Achievement of Stable Pulsed Operation at 36 MV/m in STF-2 Cryomodule at KEK

Kirk, E. Kako, T. Shishido, K. Umemori, T. Kubo, T. Konomi, G. Park, T. Saeki, T. Dohmae, M. Egi, T. Matsumoto, T. Miura, T. Takenaka, H. Nakai, Y. Kojima, K. Hara, T. Honma, K. Nakanishi, H. Shimizu

THYA02

Kirk

Outline

- STF-2 Accelerator & History
- Cavity Performance / Degradation
- X-rays Measurement
- Vector-sum operation with eight cavities @31 MV/m
- Heat Load Measurement
- Lorentz Detuning Measurement
- Summary & Future Plan

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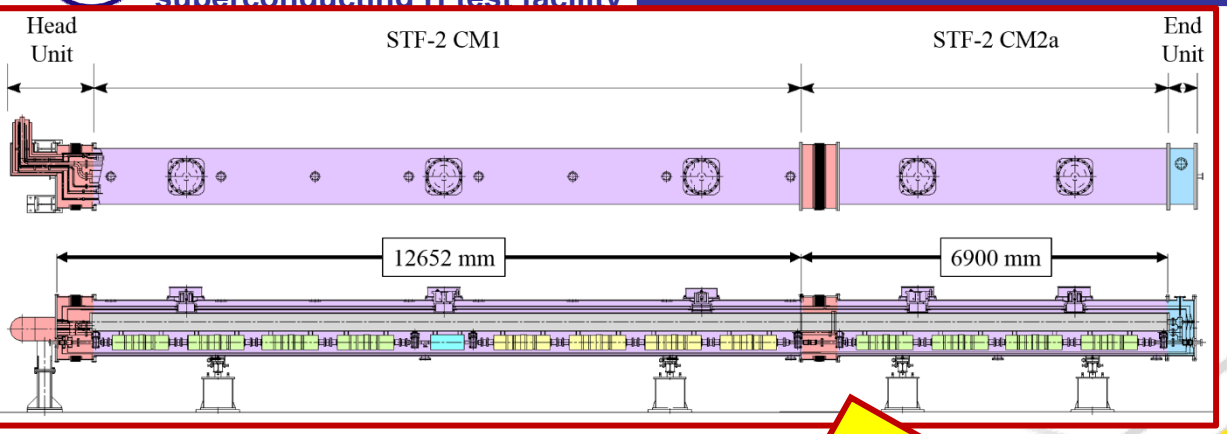
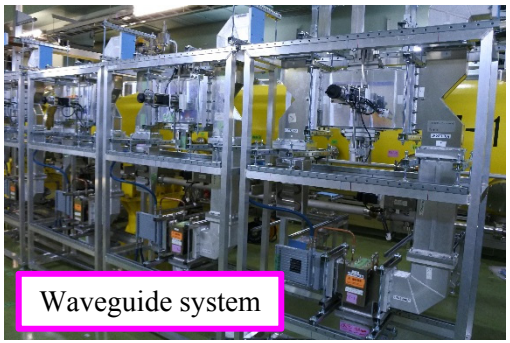
STF-2 Accelerator Layout

superconducting rf test facility

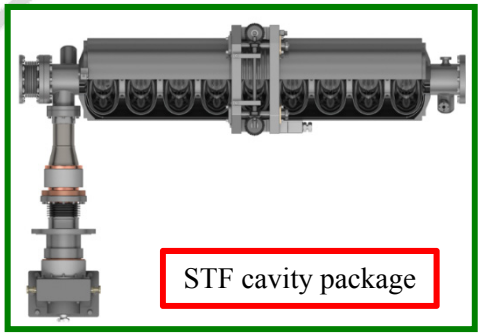


To be constructed



Cold box

CM1 + CM2a (Twelve cavities)



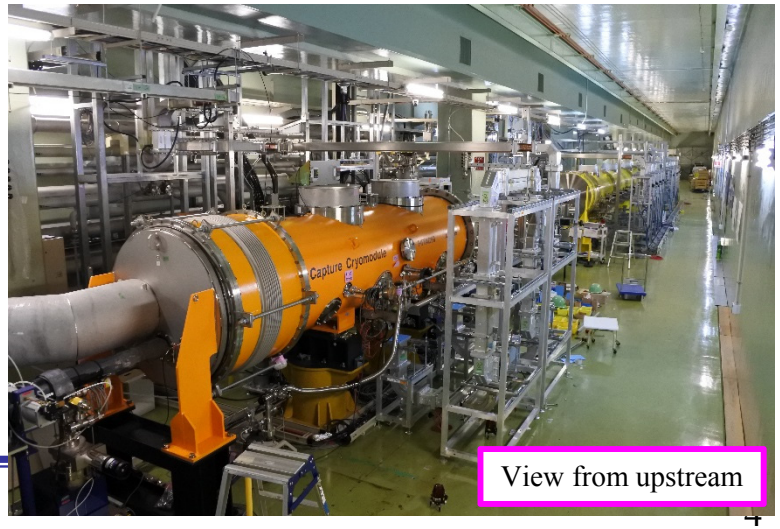
To be constructed

Cold box

Capture CM (Two cavities)

