MR magnets and QCS

Y. Arimoto

12/13/2022 Accelerator Review Committee

Contents

- MR magnets
  - NLC
  - Cooling water maintenance
  - Alignment
- QCS
  - Vacuum leak of QCS cryostat
  - Magnetic field variation
- Summary

Non-linear collimator

Non-linear collimator (NLC) installation and modification at Oho straight section

S. Nakamura

Installation of a new collimator that is less likely to cause Transverse Mode Couple Instability (TMCI)

- Conventional collimator
  - Installing at the location where β function is large
  - But the narrow collimator

  ⇒ Since βk is large, the threshold at which TMCI occurs becomes low.
- Non-linear collimator
  - The nonlinear kick of the skew sextupole magnet increases the beam size.
  - It enables to collimation of the beam at a small beta function.
  - It makes the physical aperture of the collimator large.

  ⇒Since the βk becomes small, the threshold becomes high.

In SuperKEKB, the physical aperture of the vertical collimator is narrower than that of the horizontal collimator, so the βk at the vertical collimator must be smaller to increase the TMCI threshold.

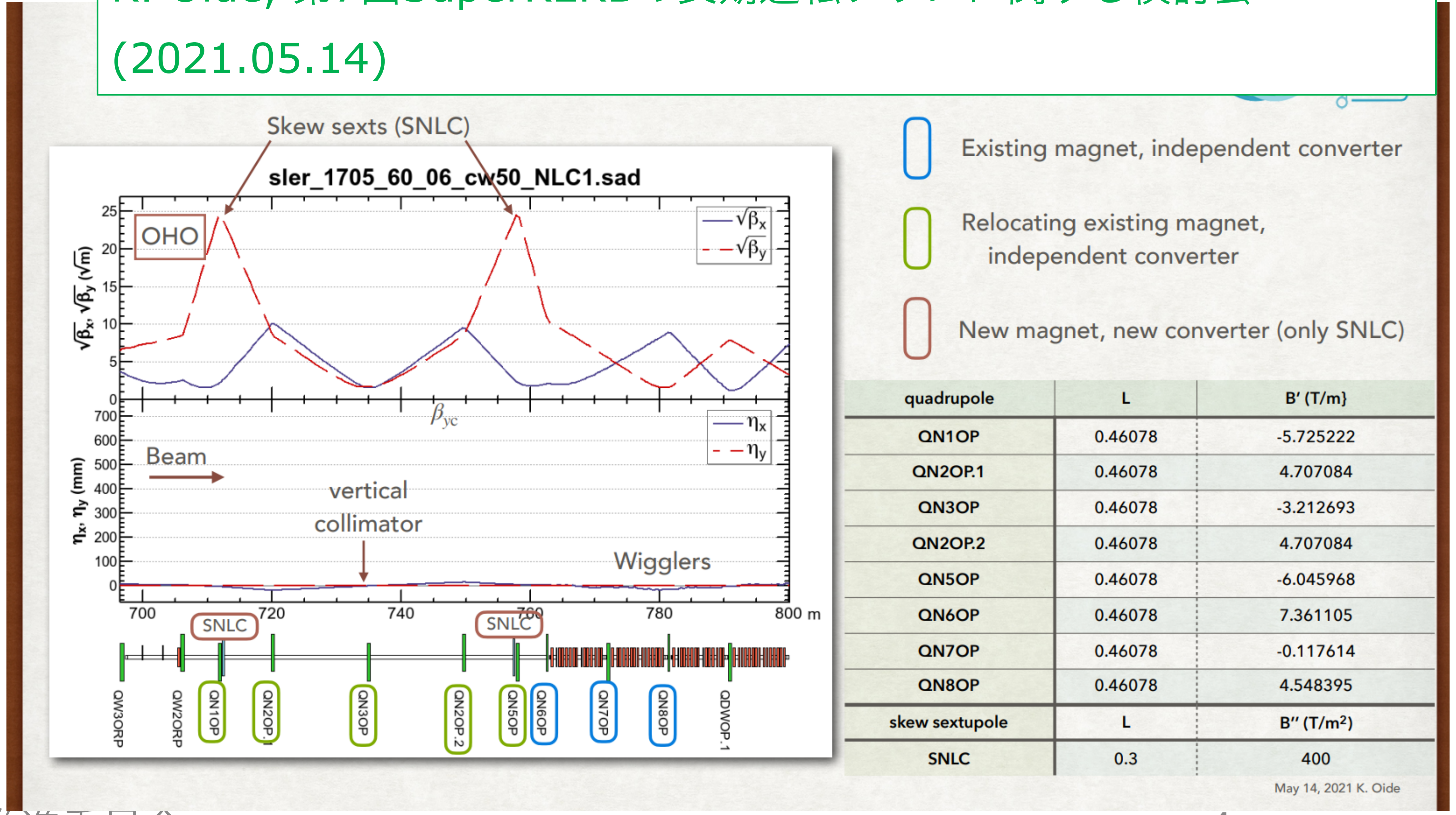
SuperKEKB Machine Parameters

2017/September/1	LER	HER	unit	
$\varepsilon_x/\varepsilon_y$	3.2(1.9)/8.64(2.8)	4.6(4.4)/12.9(1.5)	nm/pm	():zero current

Bunch current threshold at which TMCI occurs

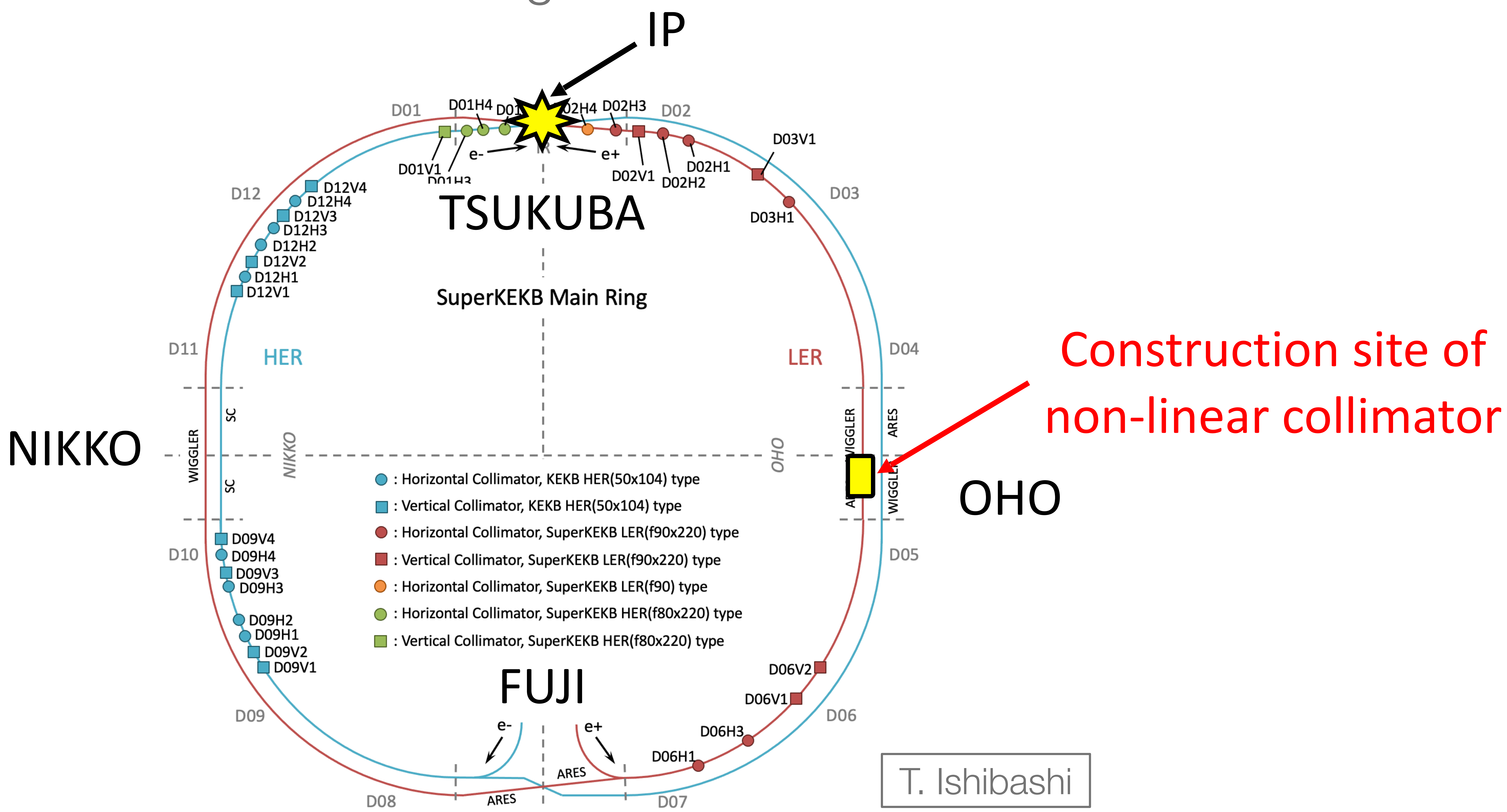
$$I_{th} \propto \frac{1}{\sum_i \beta_i k_i}$$

K. Oide, 第7回SuperKEKBの長期運転プランに関する検討会 (2021.05.14)



Non-linear collimator: Location

- NLC will be constructed at OHO straight section.



Non-linear collimator: Construction

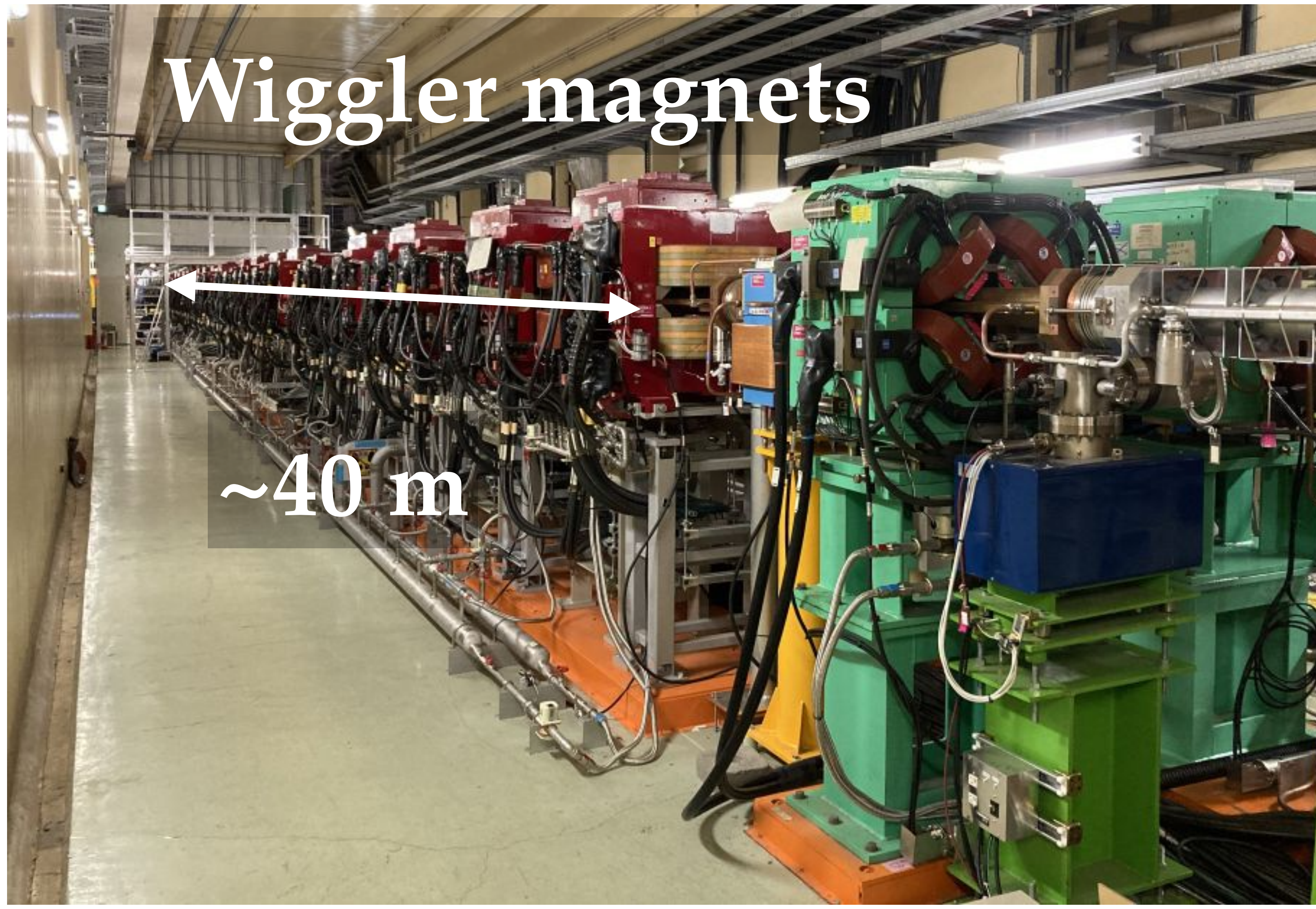
S. Nakamura

← IP (Tsukuba)

Skew sextupole magnet

New collimator (D05V1)

