Beam Background

Contents:

- Improved monitoring and diagnostics
- Phase 3 Background composition
- How to reduce backgrounds further?
- Data versus MC
- Extrapolation for 2020

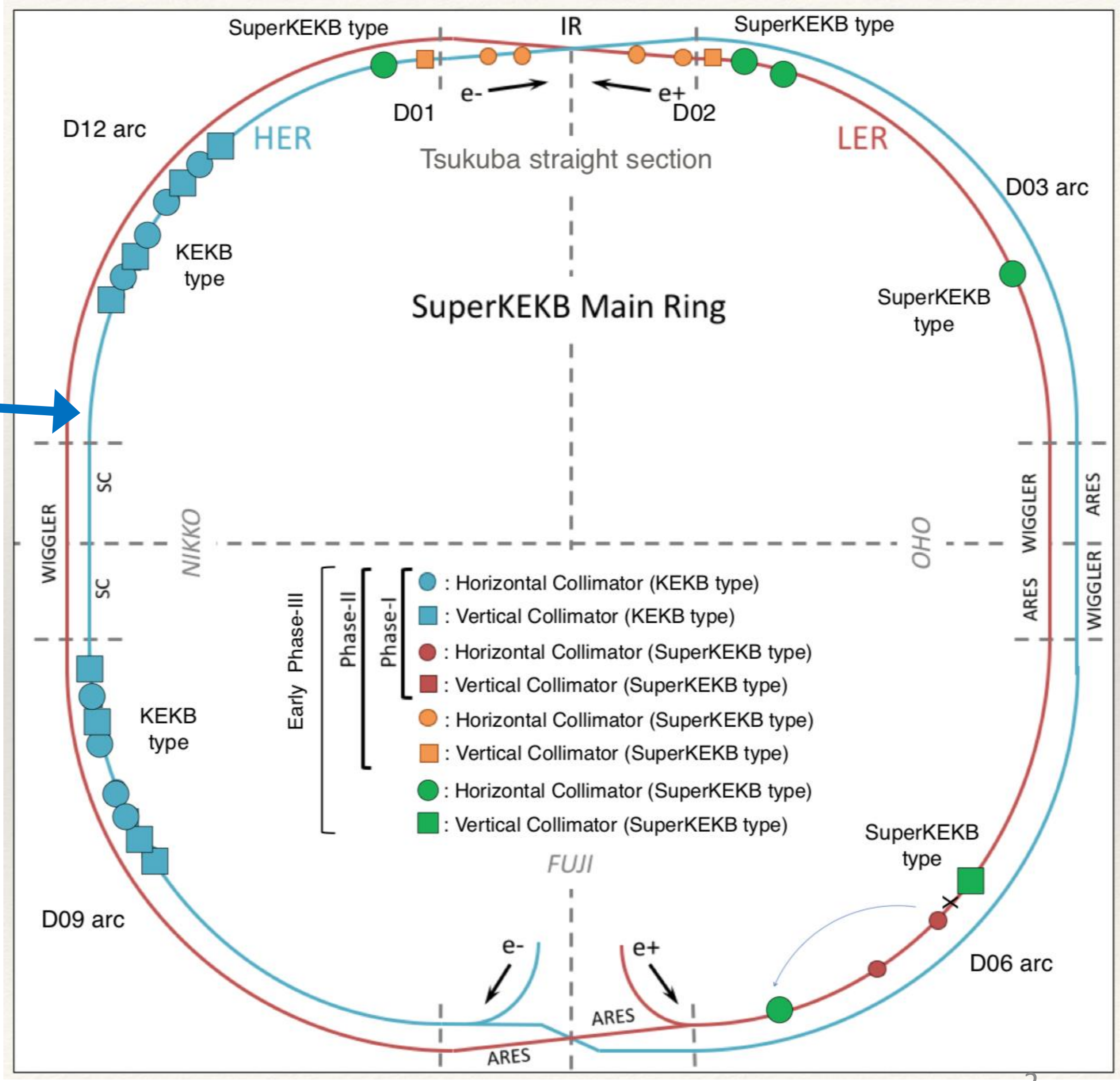
Hiro NAKAYAMA (KEK)

The 23rd Accelerator Review Committee (July 8th, 2019)

Most of slides are taken from 33rd B2GM Plenary report by Sven Vahsen

Beam Backgrounds: developments since February

- Improved BG monitoring
  - Online: Belle II rates
  - Online: Vertex distributions
  - Offline: Automated summary files
- Four new LER collimators
- Established continuous injection in both rings
- BG mitigation & study May 9-14 (Nakayama et al.)
- Beam currents increased up to 600-700 mA

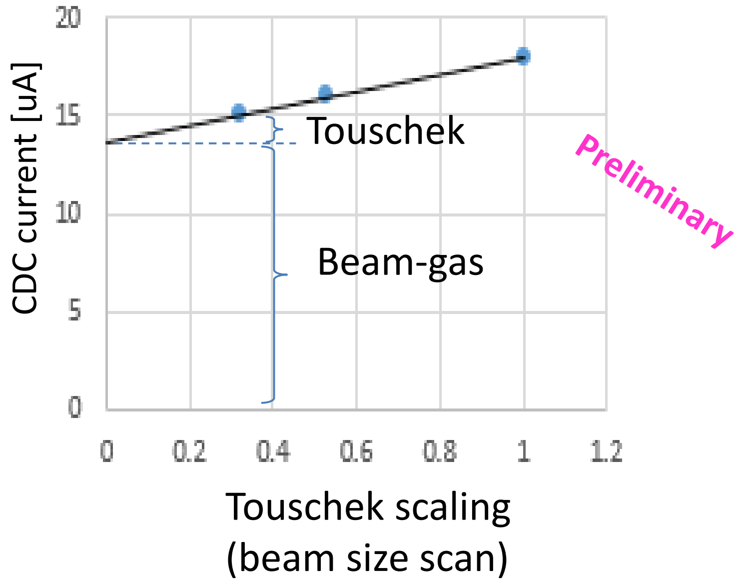


Beam Background "big picture"

(as of mid. June 2019)

- Machine parameters
  - beta_y*=3mm, 1576bunch, 650+650mA, L~0.5*10^{34}
- Our bottle-neck is CDC (and TOP)
  - CDC HV trips with large BG (storage + injection)
  - TOP PMT photocathode lifetime get shorter
- Dominant source: LER beam-gas BG
  - Touschek BG is small enough, thanks to newly-installed horizontal collimators after phase2
- Keep good injection condition is very important
  - To avoid CDC HV trip
  - To avoid loss monitor aborts at collimators (and allow us to close the collimators even narrower)

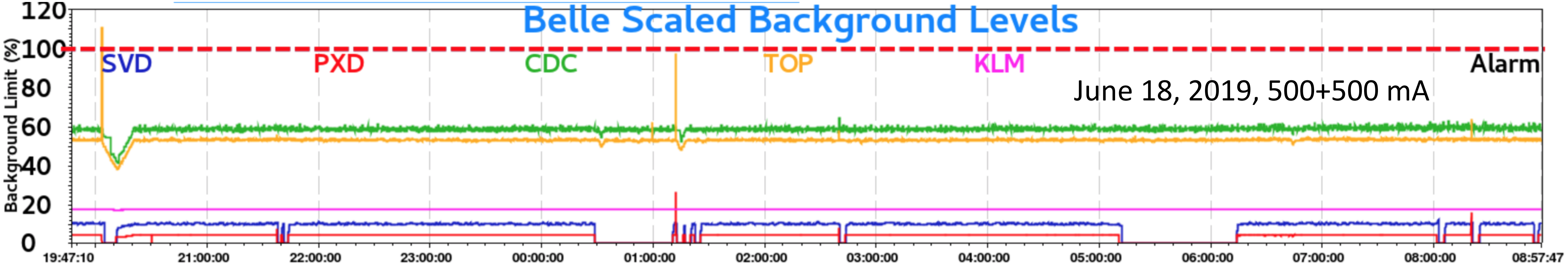
LER single-beam study
I=450mA, beta_y* = 3mm



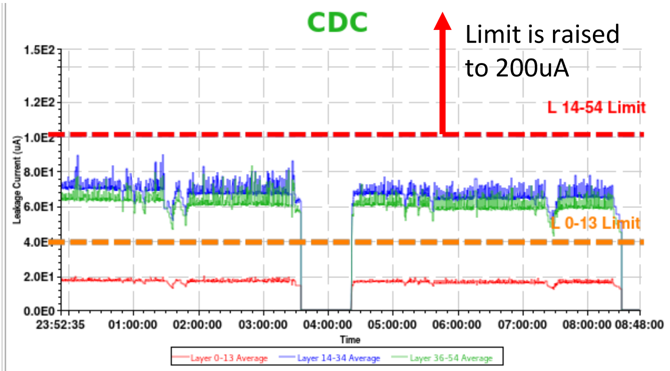
At the end of June, we moved to beta_y*=2mm optics. When L~1.2*10^{34} is achieved with 800mA, BG was three times too high to turn on Belle2.
(Note that we didn't have enough time for collimator optimization with 2mm optics)

Schueler et al.

New: Online Rate Monitoring (BCG)



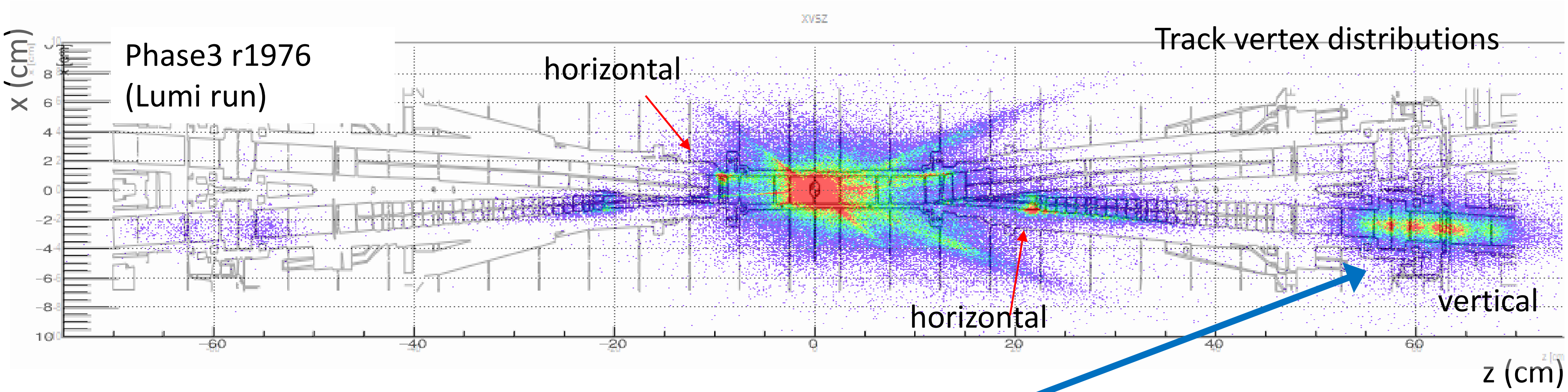
- Total (storage + injection) bkg compared against 100% "alarm limits"
- Clear how much headroom we have to raise beam currents
- Detect when bkg conditions (e.g., injection backgrounds) deteriorate → take immediate action
- Most detectors: safety factors order 5-10. Exceeding 100% implies soft performance degradation, but not physical danger
- CDC and TOP <= 2, currently limiting beam currents
- CDC: >100% can occur during injection spikes, causing HV trips, significant downtime
- TOP: >100% leads to unacceptable deterioration of PMT photocathode and efficiency loss before 2020 (or 2021)



β_y^*=3mm, 1576 bunches, 600+600mA, L~$0.5*10^{34}$

Fulsom, Spruck, et al.

New: Online Monitoring of Background Spatial Distribution (DQM)

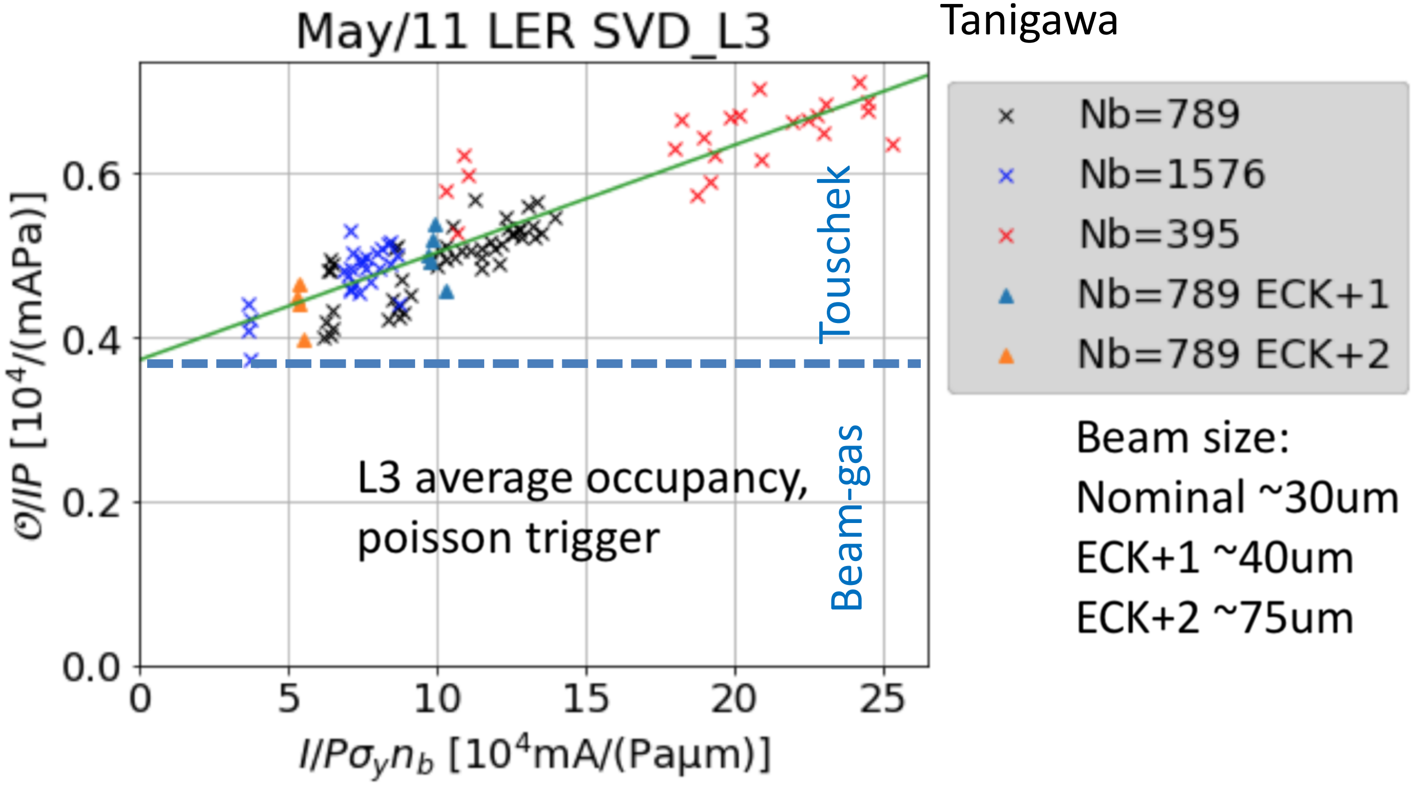


- Monitor for scraping beams
- We suspect incoming-LER scraping (at this position or at upstream QC1)
- Optimizing beam vertical steering at IP (dedicated study on June 20th) achieved 10~15% BG reduction in CDC/TOP!

Improved: fitting of single-beam storage backgrounds

- background studies performed May 11, 12, 14
- beam size scans and fill pattern scans *now agree (LER), providing unambiguous estimate of background composition*
- diamonds, PXD, SVD, TOP, analyzed in detail
- KLM, CDC groups have first results
- others detectors still forthcoming

Tanigawa



Beam size:
Nominal ~30um
ECK+1 ~40um
ECK+2 ~75um

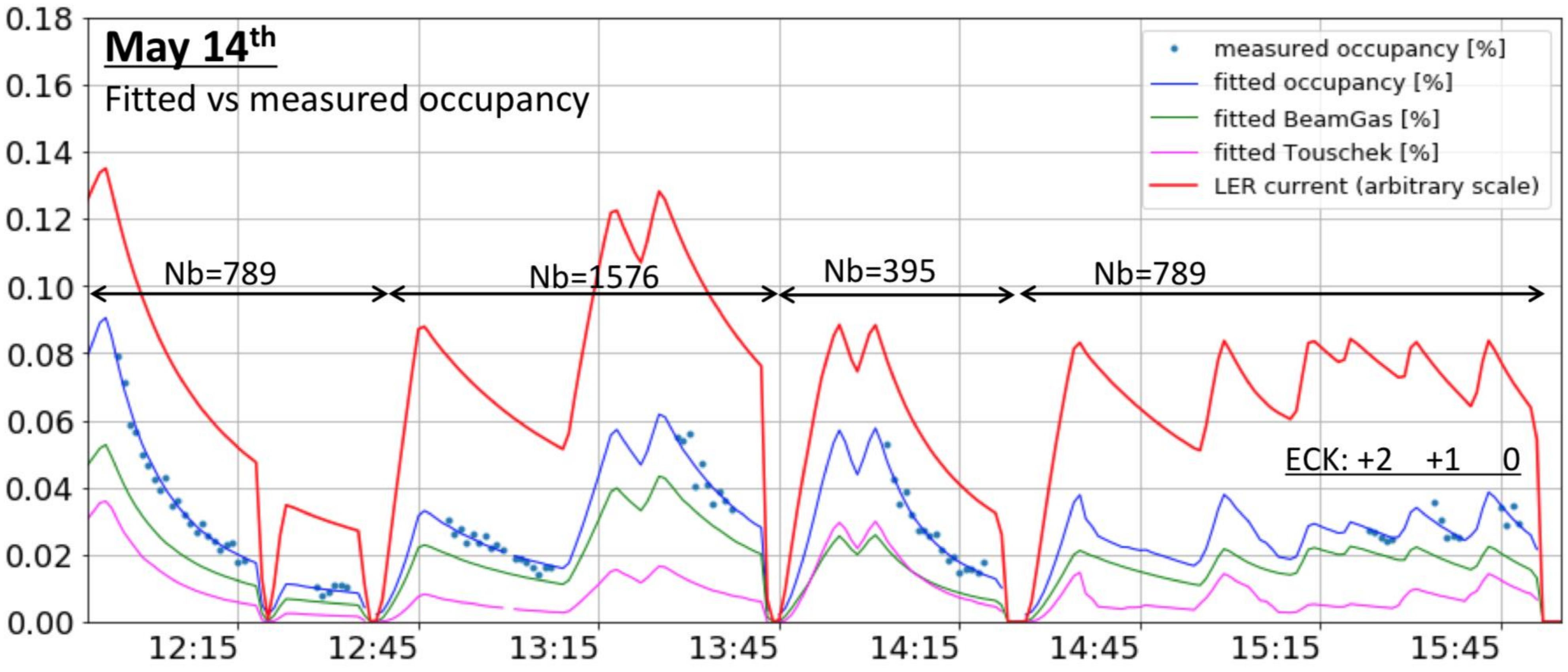
$$Rate = \underbrace{T \times \frac{I^2}{\sigma_y n_b}}_{\text{Touschek}} + \underbrace{\mathrm{B} \times \mathrm{IP}}_{\text{Beam-gas}}$$

vary both σ_y and n_b to change Touschek bkg normalization

Fitting "Beam-gas + Touschek" model to data

May 14th data are also well explained by the model.

