Demonstration of the capability of LCLS-II tuner, installed on a dressed cavity, to compensate vibrations generated inside the cavity by an ILC-shape RF pulse

Extrapolation of this demonstration on the LFD compensation when the cavity is run at $E_{acc} > 30$ MV/m

Technical note
for FNAL-ILC team by Yuriy Pischalnikov, FNAL
5/10/21

We have “on hand” two options with cold LCLS-II cavities at FNAL currently. Can we do any reasonable LFD compensation test with the cold LCLS-II dressed cavity?

Short answer: without significant effort* – NO.

Reason: Both cavities 1) at vCM (verification cryomodule for LCLS-II-HE) and 2) at HTS have very narrow bandwidth (~30 Hz & ~3 Hz) and will require significantly longer than 1 ms fill time to be run at FR-pulse mode.

Filling the cavity with several ms period will not excite vibration at the main mechanical resonance (~200 Hz). As a result, there will be no significant LF detuning during 1 ms flat top (as it is required for the ILC demonstration experiment).

Examples of filling cavity with 4 ms (and 5 ms) flat top are presented in the next slide

* *Significant efforts: replace HP coupler; process the cavity to be able to run at 30+ MV/m; test at VTS; install HP coupler; install in HTS; cool-down HTS; restore LLRF & HP RF systems at HTS; restore operational system at HTS.*

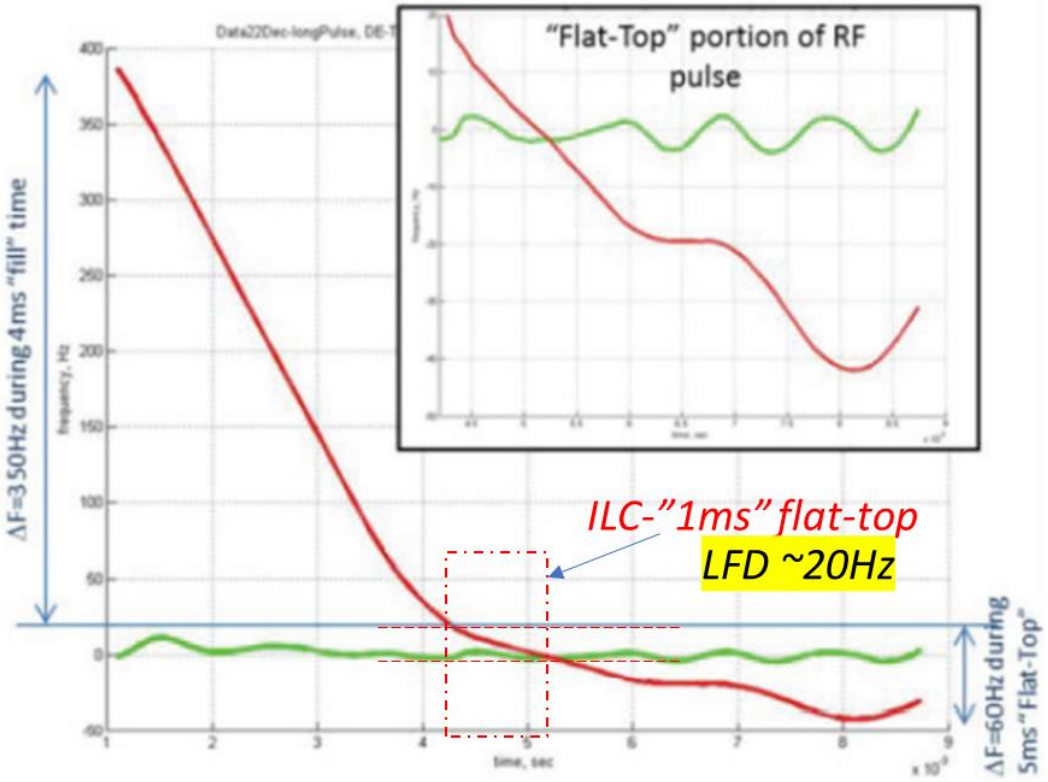

Figure 2: Detuning of the cavity *(QL=3*106 and E_{acc} = 18 MV/m)* by Lorentz forces during a 9 ms pulse. Red curve is cavity's LFD when piezo compensation is OFF. Green curve is the cavity's detuning when cavity resonance control with piezo tuner and adaptive compensation algorithm is active. Inset: zoomed window shows LFD detuning during 5 ms "flat-top" portion of RF pulse (red-piezo OFF; green- piezo ON

