Multipactor Effect: RF discharge in high-power vacuum systems

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AURORASAT™

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Overview

- Aurorasat Company
- What is Multipactor?
- Application fields
- Techniques to avoid it
- Prediction
- Testing

AURORASAT – Technology based SME

- Technical University of Valencia & University of Valencia
- Focused on Space Sector:
  - Development of CAD software tools:
    - EM analysis and design of high-frequency components. High Power phenomena prediction.

  - Design of microwave components for the satellite industry with special excellence in high power devices.
  - Development of Control Software for laboratory instrumentation.
  - Consultancy services
  - R&D Projects

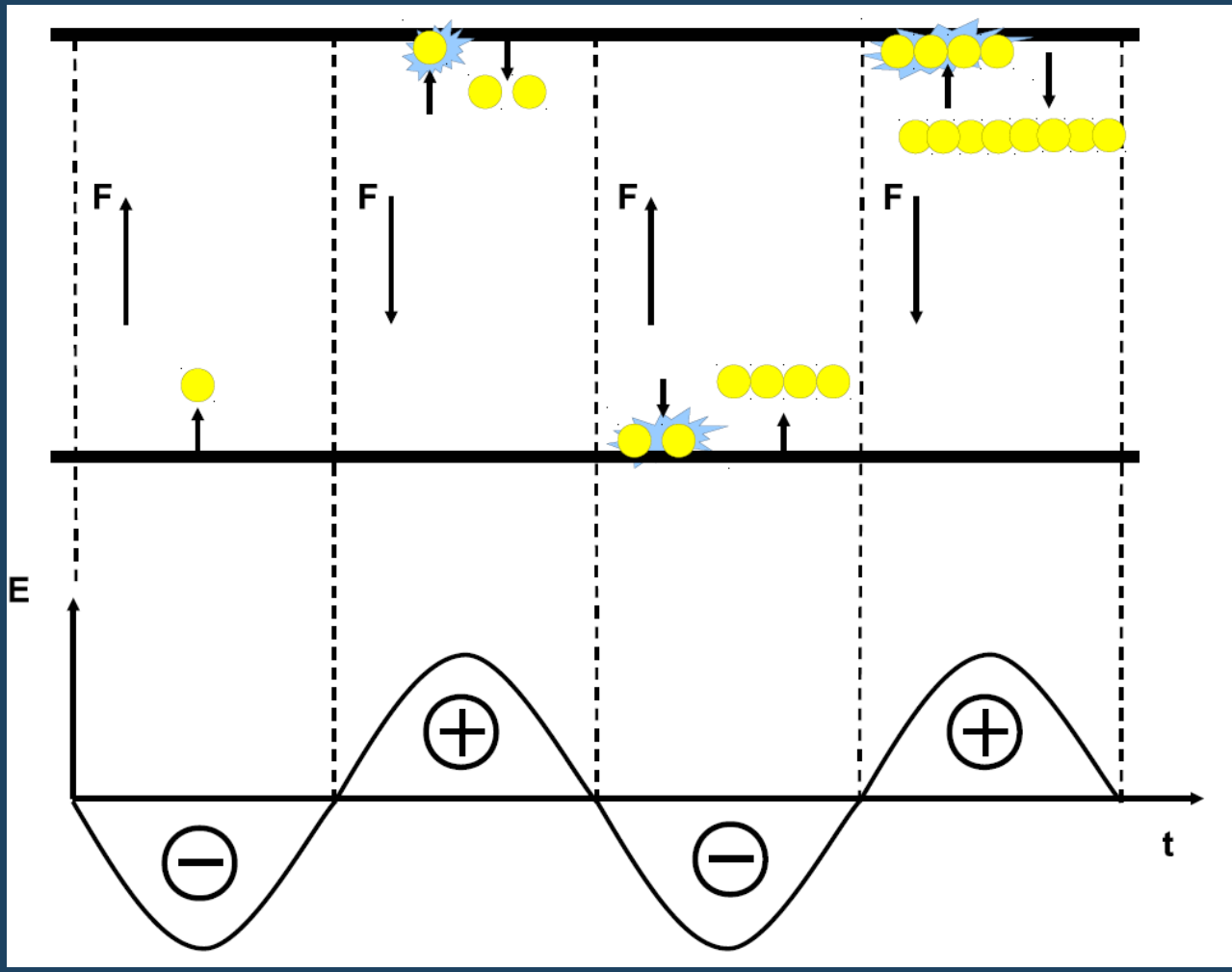
Aurora Software and Testing S.L. www.aurorasat.com
on behalf of AR Benelux, www.arbenelux.com

Multipactor

- Resonant electron avalanche
- High power signals in vacuum environments
- Free electrons (cosmic rays, field emission)

Multipactor

- Complex resonances
- Depends on device geometry and field amplitude.
- Depends on material properties, SEY (Secondary Electron Yield)



