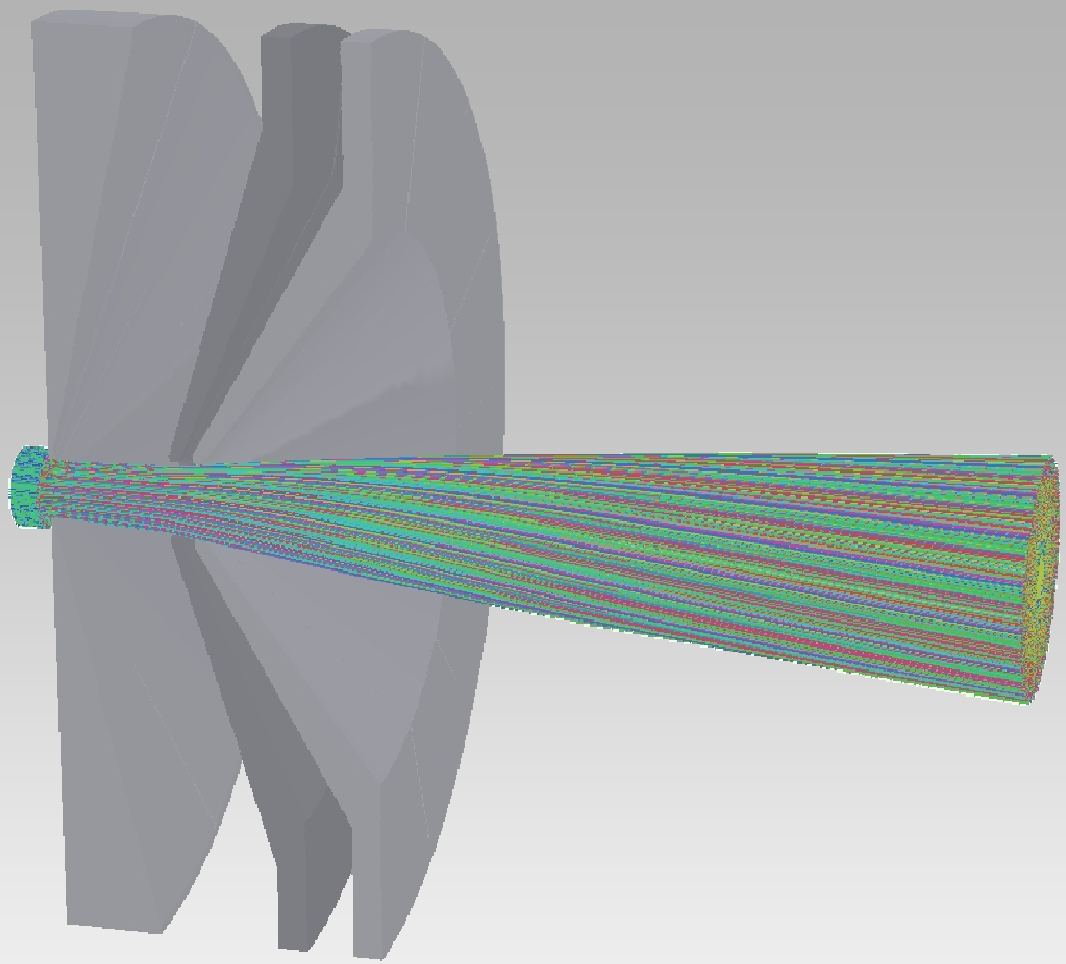

Three Dimensional Simulation of Ion Beam Extraction from an ECR Ion Source

Stephen M. Elliott, Olivier Delferriere, John Simkin, Elizabeth K. White

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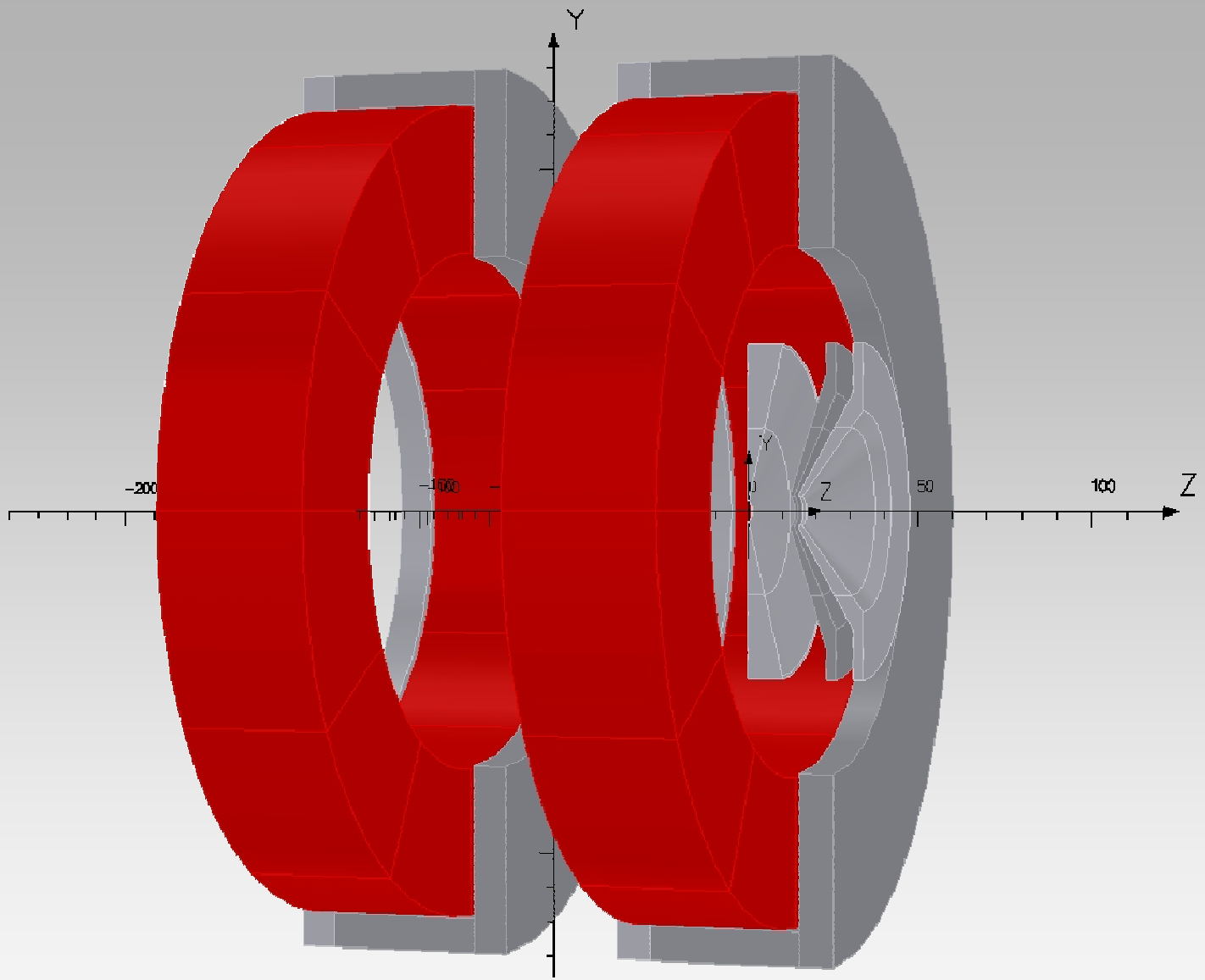
Introduction

