Event Timing System for SuperKEKB

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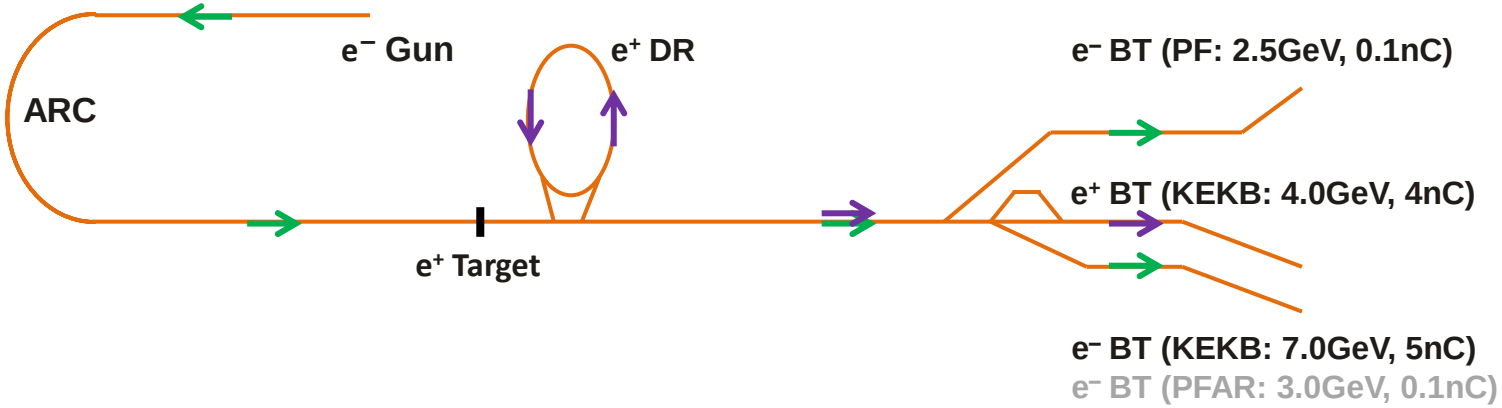
Injection control for KEK accelerators

Direction control

Linac works as 4 kinds of injectors since it delivers beam to KEKB-MRs(e^+/e^-), PF, and PF-AR.

- 50Hz in total, typical allocation: 37Hz(KEKB-e^-), 12.5Hz(KEKB-e^+), 0.5Hz(PF-e^-).
- Direction is changed in every pulse. ⇒ **Parameters of Linac are changed in every pulse.**

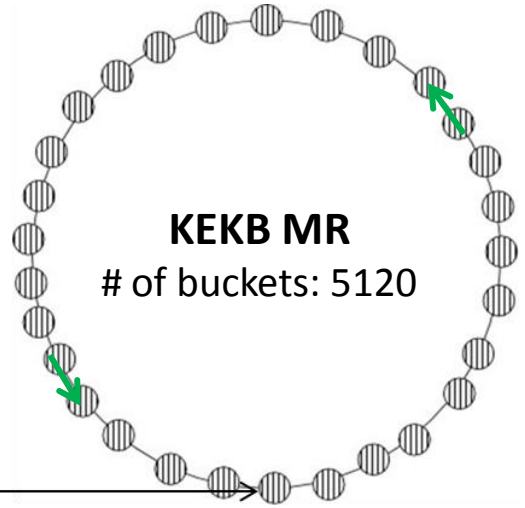


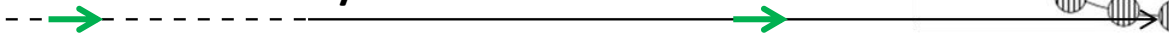
Bucket Selection at Main Ring

Today I focus on this topic.

Injection timing is delayed from revolution to select one of RF-buckets in every pulse.

- Delay values: 0-500μs, with 96ns step
- Decide, just a few pulse before, with bunch current information.





