Landau Cavity Improvements, and Issues with Drift Tube Linac Upgrades

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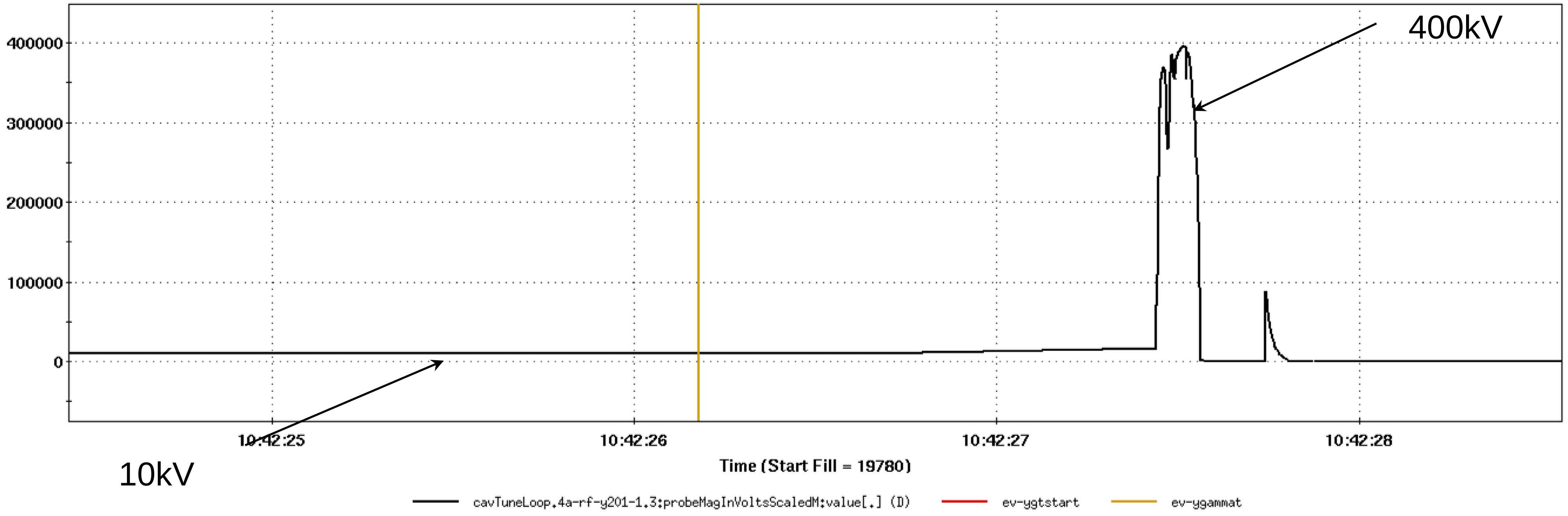
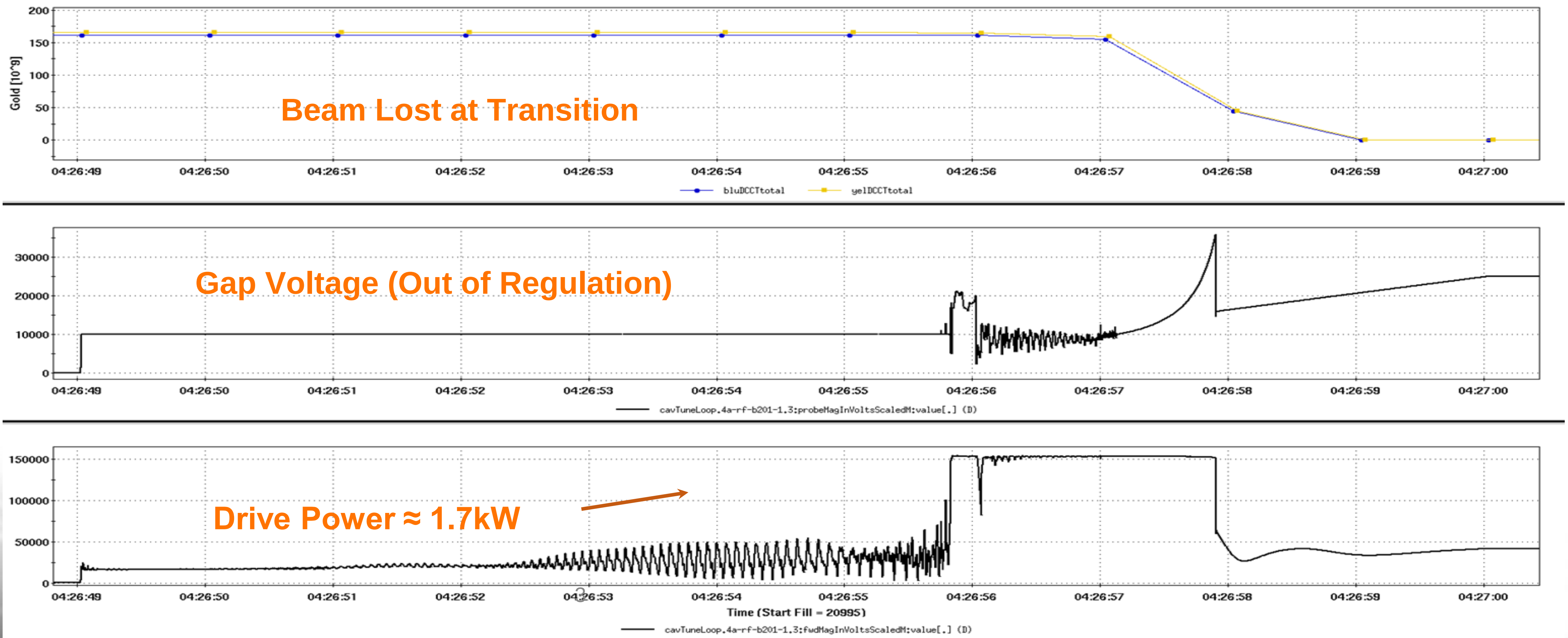
Landau cavity issues with higher beam intensities

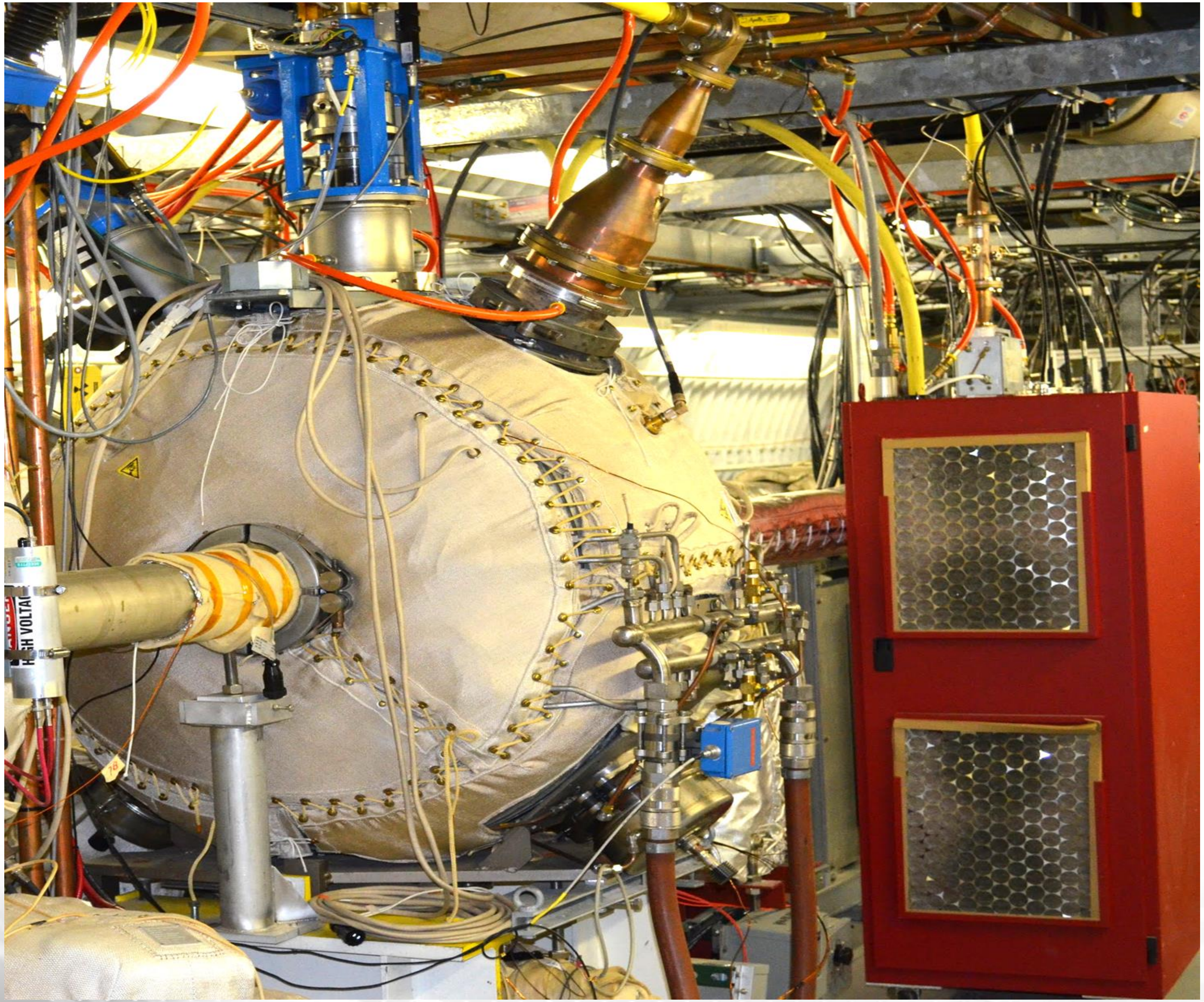
- Beam Loading
  - Beam current “overpowers” the cavity @ intensity > 2.4e9 ions per bunch
  - Over 400kV induced on the gap by the beam
  - 10kV command from the LLRF



Blue Landau System 2017 Au Run

- At the higher intensities the landau cavities were tripping at transition causing beam aborts.





RHIC Landau System

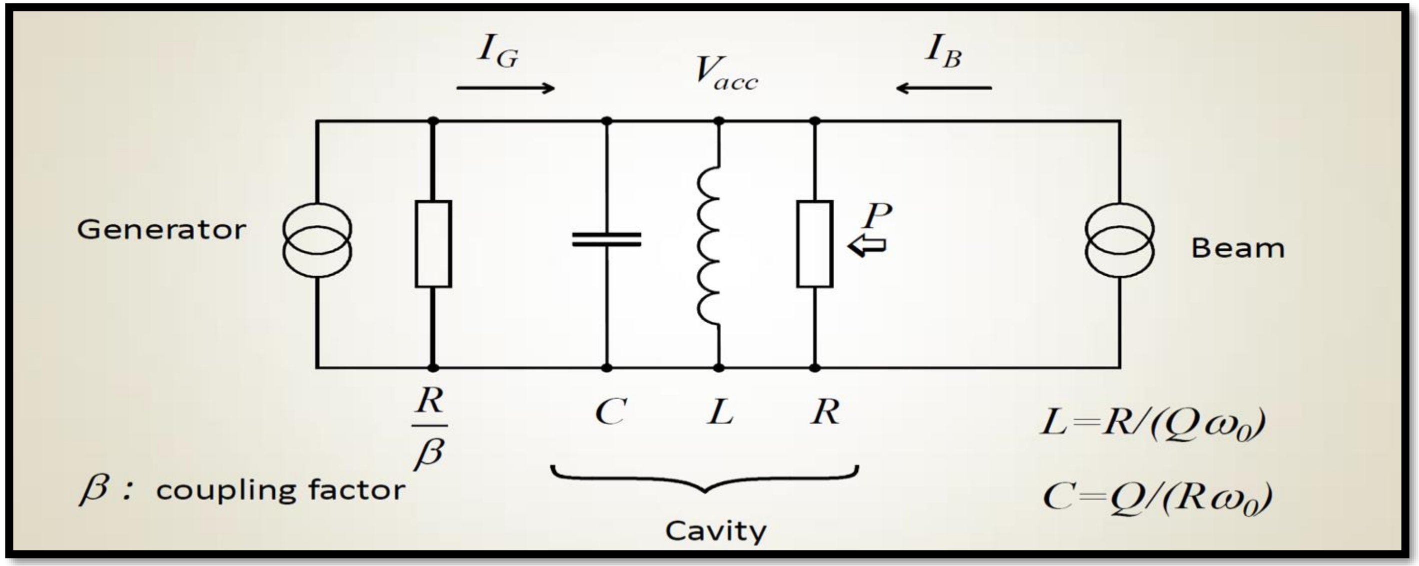
- 201 MHz
- 2 kW solid state PA
- $Q_0 = 44000$
- $R/Q = 205\Omega$
- Critically Coupled

