Injection BG duration

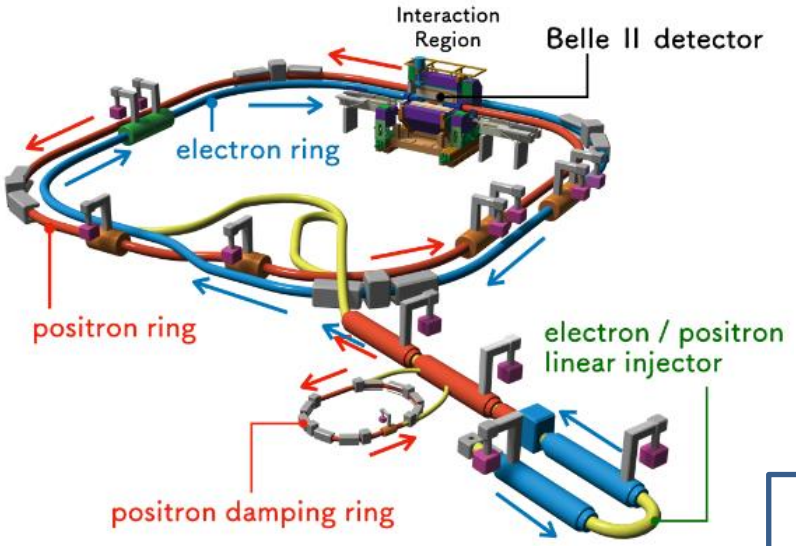
2022/11/24

T.Koga, A.Kusudo

beam injection

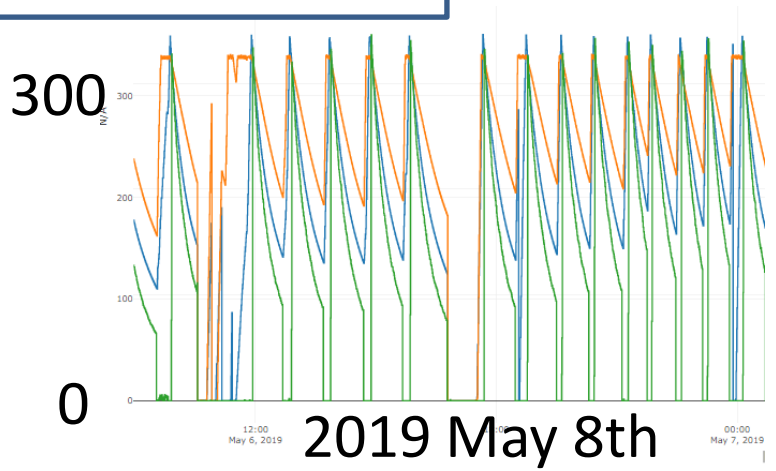
-Beam is injected to main ring from linac and positron damping ring

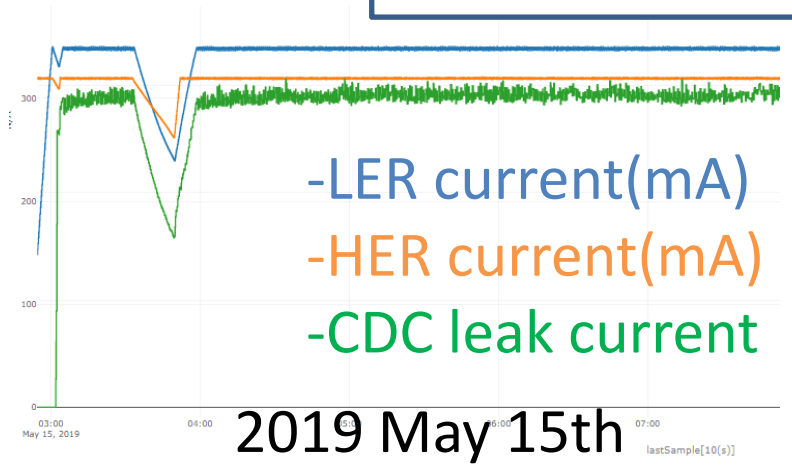
-Injection is done continuously even during physis data taking,
in order to keep beam current constant (continuous injection)



Normal injection

Continuous injection



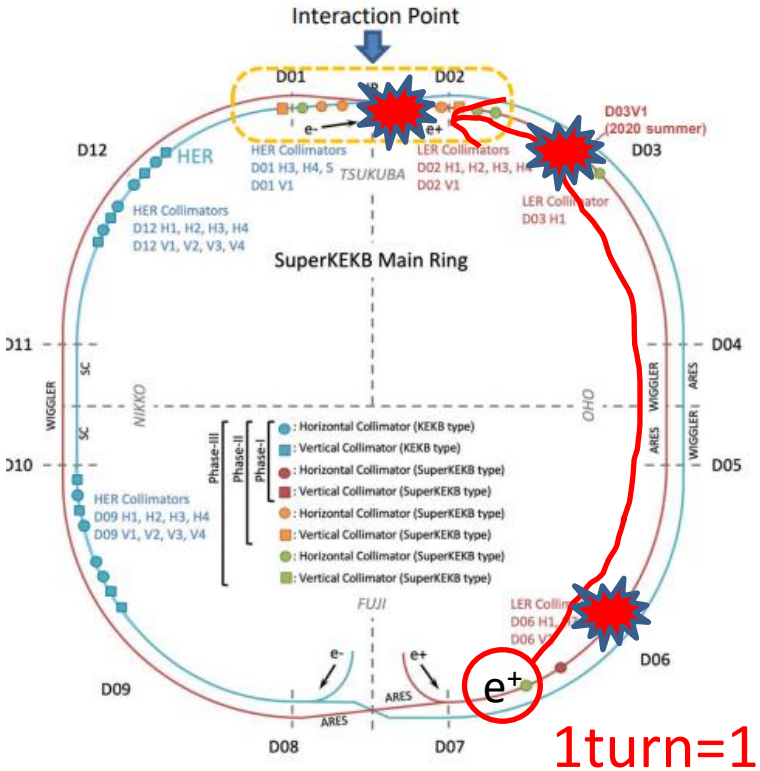


Injection BG

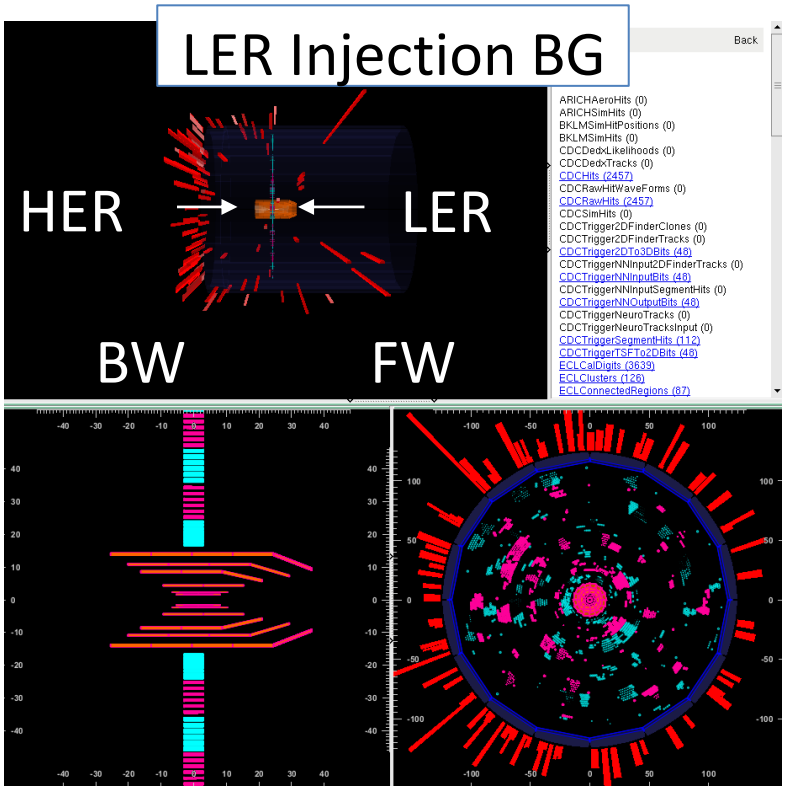
-Injected beam has different position, momentum and beam orbit from the storage beam. (Large horizontal oscillation.)

-Part (~tens of percent) of the injected electron/position has too different orbit and hits with beam pipe then cause BG (=injection BG).

-BelleII detects the injection BG when the injected beam passes through the detector, every 10μs.



1turn=10μs

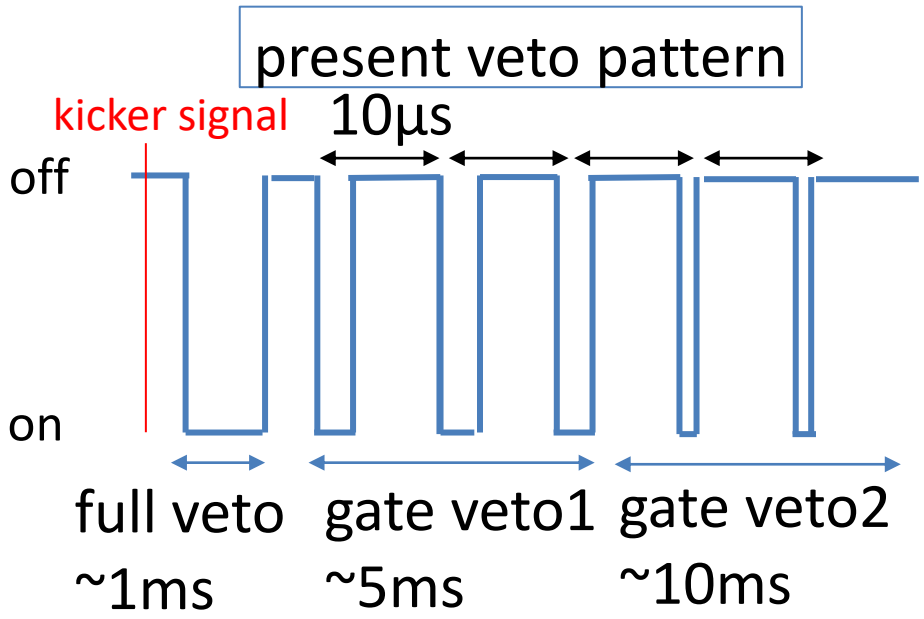


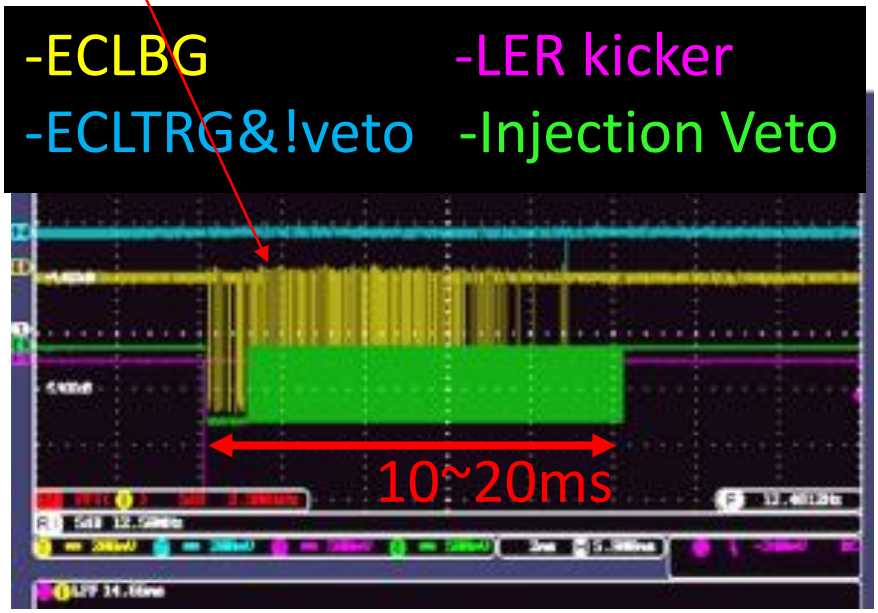
BelleII Injection veto

-To avoid DAQ crash, trigger is vetoed just after injection (injection veto)

-Veto pattern is induced by the kicker signal from superkekb
 -veto length can be tuned by parameters

-It was not expected that BG duration continues more than 10ms
 (At belle, it was ~1ms.)

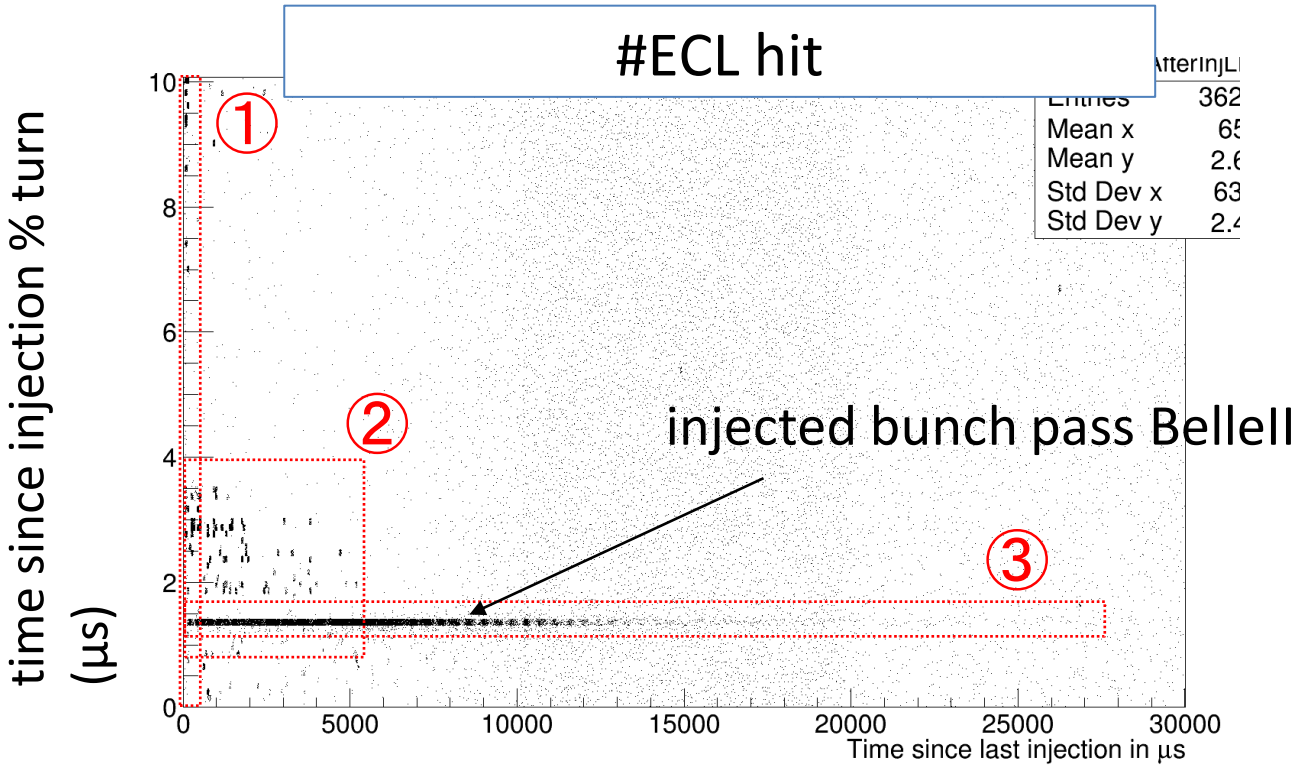




Injection veto pattern with 2D view

-Injection veto structure

- -①~0.5ms: full veto (same as Belle)
- -②0.5~10ms: gate veto1 (since 2019)
- -③10~30ms: gate veto2 (since 2020)



time since injection(μs)

