Belle II operation status and plan

Kenta Uno (KEK)

ARC-BPAC

18th December, 2025

Objectives in 2025c
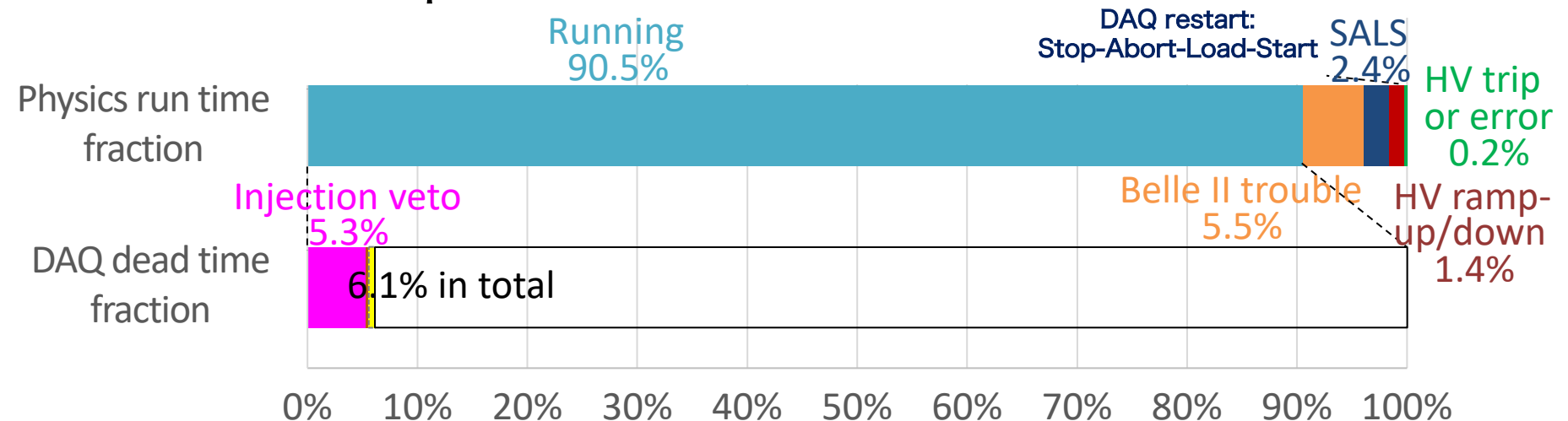
Accumulate the data of 425 fb^{-1} with acceptable background level

- **Higher data-taking efficiency is important!** (first target: 90%)

  - Key: DAQ stability, Quick recovery from DAQ error

Summary of the work is covered by K. Nakamura

Reminder: 2024c operation status

Physics run time fraction
- Running 90.5%
- DAQ restart: Stop-Abort-Load-Start
- SALS 2.4%
- HV trip or error 0.2%
- Belle II trouble 5.5%
- HV ramp-up/down 1.4%

DAQ dead time fraction
- Injection veto 5.3%
- 6.1% in total

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

We had been struggling with high background since the beginning of 2024c
→ overall data-taking efficiency = 85%

Our data taking efficiency depends on the beam background level

→ Mitigation of the background in cooperation with the SKB team is crucial
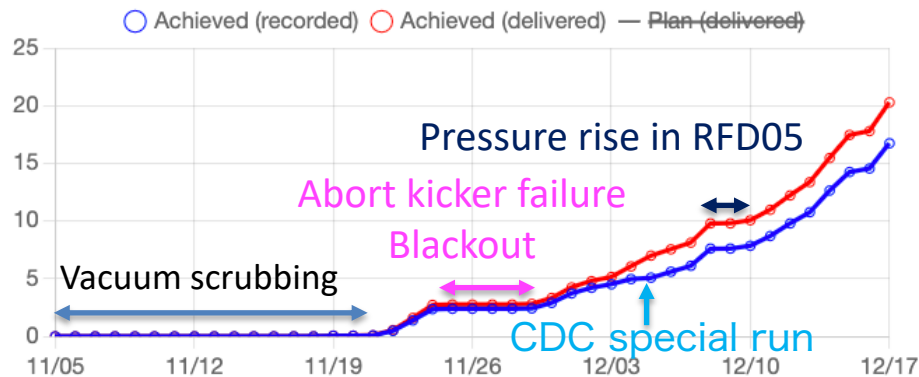
covered by H. Nakayama

Physics run in 2025c

We started physics runs on November 18

~2.2 fb^{-1}/day

Integrated luminosity (fb^{-1})

○ Achieved (recorded) ○ Achieved (delivered) — Plan (delivered)

Pressure rise in RFD05

Abort kicker failure

Blackout

Vacuum scrubbing

CDC special run

Daily integrated luminosity (fb^{-1}/day)

■ Achieved (recorded) ■ Achieved (delivered) — Plan (delivered)
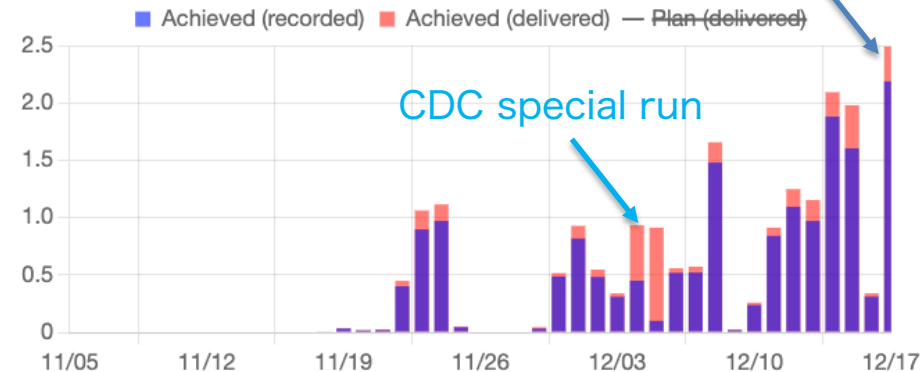
CDC special run
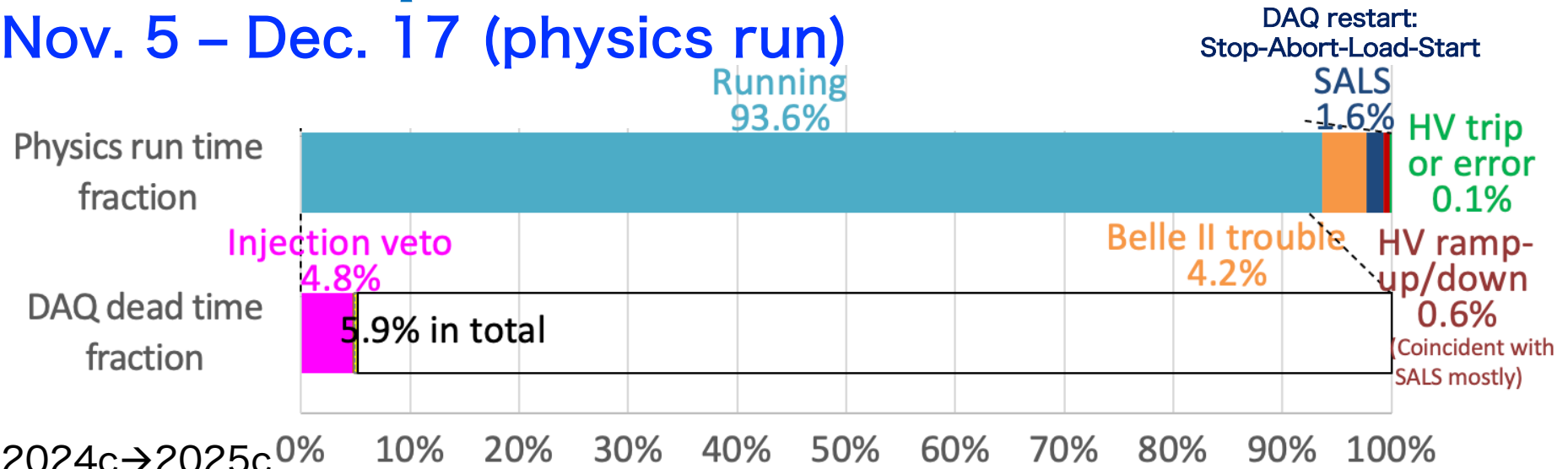
Delivered: 20.3 fb^{-1}
Recorded: 16.8 fb^{-1} + 1.0 fb^{-1} (for CDC special run)
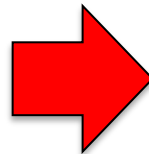
- Many machine troubles → lower physics run time

