Preliminary Summary of LFD Compensation Study S1 Global Cryomodule

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For KEK-FNAL team

IWLC2010
Presented by Yuriy Pischalnikov

Main Objective of S1 Global LFD study

- Use unique opportunity to characterize during one experiment four different type of cavity/tuner systems:

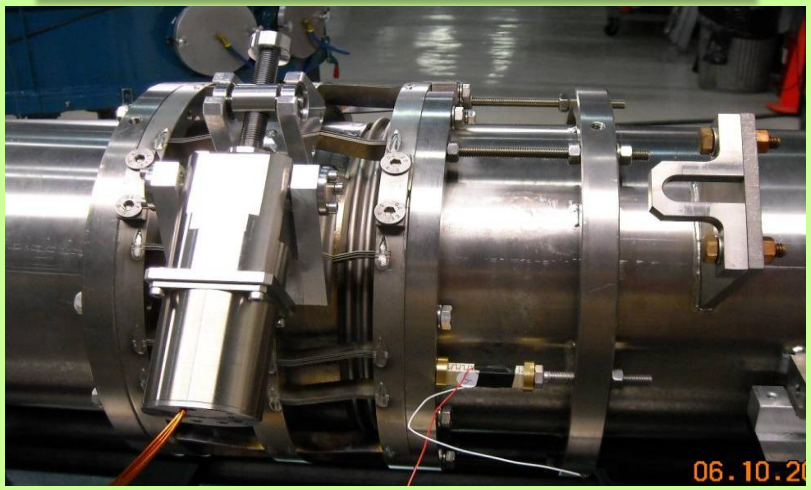
  - Sensitivity of cavity/tuner systems to LFD;

  - Deploy FNAL's LS LFD Compensation Algorithm/ FNAL's Piezo Control System* to compensate LFD at all 8 cavities at maximum E_{acc}.

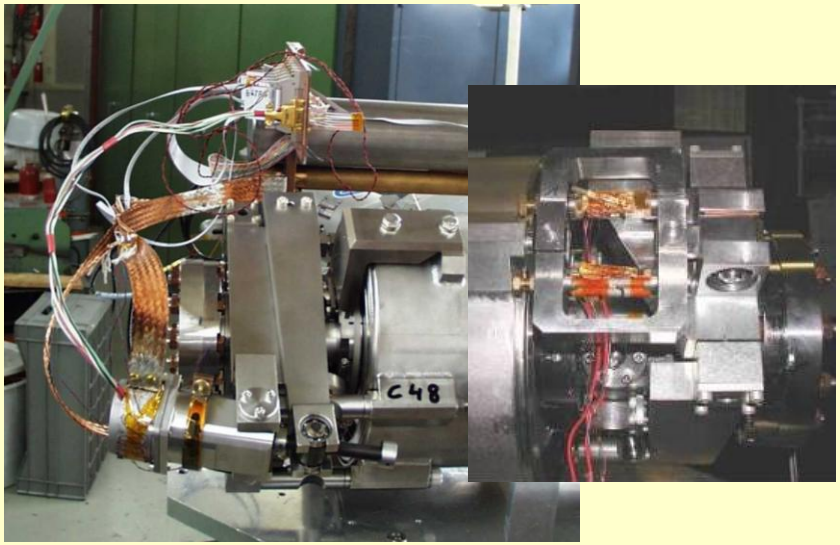
** LFD study with KEK Compensation System (A1-A4 cavities) planed for Oct. 19-22)*

S1 Global cavities/tuners

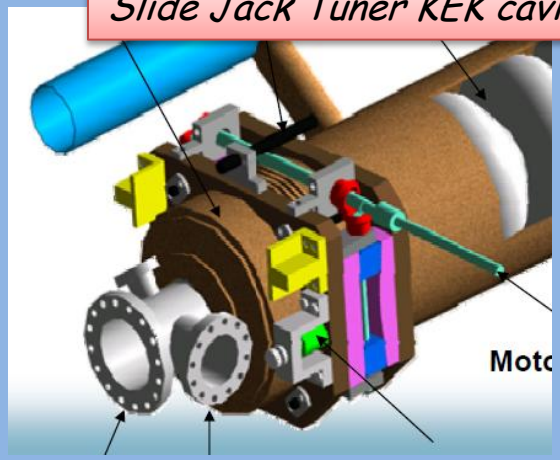
Blade Tuner FNAL/INFN cavity/tuner C1-C2

