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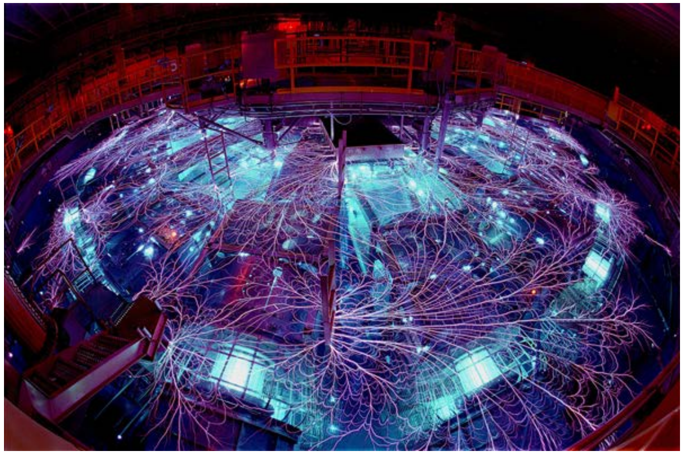
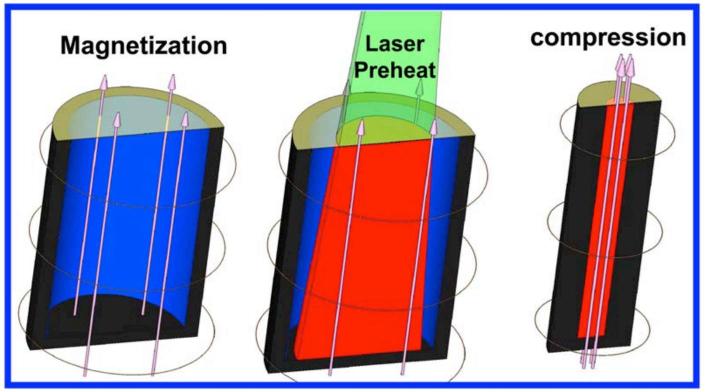
SAND2015-9392PE

Tritium on Z: The challenges and possibilities for MagLIF





D. C. Rovang, M. E. Cuneo, R. D. McBride, B. M. Jones, J. L. McKenney, H. C. Peebles, D. C. Spencer, K. N. Austin, D. B. Sinars, and G. A. Rochau

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Tritium Focus Group Workshop

Los Alamos National Laboratory, Nov. 3- 5, 2015

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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The Z facility combines the MJ-class Z pulsed-power accelerator with the TW-class Z Beamlet Laser (ZBL)

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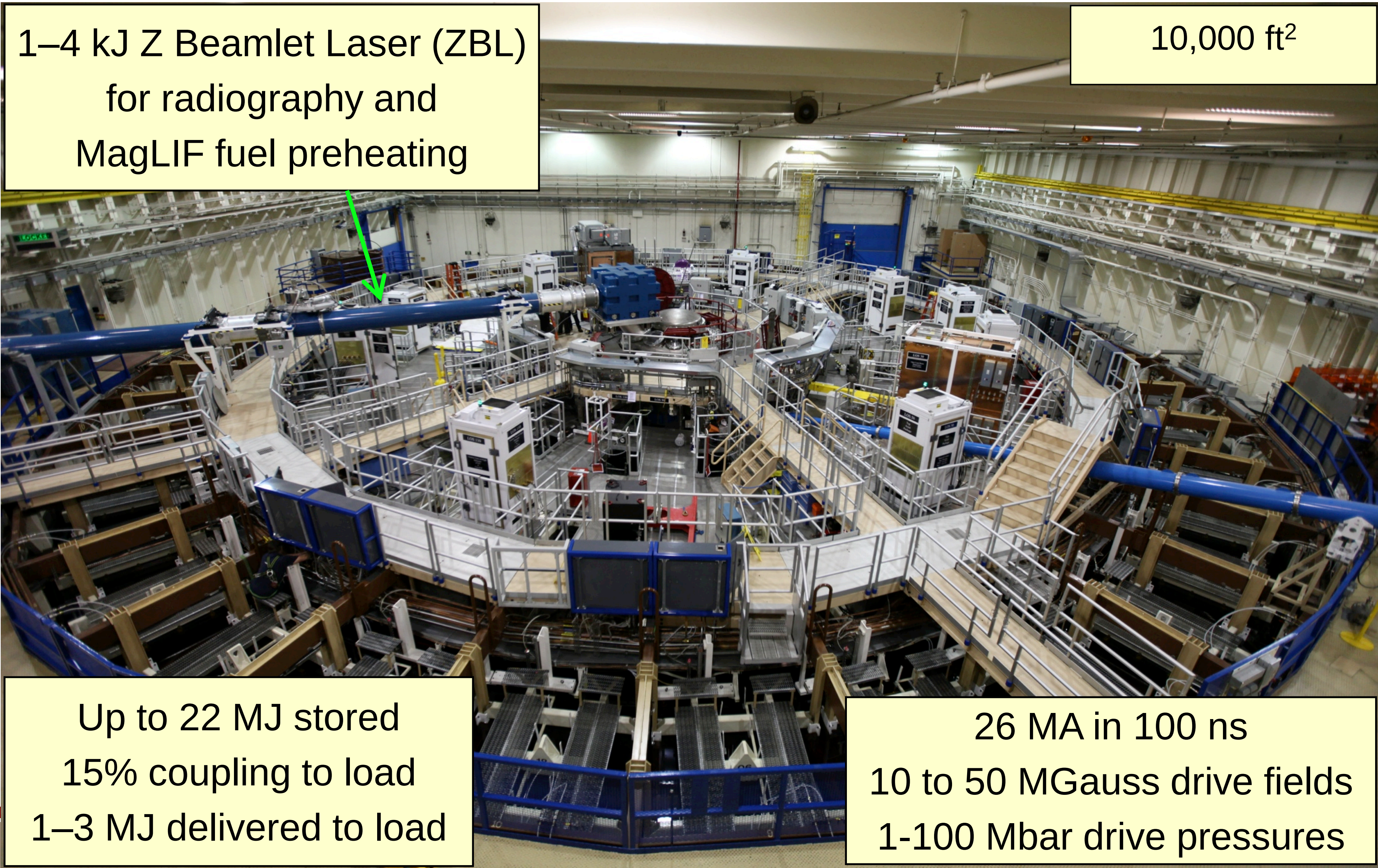

