

# MDI-related topics in 2020ab

Hiroyuki NAKAYAMA (KEK)

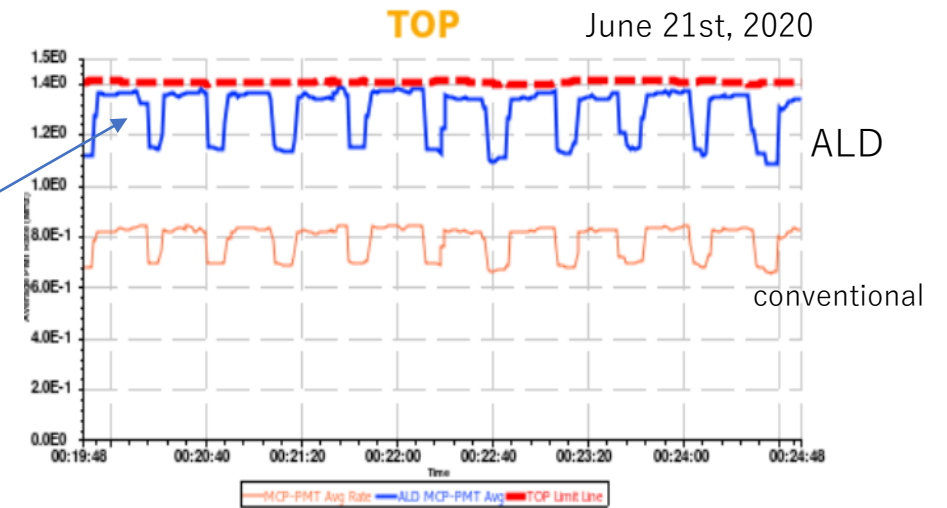
MDI meeting (B2GM satellite parallel session)	
Thursday Jun 18, 2020, 3:00 PM → 6:00 PM Asia/Tokyo	
Hiroyuki NAKAYAMA (KEK IPNS), Yoshihiro FUNAKOSHI (KEK ACCL)	
3:00 PM → 3:30 PM	<b>Overview of MDI-related topics during 2020ab</b> Speaker: Hiroyuki NAKAYAMA (KEK IPNS) 20200618_MDI_Love...
3:30 PM → 3:45 PM	<b>TOP PMT rates during 2020ab</b> Speaker: Kazuki KOJIMA (Nagoya University) 36thB2GMPMTMon... 36thB2GMPMTMon...
3:45 PM → 4:00 PM	<b>CDC operation during 2020ab</b> Speaker: Kota NAKAGIRI (KEK IPNS) Nakagiri_36thB2GM...
4:00 PM → 4:15 PM	<b>Injection BG duration</b> Speaker: Taichiro KOGA (KEK IPNS) koga_injectionveto...
4:15 PM → 4:30 PM	<b>Trigger rate study with single beam run</b> Speaker: Dr Junhao YIN (Korea Univ.) Junhao-BG-B2GM.p...
4:30 PM → 4:45 PM	<b>CLAWS for beam abort</b> Speaker: Ivan Popov CLAWS_BeamAbort...
4:45 PM → 5:05 PM	<b>QCS upgrade</b> Speaker: Norihito OHUCHI (KEK ACCL4) Study of Remodelin...
5:05 PM → 5:35 PM	<b>Open discussion</b>

Satellite MDI session on June 18<sup>th</sup>  
<https://kds.kek.jp/indico/event/34633/>

# Latest beam background status

- LER 720mA, HER 610mA\*, 978 bunch
- Delivered peak luminosity record
  - **2.402** $\times 10^{34}$ /cm<sup>2</sup>/s (June 21<sup>st</sup>, 2020)
  - on-resonance, with Belle II
- TOP PMT rates: **still below limit** 😊
- CDC HV trips: not frequent anymore 😊
- Injection rate: LER 22Hz, HER 25Hz
- Injection veto deadtime: **7~8%** (mainly LER)

\*limited by injection



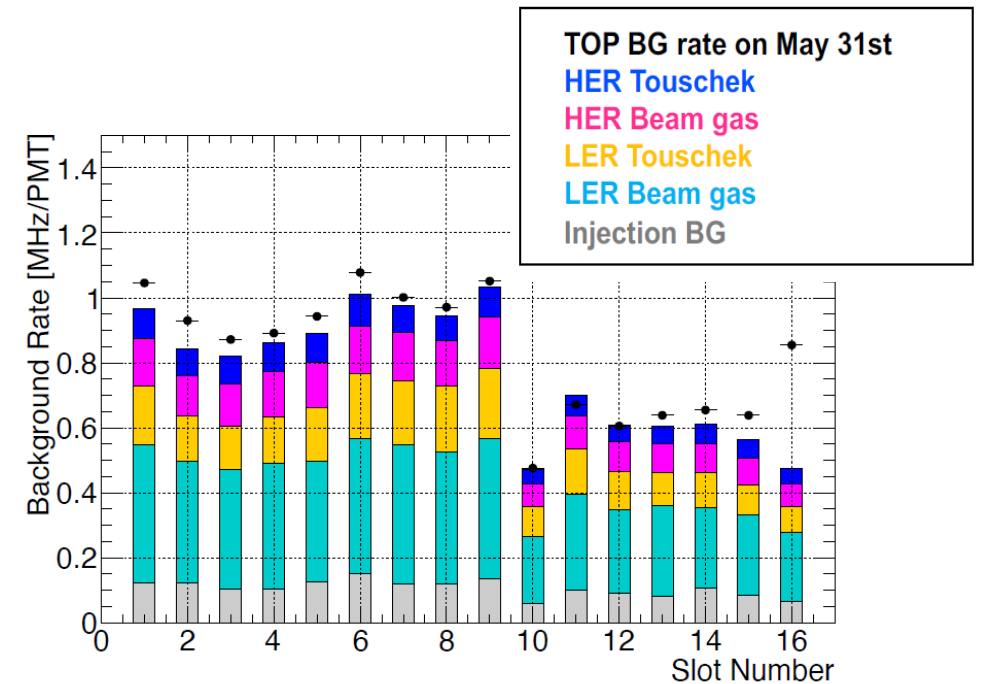
TOP limit (relaxed since June 20th)  
1.0MHz + lumi → **1.2MHz** + lumi

# Major MDI improvements in 2020ab

- New LER vertical collimator (D6V1)
- New LINAC/BT orbit monitor
- New injection BG monitors (CDC/TRG)

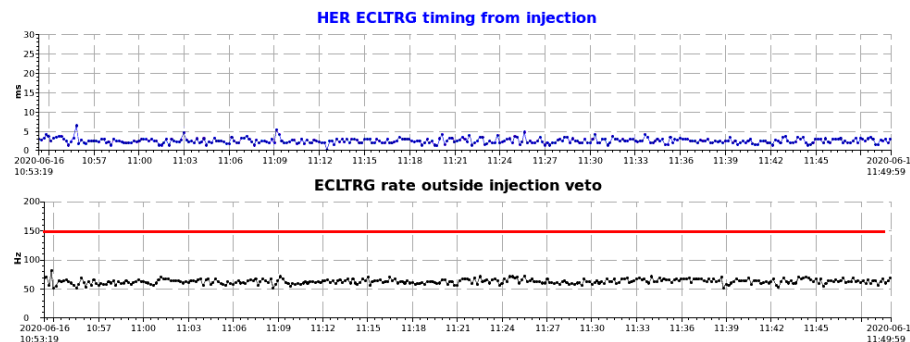
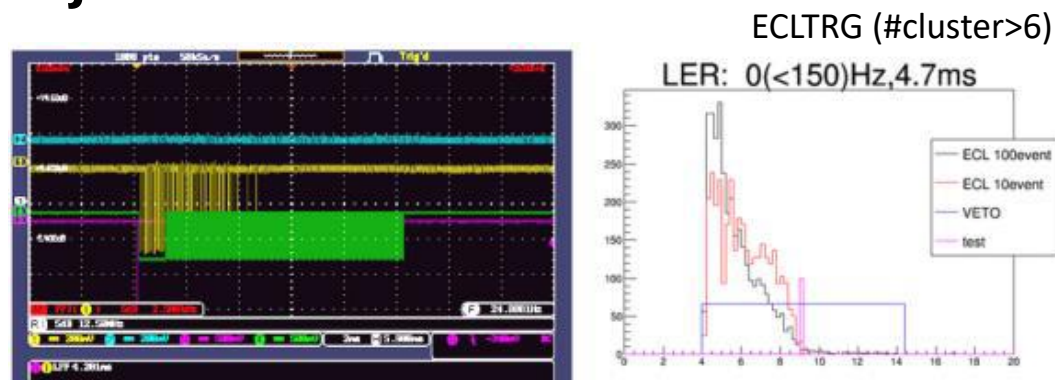
# Improvement: D6V1 and beam-gas BG

