super-
conducting
rf test
facility

Test Results of the International S1-Global Cryomodule

SRF'11 @Chicago

28/Jul/2011

Kirk

International Team for "S1-Global"

superconducting rf test facility

C. Pagani, P. Pierini, A. Bosotti, R. Paparella, INFN (Italy)

K. Jensch, D. Kostin, L. Lilje, A. Matheisen, W.-D. Moeller,
M. Schmoekel, P. Schilling, H. Weise, N. Walker, DESY (Germany)

T. Arkan, S. Barbanotti, M. Battistoni, H. Carter,
M. Champion, A. Hocker, R. Kephart, J. Kerby, D. Mitchell,
Y. Pischalnikov, T.J. Peterson, M. Ross,
W. Schappert, B. Smith, FNAL (USA)

C. Adolphsen, C. Nantista, SLAC (USA)

M. Akemoto, S. Fukuda, K. Hara, H. Hayano, N. Higashi, E. Kako,
H. Katagiri, Y. Kojima, Y. Kondo, T. Matsumoto, H. Matsushita,
S. Michizono, T. Miura, H. Nakai, H. Nakajima, K. Nakanishi, S. Noguchi,
N. Ohuchi, T. Saeki, M. Satoh, T. Shidara, T. Shishido, T. Takenaka,
A. Terashima, N. Toge, K. Tsuchiya, K. Watanabe, S. Yamaguchi,
A. Yamamoto, Y. Yamamoto(Kirk), K. Yokoya, M. Yoshida, KEK (Japan)

61 persons from 5 Labs!

Overview

- Motivation & History of S1-Global
- Cavity, Coupler and Tuner in S1-Global
- Cavity performance at V.T.
- Assembly and Cryomodule test Status
- Coupler conditioning at R.T.
- Tuner test with low power @2K
- LFD measurement
- LFD compensation by piezo
- 7 cavities operation
- Dynamic loss measurement (including Static loss)
- RF response at Quench for MHI-06
- Summary

Motivation & History of S1-Global

Motivation

- Comparison of hardware performance concerning SRF technology **for ILC**
  - Cavity
  - Power coupler
  - Tuner
  - Cryomodule
- Mutual understanding among SRF researchers, engineers and technicians

History

- This project was launched in a discussion of ILC-GDE in 2008.
- The preparation including V.T. was in progress in 2009.
- The assembly work started at the beginning of 2010.
- The cryomodule test finished on Feb/2011.

Main components in S1-G cryomodule

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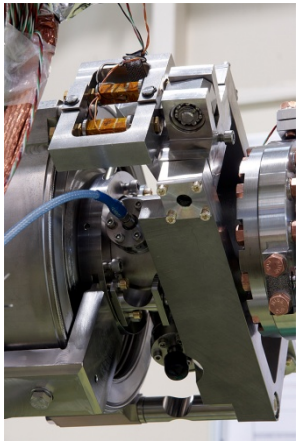
TESLA Cavity (DESY/FNAL)

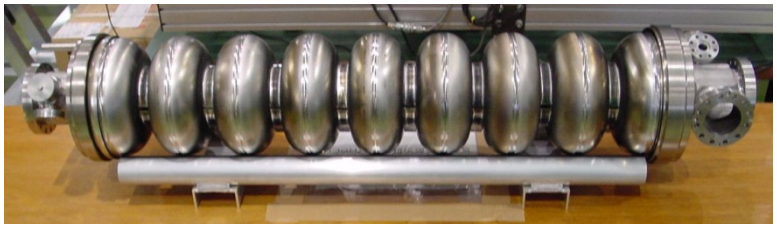
Blade Tuner (FNAL/INFN)



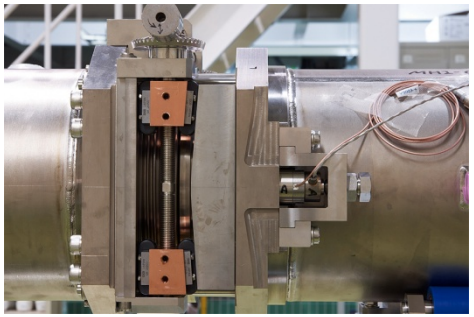
Saclay Tuner (DESY)

TTF-III Coupler (DESY/FNAL)

Comparison of Performance



Tesla-like (KEK)



Slide-Jack Tuner (KEK)

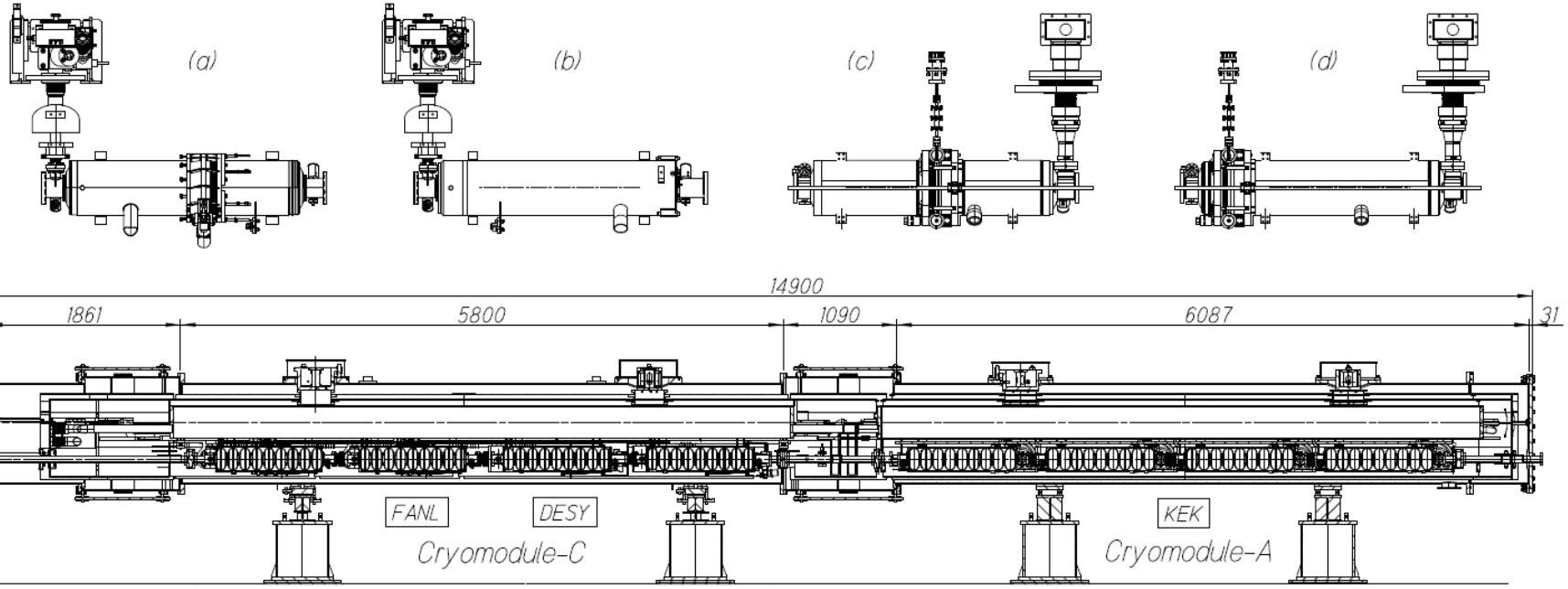
STF-II Coupler (KEK)

The coupling is variable for both couplers.

S1-Global Cryomodule

2 Blade tuners 2 Saclay tuners

4 Slide-jack tuners
(center or end)



Cryomodule-C
(4 TESLA cavities
4 TTF-III couplers)

Cryomodule-A
(4 TESLA-like cavities
4 STF-II couplers)

Cavity Performance @V.T.

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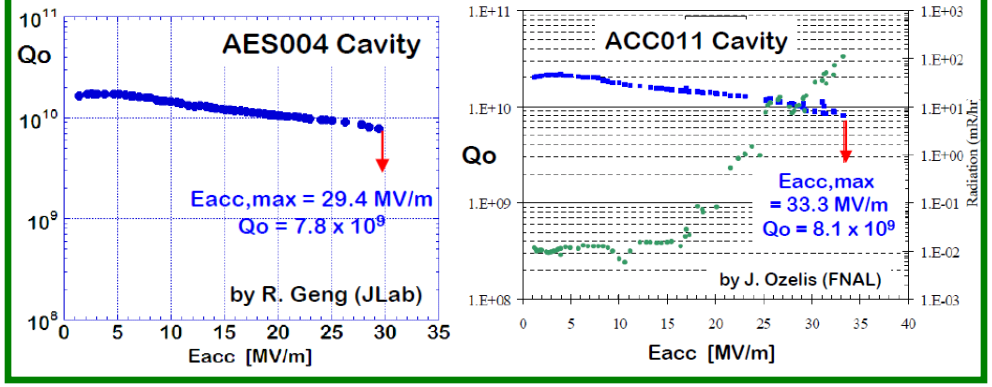
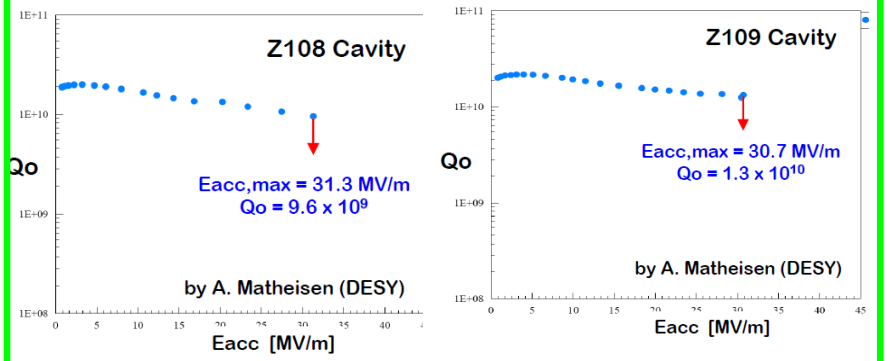
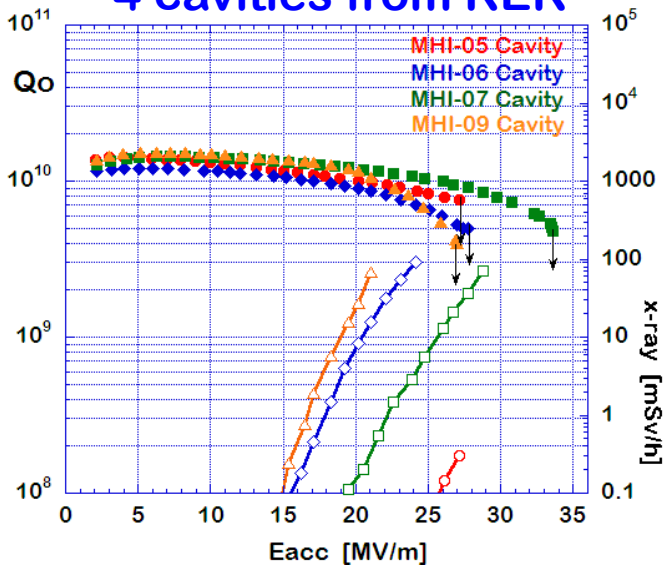
2 cavities from FNAL



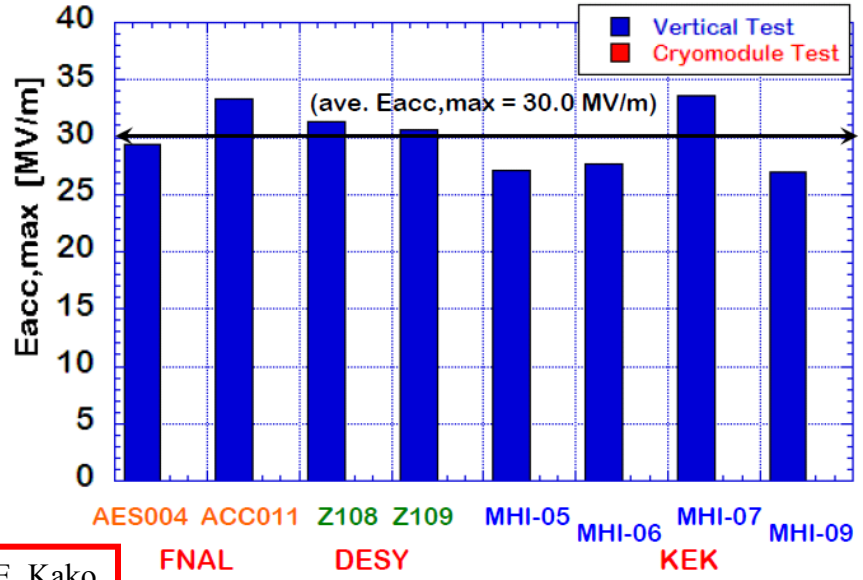
2 cavities from DESY



4 cavities from KEK



8 Cavities for S1-Global (ave. 30 MV/m)



E. Kako

Collaboration for Cryomodule Assembly

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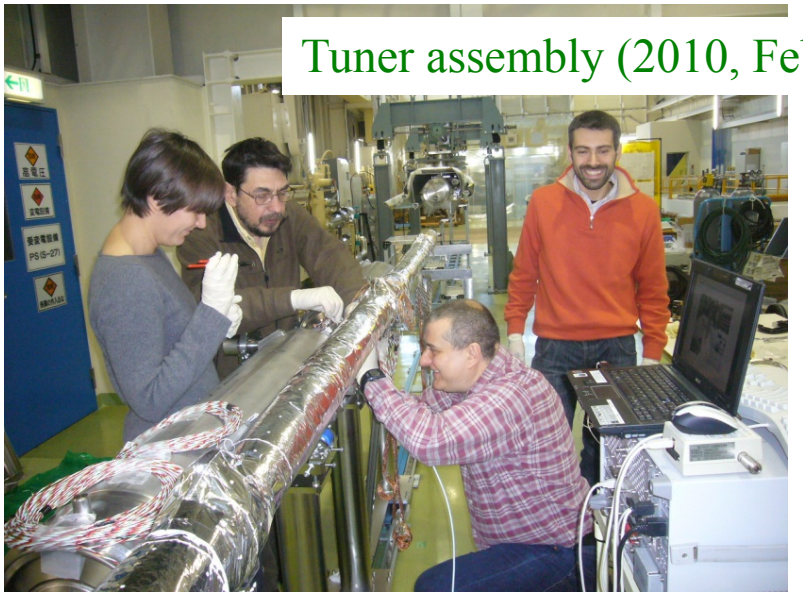
Cavity string assembly (2010, Jan.)

