Fermilab

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PXIE RFQ Tuning

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PIP-II meeting

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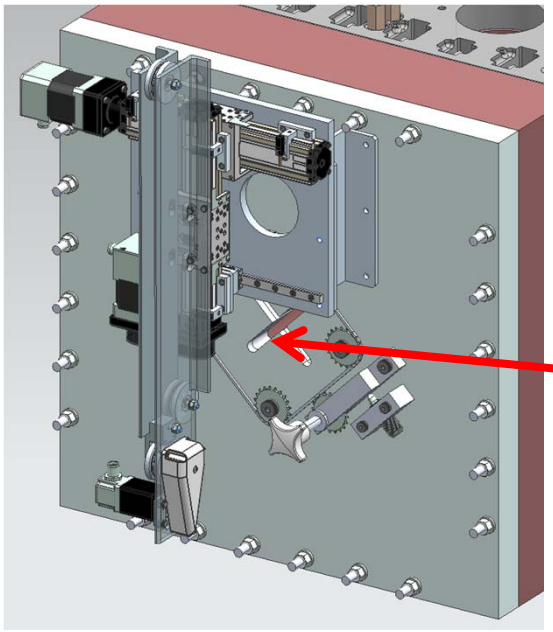
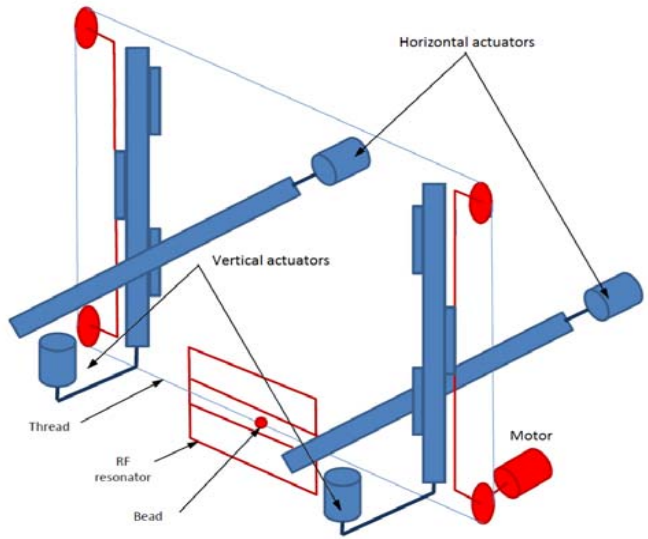
Outline

- RFQ bead pull measurements
- Field flatness tuning
- Frequency tuning
- Final field flatness tuning preserving target frequency
- Main and sensing loops Qext measurements

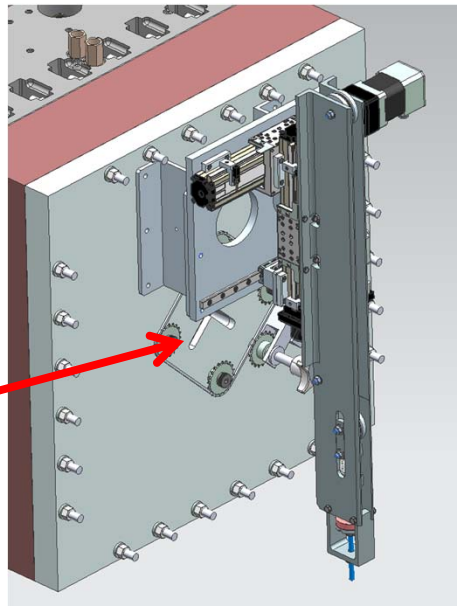
Bead pull set up

- Horizontal and vertical actuators move the bead pull line between quadrants.





