TWO AND THREE DIMENSIONAL SIMULATIONS OF DARK CURRENT IN TESLA-CAVITIES

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ABSTRACT

The current development of Linear Colliders trying to reach higher accelerating gradients involves new effects which have to be studied carefully. One of them is the generation of field- and secondary-emitted electrons from the cavity walls which can cause severe problems during operation. Those electrons may produce additional heatup in the cavity walls, and hence some undesired effects may occur, if they are accelerated as "dark current" through the Linear Collider. In the case of super-conducting material, which is used for the TESLA-cavities, the super-conductivity can be destroyed by impacting particles due to quenches.

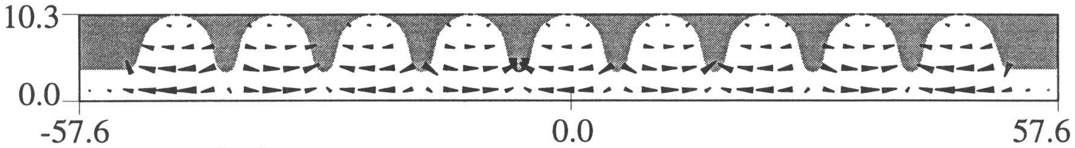
In this paper we present dark current simulations for the TESLA-cavities. The electrons were emitted from the super-conducting material at different phases of the accelerating mode. The trajectories were calculated for several accelerating gradients without space charge effects. From this the deposited thermal energy inside the cavity walls as well as the dark current rate are determined. In the region of the input coupler unsymmetric effects are studied with three dimensional simulations. The simulations were performed using the electromagnetic simulator MAFIA.

INTRODUCTION

Future e^+e^- linear colliders must provide a center of mass energy in the range of 0.3 to 1 TeV to be of interest for high energy physics. Today several possibilities to build such a linear collider are under investigation, which mainly differ in the operation frequency. At Deutsches Elektronen Synchrotron (DESY) the feasibility of a superconducting solution is studied (TESLA [1]). To achieve the desired collision energy the aim is to realize an accelerating gradient as high as possible. The probability of field emission at the surfaces increases with field gradient. In this paper we study possible effects caused by field emitted electrons from the irises.

For the examination of rotationally symmetric accelerating tubes the cylindrical coordinate system without azimuthal dependance is suitable (r, z). In that coordinate system the Maxwell's equations are approximated with the FIT-method (Finite Integral Technique [2]). After calculating the accelerating eigenmode, electrons are initialized without velocity at the iris-surface and tracked through the 9-cell-TESLA-structure. As results we evaluate the relative dark current rate at different locations and the dumped energy in the cavities. In the region of the input coupler the azimuthal dependance cannot be neglected. Thus three dimensional simulations (r, φ, z) were performed to obtain an impression on the particle behaviour near the coupler.

TWO DIMENSIONAL SIMULATION



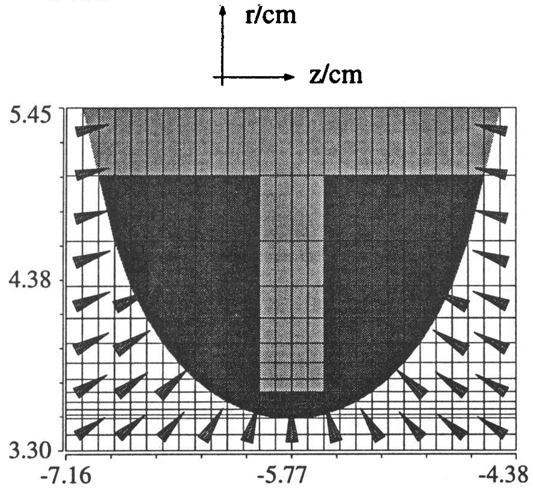


Figure 1: The electric field vector of the the π-mode ($f = 1.3008 GHz$) is shown. This mode is used for the acceleration in TESLA-cavities. The upper plot shows an entire 9-cell structure. On the left hand side the smooth approximation of the cavity-shape by triangular mesh-cells is illustrated. This enables a high precision eigenmode computation [3] and smooth surface fields, which is very important for the electron emission from the surfaces and tracking through the structure.

