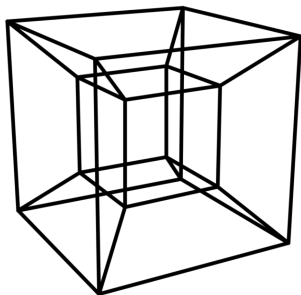
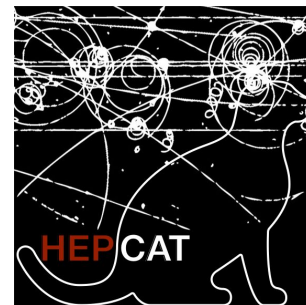


R&D Towards TESSERACT's Superfluid Helium Detector

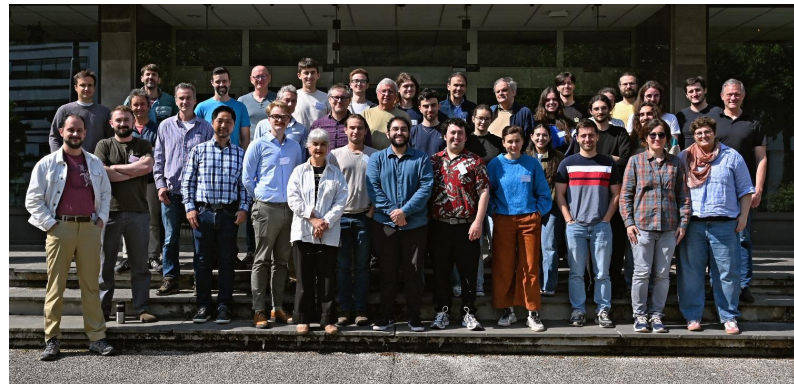
Samara Steinfeld on behalf of the TESSERACT Collaboration
CPAD Workshop
10/22/2026



The TESSERACT Project

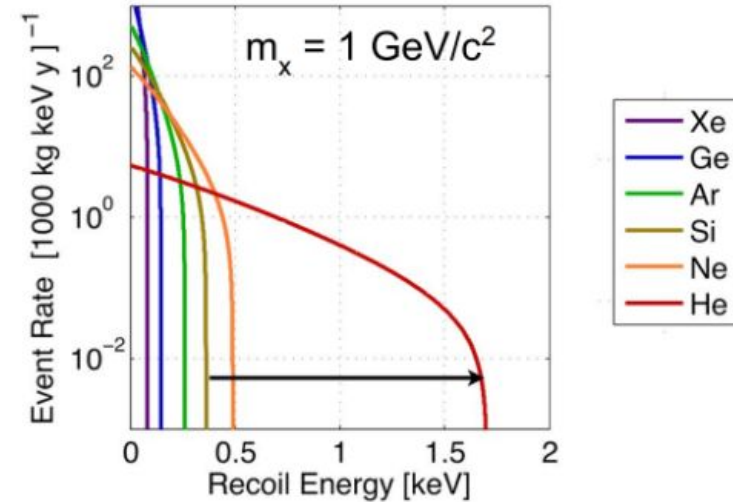
Transition Edge Sensors with Sub-Ev Resolution And Cryogenic Targets

- ~60 collaborators from 11 institutions
- Direct detection for sub-GeV particle dark matter
- Multiple targets with the same TES readout
 - GaAs
 - Sapphire
 - Germanium/silicon charge detectors
 - Superfluid ^4He (formerly HeRALD)



Advantages of Superfluid ^4He

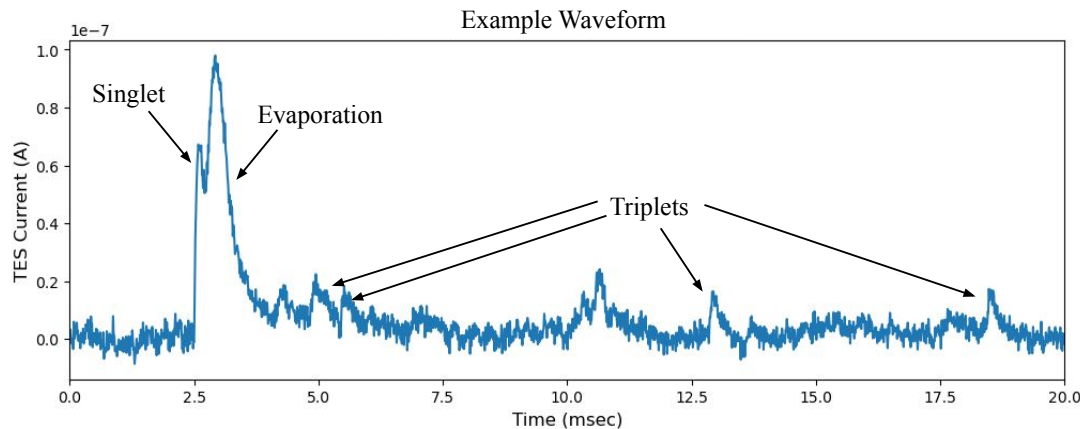
- Light atomic mass
- No observed intrinsic material background (LEE)
- No long-lived isotopes – high radiopurity
- Run at 10-20 mK – impurities frozen out
- Three signal channels



