CUTE
A “quiet” facility for cryogenic (10 mK) experiments

CUTE FACILITY @ SNOLAB

Wolfgang Rau
For the CUTE Team

Overview

Facility Overview
- Design considerations
- Facility components and layout

Facility Performance
- Cryogenics
- Vibrations
- Background

Near term ($\mathcal{O}$(year)) measurement plans
- SuperCDMS detector testing
- Dark Matter search with SuperCDMS detectors

Future of CUTE

Basic Design Considerations

CUTE: a **C**ryogenic **U**nderground **TE**st facility

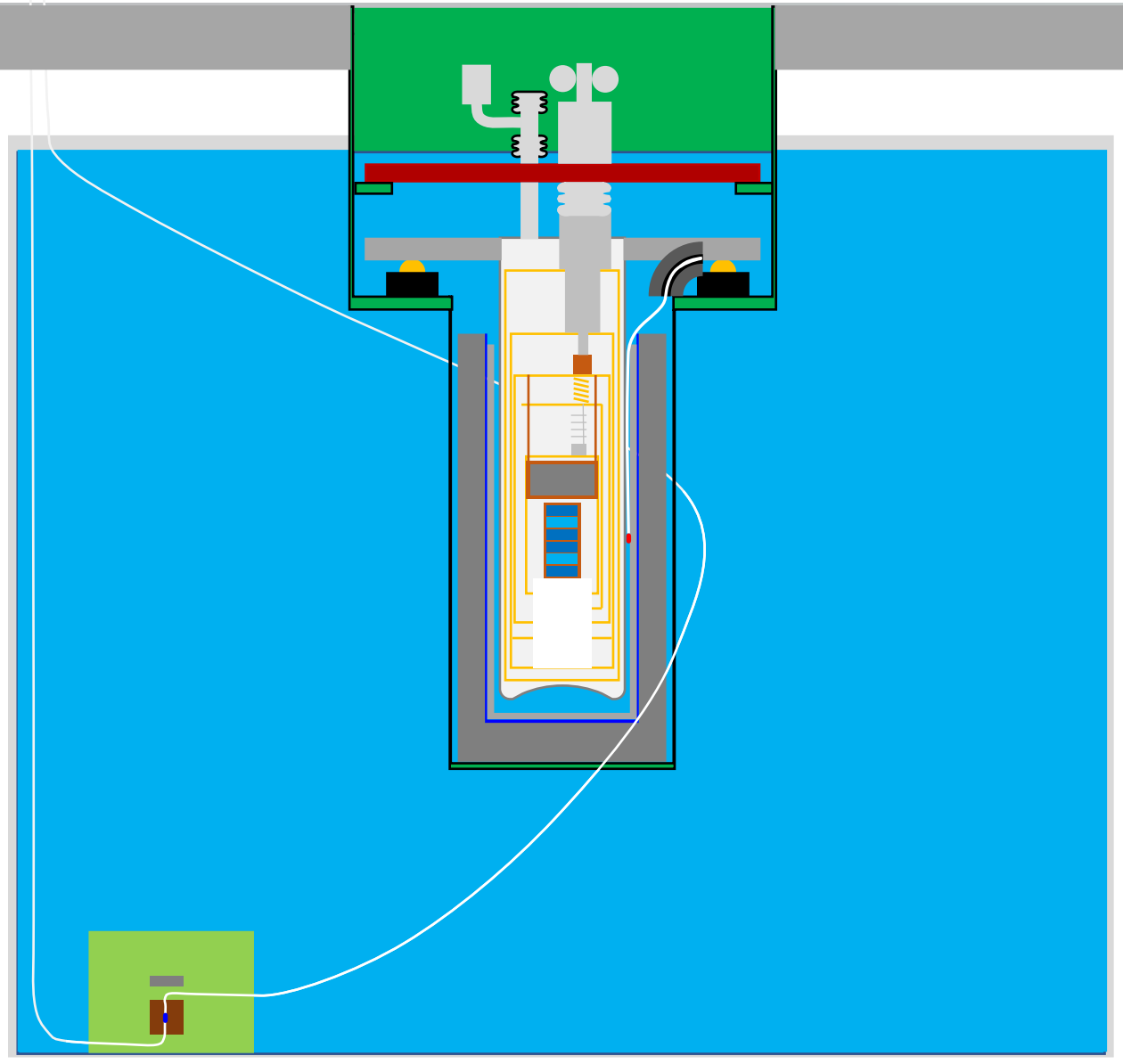
Originally developed for testing SuperCDMS detectors
Required features:

- Operational temperature as low as 15 mK
- Low overall background (large, relatively slow detectors – avoid pile-up)
- Low neutron background (show discrimination between electron/nuclear interactions)
- Minimal mechanical vibrations (can induce detector response / noise)
- Low level of electromagnetic interference (minimize noise in detectors/readout)
- Availability of calibration sources (gamma, neutron)
- Low-radon cleanroom space to change payload

“Upgrade” features:

- Background considerably lower than required for SuperCDMS detector testing
- Facility operable with minimal on-site intervention (except for payload changes)
- Presently being upgraded with full-system UPS for long-term uninterrupted operation

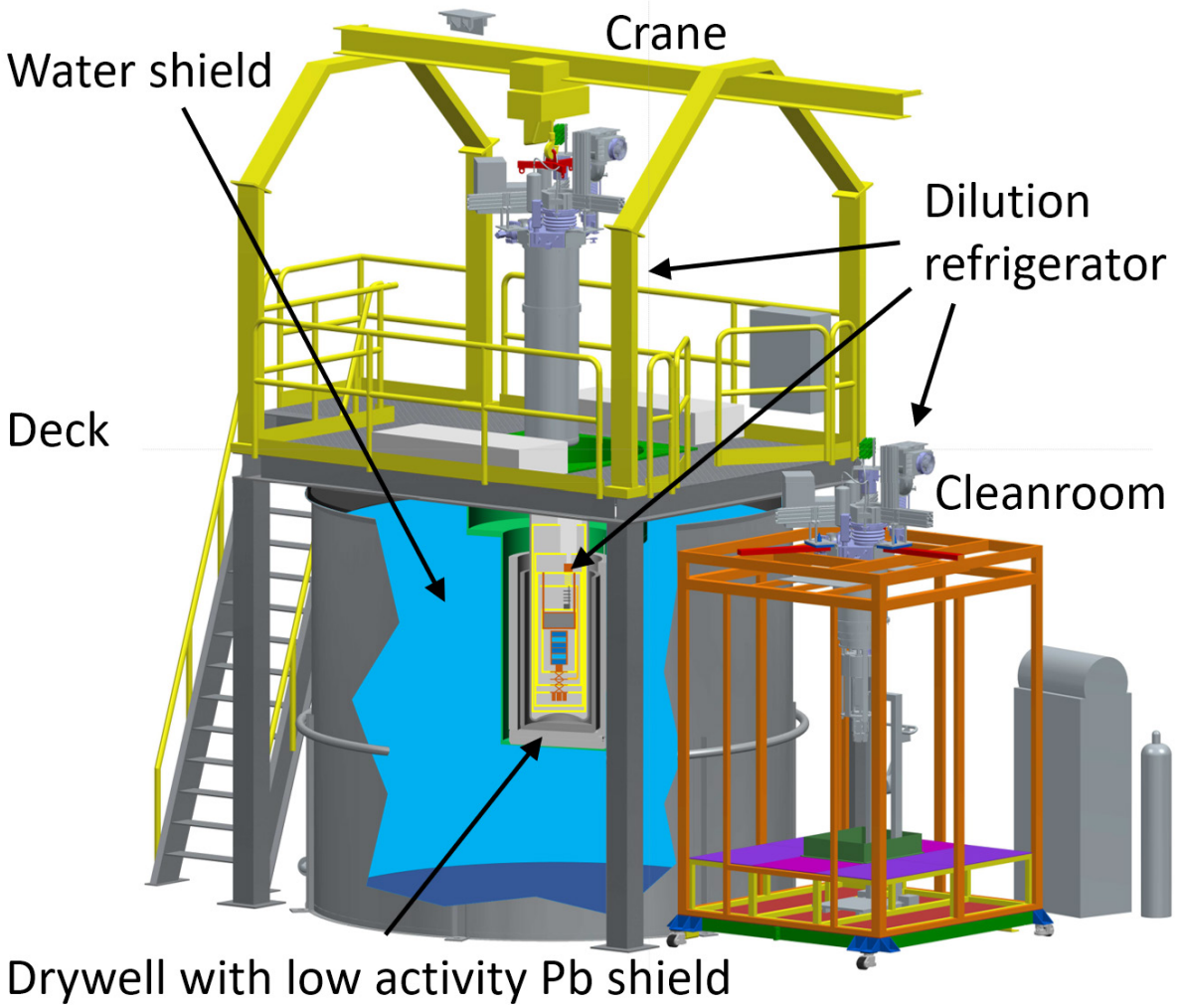
Facility Overview



Main system components:

Payload
Cryostat
Magnetic shielding
Water tank
Drywell
Deck
Low activity lead
Very low activity lead
Internal lead
Polyethylene
Suspension system
Extra frame for
  Pulse Tube (PT)/turbo
Gamma source
Neutron source

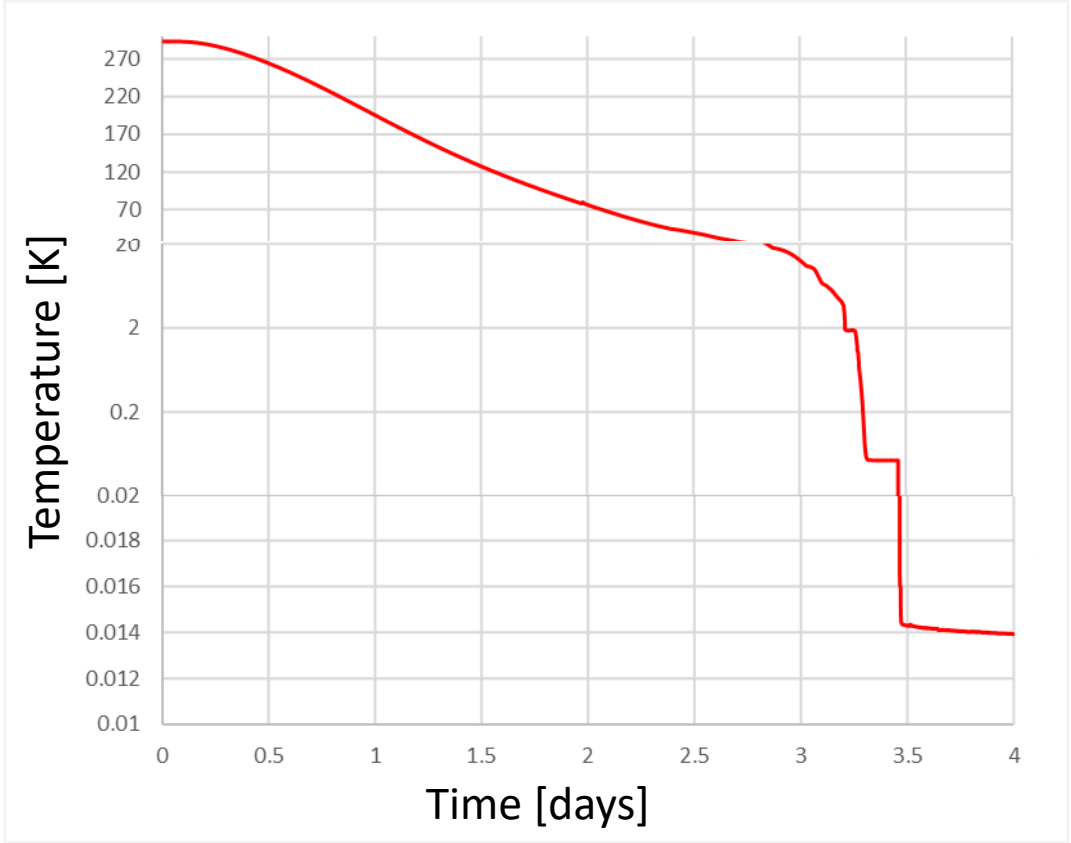
Facility Overview



Facility Performance

Cryogenics:

- Base temperature: ~10 mK (empty)/~12 mK (present payload)
- Cooldown time to 14 mK: ~3.5 days with present payload (one main limiting factor: cooling of internal Pb to <1K)
- Stable operation for $\mathcal{O}$(weeks) with no action required (LN-trap refill ~once per two weeks)

