Self-consistent simulations of Multipacting in Superconducting Radio Frequency Cavities

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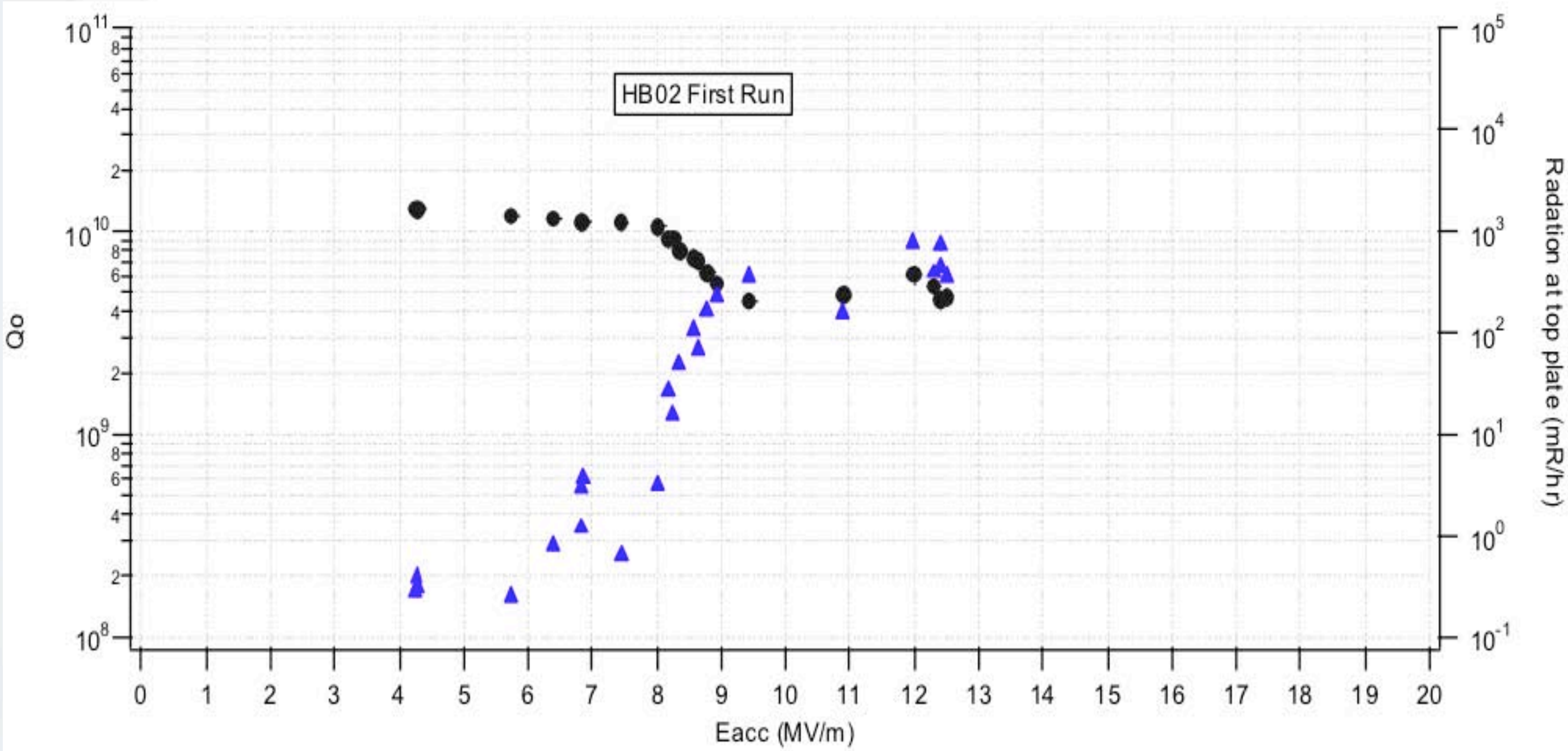
Multipacting remains a limitation to SRF accelerating cavity performance