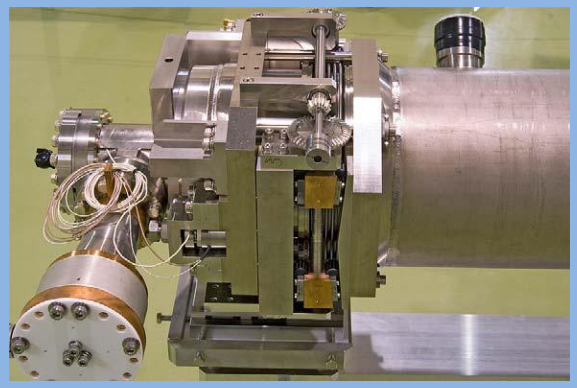


DESY/SACLAY Cavity/tunerC3—C4

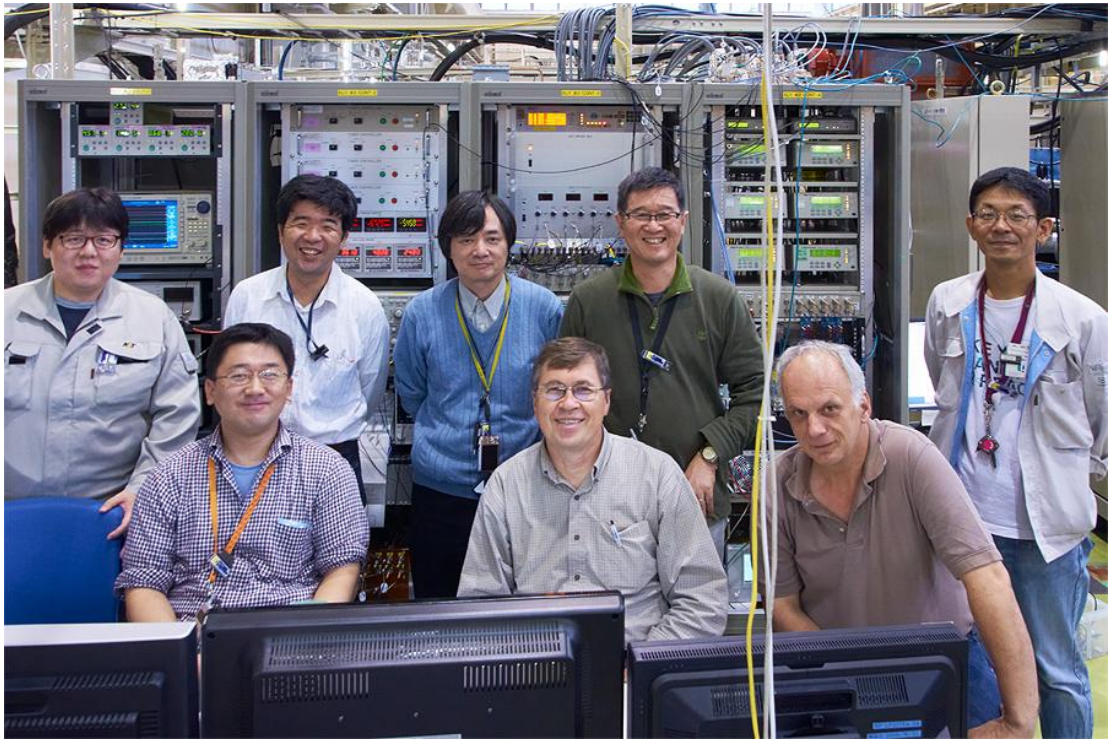


Slide Jack Tuner KEK cavity/system A1-A2&A3-A4

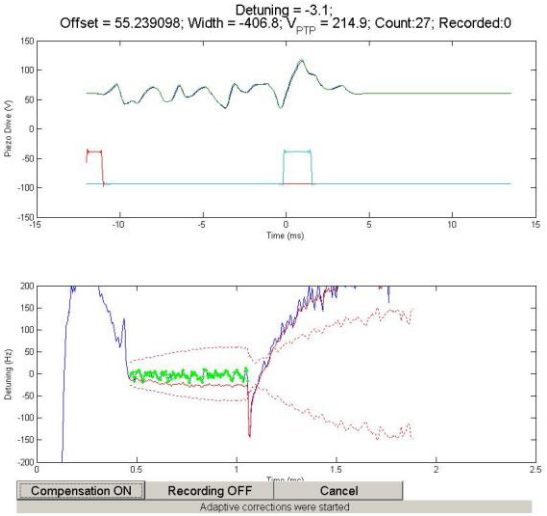




FNAL's Piezo Control System
for LFD Study at S1 Global



FNAL Piezo Control system at KEK



FNAL's Adaptive LS LFD Compensation Algorithm

(developed by Warren Schappert)

- Able to maintain flat cavity phase during both part of part of RF pulse "fill" and "flattop";
- An adaptive version of the LS procedure implemented on the FNAL HTS Piezo Control System for routine Cavity/Tuner testing (and will be part of NML –CM1 piezo control instrumentation);
- At HTS during operation LS algorithm able to automatically compensate LFD as cavity was ramped up from 15 MV/m to 32 MV/m and back up again;

Measure LFD

Extract the width and the dynamic detuning from the probe and forward IF signals

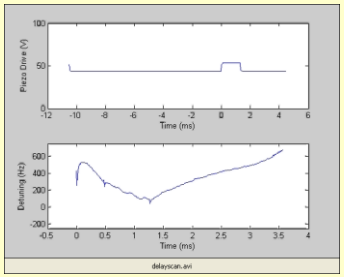
$$\frac{dP}{dt} = -\omega_{1/2} + i\delta P + 2\omega_{1/2} F$$

$$\omega_{1/2} = -\frac{\left\langle \mathrm{Re}\left(P^* \left(\frac{dP}{dt} \right) \right) \right\rangle}{\left\langle \mathrm{Re}\left(P^* P - 2F \right) \right\rangle}$$

$$\delta = -\frac{\mathrm{Im}\left(P^* \left(\frac{dP}{dt} - 2\omega_{1/2} F \right) \right)}{P^* P}$$

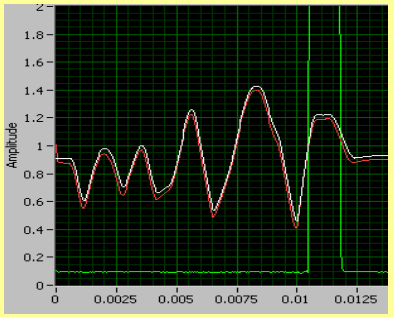
Piezo Delay Scan

Piezo/cavity excited be sequence of small (several volts) narrow (1-2ms) basis pulses at various delay and measure the detuning;



Calculate Piezo Stimulus Pulse

Invert the response matrix and determine combination of pulses needed to cancel out the mean using LS

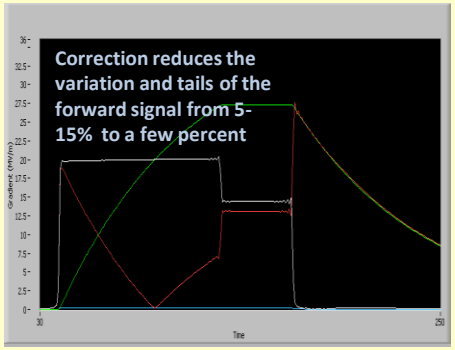


piezo

Cavity RF signals

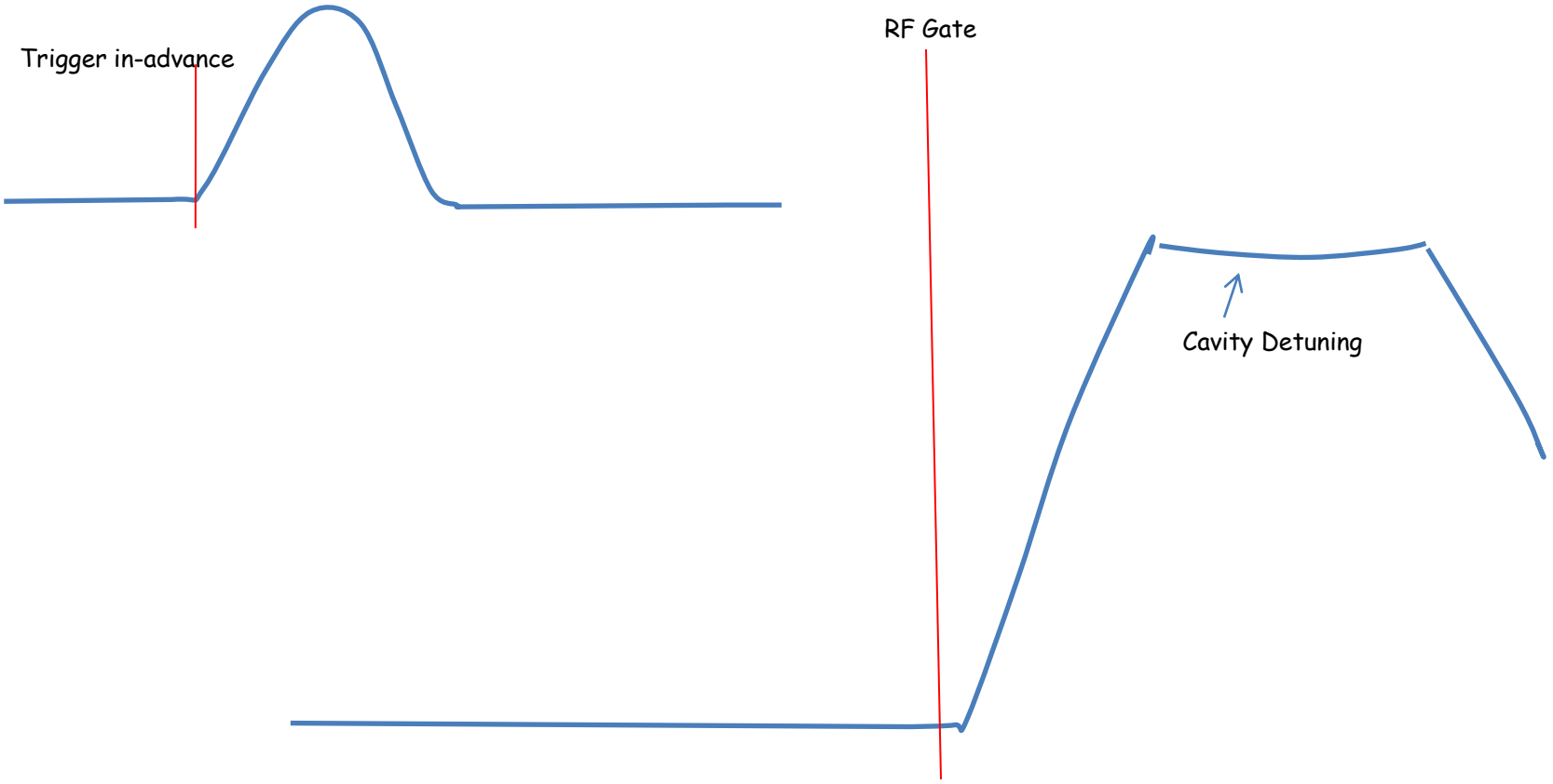
Correcting the IF Signals

Examine IF signals for saturation; Cross-contamination of forward and reflected signals