- A new LER vertical collimator: D6V1 (good phase, large beta<sub>y</sub>)
- We use D6V1 as “primary” (=narrowest), to protect downstream collimators (D2V1)
- D6V1 head will be replaced with carbon in this summer
- TOP BG by LER Beam-gas has reduced by factor  $x \sim 2$  since 2019c, thanks to:
  - new collimator (D6V1),
  - tighter settings of other collimators,
  - and vacuum baking progress.

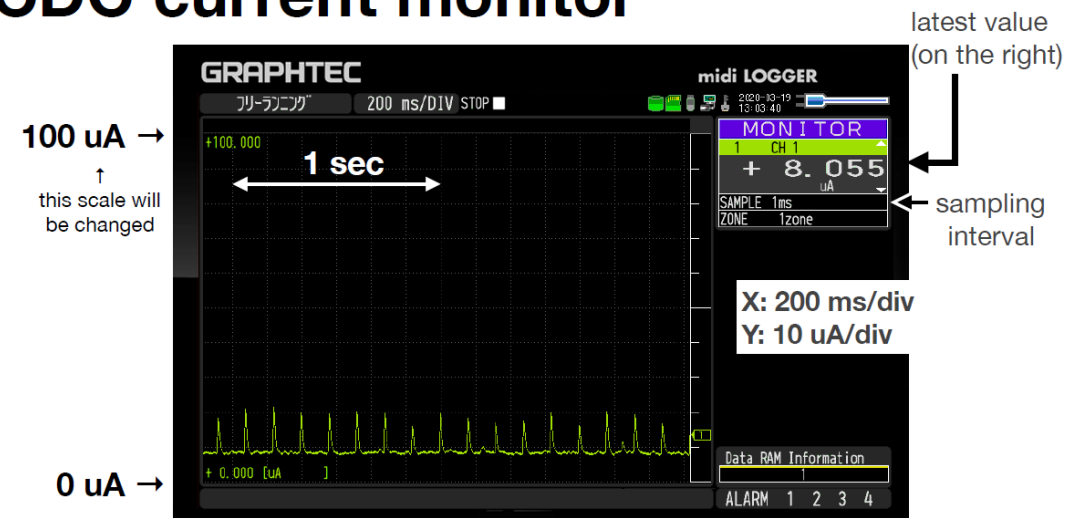


# Improvements: injection BG monitoring

## Injection BG duration monitor



## CDC current monitor



- this monitor shows the leak current of a sector (=1/4) of L15
- snapshot refreshing every 2 sec
- baseline represents storage beam background contribution
- spike structure represents injection background contribution

keep baseline < 30  $\mu$ A and baseline+spike < 80  $\mu$ A

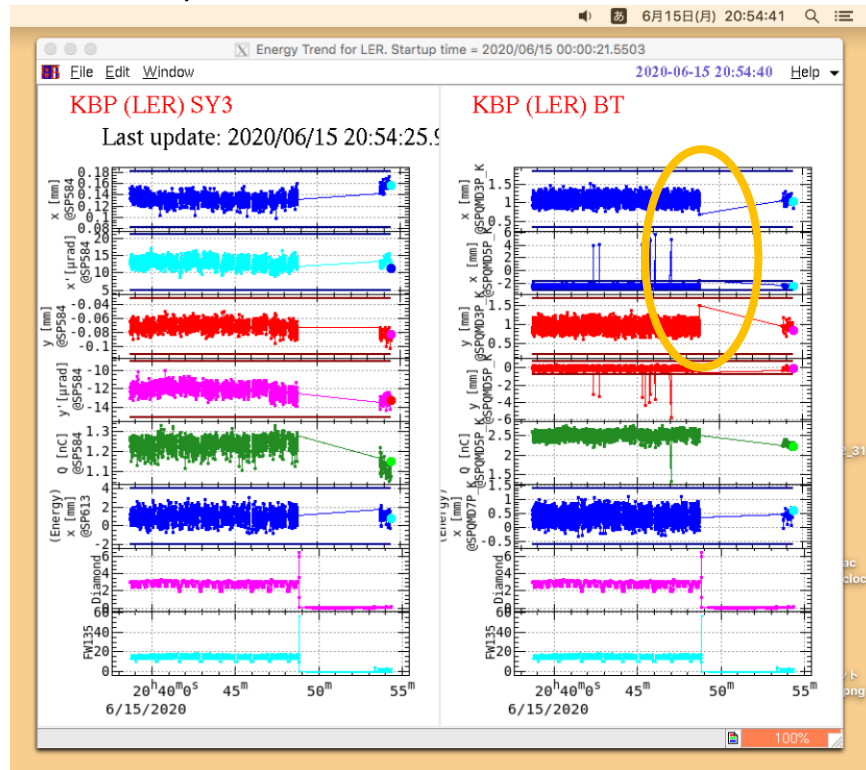
4

These plots are shown in the front display of SKB control room.  
Also available as PVs. Very useful for injection tuning by machine operators.

# Improvements: LINAC/BT monitoring

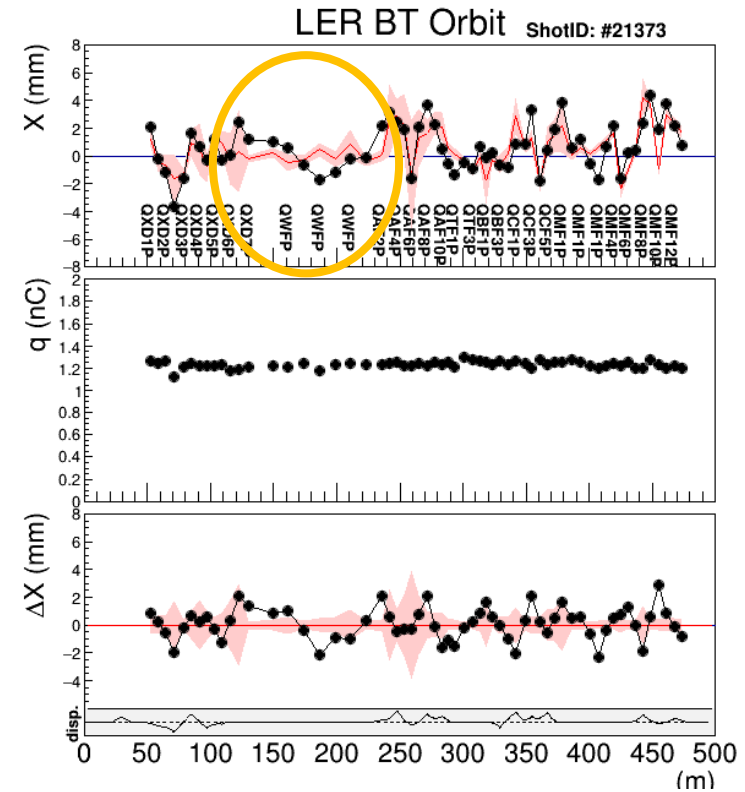
Miyahara,  
Seimiya, Kaji,  
etc..

