SPARC Central Solenoid Cable AC loss and quench detection studies

INFUSE Workshop 2020

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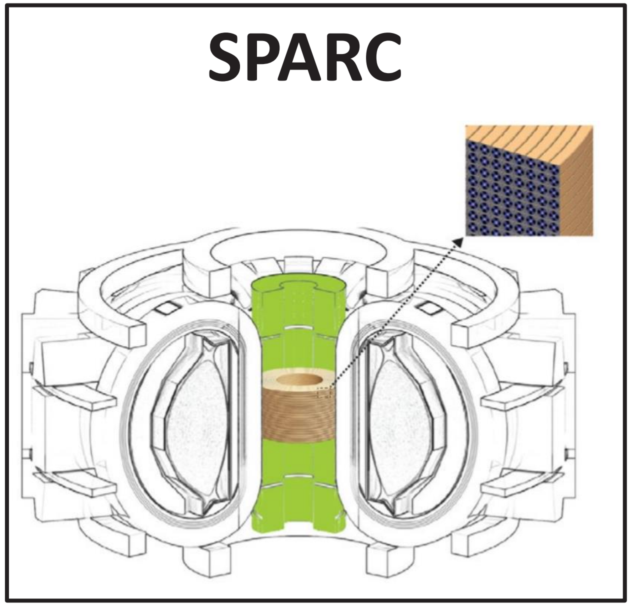
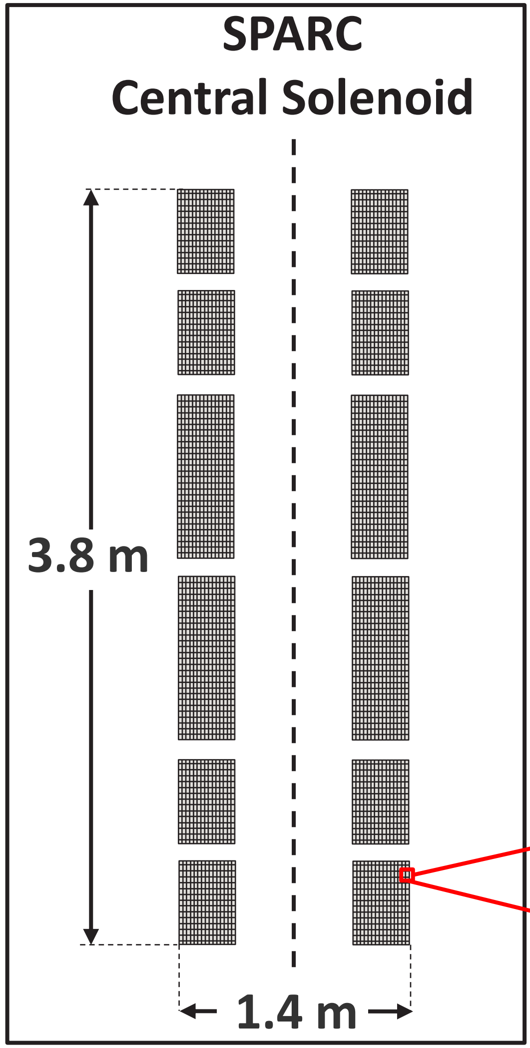
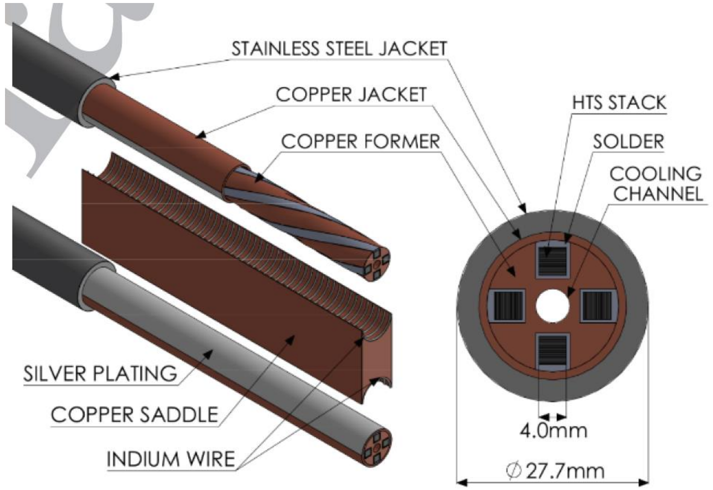
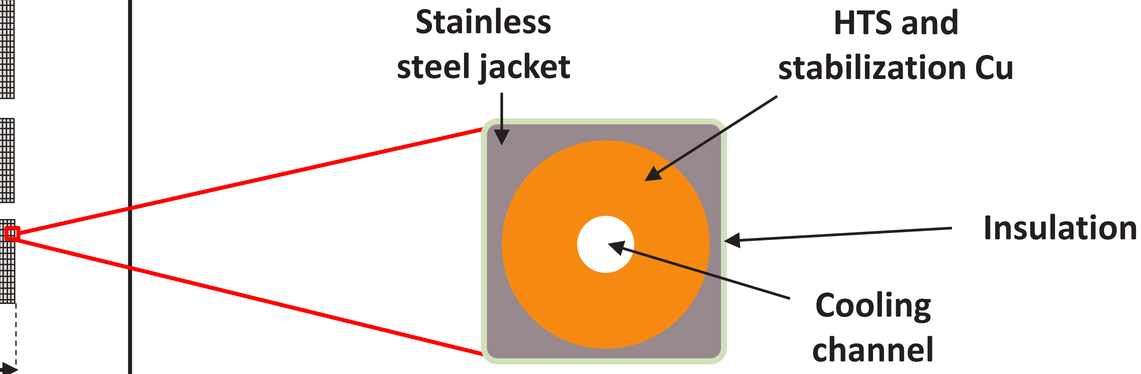
Introduction







