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Status of Applied Magnetic Field Capability on Z

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

The capability to apply external magnetic fields is of interest to several areas of research on Z

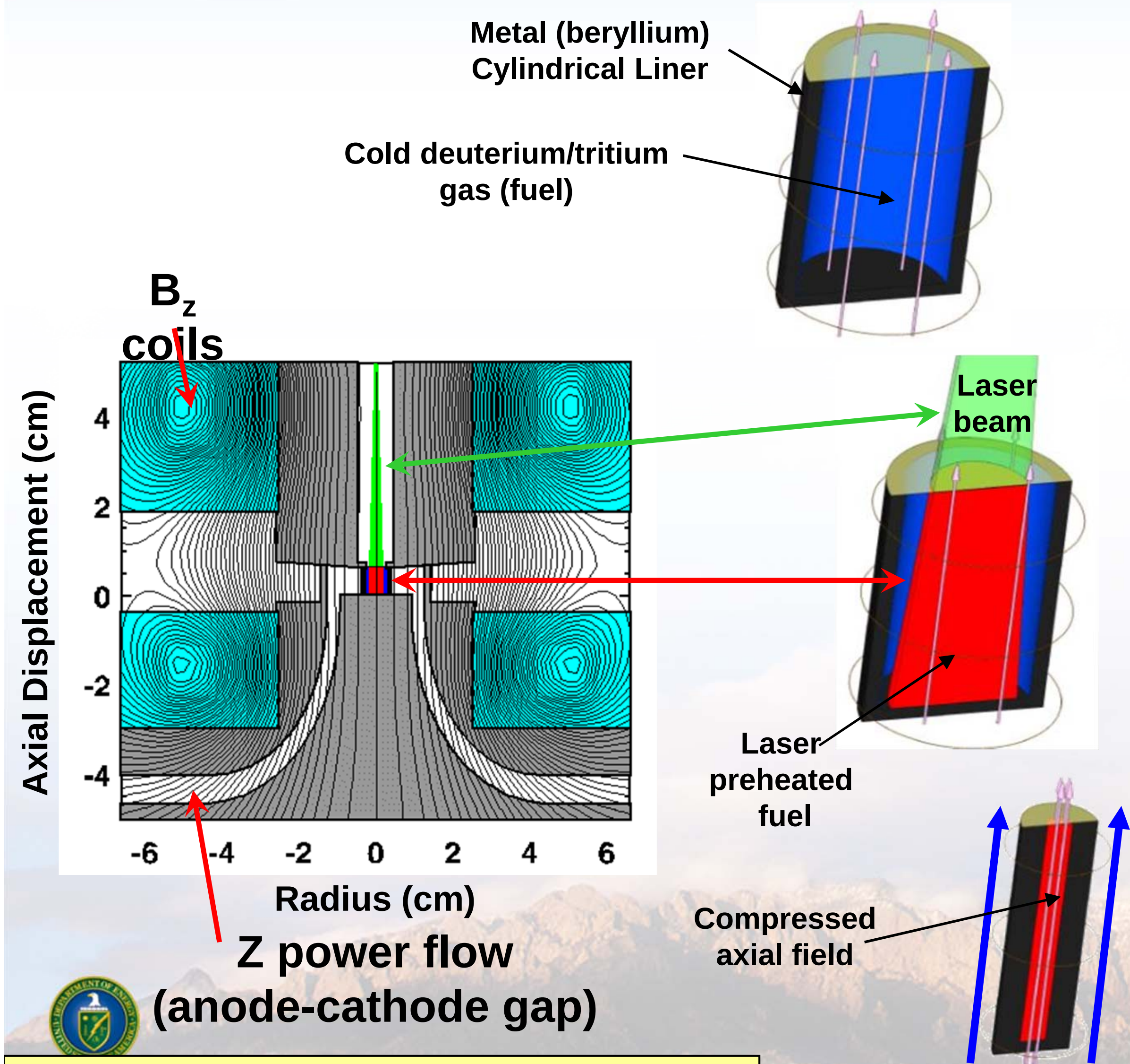
- **We are evaluating the Magnetized Liner Inertial Fusion (MagLIF)* concept as a potential path to pulsed power driven fusion**
  - We have conducted 4 magnetized MagLIF-related experiments to date
  - We plan to conduct ~ 10 more magnetized MagLIF-related experiments this year

- **We are evaluating the Magnetically Applied Pressure Shear (MAPS)** technique for measuring the shear strength of materials at high pressure**
  - We plan to conduct our first MAPS experiment today and another in September

- **Other possible applications and areas of interest:**
  - Magnetized gas puffs
  - Magnetically stabilized Z-pinch wire arrays
  - Fundamental science
    - Magnetized samples for astrophysics research

* MagLIF ref: S. A. Slutz *et al.*, Phys. Plasmas **17**, 056303 (2010).
** MAPS ref: C.S. Alexander *et al.*, JAP **108**, 126101 (2010).