## LINAC/BT orbit trend



2020/06/15 20:48  
Diamond abort  
Pulse Magnet failure  
(PC\_6,181)

## BT orbit web



Easy to detect injector problems when bad injections are observed.

# Major MDI issues in 2020ab

- QCS quenches (May 24<sup>th</sup>, June 20<sup>th</sup>)
- Beam aborts → machine down time
- Injection BG duration → injection veto dead time
- PXD SR during HER injection
- Collimator issues (activation, impedance)

# Issues: QCS quench on May 27<sup>th</sup>, 2020

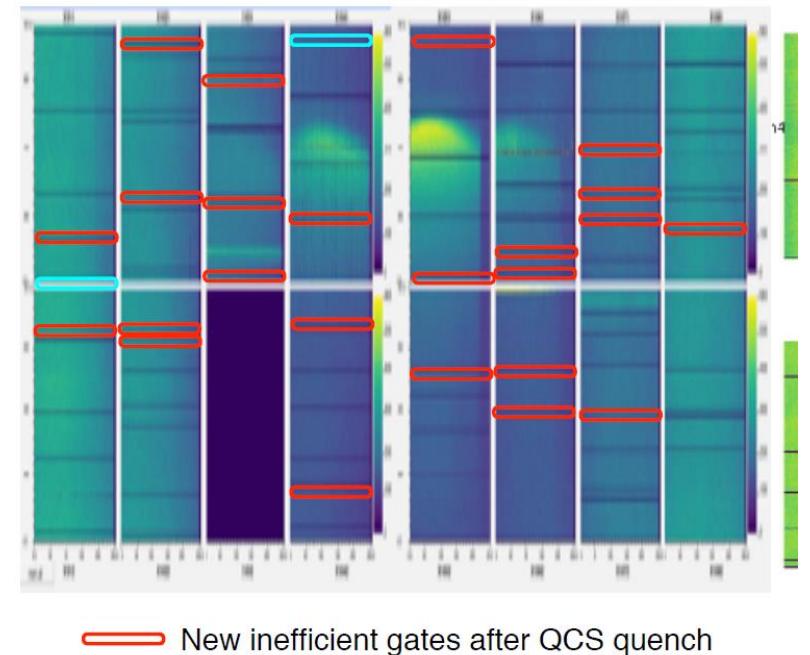
## What happened?

- LER was aborted first. Diamond abort was not issued.
- Diamond system received the abort acknowledge signal and started the data dump.
- **Diamond was blind during this data dump, while still HER is circulating the ring.**
- ~0.7 sec later, iBump fast FB strongly kicked HER beam and caused HER beam loss.
- **It resulted in QCS quench and damage on PXD.**

## Solutions

- Diamond system is modified.
  - **Dump the data only when both beams are aborted.**
- iBump fast FB is also modified
  - **Add the limiter on the FB power supply controller**

PXD after QCS quench in May 27<sup>th</sup>

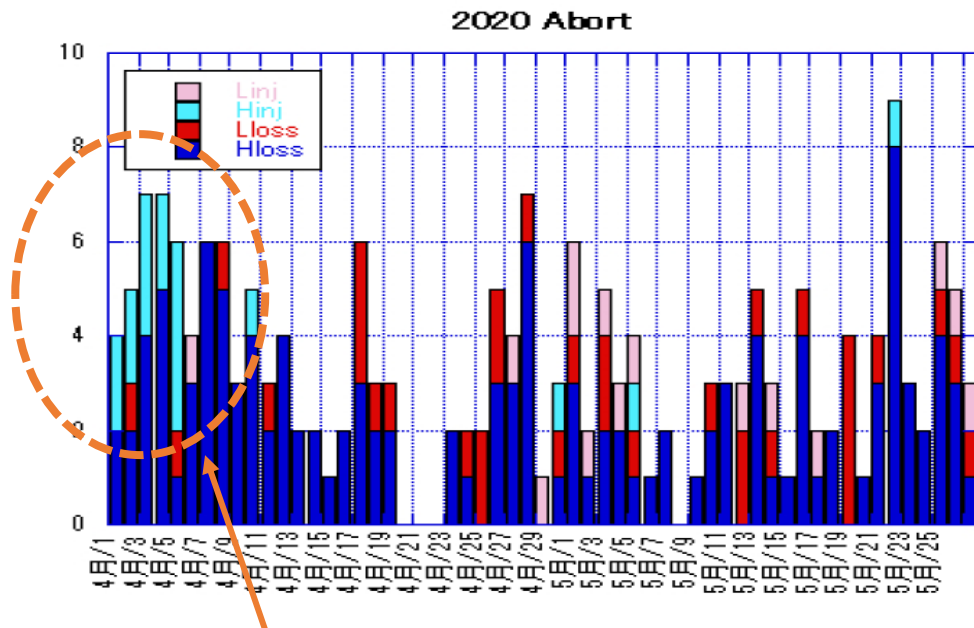


Another QCS quench occurred on June 20<sup>th</sup>. Diamond abort was issued. Caused by small LER vacuum burst?



# Issues: beam aborts

- “Beam abort” taskforce, led by Hitomi Ikeda, to investigate the possible cause of beam aborts and improve integrated luminosity by reducing machine downtime



HER aborts by bad injections  
have disappeared since Apr. 9th

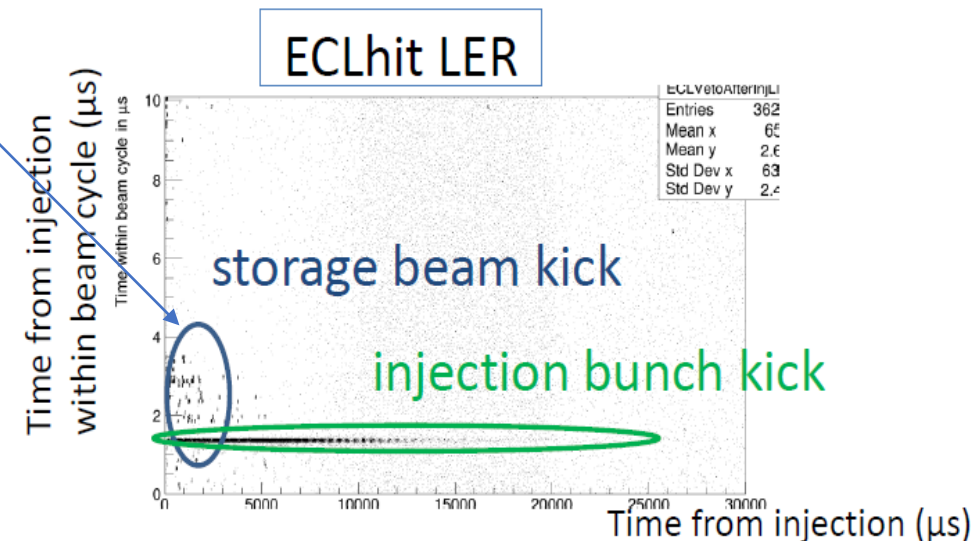
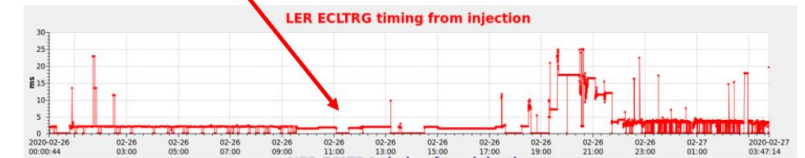
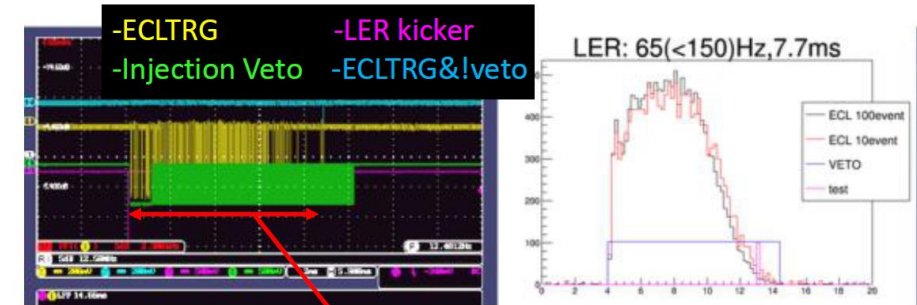
- Beam aborts in-sync with injection has significantly decreased thanks to LINAC group’s effort
- HER beam loss aborts not-in-sync with injections are dominant now.
  - No clear correlation with injection timing  
→ Not caused by “delayed” injection losses
  - Small vacuum bursts? Or any unknown causes?