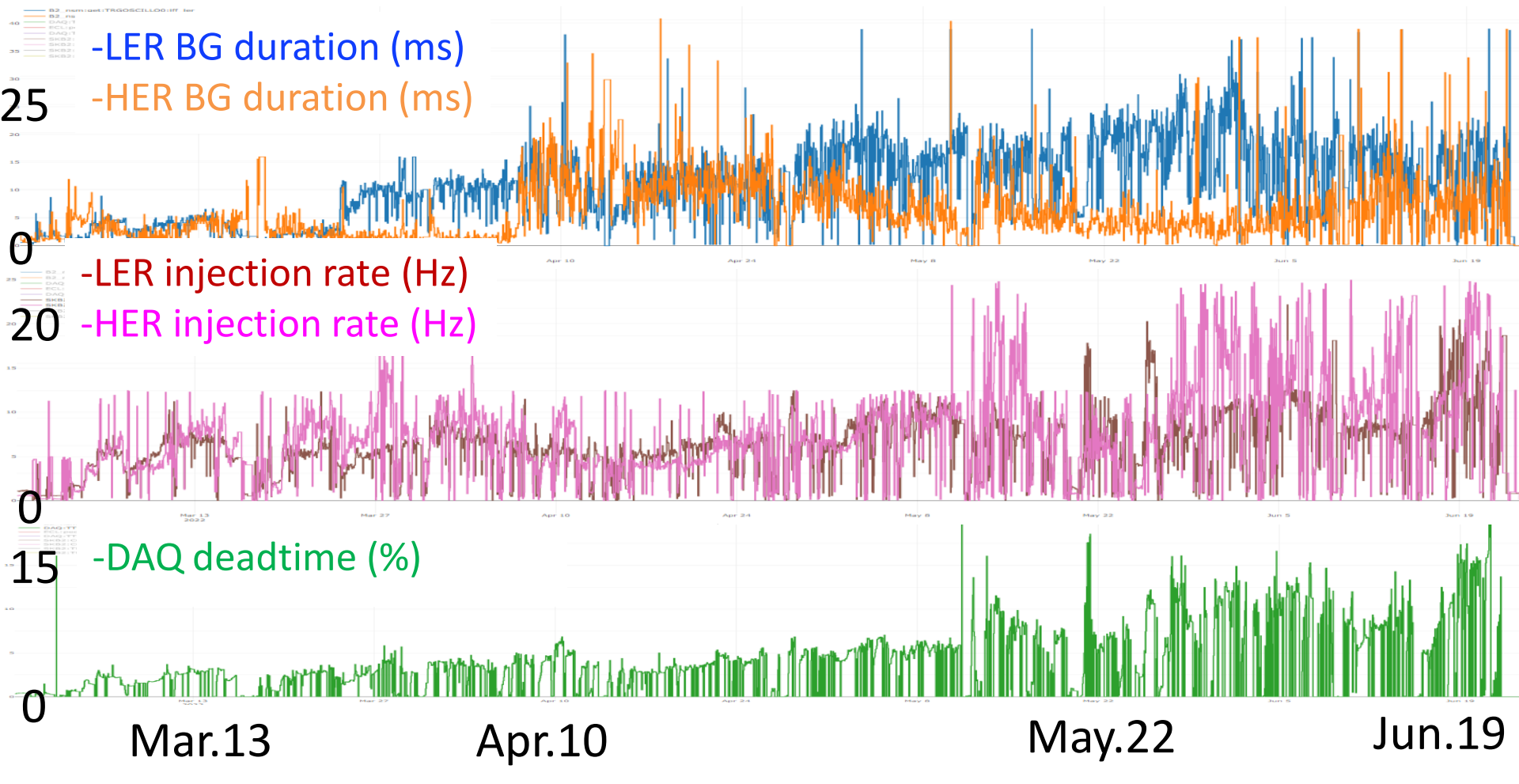
Injection veto and data taking efficiency 2022ab

-Injection veto causes the DAQ dead time:

∝ length of injection veto

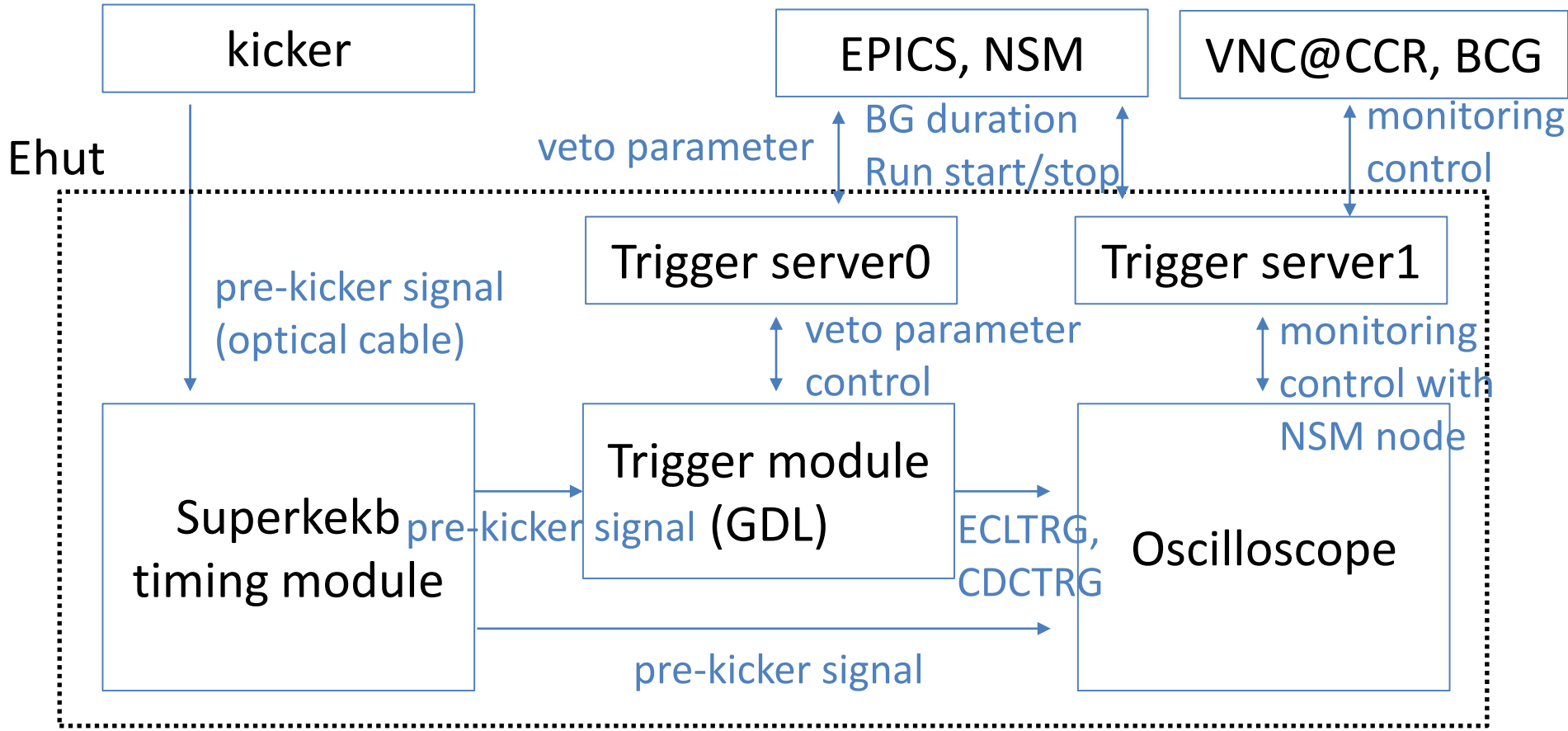
Dead time = (dead time per injection) × (averaged injection rate)

-Injection veto causes the largest DAQ deadtime (2022ab: 5~15%)



BG duration monitoring system

-From 2019 October, online monitoring has been done at control room
 -to share BG duration with KCG and machine experts

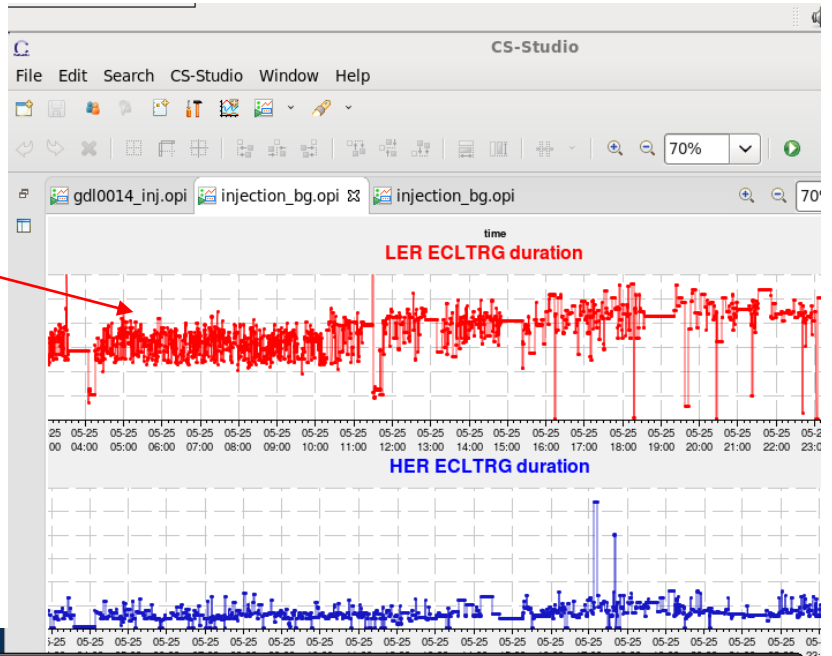


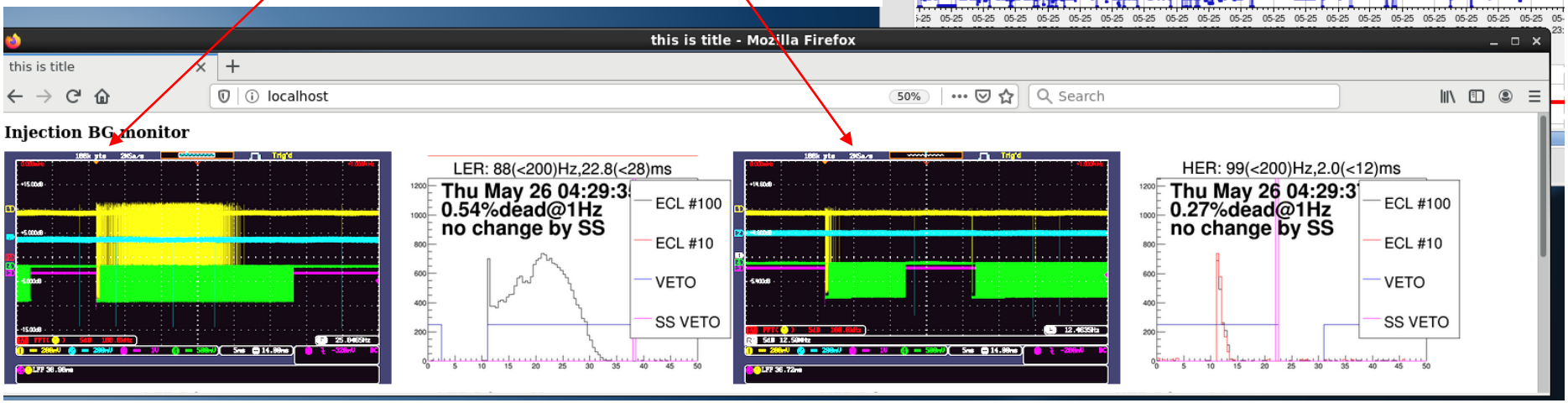
BG duration monitoring system

-From 2019 October, online monitoring has been done at control room
-to share BG duration with KCG and machine experts

Trend of BG duration
(time between kicker and longest BG)

ECLTRG signal triggered by LER/HER kicker,
and histogram of recent 100 events

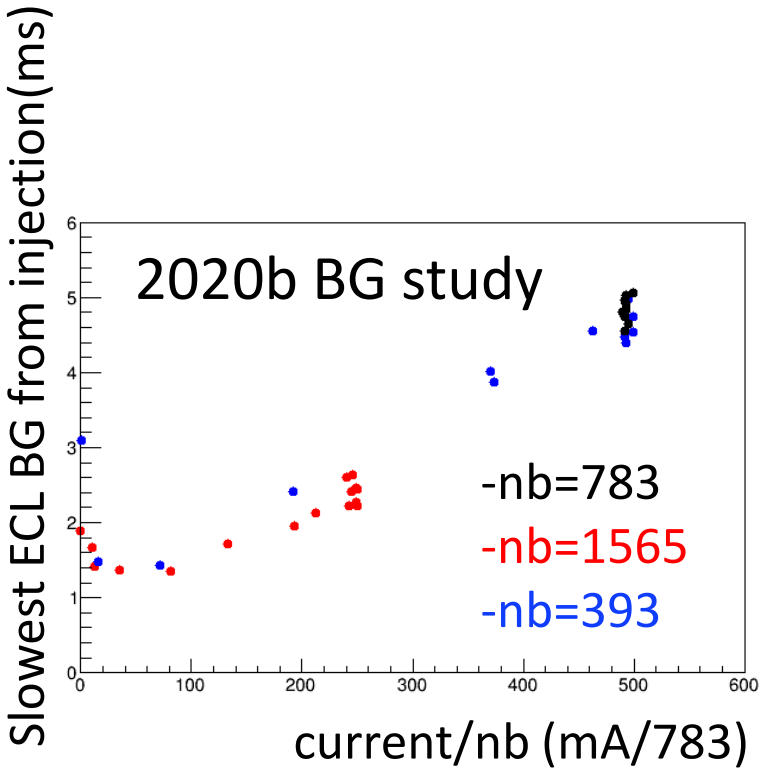




Investigation of BG duration: bunch current

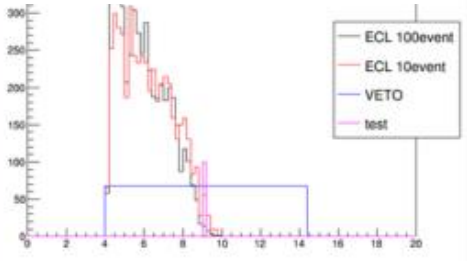
-Several features are observed by the monitoring

-②BG duration is proportional to bunch current:
interaction between injected bunch and storage bunch

