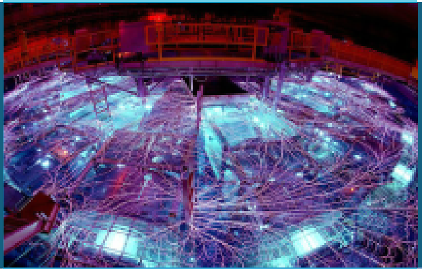
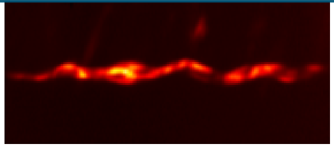
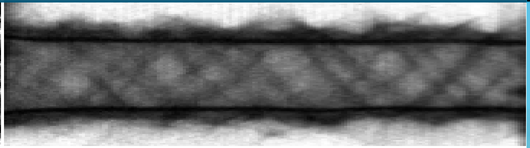
SAND2022-10097C

Sandia National Laboratories

Data-driven design and discovery for Magnetized Liner Inertial Fusion at Sandia's Z Pulsed Power Facility







PRESENTED BY

William Lewis

Collaborators: P.F. Knapp , J.R. Fein, and the entire MagLIF team

U.S. DEPARTMENT OF ENERGY NNSA

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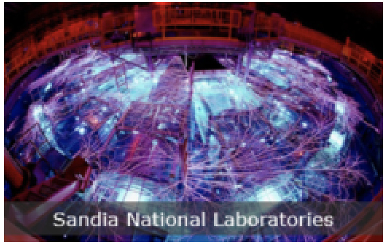
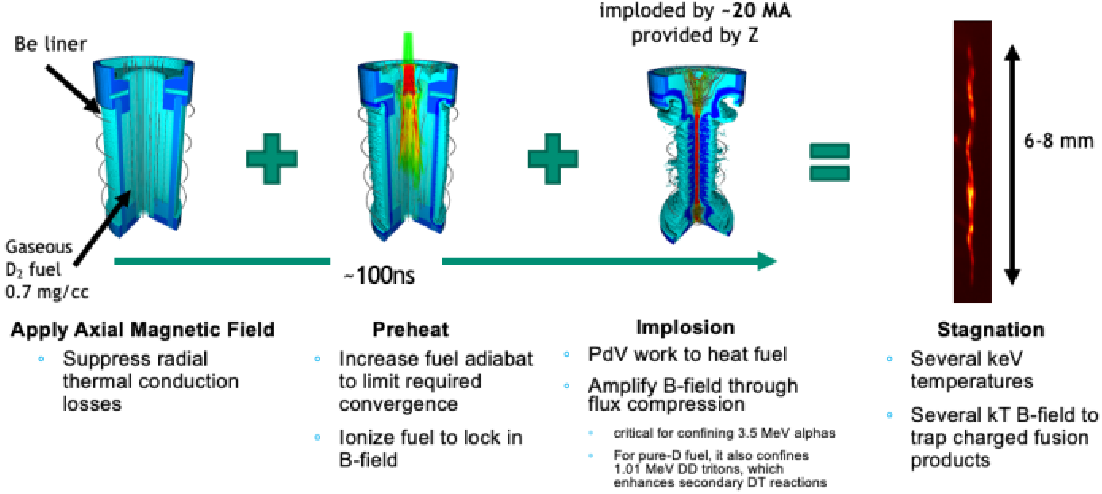
environments and highly integrated measurements challenging interpretation.



Some challenges:

- Destructive experiments
- Low repetition
  - ~ 1shot per day
  - shared across multiple platforms
  - Small data-regime (relative to ML)
- Highly integrated measurements
  - Spatio-spectral-temporal integrations
- Strong fields/environment
  - some "probes" must be self-generated
- Costly high-fidelity simulations
  - → intuition driven design

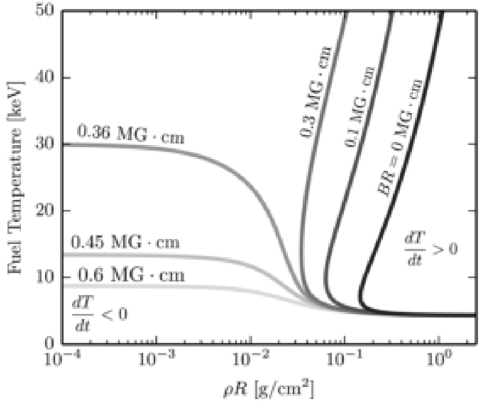
Magnetized Liner Inertial Fusion produces a hot (multi-keV), dense (~1 g/cc), and macroscopic (O(10mm) tall and O(0.1mm) diameter) cylindrical D_2 plasma with thermal pressures that can exceed 1Gbar. This platform is ideal for developing and applying data-driven solutions to some of our biggest challenges (specific example to follow).