Positron injection at SuperKEKB

Positron injection at SuperKEKB is challenging while that for electron is almost same as KEKB.

Positron injection is carried out as a part of the **long term schedule**.
- Injection through the newly constructed Damping Ring.
- Damping for 40ms, longer than "one injection period" 20ms.
- Linac should work for electron injections even during the damping.

This **long term schedule** should have a capability of **small adjustment** in each pulse period for Bucket Selection.
- Injection bucket is decided just a few pulse before.
- This is done with bunch current information.

The other reason for **long term schedule** is combination of #DR-bucket and #MR-bucket.
- A same condition/combination comes once an 11.5ms.
- The timing control must be considered both 20ms-period and this "11.5ms".

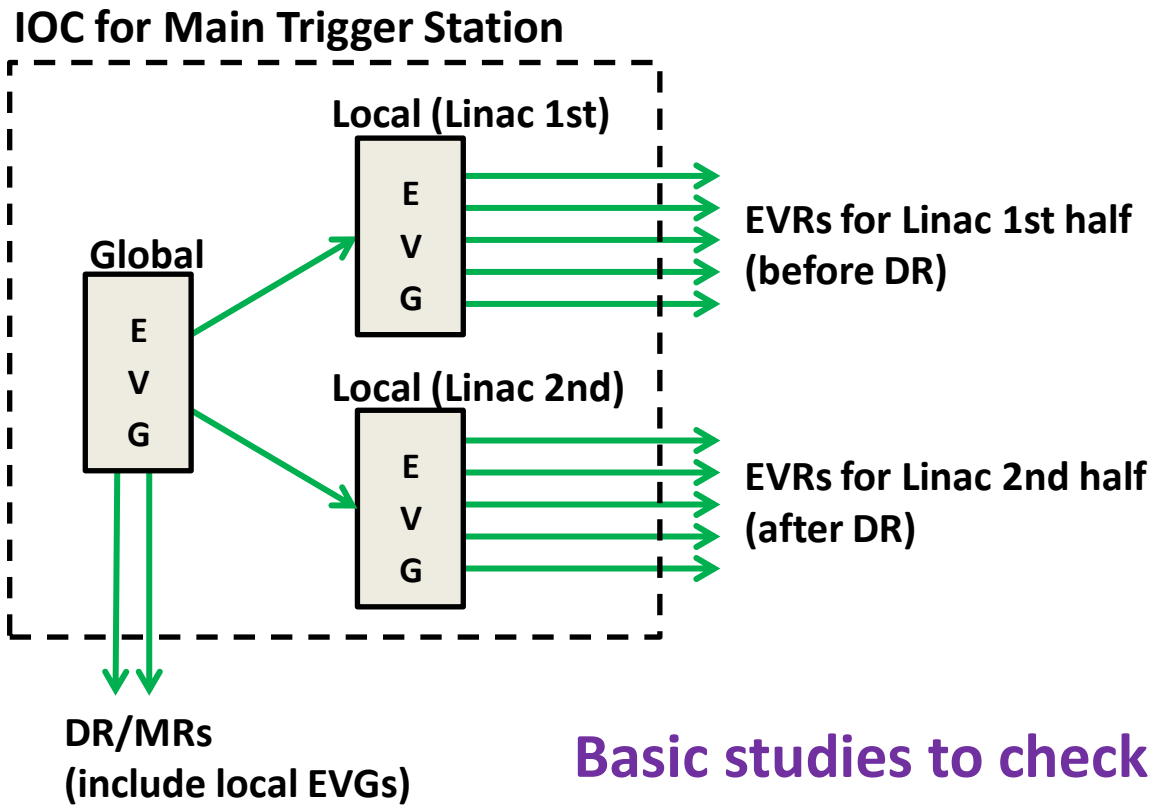
We control two timing sequences independently.

Event Timing System for SuperKEKB

Main Trigger Station of SuperKEKB is based on the Event Timing System.
We plan to put more than one EVGs on one IOC and connect them.

