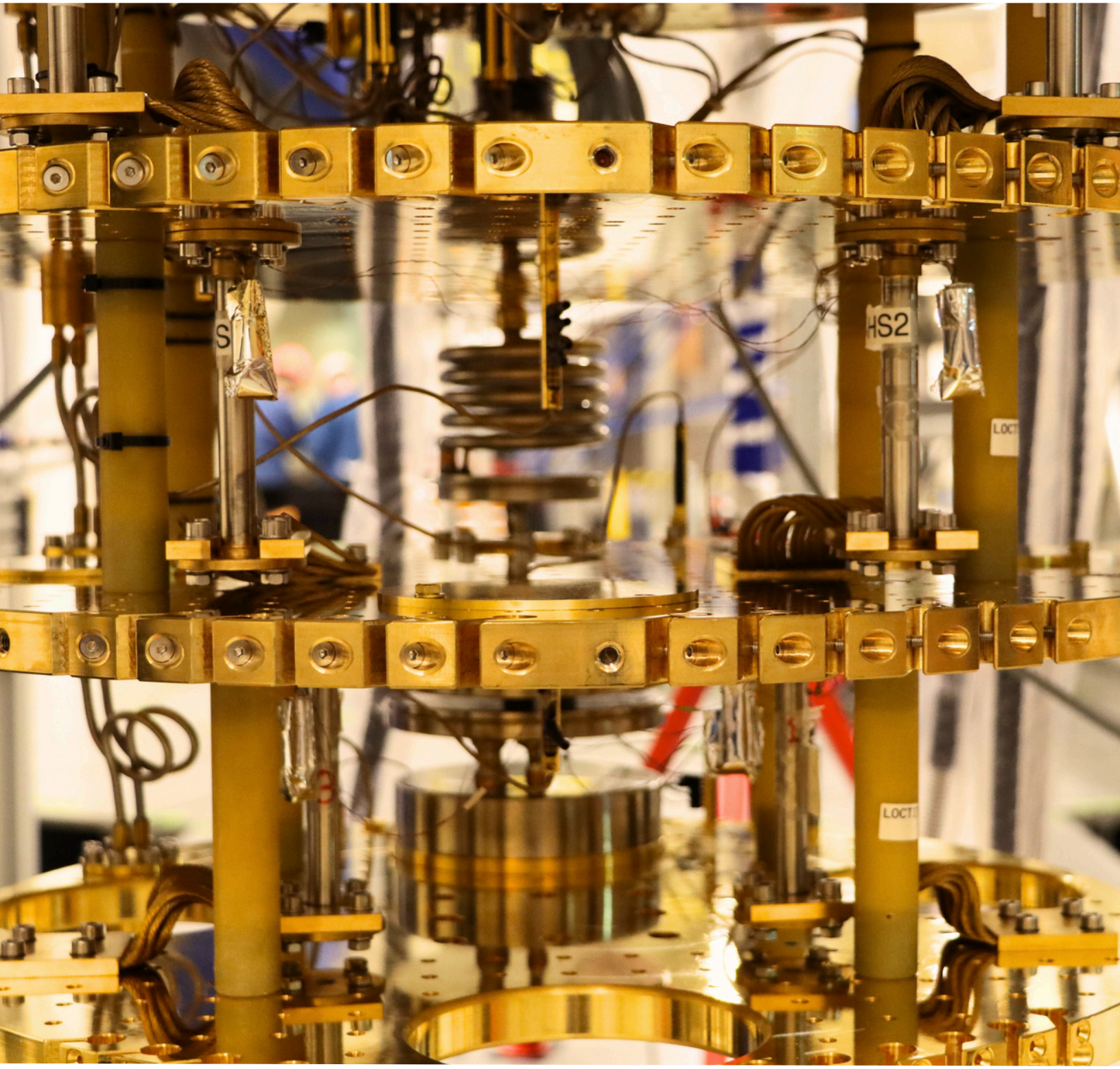
Annual Report

2023-2024

Reaching New Heights, Deep Underground



Land acknowledgement

SNOLAB is located on the traditional territory of the Robinson-Huron Treaty of 1850, shared by the Indigenous people of the surrounding Atikameksheng Anishnawbek First Nation as part of the larger Anishinabek Nation.

We acknowledge those who came before us, and honour those who are the caretakers of this land and the waters.

Our visionary partners

Our five Canadian university joint venture members ensure that SNOLAB maintains an independent and effective Board of Directors. Vale provides invaluable support through access to the two-kilometre depth in its Creighton mine.

Our funding partners

SNOLAB is generously supported by our federal, provincial, and local partners.

Their essential investments in our facilities, research capabilities, infrastructure, and operations support leading edge discovery, research, and innovation for the benefit of all Canadians.

Message from the Executive Director

Over the last decade, SNOLAB has rapidly expanded from a single-experiment site to one of the world's top underground research laboratories and a major Canadian research facility.

The past two years have been a period of renewal for SNOLAB, during which we streamlined our directorate and launched a Strategic Plan, along with an accompanying Implementation Plan. These will allow us to focus on becoming a more productive and responsive workplace, to better support SNOLAB's user groups, and to ensure SNOLAB continues to evolve into a hub of scientific endeavour with a global reach.

We are extremely well-positioned to capitalize on current and emerging global opportunities in underground science and technology. In particular, we are ready to design, host, and support large-scale, next-generation particle physics experiments with the potential to make major breakthroughs in dark matter and neutrinos. I am also excited by the possibilities for advancing quantum technologies in our unique low-radiation environment.

At the very core of our vision sits one vital asset: talented people. This includes our facility's dedicated and skilled staff as well as the diverse group of collaborators who work and train on experiments at SNOLAB. I am very proud of our dedicated team who have brought SNOLAB from its origins as a single experiment into its current position as a multi-disciplinary world leader in underground science with a bright future.

Jodi Cooley,
Executive Director | SNOLAB
Professor of Physics | Queen's University
Adjunct Research Professor | SMU

Diversity & Discovery

At SNOLAB, we believe advancing equity, diversity, and inclusion strengthens the scientific community and the quality of our research. We are committed to creating, supporting, and maintaining a learning, research, and work environment free from discriminatory and intimidating behaviour, and to work collaboratively with other stakeholders, when appropriate, to do the same.

SNOLAB recognizes challenges remain in achieving the full participation of equity-deserving groups (including, but not limited to, women, visible minorities, Indigenous persons, people with diverse gender identities, and people with disabilities) in STEM. SNOLAB is committed to improving equity across our organization and within our experimental collaborations through our 2023-2029 Strategic Plan, our EDI Committee, and task forces.

About SNOLAB

SNOLAB, the deepest-cleanest underground research facility in the world, has made Canada a leader in underground science, infrastructure, and expertise. Located two kilometres underground, our facility near Sudbury uses the Canadian Shield to protect experiments from the cosmic rays that constantly bombard the Earth's surface. Our experimental spaces have the lowest cosmic radiation flux in the world and the least possible interference from radioactivity.

This unique low-radiation environment enables delivery of our world-class astroparticle physics research program. Working with collaborators, we explore priority questions about the evolution of the universe, particularly the role of neutrinos and dark matter. We have also attracted experiments in life sciences and quantum technology to SNOLAB.

We are at a pivotal point in our evolution. International demand for access to our unique environment and capabilities has grown substantially while our organization has matured to meet it. The recent explosion in interest and investment around the world has intensified global competition in underground science. At the same time, our success has created enormous opportunities for international collaboration. To keep Canada and Canadians at the forefront of global science, we must capitalize on these opportunities or risk being left behind.

By hosting and enabling the world's most advanced and sensitive underground experiments, SNOLAB will bolster Canada's scientific reputation, attract new talent to Canada and Northern Ontario, train more highly skilled people, provide more opportunities for Canadian researchers to lead international projects, and generate economic benefits for all Canadians.

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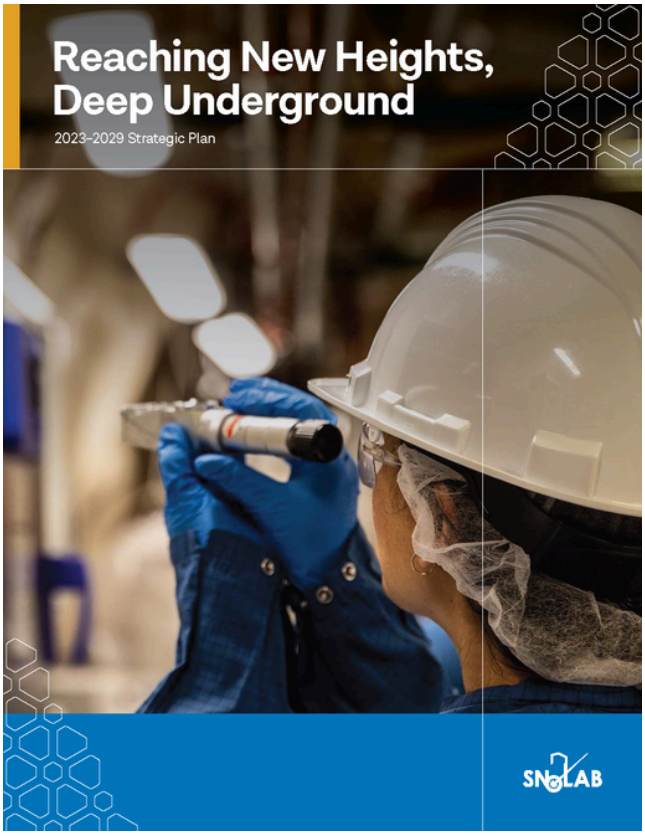
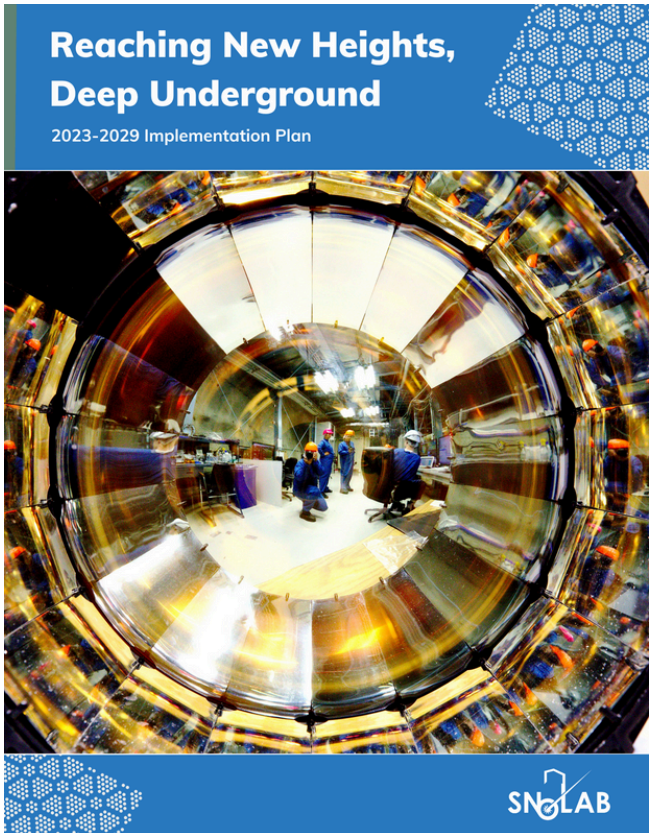
Strategic & Implementation Plans



In 2023, SNOLAB adopted its **Strategic Plan 2023-2029: Reaching New Heights, Deep Underground**. This document provides direction and focus for the organization, guides decision-making, resource allocation, and communicates our vision and mission.

