Multipacting in RF Structure

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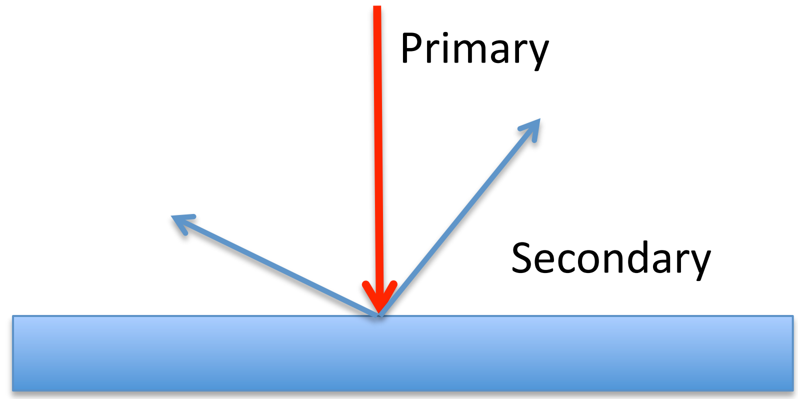
USPAS "Fundamental Accelerator Physics", June 2014

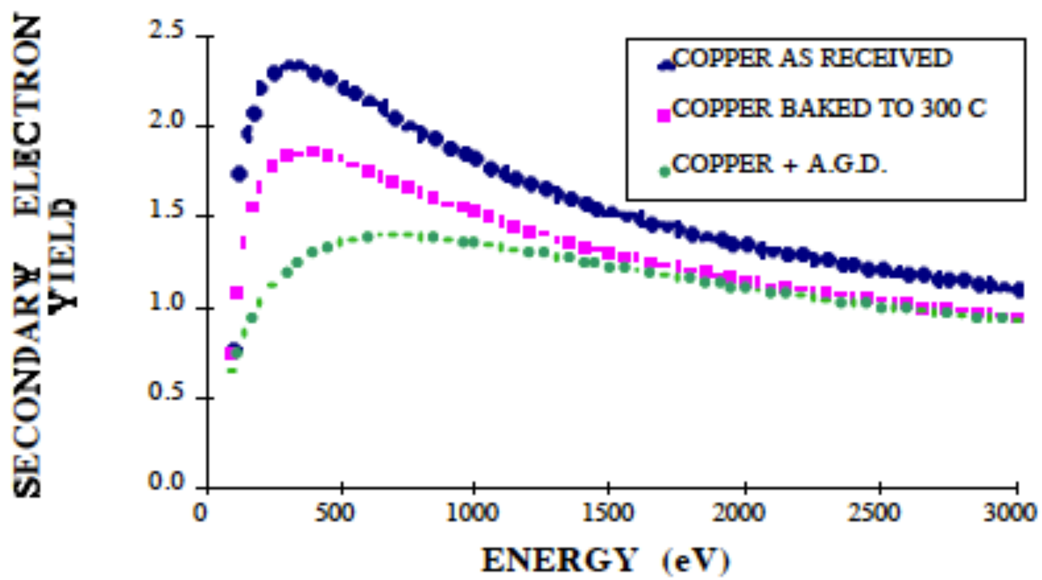
Secondary Electron Emission

- Secondary emission is a phenomenon where primary incident particles of sufficient energy, when hitting a surface or passing through some material, induce the emission of secondary particles.
- For secondary electron emission: the number of secondary electrons emitted per incident particle is called **secondary emission yield (SEY).**