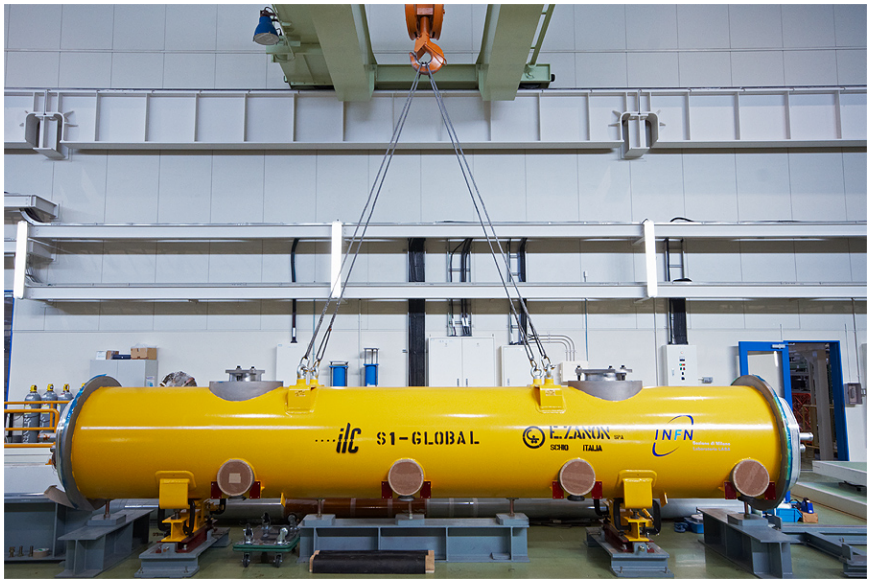


Tuner assembly (2010, Feb.)

Coupler assembly (2010, Mar.)

KEK Cavity string assembly (2010, Mar.)

Installation into tunnel



Collaboration for Cryomodule Tests

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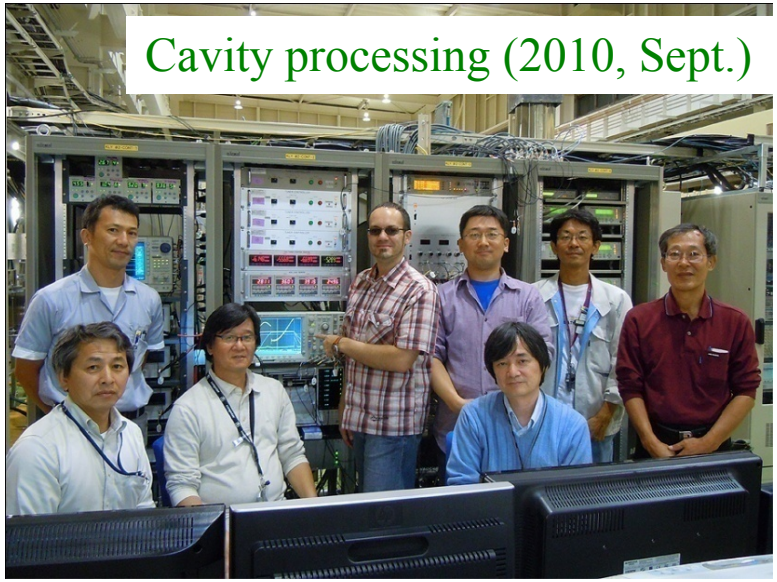
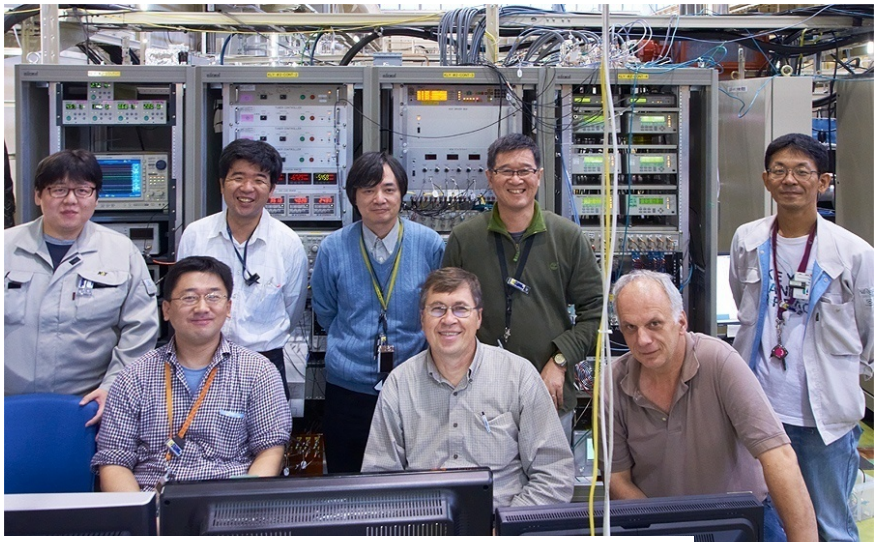
Tuner performance tests (2010, July)



Cavity processing (2010, Sept.)



Lorentz detuning tests (2010, Oct.)

Dynamic loss meas. (2010, Nov.)

RF processing of input couplers

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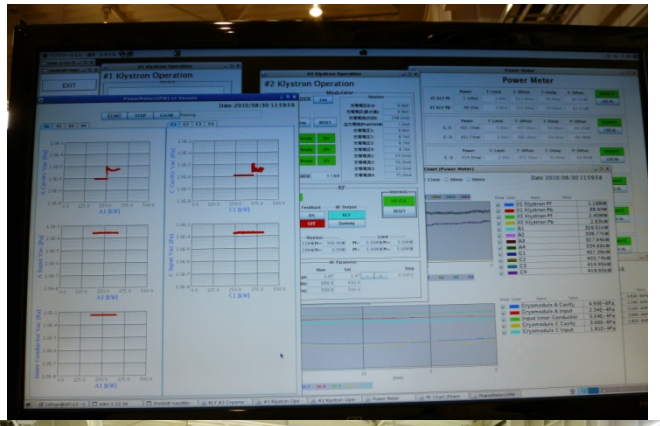

Cryomodule-C /KLY#1 (2MW)

Cryomodule-A /KLY#2 (5MW)

0.5 ms, 5 Hz, 500 kW

1.5 ms, 5 Hz, 200 kW

Aug. 25 ~ Sept. 07 (10 days)

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RF processing time of input couplers

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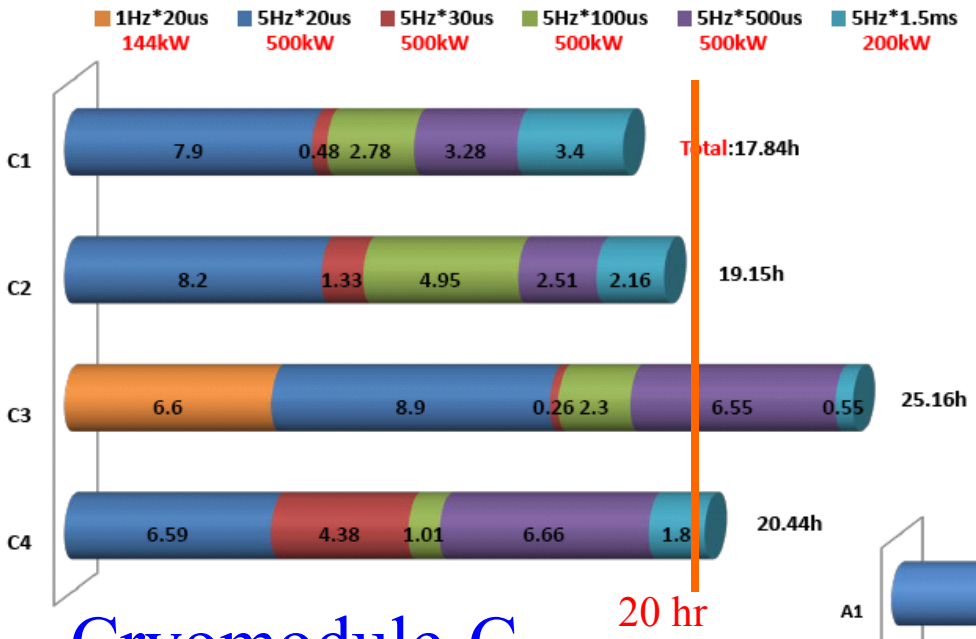
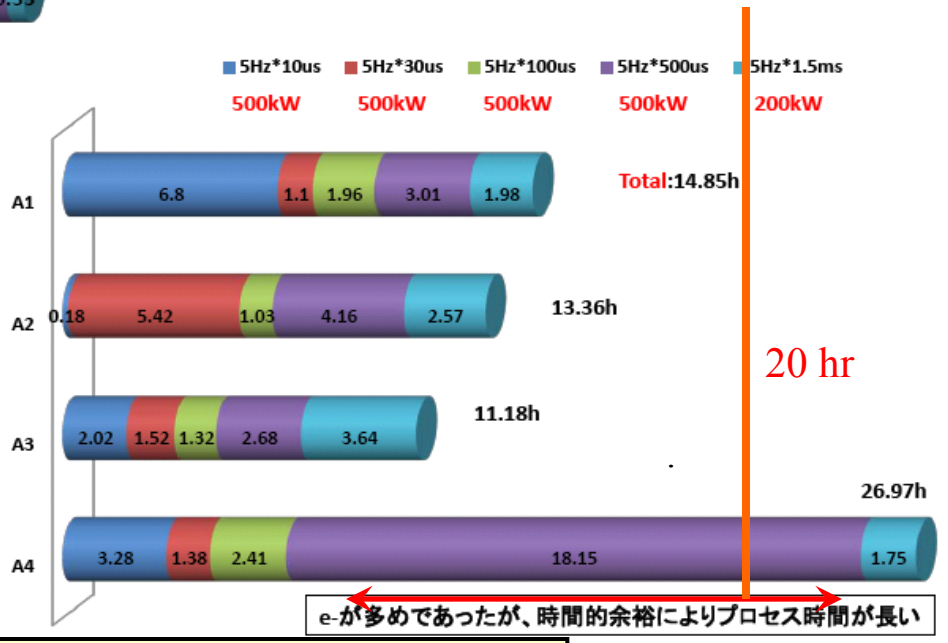
at room temperature



Cryomodule-C
(TTF-III couplers)
ave. processing time
~ 21 hours
Vacuum I/L ; $2.x10^{-4}$ Pa

Cryomodule-A
(STF-II couplers)
ave. processing time
~ 13 hours



The difference of the conditioning time between them is probably due to the structure of RF window.

Adjustment of frequency (f_0)

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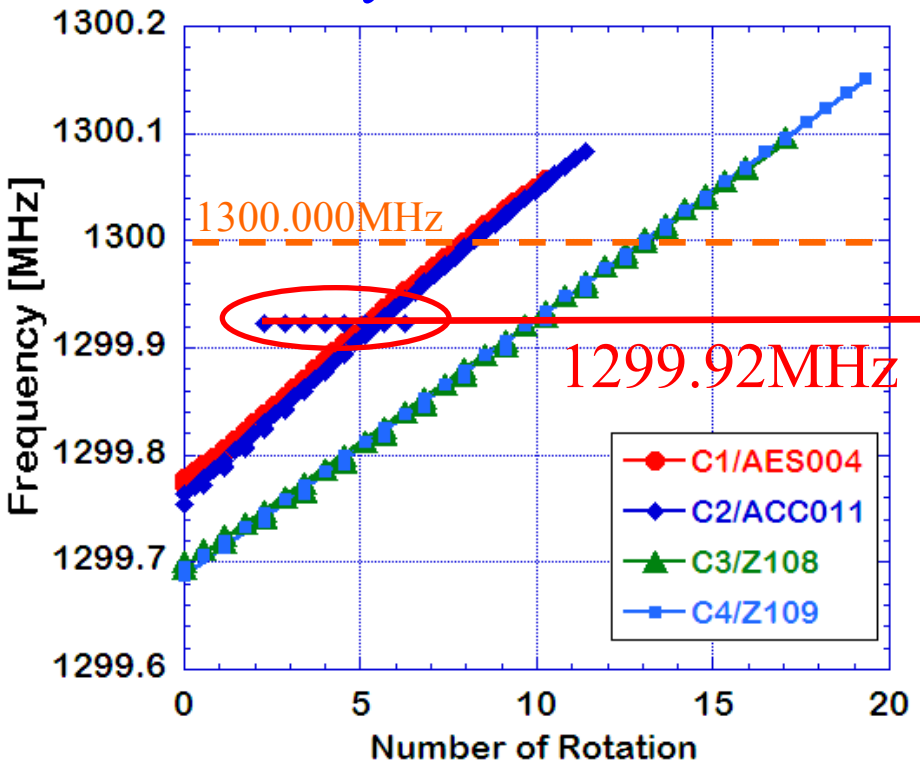
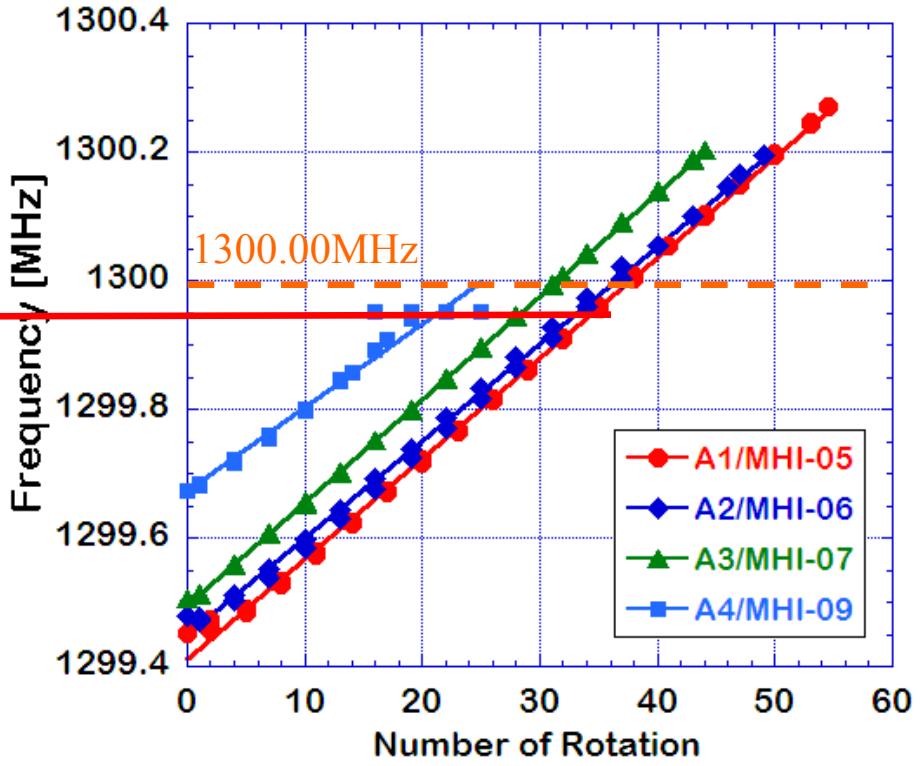
f_0 = 1299.91 MHz (operation)

Cryomodule - C



Cryomodule - A



C2/ACC011; Tuner did not work.