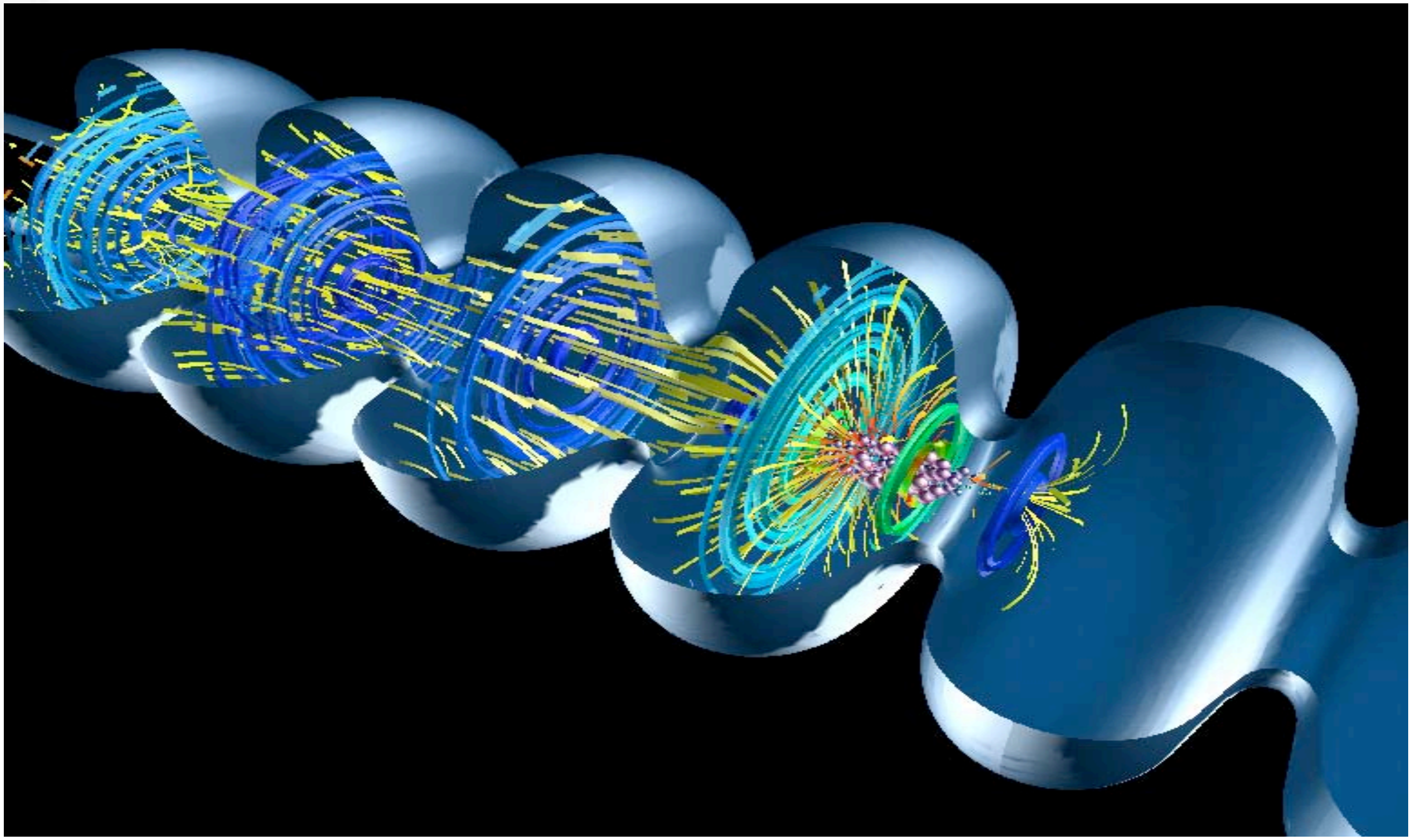


The cavity quality factor, Q, and the radiated power as a function of field gradient. Figure taken from J. R. Delayen, J. Mammosser, and J. Ozelis, “Analysis of the qualification-tests performance of the superconducting cavities for the SNS linac”, *Proceedings of Linac 2004*

Simulations can help cavity designers predict multipacting issues before fabrication

- Need to understand particle dynamics in the fields of the cavity modes.
- Field and secondary electron emission at the cavity surface plays an important role.
- To fully understand multipacting barriers self-consistent simulations are needed.

Using the Dey-Mittra cut cell boundary algorithm VORPAL can model electromagnetics in SRF cavities.