Magnetized Liner Inertial Fusion (MagLIF)* may be a promising path to high fusion yields on Z



1. An axial magnetic field (B_z) is applied to inhibit thermal conduction and enhance alpha particle deposition

2. Z Beamlet preheats the fuel

3. The Z accelerator efficiently drives a z-pinch implosion

*S. A. Slutz *et al.*, Phys. Plasmas **17**, 056303 (2010).

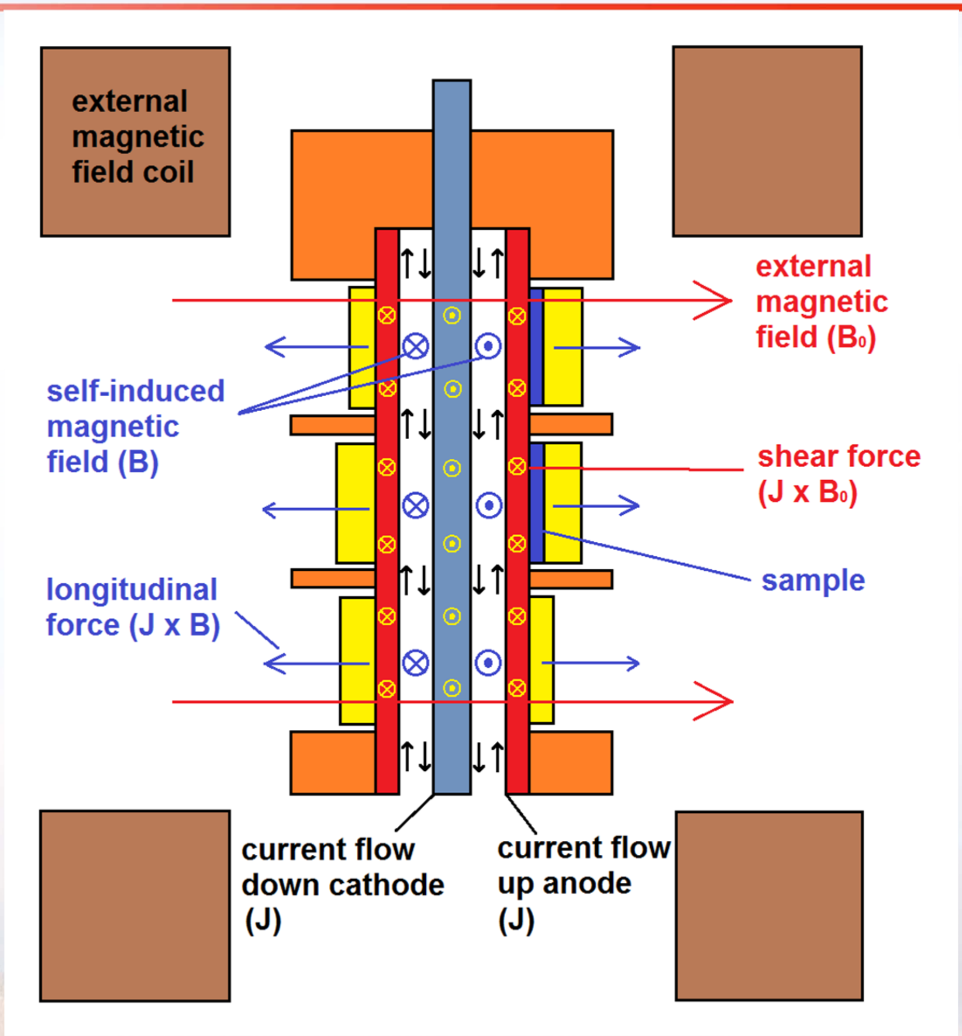
The goal of the MAPS* research is to measure the dynamic shear strength of materials at high pressure

1. Z generates a current (J) and induces a magnetic field (B) between the anode and cathode

2. The interaction J × B produces a pressure wave which compresses the anode panel

3. The interaction J × B_o produces a shear wave in the anode panel

4. The generated shear wave propagates through the sample material where it is truncated to a level determined by the sample strength