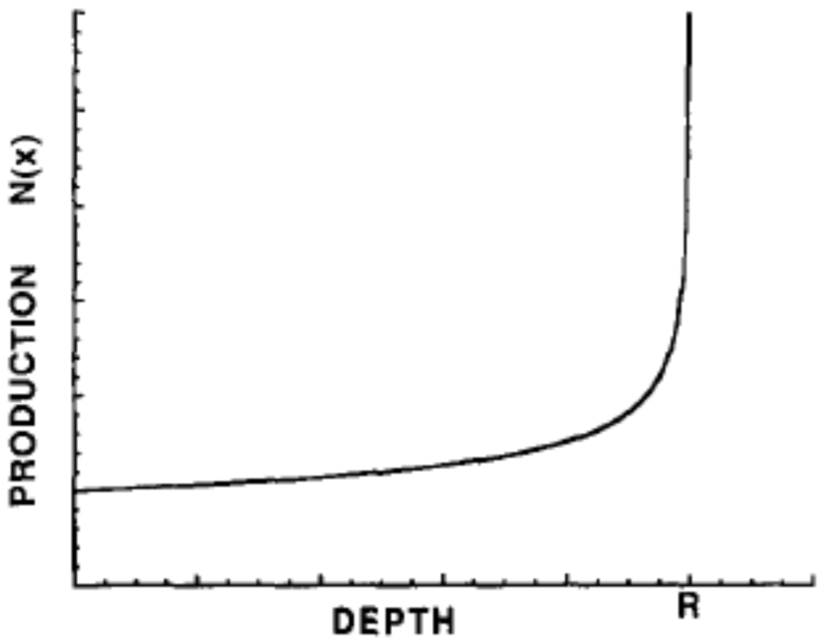
SEY depends on the material and surface condition.

When SEY > 1, more secondary electron emitted out than primary electron.



Secondary Electron Emission

- Three Steps of Secondary electron emission:
  - Production of internal secondary electrons by kinetic impact of the primary electrons.
  - transport of the internal secondary electrons through the sample bulk toward the surface
  - escape of the electrons through the solid-vacuum interface.

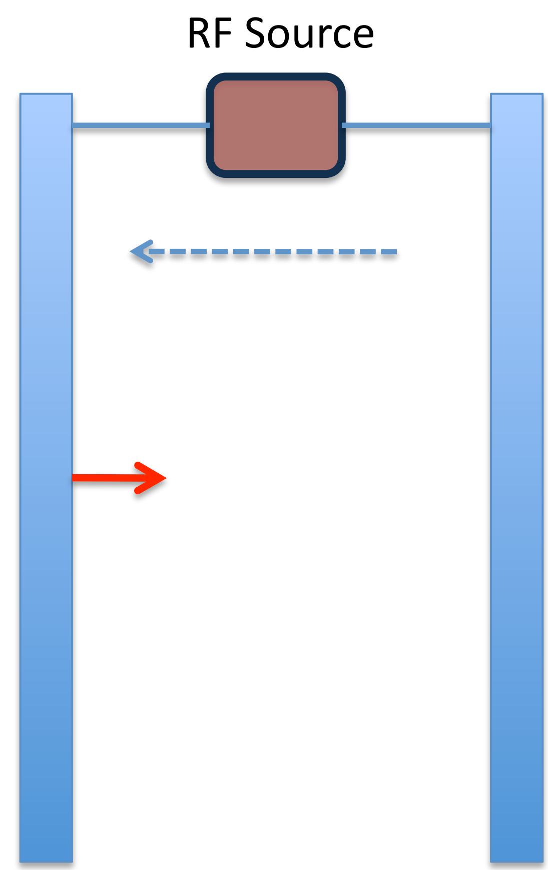


Most internal secondary electrons is generated at the end of its penetrating path.

The higher the primary E, the deeper the penetrating depth, thus harder for the internal secondary electron to escape the surface.

