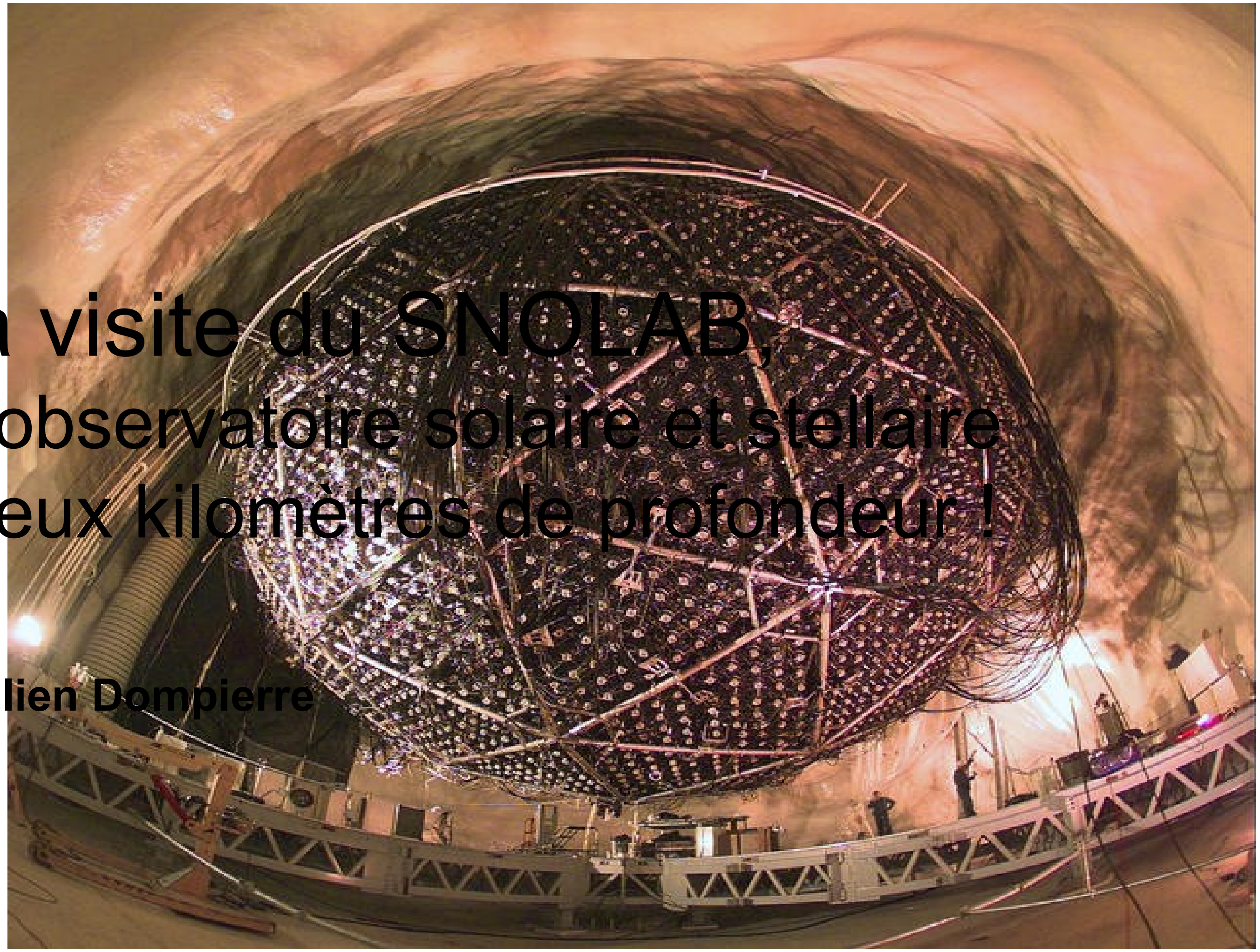


Ma visite du SNOLAB,

un observatoire solaire et stellaire à deux kilomètres de profondeur !

par Julien Dompierre

ociété
ronomie
ontréal

entre
francophone
de Montréal

SNOLAB

Sudbury
Neutrino (présentation de Lidia)
Laboratory (ma visite du 18 avril 2011)
L'astéroïde (14724) SNO a été nommé en son hommage.

SNOLAB
MINING FOR KNOWLEDGE
CREUSER POUR TROUVER... L'EXCELLENCE

Arthur Bruce McDonald, prix Nobel de physique 2015

Le 6 octobre 2015, il reçoit le prix Nobel de physique, conjointement avec le physicien japonais Takaaki Kajita pour des travaux sur l'oscillation des neutrinos.

Né à Sydney en Nouvelle-Écosse en août 1943.

Baccalauréat en physique en 1964 et une maîtrise en physique en 1965 à l'université Dalhousie.

Il a obtenu son doctorat au California Institute of Technology en 1969.

Directeur: William Alfred Fowler, prix Nobel de physique en 1983 ("Synthesis of the Elements in Stars" en 1957).

Professeur à Queen’s University à Kingston.

Directeur du SNOLAB depuis 1989.

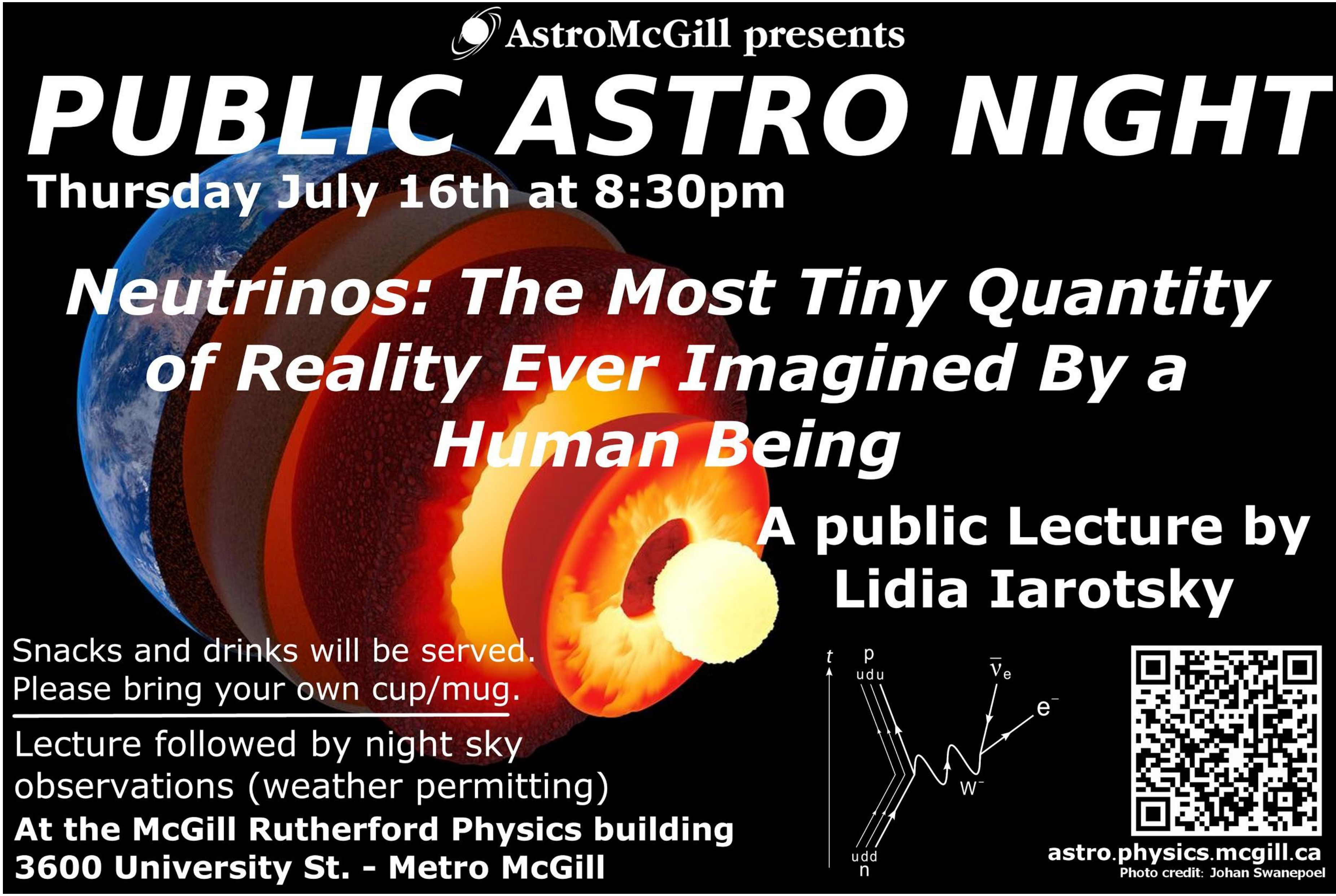
Lidia Iarotsky

Maîtrise en sciences de la Terre
Université du Québec à Montréal

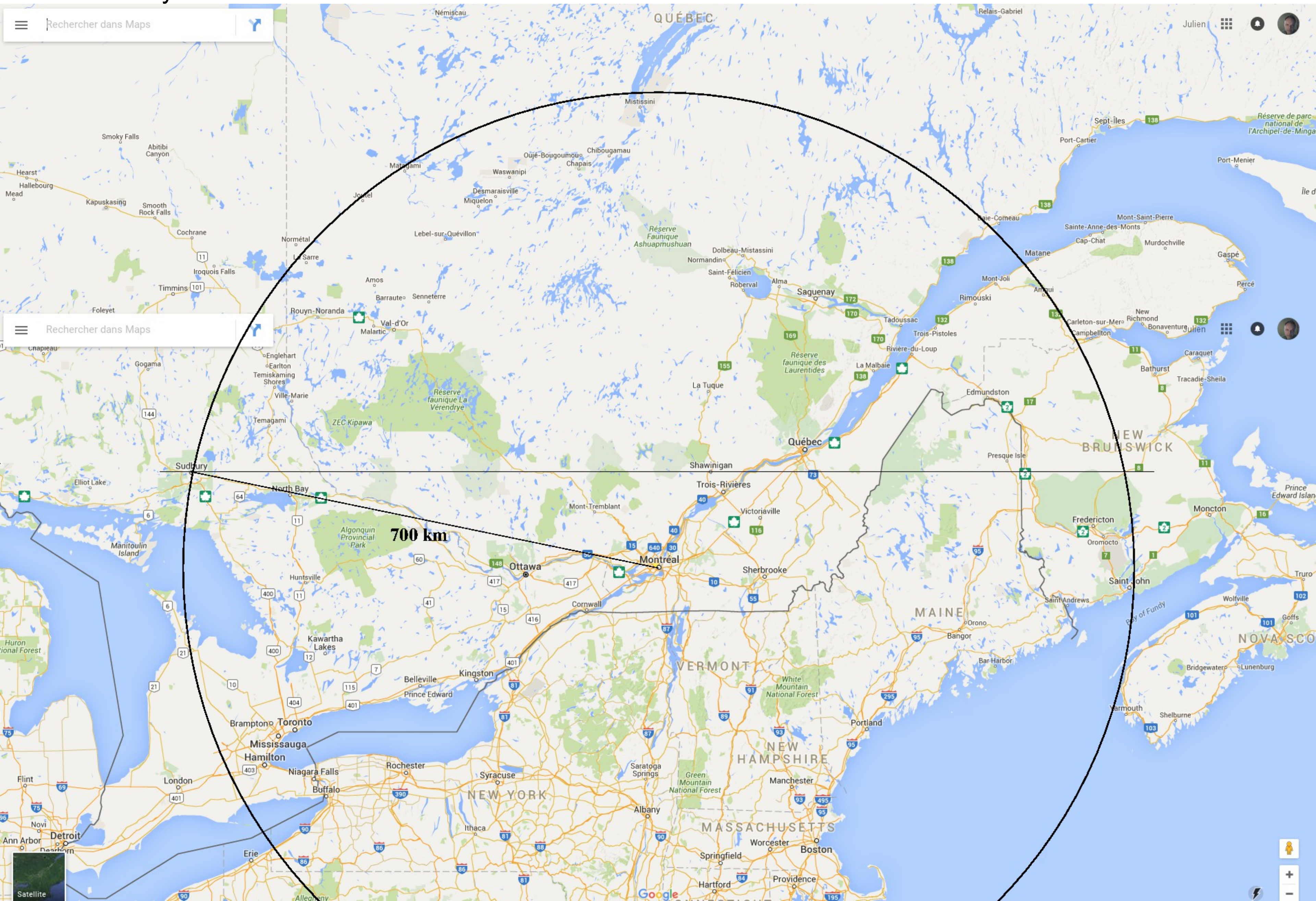
Public Astro Night,
Université McGill
Jeudi 16 juillet 2015

https://www.youtube.com/watch?v=29

Présentation de Lidia Iarotsky



Sudbury - Localisation



Sudbury - Histoire

Mission jésuite nommée Sainte-Anne-des-Pins fondée en 1883, juste avant la construction du chemin de fer Canadien Pacifique.

Découvert du cuivre et du nickel à Murray Mine lors de la construction du chemin de fer.

Sainte-Anne-des-Pins renommée Sudbury et incorporé en 1893.

Thomas Edison fait de la prospection en1901 et découvre le gisement de Falconbridge

Inco en 1902 et Falconbridge en 1928.

