Magnetized Target Fusion Using Mechanically Driven Liquid Metal Liner

generalfusion

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generalfusion

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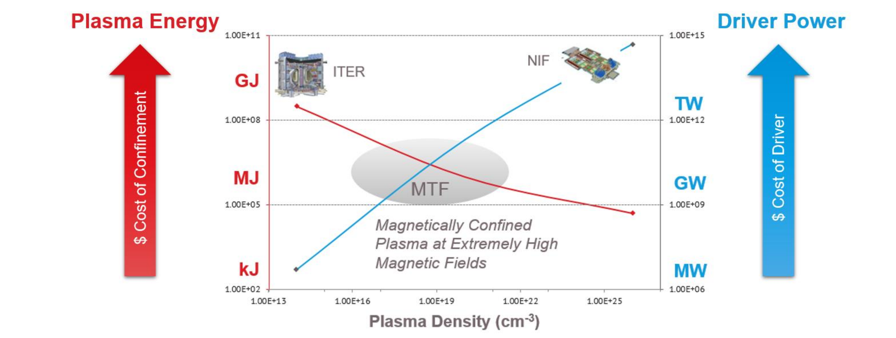
Why MTF?

MTF avoids the high cost and complexity of steady state, active confinement in MCF, and the similarly high cost of high power drivers in ICF, but keeps improved confinement from magnetic fields.



Why Mechanical Drive?

Mechanical power is cheap, compared to pulsed capacitor power, laser power, or superconducting magnets.

Why Liquid Metal?

Liquid metal can change shape without breaking, making it ideally suited for cyclical mechanical compression!

It also solves the first wall problem and won't degrade with extended exposure to neutrons or radiation from fusion plasmas.

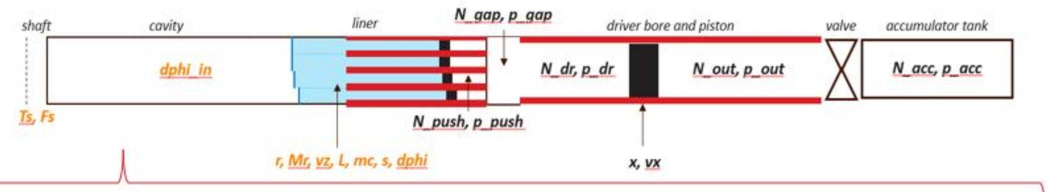
Lithium is also well known to have improve plasma confinement and purity due to its low recycling properties, low Z and aggressive chemical gettering.

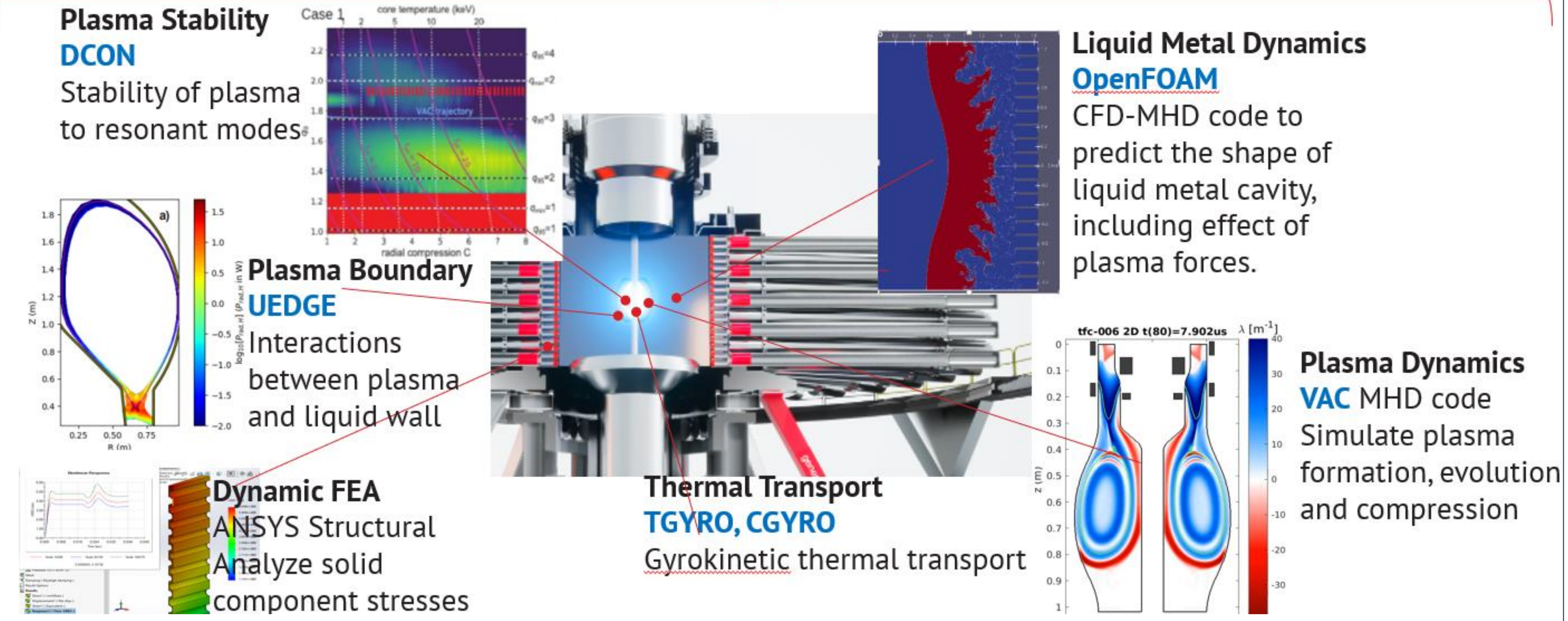
Why a Spherical Tokamak Target?