Wakefields in SRF cavity – visualization by Peter Messmer

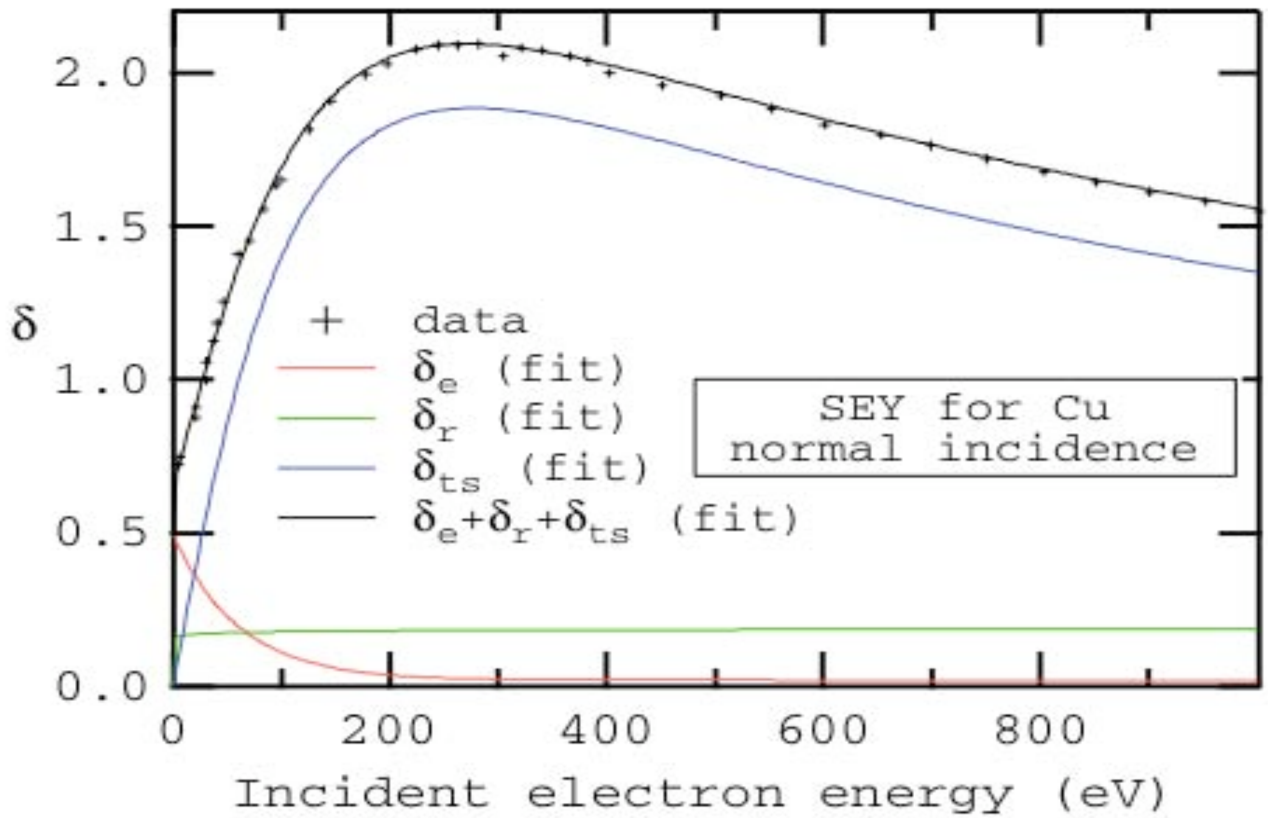
Cavity geometries can be described in multiple ways

- A basic functional description of a surface can be used.

  f(x,y,z) = 0

- More complicated functional description can me made using python or input file macros.
- VORPAL can read in surface triangulations from STL files and various CAD formats can be converted to STL using Capri.

The TxPhysics library provides advanced models for secondary electron emission



Phenomenological models combine contributions to the SEY curves from elastic, diffuse and true secondary electrons

Multipacting simulations are now possible due to recent developments in cut cell boundaries for the particles

- PIC particles can now be removed from cut cells without image charge accumulation.
- Secondary electron emission is now possible from complex surfaces.
- The new VpHistory diagnostics allow single particle trajectories to be dumped for easy post-processing.

Image charge will create non-physical fields if the standard current deposition is used