The Strategic Plan will help fulfill the vision to become the leading international underground laboratory. It leverages past investments and builds on SNOLAB's strong record of achievements and recognized strengths. It supports SNOLAB's efforts to create a more equitable, diverse, and inclusive culture that welcomes the community. It also ideally positions SNOLAB to capitalize on emerging global opportunities in deep underground science.



SNOLAB has also adopted the companion **Implementation Plan 2023-2029: Reaching New Heights, Deep Underground**. The Implementation Plan realizes the vision of the Strategic Plan, and together these documents will guide SNOLAB management in prioritizing resources. This enables a sharp focus on projects that directly support and align with the strategic goals of the SNOLAB community.

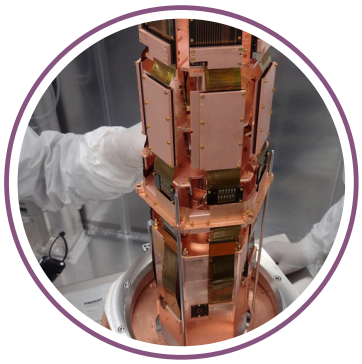
The Strategic Plan is owned by the SNOLAB Institute Board and with this Implementation Plan, will serve as benchmarking documents for oversight, to assess the effectiveness and impact of the facility and of the management team. The entire SNOLAB community drives the strategic direction, and as such, these documents provide a vehicle for continued engagement and alignment with the community SNOLAB serves.

OUR VISION: To be the leading international laboratory in deep underground science, hosting the world's most advanced experiments that provide insight into the nature of the universe.

Three core pillars drive our Strategic Plan.

Excellent Science

GOAL: Drive breakthrough discoveries at the frontiers of underground science



Cutting-Edge Infrastructure

GOAL: Continuously improve our research infrastructure to remain state of the art

Skilled People

GOAL: To foster and develop diverse talent in an inclusive environment

Our core values underpin our vision and goals.

Safety | **Excellence** | **Teamwork** | **Accountability** | **Diversity**

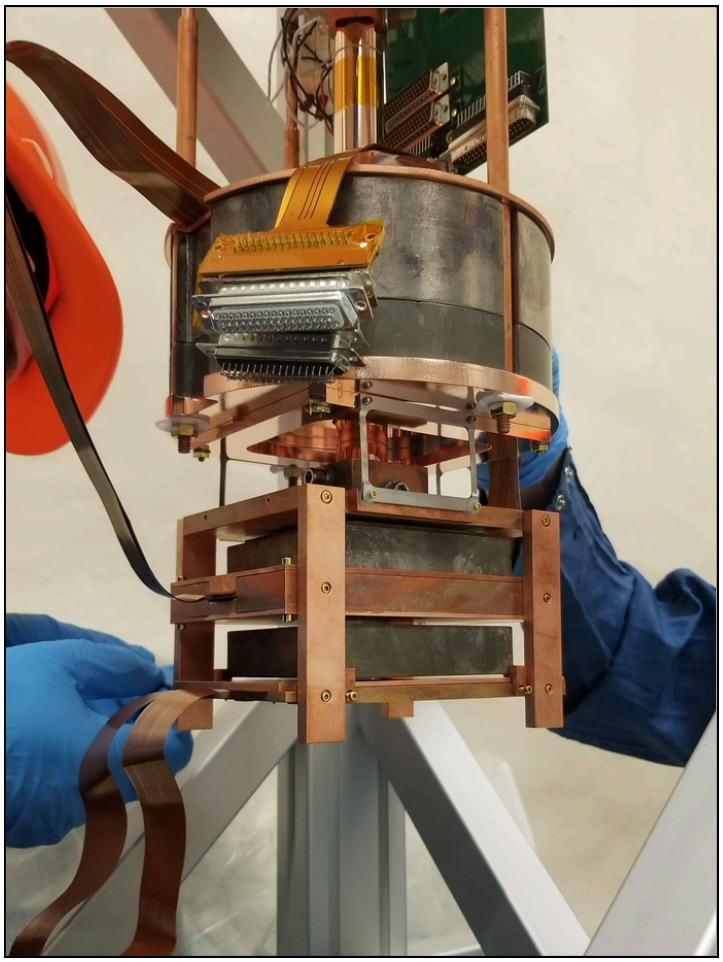
DAMIC

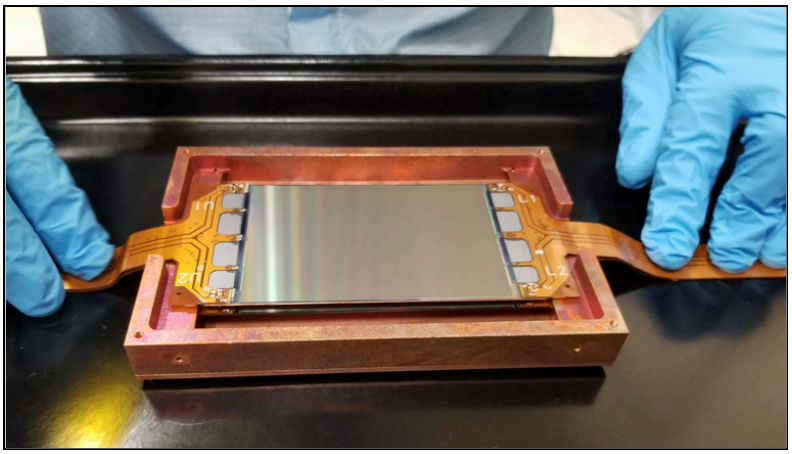
Experiment Description

DAMIC uses CCDs (charged coupled devices) to look for dark matter interactions. The silicon CCDs are electrical circuits made up of many capacitors, which are extremely sensitive to small changes in energy. When a dark matter particle interacts, that energy change can be measured, creating a signal in the data.

Did you know?

- The CCDs used in the next generation DAMIC-M will be some of the largest ever built, at 20g each.
- Interactions within the CCDs are recorded in pixels along the x and y axes, making it possible to map an interaction and determine what particle caused it.
- DAMIC is housed in a copper box which is kept in a vacuum at a temperature of 130 Kelvin, or about -140 C.





ABOVE and **LEFT**: New, more sensitive skipper CCDs are installed in DAMIC.

The success of SNOLAB's two CCD-based experiments, DAMIC and SENSEI, is such that the community plans to build an even larger-scale CCD-based experiment, called OSCURA. The laboratory of choice is SNOLAB, thanks in large part to the lab's demonstrated excellence of operations and conditions.

What's new?

The excess of ionization events in the bulk of DAMIC's CCDs, first observed in the 2020 WIMP search, was confirmed with much more sensitive skipper CCDs installed in DAMIC. The origin of the excess remains a mystery. There is no good "known-physics" explanation and the most straightforward dark matter interpretation is in tension with results from other experiments.

Measurements of the ionization spectrum at lower energies provided world-leading constraints on the existence of dark matter particles with masses in the MeV scale. For this measurement, two CCDs very similar to those at SNOLAB were operated in the Low Background Chamber (LBC) at the Modane Underground Laboratory. The collaboration developed a technique to discriminate between nuclear and electronic recoils in the CCD target. This technique has huge potential since it may allow future CCD dark matter detectors to separately study the different interaction channels (i.e., with either nuclei or electrons) of dark matter particles.

DEAP-3600

Experiment Description

DEAP-3600 uses a vessel of liquid argon to look for dark matter. When argon atoms are excited by particle interactions, they produce ultraviolet light. This light is then detected by sensors surrounding the vessel and analyzed to determine what caused it.

Did you know?

- DEAP-3600 gets its name because it uses about 3,600 kg of liquid argon as its target.
- The spherical acrylic vessel in the centre of DEAP had to be brought into the lab in orange-slice shaped pieces because it was too big to fit in the mine cage in one piece.
- The argon is kept liquid through high pressure and low temperature. If it became gaseous, it would take up almost 600 times as much volume.

What's new?

Results published from the first run of the DEAP-3600 collaboration from 2016 to 2020 allowed researchers to rule out the existence of dark matter particles over a very wide range of values in mass and interaction strength.

DEAP-3600 has since undergone a retrofit that will allow it to reach its original design sensitivity, allow it to verify the DEAP-3600 background model, and allow it to have a "zero background" data set.

ABOVE: **Mark Boulay**, Carleton University professor and Canada Research Chair in Particle Astrophysics and Subatomic Physics, surveys DEAP-3600 before its data run.

BOTTOM: DEAP-3600 has undergone a retrofit that will allow it to reach DEAP-3600 design sensitivity, allow it to verify the DEAP background model, and allow it to have a zero background data set.

HALO

Experiment Description

HALO (Helium And Lead Observatory) uses lead blocks and helium to detect neutrinos. When a neutrino hits lead, it creates neutrons. These neutrons are then recorded by the helium neutron detectors in HALO, creating a signal in the data.

Did you know?

- HALO is part of SNEWS (the SuperNova Early-Warning System), a group of detectors around the world that alert astronomers to supernovae so they can view them with telescopes.
- Most supernova neutrino detectors are only sensitive to one flavour of neutrinos, but HALO is sensitive to all three (electron, muon, and tau).
- HALO is SNOLAB's longest running experiment, in operation since 2012.

What's new?

HALO demands high uptime to catch ghost particles from the explosions of dying stars. Heavy stars will end their lives by collapsing into a terrific fireball that first produces huge numbers of neutrinos and shortly thereafter a brilliant light.

In 2023, HALO's uptime was 99.68%, running as continuously as possible. Since 2017 the HALO experiment has enjoyed 99% or better uptime thanks to the hard work of laboratory staff and experimental collaborators.

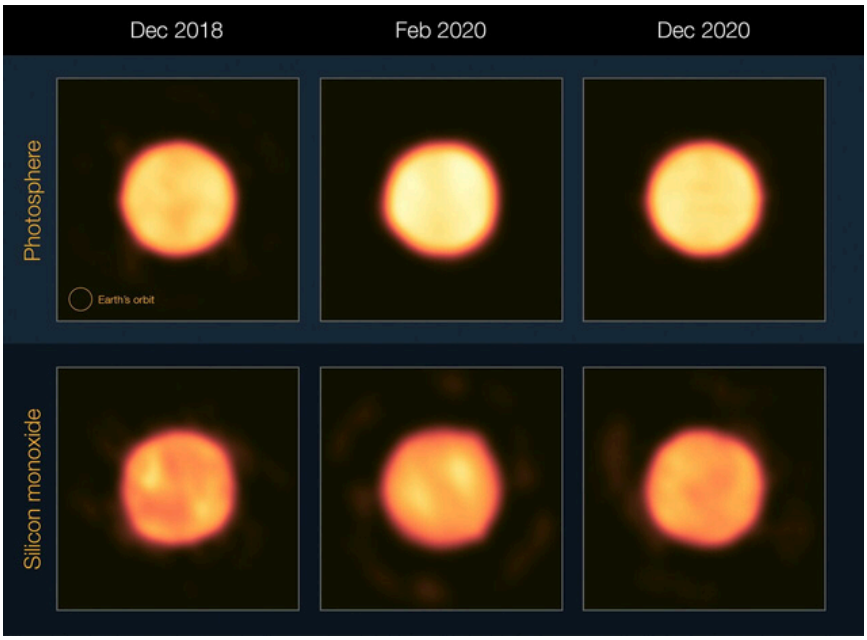


Image from European Southern Observatory

ABOVE: The star Betelgeuse in the constellation Orion was observed dimming for several years before starting to shine brighter than ever in 2023. Astronomers consider Betelgeuse the likeliest known supernova candidate in the Milky Way.

BELOW: HALO waits patiently for the next supernova in our galaxy. The experiment will see the burst of neutrinos that will reach Earth before the light from a supernova. Since neutrinos rarely interact with other matter, they can escape the collapsing star before even the light can make it out. This provides neutrino experiments on Earth, such as HALO, the unique opportunity to know when a supernova is taking place before we see it.