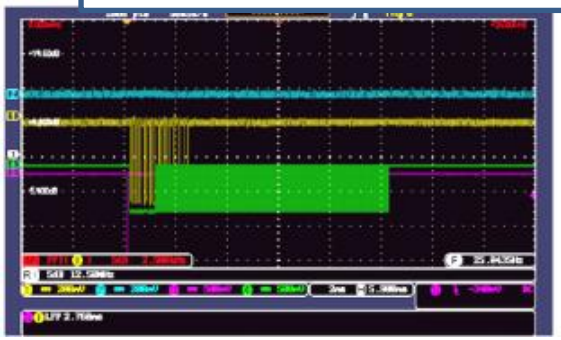


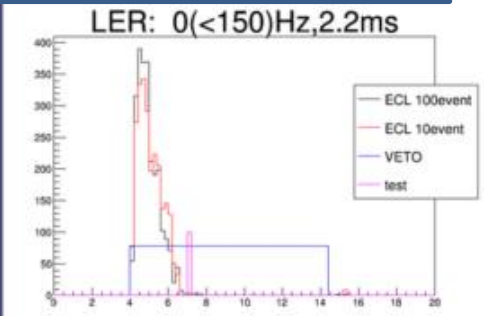
single beam LER 500mA nb=783

ECL BG timing (ms)



single beam LER 500mA nb=1565





Investigation of BG duration: collision

-Several features are observed by the monitoring

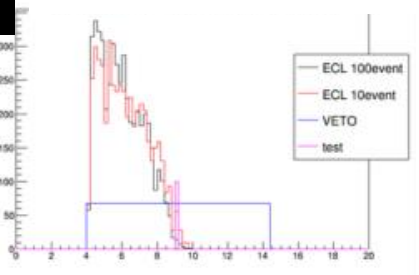
-④BG duration increases ~2times by collision than single beam:
interaction between injected bunch and collided bunch

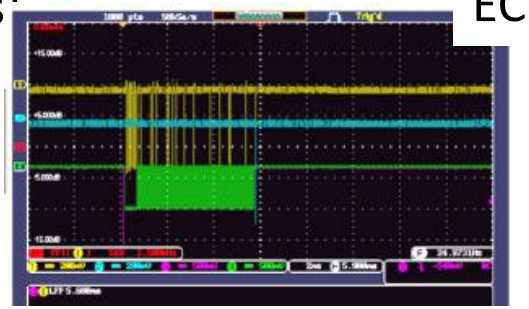
single beam LER 500mA nb=783

single beam HER 500mA nb=783

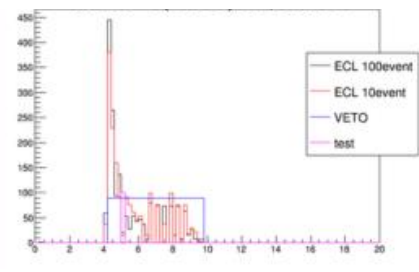
-ECLBG -LER kicker

ECL BG timing (ms)

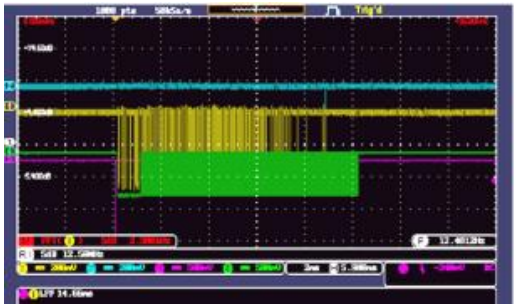


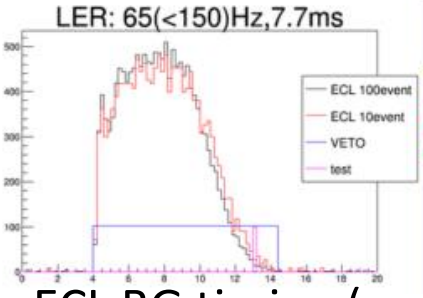


ECL BG timing (ms)

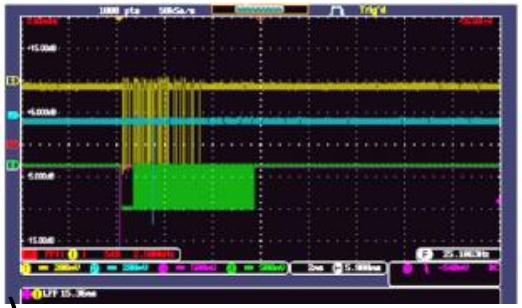


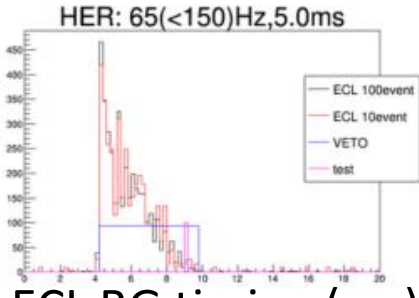
both beam LER 510mA HER=510mA nb=783 L=1.6 × 10^34





ECL BG timing (ms)





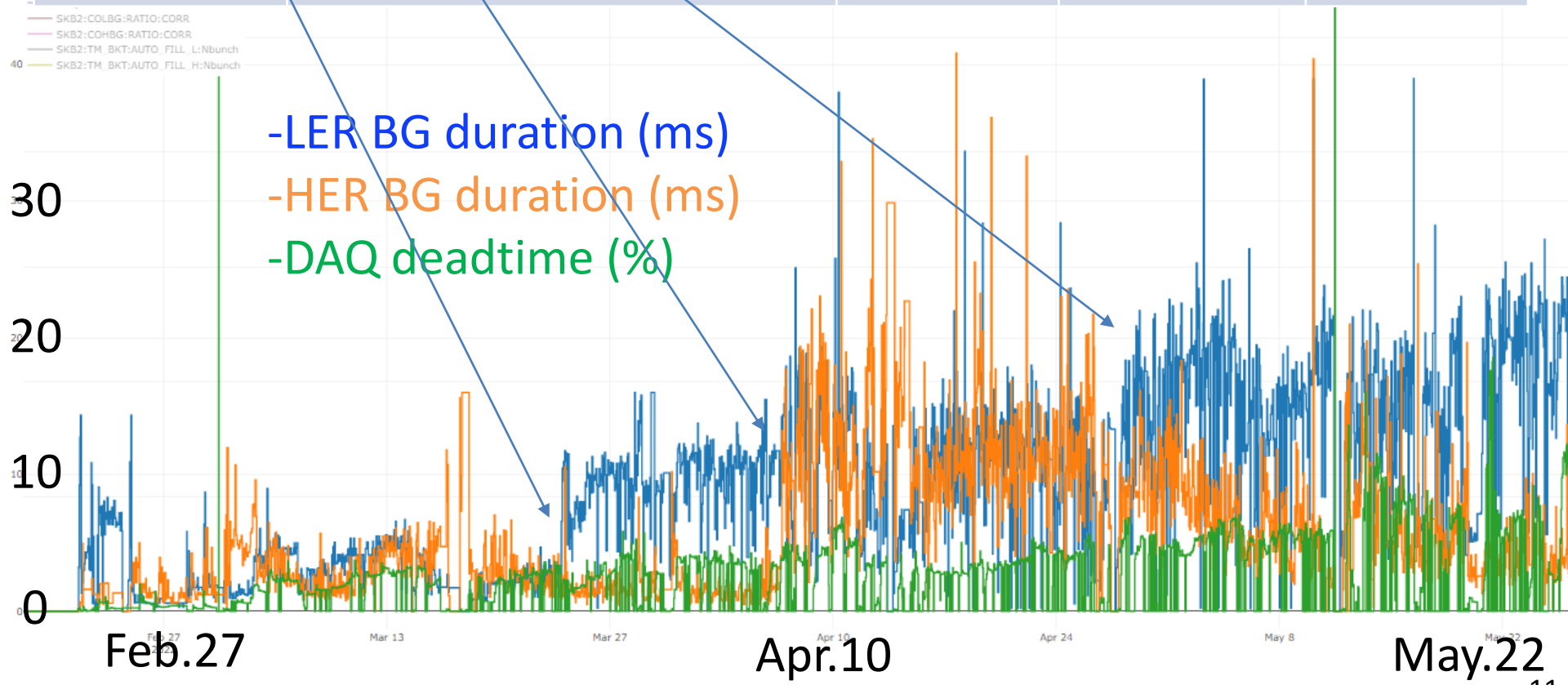
ECL BG timing (ms)

2020b BG study

Investigation of BG duration: parameter dependence

-Check change of duration and machine condition

Date	Change	LER (ms)	HER (ms)	deadtime
2022 Mar.24-	D6V1 damage and open	~10ms	~2ms	3~5%
2022 Apr.6-	Open D9V1	~15ms	~15ms	~5%
2022 Apr.27-	After maintenance, LER increasing and HER decreasing.	15->25ms	15->5ms	5~15%



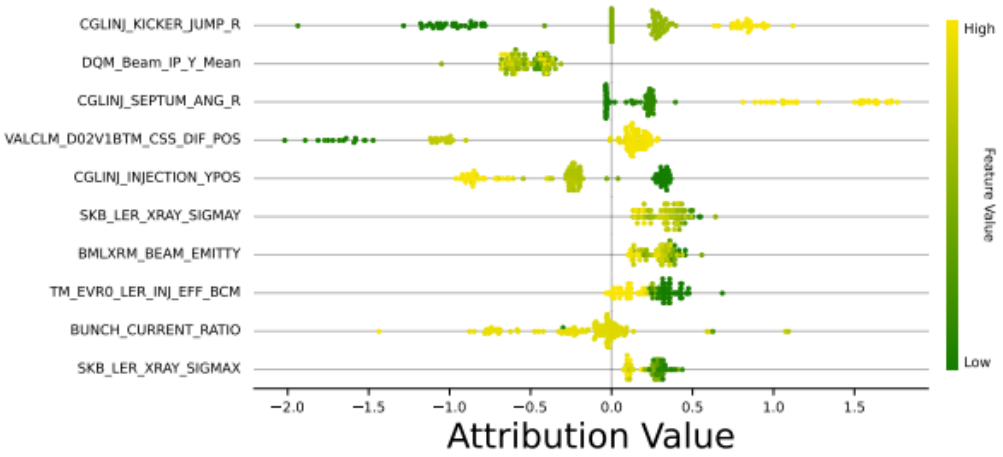
Investigation of BG duration: machine learning

-Benjamin from MDI has been checked the parameter dependence with machine learning technique

-Roughly consistent with my check,
but more detailed/small relation has been investigated well.

training

TOP 10 parameters with high importance



-data

-machine learning expectation

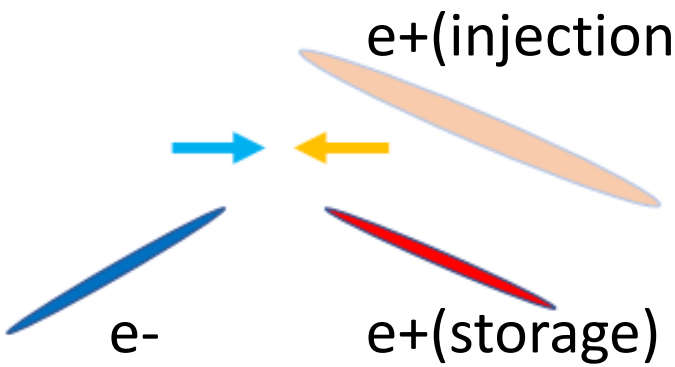
Fundamental reason of large BG duration

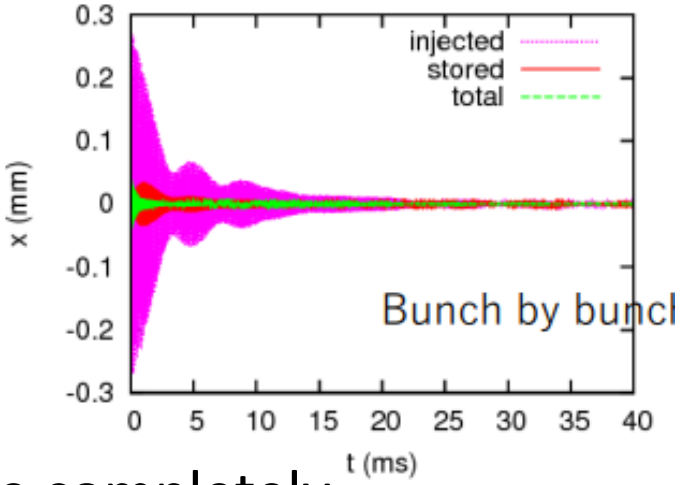
-Reason of BG duration is not understood yet

-From ①-⑤, a possible scenario is,

-Oscillation of the injected beam is remained a long time by interaction between the injected beam, storage beam and collision.
It is propagated to vertical with x-y and chromatic coupling.

-Ohmi-san's simulation study shows such effect





-Because it is difficult to solve the issue completely,
It is important to monitor the BG duration and find optimal condition

-I am thinking to join Ohmi-san's simulation study (but not time..(-_-;)).
If you are interested, please let me know !!

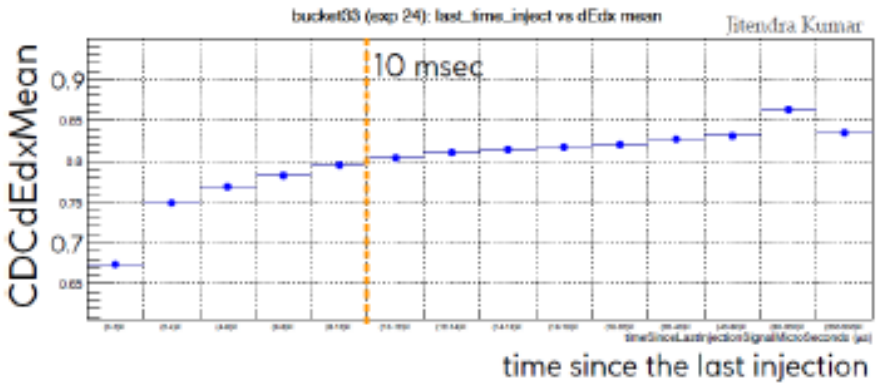
Injection veto and data quality

-TRG asked performance group to investigate data quality just after beam injection (slide at performance meeting)

-Many analyzers are checking the performance as a function of "time since injection". See Petar's talk, Thank you very much !