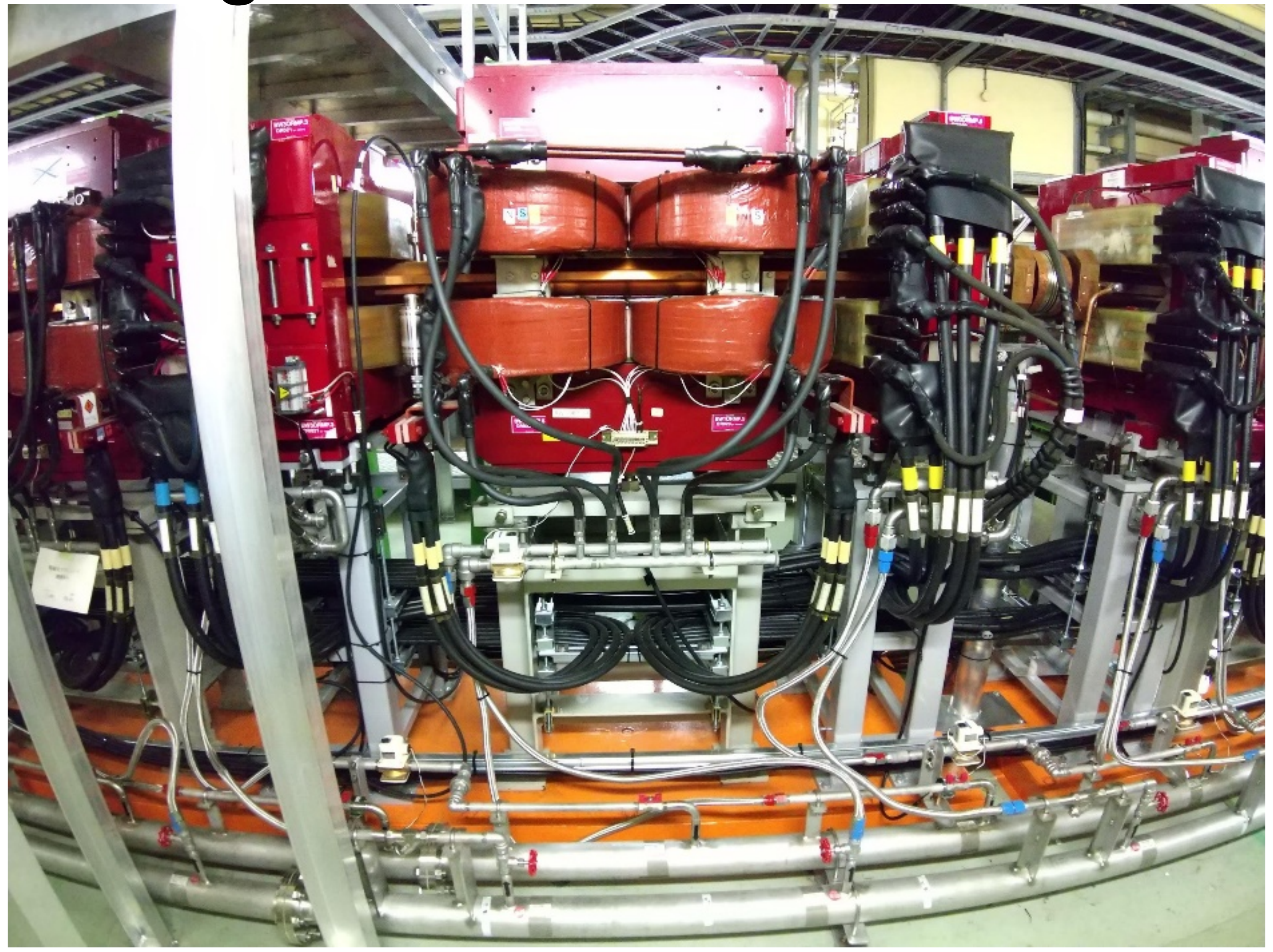
Skew sextupole magnet

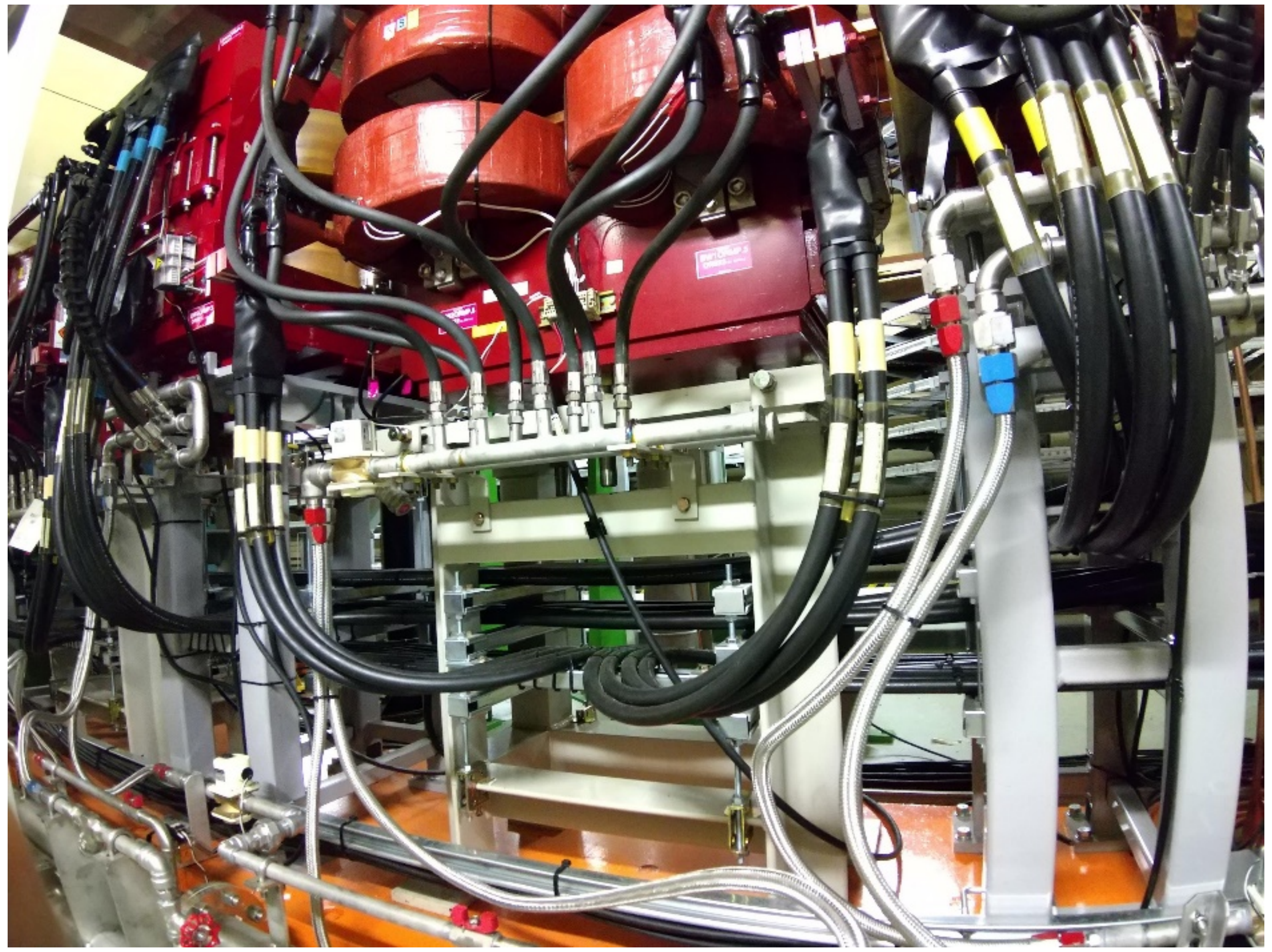


- Take away these wiggler magnets.
  Twenty double-pole magnets, ten single pole magnets, ten half-pole magnets.
  The weight of the power cable, which is removed with magnets, is about 3000 kg.
- Relocation quadrupole magnets.
- Install a pair of new skew sextupole magnet.
- Install a new vertical collimator (D05V1).

Now we are working to remove the wiggler magnets.

