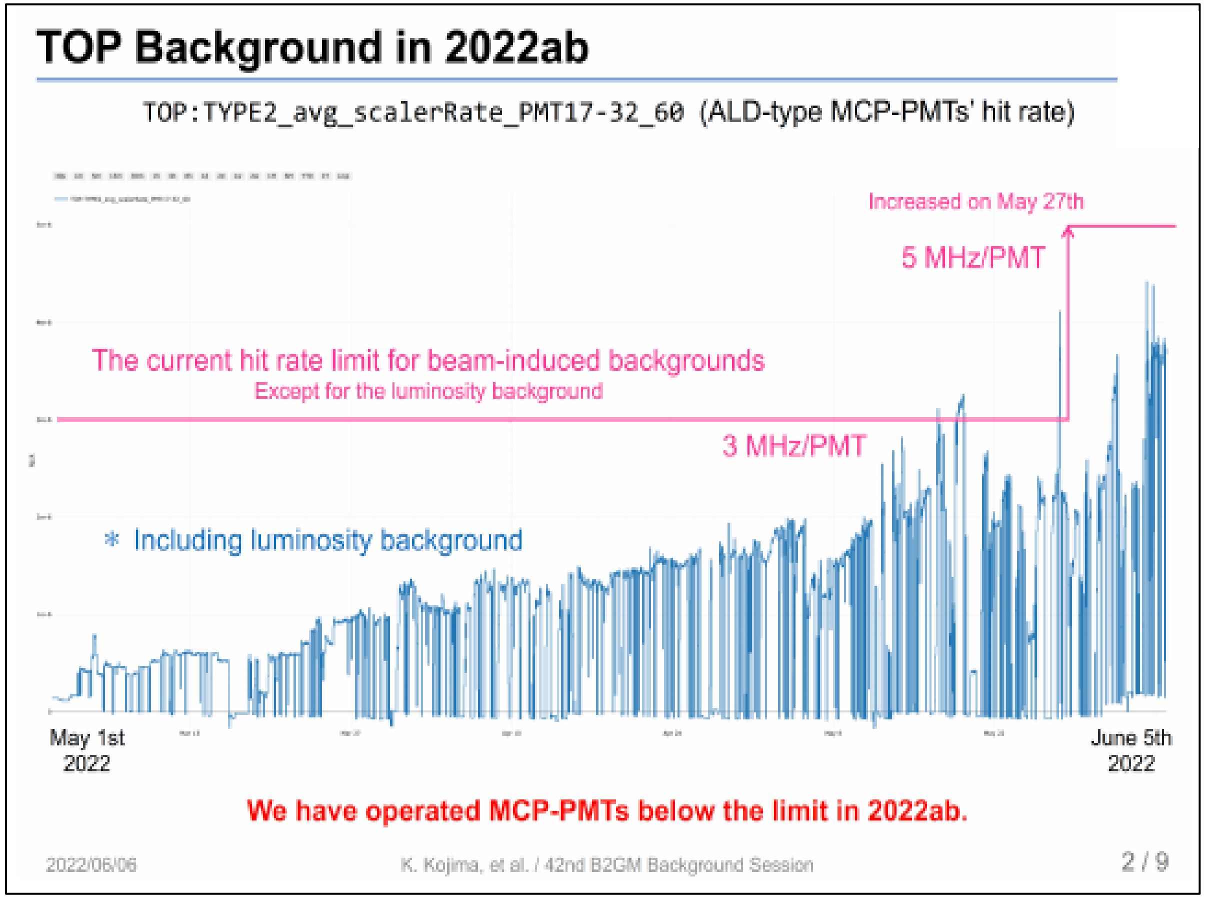
Beam Background, MDI

Hiro Nakayama (KEK)

The 26th KEKB Accelerator Review Committee
2022.12.13

2022a: Feb-Mar 2022
2022b: Apr-June 2022

Beam background in 2022a and 2022b

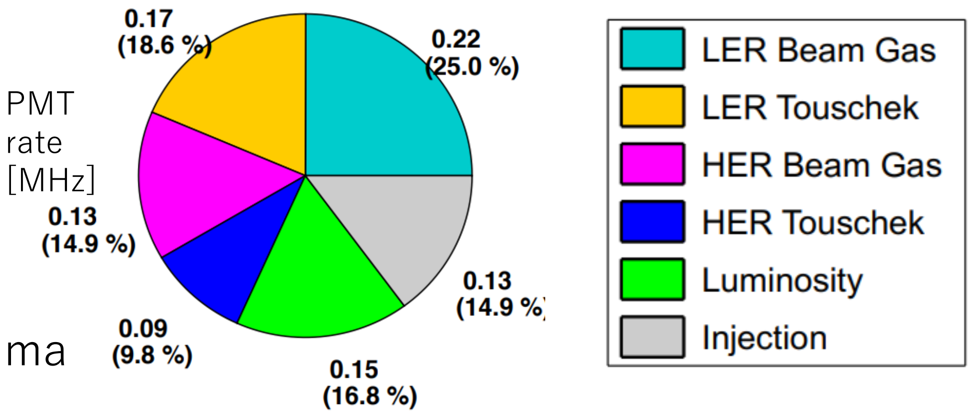


- Beam background rates have been well below the limit during 2022ab
  - TOP PMT rate limit was raised from 3→5 MHz
- Belle II background rates did not limit the beam currents
  - Limited by injection power
  - Also limited by increased number of sudden beam loss events at higher currents
- Collimators were severely damage by sudden beam loss events
  - It became difficult to control (injection) BG
- Longer LER injection BG duration
  - Larger DAQ deadtime fraction (~10%@23Hz inj.)

Belle II beam background in recent runs

- Belle II beam BG didn't limit beam currents in 2021 and 2022
  - Thanks to successful BG mitigation by collimators, vacuum scrubbing progress, etc..
  - However, it will be a problem at higher luminosity without further BG mitigation
- TOP counter is the most vulnerable sub-detector to beam backgrounds
  - Finite PMT photocathode lifetime, replacement work during long shutdown needed
  - Major contribution from LER beam-gas, LER Touschek, Luminosity BG, etc..

TOP background breakdown
during recent physics runs



K. Kojima

June 28, 2020
beta*y = 0.8mm

Input values
to calculate background rate.

$$I^{\mathrm{HER}} = 500\ \mathrm{mA}$$
$$\sigma_y^{\mathrm{HER}} = 34\ \mu\mathrm{m}$$
$$N_b^{\mathrm{HER}} = 978$$

$$I^{\mathrm{LER}} = 480\ \mathrm{mA}$$
$$\sigma_y^{\mathrm{LER}} = 66\ \mu\mathrm{m}$$
$$N_b^{\mathrm{LER}} = 978$$

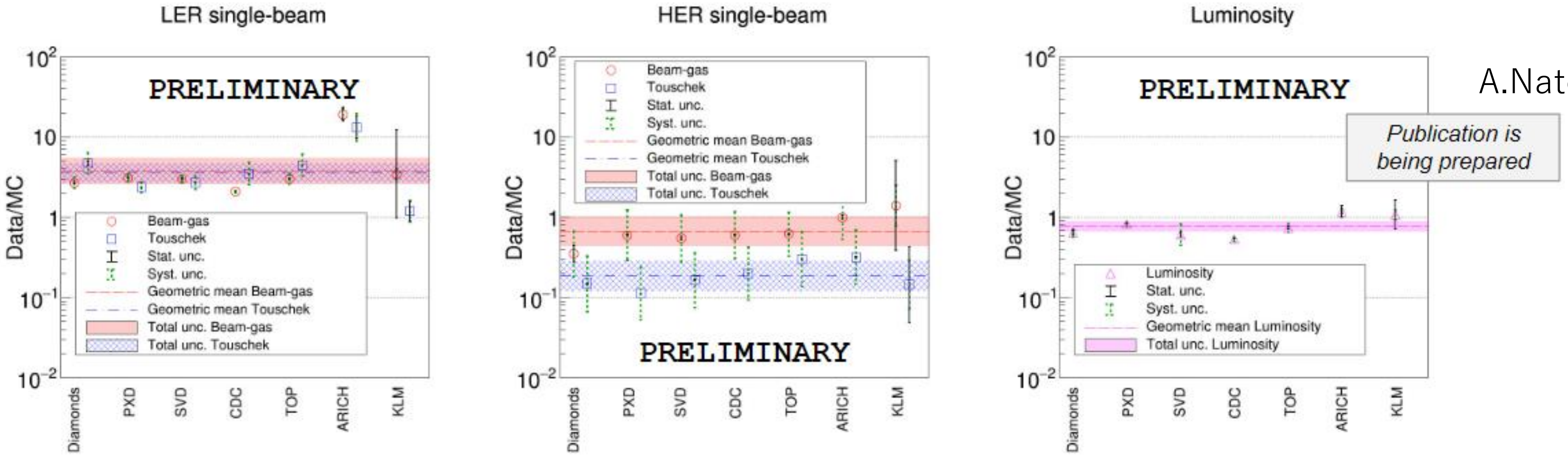
$$\mathcal{L} = 1.5 \times 10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$$

e- (7GeV,**HER**)
e+ (4GeV,**LER**)

Data/MC ratio of each BG component

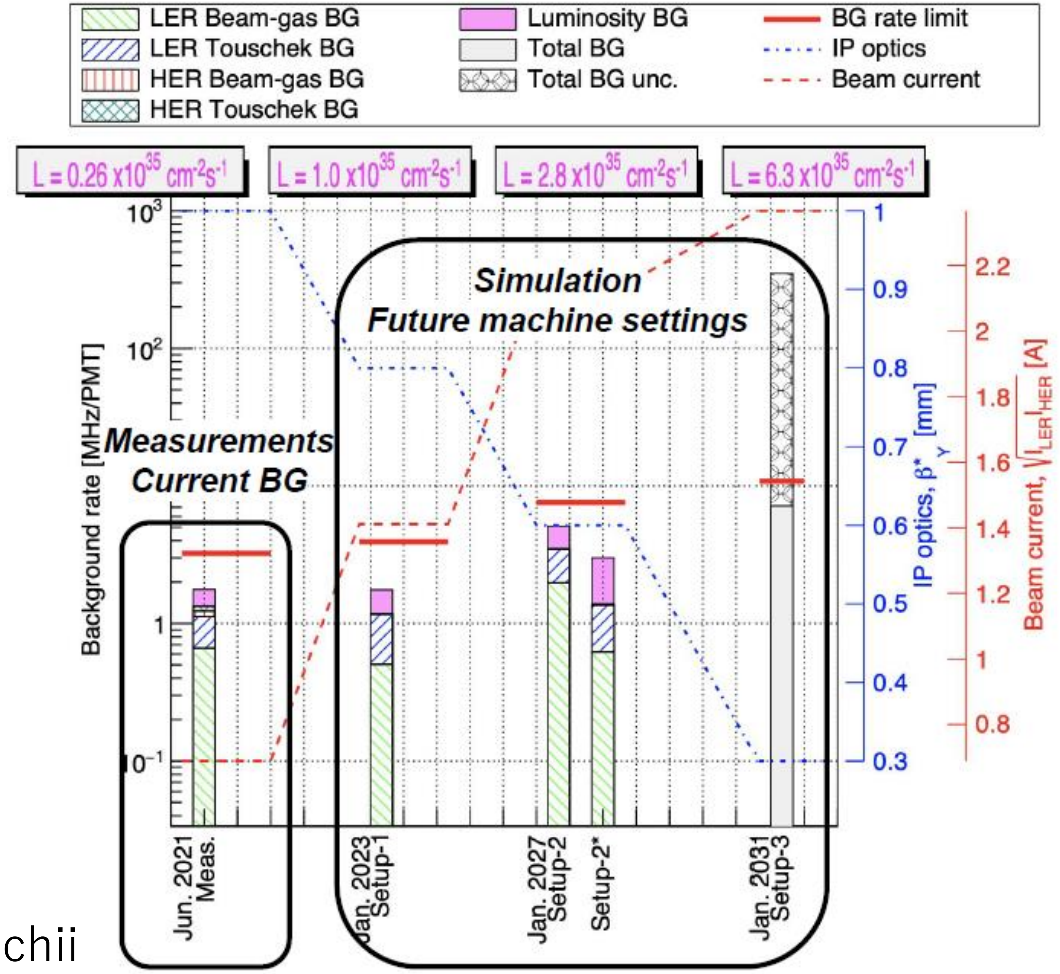
Ratios of measured (**data**) to simulated (**MC**) backgrounds based on dedicated studies in 2020-2021

A.Natochii



- Each BG component measured in dedicated machine studies in 2020/2021
- Data/MC ratio stays within one order of magnitude from unity
- Measured lumi-BG stays consistent with prediction (will dominate at full luminosity)
- This confirms our good understandings on beam loss processes at SuperKEKB
- Those ratios are used to rescale simulated beam background rates toward higher luminosity

Future prediction of beam BG



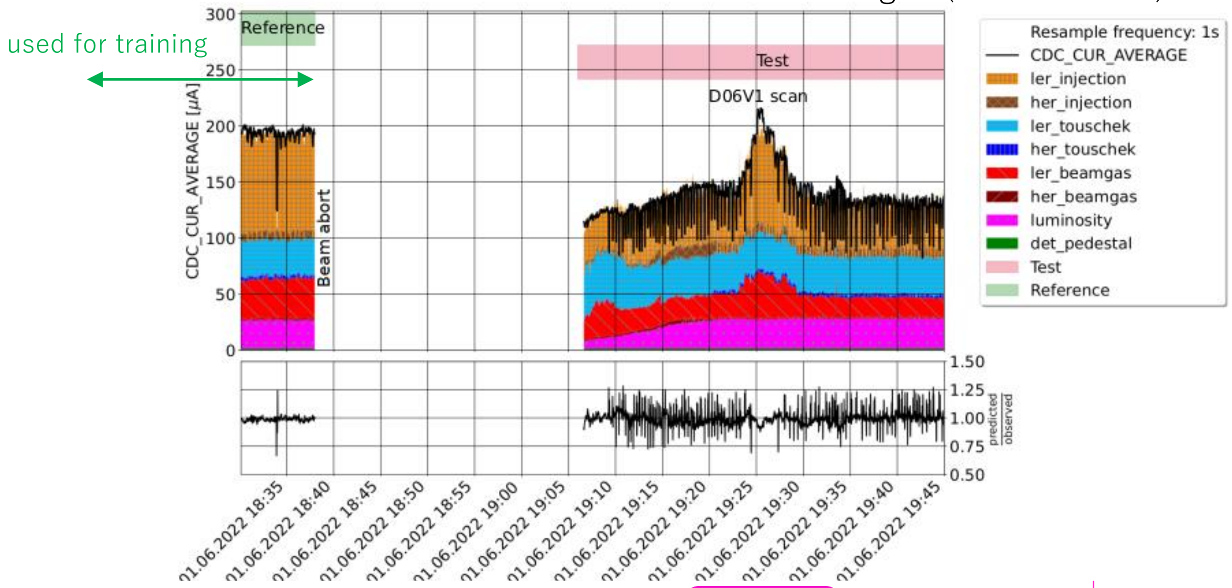
Measured and predicted Belle II backgrounds

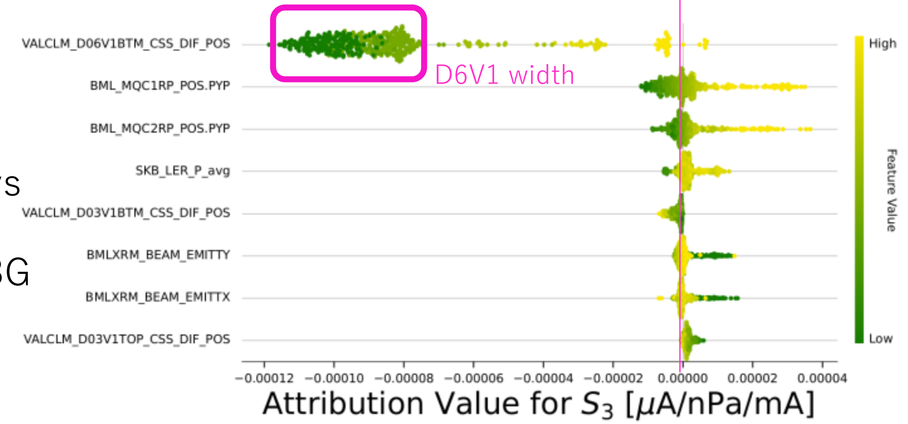
A.Natochii

- Data/MC ratio from recent BG measurements can be applied to improve BG predictions at future optics
- Latest prediction can be found in our Snowmass WhitePaper (arXiv:2203.05731)
    - Up to L~3x10^{35}, beam BG will remain high but acceptable
    - For the target luminosity (L~6x10^{35}), machine condition is very uncertain to make accurate prediction
        - major modification of IR?

