

Injector Status (1)

Masanori Satoh (Acc. Lab. Div. V, KEK)

on behalf of Injector Linac Group and Linac Commissioning Group

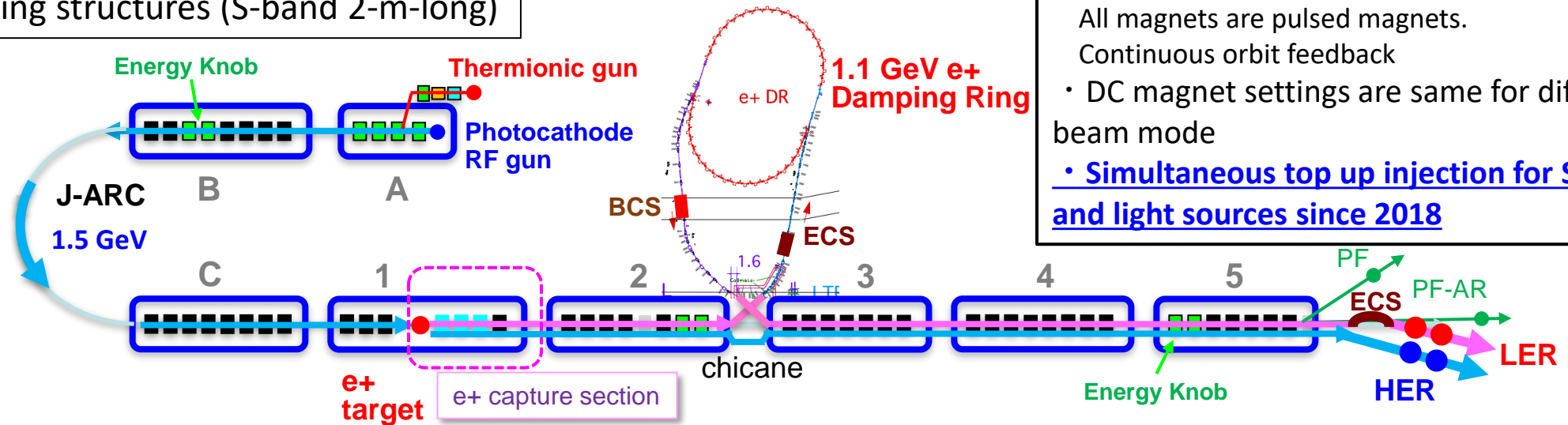
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- Summary

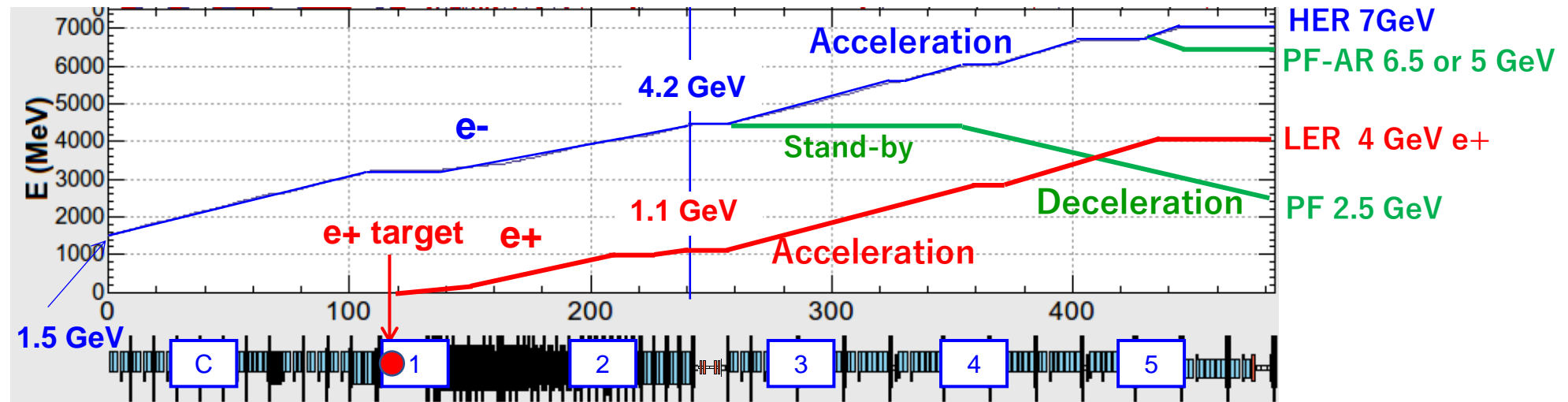
- Injector status (2) : M. Yoshida
 - Detailed RF gun status and future plan
- Injector upgrade plan: F. Miyahara
- Beam transport Line: Driss Oumbarek Espinos
- Injection tuning: T. Yoshimoto

Injector Linac Layout

Four rings share 50 Hz beam from injector
60 klystron units
240 accelerating structures (S-band 2-m-long)



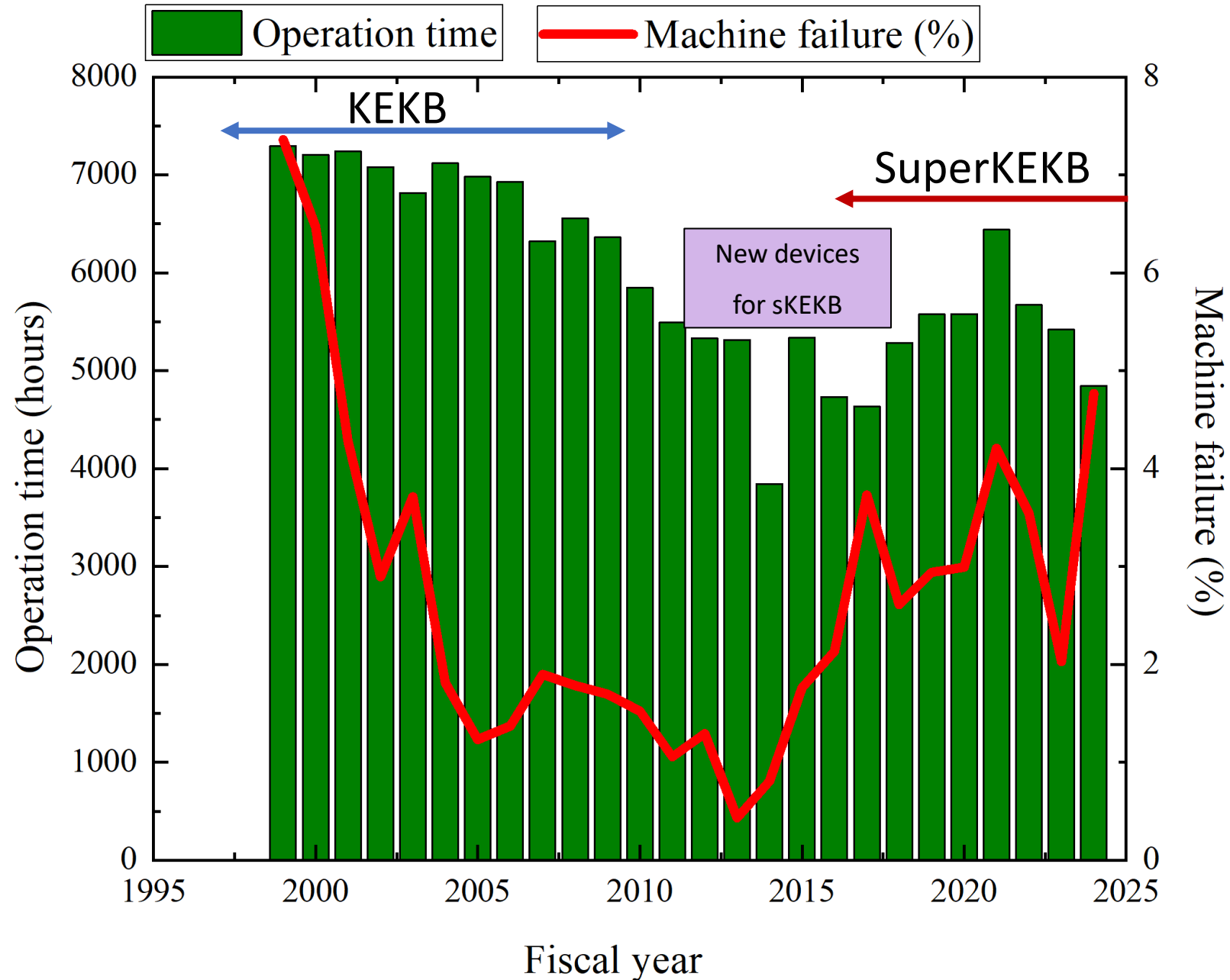
- Two electron sources:
 - RF gun: HER injection
 - Thermionic DC gun: LER, PF, PF-AR
- Sector 3-5:
 - All magnets are pulsed magnets.
 - Continuous orbit feedback
- DC magnet settings are same for different beam mode
- Simultaneous top up injection for SuperKEKB and light sources since 2018