- *Space charge simulation of ECR extraction system*
  - *Accel-Decel extraction system from plasma free surface*
  - *Combined electric and magnetic fields*
  - *Beam neutralization from gas secondary electrons*

Model

- *Ion emission from a free plasma surface*
  - *Self consistent plasma meniscus*
  - *Bohm current density*
- *Generation of secondary electrons from gas*
  - *Energy distribution*
  - *Angular distribution*



Source geometry with non-linear magnetic materials

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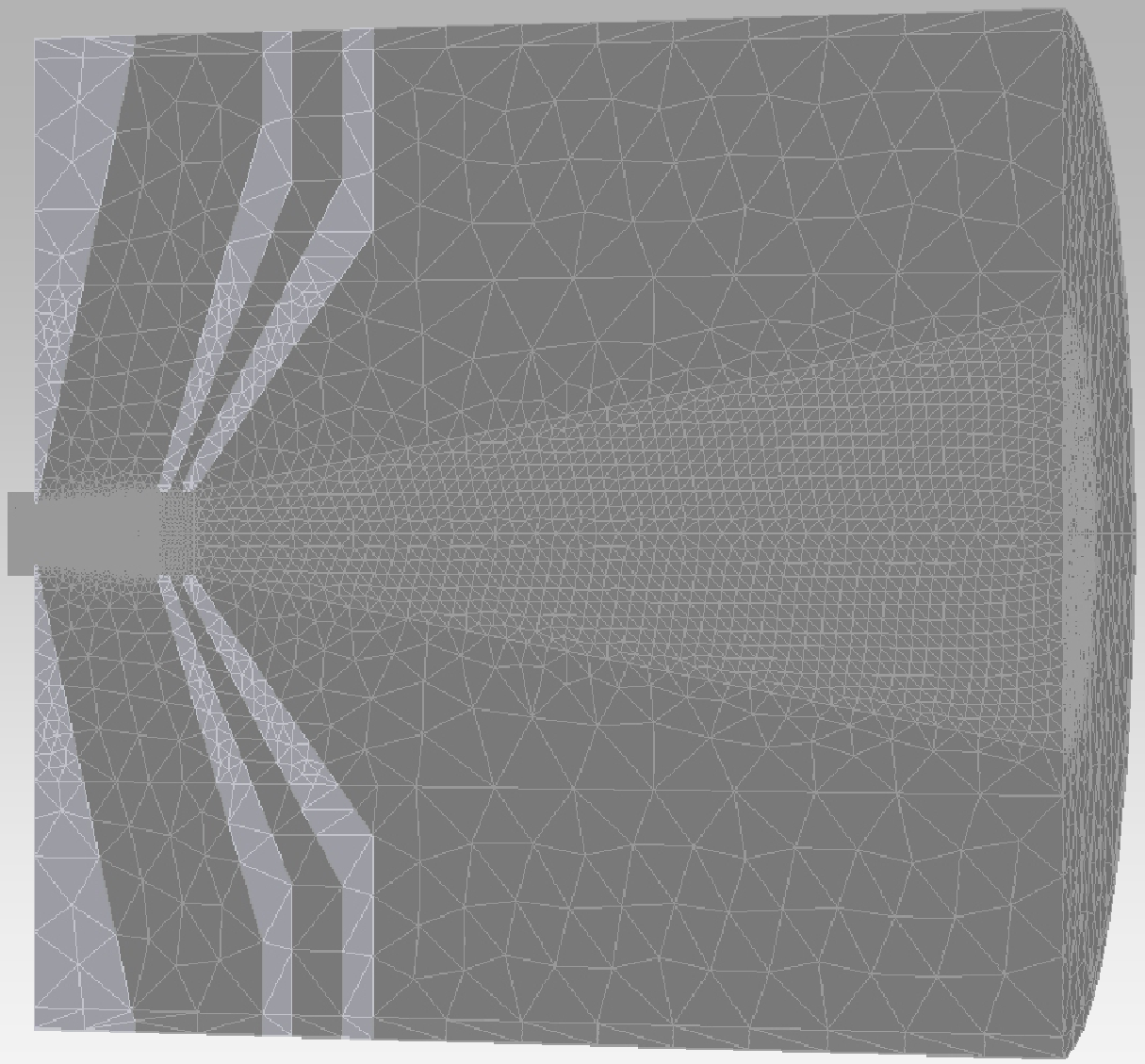

Mesh

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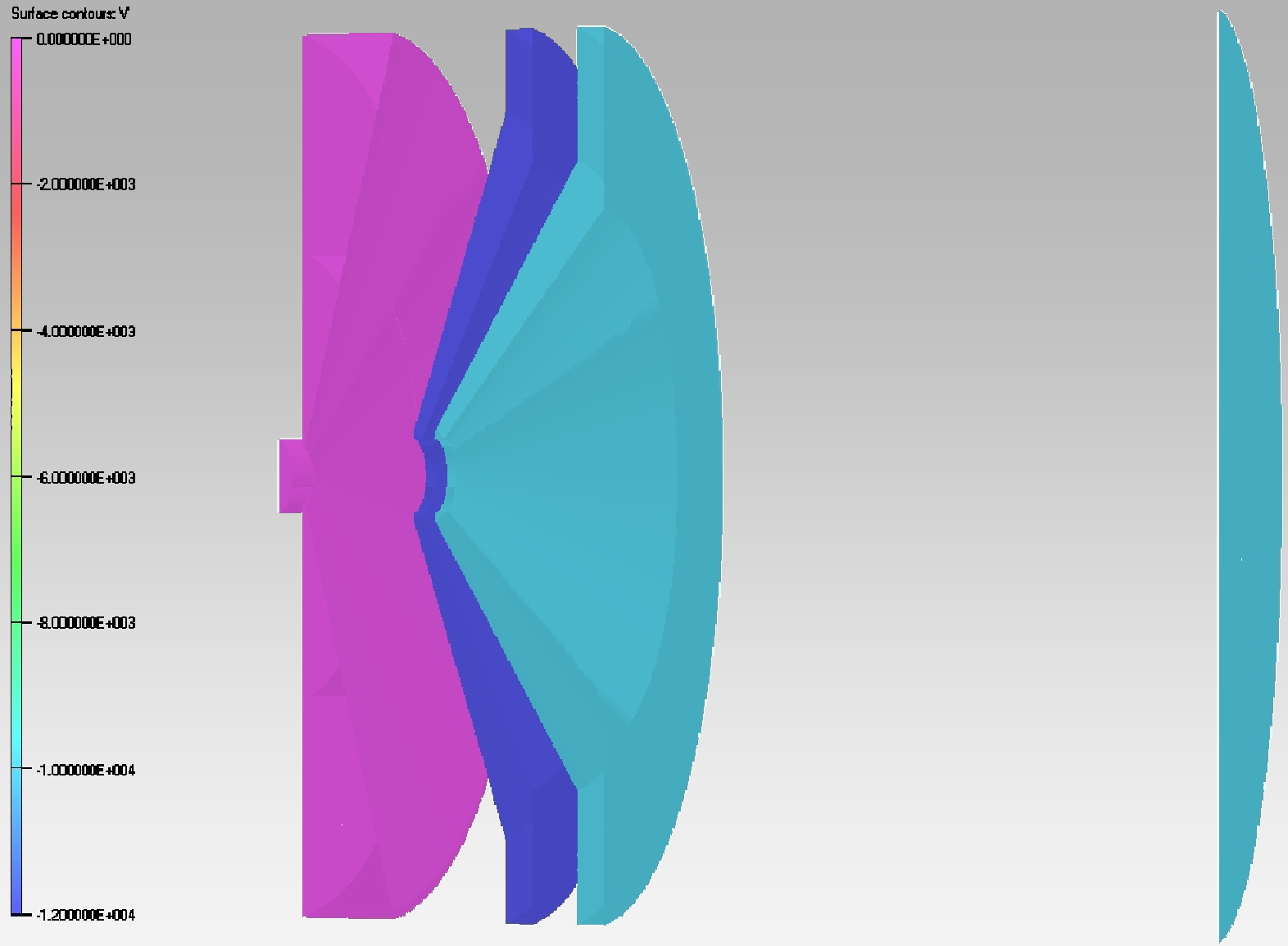