1–4 kJ Z Beamlet Laser (ZBL)
for radiography and
MagLIF fuel preheating

10,000 ft^2

Up to 22 MJ stored
15% coupling to load
1–3 MJ delivered to load

26 MA in 100 ns
10 to 50 MGauss drive fields
1-100 Mbar drive pressures

"Magnetic direct drive" is based on the idea that we can efficiently use large currents to create high pressures

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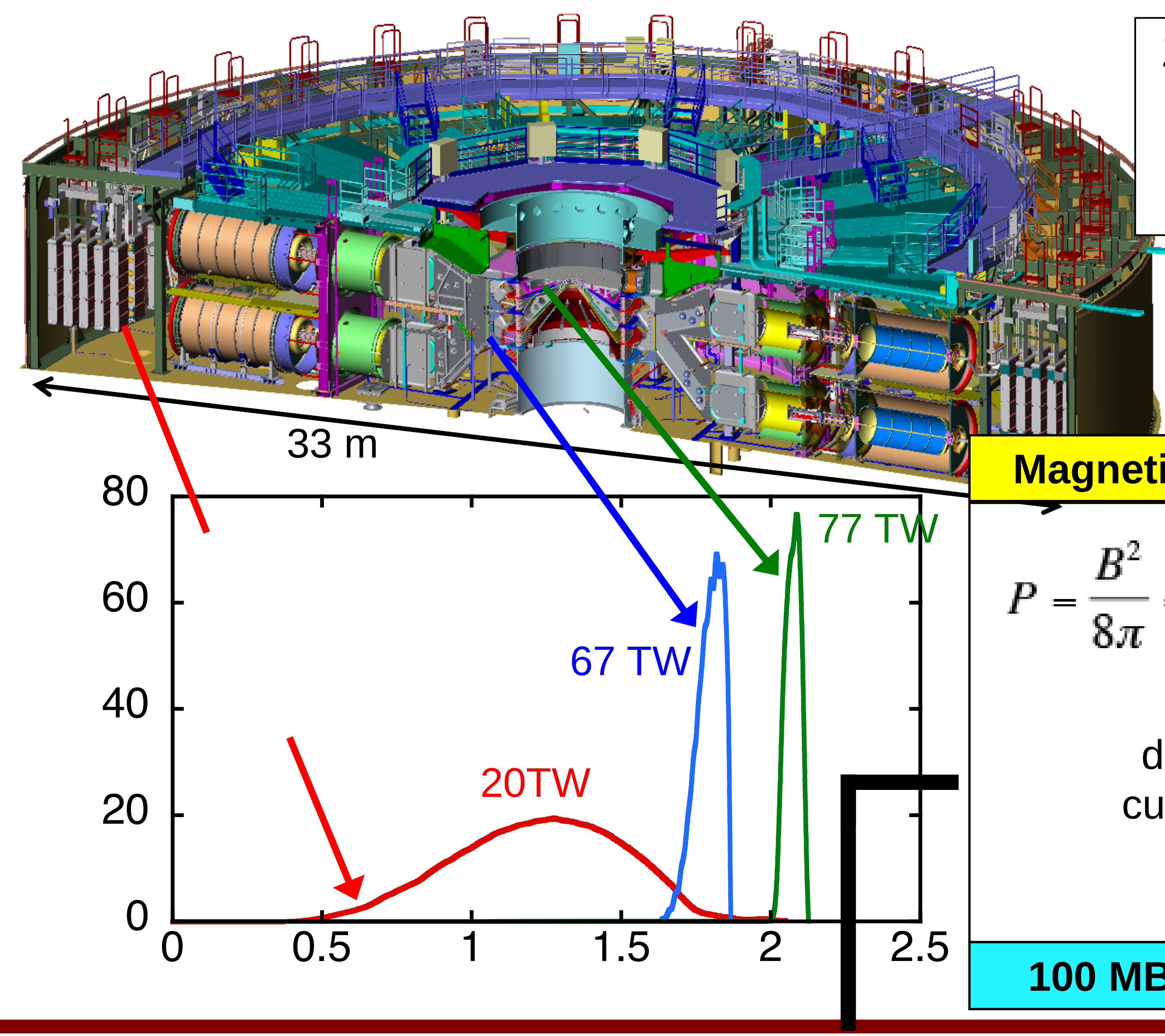
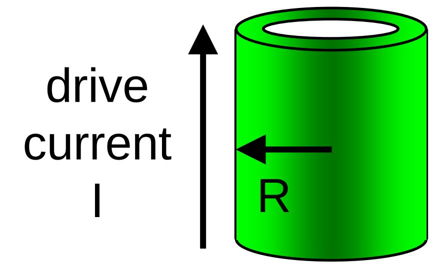


Z today couples ~0.5 MJ out of 20 MJ stored to MagLIF target (0.1 MJ in DD fuel).

Magnetically-Driven Implosion

$$P = \frac{B^2}{8\pi} = 105\left(\frac{I_{MA}/26}{R_{mm}}\right)^2 \text{ MBar}$$



100 MBar at 26 **MA and 1 mm**

Implosion time ~50 ns; stagnation ~0.1-1 ns

(1 atm = 1 bar = 10^5 Pascals)

We are presently using the Z facility to study the Magnetized Liner Inertial Fusion (MagLIF)* concept