Beam energy variation for each beam mode along the beam line after J-ARC

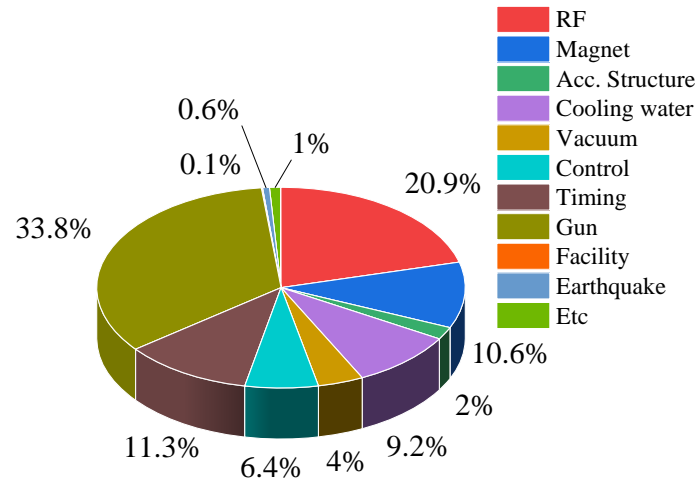
Injector operation statistics

Operation statistics

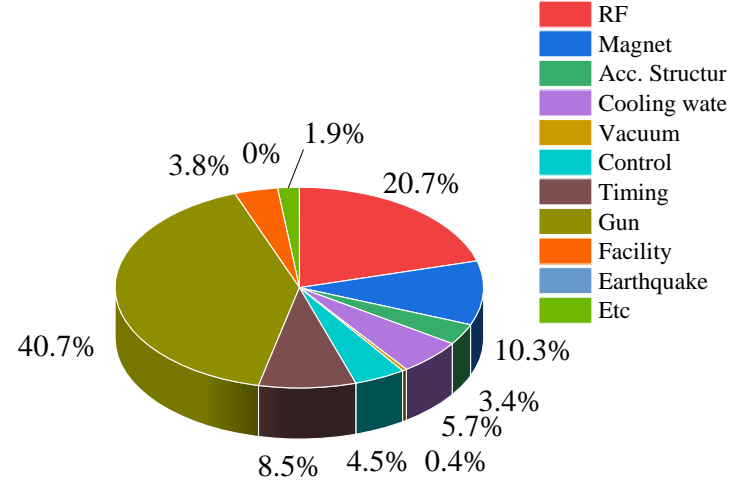


- Operation time has been gradually decrease due to High electricity cost.
- Machine failure rate increased from 2% (FY2023) to 4.7% (FY2024)

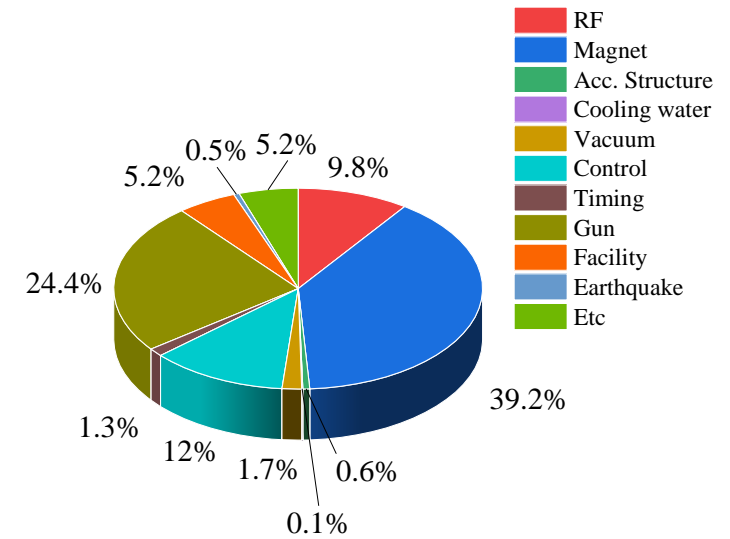
Injector beam loss time statistics (FY2020 – FY2022)



FY2020: 1.58%



FY2021: 1.83%

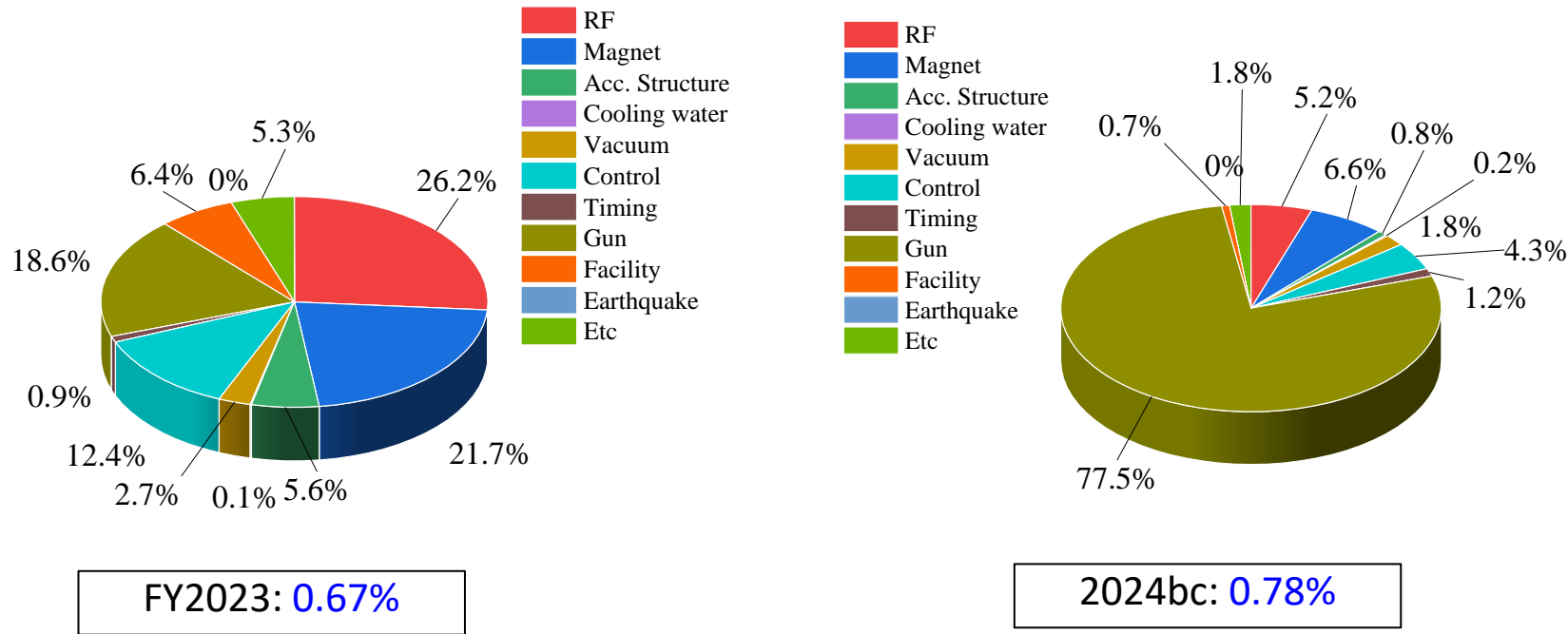


FY2022: 0.81%

- Beam operation could be interrupted by some different reasons. (RF, magnet powers supply, control software failure, ...)
- **Beam loss time ratio** is less than 2%.
- Most beam loss time are caused by RF and e- gun related troubles.
- In FY2022, beam loss time is less than 1%.
 - From 2022c to 2023c, SuperKEKB was not in operation due to LS1.
 - Linac klystron operation mode was changed from 50 Hz to 25 Hz.
- In FY2022, most of beam loss time are caused by magnet trouble.
 - Pulsed magnet controller problem.

