TWO DIMENSIONAL COMPUTER SIMULATION OF PLASMA IMMERSION ION IMPLANTATION

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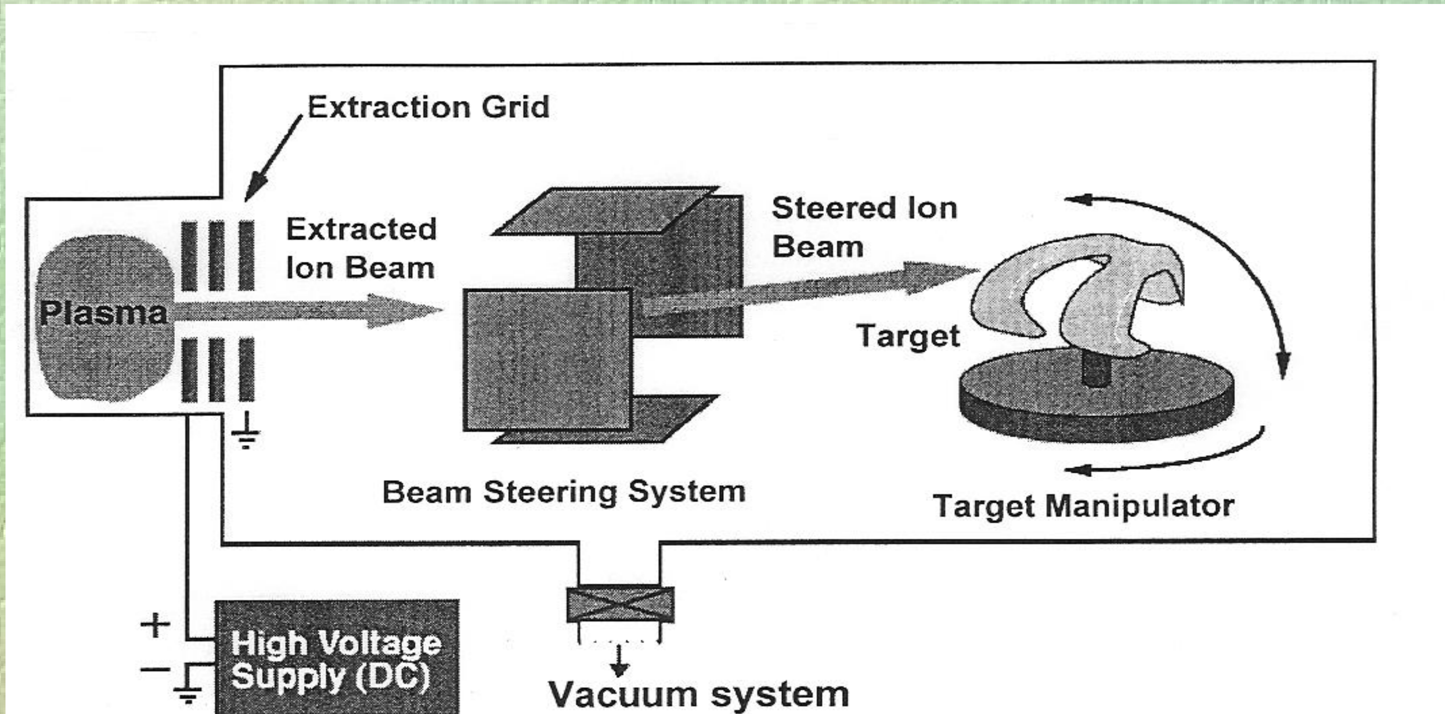
Concept of beamline ion implantation



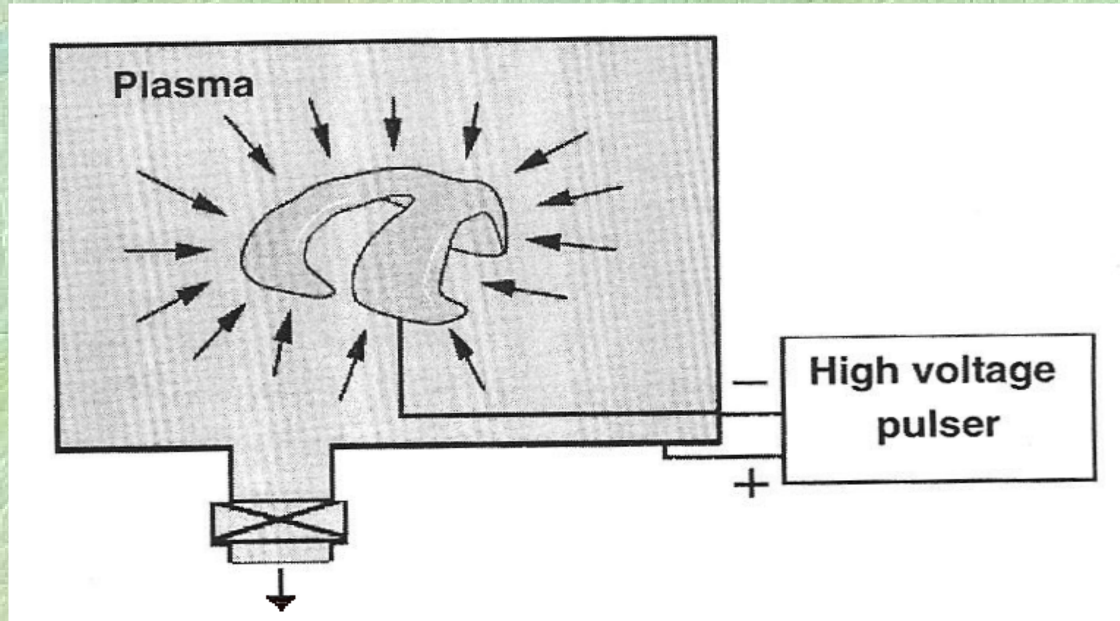
As a line-of-size, accelerator based, implantation technique beamline ion implantation has some shortcomings:

- low implantation current
- small treatment area
- not adequate for treating complex shaped objects
- requires complex target manipulation
- high production cost

Plasma Immersion Ion Implantation

A novel implantation technique especially developed for fast and efficient treatment of complex-shaped 3D targets

- higher current density
- conformal implantation
- large treatment area
- low cost
- shorter implantation time



Disadvantages

- spatial dose uniformity is a priori not guaranteed
- secondary electron emission pose X-rays hazard and could significantly reduce the PIII efficiency

Objectives

- Development of realistic, particle-in-cell (PIC), computer simulation of plasma immersion ion implantation
- Detailed investigation of plasma sheath formation and dynamics
- Study of ion dose uniformity in case of complex shaped targets
- Examining the role of secondary electrons
- Possibility for magnetic confinement of the secondary electrons

2.5D computer simulation with code KARAT

Spatial variables are limited to two dimensions (r - z coordinates in cylindrical geometry). All three components of the fields and velocities are retained.

Nitrogen plasma is generated by ionization of neutral gas using primary electrons. Probabilistic Monte-Carlo collision algorithm is employed to simulate the ionization process.

Actual mass of N_2^+ ion is used.

High voltage pulse with finite rise time is applied to the target and the evolution of the plasma sheath is followed in the time.