Solution options using existing hardware

▪ Rotating the drive loop to increase the coupling factor to a maximum β=6

▪Use a tetrode PA (brute force)

▪Externally Increase β

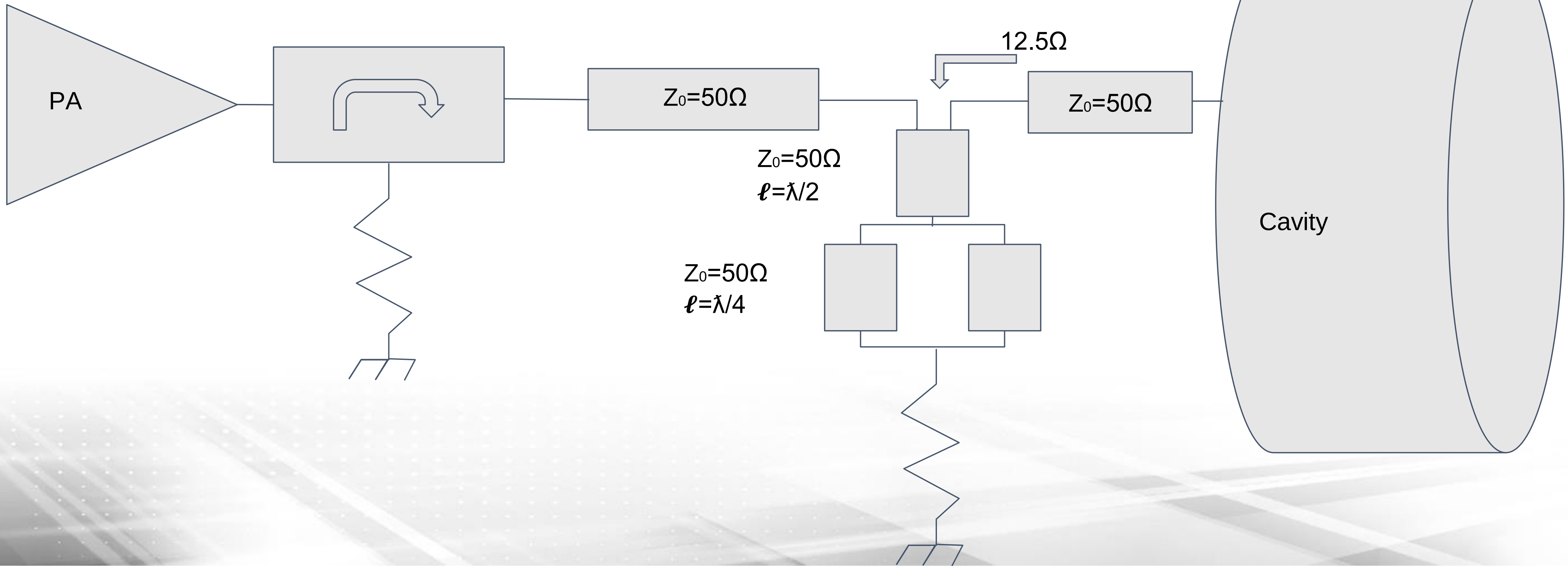


Chosen Solution:
External Loading Network

- No vacuum work required
- Can modify impedance on the fly
- Reduces stress on existing circulator
- Made from off-the shelf components

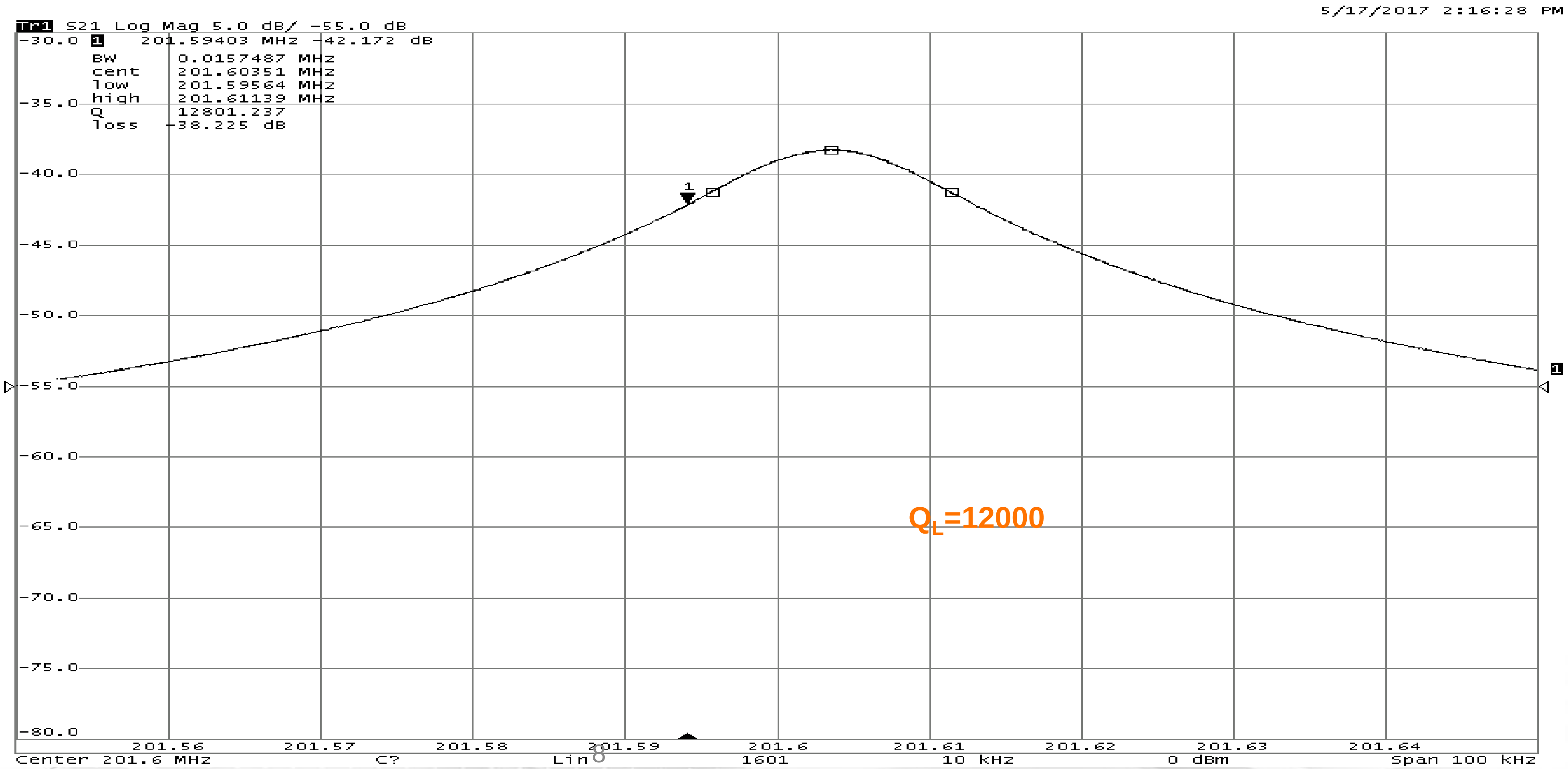
External Loading Network

Parameter	Critically Coupled	Ideal Externally Loaded
β	1	5
Q_L	22,000	8,000
R_{SL} (MΩ)	3.63	1.21
Z_{in} (Ω)	50	10
FFB Gain (dB)	40	33



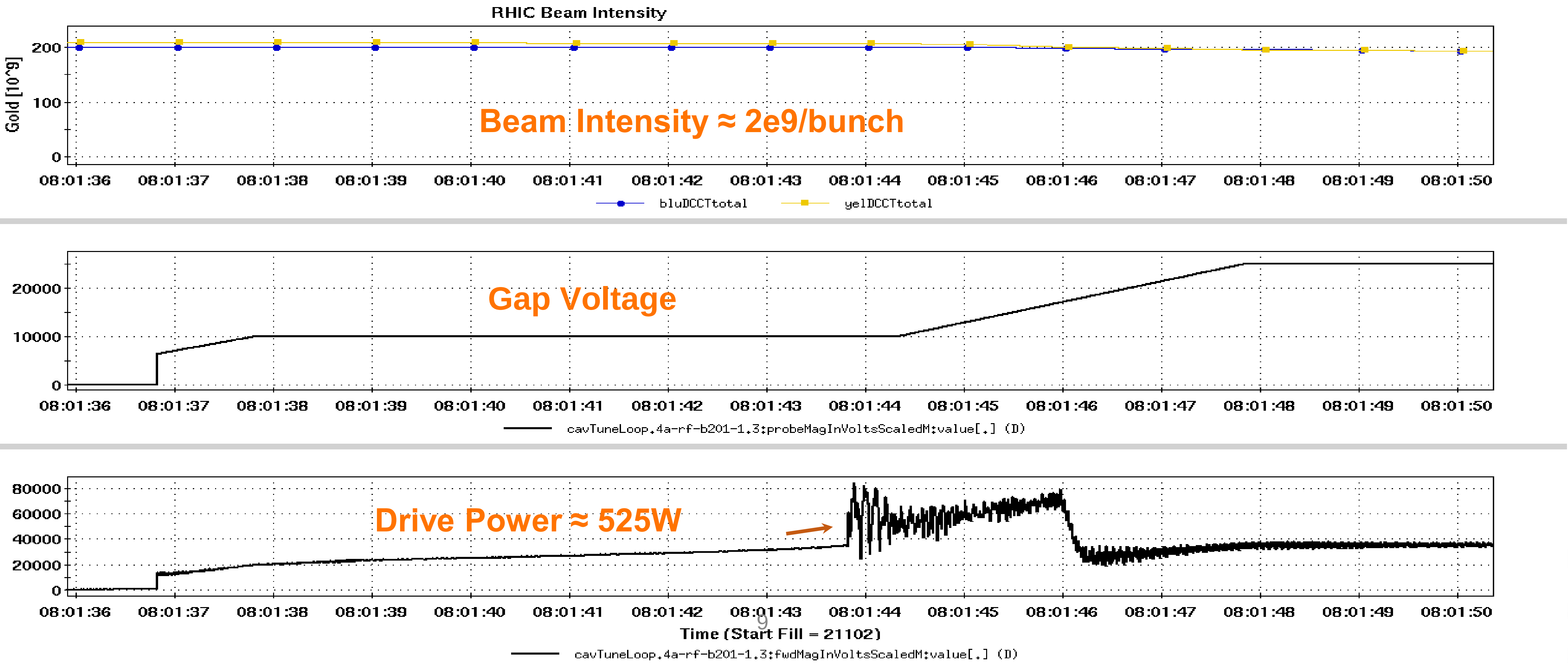
Measured Parameters

- Network not yet fully optimized
- β only 2.6



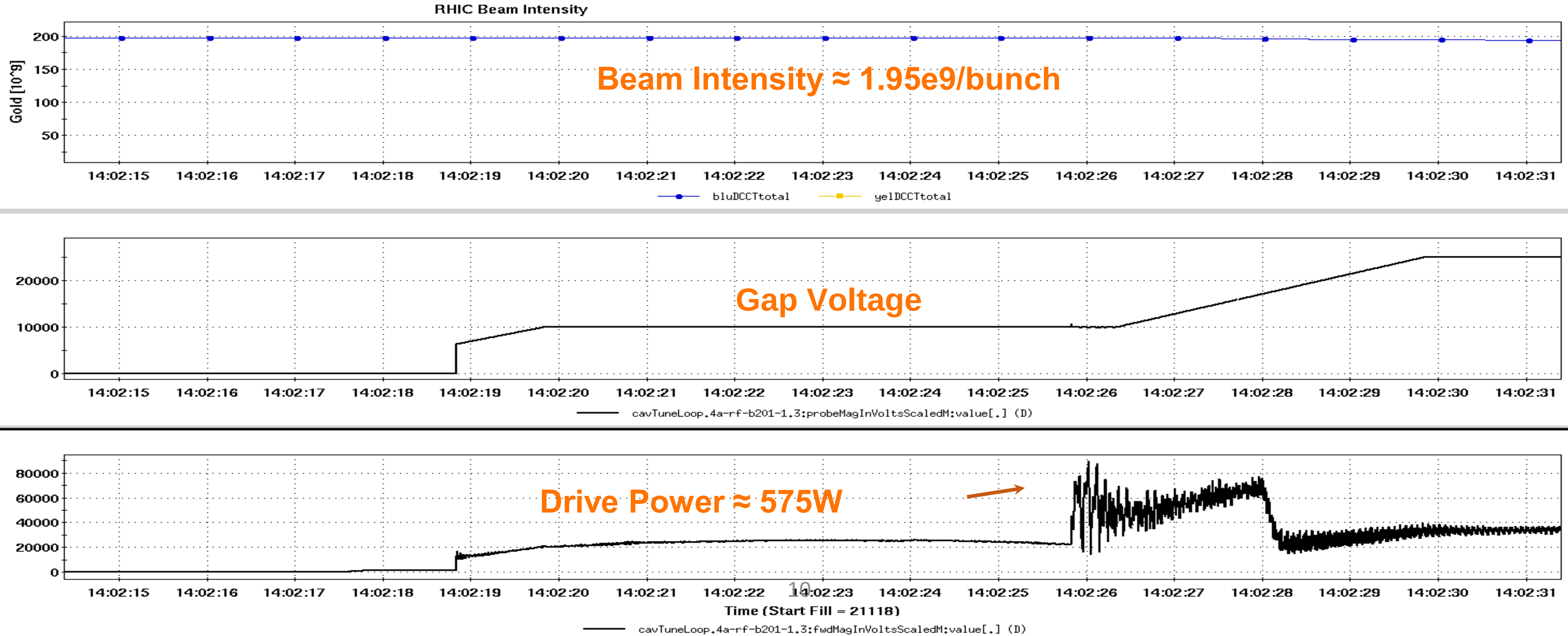
Loading Network Implementation

- 4 hour machine development (6/8/17)
  - 2017 Au run did not require high intensity beam