Injector beam loss time statistics

(FY2023 – Run2024bc)

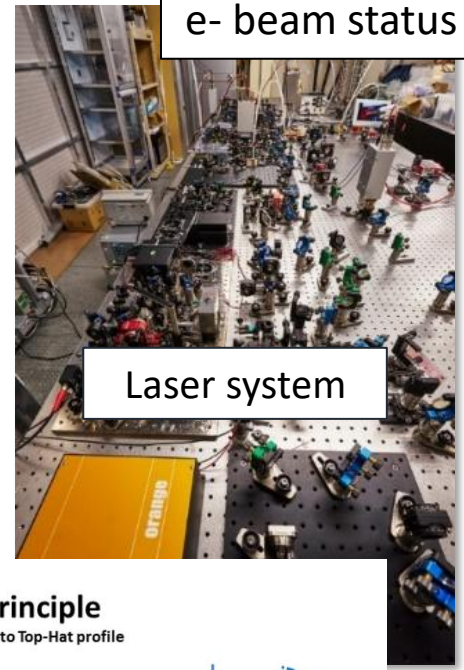
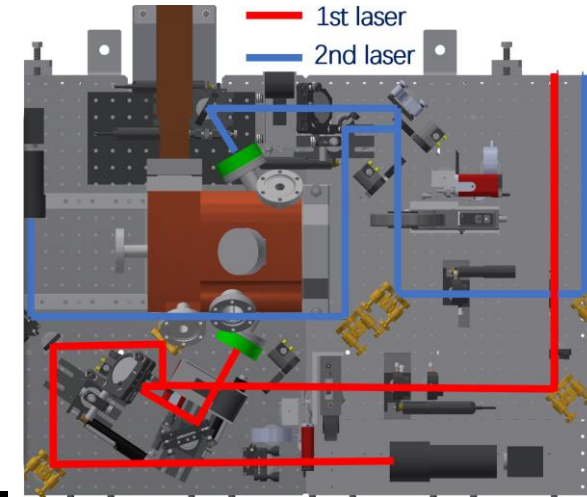
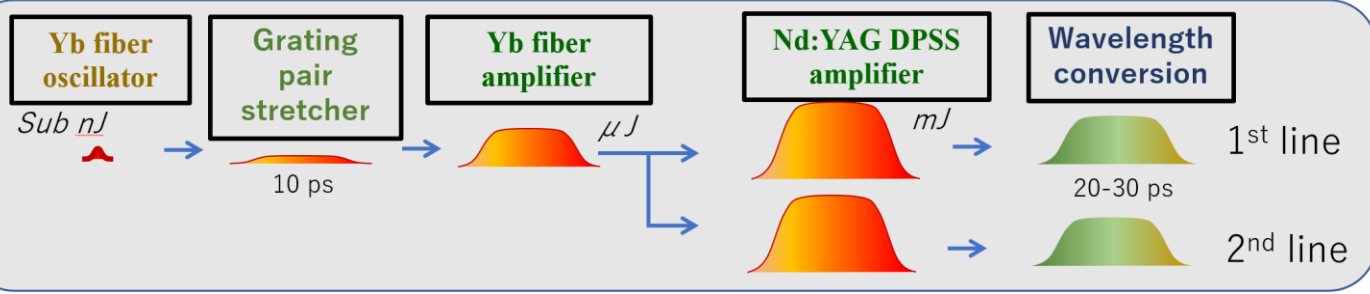


- In 2024c, all pulsed magnet control PC and software (18 units) have been replaced by new one.
 - It reduced the beam loss time due to the pulsed magnet trouble.
- In 2024c, most of gun trouble are caused by cavity discharge.

e- beam status and issue

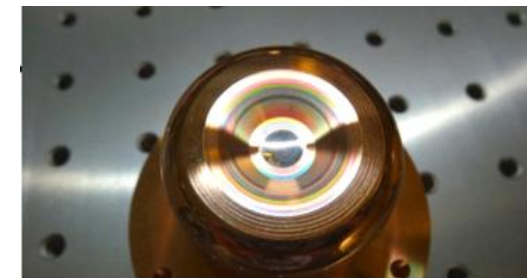
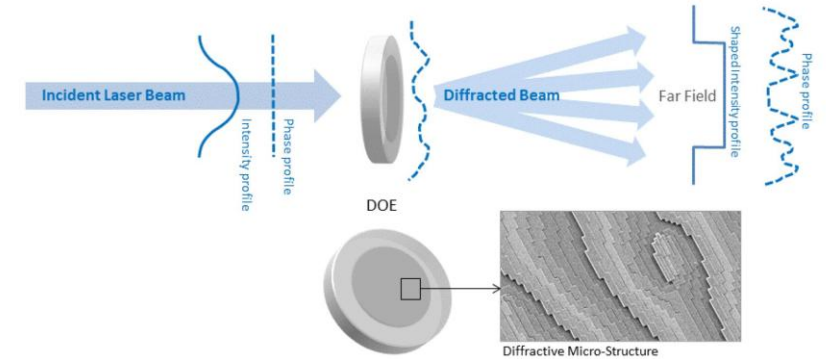
Low emittance photocathode rf e- gun

