



# Qualification Testing of SPARC's Poloidal Field Magnets

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Commonwealth Fusion Systems



# The fastest path to commercial fusion energy

## COMPLETED

Proven science  
Alcator C-Mod  
\$200M



## COMPLETED

Demonstrate  
Groundbreaking  
HTS magnets

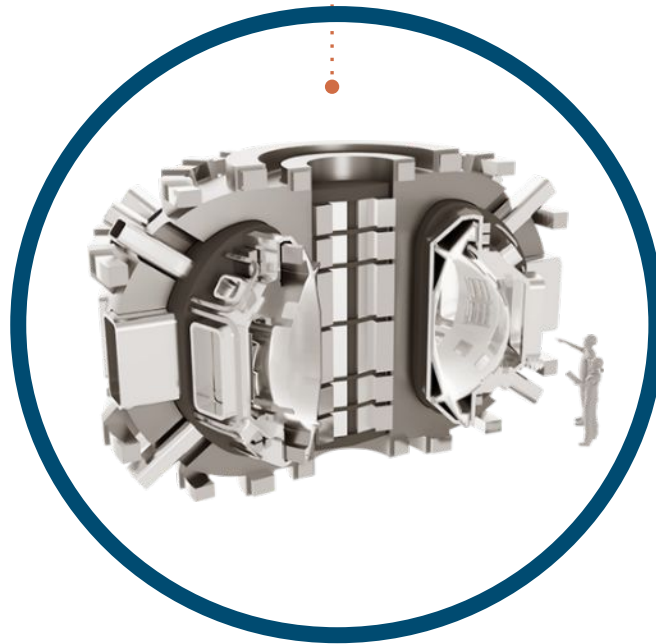


## ASSEMBLY UNDERWAY

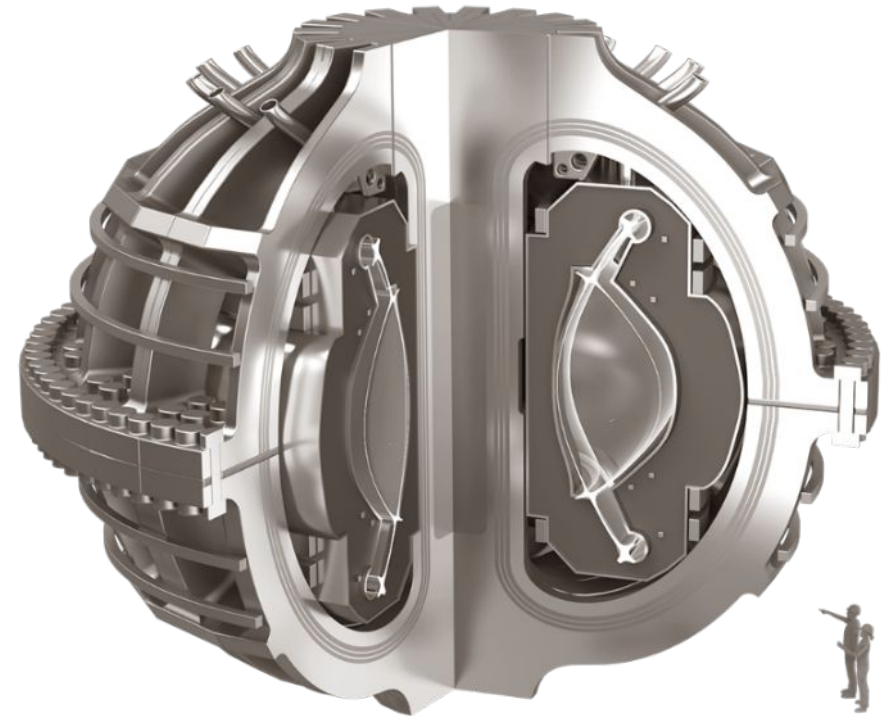
Achieve net energy  
from fusion

## Early 2030s

Fusion power on the grid  
ARC, Q>10, 200MW



**SPARC: Proof of concept**



**ARC: Carbon-free scalable commercial power**

Our magnet demonstration in 2021 gave us the funds to build SPARC, but it *didn't* retire all magnet risks.



# SPARC has two types of magnet systems

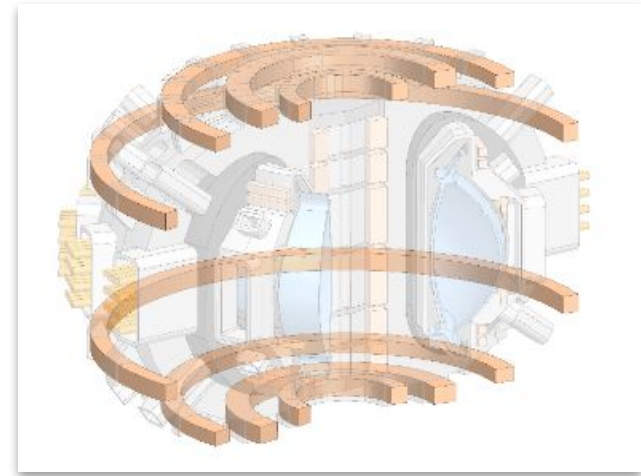
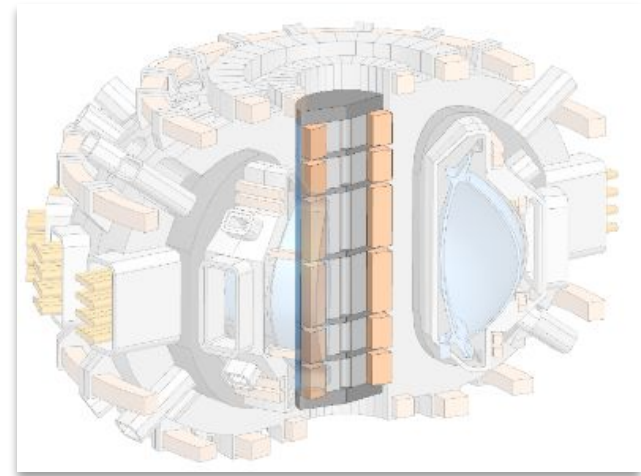
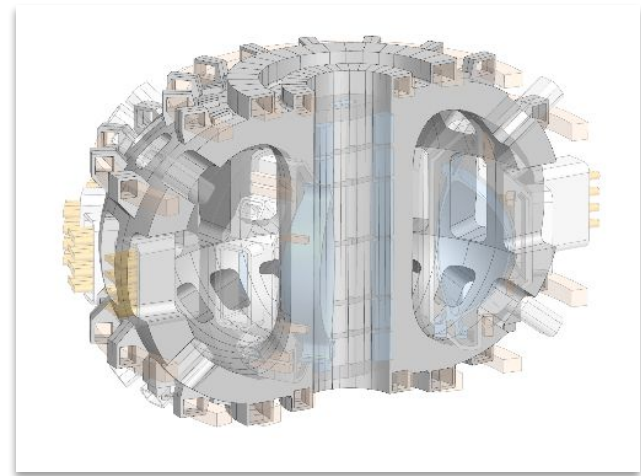
## NINT: Non-Insulated, Non-Twist