S.A. Slutz *et. al.*, PoP (2010)

A variety of plasma transport effects will modify the flux compression process. Measuring BR could provide insights into these effects.

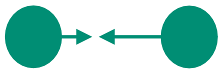
- Effective flux compression is critical for performance
  - Aids trapping of fusion products and reduction of electron heat conducti
  - Idealized calculations show ~1000x B-field amplification may be achieva
- Physical mechanisms (Nernst, resistive diffusion, etc.) may cause flux to leave fuel



Resistive diffusion

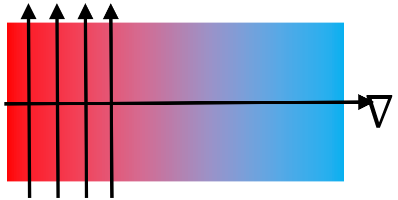
Current is disrupted by collisions causing magnetic diffusion

$\sim \; 0 \; ^2 \quad \propto$

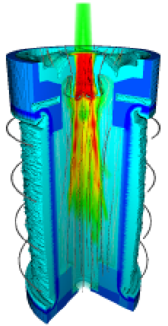


Nernst effect

B-field locked into plasma by warm electrons, so electron thermal transport perpendicular to magnetic field will transport flux.



$$v_{Nernst} = \frac{\beta_\wedge \nabla_\perp T_e}{eB}$$



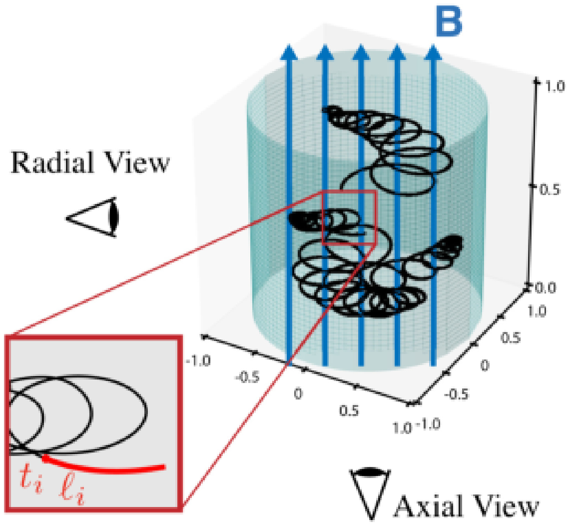
- Greater preheat increases $\nabla_\perp T_e$ increasing Nernst
- Greater B_z decreases Nernst
- Measurement could help quantify these effects

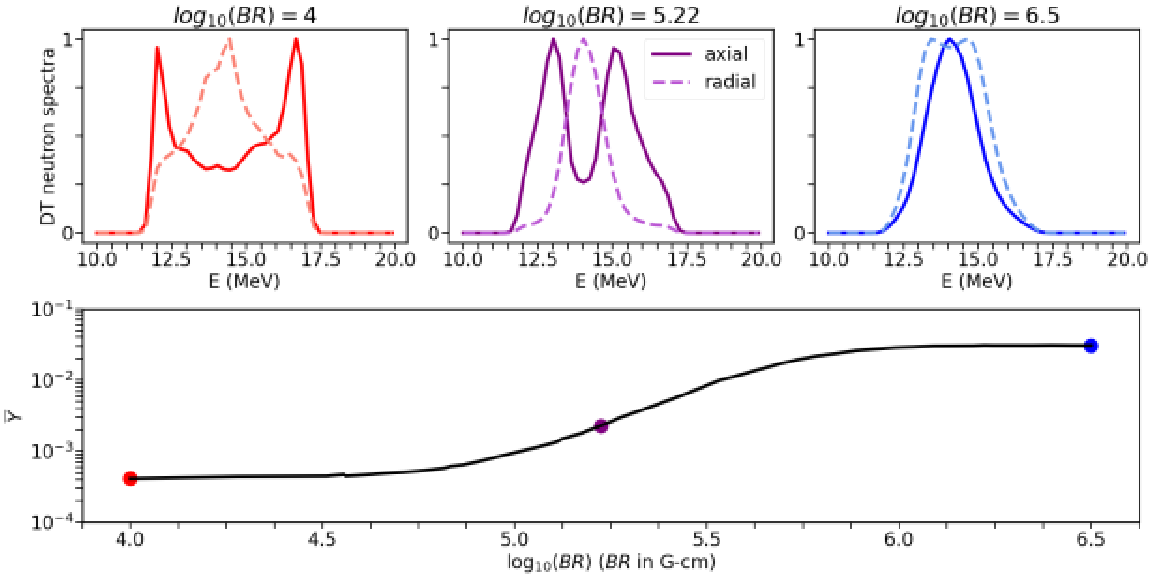
Radially and axially viewed secondary DT neutron spectra and yield ratio $\overline{Y} = Y_{DT}/Y_{DD}$ are sensitive to fuel magnetization.