Slots in end plates



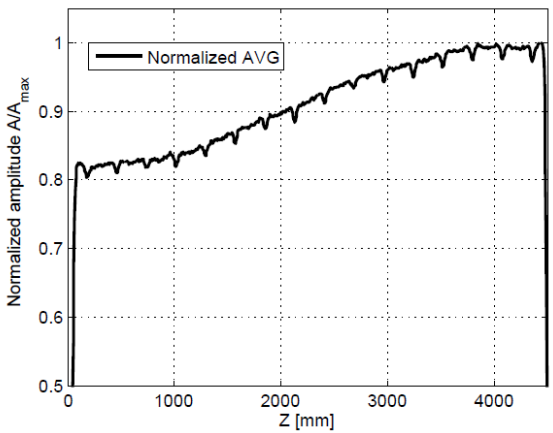
Bead pull measurements I

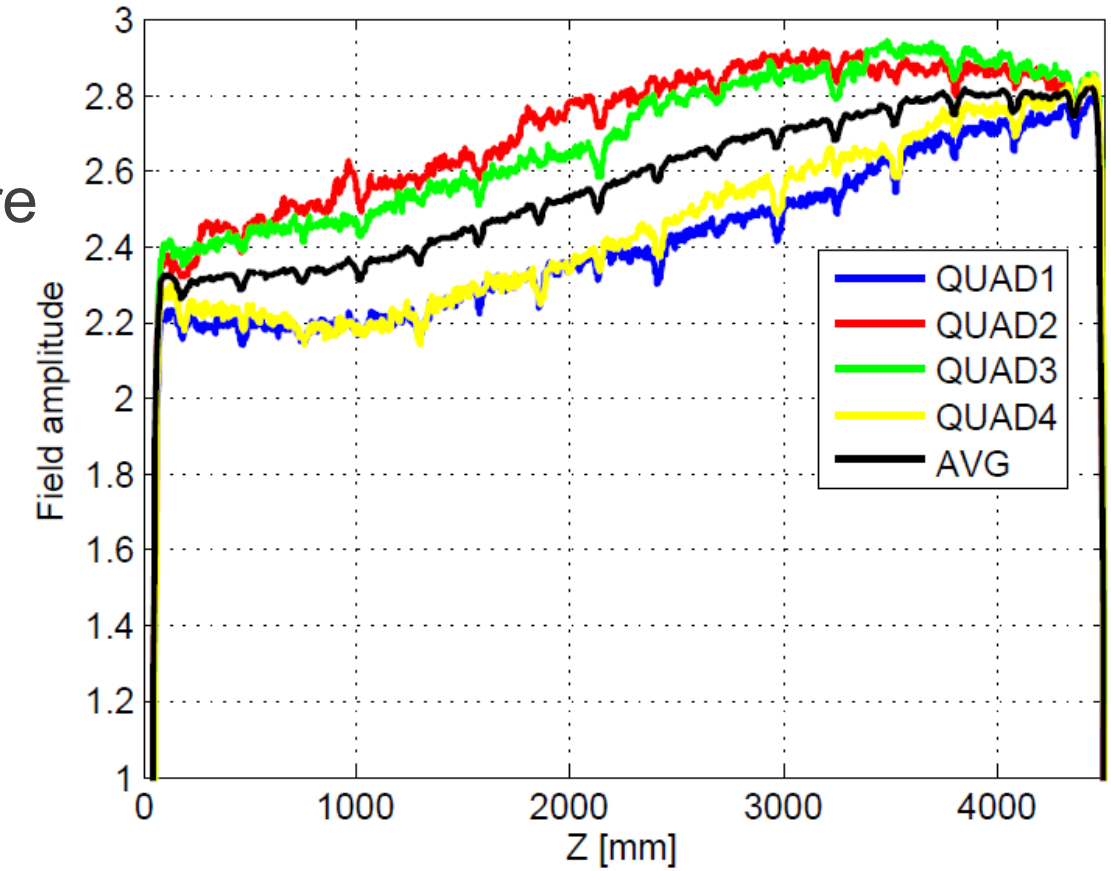
- Hollow metallic bead, diameter 9.5 mm
- Kevlar string to allow tension around 13 N to reduce sag on the line
- Maximum sag of the bead along the 4.4 m structure 0.36 mm, corrected via software
- Phase shift recorded along the RFQ length for each quadrant (1 to 4) at 30 mm radius from the center
- Total field profile calculated as the average between the four quadrants, sag does not affect the field average…
- Alignment achieved with diagonal string scan of the RFQ

Bead pull measurements II

- Quadrant measurements output: single quadrants 1 to 4 and average filed amplitude along RFQ length @ 30 mm radial offset.