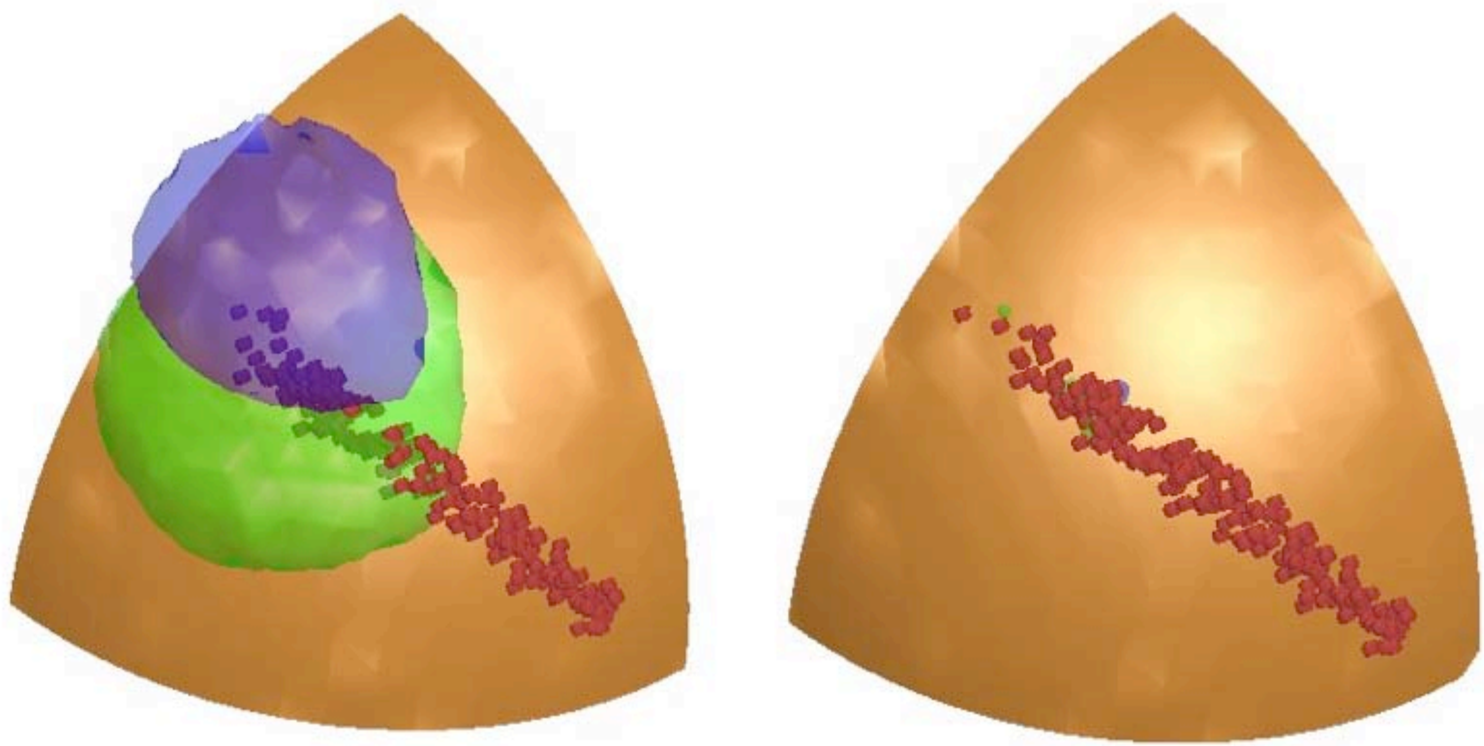
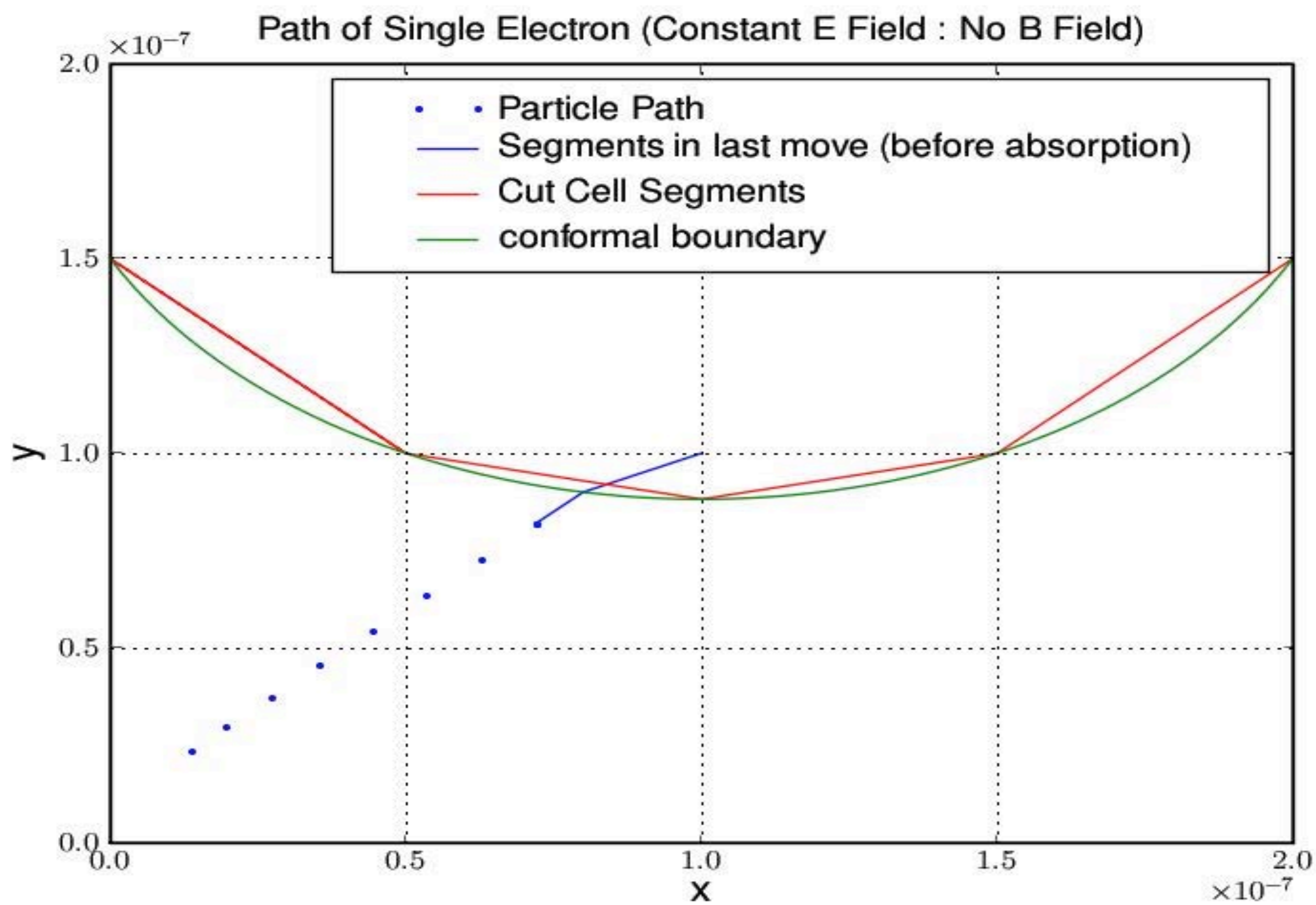