## Cables: Insulated and Twisted

### Toroidal field Coils

### Central Solenoid

### Poloidal Field Coils



#### Key risks:

- ✓ Large loads
- ✓ Manufacturability
- ✓ Scalability of HTS
- ✓ Quench protection

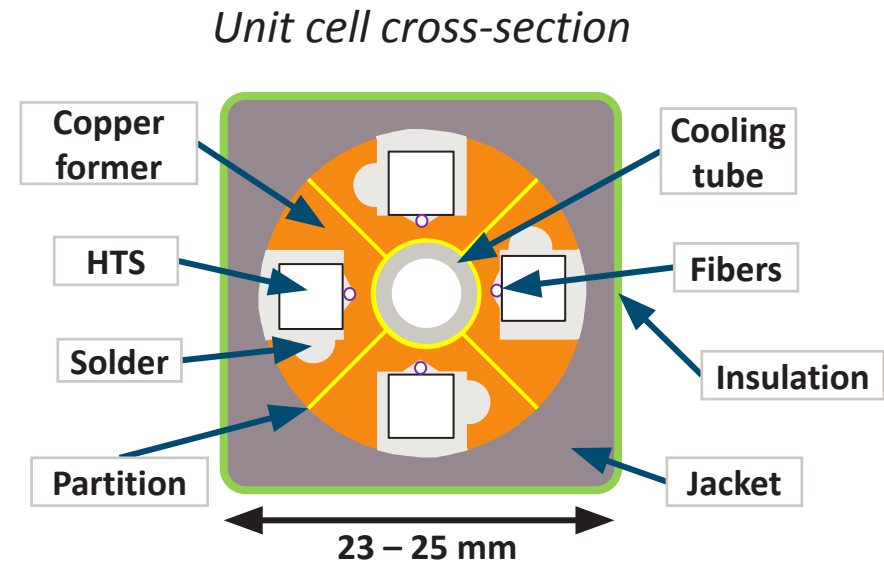
#### Key risks:

- ✓ AC losses in pulsed magnets
- ✓ Large loads from bucked tokamak design
- ✓ Quench detection and protection
- ✓ **Cable performance and manufacturability**

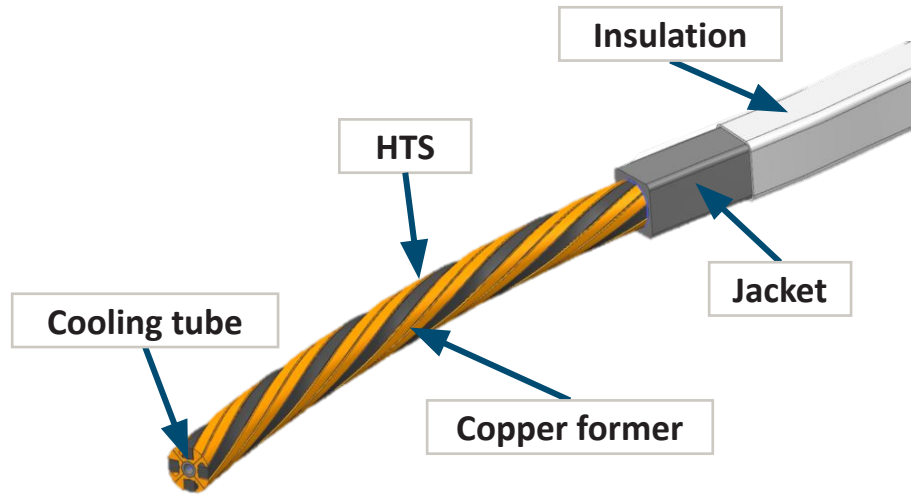
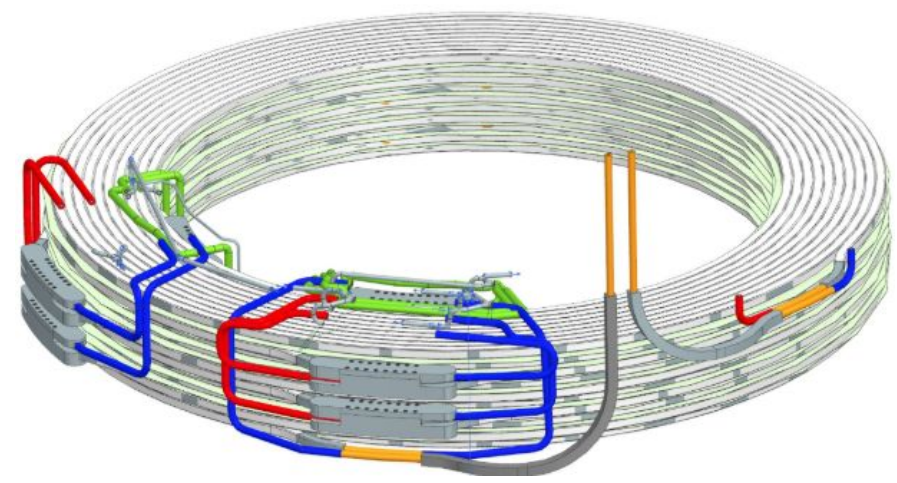


