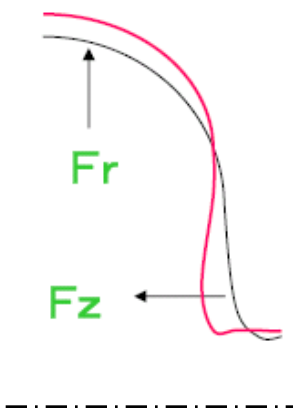
Lorentz Force Detuning

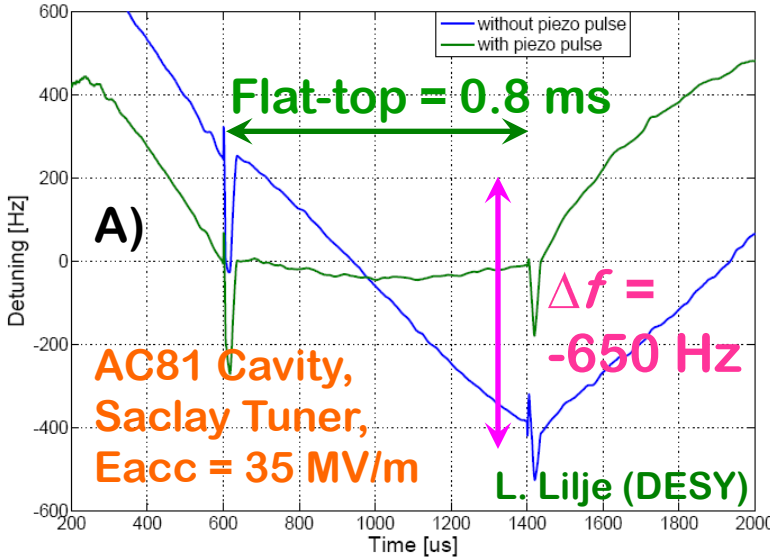
Eiji Kako
(KEK, Japan)

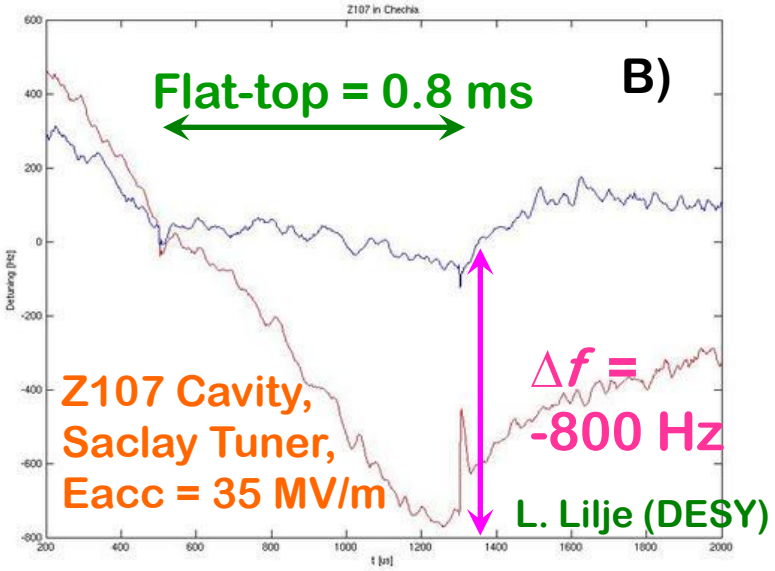
Outline

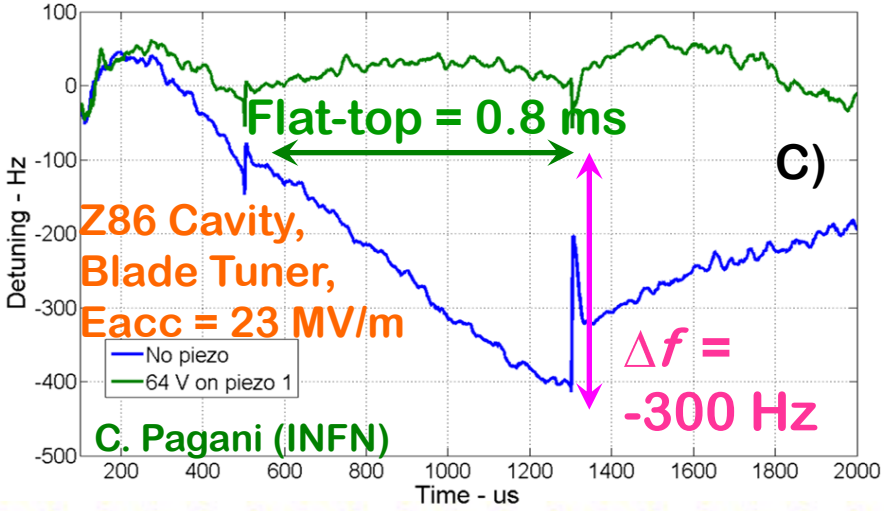
- Observation of Lorentz force detuning
- Compensation results of LFD
- Tuner performance in S1-G
- Summary

Observation of Lorentz Force Detuning









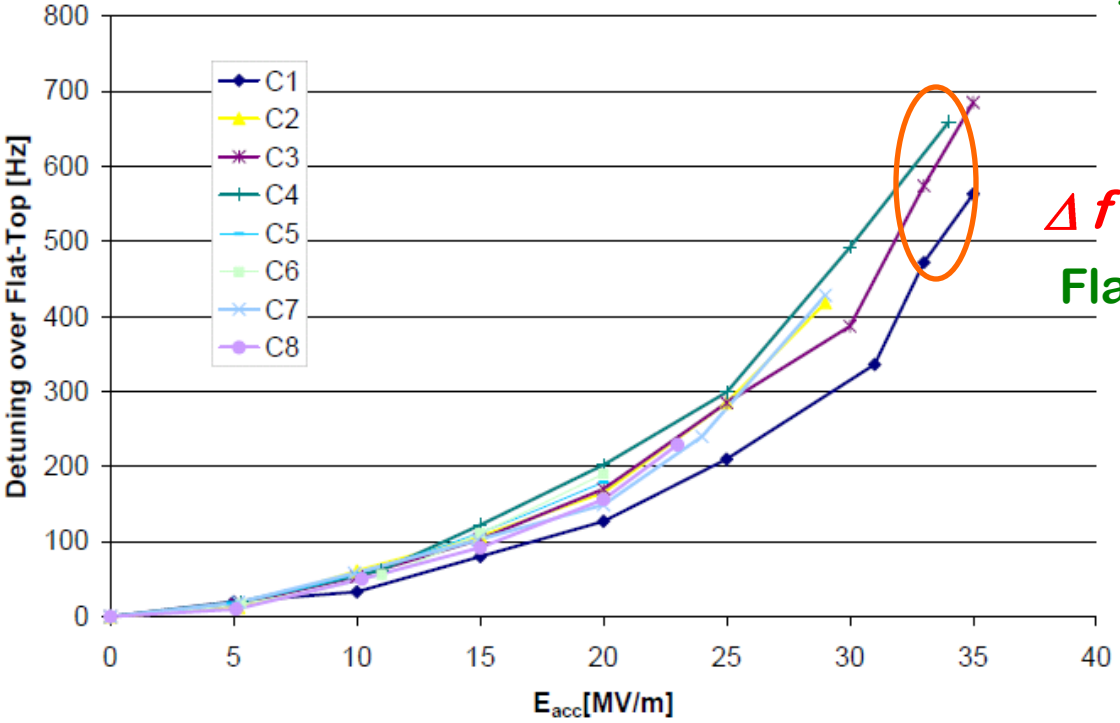
Eacc = 31.5 MV/m, Flat-top = 1.0 ms for ILC, ($Q_L = 3. \times 10^6$)

A) Δf = - 690 Hz, $\Delta \phi$ = - 72 °
B) Δf = - 810 Hz, $\Delta \phi$ = - 75 °
C) Δf = - 750 Hz, $\Delta \phi$ = - 74 °

