S1-Global Module Tests at STF/KEK

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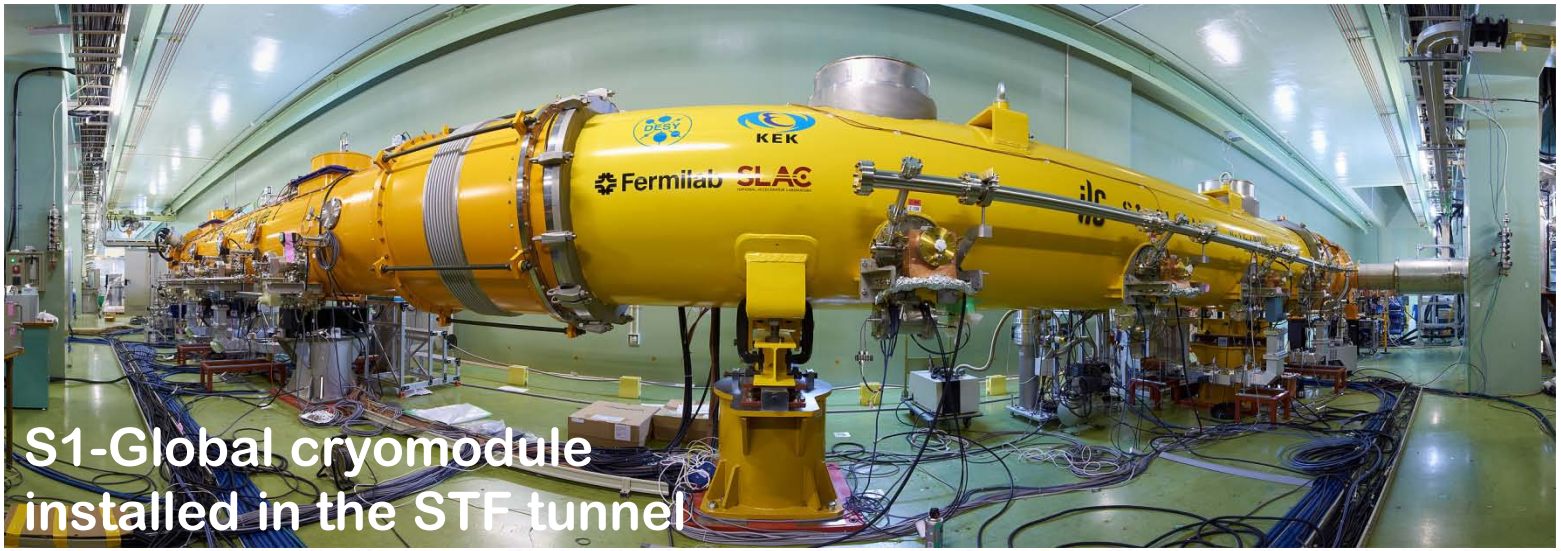
Outline

- Introduction
- Cavity high-gradient performance
- Multiple-cavities operation by one klystron
- Lorenz detuning and compensation
- Qo values measured by dynamic losses



S1-Global cryomodule installed in the STF tunnel

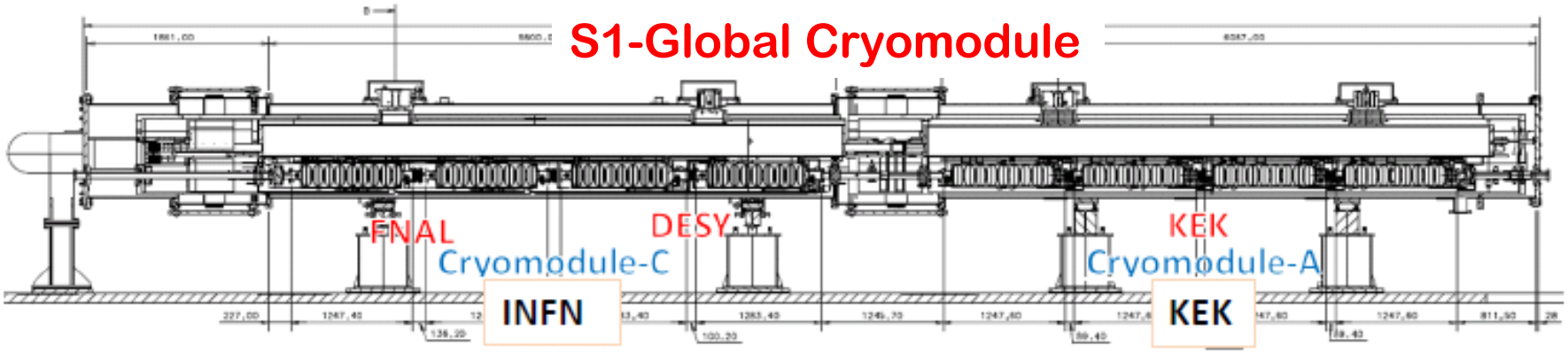
Contributions to IPAC11 on S1-Global

Poster Presentation

1. "Thermal performance of the S1-Global cryomodule for ILC",
   N. Ohuchi, *et al.*, WEPO035.
2. "Tuner performance in the S1-Global cryomodule",
   R. Paparella, *et al.*, MOPC090.
3. "Performance of the LLRF system at S1-Global in KEK",
   S. Michizono, *et al.*, MOPC157.
4. "Operation test of DRFS with circulator-less waveguide distribution in S1-Global project at STF/KEK",
   T. Matsumoto, *et al.*, MOPC156.
5. "Performance of the micro-TCA digital feedback board for DRFS test at KEK-STF", T. Miura, *et al.*, MOPC155.

What is S1-Global ?

S1-Global Cryomodule



C1	C2	C3	C4	A1	A2	A3	A4
AES004	ACC011	Z108	Z109	MHI-05	MHI-06	MHI-07	MHI-09
FNAL cavity		DESY cavity		KEK cavity			

R & D Program for ILC

S0 : Cavity performance
S1 : Cryomodule operation
S2 : Beam acceleration tests by 1 RF unit

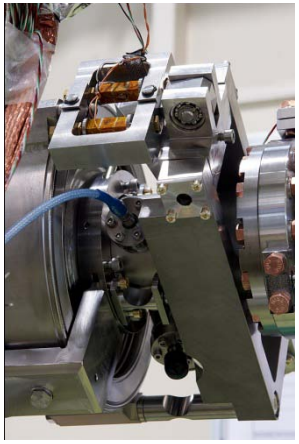
Planned research subjects in S1-Global

1. Operation at ave. Eacc of 31.5 MV/m (5Hz, 1ms), stability (amp. < 0.07% rms, phase < 0.24°).
2. Experience in design, assembly, alignment.
3. Comparative studies of cavity package.
4. Comparison of heat loads in static and dynamic.
5. Plug-compatible concept for ILC.