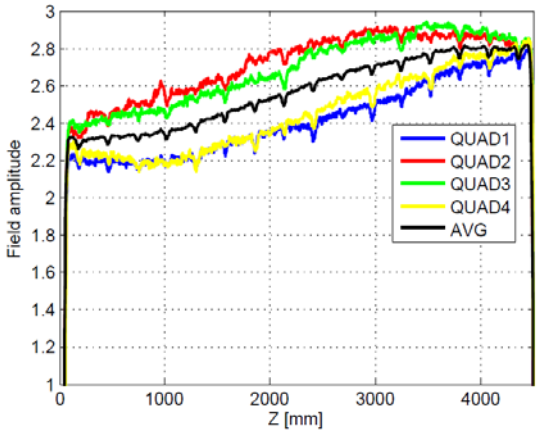
- First bead pull measurement before tuning, FF approximately 80% for avg.

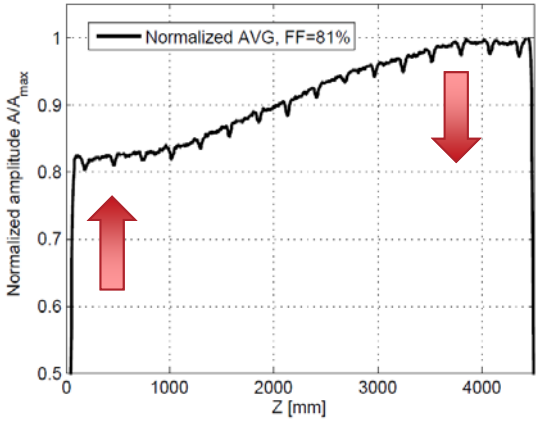




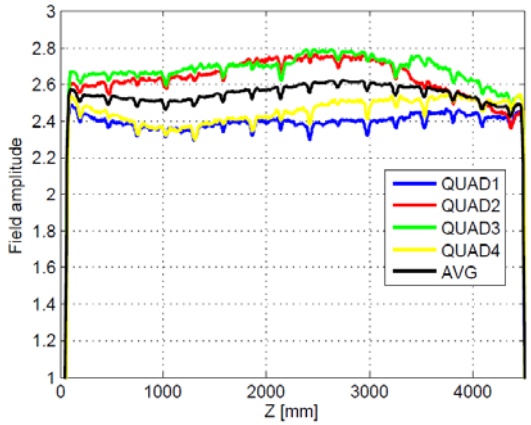
FF tuning step I

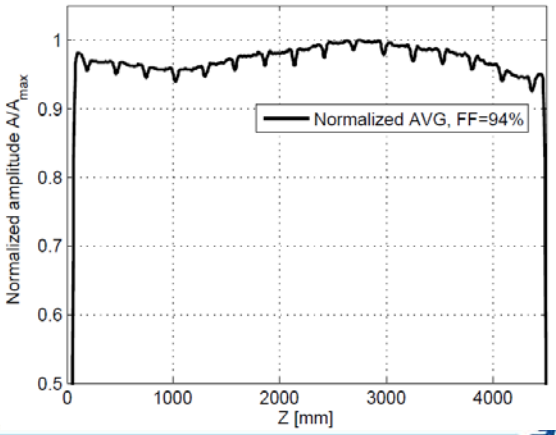
- Adjustment of the module tuners, no end plate motion.
- Before Freq= 162.361 MHz FF= 82% @ T=22 C H=48%