New: Real-time Background Composition Monitoring based on machine-learning approach

U. Gottingen (S. Schwenker)



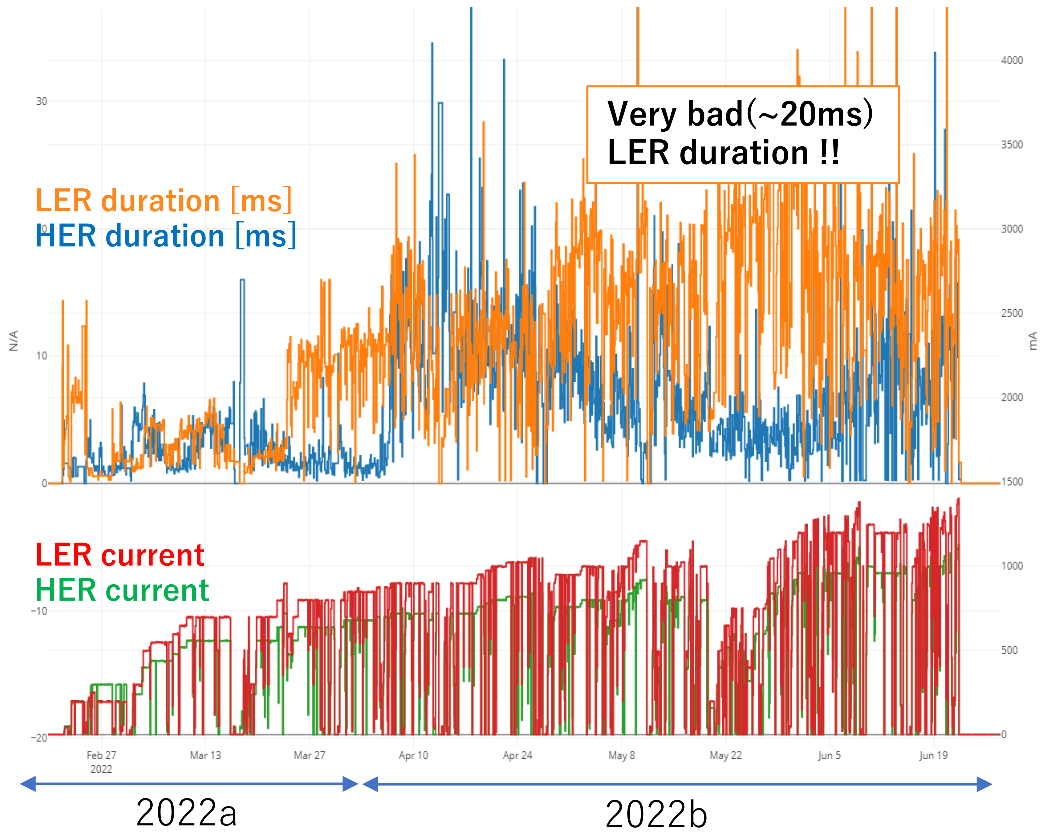


Feature attribution says D6V1 collimator width most contributed the BG change

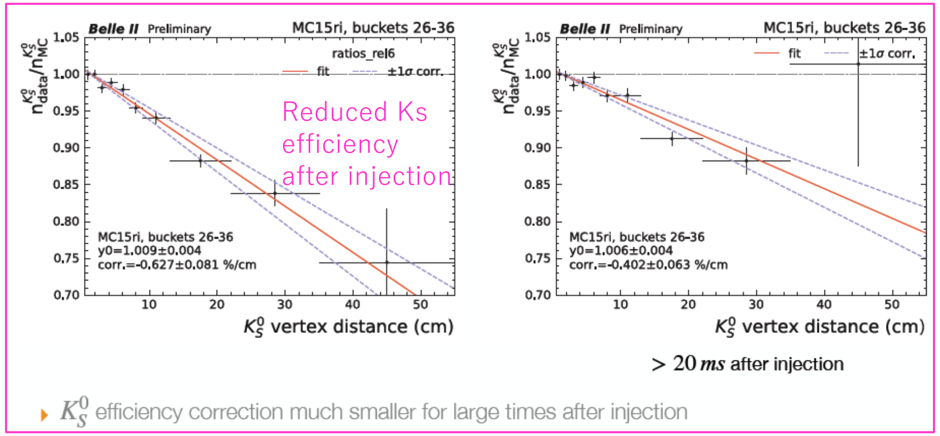
- The neural network (BGNet) is fed with archived 1Hz EPICS PVs
  - some domain knowledge is used in the model (i.e. beam gas BG rate ∝ current x pressure)
- The trained network can successfully reproduce BG levels at "future" timing (which is not used in training)
  - Larger prediction error for "far" future
- BGNet can provide real-time background composition monitoring
  - instead of BG studies which needs long machine time

"Feature attribution" method can tell us which parameter most contributed to the change of the BG rate
  - quite useful feedback for machine operators

Issue: duration of injection BG



- As beam currents increased (> 1A), duration of injection BG became worse
  - Due to severe collimator damage by sudden beam loss events, poor quality of 2-bunch injection, etc..
- Belle II trigger veto window had to be widened to reject injection BG with longer duration
  - DAQ deadtime reached ~10% (!)
- Recorded physics data (outside injection veto) shows some performance degradation



- Improvement of injection quality is crucial for physics runs after LS1 !
- Lots of injection improvement works planned during LS1 (injection talk tomorrow)

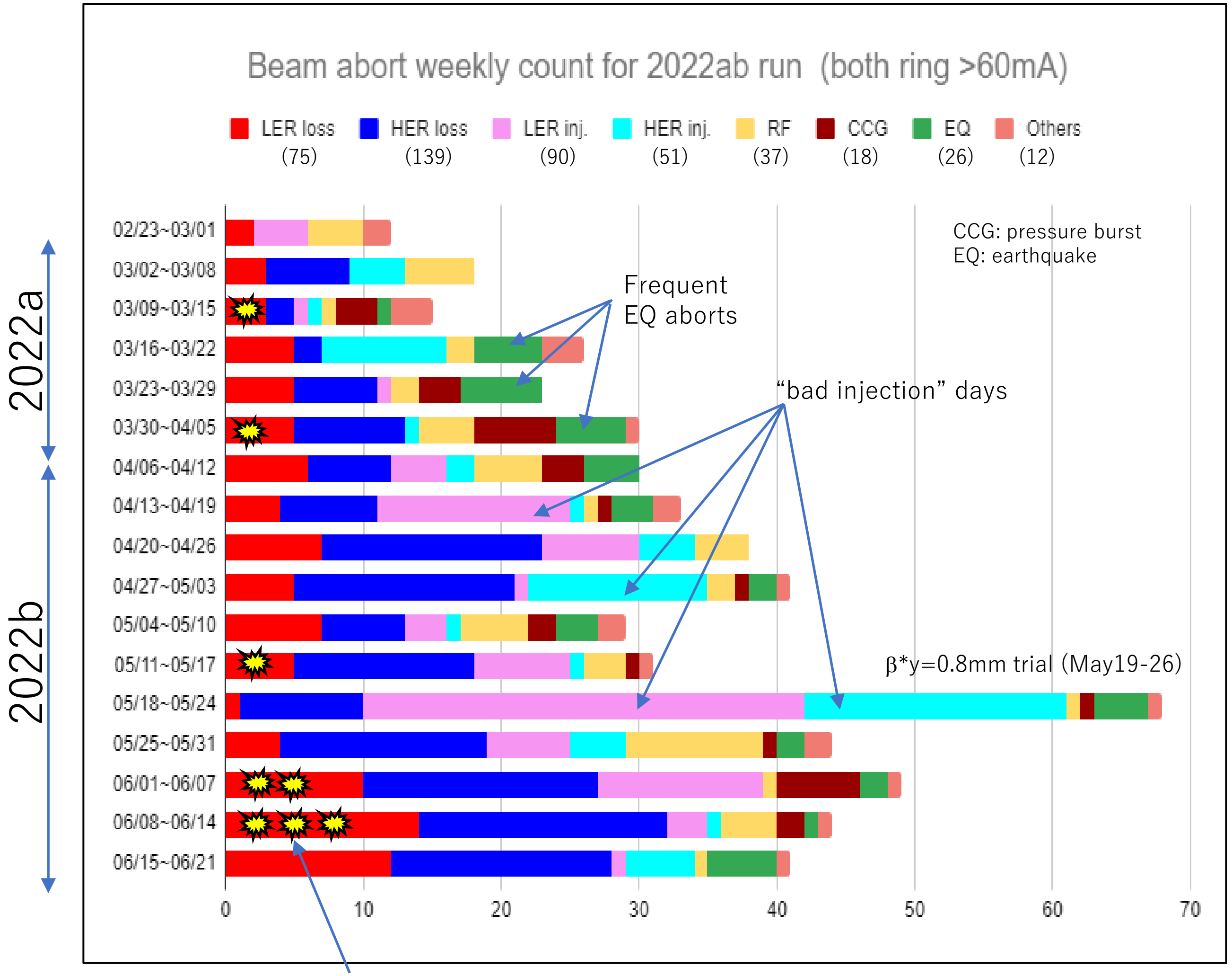
More major issues in 2022ab

- **Sudden beam loss** (mainly in LER) → sensor/collimator damage, QCS quench
  - **Storage beam suddenly becomes unstable and lost within 2~3 turns (20~30us).**
  - Large loss events caused QCS quenches x8 times (!) in 2022ab.
    D6V1/D2V1 collimators were severely damaged.
  - **Abort timing analysis using fast loss monitors made a good progress.**
  - The cause of beam loss is still unknown, but several new hypotheses are on the table.

- Injection: frequent injection aborts on "bad injection" days → operation time loss
  - Sometimes injection becomes unstable and caused frequent injection aborts
    - Due to LINAC energy drift, poor 2-bunch injection, collimator damage, narrow dynamic aperture at b*y=0.8mm, etc….
  - Mostly just above the diamond abort threshold. Slightly relaxing the threshold can suppress such aborts, but the possible risks should be carefully accessed.

- Injection: difficult to keeping a good condition for a long time → limit max currents
  - HER injection efficiency sometimes became poor and limited the max beam current.
  - HER 2-bunch injection cannot be used in 2022ab (poor quality of 2nd bunch).

Beam aborts in 2022ab



: **QCS quench by LER loss**

LER loss | HER loss

- LER/HER beam loss aborts got more frequent as beam currents became higher.
- **LER large beam loss aborts caused QCS quenches (8 times in 2022ab).**
  - If QCS quench happens, it takes ~3 hours to recover QCS and more time to reproduce a good machine condition
- Large beam loss caused damage in LER vertical collimators (D6V1,D2V1) and Belle II sensors

LER inj. | HER inj.

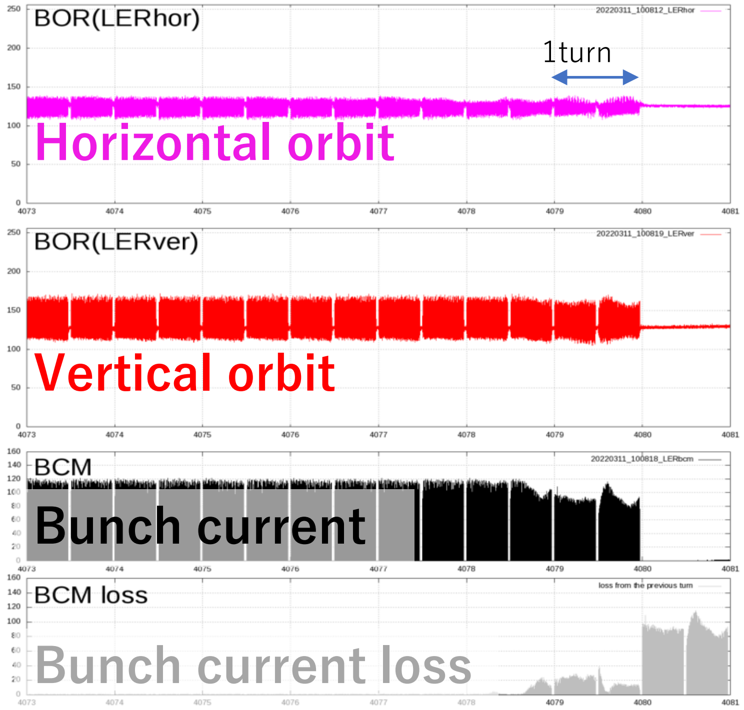
- HER/LER injection aborts become frequent on several "bad injection" days
  - Due to LINAC energy, damaged collimator, beta*y=0.8mm, etc…
- Not dangerous, but it takes 20~30minutes per abort to refill beams → loss of integrated luminosity

EQ | Others

- Large earthquake on Mar 16th. Frequent earthquake aborts due to the aftershocks continued for several weeks.
- LER Injection kicker accidental fire aborts happened in early 2022a. D6H3 collimator was damaged (again).