Testing Blue Landau's Limits

- Efforts were made to test higher beam intensities
- The machine could not provide high intensity so bunch patterns were modified to simulate higher beam intensity at landau harmonic
- Drop every 16th Bunch, Drive Power up 10%



Blue Landau Conclusions

- Extrapolating from 2017 Au data, the forward power requirement for 3.0 x 10^9 is approximately 1200w
- Landau power amplifier capable of 2000w linear
- Even with a β of only 2.6 proof of principle a success!

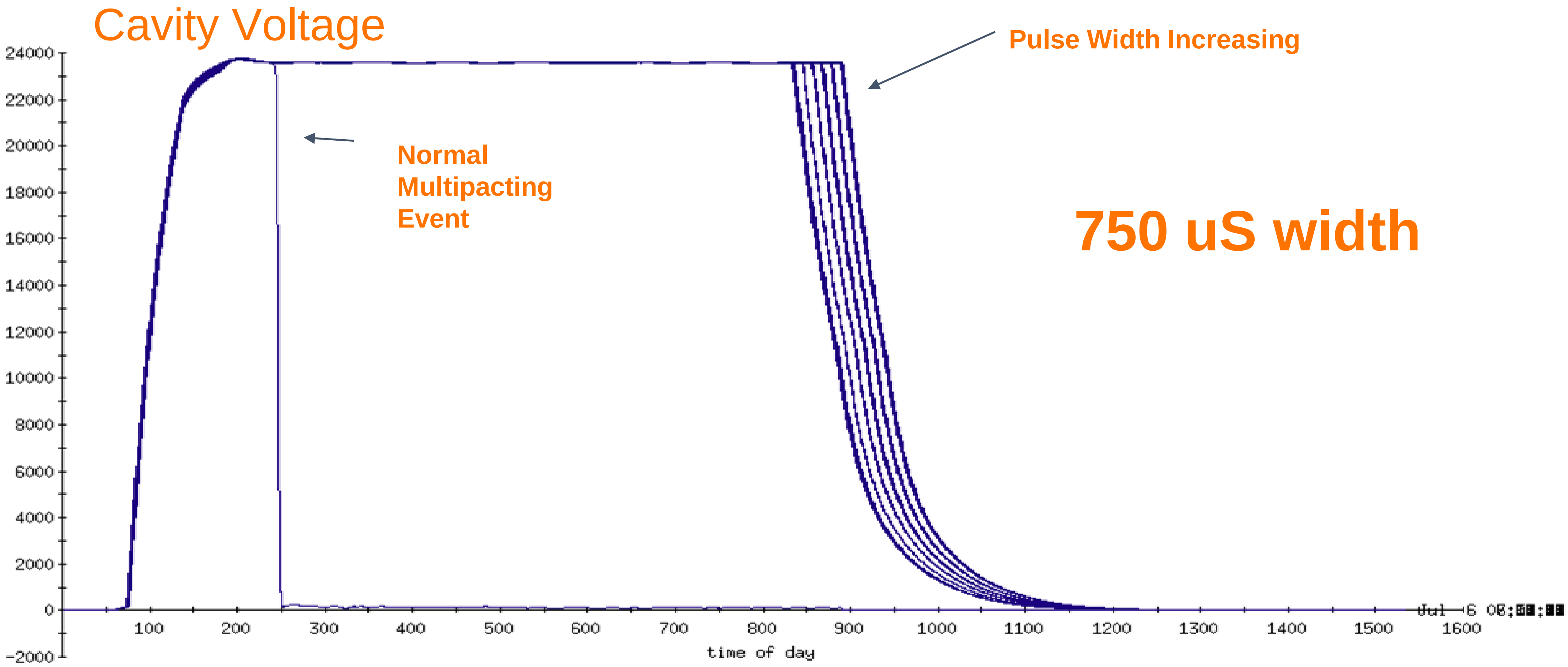
200 MeV Linac RF Pulse width increase

- Medical Isotope program requests higher average beam current
- Proposed beam pulse width increases from 450uS to 900uS
- RF pulse width increases from 650uS to 1100uS

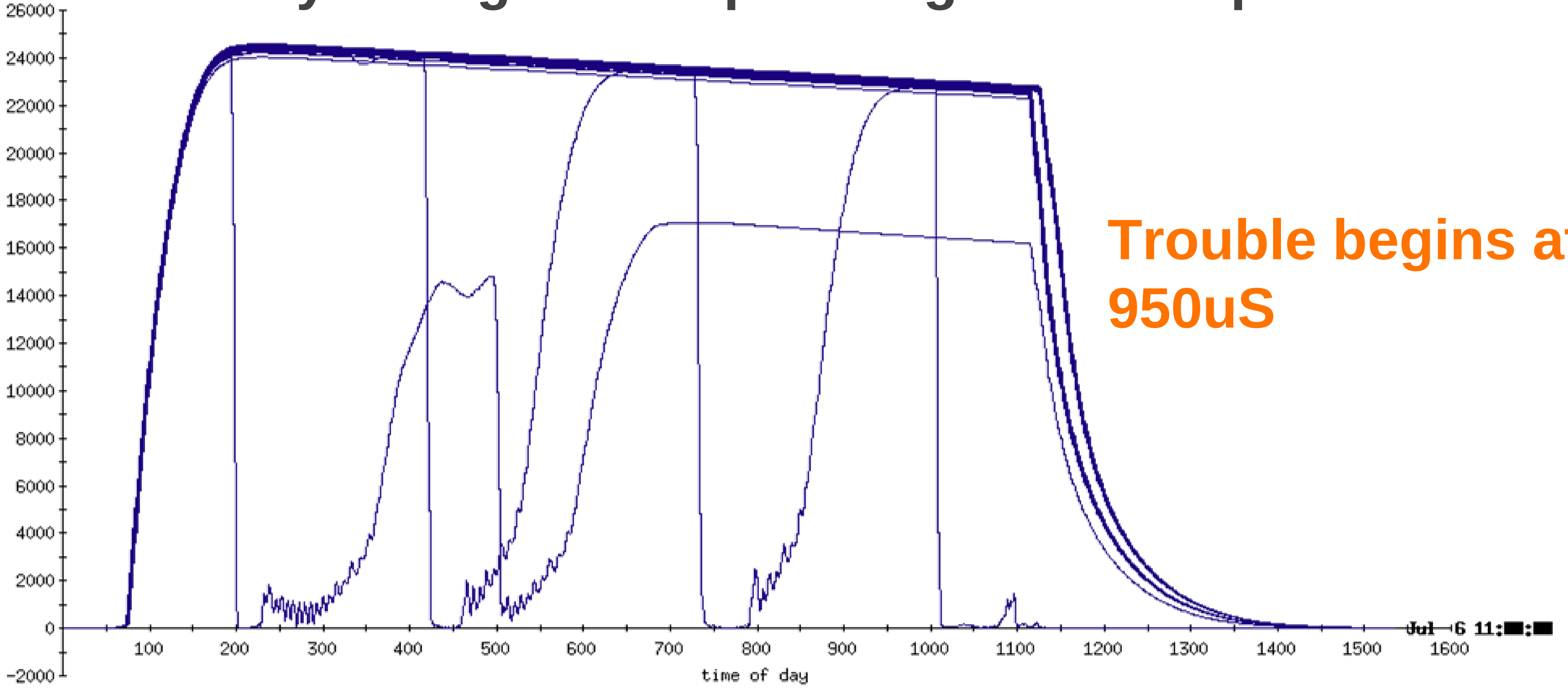
RF Equipment Upgrades

- 200kW Driver Cap bank increases from 25uF to 40uF
- 5MW PA Cap bank increases from 50uF to 84uF
- Transformer upgrades in modulator
- System performed well in test dock to 1100uS

