

Synchronized Timing and Control System Construction of SuperKEKB Positron Damping Ring

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KEK

Oct. 12, 2017

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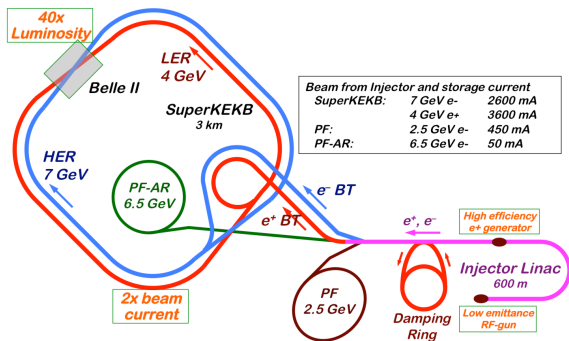
- 1 SuperKEKB Project
- 2 Event Timing System
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SuperKEKB Project

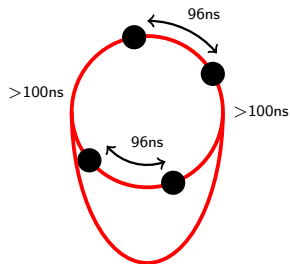
- e^+e^- collider, B-Factory
- Aim at 40-times higher Luminosity than previous KEKB project
 - $2 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ (KEKB) $\rightarrow 8 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$ (SuperKEKB)
- Twice larger storage beam \rightarrow Higher beam current at Linac
- 20-times higher collision rate with nano-beam scheme



Damping Ring (DR)

- Emittance become down to 1/500 during damping time.
- 40 ms damping while linac operate at 50 Hz
- Accomodate 2-bunches \times 2-pulses
- 2-bunches in a pulse are separated by 96.3 ns (10.385 MHz)
- Injection/extraction kickers rise/fall times are ~ 100 ns

Energy	1.1	GeV
Repetition frequency	50	Hz
Length	135.5	m
RF frequency	508.9	MHz
Harmonic Number	230	
Number of bunches	2	
Bunch spacing	96	ns

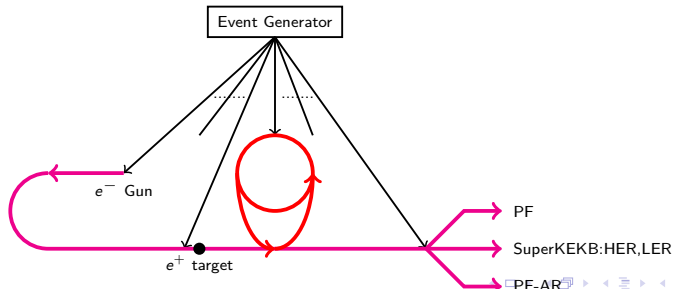


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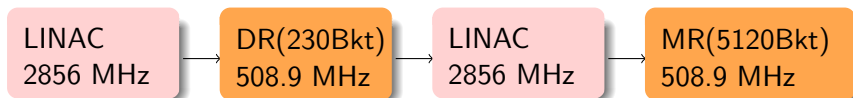
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Event Timing System for Simultaneous Top-up Injection

- Fast, global and synchronous controls
 - synchronized with 114 MHz RF clock and 16 bit/clock event/data transfer
- MRF's series Event Generator and Receivers
 - VME-EVG-230 / VME-EVR-230-RF / PXI-EVR-300
- System communicate VME64x and PCIe (VxWorks v6.8 and Windows)
- EPICS R3.14.12 with mrfioc2 (device support)



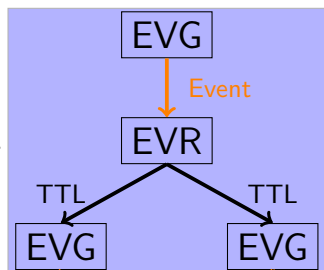
Injection and extraction timing at DR



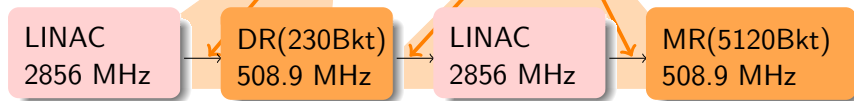
- Two timings (injection and extraction at DR) are needed
- Common frequency between 2856 MHz and 508.9 MHz is 10.38 MHz (96 ns, 49 buckets duration)
 - Chance of injection timing turns up once per 96ns (49 buckets).
- Need to consider bucket select combination each DR and MR buckets.
- The number of combination is 5120×23 (least common multiple of DR and MR)

Master Timing System

Master Timing System consists of 1-upper EVG, 1-upper EVR and 2-lower EVGs in 1-IOC. It delivers dozens kinds of timing (BPM, Kicker, Septum ...).



Upper EVG calculates which bucket is injected/extracted (bucket selection). Lower each EVGs delay timing according to bucket-ID.



