Multipacting Simulation for the PITZ RF Photo Gun

- The PITZ RF Photo Gun
- Multipactor discharge
- Field simulations
- Tracking simulation results
- Conclusions and outlook

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HELMHOLTZ GEMEINSCHAFT

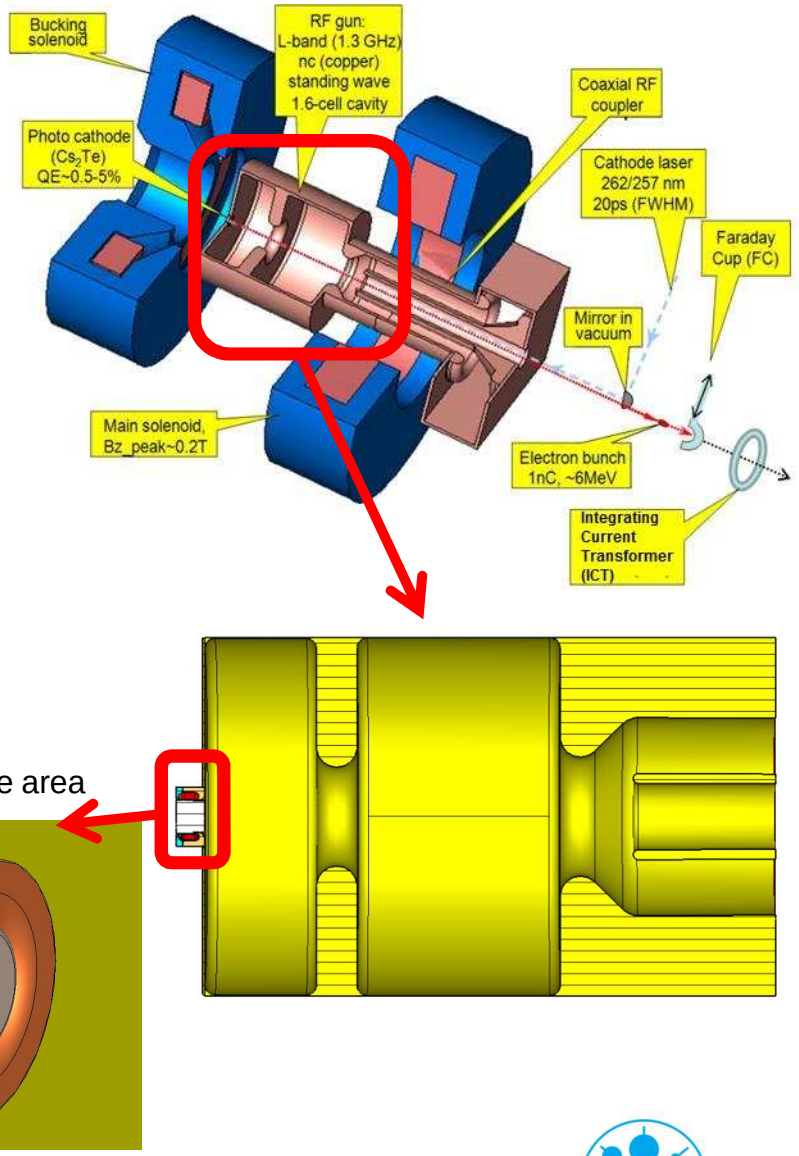
DESY

The PITZ RF Photo Gun

The RF photo gun operates with a standing wave regime in the π-mode with resonant frequency of 1.3 GHz

The gun consists of:

- normal-conducting cavity (1.6 copper cells)
- exchangeable molybdenum cathode with CuBe contact spring
- pair of solenoids



Main parameters

Accelerating gradient at the cathode, MV/m	60
Beam energy after gun, MeV	~6.8
Full RF power, MW	8
Number of bunches	1..700
RF pulse, µs	≤800
Repetition rate, Hz	10

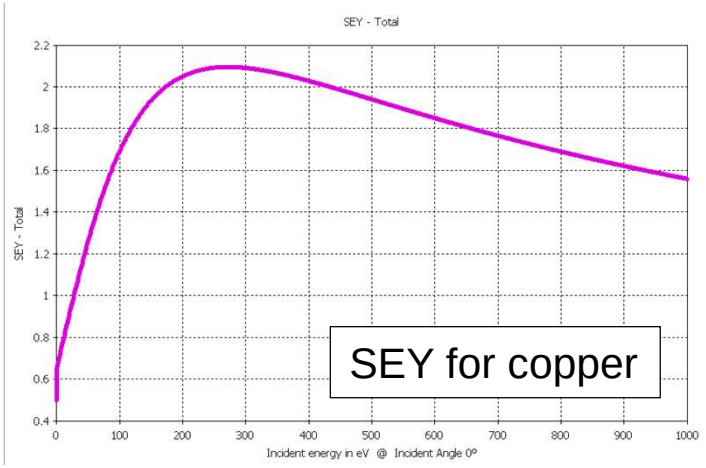
Multipactor discharge

Multipactor discharge (multipacting) is the phenomenon of a resonant secondary electron emission which occurs at certain conditions.

Multipactor discharge depends on:

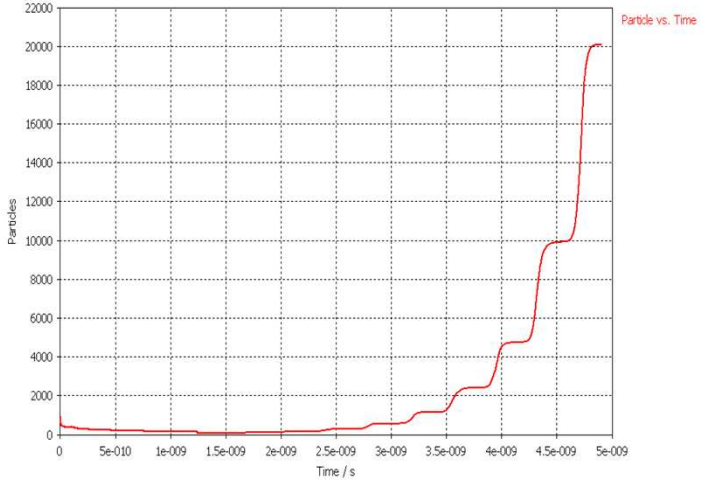
- ✓ Field configuration
- ✓ Cavity geometry
- ✓ Secondary emission yield (SEY) of the cavity material

Multipactor discharge corresponds to an exponential growth in number of electrons