# Injection BG duration

- Typical duration: **LER: 6~12ms**, **HER:1~6ms**
  - Single beam: BG duration  $\propto$  bunch current
  - Colliding beams: BG duration longer than single-beam
    - beam-beam effect
    - However, luminosity scan w/ v-offset didn't change BG duration...
  - Crab waist strength: no clear dependence
  - beta\*y squeeze: BG duration longer with small beta\*y
- Dedicated machine study shows:
  - **Not only the injected bunch, but also later bunches are lost**
  - However, “blank-shot” injections don't give any BG duration  
 → coupling btw an injected bunch and later bunches?

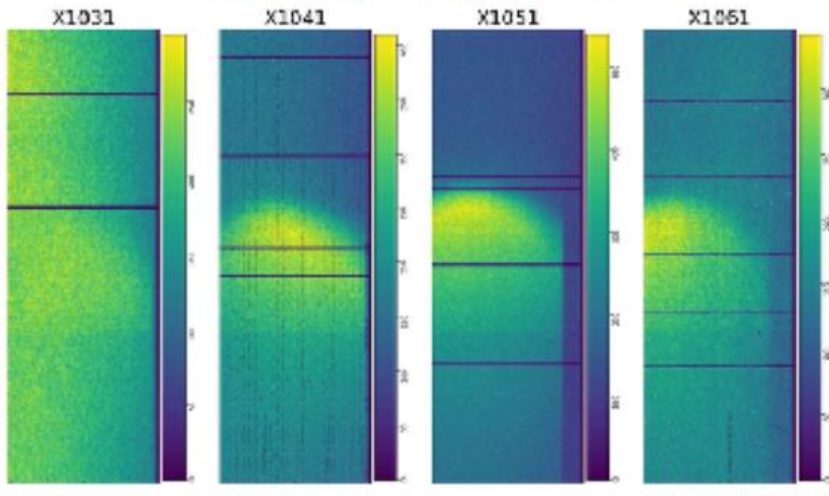
“blank-shot” injection: kickers are fired but no charge is injected

ECLTRG (#cluster>6)



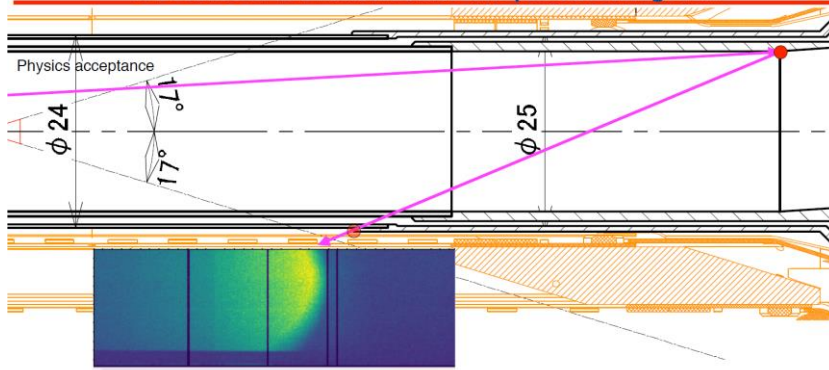
# Issues: PXD SR during HER injection

Online hitmaps for forward -x modules

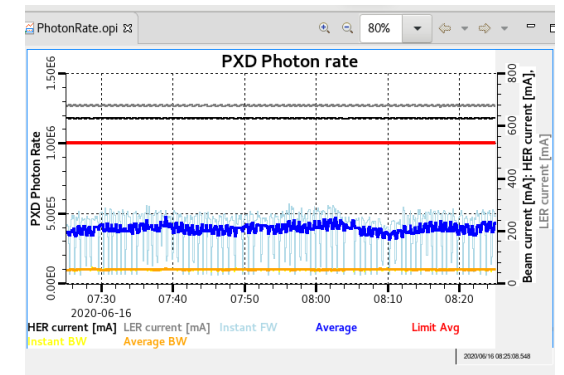


- SR hit pattern on PXD forward -X modules
- Only visible during HER injections
- Becomes stronger when HER beta\*\_x was squeezed
- SR NOT observed with “blank-shot” HER injections
- HER horizontal tune adjustment shows no significant improvement within acceptable tune range
- HER D01H collimator adjustment didn't improve SR
- SR increased with the smaller HER H angle (May 15-31), so we went back to the original angle

SR Source in Forward Modules and possible Mitigation

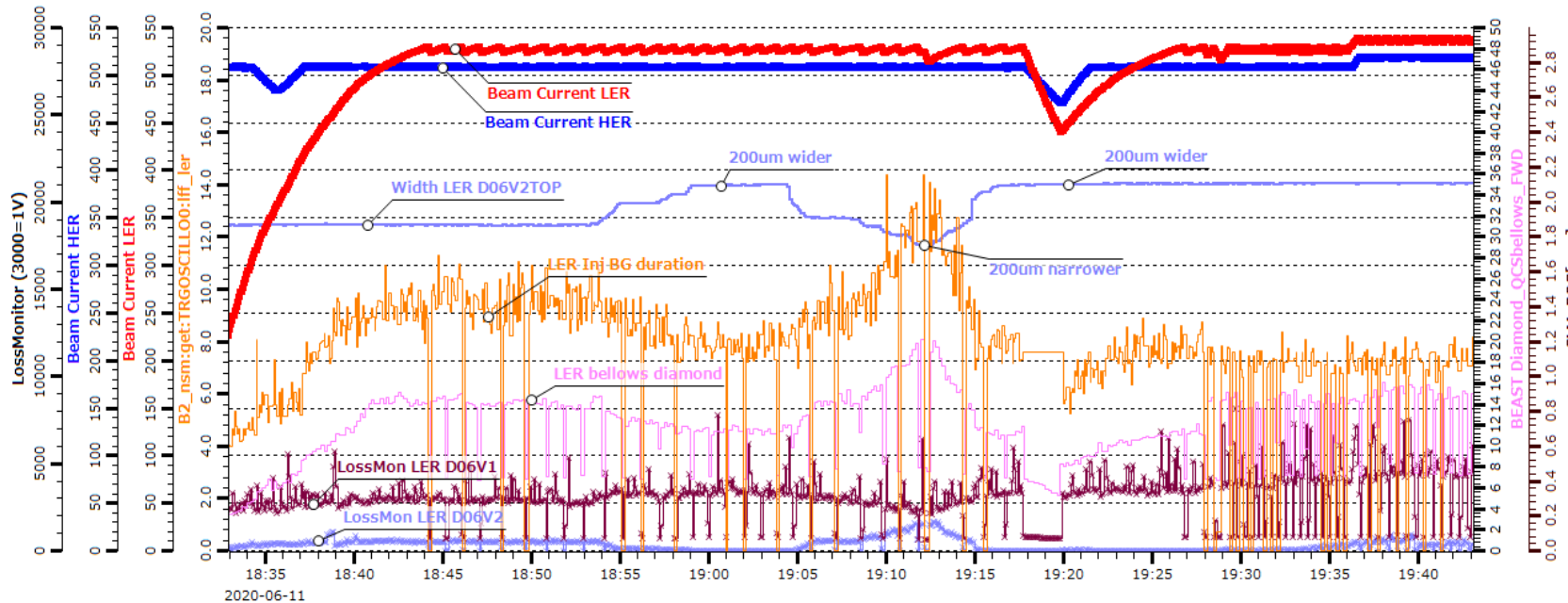


- SR rate PV is now available.
- BCG/PXD experts monitors it.



