# Synchronized Timing and Control System Construction of SuperKEKB Positron Damping Ring

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KEK

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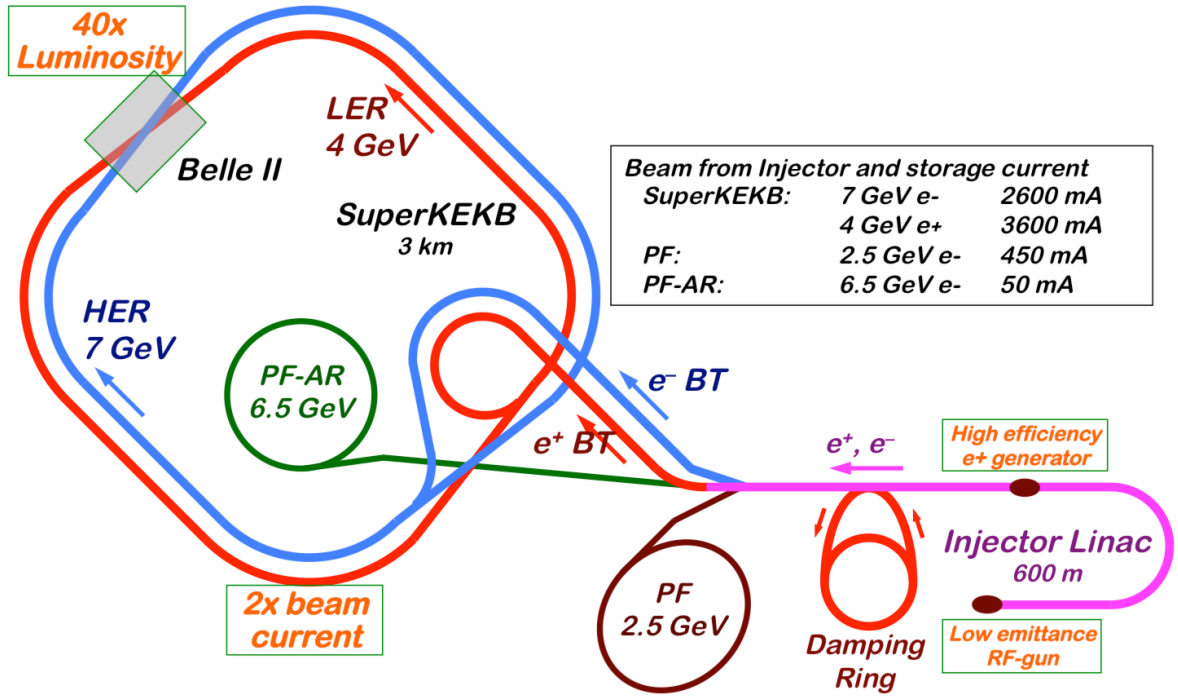
# SuperKEKB Project