Cavities, Tuners, Couplers in S1-G Cryomodule

TESLA Cavity (DESY/FNAL)

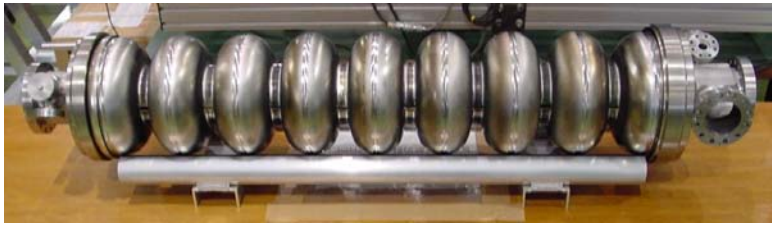
Blade Tuner (FNAL)



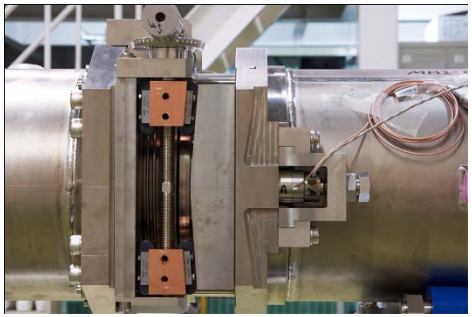
Saclay Tuner (DESY)

TTF-III Coupler (DESY/FNAL)

Comparative studies of performance



Tesla-like Cavity (KEK)

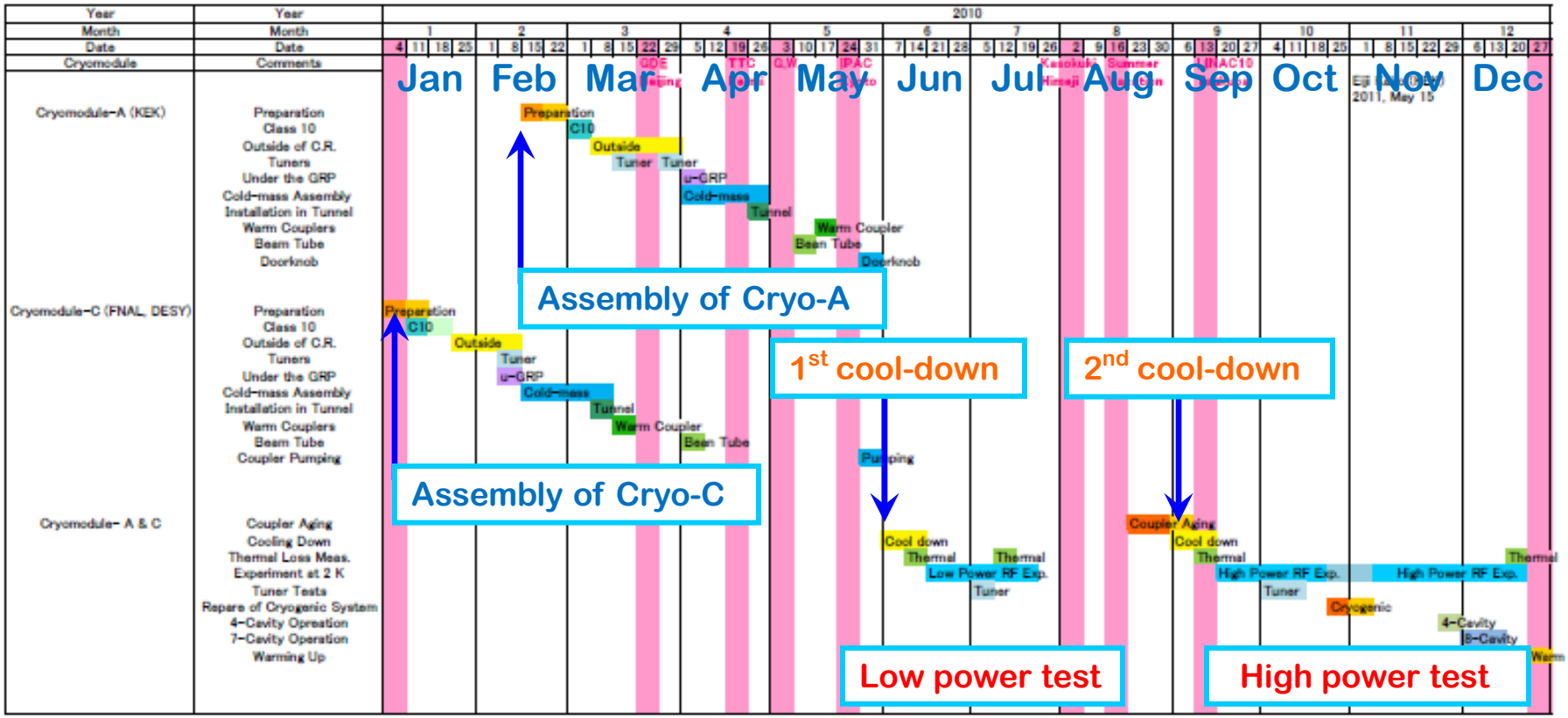


Slide-Jack Tuner (KEK)

STF-II Coupler (KEK)

Schedule of S1-Global Module Tests

CY-2010

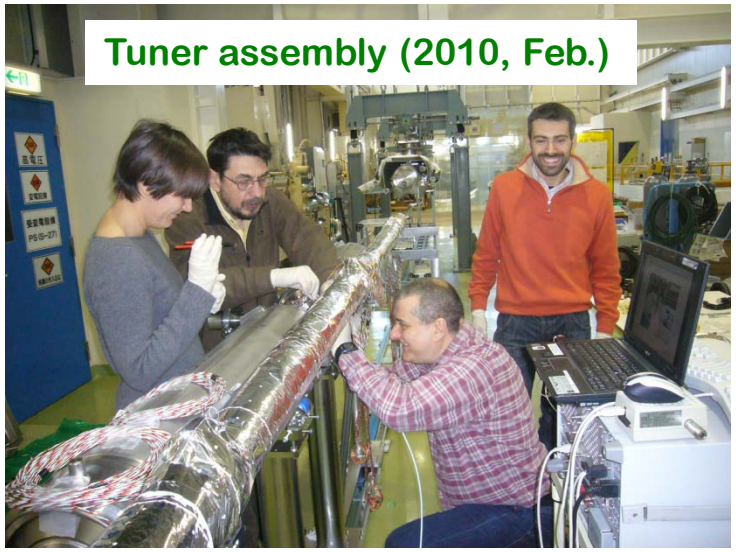


3rd cool-down 2011, Jan. – Feb.

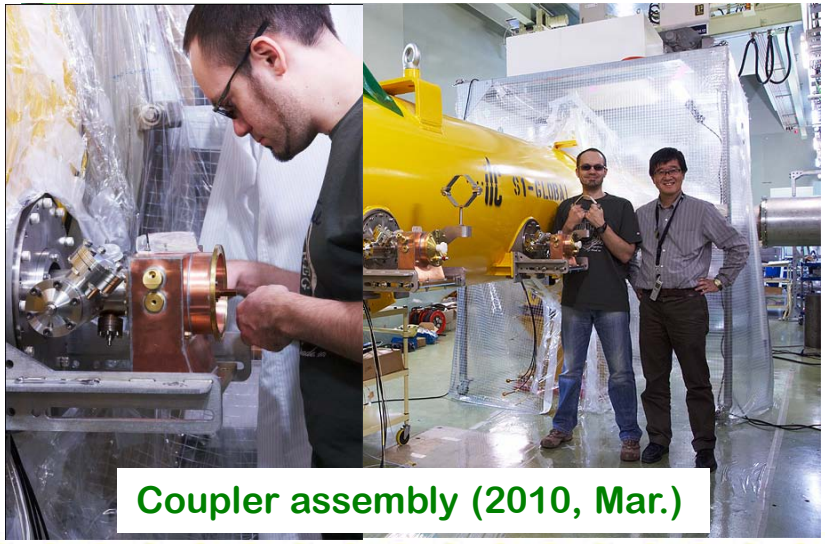
Test of Distributed RF Scheme (DRFS)

Collaborative work for Cryomodule Assembly

Cavity string assembly (2010, Jan.)



Tuner assembly (2010, Feb.)

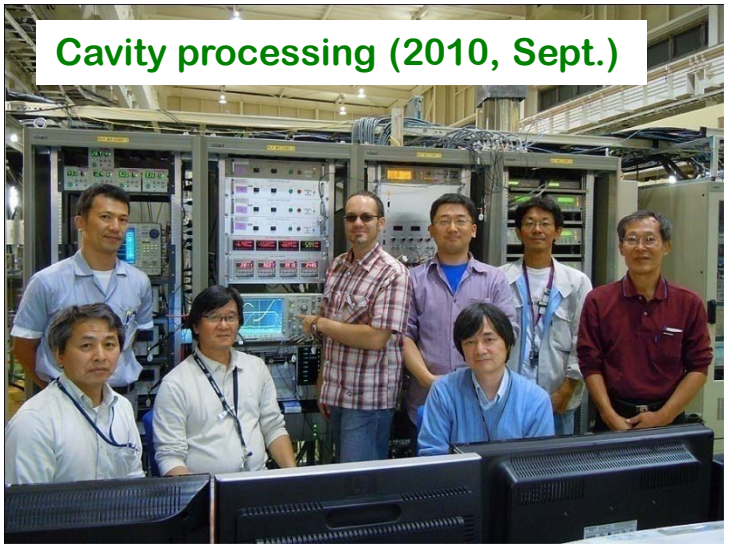


Coupler assembly (2010, Mar.)