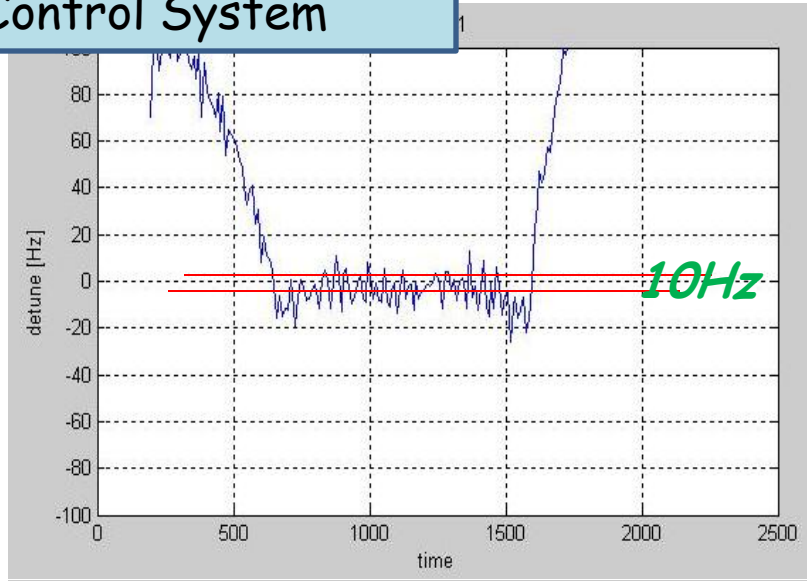


Piezo Scan Cartoon

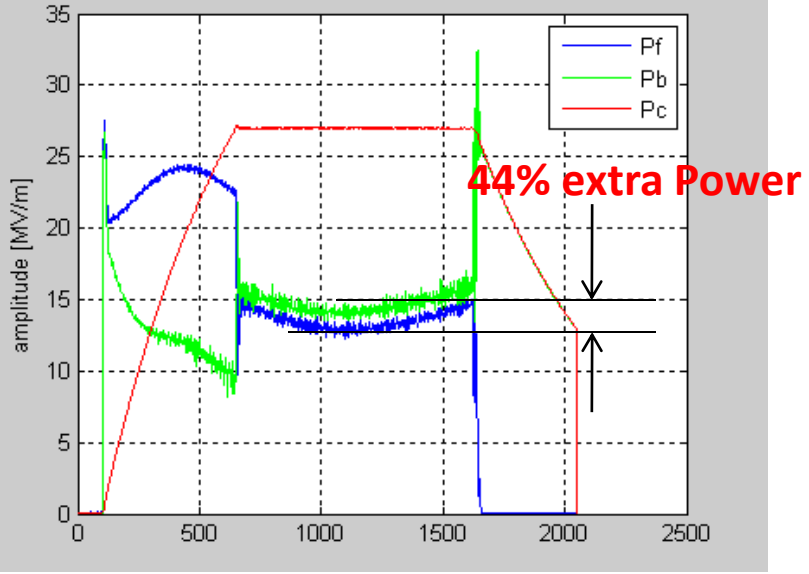
- Piezo/cavity excited be sequence of small (several volts) narrow (1-2ms) basis pulses at various delay – starting 10ms in-advance of RF gate. Measure the cavity detuning …



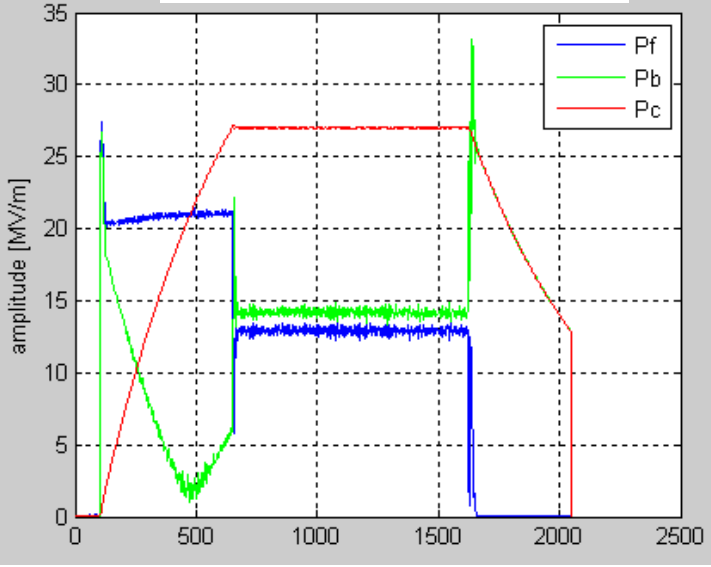
C1(AES04)- FNAL/Blade Tuner Cavity
Eacc=27MV/m, RF feedback ON
by FNAL Piezo Control System



PIEZO OFF



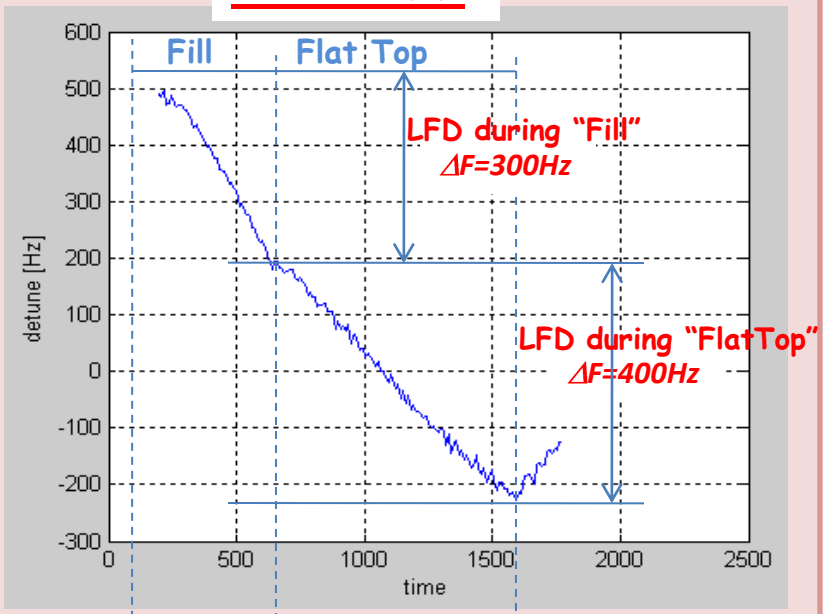
PIEZO ON (Vp-p=90V)