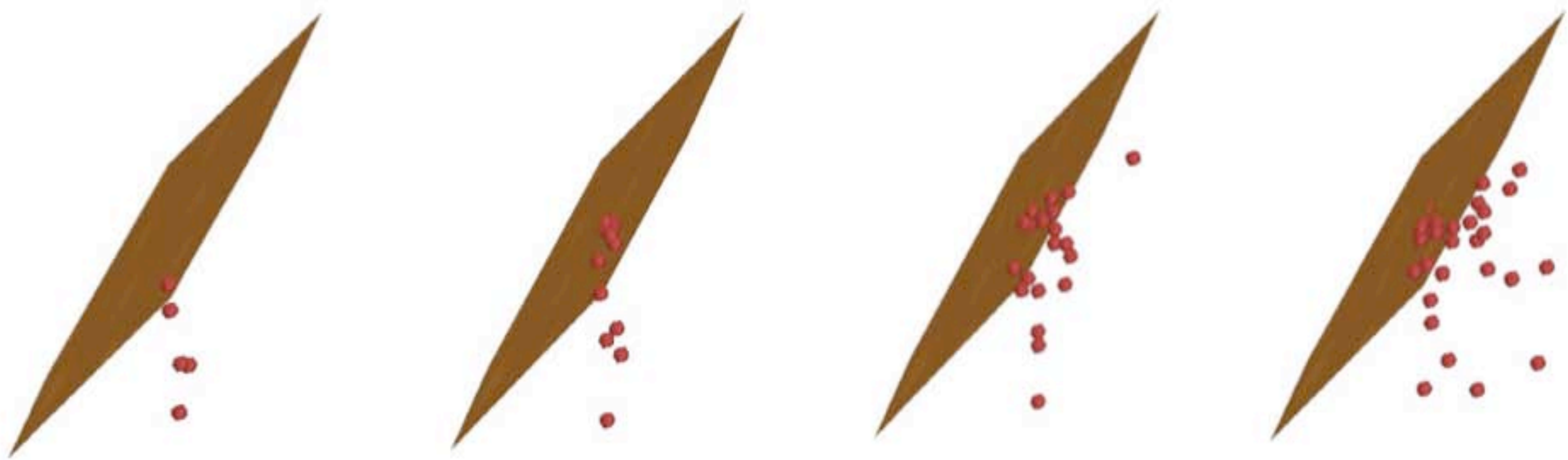


