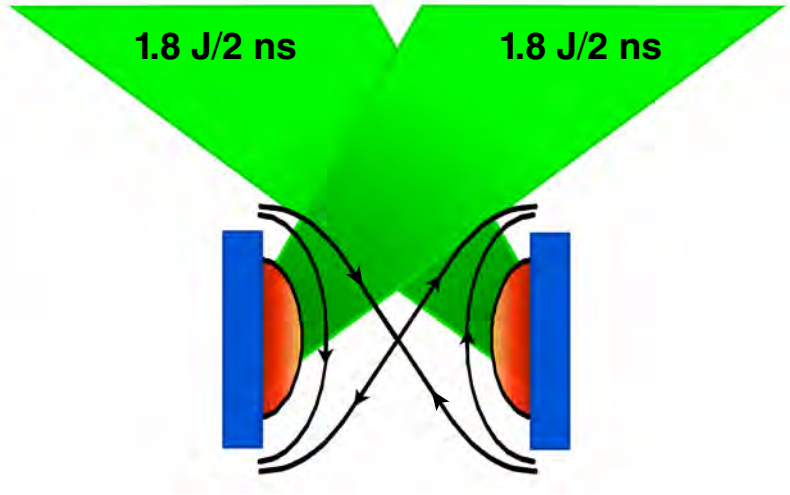
Magnetic Reconnection of an Externally Applied Magnetic Field in a High-Energy-Density Plasma

UR LLE

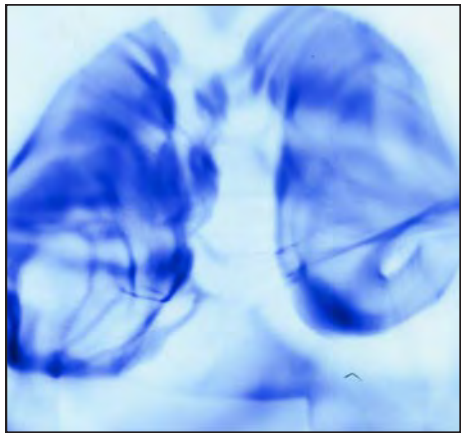
University of New Hampshire

PPPL

Experimental setup



Proton radiograph



G. Fiksel
University of Rochester
Laboratory for Laser Energetics

55th Annual Meeting of the
American Physical Society
Division of Plasma Physics
Denver, CO
11–15 November 2013

Summary

Reconnection of an external magnetic field was observed in a high-energy-density (HED) plasma

UR LLE

- Magnetic reconnection of an externally applied magnetic field in counter-propagating HED plasmas was studied on the OMEGA EP Laser System
- Formation of counter-propagating magnetized "ribbons," magnetic-flux pile-up, and reconnection were demonstrated
- Particle-in-cell (PIC) simulations closely match the experimental results

