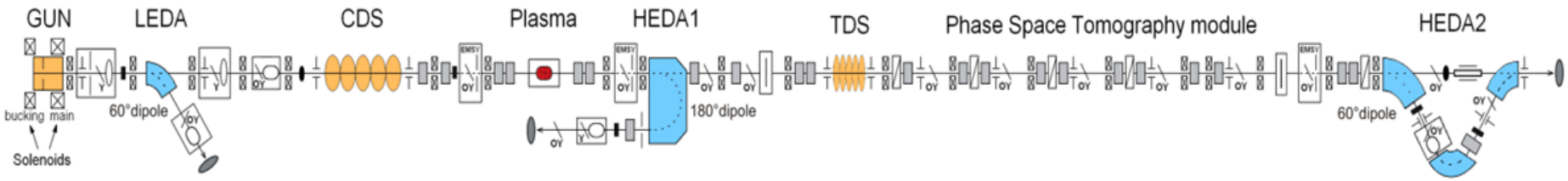
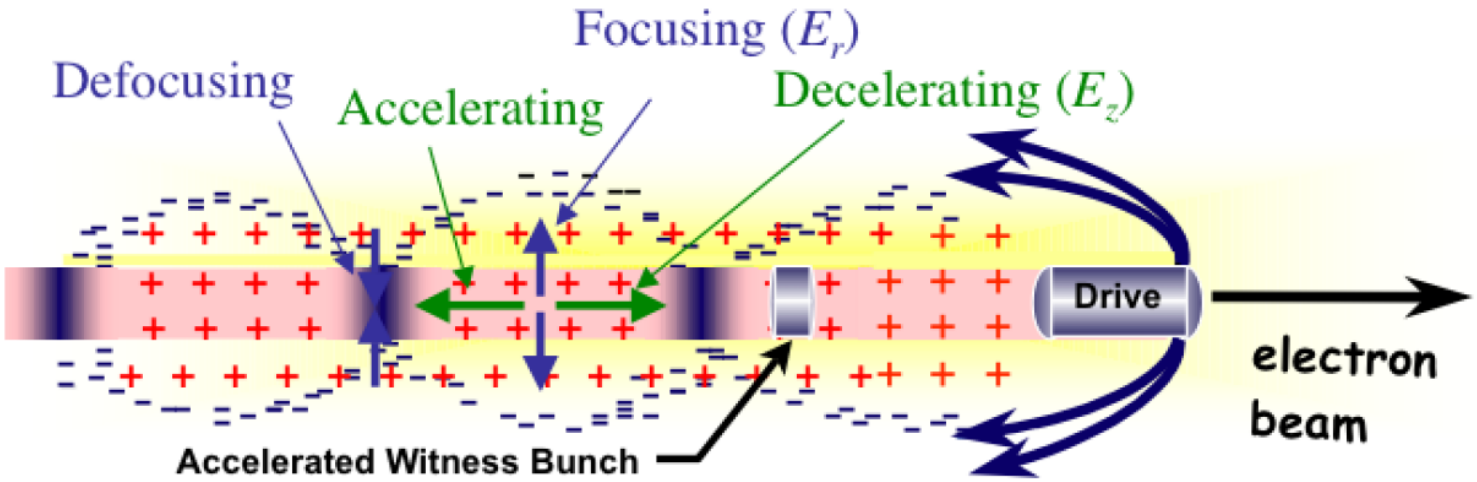
Effects of Longitudinal Profile on Plasma Simulation



