**Optimization of electron gun in continuous and pulsed operation modes**

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**Abstract.** We present results from simulation of a commercial electron gun using program SIMION. We performed continuous electron beam trace simulation for the electron energy range of (1-1000)eV, also including an influence of the electron Coulomb repulsion to the beam spot geometry. Pulsed beam operation for 5ns, 10ns and 20ns pulse widths, with 1MHz pulse repetition time has been simulated, as well.

INTRODUCTION

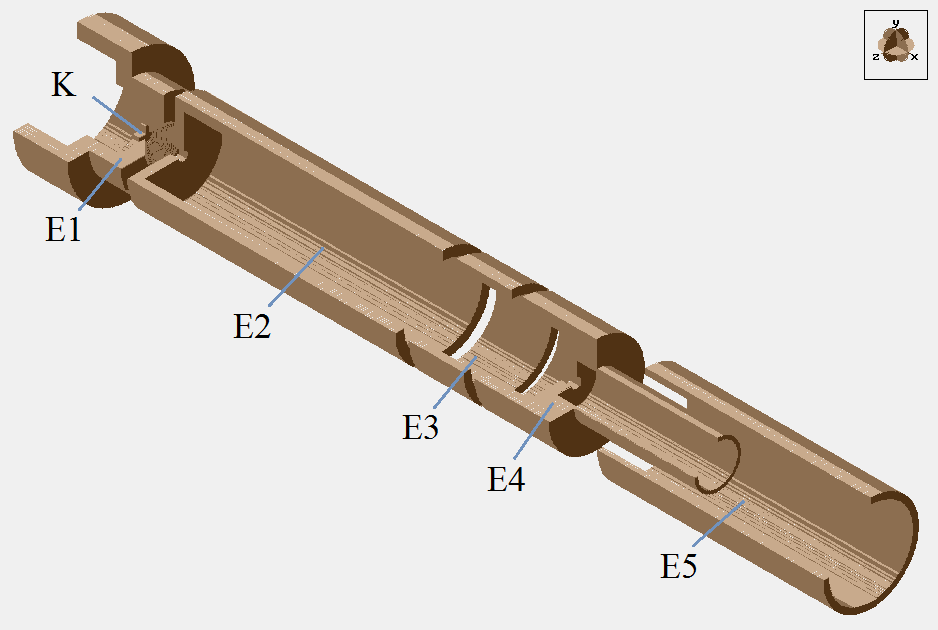
In atomic physics measurements that utilize crossed beam experiments with electrons as projectiles, it is very important to have a well-defined both the geometry and the energy of the electron beam. If the experiment doesn’t require a very high electron energy resolution, an electron gun can be used as an electron source. Most commonly, the electron gun consists of a flat (or a hairpin) cathode that emits electrons through a thermo-electron emission, as well as of a few additional cylindrical electrodes. The latter are used to achieve a precise beam geometry, a good focusing at a desired distance and for setting the electron beam energy. A difference between the potentials of the cathode and of the last electrode defines the electron beam energy, while the energy resolution is defined by a thermal distribution of electrons emerging from the cathode (usually about 0.5eV). Furthermore, various applications based on coincident or time of flight dependent experiments, require an usage of a pulsed electron beam, in order to sequence the measurements.

In this study we have made a model in SIMION8[1] of a commercial electron gun AA5516. We present the results of a 1MHz pulsed operation mode, with 5ns, 10ns and 20ns pulse widths. We have performed voltage optimization for the range of (1-1000)eV electron energy, allowing theoretically to preserve the focal point at a fixed distance of d=40mm from the exit aperture, in the continuous mode of operation, and with an influence of the Coulomb repulsion between electrons.