Health Canada

Experiment Description

The CTBT (Comprehensive Nuclear Test Ban Treaty) was adopted by the United Nations General Assembly with basic obligations banning detonation of nuclear explosions. SNOLAB partners with Health Canada in the detection of very small levels of radioisotopes that can provide crucial information about nuclear events, thereby aiding national and international security interests.

Did you know?

Health Canada's Radiation Protection Bureau partners with SNOLAB to provide services in low background counting using several instruments, including:

- gamma counting using ultra-low background germanium detectors,
- alpha counting using an XIA alpha counter,
- passive radon emanation,
- radon and thoron measurements with electrostatic counters,
- alpha-beta counters,
- X-ray Fluorescence (XRF) spectrometry and general gamma spectroscopy.

SNOLAB Scientific support staff **Dimpal Chauhan** changes out the filter at Health Canada's Canadian Radiological Monitoring Network at SNOLAB.

What's new?

SNOLAB and Health Canada have expanded their research collaboration with the addition of a radiological monitoring station located on surface at SNOLAB.

The new station, part of Health Canada's Canadian Radiological Monitoring Network (CRMN), is one of 84 fixed point stations across Canada, as well as one of 28 dedicated radiological monitoring stations also across Canada. In operation since 1959, CRMN monitors air particulates, precipitation, and water vapour at various sites.

SNOLAB's fixed point station generates data every 15 minutes. Result summaries are available on Health Canada's website, while near real-time results are publicly available at the European Radiological Data Exchange Platform (EURDEP) website.

The radiological monitoring station builds on Health Canada's existing partnership with SNOLAB's underground Low Background Counting Facility, which is used to verify compliance with the International Comprehensive Nuclear Test Ban Treaty.

NEWS-G

Experiment Description

NEWS-G (New Experiments With Spheres – Gas) uses a spherical copper vessel filled with a noble gas to search for dark matter. When a particle enters the sphere it ionizes some of the gas, generating electrons. A sensor in the middle of the sphere held at a high voltage attracts the electrons, creating a charge that can be measured.

Did you know?

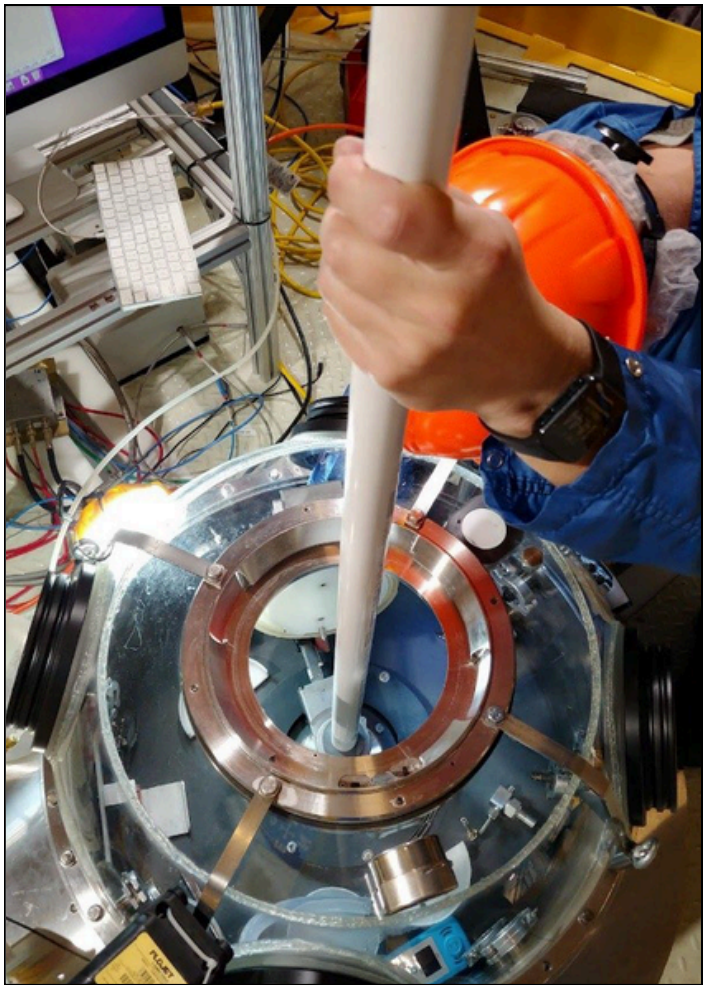
- The pieces of the detector manufactured in Europe had to be shipped to SNOLAB by sea because a flight would expose them to too much radiation.
- One of the pieces of lead shielding for NEWS-G is the heaviest object ever shipped underground to SNOLAB. Along with the specially reinforced rail car it travelled on, it weighed about 75,000 lbs.
- A prototype of the detector operated at Modane in France and was originally intended to study low-flux neutrons. Things like the detector's very low energy threshold for detection caused the collaboration to shift their focus to dark matter.

What's new?

The NEWS-G experiment welcomed new upgrades that will help the detector to continue to get reliable data for years to come.

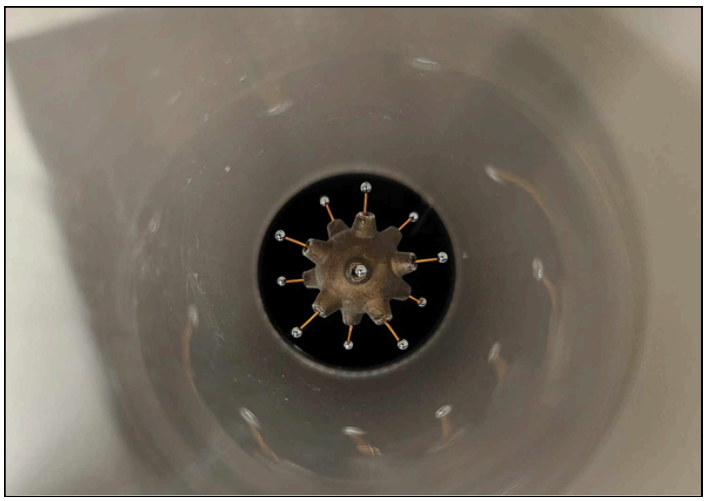
The inner vessel of NEWS-G was cleaned using a method called etching. Etching uses an acid solution to remove an outer layer, normally only nanometers thick, from a material. A special etching system was installed that avoided the detector being exposed to mine air and further contaminating the highly sensitive inner vessel.
The upgrades also included an improved sensor after a quick test showed the sensor was damaged. These sensors, known as achino sensors, are held at high voltages as a method of attracting electrons and reads out a charge.

These upgrades will reduce minute radioactive backgrounds within the experiment to new levels, allowing NEWS-G to continue taking groundbreaking physics data in the search for dark matter.



ABOVE: The detector was pumped down back to vacuum level (which involves removing any of the leftover water in the detector) and was refilled with Argon gas.

BELOW: NEWS-G's new achino sensors underwent testing and a vigorous cleaning procedure prior to being installed.



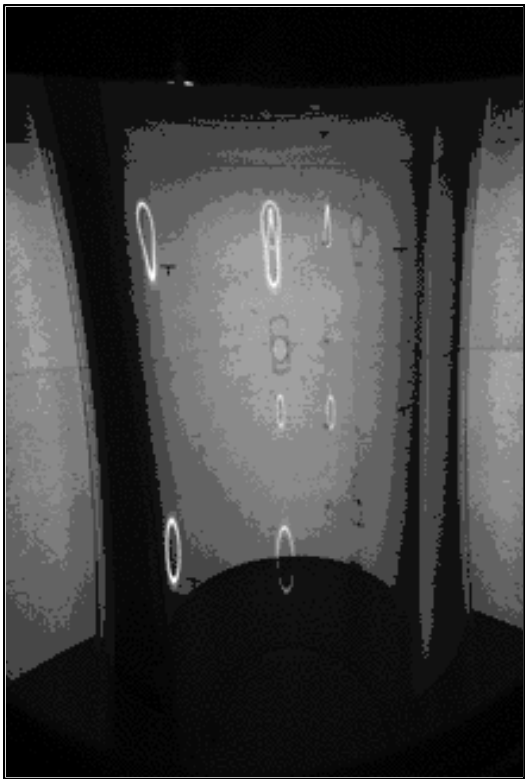
PICO-40L

Experiment Description

PICO uses a bubble chamber to look for dark matter. The fluid in the bubble chamber is superheated, so when a particle interacts, it boils and creates a bubble. This bubble is captured on camera and microphone, and studying it can tell scientists about the particle that caused it.

Did you know?

- The fluid is superheated, but since it's a refrigerant, the temperature is actually slightly cooler than room temperature.
- The fluid used is the same refrigerant formerly used in household fridges.
- The cameras are constantly firing, and each frame is analyzed to look for bubbles. When one is detected, bellows compress the liquid to prevent it all from boiling.



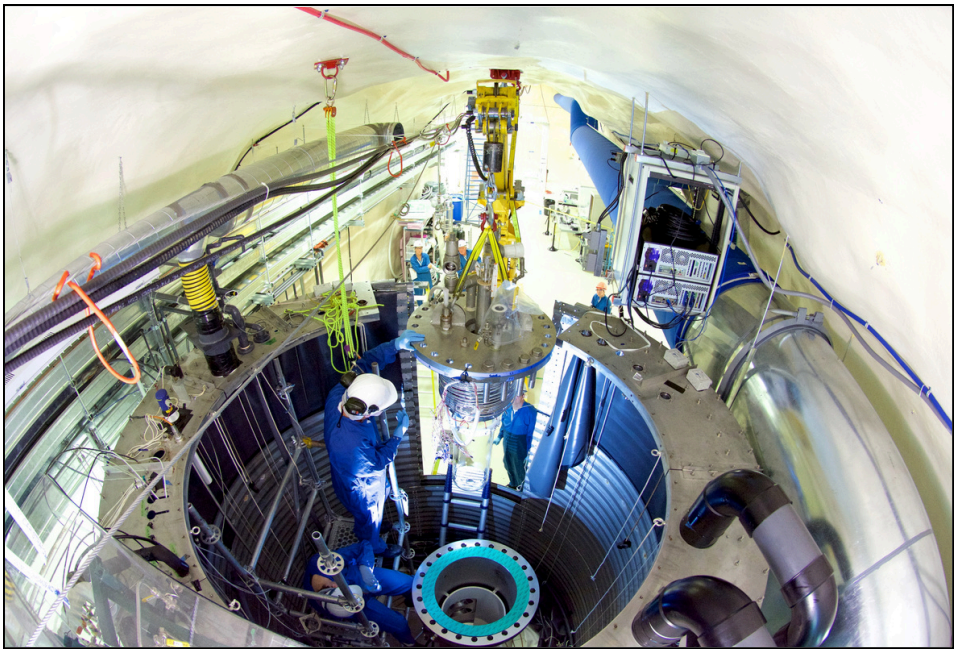
ABOVE: The most recent fill of the PICO-40L chamber with 70 kg of refrigerant, after which a single bubble event was captured during the commissioning of the pressure system.

What's new?

Three bubble chamber detectors have been constructed at SNOLAB. Following successful runs of PICO-2L and PICO-60, PICO-40L was completed in 2023. PICO-40L, which is filled with 70 kg of refrigerant, has sealed up its water shield tank and is operating.

Additionally, a scaled-up detector with a target mass of almost 500 kg (PICO-500) is fully funded and currently in the procurement and assembly phase in SNOLAB's Cube Hall. The PICO experiment has demonstrated that moderately superheated bubble chambers can be used for the direct detection of nuclear recoils.

BELOW: Looking down into the water shield during PICO 40L's assembly.