[VIPER cables]



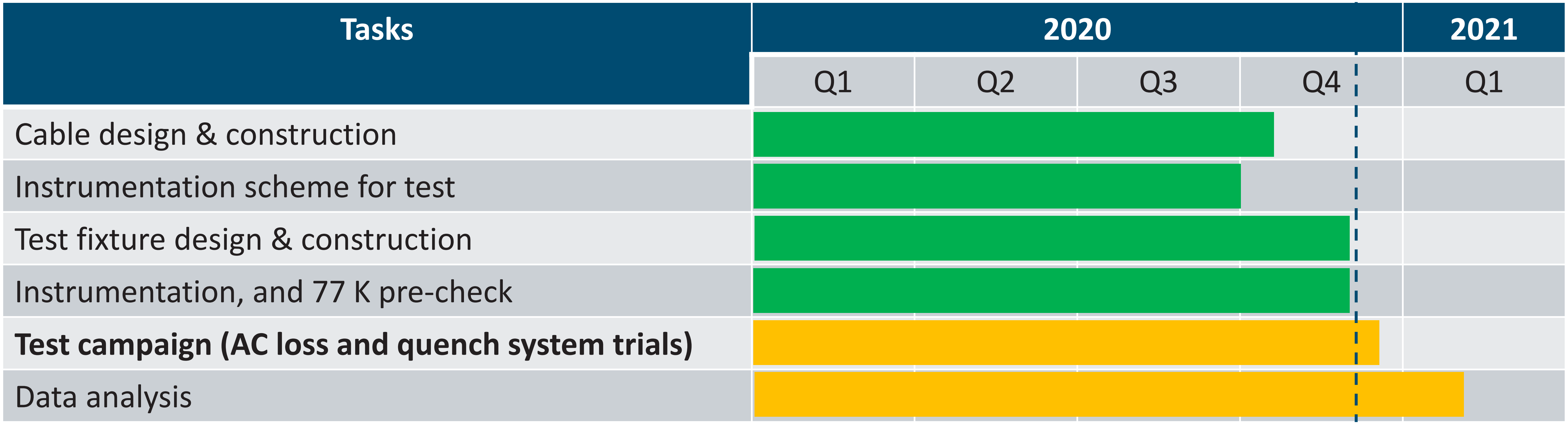
PIT VIPER (optimized for AC)

