Coupler Multipactor Studies

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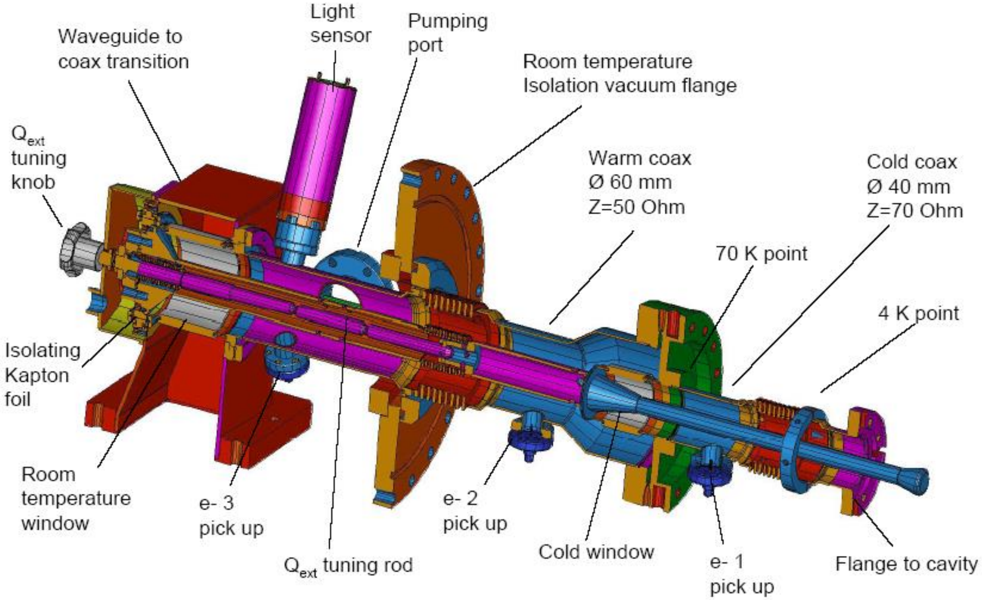
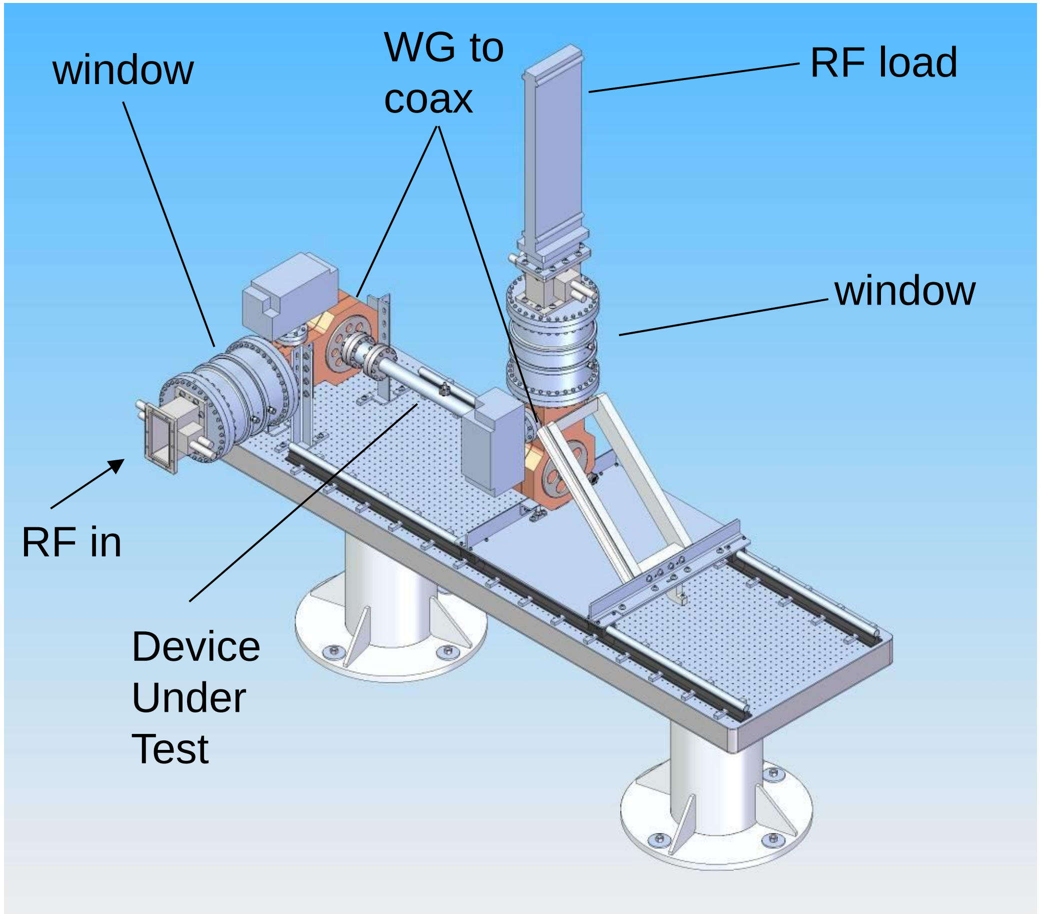
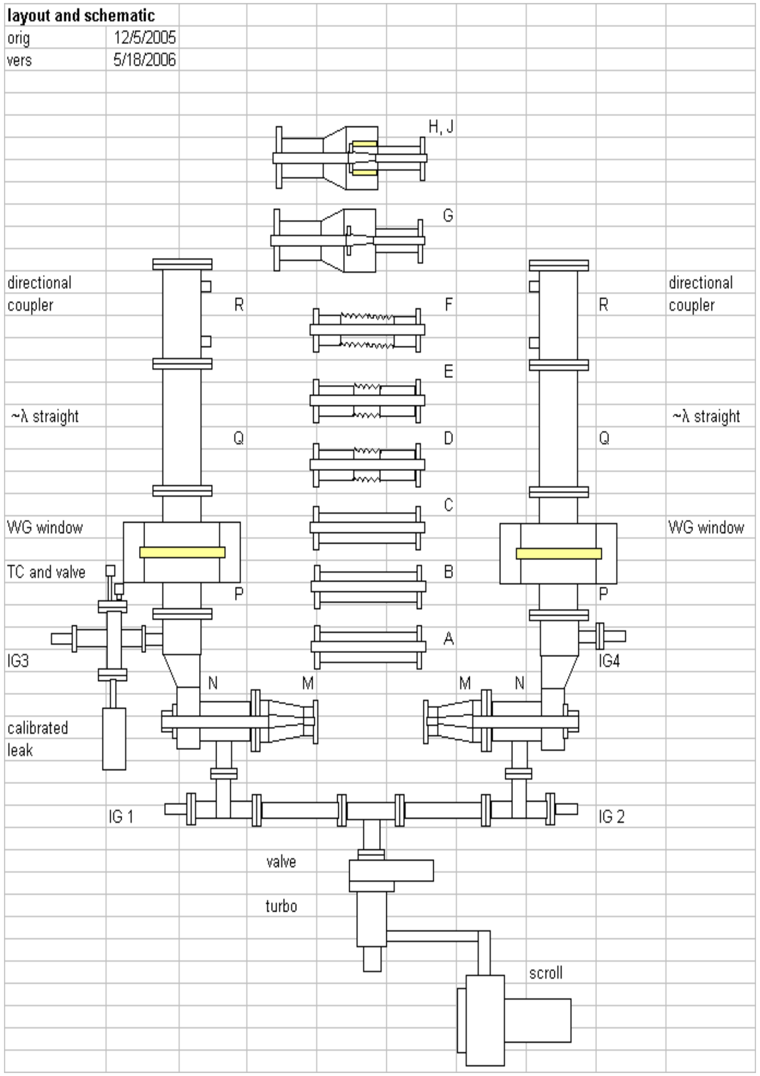
SLAC Coupler Test Stand - Evaluate Parts Individually

- An SRF coupler is a complex integration of many components
- When a coupler is conditioned, it necessarily responds in aggregate
- This makes it difficult to know which components dominate the behavior and limit performance
- As multipacting and RF conditioning are largely surface phenomena, modeling effectiveness is limited
- We developed a test stand to evaluate individual components of the TTF coupler design