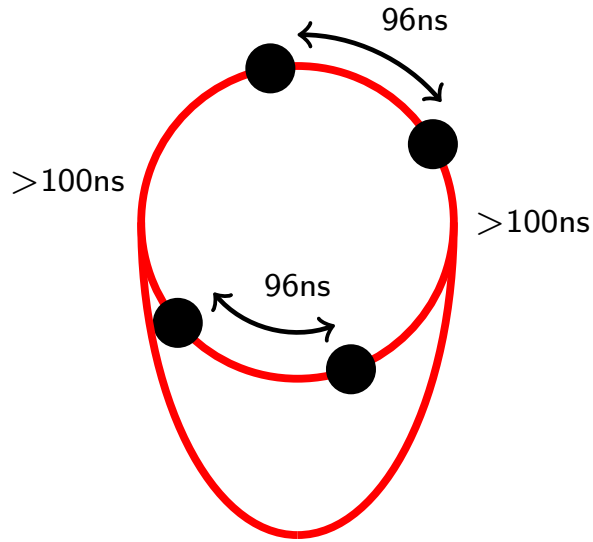
- $e^+$-$e^-$ collider, B-Factory
- Aim at 40-times higher Luminosity than previous KEKB project
  - $2 \times 10^{34}$ cm$^{-2}$s$^{-1}$(KEKB) $\rightarrow 8 \times 10^{35}$ cm$^{-2}$s$^{-1}$(SuperKEKB)
- Twice larger storage beam $\rightarrow$ Higher beam current at Linac
- 20-times higher collision 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 $\sim$ 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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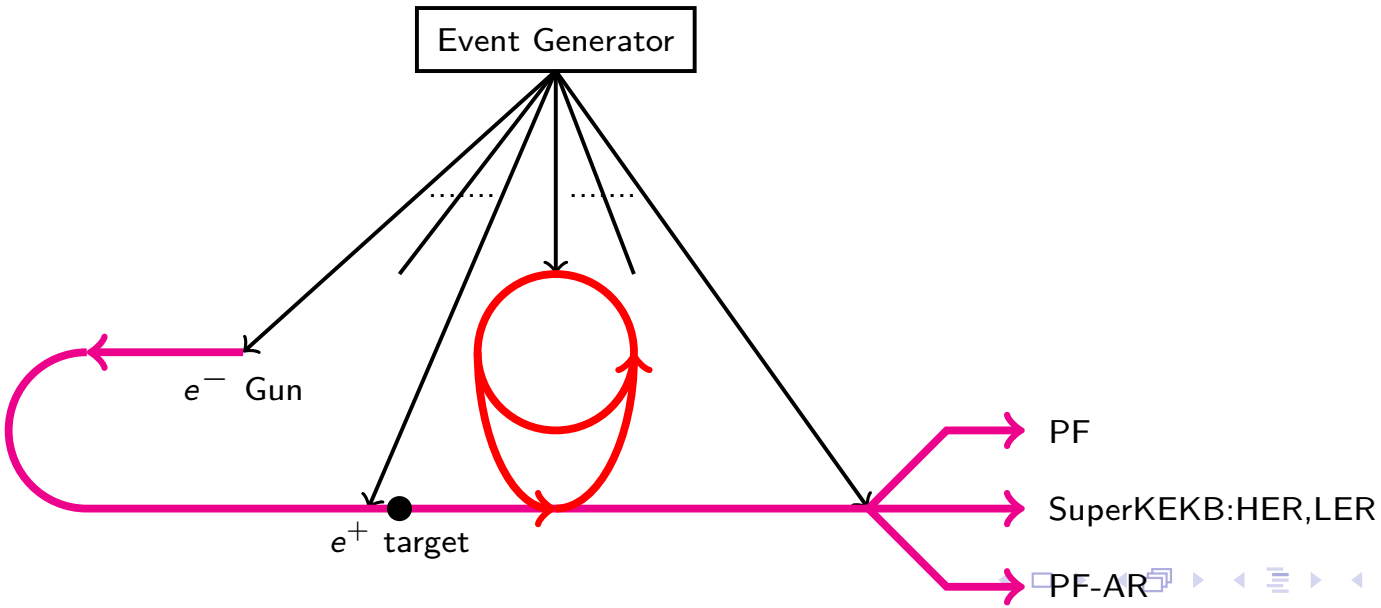
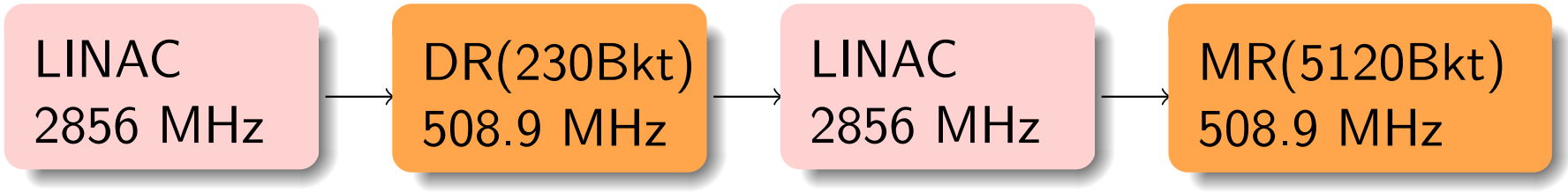
# Event Timing System for Simultaneous Top-up Injection

- 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)