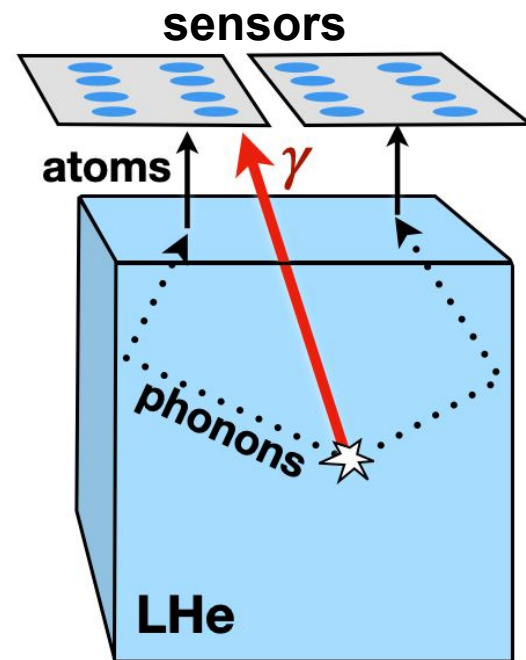
Signal Channels of Superfluid ^4He

1. Scintillation via singlet excimer deexcitation
2. Quantum evaporation via phonons and rotons
3. Scintillation via triplet excimer deexcitation

Detected with athermal calorimeters on silicon chips

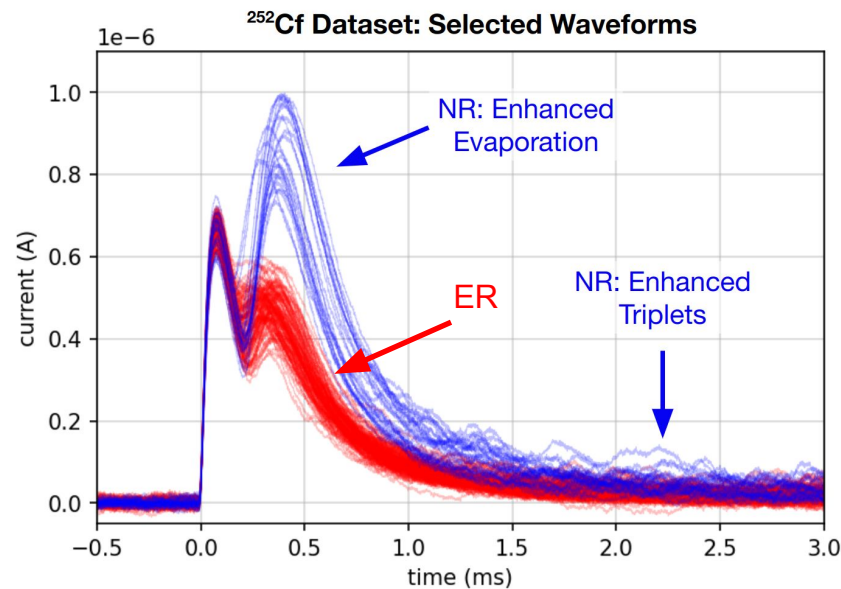


Michael Williams' talk:
RDC 7&8 Joint
Thursday at 5:30 pm



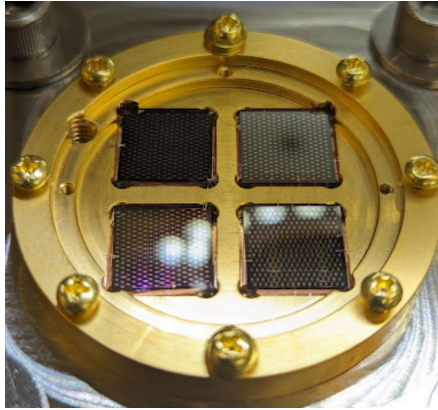
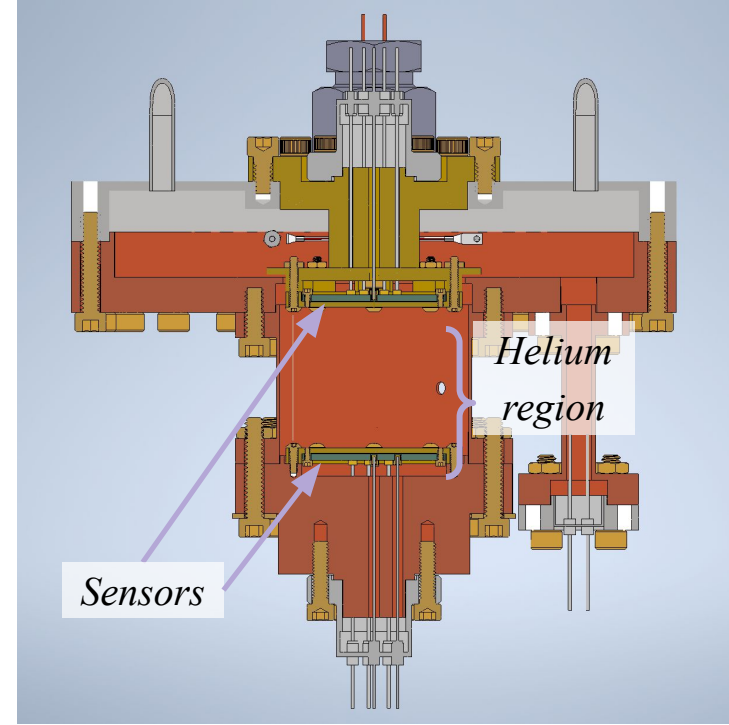
V0.1: Successful Detector Operation