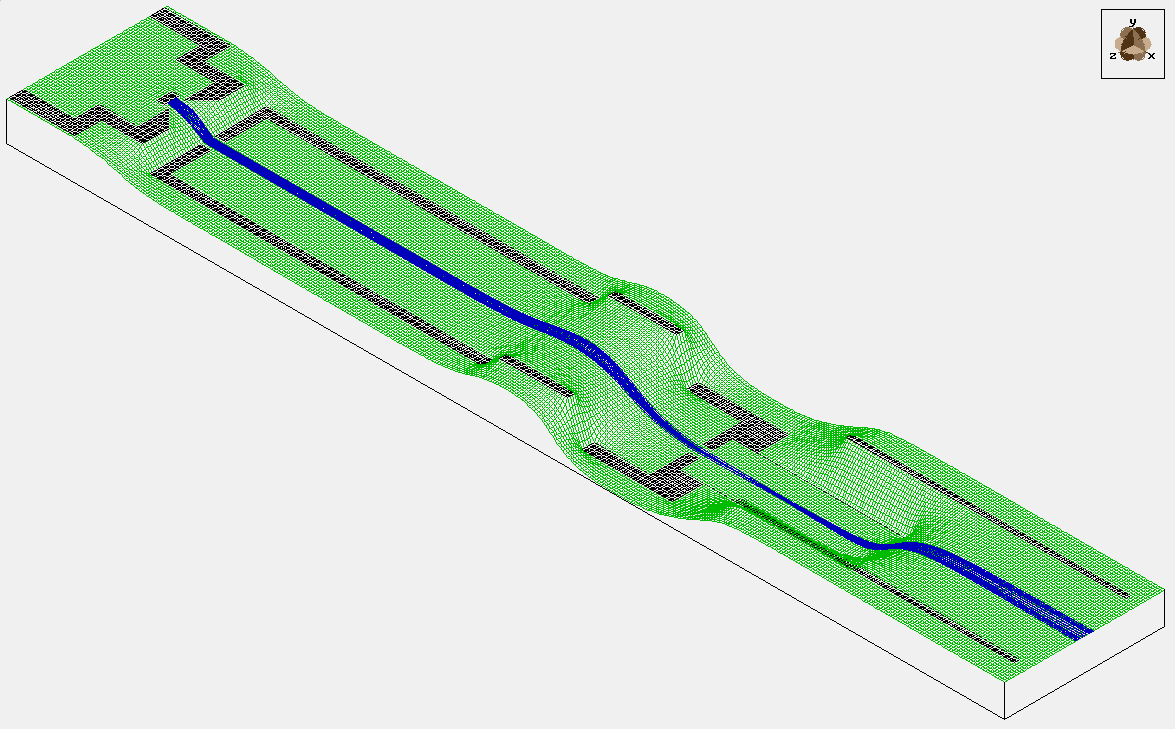
RESULTS AND DISCUSSION

The modeling and simulation of the electron gun in the present study were conducted by using the commercial program SIMION8[1]. First step in the simulation is to define a desired electron optics geometry and its electric potentials via special programming code, which creates a geometry file. The program then solves the Laplace equation for the electric potential and calculates the electric field defined by gradient of that potential by using a method of finite differences. This process gives the solution for the electric field in an empty space between electrodes. After having defined the electric field, desired charged particle initial conditions can be defined and the program solves differential equations of motion. In the final step, the program displays particle trajectories.

The present electron gun consists out of six cylindrical electrodes, with the cathode being one of them. Geometry of the electrodes and a 3D model of the electron gun are displayed in Figure1. Cathode is held at a negative potential, while the last electrode E5 is grounded. All remaining electrodes have fixed DC voltages, except for the E1 (in the pulse mode) - called Wenelt electrode. All electrode voltages are set relative to the cathode, in order to keep the electron gun’s primary electron extraction lenses at nearly the same focusing capabilities, while changing through electron energies.