(A4/MHI-09; 1299.91 MHz, limit)

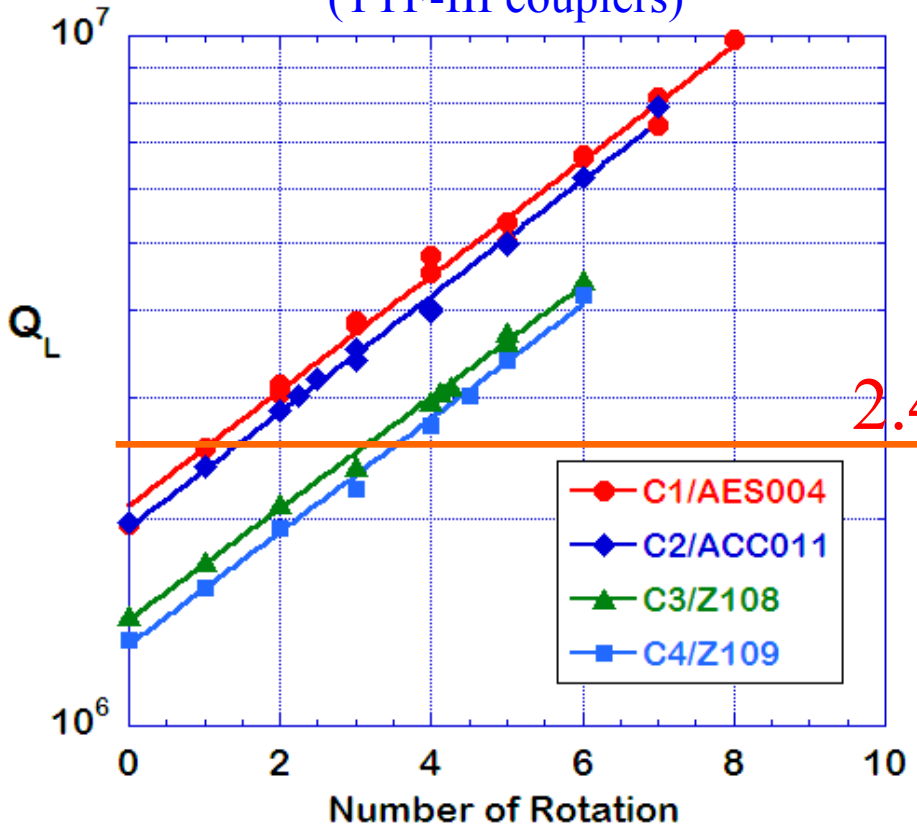
The cause of these tuner troubles are probably due to the mechanical stress.

E. Kako

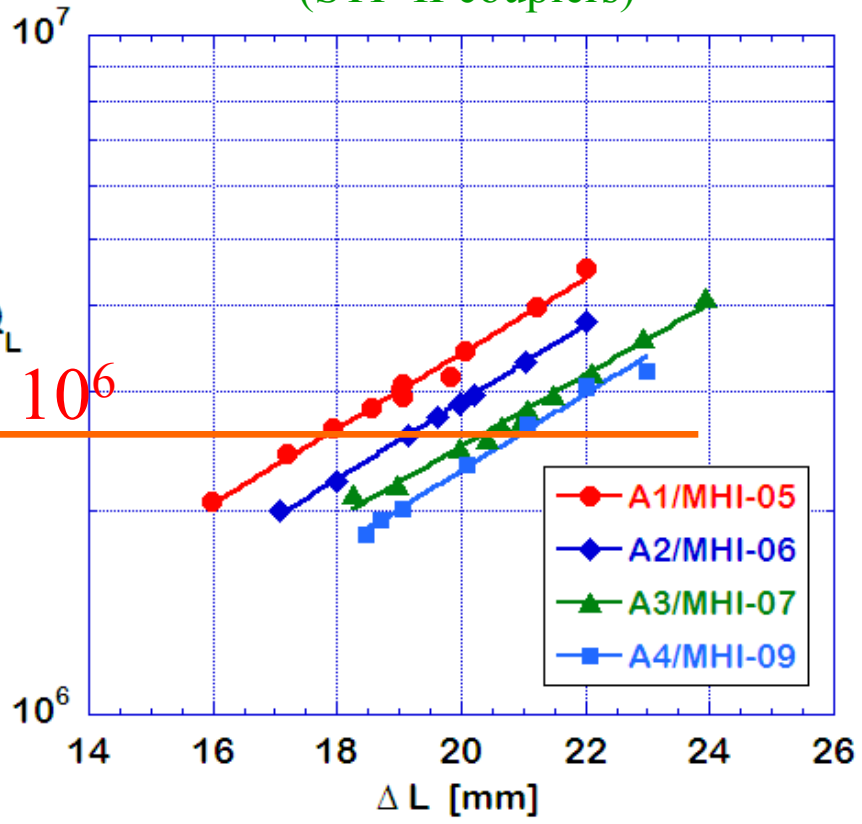
Q_L of Variable Input Coupler

$Q_L = 2.4 \times 10^6$, $\Delta f_{bw} = 542\text{Hz}$

Cryomodule – C
(TTF-III couplers)



Cryomodule – A
(STF-II couplers)



2.4 X 10^6

☺ The both couplers have a good performance for the adjustment of Q_L.

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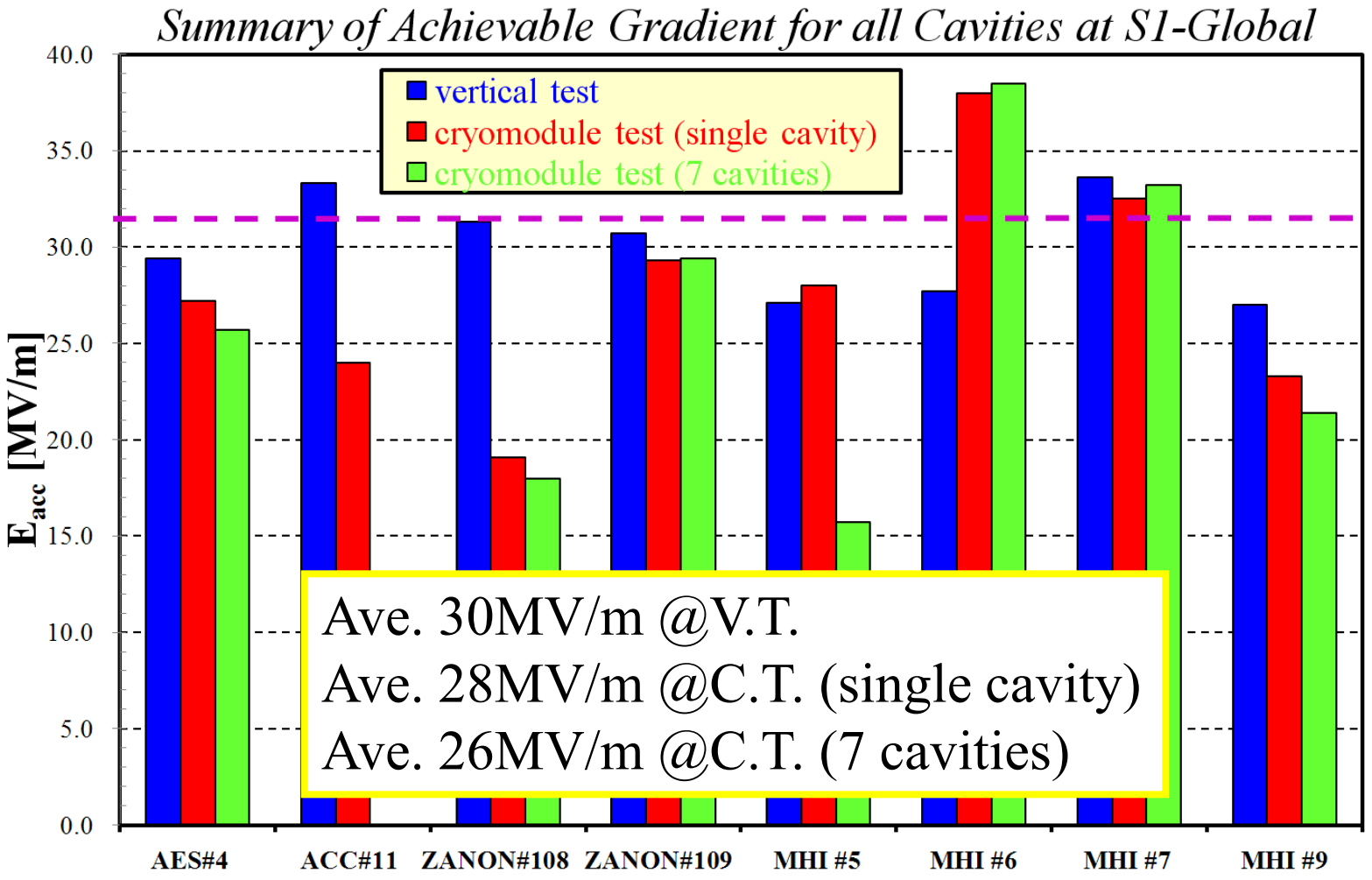
Cavity performance between V.T. and C.T.



Unfortunately, the gradient did not achieve the ILC specification!

Cavity performance between V.T. and C.T.

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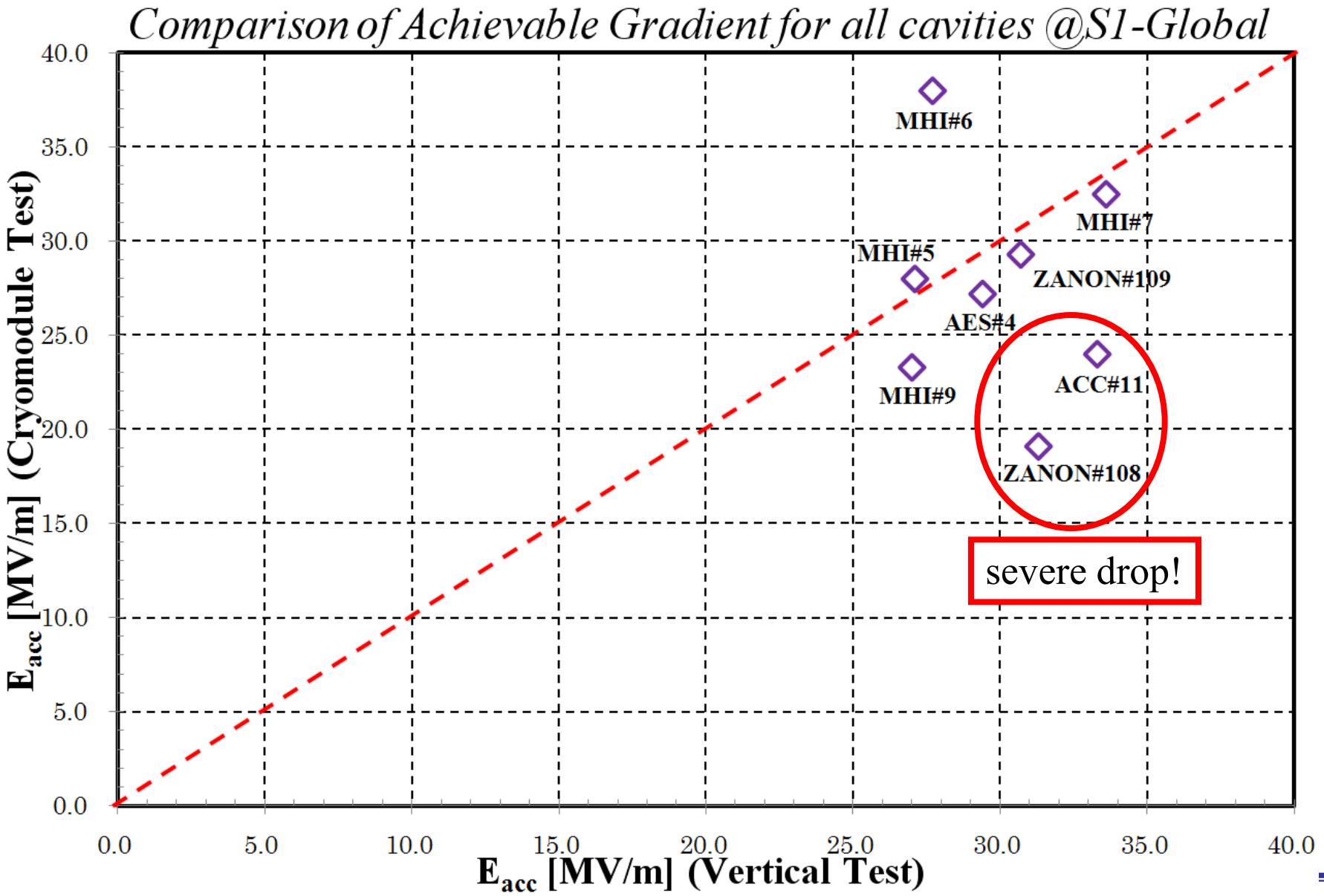

