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TUPFAV003

Stable Beam Operation at 33 MV/m in STF-2 Cryomodules at KEK

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Abstract

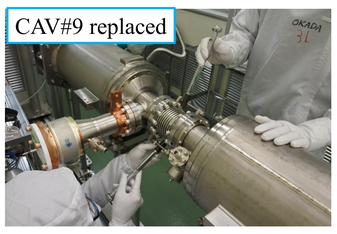
In STF at KEK, as the operational demonstration of the SRF accelerator for ILC, the STF-2 cryomodules (CM1+CM2a: one and half size CM with 12 cavities) have achieved 33 MV/m as average accelerating gradient with 7 cavities in Mar/2019. After that, one cavity with the lowest performance installed in CM2a was replaced with one N-infused cavity developed for High-Q/High-G R&D be-tween Japan and US. From Apr/2021, the beam operation started again and those CMs achieved 33 MV/m as aver-age accelerating gradient with 9 cavities including one N-infused cavity again. This is a very important milestone for the ILC project. In this report, the detailed results will be presented.

Cavity Replacement Work from 2019 to 2020

Cost reduction is essential for the ILC project.
High-Q/High-G R&D started since 2017 between Japan and US.
CAV#9 experienced n-infusion in KEK, and was installed in CM2a.

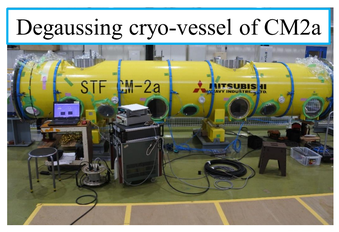
Date	Content
Aug/2019	Disassembly of CM2a
Nov/2019	Pulling CM2a out of tunnel
Jan/2020	Installing cavity string in clean room
Heb/2020	Replacing CAV#9 with n-infused cavity
Mar/2020	Installing CM2a in beamline
Work was stopped due to COVID-19	
Jun2020	Completion inspection by local government
Sep/2020	5th cooldown test

