



The Fault Diagnosis of Event Timing System in SuperKEKB

D. Wang, K. Furukawa, M. Satoh, H. Kaji, H. Sugimura,

T. Kudou, S. Kusano, Y. litsuka

KEK





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







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- 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)



- 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









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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







- 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

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	Subject EVR Error information 2019/06/28 To Me <sdcswd@post.kek.jp> 🕇</sdcswd@post.kek.jp>		
Subject	- ***Important DO NOT REPLY! This is an automatic EVR Error notification ma	Date	▲ Lo
EVR Error information 2019/07/10	Contact: Di Wang KEK (<u>sdcswd@post.kek.jp</u>)	2019-07-11, 08:34	Int
EVR Error information 2019/07/09		2019-07-10, 08:33	Int
EVR Error information 2019/07/08		2019-07-09, 08:33	Ini
EVR Error information 2019/07/07		2019-07-08, 08:33	Int
EVR Error information 2019/07/06	Error: pre and kly interval abnormal! pre mode is QFE, kly event is QFE,	2019-07-07, 08:33	Int
EVR Error information 2019/07/05	61-930521630.10575367 20 62-930521630.14355470 20	2019-07-06, 08:31	Int
EVR Error information 2019/07/04		2019-07-05, 08:32	Int
EVR Error information 2019/07/03	Error: KLY interval abnormal! pre kly is KBP, cur kly is QFE, interval i:	2019-07-04, 08:33	Int
EVR Error information 2019/07/02	42-930521630,9599947	2019-07-03, 08:33	Int
EVR Error information 2019/07/01	02-930321030.14333470	2019-07-02, 08:33	Int
EVR Error information 2019/06/30	Error: beam mode not match! pre mode is KBE, kly event is QFE, 2019-06-28	2019-07-01 <mark>,</mark> 08:33	Ini
EVR Error information 2019/06/29	21-930521630.15330891 62-930521630.34548993	2019-06-30, 08:33	Int
EVR Error information 2019/06/28		2019-06-29, 08:33	Int
EVR Error information 2019/06/27	Error: pre and kly interval abnormal! pre mode is QFE, kly event is QFE, 61-930545464 469462421	2019-06-28, 08:33	Int
EVR Error information 2019/06/26	62-930545464.472894073	2019-06-27, 08:33	Int

Event code log check	^ - ·
e	
tart: 2019/06/09 22:20:00 V End: 2019/06/09 22:30:00 V Check Start]
C X1,X2 interval LO: 18.00 HI: 21.00 🗷 X2 interval LO: 18.00	HI: 22.00 🕱 X1,X2 bmode
X5 interval LO: 19.00 HI: 21.00	HI: 21.00 ecode: 1
neck result: 5 save	detail: 549182
	<pre># Server TimeStamp, IOC TimeStamp > EventCode</pre>
X1,X2 interval NG!! X1:KBP, X2:KBP, interval:13.763, 14.471 [ms]	2019/06/09 22:27:00.528426, 928934819,453604 > 250
019/00/09 22.27.00.514502, 920954619.459055 > 41	2019/06/09 22:27:00.528384, 928934819.453954 > 64
013/00/03 22.27.00.320203, 320334013.433304 / 42	2019/06/09 22:27:00.528984, 928934819.454480 > 30
X2 interval NGLL last X2.NIM. cur X2.KBP. interval:14.211. 15.446 [ms]	2019/06/09 22:27:00.529088, 928934819.454480 > 61
019/06/09 22:27:00.514054, 928934819.438058 > 182	2019/06/09 22:27:00.529184, 928934819.454971 > 250
019/06/09 22:27:00.528265, 928934819.453504 > 42	2019/06/09 22:27:00.529141, 928934819.455151 > 68
	2019/06/09 22:27:00.530249, 928934819.456491 > 220
X1,X2 interval NG!! X1:QFE, X2:QFE, interval:3.638, 3.581 [ms]	2019/06/09 22:27:00.530609, 928934819.456990 > 220
019/06/09 22:27:00.529088, 928934819.454480 > 61	2019/06/09 22:27:00.532489, 928934819.458001 > 1
019/06/09 22:27:00.532726, 928934819.458061 > 62	2019/06/09 22:27:00.532665, 928934819.458001 > 2
	2019/06/09 22:27:00.532773, 928934819.458001 > 65
X2 interval NG!! last X2:KBP, cur X2:QFE, interval:4.461, 4.557 [ms]	2019/06/09 22:27:00.532815, 928934819.458001 > 66
019/06/09 22:27:00.528265, 928934819.453504 > 42	2019/06/09 22:27:00.532855, 928934819.458001 > 67
019/06/09 22:27:00.532726, 928934819.458061 > 62	2019/06/09 22:27:00.532726, 928934819.458061 > 62
	2019/06/09 22:27:00.532895, 928934819.458161 > 63
X1,X2 beammode not match!! X1:KBE, X2:QFE	2019/06/09 22:27:00.532937, 928934819.458161 > 250
019/06/09 22:27:00.533233, 928934819.459037 > 31	2019/06/09 22:27:00.533305, 928934819.458511 > 34
019/06/09 22:27:00.550898, 928934819.478155 > 62	2019/06/09 22:27:00.555595, 928954819.458603 > 220
	2019/00/09 $22:27:00.555255$, $928954819.459057 > 51$
	2019/00/09 22:27:00.555551, 928954819.459037 > 180
	2013/00/03 22:27:00 533433, 920934019.439278 > 225
	2013/00/03 22:21:00.003349, 928954819.400475 > 220