Boundary conditions, 0, -12kV, -10kV

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Primary Charged Particle Emission

- *Emission from a free plasma surface*
  - *Plasma free surface (specified current) - type 103 emitter*
    - *Self consistent plasma meniscus*
    - *Ion temperature much lower than electron temperature*
  - *Concave to convex meniscus*
  - *User specified Bohm variables*
    - *Particle mass*
    - *Particle charge*
    - *Electron temperature*
    - *Meniscus voltage*
    - *Current density*

Beam Interactions

- *Secondary particles*
  - *From gas collisions*
  - *From conductive surfaces*
  - *From lossy dielectric surfaces*
    - *Beam induced insulator charging*
- *Other behavior*
  - *Scattering*
  - *Recombination*
  - *Energy loss*
  - *Current loss*

- *Beam loss*
  - *Volume backscattered emission*
    - *Change current in beamlet*
    - *Change energy in beamlet*

$$Yield \Rightarrow \left[\frac{\partial I}{\partial s} / I\right] \ldots (cm^{-1})$$

$$EnergyLossFactor \Rightarrow \left[\frac{dE}{ds} / E\right] \ldots (cm^{-1})$$

where: I is primary beam current
E is primary beam energy
s is distance along trajectory

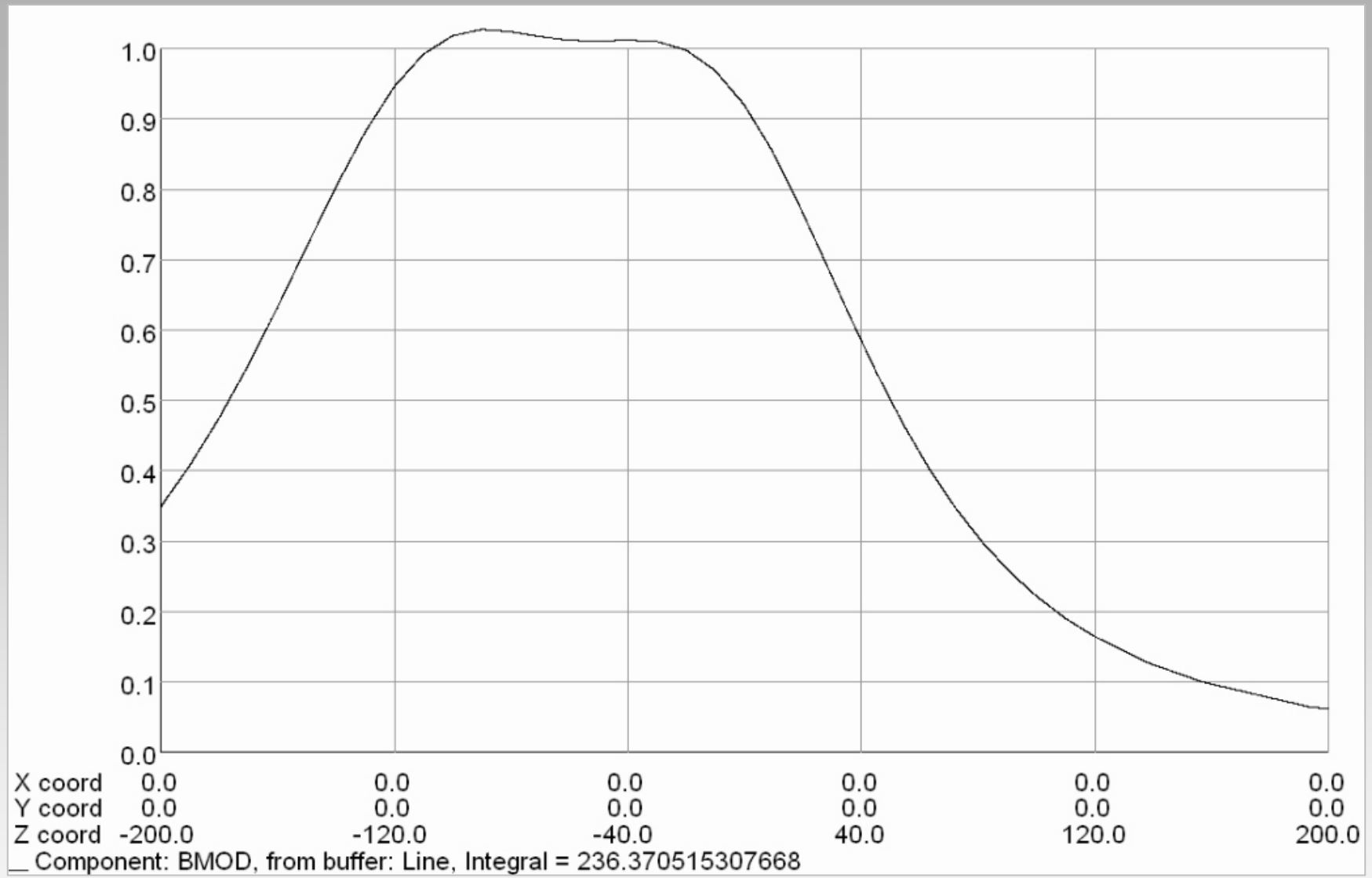
- *Volume secondaries*
  - *Secondary particles created at Maximum Trajectory Step Length characteristic spacing*

$$EmissionFraction \Rightarrow \left[\frac{dn}{ds}/(N)\right]\ldots(cm^{-1})$$

where: N is primary beam linear density
n is secondary particle linear density

Results

- *Emission from a free plasma surface*
  - *Benchmarked ion beam trajectories*
    - *Good analytical benchmark to Child's law*
    - *Good benchmark to experiment with bucket source*
- *Magnetic field*
  - *Good benchmarks with non-linear materials*