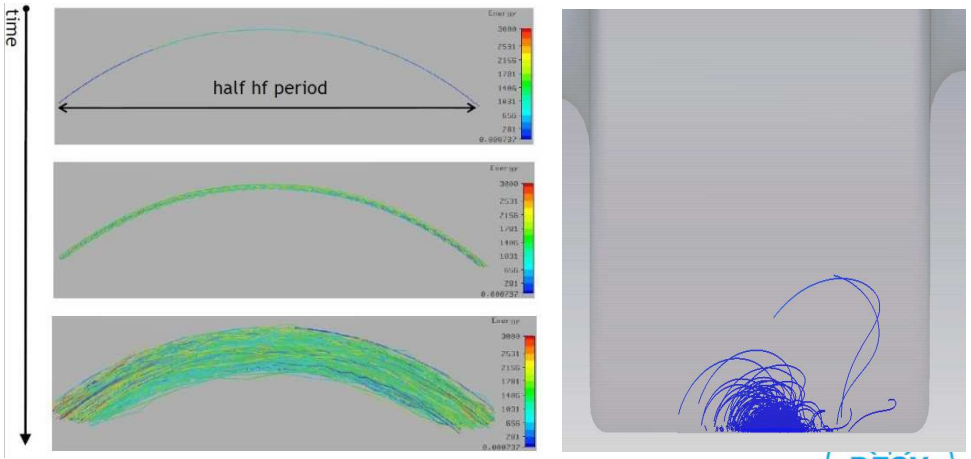


Example of multipactor discharge

Exponential growth in number of electrons



Example of multipactor trajectories



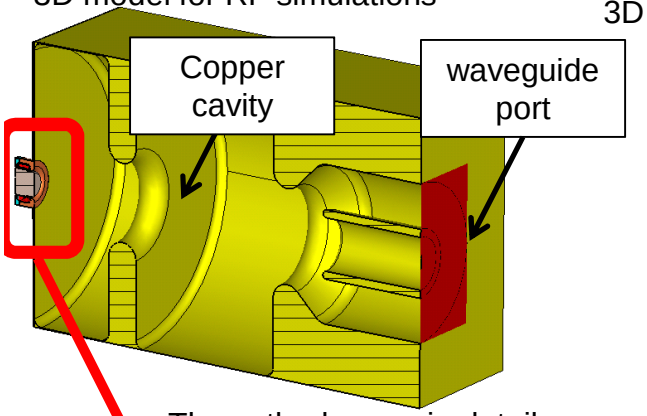
Simulation strategy

- RF fields simulation was done by CST MW Studio
- External constant magnetic field simulation by CST EM Studio
- Particle trajectories simulation by CST Particle Studio with imported fields from CST MW and EM Studios

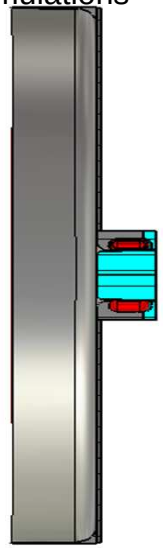
Simulation stages

a) Multipacting simulations for the cathode area

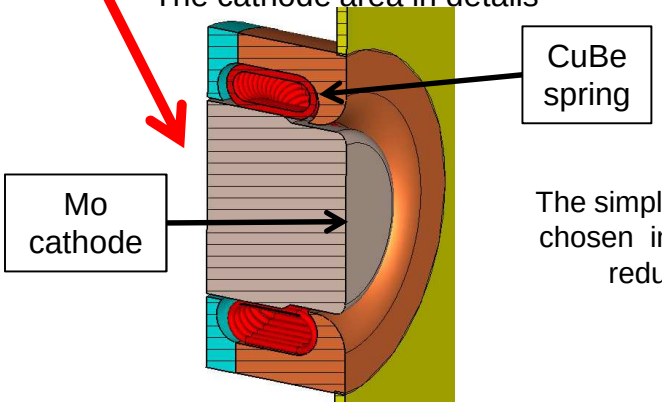
3D model for RF simulations



3D model for tracking simulations



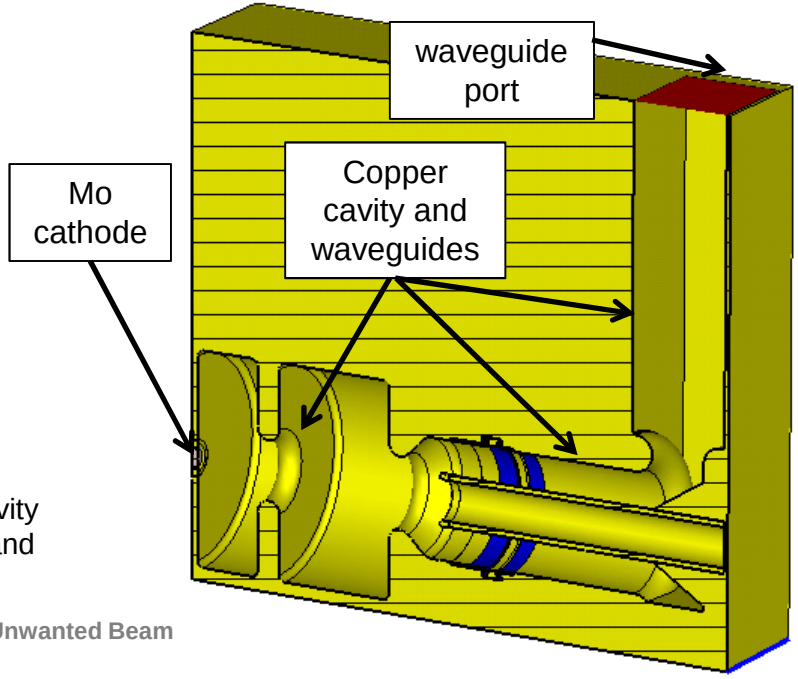
The cathode area in details



The simplified model of the gun cavity chosen in order to save memory and reduce computational time

b) Multipacting simulations for the gun cavity and the gun coupler

3D model of the gun cavity and the gun coupler with simplified cathode area (no spring and shortcut at cathode) for RF simulations