Status of high power operation

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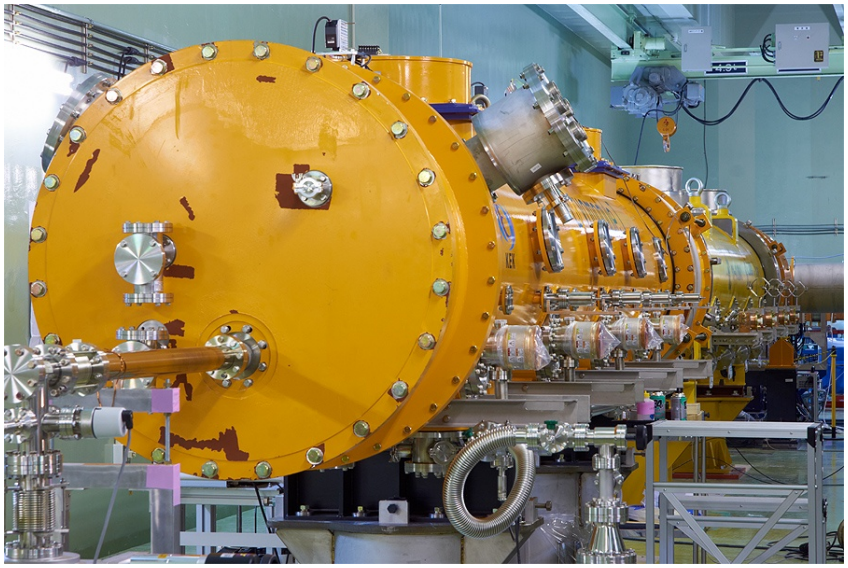
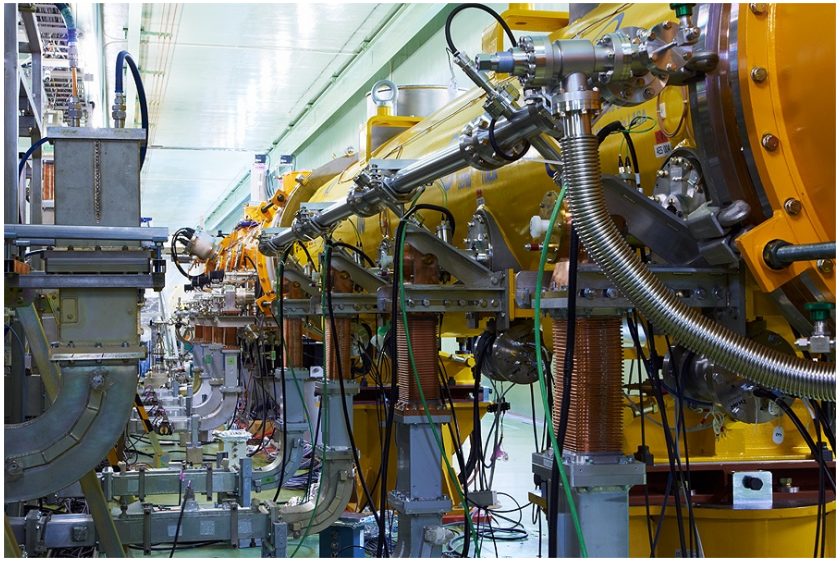
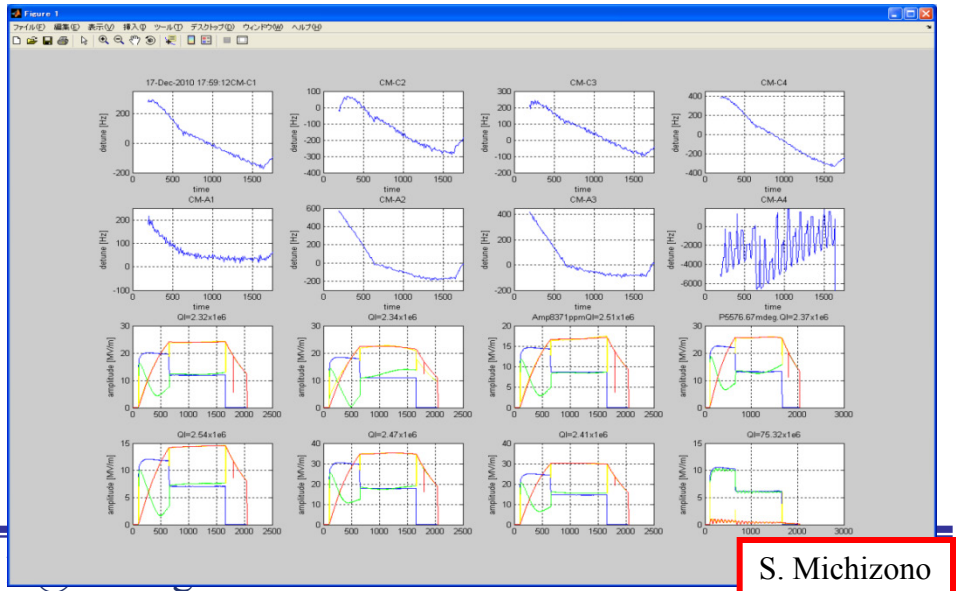




Real time detuning monitor



Frequency shift due to Lorentz detuning

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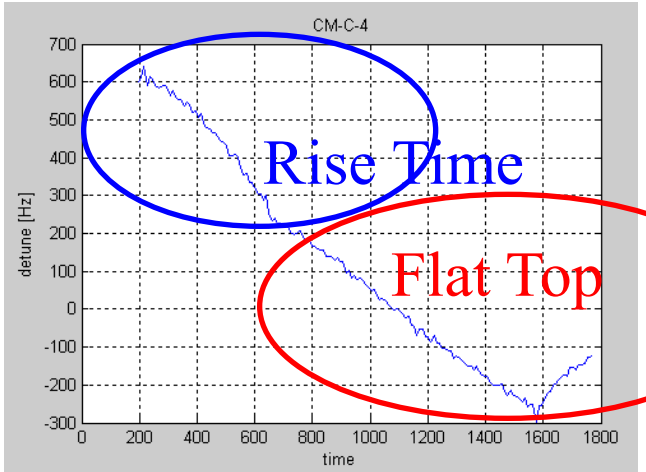
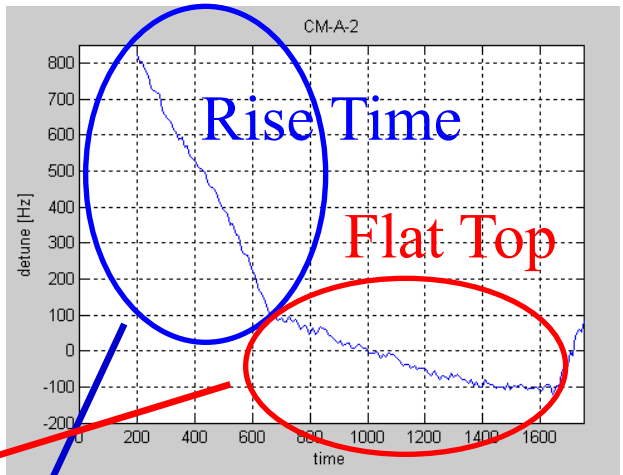
C4/Z109 (29MV/m)

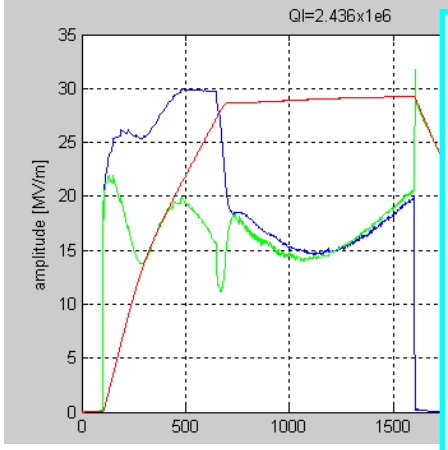
A2/MHI-06 (38MV/m)



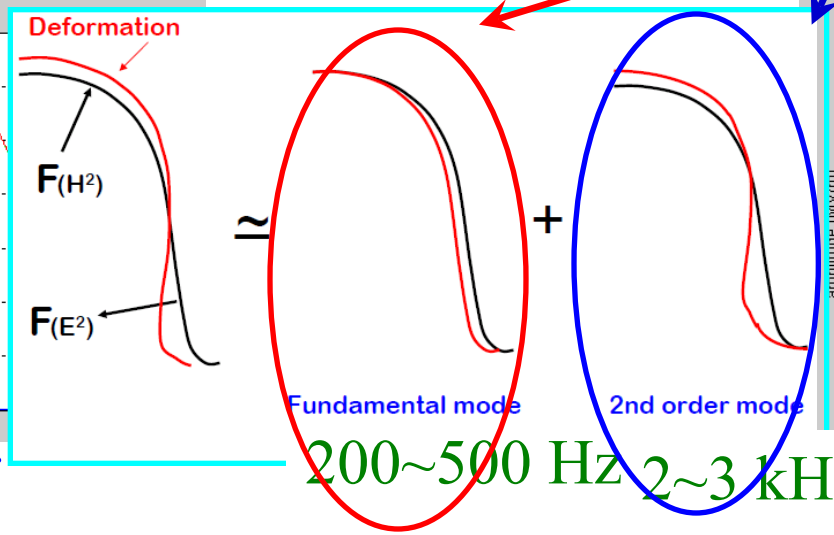
Pre-detuning
by motor tuner
& piezo tuner
with DC voltage

Compensation
by piezo tuner in
pulsed operation

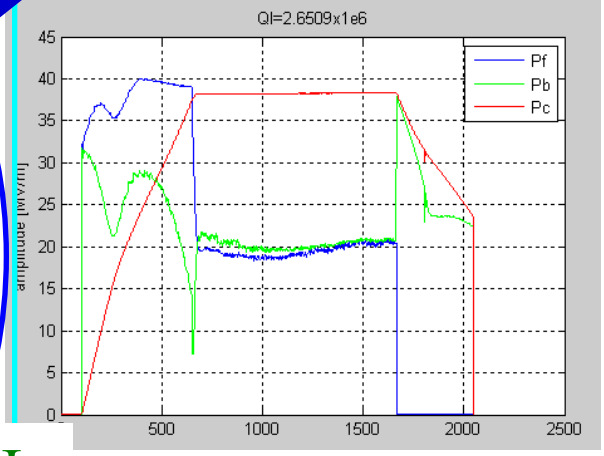




FB/on, Piezo/off



200~500 Hz 2~3 kHz



FB/on, Piezo/off

Pulse-shortening & Data Analysis method

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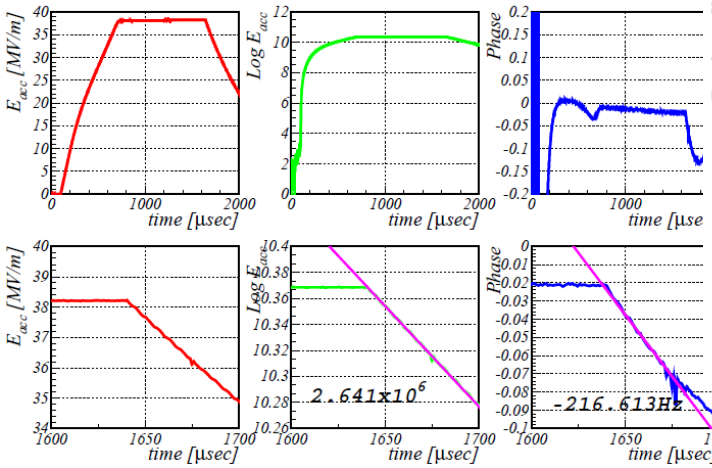
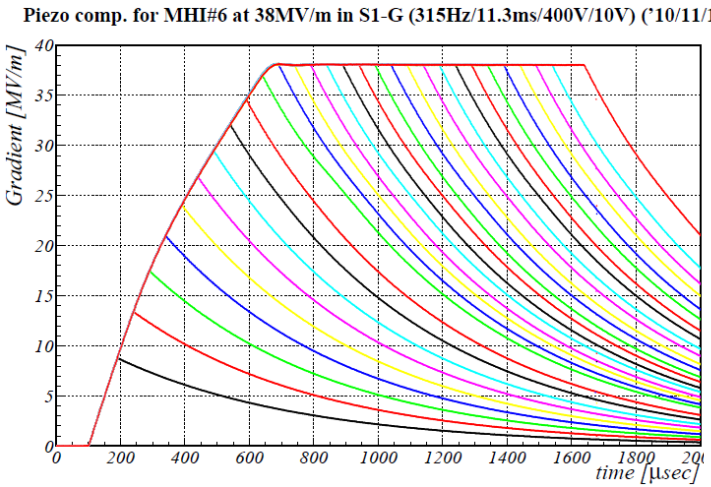
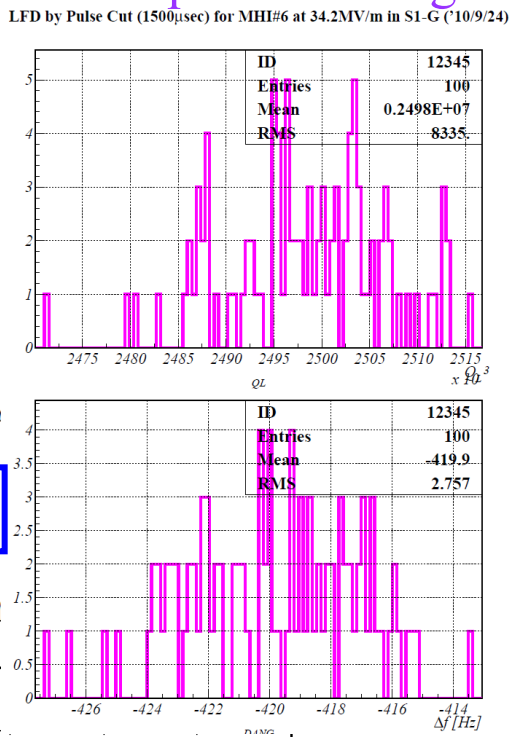
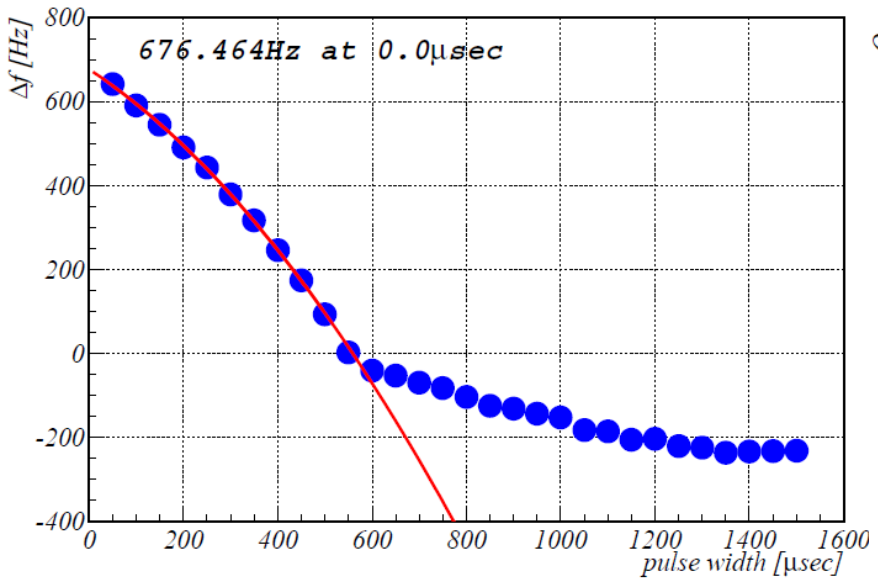