CAV#9 replaced



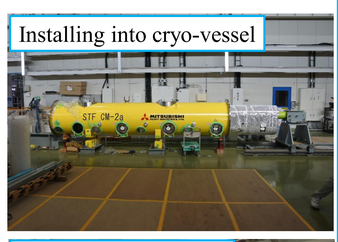
Tuner drive and HOM tuning

Degaussing cryo-vessel of CM2a



Cold mass of CM2a

Installing into cryo-vessel



Installing into tunnel

Installing into beamline

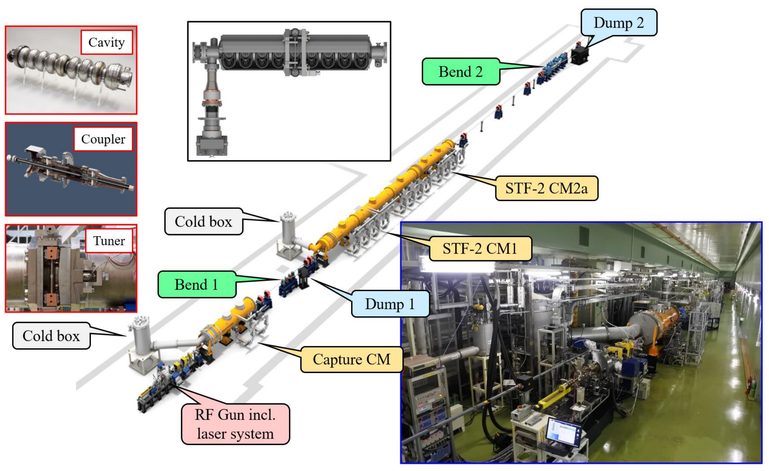
Alignment of CM2a

Beamline connection

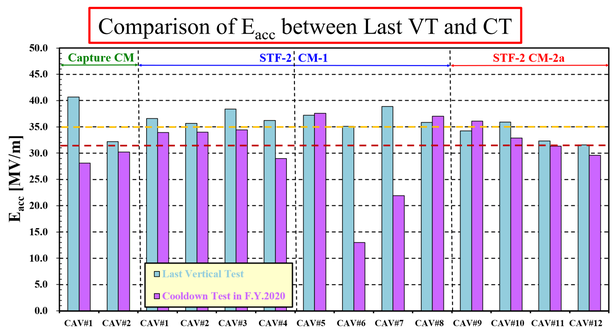
Completion inspection

Performance of Cavity and Cryomodule

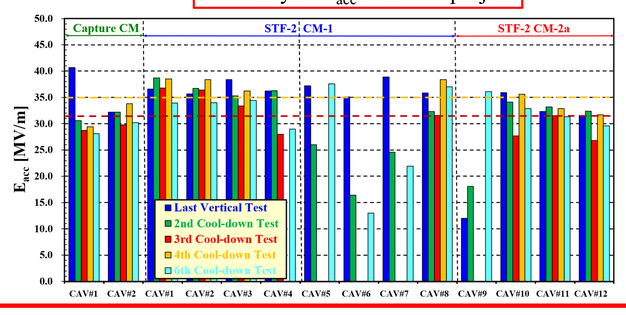
Schematic view of STF-2 accelerator



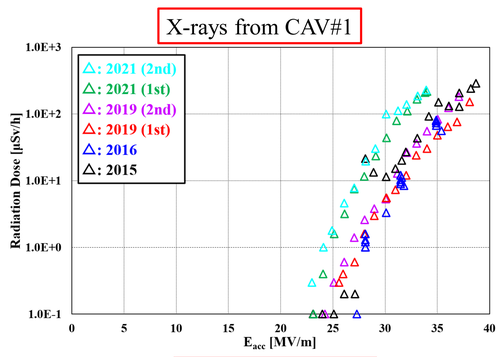
Comparison of E_{acc} between Last VT and CT



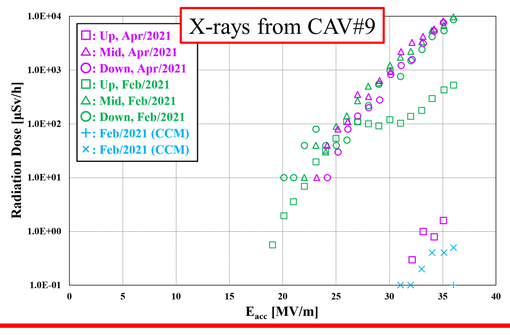
Summary of E_{acc} in STF-2 project



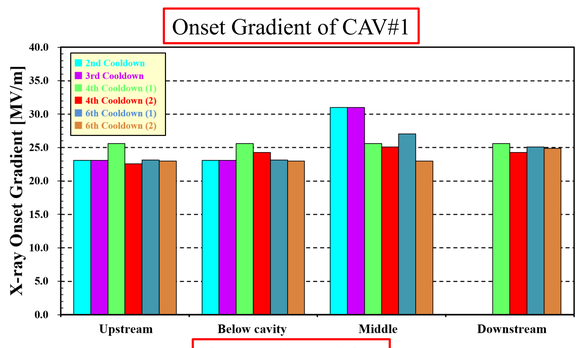
X-rays from CAV#1



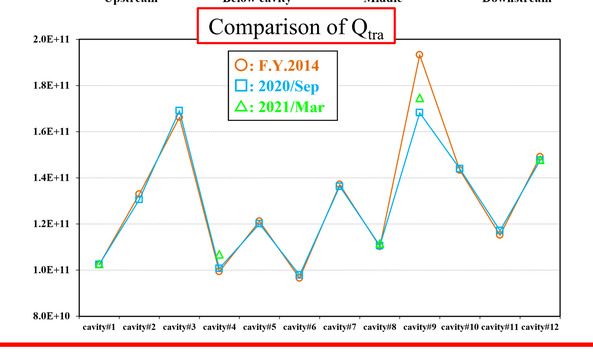
X-rays from CAV#9



Onset Gradient of CAV#1



Comparison of Q_{tra}

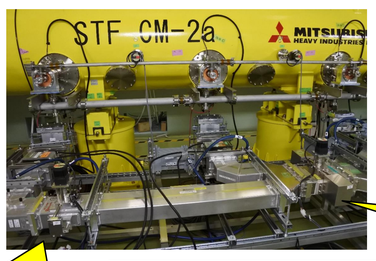


Beam Operation

Specifications of STF-2 accelerator

Parameters	Value
Max. allowable beam energy	500 MeV
Max. allowable beam intensity	3.0 μA
Max. allowable beam power	1.35 kW
Max. number of bunches per train	1000
Bunch spacing	6.15 nsec
Max. train length	6.15 μsec
RF repetition rate	5 Hz
Bunch charge	600 pC
Bunch current	97.5 mA

Maximizing accelerating gradient → Variable-hybrid
Maximizing beam energy → RF Phase Shifter