Chicane

RF Gun



Brief History for STF-2 Cryomodule

Date	Content
2010	Fabrication of cavities / power couplers
2011 ~ 2013	V.T. for 12 cavities / RF conditioning for 12 couplers
Jun/2013	Cleaning up STF tunnel
Jul/2013 ~ Apr/2014	Cavity string assembly (three times)
Oct/2013 ~ Jun/2014	Module assembly (CM1/CM2a)
Jul/2014	Complete certification for High pressure Gas Code
Oct/2014 ~ Dec/2014	1st cool-down / low power test
Apr/2015 ~ Jul/2015	5MW Klystron / Single waveguide system completed
Jul/2015 ~ Sep/2015	Coupler conditioning at room temperature
Oct/2015 ~ Dec/2015	2nd cool-down / high power test (cavity performance check)
Jan/2016 ~ Jul/2016	Multi-beam Klystron & Waveguide system completed
Jul/2016 ~ Sep/2016	Coupler conditioning at room temperature
Sep/2016 ~ Nov/2016	3rd cool-down / LFD, Q_0 measurement, 8 Cavities Operation & LLRF study
F.Y. 2018	4th cool-down test (?)
F.Y. 2018 ~	Beamline construction / Beam operation starts (?)

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Cavity performance/Degradation

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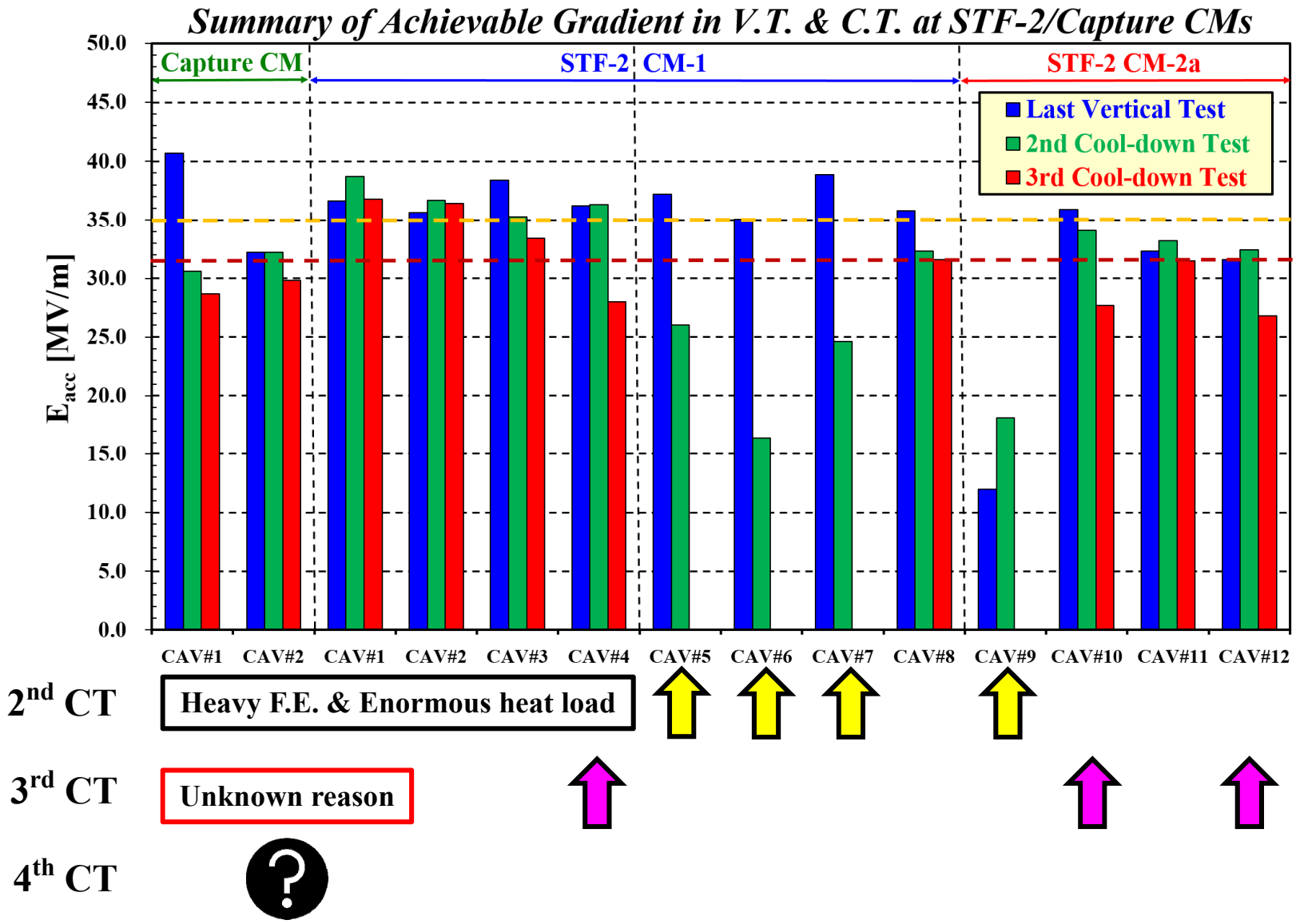

