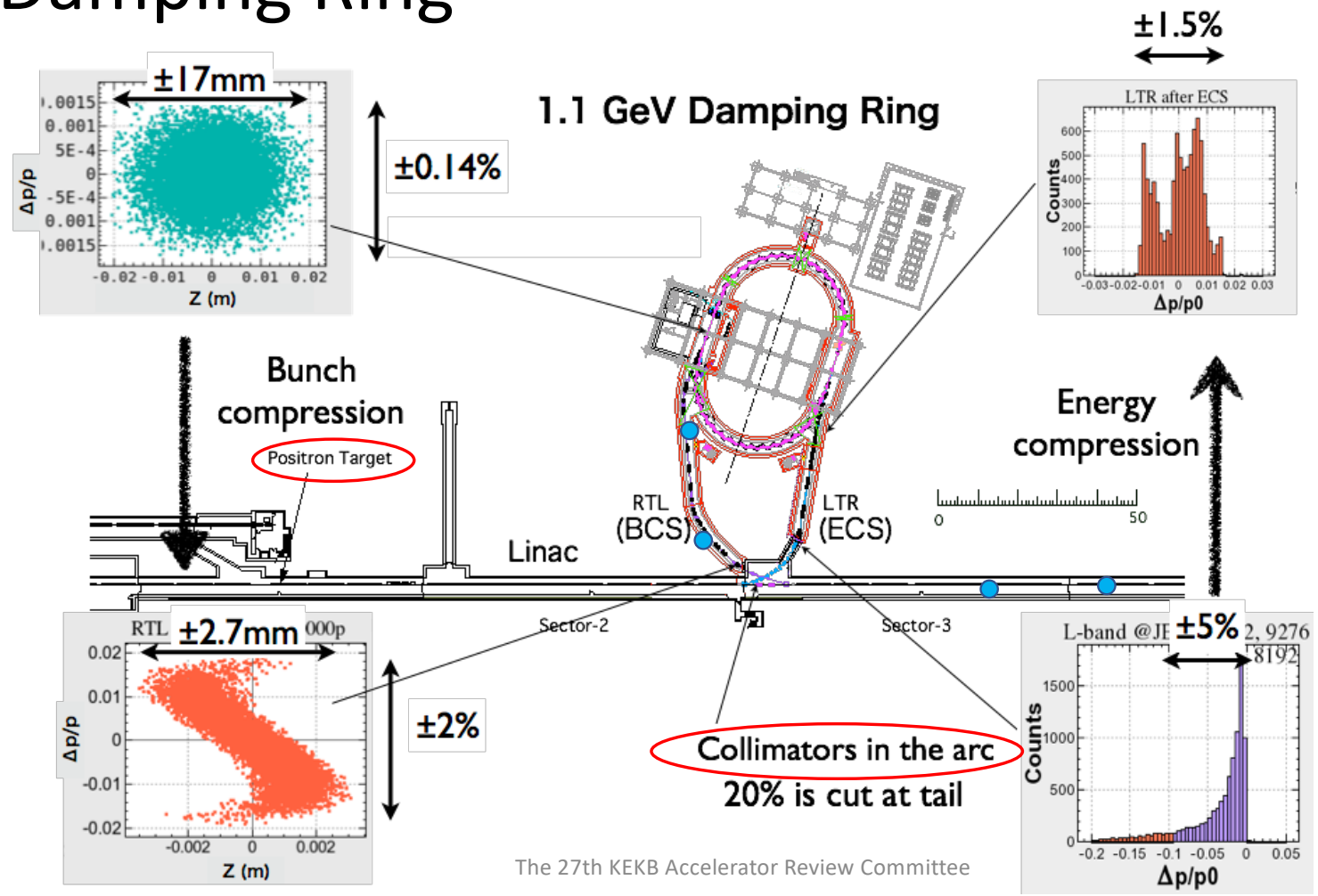
Damping Ring

M.Tawada

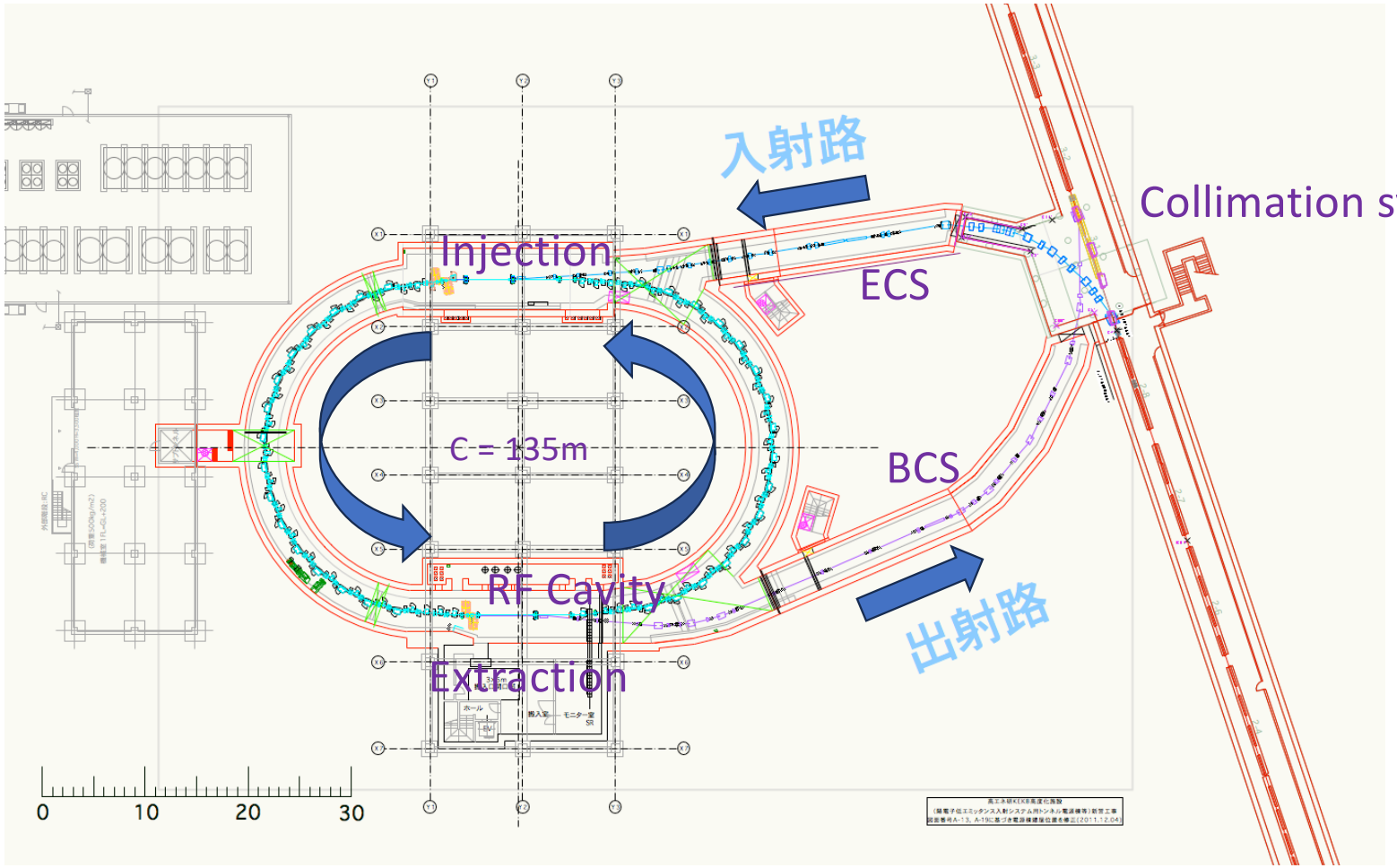
On behalf of DR group

Contents

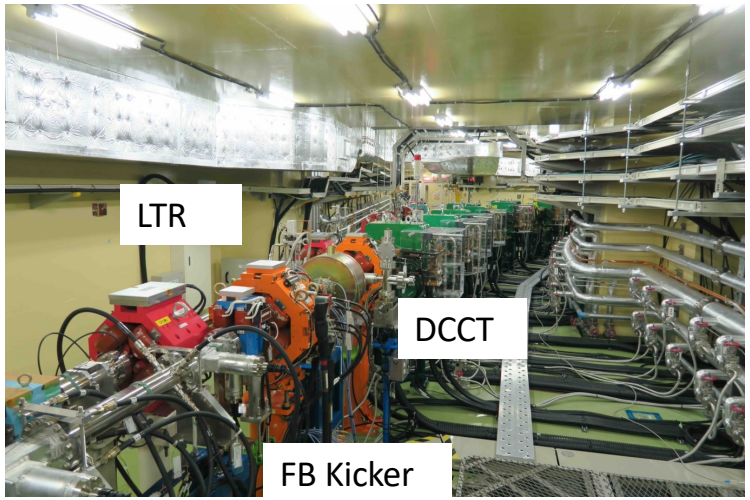
1. Damping Ring

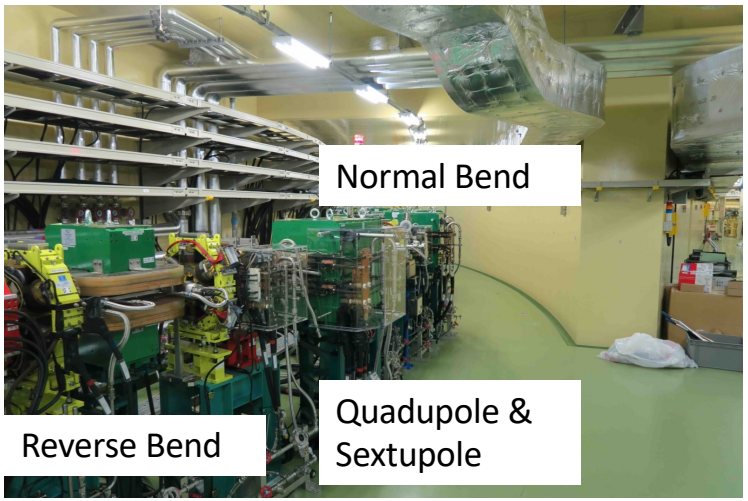


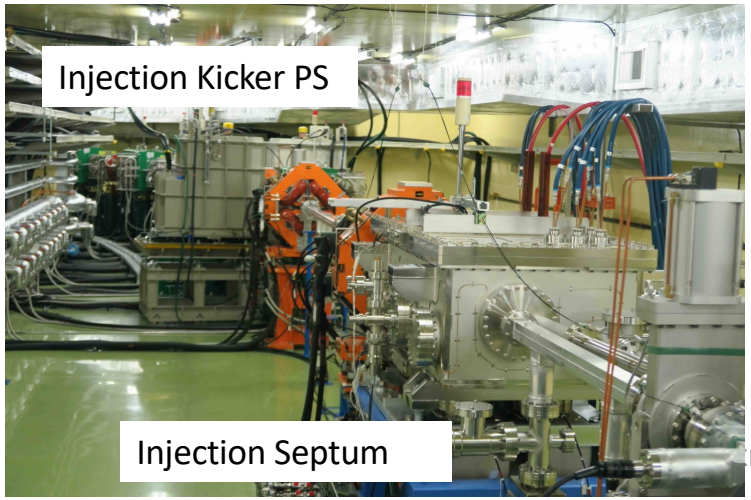
1. Damping Ring Layout

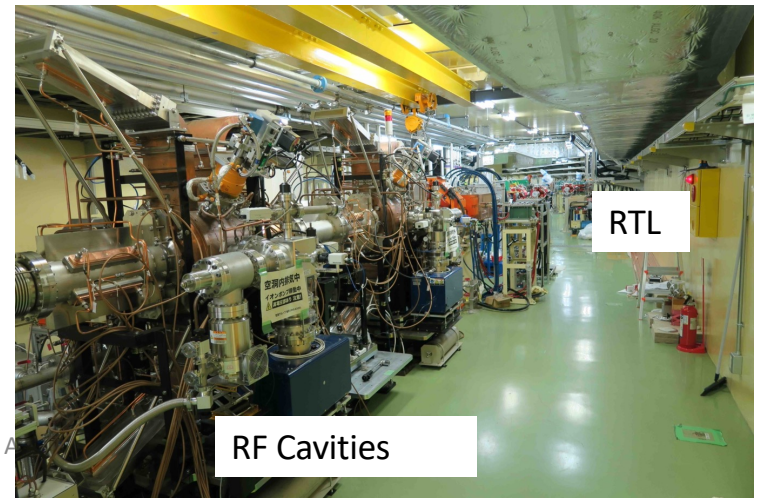


1. Pictures of DR









1. Features of the DR

- Large aperture enough to accept the Linac positron beam
- FODO with reverse-bend ensuring fast damping time of 12 ms, with lower bend field.
- Two pulses with 2 bunches each can be stored.
- Kickers with fast rise and fall-time of less than 100 ns and no ringing.
- Beam pipes with antechamber to accommodate photon masks, enabling very low transverse impedance.
- TiN coating in the vacuum chambers to mitigate electron cloud effect.
- HOM-damped, high-voltage RF cavities to ensure a large energy acceptance and high bunch charge.
- Collimation system installed at the switching yard in the Linac to cut the energy and emittance tails.

1. Parameters of DR

Parameters		
Energy	1.1	GeV
Number of bunch trains	2	
Number of bunches /train	2	
Circumference	135.498	m
Max. stored current	70.8	mA
Energy loss per turn	0.0847	MV
Damping time ($\tau_x/\tau_y/\tau z$)	11.5/11.7/5.8	ms
Injected beam emittance	1400	nm
Equilibrium emittance ($\varepsilon_x/\varepsilon_y/\varepsilon_z$)	29.2/1.5/3630	nm
nx/ny/nz	8.83/6.28/-0.018	
Energy spread	5.5×10^{-4}	
Bunch length	6.6	mm
Momentum compaction factor	0.01	
Cavity voltage	1.0	MV
RF frequency	509	MHz

The target equilibrium horizontal emittance of 30 nm has been nearly achieved.

