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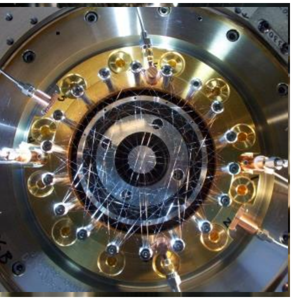

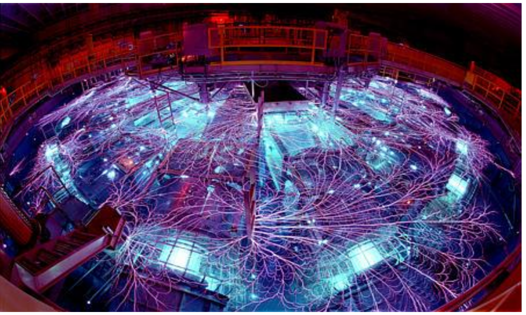

The Diagnostic Value of Tritium on Z

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Sandia National Laboratories

Exceptional service in the national interest

National HED Diagnostics Workshop
Los Alamos, NM
October 6, 2015

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Fielding tritium on Z will open the door to valuable collaborative MagLIF physics studies, but is nontrivial

- Tritium is not presently fielded on Z
  - Vacuum chamber is open every day, MITL grinding, tanks of oil and water

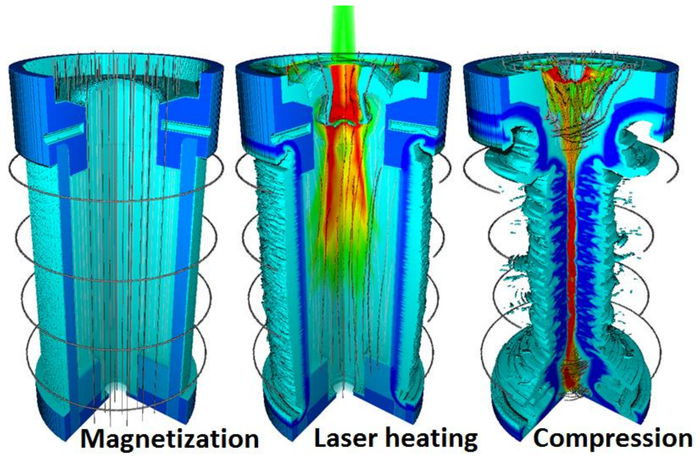
- Community needs to assess the cost-benefit of using tritium at Z

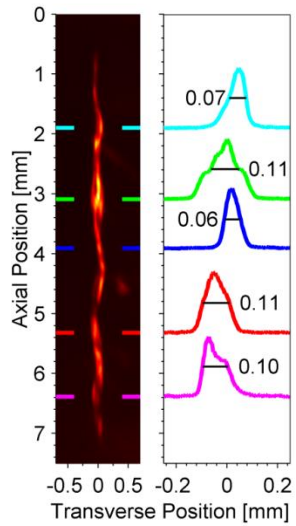
- Tritium would open the door to nuclear diagnostic techniques and target physics studies not presently possible

- These opportunities would encourage collaboration on Z with the broader HED community

ICF neutron sources at Z can have very different implosion dynamics and plasma conditions