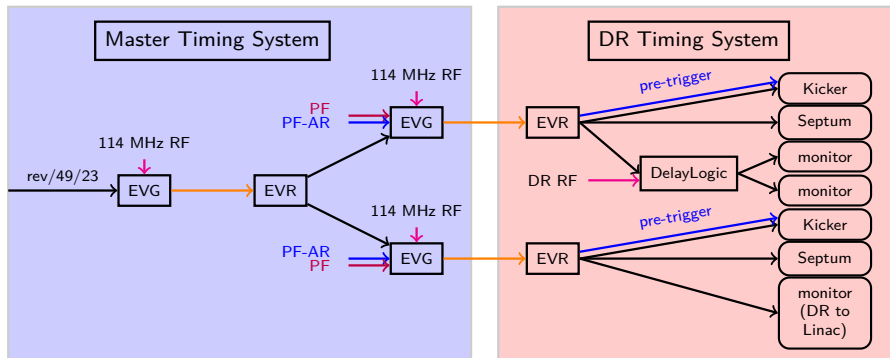
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Timing Constraints at DR

- Kicker Timing
 - Injection/extraction (especially extraction) kicker timing is most important to have effect of beam jitter.
 - Injection/extraction kicker need charging trigger ~ 15 ms before firing. We call “pre-trigger”.
- Pulse trains should be provided for BPM
 - at revolution frequency (508.9 MHz/230)
 - synchronized to one of the beam bunches in DR
- dispersion measurement
 - 508.9 MHz \pm 50 kHz
 - should be disconnected from other clocks

Event Timing System at DR



Injection and extraction timing event is sent to each EVRs.
 EVR for injection and extraction timing distribute main timing and pre-trigger timing.

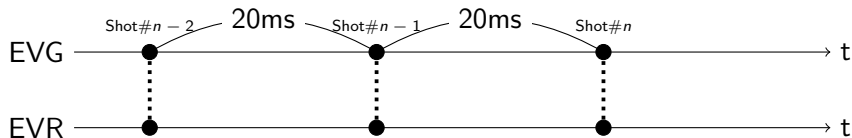
The pre-trigger timing is originally generated EVR itself.
 For dispersion measurement, valuable delay logic is added.

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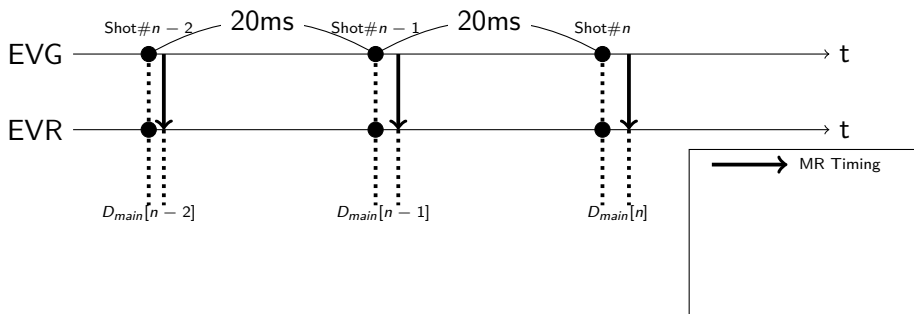
Event stream from EVG to EVR

Event is sent from EVG to EVR every 20 ms. Suppose to think about DR injection timing at Shot# n .



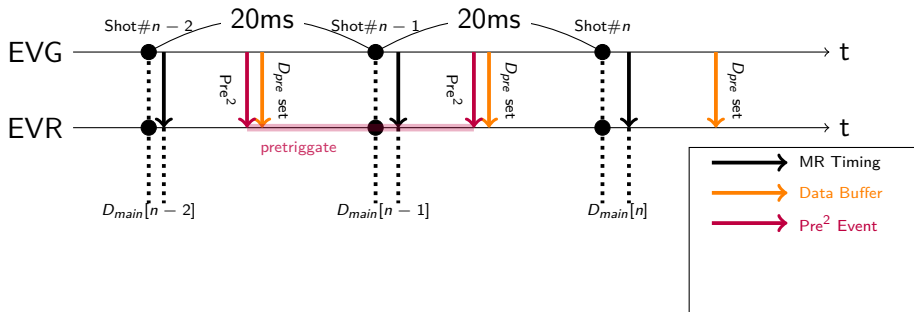
Event stream from EVG to EVR

MR timing is sent after bucket selection delay " D_{main} ". " D_{main} " would change shot by shot due to bucket selection.



Event stream from EVG to EVR

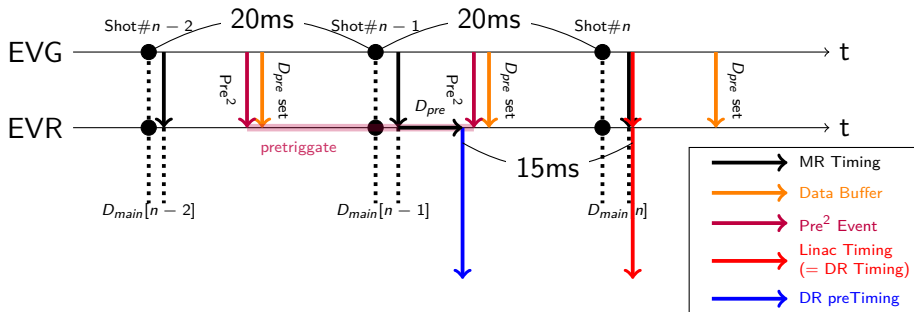
Delay time for pre-trigger (D_{pre}) is received by using “Data Buffer” before Shot # $n-1$. Then, set D_{pre} .



Event stream from EVG to EVR

Pre-trigger timing is generated from MR timing.

Main trigger timing is generated from Linac timing with no delay.



The delay time (D_{pre}) from MR timing is calculated as eq(1).

$$D_{pre}[n] = D_{main}[n] - D_{main}[n-1] + 5ms \quad (1)$$

In this system, timing jitter is measured with 30 ps jitter.

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Summary

- SuperKEKB project aims at 40 times higher luminosity than previous KEKB project
- Operation of damping ring will be started in this FY
- Injector linac, damping ring, EPICS control system, event-based synchronous system are being constructed
- Pre-trigger system was constructed with 30 ps timing jitter
- Long stability test will be started soon.