- Neutron source shows different behavior between electronic recoils (ER) and nuclear recoils (NR)
- NR events are associated with larger evaporation and triplet responses
- Allows for discrimination between ERs and NRs → opens discovery opportunity
- [PRD 110.072006](#) (2024)



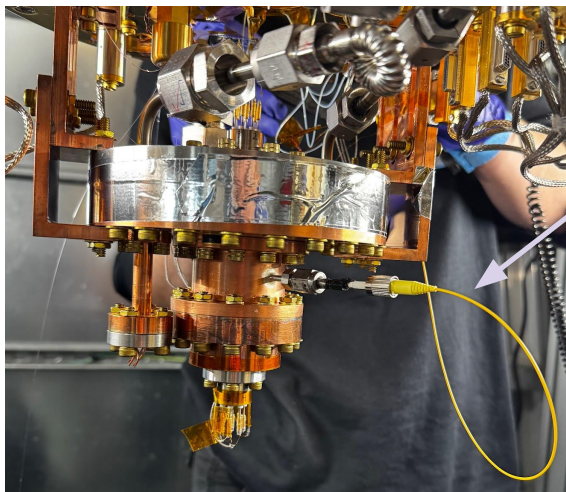
V0.2: Goal to Maximize Energy Resolution

- Use even more sensitive sensors
- Test sensors immersed in helium to boost light collection
- This is the design for the LBL test stand (V.02)

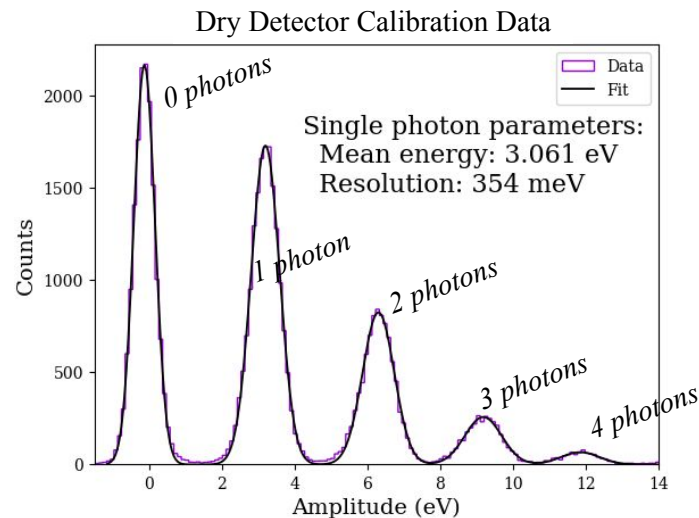


V0.2: Quantifying Dry Detector Baseline

- 3.061 eV photon calibration via a superfluid-tight feedthrough
- Down to ~ 400 meV resolution with glued sensors
- Now we can test the sensors in helium