Multipactor

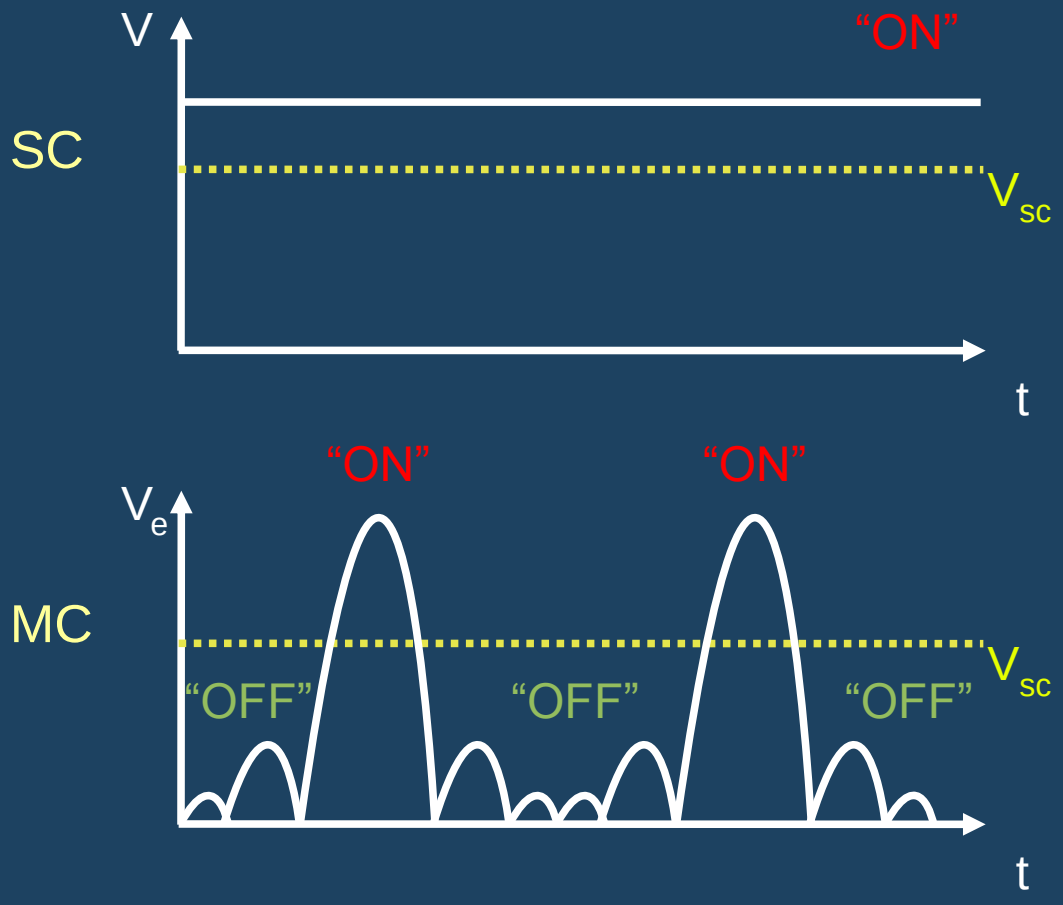
Effects:

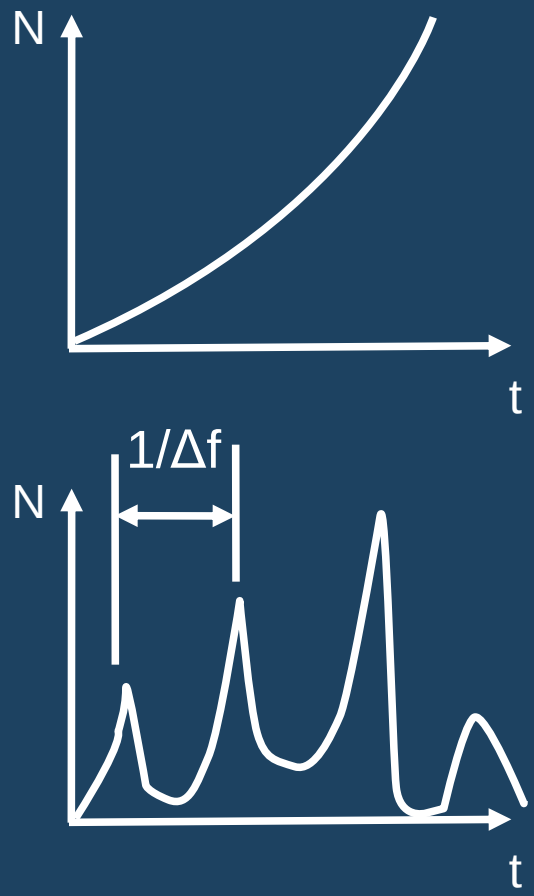
- Noise, Harmonics
- System detuning, reflected power
- Heating
- Outgassing, pressure increase, Corona discharge
- **Destruction of the component.**

Single carrier vs. multicarrier

Envelope vs. time

Electron population vs. time



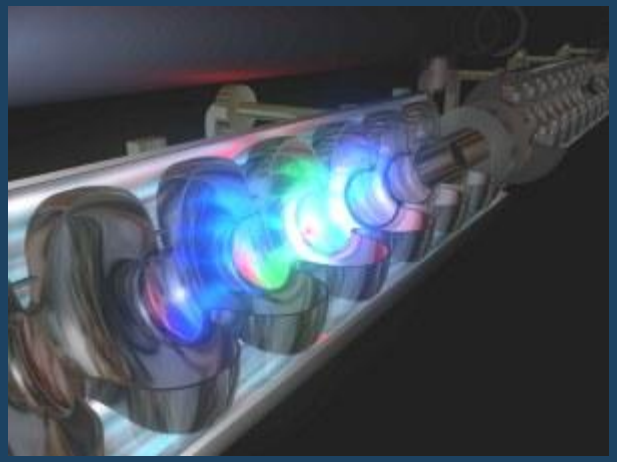


Application Fields

High power vacuum systems:

- Satellite systems

- Particle accelerators



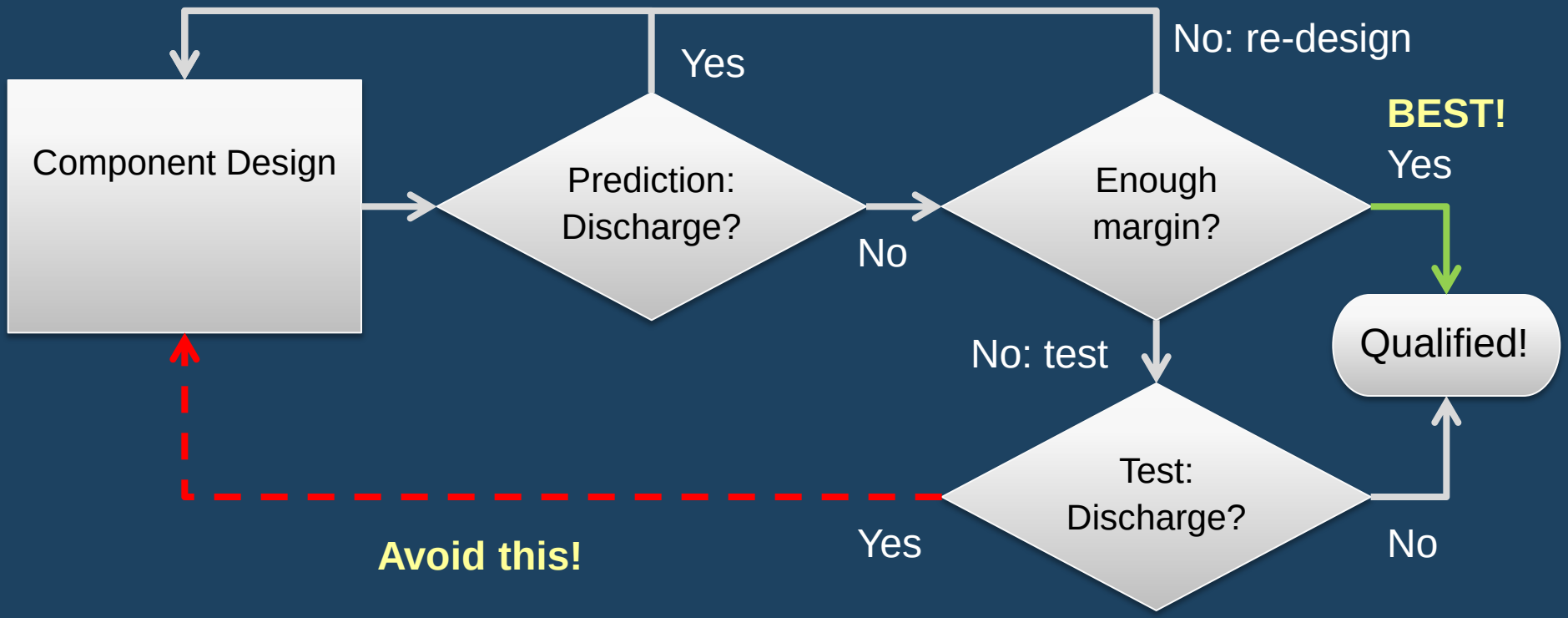
Techniques to avoid it

- Break resonance: Modify geometry in design phase.
- Avoid vacuum: pressurize or fill gaps with dielectric (implies losses, heating).
- Reduce electron emission: Low SEY materials.
- Break resonance: External DC electric or magnetic fields.

Design and test procedure

Testing is long and expensive. Should be avoided if possible.

Space Engineering: Multipacting Design and Test, ECSS-20-01A, ESA-ESTEC



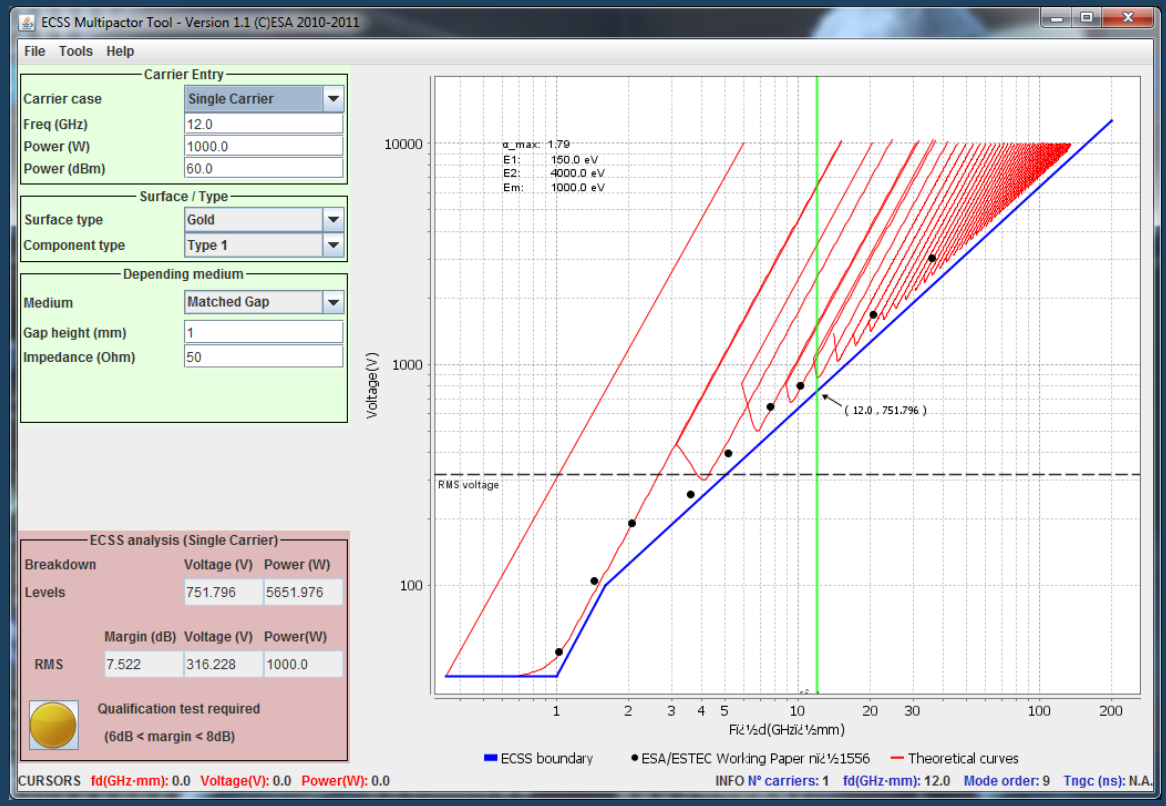
Prediction

Theory:

- Equations for electron motion and resonance.
- Parallel-plate geometry (and derived simple geometries).
- Very conservative. Not valid for complex geometries.

