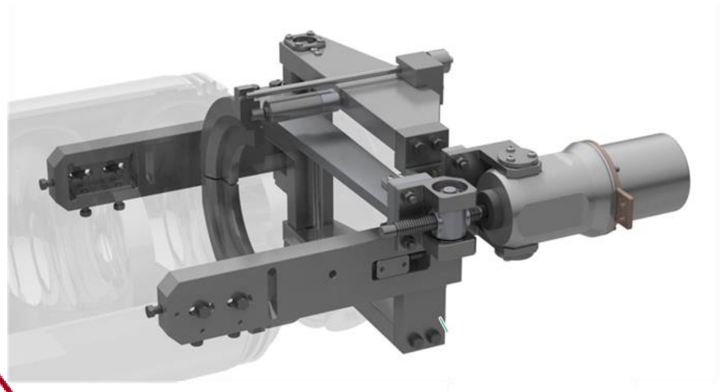
Modifications of the TUNER Frame for LCSL II HE OFO

Internal Review
SRF APSTD

Yu.Pischalnikov

10/15/2020



Tuner System For Dual Frequency Operation

Yuriy Pischalnikov

January 10, 2020

SLAC NATIONAL ACCELERATOR LABORATORY

Fermilab Jefferson Lab

U.S. DEPARTMENT OF ENERGY | Stanford University

Outline

- Required range of the Tuner for Dual Frequency Operation
- New Specs for Tuner: LCLS II HE vs LCLS II
- *tuner range*
- *specs for the Phytron electromechanical actuator*
- *specs for the piezo-actuators*
- Modification of the slow tuner frame to deliver extended range
- Capability of the Phytron actuator (LVA 52-LCLS-II-UHVC-X1) to preserve required reliability with new specifications.
- Capability of the PI piezo-actuator P-844K075 (or some other piezo-actuator) to preserve required reliability with new specifications.

Most challenging aspects for TUNER operation will be lifetime of the stepper motor and piezo actuators: BUT it is not in the agenda for today review

LCLS II HE Dual Frequency Operation /OFO *
Off Frequency Operation

Proceedings of FEL2019, Hamburg, Germany - Pre-Release Snapshot 29-August-2019 13:00 CEST

MULTI-ENERGY OPERATION ANALYSIS IN A SUPERCONDUCTING LINAC BASED ON OFF-FREQUENCY DETUNE METHOD*

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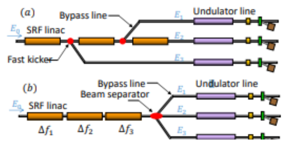
Abstract

The free-electron laser facilities driven by a superconducting radio-frequency (SRF) linac provide high-repetition-rate electron beam, which makes it feasible to feed multiple undulator lines at the same time. In this paper, we study a method of controlling the beam energy of multiple electron bunches by off-frequency detuning of the SRF linac. Based on the theoretical analysis, we present the optimal solutions of the method and the strategy to allocate linac energy for each possible off-frequency detune. The initial acceleration phases before detuning of the SRF linac can be optimized to reduce the necessary SRF linac energy overhead. We adopt

Recently, another scheme using achromatic electron delay system is proposed to produce multi-energy beams for the SRF linac-driven XFELs [9].



1. F $_{Operational}$ =1.3GHz
2. F $_{OFO}$ =1.3GHz-465kHz

Recently, another scheme using achromatic electron delay system is proposed to produce multi-energy beams for the SRF linac-driven XFELs [9].

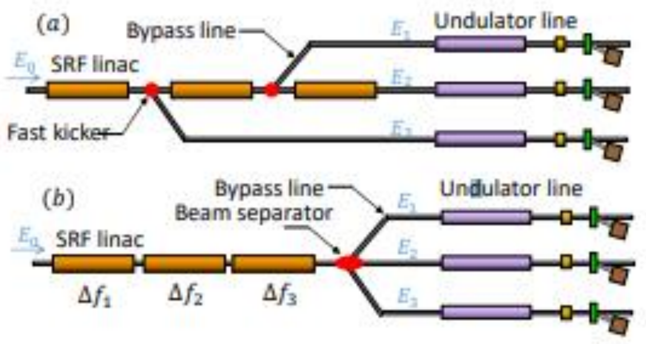


Figure 1: Two schemes of multi-energy operation of a SRF XFEL: (a) kick the beam to bypass line at desired energy

Proceedings of FEL2019, Hamburg, Germany - Pre-

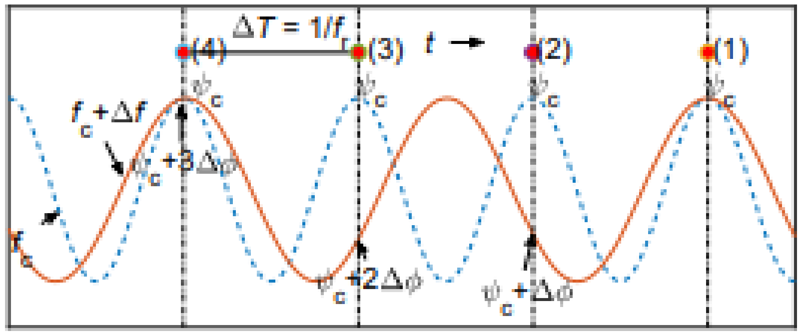
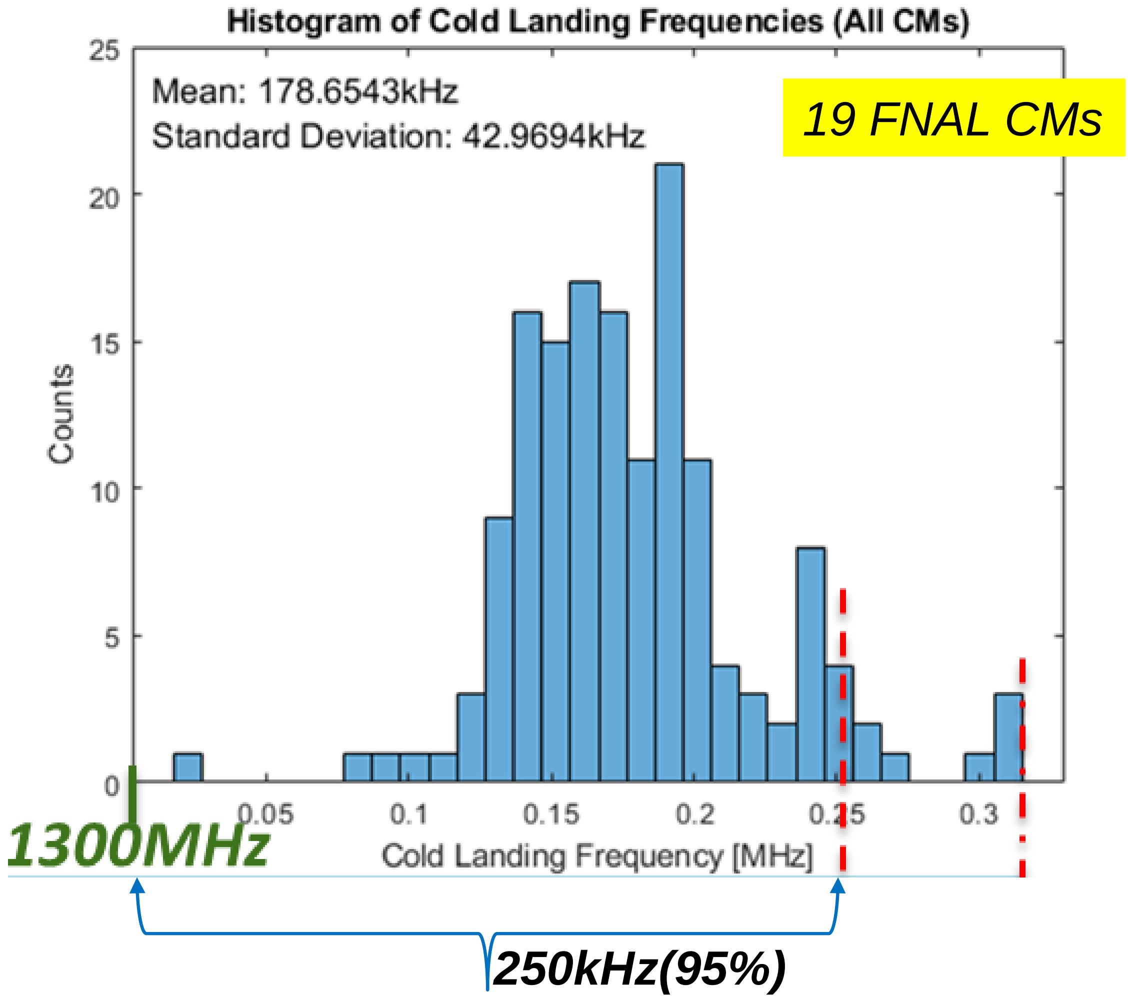


Figure 2: Acceleration phase changes of the CW electron beams by the off-frequency detune of the SRF cavities. Here we use $M = 3$ and acceleration phase of the fourth beam is the same with the first one.

Frequency of the cavities when CMs first time cool down to T=2K

$F_{T=2K\ Landing\ (mean)}$ = 1.300.180kHz (1.300.320kHz for 100% of cavities)



Frequency range for OFO

ΔF=320kHz (for normal operation F=1.3GHz)

(100% of the cavities must be tuned to 1.3GHz)

ΔF=465+250kHz=715kHz *

(for ~95% of cavities to be tune to OFO)

715/320~2.25 times

** Overall max. compression of the cavity will be up to 900kHz (it is included cavity compression at FT=2K Landing)*

GOAL of today's review to evaluate proposed modifications of the TUNER Frame

Specifications for Tuner range for LCLS II HE OFO increased in ***~2.25 times*** *(compare with LCLS II)*

To reflect specs for increased tuner range ratio of the double lever tuner was changed from 1:20 (1.4Hz/step) to 1:16 (1.75Hz/step). To deliver new ratio 4 parts of the tuner were modified. First LCLS II HE tuner prototype built & tested on the cavity at VTS. This modification delivered range increase in factor ***~1.25***

Analysis of statistics for LCLS II cavity/tuner systems assembled on the 40 CM will be presented. Based on the data and specifications for tuner stroke we are proposing some additional parts modifications.

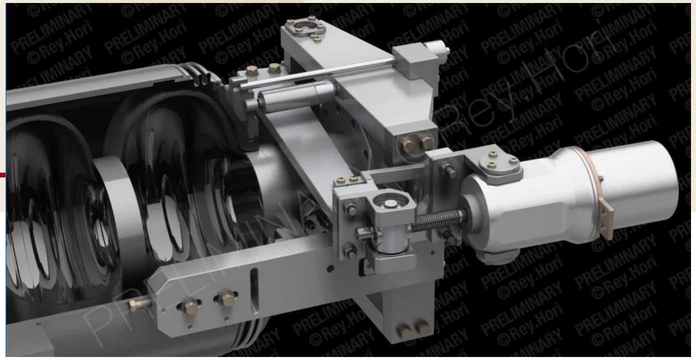
LCSL II HE project took some approach to extremely carefully review all "modifications/deviations" from design proven by construction of the 40 LCLS II 1.3GHz cryomodule.. Lessons learned: small modifications without full scope prototyping could lead to failure…

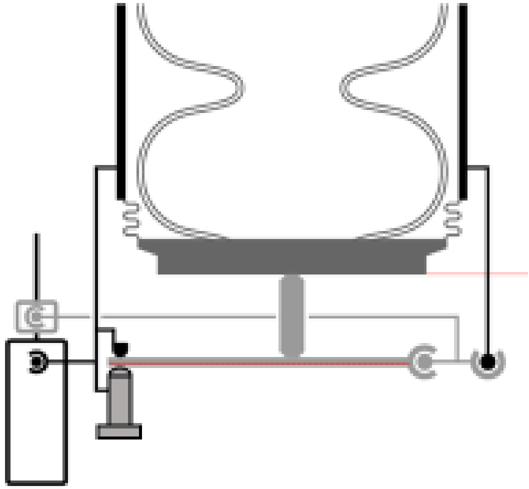
Specifications for Tuner system
LCLS II vs LCLS II HE (for Dual Freq. Operation) (I)

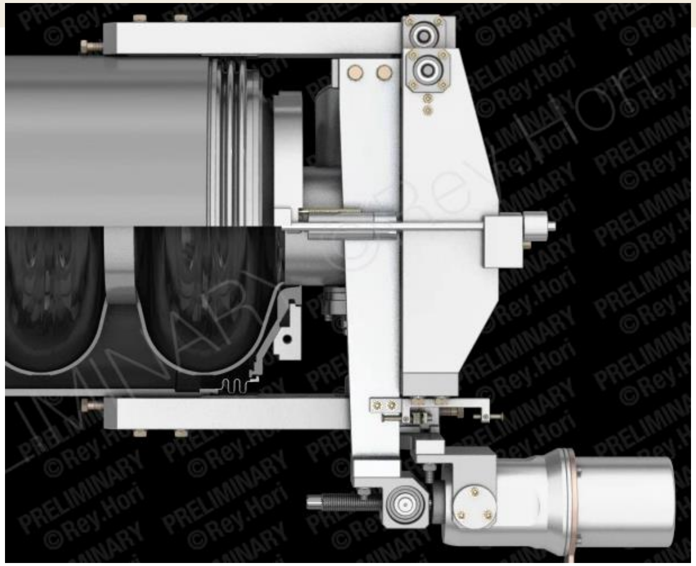
	LCLS II	LCLS II HE
Cavity frequency target, GHz	1.3GHz	1.3GHz-465kHz
Cavity frequency tuning from T=2K landing position, kHz	320 kHz	715 kHz
Forces on the Phyton Actuator	300 N	600 N
Forces on each PI piezo-actuator from compressed cavity at operational point	3 kN	6-7 kN

