



EM and Multipacting modeling for Crab Cavity development

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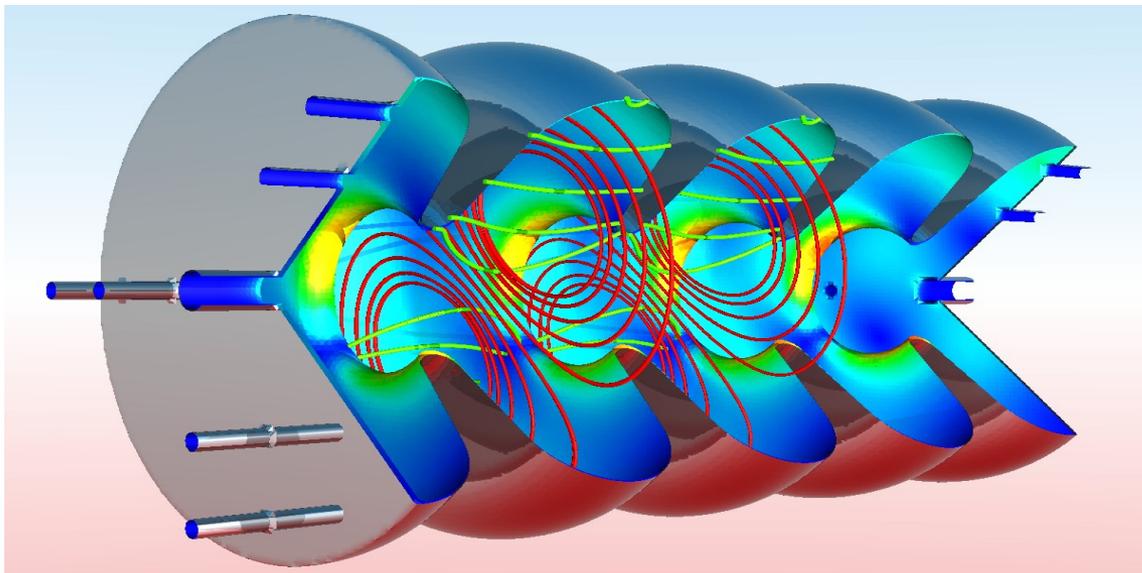


Work supported by DOE SBIR grant DE-FG02-05ER84172
And DOE SciDAC grant DE-FC02-07ER41499



VORPAL is a powerful simulation tool for studying cavity multipacting

- FDTD electromagnetics coupled with Particle-in-Cell (PIC)
- Second order accurate boundary models
- Secondary electron physics (Furman/Pivi)
- Ability to track individual trajectories





Filter diagonalization allows extraction of cavity frequencies and modes

- G.R. Werner, J.R. Cary, "Extracting degenerate modes and frequencies from time-domain simulations with filter-diagonalization", *Journal of Computational Physics*, Vol. 227, pp. 5200-5214, 2008
- Both frequencies and modes are found
- Deals with degeneracies

The screenshot shows the VorpableView software interface. The main window displays a table of extracted modes with the following data:

#	Frequency	1/Q	SVD Value	Amplitude	Phase
1	1.37656E+09	-1.107E-09	2	4.256E-02	0.414
2	1.38949E+09	1.036E-09	3	7.526E-02	1.319
3	2.14228E+09	4.135E-09	2	3.088E-02	3.679
4	2.15806E+09	2.200E-09	2	5.144E-02	4.783
5	2.34827E+09	6.626E-12	3	3.871E-02	5.513
6	4.61175E+09	6.213E-14	4	4.877E-02	0.387
7	4.99941E+09	8.270E-12	16	3.296E-02	5.496
8	5.01417E+09	1.108E-12	3	4.246E-02	0.245
9	6.20082E+09	-3.686E-12	5	8.895E-03	1.520
10	6.26084E+09	-1.027E-12	7	1.006E-01	5.717
11	7.66984E+09	2.264E-15	6	7.572E-02	0.545
12	8.19512E+09	-5.735E-13	16	2.848E-03	2.709