Multipacting

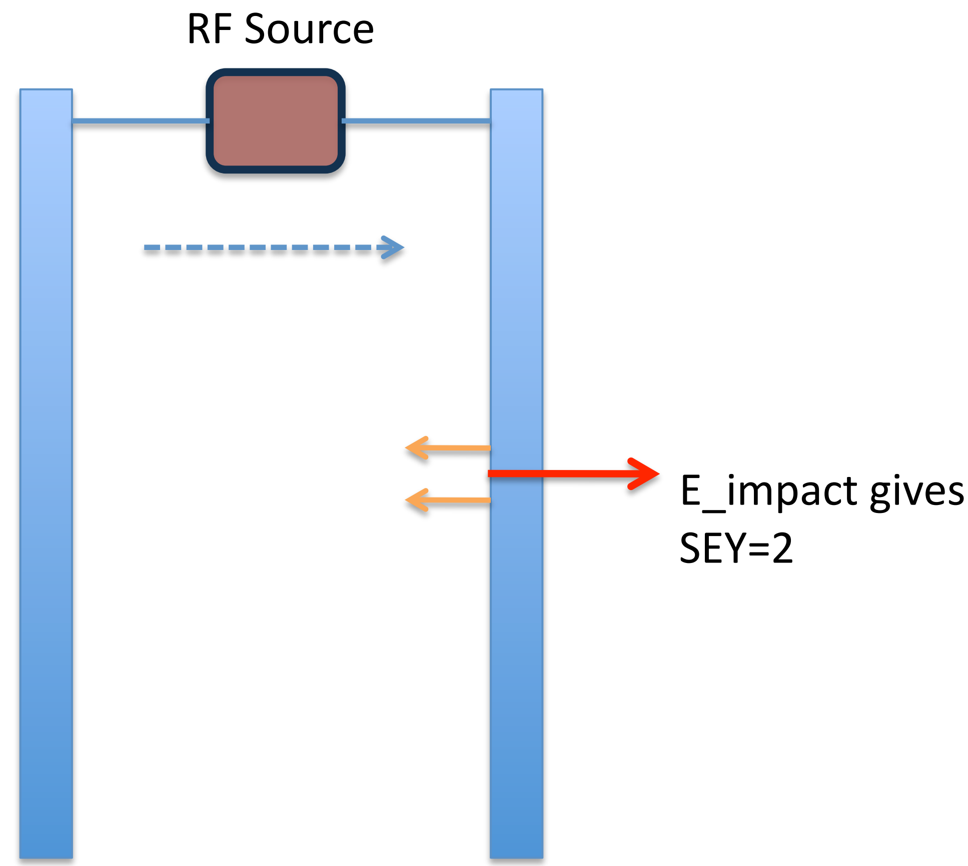
- Multipacting : multipling impacts



A parallel plates connected to a RF power source.

Multipacting

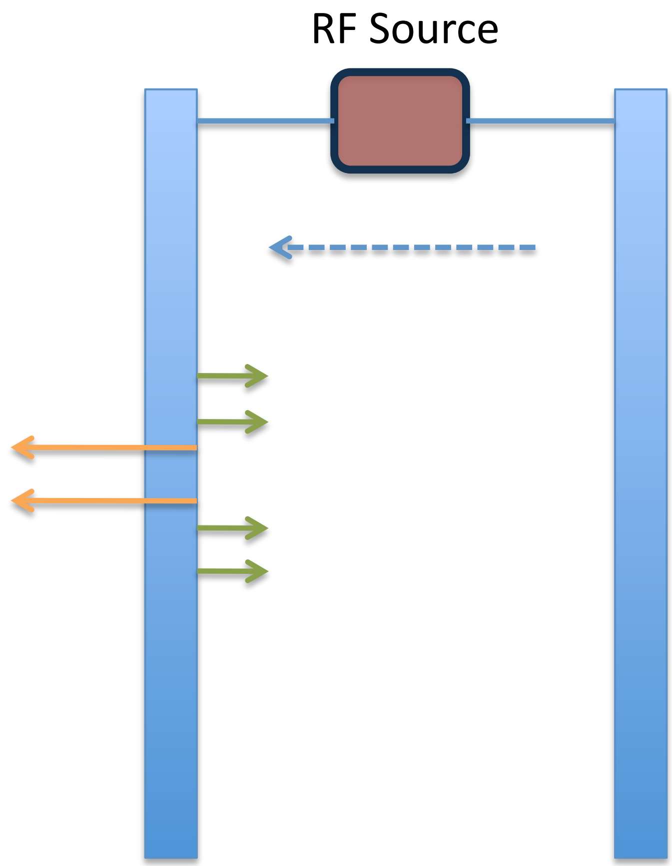
- Multipacting : multipling impacts



A parallel plates connected to a RF power source.

Multipacting

- Multipacting : multipling impacts



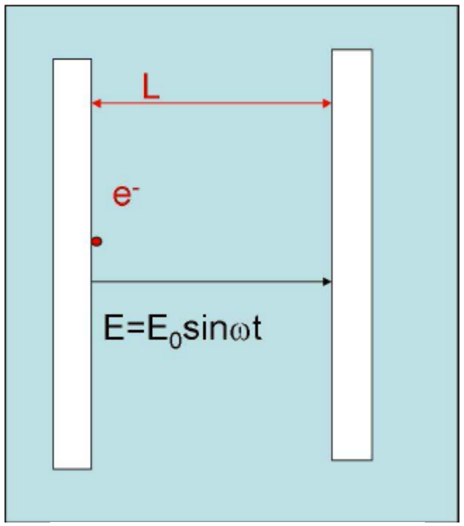
A parallel plates connected to a RF power source.