- Peak field greater than 20 T
- Ramp rate above 4 T/s
- 20 K operation

Program overview

Goal: Cable quench characterization using Brookhaven's Dipole Magnet DCC-017

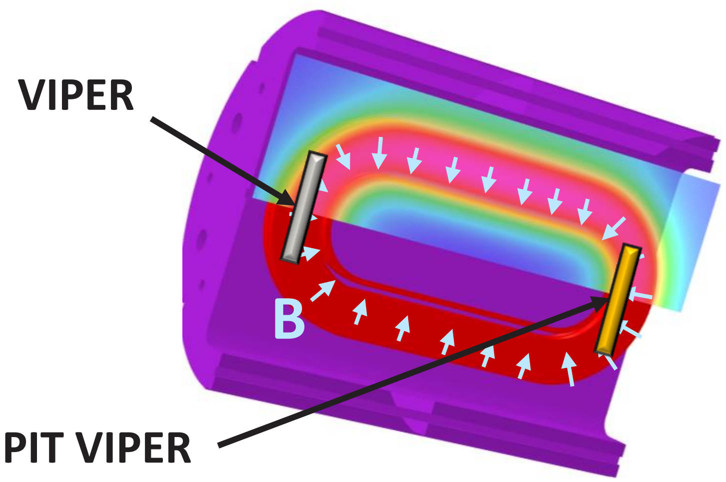
- Preliminary data obtained in January 2020 courtesy BNL internal program development funds for Fusion.
- **INFUSE program update –** Current-carrying quench dynamics test replaced with:
  - *No-current* AC loss test in vacuum.
  - *No-current* quench detection system qualification trials.
- CFS will financially support **additional test time** if necessary.
- Program is **on track** to be completed in Q1 of 2021.



Program goals

1. Characterize PIT VIPER cable AC losses at relevant dB/dt

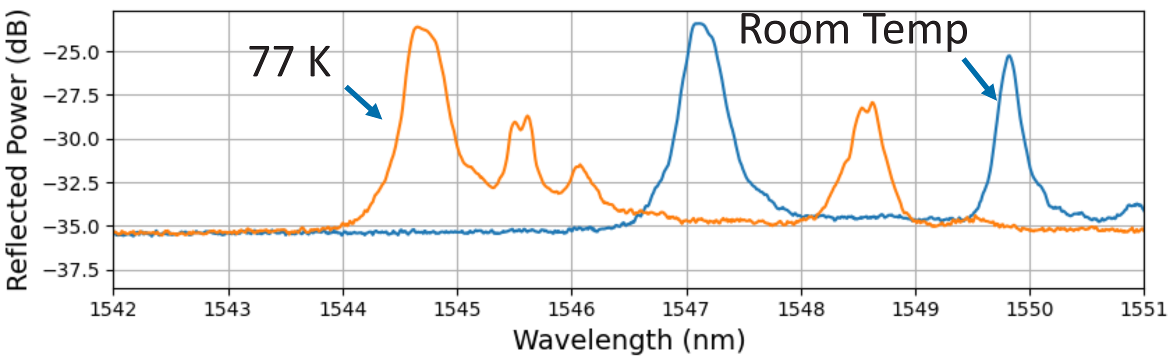
Note: induced currents from the changing magnetic field are heating up the sample (AC losses).



Preliminary measurements taken at BNL on short samples in January 2020. At high (non linear) dB/dt PIT VIPER showed a clear advantage, but experimental issues yielded inconclusive results.

2. Characterize and qualify novel quench detection systems.

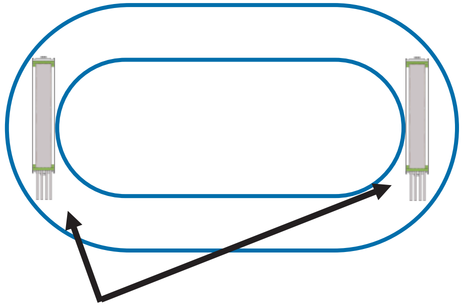
Note: quench detection systems are not being qualified with transport current, only heat pulses.

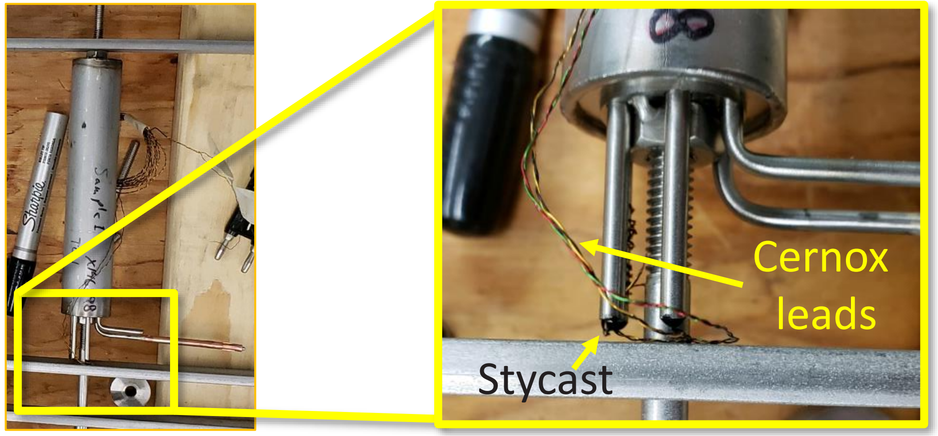


Fiberoptic signals obtained at 77 K from PIT VIPER cables.
Each peak, randomly formed by strain state of the fiber, can be used to identify rapid temperature changes in the cable.