-Based on their input, we should consider if we can loose the injection veto or not, while keeping data quality at acceptable level.

dE/dx vs time from injection



New injection veto in LS1

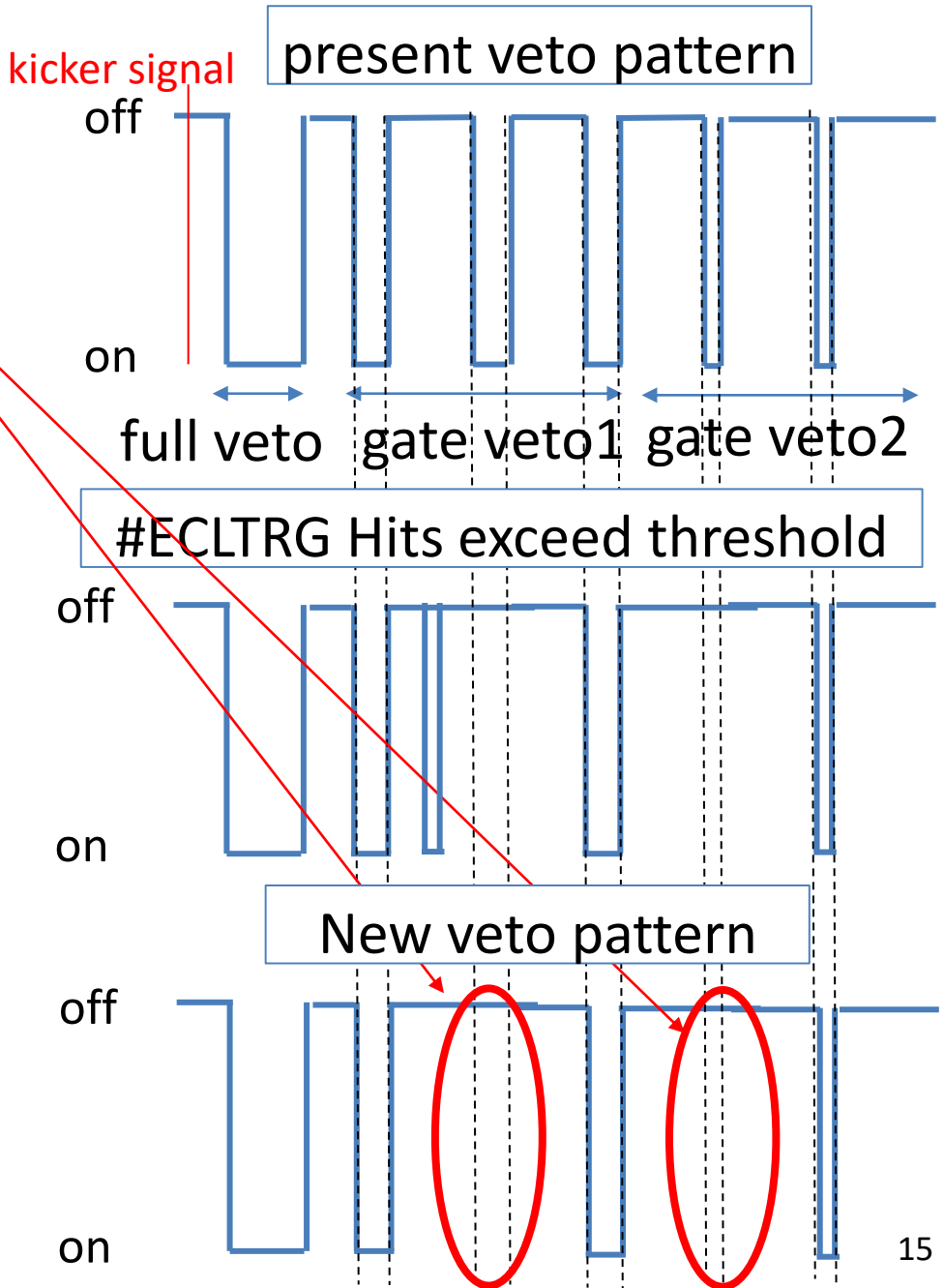
-If #ECLTRG, #CDCTRG, #TOPTRG Hits are enoughly small in the turn, gate veto is disabled.

New injection veto =
(present injection veto) AND
(#TRG Hits exceed threshold)

-Study will be performed with offline analysis, and special data will be taken in 2022b.

-Deadtime could be reduced 30~40% ??
Data quality will be worse.

-Kusudo-san started analysis.



Analysis of no-injection veto run

-Comparison of detector and trigger distribution w/o injection veto

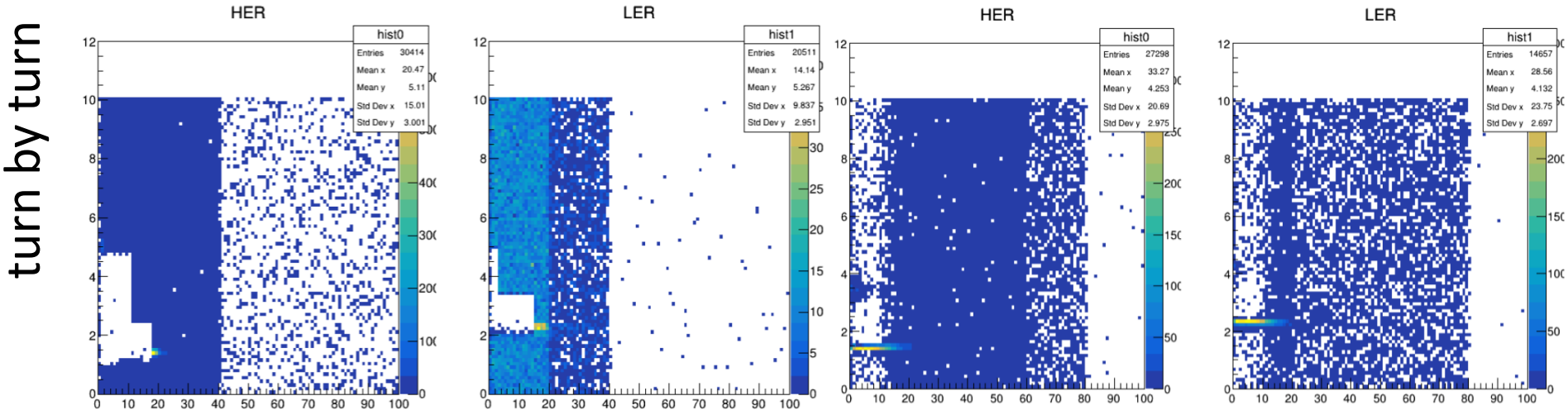
-exp26run1780: with injection veto, physics trigger

-exp26run1940: no injection, physics trigger, event separation time=1ms

-Time since injection

with injection veto

without injection veto



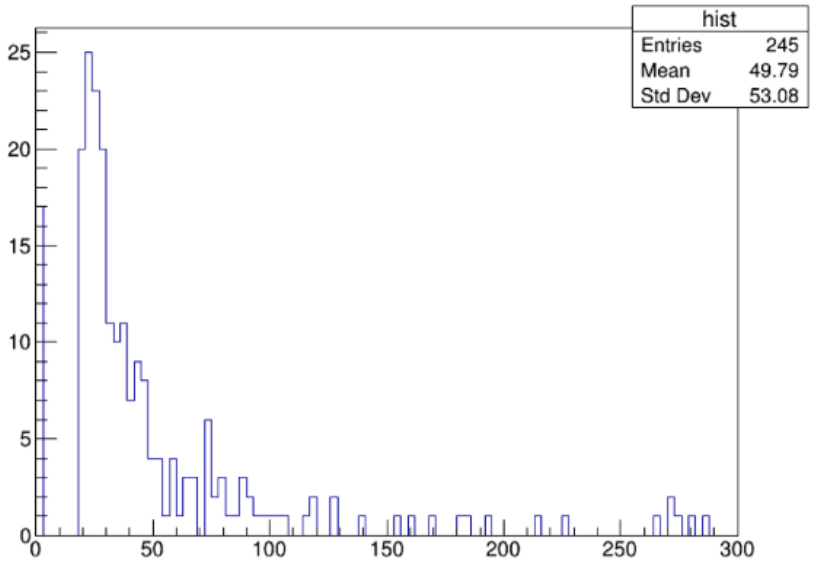
A.Kusudo

Analysis of no-injection veto run

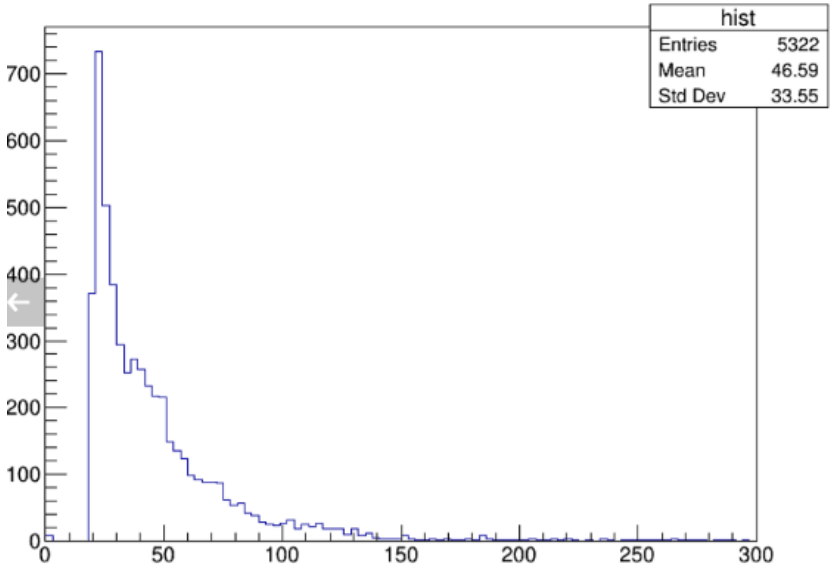
-Comparison of detector and trigger distribution w/o injection veto
  -exp26run1780: with injection veto, physics trigger
  -exp26run1940: no injection, physics trigger, event separation time=1ms

-ECLTRG energy (TC by TC)

with injection veto



without injection veto



TC energy (ADC, 1ADC=5MeV)

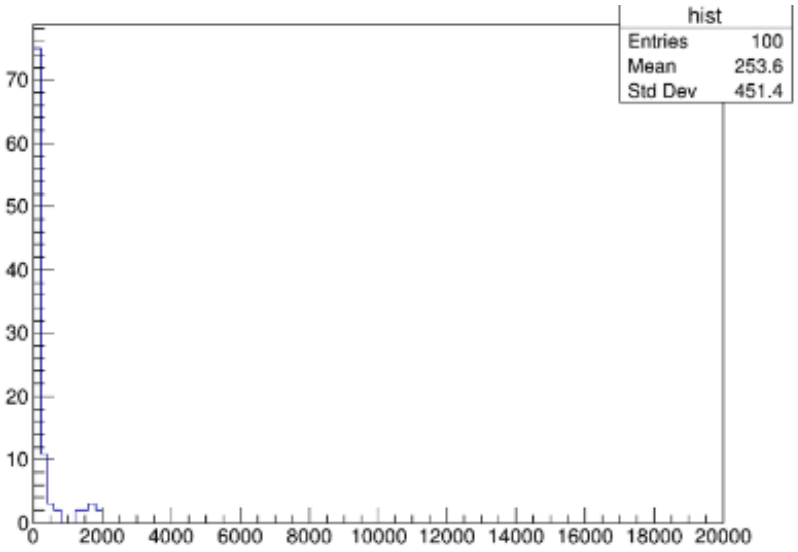
A.Kusudo

Analysis of no-injection veto run

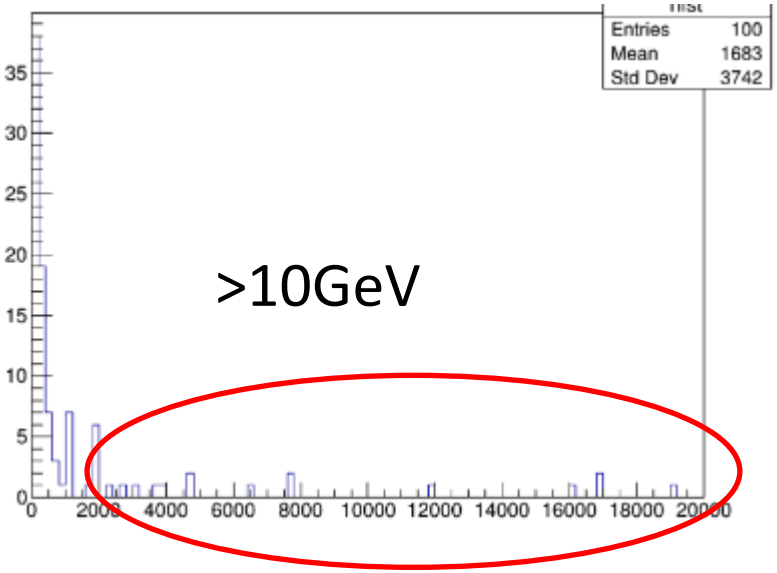
-Comparison of detector and trigger distribution w/o injection veto
  -exp26run1780: with injection veto, physics trigger
  -exp26run1940: no injection, physics trigger, event separation time=1ms

-ECLTRG energy sum (sum of all TC in an event)

with injection veto



without injection veto



TC energy (ADC, 1ADC=5MeV)

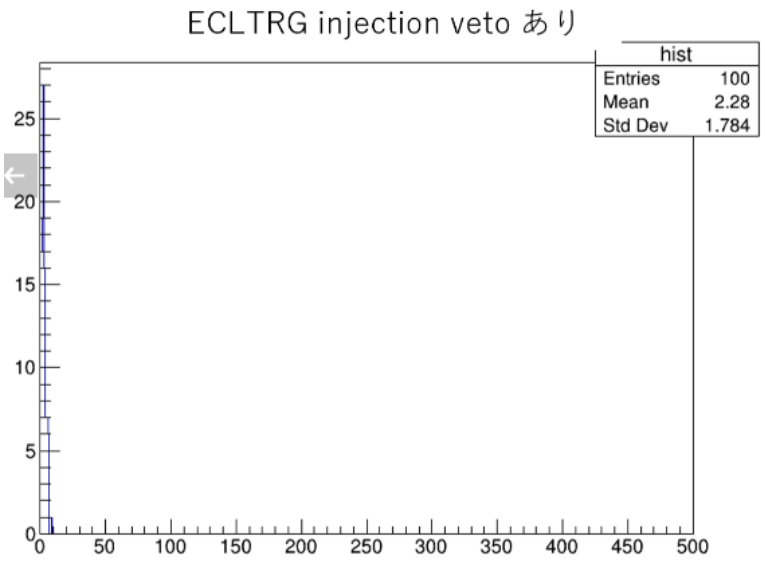
A.Kusudo

Analysis of no-injection veto run

-Comparison of detector and trigger distribution w/o injection veto
  -exp26run1780: with injection veto, physics trigger
  -exp26run1940: no injection, physics trigger, event separation time=1ms