Before the installation work started（Wiggler magnets）

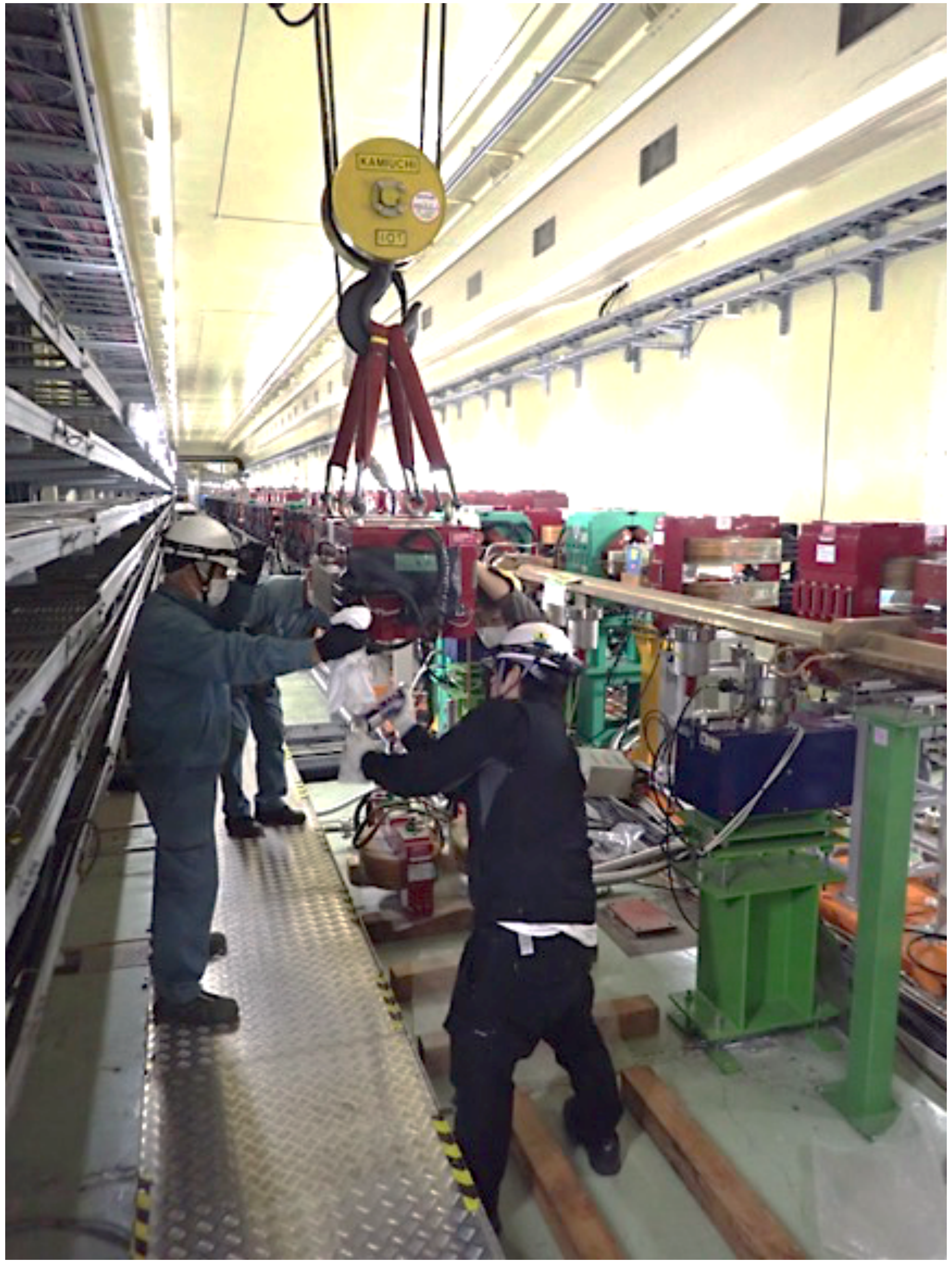


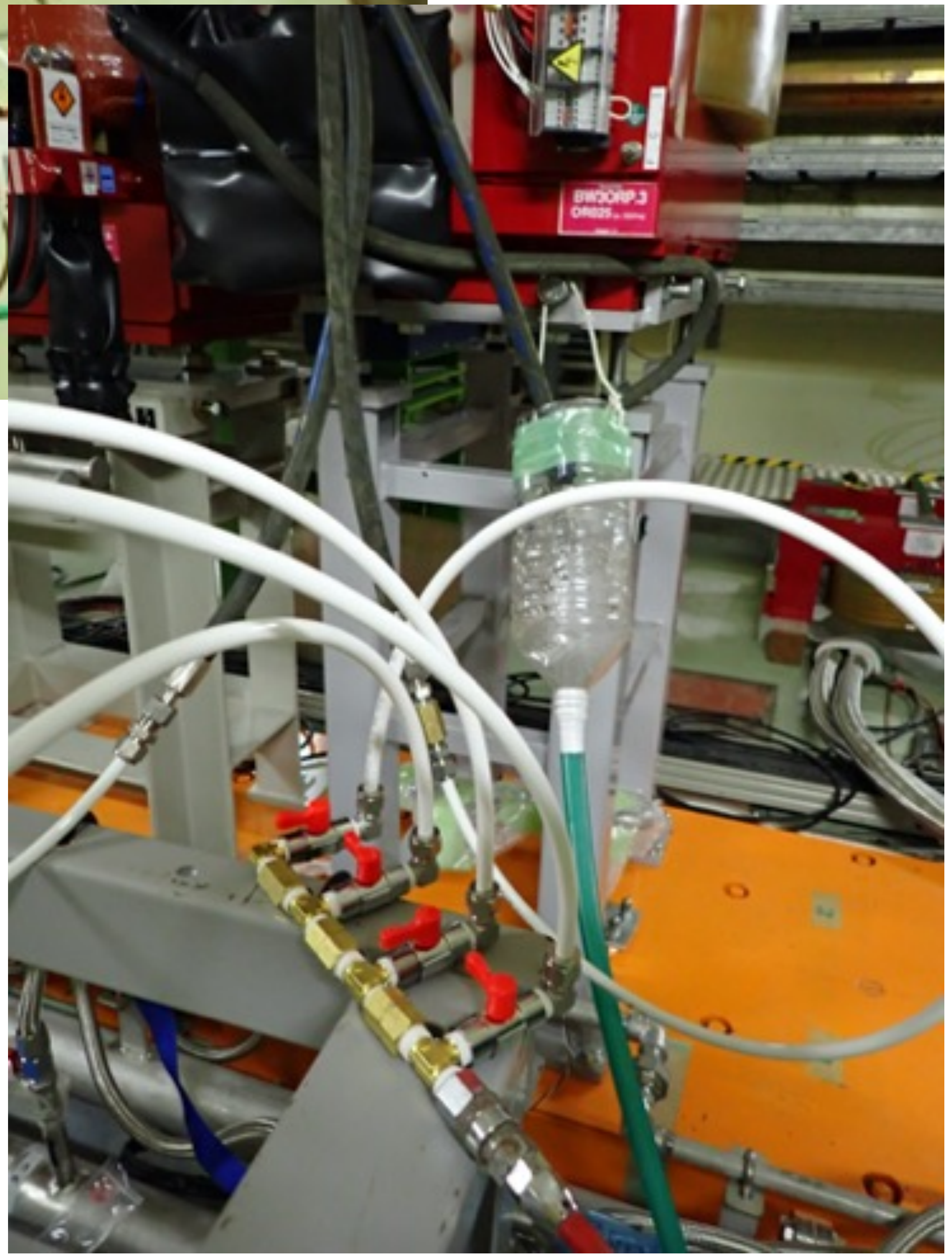


S. Nakamura

Current status

Splitting work for vacuum pipe removal

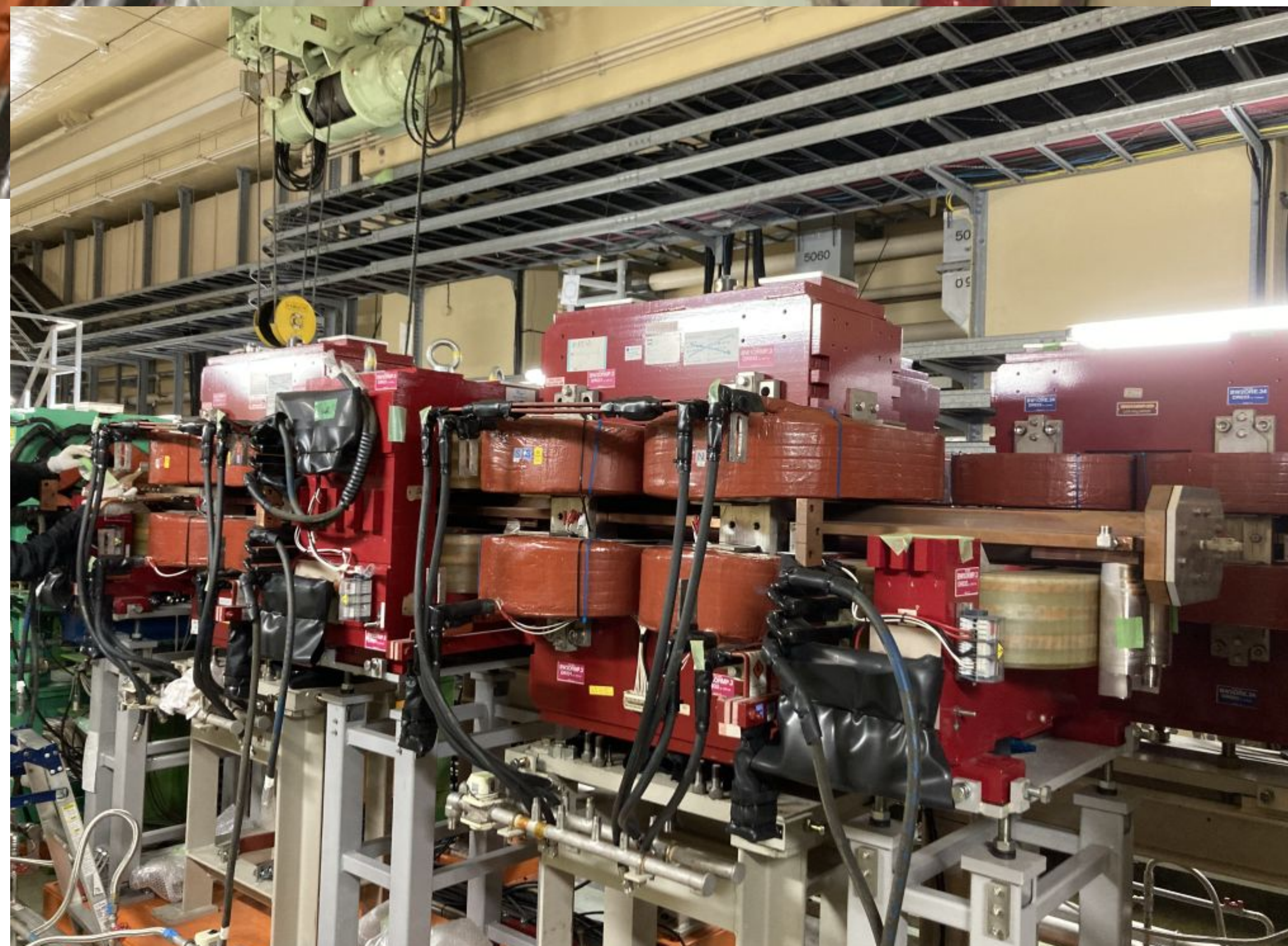




S. Nakamura

Cooling water draining operation

S. Nakamura

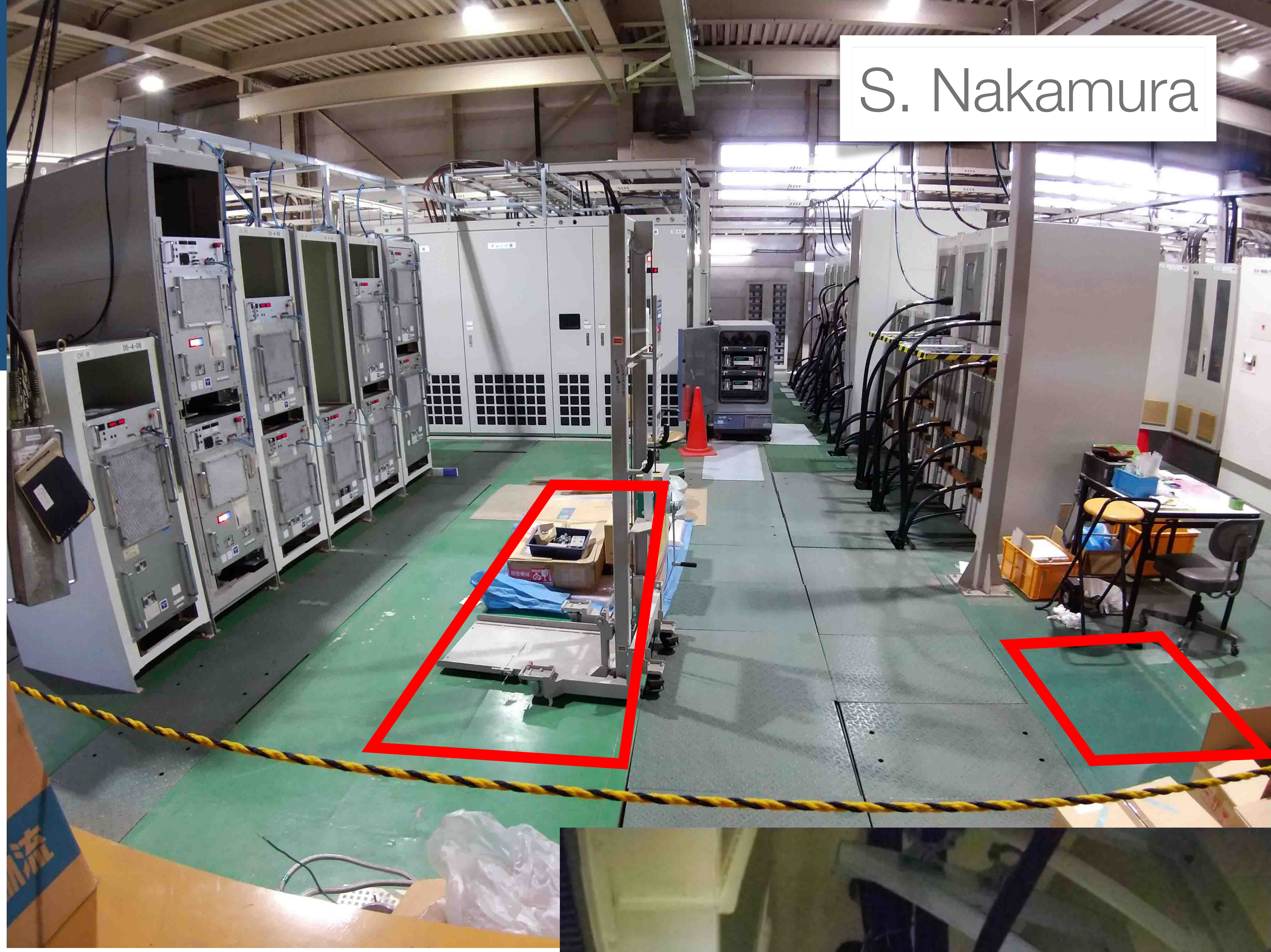


Additional magnet power supply for NLC

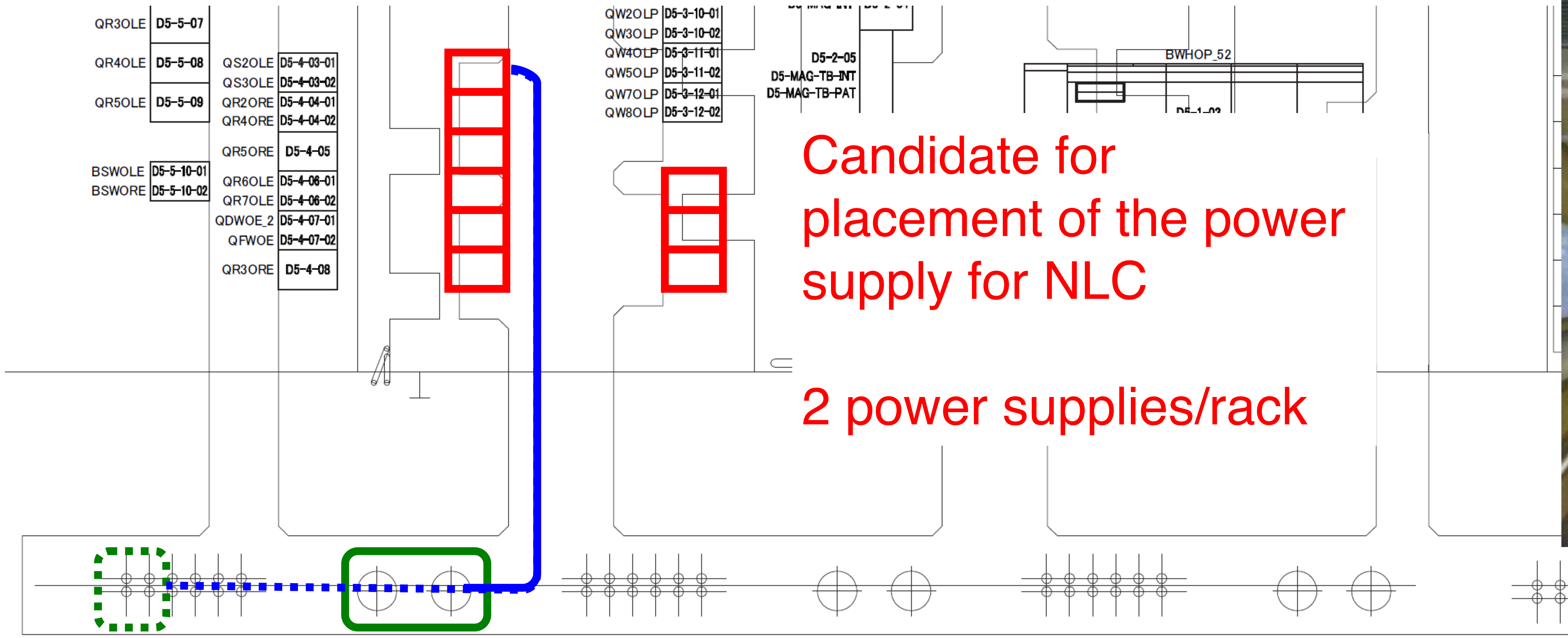
Wiring changes due to the NLC installation

S. Nakamura

Place and routing of new power supply

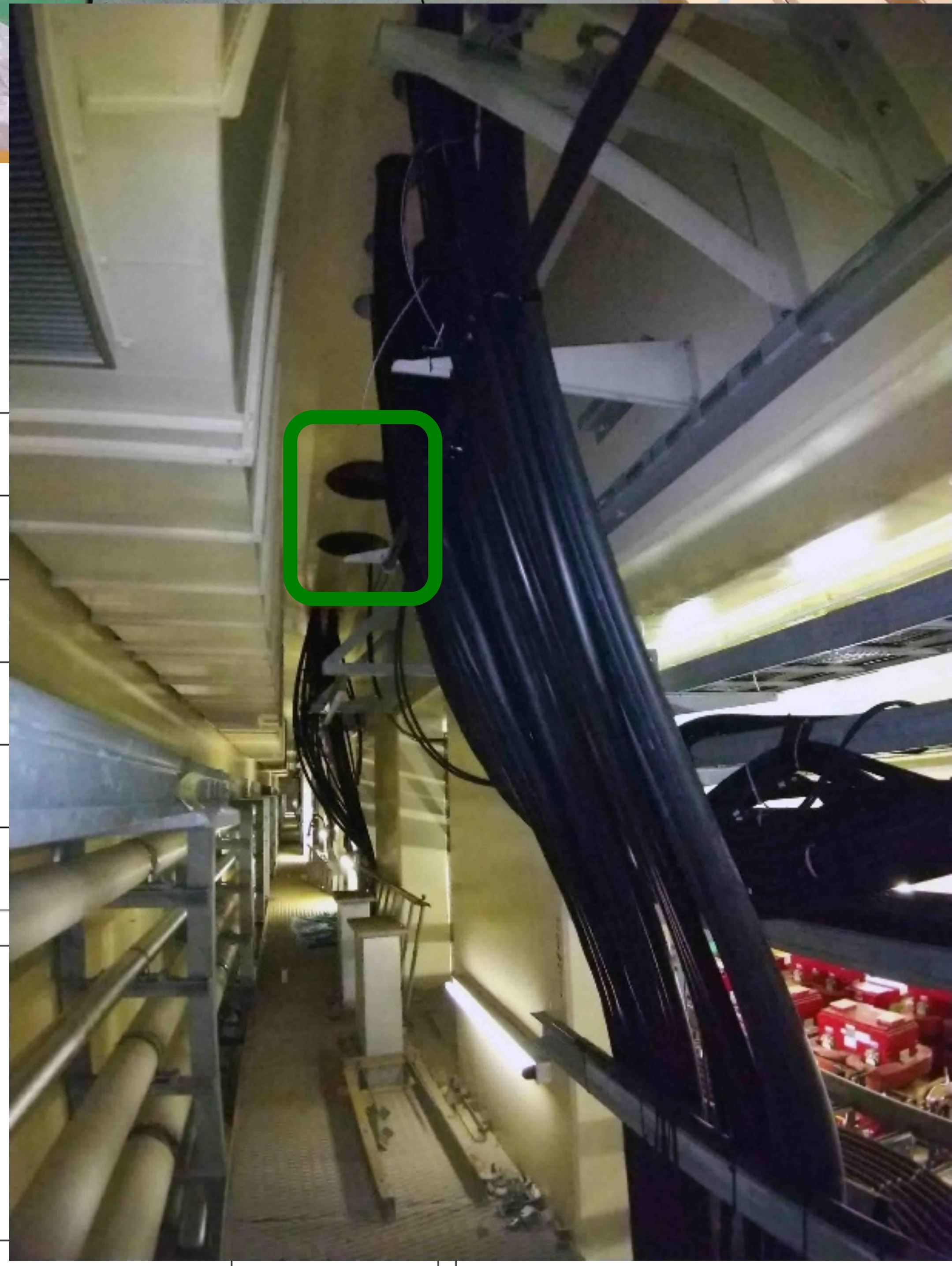


- Number of new power supplies: 10 units
- Reuse of 4 strips of the existing 2 quadrupole electromagnetic power supply systems
- A total of 16 new power cables will be installed.
    - Quadrupole electromagnets are rated at 500A
    - Skew sextupole electromagnets are rated at 600A
- 400 sq-1c cable to be installed



Candidate for placement of the power supply for NLC

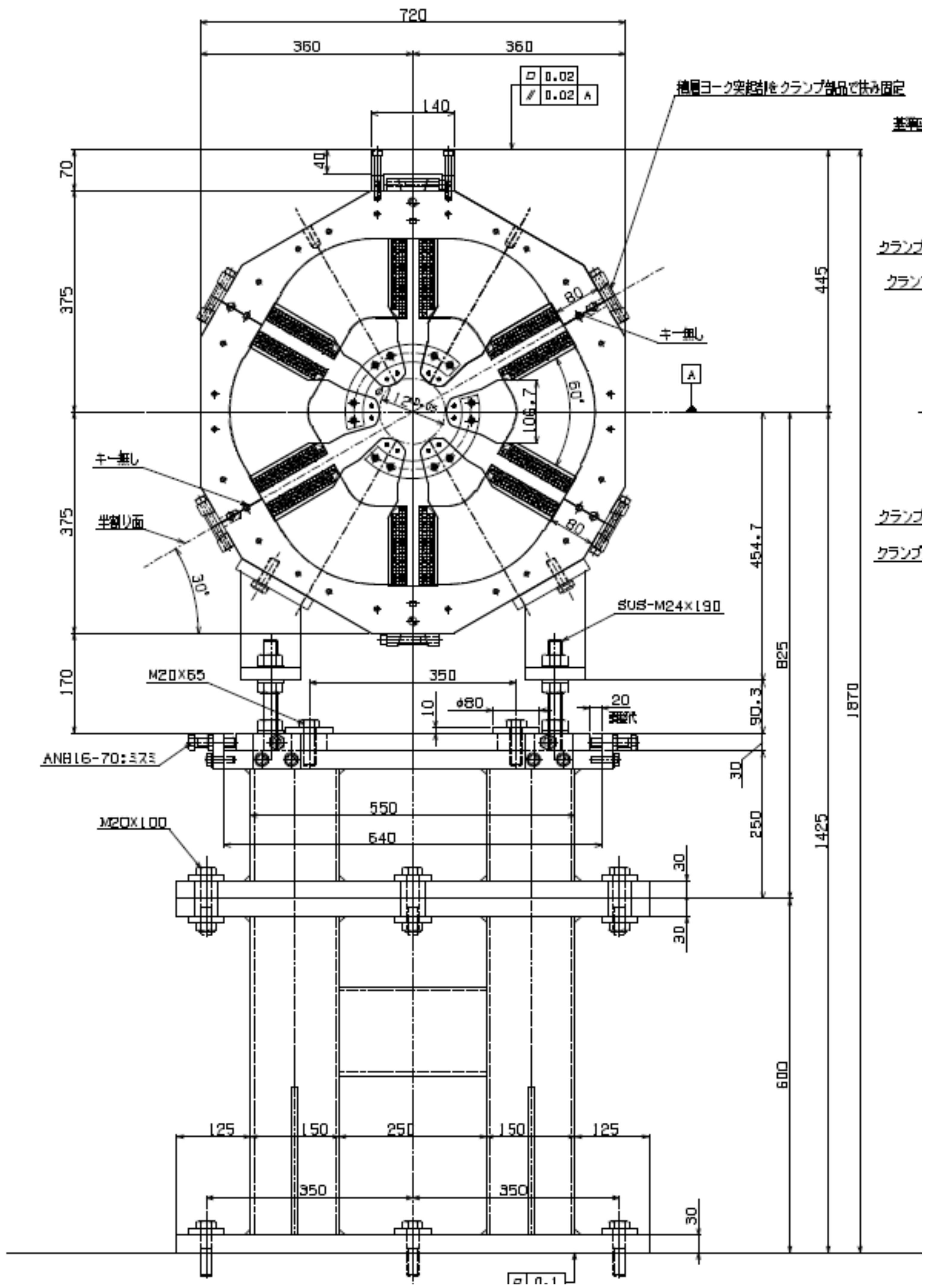
2 power supplies/rack



Skew sextupole magnets for NLC

- Two new sextupole magnets need to be produced for NLC.
- Since due to COVID-19, it takes more than ten months to obtain a hollow conductor, if we purchase the new one, the skew sextupole magnets will not be ready for operation in fall 2023.

