Cryogenic and magnet design for the Princeton aXion Search

Joëlle-Marie Bégin

SIMONS FOUNDATION

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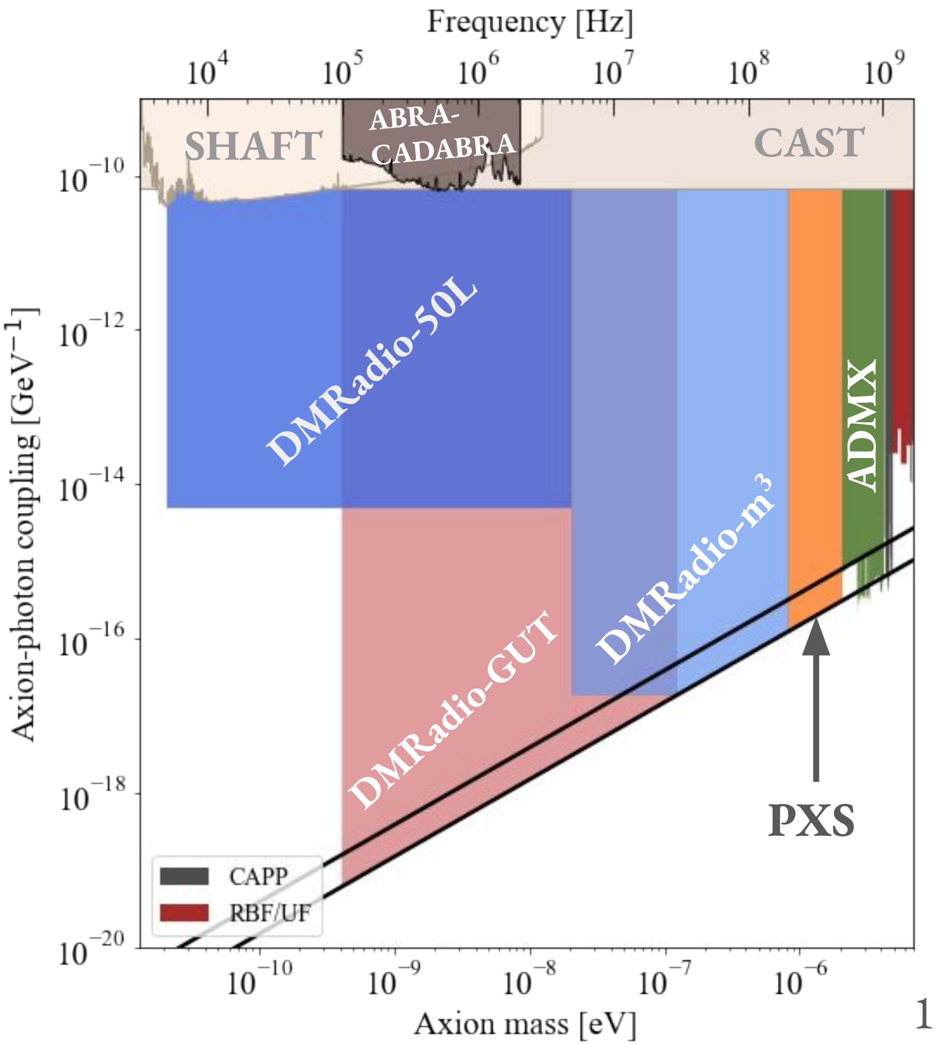
PRINCETON PLASMA PHYSICS LABORATORY

JPL
Jet Propulsion Laboratory
California Institute of Technology

The Princeton aXion Search (PXS)

- 0.4 m^3 cavity immersed in a ~0.8 m bore, 5 T conductively cooled magnet.
- Travelling wave parametric amplifier (TWPA) readout.

- Cavity and first stage amplifiers cooled to 40mK with dilution refrigerator.
- Magnet cooled to 4K with two PT420 pulse tube cryocoolers.