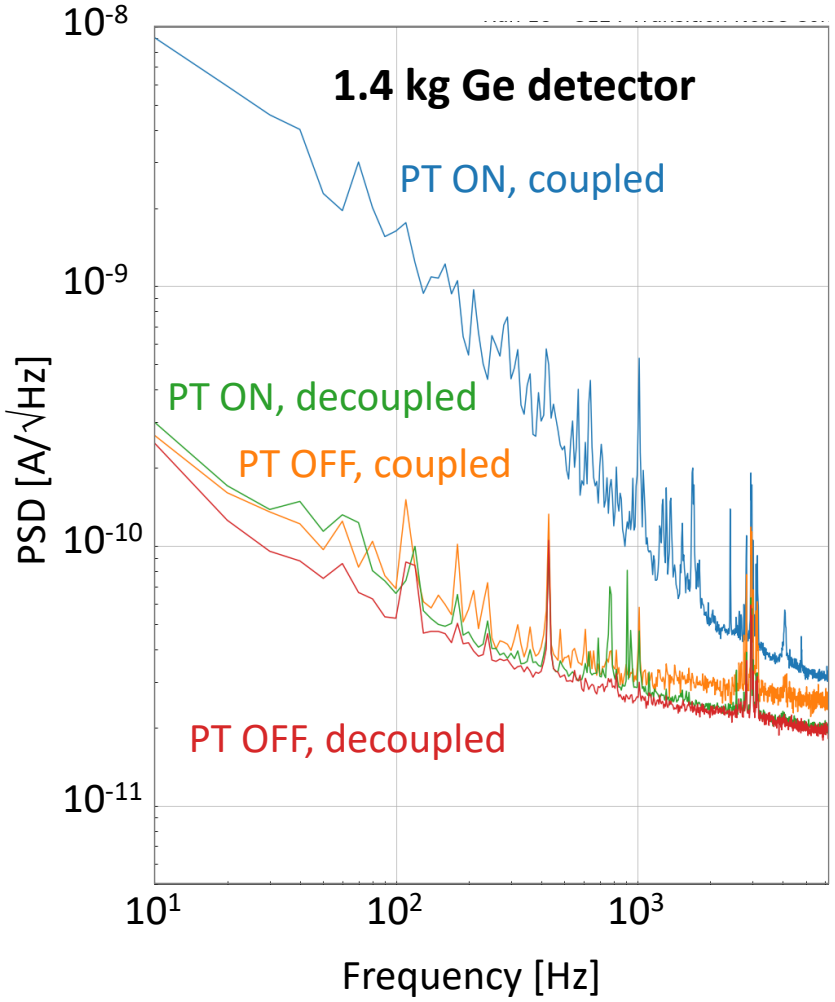


Facility Performance

Vibrations:

- Accelerometers on fridge; limited by acoustic and readout noise (need improvements)
- Use detectors for testing suspension system performance:
  - Noise with fridge coupled to pumps, pumps on
  - Noise with fridge decoupled, pumps on
  - Noise with fridge coupled, pumps off
  - Noise with fridge decoupled, pumps off