Trigger of Global EVG must be coincidence of
50Hz and one cycle of DR/MR conditions(11.5ms period) ⇒ Rate becomes <50Hz.

Generate more than one pulse with 50Hz rate, once sequence is triggered.
Schedule up to ~100 injection pulses (~2sec of sequence).



Local EVG is operated with trigger of Event from Global EVG.

Two Local EVGs add delay to Event timing for selecting DR/MR bucket.

Sequence RAM produce delay and is rewritten in every 20ms.

Local EVGs knows DR/MR conditions for every pulse since they are placed with global EVG on one IOC.

Basic studies to check possibility are performed.

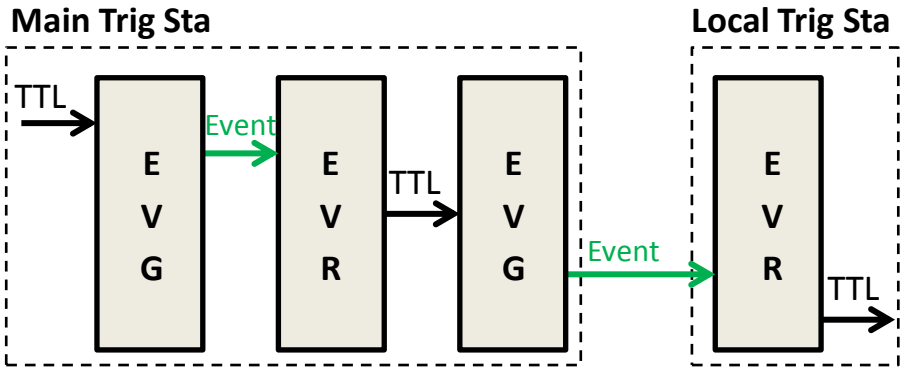
EVGs “connection in series”

We considered MRF products.
- VME-EVG-230
- VME-EVR-230RF

We have experiences about them at KEKB.

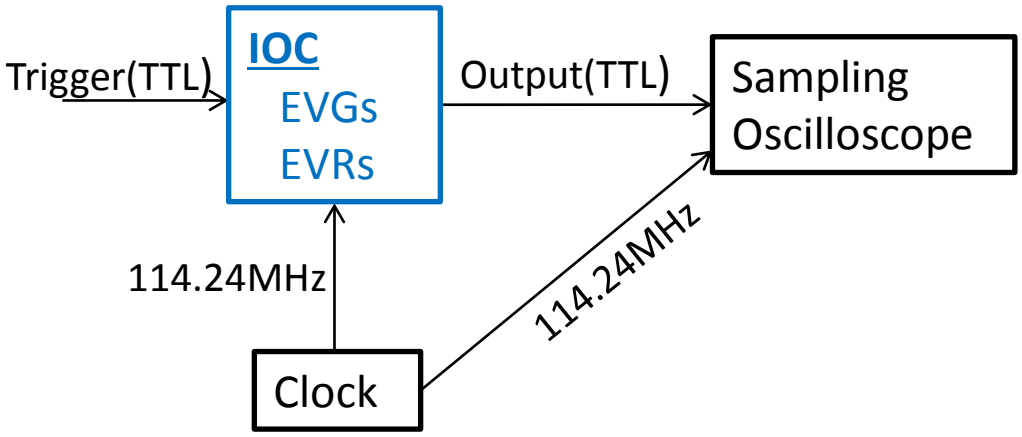
One EVR is needed between EVGs to produce TTL trigger.

