New coupler and other problems

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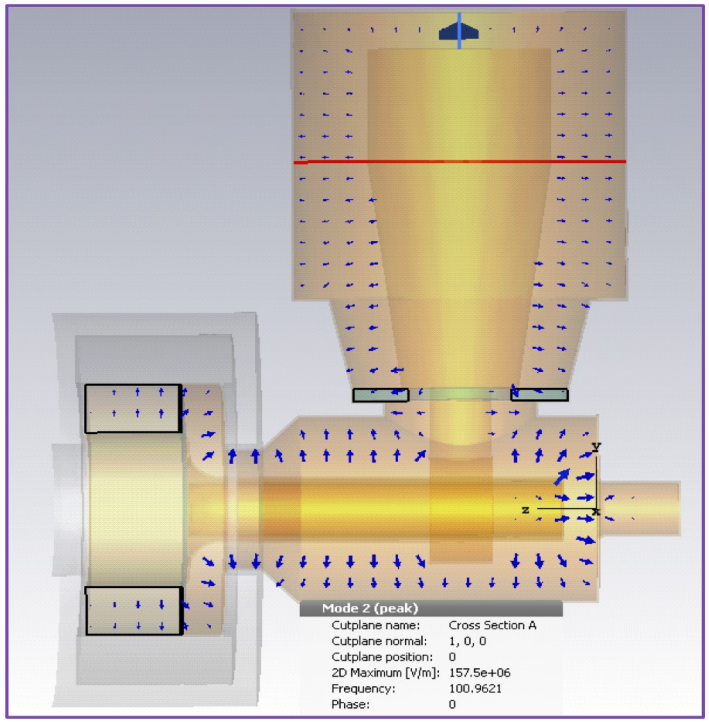
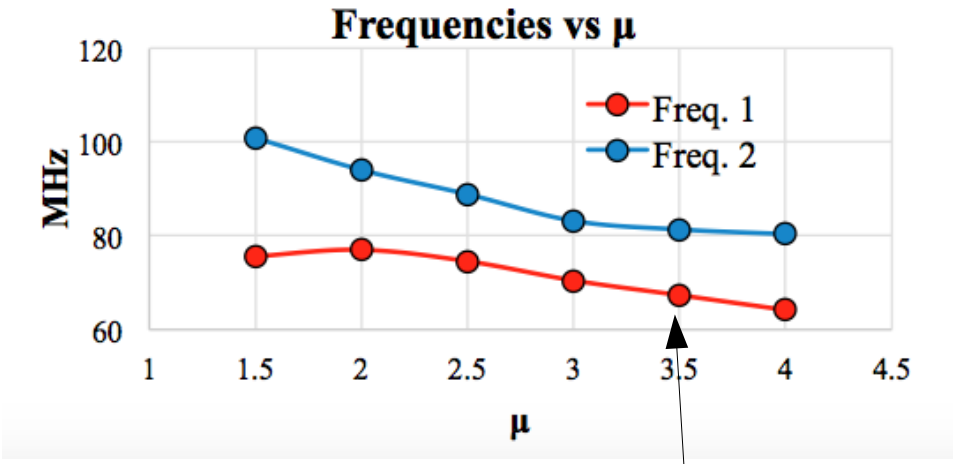
Problems that required redesign

- Gennady showed that in MWS, with the coupler added, the normal modes are actually quite close.