$$\text{Primary:} \quad D + D \rightarrow \begin{cases} n\ (2.45\text{MeV}) + {}^3He \\ p + T\ (1.01\text{MeV}) \end{cases}$$

$$\text{Secondary:} \quad D + T \rightarrow n\ (14.1\text{MeV}) + \alpha$$

$\mathcal{P}_{DT} \propto \langle \rho_D \ell \rangle \sigma_{DT}$ —Magnetized→ $\ell \propto$ ( )



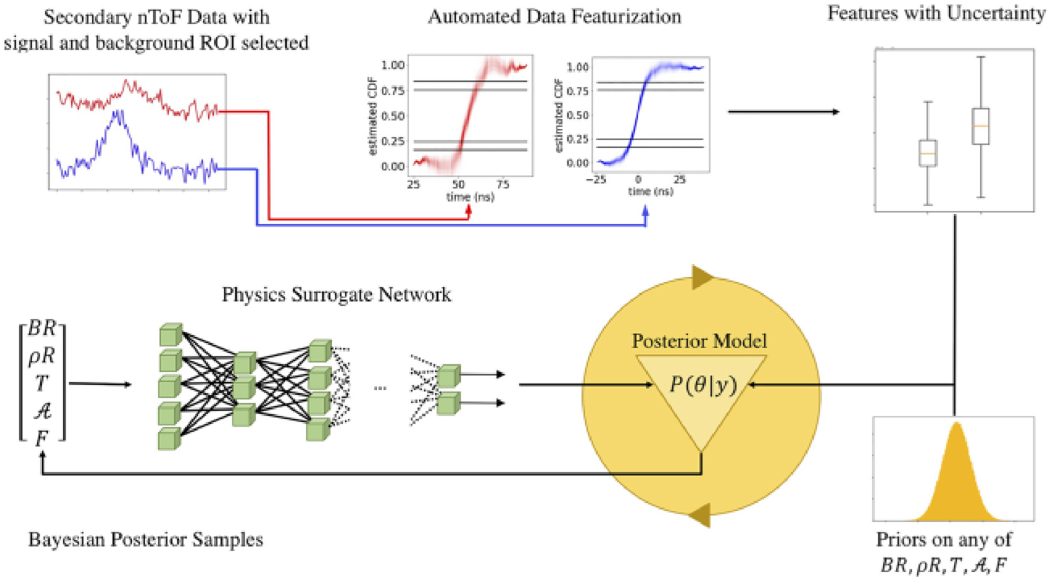


P.F. Schmit *et al.*, PRL (2014)
P.F. Knapp *et. al.*, PoP (2015)

W.E. Lewis *et al.*, accepted Phys. Plasmas (2021).

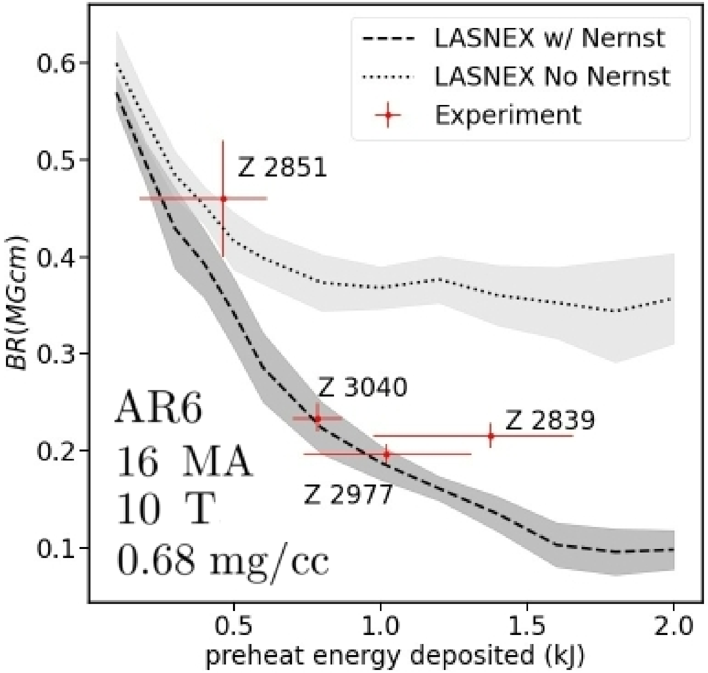
neural network surrogate enables Bayesian inference for UQ.

- 10-100 CPU hours per model evaluation
  - 10’s of thousands of evaluations for Bayesian UQ per experiment
- Replace forward model with NN (including surrogate model uncertainty)
  - <1ms forward model evaluation on personal machine



Uncovered experimental evidence that Nernst is integral to performance scaling in MagLIF.