- Challenges in reaching high luminosity → lower peak luminosity

  - $L \sim 3.0{\times}10^{34}$ cm^{-2} s^{-1} during this weekend

- Machine stability improved! → Fewer beam aborts during physics runs

2025c operation status
Nov. 5 – Dec. 17 (physics run)

Physics run time fraction

Running 93.6%

SALS 1.6%

HV trip or error 0.1%

Belle II trouble 4.2%

DAQ dead time fraction

Injection veto 4.8%

5.9% in total

HV ramp-up/down 0.6% (Coincident with SALS mostly)

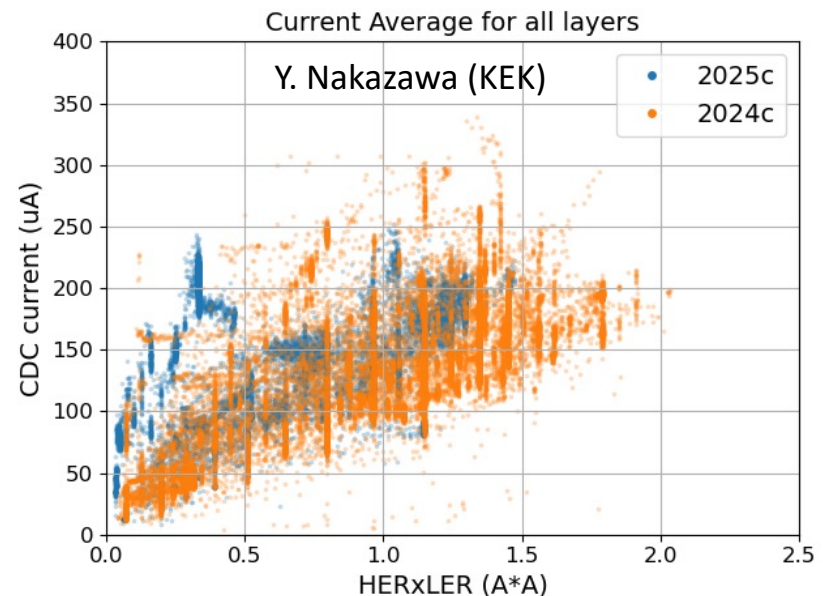0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

2024c→2025c

- Belle II trouble: 5.5% → 4.2%
- SALS: 2.4% → 1.6%
- HV ramp up/down 1.4% → 0.6%

Overall data taking efficiency is 88.1%

※ The bkg level in 2025c is comparable to that in 2024c.

Our DAQ stability is more robust, even under high bkg conditions

Current Average for all layers

Y. Nakazawa (KEK)

- 2025c
- 2024c

CDC current (uA) vs HERxLER (A*A)

2025/12/18

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Improvement: auto subrun restart

The new scheme helps to improve our data-taking efficiency

AUTO SUBRUN RESTART: QUICK RECOVERY WITHIN A RUN   S. Yamada (KEK)

> ➤ In data-taking, link errors between modules have occurred rather frequently :
>> ➤ **b2llost**: link lost between FEE and readout board(PCIe40)
>> ➤ **ttlost** : link lost between FEE and Trigger/Timing distribution modules(FTSW)

➤ In 2025c run, we implemented a feature to resume data-taking within a few sec. by only issuing an error reset signal to the FEEs. (A usual run restart takes 20-90sec. for software initialization.)

> ➤ The same run continues with an incremented subrun number.

Exp # : 36
Run # : 2050
Sub # : 1

➤ Since a link can be lost at arbitrary timing, recovery sometimes ends in data corruption or buffer full. Nevertheless, this mechanism has clearly contributed to reducing downtime. Efforts for the improvement is ongoing.

Success rate of subrun restarts from Nov. 20 to Dec. 3

Errors type	# of subrun restarts	Success	Failure	Success rate
CDC ttlost	31	22	9	71%
CDC b2llost	52	22	30	42%
TOP b2llost	2	2	0	100%
ARICH ttlost	2	2	0	100%
KLM b2llost	12	0	12	0%

Note: For specific error types, such as TOP ttlost (20 occurrences during the period, not listed in the table), subrun incrementation did not occur because the error reset failed beforehand. This is also an item to be improved.

Run stop reason in 2025c

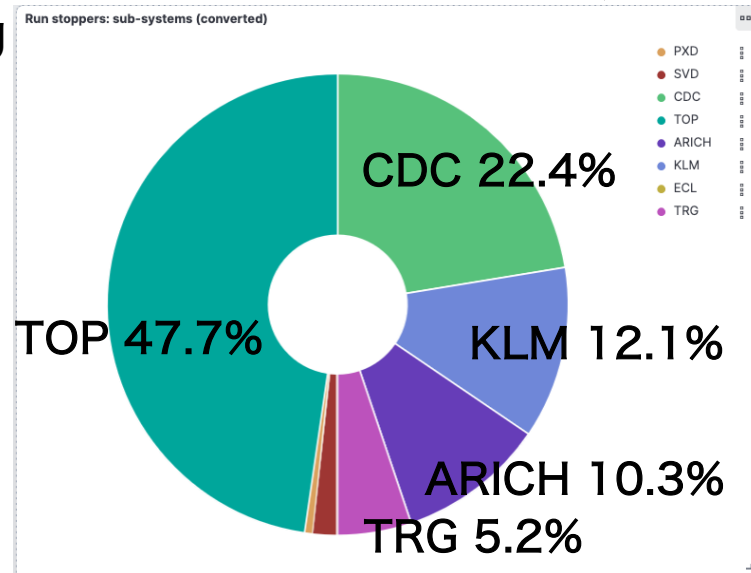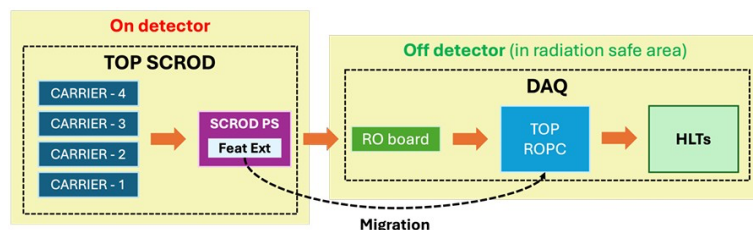**47.7% of the run stoppers were caused by TOP**

- Stopped the front-end electronics from SEU

M. Bessner (Hawaii)

Feature extraction on computers

- Single event upsets interrupt feature extraction on frontend electronics
  - Stop run, mask, resume run. Downtime from run restart process
  - Reprogram in background and include back in next run
- Most common run stop reason in Belle II at the moment
- New firmware sends full waveforms to readout PC instead
  - Feature extraction in ehut, away from single event upsets
  - Concept has been demonstrated, debugging some issues seen in physics runs

Run stoppers: sub-systems (converted)

PXD
SVD
CDC
TOP
ARICH
KLM
ECL
TRG

CDC 22.4%
TOP 47.7%
KLM 12.1%
ARICH 10.3%
TRG 5.2%

1

The original schedule was to use the firmware in 2025c, but not ready yet.

