Present Status of KARA RF System

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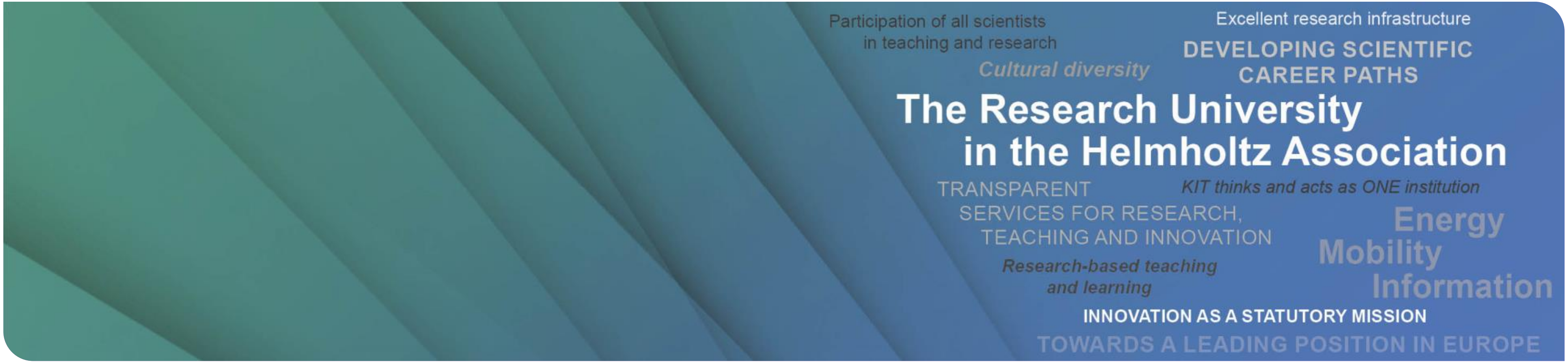
And Laboratory for Application of Synchrotron Radiation (LAS)



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- Introduction: The **<u>Ka</u>**rlsruhe **<u>R</u>**esearch **<u>A</u>**ccelerator **<u>KARA</u>**
  - Microtron, Booster Synchrotron, and Storage Ring
- RF System in KARA Storage Ring
  - Main parameters, Cavities, and Klystrons
- Updates and Failure Report
  - Water leakage problem and the countermeasures
  - RF System Calibration
- Plans and Ideas to the Future

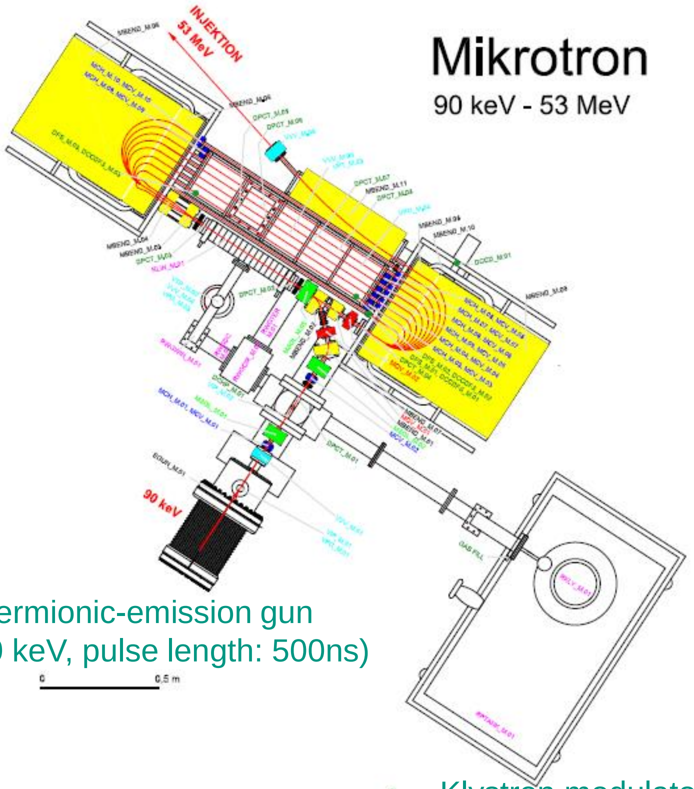
Introduction: KARA storage ring

- Flexible operation at KARA as an accelerator test facility
  - Extended DBA lattice ... Low-alpha (short bunch) operation
  - Operation energy ... from 500 MeV to 2.5 GeV
  - Energy ramping up and down by keeping beams
  - Optional filling pattern (multi, single, partial, unique pattern)
  - RF ... phase and amplitude modulation with LLRF
  - Systemetic beam diagnostics measurements with timing network

Within EU Project EURO-LABS we offer Transnational Access.
Any collaborations are highly welcome!

Beam energy	< 2.5 GeV
Circumference	110 m
RF frequency	499.7 MHz
Harmonic number	184
Number of RF station	2
Number of cavity in 1-station	2
Acc. voltage	1.4 MV (2.5 GeV)
Ring lattice	DBA

Introduction: Microtron

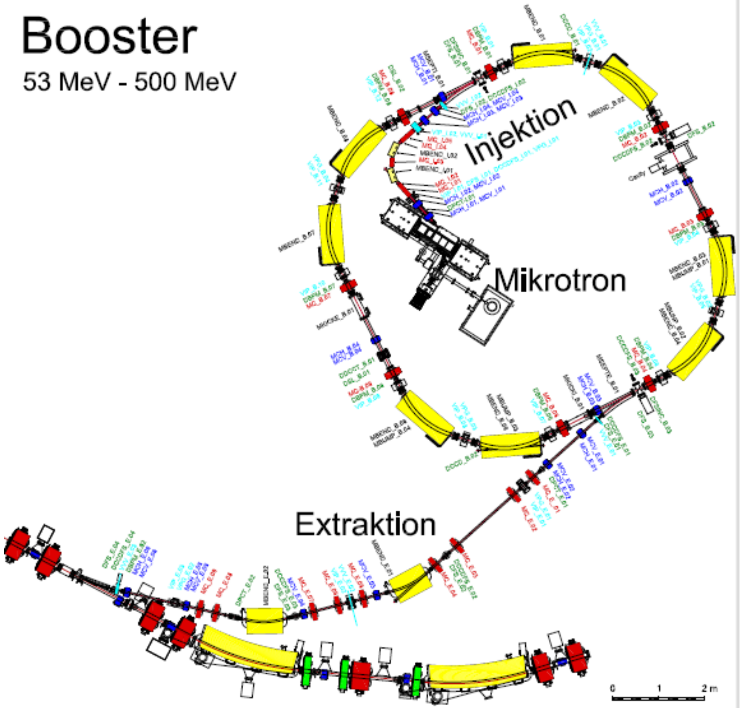


Thermionic-emission gun
(90 keV, pulse length: 500ns)

