The Dynomak Reactor System[1]

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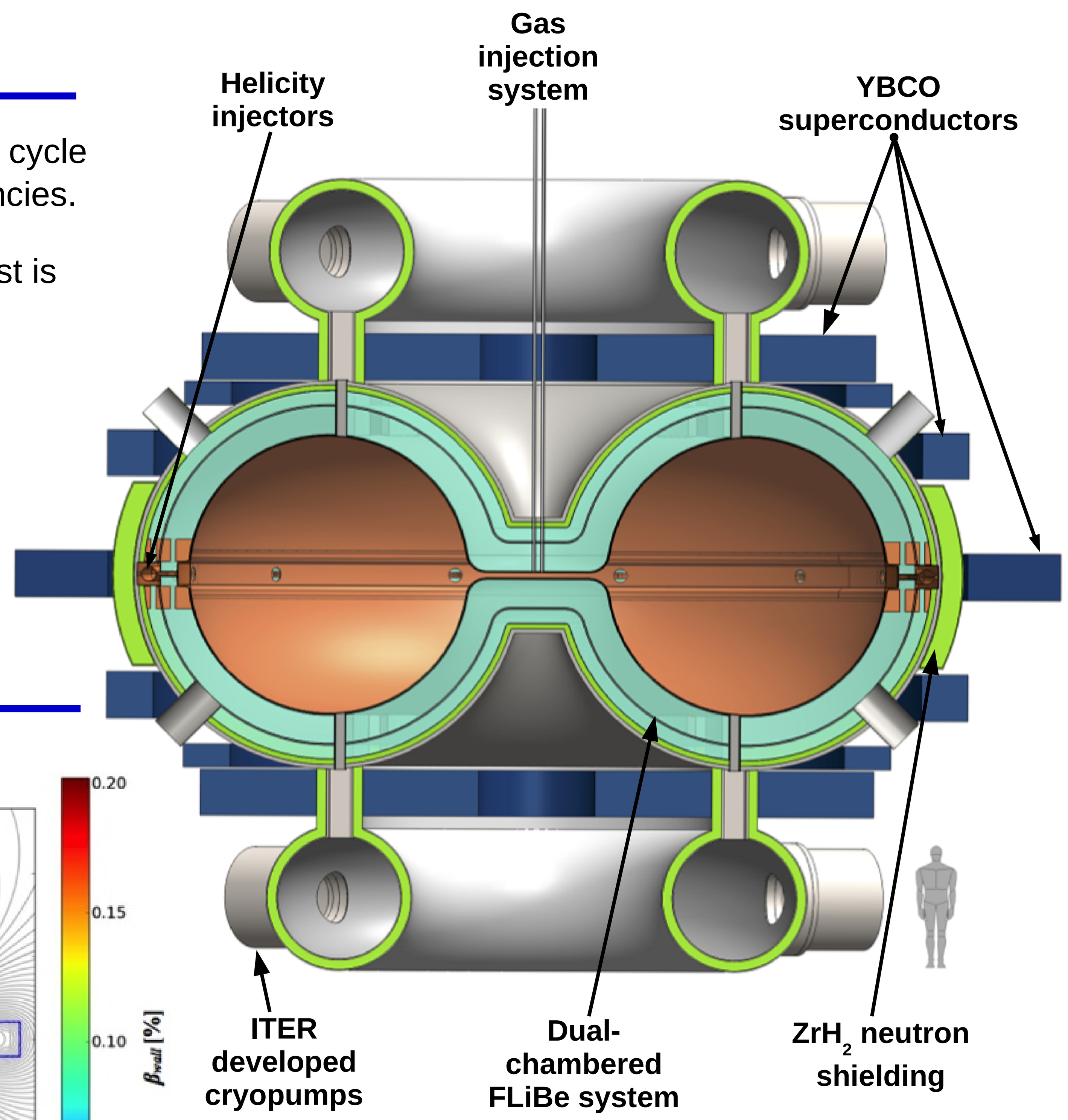
Dynomak Reactor System Highlights

