Beam Interaction with Chamber Aerosols

D. R. Welch and D. V. Rose, MRC

C. L. Olson, SNL

S. S. Yu, LBNL

October 2-4, 2002

Presented at the ARIES Project Meeting at PPPL, Princeton, NJ.

Work supported by ARIES and LBNL through PPPL

Purpose: Assess the effects of aerosol droplets on HIF beam propagation

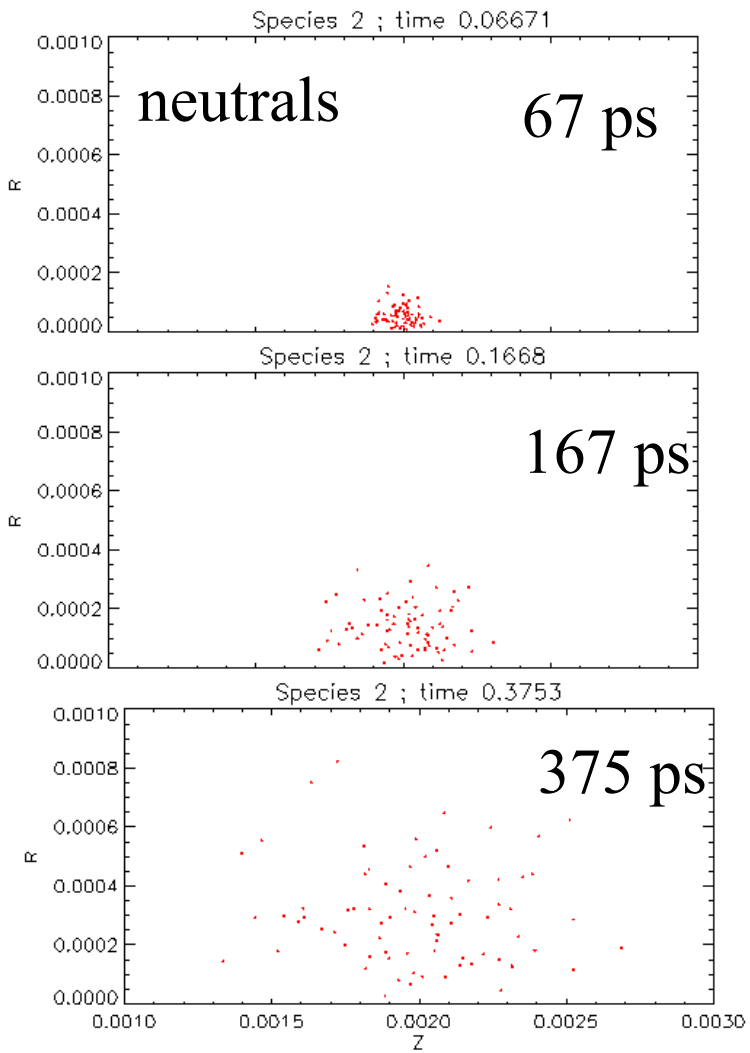
- Time-dependence of effect
- Electrostatic charging of droplet:
  - impact ionization, beam stripping and slowing down of co-moving electrons can remove or deposit additional electrons onto droplet