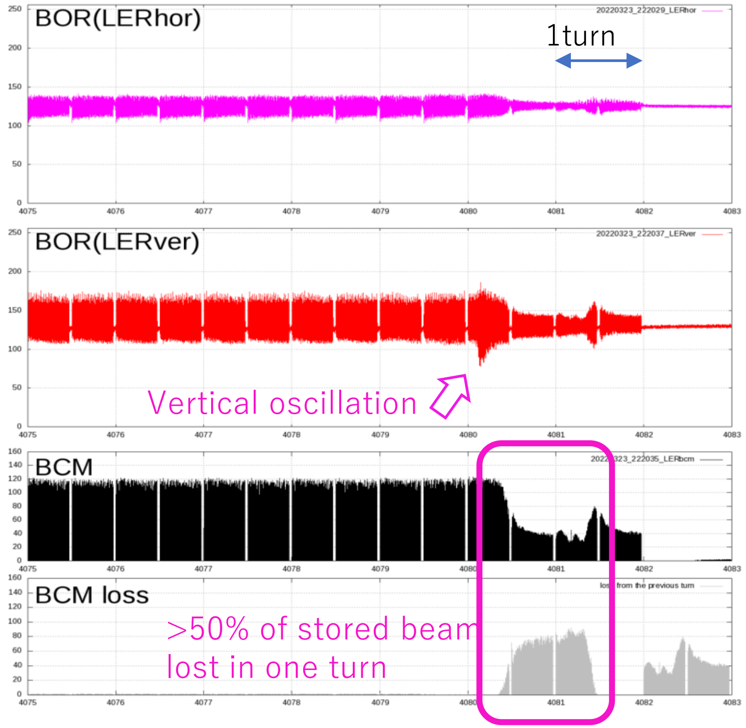
Major LER beam loss events in 2022ab (1/3)

2022-03-11 10:08



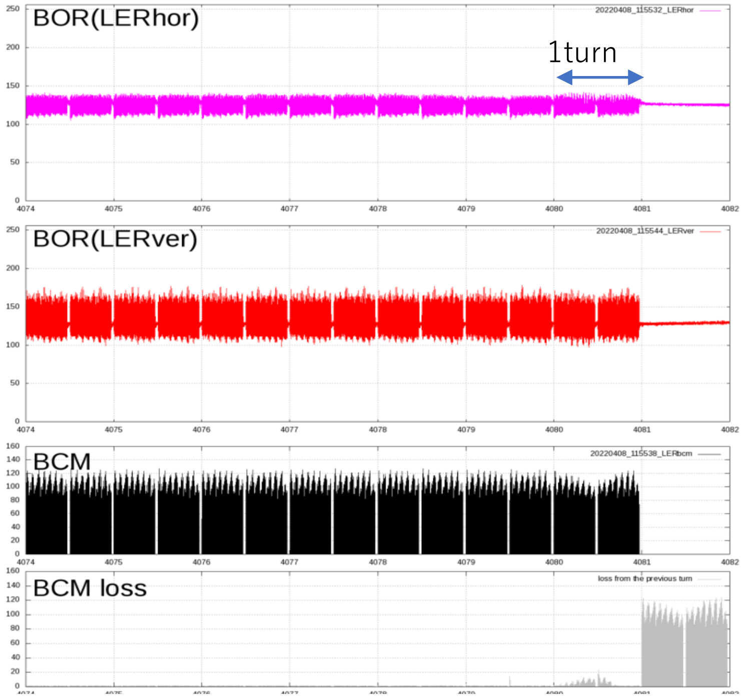
- **QCS quench (#1 in 2022ab)**
- HUGE IR loss (544mRad)
- **Severe D2V1 damage**
  (pressure burst >10^{-5} Pa)

2022-03-23 22:20



- IR loss was small (12mRad)
- This is not QCS quench, but..
- **Severe D6V1 damage**
  (pressure burst >10^{-4} Pa !)

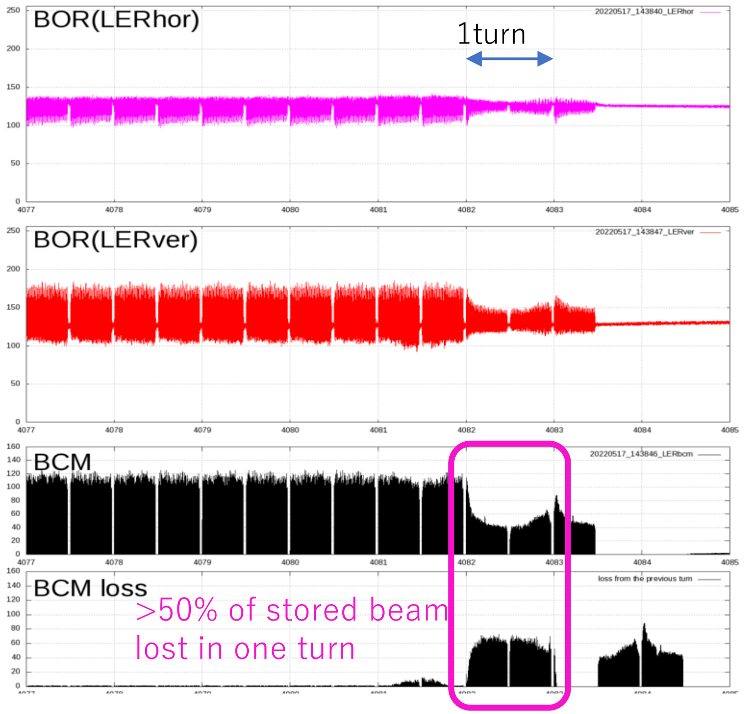
2022-04-08 11:55



- **QCS quench (#2 in 2022ab)**
- **QCS quench occurred although IR loss was rather small (91mrad). WHY??**

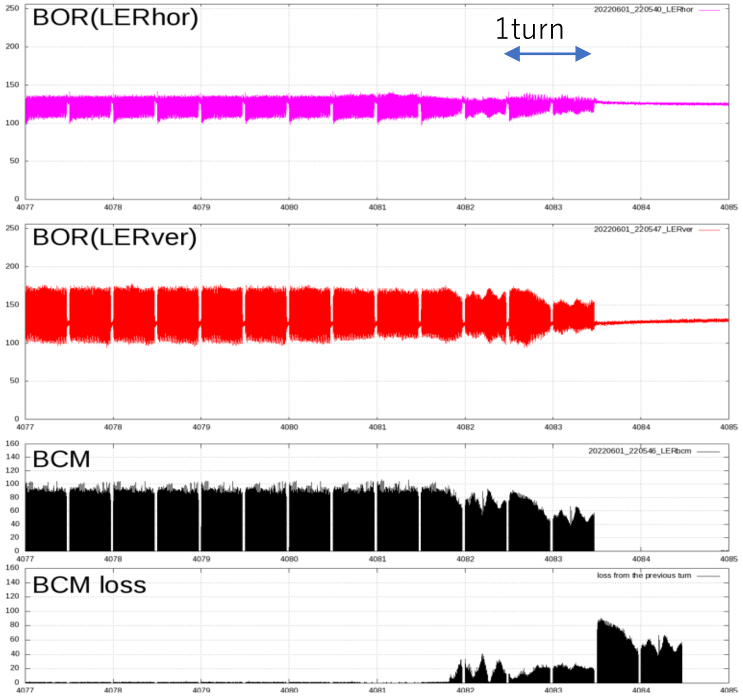
Major LER beam loss events in 2022ab (2/3)

2022-05-17 14:38



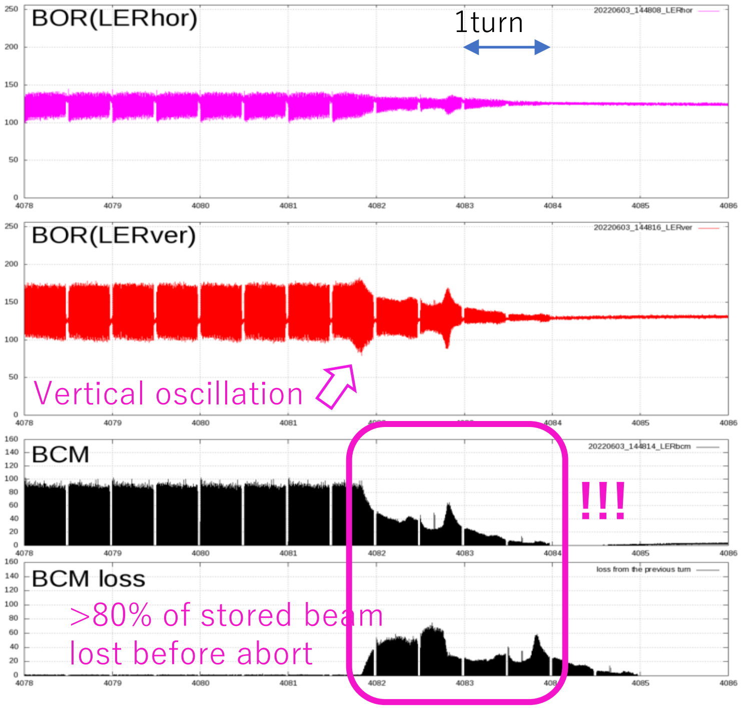
- **QCS quench (#3 in 2022ab)**
- HUGE IR loss (471mRad)
- **Severe D6V1 damage**
  (pressure burst >10^{-5} Pa)
- **After this abort, D6V1 cannot be closed and wider than D2V1**

2022-06-01 22:05



- **QCS quench (#4 in 2022ab)**
- HUGE IR loss (739mRad)
- No pressure burst

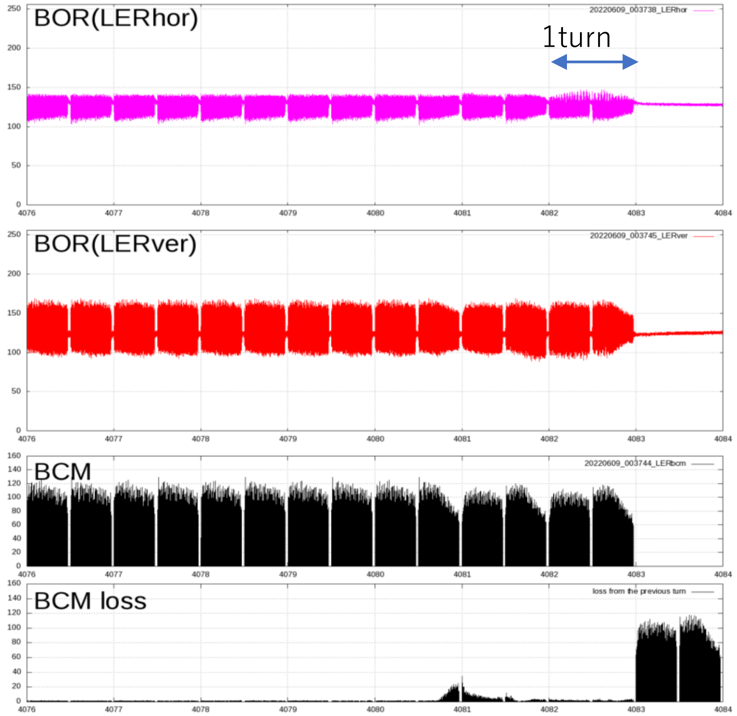
2022-06-03 14:48



- **QCS quench (#5 in 2022ab)**
- HUGE IR loss (>>1000mRad)
  (**diamond saturated !**)
- **Severe D2V1 damage**
  (pressure burst > 10^{-5} Pa)

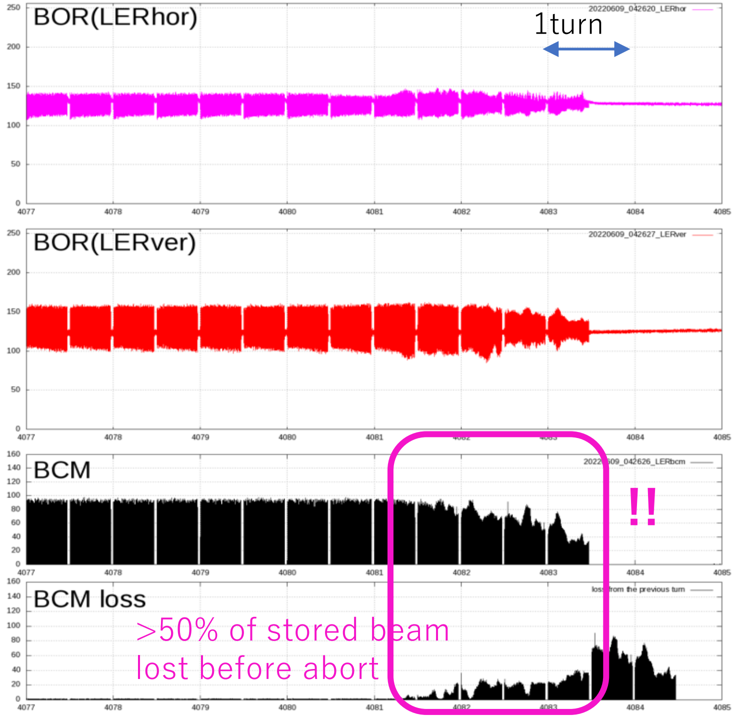
Major LER beam loss events in 2022ab (3/3)

2022-06-09 00:37



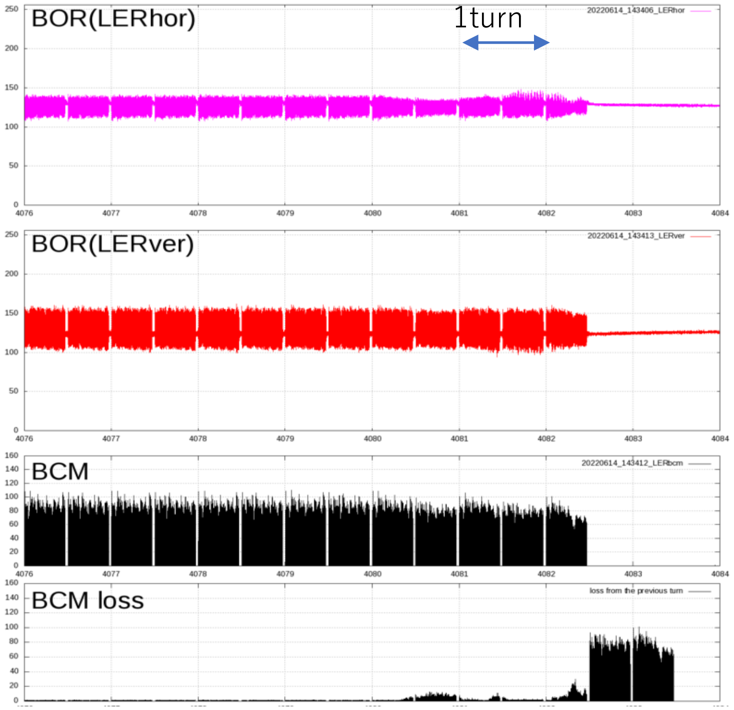
- **QCS quench (#6 in 2022ab)**
- HUGE IR loss (644mRad)

2022-06-09 04:26



- **QCS quench (#7 in 2022ab)**
- HUGE IR loss (>>1000mRad)
  (**diamonds saturated !**)
- Severe D6V1 damage
  (pressure burst ~10^{-5} Pa)
- **PXD sensor damage**

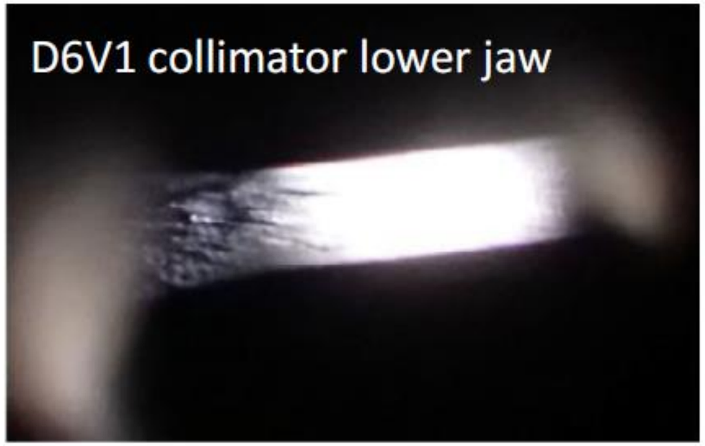
2022-06-14 14:34



- **QCS quench (#8 in 2022ab)**
- HUGE IR loss (1056mRad)
- Severe D2V1 damage
  (pressure burst > 10^{-5} Pa)

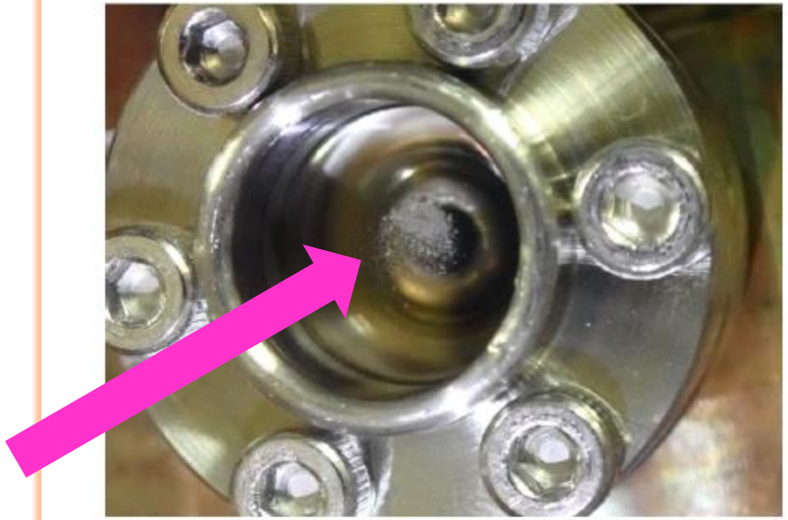
What is the cause of those "catastrophic" beam loss ??