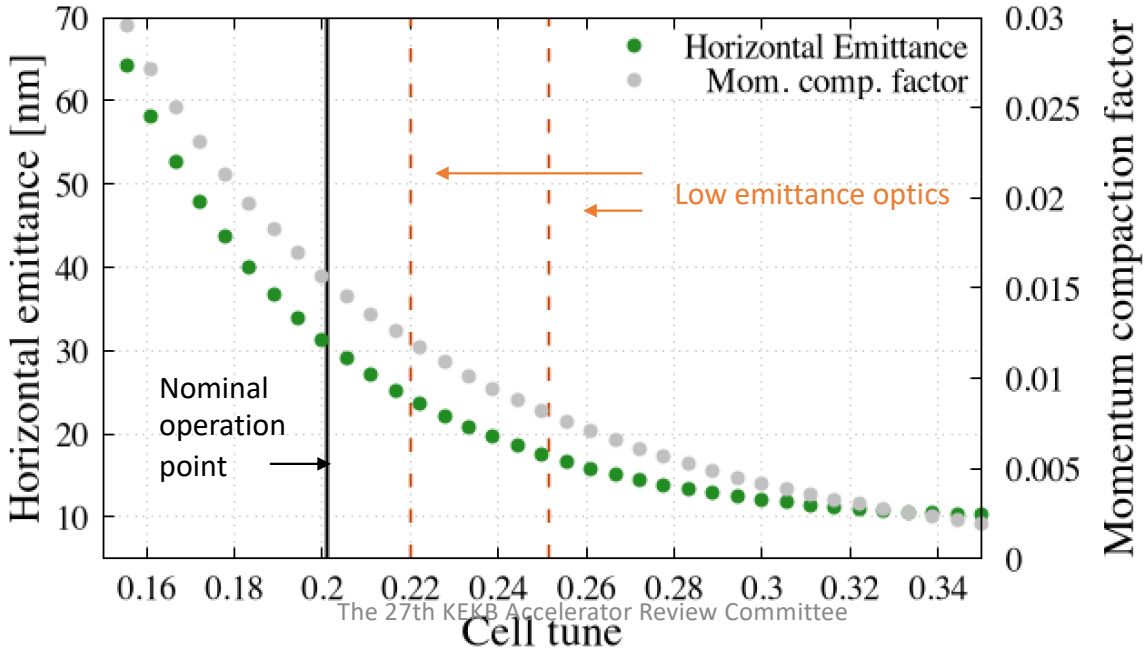
2. DR status & Issues

- DR commissioning stated in Feb. 2018.
- The Operation of DR is ongoing smoothly without any major trouble after LS1.
- Issues
  1. Due to unexpected emittance growth after DR and small dynamic aperture of LER, lower emittance of the DR is required. However, several attempts at lower emittance operation have failed.
  2. Beam orbit drifts and fluctuations in the DR, making optics corrections challenging.
  3. Extracted beam orbit drifts are observed, stemming from the temperature dependence of output current of extraction kickers.

H. Sugimoto

(1) Lower emittance optics

- Thanks to the FODO cell with reversed-bend, DR is capable of lower emittance operation by increasing arc cell tunes and lowering momentum compaction factor.
- Several attempts at lower emittance operation were conducted.
- These attempts failed due to unexpected large optics distortion, resulting in beam losses during beam injection.

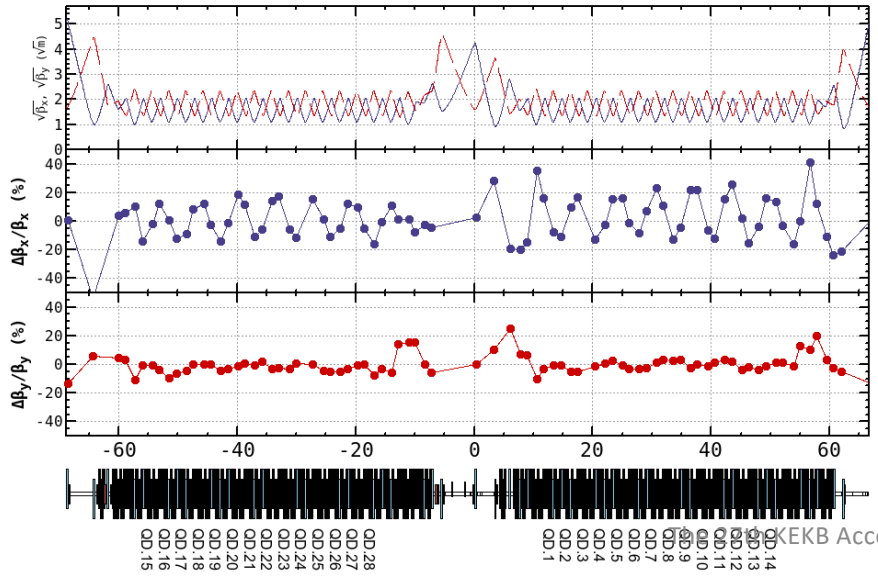


H. Sugimoto

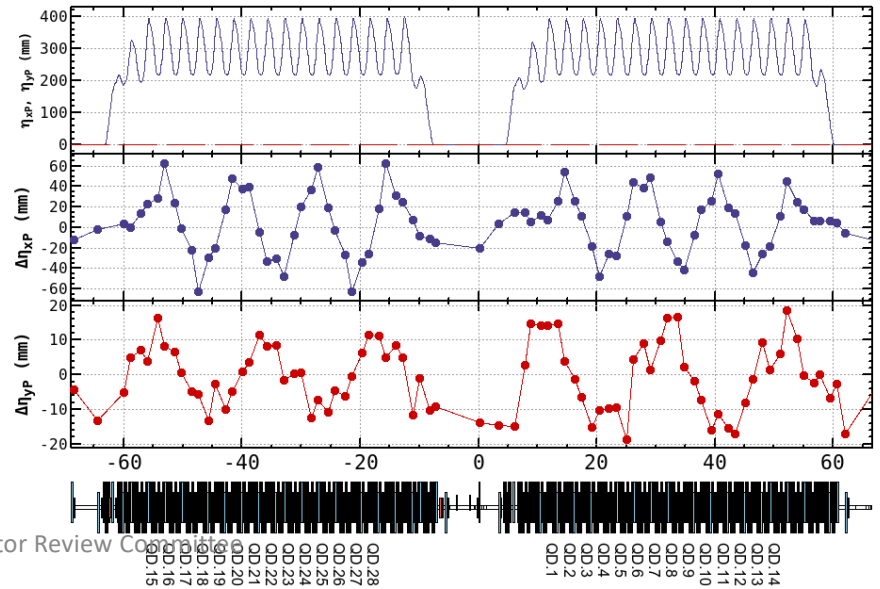
(1) Lower Emittance Operation Trials

- Several trials failed due to unexpected large optics distortion.
- The optics distortions could not be corrected by the quadrupole families.
- Adjustment of main bending magnets may improve the situation. (Not tried yet.)

Beta Beating



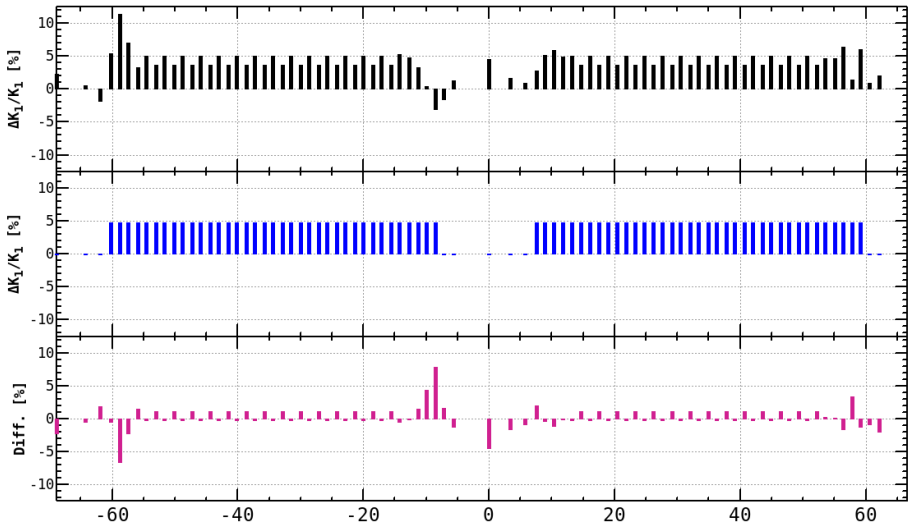
Residual Dispersions



H. Sugimoto

(1) Lower Emittance Operation Trials

- **Uncertainty of the implemented excitation curves in the magnet system**
  - Last year, It was reported that there was a mistake in the calculation of the excitation curve of arc quadrupole magnets.
  - The report is consistent with the correction factors identified by optics corrections.
  -Using these correction factors, we attempted lower emittance operation again, but unfortunately, it still didn't succeed.