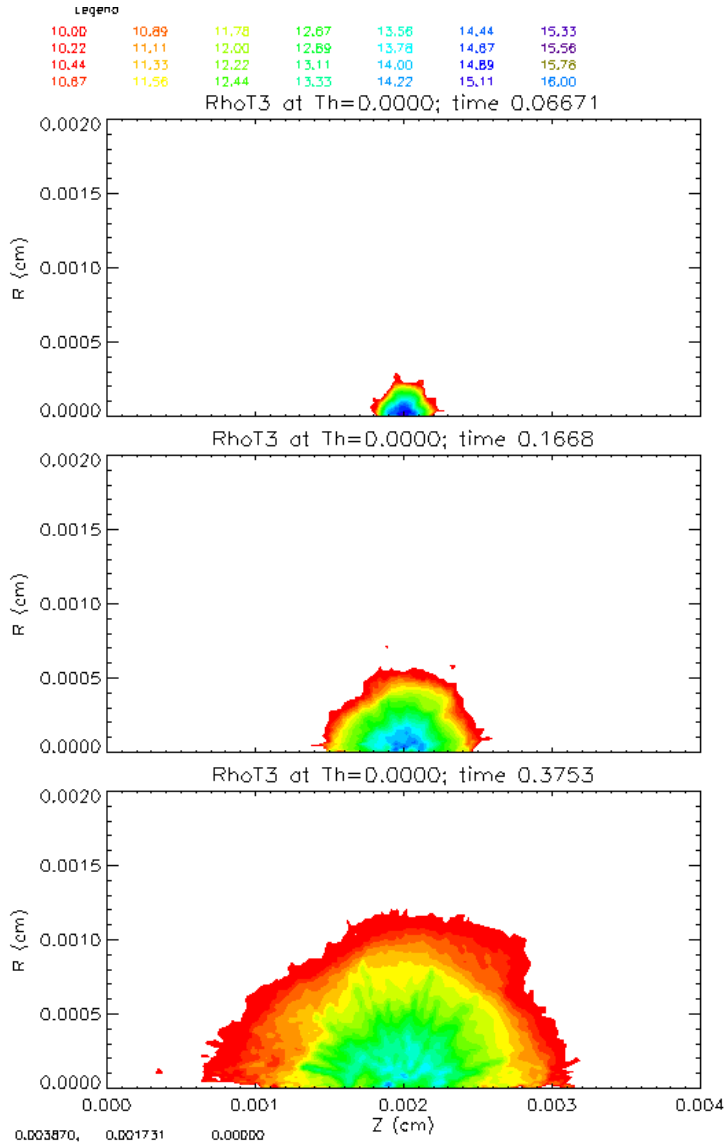
Using LSP, carry out 2-D simulations of a single, micron-scale-size, cylindrical droplet impacted by a uniform heavy ion beam.

2-D cylindrical LSP simulation parameters:

- Beam initial conditions:
  - 320 A/cm^2 , 3.8 GeV Pb^+ ions
  - co-moving electron cloud
- Droplet initial conditions
  - neutral H_2 , 10^{21} cm^{-3} density, 1 eV, 0.2-5.0 μm radius
- Simulation physics
  - 2-D cylindrical, 200-μm length, 100-μm radius vacuum chamber
  - electrostatic field solver
  - impact ionization, stripping
  - slowing down, elastic scattering, and charge exchange