STs have significantly better thermal confinement than other plasma targets like Spheromaks or FRCs. This better confinement opens up the design space for the mechanical system, permitting slower compressions, (where "slow" is still measured in milliseconds!)

Simulation: Discrete codes applied to all aspects of plasma compression

Integrated Model
Simple, 1D, 2D model of entire system
Used to explore and optimize in a wide space of parameters (size, speed, cavity shape, plasma)





Plasma Stability
DCON
Stability of plasma to resonant modes

Plasma Boundary
UEDGE
Interactions between plasma and liquid wall

Liquid Metal Dynamics
OpenFOAM
CFD-MHD code to predict the shape of liquid metal cavity, including effect of plasma forces.

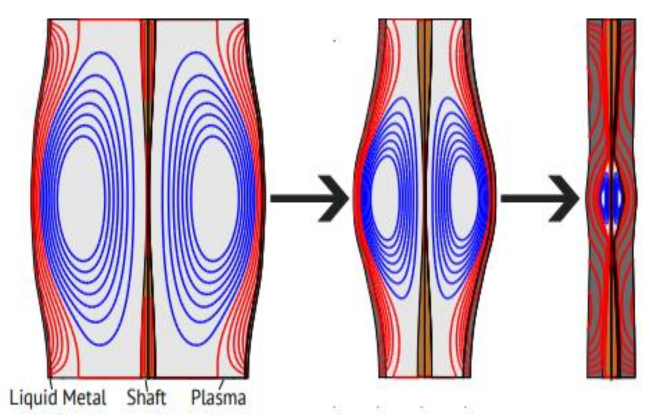
Plasma Dynamics
VAC MHD code
Simulate plasma formation, evolution and compression

Dynamic FEA
ANSYS Structural
Analyze solid component stresses

Thermal Transport
TGYRO, CGYRO
Gyrokinetic thermal transport

See PP11.00037 – L. Carbajal – Edge modeling and simulation of Plasma Injector (Pi3) plasmas with lithium walls – Wednesday, October 18 2:00 PM – 5:00 PM
PM09.00005 – M. Hildebrand – Update on Active INFUSE projects at General Fusion – Wednesday, October 19 2:00PM – 5:00 PM
UP11.00007 – I. Khalzov – Steps towards 3D Integrated System Model of Magnetized Target Fusion at General Fusion Thursday, October 20 2:00 PM – 5:00 PM

Pulsar Project: In addition to applying our existing code base, we are also developing a next gen MTF code aiming to capture all relevant physics for a powerplant. The liquid metal wall, plasma boundary interactions, and plasma core will all be modelled in the same grid and closely coupled. **Pulsar** is Open Source, exascale capable, and uses the AMReX framework.