- To be ready for the next operation,
  - The iron yoke will be newly fabricated.
  - The coil will be reused from the other sextupole magnets (SL0.3).
    (We have a spare magnet and one set of spare coils.)
- Magnets will be delivered in August 2023.



Drawing of magnets for NLC

- Bore radius: 56 mm
- Lamination Length: 300 mm

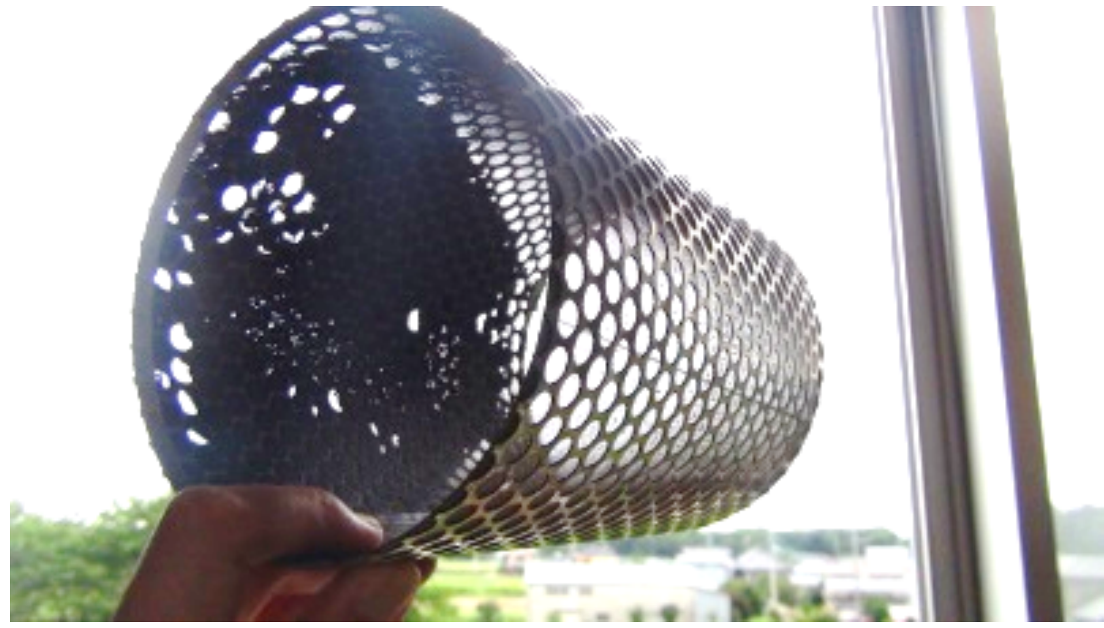
R. Ueki

Cooling water system for MR Magnet

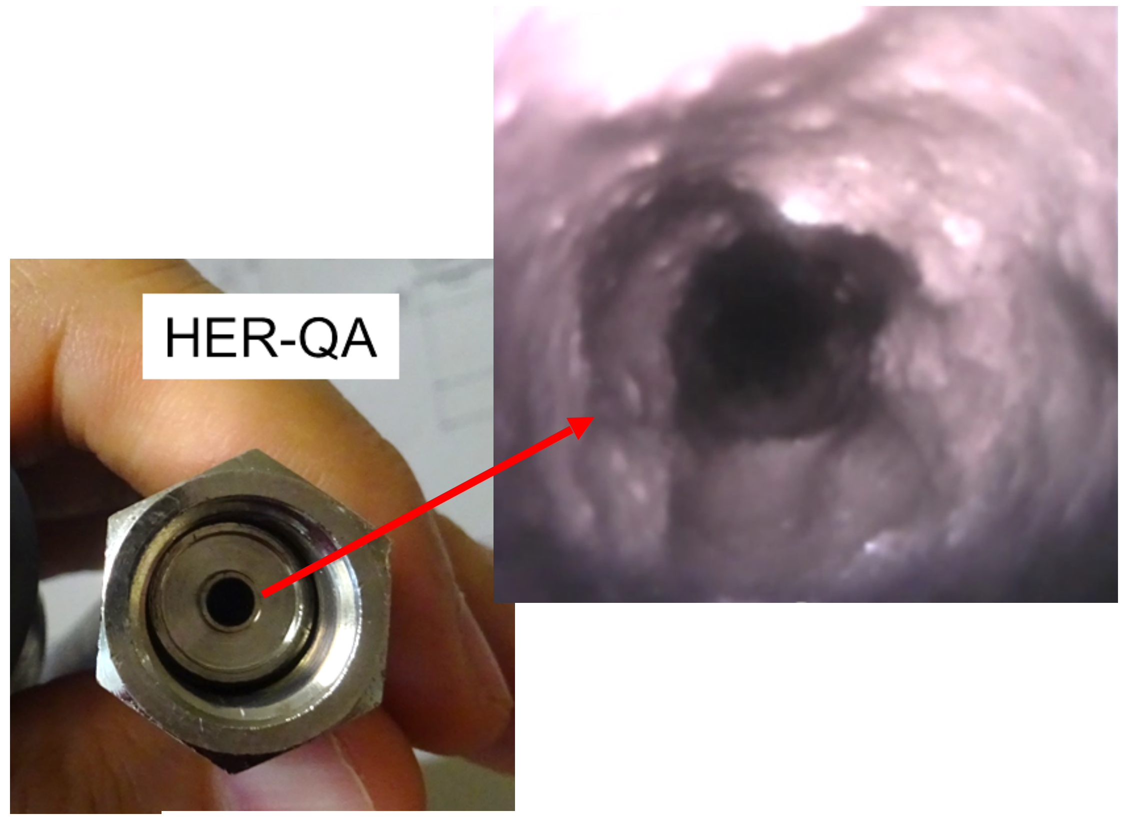
- 1750 water cooled magnets are installed in SuperKEKB tunnel.
- Pure cooling water is supplied to these magnets at 8 location pump system.
- The routine maintenance is important to remove impurities and keep the system in good condition.
  - Strainer cleaning once a month
  - Cleaning flow paths of magnets low flow rate
  - Replace aging components

  etc.

Example of impurities



A strainer just before a pump



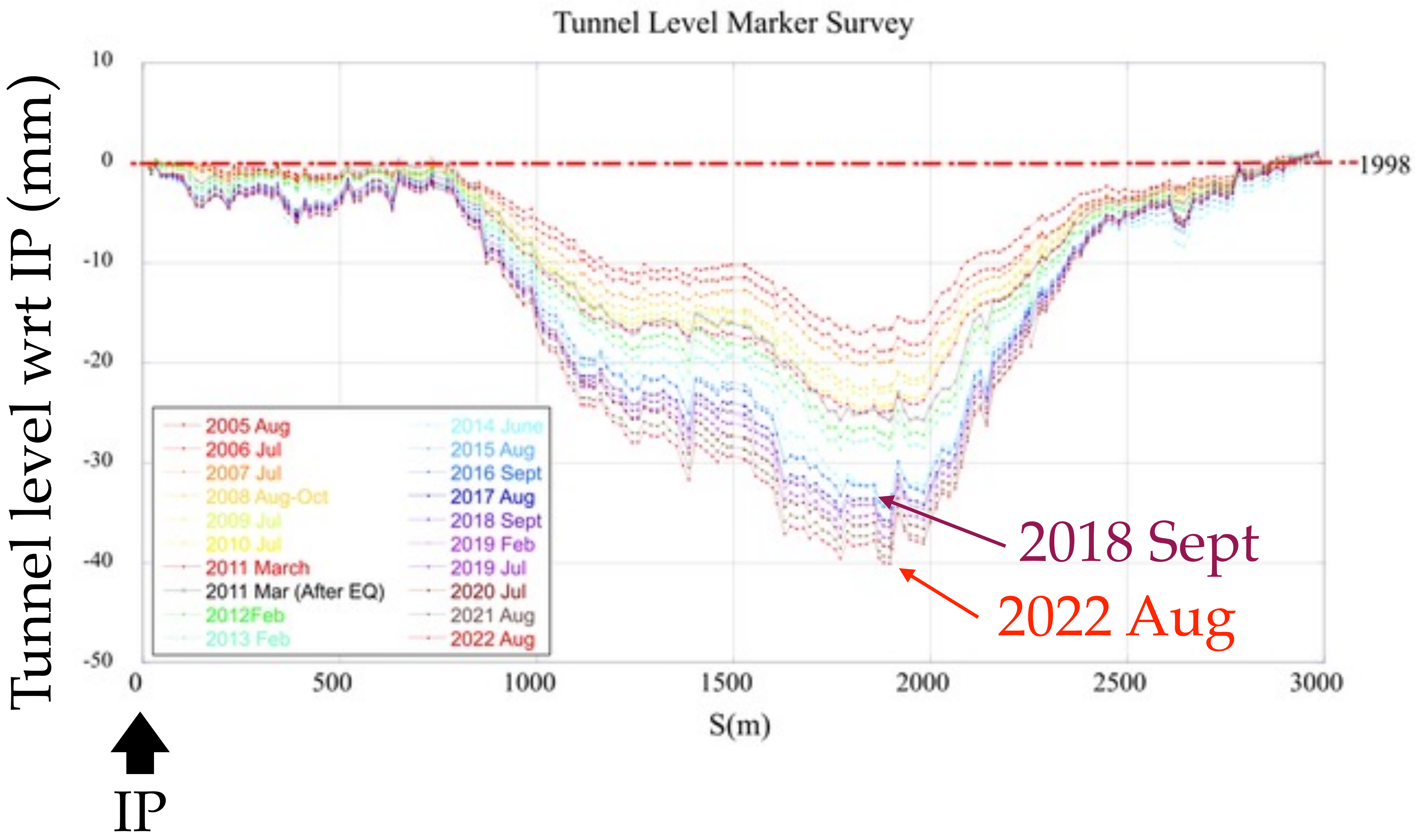
Entrance of water hose of a magnet

R. Ueki

- Thanks to the routine maintenances,

no failure of magnet cooling water has occurred for **31 months** since October 2019.

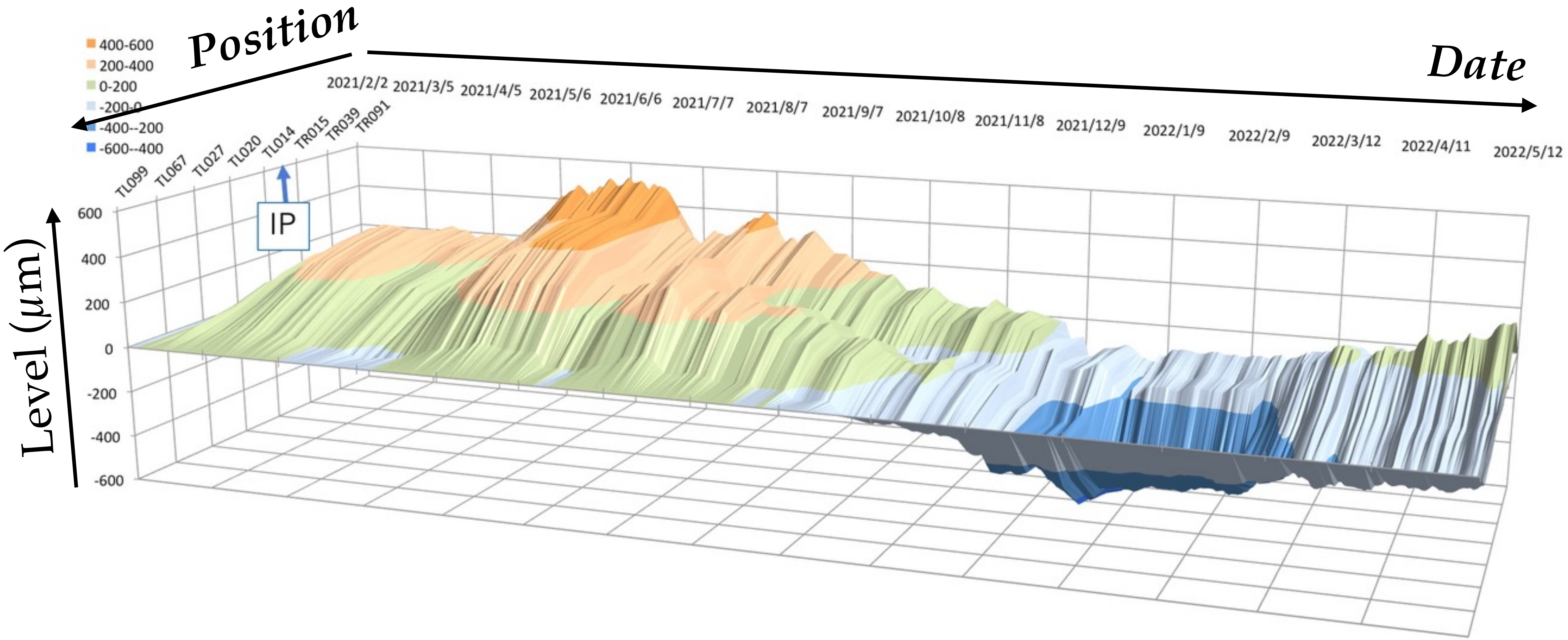
Tunnel level variation every year wrt IP



- The tunnel level goes down about 5 mm from 2018 to 2022.