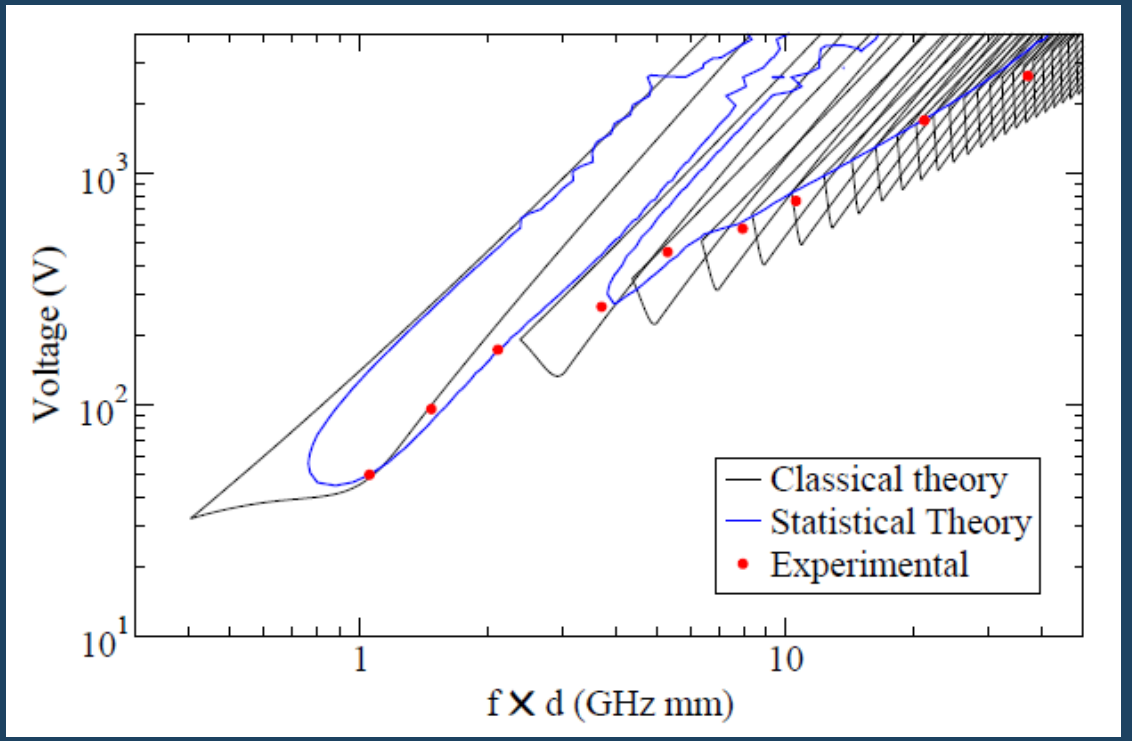
Prediction

- ECSS multipactor tool
- Fixed materials
- Single and multi-carrier



Prediction

- Non-stationary theories
- More accurate
- Arbitrary materials
- single and multi-carrier



S. Anza, C. Vicente, J. Gil, V. E. Boria, B. Gimeno, and D. Raboso. Nonstationary statistical theory for multipactor. Physics of Plasmas, 17(6):062110, June 2010.

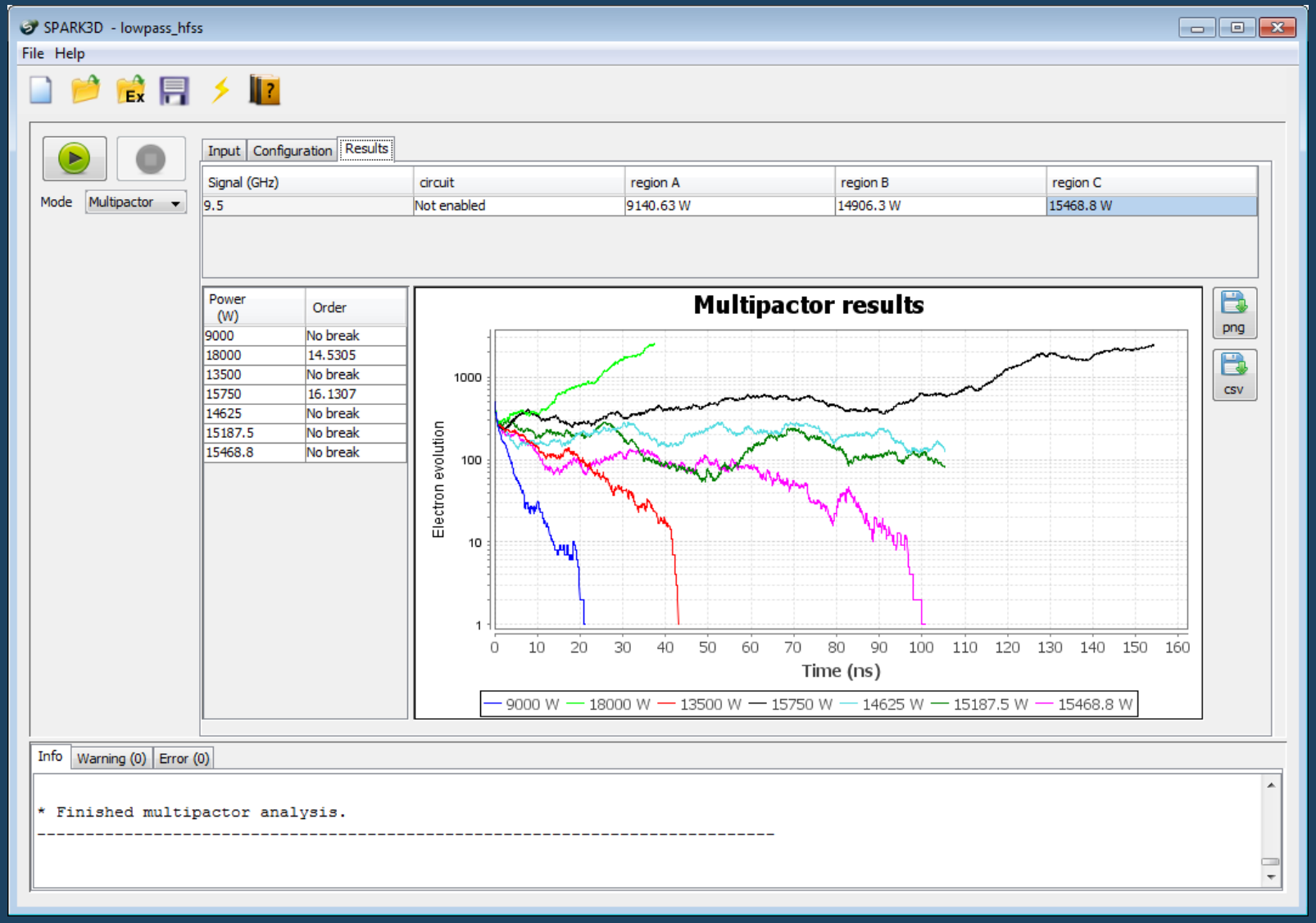
S. Anza, M. Mattes, C. Vicente, J. Gil, D. Raboso, V. E. Boria, and B. Gimeno. Multipactor theory for multicarrier signals. Physics of Plasmas, 18(3):032105, 2011.