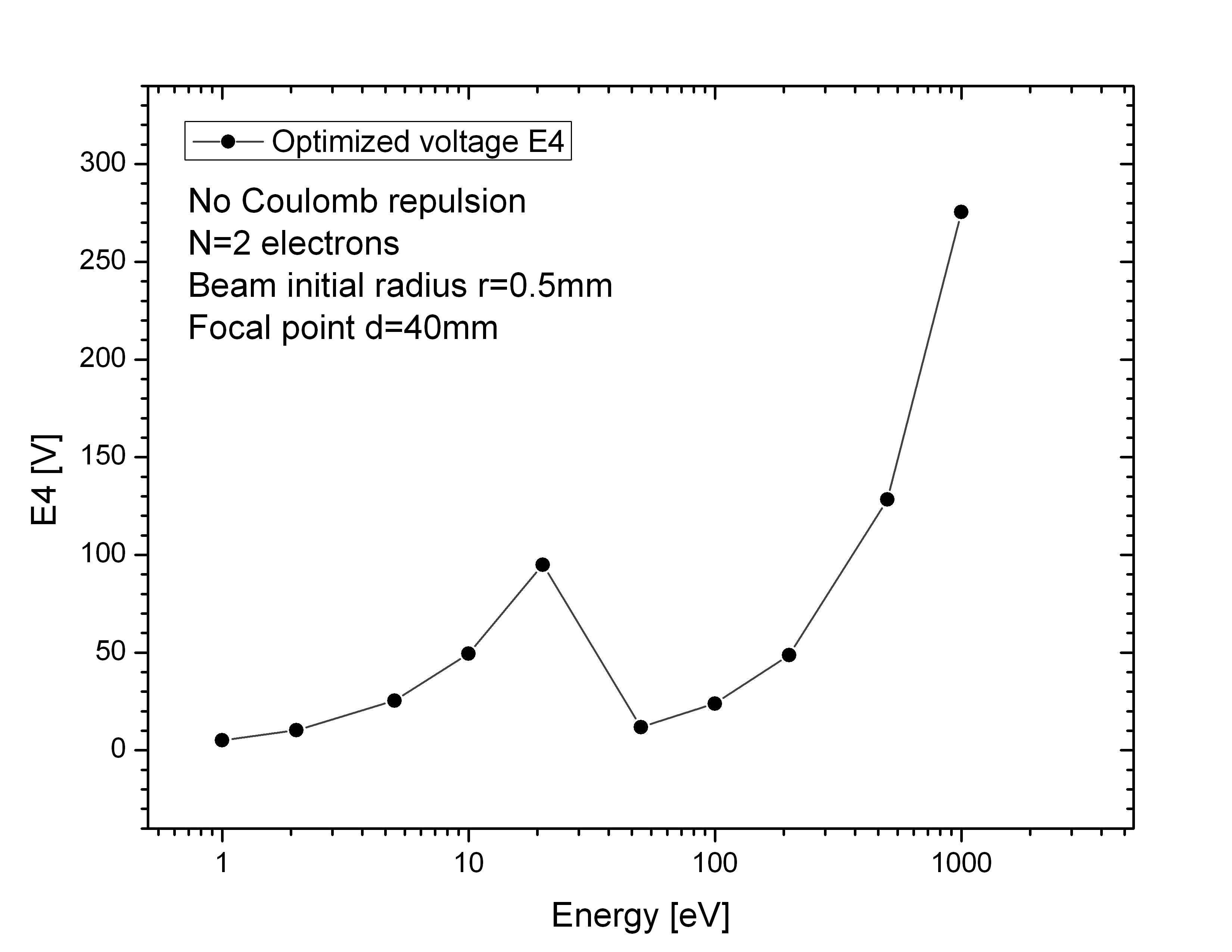
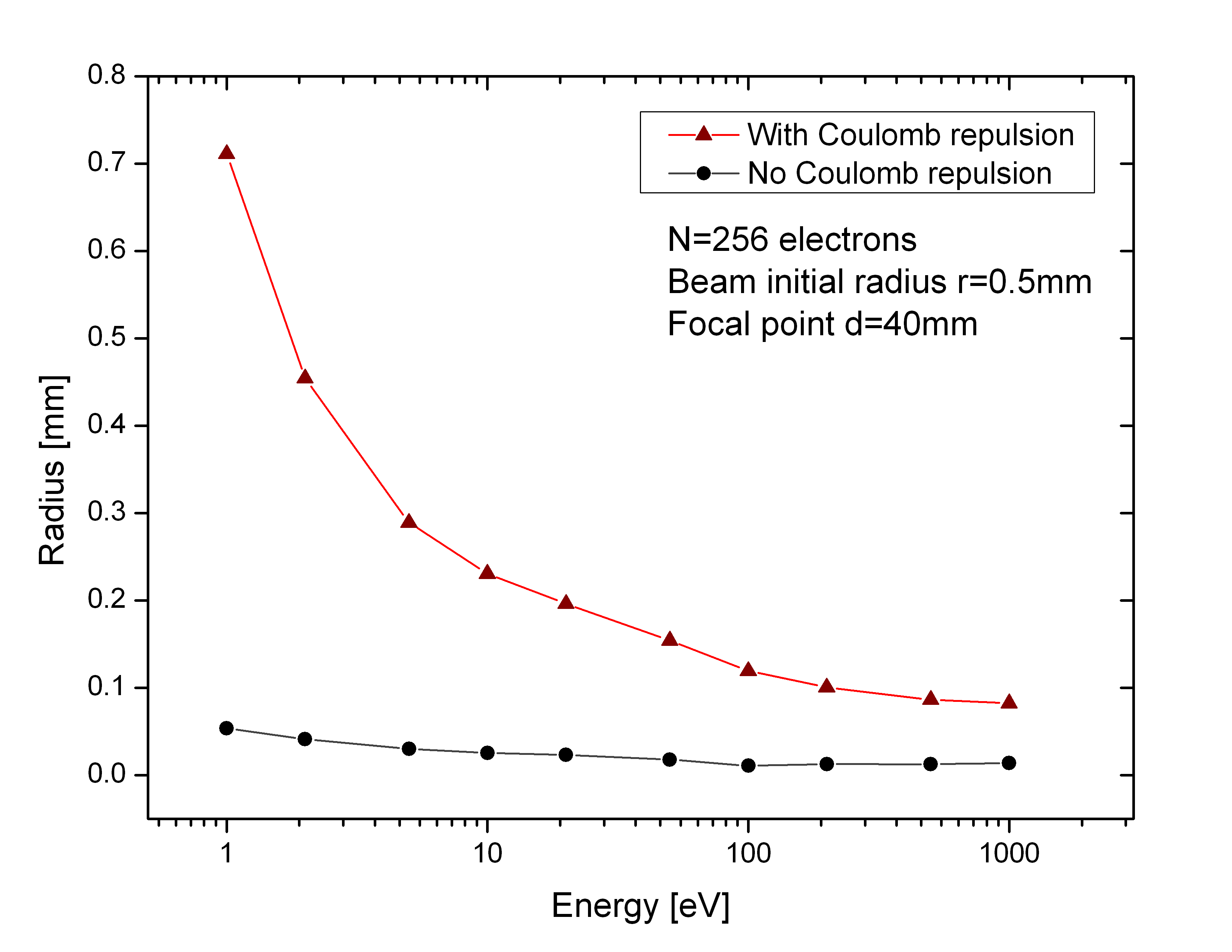