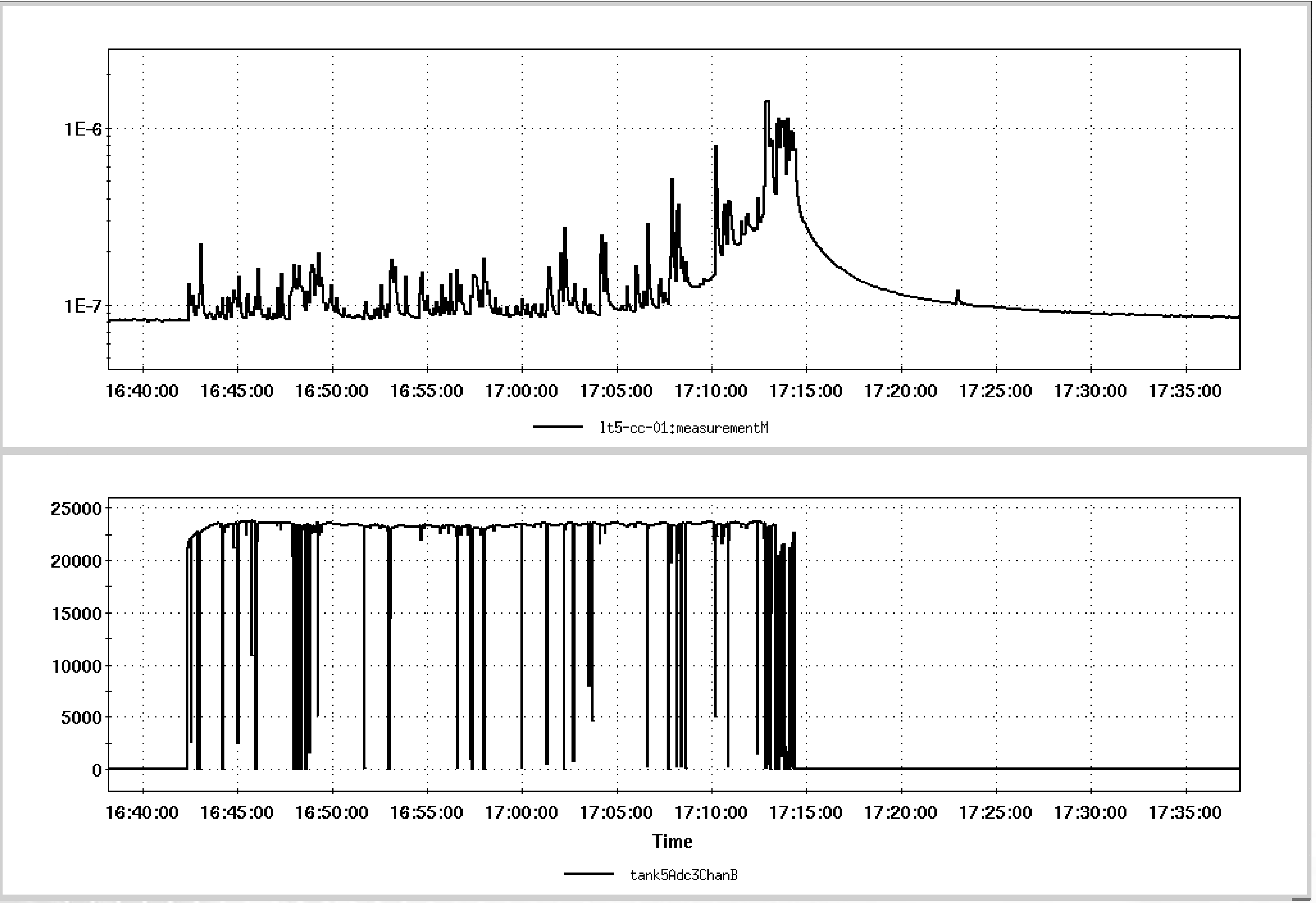
Increasing Pulse Width on Tank 5



Cavity voltage with open magnitude loop

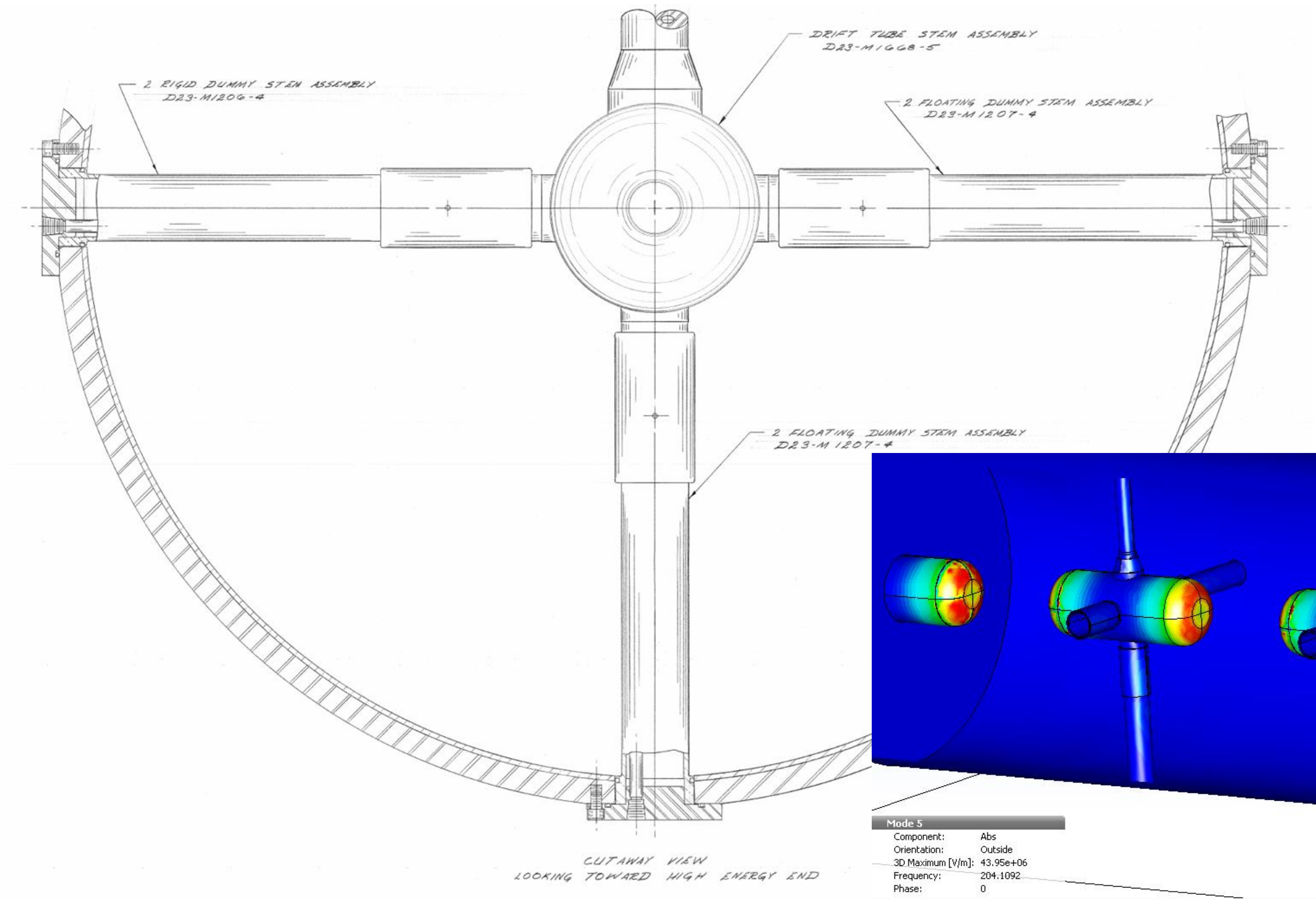


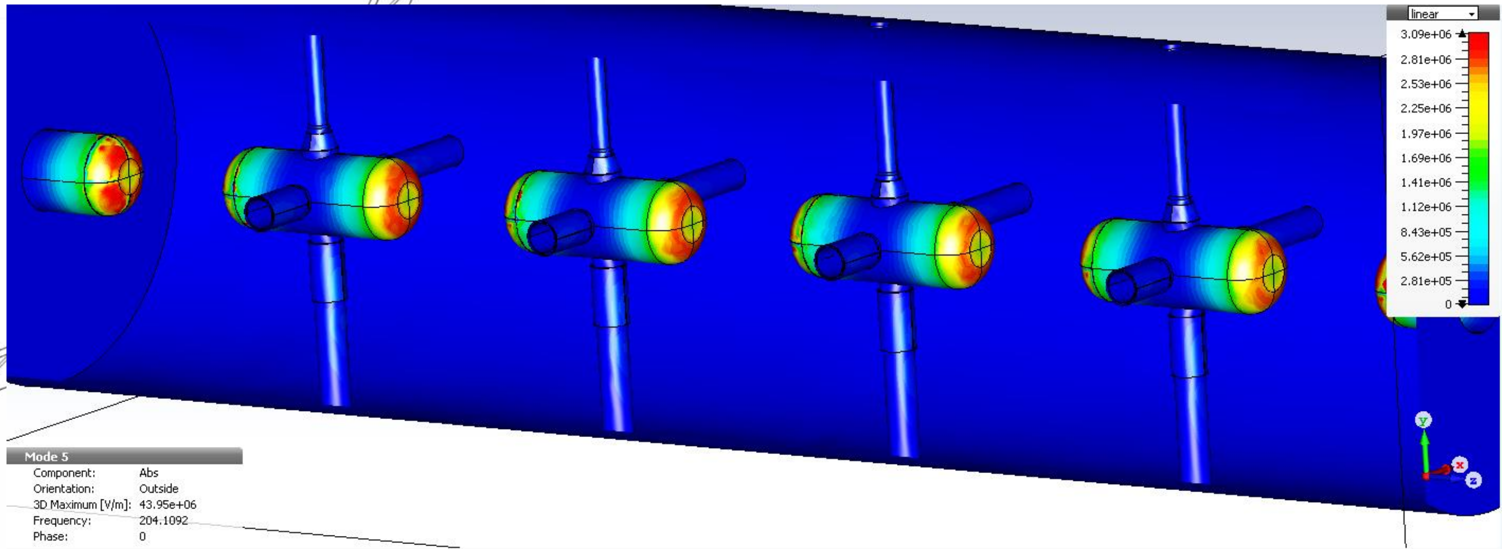
Trouble begins at 950uS



- Shut system down to let vacuum recover
- Ended testing after observing excessive vacuum activity
- Opened up Tank 5 to inspect damage