Numerical parameters

KARAT is run in electrostatic mode

vacuum camera radius R = 13 cm and length L = 38 cm

neutral gas density $n_0 \sim 10^{14}$ cm^{-3}

bias voltage V = -10 kV

high voltage pulse starts at t= 1.25μs and has rise time t_r = 0.25μs

typical mesh size Δr = 1.3-1.5 mm, Δz = 4-4.5 mm

time step Δt ~ 2.0 ps

number of macro-particles ~ 140000

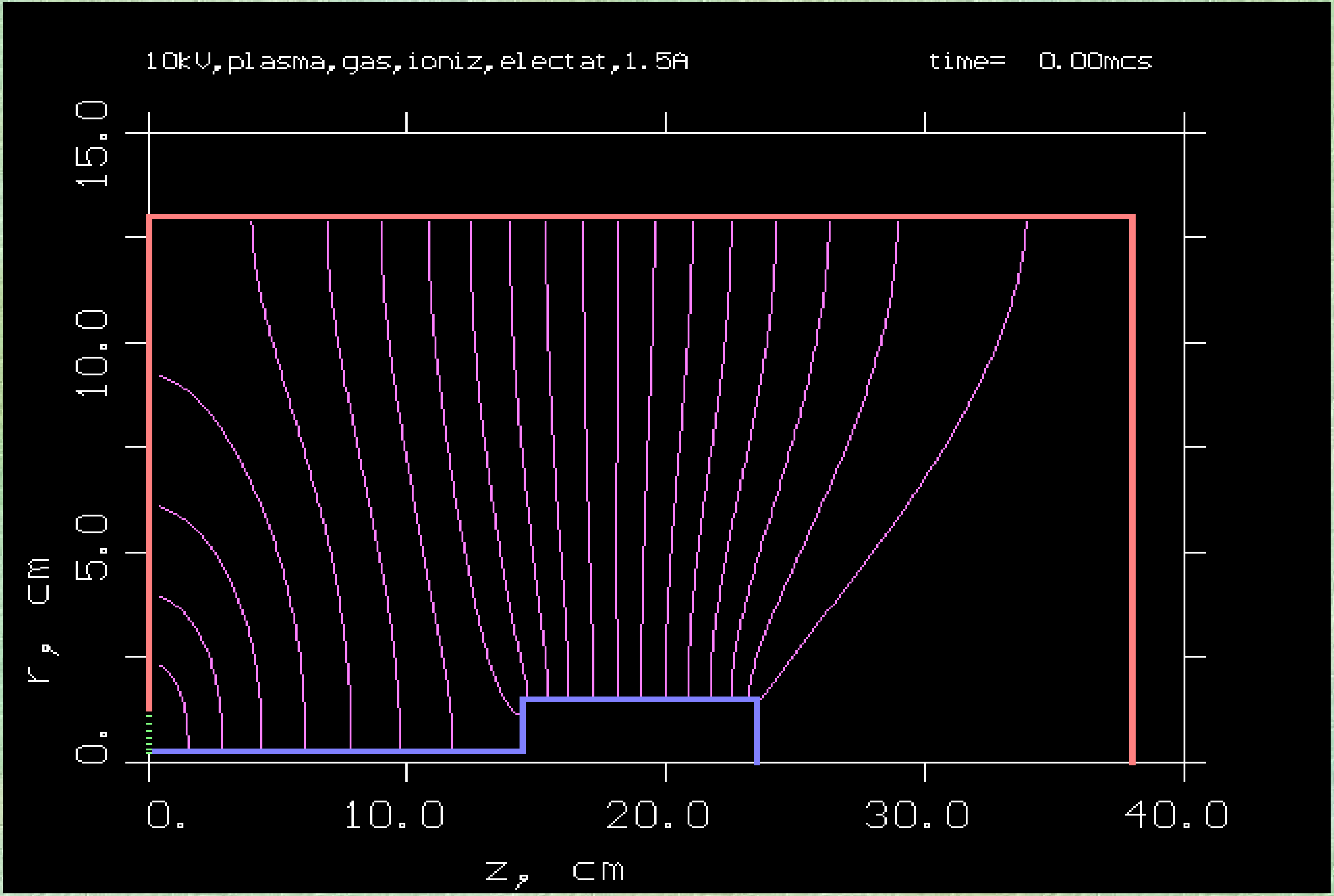
secondary electron yield γ = 4

external axial magnetic field B = 0.04 T

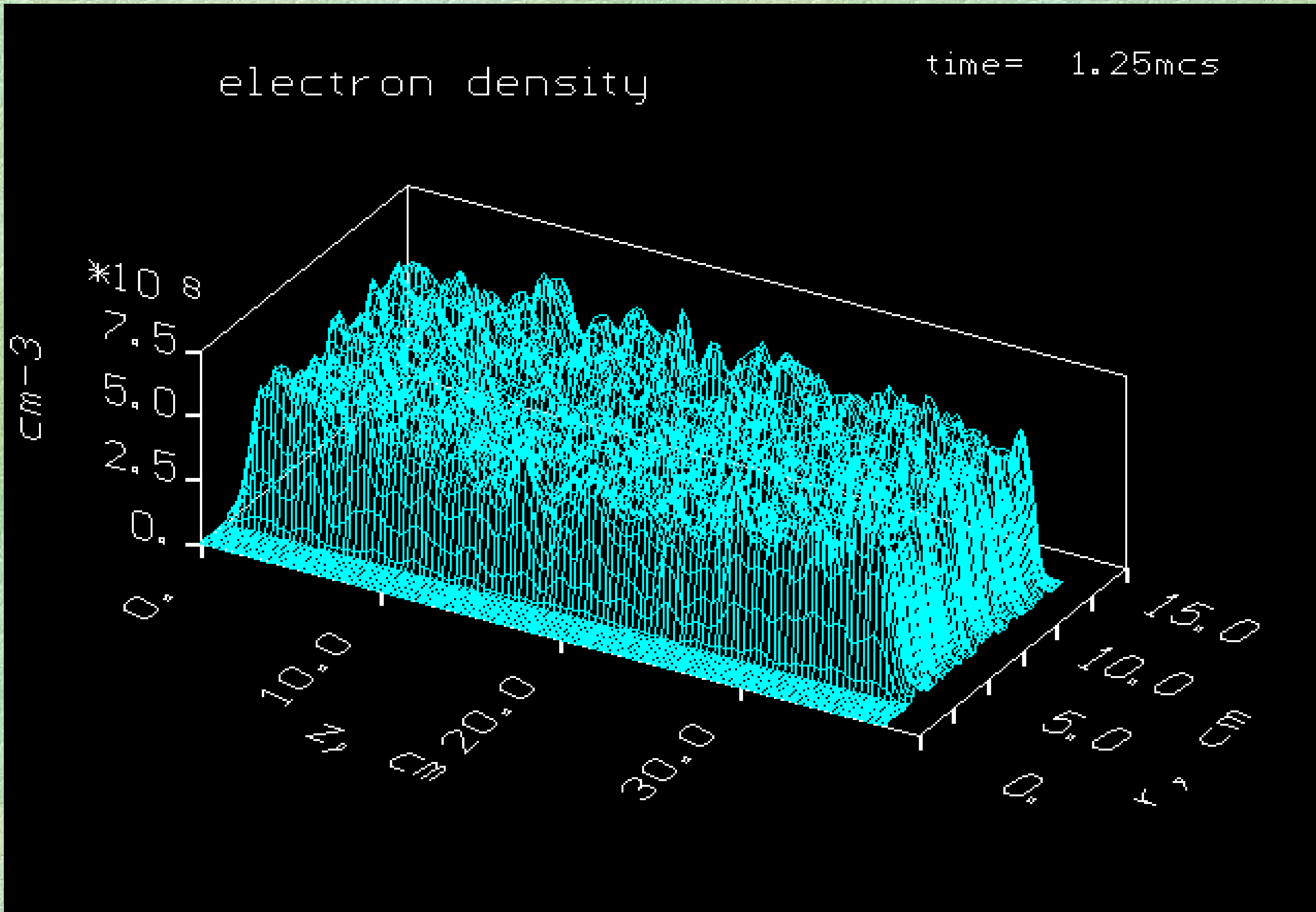
plasma density achieved in the simulation ~ 10^9 cm^{-3}