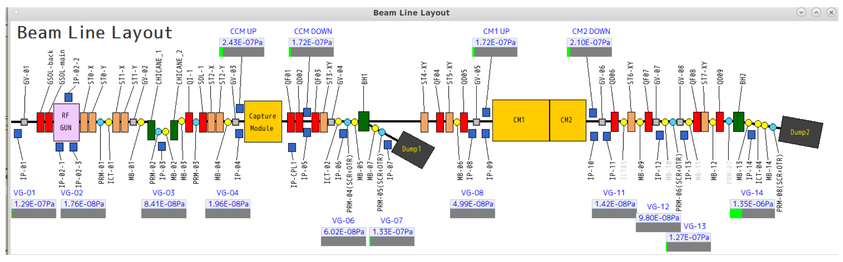


Variable-hybrid

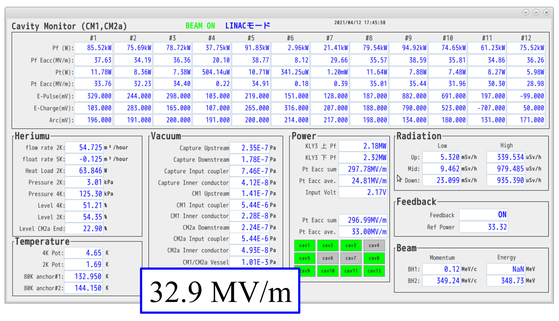
Phase shifter

Control display

Beamline Components of STF-2 accelerator

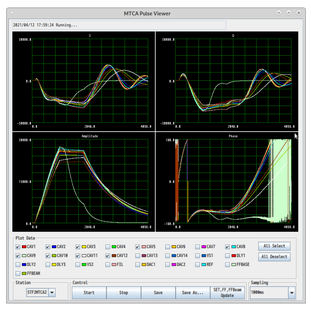


Max. average E_{acc} operation

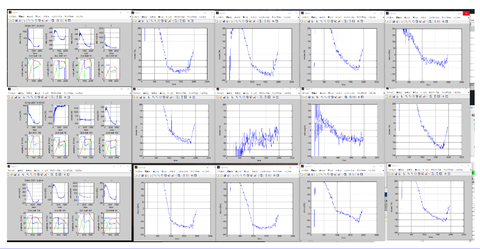


32.9 MV/m

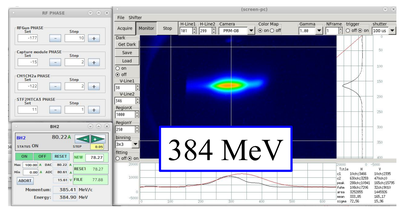
Cavity quenched



LFD compensated by piezo

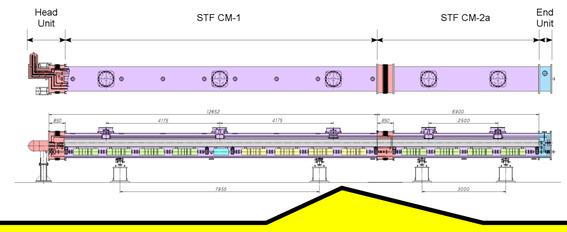


Beam profile @PRM-08



Normalized emittance @CCM and CM1/2a

Location	X [mm mrad]	Y [mm mrad]
Capture CM	1.8	1.4
CM1/2a	18.4	25.5



There seems to be something in CM1/2a that is causing the emittance growth?

Summary of Beam Operation in 6th Cooldown Test

Parameters	Mar/2019	Apr/2021
Number of cavities incl. CCM used for operation	7 + 2	12 + 2
Beam energy	280 MeV	384 MeV
Beam intensity	0.28 μA	1.8 μA
Beam power	78 W	677 W
Total charge per pulse	56 nC	360 nC
E_{acc} from beam energy	33.1 MV/m (7 cavities)	32.9 MV/m (9 cavities)
E_{acc} from RF power (P_{tra})	33.8 MV/m (7 cavities)	33.0 MV/m (9 cavities)

Conclusion

The cavity replacement work for CAV#9 in CM2a was successfully done. In the 5th cooldown test of the STF-2 cryomodules, it was confirmed that there was no problem in driving all tuner systems. In the 6th cooldown test, beam acceleration test with 14 cavities including CCM was carried out, and it was confirmed that the average accelerating gradient obtained from the beam energy reached 32.9 MV/m, and the maximum beam energy reached 384 MeV. This is a very important milestone for the ILC project. The next goal is the beam operation with long bunch train as ILC. In this beam operation, the beam power will increase by 5 times.