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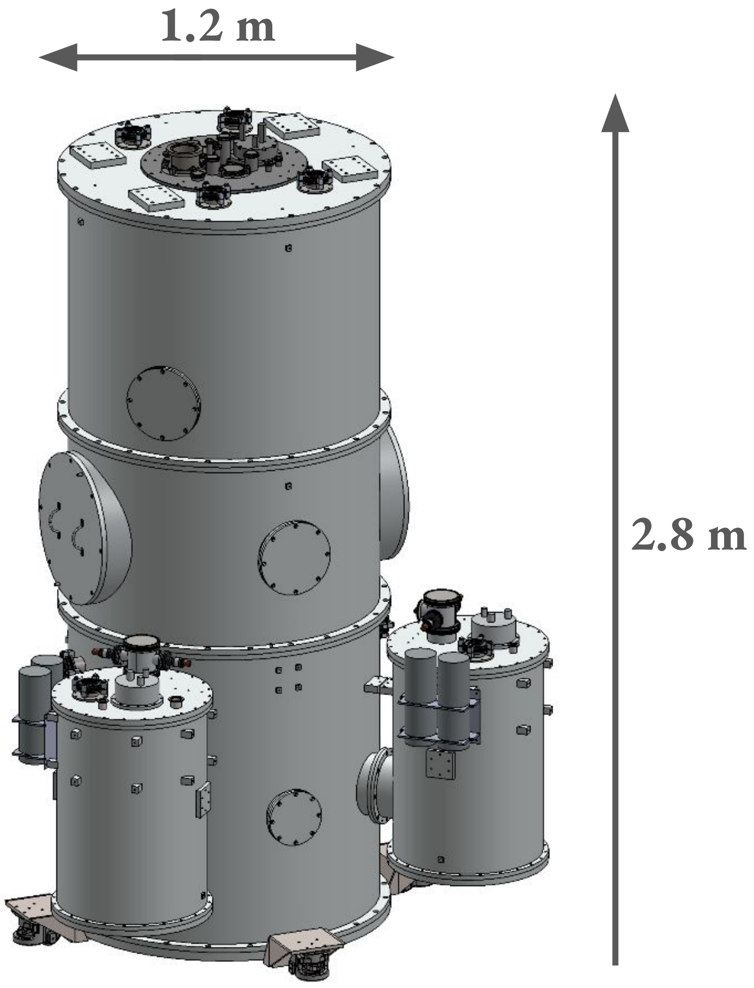
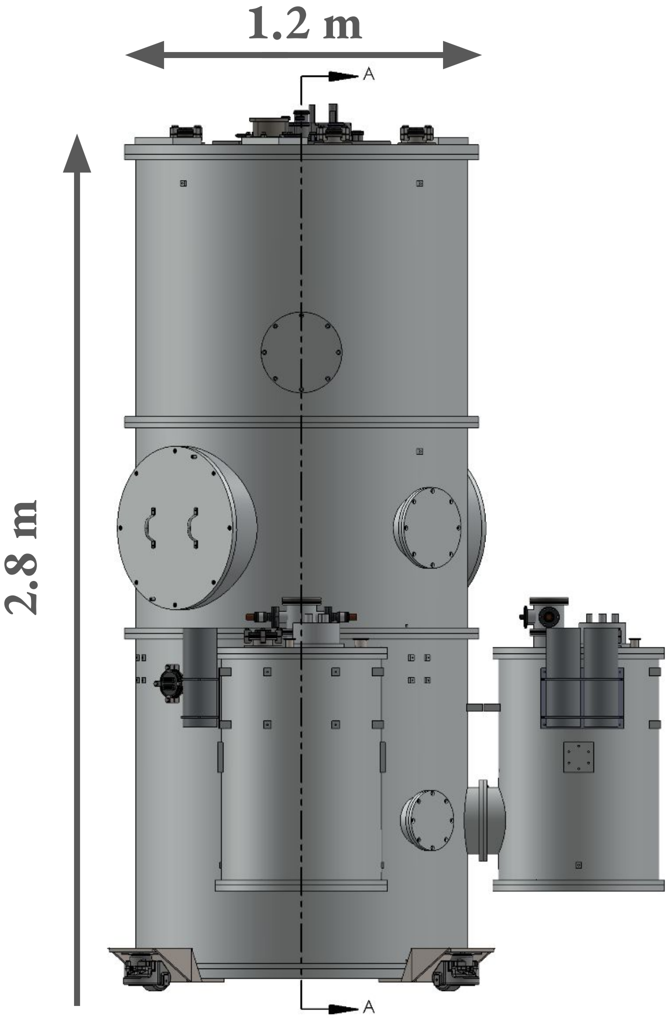
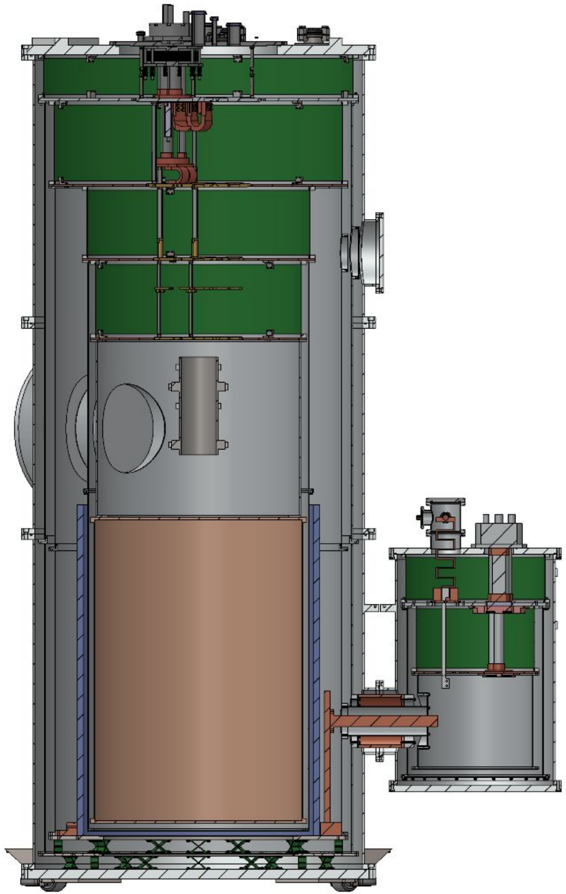
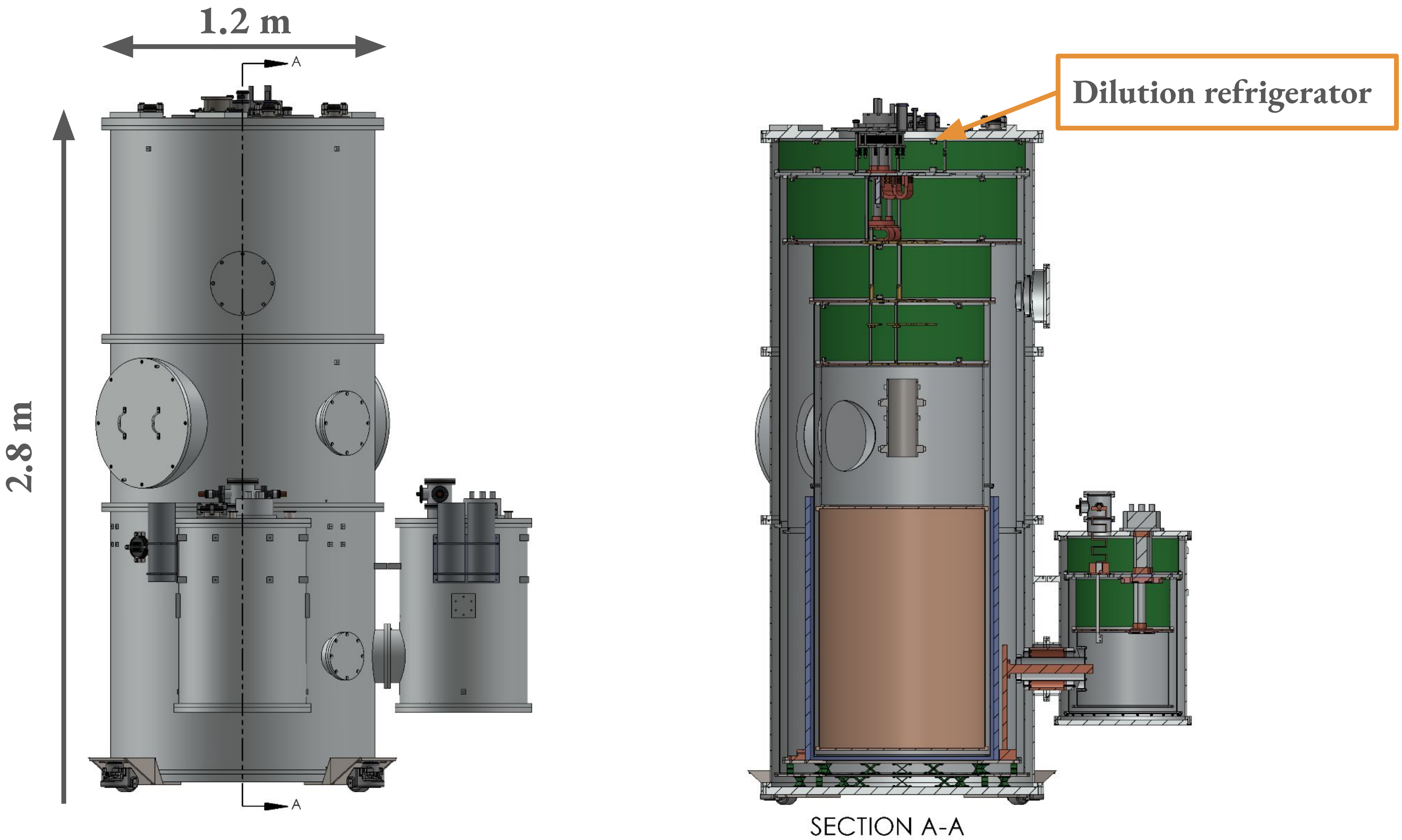
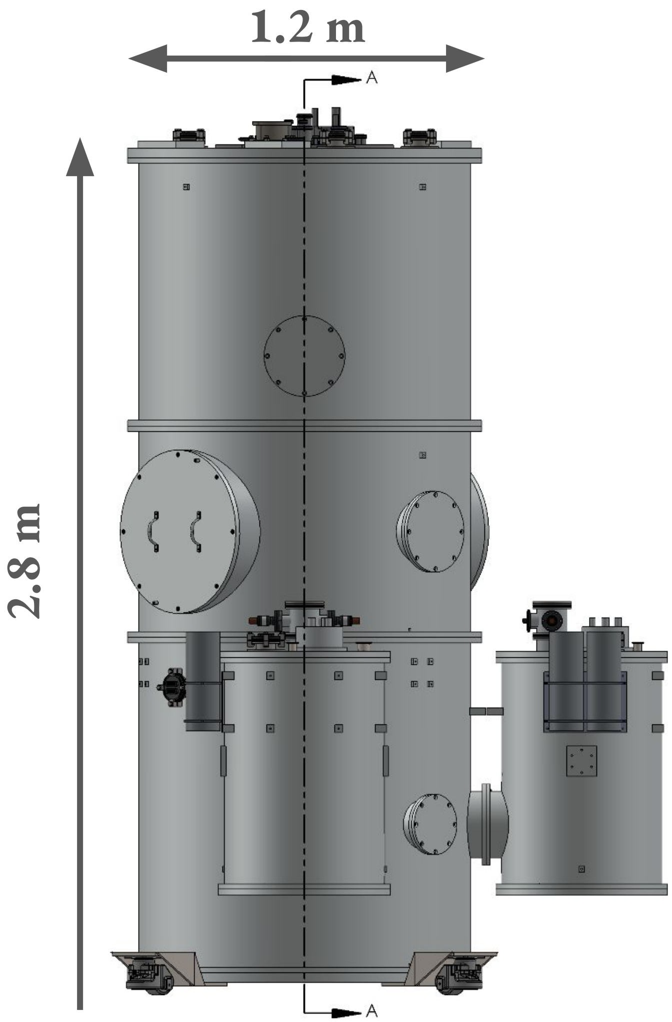