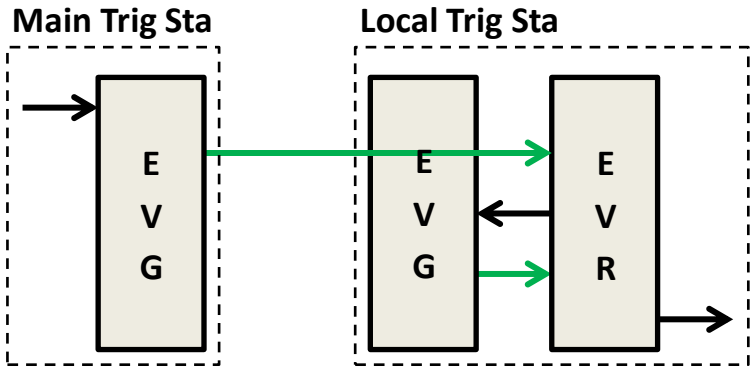
Here is two possible connections.



Suitable for Bucket Selection.
We plan to use as the Main Trigger Station at SuperKEKB.

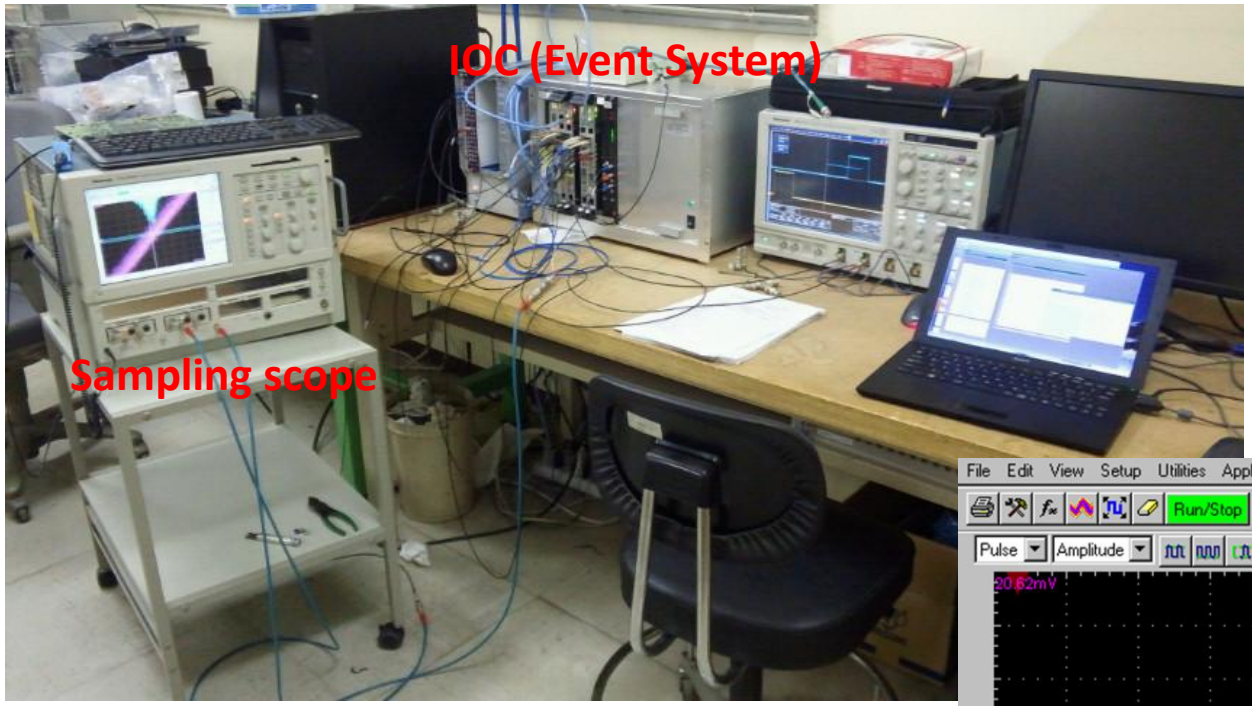
Timing study is performed in both setups.





This system is partially used at the Local Trigger station.

