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Sandia National Laboratories

EMPIRE Simulation of the RKA Electron Beam

B. Medina, C.H. Moore, M. Bettencourt, K. Cartwright, T. Powell, T. Pointon, E. Phillips, K. S. Bell
Sandia National Laboratories

J. Gardelle, B. Cassany, P. Modin, N. Szalek, D. Hebert
CEA/CESTA

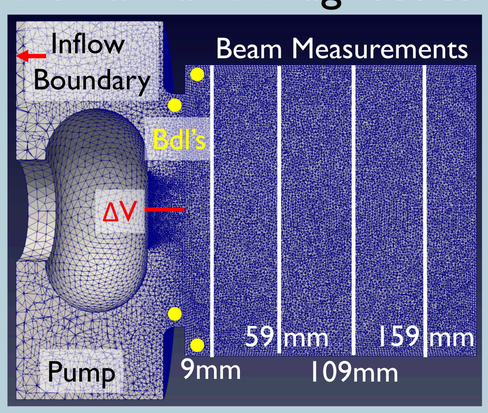
Abstract

As part of a continued validation effort for Sandia's new plasma code, EMPIRE [1], we have modeled and are simulating the RKA beam experiment [2, 4P20 PPPS2019]. The current EMPIRE validation effort is ultimately concerned with the electron-beam transport (e.g. electron-neutral chemistry) through an Ar-filled gas cell at various pressures from vacuum to ~1 Torr. Specifically, we have begun simulations of the RKA diode and beam transport through the gas cell.

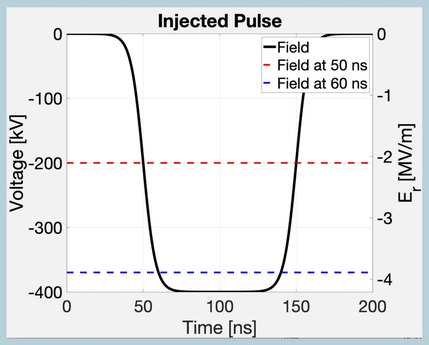
EMPIRE Overview

- EMPIRE (ElectroMagnetic Plasma In Realistic Environments): 3D EM Finite Element plasma code on unstructured mesh
- Goal is Hybrid PIC-Fluid simulation for a 30B+ element simulation on next-generation HPC architectures
- EMPIRE has a breadth of physics capable of modeling low temperature discharge plasmas to high energy e- beam transport including complex gas chemistries and plasma-surface interactions.
- Electron-neutral collisions modeled using the Direct Simulation Monte Carlo (DSMC) method