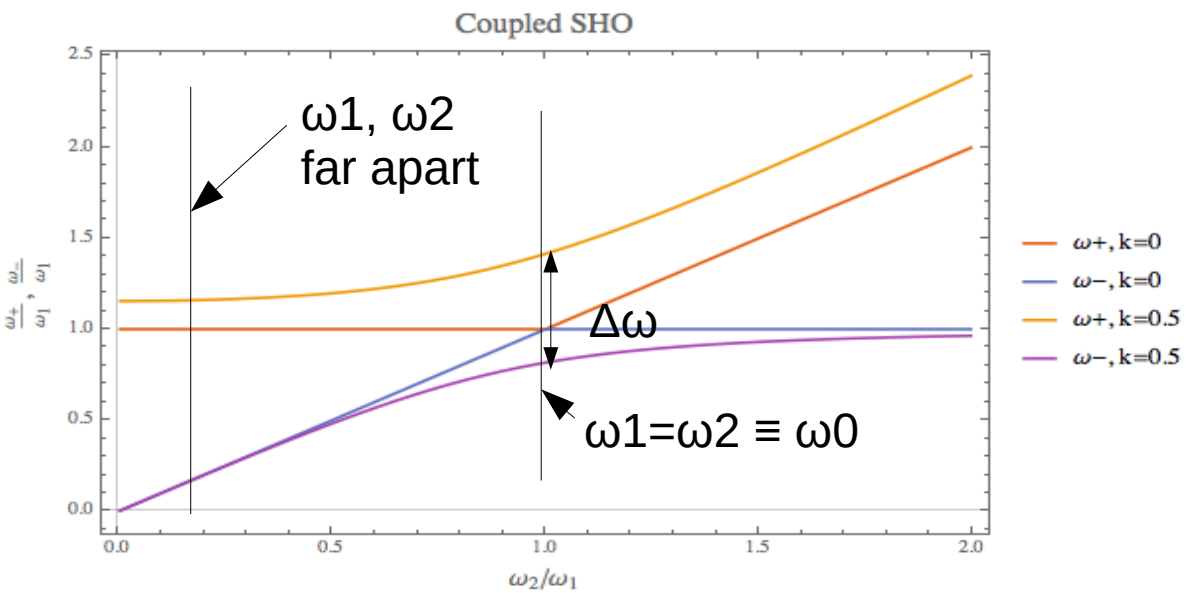


Frequency separation is 14 MHz!

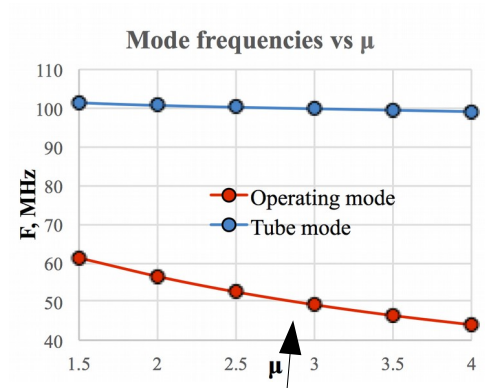
Problem is with such close normal modes, energy is also in the power coupler which is not good.

Why?

- The reason is that the power coupler and the accelerating cavity have natural frequencies that are too close.
  - This is the classic coupled harmonic oscillator problem with 2 pendulums and a spring coupler.