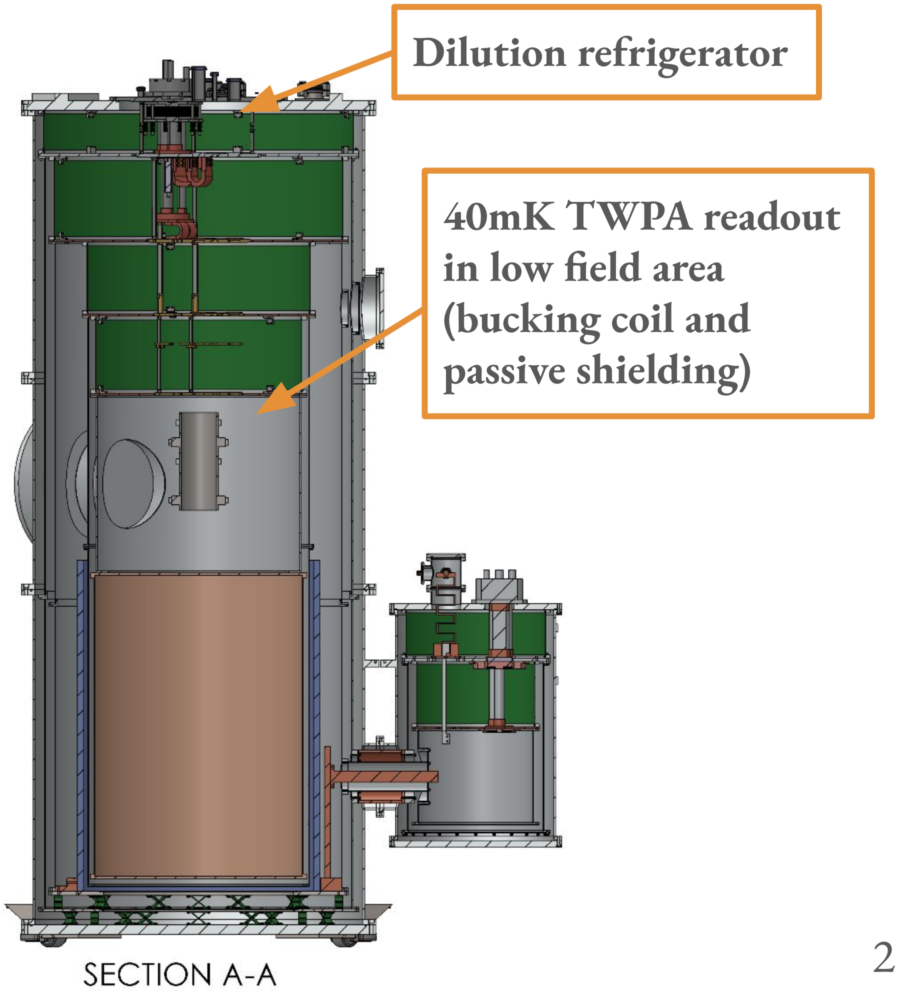


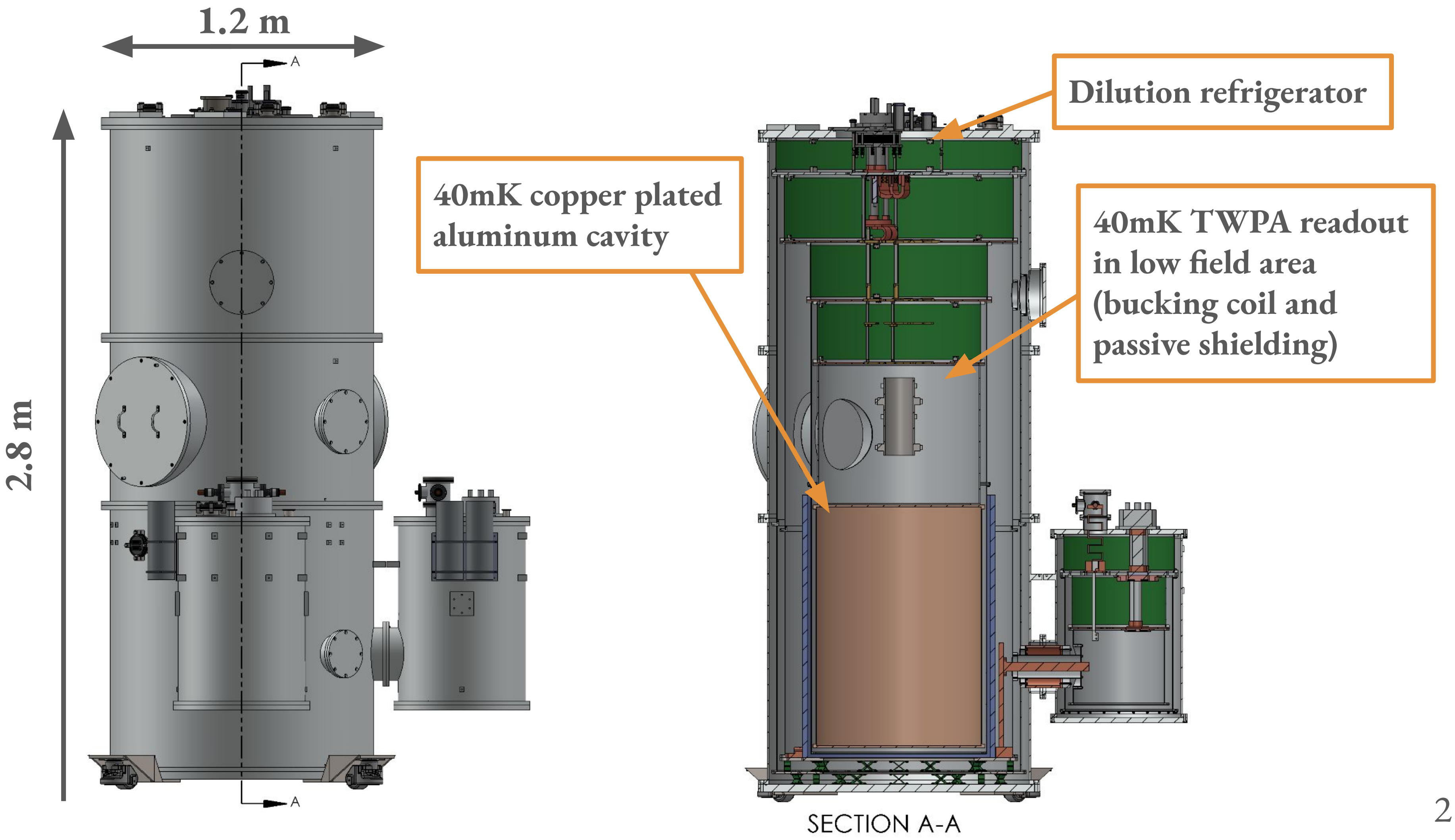


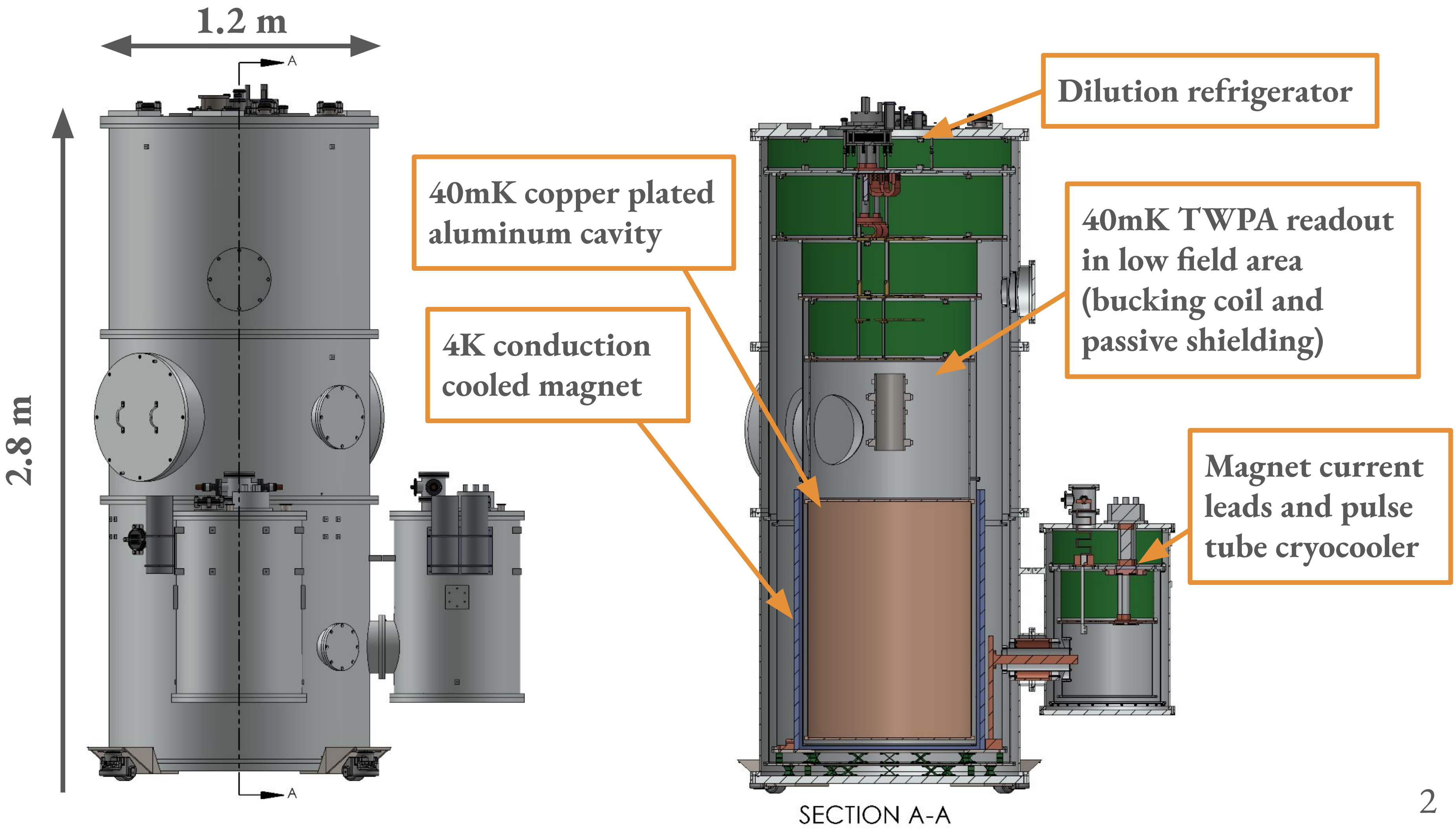
SECTION A-A

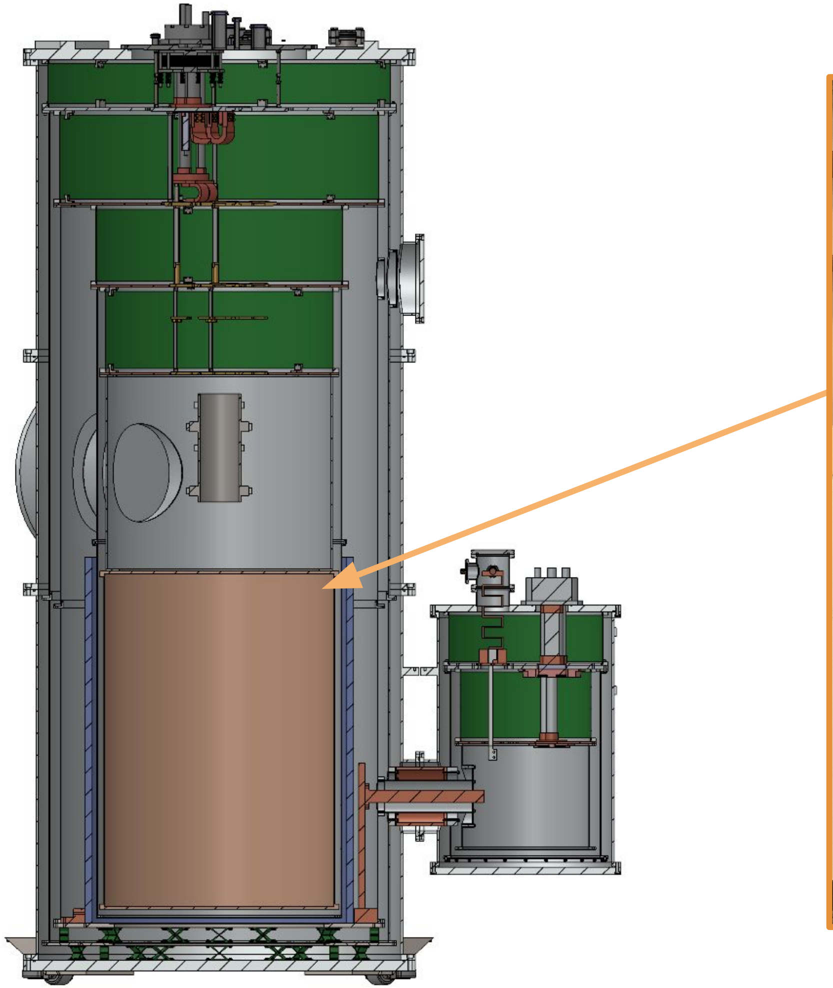

1.2 m
2.8 m
A
A
Dilution refrigerator
SECTION A-A


1.2 m
2.8 m
A
A


Dilution refrigerator
40mK TWPA readout
in low field area
(bucking coil and
passive shielding)
SECTION A-A

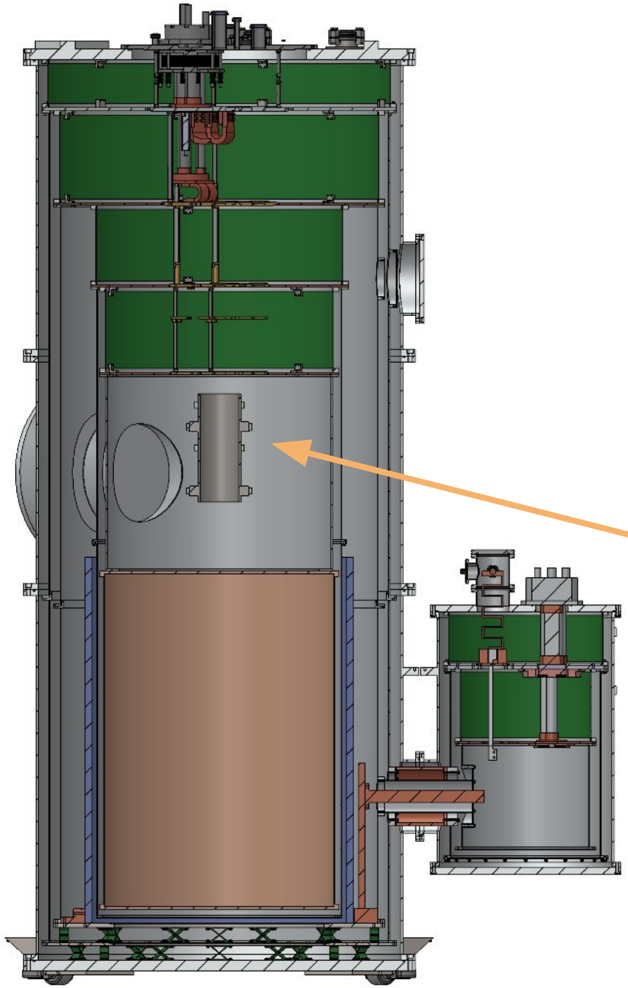

1.2 m
2.8 m
A
A
40mK copper plated aluminum cavity
Dilution refrigerator
40mK TWPA readout in low field area (bucking coil and passive shielding)
SECTION A-A


1.2 m
2.8 m
A
A