Prediction

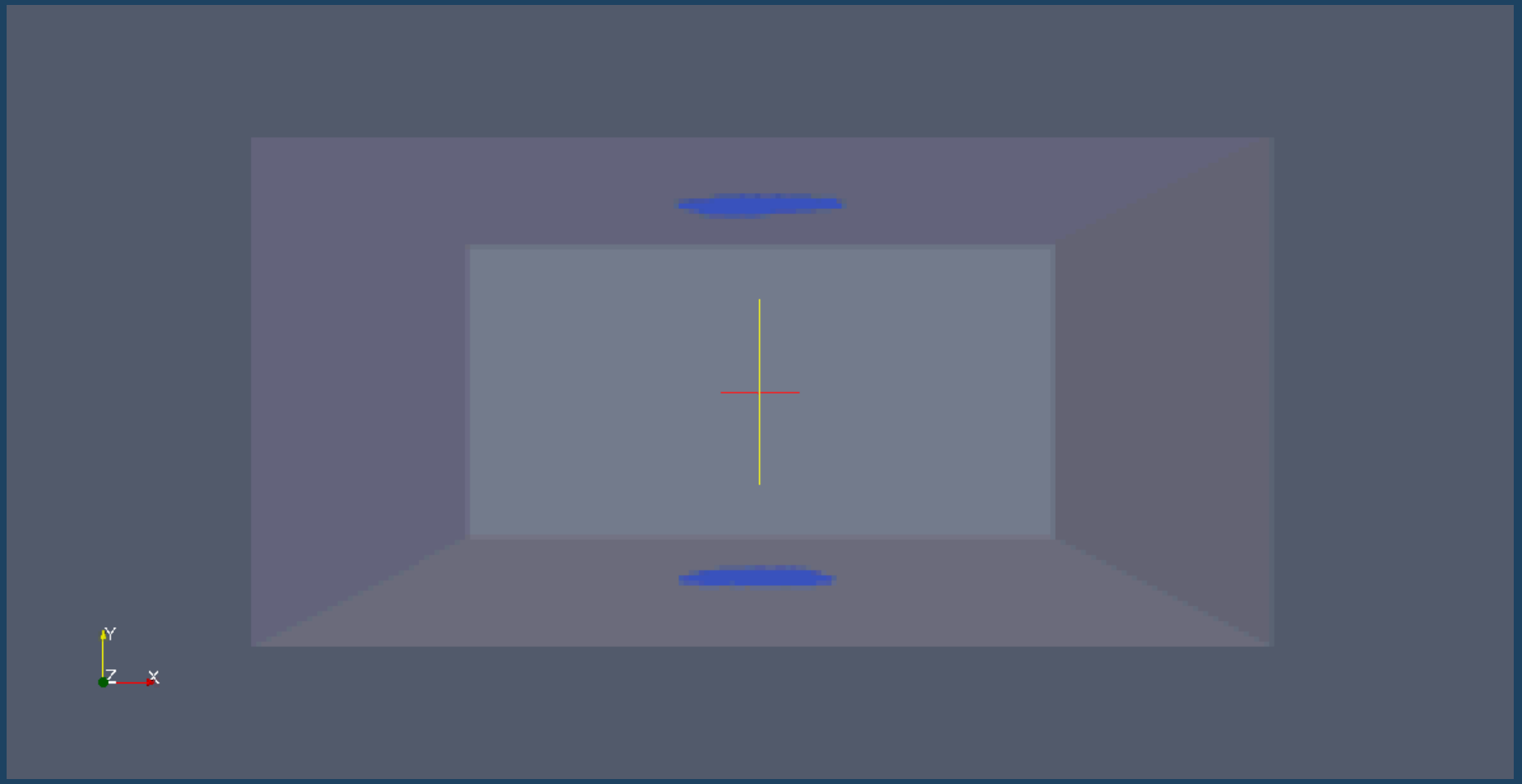
Electromagnetic + PIC numerical solvers:

- Real structures
- More accurate
- SPARK3D, FEST3D

Prediction

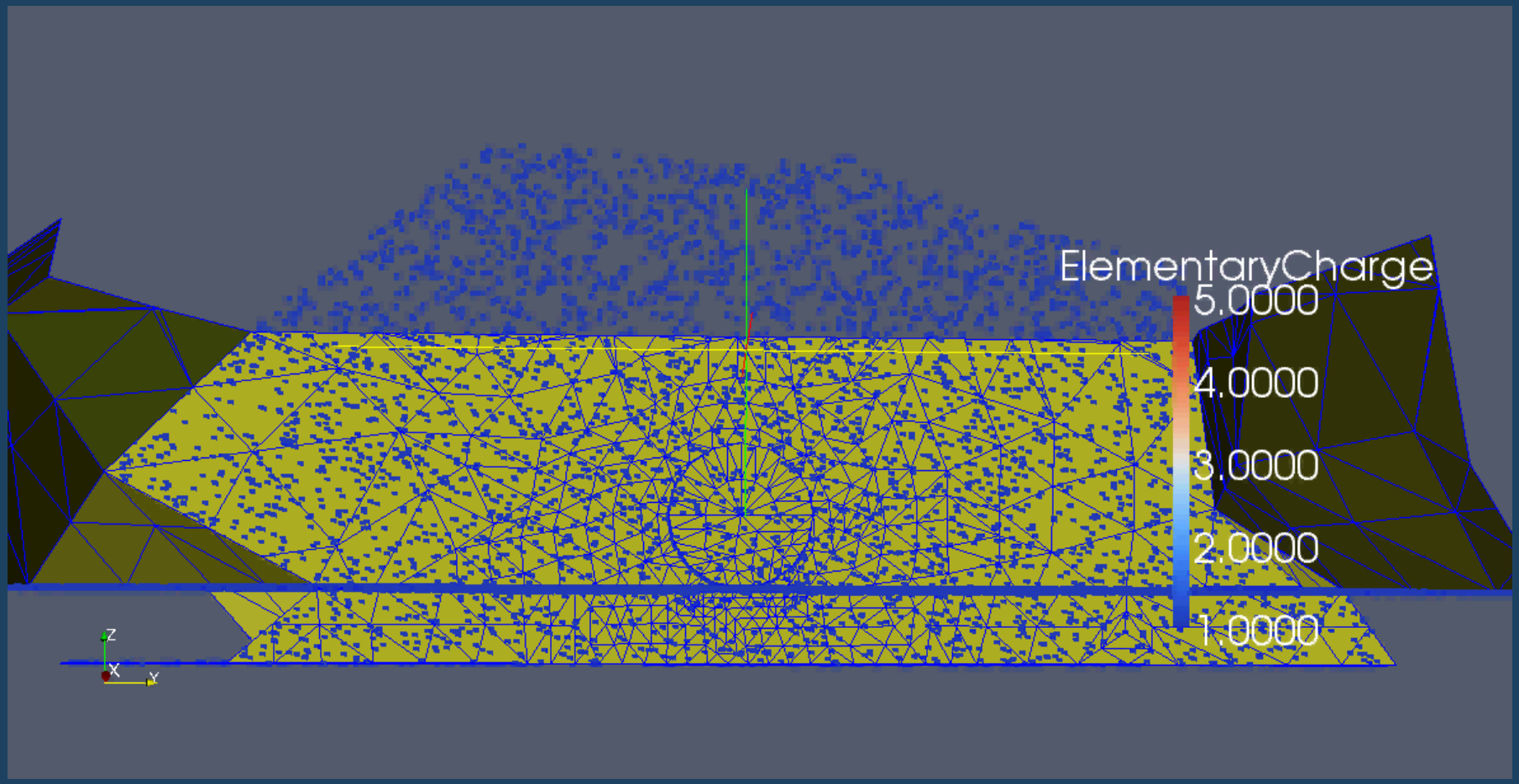

SPARK3D - lowpass_hfss
File Help
Mode Multipactor
Input Configuration Results
Signal (GHz) circuit region A region B region C
9.5 Not enabled 9140.63 W 14906.3 W 15468.8 W
Power (W) Order
9000 No break
18000 14.5305
13500 No break
15750 16.1307
14625 No break
15187.5 No break
15468.8 No break
Multipactor results
Electron evolution
Time (ns)
9000 W 18000 W 13500 W 15750 W 14625 W 15187.5 W 15468.8 W
png
csv
Info Warning (0) Error (0)
* Finished multipactor analysis.