Coupling k =Δω/ω0

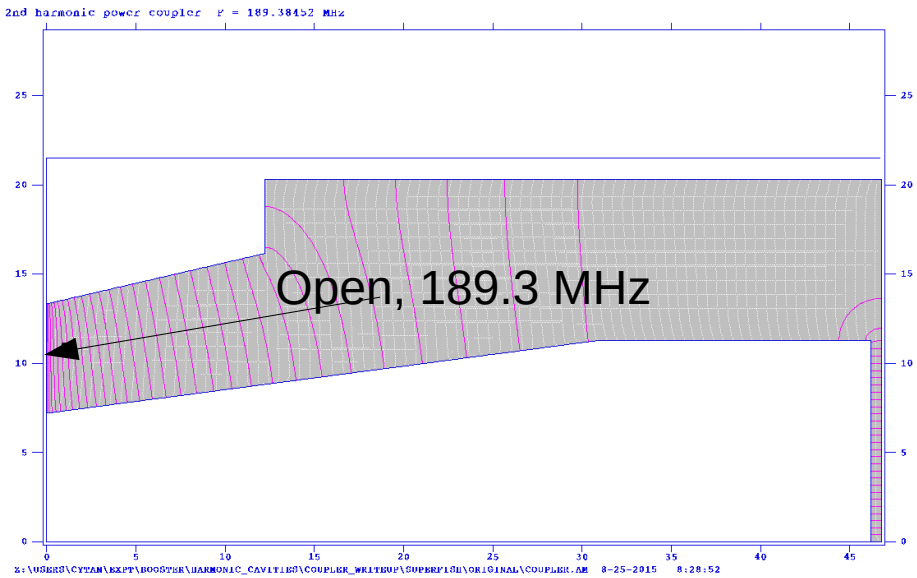


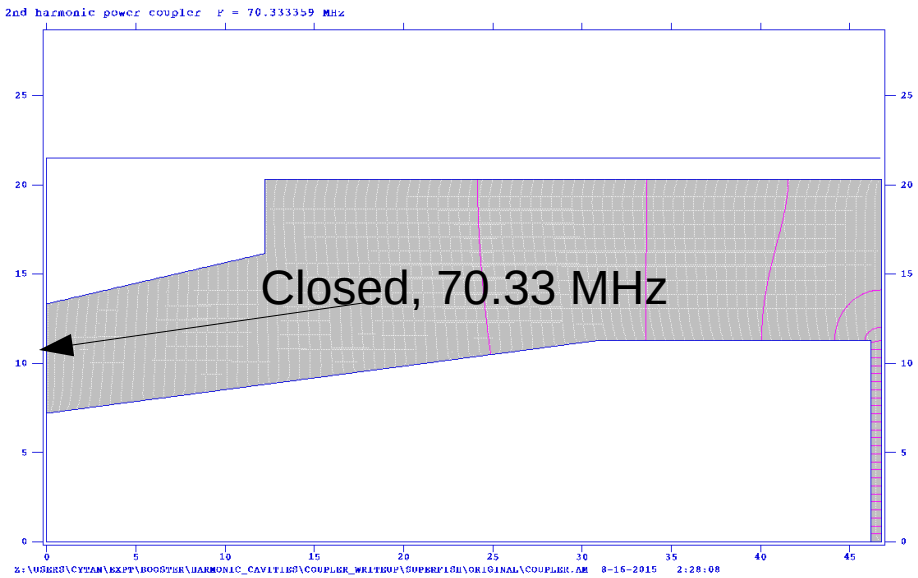
TRIUMF results

Possible solution

- Separate the two oscillator's natural frequency, so that they don't affect each other even when strongly coupled.
- We need to see what the “natural” frequencies of the coupler and the accelerating cavity are.
  - This is where things get confusing
    - From both Superfish and transmission line model, the power coupler's natural frequency when the end is <u>open</u> is FAR from the natural frequency of the accelerating cavity!

Original power coupler



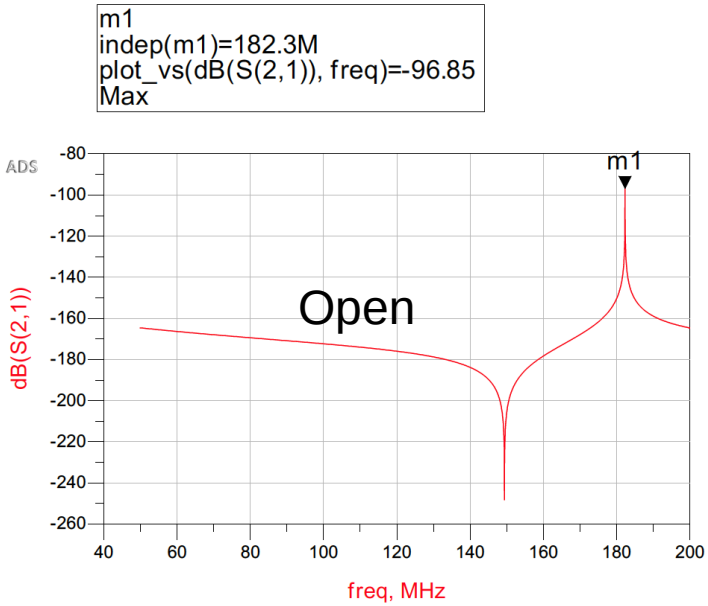


Right boundary has been set so that the gap gives 60 pF.

Notice that when the boundary is OPEN, the resonant frequency of the coupler is 189 MHz > 2x resonant frequency of accelerating cavity.

In principle, this should be far enough so that the two normal modes should be far from each other.

Transmission line model



In transmission line, the coupler with open also shows that the resonant frequency is 182 MHz.

This is close to the Superfish model.

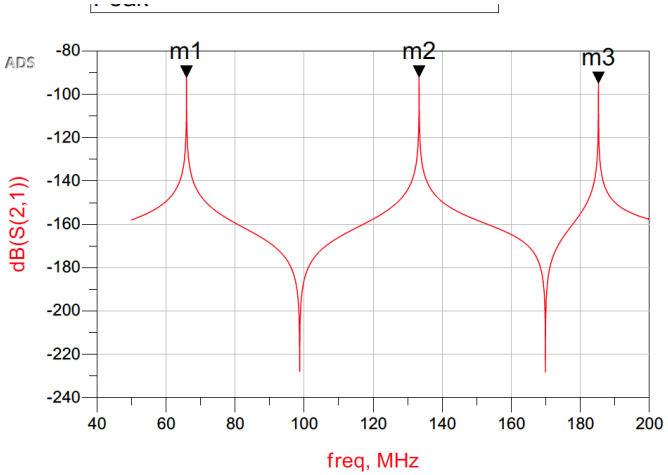
Some of the difference comes from not modeling the taper quite correctly. However, Robyn, also approximated the taper with 10 sections of transmission line: ~2 MHz correction (184 MHz) with better approximation.