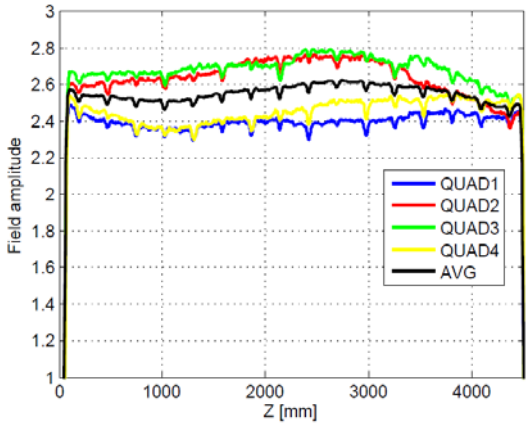
- After Freq= 162.445 MHz FF= 94% @ T=22 C H=48%

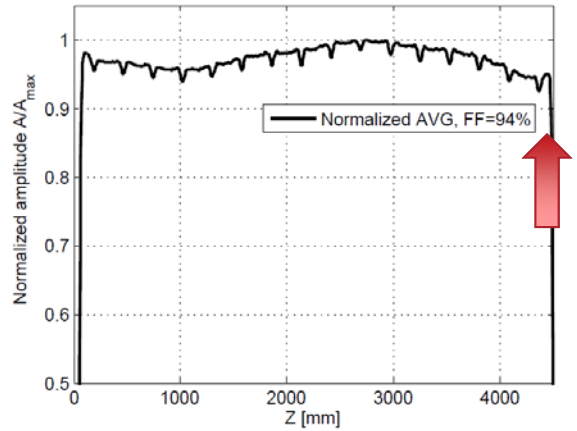




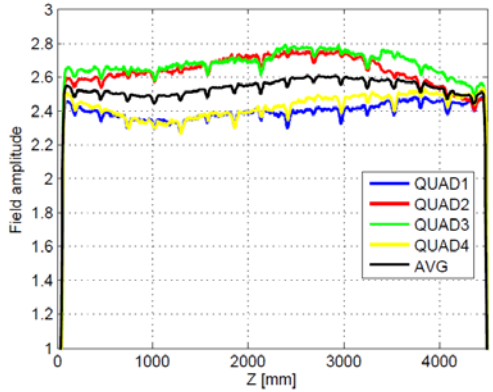
FF tuning step II

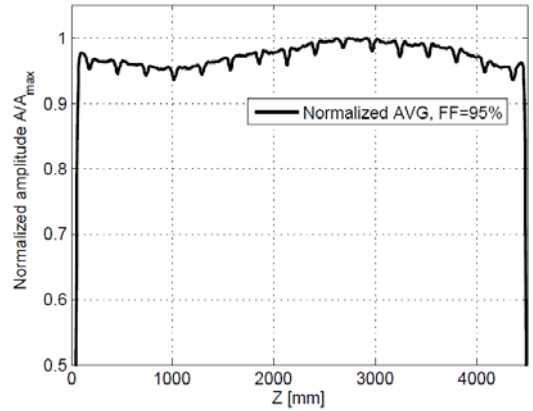
- Downstream end plate moved in (-9kHz) to increase the field.
- Before Freq= 162.445 MHz FF= 94% @ T=22 C H=48%





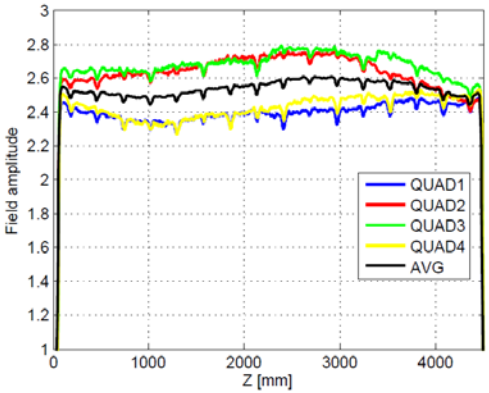
- After Freq= 162. 436 MHz FF= 95% @ T=24 C H=47%