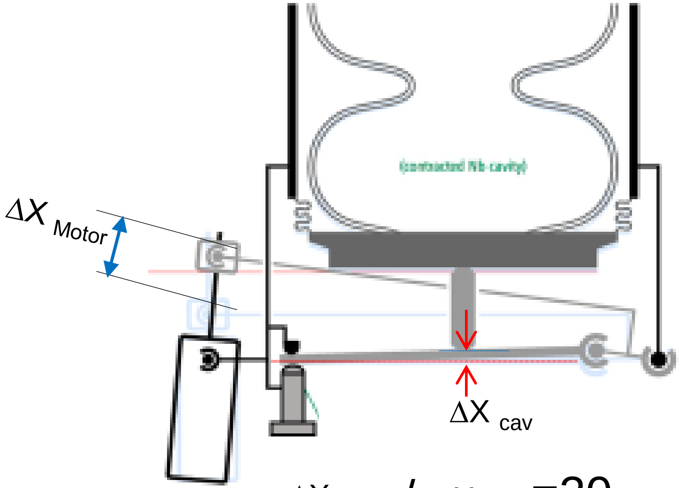
LCLS II Compact Double Lever Tuner

(principle of operation)

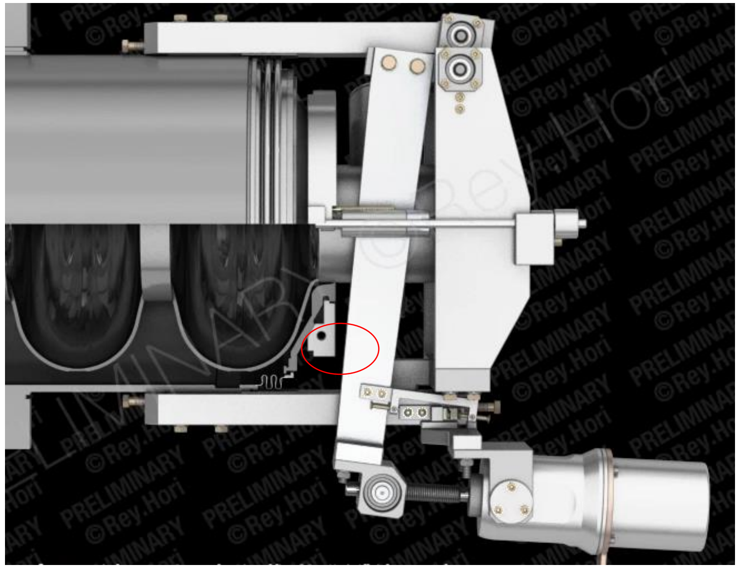


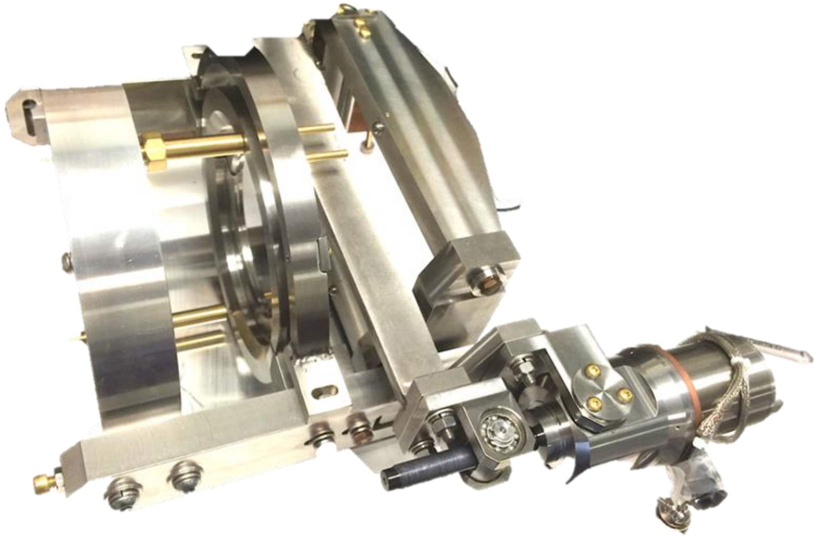






$\Delta X_{Motor} / \Delta X_{cav} = 20$





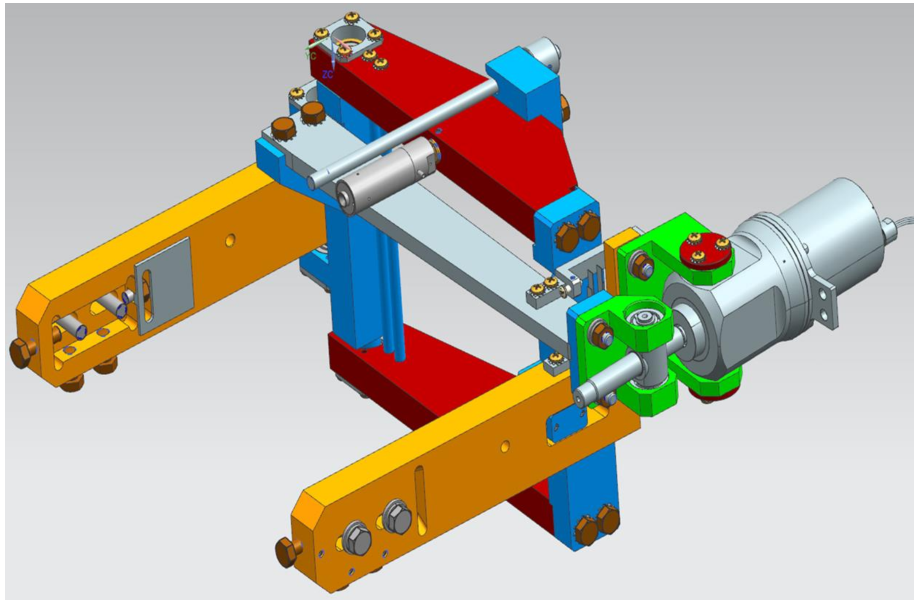
VIDEO of the Tuner

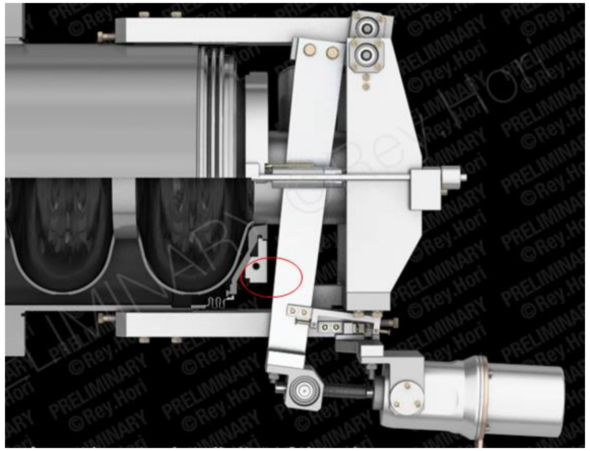
Can the Slow Tuner “as-is” deliver >700kHz tuning range?

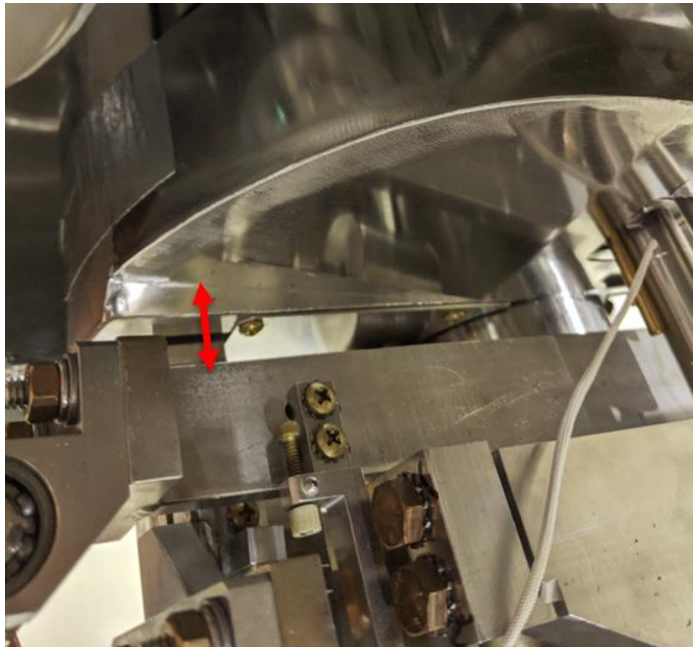
“As is” LCLS II slow tuner could not deliver ΔF=700kHz

– Tuner motor arms motion will be limited by existing space between tuner and end-cup magnetic shielding of the cavity.

- In addition length of the Phytron actuator shaft will be not enough for required travel of the nut. (700/kHz/1.4Hz/step~50mm)







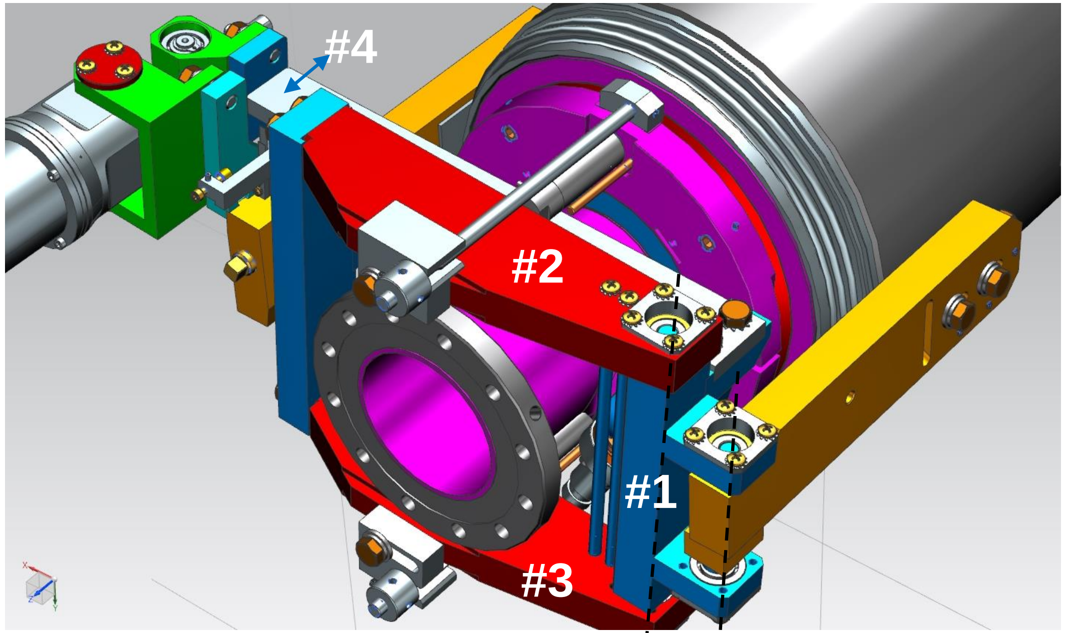
Modification of the Slow Tuner frame to deliver 700kHz tuning range

Change of the double-lever tuner ration from 1:20 to 1:16

We took following approach:

- make minimal tuner modifications (preserve all tuner/cavity/He Vessel interfaces);

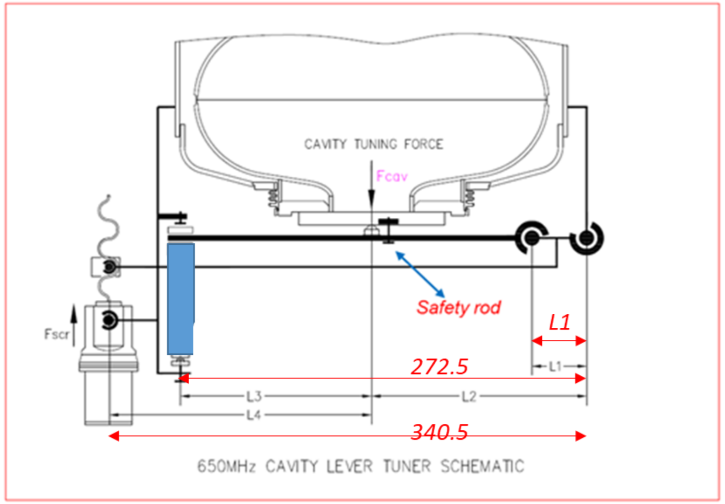
-change the length of lever L1 from 30mm to 37.5mm we delivered tuner ratio 1:16 (instead of 1:20)



37.5mm (vs 30mm)

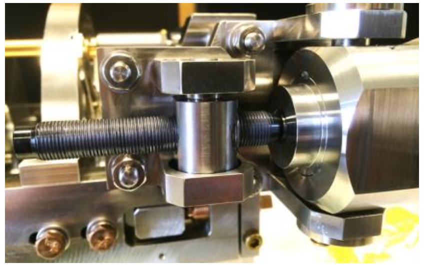
Four components of the existing need to be changed. (see labels)

This design modifications will work for all cavities, including special design tuner for cavity#1.



