Diocotron instability
- toy simulation -

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29 April 2021

Simulation overview

Plasma parameters

- $n_e = 3 \times 10^{13}$ m^{-3}
- $R_p = 2$ mm
- $T = 1$ eV
- L ≈ 10 cm
- D = 3 mm

- B = 3 mT
- V = 5 V
- $R_w = 2$ cm

- "Long, thin" plasma
  - $R_w \ll L, R_p \ll R_w$

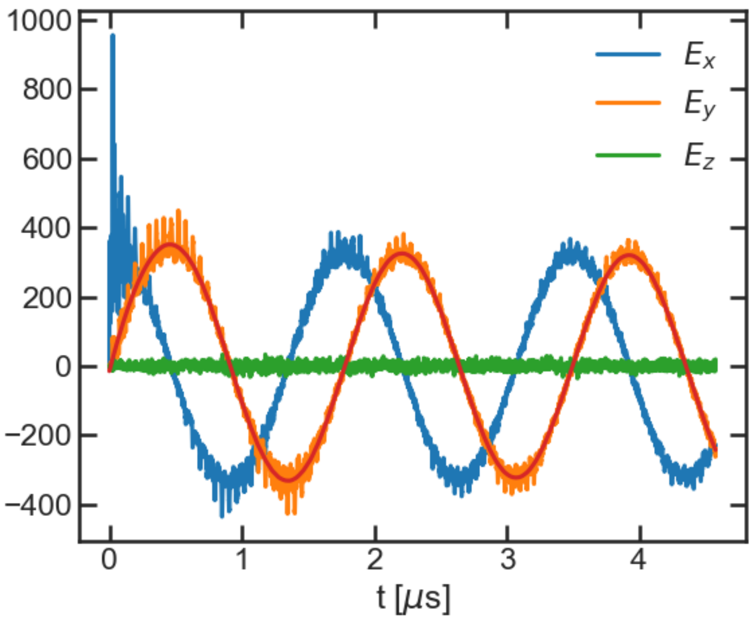
Analytical model

$$f_d = \frac{eN}{4\pi^2 \epsilon_0 BLr_w^2}\left[\frac{1}{1-(d/r_w)^2}\right]$$

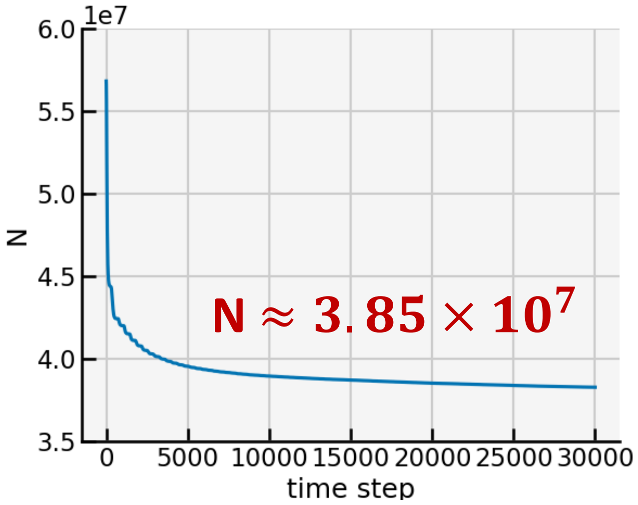
(no corrections)

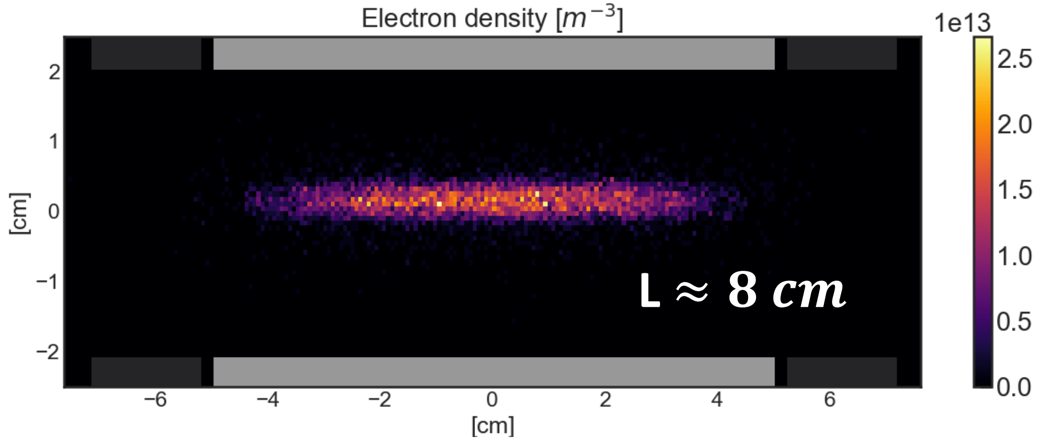
Run 1

- $dx = 0.7$ mm
- $dz = 0.7$ mm
- $dt = 1.5 \times 10^{-10}$ s
- Mptcls_per_cell = 27