Magnetic flux density on axis

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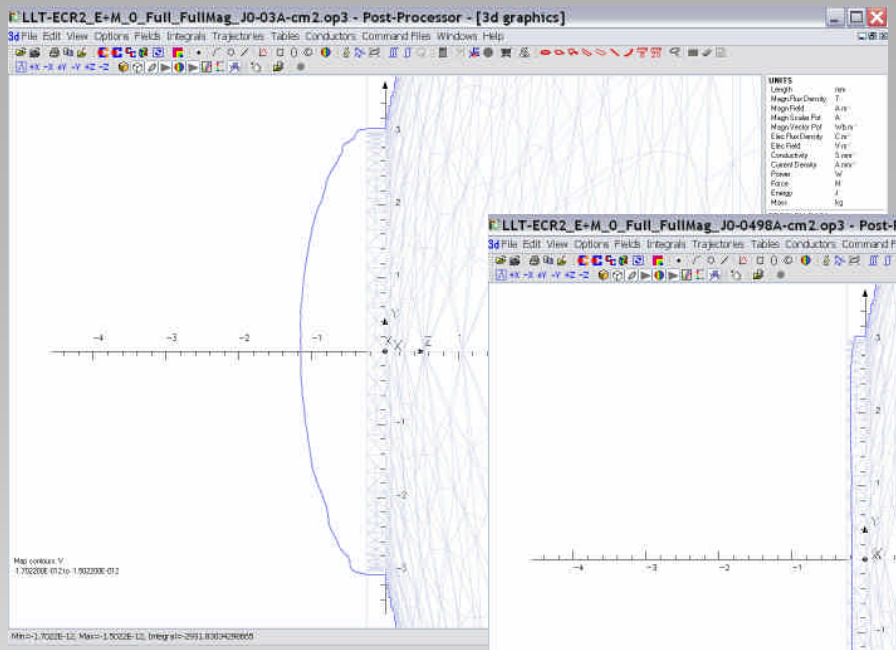
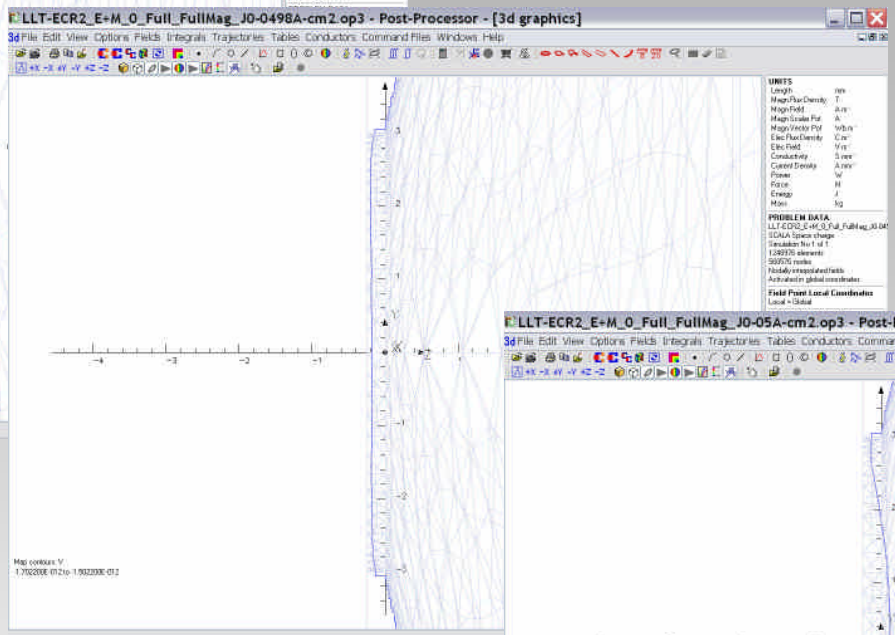
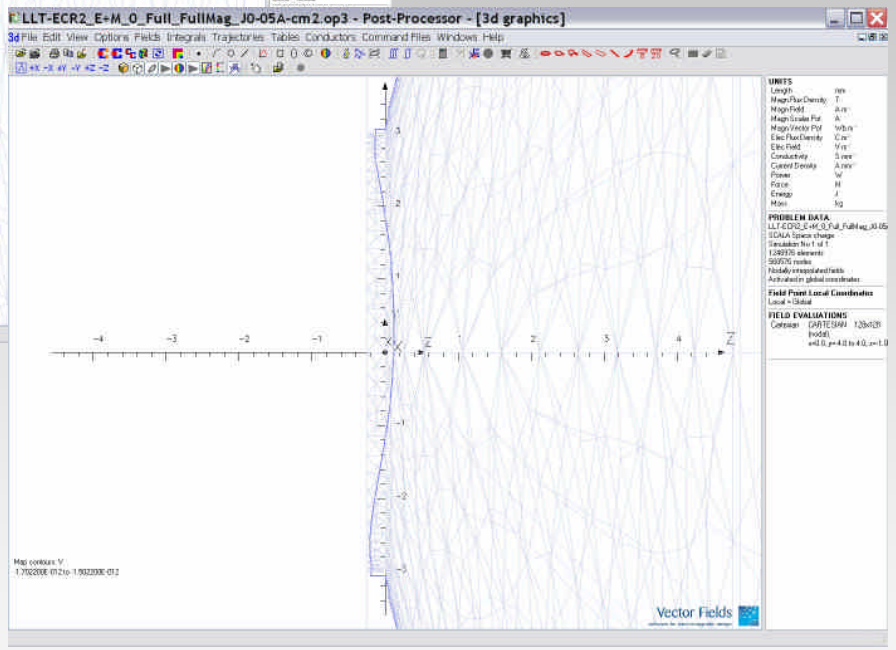


$J = 0.0\ 300\ A{\cdot}cm^2$



$J = 0.0\ 498\ A{\cdot}cm^2$



$J = 0.0\ 500\ A{\cdot}cm^2$

Plasma meniscus shape varies with current density

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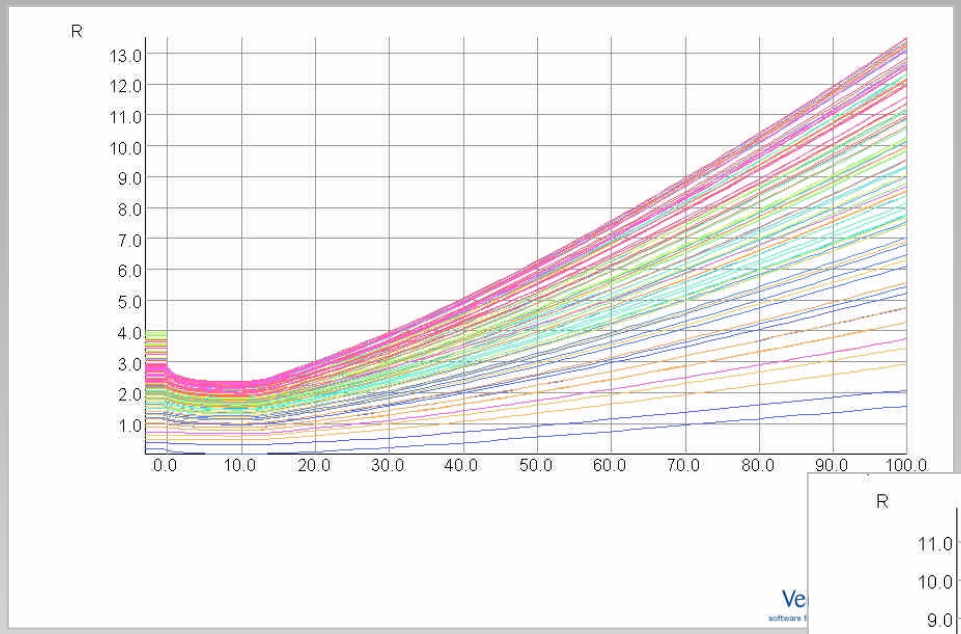
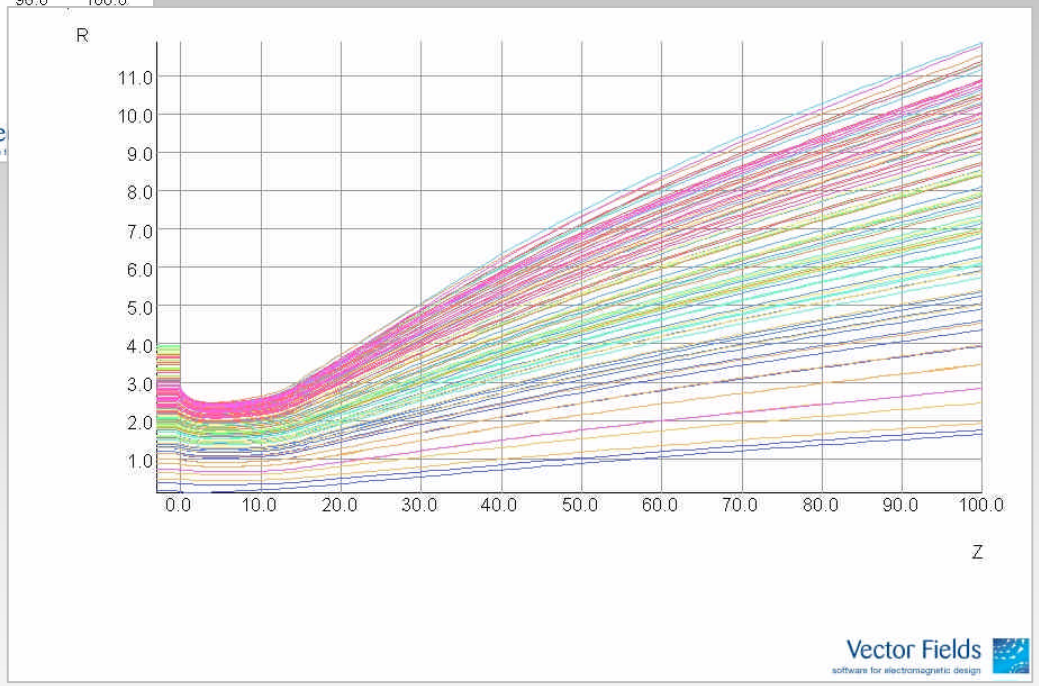