Klystron modulator

Beam energy	< 53 MeV
RF frequency	2.999 GHz
Number of turns	10 (up to 53 MeV)
Linac structure	(1/2+7+1/2)Cells, Side Couple
Mode	Π/2 mode
Klystron peak pulse power	~ 5MW

Introduction: Booster Synchrotron



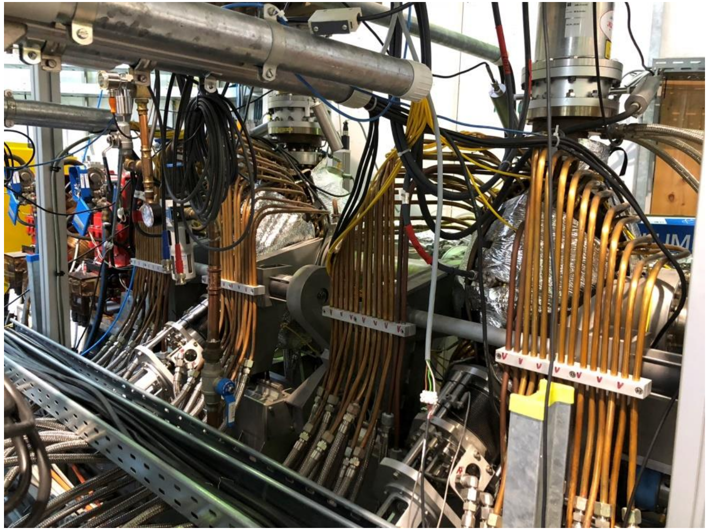
Beam energy	< 500 MeV
Circumference	24 m
Harmonic number	44
Number of RF station	1
Operation rep. rate	1 Hz

Some plans regarding beam diagnostics are going on.

RF-related Parameters of KARA Storage Ring

Parameters	500 MeV (Injection)	2.5 GeV (User Operation)
RF / Revolution freq.	499.7 MHz / 2.72 MHz	
Harmonic number	184	
Total RF voltage	400 kV (Typ.)	1.4 MV (Typ.)
Energy loss per turn	995.9 eV	622.4 keV
Synchronous angle	0.05 deg.	6.38 deg.
Momentum compaction	0.0105	0.00867
Synchrotron frequency	40.0 kHz	34.0 kHz
Energy spread (rms)	1.82×10^{-4}	9.08×10^{-4}
Bunch length (rms)	8.67 ps	36.9 ps
Total klystron output	5.2 kW (150 mA)	140 kW (140 mA)
Ramping time	-	3 minutes
Typical filling pattern	Partial (30~33x3 bunches) or (30~33x4 bunches)	

Cavities and Klystrons at KARA



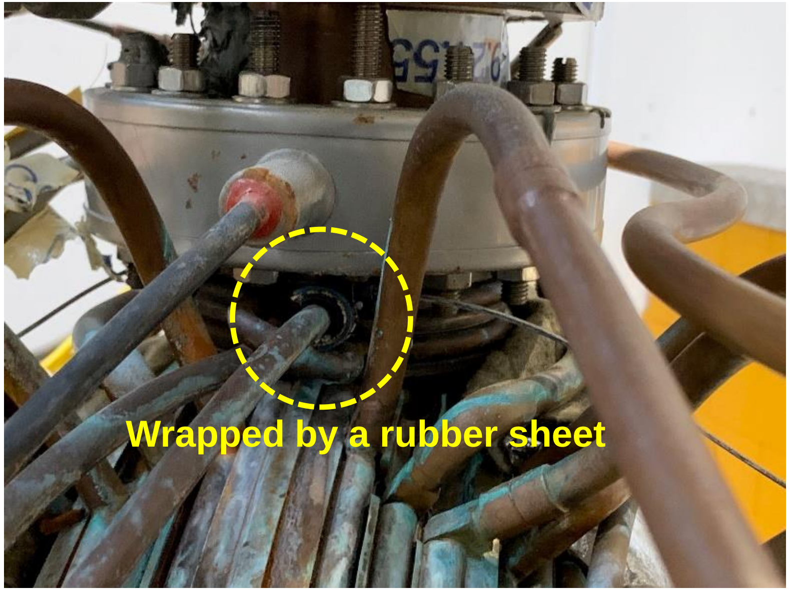
One RF station has two Elettra cavities per station,
Two RF stations in KARA

Water leakage happened at the cooling water channels around the input coupler port.

One EEV klystron (250 kW max.) drives two RF cavities (one station) with separating the power by magic-tee.

A backup plan to feed the power into only one cavity is underway in case one cavity is out of operation (water leakage etc)

Trouble & Recovery: Water Leakage at Cavities



- Water leakage happened at the cooling channels for the input coupler port.
  - It was around the port of the input coupler, where demineralized and cool (20-degree) water was used.
  - Pin-hole leakages, at three of four cavities.
  - As the countermeasure, a piece of rubber sheet was wrapped tightly around the pinhole.
  - But the leakage and the accompanying downtime started to occur frequently, so we needed a fundamental solution.
- From water to pressurised air cooling
  - After the discussion and suggestion from the Elettra RF group, we decided to switch the cooling method from water to pressurised air.
  - The pressurised air has been used to cool the ceramic window of the input coupler.
  - First, we switched the cooling method for one cavity (cav-1 in sector-4) and compared the vacuum and temperature with that for the cavity in the same sector.