LORENTZ FORCE COMPENSATION FOR LONG PULSES IN SRF CAVITIES

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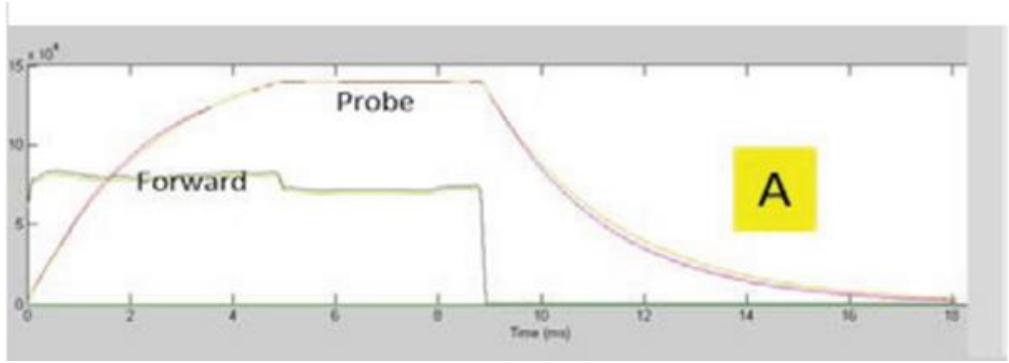
The loaded quality factor Q_L of both cavities can be varied between 10^6 ($f_{1/2}$ = 650 Hz) and to 10^7 ($f_{1/2}$ = 65 Hz) by adjusting the ratios of the power couplers. Cavity baseband waveforms were recorded for the following matrix of operating conditions:

- Q_L: $3*10^6$; $6*10^6$; $1*10^7$
- E_{acc}: 15 MV/m; 20 MV/m; 25 MV/m;
- RF power per cavity: 40 kW; 50 kW, 60 kW.

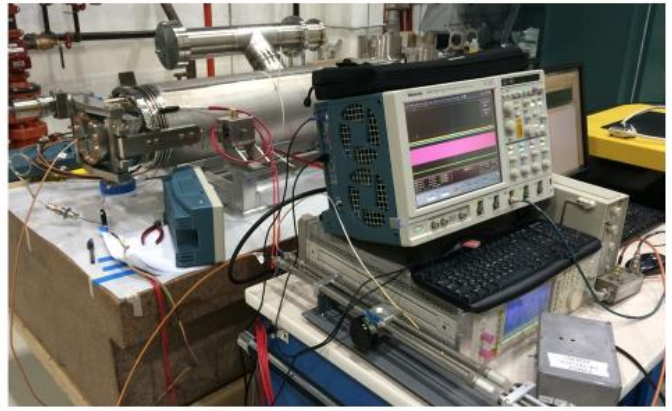


Possible tests [with WARM cavity] to confirm that

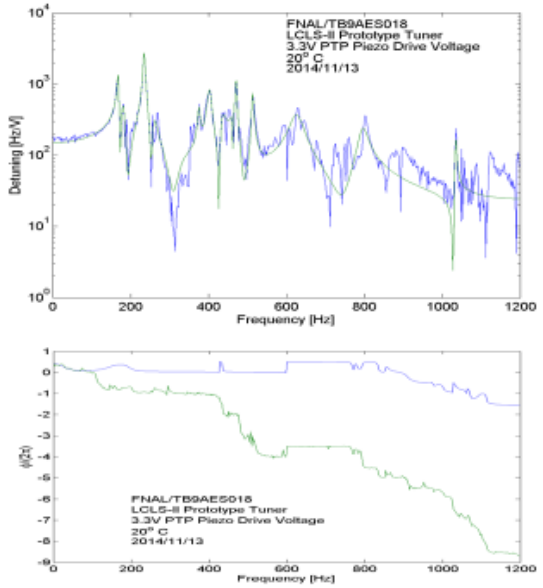
a) dynamic parameters of the dressed cavity/LCLS-II tuner will be not significantly different from previously tested at S1Global dressed cavities/tuner systems (Slim Blade Tuner or XFEL or Slide Jack Tuners)
b) the LCLS-II tuner will be capable to compensate vibrations that are similar to vibrations generated inside the cavity with an RF pulse (ILC type)