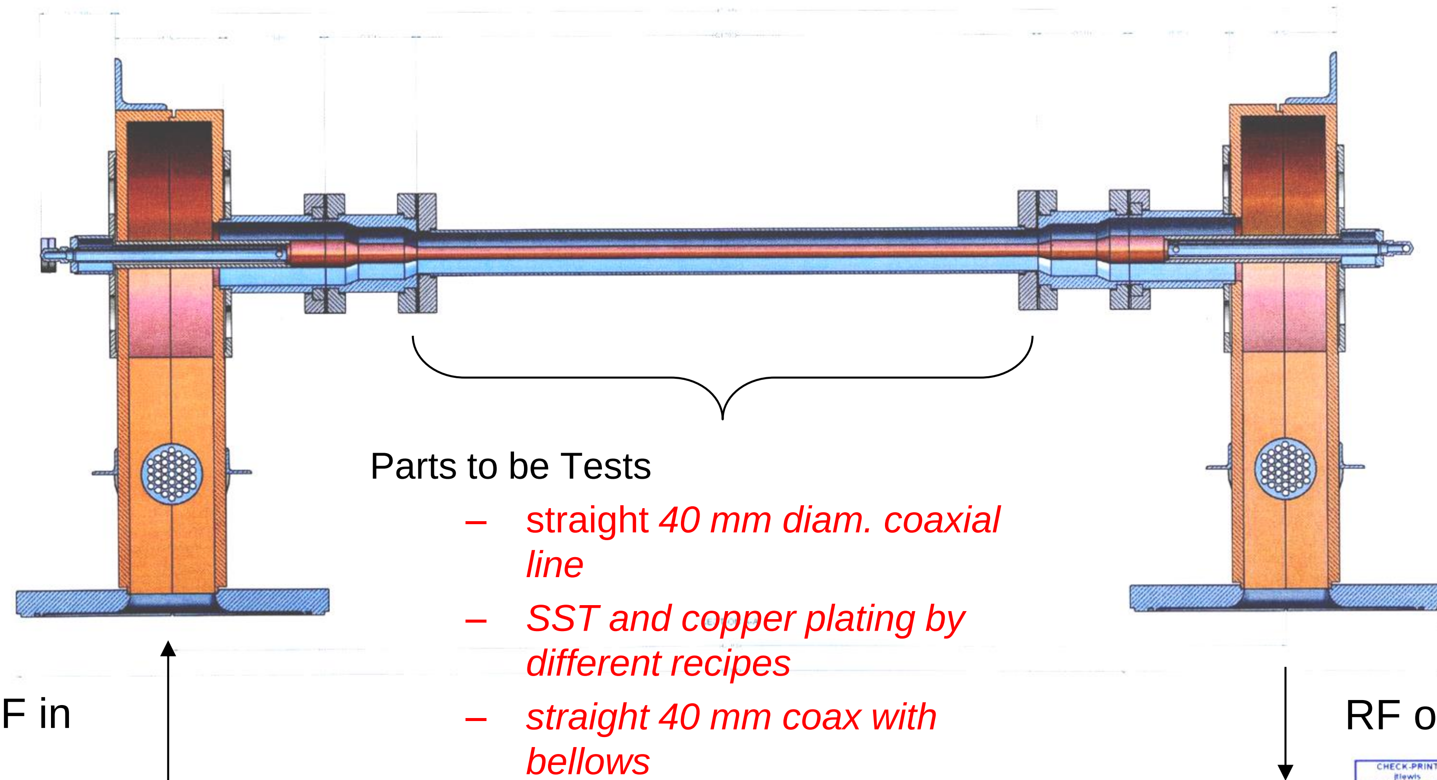


Schematic Layout of Test Stand with Parts to be Evaluated





More Detailed Cross Section of the Test Fixture



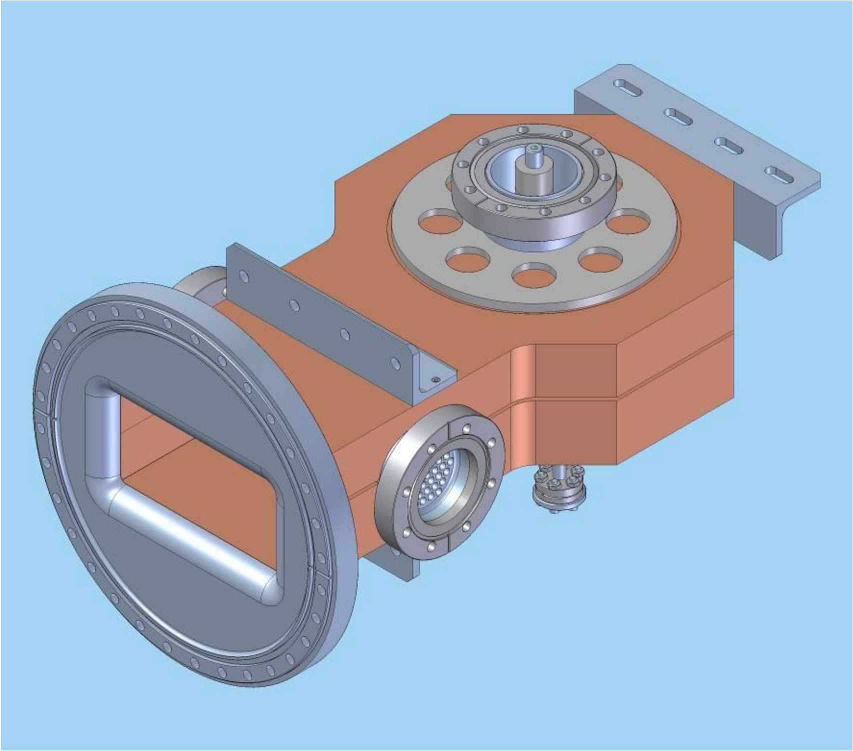
Parts to be Tests

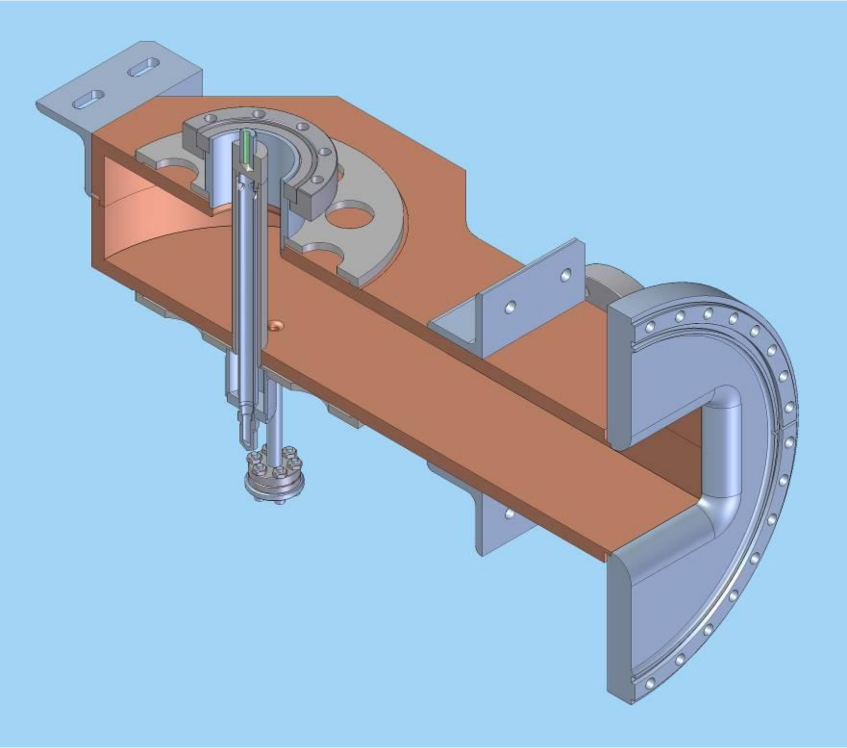
– straight *40 mm diam. coaxial line*
– *SST and copper plating by different recipes*
– *straight 40 mm coax with bellows*
– *cold window assembly with window*
– *cold window assembly without window*

RF in

RF out

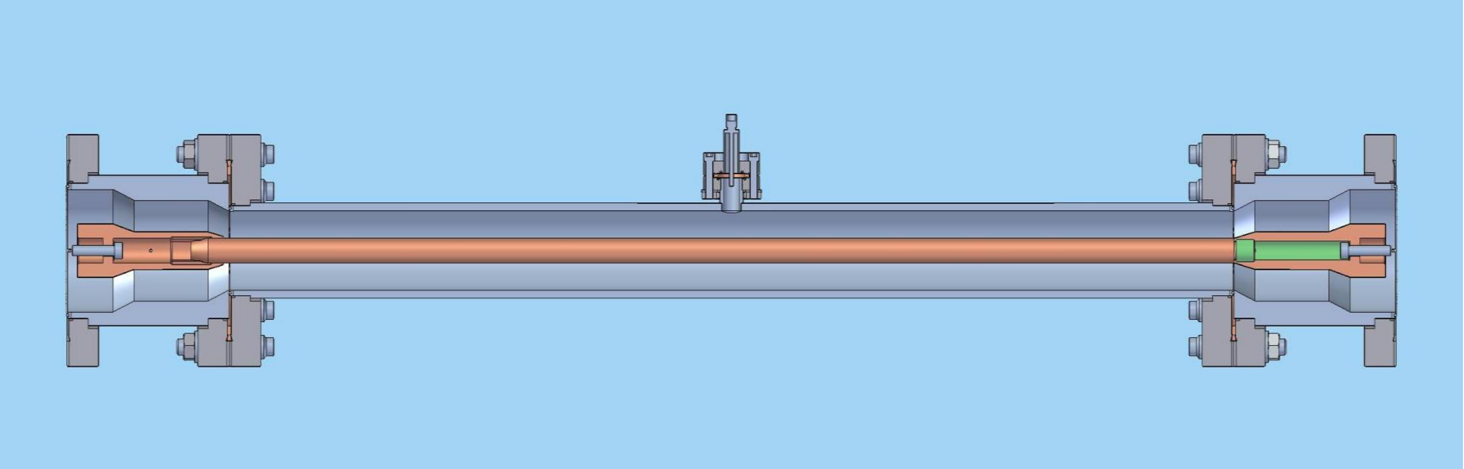
Specialized Vacuum WG-to-Coax Transitions

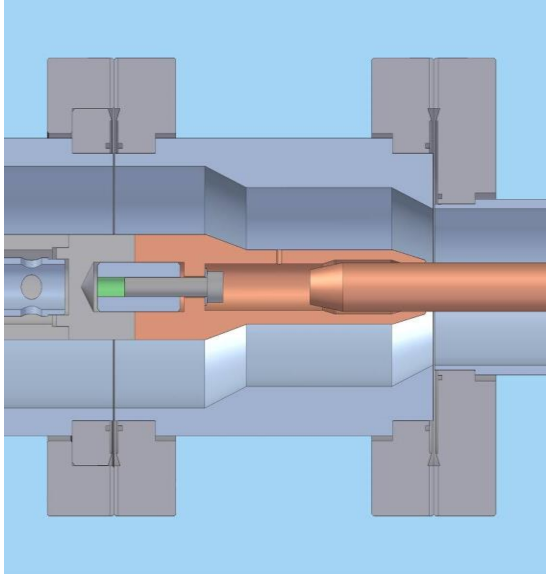




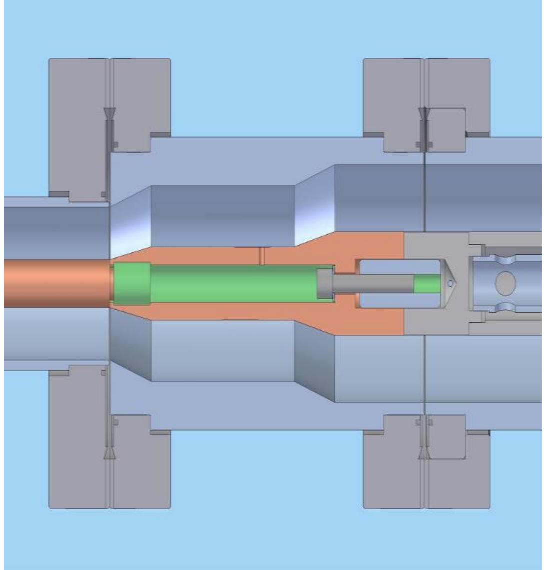
Designs accommodated existing high-power
vacuum windows at SLAC

