SBU Update on Coupling of Lagrangian Particle and M3D-C1 Codes for Pellet Simulation

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Problem formulation

M3D-C1 simulation in 2D:

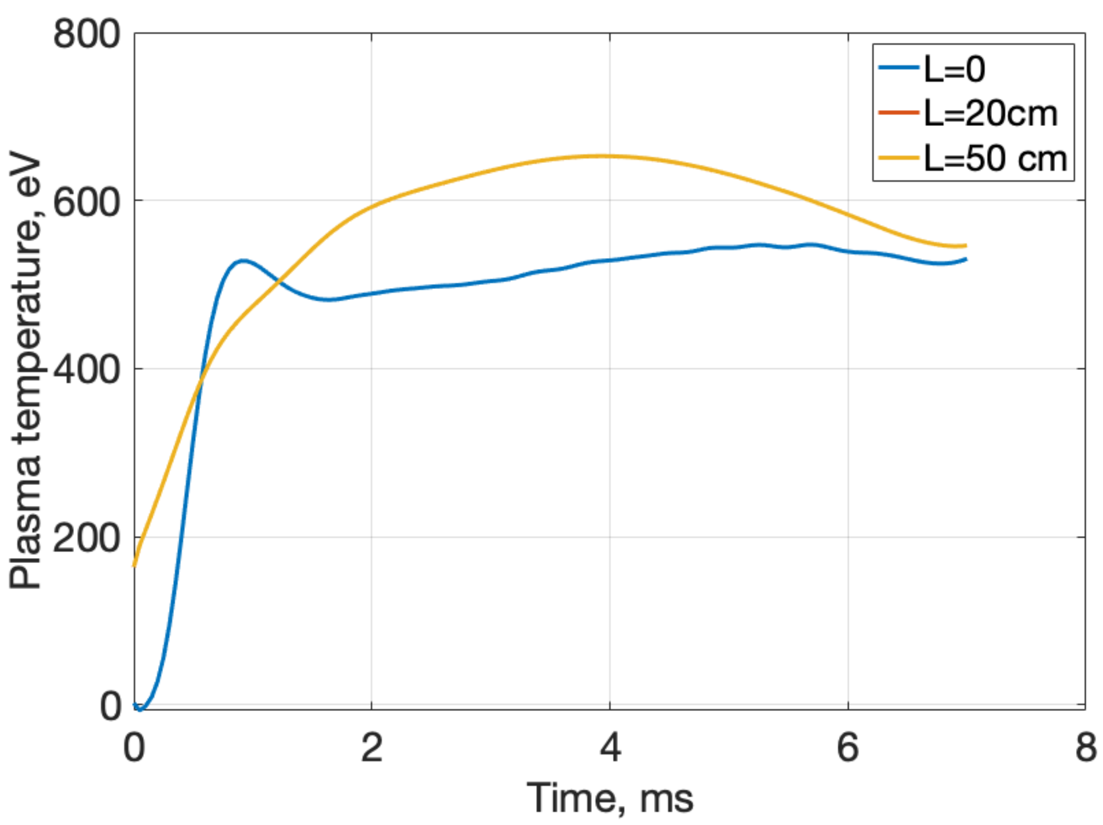
- 1-mm, pure-neon pellet was injected radially inward at Z=0.089 m at 80 m/s (parameters for the extruder given by Daisuke Shiraki).
- The ablated material is deposited in an axisymmetric annulus centered on the pellet with a Gaussian half width 20x the pellet radius (changes over time). The time_***.h5 output files are given every 50 microseconds.

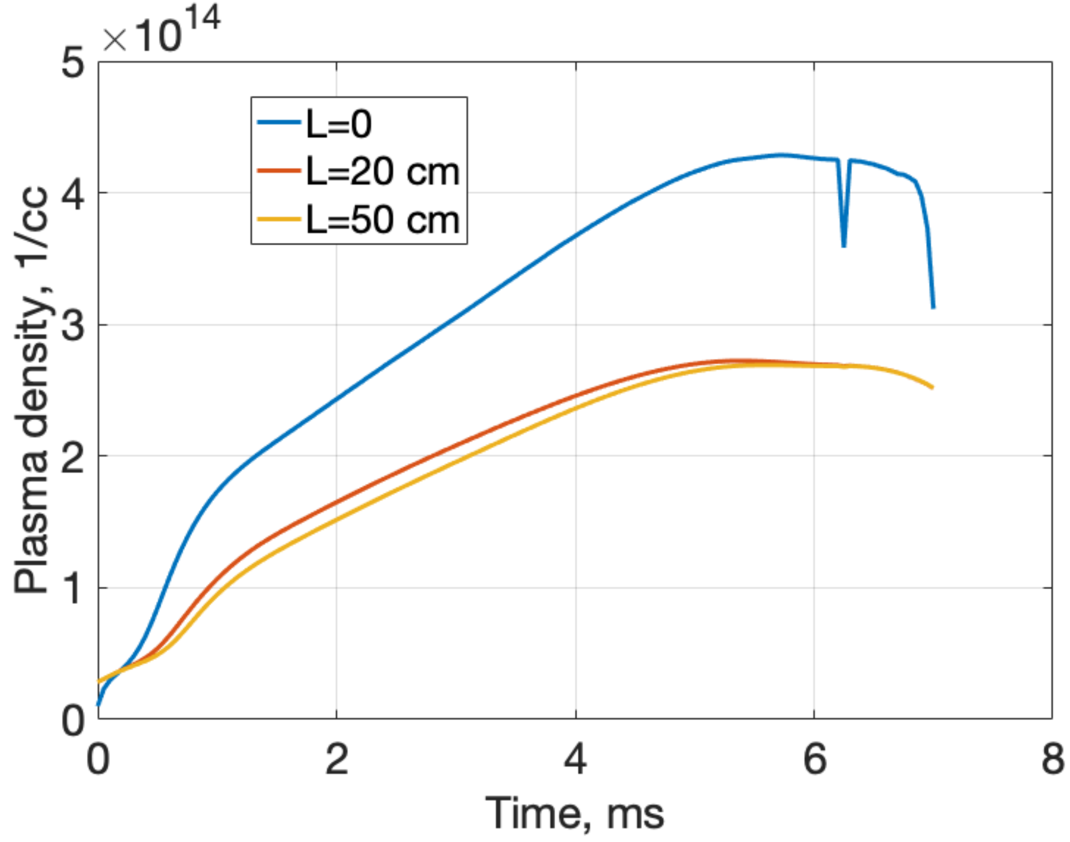
Lagrangian Particle simulation:

- Using the script provided by Brendan Lyons, we examined the sensitivity of plasma states to the location and size of the averaging domain
- Using ne(t), Te(t), B(t) near the ablating pellet (but not affected by the analytic source term) we performed LP simulations and compared ablation rates
- In addition, we performed several steady-state simulations along the pellet trajectory using the pellet radius and plasma states from M3D-C1
- Finally, we performed LP simulations with shrinking pellet using fixed plasma states and compared ablation rates with the scaling law in pellet radius

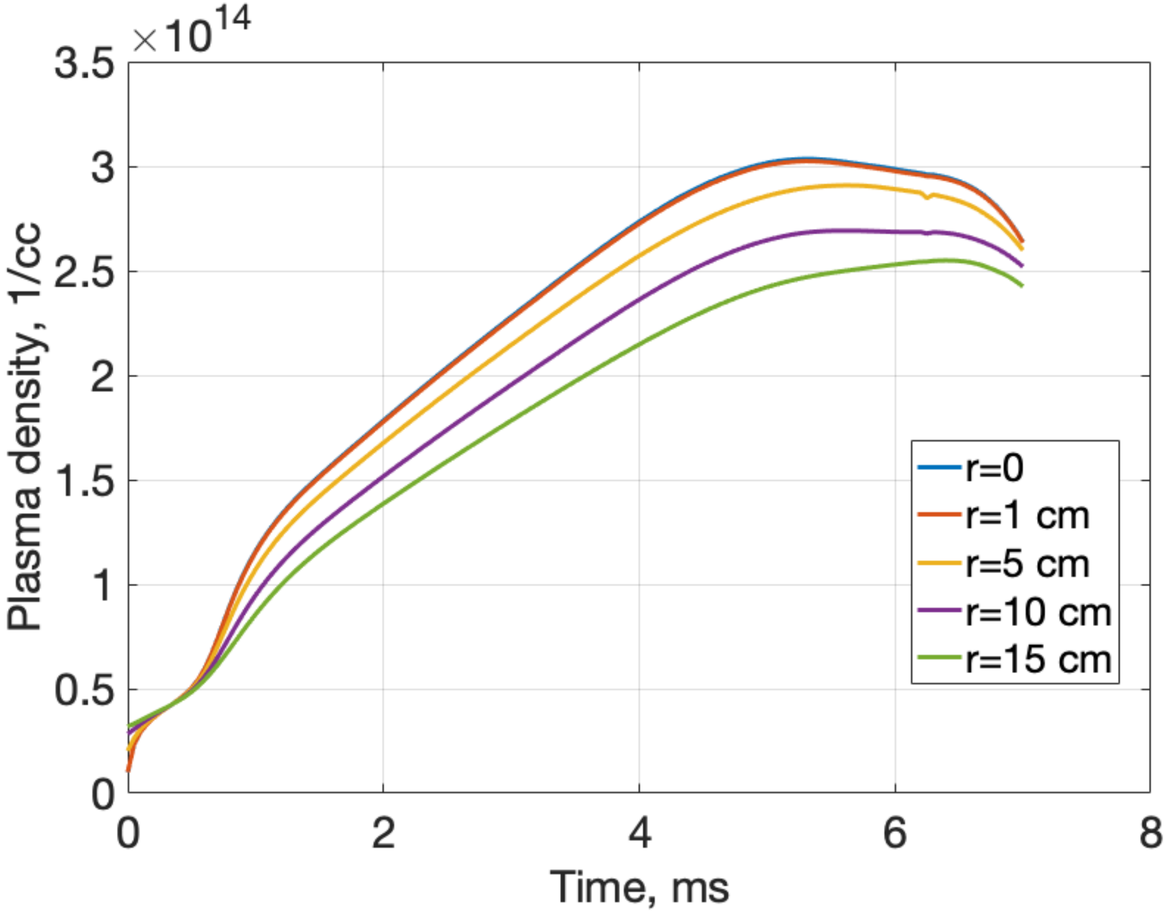
Plasma states near ablating pellet: longitudinal dependence