(1) Correction factors applied in the operation (Determined by optics corrections)

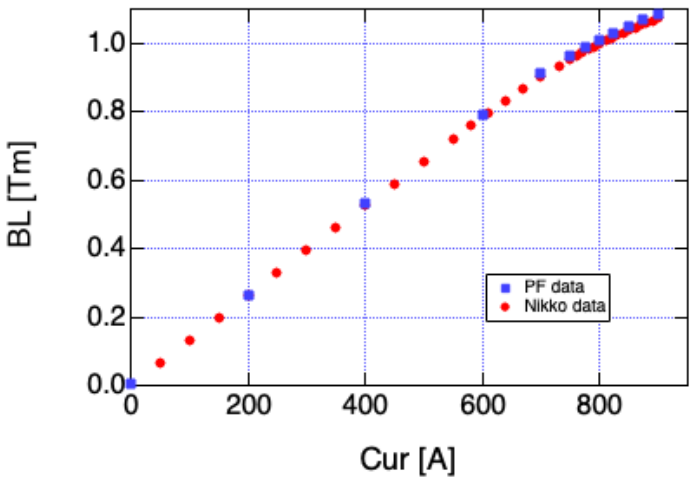
(2) Correction factors anticipated due to the mis-implementation of the excitation curve.

(3) = (2) - (1)

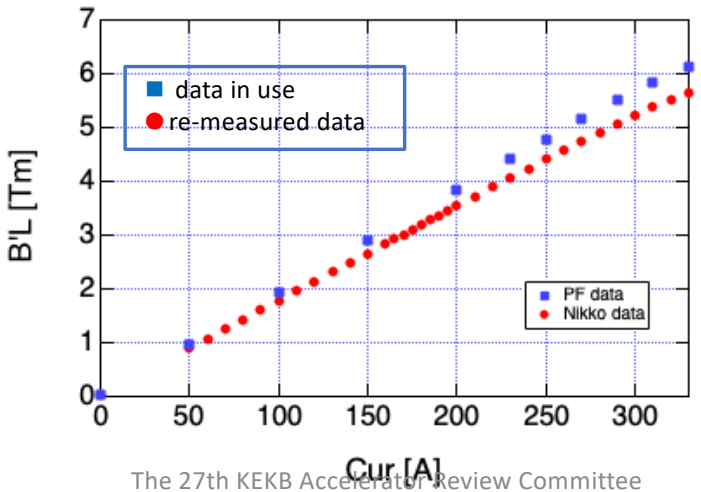
(1) Magnetic field measurement data comparison

- Re-measurements of the spare magnets using different measurement system indicate significant correction factors, a few % for bending magnet and 5 -10 % for quadrupole magnets.
- For quadrupole magnets, there is also a significant variation in implemented excitation curves.
- We intend to re-measure the remaining spare magnets using an alternative system and replace excitation curves.

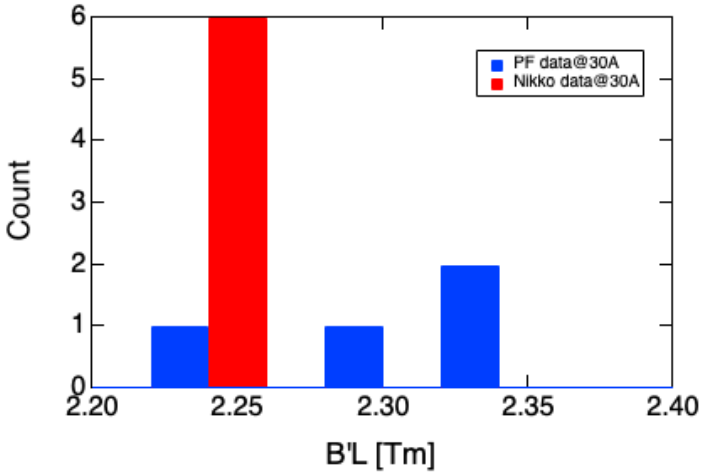
DR main dipole



DR-Arc Quad

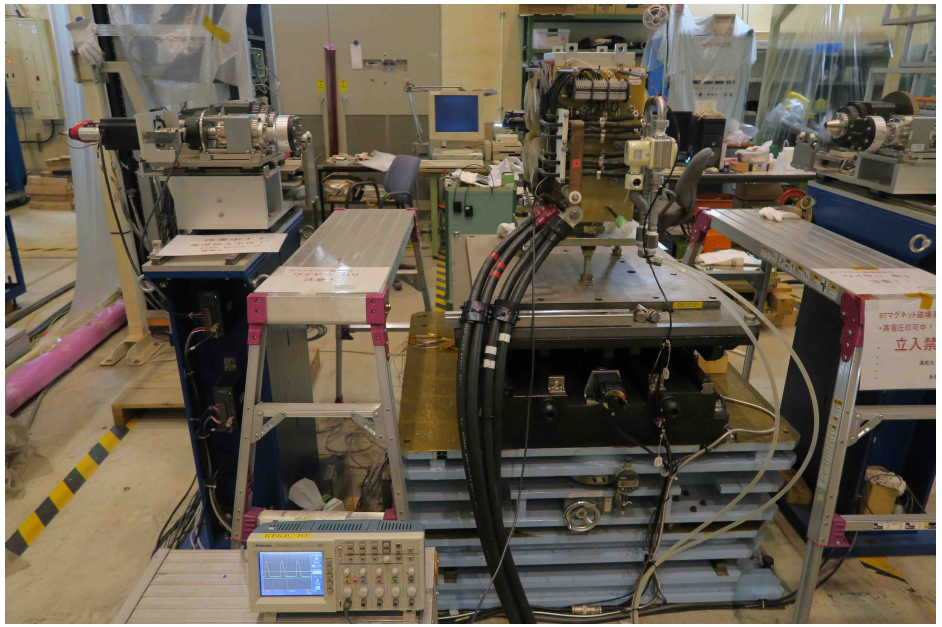


RTL-Quad @30A



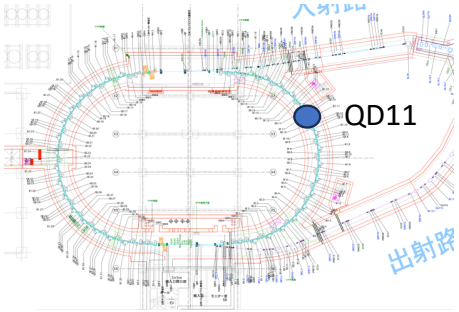
Magnetic field measurement devices

Implemented data were measured by using this harmonic coil.