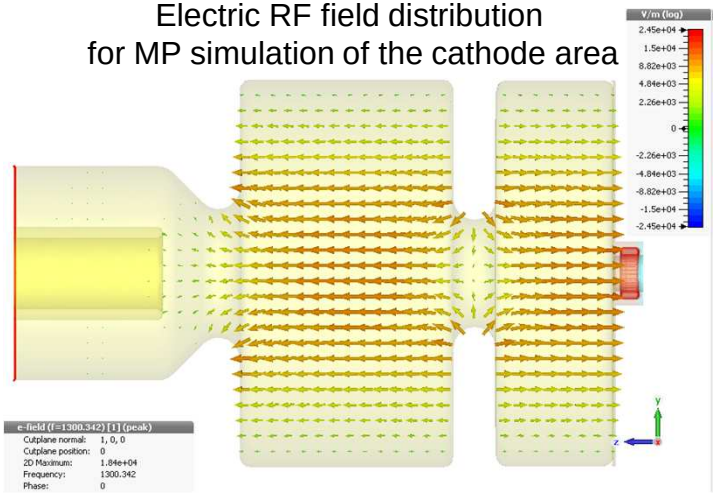


RF and external magnetic fields simulation

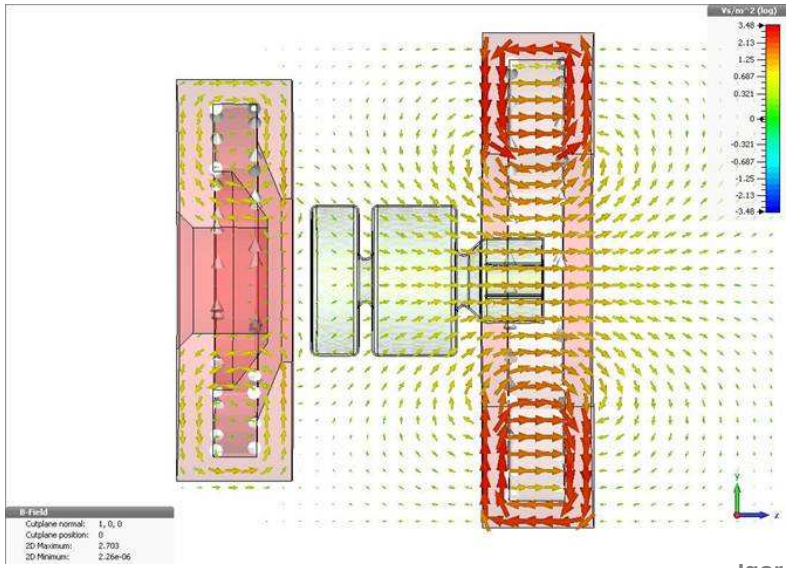
1. RF field simulations (CST MWS):
   - Frequency domain solver (F-solver)
   - Tetrahedral mesh
   - Half structure symmetry

2. External magnetostatic fields (CST EM):
   - Magnetostatic solver (Ms-solver)
   - Hexahedral mesh (2 600 000 per ¼)
   - Currents: I_{main} = 350 A, $I_{bucking}$ = -29 A

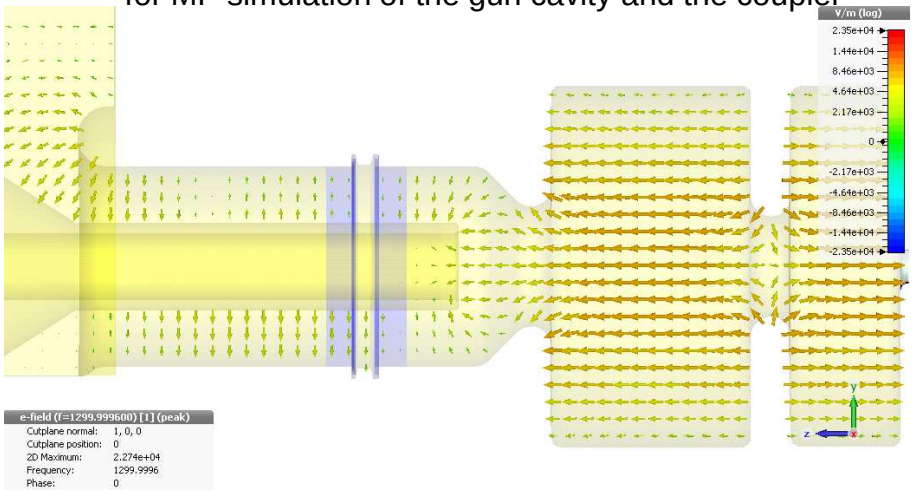
Electric RF field distribution
for MP simulation of the cathode area



Magnetostatic field distribution

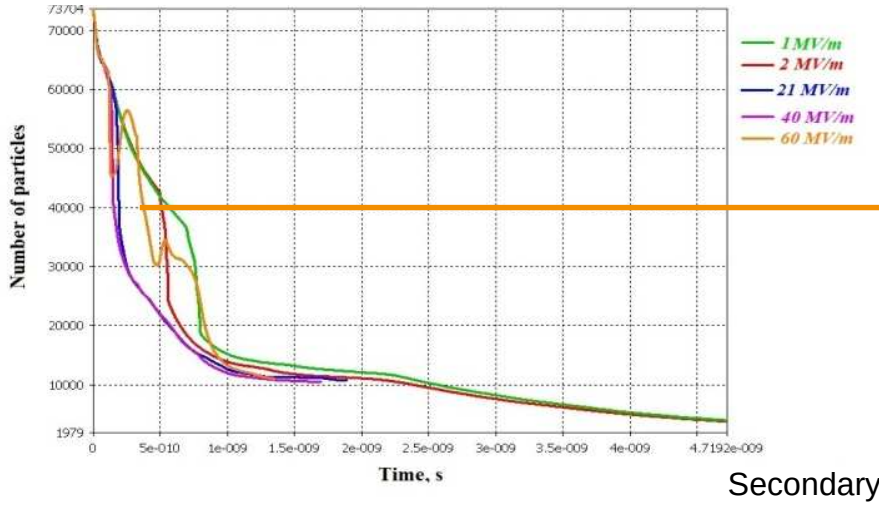


Electric RF field distribution
for MP simulation of the gun cavity and the coupler

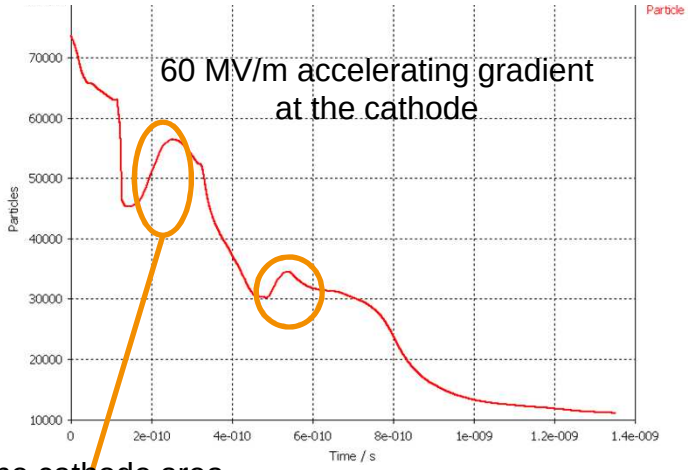


Multipacting simulations for the cathode area

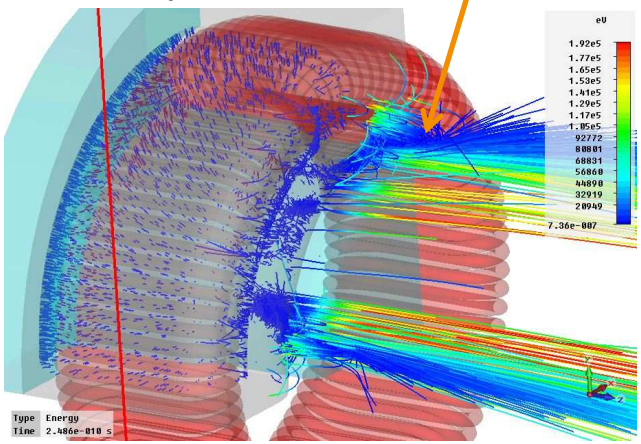
The number of particles as a function of time