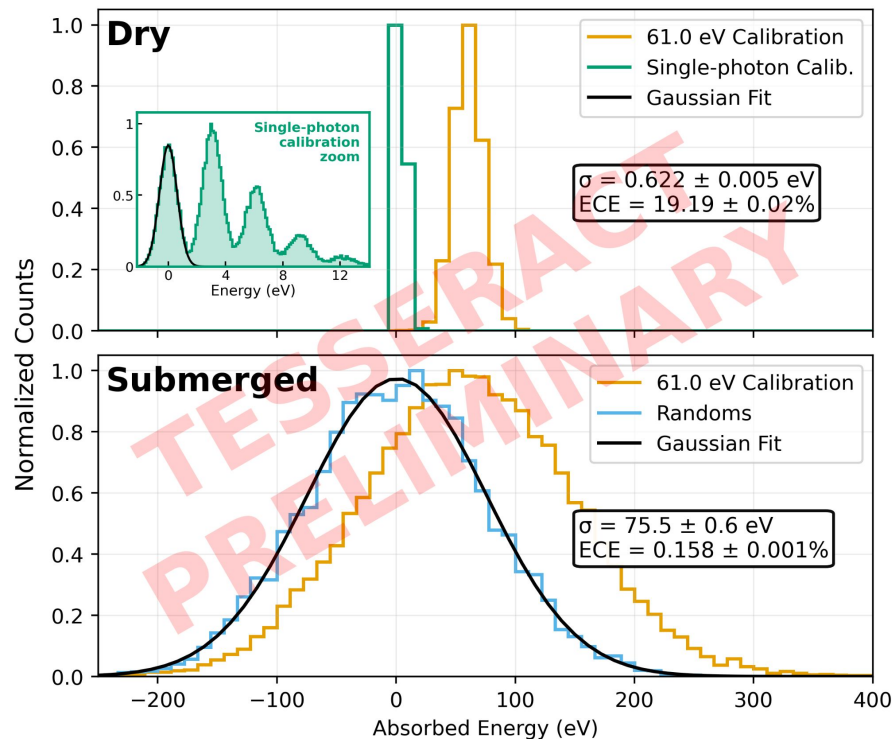


Optical fiber



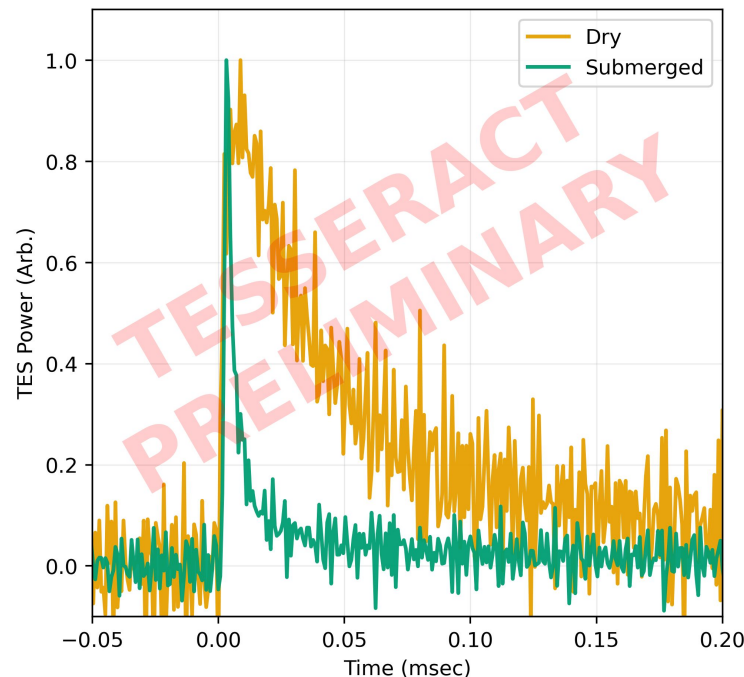
Superfluid Helium Dramatically Degrades Resolution

- Injecting 61 eV of photons for calibration
- With helium, energy collection efficiency (ECE) falls by two orders of magnitude (19% to $\sim 0.16\%$)
- Resolution also degrades two orders of magnitude, from 0.6 eV to ~ 70 eV



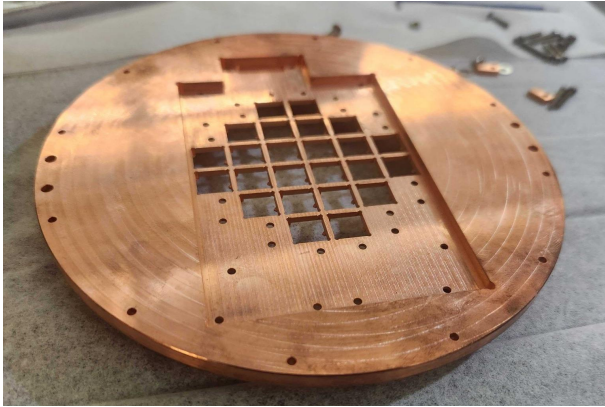
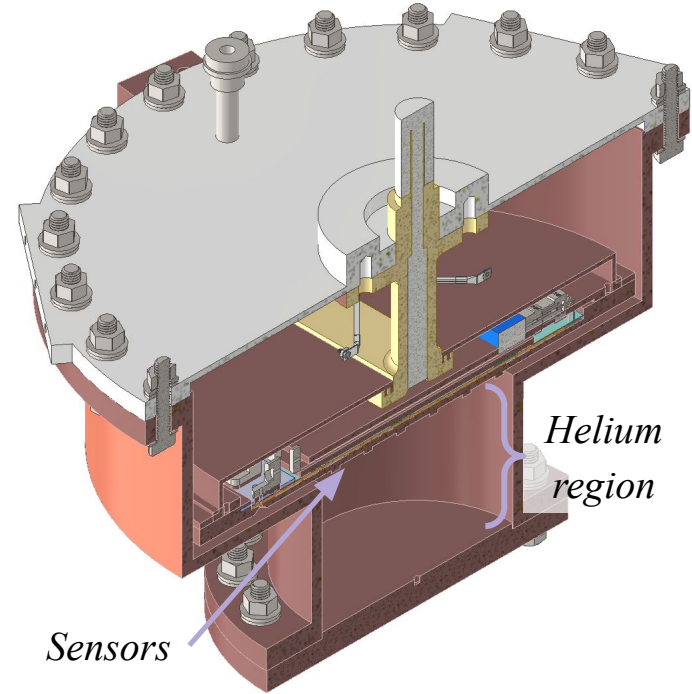
Efficient Transmission of Athermal Phonons into Helium

- Pulse shape, specifically fall time, also changes with addition of helium
- Indicates we are collecting less athermal phonons
- They are leaking into the helium instead
- Paper very close to publication!
- R&D in progress: looking for direct hits (photons) to TES metal films