$T \approx 1.8\ \mu s$

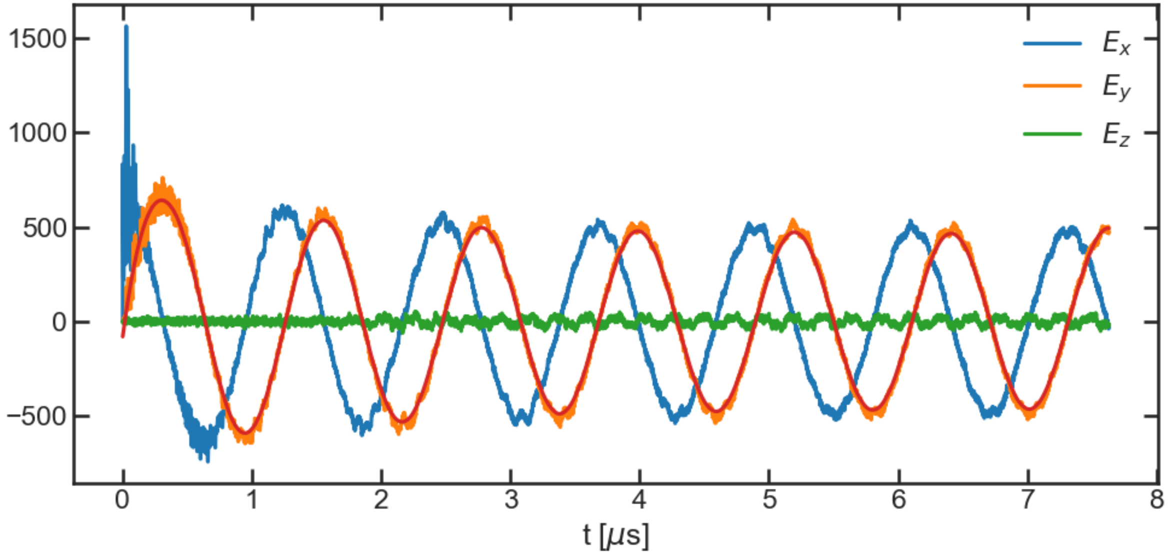




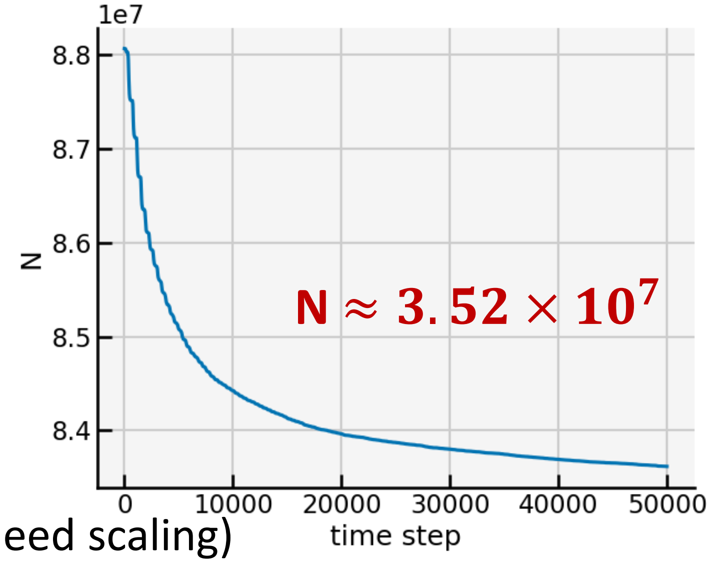
$T_d \approx 5.4\ \mu s$

Run 2

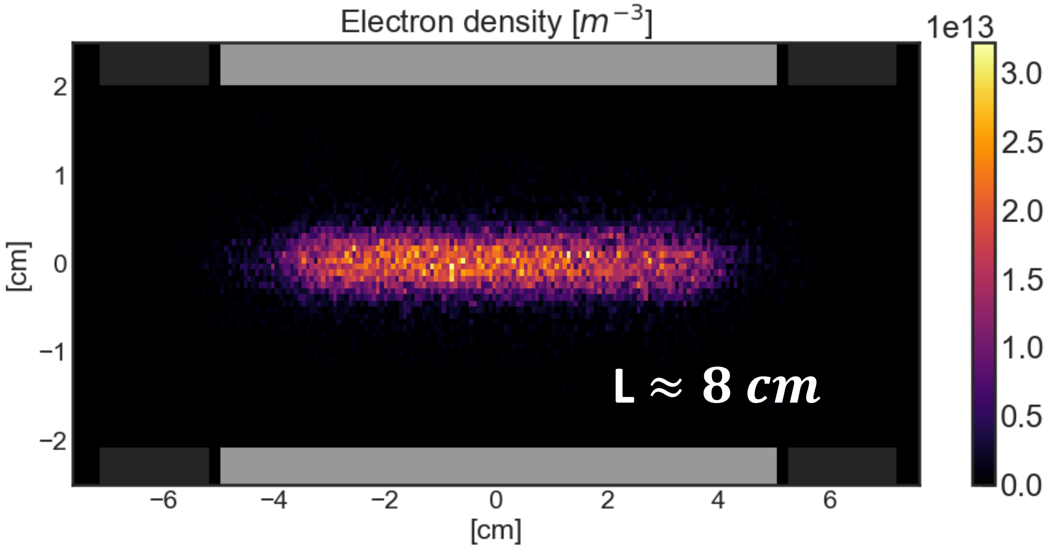
- $dx = 0.7$ mm
- $dz = 0.7$ mm
- $dt = 1.5 \times 10^{-10}$ s
- Mptcls_per_cell = 64



$T \approx 1.3\ \mu s$



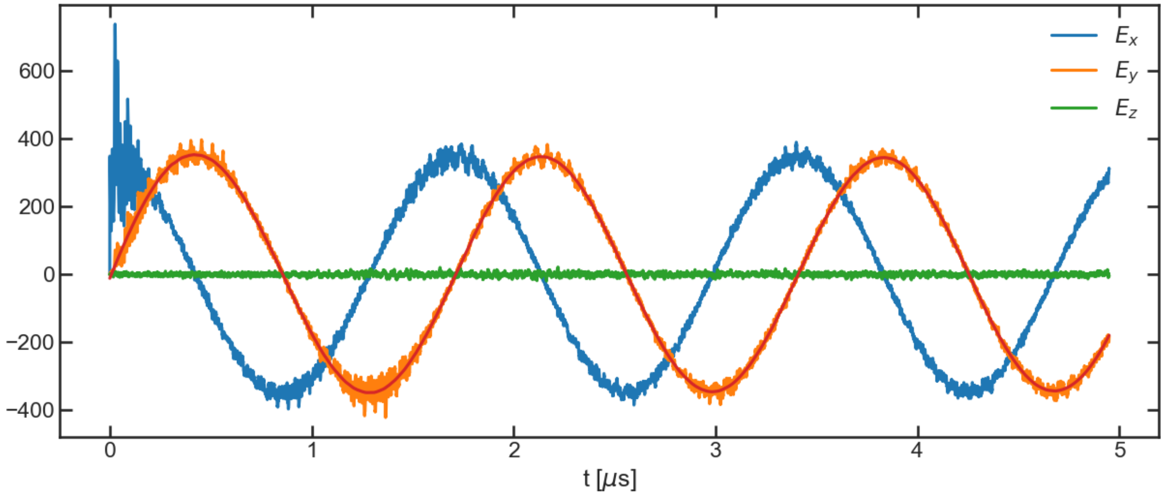
(need scaling)