Detachable Center Conductor

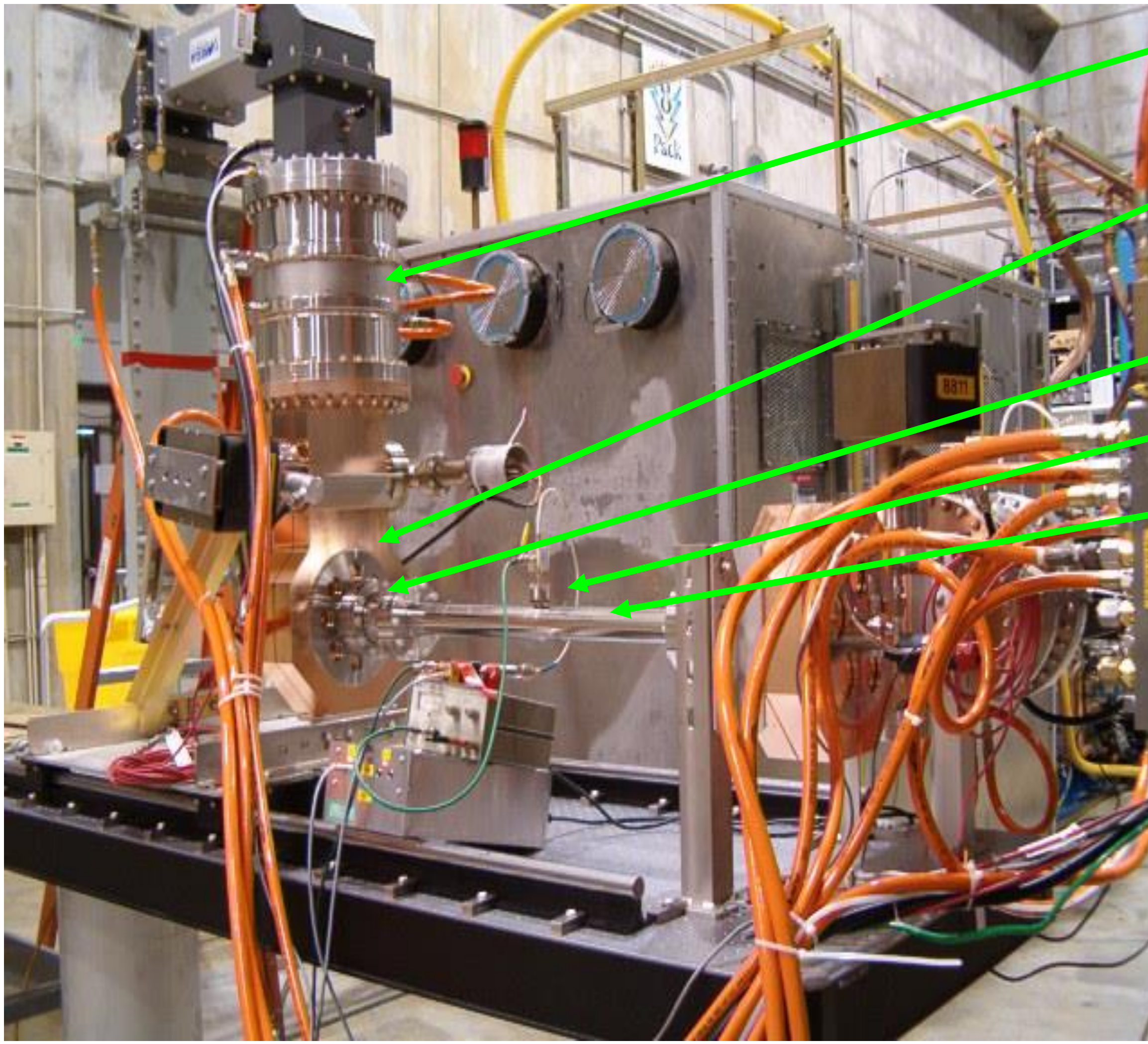




Significant effort went into ensuring the center conductor could easily disconnect upon opening the test stand, but still maintained solid electrical and thermal contacts with the anchors on each side. This was done by screw-attaching the center-conductor length on the right, and having the center slide into a 4-jaw BeCu receiver on the left.



Test Stand Set Up



WR650 vacuum window

custom waveguide-to-coaxial transitions

coaxial step transitions from 62 to 40 mm

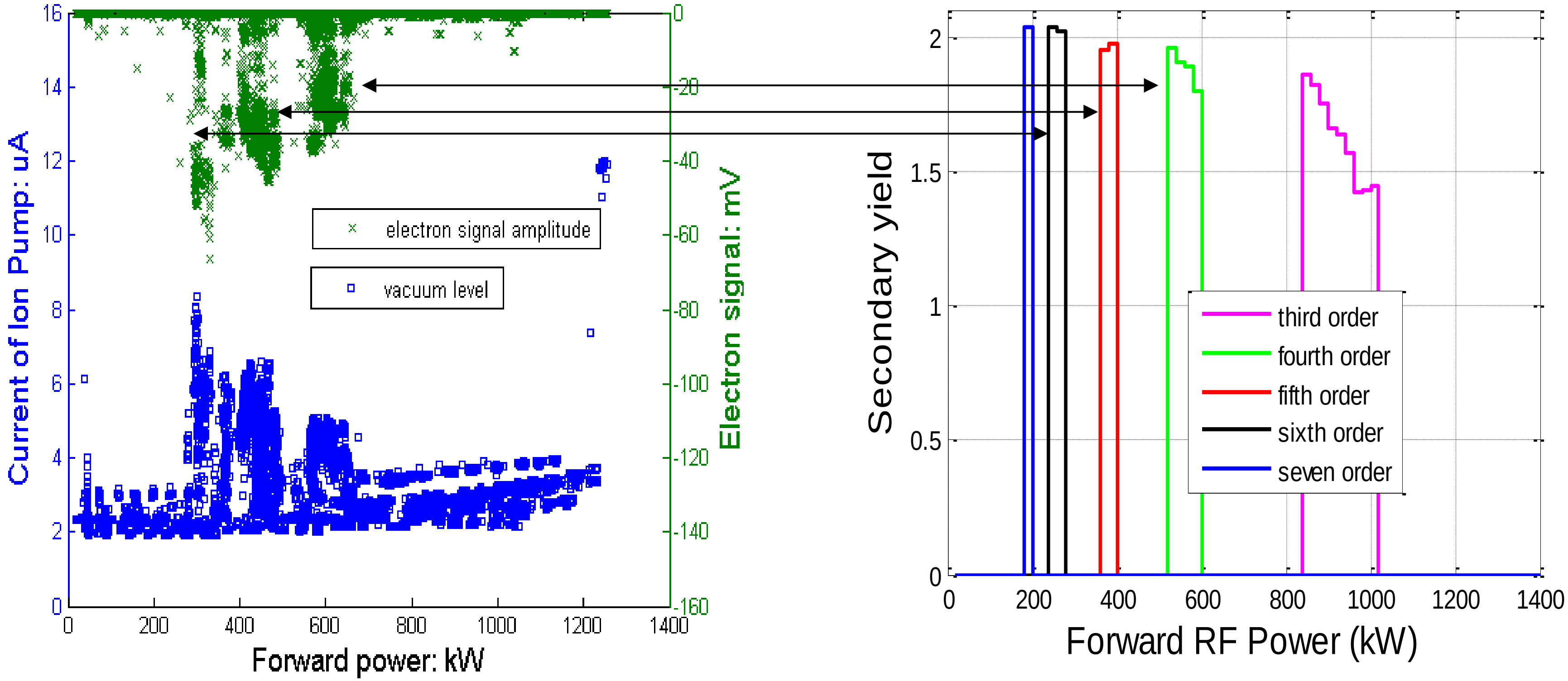
electron pickup probe

straight coax Device Under Test

The coupler component test stand at SLAC can test components up to 5 MW at 1.3 GHz at pulse lengths up to 1 msec.

Artist View of our Setup (Viewed Through Plastic Screen)

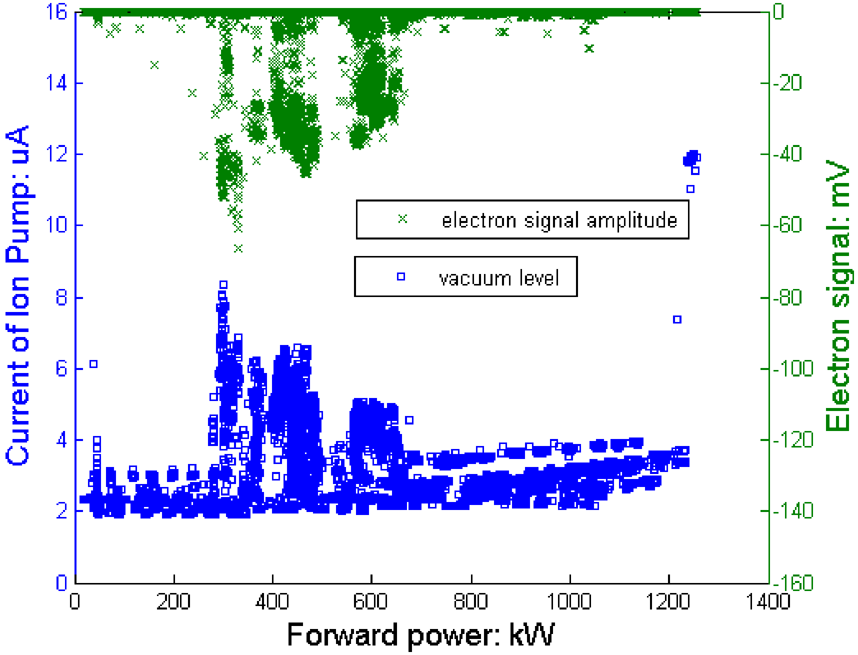
Plot Showing Vacuum Activity Consistent with Expected Multipacting Bands for a Straight Coax