The number of particles as a function of time



Secondary electrons in the cathode area



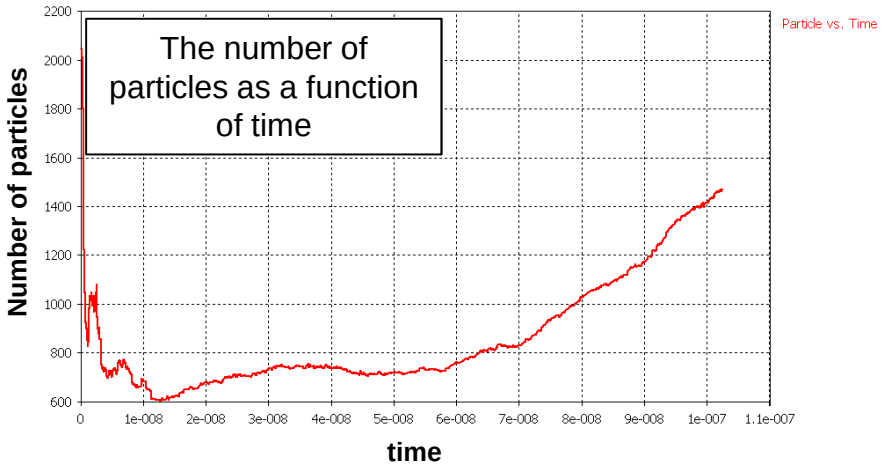
High probability for the secondary electron emission between the cathode and the blending part of the outer cylinder but

There is no continuous growth in the number of particles

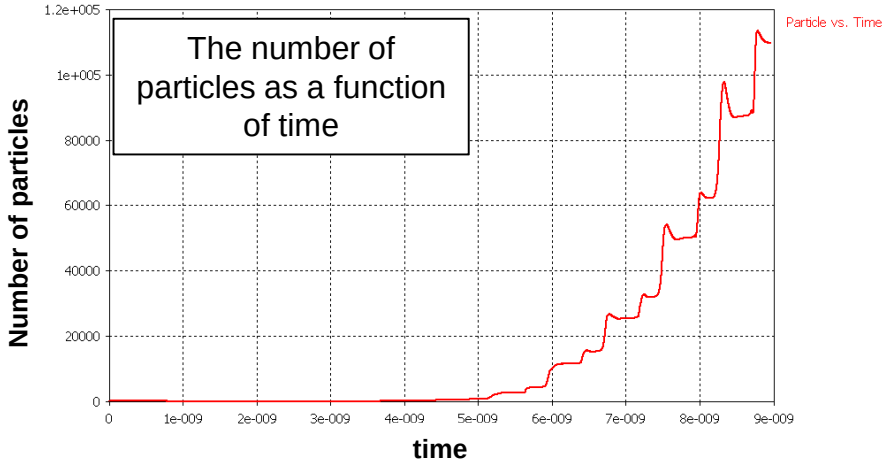
Multipacting simulations for the gun cavity and the gun coupler

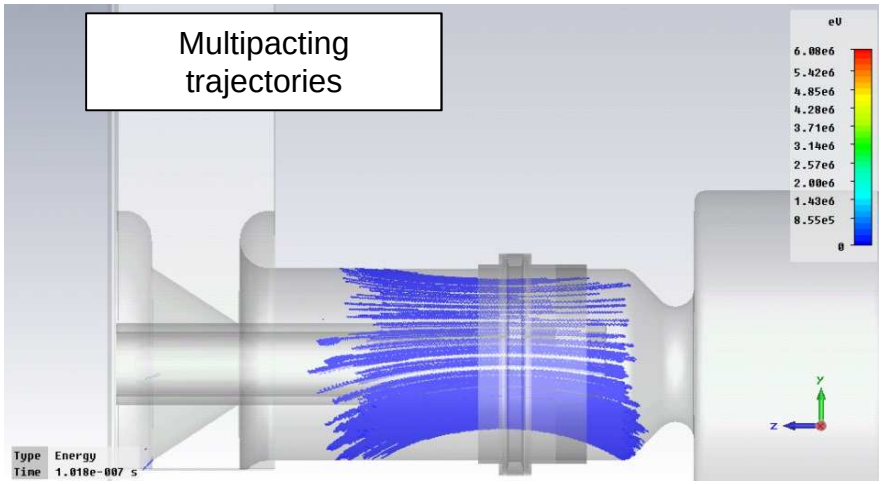
Multipacting trajectories observed at accelerating gradient at the cathode of 60 MV/m (~6.5 MW power in the gun)

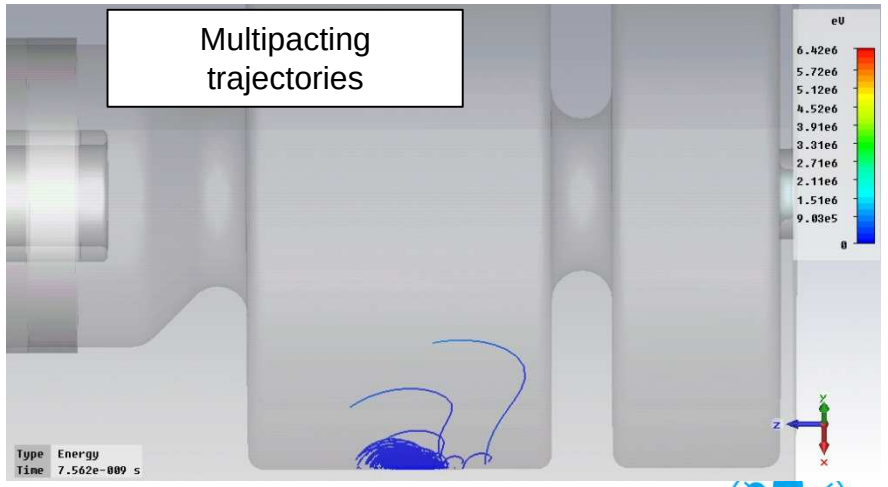
Multipacting trajectories inside the coaxial waveguide (between walls of outer conductor)