M. Masuzawa

Seasonal variation of tunnel levels

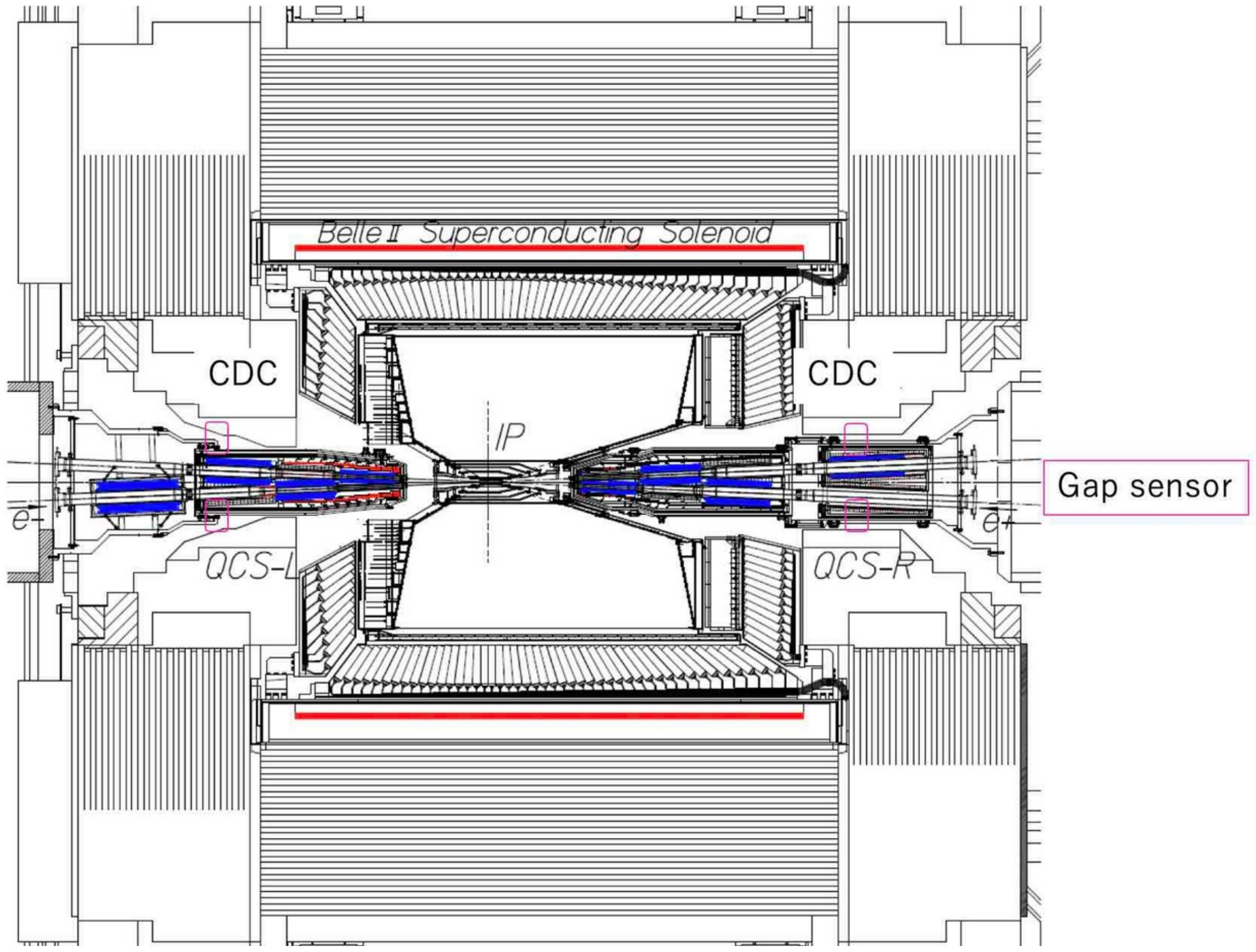


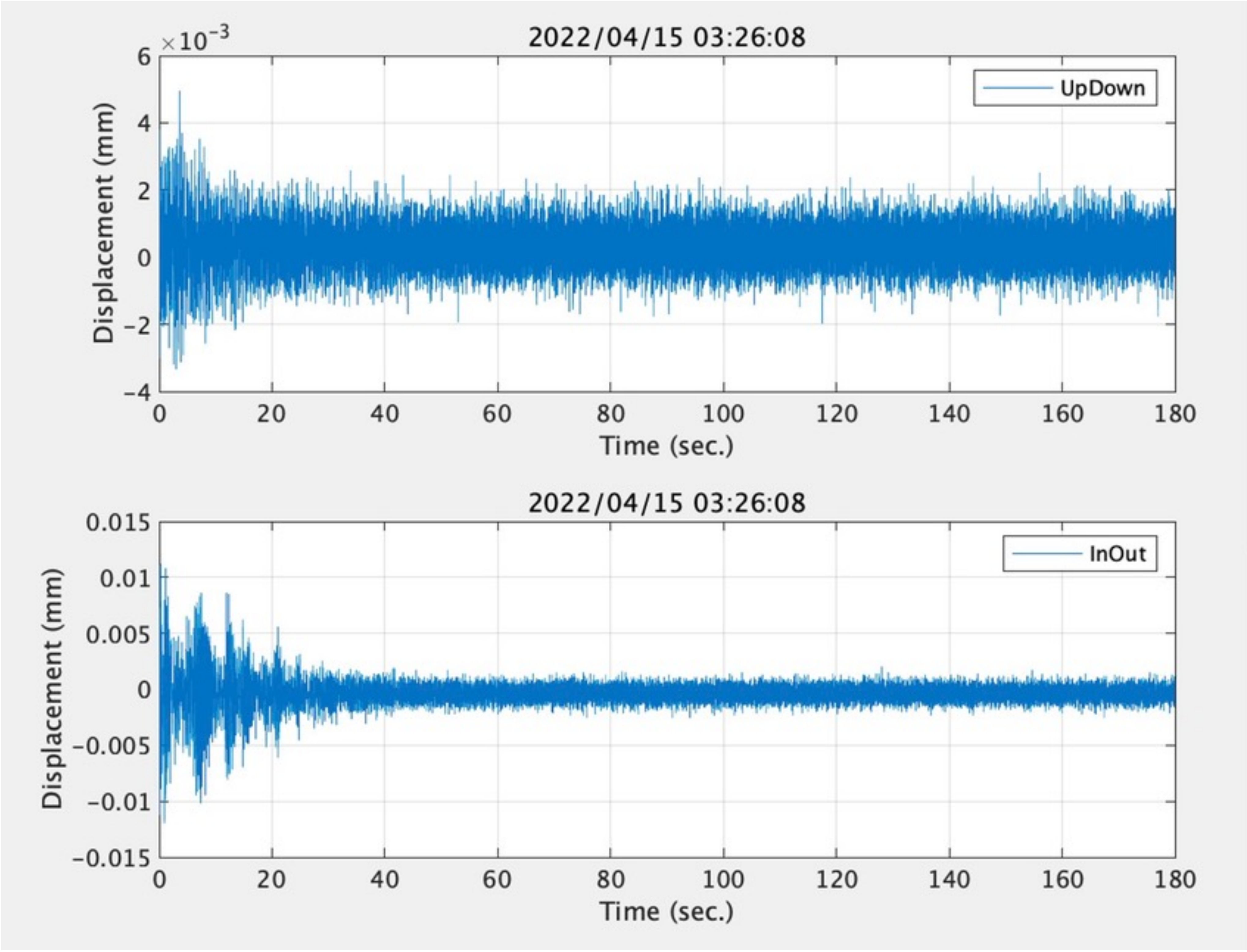
Seasonal variation of about ± 0.5 mm is observed

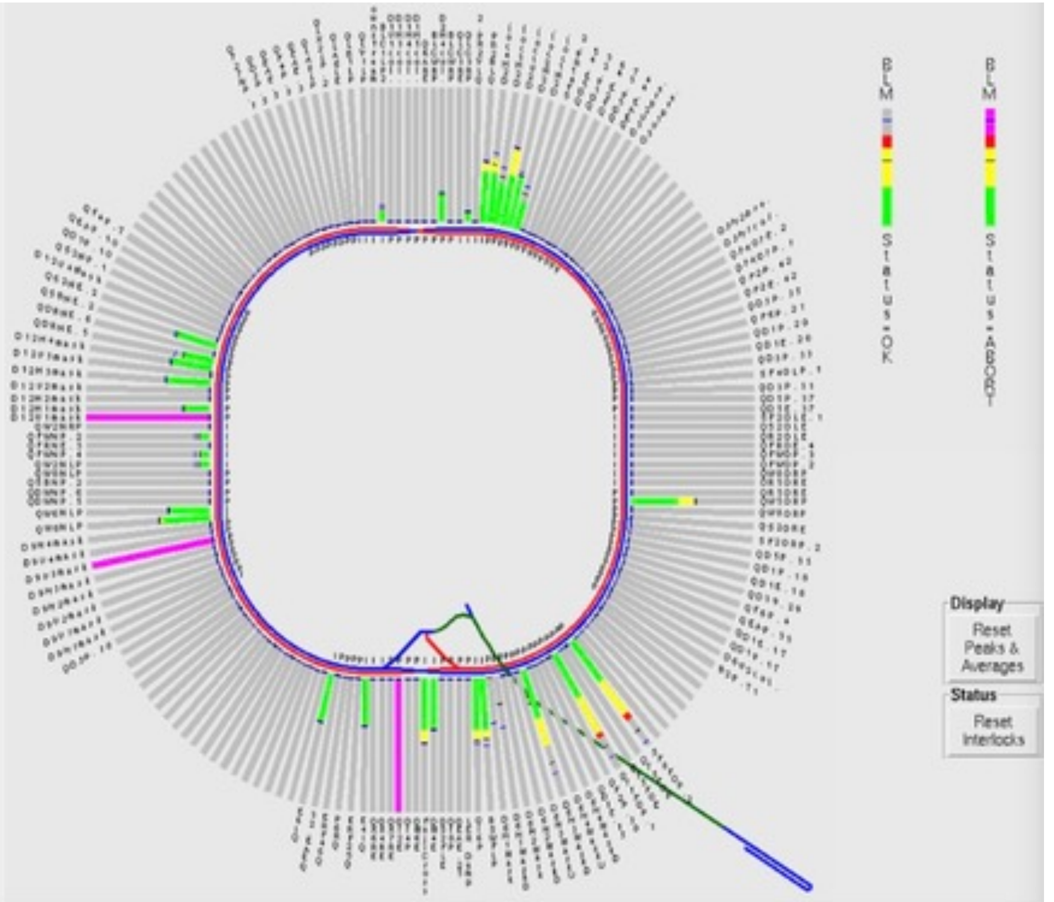
M. Masuzawa

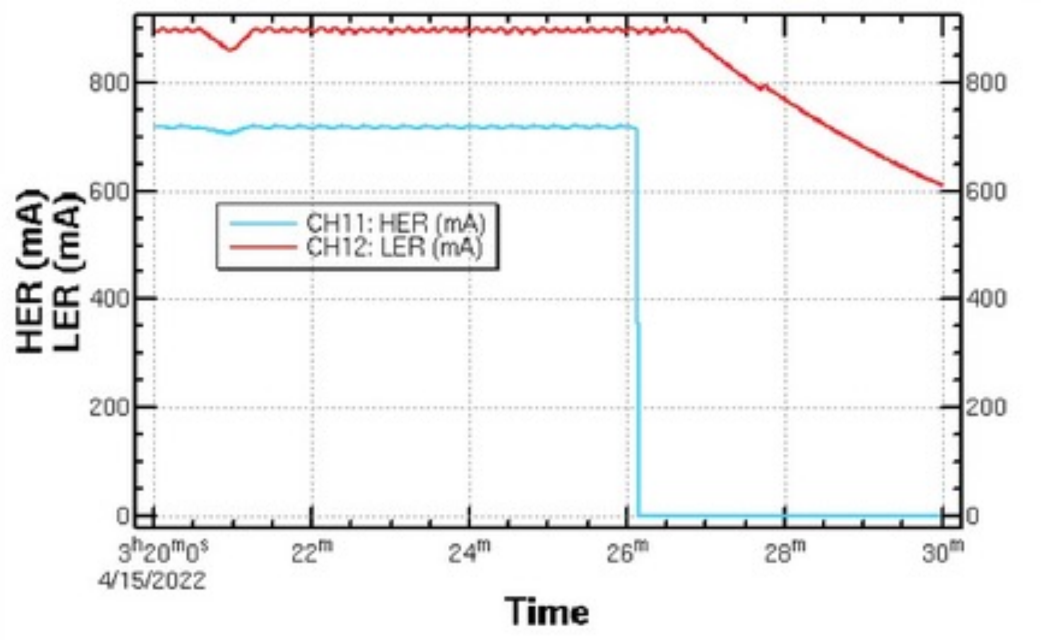
QCS cryostat oscillation at earthquake

- When earth quake happened, we observed oscillation signal with the gap sensors at QCS cryostat
- The gap sensor shows that the oscillation amplitude in the vertical direction is two times smaller than the horizontal direction.