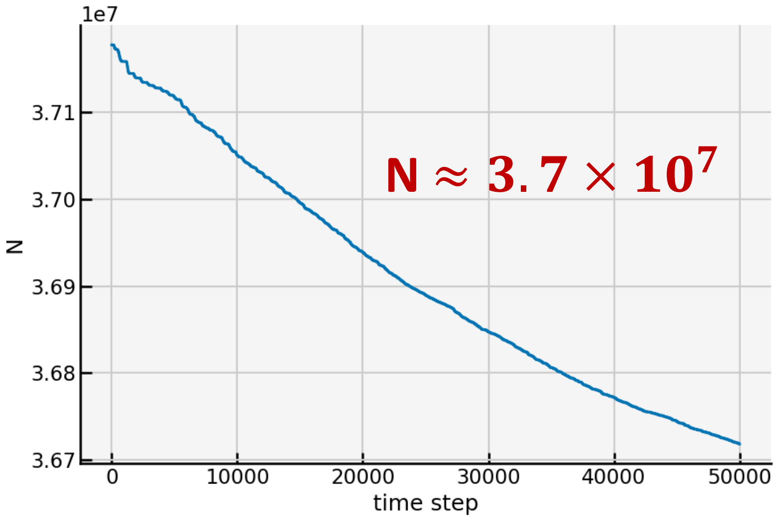
$T_d \approx 5.7\ \mu s$

Run 3

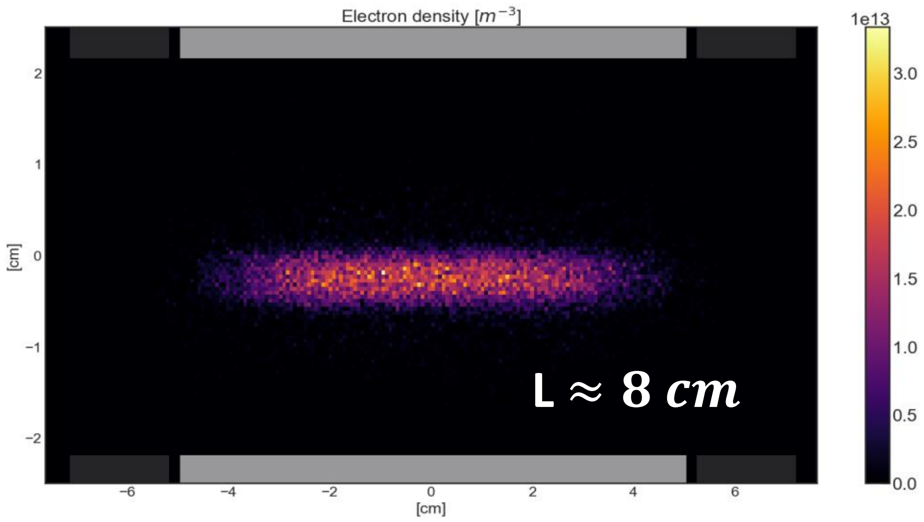
- $dx = 0.4$ mm
- $dz = 0.7$ mm
- $dt = 1.5 \times 10^{-10}$ s
- Mptcls_per_cell = 27



