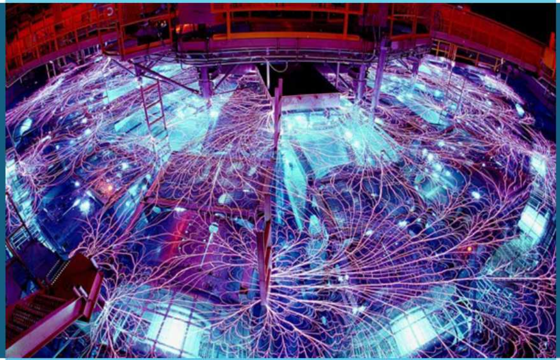
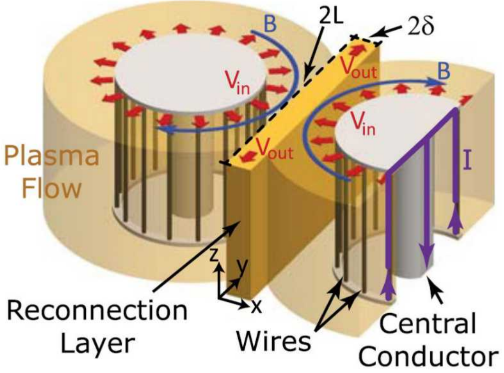
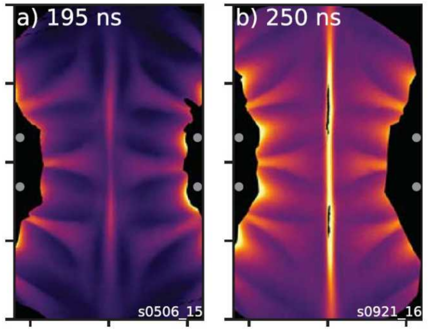
SAND2020-7933C

Vision for magnetized HED fundamental science experiments on Z







Hare et al., *Phys. Plasmas* 2018

PRESENTED BY

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Z Fundamental Science Workshop
Magnetized HED Breakout Session
August 4, 2020

Magnetized HED experiments are notably absent from the present Z Fundamental Science Program

Existing ZFS platforms:

- Z Astrophysical Plasma Properties (ZAPP):
    - Standard X-ray source (dynamic hohlraum) irradiates nearby experiments.
    - Magnetic field → X-rays → lab astro experiments (unmagnetized).
- Dynamic materials platform:
    - Standard stripline configuration drives multiple material samples to extreme states.
    - Magnetic field → drive pressure → materials experiments.

What about magnetized HED fundamental science?

- *Promise:* Z generates megagauss fields at centimeter scales → Untapped FS resource.
- *Challenge:* No existing Z platform can readily serve as a magnetized HED experiment.
- Can we motivate the development of one or more magnetized HED platforms on Z?

What are the key ingredients of a magnetized HED platform for Z?

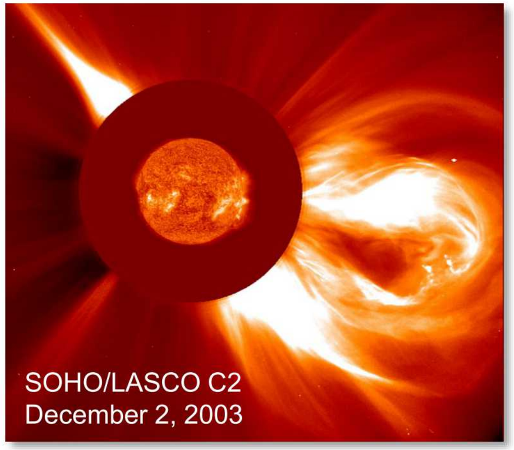
My perspective on the key ingredients of a magnetized HED platform for Z:

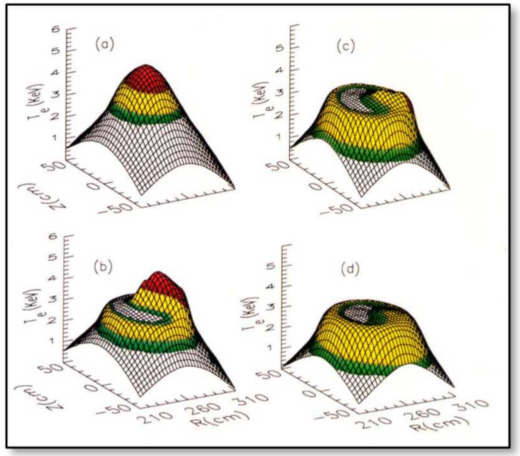
1. Strong fundamental science motivation (e.g., astrophysical applications).
2. Demonstrated at the 1-MA scale (or similar). → Not enough Z shots to develop from scratch.
    - Z is a world-leading tool for scaling up in dimensionless parameter space.
    - University collaborators will play a key role in developing scalable platforms.
3. Z-compatible power flow. → Z has substantial power flow constraints (e.g., load inductance).
4. Diagnosability on Z. → Z has powerful X-ray diagnostics, but we're more limited in the visible.
    - Likely requires predictive simulation of key observables.
    - Future diagnostic advances could enable new measurements (e.g., X-ray streak cameras)