HELMHOLTZ ASSOCIATION

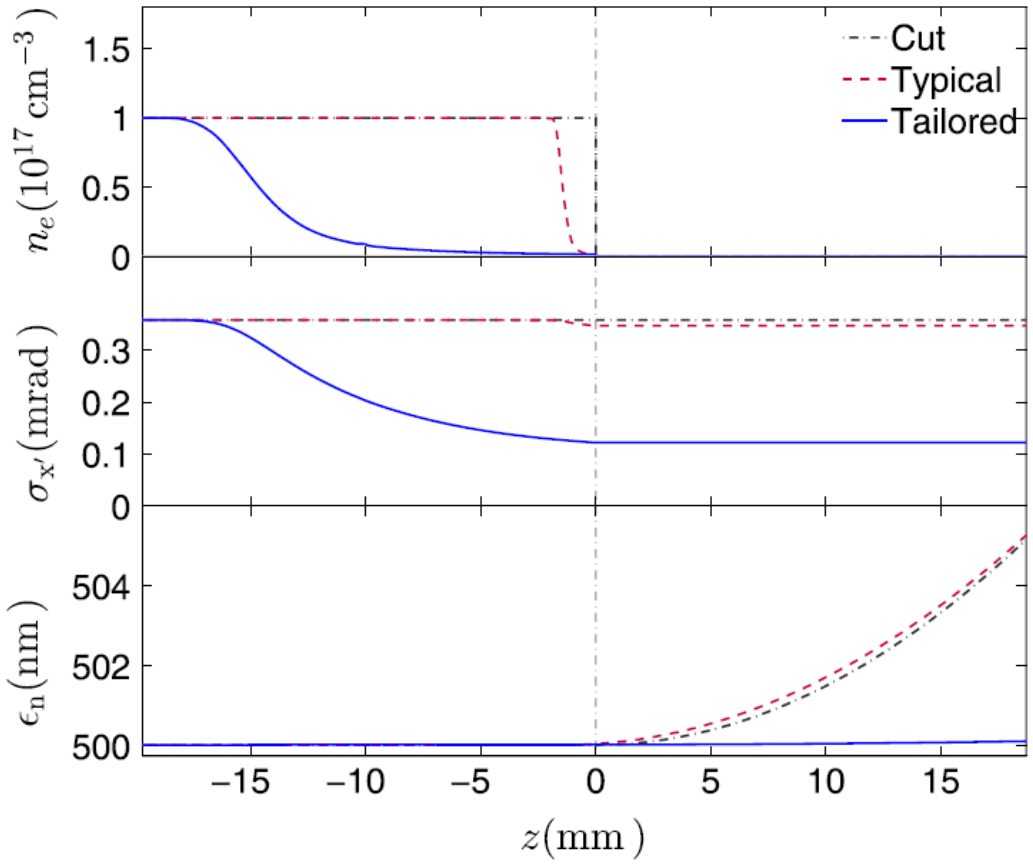
DESY

Beam Driven Plasma Acceleration



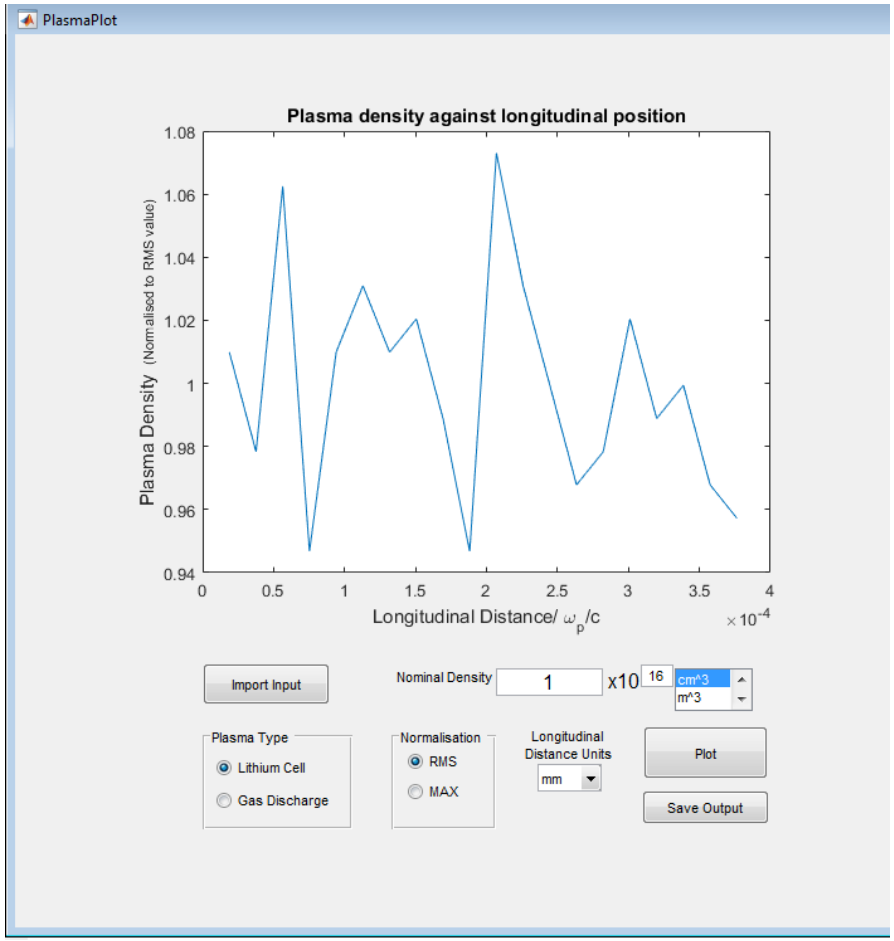
- Plasma Wavelength is determined by:
- $\lambda_p = 2\pi c \left(\frac{m_e}{4\pi e^2 n_e}\right)^{1/2} = 3.17 \times 10^{12} (n_e)^{-1/2}$
- Density will affect the wavelength and acceleration of witness bunch