# The PIT VIPER cable

- PIT VIPER is the second generation of the VIPER cable developed by CFS and MIT
- Optimized for scalability, low-AC losses, and high EM loads
  - Used in 14 magnets
  - Operates at 50kA, 25T, and 5T/s
  - > 40MJ per magnet at 50kA



*Magnet made from PIT-VIPER cable*

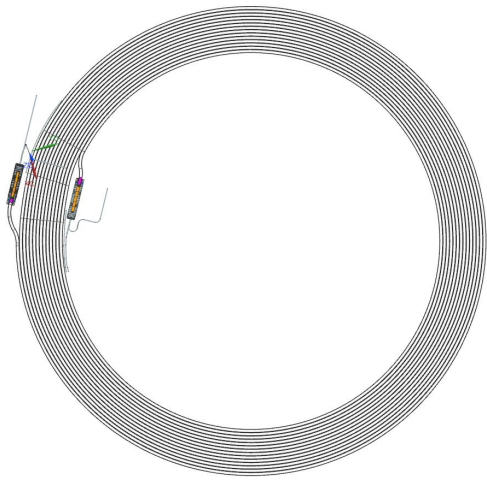


Charlie Sanabria et al 2024 Supercond. Sci. Technol. 37 115010

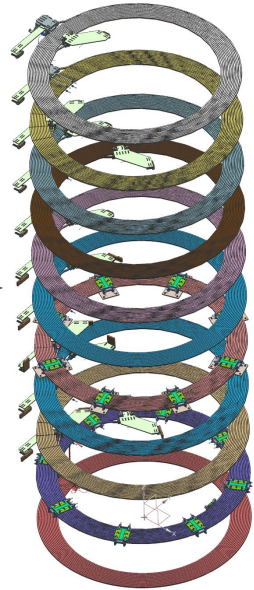


# Testing at each stage of production

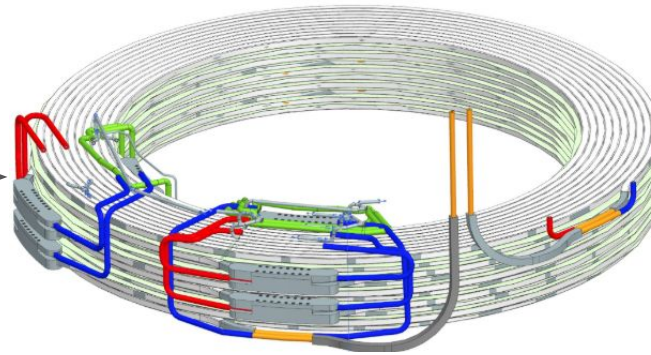
Production pancake



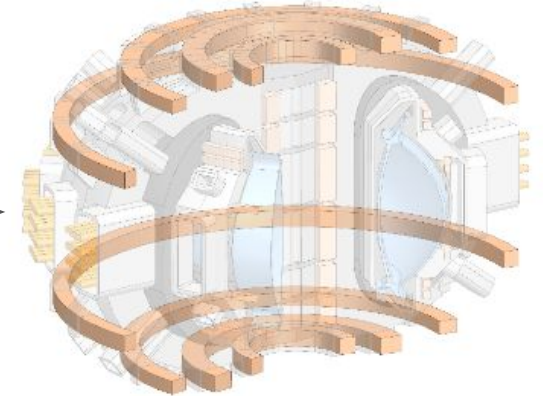
Pancake stacking



Complete magnet

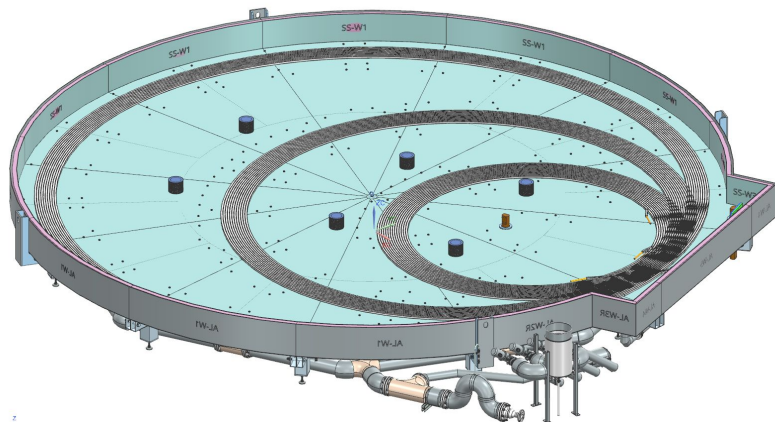


SPARC assembly



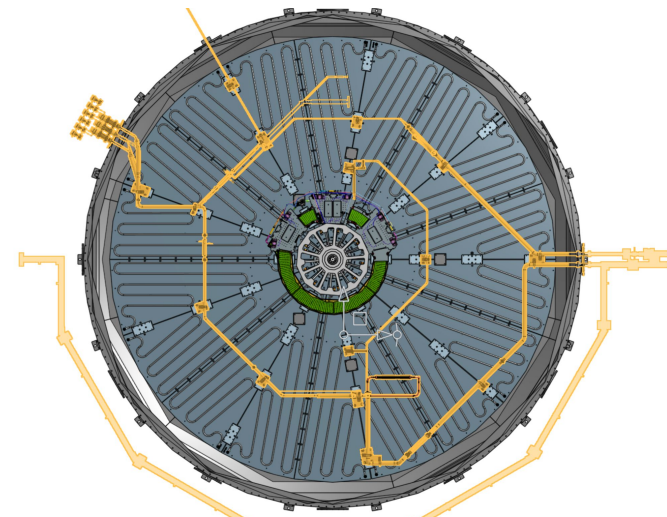
Single pancake test capability:

- LN2 (77.3K)
- < 20kA



Full magnet test capability:

- SHe (20K)
- < 50kA





# Testing at each stage of production

Production pancake

Pancake stacking

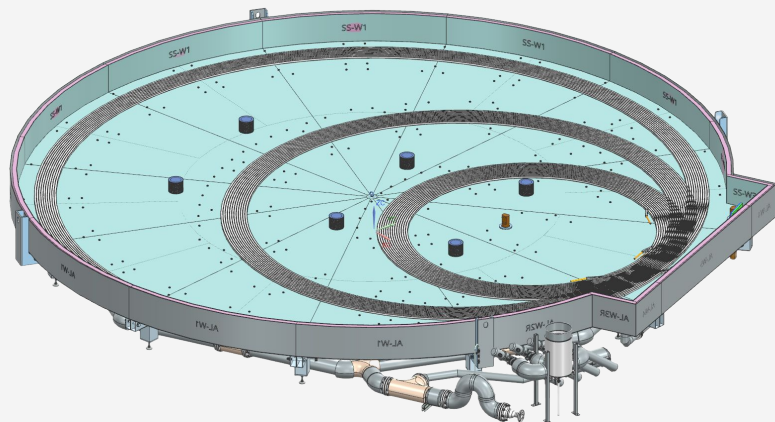
Complete magnet

SPARC assembly

**How do you *test* a pancake?**  
**How do you *assess* pancake performance?**

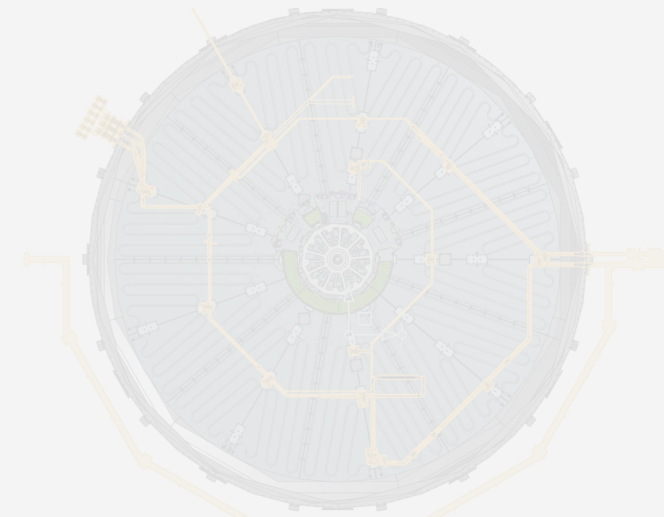
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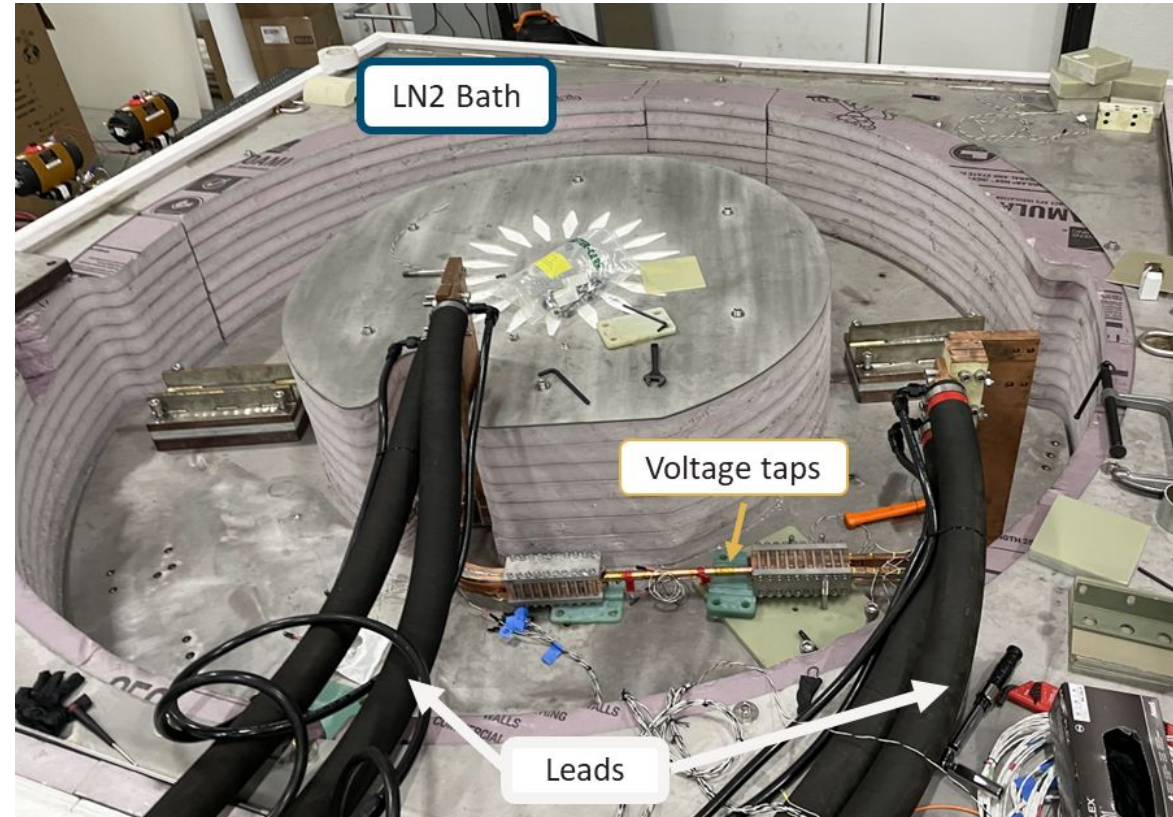
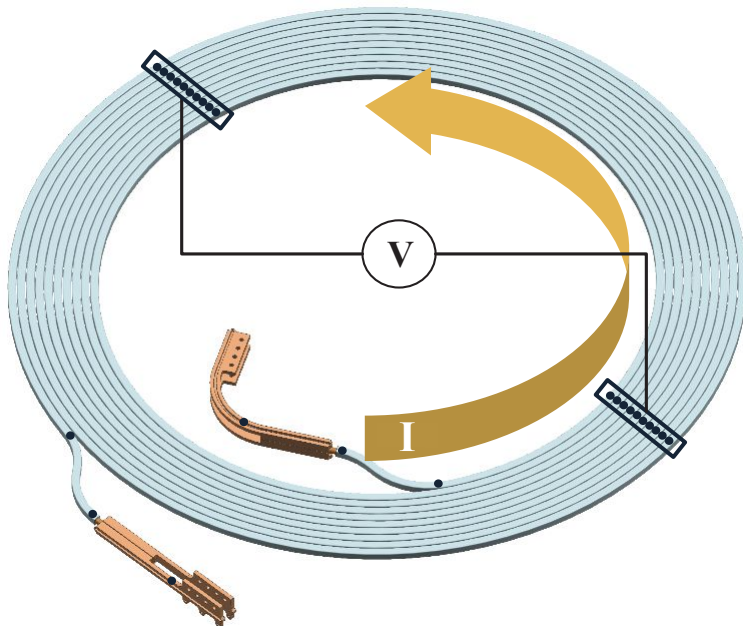
# How do you test a pancake?