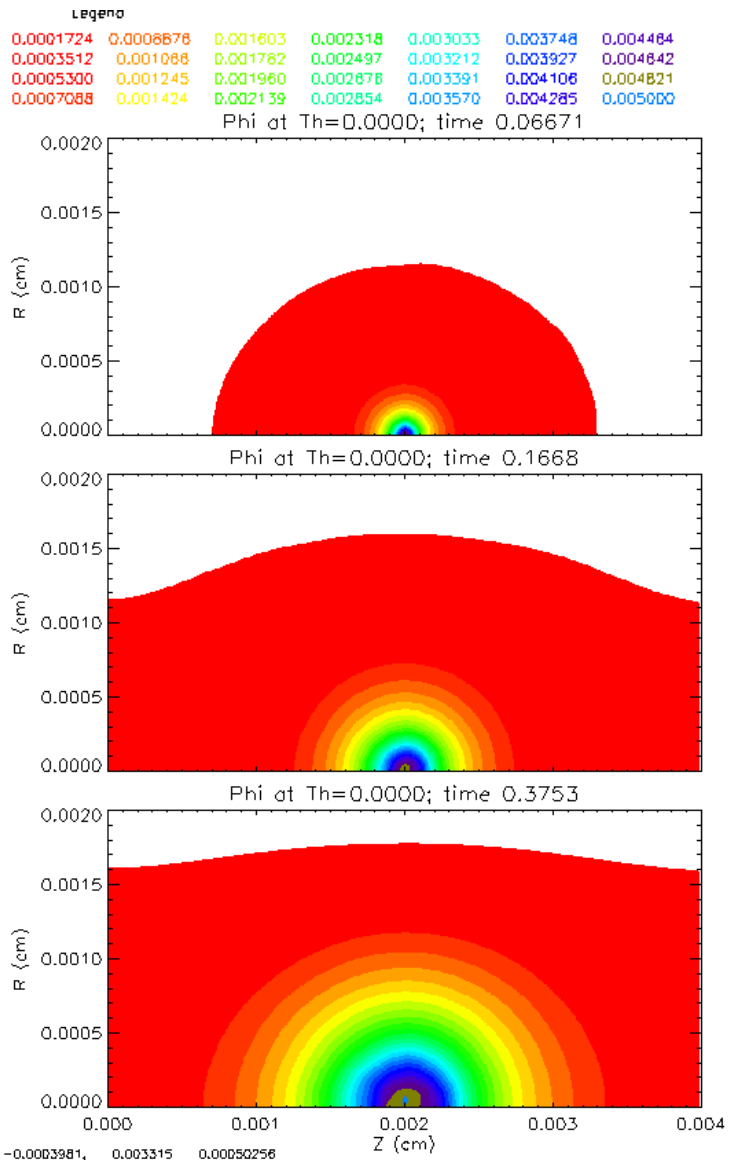
0.2 μm droplet expands at 20 cm/μs





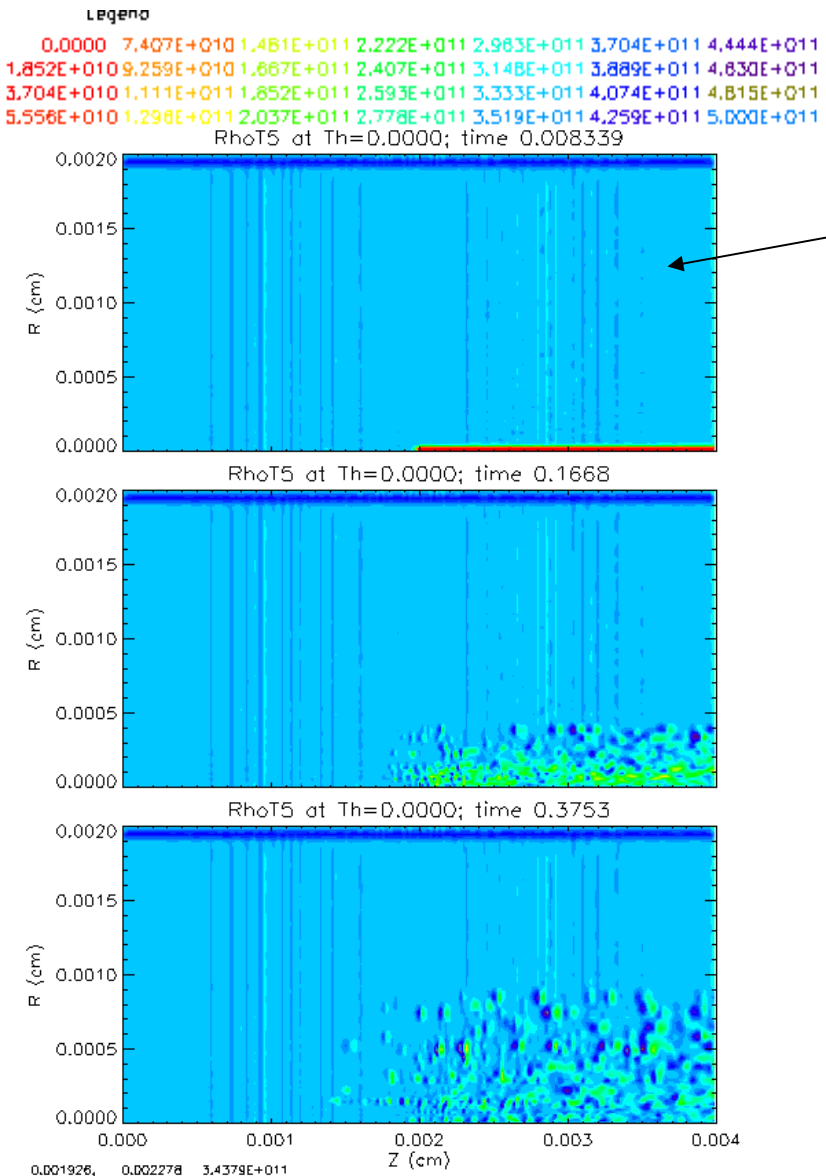
- Neutrals are heated 20% (to 1.2 eV) from collisional interaction with plasma ions