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X-rays measurement

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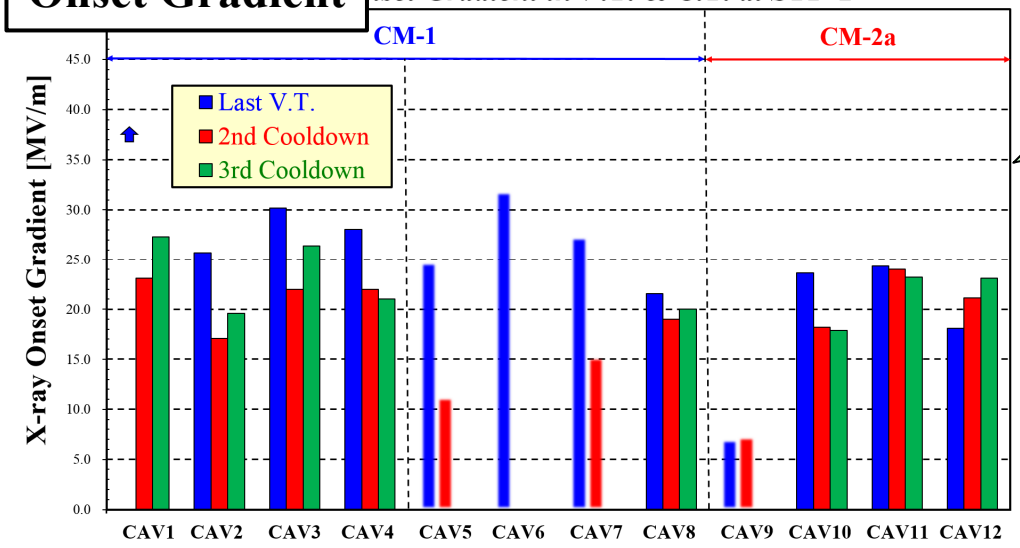
Onset Gradient

nset Gradient in V.T. & C.T. at STF-2

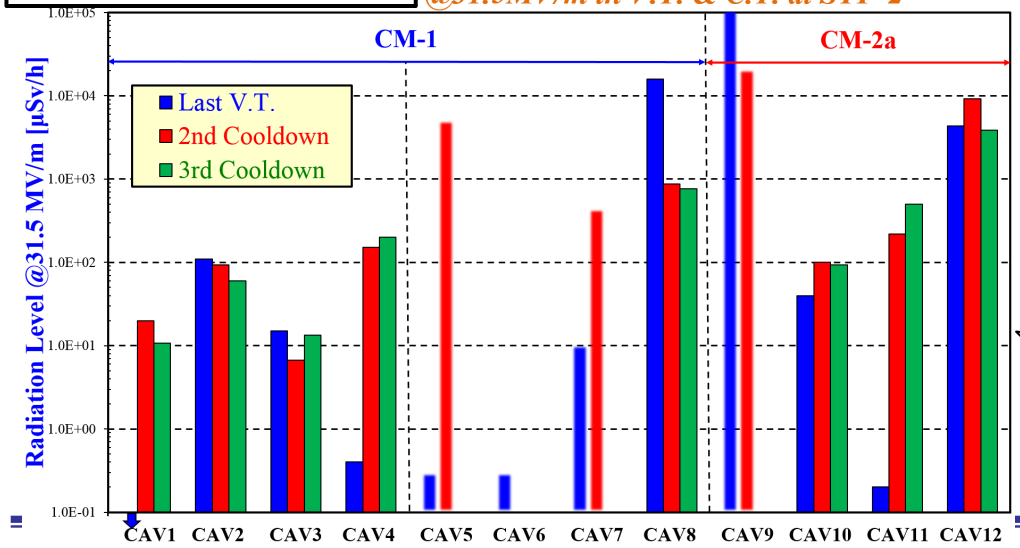


- ✓ CAV5, 6, 7, and 9 not tested in 3rd cooldown
- ✓ CAV1 had no x-rays in last V.T.
- ✓ **A little bit higher gradient in 3rd test as resulting from RF conditioning**

F.E. was not related to the degradation between 2nd and 3rd cool-down test!