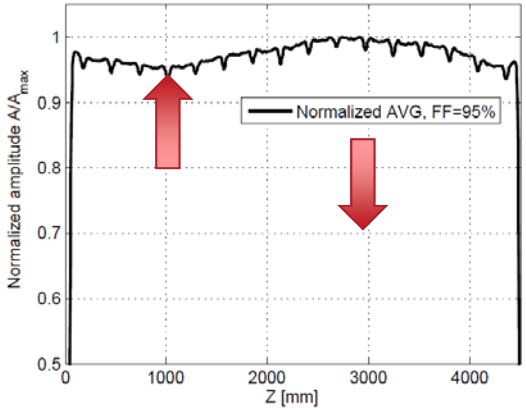




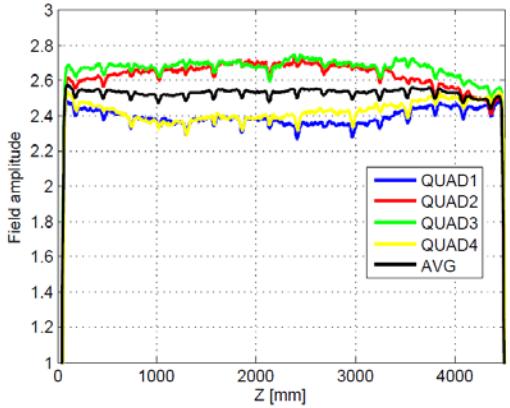
FF tuning step III

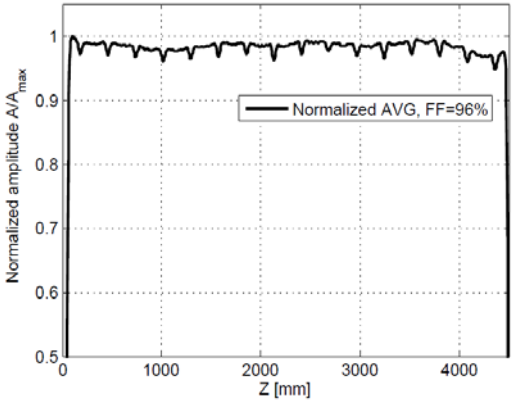
- Tuners adjusted to flatten the field dF=+162 kHz .
- Before Freq= 162. 436 MHz FF= 95% @ T=24 C H=47%





- After Freq= 162. 598 MHz FF= 96% @ T=25 C H=45%



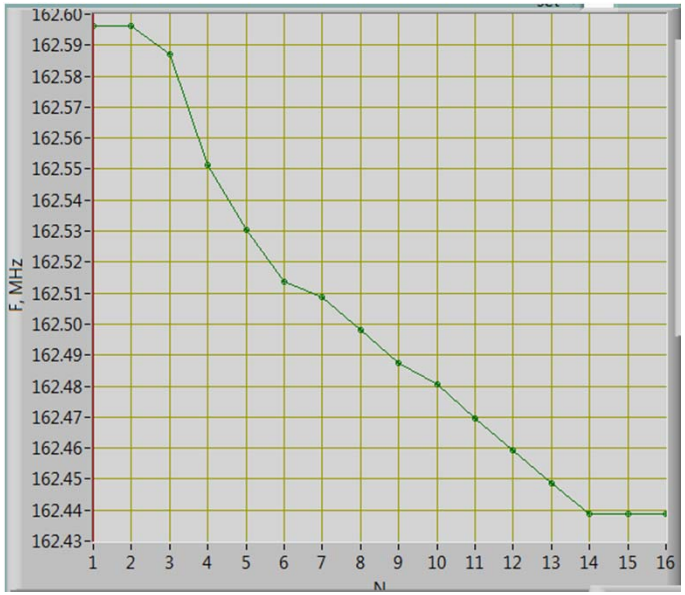


Frequency tuning

- After 96% FF tuning, the frequency needs to be adjusted to match the target value. All tuners moved by the same amount to preserve the field profile.