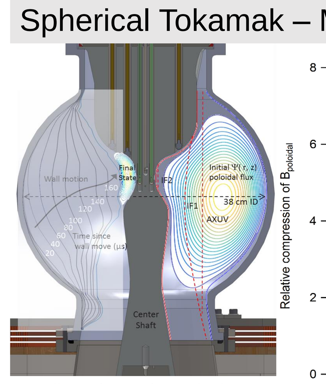


See UP11.00006 – C. McNally – Physical Properties and Global Modelling of General Fusion's Magnetized Target Fusion Plasma – Thursday, October 20 2:00 PM – 5:00 PM

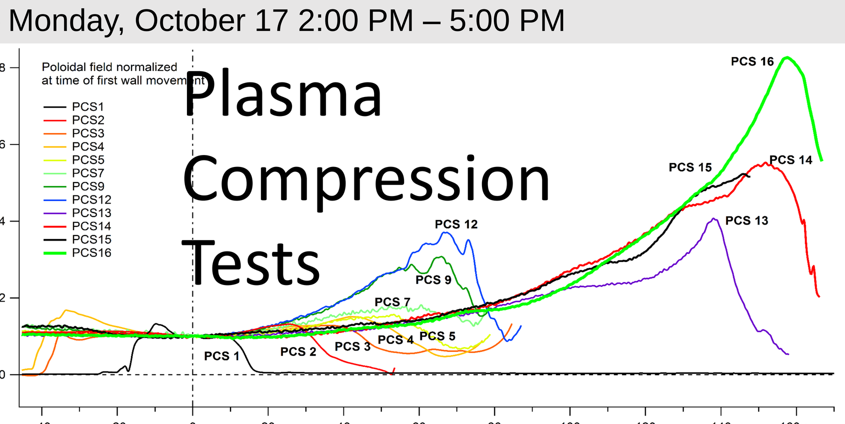
Liquid Metal Plasma Testing

In preparation for larger scale liquid metal operations in FDP, GF has run extensive experiments with ST plasmas interacting with thick liquid lithium free surfaces in our SLiC experiment.

See CP11.00013 – S. Howard – Heated and Lithium-coated Marshall Gun CHI performance on SLiC Spherical Tokamak – Monday, October 17 2:00 PM – 5:00 PM



Wall trajectories during a PCS compression tes,



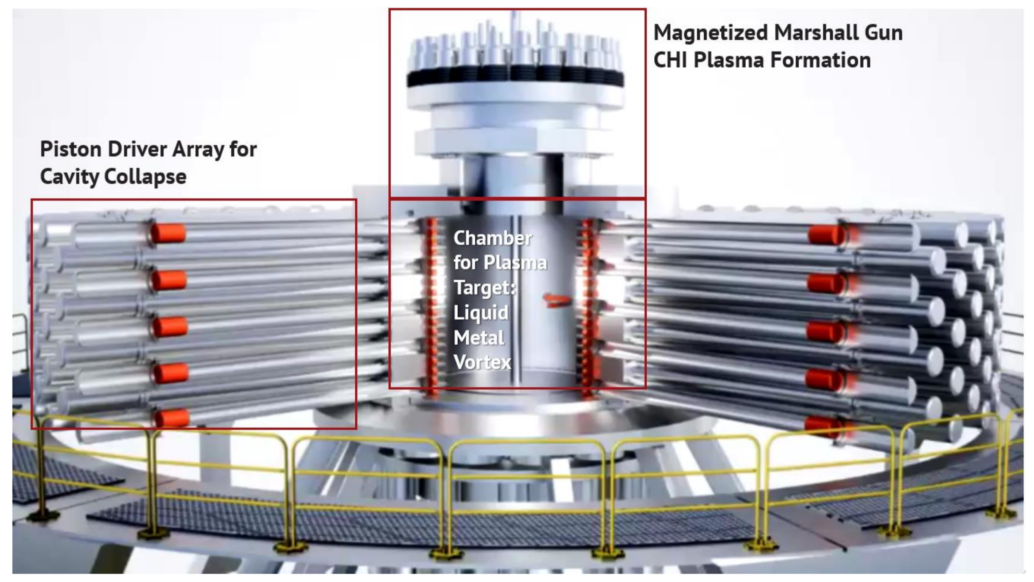
Plasma Compression Tests

GF has conducted a series of subscale MTF tests compressing ST plasmas with high explosives. While this program is no longer active, we learned a lot about how to diagnose a moving, compressing target