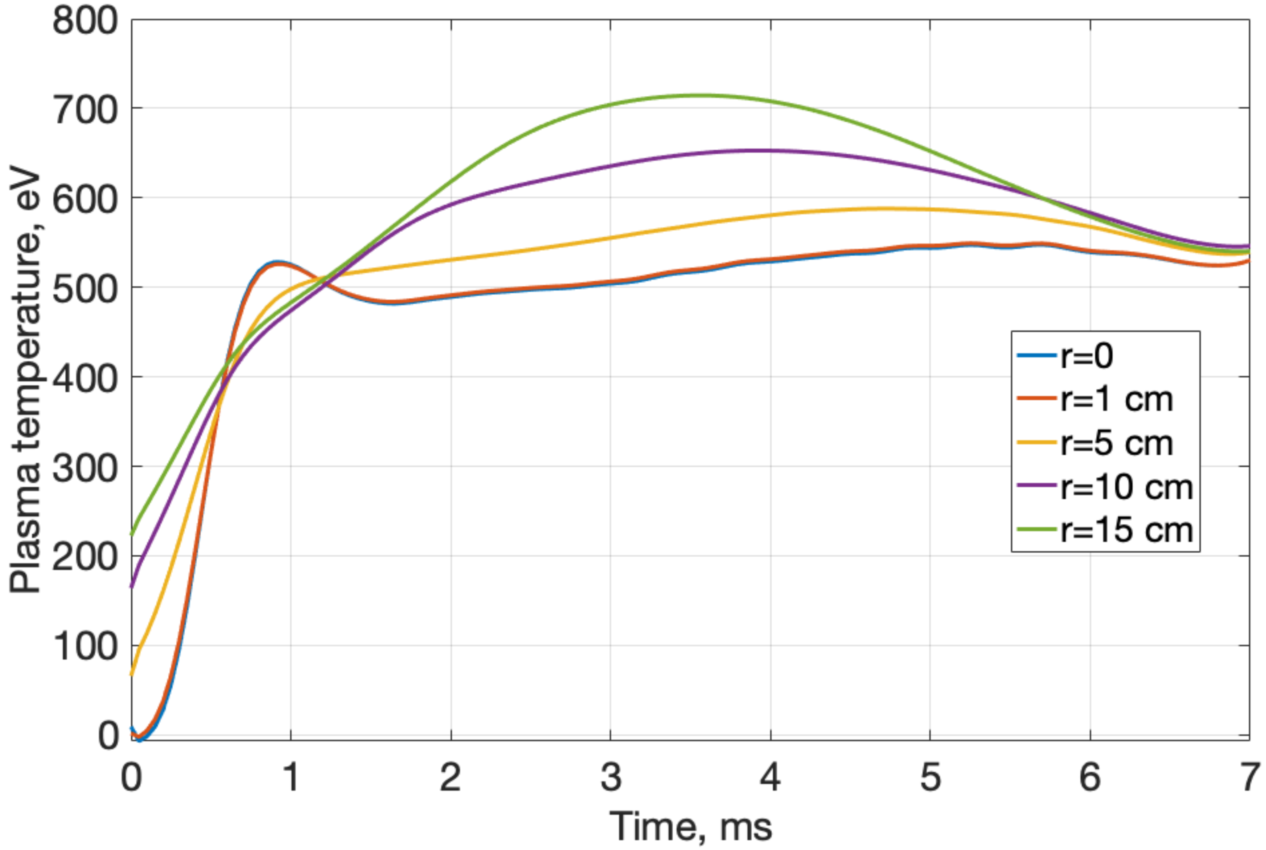
L = 0: states at the pellet location
L = 20 cm: states averaged within two 10 cm radius disks located at 20 cm from the pellet along the magnetic field in both directions
L = 50 cm: the same as before except the distance was 50 cm





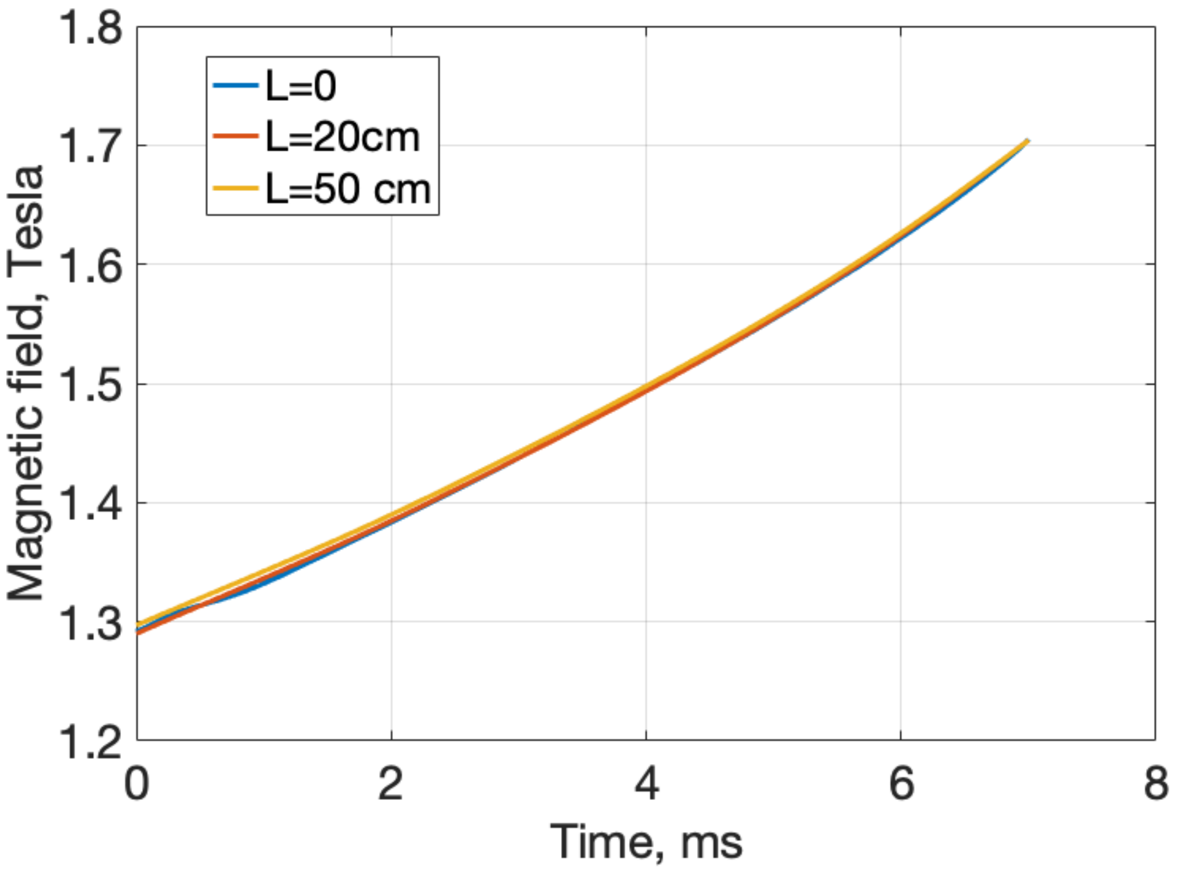
Plasma states near ablating pellet: transverse dependence