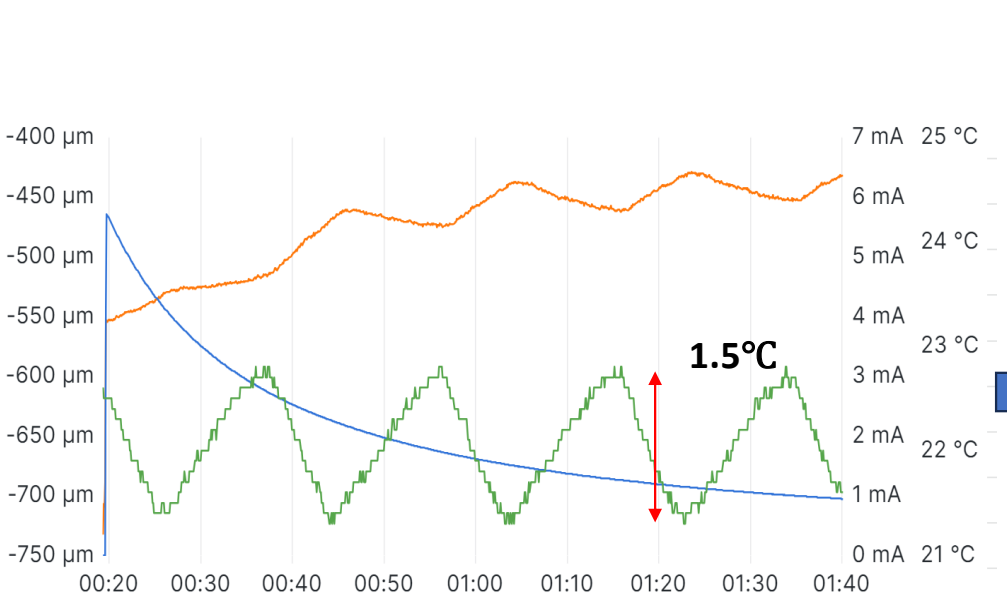
Rotating stretched-wire coil as an alternative measurement device

(2) Orbit drift problem

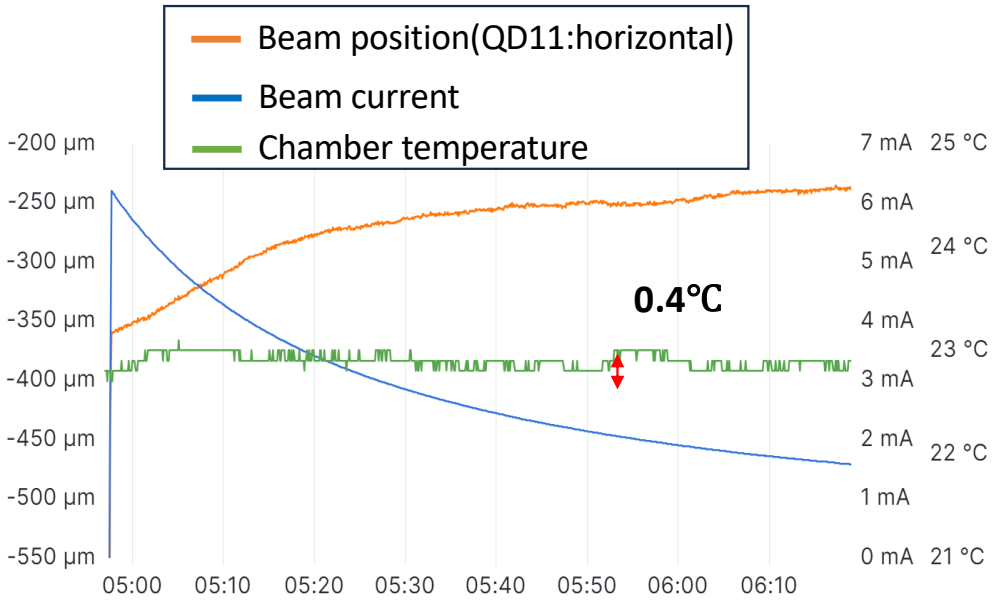


T. Ueda

- Beam orbit fluctuations and drifts were observed in a decay mode in the DR. The fluctuations depend on the temperature of vacuum chamber, which is cooled by the water chiller system.
- Narrowing the temperature setting range of the cooling water chiller unit decreased the orbit fluctuations. However, slow orbit drifts are still observed depending on the beam currents.

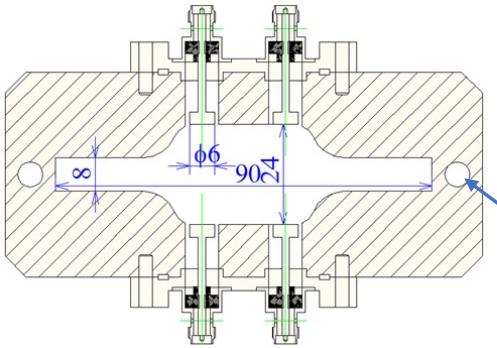


Before improvements



After improvements

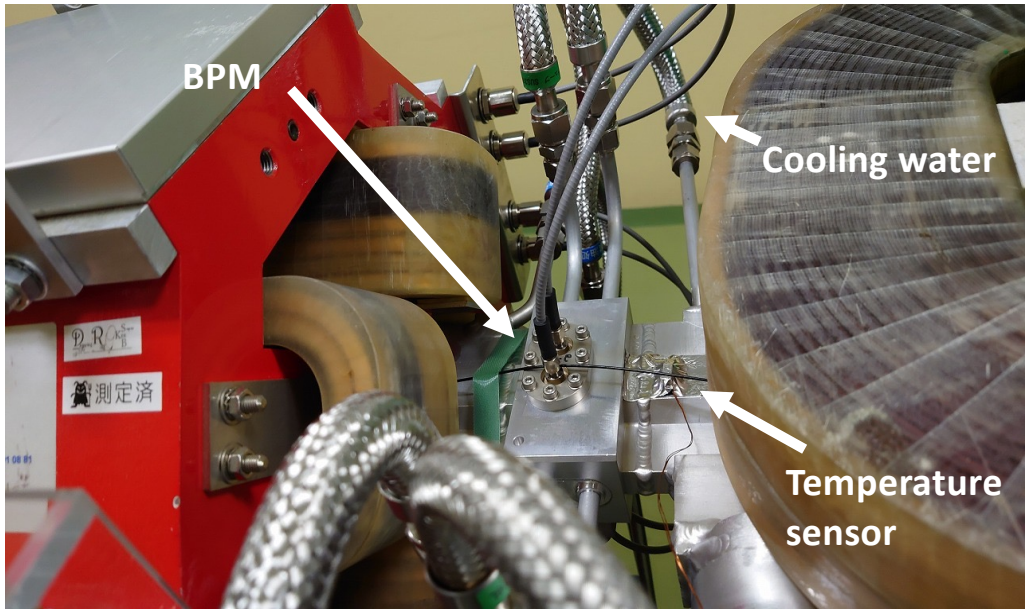
(2) Orbit drift problem



Cooling water channel

T. Ueda

Water Chiller unit for vacuum chamber
（Installed in power supply building）



BPM blocks, which are fixed to the Q-magnets.