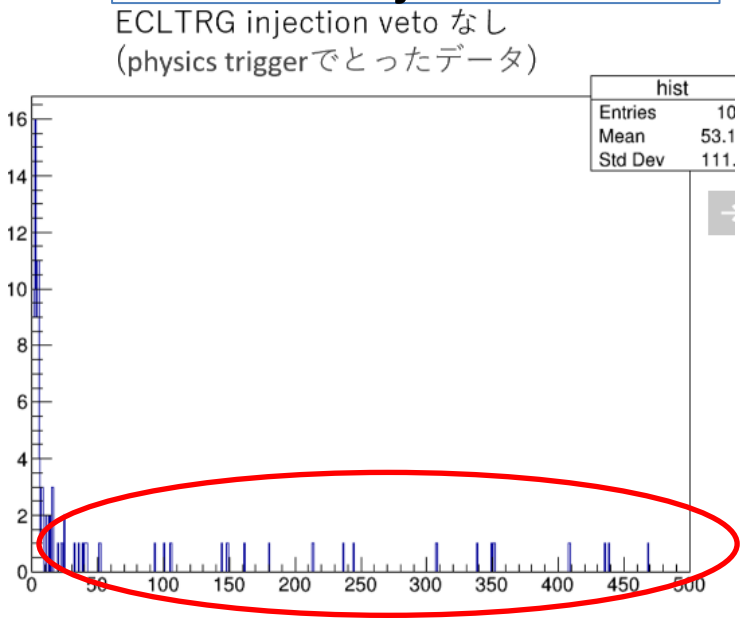
-ECLTRG #cluster(#TC in an event with >100MeV)

with injection veto



#TC

without injection veto



A.Kusudo

Analysis of no-injection veto run

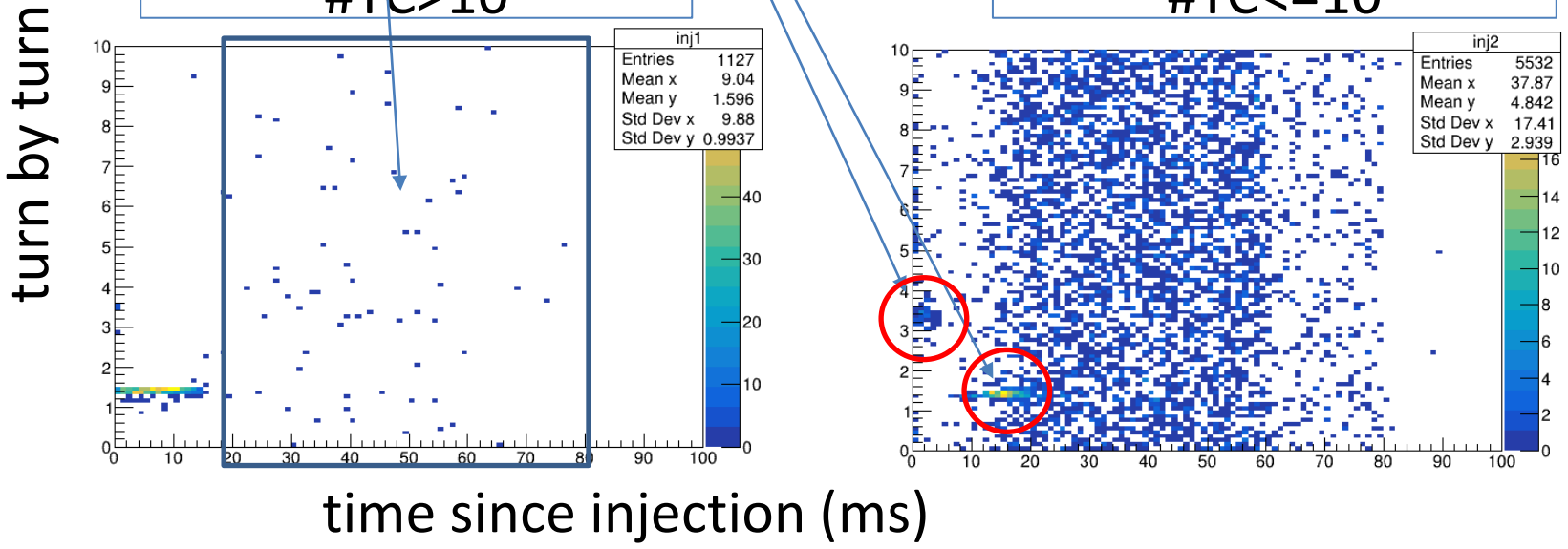
-Time since injection with #TC>10 and <=10 (primary criteria for veto)

- -~1% impact for physics efficiency at maximum
- -some leakage of injection BG.
- Need to check TOP #hits if DAQ crashes or not.

-Need further study but not bad as the first trial

without injection veto
#TC>10

without injection veto
#TC<=10



Summary

-Introduce studies of Injection BG duration performed so far

-interaction of injected bunch and stored bunch may be the reason

-in 2022ab, collimator configuration was sensitive to BG duration

-It is important to monitor the BG duration and find optimal condition with machine experts time to time.

-BG duration will be a key factor to improve data taking efficiency

-Deadtime is 10~15% at the end of 2022ab.
It will increase more with bunch current in future.

-R&D is on-going for new injection veto scheme during LS1.
If goes well, 30~40% dead time reduction is possible.
But data quality will be degradated further.

backup

Investigation of BG duration ⑤parameter dependence

-Several features are observed by the monitoring

-⑤BG duration changes by many parameters.

Effective parameters are different time to time.

(βy*, tune, knob, collimator, room phase,...)

Major changes of BG duration

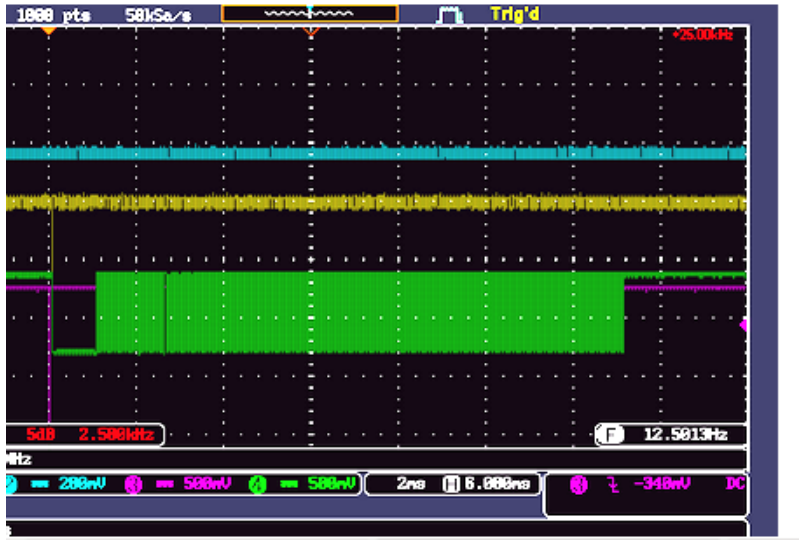
Date	Change	LER (ms)	HER (ms)	deadtime
2021 Feb. 28-		~5ms	~5ms	1~2%
2021 Mar. 20-	D6V1 damaged	~15ms	3~5ms	4~5%
2021 Apr. 9-	current increase	15~25ms	3~5ms	8~10%
2021 Apr.21-	HER loss issue, low current	10~15ms	5~8ms	~5%
2021 Apr.30-	Optics correction	~10ms	5~8ms	5~7%
2021 May 9-	HER R4' scan	~10ms	1~5ms	3~5%
2021 May 28-	QCS quench	~15ms	~8ms	4~6%
2021c	(very stable)	5~10ms	5~10ms	~4%
2022 Mar.24-	D6V1 damage and open	~10ms	~2ms	3~5%
2022 Apr.6-	Open D9V1	~15ms	~15ms	~5%
2022 Apr.27-	After maintenance, LER increasing and HER decreasing.	15->25ms	15->5ms	5~15%

Investigation of BG duration: 空うち

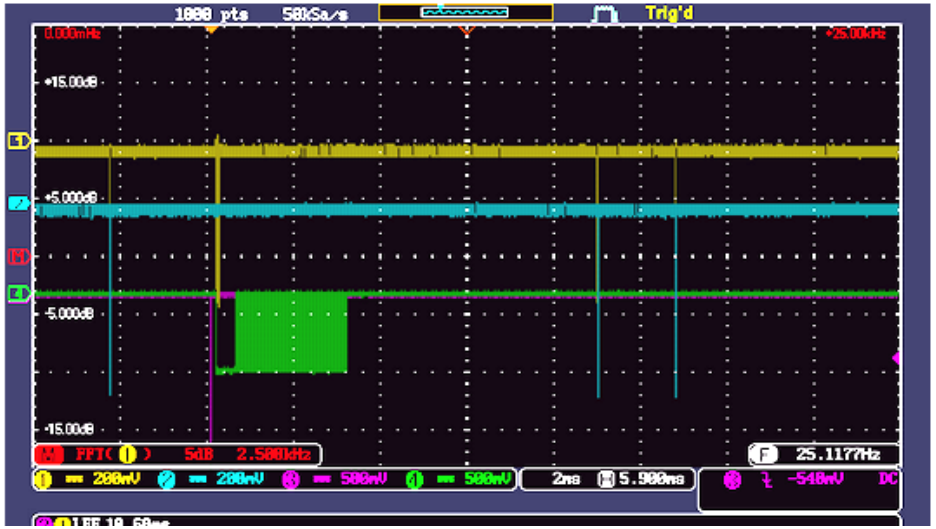
-Several features are observed by the monitoring

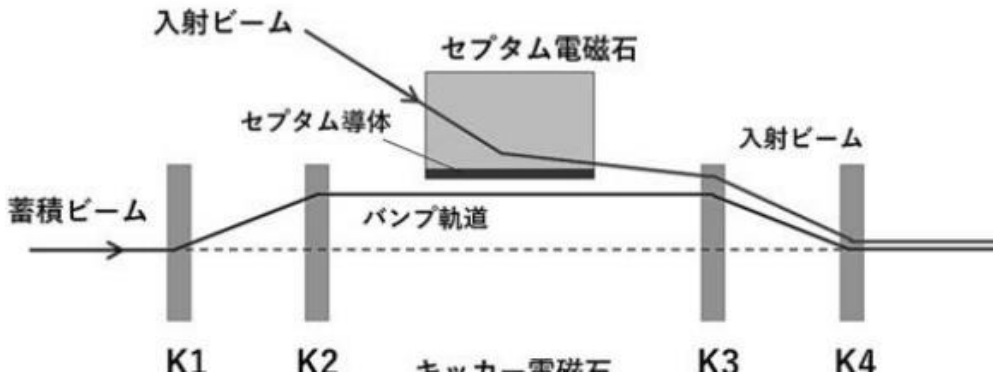
-①no BG duration is seen by 空うち: storage beam is not reason

LER ECL 12.5Hz



HER ECL 25Hz





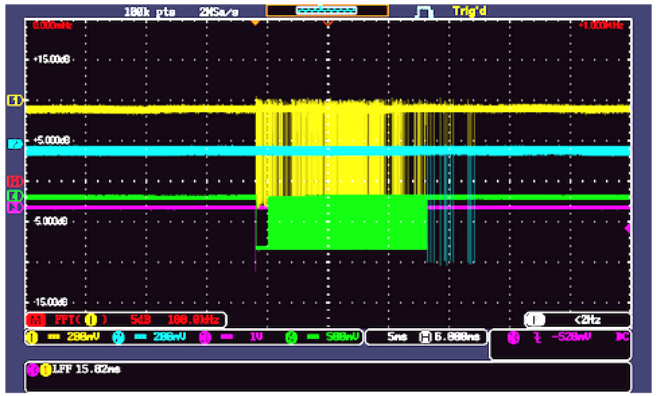
Investigation of BG duration ③ single bunch

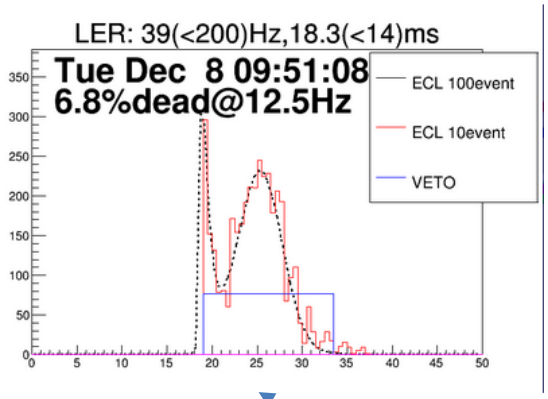
-Several features are observed by the monitoring

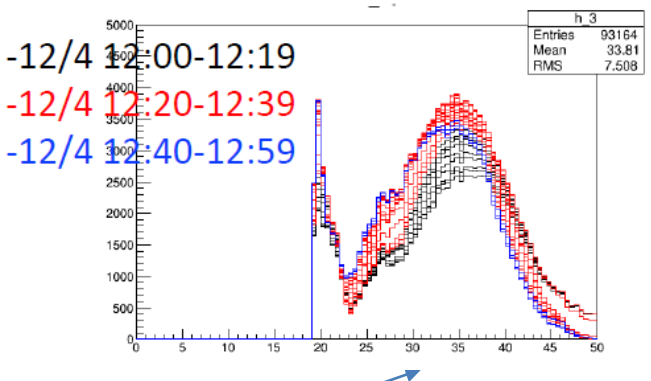
-③BG duration is seen by single bunch (1.0mA):
not caused by multi bunch interaction

LER single bunch (1.0mA) run時のBG duration 2020/12/8, 12/4

Injection BG monitor







2peakみえた

Injection veto structure

-Injection veto has three patterns

-full veto: veto all of turn

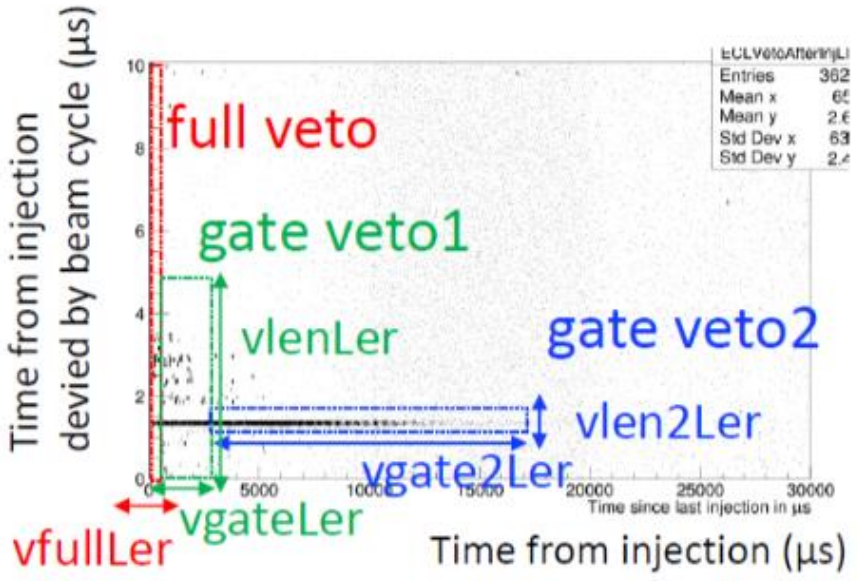
-parameter: veto length (B2_nsm:get:TRGGDL:vfullL(H)er, 10μs)

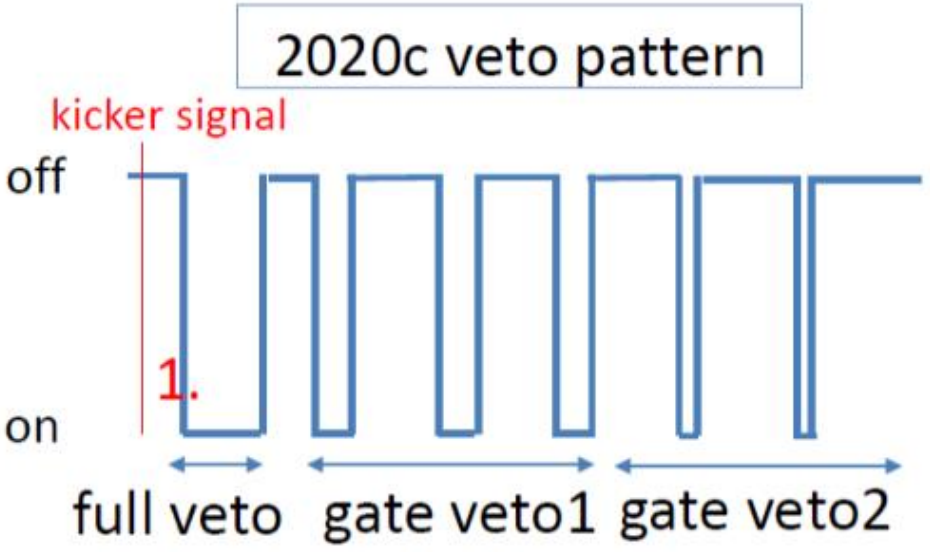
-gate veto: veto part of turn

-parameter: veto length (B2_nsm:get:TRGGDL:vgate(2)L(H)er, 10μs)

turn by turn veto width (B2_nsm:get:TRGGDL:vlen(2)L(H)er, 8ns)