L1, mm	30	37.5
Tuner Ration	20	16
Hz/step	1.4	1.75

700kHz/1.75Hz/step
=40kSteps
=40mm on the shaft



First prototype of modified/ extended range Tuner for LCLS II HE

- Four new components have been machined.
- Modified tuner assembled by replacing these new components in tuner removed from CM5.
- New tuner has been installed on the dressed LCLS II cavity for VTS test.
- Results of the test will presented later in separate talk.

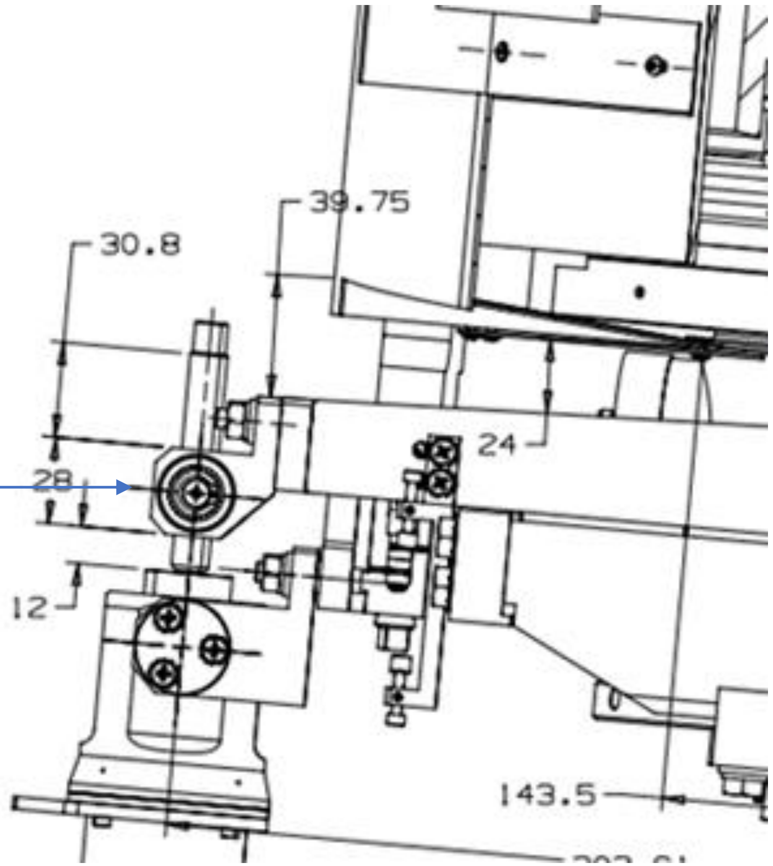
Additional efforts to minimize required stroke on the motor shaft

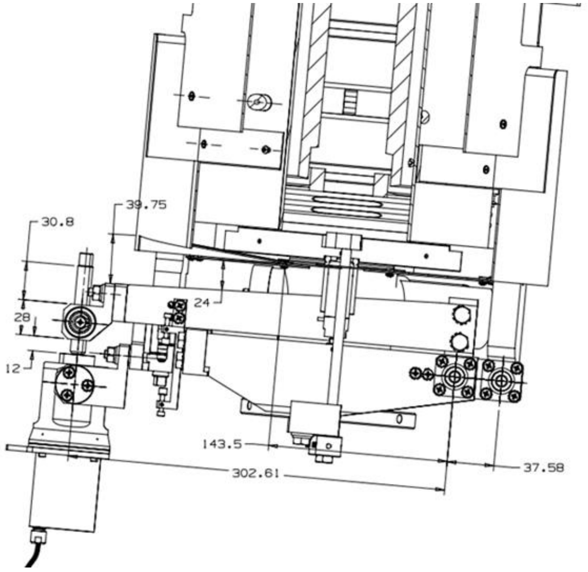
1. For LCLS II HE tuner will be mounted on the cavities when beamline will be under vacuum (during LCLS II project we done it with beamline back-filled with N2, 1bar) … this will deliver additional cavity compression ~ -60kHz.
2. During installation of the tuner on the LCLS II CMs we preloaded piezo (compressed warm cavity) on -50kHz.   For LCLS II HE we planning to increase this value to -100kHz.

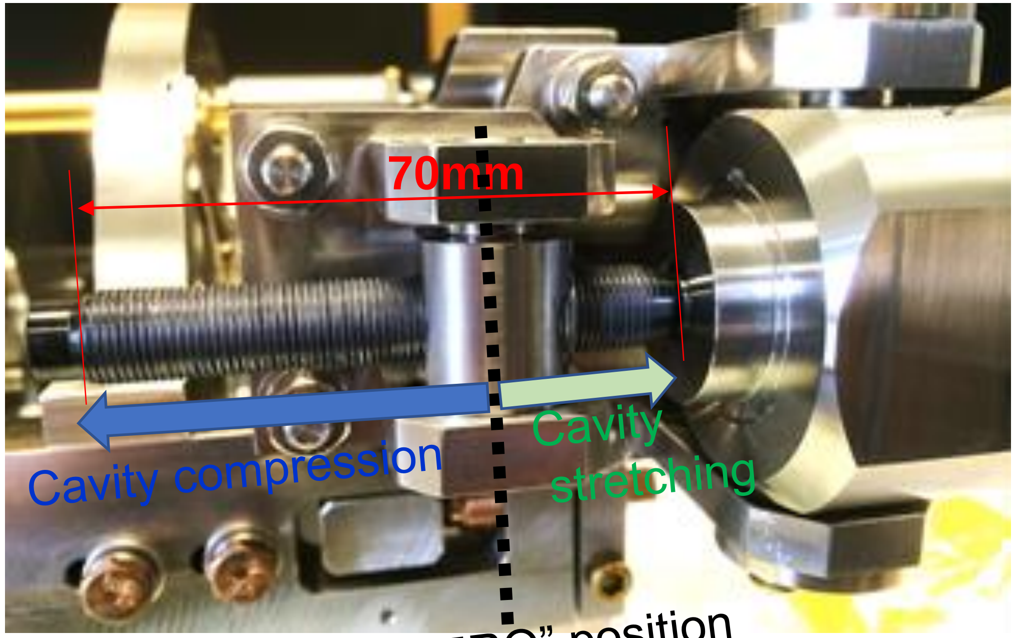
Both efforts will decrease overall *slow tuner frequency range* for LCLS II HE OFO on ~ (-110kHz)

Stepper motor actuator
Translation of the rotation to linear stroke.
Shaft =70mm…
Available for tuning range ~40mm