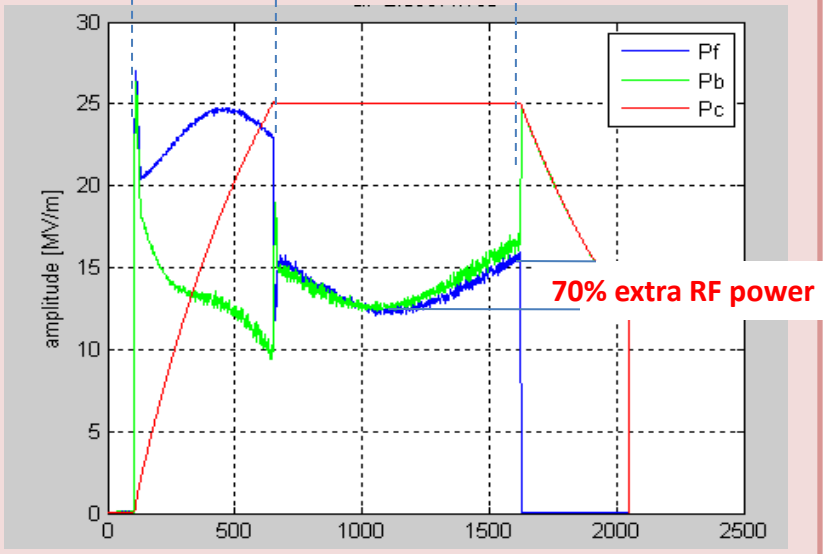


C4-DESY Cavity/Tuner System LFD at Eacc=25MV/m

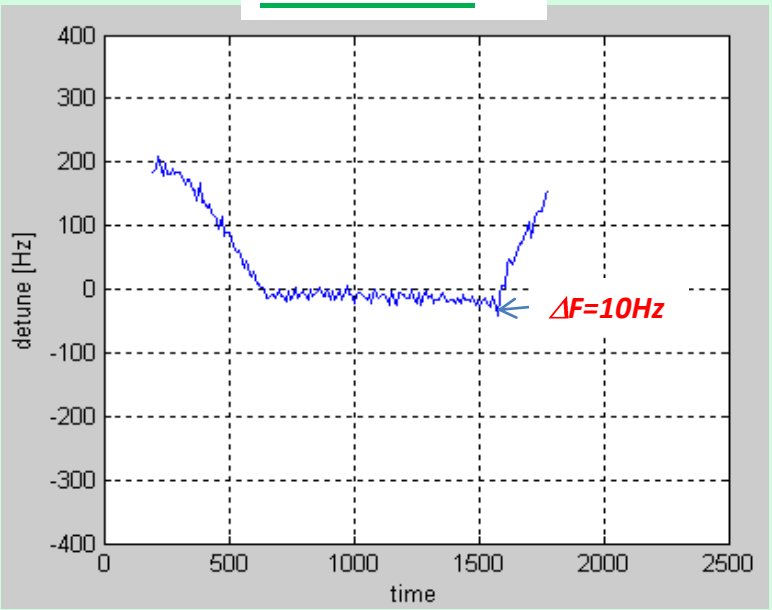
RF feedback ON; LFD Compensation "FlatTop" only