MagLIF

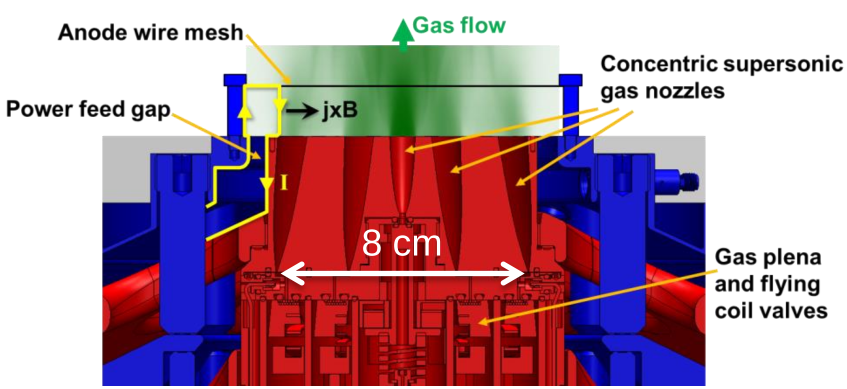


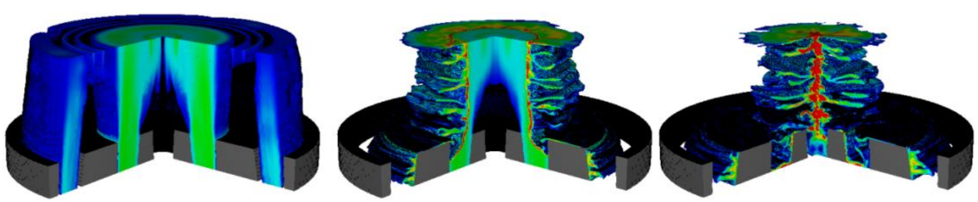


MagLIF:
M. R. Gomez *et al.*,
PRL 113, 155003 (2014).

D_2 gas puff:
C. A. Coverdale *et al.*,
PoP **14**, 022706 (2007).