- Still debugging. Aim to be ready by 2026a

→ **Most of the TOP-related errors would be eliminated.**

Status of the beam bkg

In this shutdown, several beam pipes were opened/cleaned

- Higher pressure level is expected → higher beam-gas induced bkg

Current Average for all layers

Threshold: 280 uA

Config: lower HV in all layers
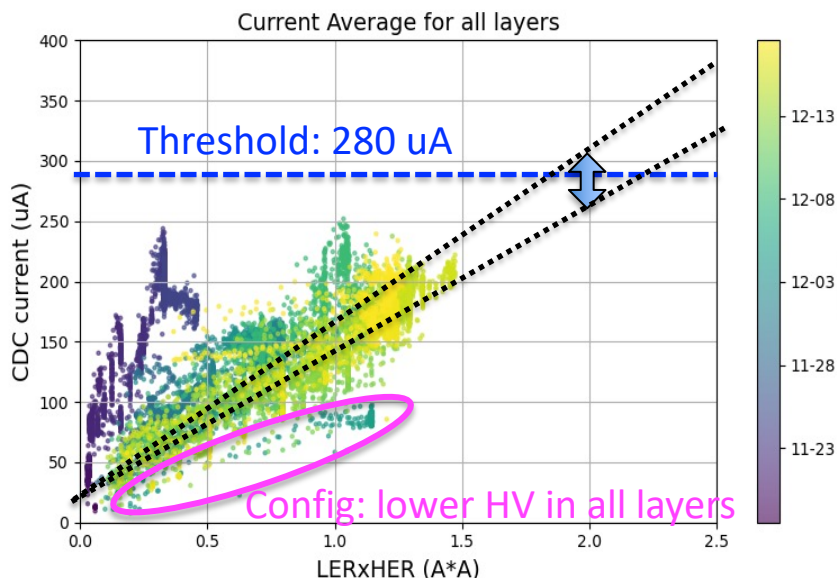
The background level has decreased

- Pressure level has gradually improved.

- The collimator optimization helps.

→ The leak current would reach 260 – 300 uA for $I_{LER} \times I_{HER} = 2.0\ A^2$
   1.6 A, 1.3 A: $\mathcal{L} = 5 \times 10^{34}\ cm^{-2}\ s^{-1}$

Threshold of CDC leak current (280 uA) is not hard limit

→ Gradually raise the threshold while carefully monitoring the CDC status

## Countermeasures to protect CDC: operation with lower HV

- The leak current is reduced, but the performance degradation is expected

- Collected ~1 fb^{-1} for both datasets with lower HV (all layers; only SL0-SL1).

  → Evaluation of physics performance is ongoing.

# Strategy for 10^{35} cm^{-2} s^{-1} run

$\mathcal{L} = 1.0 \times 10^{35}$ cm^{-2} s^{-1} → LER 2.6 A, HER 1.8 A at $\beta_y^* = 0.9$ mm

- Require improved machine quality

  - Improve inj. eff. and reduce inj. bkg

- If the bkg level is still not acceptable;

  - Tighten the NLC more aggressively

  - Lower CDC HV (if the performance allows)

  - If still insufficient, also close D06V1 collimator

bkg level on QCS

D06V1

NLC

effective for inj. bkg reduction

Open   Close
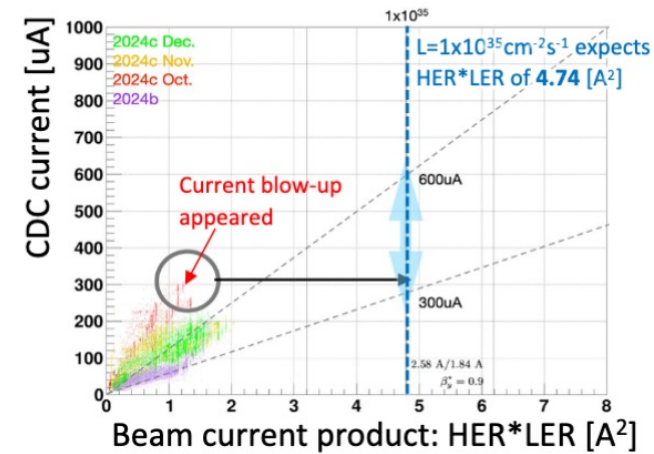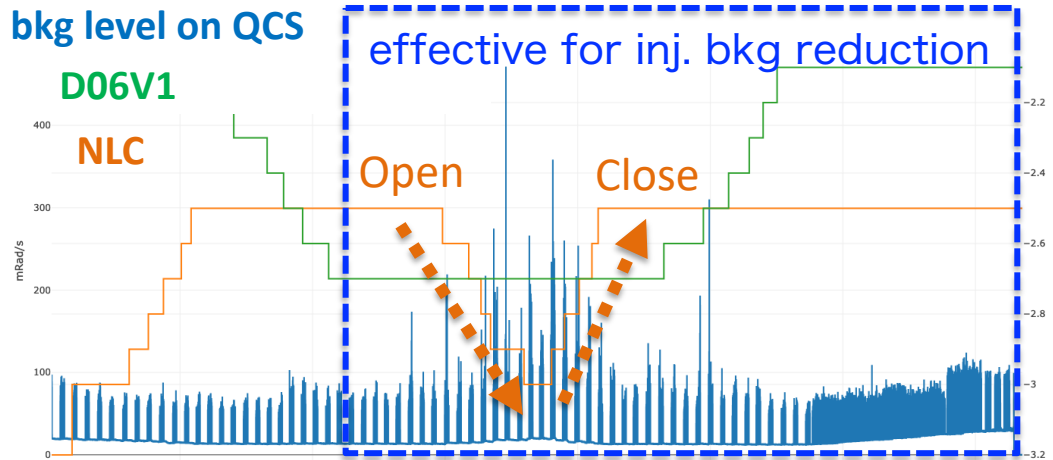
Vertical Emittance with/without BxB Feedback
(ν_x=0.5312, ν_y=0.59, $\Sigma\beta_y k_y$=3.33e16 V/C (calc.))