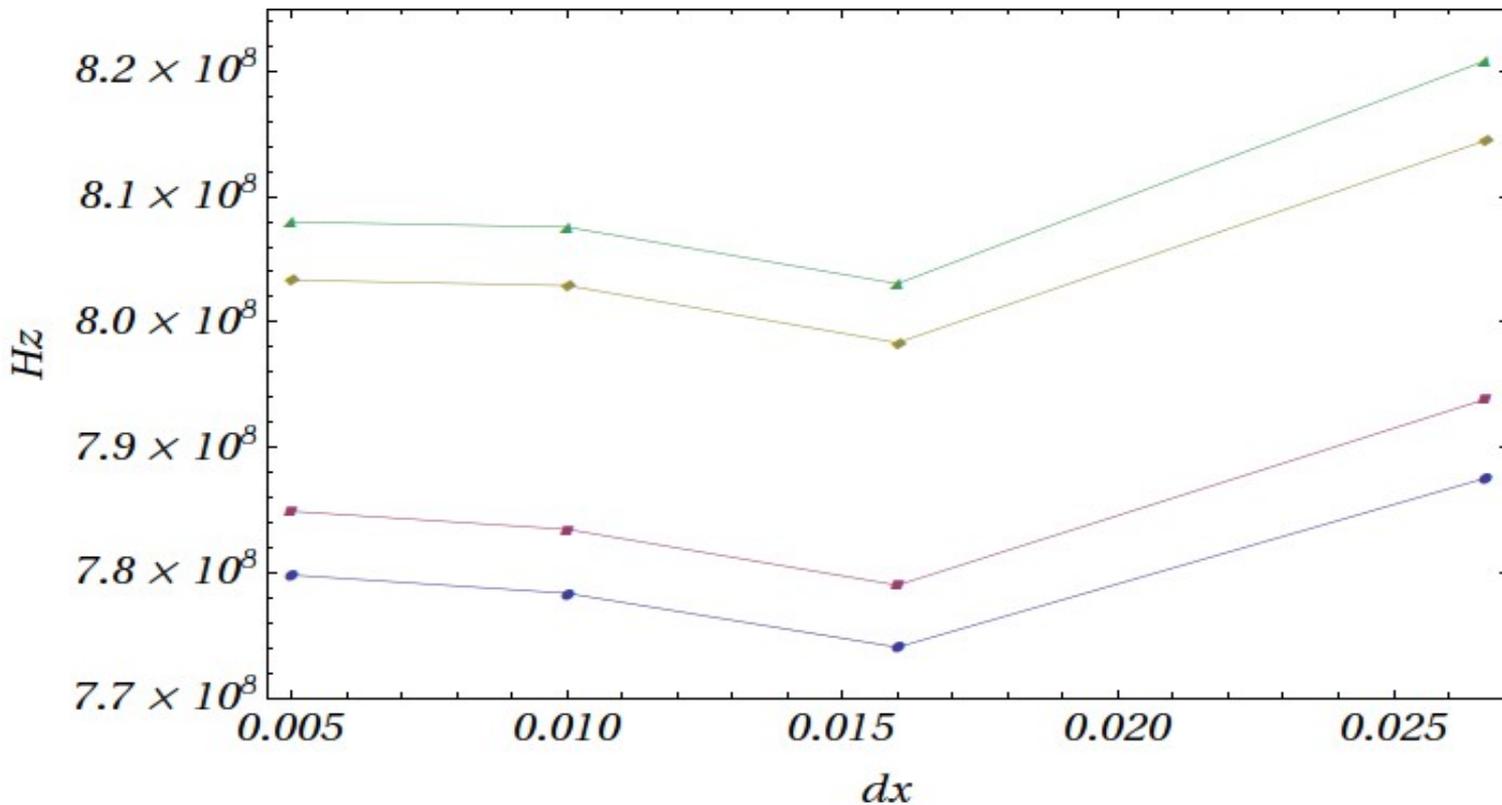
Control parameters on the right side of the interface include:

- Number of Modes in SVD: 12
- Lower Frequency Limit of Excitation (Hz): 1.0000E+09
- Upper Frequency Limit of Excitation (Hz): 8.0000E+09
- Duration of Excitation (seconds): 2.2200E-08
- Dump Number Range for SVD: 5 to 105
- Spatial Sampling: Nx=20, Ny=20, Nz=1
- Uniform Random Single Component
- Load Data and Compute SVD
- Name for eigenmodes: Eigenmode
- Compute Eigenmodes (This may take awhile)
- Status: Percentage of points which are zero: 81%



Filter diagonalization applied to UK crab cavity design finds all modes

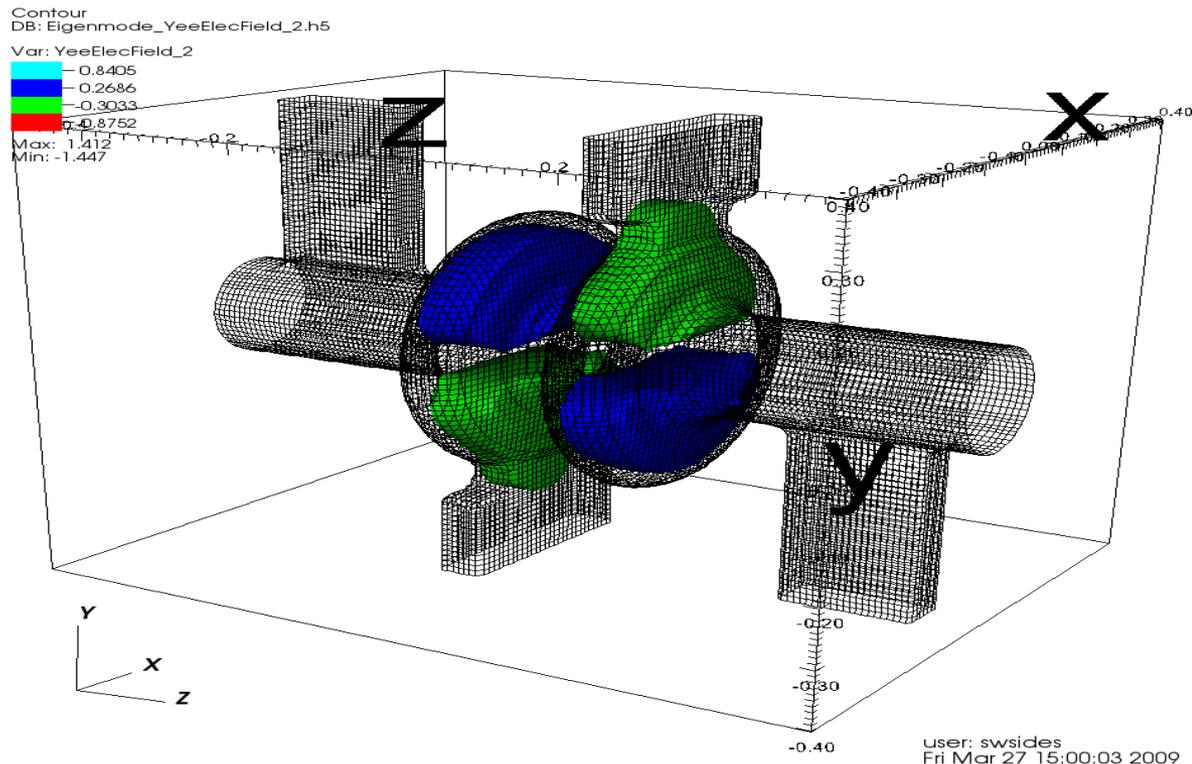
- Gets separation between polarization states
- Gets separation between pi and zero modes