Observation of Lorentz Force Detuning at DESY

Lorentz Force Detunings in Module 6 cavities

L. Lilje (DESY)



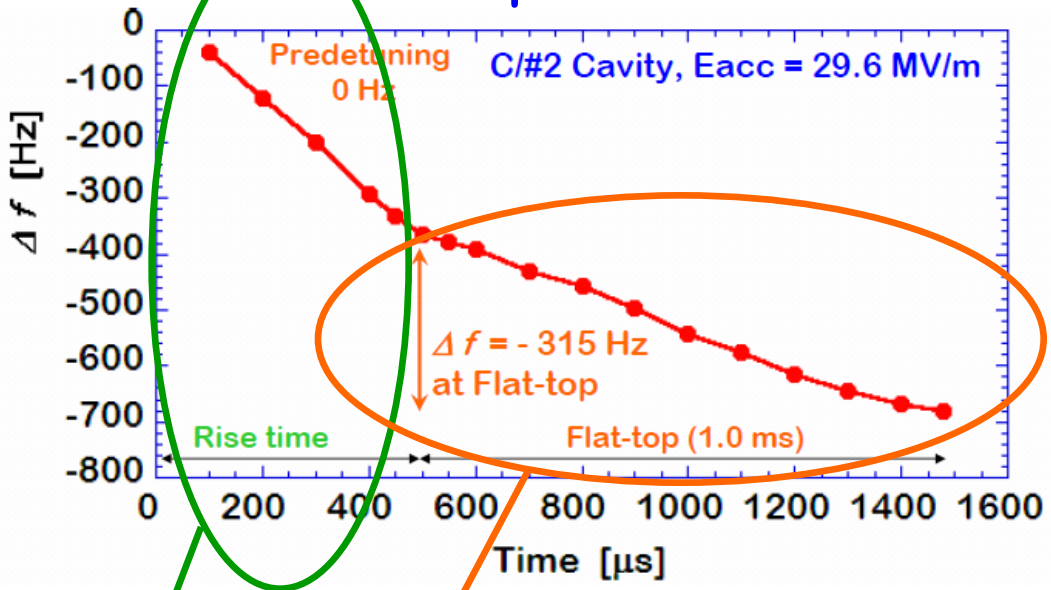
Δf = 500~700 Hz

Flat-top = 0.8 ms

6.2.2007 Beijing ILC Workshop Global Design Effort 20

Observation of Lorentz Force Detuning at STF

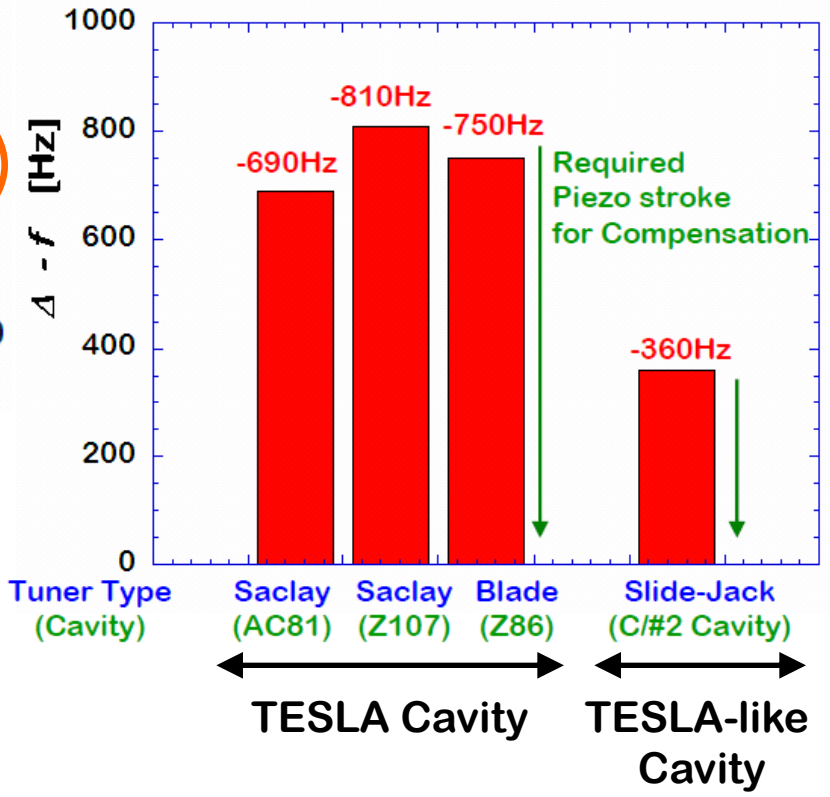
Experiment at STF-1



Compensation of -315Hz
by piezo tuner

Pre-detuning of +350Hz by motor tuner

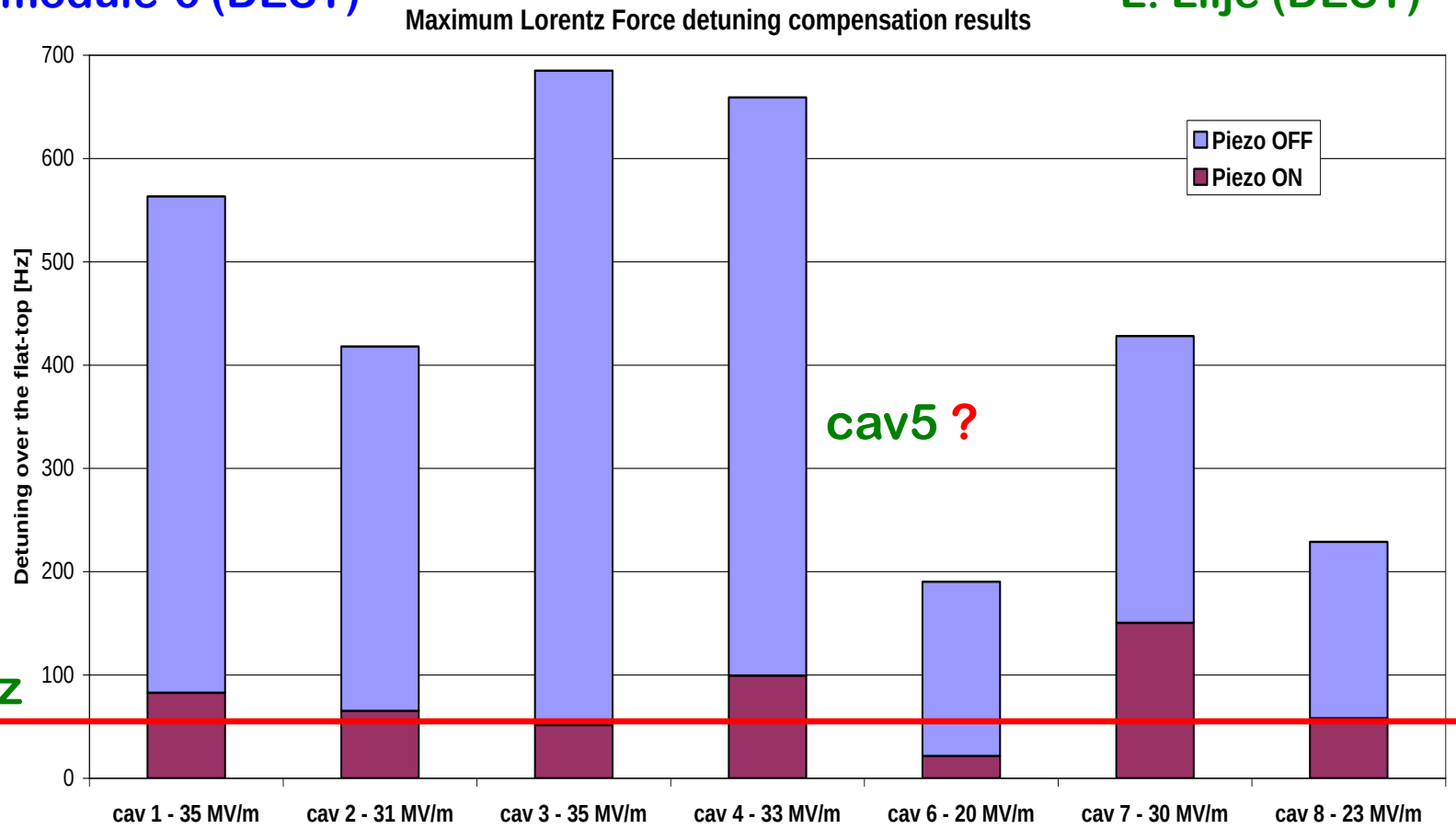
Comparison of Detuning Frequency (Δf)
Eacc = 31.5 MV/m
Flat-top = 1.0 ms



Compensation results of LFD at DESY

Cryomodule-6 (DESY)

