Recent activities regarding 9-cell TESLA-type cavities at KEK







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Abstract

In this contribution we report on two topics regarding recent activities on 9-cell TESLA-type cavities at the High Energy Accelerator Research Organization (KEK). First, we give an overview of the inner surface treatments and vertical test (VT) results of four fine grain 9-cell TESLA-type cavities over the last one and a half years. Secondly, we report on the upgrade of the VT DAQ system at the Superconducting RF Test Facility (STF) at KEK. In this upgrade, most components of the VT system were integrated in an EPICS control system. Based on Control System Studio (CSS) and Python a new user interface was created, improving the workflow during and after VTs at STF.

TESLA-type cavity testing

Since 2018 four 9-cell TELSA-type 1.3 GHz are being treated at tested at KEK. They are called MT-3, MT-4, MT-5, and MT-6 and were produced by Mitsubishi Heavy Industries. They are shown in Figure 1.



Figure 1: Top left: MT-3, top right: MT-4, bottom left: MT-5, bottom right: MT-6

All four cavities have a RRR > 300 and are manufactured from fine grain Niobium. The goal of the treatment and testing campaign is cost reduction R&D for the International Linear Collider (ILC) [1].

Table 1 shows an overview of all treatments and VT results. The VT results are the highest recorded gradients during the final π -mode measurement. As a first step, a reference measurement for every cavity was recorded. To this end the cavities received a standard treatment. This includes as two major steps an EP2 for a surface refresh and a 120 °C baking for 48 hours. These were the final reference measurement results:

- MT-3, VT4: Eacc,max = 30.3 MV/m, limited by quench C6 60° equator
- MT-4, VT4: Eacc,max = 39.2 MV/m, limited by quench C3 150° down
- MT-5, VT1: Eacc,max = 35.1 MV/m, limited by quench C1 90°-120° equator
- MT-6, VT5: Eacc,max = 42.8 MV/m, reached power limit

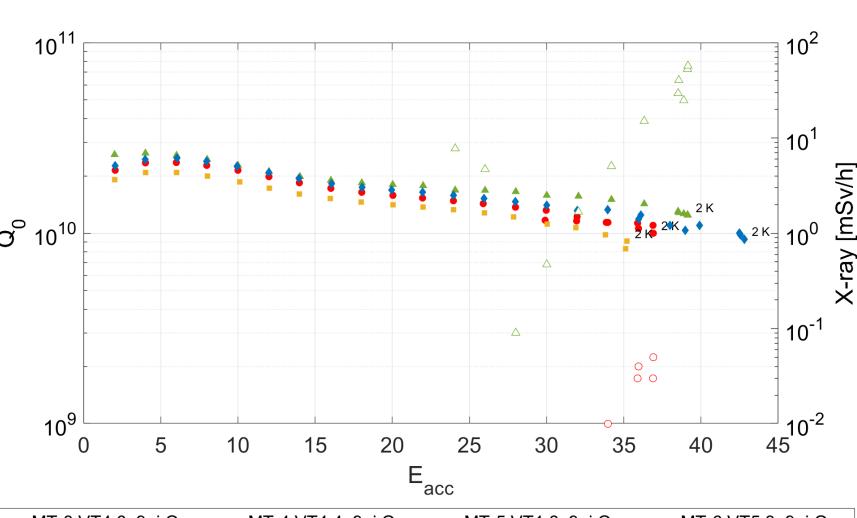
As a next step, special surface treatments were applied. These were:

- Two-step baking [2] for all cavities
- N-doping [3] for MT-5

The two-step baking treatment is the same process as the for the standard recipe, except that before the 120 °C baking for 48 hours a 75 °C baking for 4 hours is added. For the N-doping a 2/0 scheme was applied. For the detailed results see SRF'21 contribution "High-Q/High-G R&D at KEK using 9-cell TESLA shape Niobium cavities" (MOPCAV06) by Ryo Katayama (KEK).