Setup and result example



Result example

Setup

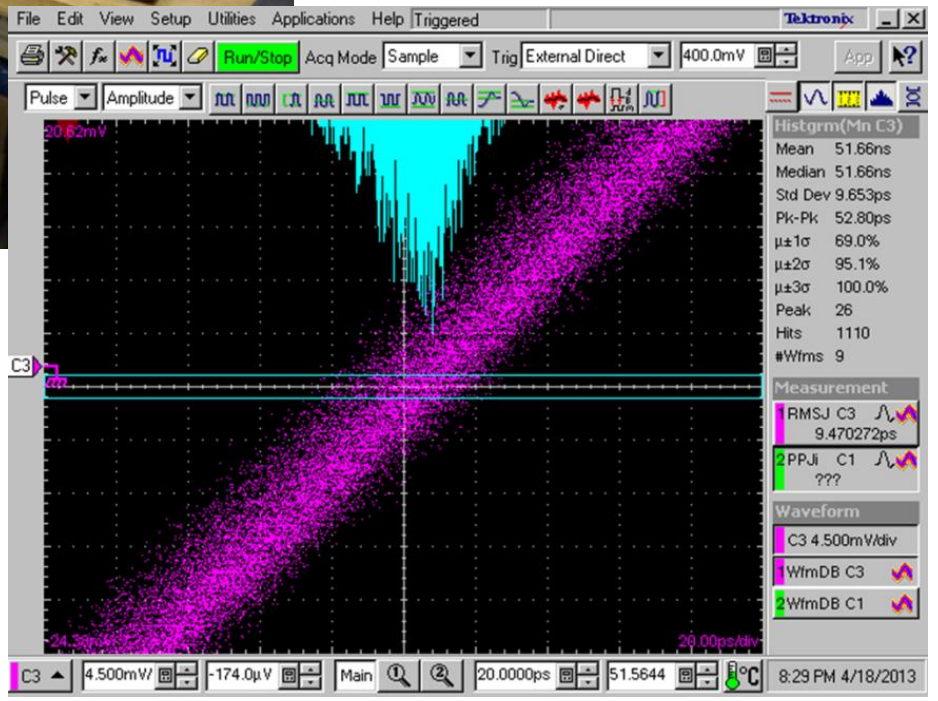
EVG⇒EVG⇒EVR

Delay value

Global: D=100clocks (870ns)

Local: D=0clocks

~1000hits are collected during 20min operation.