Filter diagonalization applied to Crab cavity design finds all modes

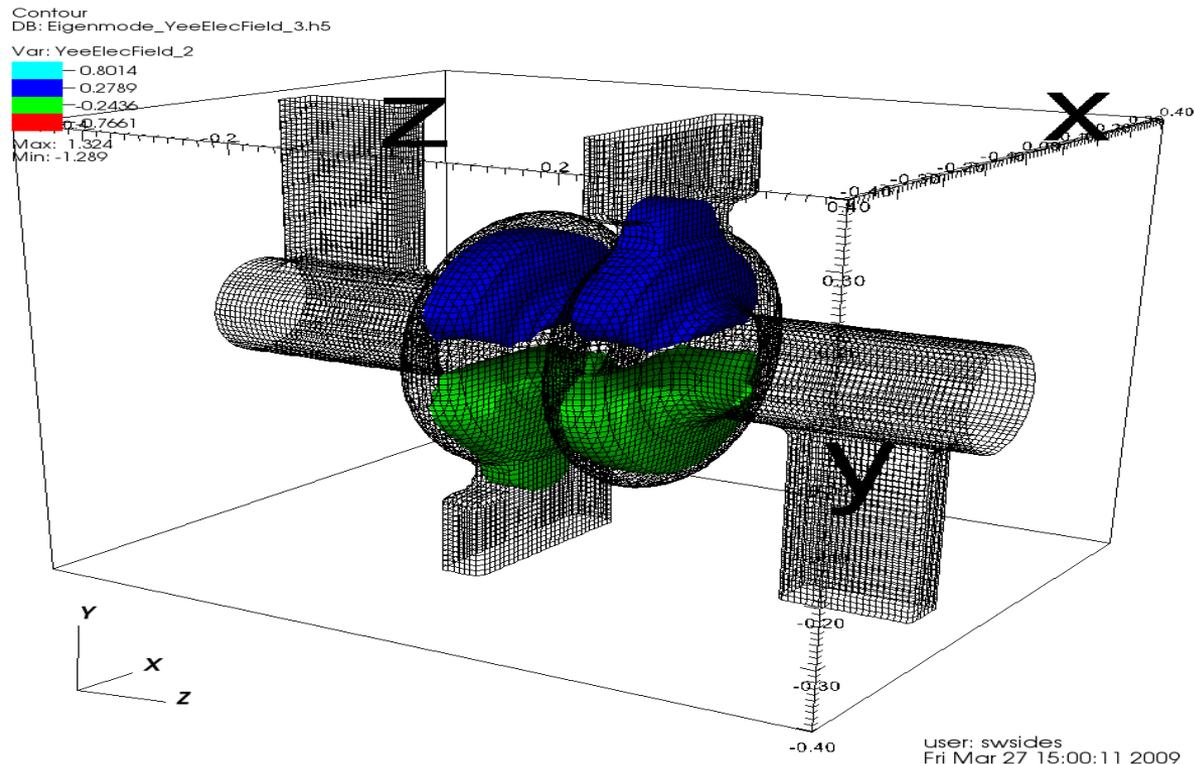
- Pi mode that couples to the waveguides