**Figure1.***3Dmodel image from SIMION8 of the electron gun and geometry of its electrodes.*

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**Figure 2**.*Potential energy (green) from SIMION8 of the electron gun and electron beam trace (blue).*

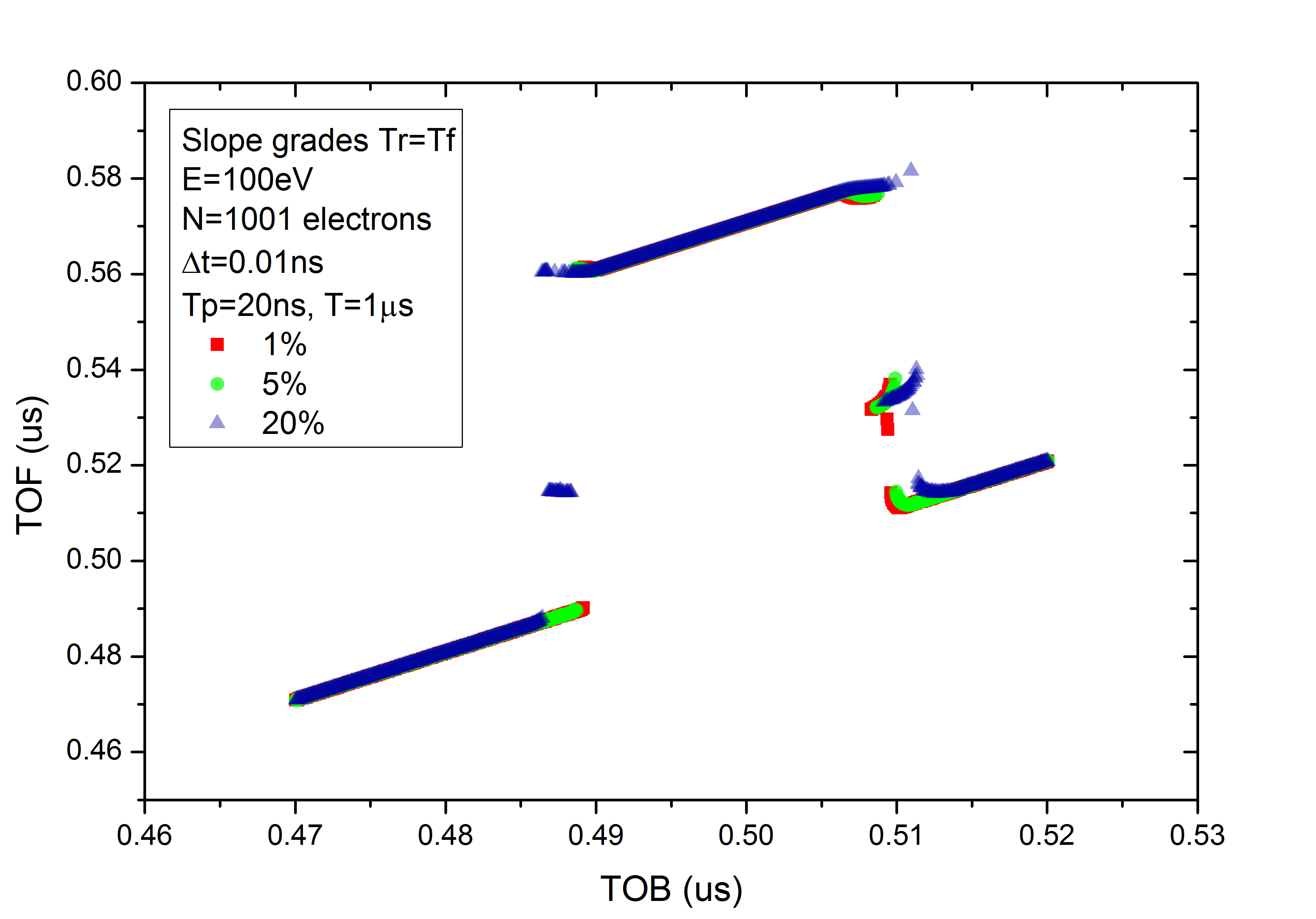
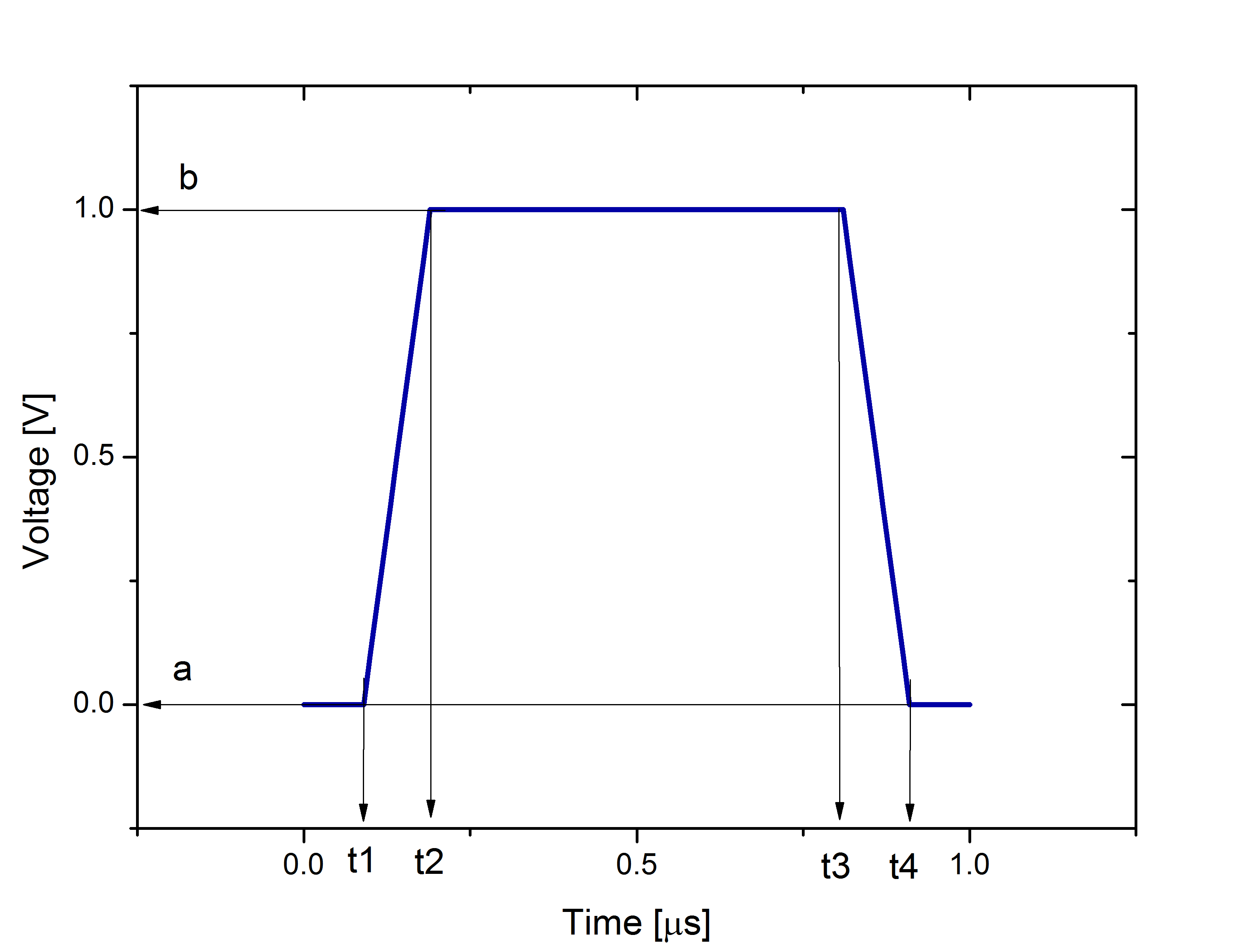
The voltage on the electrode E4 was optimized via special iterative LUA programing code in SIMION8[1], in order to obtain minimal possible beam radius at the distance of d=40mm, from the last (exit) electrode E5. Only two electrons are flown from the cathode with the initial energy of 0.1eV from Y=±0.5mm and Z=0mm (X is the axial direction). Results from the voltage optimization of electrode E4 are shown in Figure 3 (left).