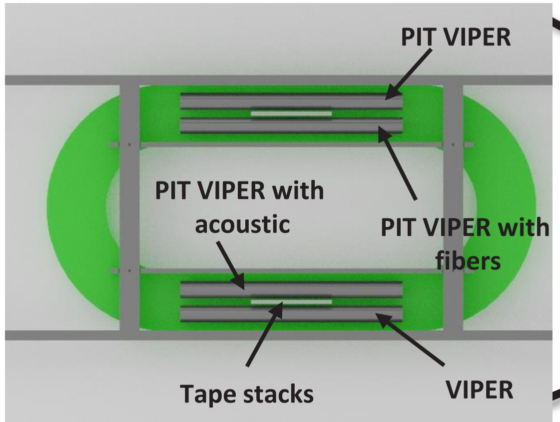
Current status and lessons learned

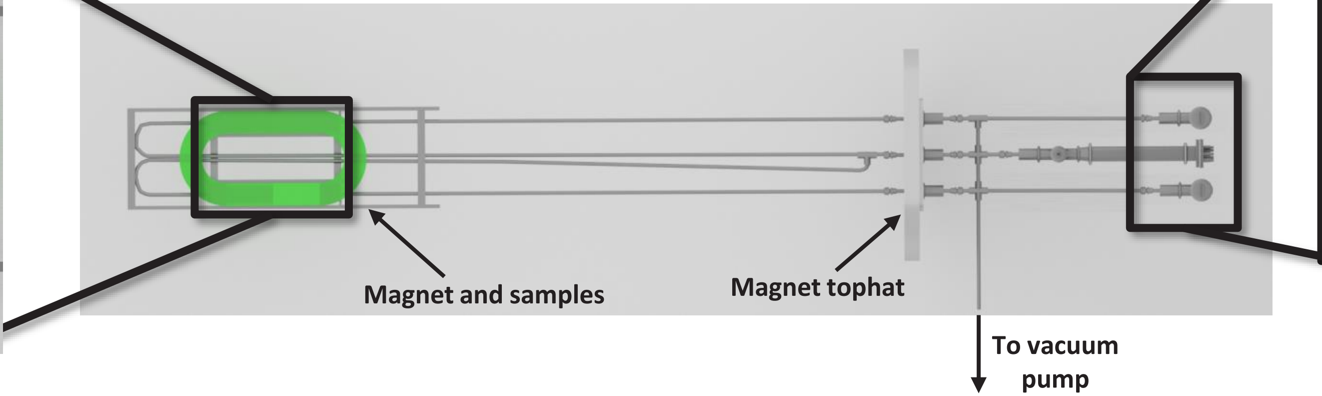
- Vacuum is used as thermal insulation from the liquid He.
- Our preliminary test approach (Jan 2020) used Stycast in thin tubes as instrumentation feedthroughs.

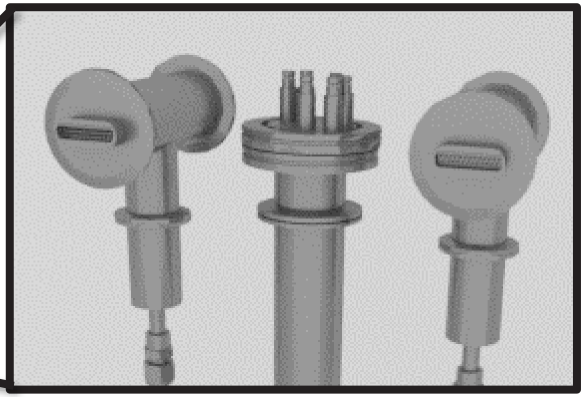




The actual test will use more reliable equipment, longer samples, and additional instrumentation.