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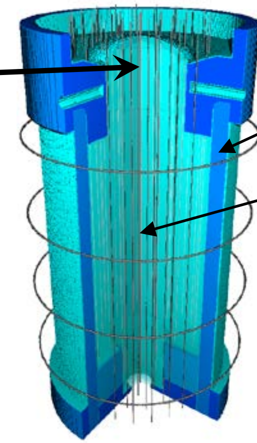
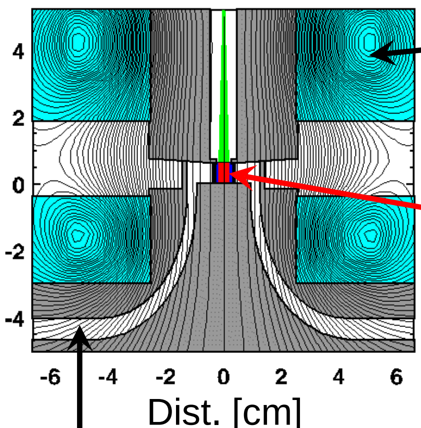
1. A 10–50 T axial magnetic field (B_z) is applied (~3-ms rise time) to inhibit thermal conduction losses and to enhance alpha particle deposition



Liner (Li, Be, or Al)

Cold DD or DT gas (fuel)



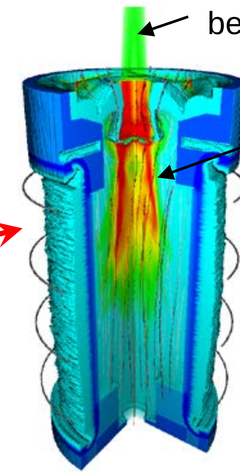
B_z coils

Z power flow (A-K gap)

2. ZBL preheats the fuel to ~100–250 eV to reduce the required compression to CR≈20–30

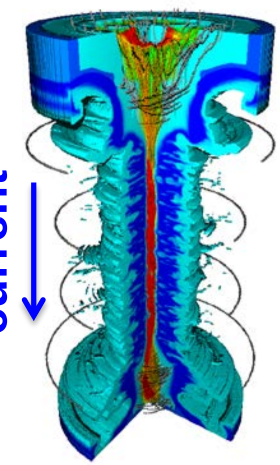
ZBL beam

ZBL preheated fuel



3. Z drive current and B_θ field implode the liner (via z-pinch) at 50–100 km/s, compressing the fuel and B_z field by factors of 1000

current

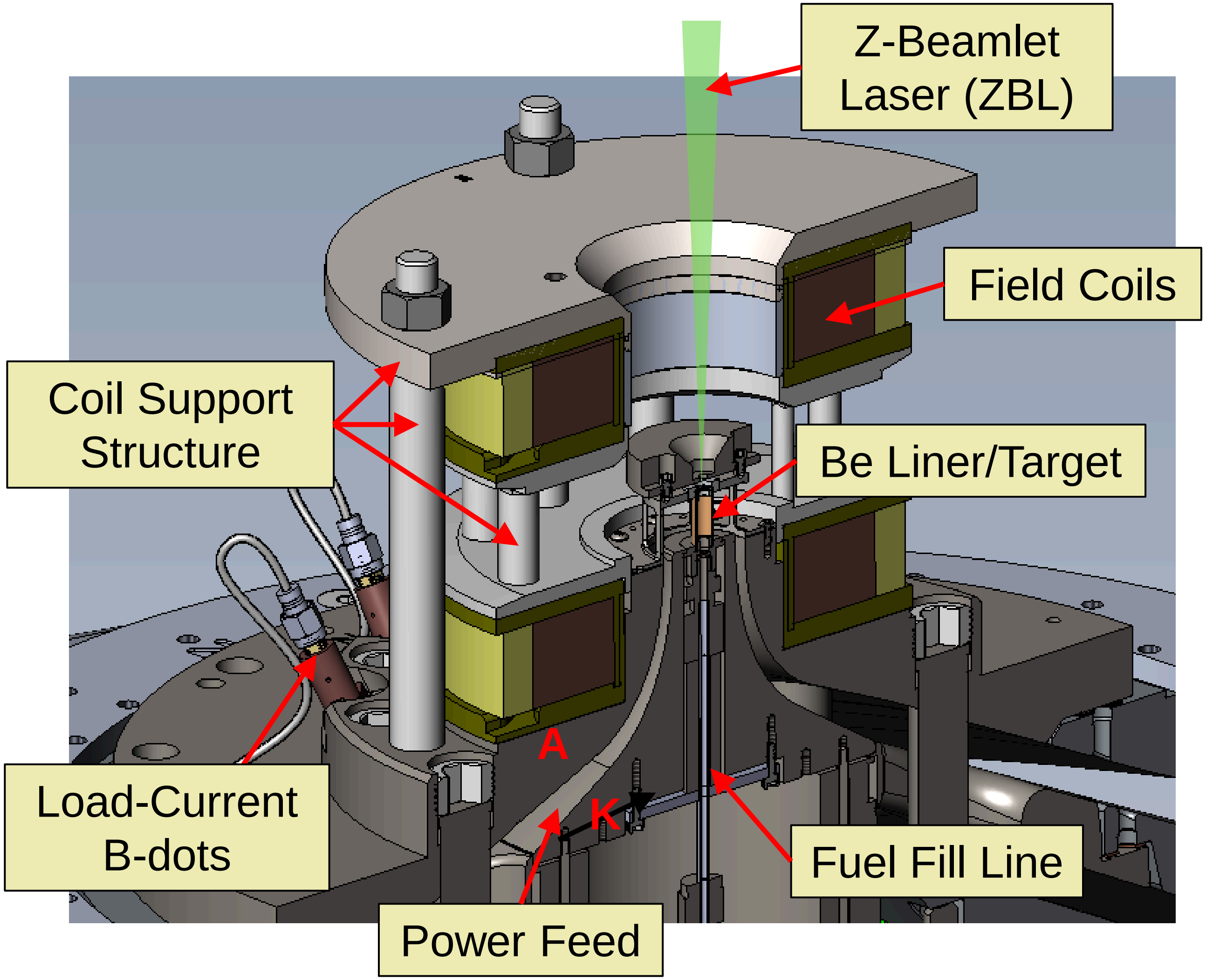


With DT fuel, simulations indicate scientific breakeven may be possible on Z (fusion energy out = energy deposited in fusion fuel)

* S. A. Slutz *et al.*, PoP **17**, 056303 (2010). S. A. Slutz and R. A. Vesey, PRL **108**, 025003 (2012).