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**Figure 3.**Left: *Optimized voltage on electrode E4, without electron Coulomb repulsion, in order to maintain focal point at the distance of d=40mm from the exit electrode, simulated for 2 electrons starting from Y=±0.5mm.Right: Beam radius with and without including electron Coulomb repulsion, at the focal point of 40 mm from the exit aperture, simulated for 256 electrons starting from anuniform disc grid with 0.5mm radius.*

Using the optimized voltages at the electrode E4 obtained for 2 electrons, a radius of the electron beamfor 256 electrons at the focal point d=40mm, was recorded for the energy range of (1-1000)eV. All 256 electrons were set to start from the cathode at the same time with 0.1eV energy, with an uniform 2D grid distribution from a disc of a radius of r=0.5mm. Two data sets were recorded, one with included Coulomb repulsion between electrons and the other without it. Figure 4 (right) shows that the beam radius is much smaller when the Coulomb repulsion is not included in the simulation.

Pulsed mode of operation was achieved by applying a time dependent voltage on the Wenelt electrode E1. Voltage on this electrode has a pulsed time dependence in order to simulate pulsed operation mode and is shown on Figure 4 (left).

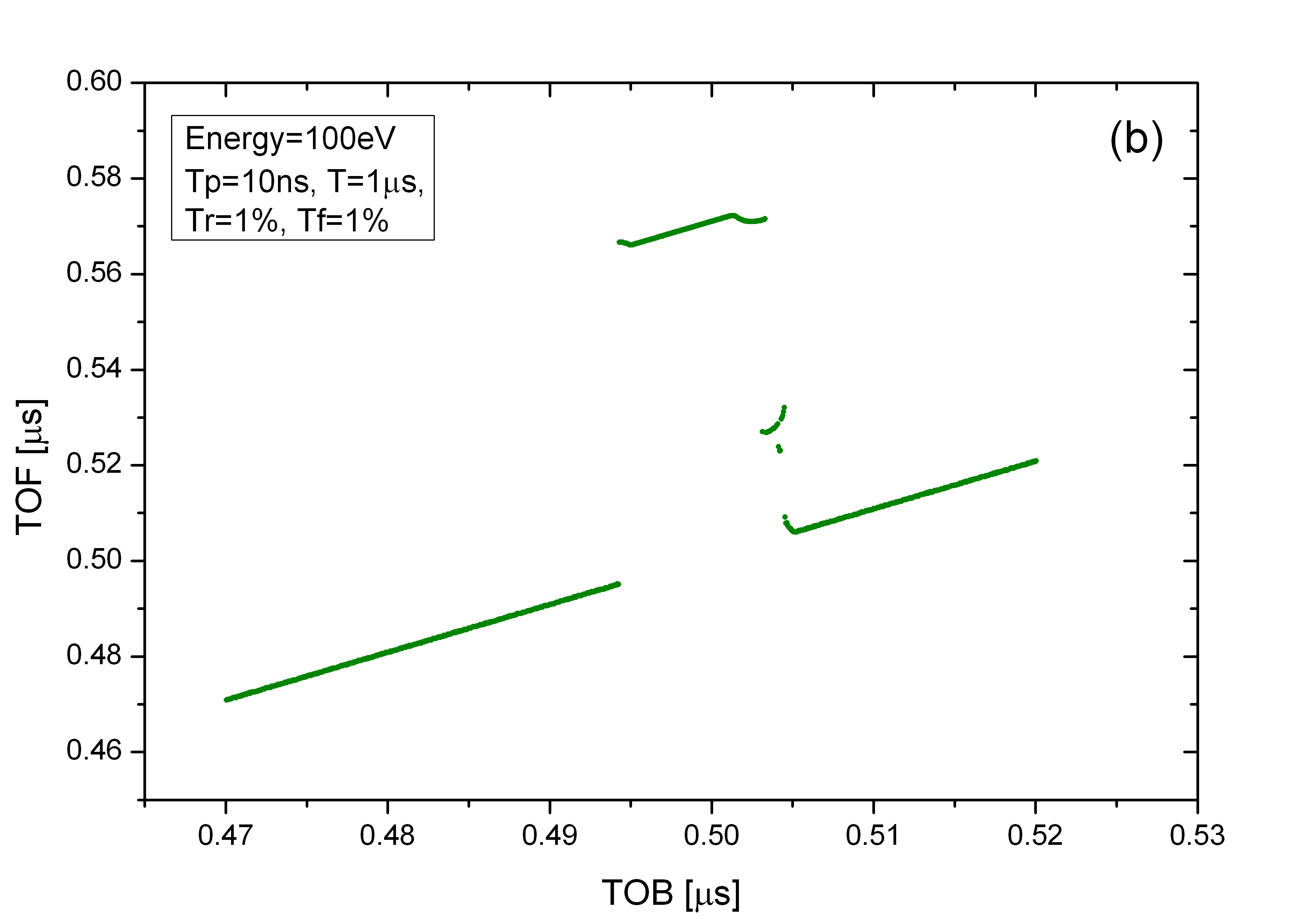
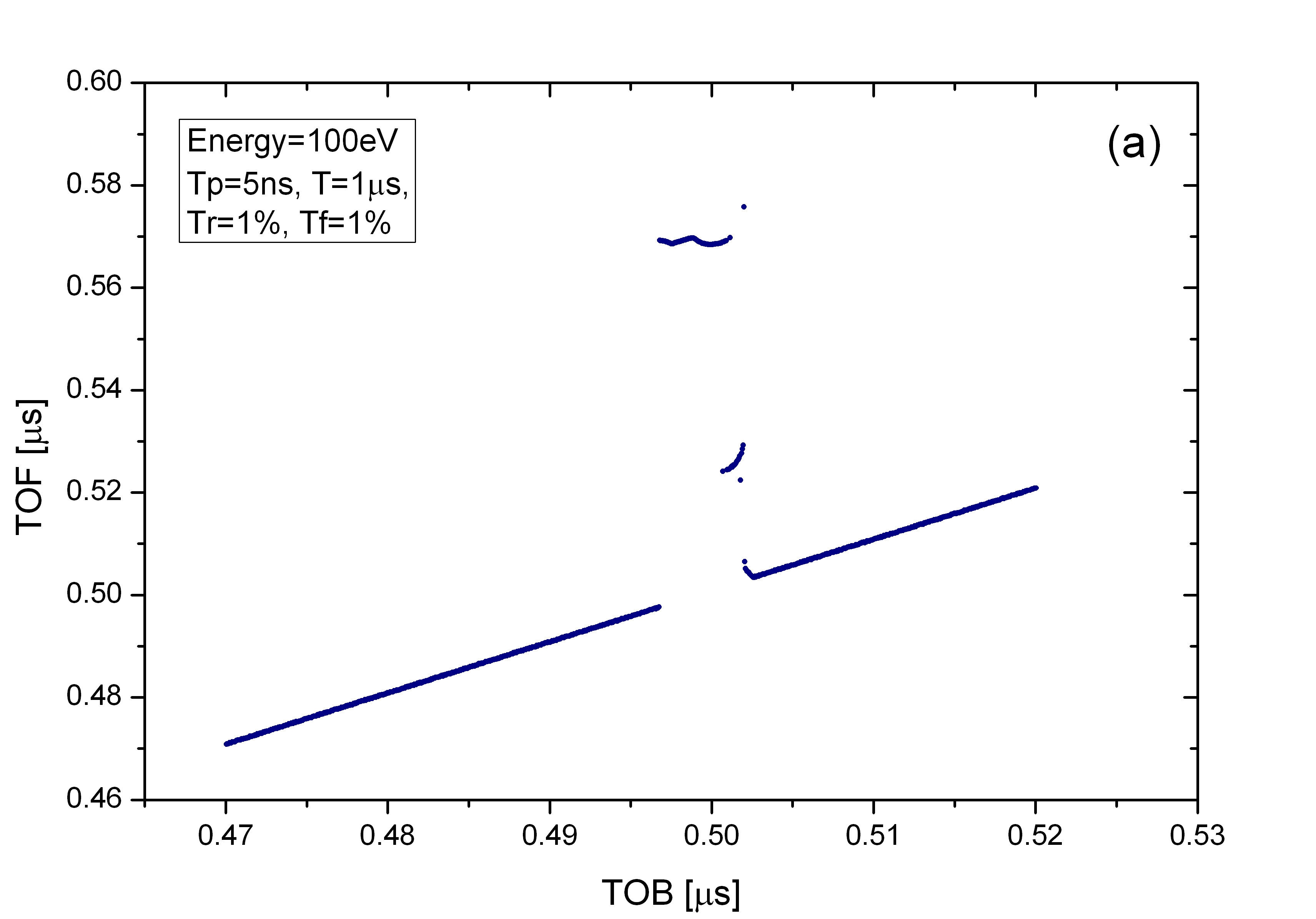


