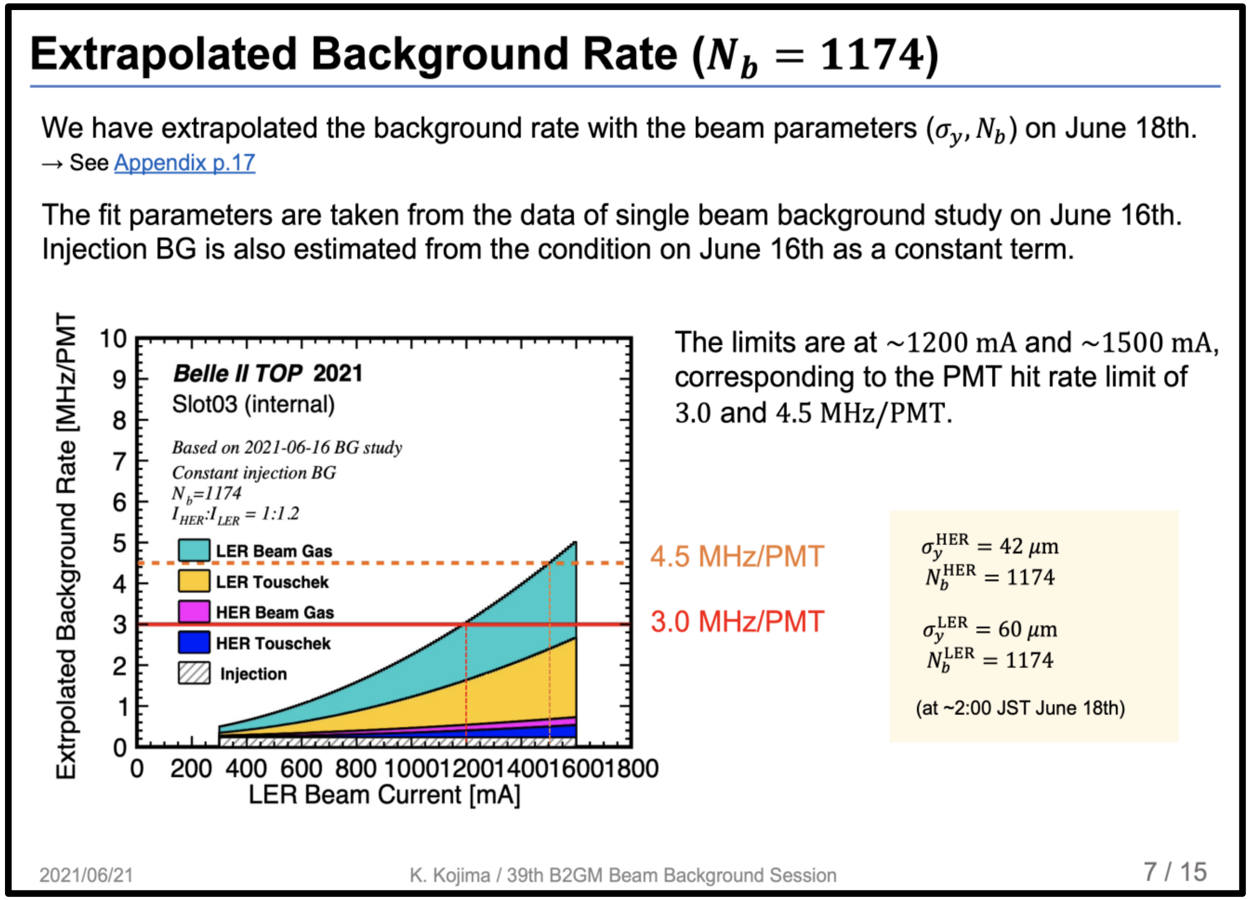
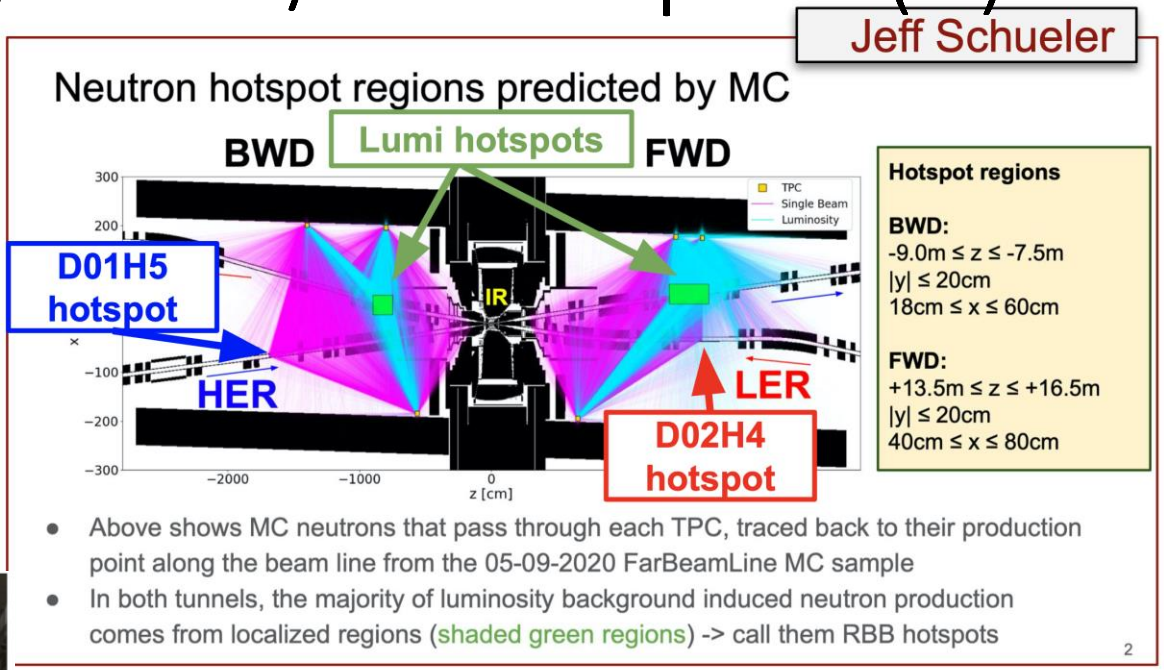
Short summary of background/MDI report (1)

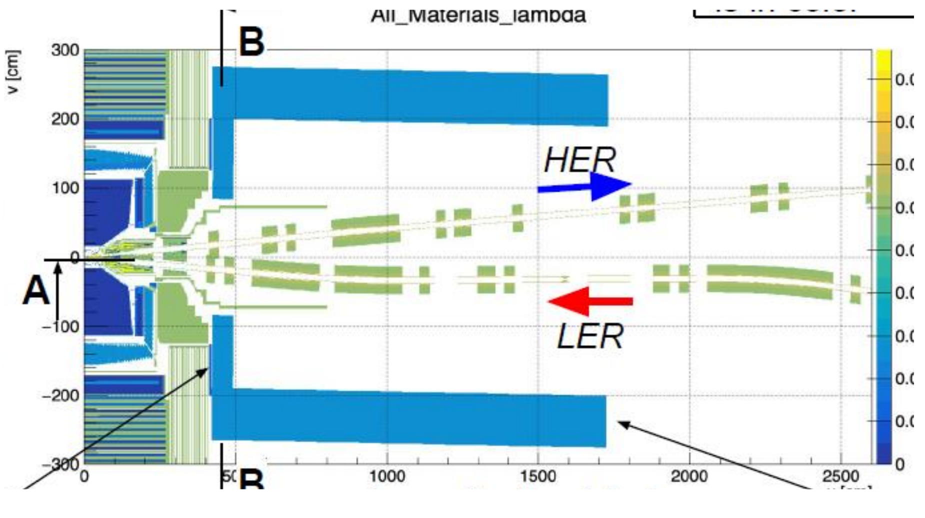
- Steady background rates in 2021ab was acceptable for Belle II (p.5,6)
  - TOP rate limit relaxed to 3MHz and can tolerate I_{LER}=1.2A now
  - or 1.5A if limit is further relaxed to 4.5MHz
- Extrapolated background rates seems acceptable for most subdetectors (p.7)
  - large uncertainty due to collimation etc. though…
- Simulation for storage background getting more accurate (p.8)
  - data/MC for important background sources are now O(~1)



Short summary of background/MDI report (2)

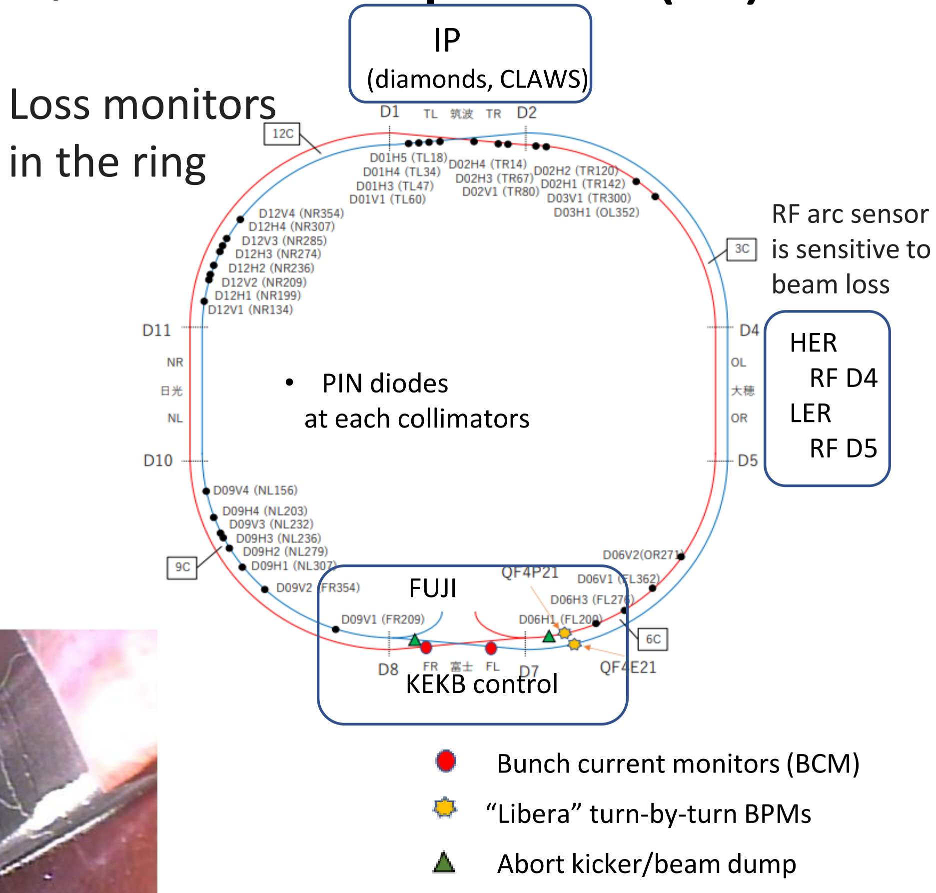
- <u>Good progress on neutrons from the tunnel: measurements and simulation</u>
  - additional shield design started (p.10)
  - tighter upstream collimator can reduce loss on the collimator near IP and neutron rates on Belle II EKLM (p.12)
  - improved tunnel GEANT4 geometry (p.13-14)

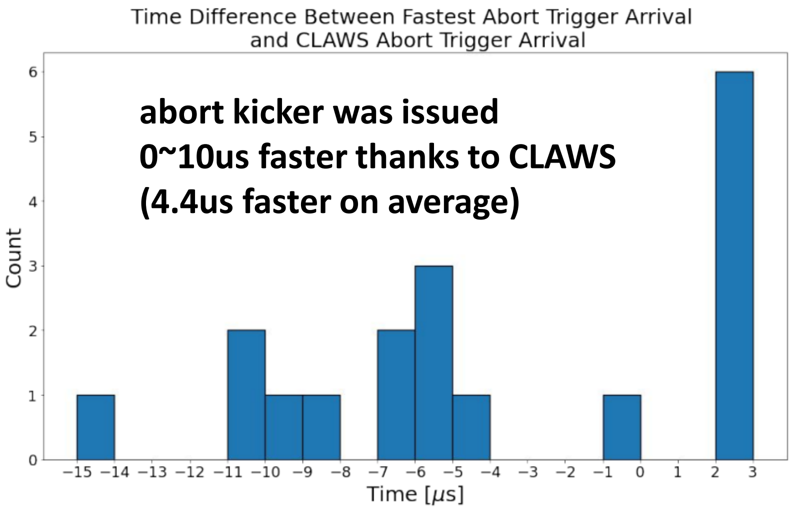


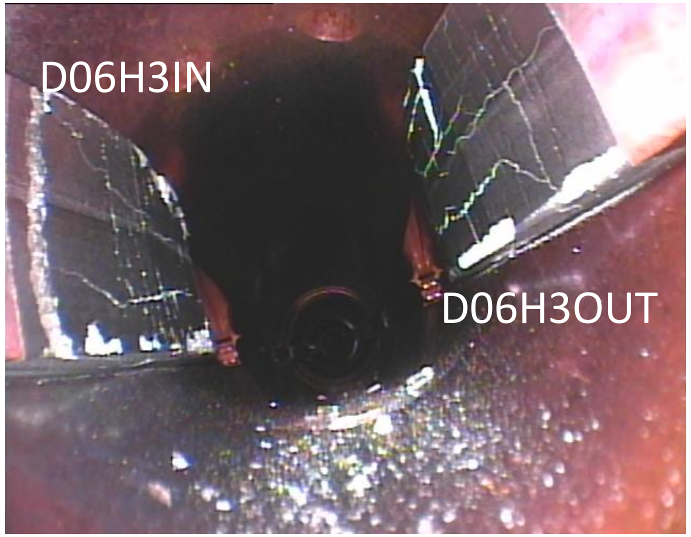


Short summary of background/MDI report (3)

- Catastrophic beam loss caused severe damage on collimator and Belle II
  - post-mortem abort analysis to find the initial beam loss location, using loss monitor data (need more sensors?) → p.23-26
  - faster abort request by CLAWS at IP (~4us faster than IP diamonds) →p.22



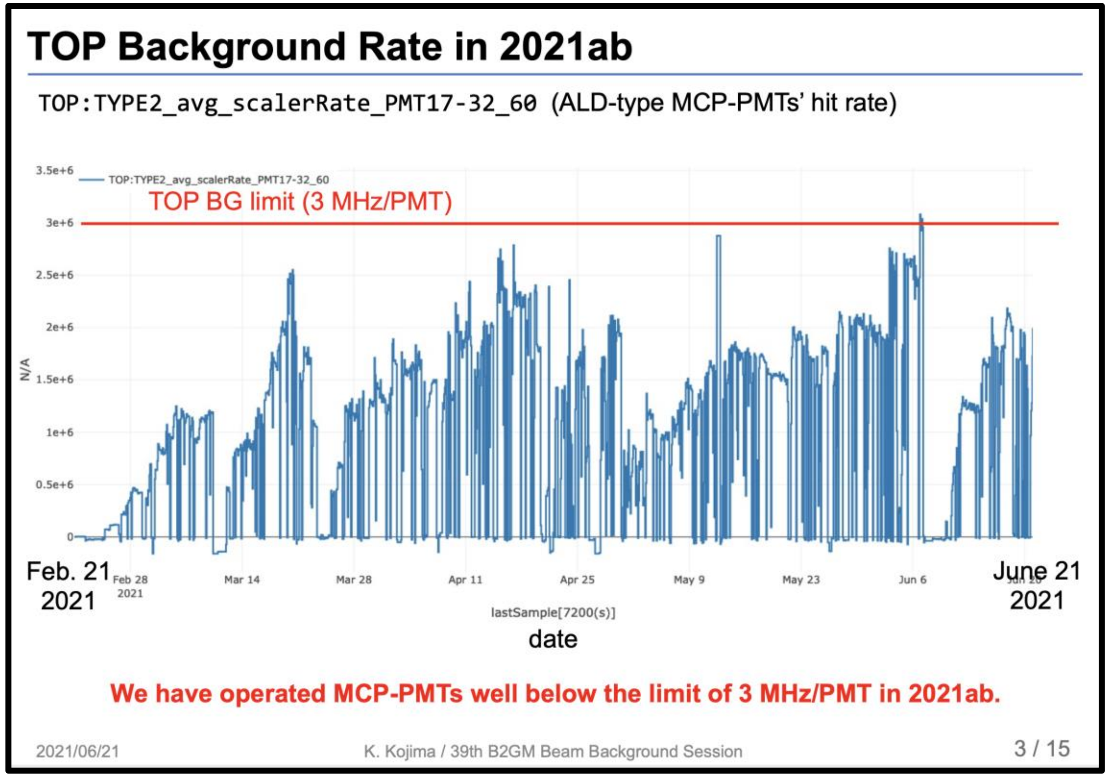




Beam background and MDI

H. Nakayama (KEK)

Beam background status in 2021ab



- Summary: Recent background rates in Belle II acceptable – all well below administrative limits and therefore not limiting beam currents
- Main background concerns in short term are catastrophic losses and stable operation

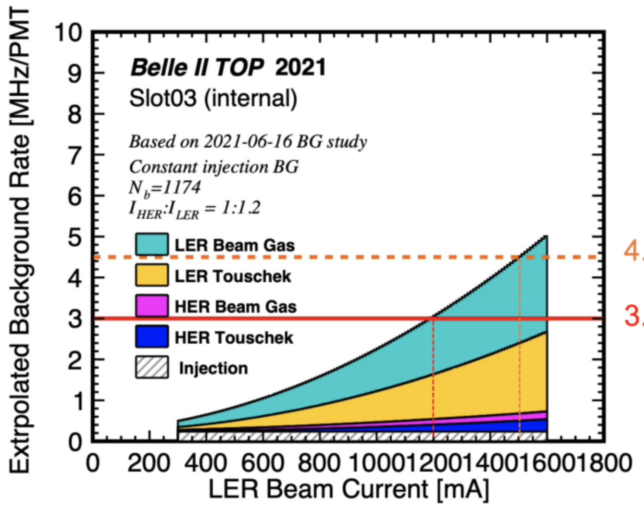
Note: “3 MHz/PMT” is the limit for the sum of single beam and injection backgrounds. It does not include the luminosity background.

