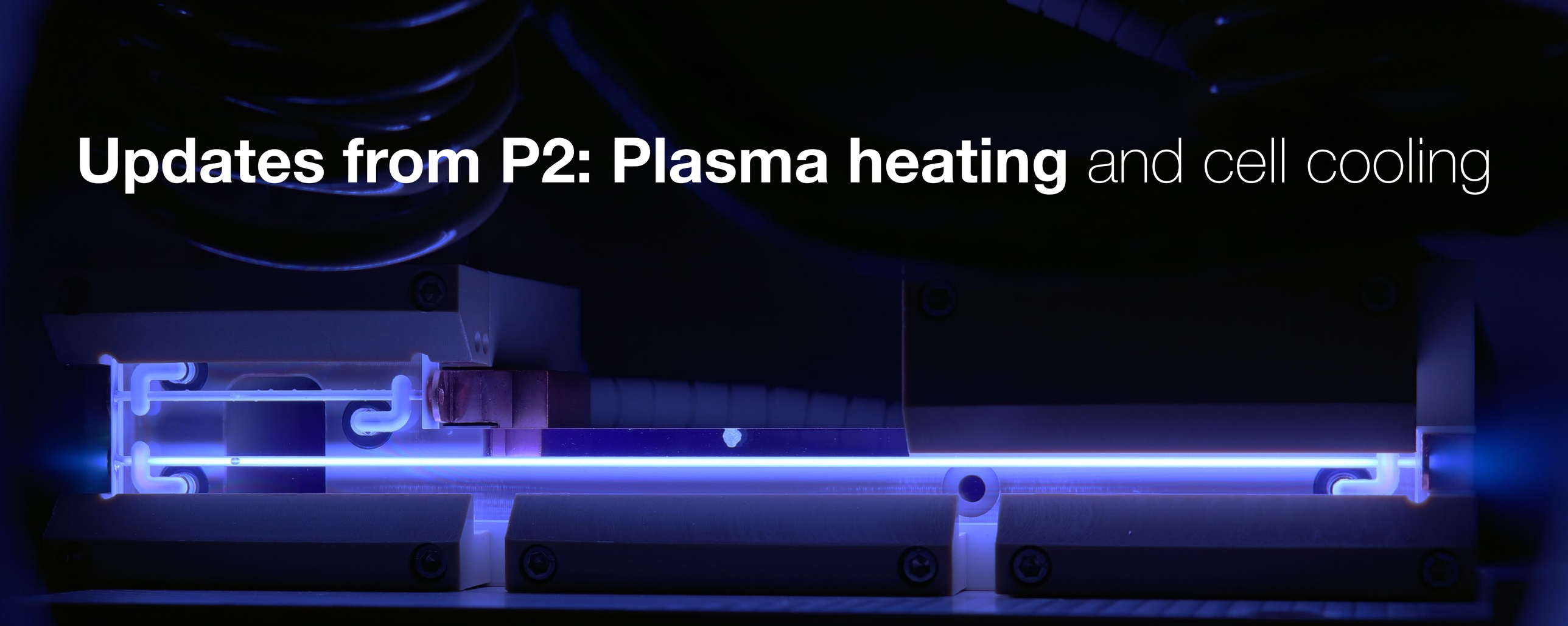
Updates from P2: Plasma heating and cell cooling



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02/10/2025 | HALHF Monthly Meeting | Online

Path towards self-consistent simulations of the HALHF bunch train

- **Goal —** Simulate **1)** the long-term plasma motion between acceleration events, **2)** the increase in plasma temperature, and **3)** the impact that temperature has on the subsequent wakefields
- **Requirement —** Self-consistent simulations of plasma evolution between bunches (*16 ns for HALHF*)
- **Challenge —** Full 3D PIC simulations over this time frame are computationally prohibitive