Filter diagonalization applied to Crab cavity design finds all modes

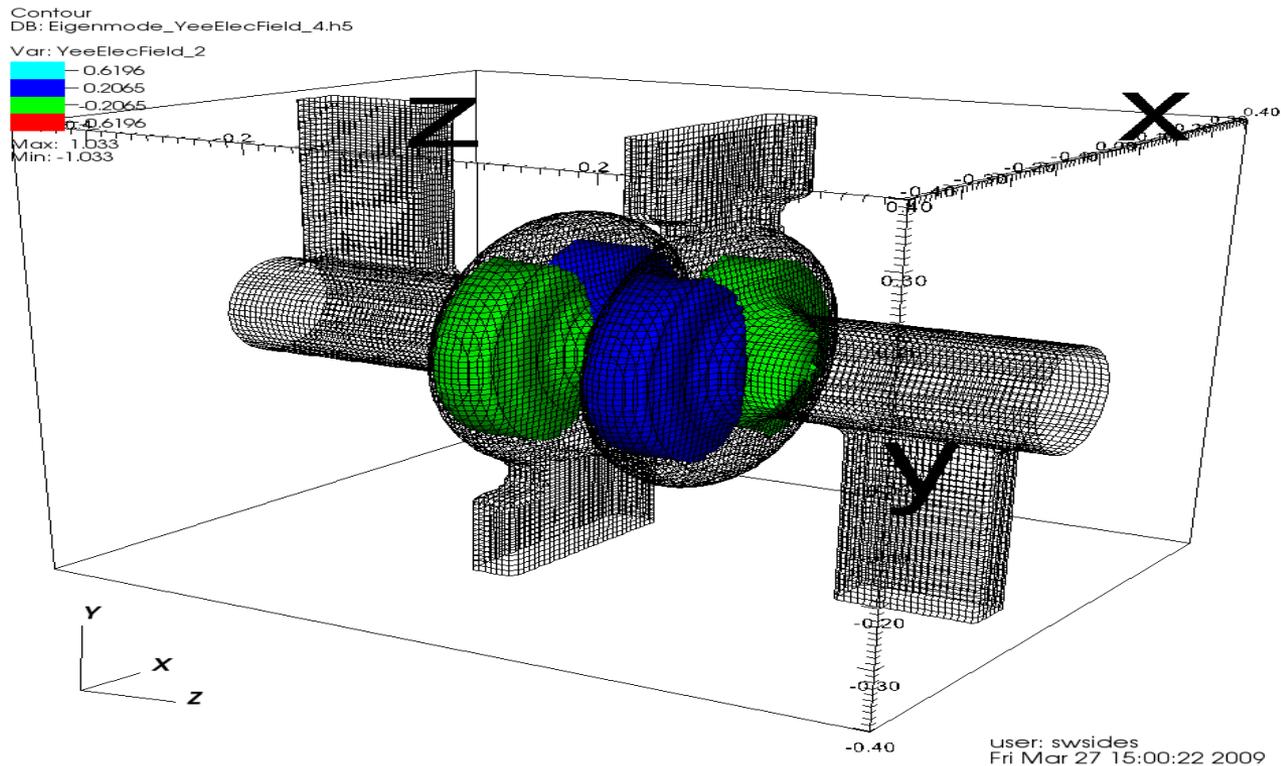
- Zero mode that couples to the waveguides





Filter diagonalization applied to Crab cavity design finds all modes

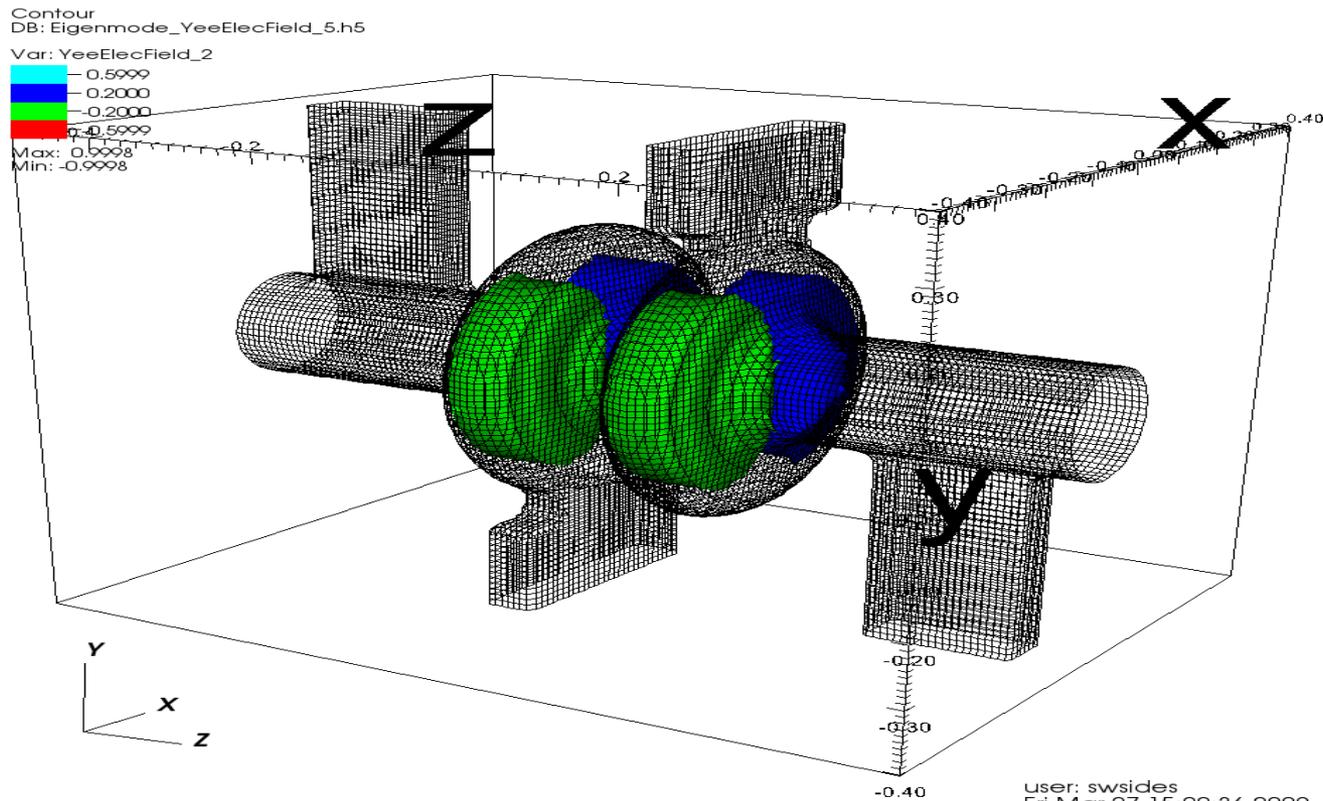
- Pi mode that does not couple to the waveguides





