

QUEST-DMC WP1&2 Meeting

Introduction

Thank you

Its great to get together in person! (Dec.'22, Dec.'23, Jul.'24, today!)
Thank you everyone for travelling.

Thank you to Juri for hosting and Juri+Ashlea for organising!

Motivation and Goal

1E-7 eV per quanta

cf. ionisation quanta in Si: ~1 eV, Xe: ~10 eV, Ar: ~20 eV

Goals: reach 10 eV threshold (WP1), solve the AB nucleation problem (WP2)

Big Picture - Since Project Start in 2021...

Dec. '22 Meeting:

Our (WP1) goal was to develop an end-to-end model to update the sensitivity projection from the proposal (SD elastic scattering)

- We have done this, and published it!

Our goal was to develop the larger physics case of what QUEST can do

- We have done this, and published it! As well as finding new physics targets...

Our goal was to develop an analysis framework to handle bolometer data in a way that enabled distributed simulation, development and analysis

- We have done this, and extended to apply it in multiple cells. Bottom line from “gen 1” bolometers is ~ 10 keV threshold.

Our goal was to deploy multi-lake cavities and SQUID readout of nanowires (“gen 2”)

- We have done this, reaching ~ 1 keV threshold (100x to go!)

goal: working on understanding our data ... some big mysteries to solve.

Big Picture - Since Project Start in 2021...

Dec. '23 Meeting:

Our goal was to get multiple cells operating (at Lancs and RHUL)

- We have done this, and published in both WP1 and 2!

Our (WP1) goal was to understand the energy scale and the background model (WP1 and WP2)

- Significant progress, not yet done but >700 hour Fe-55 calibration data set collected, demonstrating 50% lifetime over long-term operation (WP1), material assays for experiment cells (WP1 and 2)

Our goal was to validate background model — are we limited by shot noise?

- We have answered this question: no!

Our goal was to complete DM search analysis on Fridge 4 data (WP1), and g4sims establishing energy deposition distribution in He (WP2)

- We have done (most of) this, and developed toolkit to identify operating conditions that optimise for energy threshold.

Lots of Good News (technical)

- We have successfully run experiments in WP1 and 2
- Explored non-linear drive over broad range of operating conditions in “gen 1”
- collected a globally unique dataset in “gen 1” in which we have (nearly) done end-to-end DM search - learned a huge amount
- “gen 2” QUEST cells operating/underway at both Lancs and RHUL, demonstrated SQUID readout, multiplexed SQUID readout, explored parametric drive with SQUID readout in “gen 2” bolometers ...
- Major progress in building/understanding background models, with important new components (acoustic noise! correlated across cells!), in-situ normalisation
- Constructed numerical simulators for phase transitions (WP2)
- O(8) papers submitted/accepted + 1 in advanced draft. Congratulations!!

Lots of Good News (people)

- Promoting career development for postdoctoral researchers (EPSRC Fellow, Quantum Technology Career Development Fellow, 2x Future Leader Fellowships — congratulations!)
- Grants success, e.g. 8/8 on QTFP PDRA Extension Funding Request, extended project funding through 3/25 + supported 4 Fellowship applications this year.
- Brilliant Royal Society Summer Science Exhibition (2024)
- 1st QUEST PhD student to submit thesis on Sunday! 3+ PhD students in the pipeline and counting...
- Collaboration is growing! (since proposal, +Liverpool, +RAL, +Rheinmann Hochschule, potentially +US groups)

Lots of Good News (strategic)

- Established important link with radiation impact on phase transitions (WP2) and on superconducting qubits community (WP1) (SQMS partnership ++)
- $O(10^6)$ CPU hours of supercomputing time obtained + 10^5 GPU hours ++
- Submitted highest ranked (although not funded) proposal for Mid-scale DM Search Experiment at Boulby, following on from UKRI Preliminary Infrastructure bid selected by PPRP and PPAP
- Proteox fridge purchased for deployment at Boulby, via NQCC — platform that enables lower cost of future QUEST deployment underground
- Strongly positioned for QTFP Phase II when it arrives, and we are navigating the interim between Phase I and Phase II

Big Picture

We have established the QUEST concept.

We have yet to demonstrate 10 eV energy threshold for dark matter search, or nailed down how the A-B phase transition happens.

Goals

Next 6 months

1. Demonstrate we understand energy scale, threshold with calibration sources
2. Demonstrate that we understand energy deposition events in He and how they trigger phase transitions in data
3. Demonstrate we can reduce background rates!
4. Reach sensitivity to shot noise with SQUID readout - understand baseline!
5. Operate at lower temperature (proposal goal $T/T_c = 0.12$)
6. SD Dark Matter Search analysis (pulse/non-pulse!) with data from “gen 2”
7. Operate nanofabricated resonators with SQUID readout and Lancaster cell

Next 12 months

6. Demonstrate cosmic ray rejection
7. First publication(s) with data
8. Demonstrate the path to realising the potential of $1\text{E-}7$ eV/quanta -
Larger-area resonators? Nanofab bolometers?

To do list notes from Oct.'25 in-person meeting