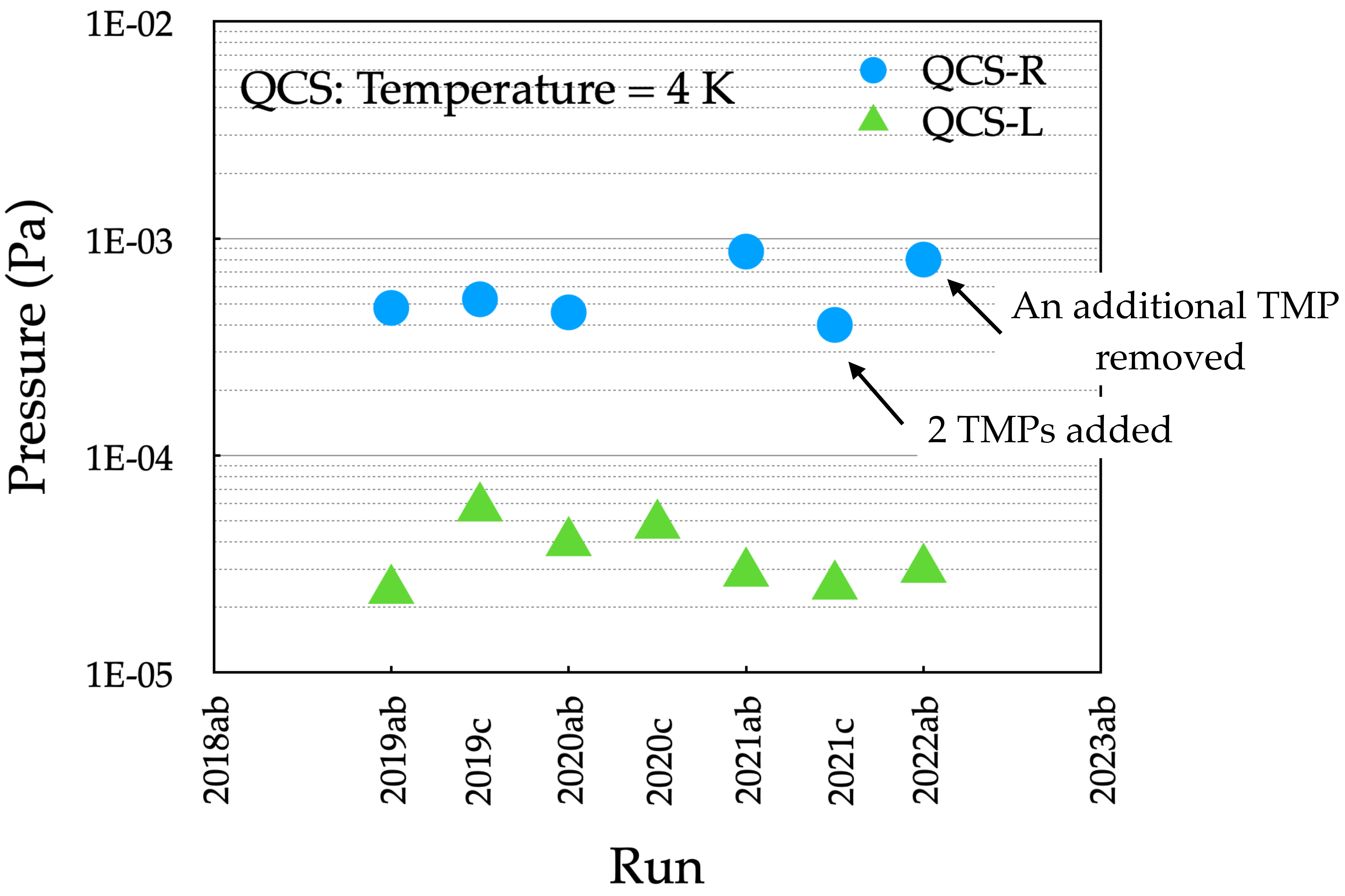
M. Masuzawa

QCS

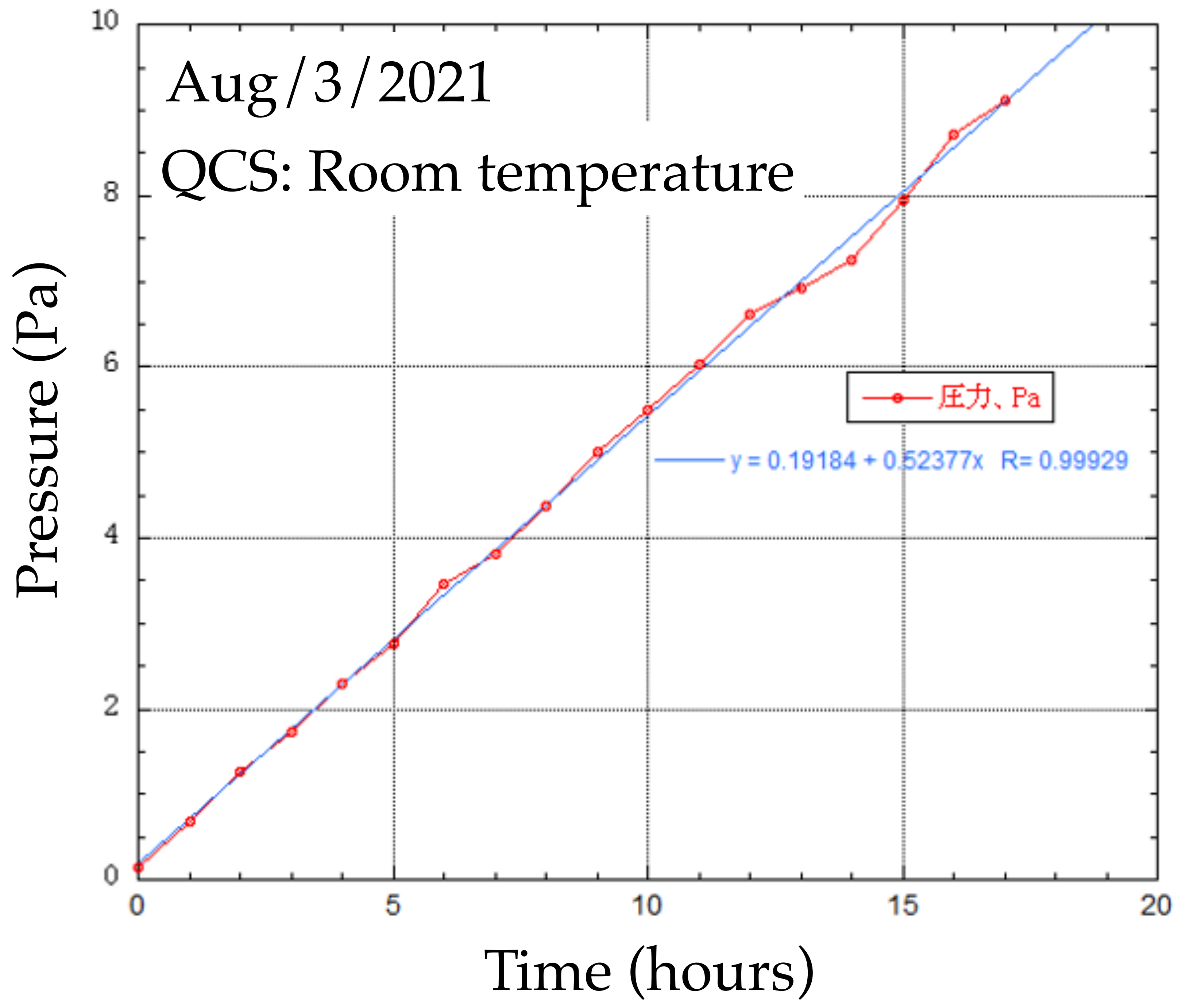
Vacuum leak of QCS-R cryostat

Vacuum pressure of QCS cryostats

Vacuum Pressure for one month after reaching 4K



Degradation of vacuum pressure of QCS-R

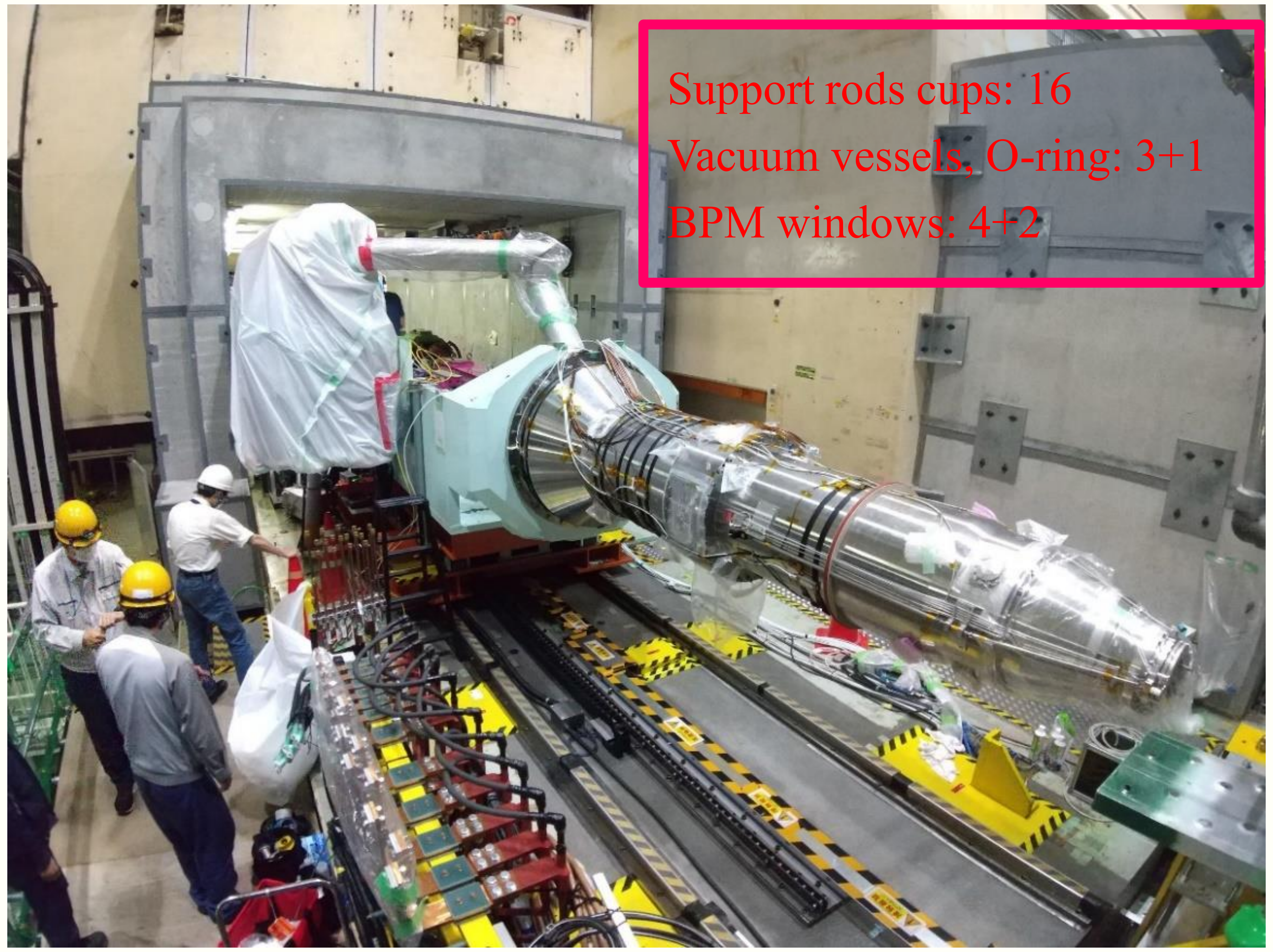


Leak rate: 4×10^{-4} Pa m^3/s

He Leak check performed at LS1

- Sep/2022
- We made He-traps around O-rings.
- We waited 5 minutes to see if the vacuum level changed.
- We performed this leak check in cooperate with QCS and the vacuum group.
- We found a leak at the service cryostat.
- We will open the service cryostat and repair at the end of this fiscal year.

- OリングところにHe-trapを作る
  - Heガスが空気より軽くて直ぐに逃げる
- Heガスを付いている時間（>5分）
  - クライオスタットのボリュームが大きいのでHe Detectorまで時間がかかる
- リークdetectorの排気能力
- QCS-LとRの比較（Oリングの透過率の確認）