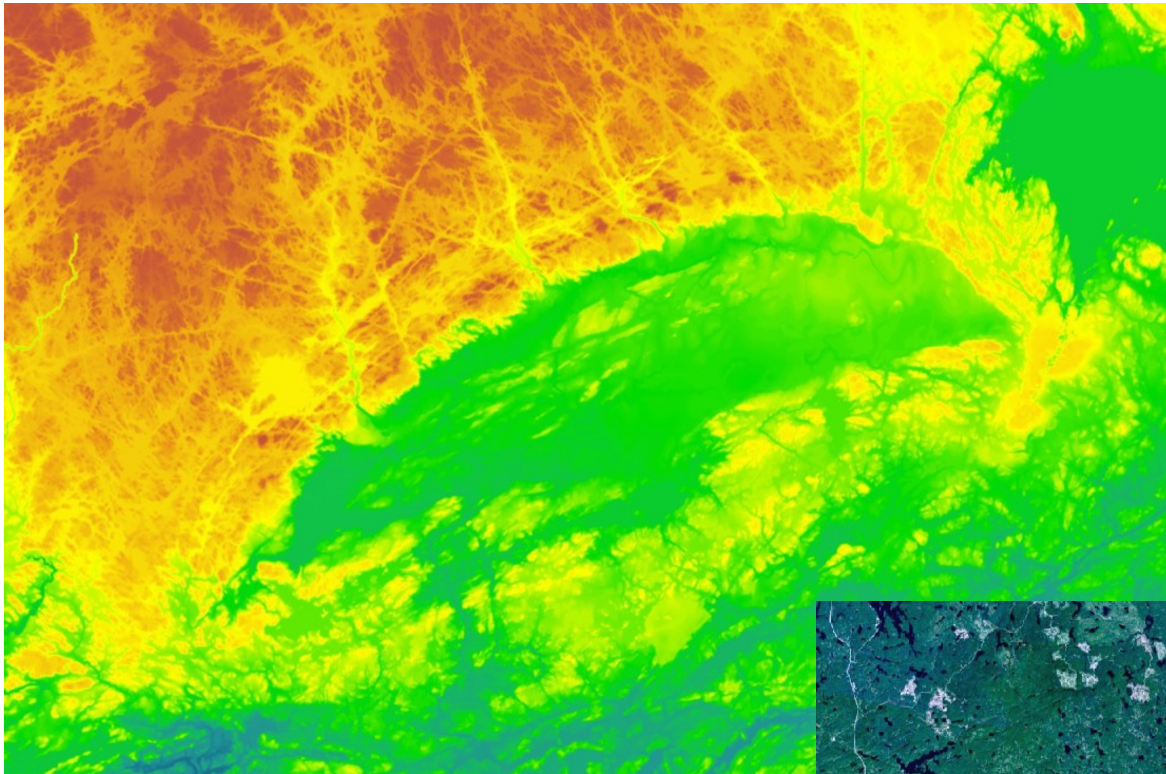
Université Laurentienne en 1960

Drapeau franco-ontarien en 1975

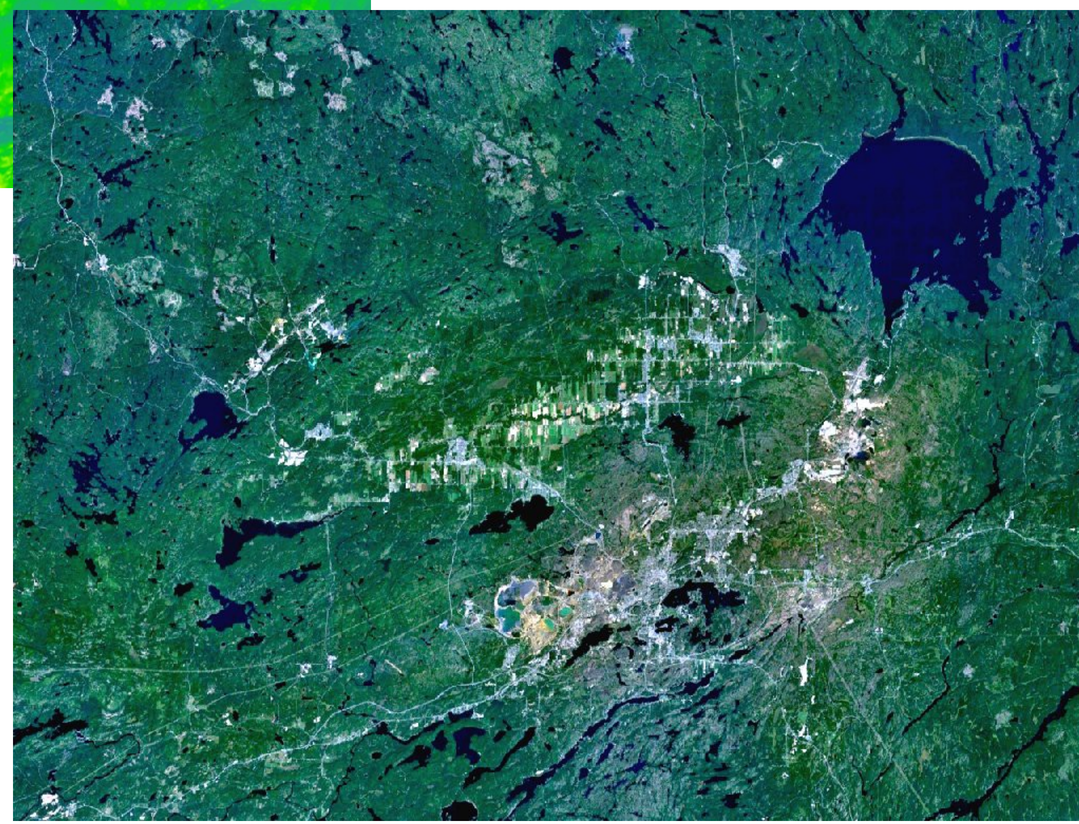
Fusion municipales en 2001.

La plus grande ville de l’Ontario

165 000 habitants, 40% francophones

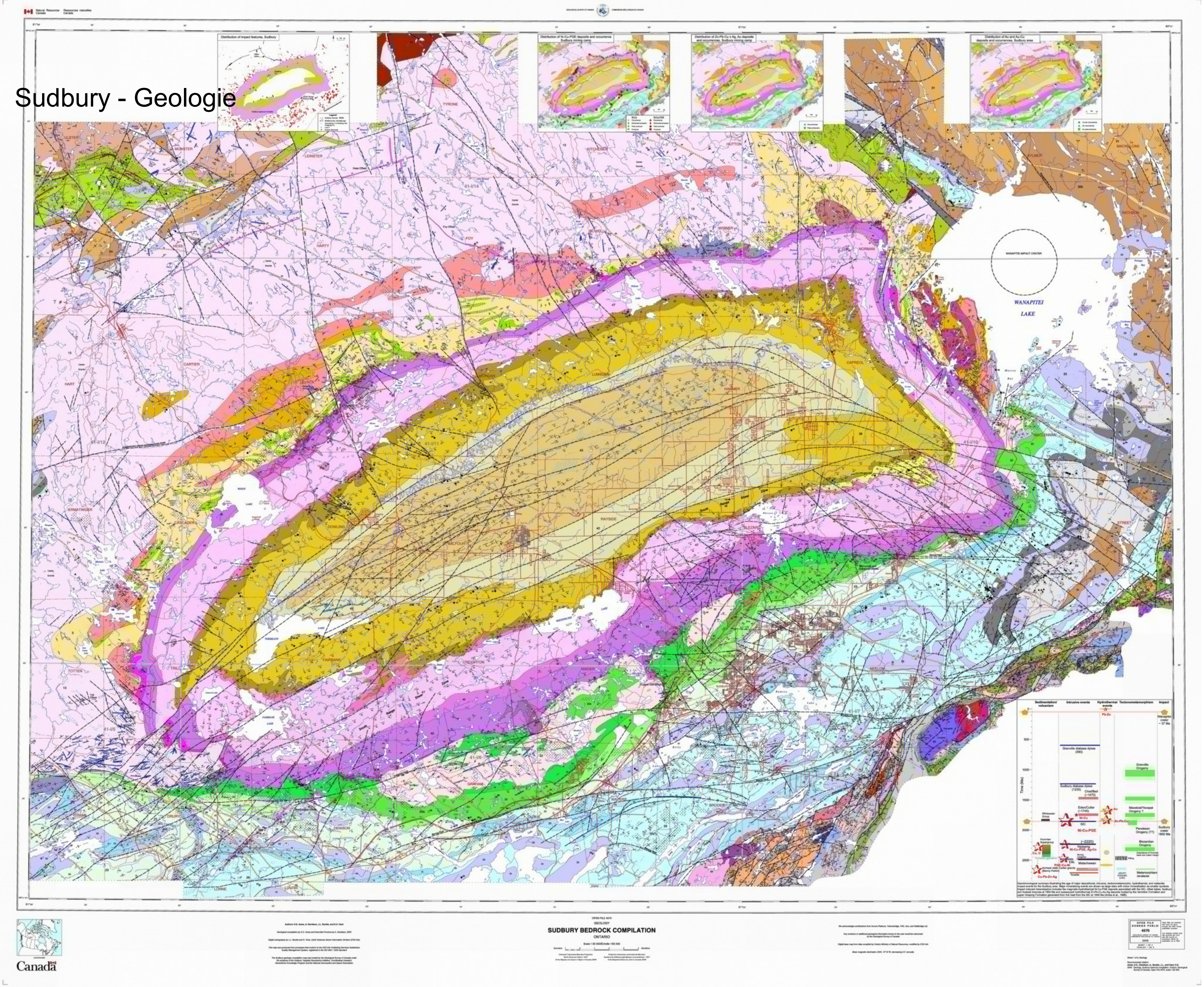


Sudbury - Cratère



- 130km de diamètre
- Second plus grand cratère d'impact connu sur Terre
- 1.850 milliards d’années
- Le cratère est rempli de magma contenant du nickel, cuivre, platine, palladium, or et autres métaux.

Sudbury - Geologie



Sudbury - Mines

Sudbury - Sidérurgie

Inco Superstack: hauteur de 380 mètres (1,250 ft)

Construite en 1970

Plus grande cheminée au Canada, la deuxième plus grande au monde.

Deuxième plus haute structure au Canada après la tour du CN (553.33 m, construite en 1976)

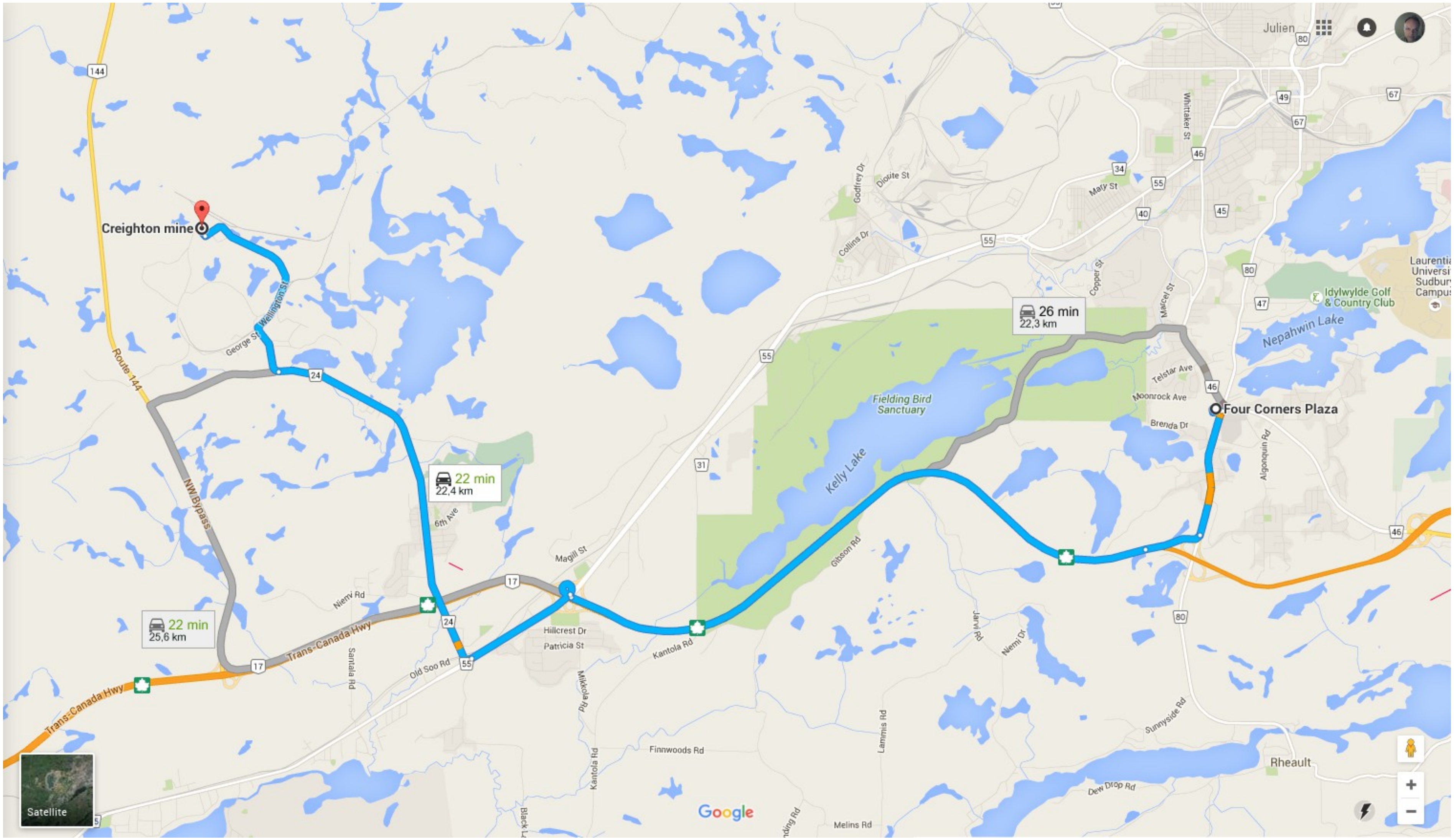
Maintenant, c’est la 33ième structure auto-portante au monde.

C’est la cheminée de la fonderie de nickel de Copper Cliff.

C’est la plus grande fonderie de nickel au monde.

Sudbury - Big Nickel

Creighton Mines



Creighton Mines - Vale

SNOLAB - Time line

June 2008 -- Release of NCD-phase results
May 2007 -- D2O drained from acrylic vessel
Nov 2006 -- End of datataking for 3rd phase
Feb 2005 -- Release of 391-day salt-phase results
Feb 2004 -- Start of 3rd phase of data taking
Sept 2003 -- Release of salt flux results
April 2002 -- Release of neutral current and day/night results
June 2001 -- Release of first scientific results
May 2001 -- Start of 2nd phase of data taking (salt fill)
June 2000 -- SNO hosts the Neutrino-2000 meeting.
Nov 1999 -- Production data taking begins
May 1999 -- First neutrinos found
Apr 1999 -- Water fill complete
Jul 1998 -- All electronics channels on-line
Apr 1998 -- Start of water fill
Jan 1998 -- Photomultiplier support sphere and photomultiplier installation complete.
Nov 1997 -- Acrylic vessel completed
Jan 1997 -- Upper half of acylic vessel suspended on it's support ropes and lifted into place.
Mar 1997 -- Completed first row below equator of the acrylic vessel.
Oct 1995 -- Photomultiplier support upper hemisphere completed

Aug 1995 -- Start of acrylic vessel assembly

Nov 1994 -- Start of clean room assembly phase

May 1993 -- End of cavity excavation

Mar 1990 -- Start of cavity excavation

Jan 1990 -- SNO funding announced

1984 -- Herb Chen at the University of California at Irvine presented a paper at the Homestake conference pointing out the advantages of using heavy water as a neutrino detector.

SNOLAB - Stephen Hawking

Stephen Hawking a visité le SnowLab pour son inauguration en avril 1998. Il l’a visité une deuxième fois le 15 septembre 2012.

SNOLAB - Stephen Hawking

SNOLAB - Stephen Hawking

SNOLAB - Stephen Hawking

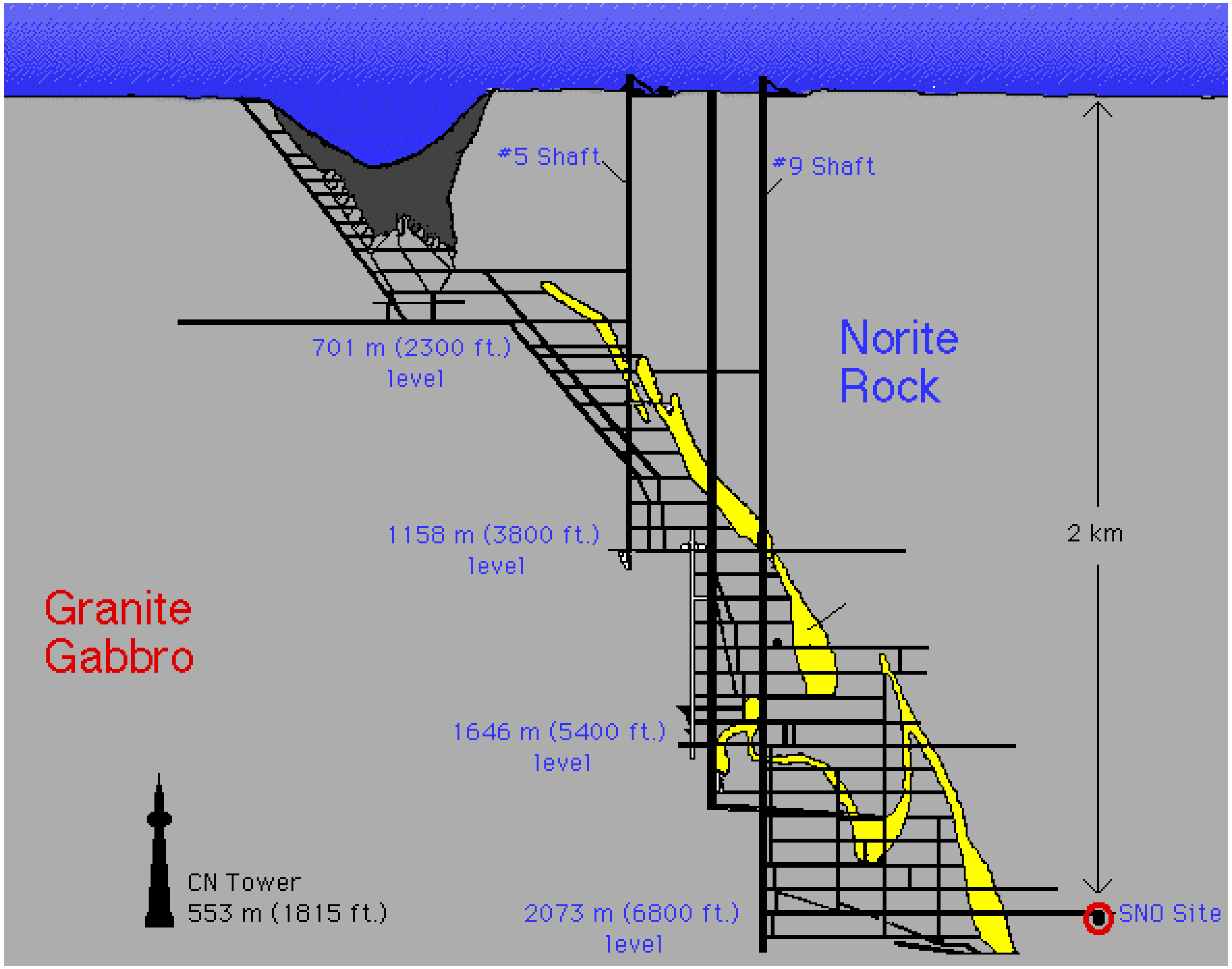
SNOLAB - Installations en surface

Bâtiment de 3100 m2. Bureaux, salle de conférence, salles blanches, laboratoires électroniques, système informatique, entrepôt, salle d'habillage