Motivation for Longitudinal Profile Studies

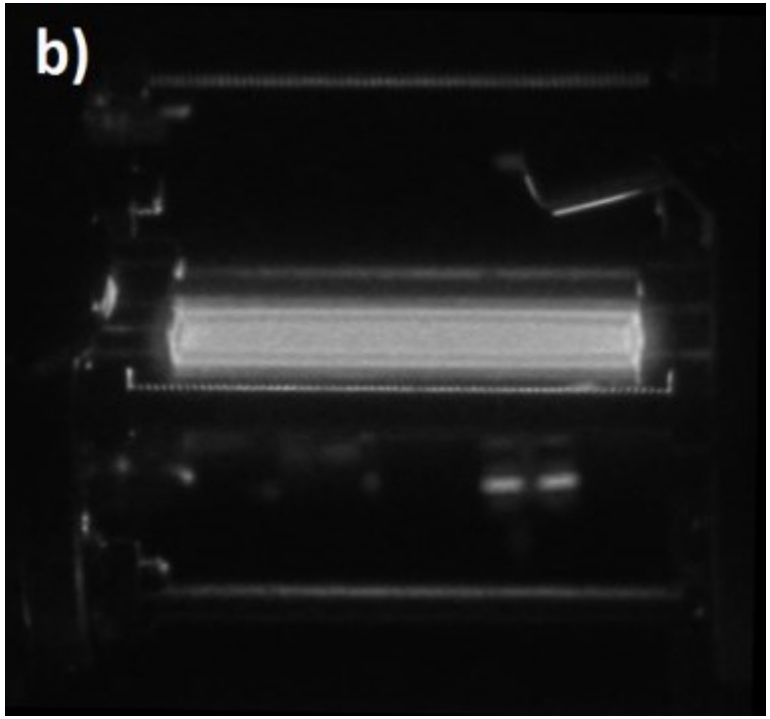


- Simulation showing density profile, transverse divergence of witness bunch and emittance as a function of longitudinal displacement.
- Hence longitudinal profile affects the quality of accelerated witness bunch!