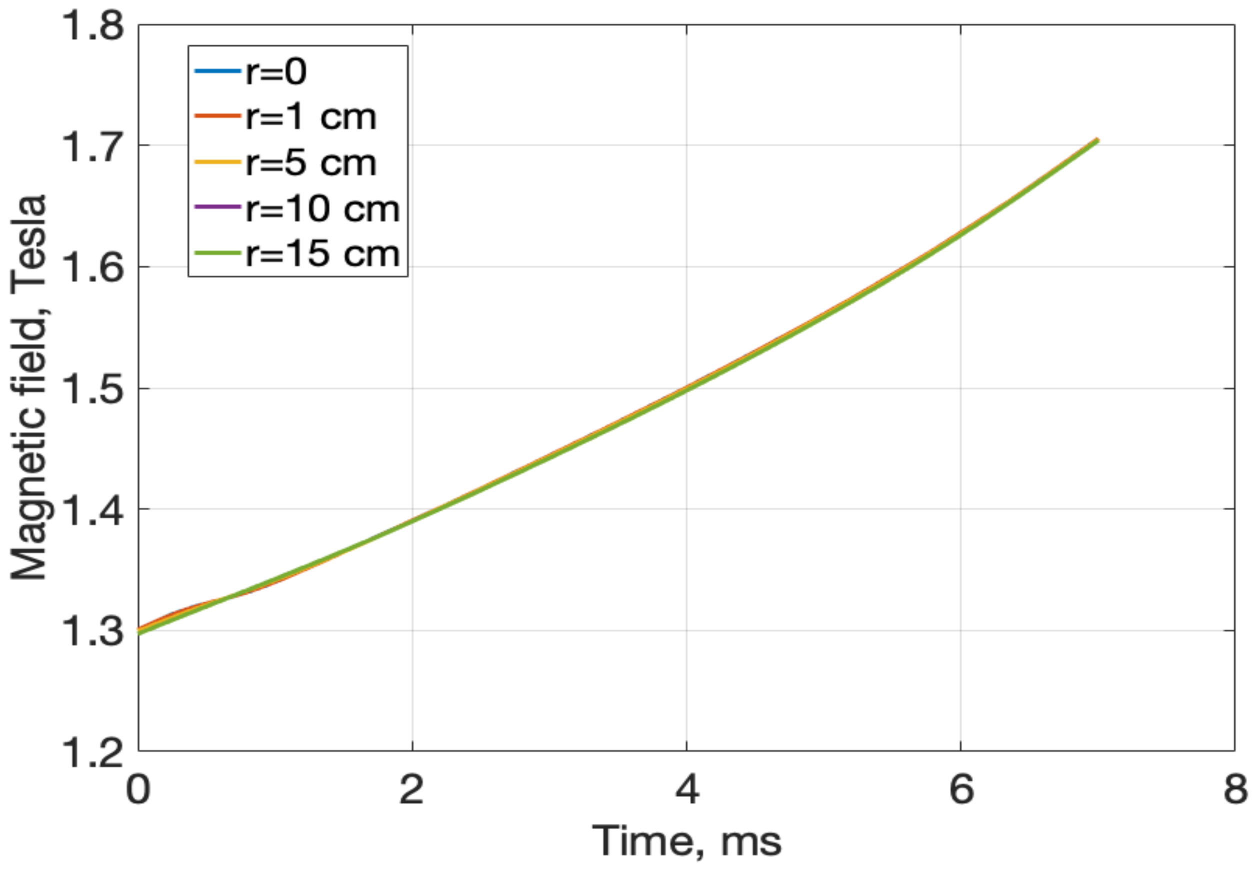




Plasma states were averages at +- 50 cm from the pellet within disks ranging from 0 to 15 cm in radius.