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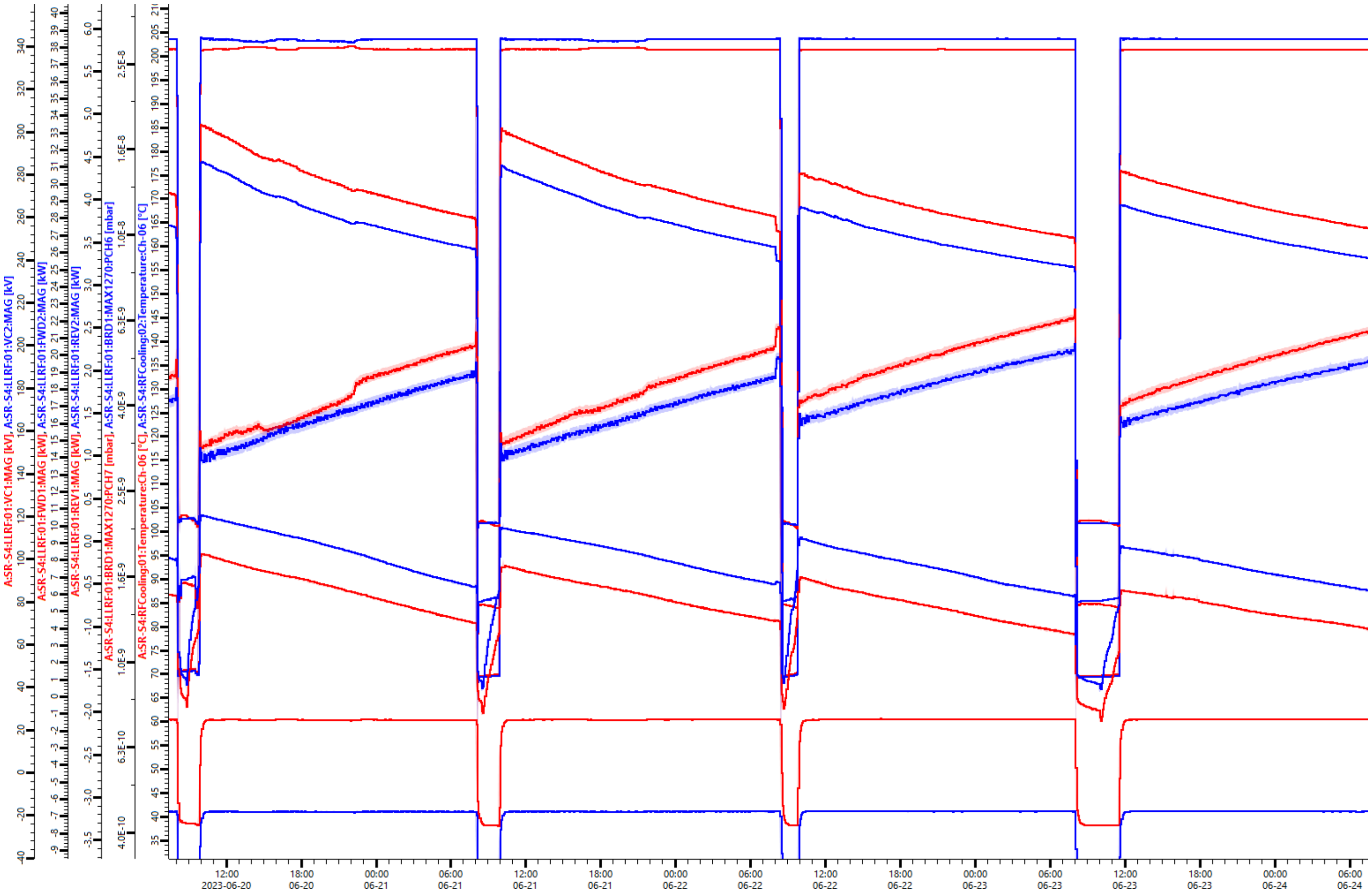
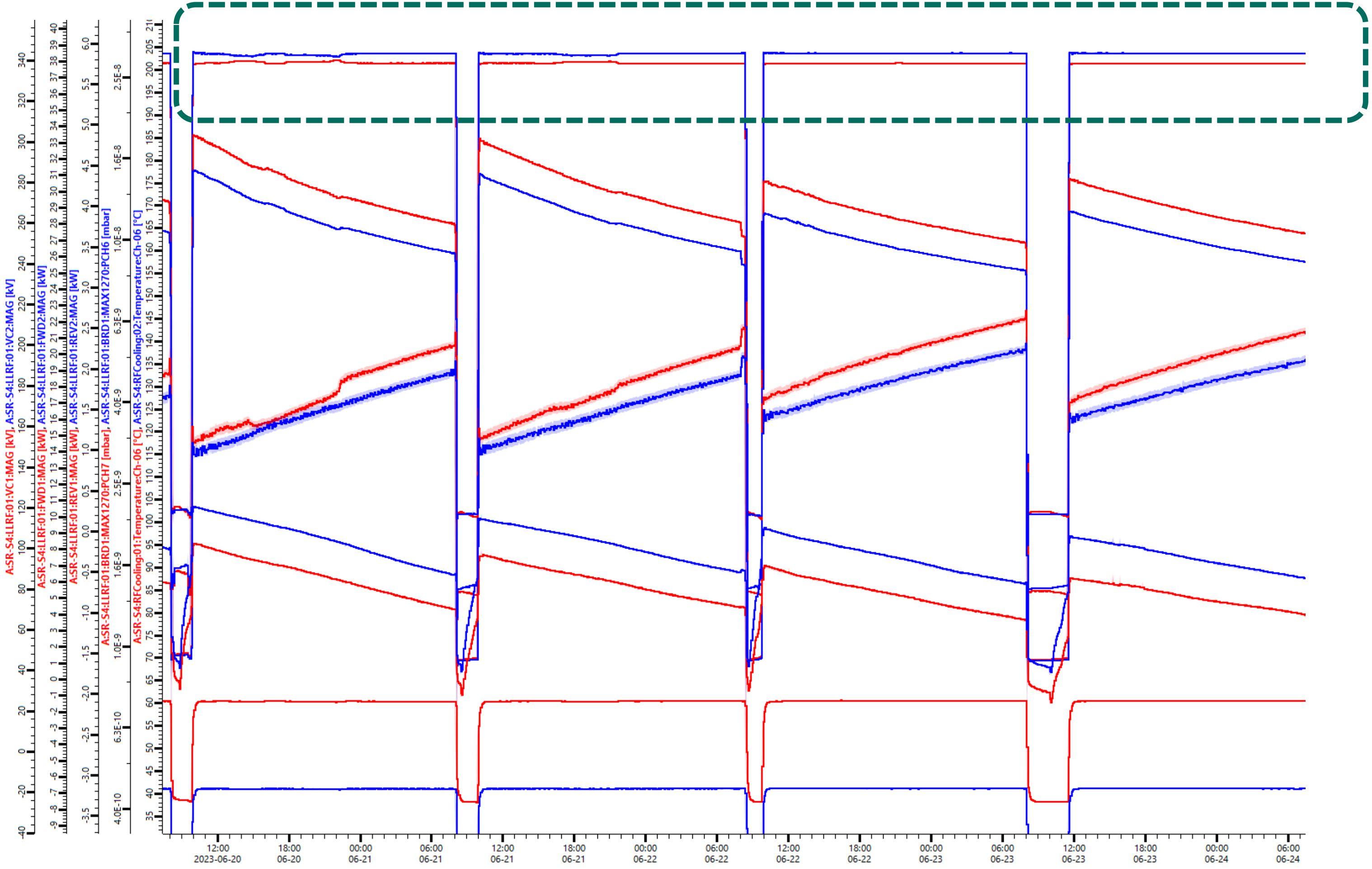


A data log in CW25, 2023 (user operation)

Red (Cav1): pressurised air cooling

Blue (Cav2): water cooling (original way)

Notice: these two cavities are connected in a vacuum environment.