GUI/Plasma Cell



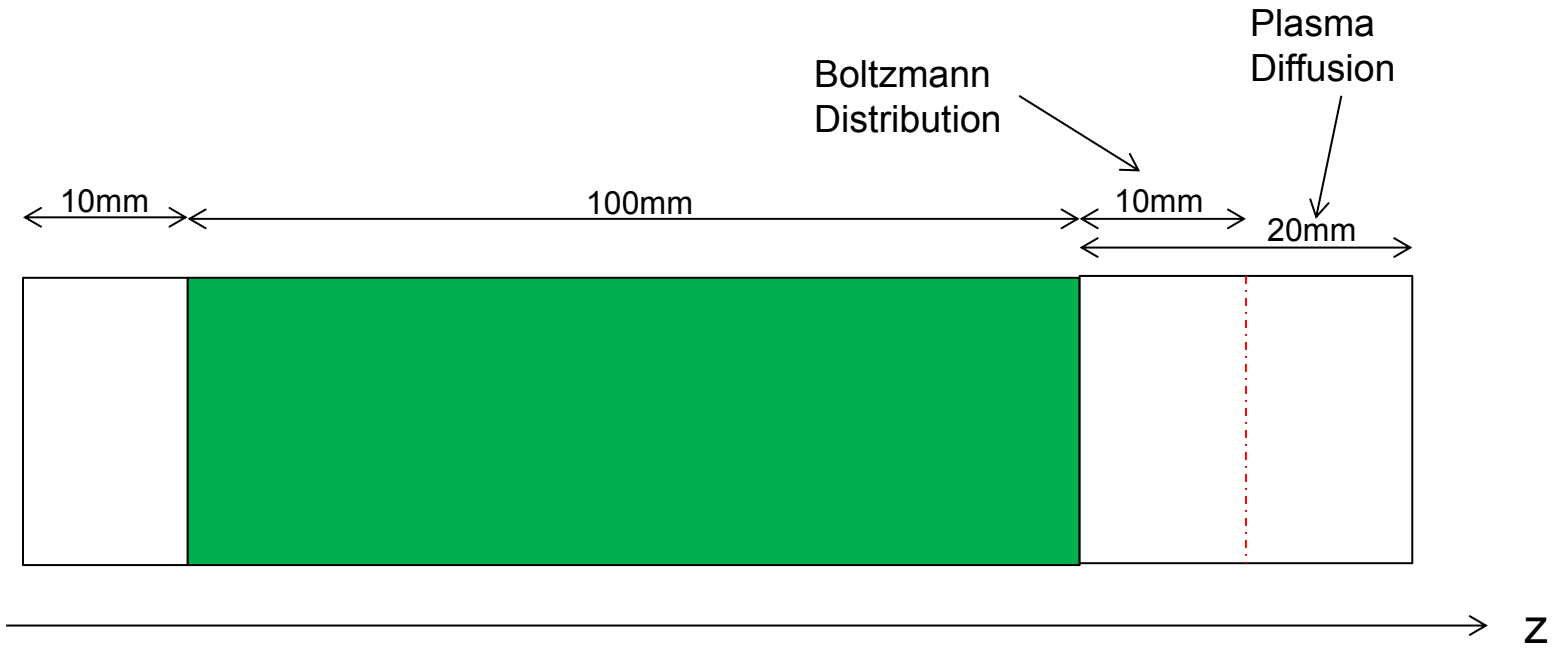
MATLAB GUI



Gas Discharge Plasma Cell

Dimensions Assumed for Plasma Density at edges

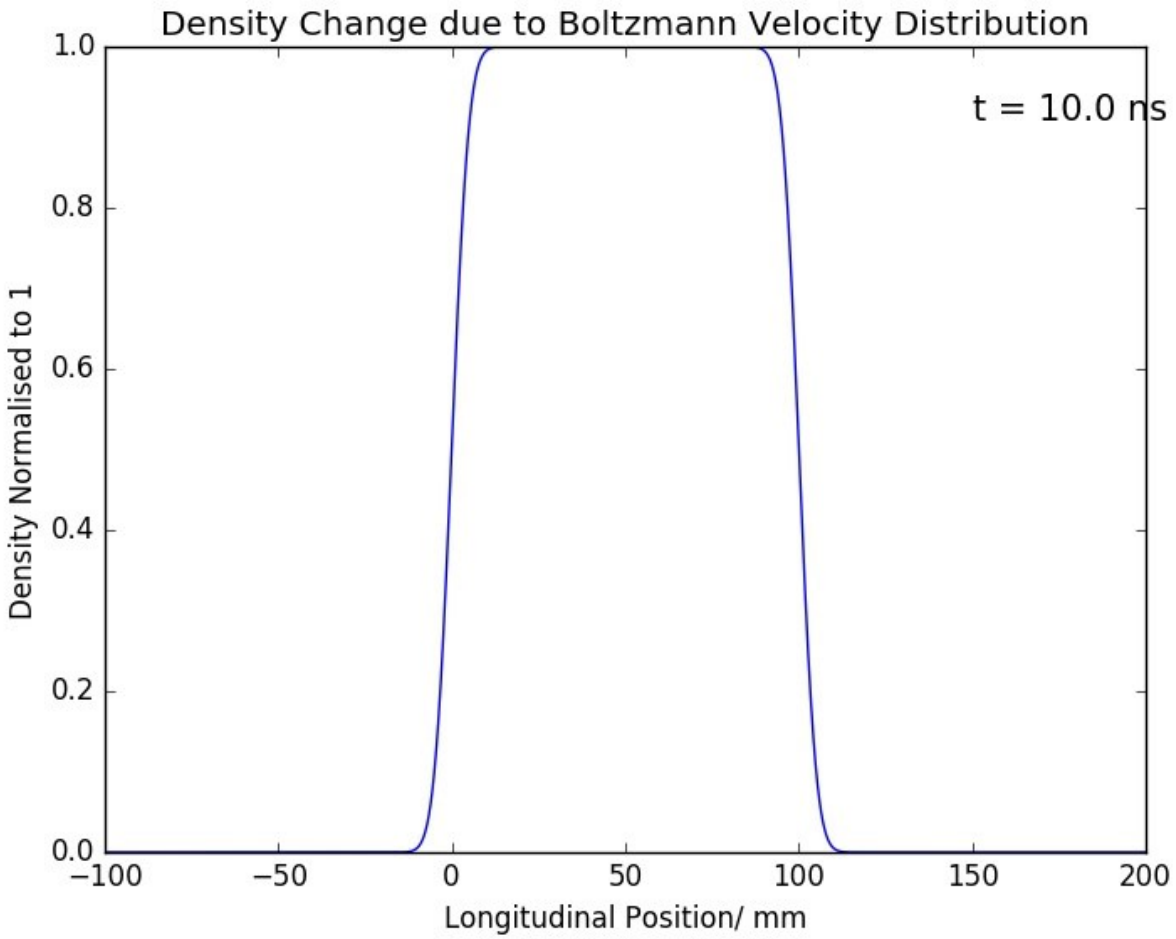
- Due to clamp, the plasma density cannot be measured at the edges.
- Make a rough estimation for the flow of plasma.
- Used a geometry assuming transverse symmetry:



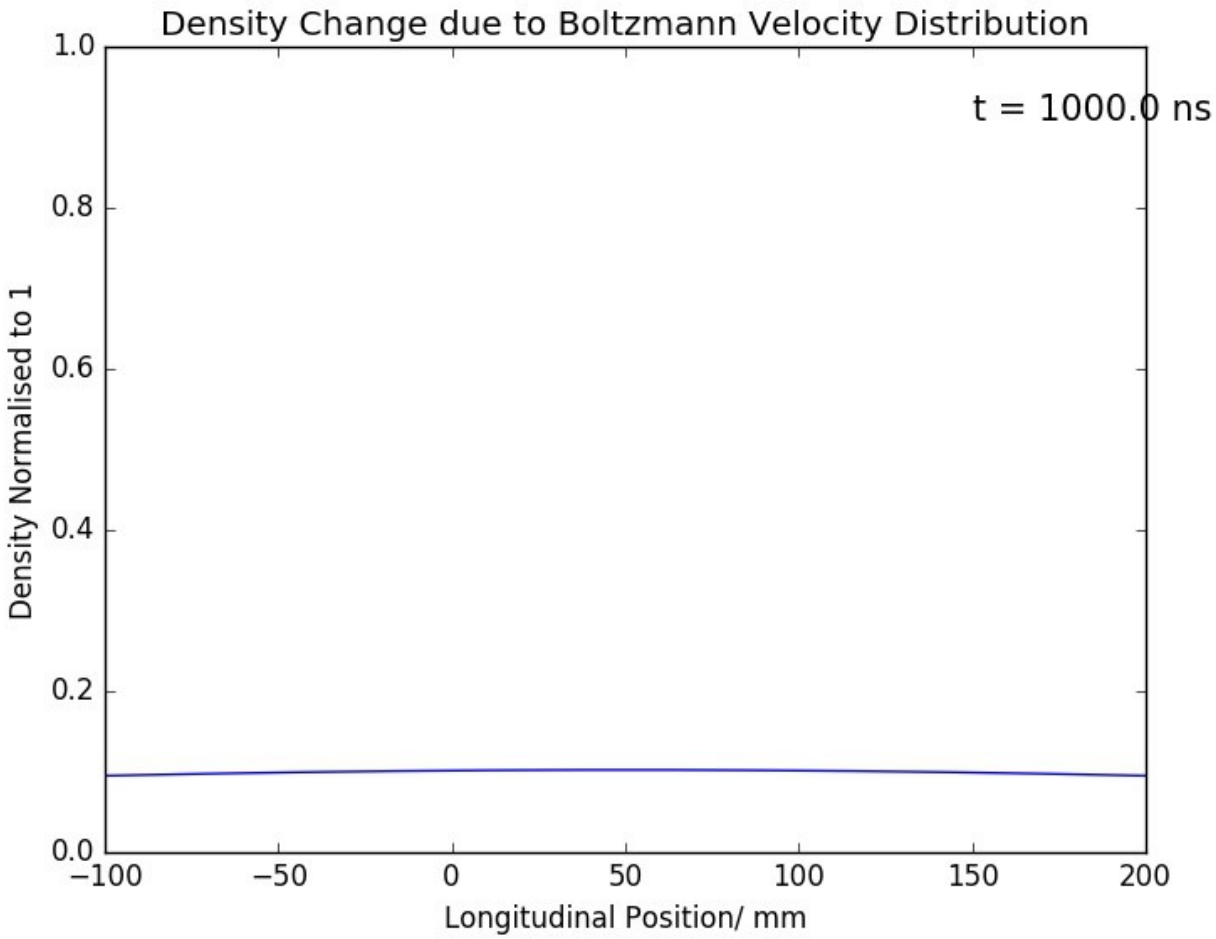
Edge Diffusion

- Attempted with Boltzmann distribution, assuming no collisions.
- After time t, the density at z is:
- $n(z,t) = \int_{50mm}^{-50mm} \sqrt{\frac{m}{2\pi kT}}\, e^{-\frac{m}{2kT}\left(\frac{z'-z}{t}\right)^2} dz'$
- Diffuses 3 orders of magnitude too fast.
- Due to mean free path (~60microns)<< plasma cell dimensions.

Boltzmann Diffusion distribution



Boltzmann Distribution Diffusion



Diffusion Equation

- Full discussion can be found in FF.Chen plasma book.
- Did assuming no recombination of plasma.
- Plasma recombines at the ends(windows) of the plasma cell.
- Only considered diffusion across longitudinal(z-axis) position.
- Solved the following equations using separation of variables:

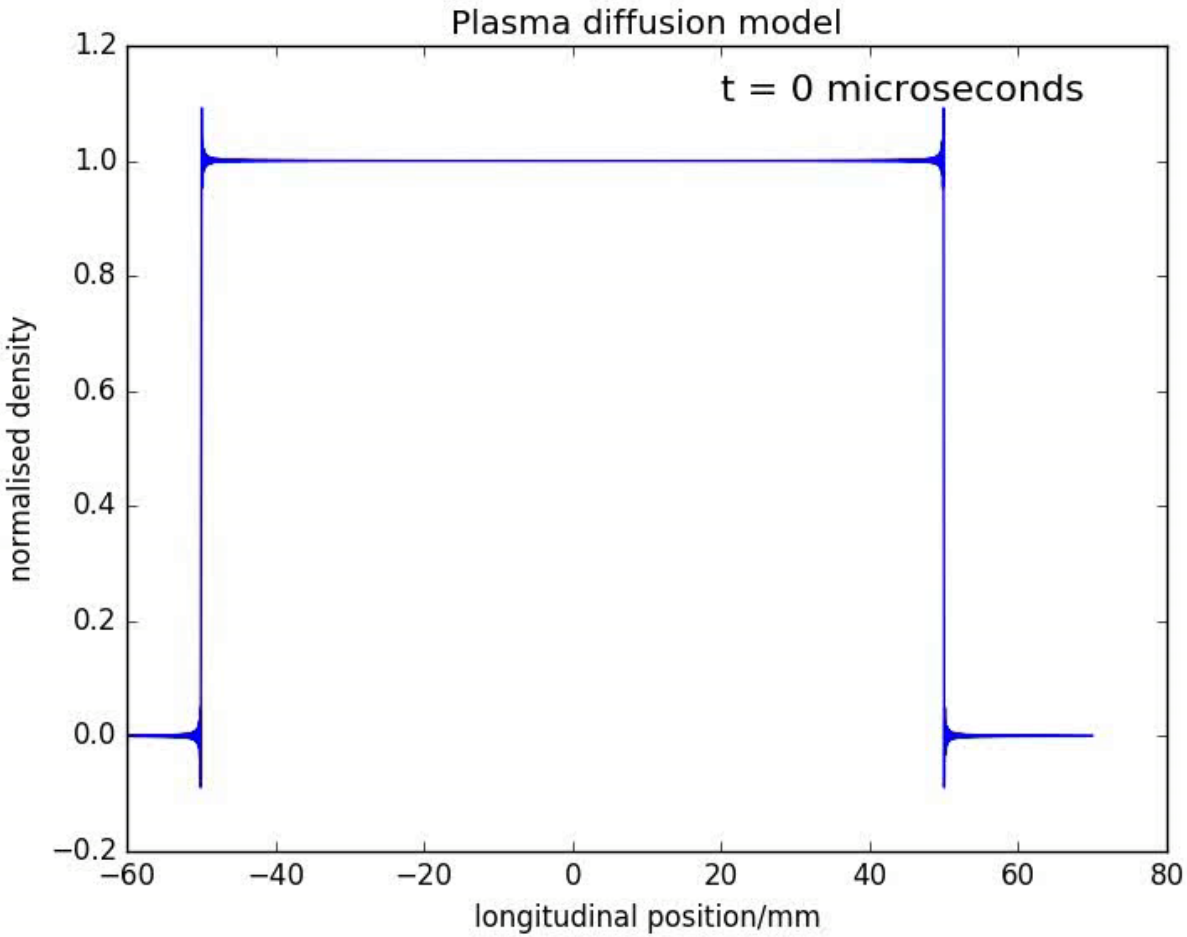
$$\frac{\partial n}{\partial t} = D\nabla^2 n$$

- With the solution:

$$n(z,t) = a_0 + \sum_{n=1}^{\infty} e^{-t/\tau_n}(a_n \cos(k_n z) + b_n \sin(k_n z))$$

$$k_n = \frac{n\pi}{L}$$

Plasma Evolution due to Diffusion



Further Work

- Include recombination.

$$\frac{\partial n}{\partial t} = D\nabla^2 n - \alpha n^2$$

- Solve numerically.
- Density blows up.