Multipacting trajectories inside at the outer cylinder of the gun cavity

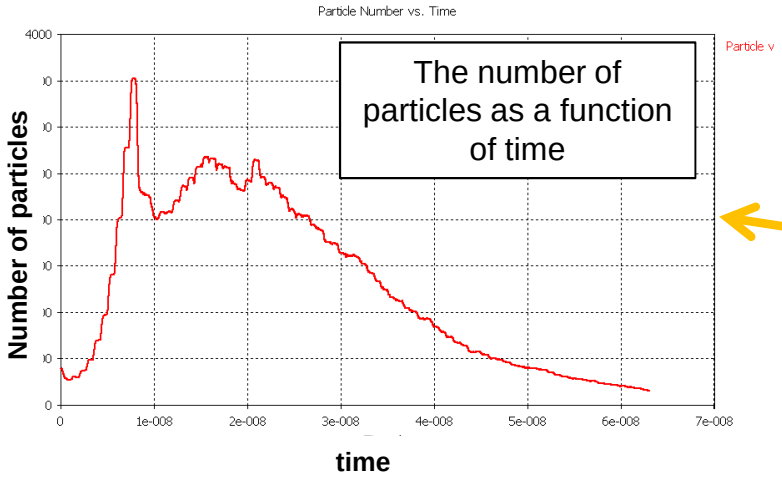






Multipacting simulations for the gun cavity and the gun coupler

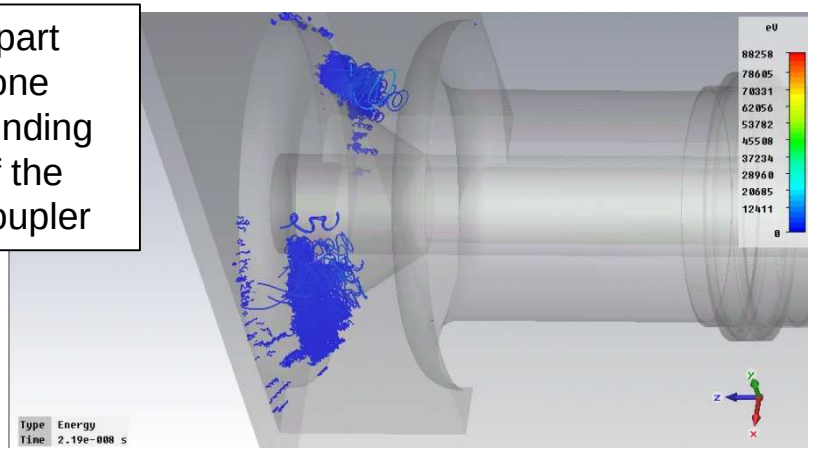
Stable(but not multipacting) trajectories observed at accelerating gradient at the cathode of 60 MV/m (~6.5 MW power in the gun)



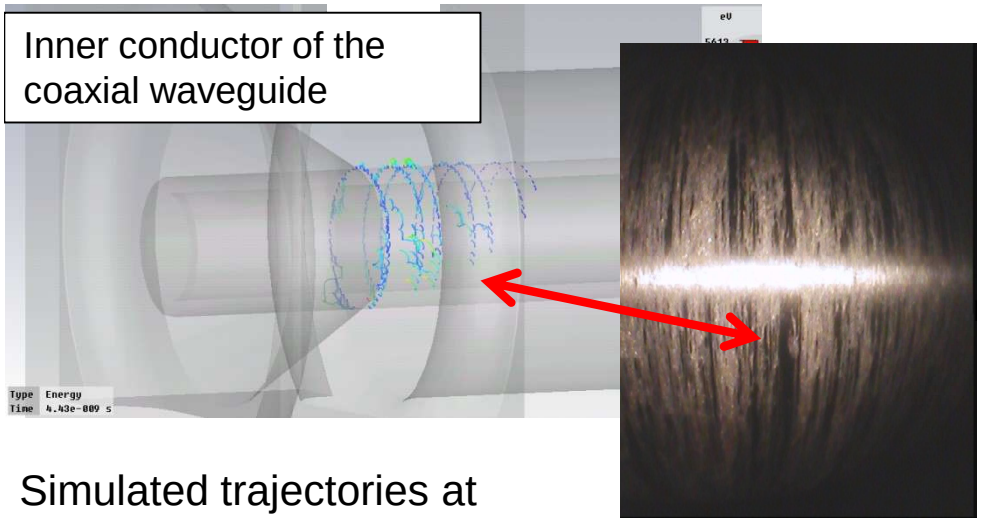
The number of particles as a function of time

Simulations show that stable secondary trajectories can appear in the gun structure for a short time but they are not able to induce multipactor discharge.

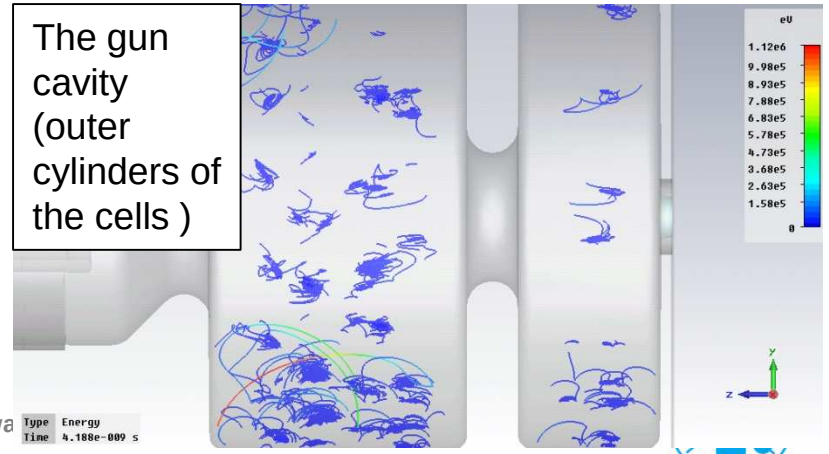
Cone part and cone surrounding part of the gun coupler



Inner conductor of the coaxial waveguide



The gun cavity (outer cylinders of the cells)