Proposal to test a WARM dressed cavity with the tuner installed

Setup for WARM Tuner/Cavity (AES027) study



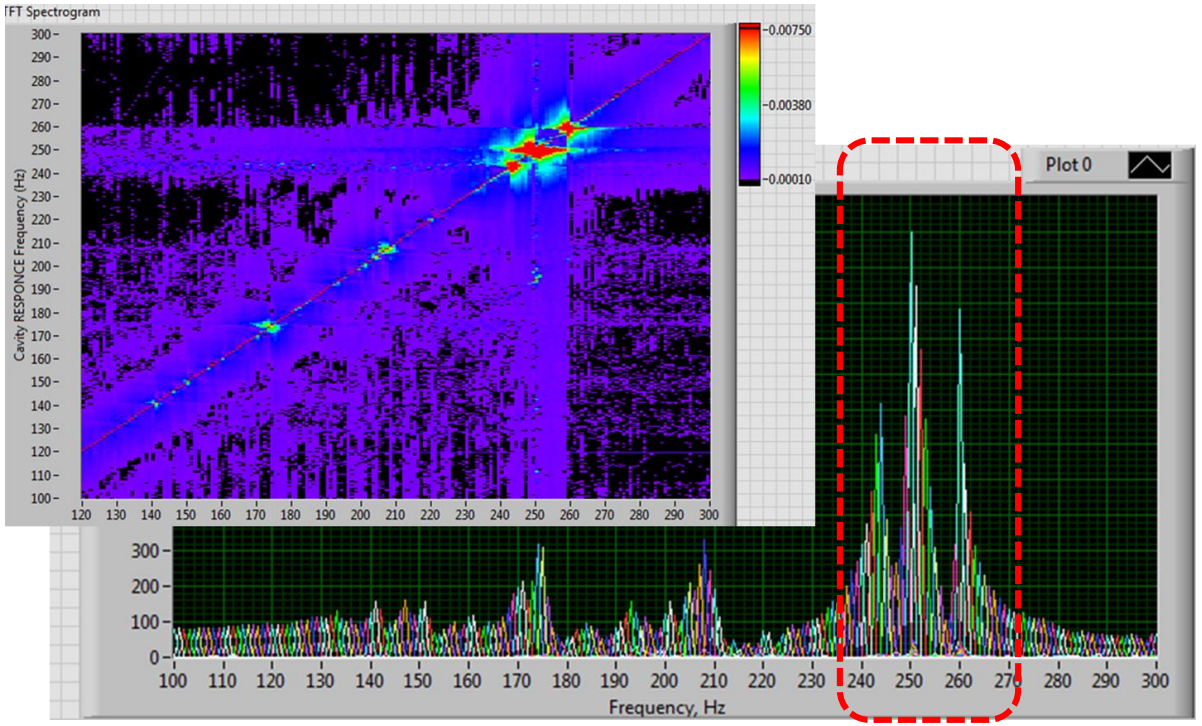
WARM
Cavity Transfer Function (Piezo-to-Cavity)



#	f(Hz)	tau(ms)	kappa(Hz/V)	Strength
1	**235**	49	14.5	***0.65***
2	**168.1**	41	6.86	***0.1***
3	**471.2**	46	5.79	***0.09***
4	**402.2**	17	1.29	***0.04***
5	**232.6**	126.4	1.29	***0.03***

Cavity driven with 3.3Vpp sinusoidal drive signal and frequency was stepped between 1Hz to 1200Hz with increment of 1Hz.
Forward and probe signals feed of an AD8032 analog phase detector.
Output digitized for 5sec interval at rate of 10kHz.