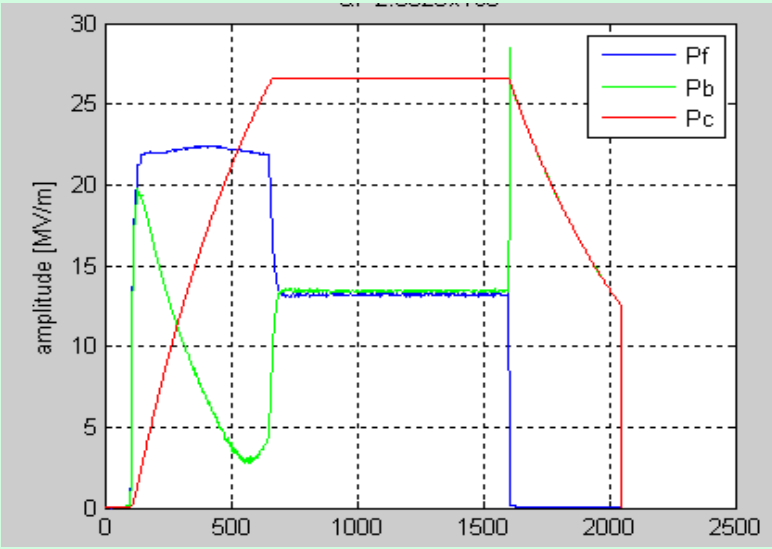
Piezo OFF



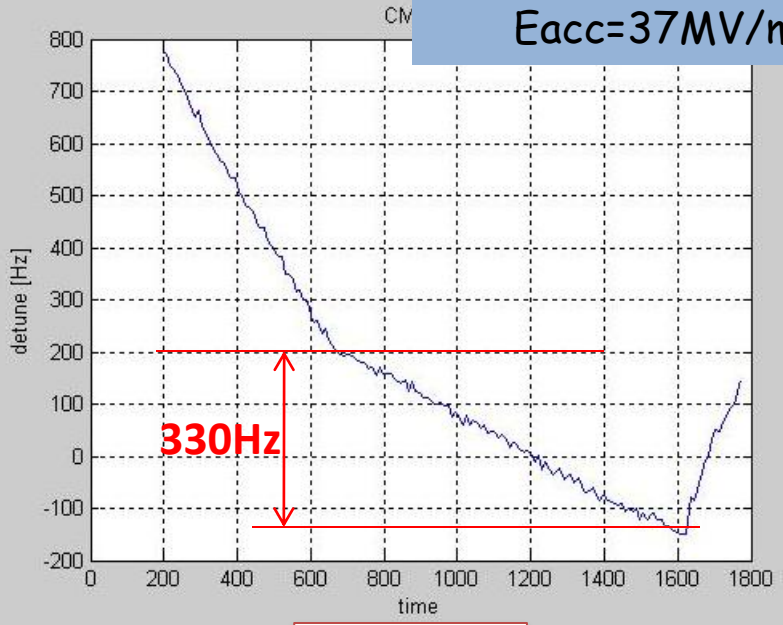


Piezo ON

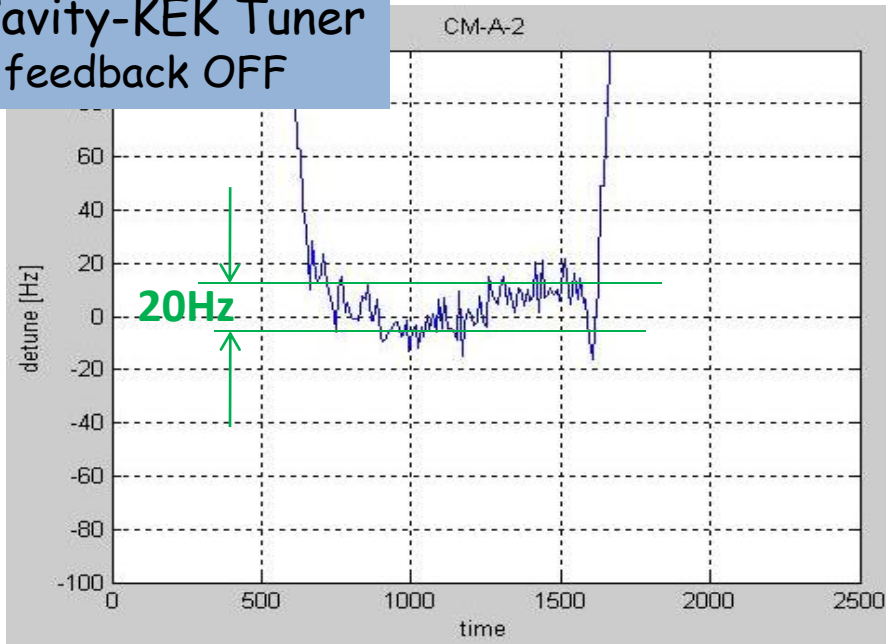




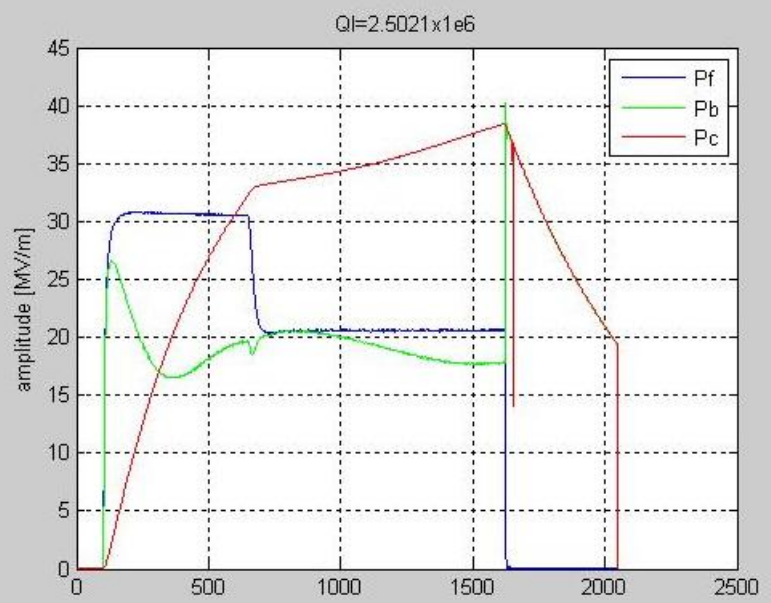
S1 Global A2(KEK) Cavity-KEK Tuner
Eacc=37MV/m, RF feedback OFF

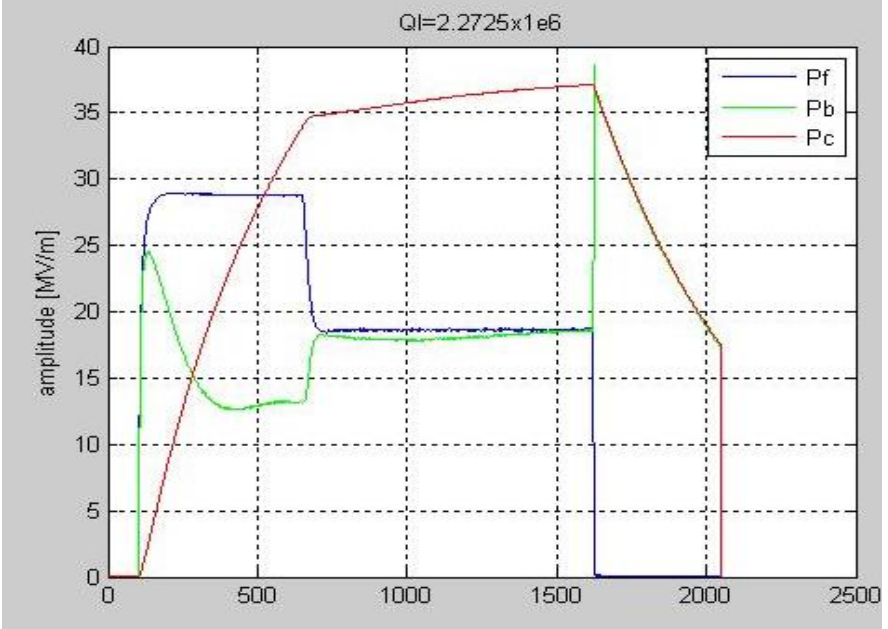


Piezo OFF



Piezo ON; Vp-p=300V

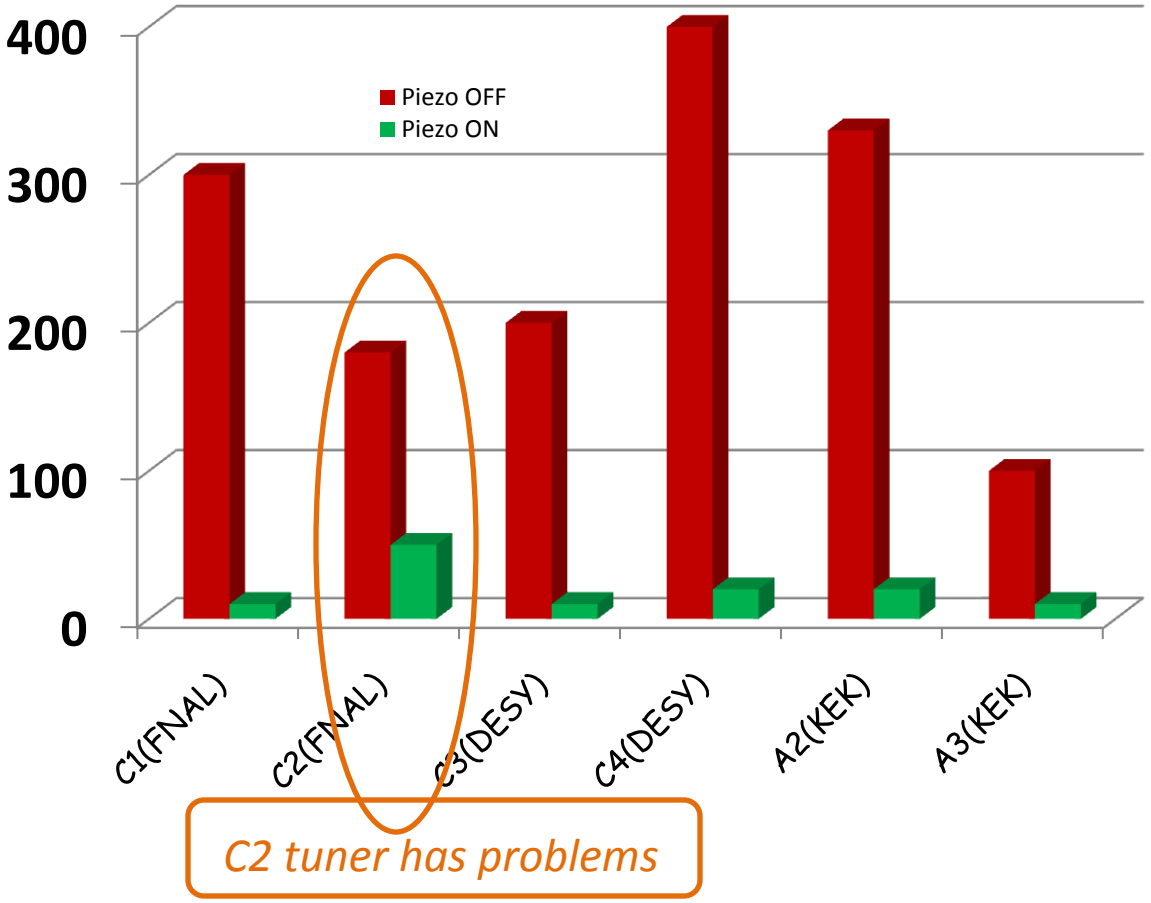




Lorentz Force Detuning (Hz)