Optional, manually check detailed data



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Beam mode repeat

Excerpt of the abnormal

	C	D	E	F	G	Н	I	J			L		M	N	0		P		Q	
	р	re pulse	pre kly t	imestamp ir	nterval (ms)	cu	irrent puls	e c	current kly	nestamp	interval	(ms)	nex	kt pulse		next kly tir	nestamp		time	
			42	61	-	30	930	272424	4.5582	1267	5		20	0.00		62		31	180	19
			42	61		30	9302	27242	5.5015	64433	6		19	.72		42		61	30	9
			42	181		30	9302	27243	5.2931	8322	8		19	.72		42		181	30	9
	182	181	40 930272435.2	2/3463366 🦳 🕇		~ 42	2 7181	30793	£02/2435.293	183228	~ ,	19.72	42 0	าส	30	9302/2435.	316029315	~ •	2019-06-25 10:00:35	
	182	31	1 180 930272436.296947706 11 180 930272436.336880479			182	181	60 93	80272436.3170	021848	2	20.07	182	61	180	930272436.	336880479		2019-06-25 10:00:36	
	182	61				182	61	180 93	30272436.359	726566	2	22.85	182	181	40	930272436.	377026146		2019-06-25 10:00:36	
	182	181	40 930272436.3	377026146		182	181	40 93	30272436.3970	026137	2	20.00	182	41	180	930272436.	416750358		2019-06-25 10:00:36	
	182	181	181 40 930272442.958951776 181 30 930272442.998389215 61 180 930272445.025169494			182	181	40 93	80272442.981	797864	2	22.85	42	181	30	930272442.	998389215		2019-06-25 10:00:42	
	42	181				42	181	30 93	30272443.0184	411353	2	20.02	182 31 180 930272443.0		038913331	2019-06-25 10:00:43				
	182	61				182	181	40 93	80272445.0453	382379	2	20.21	182 181 40 930272445.0682		068228466	2019-06-25 10:00:45				
	182	182 181 40 930272445 068228466			42	2 181 30 930272445 (<u>/</u> 1672			42 181		30 930272445 104949798			2019-06-25 10:00:45			
15.36 15.26 15.88 15.46		5.36	62		31		180	30 930442228		8.038239154		.54			4.88		62	2	31	
		5.26	62	1	31	:	180	93045	7499.	6545	729	07			4.8	3	62	2	31	
		5.88	62	1	31		180	93052	1630.	0143	554	70			4.7	6	62	2	31	
		5.46	62	: :	181		180	93054	5464.	4728	940	73			4.4	1	62	2	181	
Τ	42	42 61 30 930707588.269066456 15.		15.44	62	31	180 93	0707588.27	811808		4.75	62	31	180	930707588.	293819502		2019-06-30 10:53:08		
	42	42 61 30 930708428.139723415 15.18 42 61 180 930720659.424868872 15.66			15.18	62	31	180 93	80708428.14	441999		4.72	62	31	180	930708428.	164375455		2019-06-30 11:07:08	
	42				15.66	62	181	180 93	30720659.42	130794		4.26	62	181	180	930720659.	448975665		2019-06-30 14:30:59	
	182	181	81 30 930970807.762007265			32	181	180 93	30970807.78	727162	1	19.72	32	181	180	930970807.	804573249		2019-07-03 12:00:07	
	182	181	30 931273231.4	402987394		32	181	180 93	31273231.42	707291	1	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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- 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



- <u>Di. Wang</u>
- <u>sdcswd@post.kek.jp</u>
- KEK Linac