electron temperature T_e ~ 3 eV

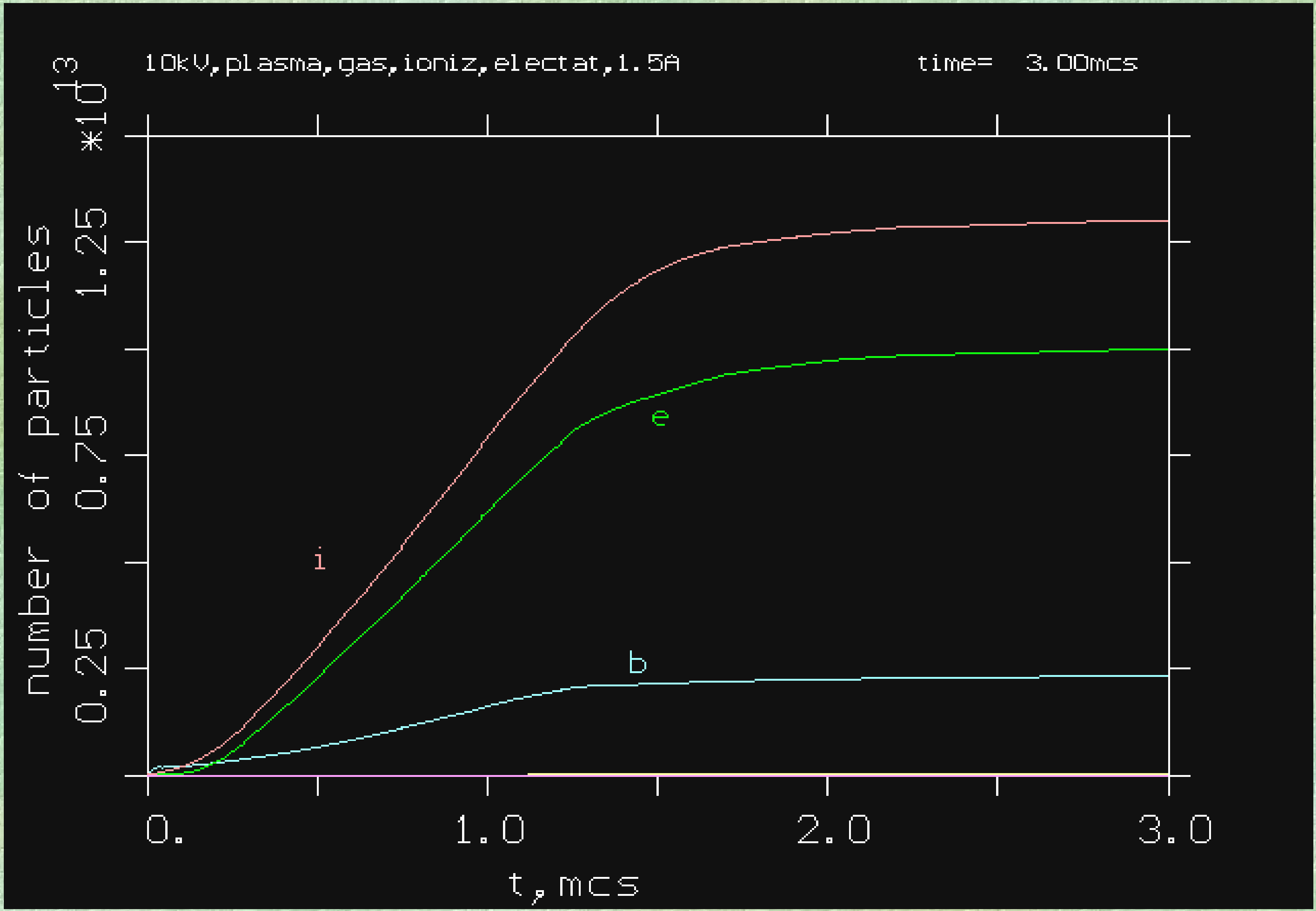
Simulation geometry



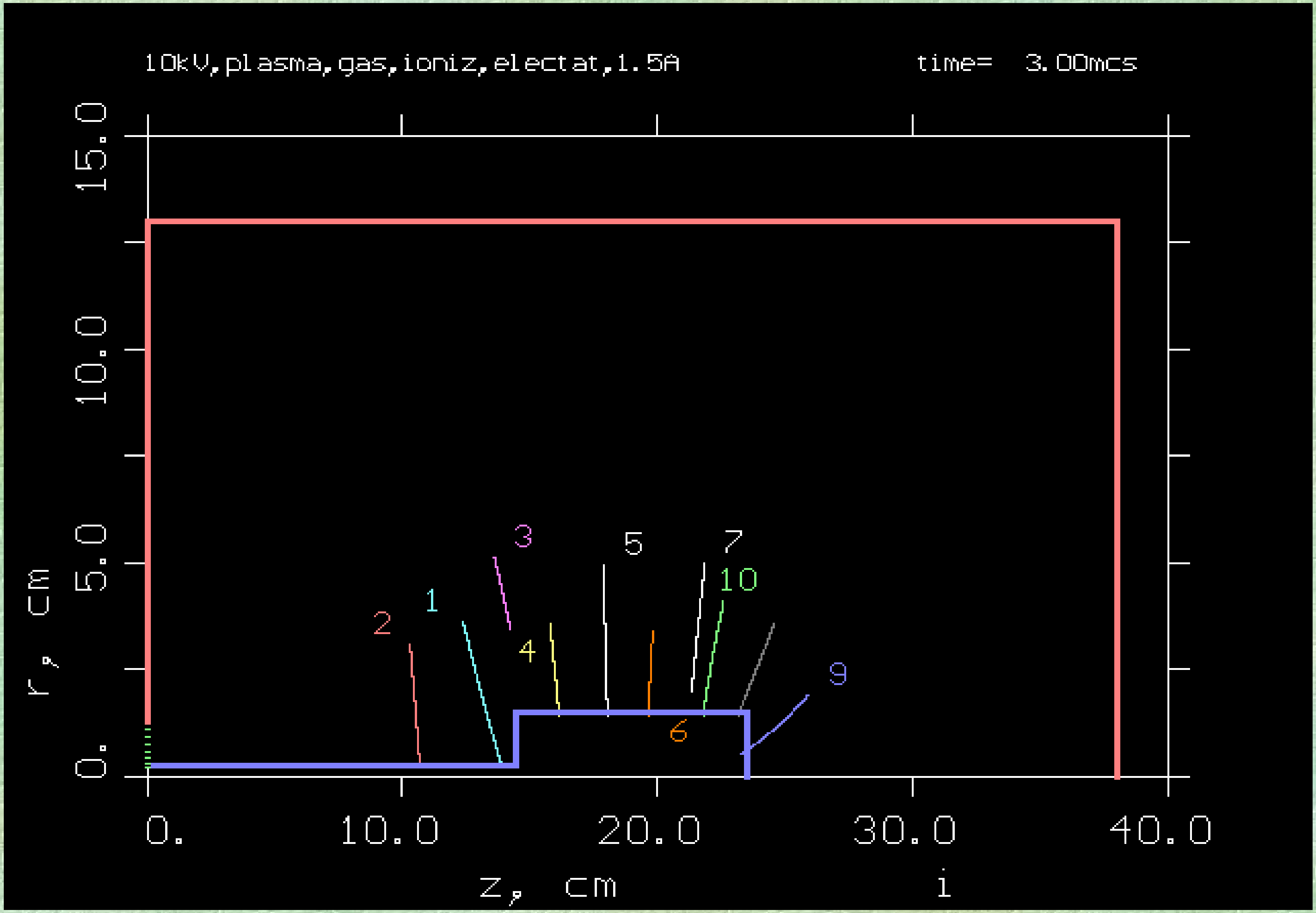
Initial electron density distribution



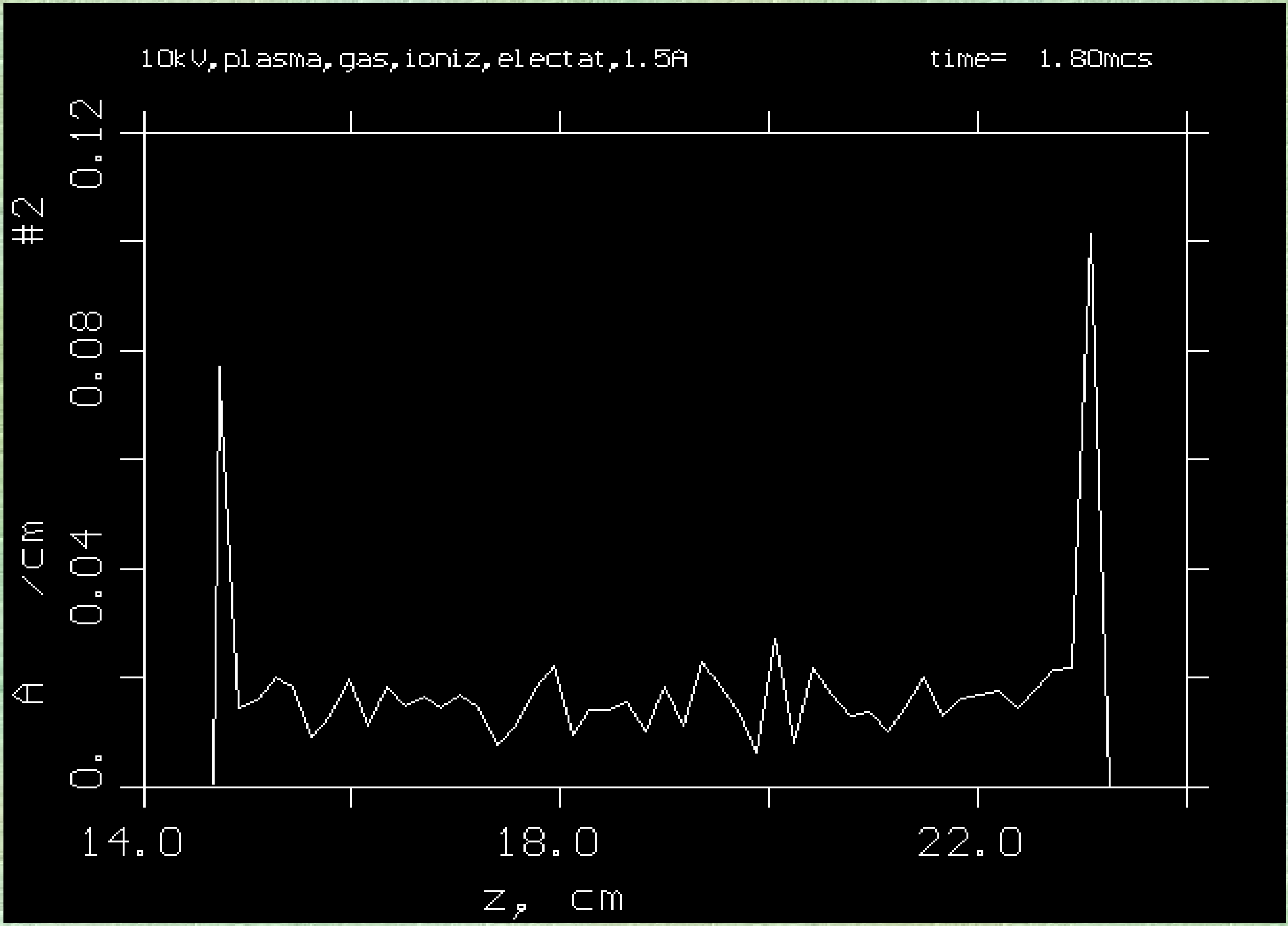
Balance of plasma particles (B=0 T and γ=0)