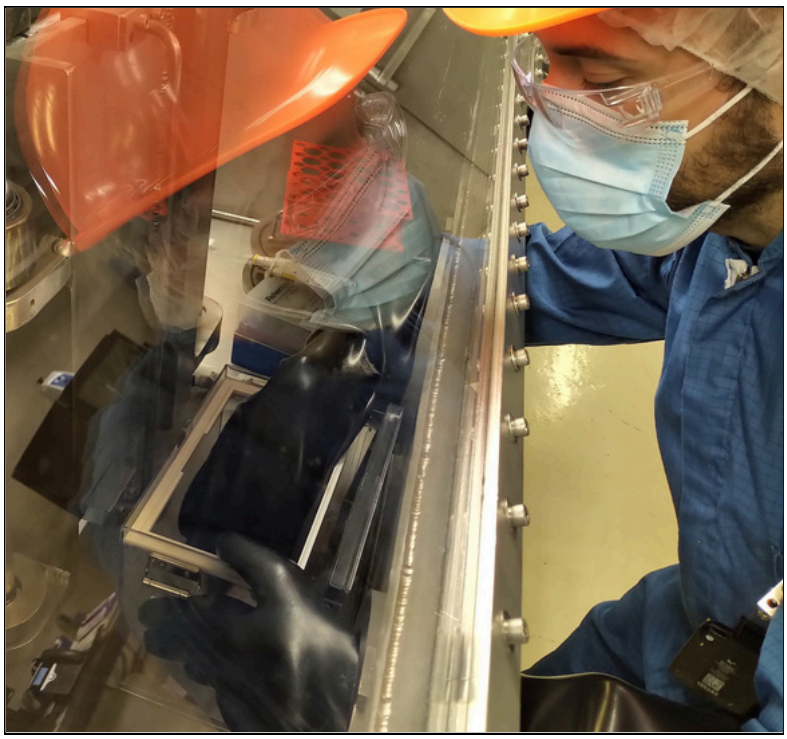
REPAIR

Experiment Description

REPAIR (Researching the Effects of the Presence and Absence of Ionizing Radiation) studies the effects of very low background radiation levels on living organisms. It looks for cancer risk and DNA changes in human cells, and whole-organism development and growth in lake whitefish embryos, desiccated yeast, and human skin cells.

Did you know?

- REPAIR is one of the deepest biological life sciences research projects in the world.
- REPAIR is testing the hypothesis that because all life on Earth evolved in the presence of natural background radiation, the absence of it could be detrimental to biological systems.
- Lake Whitefish were chosen because they remain as embryos for 100-200 days (a long time for fish). This allowed scientists to monitor very subtle changes as they developed.



Michel Lapointe, a postdoctoral fellow at Laurentian University, examines yeast cultures in the glove box in SNOLAB's underground chemistry lab.

What's new?

REPAIR has conducted three experiments to date. First, cultivation of of human hybrid CGL1 cells in a 30-times reduced radiation environment at SNOLAB for 16 weeks compared to a surface control, found increased alkaline phosphatase (ALP) activity in SNOLAB-cultured cells, suggesting elevated transformation rates.

Second was the desiccation and storage of yeast in a seven-times reduced radiation environment at SNOLAB for up to 48 weeks. Reduced survival and metabolic activity in the sub-background environment indicate a negative response to the absence of background radiation.

Third, further reduction in desiccated yeast background dose rate using lead shielding and a tailored yeast broth with a low concentration of the radioactive isotope potassium-40. This experiment achieved a 550-times reduction in background dose rate, and its impact on yeast metabolic rates was significant.

Research published by REPAIR noted that yeast exposed to the lower-radiation underground environment were more likely to die off when re-exposed to the nominal surface radiation environment.

Chris Thome, assistant professor at NOSM University, inspects a CubeSat mockup at NASA's Kennedy Space Center. A yeast sample deployed in a BioSentinel CubeSat satellite from the 2022 Artemis 1 mission was designed to test yeast to deep space radiation between 30 and 50 million kilometres from Earth. Unfortunately, the CubeSat did not deploy correctly.

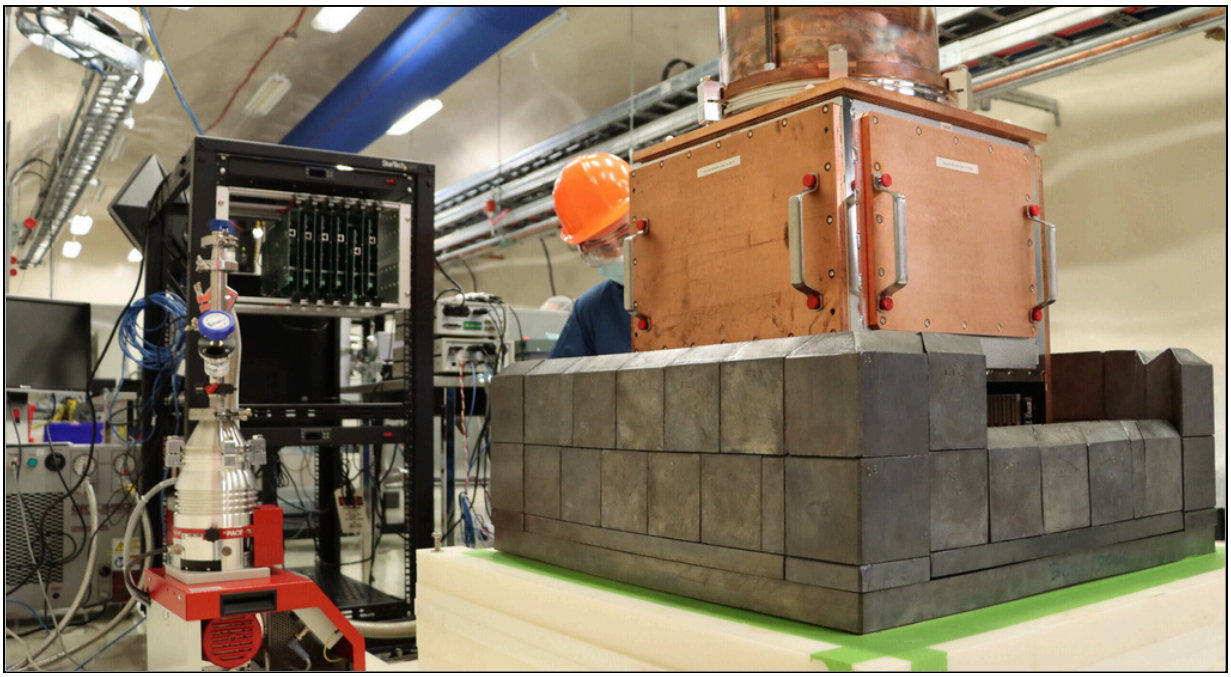
SENSEI

Experiment Description

SENSEI (Sub-Electron Noise Skipper Experimental Instrument) uses Charge-Coupled Devices (CCDs), the same technology found in cell phone cameras, to search for dark matter. When a particle interacts, it causes a small energy change which is captured by the CCD. The CCDs have millions of pixels, and SENSEI is able to count every electron within a pixel, leading to incredibly accurate measurements with no background noise.

Did you know?

- The latest generation of CCDs are so sensitive we can now precisely count each individual electron in each pixel of a large CCD consisting of millions of pixels, whether the pixel contains only zero or one electron, or if it contains more than 1,000 electrons.
- Members of the SENSEI collaboration were awarded the 2021 New Horizons in Physics Breakthrough Prize.
- Though designed and built at Fermilab, SENSEI was assembled at SNOLAB entirely by SNOLAB staff because of COVID-19 pandemic travel restrictions. Extraordinary teamwork between physicists on both sides of the border ensured it moved forward on schedule.



A collaboration member installs lead shielding around the base of SENSEI, one of two CCD-based dark matter experiments in SNOLAB.

What's new?

SENSEI is the first experiment to use Skipper-CCDs in the search for dark matter, and to publish world-leading results using this technology. The experiment's six original CCDs took data from October 2022 to April 2023, capturing 129 images, including 45 good non-blinded commissioning images and 37 good blinded images. The collaboration is using this data to set world-leading constraints on sub-GeV dark matter interacting with electrons and nuclei.

In 2023, SENSEI completed a maintenance and upgrade period and has taken another sample of data, which the collaboration is analyzing.

SNO+

Experiment Description

SNO+ uses a liquid scintillator to detect neutrinos. When a neutrino hits the detector it creates charged particles. When these particles hit the scintillator it gives off light which is detected by thousands of sensors surrounding the vessel. Tellurium will also be added to the scintillator in the future in hopes of detecting neutrinoless double beta decay.

Did you know?

- The liquid scintillator in SNO+ is lighter than regular water, while the heavy water in SNO was heavier. This means the vessel now has ropes holding it down instead of lifting it up.
- A company in Quebec produces the liquid scintillator used in SNO+.
- SNO+ researchers paddled around inside the vessel in small inflatable dinghies to inspect the acrylic walls.

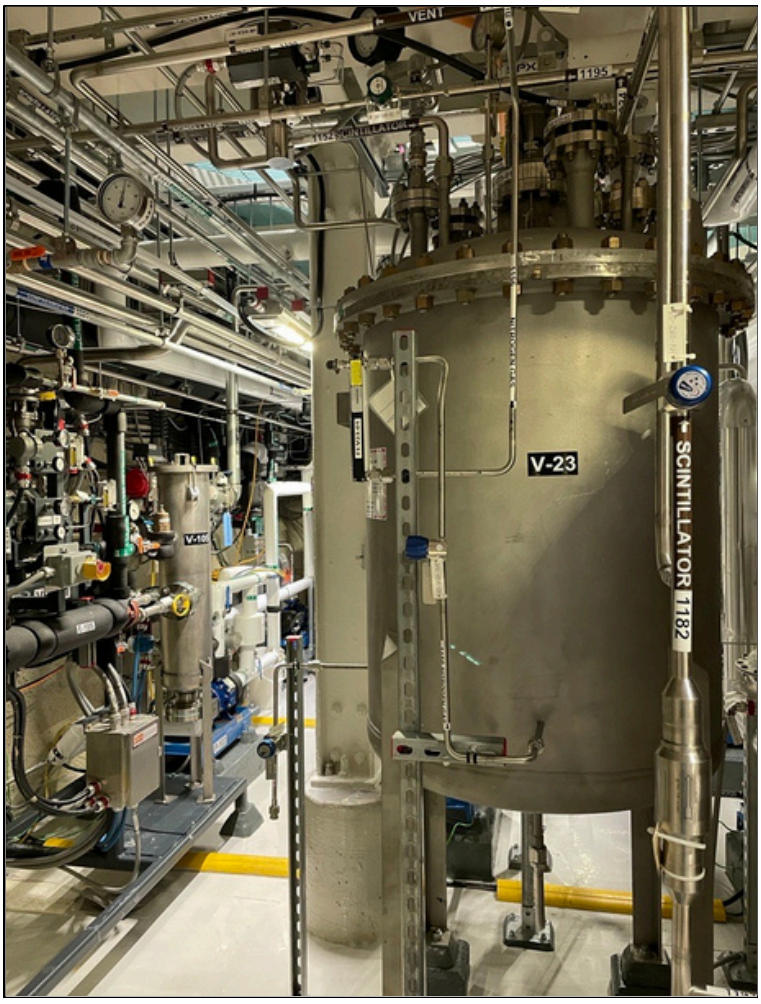
What's new?

The SNO+ collaboration, with support from SNOLAB staff, completed the liquid scintillator detector fill and PPO loading marking a huge milestone for the experiment. The acrylic vessel now holds 780 tonnes of liquid scintillator along with two tonnes of a dissolved chemical compound called PPO. The PPO powder, roughly the weight of four grand pianos, was carefully added in small batches, ensuring it fully dissolved in the liquid scintillator.