# Basic test methods

One of the most effective ways to determine if a superconductor performs as expected is to do a transport current test

- Ramp current
- Measure voltage
- Fit  $I_c$  and  $n$ -value

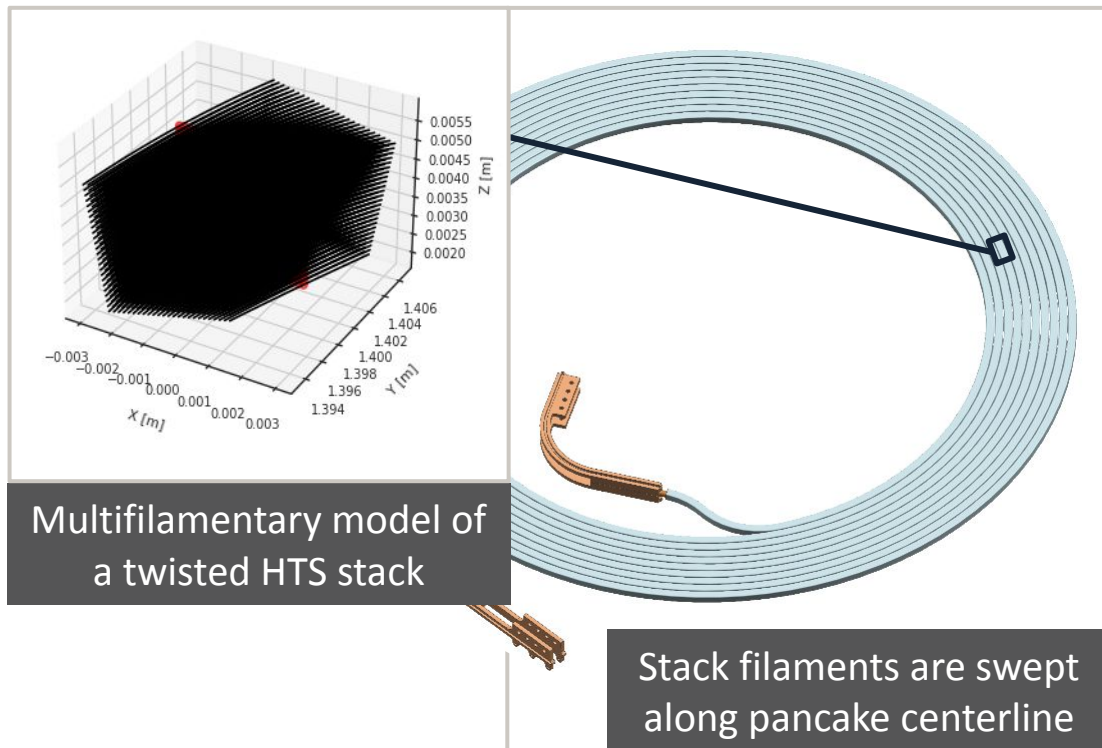




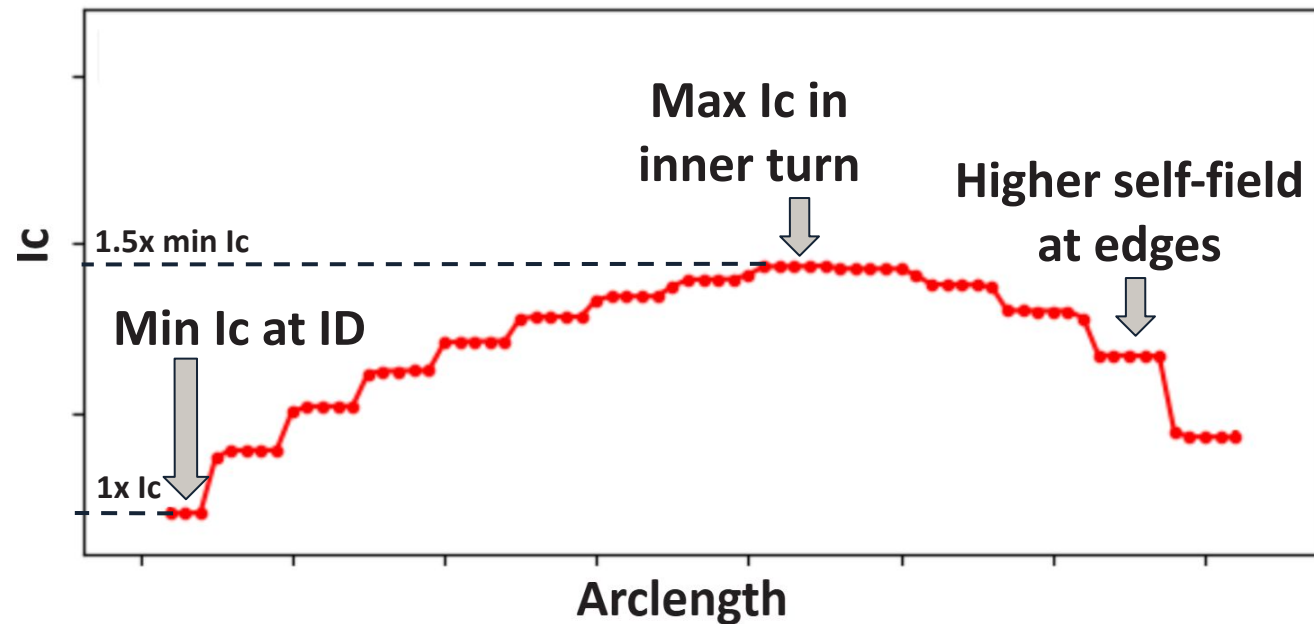
# Challenge: $I_c$ varies along the pancake's length

- Magnetic field profile causes  $I_c$  variation along the length up to several kA