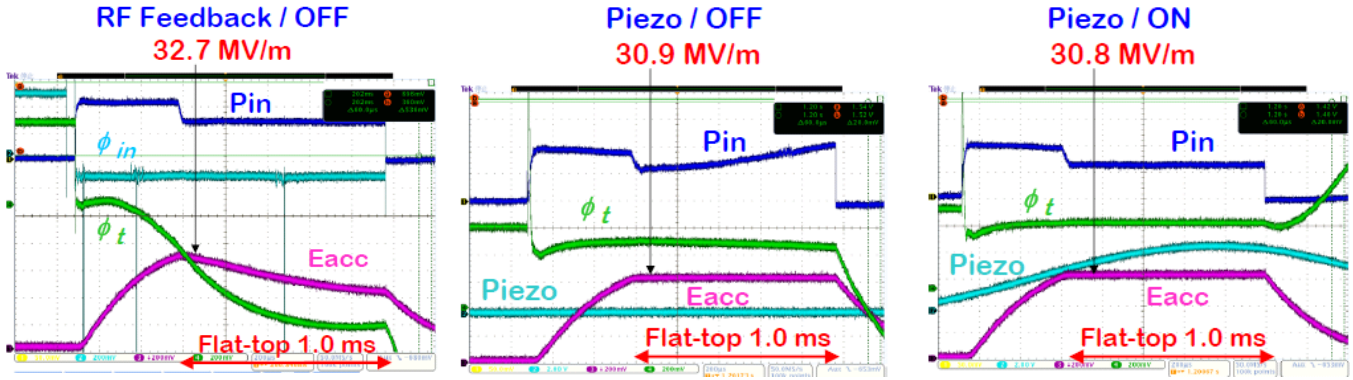
L. Lilje (DESY)

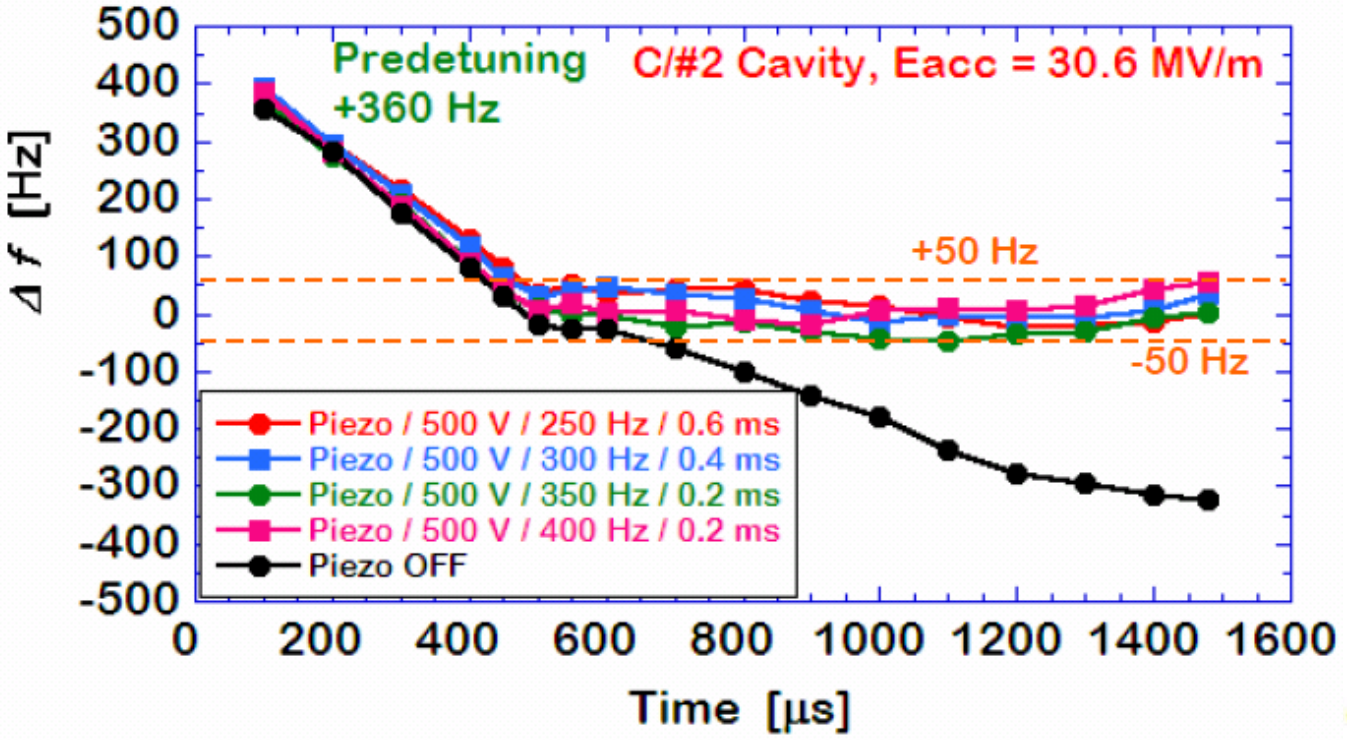


Δf = 50 Hz

Δf = 50 ~ 150 Hz (Eacc > 30 MV/m)

Compensation of Lorentz Force Detuning at STF





Optimization of Piezo Drive Pulse

1. Waveform
2. Amplitude
3. Frequency
4. Delay time

Δf < +/- 50 Hz in wide parameters

Δf < +/- 30 Hz in best case

Stability of LFD compensation at STF

Pulse stability test

2000 pulses data

F.B. ON

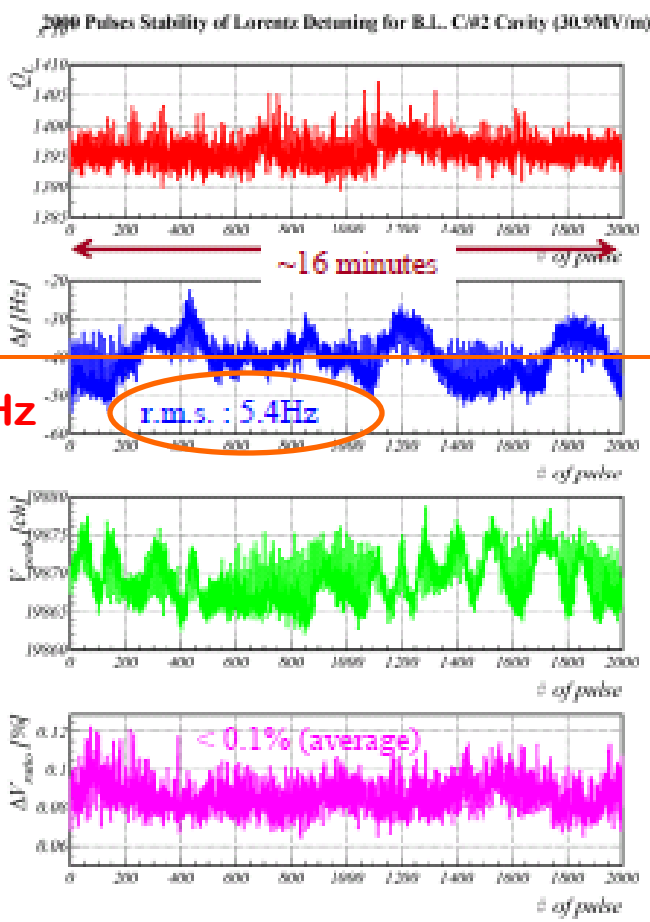
Q_L

Δf

Δf = -40 Hz

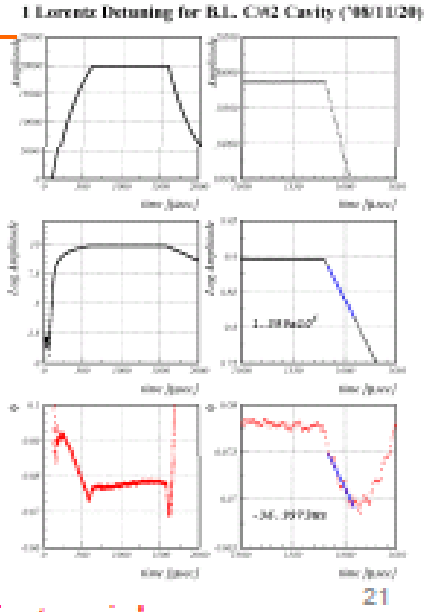
peak field at flat-top
(ADC counts)

peak-to-peak ratio
at flat-top
(field degradation)



During the high power test,
one situation was kept for 16 minutes
at the driving condition of Piezo.
(V_{piezo}/f_{Piezo}/t_{piezo} = 500V/350Hz/0.5msec)