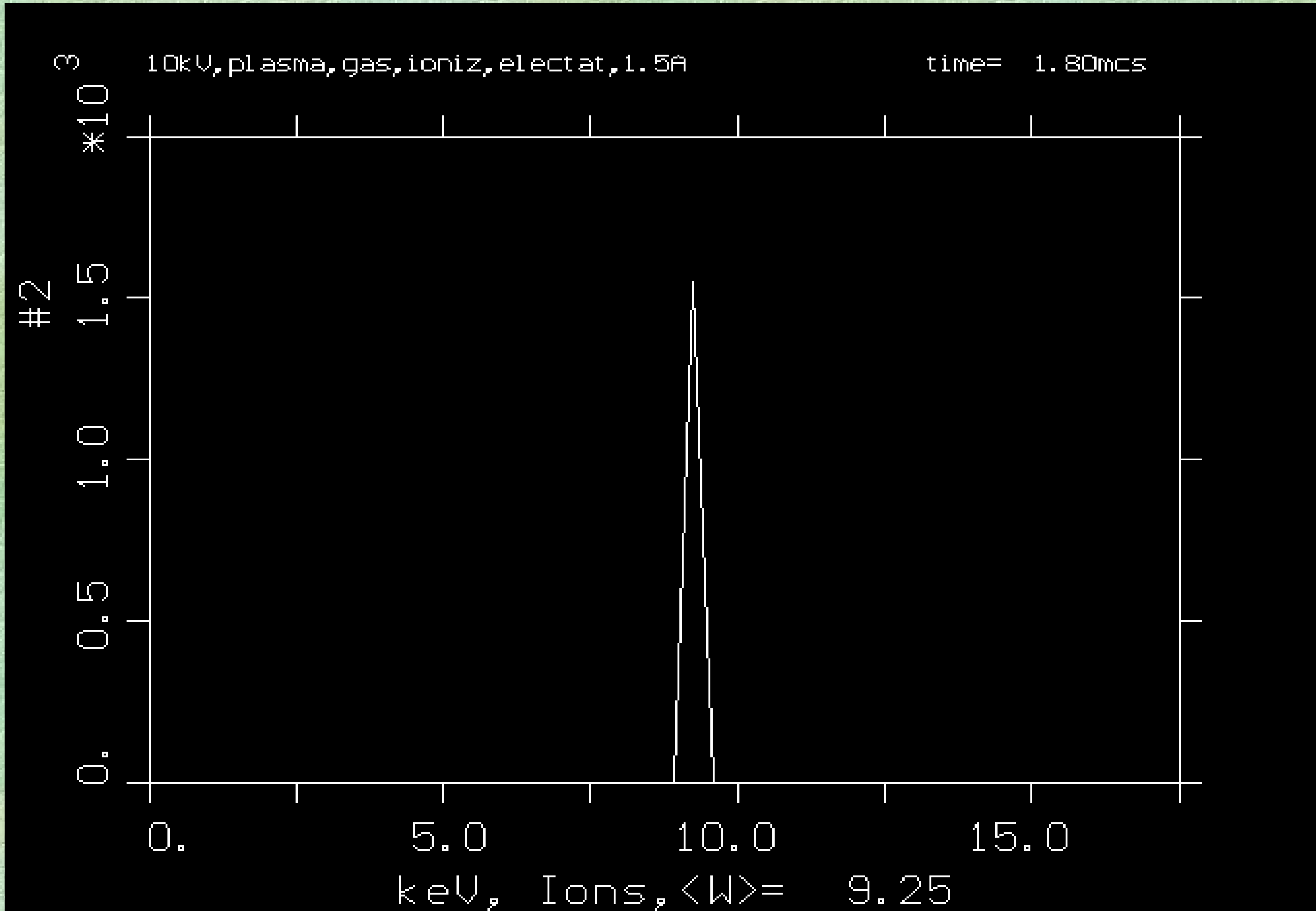
Ion trajectories



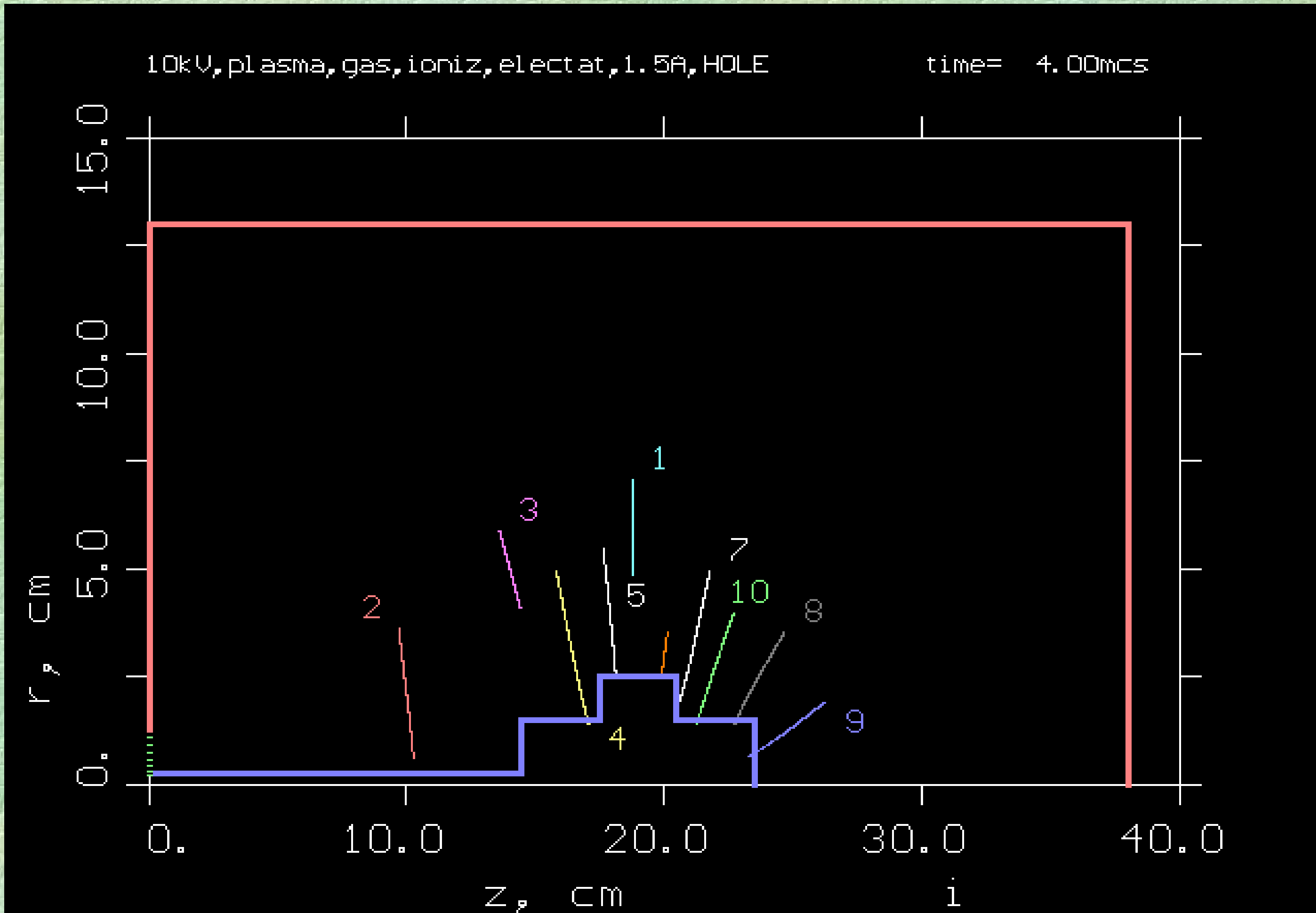
Axial distribution of implantation current