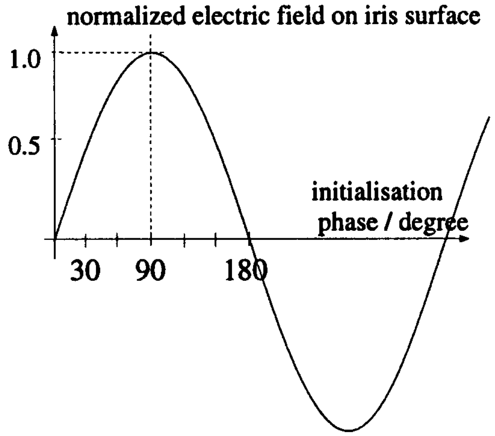


Figure 2: The definition of initialisation phase is illustrated. For phase equal 90 degree the surface field and thus the probability of field emission is largest. Here three different ranges of this phase are considered: (a) 60 to 80 degree (b) 80 to 100 degree and (c) 100 to 120 degree. All the following diagrams are drawn separately for these three cases.

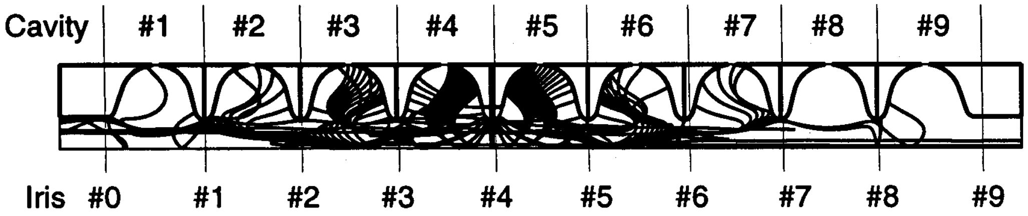


Figure 3: The trajectories of the electrons for an accelerating field gradient of $25 MV/m$ are shown. The particles are initialized at the surface of the 4th iris uniformly between phase 80 and 100 degree. The irises and cavities are numbered as illustrated here. This numbering scheme is used in the following diagrams.