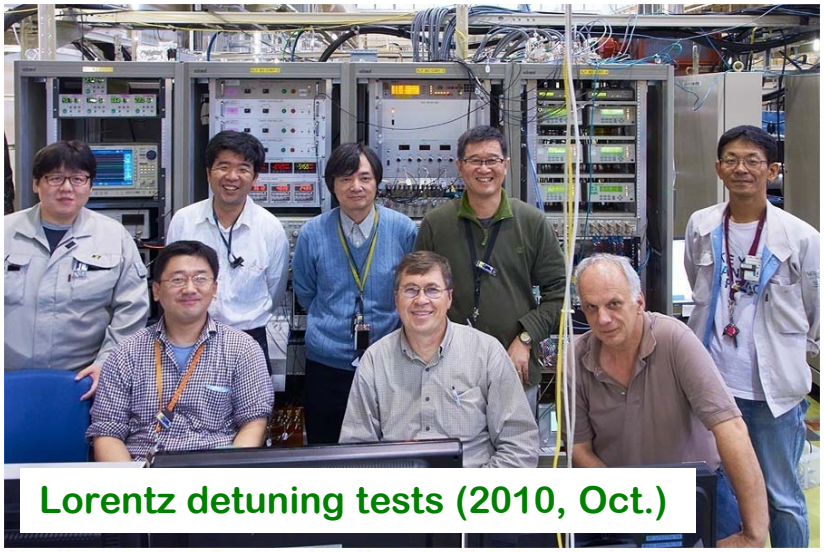
KEK Cavity string assembly (2010, Mar.)

Collaboration for Cryomodule Tests

Tuner performance tests (2010, July)



Cavity processing (2010, Sept.)

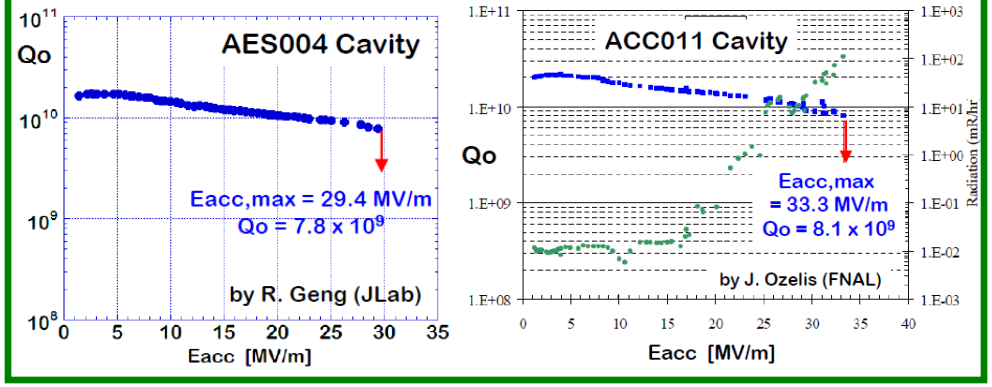


Lorentz detuning tests (2010, Oct.)

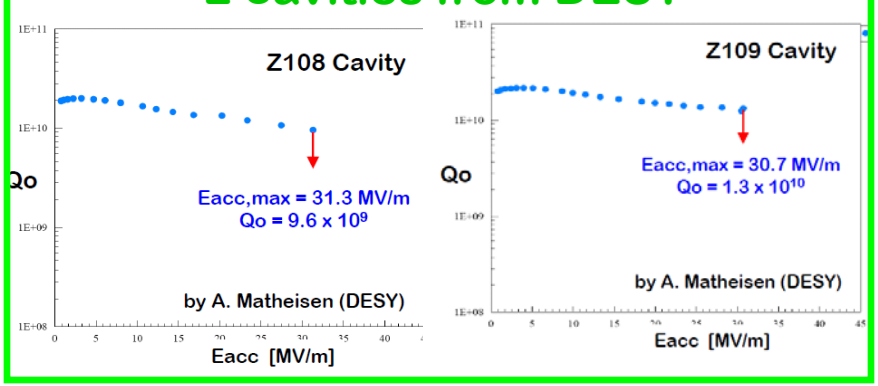
Dynamic loss meas. (2010, Nov.)