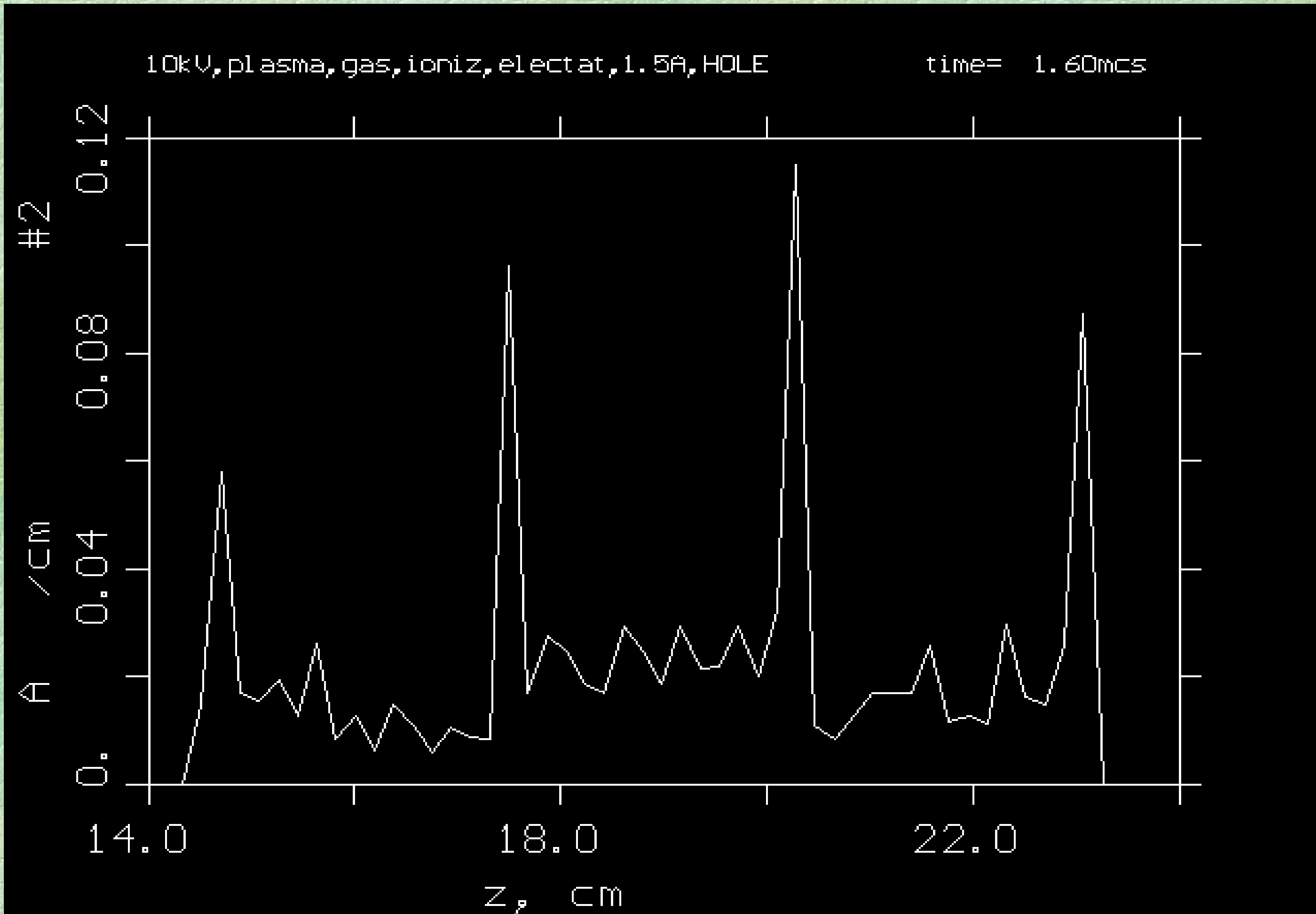
Energy distribution of incident ions



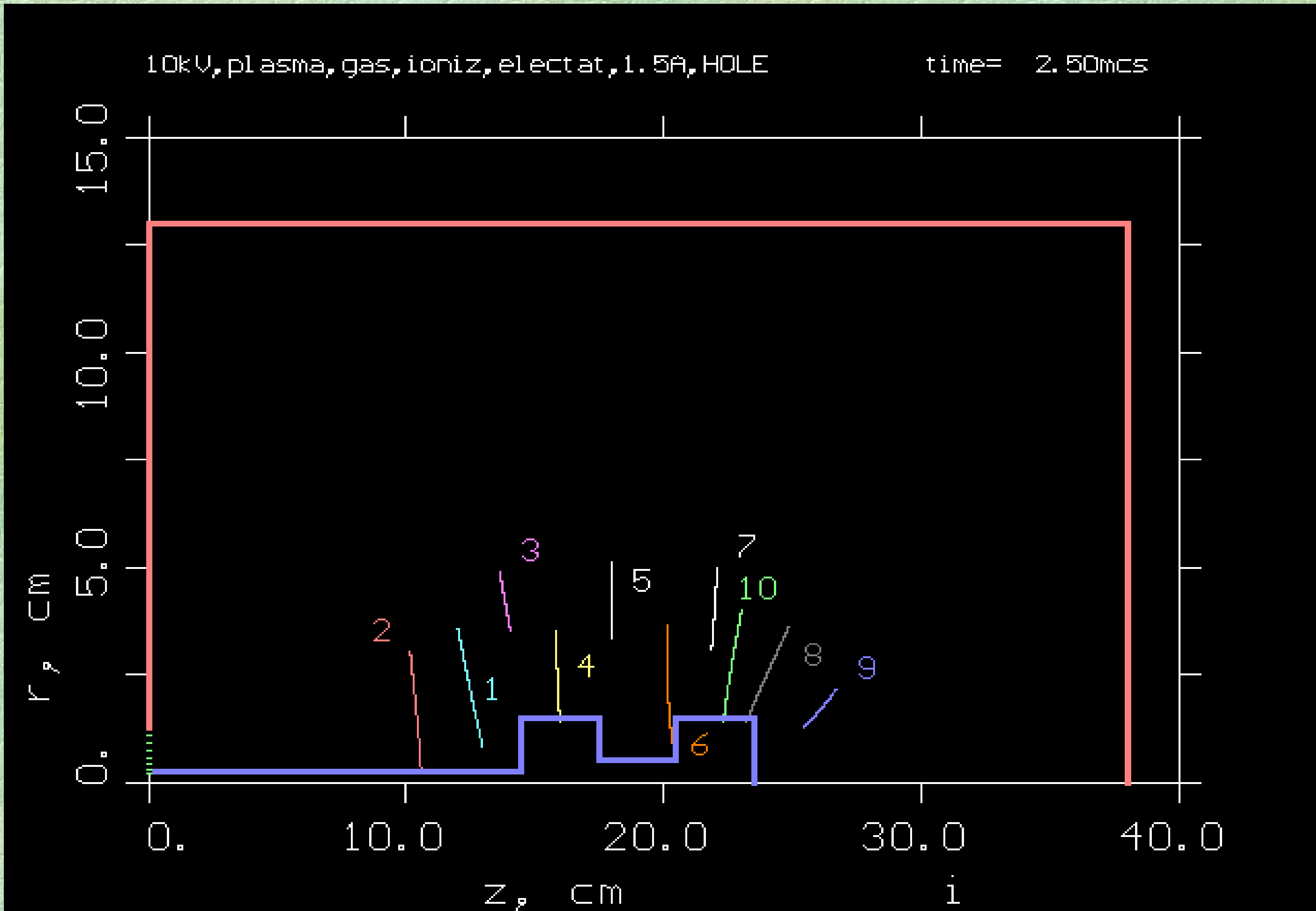
Ion implantation into convex sample



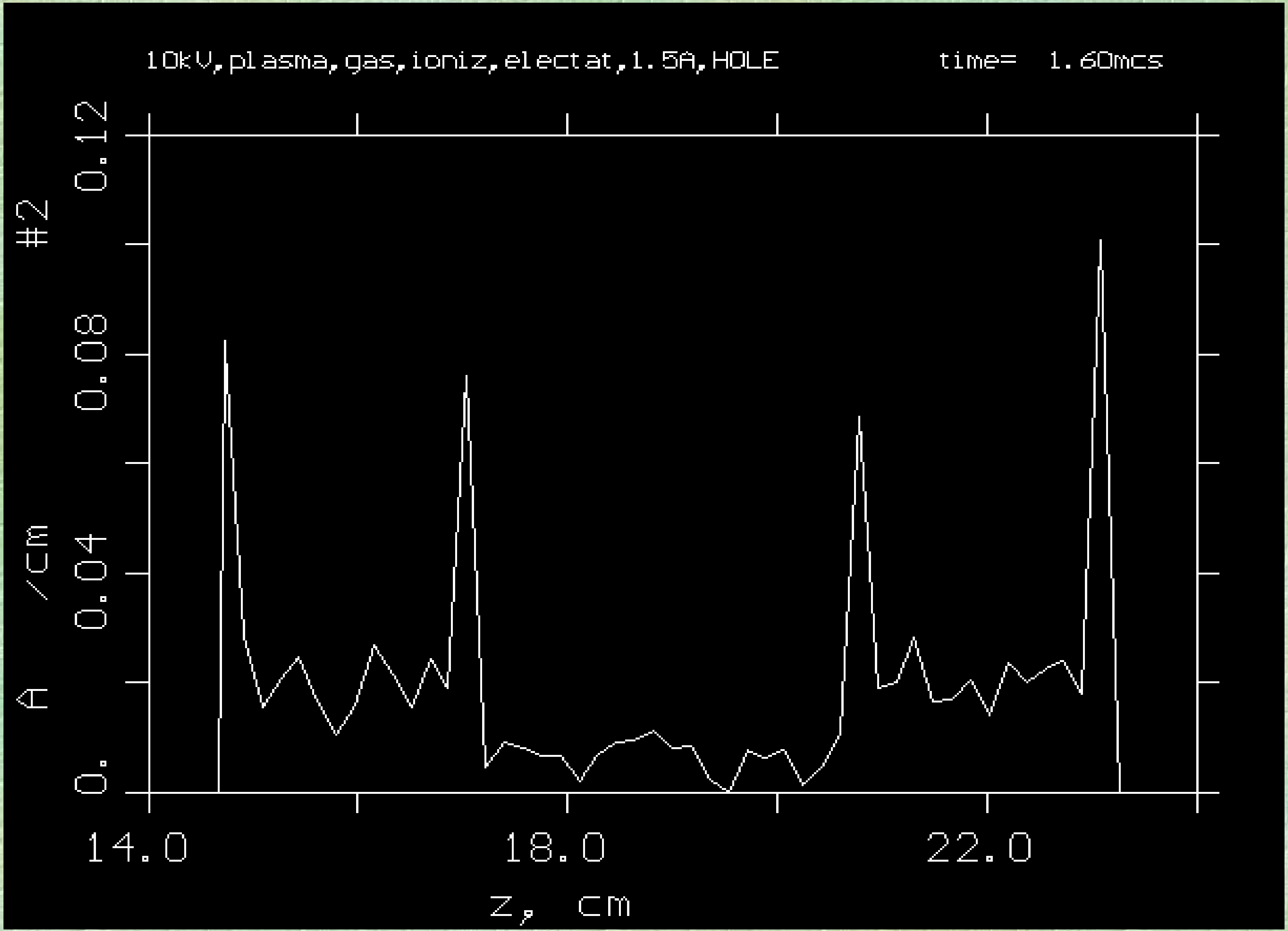
Current distribution for convex sample