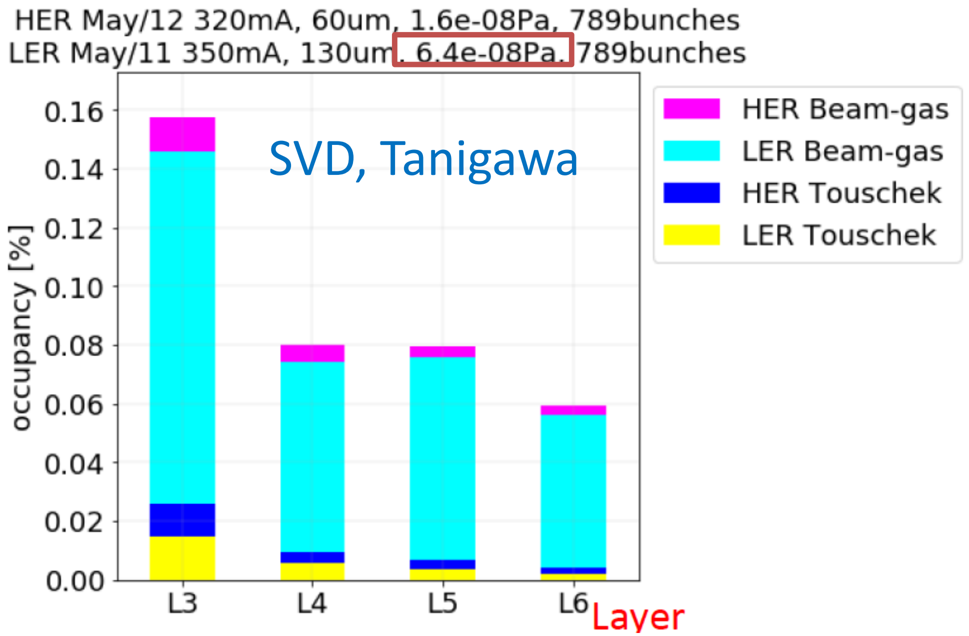
Tanigawa (SVD)

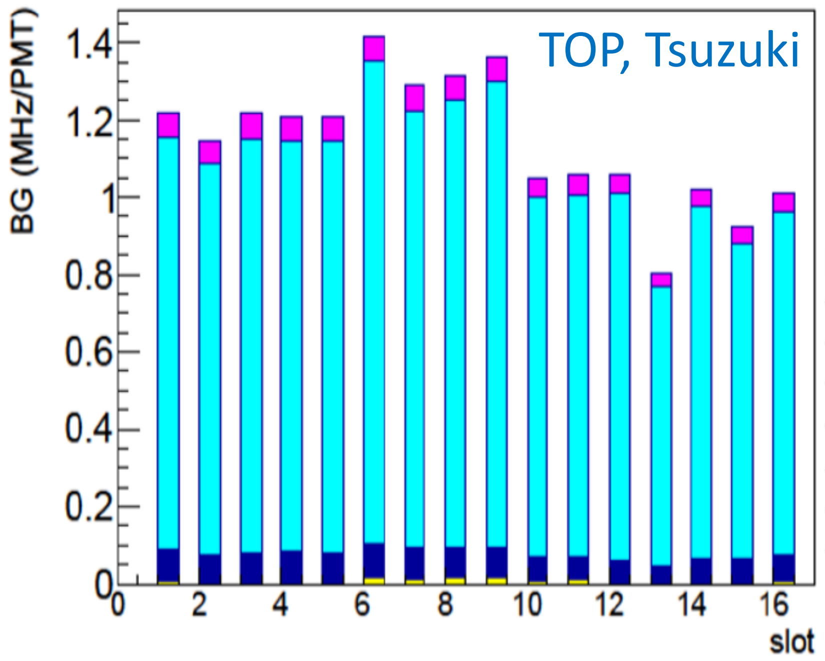


Diamonds, SVD, TOP well described by simple beam-gas + Touschek model
PXD not yet fully understood, suspect due to Synchrotron Radiation

Updated Beam Background Composition

May background studies, HER 320mA, LER 350mA, 789 bunches





- Exact composition depends on collimator settings and detector, but…
- LER storage bkg >> HER storage bkg. Ratio LER/HER >= 4
  - LER beam gas dominates (~70% of total)
  - LER Touschek small in SVD, negligible in TOP

From beam lifetime

Data vs. MC

- bkg simulation perfect ⬄ data/mc = 1
- Typically, data/mc >1. We use data/mc as correction factor for simulation, for instance to estimate backgrounds at design luminosity
- Three groups have results
  - Diamonds: observe data/MC ~ 1
  - SVD/TOP: shown to right

Tanigawa, Tsuzuki

Data/MC in SVD,TOP

	total loss	SVD L3	(SVD L4-6)	TOP
LER beam-gas	**1.9-4.1**	**12-13**	(5.4-6.9)	**12**
LER Touschek	**1.3-1.8**	**1.0-1.1**	(0.87-1.1)	**0.16**
HER beam-gas	**10**	**16**	(19-27)	**7.7**
HER Touschek	**3**	**1600**	(760-900)	**510**

- Total loss rate data/MC <=10. SAD simulation *reasonably* accurate.
- LER Touschek: good.
- HER Touschek: suspect simulation problem (Data rate is small. MC rate is toooo small).
- Beam gas: data/mc high even for total loss rate. Note that dynamic pressure is already accounted for in these ratios and does not include measured Z_{eff}. Need to investigate beam-gas normalization. Gas injection study?

Major issue: LER Dynamic Pressure

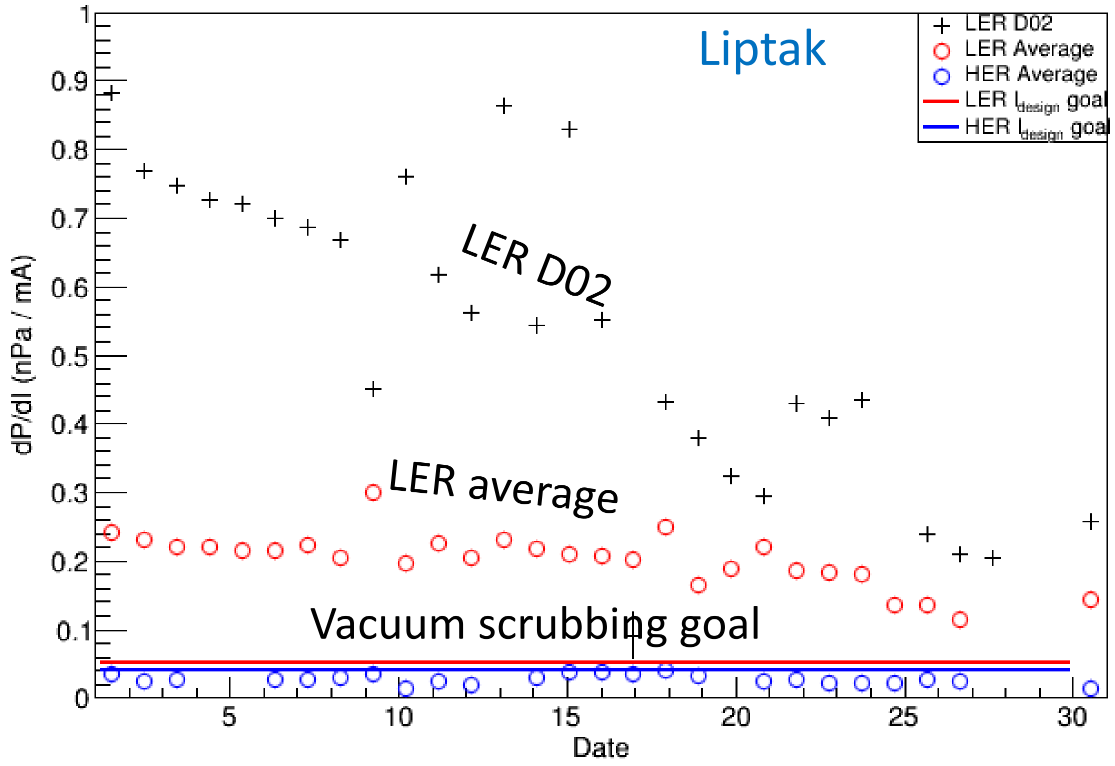
- Why is LER beam gas bkg so high?
- Because dynamic pressure is high in all of LER, especially in D02, where we installed collimators after Phase2

- We need to replace the collimator head of D02V1 damaged by June 9th accident.
- Intensive vacuum scrubbing after the replacement is important!

Touschek Beam-gas

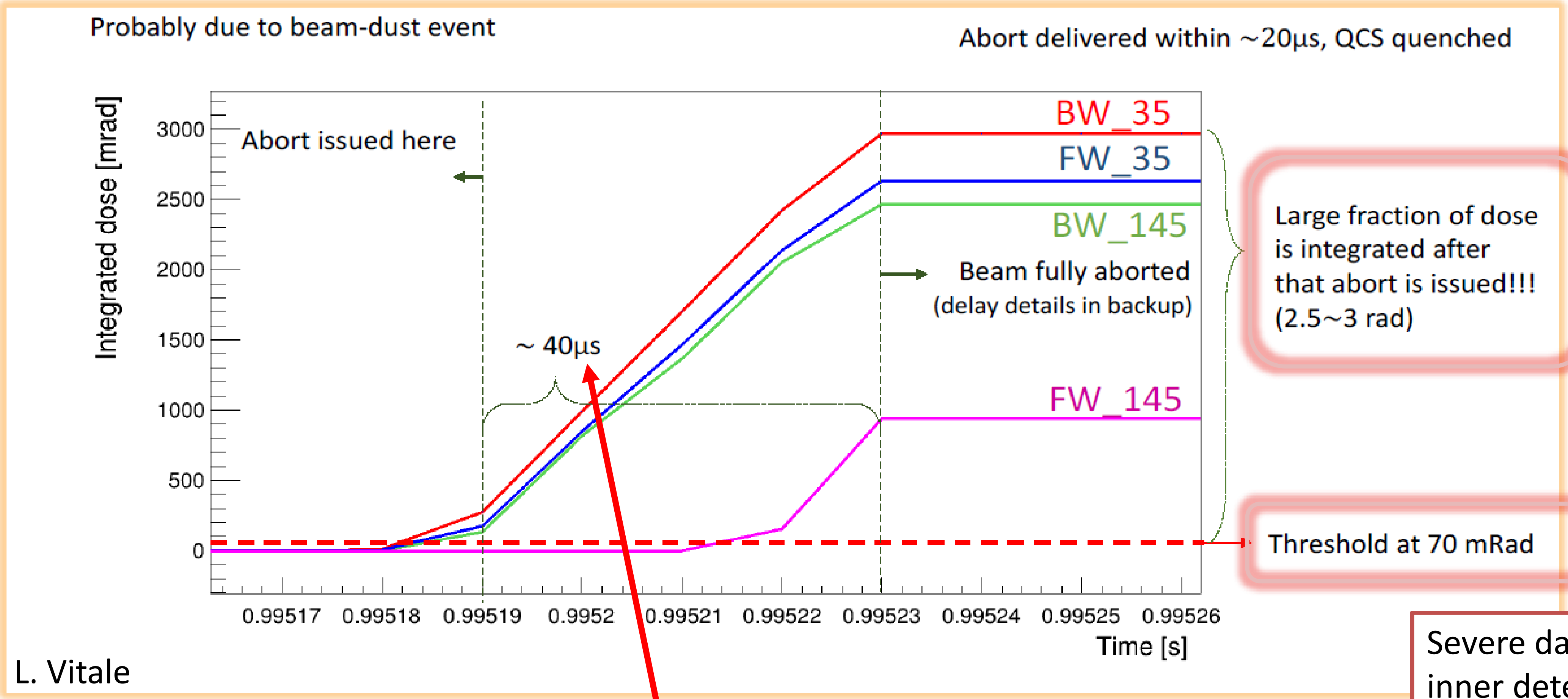
$$Rate = T \times \frac{I^2}{\sigma_y n_b} + \mathrm{B} \times \mathrm{IP}$$

$$Rate = T \times \frac{I^2}{\sigma_y n_b} + \mathrm{B'}Z_{eff}^2 \times \mathrm{I}(P_0 + \mathrm{I}\ \underline{\mathrm{dP/dI}})$$



Another major issue: Severe Background burst

June 9th



Severe damage on inner detectors

Can we minimize this delay?

See Ikeda-san's talk later

Latest SKB roadmap till 2020

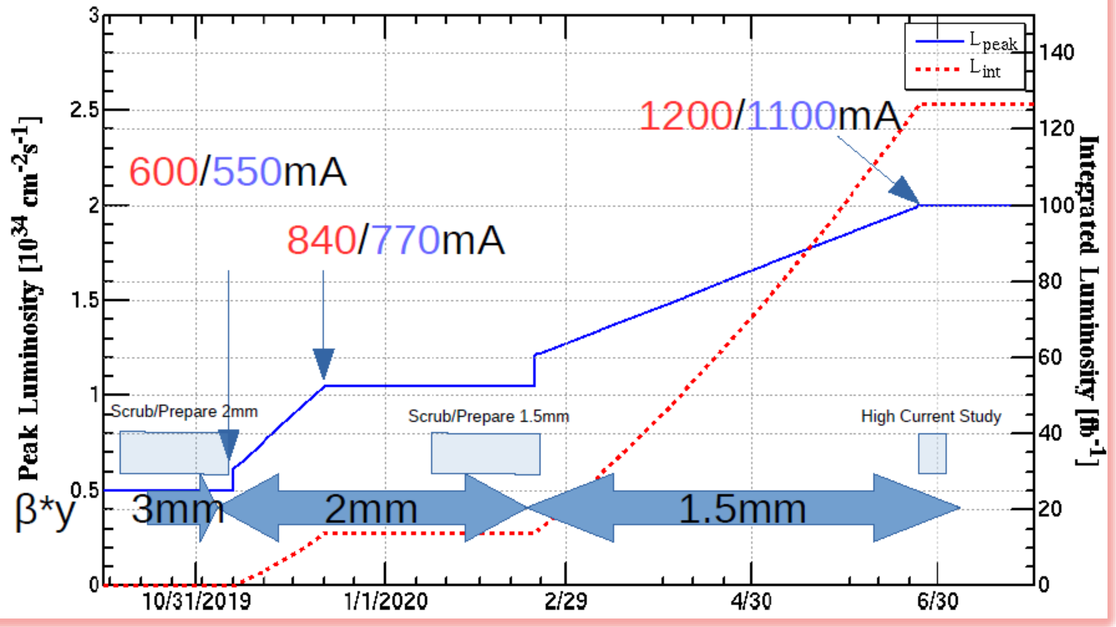
recently updated at 33rd B2GM

ASSUMPTIONS

(*risky* ⟷ *realistic*)

- Integral Efficiency (~65%)
  - Integration Time Efficiency ~90%
    - 8H maintenance & 4H startup / 2weeks
    - 12H linac study / week
  - SuperKEKB Availability 85%
  - Belle2 Availability 85%
    - Availability @ 2019-06-02 is 89.6%.
- Luminosity Performance
  - Baseline: 0.5×10^{34} @ 600/550mA(n_b=1576, β*y=3mm)
  - No beam-beam parameter improvement
  - β*y staging: 2mm @ 2019-11 → 1.5mm @ 2020-02
  - Improvement by squeezing β*y: 1/√β*y → 1/β*y during operation period
    - **Assuming detector background independence with β*y.**
  - Beam current limit improvement: x√2 @ 2019-12-12 → x2 @ 2020-06-24
    - **Assuming factor 2 improvement of CDC current limit until next summer.**
    - **Assuming no current limit for protecting detector.**
- Machine Study
  - ***No future beam development time is counted.***

Integral Luminosity
13.9 fb^{-1} (2019-10 ~ 2019-12)
112.8 fb^{-1} (2020-01 ~ 2020-07)



In this slide, we assume
2019 winter: 0.84/0.77A, beta_y*=2.0mm, L=1.0*10^34
2020 summer: 1.20/1.10A, beta_y*=1.5mm, L=2.0*10^34

BG extrapolation toward 2020 summer

This extrapolation based on the scaling the latest BG measurement using machine parameters.
Another approach is being prepared, to scale the BG simulation with future optics, using latest Data/MC ratio.