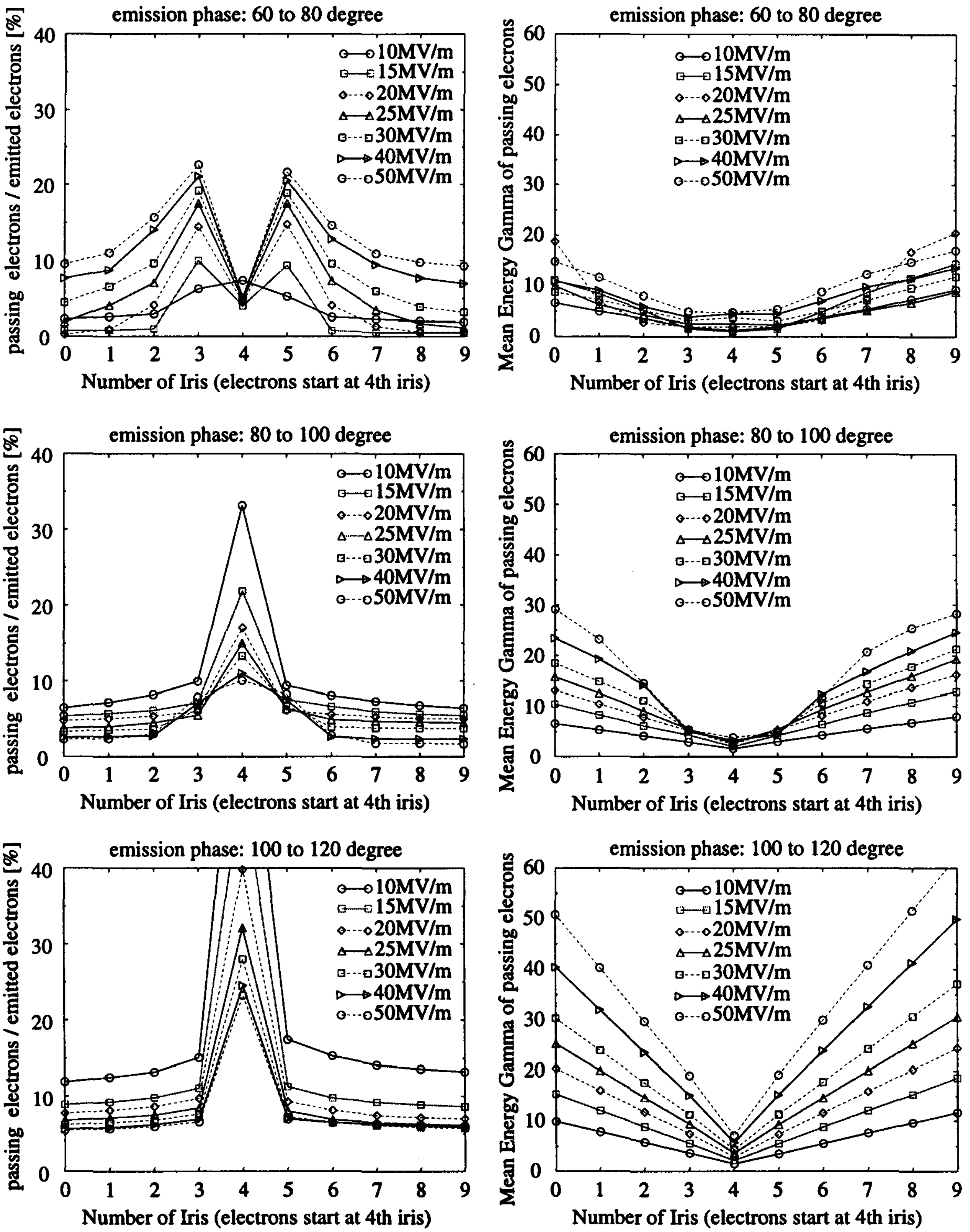
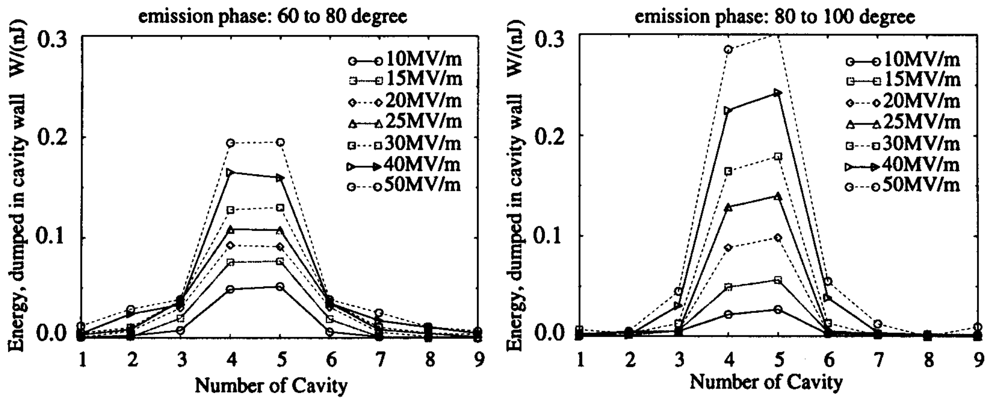


Figure 4: These plots show the results of the simulation. At the 4th iris of a 9 cell TESLA-structure 2000 electrons were emitted, uniformly distributed over time and surface of the iris. The left plots show the percentage of passing electrons at the irises for three different phase ranges (electric field reaches its maximum for the phase of 90 degree). The plots on the right hand side show the corresponding mean energies of the passing particles.