The collaboration also published its first results from the ultra pure water phase. The results, from 190 days of data in 2018, showed an antineutrino signal that came from the Bruce, Darlington, and Pickering nuclear generating stations hundreds of kilometres away. This suggests it is possible to use neutrino detectors such as SNO+ to continuously monitor a reactor's power production from a great distance, and that it is possible to build neutrino detectors with ultrapure water, a non-toxic, inexpensive, and easy-to-handle material.

TOP: The SNO+ collaboration and SNOLAB staff celebrate the liquid scintillator detector fill and PPO loading.

BELOW: The liquid scintillator plant, effectively a small underground oil refinery, is in full operation.



SuperCDMS

Experiment Description

SuperCDMS uses silicon and germanium crystals to detect dark matter. When a dark matter particle hits the crystals, it deposits a small amount of energy in them, which can be measured. The crystals are arranged in towers and connected to electronics that monitor the data, looking for an interaction.

Did you know?

- The crystals are kept at extremely low temperatures to reduce thermal noise created by the crystals themselves. SuperCDMS will operate at 15 milliKelvin (absolute zero is 0 Kelvin).
- SuperCDMS is designed to look for “light dark matter,” in this case, light refers to its mass and dark refers to it being impossible to see.
- Each of the germanium and silicon crystals (10 cm across) has 1,000 sensors on each side to detect energy from interactions.

What’s new?

The dilution fridge and four detector towers arrived at SNOLAB from the U.S. Department of Energy-run Fermilab and SLAC respectively. All are in the underground lab while the shielding is completed. Delivery of other pieces coming from Jefferson Lab and Pacific Northwest National Lab are being scheduled in the coming year.

ABOVE: Postdoc **Vijay Iyer** moves one of four detector towers that will be at the heart of SuperCDMS into the Ladder Labs.

CENTRE: Detector tower three is loaded into CUTE for a five-month test run.

BOTTOM: The rest of the towers wait in the SuperCDMS low radon clean room awaiting the Outer Vacuum Chamber (OVC) and shielding assembly.

Facility Capabilities

Cryogenic Test Stand
Millikelvin, low-background facility for pure and applied research. 10 mK base temperature with 1-week experiment turnaround time. Currently used for quantum device characterization and low mass dark matter searches.

Low Background Counting Facility
The Low Background Counting Facility at SNOLAB provides material assay and screening and environment monitoring capabilities. The facility instrumentation includes HPGe detectors, alpha counters, and neutron detectors.

Life Science & Chemistry Lab
Located in the underground clean room, this lab is specialized for analytical chemistry and life science experiments. The facility has bench space, a fume hood, an ultra pure water system, an analytical balance, chemical storage, and ultrasonically cleaned equipment.

Surface clean lab
The surface clean lab provides space for prototyping, compatibility testing, and staging and assembly of experiments before they are shipped underground.

Machine Shop
An underground shop was set up so that experiment components and equipment can be machined without being exposed to surface levels of background radiation. Currently, the shop contains a lathe, milling machine, drill press, cut off saws, and a band saw.

Scientific Support
SNOLAB's scientific support staff provide a wide range of physics support, chemical and radiological assay, chemical process development, surface laboratory operations, and a chemical safety program.

Experiment Areas
SNOLAB offers 5,000 square metres of underground Class 2000 clean space. The SNO cavern, Cryopit, and Cube Hall are experimental caverns for large experiments, and the Ladder Labs are drift areas for small and medium-sized experiments.

Underground Monitoring
The underground laboratory has instrumentation to continuously monitor its radon levels. In addition, the laboratory employs instrumentation for seismic monitoring and a radio frequency spectrum analyzer to survey and catalog areas for electrical noise.

Liquid Nitrogen Plant

SNOLAB has opened its new Liquid Nitrogen (LN2) plant to provide the 2,000 litres per week of LN2 the lab's experiments and systems use. Nearly every group at SNOLAB played a role in achieving this major facility milestone, including engineers, designers, electricians, scientific support, and researchers. SNOLAB's cryogenics needs are expected to grow in the coming years and producing LN2 onsite that is 99.998% pure positions SNOLAB well to host next-generation experiments with greater cryogenic requirements.

LEFT: SNOLAB commissioned a new **Liquid Nitrogen Plant** to meet most of the lab's cryogenic needs, and celebrated it (**INSET**) by making LN2 ice cream underground.

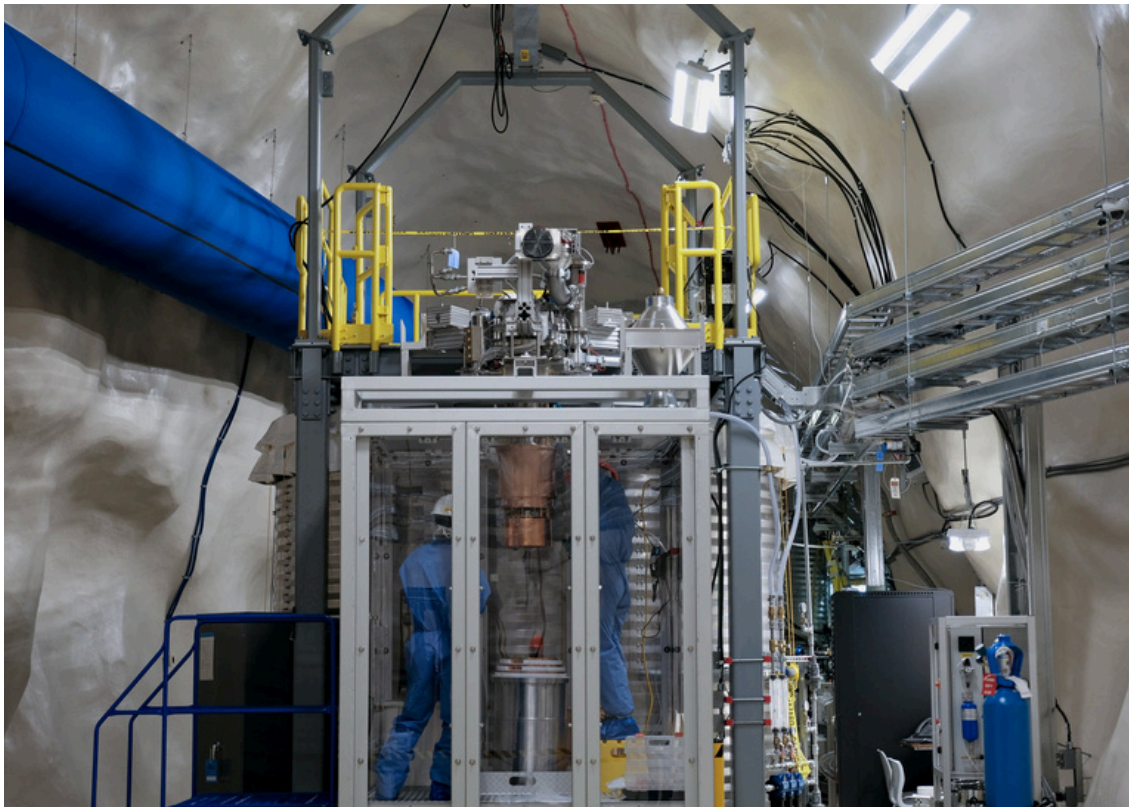
Water Jet Cutter

SNOLAB has installed a new water jet cutter in the surface machine shop, with cutting envelope greater than 8x4 feet and output of 60,000 psi. The addition means major components can be custom fabricated onsite and no longer need to be contracted out.

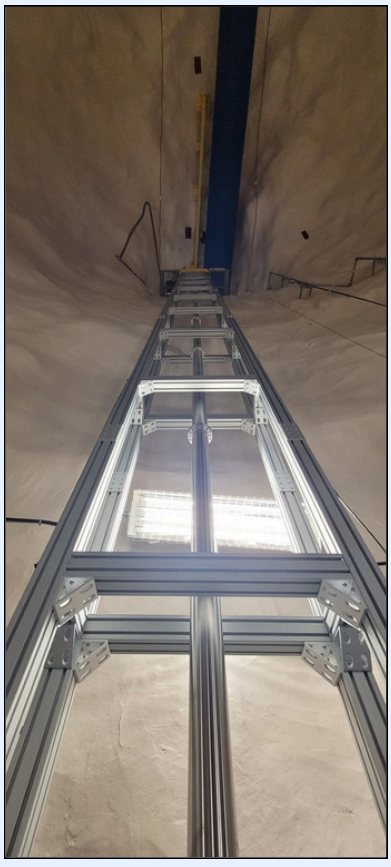
RIGHT: SNOLAB Industrial Technologist **Steve Brunelle** cuts the lid for PICO 500.

CUTE

RIGHT: CUTE (Cryogenic Underground Test facility), is owned and operated by SNOLAB to test components of other experiments. It is well shielded from background radiation, can operate at very low temperatures, and is designed to prevent micro-vibrations that could interfere with testing. One of the detector towers for SuperCDMS was installed in CUTE for a five-month test run. Future plans for CUTE include testing quantum components.



Xenon Still



LEFT: Future searches for neutrinoless double beta decay may require more than five tonnes of enriched xenon, driving the need for increased xenon production as well as efficient enrichment methods. Cryogenic distillation is a proposed alternative that depends on the relative vapour pressure differences of the xenon isotopes. SNOLAB has hosted the first credible measurement of these parameters for xenon using a 14-metre tall xenon still in the Cryopit since 2020.

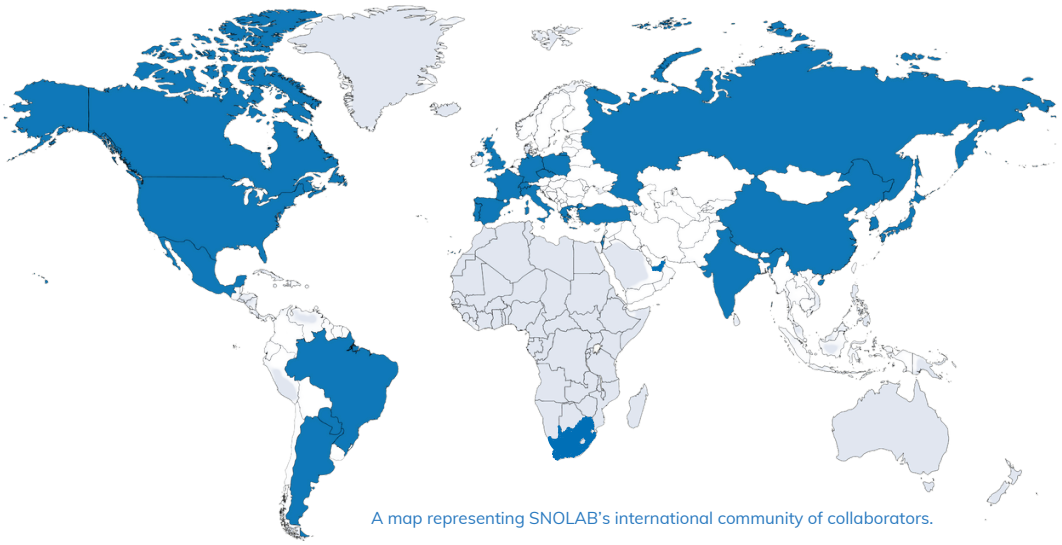
UPW degasser

RIGHT: SNOLAB installed a new Dolphin pump and degasser to support the underground ultra pure water plant, which produces water free of particulates, organic material, ions, and gases.

SNOLAB by the Numbers

SNOLAB and the world

SNOLAB is the partner of choice for deep underground science nationally and internationally. Our scientific program currently supports more than 1,000 annual academic users and collaborators, of which around 25% are Canadian researchers. Our international collaborators come from 24 countries and are based at 165 different institutions.



