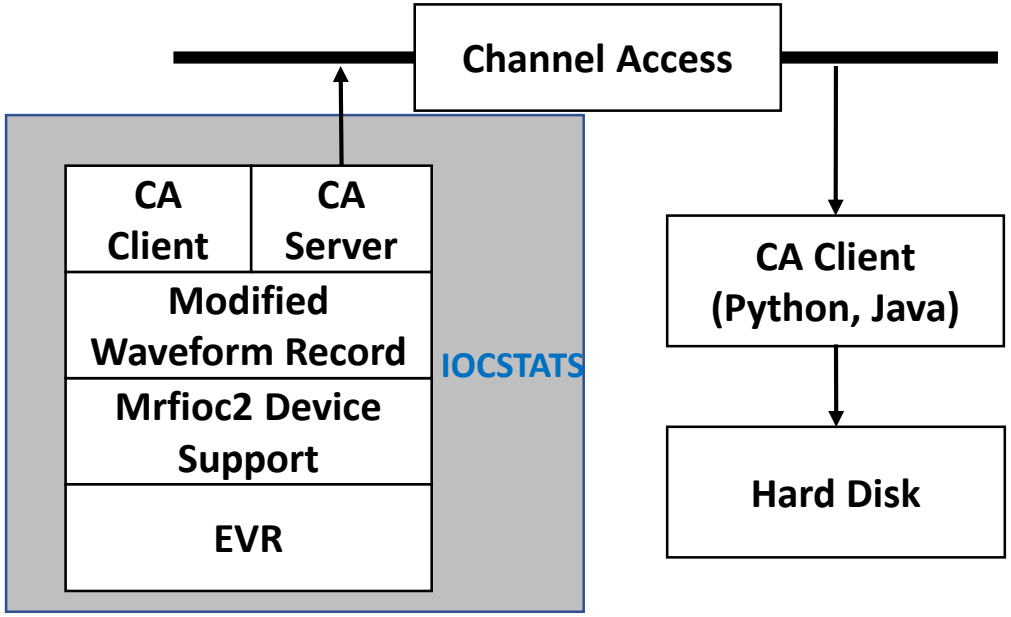
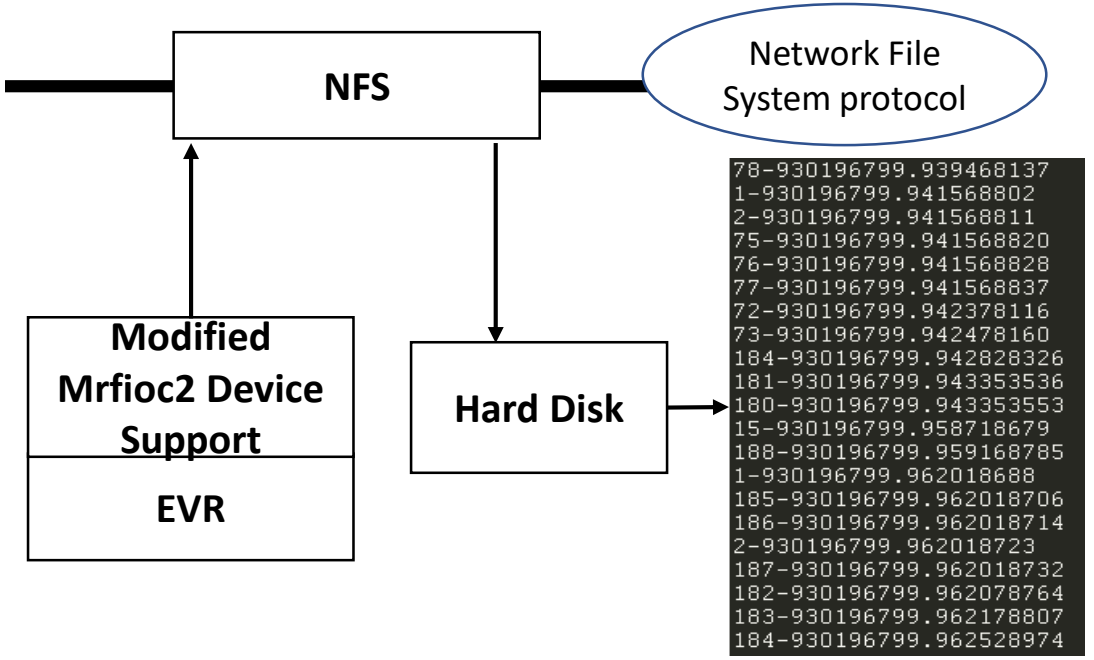
Data Acquisition