Vertical Test Results of 8 Cavities

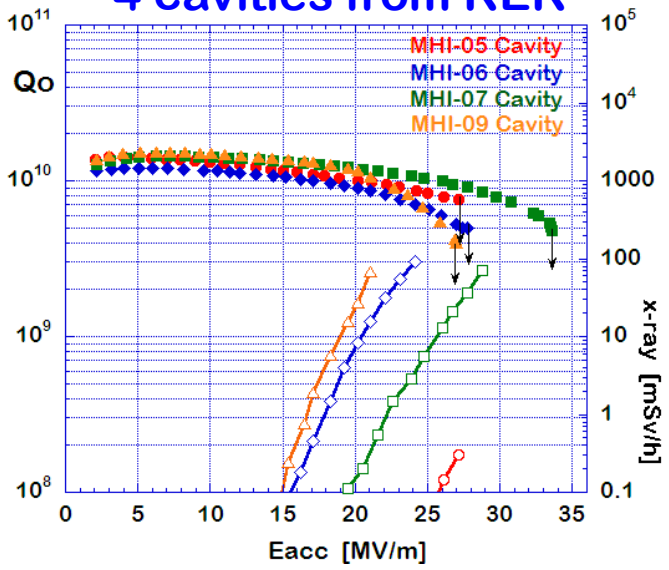
2 cavities from FNAL



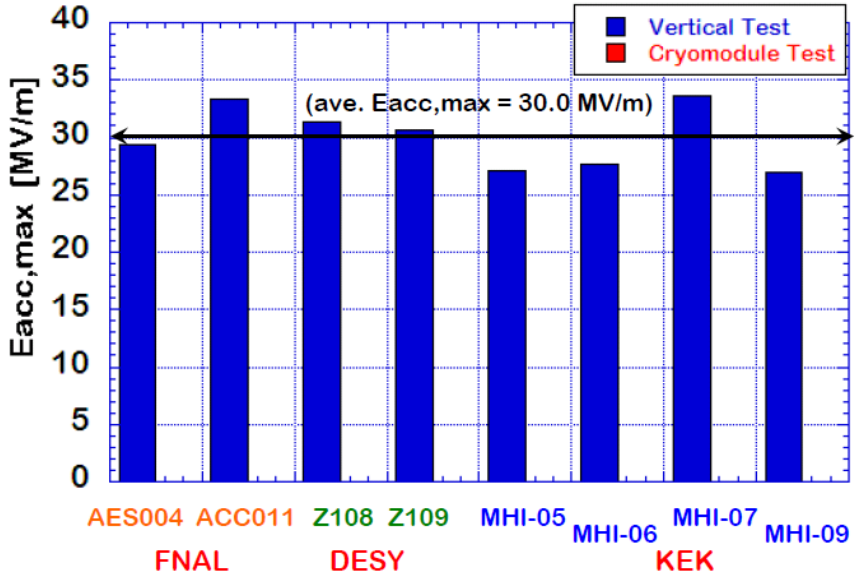
2 cavities from DESY



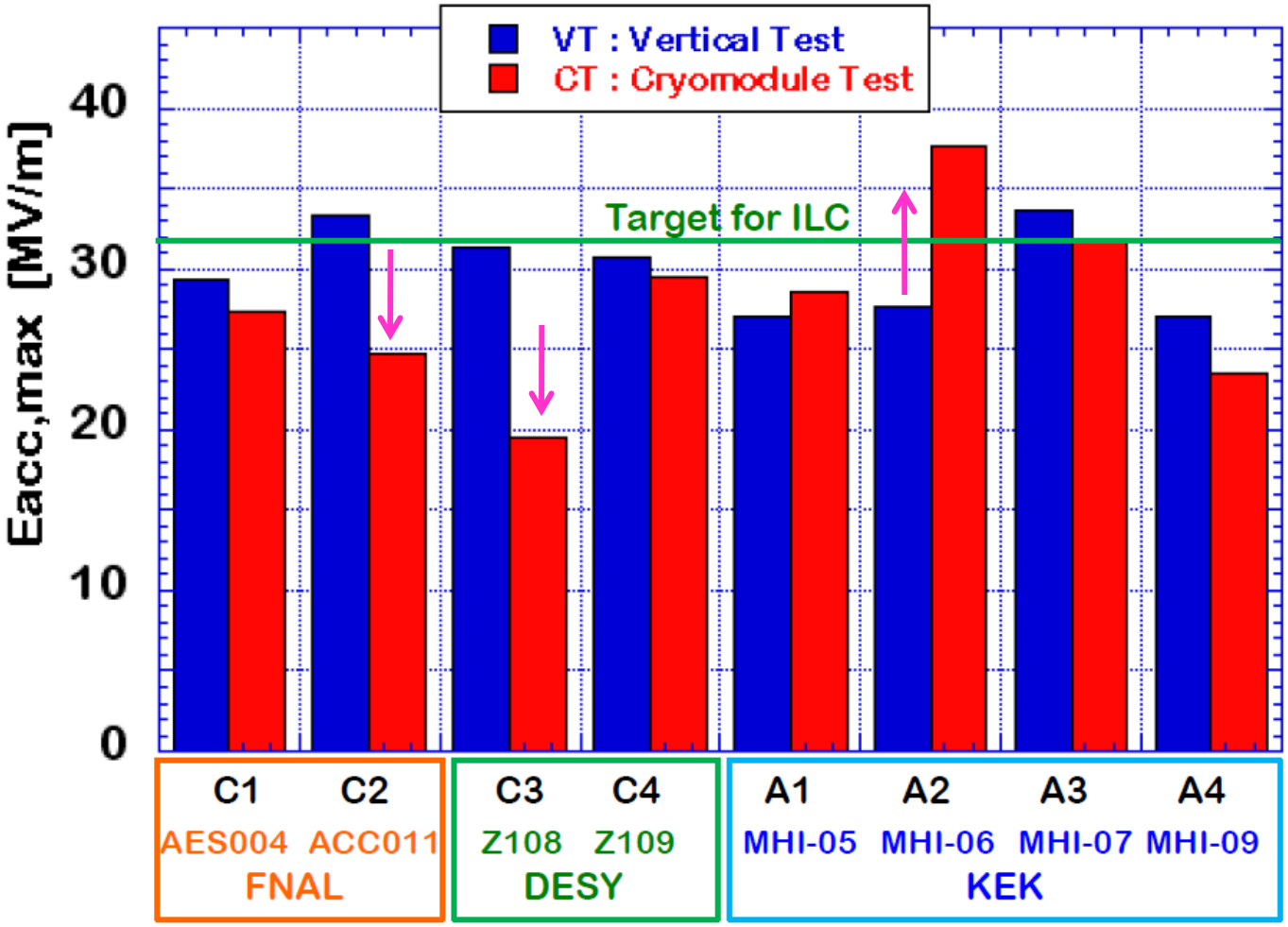
4 cavities from KEK



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



Comparison of cavity performance

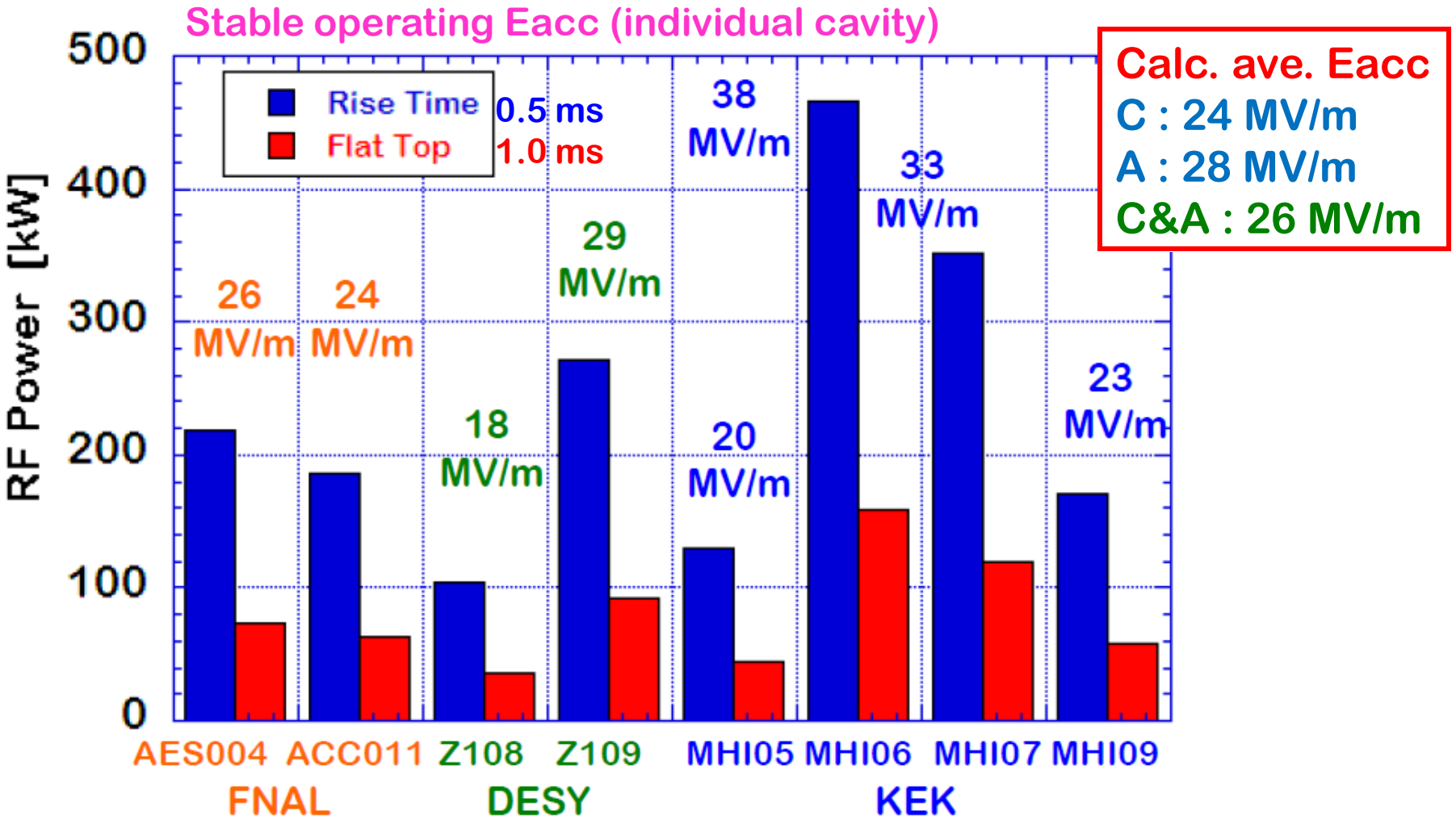


ave. Eacc,max
VT : 30.0 MV/m
CT : 27.8 MV/m
(1-cavity operation)