Storage backgrounds: near term outlook

Extrapolated Background Rate ($N_b = 1174$)

We have extrapolated the background rate with the beam parameters (σ_y, N_b) on June 18th.
→ See Appendix p.17

The fit parameters are taken from the data of single beam background study on June 16th.
Injection BG is also estimated from the condition on June 16th as a constant term.



The limits are at ~1200 mA and ~1500 mA, corresponding to the PMT hit rate limit of 3.0 and 4.5 MHz/PMT.

$\sigma_y^{\mathrm{HER}} = 42\ \mu\mathrm{m}$
$N_b^{\mathrm{HER}} = 1174$

$\sigma_y^{\mathrm{LER}} = 60\ \mu\mathrm{m}$
$N_b^{\mathrm{LER}} = 1174$

(at ~2:00 JST June 18th)

Kazuki Kojima
Anja Novosel

2021/06/21 K. Kojima / 39th B2GM Beam Background Session 7 / 15

- TOP group already analyzed BG composition using June 16th 2021 campaign
- On average, the total single beam BG increased by a factor of 1.23 ± 0.06 over 2020
  - LER Touschek increased by factor 2.35 ± 0.11
  - Relaxed collimator settings are used in this run to allow higher injection efficiency and longer lifetime (TOP limit was relaxed)
- The data/MC ratios of luminosity background are 0.76 ± 0.08 on average (was 0.98 ± 0.04 in 2020). This is an unexpected discrepancy with simulation, but consistent with other detectors. *Analysis artifact? Good news if correct.*

Needs to understand - affects design luminosity outlook

Storage backgrounds: long term outlook

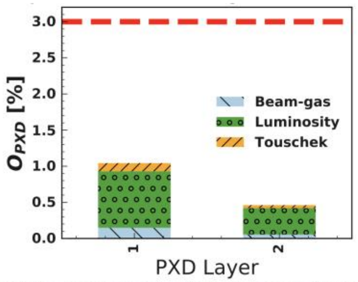


Figure 2: Predicted Belle II pixel detector occupancy at design luminosity, versus layer number. Ten background components have been simulated for each layer, and each component has been re-scaled based on data/MC measurements. We show a simplified summary, grouping these ten components into the three main classes of backgrounds: beam-gas, Touschek and luminosity background. The PXD occupancy is dominated by two-photon events, a specific luminosity background that produces curling, low-energy electron tracks that mainly affect the innermost detectors.

Slavomira Stefkova

Table 2: Background forecast for each Belle II detector at a luminosity of 8 x 10^{35} $cm^{-2}s^{-1}$. Injection background is not yet included. The TOP rate forecast includes the vacuum scrubbing uncertainty for the beam-gas component. A tentative 5 MHz TOP PMT rate limit on single-beam backgrounds is part of the new 2021 run plan and will allow for higher luminosities. We expect to replace 224 short-lifetime PMTs in 2022, and a second round of replacements during the 2026 interaction region upgrade appears likely.

(*) will be relaxed by a factor of about 2 (TBC) with hit time selection.

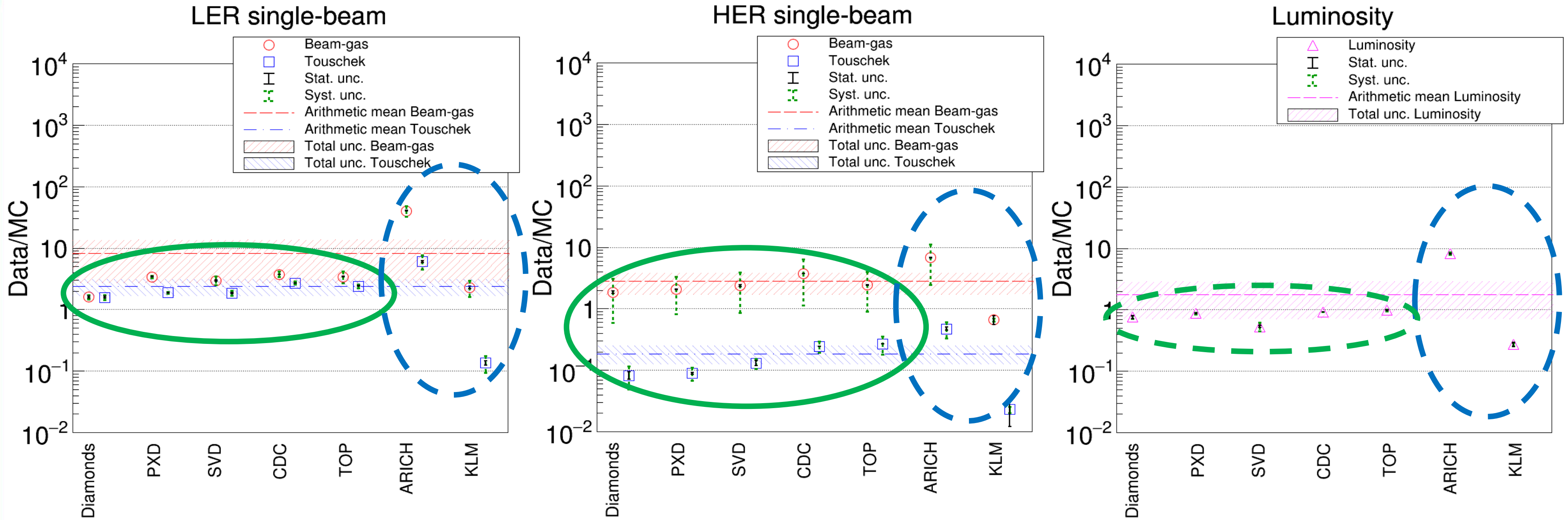
Detector	Expected rate or occupancy	Maximal acceptable rate or occupancy	Current prognosis
PXD, layer 1	1%	3%	OK
SVD, layer 3	4%	~3% (*)	OK
CDC	100-200 kHz / wire	> 200 kHz /wire (not clearly established)	uncertain
ECL	n/a	n/a (main effect of backgrounds is on energy resolution)	OK
ARICH	50 hits/event	> 500 hits/event	OK
TOP, slot 3-9 (ALD type PMTs)	2-7 MHz / PMT for non-luminosity component (lower estimate based most recent vacuum scrubbing extrapolation)	3-5 MHz / PMT for non-luminosity component	need two PMT replacements (2022, 2026) for 5 MHz
KLM Scintillators KLM RPCs	2-2000 Hz/cm² 0.1-2 Hz/cm²	~1 % drop in muon identification efficiency for nominal rates	OK

The extrapolation assume: 1) collimator settings re-optimized for an optimal tradeoff between beam lifetime and backgrounds at design optics, 2) Vacuum pressure of 1nTorr in both rings."

Preliminary summary by Sven May 2021. To be updated based on June 2021 studies.
Still assuming L= 8 x 10^{35} $cm^{-2}s^{-1}$ and original design optics, collimation

Storage background Simulation Accuracy

Natochii



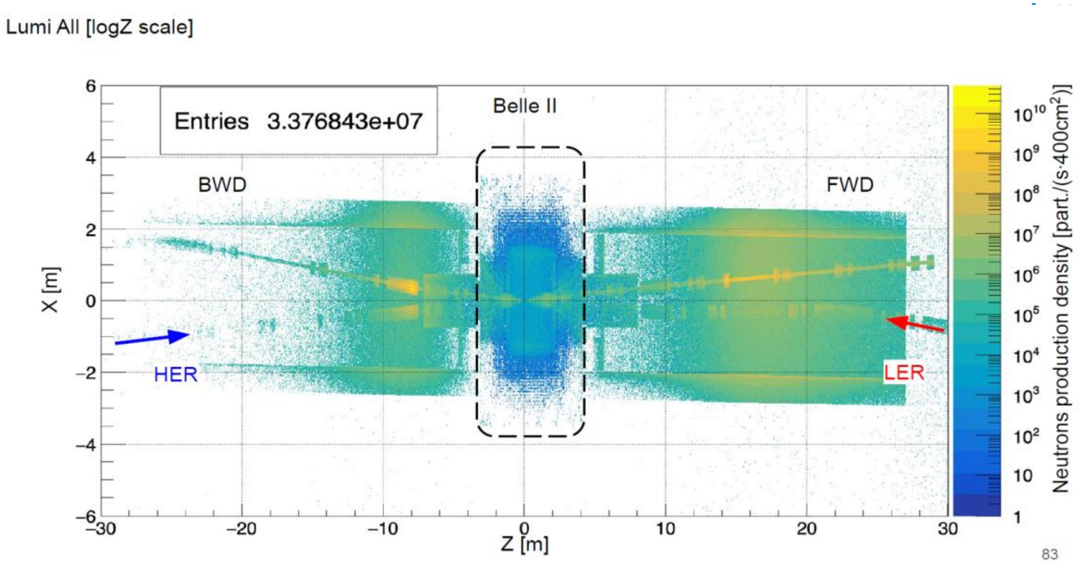
2020 BG study

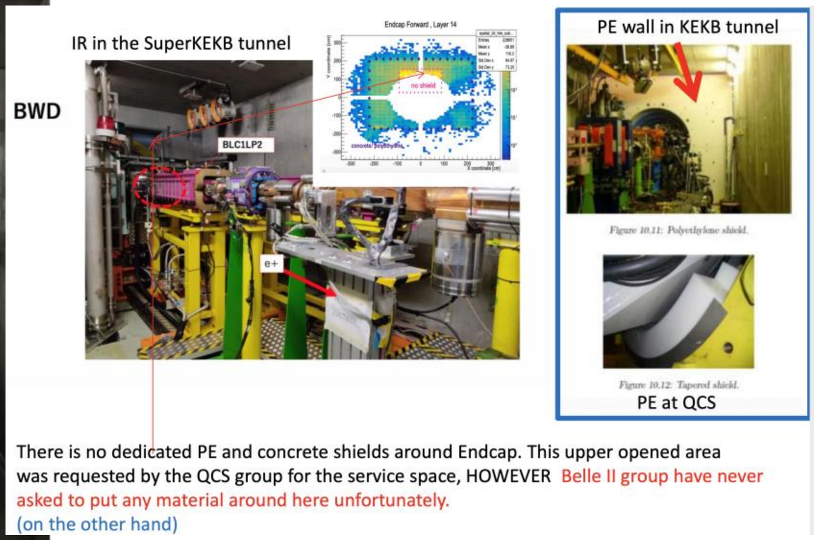
- Diamonds, PXD, SVD, CDC, TOP: Four of five storage background components have data/MC of order 1 !
- KLM and ARICH included into common analysis for first time. Still need refinement at detector level.
- Plan: Include 2021 measurements. Add ECL. Improved error analysis. Then publish the results.
- Puzzle: luminosity background in 2021 data seems 20-25% lower than predicted in some subdetectors
- We use these data/MC factors to correct extrapolations of backgrounds to design luminosity.
- Systematic errors are small for Lumi and LER (largest backgrounds at design parameter), reducing the extrapolation uncertainty.
- Effort for injection BG simulation has already started

Neutron background

Neutron shielding

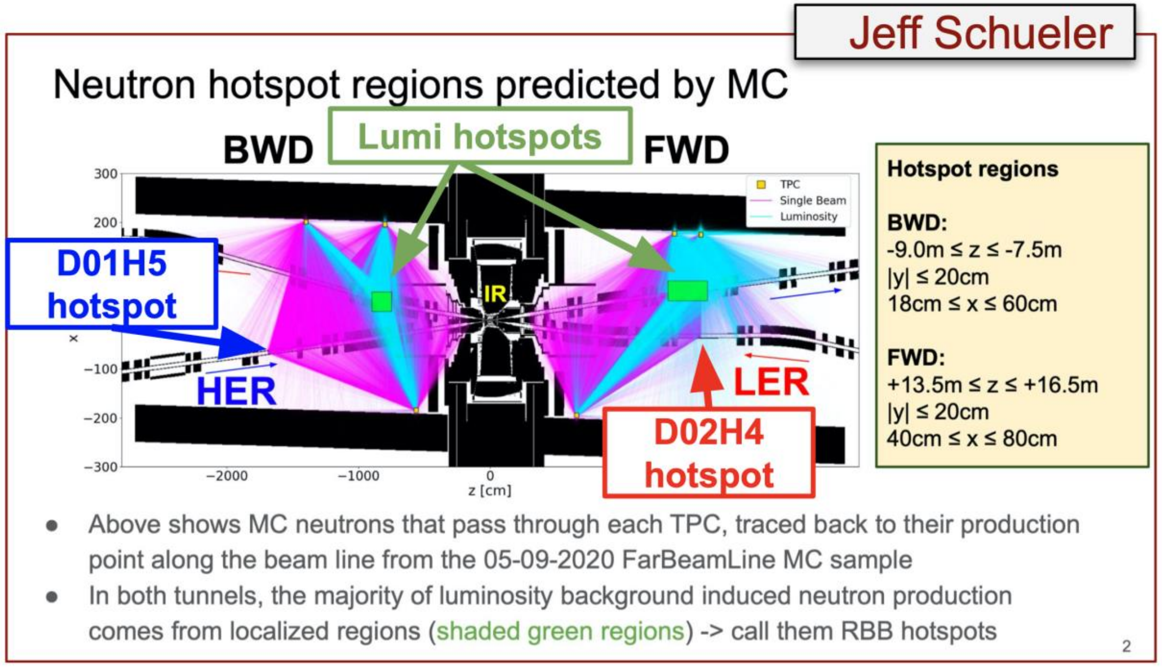
- Neutrons generated both inside and outside Belle II
    - New background MC samples w/ truth can be used by detector groups to study their neutron sensitivity
- Neutron background reduction can reduce SEU rates of CDC/TOP FPGAs
- Shielding design for 2022 installation urgent → new inter-detector group formed
    - Neutron dosimeters installed to assess the situation
    - Strategy is to install as much polyethylene as possible
    - Background group will simulate preliminary /conceptual designs





Cavern Neutrons

- Greatly improved understanding
  - Spectral and directional measurements with TPCs (fast neutron detectors)
  - EKLM hit distributions
  - New far beamline “cavern backgrounds” included in simulation
  - Corrected simulation of beam particle interaction with collimator jaws
- Most neutrons from two mechanisms
  - RBB photon hotspots at downstream of IP
  - Touschek losses at collimators just upstream of IP



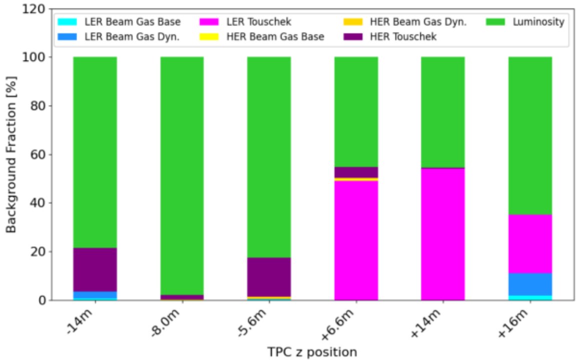


Figure 11: Fractional background contributions extrapolated to machine conditions consistent with the continuous injection fill period of the luminosity background study. Machine parameters assumed in this extrapolation are shown in Table 3.