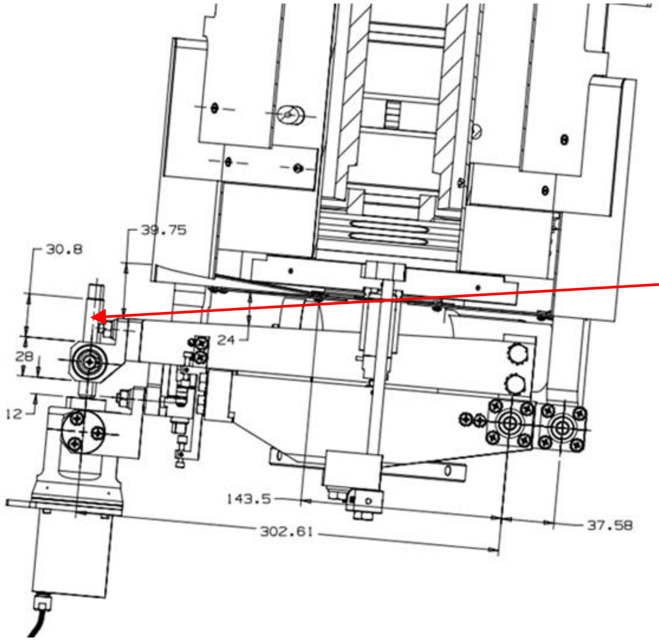
FROM
T=2K
Landing position

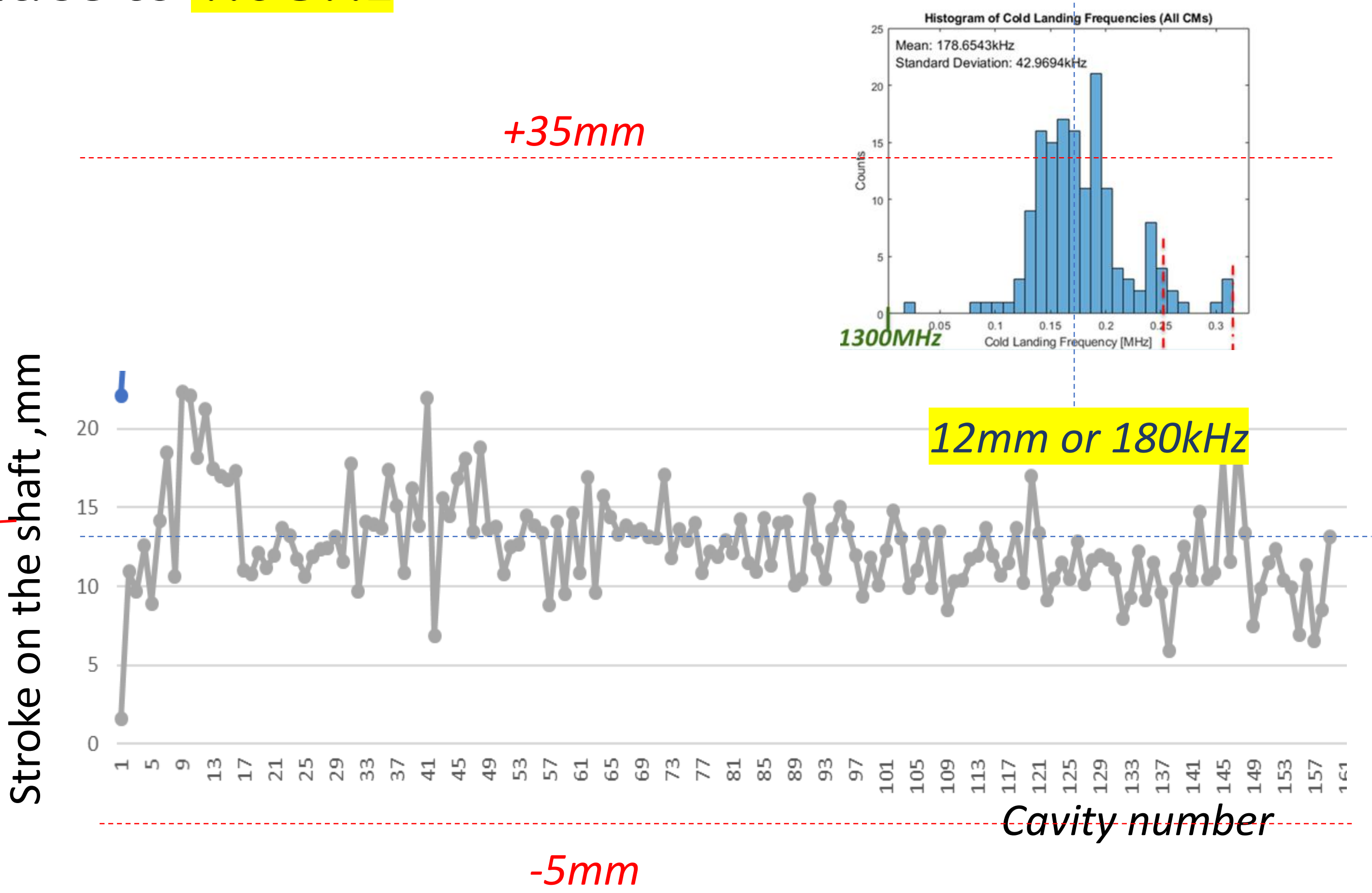




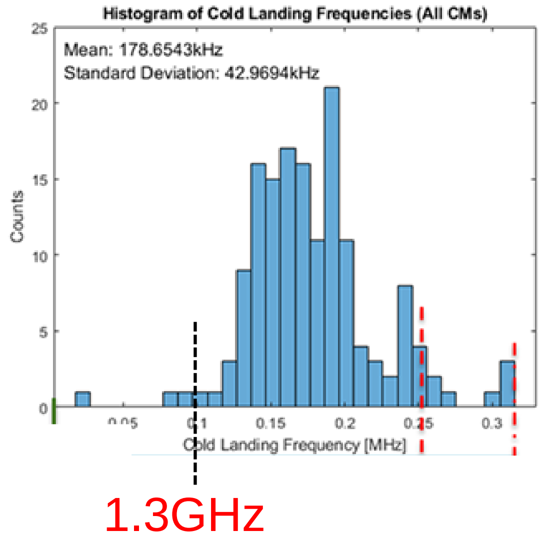


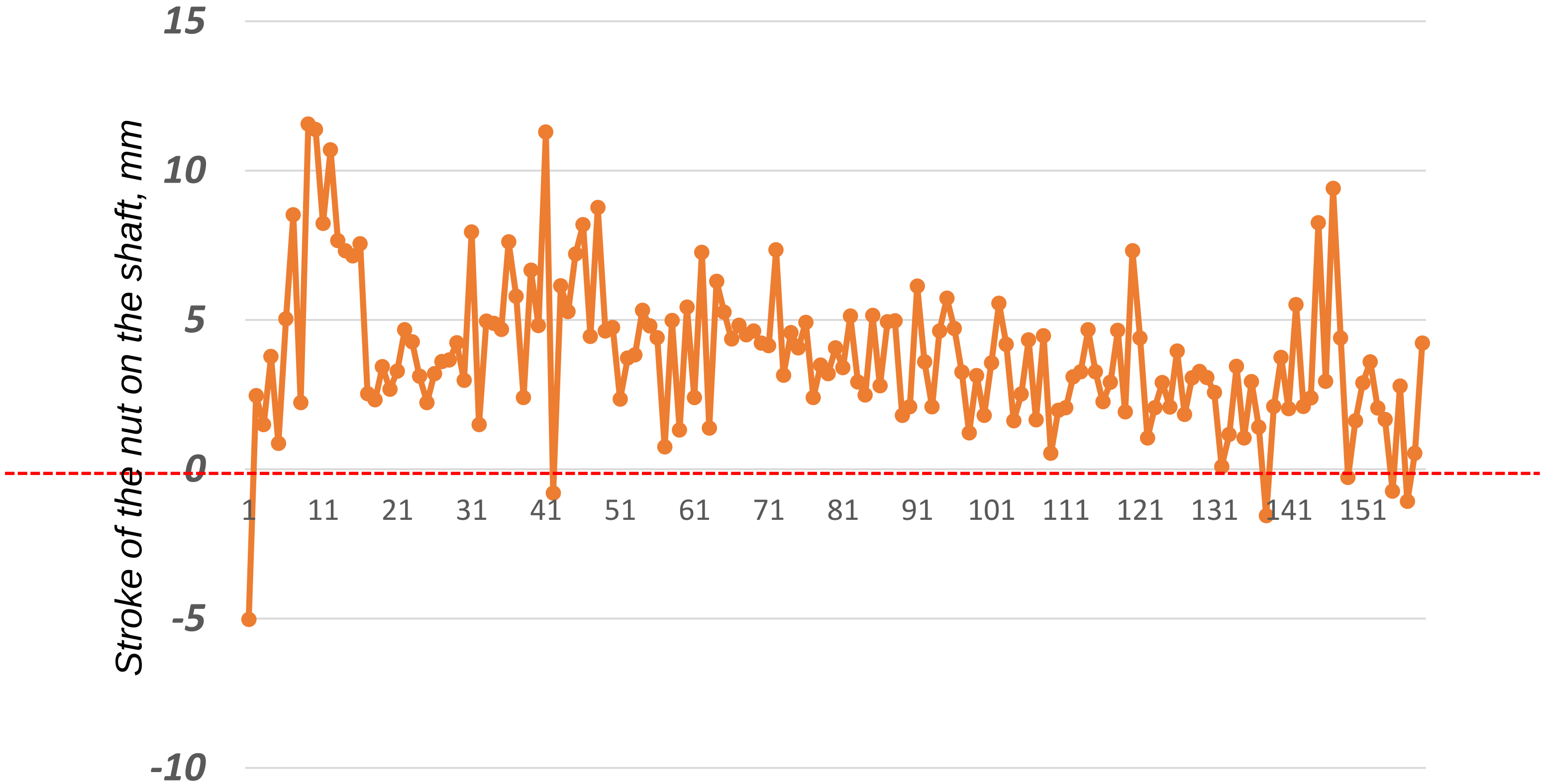
Stroke on the stepper motor shaft for LCLS II FNAL's 20 CMs to tune cavities to 1.3GHz



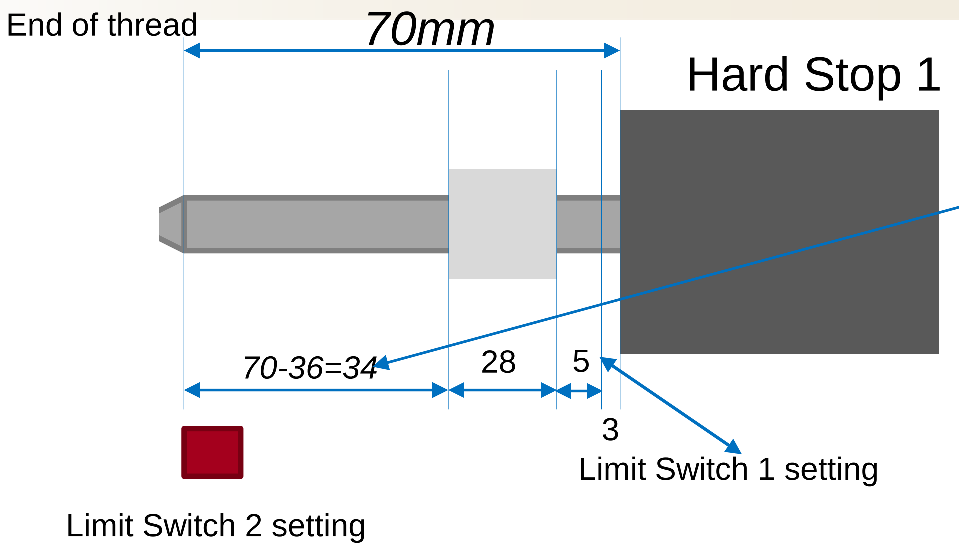


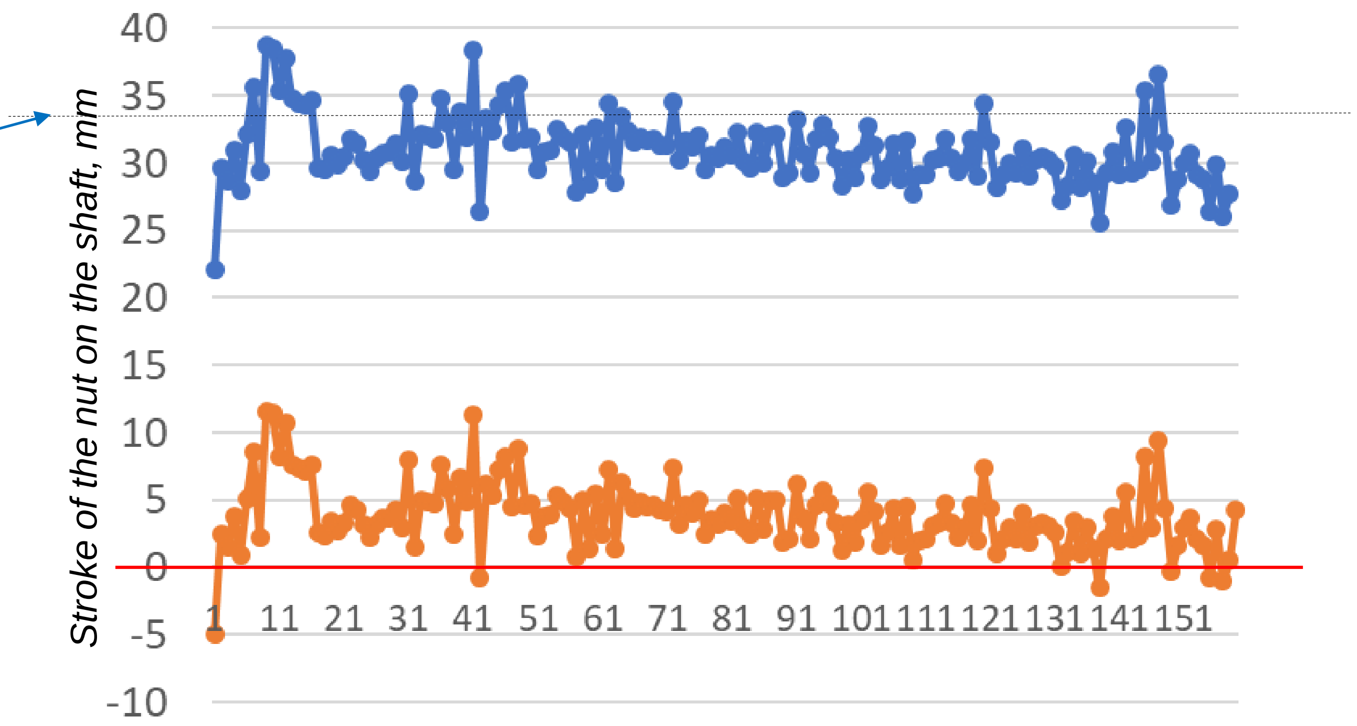
Stroke on the stepper motor shaft for LCLS II HE to tune cavities to 1.3GHz, *assuming the same statistical distribution*

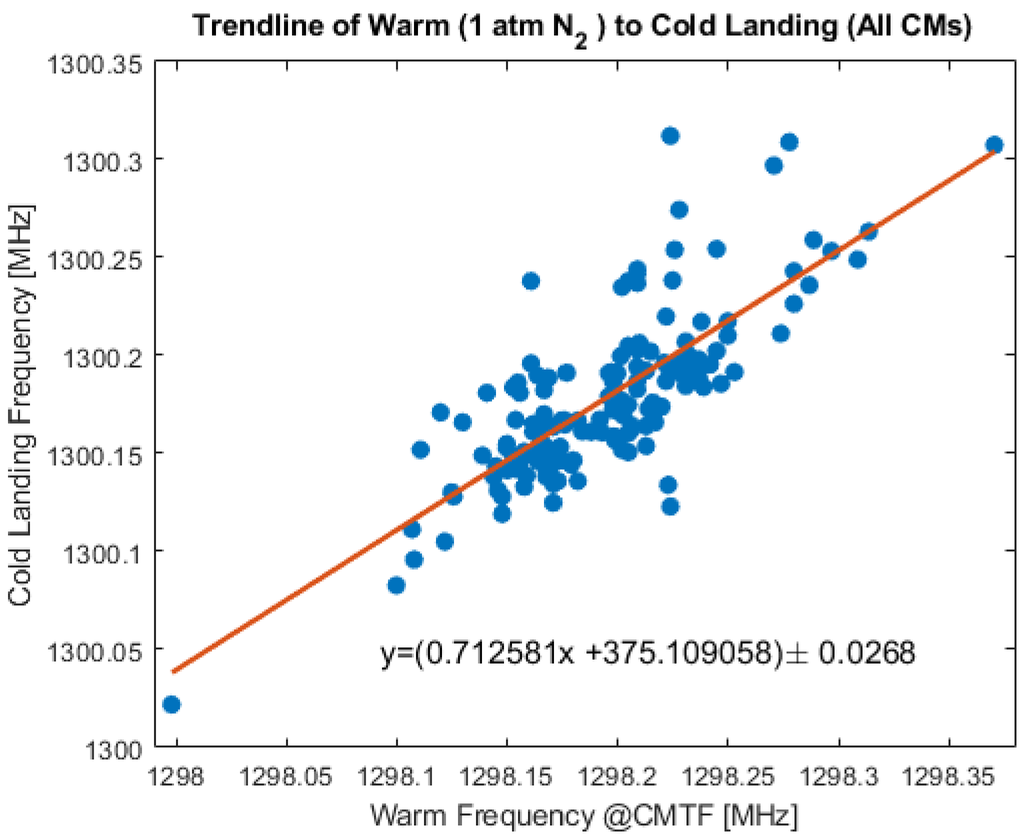


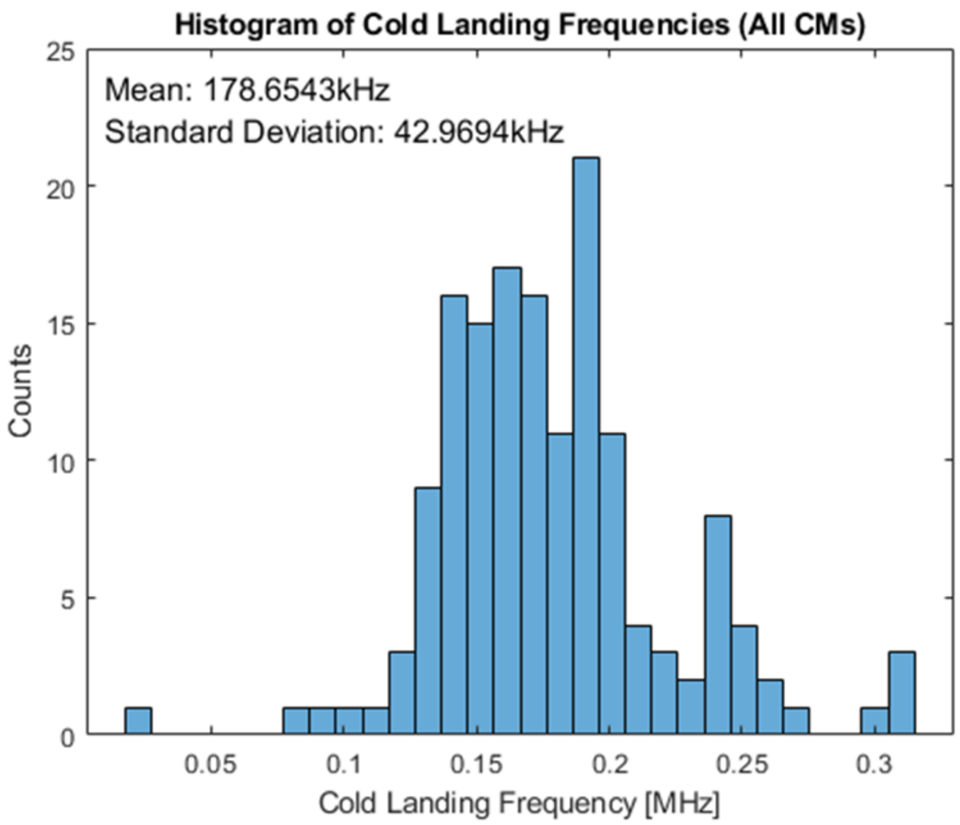


Stroke on the stepper motor shaft for LCLS II HE to tune cavities to 1.3GHz and to 1.3GHz-465kHz , *assuming the same statistical distribution*









There are some plan during tuner setting to use "custom tuner setting" that will use value of warm cavity frequency

Stepper Motor Actuator Shaft

Can project benefit from increasing actuator shaft threaded length on 10mm
From 70mm to 80mm

Definitely.