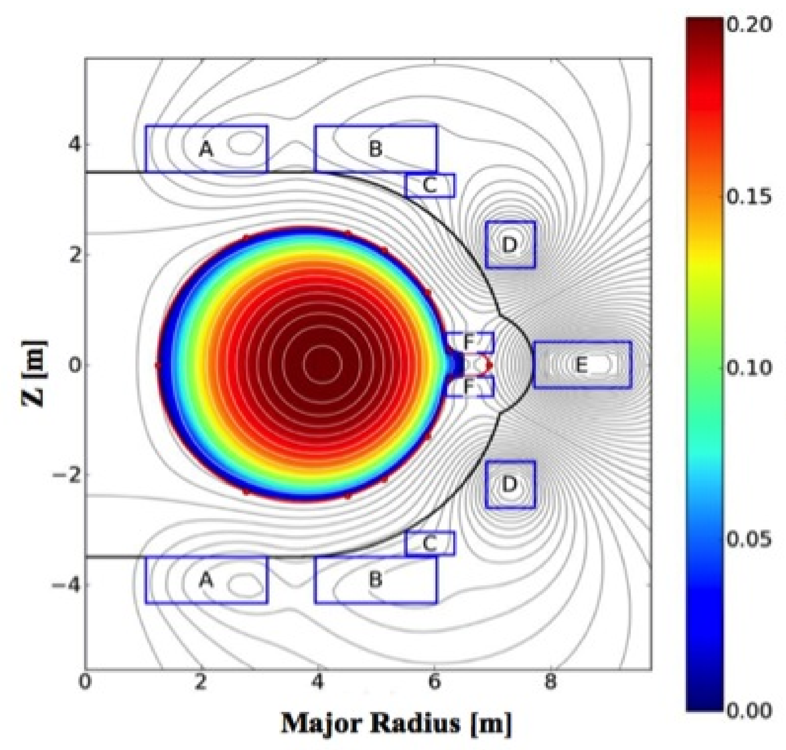
- Imposed dynamo current drive (IDCD) and a superconducting coil set enables an energy efficient reactor system.
- An molten-salt (FLiBe) immersion blanket system allows for sufficient tritium breeding ratio (TBR).
- Blanket system has unified, single working fluid design.
- A supercritical CO_2 secondary cycle allows for high thermal efficiencies.
- Dynomak overnight capital cost is competitive with conventional power sources.



Parameter	Value
R_o [m]	3.75
$A = R_o/a$	1.5
I_p [MA]	41.7
n_e [x 10^{20} m^{-3}]	1.5
$<\beta_{wall}>$ [%]	16.6
$T_{e,o}$ [keV]	20
TBR	1.125
P_{CD} [MW]	58.5
$<W_n>$ [MWm^{-2}]	4.2
$P_{thermal}$ [MW]	2486
P_{aux} [MW]	58.5
$P_{electric}$ [MW]	1000
Thermal efficiency [%]	$\geq$ 45
Global efficiency [%]	$\geq$ 40

IDCD and superconducting coil set enables energy efficient spheromak reactor system