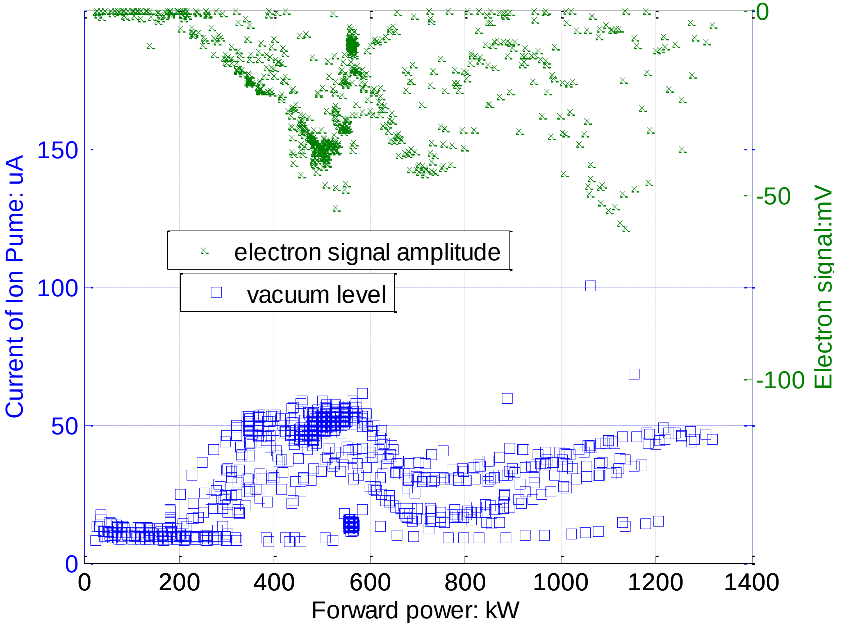


While observed bands generally agreed with simulations, there were difference in the power level and width. The variations are being further investigated, but are suspected to be related to either onset delays in MP emission relative to the RF wave or space charge effects, neither of which are present in the simulations.

600mm long straight SS coax section test results

600mm long straight Copper plated SS coax section test results





Strong MP around 300kW!

Magic Simulations

24 cm coax line, OD 40mm, ID 12.5mm, 1.3 GHz RF, TW

Secondary electron energy:

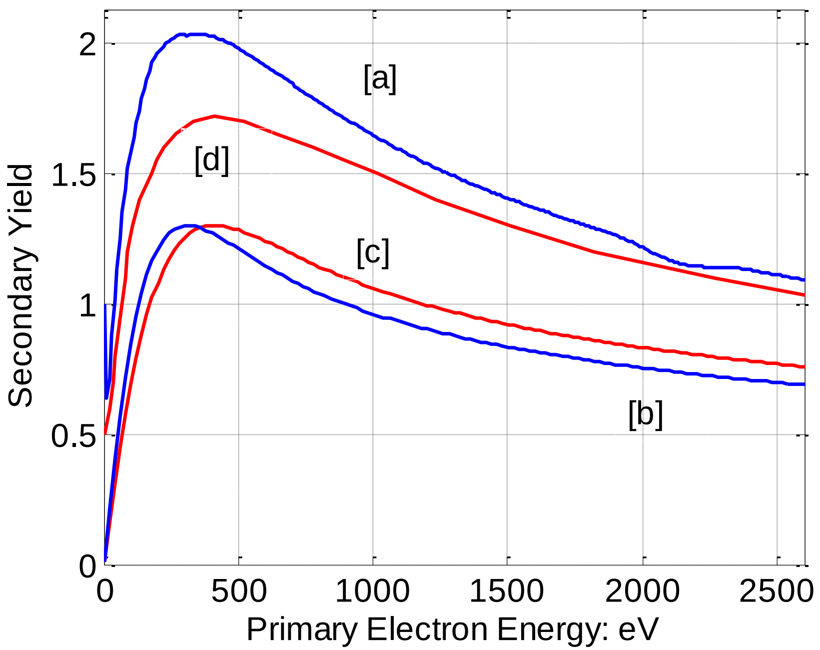
$$f(U_s) \sim \frac{U_s}{(U_s + \Phi)^4}$$

Φ is the work function of material (4.31 for Fe and 4.98 for Cu)

The peak of secondary electron is at $\Phi / 3$

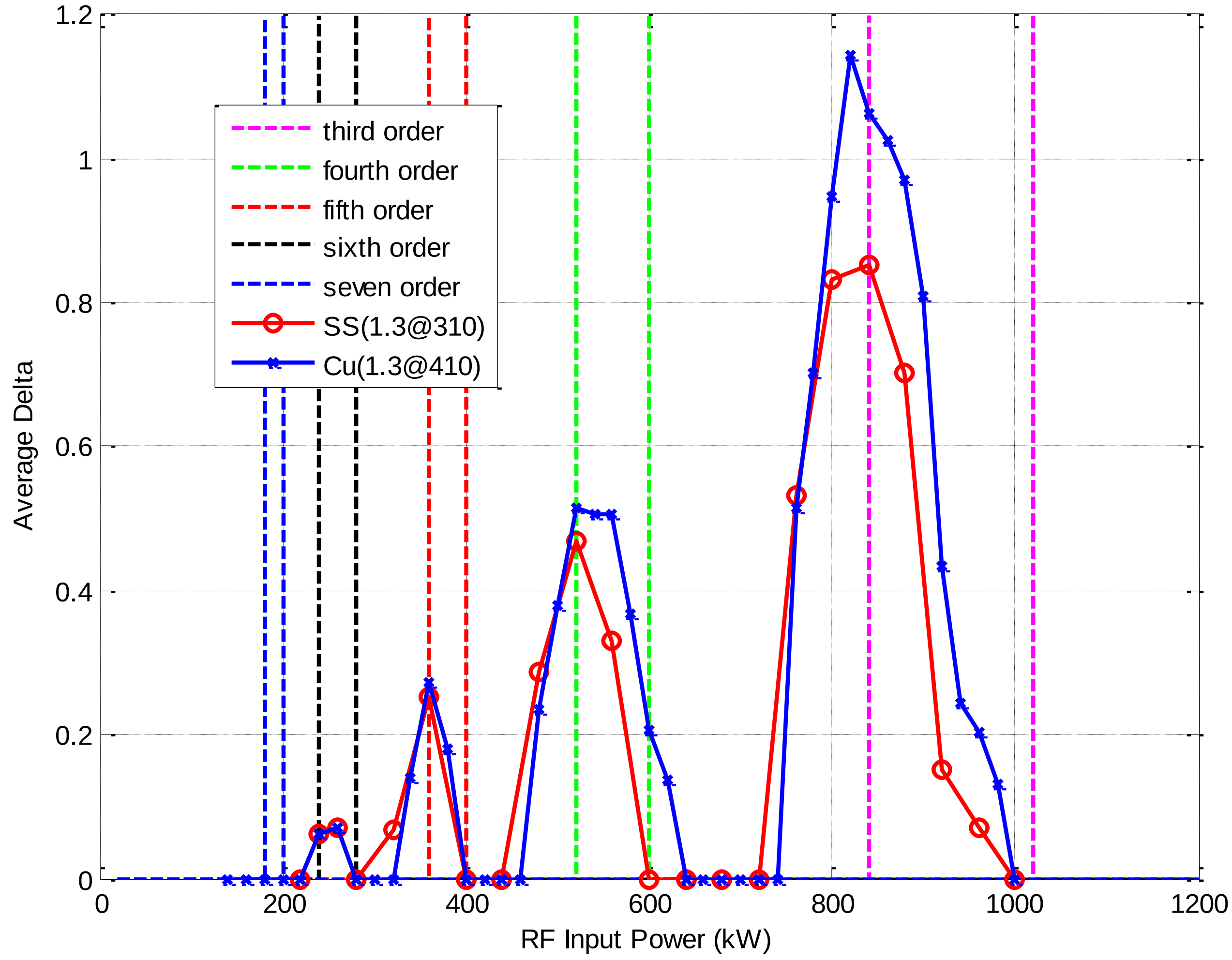
Simulation results depends on the Secondary electron distribution

Red for Copper and blue for SS

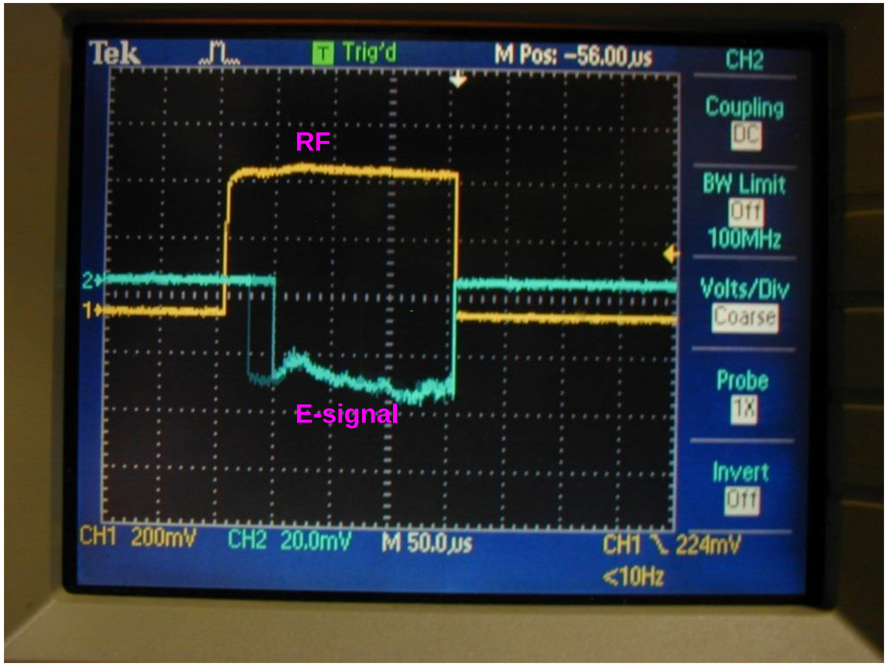


[a,d] SEY based on the measurements
[b c] scaled to better match data

MAGIC Multipacting Simulation and 'Resonant Finder' Results for a 40 mm Coax Line