Effect of the bunch-by-bunch vertical feedback
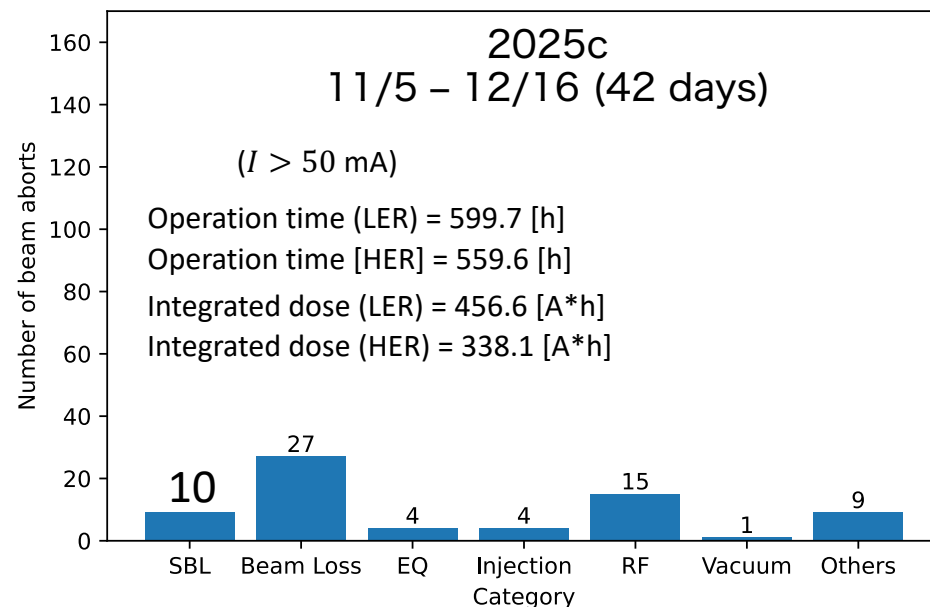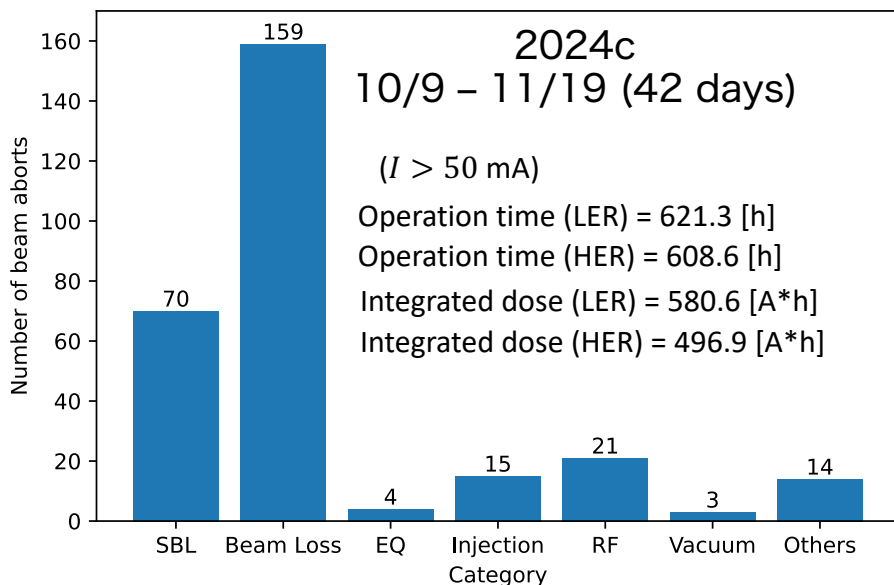(Mar 1, 2022)
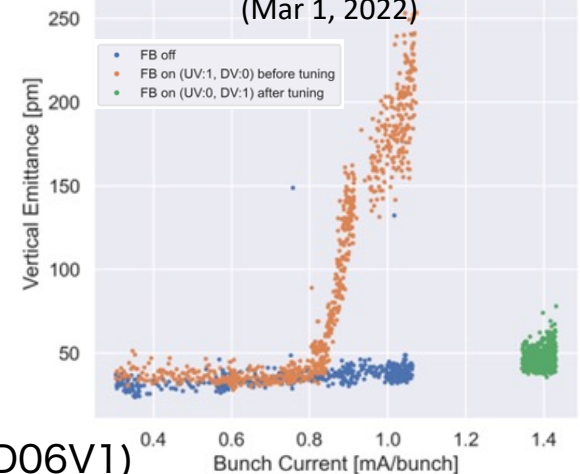
- The TMCI threshold is around 0.8-0.9 mA/bunch (if close the D06V1)
- The blow-up due to −1 mode instability can be suppressed by tuning the feedback
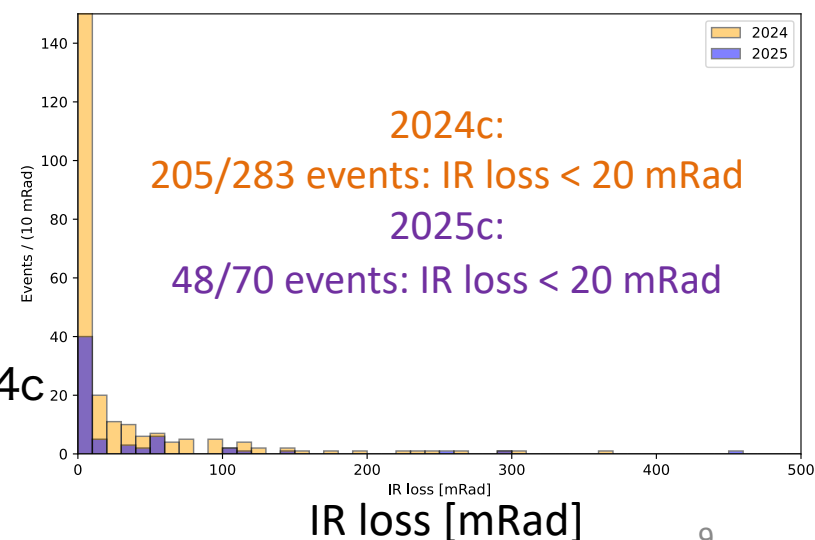
Machine stability

#aborts = 283

#aborts = 70

2024c
10/9 – 11/19 (42 days)

($I > 50$ mA)

Operation time (LER) = 621.3 [h]
Operation time (HER) = 608.6 [h]
Integrated dose (LER) = 580.6 [A*h]
Integrated dose (HER) = 496.9 [A*h]

2025c
11/5 – 12/16 (42 days)

($I > 50$ mA)

Operation time (LER) = 599.7 [h]
Operation time [HER] = 559.6 [h]
Integrated dose (LER) = 456.6 [A*h]
Integrated dose (HER) = 338.1 [A*h]

- **#of beam aborts is much reduced.**

→ #of SBLs is also reduced.

Keep monitoring the situation in higher current

The impact of IR loss has been reduced.

- #aborts with large IR loss is lower than in 2024c

2024c:
205/283 events: IR loss < 20 mRad
2025c:
48/70 events: IR loss < 20 mRad

IR loss [mRad]

2025/12/18

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Sudden Beam Loss

1 HER SBL

9 LER SBLs

- 8 SBLs with pressure burst at D11_L21

- 1 SBL without any pressure bursts

  - detuned optics

Monitor of the electrode signals

- No signals from the electrode near D11_L21 even when SBLs occur.