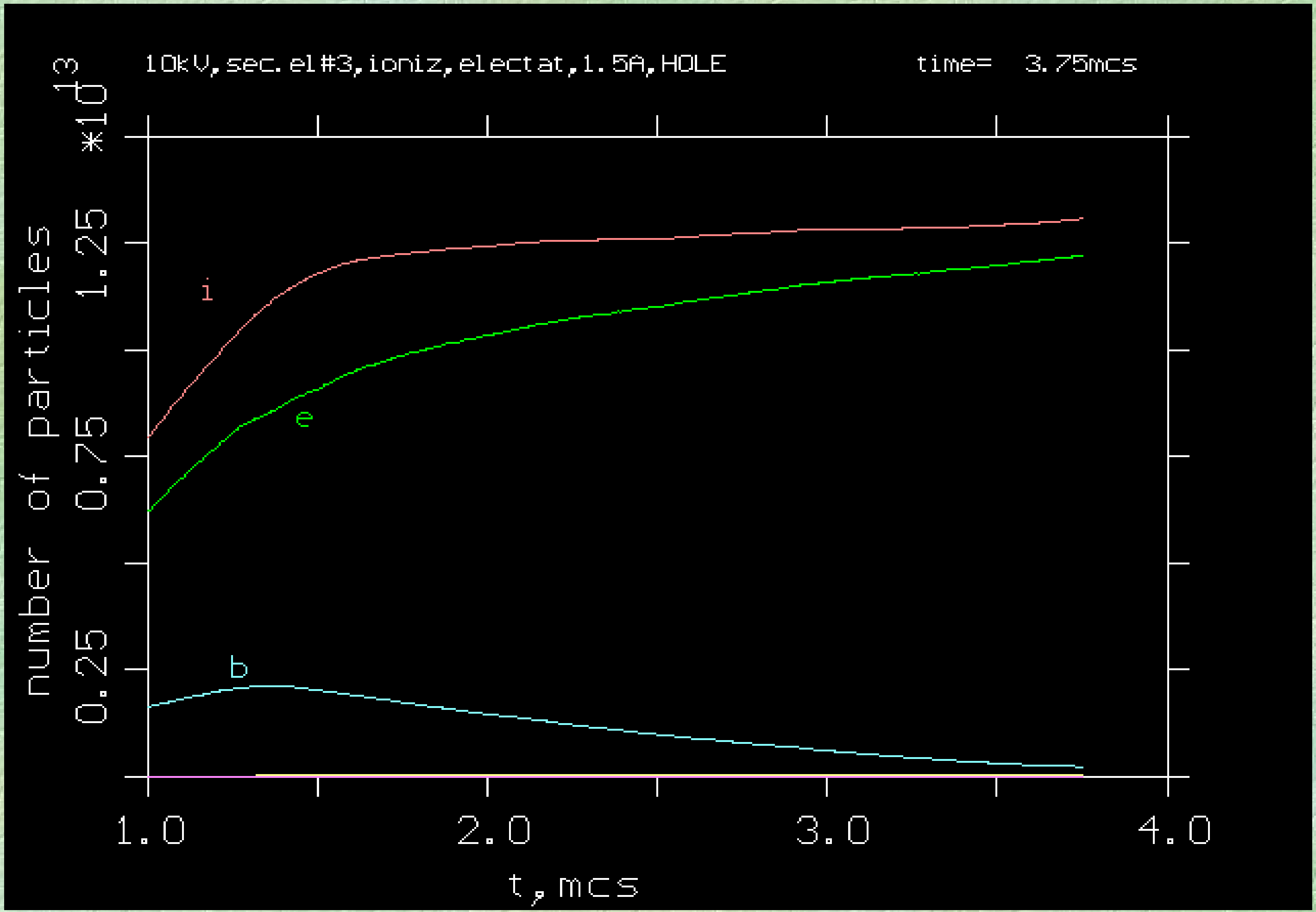
Ion implantation into concave sample



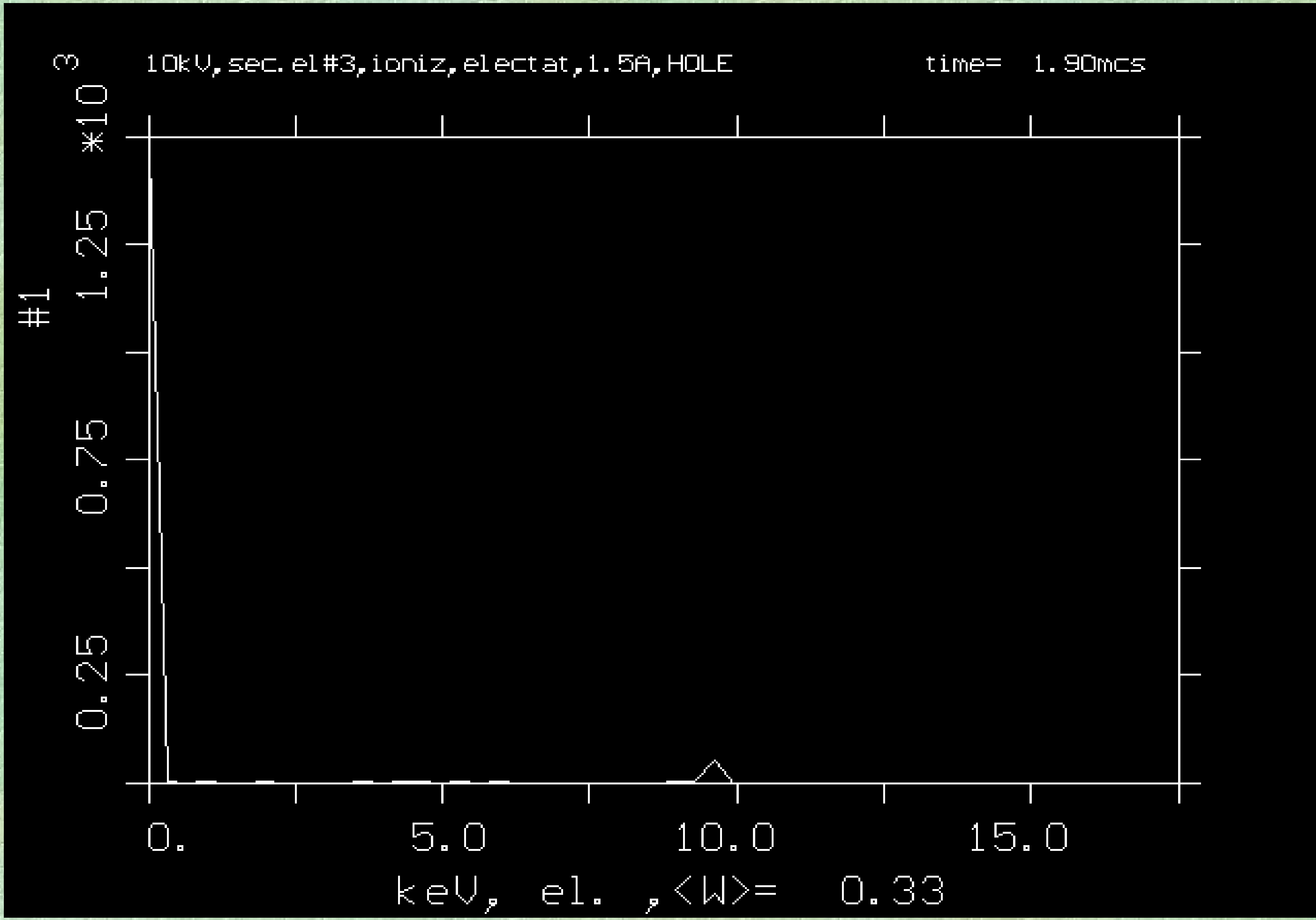
Current distribution for concave sample



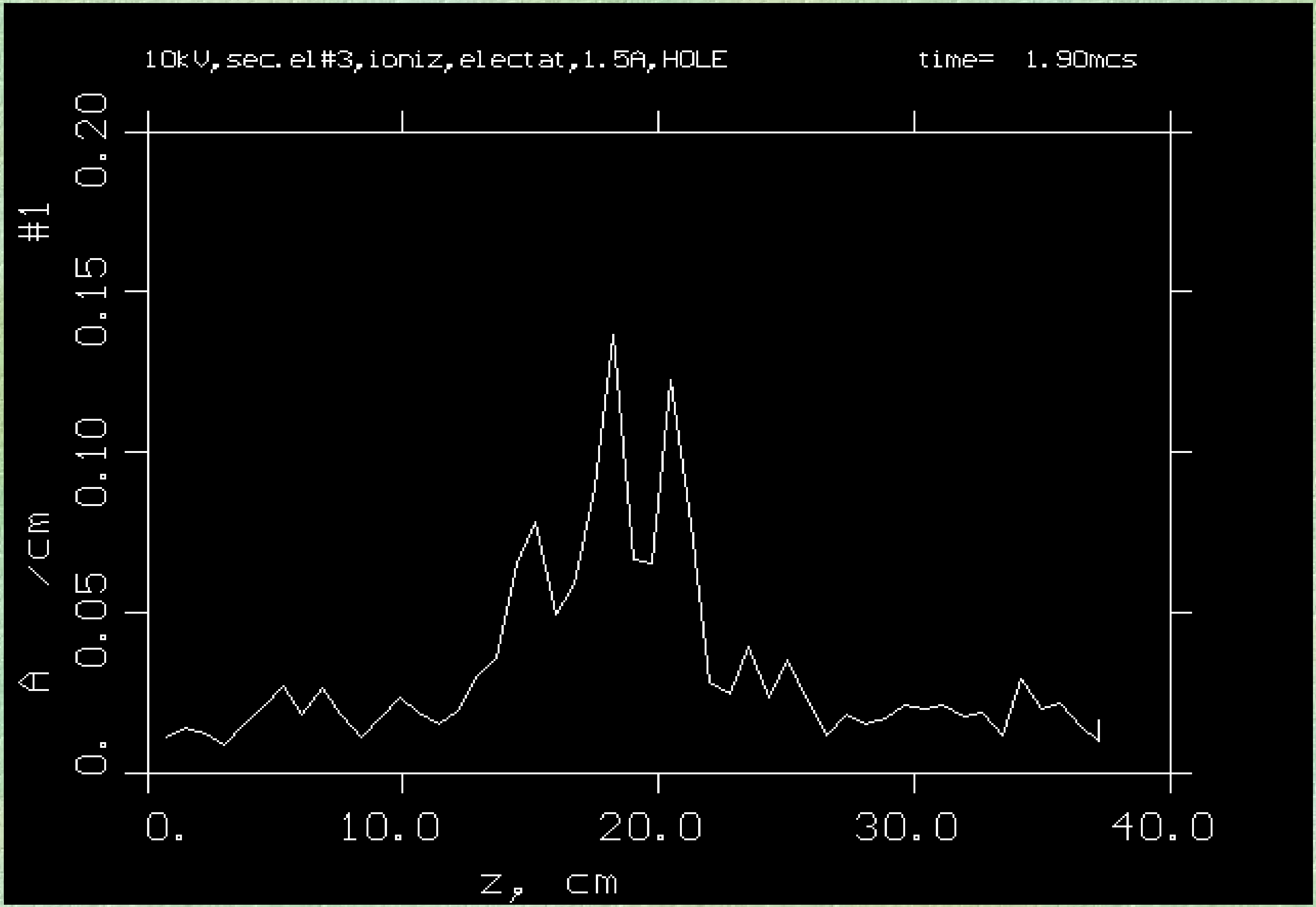
Role of secondary electrons in plasma net balance (B=0 T and γ=4)