In this slide, we assume
2019 winter: 0.84/0.77A, beta_y*=2.0mm, L=1.0*10^34
2020 summer: 1.20/1.10A, beta_y*=1.5mm, L=2.0*10^34

LER Touschek	2019 winter	2020 summer
Beam current (I^2)	x2(0.84A)	x4(1.2A)
Collimator reduction factor	x1	x1
Total	**x2**	**x4**

LER Beam-gas	2019 winter	2020 summer
Beam current(I^2)	x2(0.84A)	x4(1.2A)
1/beta_y*	x1.5	x2
Vacuum scrubbing (dP/dI) *	x2/3	x1/2
Collimator reduction factor **	x1	x1
Total	**x2**	**x4**

*   My personal guess
** “x1” might be optimistic. Vertical collimation at squeezed optics will be more difficult

- HER Touschek, HER Beam-gas are assumed to be much smaller than LER also in 2020.
- Lumi-BG is not yet measured in Phase3. We expect x2(x4) lumi-BG in 2019(2020) than now, which we assume to be smaller than LER BG.
- Based on these assumptions, LER beam-gas will be still a dominant background source in 2020

Simply increasing beam currents will lead to intolerable BG, even with vacuum scrubbing

- **New LER collimator(s)**
- **Optics adjustments**
- **Intensive vacuum scrubbing**

Possible Background Mitigation

- Possible options for reducing LER beam-gas
  - reduce dynamic pressure(dP/dI)
  - adjust IP beam steering → it might also improve luminosity
  - modify optics to match existing collimator phases better
  - add LER vertical collimator(s) → Add D06V1 in 2019 winter shutdown. Add D03V1 next.
- Recommendation: pursue all four options
- Dynamic pressure reduction via
  - Intensive vacuum scrubbing period with detuned beams, Belle II off
  - Beam pipe heating
  - Additional / improved pumping (need beam pipe modification)

Summary

- Status
  - Horizontal collimators are added after Phase2, and they suppress Touschek bkg
  - LER beam gas bkg now dominates (>= 70% of total background)
  - CDC and TOP limit max beam currents
  - Injection bkg bursts are a persistent problem, causing CDC HV trips
  - QCS and (we think) beam-dust related background bursts endanger detectors
- Recommendations
  - LER beam gas reduction: beam steering study, optics modification, new vertical collimators, intense LER vacuum scrubbing
  - Improve HER simulation for improved long-term bkg prognosis
  - Check beam-gas normalization with gas injection study
  - Improve injection further, especially for HER
  - Improved / faster / redundant abort system (See Ikeda-san's talk later)

backup

High Level Status

*Generally speaking, we want to **measure, fully understand, and mitigate** the following beam background components to*

Background Component	Simulation Method
Touschek	SAD (accelerator tracking code) generates and tracks scattered particles. If lost near IP: passed to GEANT4.
Beam-gas Coulomb	
Beam-gas Bremsstrahlung	
Radiative Bhabha	BBBrem/BHWide → GEANT4
QED 2-photon	Aafh → GEANT4
Synchrotron Radiation	SR generation in GEANT4
Injection BG	Injection particles provided by accelerator group→ SAD →GEANT4
Beam dust	-
Neutrons	All of above

Measured in early phase3.
Too high for going higher currents.
Large data/mc discrepancy

Expected to dominate at higher Luminosity
Marginal observation in early phase3
Lowest simulation uncertainty.

measured in early phase3. ~OK

measured in early phase3
LER injection BG is very clean
mitigation is purely experimental
(injection tuning is not simulation based)

Backgrounds: The road ahead

Still would like to

- check if collimator effectiveness can be improved
- confirm simulated origin points of the dominant LER beam-gas storage background, and measure uncertain normalization factor Z^2
- optimize beam steering near IP, to reduce apparent new scraping backgrounds

Additional studies already requested by Nakayama

- 1. Vacuum bump study (1shift), LER only , Belle2 HV=STANDBY(6/13 owl shift

  2. IR orbit adjustment (~0.5 shift), Collision Beams, Belle2 HV=PEAK

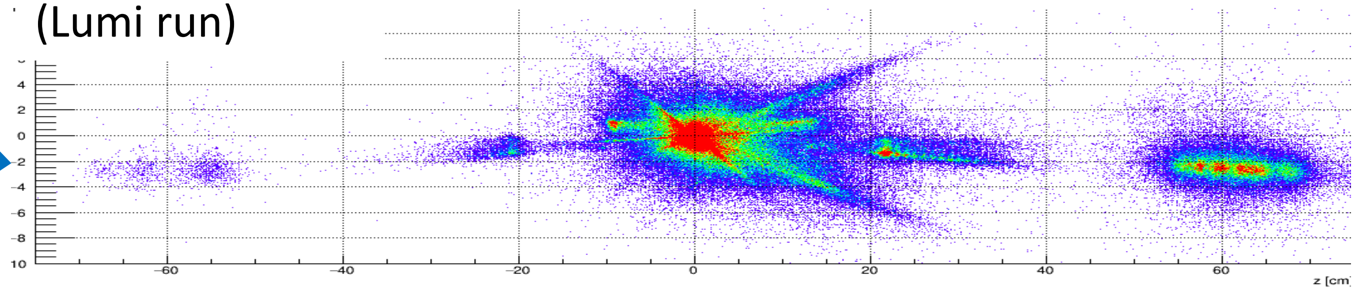
  3. LER D06V2 vertical phase adjustment(~1.0 shift), LER only, Belle2 HV=STANDBY

  4a. Quick LER beam-size scan study (~0.5 shift) after all adjustments, LER only, Belle2 HV=PEAK,

  (4b. Quick HER beam-size scan study (~0.5 shift) after all adjustments, HER only, Belle2 HV=PEAK)

  (5. N2 gas injection on LER D03 region?)

Phase3 r1976
(Lumi run)



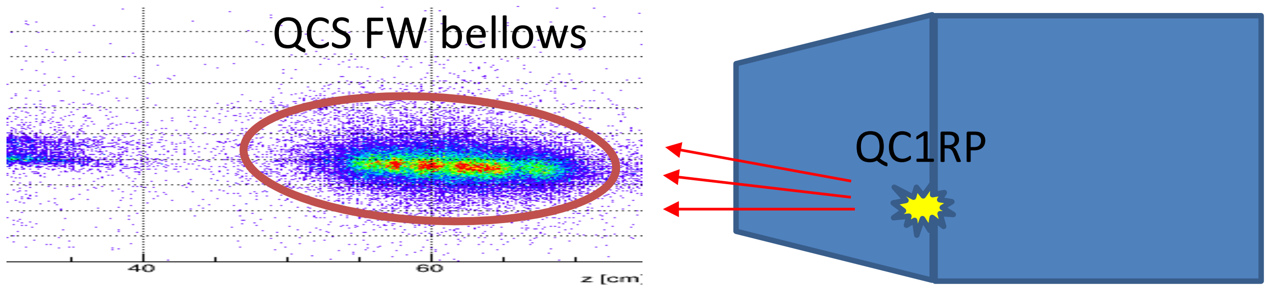
Then, decide on best strategy: increase beam currents or change optics?

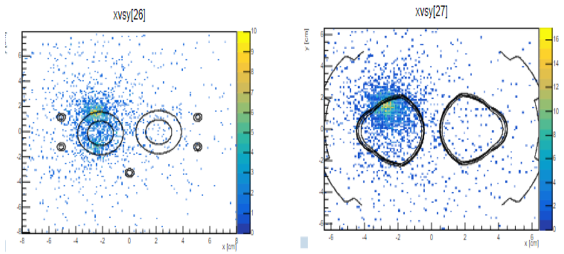
My *PERSONAL* understandings/guess on the current BG situation

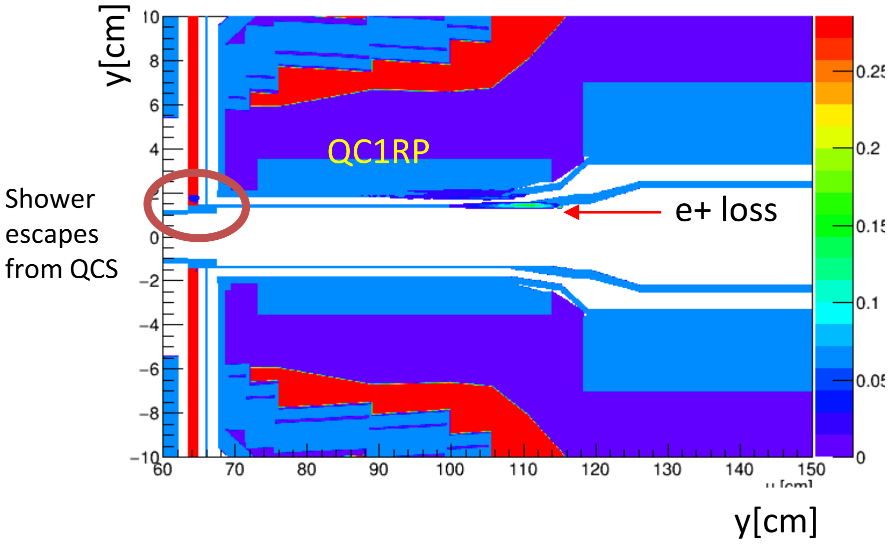
- LER beam-gas scattered particles are lost vertically inside QC1RP, at z=+1.1m. Simulation can reliably predict it.
- Showers generated at z+1m develops toward –z direction and reaches to QCS bellows at z=0.6m. If the showers are still localized in +y or –y direction at z=0.6m (should be confirmed by Geant4 simulation), it can explain observed V0 vertex distribution
- There are no shielding around z=0.6m, so the secondary particles generated at the material in that region (bellows flanges etc.) can be directly seen by outer detectors (CDC,TOP,…) and therefore becomes dominant BG source

- We observe D02V1BTM is more effective to suppress BG rates than D02V1TOP. Since LER D02V1 and QC1RP have opposite nu_y, D02V1BTM can suppress +y loss at QC1RP. This supports the hypothesis the hot spots on bellows are originated from loss in QC1RP.

- Data/MC ratio should be revisited after using section-by-section pressure values in MC. Z_eff difference should also be taken into account







Effect of new collimators

- Simulation: IR loss rates in MHz Paladino

	Phase 2	Phase 3 LER: 5/14 HER: 5/12	Change
LER beam-gas Coulomb Brehms	188 186 2	45 44 1	75% ↓
LER Touschek	160	37.6	75% ↓

Assume 1nTorr for entire ring

- Measurement: SVD occupancy in % Tanigawa

Compared BG rates on the sensors at approximately same position

- Phase 2: L3 sensors in +X direction (phi=0)
- Phase 3: L3.1 sensors (phi = – 18 deg)

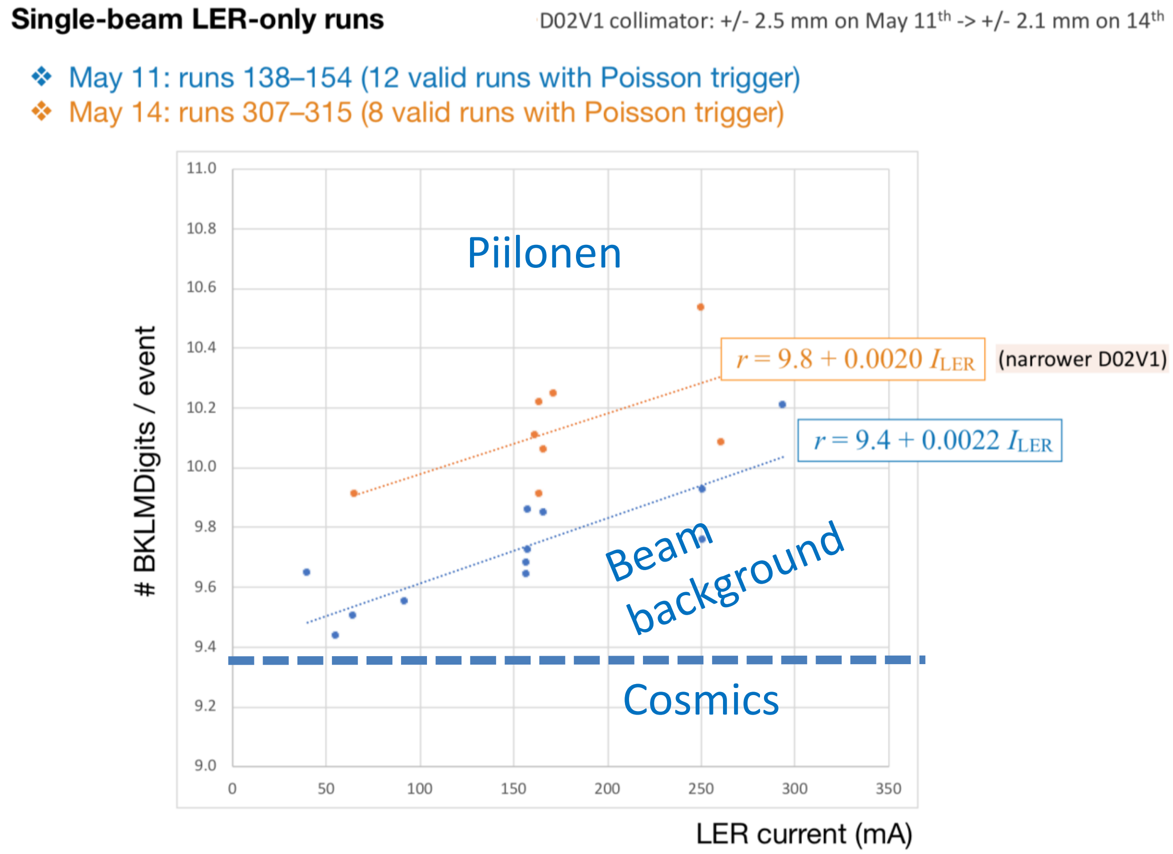
	Phase 2 *	Phase 3 **	
LER beam-gas	0.10	0.14	40%↑*)
LER Touschek	0.04	0.02	50%↓

- Compared to Phase 2, LER Touschek reduced by factor 2-3 with new horizontal collimators.
- LER vertical collimators also reduce LER Coulomb beam gas component effectively

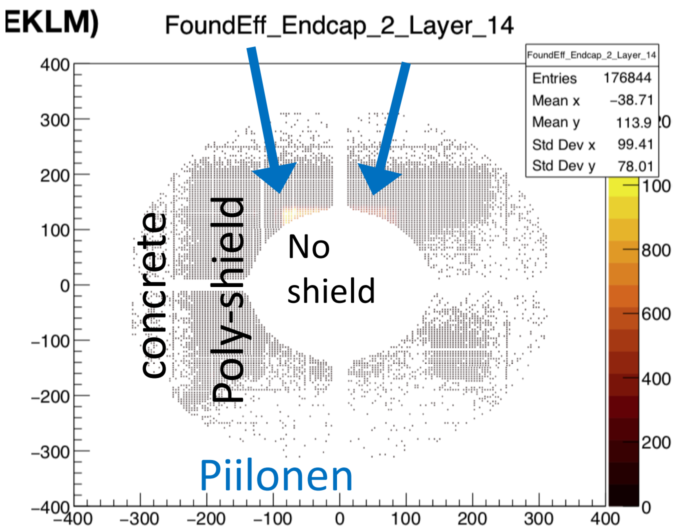
  *) Measure increase is due to the increased pressure around D02 section