$\Rightarrow$ Only marginal difference between pumps on/off

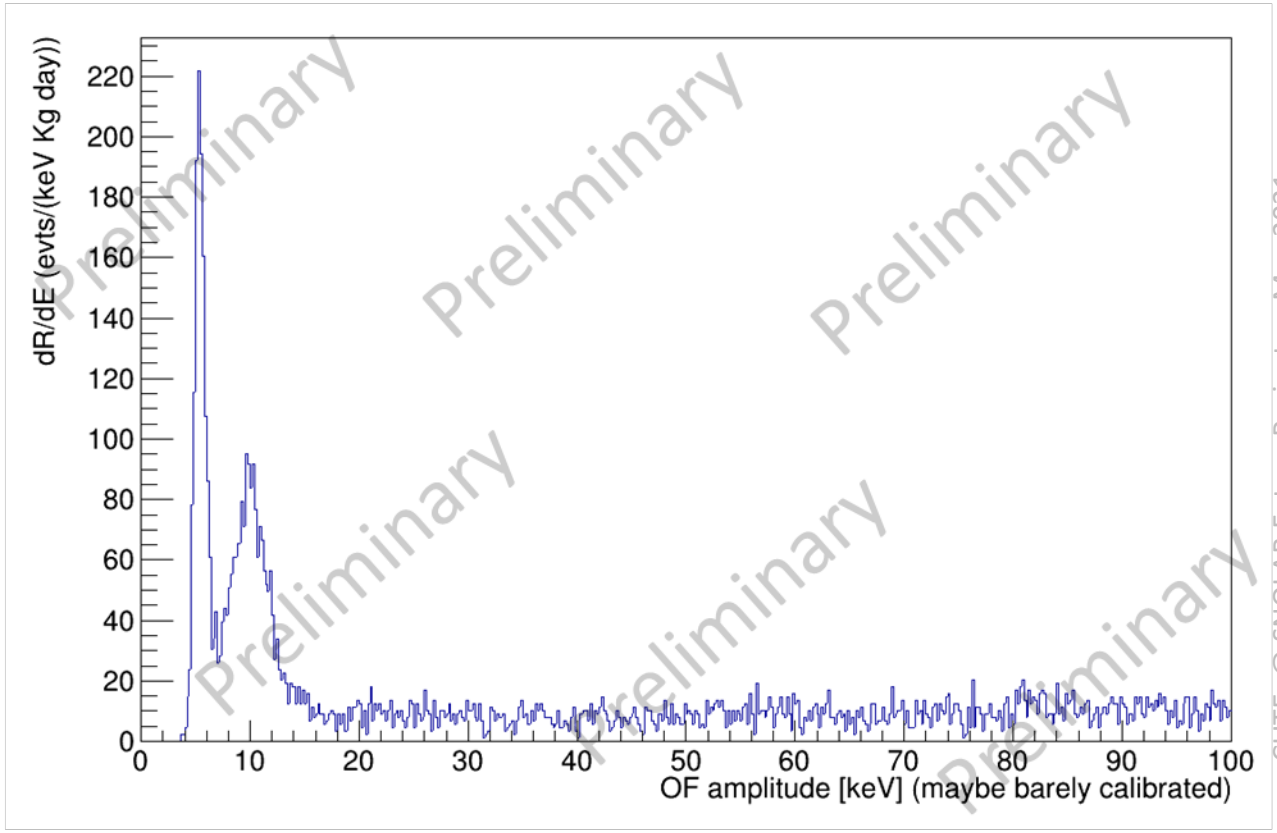


Facility Performance

Background:

- Measurement done with a 600 g Ge detector
- Range of analysis: 10-100 keV: ~7 evts/keV/kg/day
- Below 10 keV: detector intrinsic background dominating
- No good measurement at lower energy yet (expect Compton background to stay ~flat)

- Simulations are being performed to fully understand the measured spectrum and guide possible future improvements



