Michael Williams
On Behalf of the TESSERACT Collaboration
CPAD 2023
7th-10th November, 2023
Sub-GeV dark matter consistent with thermal production and freeze out after inflation (similar to WIMPs)

Ultralight Bosonic DM is another viable candidate for DM

Like WIMPs, these particles can recoil off electrons or nucleons or be absorbed and make signals that detectors can measure

An experiment that has low threshold and multiple targets is ideal - TESSERACT!
- Collaboration of ~40 people from 9 institutions
- Searching for low mass DM
- Use of three detector targets
- TES readout
SPICE - Polar Crystals

● **Sapphire** (Al$_2$O$_3$):
  ○ **Sapphire** supports optical phonon modes.
  ○ DM recoiling off the lattice, ‘exciting a phonon’
  ○ Coupling to E&M-like inputs due to electric dipole → **dark photon sensitivity**

● **GaAs**:
  ○ **Polar crystal & bandgap** well matched to kinematic region of low mass DM
  ○ **Background discrimination** using phonon/photon ratio
  ○ Photon-photon and phonon-phonon coincidence can reduce instrumental bkgds
  ○ High light yield (125 ph/keV, 1904.09362)
Photon Calibration System

- Fiber optic system designed to send in short photon bursts directly onto detector
- ~3eV photons with known trigger - low energy pulse shape measurements!
- We see single photons mediated through phonons!
- Calibrate the energy response to the known photon energy
- First of its kind result!
World Leading Energy Resolution

- Two different coverage devices tested
- 1% - 273meV energy resolution in phonon system
- 0.25% - 460meV energy resolution in phonon system
- First of its kind results and the most sensitive TESs tested to date!
- 5x more sensitive than nearest competitors!

See R. Romani’s talk
Session RDC 7+8 11/09 16:00!
Understanding the Low Energy Excess

- “LEE” is known problem in the field
- By using two channels on same substrate we can find a way to understand the sources
- Singles and shared events both go down over time - singles faster
- Evidence to suggest this excess contributes to excess power noise

See R. Romani’s talk
Session RDC 7+8 11/09 16:00!
New IrPt TES for Dark Matter

- Spurred by LEE, development of new devices is critical
- IrPt bilayer devices allow tunable Tc -> better resolution
- Measure device characteristics of two different dimension TESs
  - AC/DC responses
- Look for “single” and “shared” events and measure rates
- New ~100meV energy resolution devices!
- Interesting characteristics found in spectrum!

See M. Reed’s talk
Session RDC 7 11/08 16:45!
Primary Signal Channel: Prompt Photon
- A single quasiparticle may liberate a single atom from liquid surface
- Phonon energy in He-4: $\sim 1$ meV
- Atomic binding energy: 0.62 meV

Secondary Signal Channel: Quantum Evaporation
Signal from the binding of He atoms onto the surface of the calorimeter
- Typical binding energy: $10$ meV
arXiv:2307.11877
Signals in LHe

- Signals are analogous to Xe dual phase TPCs
  - S1 - prompt scintillation (singlets)
  - S2 - evaporation
Measured Signals

- Wanted two pulses - got two pulses!
- Pulses from a low energy x-ray source
  - $^{55}\text{Fe}$ 5.9 keV
  - Al 1.5 keV
● Use Cf-252 for n and $\gamma$
● Larger evaporation to scintillation ratio for neutrons
● Larger triplet fraction
  ○ Above $\sim 10$ keV
Coming HeRALD Tests at UMass

- New split CPD being used now!
- Hope to lower threshold with LEE rejection!
- New DR installed at LBNL will serve as testbed for helium detectors
- 4 immersed and 4 suspended calorimeters
  - Important to reject LEE events!
- Calibrations with immersed x-ray source and compton scatters

See V. Velan’s talk
Early Career session 11/09 9:30!
Bringing It Together Underground

- Novel shielding concept: TESSERACT Design
  - Simulated in various underground labs
  - 1.2 DRU at 1 keV
  - About 0.75 DRU with ancient lead

- Advanced design considering fabrication, installation, operations, budgeting & underground constraints

We plan to go underground soon!
Summary

- **TESSERACT** brings together multiple novel detectors to search for low mass dark matter
- **SPICE** uses polar crystals for and TESs for exceptional ER DM reach
- New optical calibration mechanism for TESs shows single photon detection and new low energy resolution
- Dual channel devices can help us understand, and potentially mitigate, LEE
  - These events may be contributing to excess power noise seen before
- **HeRALD** uses superfluid helium and TESs
  - HeRALD is seemingly unplagued by LEE thanks to quantum evaporation
- First proof of principle shows detection mechanism works as planned!
- Coming HeRALD runs aim to calibrate down to 1keV and below!
- **TESSERACT** has developed underground shielding designs for the underground detector
- Underground in the coming years! More world leading physics to follow!
Thank you!