Structured Cable-in-Conduit for High-Performance Toroids

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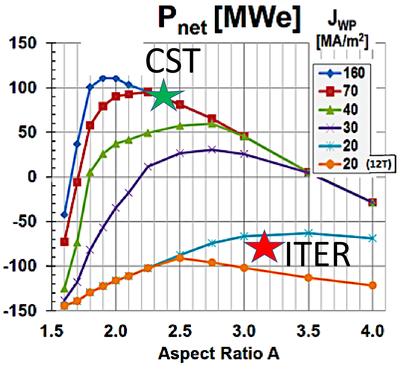
The challenge: Next-generation fusion magnets require high current density, high magnetic field, affordable cost.

Need J_{WP} = 100 MA/m²

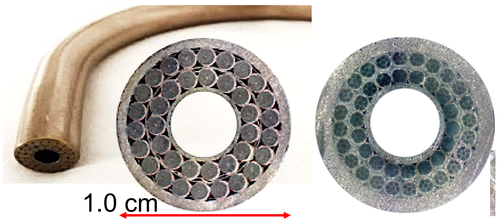


Net electric power from simulations of tokomak designs, as a function of aspect ratio A and the current density J_{wp} in the winding package.

Super-CIC: SuperCIC preserves the full supercurrent density of Nb_3Sn and Bi-2212. Super-CIC provides a practical basis for hybrid windings that use each superconductor in the region of the winding where its performance is optimum.

2-layer Super-CIC for fusion magnets:

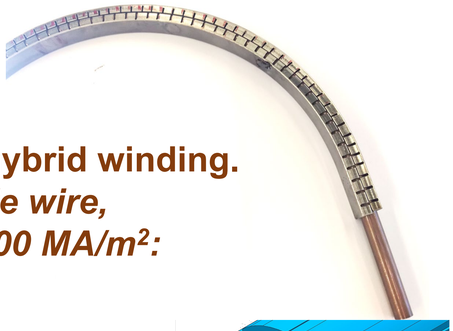
2-layer cable successfully fabricated in Nb_3Sn, Bi-2212.



42-strand Nb_3Sn CIC: **30 kA @ 17 T**

42-strand Bi-2212 CIC: **30 kA @ 12 T**

Co-wound armor: high-strength alloy armor, co-wound with Super-CIC, gives ultimate stress management and retains full performance of both superconductors.

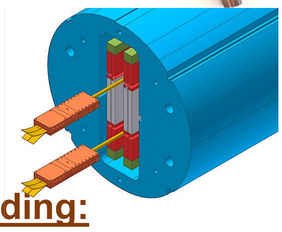


Super-CIC + Co-wound armor ➡ layer-wound hybrid winding.
We could build a next-gen tokamak with *available wire, affordable cost, and winding current density > 100 MA/m²:*
Plasma radius R_0 = 1.2 m, Aspect ratio A = 2.4

Next step to prove performance:

- Build long-length Super-CIC cable using Nb_3Sn
- Heat-treat, test sub-winding in background field to validate performance

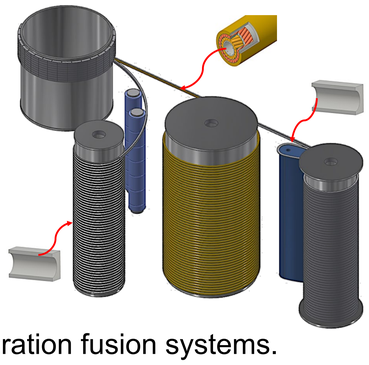
Cost: $250,000 ***Ready to start now.***
Schedule to build & test: 1 year after funding



Then ready to build a prototype solenoid with hybrid winding:

- Build 14 T solenoid with 50 cm bore, 50 cm length
- Layer-wound hybrid coil comprising Bi-2212 and Nb_3Sn sub-windings with co-wound armor.
- *Outcome*: Prove hybrid-coil Super-CIC ready for tokamak windings

Cost: $1,500,000
Schedule to build and test: 2 years after funding

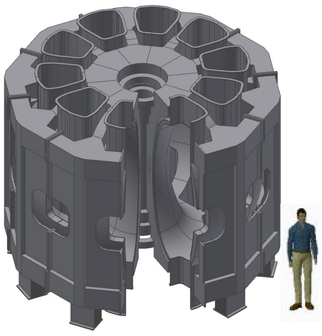


Benefits to fusion program:

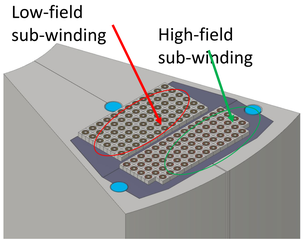
- Establishes a credible cable technology, hybrid coil technology, and stress management strategy for >16 T toroids and solenoids.
- Adapts well for topological windings for stellarators.
- Uses commercially available superconducting wire so performance and cost can be credibly projected.
- Rapid progress to validate SuperCIC hybrid windings for next-generation fusion systems.

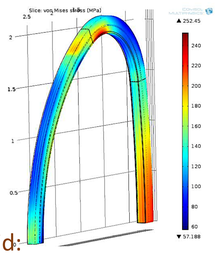
Two examples of Super-CIC hybrid-coil Compact Spherical Tokamak:

Both with R_0 = 1.2 m, A = 2.4



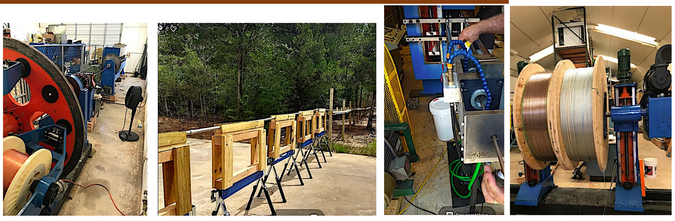
	Low Field Toroid	High Field Toroid
B@R_0,	4.75 T	6.7 T
B_{max}@coil	11.4 T	17.4 T
I_{op},	22 kA	29 kA
I_{op}/I_c @4.2K	0.7	0.7
Winding package J_{WP}	102 MA/m²	142 MA/m²
Total SC wire in 10-sector toroid:		
NbTi	305 km = $988,000	
Nb_3Sn	290 km = $2,151,000	305 km = $1,015,000
Bi-2212		290 km = $29,349,000
	$3,139,000	$30,364,000





Stress-managed High-Field Toroid:
250 Mpa max stress – no degradation

Public-Private Partnership:Texas A&M University, Acelerator Technology Corp:



Cabling & winding facility, team expertise -150 m lengths of 2-layer Super-CIC