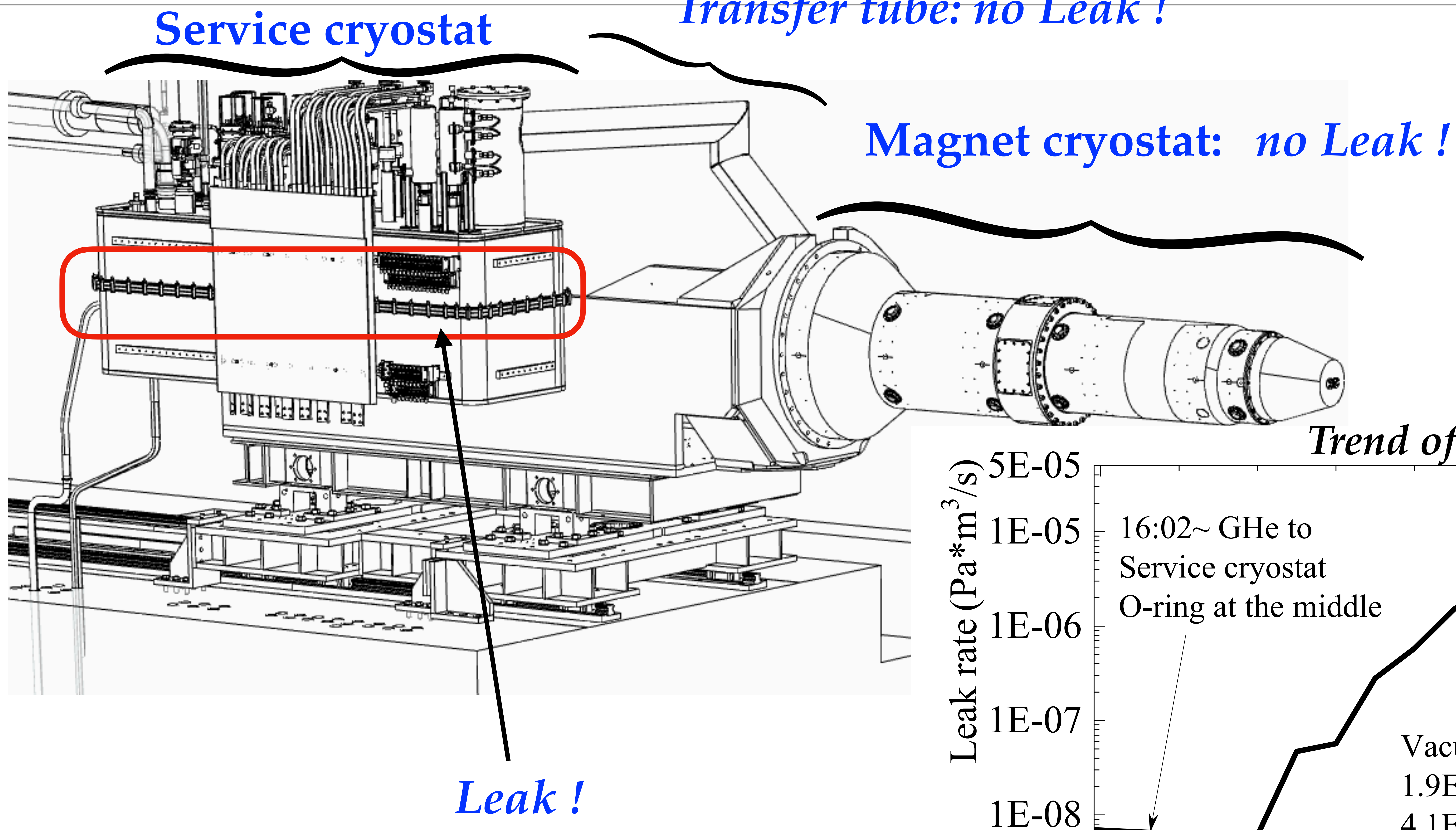


2022/10

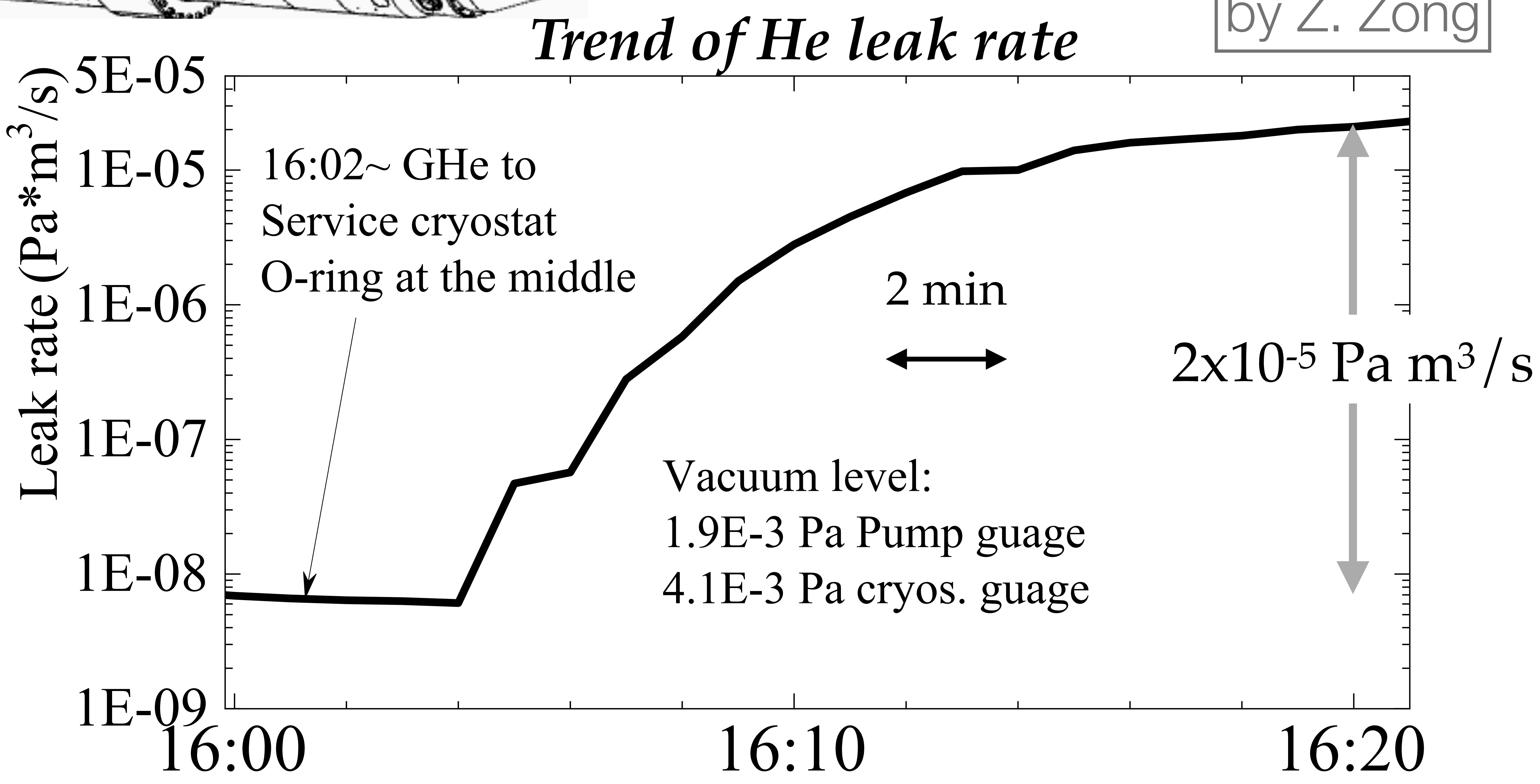
Helium Leak Test of QCS Cryostat

by Z. Zong

Leak area of QCS-R

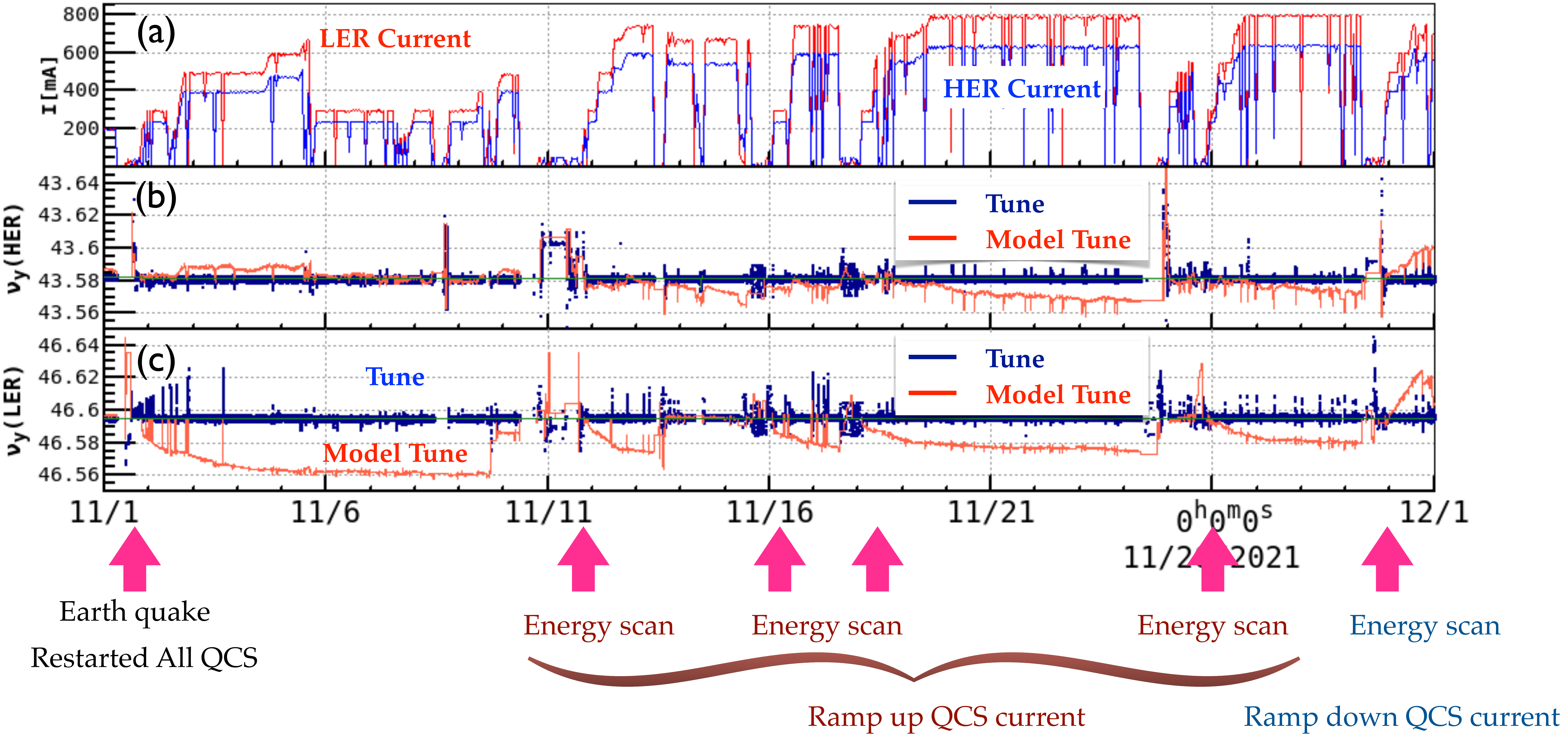


by Z. Zong



Drift of vertical model tune

Model tune variation (Nov/2021)



Flux creep

- The long-term drift of the magnetic field on the accelerator magnets has been reported by Fermilab, DESY, BNL.
- They mention that the flux creep is the cause of the drift.
- The flux creep is a fundamental phenomenon on type II superconductors (SC).
  - The pinning center in the SC moves, and some pins go out of the SC.
  - This reduces the magnetization in the SC.
- The time dependence is given by:

$$B(t) = a \log t + b$$

Flux creep

Time variation of B_3 component observed at the dipole magnet of DESY

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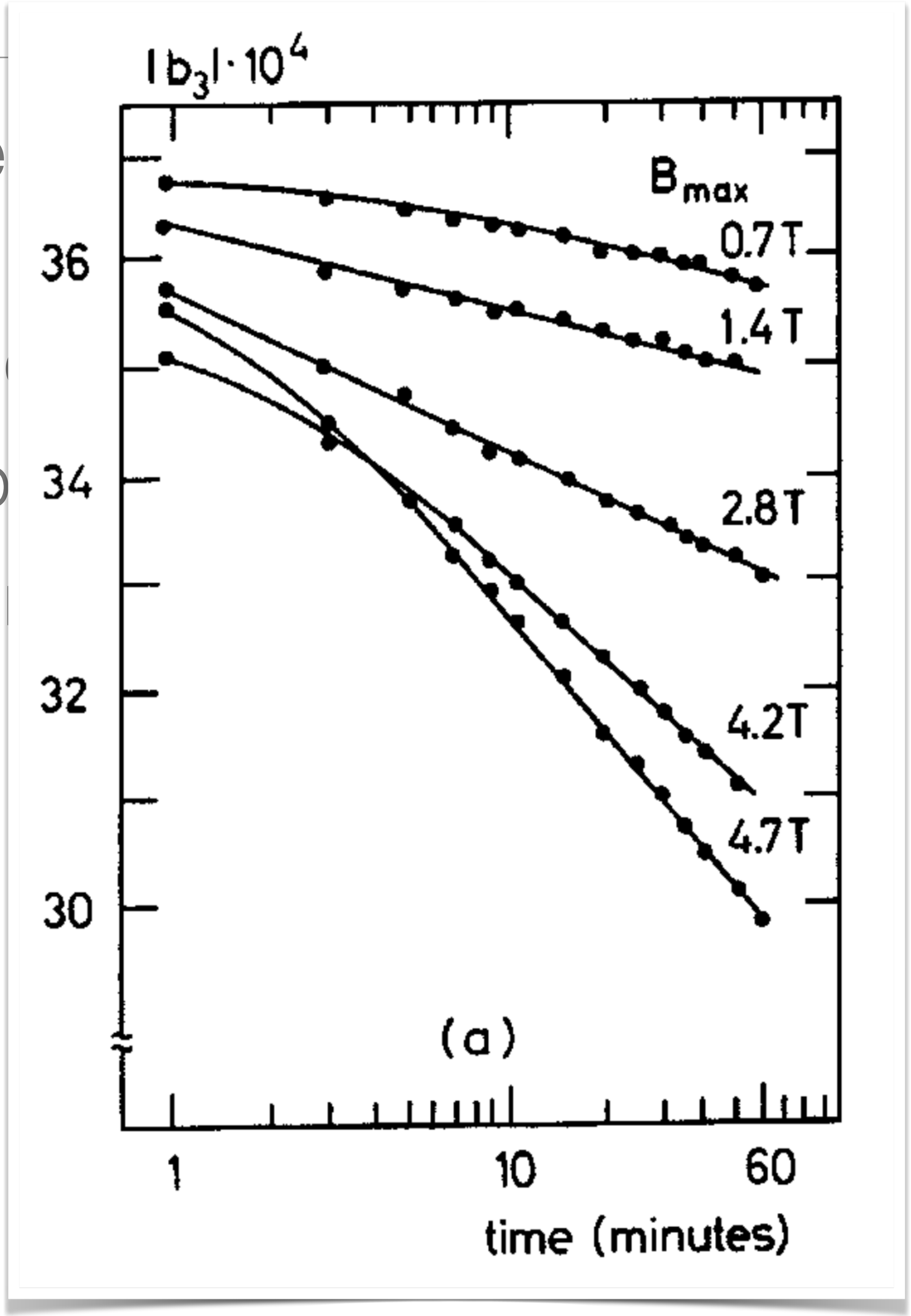
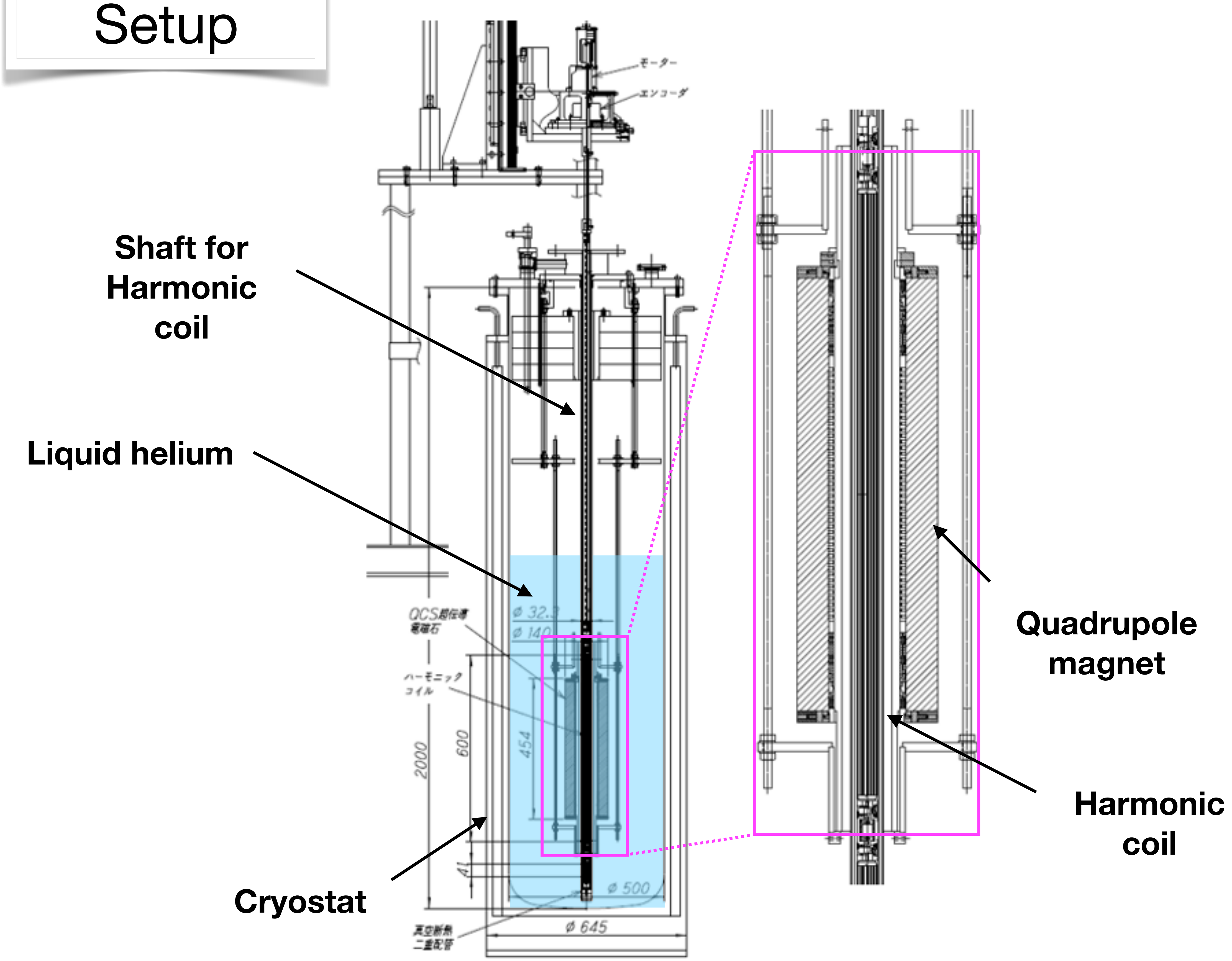


Long-term measurement of quadrupole field

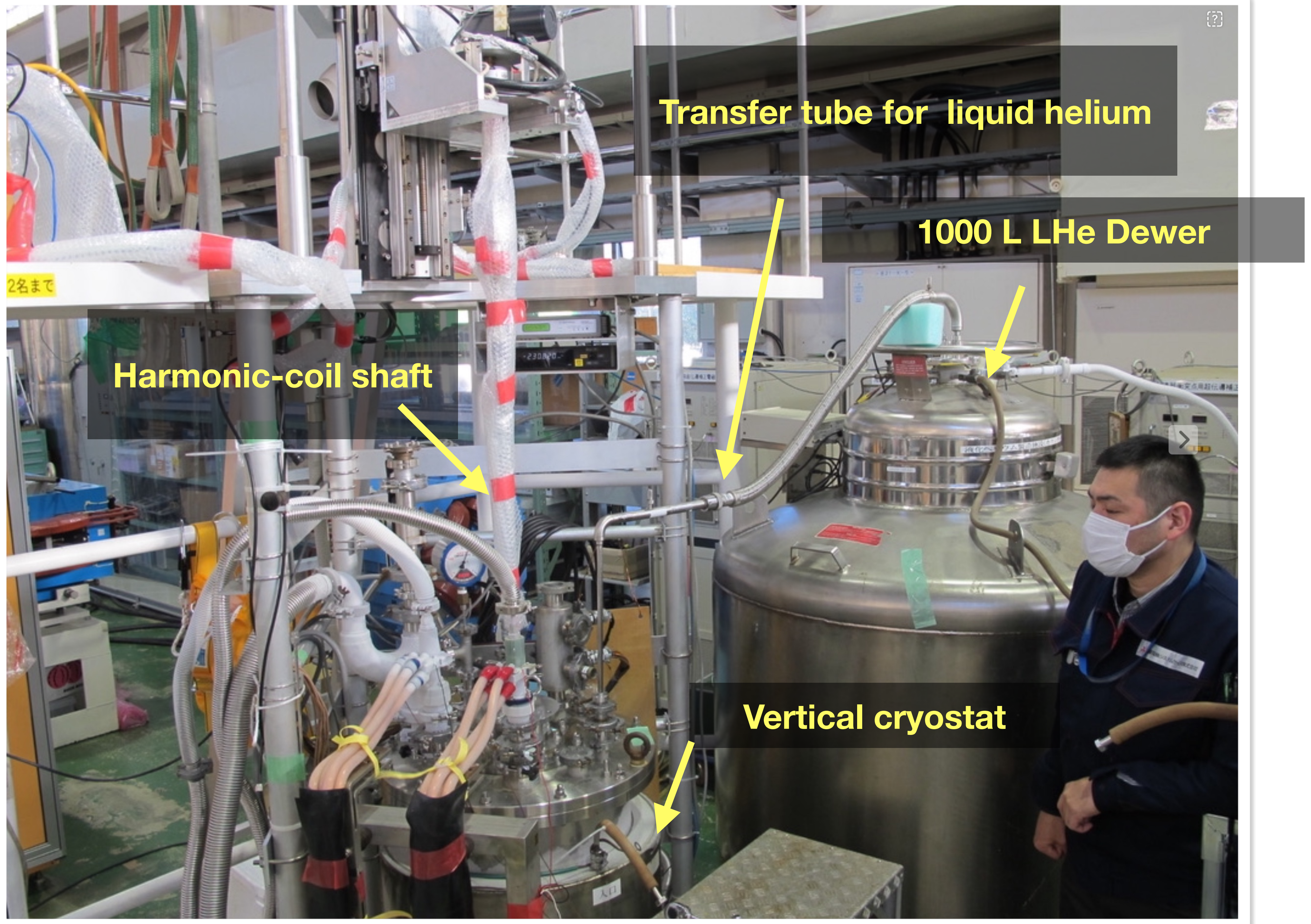
- Jul/2022 - Mar/2022
- Quadrupole field and multipoles were measured with the harmonic coil.