- 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
- 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

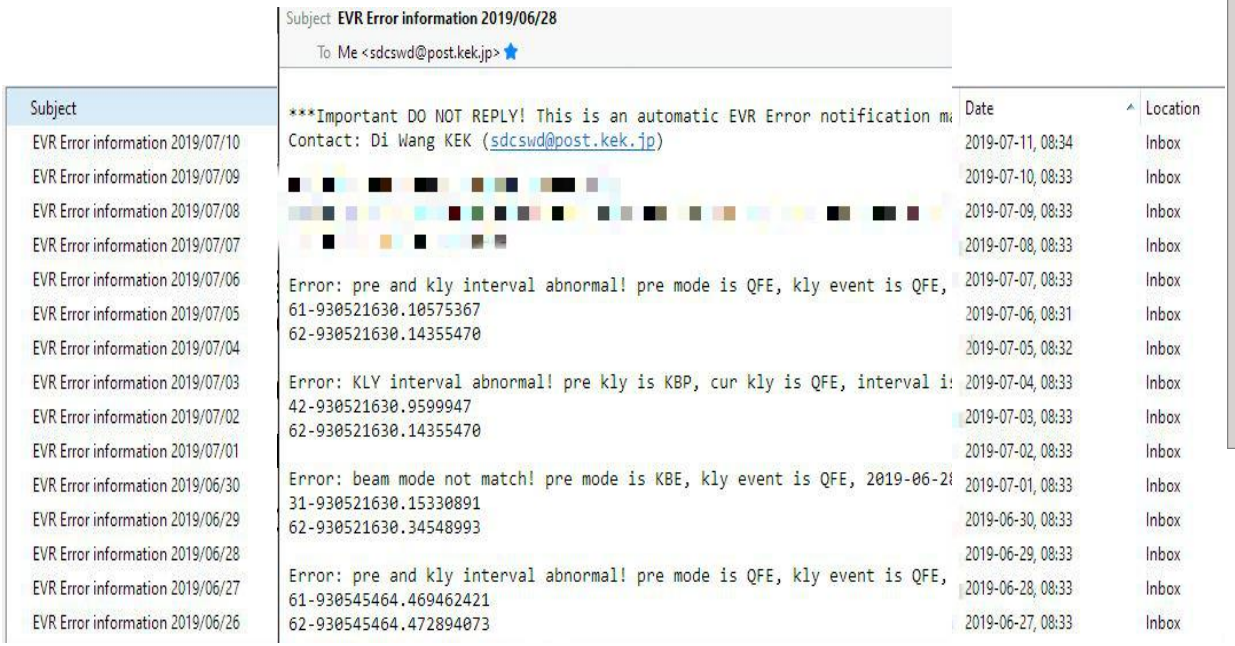


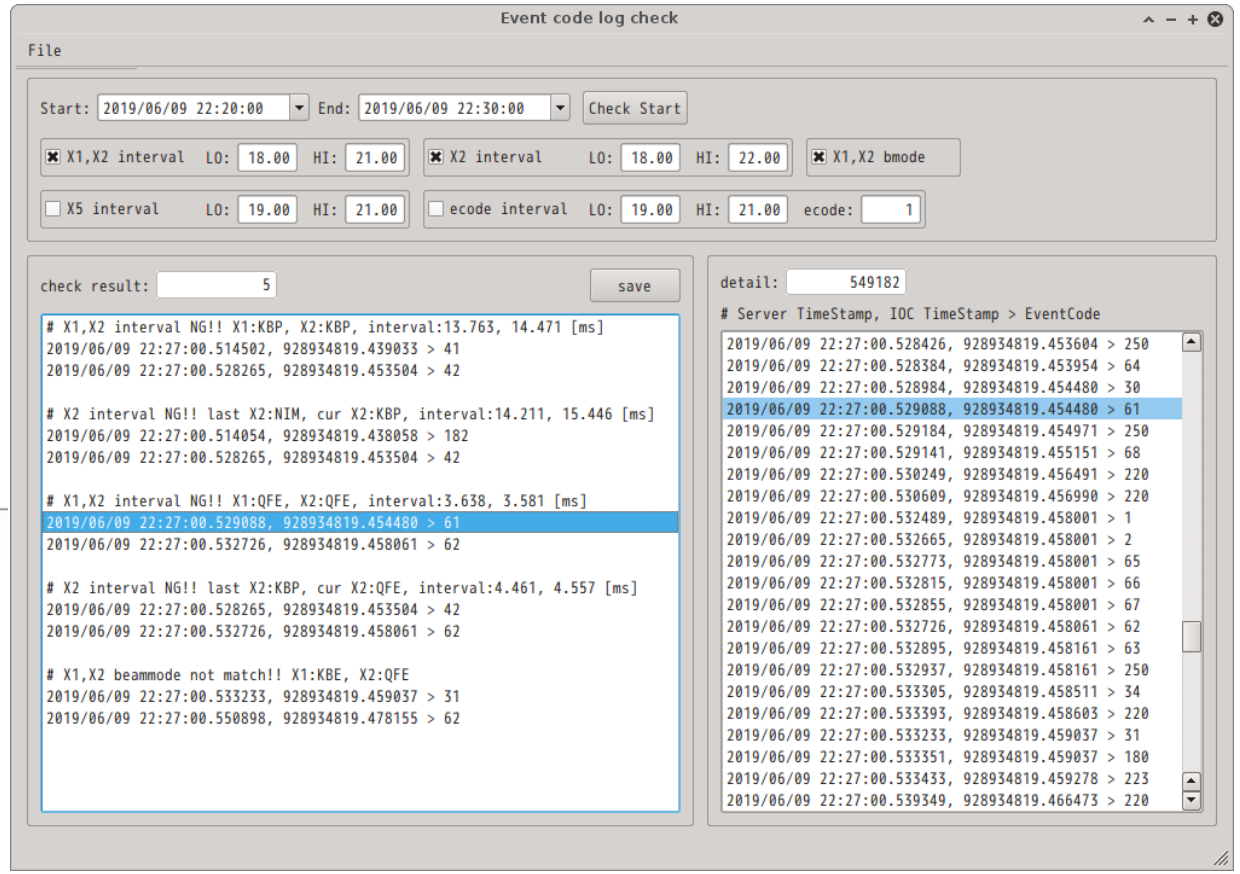




Data Processing

- 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

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Fault Diagnosis

Beam mode repeat

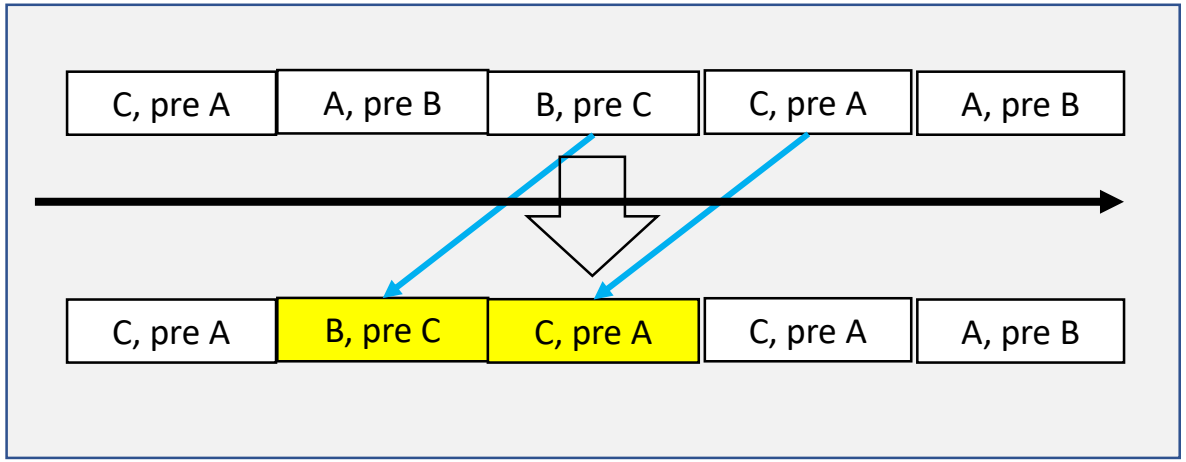
Excerpt of the abnormal