D_2 gas puff

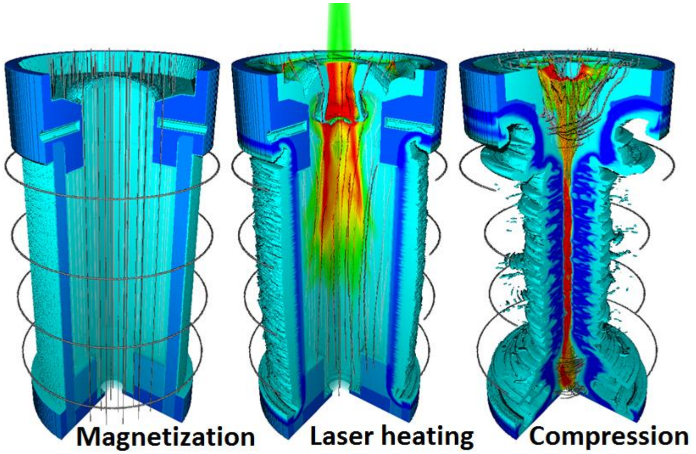


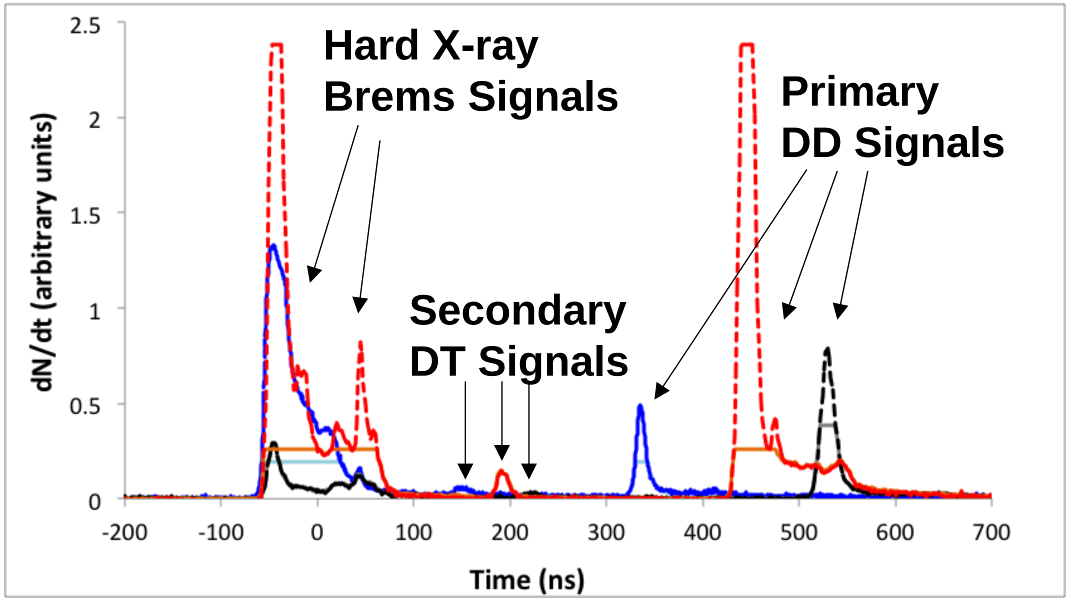


	Y_n(DD)	Y_n(DT)	T_e (keV)	T_i (keV)	n_i (cm^{-3})	Δt (ns)	Diameter
MagLIF	3×10^{12}	5×10^{10}	~3	2.5	~ 10^{23}	< 2	~50 μm
D_2 gas puff	4×10^{13}	<4×10^{9}	2.2	~10	2×10^{20}	~30	6 mm

Adapting diagnostic technology to the Z environment can be challenging and rewarding

MagLIF





- Significant brems on Z can overdrive scopes, obscure the secondary DT neutron signal on nTOF detectors
- Fuel magnetization inferred from DT secondary spectrum

P. Schmit *et al.*, PRL **113**, 155004 (2014).

Key Collaborations on nTOF		
NSTec R. Buckles I. Garza K. Moy	**LLE** V. Glebov	**LLNL** D. Fittinghoff M. May
Gated PMTs, fast scintillators, close-in nTOF, clipper circuits, CVD diamonds		

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			■

Diagnostic Capabilities enabled by tritium use will open new physics understanding for MagLIF

- Better SNR, higher dynamic range n-spectral measurements
  - More precise ion temperature
  - High precision Be down scatter measurements for liner ρR
  - MRS or CRS measurements both axially and radially
- Neutron imaging enabled by higher yields
  - Is the neutron producing volume the same as the x-ray producing volume?
  - Down-scatter image for liner ρR uniformity measurements
- γ reaction history enabled by higher yields and preferable γ–branching ratio
  - Is the x-ray history the same as the γ-history?
  - Does the reaction history have structure indicating multiple isolated burn regions?
- Novel mix studies are enabled by separated reactant experiments using tritium or tritiated hydrogen gas
  - Deuterated window to study window mix
  - Deuterated coating on liner interior to study liner mix
  - Deuterated top/bottom caps to study mix from laser interactions
  - Combine w/ neutron imaging to study transport of mix material

Gradual increase in MagLIF tritium fuel content will provide increasing scientific opportunities

Proposed Z Timeline

FY15	FY16	FY17	FY18	FY19

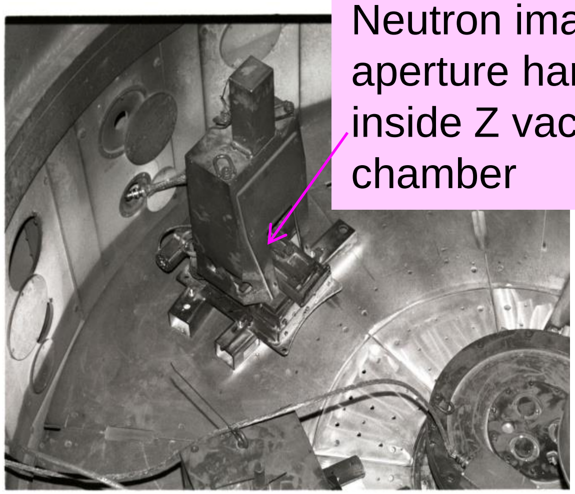
- Tritium Surrogates D_2, ^3He
- Trace Tritium ES&H <0.1%
- Trace Tritium 10x DT Yield ~0.1%
- Minority Tritium >10^{13} DT Yield ~1%
- Tritium Operations 10-50%

FY15	FY16	FY17	FY18	FY19
		DT yield scaling, ion temperature and non-thermal population		
			Nuclear tracers for liner/fuel mix	
	Neutron imaging, high sensitivity for DD MagLIF, mixed DD/DT imaging (CR-39?)			
Brems background measurements for GCD, shielding studies			GRH/GCD, Thompson parab., CVD dia.	
	Wedge range filter, CRS design		MRS neutron spectroscopy	

We are collaborating with other National Laboratories to improve Z's neutron diagnostic suite

- **LLNL:** D. Fittinghoff, M. May
  - Neutron-imager
    - Goal (~1-2 yrs): Improve existing neutron imager at Z to achieve ~0.5-1 mm resolution (along ~ 5 mm length column) for > 5e12 DD yields (for DT in ~3 yrs).
  - CVD diamonds (with NSTec)
    - Goal: Measure neutron burn history with ~1-2 ns resolution for > 1e13 DD yields (for DT in ~ 3 yrs).