PXD SR is not critical right now, but we need to keep our eyes on it.

# Issues: LER D6V2 “mystery”



	DIF_POS [mm]	beta_y [m]	nu_y	Nsigma (beta)
D06V1TOP	2.30	67.3	28.86	61.3
D06V1BTM	-2.33	67.3	28.86	62.0
	0.33			
D06V2TOP	2.06	20.6	30.50	99.2
D06V2BTM	-2.11	20.6	30.50	101.3
	0.21			
D02V1TOP	1.28	13.9	44.87	74.6
D02V1BTM	-1.35	13.9	44.87	78.8
	0.16			
QC1 (1.12m)	13.5	782.2	46.34	105.3
				11.1

- When we **opened** D6V2, injection BG duration (and injection BG on diamonds) **improved**.
- Now we use ~400um wider D6V2 settings.

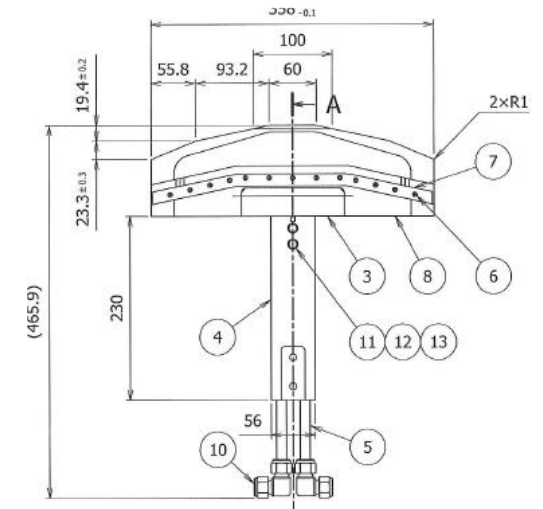
## Why?

- Tip-scattering of injection charge? → seems unlikely to reach IR from D6 or affect BG duration.
- **Collimator impedance issue?** (why only in D6V2?)

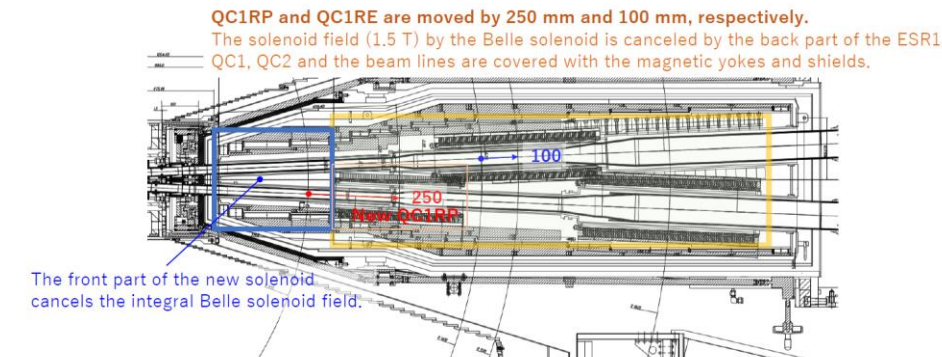
# Ongoing projects for further improvements

- Collimator works in mid-September 2020
  - **Replace D6V1 with carbon head, install LER D3V1 collimator**
  - Simulation study including tip-scattering is ongoing
- LINAC works aiming for **higher beam currents**
  - LER injection at 18Hz, 2-bunch injections
  - Increase injection charge while keeping good emittance
- **Additional shield around QCS bellows**
  - Further BG reduction for TOP/CDC
  - K. Nakamura's [report](#) in background session
- **QCS remodeling**
  - Wider beam pipe aperture. More space to add tungsten shield?
  - Ohuchi-san's [report](#) at MDI session
- VXD diamond & beam abort system upgrade (RMBA task force)
  - [A dedicated B2GM parallel session](#) on June 24th

Carbon collimator head for D6V1



QCS remodeling





# Summary

- New LER collimator(D6V1) → works very well to reduce BG
- QCS quench → problems found and already fixed
- Beam aborts → much less injection-related aborts
- Injection BG duration → better understandings now
  
- Several projects ongoing, for further BG improvement  
(new collimators, additional shield, QCS remodeling, etc..)

backup

# Machine study plan in remaining 2020b run

- HER/LER single-beam BG studies + lumi-BG study (June 27<sup>th</sup> day)
  - Similar with May 9th study, but with the latest optics (hopefully at  $\beta^*y=0.8\text{mm}$ )
  - Will be used to background extrapolation for future optics
- Collimator study (June 18th)
  - Try to open collimators with large activation
  - Injection tuning with wider collimator settings (use Belle II diamond as a tuning guide)
- Injection studies (June 24<sup>th</sup> swing)
  - 2-bunch injection challenge
    - LER BTend feedback using the average orbit of 1st/2nd bunch
  - PXD SR vs. injection charge, iBump height
  - Synchrotron injection challenge (2020c?)



# MDI

## Issues in 2020ab

- Beam aborts
  - Machine down time → luminosity loss
  - Aborts by bad injections are significantly decreased
  - HER aborts not-in-sync with injection are dominant (causes still unknown)
- Injection BG duration
  - Veto deadtime → luminosity loss
  - Trying to understand its mechanics by systematic machine studies
- QCS quench on May 27th
  - Problem in machine FB system and diamond abort system are already fixed
- PXD SR
  - PXD sensors on -X side see SR hit pattern, back-scattering from +Z?
- Collimator activation
- Collimator impedance issue?

## Improvement plans

- Collimator enforcement
  - LER D6V1 → carbon head
  - Add LER D3V1
- Higher beam currents
  - 2-bunch injection, LER 18Hz injection
  - Larger injection charges with good emittance
- Add QCS bellows shield
  - Mechanical design/ simulation ongoing
- Radiation monitor/beam abort upgrade
  - RMBA taskforce
- QCS remodeling
  - Luminosity improvement
  - Less single-beam BG

# Issues: activation of collimators

- LER survey (June 2020)

D06H3 : 400  $\mu\text{Sv/h}$

D06V1 : 400  $\mu\text{Sv/h}$

D06V2 : 260  $\mu\text{Sv/h}$

D02V1: 130  $\mu\text{Sv/h}$

D02H3: 950  $\mu\text{Sv/h}$

- D6V1: “primary”  
(=narrowest) LER vertical collimator
- D2V1: Low activation is thanks to D6V1

	DIF_POS [mm]	beta_y [m]	nu_y	Nsigma (beta)	LM
D06V1TOP	2.60	67.3	28.85	69.3	0.07
D06V1BTM	-2.61	67.3	28.85	69.6	
	0.33				
D06V2TOP	1.79	20.6	30.49	85.8	1.28
D06V2BTM	-1.83	20.6	30.49	88.2	1.35
	0.19				
D02V1TOP	1.32	13.9	44.86	77.1	0.00
D02V1BTM	-1.33	13.9	44.86	77.7	
	0.17				
QC1 (1.12m)	13.5	782.2	46.33	105.3	
				10.8	Dia QCSFW

- HER survey (Apr. 2020)