$T \approx 1.8\ \mu s$



$N \approx 3.7 \times 10^7$

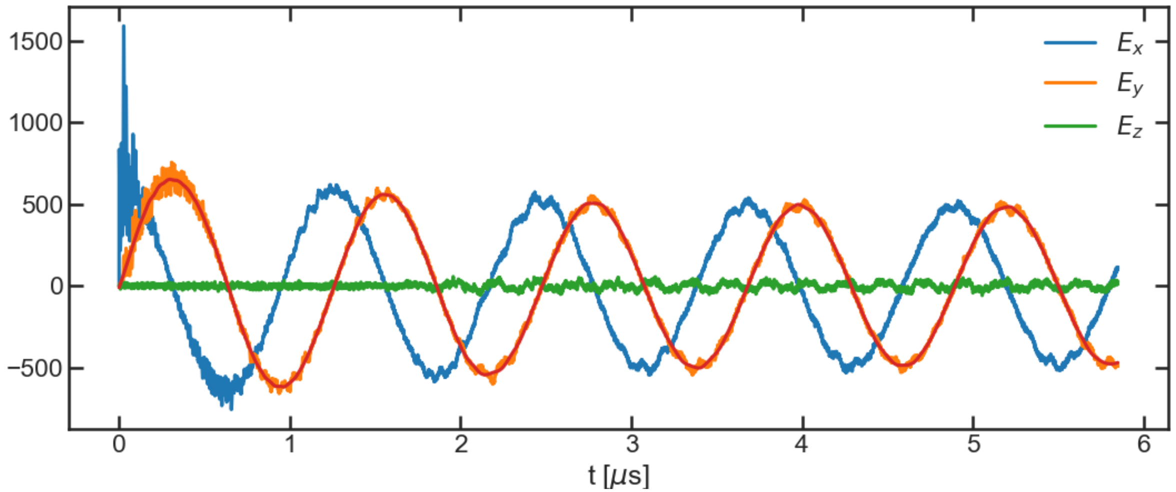


$L \approx 8\ cm$

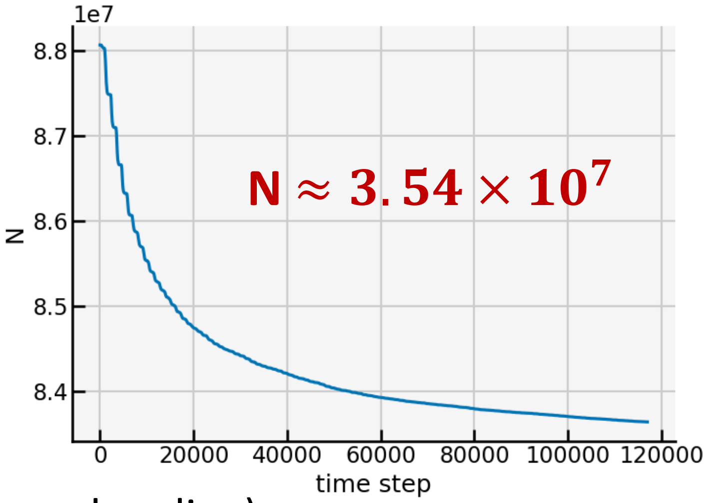
$\rightarrow$ $T_d \approx 5.6\ \mu s$

Run 4

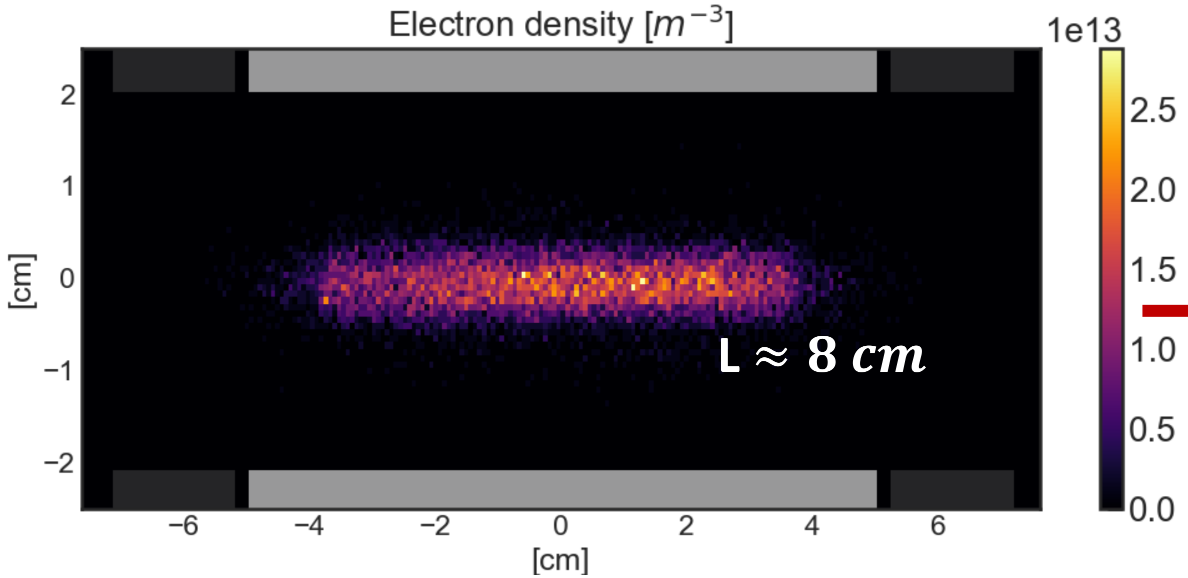
- $dx = 0.7\ \mathrm{mm}$
- $dz = 0.7\ \mathrm{mm}$
- $dt = 0.5 \times 10^{-10}\ \mathrm{s}$
- Mptcls_per_cell = 64



$T \approx 1.2\ \mu s$



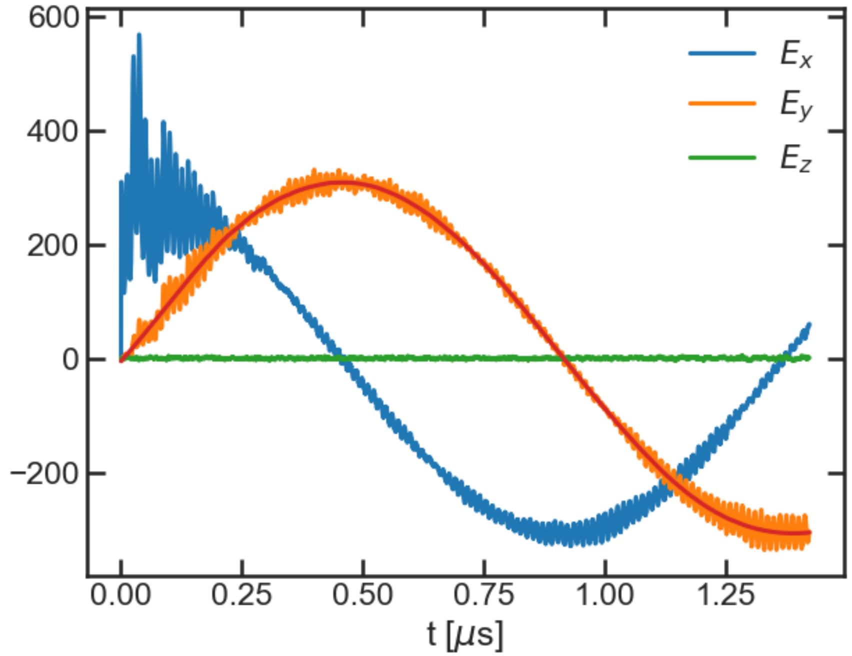
(need scaling)