- Yb doped fiber and Nd:YAG DPSS module Amplifier

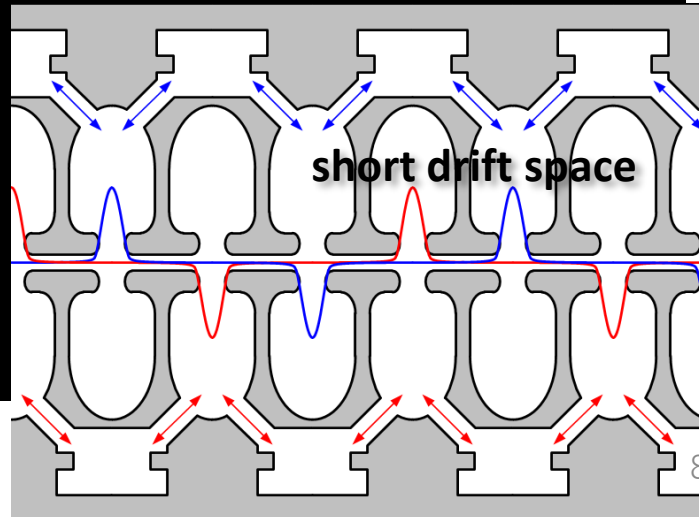


DOE Basics : principle

Example : Conversion Gaussian to Top-Hat profile



Ir7Ce2 cathode

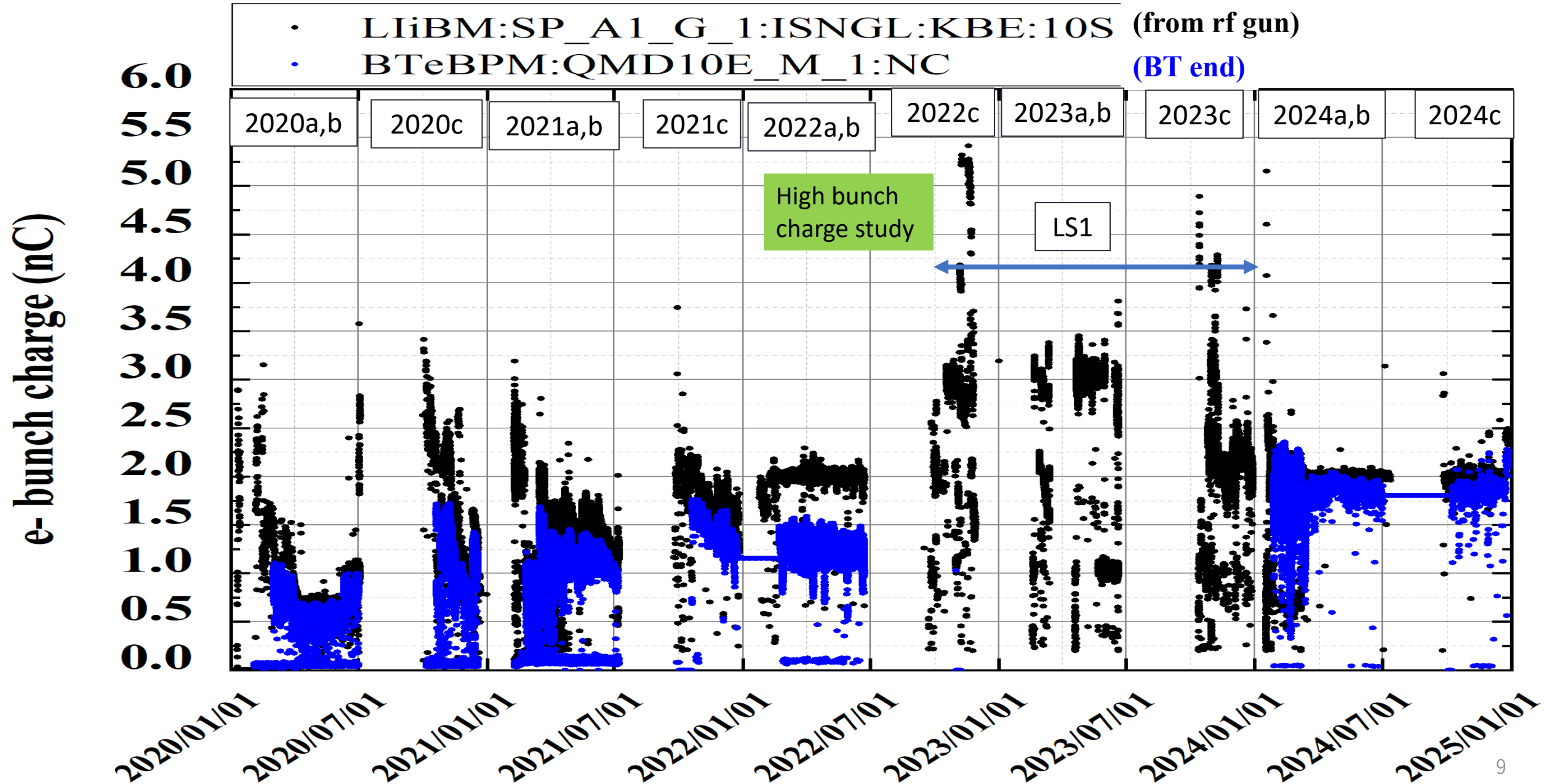


M. Yoshida, R. Zhang, X. Zhou *et al.*

6, 2025

e- bunch charge history (2020a to 2024c)

e- beam status



e- beam summary

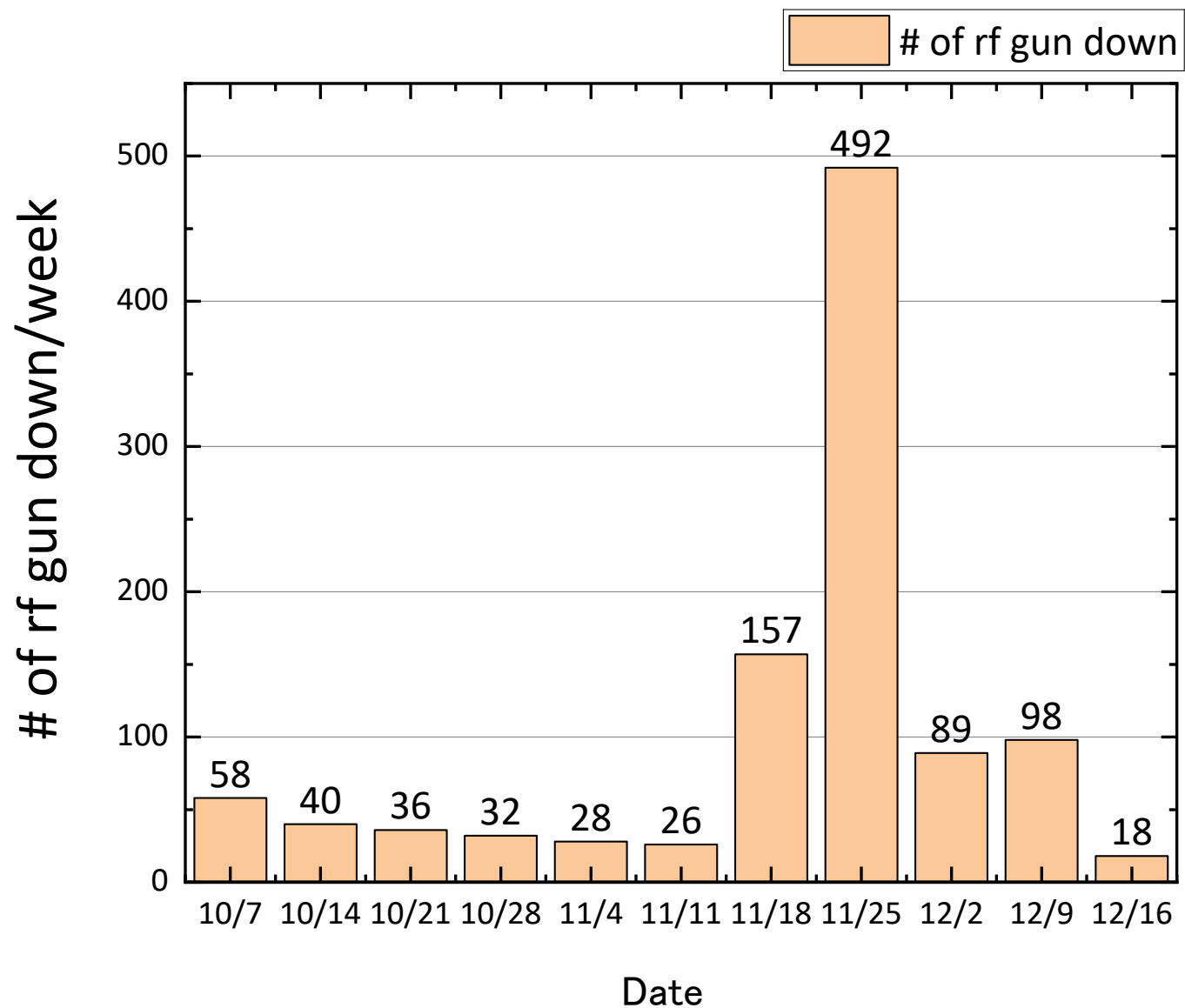
- Status

- Photocathode rf e- gun laser system has worked fine without any significant trouble.
- Bunch charge of 2 nC has been stably delivered to BT end w/ bunch charge feedback.
- Laser position feedback has also worked fine.