Since, the coupler mode is far from the accelerator mode, we do not expect to see the normal modes to be close in the transmission line model.

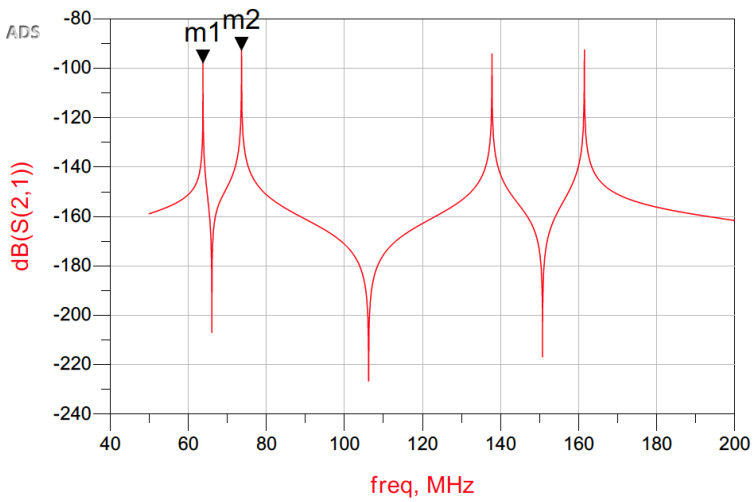
Indeed this is the case!

m1=66 MHz, m2=133 MHz.

This is 2x between the two normal modes and not 1.3x in Gennady's results!



Make “natural” frequencies closer



By making the coupler “open” resonant frequency about 73 MHz, the coupling effect becomes exaggerated and we can see that the two normal modes are close together!

Therefore, for whatever reason, the MWS model shows a much <u>lower</u> resonant frequency for the power coupler than the transmission line model.

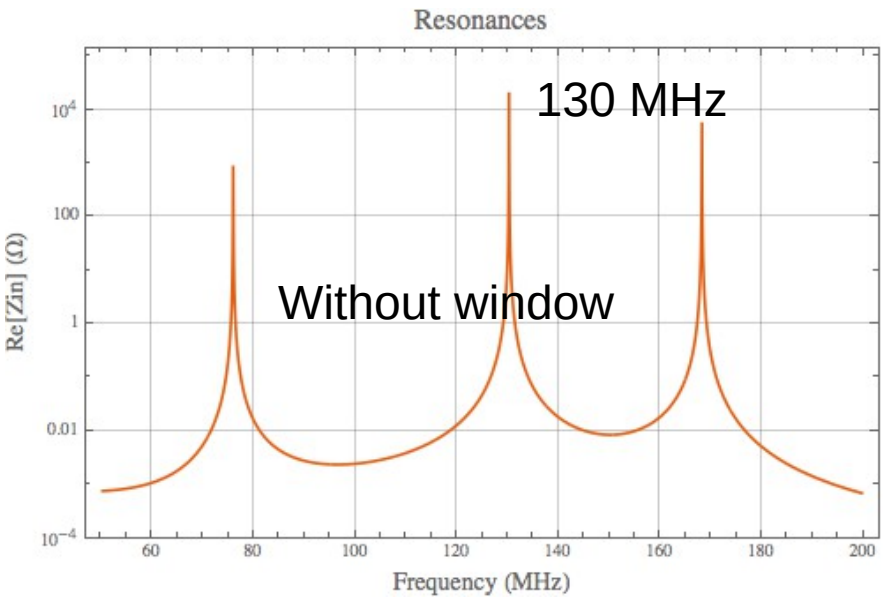
Why???? What is missing in the transmission line model???