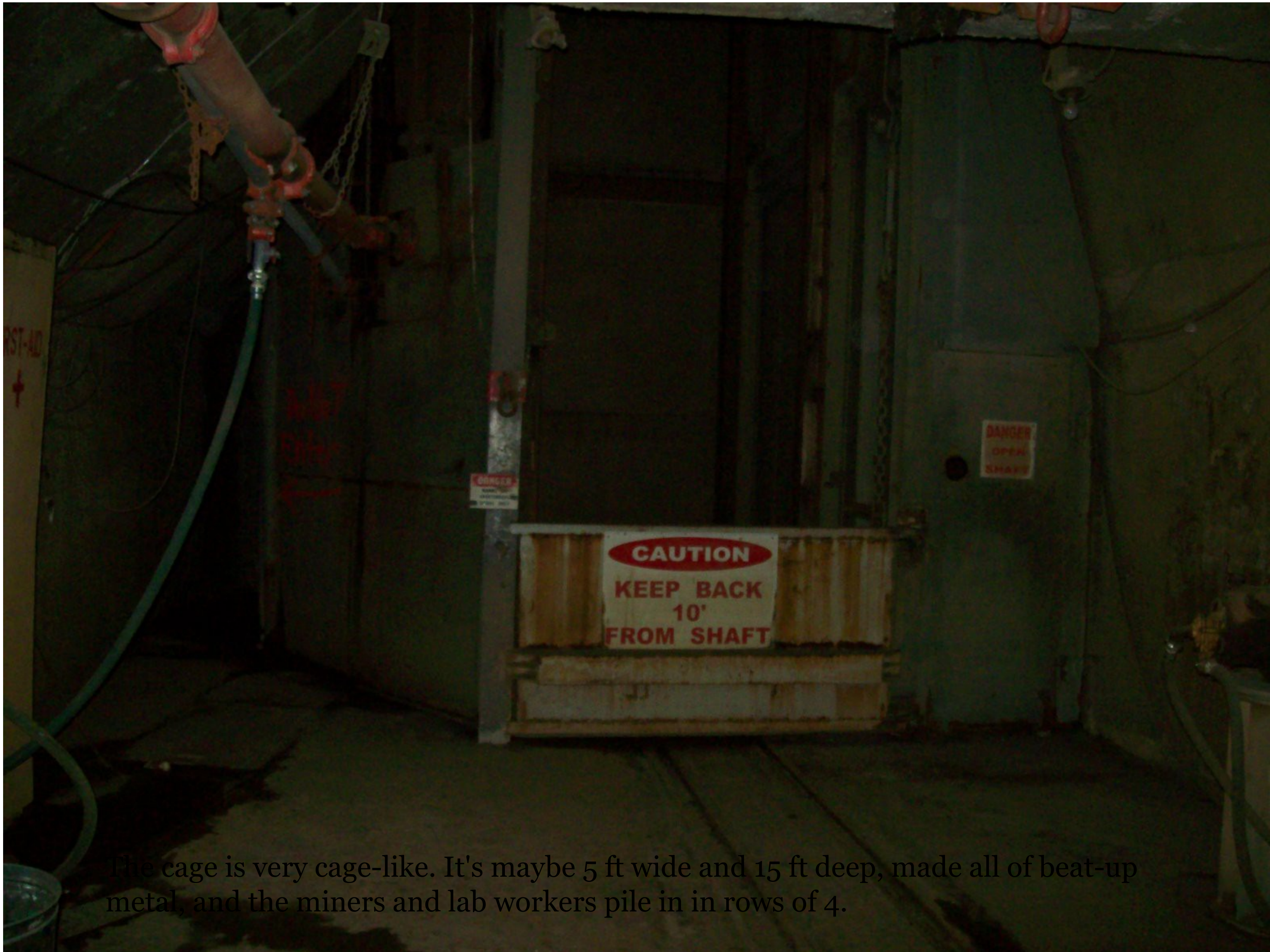
Équipement de mineur

Salle de conférence

Ascenseur - 2km de hauteur



La cage



The cage is very cage-like. It's maybe 5 ft wide and 15 ft deep, made all of beat-up metal, and the miners and lab workers pile in in rows of 4.

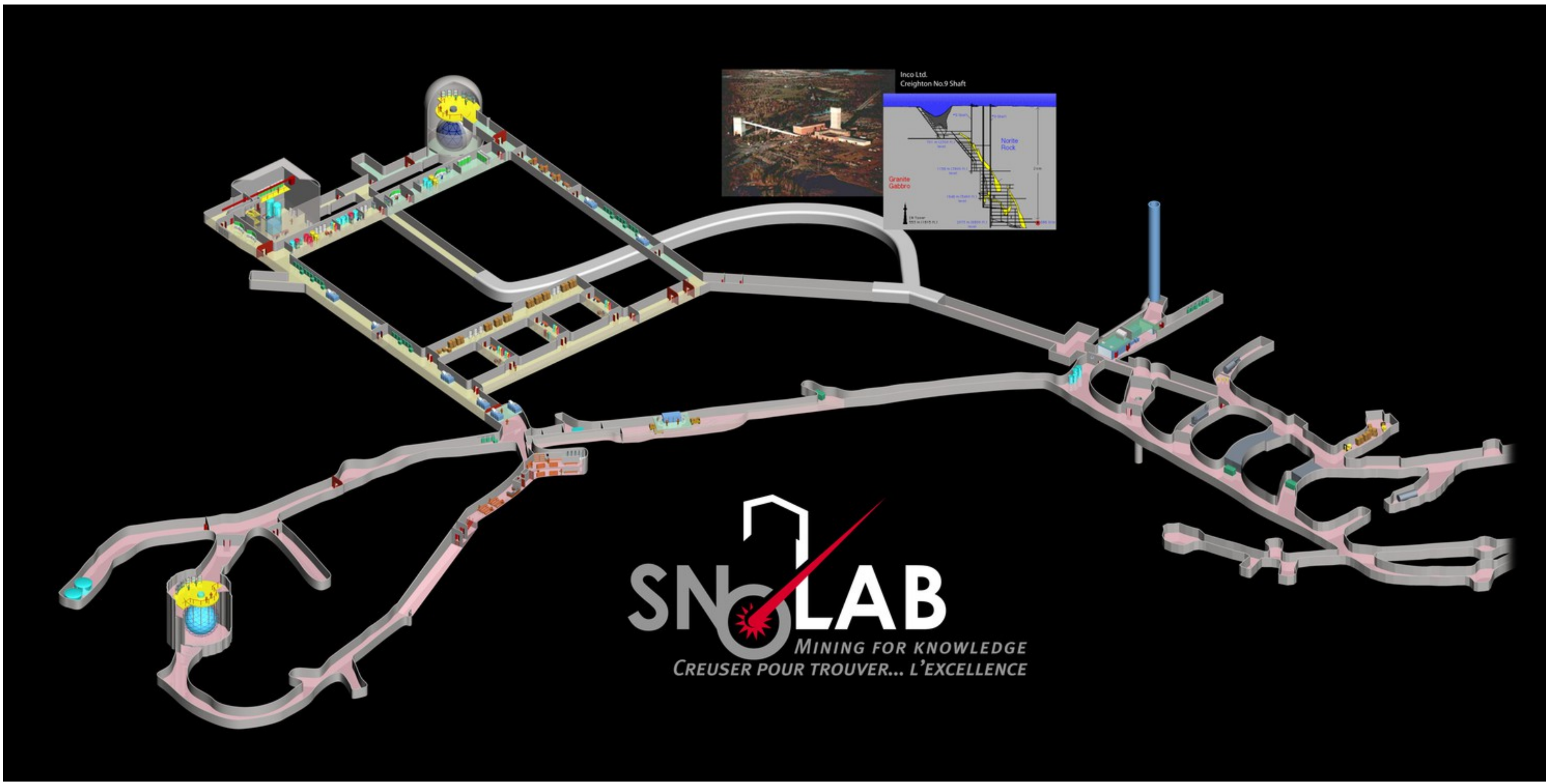
Température et pression

La pression atmosphérique est environ 25 à 30 pour cents de plus qu'en surface. L'eau bout à 106.5 degrés (loi de Clausius-Clapeyron).

La température naturelle de l'air à 2km de profondeur est de 42 degrés celcius. La ventilation maintient la température entre 25 et 30 degrés.

Plan des installations

SNOLAB a 5,000 m2 de salles blanches sous-terraines pour les expériences. L’accès du SNOLAB est au niveau 6800, via le puits #9 qui et il est situé à 1.8 km de l’entrée du laboratoire.



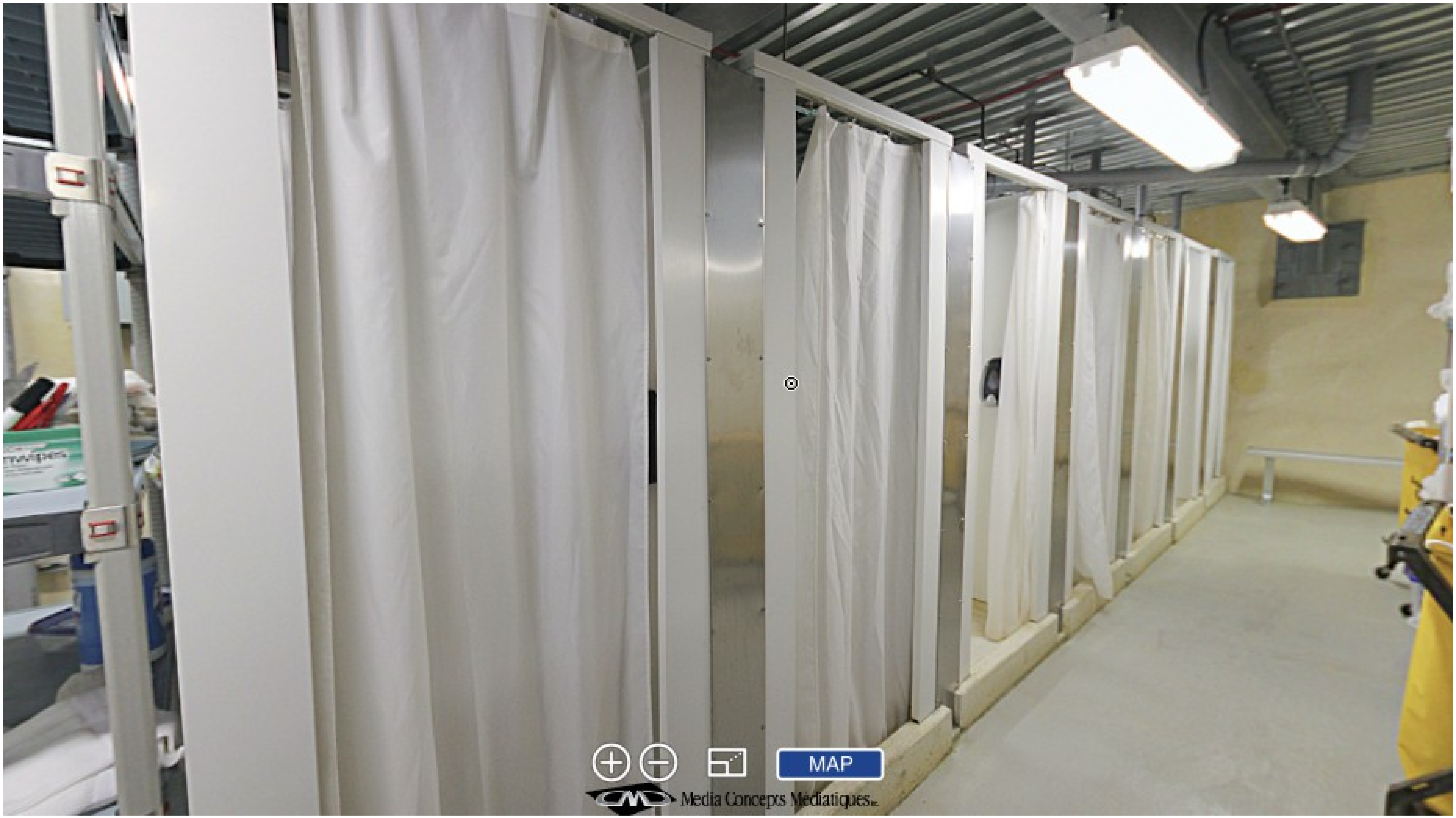
Marche d’approche

Traitement des eaux

Filtres à air

Car wash

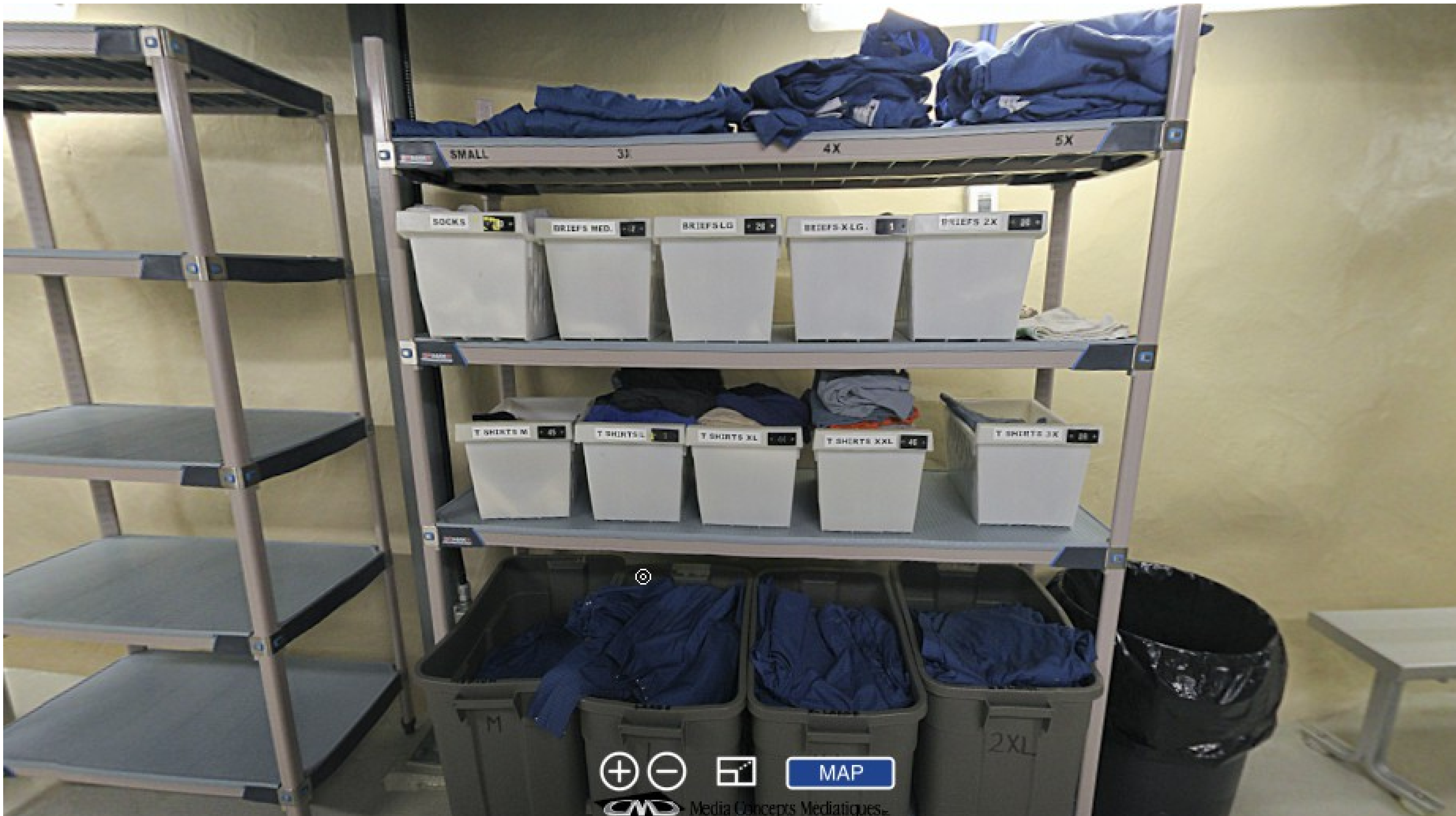
Douches



Douches

http://www.gnomeexperiment.com/

Salle d’habillage



Schtroumph !-)

Schtroumph Padawan

Collation

Briefing

Casques

Visite avec Jacques Farine

Corridors

Les murs sont couvert de mortier projeté d’au moins 7.5 cm d’épaisseur. Les planchers sont en béton d’au moins 10cm d’épaisseur.