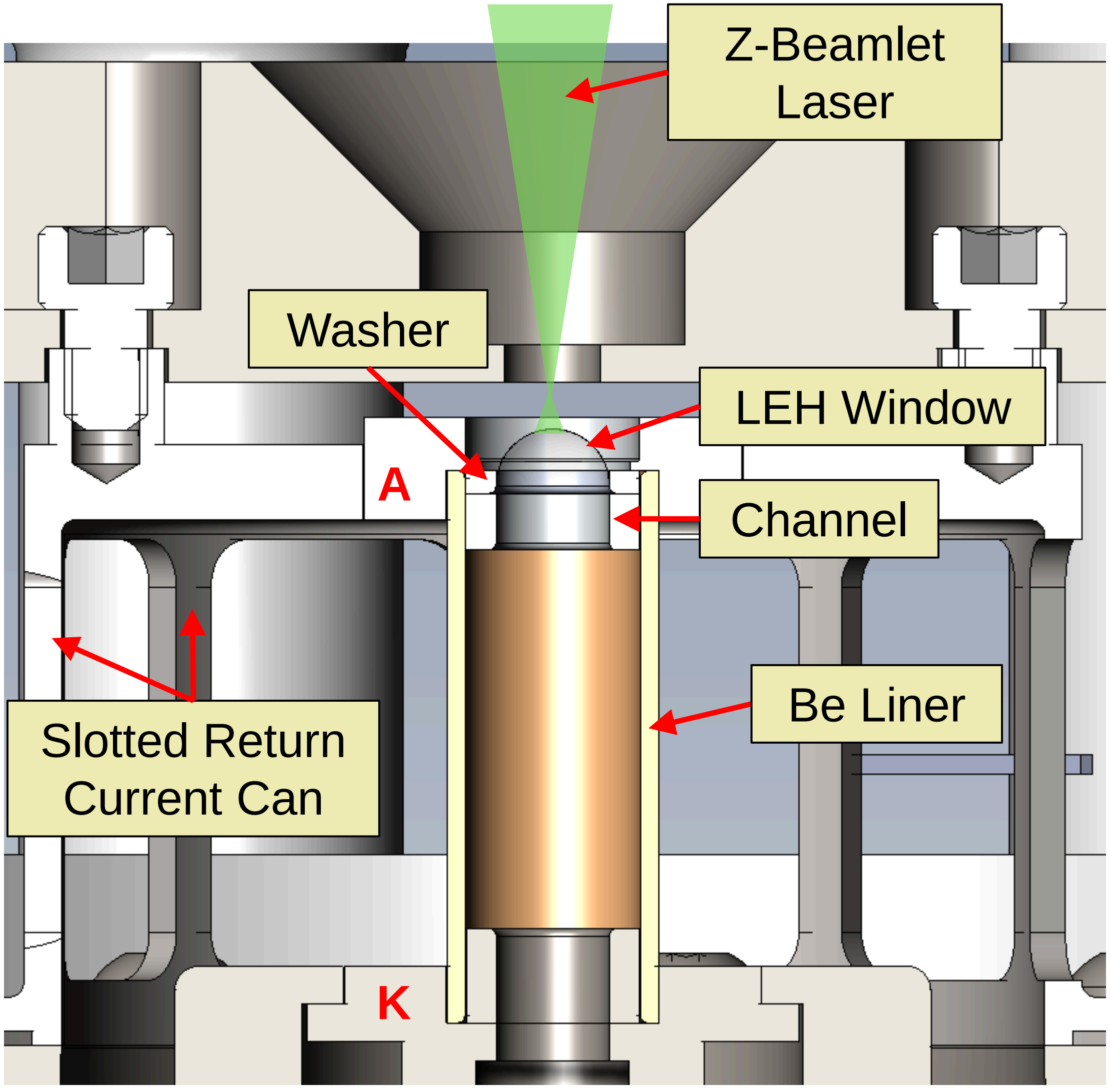
Anatomy of a MagLIF Experiment

- **Field Coils**: Helmholtz-like coil pair produce a 10-30 T axial field w/ ~3 ms rise time
- **ZBL**: 1-4 kJ green laser, 1-4 ns square pulse w/ adjustable prepulse (prepulse used to help disassemble laser entrance window)



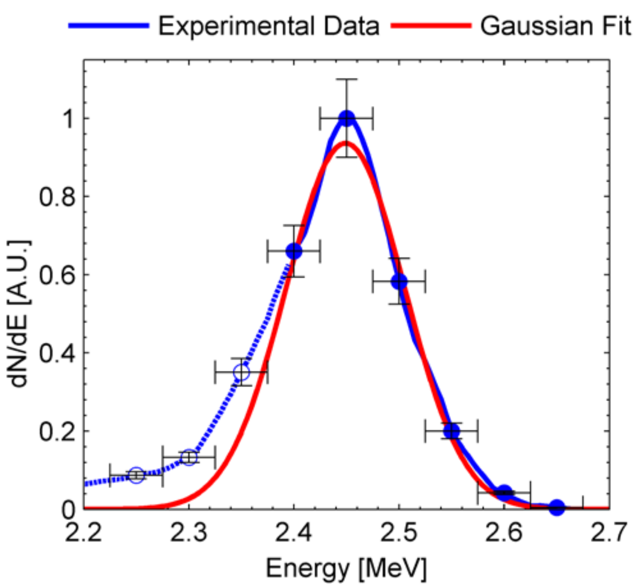
Anatomy of a MagLIF Target

- **Be Liner**: OD = 5.63 mm, ID = 4.65 mm, h = 5–10 mm
- **LEH Window**: 1-3 µm thick plastic window. Supports 60 PSI pure D2 gas fill.
- **Washer**: Metal (Al) washer supporting LEH window
- **Channel**: Al structure used to mitigate the wall instability (also referred to as a "cushion"). Also reduces LEH window diameter to allow thinner windows
- **Return Can:** Slotted for diagnostic access