Collaborators

D. H. Barnak, P.-Y. Chang, S. X. Hu, P. M. Nilson, and R. Betti

Laboratory for Laser Energetics
University of Rochester

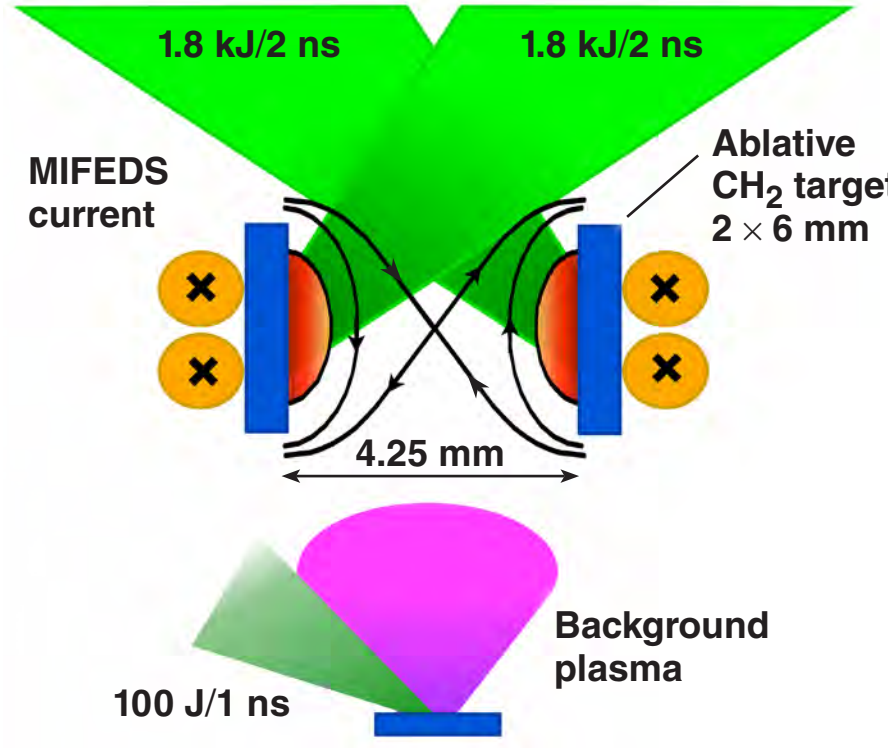
W. Fox and A. Bhattacharjee

Princeton University

K. Germaschewski

University of New Hampshire

We studied the reconnection of an external B field by colliding two HED plasma bubbles on the OMEGA EP Laser System