D09V4 : 80 $\mu\text{Sv/h}$       D12V1    200 $\mu\text{Sv/h}$

D09H4 : 60 $\mu\text{Sv/h}$       D12H1    15 $\mu\text{Sv/h}$

D09V3 : 40 $\mu\text{Sv/h}$       D12V2    35 $\mu\text{Sv/h}$

D09H3 : 9 $\mu\text{Sv/h}$         D12H2    20 $\mu\text{Sv/h}$

D09V1 : 380 $\mu\text{Sv/h}$       D12H3    65 $\mu\text{Sv/h}$

D09V2 : 15 $\mu\text{Sv/h}$       D12V3    350 $\mu\text{Sv/h}$

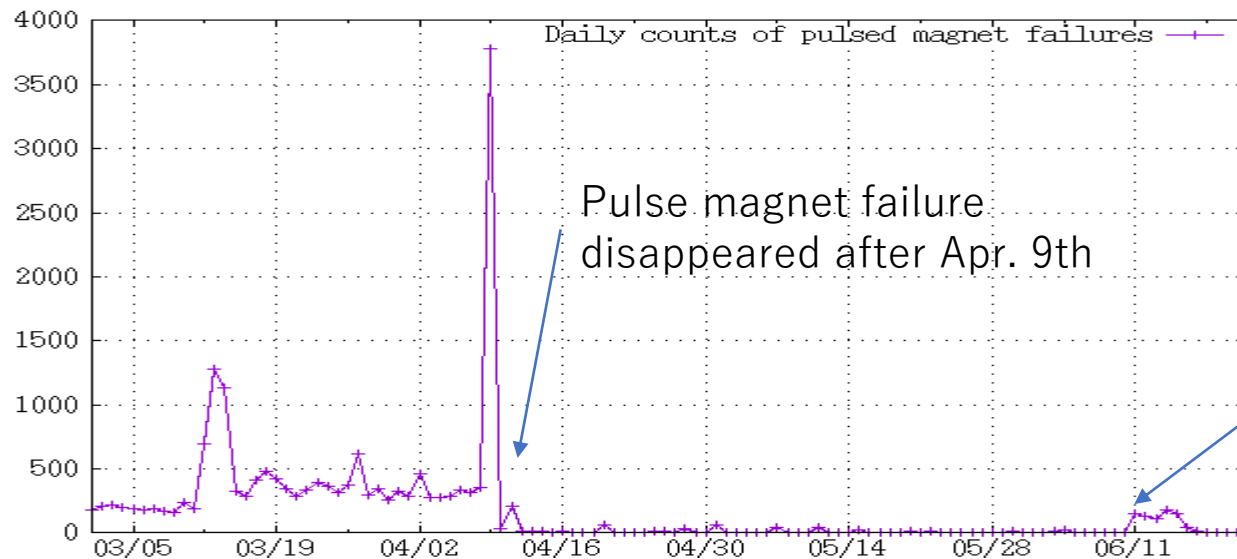
D09H1 : 25 $\mu\text{Sv/h}$       D12H4    45 $\mu\text{Sv/h}$

D09H2 : 75 $\mu\text{Sv/h}$       D12V4    2 $\mu\text{Sv/h}$

- HER D09V1(and D12V1,3) show large activation, but the loss monitors at those collimators show small values
- Several collimators are opened, especially ones with higher activation, by carefully looking at injection BG

# Issues: injection-related beam aborts

- **Pulsed magnet misfire** events caused many (HER) beam aborts in March/early April.
- The control software replacement on April 9<sup>th</sup> → **misfire reduced significantly**.
- HER aborts in-sync with injection have completely disappeared.
- LER aborts in-sync with injection still exist. Some are due to **LINAC Klystron down**.



**RF gun pressure bursts** cause HER injection spikes in VXD diamonds, but they do not cause beam aborts so far.

During June 11-16<sup>th</sup>, pulse magnet misfire event appeared again We see **LER** aborts due to bad injections.

# Weekly beam abort counts

Nakayama

HER aborts in-sync with injections due to LINAC pulse magnet misfires (till April 9th)

LER aborts in-sync with injection due to LINAC Klystron down or other unknown reasons

**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	
4/1~7	26	7	3	0	0	3	0	1	40	
4/8~15	19	0	3	0	0	0	0	3	25	
4/16~23	9	0	3	0	0	2	1	2	17	
4/24-30	13	0	8	1	8	0	6	3	39	4/24~ HER CW start
5/1-7	12	0	3	5	3	2	5	1	31	
5/8-14	11	0	5	2	0	2	1	0	21	5/11~14 off resonance
5/15-20	8	0	7	0	1	1	2	1	20	5/14~31 HER angle
5/21-27	18	0	5	2	1	0	0	6	32	5/21~ LER high $\epsilon_x$
5/28-6/3	10	0	5	1	0	7	0	1	24	
6/4-11	9	0	8	0	0	0	1	2	20	6/11 D6V2 open
6/12-17	10	0	15	8	0	2	2	2	39	6/10~16 off resonance

What is the cause of those HER aborts **not** in-sync with injections?

Due to higher beam currents? or D6V2 open on 6/11?

LINAC pulse magnet misfires appeared again (June 11-)

# CDC HV trips – much less frequent now

## # of TRIP events in 2020 run

**Mar.**

日曜	月曜	火曜	水曜	木曜	金曜	土曜
					1	1
	1					
						1
		1	3			
2		1				

**Apr.**

日曜	月曜	火曜	水曜	木曜	金曜	土曜
					1	
1						
				1	4	1
	1					

**May**

日曜	月曜	火曜	水曜	木曜	金曜	土曜
					1	
						2
					1	

**Jun.**

日曜	月曜	火曜	水曜	木曜	金曜	土曜
					1	
1						

- Only few CDC HV trips in 2020ab (using higher trip thresholds)
- Inner layers( $\in$ SL0) were tripped
- Mostly caused by HER injections
- Trip frequency seems to be decreasing over time, although the beam currents gets higher
- Still acceptable trip rates at higher beam currents?