But project don’t want to change it ..

It is not technical but more organizational issue..

And it is not in the scope of today’s review.

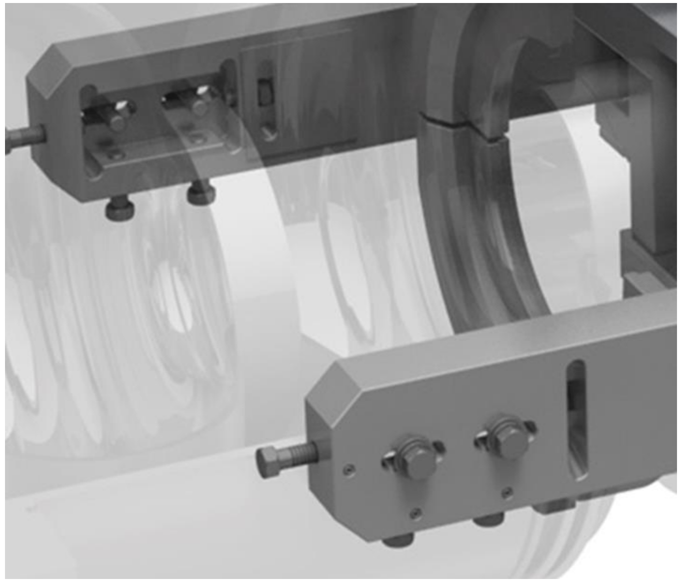
Tuner Arms length. … Are arms "as is" could create problems?

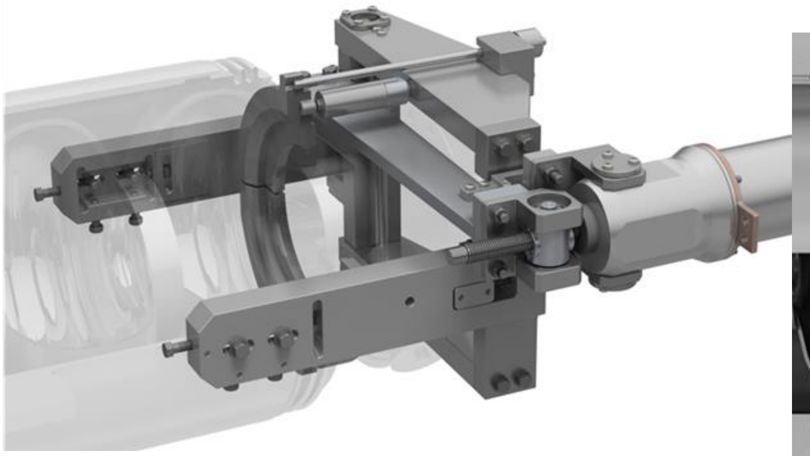
For some cavities it will be problem:

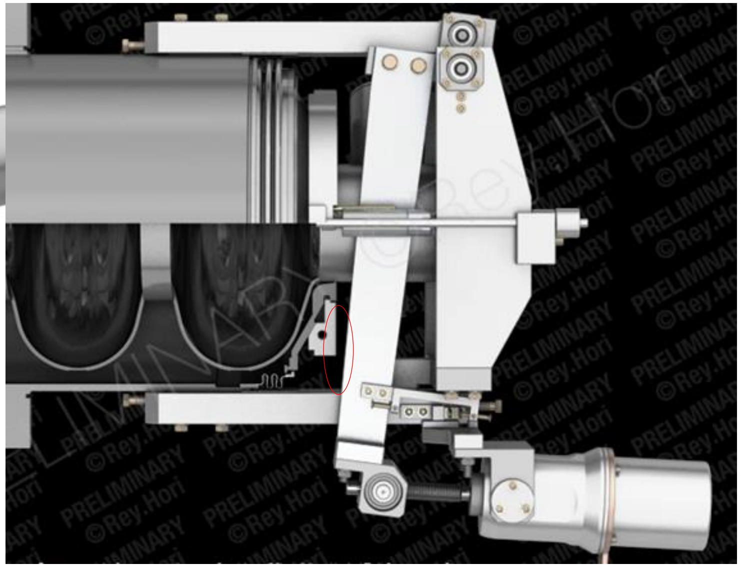
- ***Cavity's length are quite different … some cavities were quite long.***

Cavity's HPC side is fixed to He Vessel and as results some cavity were sticking out too far from He Vessel.

Tuner arms have slots to accommodate different cavity's length but for some cavities it was not enough. Approximately 10 Zanon cavities required to re-machine slot … otherwise piezo-actuator will not fit between split ring and main arm.



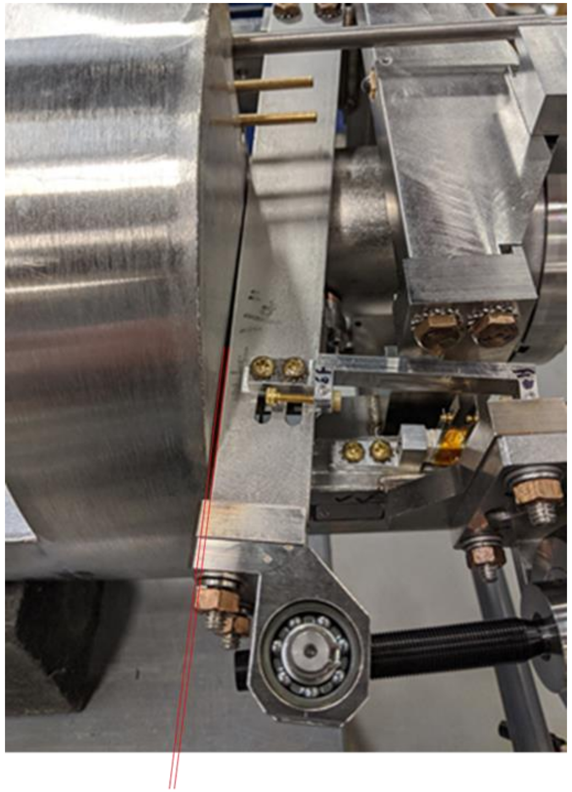




Tuner Arms length. … Are arms “as is” could create problems?

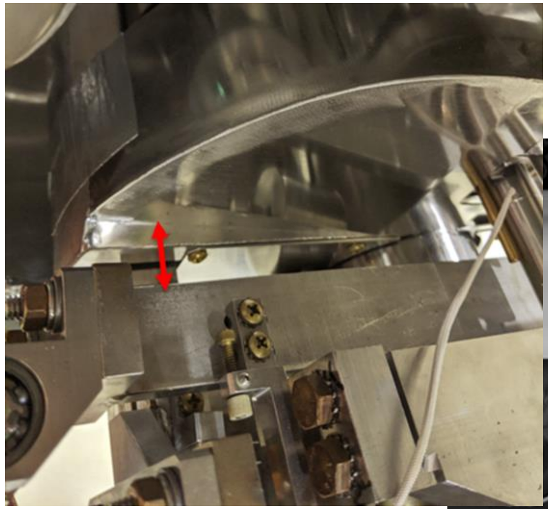
Magnetic Shielding (Endcap near tuner) could create additional challenge cavities it will be problem:

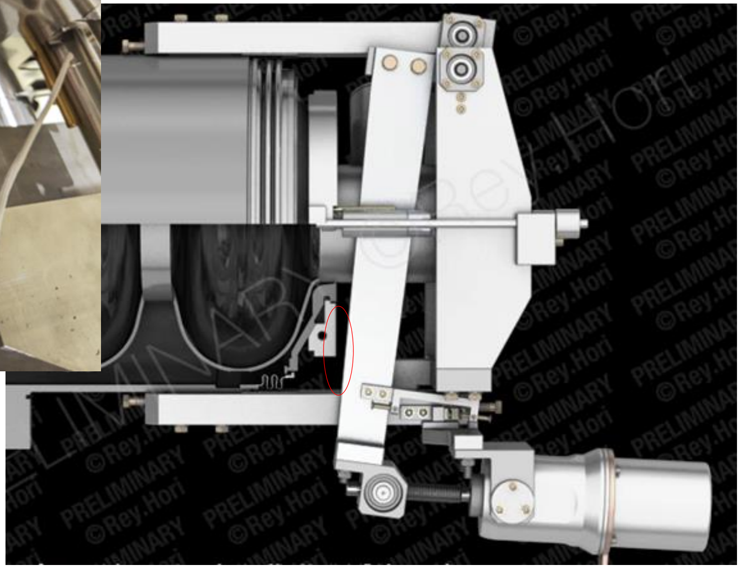
- ***Magnetic Shielding is a part that made with some tolerances and process of shield installation assuming some limited precision***



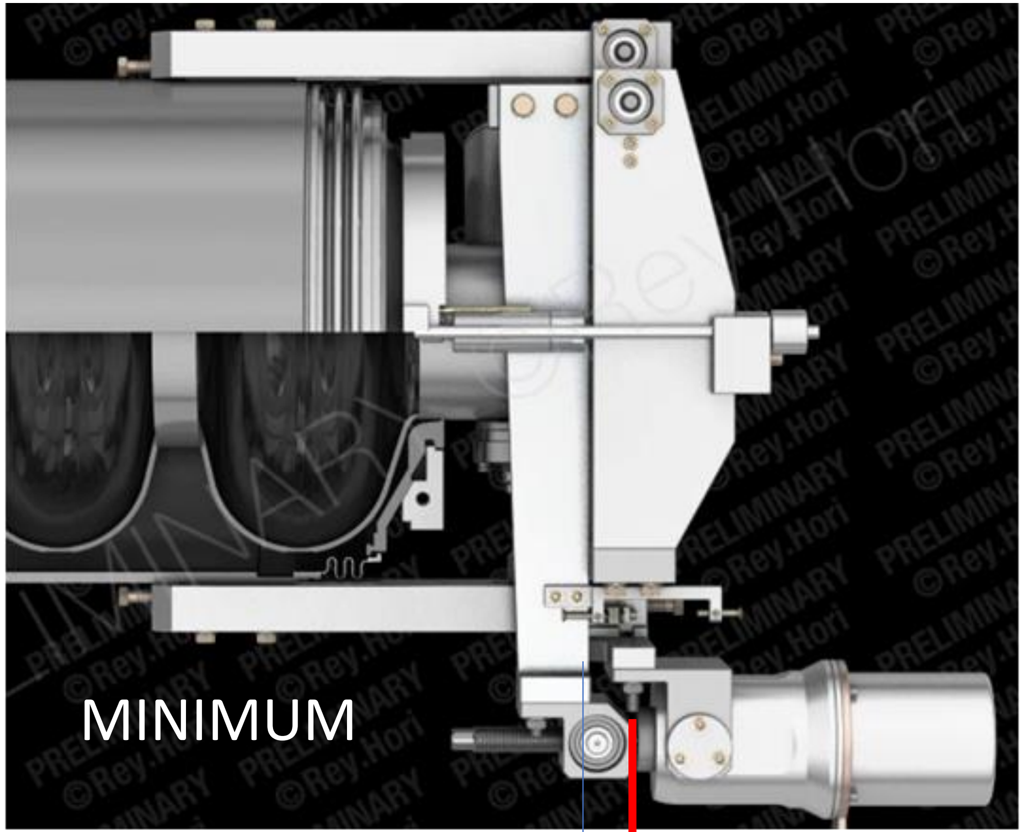
Cavity 215 that used for VTS test for OFO Tuner with 1:16 and motor’s lever arms open to deliver 1.3GHz-465kHz (no piezo- warm cavity didn’t compressed).