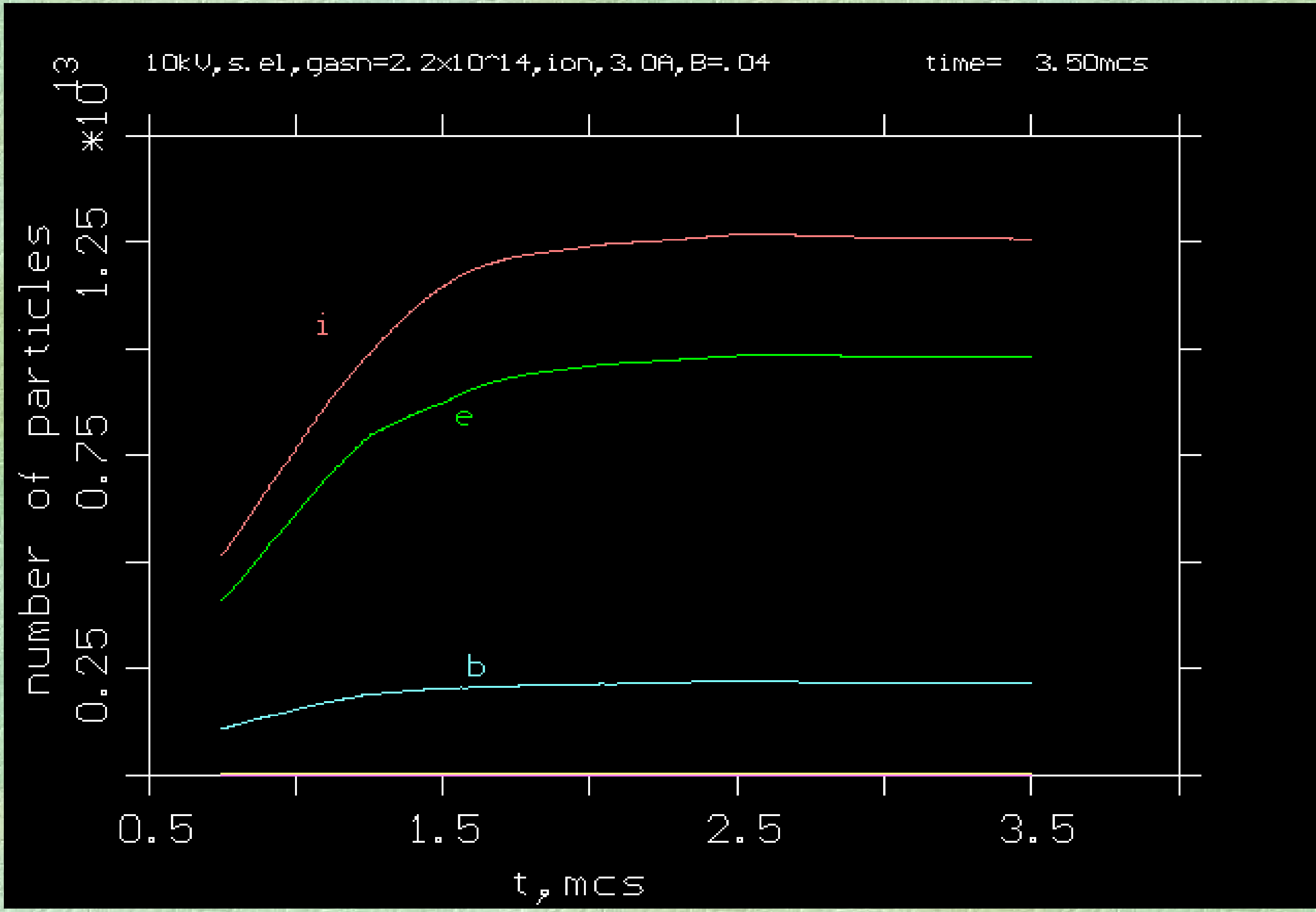
Effect of energetic secondary electrons



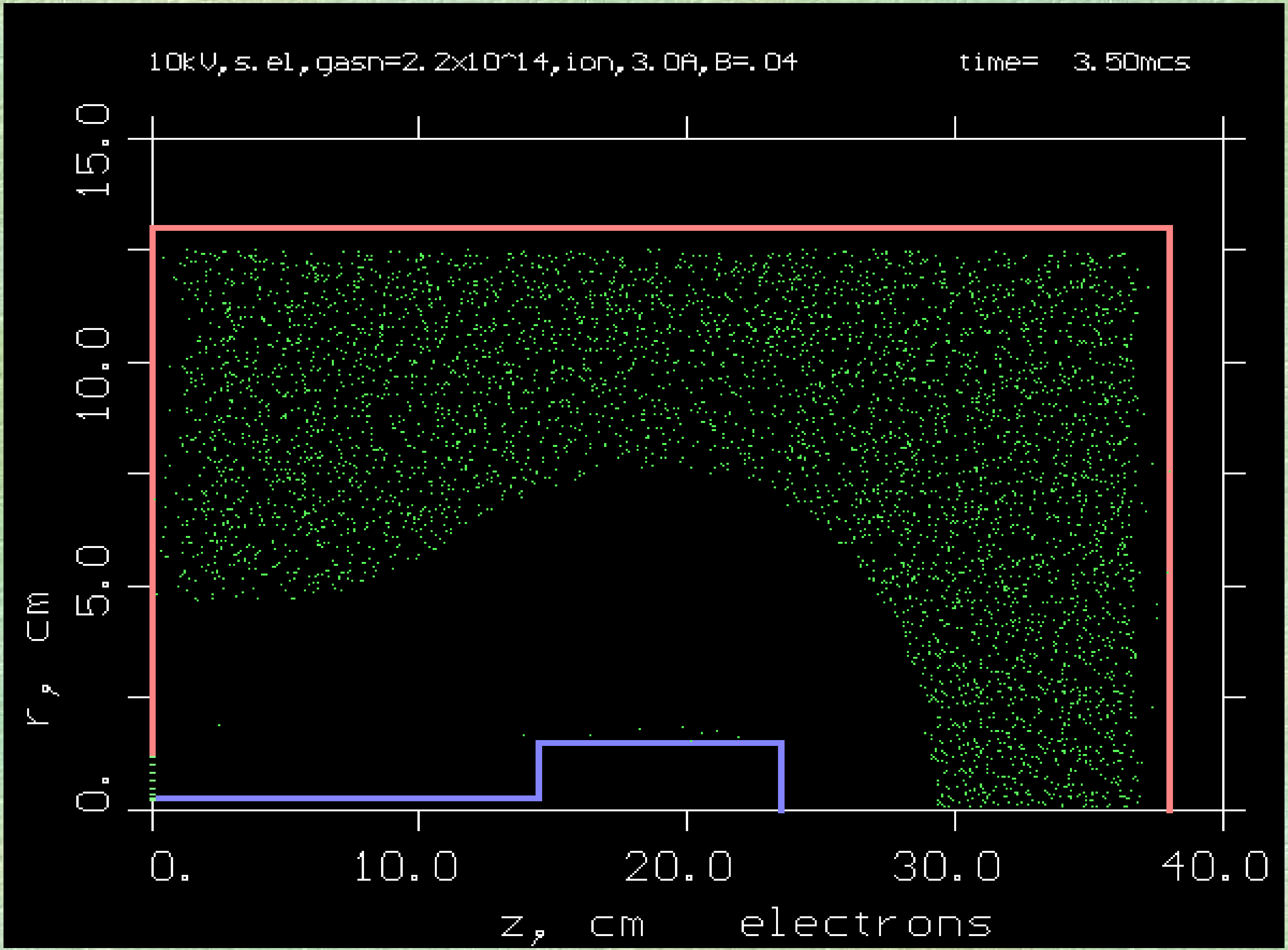
Axial distribution of electron current



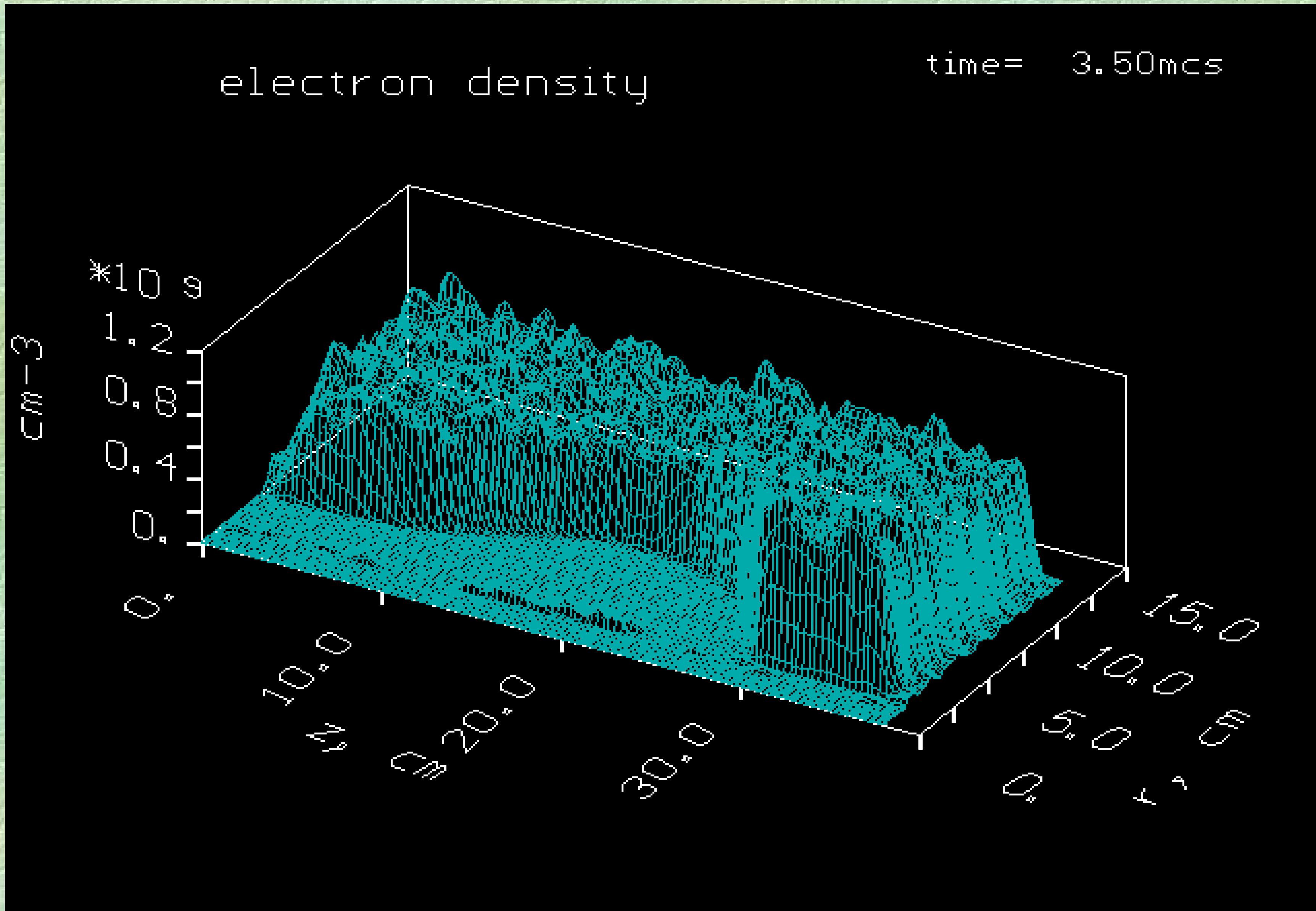
Effect of axial magnetic field (B=0.04T, γ=4)