Severe collimator damage

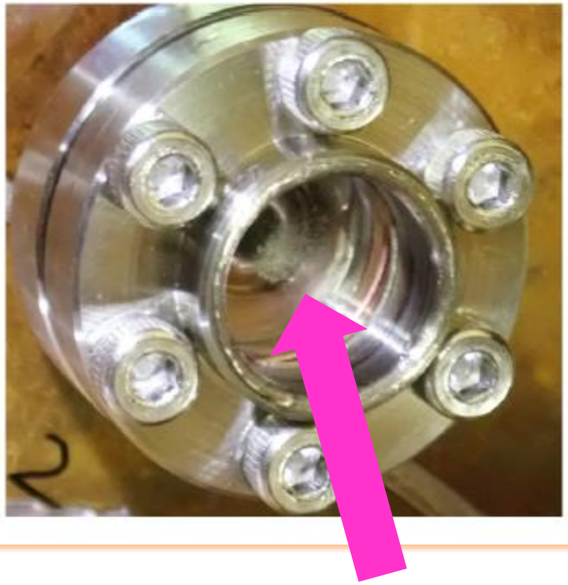


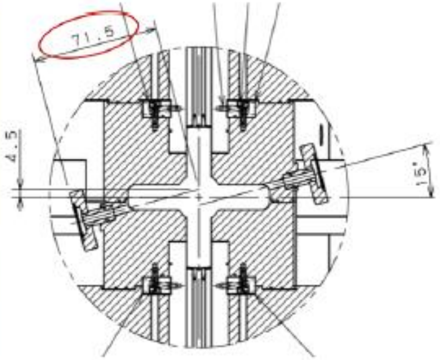
- After the visual inspection, the collimator damage was confirmed.
- **Our operation is not much affected by the D02V1 damage while the D06V1 damage impacts on our operation.**

View port (Top)



View port (Bottom)



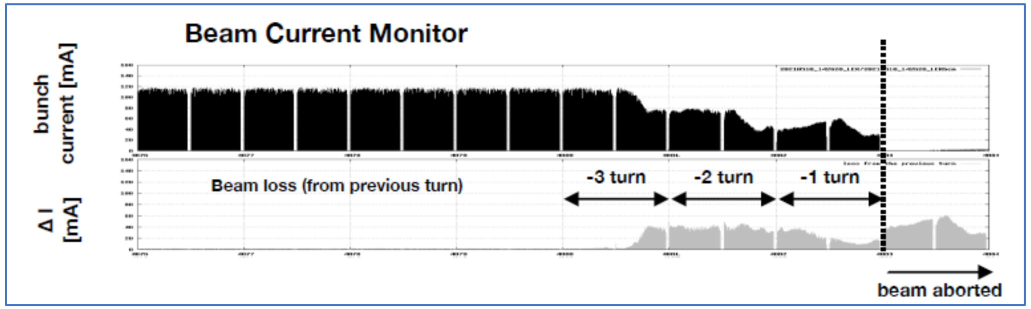


D02V1 collimator

A direct hit from the crazy beam melted the collimator head and splattered it all over, even onto the viewport window.

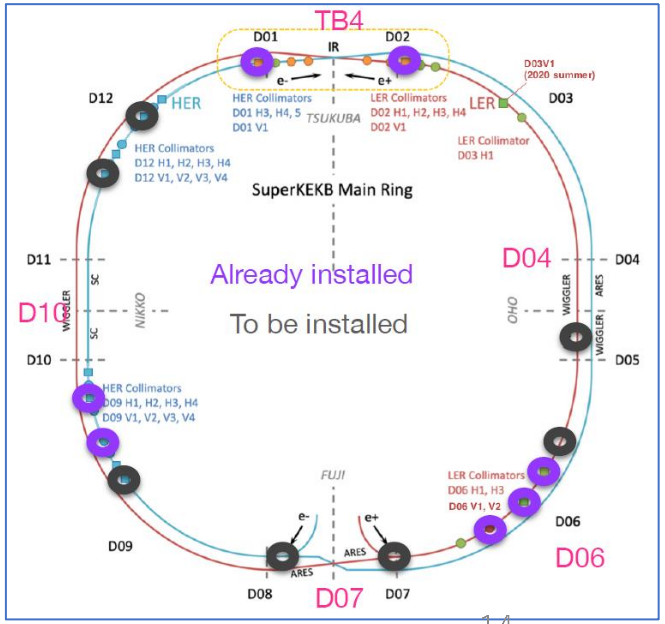
Sudden Beam Loss (SBL)

A dedicated talk by Ikeda-san tomorrow morning

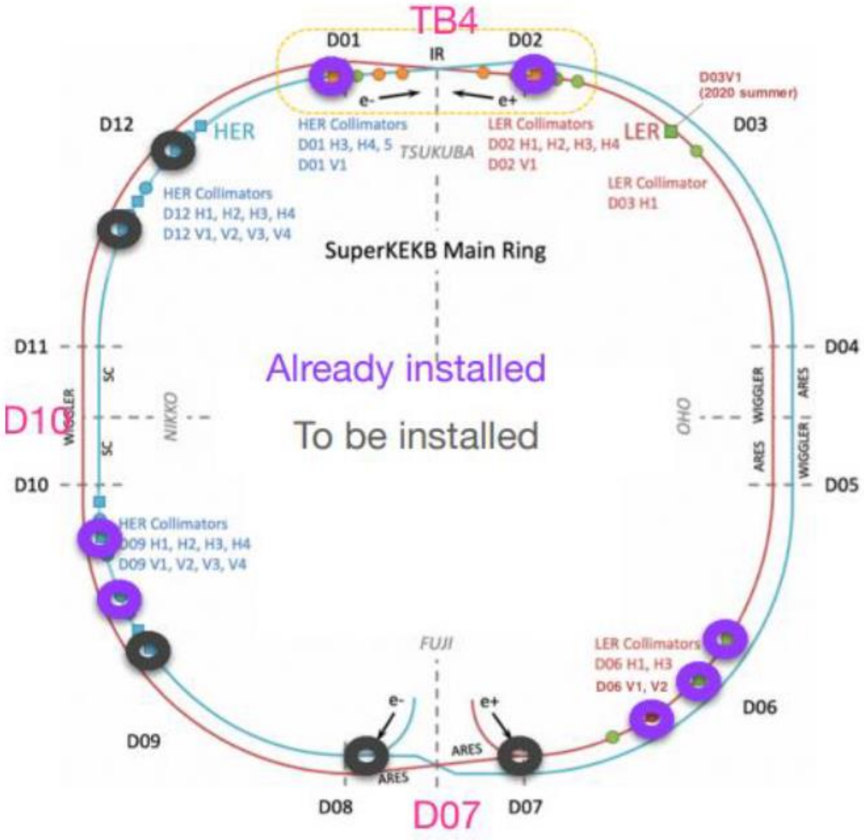


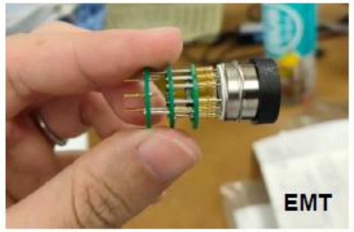
- **Sudden Beam Loss (SBL)**
  - Stored beam is suddenly lost within a few turns
  - The cause is not fully understood yet
  - Sometimes lead to QCS quench, or severe damage on collimator head and VXD sensors
  - Major limitation for the machine operation, especially at higher beam currents

- Ongoing efforts to understand the cause of SBLs
  - **Fast loss monitors** installed around LER collimators
    - "More eyes" to find the hint for SBL
  - **SBL documentation** now available (link)
  - **SBL subgroup** formed under the SuperKEKB International Task Force (ITF)
    - 1st meeting on Aug 31st, 2nd meeting on Oct. 14th
    - Fruitful discussions inviting experts outside B2/SKB collaboration



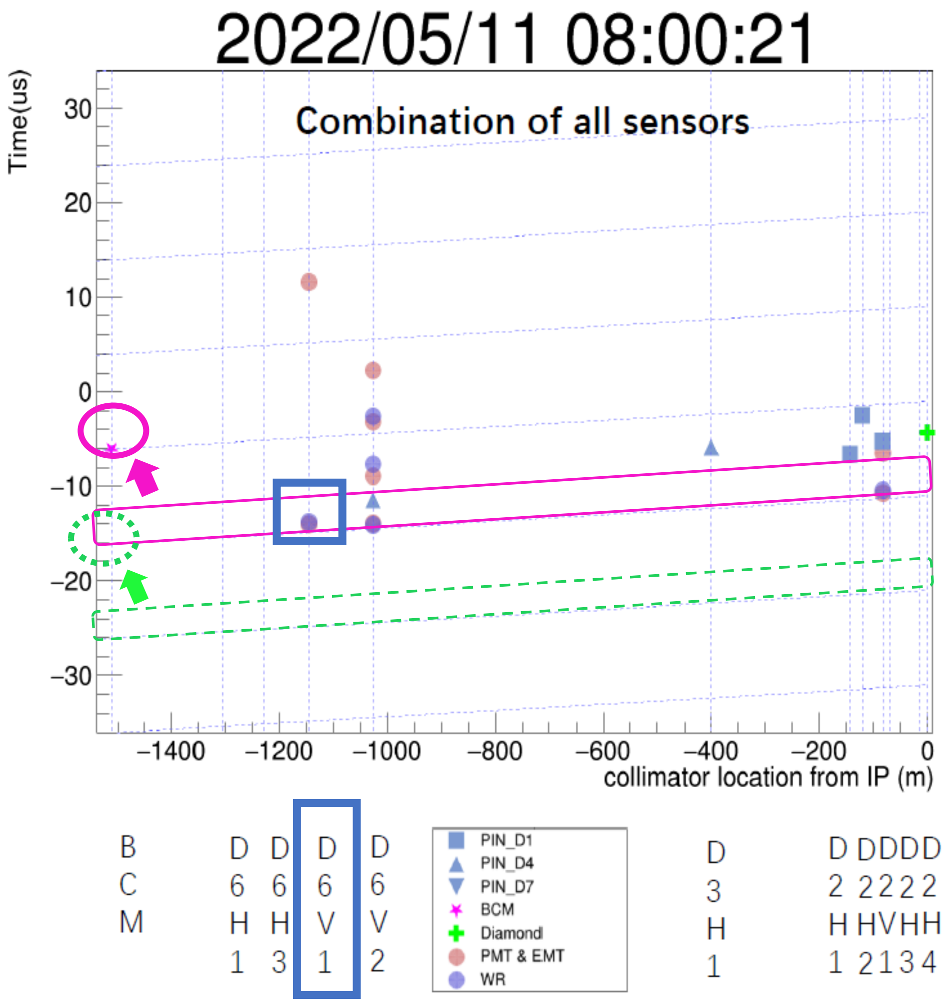
Fast loss monitors and timing analysis





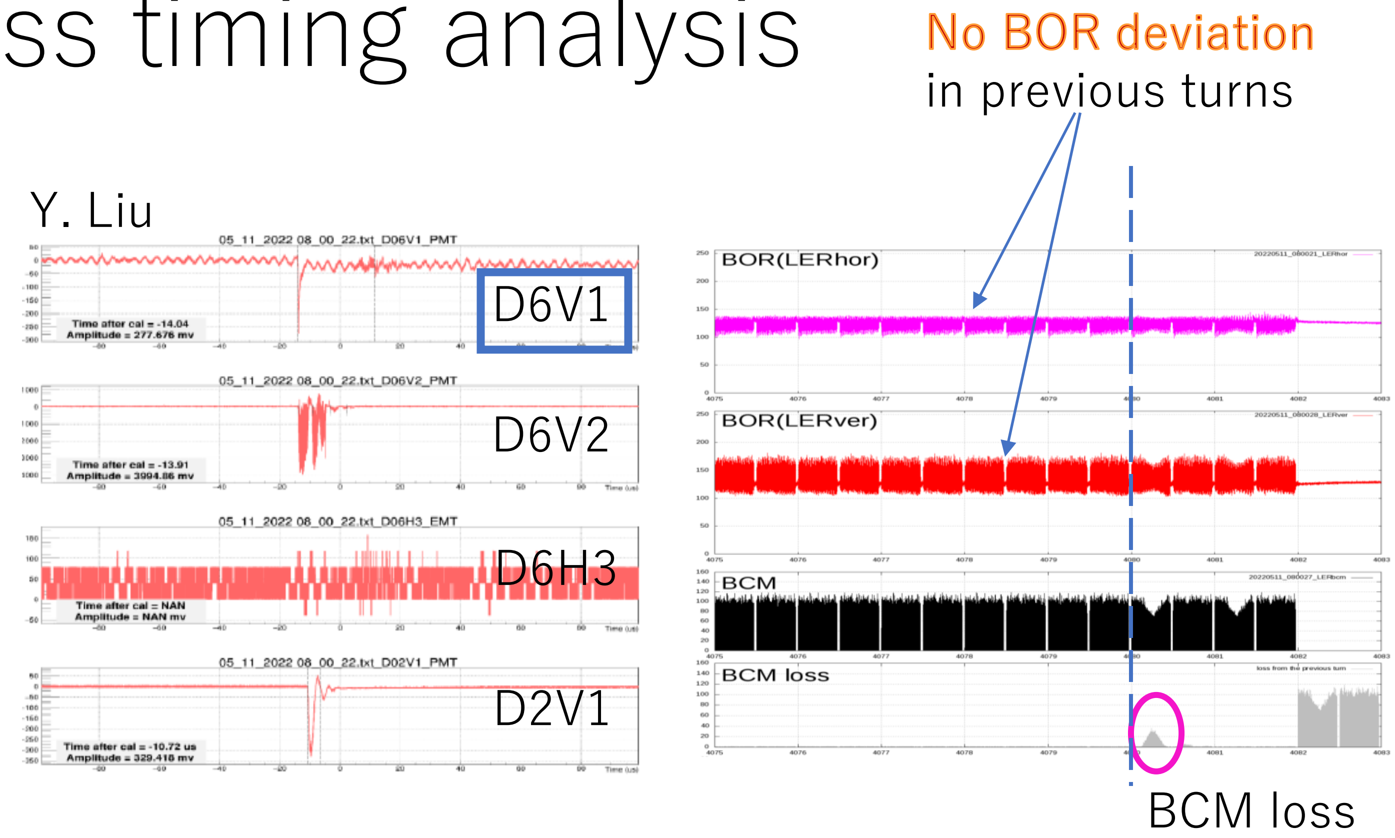
- 7 beam loss sensors (CSI+PMT, EMT) installed near LER collimators (shown in thering map on the left)
  - more sensors will be added during LS1, at injection points, NLC, HER, etc..
- Each sensor equipped with precise timing system
  - Beam loss signal waveforms are recorded by the oscilloscopes & beam loss timings are precisely measured by timestamps of White Rabbit modules
- By comparing beam loss timings at different ring positions, we can tell where in the ring the beam loss initially started
- A Joint project with Belle II and SuperKEKB members
- Also, by comparing beam loss timing w.r.t the KEKB revolution signal timing, we can tell which bunch caused the beam loss (calibration done by injection loss)

Example of beam loss timing analysis



BOR = Beam Orbit Recorder
BCM = Bunch Current Monitor

Y. Liu



- D6V1 was the earliest sensor to see beam loss
- **BCM loss** started from the next turn
  => First beam loss occurred within BCM~D6V1, not BCM upstream
- No BOR deviation seen before the BCM loss
  => First beam disturbance also occurred within BCM~D6?