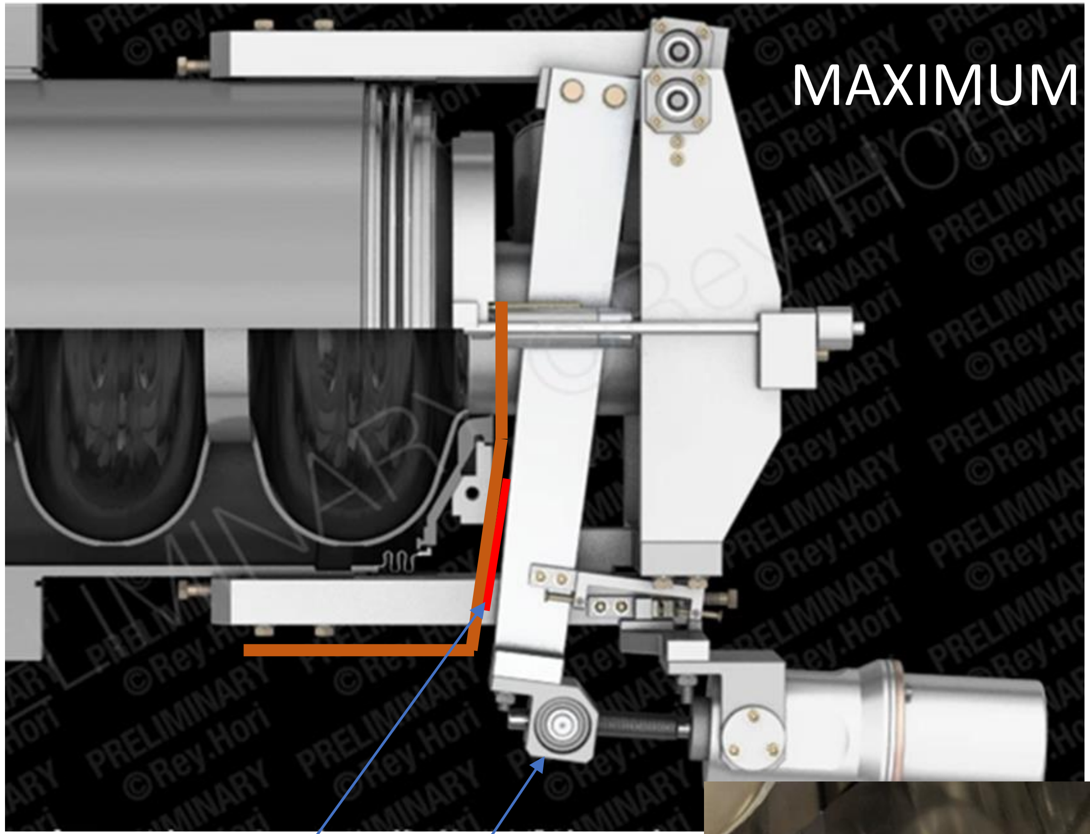
Motor arm is “ too close” to magnetic shield to keep this arrangement/setting procedure as part of production procedure.





LCLS II TUNER &LIMIT Switches setting





“Tuner ZERO” position

3mm shim

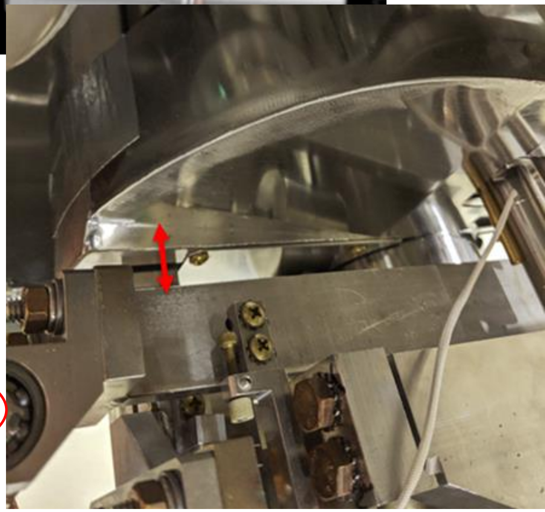
Limit switches roles:
To prevent Hard Stop… Hard Stop is event when Traveling nut will collide with dressed cavity part. Hard stop will cause damage of the TECASIN insert of the traveling nut… that in some situations could damage (permanently) SRF cavity

One of the two conditions

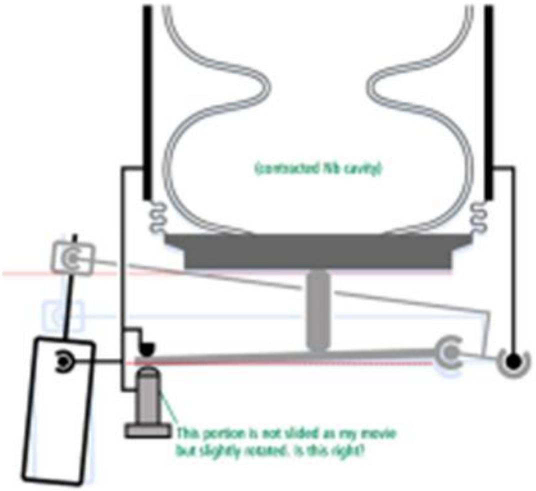
1. Traveling nut on the edge of the shaft

OR

2. 3mm shim between Motor arms and Magnetic Shielding



Tuner arms length need to be increase on 7mm to provide wide enough swing of the motor arms to increase amount of cavities that could be tune to OFO after cooldown.



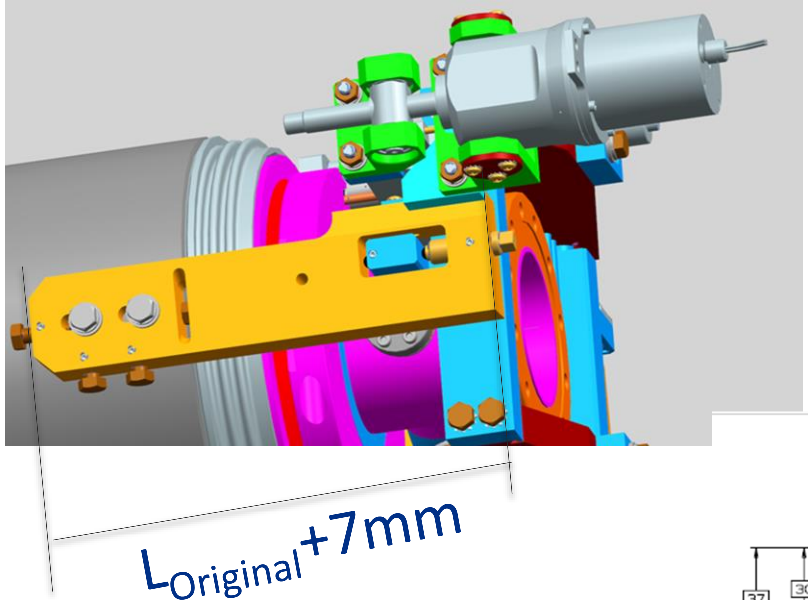
Yuriy Pischalnikov

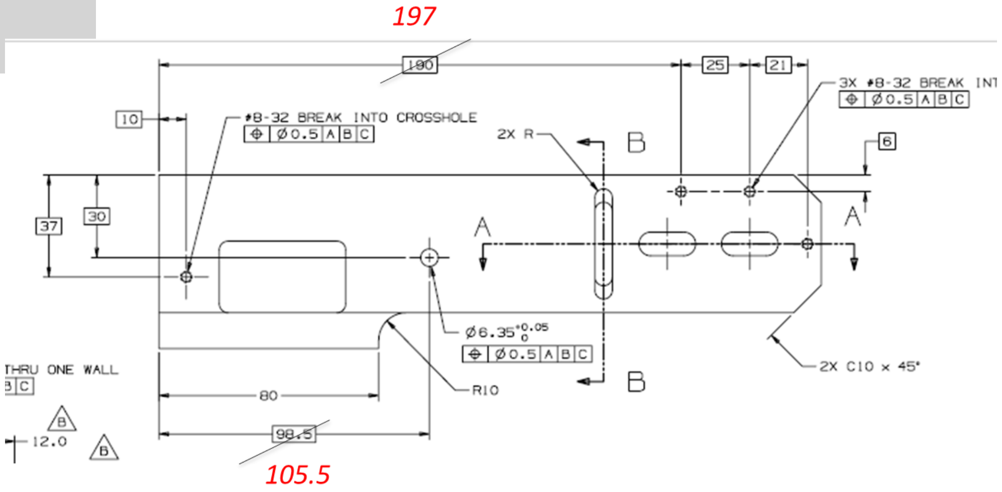
10/12/2020

What tasks need to be address (review in 3-D model of the tuner) to see how particular components will be impact by changing Tuner's arms length on 7mm

Task#0

Increase the length of the arms on 7mm





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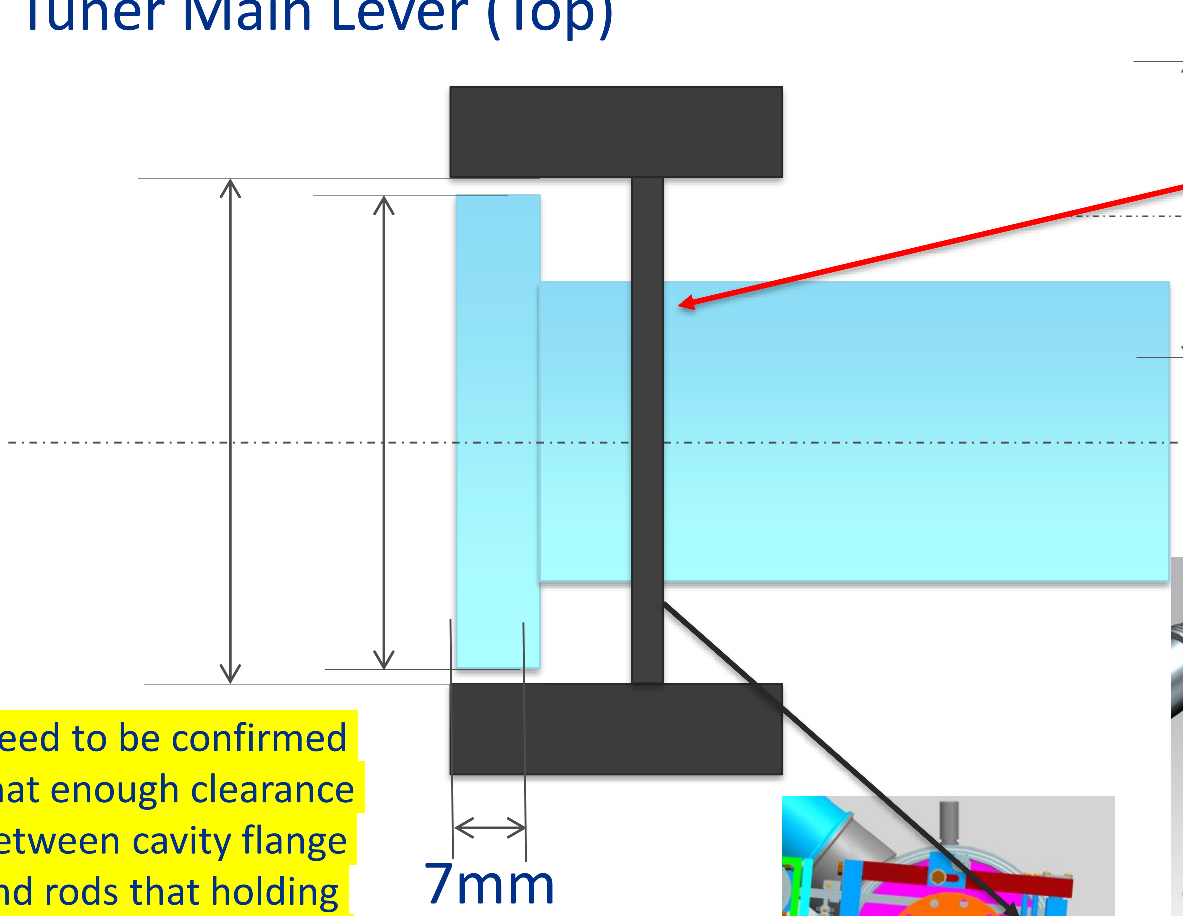
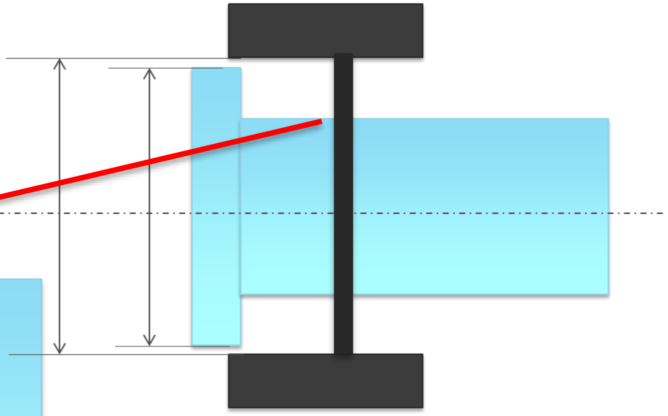
Next several slides outlined 3 tasks that need to be addressed to satisfy TASK#0- increasing of the TUNER arms on 7mm

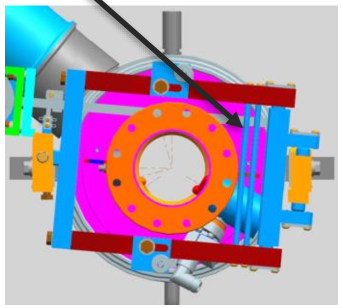
Task#1

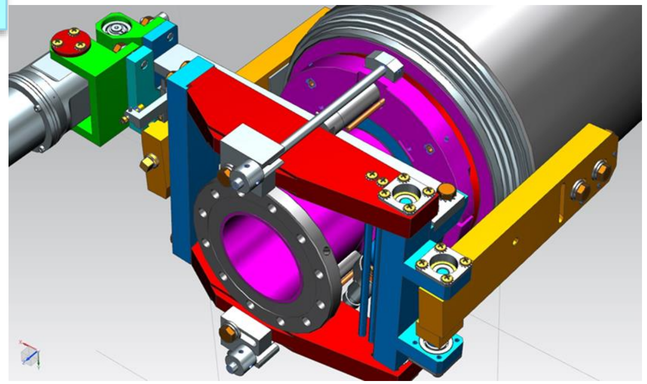
Tuner Main Lever (Top)





Need to be confirmed that enough clearance between cavity flange and rods that holding Top and Bottom Main Tuner arms.
AFTER arms length increase on 7mm