Multipacting

- Multipacting (MP) is a resonant RF electron discharge in vacuum with electron multiplication due to the secondary electron re-emission process.
- To have multipacting one need the occurrence of two conditions:
  - electron synchronization with the RF fields: the time interval between two impacts is an integer of half RF period.
  - electron multiplication via secondary: SEY >1 (even slightly), with right impact energy.

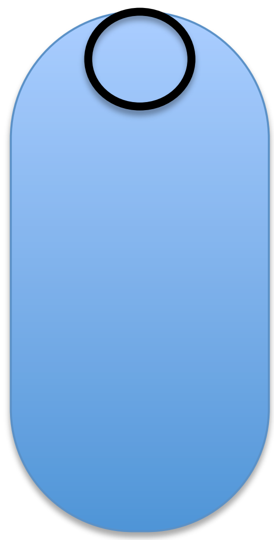
Solve MP Analytically

For simple geometry, sometimes with proper approximation, we can solve the resonant trajectory of MP analytically.

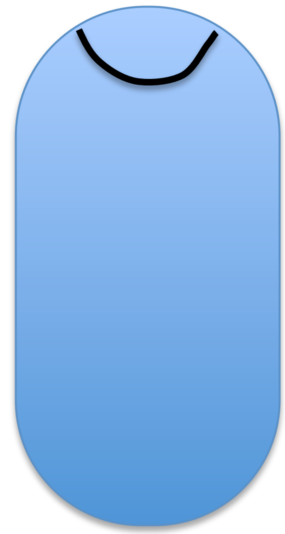


$$\ddot{x} = \frac{eE_o}{m_o} \sin \omega t \,.$$

$$t = \frac{T}{2}(2n-1) = \frac{1}{2\nu}(2n-1) = \frac{\lambda}{2c}(2n-1)\,,$$



$$\frac{1}{T \cdot n} = \frac{\upsilon}{n} = \frac{eB_0}{2\pi m_0} \,.$$



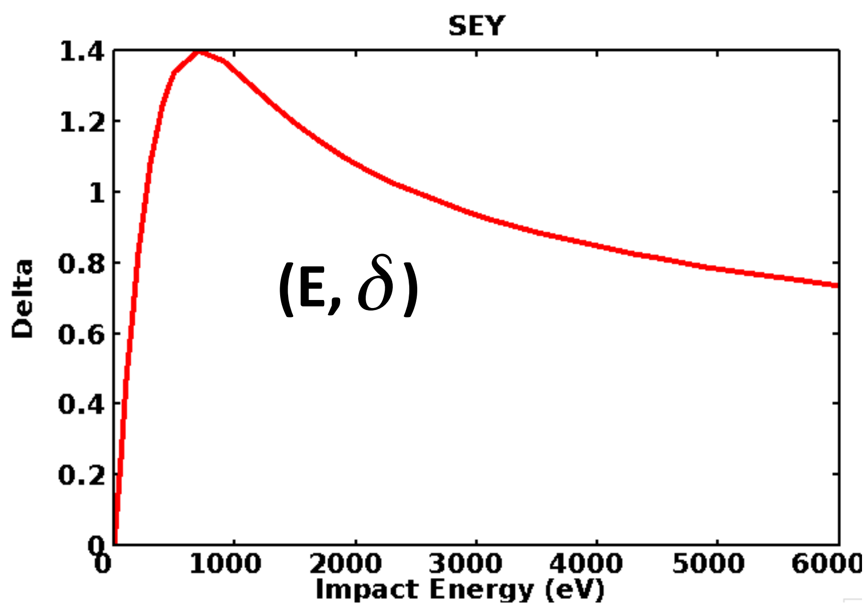
$$\frac{2}{T \cdot (2n-1)} = \frac{2\upsilon}{2n-1} = \frac{eB_0}{2\pi m_0} \,.$$