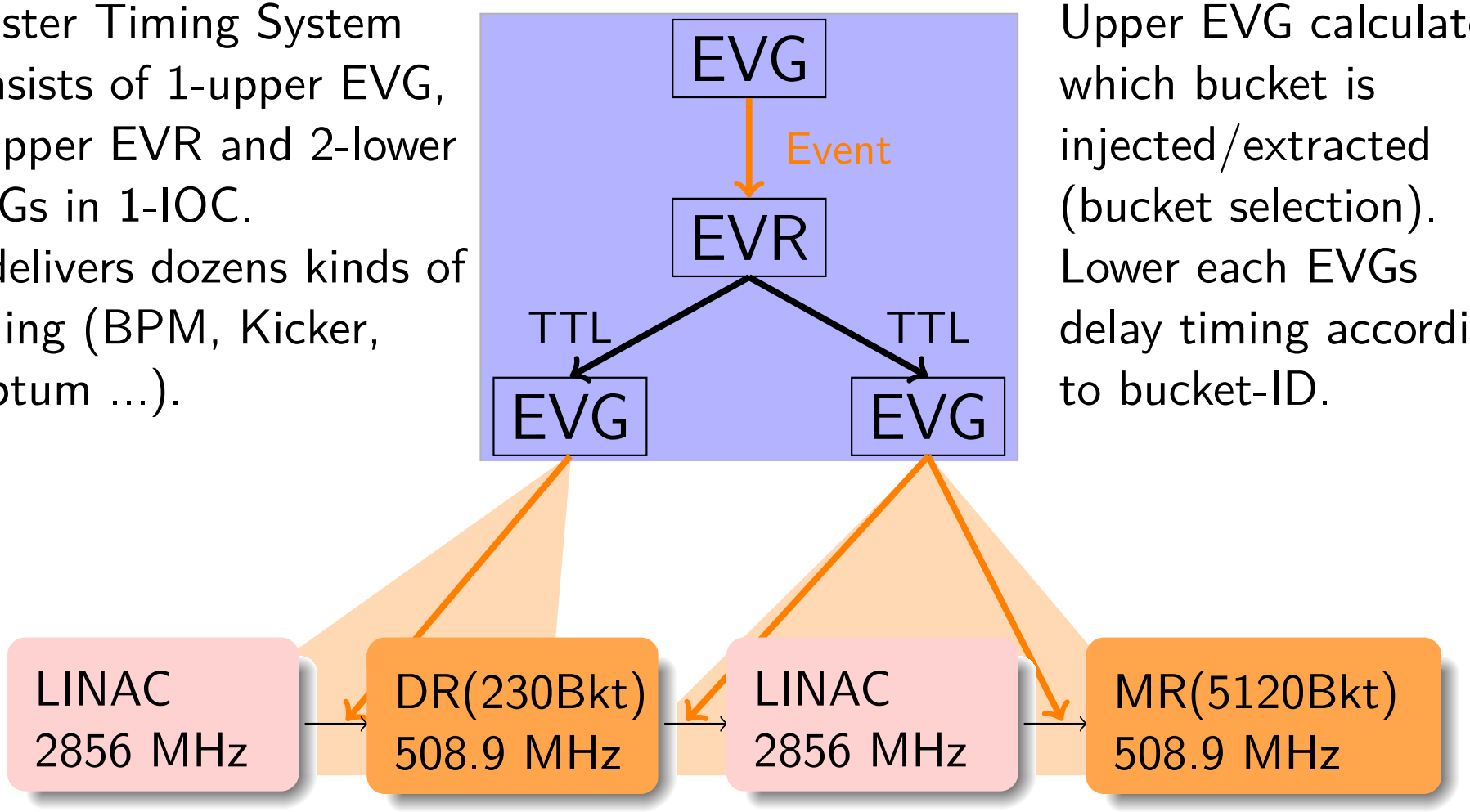
# Injection and extraction timing at DR




- 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 $5120 \times 23$ (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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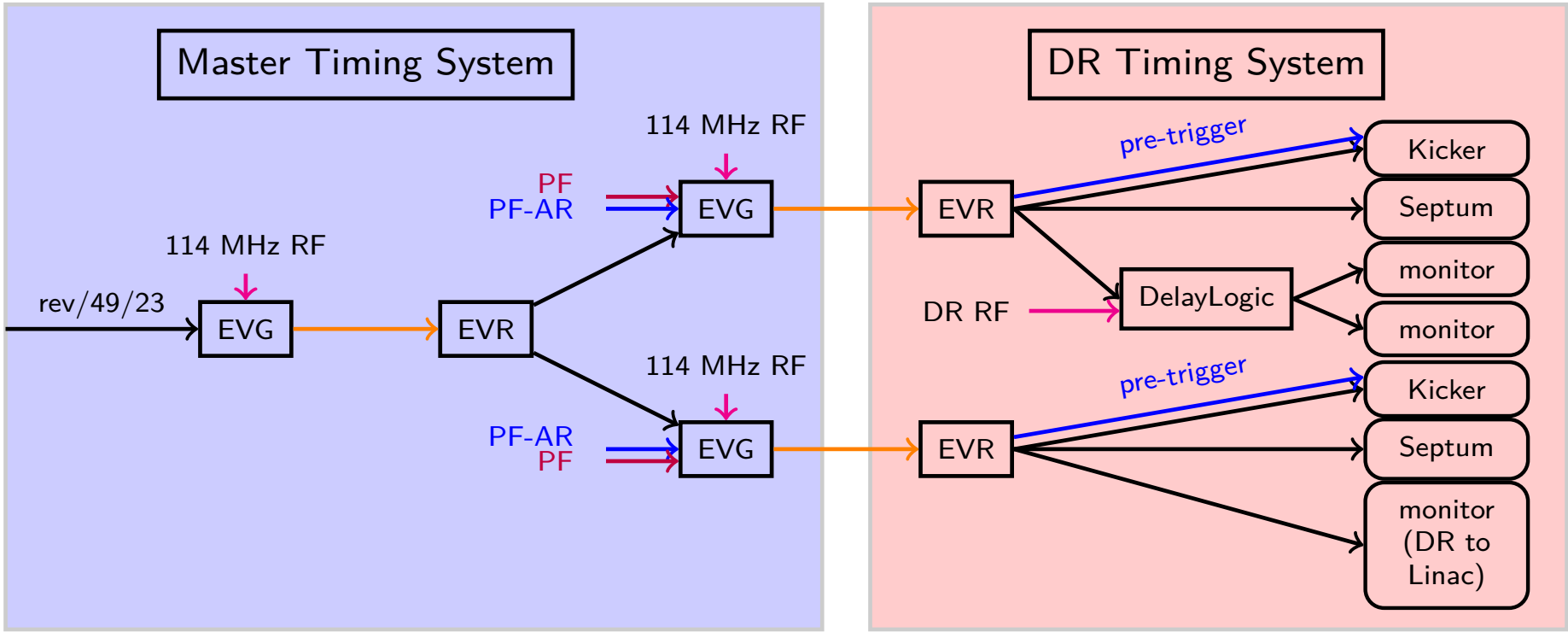
# Timing Constraints at DR