Filter diagonalization applied to Crab cavity design finds all modes

- Zero mode that does not couple to the waveguides





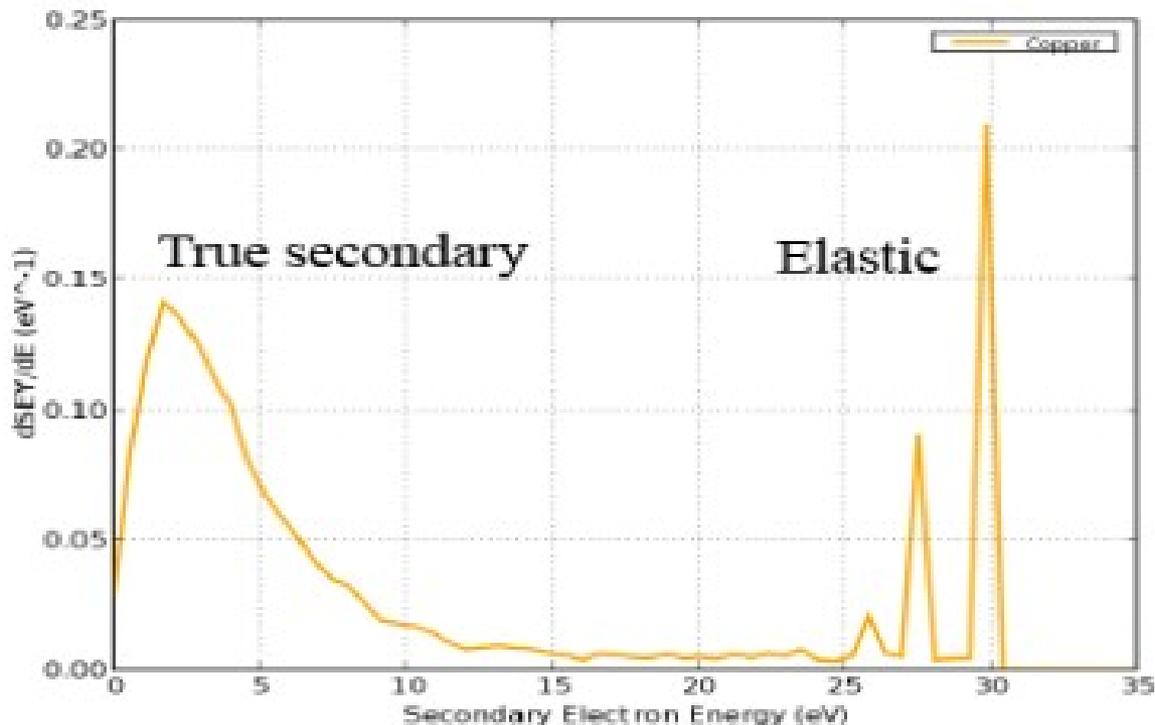
Filter diagonalization compares favorably with results from Microwave Studio

	VORPAL	Microwave Studio
Undamped Zero mode	0.8031 GHz	0.8045 GHz
Undamped Pi mode	0.7983 GHz	0.8004 GHz
Damped Zero mode	0.7790 GHz	0.783 GHz
Damped Pi mode	0.7740 GHz	0.778 GHz



VORPAL's secondary electron emission models allow multipacting studies

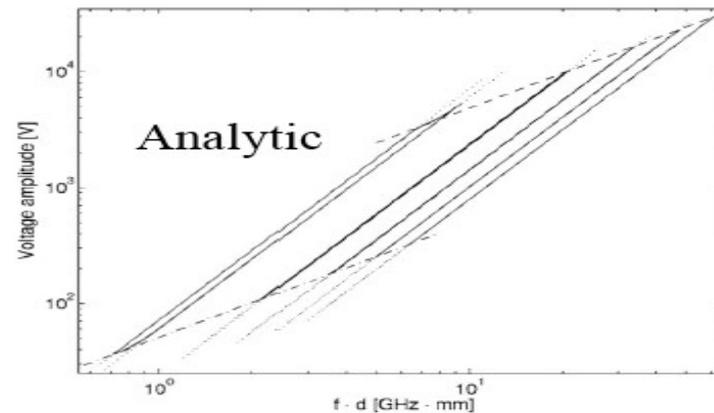
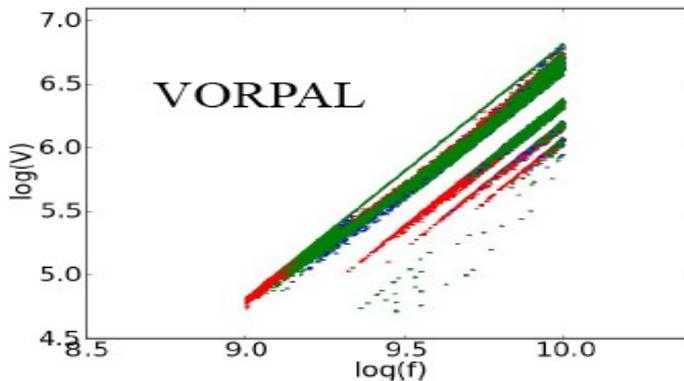
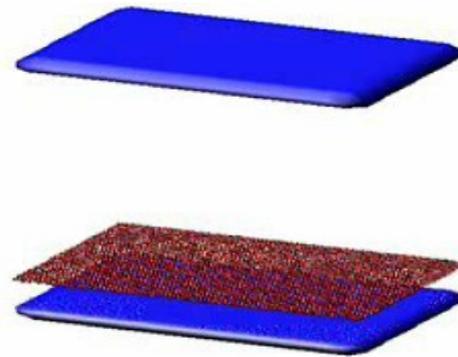
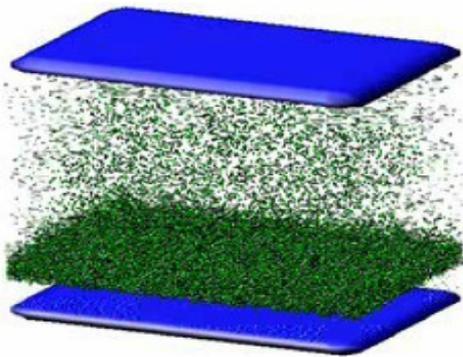
- Simple secondary emission – one secondary emitted at normal incidence
- Phenomenological model – true, diffuse and elastic secondaries
- M.A. Furman and M. Pivi, Phys. Rev. ST Accel. Beams 5, 124404 (2002)