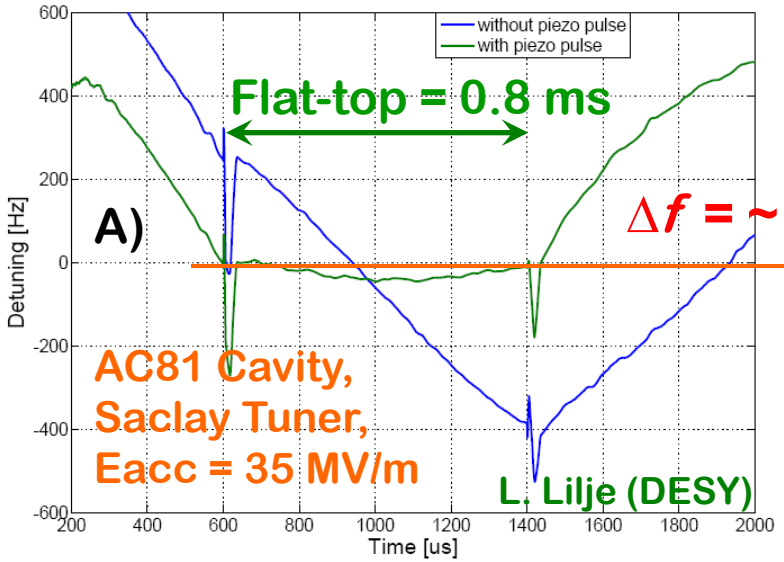
example of one pulse

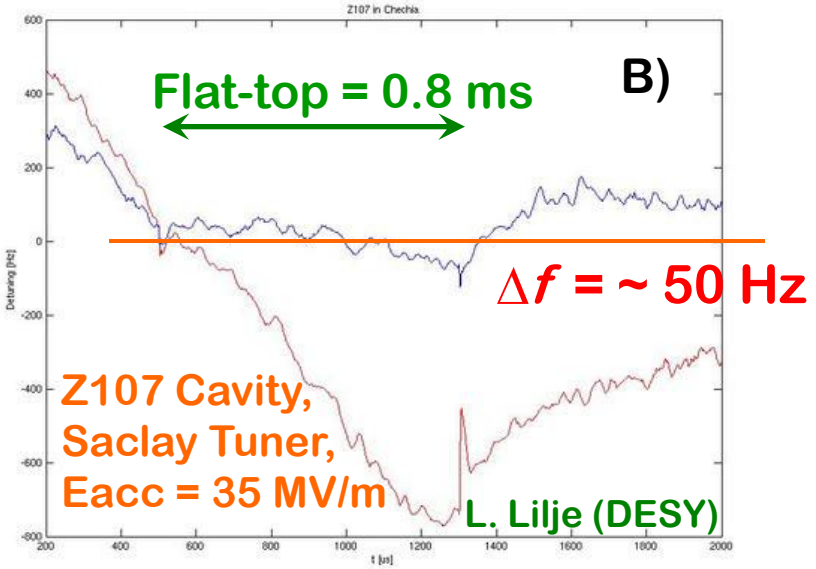


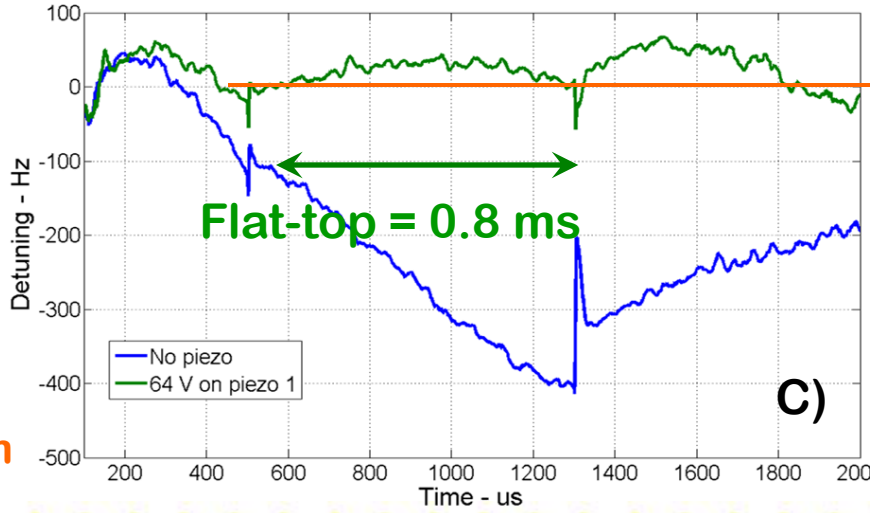
We will try the stability test for a longer time in S1-Global project again!

K. Yamamoto (KEK)

Compensation of Lorentz Force Detuning







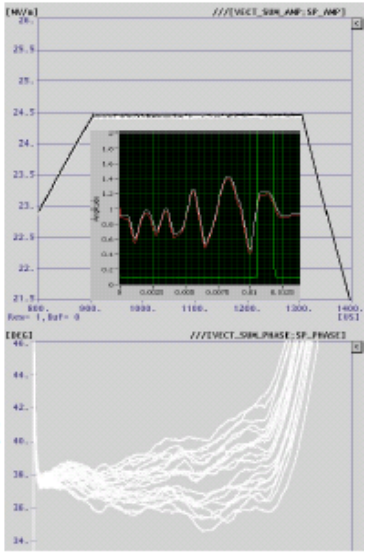
Z86 Cavity,
Blade Tuner,
Eacc = 23 MV/m

C. Pagani (INFN)

Recent LFD control results at FNAL

LS LFD Compensation

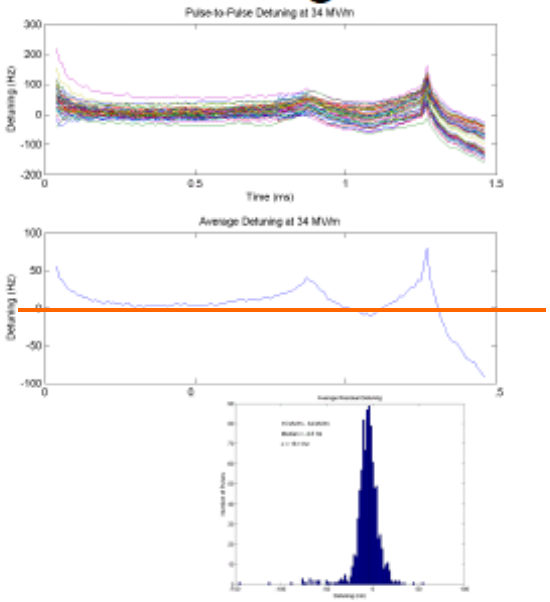
- Implemented an adaptive version of the LS procedure that worked successfully in CCII
- Able to maintain flat phase during both fill and flattop
- Able to track the resonance as cavity was ramped down from 15 MV/m to 35 MV/m and back up again
- Flattop square and phase flat to few degrees at 35 MV/m
- LFD reduced to level of microphonics



Y. Pischalnikov (FNAL)
W. Schappert (FNAL)

Residual Detuning

- Detuning at 35 MV/m after compensation is comparable to microphonics
  - 50 Hz Peak
  - 15 Hz RMS
- Probably limited by low pass filter in FF loop
  - May be possible to reduce residual detuning further by increasing the LPF cutoff frequency



This method is under preparation for studies of Lorentz force detuning in S1-G cryomodule.