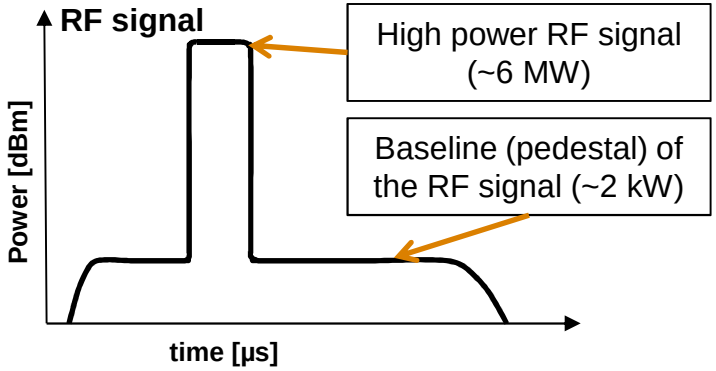


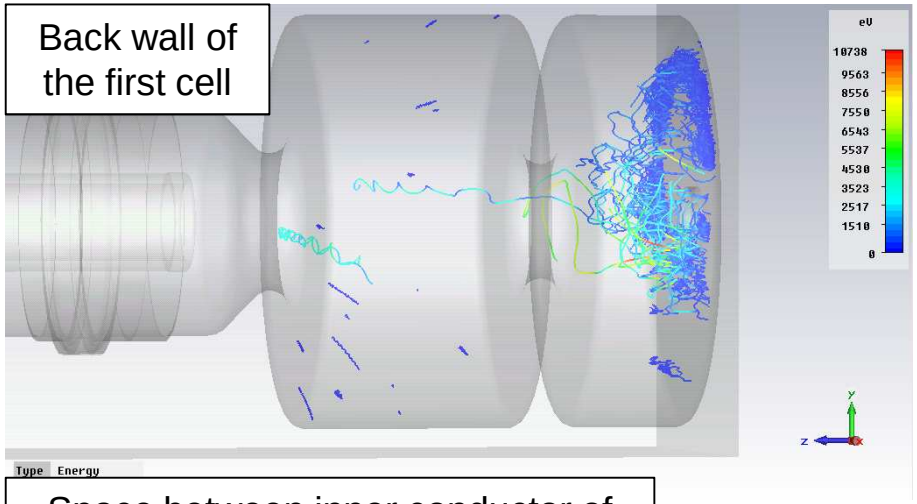
Simulated trajectories at the inner conductor of the coaxial waveguide correspond to the traces observed at the coaxial coupler from the gun3.2

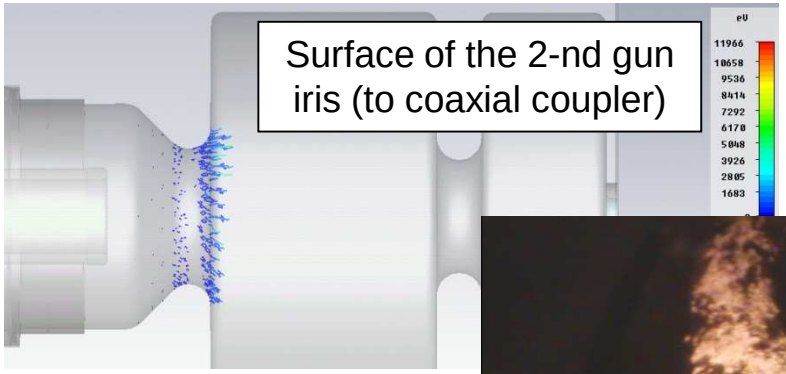
Multipacting simulations for the gun cavity and the gun coupler

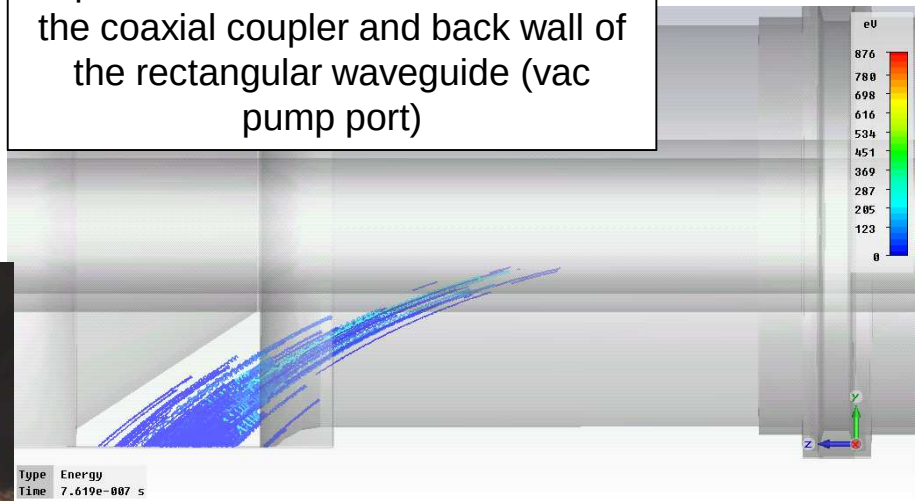
Multipacting trajectories observed at accelerating gradient at the cathode of 1 MV/m (~2 kW power in the gun)

Power level of ~2kW (which corresponds to accelerating gradient at the cathode of 1 MV/m) is the baseline of the RF signal