- Issue

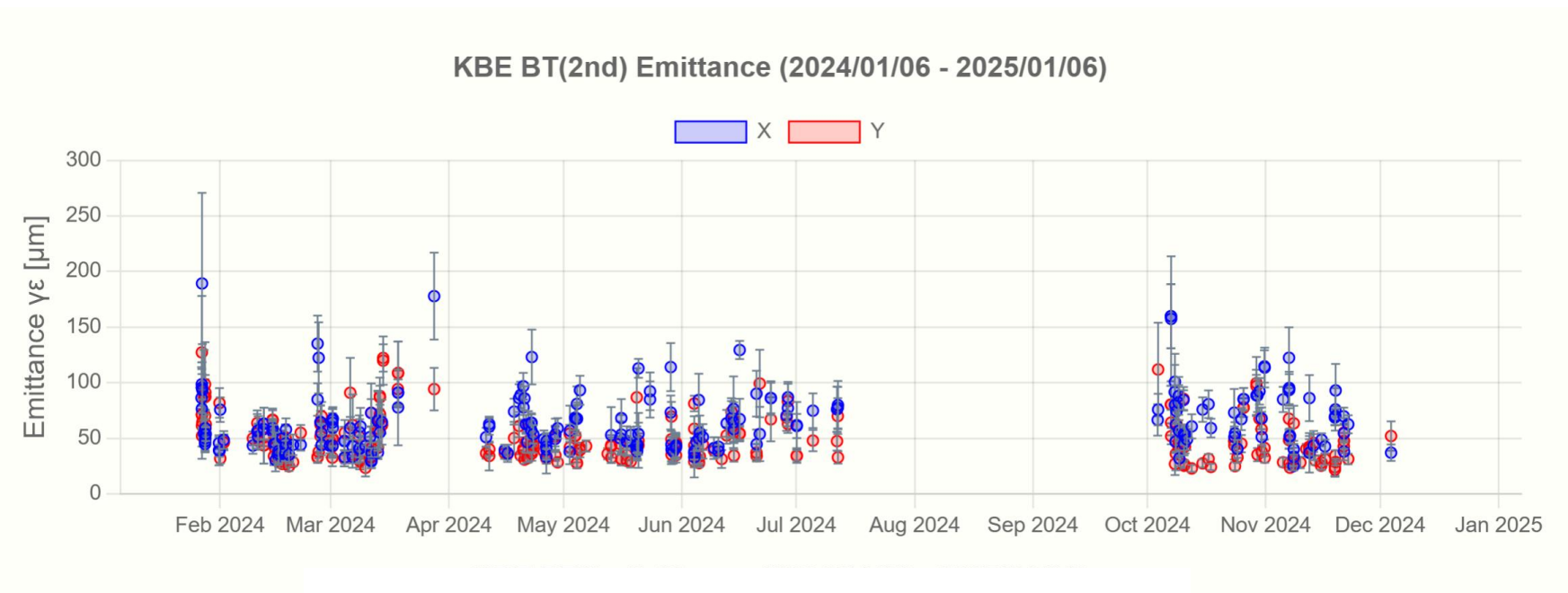
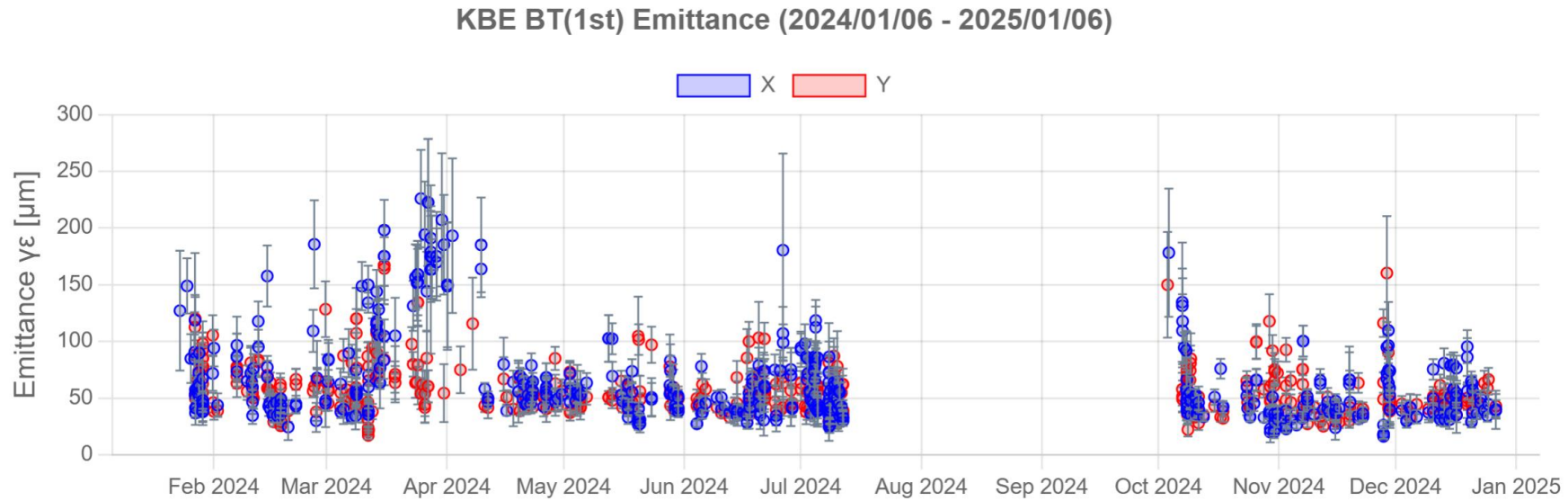
- Current rf gun cavity has been in operation since Oct. of 2013. Breakdown rate of rf gun cavity has gradually increased.
- In the previous run 2024c, rf gun down rate increased after the end of Nov. Rf conditioning of cavity was required 2 ~ 3 days to get back to operation.
- Rf gun cavity should be replaced by new one for stable e- beam operation.
- Reproducibility of the beam quality is also issue. Expanding the ML based auto beam tuning and a big data analysis could help this.

RF gun down due to cavity discharge in 2024c



e- beam emittance history at BT1 in 2024abc

e- beam status

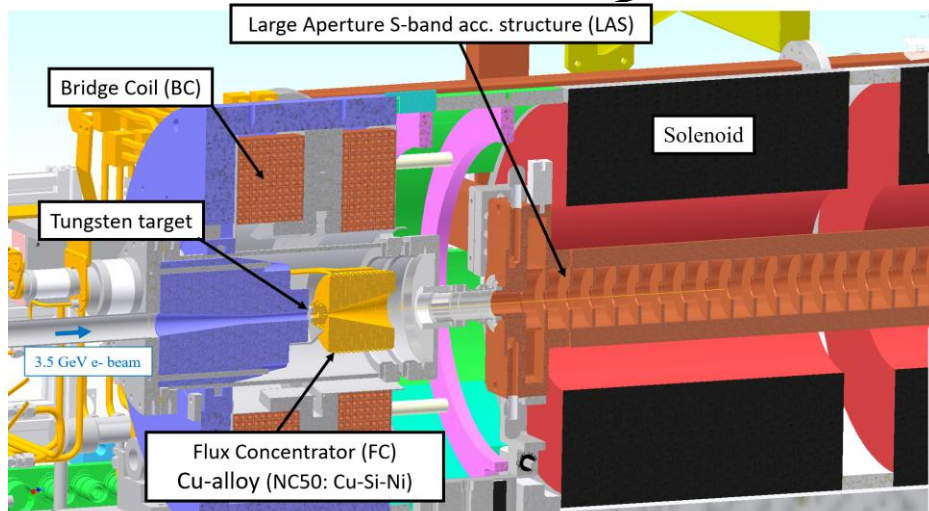
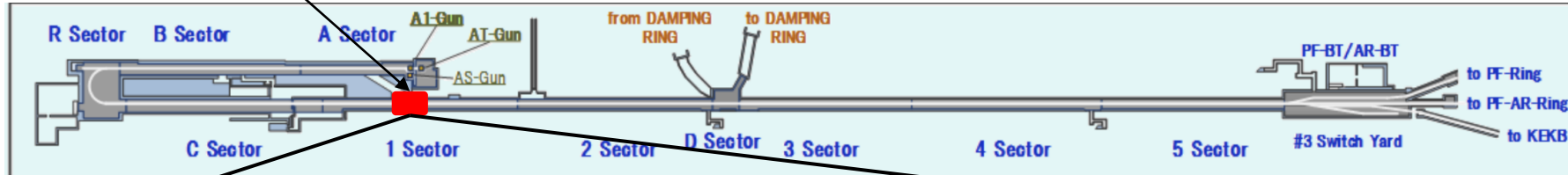