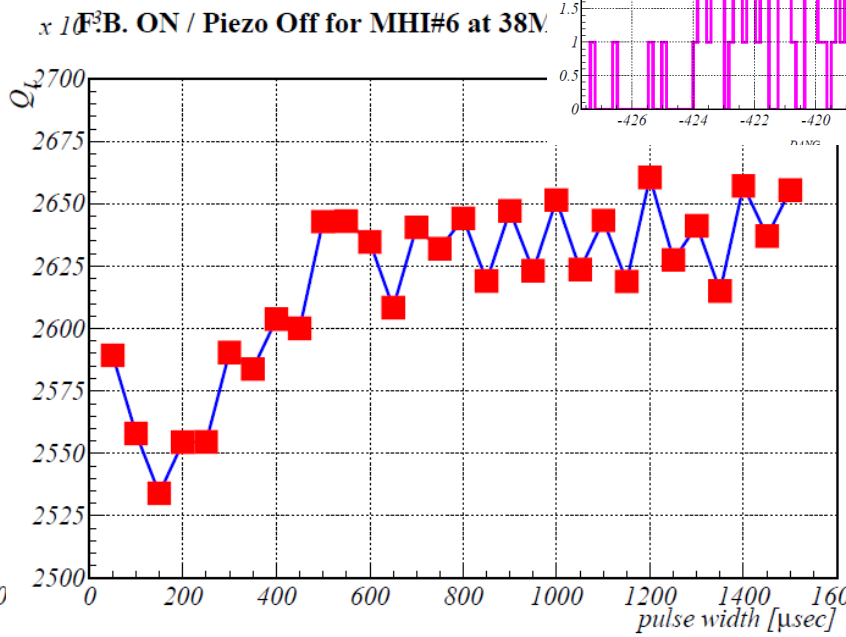


100 pulses average



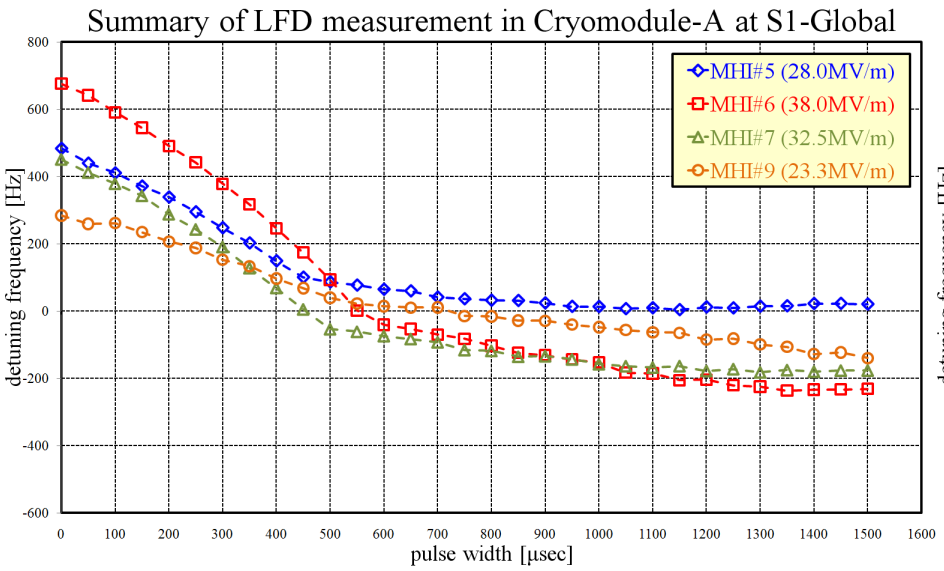
50μsec step shortening



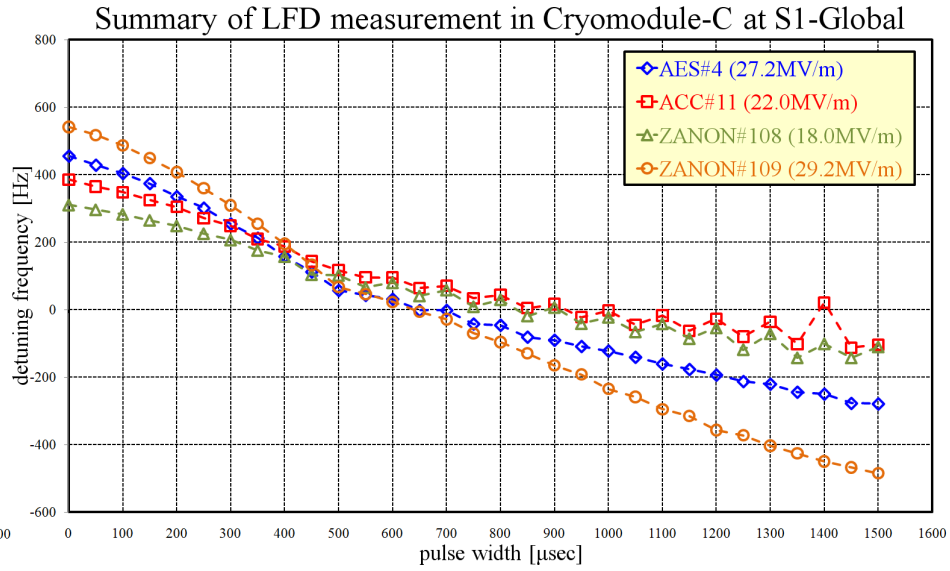


Result of LFD measurement

Cryomodule-A



Cryomodule-C



We can estimate the detuning frequency
for the period of rise-up, flat-top and full-pulse.

$$\Delta f_{\substack{\text{rise-up}\\ \text{flat-top}\\ \text{full-pulse}}} = K_{\substack{\text{rise-up}\\ \text{flat-top}\\ \text{full-pulse}}} \cdot E_{acc}^{2}$$

$K\ [\mathrm{Hz/(MV/m)^2}]$

stiffness parameter

Comparison of Detuning Frequency by LFD

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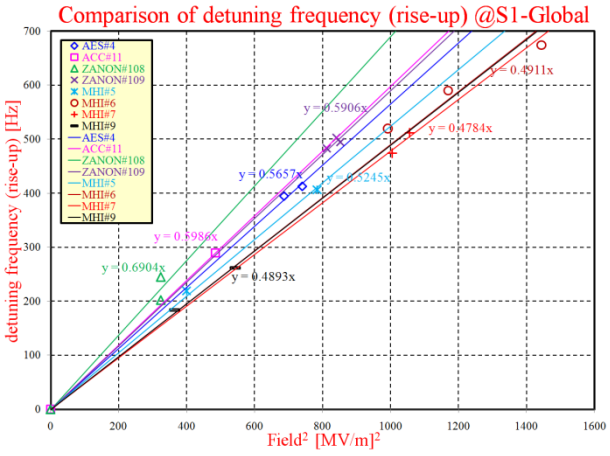

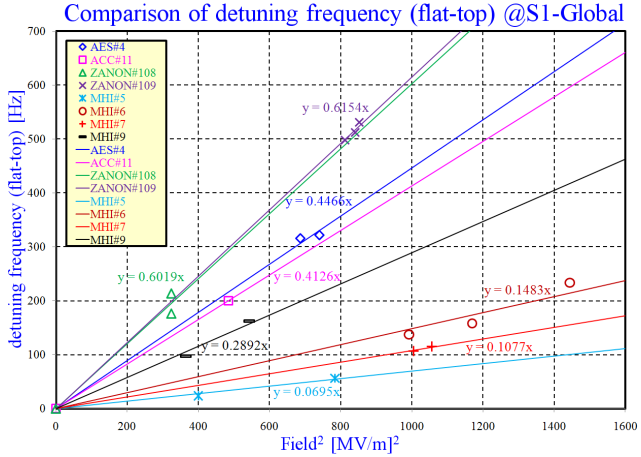

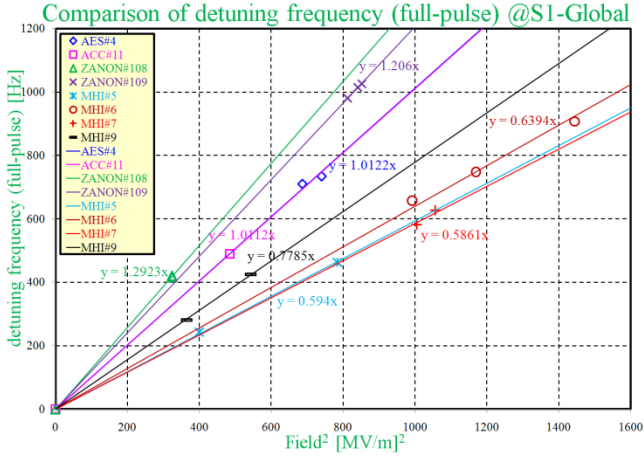

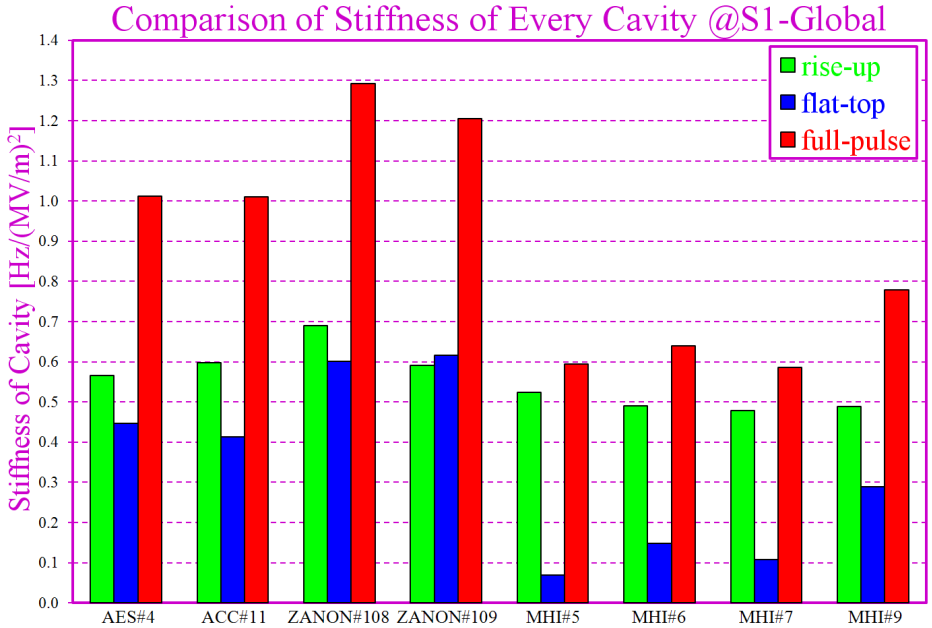

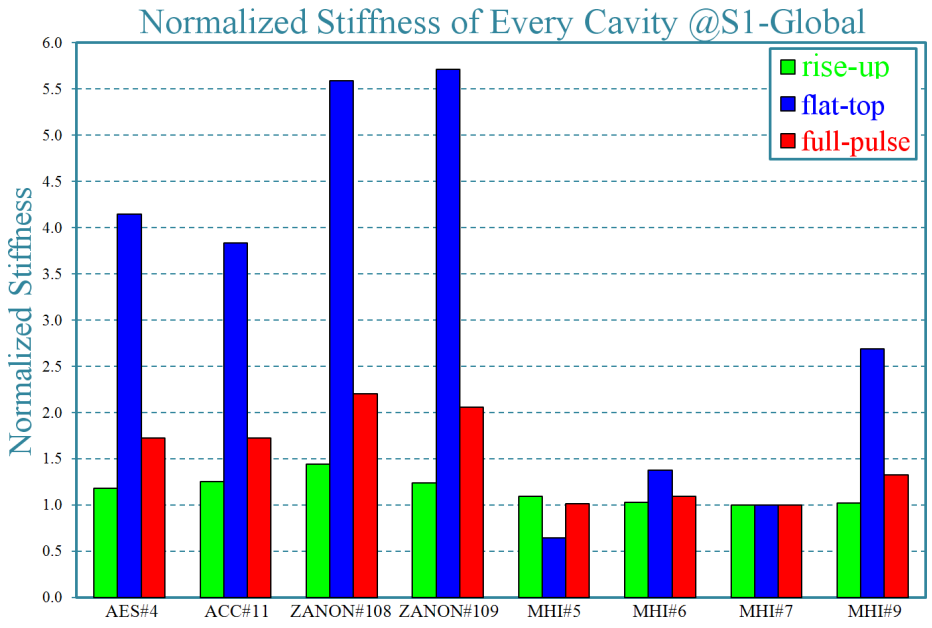

TESLA-like cavity package has a stiffer structure than others!

Parameters of Piezo drive pulse

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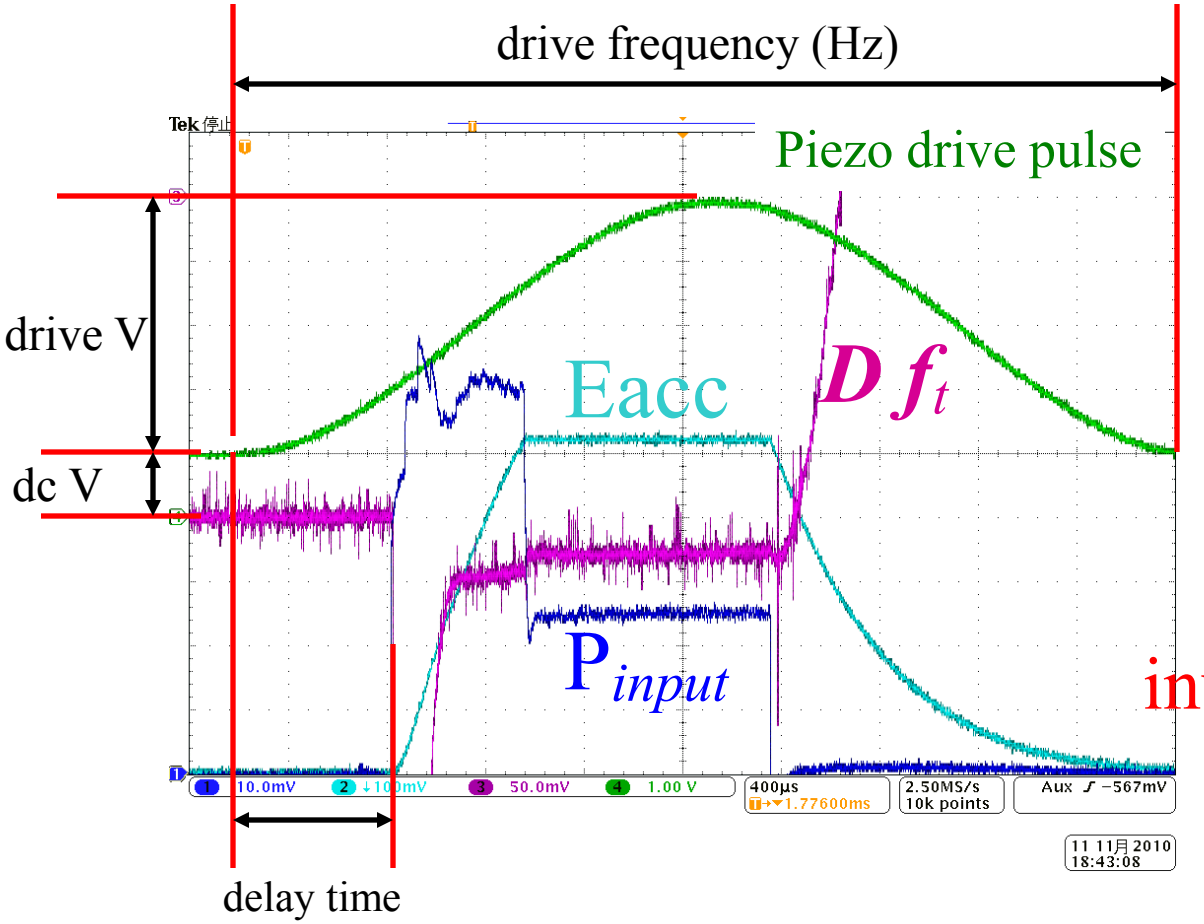
Pre-detuning by motor tuner



control panel

Single pulse of inverse cosine waveform

E. Kako

Result of Piezo Compensation for LFD

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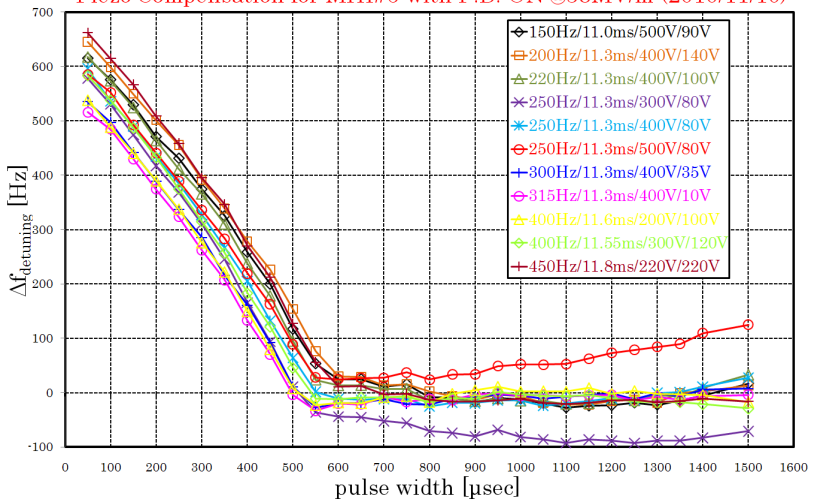
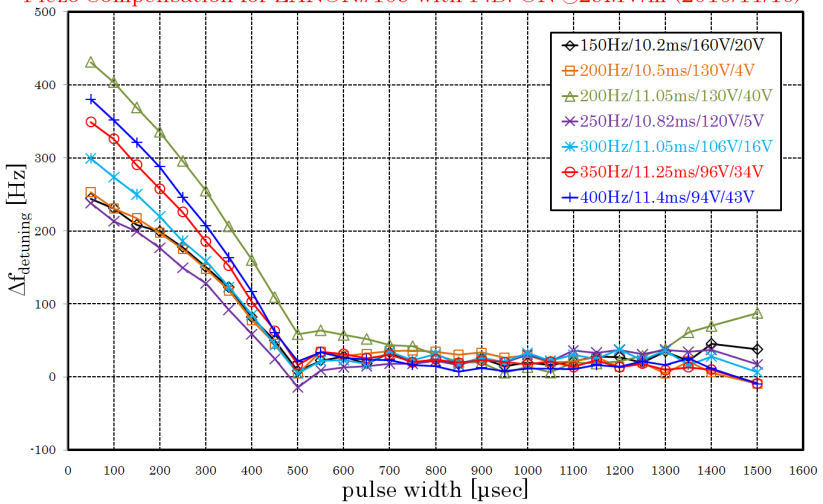
Piezo Compensation for MHI#6 with F.B. ON @38MV/m (2010/11/10)