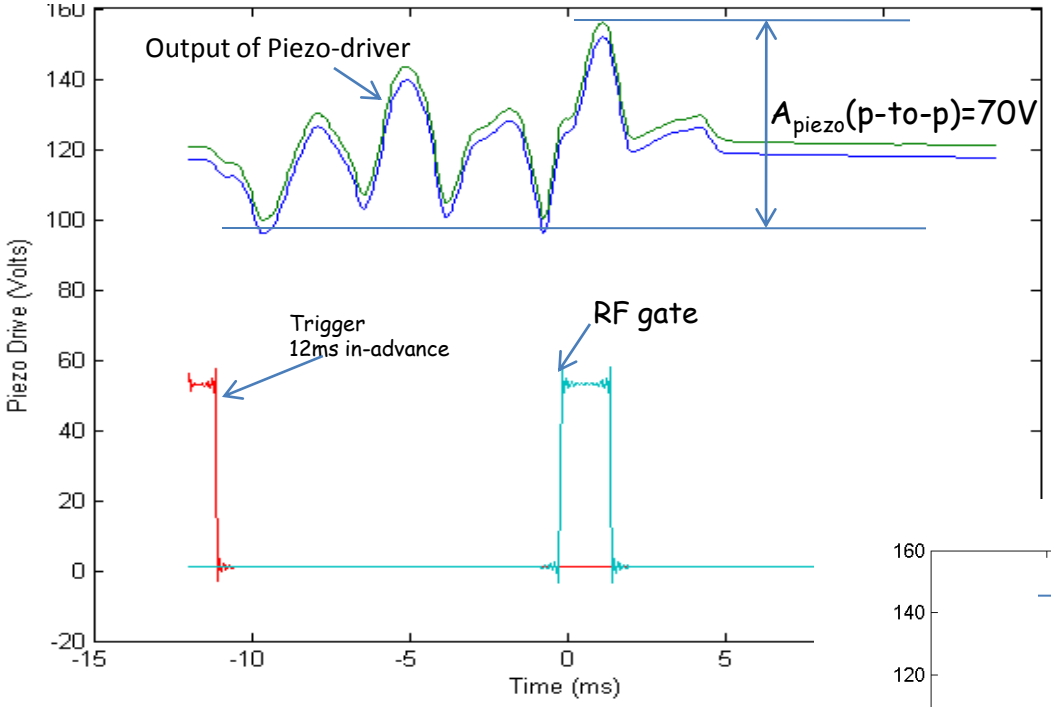
(during 1ms Flat-Top)

before and after Compensation

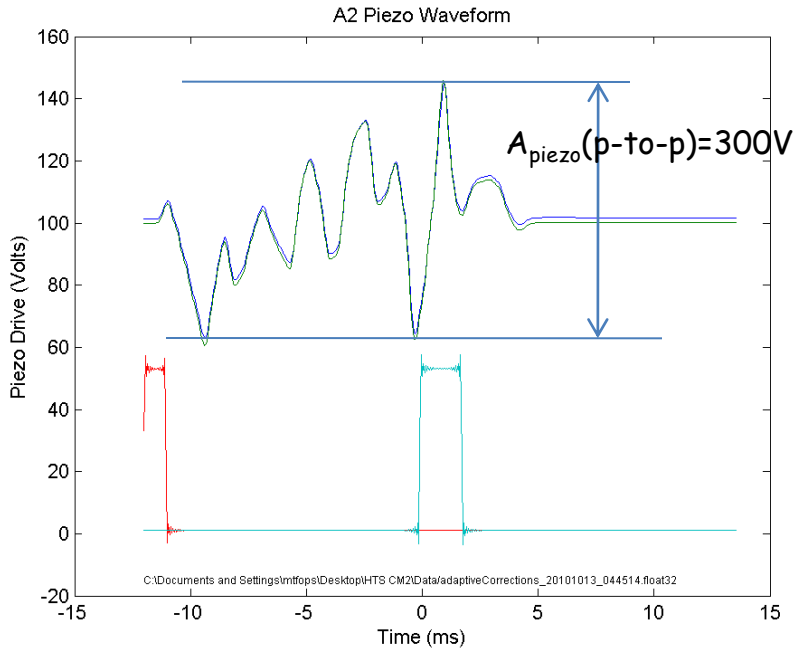


	Eacc	Piezo OFF	Piezo ON
C1(FNAL)	**27**	300	10
C2(FNAL)	**22**	180	50
C3(DESY)	**18**	200	10
C4(DESY)	**25**	400	20
A2(KEK)	**39**	330	20
A3(KEK)	**31**	100	10

Piezo Impulse Calculated by LS LFD algorithm
Cavity C1, compensation during "Flat-Top"