Behavior of the Electron Pickup Signal

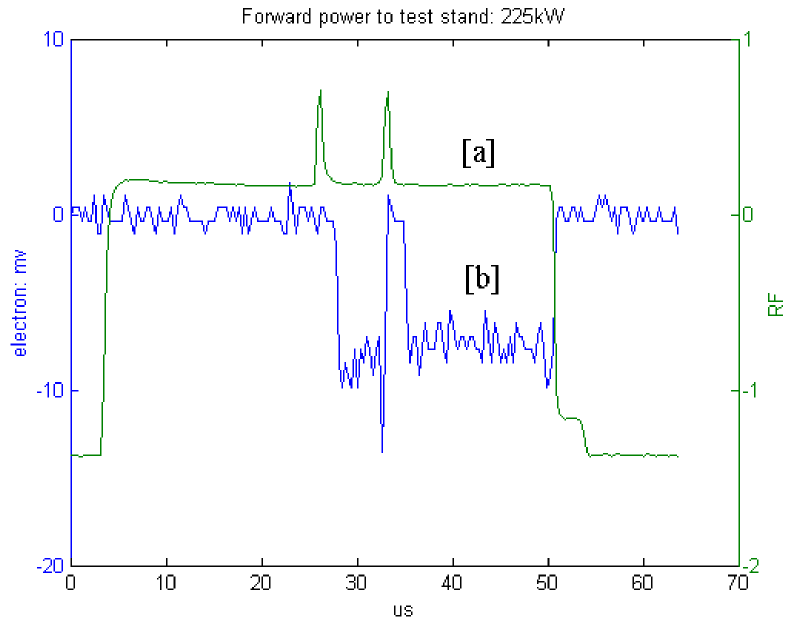


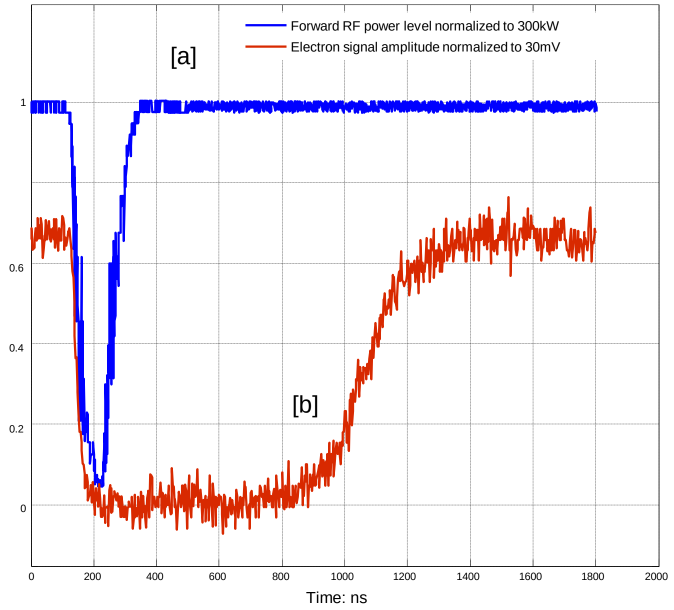
The electron signal turn-on time is unstable after initial processing, likely due to insufficient electrons available to seed the onset of multipacting.[1]

[1] D. Raboso, A. Woode, "A new method of electron seeding used for accurate testing of multipactor transients", Vol.1, Oct. 1995.

Multipactor Seeding and Time Response

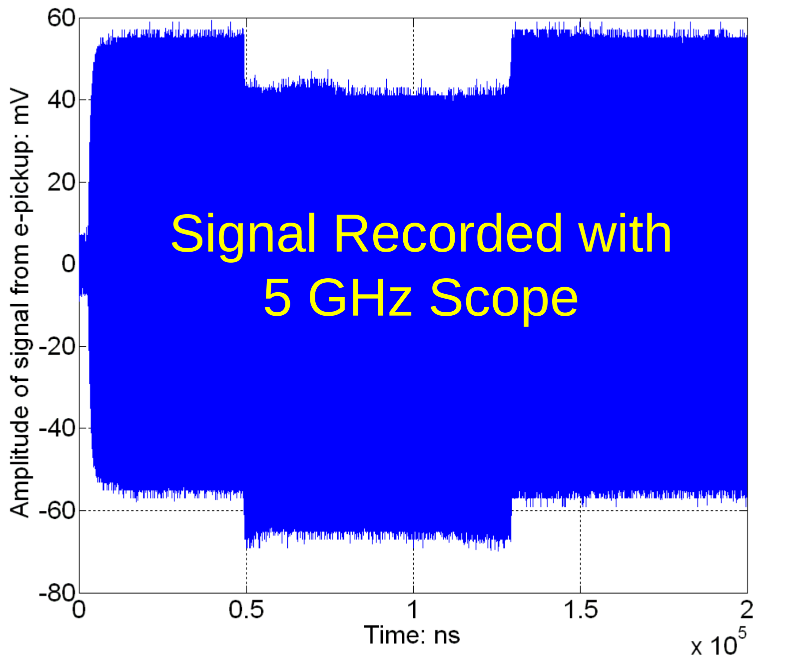
[a] 200ns RF pulse Spike
[b] Multipacting electron signal.

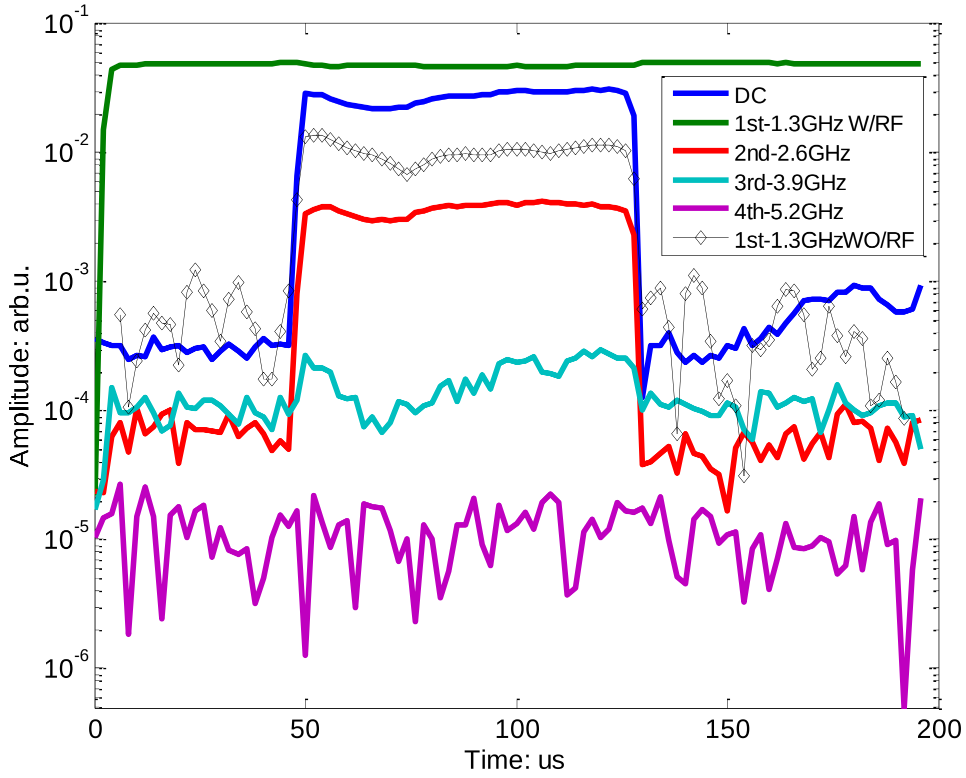


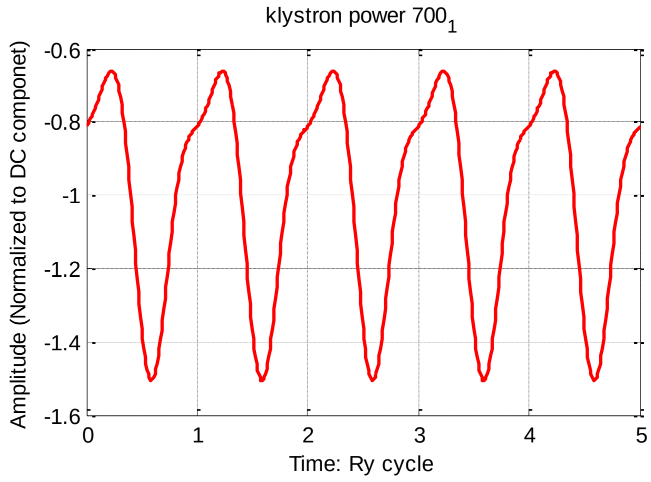


[a] The RF pulse with a 1us high power (3MW) spike;
[b] The multipacting electron signal.

Harmonics of the Electron Probe Signal







Reconstructed electron signal

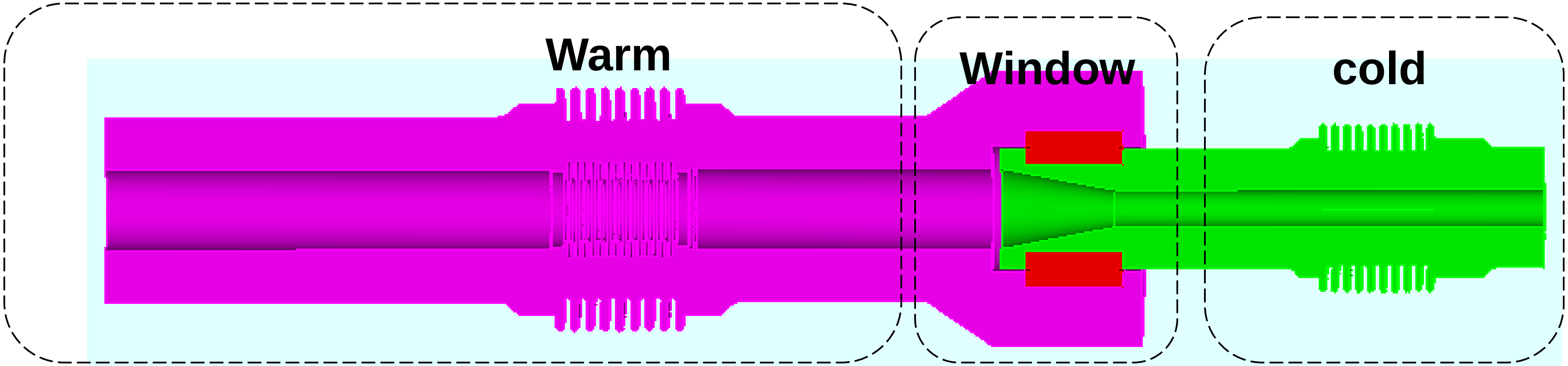
TTF3 Coupler Multipacting Simulation Using Parallel Code Track3P