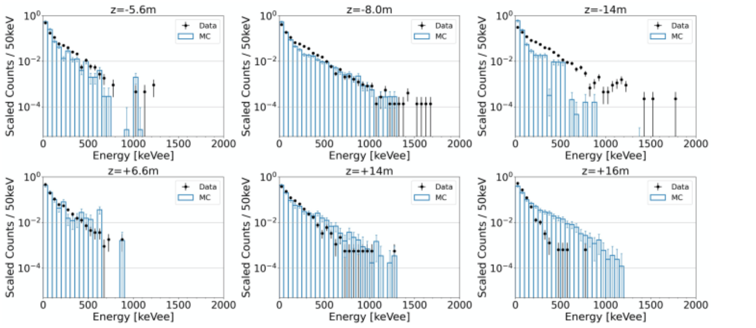
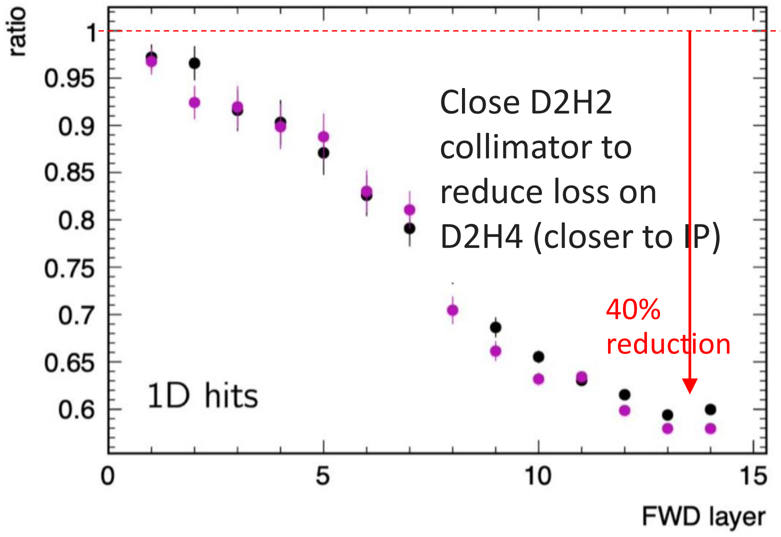


Figure 12: Comparison of data and MC recoil energy spectra in each TPC. The data shown is from the continuous injection luminosity study period shown in Figure 8. The lowest energy bin only includes events above the X-ray veto threshold described in Section 4.3. Distributions are normalized to an integral of unity in both data and MC. The title of each plot indicates the Belle frame z position of its corresponding TPC.

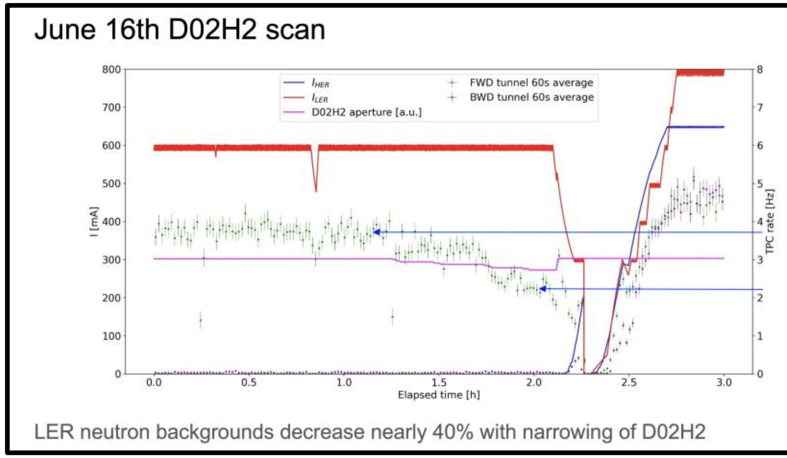
Cavern Neutrons

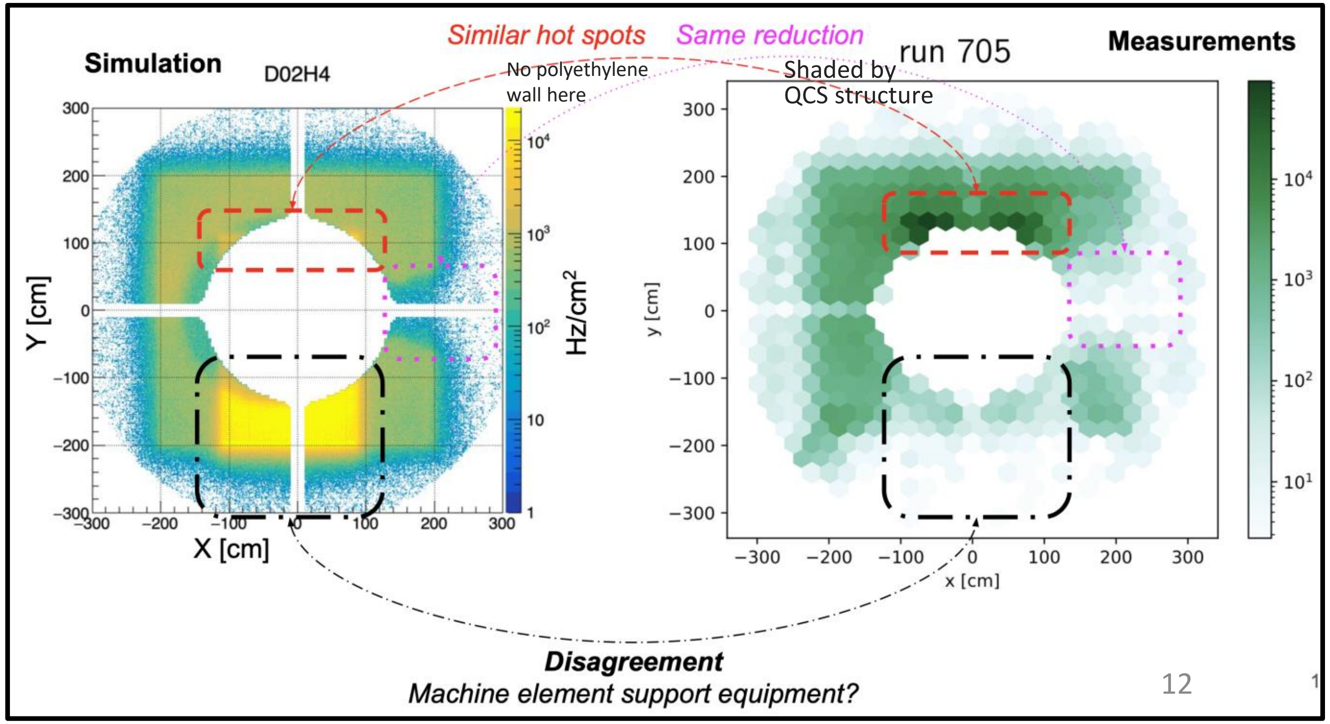
- Armed with this improved knowledge, performed experiment to verify
- Achieved 40% EKLM Touschek neutron reduction via modified collimation
- Also directly observed the reduced fast-neutron flux in the tunnel with the TPCs
- This confirms the Touschek-collimator neutron hypothesis
- Data/MC comparison indicates some materials are missing in our simulation → need to fix the geometry in GEANT4 (see following pages)

KLM, April 27



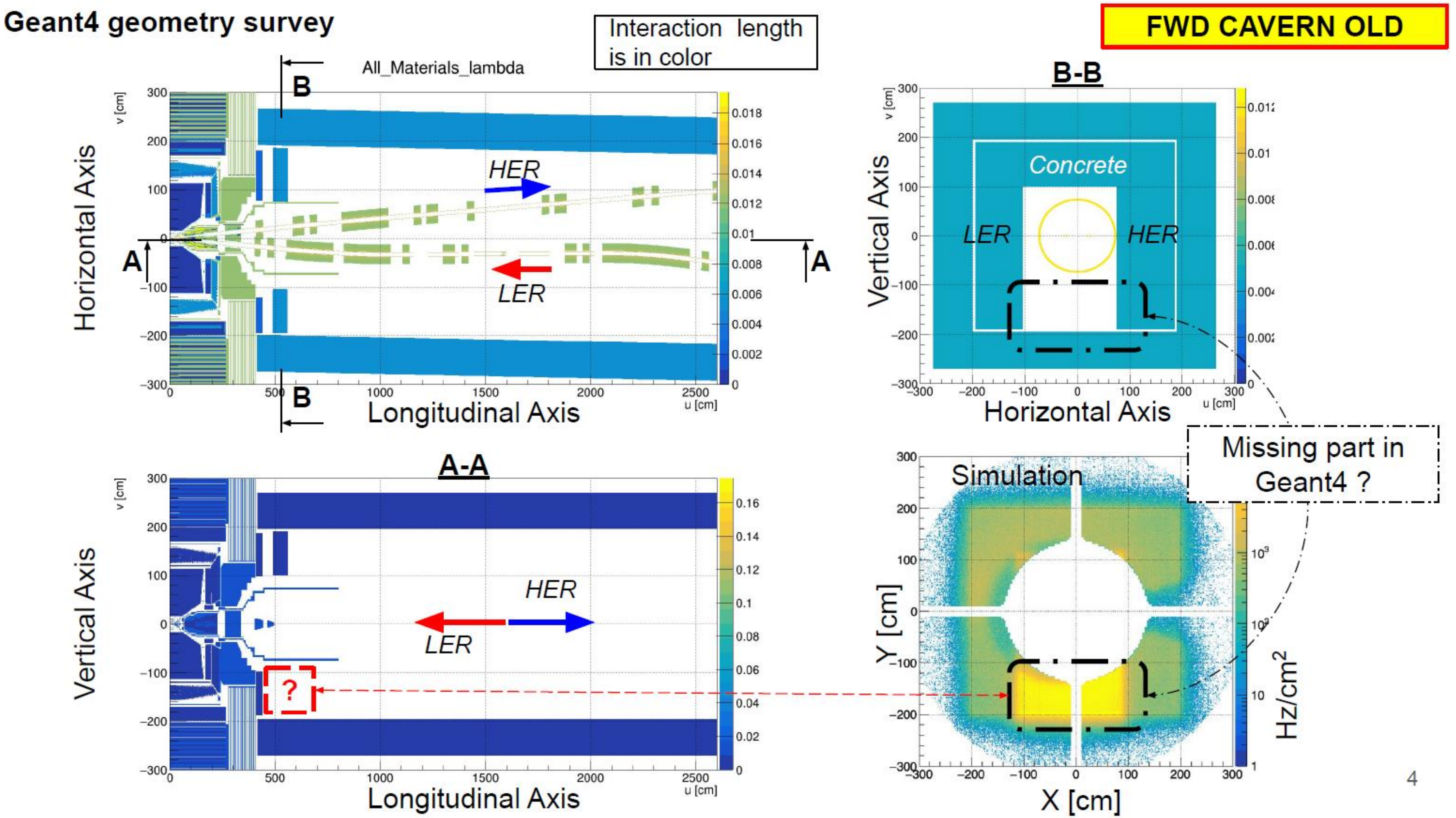
TPCs





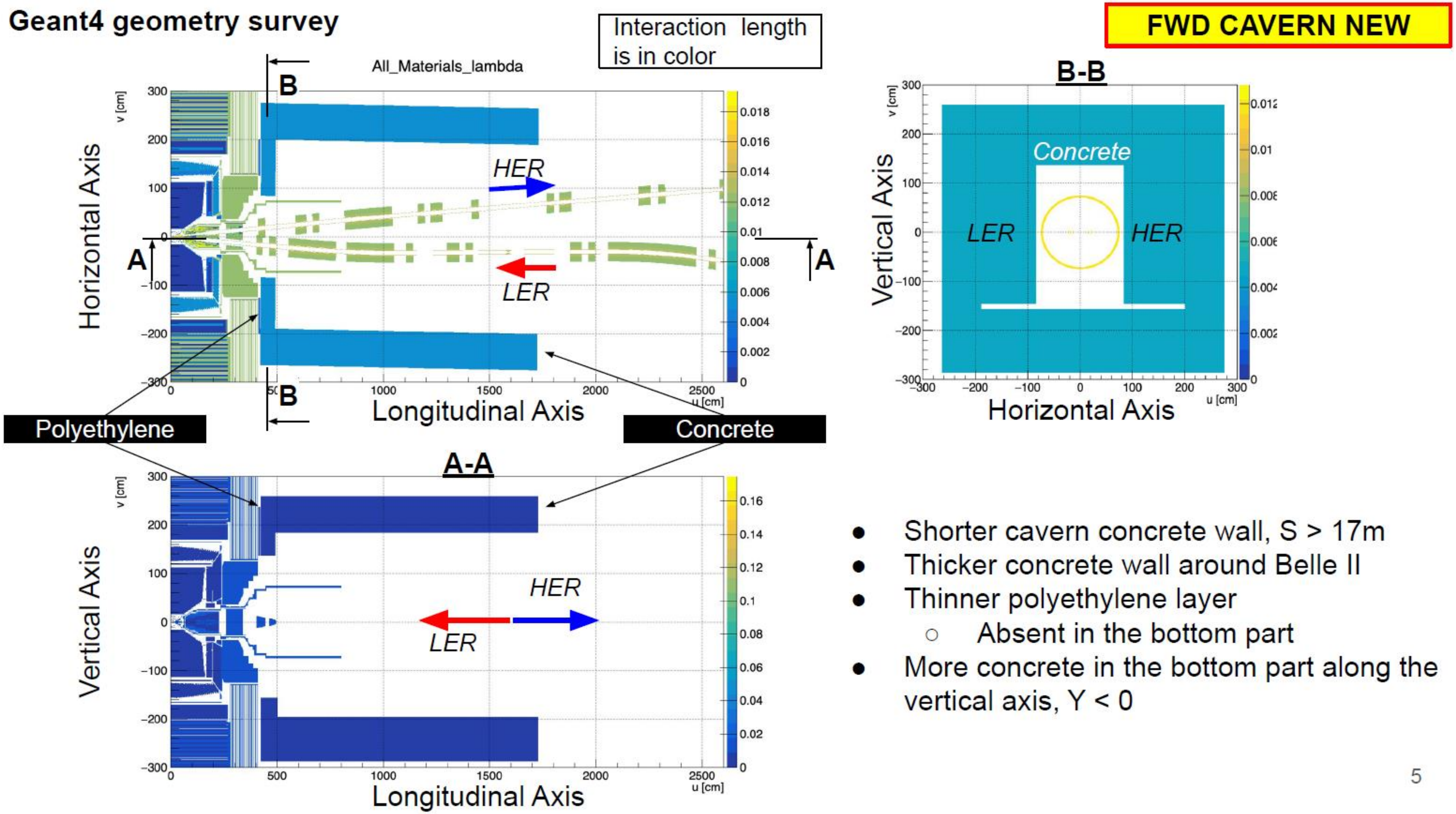
GEANT4 geometry (OLD)