VORPAL has been benchmarked against analytical multipacting results

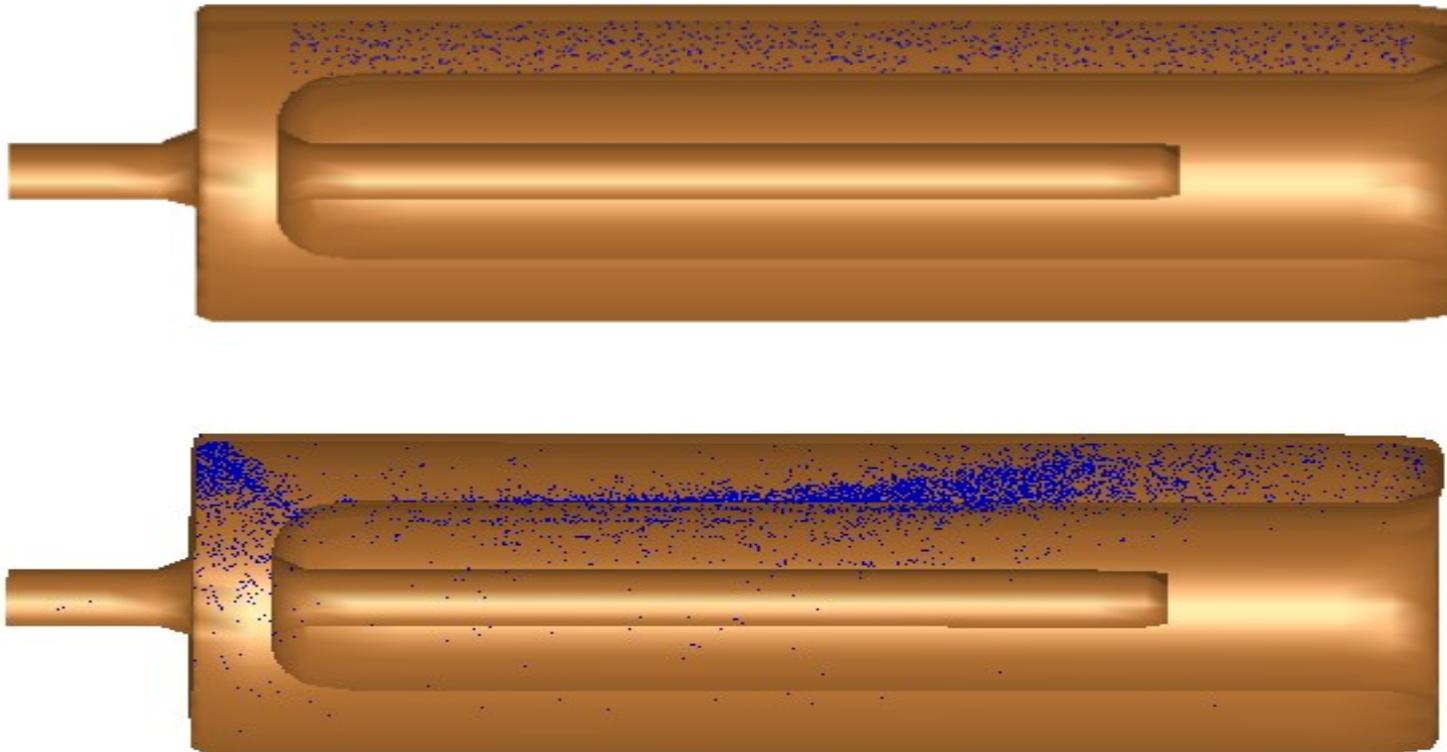
- Both simple and phenomenological model reproduce multipacting bands