Error of Lorentz detuning compensation

Merit of Over-Coupling #2 ; DLD

Lorentz Detuning Compensation Error ; Δf

Detuning Angle ; $\psi = \tan^{-1}\left(2 Q_L \frac{\Delta f}{f_0} \right)$

Energy Gain Reduction ; $\left| \cos^2 \psi \right| \geq 0.99$

$\left| \psi \right| \leq 5.5\,\mathrm{deg.}$

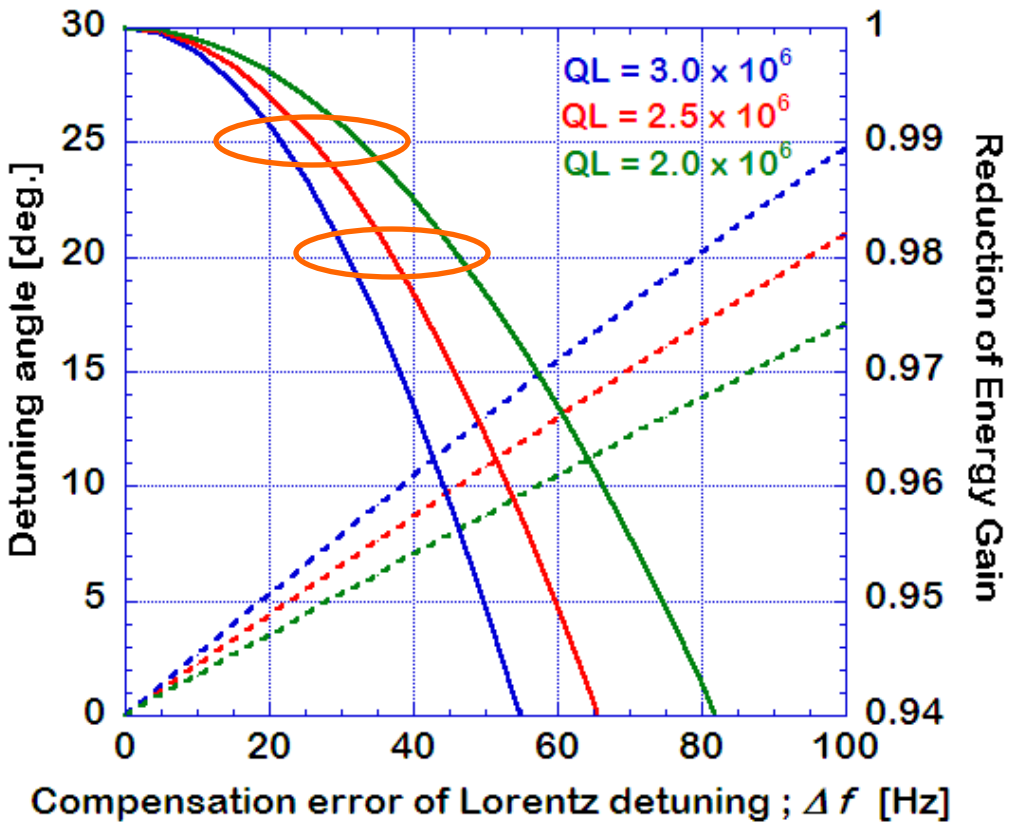
Δf / Band width ≤ 0.096

Beam Dynamics

0.98 for DRFS (2 Cavities)

BAW at KEK 2010.9.8, S.Noguchi 10

S. Noguchi (KEK)



QL = 2. ~ 3. x 10^6

1% reduction ; Δf < 20~30 Hz

2% reduction ; Δf < 30~50 Hz

Error of Lorentz detuning compensation

Simulation results

Shin Michizono (KEK)

		RDR	DRFS (PkQl)	DRFS(Cavity grouping)
RF power	Operation gradient	Max. 33 MV/m	Average 31.5 MV/m	Max. 38 MV/m
	RF source	10 MW		800 kW
	Waveguide loss	8% power	2% power	2% power
	Static loss (Ql, Pk)	2% power	2% power	2% power
	Kly Hv ripple	2.5% power	2.5% power	2.5% power
	Microphonics	2% power	2% power	2% power
	Reflection	0% power	14% power	0% power
	Other LLRF margin	10% power	10% power	5%~10% power
Tolerance	Ql tolerance		3% (2)	3% (2)
	Pk tolerance		0.2dB (2)	0.2dB (2)
	Detuning tolerance		15Hz rms(3)	20Hz rms (3)
	Beam current offset		2% rms (3)	

(1) LLRF overhead ~5%
(2) Cavity gradient tilt (repetitive) ~5%
(3) Pulse-to-pulse gradient fluctuation ~1%rms

- We have to examine these numbers experimentally.
- Tolerance should be discussed with cavity and HLRF group. If the tolerance is smaller, better gradient tilt would be possible.

BAW1 (Sep.,2010)

5

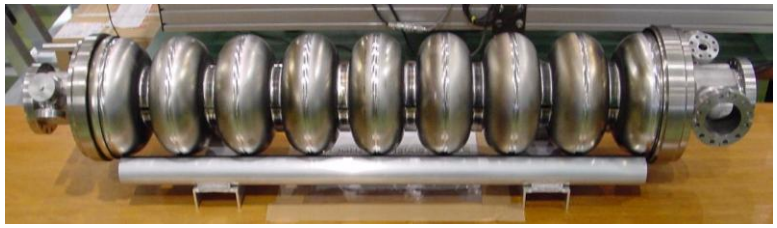
S1-Global Cryomodule

TESLA Cavity (DESY/FNAL)

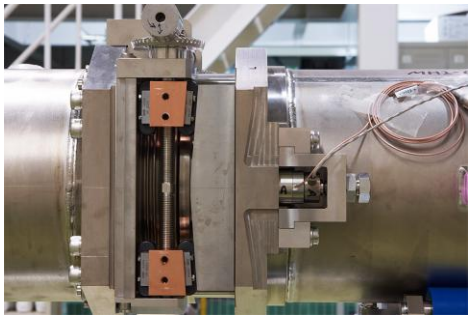
Blade Tuner (FNAL)

Saclay Tuner (DESY)

TTF-III Coupler (DESY/FNAL)



Tesla-like (KEK)



Slide-Jack Tuner (KEK)

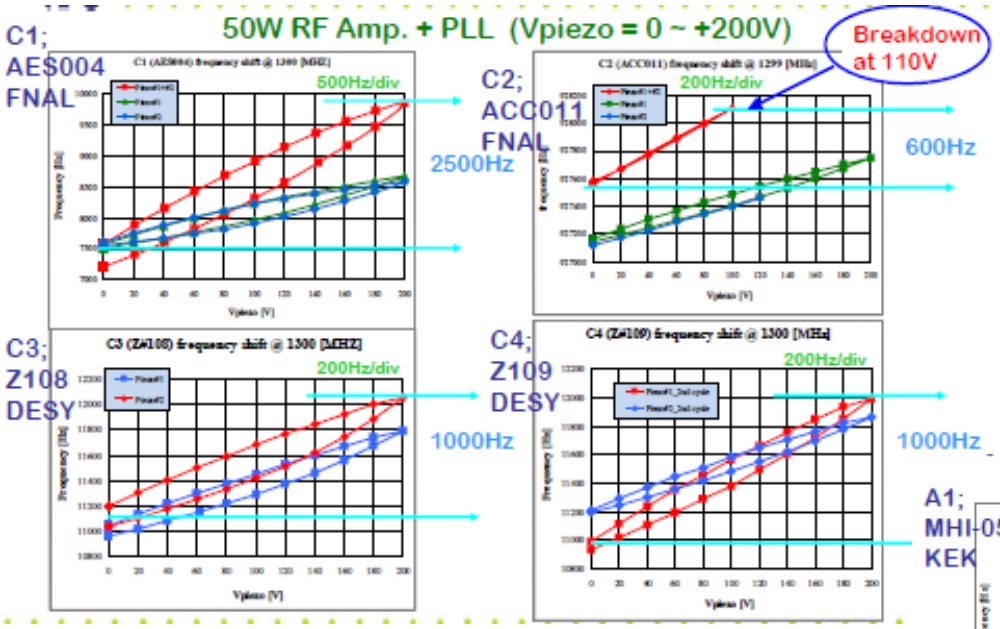
STF-II Coupler (KEK)

Low RF power tests in S1-Global

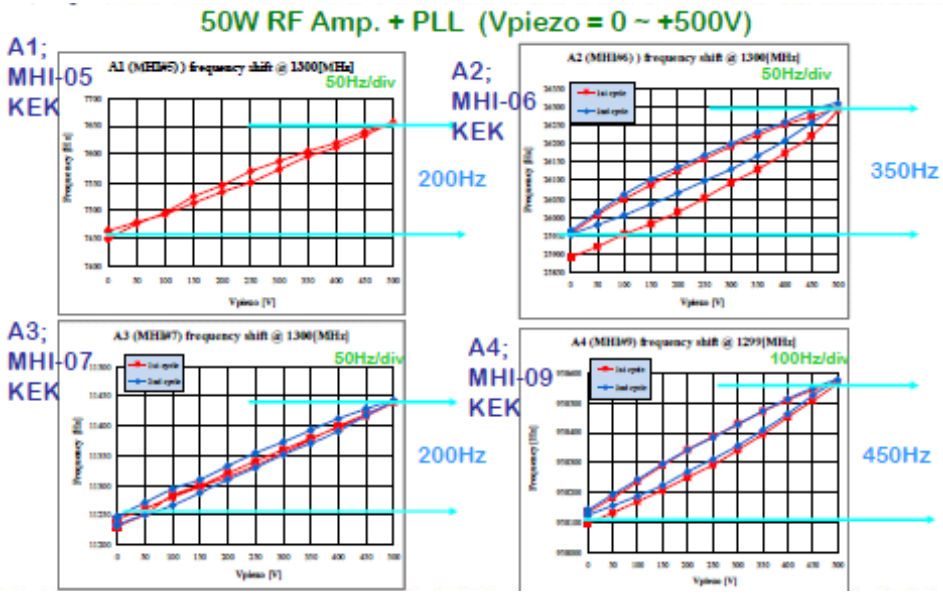
Tuner performance tests in collaboration with INFN / FNAL / KEK