Image charge build up is avoided by continuing a removed particle to a grid node.



Secondary electron emission now works off of complex boundaries



Time series of an electron beam impacting a conductor producing secondary electrons.

Preliminary multipacting simulations demonstrate VORPAL capabilities

- Cavity mode is excited with a current source oscillating at a specific mode frequency.
- Electron is emitted at the cavity surface.
- Cavity fields accelerate the electron across the cavity.
- Secondary emission results in a multipacting trajectory which moves back and forth across the cavity.
- Small changes in the initial conditions can have large effects on the multipacting trajectory.

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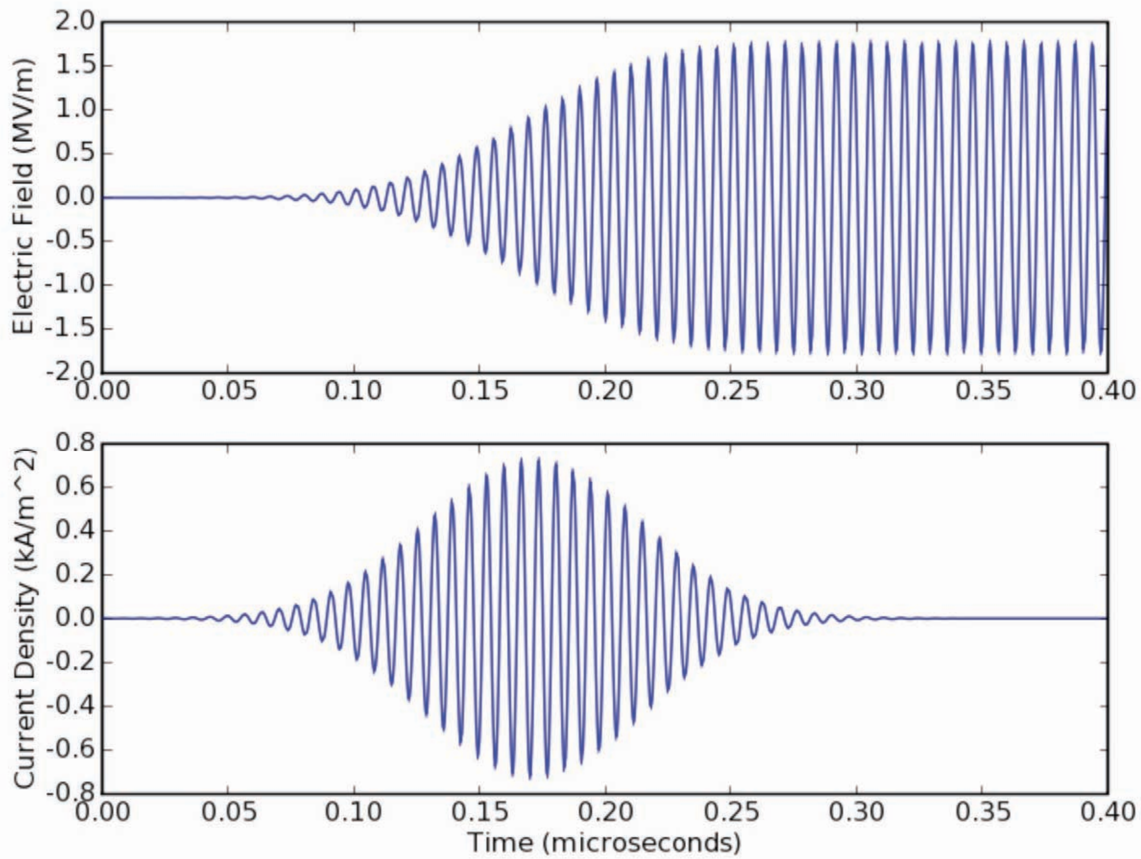
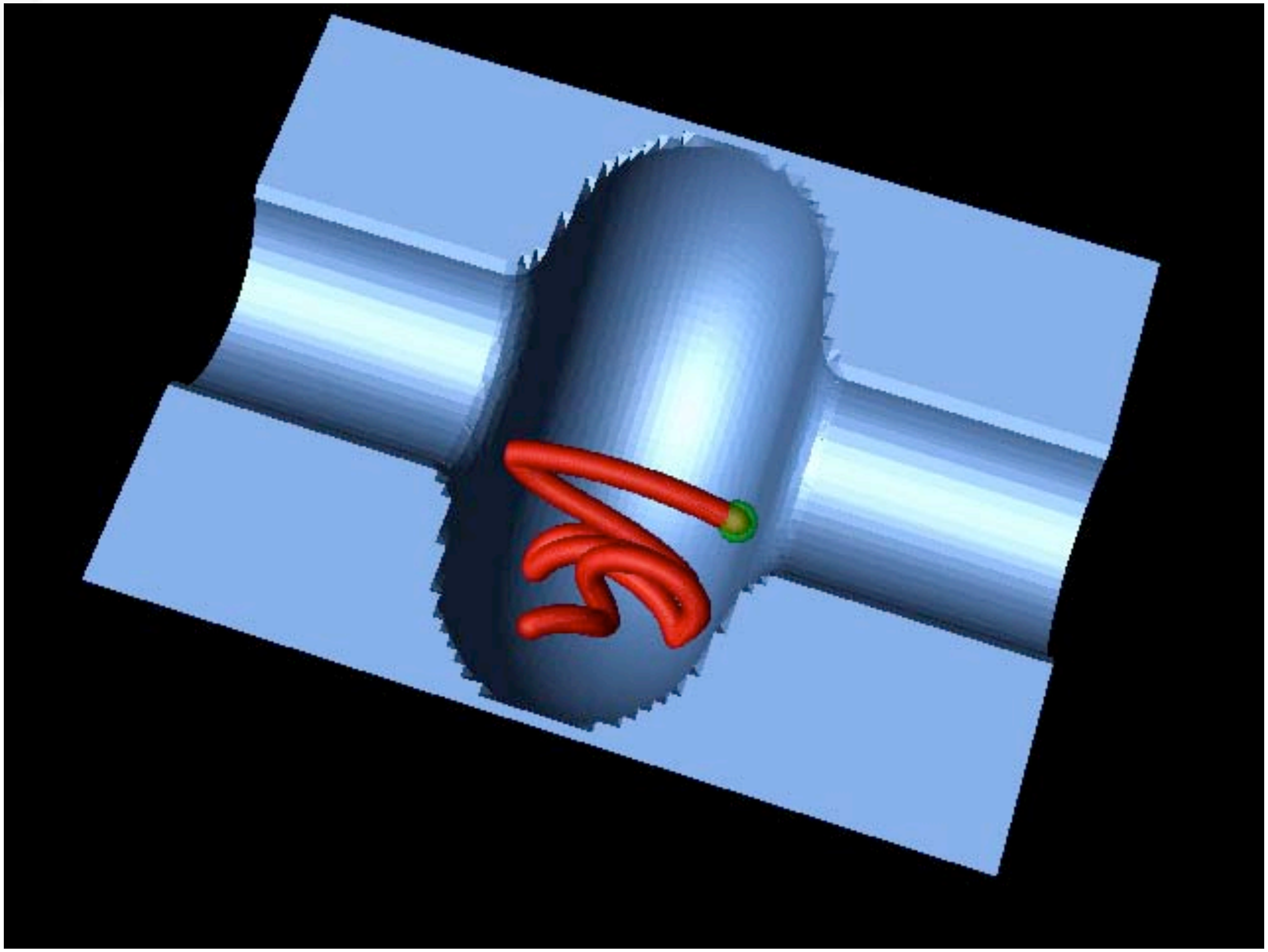