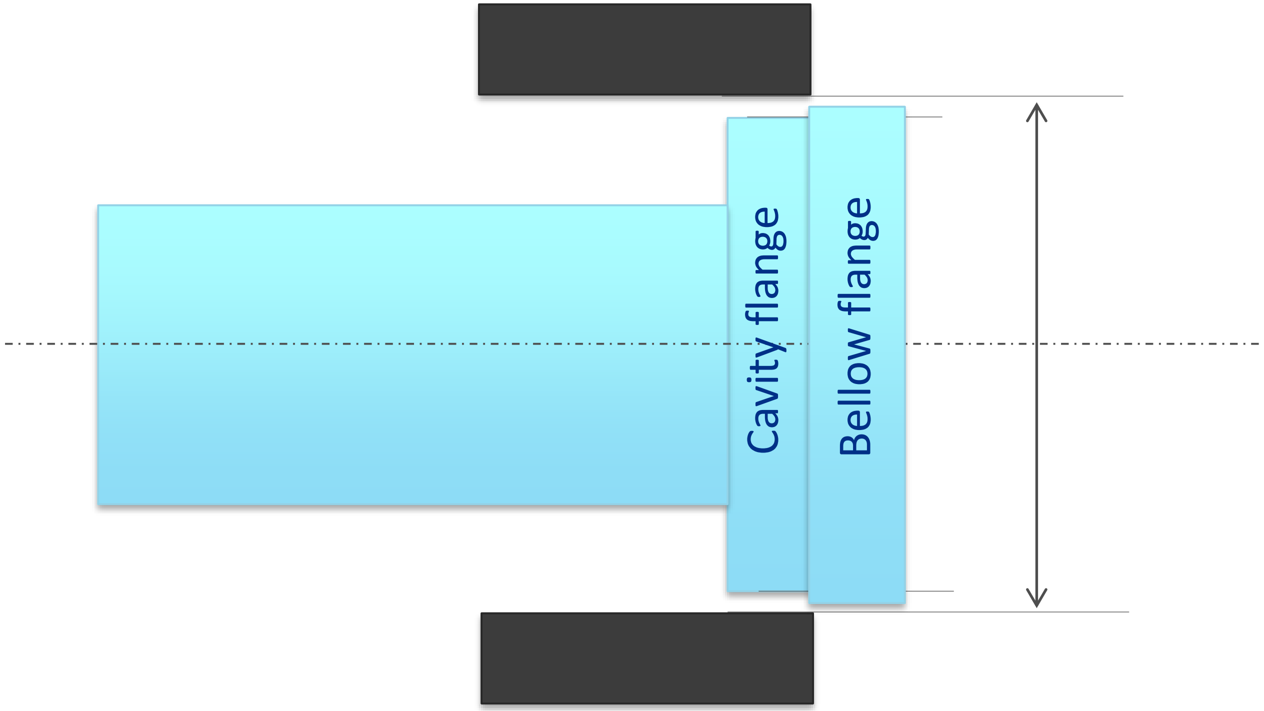


Task#2.

Ideal installation of the tuner on the dressed cavity

Small tolerance between Top/Bottom Main Lever and cavity beamline& Bellow flanges

Tuner Main Lever (Top)



Tuner Main Lever (Bottom)

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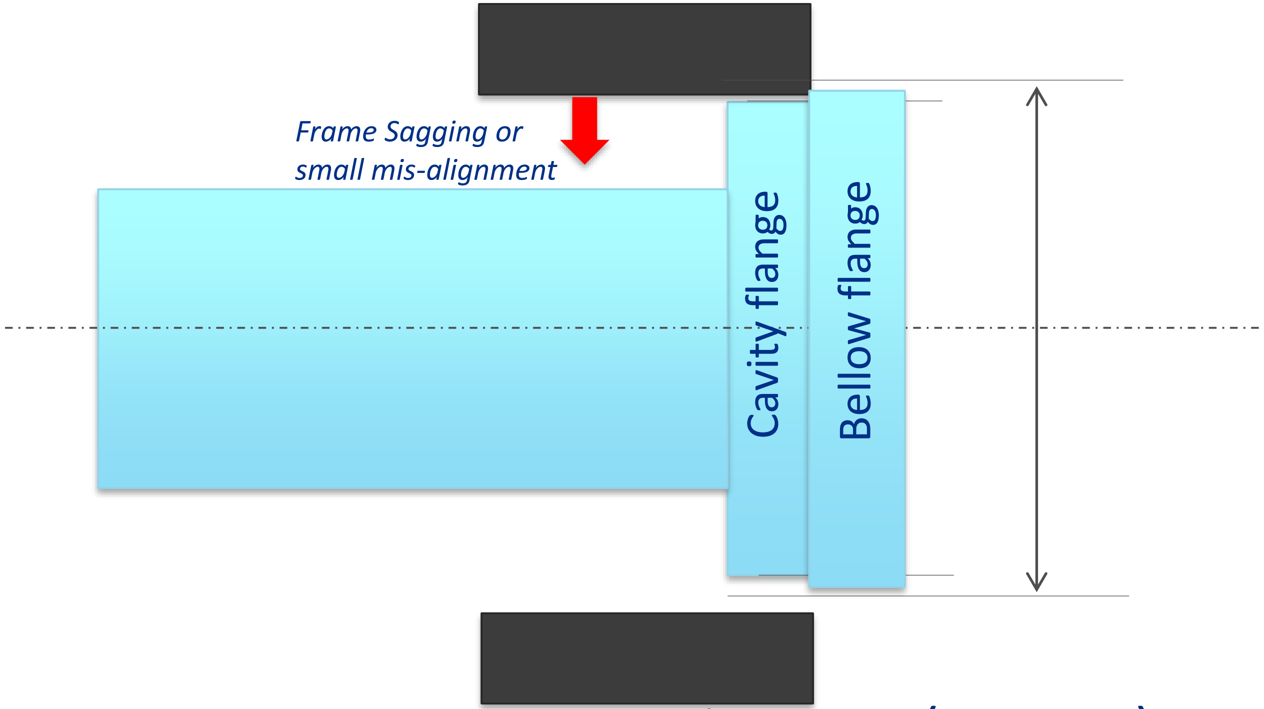
Task#2.

Real installation of the tuner on the dressed cavity

Frame Sagging or small mis-alignment could lead interference.

Tuner Main Lever (Top)

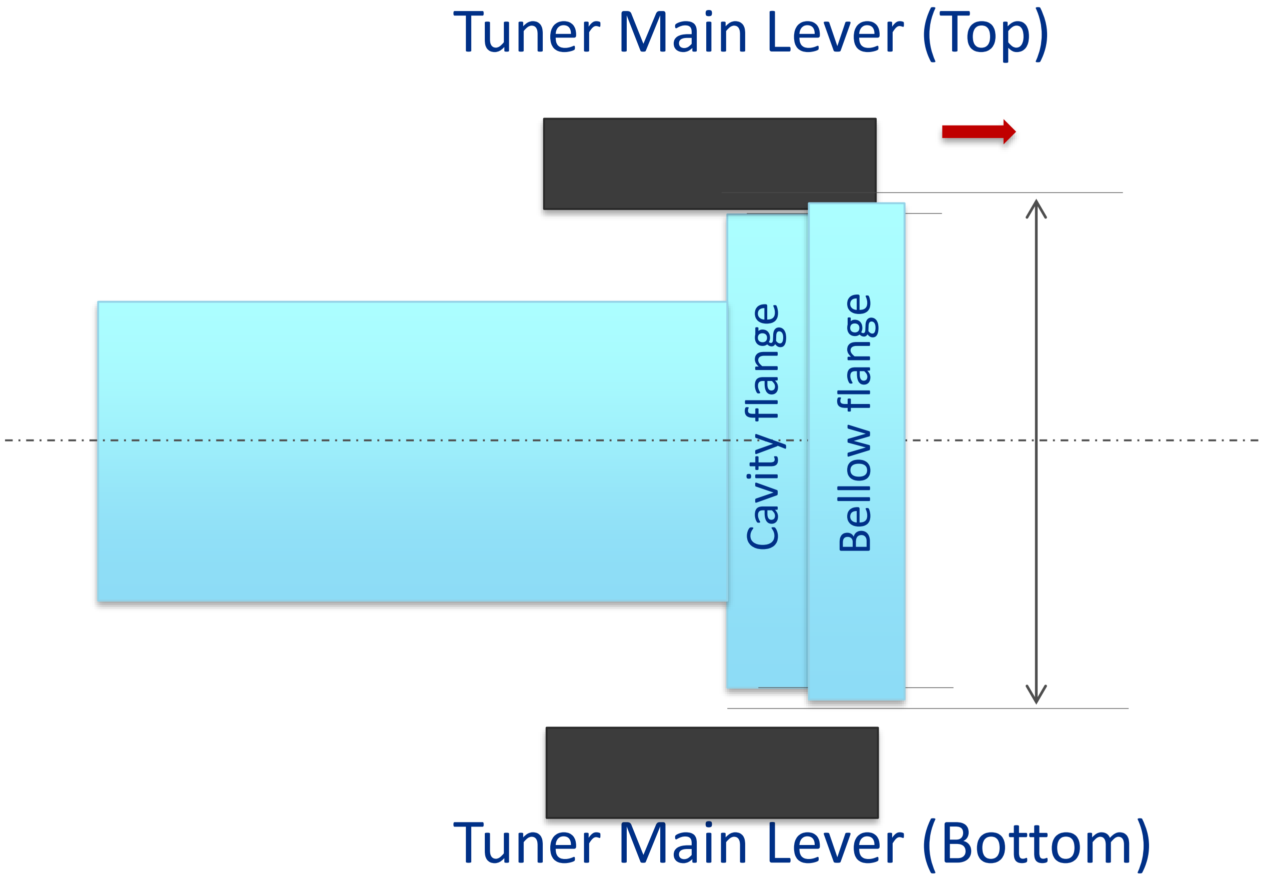


Tuner Main Lever (Bottom)

Task#2.

Ideal installation of the tuner on the dressed cavity

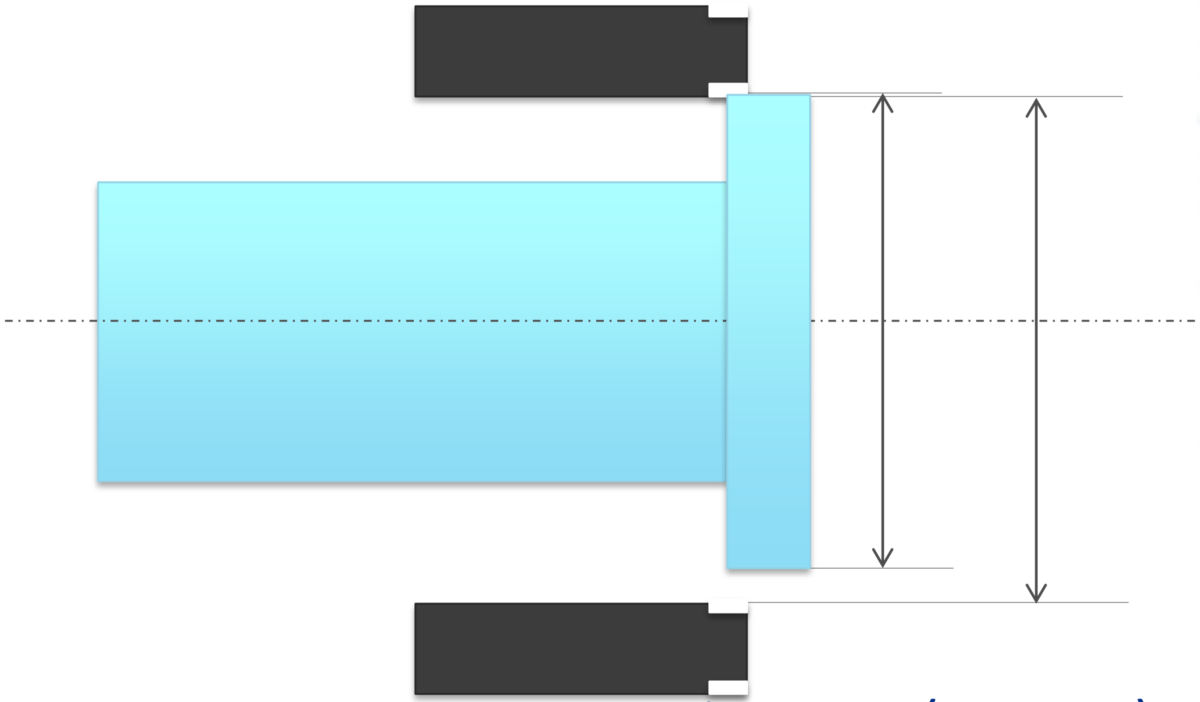
Small tolerance between Top/Bottom Main Lever and cavity beamline flange

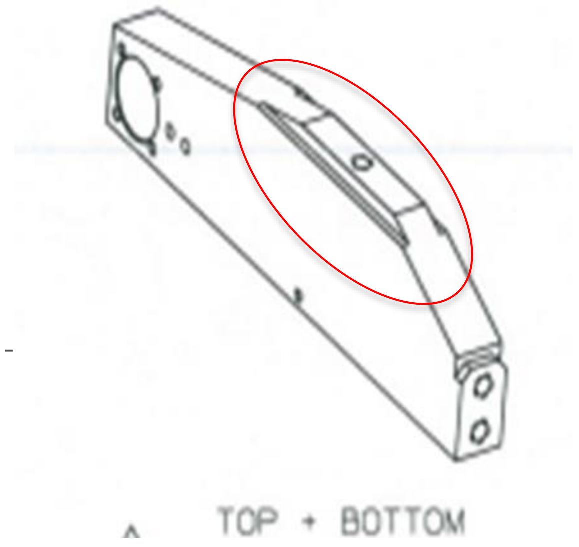


Task#2.