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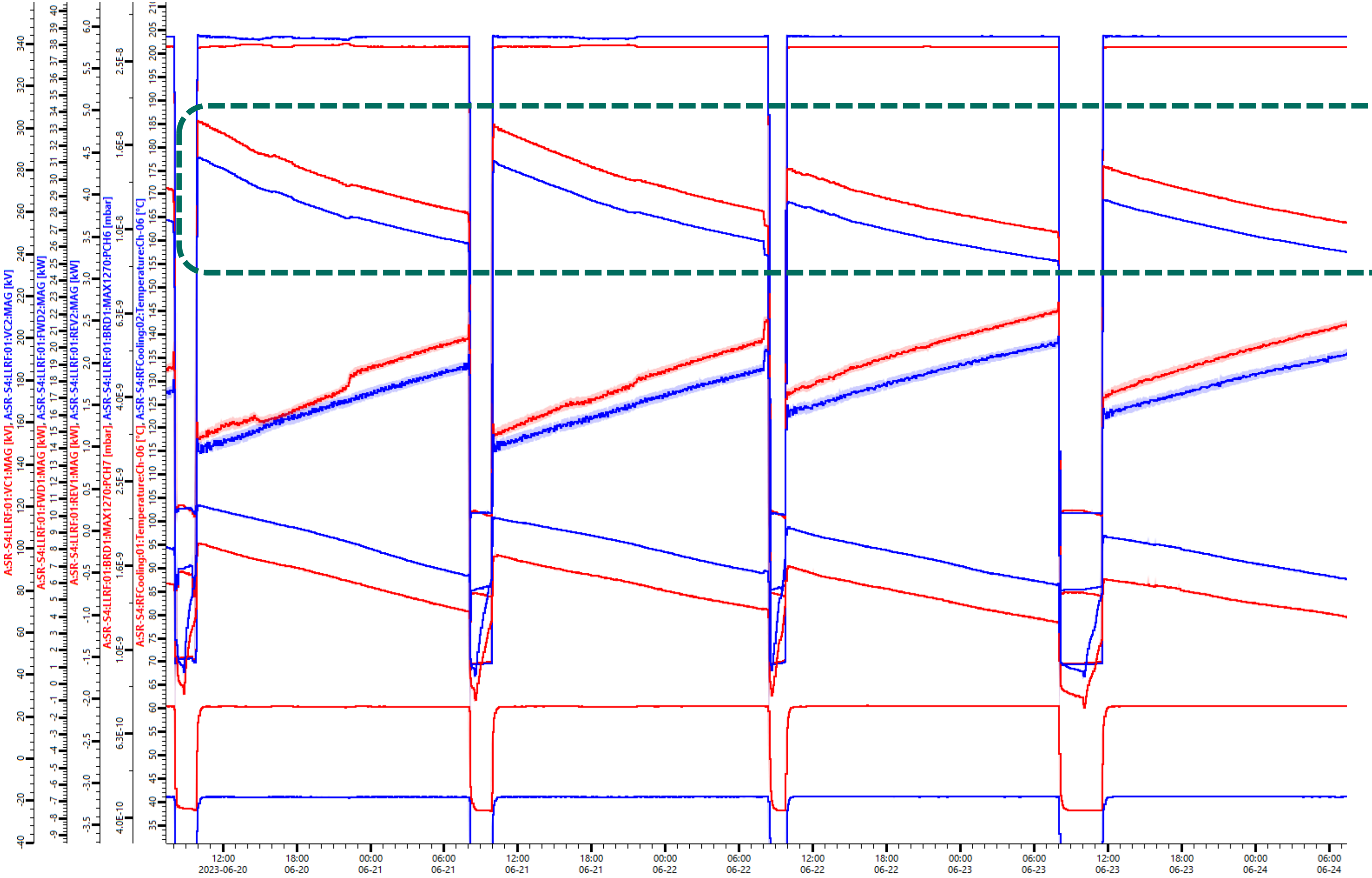

Fwd Pow.
33 / 31 kW for
Cav1 / 2.