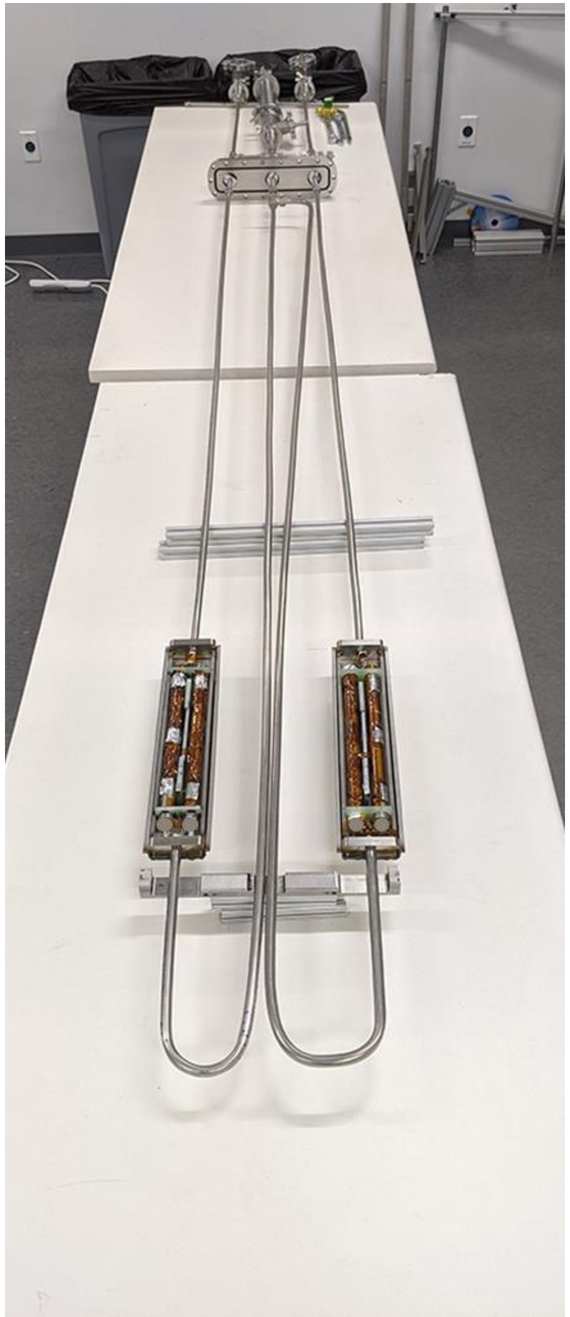


Room temperature vacuum feedthroughs for electrical and fiberoptic sensors outside of the magnet pit

Recent and future steps

- We have recently sealed the sample rig, tested the welds for leaks, and did a **mock run** at liquid nitrogen temperatures.
- Samples are being **delivered** to BNL as we speak.

- **Test** will be carried out in December 9th – 11th
- A series of **linear ramp rates** will be induced on the samples in order to understand the heating due to AC losses.
- Results will be used to **validate models**, and models will be used to **extrapolate** to SPARC's operational dB/dt.
- Heat pulses will be induced on the samples in order to qualify quench detection system **response**.



Risks and mitigation

- **COVID-19** is our main risk at the moment. The possibility of travel bans or lab closures may delay the test.
  - Remote testing is being considered, but it shouldn't be needed as long as New York state does not impose lockdowns or travel bans.

- **Leaks** in the instrumentation at liquid He temperatures are always a threat.
  - Room temperature He leak checks on welds are usually reliable down to 4 K.
  - High vacuum is not required (a few mTorr should do)

- Cernox (temperature sensors) or other **sensor failures** are always possible.
  - Redundancy and control-sample sensors are implemented.

Impacts on SPARC

- SPARC's central solenoid (CS) will ramp from ~25 T to "negative" ~25 T in less than ten seconds.
- We are expecting a significant advantage on AC losses using PIT VIPER over VIPER, but this must be confirmed experimentally.
- If the experiments and the models project manageable AC losses for the present PIT VIPER design, SPARC's CS design will be able to move forward.

2019 INFUSE Programs on the SPARC Timeline

SPARC

Divertor Component Testing
Oak Ridge National Laboratory

Divertor Plasma Simulations
Lawrence Livermore National Laboratory

Divertor CDR

Materials Downselect

Plasma Facing Components PDR

2020 (Q4) | **2021 (Q1)** | **2021 (Q2)** | … | **2025**

Toroidal Field CDR

Central Solenoid CDR

Limiter CDR

Central Solenoid Model Coil PDR

SPARC commissioned

Alpha Particle Diagnostics
PPPL
PRINCETON PLASMA PHYSICS LABORATORY

Superconducting Cable AC Loss and Quench Detection
BROOKHAVEN NATIONAL LABORATORY