Magnetic field near ablating pellet

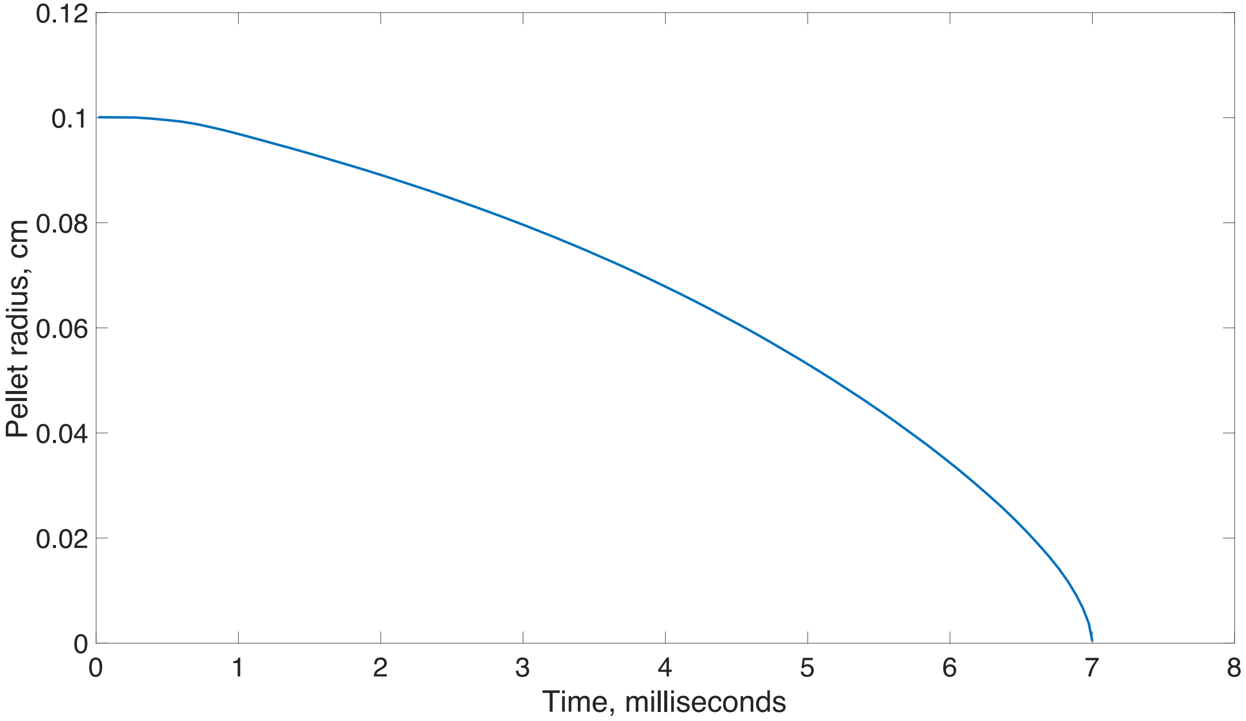


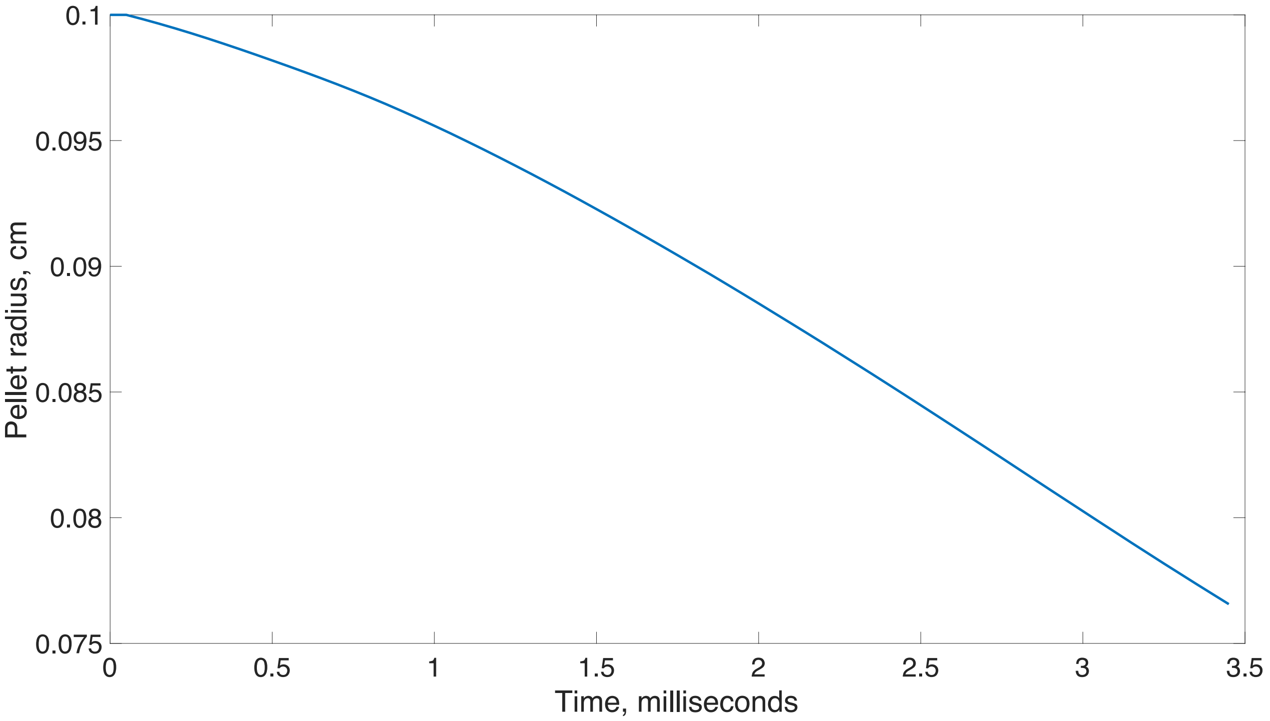


Magnetic field is not sensitive to the location of diagnostic domain

Shrinking pellet LP simulation using data file from M3D-C1

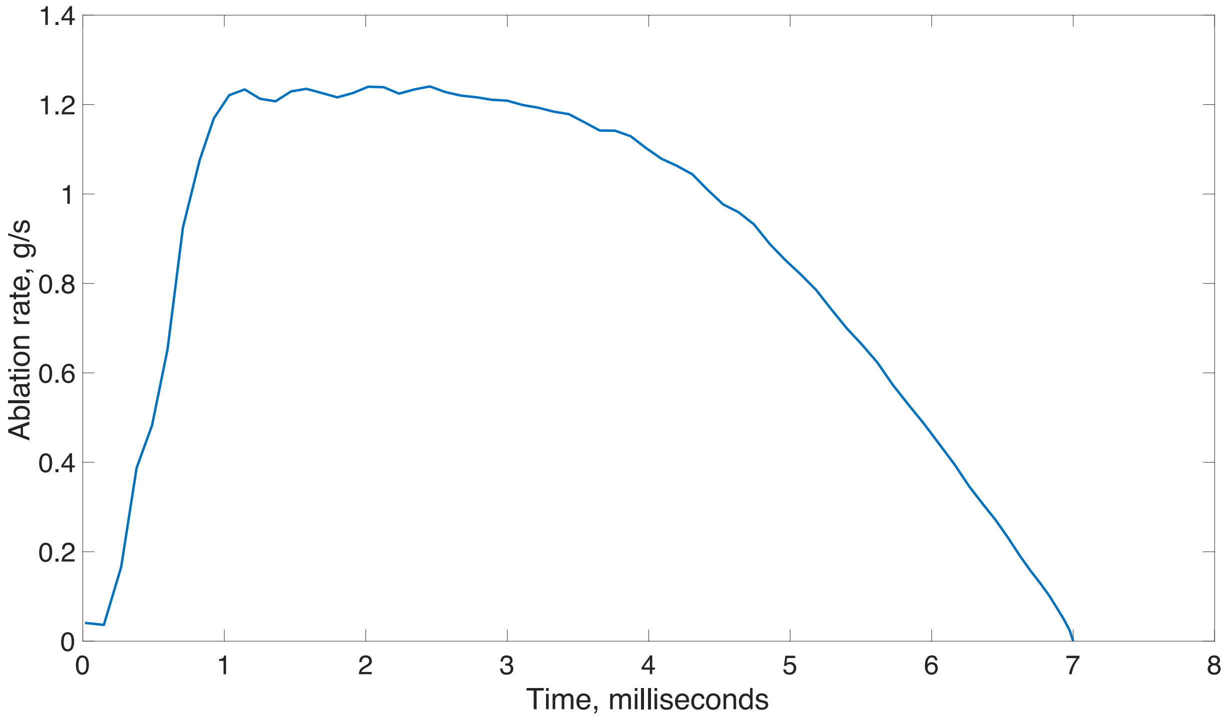
- Pellet radius plot vs time, M3D-C1 (left) and LP (right)