2010, July

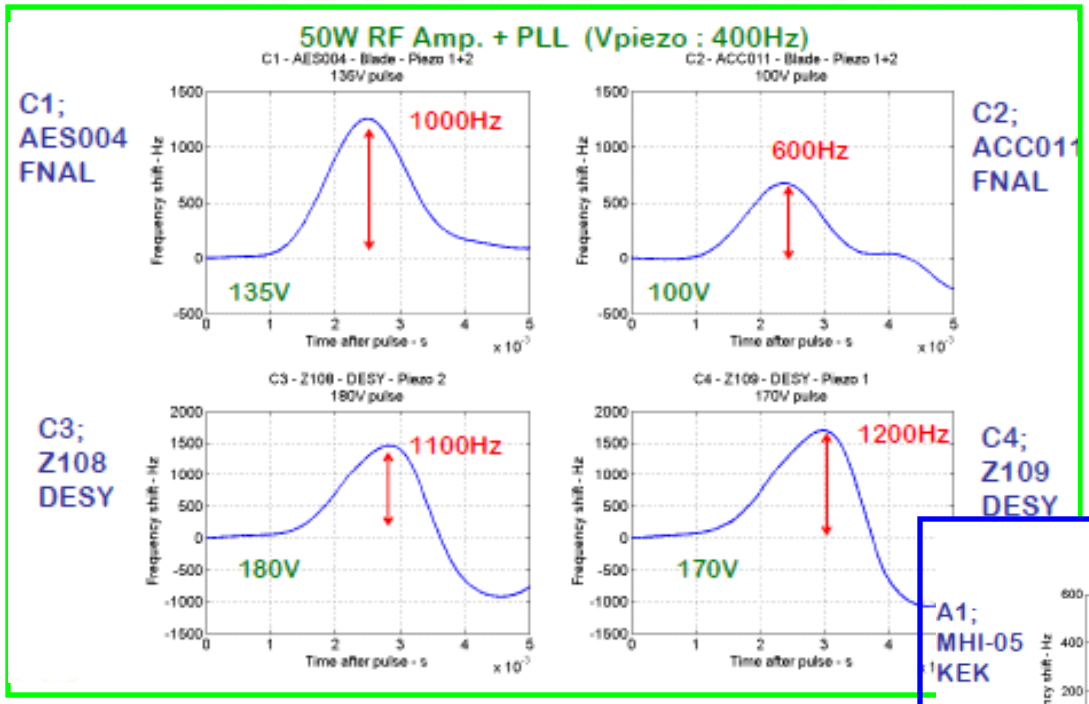
Hysteresis of Piezo Tuner (Cryo-C/A)



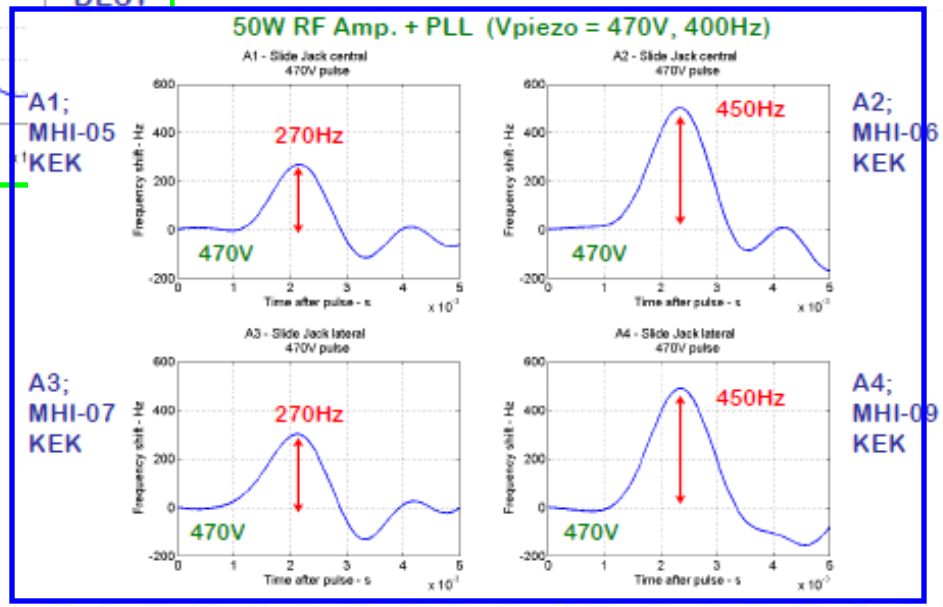
Tuner performance tests in collaboration with INFN / FNAL / KEK



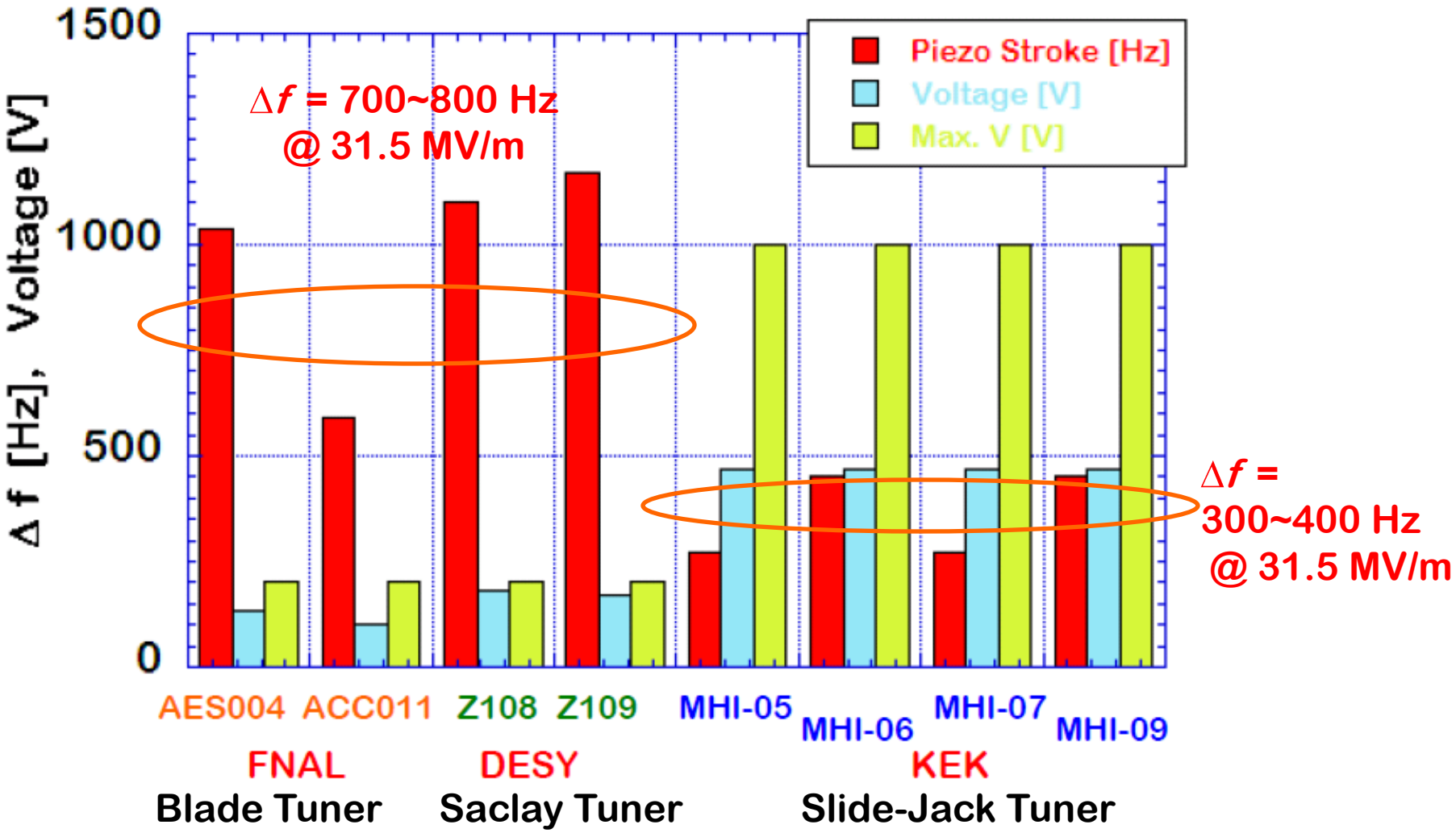
Single pulse response (Cryo-C/A)