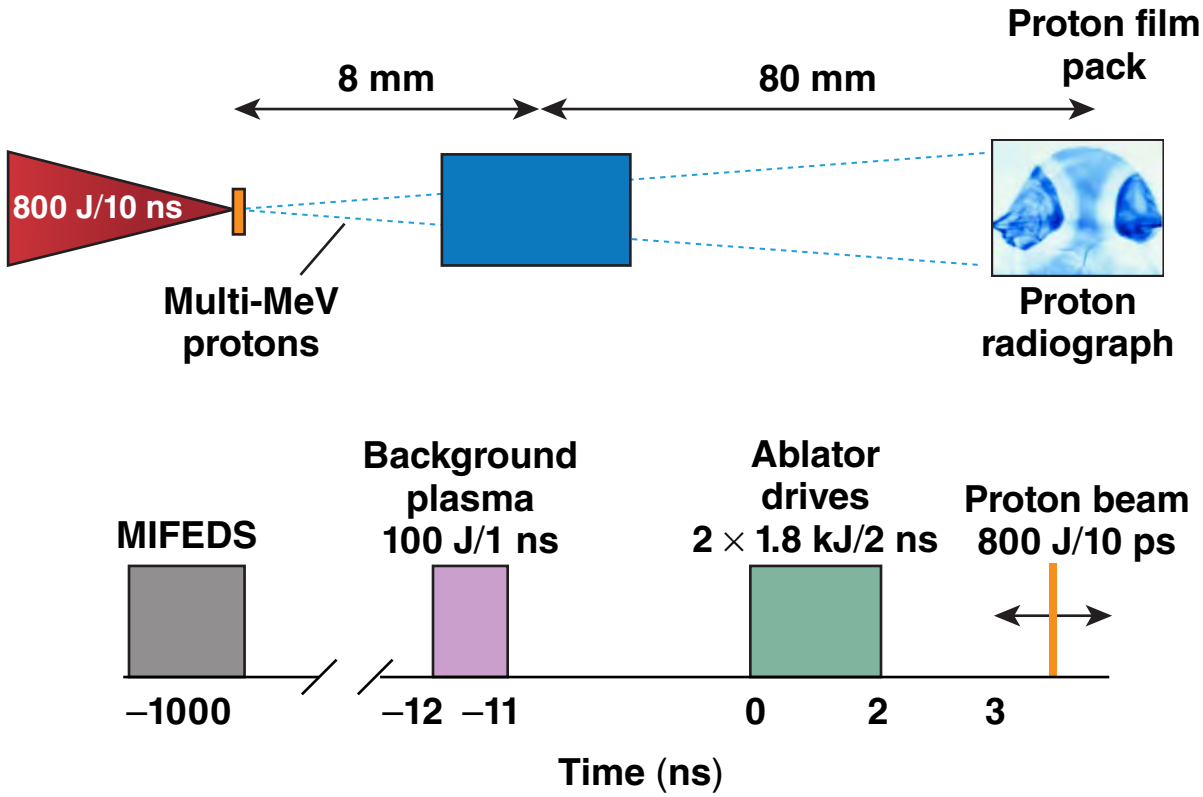


The external field (8 T at the target) is created by a pulsed current generator magneto-inertial fusion electrical discharge system (MIFEDS).*

The reconnection volume is prefilled by tenuous background (BG) plasma.

*O. V. Gotchev *et al.*, Rev. Sci. Instrum. 80, 043504 (2009).

The interaction region was probed by laser-produced fast protons

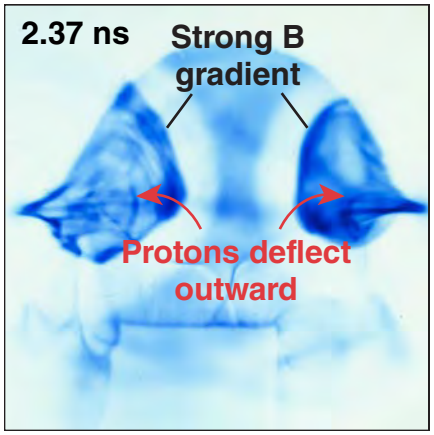


E22617

Proton (13-MeV) radiography images show the formation of high-B ribbons, flux pile-up, outflow, and reconnection

UR LLE

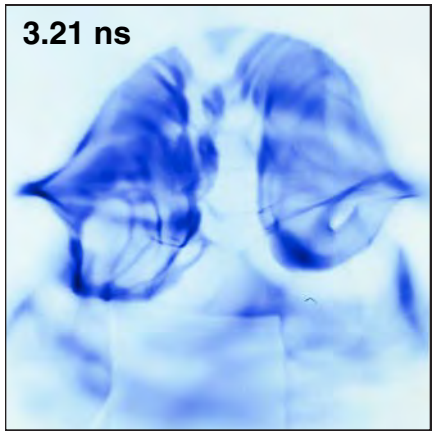
High-B ribbons flux pile-up



–2 0 2

x (mm)

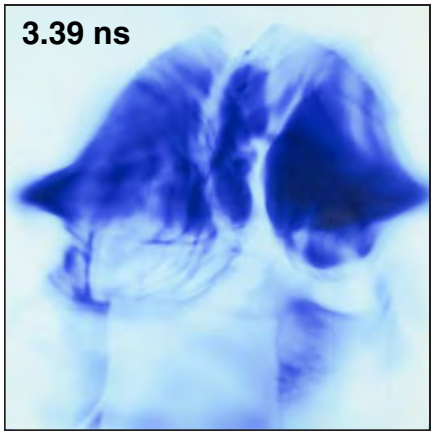
Merging and outflow current sheath breakup



–2 0 2

x (mm)