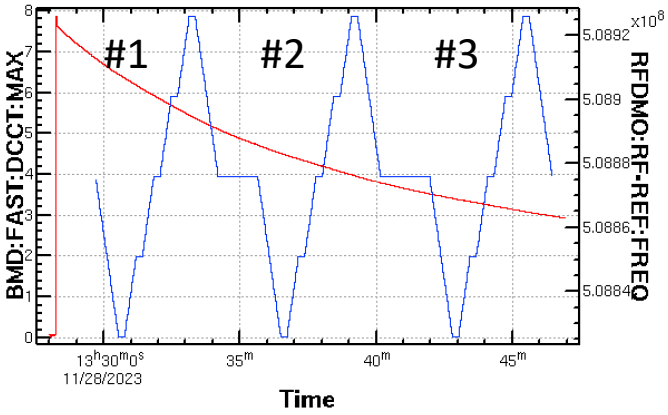
H. Sugimoto

(2) Orbit drift problem on DR Optics Control

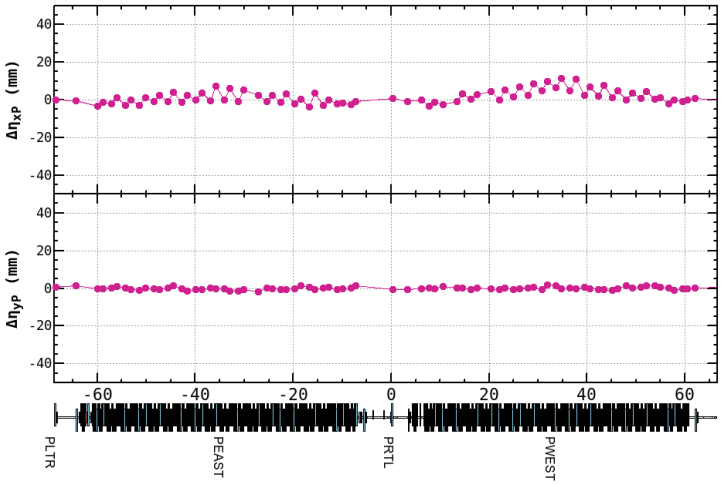
- **Beam current-dependent (apparent?) dispersion function**
  - BPM reading depends on beam current, especially when RF frequency is changed.
  - Three consecutive dispersion measurements show systematic dispersion changes.

Red: Beam current

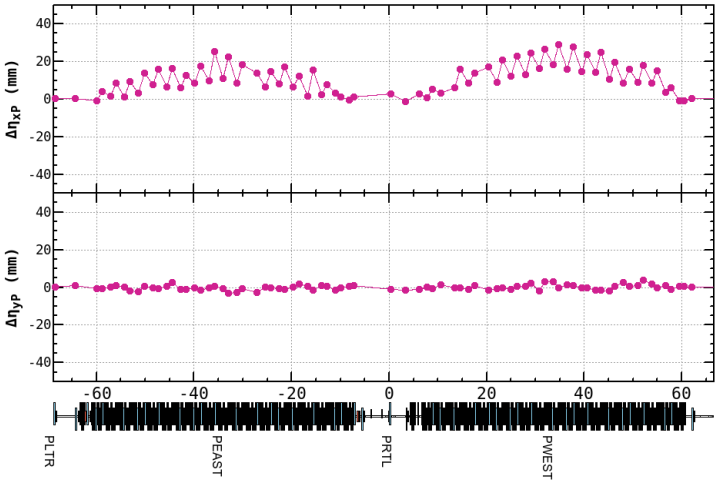
Blue: RF frequency



Dispersion #2- #1



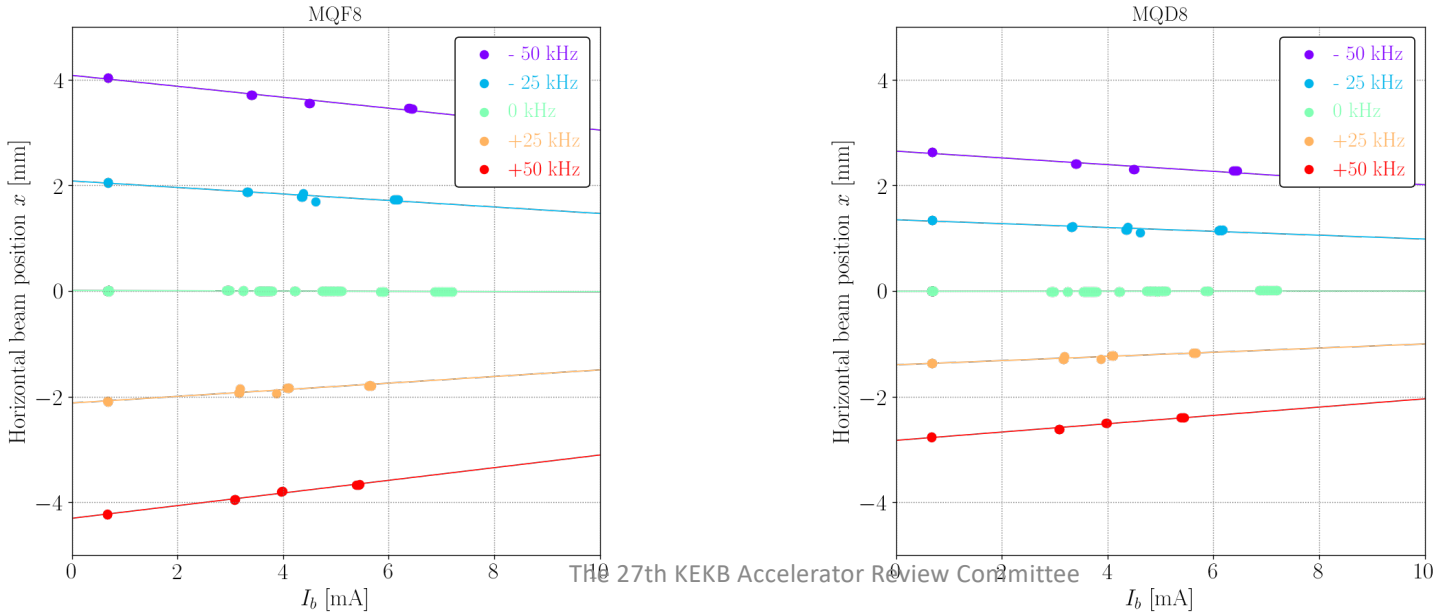
Dispersion #3- #1



H. Sugimoto

(2) Orbit drift problem on DR Optics Control

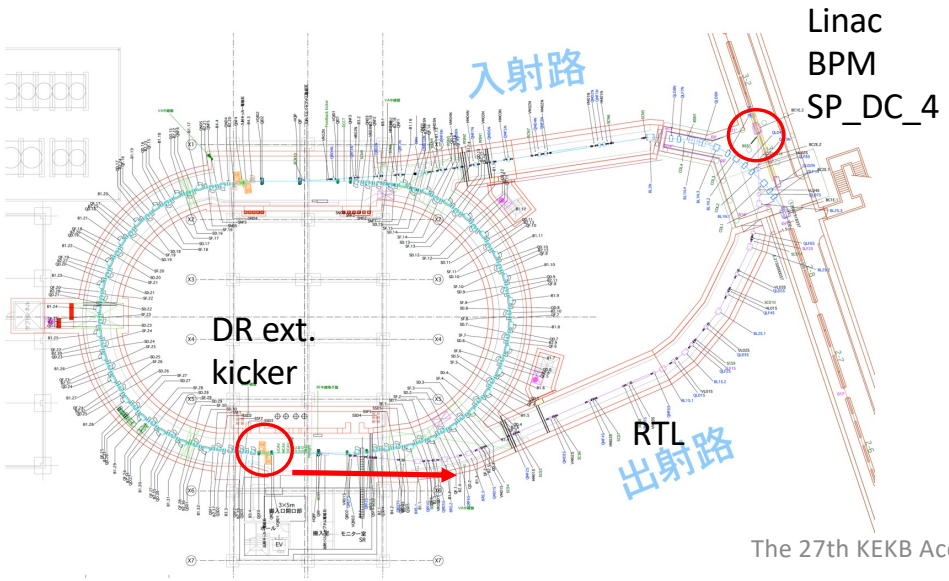
- Two examples of BPM readings vs beam current with different RF frequencies.
  - The beam current dependency depends on RF frequency.
  - A hundred-micron difference in beam position at frequencies of +-50KHz results in a 10 mm difference in the measured dispersion functions.
  - What is the best way to extract the dispersion function for optics correction?