- **Want to measure  $I_c$  everywhere, not just at the minimum  $I_c$  location**

### Magnetic field model



### Minimum $I_c$ vs. arclength

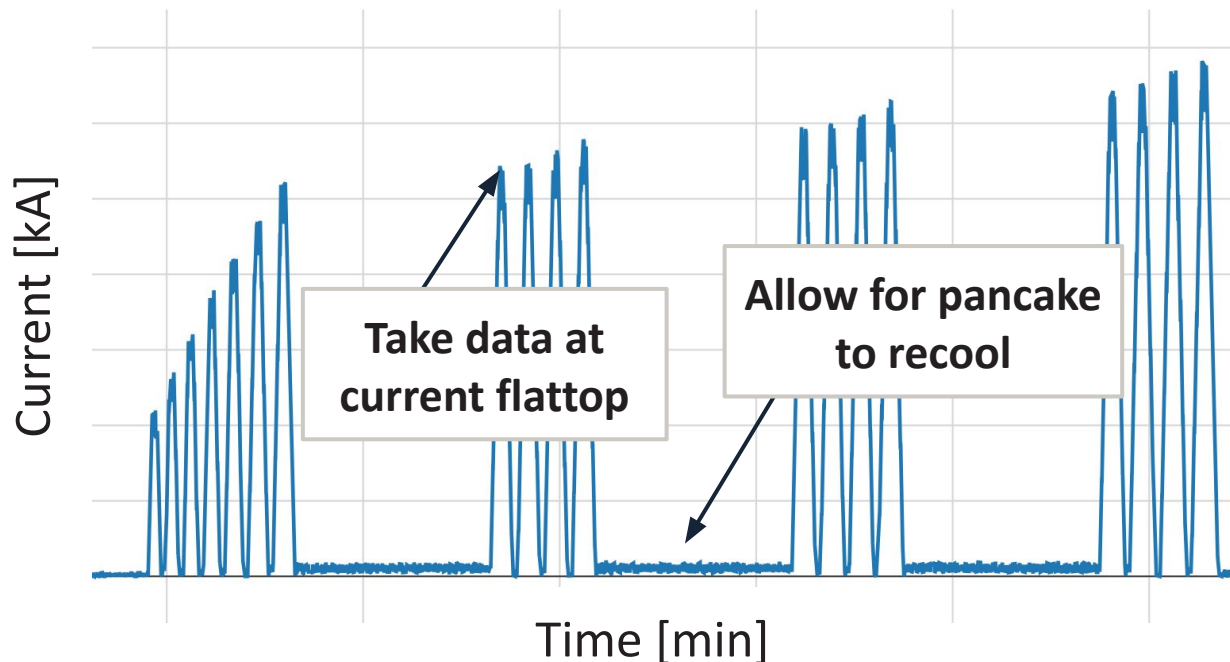




# Solution: overcurrent the pancake

- Only way to measure high  $I_c$  regions is to overcurrent the pancake
- Possible in insulated HTS magnets due to high heat capacity and stability
- Risk of burning the pancake if pushed too high above  $I_c$