e⁺ beam status and issue

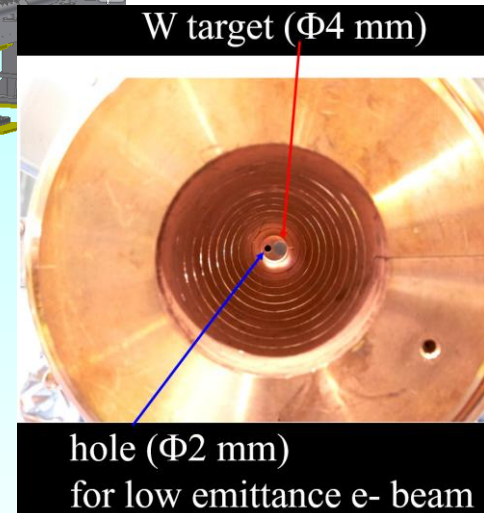
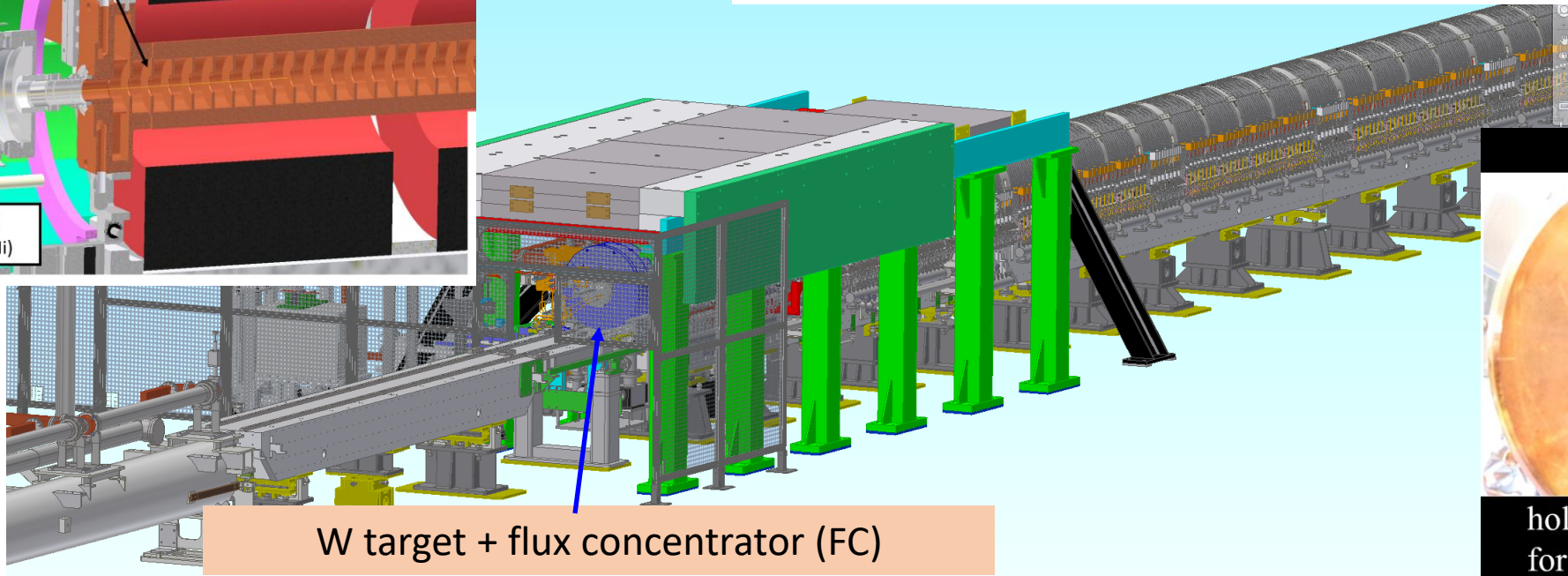
Positron source and capture line at Sector1

e+ beam status

Positron target and capture section



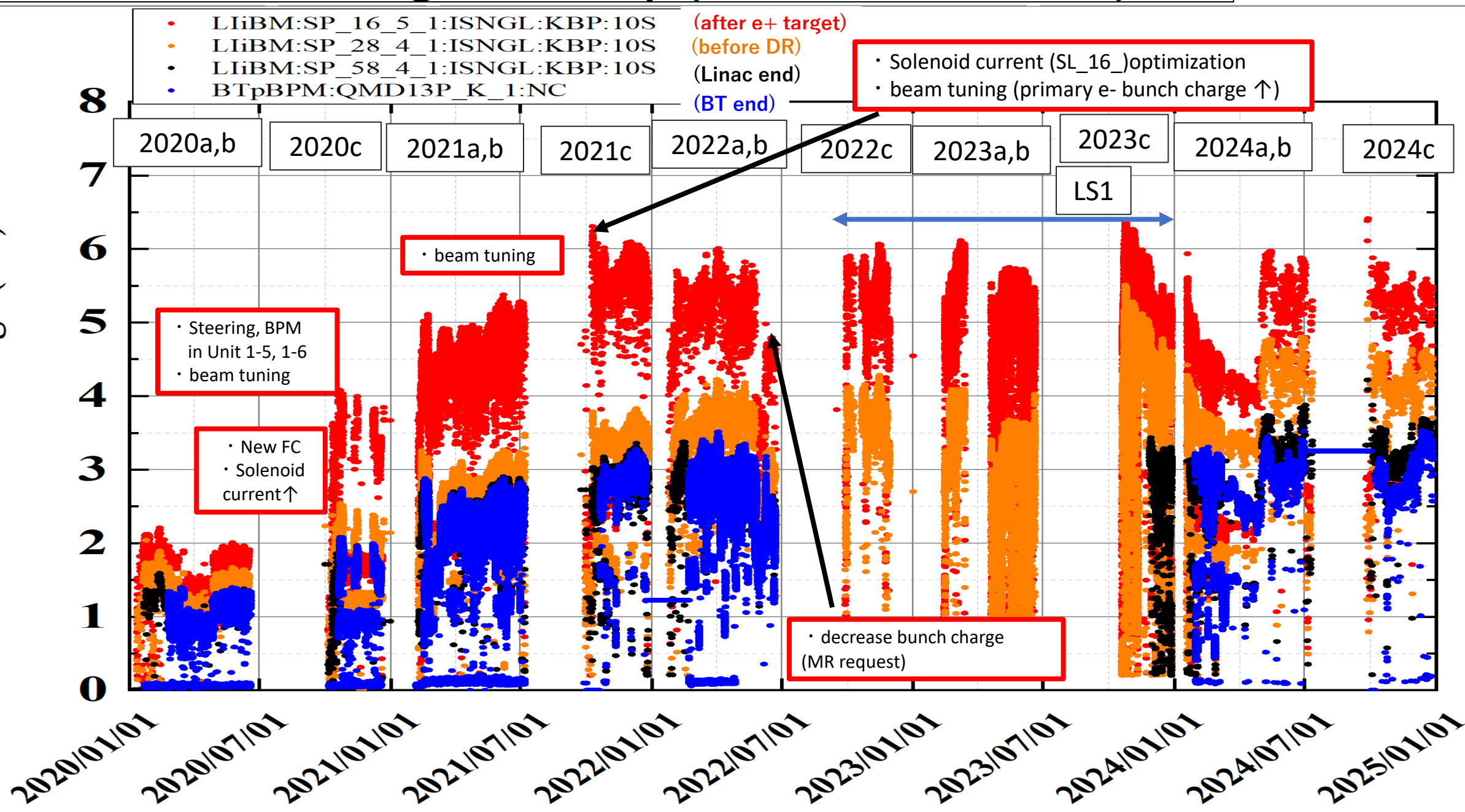
DC solenoid
Large aperture S-band acc. Structures (x10)



e+ bunch charge history (2020a to 2024c)

e+ beam status

e+ bunch charge (nC)



e+ beam summary

- Status

- Machine learning based automatic tuning can help to increase the e+ bunch charge (current design goal is 4 nC)
 - 5.5 nC at the end of Sector2
 - 4.2 nC at linac end
- DR stored current is limited up to 35 mA (radiation safety). This restriction will be increased in the next run.
- Flux concentrator operation has been very stable.
 - A few times HV down due to controller problem (PXI based digitizer).

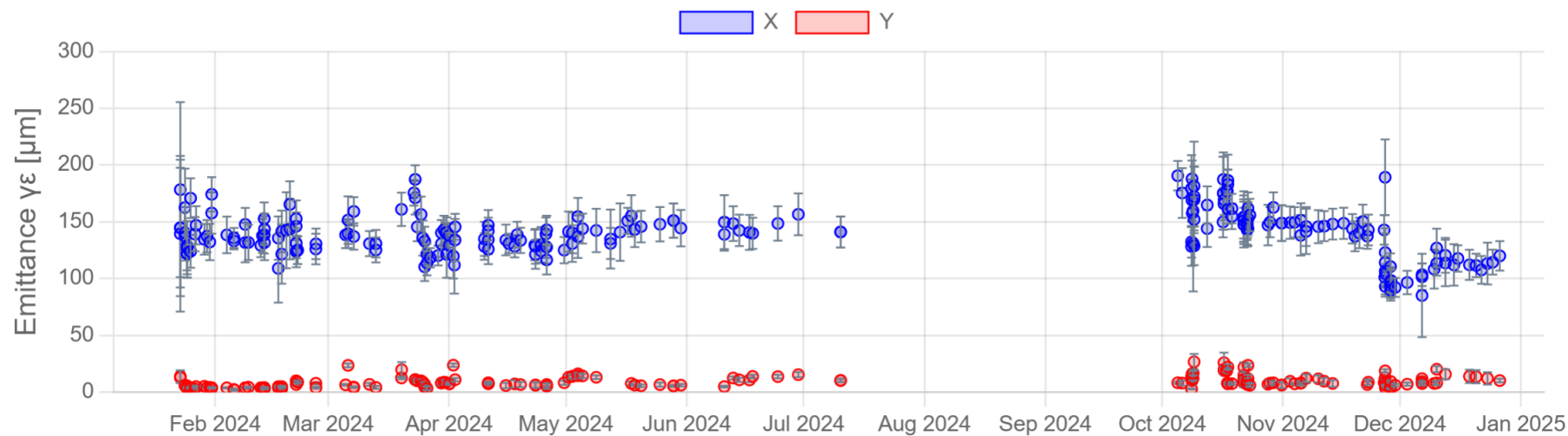
- Issue

- Existing FC control system (Windows/LabVIEW) should be updated to a similar system of pulsed magnet control system (Linux/EPICS IOC).
- Emittance after DR should be decreased to around design value.