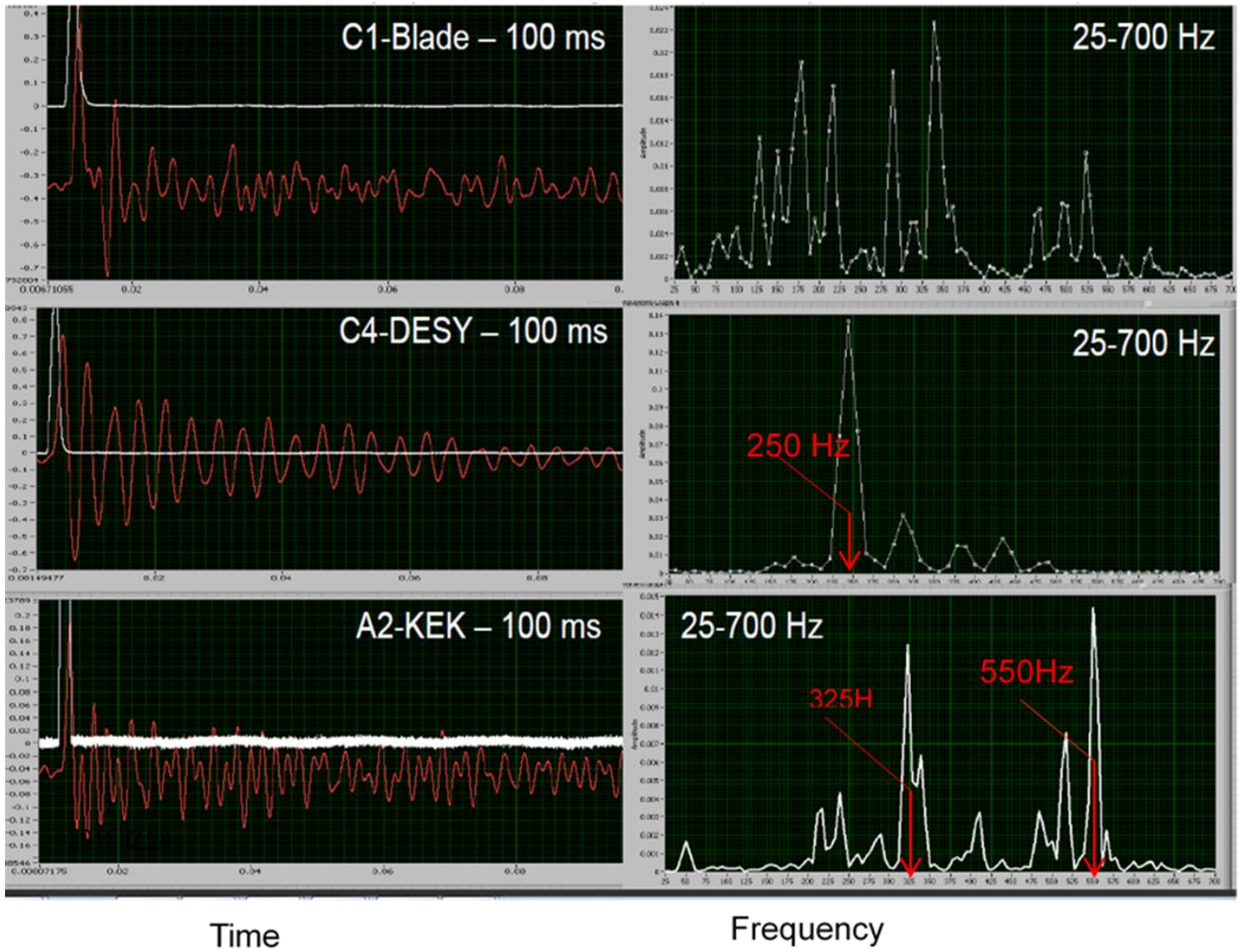
COLD Transfer Function



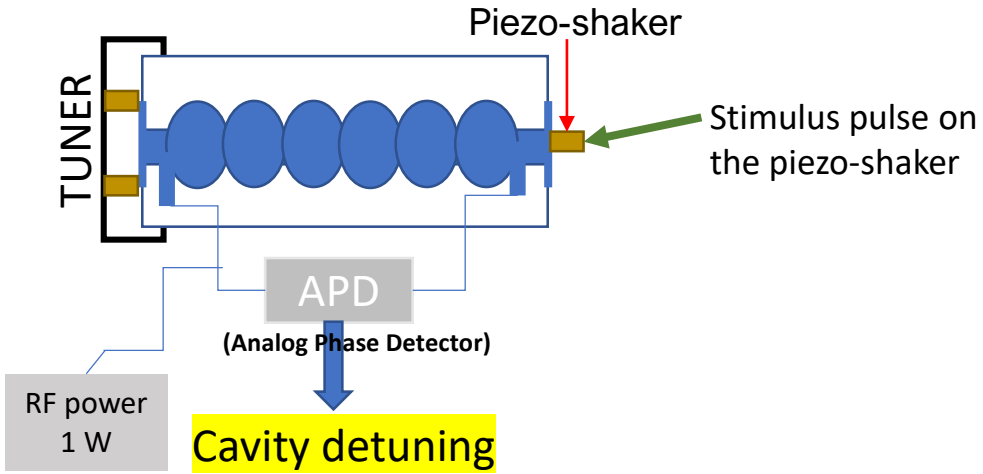
Very strong correlations between measurements of WARM vs. COLD transfer functions

Summary of the S1Global testing of the 3 tuner types.

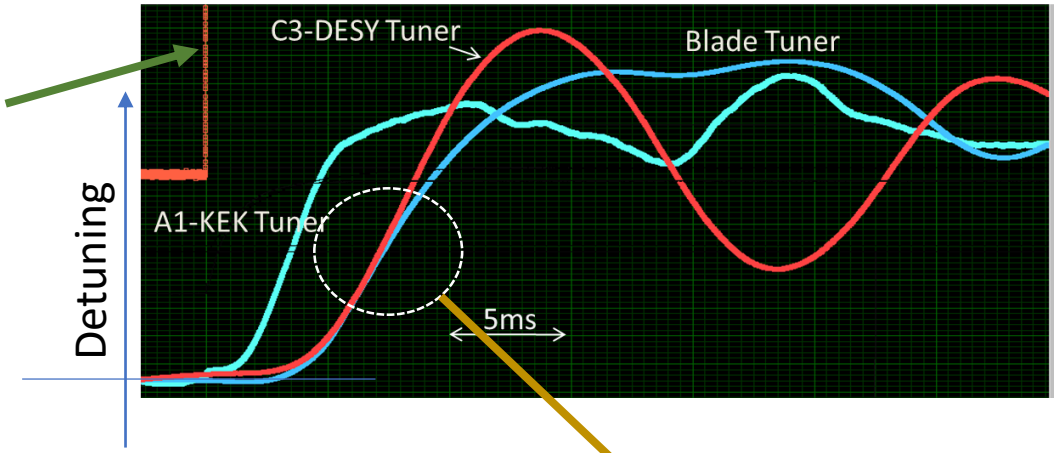
Test of the response of the dressed cavities (with CW RF power of 1 mW) on the short stimulus pulse sent to piezo-actuators



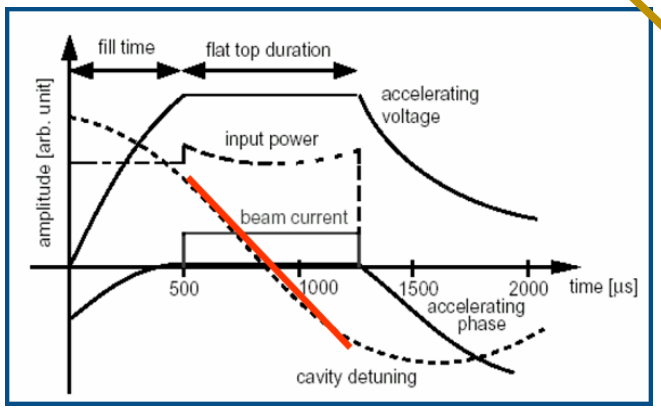
Proposed experiment on the WARM LCLS-II cavity/ GENERATE DETUNING (the same as LFD)