Tapis collants par terre

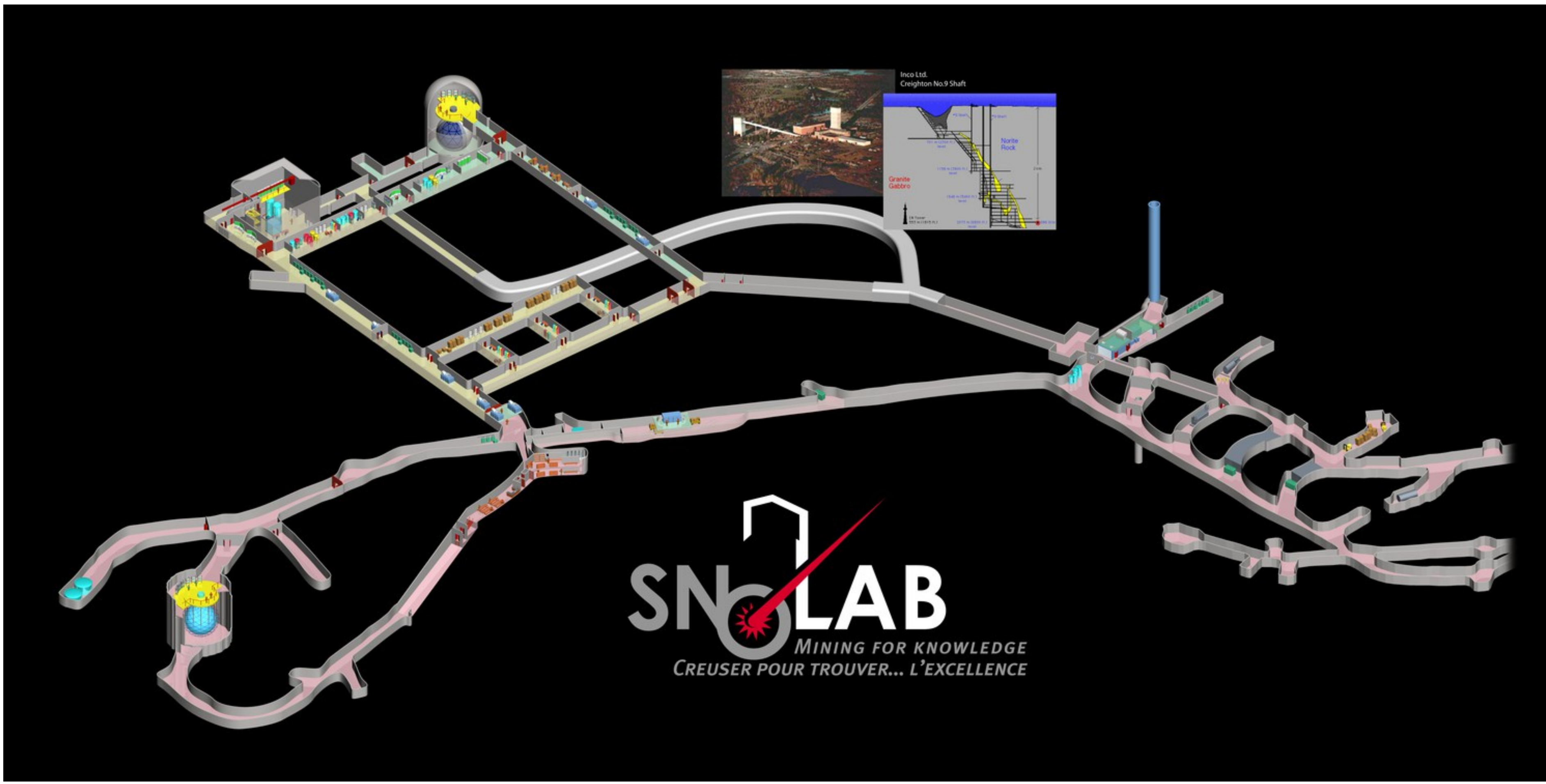
Douche à air

Moniteur de rayonnement

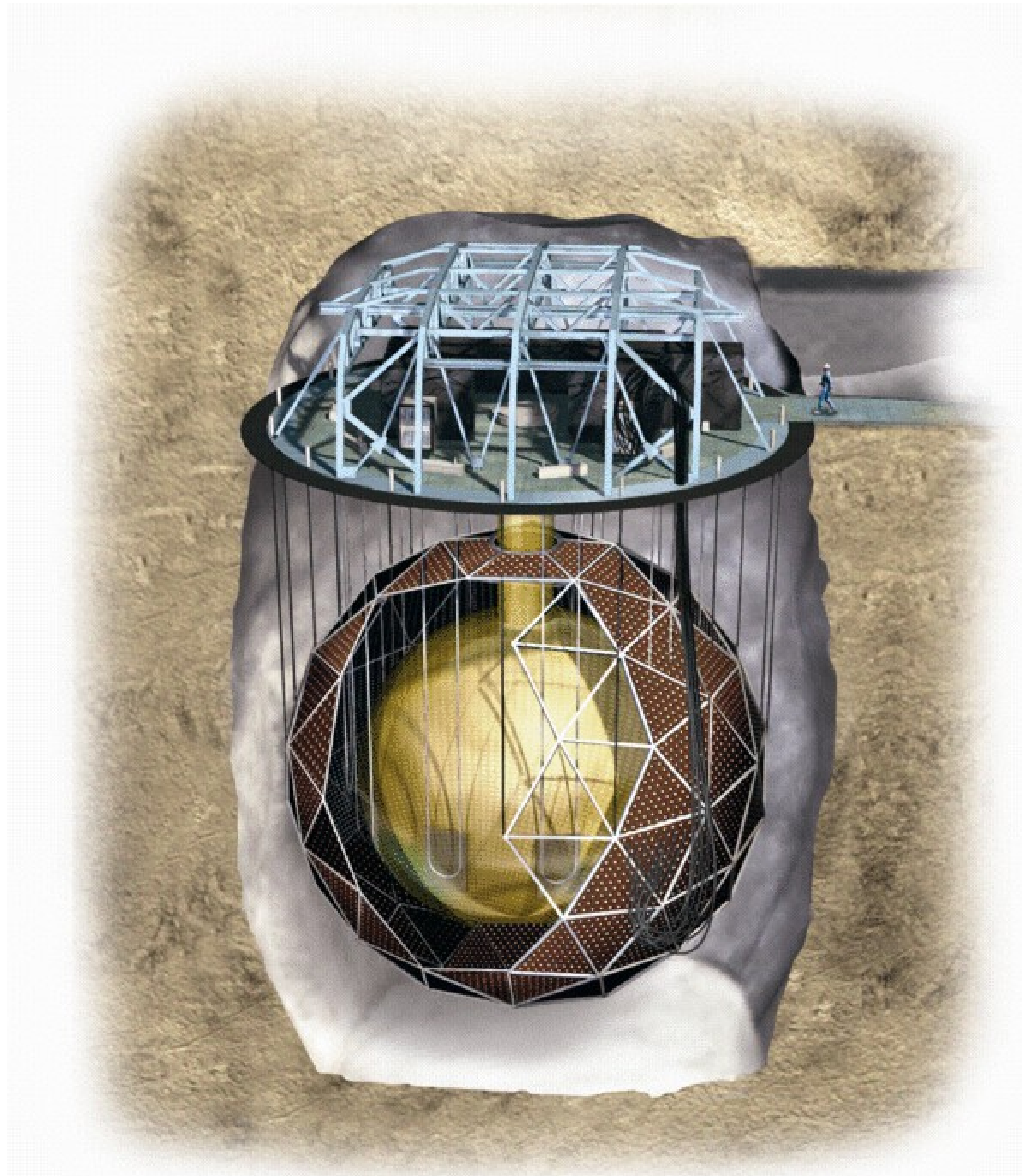
SNOLAB achieves a muon flux of 0.27 μ/m²/day. For comparison, the rate on the surface, at sea level, is about 15 million μ/m²/day which is about 50 milion more.

Plan des installations

SNOLAB a 5,000 m2 de salles blanches sous-terraines pour les expériences. L’accès du SNOLAB est au niveau 6800, via le puits #9 qui et il est situé à 1.8 km de l’entrée du laboratoire.



Détecteur SNO



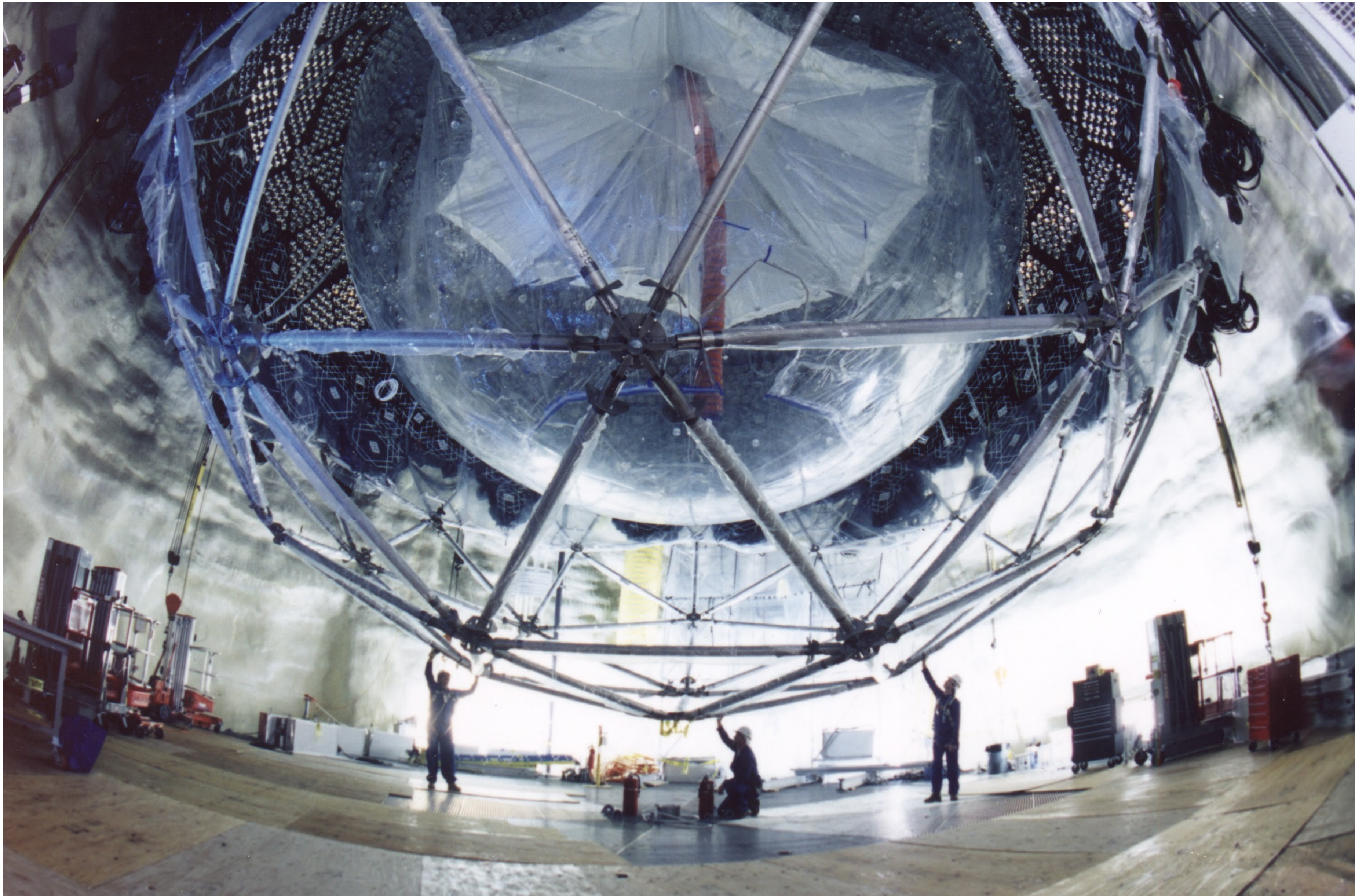
La caverne a une forme de baril de 30 mètres de haut (10 étages) et de 22 mètres de diamètre au milieu.

C’est la plus grande caverne au monde à cette profondeur.

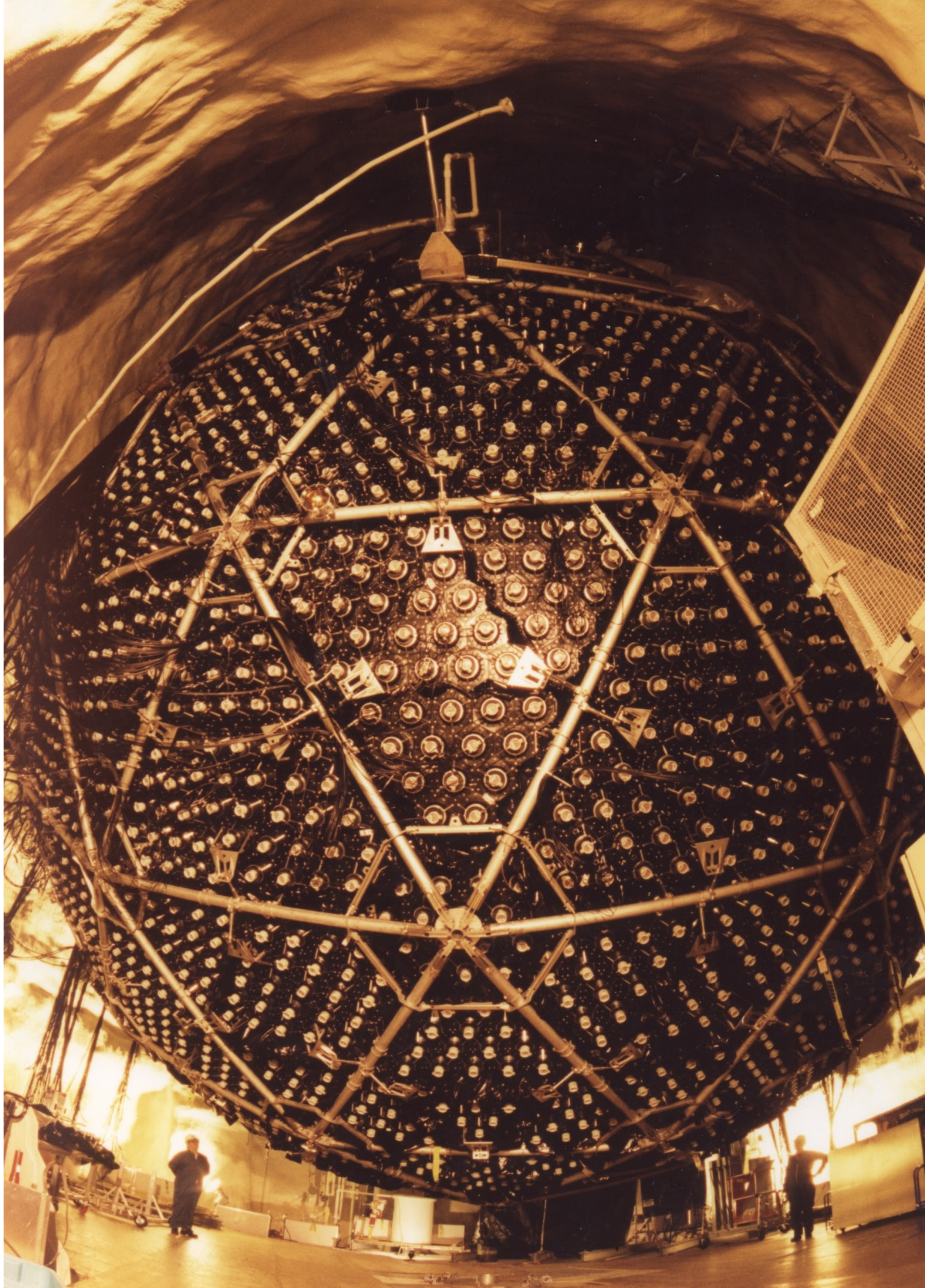
SNO - La cuve d’acrylique

Le *vessel* (vase, cuve, récipient) d’acrylique est une sphère de 12 mètres de diamètre et de 5 cm d’épaisseur fait de 122 panneaux polis de qualité optique.