40mK copper plated aluminum cavity
4K conduction cooled magnet
Dilution refrigerator
40mK TWPA readout in low field area (bucking coil and passive shielding)
Magnet current leads and pulse tube cryocooler
SECTION A-A



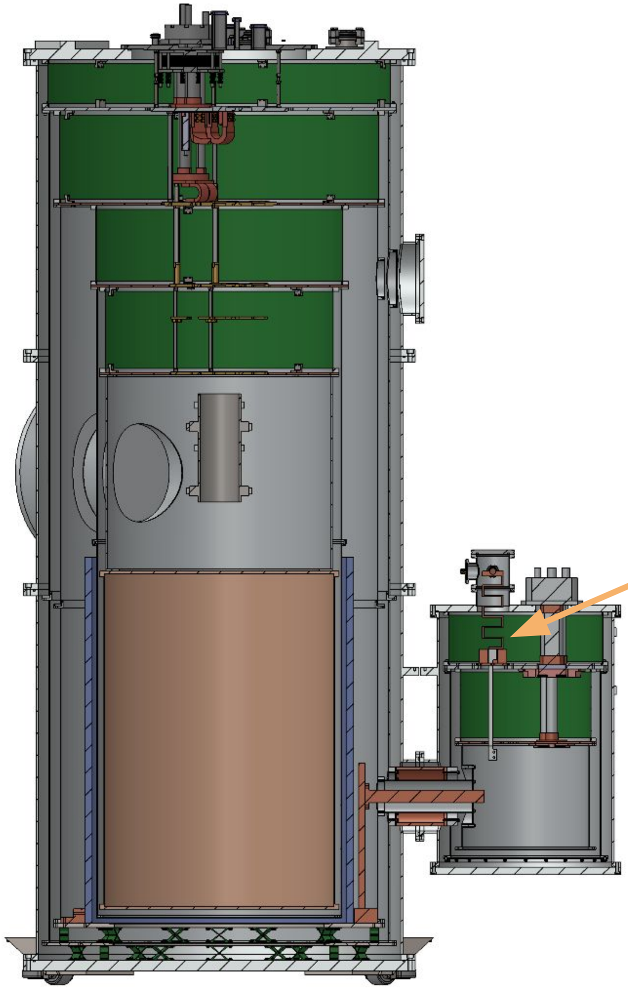
Full scale cavity prototype

Nate Otto



First TWPA and RF chain testing

Joe Wiedemann



⅓ scale coil prototype

The PXS magnet

- ~0.8 m bore
- ~1 m height
- 6MJ, 5 T, field profile on right
- **Conductively cooled** by two PT420 cryocoolers

Magnet development in collaboration with the Princeton Plasma Physics Laboratory.