B-field annihilation

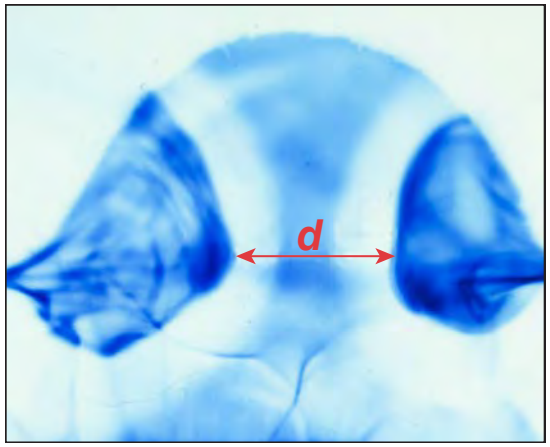


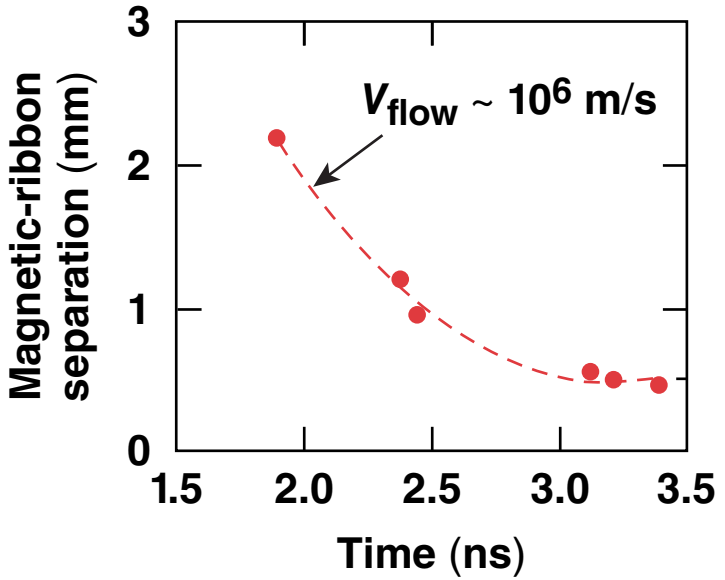
–2 0 2

x (mm)

E22618

The ribbons collide with a high velocity, greater than the ion-acoustic speed c_s and Alfvén velocity V_A

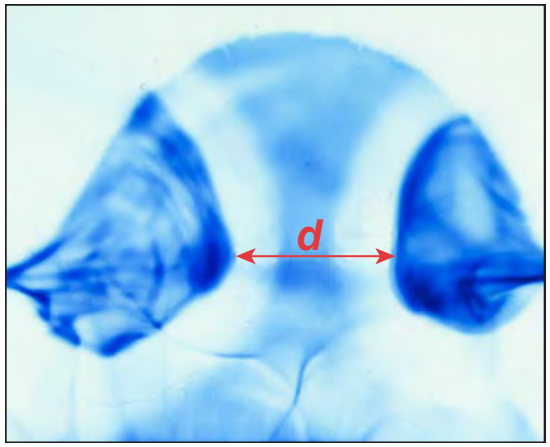


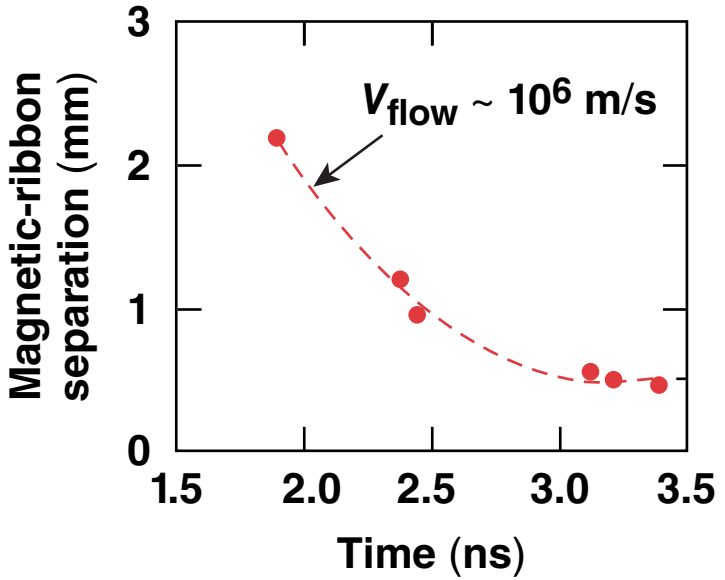


Flow (m/s)	1×10^6
V_A (m/s)* (estimated*)	2×10^5
c_s (m/s)* (estimated*)	3×10^5

E22619

The ribbons collide with a high velocity, greater than the ion-acoustic speed c_s and Alfvén velocity V_A