- Observed one abnormal signal on Dec. 11 at 5:38 a.m. (JST)

  - No beam abort at that time, but we observed the pressure burst
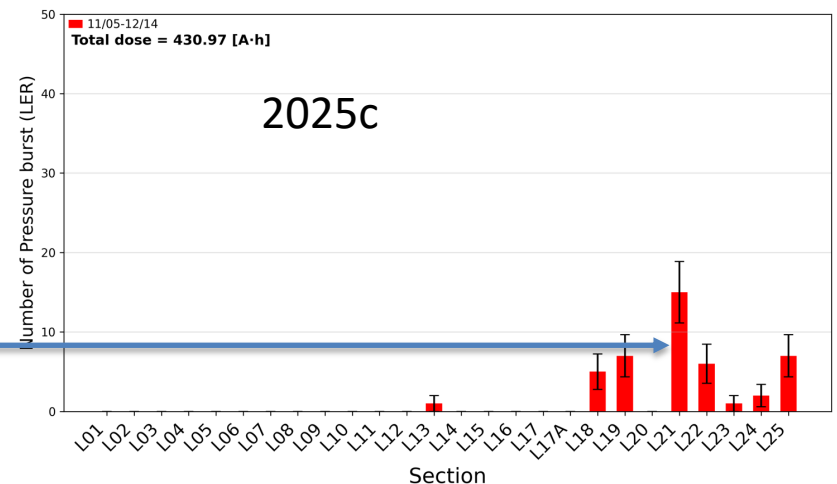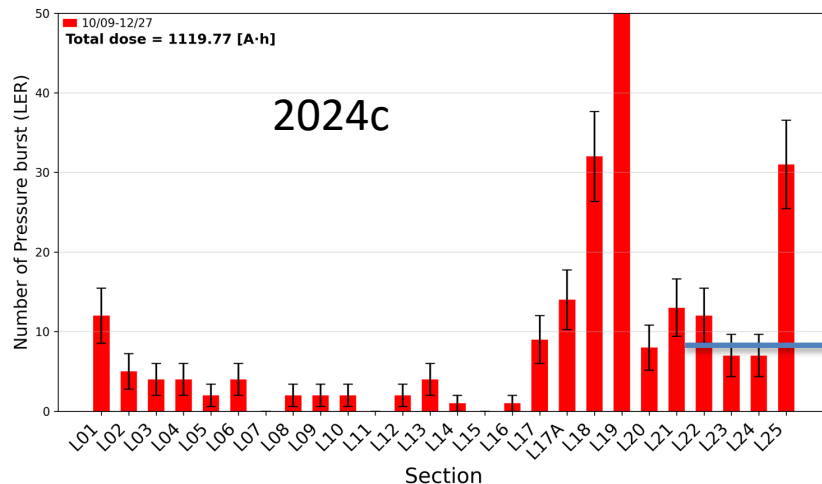
$\Delta p = 1.05$
(small)

2025/12/18

Self-trigger

Abnormal signal
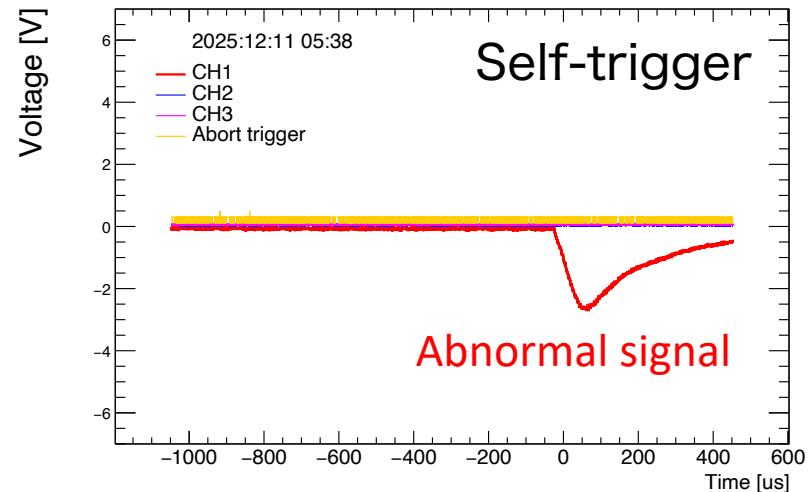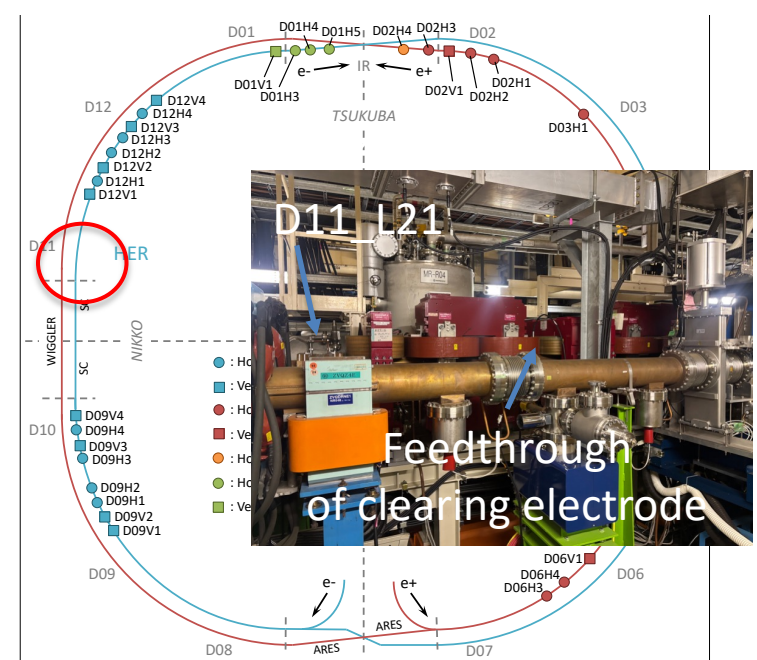
Pressure bursts at D11

Location (D11_L21): Nikko Wiggler Section

- They opened the beam pipe during the shutdown.

→ However, no indication that VACSEAL had been used. Anyway, they cleaned it.

Number of pressure bursts at D11

Current observation in 2025c

- Strong correlation between the pressure burst and LER SBLs

- However, no abnormal signals from the electrode.

 → Is the source different location? More investigation is necessary

Strategy to turn on PXD

We had discussion on December 12

- Importance of PXD for physics analysis

- The improved machine stability and frequency of SBLs

Jim Libby @ September 2024 BPAC meeting

Also ... novel tag-side decay time CPV measurements

Studies with PXD2 off

- Given 2024c data taking likely to be without PXD2 the time-dependent WG has investigated the impact on lifetime resolution and sin 2β
- B-lifetime resolution ~40% worse
  - Two different beam background scenarios tested – similar results
- For sin 2β from B→J/ψK_S the preliminary studies show a ~20% degradation
  - Study with sample with comparable size to current data
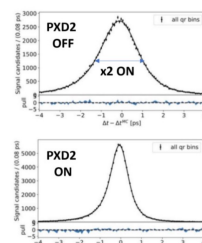
sin 2β value and uncertainty with and without PXD

Exp 0	PXD ON	PXD OFF
mean	0.715 ± 0.003	0.713 ± 0.003
width	0.035 ± 0.002	0.042 ± 0.002

Physics September 2024 BPAC   15

Based on study in TDCPV WG

- ϕ_2 measurement from $S_{\pi^0\pi^0}$
  - Uses only B_{tag} decay vertex and nano beam spot
  - 20x better sensitivity than method in Belle II Physics Book
  - Resolves discrete ambiguities

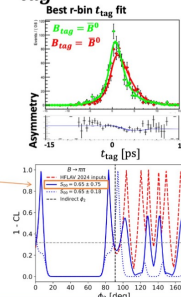- Vertex resolution from PXD is crucial !