Dmitri, Andrii



GEANT4 geometry (NEW)

Dmitri, Andrii



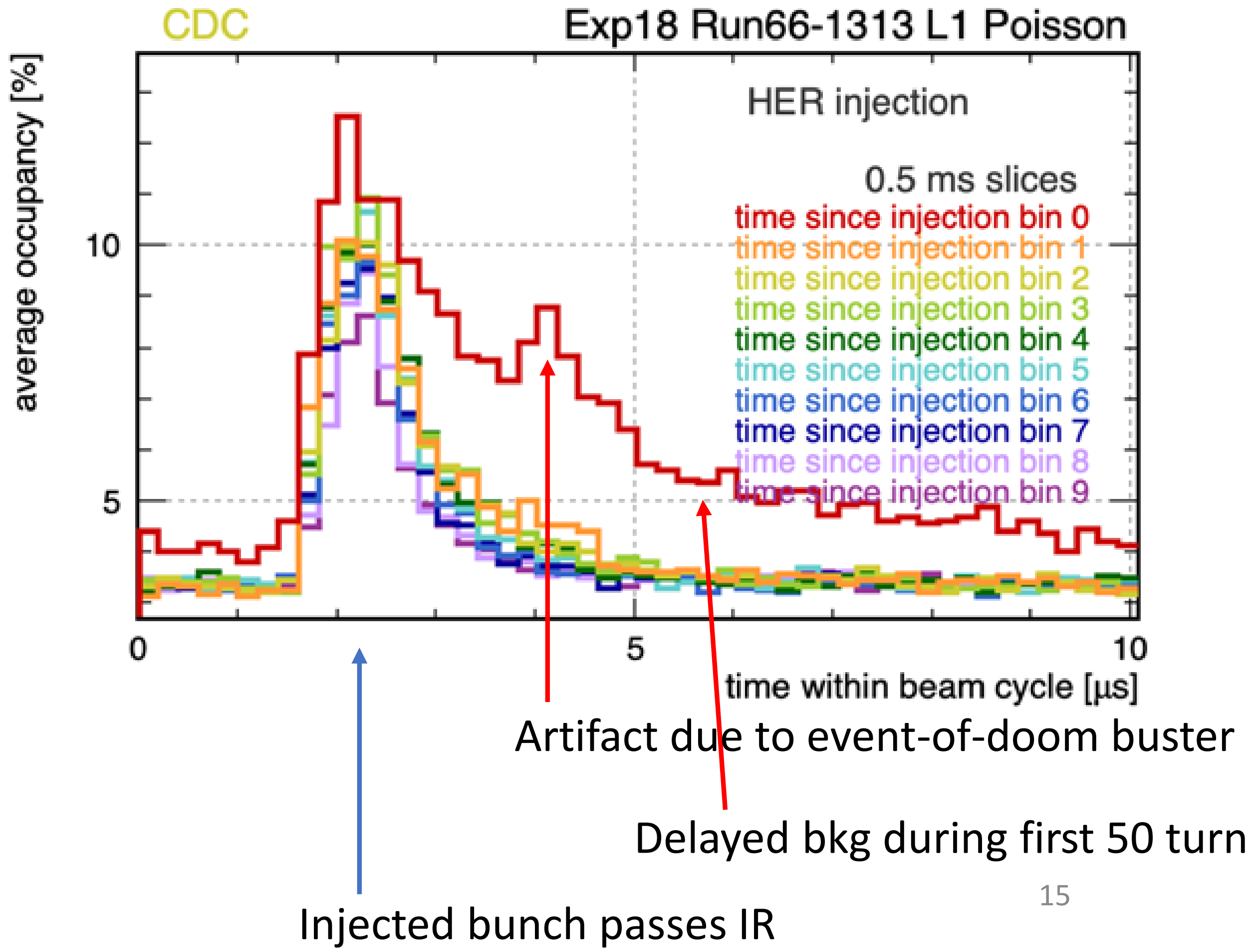
- Shorter cavern concrete wall, S > 17m
- Thicker concrete wall around Belle II
- Thinner polyethylene layer
  - Absent in the bottom part
- More concrete in the bottom part along the vertical axis, Y < 0

5

New cavern geometry looks much more realistic.

Are Belle II detectors seeing delayed neutrons from injection background losses at collimators?

- Utilizing new 2Hz Poisson trigger which extends into injection veto period.
- CDC occupancy evolves during one revolution (10 µs) and on ms time scales
- Only in the first bin (<0.5ms after injection) there's a significant delayed component
- MeV neutrons originating from the horizontal collimator D01H5 ?
- Check if MC sample can reproduce such events
- Another hypothesis: instability due to some coupling between the injected bunch and later bunches?

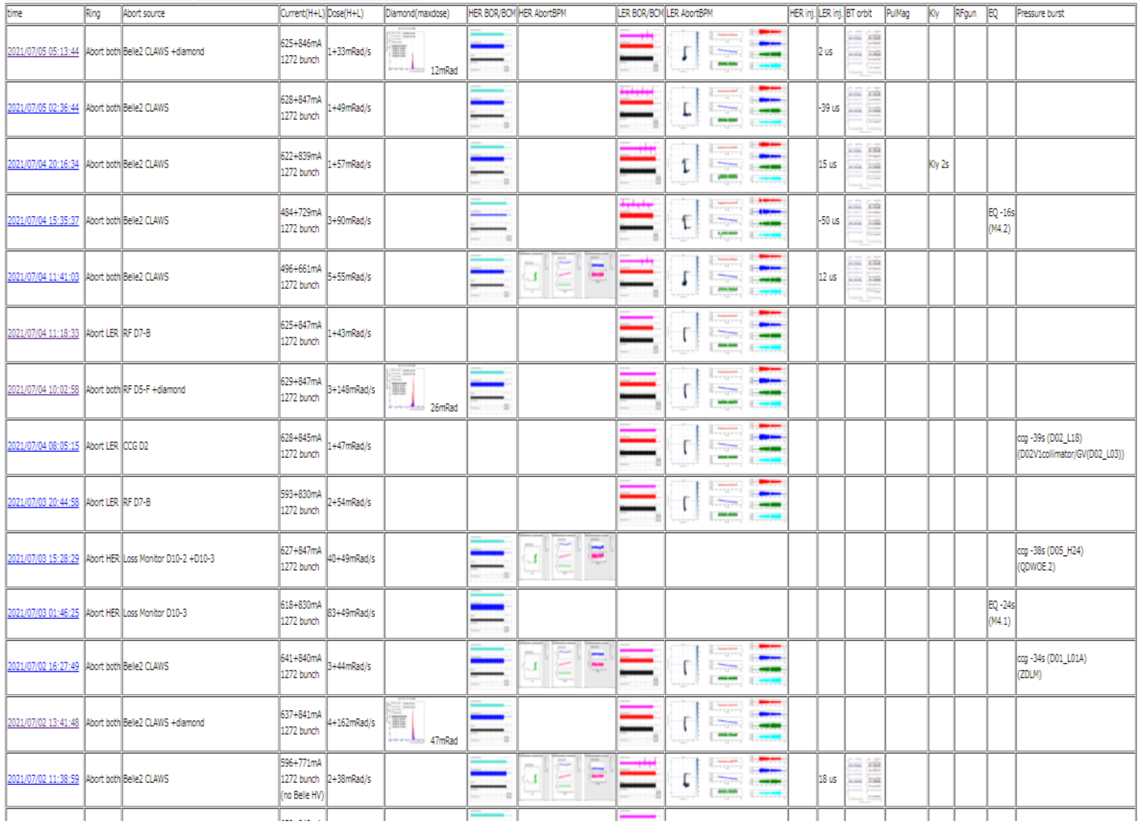


Catastrophic beam loss events

Abort summary page

H. Nakayama

http://kekb-co-web.kek.jp/doc/Image/BELLE/abort_summary/web/abortlist.html



Beam abort summary table (both ring >60mA)

show all aborts (except manual and both ring <1mA)

Last Updated: Mon Jul 19 16:41:51 JST 2021(updates every 5~10 minutes)

Some BOR/AbortBPM plots around May 12-13 are missing due to trouble.

Ikeda-san's abort manual

[Diamond plots] [Diamond plots (zoom up)] [CLAWS plots] [BOR/BCM plots] [BTorbit plots] [AbortBPM plots] [RF abort verification]

[List of ressure burst events] [List of CDC HV trip events] [List of VXD injection inhibit events] [List of earthquakes(jma.go.jp)]

time	Ring	Abort source	Current(H+L)	Dose(H+L)	Diamond(maxdose)	HER BOR/BCM	HER AbortBPM	LER BOR/BCM	LER AbortBPM	HER inj.	LER inj.	BT orbit	PulMag	Kly	RFgun	EQ	Pressure burst
2021/07/05 05:13:44	Abort both	Belle2 CLAWS +diamond	625+846mA 1272 bunch	1+33mRad/s	12mRad						2 us						
2021/07/05 02:36:44	Abort both	Belle2 CLAWS	628+847mA 1272 bunch	1+49mRad/s							-39 us						
2021/07/04 20:16:34	Abort both	Belle2 CLAWS	622+839mA 1272 bunch	1+57mRad/s							15 us			Kly 2s			
2021/07/04 15:35:37	Abort both	Belle2 CLAWS	484+729mA 1272 bunch	3+90mRad/s							-50 us					EQ -16s (M4.2)	
2021/07/04 11:41:03	Abort both	Belle2 CLAWS	496+661mA 1272 bunch	5+55mRad/s							12 us						
2021/07/04 11:18:33	Abort LER	RF D7-B	625+847mA 1272 bunch	1+43mRad/s													
2021/07/04 10:02:58	Abort both	RF D5-F +diamond	629+847mA 1272 bunch	3+148mRad/s	26mRad												
2021/07/04 08:05:15	Abort LER	CCG D2	628+845mA 1272 bunch	1+47mRad/s													ccg -39s (D02_L18) (D02V1collimator/GV(D02_L03))
2021/07/03 20:44:58	Abort LER	RF D7-B	593+830mA 1272 bunch	2+54mRad/s													
2021/07/03 15:28:29	Abort HER	Loss Monitor D10-2 +D10-3	627+847mA 1272 bunch	40+49mRad/s													ccg -38s (D05_H24) (QDWOE.2)
2021/07/03 01:46:25	Abort HER	Loss Monitor D10-3	618+830mA 1272 bunch	83+49mRad/s												EQ -24s (M4.1)	
2021/07/02 16:27:49	Abort both	Belle2 CLAWS	641+840mA 1272 bunch	3+44mRad/s													ccg -34s (D01_L01A) (ZDLM)
2021/07/02 13:41:48	Abort both	Belle2 CLAWS +diamond	637+841mA 1272 bunch	4+162mRad/s	47mRad												
2021/07/02 11:38:59	Abort both	Belle2 CLAWS	596+771mA 1272 bunch (no Belle HV)	2+38mRad/s							18 us						

- Aggregates relevant information in one page
  - abort time, earliest abort source, link to abort timestamp page
  - beam currents, number of bunches, Belle HV status
  - bellows diamond doses, IP diamond plot and integrated dose
  - BOR/BCM plots, abort BPM plots
  - time difference since the last injection, BT orbit plots
  - LINAC trouble information (Pulmag misfire, Kly down, RF gun pressure burst)
  - earthquakes, LER/HER pressure bursts

Very useful for beam abort diagnosis

Beam aborts in 2021ab

List of beam aborts @ large currents (both beams >60mA)

	HER loss no inj.	HER loss inj.	LER loss no inj.	LER loss inj.	RF	CCG	EQ	Others	Total
2/25~3/03	4	6	1	0	2	2	0	0	15
3/04~3/10	6	10	2	1	4	10	1	0	34
3/11~3/17	2	6	2	1	0	2	2	1	16
3/18~3/24	0	1	7	0	8	1	2	0	19
3/25~3/31	5	3	1	0	4	0	0	2	15
4/01~4/07	9	3	10	6	2	3	0	0	33
4/08~4/14	15	4	10	1	9	4	1	1	45
4/15~4/21	★ 28	8	10	0	12	3	2	0	63
4/22~4/28	1) 21	5	2	0	9	1	2	1	41
4/29~5/05	14	4	10	0	2	0	3	0	33
5/06~5/12	15	0	★ 5	0	8	3	0	0	31
5/13~5/19	8	5	8	1	3	1	5	2	33
5/20~5/26	6	0	★ 8	1	3	2	4	1	25
5/27~6/02	12	2	★★ 10	1	6	0	5	0	36
6/03~6/09	2	3) 0	★ 9	7	0	1	1	1	21
6/10~6/16	0	19	3	4	6	1	3	0	36
6/17~6/23	8	1	0	4) 25	2	5	0	0	41
6/24~6/30	12	4	1	3	4	2	3	2	31
7/01~7/05	3	1	4	5	2	3	2	0	20
Total	1) 170	82 (+-200us)	2) 103	56 (+-200us)	86	44	36	11	

D2V1 replaced (June 9th)

CLAWS abort since May 28th

★ : QCS quench due to HER beam loss

★ : QCS quench due to LER beam loss

1) HER beam aborts not in coincidence with injection are most frequent. Especially, HER was quite unstable in late April.

2) LER beam aborts not in coincidence with injection are also frequent. Some are catastrophic and caused QCS quenches and hardware damage (see next page)

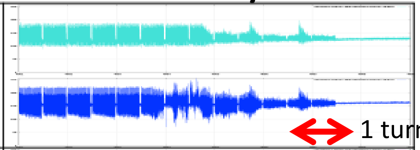
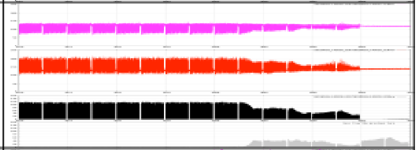
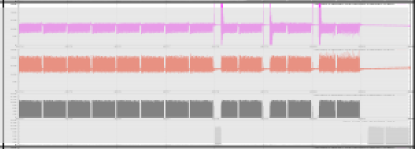
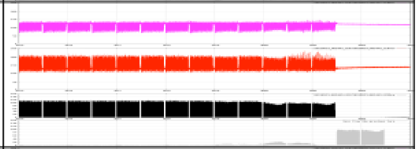
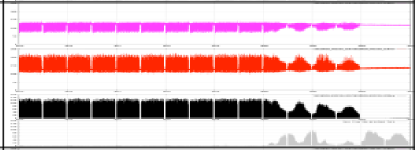
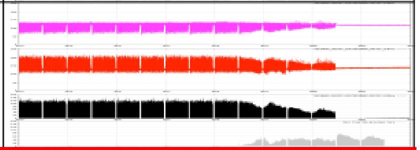
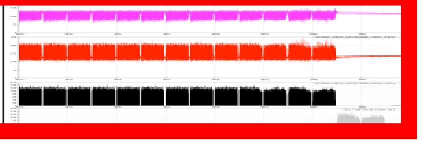
3) HER aborts due to injection increased by installing CLAWS abort on May 28th, but became less after June 18th (CLAWS threshold adjusted).

4) LER aborts due to injection increased in mid June, probably due to LINAC energy feedback trouble.