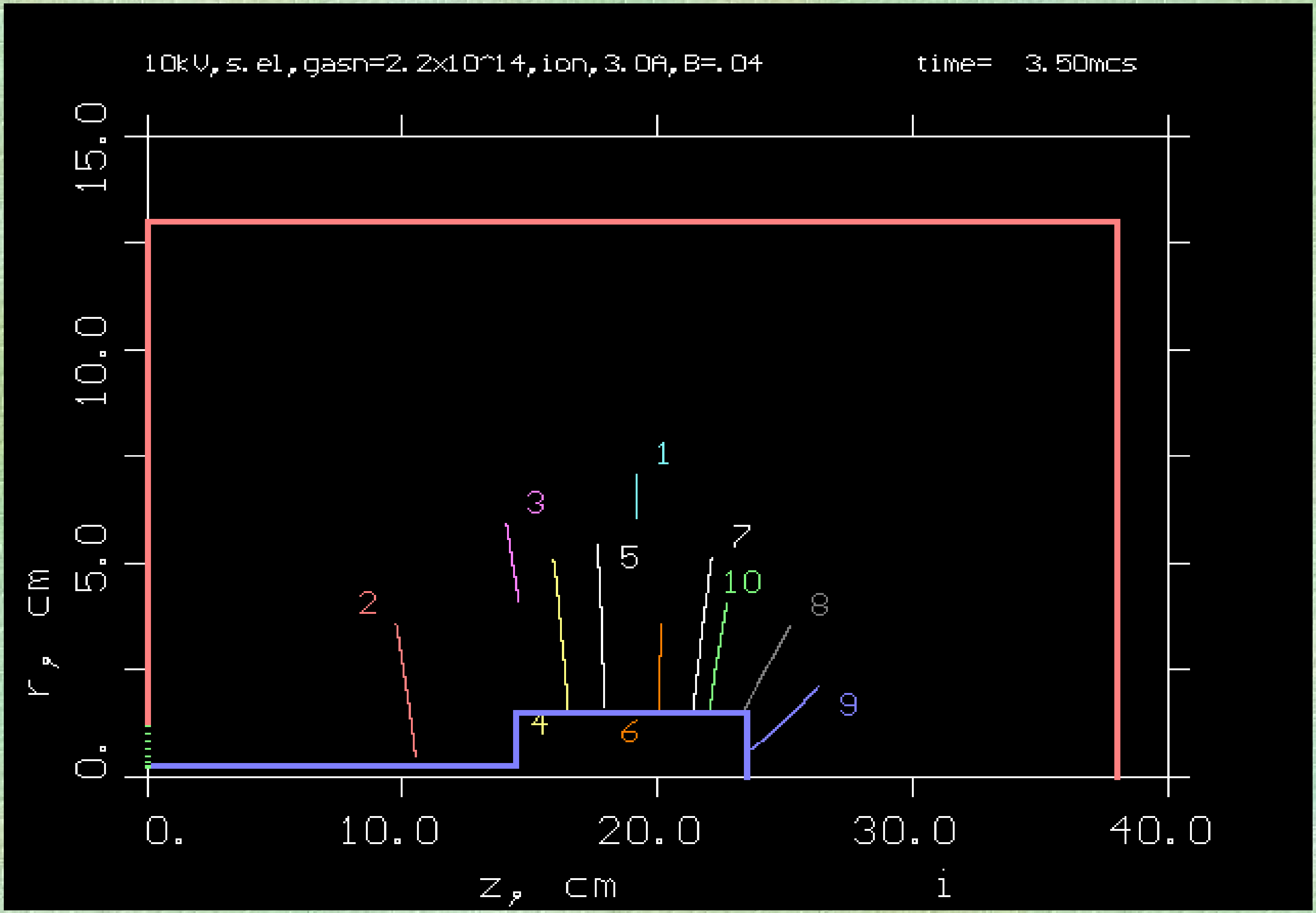
Plasma sheath with external magnetic field



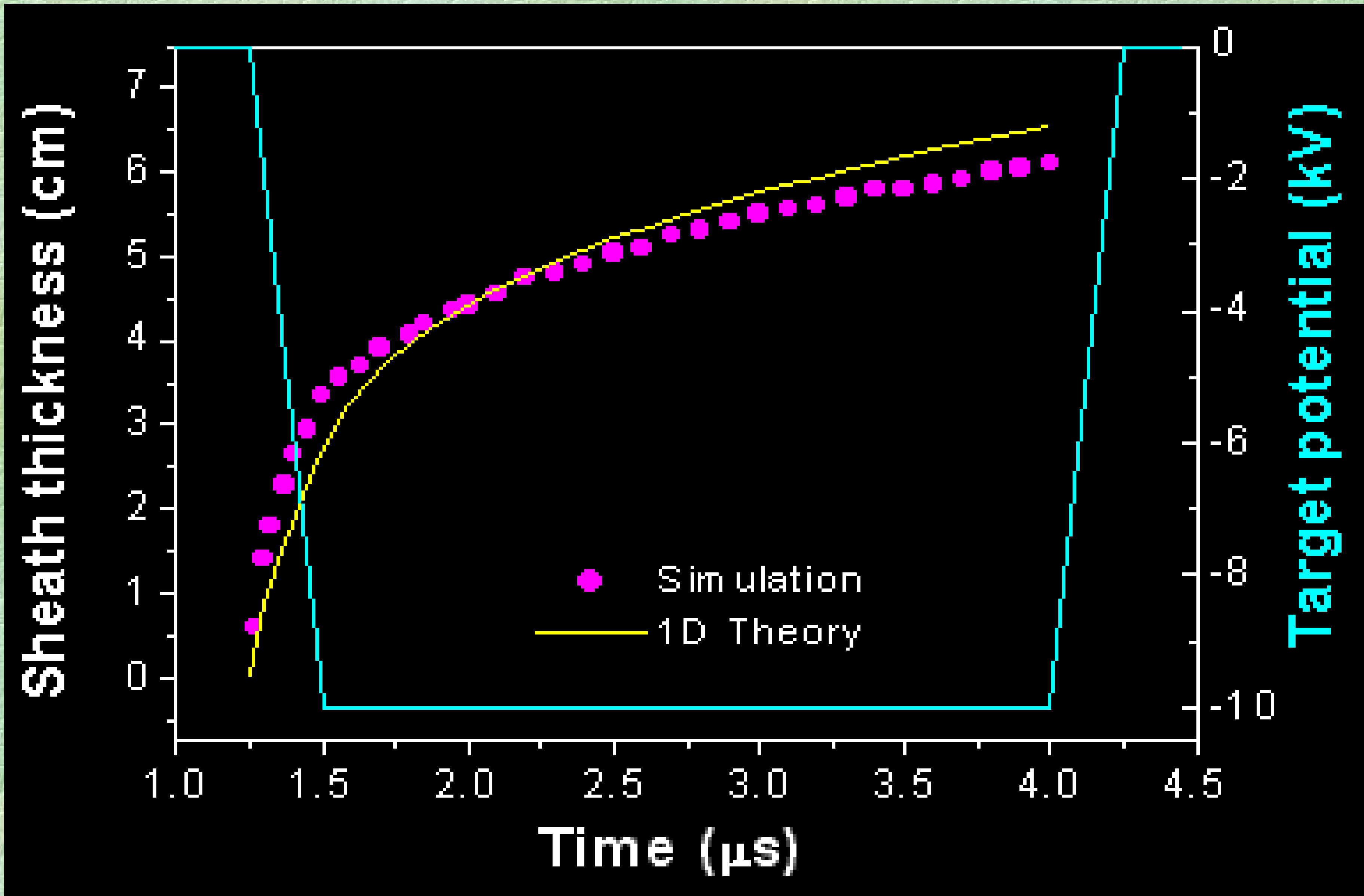
Confinement of secondary electrons



Ion trajectories in magnetized plasma



Plasma sheath expansion



Conclusions and Future Work

•Realistic PIC computer simulation of PIII process has been developed

•Steady-state plasma was generated by ionization of neutral gas

•Implant conformality for complex shaped samples has been studied

•Time evolution of plasma sheath has been investigated

•Effect of secondary electron emission has been included

•Magnetic confinement of secondary electrons has been examined

•Further refinement of numerical algorithm

•Achievement of higher plasma density in order of 10^{10} cm^{-3}

•Use of electromagnetic mode for better simulation of transient processes

•Study of plasma sheath collapse

•Investigation of PIII in nonconductive materials