K. Amos , M. Dorigo , S. Raiz , D. Tonelli , R. Žlebčík

First TDCPV measurement with t_{tag}

- Selection freely inspired to Oskar's paper
- Resolution model from $B^0 \to D^-\pi^+$
- $B^0 \to J/\psi K_S^0$ 365 fb^{-1} data
- Fit to t_{tag} with sWeight from ΔE
- $S(t_{tag}) = 0.844 \pm 0.089$ ($S(\Delta t) = 0.724 \pm 0.033$)
  → Consistent!
- → Precision as expected: only 3x worse than with Δt
- Project S precision on $\pi^0\pi^0$ sample size (neglecting difference in background)
  →Expected precision $S(\pi^0\pi^0)$ around **0.7**

Ready for the first $\pi^0\pi^0$ TDCPV measurement!
Will be done for Moriond 2026

https://indico.belle2.org/event/16060/contributions/100020/

R. Okubo, October 2025 B2GM TDCPV WG summary

PXD can be considered safe only with following conditions

- Acceptable SBL rates (with smaller IR loss)

- Fast hardware shutdown

- Reliable precursor signals arriving ~30 us before a high-radiation event at IR.

→ No signals from the clearing electrode in 2025c → No reliable precursor signals.

   → How to define "safe condition for PXD" in this case?
   No conclusion yet. Need more discussion to determine the criteria

Summary

- 2025c: Integrated luminosity: 16.8 fb^{-1} (recorded)

  - Several machine troubles, peak luminosity lower than planned

- Data taking efficiency 88.1% under bkg conditions similar to 2024c

  - Eg. Auto-subrun restart works well.

  - Further improvements are expected with the new TOP firmware.

- Machine stability improved: #SBLs is much reduced.. (but not zero)

→ We need to determine the criteria to turn on PXD as soon as possible.

Goal of 2026a-2026b

- Averaged. $L = 5 \times 10^{34}$ cm^{-2} s^{-1}

  - $5.0 \times 10^{34} \times 0.85 \times 85$ days = 406 fb^{-1}

    Data-taking efficiency   130 * 0.65 ~ 85 days

Target parameter values

G. Mitsuka

| Parameters	Target values	Comments
Peak luminosity (cm^{-2}s^{-1})	1x10^{35}	
HER beam current (A)	1.9 A	LER current x 0.75
HER bunch current (mA)	0.8 mA	for 2346 bunches
LER beam current (A)	2.6 A	
LER bunch current (mA)	1.1 mA	for 2346 bunches
Specific luminosity (cm^{-2}s^{-1}mA^{-2})	4.9×10^{31}	
Operation efficiency (%)	> 65%	
Physics run period (days)	85 (physics) + 45 (others)	

Includes machine trouble & maintenance time, e.g.
- Hardware trouble ~15% (average over 2022-2025)
  - + Liquid He work ~10%, i.e., 2 shifts every week
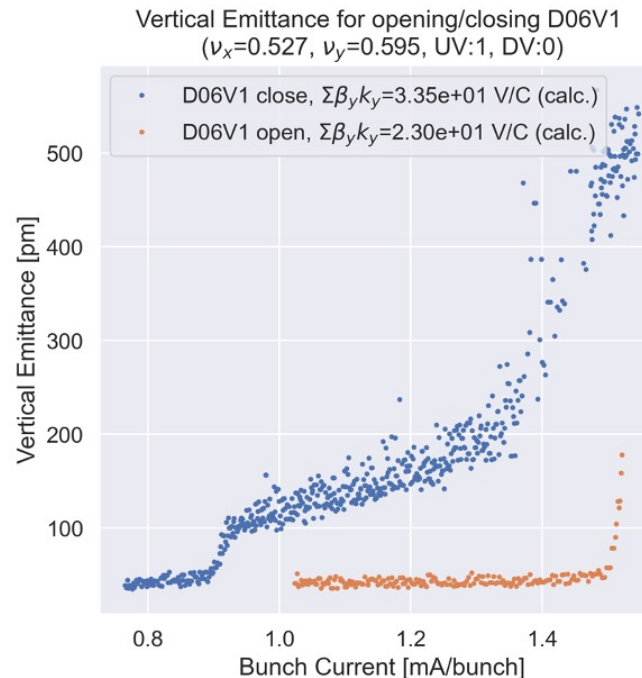- Monthly maintenance day ~3%

Backup

TMCI

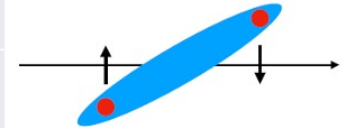### Effect of the bunch-by-bunch vertical feedback (Mar 1, 2022)
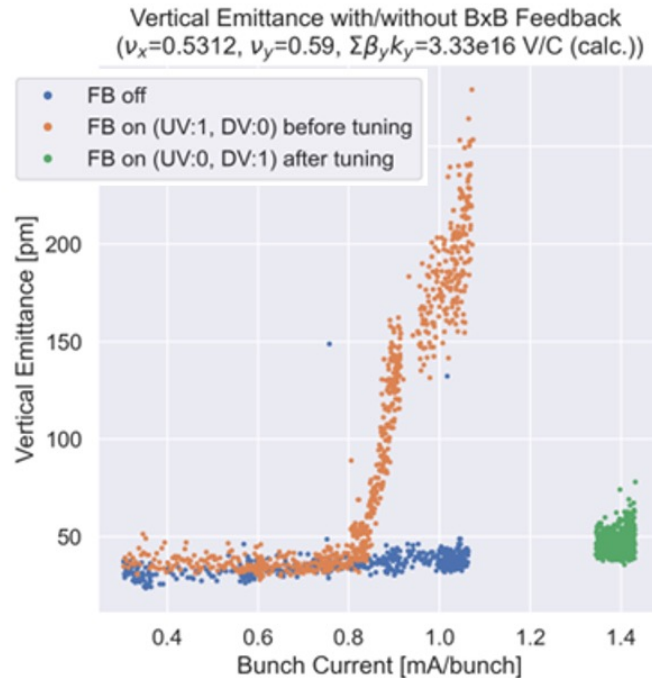
Effect of D06V1 collimator (Feb 28, 2022)

0 mode instability

−1 mode instability

Same eigen frequency at high I_b

Transverse mode coupling instability (TMCI)

Ishibashi-san's report:
https://kds.kek.jp/event/41509/contributions/209154/attachments/153746/194916/20220324_TMCI.pptx