Understanding the cause of LER/HER aborts (not in coincidence with injections) is very important for safe & stable operation

Catastrophic beam loss abort events in 2021b

(which caused QCS quenches)

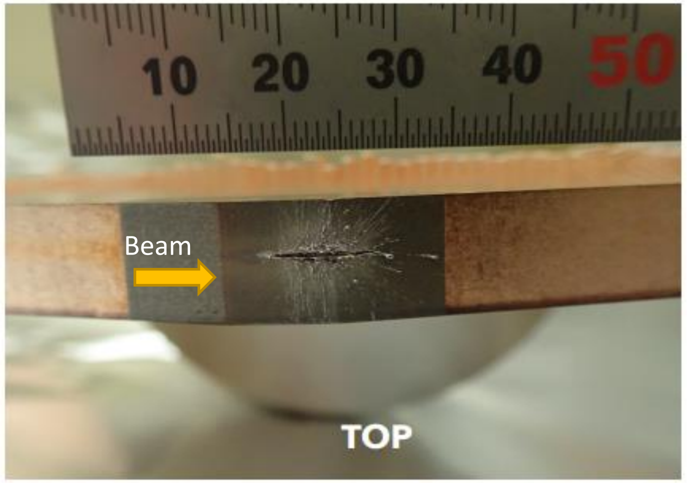
				BOR/BCM
4/19 (MO) Owl	**1:07**	**QCS quench QC1LE**	**HER 820 mA**	 1 turn=10us
5/10 (MO) Day	**14:26**	**QCS quench QC1LP, QC1RP**	**LER 910 mA**	
5/14 (FR) Owl	0:35	QCS quench QC1RP	LER 840 mA LER kicker trouble	
5/23 (SU) Owl	**8:24**	**QCS quench QC1LP, QC1RP**	**LER 840 mA**	
5/28 (FR) Owl	**3:21**	**QCS quench QC1RP**	**LER 840 mA**	
6/2 (WE) Swing	**20:13**	**QCS quench QC1LP, QC1RP**	**LER 840 mA**	
6/6 (SU) Day	**16:06**	**QCS quench QC1LP, QC1RP**	**LER 840 mA**	

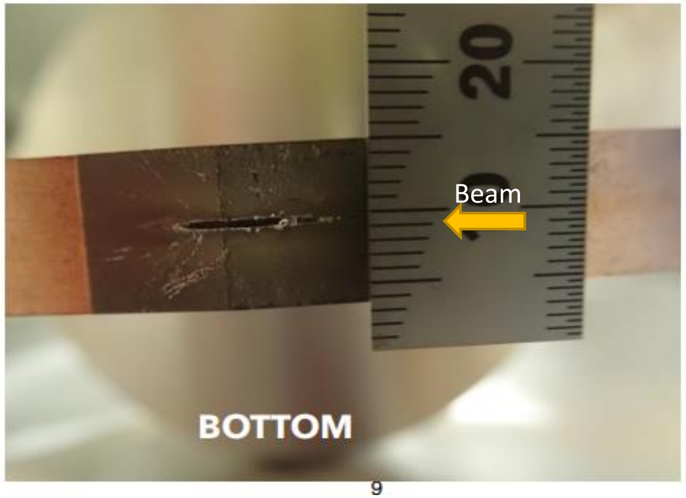
This event caused a severe damage on LER D2V1 collimator

Most of them are caused by huge beam loss in LER, several turns before the abort.

Dangerous for Belle II inner sensors. In some cases, diamonds on IP beam pipes saw >1500mrad (saturated) and PXD was damaged

Severe damage on LER D02V1 collimator after the huge beam loss on June 6th

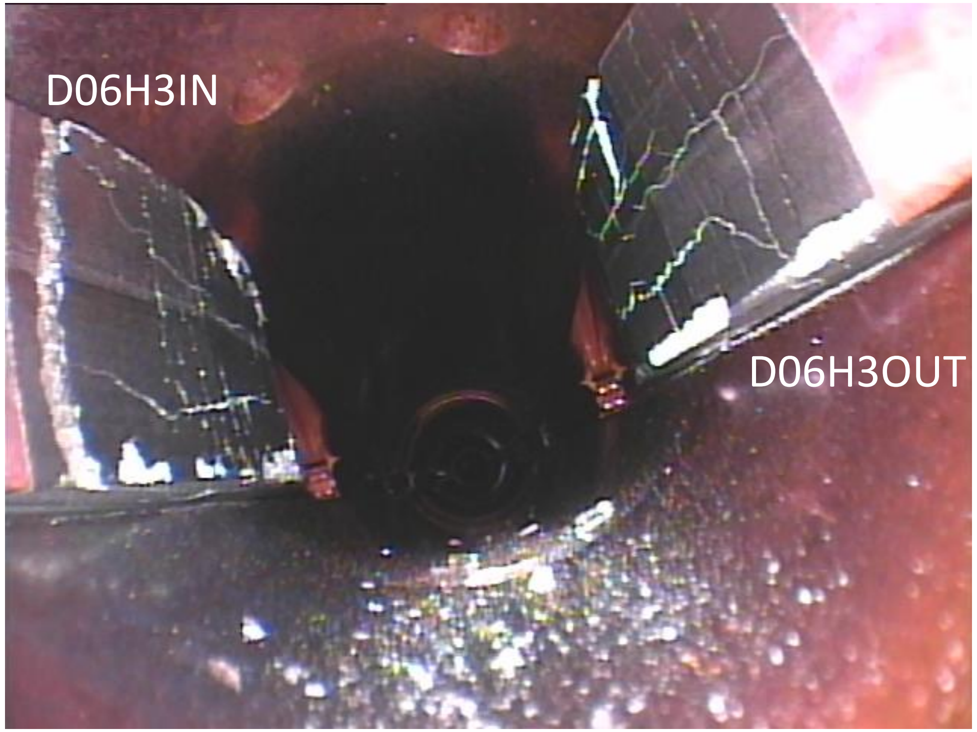




- After the huge beam loss event on June 6th, LER BG increased significantly
- D02V1 collimator jaws were severely damaged (deep scar on the bottom jaw)
- We lost 3~4 days for the collimator replacement work and the baking runs

Understanding the cause of huge beam loss events is essential for the stable operation at high beam currents. Where in the ring the beam abnormality initially occurs? Adding more sensors to the key collimators will help to understand the initial beam loss position.

Severe damage on D6H3 collimator, probably due to kicker misfire event on May 14th



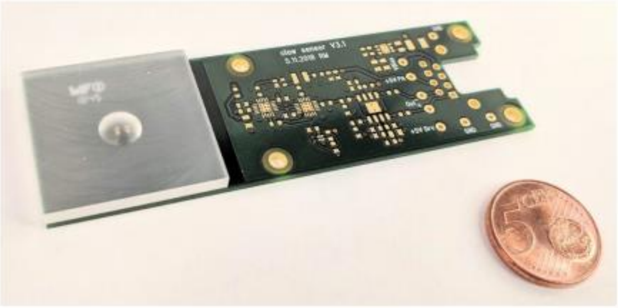
Terui-san's report on July 15th

- Kicker misfire happened on May 14th
- QCS quench occured
- Pressure burst at D6H3 was also observed
- However, we realized the severe damage only after the run end (in July), not just after the incident
  - Loss monitor PINs got easy saturated and can't tell if the beam loss is huge or moderate

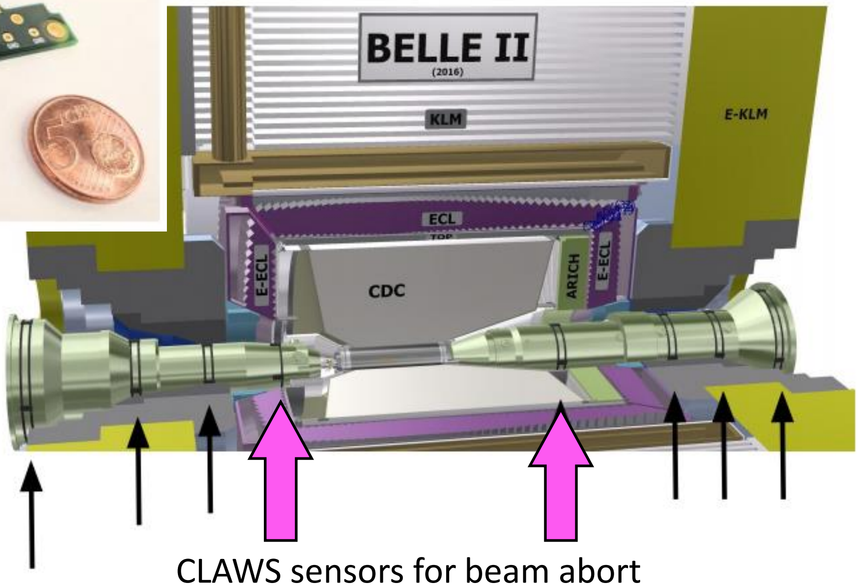
- Dust particles falling off from D6H3 could be a cause of catastrophic events in LER?
  - Ikeda-san's post-mortem abort analysis using loss monitor data is ongoing
  - *If yes, why huge loss disappeared after D2V1 replacement?*

Even faster beam abort: CLAWS

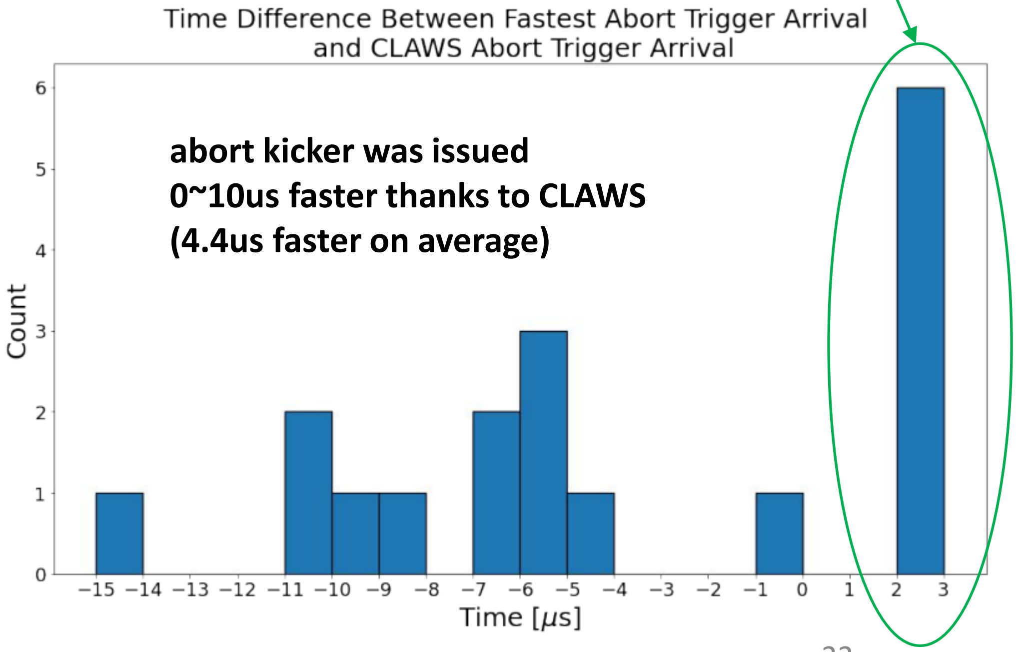
- 4+4 CLAWS sensors (on QCSL and QCSR) are used to issue beam aborts (since May 26th, 2021)
- **Thanks to CLAWS, abort kicker can be fired faster by ~4.4us on average**
  - For some LER aborts, CLAWS are outperformed by LER RF D5-F, which is located at better ring position
  - Adding new beam loss sensors (upstream of IP and downstream of initial beam loss) might be able to make abort even faster



$3x3\ cm^2$ plastic scintillator
+ Hamamatsu SiPM

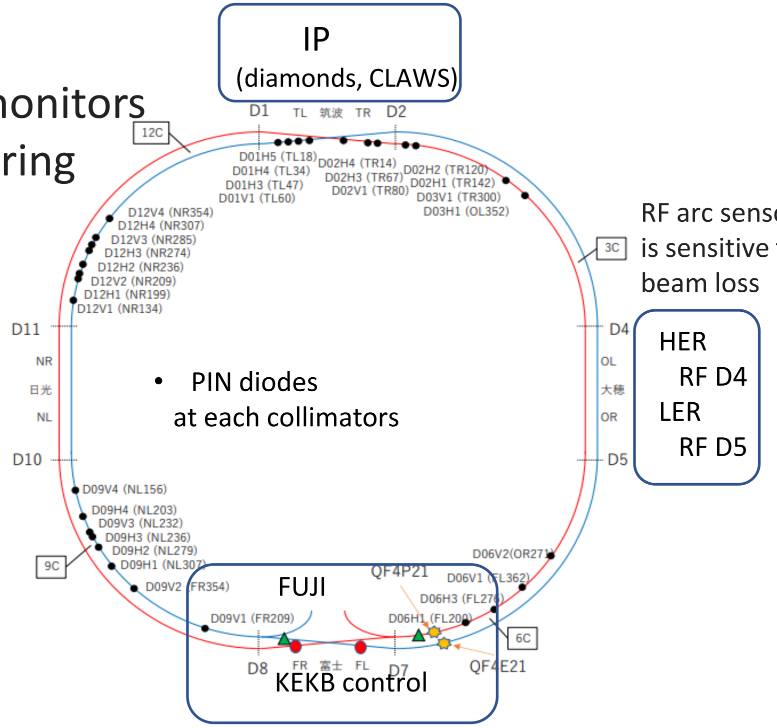


CLAWS sensors for beam abort



Where's the location of initial beam loss?

Loss monitors in the ring



RF arc sensor is sensitive to beam loss

HER
RF D4
LER
RF D5

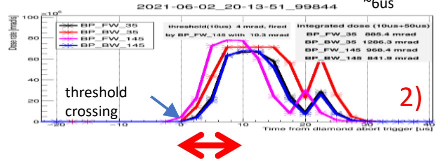
Bunch current monitors (BCM)

"Libera" turn-by-turn BPMs

Abort kicker/beam dump

Diamonds

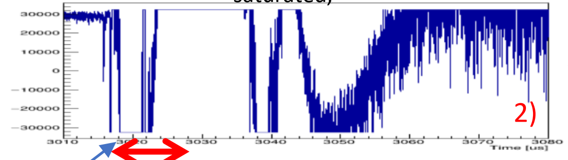
Internal delay ~6us



1 turn=10us

CLAWS

saturated,



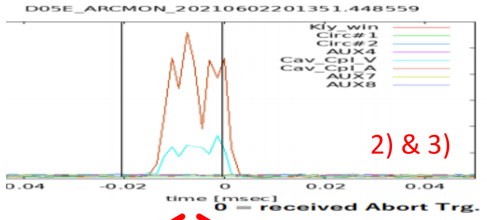
Internal delay ~0.2us

threshold crossing

10us

Timing between sensors are synchronized by 1) abort kicker trigger signal, 2) abort request signal, or 3) "all beam kicked out" timing

RF D5-E

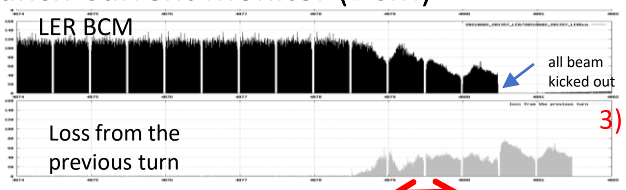


10us

PIN diodes on collimators

Long integration time

Bunch Current Monitor (BCM)



10us

"Libera" BPM

10us

all beam kicked out?

3)

- By comparing beam loss timing among several sensors along the ring, we can find the possible region where initial beam loss occurred.

- If we can add new beam loss sensors at some important collimators, it might help us pin-down the initial beam loss position of dangerous aborts.