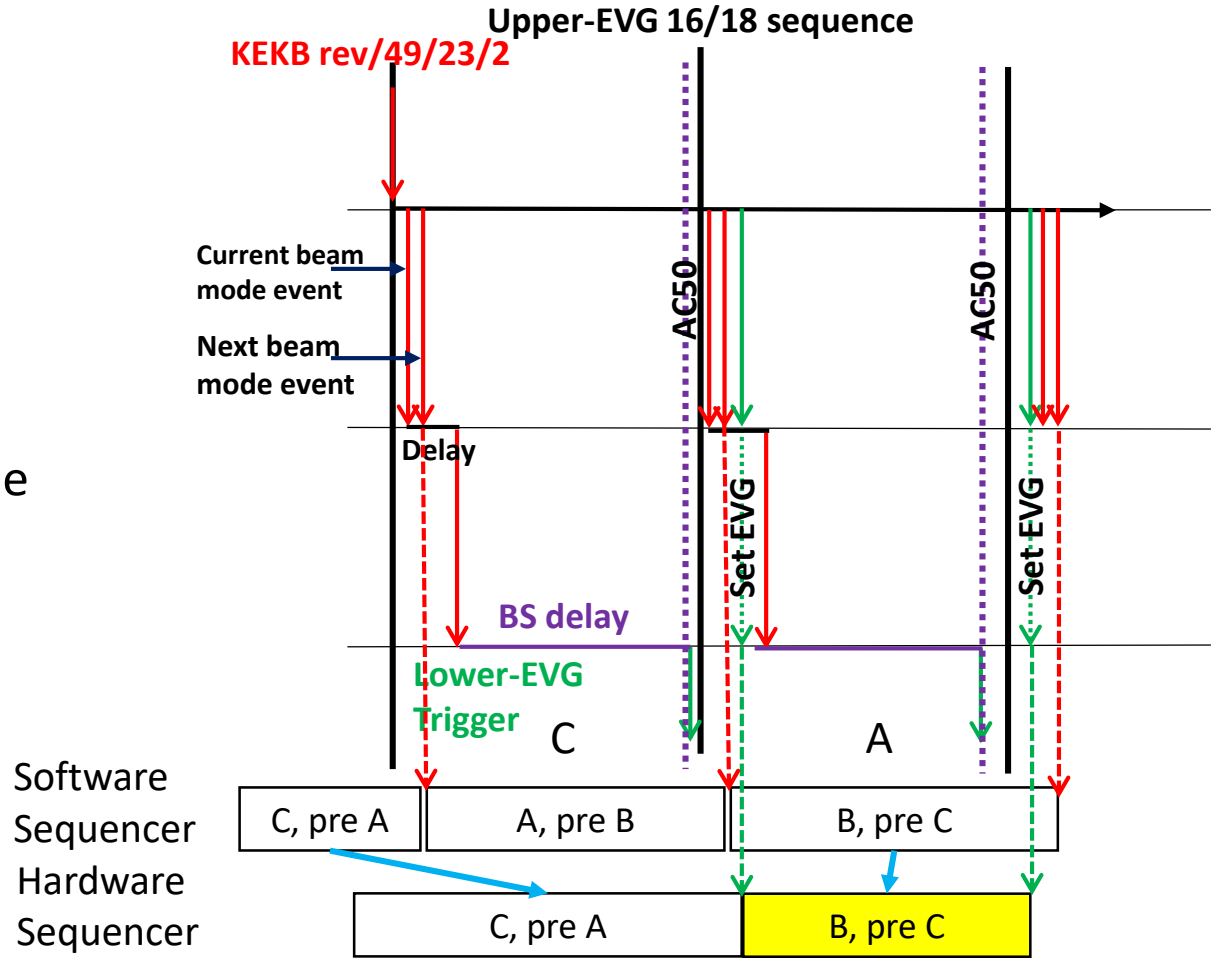
C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
pre pulse			pre kly timestamp	interval (ms)	current pulse			current kly timestamp	interval (ms)	next pulse			next kly timestamp	time
		42	61		30	930272424.558212675				20.00		62	31	180
		42	61		30	930272425.501544336				19.72		42	61	30
		42	181		30	930272435.293183228				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[illegible]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[illegible]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[illegible]130794	4.26	62	181	180	930720659.448975665	2019-06-30 14:30:59
182	181	30	930970807.762007265		32	181	180	930970807.78[illegible]727162	19.72	32	181	180	930970807.804573249	2019-07-03 12:00:07
182	181	30	931273231.402987394		32	181	180	931273231.42[illegible]707291	19.72	32	181	180	931273231.445553378	2019-07-07 00:00:31