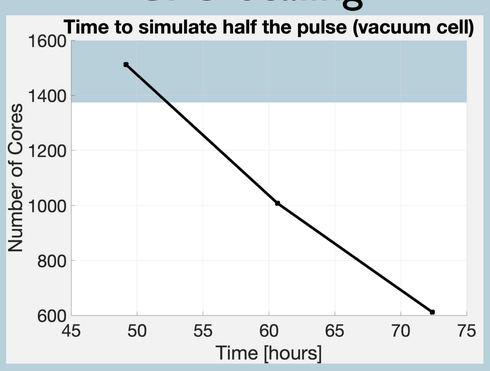
Domain and Diagnostics



Half Inflow Driver



CPU Scaling

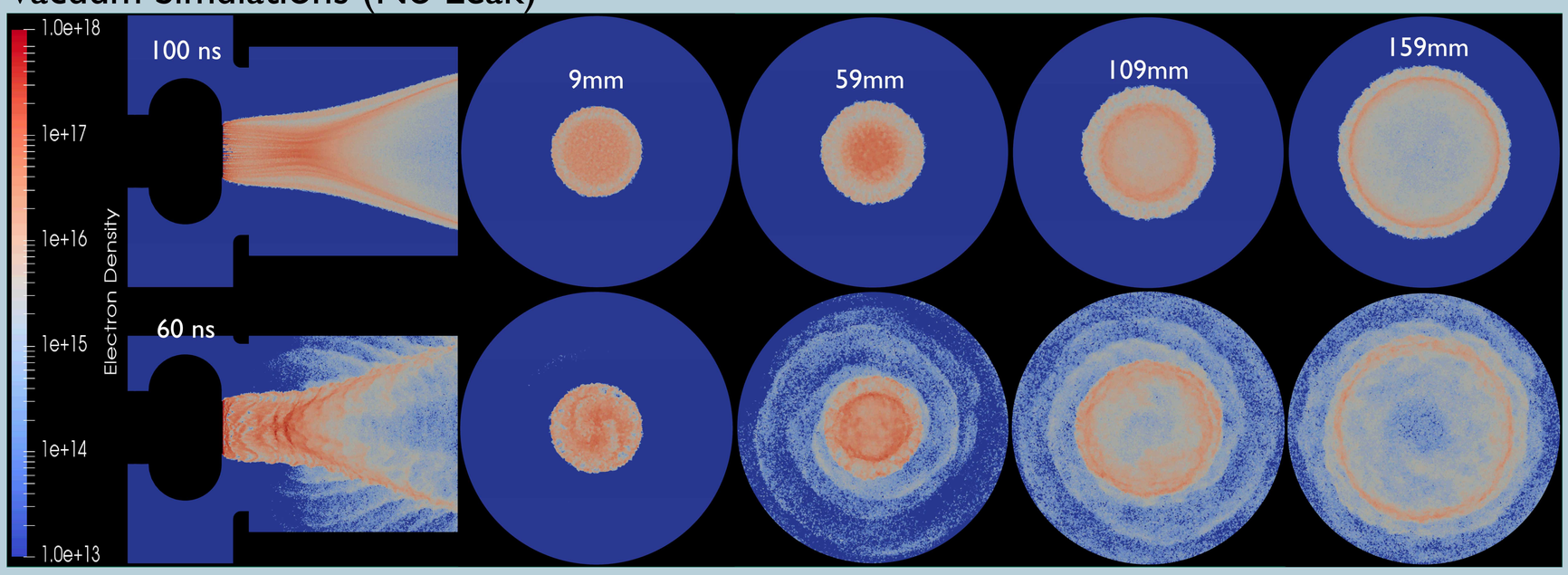


Future Work

- Add scattering boundary condition at the anode foil.
- Add relativistic, anisotropic collisions
- Simulate RKA beam transport with MCC and EMPIRE-hybrid collision models as part of each algorithm's verification & validation
- Further explore EMPIRE's performance on CPUs and GPUs.

[1] 1. Markosyan, A. et al, 45th ICOPS, June 24-28 2018.
[2] K. Pepitone, J. Gardelle and P. Modin, Journal of Applied Physics **117**, 183301 (2015);
[4P20] PROPAGATION OF ELECTRON BEAMS IN GAS CELLS, PPPS 2019

Vacuum Simulations (No Leak)

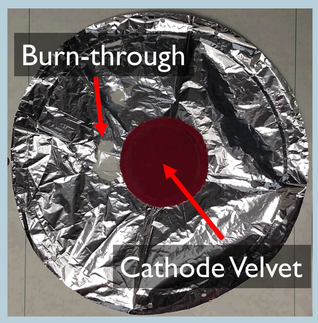


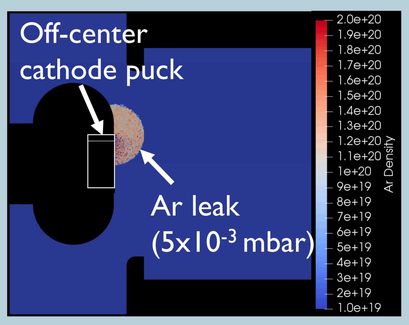
Takeaways

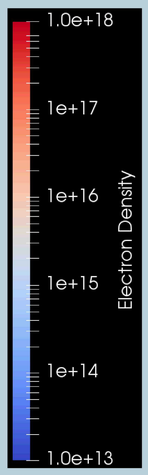
- Beam space charge sufficient to spread the beam
- Lack of scattering model for the anode foil results in sharp beam profile
- Investigating whether the simulated instability is due to noise or numerical error

Vacuum Simulations (Argon Leak)

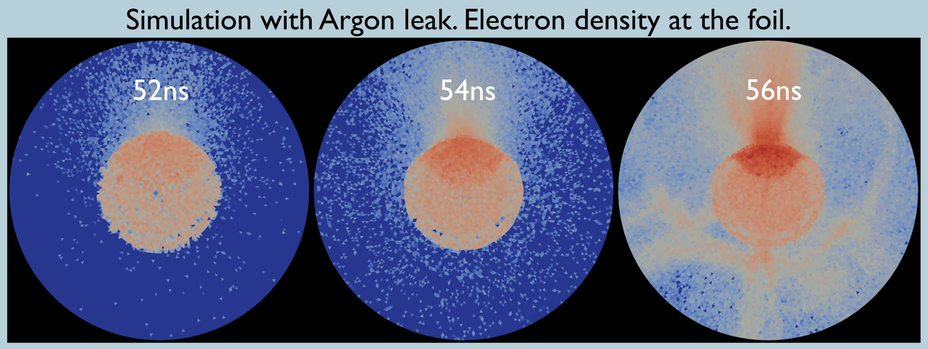
- Under ideal conditions RKA is capable of multiple shots without breaking vacuum
- Occasionally small holes appear in the mylar/Al anode foil which require RKA to be opened
- It was hypothesized that the interchangeable puck holding the cathode velvet could potentially trap air resulting in a virtual leak which we model here as an off-center cathode puck
- Simulating a leak near the cathode produces a "hot-spot" at the foil