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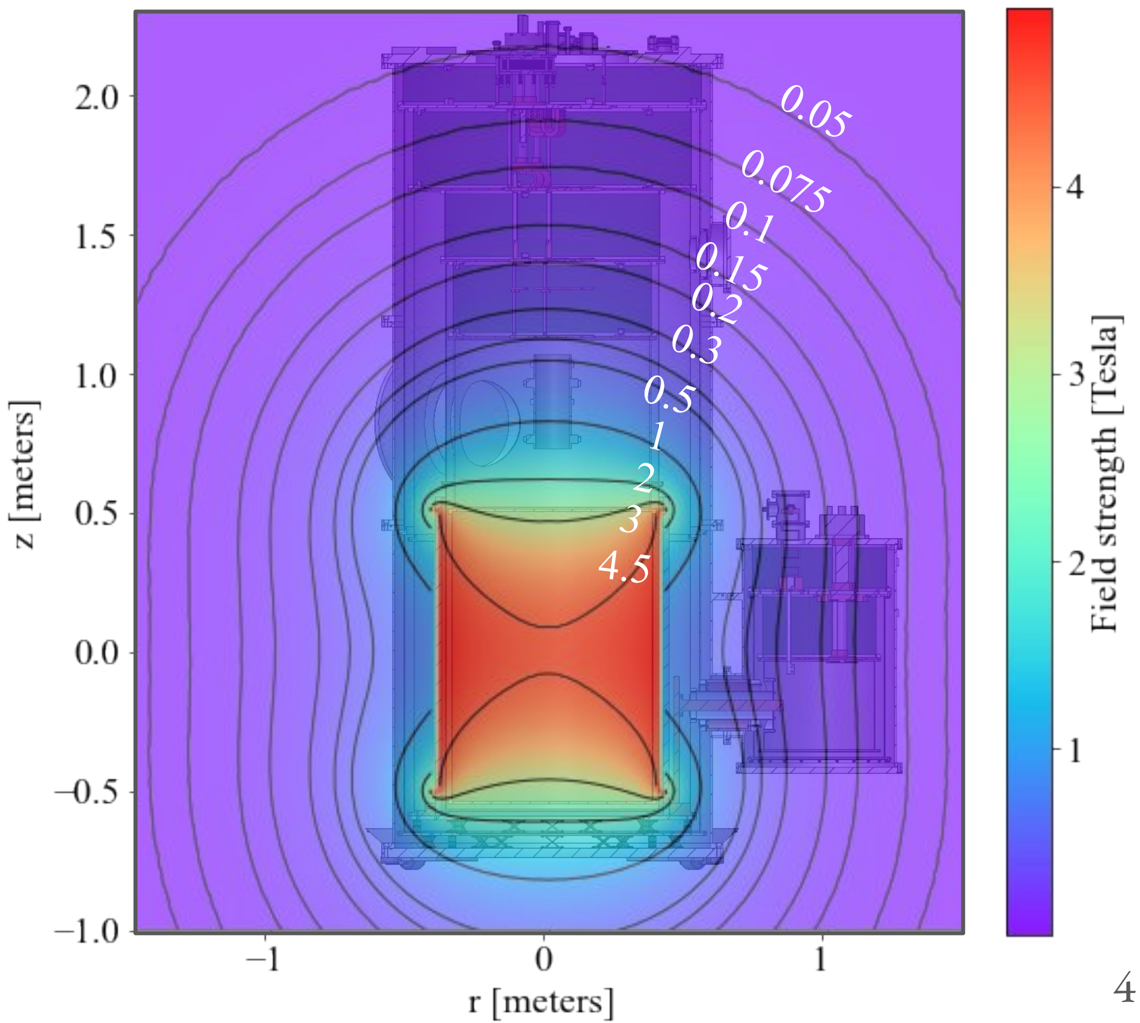
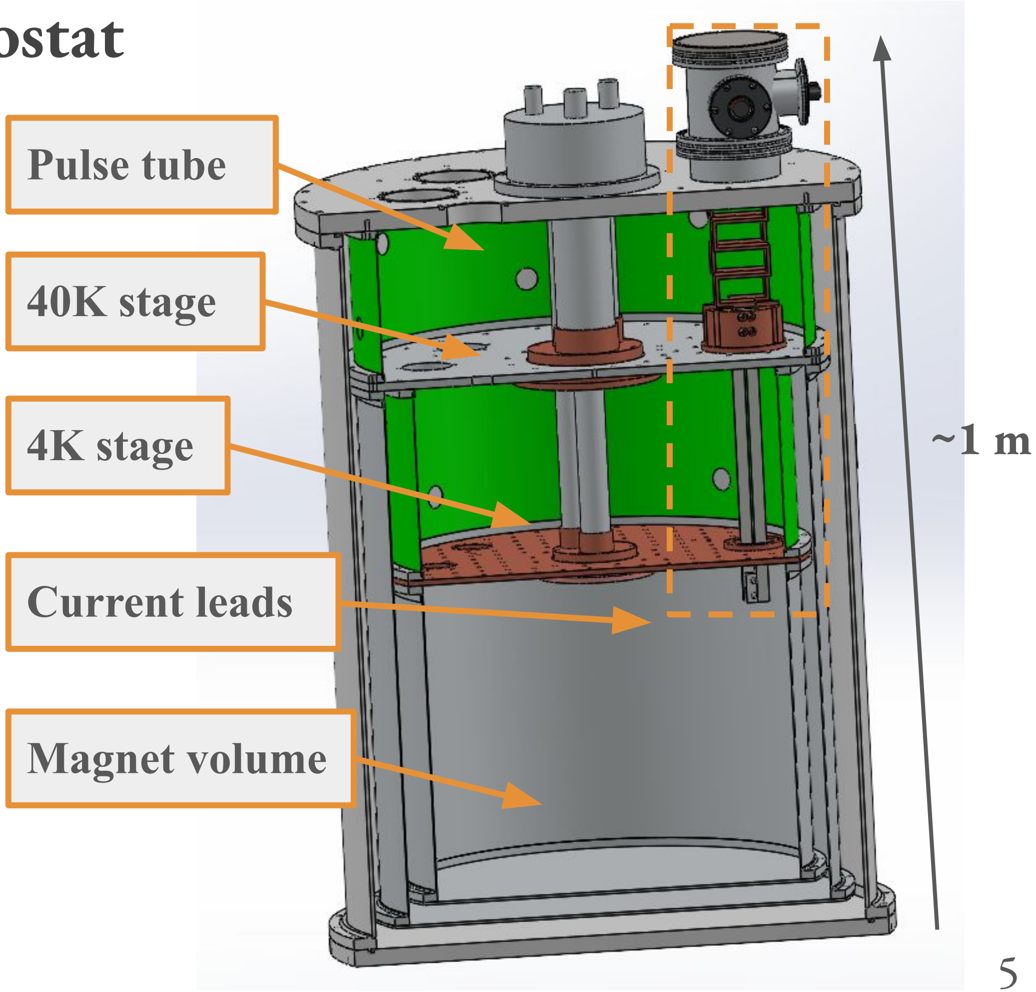
PRINCETON PLASMA PHYSICS LABORATORY

Yuhu Zhai
Griffin Bradford
Siwei Chen

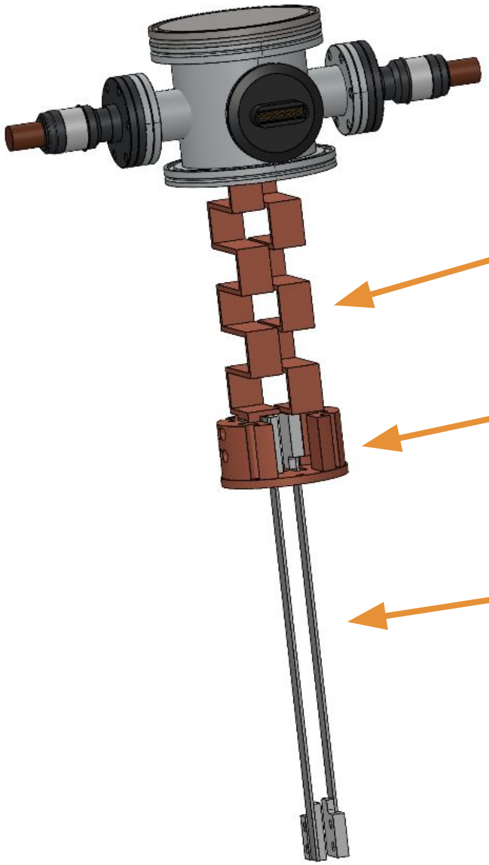


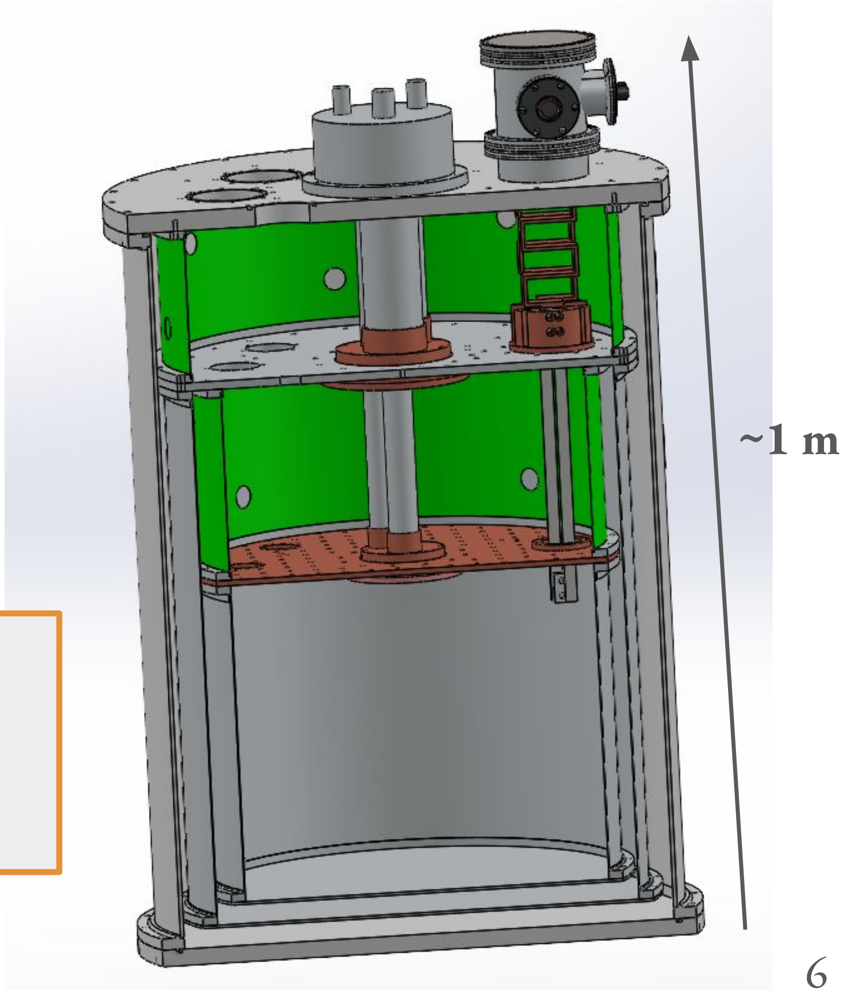
PXS model coil and test cryostat

- 5 T coil about ~1/3 scale of full size coil
- Nb3SN cooled to 4K
- Coil protype is currently under construction, first cooldowns this summer