SNO - La sphère géodésique de 18.4 m



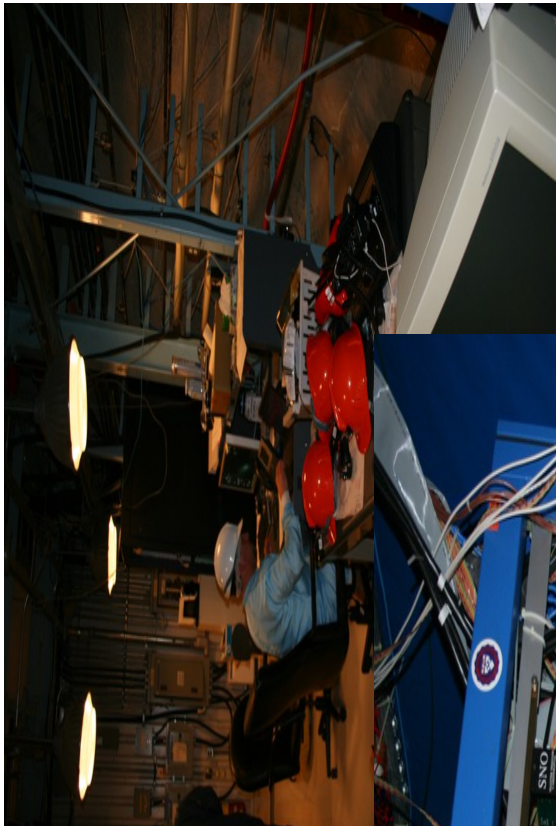
SNO - 9600
Photomultiplicateurs

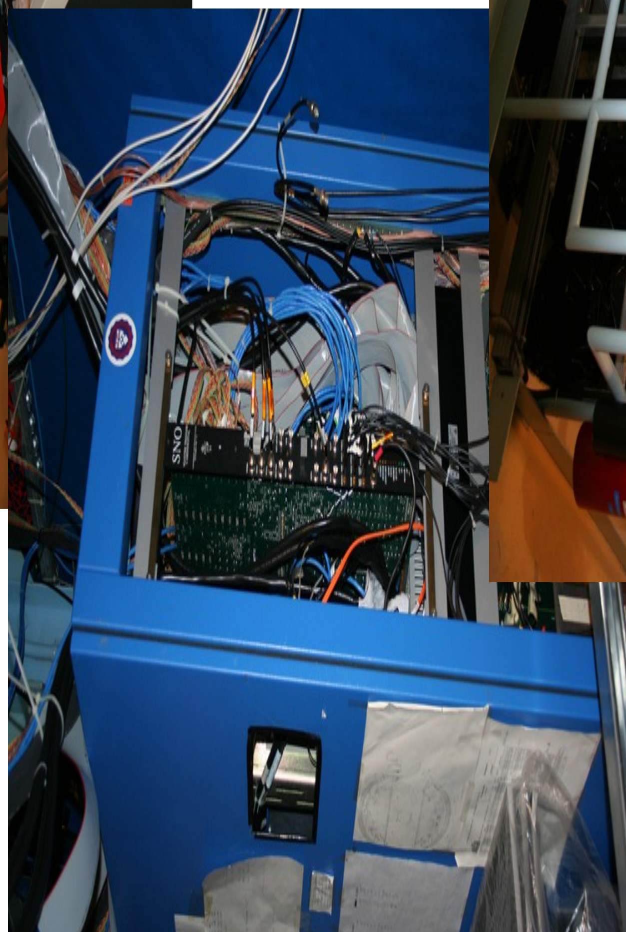


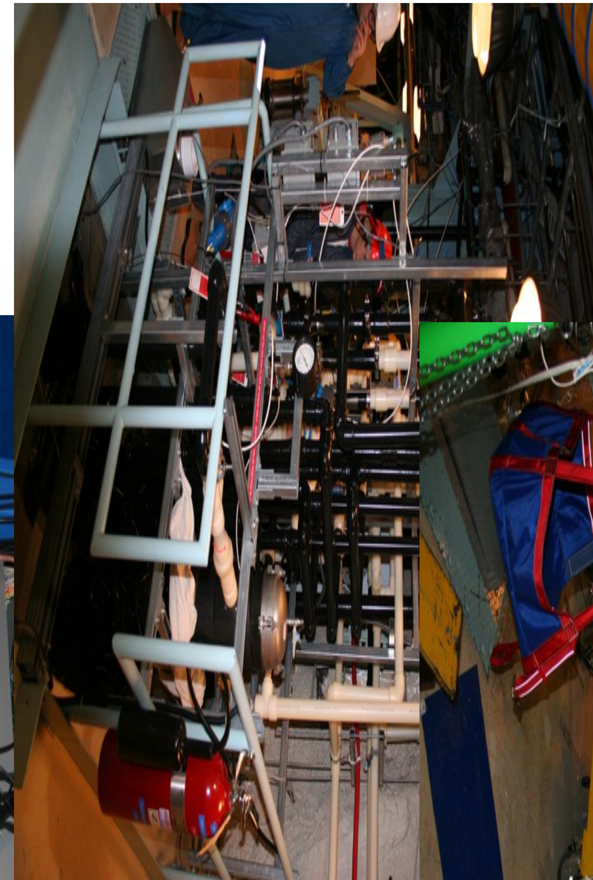
La cuve d’acrylique est remplie de 1000 tonnes d’eau lourde D_2O.

L’ensemble est submergé dans 7000 tonnes d’eau “ordinaire” ultra pure.