- Kicker Timing
  - Injection/extraction (especially extraction) kicker timing is most important to have effect of beam jitter.
  - Injection/extraction kicker need charging trigger $\sim$ 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 bunces 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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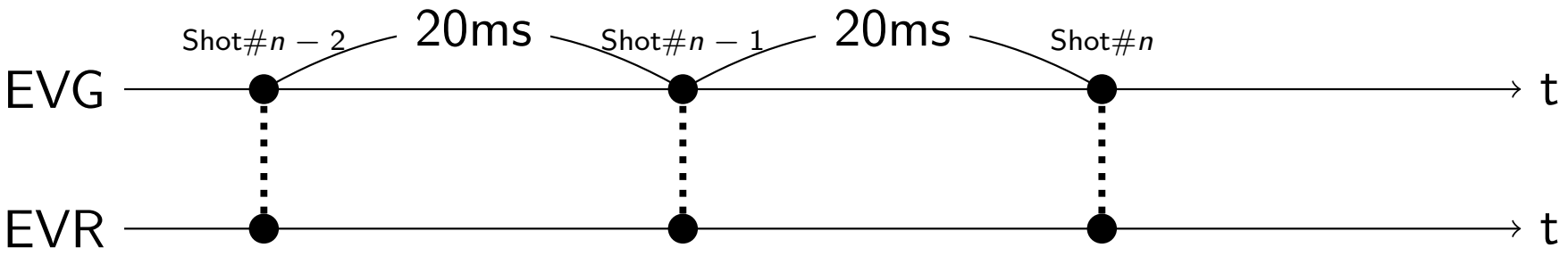
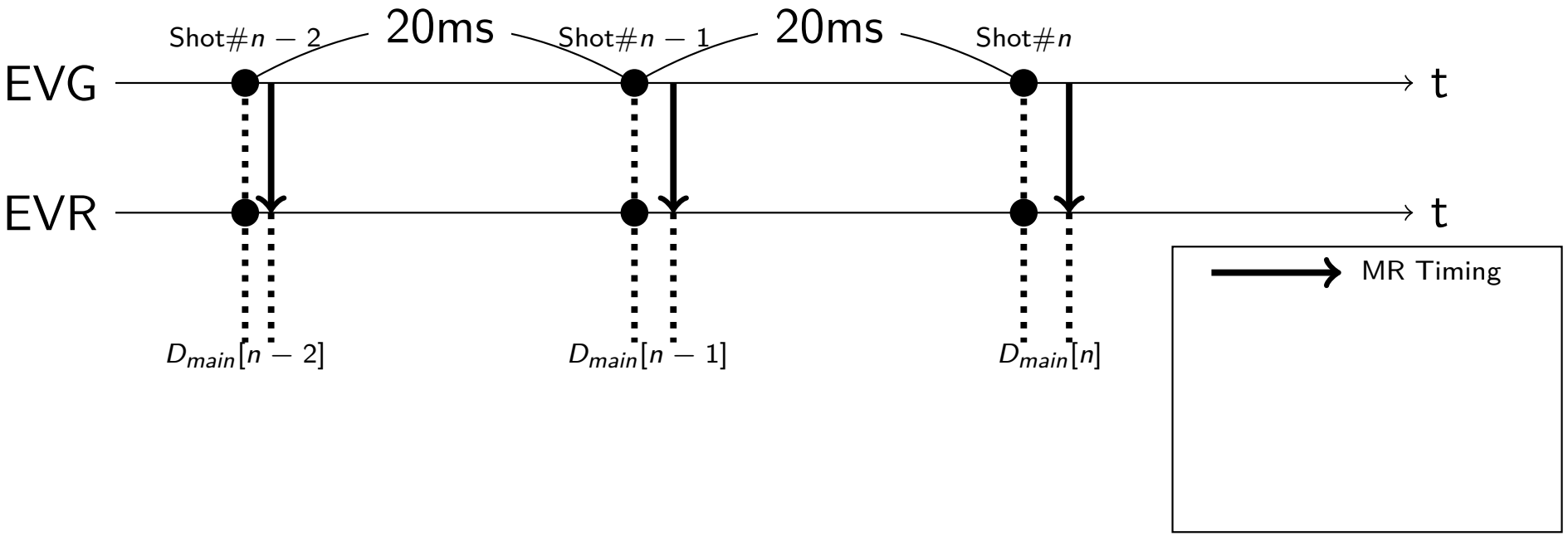
# Event stream from EVG to EVR