Lixin Ge

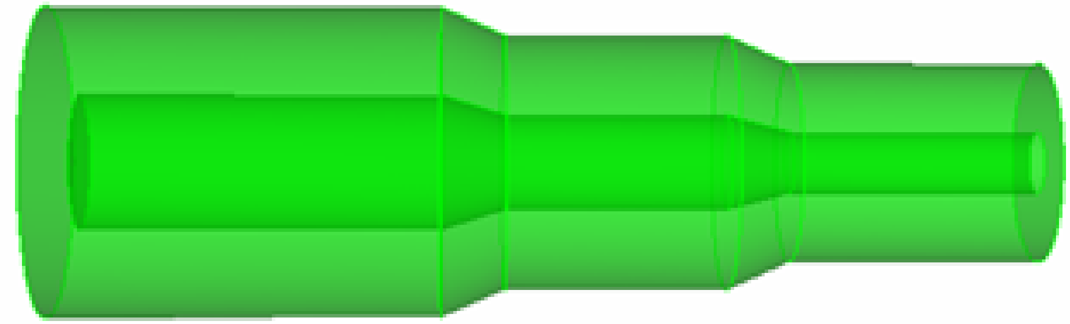
Advanced Computations Department

SLAC

TTF3 Multipacting Simulation Components

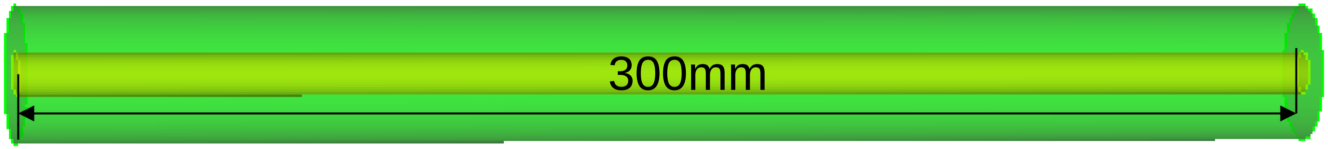


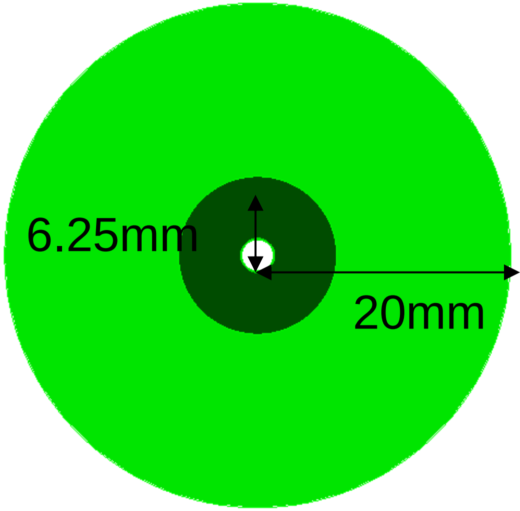
Taper Region



Input Power: 0-2MW, Scan interval: 50KW.

Cold Coax





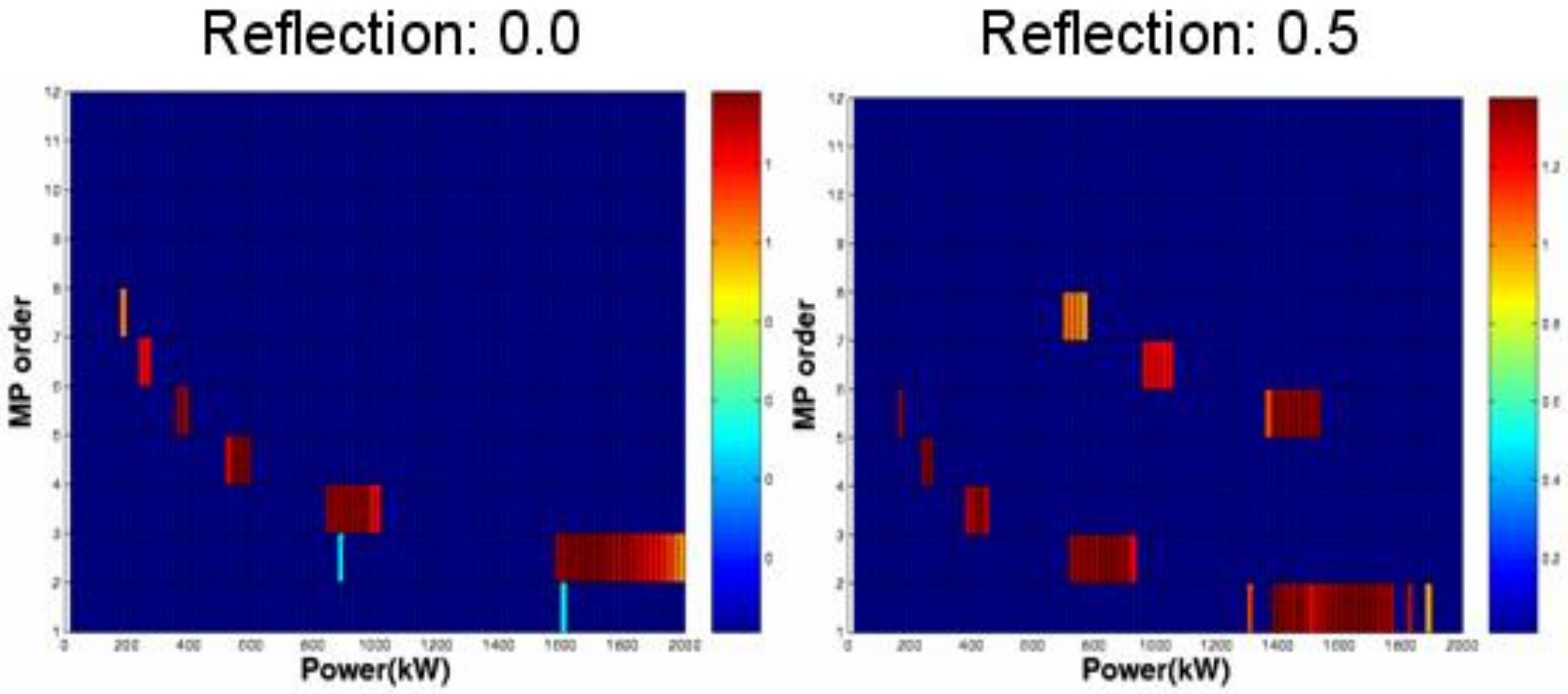
Simulation Cases:

1. with/without reflection
2. with/without external magnetic field
3. with variable center conductor DC biases

Conclusions:

Our multipacting simulation results are in excellent agreement with theoretical calculations and experiment measurements at SLAC.

40 mm Diameter Coax Simulations



Delta as a function of RF input power and Multipacting order

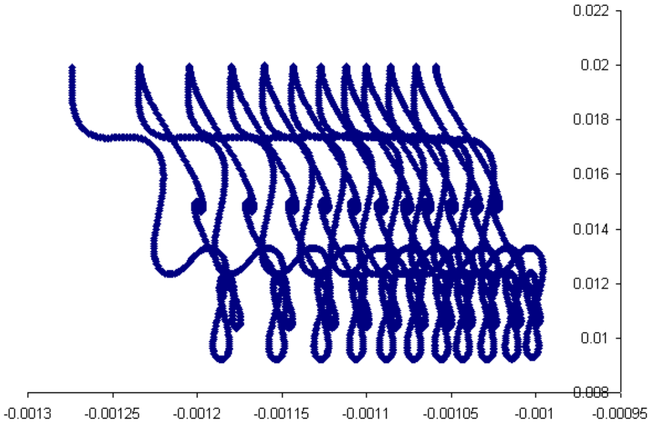
Samples of particle’s resonant trajectory