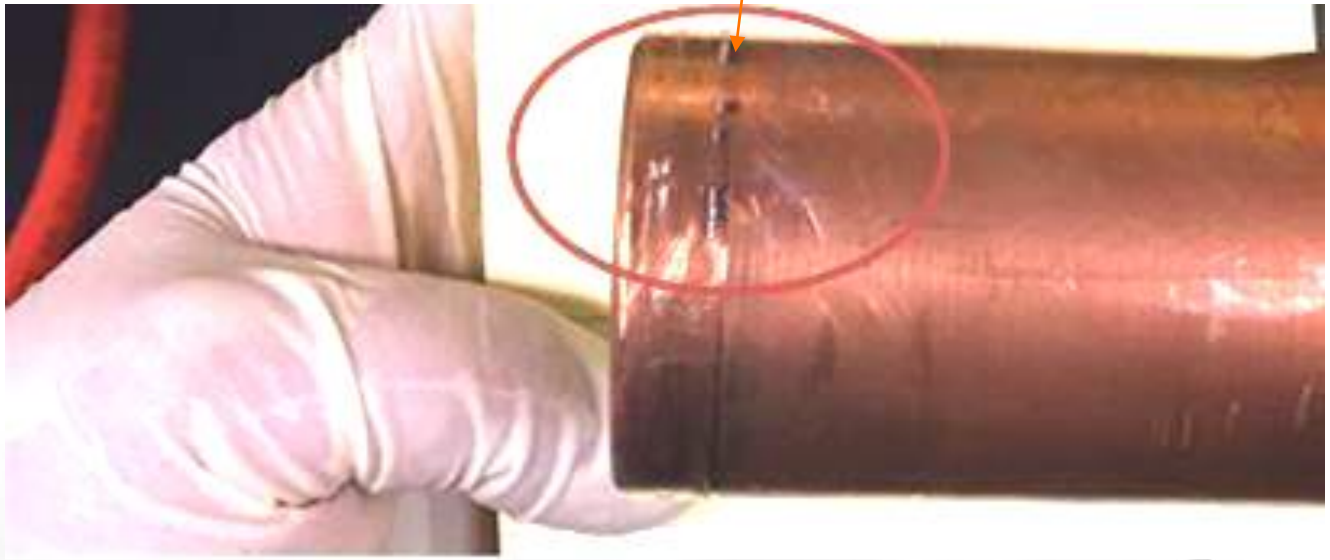
Opening Tank 5 for inspection





- Drift tube stem and collars were overheating

RF Spring ring remnants



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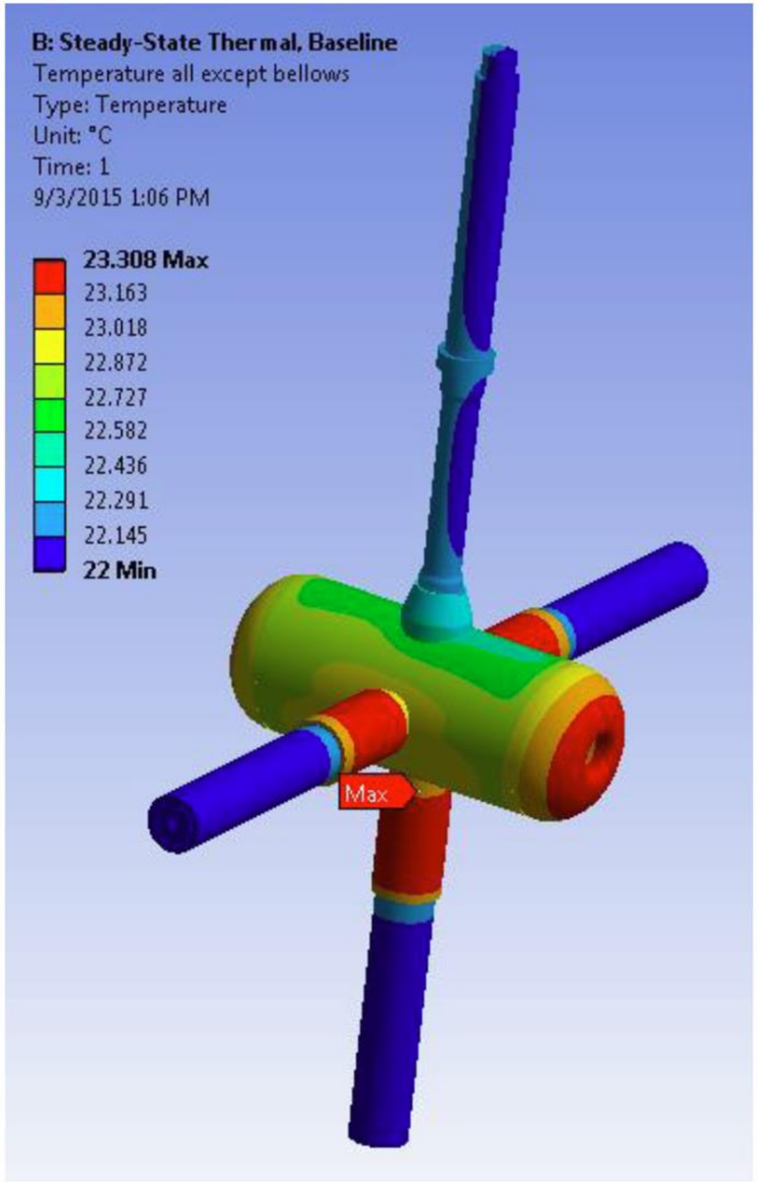
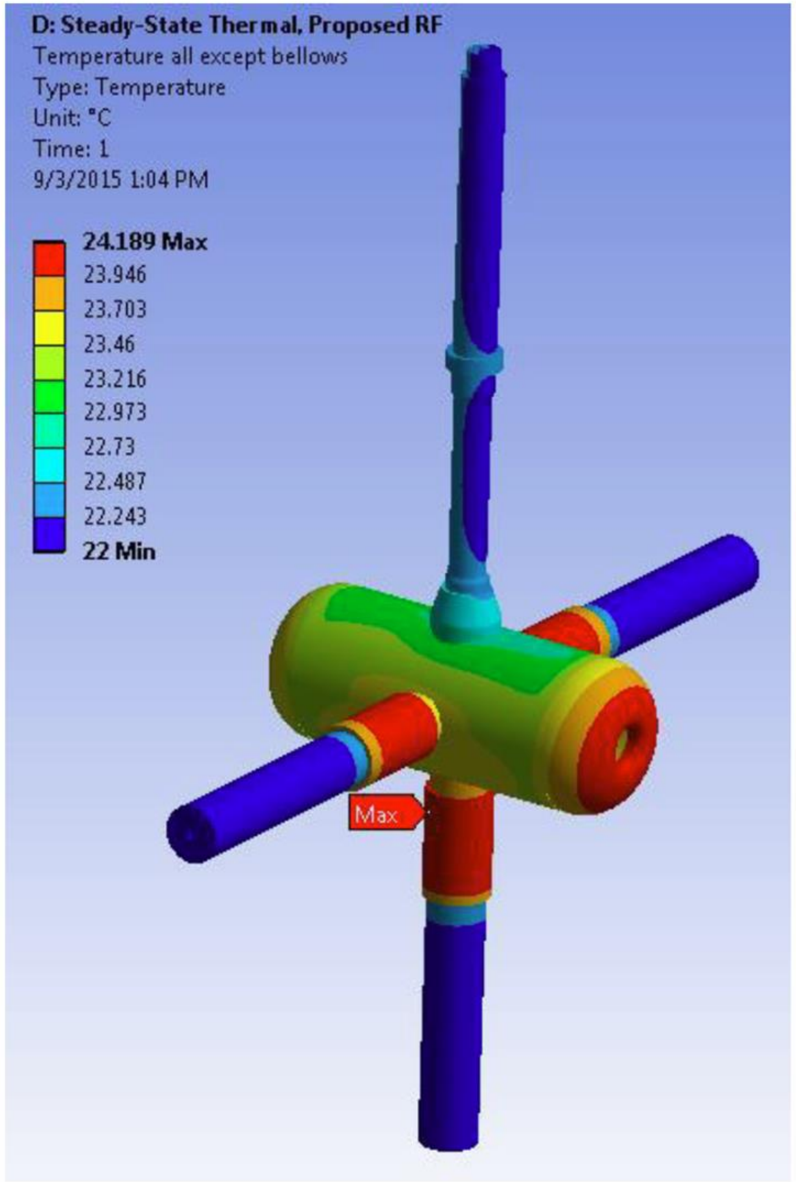
- Silver plated beryllium copper RF spring ring melted
- BeCu melting point = 800-900℃

12 of 96 stems/collars suffered damage

Where did feasibility study go wrong?

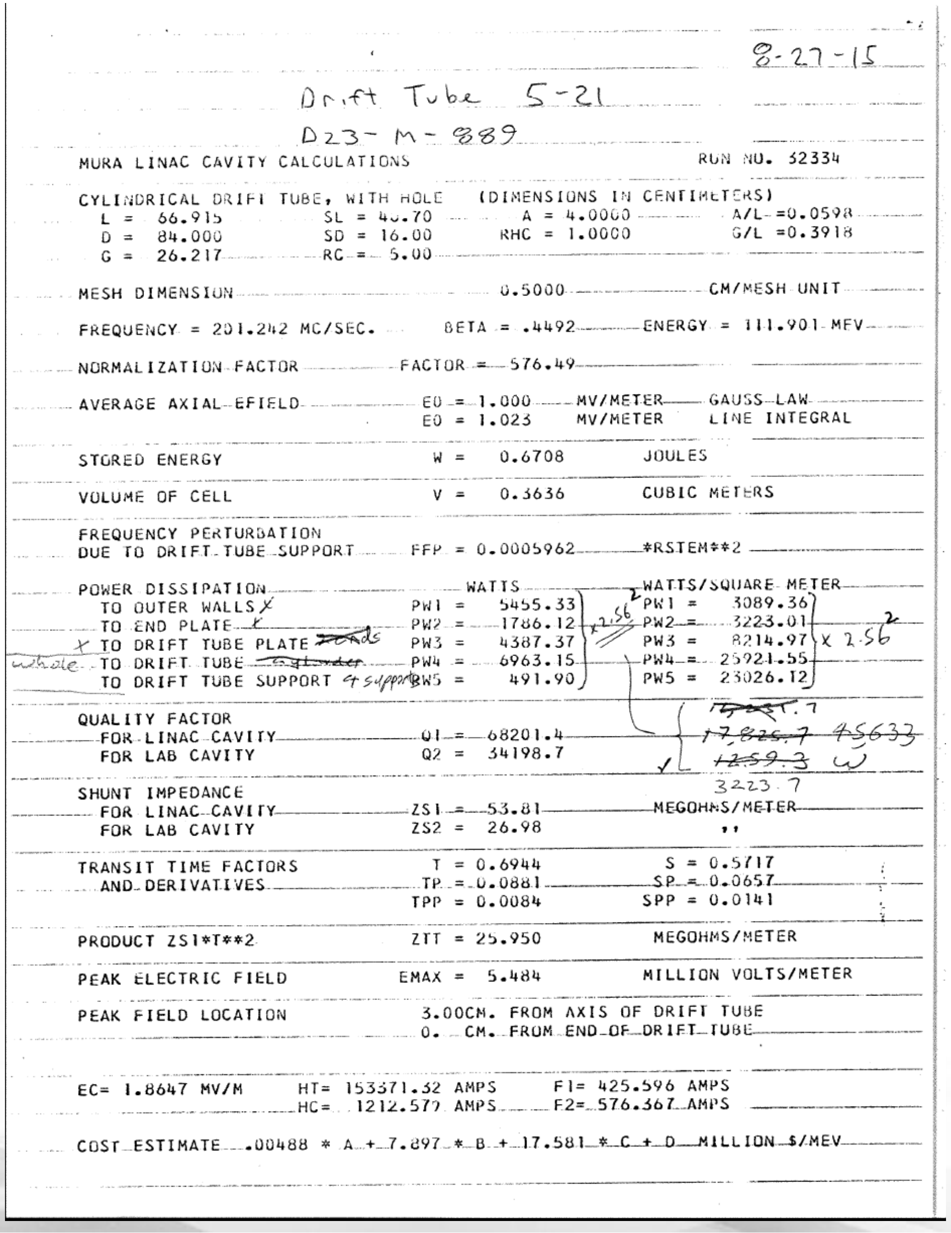




- Thermal analysis shows < 1℃ rise over the normal operational conditions.
- Max of 24.2 ℃

How was the thermal analysis performed?

- Scaled Messy Mesh power dissipation calculations from 1968 by 170%
- Assumed even distribution of RF heating and perfect thermal junctions



8-27-15

Drift Tube 5-21

D23- M- 889

MURA LINAC CAVITY CALCULATIONS RUN NO. 32334

CYLINDRICAL DRIFT TUBE, WITH HOLE (DIMENSIONS IN CENTIMETERS)

L = 66.915	SL = 40.70	A = 4.0000	A/L =0.0598
D = 84.000	SD = 16.00	RHC = 1.0000	G/L =0.3918
G = 26.217	RC = 5.00		

MESH DIMENSION 0.5000 CM/MESH UNIT

FREQUENCY = 201.242 MC/SEC. BETA = .4492 ENERGY = 111.901 MEV

NORMALIZATION FACTOR FACTOR = 576.49

AVERAGE AXIAL EFIELD E0 = 1.000 MV/METER GAUSS LAW
E0 = 1.023 MV/METER LINE INTEGRAL

STORED ENERGY W = 0.6708 JOULES

VOLUME OF CELL V = 0.3636 CUBIC METERS

FREQUENCY PERTURBATION
DUE TO DRIFT TUBE SUPPORT FFP = 0.0005962 *RSTEM**2

POWER DISSIPATION	WATTS	WATTS/SQUARE METER
TO OUTER WALLS	PW1 = 5455.33	PW1 = 3089.36
TO END PLATE	PW2 = 1786.12	PW2 = 3223.01
TO DRIFT TUBE PLATE ~~ends~~	PW3 = 4387.37	PW3 = 8214.97
whole TO DRIFT TUBE ~~cylinder~~	PW4 = 6963.15	PW4 = 25921.55
TO DRIFT TUBE SUPPORT 4 supports	PW5 = 491.90	PW5 = 23026.12

x 2.56²   x 2.56²

QUALITY FACTOR
FOR LINAC CAVITY Q1 = 68201.4
FOR LAB CAVITY Q2 = 34198.7

~~17,825.7~~ 45633
~~1259.3~~ W
3223.7

SHUNT IMPEDANCE
FOR LINAC CAVITY ZS1 = 53.81 MEGOHMS/METER
FOR LAB CAVITY ZS2 = 26.98 ''

TRANSIT TIME FACTORS T = 0.6944 S = 0.5717
AND DERIVATIVES TP = 0.0881 SP = 0.0657
TPP = 0.0084 SPP = 0.0141

PRODUCT ZS1*T**2 ZTT = 25.950 MEGOHMS/METER

PEAK ELECTRIC FIELD EMAX = 5.484 MILLION VOLTS/METER

PEAK FIELD LOCATION 3.00CM. FROM AXIS OF DRIFT TUBE
0. CM. FROM END OF DRIFT TUBE

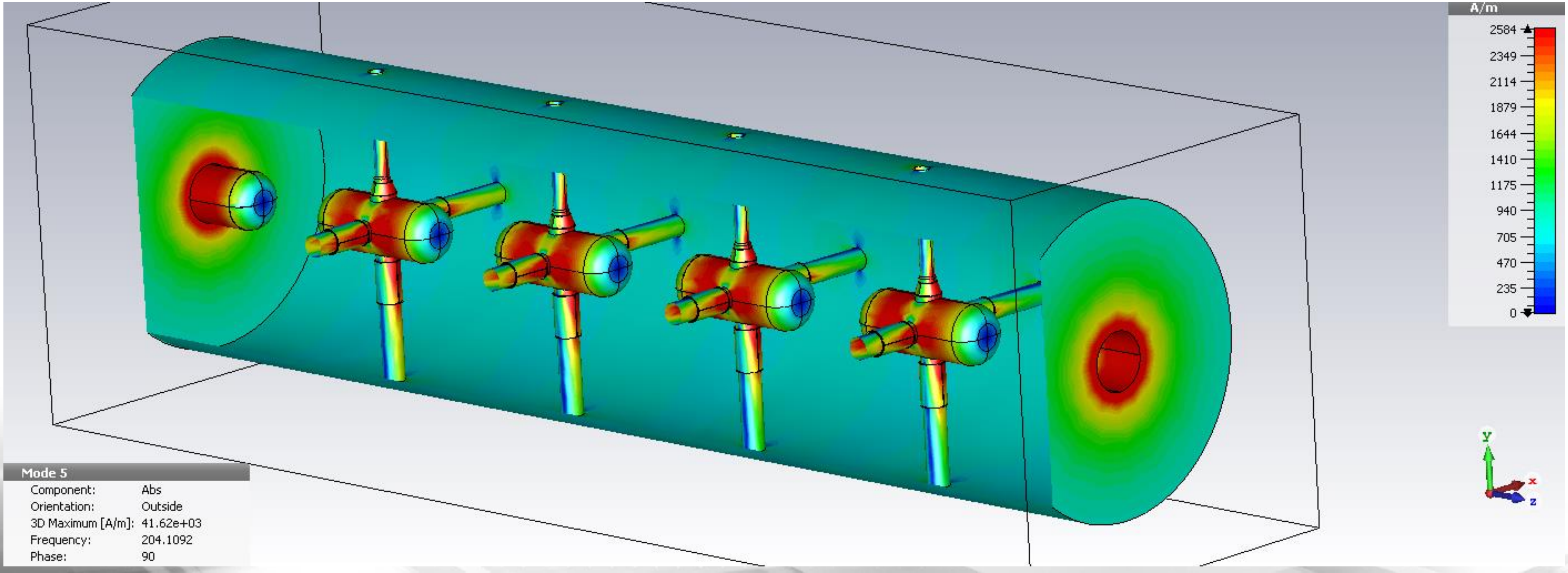
EC= 1.8647 MV/M HT= 153371.32 AMPS F1= 425.596 AMPS
HC= 1212.577 AMPS F2= 576.367 AMPS