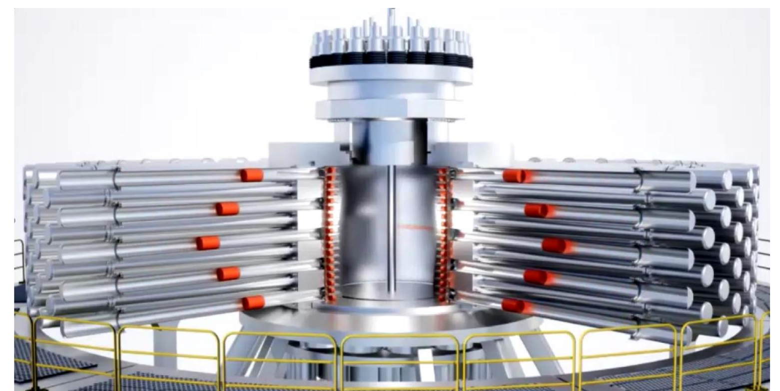
The Concept:

A pulsed reactor compressing with a liquid wall

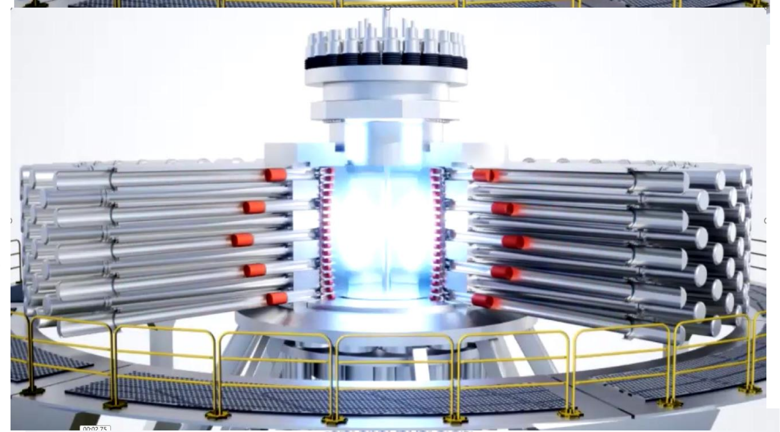
Step 0
In the pre-compression state, the cavity walls are held vertical by rotation



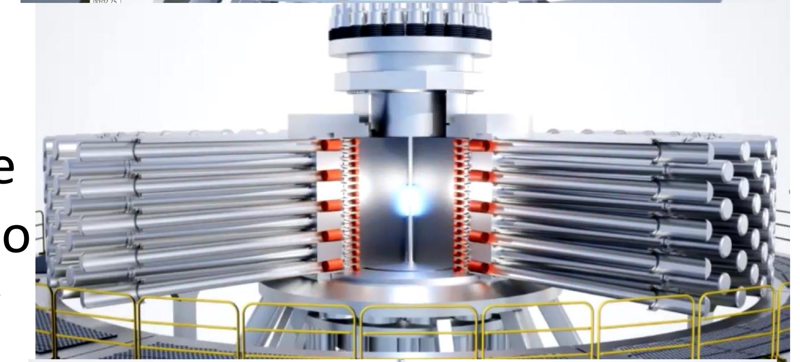
Step 1
The compression system is launched. ~100 ms elapses before significant deformation of the cavity wall.