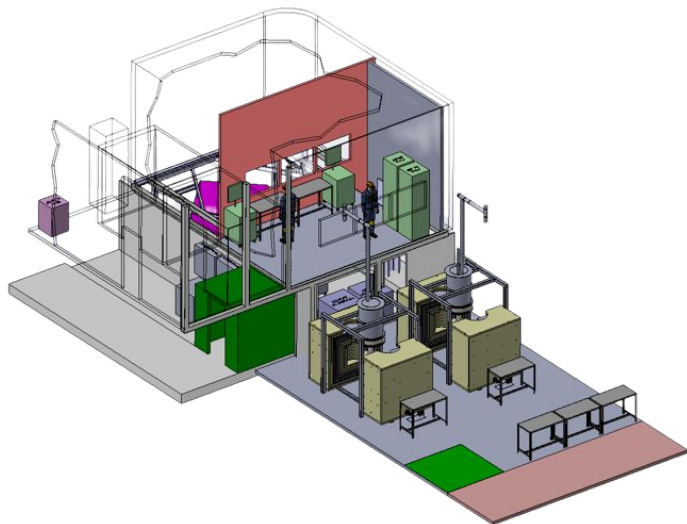
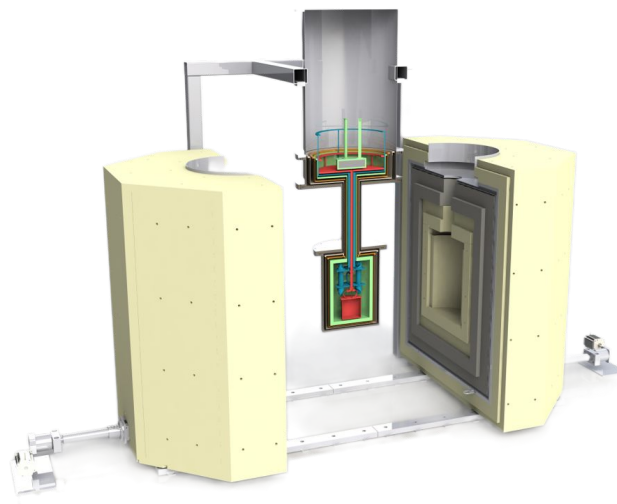
TESSERACT Project Helium Target (V1.0)

- No submerged sensors
- Array of 24 sensors, each 1 cm x 1 cm
- ~10 grams of helium
- Some components undergoing testing now!



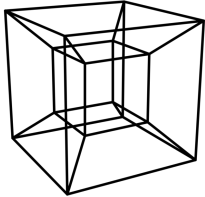
TESSERACT Project (V1.0) Moving Underground in 2028

- 2027: begin fridge commissioning at LPSC and UC Berkeley
- 2028: begin underground installation at LSM
- 2029 - at least 2031: begin science data



Conclusion

- Helium target has been demonstrated in two test stands
- Athermal phonon calorimeters submerged in helium have significantly degraded energy collection efficiency
- For this reason, we will not use submerged sensors in V1.0
- V1.0 testing in progress



Backup Slides

Overview of Sensors

Our sensors are QETs, which are extensions of transition edge sensors (TES)

- A particle deposits energy in the absorber, creating athermal phonons
- The phonons can break cooper pairs in the aluminum fins
- Some of the resulting quasiparticles will travel into the tungsten TES, thermalizing and causing a signal