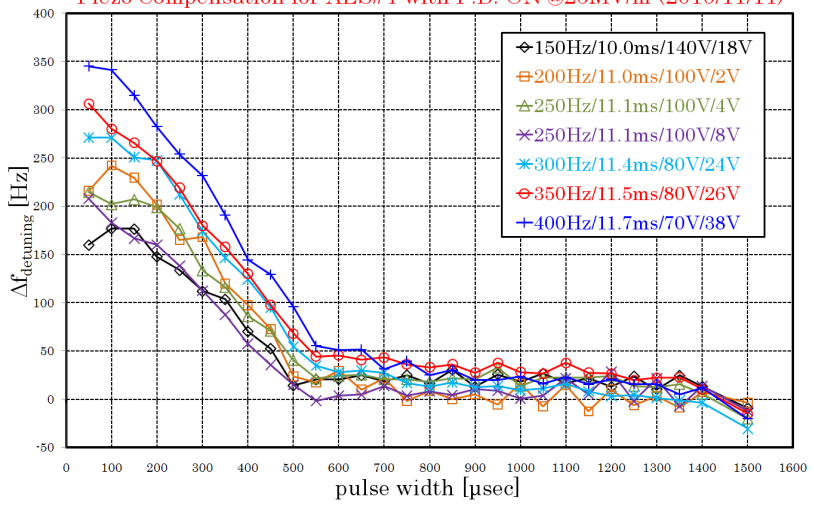


Piezo Compensation for ZANON#109 with F.B. ON @29MV/m (2010/11/10)

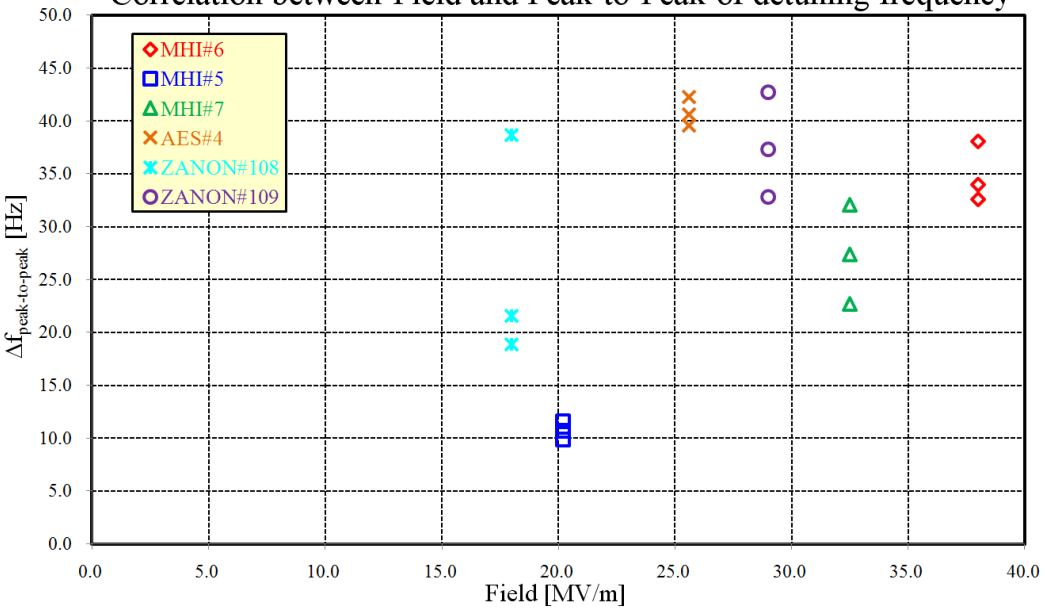


$\updownarrow \Delta f_{peak\text{-}to\text{-}peak}$

Piezo Compensation for AES#4 with F.B. ON @26MV/m (2010/11/11)

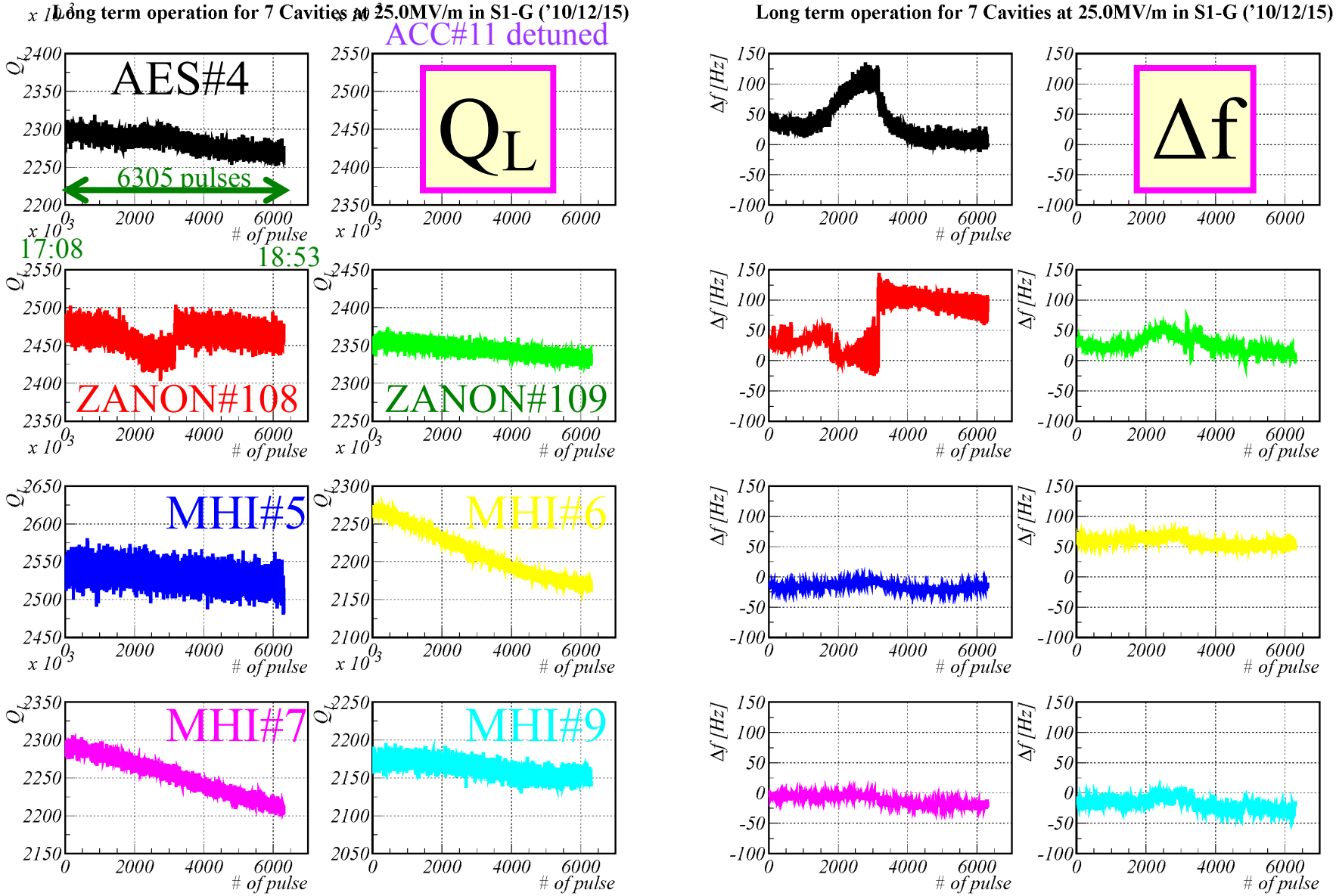


Correlation between Field and Peak-to-Peak of detuning frequency



7 Cavities Operation

superconducting rf test facility

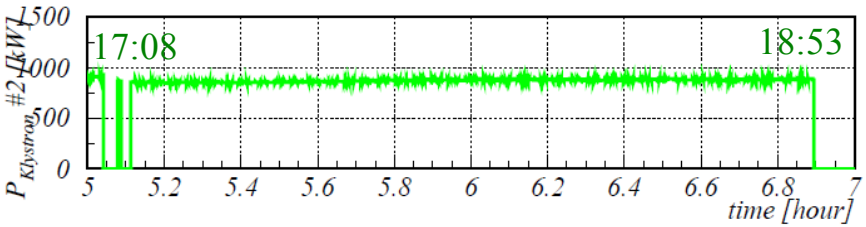


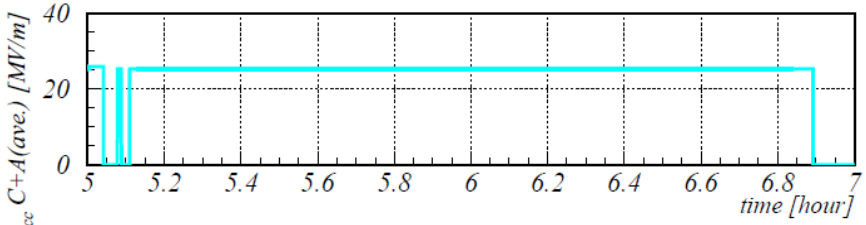
Long term operation for 7 Cavities at 25.0MV/m in S1-G ('10/12/15)

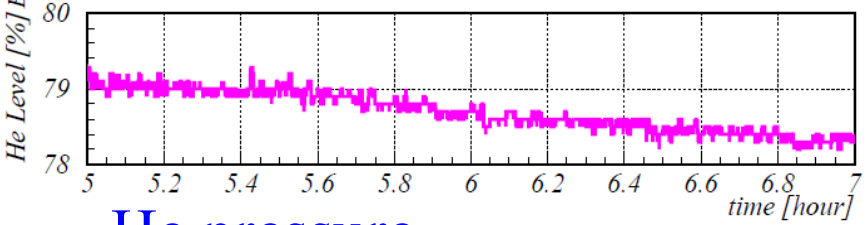
7 Cavities Operation

superconducting rf test facility

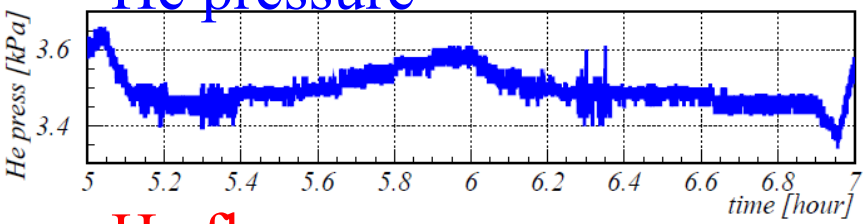
High Power Test in S1-Global ('10/12/15)