VORPAL simulations can be used to identify potential multipacting

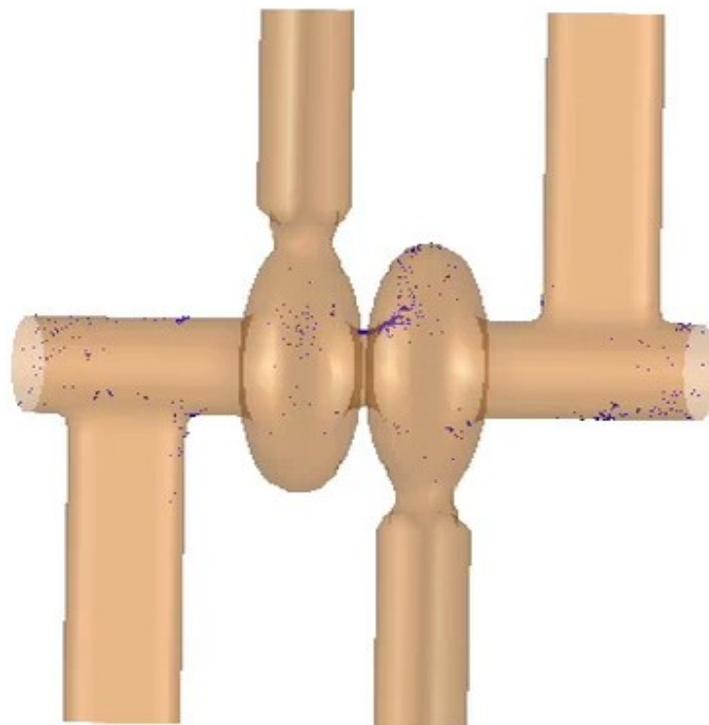
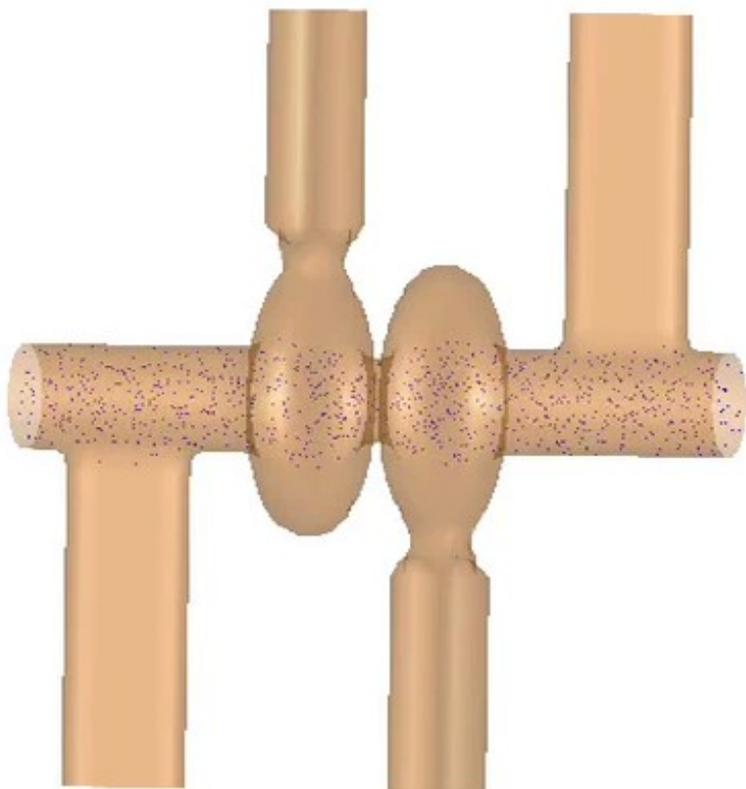
- Multipacting occurring in BNL quarter wave cavity





Preliminary simulations show possible multipacting in UK crab design

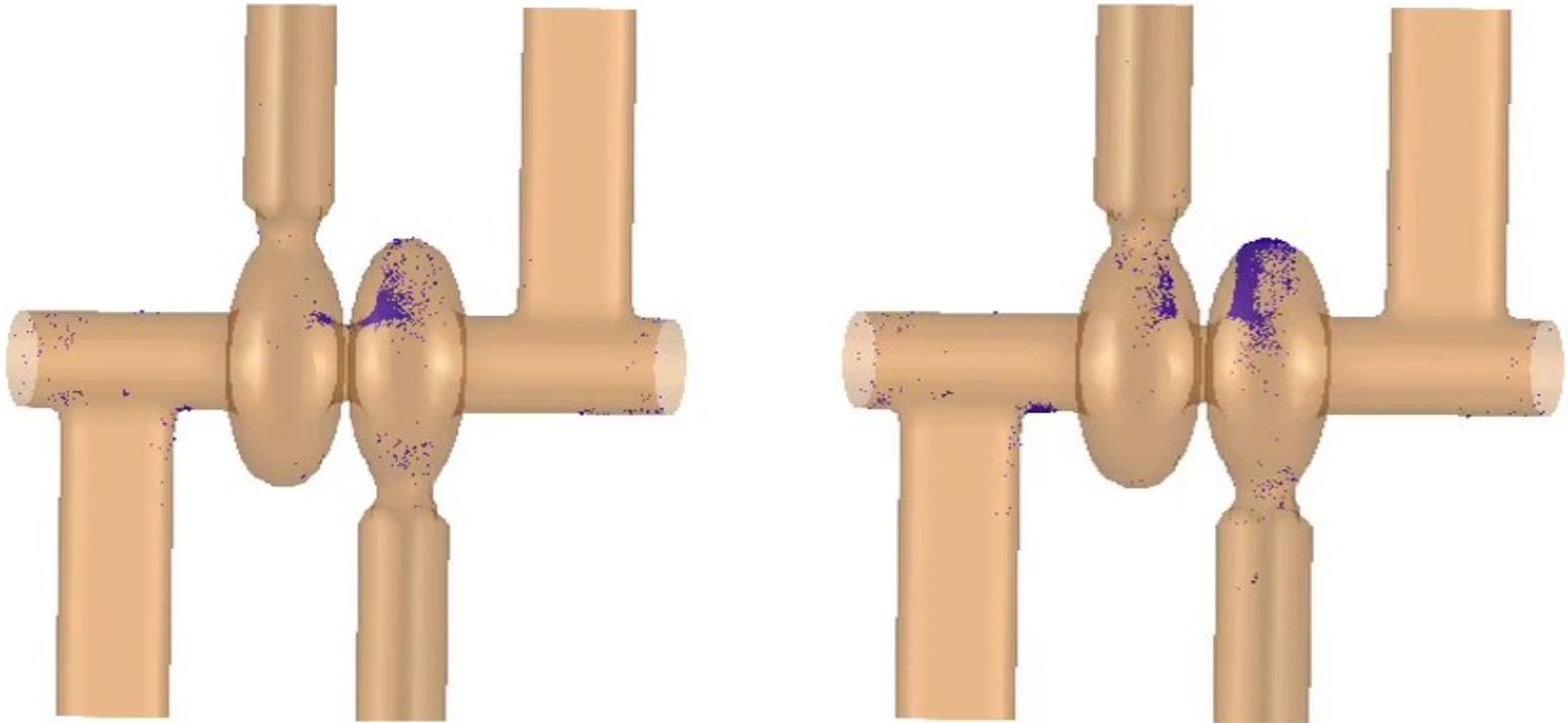
- $E_{\text{peak}} \sim 10 \text{ MV/m}$