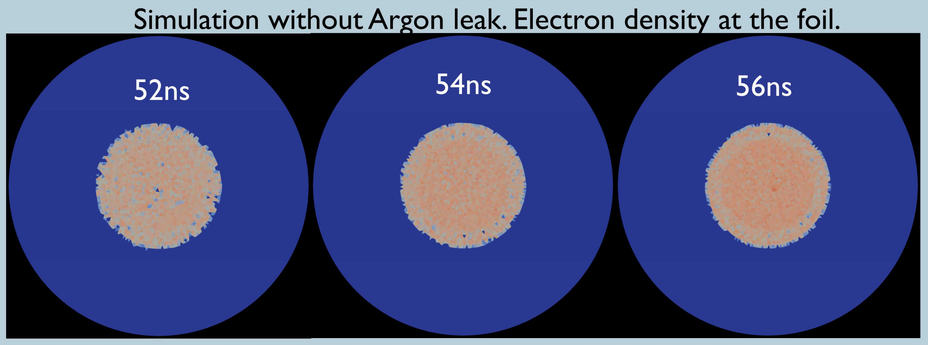




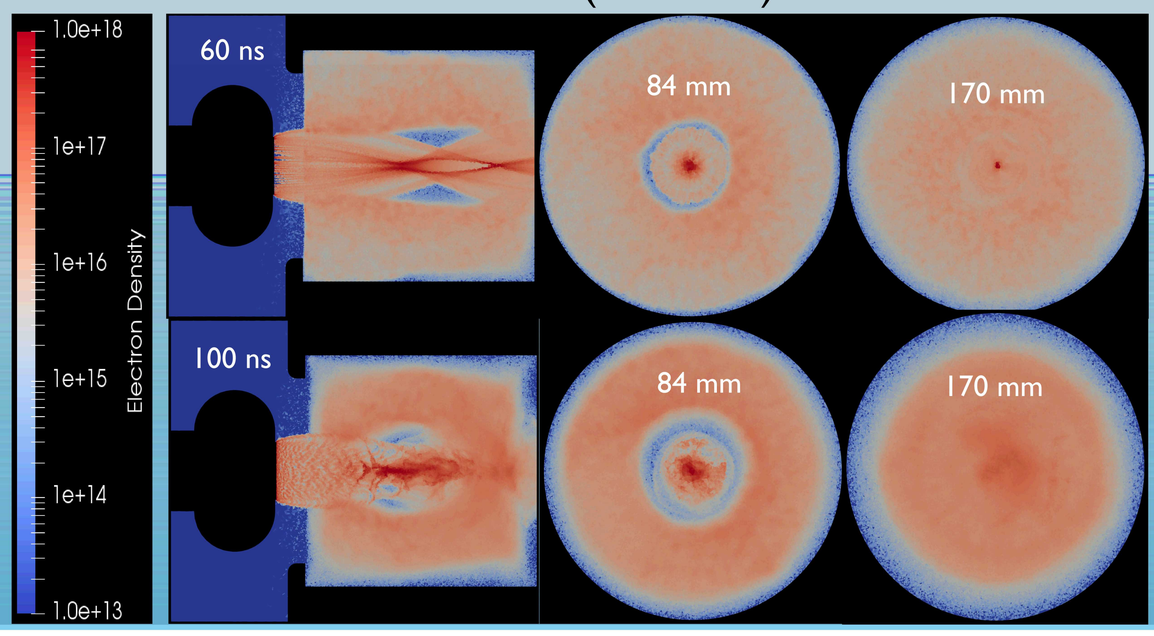
Simulation with Argon leak. Electron density at the foil.



Simulation without Argon leak. Electron density at the foil.



0.1mbar Pressurized Simulations (No Leak)



Takeaways

- EMPIRE is capable of simulating the RKA's electron beam through various gases.
- As expected, these simulations show that low background pressures favorably influence the beam intensity.
- Isotropic scattering model for e-Ar collisions results in significantly more electron diffusion in the gas cell.
- e-Ar interaction rates will be altered with the addition of relativistic collisions
- Future EMPIRE simulations will be able to pinpoint the location(s) where the electron beam has the highest intensity.

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