MT-3	MT-4	MT-5	MT-6
100 μm EP1 900 °C 3h 20 μm EP2 120 °C 48h VT1 (16.3 MV/m)	100 μm EP1 900 °C 3h 30 μm EP2 120 °C 48h VT1 (cold leak)	100 μm EP1 900 °C 3h 20 μm EP2 120 °C 48h VT1 (35.1 MV/m)	100 μm EP1 900 °C 3h 30 μm EP2 120 °C 48h VT1 (28.7 MV/m)
HPR 120 °C 48h VT2 (cold leak)	HPR VT2 (4.1 MV/m)	20 μm cold EP 75 °C 4h & 120 °C 48h VT2 (34.0 MV/m)	30 μm EP2 120 °C 48h VT2 (26.0 MV/m)
HPR 120 °C 48h VT3 (30.3 MV/m)	100 μm EP1 800 °C 3h 30 μm EP2 120 °C 48h VT3 (37.7 MV/m, cold leak)	5 μm cold EP N-dope (2/0) 5 μm cold EP VT3 (22.0 MV/m)	20 μm cold EP 120 °C 48h VT3 (23.4 MV/m)
20 μm EP2 120 °C 48h VT4 (36.9 MV/m)	HPR VT4 (39.2 MV/m)	5 μm cold EP VT4 (26.3 MV/m)	30 μm EP2 120 °C 48h VT4 (31.0 MV/m)
10 μm cold EP 75 °C 4h & 120 °C 48h VT5 (35.4 MV/m)	5 μm cold EP 75 °C 4h & 120 °C 48h VT5 (36.0 MV/m)	100 μm EP1 900 °C 3h 10 μm cold EP 75 °C 4h & 120 °C 48h VT5 (30.9 MV/m)	Iris wiping 30 μm EP2 120 °C 48h VT5 (42.8 MV/m)
	HPR VT6 (31.3 MV/m)	20 μm cold EP 75 °C 4h & 120 °C 48h VT6 (40.5 MV/m)	10 μm cold EP 75 °C 4h & 120 °C 48h VT6 (38.0 MV/m)
	Local grinding iris 2-3 10 µm cold EP VT7 (31.7 MV/m)		
	9 μm cold EP + 10 μm cold EP 75 °C 4h & 120 °C 48h VT8 (cold leak)		

Table 1: Treatments and VT results (highest recorded gradient during the final π -mode measurement) of MT-3 to MT-6.



MT-3 VT4 6: 9pi Q₀
MT-4 VT4 4: 9pi Q₀
MT-5 VT1 6: 9pi Q₀
MT-6 VT5 3: 9pi Q₀
MT-6 VT5 3: 9pi Q₀
MT-7 VT4 6: 9pi Xray
MT-8 VT4 4: 9pi Xray
MT-7 VT1 6: 9pi Xray
MT-8 VT5 3: 9pi Xray
MT-6 VT5 3: 9pi Xray
Figure 2: Reference measurement results for MT-3 (red), MT-4 (green), MT-5 (orange), and MT-6 (blue).

In a few cases, non-conformities occurred:

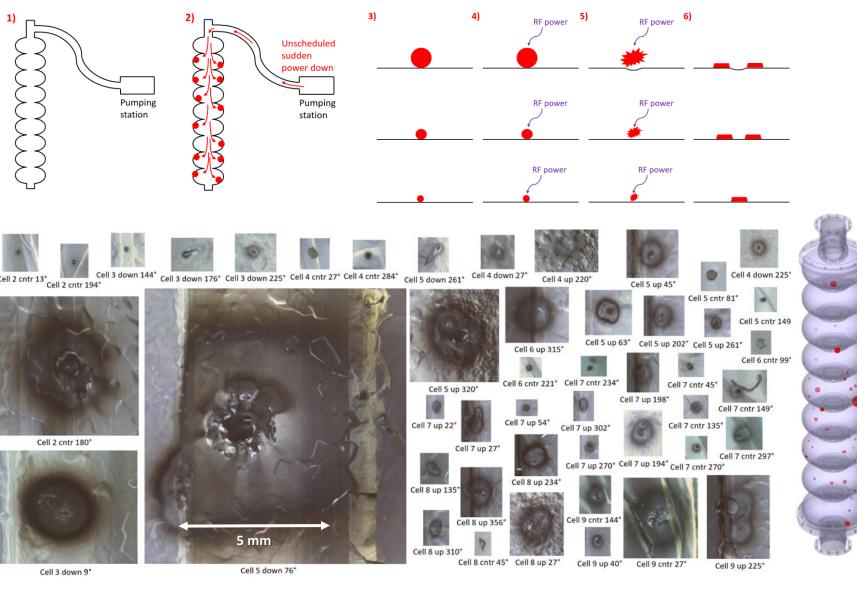


Figure 3: Top: Illustration of events, Bottom left: defects on MT-4 inner surface after performing VT2 (all pictures are at the same scale), Bottom right: locations of the defects.