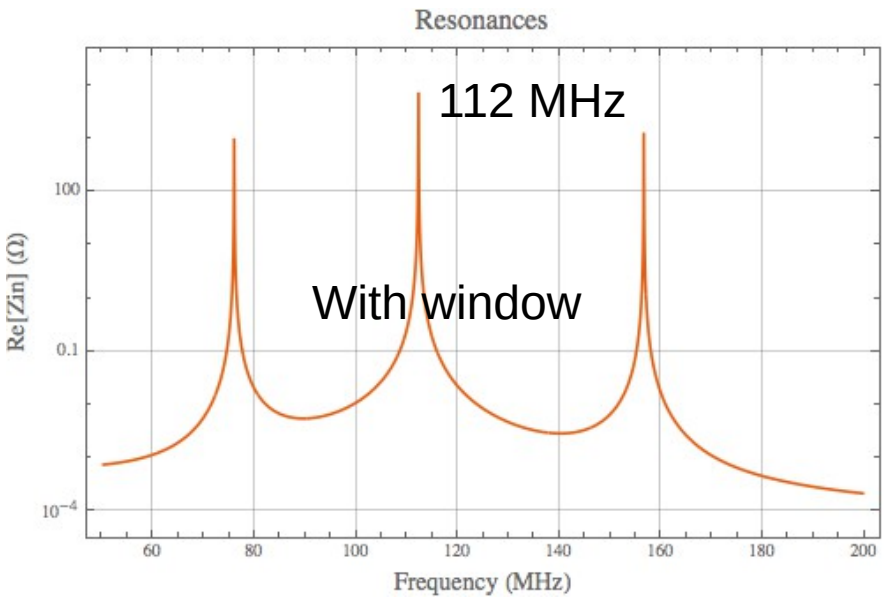
Is it the window?

Window capacitance

Assuming that the window is 2.84 inches inner radius, outer radius 5.25 inches and 1 inch thick. Using the coaxial capacitor formula, I get Cwindow = 23 pF. (Note: if this is 12 pF then the freq change is not dramatic)

It does look like it is the window that is causing some of the problem. Need MWS to verify this! However, this cannot be the complete story because from Gennady's calculation, the frequency separation at 76 MHz is ~14 MHz while we still have 36 MHz difference.

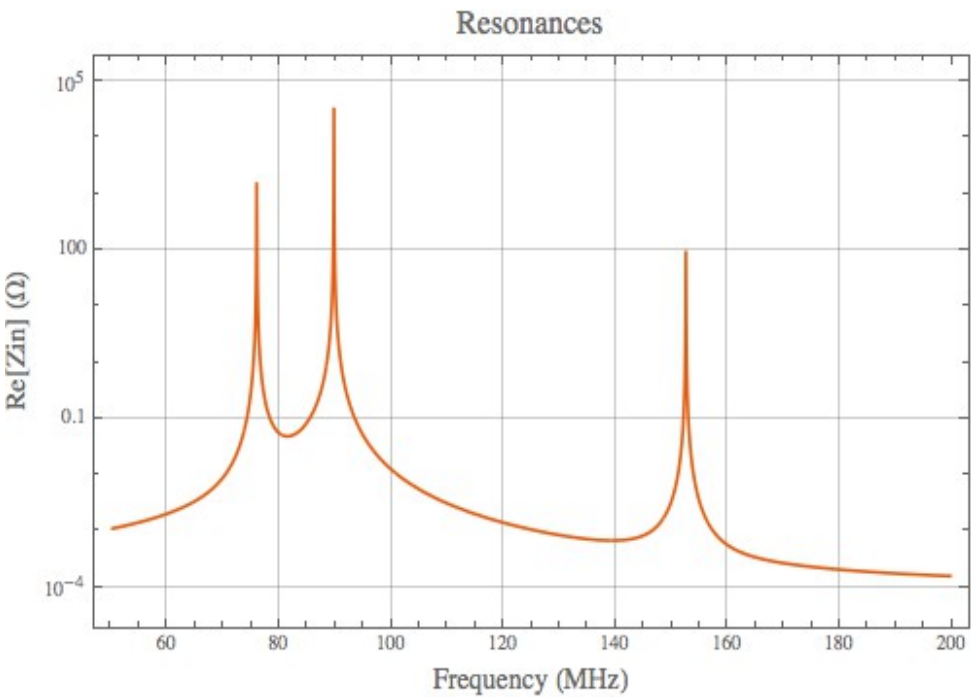




Shift is about 18 MHz.

Again, we need MWS to verify that the reason why the coupler resonance moves closer to the accelerating resonace is because of the window.

How much capacitance to add?