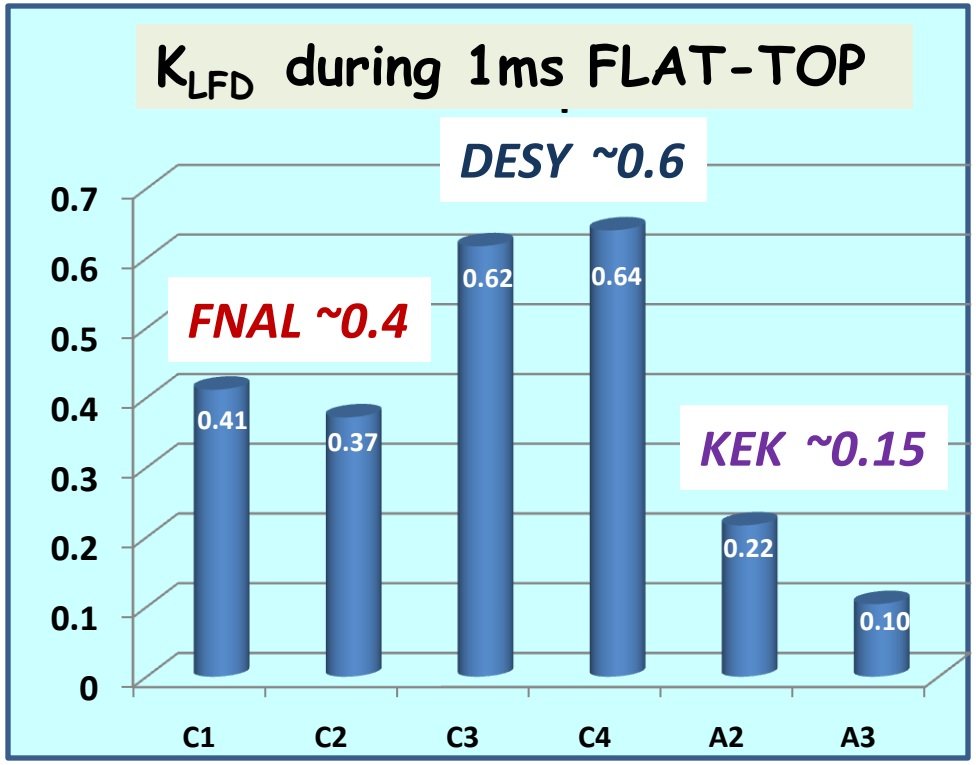
KEK A2 Cavity

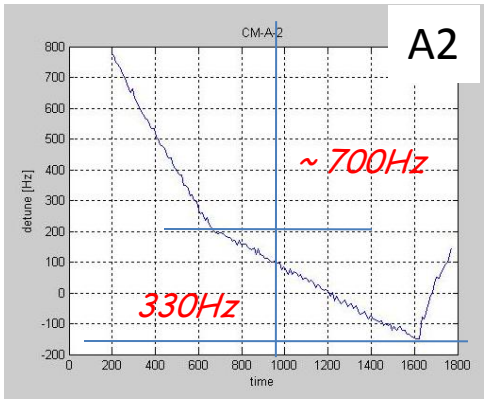


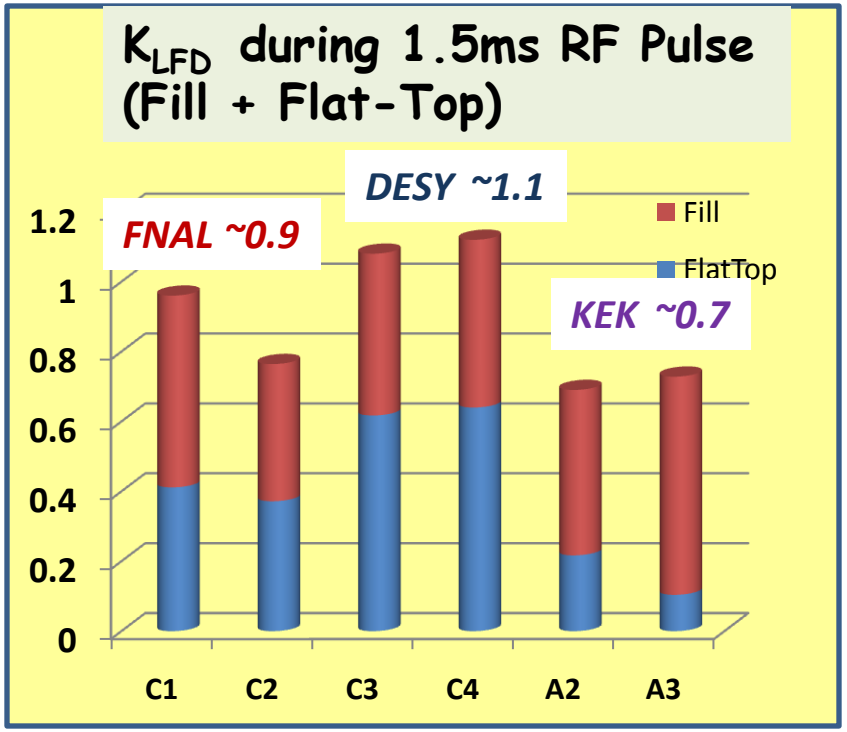
Cavity/Tuner LFD sensitivity

Blade(FNAL/INFN) vs. DESY/SACLAY vs. KEK(Slide Jack)

$\Delta F = -K_{LFD} * E_{ACC}^2$ → K_{LFD} – Cavity/Tuner Detuning Sensitivity to LFD





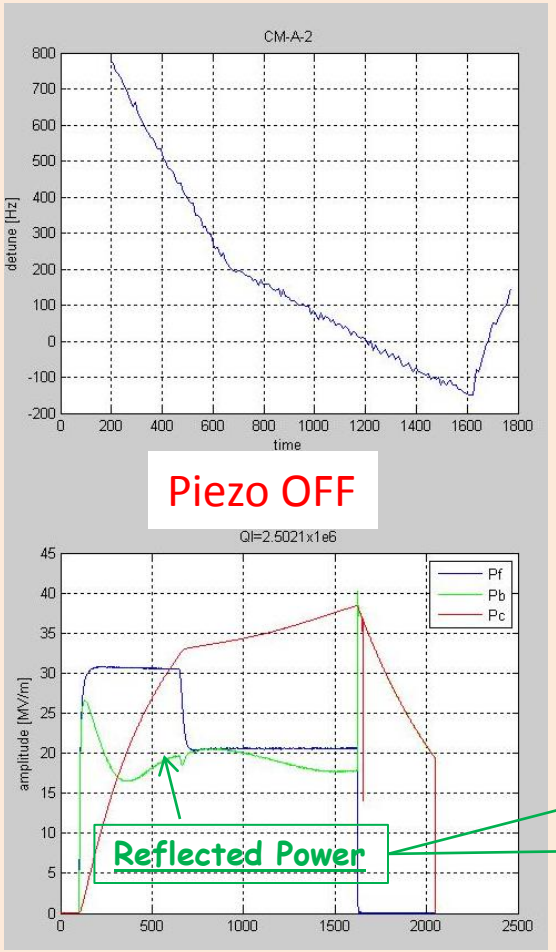


	FNAL/INFN	DESY/Saclay	KEK
K_{LFD} (1ms FLAT-TOP)	0,4	0,6	0,15
K_{LFD} (1,5ms RF pulse)	0,85	1,1	0,7

One of the advantage of FNAL's adaptive LS LFD Algorithm:

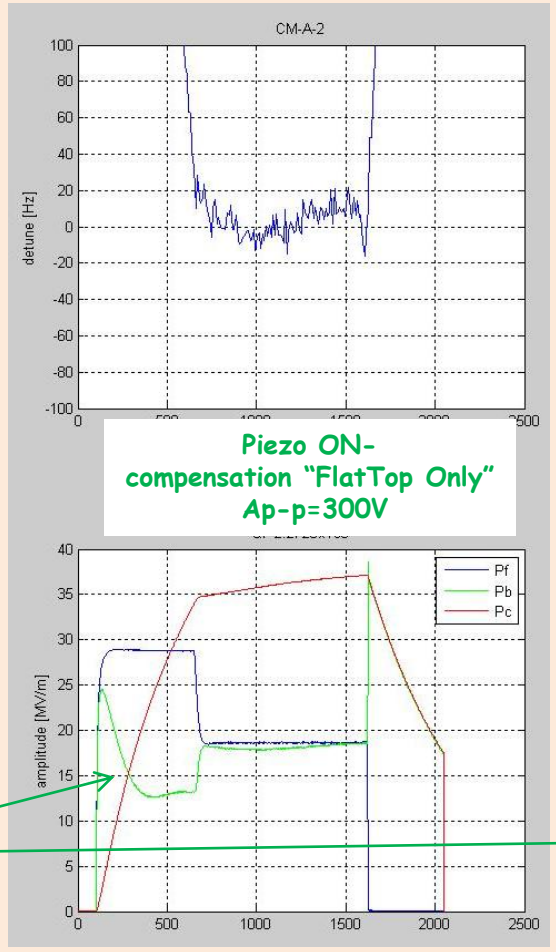
any part of RF pulse could be chosen for compensation ("Fill+FlatTop" or "FlatTop only")