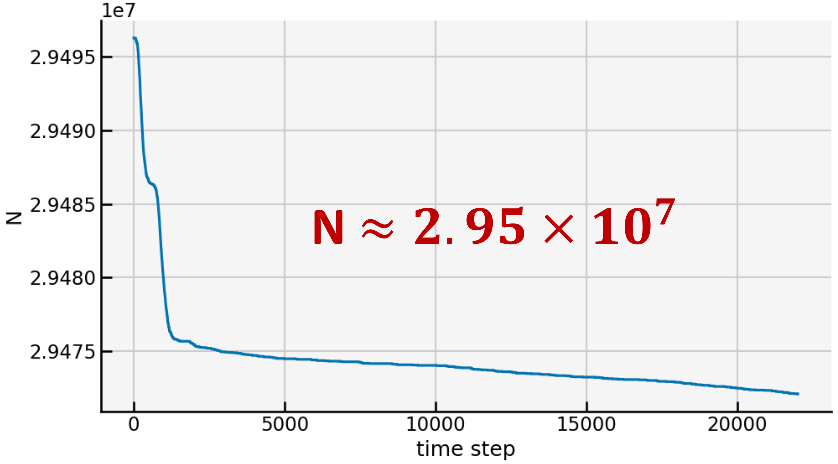
→ $T_d \approx 5.8\ \mu s$

Run 5

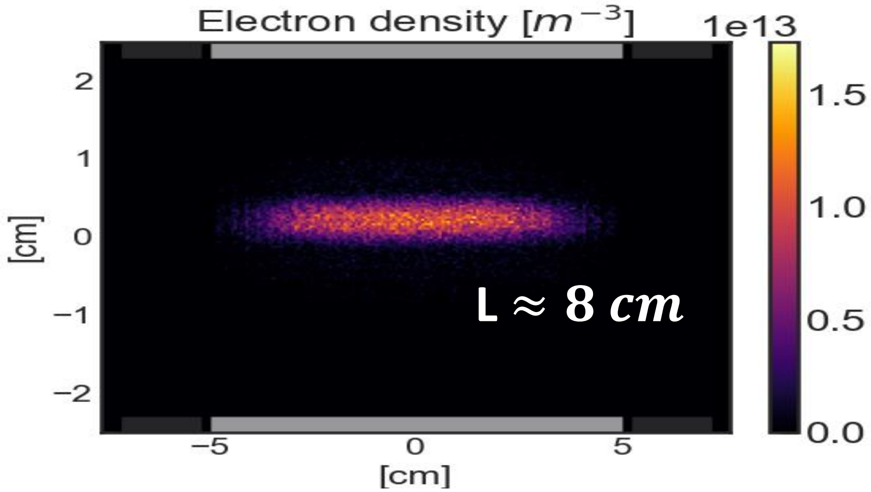
- $dx = 0.25\ \text{mm}$
- $dz = 0.7\ \text{mm}$
- $dt = 0.65 \times 10^{-10}\ \text{s}$
- Mptcls_per_cell = 64



$T \approx 1.6\ \mu s$



(need scaling)



$\rightarrow$ $T_d \approx 7.0\ \mu s$

Corrections

$$\frac{f_{dio}}{f_{\infty}} = \frac{F_{tot}}{F_{i,\infty}} = 1 + \left[\frac{j_{01}}{2} \left(\frac{1}{4} + \ln\left(\frac{R_W}{R_p}\right) + \frac{T}{N_L e^2} \right) - 0.671 \right] \left(\frac{R_W}{L_p}\right)$$

"Plasma electrostatic pressure"

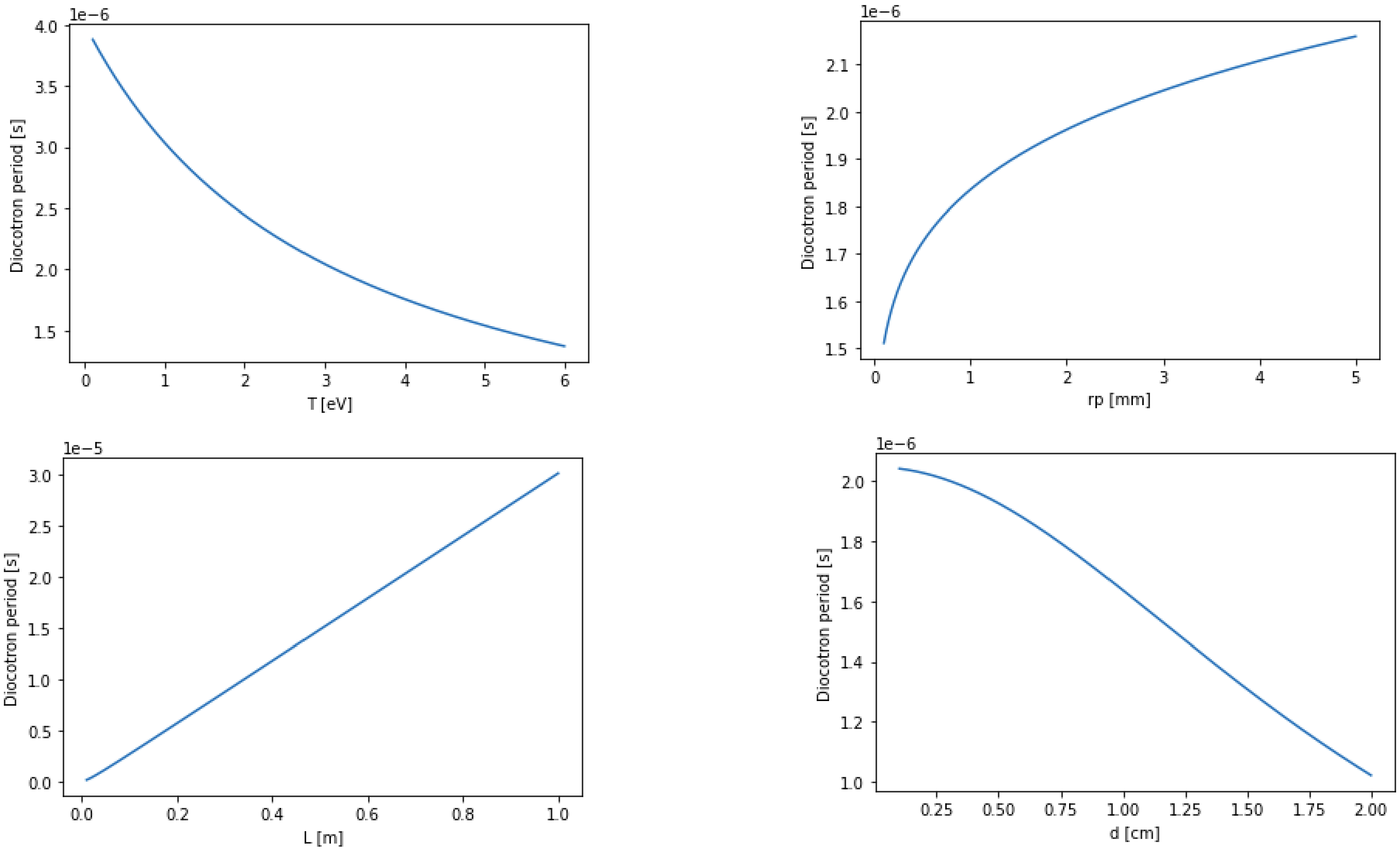
"Plasma kinetic pressure"