-two gate veto with independent parameters





Veto parameters in 2020c

2020ab

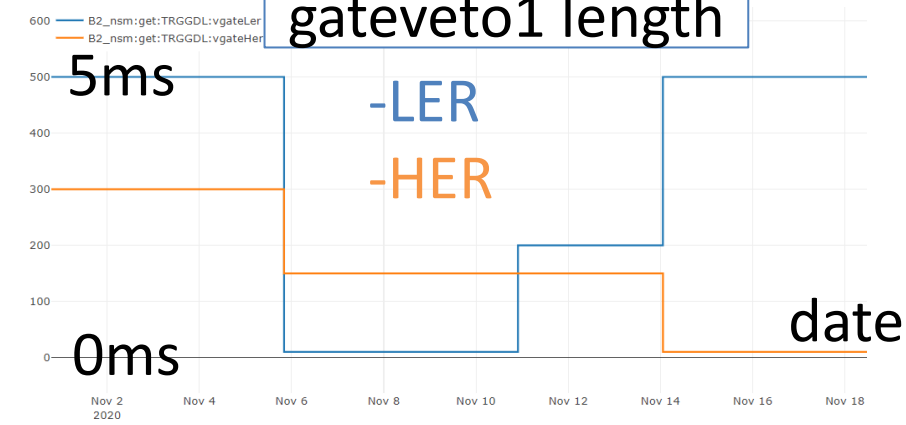
parameter	LER	HER
full veto	1~2ms	0.5~1ms
gate veto1	-	-
gate veto2	6~15ms, 2.4μs	2~10ms, 1.6μs

2020c

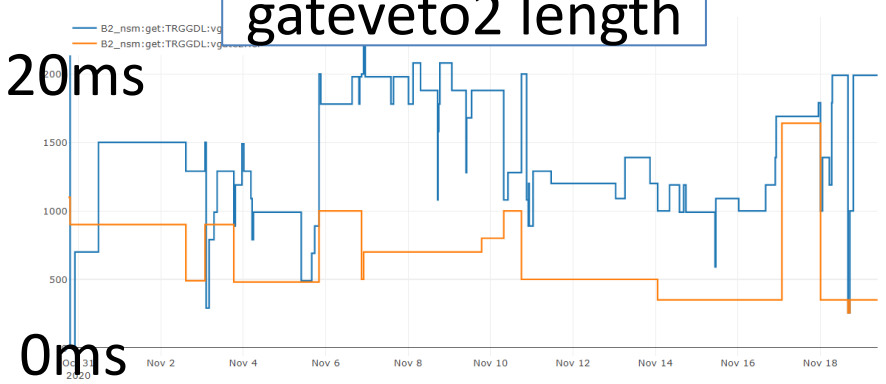
parameter	LER	HER
full veto	0.1ms	0.5ms
gate veto1	0~5ms, 2.8~4.0μs	0~3ms, 1.6~6.4μs
gate veto2	5~20ms, 1.6~2.4μs	4~10ms, 1.6μs

worse

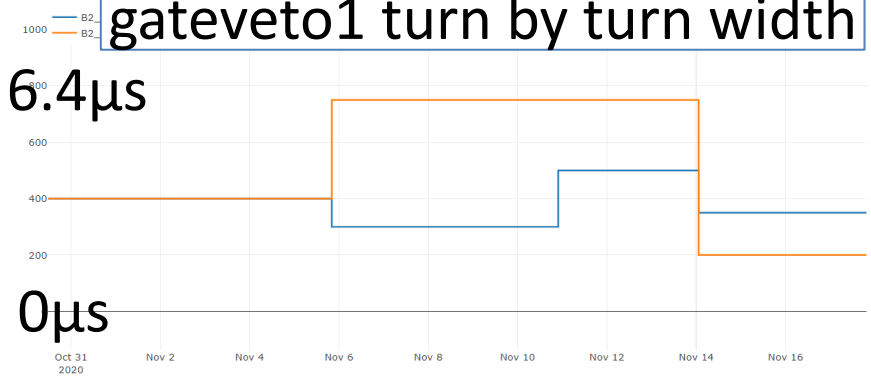
gateveto1 length



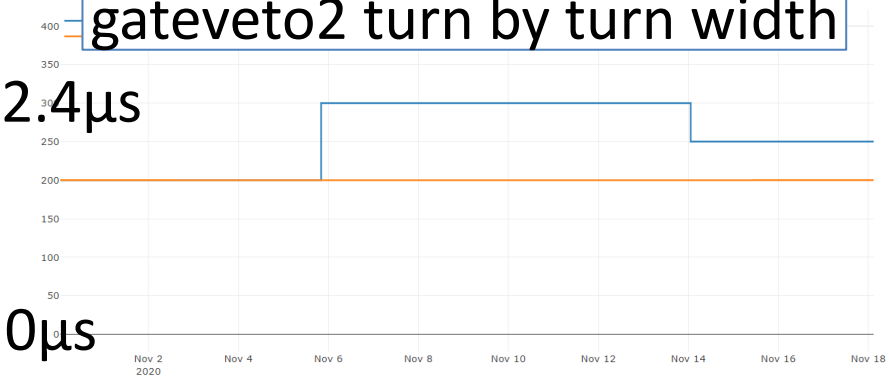
gateveto2 length



gateveto1 turn by turn width



gateveto2 turn by turn width



ECLTRG BG histogram

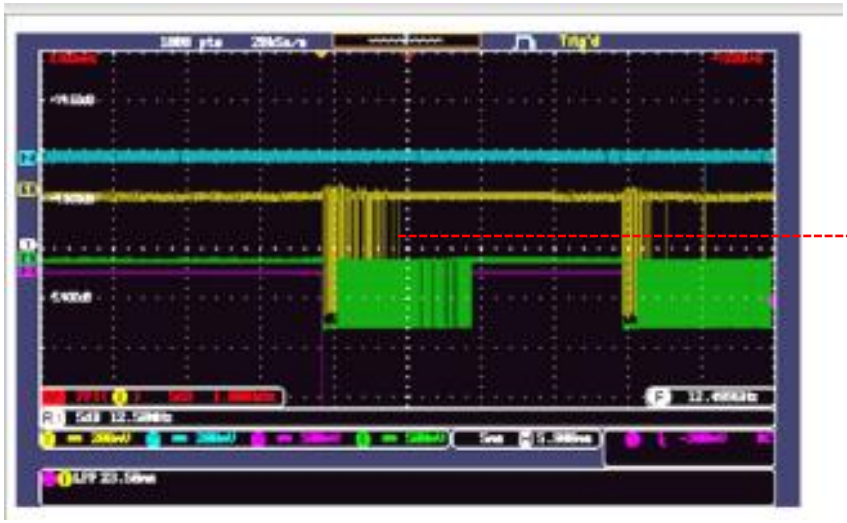
-ECLTRG signal (#cluster>6) timing is filled to histogram

-Triggered by LER (left) and HER(right) kicker.
Past 100 and 10 events are filled. (10 is normalized to 100.)

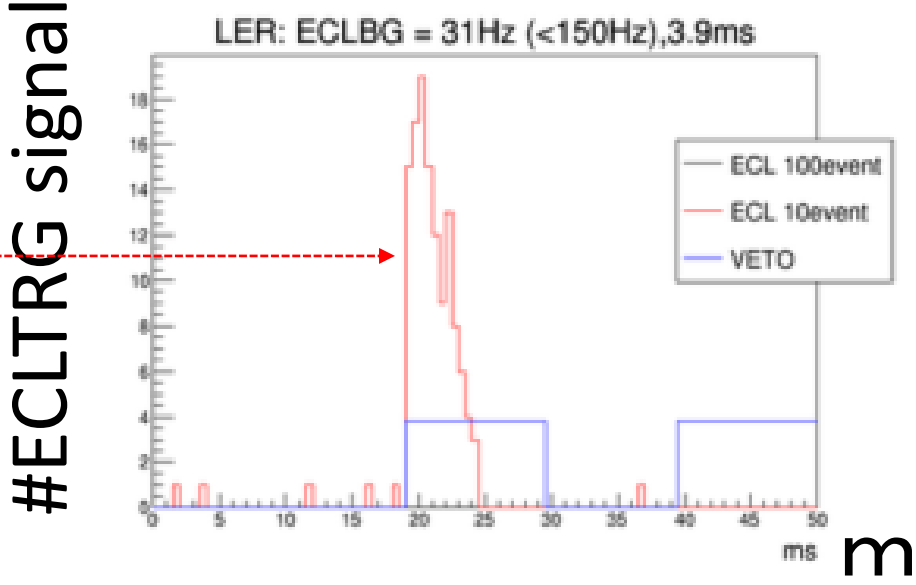
-Updated every ~10second (if no injection, no update), independent from DAQ status

-If LER and HER injections overlap within an oscilloscope window, histogram is not updated.

Single injection



Recent 100 injection (sampled)

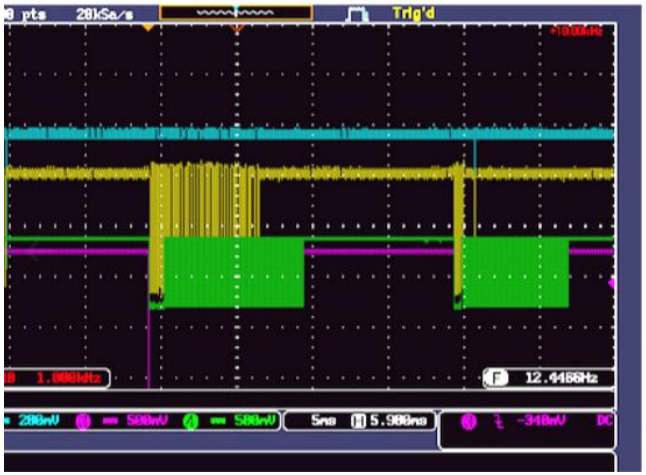


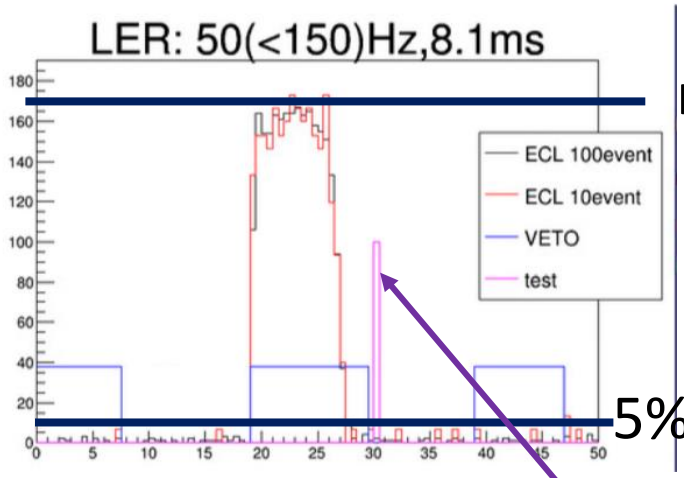
Automatic gate veto adjustment

-Gate veto width can be adjusted automatically based on ECLTRG BG timing structure. If pulse hight is smaller than 5% of max pulse hight, veto width is set. Small tails are ignored. Average of 100 pulses are taken during physics run is running.

-For safety:
- -Add +2~5ms to the estimated veto width as a margin.
- -Limit is set: HER: 6~30ms, LER:6~30ms

-Gate veto length is changed automatically when run is STOP.