COST ESTIMATE .00488 * A + 7.897 * B + 17.581 * C + D MILLION $/MEV

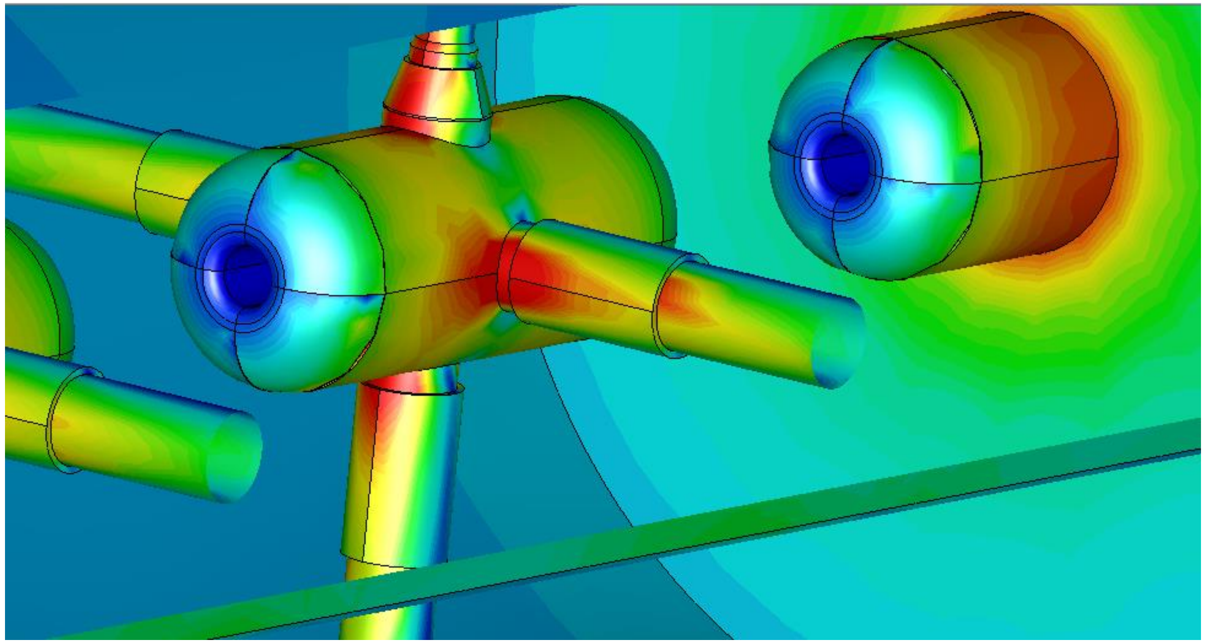
Using CST simulation to find out what’s actually happening

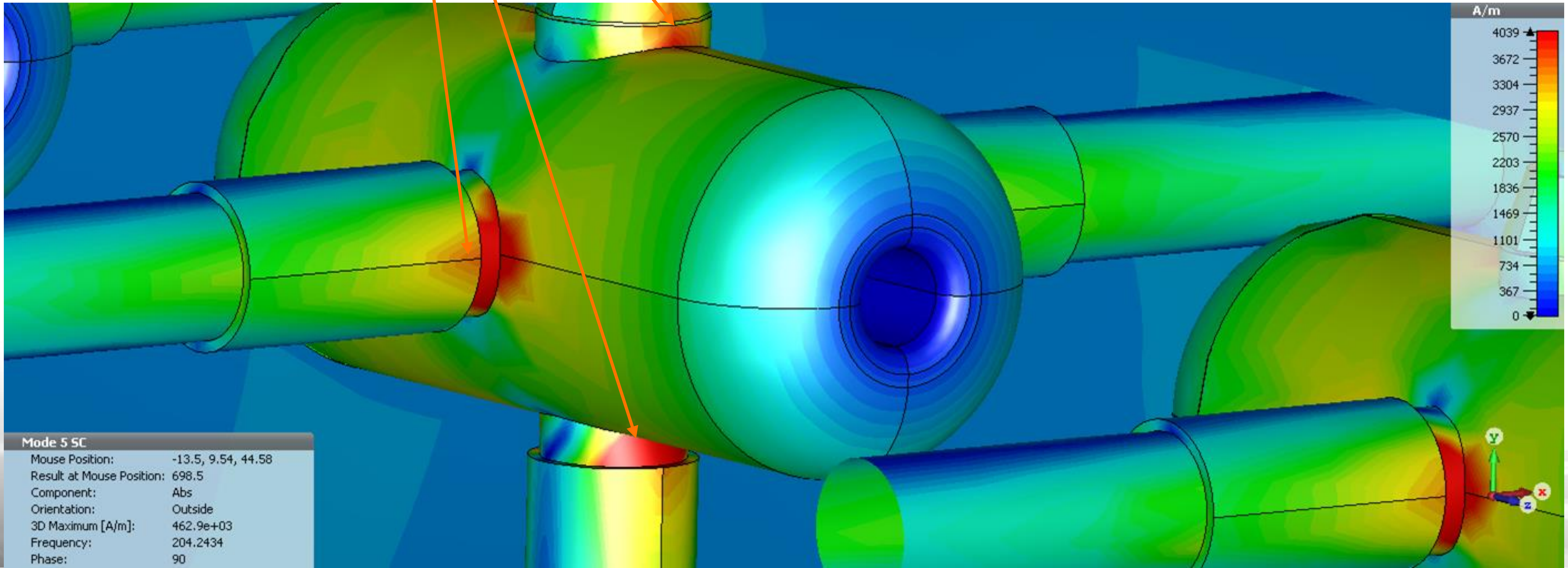
- Only simulated a 5 cell cavity

Surface H field simulation shown here

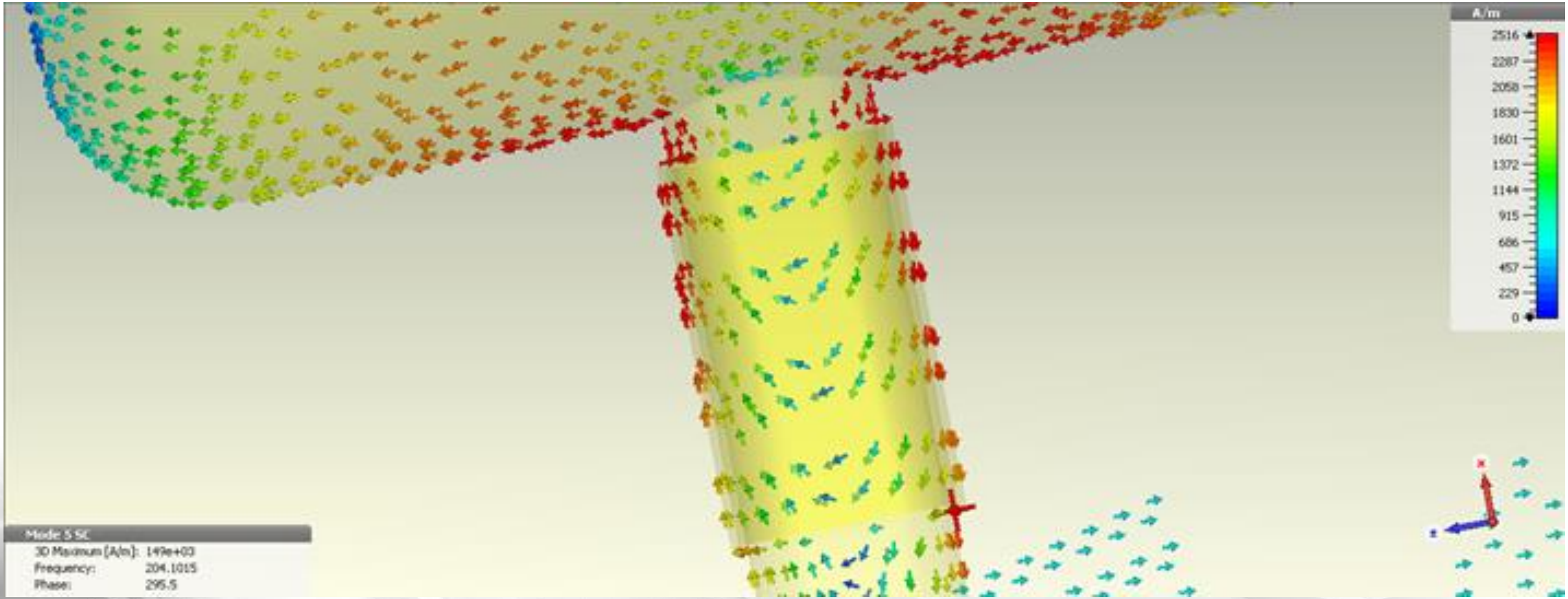


Charge crowding at stems!

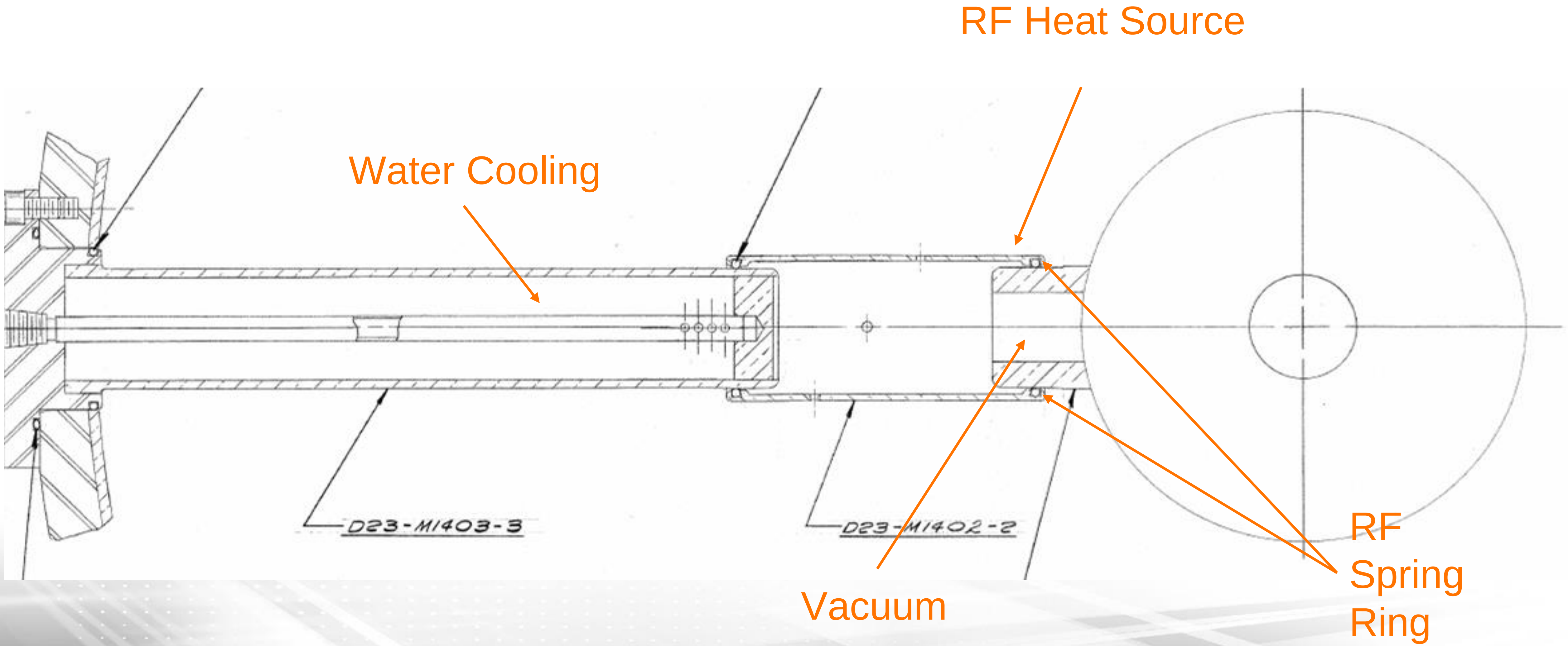




Fields cancel down the length of the collar and stem, but not before dissipating ~ 50W into the collar.