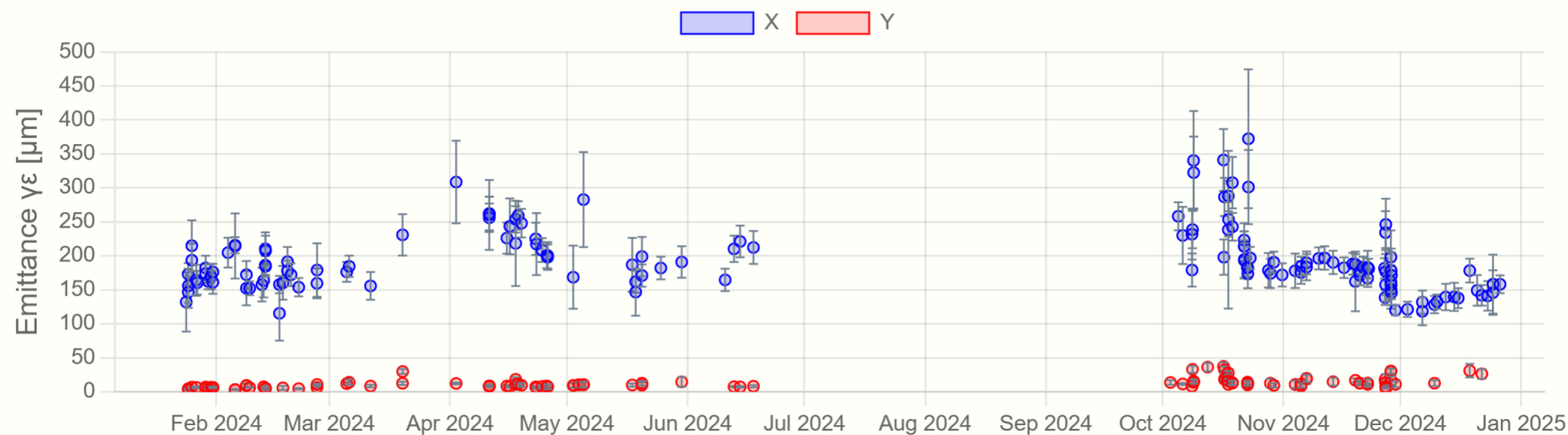
e+ beam emittance history at BT1 in 2024abc

e+ beam status

KBP BT(1st) Emittance (2024/01/06 - 2025/01/06)



KBP BT(2nd) Emittance (2024/01/06 - 2025/01/06)



Recent progress

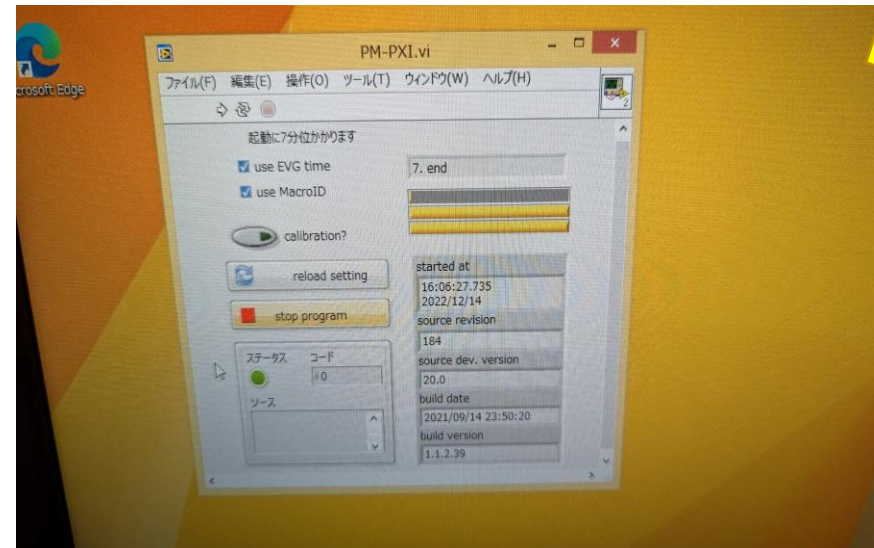
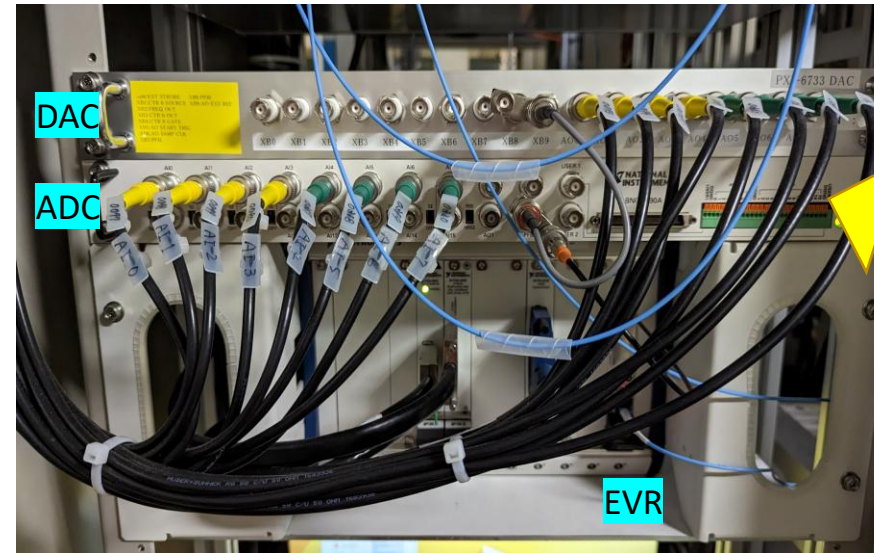
Recent progress