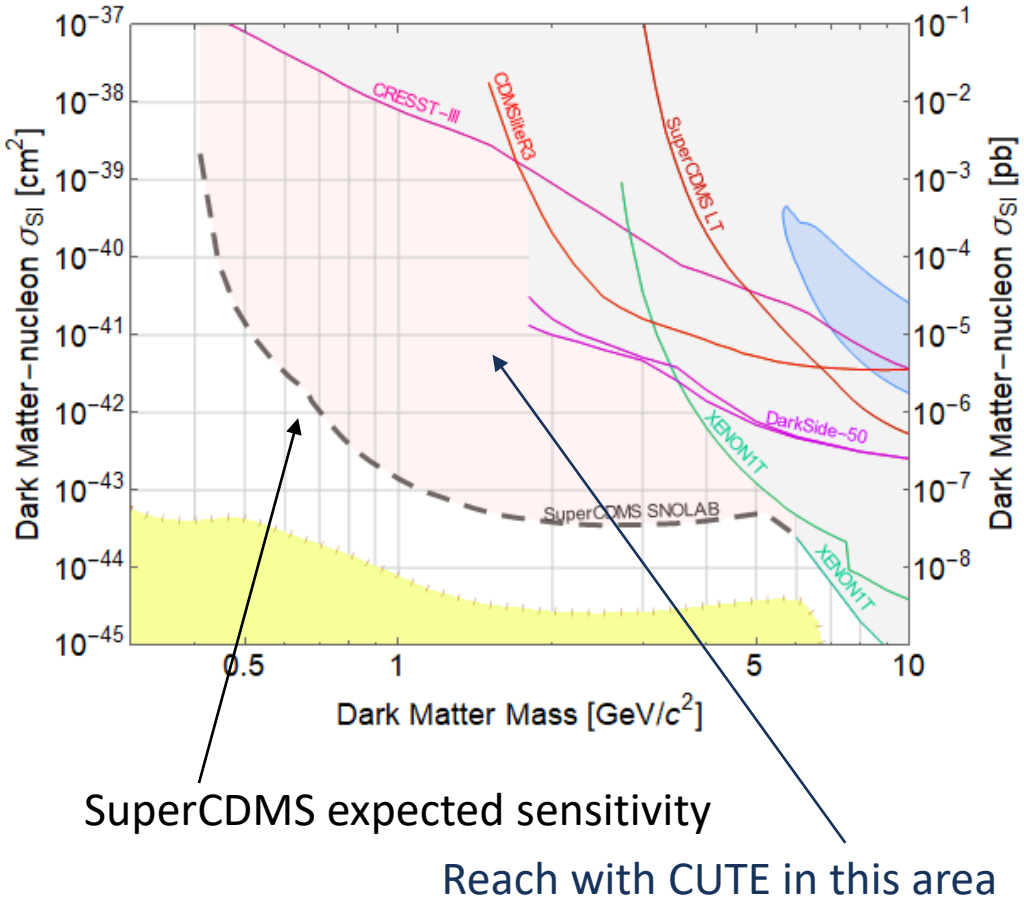
Near Term Plans: SuperCDMS

SuperCDMS Detector Testing:

- First measurement of SuperCDMS Ge HV detector (1.4 kg) at low background and with HV (imminent)
- SuperCDMS Si HV detector (~600 g) test later this summer
- First “tower” (6 detectors) of Ge iZIP detectors (winter 2021/22 or spring 2022)

SuperCDMS Dark Matter Search options in CUTE

- Single Si HV detector
- Full tower with HV detectors (Si/Ge)
- CPD - small low-threshold detector (11 g, Si)



Future of CUTE

CUTE Upgrade options

- Full system UPS (to bridge to backup generator) for uninterrupted long-term operations (will happen)
- Improvements to slow-control system and remote operability (very likely)
- Further background reductions (subject to available funding): improve shielding (close gaps), lower activity materials for some components (e.g. cans) …

CUTE will become a user facility at SNOLAB

- Will collect proposals
- An expert committee will make recommendations
- CUTE management will negotiate terms with potential users (time allocation, potential modifications to facility such as wiring, DAQ, environmental requirements etc.)
- Users will work with CUTE team to implement their experiment

Possible future uses

- Detector testing for future dark matter and other rare event searches (may include upgrades to SuperCDMS or single-photon IR sensors)
- Small scale rare event search experiments (payloads with a total mass of about 20 kg are possible; may e.g. include low-mass DM searches or searches for rare nuclear decays such as ^{50}V)
- Possible non-particle physics application: superconducting Q-bits (testing effect of back-ground on coherence time)

RF wiring (e.g. for Q-bit work) in a similar facility (NEXUS) at Fermilab

The CUTE Team

PI	until 2020: G. Gerbier (W. Rau: Co-PI)
	since 2020: W. Rau
Project Manager	until 2017: Ph. Camus
	2018-2020: S. Nagorny
Operations Manager	since 2021: S. Scorza
SNOLAB team	S. Scorza, A. Kubik, J. Hall (Research Scientists)
	J. Gauthier (Operations Engineer)
	J.M. Olivares (Technical support)
	M. Baiocchi (student)
	Support from SNOLAB technical team
On-site work	J. Corbett, M. Ghaith, S. Nagorny (until 2020)
Off-site	R. Germond (slow control)
	Z. Hong (facility upgrades)
	T. Aramaki (payload)
	B. Serfass, E. Fascione, E. Michielin,
	R. Underwood, Y. Liu et al (DAQ)
	P. Pakarha (2018/19, calibration)
	K. Dering, S. Crawford (design engineering, until 2019/20)

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Conclusion

- CUTE is a cryogenic (~10 mK) low-background (evts/keV/kg/d) low-noise facility operational at SNOLAB
- Payload up to ~20 kg possible; large volume sample chamber
- Thermal cycle: 4 days cool-down, X days measurements, 3 days warm-up, 1-2 days to open/close + payload work
- Operational since 2019; recent progress only possible due to a strong local (SNOLAB) support team
- Facility is being maintained and continuously improved
- Near term use: SuperCDMS detector testing, DM searches with SuperCDMS detectors
- Future use: proposal-based; expect to start this process in 2022

If you have an interesting project that requires a low-background cryogenic facility, get in touch!