X-rays @31.5MV/m

@31.5MV/m in V.T. & C.T. at STF-2



- ✓ CAV5, 6, 7, and 9 not reached 31.5 MV/m in 2nd cooldown
- ✓ CAV10 and 12 not reached 31.5 MV/m in 3rd cooldown
- ✓ **Almost same level between 2nd and 3rd test**

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Vector-sum Operation with 8 Cavities

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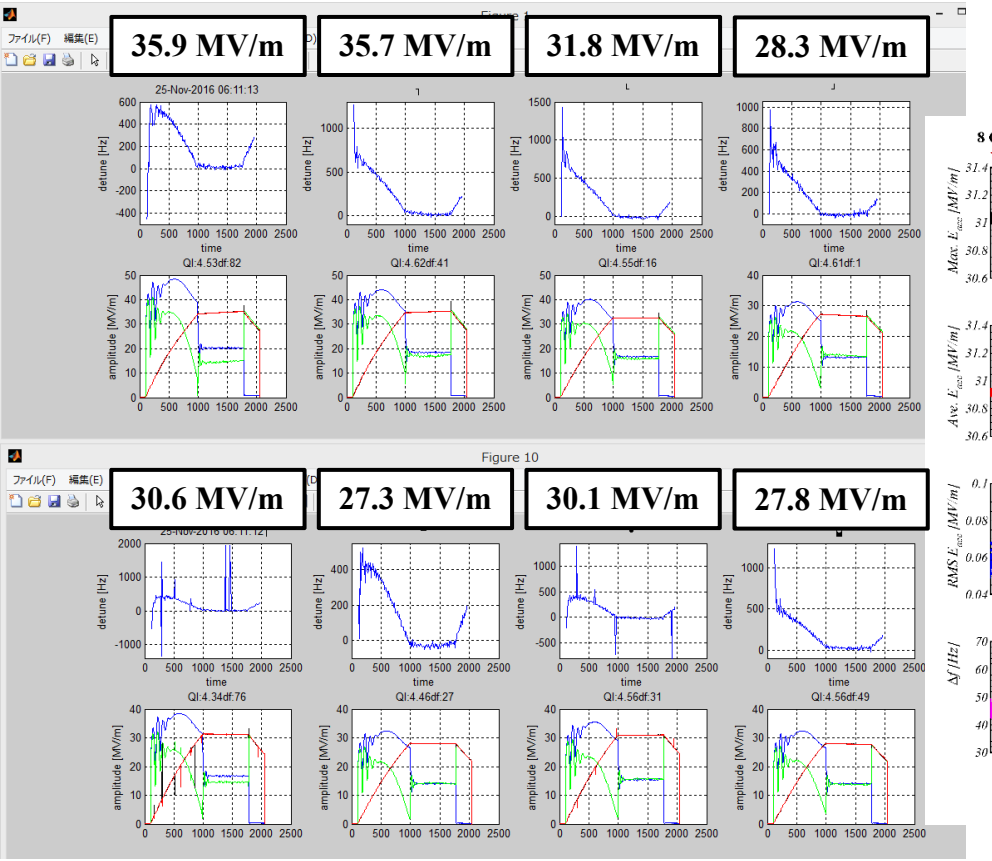
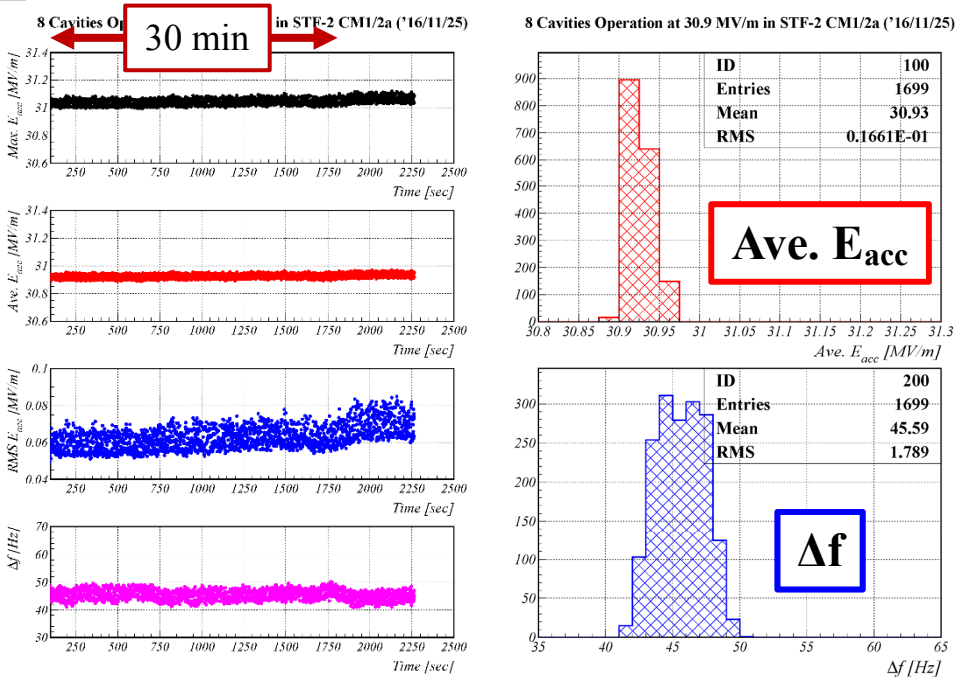
Each pulse for 8 cavities



Trend graph of Ave. E_{acc} and Δf during vector-sum operation



30.9 MV/m ± 0.02 MV/m

46Hz ± 1.8Hz

They almost satisfied the ILC specification!