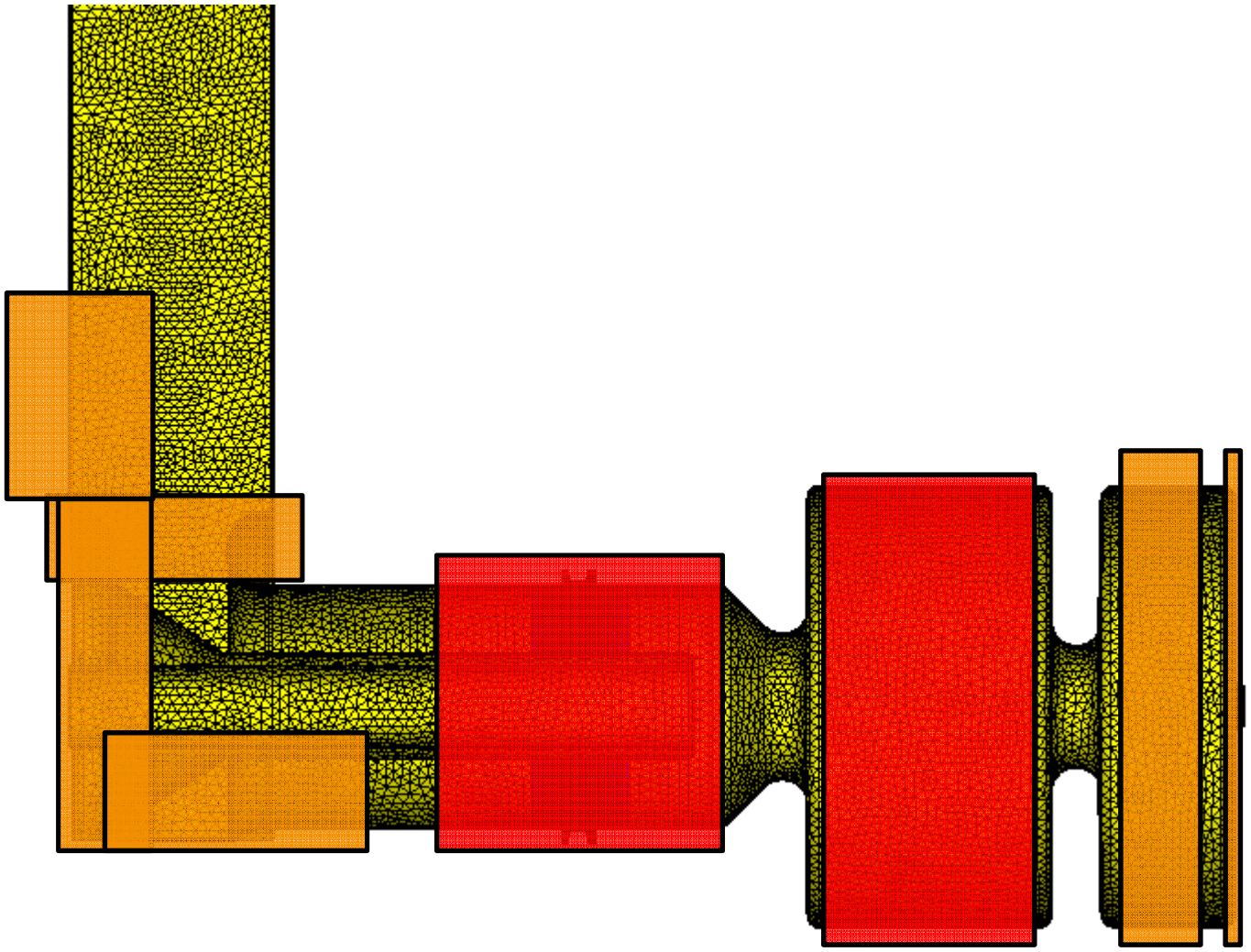


Simulated trajectories correspond to observed traces at the coaxial coupler from the gun3.2

Conclusions and outlook

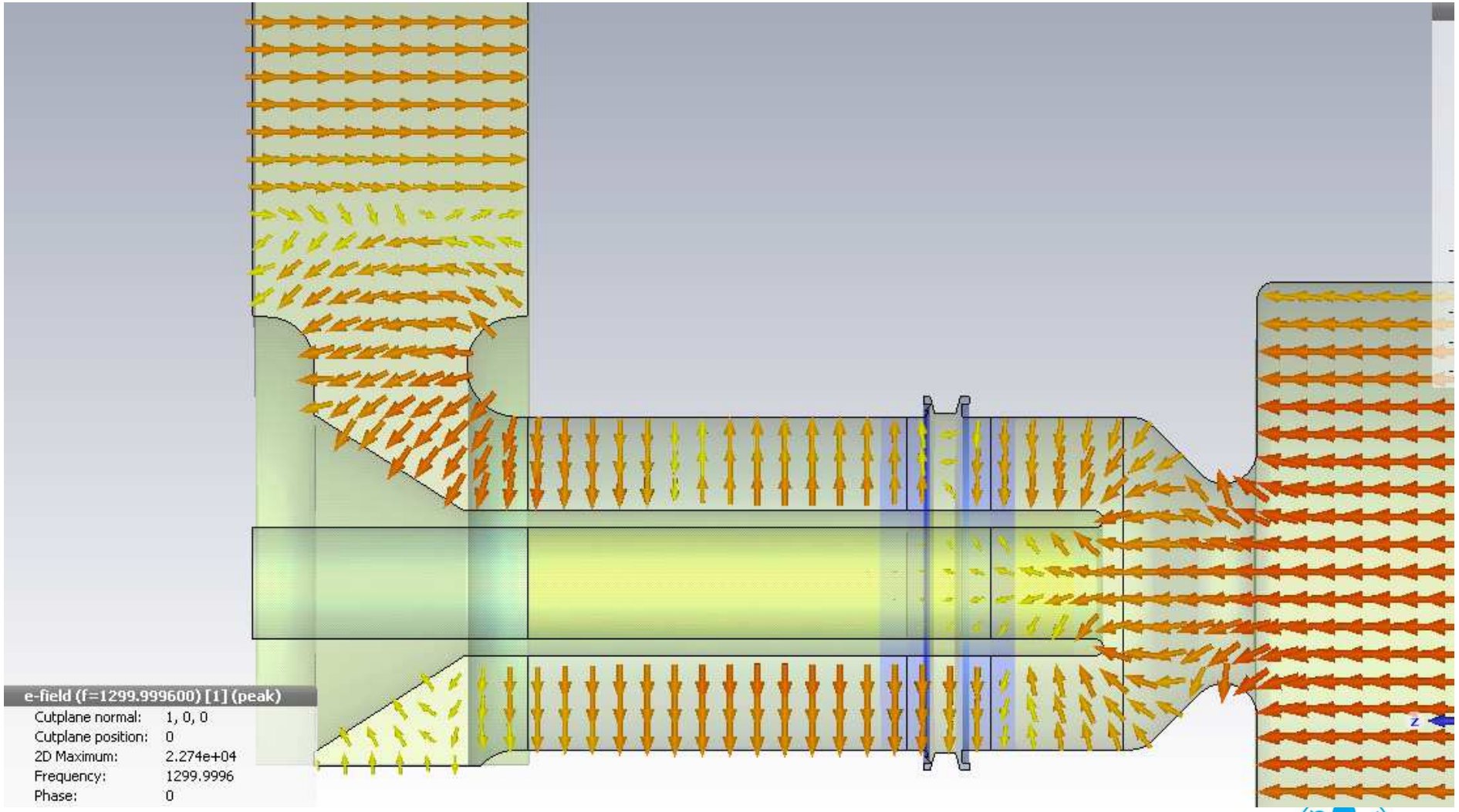
- Multipacting trajectories observed inside the coaxial waveguide and at the outer cylinder of the gun cavity for accelerating gradient at the cathode of 60 MV/m
- For accelerating gradient of 1 MV/m multipacting trajectories observed at the surface of the 2-nd gun iris (to coaxial coupler), the back wall of the first cell and space between inner conductor of the coaxial coupler and back wall of the rectangular waveguide
- There is no monotonic growth in the number of particles at the cathode area. However, the area between the cathode and the blending part of the outer cylinder undergo the secondary electron emission at operating levels of the accelerating gradient of about 60 MV/m
- Stable but not multipacting trajectories observed in the gun cavity and the gun coupler parts. Such particles can not induce constant growth of number of electrons but nevertheless could be a reason of surface damage if there exist strong additional particle source
- Additional calculations are needed to investigate all possible resonant conditions of multipactor discharge in the PITZ RF photo gun

Thank you for your attention.