"Window" capacitance has to be 100 pF to get frequency difference of 14 MHz (76 MHz and 90 MHz)

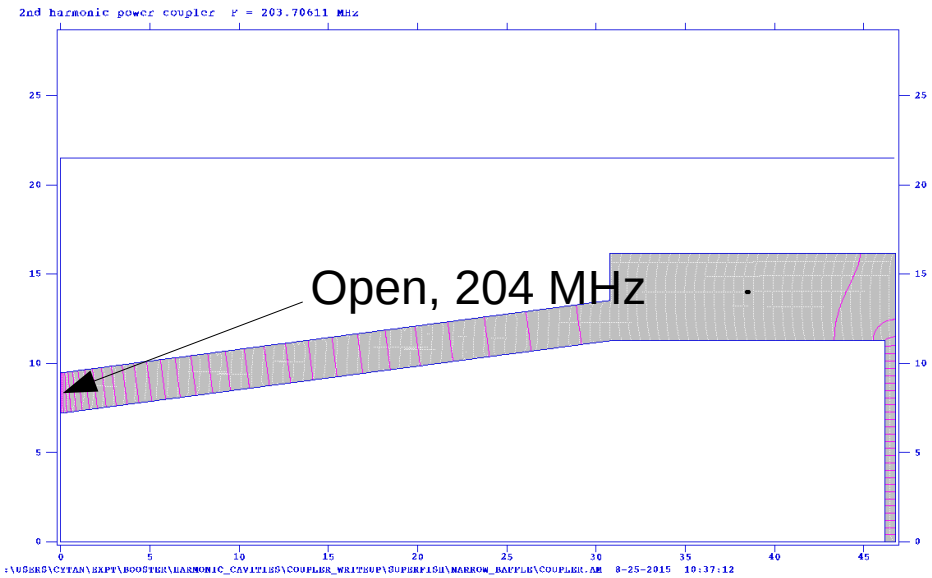
That is a lot of capacitance to add!

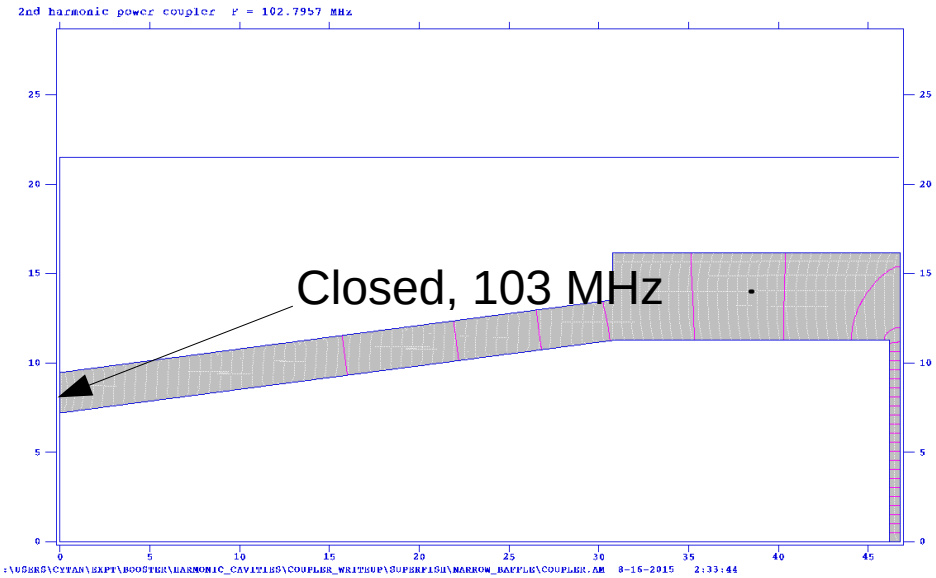
Where does this extra capacitance come from?

Problems

- If the window is the reason why the normal modes are so close
  - The input impedance seen by the tube is horrible. At 76 MHz it is 3 kΩ and gets worse from there to 80 kΩ at 106 MHz!!!!
  - Step up ratio goes down from 10 to 7 at 76 MHz and goes down even further to 2 at 106 MHz!
- We need to reoptimize if this is verified in MWS.
- This is old design. New design next slide.

New design





Make the outer coax wall have a smaller radius.

This increases the resonant frequency of the closed coupler from 70 MHz to 103 MHz, a gain of 30 MHz.

However, for the open coupler, frequency gain is only 10 MHz.

Is MWS going to see a larger increase in normal mode separation????

Conclusion

- Need to confirm that it is the window that is affecting the resonant frequency of the coupler (may not be complete story)
  - If we believe from the coupled SHO model, the coupler must have a much lower resonant frequency than expected.
  - Looks like it part of it comes from the window but MWS needs to confirm this.
- We have reoptimize because the results affects the input impedance seen by the PA, shunt impedance etc.
  - We will reoptimize with the “new” coupler design once MWS says that it works.