How to remove the heat



Testing RF Spring thermal junction

- A test setup was installed on a spare stem and collar assembly
- (2) 30W resistors were mounted to the collar to simulate RF heating
- Thermocouples were used to measure the junction's ΔT
- The entire assembly was then stuffed and wrapped in nomex to simulate vacuum

Steady State Thermal Testing Results

Interface	Fit	Thermal Resistance (℃/W)
.140” BeCu spring ring	Loose	1.24
	Interference	.51
Cu Conflat vacuum gasket	Loose	1.28
	Interference	.225

*Thermal Runaway conditions not shown

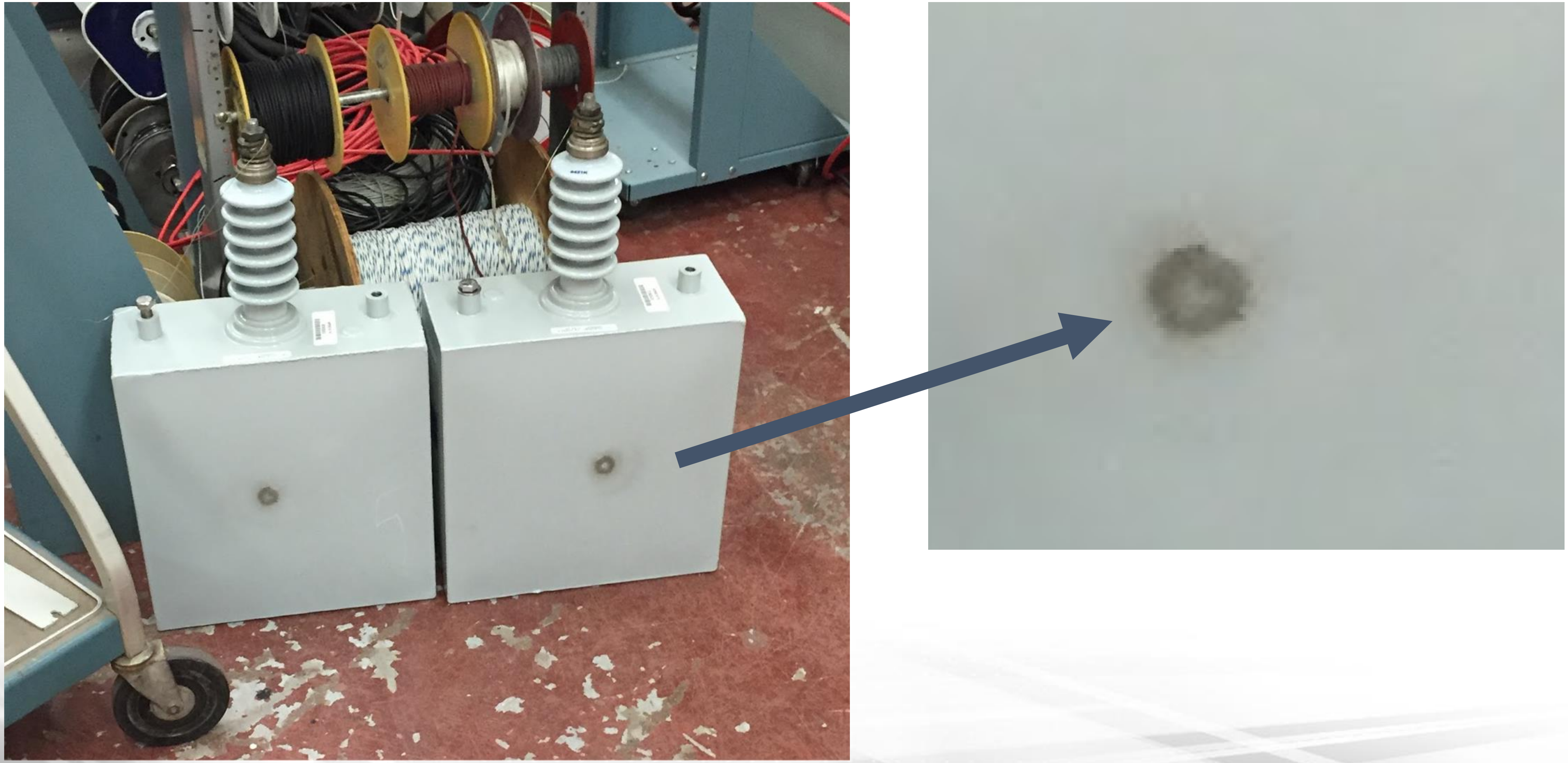
- Interference fit performed by shrink-fitting method
- Loose fit comparable to current installation methods
- Difficult to recreate consistent results with spring ring
- Conflat seal too tight to remove

- New method to be installed on Tank 5 and Tank 7 this shutdown

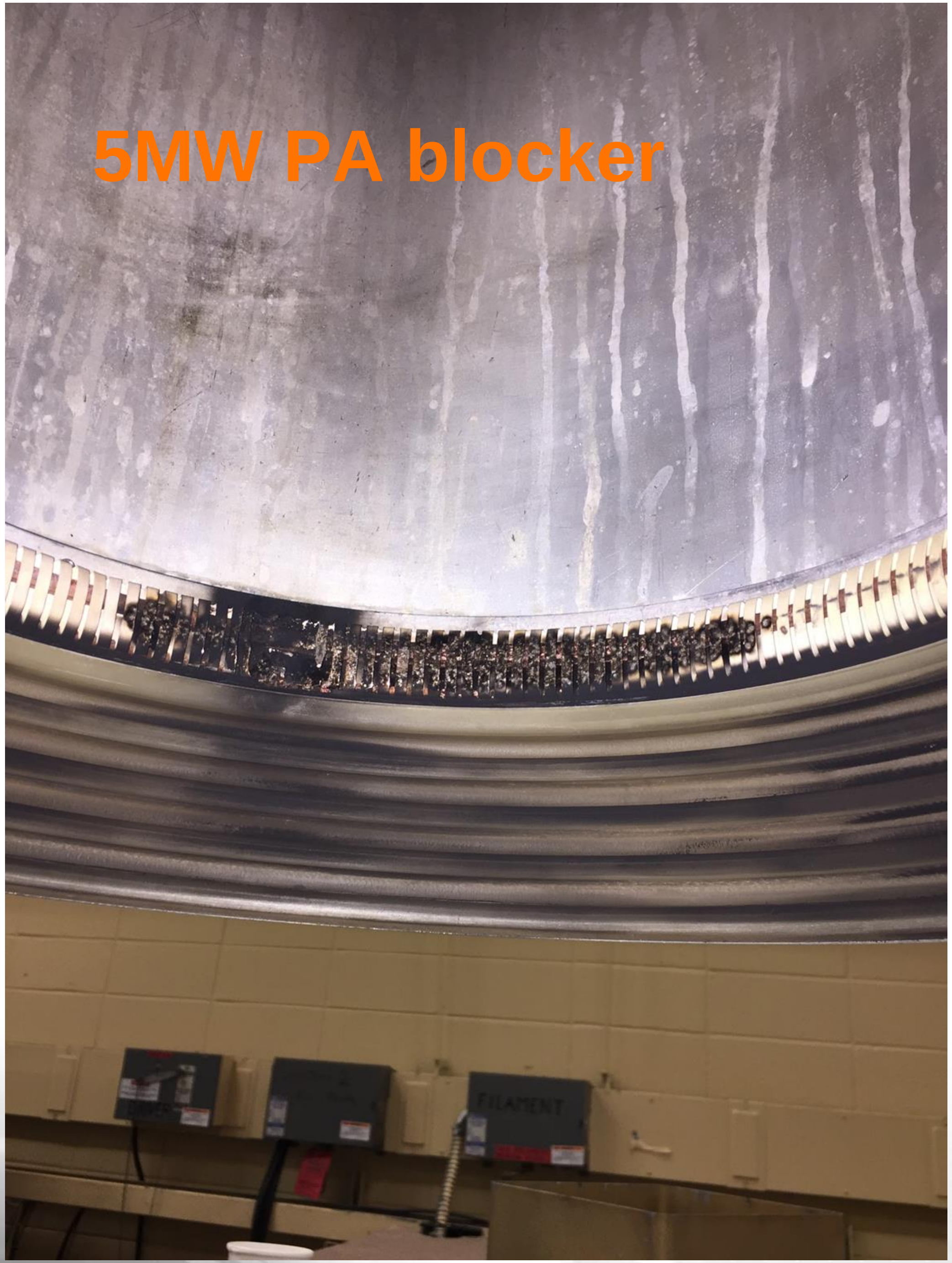
Failures!