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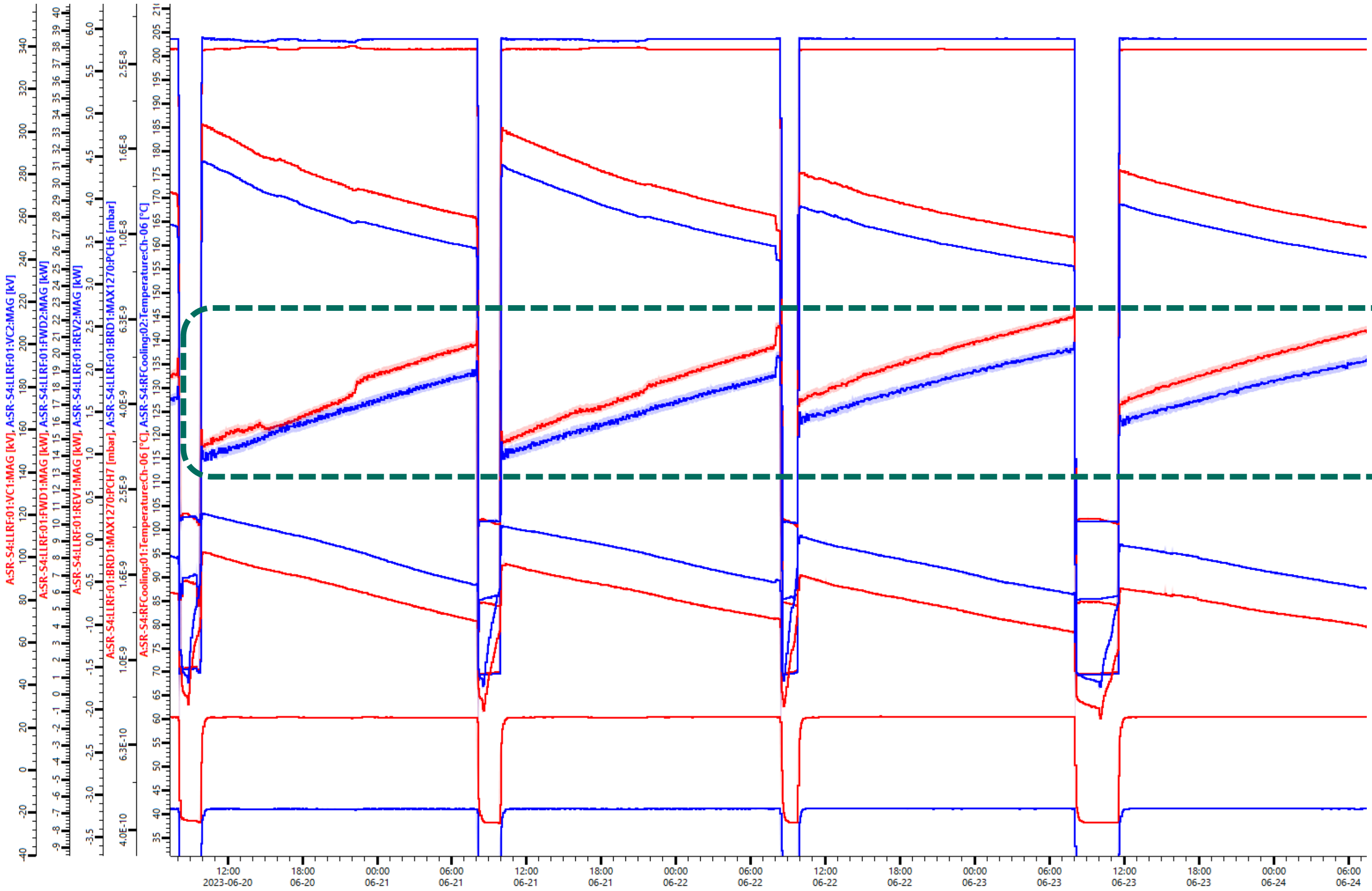
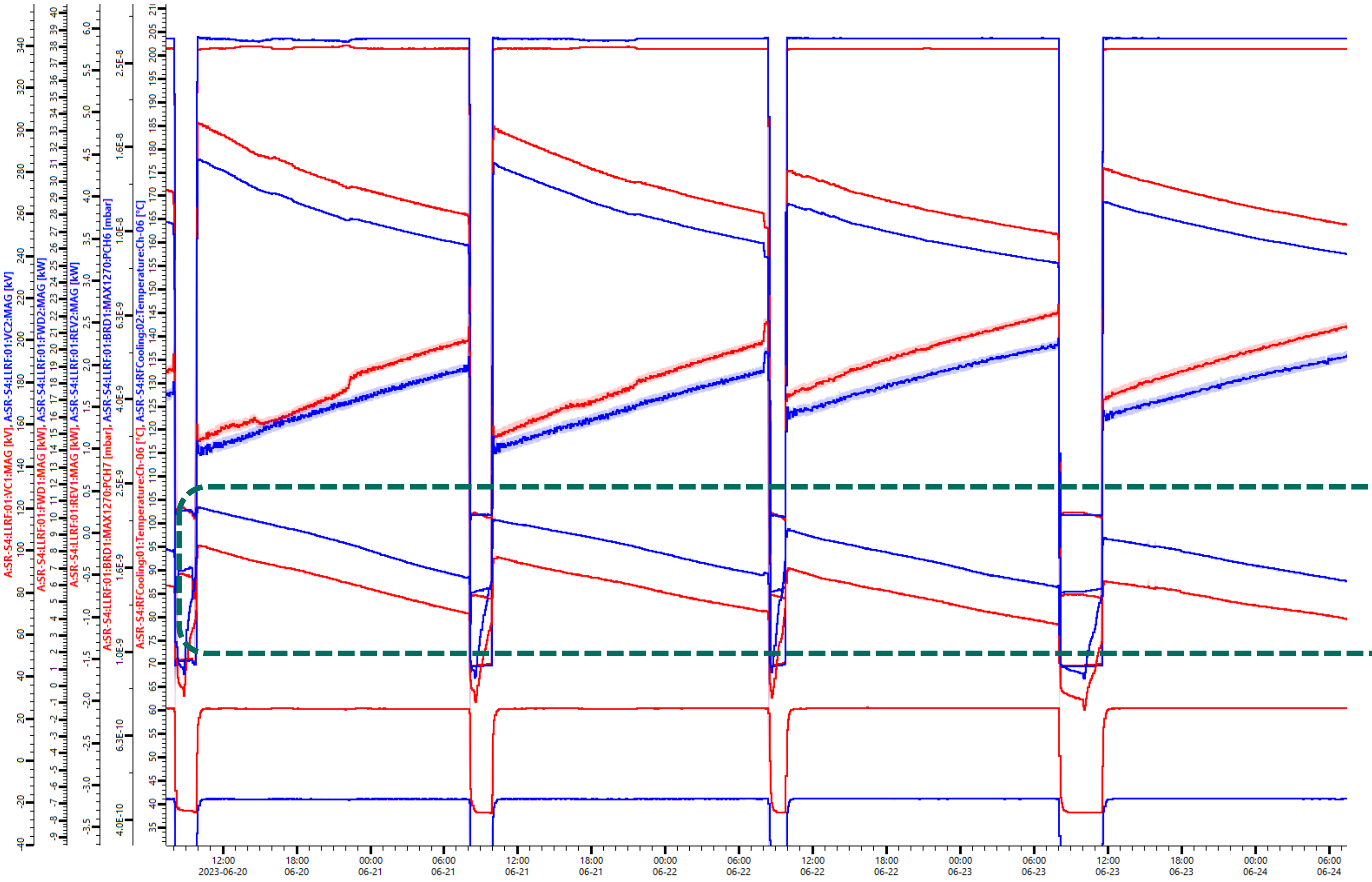