Similar observations for most of LER beam loss events

Find more plots at http://bpc-3-406-2.kek.jp/image_new/2022b_TVL/index.html

Y. Liu

SUMMARY TABLE

Event	Bunch Current Monitor	Diamond	D02V1 PMT	D06V1_PMT	D06V2_PMT	D06H3_EMT
2022/5/17 14:38	-7.24	NAN	-13.81|631	NAN|5119	NAN|5109	NAN
2022/5/14 13:21	-0.61	0.6	-3.26|932	-8.46|914	-9.80|37	NAN
2022/5/11 08:00	-6.09	-4.4	-10.72|689	-14.04|650	-13.91|534	NAN
2022/5/10 23:01	-6.33	-9.4	-11.11|3036	-15.26|2561	-14.92|2548	NAN
2022/5/8 02:44	-4.33	-4.4	-11.84|4033	-16.92|NAN	-18.17|1798	NAN
2022/5/7 14:17	-7.49	-14.4	-11.23|4853	-19.32|2146	-19.27|1786	NAN
2022/5/7 08:40	2.81	-1.9	-3.25|3597	-18.79|968	-18.50|893	NAN
2022/5/2 1:19	-5.47791	-9.4	-10.24|3554	-13.60|3450	-13.32|3363	NAN

Show the first one of each event.

In the unit of μs

A|B show the timing from scope and Bucket number from WR

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SUMMARY TABLE

Event	Bunch Current Monitor	Diamond	D02V1 PMT	D06V1_PMT	D06V2_PMT	D06H3_EMT
2022/4/29 5:12	1.75272	-9.4	-12.87|2336	-10.87|5110	-10.49|5097	NAN
2022/4/28 17:25	-2.40489	-19.4	-9.57|25	NAN|NAN	NAN|2774	NAN
2022/4/21 11:08	-7.11462	-11.9	-11.842|2682	-16.044|2260	-16.438|2002	NAN
2022/4/20 23:36	-5.8748	0.6	-11.838|3497	-15.26|2562	-15.69|2247	NAN
2022/4/19 0:58	2.57206	-4.4	-8.49|4430	-7.87|1970	-14.90|2561	NAN
2022/4/15 23:30	0.218176	0.6	-9.95|1160	-8.95|3255	-13.43|847	NAN
2022/4/11 12:09	-3.71741	-6.9	-8.78|1711	-12.204|1709	-13.56|1422	NAN

Show the first one of each event.

In the unit of μs

Time replaced D06V2 with an EMT

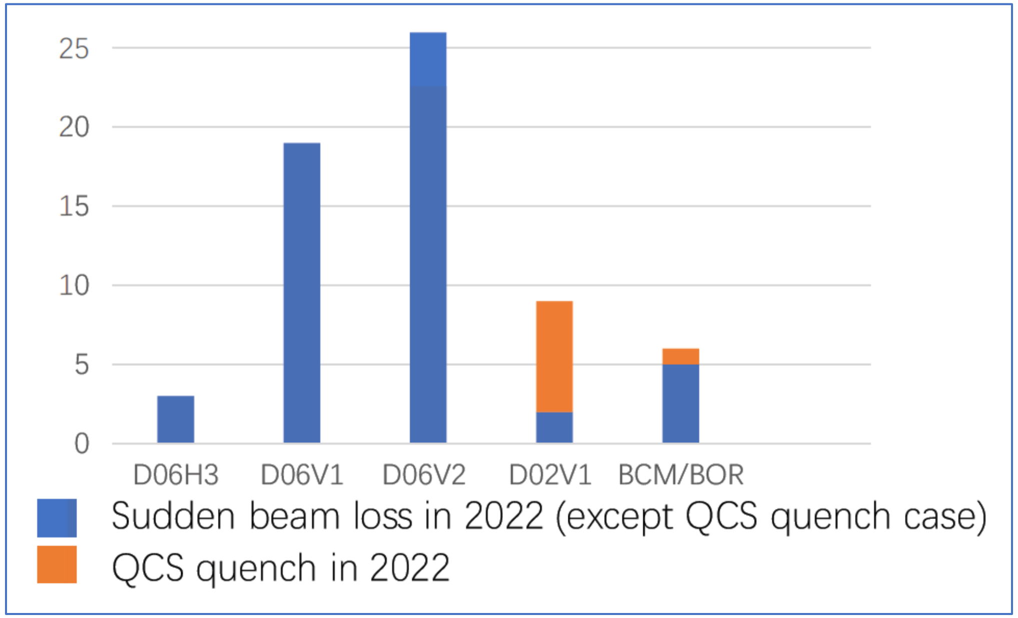
Most abort first detected around D6 section

11

In most cases in April/May, earliest beam loss is detected by **D6 loss monitors.**
→ The initial beam disturbance occurs at the upstream of D6 section?

After D6V1 was severely damaged by May 17 abort, it had to be used very wide (BG *increased* when we closed D6V1).
In some of recent aborts which caused QCS quenches, D2V1 saw the earliest loss (D2V1 was not protected by D6V1)

Timing analysis summary



- **Timing analysis result of 2022ab events**:
  - The initial loss was found to be detected mainly at **either D06V1 or D06V2.**
  - D06V2 or D02V1 loss became more frequent as damaged D06V1 collimator's aperture gets wider and D06V2 narrower.
  - If the initial loss is detected **at D02V1**, the large beam loss tends to happen at IR resulting in QCS quench.

More details in Liu-san's talks at the MDI meetings
https://kds.kek.jp/event/42104/
https://kds.kek.jp/event/42881/

New SBL subgroup under ITF

- A new SBL subgroup was formed under the SuperKEKB International Task Force (ITF)
  - Contact person: **H. Ikeda** (SuperKEKB)
  - Sub-contact: H. Nakayama (Belle II)
- Invite **experts outside our collaboration** to the meeting for wider discussion

- 1st meeting on Aug 31st (indico)
  - Fruitful discussions on proposed hypotheses for SBL:
    - "X-aborts" in KEKB, due to RF finger failure ? → seems not (SBLs are much faster)
    - "Dust events", as seen in Phase1/2 ? → seems not (SBL loss is mainly vertical , not horizontal)
    - "Fireball hypothesis" (vacuum arching) ? → not sure (need more data with acoustic sensors)
    - Feedback system issue, as in BEPC II ? → seems not (SBLs are much faster)
- 2nd meeting held on Oct. 14th (indico)

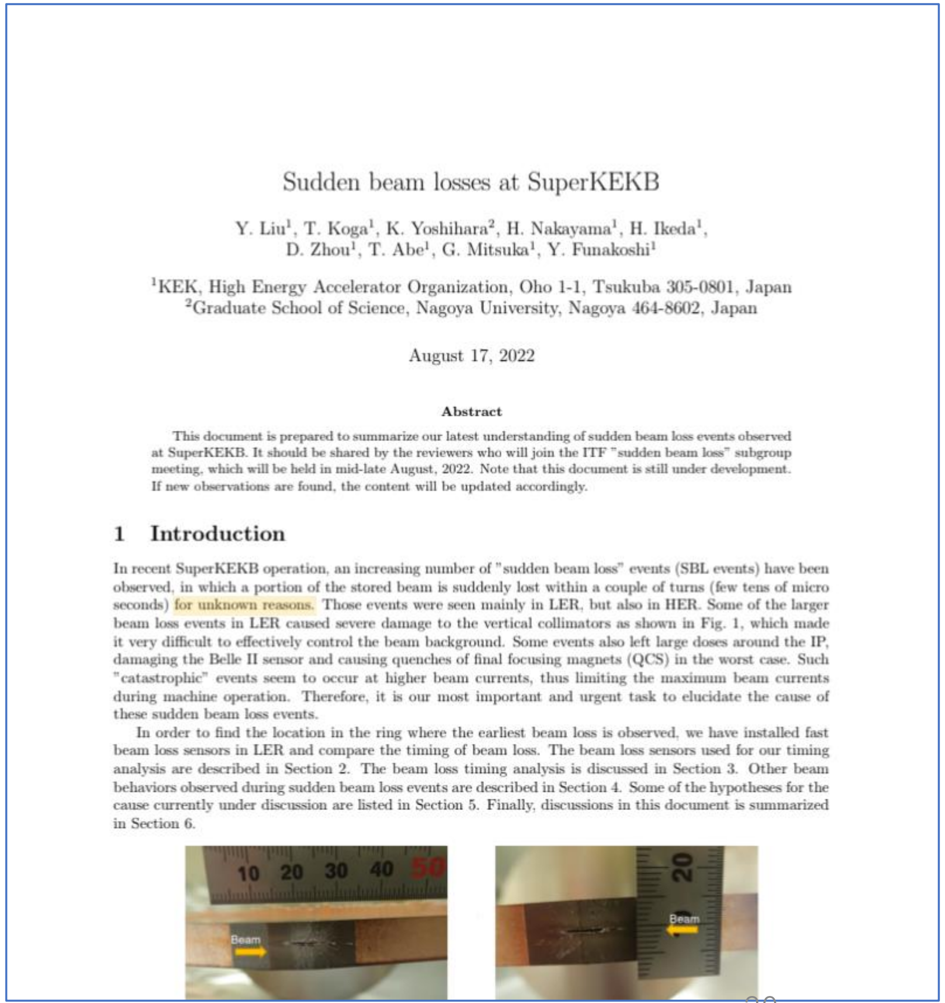
SBL documentation

Coordinator: H. Nakayama

- SBL documentation available (1st version)
  - Prepared for the 1st SBL International taskforce (ITF) meeting
  - Shared with the external experts invited to the SBL ITF

- Outline of the documentation:
  1. Introduction
  2. Beam loss sensors
  3. Beam loss timing analysis
  4. Observation by other sensors (BCM, TbT BPM, etc..)
  5. Hypothesis of the cause
  (collective effects, beam dust, fireball, etc..)

- Plans
  - Include discussions at the recent SBL ITF meetings
  - Belle II note, publication



Sudden beam losses at SuperKEKB

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August 17, 2022

Abstract

This document is prepared to summarize our latest understanding of sudden beam loss events observed at SuperKEKB. It should be shared by the reviewers who will join the ITF "sudden beam loss" subgroup meeting, which will be held in mid-late August, 2022. Note that this document is still under development. If new observations are found, the content will be updated accordingly.

1 Introduction

In recent SuperKEKB operation, an increasing number of "sudden beam loss" events (SBL events) have been observed, in which a portion of the stored beam is suddenly lost within a couple of turns (few tens of micro seconds) for unknown reasons. Those events were seen mainly in LER, but also in HER. Some of the larger beam loss events in LER caused severe damage to the vertical collimators as shown in Fig. 1, which made it very difficult to effectively control the beam background. Some events also left large doses around the IP, damaging the Belle II sensor and causing quenches of final focusing magnets (QCS) in the worst case. Such "catastrophic" events seem to occur at higher beam currents, thus limiting the maximum beam currents during machine operation. Therefore, it is our most important and urgent task to elucidate the cause of these sudden beam loss events.

In order to find the location in the ring where the earliest beam loss is observed, we have installed fast beam loss sensors in LER and compare the timing of beam loss. The beam loss sensors used for our timing analysis are described in Section 2. The beam loss timing analysis is discussed in Section 3. Other beam behaviors observed during sudden beam loss events are described in Section 4. Some of the hypotheses for the cause currently under discussion are listed in Section 5. Finally, discussions in this document is summarized in Section 6.

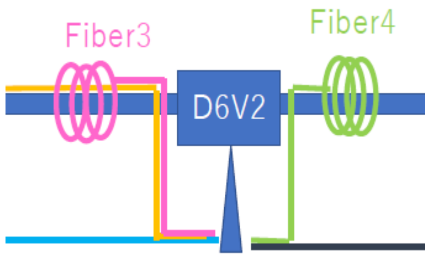
Recent new efforts for beam loss location hunt

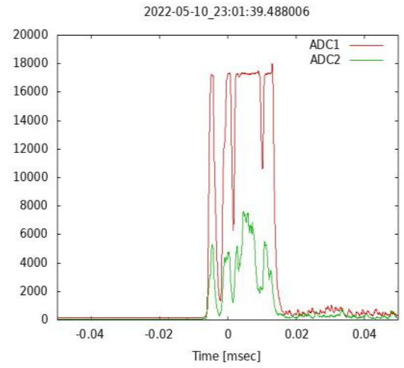
- Fiber loss monitors around D6V1/D6V2 (Ikeda)
    - It can issue beam aborts now (could be faster than IR sensors)
- Additional PINs around D6V1/D6V2 (Ikeda)
- Acoustic sensors around D6V1/D6H3 (Abe)
    - To monitor the sound of electric discharge (“fireball” hypothesis)
- Simplified BOR/BCM around D6V1 (Fukuma)
    - Limited accuracy for 2-bucket-spacing bunches
- Others
    - CT (Current Transformer) as a beam current monitor
    - QCS bellows diamonds with larger dynamic range
- And more …?