A map representing SNOLAB's international community of collaborators.

1000+ annual academic users/collaborators

25% of those users/ collaborators are Canadian researchers

23 Our international collaborators come from 23 countries

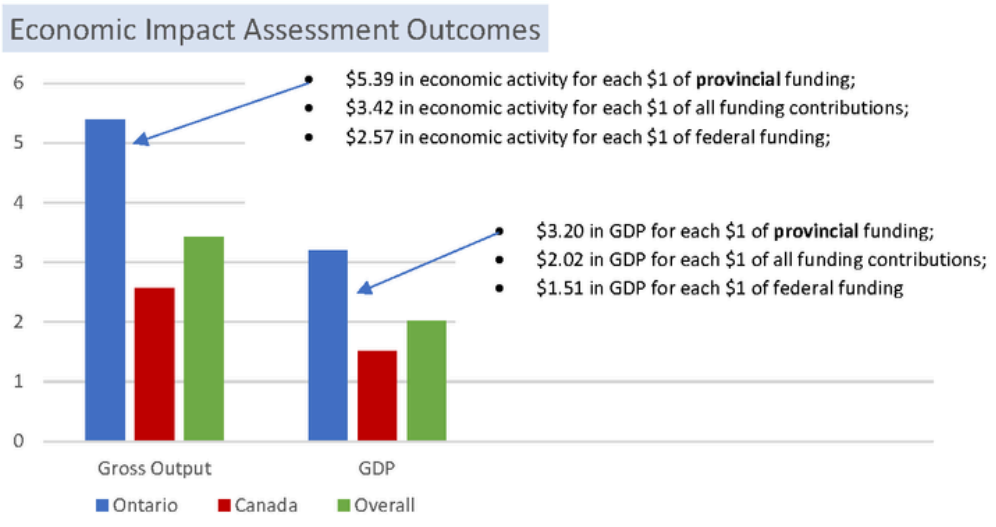
165 Our international collaborators come from 165 institutions

Country	Institutes	# of Users
Belgium	1	1
Canada	**20**	**280**
China	2	17
Czechia	1	10
France	6	21
Germany	8	72
Greece	1	2
India	2	9
Israel	1	8
Italy	17	71
Japan	3	15
Mexico	1	17
Poland	2	10
Portugal	1	9
Russia	12	78
Slovakia	1	5
South Africa	1	4
South Korea	2	5
Spain	2	11
Switzerland	2	12
Turkey	1	1
UAE	1	1
UK	11	50
USA	66	428
Total	**165**	**1,137**

SNOLAB is an economic powerhouse

In 2022, KPMG concluded: SNOLAB's operations contribute:

- **$464 million** to the Canadian economy in gross output;
- **$275 million** to the country's Gross Domestic Product (GDP);
- More than **$200 million** in labour related income nationally; and
- More than **2,200 person-years** of employment across Canada.



SNOLAB by the Numbers

18 Experiments at SNOLAB

9 dark matter experiments: DAMIC, SENSEI, SBC, DEAP-3600, NEWS-G, Oscura, PICO-40L, PICO-500, SuperCDMS

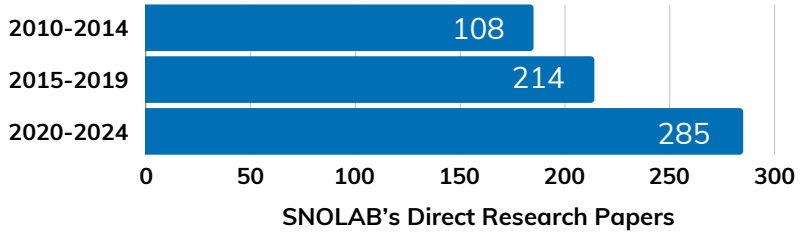
5 neutrino experiments: SNO+, SNO+ Te, HALO, LEGEND-1000, nEXO

2 life sciences experiments: REPAIR, FLAME

1 nuclear monitoring experiment with Health Canada

1 quantum computing collaboration with the Institute for Quantum Computing

Research With Impact



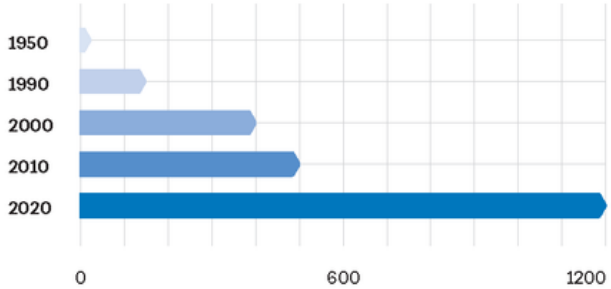
SNOLAB's Direct Research Papers

2:1

SNOLAB's research has leverage. For every paper that is a direct result of SNOLAB personnel or projects, two papers by external researchers cite or use our results in some way. SNOLAB's work spurs the innovative work of others.

Growth in Underground Science

The scientific literature in underground science has exploded, from 150 papers in 1990 to more than 1,000 papers in 2020.



No. of Papers or Publications per year

1 Nobel Prize in physics

5 Tonnes of liquid xenon needed for nEXO, about 10% of the global annual supply

10 Times per hour HEPA filters change the air in both the underground and surface labs

15 Number of co-op students students at SNOLAB in each of three sessions

26 Unique earned media engagements in 2023

31 Conferences/symposia/tours hosted at SNOLAB

99.68 Percentage of up-time for HALO experiment

128 High purity germanium counter measurements of background redioactivity

130 130 + full time staff

300 Railcars of materials shipped underground

780 Tonnes of liquid scintillator currently in SNO+ vessel

1,056 Days without a Loss Time Injury

2,070 SNOLAB depth in metres

4,200 Web searches for SNOLAB

5,400 Visits to SNOLAB.ca

7,000 Tonnes of ultra pure water circulating around SNO+ vessel

9,000 Showers taken by staff and visitors before entering the lab

11,800 SNOLAB followers of Facebook, Instagram and Twitter (X)

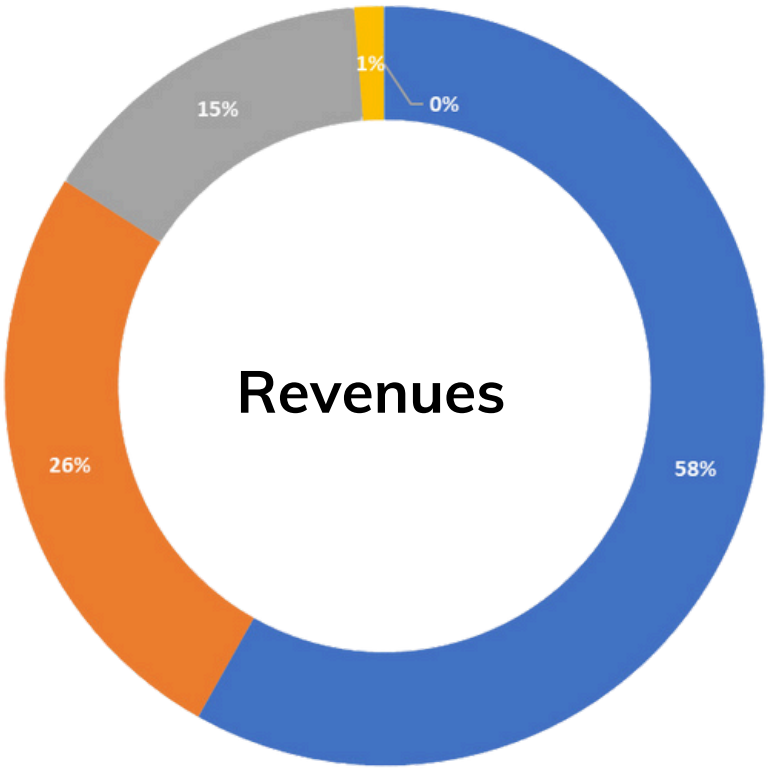
12,000 People reached by outreach programs since 2017

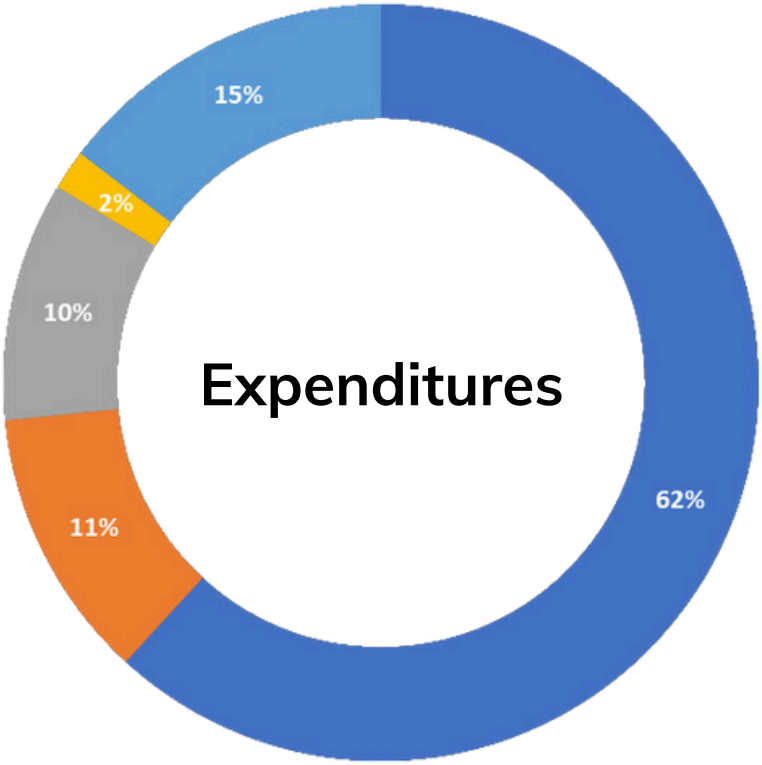
13,500 Views on SNOLAB's YouTube page

50,000,000 Factor of background radiation reduction in the lab

100,000,000 Factor of radioactivity reduction in the interior of a typical SNOLAB detector

Financial FY 2023/24





$13,467,982	Canada Foundation for Innovation
$6,000,000	Ontario MCU
$3,389,106	Amortization of deferred capital
$288,269	McDonald Institute
$8,106	Other

Total $23,153,463

$14,312,822	Salaries and Benefits
$3,389,106	Amortization of capital assets
$2,689,008	External Contracts
$2,373,467	Equipment and Supplies
$394,506	Travel

Total $23,158,909

Financial FY 2022/23

Revenues

Canada Foundation for Innovation	$11,975,215
Ontario MCU	$8,880,962
Amortization of deferred capital	$2,962,514
McDonald Institute	$1,008,182
Other	$52,526

Total $24,879,399

Expenditures

Salaries and Benefits	$15,059,837
External Contracts	$3,434,883
Amortization of capital assets	$2,962,514
Equipment and Supplies	$2,952,478
Travel	$472,415

Total $24,882,127

Deena Fabris,
Chemical Technologist

How long have you been at SNOLAB?
I have been a SNOLAB chemical technologist since 2014, so 10 years. I started working with SNO+ in 2013 in materials management. I ensured the materials ordered for the SNO+ scintillator plant made it underground and placed the staging areas. I also worked in the warehouse for a month while SNOLAB selected a new warehouse person.

What does a day at SNOLAB look like for you?
A day of my life at SNOLAB is busy! As a chemical technologist I am calibrating and verifying instruments, analyzing samples, monitoring the ultra pure water systems, assisting with cleanliness monitoring, updating SNOLAB's Safety Data Sheets list, creating reports, writing procedures, and updating SNOLAB's DocuShare.

What do you hope to be doing 10 years from now? 20 years from now?
In 10 years, I hope to be more adept at understanding and assisting with SNOLAB's wide range of topics and challenges. Over the next 20 years, I'd love to see advancements in technology and knowledge that could enrich my interactions and expand the ways I can support and engage with people.