Bwd Pow.
2.6 / 2.2 kW



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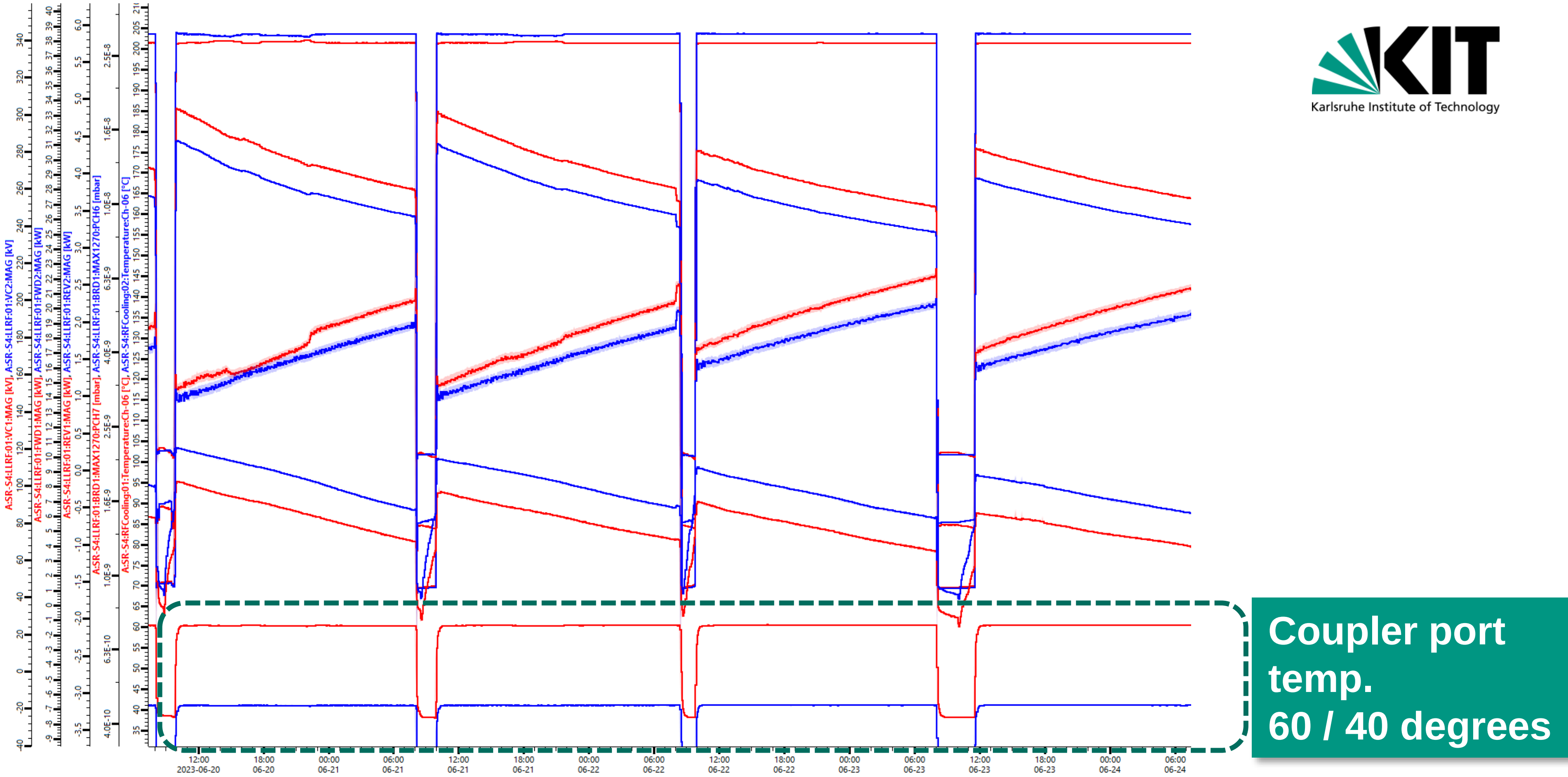
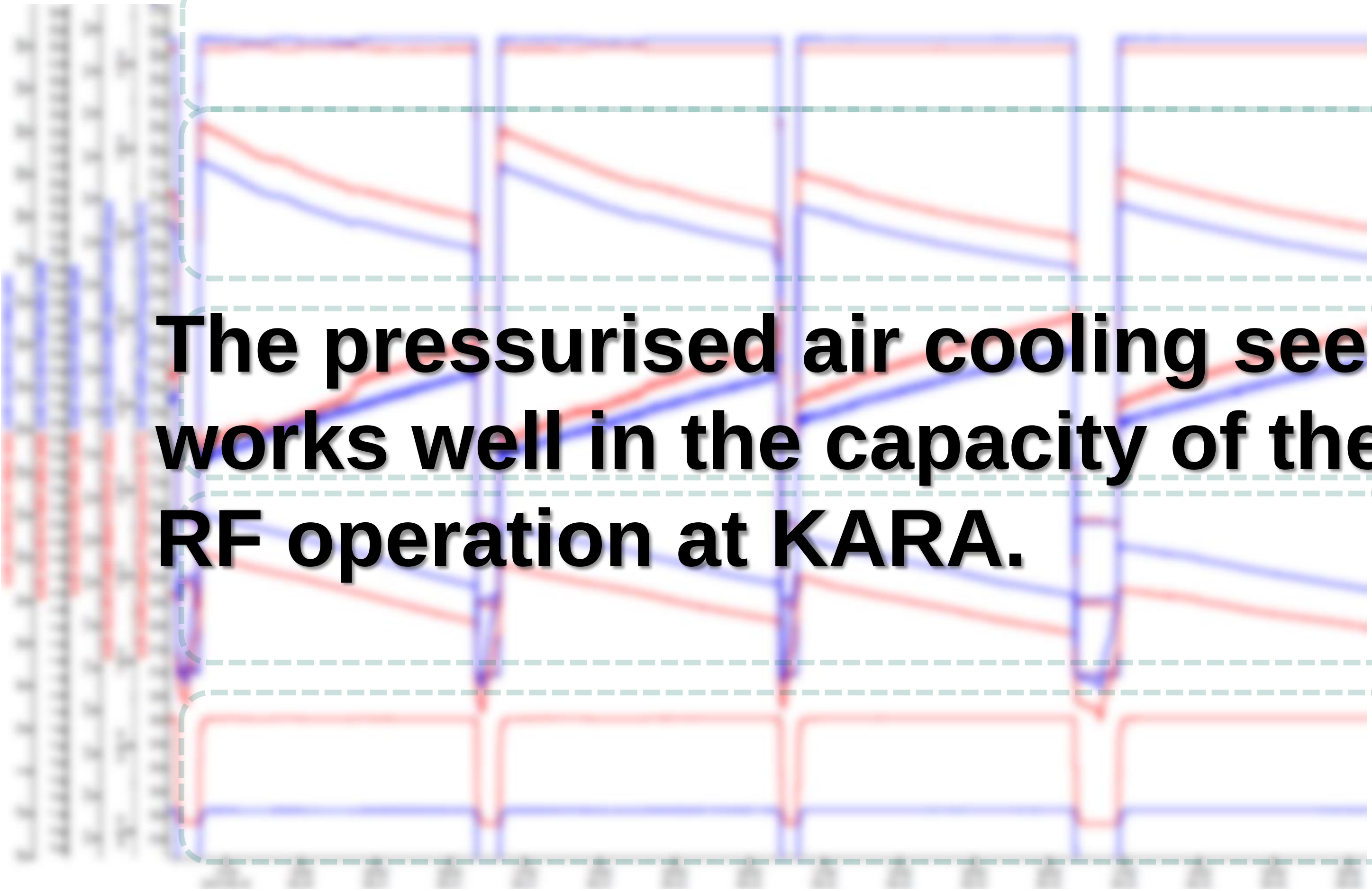
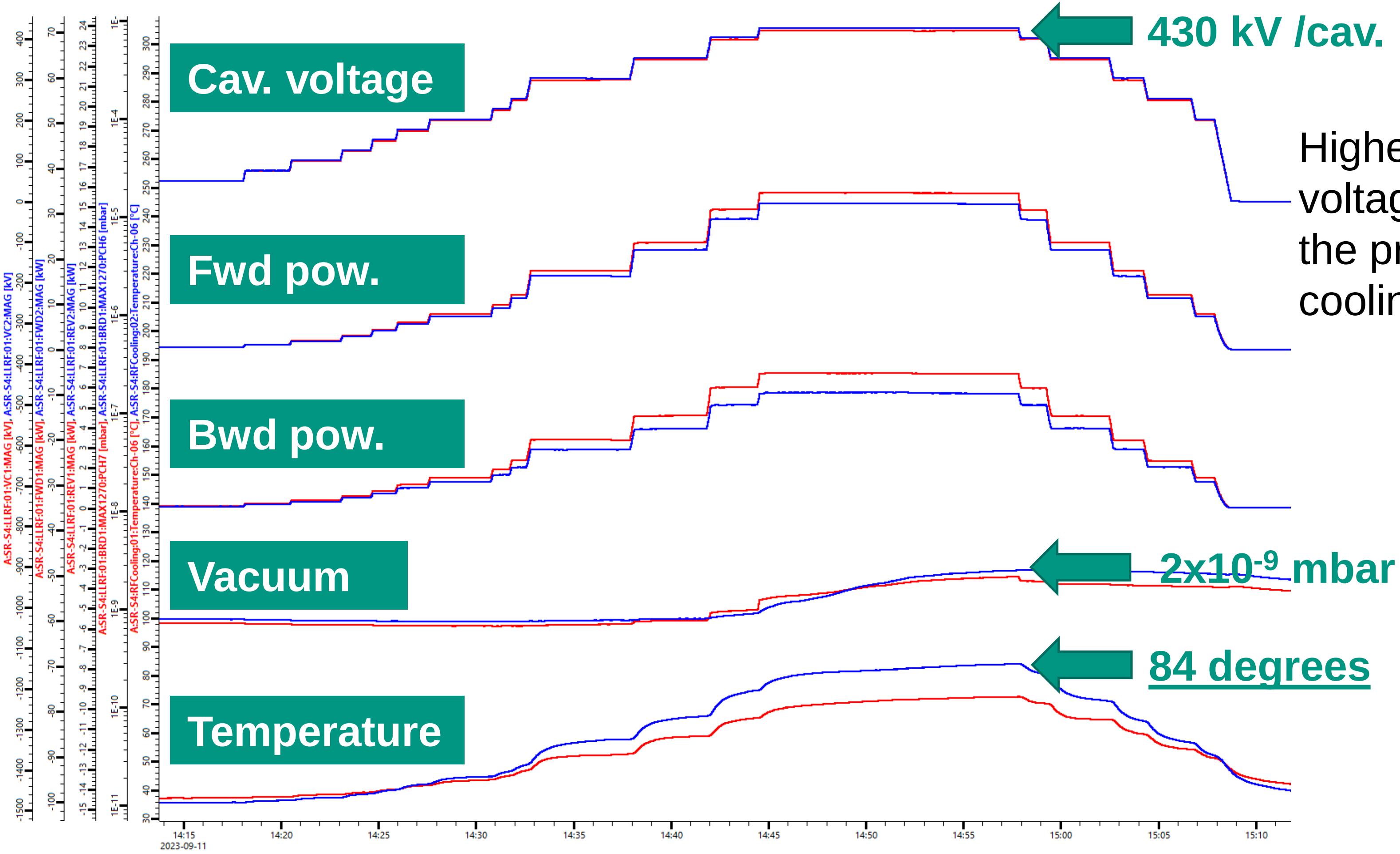
Cav. Vacuum
1.7 / 2.1 x10^{-9} mbar