No magnetic field

Note vertical scale

With magnetic field



Influence of magnetic field on non-neutralized ion beam

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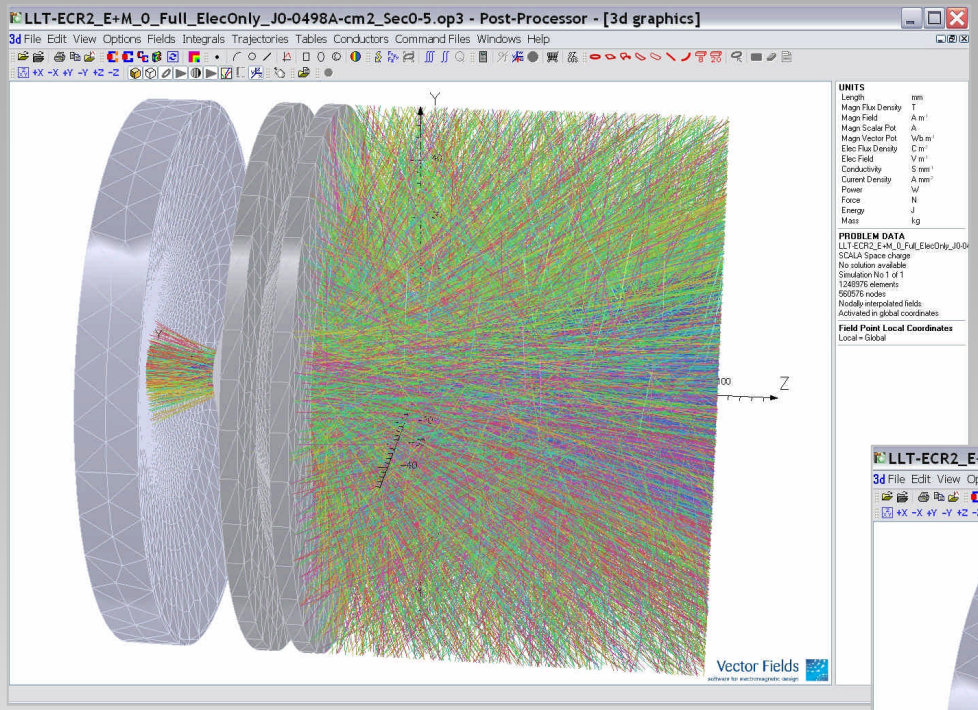
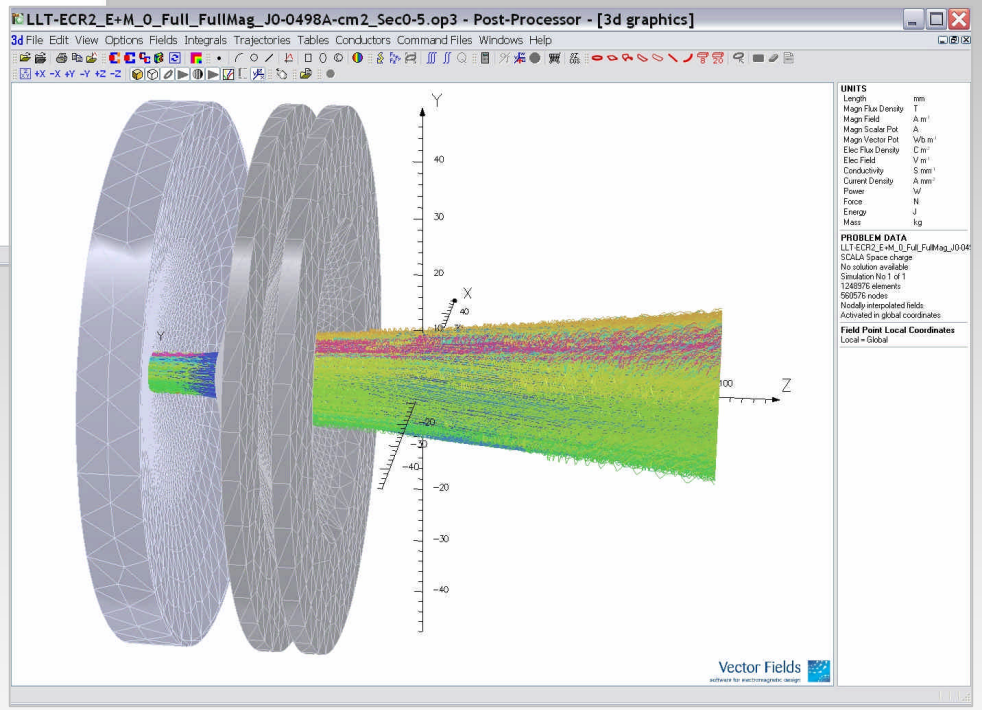