Operating Freq [MHz]	162.500
ε_r air	1.00059
dF/dT [kHz/C]	-2.7
ΔF gradient [kHz]	-7
Op Temp [C]	30
Tuning Temp [C]	25

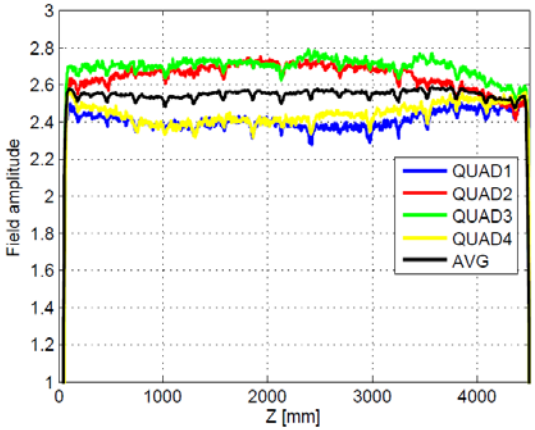
Tuning Freq [MHz]	162.445

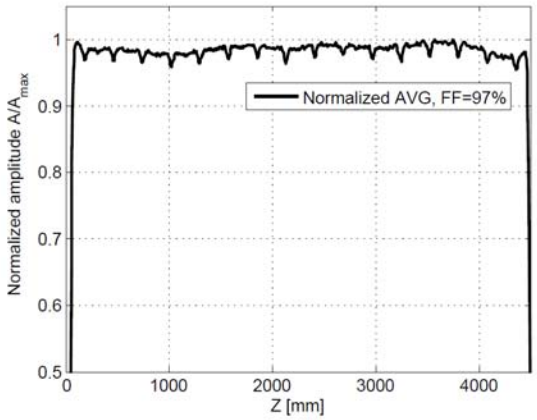


- Frequency has been tracked with the NWA during the process, after tuning 162.440 MHz.

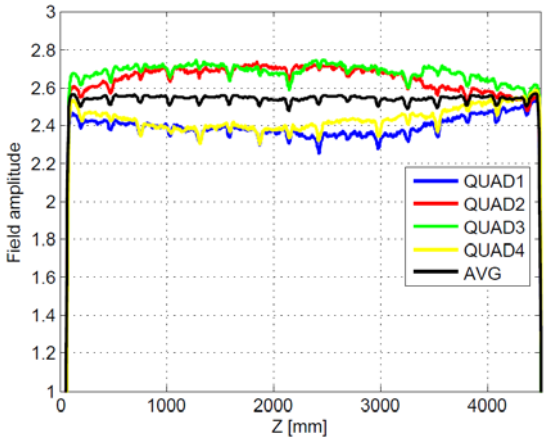
Final FF tuning

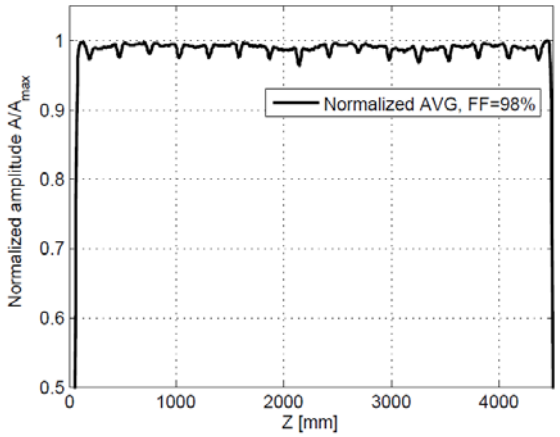
- After frequency tuning: Freq= 162.440 MHz FF=97%