Reduction
by 7% from VT

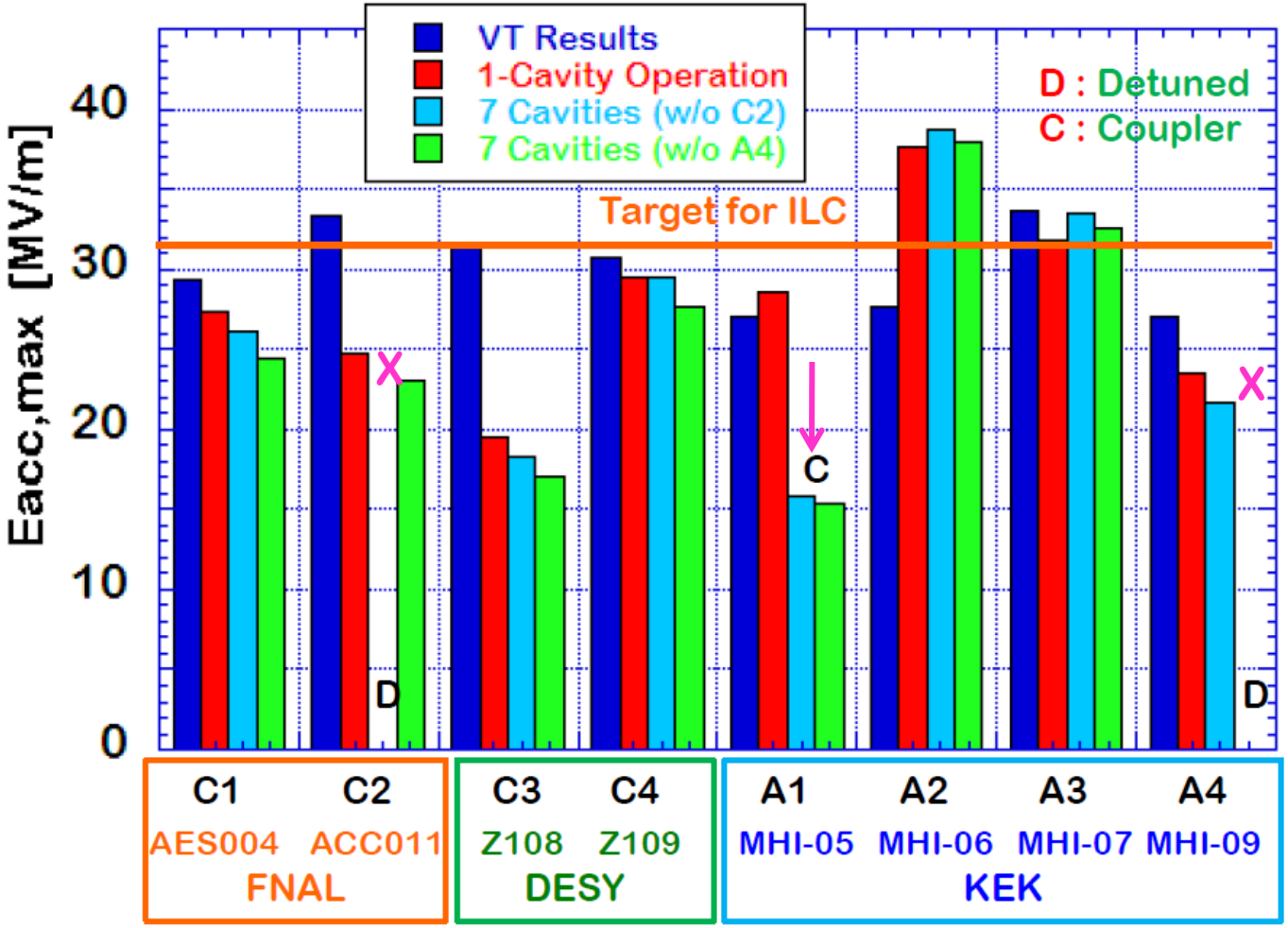
Significant degradation of the cavity performance was observed in two cavities, (C2 & C3).
Conditioning at high-power & short-pulse operation may have facilitated the improvement, (A2).

Required RF power for 8-cavity operation



Individual cavities have different max. gradient performance. Input RF power to cavities was adjusted accordingly with variable power dividers to distribute the RF power from 5-MW Kly.

Simultaneous multiple cavities operation



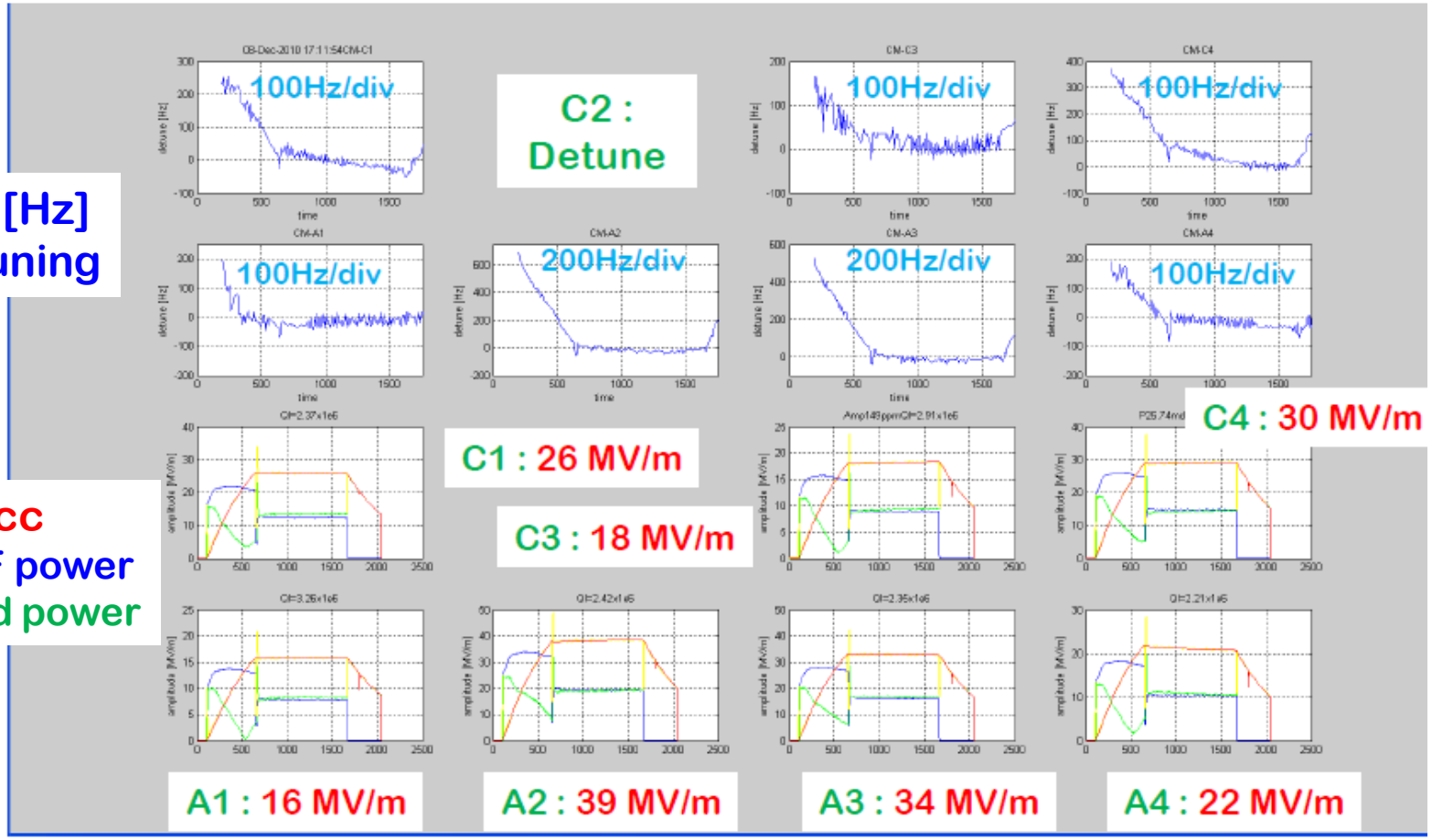
ave. Eacc,max
VT : 30.0 MV/m
1 cav : 27.8 MV/m
7 cav : 26.2 MV/m
7 cav : 25.4 MV/m

Reduction by 13% from VT

Simultaneous operation of 8 cavities was not possible, because slow frequency tuners of two cavities (C2 & A4) got stuck. Deterioration of vacuum pressure was occurred in the A1 coupler.