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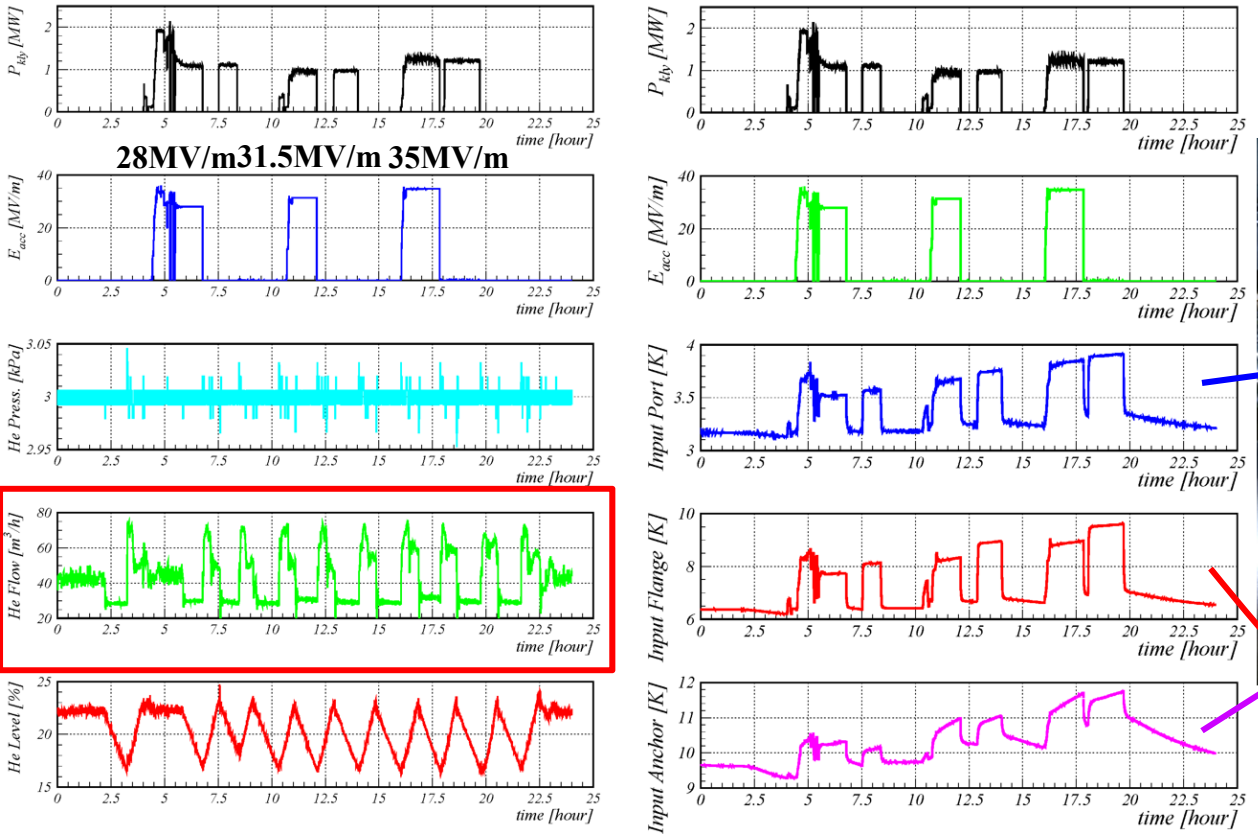
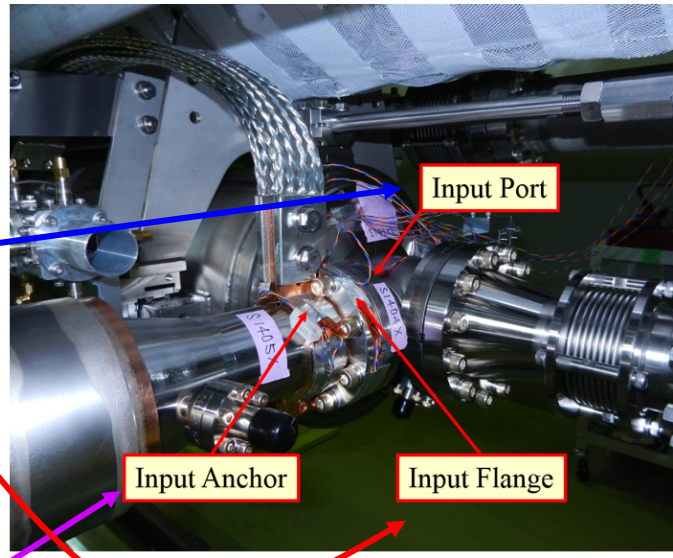
Daily Trend during the heat load measurement

We can estimate the heat load from the helium mass flow rate.





The heating around the power coupler remained in the next day.
This effect might generate the **larger** systematic error.