What advice would give young(er) people who want to work in science?
My advice to young people who want to study science is stay curious and never stop asking questions. Stay persistent because science is challenging and sometimes frustrating. Embrace failure since failure is part of the scientific process. And last of all, follow your passion by choosing an area of science that excites you.

Colin Ockenden,
Cleaner Maintainer

How long have you been at SNOLAB?
I have been working at SNOLAB for 18 years. I was working at Laurentian University as a cleaner for nine years before coming to SNOLAB.

What does a day at SNOLAB look like for you?
My day can be a lot of different things, and no two days are the same.

Anything could come through the carwash underground for cleaning before going into the lab, from nuts, bolts, and washers, to spools of cable, to forklifts.

At SNOLAB I have done a lot of different jobs, including warehouse and changing air handling filters in the drift. I helped work on the new part of the lab to make it what it is today.

What advice would you give young people who may want to work at SNOLAB?
To stay in school and get a good education. So you can get the good job to help advance in your future goals.

Dr. Christine Kraus, Research Scientist

How long have you been associated with SNOLAB?
I completed my PhD in 2004 at Johannes Gutenberg Universität Mainz (Germany), focusing on the final measurements of the Mainz Neutrinos Mass Experiment. Following my PhD, I did a postdoc at Queen's University working on the Sudbury Neutrino Observatory experiment. I then came to SNOLAB as a research scientist working on SNO+ before moving to Laurentian University where I earned a Canada Research Chair Tier II in particle astrophysics.

What does a typical day look like for you?
A typical day might involve going underground, analysis of data, or building and commissioning parts of the detector depending on the day and what SNO+ needs at a given time. There will also be meetings with students and team members. I especially enjoy mentoring and supervising students and then getting to see them learn, grow, and succeed.

Why did you choose physics?
From a young age I was always curious about things. I took long walks with my grandfather through the woods, learning what nature had to offer. I drove my mother crazy by always asking questions. Physics asks questions, and when we answer one there are always more questions to ask – digging deeper and deeper as we build our knowledge. Learning new things is very exciting to me.

Mehwish Obaid, Manager of Project Management Office

How long have you been at SNOLAB?
I started at SNOLAB in June 2014. I was working as an estimator/project manager and moved from a construction company in Toronto to SNOLAB. After moving to Sudbury for SNOLAB, I started working as a project coordinator, and was promoted to project manager. In 2019, I was recruited by the Operations Director for Integration Manager position and after five years in that role, I am now the manager of the Project Management Office in the Research Division.

I am a licensed professional engineer and a certified project manager. Before coming to SNOLAB, I worked as a technical writer, service coordinator, estimator, and project manager.

What does a day at SNOLAB look like for you?
My day involves overseeing multiple projects, coordinating with my project coordinators, project managers, project engineers, and project controllers for updates and communication. I am usually reviewing progress against goals, reviewing policy and procedure for updates, and ensuring the program aligns with strategic objectives at SNOLAB. I am also reviewing project status reports to monitor timelines, budget, resource allocation, and overall status of the project.

What do you enjoy most about working at SNOLAB?
Ever since I started working at SNOLAB, I feel accomplished. I am constantly involved in solving complex and unique technical and operational challenges. I am constantly improving myself and SNOLAB is a true example of innovation. SNOLAB fascinates me in many ways and working with a team that is also very passionate about managing projects makes me very happy at work. Not one project that I have worked on is like another.

I am surrounded by friendly, motivated, and talented people who share a common goal of advancing scientific knowledge.

Yusuf Ahmed,
Co-op student

How long have you been at SNOLAB, and what projects have you worked on?
I am grateful to be starting my fifth term at SNOLAB. My first year was spent on improving radon mitigation and counting systems for SNOLAB and SNO+. I worked on characterizing the radon trapping ability of an activated charcoal trap and the radon emanation rate of a calibration source, and also made improvements to the radon assay methodology, wrote Monte Carlo simulations, and made hardware changes to enable testing of a new radon counting instrument (spherical proportional counter). I have joined a new project at SNOLAB's CUTE facility which aims to characterize and mitigate decoherence sources in superconducting qubits.

What does a day at SNOLAB look like for you?
The major part of my first-year project required hands-on experimentation in the surface clean lab where I spent most of my hours. I preferred to start my work early mornings so that I could collect more data. Outside the lab, planning every week's work, discussions and interpretation of results with my supervisor were regularly done. I am now on the CUTE-qubit project and I am learning its physics, design, and scope.

What do you enjoy most about working at SNOLAB?
Its environment of learning. In my experience, SNOLAB encourages its students to explore new skills, ideas, and to take initiatives, and scientists are welcoming to questions and willing to devote time to help you understand a concept and/or give you feedback.

What do you hope to be doing 10 years from now? 20 years from now?
Work that I find fulfilment in. This includes, but is not limited to, doing research that is close to fundamental physics, likely in the emerging overlapping field of particle physics and quantum technology. Also, pursue some hobbies, science education, social work for underserved communities, and doing right by those dependent on me.

Awards and Recognitions

SNOLAB Executive Director **Dr. Jodi Cooley** has been named a Fellow of the American Physical Society. The APS Fellowship Program recognizes members who have made exceptional contributions to physics research, important applications of physics, leadership in or service to physics, or significant contributions to physics education. Cooley was recognized for her "outstanding contributions to searches for dark matter particles," the APS announced.

Cooley, who served as Deputy Operations Manager for SNOLAB's SuperCDMS collaboration, took up her role at SNOLAB in 2022. She remains an adjunct professor of physics at Southern Methodist University.

SNOLAB Research Scientist **Dr. Christine Kraus** has been named a Fellow in the Canadian Association of Physicists (CAP). Kraus is among 19 Canadian physicists to earn this honour in this cohort. The CAP Fellowship Program recognizes members of the CAP who have made significant contributions to the Canadian physics community.

Kraus was recognized for her service to the Canadian Association of Physicists in various organization and administrative roles, often with a focus on equity, diversity, and inclusion; and for major research contributions to the SNO and SNO+ experiments, increasing the impact of Canadian physics research.

SNOLAB's **Blaire Flynn** was named a Sudbury YWCA Women of Distinction 2023 for the category of science, engineering, technology, and trades.

Flynn, Senior Education and Outreach Officer at SNOLAB since 2016, was recognized for her leadership in Sudbury, creating space for women and equity-deserving groups to develop their science communication skills and participate in mentorship and networking activities.

Laurentian University recognized 42 faculty who have attracted external grant funding over the past two years. Among those recognized were SNOLAB research scientists **Drs. Richard Ford**, **Jeter Hall**, **Chris Jillings**, **Christine Kraus**, and **Ian Lawson**, all of whom hold both positions at SNOLAB and faculty positions at Laurentian University that allow them to attract and manage research grants in support of SNOLAB science.

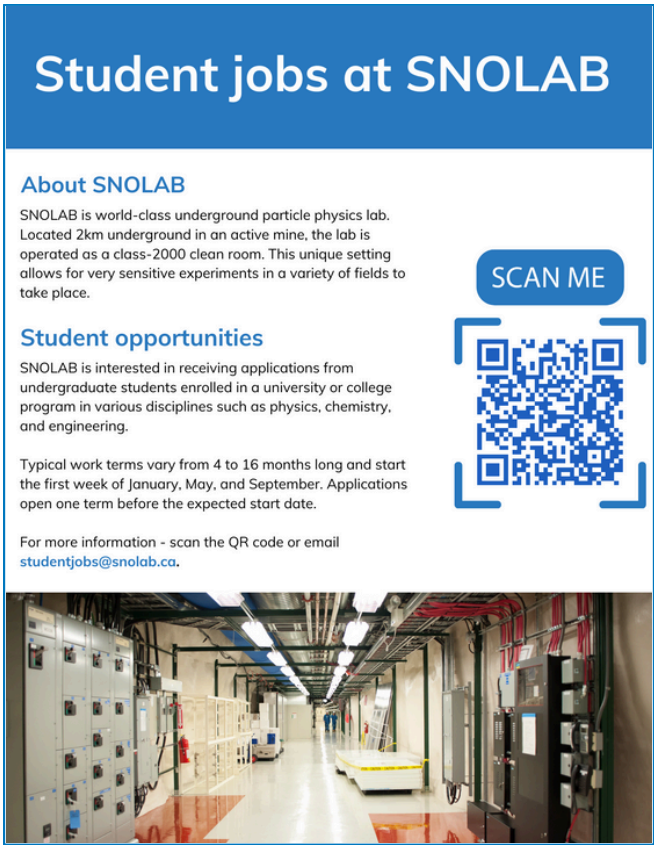
As part of its 2023 fall convocation ceremonies, Carleton University bestowed an honorary degree of Doctor of Science, honoris causa, on **Dr. David Sinclair** in recognition of his outstanding contributions to the field of experimental sub-atomic physics and for his leading role as a builder of both SNO and SNOLAB.

SNOLAB Student Program

LEFT: **Sierra Jess**, an undergraduate student from the University of Waterloo, meets Minister of Industry **François-Philippe Champagne** in the underground lab. Jess, who was a previous CASST competition winner, worked on CUTE.

ABOVE: SNOLAB students participate in site specific training underground before being able to work in the lab.

RIGHT: SNOLAB hires three cohorts of students every year, in the summer, fall and winter. Applying for an exciting student employee experience at SNOLAB is a scan and click away.



CASST Competition

SNOLAB's Student Talk Competition is an opportunity for students from the summer, fall and winter cohorts to show off their hard work from the term and to practice giving presentations in a supportive, professional environment.

The **Canadian Astroparticle Summer Student Talk Competition** is hosted jointly with McDonald Institute each August and it invites participation from students from across Canada. It offers students the opportunity to earn a spot to present their talk at the annual Canadian Association of Physicists Congress.

ABOVE: First place in the second annual Canadian Astroparticle Summer Student Talk Competition was shared by two outstanding undergraduate students. **Sarah Rourke** was recognized for her talk titled "Producing the World's Cleanest Noble Gas for DEAP-3600," and **Sierra Jess** was awarded joint first for her talk titled "CUTE Neutron Calibration System."

ABOVE: The third annual Canadian Astroparticle Summer Student Talk Competition was held at Laurentian University over two days in August, 2023. This hybrid competition featured 44 talks from undergraduate students at institutions across Canada and around the world, including students from India and Indonesia.

SNOLAB Outreach

LEFT: Members of the SNOLAB E&O team, k2i Academy, directors of education at public school boards in Ontario, secondary school principals and Indigenous leaders in education gather at SNOLAB before travelling underground to the laboratory.

Inspiring the next generation

The Education and Outreach team at SNOLAB focuses on strengthening outreach to kindergarten-12 students and educators. In 2023 a quarterly “SNOLAB Educator Newsletter” was developed and continues to be distributed. The purpose of the newsletter is to maintain connections with teachers in our network, advertise new and relevant educator resources, and connect classrooms to SNOLAB science. In the Spring of 2023 SNOLAB partnered with k2i and Science North to bring a group of 16 leaders in education from school boards with high populations of Black and Indigenous learners to Sudbury for a two-day focus group on the future of STEM education in our region. This team delivered in-person and virtual class visits to students acrossthe region and hosted educator workshops for the Ontario Association of Physics Teachers, the Science Teachers of Ontario, and at the CAP Congress Teachers Day.