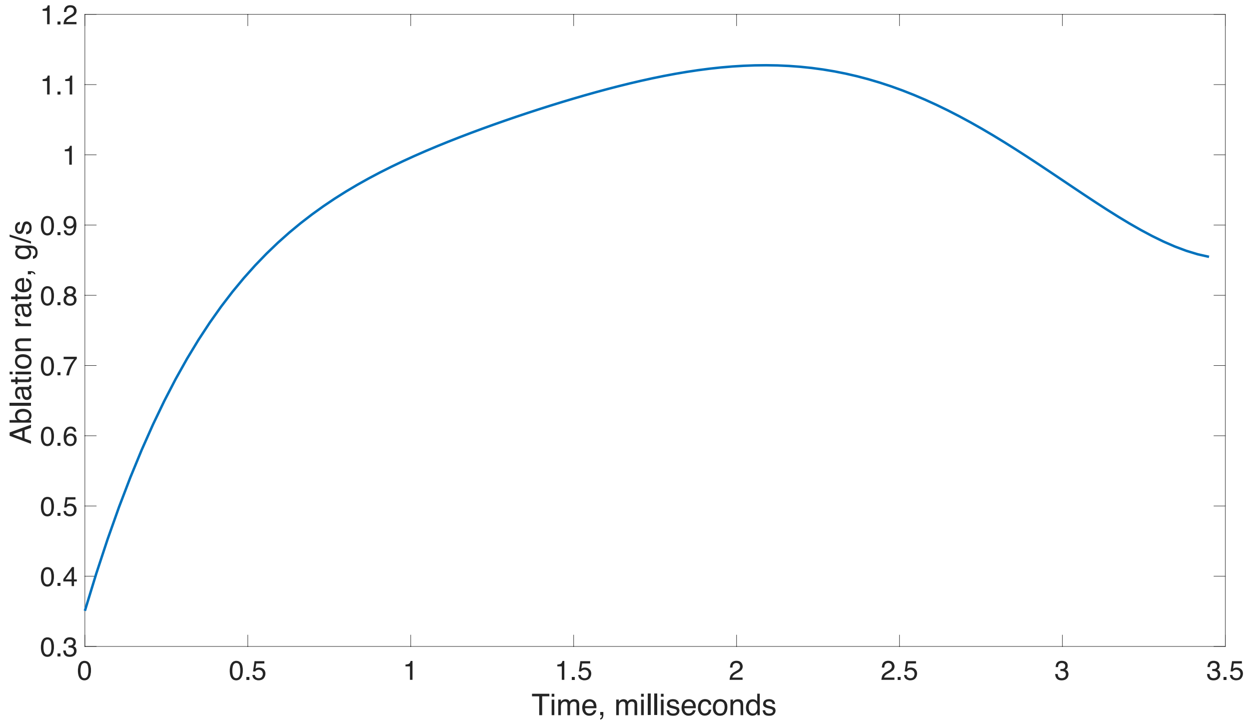




Shrinking pellet LP simulation using data file from M3D-C1 (cont'd)

- Ablation rate plot vs time, M3D-C1 (left) and LP (right, with some numerical noise smoothed out)





Steady-state LP simulations along pellet trajectory vs M3D-C1

- Grad-B drift, Neon, B = 1.35 T, r_p = 0.95 mm

Neinf, 1/cc	Teinf, eV	G (LP), g/s	G (M3D-C1), g/s
1.1e14	500.8	1.19	1.22

- Grad-B drift, Neon, B = 1.5 T, r_p = 0.68 mm

Neinf, 1/cc	Teinf, eV	G (LP), g/s	G (M3D-C1), g/s
2.36e14	652.73	1.05	1.1

Steady-state LP simulations vs Scaling law in r_p

$$G \sim T_e^{5/3} n_e^{1/3} r_p^{4/3}$$

$$G(t) = G_0 \left(\frac{r_p(t)}{r_0}\right)^{4/3}$$

- Finding G_0
- Grad-B drift, Neon, B = 2 T, r_p = 2 mm

Neinf, 1/cc	Teinf, eV	G (LP), g/s
1e14	2000	24
4e13	2000	20.9

r_p changed from 2 mm to 1.5 mm

Neinf, 1/cc	Teinf, eV	G (LP), g/s	G (scaling law in r_p), g/s
1e14	2000	16.3	16.35
4e13	2000	13.8	14.2

Steady-state ablation rates from LP simulations in magnetic field with grad-B drift are in good agreement with the scaling law in r_p

Shrinking pellet LP simulation: comparison with the scaling law

Using the analytic scaling law $G(t) = G_0 \left(\frac{r_p(t)}{r_0}\right)^{4/3}$