KLM: LER neutron cavern backgrounds

- KLM generally robust against bkg

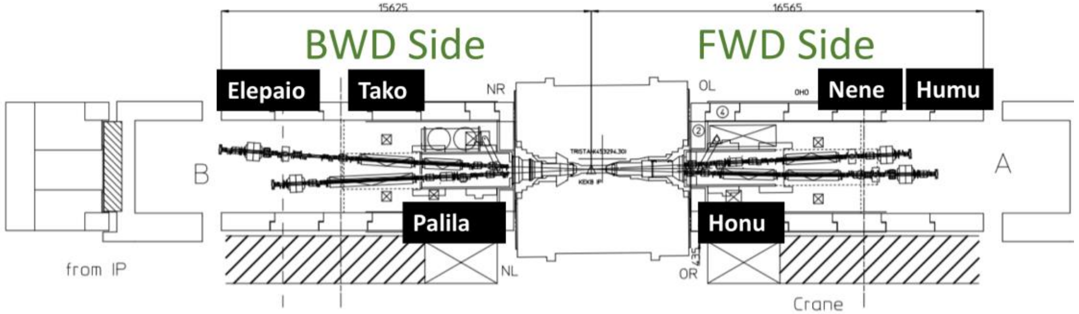


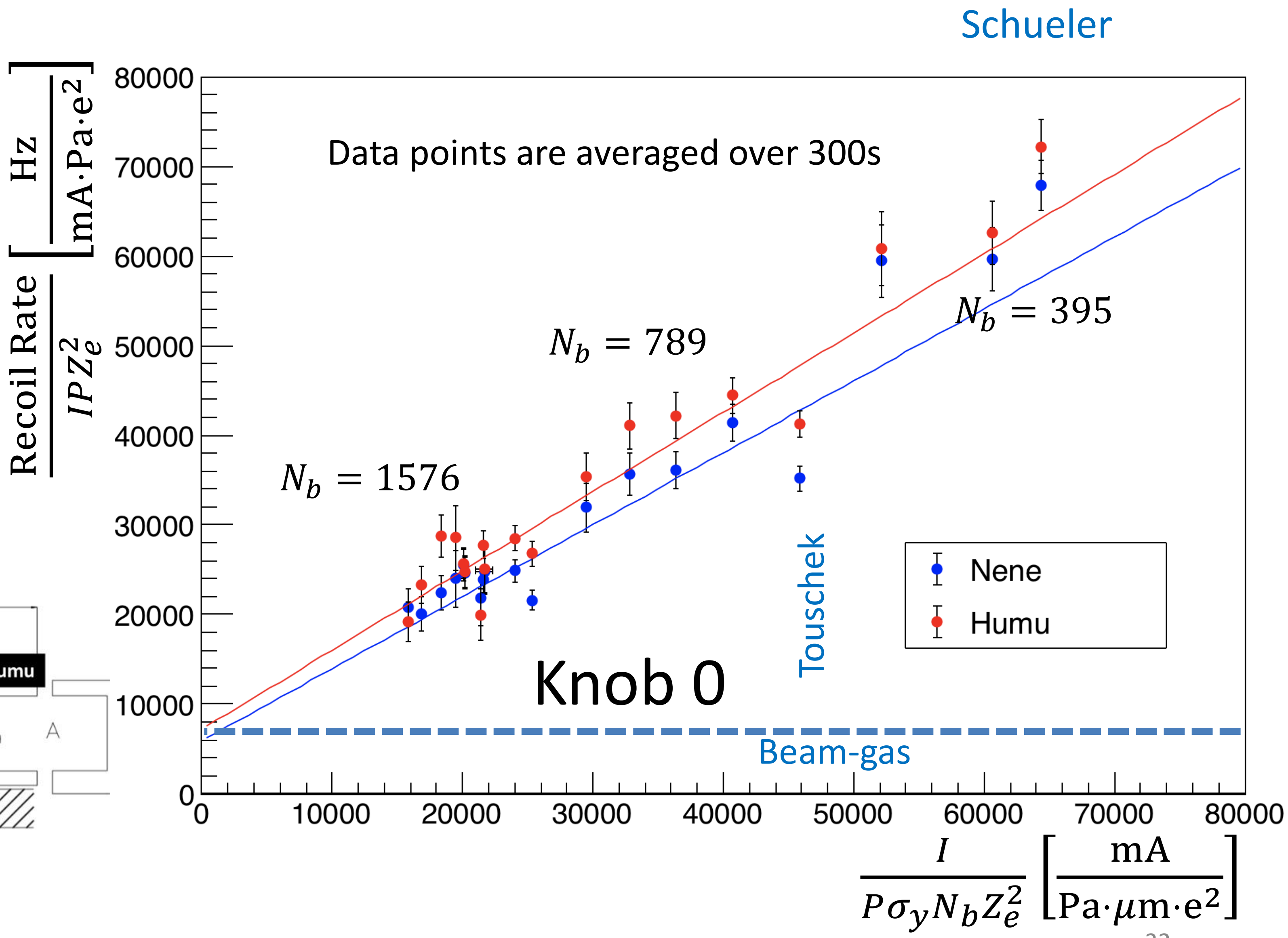
- But, now see neutron bkg in the outer, forward KLM endcap
- Extra shielding may be required
  - Inside polyethylene square
  - Is current square thick enough?



Neutron source? Touschek!?

- TPC fast neutron detectors now mounted in accelerator tunnel
- Suggest KLM endcap neutrons originate from *Touschek background (surprise!)*
- Generated at upstream collimators? More work needed to investigate.





Beam BG extrapolation toward 2020 summer

H. Nakayama (KEK)

2019 June BPAC

Latest roadmap toward 2020

Updated by SKB group at the 33rd B2GM last week.

ASSUMPTIONS

(risky ⟷ realistic)

- Integral Efficiency (~65%)
  - Integration Time Efficiency ~90%
    - 8H maintenance & 4H startup / 2weeks
    - 12H linac study / week
  - SuperKEKB Availability 85%
  - Belle2 Availability 85%
    - Availability @ 2019-06-02 is 89.6%.
- Luminosity Performance
  - Baseline: 0.5 x 10^{34} @ 600/550mA(n_b=1576, β*y=3mm)
  - No beam-beam parameter improvement
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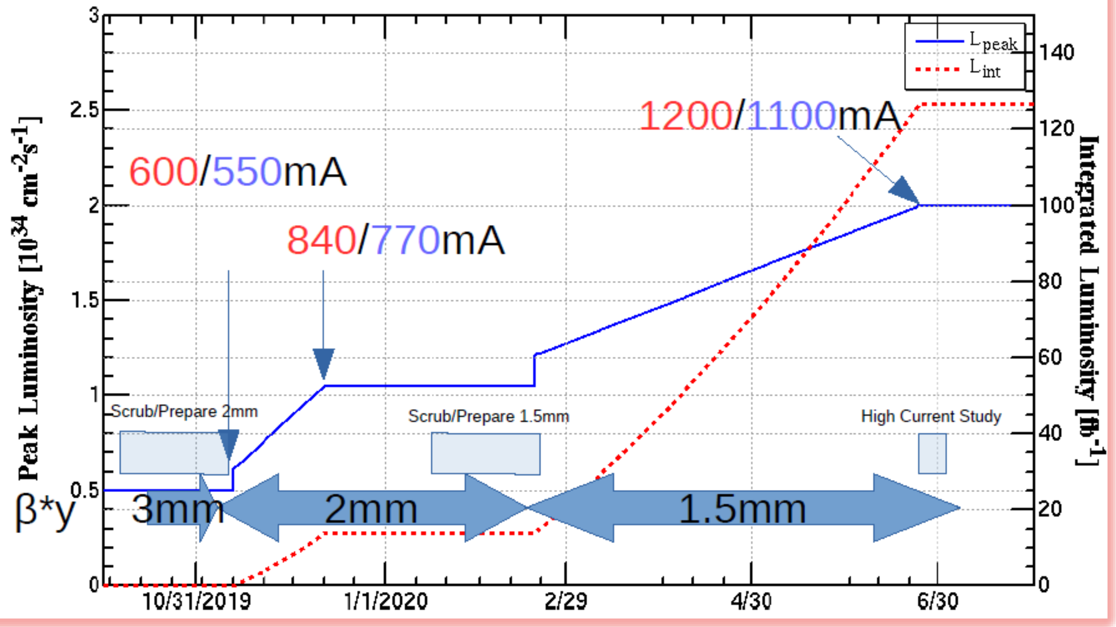

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2020 summer: 1.20/1.10A, beta_y*=1.5mm, L=2.0*10^34

Extrapolation methods

The smaller beta_y* optics files are not prepared by SuperKEKB optics group yet.

- Method 1:
  - Run beam-loss simulation using <u>future optics files</u>
  - Apply the <u>latest data/MC ratio</u> on simulated loss rates

Analysis of May 2019 BG study is ongoing

- Method 2:
  - Calculate extrapolation factor using machine parameters(*)
  - Apply the factor on the latest BG measurement

What I can show today is based on method 2.

Extrapolation based on machine parameters

- Touschek BG:
  - Proportional to I^2
  - Assume the same collimator reduction factor
    - LER horizontal collimators should be narrowed (βx^*: 200mm to 100mm)
    - Re-optimization seems possible
- Beam-gas Coulomb BG:
  - Proportional to P * I * / βy^*. (Note that P=P0+dP/dI *I, almost proportional to I)
    - Vacuum scrubbing can reduce IR loss
    - Assume factor 2/3 for 2019 winter and factor 1/2 for 2020 summer (my personal guess!)
    - Installing a new collimator makes the vacuum worse
  - Assume the same collimator reduction factor(*)
    - We need to further close LER vertical collimators as βy^* goes 3.0→2.0→1.5mm
    - LER vertical collimators are already very tight. Can we really close them further without beam instability or injection loss monitor abort?? This assumption might be optimistic.

BG extrapolation toward 2020 summer

In this slide, we assume
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Simply increasing beam currents will lead to intolerable BG, even with vacuum scrubbing

- New LER collimator(s)
- Optics adjustments

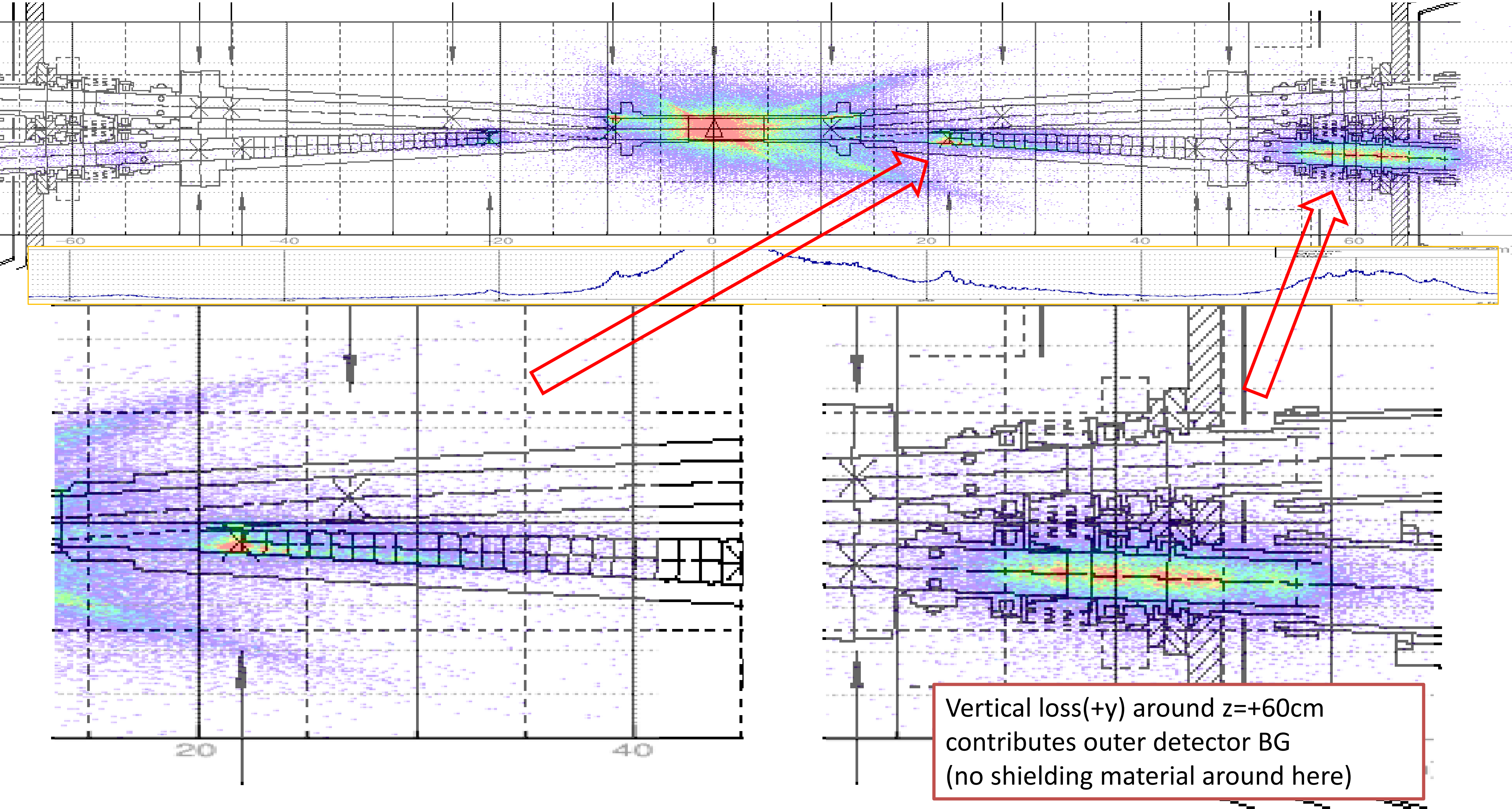
Mitigation ideas?

- IR orbit adjustment
  - 10~15% reduction seen during vertical orbit scan (June 20th)
- Add more LER vertical collimator(s)
  - It could reduce LER beam-gas BG.
  - The location of the new collimator is being discussed (D06V1/D03V1/D03V2)
- Intensive vacuum scrubbing at LER D02 section
  - Still worse vacuum (breached by collimator work before 2019 spring run)
  - Reinforcement on pumping? (need beam pipe remodeling work)

- LER D06V2 vertical phase adjustment
  - Change wiggler section phase advance to adjust D06V2 phase
  - A big work, study is postponed to winter run or later
- LER D02V1 vertical phase improves as beta_y* squeezed
  - Not a big effect at beta_y* = 2mm or 1.5mm

IR orbit adjustment

Phase3 r1976 (Lumi run)

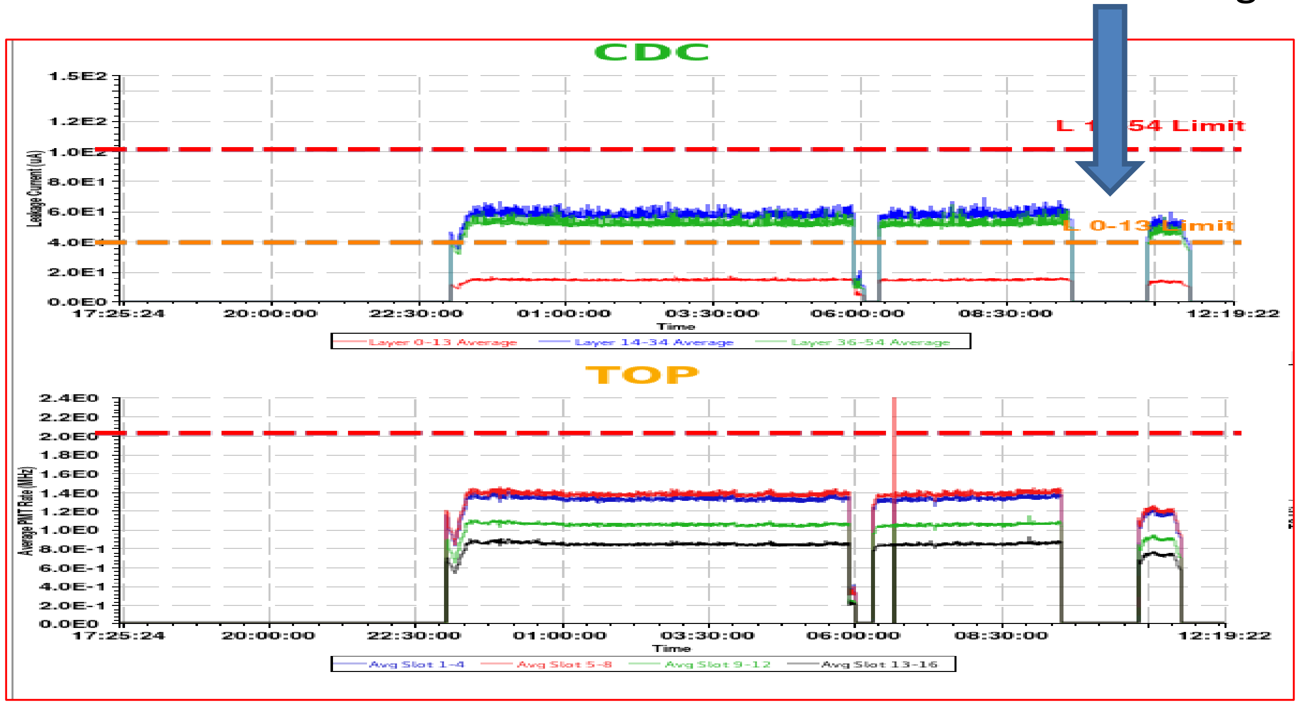


Vertical loss(+y) around z=+60cm
contributes outer detector BG
(no shielding material around here)

BG reduction by IR orbit vertical scan

June 20th (TODAY)