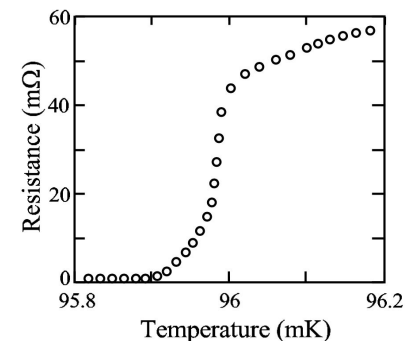


Diagram from Irwin and Hilton

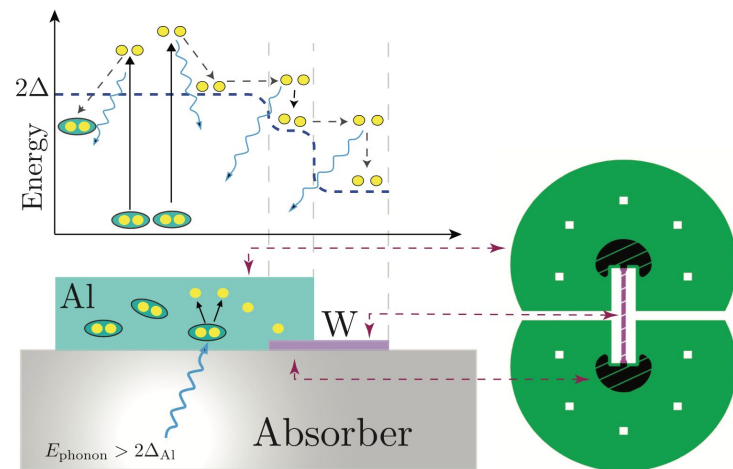


Diagram from Caleb Fink

Cesium Film-Stopping

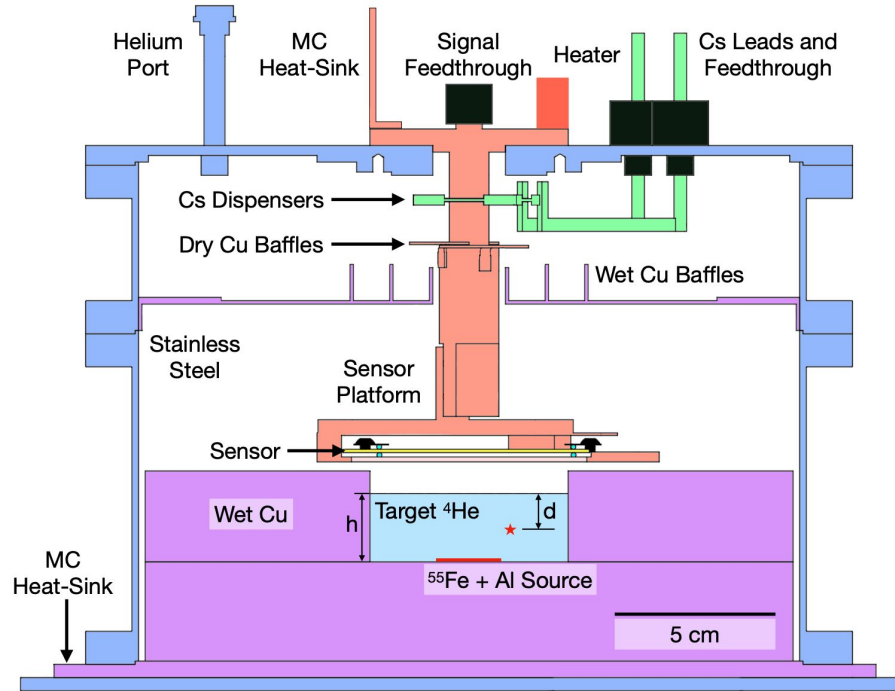


Diagram from Hailey Pinckney's thesis

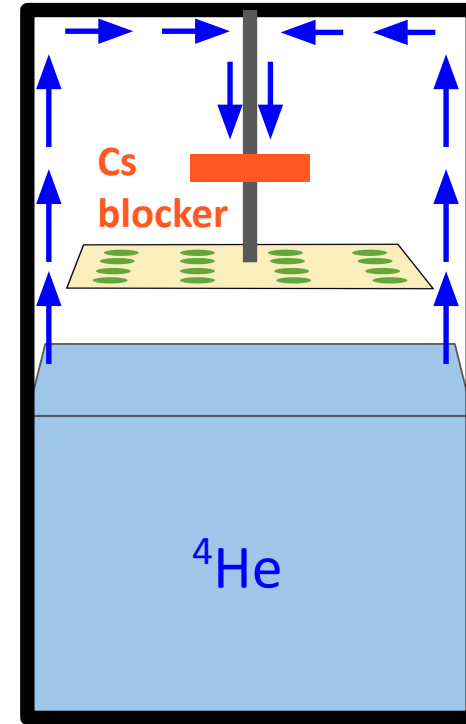
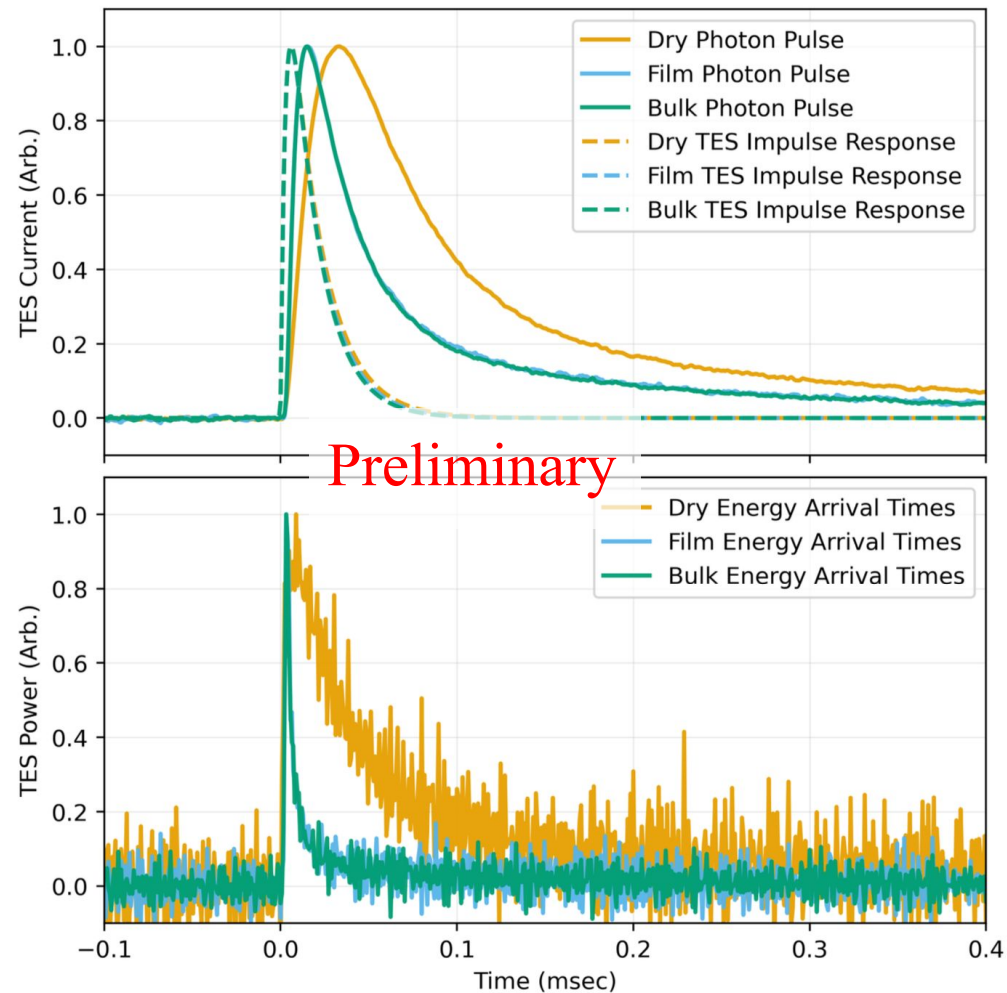