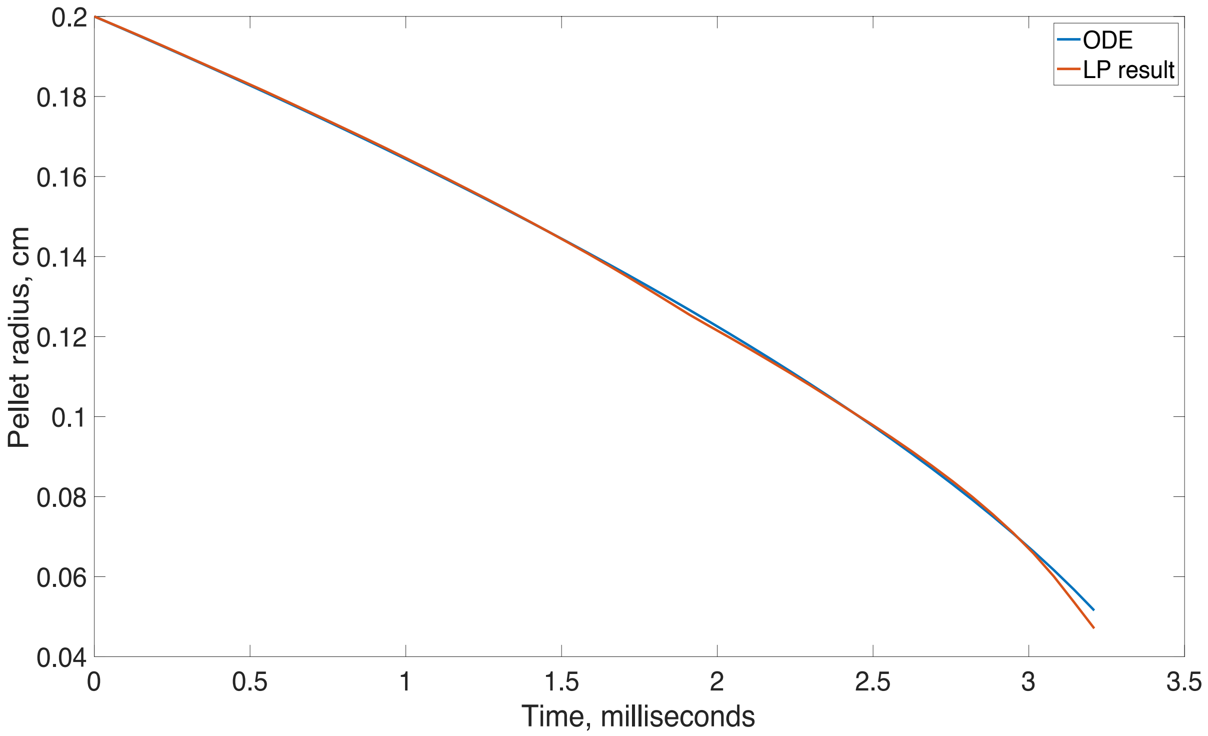
and the mass conservation relation $\frac{d}{dt}\left(\frac{4}{3}\rho_p \pi r_p^3\right) = -G(t)$

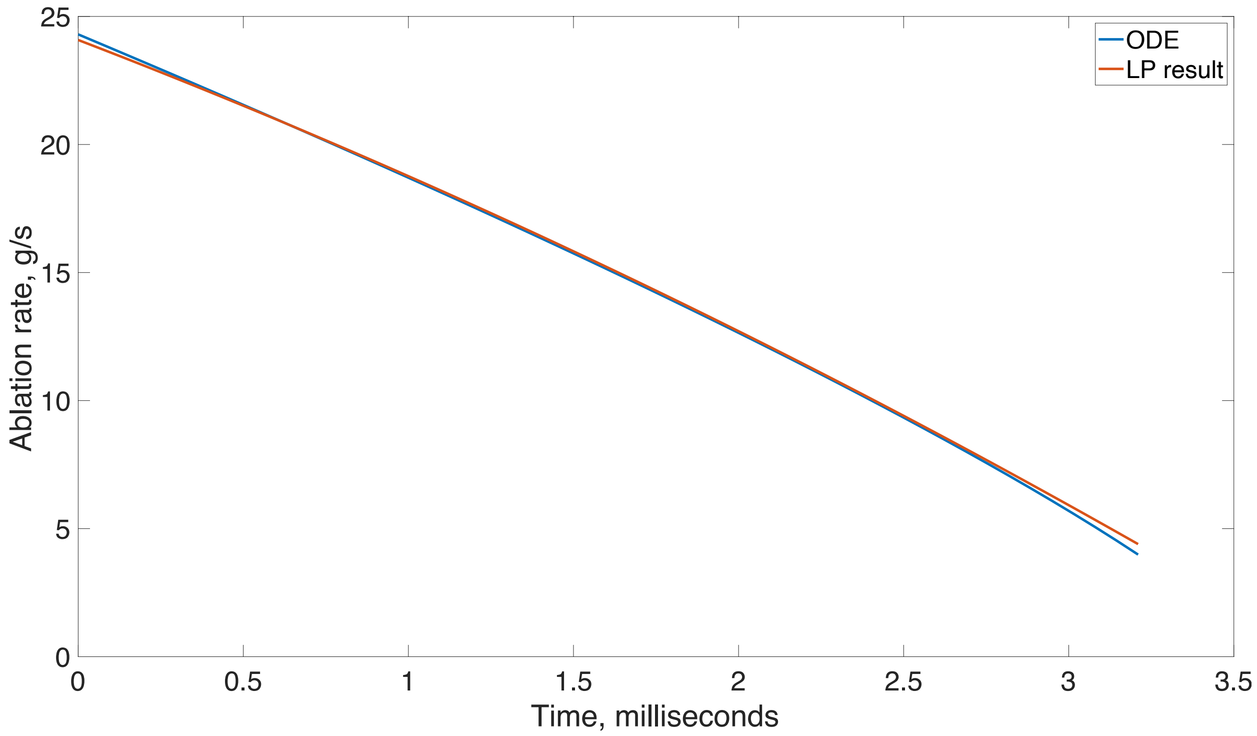
We obtain the following ODE $\frac{dr_p(t)}{dt} = -\frac{G_0}{4\pi\rho_p r_0^{\frac{4}{3}} r_p(t)^{\frac{2}{3}}}$ with the initial condition $r_p(0) = r_0$

The solution is $r_p(t) = \left(r_0^{\frac{5}{3}} - \frac{5\, G_0 t}{12\, \pi \rho_p r_0^{\frac{2}{3}}}\right)^{5/3}$