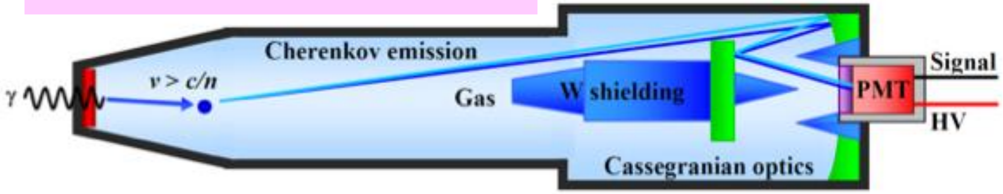
Neutron imager aperture hardware inside Z vacuum chamber



- **LANL:** H. Herrmann, R. Leeper
  - Gas Cherenkov Detectors
    - Goal (1-2 yrs): Measure Z background gamma spectrum, consider D-^{3}He
    - Goal (~3-5 yrs): Measure neutron burn/reaction history with ~1-2 ns resolution for > 5e12 DT yields.

CVD Diamond Detectors

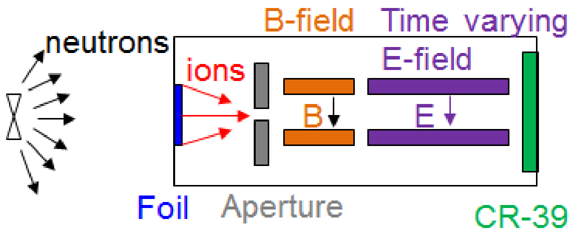
Gas Cherenkov Detector



We are collaborating with universities to improve Z's neutron diagnostic suite

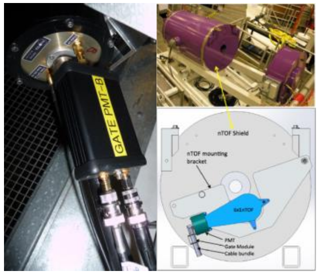
- **UNM:** G. Cooper and J. Styron
  - Thomson Parabola
    - Goal: Measure neutron burn history for > 1e13 DD (or DT) yields with 1-2 ns resolution.

Thomson Parabola

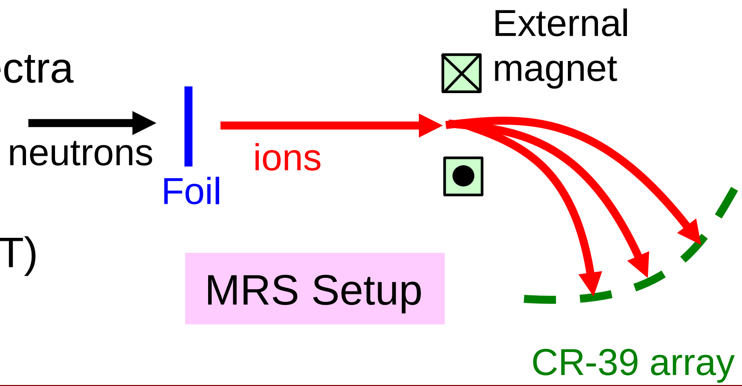


- **UR, LLE:** V. Yu. Glebov
  - Gated and alternative nTOF detectors
    - Goals: Suppress large brems signal contributions to enhance small signals (DT and n-Be tails) and improve precision (for T_{ion}).