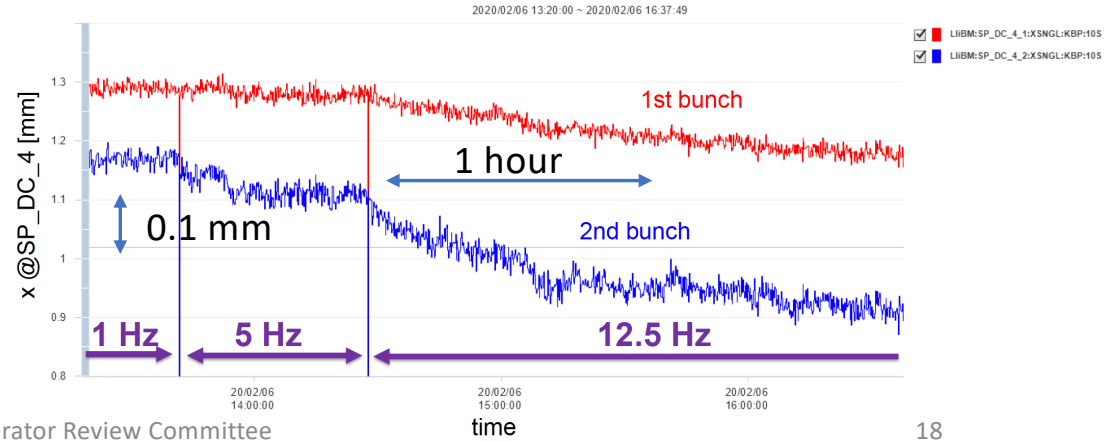


S. Miyahara

(3) Extracted Beam Orbit Drift Issue

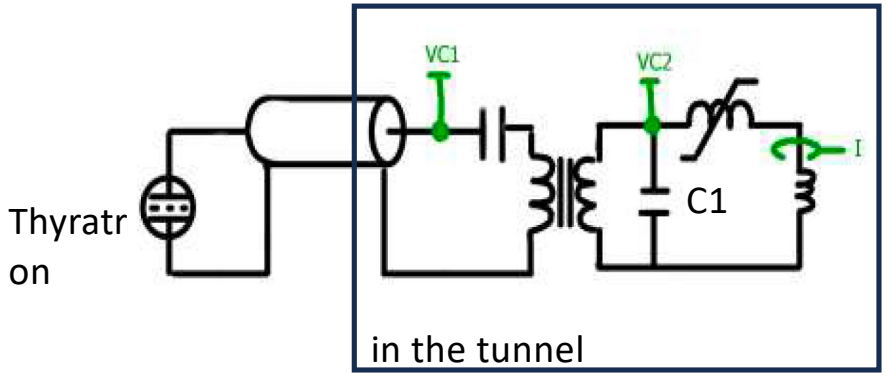
- A slow orbit drift of extracted beam was observed at the Linac BPM. These orbit drift changes when the repetition changed, which is much clearer for the 2nd bunch.
- It takes a long time to reach equilibrium for the high repetition rate (> 2 hour for 12.5Hz).
- The cause is identified as the temperature dependence of the output current of the extraction kicker.

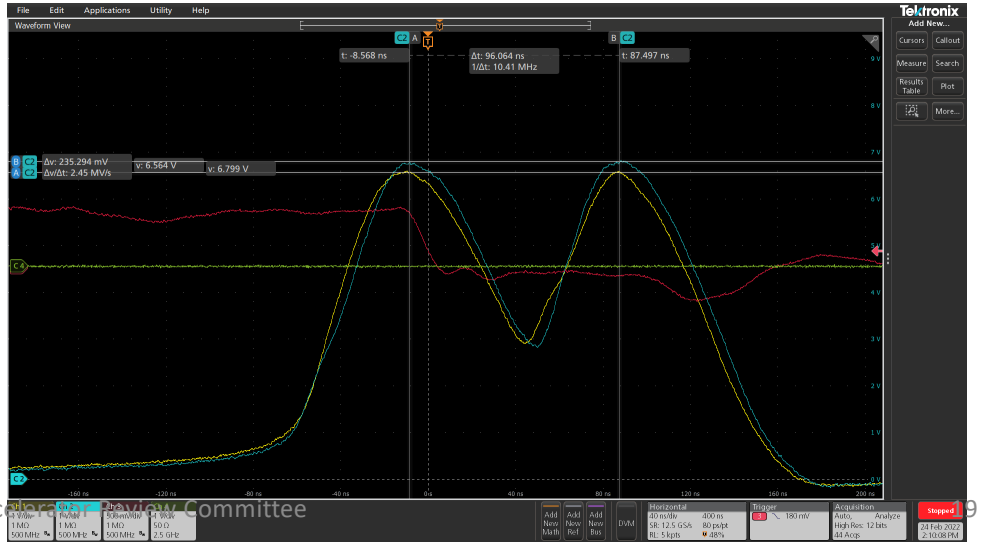




(3) DR extraction kickers

- No. of magnets: 2
- Deflection angle: 4.7 mrad
- Pulse shape: double half sine
- Pulse width: < 300 ns
- Rise /Fall time: < 100 ns
- Peak currents: 1546 A





(3) R&D for reducing temperature dependence

- The temperature dependence has decreased to about 1/3 by
  - Using mica capacitors in stead of ceramic capacitors,
  - Switching from natural oil cooling to forced oil cooling.
- Successfully operated it for over 100 hours at rated voltage using mica capacitors.
- However, the test didn’t meet the installation deadline, unfortunately.