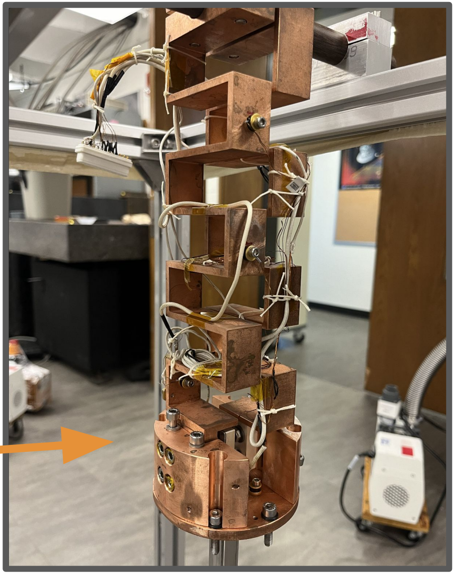


Delivering 600 amps to 4 K



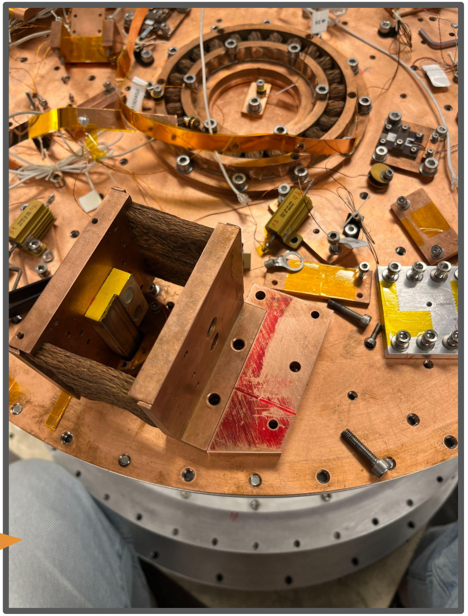


Cryogenic performance of current leads at 600 A

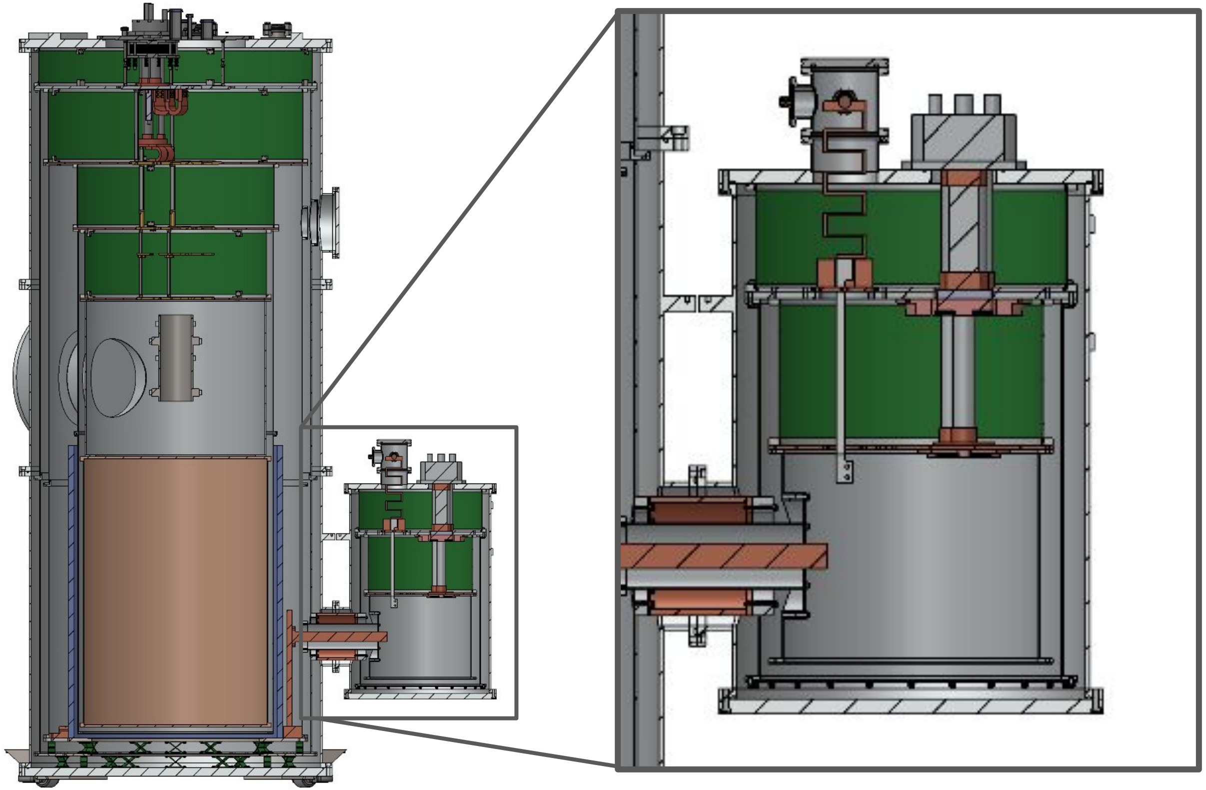


40.5 K on PT first stage coldhead
~50 W total heat load

2.9 K on PT 4K stage
~0.5 W total heat load



This current lead design will be used for the full scale PXS coil



Conclusions

- PXS cryostat out for bid
- ⅓ scale Nb_3Sn model coil operating Summer 2025
- Full scale coil 2027
- More from Nate and Joe on cavity and readout!

Thank you!