- **TMCI threshold was found to be slightly higher than the design bunch current.**
- The beam size blow-up due to −1 mode instability can be suppressed by tuning the feedback or opening the collimator.
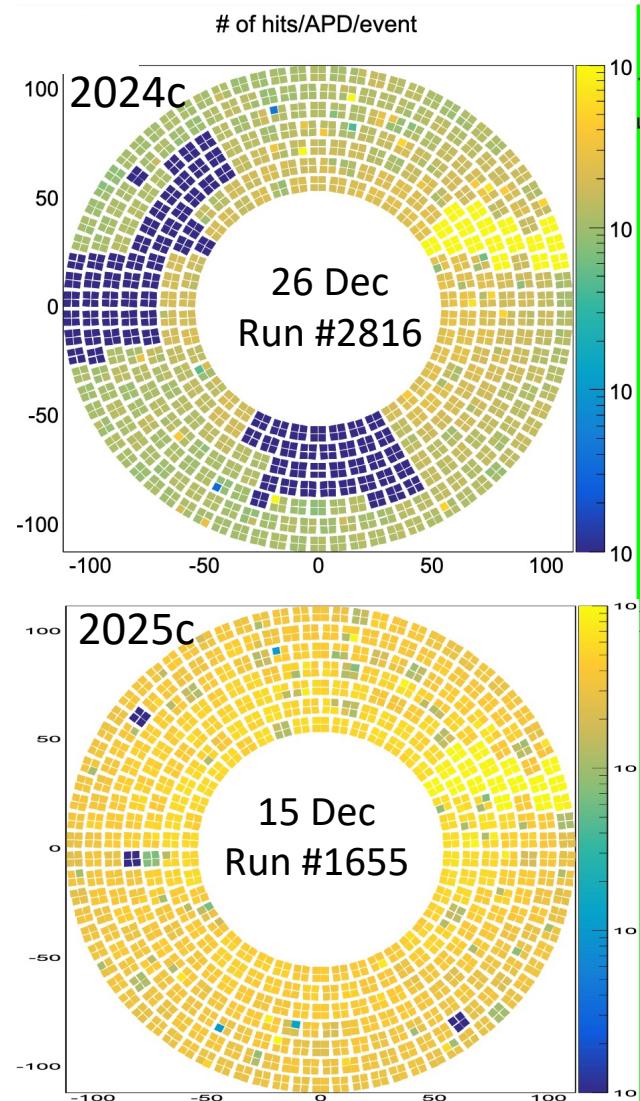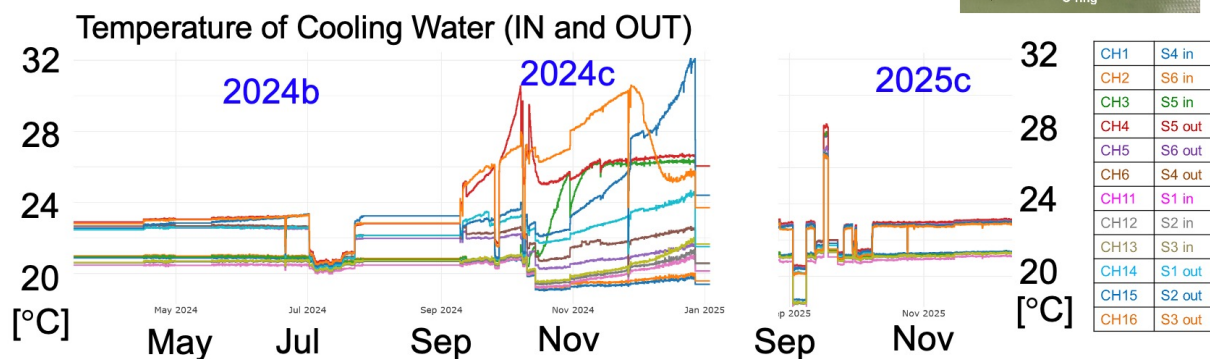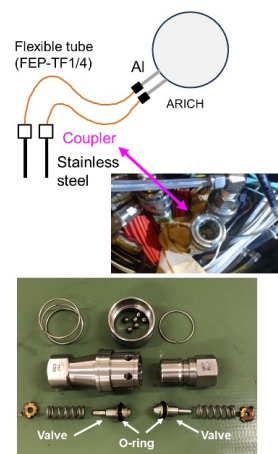
Other improvement: ARICH

S. Nishida (KEK)

BPAC report on June [Link]

# of hits/APD/event

ARICH Cooling Problem Solved

- Flow of the ARICH cooling water decreased in 2024c operation.
  - ✓ 10-20% of channels were needed to be off in 2024c.
- Green muddy water was found in the pipe; we suspected that pipes were clogged.
  - ✓ We thought the new chiller with copper and anti-corrosion agent were related.
- We opened the forward end yoke to access the ARICH pipes in summer 2025.
- Found that the couplers were clogged due to swelling of O-ring.
- We removed the couplers.
- In 2025c, the flow is recovered and ARICH is fully operated.

Flexible tube (FEP-TF1/4) Al ARICH

Coupler Stainless steel

Valve O-ring Valve

Temperature of Cooling Water (IN and OUT)

2024b   2024c   2025c

CH1	S4 in
CH2	S6 in
CH3	S5 in
CH4	S5 out
CH5	S6 out
CH6	S4 out
CH11	S1 in
CH12	S2 in
CH13	S3 in
CH14	S1 out
CH15	S2 out
CH16	S3 out

2024c
26 Dec
Run #2816

2025c
15 Dec
Run #1655

The data quality has returned to nominal.
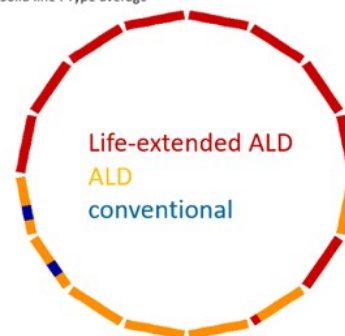
- Estimated with lifetime obtained in the test bench
  - Note that PMTs show faster degradation.
- Will replace ALD PMTs in 2028-2029, life-extended ALD PMTs in 2036-2037
  - In most optimistic case.
  - Need additional budget for later PMTs.
    - ~320 PMTs for all life-extended.
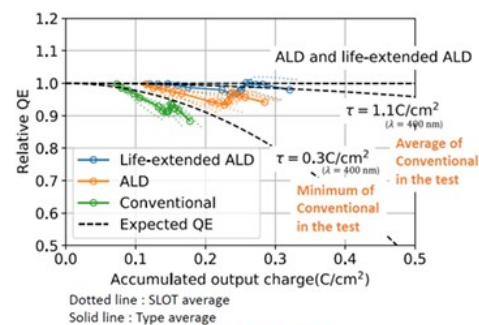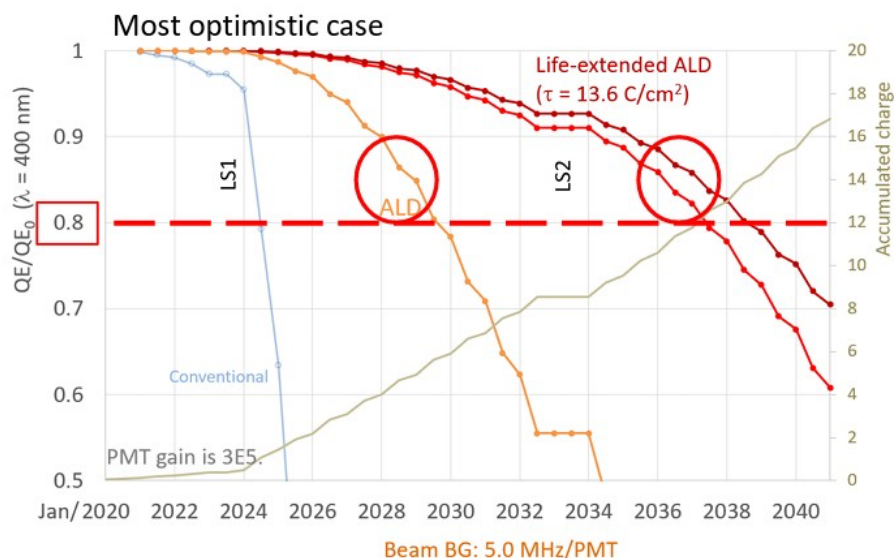
K. Inami
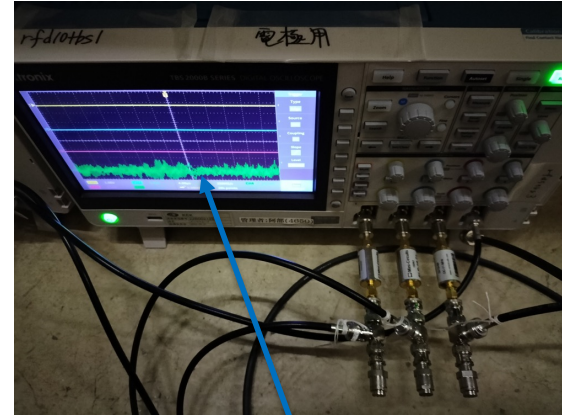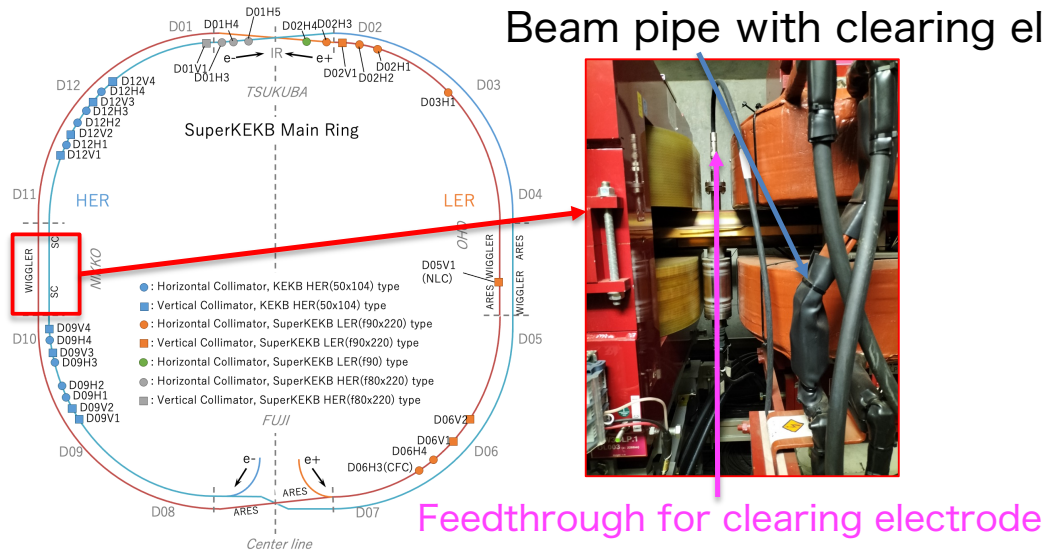TOP parallel session
of Feb 2025 B2GM