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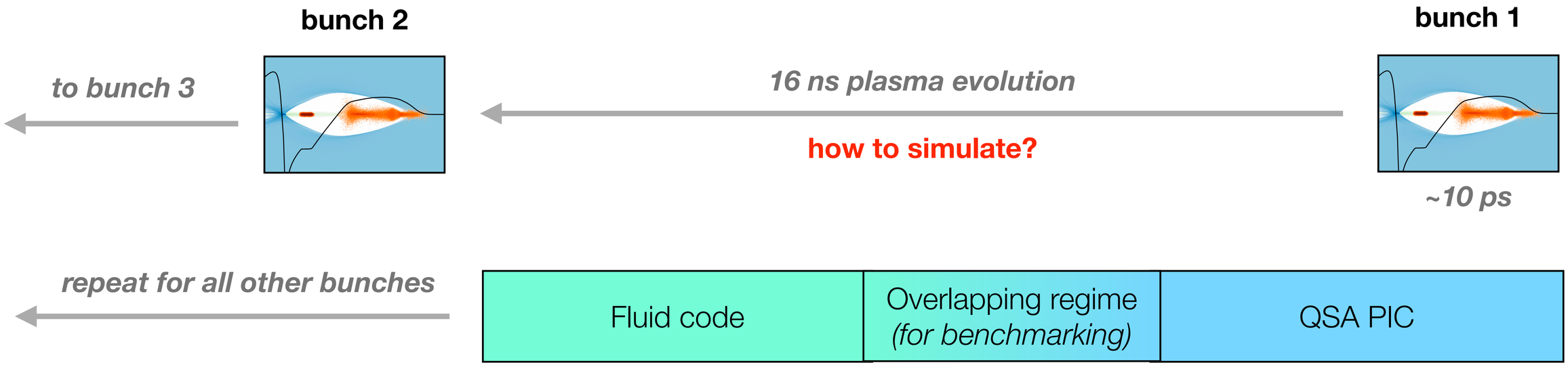
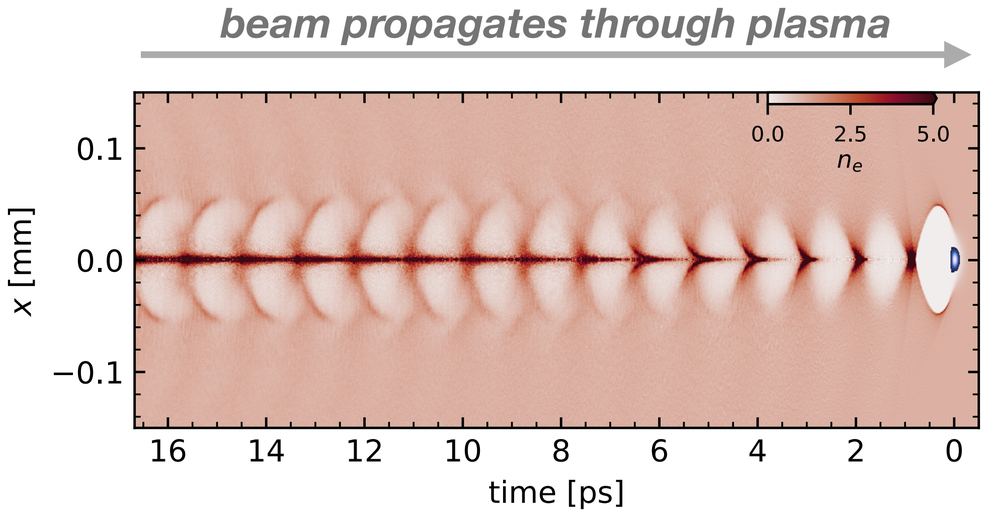


- **Plan — 1)** Test the validity of the quasi-static approximation (QSA) to simulate long timescales, **2)** Run as long as computationally possible in QSA, **3)** transport to fluid code for the remaining time

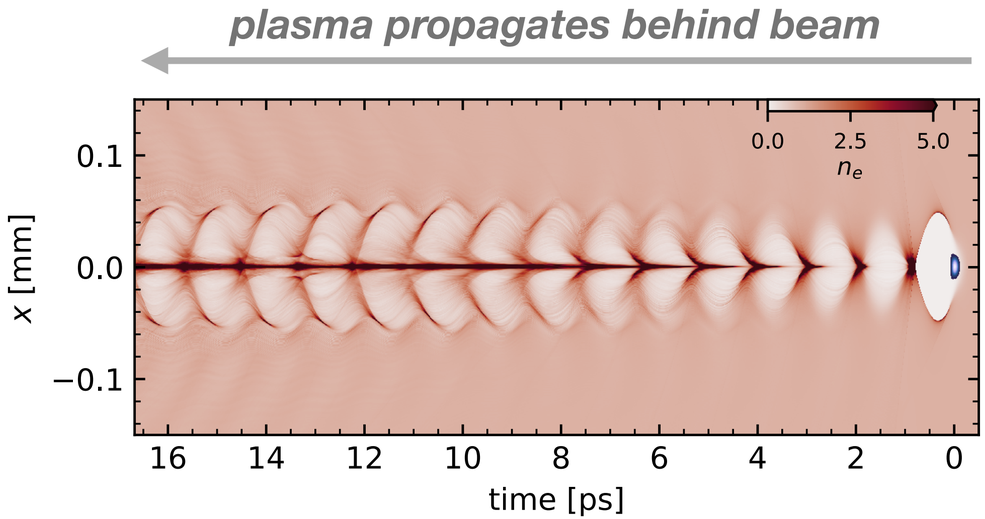
Validating QSA over long timescales w/ FLASHForward parameters

simulations performed by Ibrahim Najmudin



FBPIC (spectral-cylindrical code)