- Nernst limits the gains that can be obtained by increasing preheat
  - Fill density, Applied B field, and peak current should be improved to enable performance gains



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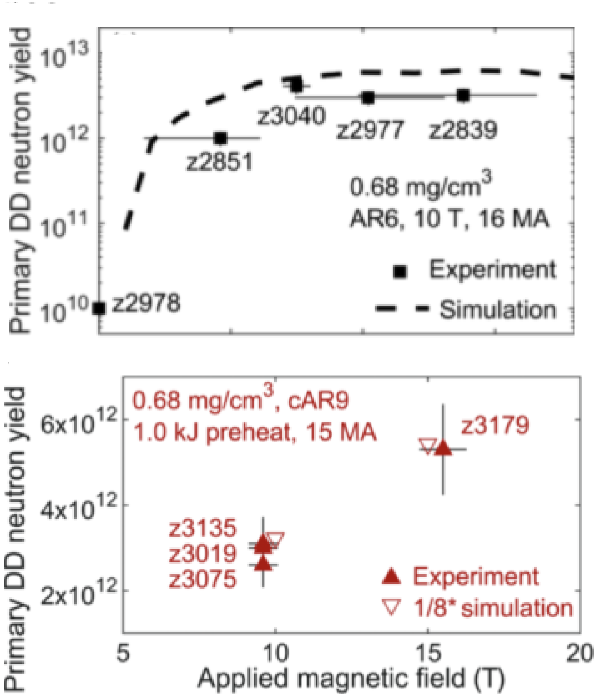
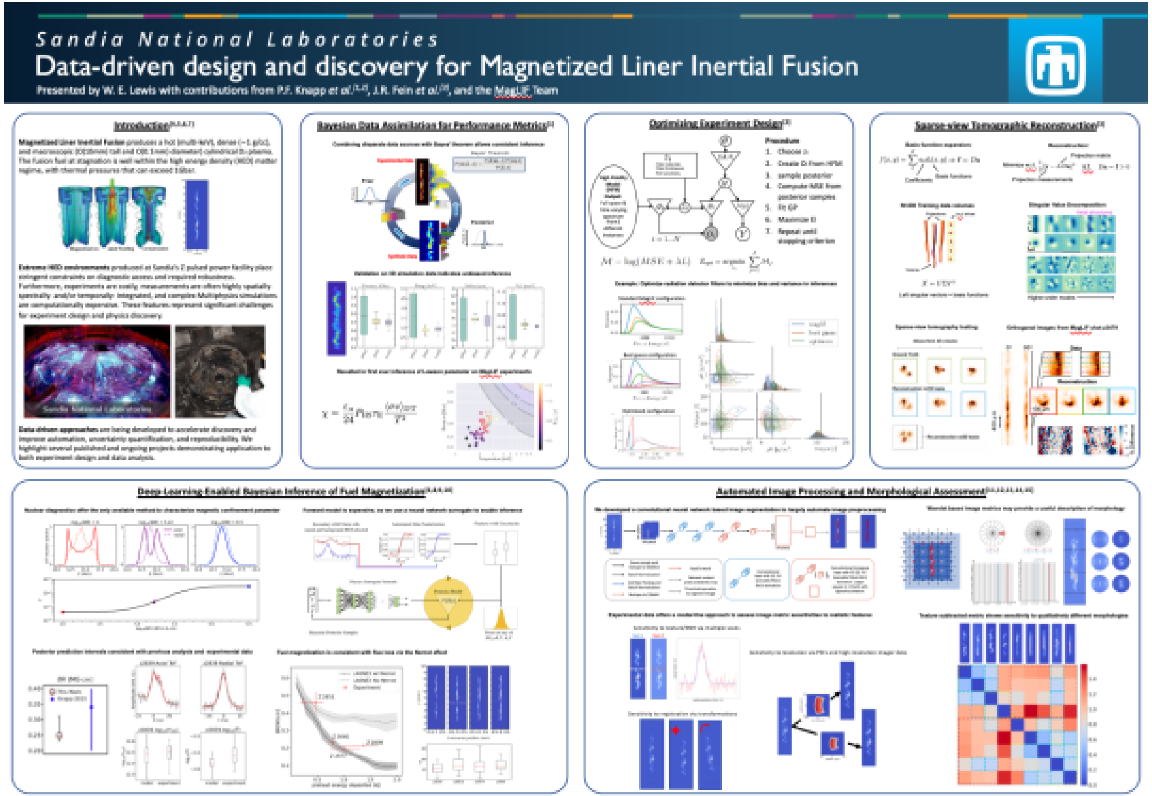


M.R. Gomez *et al.*, PRL **125**, 155002 (2020).

Stop by poster to see other applications and learn more.



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[15] D.J. Ampleford *et al.*, In Preparation.