Shrinking pellet LP simulation 1

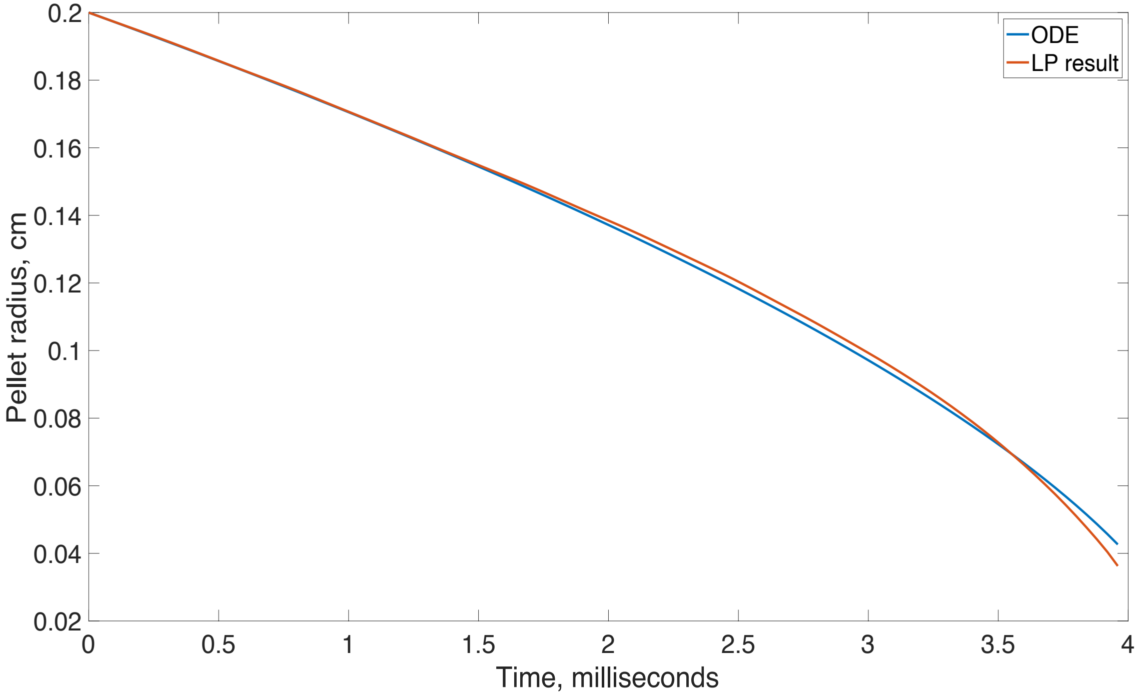
- Grad-B drift, Neon, B = 2 T, r_{p0} = 2 mm, n_e = 1e14 1/cc, T_e = 2000 eV

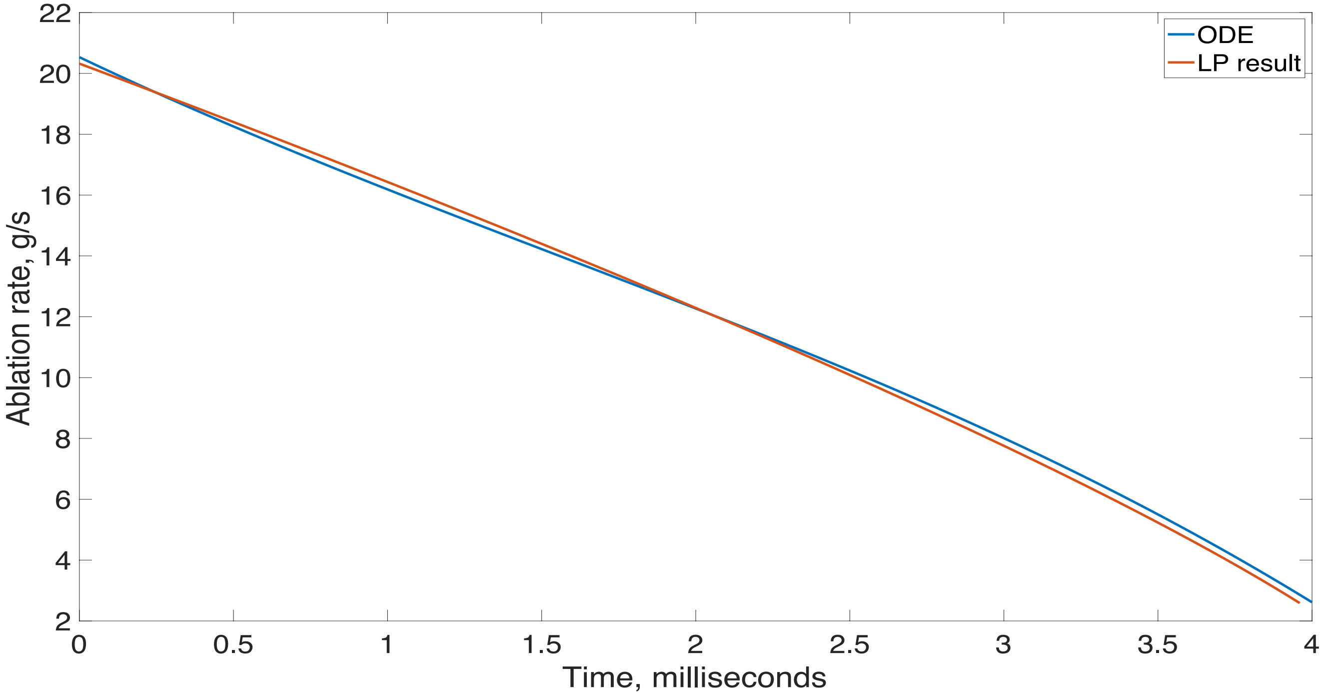




Shrinking pellet LP simulation 2

- Grad-B drift, Neon, B = 2 T, r_{p0} = 2 mm, n_e = 4e13 1/cc, T_e = 2000 eV





Evolution of ablation rate and pellet radius in time from LP simulations are in good agreement with the scaling law in r_p