Abnormal PF beam mode interval

Beam Mode Replacement

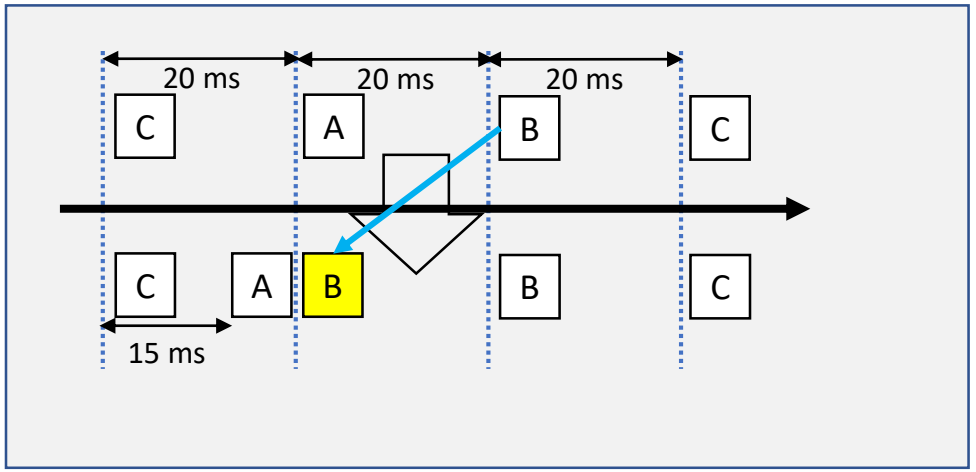
- AC50 comes very late
  - AC power fluctuation
  - Alternating during 16/18 sequences injection
- Bucket Selection delay increases
- 'Set EVG' signal comes late than pre event
- Current beam mode is replaced by the next beam mode
- Happened 15 times during 2-weeks operation in June