Diagram from Junsong Lin

Electrothermal Response



Bias Power

Change in bias power is due to helium, not a gradual trend over run time. Hypotheses:

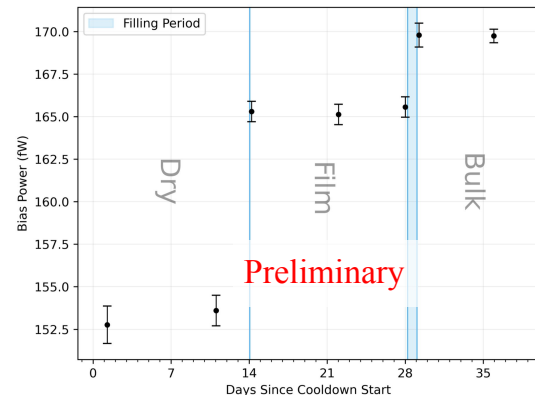
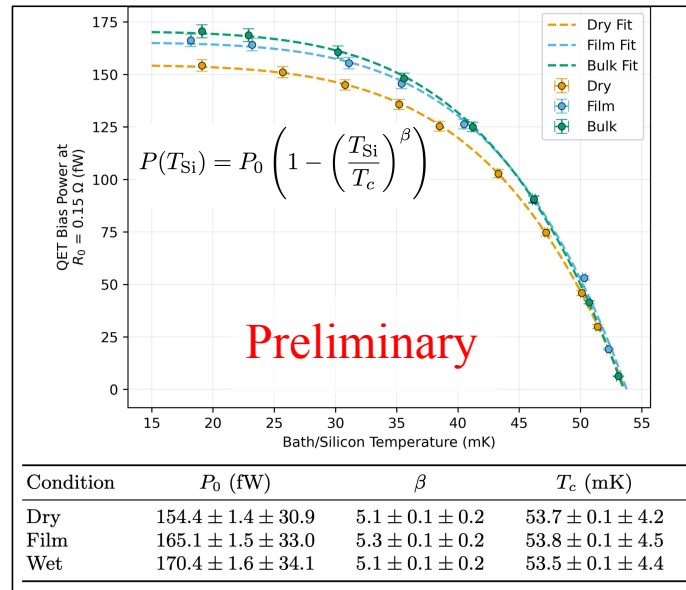
1. Superfluid cools the TES via conduction.

Expect change in P_0 .

OR

2. Cooling stems from a reduction in parasitic power. Expect change in P_0 and T_C .

P_0 change is larger than expected from excess cooling conduction alone. Observations are in tension



TESSERACT Sensitivity

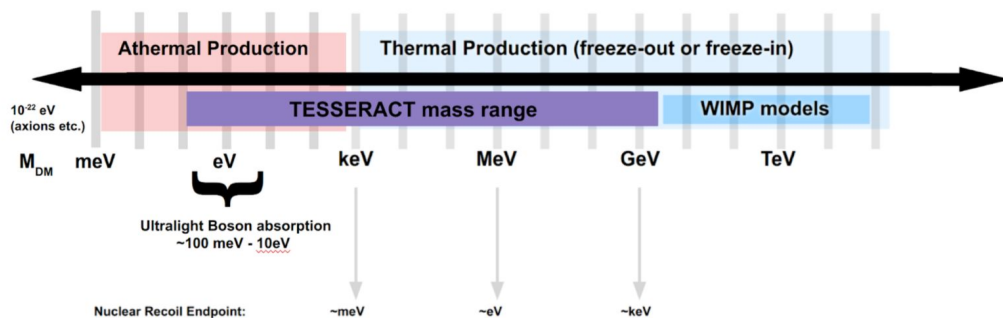
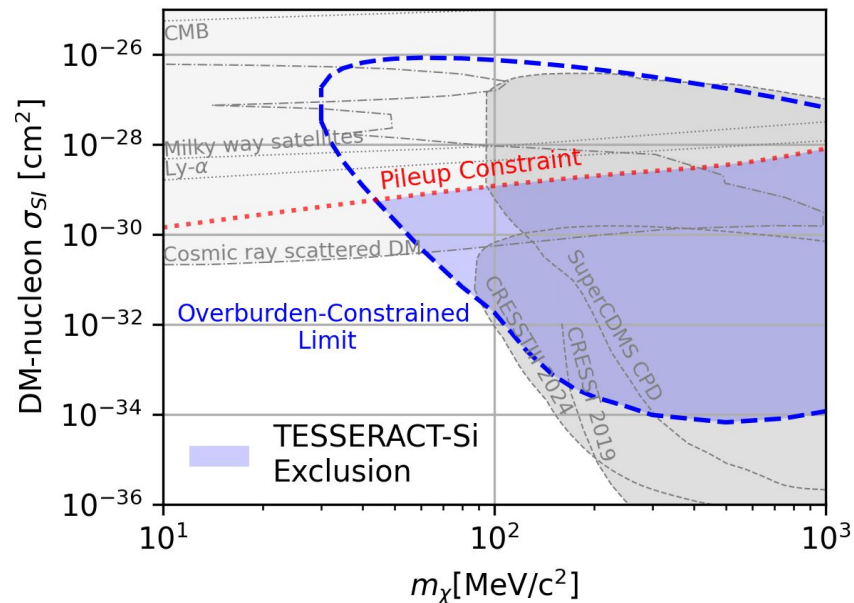