Prediction



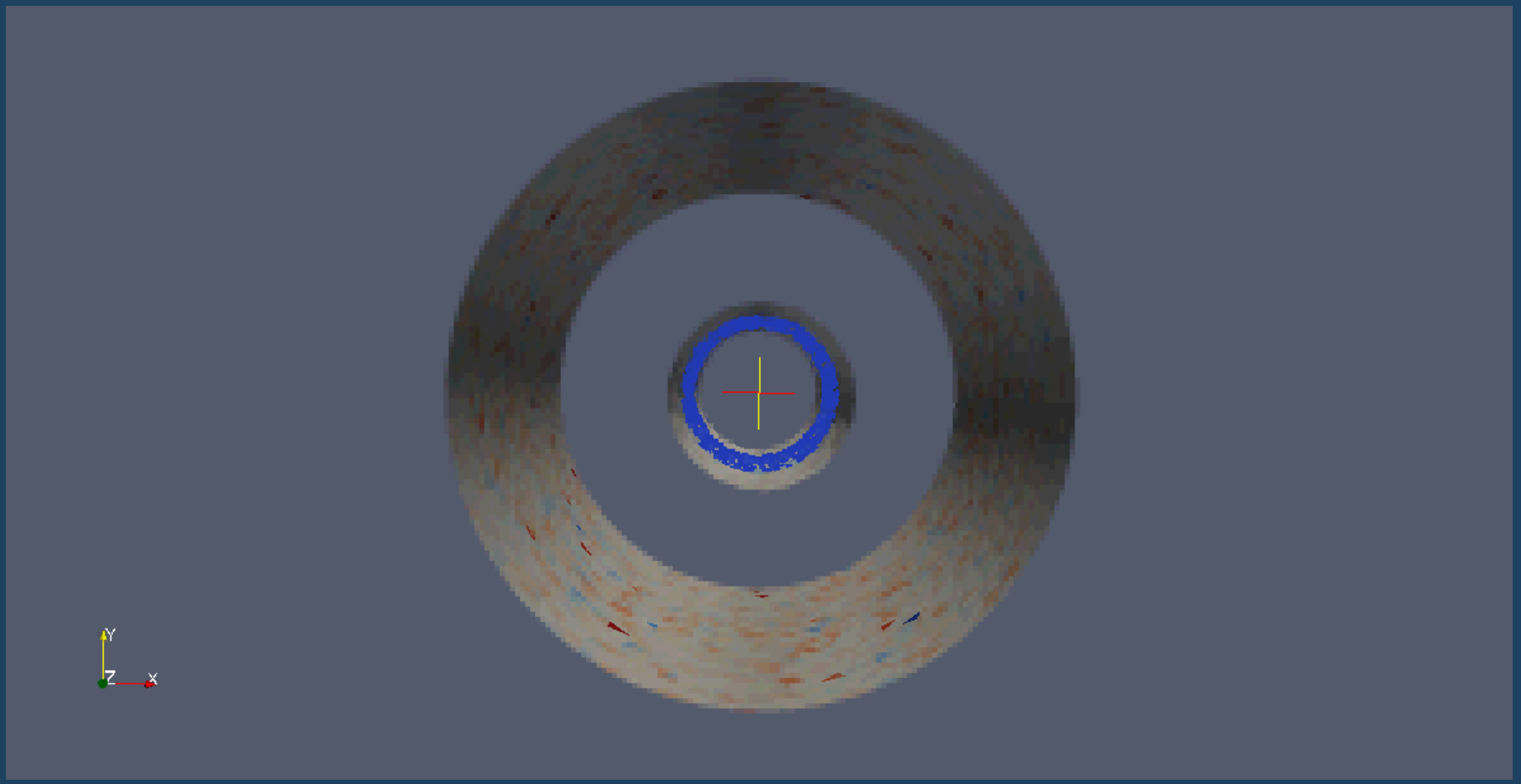
Simulated with FEST3D / SPARK3D

Prediction



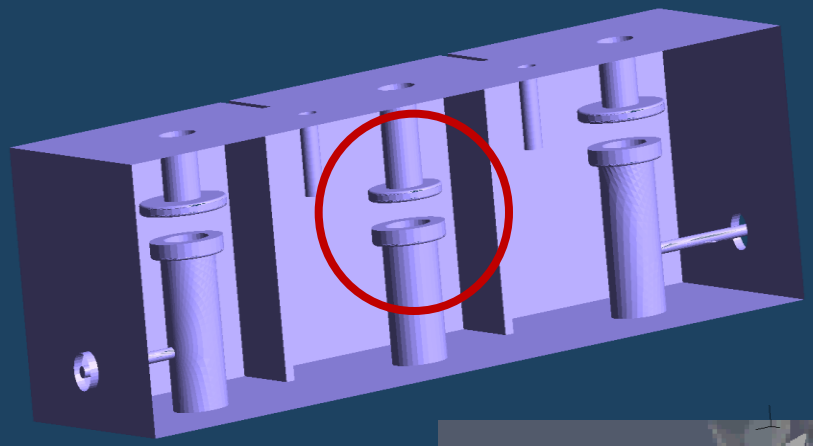
Simulated with FEST3D / SPARK3D

Prediction



Simulated with FEST3D / SPARK3D

Prediction



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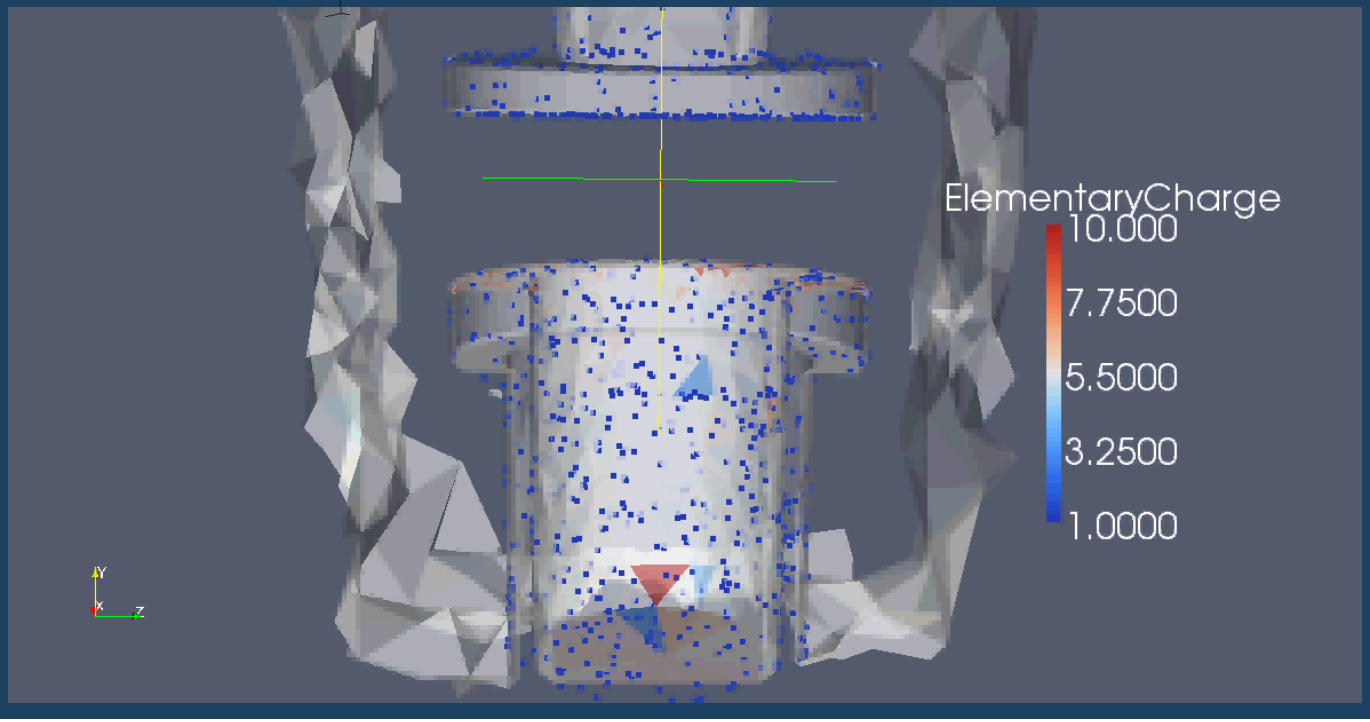
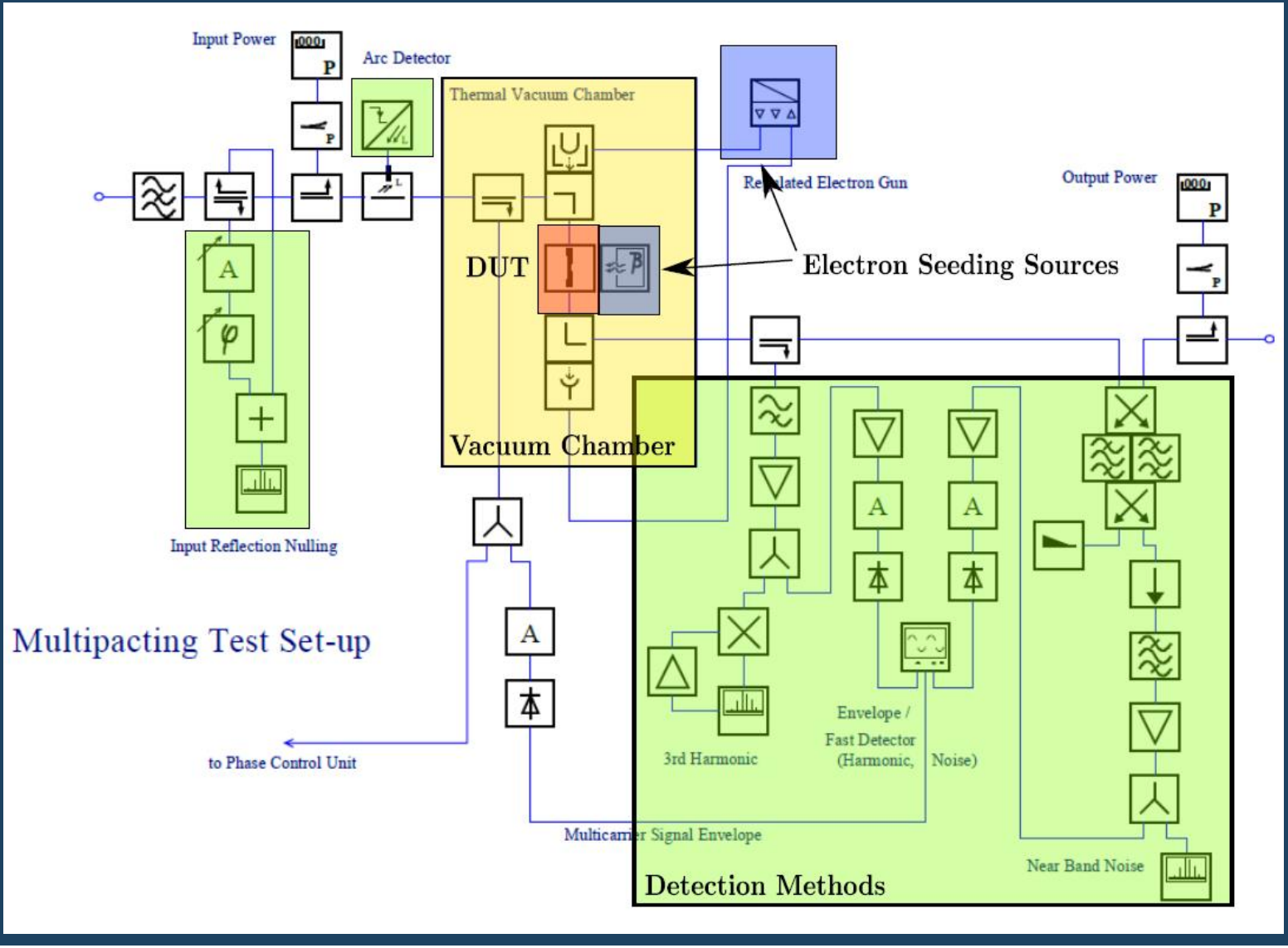