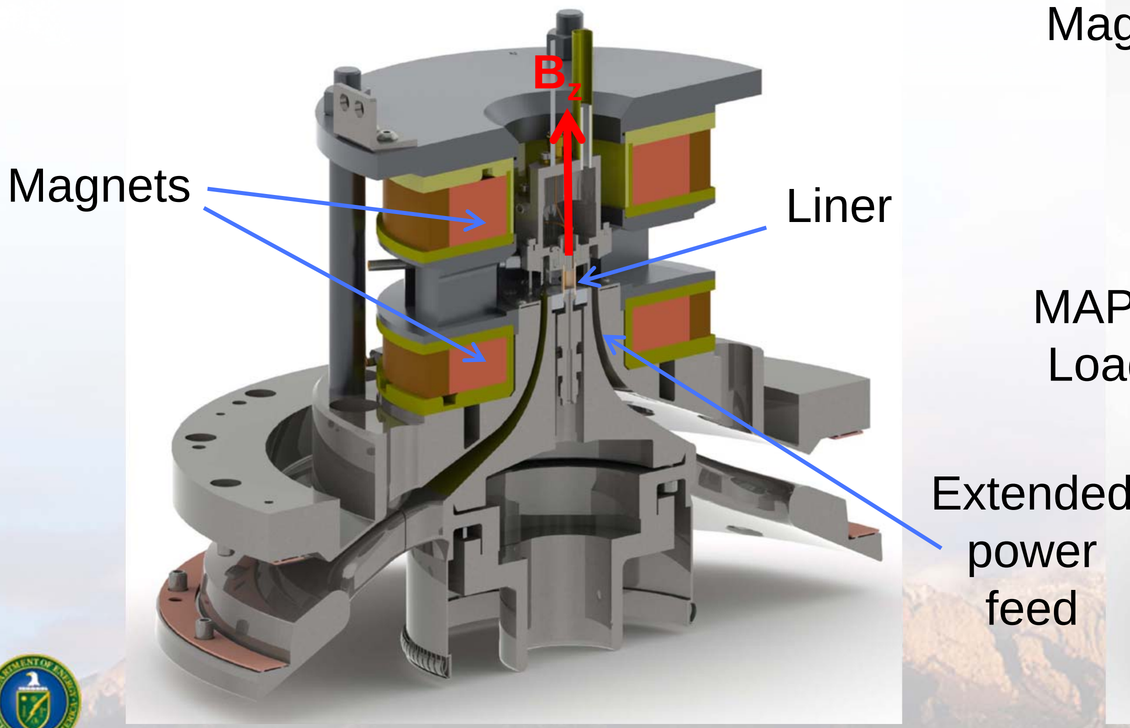
*Session 8E: T. A. Haill et. al, "Design and Optimization of MAPS Experiments on Sandia's Z Machine"

*C.S. Alexander *et al.*, JAP **108**, 126101 (2010).

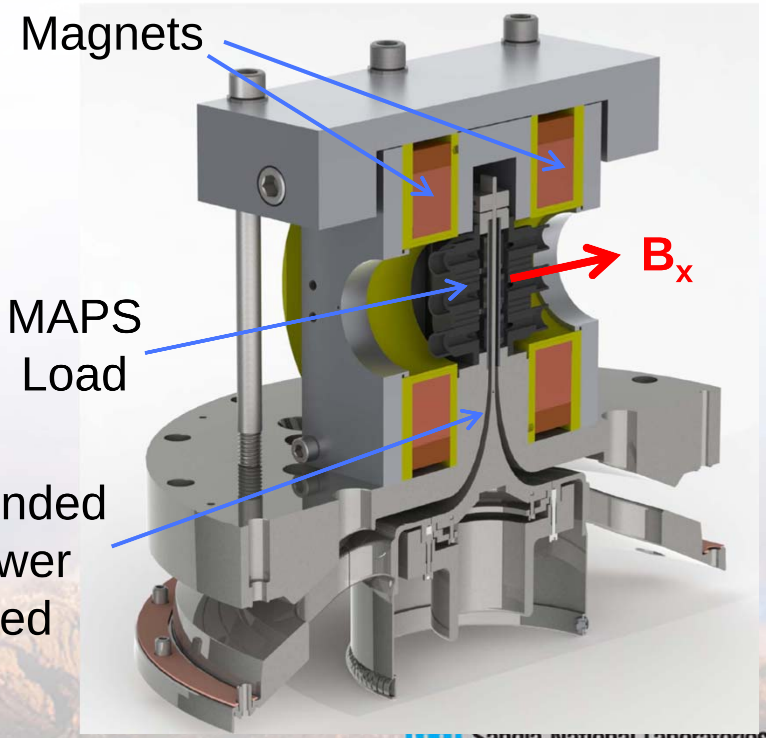
The magnetic field requirements for both MagLIF and MAPS are very similar