Solve MP Numerically

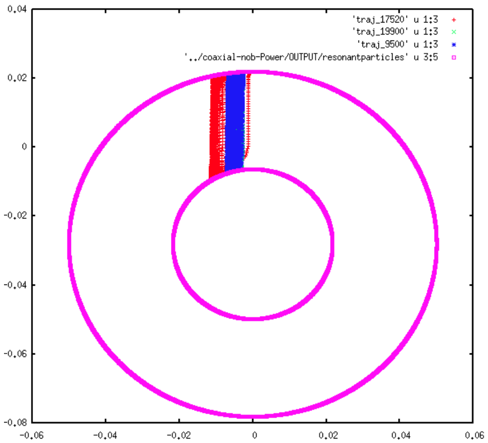
- Numerical simulation tools: FishPac (2D), CST Particle Studio (3D), SLAC ACE3P (3D).
- Solve the RF field in the structure.
- Track electrons' motion in the time varying RF field, adding any external static E or B field, and identify the resonant trajectories and impact energy.
- With the material SEY information, one can indentify the multipacting.

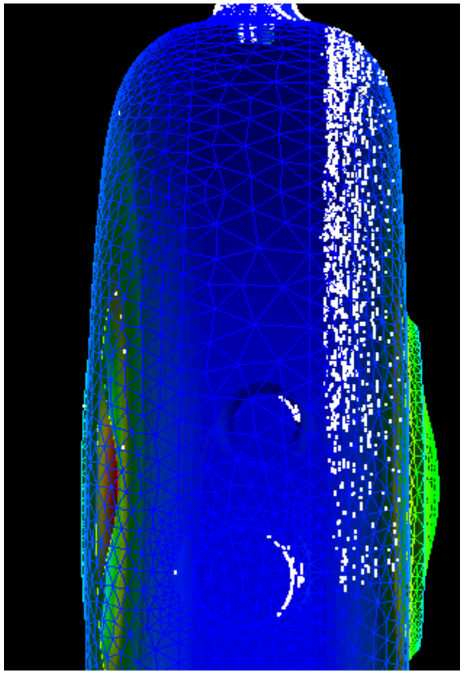
Enhancement Counter:

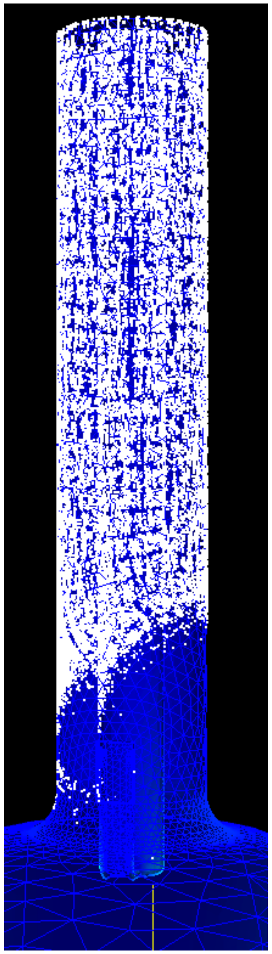
$$EC = \delta_1 * \delta_2 * ... * \delta_m$$