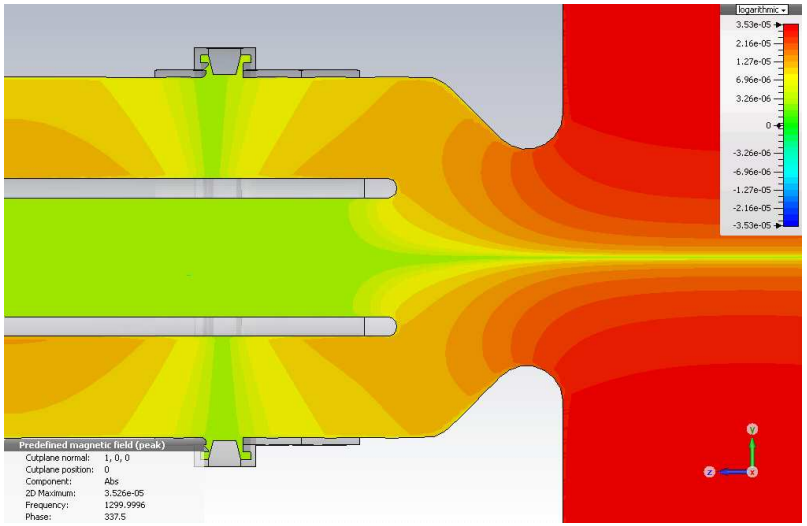
RF field asymmetry in the PITZ RF photo gun

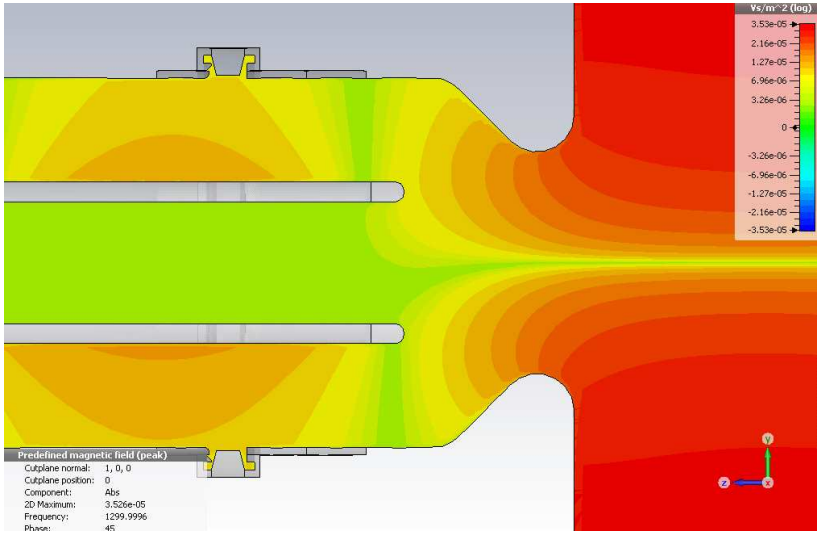
E-fields, x-cut plane
Phase=0 deg

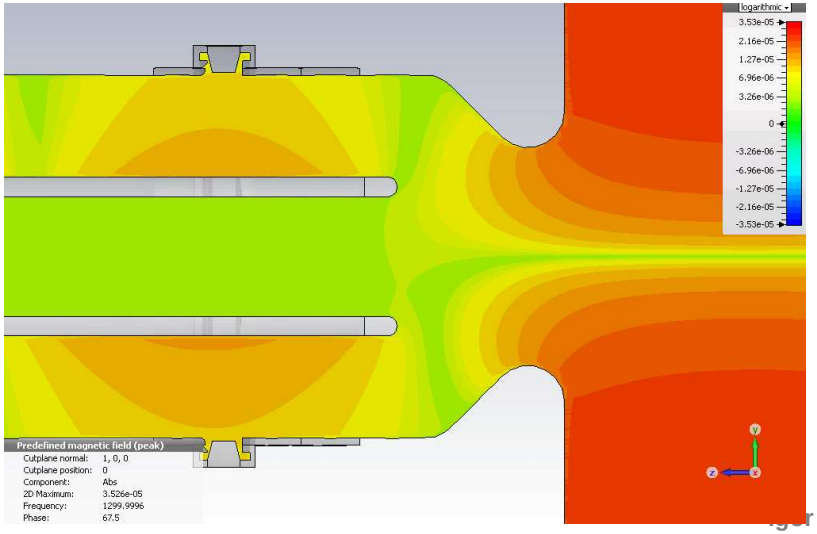


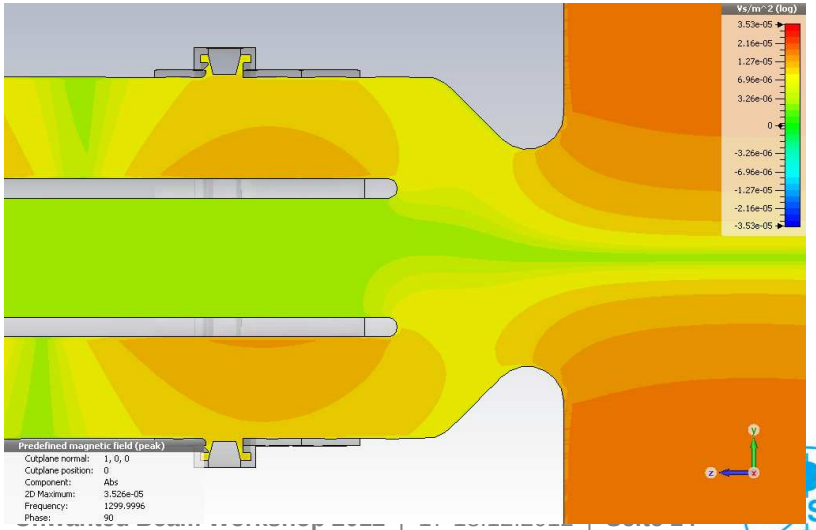
RF field asymmetry in the PITZ RF photo gun

RF H-fields, abs component, x-cut plane









Gun 3.2 visual inspection, done on 13.06.2008