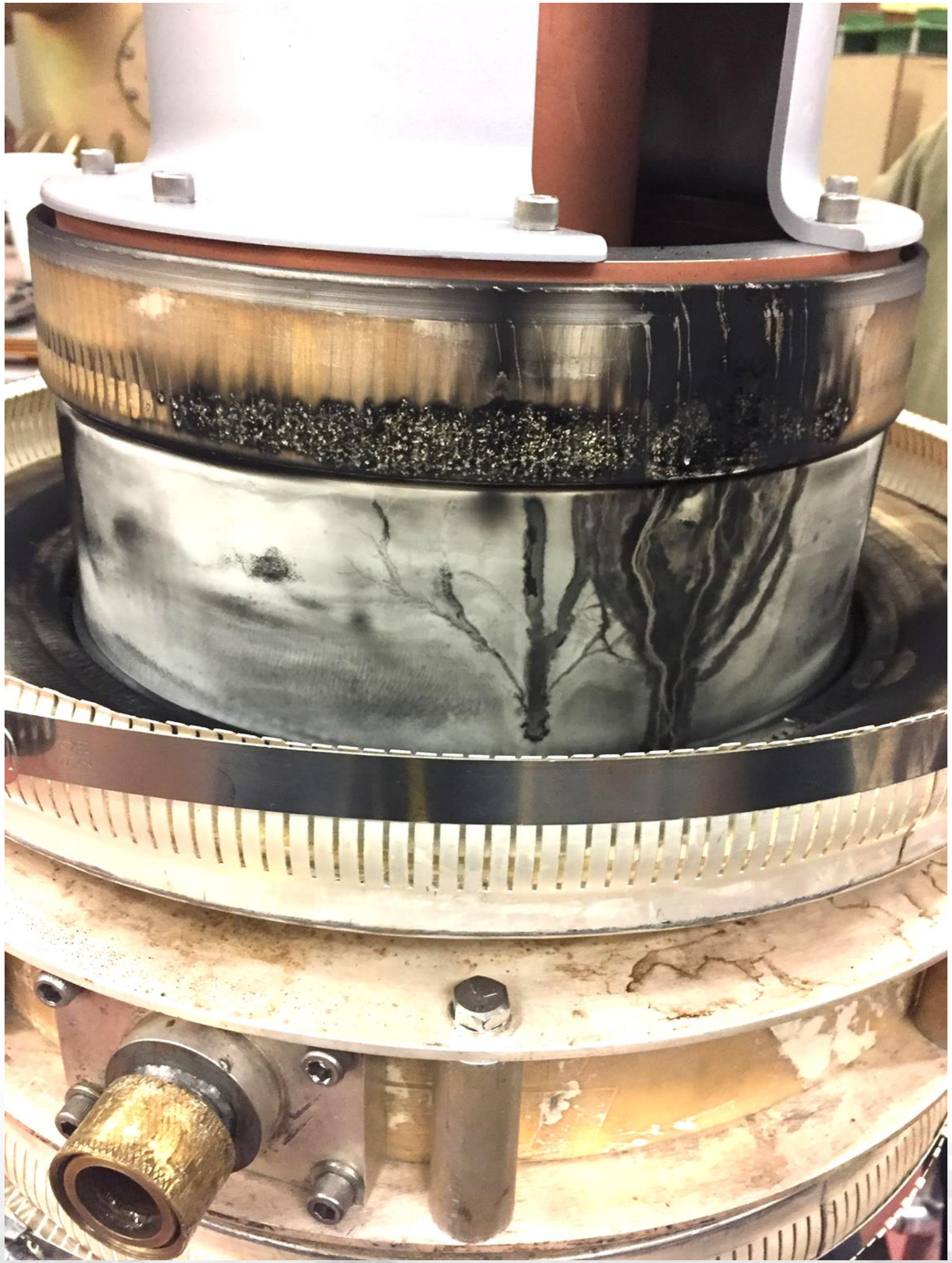
200 kW Driver

High Voltage Capacitor

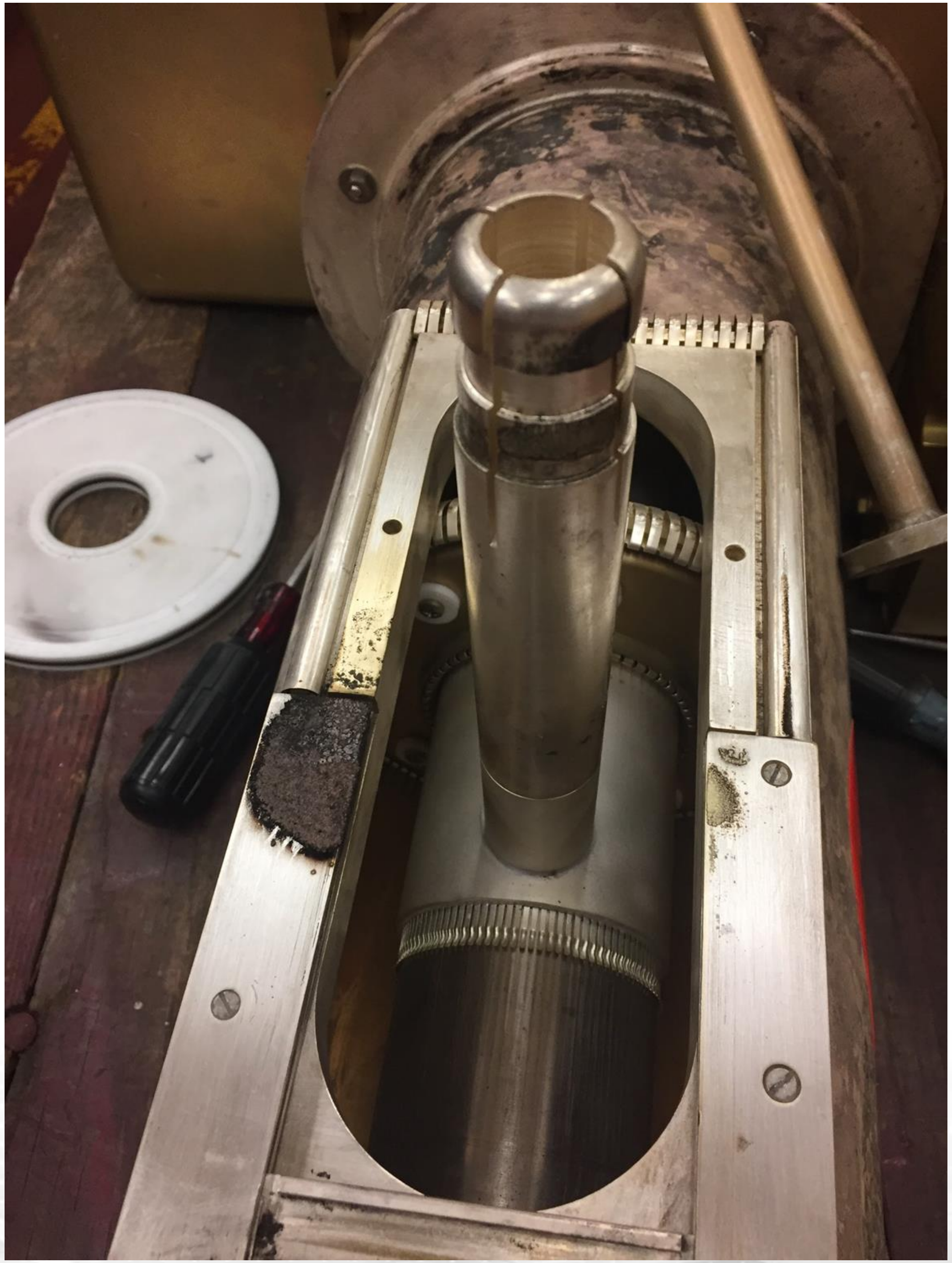


5MW PA blocker





7835 PA
Input Section

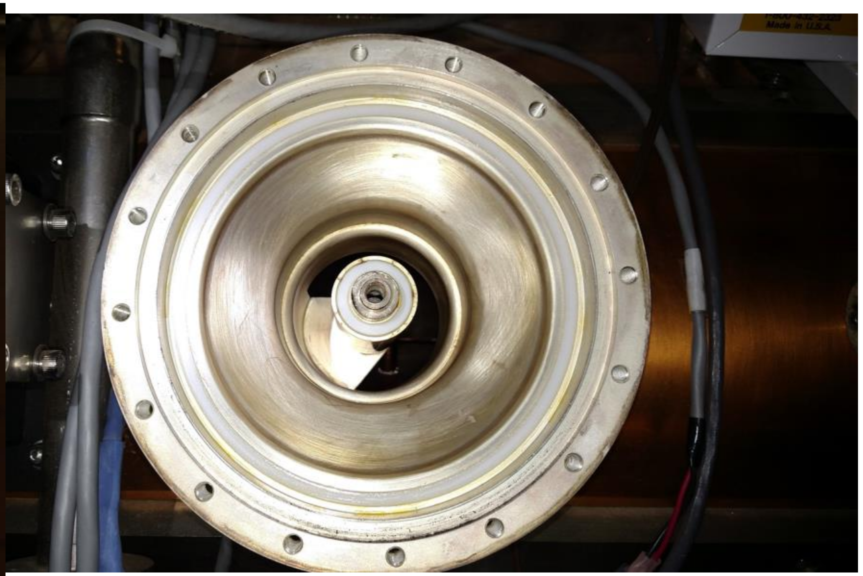



KIMTECH


12” to 3 ⅛” coax transition

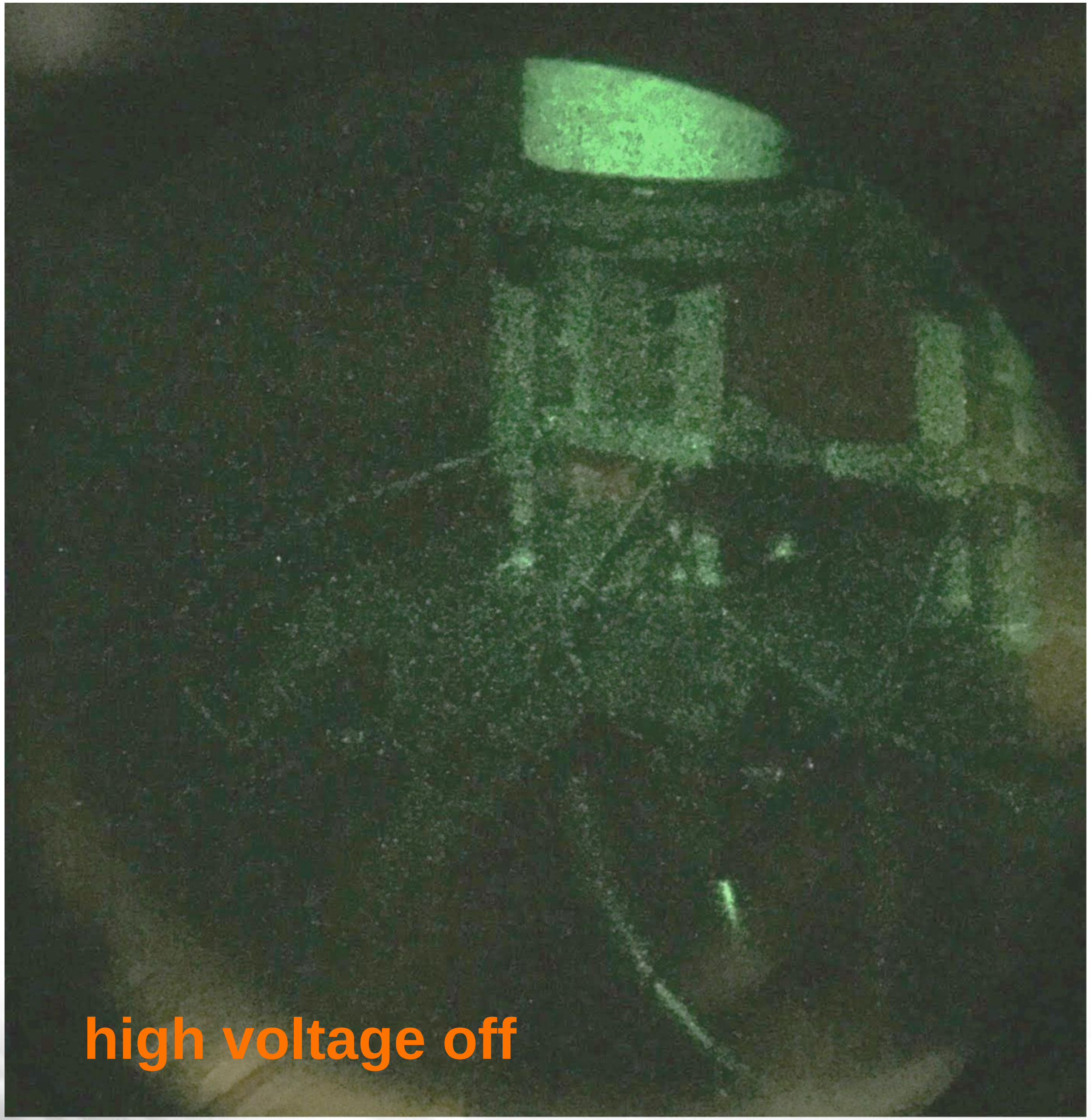
7835
potting

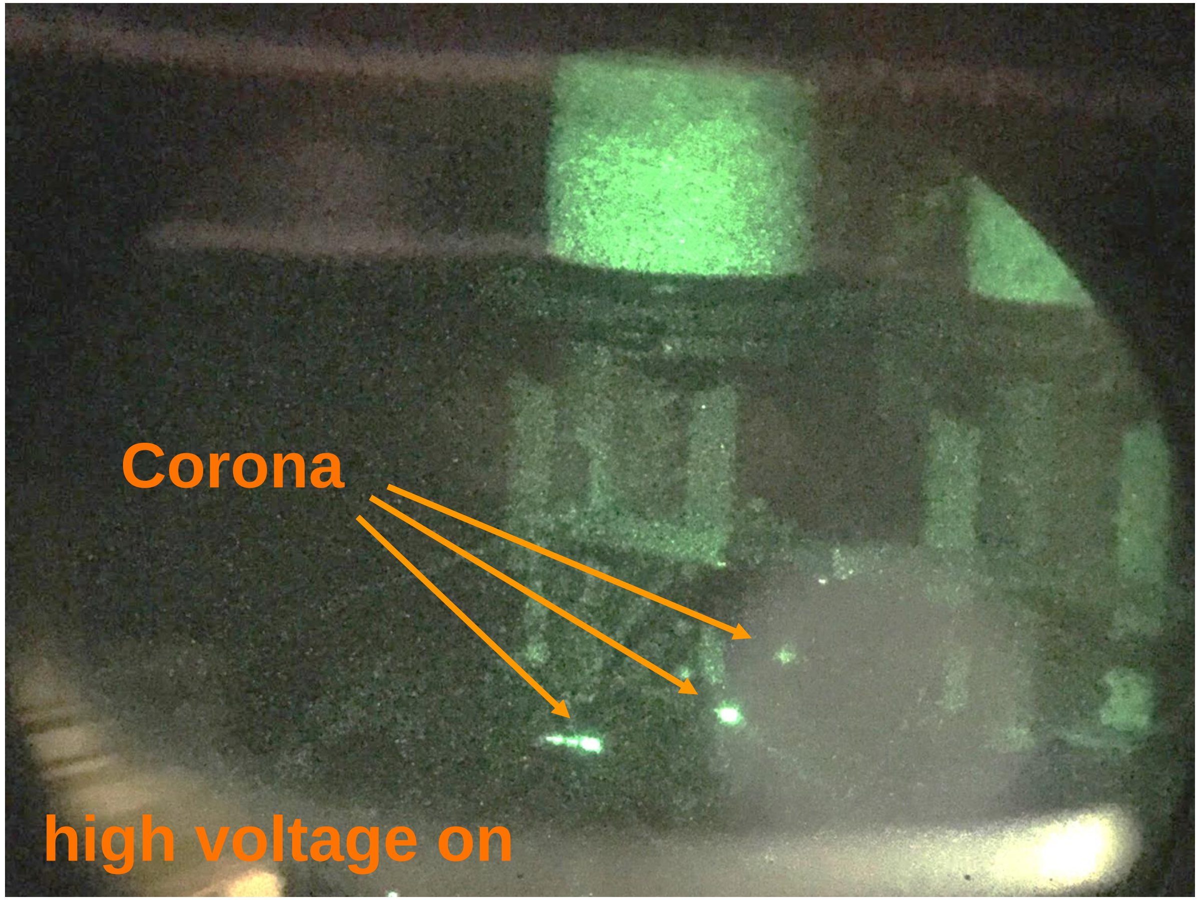
Cathode
Cable



RFQ Drive Window

8618 Modulator Deck





8618 Modulator

Thank You!