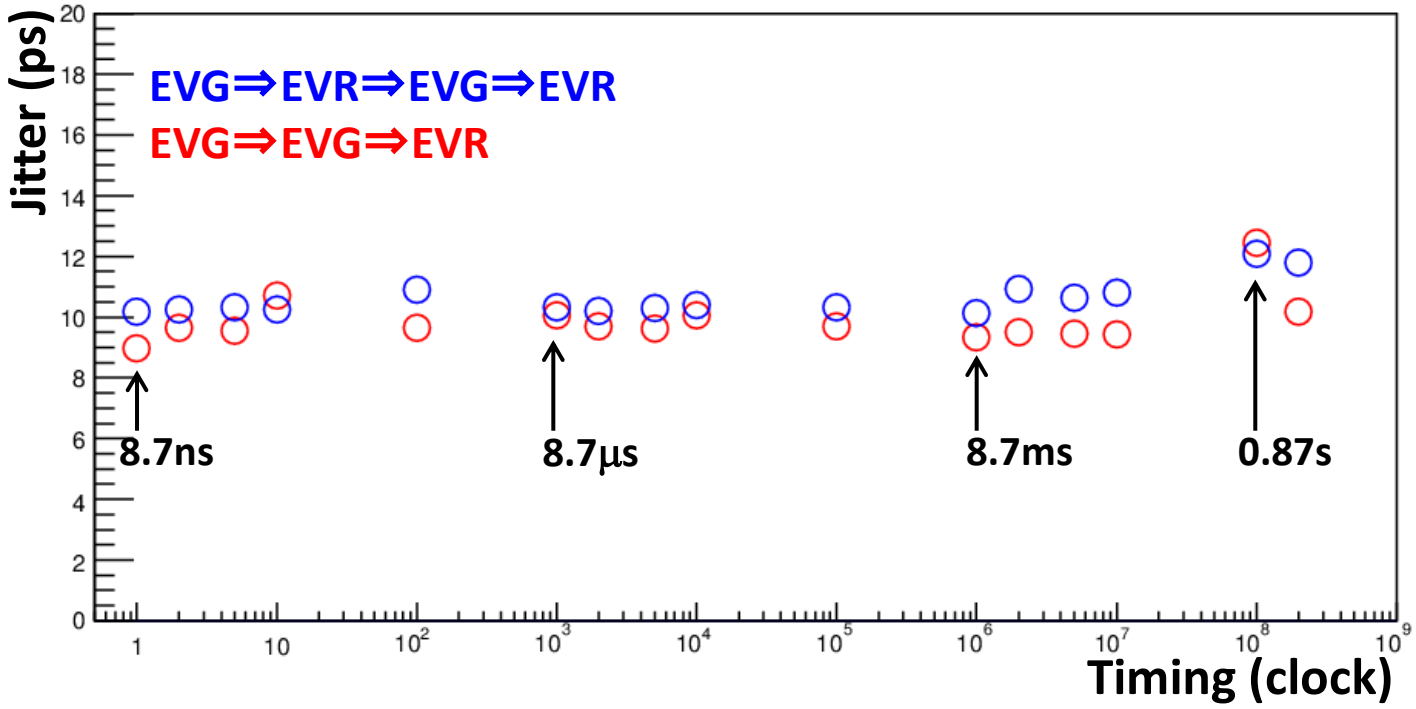


CPU: MVME5500
EPICS version: 3.14.9
MRF device driver: mrfioc
http://www-linac2.kek.jp/cont/atf/mrfioc_atf.tar.gz
EVG firmware: E403
EVR firmware: D507
RF clock: 114MHz (8.7ns step)
Trigger: 50Hz, TTL

Mean and standard deviation are checked.

Timing study with long delay

Timing jitter is tested with changing event-sending timing.
Timing at global(upward) EVG is changed and that for local (downward) EVG is fixed to be zero during the study.

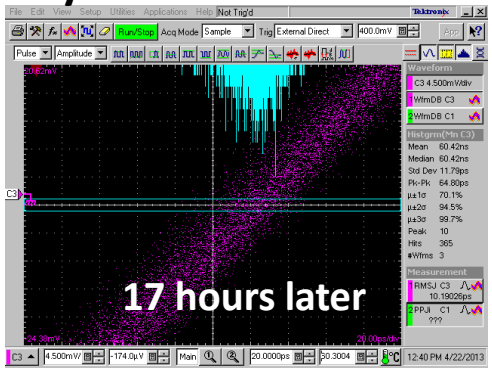


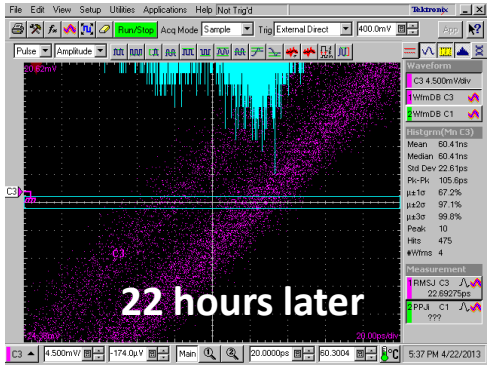
Timing jitter is to be ~10ps and no significant difference among timing values.
Good performance even at "EVGs in series" setup.