- After final FF tweak: Freq= 162.443 MHz FF=98%

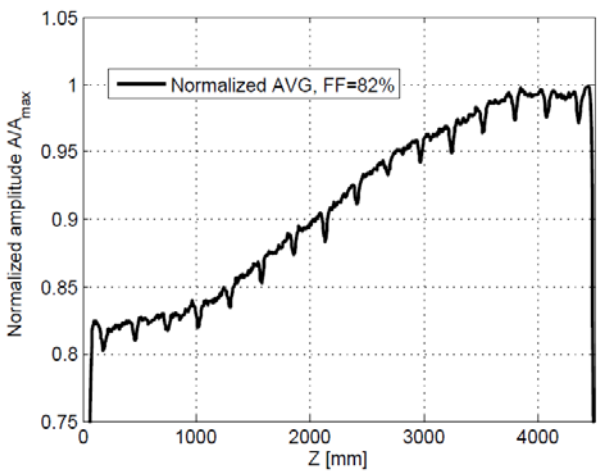




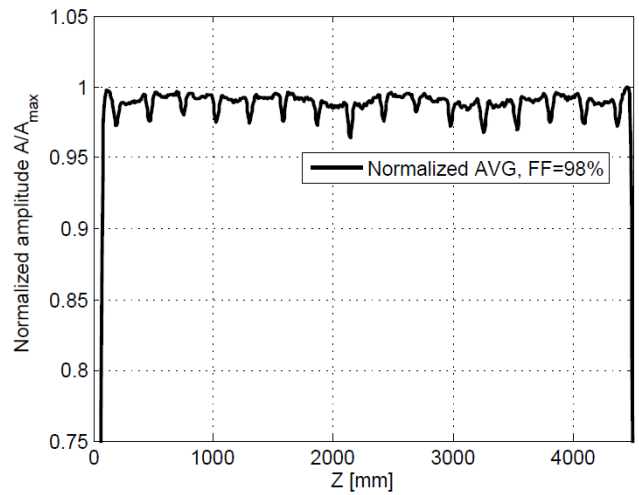
Tuning Summary

- The tuners have been adjusted along with the exit end plate to flatten the field profile.
- The frequency has been tuned inserting all tuners by the same amount once the field profile was 96% flat.
- Finally the frequency has been kept constant and the field flatness has been improved to 98%.