2

Signals in clearing electrode

Monitor signals from some clearing electrodes at D10 in 2024c

SuperKEKB Main Ring

Beam pipe with clearing electrode

Feedthrough for clearing electrode

Monitor the signal
from the feedthrough

Observed an abnormal signal at D10

- Signals at the electrode near the area where the pressure burst occurred.
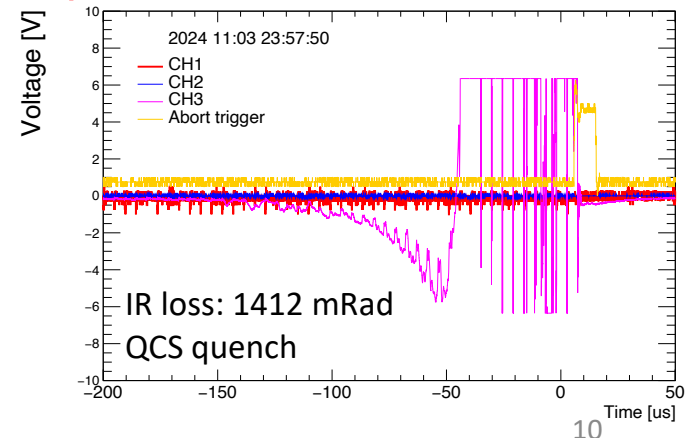
  - No signals from other locations

  Strong correlation with SBL!

Let's use this signal to protect Belle II

2025/6/16

LER SBL on Nov. 3 23:57
(pressure burst at D10_L02/D10_L03)

2024 11:03 23:57:50

CH1
CH2
CH3
Abort trigger
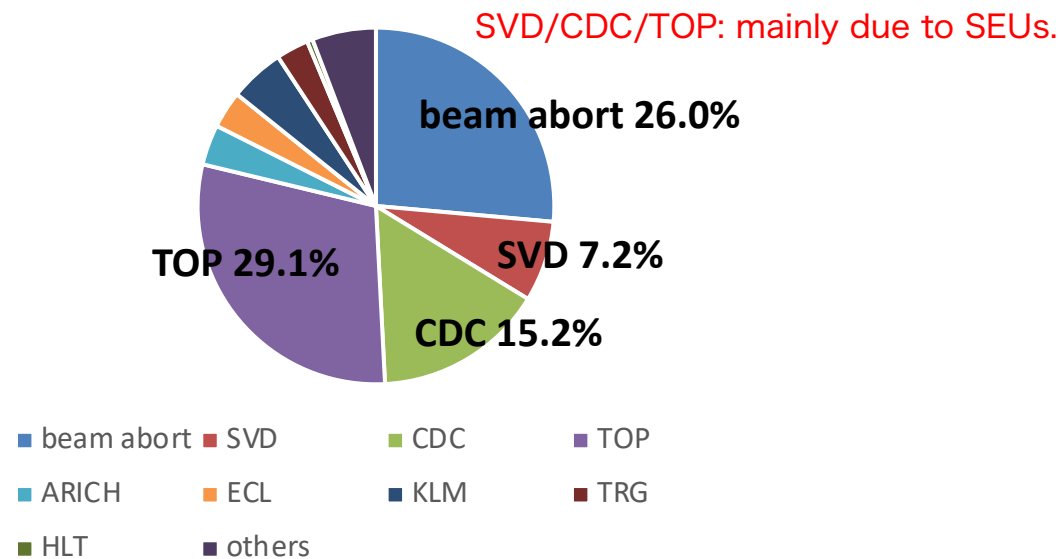
IR loss: 1412 mRad

QCS quench

Run stop reason in 2024c

2024c: 10/9 – 12/7

- Run stop reason:
  - TOP: 29.1%
  - beam abort 26.0% .
  - CDC: 15.2%.
  - SVD: 7.2%
  - KLM: 4.9%
  - ARICH: 3.6%
  - ECL: 3.3%
  - TRG: 2.9%.
  - HLT: 0.5%
  - others: 5.7%

run stop reason

SVD/CDC/TOP: mainly due to SEUs.

beam abort 26.0%

SVD 7.2%

CDC 15.2%

TOP 29.1%

■ beam abort ■ SVD ■ CDC ■ TOP
■ ARICH ■ ECL ■ KLM ■ TRG
■ HLT ■ others

As the BG increases, the frequency of DAQ errors becomes higher

- Eg. our data taking efficiency in the last week was 71.7% (ref. 85% overall)

Challenge of SuperKEKB   Challenge of Belle II

We must improve both aspects: BG reduction, high detector robustness

- May have to accept the BG level in the future ($\mathcal{L}_{peak} > 10^{35}$ cm^{-2} s^{-1})

Eg. Firmware update in SVD: Automatic recovery from DAQ errors related to SEU.

K. Nakamura's talk