2D study of current distribution evolution in exploding wires with the FLASH code

O. Zajan[1], A. M. Bedel[2], B. Cikhardtova[1], J. Cikhardt[1], N. G. Chalmers[3], J. M. Chen[2], N. M. Jordan[2], P. Kubes[1], J. Malir[1], V. Munzar[1], J. Novotny[1], K. Rezac[1], L. R. Tafoya[2], D. A. Hammer[3], R. D. McBride[2], D. Klir[1]

[1]Czech Technical University in Prague, Faculty of Electrical Engineering, Prague, Czech Republic
[2]Department of Nuclear Engineering and Radiological Sciences, University of Michigan, USA
[3]Laboratory of Plasma Studies, Cornell University, Ithaca, New York, USA

Motivation

MHD simulations are utilized to analyse the corona of the exploding wire's plasma and compared with radiographs taken from x-pinch facilities in Cornell (XP) and Michigan (MAIZE).

- Diagnostics of the plasma corona is experimentally challenging.
- Better interpretation of the proton radiographs.
- Dependence on current rise time: $\tau_{XP} = 70$ ns, $\tau_{MAIZE} = 140$ ns.
- Influence of the skin effect, anomalous resistivity, and magnetic diffusion.

Experimental setup

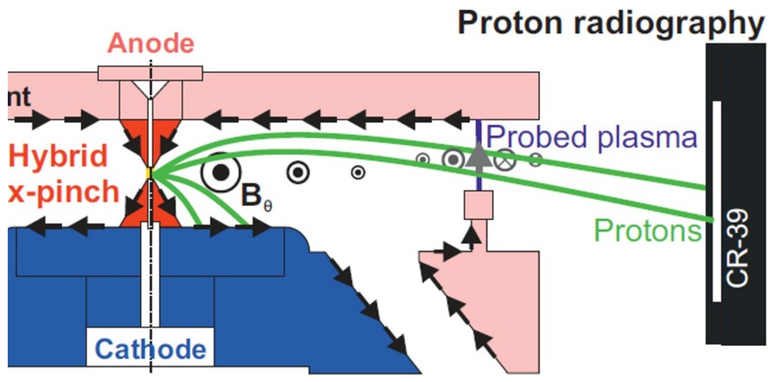

Fig. 1: Schematic of hybrid X pinch facility on MAIZE, with proton radiography [1].

Simulation

- **Code:** FLASH, resistive MHD, 2D cylindrical geometry
- **Initial condition:** Aluminum wire, $25\ \mu$m in diameter with Gaussian decay, 2.0 eV wire temperature, 0.5 eV vacuum temperature
- **EOS:** IONMIX tabulated
- **Solvers:** unsplit staggered mesh scheme, hybrid Riemann solver, implicit diffusion
- **Grid:** AMR with resolution up to $6.5\ \mu$m

Results

XP ($\tau_{XP} = 70$ ns, 120 kA)

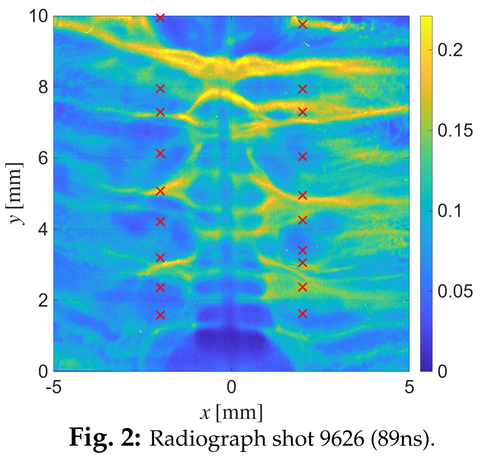

Fig. 2: Radiograph shot 9626 (89ns).

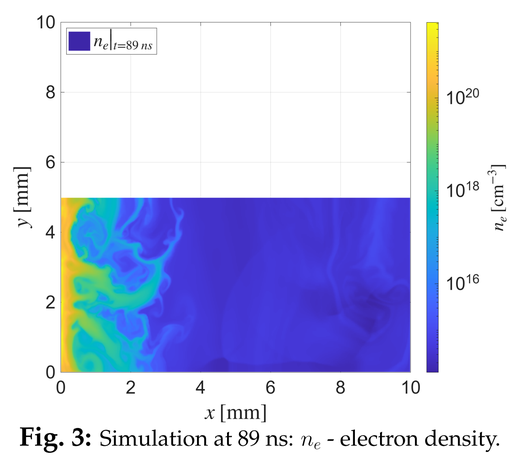

Fig. 3: Simulation at 89 ns: n_e - electron density.

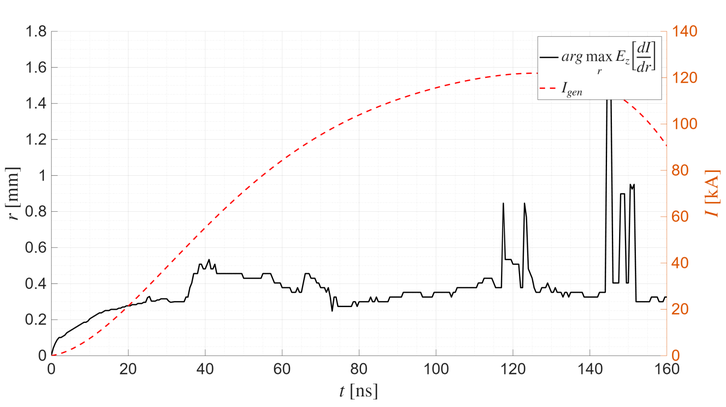

Fig. 4: Simulation - current distribution.