Vertical orbit angle shift



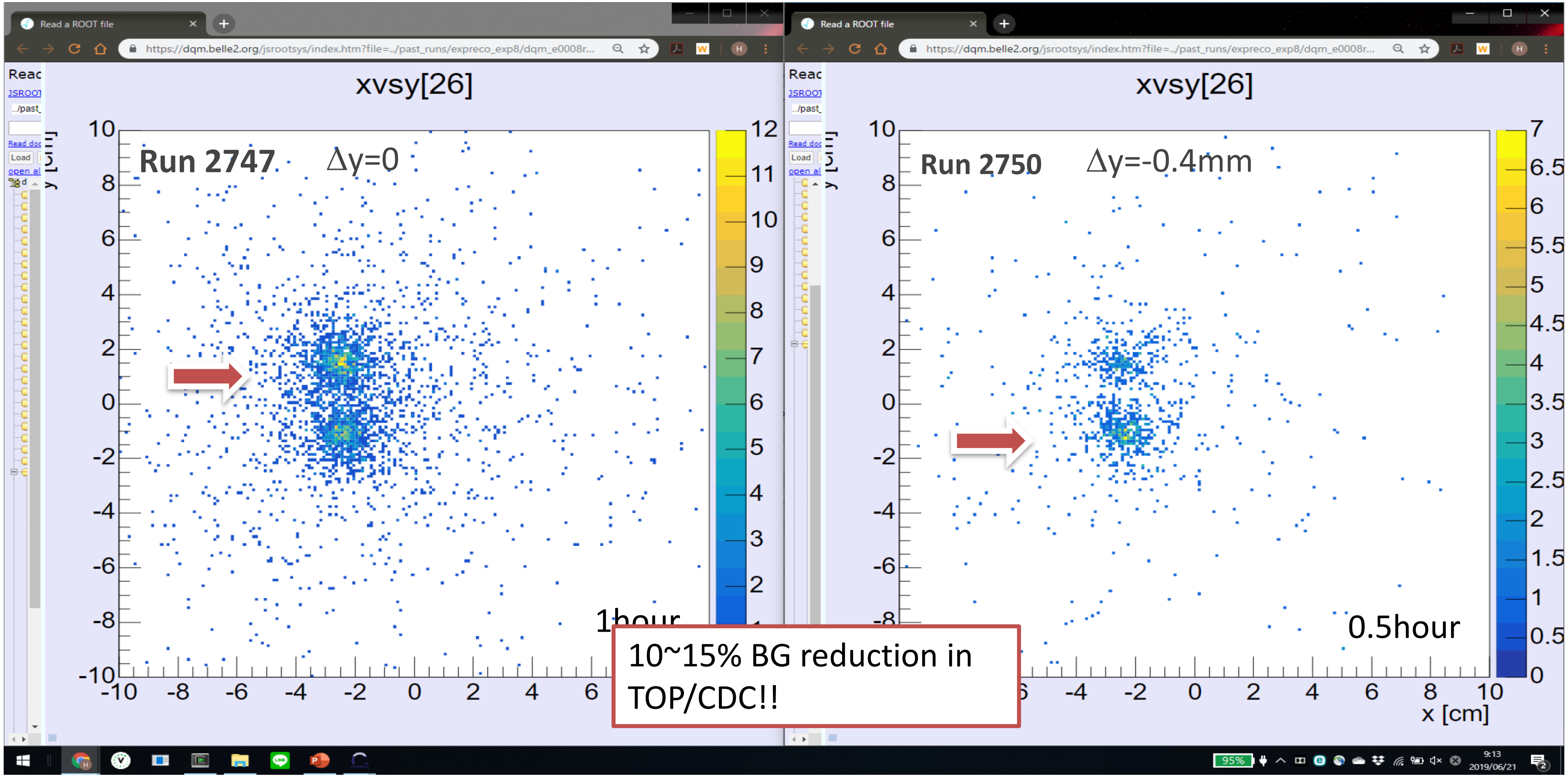
LER upstream orbit is moved downward by 0.4~0.5mm around QC1

TOP/CDC/ECL rates decreased by 10~15%

QCS_FWD diamonds rate decreased by 40%

PXD/SVD occupancies did not change significantly

Vo vertex x-y view at z=+60cm before/after vertical IR orbit scan

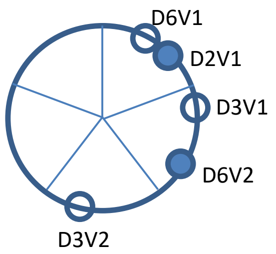


10~15% BG reduction in TOP/CDC!!

NEW LER collimators

(2.0/1.5mm optics)

Add LER V collimator for 2020



- D06V1
  - Pro: Good phase, can effectively reduce IR loss and reduce burden on D02V1
  - Pro: Large beta_y (easier handling)
  - Con: far from IP (no impact on particles scattered in D06-D03)
  - Con: impedance budget issue at design optics and full current

Vacuum bump study on June 13th suggests beam-gas scattering at D01/D12-D07 can contribute to IR loss

- D03V1
  - Pro: near from IP
  - Con: unmatched phase, but might have some impact on particles scattered in D06-D03
- D03V2
  - Pro: completely unmatched phase, might be effective to protect IR from crazy beam
  - Pro?: near from IP, but it does not help because of ↓
  - Con: completely unmatched phase, expect no impact on particles scattered in D06-D03

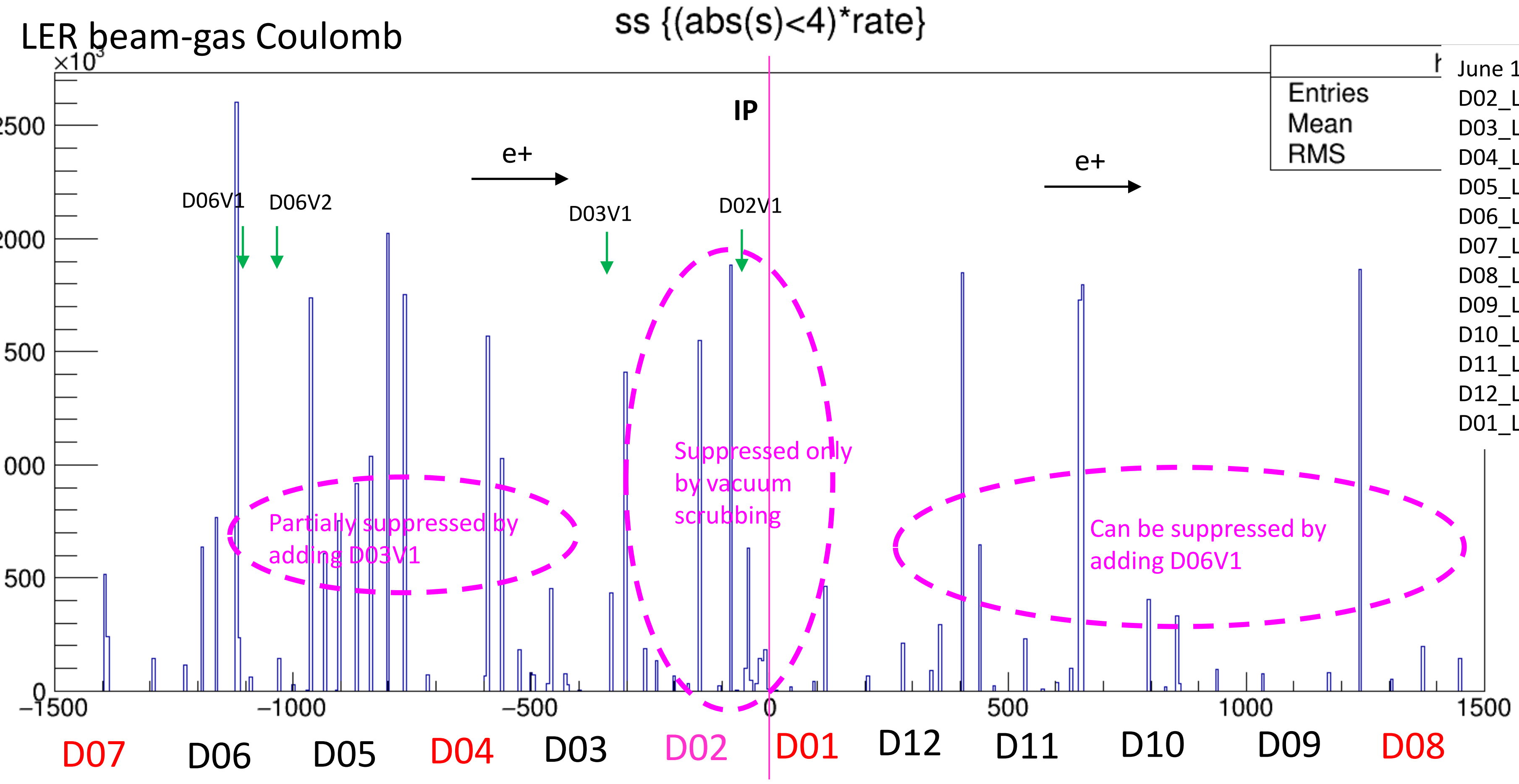
I propose to install **D06V1** in 2019 winter shutdown.
For the next opportunity, I propose to install **D03V1**.

Simulated scattered positions of IR loss

May 14th setting
D06V2=3.1mm
D02V1=2.1mm

1nTorr uniform pressure assumed
(should be scaled using pressures at each section)

Single-turn loss only



June 1st, 500mA	
D02_LER	13.9E-08
D03_LER	4.3E-08
D04_LER	7.7E-08
D05_LER	4.1E-08
D06_LER	4.9E-08
D07_LER	8.7E-08
D08_LER	9.1E-06
D09_LER	2.4E-08
D10_LER	5.7E-08
D11_LER	4.4E-08
D12_LER	1.7E-08
D01_LER	7.7E-08

Scattering at D02 is dominant source of IR loss.

Summary

- Simple extrapolation using machine parameters shows:
  - x2 BG rates at 0.84/0.77A, beta_y*=2mm (2019 winter)
  - x4 BG rates in 1.20/1.10A, beta_y*=1.5mm (2020 summer)
  - Preparing detailed extrapolation using latest data/MC ratio

- Further BG reduction is necessary to achieve higher currents planned for 2020.
- New LER V collimator(s), intensive LER vacuum scrubbing, and optics adjustments are important.

Additional LER V collimator for 2020

Candidate location: **D06V1, D03V1, D03V2**

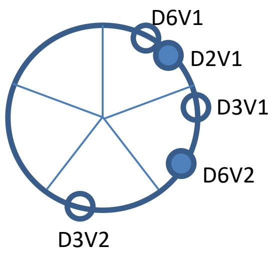
	Vertical betatron phase at beta_y*=2mm (0.27mm)	beta_y	Distance from IP
D06V1	+**0.04** (+0.10)	**61m**	Far(-1146m)
D03V1	+0.12 (+0.17)	17m	**Near(-301m)**
D03V2	+0.28 (+0.34)	17m	**Near(-225m)**
Comment	Closer phase with QC1R? → **D06V1 preferred.** Diversity in phase to stop crazy beam? → D03V1/V2	D06V1 can be used with wider width, but we face impedance budget issue with large beta_y at full current.	Beam-gas scattering at near section can only be stopped by near collimators (single-turn loss).

D06V2: +0.18 (+0.24)
D02V1: +**0.06** (+0.01)

D06V2: 19m
D02V1: 20m (110m)

D06V2: -1026m
D02V1: -82m

beta_y*=2mm



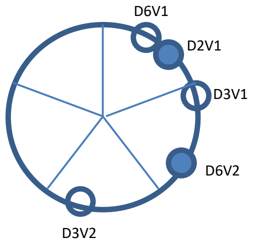
Phase adjustment for D06 collimators is really possible?

Possibility to move D06V2 to other place?

LER vertical collimators at different beta_y*

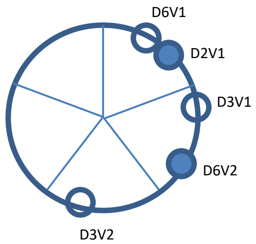
beta_y*=3mm

Phase2.1.7	beta_y	nu_y	Δnu	d[mm]
PMD06V1	61.43	28.90	+0.04	6.6
PMD06V2	**19.24**	**30.53**	+0.17	3.7
PMD03V1	16.96	41.47	+0.11	3.4
PMD03V2	16.96	42.63	+0.27	3.4
PMD02V1	**21.57**	**44.93**	**+0.07**	3.9
QC1RP995	**260.7**	**46.36**	+0	13.5



beta_y*=2mm

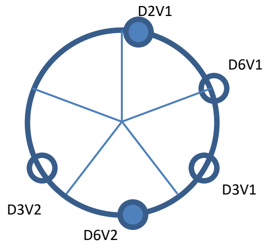
Phase2.1.7	beta_y	nu_y	Δnu	d[mm]
PMD06V1	61.43	28.90	+0.04	5.4
PMD06V2	**19.24**	**30.54**	+0.18	3.0
PMD03V1	16.96	41.47	+0.12	2.8
PMD03V2	16.96	42.63	+0.28	2.8
PMD02V1	**20.81**	**44.91**	**+0.06**	3.1
QC1RP995	**391.1**	**46.35**	+0	13.5



…

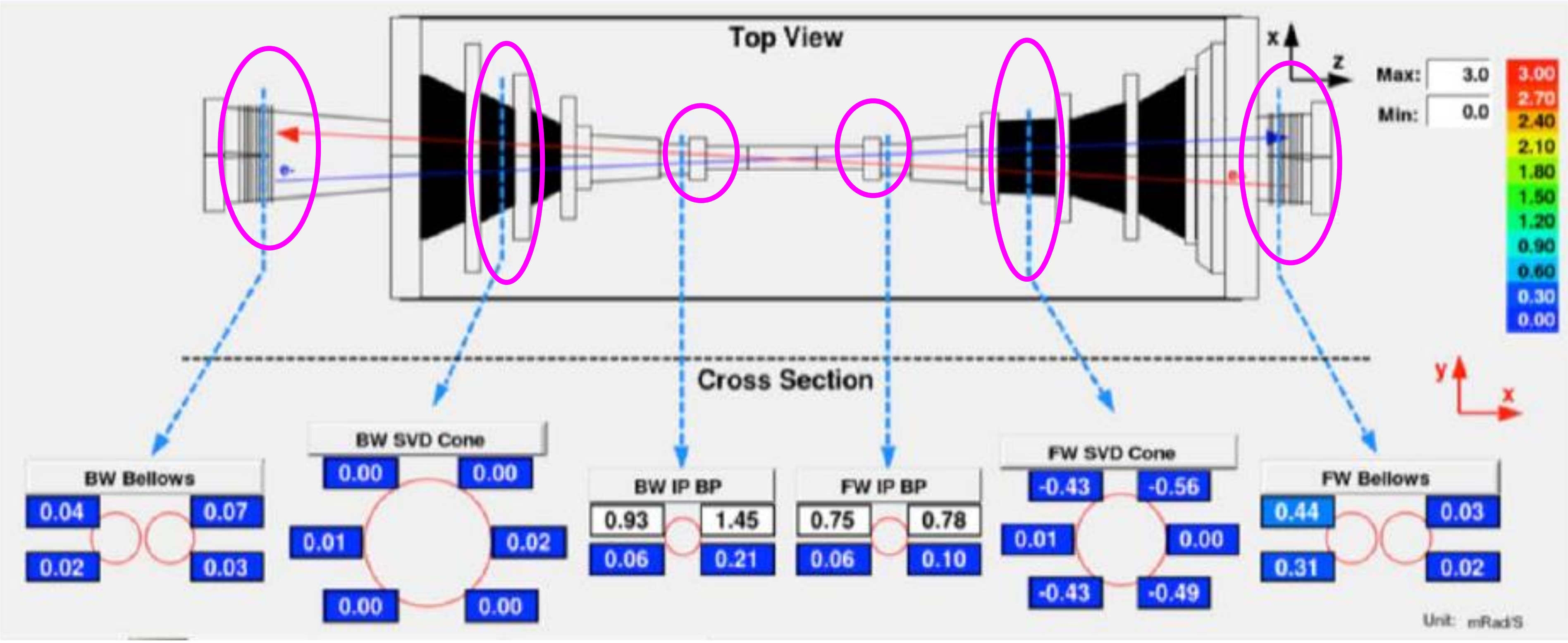
beta_y*=0.27mm (design)

Phase3	beta_y	nu_y	Δnu	d[mm]
PMD06V1	61.43	28.92	+0.10	2.0
PMD06V2	**19.24**	**30.56**	+0.24	1.1
PMD03V1	16.96	41.49	+0.17	1.1
PMD03V2	16.96	42.66	+0.34	1.1
PMD02V1	**111.75**	**44.83**	**+0.01**	2.7
QC1RP995	**2794.00**	**46.32**	+0	13.5



Beam abort

VXD abort diamond setup for Phase 3



<u>28 diamonds installed for phase3</u>

8: beam pipe (BP)

12: SVD cones (SVD)

8: QCS bellows (QCS)

Added in Phase3

QCS bellows diamonds show good correlation with outer detector background rates. Very useful to monitoring/tuning of beam BG !!