Gated nTOF

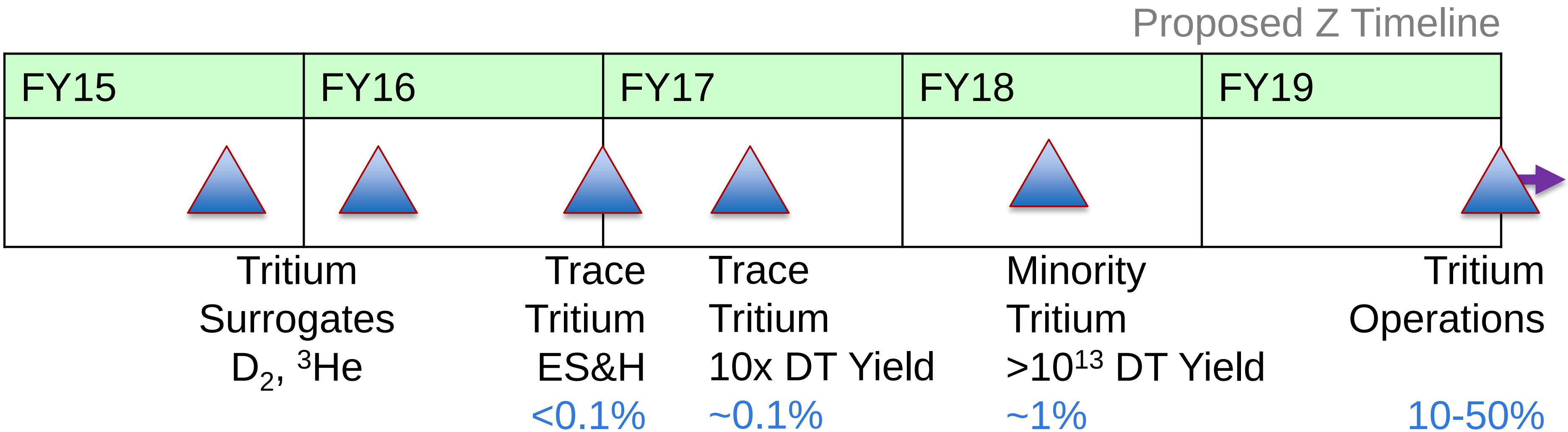


- **MIT:** R. Petrasso, J. Frenje, F. Seguin, M. Gatu-Johnson, H. Han
  - Neutron recoil spectrometers
    - Goals for next 1-2 yrs: Measure yield and spectra for 1e11 - 5e13+ experiments.
    - Longer term goal (~ 3-5 yrs): MRS-Magnetic Recoil Spectrometer (>1e13 DT)



MRS Setup

Gradual increase in MagLIF tritium fuel content and essential collaborations will provide increasing scientific opportunities



Key Collaborations for Z Neutron/Nuclear Diagnostics (blue=tritium needed)

NSTec	**LLE**	**LLNL**	**LANL**	**UNM**	**MIT**
R. Buckles I. Garza K. Moy	V. Glebov	D. Fittinghoff M. May	H. Herrmann A. McEvoy	G. Cooper J. Styron	R. Petrasso et al.
Gated PMTs, NRPU clipper circuits, CVD diamonds	Gated PMTs	**Neutron imaging**, close-in nTOF, fast scintillators, CVD diamonds	**Gas Cerenkov Detectors for DT burn history**, study D^3He reactions	**Thompson parabola design study**, diagnostic calibration, etc.	DD spectrometer (CR-39) leading to **CRS/MRS**

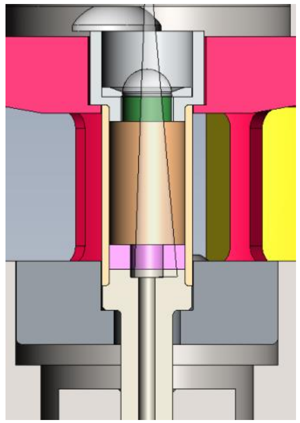
Our ability to minimize the impact on the facility depends on the ability to purge the tritium from the Z target chamber