BOR = Beam Orbit Recorder
BCM = Bunch Current Monitor

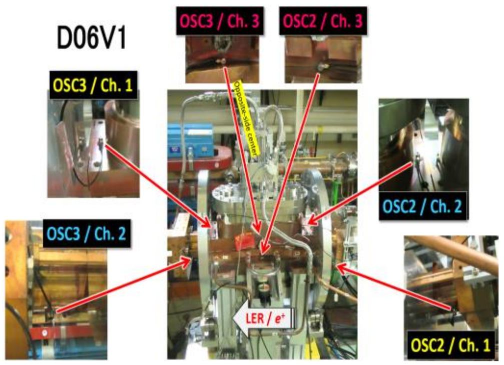
> - We really appreciate those new contributions, especially from SKB experts !
> - We are now trying to incorporate those new inputs to our beam loss timing analysis

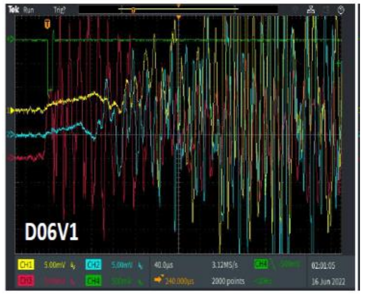
Fiber loss monitors





Acoustic sensors





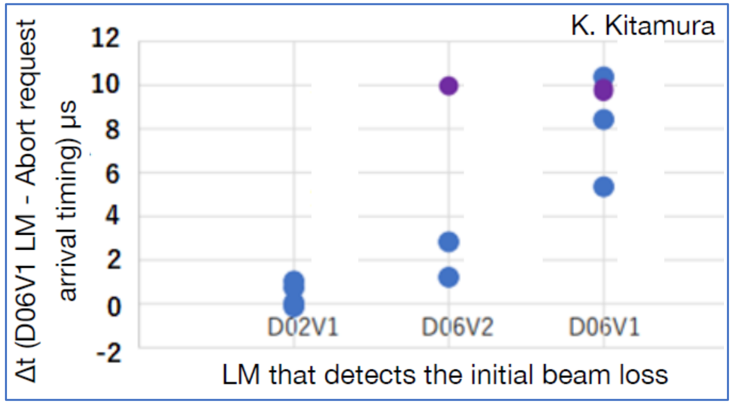
Faster beam abort delivery

Note: abort delivery has been already improved significantly in the past years (for example, by introducing two abort gaps). Further improvement by the items shown below would not be so dramatic.

<u>Faster beam abort can mitigate the damage from SBLs.</u>

1. Add an abort sensor in the upstream section

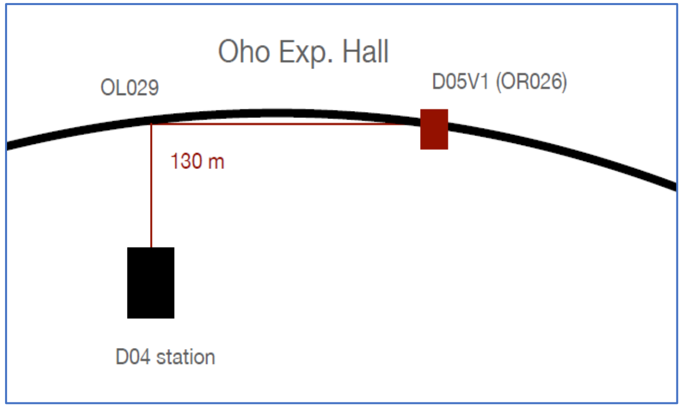
- Loss monitor in D06 section should provide faster beam aborts (thanks to better location)
- Confirmed by the D06 fiber loss monitors and D06V1 fast loss monitors installed in 2022b



Faster beam aborts by D6V1 loss monitor

2. Abort sensor with faster response

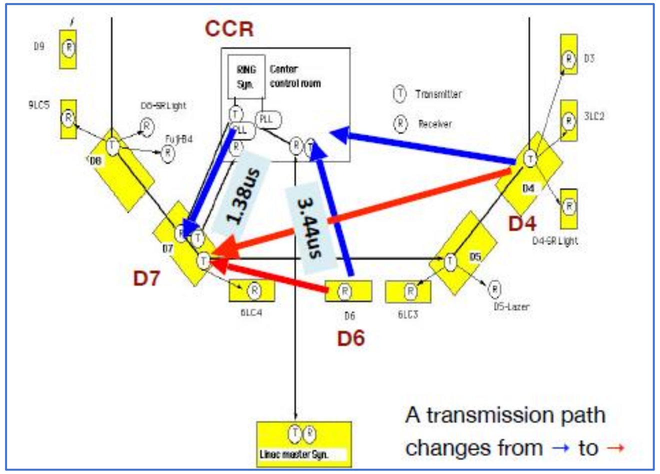
- CLAWS response time is very fast (~200ns)
- Additional CLAWS system can be installed at D05(NLC), or D06 section, etc..



CLAWS at NLC

3. Shorter transmission path of abort request

- Abort request sent directly to the abort kicker, not via CCR
- R&D started for field wireless system or laser in the tunnel



Abort request directly sent to the kicker

Other MDI-related topics

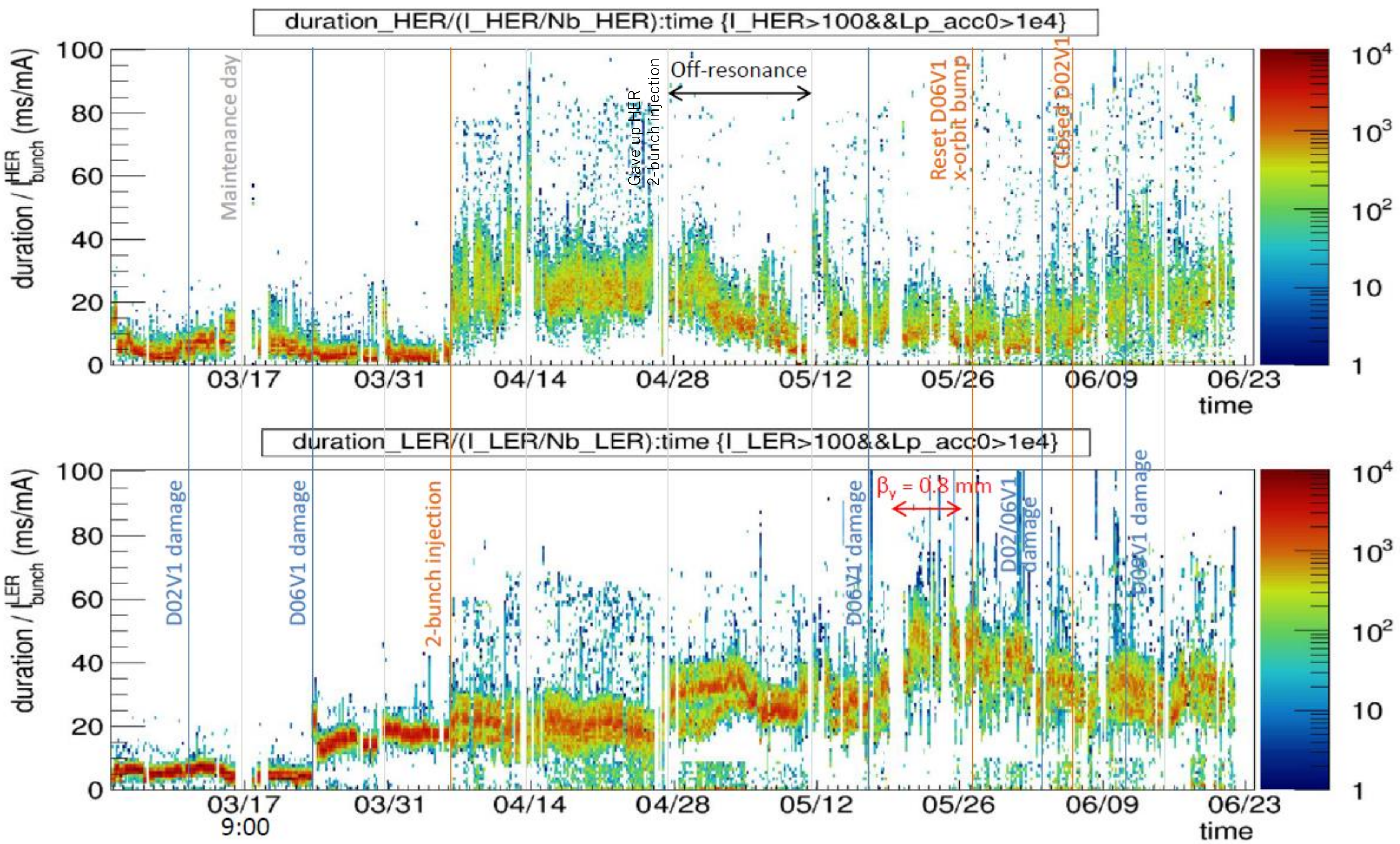
- CLAWS abort system
  - CLAWS injection veto works as intended to suppress large number of (unnecessary) injection aborts.
  - Discussion started for **another CLAWS abort system around NLC,** for faster abort delivery.
  - Discussion also started for **direct abort delivery** from sensor to the abort kicker (not via SKB central control room)
- Diamond abort system
  - Recent frequent injection aborts on “bad injection days” are issued by diamonds only. Dose are just above the 4mrad threshold
  - We had intensive discussions for relaxing the diamond threshold, with all risks considered (threshold not yet changed so far)
  - QCS diamond range was changed to provide dose/timing measurement for large loss without saturation (from June 15th)
- Injection status
  - HER injection efficiency fluctuate a lot even within a day (temperature?) → makes injection tuning quite difficult
  - To reach the target current, HER 2-bunch injection (now 2nd bunch has poor quality) is must
  - To further increase LER injection charge, unnecessary injection aborts should be suppressed
- NLC (Non-linear collimator)
  - NLC should reduce vertical impedance significantly, while keeping BG at similar level.
  - **We have decided to install NLC during LS1.**
  - How to cope with “crazy beam” and avoid collimator head damage is under discussion.
- Machine-Learning approach for beam background prediction
  - Using variety of SuperKEKB 1Hz EPICS PVs as input to the neural net
  - Also applicable to injection tuning or luminosity tuning?

Summary

- **Beam background in 2022ab: below the Belle II detector limit**
  - TOP PMT rates dominated by LER single-beam BG and luminosity BG
  - Belle II did not limit the max beam currents for operation
- **Injection BG duration got worse at higher beam currents**
  - Need wider injection veto window → large DAQ deadtime: ~10%!
  - Also affected recorded data: some degradation seen in CDC performance
- **Major issue: Sudden Beam Loss events (SBLs)** ← A dedicated talk by Ikeda-san tomorrow morning
  - QCS quenches x8, with severe collimator damage
  - Become frequent at higher (bunch) current? → limit the max beam currents for operation
- **Investigation on SBL issue made good progress**
  - Timing analysis using fast beam loss monitors shows initial beam loss location
  - International taskforce launched: fruitful discussion inviting experts from other collaborations
  - Several hypotheses are on the table, but conclusion not reached yet (homework for runs after LS1)
- **Another major issue: stability of injection performance**
  - Difficult to keep good condition for a long time → limit the max beam currents for operation
  - Many improvement works planned during LS1 (inj. efficiency, emittance, inj. kicker, etc…)

backup

Injection background duration



Injection background duration increased due to D06V1 damage and bad 2-bunch injection.

Request from BPAC reviewers:
> 2) Some more details on the injection background issues such as the radiation issue and dead time would be appreciated.

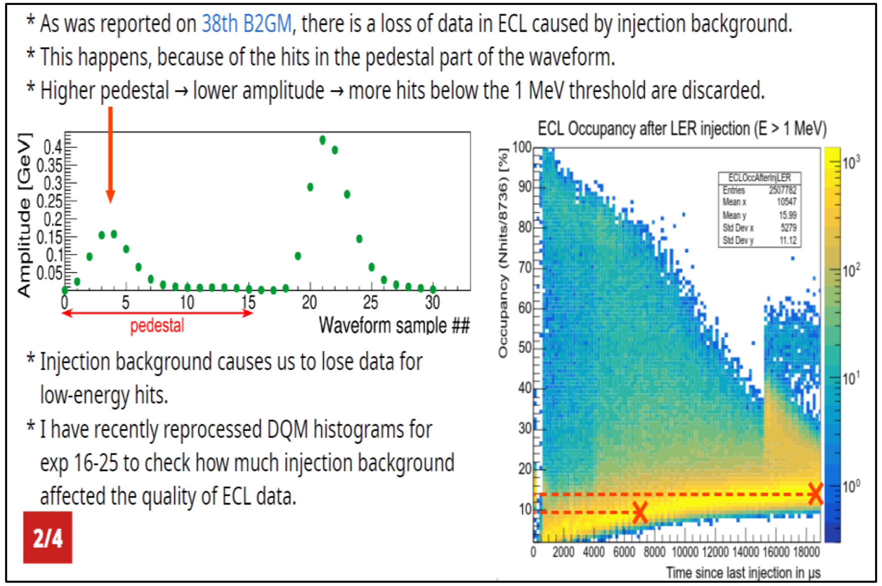
Dead time?

- Dead time fraction due to injection loss is determined by:
  [duration of injection background] x [averaged injection repetition rate].
  * The dead time fraction is getting larger recently, since we need maximum repetition rate (23Hz) to reach the highest currents.
- In 2020, we conducted series of machine studies to investigate the injection BG duration.
- This slide by Koga-san nicely summarizes the discussion on injection BG duration.
  https://kds.kek.jp/event/41955/contributions/211658/attachments/155748/198302/koga_injectionveto_2022_5_26.pdf
  * When we fired injection kicker but did not inject any charge, no beam loss was observed.
  * The injection background duration becomes longer with higher bunch current.
  * The duration is longer with colliding beams than single-beam.
  * The duration depends on various main ring optics parameters and injection parameters.
  * The duration can also change by the collimator settings. If the collimator is damaged and had to be used wider than desired, it could increase the duration of injection background.
- Taken all together, these observations suggest the following scenario:
  * Oscillation of the injected beam remains for a while by interaction between the injected beam, storage beam and collision
  * The oscillation propagates to vertical plane with x-y and chromatic coupling.
  * Ohmi-san's simulation also shows such effect.

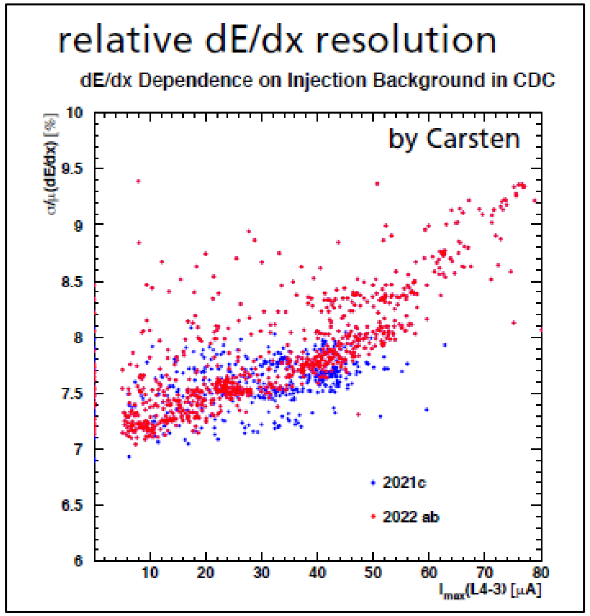
Request from BPAC reviewers:
> 2) Some more details on the injection background issues such as the radiation issue and dead time would be appreciated.

Impact on data quality?