No magnetic field



With magnetic field

Influence of magnetic field on gas secondary electrons

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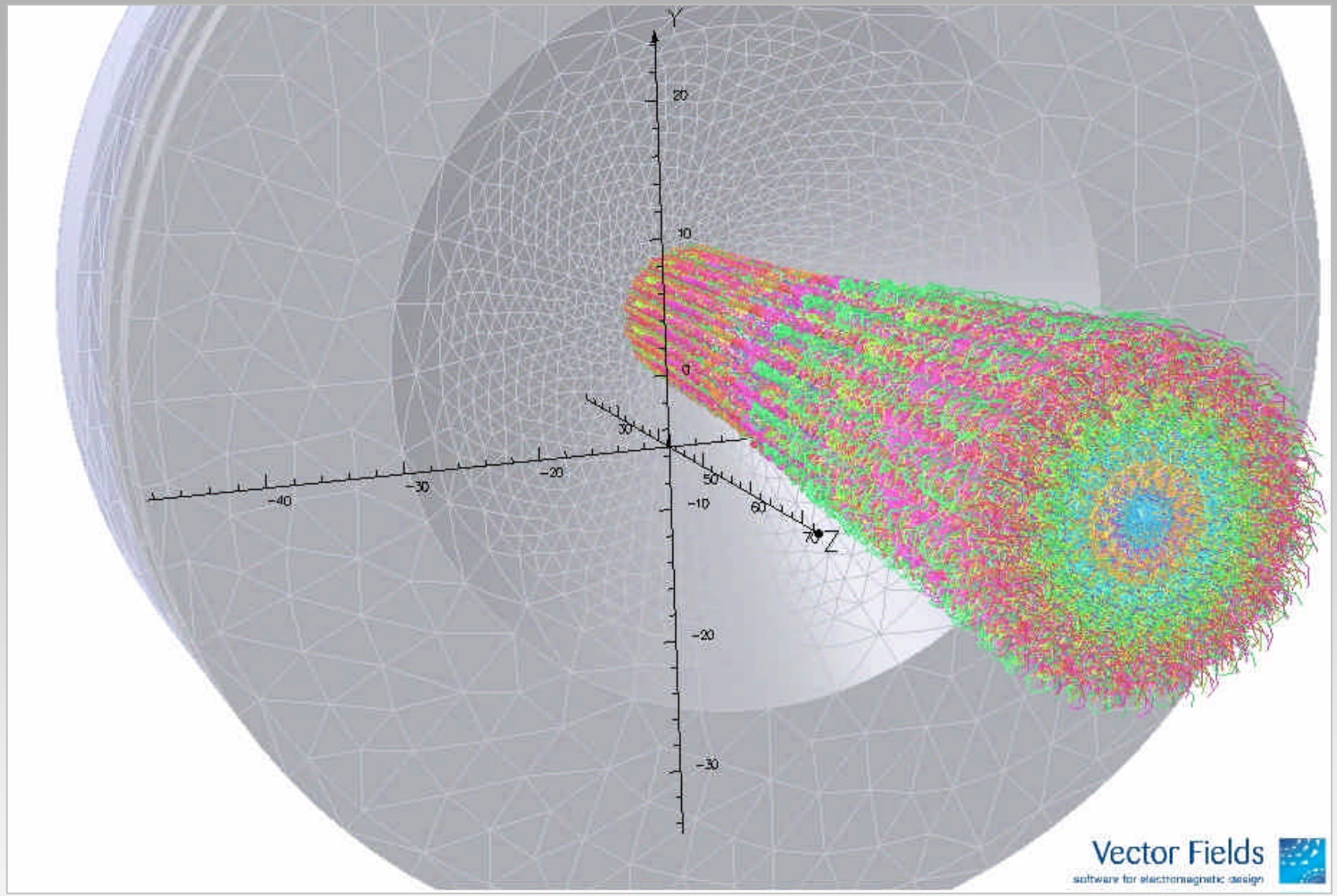

Magnetized gas secondary electrons

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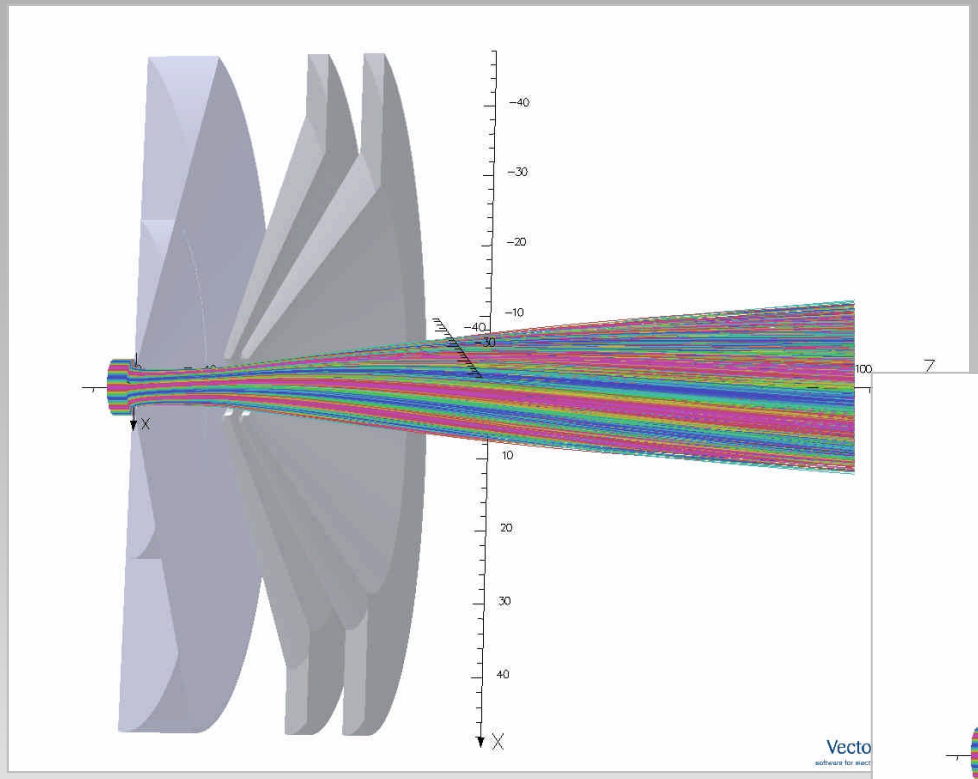
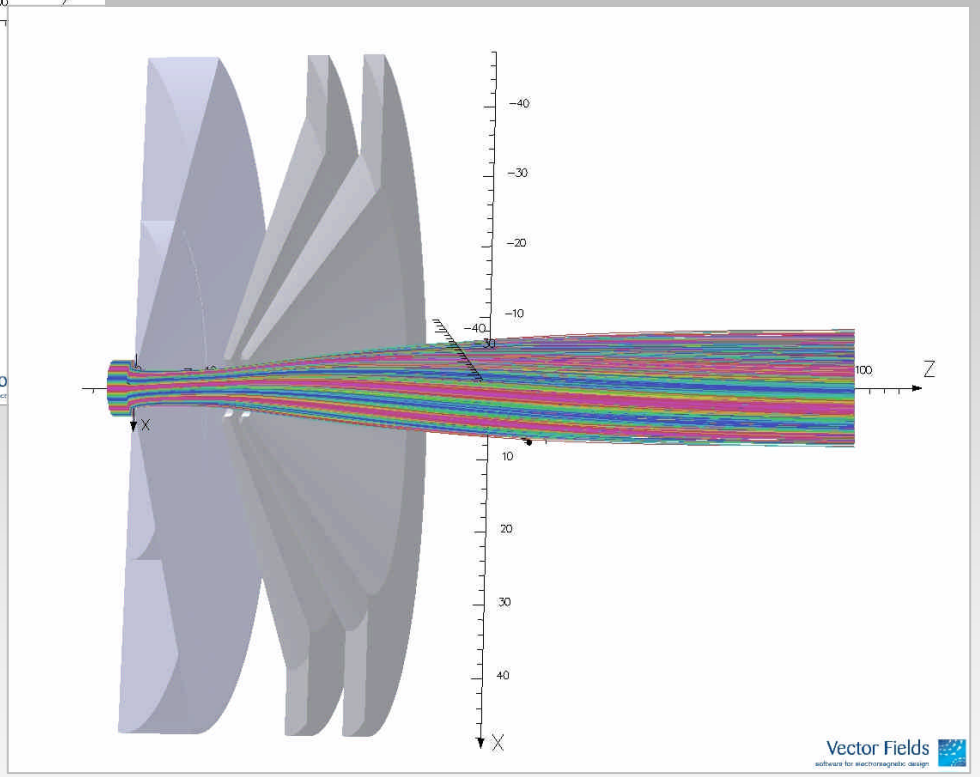