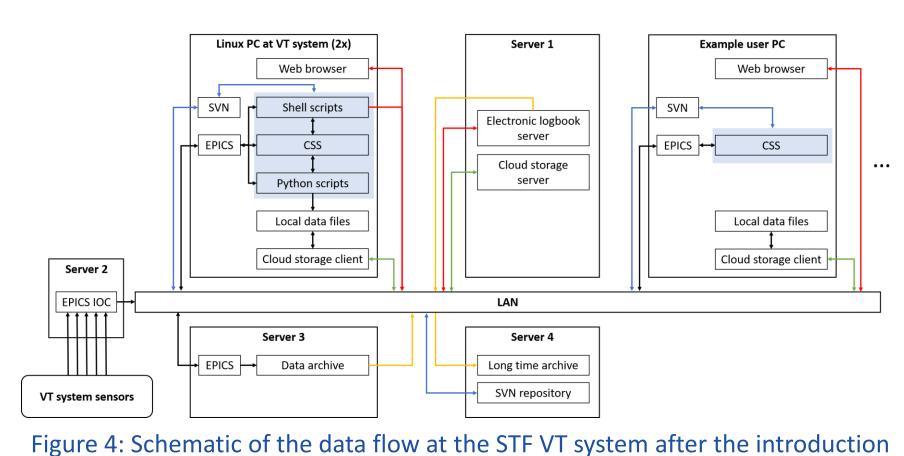
Cold leaks during VT2 of MT-3 and VT-1 and VT8 of MT-4 occurred. The first
two were due to an issue with the vacuum piping of the VT stand. The piping
was disassembled and reassembled. Afterwards no further issues occurred.
The cold leak during VT8 of MT-4 occurred at the bottom HOM flange.

STF VT DAQ System Upgrade

The VT stand at STF is used to measure the cavity performance of a large variety of SRF cavities (e.g., 1-cell, 3-cell, 9-cell, TESLA-type, STF-type, etc.) on a weekly basis. Since it was built and commissioned over two decades ago, it consists largely of analog components. In order to modernize the test stand, the following upgrade was implemented in the summer of 2020:

- Two Linux PCs were setup at the VT stand control room and connected to
- the local area network (LAN)
 All devices required for a VT were included in the EPICS control system [4]
- A new CSS [5] front-end was established

Figure 4 shows the schematic of how hard- and software components were setup. Server 2 aggregates the data of all the sensors of the VT stand and makes them available via the LAN as EPICS records. During VTs, selected records as e.g., power levels, temperatures, radiation levels, etc. are stored in a data archive on Server 3. These and further EPICS records are also monitored and recorded using the newly implemented CSS-based user interface on the Linux PC in the control room of the VT stand. Figures 5 to 8 show the most used CSS panels during a VT.



of EPICS and CSS

Preparation	Cool-down	VT		
Define Cavity	Cool-down Cockpit	DAQ	DAQ Control	
Configure Z Table & geom. fac.	Cool-down Measurement	VT.C	VT Cockpit	
Cable Calibration		SD 1 Cell	TX-M. 1 Cell	
		SD 1.6 Cell	TX-M. 1.6 Cell	
		SD 3 Cell	TX-M. 3 Cell	
		SD 9 Cell	TX-M. 9 cell	
		Q0 vs Eacc I	Measurement	
Warm-up	NAT	Tools		
Warm-up Cockpit	Record value	Record	I f, QL, T	
Warm-up Measurement	Power Meter Control	Record	Fluxgate	
Warm-up Measurement	Power Meter Control	<u> </u>	Fluxgate ad modes	
Warm-up Measurement	Power Meter Control	Passban		
Warm-up Measurement	Power Meter Control	Passban Eacc and Pt	nd modes	
Warm-up Measurement	Power Meter Control	Passban Eacc and Pt Eacc plot & Eacc a	nd modes ran,raw table	
Warm-up Measurement	Power Meter Control	Passban Eacc and Pt Eacc plot & Eacc a	nd modes ran,raw table and Ptran,raw table	