- Field strength : 1 – 10's of T
- Bore size and magnet length: 1 – 10 cm
- Pulse length (rise time): 1 – 10 ms
- Split-magnet for sample and diagnostic access

MagLIF



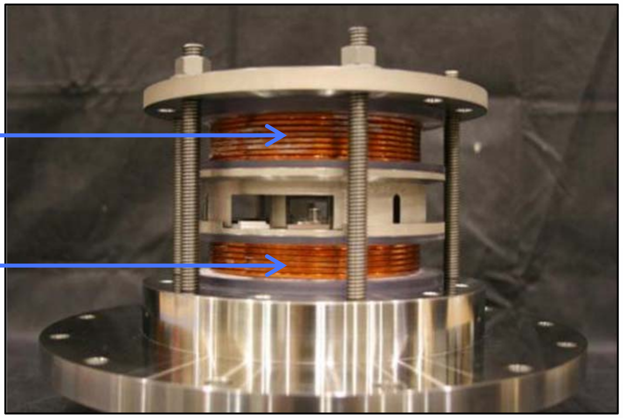
MAPS



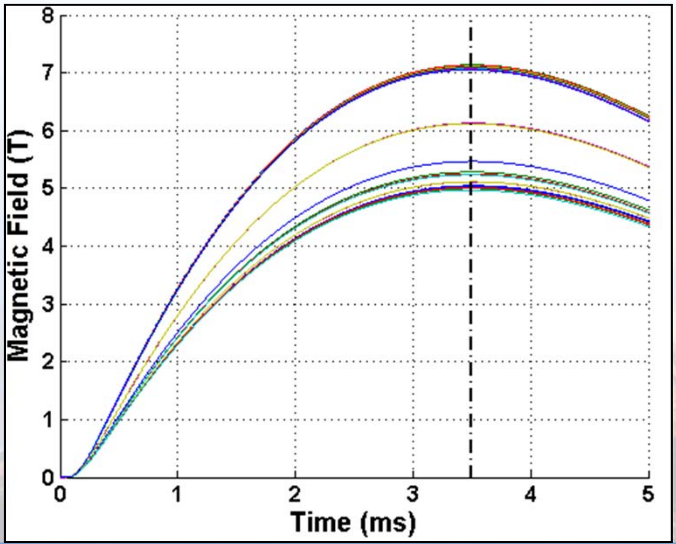
We use large capacitor banks to drive compact electromagnets to meet these requirements

Capacitor bank system on Z
900 kJ, 8 mF, 15 kV

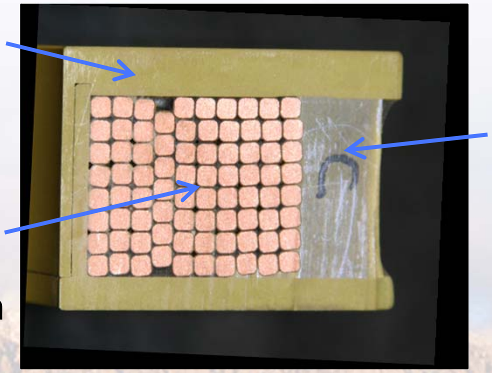
MagLIF prototype assembly with test windings of coils



MagLIF on-axis magnetic field data taken at our Systems Integration Test Facility in Bldg. 970