SIMONS FOUNDATION

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PRINCETON UNIVERSITY

Saptarshi Chaudhuri
Lyman Page
Roman Kolevatov
Joe Wiedemann
Nate Otto

PPPL PRINCETON PLASMA PHYSICS LABORATORY

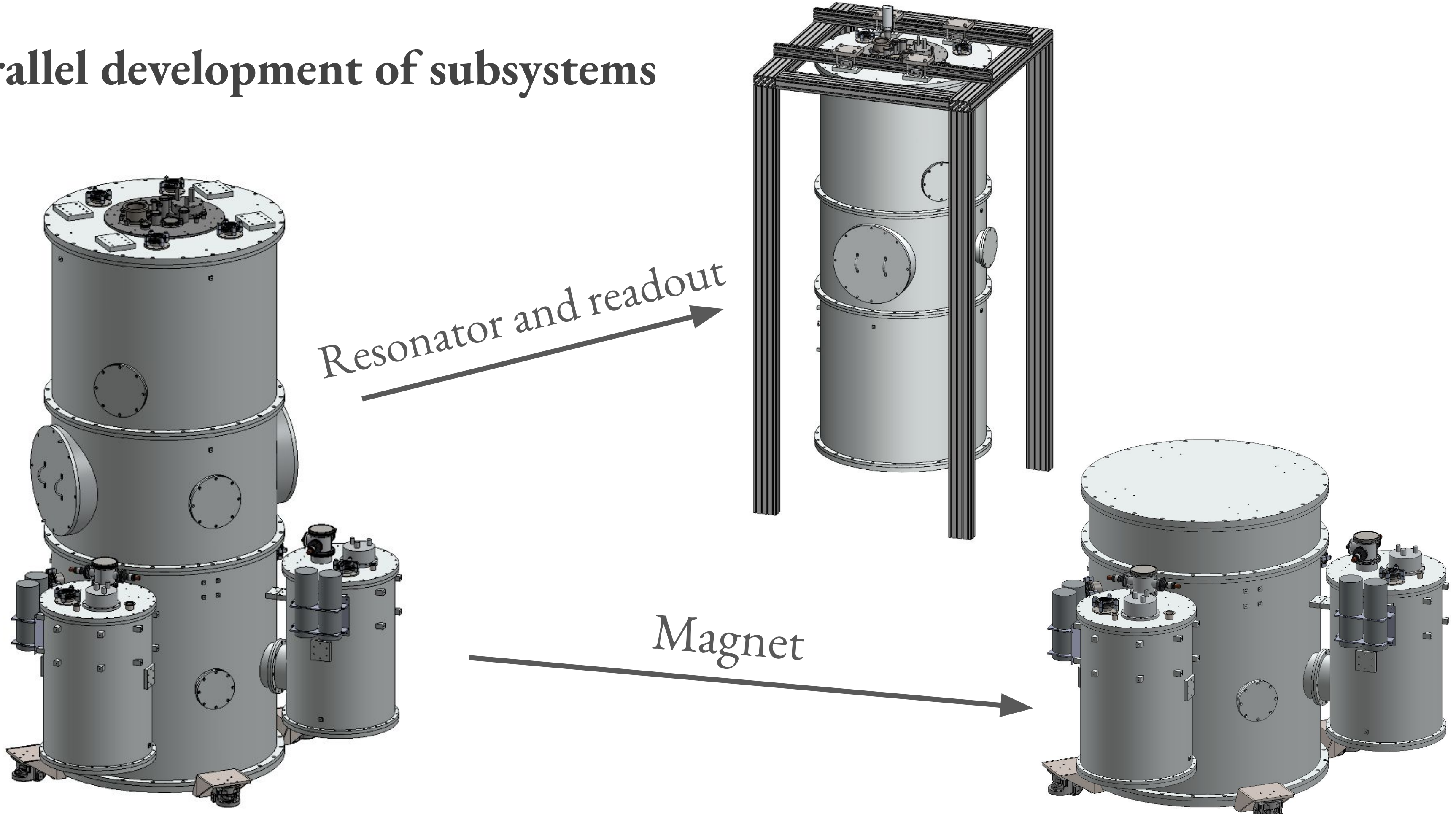
Griffin Bradford
Yuhu Zhai
Siwei Chen

JPL Jet Propulsion Laboratory California Institute of Technology

Peter Day
Farzad Faramarzi
Jonas Zmuidzinas

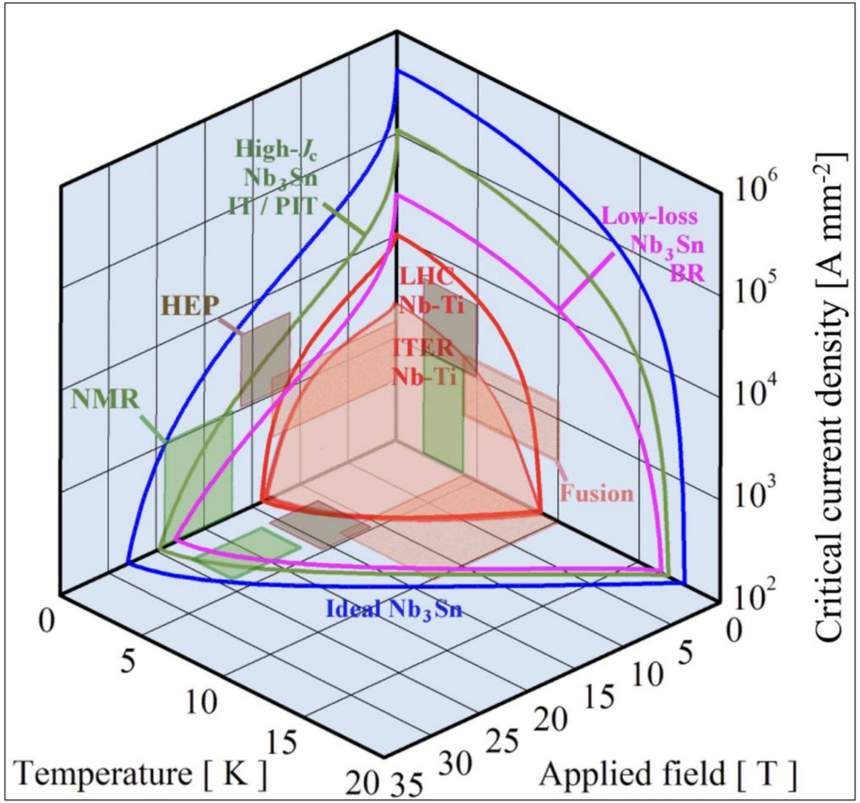
Backup slides

Parallel development of subsystems



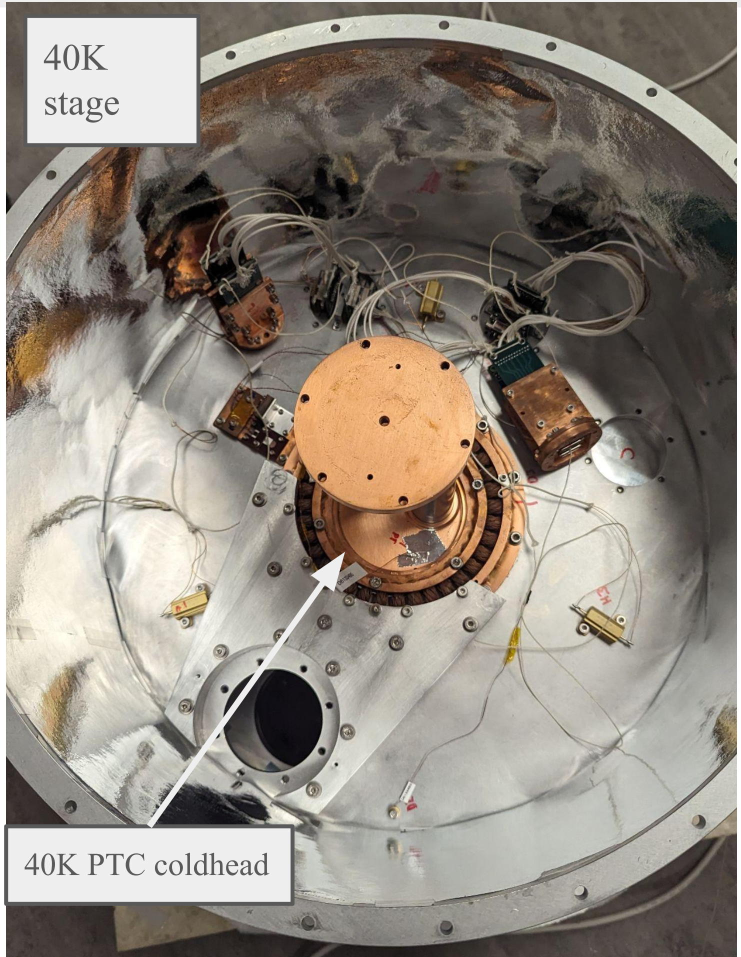
Conduction cooled Nb_3Sn magnets are the future

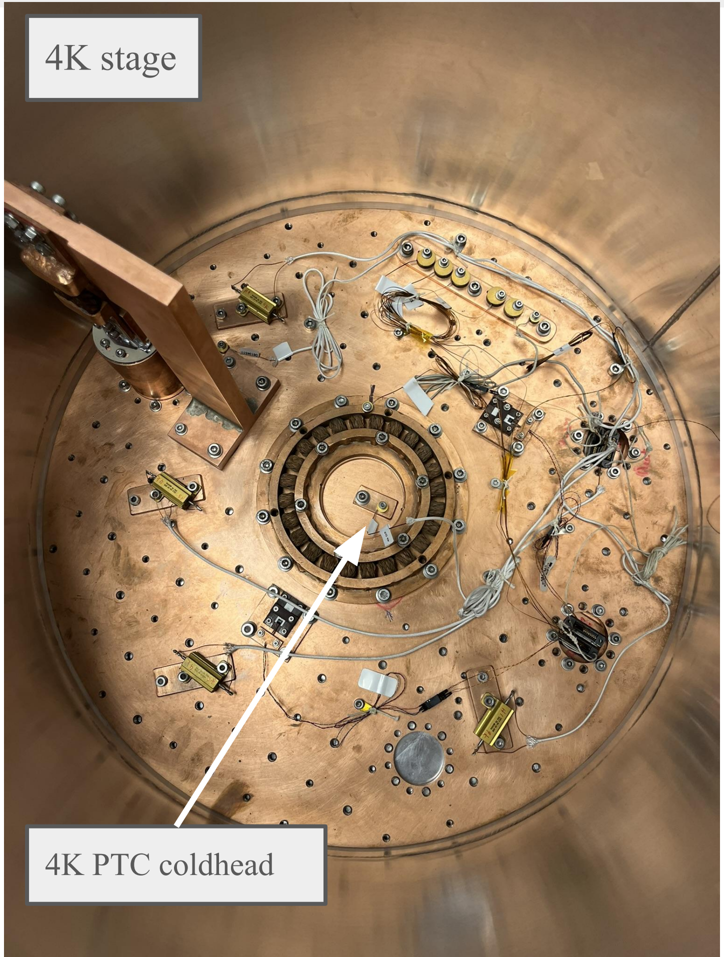
- Magnets are *everywhere*
  - Particle accelerators, fusion, medical physics, NMR, axions, etc
- Wet magnets (immersed in liquid helium) vs conduction cooled magnets
  - Benefit of conduction cooled: no liquid helium ($$). Safety (vaporized LHe goes boom).
- Nb3Sn can operate under much higher critical currents than NbTi, in principle being able to support fields up to 18T