(3) R&D for reducing temperature dependence

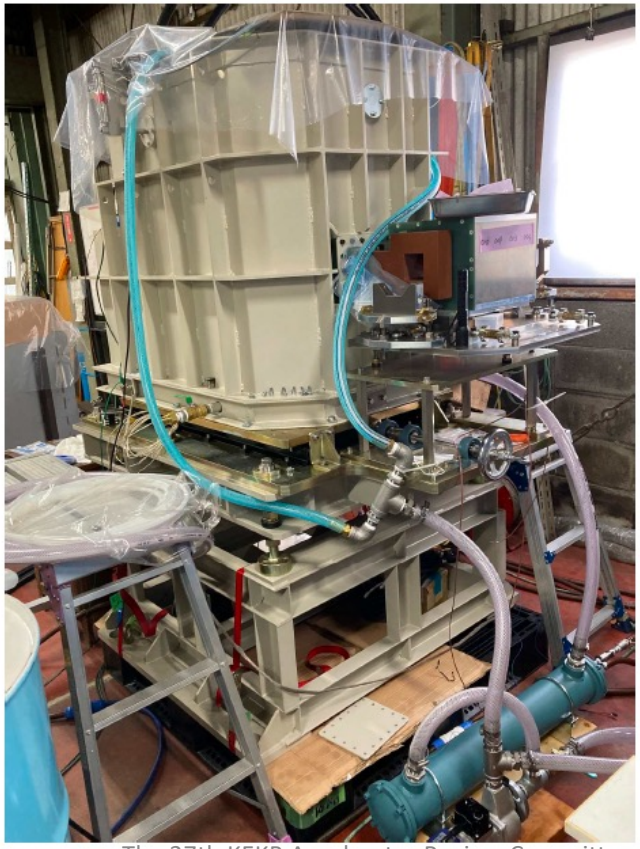
Ceramic	Capacitor temp. (℃)	C1-C2 time (s)	C2-time (s)	C1Volt (kV)	C2 Volt (kV)	Output Cur(A)
Start time	24.5	3.36E-07	1.877E-07	27.24	36.3	1044
End time	30	3.337E-07	1.851E-07	27.245	36.545	1023
ΔT	5.5	-2.3E-09	-2.6E-09	0.005	0.245	-21
ΔI(%)		-0.685%	-1.385%	0.018%	0.675%	-2.011%
ΔI/ΔT(%)		-0.124%	-0.252%	0.003%	0.123%	-0.366%
mica	Capacitor :temp. (℃)	C1-C2time (s)	C2-time (s)	C1 Volt (kV)	C2 Volt (kV)	Output Cur (A)
Start time	11.5	3.196E-07	2.131E-07	27.242	35.79	724
End time	26.1	3.202E-07	2.114E-07	27.265	35.74	736.5
ΔT	14.6	6.000E-10	-1.700E-09	0.023	-0.05	12.5
ΔI(%)		0.19%	-0.80%	0.08%	-0.14%	1.73%
ΔI/ΔT(%)		0.013%	-0.055%	0.006%	-0.010%	0.118%

Temp. depedendence

Stability specification is < ±0.1%

(3) R&D for reducing temperature dependence

Mica capacitors



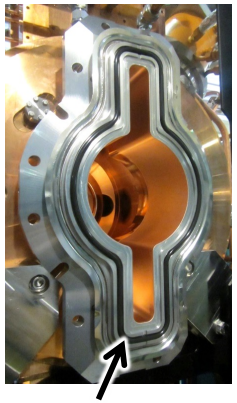
Force oil cooling system

3. Work on DR during LS1

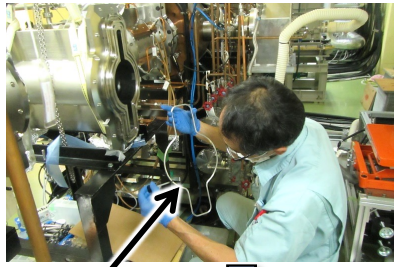
- During LS1, two tasks were carried out.
  - Change the material of the vacuum seal from Viton to metal. It will be reported later.
  - Repair of minor oil leaks in the magnetic switch tanks of the extraction kickers.

DR / RF Vacuum improvement by O-ring replacement during LS1

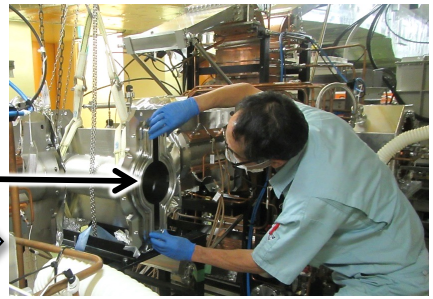
T. Abe



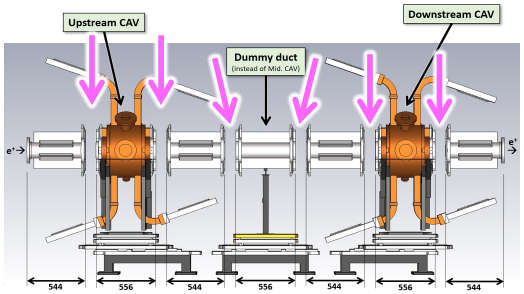
Viton O-ring

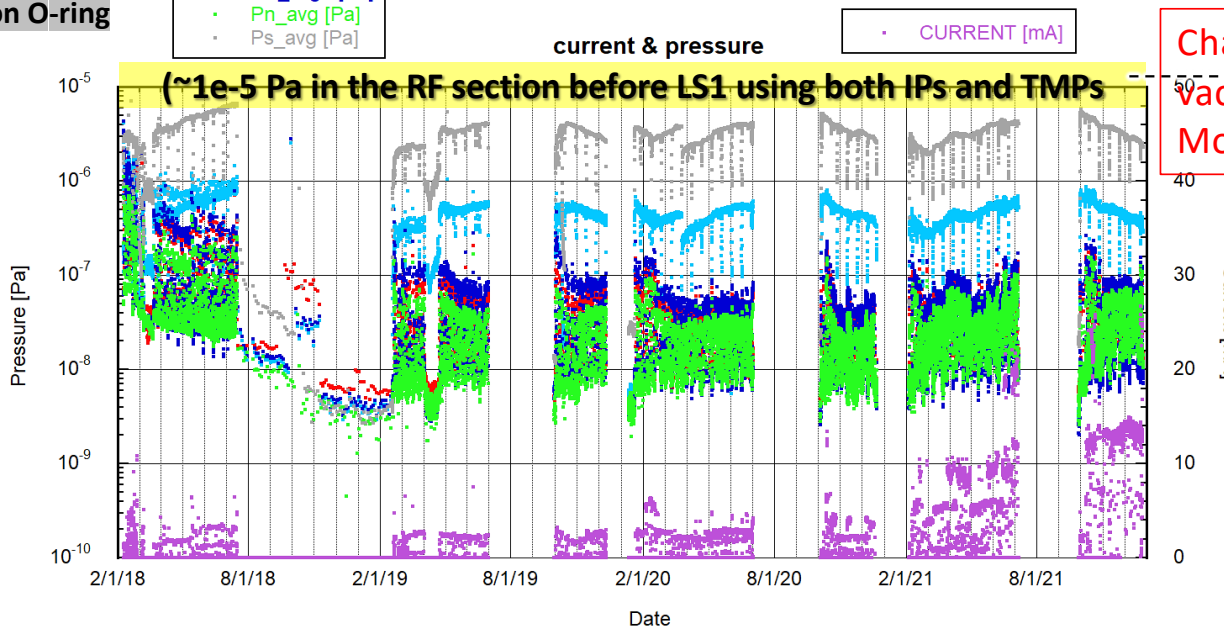


Metal O-ring



for the six connections between the cavities and beam ducts





Changing from Viton O-rings to metal seals improved vacuum levels significantly.
More details will be reported by Abe-san later.

~1e-7 Pa in the recent RF section using IPs only

Vacuum improvement in the DR / RF section by two orders of magnitude during DR beam operation

IP: sputter-Ion Pump (400L/s)
TMP: Turbo-Molecular Pump (300L/s)

Fixing oil leaks from welded bead

- Minor oil leaks were detected in the magnetic switch tanks of the extraction kicker.
- The exact leak location couldn’t be identified in the tunnel.
- Tanks were removed from the tunnel for repair during LS1 and subsequently reinstalled.

4. Summary

- DR operation is ongoing without any major trouble.
- We will attempt lower emittance optics again by replacing excitation curves.
- Due to the temperature dependence of the beam orbit, optics corrections have become challenging.
- The vacuum level of the RF cavity has ben significantly improved.
- To enhance reliability of kickers, we are conducting further tests using a mica capacitor at higher voltages for a longer durations.