7-cavity operation in Cryomodule-C&A

Ave. Eacc = 26.2 MV/m ; FB /on, Piezo /on, fo = 1299.900 MHz

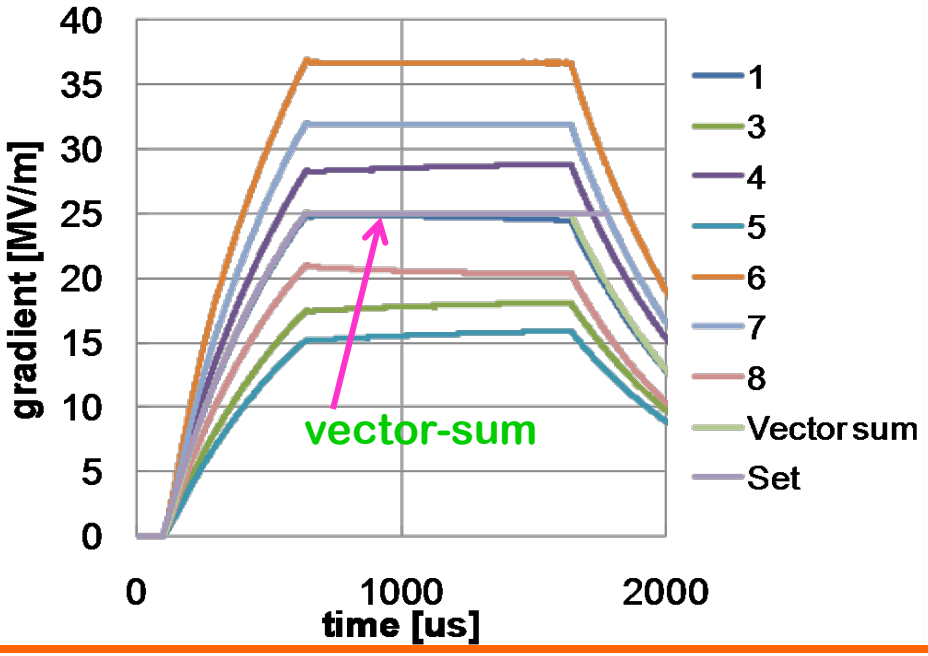


LLRF feedback based on a vector-sum control and dynamic compensation of Lorentz force detuning by a piezo tuner was successfully demonstrated in stable operation of 7-cavities.

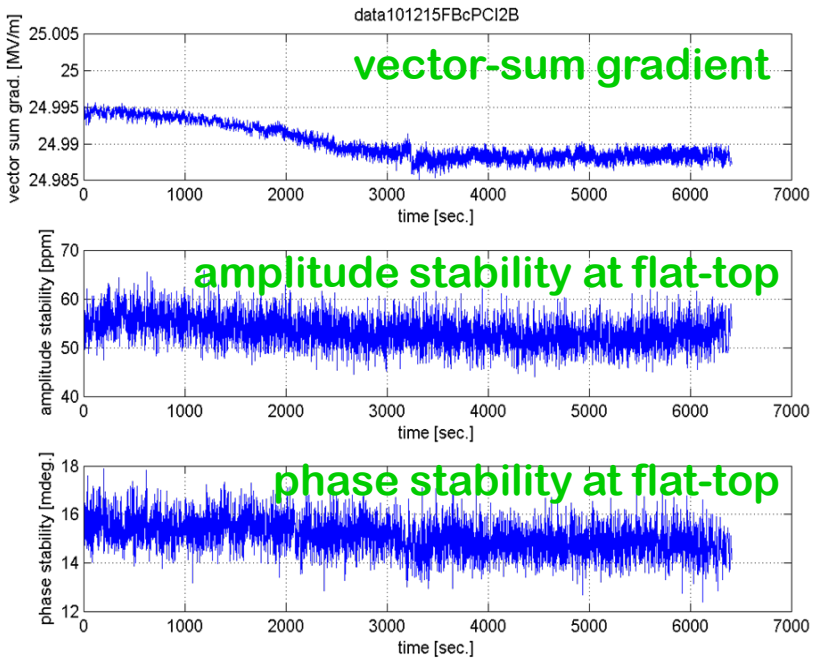
7-cavity operation in Cryomodule-C&A

LLRF-study with 7 cavities operation at 25MV/m.

Field Waveform of each cavity



Stability in 6300 sec (1.8 h).



ILC specification :
< 0.07% amplitude
< 0.24° phase

Vector-sum stability : 24.995 MV/m ~ 24.988 MV/m, (~0.03%)
Amplitude stability at flat-top : < 0.005% rms
Phase stability at flat-top : < 0.017°

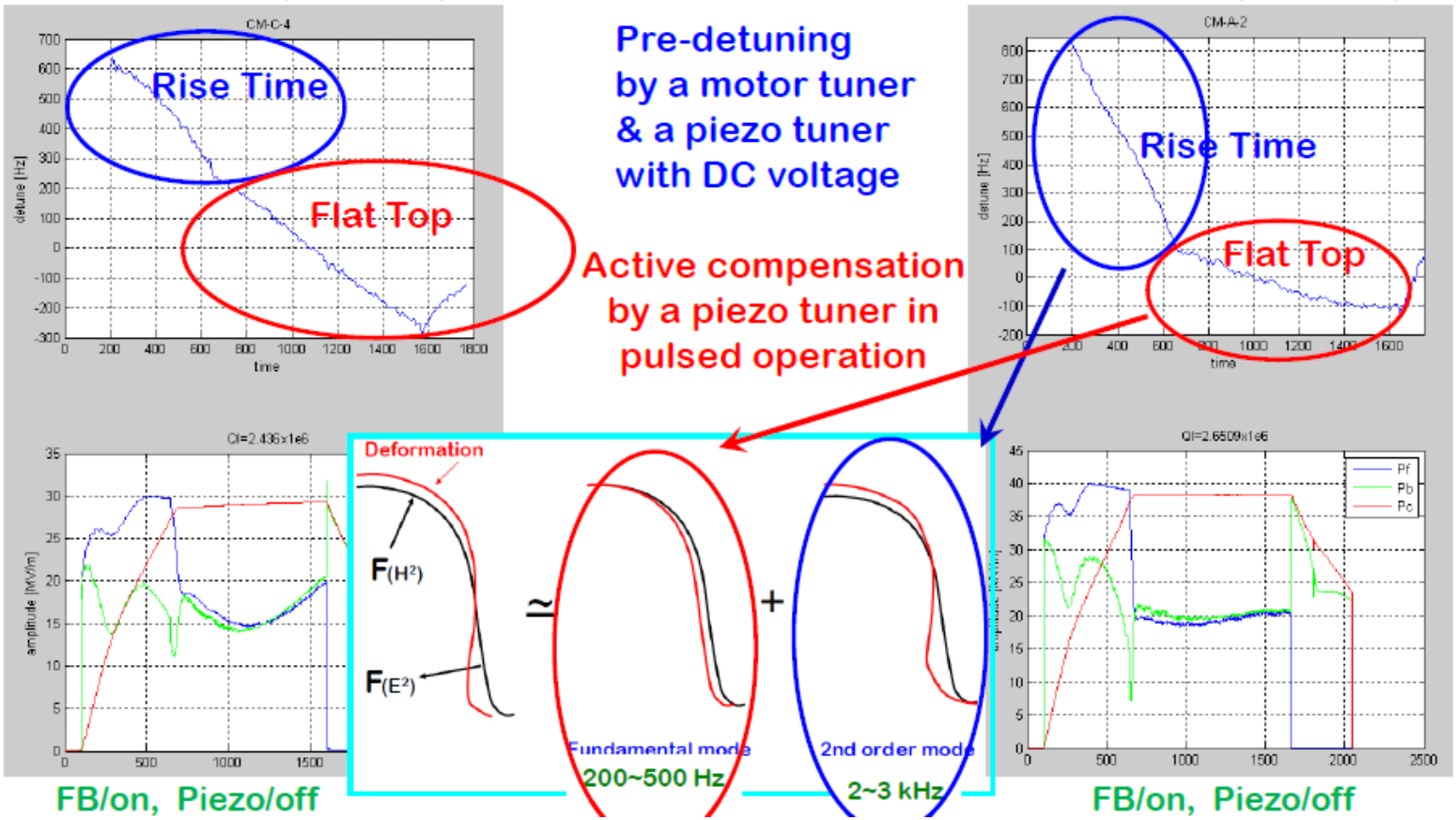
Frequency shift due to Lorentz detuning

C4/Z109 (29MV/m)