Flow (m/s)	1×10^6
V_A (m/s)* (estimated*)	2×10^5
c_s (m/s)* (estimated*)	3×10^5

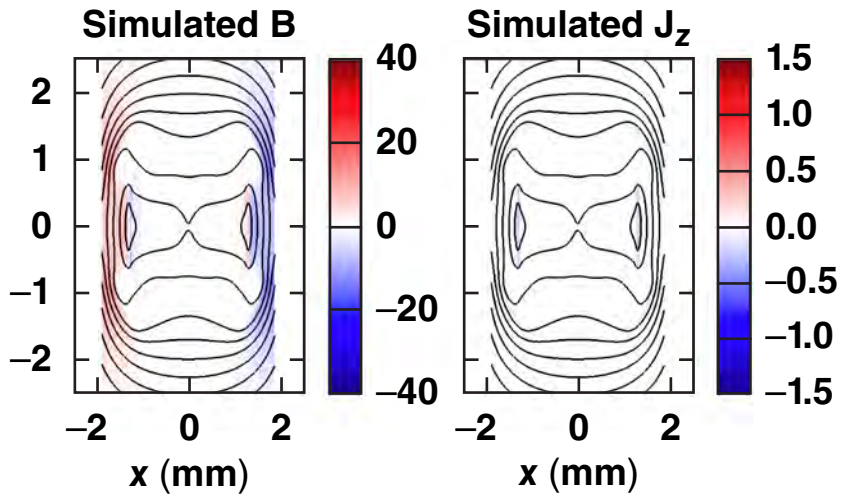
Density (cm^{-3})	2×10^{19}
B (T)	30 (β ~ 10)
d_i (mm)	4×10^{-2}

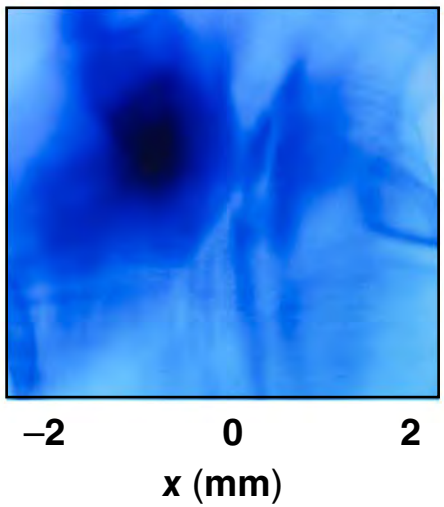
E22619a

The background plasma is necessary for reconnection by allowing for the inboard current