Contributing to physics outreach in Canada

The SNOLAB team contributes to outreach in Canada by participating in the Canadian Association of Physicists outreach group that brings together outreach leads at physics institutions in Canada to work together on initiatives and discuss best practices. SNOLAB worked with the McDonald Institute to deliver the Canadian Astroparticle Physics Summer School (CAPSS) and the Canadian Astroparticle Student Summer Talk (CASST) competition, both opportunities for undergraduate students. SNOLAB delivered science communication workshops to students attending the Canadian Undergraduate Physics Conference, the Canadian Conference for Undergraduate Women in Physics, and to the three cohorts of co-op students at SNOLAB.

> *It was incredible to see such a cutting-edge lab and its experiments up close. The opportunity was incredible, and I am so grateful for it.*
>
> **Quote from a CAPSS 2023 participant**

SNOLAB Outreach

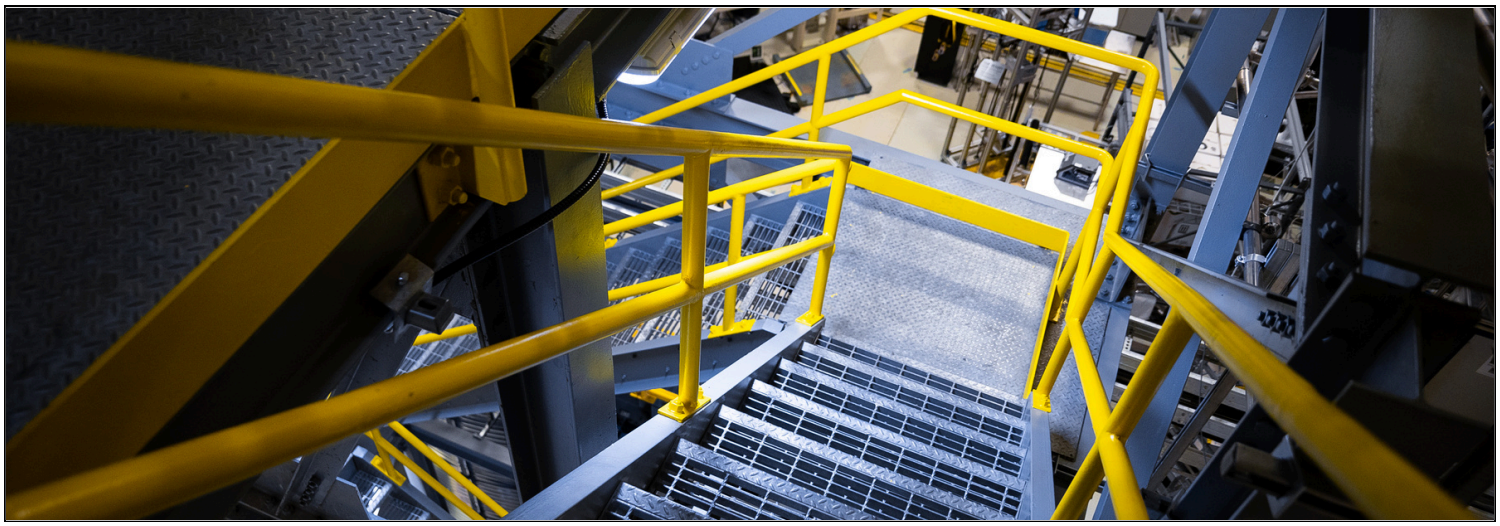
International outreach initiatives

SNOLAB is contributing to the field of physics outreach internationally through participation in the Interactions Collaboration, a group of communication and outreach specialists from the world's particle physics labs. SNOLAB takes a leadership role in organizing Dark Matter Day, a global outreach initiative that aims to bring the search for dark matter out of the lab through publicly hosted events.

In 2023 the SNOLAB team lead a rebranding effort producing new creative assets. SNOLAB E&O co-led the creation of a new podcast called ***Particle Mysteries*** and a delivered a series called ***The Coldest Case*** about the search for dark matter.

The art of physics outreach

In partnership with the McDonald Institute and the Agnes Etherington Gallery, SNOLAB initiated an artist residency, ***Drift: Art and Dark Matter*** that brought two Canadian and two international artists to SNOLAB. This program saw the creation of new works and an exhibit tour. In 2022 a digital exhibition was created and in 2023 a book was published and printed about the project that is now available as an open access digital publication. In 2023, the E&O team initiated an international dark matter poster design contest to get k-12 students engaged in particle physics and to celebrate Dark Matter Day.



A Year in Pictures

ABOVE: SNOLAB Executive Director **Jodi Cooley** (centre) and Minister of Industry **François-Philippe Champagne** celebrate a funding announcement on the SuperCDMS seismic platform surrounded by Sudbury MP **Viviane Lapointe**, Nickel Belt MP **Marc Serre**, former SNOLAB EDs **Clarence Virtue** and **Art McDonald**, CFI President **Roseann O'Reilly Runte**, Canada's Chief Science Advisor **Mona Nemer**, Queen's University VPR **Nancy Ross,** and members of the SuperCDMS collaboration.

RIGHT: The leadership group from Great Britain's Boulby Underground Laboratory tour SNOLAB's underground lab. Boulby is expanding its lab and its experiment portfolio, and "are keen to see how things are done at SNOLAB," said director **Sean Paling.**

LEFT: Magnetawan artist **Mishiikenh Kwe** created a mural honouring Anishinaabe sky stories for SNOLAB. The artist freehanded the mural, outlining it first in pencil, and then painting it in. It took about 13 hours over two days to complete.

LEFT: Canadian astronaut **Cmdr. Chris Hadfield** takes an air shower while touring SNOLAB.

BELOW: SNOLAB Executive Director **Jodi Cooley** (centre) tours Ontario Minister of Colleges and Universities **Jill Dunlop** (right) and Queen's University VPR **Nancy Ross** through the lab.

ABOVE: SNOLAB Executive Director **Jodi Cooley** meets Speaker of the House **Greg Fergus** at the Canadian Science Policy Conference in Ottawa.

ABOVE LEFT: SNOLAB ED **Jodi Cooley** and Research Director **Jeter Hall** prepare to lead Laurentian University's leadership group on an underground tour.

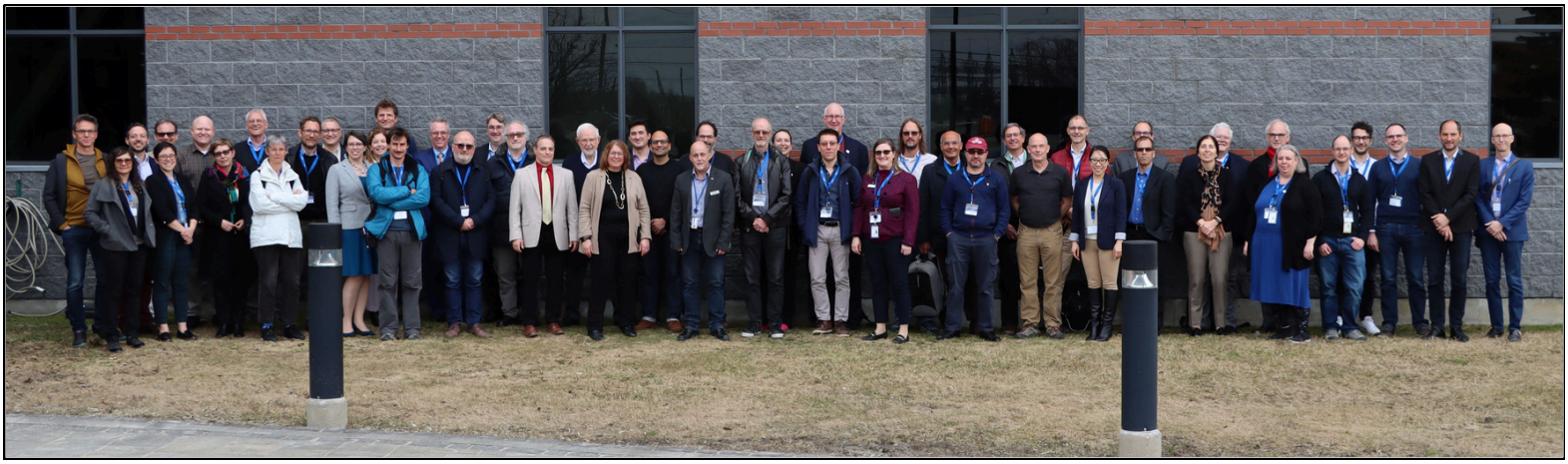
LEFT: **Stephen Sekula,** Honorary Science North blue coat (and full-time SNOLAB Research Manager), poses with MiniCLEAN, now on display at Science North.

BELOW: Postdoctoral researcher **Sean Daugherty** explains DEAP to the leadership group from Carleton University.

RIGHT: SNOLAB knowledge carrier **Will Morin** delivers a public talk on First Nations star stories at Laurentian University's Doran Planetarium. SNOLAB and the Planetarium have collaborated several times as they move toward a formal relationship.

LEFT: SNOLAB ED **Jodi Cooley** sits down with **Mike Commito** and **Steve Gravel** for the ***Unlikely Innovators*** podcast produced by Cambrian College's Technology Access Centre. It was, unofficially, the world's deepest recorded podcast episode.

BELOW: A select group of more than 60 of the world's leading particle physicists and representatives from science funding bodies gathered at SNOLAB for a Summit on the Future of Neutrinoless Double Beta Decay. Neutrinoless double beta decay experiments are a priority of the international particle physics community. Summit participants agreed to continue efforts to pursue this exciting field of study, and SNOLAB is well positioned to play a significant role.



RIGHT: SNOLAB partnered with Queen Mary University of London's School of Physical and Chemical Sciences to host a Quantum Workshop to find common cause between researchers pursuing quantum technology and fundamental physics. This joint effort brought together more than 40 experts in fundamental particle physics and cutting-edge quantum sensors.

LEFT: SNOLAB Executive Director **Jodi Cooley** serves lunch to staff at the winter All-Hands meeting.

BELOW: SNOLAB's Human Resources team sends Valentines to everyone working underground.

RIGHT: **Joe Muise**, a Canadian Association of Physicists (CAP) Award for Excellence in Teaching High School/CEGEP winner, visits SNOLAB. Muise is a teacher at St. Thomas More Collegiate in Burnaby, British Columbia, who has not only increased the number of students in his physics classes, but the diversity in his classes as well. As part of his award, Joe made the trip to Sudbury for an in-depth look at the science taking place at SNOLAB.

LEFT: SNOLAB acknowledged National Indigenous Peoples Day by unveiling a new mural to staff and users. **Will Morin**, a local artist and knowledge carrier, created the piece that now hangs in the lobby of SNOLAB. The mural features the Dream Catcher in the centre, where the spiral paths of the neutrinos emerge from within, radiating out in all directions. Several other recognizable elements present in the mural include: **Waasinoode** (meaning Northern Light); **M'tigwaaki** (meaning forest); **Jiibay Miikana** (meaning Milky Way); **Ode-min** (meaning strawberry), and **Kiiwe-di-nang** (meaning going home star).

ABOVE: The inaugural SNOLAB New Opportunities Day, or SNODAY, was held in September at Laurentian University. The cross-divisional retreat was intended to facilitate new opportunities, new collaborations, new ideas, and new directions.

ABOVE: SNOLAB celebrated 10 years of SNOLAB science by joining forces with the REPAIR Collaboration at NOSM and Forty Six North Brewing. Brewing yeast from REPAIR was cultured in the underground chemistry and life science lab at SNOLAB, transported back to surface, and brewed into a signature beer – Cosmic Rays – at Forty Six North. All proceeds for this charity beer were donated to the Northern Cancer Foundation.

ABOVE: SNOLAB's **Blaire Flynn** and **Adil Hussain** use liquid nitrogen to make ice cream for the Creighton Mine Friends and Family Day celebration.

RIGHT: A telescope set up by SNOLAB's **Christa Paquette** was well used by children during Vale's Friends and Family Day Celebration.


SNOLAB