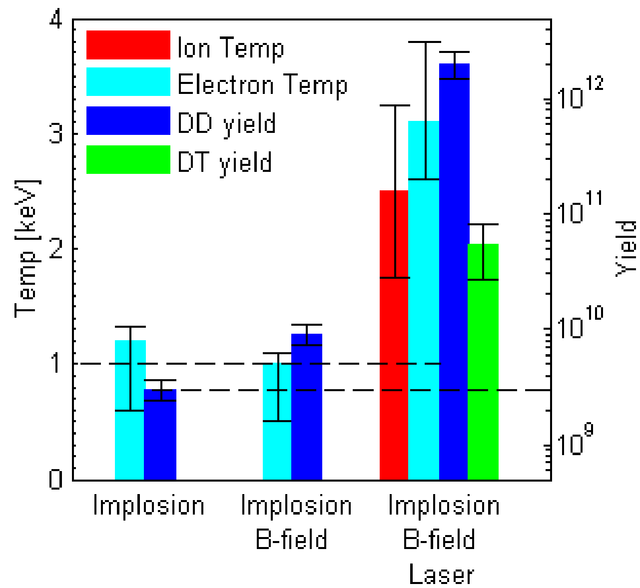
Our initial MagLIF experiments have been very successful, demonstrating several key aspects of magneto-inertial fusion

Thermonuclear neutron generation



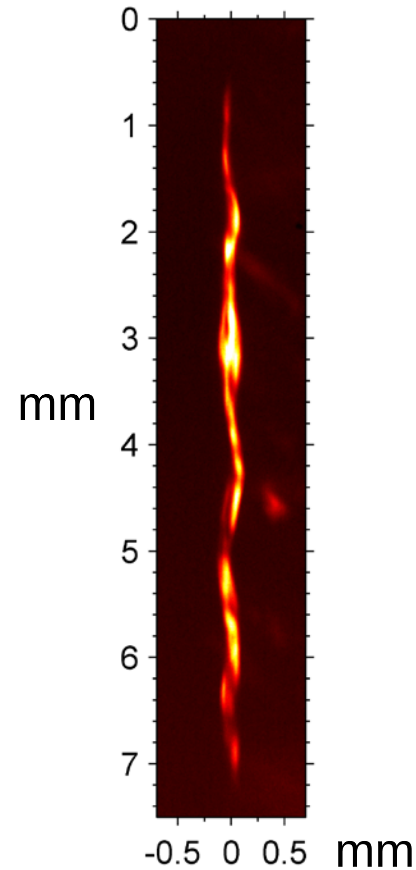
Isotropic, Gaussian DD neutron spectra

High yields and temperatures



Max DD neutron yield = 3e12
Max ion temp = 2.5 keV

A high aspect ratio stagnation column FWHM 50 – 110 μm



M. R. Gomez et al., Phys. Rev. Lett. 113, 155003 (2014). P. F. Schmit et al., Phys. Rev. Lett. 113, 155004 (2014).

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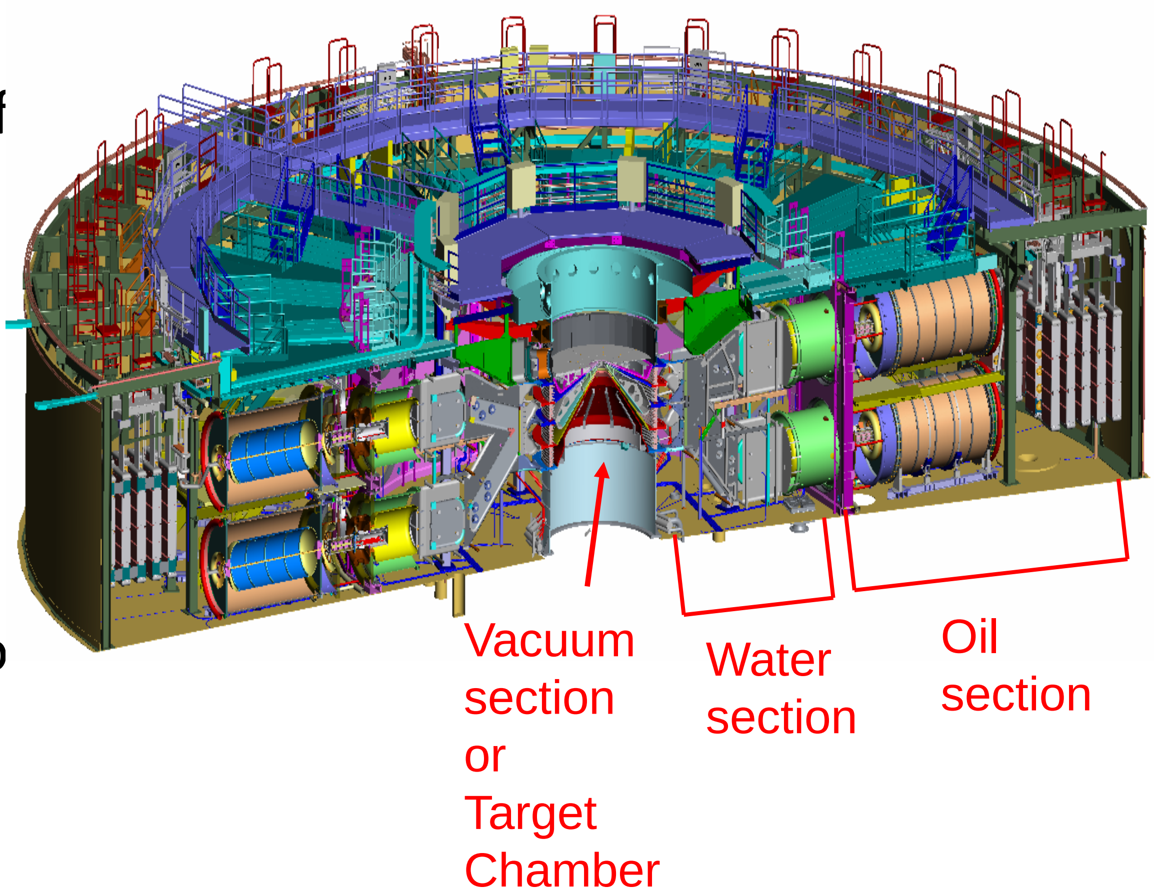
Several key physics issues could be addressed with DT experiments