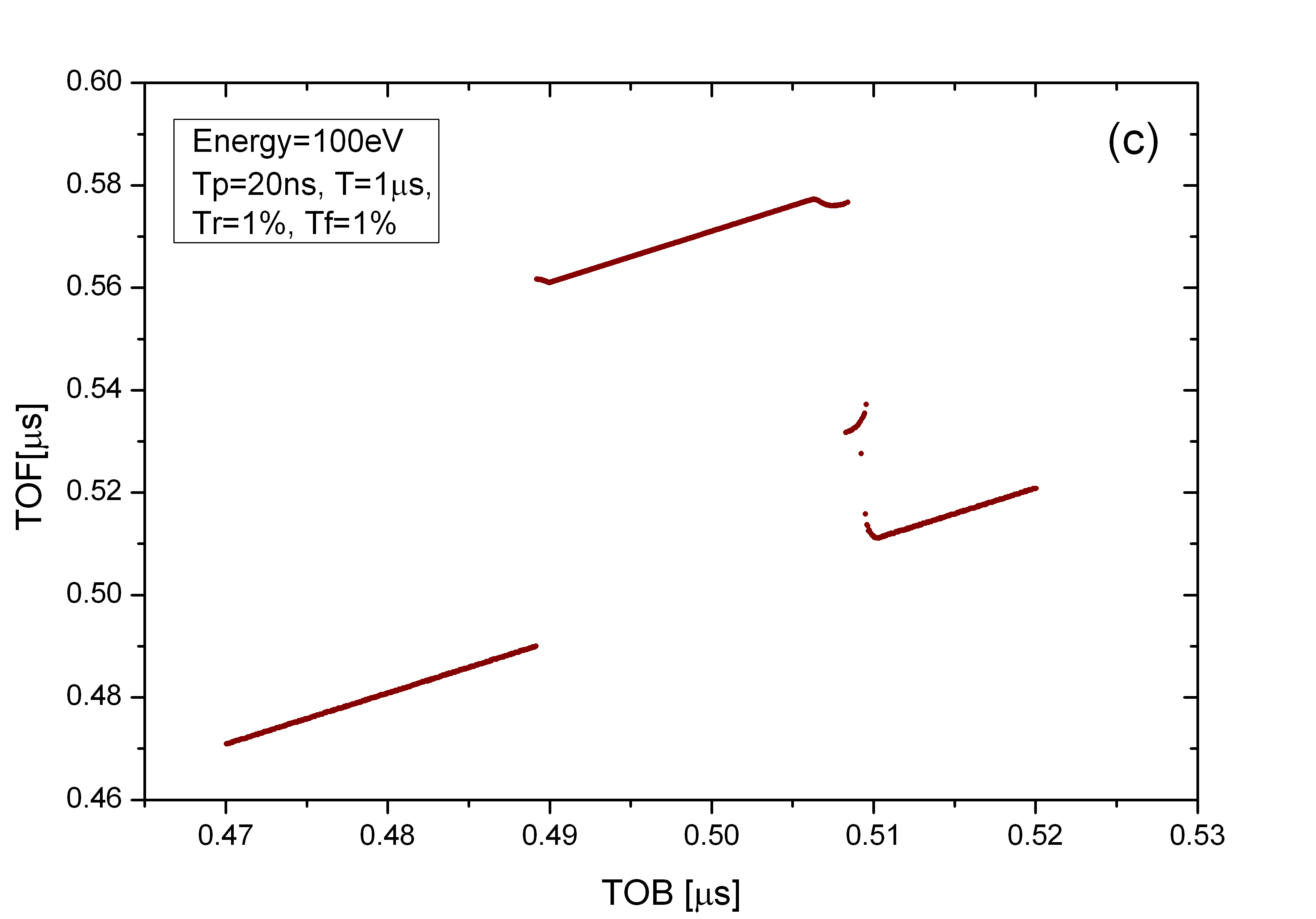
**Figure 4.***Left: Pulsed voltage time shape of one full period of 1MHz pulse on electrode E2. Voltages b and a are arbitrary on and off trigger voltages respectively. Pulse width and slope grades are defined with simulation variables t1, t2, t3 and t4. Right: Slope grades for 1001 electrons starting random from 0.5mm disc with a time delay of 0.01ns, for a 20ns pulse width and the electron energy of 100eV, for slope grades of 1%, 5% and 20%.*