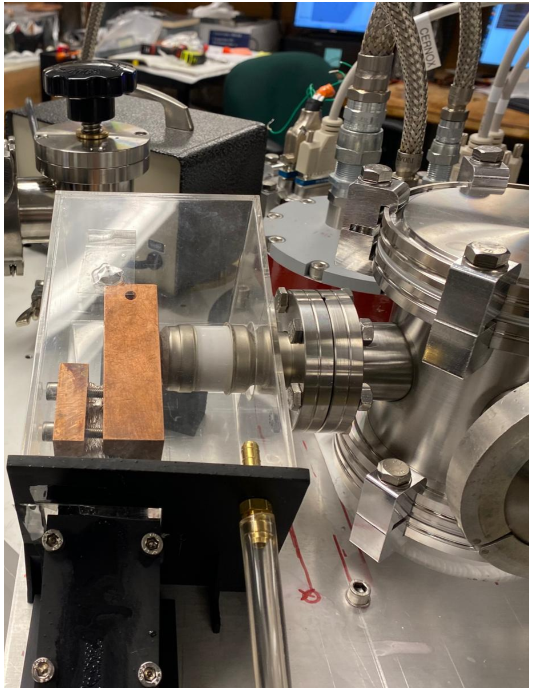
Credit: Ian Pong, Arno Godeke

PXS model coil and test cryostat



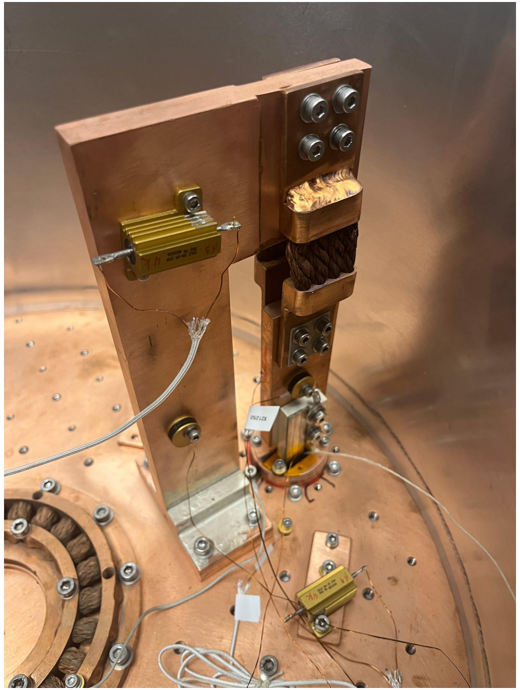


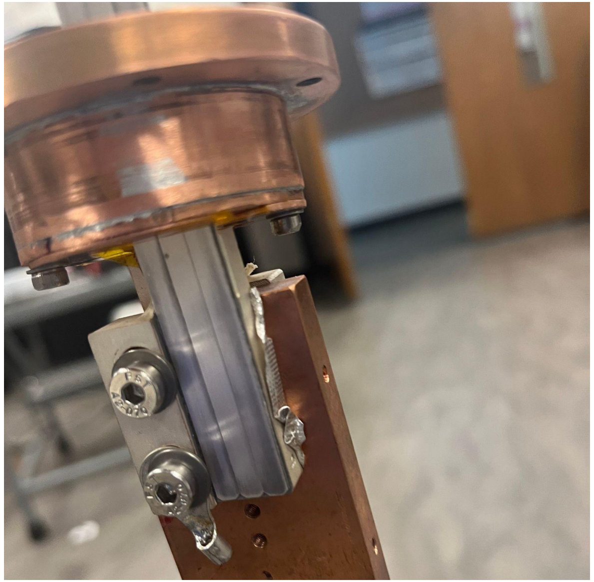
300K connection

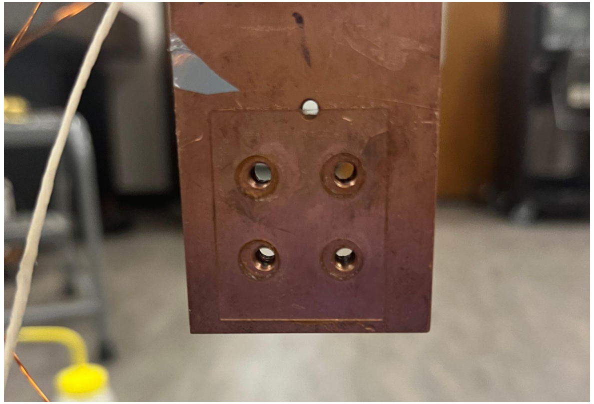


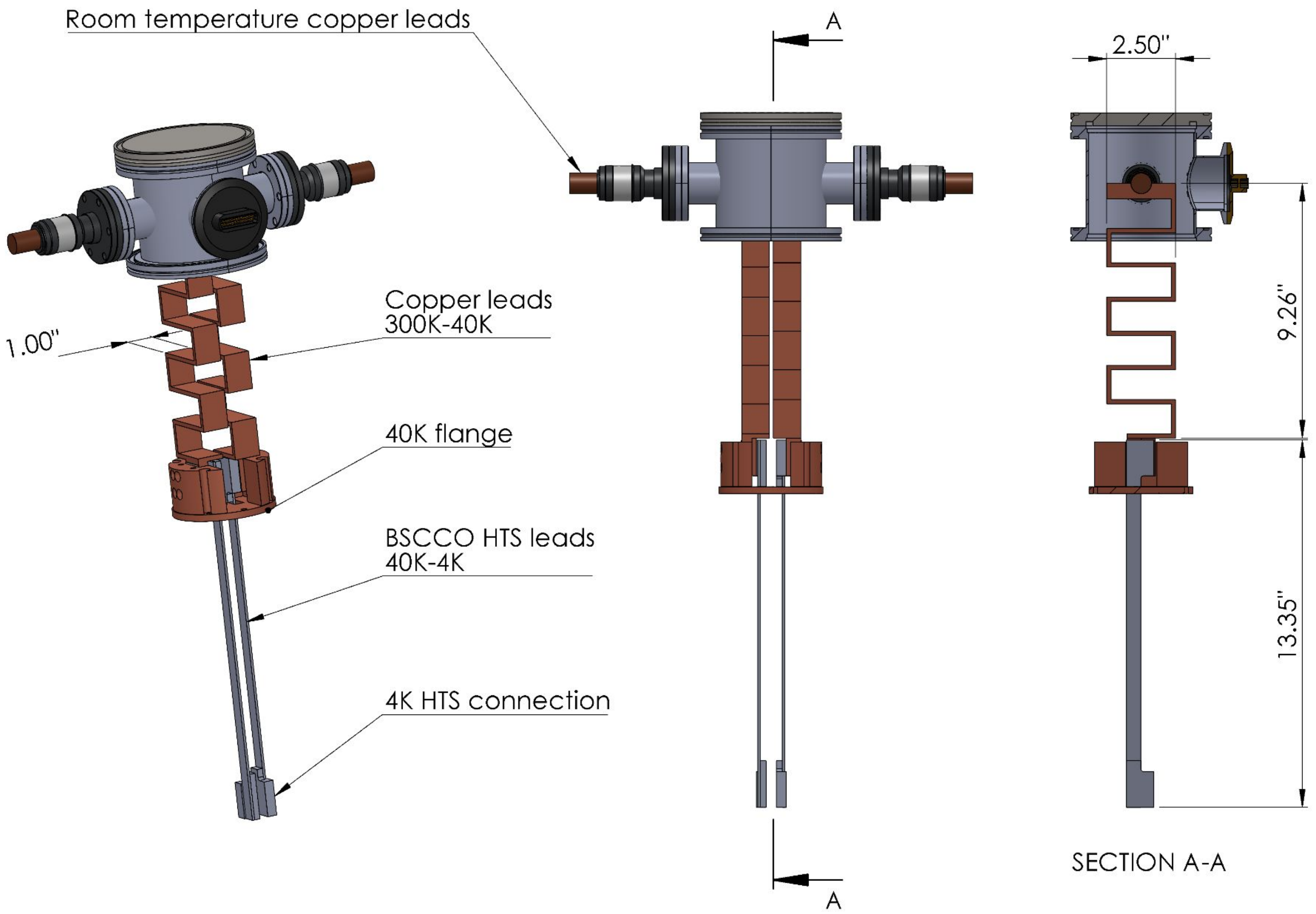
300K-40K leads

4K HTS connection








Room temperature copper leads
Copper leads
300K-40K
1.00"
40K flange
BSCCO HTS leads
40K-4K
4K HTS connection
A
A
2.50"
9.26"
13.35"
SECTION A-A