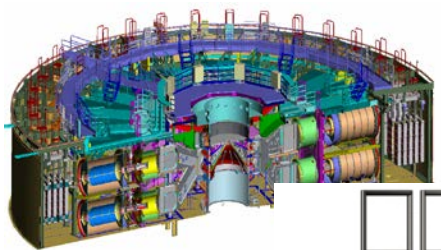
		Tritium fuel content		
Physics	**Measurement**	**<0.1%**	**0.1%**	**1%**
Behavior of tritium in the Z pulsed power environment	Sampling of tritium contamination, migration			
Scaling of yield to DT—thermonuclear?	DT yield			
Ion temperature and non-thermal population	Precision nTOF and DT/DD yield ratio			
Liner/fuel mix	DT yield with tritiated gas fill and deuterated liner			
Fuel morphology	Neutron imaging			
Thermonuclear reaction history	Gamma Ray History/GCD, Thompson parabola			
Liner/fuel density, non-thermal effects (peak shifts)	Compact/Magnetic Recoil Spectrometer (CRS/MRS), precision nTOF			

There are risks and hazards associated with implementing tritium on Z

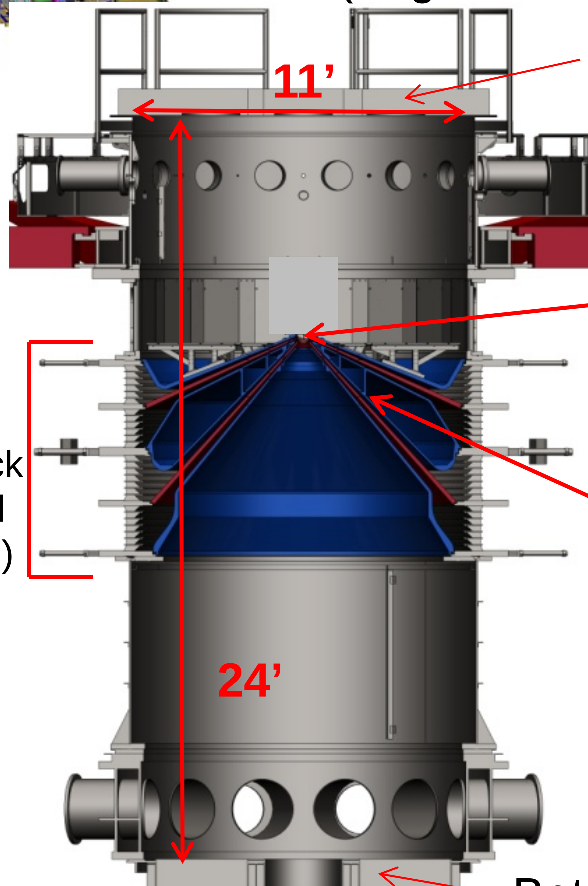
- Z is roughly 100’ in diameter and 20’ high
- It uses large of amounts of oil and water for energy storage and pulse forming
- MagLIF experiments will release tritium into the vacuum section
- Tritium could affect day to day operations and could have potential legacy issues



Z offers different challenges (and opportunities) as an HED facility



Z vacuum center-section (target chamber)



Top Vacuum Lid

Target or load region

Vacuum stack (alternating stack of Rexolite and aluminum rings)

Magnetically Insulated Transmission Lines (MITLs)

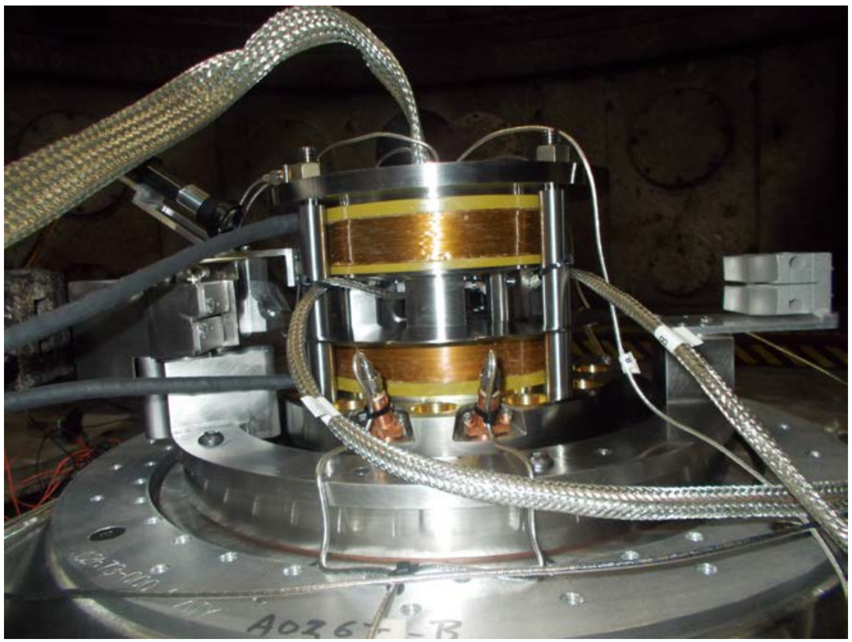
Bottom Vacuum Lid

Z operations requires people to work in the target chamber for every shot

The MITLS must be removed and cleaned between every shot

Z presents a challenging and harsh environment due to the energetics and amount of hardware destroyed during a MagLIF experiment

Pre-shot picture of MagLIF experiment

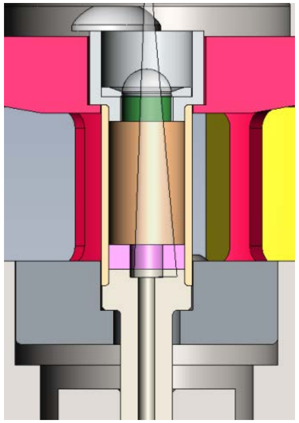


Post-shot picture of MagLIF experiment

D. C. Rovang et al., Rev. Sci. Instr. 85, 124701 (2014).

How much tritium in a MagLIF Target?