Figure 5: CSS main menu

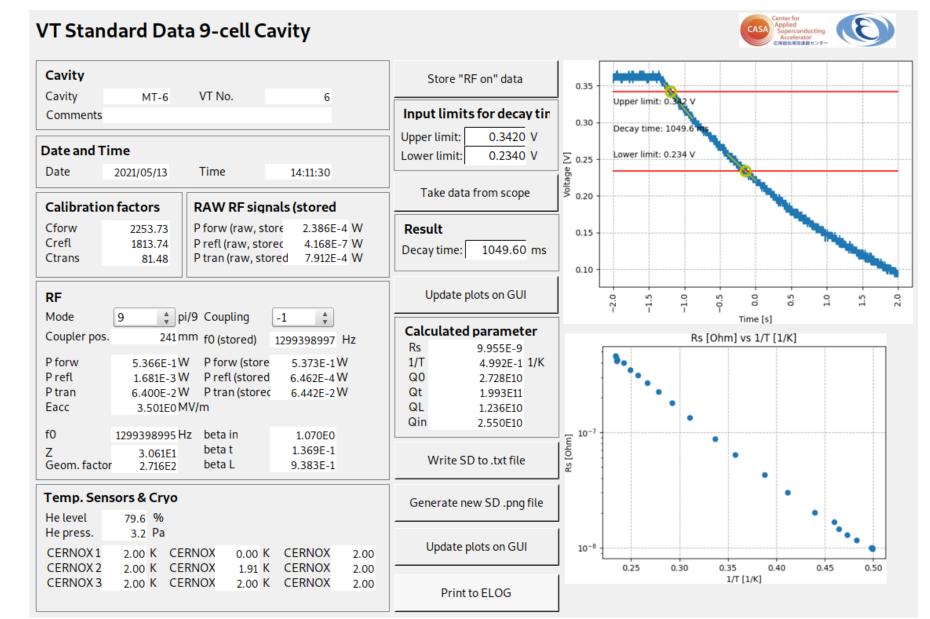


Figure 6: CSS panel for taking standard data

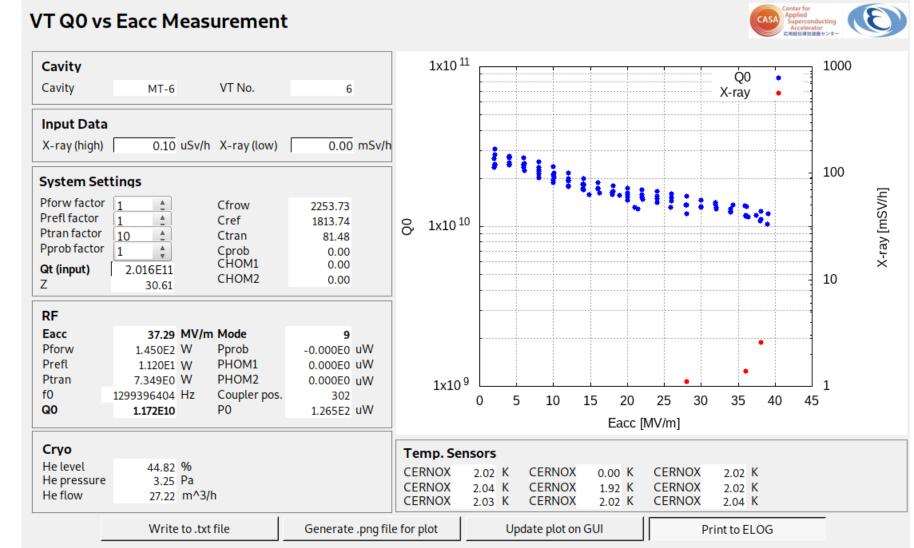


Figure 7: CSS panel for recording Q₀ & X-ray vs Eacc data

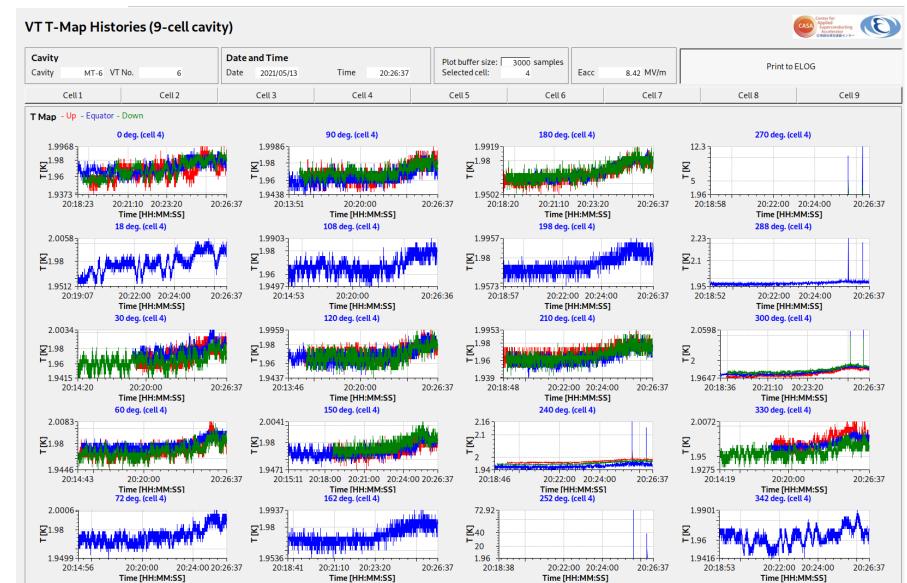