Setup



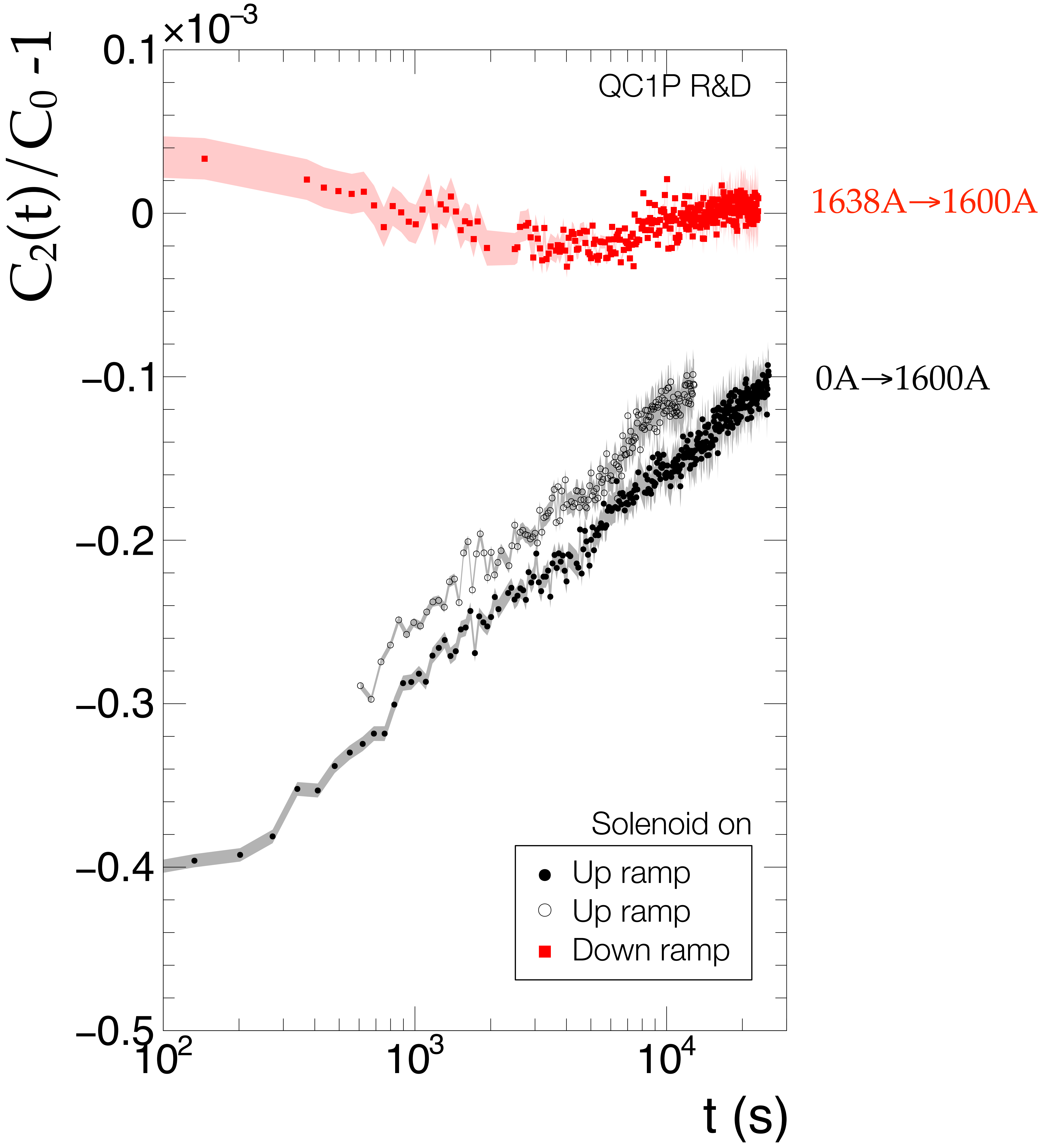
QC1P R&D magnet

QC1E Prototype magnet



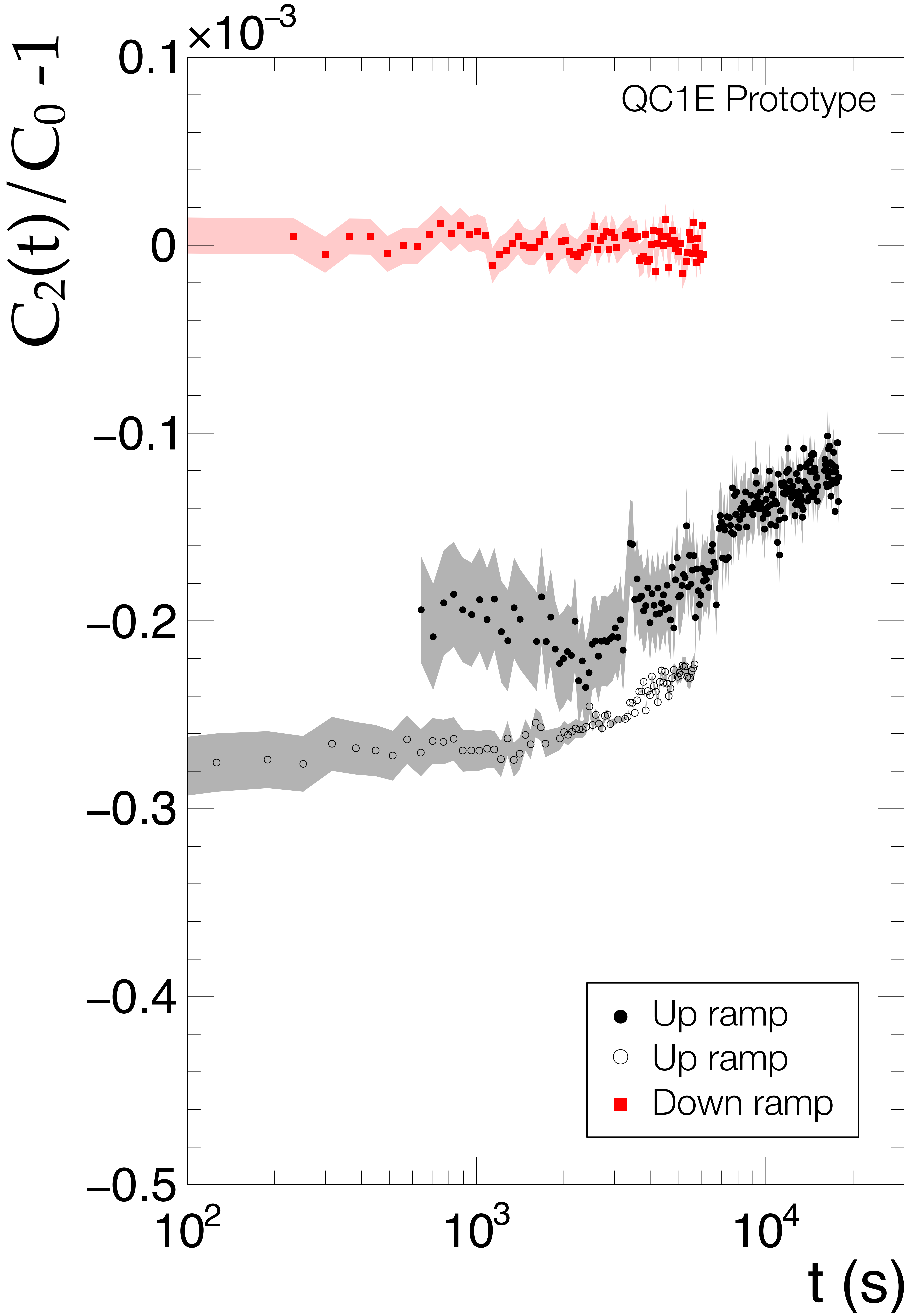
Measurement results: QC1P

- We observed the variation of quadrupole component. They vary with a function of $log(t)$.
- It indicates the variation caused by the flux creep.
- The time dependence of the variation depends on the excitation pattern.
- The variation is large if we set the current in the up-ramp direction.
  - The quadrupole components of QC1P were varied by 3×10^{-4} in 6 hours
- If we set the current in the down-ramp direction, we can reduce the time variation of the quadrupole field less than 0.5×10^{-4}.



Measurement results: QC1E

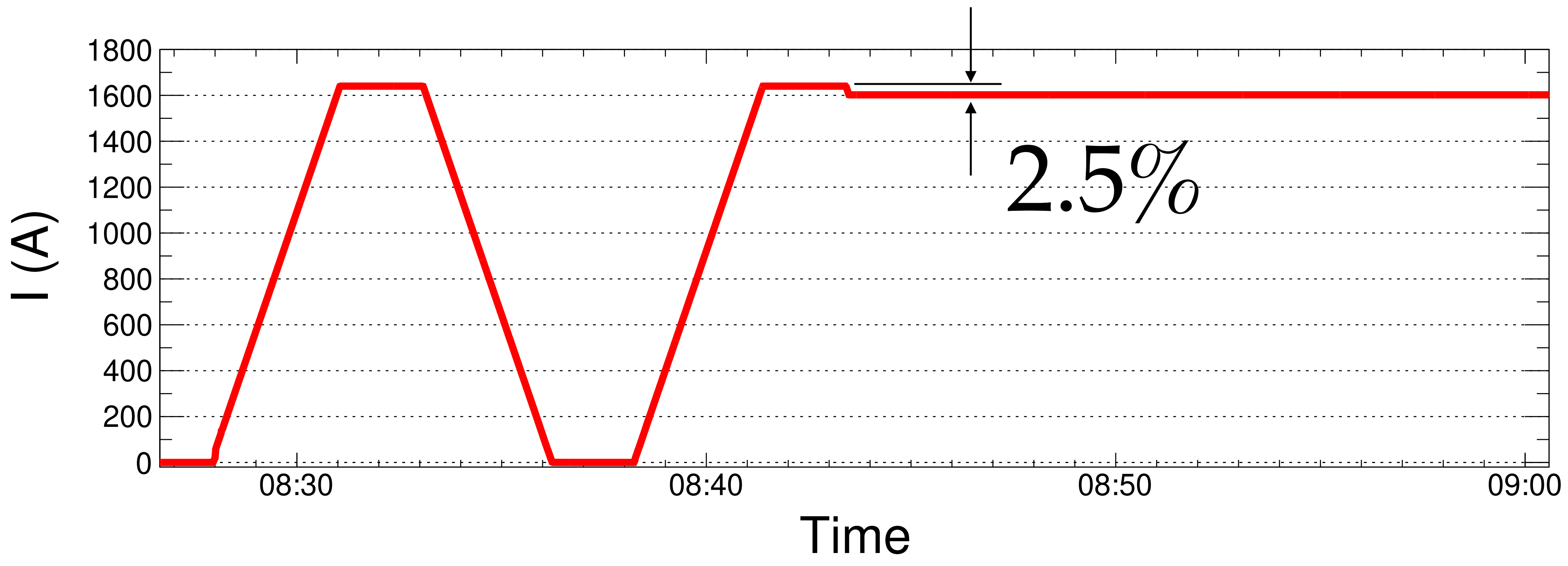
- When we set the current in the up ramp direction, quadrupole component increased by 1x10^{-4} in 6 hours.
- The variation is almost zero when we set the current in the down ramp direction.
- The variation is smaller than QC1P.

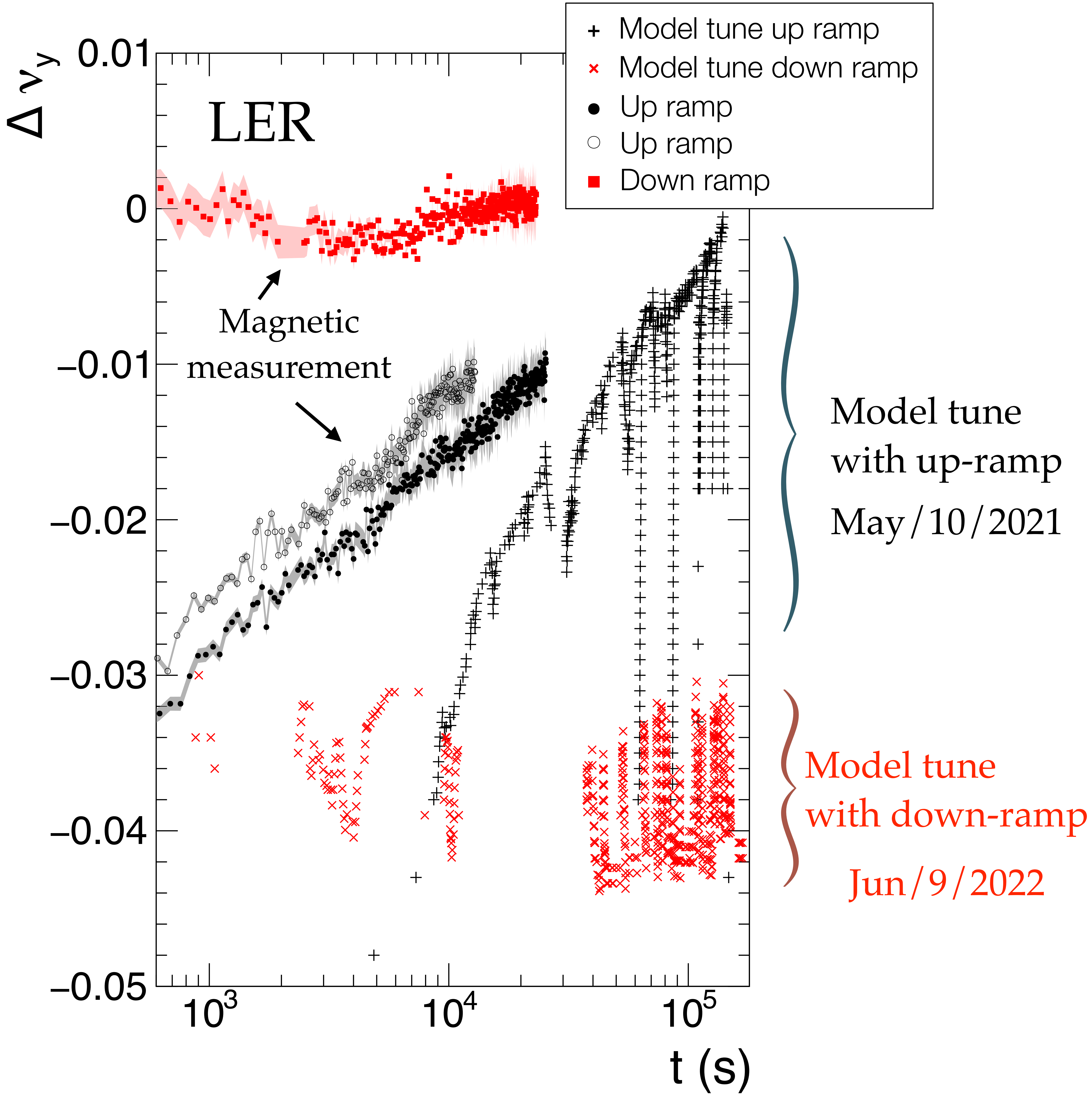


Model tune with down-ramp on LER

- After this measurement, we set the current of the QCS in the down-ramp direction.
- After the beam-induced quench of QC1(R/L)P on Jun/9/2022, we restarted the magnets in the down-ramp direction and observed no significant drift of the vertical model tune for LER.

Initialization pattern of QC1P





Summary

- MR Magnet
  - Installation work of NLC is underway
  - Thanks to routine maintenance, we have had no failure in cooling water since 2019.
  - Tunnel level survey shows that the ring goes down 5 mm from 2018 and seasonal level variation was about ±0.5 mm.
- QCS
  - We found the leak at the service cryostat of QCS-R. We will repair this at end of this fiscal year.
  - We confirmed that the magnetic field of the quadrupole magnet varied 3×10^{-4} by 6 hours. We can reduce the drift by setting the current with down ramping.