Beam abort timing chart (LER)

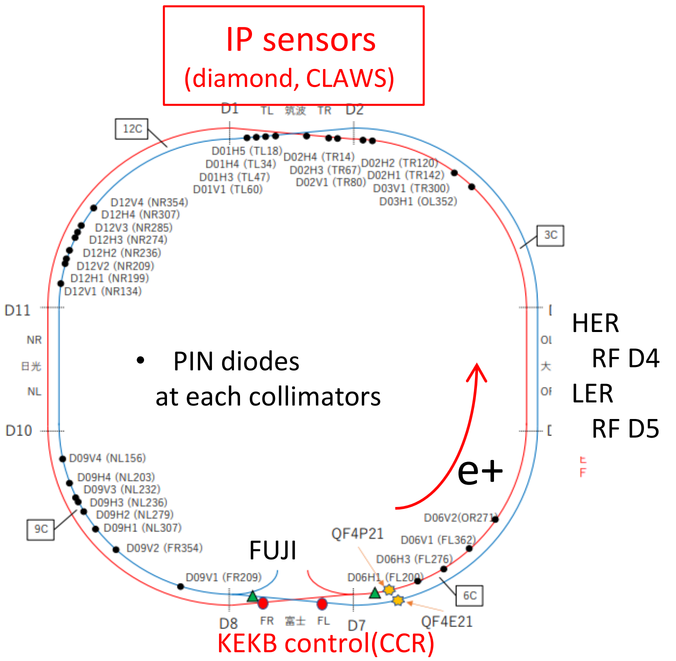
In case the earliest abort request issued by IP sensors (CLAWS/diamond)

a) Disturbed bunch arrives at the sensor position

b) Abort request signal arrives at the Central Control Room (CCR)

c) All bunces are kicked out and no beam loss seen by the sensor

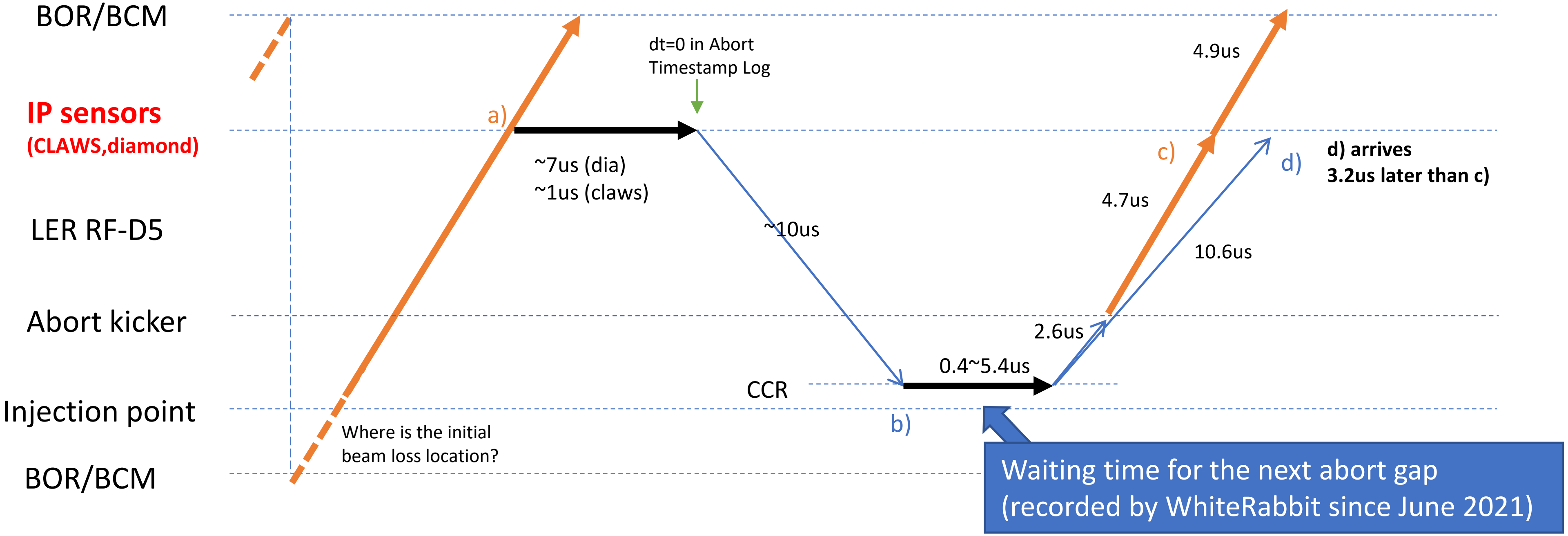
d) Abort kicker signal arrives at the sensor position



Bunch current monitors (BCM)

"Libera" turn-by-turn BPMs

Abort kicker/beam dump

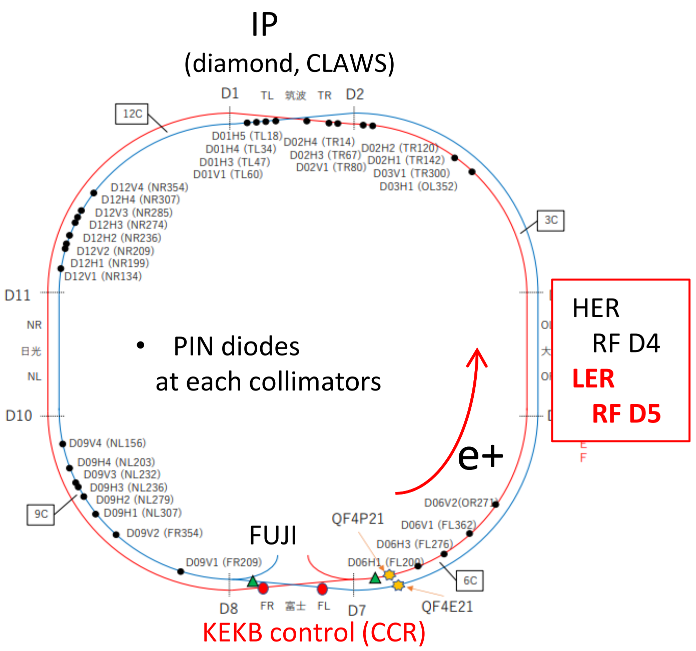


If the earliest abort was issued by CLAWS,
a)→c) takes 1+10+(0.4~5.4) +2.6+4.7 = **18.7~23.7 us**

If issued by diamonds,
a)→c) takes 7+10+(0.4~5.4) +2.6+4.7 = **24.7~29.7 us**

Beam abort timing chart (LER)

In case the earliest abort request issued by <u>RF D5 arc sensor</u>



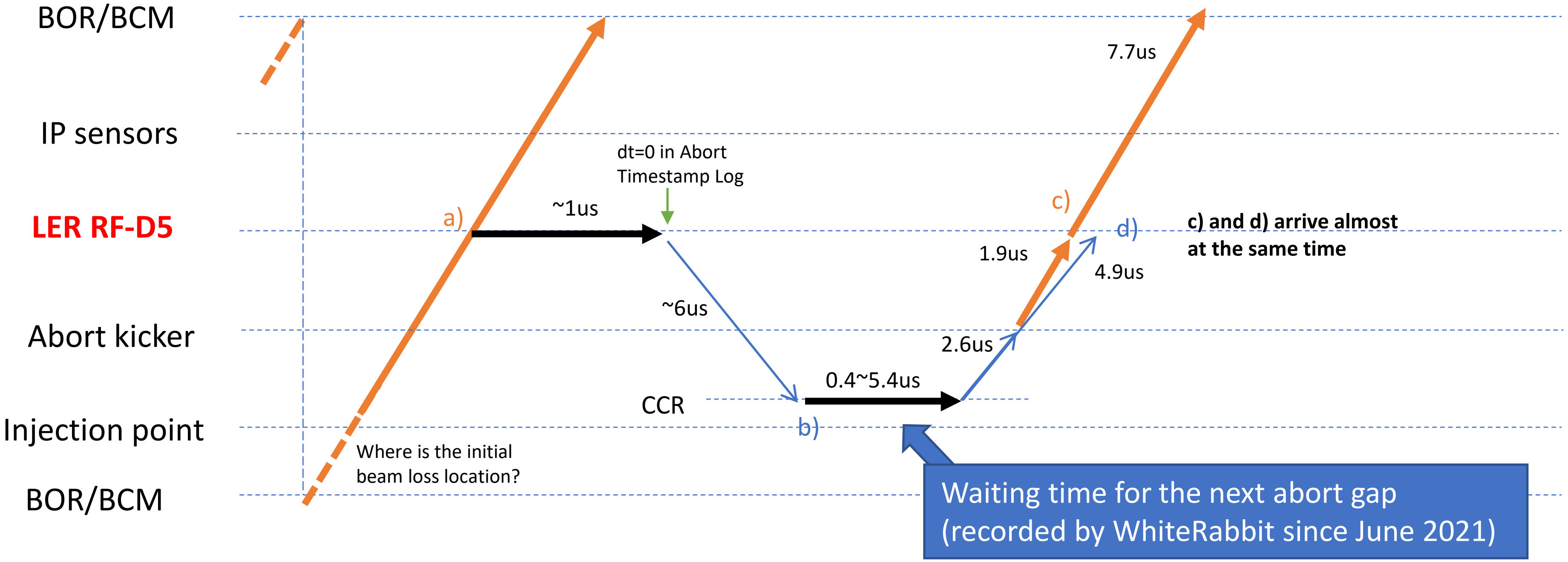
Bunch current monitors (BCM)
"Libera" turn-by-turn BPMs
Abort kicker/beam dump

a) Disturbed bunch arrives at the sensor position

b) Abort request signal arrives at the Central Control Room (CCR)

c) All bunces are kicked out and no beam loss seen by the sensor

d) Abort kicker signal arrives at the sensor position



a)→c) takes
1+6+(0.4~5.4)+2.6+1.9
= **<u>11.9~16.9 us.</u>**

LER abort kicker:
RF D5-F: s~2180m
RF D4-H: s~2320m

2021/06/02 20:13:51(QCS quench)

20us

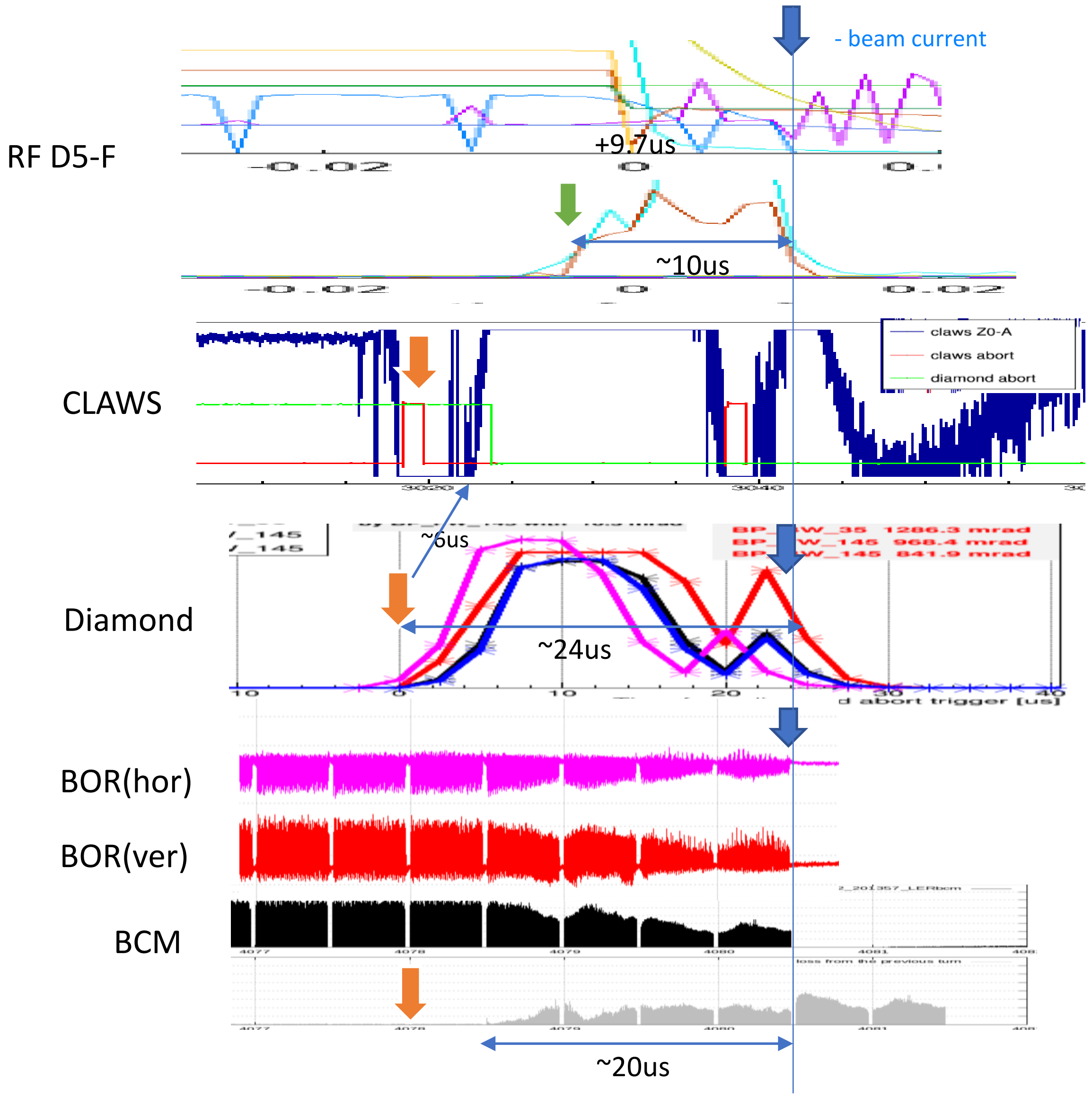
:beam dump

RING	MESSAGE	DATE	DELTA
LER	Belle2 CLAWS	2021-06-02 20:13:51.448190900	0.000 000 000
HER	Belle2 CLAWS	2021-06-02 20:13:51.448191100	0.000 000 200
LER	Belle2 VXD diamond	2021-06-02 20:13:51.448196000	0.000 005 100
HER	Belle2 VXD diamond	2021-06-02 20:13:51.448196200	0.000 005 300
HER	COHSAFE:CCC:ABORT:D2	2021-06-02 20:13:51.448200600	0.000 009 700
LER	RF D5-F	2021-06-02 20:13:51.448200600	0.000 009 700

- **Earliest abort request arrived at CCR was issued by CLAWS**
- Abort gap waiting time at CCR was **4.4us** for this abort
- All bunches kicked out after 1us+10us+4.4us+2.6us+4.7us = **22.7us** (a→c)
- Diamond abort request arrived at D2 4.9us later than CLAWS. It means CLAWS and diamond issued their aborts by seeing almost same bunch. In diamond plot, all bunches should be kicked out at t=24us (abort was issued at t=0 in the plot) (a→c). The observed signal waveform has a peak around t=23us and the tail follows for ~6us.
- **BCM start to see the beam loss in the same turn with initial loss in diamond and CLAWS. The observed beam loss in RF D5-F** starts 1 turn later than CLAWS/diamond. (Why?)

- **Initial beam loss seems to occur at: downstream of BCM and upstream of IP (i.e. right half of the ring).**

- D6,D2 loss monitor waveforms are being analyzed by Ikeda-san.