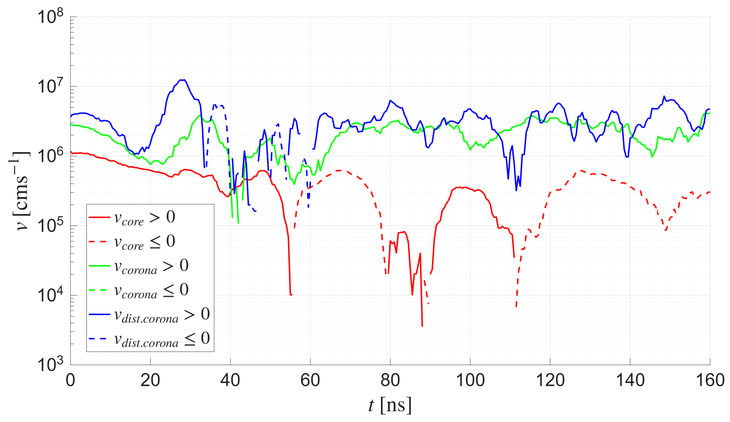

Fig. 5: Simulation - radii speed.

MAIZE ($\tau_{MAIZE} = 140$ ns, 93 kA)

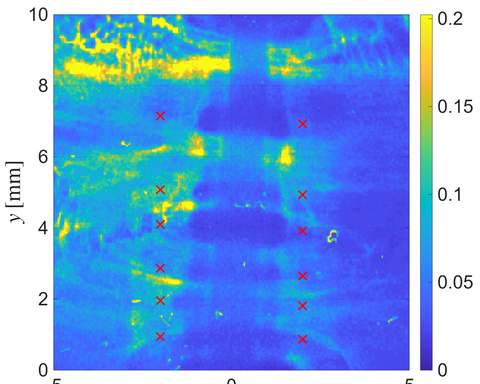

Fig. 6: Radiograph shot 3369 (74ns).

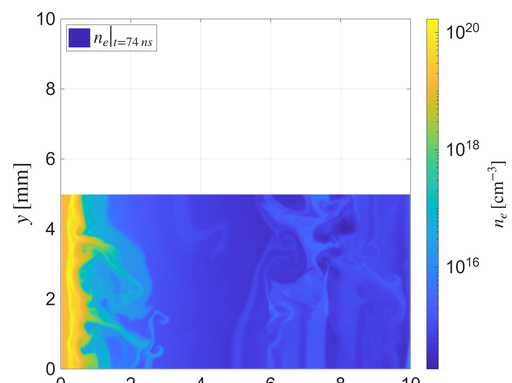

Fig. 7: Simulation at 74 ns: n_e - electron density.

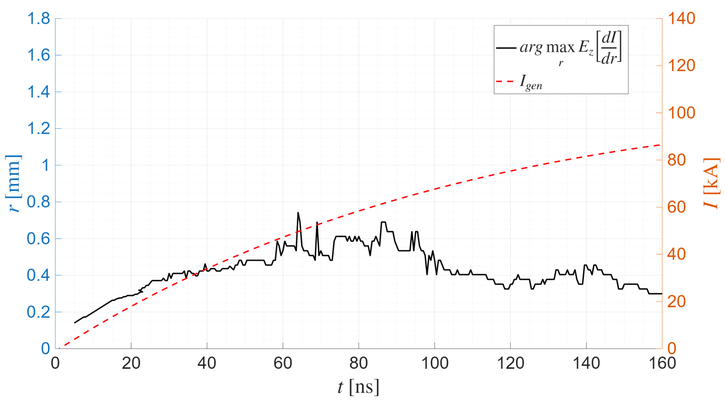

Fig. 8: Simulation - current distribution.

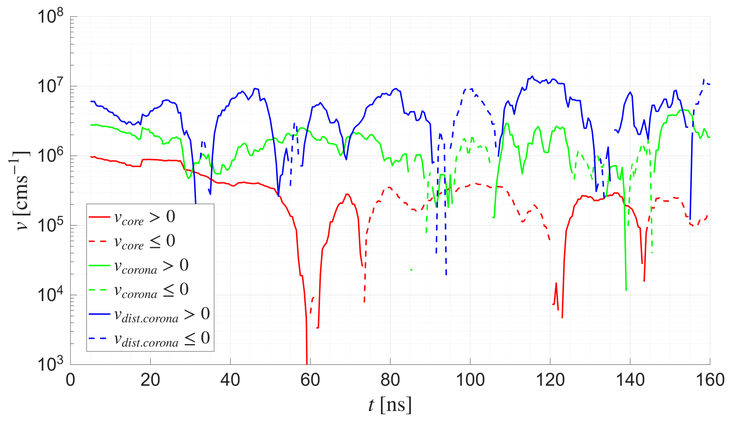

Fig. 9: Simulation - radii speed.

Conclusion

- **Radiographs:** The simulation does not fully replicate the experimental data. This study demonstrates that further investigation is required regarding the radiographs exposure time and the more precise current estimation through the exploding wire.
- **Expansion velocity:** The slower rise time leads to a more erratic evolution and greater overall plasma expansion.
- **Current distribution:** Follows the expansion of the plasma.
- **Future work:** More complex simulations and further analysis of the current distribution and plasma dynamics remain a subject of ongoing research.

Acknowledgement & References

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[1] D. Klir et al., "Observation of Radially Emitted Proton Beams from Low-Mass X-Pinch Plasmas," *Physical Review Letters*, vol. 136, no. 14, p. 145 101, Apr. 7, 2026. DOI: 10.1103/qdgp-tydj Accessed: Apr. 17, 2026. [Online]. Available: https://link.aps.org/doi/10.1103/qdgp-tydj

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