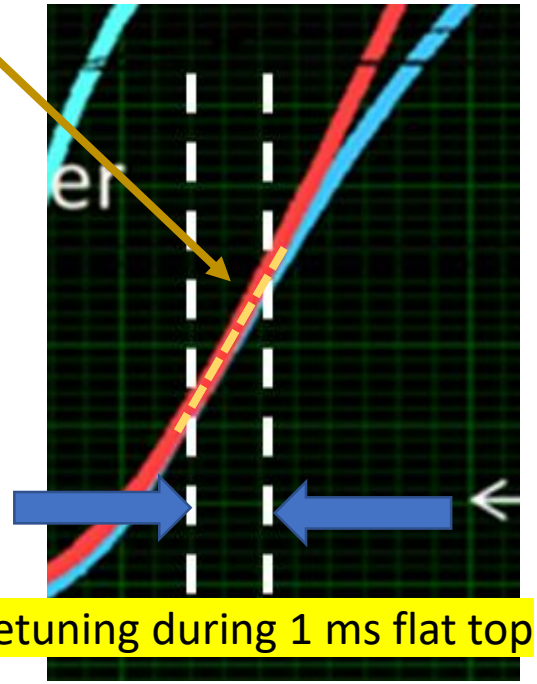


Stimulus pulse on the piezo-shaker



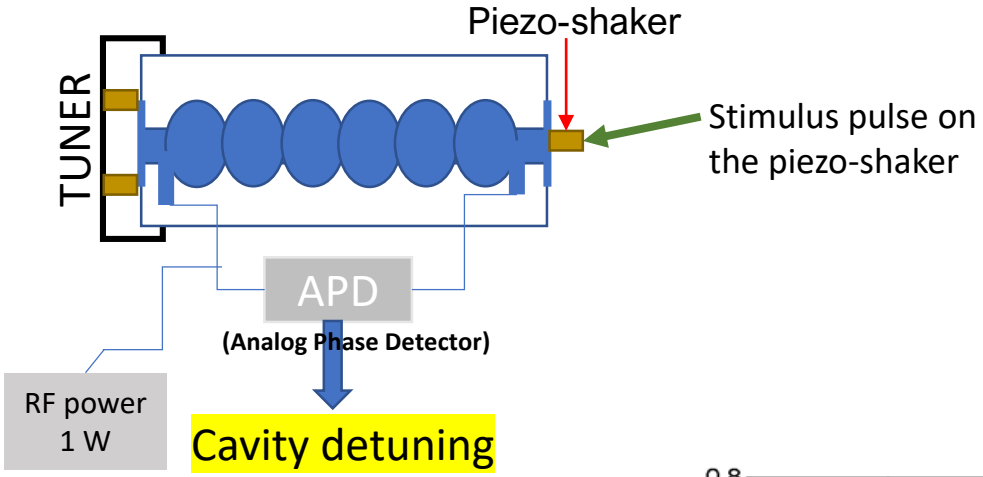
Short (or step) stimulus pulse on the on the Piezo-shaker will generate vibration inside the cavity. It will be simulated LF detuning inside the cavity. Tuner piezo will compensate detuning (make the cavity detuning FLAT) during 1 ms timing interval.