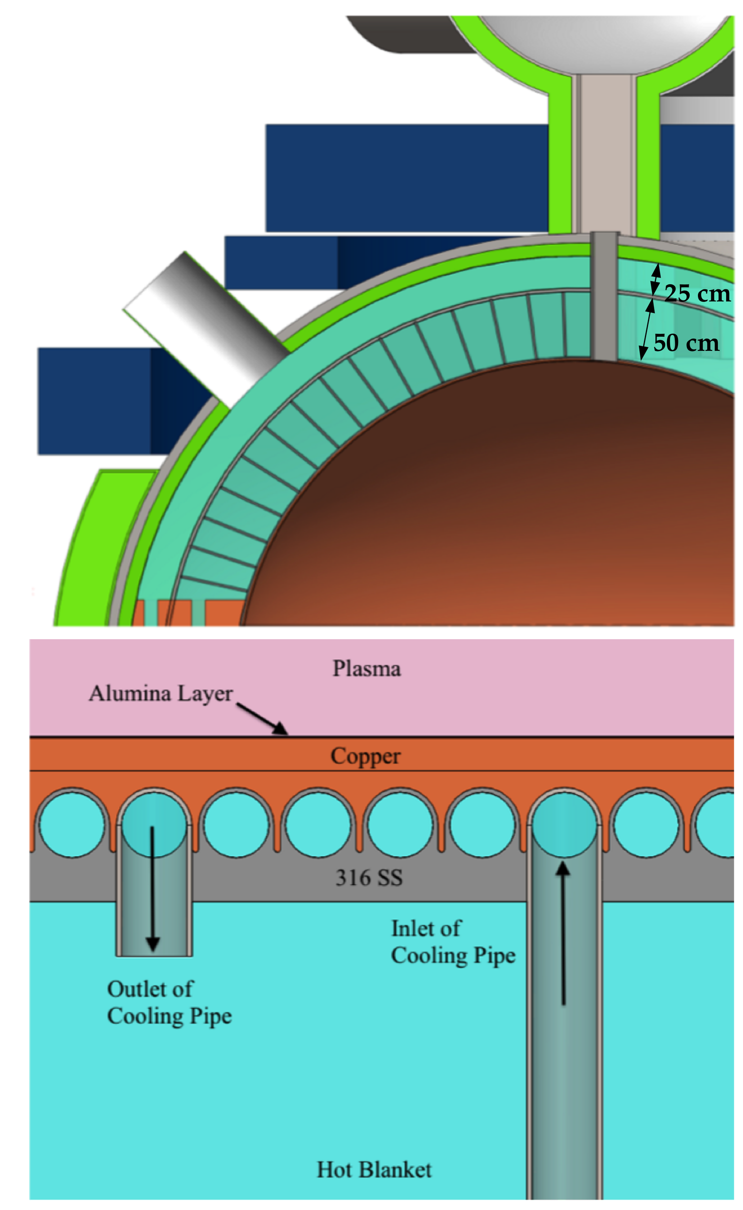
- IDCD perturbs and sustains a stable spheromak equilibrium.[2]
- Dynamo current drive is achieved without presence of gross plasma instabilities.
- Six inductive helicity injectors provide necessary edge currents and magnetic fluctuations ($\delta B/B \sim 10^{-4}$) for current penetration.
- An enhanced Grad-Shafranov code imposed marginal Mercier stability on each flux surface with $\lambda a = 2.4$ and an aspect ratio of 1.5.
- An optimized flux conserver provides high wall-averaged β of 16.6%.
- YBCO superconductors were used for coil set that are sub-cooled with liquid nitrogen.
- Twelve ITER-developed cryopumps connected to pumping manifold.
- Helium concentration limited to 3%.



Coil Set	MA-turns
A	-16.3
B	-5.2
C	0.4
D	-11.0
E	16.8
F	2.6

FliBe immersion blanket system allows for sufficient TBR of 1.125

- FLiBe was chosen as the liquid blanket material.
- A dual-chambered, pressurized blanket system enables single working fluid design.
- Minor radial cooling pipes connect pressurized outer blanket to first wall cooling system.
- FLiBe system couples to supercritical CO_2 secondary cycle with a thermal efficiency of greater than 45%.
- Global blanket temperature change is 100 °C.



Dynomak reactor system is most attractive of recently designed DEMOs

- Use of superconductors in a compact design allows for low recirculating power fraction.
- IDCD enables energy efficient current drive.
- Highest neutron wall loading out of reactor designs.
- FLiBe blanket offers high blanket power density due to excellent moderation capabilities.

Parameter	Compact Stellarator*	Tokamak*	Spherical Tokamak*	Dynomak
R_o [m]	7.1	6.0	3.2	3.75
$A = R_o/a$	4.5	4.0	1.7	1.5
I_p [MA]	3.3	11.6	26.2	41.7
P_{fusion} [MW]	1794	2077	2290	1953
P_{aux} [MW]	18	100	60	58.5
Q_p – Plasma gain	100	20.8	38.2	33
Q_e – Engineering gain	6.5	3.4	2.8	9.5
$<W_n>$ [MWm^{-2}]	2.8	3.0	3.4	4.2
$P_{electric}$ [MW]	1000	1000	1000	1000