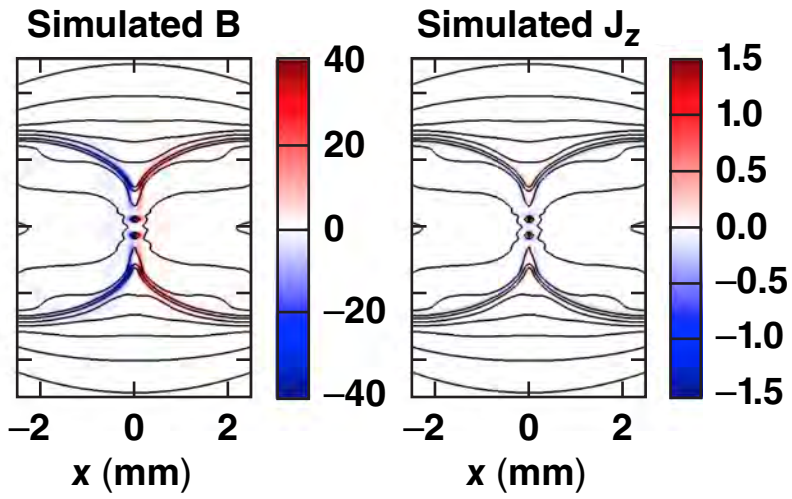
UR LLE

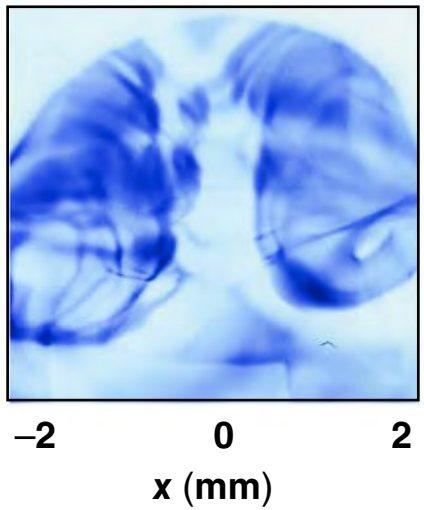
No background plasma





Background plasma



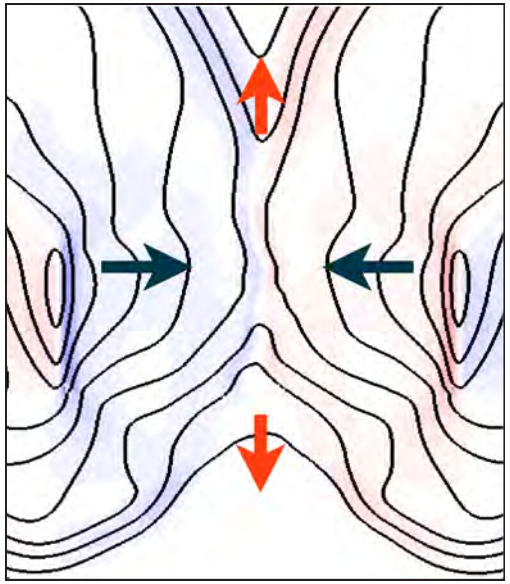


E22620

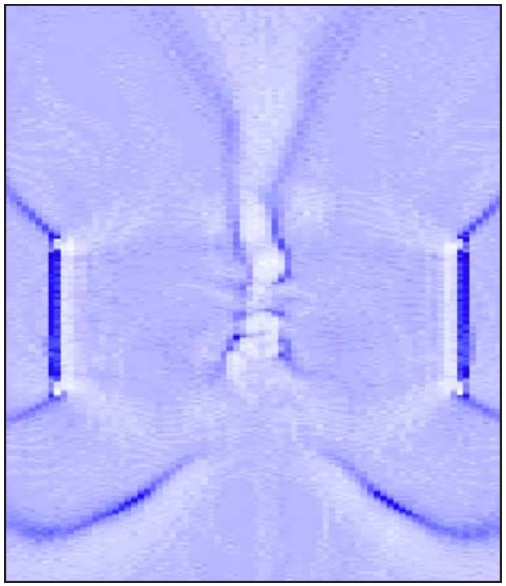
Simulated and experimental proton radiography images agree reasonably well