Error estimation in heat load measurement

- Reproducibility of Static Heat Load
  - **0.36 [W]** on average for 28 times measurements
- Distribution of Helium Mass Flow
  - **3.9%** on maximum for every heat load measurement
- Stability in Accelerating Gradient for Flat-top of Pulse
  - 0.05% (very stable)
- Stability in RF Duty Factor
  - 0.85% (stable)
- Latent Heat of Vaporization
  - Negligible small
- Helium Mass Flow Meter
  - ±0.3% according to spec. sheet
  - Calibrated by heater in the STF-2 cryomodule

Comparison of Q_0 – E_{acc} and X-rays

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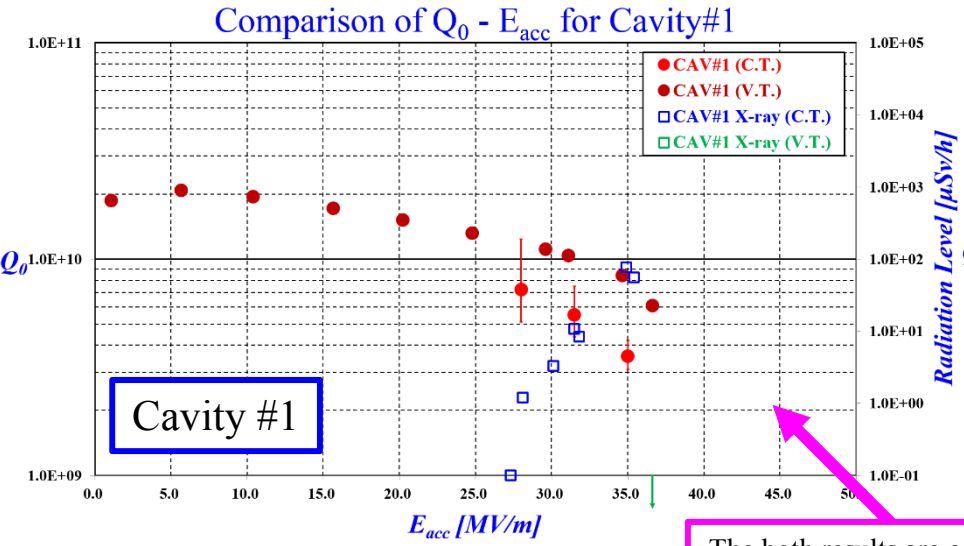
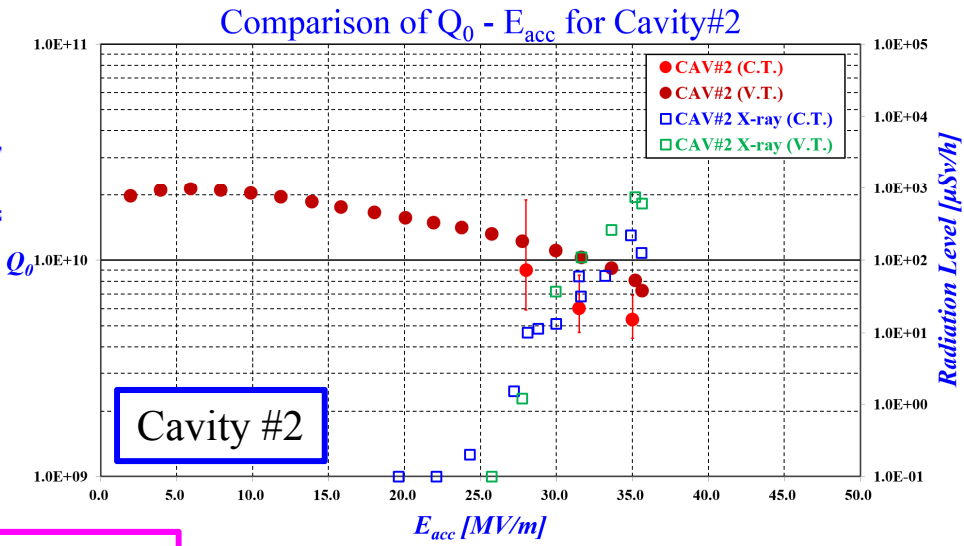
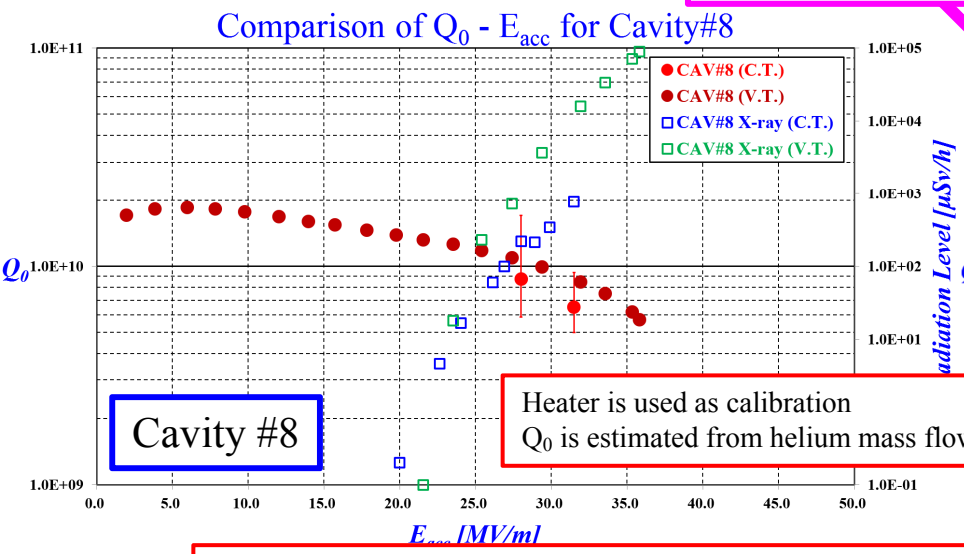
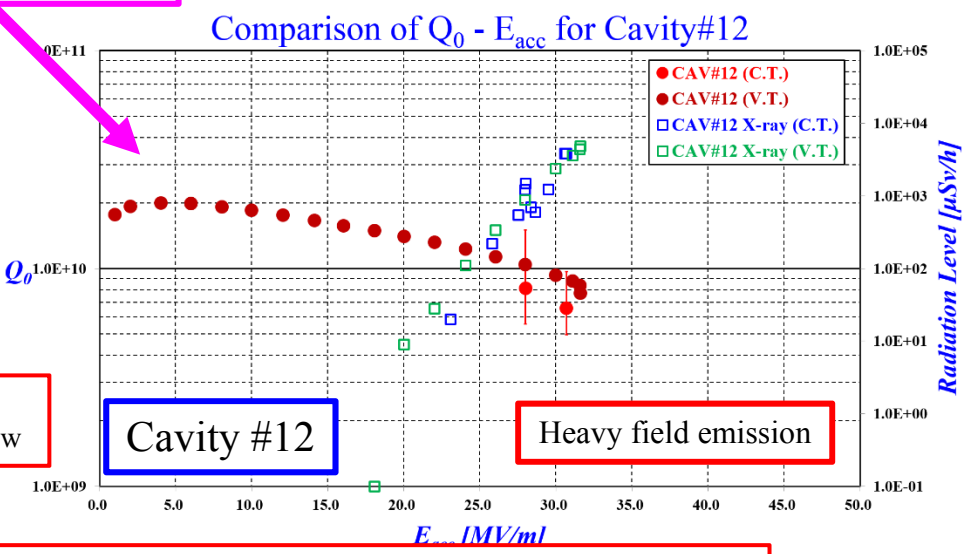