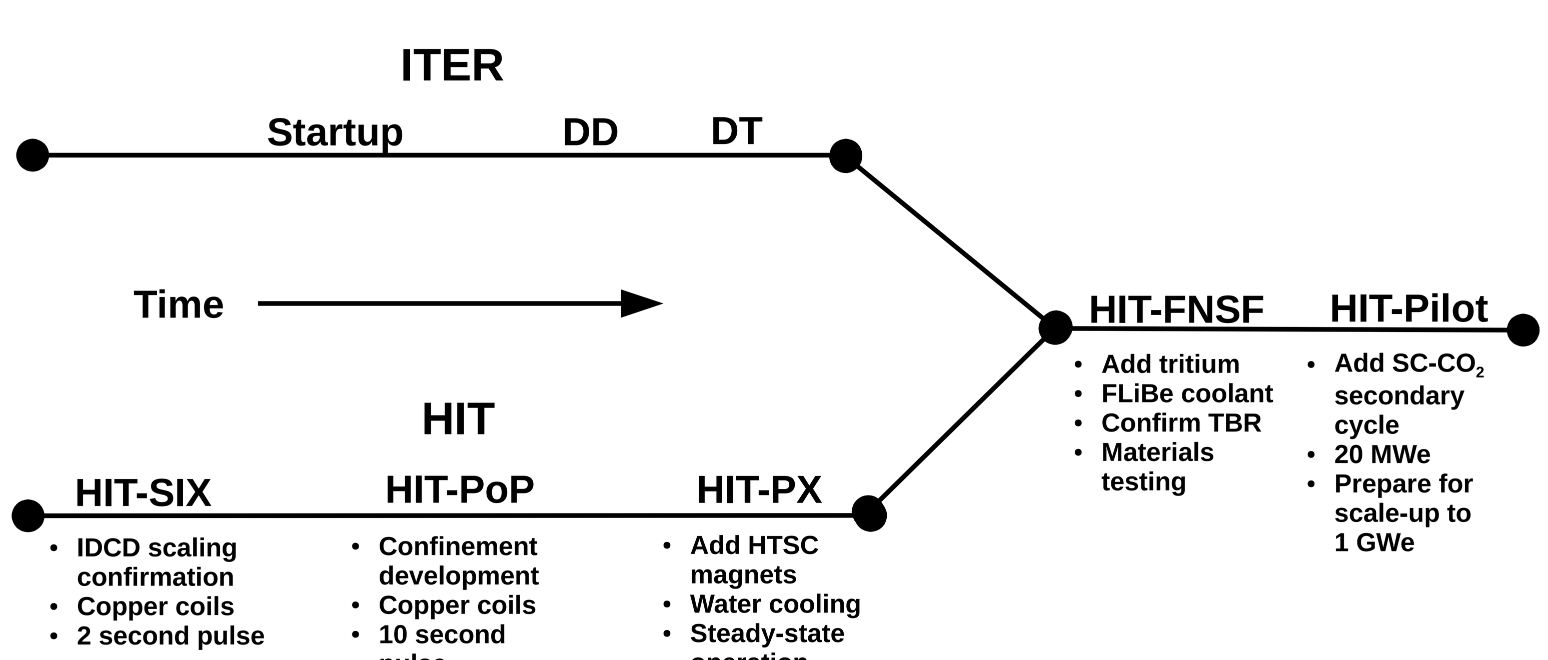
* J.E. Menard, et al., *Prospects for pilot plants based on the tokamak, spherical tokamak, and stellarator*, **Nuc. Fusion** 51 (2011).

Dynomak is economically competitive with conventional power sources

- Cost of reactor unit was determine via:
  - Scalings from the HIT-SI device
  - ITER priced components.
  - Estimations of bulk and secondary cycle costs from fission power plants.
- **The total overnight capital cost is estimated to be $2.713 billion.**
- Overnight capital cost of this reactor system undercuts fission and is on par with coal-fired power plants.
- First-wall is made of relatively cheap materials – reasonable maintenance costs
- Liquid immersion blanket does not require repair – modest introduction of Li-6 over time.

Dynomak development path includes multiple upgrades and ITER data

- Development path begins with pulsed, IDCD scaling experiment (HIT-SIX).
- Cost of fusion development is distributed.
- Total cost estimated at less than 1 GW power plant.



Summary

- A high-β spheromak reactor concept has been designed with a competitive overnight capital cost.
- An FLiBe immersion blanket allows for sufficient TBR.
- Conventional nuclear materials and ITER-developed technologies were used.
- Overnight capital cost is competitive with conventional power sources.
- Superconducting coil set and IDCD enable low recirculating power fraction.
- Future work includes:
  - HIT-SI3 injector physics.
  - Developing validated computer codes.
  - Demonstrate IDCD scaling in HIT-SIX

[1] D.A. Sutherland, et al., The dynomak: An advanced spheromak reactor concept with imposed-dynamo current drive and next-generation nuclear power technologies, *Fus. Eng. Design* **89** (2014) 4, 412-425.

[2] B.S. Victor, et al., Sustained spheromaks with ideal n = 1 kink stability and pressure confinement, *Phys. Plasmas* **21** (2014) 082504.