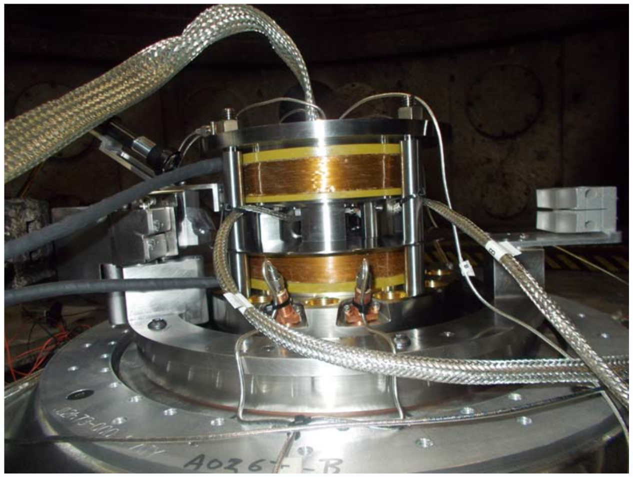
Cross section of 80-turn coil prototype



Prototype coil development: Jim Puissant, Raytheon-Ktech, Albuquerque
Production coils for Z: Milhous Corporation, Amherst, VA.

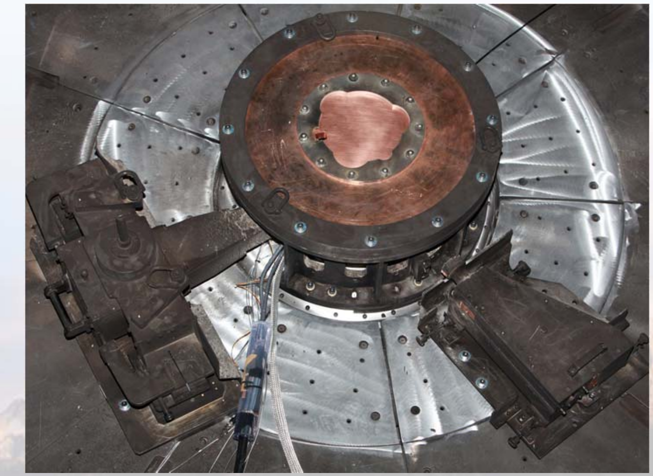
Z presents a challenging and harsh experimental environment for magnetized experiments