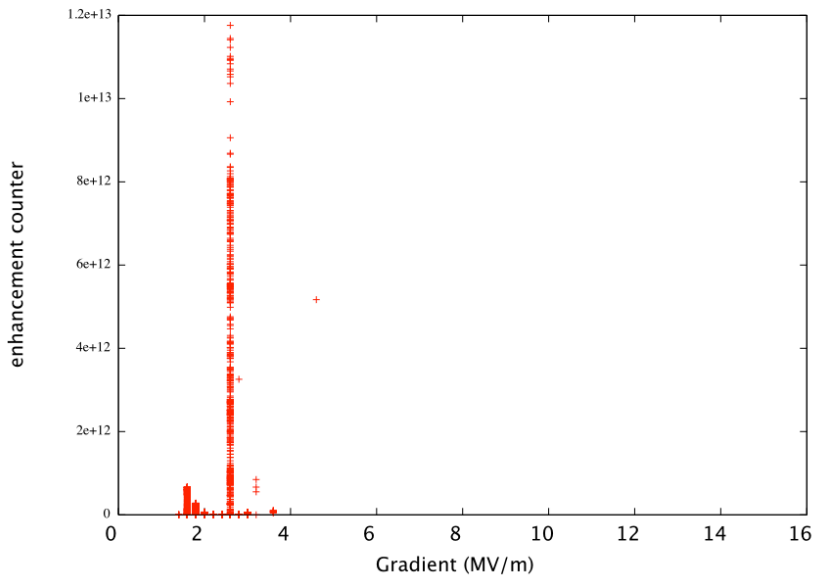


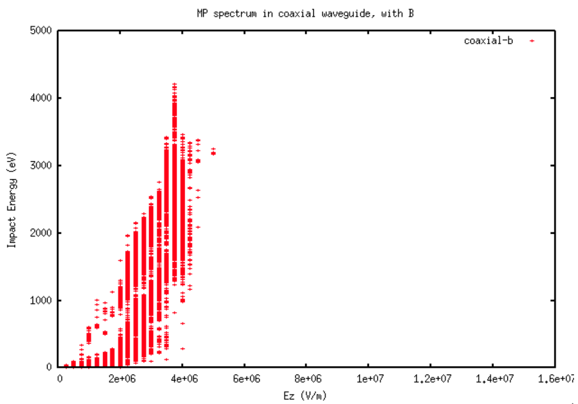
Solve MP Numerically









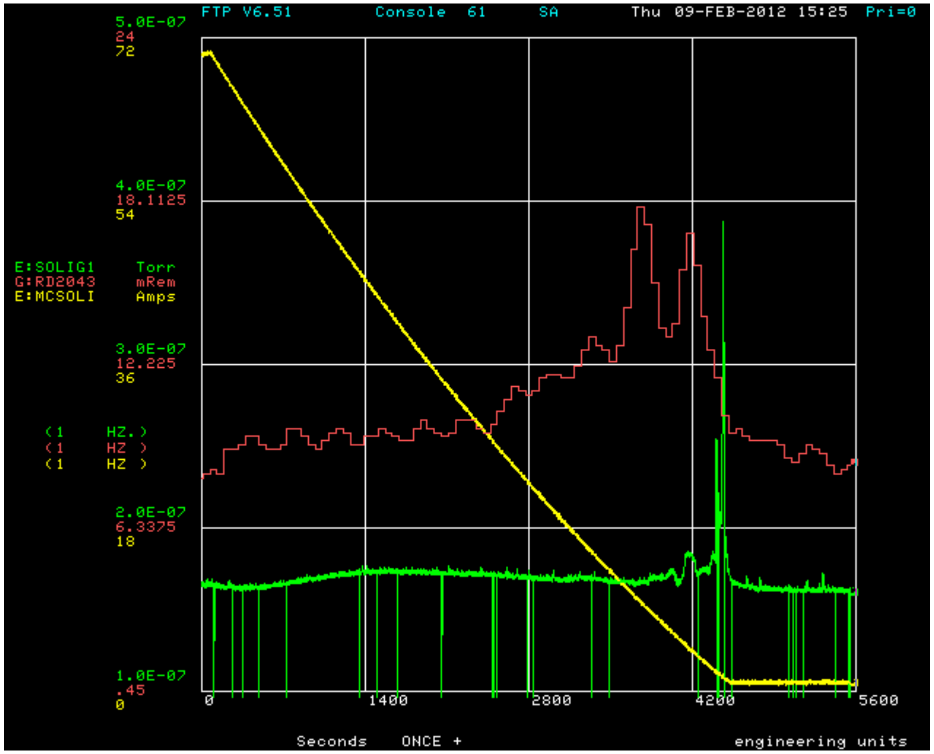


Possible Damage from MP

- Heating.
- Out gassing: vacuum loss.
- Change the coupling: power reflection.
- Energy absorption: can't increase the voltage.
- Sparking, RF breakdown.
- Severe damage of cavity, unrecoverable.
- CW and superconducting RF cavity are especially vulnerable to MP.

RF cavity test at Fermilab MTA, from Al Moretii

Yellow Mag I eq. 0.391T/Unit, ***Red*** – radiation mRem/hr
Green – vacuum In Torr. E-7, The X axis is time in sec.



How to Suppress MP

- Improve the RF structure design.
- Add external static E or B field.
- Cavity surface treatment: baking, Argon Glow Discharge, TiN coating etc, to lower the surface SEY.