Before tuning F=162.361 MHz

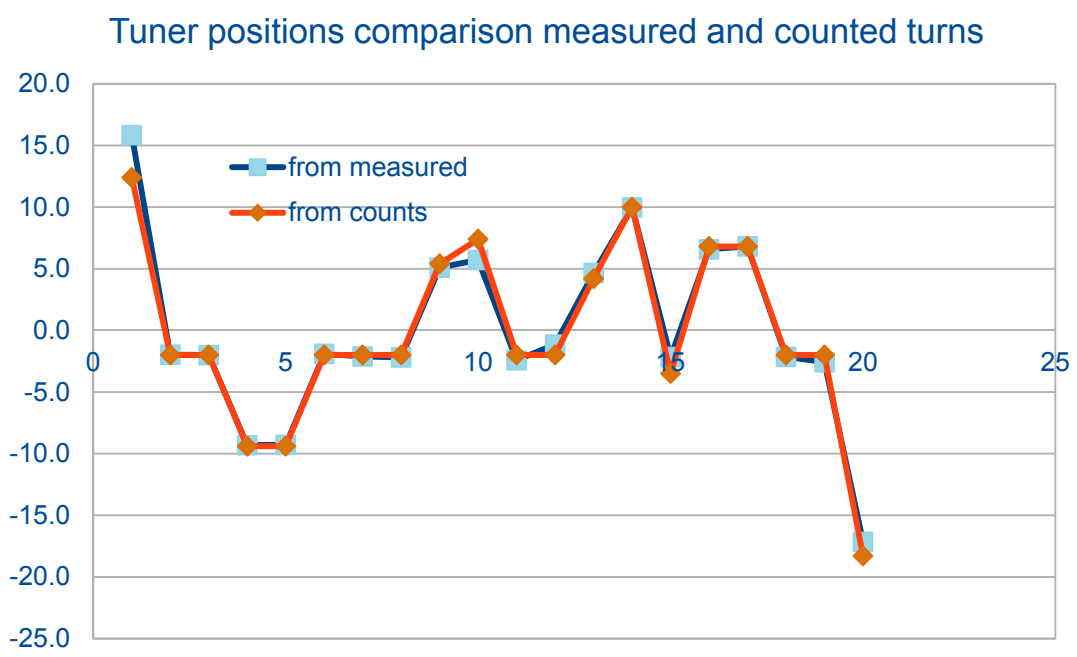


After tuning F=162.443 MHz



Tuners data analysis

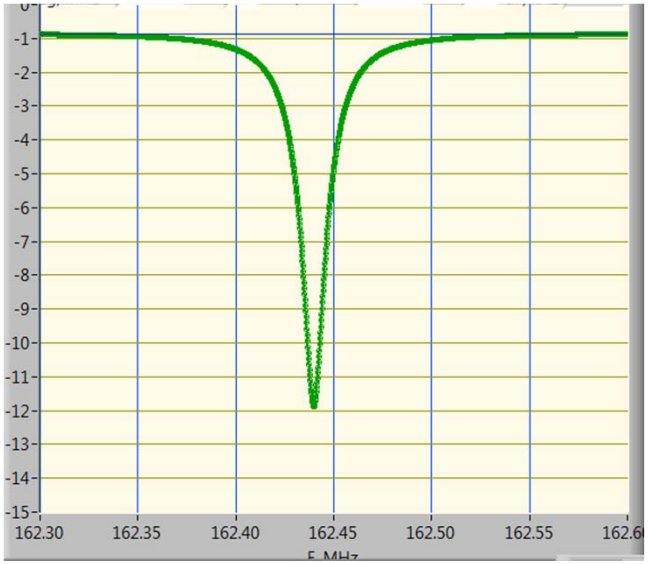
- Before tuning all tuners inserted by 20 mm into the RF volume, depth measurements were taken.
- Depth measurements have been repeated after tuning.
- The difference between initial and final tuner measurements was compared with total number of turns applied during tuning.
- Good agreement, tuners will be measured accurately, once taken off, before final machining.



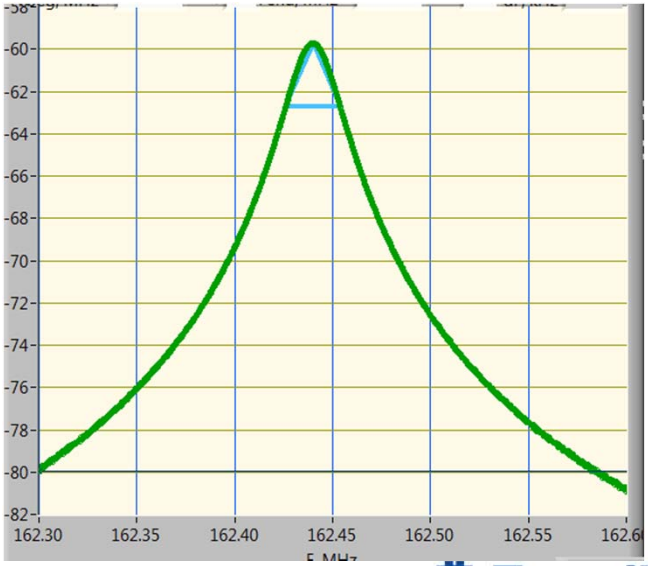
Qext Main loops and sensing loops

- S21 and S11 measurements to calculate: Qext and Q0.
- Q0= 9000, lower than the expected (Al tuners and end plates).
- Qext Main Loops 1.6E4.
- Qext Sensing loop 7.1E9

S11 Main loop



S21 Main loop to PU



Summary

- The tuning procedure went as expected, FF=98% and frequency 2 kHz from target value.
- Qext of main coupler and sensing loops were checked, slightly under coupled (due to aluminum tuners and end plates).
- LBNL colleagues know how to run bead pull measurements to verify the final field profile, after fixed tuners assembly.