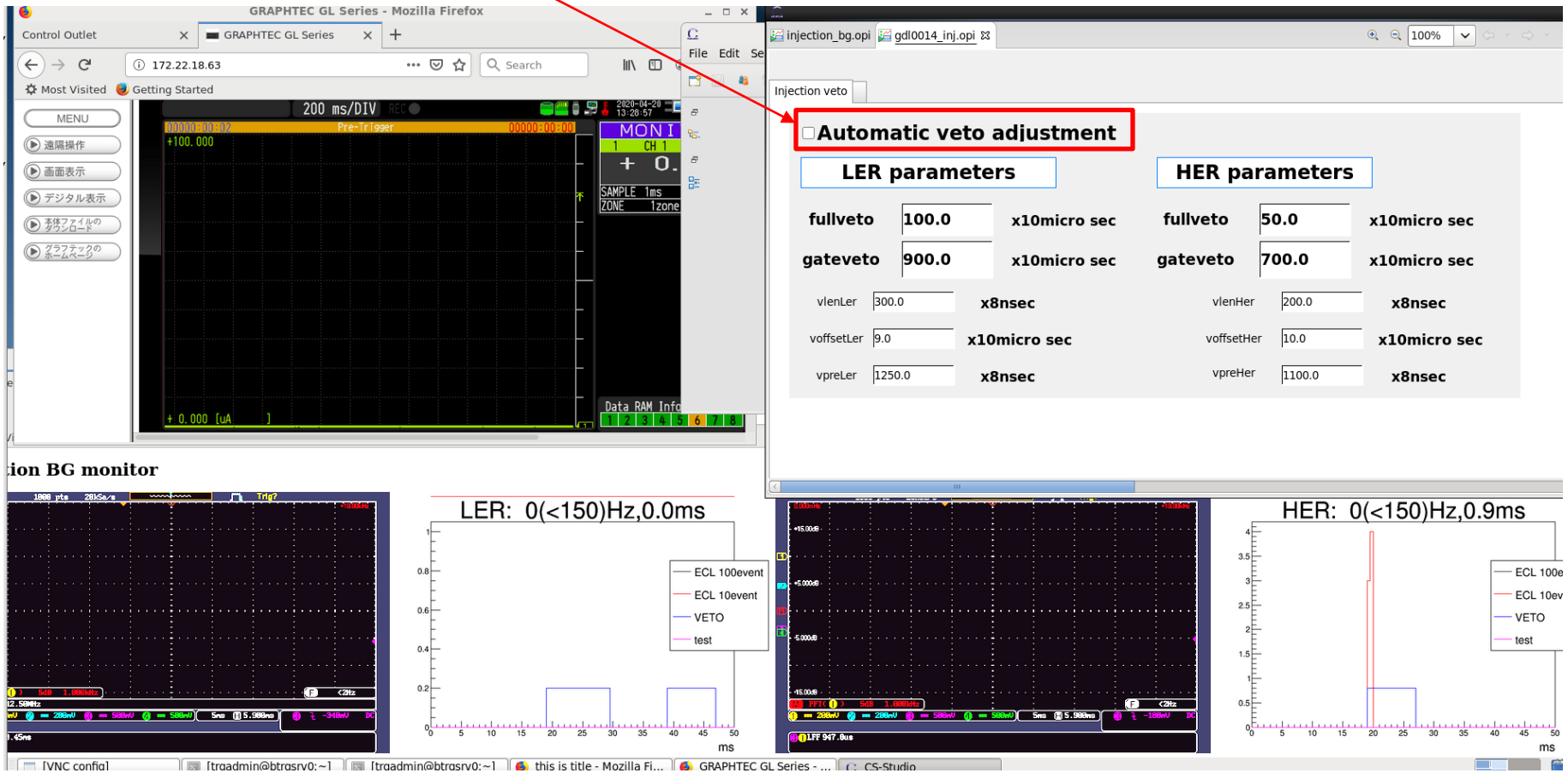




Enable/disable the automatic adjustment

-The automatic veto adjustment can be enable/disable from BCG

-Click this check box



BG duration ターンごとの時間構造

-3つの時間構造

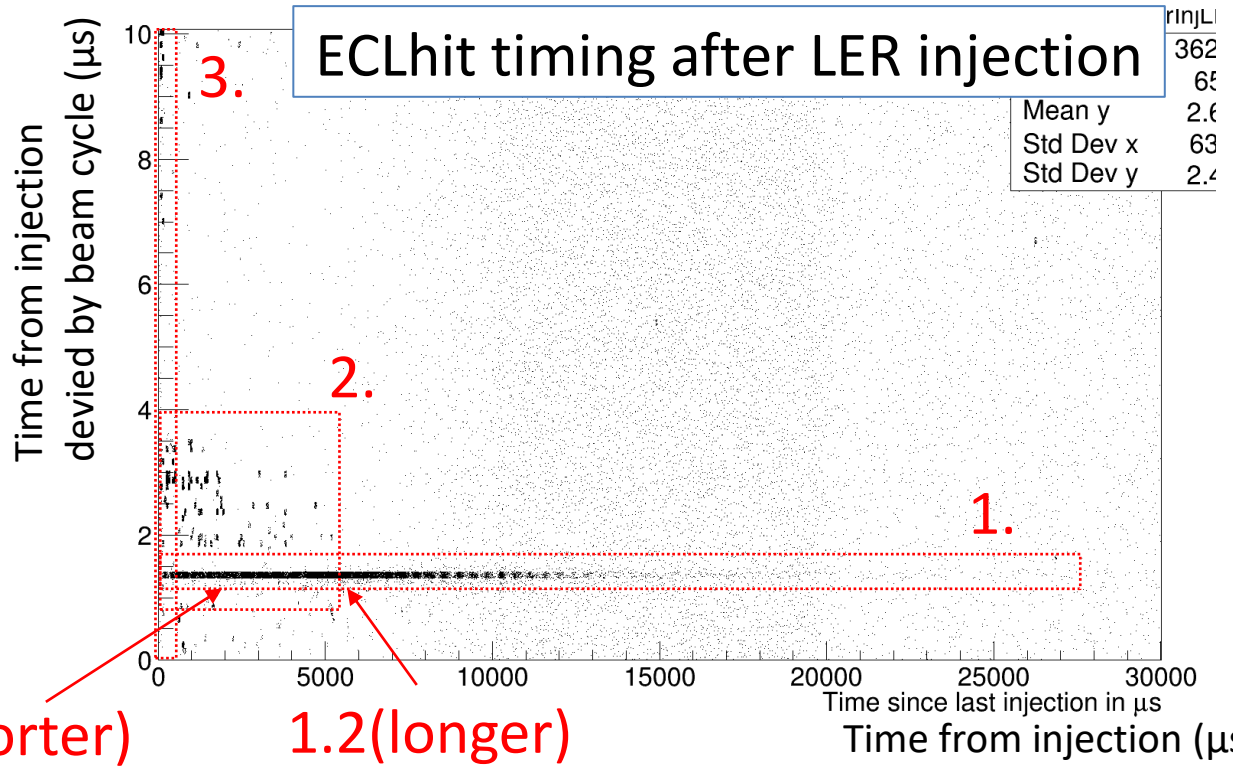
-1. 入射後 0~20ms, 入射バンチ周辺

-1.1 single beam: 数~10ms

-1.2 beam-beam: 数~20ms

-2. 入射後 0~3ms, 入射バンチ後 ~2μs

-3. 入射後 0~0.5ms



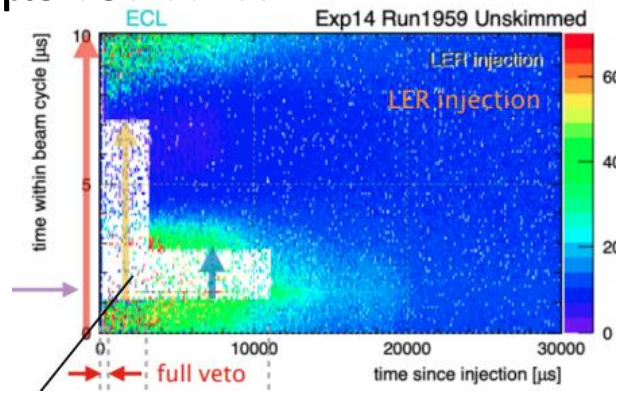
2020/6
no veto run
all event

1. 入射バンチ周辺 ターンごとの時間の広がり

-Tuen by Turnの時間広がり: ~1.5μs for LER, ~1.0μs for HER

-CDCTRGの方がECLTRGより~0.5μ程度広がり大
(drift time または geometricalな効果？)

-small energyのものも入れるとさらに広がり大



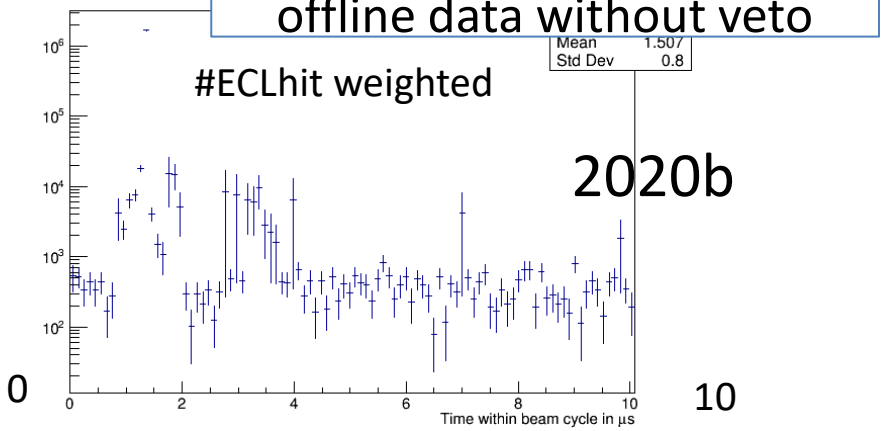
1MeV threshold

-原因?

-複数のバンチがinjected bunchの影響を受けている?

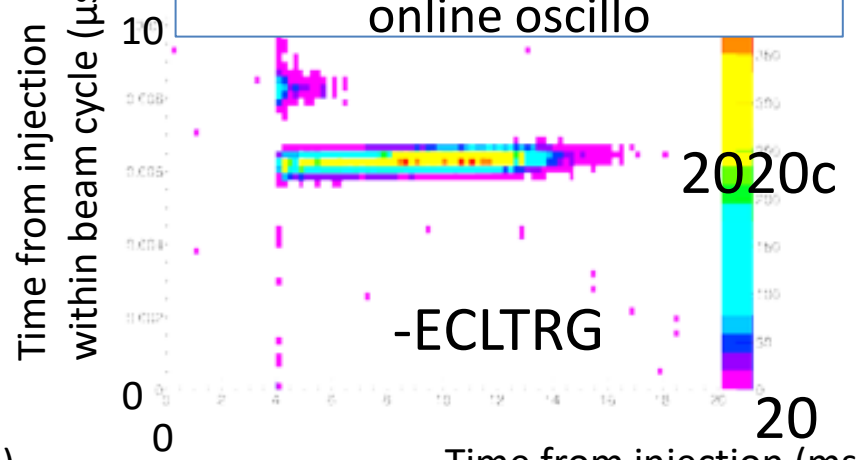
-Injectied bunch だけがnoisy、シャワーBG が時間的に広がっている?

L1 timing from LER injection
offline data without veto



Time from injection within beam cycle (μs)

L1 timing from LER injection
online oscillo



1. 入射バンチ周辺　Single bunch run

-Single 0-th bunchでも同様の時間広がりが確認できた

-BGのピークのタイミングは 0th-bunch (4856±4, offset estimated by abort gap)のタイミングと一致

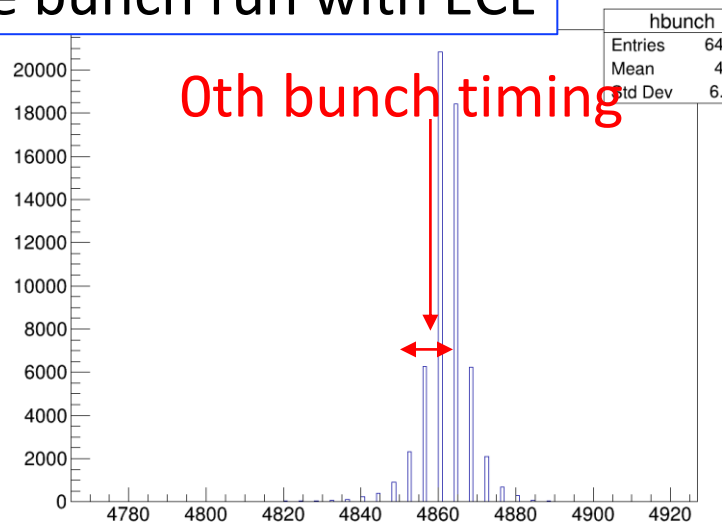
-原因?

-複数のバンチがinjected bunchの影響を受けている?

こっち?

-Injectied bunch だけがnoisy、シャワーBG が時間的に広がっている?

L1timing (ctime*4)
Single bunch run with ECL



#bunch+offset

L1timing turn by turn
Single bunch run with ECL

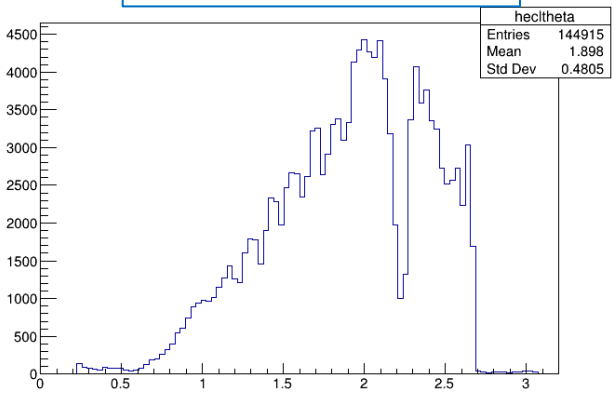
Time from injection within beam cycle (μs)

1. 入射バンチ周辺 BG Event display

-Mainly BW and barrel

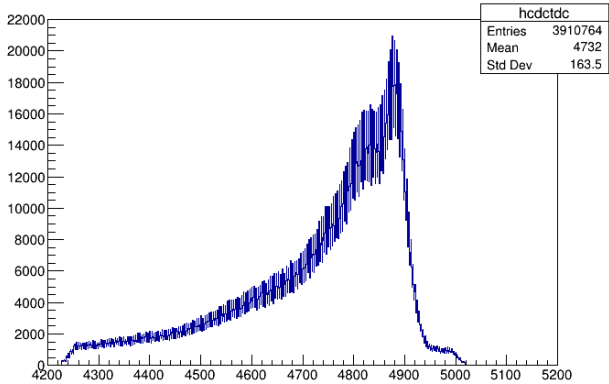
-CDC multi hits. Charged particle sometimes.

ECL cluster θ



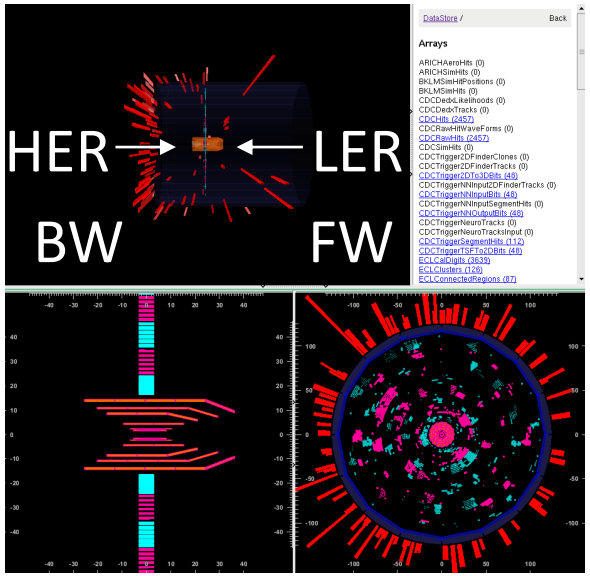
rad.

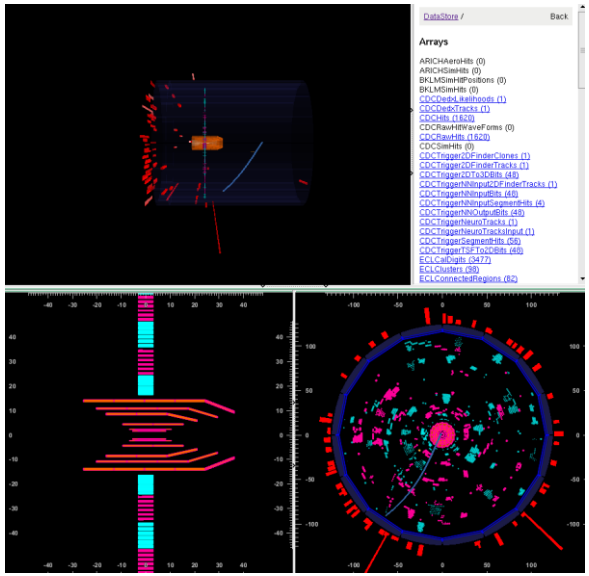
CDC TDC

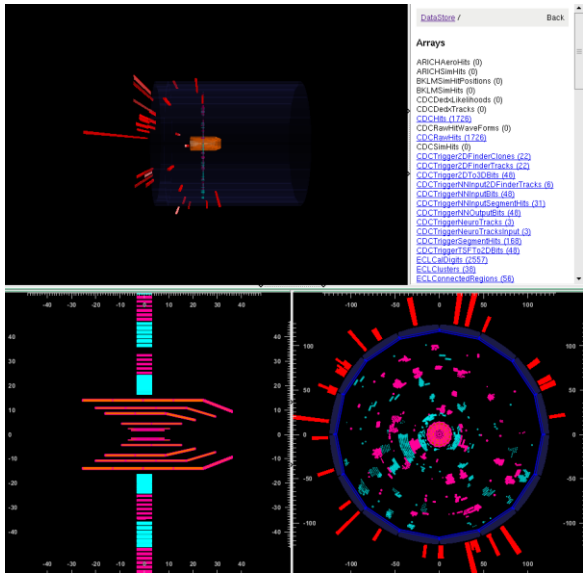


tdc(ns)