To avoid possible interference (after pCM) introduced small (3X5mm) notches.

Tuner Main Lever (Top)





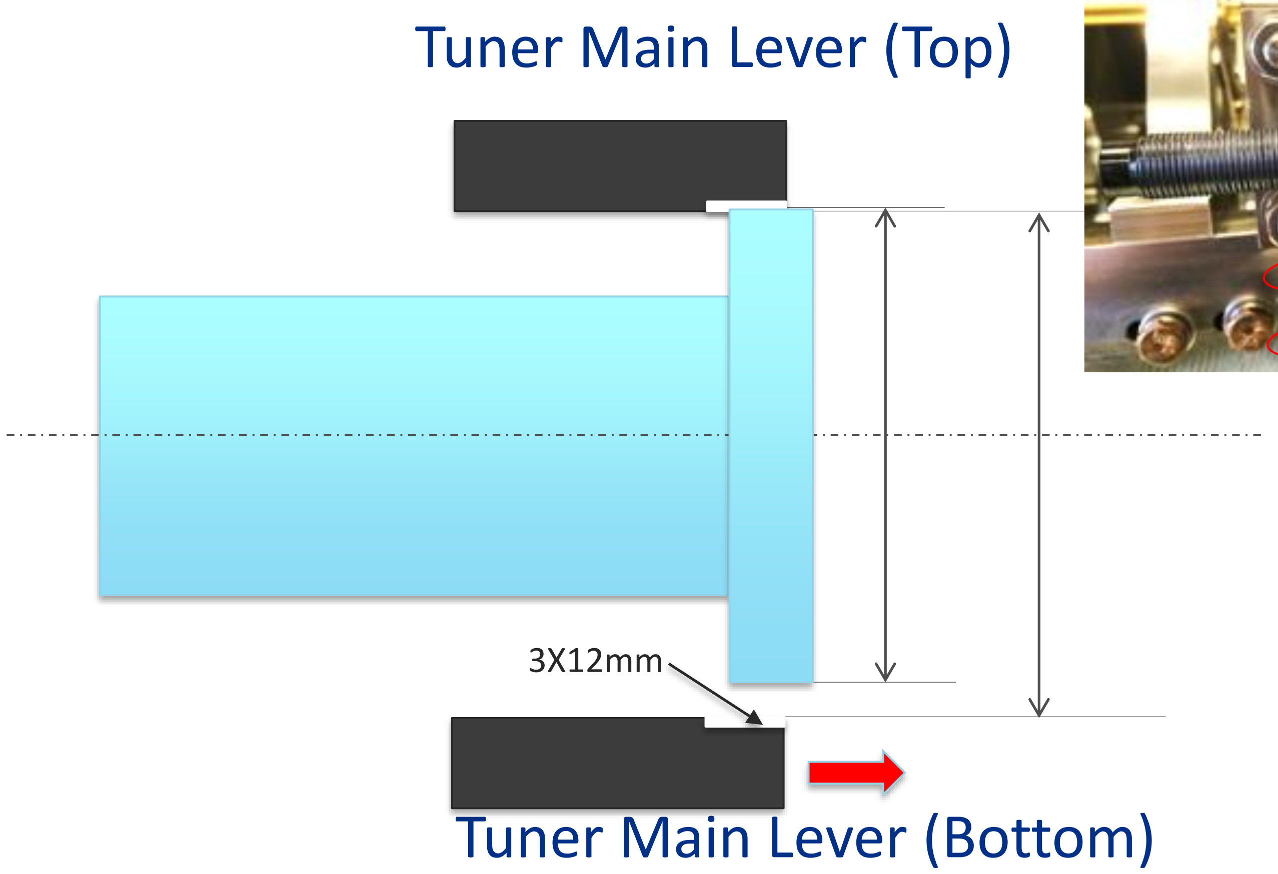
Tuner Main Lever (Bottom)

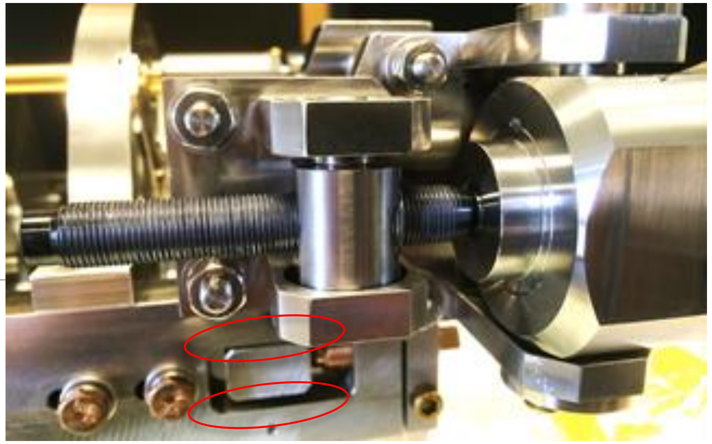
Task#2.

For OFO operation we will need to move tuner’s Main Lever on 7mm (for some cavities) from split ring.. As results 2X5 mm notch could not enough

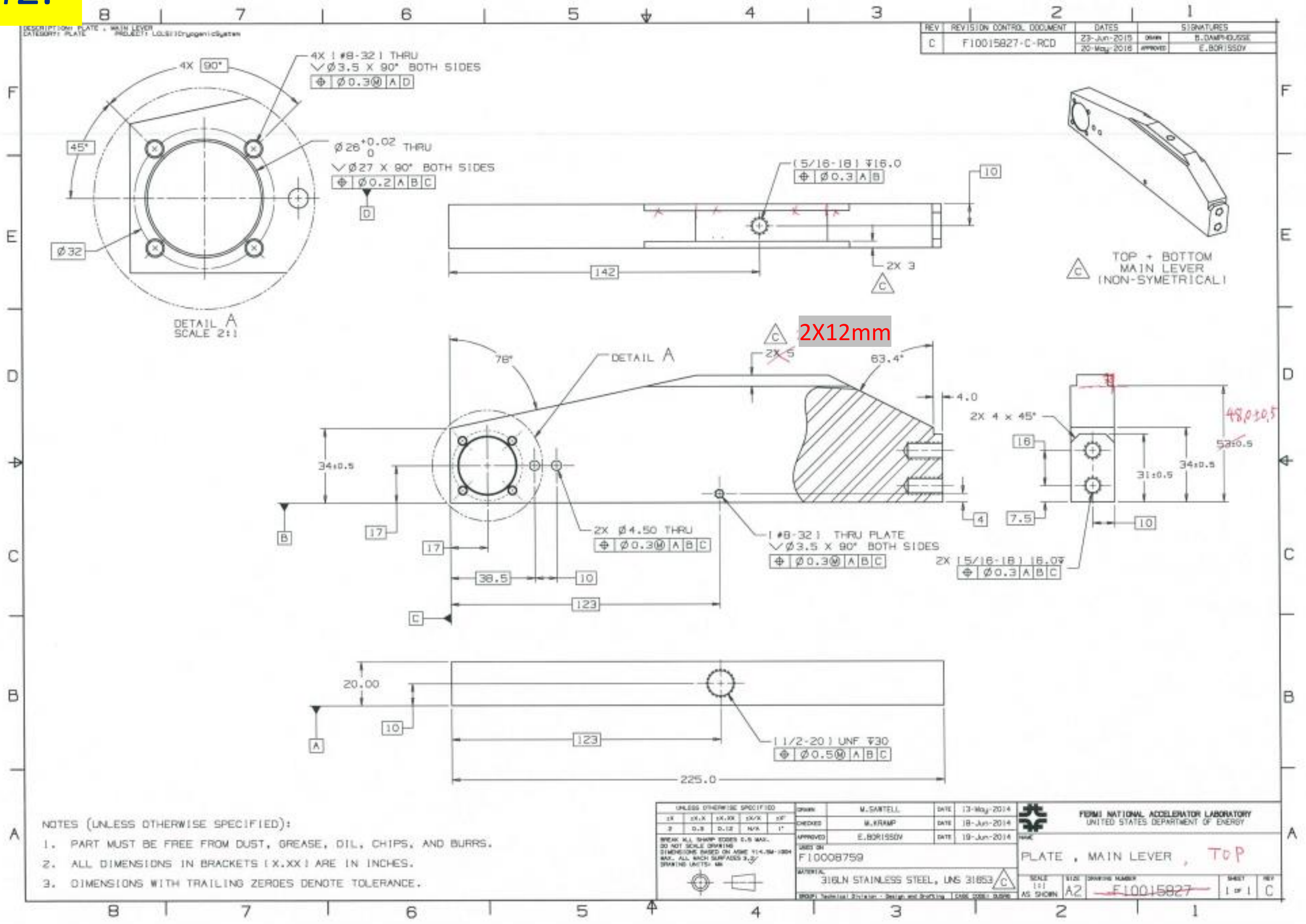
We need to increase dimension on 2X12mm (and do it only from on side)

(Top and Bottom Lever will be not replaceable)



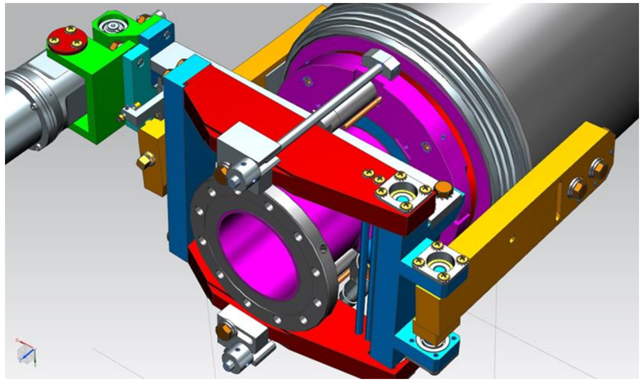


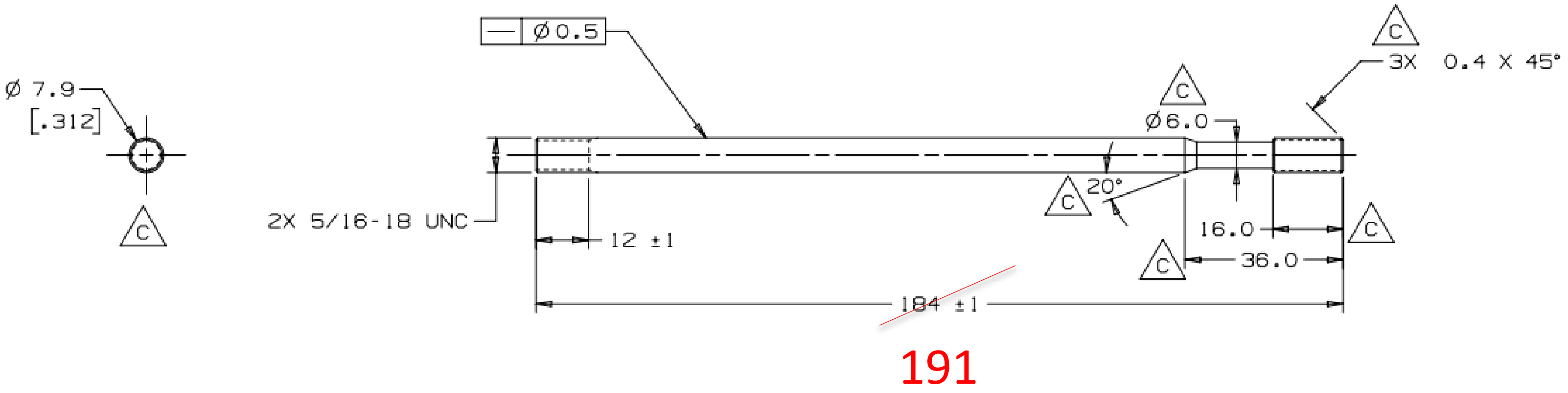
Task#2.


2X12mm
NOTES (UNLESS OTHERWISE SPECIFIED):
1. PART MUST BE FREE FROM DUST, GREASE, OIL, CHIPS, AND BURRS.
2. ALL DIMENSIONS IN BRACKETS [X.XX] ARE IN INCHES.
3. DIMENSIONS WITH TRAILING ZEROES DENOTE TOLERANCE.
TOP + BOTTOM MAIN LEVER (NON-SYMETRICAL)
DETAIL A SCALE 2:1
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY
PLATE , MAIN LEVER , TOP
316LN STAINLESS STEEL, UNS 31653
F10015827

Task#3

Extend length of the safety rod on 7mm





Summary

To accommodate large stroke of the traveling nut on the shaft (for OFO) and avoid interferences with magnetic shielding (also to avoid re-machining slot for extra long cavities) we proposing to increase tuner arms length on the 7 mm.
Based on our preliminary analysis increasing arms length will not cause any interferences between tuner and other components of the cryomodule.
In return it will simplify tuner setting procedure (minimized errors) and increase % of the cavities capable to be tuned to 1.3GHz-465kHz

Based on our analysis (and LCLS II experience) changing the length of the arms on 7mm will cause any negative impacts on the performance of the tuner or any interferences with other components of the cryomodule

Fermilab