Plasma expansion is driven by ambipolar diffusion from 6 eV ionization electrons



- Peak electrostatic potential remains at roughly 5 eV, but the extent of the well grows with the expanding10^{15} - 10^{16} cm^{-3} density plasma
- In time, more ions are affected but by a very weak potential - **should be no measurable electrostatic effect**

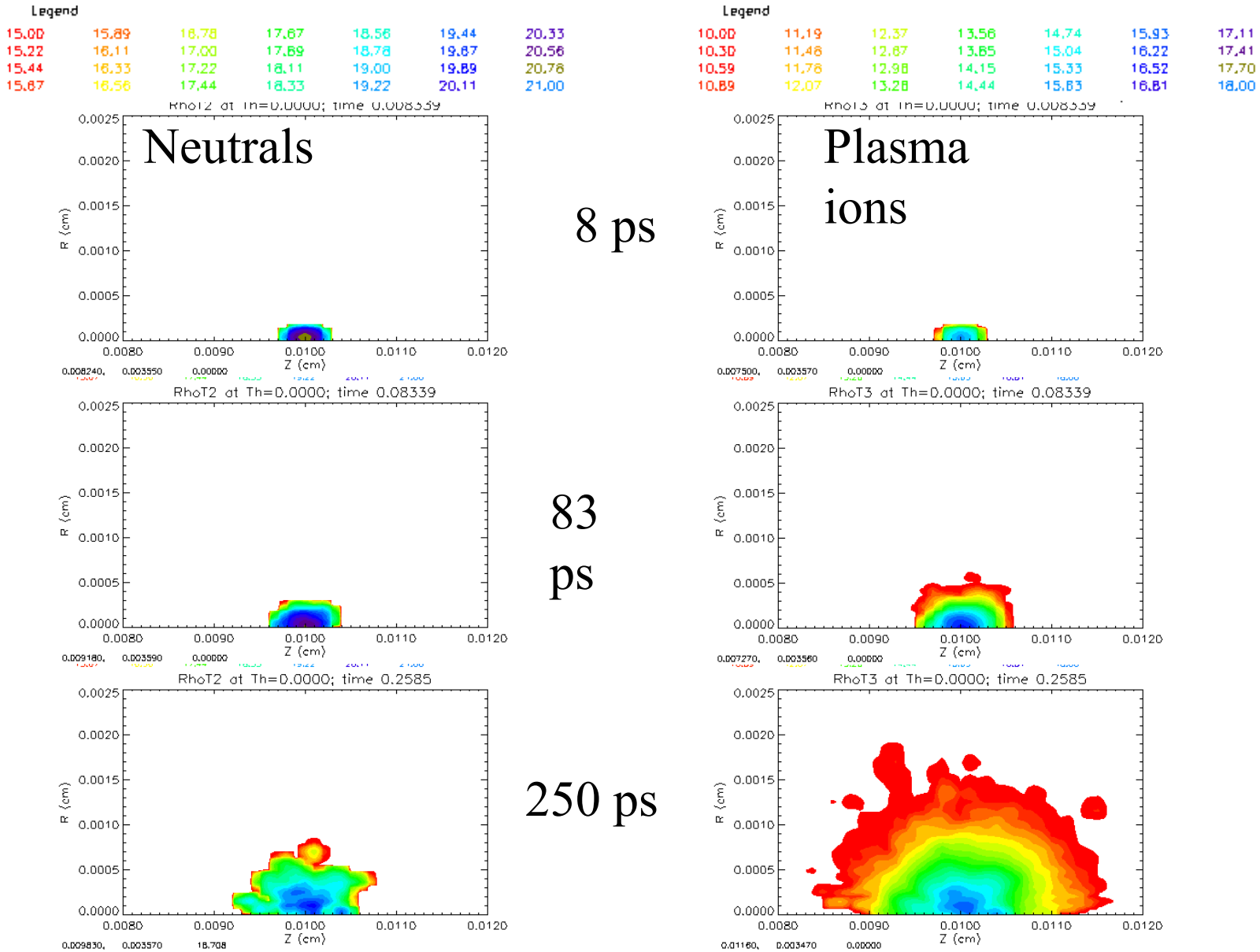
Initially, stripping is large for a few beam ions, then becomes small to subsequent ions.