"finite length on image charge"

Up to factor of 2 or 3

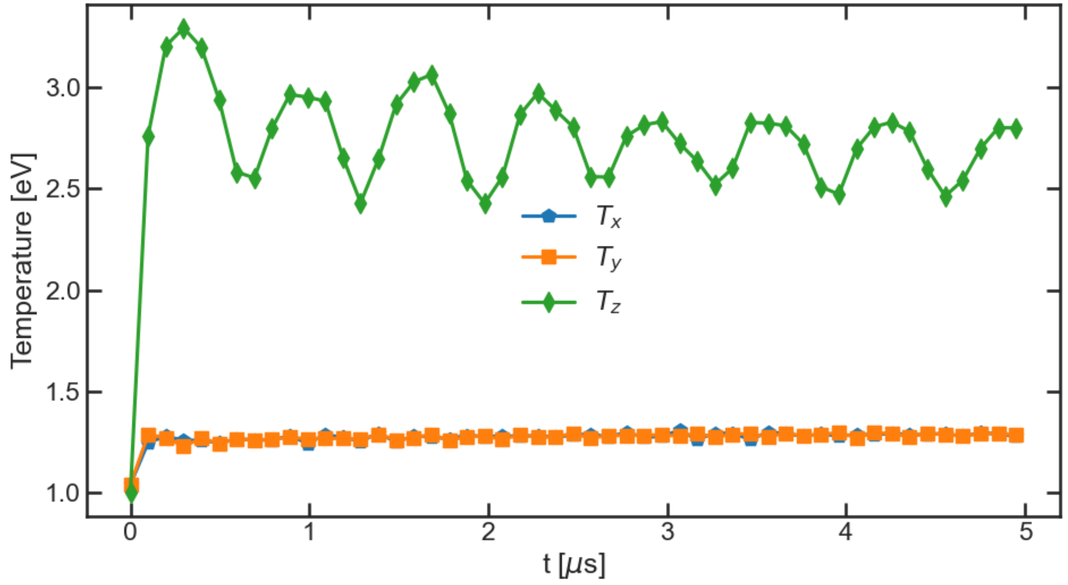
K.S Fine and C.F. Driscoll Phys .Pla. 5, 601,(1998)