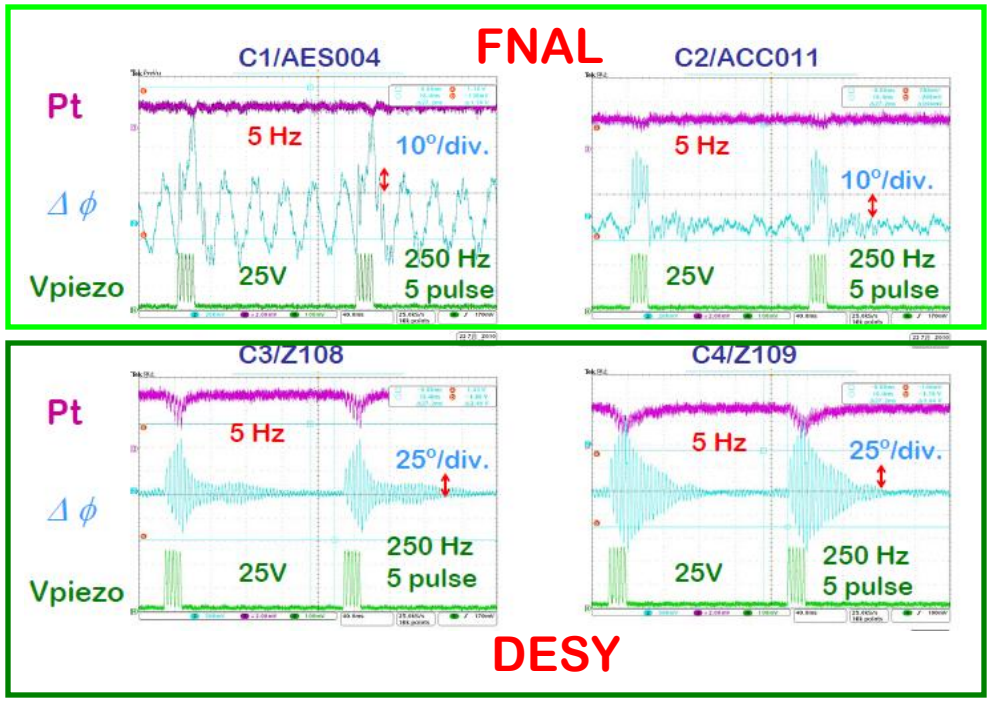
Tuner performance tests in collaboration with INFN / FNAL / KEK



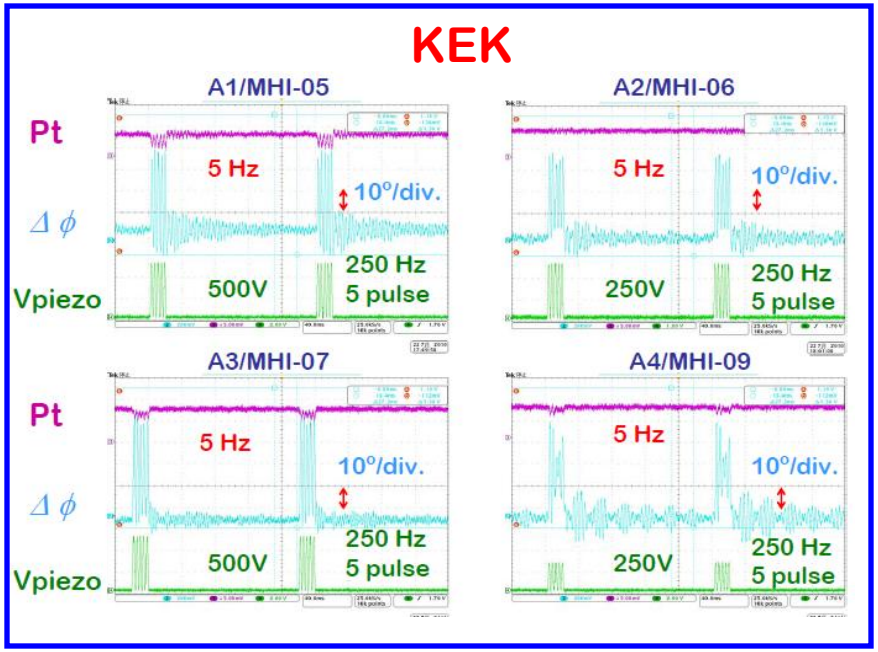
Piezo stroke by pulse response



Mechanical Vibration Modes (Cryo-C/A)



$Q_L = 3. \times 10^6$

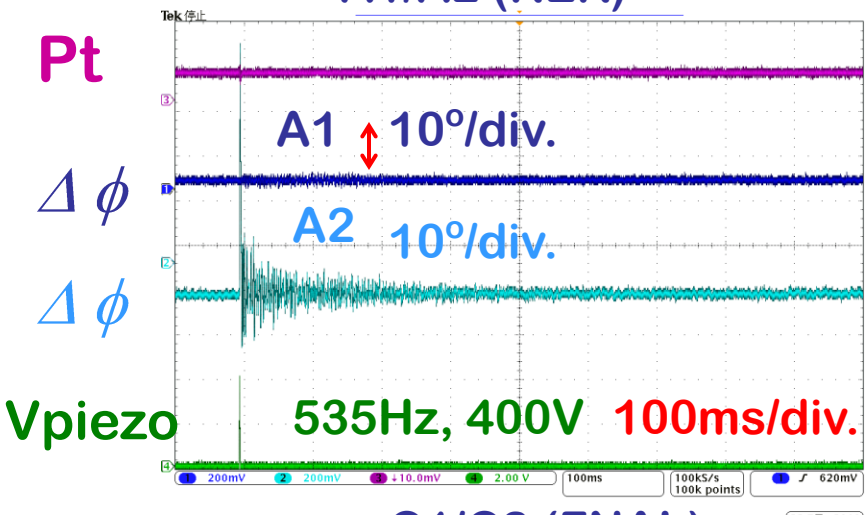


Difference is very clear.

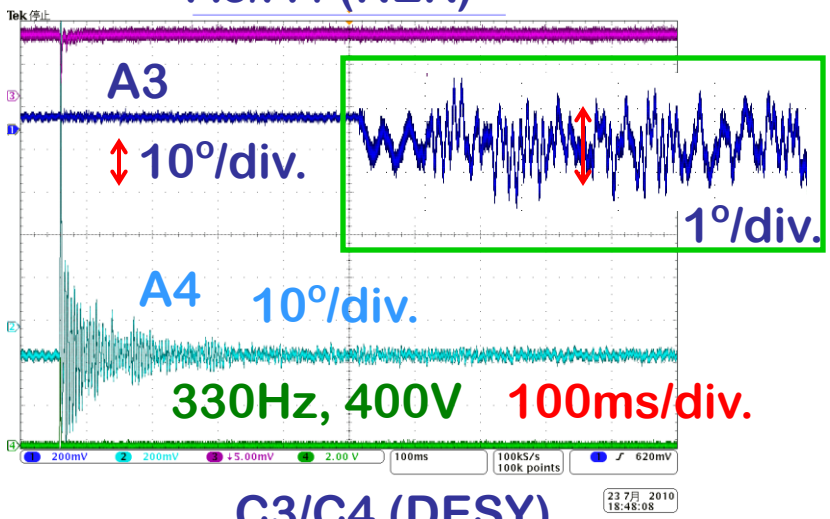
1. **TESLA cavity + Blade tuner**
2. **TESLA cavity + Saclay tuner**
3. **Tesla-like cavity + Slide-jack tuner**