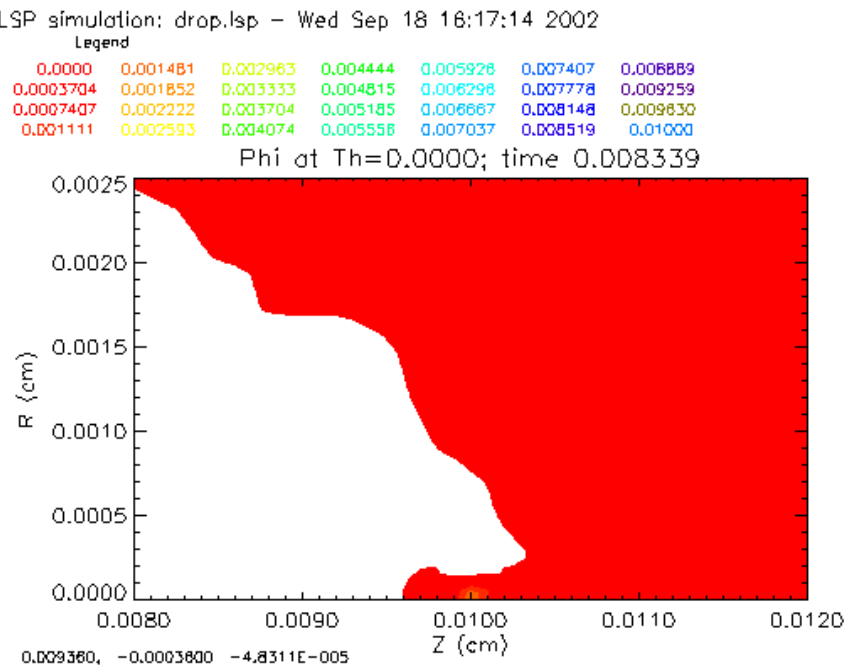
- Pb^{+1} beam density
- At early times the droplet shadows the beam; beam is highly stripped
- Later, more beam ions are affected but only weakly

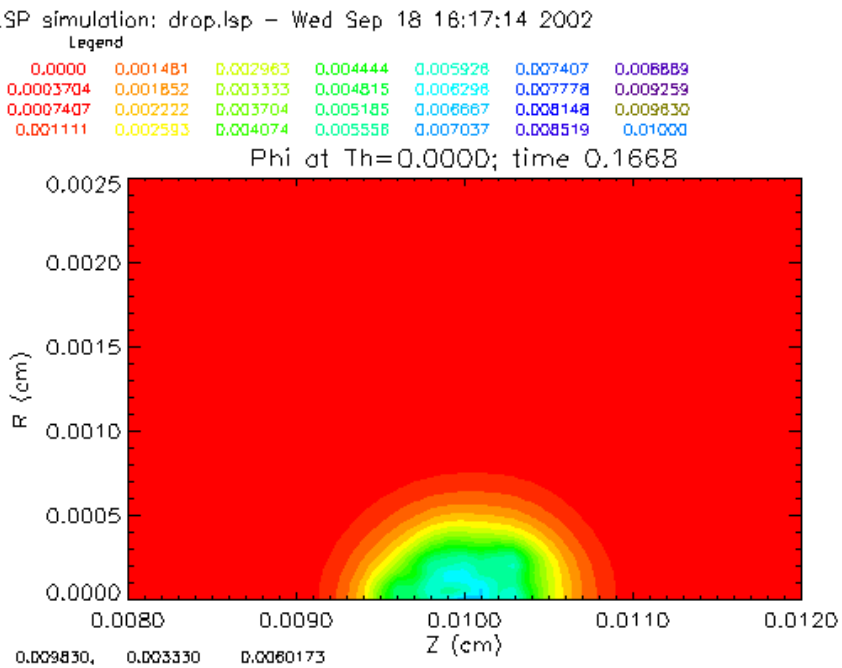
Effect approaches continuous limit of line-gas density