SNO - Salle de contrôle

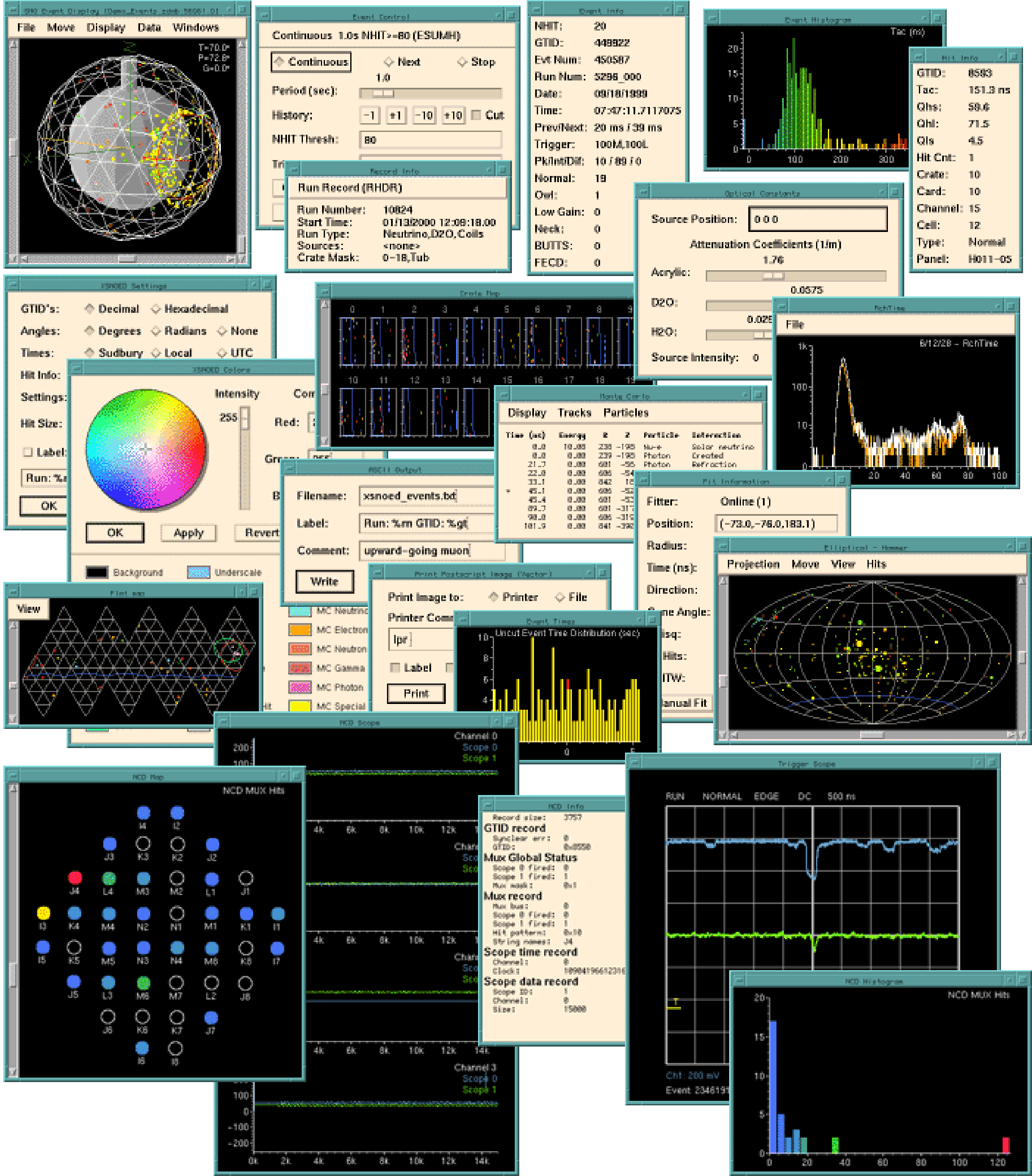




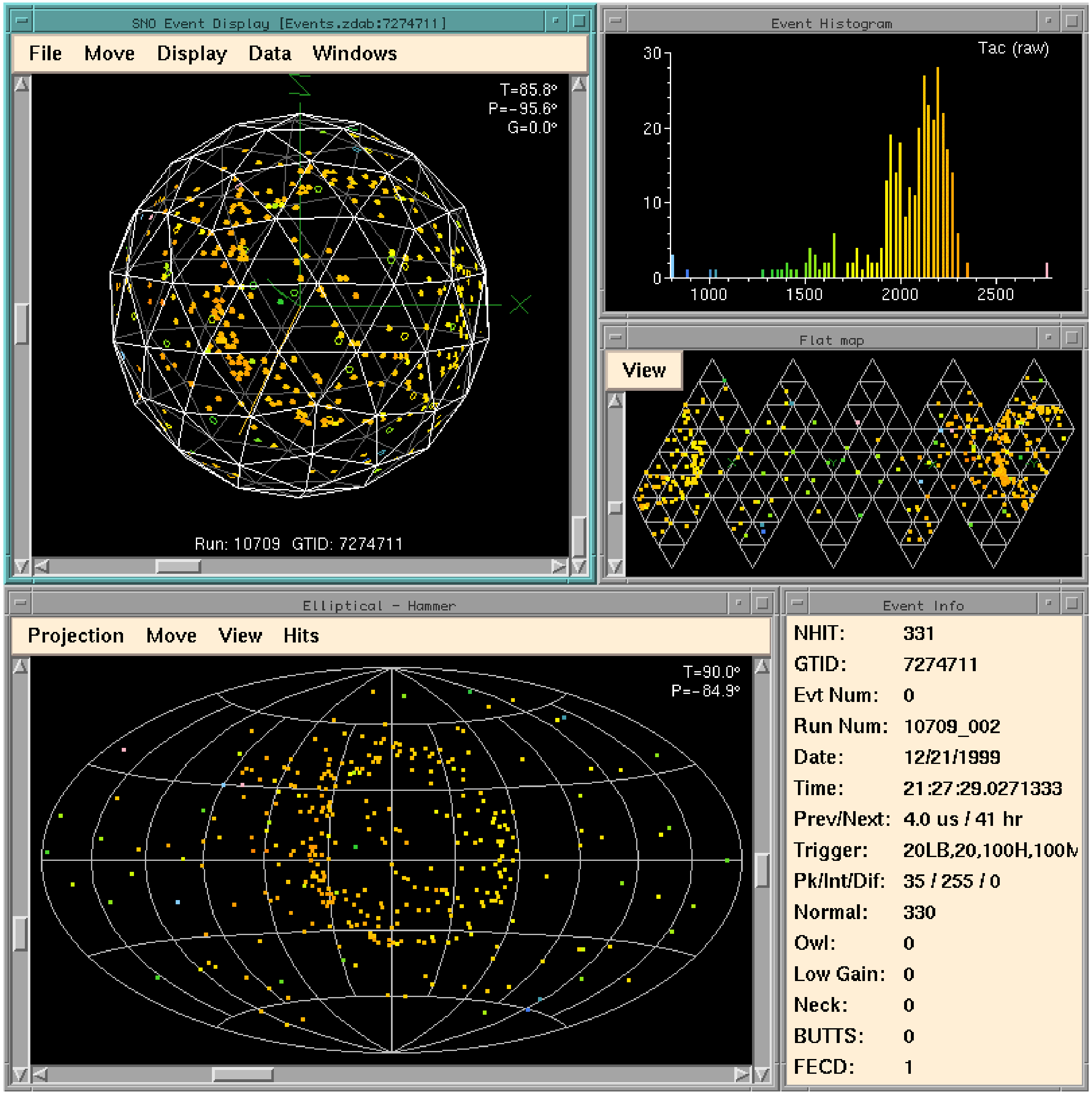


Photomultiplicateurs

Effet Tcherenkov



Effet Tcherenkov

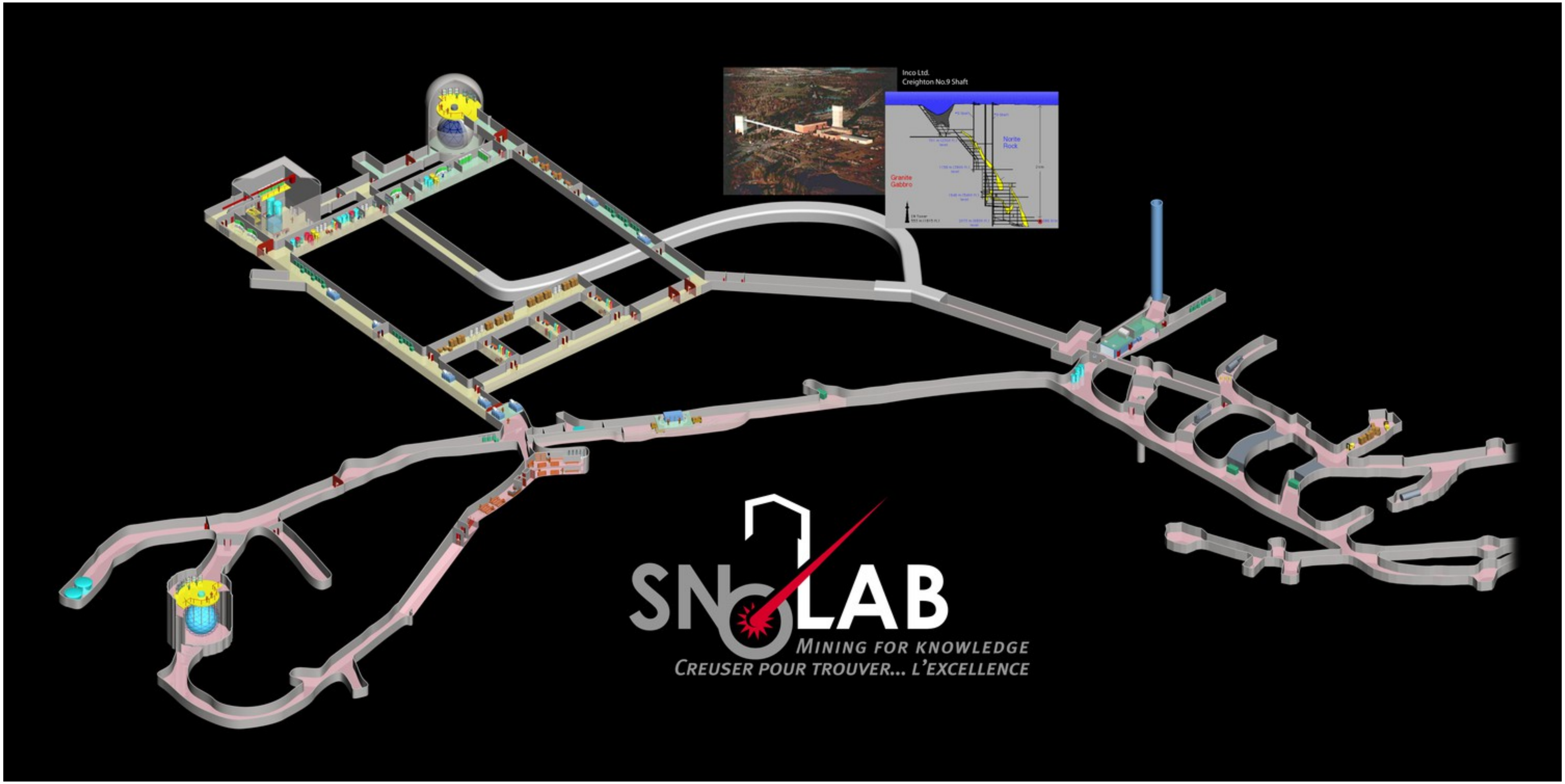


Autres expériences dans les laboratoires

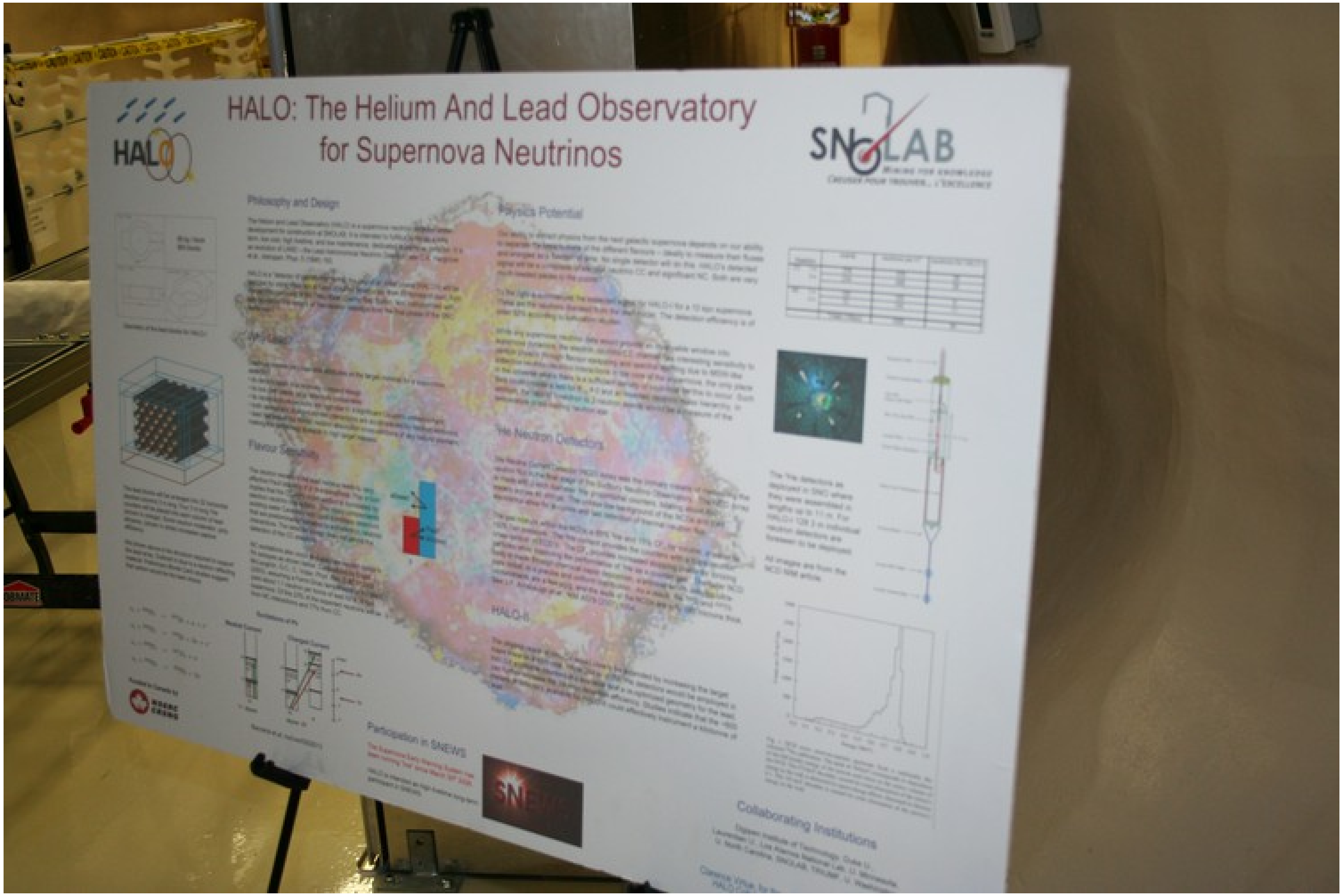
Expériences passées: SNO, PICASSO et PUPS.

Expériences en cours: SNO+, EXO, HALO, DEAP-1 DEAP-360, MiniCLEAN, PICO, DAMIC.

HALO : Détecteur de supernovae

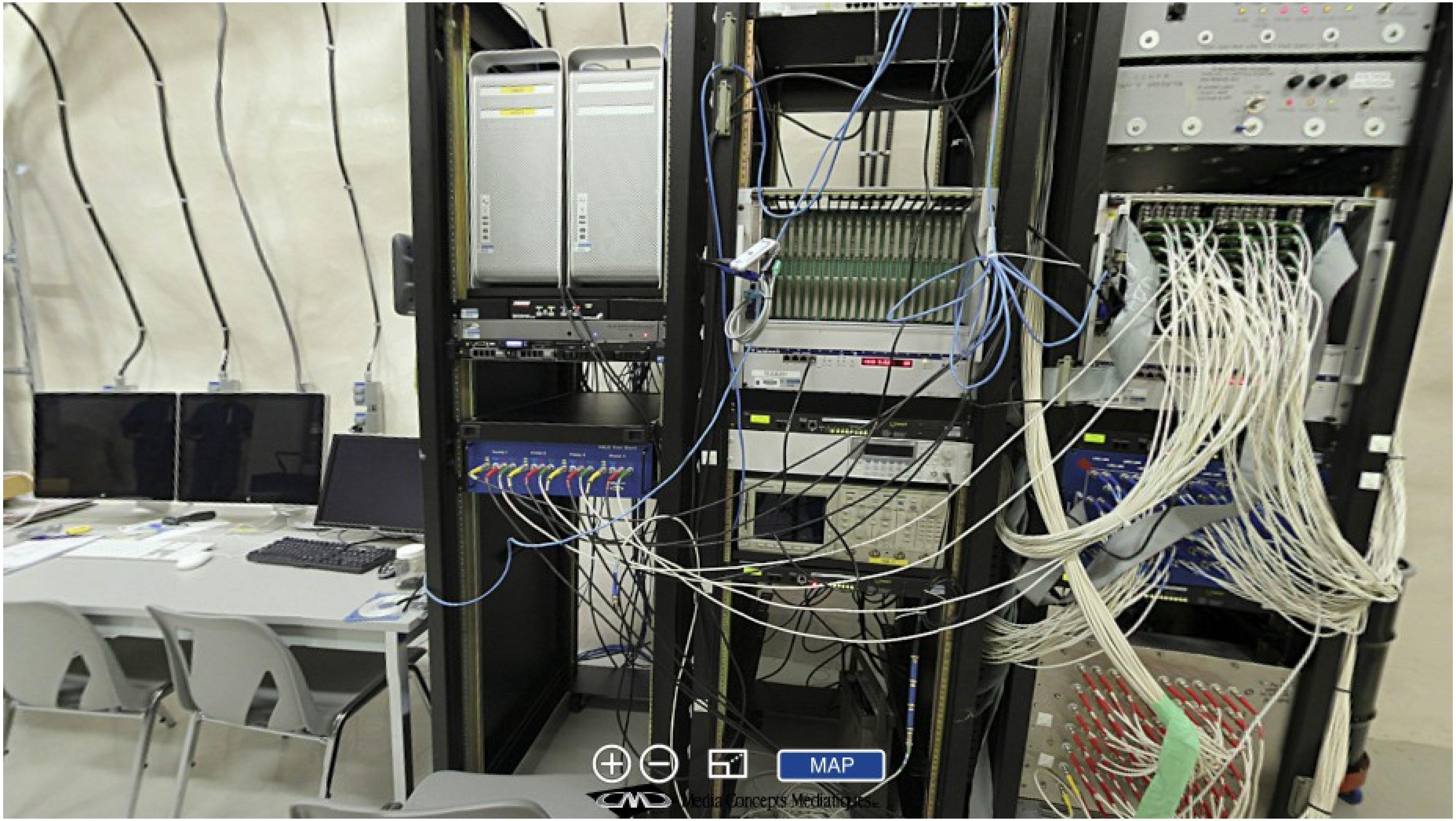


HALO : Détecteur de supernovae

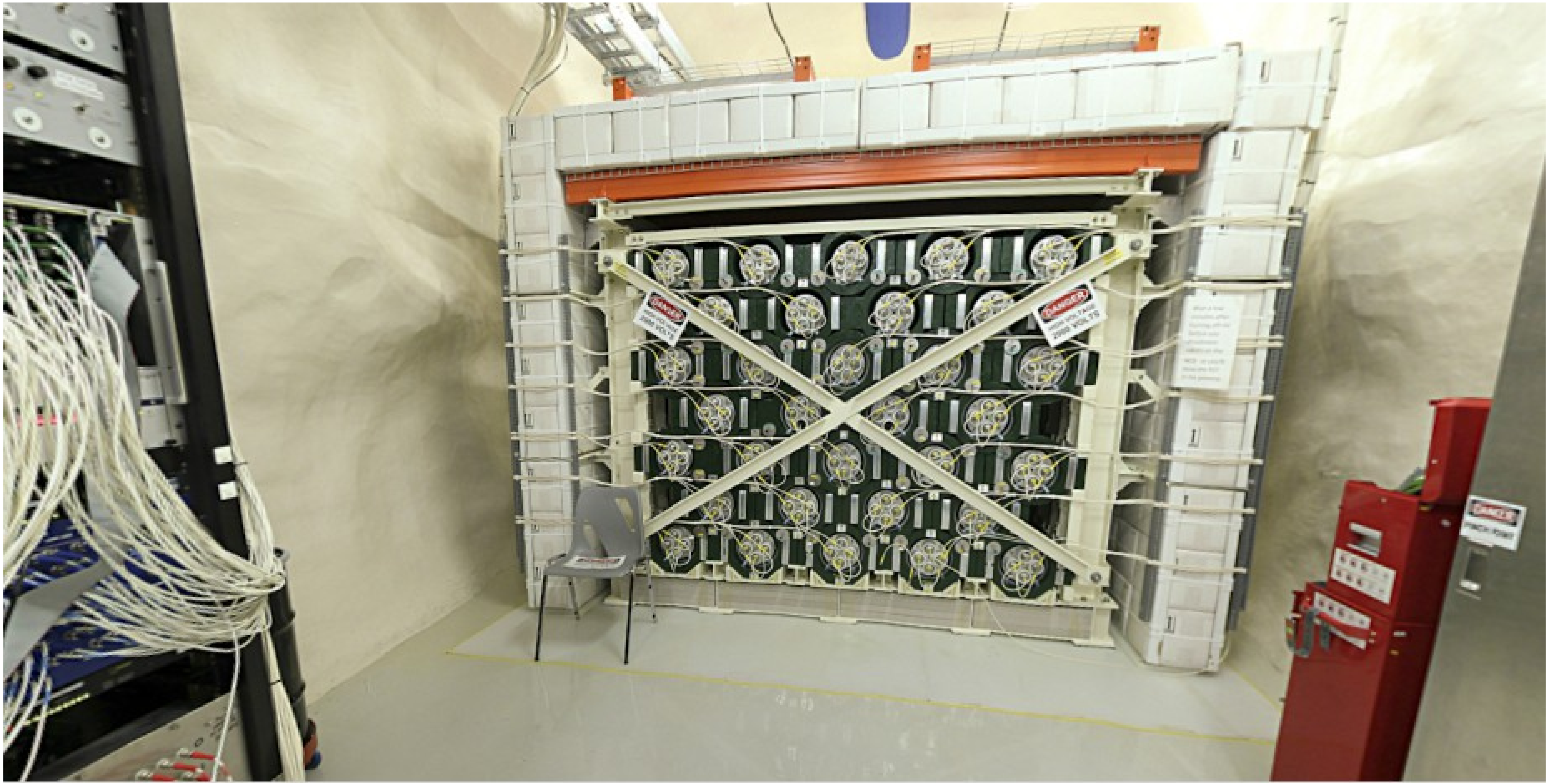


HALO : Détecteur de supernovae

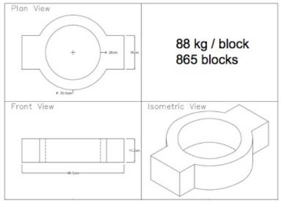
HALO : Détecteur de supernovae



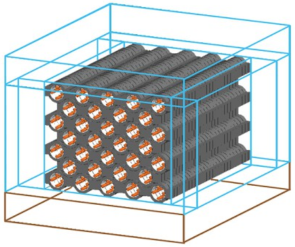
HALO : Détecteur de supernovae



HALO: The Helium And Lead Observatory for Supernova Neutrinos



Geometry of the lead blocks for HALO-I



The lead blocks will be arranged into 32 horizontal stacked columns 3 m long. Four 3 m long ^{3}He counters will be placed into each column of lead (shown in orange). Some neutron moderator, poly-ethylene, (shown in white) increases capture efficiency.

Not shown above is the structure required to support the lead array. Outlined in blue is a neutron reflecting material. Preliminary Monte Carlo studies suggest that carbon would be the best choice.

$$\nu_e + {}^{208}\text{Pb} \rightarrow {}^{207}\text{Bi} + n + e^-$$
$$\nu_e + {}^{208}\text{Pb} \rightarrow {}^{206}\text{Bi} + 2n + e^-$$
$$\nu_x + {}^{208}\text{Pb} \rightarrow {}^{207}\text{Pb} + n$$
$$\nu_x + {}^{208}\text{Pb} \rightarrow {}^{206}\text{Pb} + 2n$$

Philosophy and Design

The Helium and Lead Observatory (HALO) is a supernova neutrino detector under development for construction at SNOLAB. It is intended to fulfill a niche as a long term, low cost, high livetime, and low maintenance, dedicated supernova detector. It is an evolution of LAND – the Lead Astronomical Neutrino Detector; see C.K. Hargrove et al., Astropart. Phys. 5 (1996) 183.

HALO is a "detector of opportunity" in that the cost of an initial phase (HALO-I) will be kept low by using materials at hand. It will be constructed from 80 tonnes of lead, from the decommissioning of the Deep River Cosmic Ray Station, and instrumented with approximately 384 meters of ^{3}He neutron detectors from the final phase of the SNO experiment.

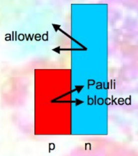
Why Lead?

Lead has several very desirable attributes as the target material for a supernova detector:

- its density leads to a relatively compact design
- its low cost makes large detectors conceivable
- its neutrino cross-sections are high due to a significant Coulomb enhancement
- both neutral and charged current interactions are accompanied by neutron emission
- lead has one of the lowest neutron absorption cross-sections of any natural element making the technology scalable to high target masses

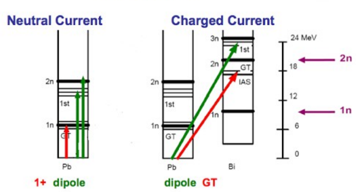
Flavour Sensitivity

The neutron excess in the lead nucleus leads to very effective Pauli blocking of p → n transitions. This in turn implies that the CC ν-Pb cross-section is dominated by electron neutrino interactions. This nicely complements existing water Cerenkov and liquid scintillator detectors that are predominantly sensitive to anti-electron neutrino interactions. The detector design does not permit the detection of the CC electrons.



NC excitations also occur and populate excited states in Pb isotopes as shown below. Calculations by Engel, J., McLaughlin, G.C., C. Volpe, Phys. Rev. D **67** 013005 (2003), assuming a Fermi-Dirac temperature of 8.0 MeV, yield about 1.1 neutron per tonne of lead for a 10 kpc supernova. Of this 23% of the expected neutrons will be from NC interactions and 77% from CC.

Excitations of Pb



Bacrania et al. nucl-ex/0202013

Physics Potential

Our ability to extract physics from the next galactic supernova depends on our ability to separate the contributions of the different flavours – ideally to measure their fluxes and energies as a function of time. No single detector will do this. HALO's detected signal will be a composite of electron neutrino CC and significant NC. Both are very much needed pieces to the puzzle.

To the right is summarized the expected signal for HALO-I for a 10 kpc supernova. These are the neutrons liberated from the lead nuclei. The detection efficiency is of order 50% according to simulation studies.