- ~15 mins on 4 x GPUS
- Significant memory usage (full memory per timestep)



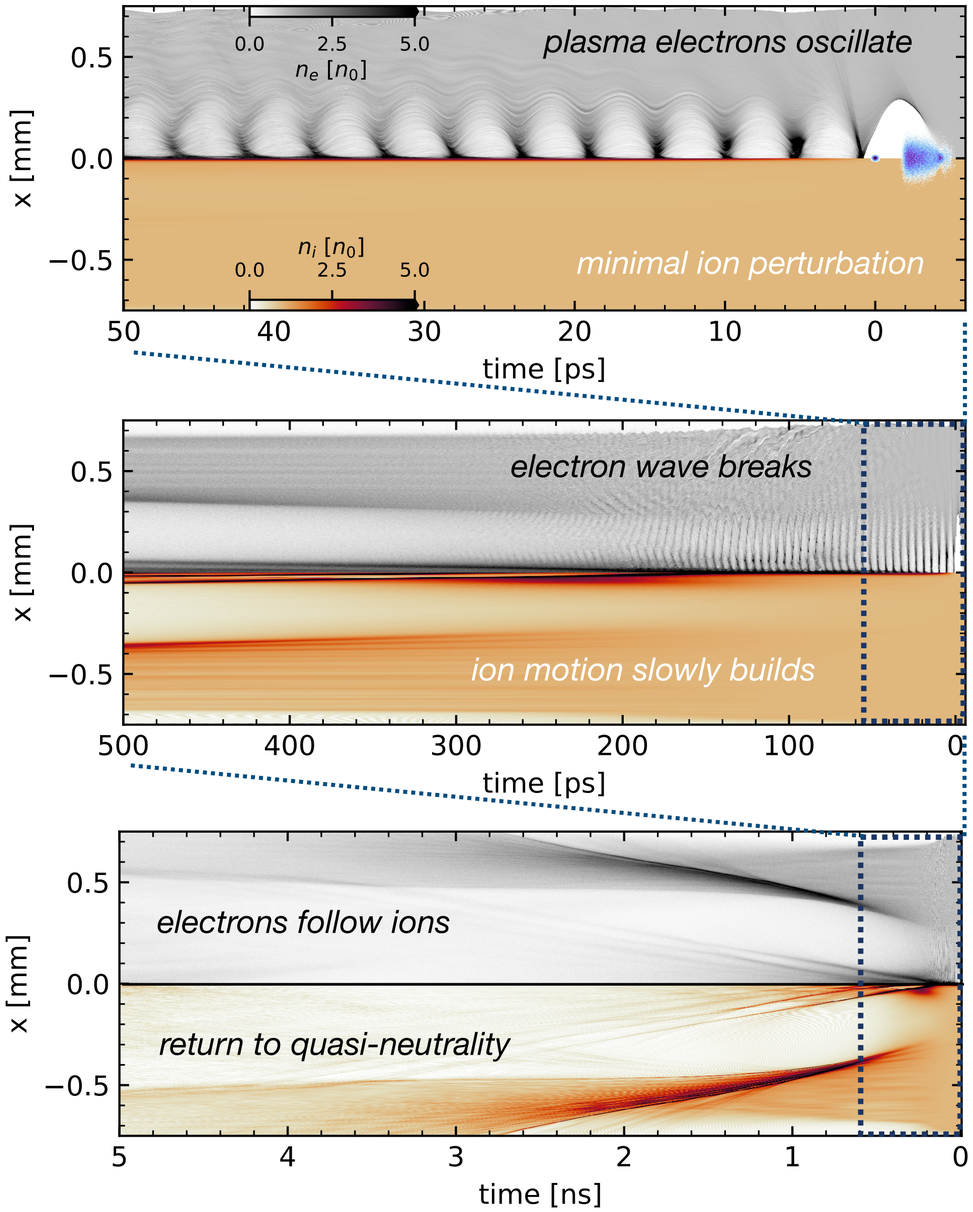
HiPACE++ (quasi-static code)

- ~5 mins on 1 x GPU
- Minimal memory usage (only one timestep)

- ~10x HiPACE++ sims for one FBPIC sim → important for *parameter scans*
- ~10x longer HiPACE++ sims for one FBPIC sim → important for *plasma evolution*

Simulating longer timescales in HiPACE++

- Interesting physics can already be seen on these relatively short timescales
  - Breaking of the plasma-election wave
  - On-axis ion density spike
  - Outwardly propagating ion wave
  - Plasma electrons follow motion of plasma ions
    → ***fluid-like behaviour?***
- All experimental signatures observed in the FLASHForward recovery time result
- Have now simulated up to 10 ns(!)