UR LLE

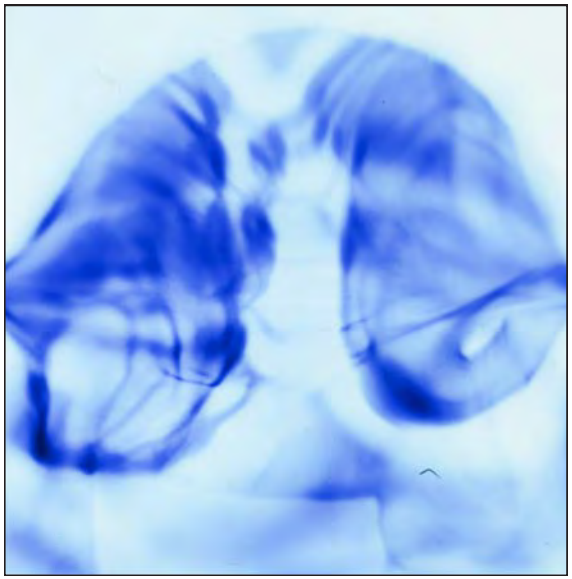
Simulated B flux contours



Simulated proton tracks



Measured,
13-MeV proton tracks



- Up–down asymmetry caused by background plasma flow (from below)
- Colliding and reconnecting magnetic ribbons
- Clumps in the reconnection layer (island formation?)

E22621

*W. Fox, A. Bhattacharjee, and K. Germaschewski, Phys. Plasmas 19, 056309 (2012).

Summary/Conclusions

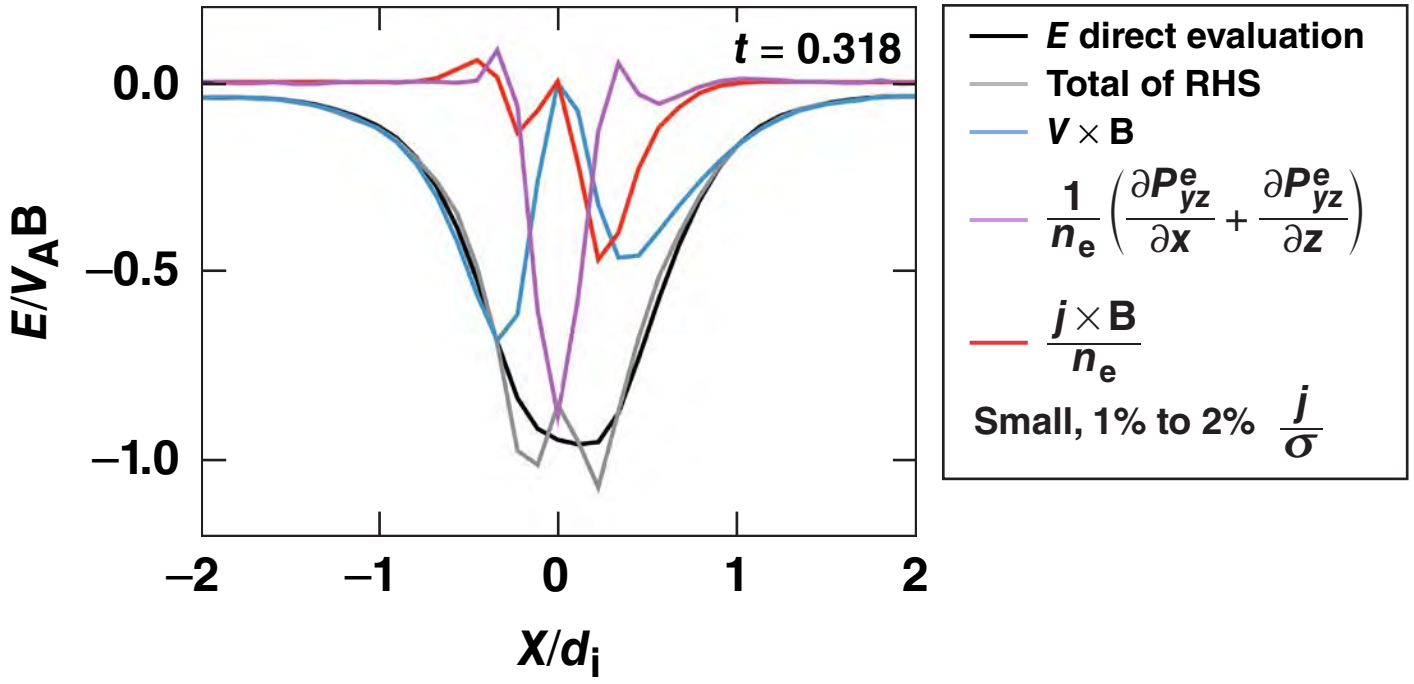
Reconnection of an external magnetic field was observed in a high-energy-density (HED) plasma