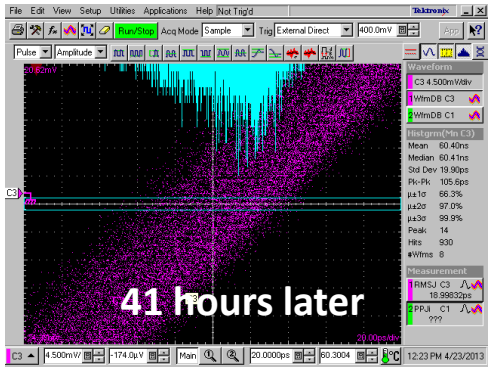
Timing drift in long term operation

Timing drift is observed in the long term operation.

>1day continuous data taking

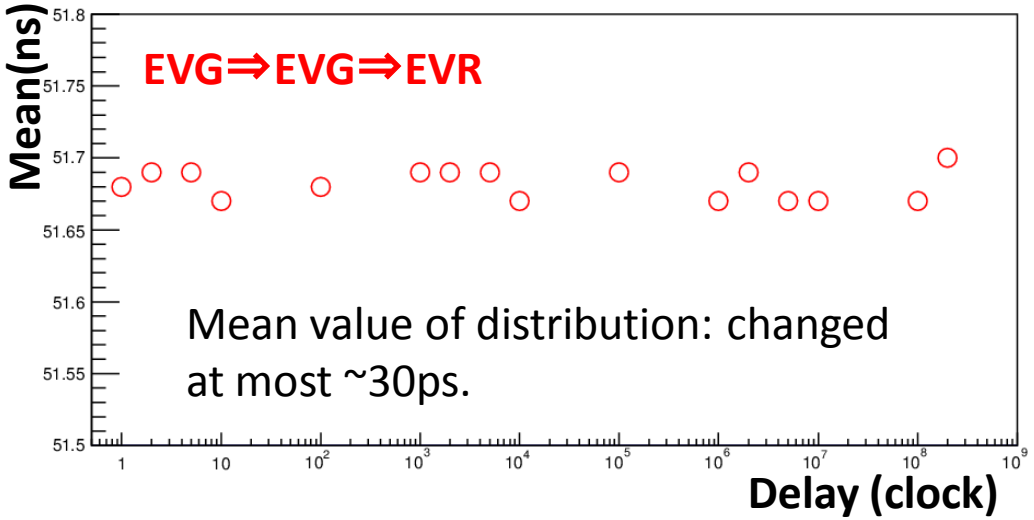






Same thing can be seen in the mean value of the previous study.

Long term stability can be checked.
Note, we took one week for collecting all data points.



This drift of ~30ps (very preliminary) must be considered in accuracy of timing.
Further studies are ongoing to understand these "timing drift".

Summary

Positron injection at SuperKEKB becomes challenging since newly constructed Damping Ring is used for it.

- Damping time of 40ms is longer than injection pulse period, 20ms.
- Combination of DR/MR buckets must be considered at Bucket Selection.

Injection must be carried out as a part of the long term schedule.

Basic studies for Main Trigger Station of SuperKEKB are performed.

We studies followings:

- MRF Event System modules
- Setup: EVGs “connection in series”.

Timing jitter is measured in two setups.

- Jitter in the short term is observed to be ~10ps.
- There is no significant difference among timings up to ~2sec.

Timing drift is observed in the long term operation.

- ~30ps (very preliminary) during one week.
- This must be considered in the accuracy of timing.

Further study is ongoing.

Back up

Other issues

Special treatments are needed when appropriate DR-bucket have already been occupied.

- Plus or minus ~50buckets from occupied bucket also cannot be used because of rise/down times of kicker.
- Delay for Bucket Selection is expanded, >500μs.
- Make an irregular injection timing by changing the RF phase at 2nd half of Linac.

Interruption of sequence when abort signal is launched.

- Sequence of Global EVG must be stopped immediately.
  ⇒ Otherwise it continues injections.
- Reserved inputs of MRF-EVG-230 will be tested for this purpose.
- Special care (dumping?) for positron stored at DR when MR-e^+ is aborted.

Top up injection also to PF and PF-AR.