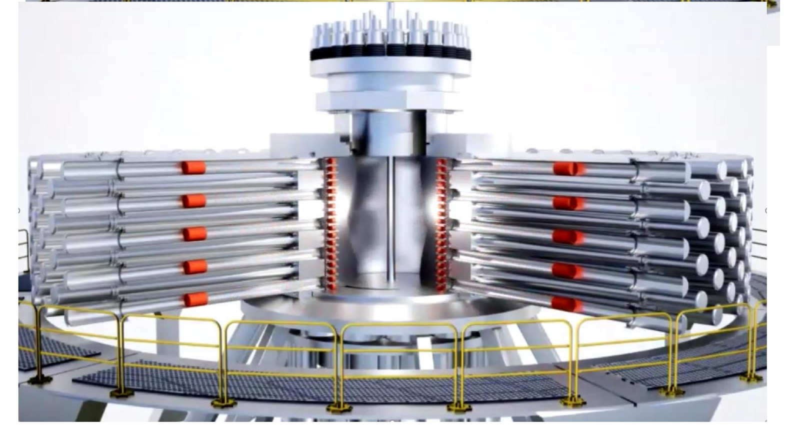
Step 2
As the wall accelerates inward, the Marshall Gun is fired and injects a ST plasma into the cavity.



Step 3
The liner compresses the cavity by ~10:1 radial ratio in ~5 ms, compressively heating the plasma to fusion conditions



Step 4
The liner rebounds, resetting the cavity for repeat compression

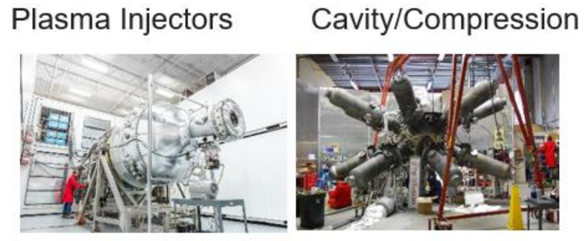


See BM10.00013 – J. Brister – Transforming the Way We Energize the World – Monday, October 17 9:30 AM – 12:30AM

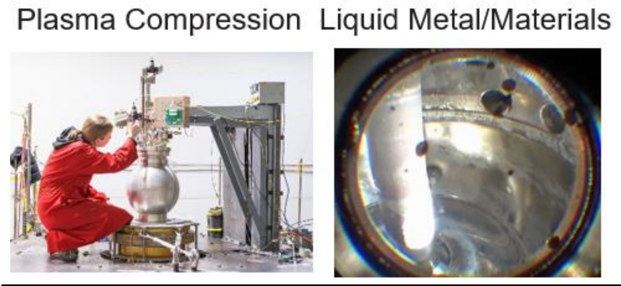
The Path: Building blocks, then integration

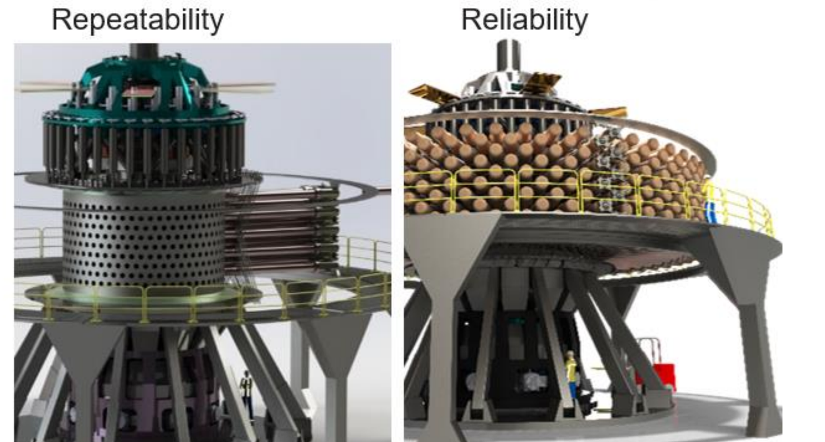
Science and Technology Development → Integrated Large Scale Demonstration → Commercial System

Plasma Injectors | Cavity/Compression | Integrated Solution, Fusion Temperatures, Repeatability | Repetition Rate, Closed Fuel Cycle, Reliability