A:SR-S4:LLRF:01:VC1:MAG [kV], A:SR-S4:LLRF:01:VC2:MAG [kV]
A:SR-S4:LLRF:01:FWD1:MAG [kW], A:SR-S4:LLRF:01:FWD2:MAG [kW]
A:SR-S4:LLRF:01:REV1:MAG [kW], A:SR-S4:LLRF:01:REV2:MAG [kW]
A:SR-S4:LLRF:01:BRD1:MAX1270:PCH7 [mbar], A:SR-S4:LLRF:01:BRD1:MAX1270:PCH6 [mbar]
A:SR-S4:RFCooling:01:Temperature:Ch-06 [°C], A:SR-S4:RFCooling:02:Temperature:Ch-06 [°C]
12:00 2023-06-20
18:00 06-20
00:00 06-21
06:00 06-21
12:00 06-21
18:00 06-21
00:00 06-22
06:00 06-22
12:00 06-22
18:00 06-22
00:00 06-23
06:00 06-23
12:00 06-23
18:00 06-23
00:00 06-24
06:00 06-24
Coupler port temp.
60 / 40 degrees



The pressurised air cooling seemingly works well in the capacity of the usual RF operation at KARA.



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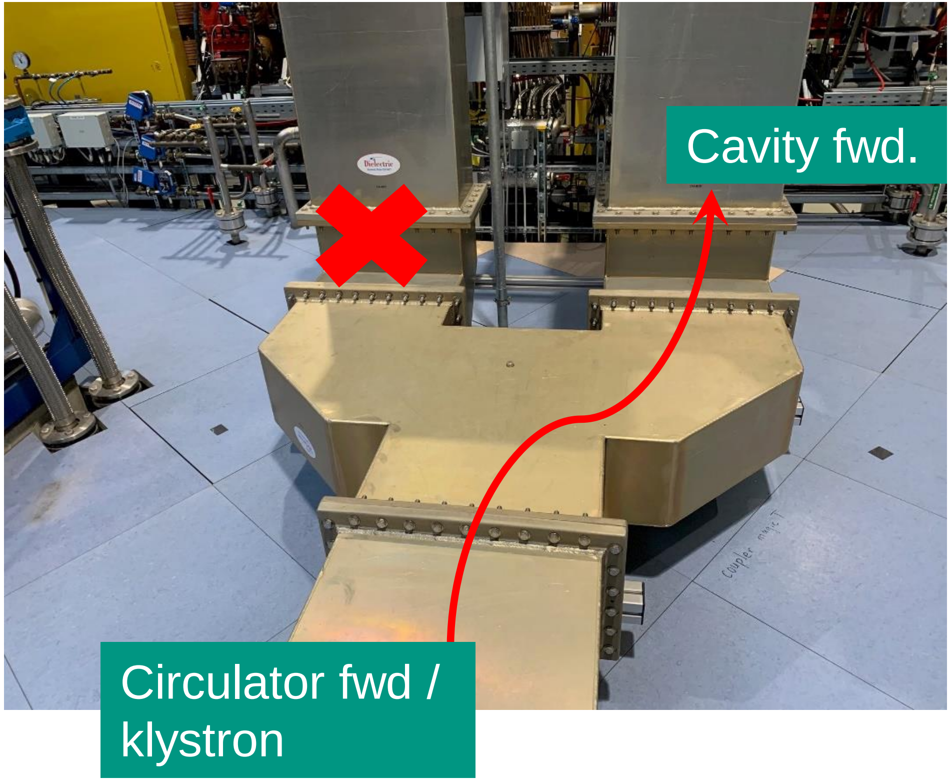
Higher cavity voltage operation at the pressurised air cooling (w/o beam)