UR LLE

- Magnetic reconnection of an externally applied magnetic field in counter-propagating HED plasmas was studied on the OMEGA EP Laser System
- Formation of counter-propagating magnetized "ribbons," magnetic-flux pile-up, and reconnection were demonstrated
- Particle-in-cell (PIC) simulations closely match the experimental results

PIC simulations provide details of the electron momentum balance at reconnection

$$E = -V \times B + \frac{j}{\sigma} - \frac{j \times B}{n_e} - \frac{\nabla \cdot \hat{P}_e}{n_e}$$

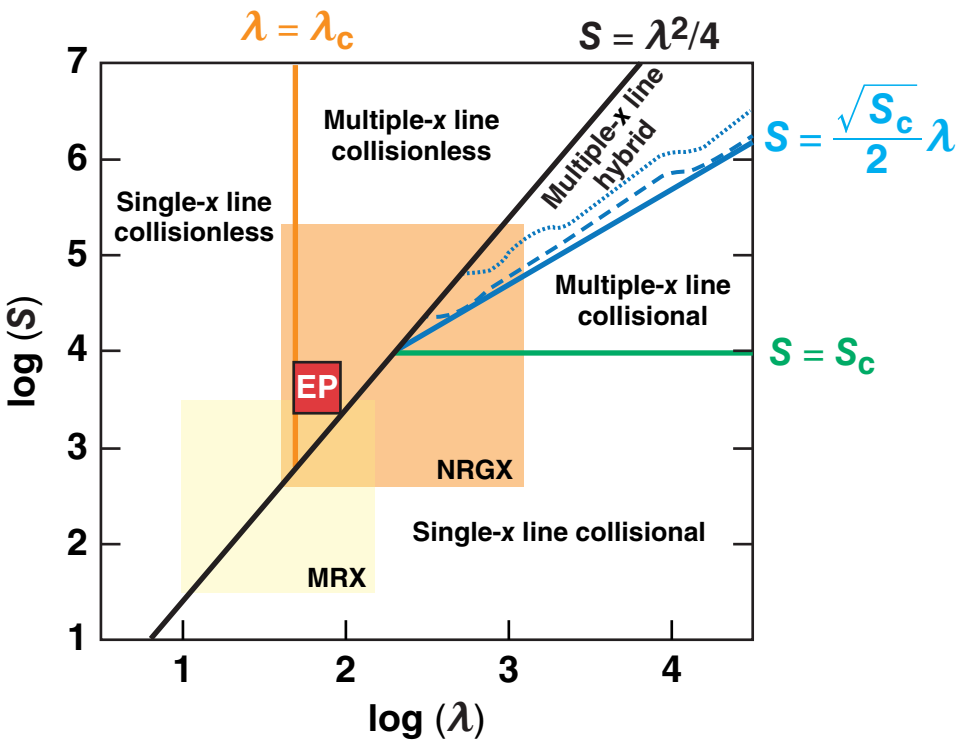


E22622

High beta, high S, supersonic, and super Alfvénic flow may position the experiment into the multiple-x line, collisionless sector of the reconnection phase diagram

Density* (cm^{-3})	2×10^{19}
T_e, T_i* (eV)	500
B (T)	30
L_{CS} (CS length) (mm)	3
Flow (m/s)	1×10^6
V_A (m/s)	2×10^5
c_s (m/s)	3×10^5
β	10
Lundquist S	3500
d_i (mm)	4×10^{-2}
ρ_i (mm)	3×10^{-2}
log (S), log (L_{cs}/d_i)	3.6, 1.9

Reconnection phase diagram**



*DRACO simulations

**H. Ji and W. Daughton, Phys. Plasmas 18, 111207 (2011).

E22623