Plasma Compression | Liquid Metal/Materials





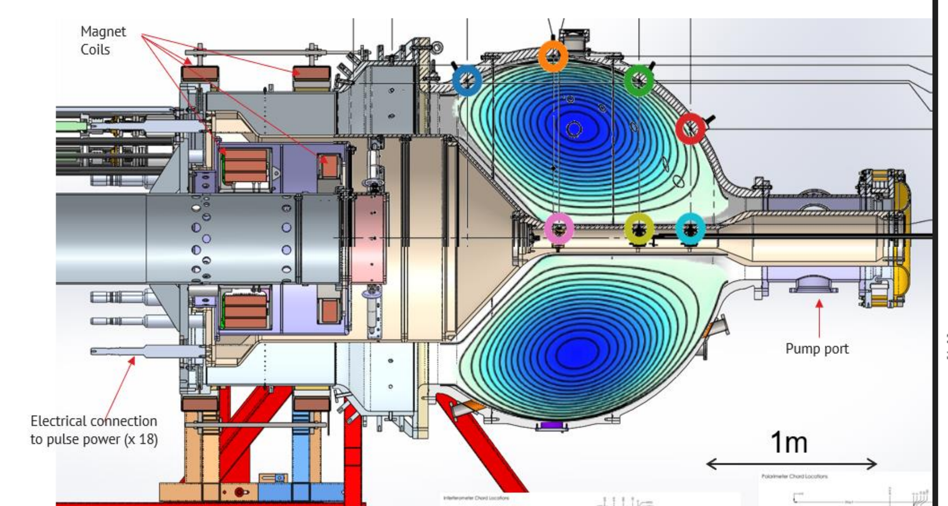
We're Hiring! For opportunities in Research Software Engineering, Computational Plasma Physics, Experimental Plasma Physics and more see generalfusion.com/careers. Informal inquiries to alex.mossman@generalfusion.com

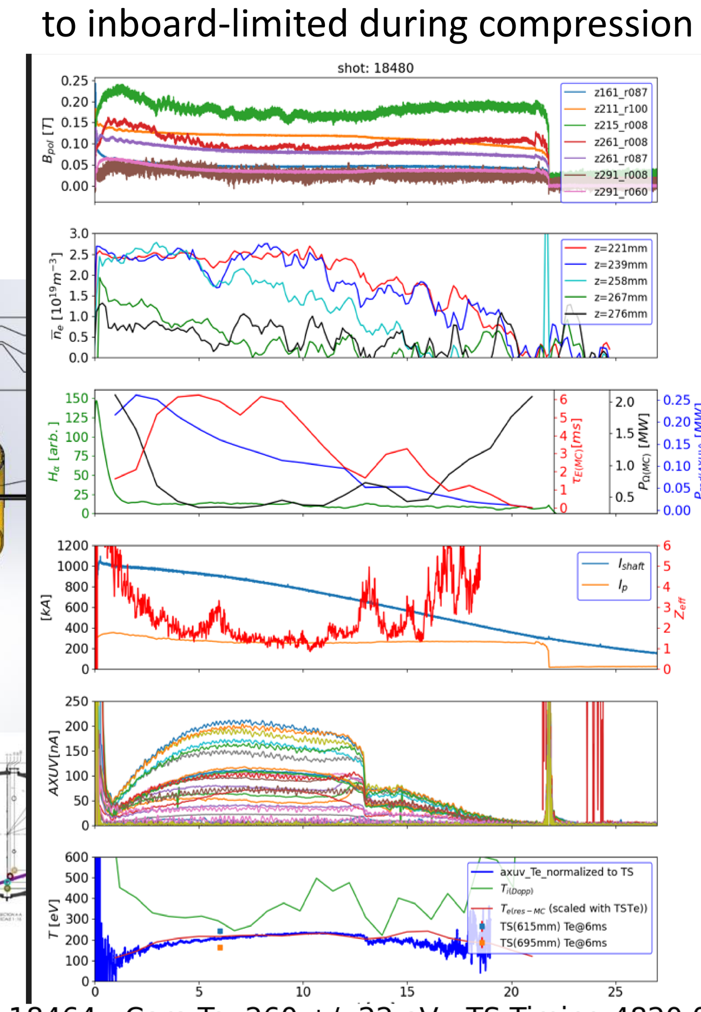
Plasma Target Development:

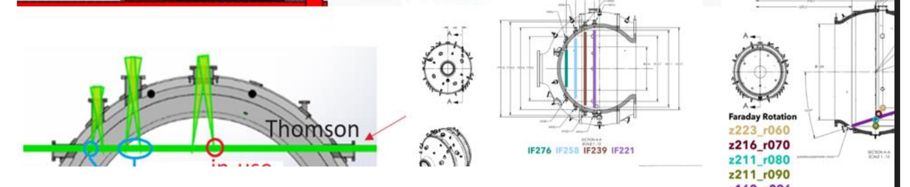
A Simpler ST Designed for Compression

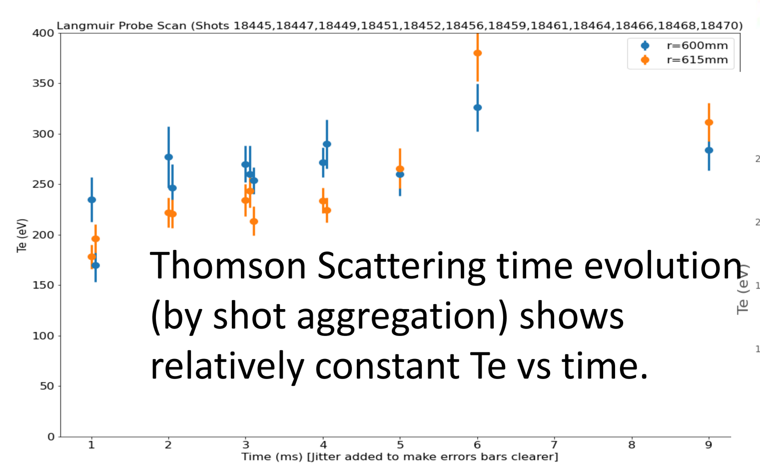
- 100% CHI Formation — Plasma formation system physically separate from compression chamber
- Liquid Lithium Wall — Low Recycling, low Z
- No Current Drive — Plasma current is created by initial CHI process, and then decays
- No Auxiliary Heating — Pre-compression heating achieved by plasma current decay as ohmic power
- No Fueling — Initial gas puff from formation lasts through compression
- No Active Magnetic Stabilization — Liquid wall serves as flux conserver, possibly supplemented by DC field
- No Divertor — Magnetic config evolves from diverted to inboard-limited during compression

Plasma targets are currently formed and diagnosed in Pi3, GF's target development experiment with solid Al walls evaporatively coated with Li