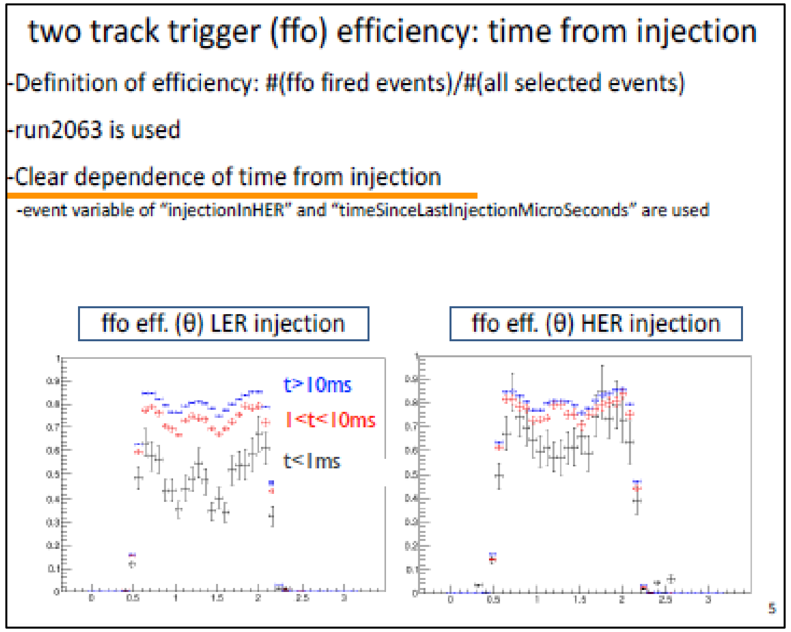
ECL data loss



CDC (dE/dx)



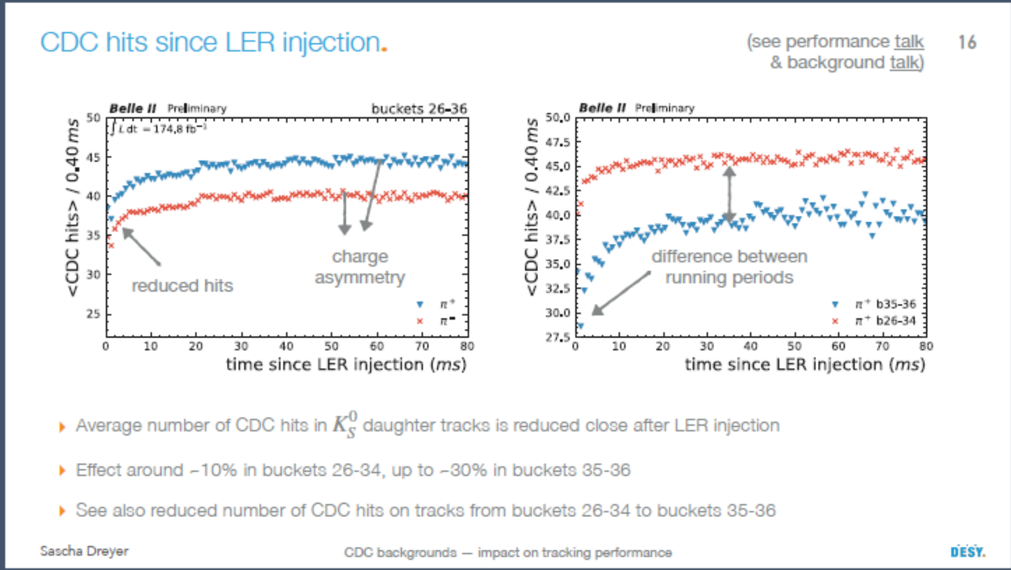
CDCTRG

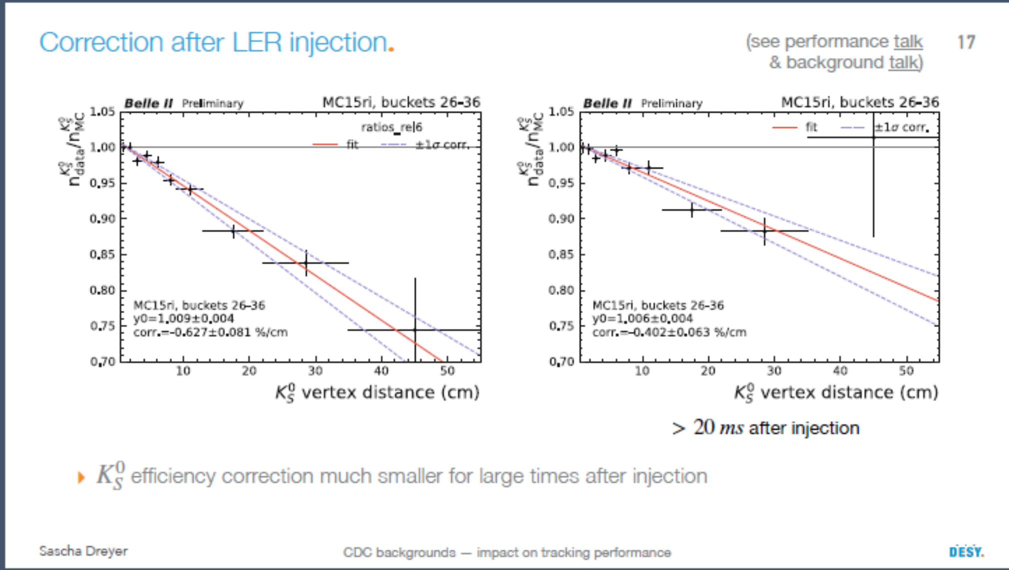


- Data quality seems affected by injection background.
- Further investigations are needed.

CDC performance degradation

(S. Dreyer)



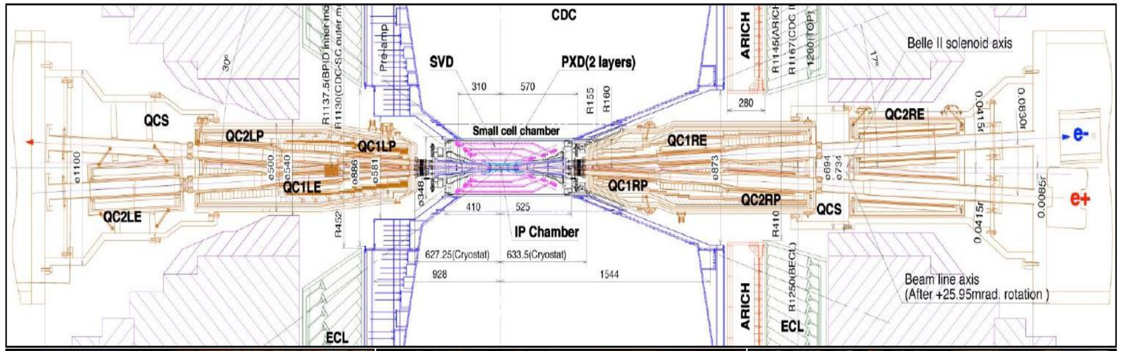


- Ks-daughter study:
  - Reduced number of CDC hits after injection
  - Reduced Ks efficiency after injection
- Probably mix of effects (gain reduction, higher hit-rate, trigger veto), needs further study
- Plan: summarize in background paper as example of backgrounds impacting performance

Flexible Boron sheet around QCS cryostat? (for neutron SEU mitigation)

Space around QCS

There is no much space available for the new shielding around QCS



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Flexible sheets: Specification

SWX-238 flexi-boron (27.6% of B)

- Recommended temperature limit ~200°C
- Self-extinguishing when exposed to flame
- Flexible sheet material (silicone elastomer)
- Thermal attenuation factor of ~260
- Thickness 3 mm, 1 m^2 = $910

SWX-227ATH borated flexi-panel (9.3% of B)

- Recommended temperature limit ~80°C
- Self-extinguishing when exposed to flame
- Flexible sheet material (polyurethane)
- Includes a hydrogenous additive to slow down fast neutrons
- Thickness 8 mm, 1 m^2 = $330

shieldwerx
https://www.shieldwerx.com

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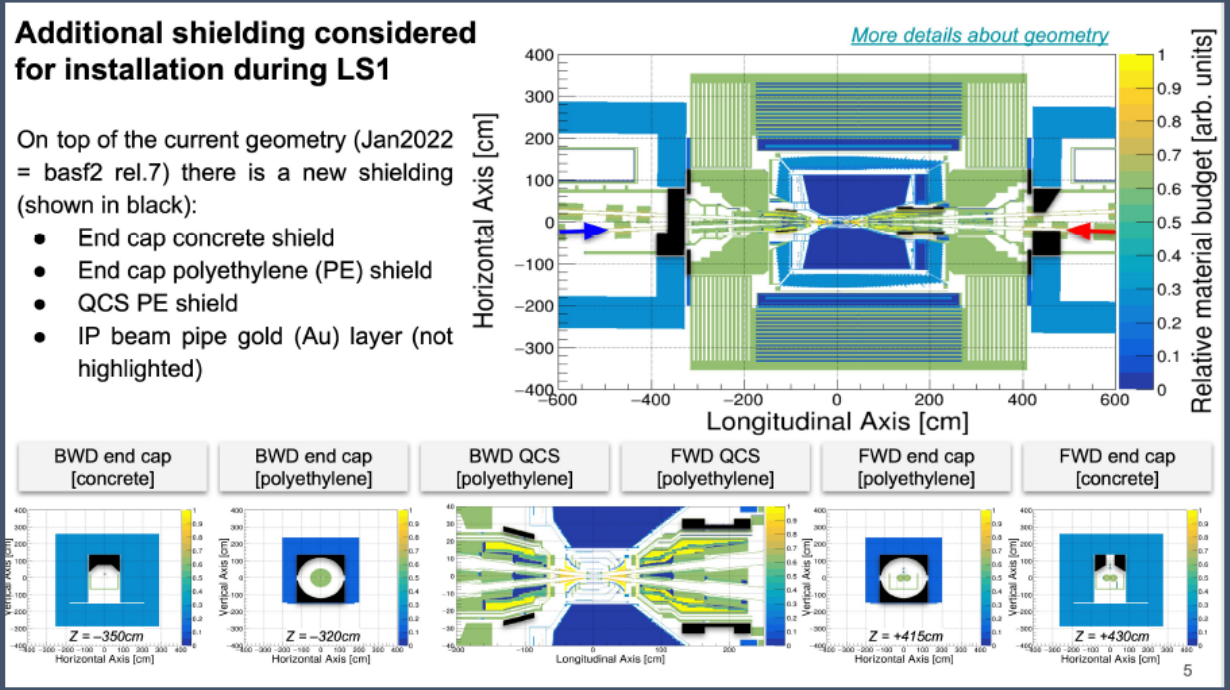
More details can be found in Andrii's talk at the Background meeting
https://indico.belle2.org/event/8224/

Evaluation of Belle II neutron shielding upgrade

(A. Natochii)

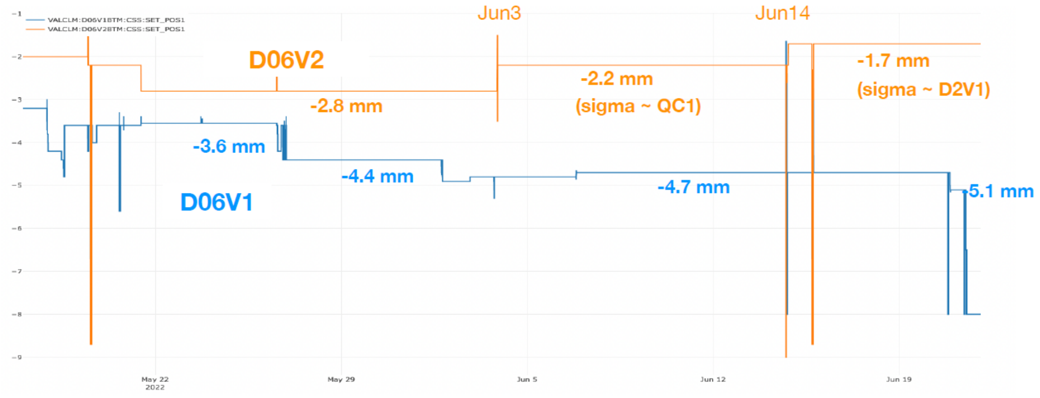
- 2022b: Neutron backgrounds and/or SEUs observed in many Belle II system: EKLM, TOP, ARICH, PXD power supplies…
- Dedicated shielding to be installed in LS1.
- Updated simulation for this B2GM, includes both luminosity and single-beam bkgs.
- Concrete + PE endcap shields (=baseline) reduce EKLM neutron rates by factor ~2
  - No boron required here
- Borated (>~3%) PE shielding only required around QCS
- Pure PE QCS shields would *increase* thermal neutron flux in ARICH FEBs by ~60% (and ~10% in CDC EBs)



- Shielding designs were added to Geant4 model. Many combinations evaluated.
- Especially QCS shield shape should be considered conceptual design.

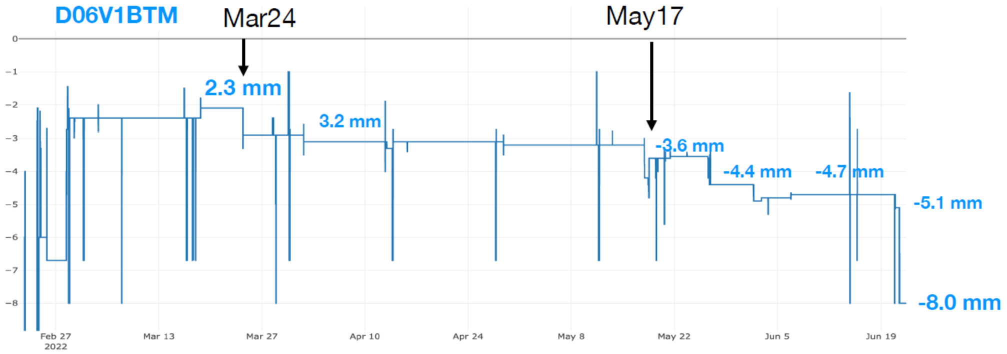
Collimator aperture vs QCS quench

- QCS quench: Mar11, Apr8, **May17**, Jun1, Jun3, Jun9, Jun9, Jun14
- The quench became more frequent after D06V1 was damaged on May17.
- As the D06V1 gets wider, the D02V1 is no longer protected?