The both results are contradictory!





Lower Q_0 may depend on cooldown rate (@LCWS2016) → Will be tried in next cool-down test

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Lorentz Detuning Measurement

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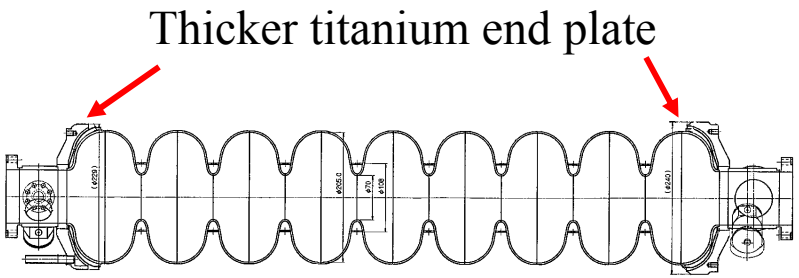
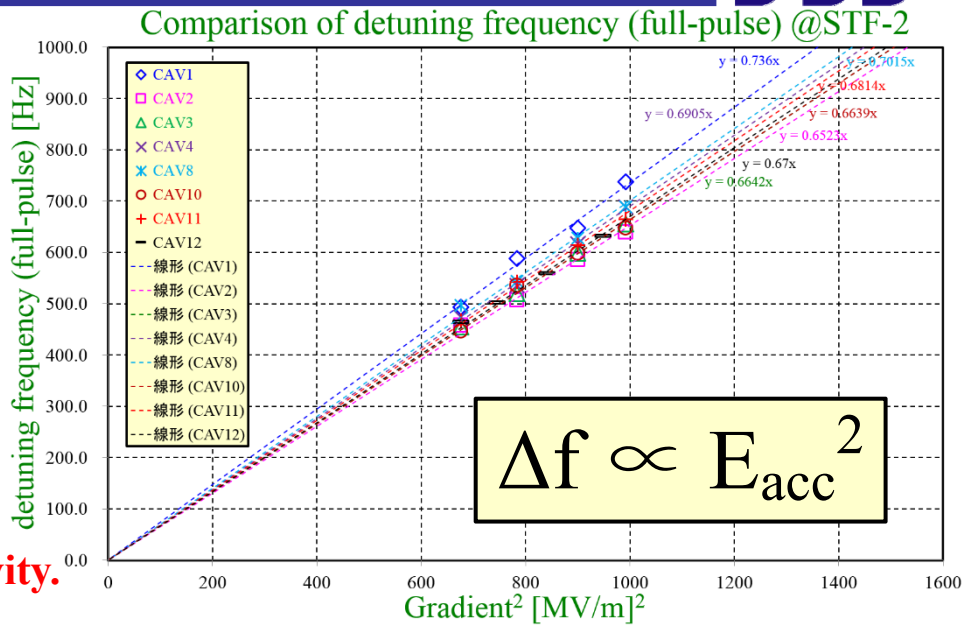
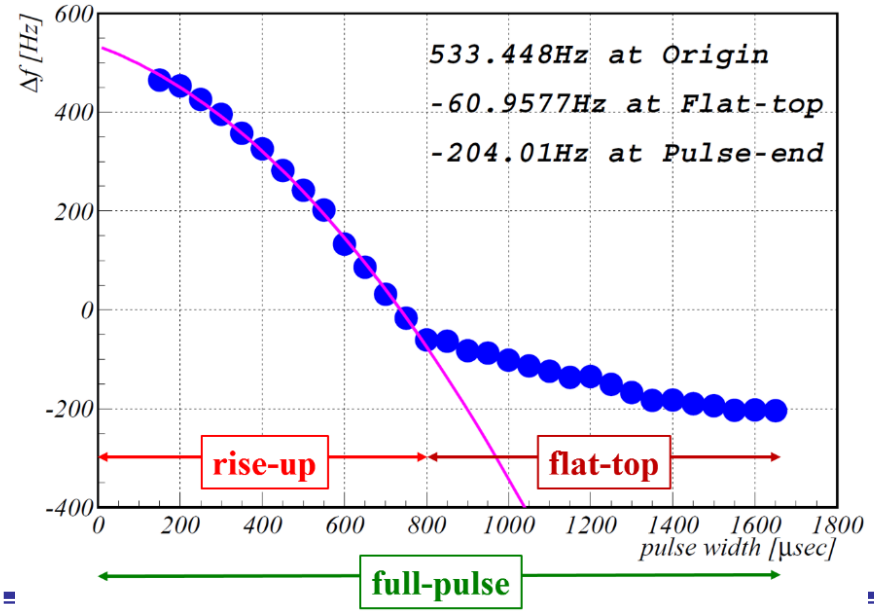
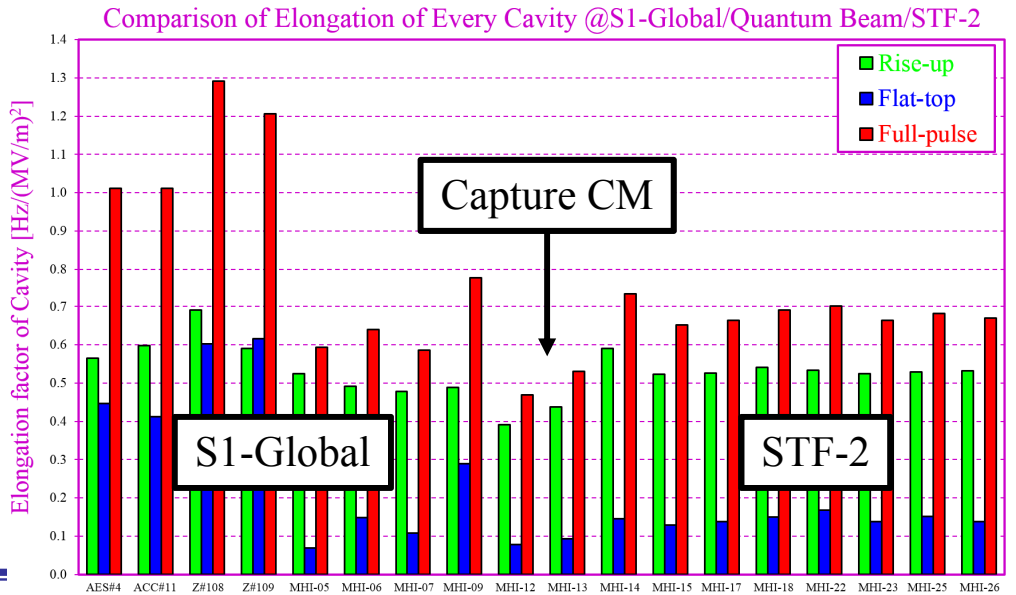




The STF cavity has more stiffness than TESLA cavity.





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Summary for STF-2 Cryomodule

- STF-2 Cryomodule was constructed, installed and tested since 2013
- 8 cavities achieved above 31.5 MV/m in the single cavity operation
- 3 cavities had “more” degradation in 3rd cool-down test
- X-rays was never changed in two cryomodule tests
- Vector-sum operation with 8 cavities at 30.9 MV/m successfully done
- Lower Q_0 for every cavity

Future Plan

- Change of cool-down method (like FNAL)
- Beam commissioning ← Final goal for STF-2


Thank you very much for your attention!