Studies on Plasma-Solid Lithium Wall Interaction in DIIID

C. Ribeiro, September 13, 2023

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generalfusion®

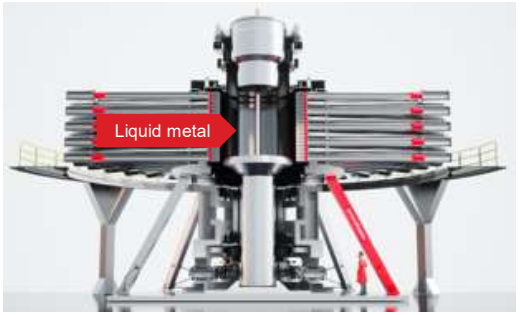
Acknowledgments

Discussions with Tyler Abrams, Michel Laberge, Kristin Skrecky, Xiande Feng

MOTIVATION: LITHIUM IS INTRINSIC PART OF GENERAL FUSION (GF) REACTOR CONCEPT

General Fusion's Magnetized Target Fusion Basics: Example the Fusion Develop Plant (FDP)-a Demo-like Proposal

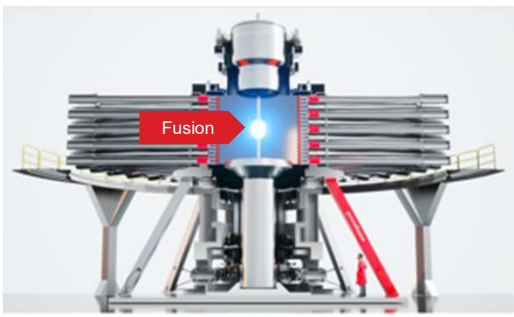
Form liquid metal (Li) cavity (liner) inside the vacuum vessel



Inject magnetized plasma[1] into the Li cavity (liner)

Compress plasma with Li using mechanical drivers

Fusion and energy conversion



Repeat

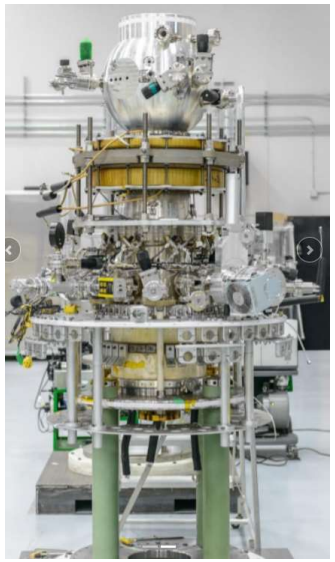
Magnetized plasma compressed fluid-mechanically to fusion conditions

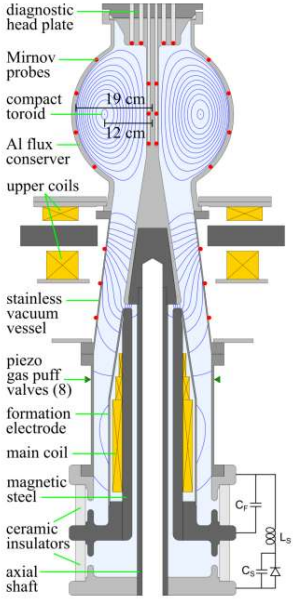
1. General Fusion's plasma injectors form spherical tokamak plasma targets using a 100% coaxial helicity injection (CHI) process. Targets are formed into a chamber with solid metal walls. There is no active feedback; plasma position and stabilization is accomplished entirely through the metal walls acting as a flux conserver.

GF research devices are routinely coated by Li (evaporation)

The Lithium coated wall Spector(SPhErical Compact TORoid) Spherical Tokamak (2014-2017)

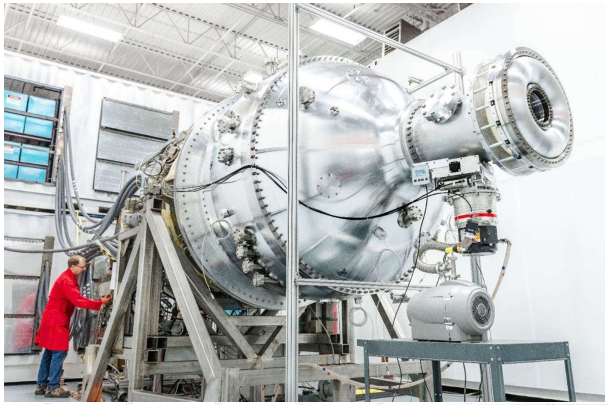
Spector typical Parameters	
I_p(kA)	300-800
B_T(T)	0.4
a(m)	0.077
R(m)	0.11
R/a	1.4
k	1.9
$\bar{n}_e$ ($10^{19}m^{-3}$)	4.2
T_e(eV)	200-500
T_i(eV)	~300
Pulse (ms)	2-3ms