Collimator damages (cont'd)

- D06H3: Feb25, Mar18 — no indication of BG increase
- D06V1: Mar23, **May17**, Jun3 — **significant impact on BG**
- D02V1: Mar11, Jun3 — no indication of BG increase
- D09V1: Jun11 — couldn't increase the beam current



New SBL subgroup under ITF

- A new SBL subgroup was formed under the SuperKEKB International Task Force (ITF)
  - Contact person: **H. Ikeda** (SuperKEKB)
  - Sub-contact: H. Nakayama (Belle II)
- Invite **experts outside our collaboration** to the meeting for wider discussion

- 1st meeting on Aug 31st (indico)
  - Fruitful discussions on proposed hypotheses for SBL:
    - "X-aborts" in KEKB, due to RF finger failure ? → seems not (SBLs are much faster)
    - "Dust events", as seen in Phase1/2 ? → seems not (SBL loss is mainly vertical , not horizontal)
    - "Fireball hypothesis" (vacuum arching) ? → not sure (need more data with acoustic sensors)
    - Feedback system issue, as in BEPC II ? → seems not (SBLs are much faster)
- 2nd meeting held on Oct. 14th (indico)

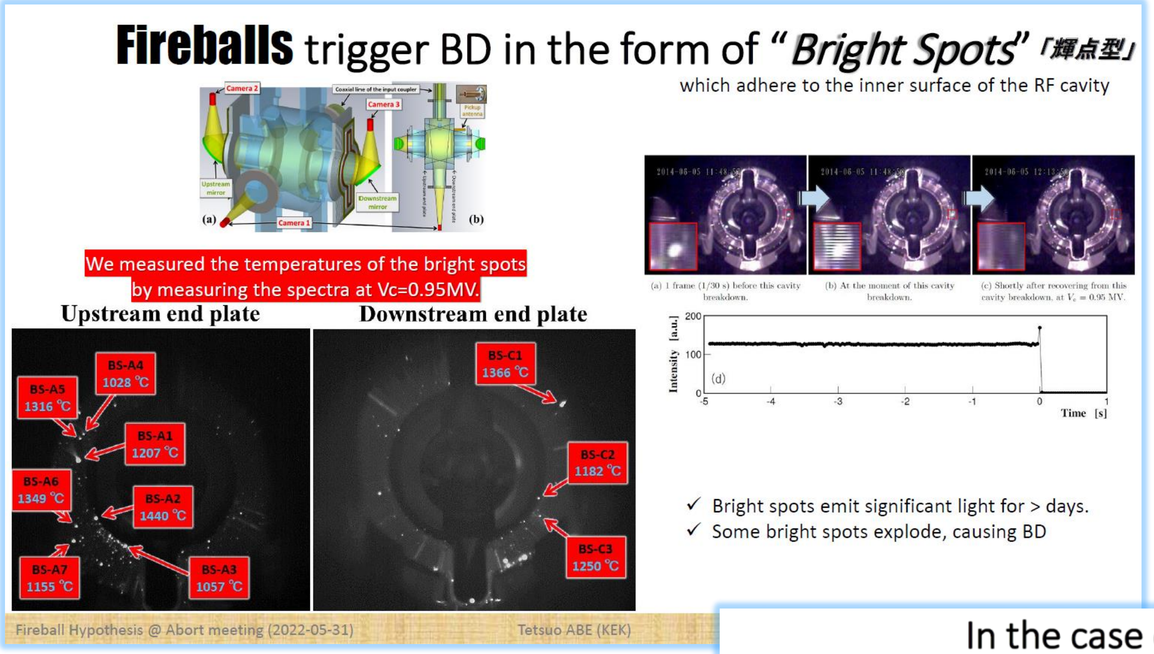
Y. Funakoshi, at the abort meeting on May 31th, 2022
https://kds.kek.jp/event/42366/

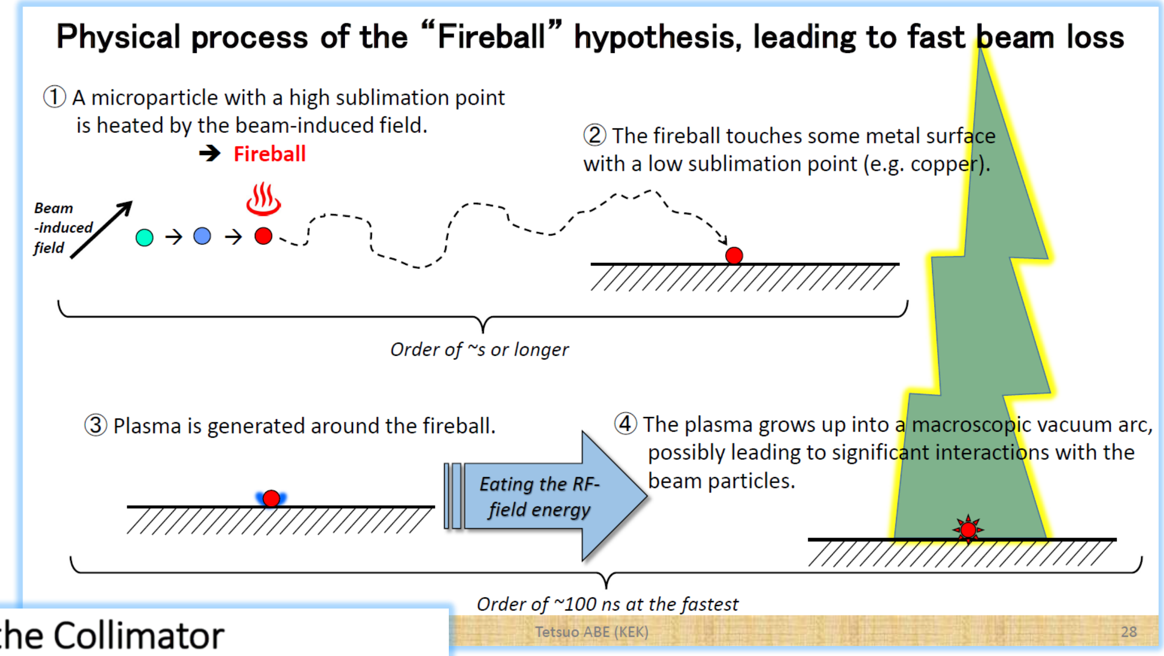
What is cause of large beam loss?

- Usual beam instability may not be the cause.
  - Too fast beam loss (< 3 turns)
- Dipole oscillation?
  - Almost no dipole beam oscillation was observed before previous turns of beam loss by BOR (bunch oscillation recorder).
  - In some cases, some dipole oscillation was observed. Before the dipole oscillations are observed by BOR, the oscillated beam particles are lost?
- Energy loss
  - Beam loss is not significant at horizontal collimators where the dispersion is large.
  - No large orbit change was observed at Libera monitor where the dispersion is large.
  - In the simulations on collision with dust particles, the main cause of beam loss is energy loss.
- Beam size blowup?
  - Beam size blowup has not been measured with fast beam size monitor yet.
  - In the simulations on collision with dust particles, the beam size blowup due to multiple scattering is small.
- Dipole kick associated with some discharge events in beam pipe?
  - Damaged collimator head can be the source of discharge event.
  - The devise of source of dipole kick is not itself damaged in one turn.
- Observation Tools
  - Another BOR may be helpful to understand the cause.
  - Identifying where the beam loss starts is helpful to understand the phenomena.

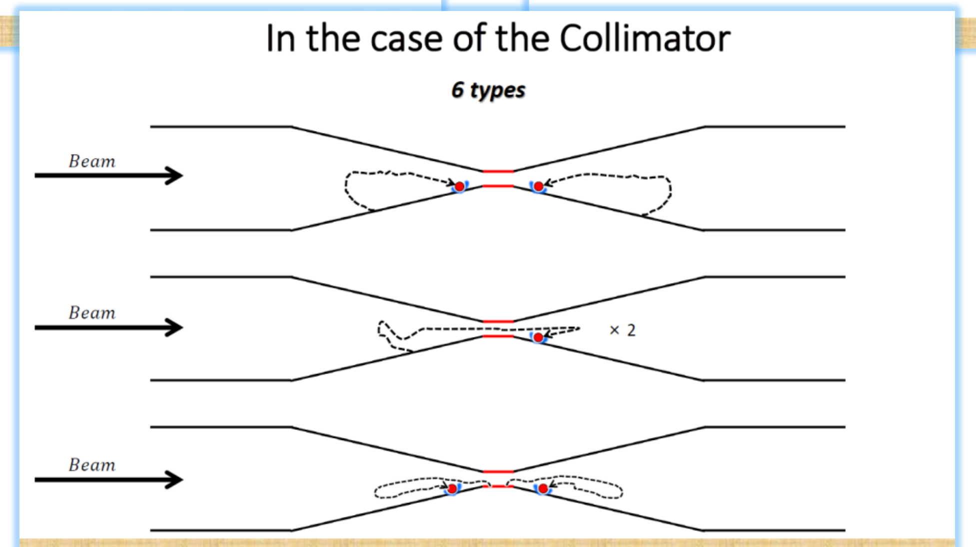
Having more eyes is important. Not only loss monitors, but also beam monitors such as BOR/BCM

A new "Fireball" hypothesis (by T. Abe-san)





Observed by camera in RF cavity. How about collimators?



When a tiny particle is heated up by the beam-induced field (particle should be close enough to the beam) and then touches some metal surface, it generates plasma and could causes a vacuum arc, which could interact with beam particles.

(different from the dust-captured-in-beam hypothesis)

From the abort meeting on May 31th, 2022
https://kds.kek.jp/event/42366/

Mike Sullivan

Ulrich Wienands?

MOPLS049 Proceedings of EPAC 2006, Edinburgh, Scotland

ANOMALOUS HIGH RADIATION BEAM ABORTS IN THE PEP-II B-FACTORY*

M. Sullivan†, Y. Cai, S. DeBarger, F-J. Decker, S. Ecklund, A. S. Fisher, S. Gierman, S. Heifets, R. Iverson, S. Metcalfe, A. Kulikov, N. Kurita, A. Novokhatski, J. Seeman, K. Sonnad, D. Teytelman, J. Turner, U. Wienands, D. Wright, Y. Yan, G. Yocky, SLAC, Menlo Park, CA 94025, USA

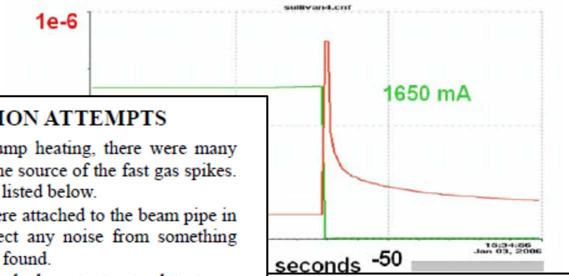
Abstract

The PEP-II B-Factory at SLAC has recently experienced unexpected beam losses due to anomalously high radiation levels seen in the BaBar detector. The problem was traced to the occurrence of very high (>100 nTorr) pressure spikes that had a very short duration (a few seconds). We describe the events, show analysis predicting where in the vacuum originated, and show what we eventu source of these vacuum events.

INTRODUCTI

In October 2005, just before shuttin

Fig. 2 shows a time plot of a typical event. The fast rise and fall in pressure was also seen in events in which the beam did not abort.



LOCALIZATION ATTEMPTS

Aside from the NEG pump heating, there were many other attempts to localize the source of the fast gas spikes. Some of these attempts are listed below.

- Acoustic sensors were attached to the beam pipe in order to try to detect any noise from something like an arc. Nothing found.
- An antenna was hooked up to try to detect any electromagnetic pulse from a possible arc. Nothing seen.
- An analysis of the gas pulse shape as seen at the local gauges and the observation of pulse widening for gauges that are farther away from the source.
- A careful analysis of the timing of the background pulses seen by the detector led to a projected z location.
- Data from the BaBar detector was collected with a trigger that accepted a wider z distribution in the hope of finding a vertex cluster near the source.
- The arrival time of the gas pulse to the various gauges was used to project a z location.

This brief summary does not do justice to the tremendous amount of work that went into the effort of trying to track down the location of these fast gas spikes.

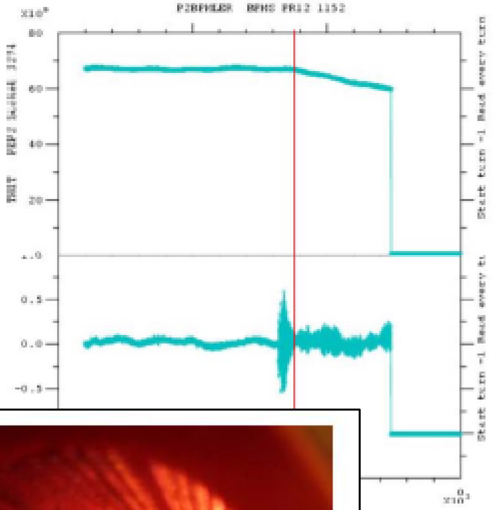
SLAC-PUB-12522

TRACKING DOWN A FAST INSTABILITY IN THE PEP-II LER*

U. Wienands†, R. Akre, S. Curry, S. DeBarger, F.-J. Decker, S. Ecklund, A.S. Fisher, S. Heifets, A. Krasnykh, A. Kulikov, S. Novokhatski, J. Seeman, M. Sullivan, D. Teytelman, D. Van Winkle, G. Yocky; SLAC, Stanford, CA, USA

Abstract

During Run 5, the beam in the PEP-II Low Energy Ring (LER) became affected by a predominantly vertical instability with very fast growth rate of 10…60/ms and varying threshold. The coherent amplitude of the oscillation was limited to approx. 1 mm peak and would damp down over a few tens of turns, however, beam loss set in even as the amplitude signal damped, causing a beam abort. This led to the conclusion that the bunches were actually blowing up. The appearance of a $2\nu_s$ line in the spectrum suggested a possible head-tail nature of the instability, although chromaticity was not effective in changing the threshold. The crucial hints in tracking down the cause turned out to be vacuum activity near the rf cavities and observance of signals on the cavity probes of certain rf cavities.



INTRODUCTION

Fig. 1 shows the signature in the vertical pla observed transverse instability in the PEP-II LE

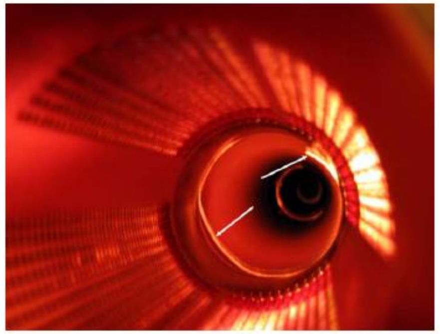


Figure 9: Dislocated rf seal in the LER vacuum chamber.

Injection upgrade plans

From the minutes of August MDI meeting, input from Iida-san and Mori-san

a) Items to be implemented during LS1

* Electron two-bunch injection suffered from vertical orbit shift and emittance growth of the 2nd bunch.
--> Fast kicker in LINAC will be installed to solve the orbit shift.

* HER beam chamber aperture at the injection point was found to be insufficient.
--> The chamber will be modified and replaced.

* LER injection kicker accidental fire ruins D6H3 collimator.
--> To mitigate the damage, carbon-head collimator will be installed.
(For a longer term, using a common power supply for all kickers is considered)

* LER kicker waveforms have larger residual than HER.
--> Ceramic ducts will be modified or metal film will be installed to reduce the residual.

* We need continuous monitoring of energy spread and vertical beam size in BT.
--> SRM are already installed in BT.

* Electron injection amplitude is found to be too large.
--> Most downstream HER septum magnet (SE1) will be replaced to reduce injection beam loss and improve injection efficiency .

Injection upgrade plans (contd.)

From the minutes of August MDI meeting, input from Iida-san and Mori-san

b) Items which might be implemented during LS1 or later

* Electron emittance growth in BT is a serious issue.
The cause of vertical emittance blowup is still unknown.
Horizontal emittance growth should be understood by ongoing CSR simulation
--> Beam chambers might be replaced to suppress CSR if confirmed by the simulation

* Positron emittance growth in BT is also a serious issue, especially above 2.6nC.
CSR simulation is ongoing too. CSR in DR-sector3 is also suspected as a source.
The cause of vertical emittance blowup is still unknown.

c) Other items

* Injection tuning is quite complicated and can be performed by a limited number of experts.
--> If we can establish an automatic tuning scheme, it might help non-experts.

* In LER, injection beam loss in the LER continues for ~10msec, while in HER it lasts only for ~1msec.
Why and where in the ring the LER injection loss occurs should be investigated.
--> Dedicated analysis using beam loss monitors might help understand this.