※Only CDC+ECL





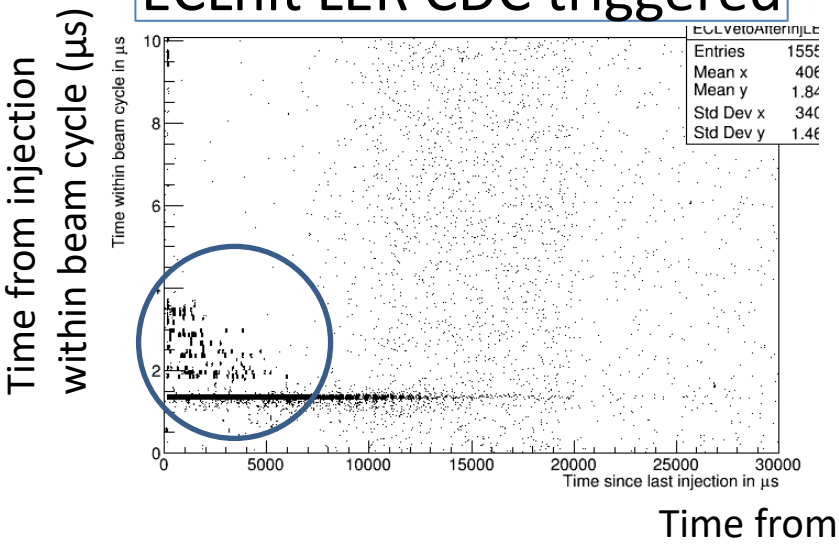


2.入射後 0~3ms, 入射バンチ後 ~2μs

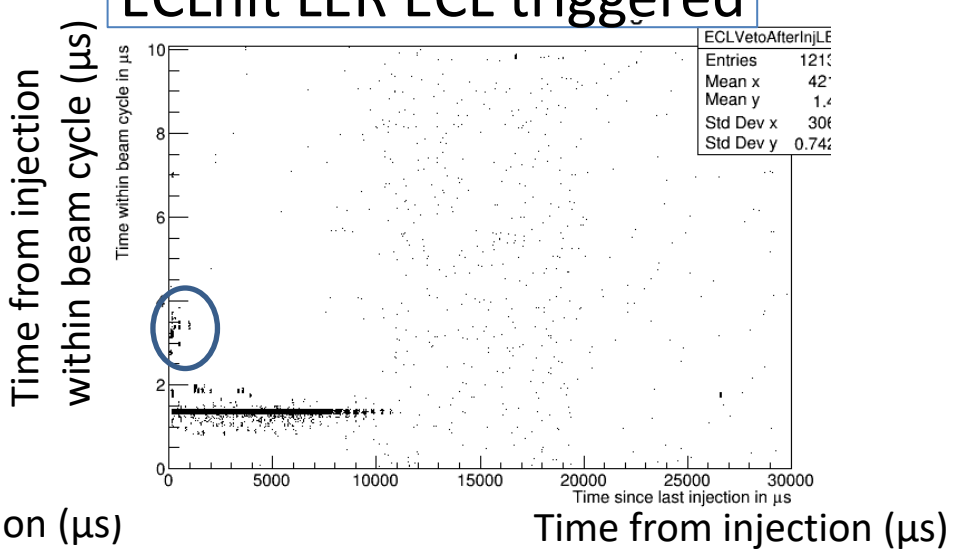
-Second peak appear ~2μs later than injected bunch

-Timing structure does not change frequently.
Mainly changed only before/after maintenance.

ECLhit LER CDC triggered



ECLhit LER ECL triggered



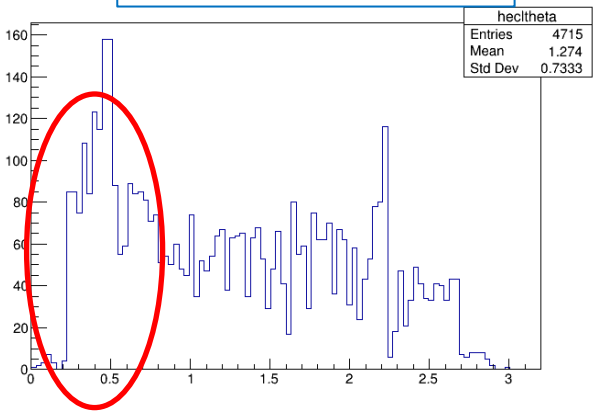
2.入射後 0~3ms, 入射バンチ後 ~2μs

-Mainly ECL FW (LER)

-Very high occupancy CDC hits. tdc is random like. Neutron ??

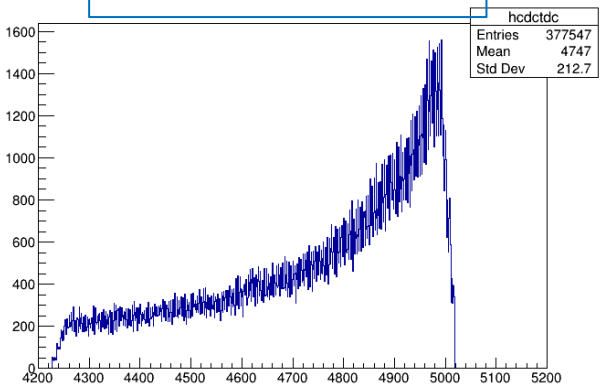
-Feature of BG looks different from 1.

ECL cluster θ



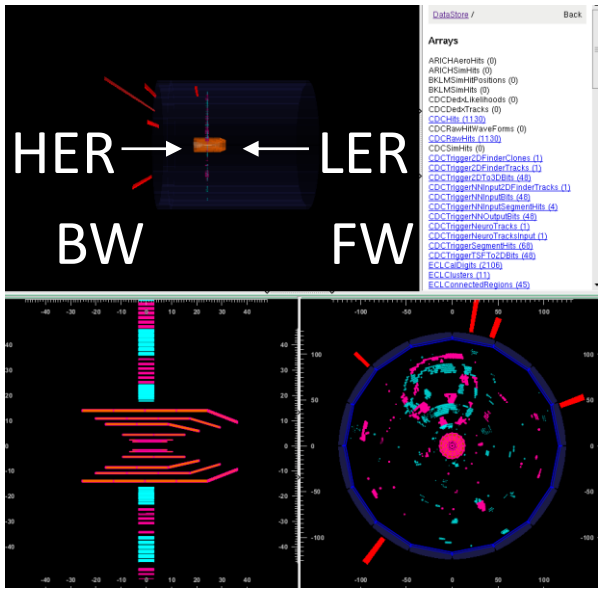
rad.

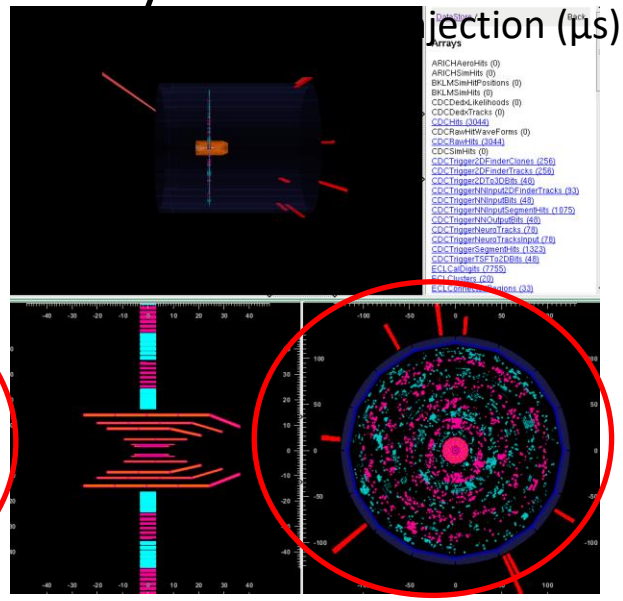
CDC TDC



tdc(ns)

※Only CDC+ECL





jection (μs)

BG duration feature (3. full turn in 0~0.5ms)

-BG is seen in all turns

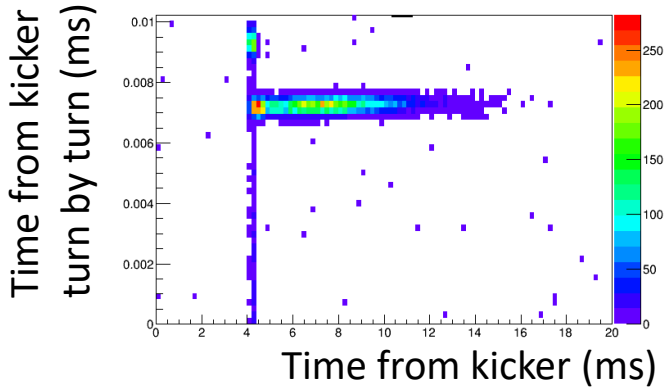
-Not changed frequently. Mainly changed only when maintenance.

-HER is worse than LER

-HER day by day

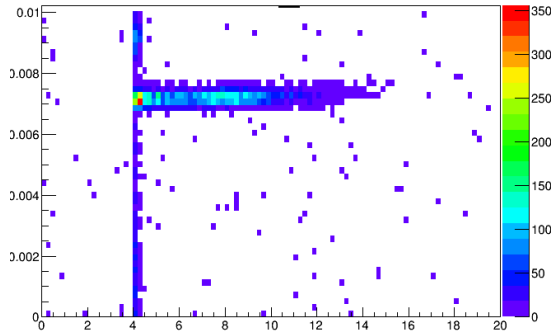
11/4

z=ECLTRG

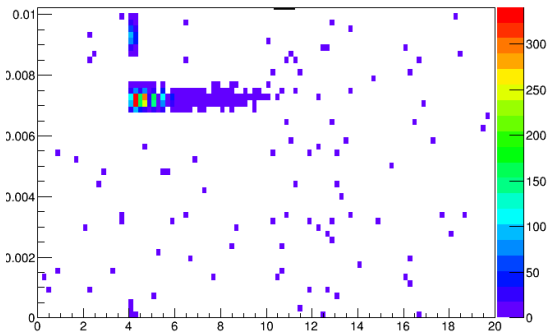


11/11

LER,HER 450,400mA→490,450

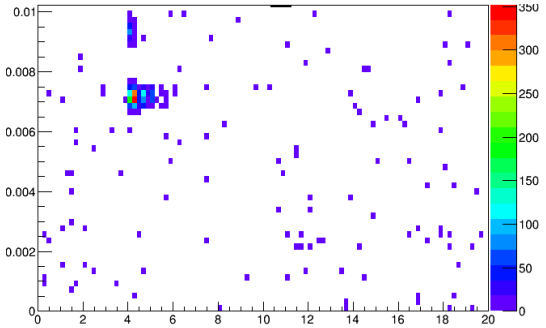


11/13 Maintenance collimator tuning



11/15

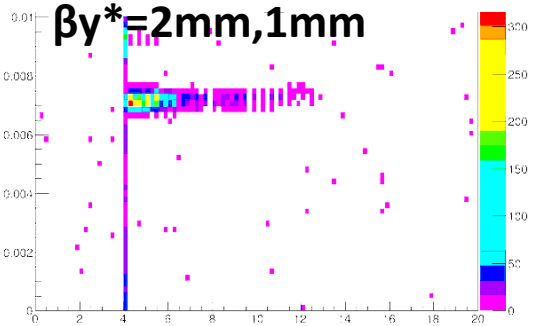
LER,HER 490,450mA→510,470



11/28 Replace D2V1

LER,HER 300,300mA

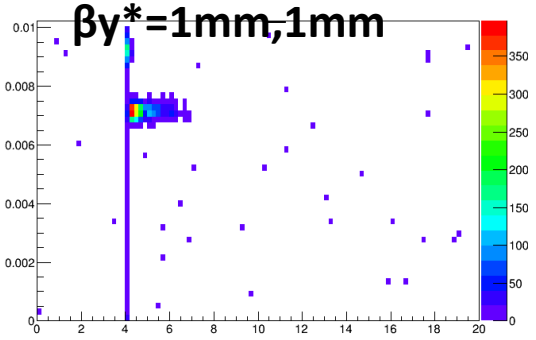
βy*=2mm,1mm



12/1

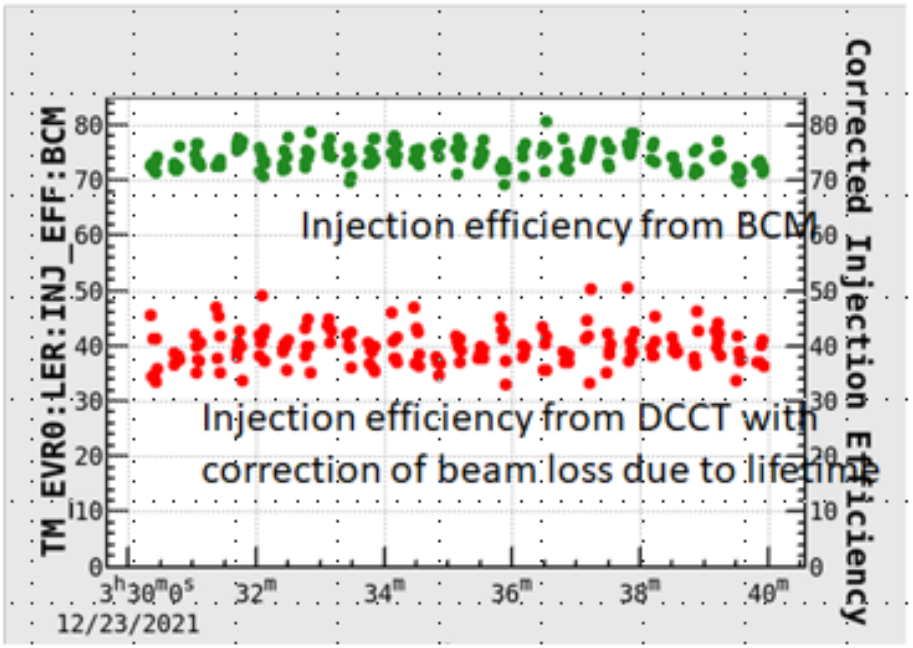
LER,HER 300,300mA

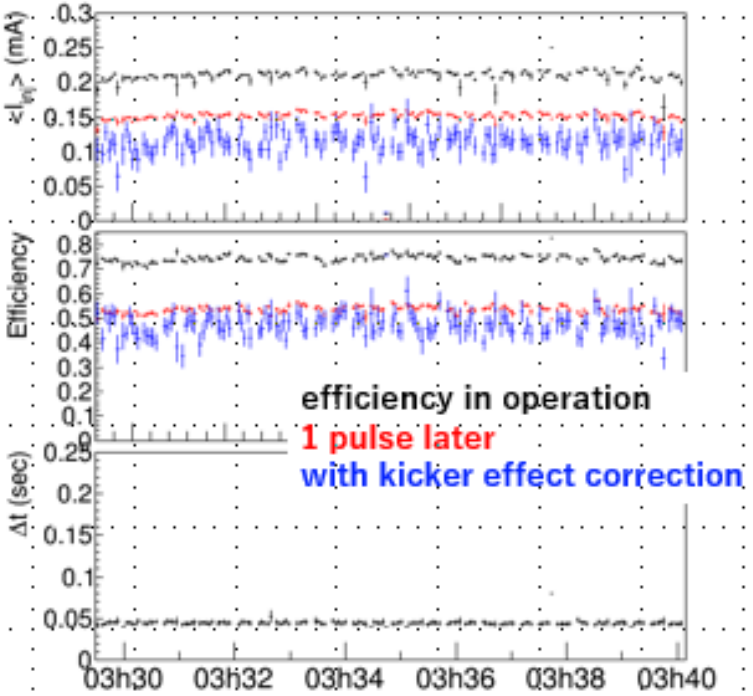
βy*=1mm,1mm



βy*=1mm in 2021c

Y. Funakoshi, H. Kaji





Left-red and **right-blue** can be compared, directly.