"The more eyes, the better"

VXD abort diamonds
~lessons from recent QCS quench accidents~

- **Two severe QCS quenches in Phase 3**
  - QCS quench on May 28th: caused by QCS power supply failure
  - QCS quench on June 9th : probably caused by "beam-dust" event
  - Serious damage on Belle2 sensors and collimator head

A tiny dust in the beam pipe vacuum falls onto the beam and get trapped

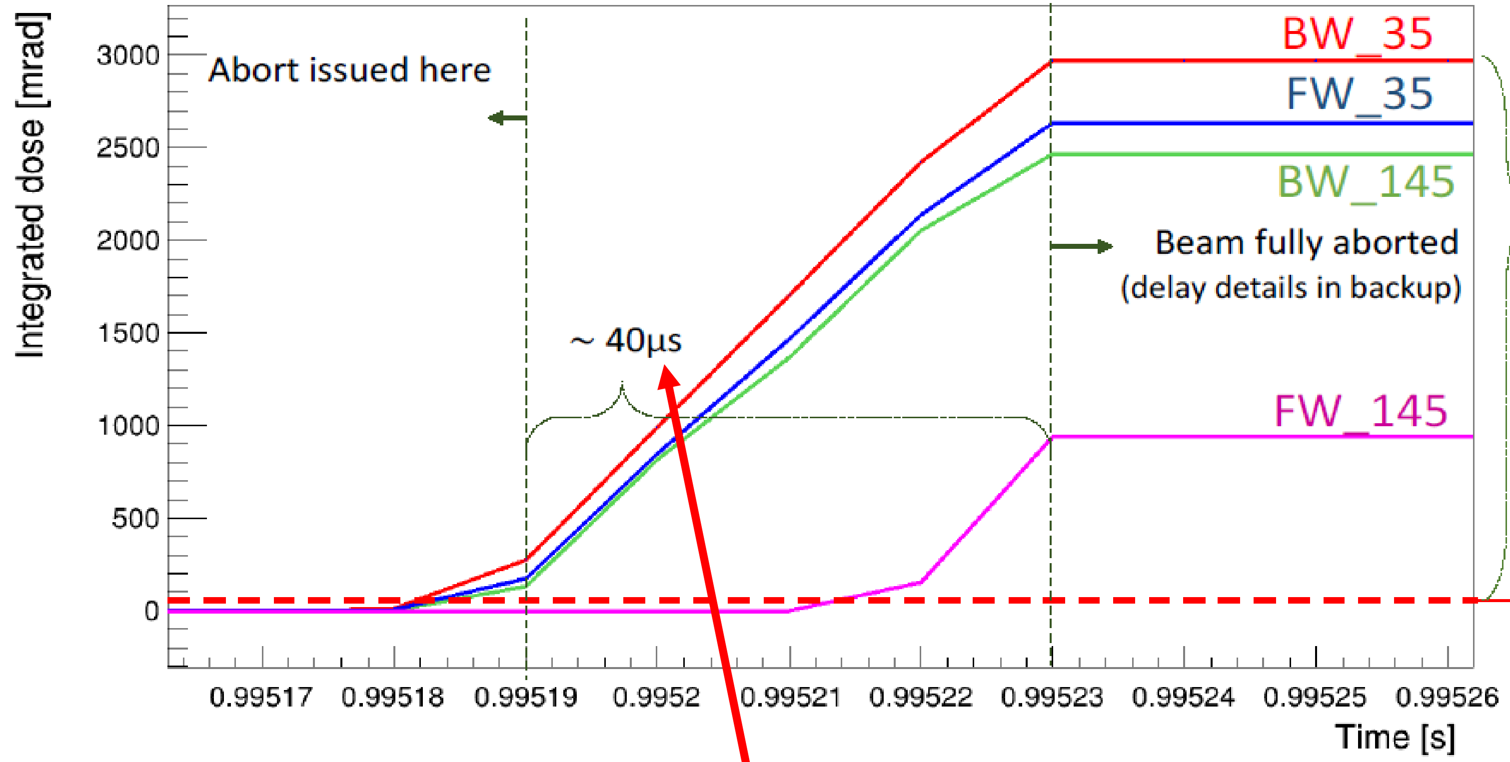
- **Protection by VXD diamond**
  - At May 28th event, diamonds were saturated and didn't issue the beam abort.
    - accelerator loss monitors issued the abort earlier than diamonds
  - Diamond gain/threshold were adjusted on June 6th
  - At June 9th event, diamonds issued the beam abort !
    - earliest abort among all abort sensors in the ring
    - **however.**. (see next page)

L. Vitale

June 09 large background burst

Probably due to beam-dust event

Abort delivered within ~20µs, QCS quenched



Large fraction of dose is integrated after that abort is issued!!! (2.5~3 rad)

x40!

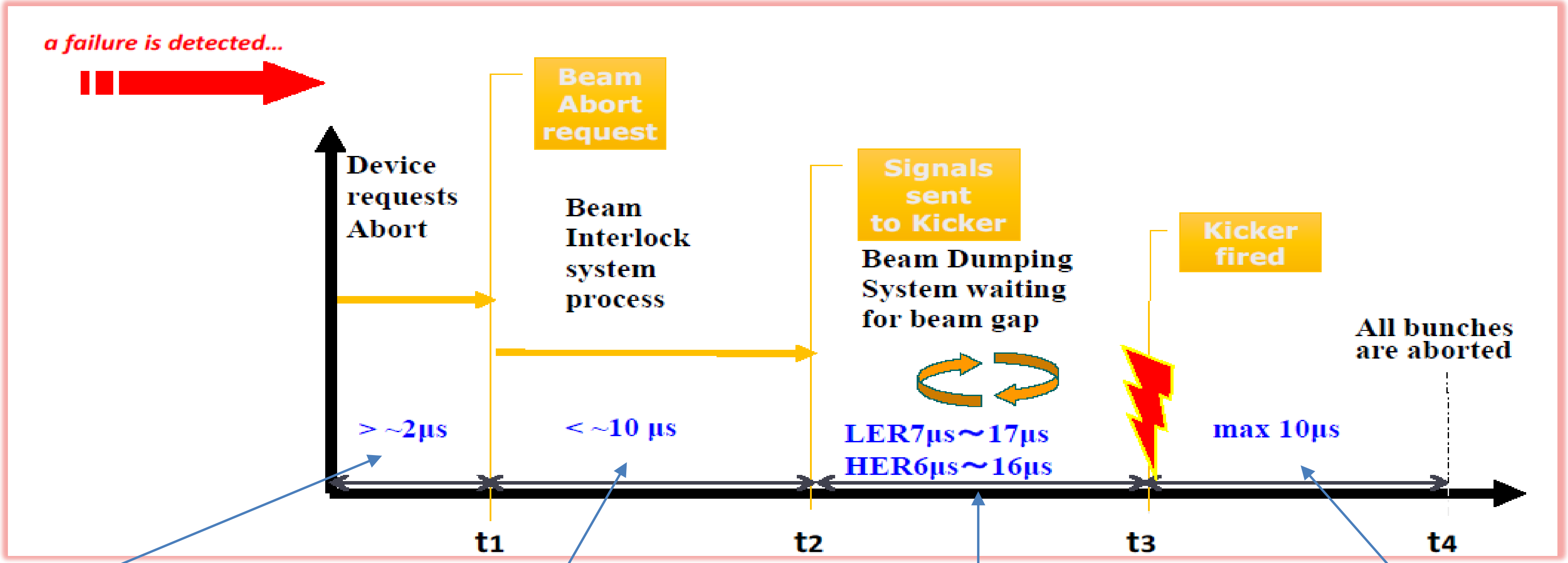
Threshold at 70 mRad

Severe damage on inner detectors

Can we minimize this delay?

Beam abort delays

H. Ikeda



Detector response time

Diamond needs 0~10us from the start of beam loss to detection (100kHz reading)

Distance to KEKB control:

10μs for D1/D2(near IP)
2μs for D7/D8

Wait for the abort gap: 0~10us
+ delay in kicker module: 4/3us
+ etc..

Need 1 turn (10us) to kick out all bunches

Ideas for minimizing the abort delay

SKB side
Belle2 side

<u>Shorter detector response time</u>

- **Lower threshold on loss monitor PINs** (need to veto injection spikes)
- **Faster VXD diamond sampling rate** (for example, 200kHz sampling) → <u>0~5us faster</u>

<u>Shorter distance to KEKB control</u>

- **Beam loss detection by a monitor near** KEKB control, not IP → <u>0~8us faster</u>

<u>Shorter waiting time for abort gap</u>

- **Increase abort gap from 1 to 2** → <u>0~5us faster</u> (~1year to update the system)

All possibilities are under active discussion in MDI group

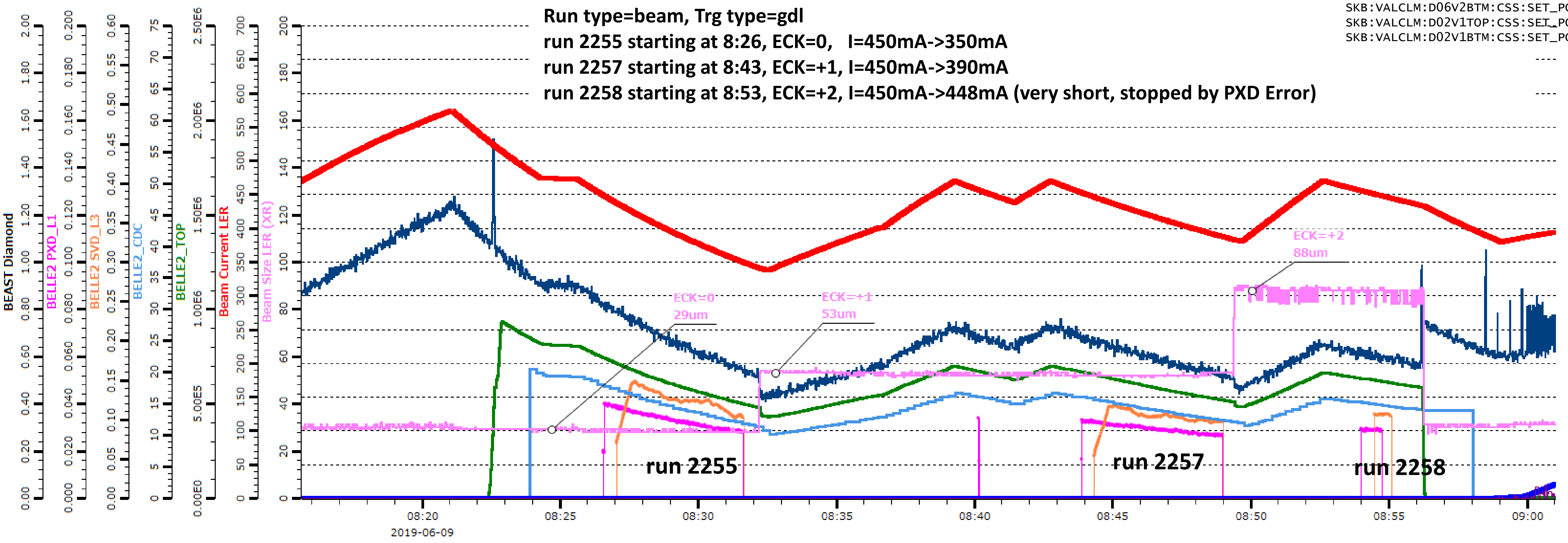
Recent BG studies

LER single-beam study on June 9th, 2019

H. Nakayama(KEK)

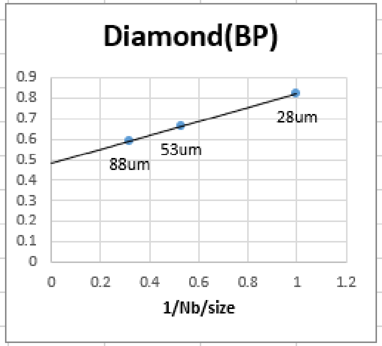
LER single-beam study on June 9th

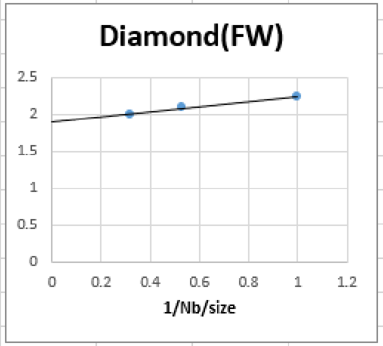
```
SKB:VALCLM:D06H1OUT:CSS:SET_POS1 11.5
SKB:VALCLM:D06H1IN:CSS:SET_POS1 -11.5
SKB:VALCLM:D06H3OUT:CSS:SET_POS1 13
SKB:VALCLM:D06H3IN:CSS:SET_POS1 -13
SKB:VALCLM:D03H1OUT:CSS:SET_POS1 12
SKB:VALCLM:D03H1IN:CSS:SET_POS1 -12
SKB:VALCLM:D02H1OUT:CSS:SET_POS1 9
SKB:VALCLM:D02H1IN:CSS:SET_POS1 -9
SKB:VALCLM:D02H2OUT:CSS:SET_POS1 11
SKB:VALCLM:D02H2IN:CSS:SET_POS1 -11
SKB:VALCLM:D02H3OUT:CSS:SET_POS1 23
SKB:VALCLM:D02H3IN:CSS:SET_POS1 -23
SKB:VALCLM:D02H4OUT:CSS:SET_POS1 10.5
SKB:VALCLM:D02H4IN:CSS:SET_POS1 -10.5
SKB:VALCLM:D06V2TOP:CSS:SET_POS1 2.6
SKB:VALCLM:D06V2BTM:CSS:SET_POS1 -2.3
SKB:VALCLM:D02V1TOP:CSS:SET_POS1 2.1
SKB:VALCLM:D02V1BTM:CSS:SET_POS1 -1.8
```

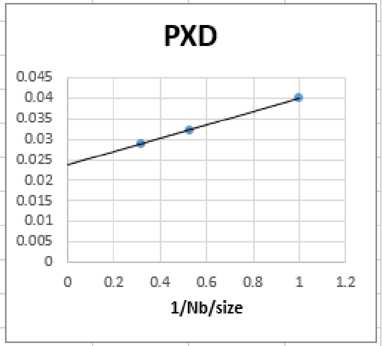


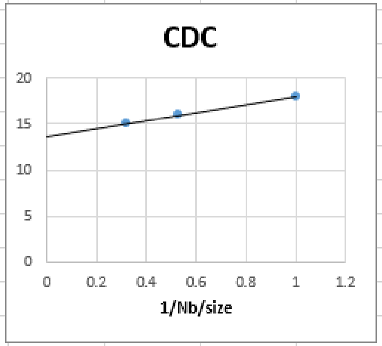
Belle2 rates vs. beam size

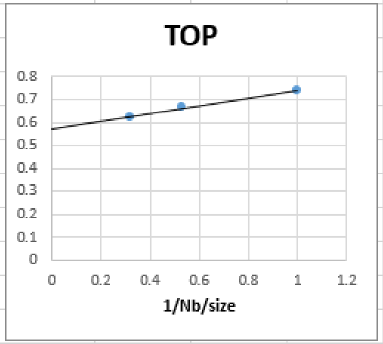
LER single-beam study on June 9th, I=450mA

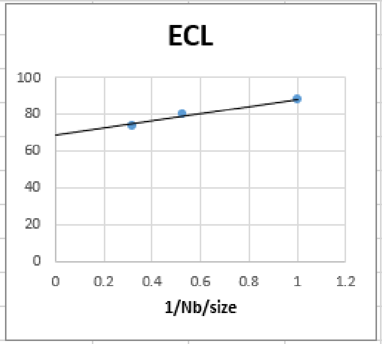


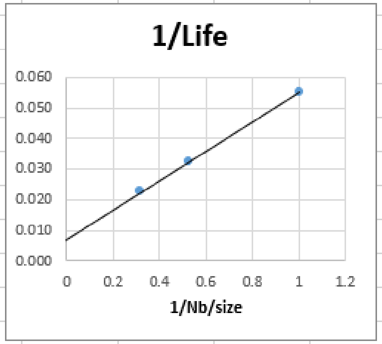












LER, 450mA	Dia_BP	Dia_FW	PXD	CDC	TOP	ECL	1/life
slope	0.34	0.34	0.02	4.37	0.17	19.93	0.047874
Beam-gas(intercept)	0.48	1.90	0.02	13.64	0.57	68.40	0.007279
Touschek@100um	0.10	0.10	0.00	1.27	0.05	5.78	0.013883
T/(T+B)	17%	5%	17%	9%	8%	8%	66%

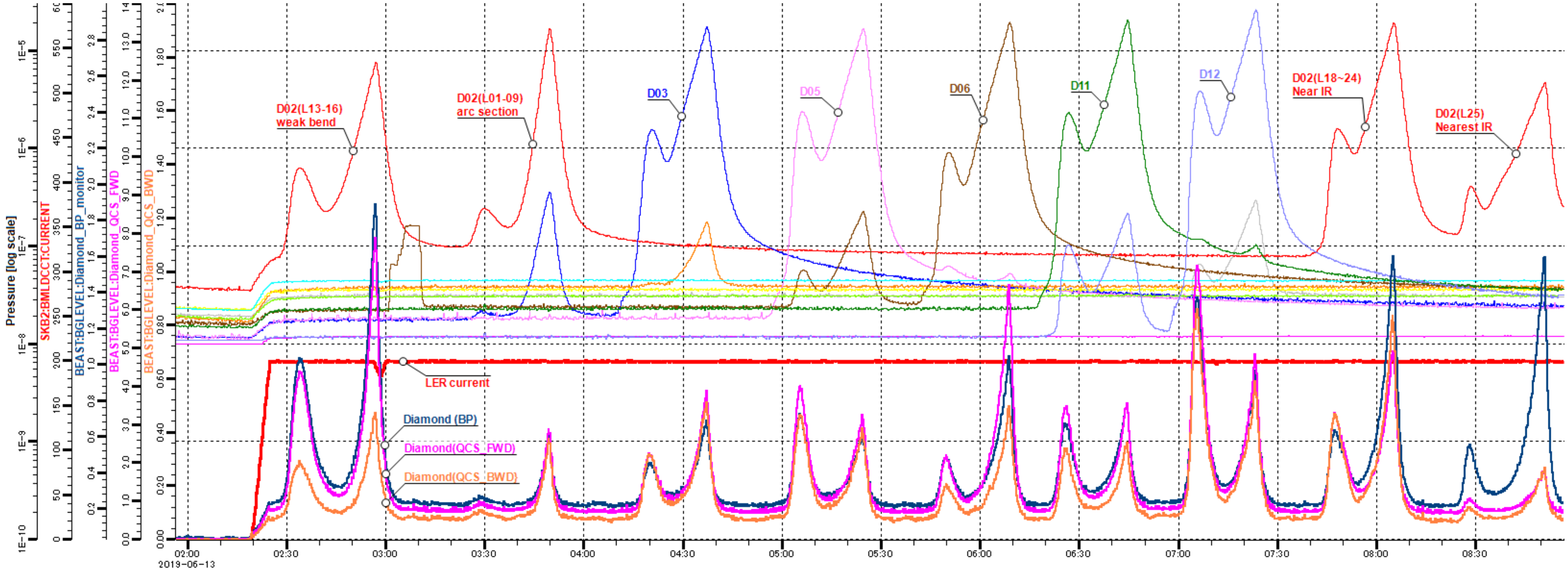
At 450mA and 100um(nominal beam size during collision), LER Touschek is <10% in outer detectors and QCS_FW diamonds, ~17% in PXD and BP diamonds

LER Vacuum bump study on June 13th

Hiro Nakayama (KEK)

LER Vacuum bump study on June 13th

Pressures are shown in log scale!!