Test current profile vs. time



LN2 bath provides heat sink



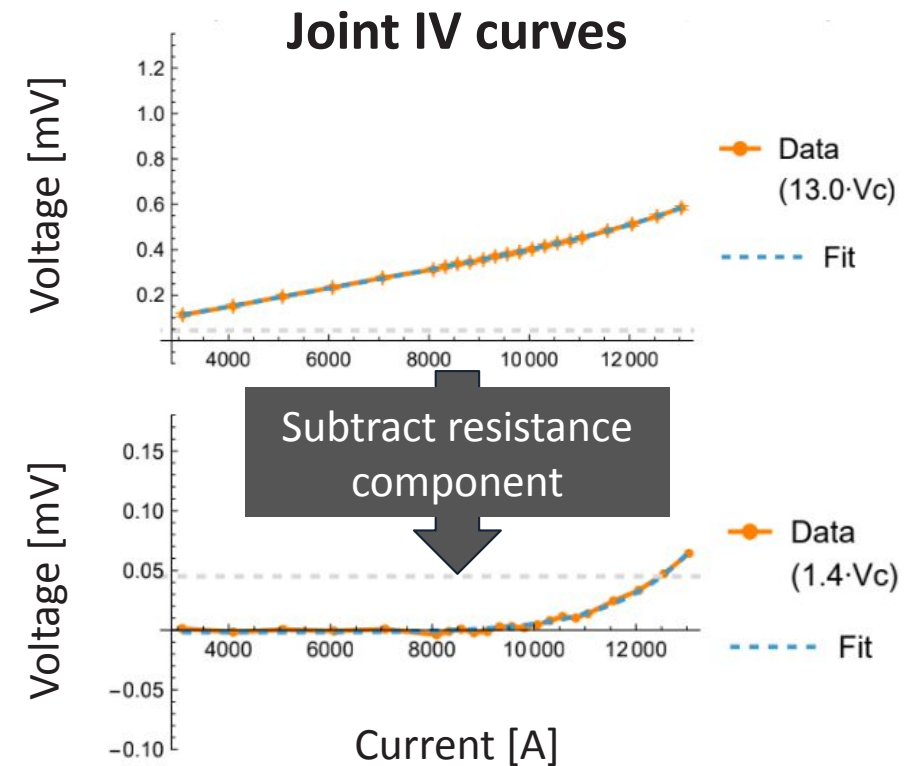
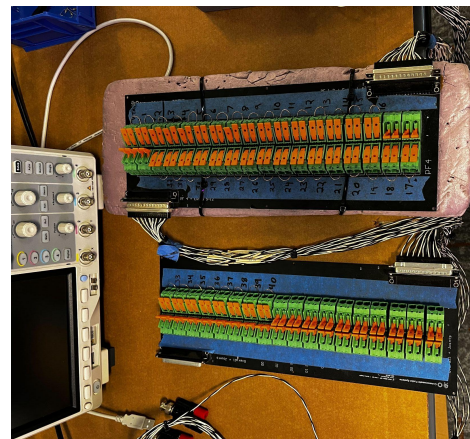
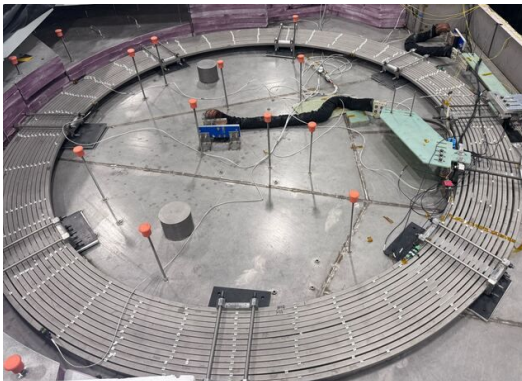
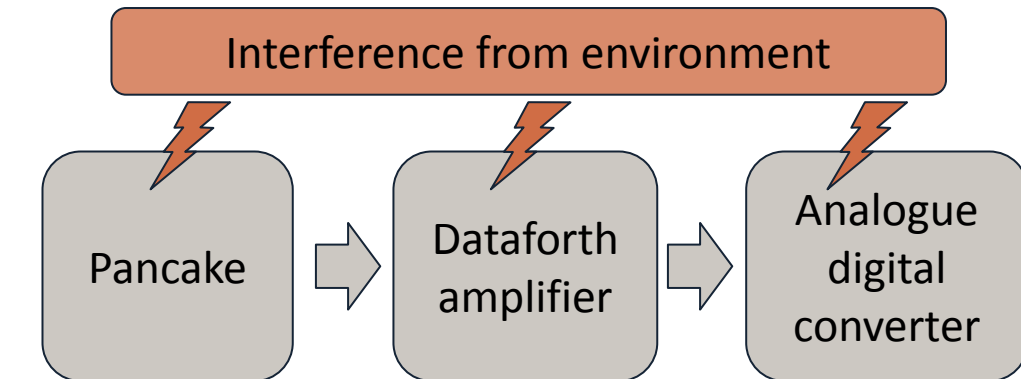