MagLIF experimental set-up on Z

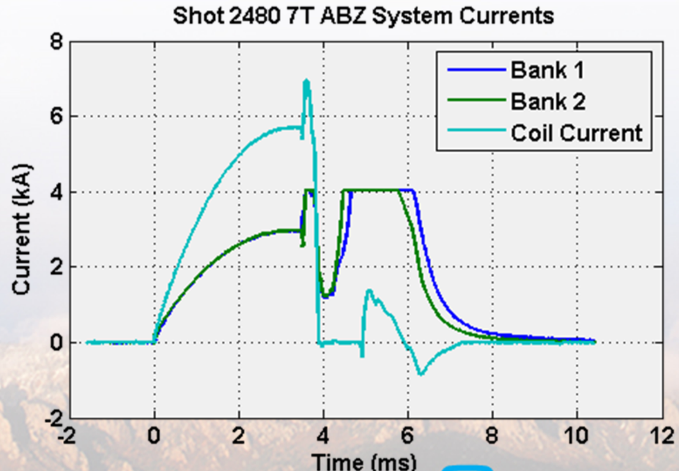


Post-shot picture inside the debris shield

Pre-shot picture from outside the debris shield



Coil System Current Monitors



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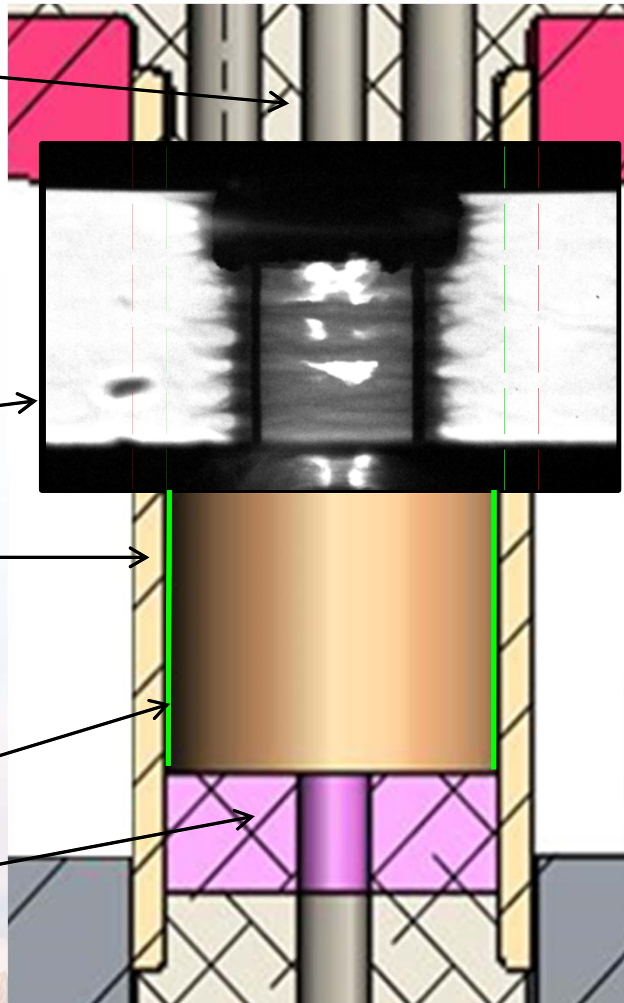
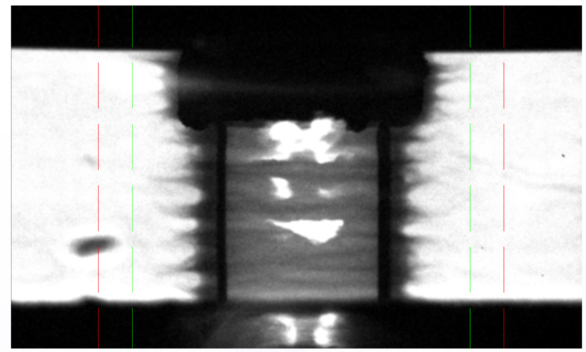
We have used the 2-frame, 6.151 keV backlighter* to extensively study liner stability** without applied-B_z

Target design for z2465



Frame #2 for z2465



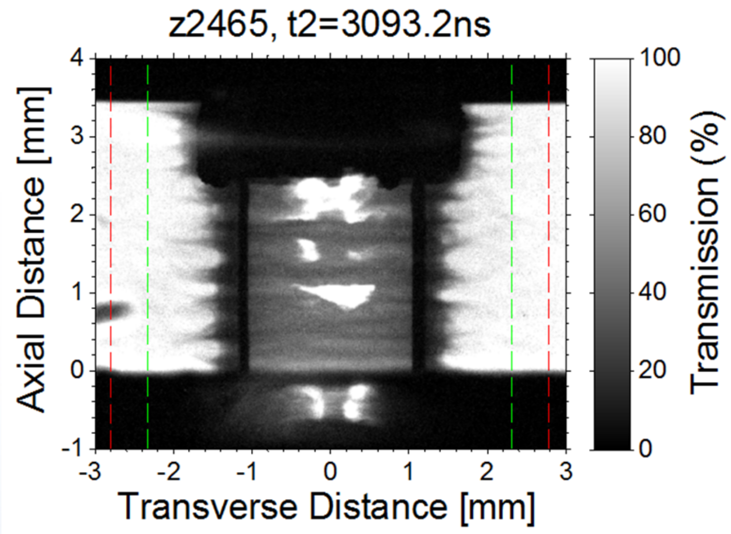
- **z2465 was a precursor experiment to integrated MagLIF experiments**
  - D_2 gas fill
  - Raised/extended power feeds
  - No Applied Magnetic Field
  - No Laser Preheat

* G. R. Bennett *et al.*, RSI **79**, 10E914 (2008)

** R. D. McBride *et al.*, PRL **109**, 135004 (2012); Phys. Plasmas **20,** 056309 (2013)

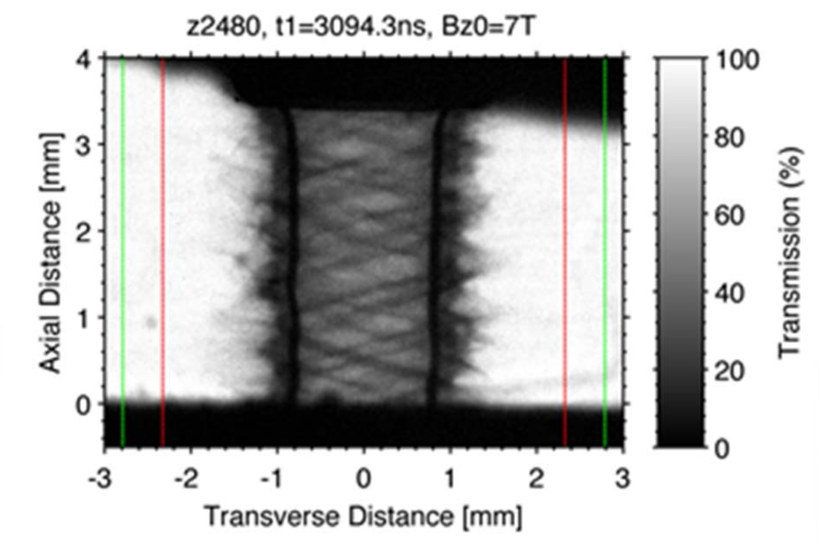
We have found that the applied-B_z field dramatically alters the Magneto-Rayleigh-Taylor (MRT) structure*