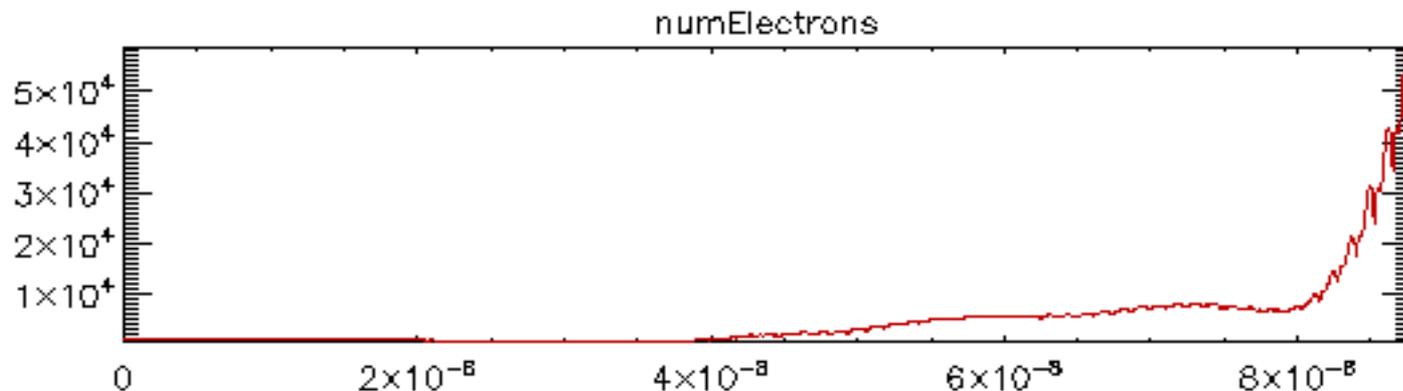
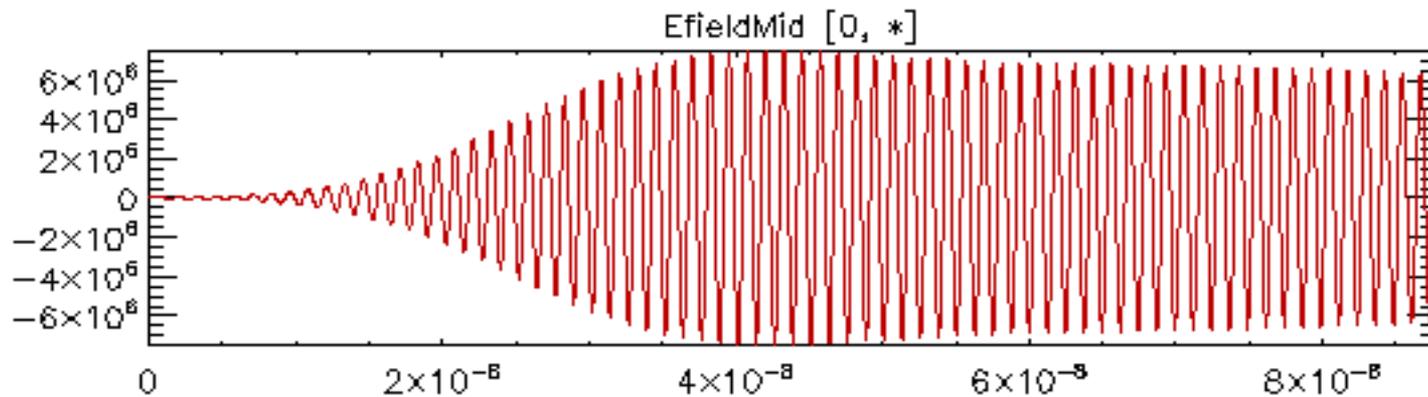
Preliminary simulations show possible multipacting in UK crab design

- $E_{\text{peak}} \sim 10 \text{ MV/m}$
- Movement towards equator implies soft barrier multipacting



Preliminary simulations show possible multipacting in UK crab design

- $E_{\text{peak}} \sim 10 \text{ MV/m}$





Further simulations needed to clarify the nature of the multipacting

- With full secondary model simulations become very slow
- Once sites of multipacting are identified we can look at individual trajectories
- Identifying whether multipacting produces soft or hard barriers can be done with scans over power



Simulation studies of UK crab cavity design will continue

- J. Smith will be running simulations with VORPAL
- Runs will include benchmarking with other tracking codes
- Simulation results will help guide cavity design