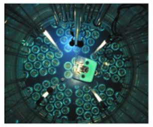
Reaction		events	neutrons per kT	neutrons for HALO-I
CC	1-n	378	378	29
	2-n	234	468	36
NC	1-n	105	105	8
	2-n	72	144	11
		Totals (10kpc)	1095	84

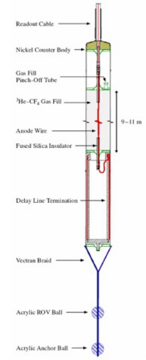
While any supernova neutrino data would provide an invaluable window into supernova dynamics, the electron neutrino CC channel has interesting sensitivity to particle physics through flavour-swapping and spectral splitting due to MSW-like collective neutrino-neutrino interactions in the core of the supernova, the only place in the universe where there is a sufficient density of neutrinos for this to occur. Such data could provide a test for $\theta_{13} \neq 0$ and an inverted neutrino mass hierarchy. In addition, the ratio of 1-neutron to 2-neutron events would be a measure of the temperature of the cooling neutron star.

^{3}He Neutron Detectors

The Neutral Current Detector (NCD) Array was the primary means of measuring the neutron flux in the final stage of the Sudbury Neutrino Observatory. The NCD Array Is made with 2-inch diameter ^{3}He proportional counters, totaling about 400 meters across 40 strings. The unique low-background of the NCDs and their electronics allow for accurate and fast detection of thermal neutron flux.

The gas mixture within the NCDs is 85% ^{3}He and 15% CF_4 by volume, at close to 1928 Torr pressure. The ^{3}He content provides the counters with a huge neutron cross-section of 5330 b. The CF_4 provides increased stopping power for ionizing particles while improving the performance of ^{3}He as a counter gas. The outer NCD body is made through chemical vapor deposition, a process which delivers ultra-pure nickel, in a precise and uniform distribution. As a result, the ^{238}U and ^{232}Th contaminants are a few pg/g, and the walls of the NCDs are only 380 microns thick. See J.F. Amsbaugh et al., NIM A579 (2007) 1054.





The ^{3}He detectors as deployed in SNO where they were assembled in lengths up to 11 m. For HALO-I 128 3 m individual neutron detectors are foreseen to be deployed.

All images are from the NCD NIM article.

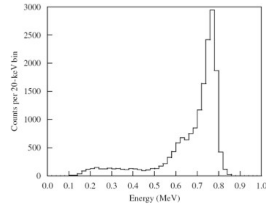


Fig. 1. NCD array neutron-capture spectrum from a uniformly distributed ^{24}Na calibration. The peak at 764 keV corresponds to deposition of the full kinetic energy of the proton and triton in the active volume of the NCD. The 573-keV shoulder, caused by total absorption of the triton's energy in the wall, is distorted by space-charge effects, discussed in Section 6.1. The 191-keV shoulder is caused by total absorption of the proton's energy in the wall.

HALO-II

The physics reach of HALO-I would clearly be extended by increasing the target mass towards a kilotonne. While 384 m of the ^{3}He detectors would be employed in HALO-I additional counters are available and a re-optimized geometry for the lead, can further increase the neutron detection efficiency. Studies indicate that the ~600 meters of detectors available for HALO-II could effectively instrument a kilotonne of lead.

Participation in SNEWS

The Supernova Early Warning System has been running "live" since March 30th 2006.

HALO is intended as high-livetime long-term participant in SNEWS.

SNEWS

Collaborating Institutions

Digipen Institute of Technology, Duke U., Laurentian U., Los Alamos National Lab, U. Minnesota, U. North Carolina, SNOLAB, TRIUMF, U. Washington

Clarence Virtue, for the HALO Collaboration

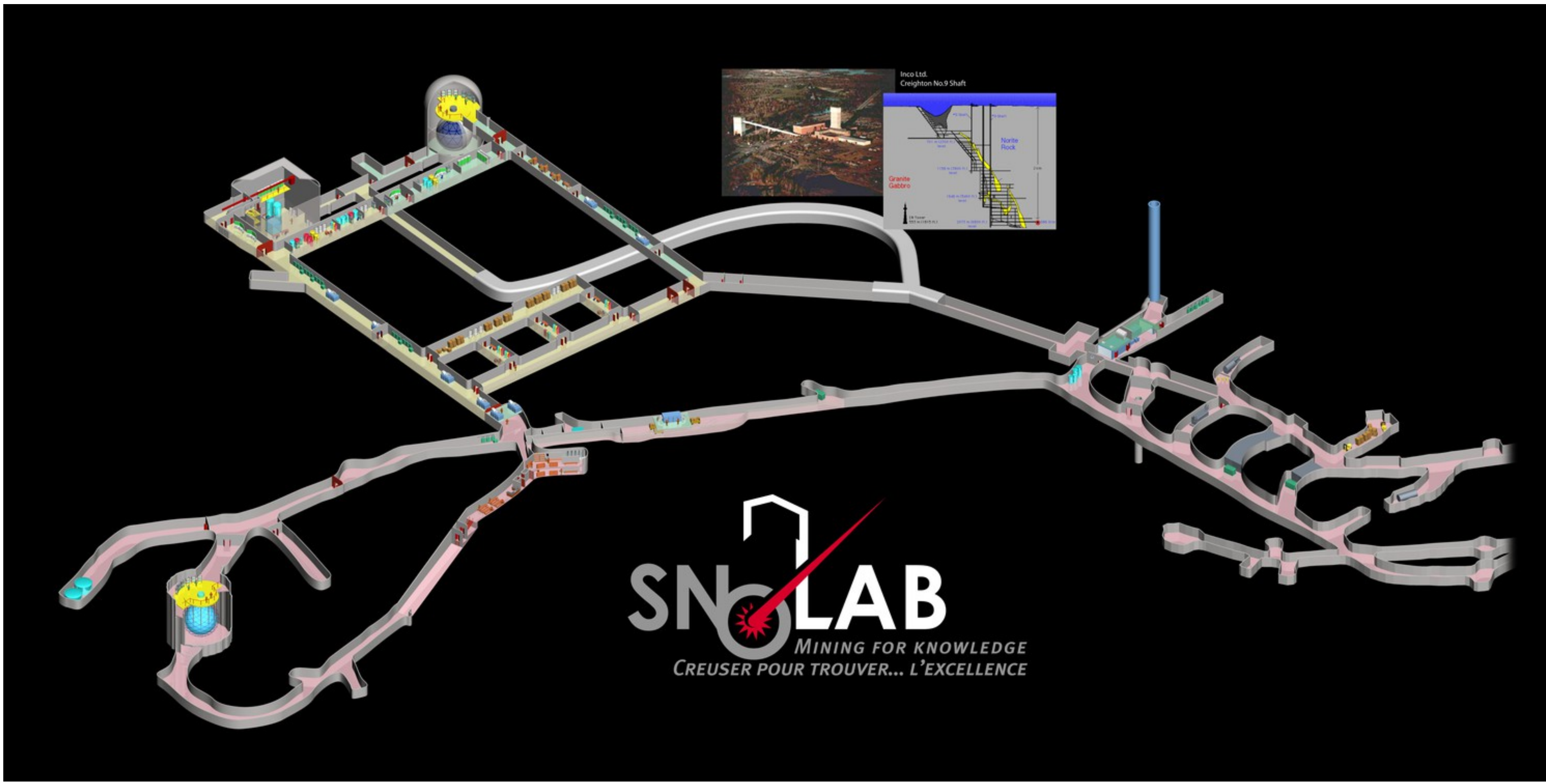
Laurentian University Université Laurentienne

Funded in Canada by

NSERC CRSNG

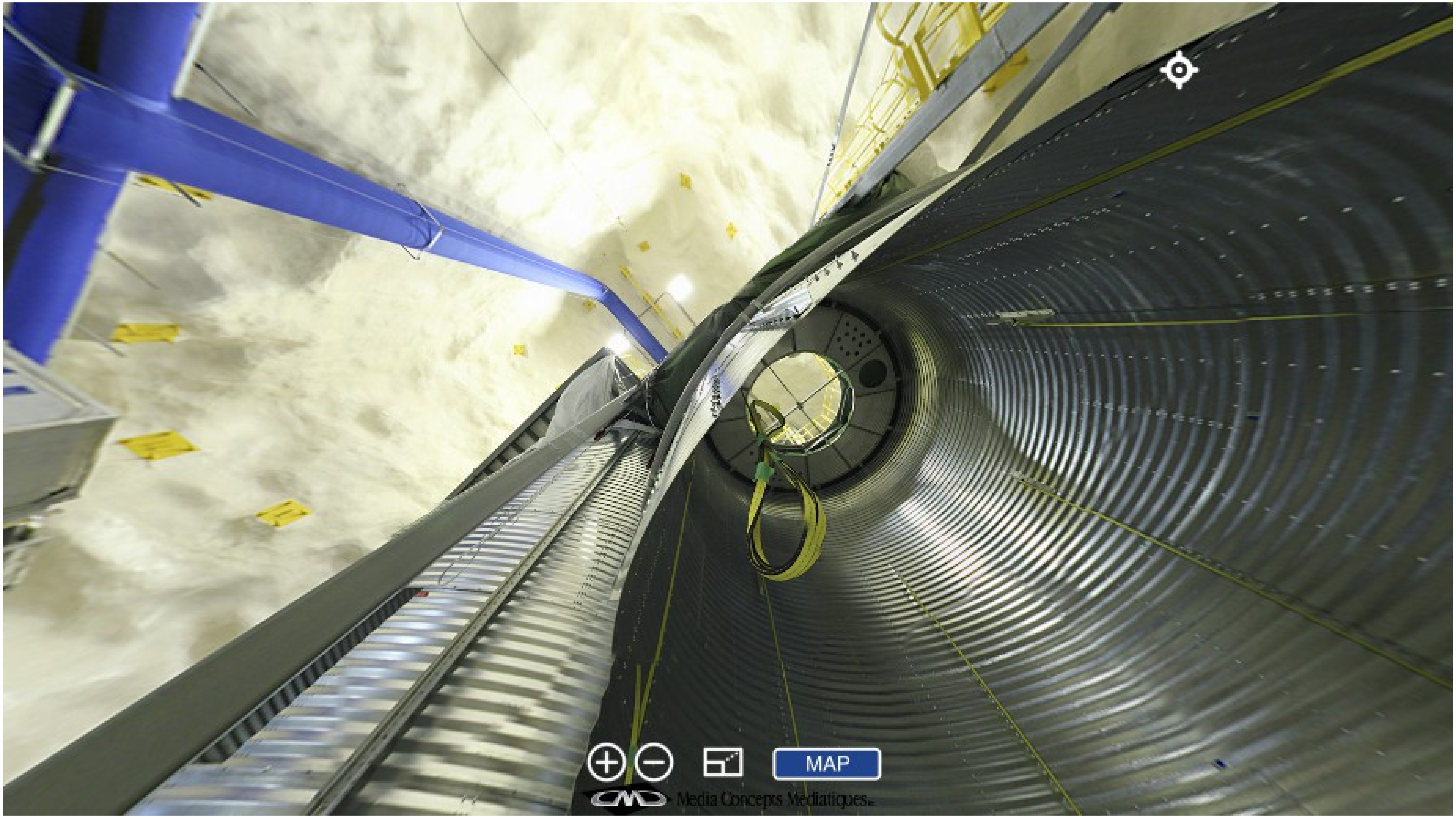
SNOLAB Mining for knowledge Creuser pour trouver... l'excellence

Cube Hall

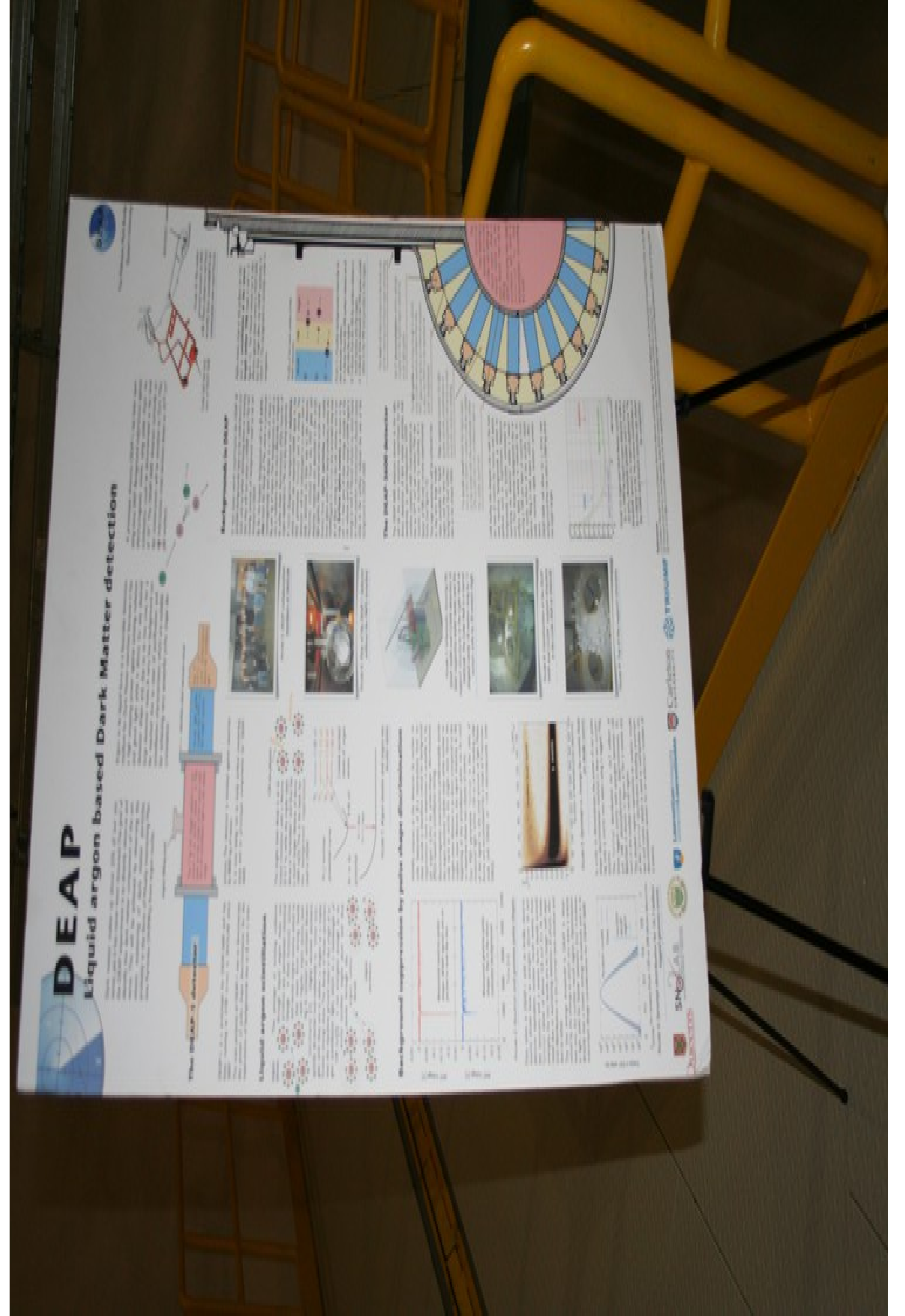

Inco Ltd.
Creighton No.9 Shaft
Norite Rock
Granite Gabbro
SNOLAB
MINING FOR KNOWLEDGE
CREUSER POUR TROUVER... L'EXCELLENCE

Cube Hall

Cube Hall



DEAP - Liquid argon based Dark Matter detection



DEAP - Détecteur de matière noire

DEAP

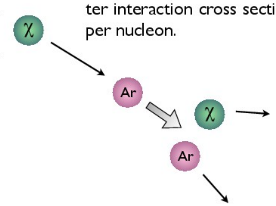
Liquid argon based Dark Matter detection

Tina Pollmann, Mark Boulay
Queen's University

Dark matter makes up about 25% of our universe, yet it has never been detected. The goal of the DEAP experiment is to directly observe and identify this dark matter component of the universe. This will be achieved by observing the elastic scattering of dark matter particles, probably in the form of Weakly Interacting Massive Particles (WIMPs), from argon nuclei.

Argon in its liquid form is a favorable detection medium for Dark Matter searches because it has a high stopping power against ionizing radiation and good light yield, it allows for any desired detector shape and, due to its low cost, for a large detector mass. A very low background can be reached due to ease of purification and scintillation characteristics which are suitable for achieving very powerful pulse shape discrimination.

A prototype detector, DEAP-1, has been operating since 2007. Background suppression against electromagnetic events using pulse shape discrimination could be demonstrated at the level of 10^{-7}. The DEAP-3600 detector currently under construction will be sensitive to Dark Matter interaction cross sections down to 10^{-46} cm^2 per nucleon.