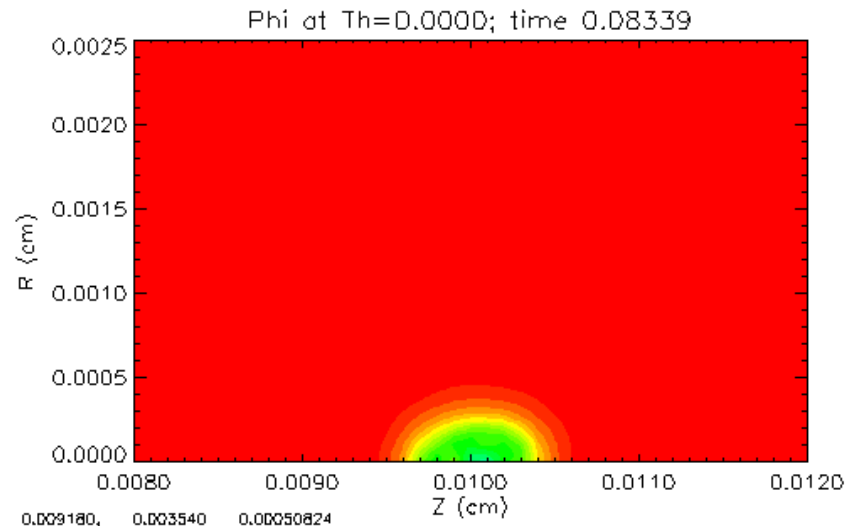
1-μm droplet behaves similarly to 0.2-μm case

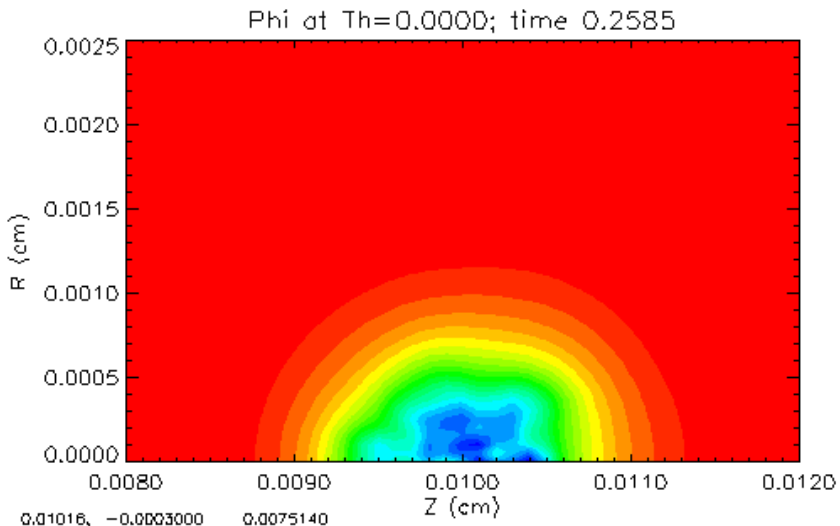


Again, potential consistent with electron temperature (5-8 V)









In regimes of interest, simulations suggest effect of droplets can be calculated purely from their line-integrated density

- Droplet charging effects are very weak
  - peak potentials of order 5-8 Volts
- Small vaporized (<0.1 micron) droplets will expand with density approaching uniform on time scale of beam for $>10^6$ droplets uniformly spaced
- Conclusion: Tolerable line-integrated density is roughly 10^{16} cm^{-2} due to beam stripping (same as vapor pressure limit)

Farrokh's Three Questions:

- Wrap up? The preliminary simulations should be refined (not a major effort). Scaling with aerosol parameters should also be quantified.
- Impact On ARIES IFE Studies? A metric has been provided for evaluating the impact of aerosols on beam transport. Thus, constraints on the aerosol number density and particle size can be obtained, an important aspect of the chamber conditions/design criteria.
- Experiments? Near term heavy-ion beam experiments unlikely. Light-ion beam propagation through aerosol environments may be feasible and provide data on scattering/emittance growth (not beam-ion stripping).