No applied magnetic field
z2465, B_z = 0 T



- Cylindrically-symmetric MRT structure
- Significant on-axis time-integrated self-emission of multi-keV x-rays

With applied magnetic field
z2480, B_z = 7 T



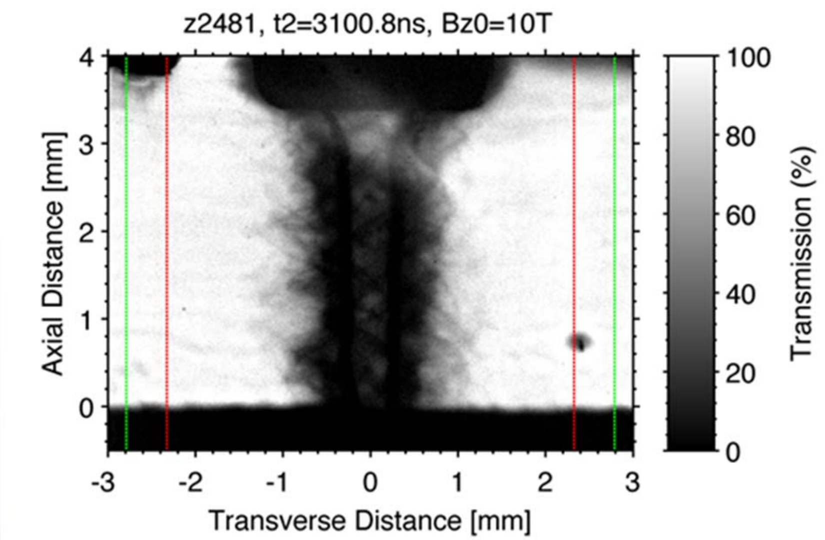
- Helically-shaped MRT structure
- No apparent on-axis time-integrated self-emission of multi-keV x-rays

*T. J. Awe *et al*., Manuscript in Preparation.

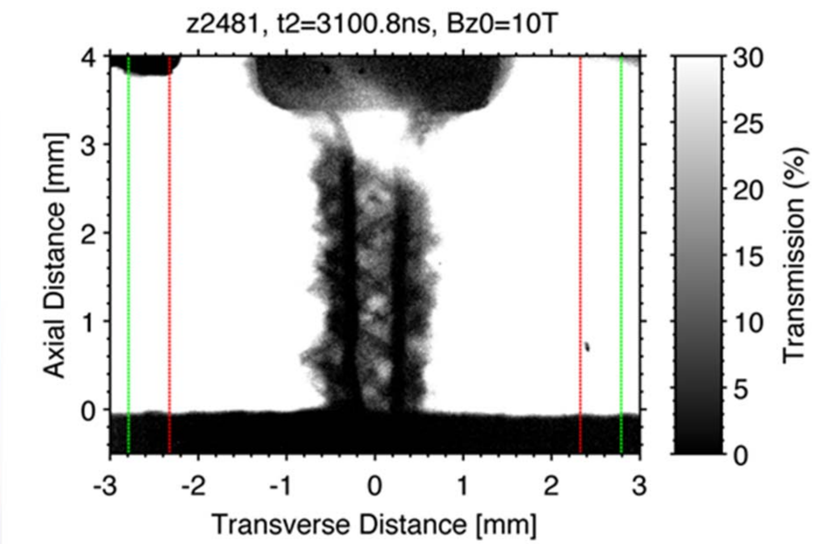
On z2481, we captured an image of a magnetized liner with a convergence ratio near seven, CR ~ 7*

With applied magnetic field
z2481, B_z = 10 T

Full-scale transmission = 100%



Full-scale transmission = 30%



- **Helically-shaped MRT structure persists**
- **Relatively good liner uniformity**
- **Evidence of some on-axis time-integrated self-emission of multi-keV x-rays**

*T. J. Awe *et al*., Manuscript in Preparation.