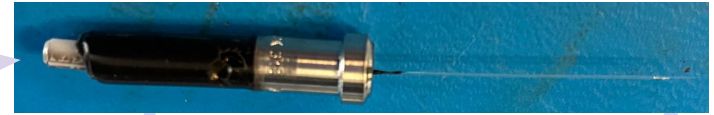
Diagram from Michael Williams



[arXiv:2503.03683](https://arxiv.org/abs/2503.03683)

Fiber System Hardware

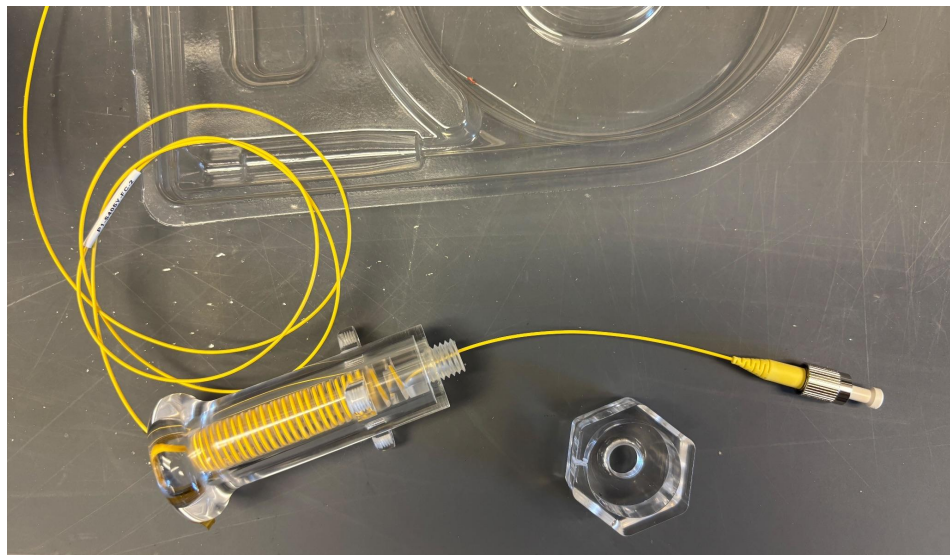
- Currently use a hytrel-jacketed patch cable and custom superfluid-tight feedthrough for connection into helium cell
- R&D in progress for IR reduction, radiopurity, and strain relief



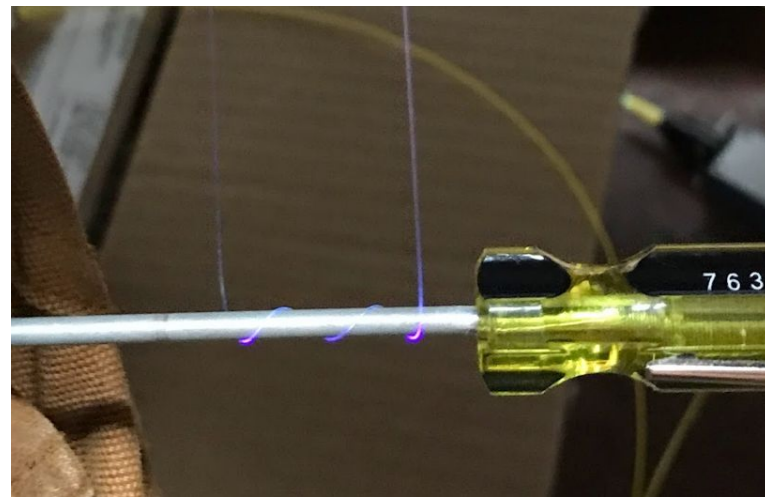
*Stycast to be
superfluid-tight*

*Diffuser - goes
inside cell*

IR Wrap Filter



*Prototype by
Yen-Yung Chang*



Signal Partitioning

[PRD.100.092007](#)