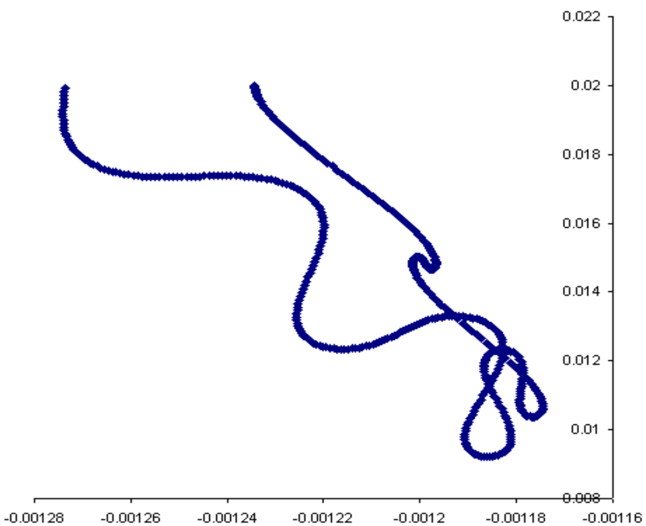
Reflection: 0.4

Input power level: 160KW

Order: 5th order

Impact Energy region: 542-544 eV



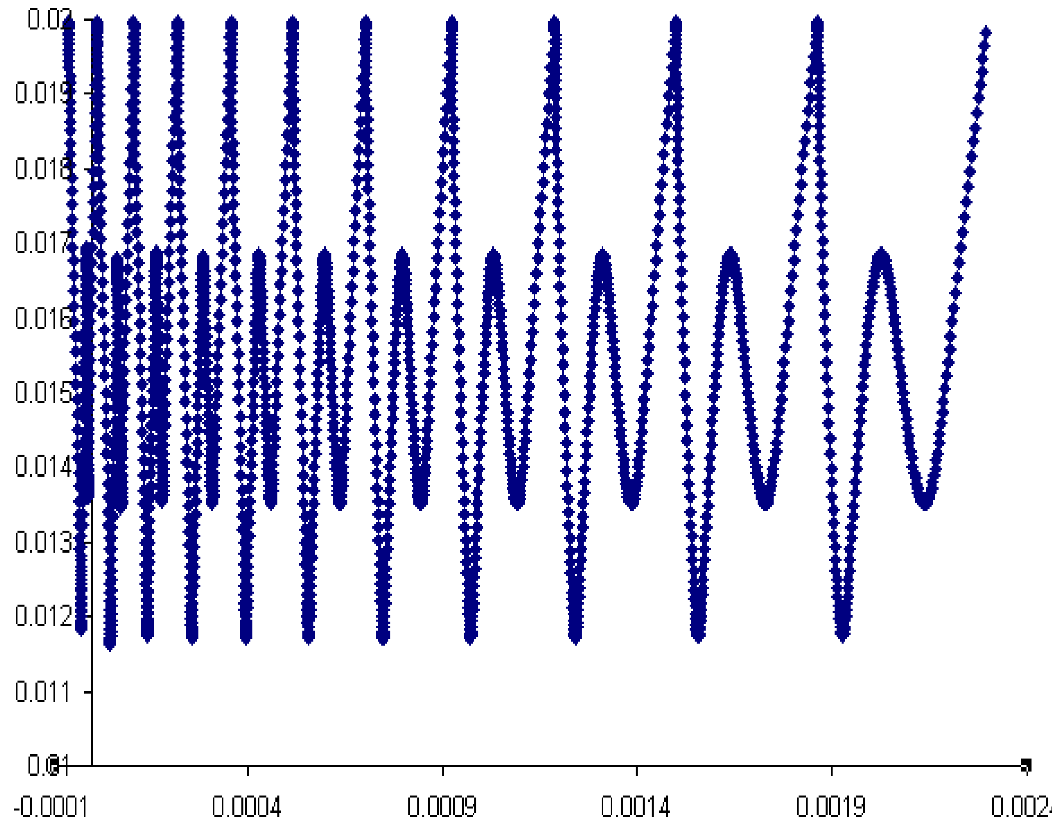


Reflection: 0.8

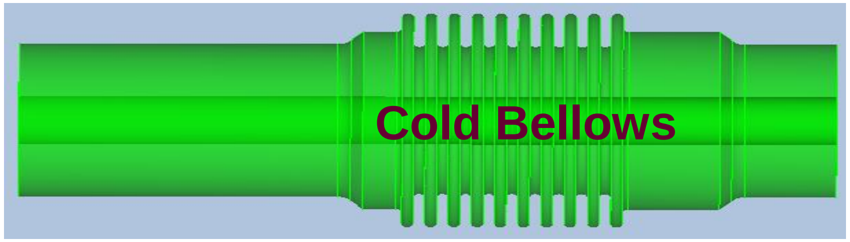
Input power level: 580KW

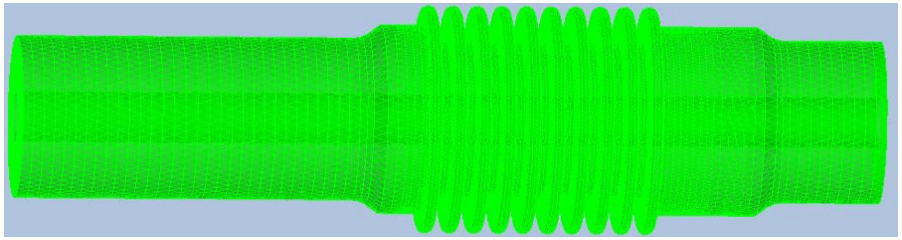
Order: 2nd order

Impact Energy region: 1100-1200 eV



Cold Coax with Bellows



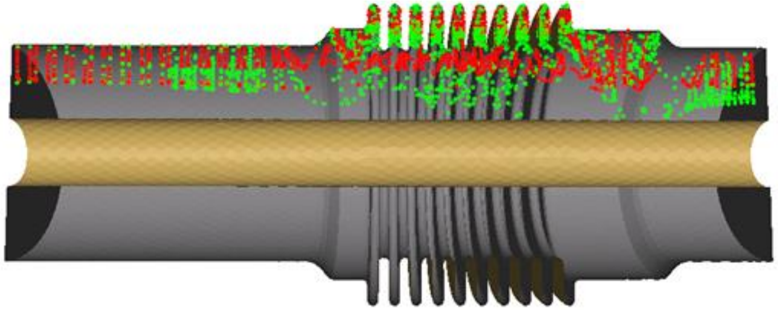


Model

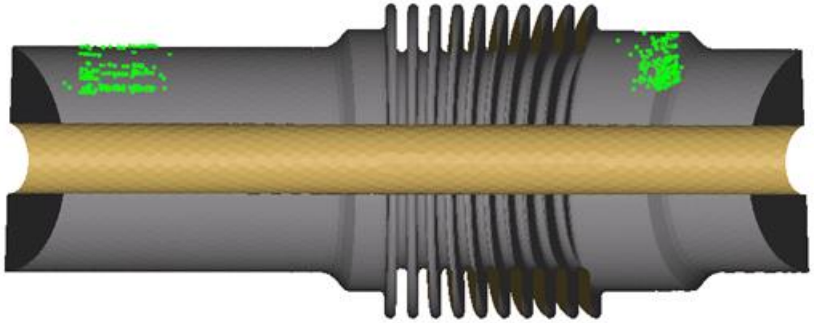
Mesh

NO multipacting activities in the bellows region

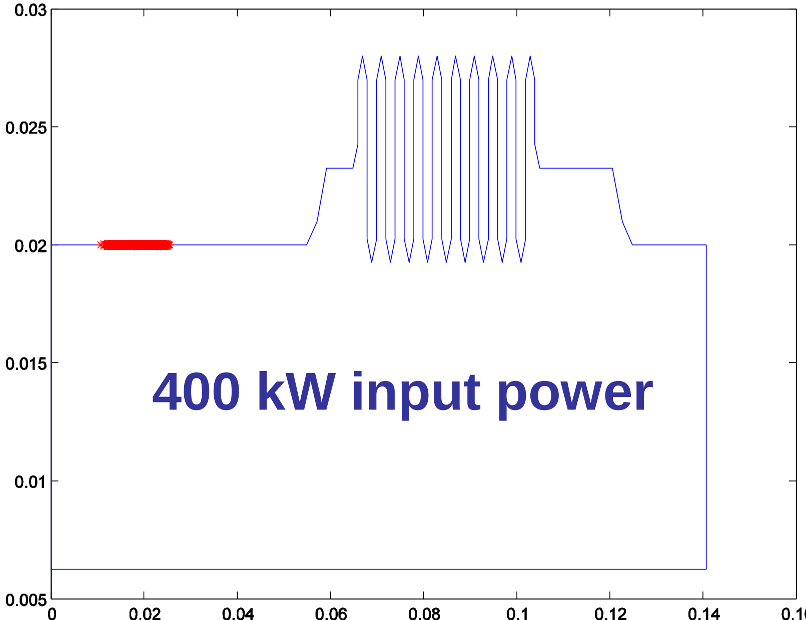
Particles Distribution at 2nd Period



Particles Distribution at 100th Period

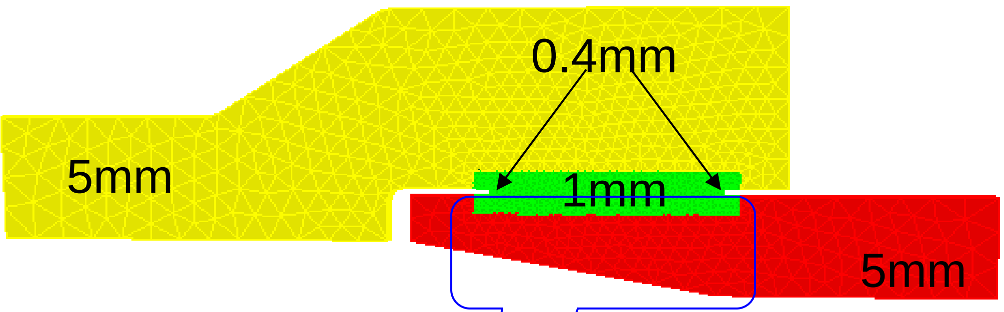


Particles Distribution after 20 impacts



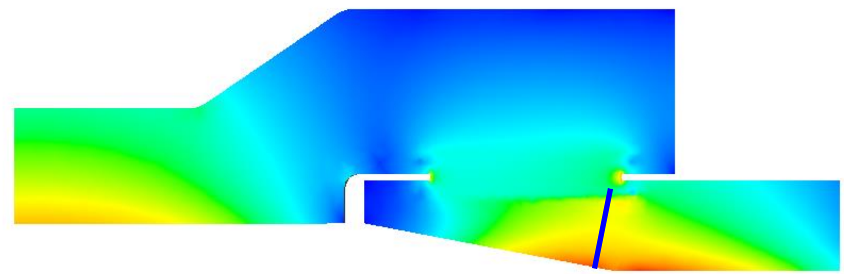
Ceramic Window Region

Model and mesh

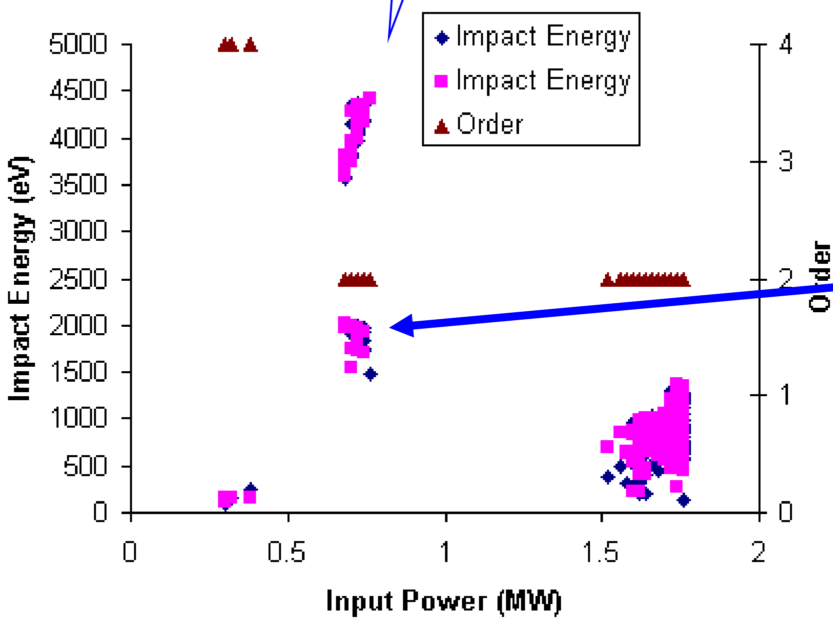


Mesh: mesh.ncdf