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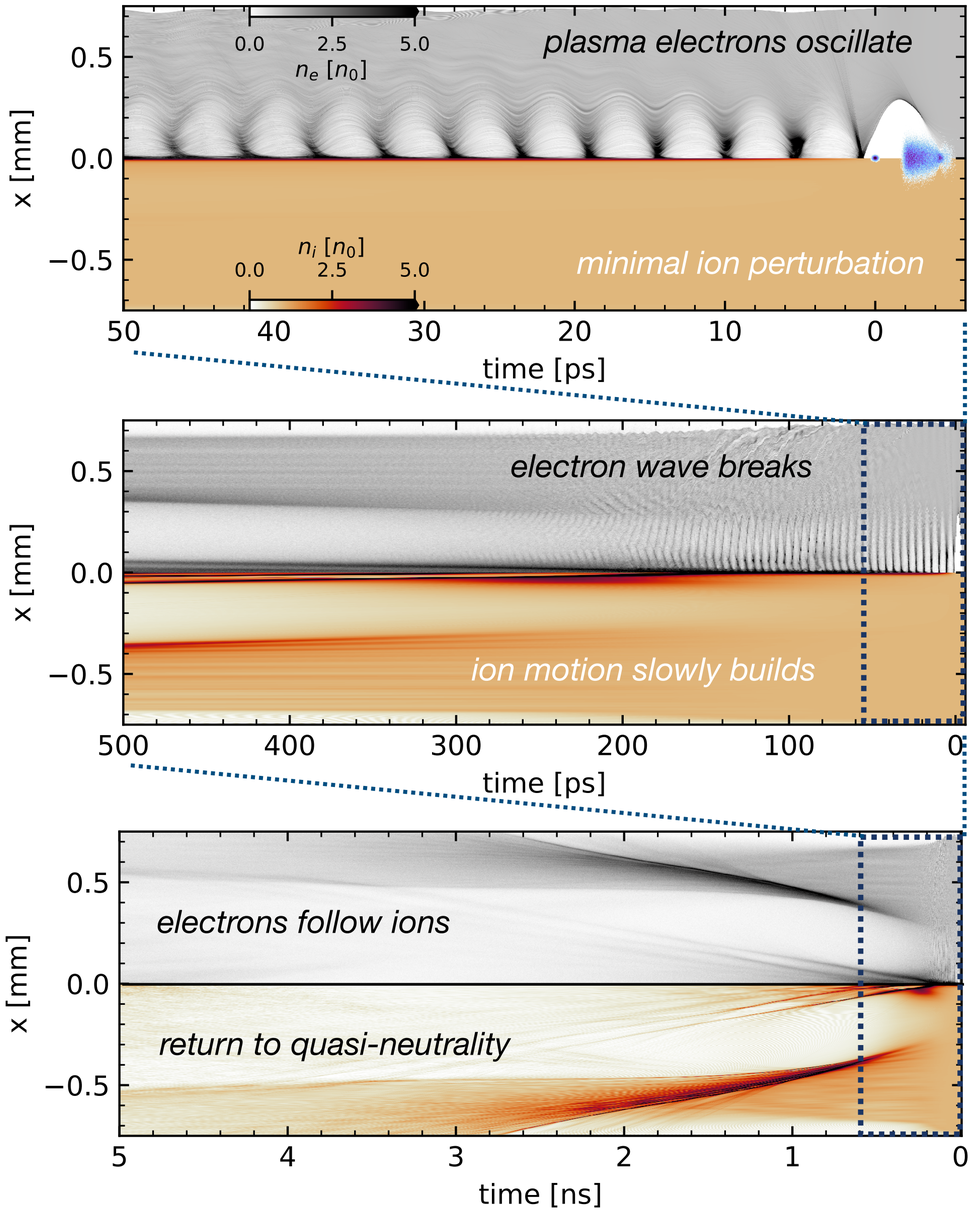

Next steps

- Test limits of QSA then transition to fluid code
- Rerun simulations for HALHF parameters
- Investigate parametric scalings to equate 63 ns FF recovery time to that with HALHF v2 parameters

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