# VXD abort modification after QCS quench

Yifan Jin

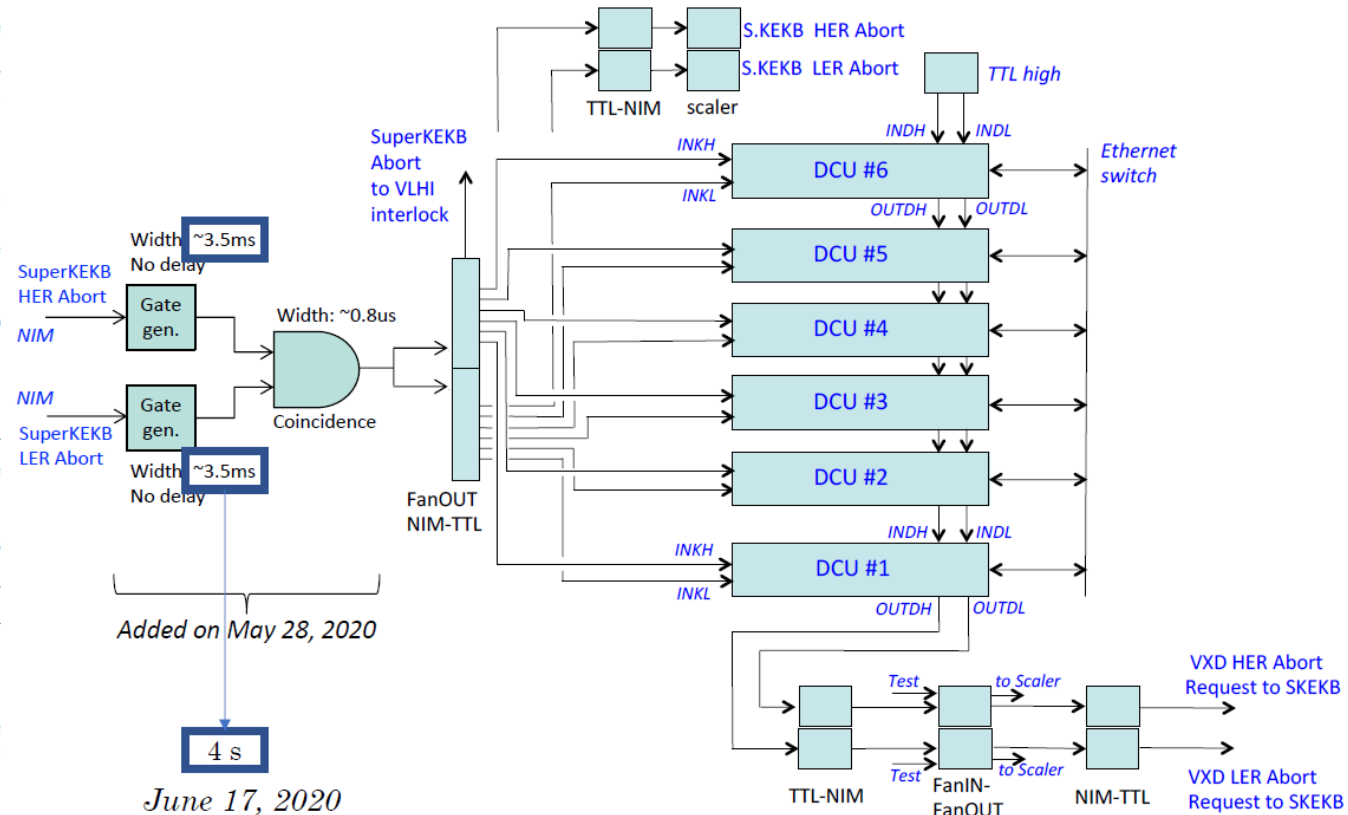
To avoid blind time

From May 28<sup>th</sup> 2020, we have applied a coincidence module on the incoming “SKB LER(HER) abort timing” signals.

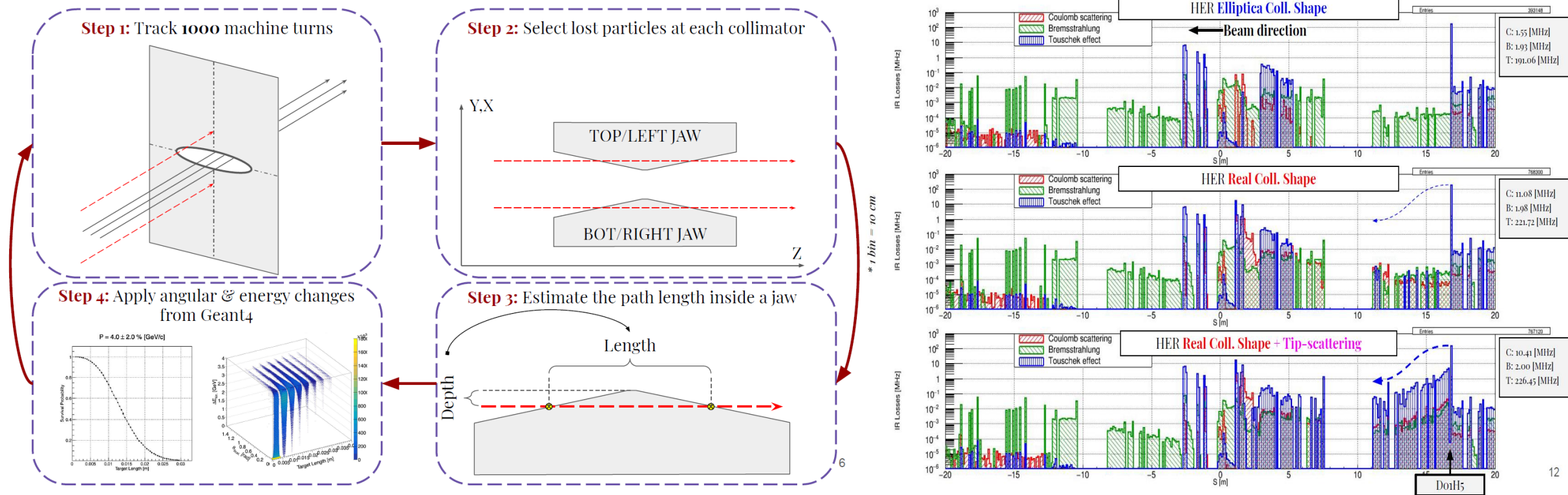
“SKB LER(HER) abort timing” are rather short, 10  $\mu$ s. We extend them before coincidence. Initially, we extended them to 3.5 ms.

If “SKB LER abort timing” and “SKB HER abort timing” have separation larger than 3.5 ms, the Diamond system would not receive the coincidence => would not dump memory file => would not be blind.

On June 17, we extended the “SKB HER/LER abort timing” signal width to 4 s.



# Beam loss simulation with collimator tip-scattering



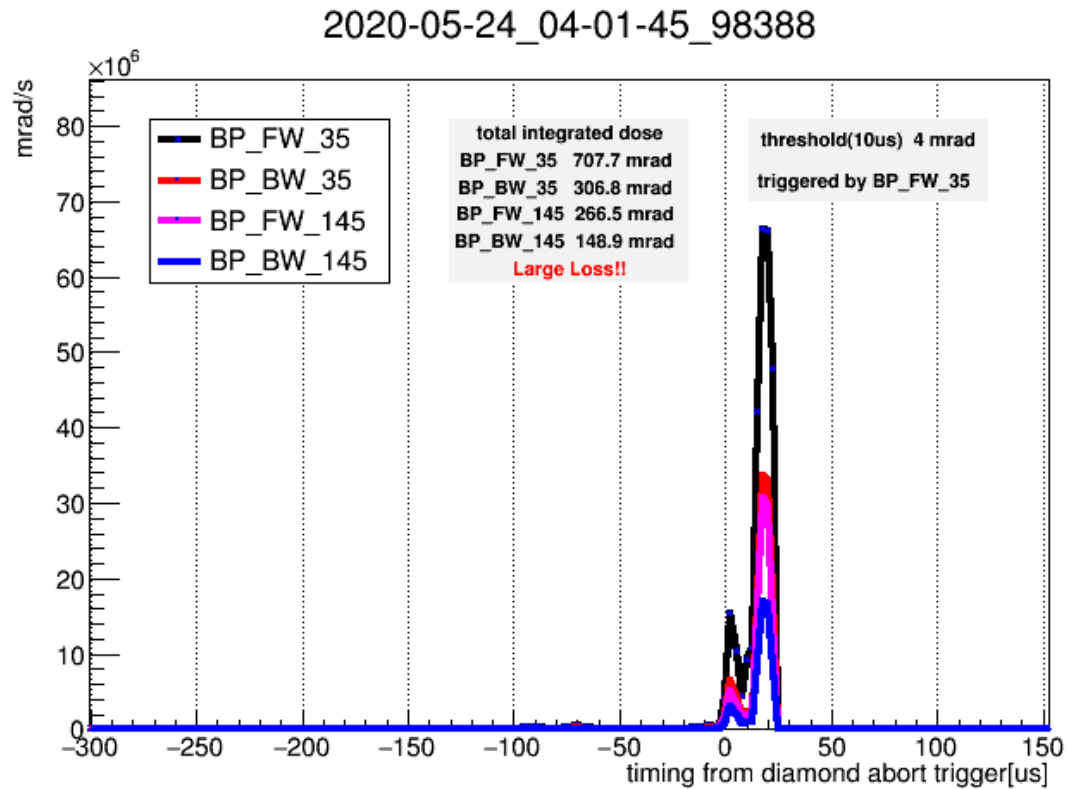
Simulated IR loss rate of HER Touschek/Coulomb significantly increases by using realistic collimator shape and adding tip-scattering effect