A2/MHI-06 (38MV/m)

Δf [Hz] detuning

Eacc
P-input
P-reflect



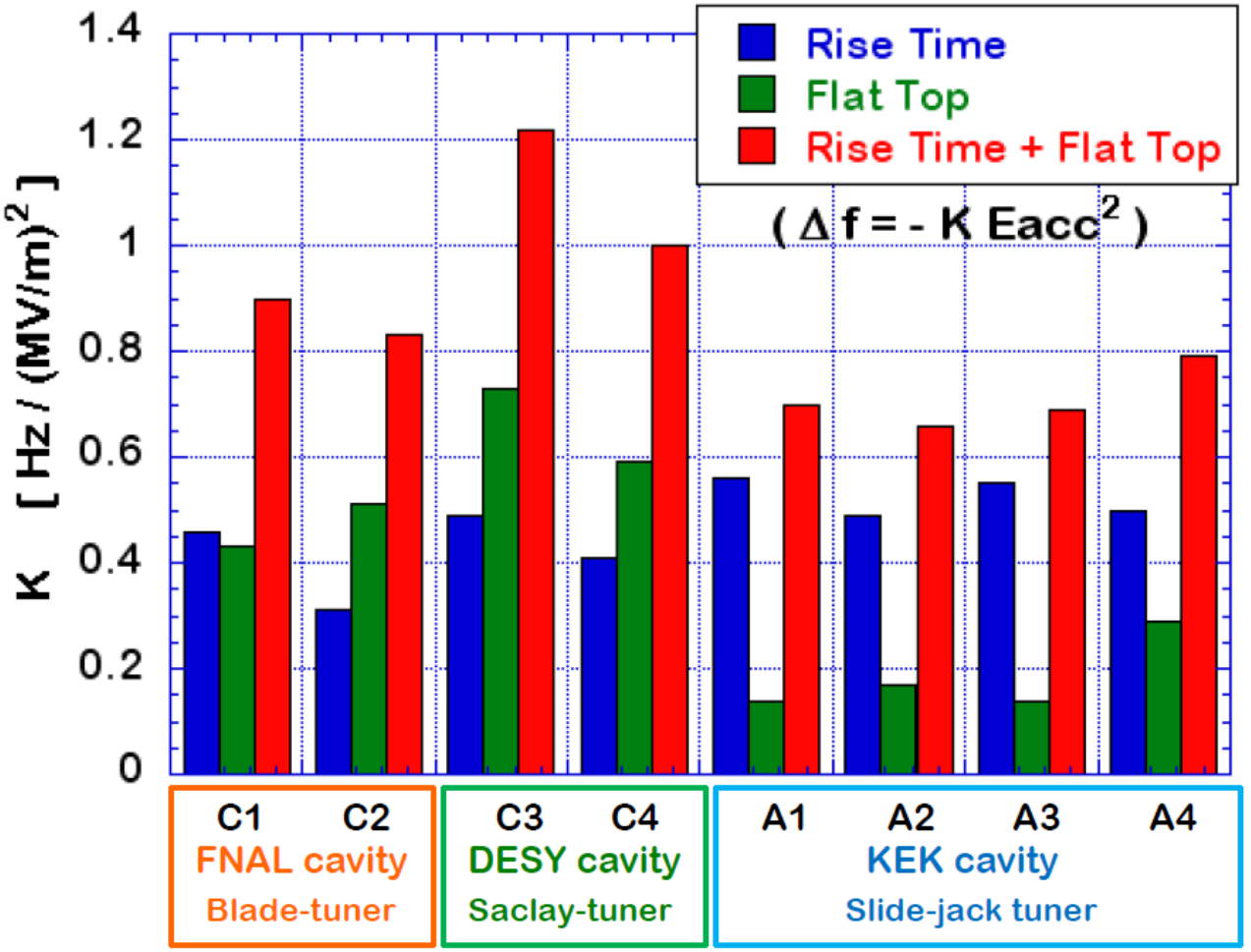
Deformation of cell-shape by Lorentz force consists of mainly two components.

Change of axial cell-length (ΔL)

No change of axial cell-length

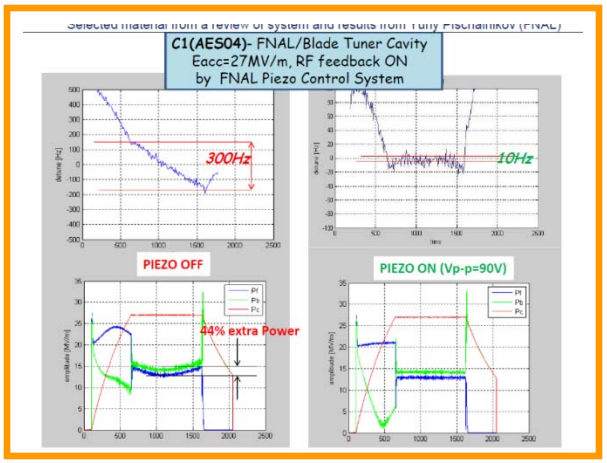
Comparison of Detuning Frequency by LFD

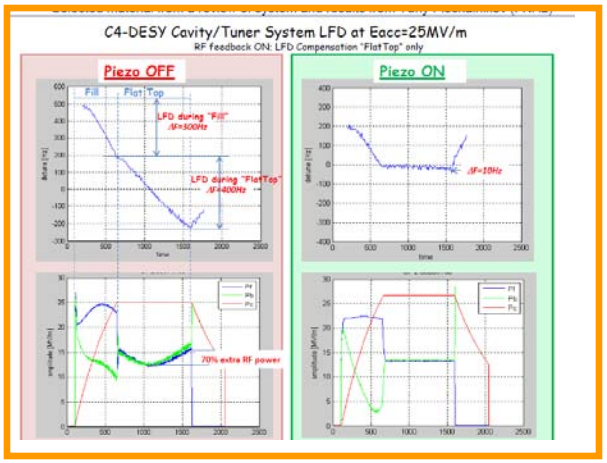
Lorentz force detuning coefficient "K" ($\Delta f = -K * Eacc^2$) characterized the specific cavity and tuner design.



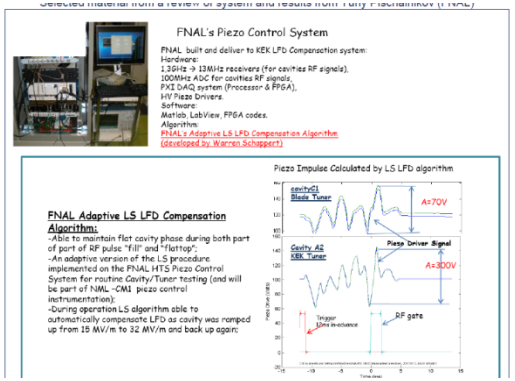
Cavity supporting system with larger stiffness in the KEK cavities restricts deformation of cell-shapes to a smaller level. A smaller Δf at flat top helps to reduce stroke required for a piezo.