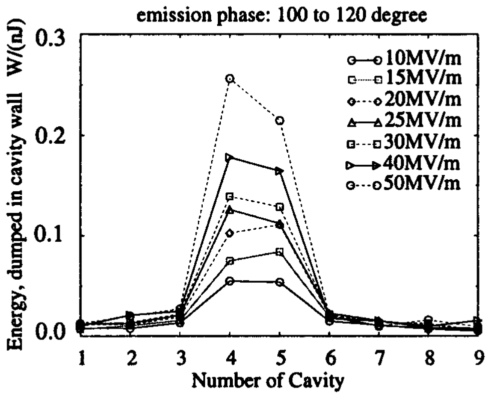


Figure 5: In these diagrams the energy is plotted, which is deposited in the cavity walls due to impacting particles. The energy is given separately for each cavity and for three different ranges of emission times. The values refer to the systematic emission of 2000 electrons at the 4th iris, which is located between the 4th and the 5th cavity.

THREE DIMENSIONAL SIMULATION

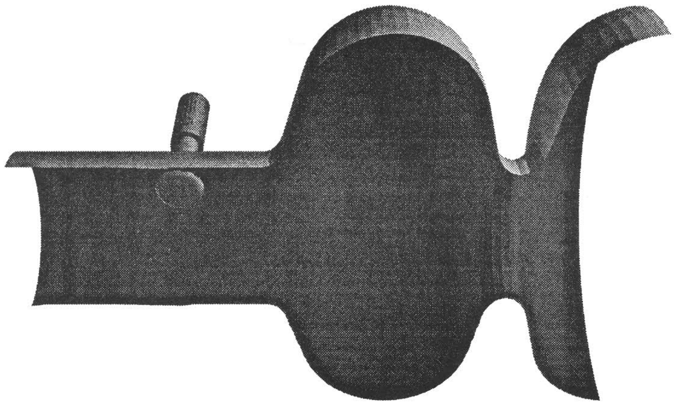


Figure 6: A three dimensional simulation (in r, φ, z coordinates) is performed to study the particle movement in the region of the coaxial input coupler. It is possible that electrons hitting the coupler cause secondary electrons. Those charges may disturb the coupling from the structure to the rf power supply.

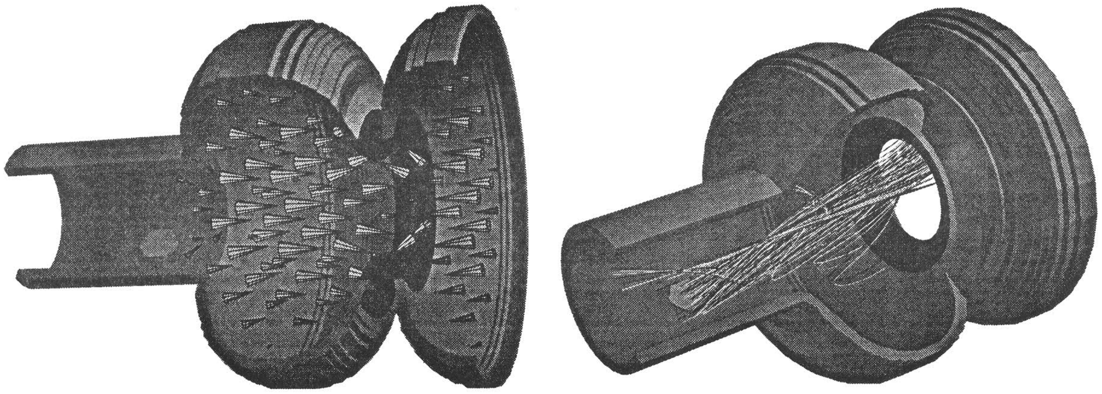


Figure 7: The left plot shows the electric field at the beginning of the 9-cell-TESLA-structure. On the right hand side the trajectories of electrons are drawn which start from the first iris for an accelerating gradient of 40 MV/m. Obviously some electrons hit the coupler and may cause undesired secondary effects.

CONCLUSION

In this paper we presented the simulation of effects caused by field emitted electrons in the TESLA Linear Collider structure. For different accelerating gradients the trajectories, deposited energies and dark current rates were evaluated. The most critical emission time range is between 100 and 120 degree. In that range up to 20% of the emitted particles are captured. Furthermore these electrons gain much energy from the accelerating field, because they fly in phase with the electric field.

With three dimensional simulations we could follow the trajectories in the coupler region. We found electrons hitting the coaxial input line, which may cause some undesired effects.

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