Summary

- Steady state beam backgrounds in 2021ab mostly acceptable for Belle II
  - TOP PMT replacement still expected in 2022, of course
- First full single-beam + luminosity BG study since 1 year ago
  - At higher luminosity, BG extrapolation update
  - Systematic overestimate of luminosity bkg in all detectors (~20-25 % effect) not yet understood
- Long term extrapolations: most detectors safe
  - Large uncertainties related to collimation etc..
  - CDC and TOP uncertain ← more work needed, ECL not really studied but “probably fine”
- Good progress on neutron studies, shielding design is starting
- Promising new efforts on injection backgrounds (see backup)
- Catastrophic losses / abort events dangerous for inner detectors
  - Abort summary page is prepared
  - CLAWS can issue faster beam abort request than diamonds
  - Post-mortem analysis will indicate the initial beam loss positions

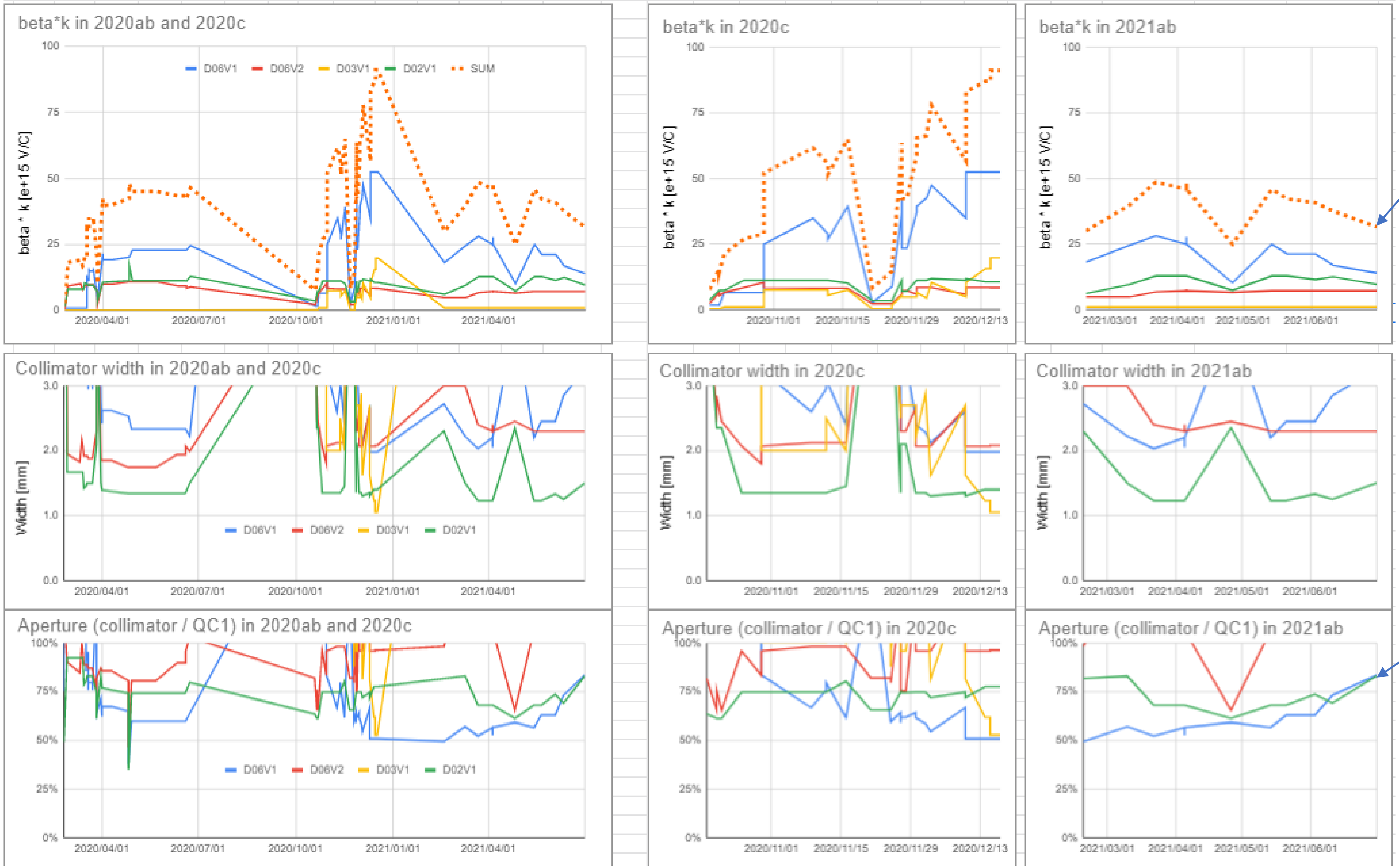
backup

LER collimator aperture setting history

beta x k

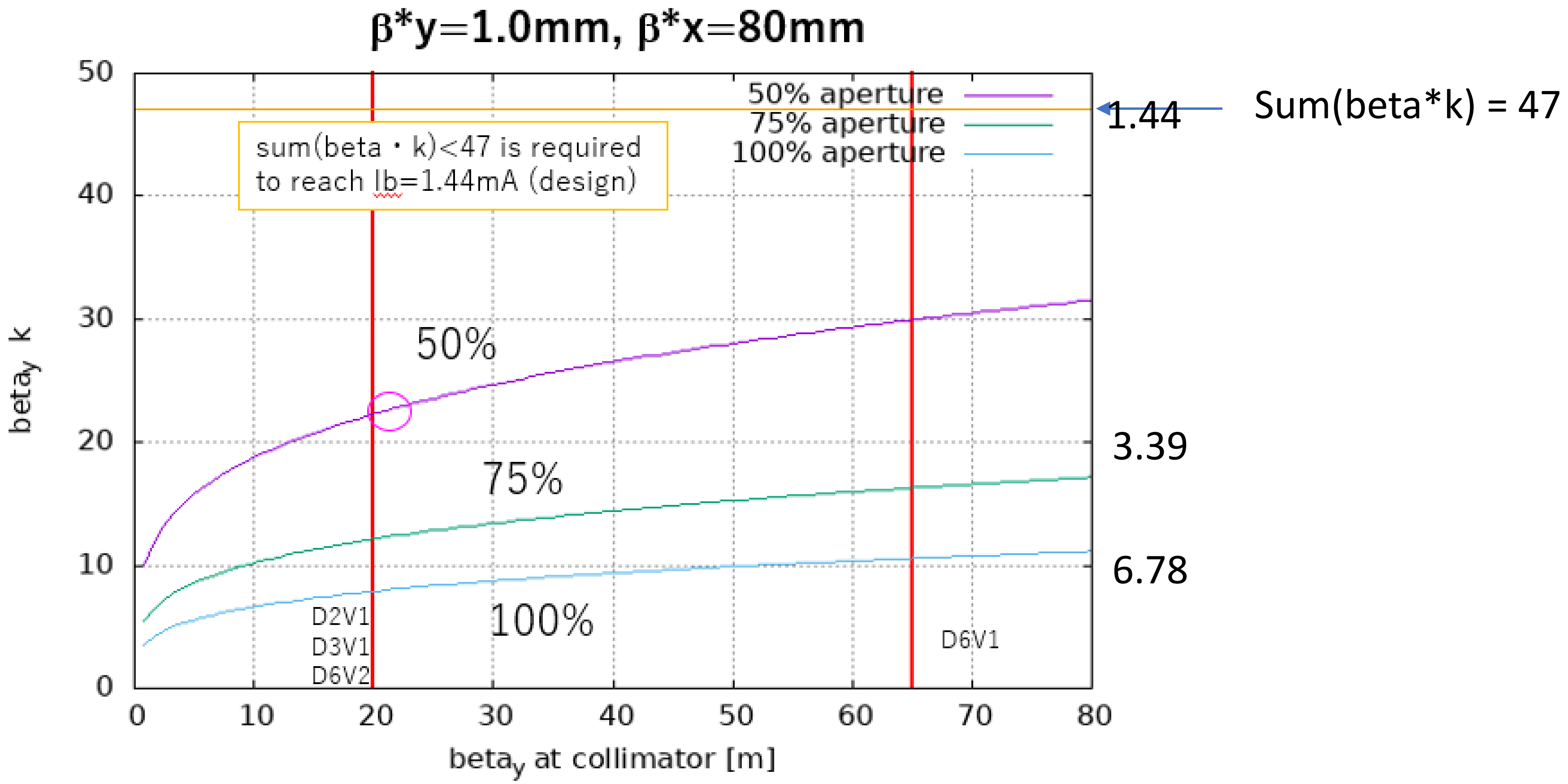
width

How much narrower than QC1 aperture?



Relaxed on July 1st beta*k~30

Two collimators with 80% aperture



β*y=1.0mm, β*x=80mm
sum(beta・k)<47 is required
to reach Ib=1.44mA (design)
50% aperture
75% aperture
100% aperture
50%
75%
100%
D2V1
D3V1
D6V2
D6V1
beta_y k
beta_y at collimator [m]
1.44
Sum(beta*k) = 47
3.39
6.78

Background Publications Status

Submitted

- A. Natochii et al., *Improved simulation of beam backgrounds and collimation at SuperKEKB*, PRAB

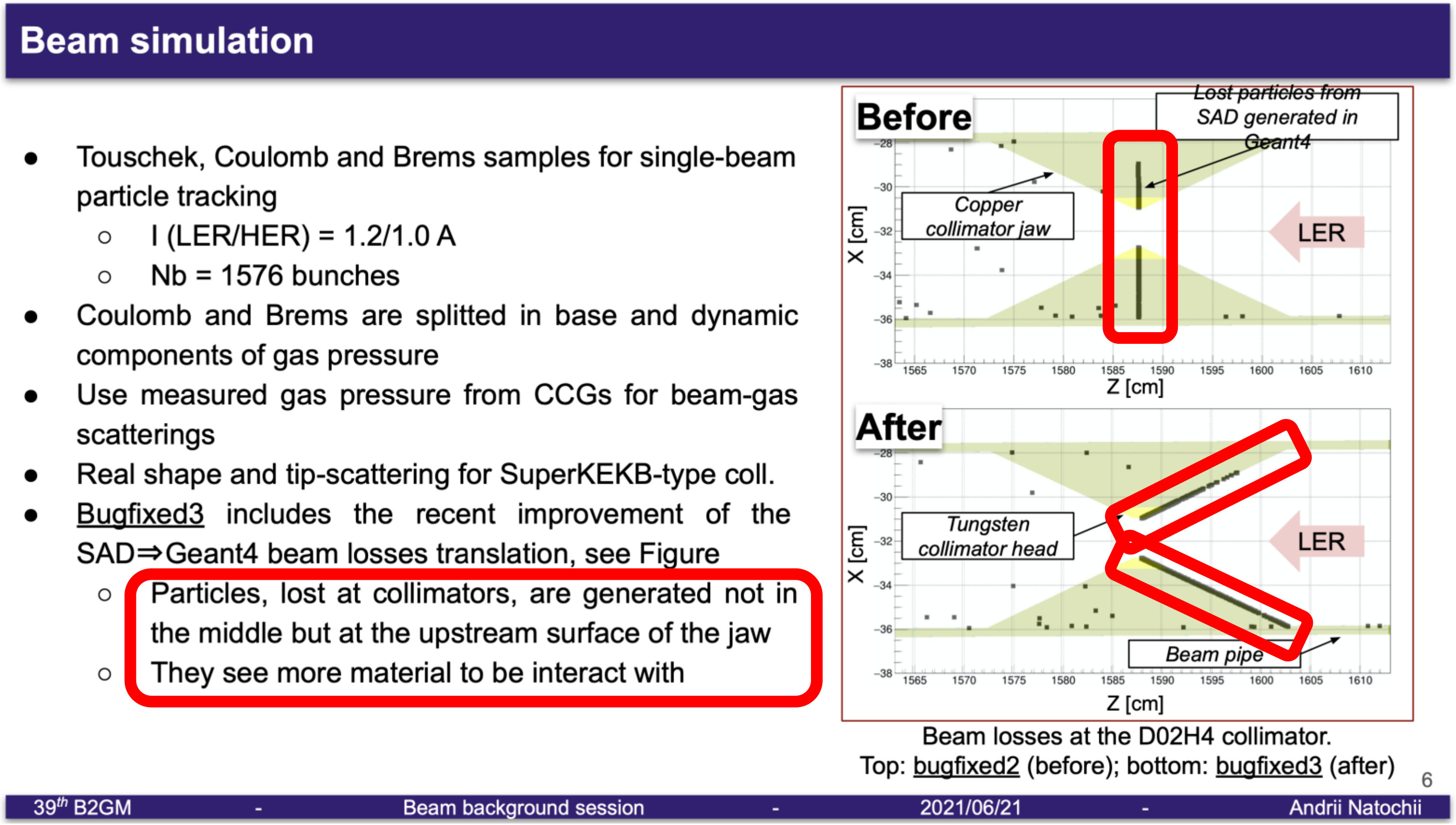
Review by authors / authorship process ongoing

- Z. Liptak et al., *Measurements of Beam Backgrounds in SuperKEKB Phase 2, NIMA*
- M. Hedges et al., First deployment of novel vector tracking nuclear recoil detectors for directional neutron measurements at SuperKEKB, NIMA
- J. Schueler et al., *Directional cavern neutron background measurements at SuperKEKB,* NIMA

Just started / planned

- Phase 3 paper: simulation, data/MC up to now, BG19c forecast, NIMA.
- Snowmass paper: background forecast + mitigation plan to reach 2026. Now due March 15, 2022

Cavern Background Simulation Improvements



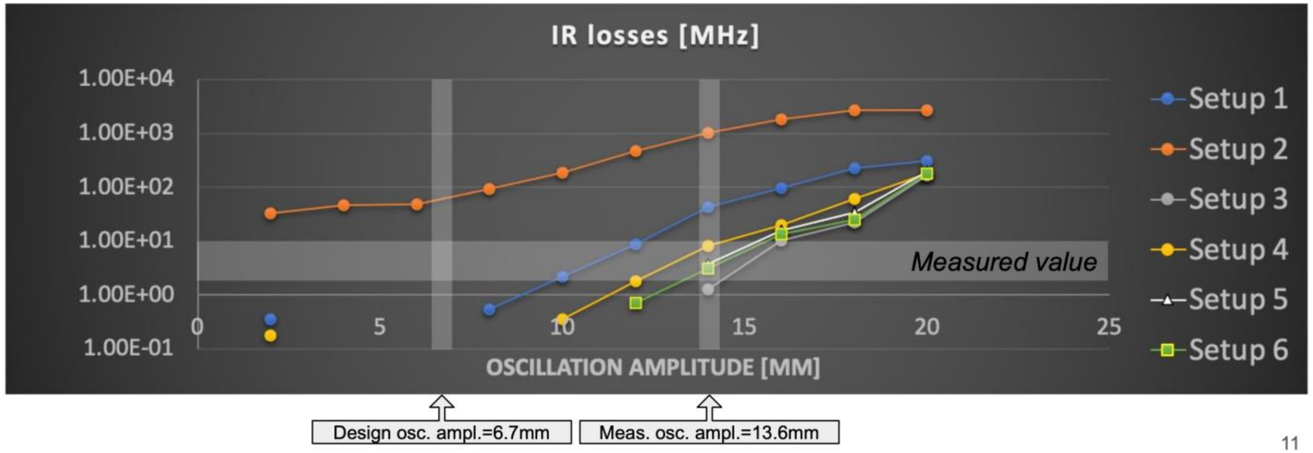
Natochii

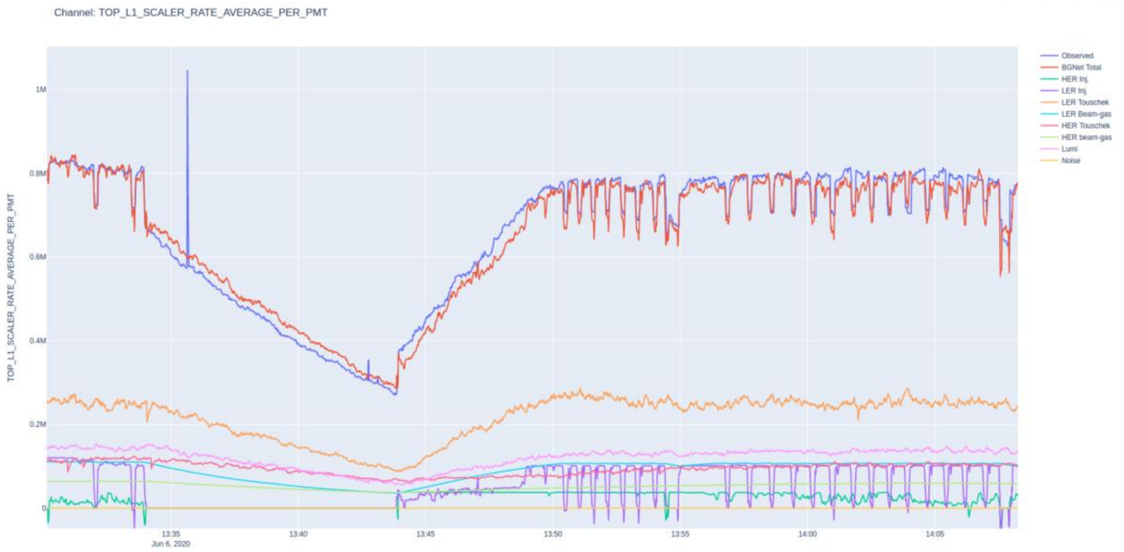
More realistic handling of beam loss at the LER D2H4 collimator