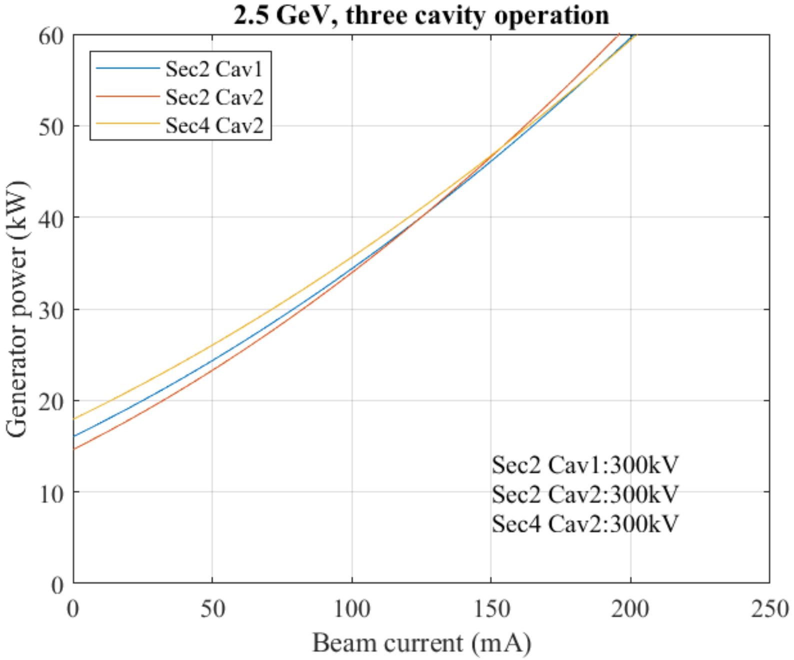
A backup plan: single-cavity in one RF sector



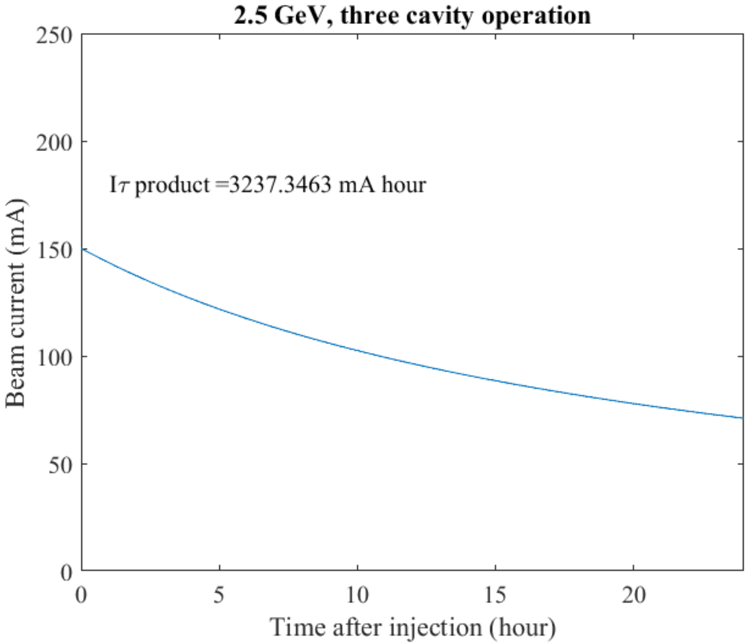
A backup plan to feed the RF power to one cavity is considered in case one cavity is not in operation (e.g. due to water leakage etc.).

- Single cavity operation (a plan, just in case)
  - Dismount one whole cavity, including the waveguide parts and the magic tee.
  - Connecting the RF section with a straight vacuum chamber.
  - Connecting the circulator forward with the cavity input by a horizontal chicane waveguide.
  - Preparation for the chicane waveguide part is underway now.

Beam Lifetime Estimation for 3-Cavity Operation



The beam current and cavity voltage are restricted up to 150 mA and 300 kV because of the upper limitation of the input power to the cavity (50 kW).



The Iτ-product from the Touschek lifetime reduces by 30% of the regular four-cavity operation.

RF System Calibration

- We measured the FDW and BWD power to/from all cavities with two beam current conditions by keeping the cavity voltage the same.

Input (kW) Sec2 Cav1	Input (kW) Sec2 Cav2	Input (kW) Sec4 Cav1	Input (kW) Sec4 Cav2	Beam Current (mA)
33.9	33.6	35.5	34.6	131.2
27.6	27.0	28.3	27.4	71.1

***Input = (Cav. FWD) – (Cav. BWD)**

- From the difference in the input power under the different beam current conditions, we evaluated the beam loading values and the cavity dissipated powers for each cavity.

RF System Calibration

- Beam loading (kW/mA) at 2.5 GeV:

Sec2 Cav1	Sec2 Cav2	Sec4 Cav1	Sec4 Cav2	Total
0.105	0.110	0.120	0.120	**0.454**

Beam loading value: 0.454 (kW/mA) at KARA 2.5 GeV

- Cavity dissipation power (kW)

Sec2 Cav1	Sec2 Cav2	Sec4 Cav1	Sec4 Cav2	Total
20.15	19.19	19.78	18.88	**78.00**

- Cavity voltage estimated from the dissipation power

***By using the measured shunt impedance values**

Sec2 Cav1	Sec2 Cav2	Sec4 Cav1	Sec4 Cav2	Total
375.54	351.02	362.43	364.60	**1453.58**

Read value by the pickup and LLRF unit: 1444 kV

RF System Calibration

- Calculated / measured synchrotron frequency

Parameters	Values
Beam Energy	2.477 GeV
Bending Radius	11.25 m
Momentum Compaction	0.0089
RF Frequency	499.740 MHz

f_s (calc)= 33.24 kHz

f_s (meas)= 30.0 kHz, with α_c = 0.008

f_s (calc) = 31.41 kHz with α_c = 0.008.

- The discrepancy comes from the over-voltage factor (IDs and loss factor etc.) and the values of the momentum compaction factor.

Plans and Ideas to the Future

- PLC renewal
  - The PLC system has been renewed from the old (in-house) one to the new system for one sector (sector-4) with the exchange of the pre-amplifier.
  - The renewal for another sector (sector-2) will come soon.

- A possible future configuration at KARA
  - Work on fall back solution to operate with 3 cavities
  - Evaluating the potential for energy saving by powering each cavity by a SSA and operation with only 3 cavities