Emitting an electron on the cavity surface results in a multipacting trajectory



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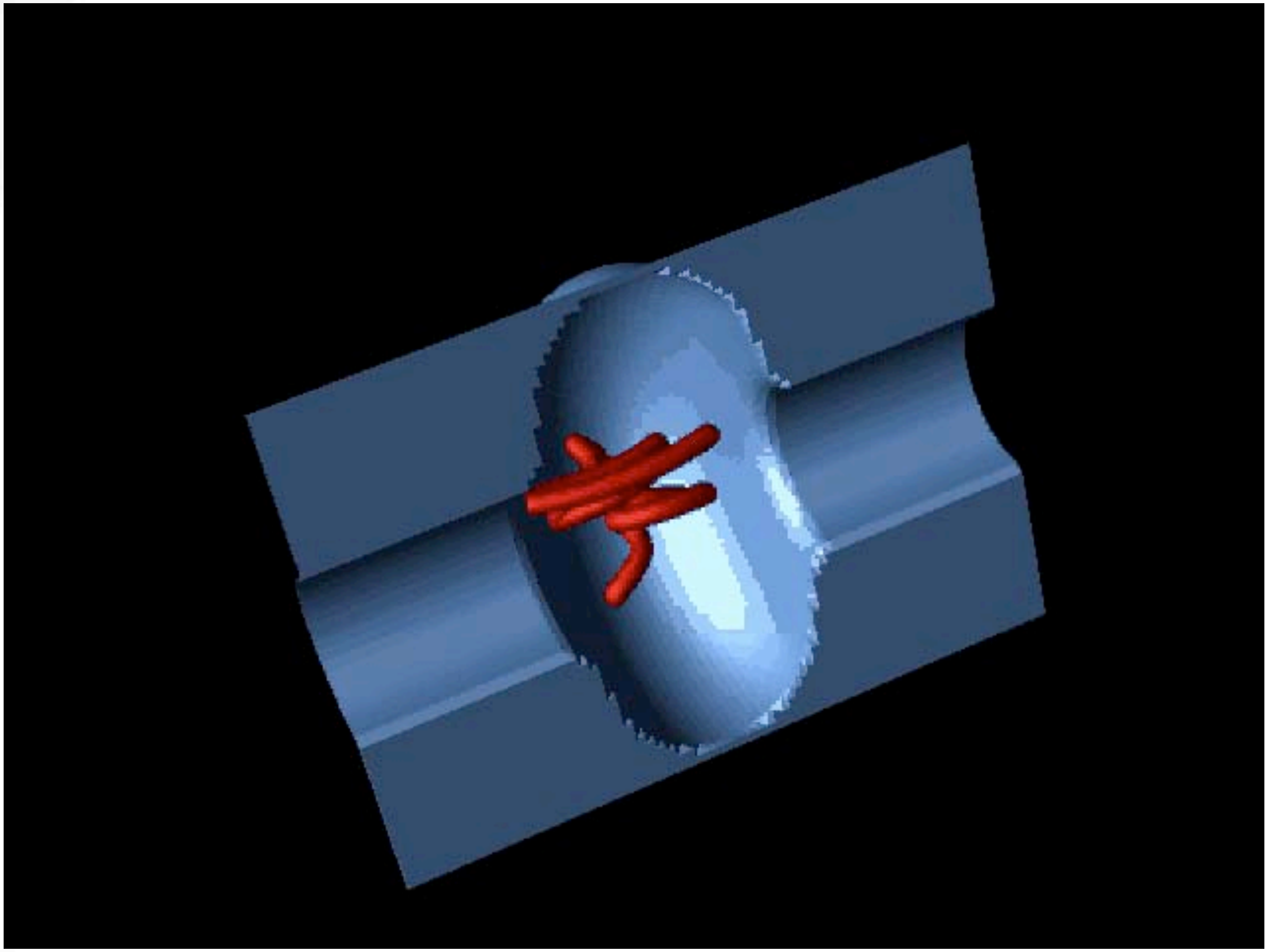
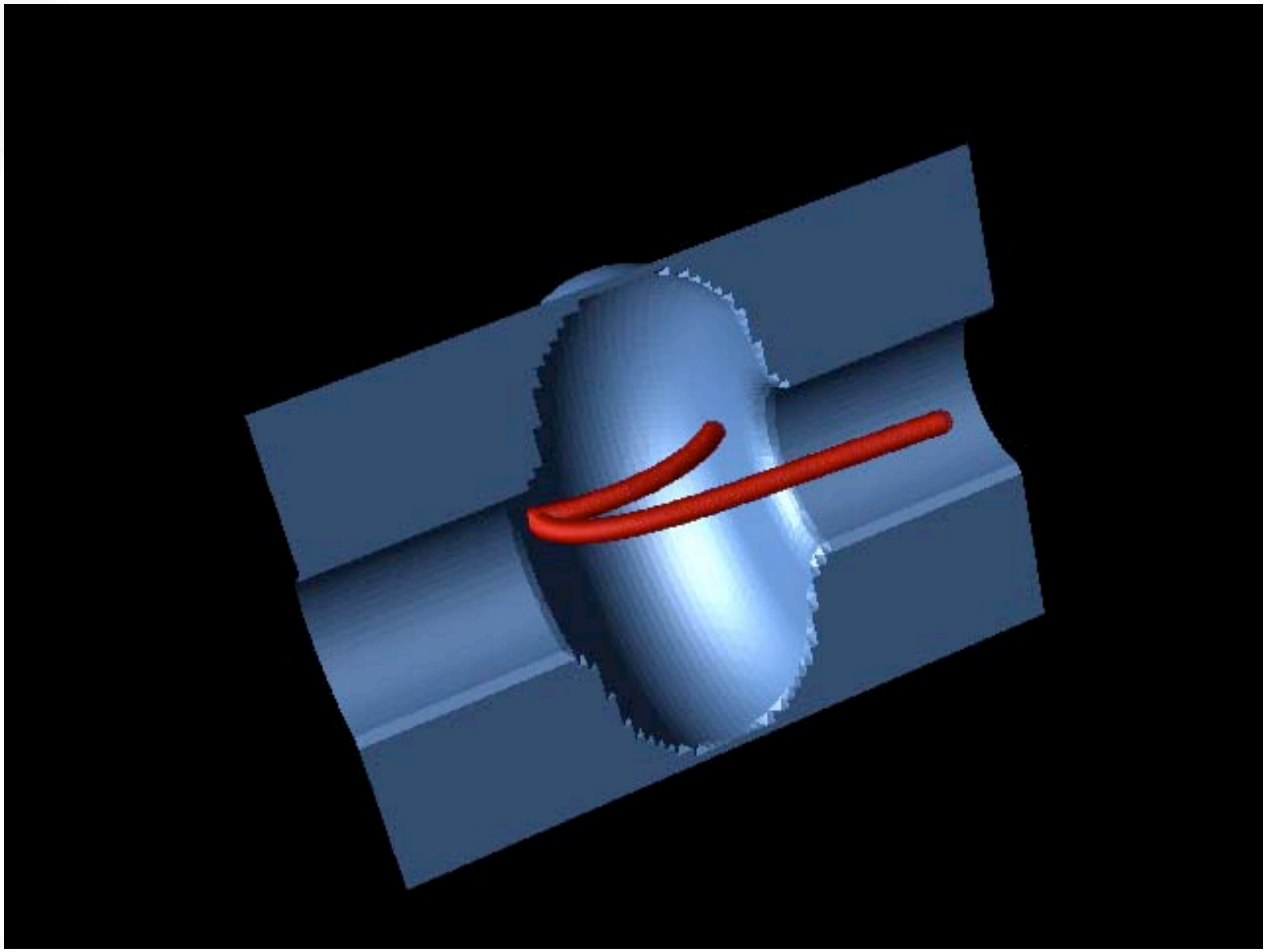


Delaying the emission time of the electron by a small fraction of the mode period gives a different trajectory



VORPAL is becoming a powerful tool to simulate multipacting in SRF cavities

- Complex geometries are handled with the Dey-Mittra cut cell method.

- Charged particle removal from cut cells is done without image charge build up.

- Secondary electron emission can modeled from complex boundary surfaces.

- VORPAL has the capacity to model multipacting from simple single particle trajectories to the build up of large amounts of multipacting electrons.