Corrections

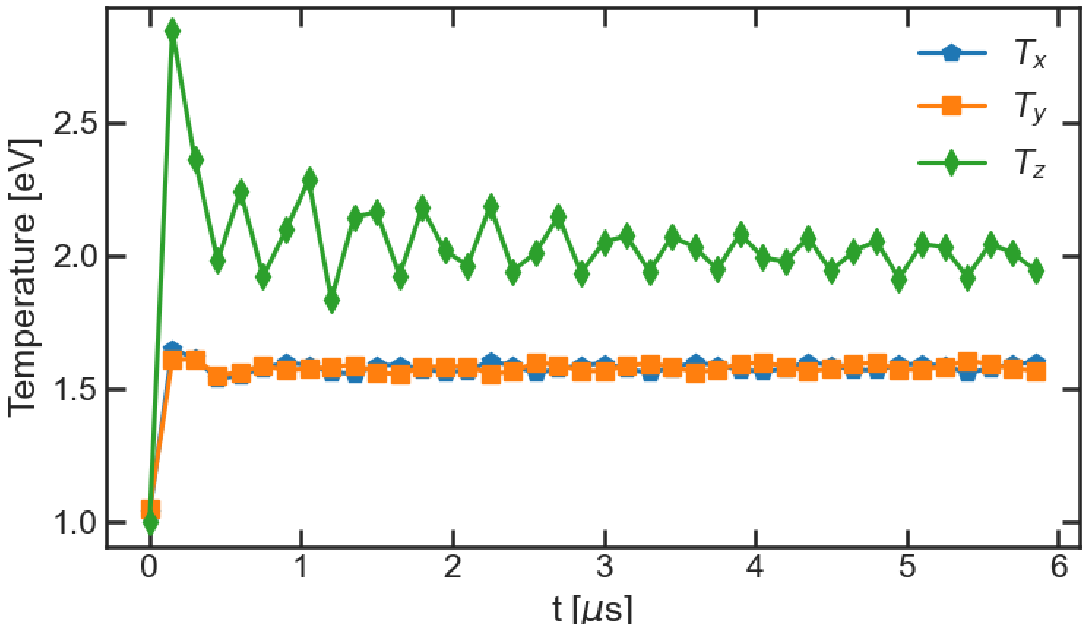


Temperature

- Extracting a temperature from simulation is an issue



Run 3



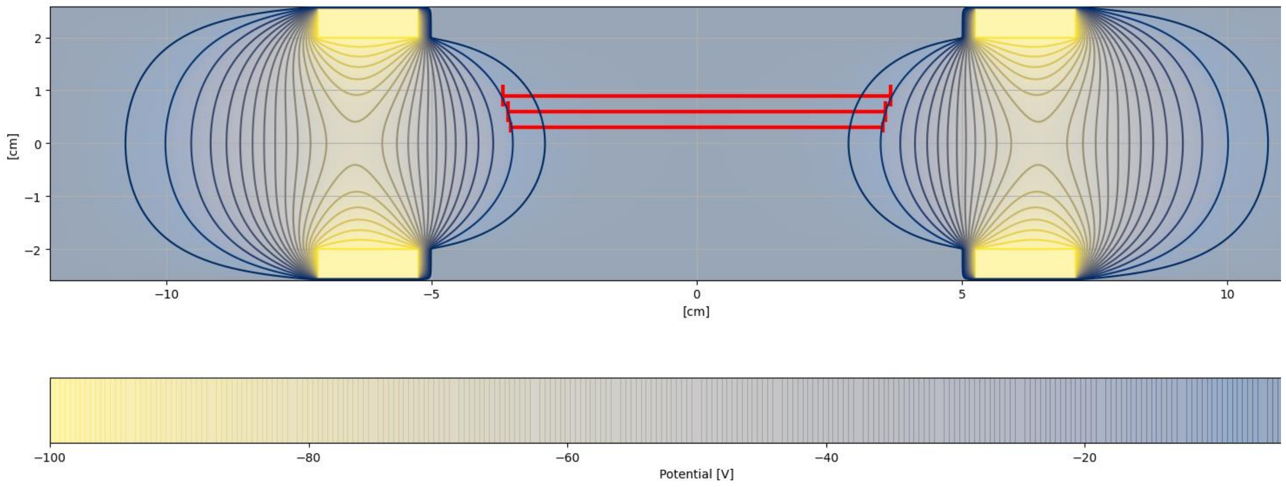
Run 4

Initial conditions

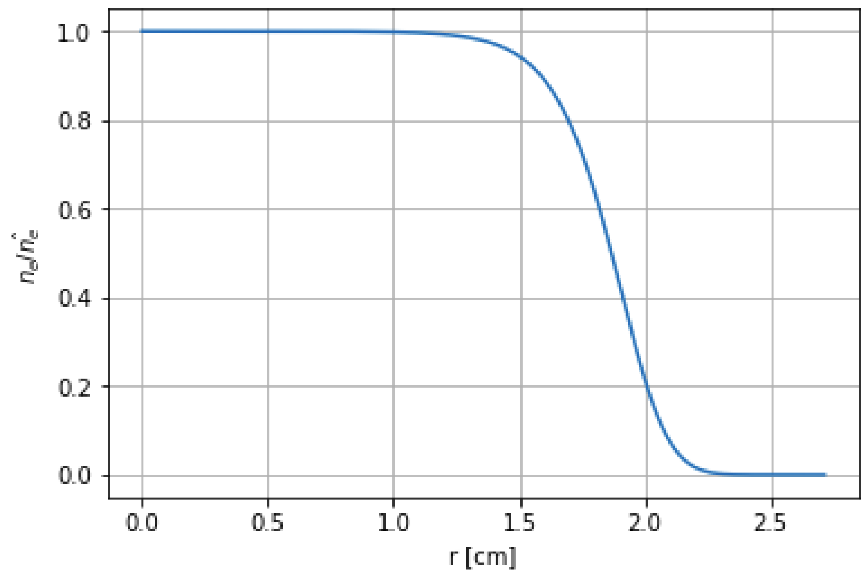
- Calculate the “equilibrium” length of the plasma (different from anode length)
- Similar method to

Finite-Length, Large-Amplitude Diocotron Mode Dynamics

N. C. Hurst, J. R. Danielson, C. J. Baker and C. M. Surko

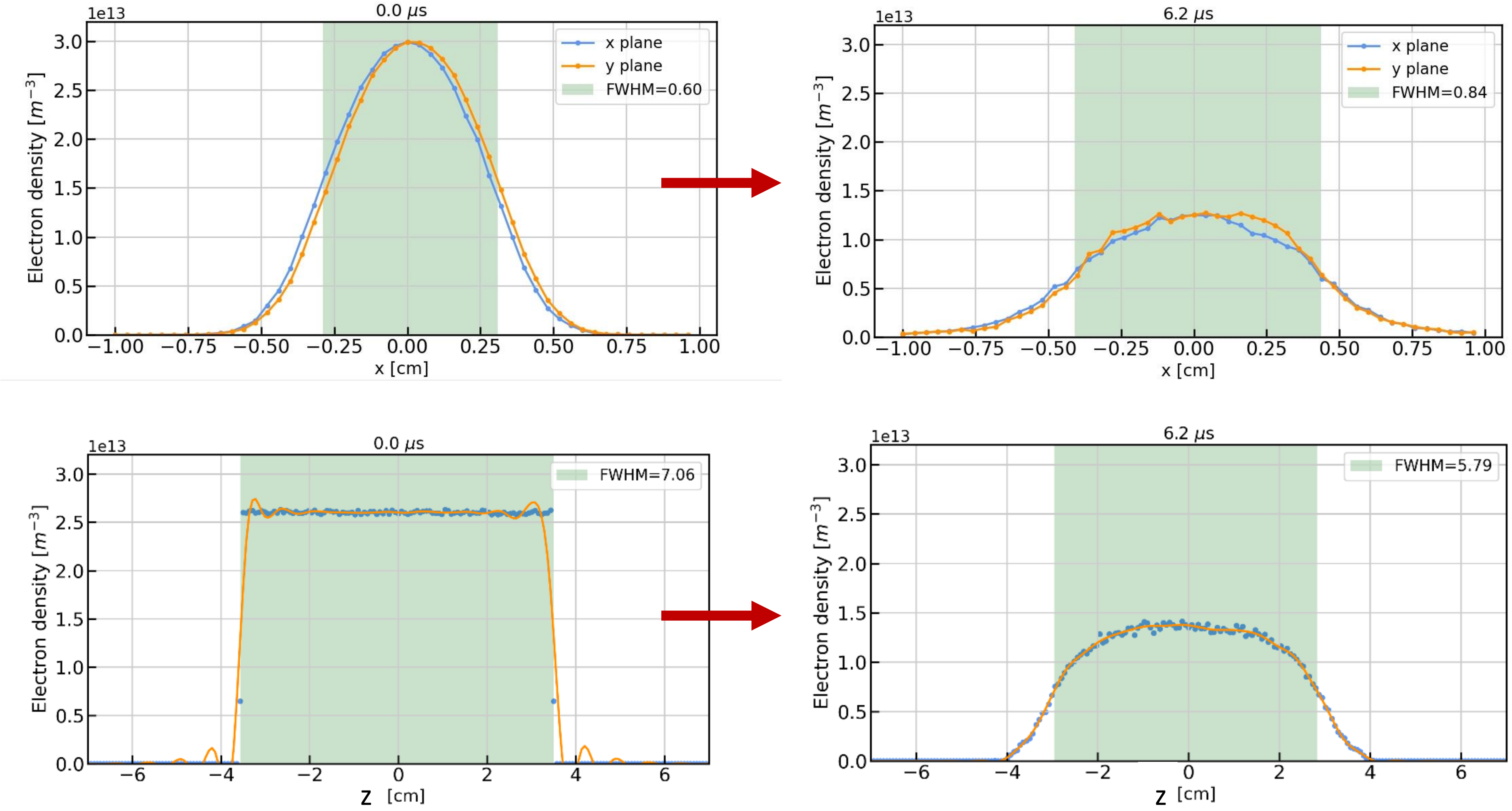


- Calculate the “equilibrium” radial profile for the electron density
- Solve radial Poisson’s equation