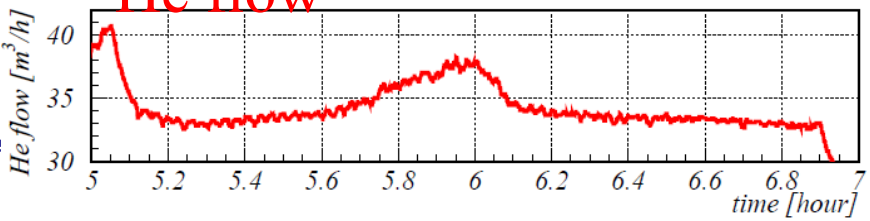




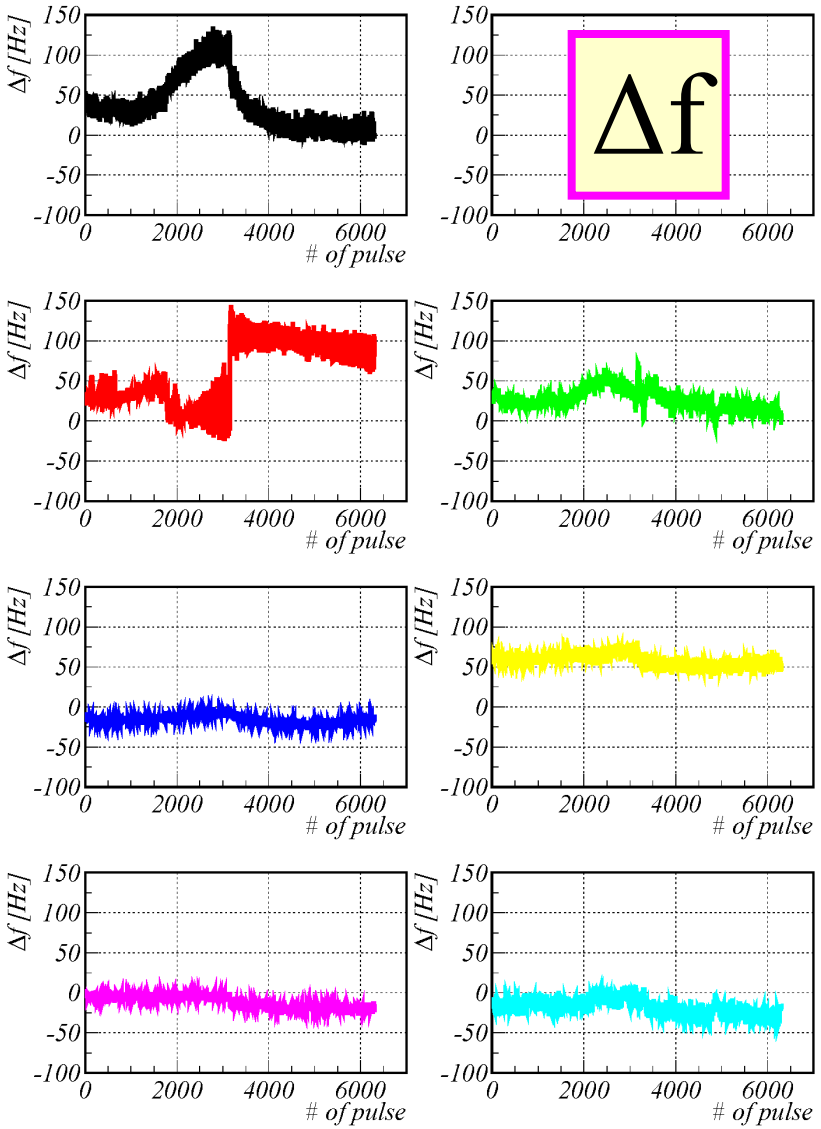
He pressure



He flow

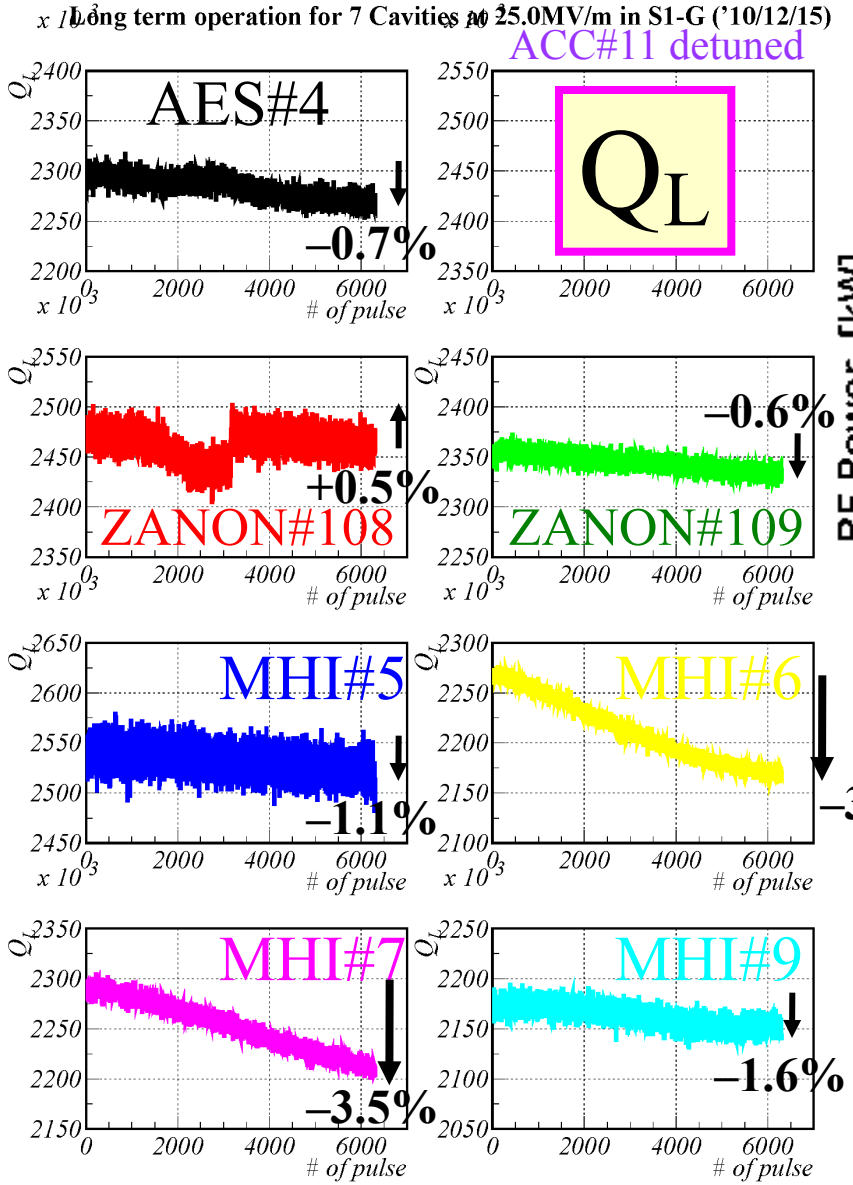


Long term operation for 7 Cavities at 25.0MV/m in S1-G ('10/12/15)

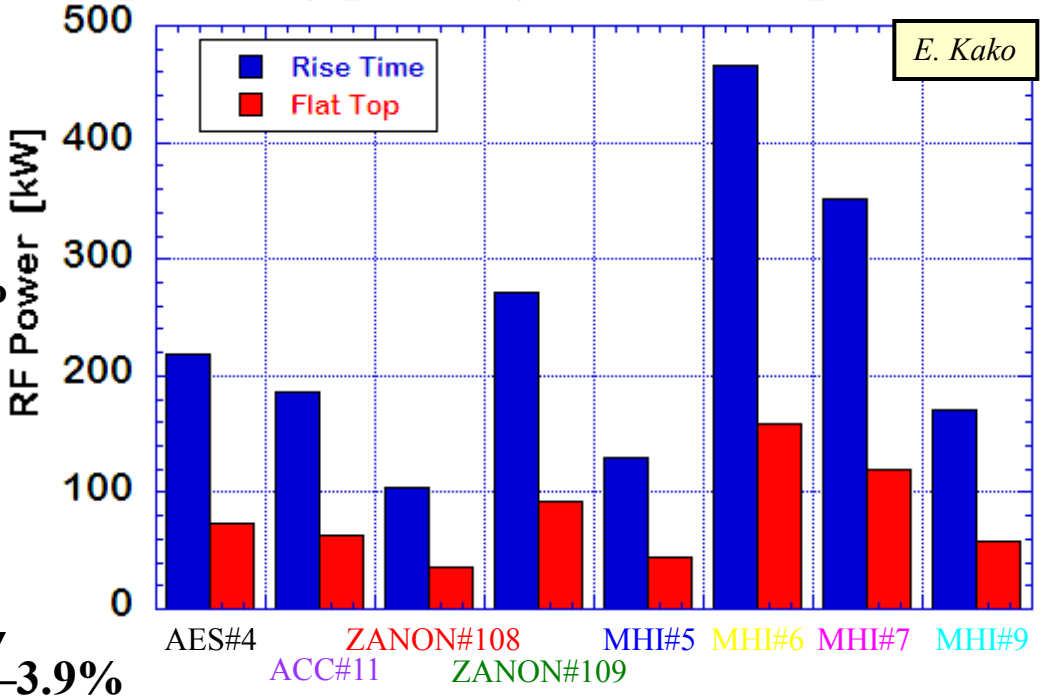


7 Cavities Operation

superconducting rf test facility



Required rf power for 8-cav. operation

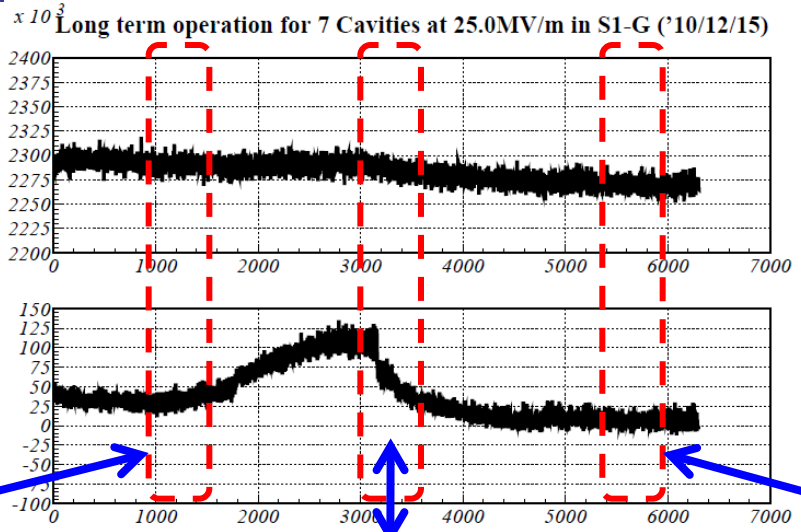


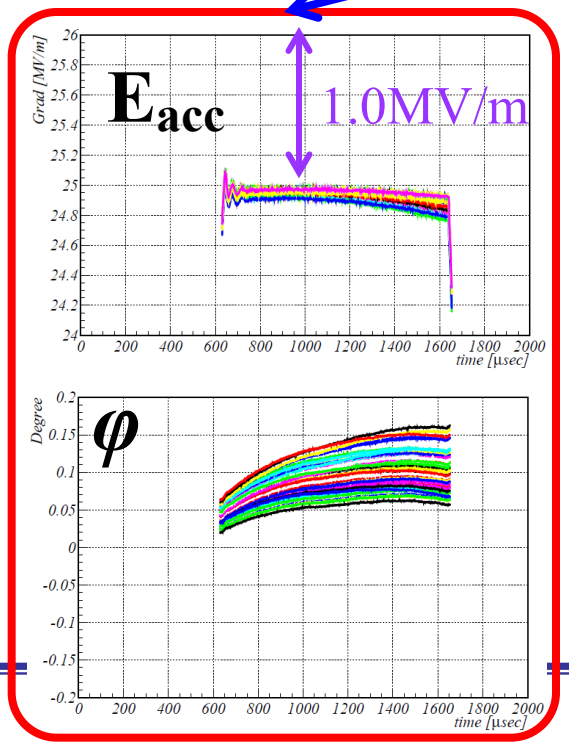
More RF power is necessary for MHI#6 and #7.
This means the inner conductor of the input coupler may be expanded due to the heating.
The couplers lead to more over-coupled situation.