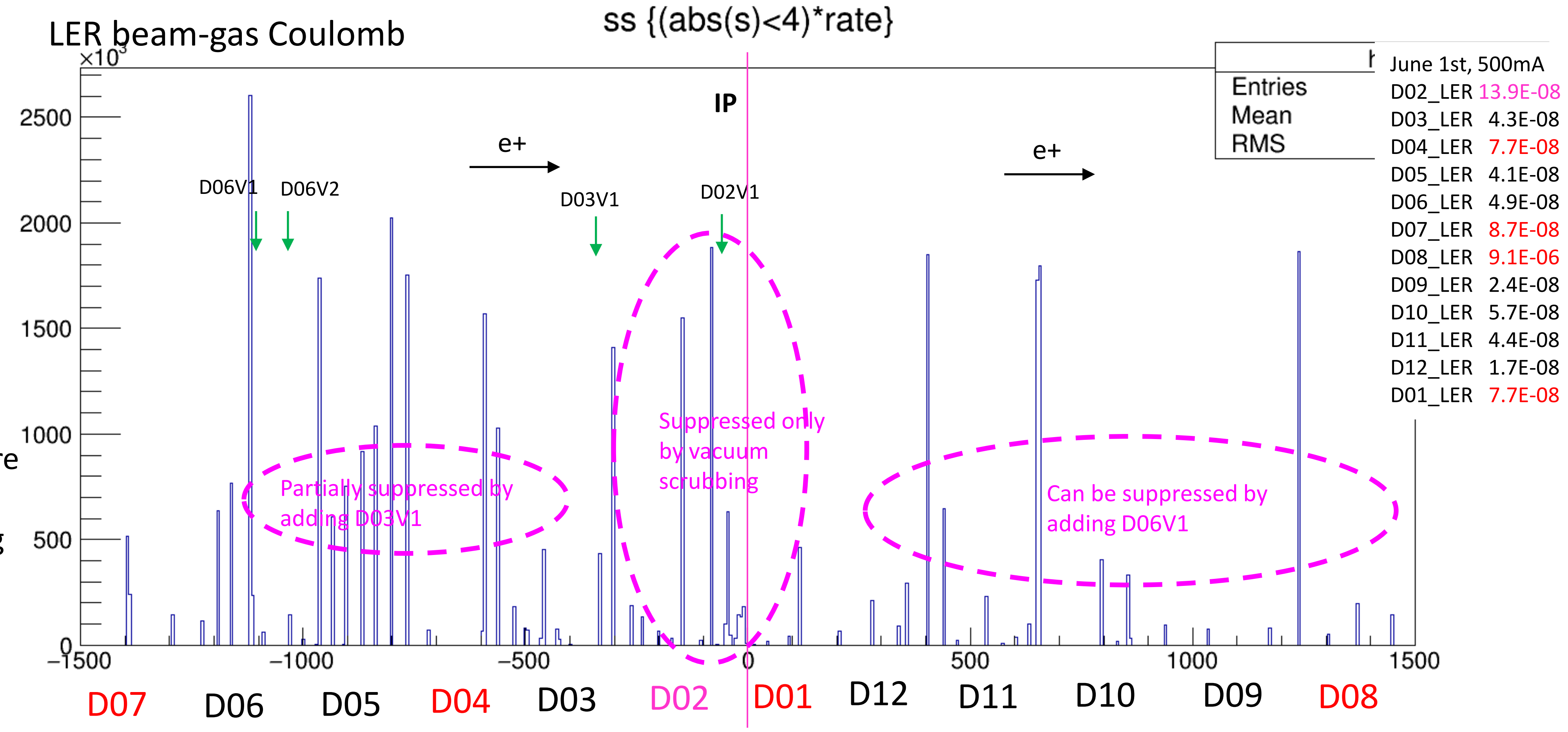
- NEG heating at all (tried) sections had impact on diamond rates as predicted by simulation
  → installing D06V1 (far from IP) can still suppress loss from D07-D12, D01
- D02, D06, D11 seems more sensitive than other sections
- Diamonds on beam pipe, QCS_FW bellows, QCS_BW bellows showed proportional increase in most cases, but the response was different for D02 bump (near IP).
  - Beam pipe diamonds directly sees interaction with beam and gas in IP beam-pipe?

Simulated scattered positions of IR loss

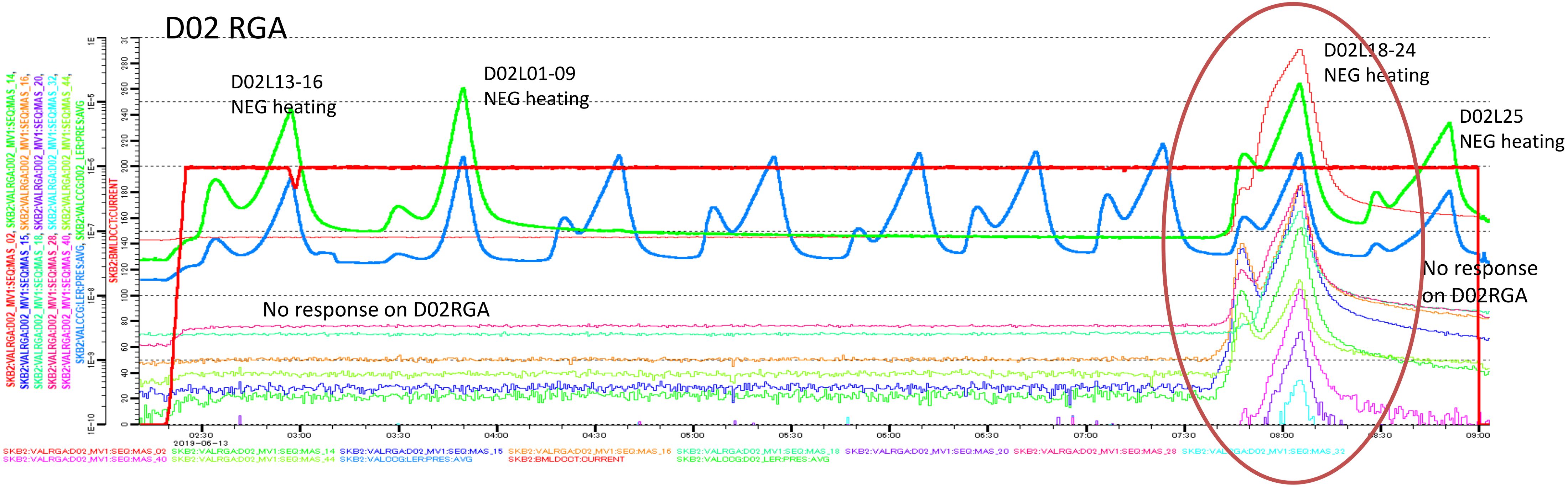
May 14th setting
D06V2=3.1mm
D02V1=2.1mm

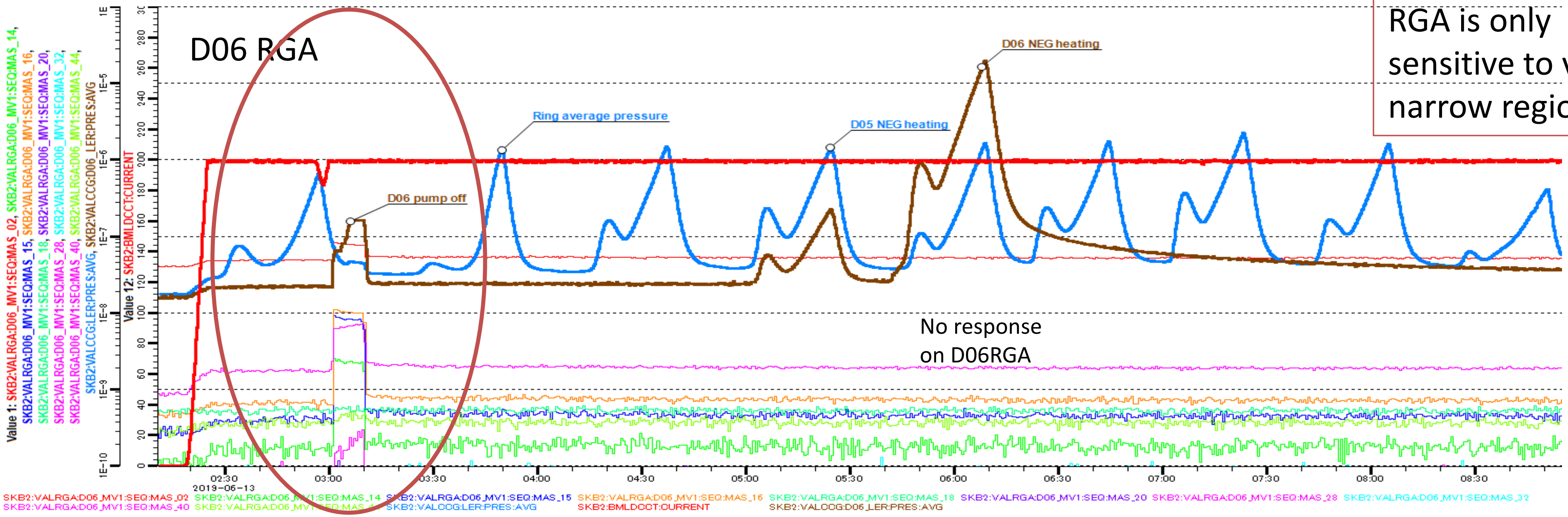
1nTorr uniform pressure assumed
(should be scaled using pressures at each section)

Single-turn loss only



Scattering at D02 is dominant source of IR loss.



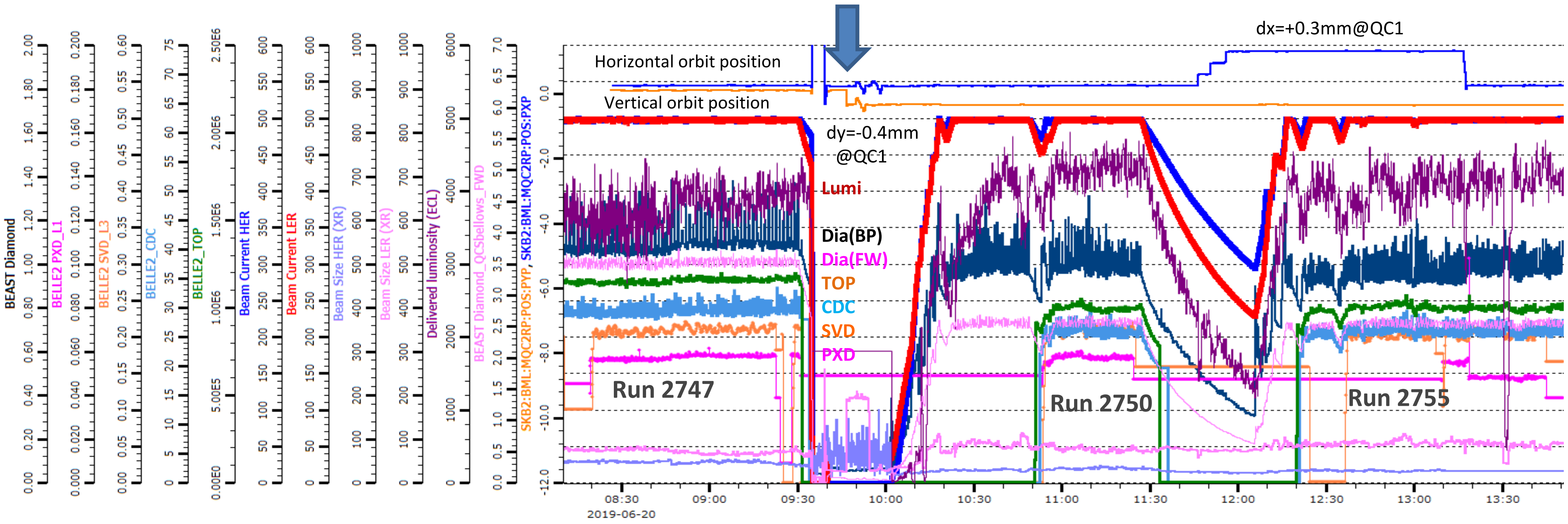


RGA is only sensitive to very narrow region

LER orbit scan study on June 20th, 2019

Hiro Nakayama (KEK)

LER orbit scan study on June 20th



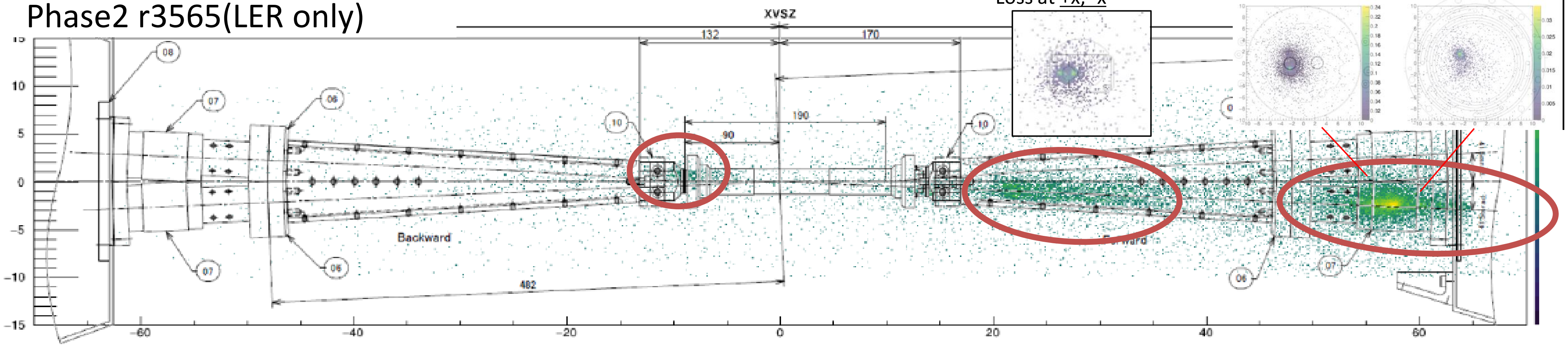
dpy=-1.0mrad (move LER upstream orbit vertically downward)
--> Diamond(QCS_FW) decreased by 30%, CDC/TOP decreased by ~15%, SVDL3/PXDL1 didn't change.
--> Luminosity becomes better (HER size smaller)
--> V0 hotspot at z=60cm moved from +Y to -Y.

dpx=-0.3mrad (move LER upstream/downstream orbit closer to Belle2 solenoid axis)
--> no significant change in Belle2/diamond rates, V0 hot spot, luminosity.

Phase3 MDI/BG topics

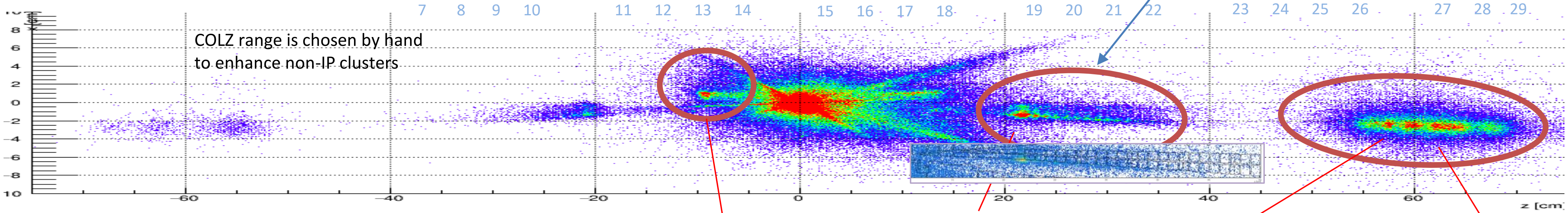
6. V0 vertex display ~ a powerful tool to show “hot spots” ~

Phase2 r3565(LER only)

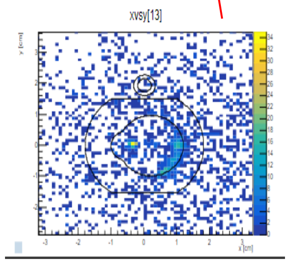


Phase3 r1976 (Lumi run)

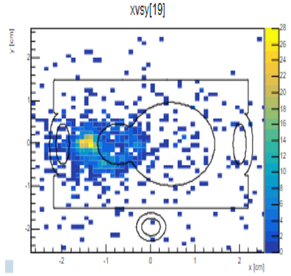
Hot spots on ridges?