The full period is T=1µs, the electron pulse width is defined with Tp and the pulse signal slope grades were defined bya raise and a fall time: Tr and Tf, respectively:

The slope grades were introduced into the pulse signal to approximately study the influence of the pulse generator signal quality, at low pulse widths ofthe order of nanoseconds. The influence of the slope grades on the electron pulse is shown in Figure 4 (right).

For a fixed slope grade of 1% and the electron energy of 100eV, different electron pulse widths were recorded for 1001 electrons and displayed in Figure 5. TOB is time of electrons birth, while TOF is time of electrons flight.





**Figure 5.***Electron pulse for the fixed energy of 100eV and the slope grade of 1%, for 1001 electrons starting from 0.5mm radius disc with the time delay of 0.01ns: a)5ns pulse width, b)10ns pulse width and c)20ns pulse width.*

CONCLUSIONS

Program SIMION8[1] was used for simulation of a commercial electron gun working in both continuous and pulsed mode. We investigated a possibility of obtaining a fixed focal point in a wide energy range by tuning only one electrode potential. Also, we presented in this study a possibility of turning from the continuous into the pulsed mode of operation by setting a pulsed voltage on the Wenelt electrode E1, down to nanosecond pulse width and 1MHz repetition period.

ACKNOWLEDGMENTS

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REFERENCES

[1] D. J. Manura and D. A. Dahl, SIMION Version 8.0, User Manual, Scientific Instruments Services, Inc. (2007)