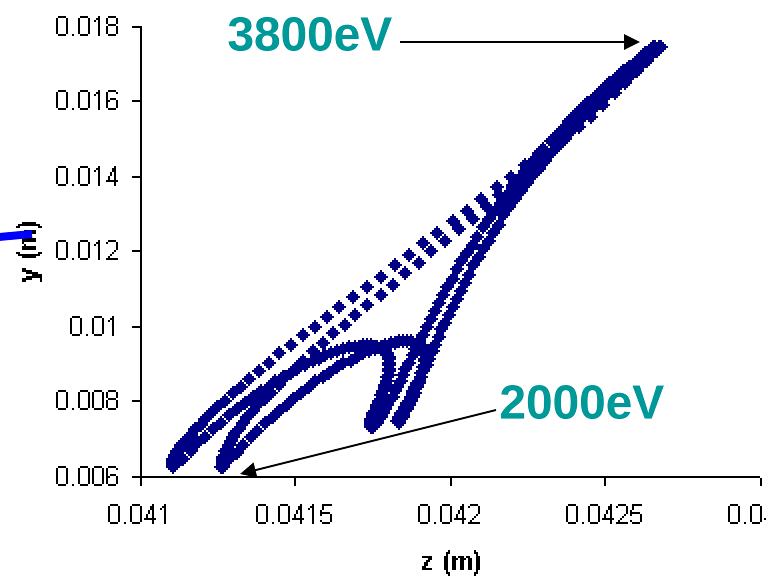
Field



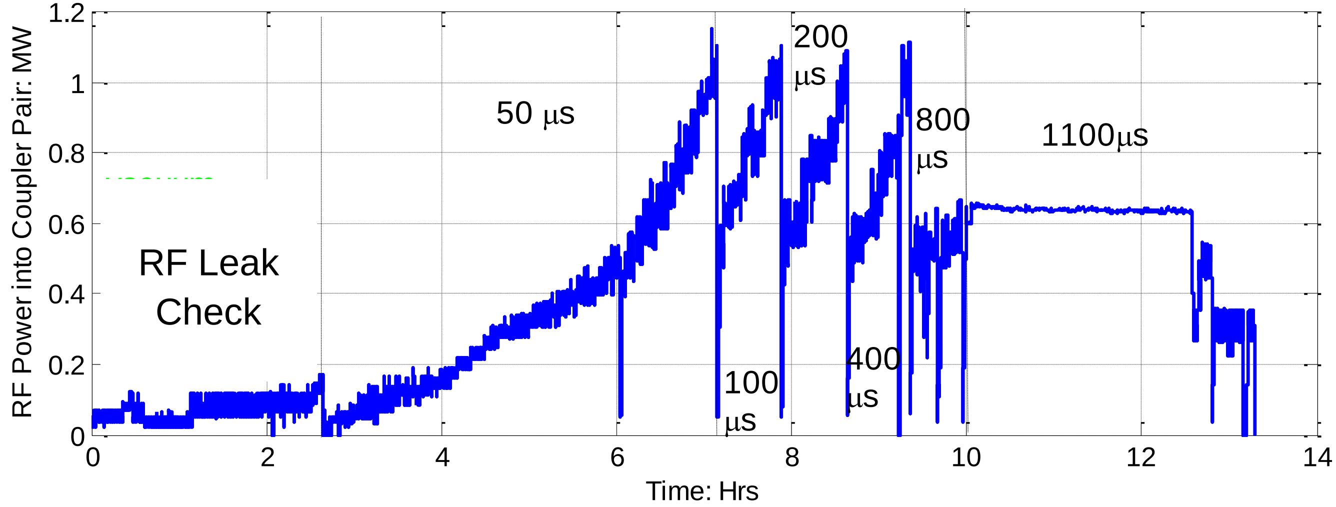
Distribution of two points resonant particles' impact energies, orders versus Input Power between the ceramic window and cold cavity

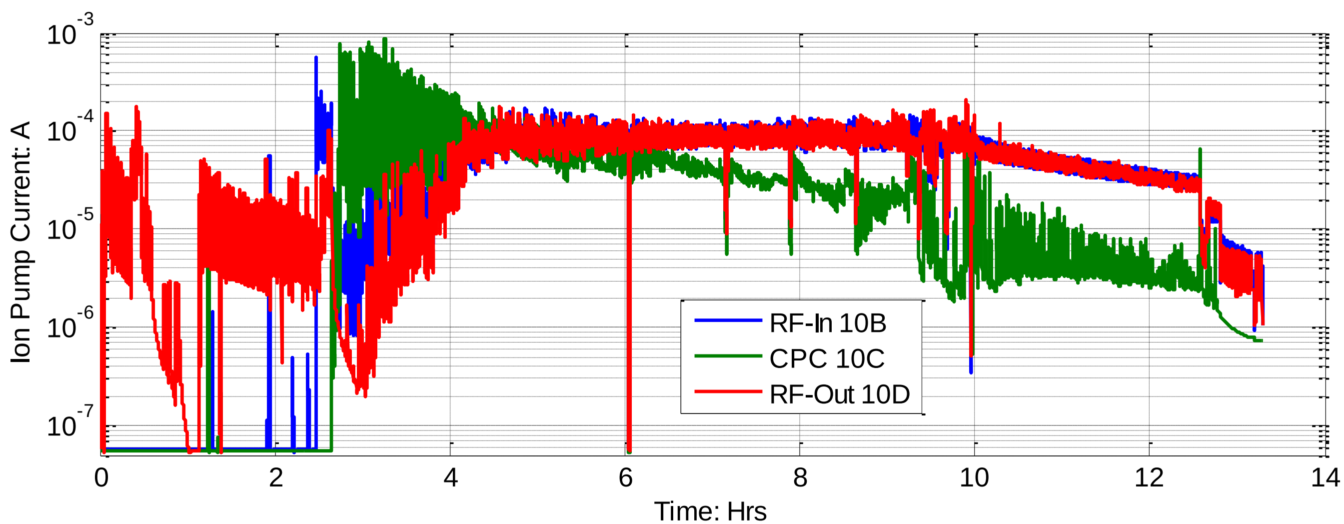


One resonant particle's trajectory at 0.68 MW input power

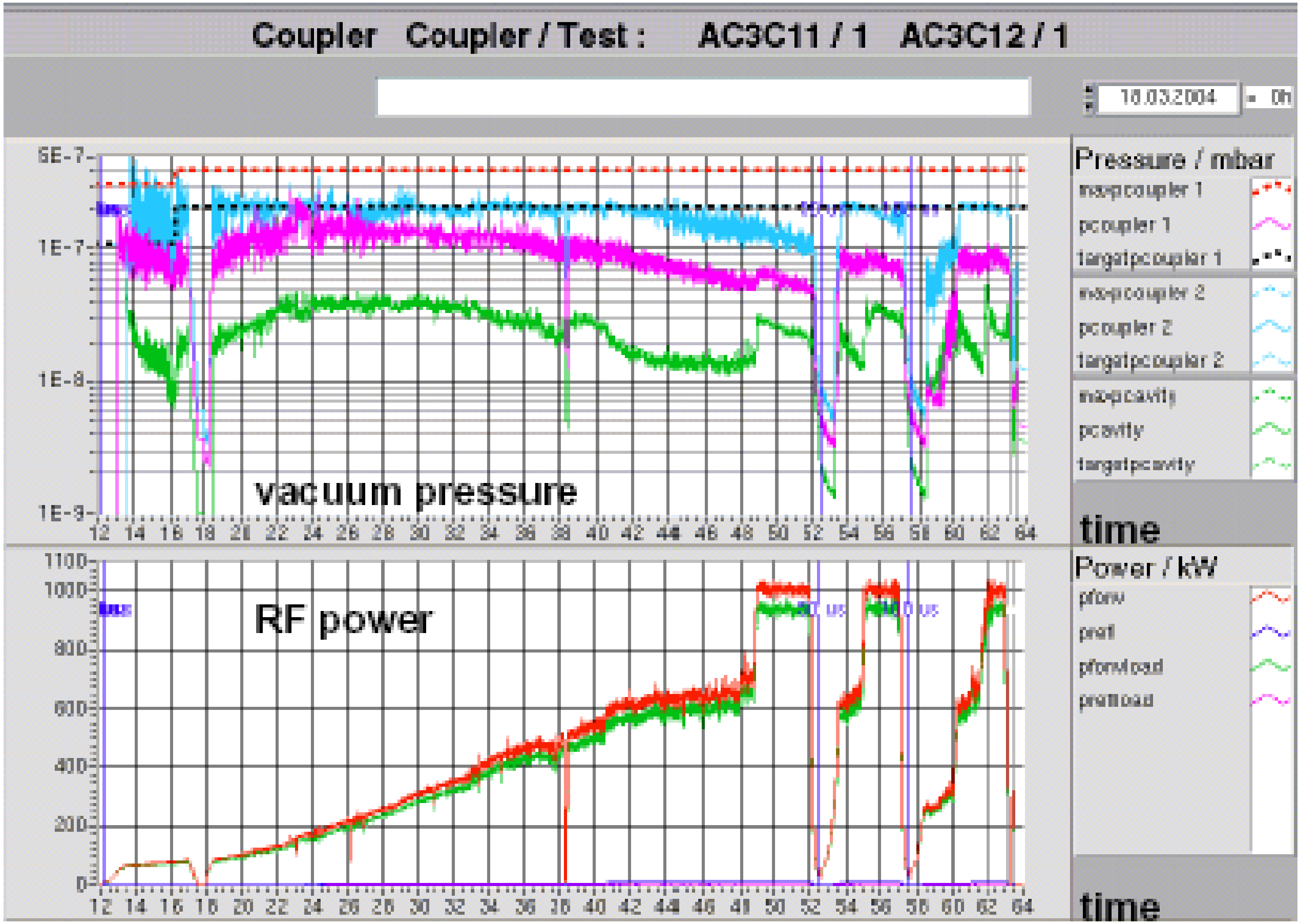


Example of RF Processing History – See Smooth Ramp-Up in Power (Slight Dwell at 300 kW)





Similar Results at DESY/Orsay



- D. Kostin, XFEL ElFast XFEL mtg 2006

Overall Summary

- Predicted MP is not always observed due to smearing effects, especially for high order resonances
- Due to absorbed gases on WG surfaces, SEY initally high, producing noticeable MP – however it diminishes as gas is removed from electron/rf interactions
- TTF3 coupler shows no noticeable MP ‘barriers’ during processing.