MagLIF target



<u>Present target size and inventories</u>

h = 7.5 mm
r_{fuel} = 2.32 mm
V = 127 mm3
P = 60 psi
ρ = 0.7 mg / cc

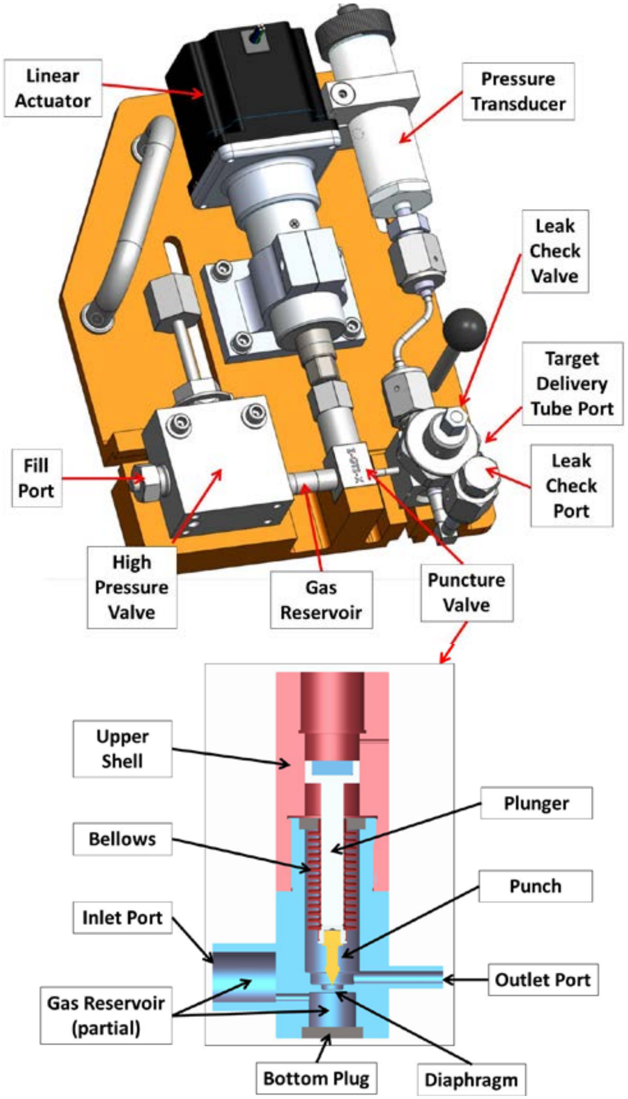
0.1% T = 1.23 mCi
1.0 % T = 12.3 mCi
10% T = 123 mCi
50% T = 0.62 Ci

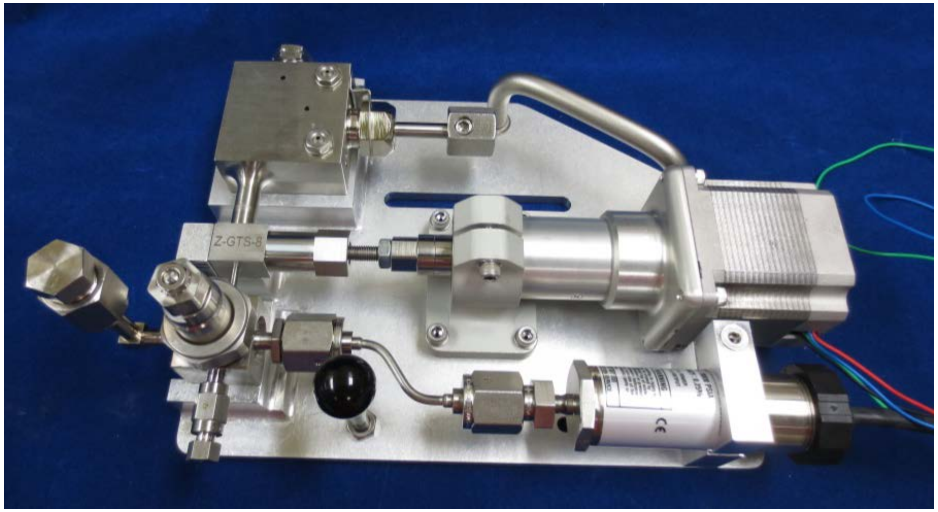
<u>Projected target size and inventories</u>

h = 10 mm
r_{fuel} = 2.75 mm
V = 238 mm3
P = 130 psi
ρ = 1.5 mg / cc

0.1% T = 4.11 mCi
1.0 % T = 41.1 mCi
10% T = 411 mCi
50% T = 2.55 Ci

We recently completed development of the Z Gas Transfer System (ZGTS)* capable of filling MagLIF targets in-situ on Z





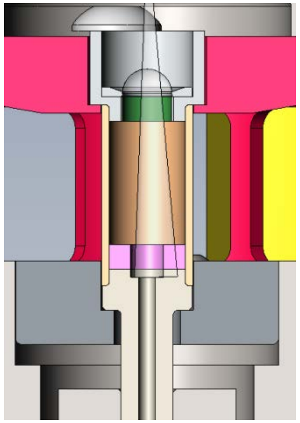
- Robust tritium capable gas transfer system
  - Uses metal diaphragm puncture valve
  - Minimizes tritium inventory
  - Controls when and where tritium is used
  - Fills target in-situ just prior to shot

* Initial joint development with Art Nobile and Mike Rogers from LANL

The ZGTS would increase the total inventory but the residual tritium would be introduced to Z in an elemental state

- Elemental tritium easier to purge or remove from the Z chamber
- We are considering ways to trap the residual tritium in the ZGTS
- Total inventories for initial low T (~ 1 %) operations seem acceptable to “stack” without trapping or tritium capture

MagLIF target



<u>Present target size and inventories</u>

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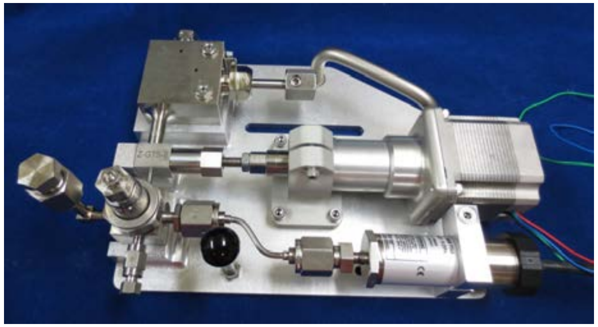