No neutralization



With neutralization

Influence of gas secondary beam neutralization

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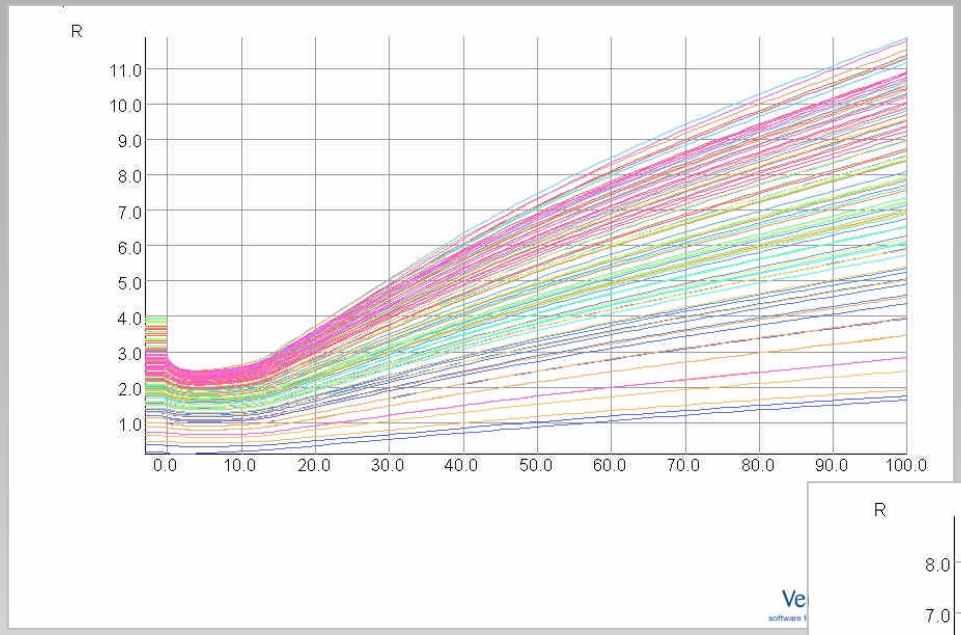
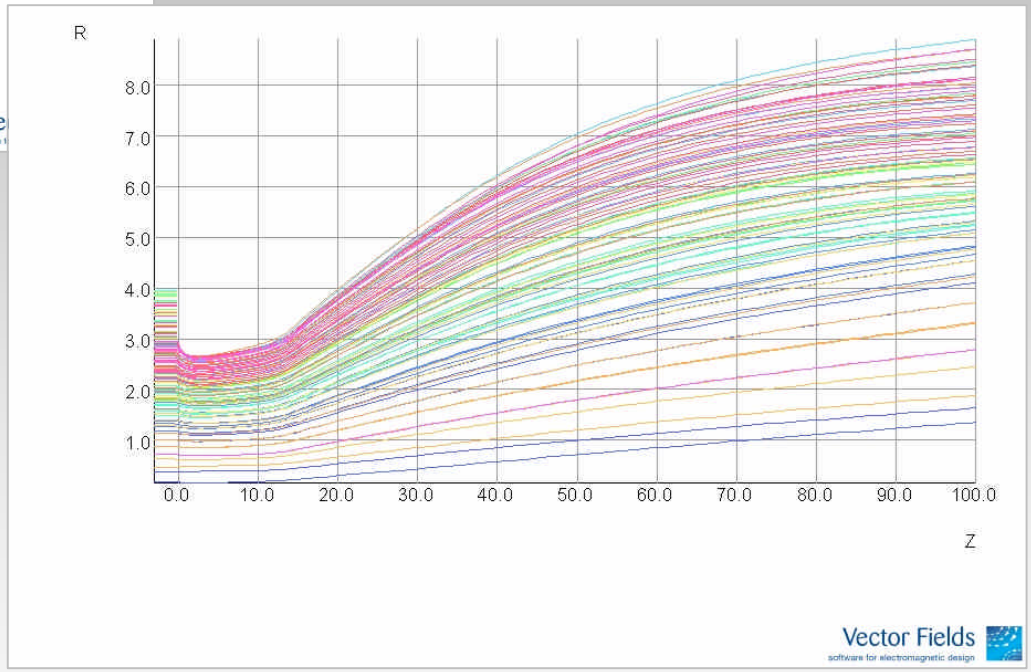


No neutralization

Note vertical scale

With neutralization



Influence of gas secondary beam neutralization

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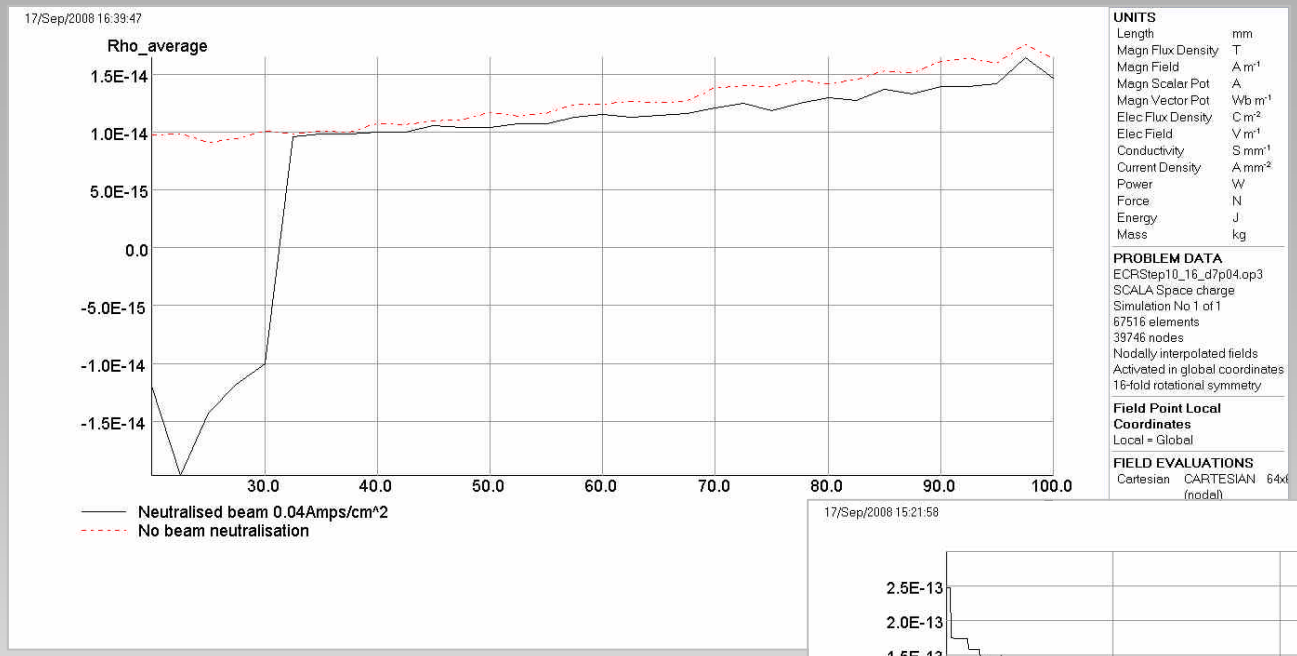
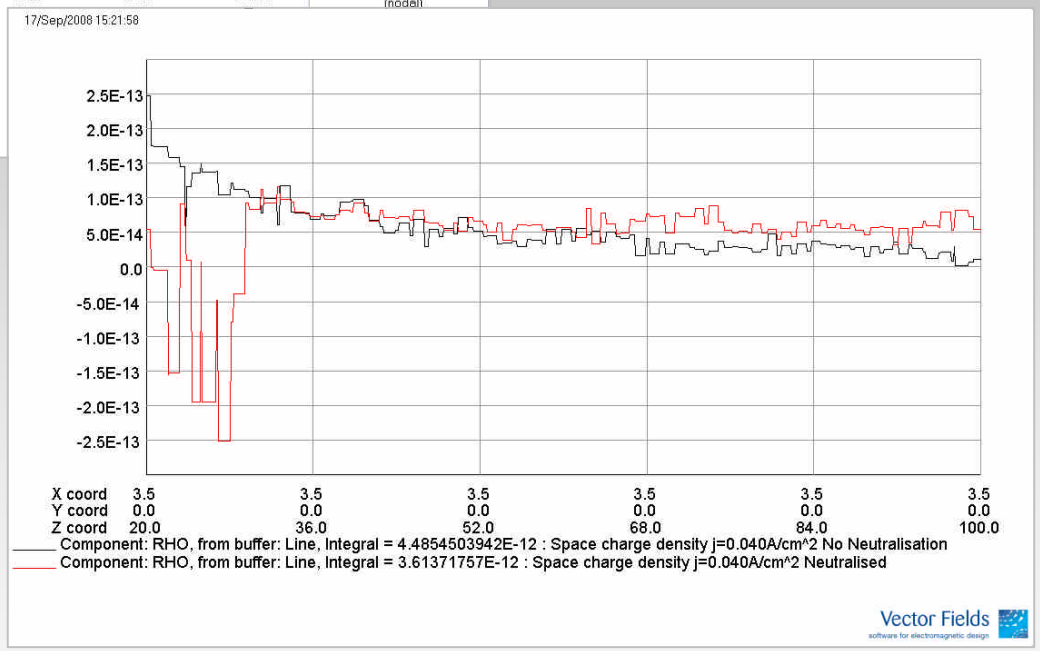