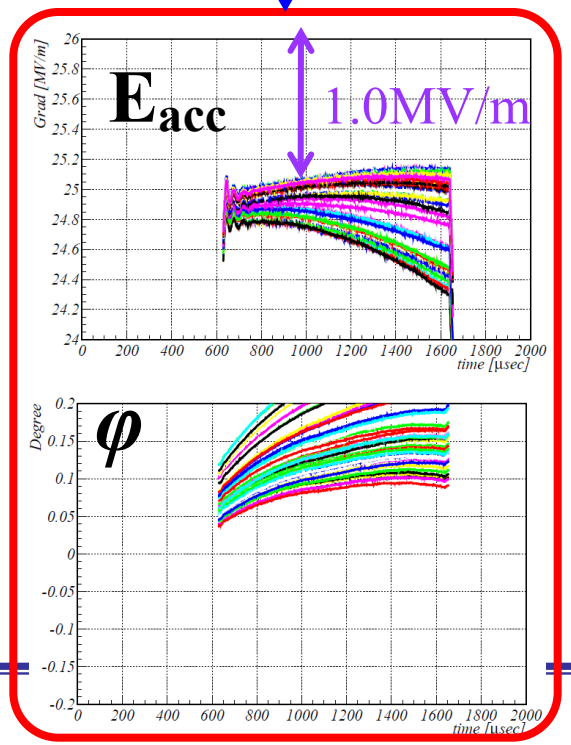
7 Cavities Operation

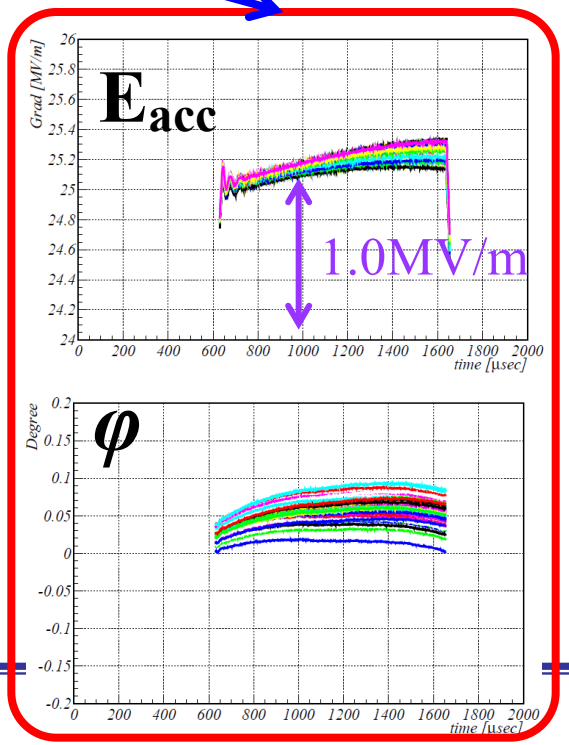
superconducting rf test facility

AES#4









7 Cavities Operation

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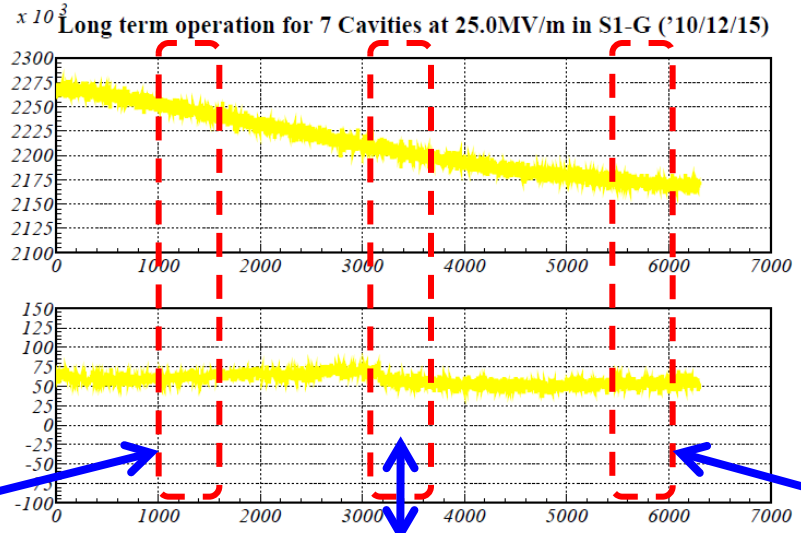
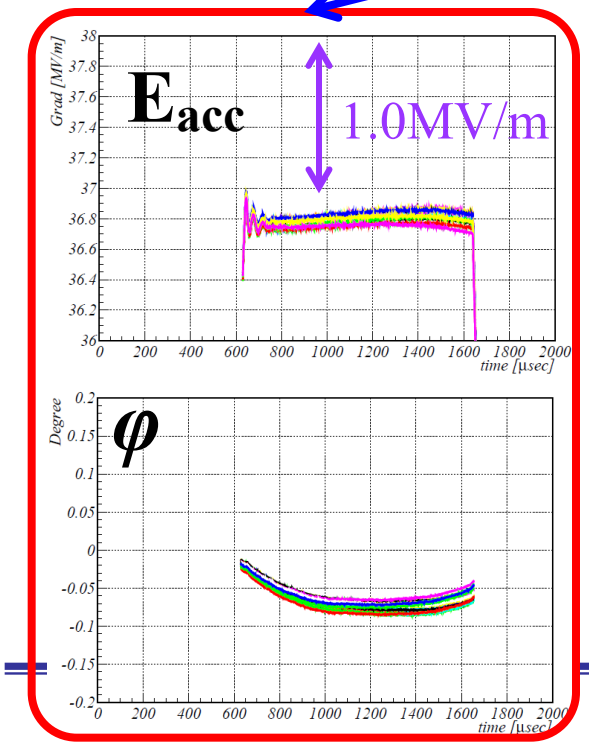
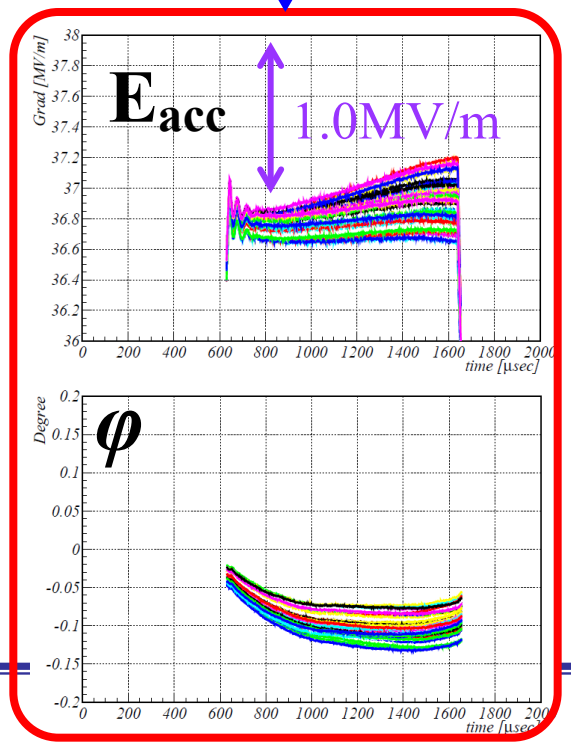
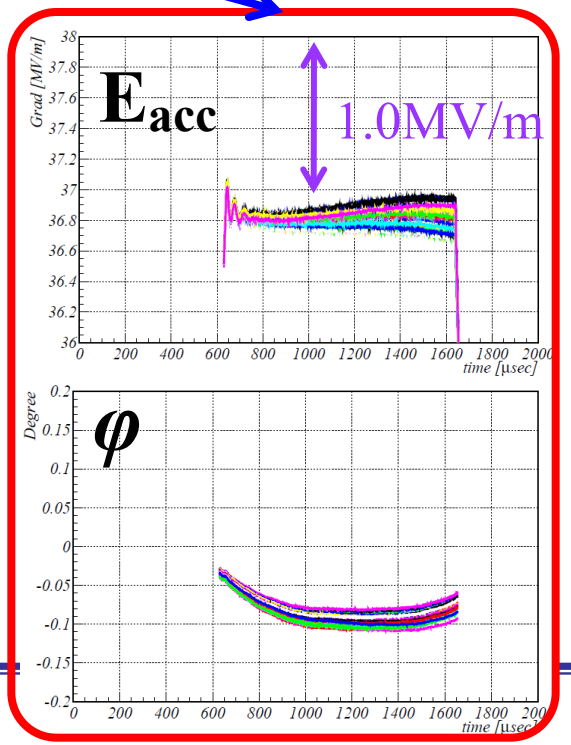
MHI#6









RF response of Quench for MHI#6 @40MV/m

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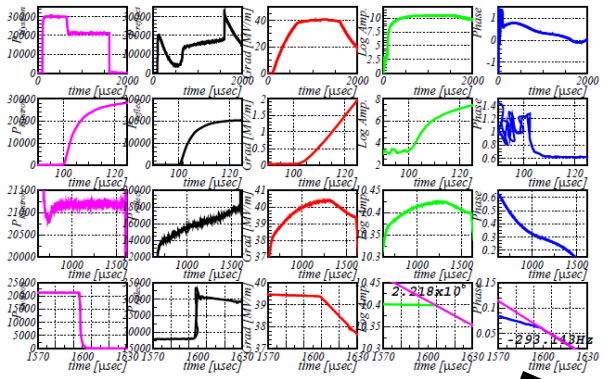
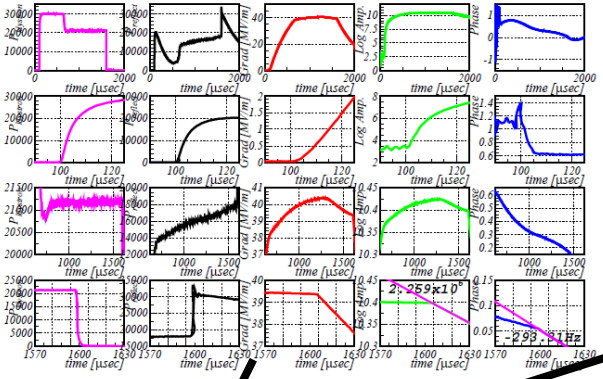
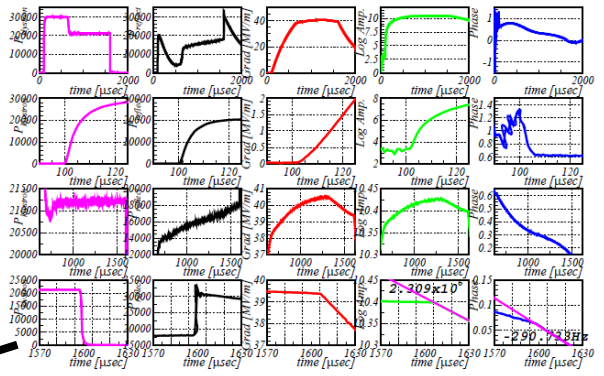
#141 Pulse before Quench for MHI#6 at 40.0MV/m in S1-G ('10/10/13)



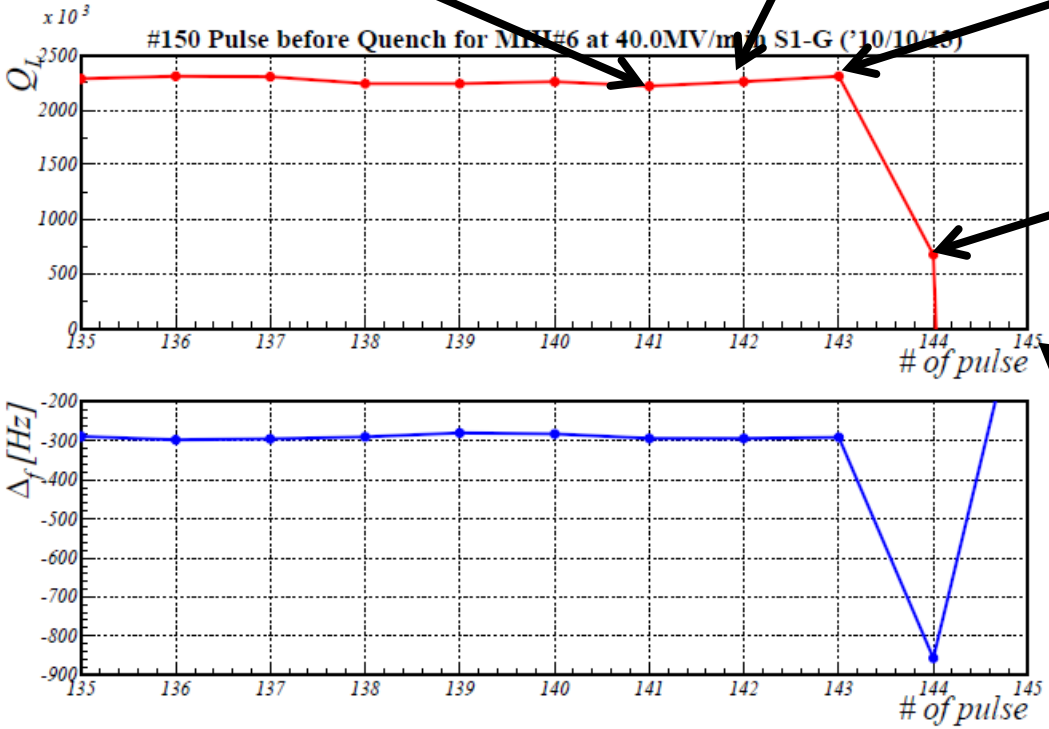
#142 Pulse before Quench for MHI#6 at 40.0MV/m in S1-G ('10/10/13)



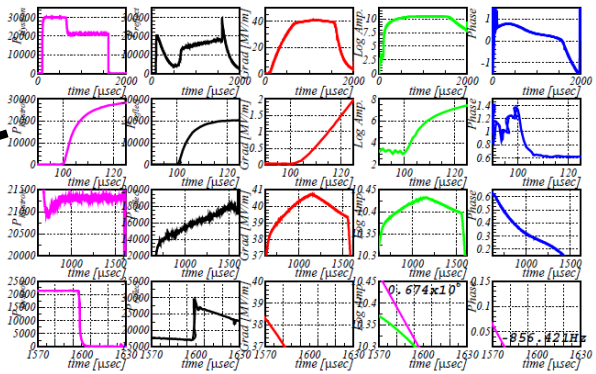
#143 Pulse before Quench for MHI#6 at 40.0MV/m in S1-G ('10/10/13)



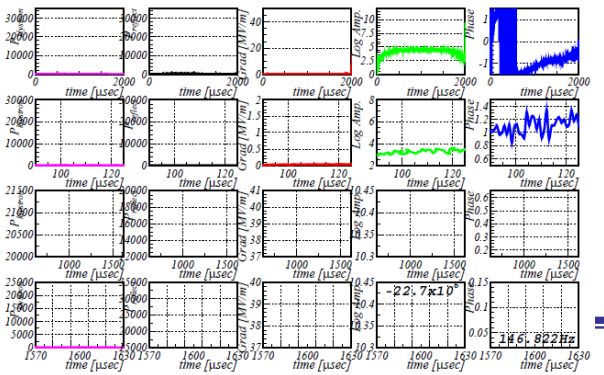
#150 Pulse before Quench for MHI#6 at 40.0MV/m in S1-G ('10/10/13)



#144 Pulse before Quench for MHI#6 at 40.0MV/m in S1-G ('10/10/13)



#145 Pulse before Quench for MHI#6 at 40.0MV/m in S1-G ('10/10/13)

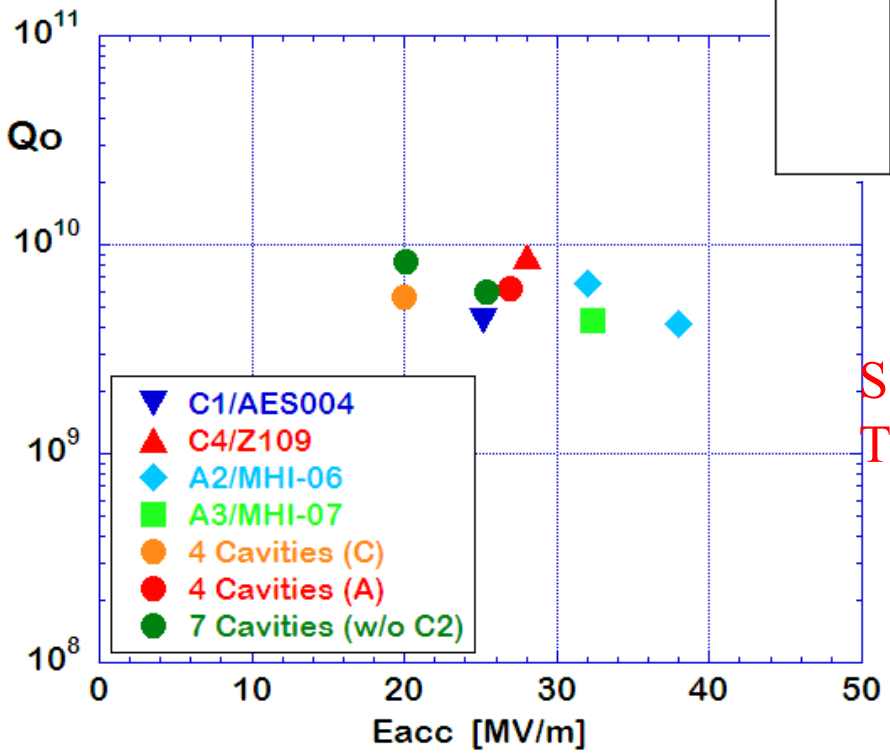


Dynamic Loss measurement

superconducting rf test facility

Summary of dynamic loss measurements

	C-4 Z109	C-1 AES004	A-3 MHI07	A-2 MHI06	A-2 MHI06	4 C Cavities	4 A Cavities	4 C Cavities	4 A Cavities	7 Cavities	7 Cavities
Date	Nov. 17	Nov. 19	Nov. 23	Nov. 24	Nov. 25	Nov. 26	Nov. 30	Dec. 2	Dec. 3	Dec. 9	Dec. 10
Gradient [MV/m]	28	25.2	32.3	38	32	32 Detune	32 Detune	20 .0 Average	26.9 Average	25.4 Average	20.4 Average
Q_D, W	0.84	1.4	2.8	4.8	2.6			2.7	6.9	9.6	4.8
$Q_{D\text{-}det}$, W	0.09	0.18	0.7	1.8	1.2	0.5	4.6	0.2	2.5	2.6	1.6
$Q_{D\text{-}cav}$, W	0.8	1.3	2.0	2.9	1.3			2.5	4.4	7.0	3.2
Q_0	8.8E9	4.3E9	4.3E9	4.2E9	6.5E9						
								C1=22.2 C2=18.9 C3=14.9 C4=24.3	A1=15.8 A2=37.6 A3=32.9 A4=21.4	C1=25.2 C2=NA C3=17.6 C4=28.8 A1=15.3 A2=37.4 A3=32.4 A4=20.9	C1=20.1 C2=NA C3=14.1 C4=23.0 A1=12.3 A2=30.4 A3=26.0 A4=16.7

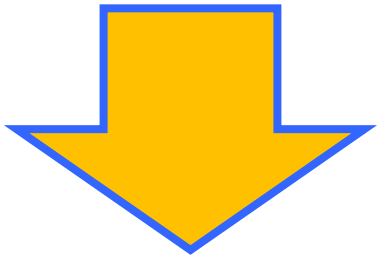


STF-II coupler has more heat loss than TTF-III.
This point should be improved in the near future.

Troubles

- ✓ The performance of the two cavities dropped between V.T. and C.T.

- ✓ The tuners of the two cavities did not work at 2K.



These problems are investigated in the near future.

Summary

- Assembly work by the S1-Global team was successful.
- 6 of 8 cavities reached the almost same gradient at the cryomodule test as the vertical test.
- Mechanical vibration modes were found to vary from cavity to cavity.
- LFD measurement was successful. MHI cavity turned out to be stiffer.
- Compensation by piezo was successful. All types of the tuners tested have demonstrated good effectiveness.
- Simultaneous operation of seven cavities was comparatively stable. The Q_L decreased gradually during the operation for every power coupler.
- From the results of the dynamic loss measurement, it was observed the STF-II coupler has a larger heat loss.
- Communication among the international members of the S1-Global team worked well.

Thank you for your attention.