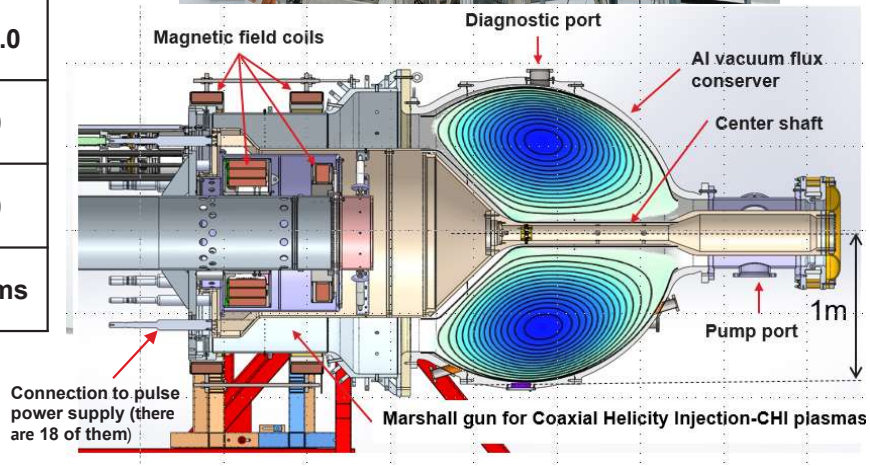




The Lithium coated wall PI3(Plasma Injector 3) Spherical Tokamak (2018- in operation)

PI3 typical Parameters	
I_p(kA)	300-500
B_T(T)	0.23
a(m)	0.37
R(m)	0.62
R/a	1.7
k	1.7
$\bar{n}_e$ ($10^{19}m^{-3}$)	2.0-4.0
T_e(eV)	300
T_i(eV)	400
Pulse (ms)	< 50 ms