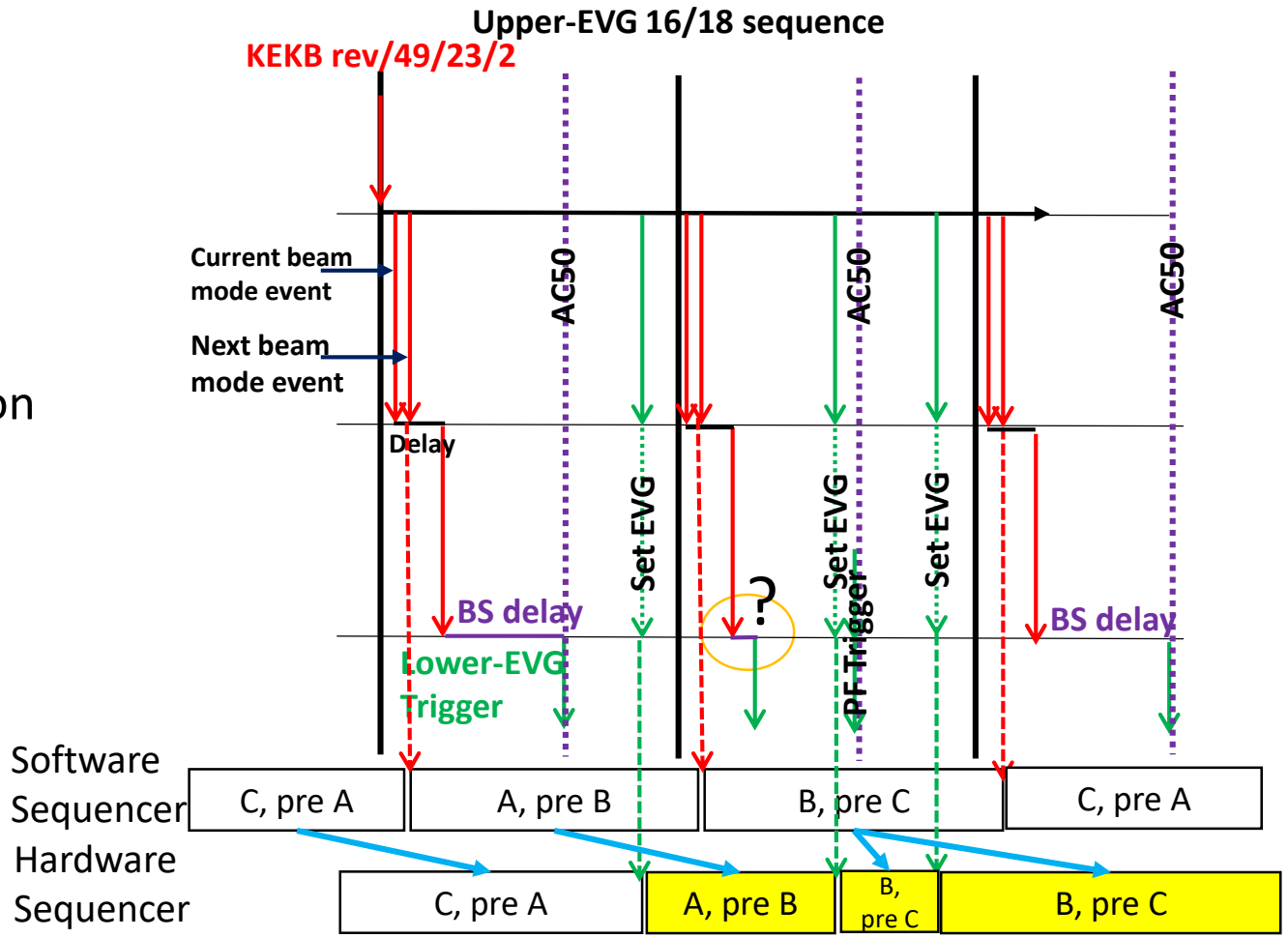




Redundant Beam Mode

- 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





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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

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