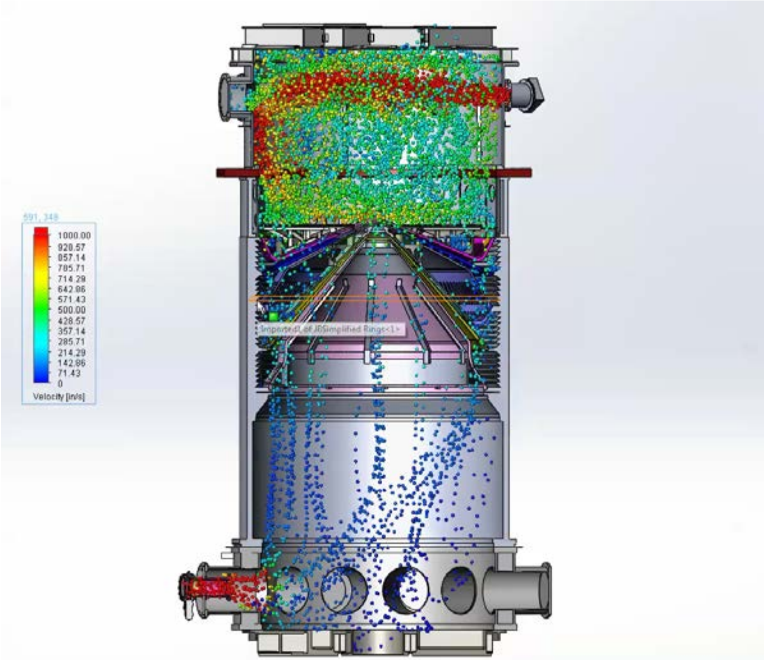
<u>ZGTS residual inventories</u>

0.1% T = 16 mCi
1% T = 160 mCi
10% = 1.6 Ci
50% = 8.0 Ci

Our ability to minimize the impact on the facility depends on the ability to purge the tritium from the Z target chamber

- Z maximum shot rate is presently 1 shot / day
- Z must be vented and opened after every shot
- Can we use this to our advantage?
- PSAX was designed and implemented to eliminate hazardous decomposition products
- Is it sufficient for T?
- Or do we need PSAX x2, x10?
- Overnight or extended purge vs. ½ hour?
- Other ideas?

Flow analysis of the Post Shot Air Exchange System (PSAX) for Z target chamber



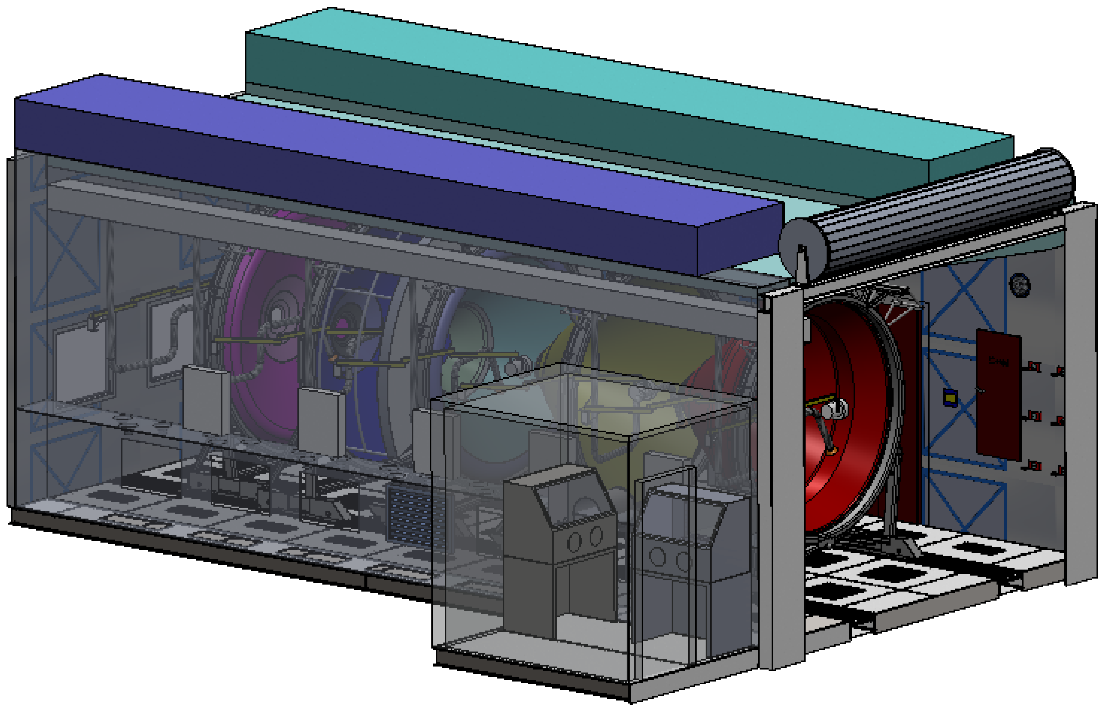
Volume Z Target Chamber = 66 m^3
Total surface area = 464 m^2

PSAX Flow rate = 765 CFM
20 air exchanges / hr.
Typical purge time = ½ hour

We will implement a new MITL refurbishment enclosure in CY16

- New enclosure will be more compatible with tritium operations
- Totally enclosed Perma-Con structure with single pass ventilation
- May provide for contingency ventilated decontamination of MITLS
  - Better airflow over surfaces with gaps between MITLS

New MITL refurbishment enclosure



We may want to consider a removable target chamber concept to help minimize impact on the facility

- Basic concept is to keep most of the tritium and debris inside a large removable chamber
- This chamber would be removed and refurbished at a separate facility
- Goal is to minimize clean up and decontamination required of the main Z chamber including the MITLS and stack