# How do you assess pancake performance?



# Understanding I-V measurements

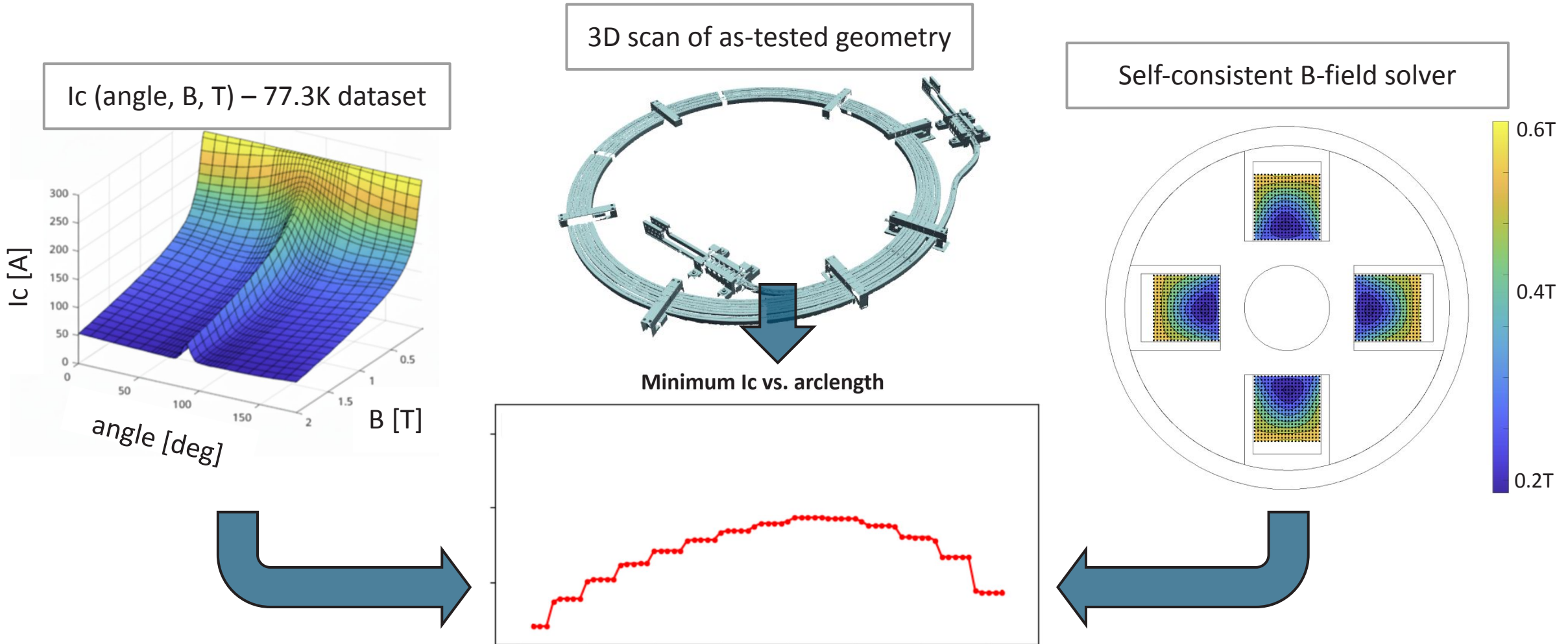
- Fit voltage vs. current to find  $I_c$  and  $n$ -value
- Propagate uncertainties: systematic uncertainty and noise in the test hardware, and uncertainty from the quality of the fit to the data
- In joints, subtract the resistance component to isolate the non-linear transition





# Compare measurements against “ideal” predictions

- Individual  $I_c$  predictions are made for each pancake using a Biot-Savart model
- Model captures each pancake’s unique set of HTS tapes and geometry

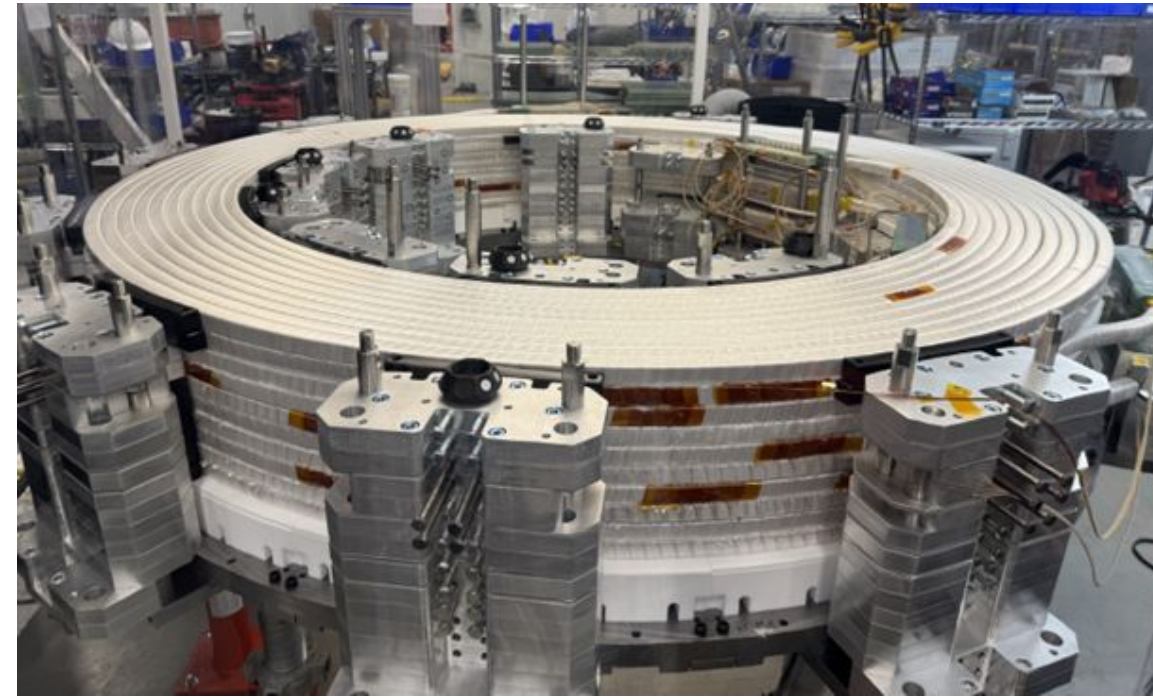




# We have tested and qualified several pancakes

- Acceptance criteria determines if pancakes go into SPARC
- Now preparing for 20K integrated magnet tests

PF testing status	
Pancakes tested	33
Pancakes turn insulated	22
Pancakes stacked	20
Winding packs complete	1





# Conclusions and discussion

We know how to test pancakes:

- Can **Ic test all regions of of our pancake** with no risk of damage
- Thermo-electric models predict quench temperature rise during test

We know how to assess pancake performance:

- Understand uncertainty and noise from hardware and fitting IV curves
- Can **predict Ic performance**, accounting for the as-built geometry and HTS usage

# Thank you!