- Initial motivation: significantly affects neutron production in tunnel close to Belle II, and thereby EKLM
- But also found to have subtle effects on other Belle II detectors
- First feedback: TOP ~ no effect, PXD: ~20% reduction in occupancy, CDC: ~20% hit rate increase

Injection Backgrounds

- Two new efforts
  - Natochi: Simulation of injection background now *can* produce IR backgrounds
  - Schwenker: Machine learning can identify injection backgrounds with rather good accuracy
- What we still need
  - Validation of simulated injection backgrounds vs inj. parameters
  - Identify most predictive parameters
  - Method for extrapolating injection backgrounds





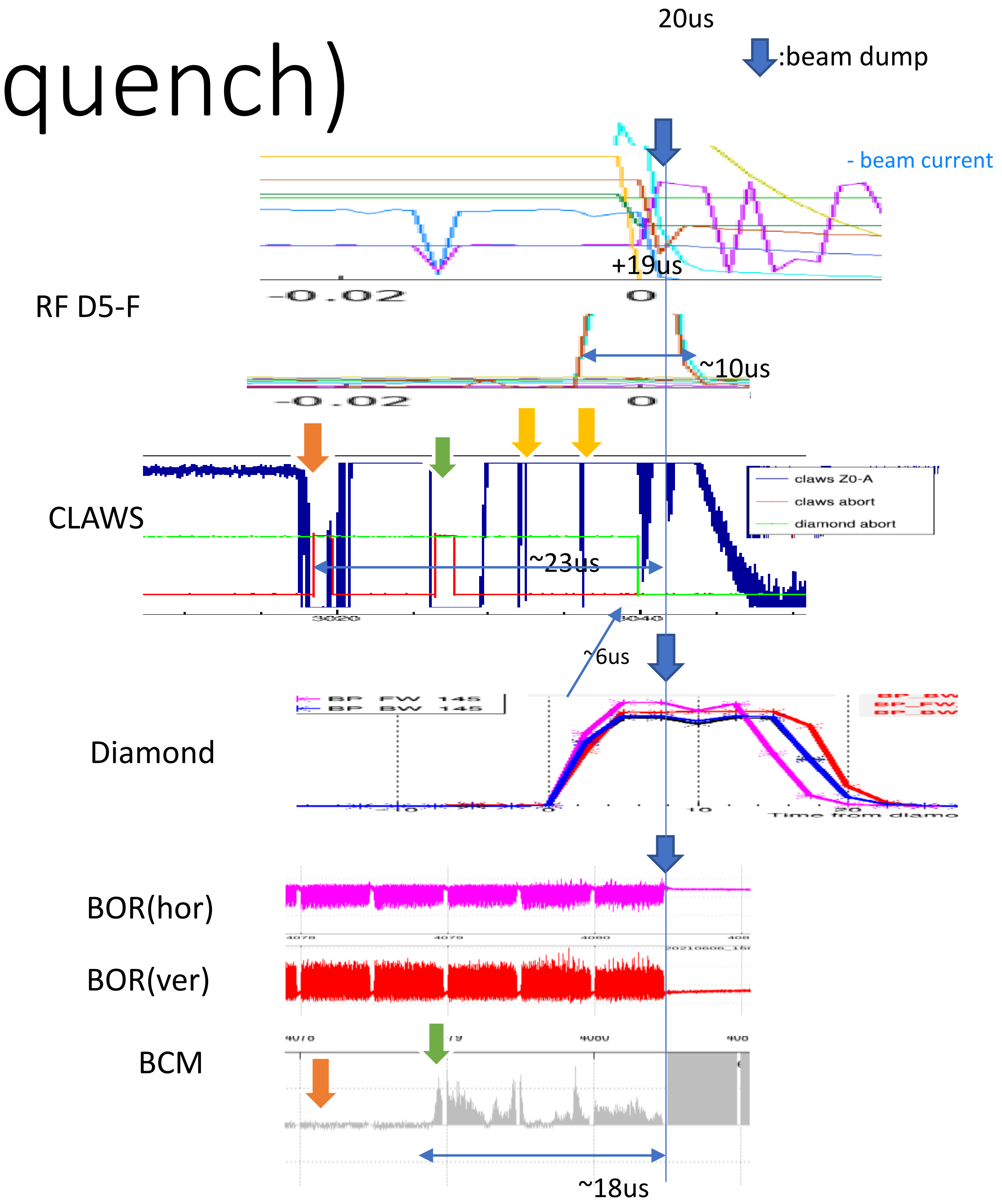
2021/06/06 16:06:10(QCS quench)

RING	MESSAGE	DATE	DELTA
LER	Belle2 CLAWS	2021-06-06 16:06:10.975944300	0.000 000 000
HER	Belle2 CLAWS	2021-06-06 16:06:10.975944400	0.000 000 100
HER	COHSAFE:CCC:ABORT:D2	2021-06-06 16:06:10.975953800	0.000 009 500
LER	COLSAFE:CCC:ABORT:D2	2021-06-06 16:06:10.975953900	0.000 009 600
LER	RF D5-F	2021-06-06 16:06:10.975963300	0.000 019 000
LER	Belle2 VXD diamond	2021-06-06 16:06:10.975965400	0.000 021 100
HER	Belle2 VXD diamond	2021-06-06 16:06:10.975965500	0.000 021 200
LER	COLSAFE:CCC:ABORT:D5	2021-06-06 16:06:10.975968800	0.000 024 500

- **CCRに届いたのはCLAWSが最速。**
- このLERアボートの CCRでのAbortGap 待ち時間は **5.000 us**
- ビームがなくなるのは、1us+10us+5.0us+2.6us+4.7us = **23.3us後**(a→c)
- CLAWSとdiamondのD2到達時間差は21.1usなので、 diamondはCLAWSより15us遅れのバンチを見てアボートを出している。diamondでビームがなくなるのはdiamondがアボートを出したt=0から約8us後になるはず。観測された信号波形では、8us後はflat top(サチってる最中)で、さらに約15usくらいtailを引いている。
- RF D5-Fでは、約1ターン遅れてロスが見え始めている。

- **まとめ：CLAWSが最初にロスを見ている。1ターン遅れでdiamond, RF D-5が反応している。**

- D6,D2のLoss Monitorはどうか？(→池田さん)

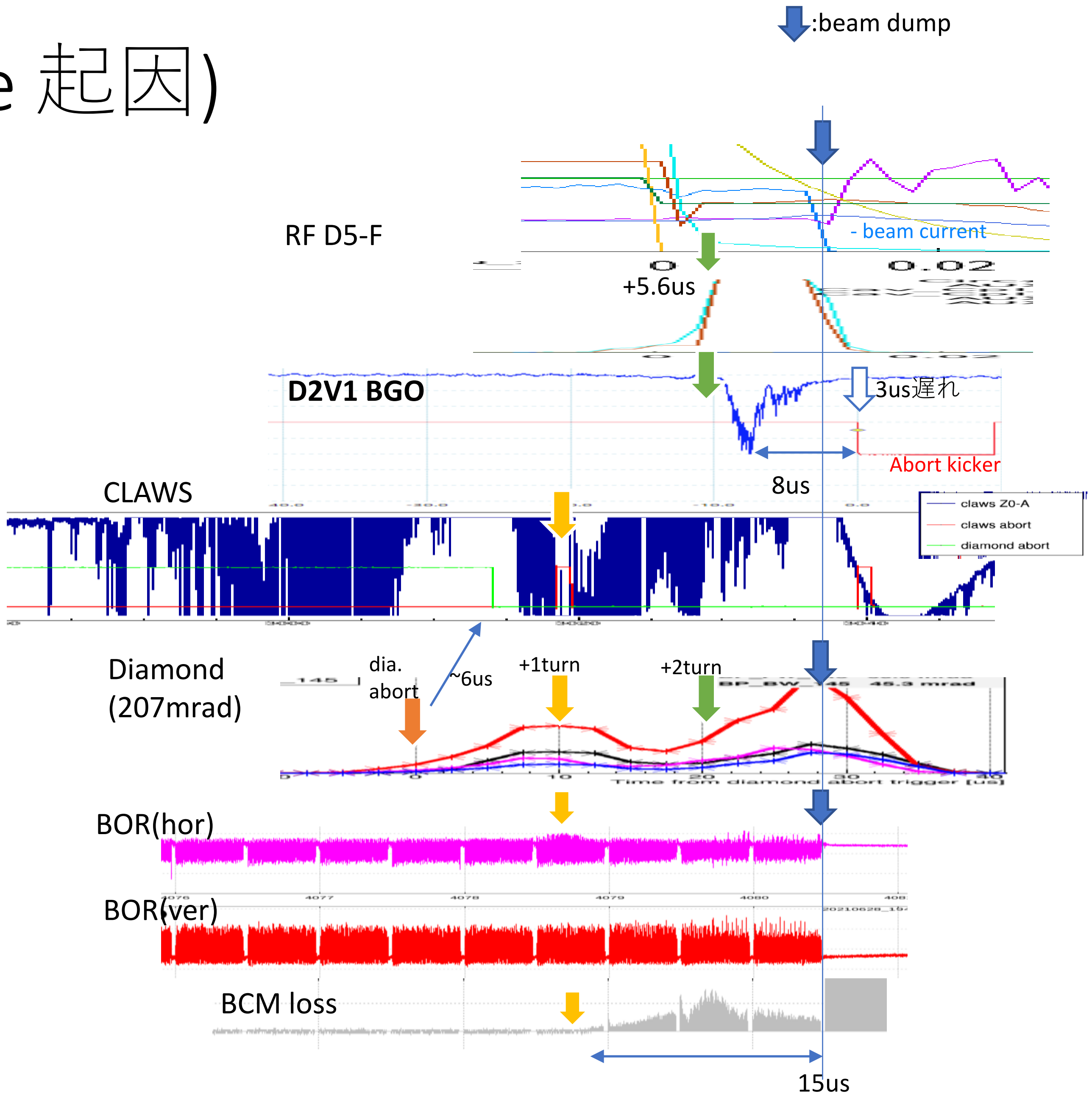


D2V1 BGO 追加
2021/06/28 19:43 (LER storage 起因)

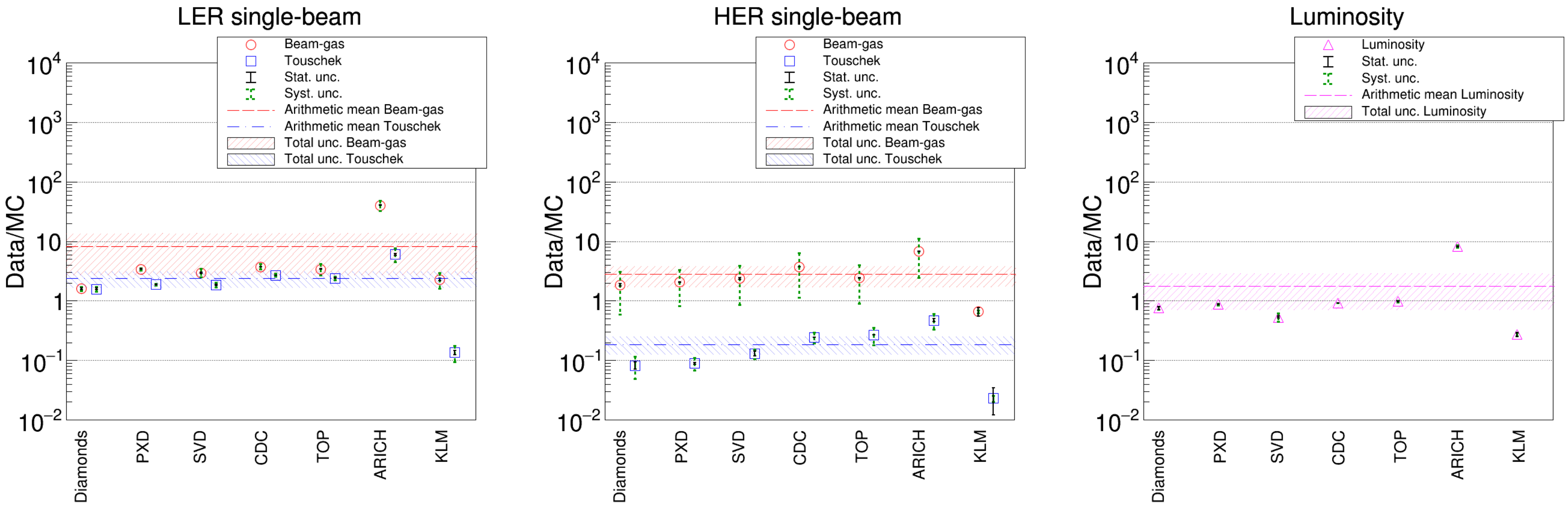
RING	MESSAGE	DATE	DELTA
LER	Belle2 VXD diamond	2021-06-28 19:43:18.074015200	0.000 000 000
HER	Belle2 VXD diamond	2021-06-28 19:43:18.074015600	0.000 000 400
LER	Belle2 CLAWS	2021-06-28 19:43:18.074019800	0.000 004 600
HER	Belle2 CLAWS	2021-06-28 19:43:18.074020200	0.000 005 000
LER	RF D5-F	2021-06-28 19:43:18.074020800	0.000 005 600
HER	COHSAFE:CCC:ABORT:D2	2021-06-28 19:43:18.074024900	0.000 009 700
LER	COLSAFE:CCC:ABORT:D2	2021-06-28 19:43:18.074025200	0.000 010 000
LER	COLSAFE:CCC:ABORT:D5	2021-06-28 19:43:18.074026600	0.000 011 400

- **CCRに届いたのはDiamondが最速。DiamondがCLAWSより早いのは珍しい。**
- このLERアボートの CCRでのAbortGap 待ち時間は **1.864 us**
- Diamondでビームがなくなるのはdiamondがアボートを出したt=0から7us+10us+1.9us+2.6us +4.7us = **26.2us後**(a→c)。観測された信号波形では、28us付近が最大のピークで、さらにtailが8us程度残っているように見える。
- D2V1 BGOでは、abort kicker signal はビームがなくなってから3us遅れてくる。diamondアボートを出したバンチ通過の26.2+3.2 = 29.4us後(a→d)。観測では8us後だから、diamondより2ターン遅れてロスが見え始めていることになる。
- CLAWSとdiamondのD2到達時間差は-4.6usなので、 CLAWSはdiamondより約1ターンあとのバンチを見てアボートを出している。ただし、CLAWS波形を見ると、ダイアモンドと同じバンチでも信号は見えている（閾値以上の持続時間が短かったため、アボートを出し損ねている）。
- RF D5-Fでは、2ターン遅れてロスが見え始めている。
- BORは、diamondより1ターン遅れてhorizontalに揺れ、そのあたりからBCMでビームロスが見え始めている。

- **まとめ：diamond・CLAWSが最初にロスを見ている。1ターン遅れてBORが水平方向の軌道変動を感じ、2ターン遅れでRF D-5, D2V1のBGOが反応している(垂直方向のロス？)。**
- D6,D2のLoss Monitorはどうか？(→池田さん)



Data/MC ratio (2020 measurements)



Data/MC ratio (2020+2021 measurements)