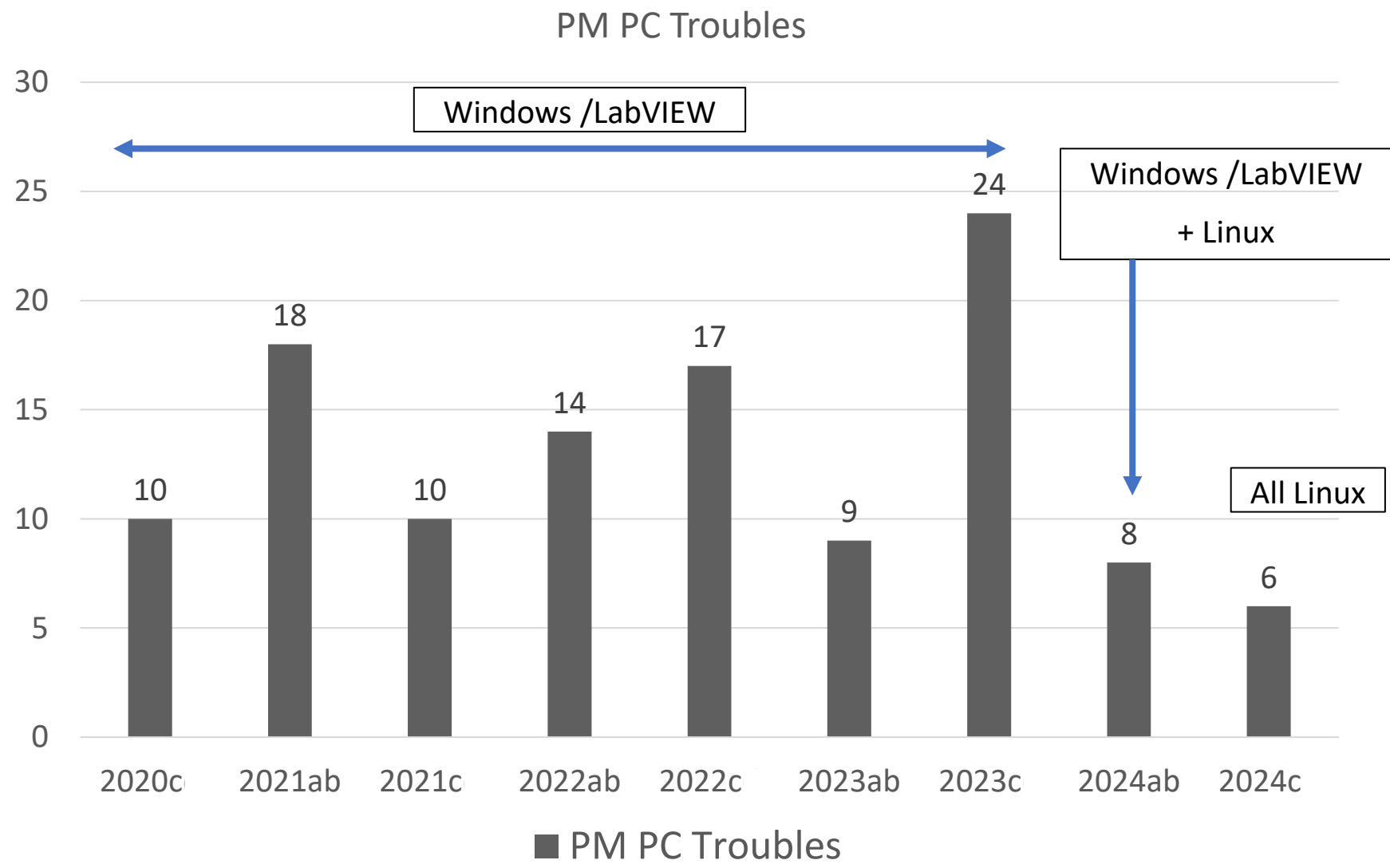
- Pulsed magnet control system update
 - Control PC hardware and software
- New accelerating structure
- Injector upgrade plan (F. Miyahara)
 - Fast Kicker to correct 2nd bunch orbit
 - Beam diagnostics Line with pulsed magnets
 - Beam tuning programs
 - Bigdata analysis
 - HER BT Energy Compression System (ECS)

Pulsed magnet control system update

Recent Progress

- Windows/LabVIEW/PXI system
 - Started since 2017
 - Sometimes control PC or LabVIEW program freeze.
 - It takes around 10 minutes or more for restarting system.
- Linux/EPICS IOC/PXI
 - Decided to migrate to Linux/EPICS IOC (2022/12)
 - NI DAC&ADC driver (2023/02)
 - EVR driver (2023/03)
 - EPICS IOC (2023/04)
 - OPI & Monitoring (2023/05)
 - Experiment (2023/06)
 - Revision (2023/07)
 - Stability test (2023/07)
- All system were replaced by new PC and software in 2024 summer shutdown.



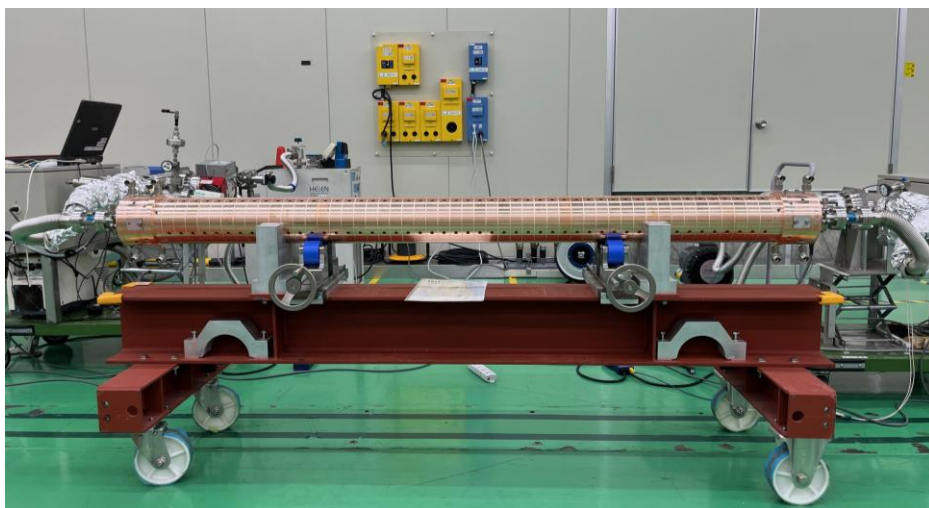


(*) The PM PC troubles caused by timing system/network packet increase are not included.

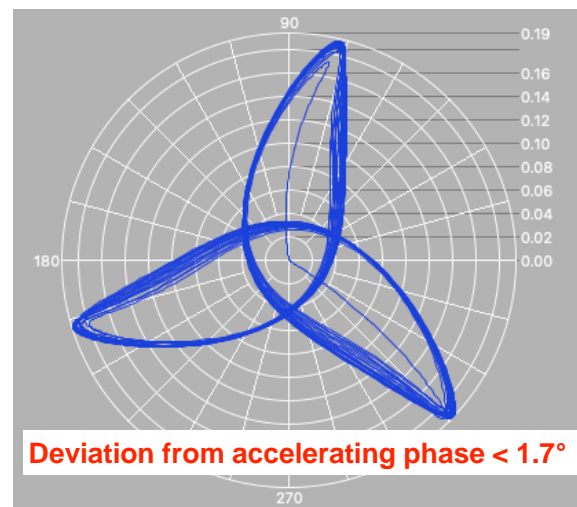
Production status of new S-band accelerating structures

3-year plan of the S-band structure production (2023-2025)

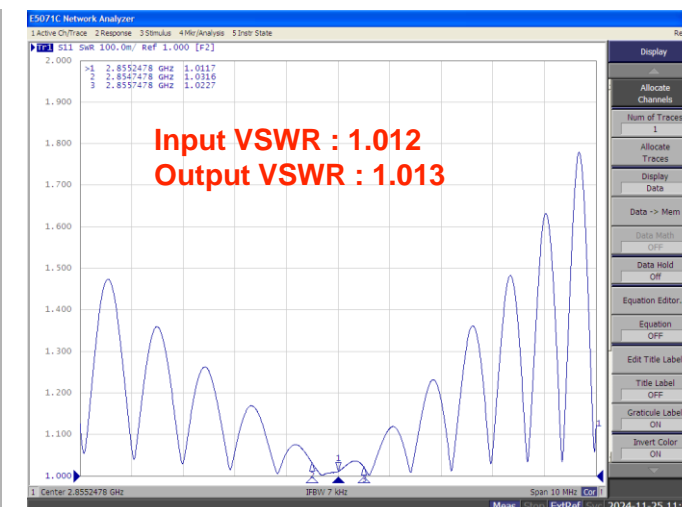
- Steady production of 6 structures in FY2024
 - * Four structures completed as designed and ready for RF conditioning
 - * The other two structures in the process of RF tuning
- The last 6 structures scheduled to be produced in FY2025



New structure under vacuum-leak test after RF tuning



Results of fine RF tuning



Recommendation in MAC 2024

- R4.1: Priority should be given to optimize the injector and injection for electron bunches.
 - New rf gun cavity could help the stable e- beam operation.
 - Sufficient input power into rf gun cavity can realize the high quality (low emittance, small energy spread) beam with high bunch charge from rf gun.

Summary

- **Operation overview**
 - **Simultaneous top up injection has been successfully conducted.**
- **e- beam**
 - **Laser system has worked fine without any significant trouble.**
 - **Frequent rf gun cavity down due to discharge in the previous run 2024c. Rf gun cavity should be replaced by new one in the near future for stable e- beam operation.**
- **e+ beam**
 - **e+ generation system (flux concentrator, power supply, DC solenoid) has worked fine.**
 - **Machine learning based automatic tuning can help to increase the e+ bunch charge (current design goal is 4 nC)**
 - **5.5 nC at the end of Sector2**
 - **4.2 nC at linac end.**
- **Recent progress and future plan**
 - **Pulsed magnet controller availability has been much improved by replacing new Linux-OS/EPICS IOC based system.**
 - **Fast Kicker, beam diagnostics line with pulsed magnets, beam tuning programs, bigdata analysis, HER BT Energy Compression System (ECS) can help improve the beam operation quality.**
 - **Improvement of the beam quality reproducibility could be helped by AI/ML technology.**