KEK Cavity A2 at E_{acc}=35-37MV/m

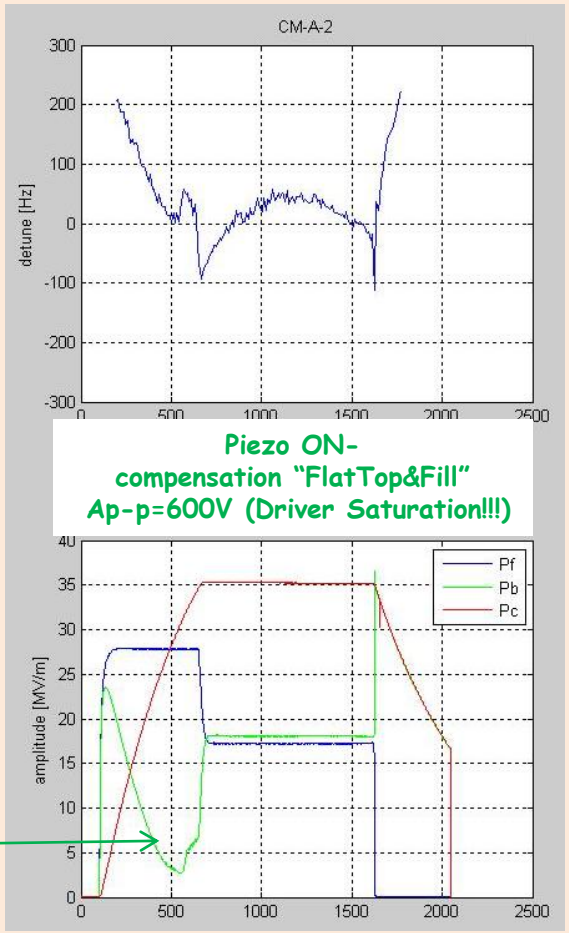


Piezo OFF

Reflected Power

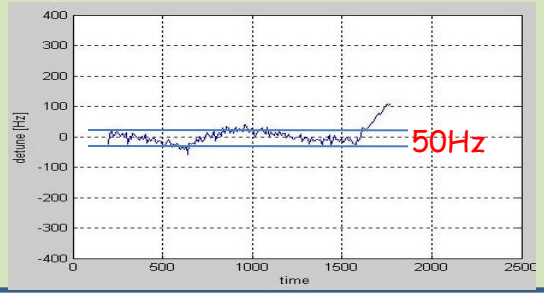


Piezo ON-
compensation "FlatTop Only"
Ap-p=300V

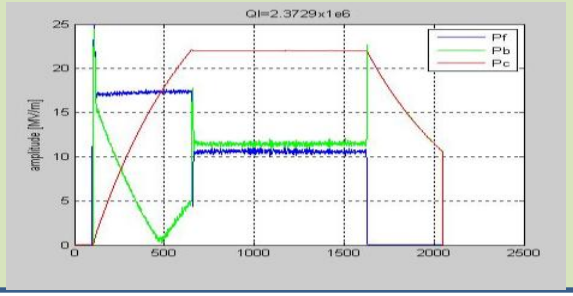


Piezo ON-
compensation "FlatTop&Fill"
Ap-p=600V (Driver Saturation!!!)

FNAL Cavity C2



50Hz

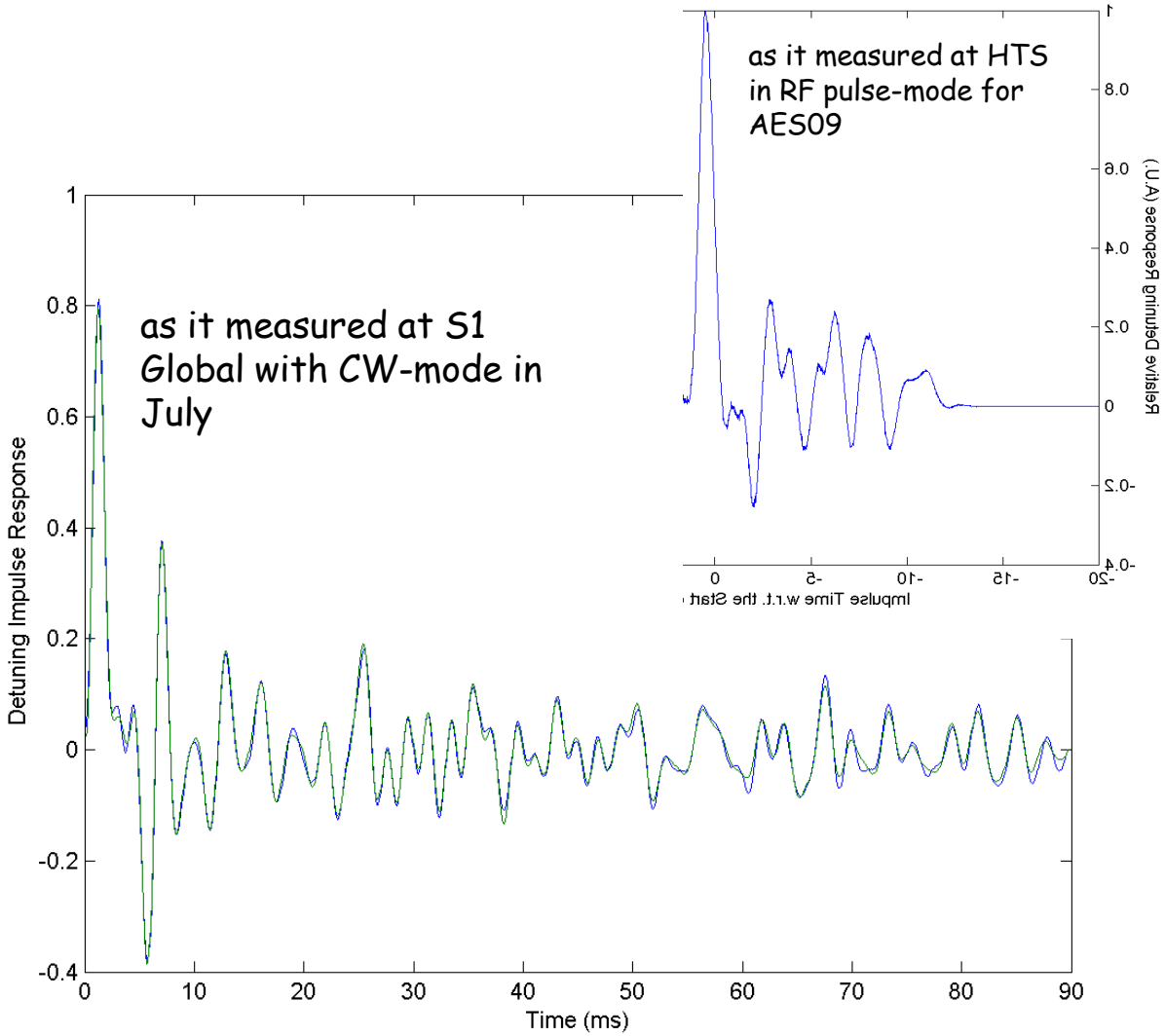


How to compare different tuner?

1) The LFD sensitivity K_{LFD} of the tuner "FlatTop" & "Fill+FlatTop"
2) The peak residual LFD after compensation using the optimized waveform; LFD compensation during only "Flat Top" OR "Fill +Flat Top".
3) The ration of the peak magnitude of the optimized waveform to the maximum voltage rating of the actuator;

4) The level of pulse to pulse variation as a function of the repetition rate to estimate the relative detuning contributions of microphonics and residual vibration.
5) To measure the complete transfer function in pulsed mode (but it is time-consuming measurements…)

Detuning Impulse Response of Blade Tuner



HTS RF-pulse Mode

Frequency		Strenght
147		**0.27**
387		**0.14**
470.88983		0.128047
250.230337		0.112473
584.549135		0.108575
21.315943		0.079539

S1 Global CW-mode

Frequency		Strenght
145		0.185
350		0.147
160.2395		0.087984

Summary

- LFD sensitivities (K_{LFD}) of 6 cavities with all 4 different types of tuners has been evaluated at maximum operated gradient
- Adaptive LS LFD algorithm working well for all type of tuners: (residual detuning was in the range of 10-20Hz)
- Large amount of data collected (using KEK & FNAL DAQ) to perform detail analysis of S1 G tuners characteristics.
- S1 Global LFD study during Oct. 5-15 was successful