TEST

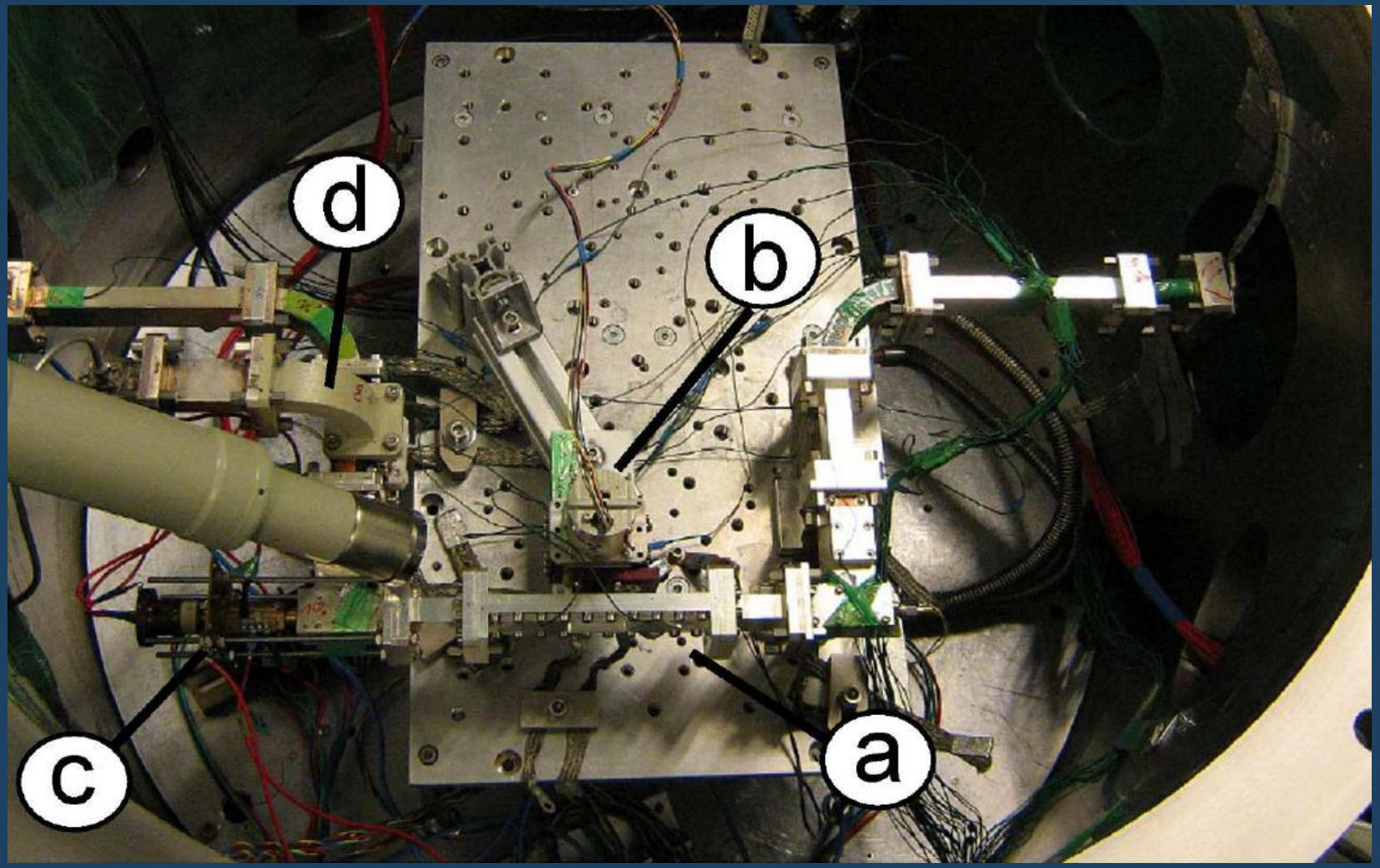
Feed input power to Device Under Test and measure multipactor.

- Provide vacuum environment (<10^{-8} bar)
- Provide artificial electron seeding
- Must be very sensitive and continuously monitorized (DUT can be damaged).
- Increase power in steps. Wait a minimum of 10 minutes.

TEST


Input Power
Arc Detector
Thermal Vacuum Chamber
Output Power
DUT
Electron Seeding Sources
Vacuum Chamber
Input Reflection Nulling
Multipacting Test Set-up
to Phase Control Unit
3rd Harmonic
Envelope /
Fast Detector
(Harmonic,
Noise)
Multicarrier Signal Envelope
Near Band Noise
Detection Methods

TEST



TEST

Signal generators and power amplifiers:

- Continuous wave / pulsed mode: Typ. 5% Duty Cycle
- Usually un-modulated signals.

Electron sources

- Radioactive sources (Sr90)
- UV light
- Electron gun

Detection methods

- Local: Electrometer, Photodetector
- Global: Third harmonic, reflection nulling.


THANK YOU!