Figure 8: CSS panel showing temperature histories of cell 4 of cavity MT-4

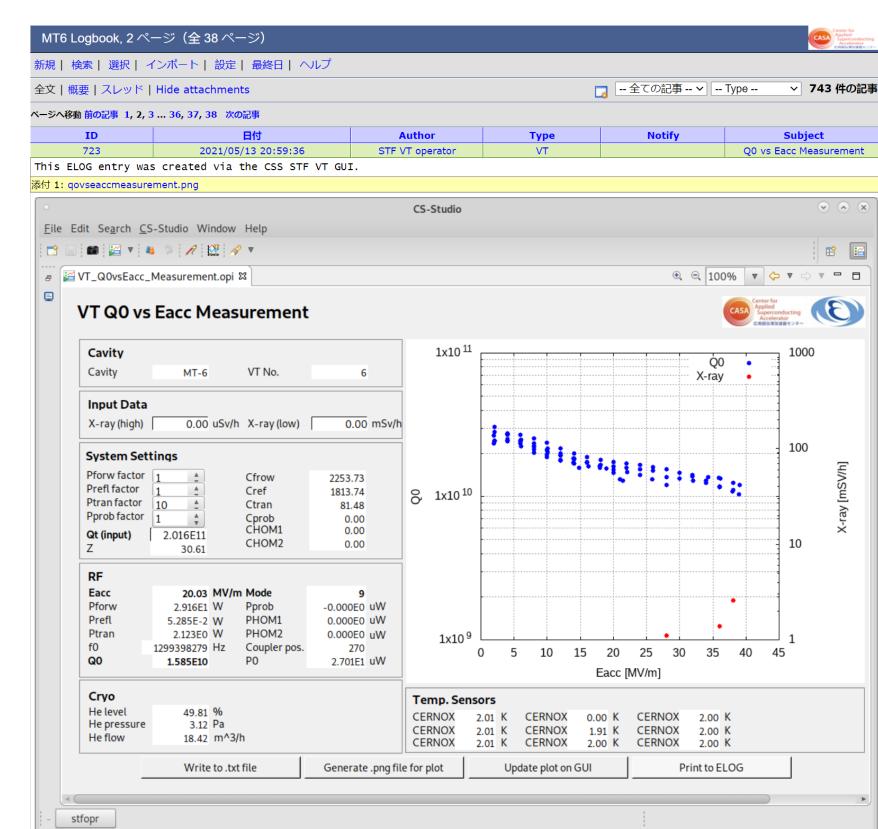


Figure 9: Example of CSS panel documented in the electronic logbook

Aknowledgement

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References

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