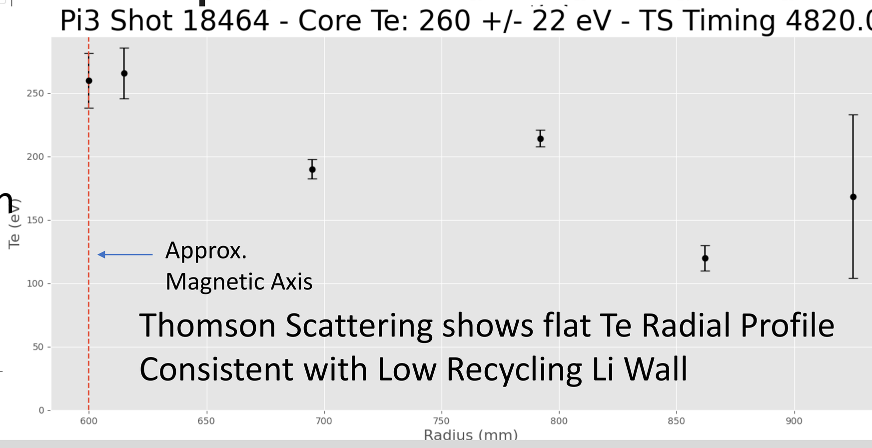








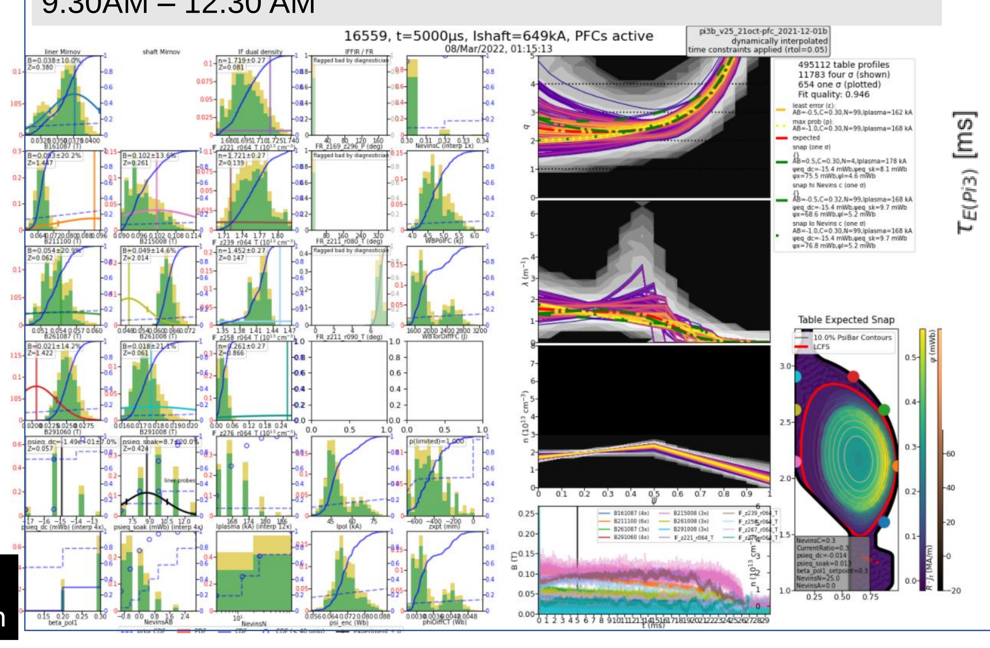
Pi3 Shot 18464 - Core Te: 260 +/- 22 eV - TS Timing 4820.0



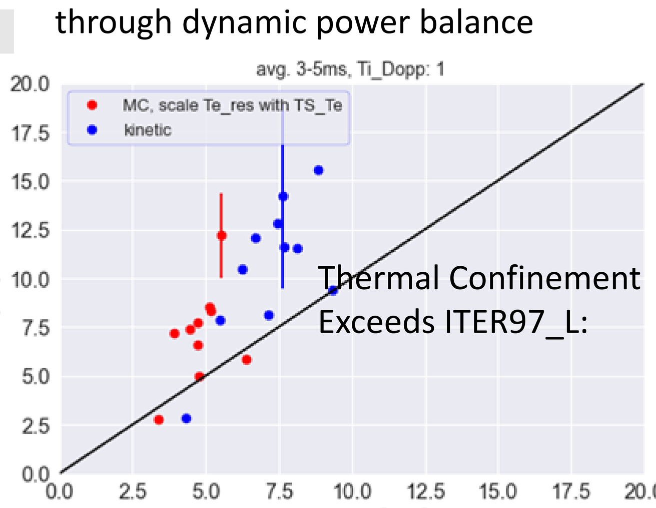
See also UP11.00008 – F. Braglia – Improved magnetic diagnostics on General Fusion Plasma Injector 3 – Thursday, October 20 2:00 PM – 5:00 PM
And YP11.00015 – C. Ribeiro – Triple Langmuir Probes in Lithium-Driven Low Recycling Regimes in the Spherical Tokamak Pi3 at General Fusion Inc – Friday, October 21 9:30 AM – 12:20 PM
JM09.00015 – K. Fujii – Conceptual Design of Ion Temperature Diagnostics for the PI4 device at General Fusion – Tuesday, October 18 2:00 PM – 5:00 PM
JP11.00145 – B. Brown – Design of a Four-Pin Triple Langmuir Probe for the Pi3 Spherical Tokamak at General Fusion Inc. – Tuesday October 18 2:00 PM – 5:00 PM

Plasma Reconstruction

See BP11.00003 – R. Zindler – Bayesian Equilibrium Reconstruction for General Fusion Demonstration Plant – Monday, October 17 9:30AM – 12:30 AM



Thermal confinement time determined through dynamic power balance



See PP11.00090 – C. Ribeiro – Progress on Transport Studies in the Spherical Tokamak (ST) Pi3 at General Fusion Inc – Wednesday, October 19 2:00 PM – 5:00 PM