We are exploring and pursuing multiple paths to higher fields for both MagLIF and MAPS

Higher field options

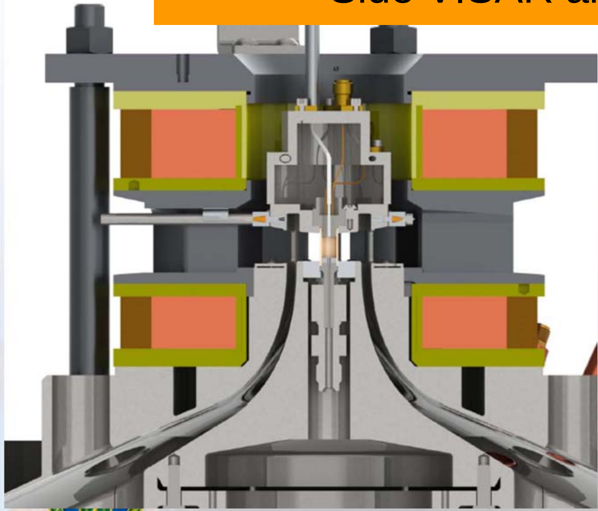
- **Trade-off radial diagnostic access for coil volume**
- **Exploit single-use (quarter-cycle) coil lifetime**
- **Adopt additional state-of-the-art high-field coil technologies**
  - Internally reinforced magnets
  - High strength conductors, e.g. Glidcop, CuNb

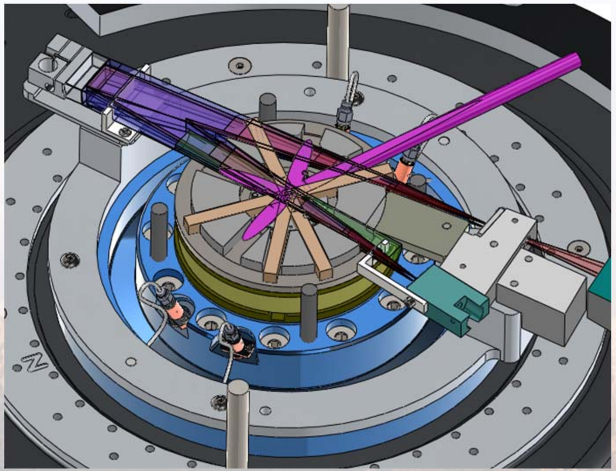
Split-magnet configuration

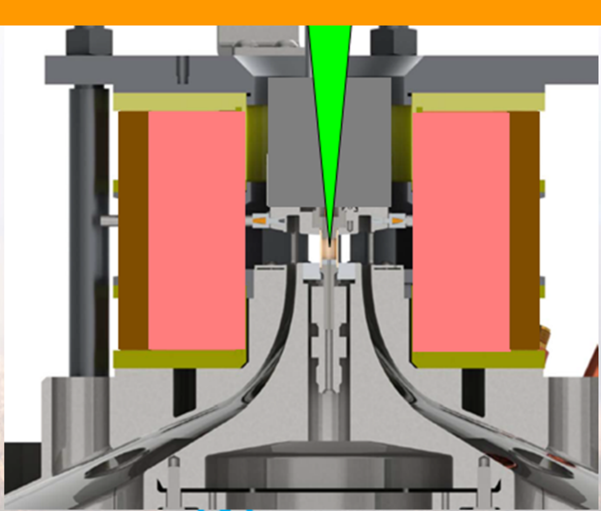
- Full radial diagnostic access
  - 2-frame backlighter
  - Diagnostic Lines-of-Sight @ 12 deg.
  - Side VISAR and µB-dots

Solid-magnet configuration

- Design for highest fields
- Allows laser preheat access
- Primary diagnostic is neutrons







Plans for experiments in 2013 and multi-year magnet system development / deployment

2013

7 – 10 T

- **June** **MAPS Experiment**
- **July** **MagLIF Preheat Testing on Z (B_z + Preheat)**
- **August** **MagLIF Integrated Experiments (B_z + Preheat + Z)**
- **September** **MAPS Experiment**

10 – 15 T **(15-T is split-magnet with reduced radial access)**

- **December** **MagLIF Integrated Experiments (B_z+ Preheat + Z)**
- **December** **Flux Compression Experiments (B_z + Z)**

2014

10 – 15 T MAPS Split-magnet

15 – 20 T MagLIF Split-magnet

20 – 25 T MagLIF Solid-magnet

2015

25 – 30 T MagLIF Solid-magnet