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



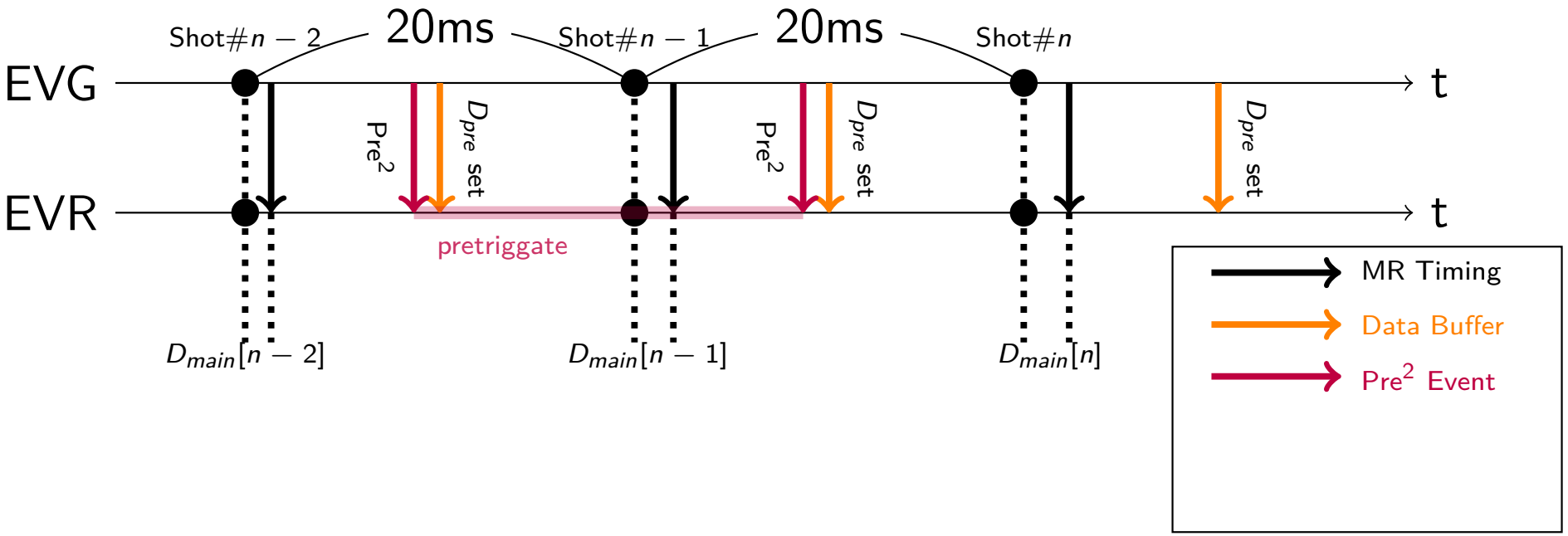
# Event stream from EVG to EVR

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



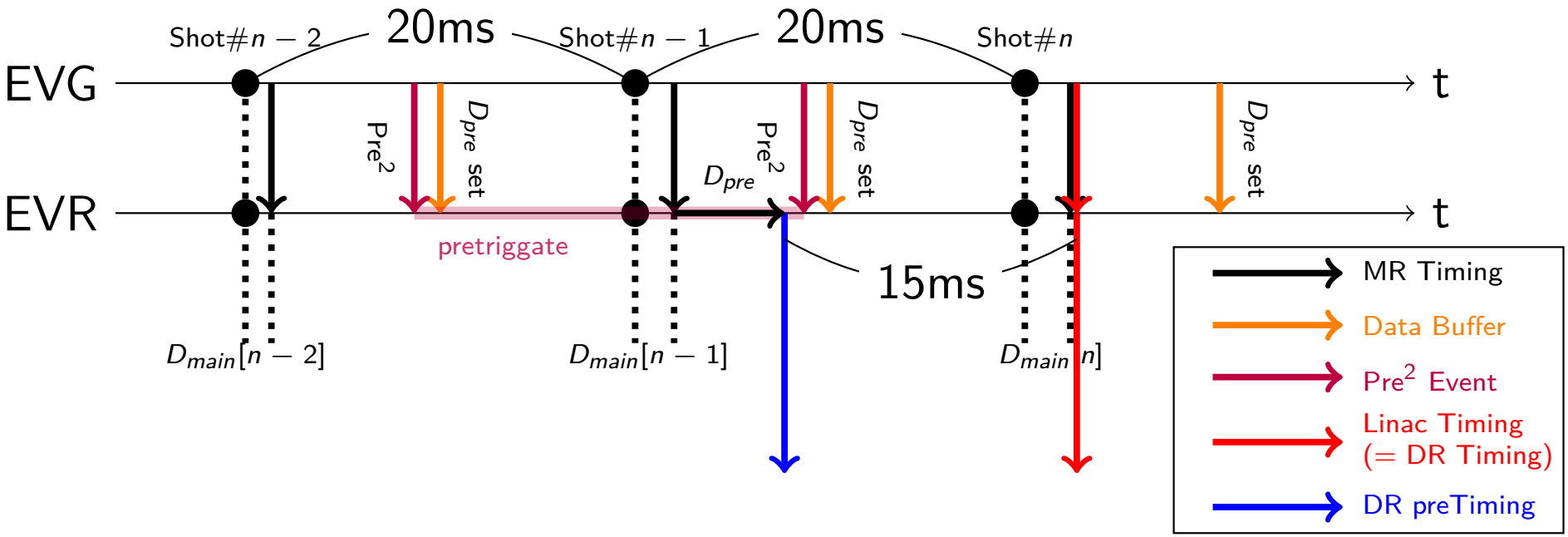
# Event stream from EVG to EVR

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 beging constructed
- Pre-trigger system was constructed with 30 ps timing jitter
- Long stablity test will be started soon.