Compensation of LFD by a piezo tuner

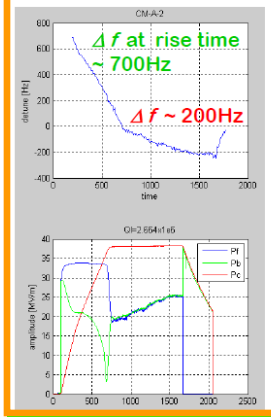




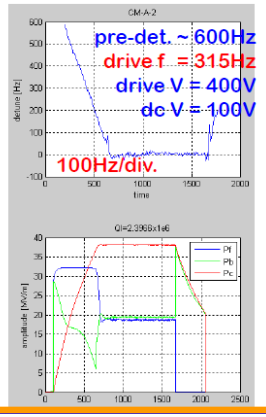
FNAL piezo control system



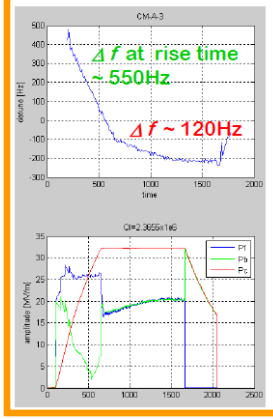
A2/MHI-06
38 MV/m
FB/on, Piezo/off



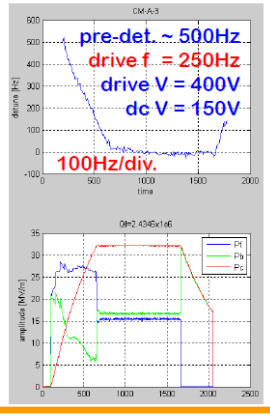
A2/MHI-06 (Slide Jack)
38 MV/m
FB/on, Piezo/on



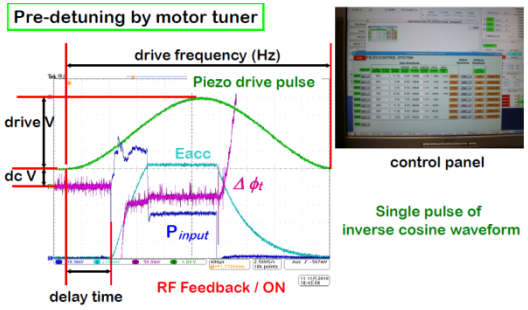
A3/MHI-07
32.5 MV/m
FB/on, Piezo/off



A3/MHI-07 (Slide-Jack)
32.5 MV/m
FB/on, Piezo/on

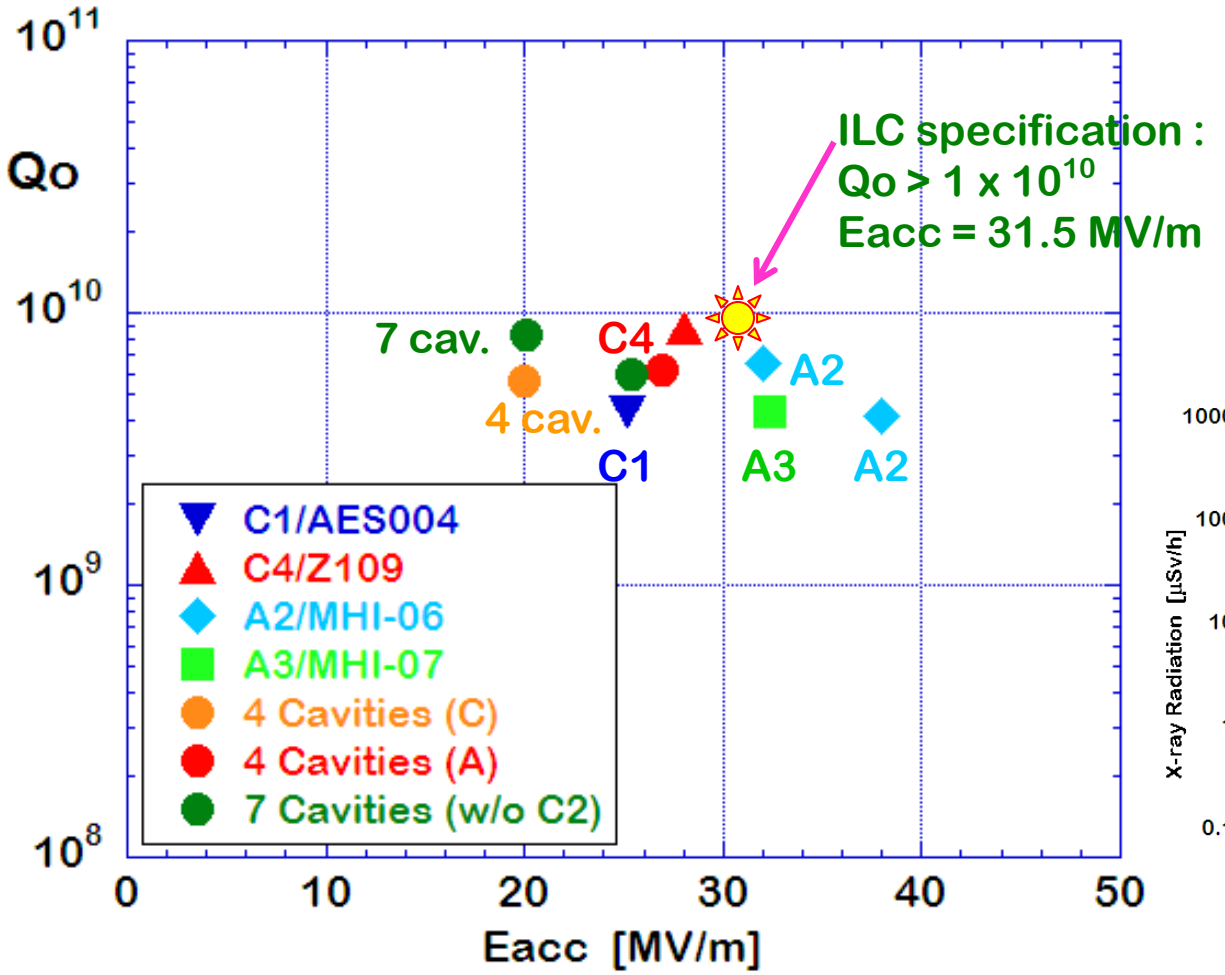


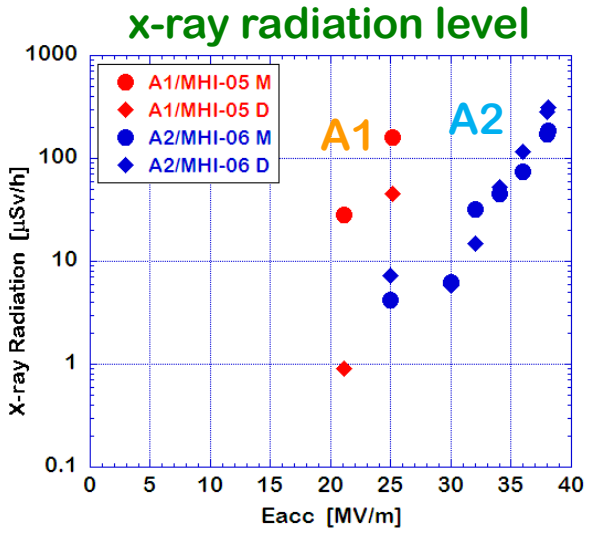
KEK piezo control system



Residual frequency error of few Hz level was achieved by all three types of tuner system.

Qo values measured by dynamic losses





The reason for low Qo values of 5 – 9 x 10^{9} in these cavities is thought to be mainly due to field emission with heavy x-rays radiation.

SUMMARY

- The cryomodule tests in the S1-Global project were extensively carried out, and the stable 7-cavities operation with compensation by piezo tuners was successfully demonstrated at 25 MV/m in average E_{acc}.
- All the three types of piezo tuners showed similar excellent performance in compensating the Lorentz detuning frequency.
- The cause of the performance degradation of two cavities (C2 and C3) in the cryomodule is under investigation.
- The problem of two slow frequency tuners (C2 and A4) and vacuum deterioration in the input coupler (A1) will be investigated after disassembly of the cryomodule.

END



Thank you for your attentions !