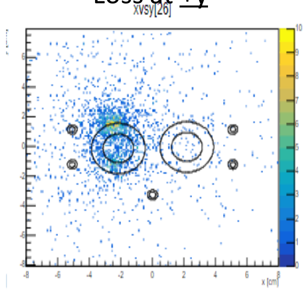
Loss at +x



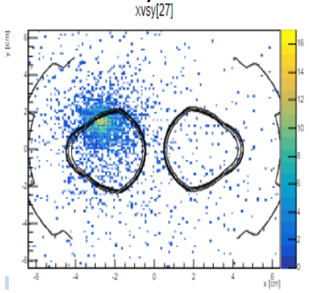
Loss at -x



Loss at +y

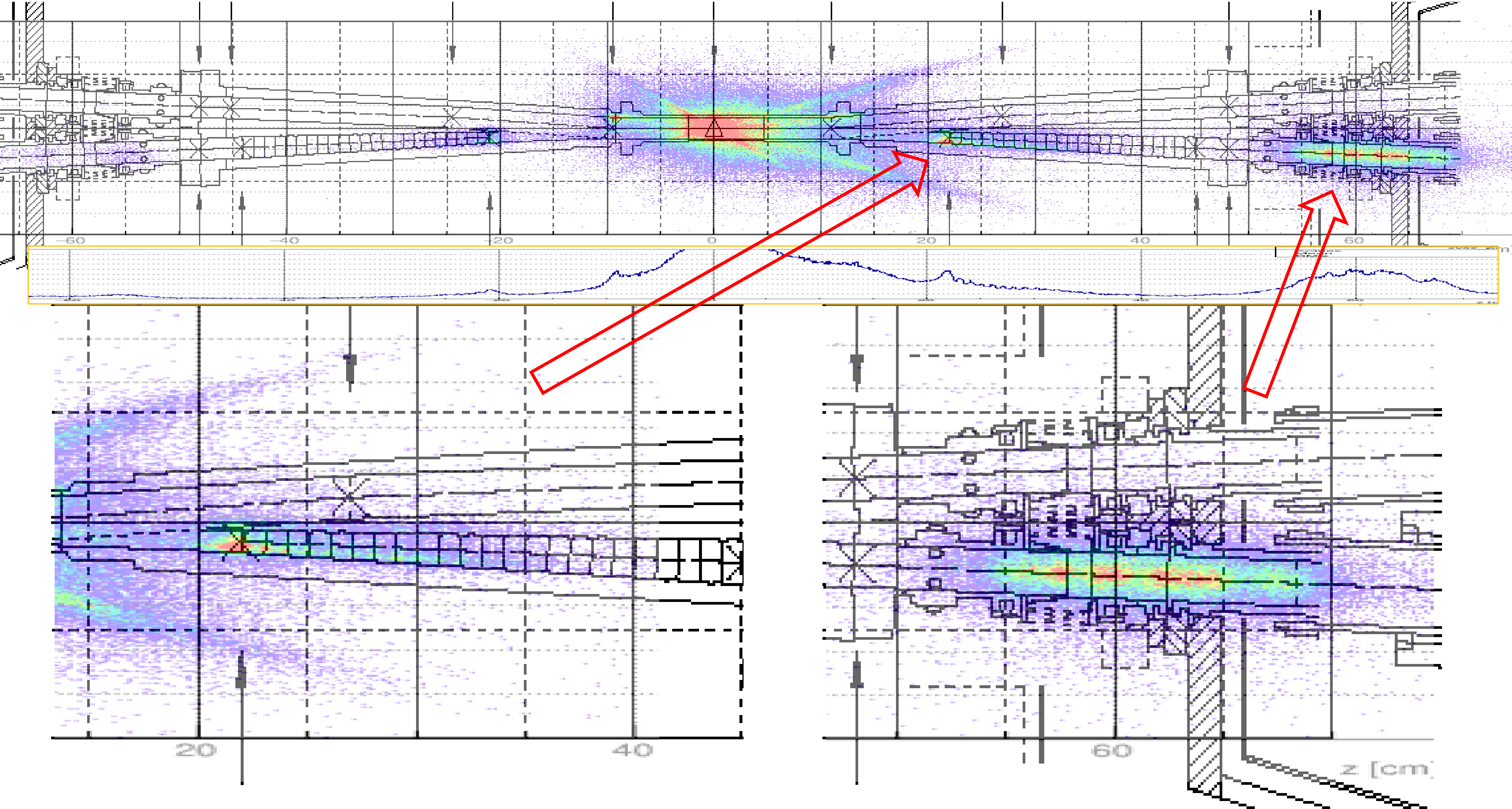


Loss at +y

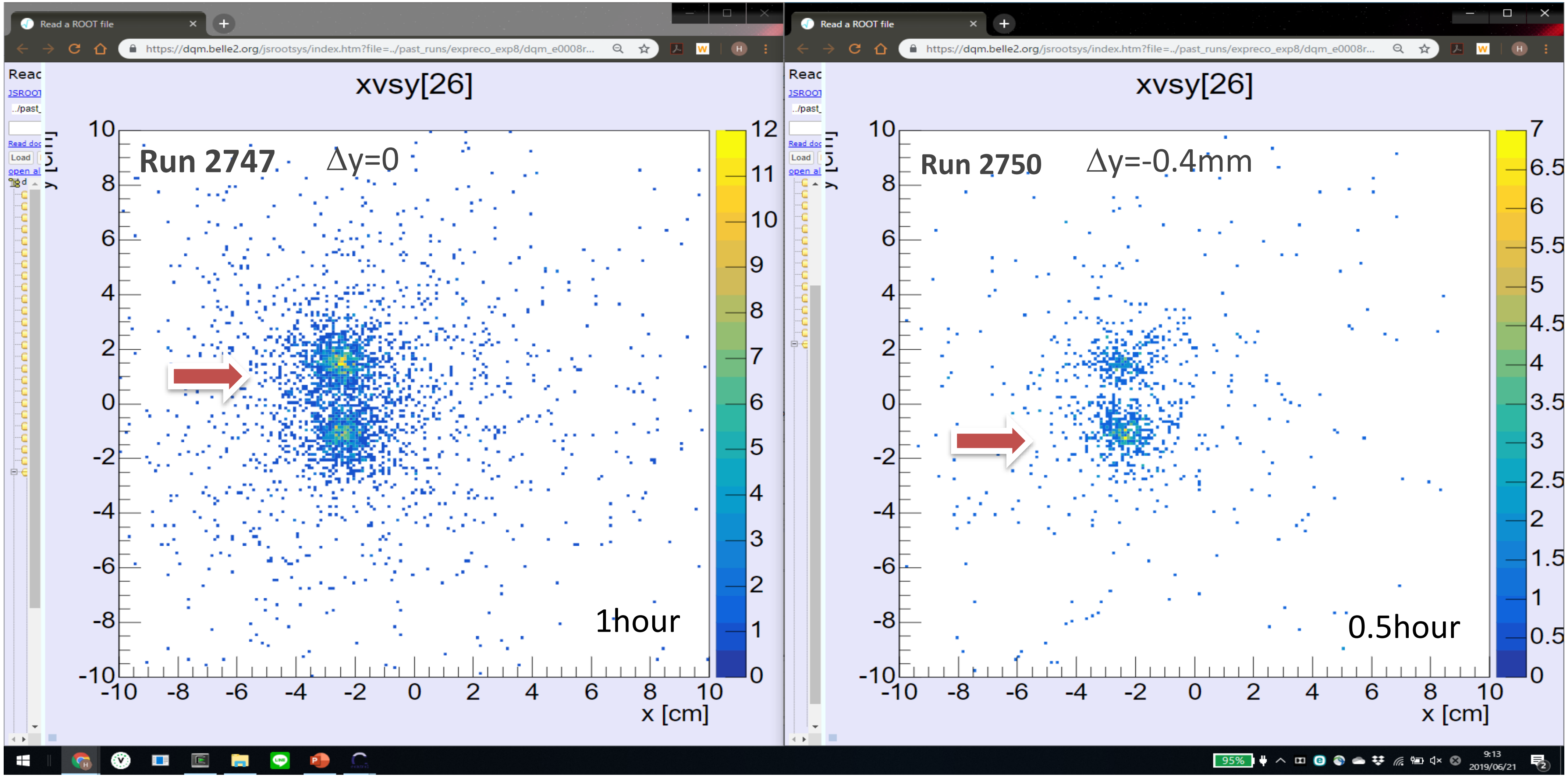


LER “hotspot” is different from phase2 → IR orbit adjustment might reduce IR loss? Study planned in this week.

Phase3 r1976 (Lumi run)



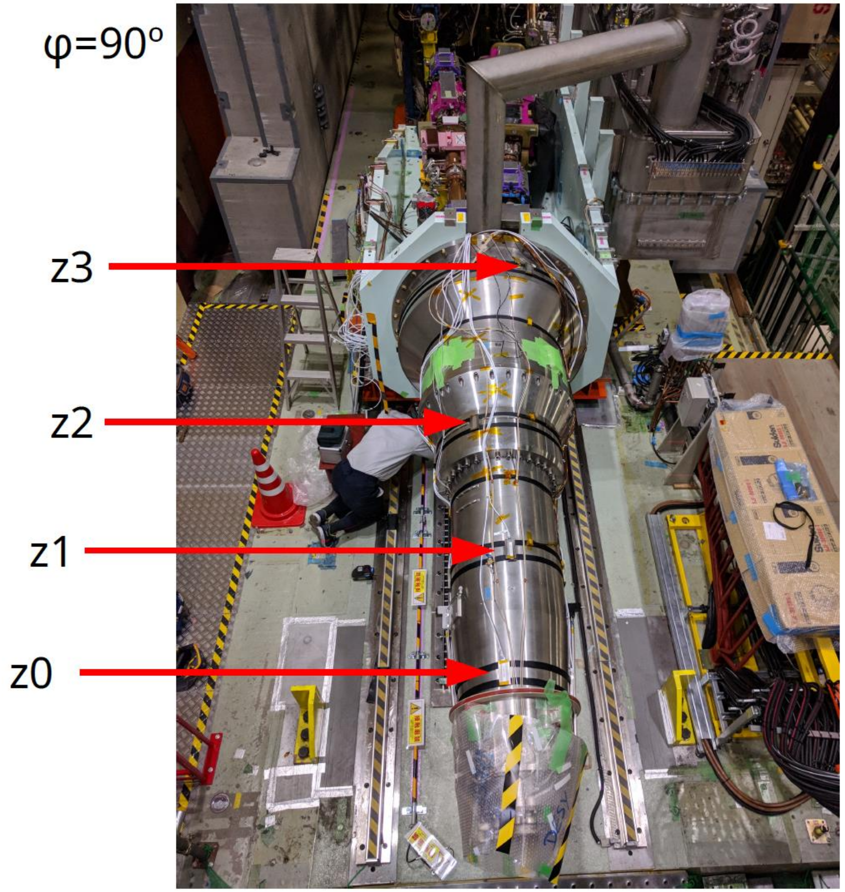
x-y view at z=+60cm
before/after vertical IR orbit scan



Phase3 Beast detectors

BEAST Detectors in Phase 3

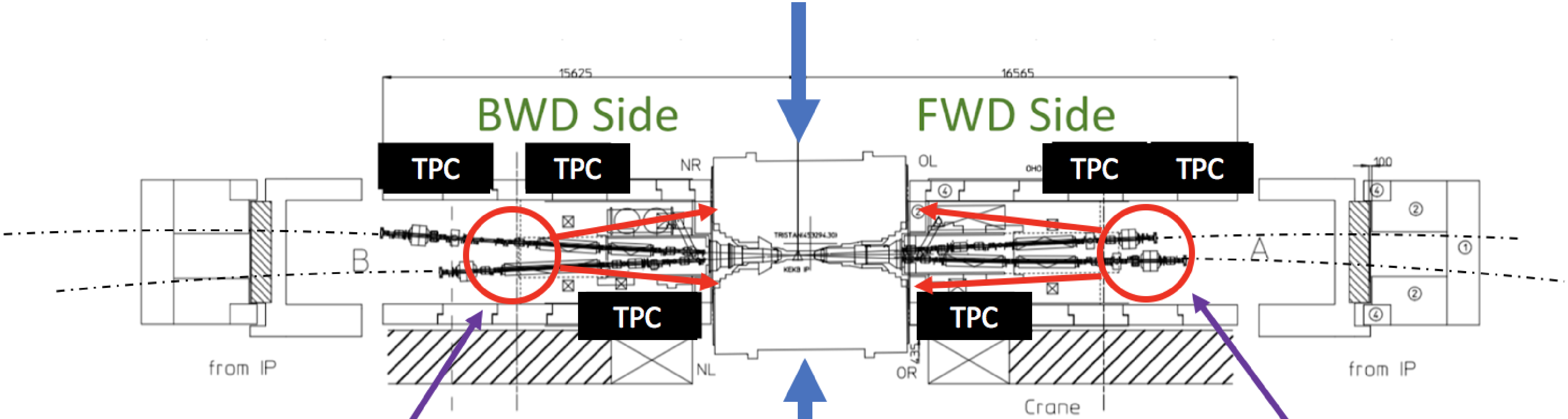
- Most of "BEAST" retired
- A few dedicated BG detectors remain
  - Diamonds
  - CLAWS++ on QCS
  - PINs on QCS
  - He-3 in tunnel
  - TPCs in tunnel
- BEAST online DAQ for BG monitoring via EPICS will keep running

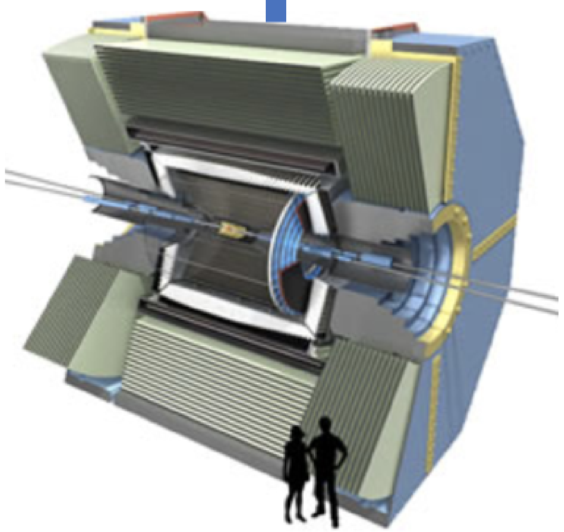


- We will display rates + rate limits of all Belle II and BEAST detectors in SuperKEKB control room (see BCG meeting talk by Jeff Schueler)
- BCG Shifters will monitor BEAST, call experts if there is trouble

Phase 3 TPC System

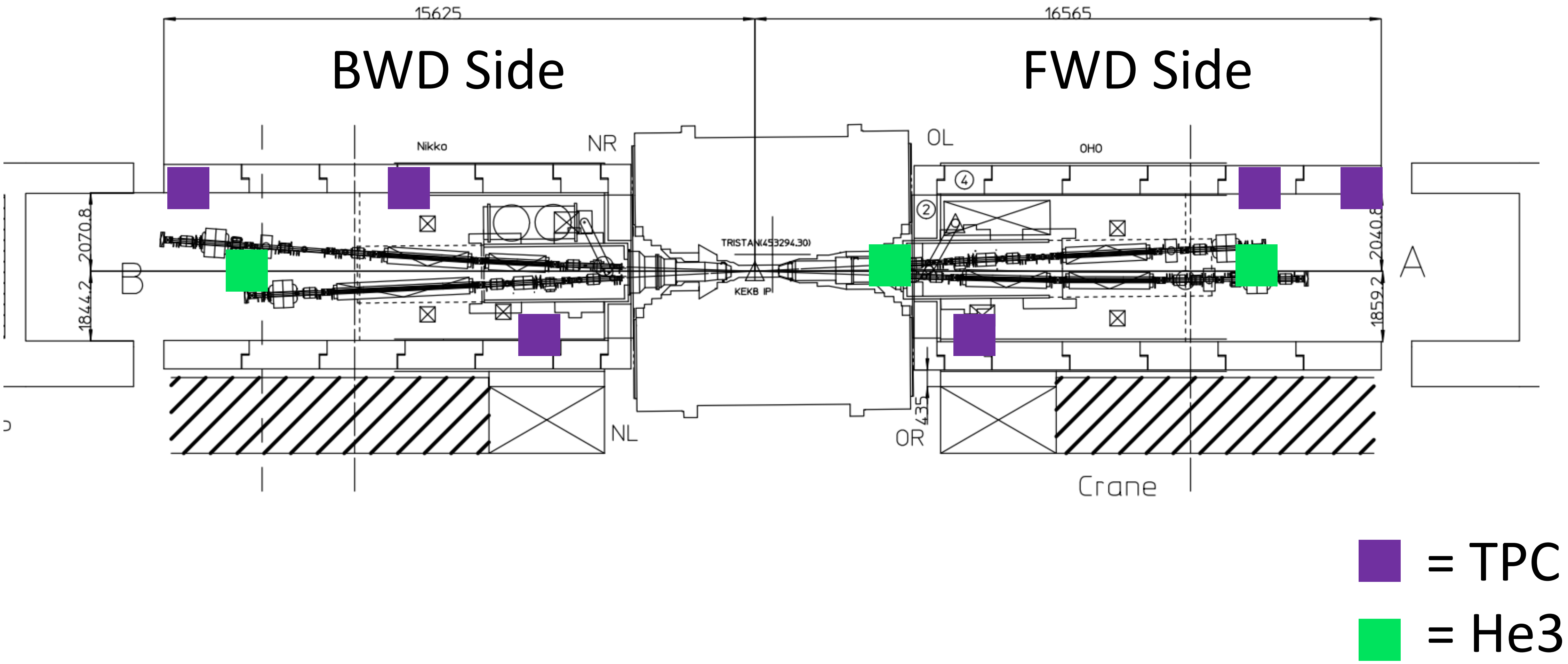
Top-down view of Belle II





Radiative Bhabha Hotspot produces neutrons that fly back toward Belle II (red arrows)

Radiative Bhabha Hotspot produces neutrons that fly back toward Belle II (red arrows)


15625
16565
BWD Side
FWD Side
Nikko
NR
OL
OHO
TRISTAN(453294.30)
KEKB IP
2070.8
1844.2
2040.8
1859.2
B
A
NL
OR
435
Crane
= TPC
= He3