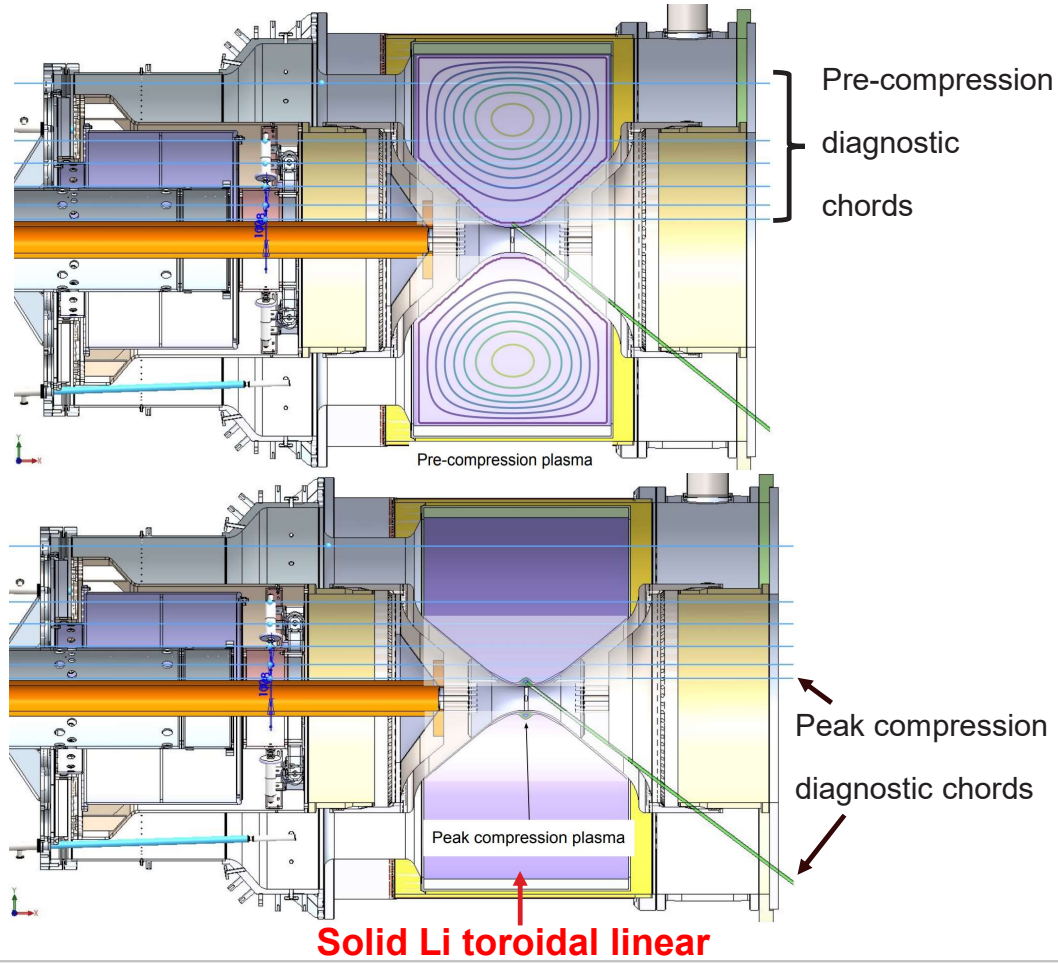


GF New Device LM26 coated by Li evaporation and solid Li liner

LM26 experiment:

- **Marshall Gun forms magnetized plasma and pushes it into 1 m radius target chamber lined with solid Li**
- **Magnet coils around target chamber are pulsed and push solid Li liner, which collapses on plasma**
- **10:1 radial compression in 3 ms**
- **Temperature: 300 eV → 10 keV**
- **Density: 5×10^{19} m^{-3} → 10^{23} m^{-3}**
- **B-field: 1 T → 100 T**
- **Natural Negative Triangulary (N-NT): high τ_E , N_G**
- **Passive stabilization: high β**

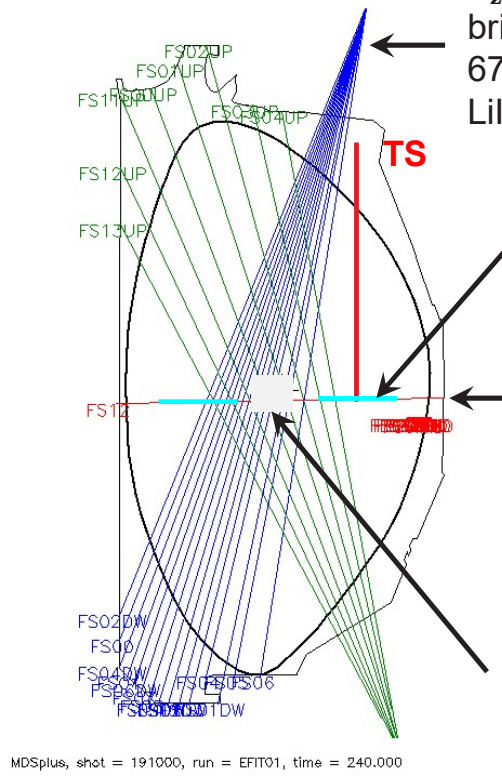
LM26 diagnostic chords (from P. Carle presentation)



What does LM26 requires from DIIID?

Studies on Plasma-Solid Lithium Wall/Liner Interaction: What is the Li density in space and time?

Experiment with full diagnostic **Target plasma: NBI/Ohmic, limiter**



n_z: Calibrated filterscope for bright Li lines (nm): Li I (610, 670, 810), Li II (548nm), and LiIII (in the core)

Can extra chords at the outboard of plasma be added?

$T_i(r)$: charge exchange recombination (CER) spectroscopy

Radial scan of solid Li at Midplane Materials Exposure Station (MiMES)

Upgradable with WITS (larger sample, temperature control)

n_z: absolutely calibrated extreme ultraviolet spectrometer system, SPRED-UV, with a tangential view through the plasma centre.

Simulations of the Li dynamic via the codes

UEGDE, DIVIMP, 3DLIM, EMC3-EIRENE, SOLPS-ITER, GITR

From Experiments & Simulations

1- Determined where the Li density is in space and time;
2- Quantify the fraction of Li (e.g., LiIII) impurity reaching the core giving our transient time scale (several ms) including the compression time (~3ms)?
3- Extrapolate DIIID results to LM26. Example: how to infer the minimum distance (buffer) between the Li liner and the LCFS to minimize Li contamination?
4- Improve GF technical capability in Li-related diagnostics and predictions(codes).

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