→ data/MC discrepancy is relaxed

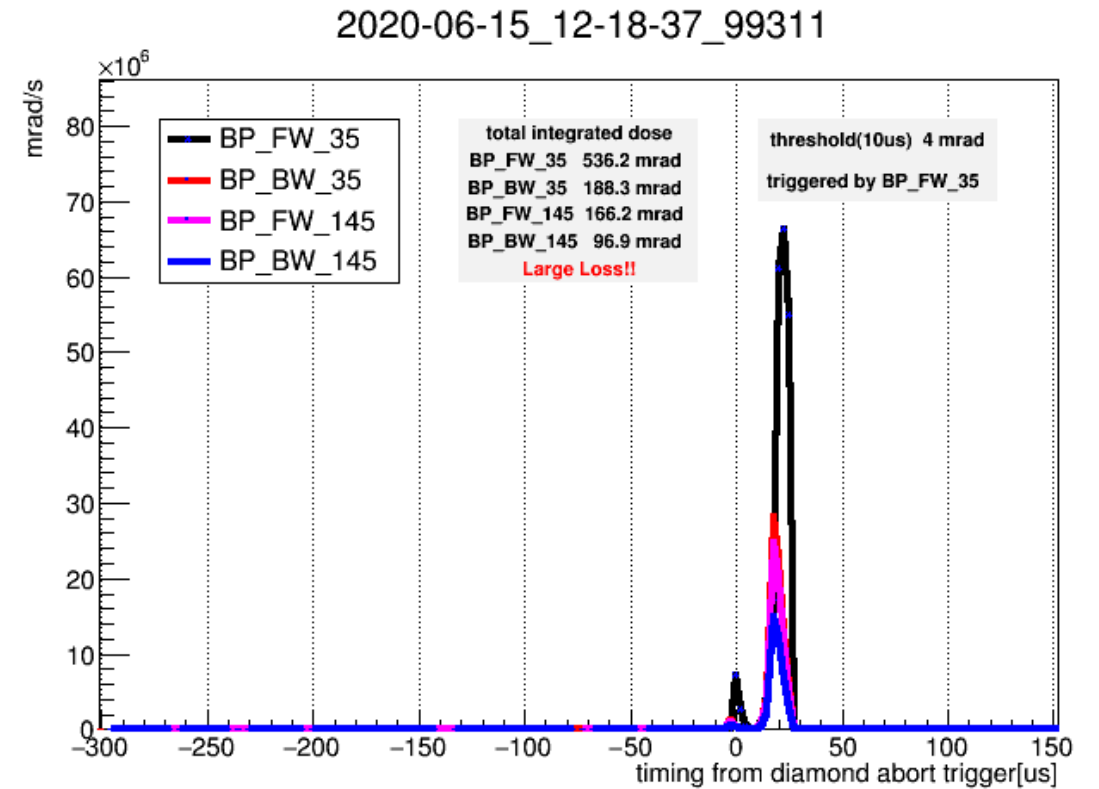
[Link to Andrii's slides at MDI meeting, June 11th](#)



# Diamond abort with large loss



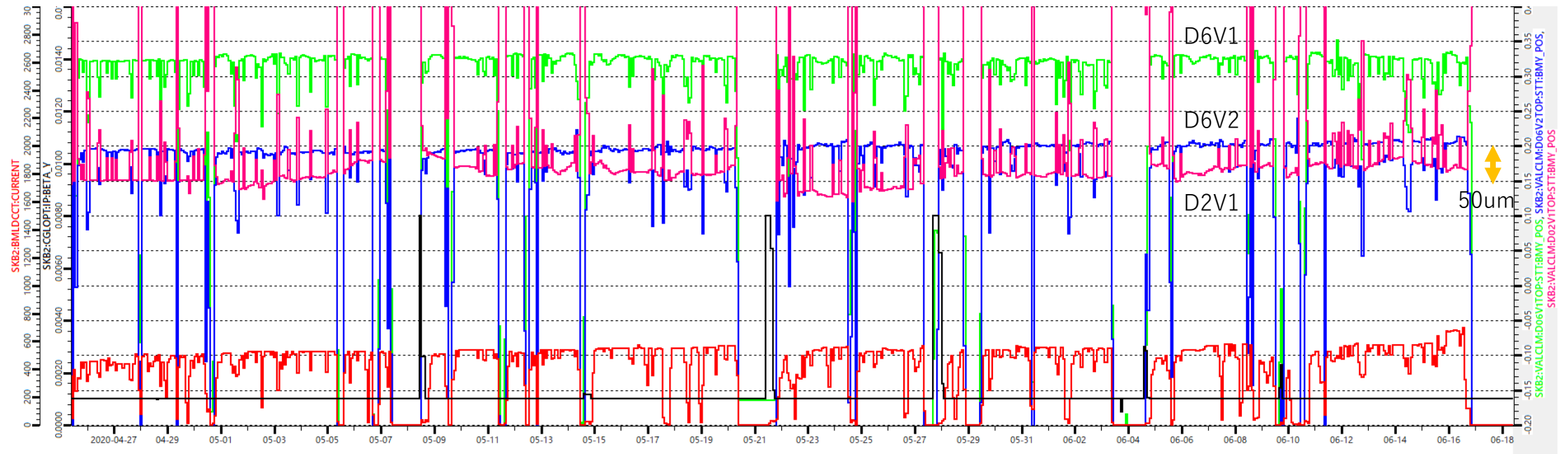
Small pressure burst ( $\sim 5.5 \times 10^{-8}$  Pa) at HER D01\_H10



Small pressure burst ( $\sim 8 \times 10^{-8}$  Pa) at HER D01\_H15



# Beam orbit drift on LER D2V1



# MR collimator installation plans (from Ishibashi-san)

- We plan to replace D06V1 during this summer shutdown. However, the delivery date of the low-Z heads is this mid-September, and we want to bake-out the collimator in-situ after the installation (it takes for about 1-2 weeks), so there is a possibility that it won't install the low-Z heads depending on the starting time of 2020c run.
- We have started manufacturing a vertical collimator for LER and plan to install it at D03V1 during this summer shutdown (mid-September maybe) so far. Then, we can change the installation site if required.

# Long-term Radiation Monitor & Beam Abort w.g.

- RMBA working group, started in Feb. 2020 at the 35<sup>th</sup> B2GM

## Membership:

representatives from Belle II subsystems and SuperKEKB; open to participation coordinated by L.Vitale (INFN and Univ. Trieste)

## Charge:

study of long-term future of beam-loss (BL) radiation monitoring and beam abort in the interaction region

Initial focus: upgrade of the diamond system electronics

## Preliminary work plan:

Review of existing BLM systems at colliders; update of requirements and specifications for Belle II / SuperKEKB; comparison of upgrade options

- Documentation, meetings, mailing list

<https://confluence.desy.de/display/BI/Long-term+future+of+Radiation+Monitoring+and+Beam+Abort>

# RMBA working group: meetings

- **1<sup>st</sup> meeting, May 29<sup>th</sup>, 2020:** <https://indico.belle2.org/event/2287>  
W. Viganò, E.Calvo Giraldo (CERN): “The BLM system of the LHC injector complex”  
I. Popov (MPI Munich): “CLAWS for beam abort in SuperKEKB”
- **2<sup>nd</sup> meeting, June 11<sup>th</sup>, 2020:** <https://indico.belle2.org/event/2373>  
M.Tortora, P.Scarbolo (CAENels): “MTCA beam abort at IBS and future developments”
- **Next meeting (B2GM): June 24<sup>th</sup>, 2020 at 14:00 JST**  
H. Ikeda (KEK): “Beam loss monitor and beam abort at SuperKEKB”  
(discussion: drafts of requirements for upgrades; organization)
- **Main present discussion topics:**  
*Diamond electronics upgrade:* dynamic range in current measurements, access to buffer memories without disabling beam abort, synchronization and integration with SuperKEKB  
*Update of requirements,* comparison of upgrade options  
*New opportunities,* for instance CLAWS beam abort