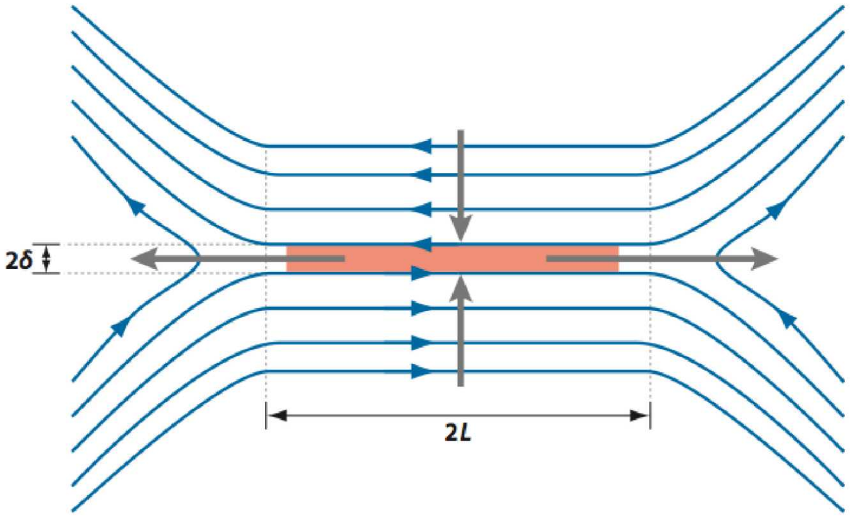
Can the platform have configuration flexibility to address different physics on different shots?

It's clear that developing these key ingredients will require strong coordination between Z scientists and university collaborators.

Example topic: Magnetic reconnection is a fundamental process that controls topological change and energy conversion in magnetized plasmas







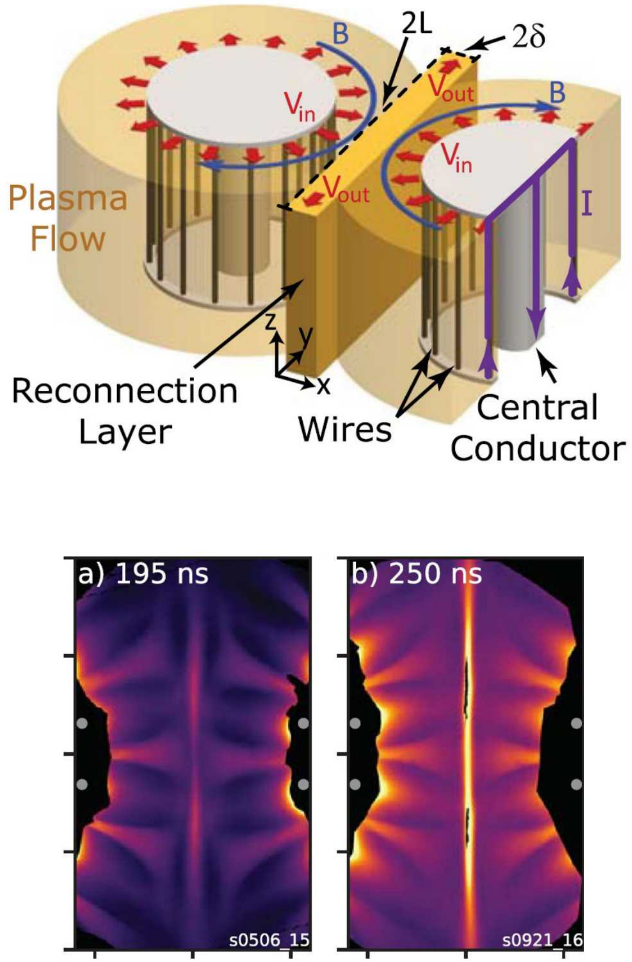
- MHD reconnection theory was developed in the 1950's by Peter Sweet and Eugene Parker
- Predicts a thinner sheet and slower reconnection with increasing *S*:

$$\delta = L/\sqrt{S} \qquad \tau_{rec} = \sqrt{S}\,\tau_A$$

- According to MHD, solar flares should take way too long!

$$\tau_{rec} \sim 10^6 \cdot (100 \text{ sec}) = \text{many months}$$
$$\tau_{flare} \sim 15 \text{ minutes}$$

Pulsed-power reconnection studies have been pioneered using side-by-side inverted wire arrays on MAGPIE



Hare et al., *Phys. Plasmas* 2018

Experimental setup:

- Two inverse wire arrays are driven in parallel.
- Heavy wires are used so that magnetized ablation streams emanate from each wire array.
- The ablation streams from the two wire arrays collide on axis to form a dense reconnection sheet.

Could we bring this to Z?

- We are actively developing split power flow geometries to drive parallel loads on Z.
- Consider non-imploding planar arrays to minimize inductance while maximizing effective system size?
- Could magnetized ablation streams generated with this technique serve multiple physics goals (e.g., reconnection, turbulence, etc.)?

What are the goals of this session?

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1. Strong fundamental science motivation (e.g., astrophysical applications).
2. Demonstrated at the 1-MA scale (or similar).
3. Z-compatible power flow.
4. Diagnosability on Z.

Plant the seeds for one or more ZFS magnetized HED proposals:

- What are the most interesting problems to tackle?
- What are the problems that we are ready to tackle?
- How do we identify the proposal team(s)?
- Where can we find synergies to maximize value?