Propagation of Mechanical Vibration

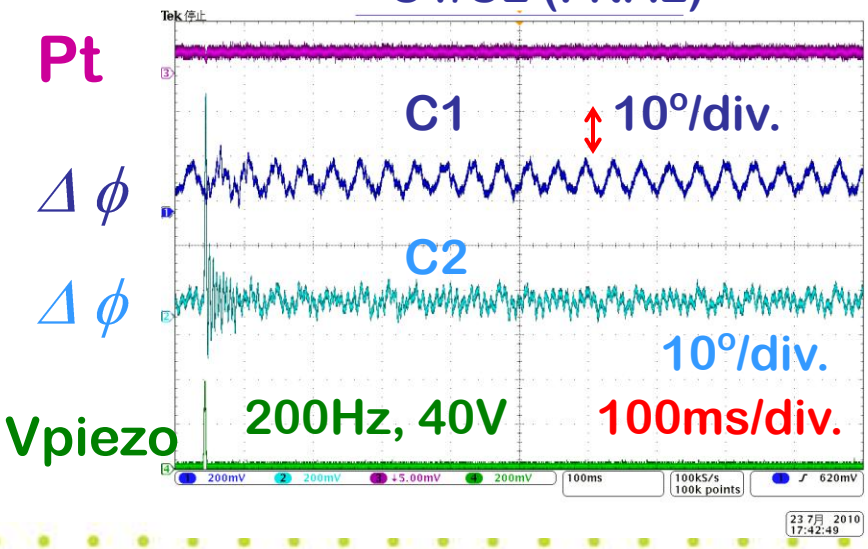
A1/A2 (KEK)



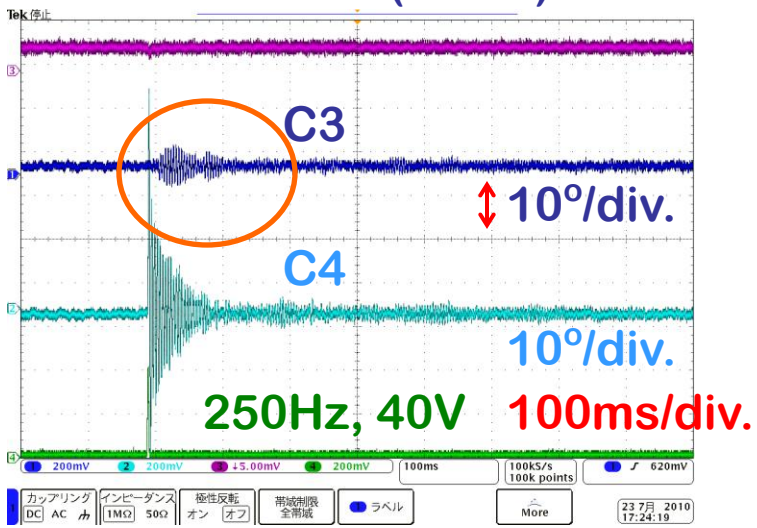
A3/A4 (KEK)



C1/C2 (FNAL)

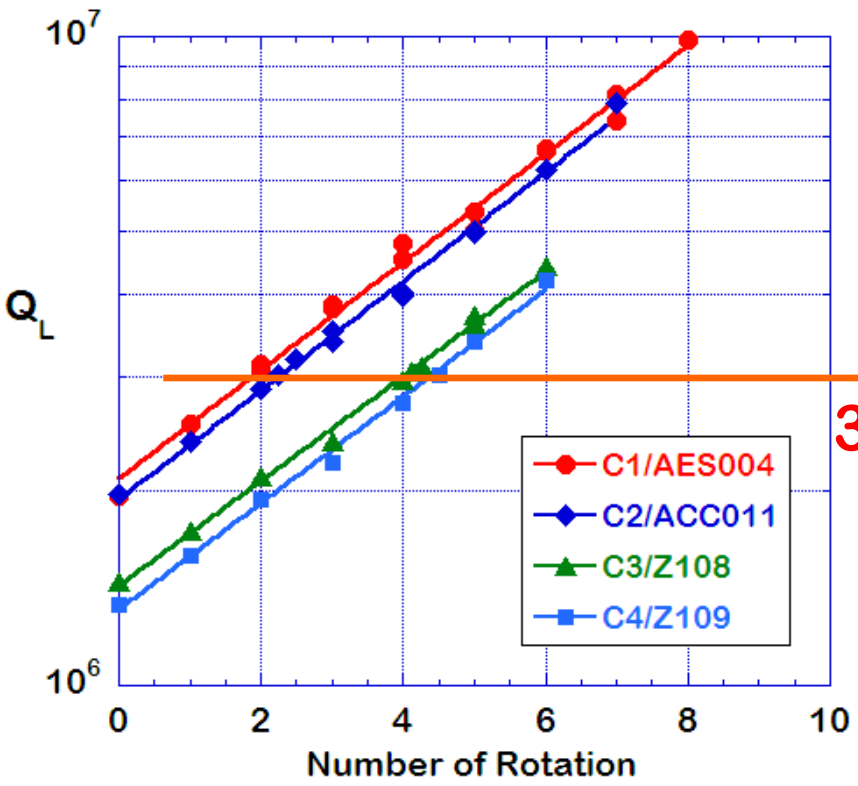


C3/C4 (DESY)

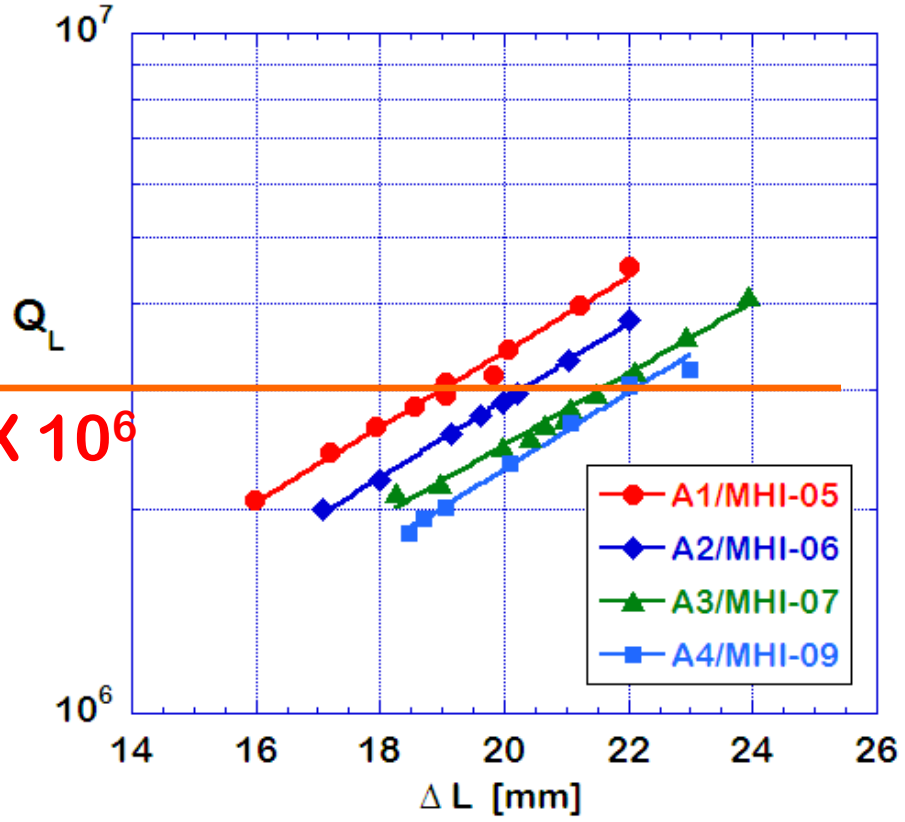


Q_L of Variable Input Coupler

Cryomodule - C



Cryomodule - A



$3. \times 10^6$

$Q_L = 2.0 \sim 8. \times 10^6$ (FNAL)
$Q_L = 1.3 \sim 4. \times 10^6$ (DESY)

$Q_L = 2.0 \sim 4. \times 10^6$ (KEK)

List of studies in S1-G cryomodule tests

Sept. ~ Dec. in 2010 ;

- High gradient performance
- Observation of Lorentz force detuning
- Compensation of Lorentz force detuning
- Dynamic heat loss measurement
- LLRF control in 8-cavity operation
- DRFS

LLRF control with LFD compensation in 8-cavity operation

SUMMARY

- In the horizontal tests of one-cavity operation, LFD compensation error of Δf < 50 Hz was demonstrated in different types of piezo tuner.
- Results of the piezo-tuner performance will be directly compared in high power tests of the S1-G cryomodule, very soon.