$h = 10$ mm
$r_{fuel} = 2.75$ mm
$V = 238\ mm^3$

$\rho = 1.5$ mg / cc

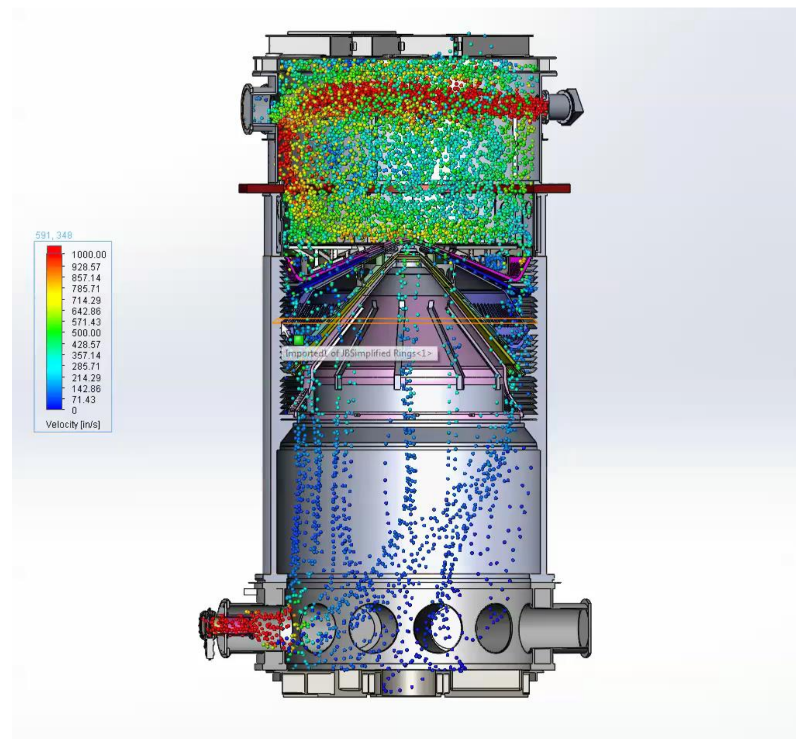
1 % T = 41.1 mCi

MagLIF target



Flow analysis of the Post Shot Air Exchange System for Z center section

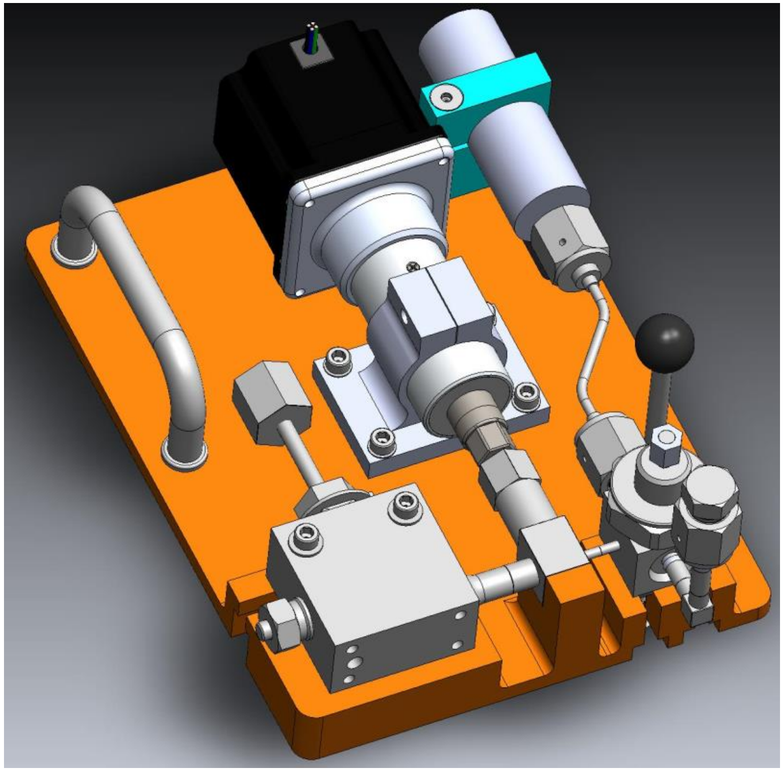
Volume = 66 m^3
Total surface area = 464 m^2



- Purge efficiencies required to keep Z below control limits for tritium
  - Assuming entire surface area
  - 99.5 % for 10,000 dpm / 100 cm^2 (Contaminated area)
  - ~ 50 % for 1 e6 dpm / 100 cm^2 (Highly contaminated area)

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

ZGTS



- 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