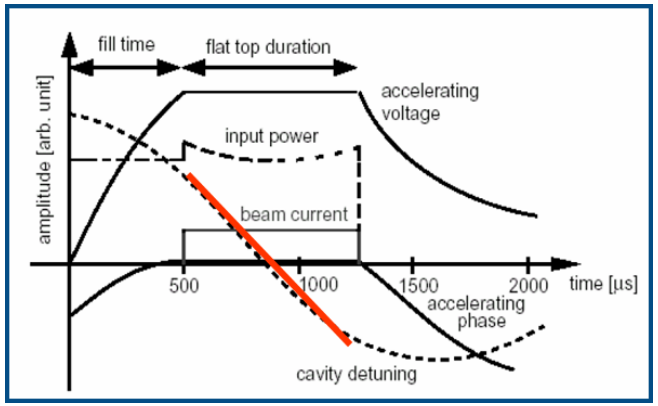


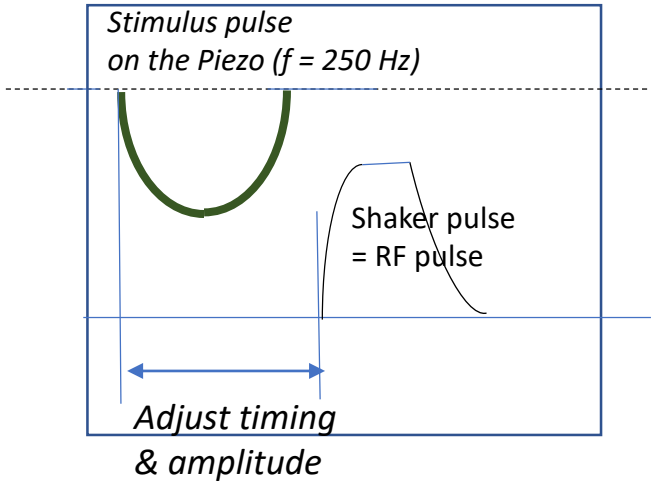


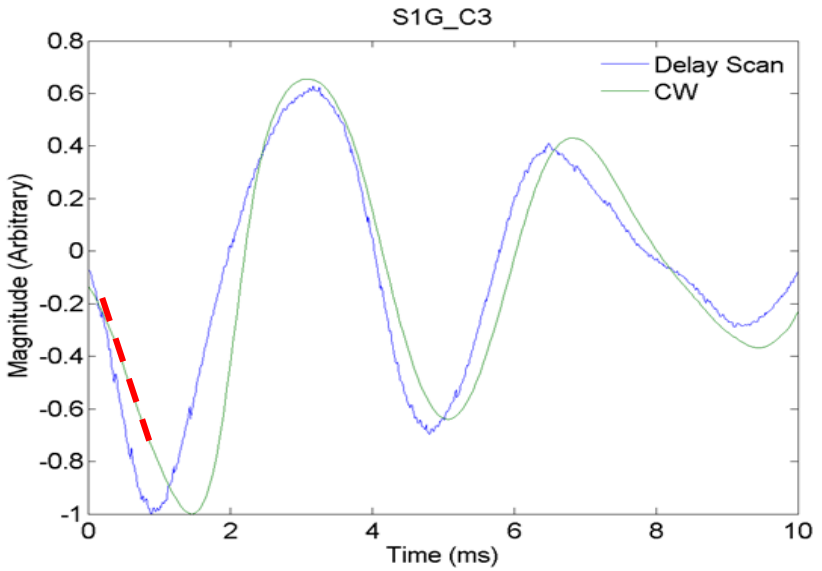
Detuning during 1 ms flat top

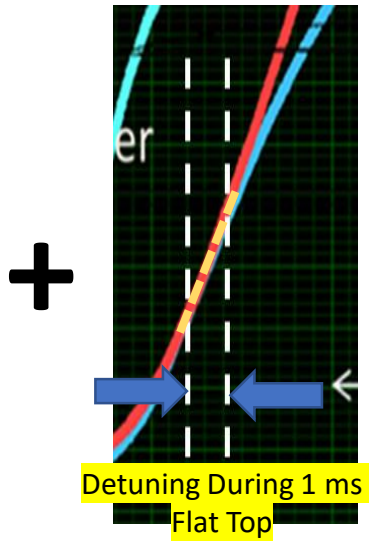
Proposed experiment on the WARM LCLS-II cavity / COMPENSATION

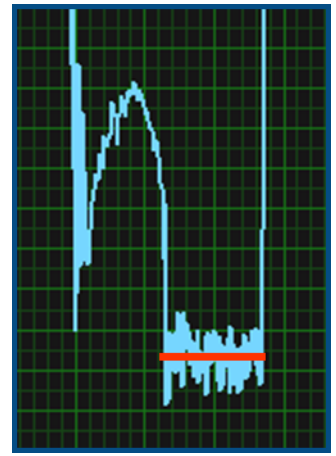












Cavity response from tuner's piezo