Run 6

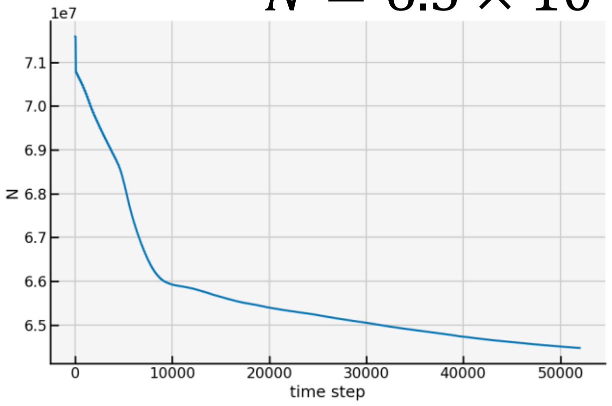
- $dx = 0.4$ mm
- $dz = 0.7$ mm
- $dt = 0.9 \times 10^{-10}$ s
- Mptcls_per_cell = 64



Plasma still expands in the initial few time steps

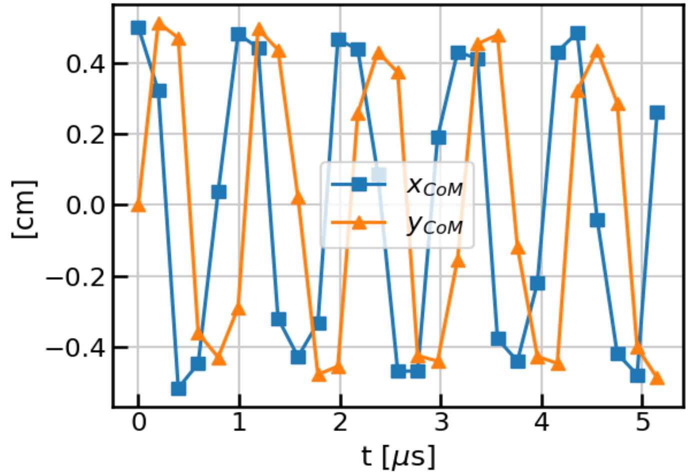
Run 6

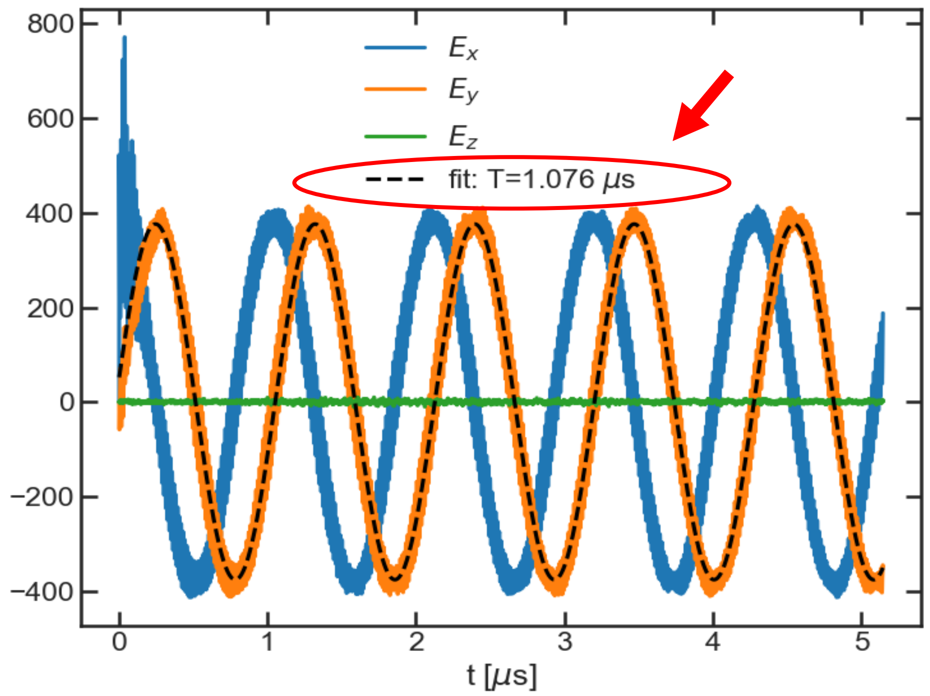
- $N = 6.5 \times 10^7$



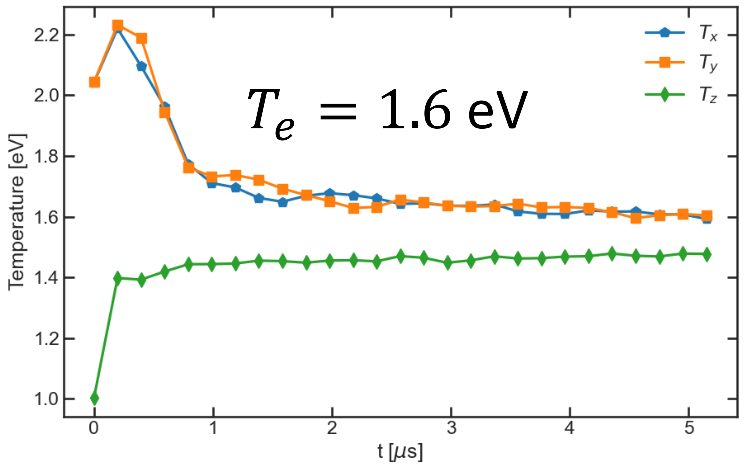
- $r_p = 0.42$ cm
- L = 5.79 cm

$D = 0.5$ cm





$T_e = 1.6$ eV



Analytical model with corrections:

$$T_d \approx 1.21\ \mu s$$

(uniform density assumed)