Average across beam diameter



Along line at radius = 3.5 mm

Space charge, Coulombs/mm³

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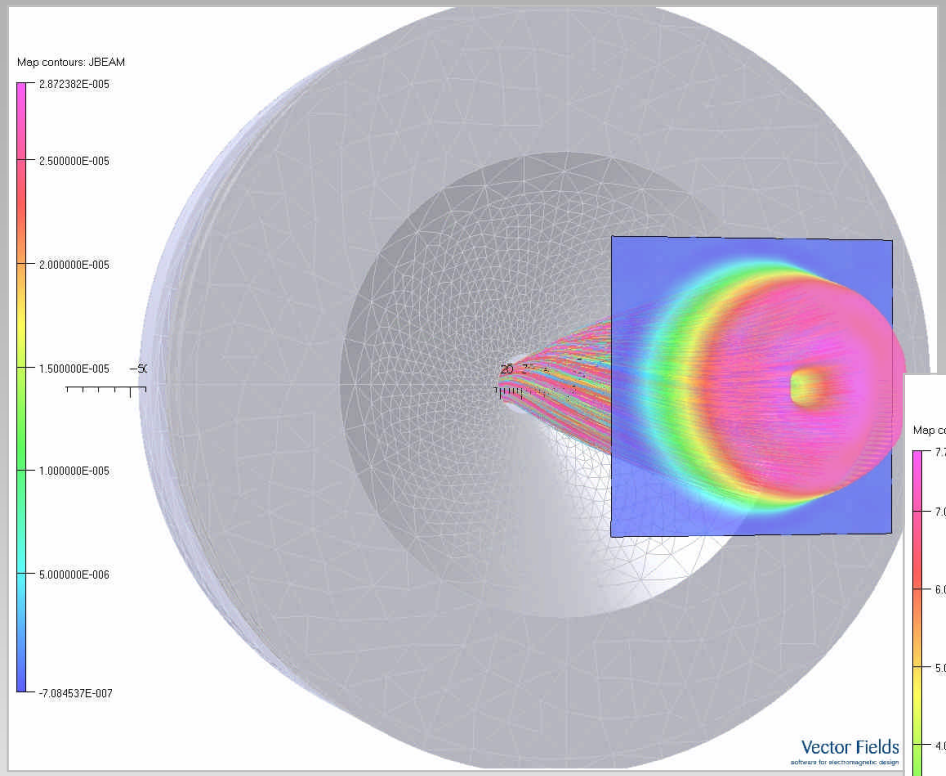
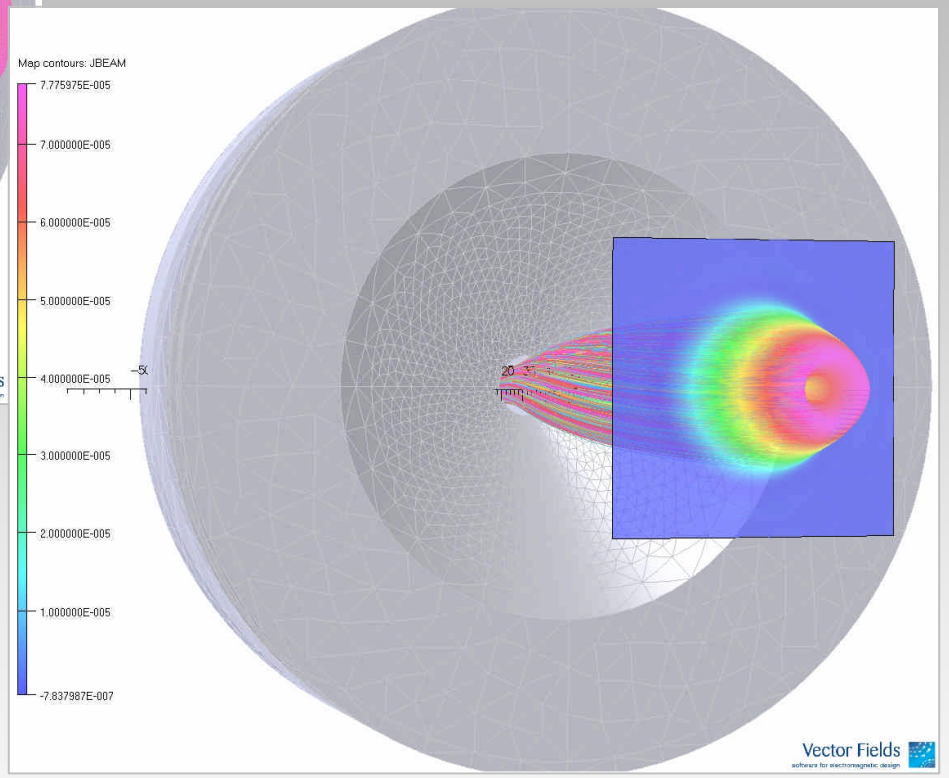


No neutralization



With neutralization

Influence of gas secondary beam neutralization

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Conclusions

- *Suitable plasma free surface emitter*
  - *Good agreement to bucket source*
  - *Can simulate complex aperture shapes*
- *Secondaries from gas collisions*
  - *Automatic sampling with FEM*
    - *No PIC code*
  - *User controlled emission laws*