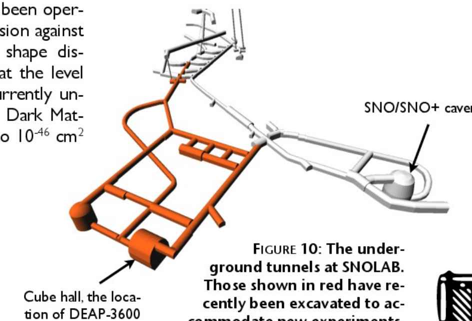
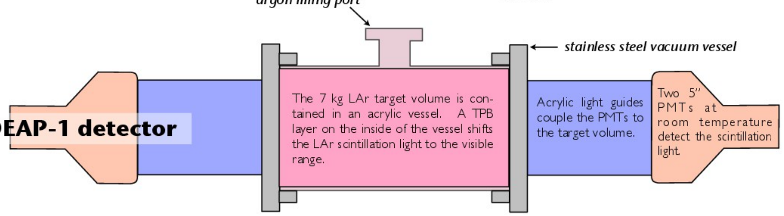


FIGURE 10: The underground tunnels at SNOLAB. Those shown in red have recently been excavated to accommodate new experiments.

The DEAP-1 detector



DEAP-1 is a prototype for DEAP-3600 and has been running at 3100 m.w.e. in SNOLAB since 2007.

The main purpose of DEAP-1 was to demonstrate the power of pulse shape discrimination for the suppression of backgrounds due to β and γ interactions. The detector is shielded against neutrons by 8000 kg of water.

It is now being run to study surface contaminations and to prototype components for DEAP-3600.

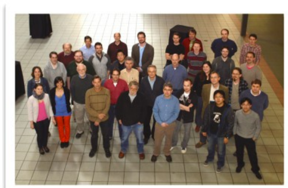
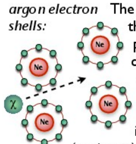


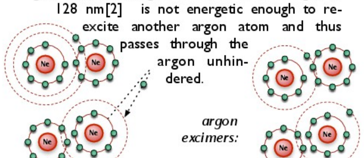
FIGURE 5: DEAP collaboration members.

FIGURE 6: View of the DEAP-1 detector without the PMTs installed.

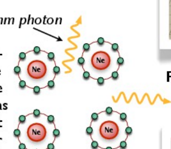
Liquid argon scintillation



The passage of ionizing radiation through liquid argon does not produce any permanent chemical change. It does however ionize and excite argon atoms, which in that state form strong bonds with regular argon atoms, leading to ionized or excited dimers (excimers) [1]. Highly excited excimers quickly de-excite non-radiatively to lower energies until they are in either a singlet or a triplet lowest energy state. The decay of those excimers into the repulsive ground state is the origin of argon scintillation light, which at a wavelength of 128 nm[2] is not energetic enough to re-excite another argon atom and thus passes through the argon unhindered.



The singlet state decay is an allowed transition with a lifetime of 6.7 ns, while the triplet state decay is "forbidden" and thus has a much longer lifetime of about 1600 ns[3]. This is the basis for the background suppression used in DEAP.



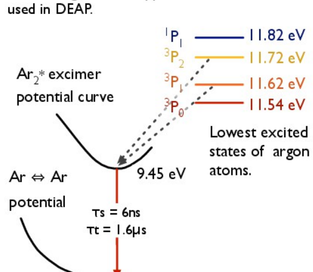


FIGURE 1: Argon atomic and argon

Backgrounds in DEAP

In rare event search experiments like DEAP all possible backgrounds have to be understood and dealt with by either eliminating them or showing that they will not mimic a WIMP signal. The following sources of background need to be addressed in DEAP:

By far the largest background will be **β particles** from the decay of ^{39}Ar, which is produced cosmogenically and decays at a rate of about 1 Bq per kg of argon. This background, as well as any γ radiation, can be very effectively mitigated by pulse shape discrimination (PSD). Sources of argon depleted in ^{39}Ar are also being explored.

A more dangerous background are **neutrons**, which mimic the expected WIMP signal in the PSD parameter Fprompt and in energy. The detector will be submerged in a water tank to stop neutrons on their way to the detector. Neutrons emitted from the PMT glass and detector materials are absorbed in the acrylic light guides, filler material and the acrylic vessel.

Events from **alpha particles**, most notably from radon and radon decay products, mimic the WIMP signal in Fprompt, but, provided they lose all of their energy in the LAr volume, not in energy. **Surface alpha events**, as shown in figure 11, lose part of their energy outside of the LAr volume, and can thus mimic a WIMP signal in energy as well. A fiducial volume cut which based on event position reconstruction discards events close to the surface reduced the rate of this background in DEAP-3600.

Alpha events close to the surface can also lead to **scintillation of the wavelength shifter TPB** (cases b and c in figure 11). The fiducial volume cut is also effective against these events in DEAP-3600, but they might affect the WIMP sensitivity of DEAP-1. This background is currently under investigation.

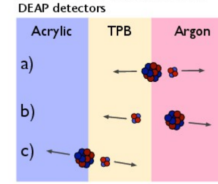
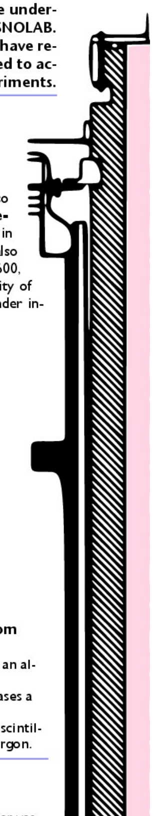


FIGURE 11: Possible backgrounds from the inner detector surface.
a) A decay from the TPB surface releases an alpha into the argon.
b) A decay from the TPB the surface releases a recoil nucleus into the argon.
c) A decay from beneath the TPB causes scintillation in the TPB and possibly in the argon.



The neck will allow access to the inner ves-

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FIGURE 1: Argon atomic and argon molecular states.

Background suppression by pulse shape discrimination

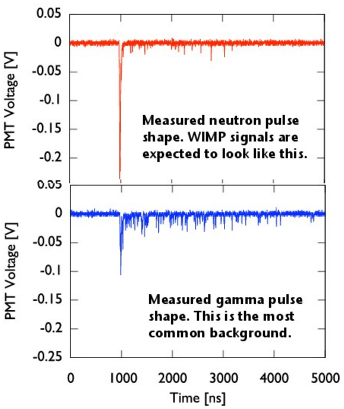


FIGURE 2: Neutron and gamma pulse shapes.

WIMPs interact in the detector by nuclear recoils. Separation of β-γ interactions from nuclear recoils is therefore critical for background suppression. Such a separation is possible in liquid argon (LAr) by pulse-shape discrimination (PSD) based on scintillation timing.

Electromagnetic interactions preferentially excite the argon excimer triplet state while nuclear recoils tend to excite the singlet state. Since the singlet state lifetime is so short compared to the triplet state lifetime, the signal intensity at the beginning of the scintillation pulse can be used to separate these two classes of events.

Our PSD parameter Fprompt is the ratio of measured light within 150 ns of the leading edge of the signal to the total amount of light. Waveforms are accumulated for a total of 9 microseconds (old DAQ) or ~14 microseconds (new DAQ).

Data taken in DEAP-1 with an AmBe neutron source shows how, at energies above 20 keV electron equivalent, nuclear recoil events from the neutrons and γ events form bands around Fprompt values of about 0.8 and 0.3. At lower energies, the two bands are no longer well separated due to worsening statistics of photo electron distribution in the prompt time window and due to noise.

The low energy threshold in DEAP is determined by the energy at which too many γ events leak into the nuclear recoil region. Optimization in light yield for better statistics thus translates directly into a lower energy threshold and is an important design consideration for DEAP-3600.

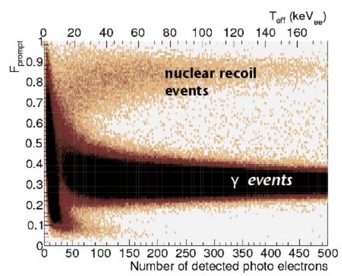


FIGURE 3: Fprompt vs. Energy for events from an AmBe source.

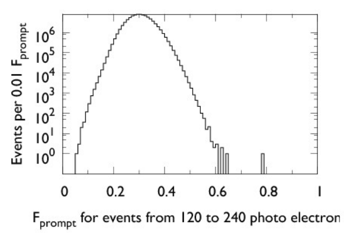


FIGURE 4: Fprompt distribution for 110 million tagged gamma events. Probability for one or more random pileups was 36%

In order to demonstrate the power of our pulse shape discrimination method, a data set containing only γ events was taken using a tagged ^{22}Na source.

The Fprompt distribution for 16.7 million of these tagged events with energies between 120 and 240 photoelectrons (approximately 43-86keVee) is shown in figure 4. No γ events are seen in the nuclear recoil region.

The shaded region represents an analytic model of the Fprompt distribution including uncertainties and noise, which is used to extrapolate the discrimination power for an arbitrary number of γ events.

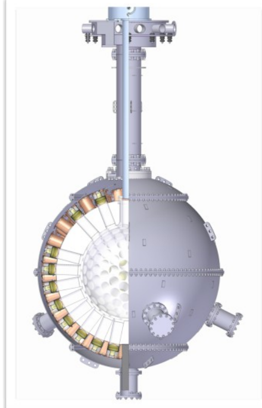


FIGURE 7: 3D rendering of the DEAP-3600 detector showing the acrylic vessel, light guides, PMTs and shell.

FIGURE 8: Construction of the DEAP-3600 and CLEAN support structure in the Cube Hall at SNOLAB.

FIGURE 9: Top of the support structure.

The DEAP-3600 detector

The DEAP-3600 detector, shown to the right, will be the most sensitive experiment for the direct detection of dark matter particles, with sensitivity to spin-independent WIMP-nucleon scatters with cross-sections as low as 10^{-46} cm^2 per nucleon. This represents an increase in sensitivity of a factor of 500 over current experimental limits (see figure 12).

This high sensitivity will be achieved due to the very large target mass possible for liquid argon, and the very low background level achievable at the unique SNOLAB facility, the deepest site with the lowest rate of cosmic-ray muons and associated neutron backgrounds in which to perform such an experiment. Neutron backgrounds are further minimized by operating the detector within a water tank. The dangerous background due to surface alpha events is reduced by removing a 500 μm layer of material from the inside surface of the acrylic vessel before filling it with argon, which effectively removes alpha emitters present there.

DEAP-3600 will allow for a three year background-free run with a 1000 kg sensitive argon target.

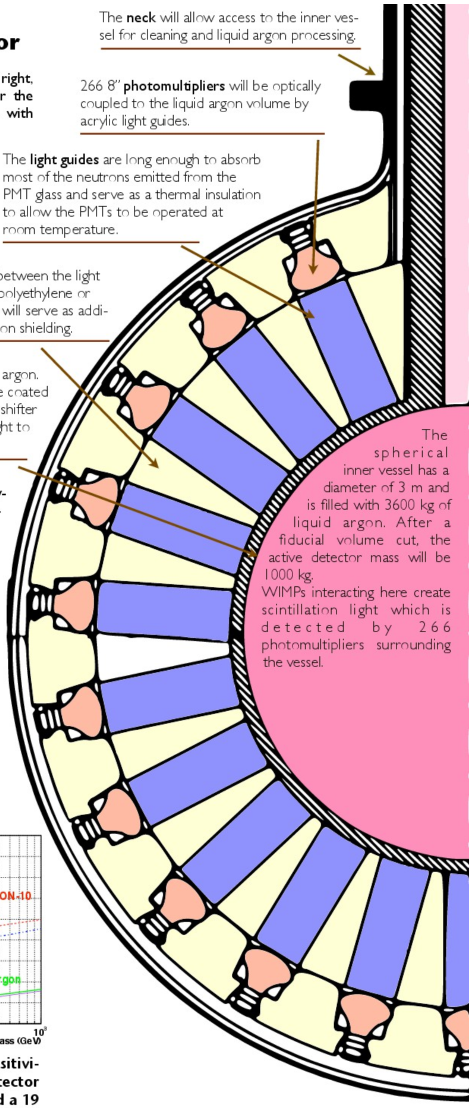
The **neck** will allow access to the inner vessel for cleaning and liquid argon processing.

266 8" **photomultipliers** will be optically coupled to the liquid argon volume by acrylic light guides.

The **light guides** are long enough to absorb most of the neutrons emitted from the PMT glass and serve as a thermal insulation to allow the PMTs to be operated at room temperature.

Filler material between the light guides (acrylic, polyethylene or polypropylene) will serve as additional the neutron shielding.

The **acrylic vessel** holds the liquid argon. Just as the DEAP-1 vessel, it will be coated on the inside with the wavelength shifter TPB to shift the LAr scintillation light to the visible spectrum.



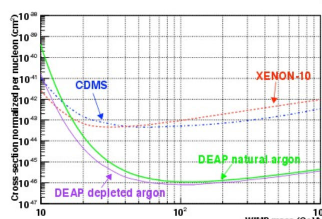


FIGURE 12: Expected Dark Matter sensitivities for a 1000 kg liquid argon detector with a 20 keV$_{ee}$ threshold (purple) and a 19 keV$_{ee}$ threshold (green) for argon depleted in ^{39}Ar by a factor of 20. The current sensitivities of the CDMS and XENON detectors are shown for comparison.

References

[1] Mulliken. *Potential Curves of Diatomic Rare-Gas Molecules and Their Ions, with Particular Reference to Xe.* The Journal of Chemical Physics (1970) vol. 52 (10)

[2] Thonnard and Hurst. *Time-Dependent study of VUV emission in Argon.* Physical Review A (1972) vol. 5 (3) pp. 1110

[3] Hitachi et al. *Effect of ionization density on the time dependence of luminescence from liquid argon and xenon.* Physical Review B (1983) vol. 27 (9) pp. 5279

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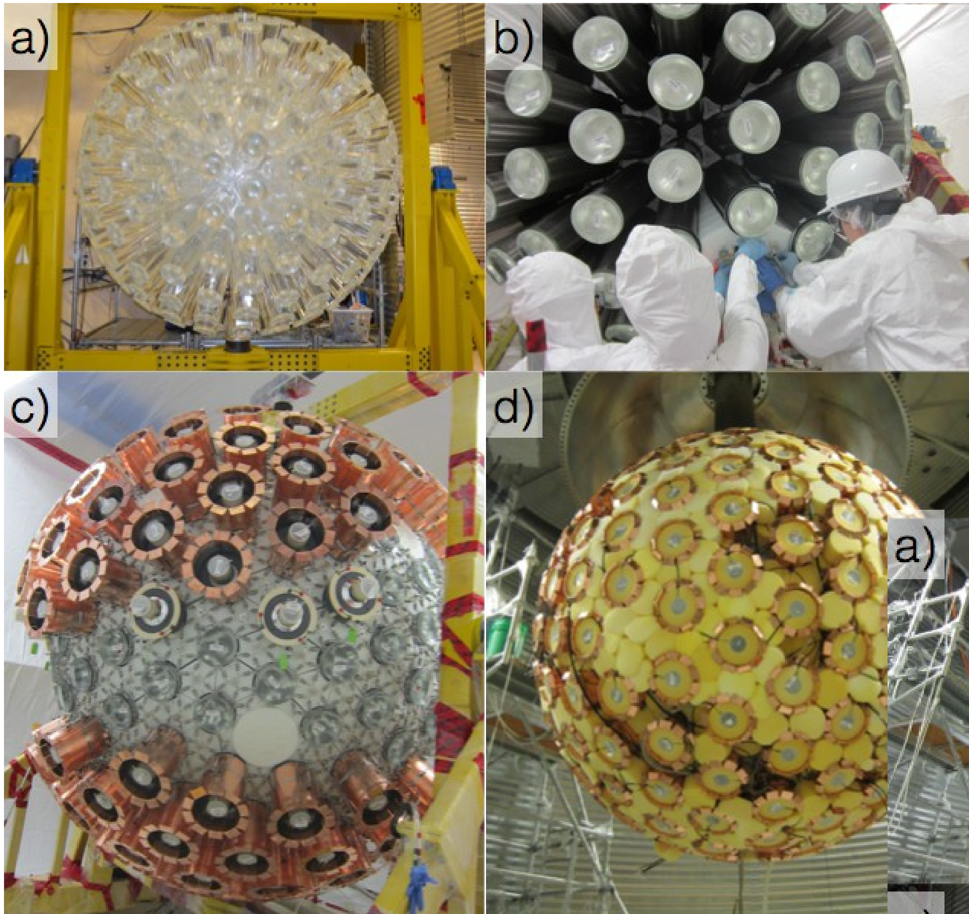
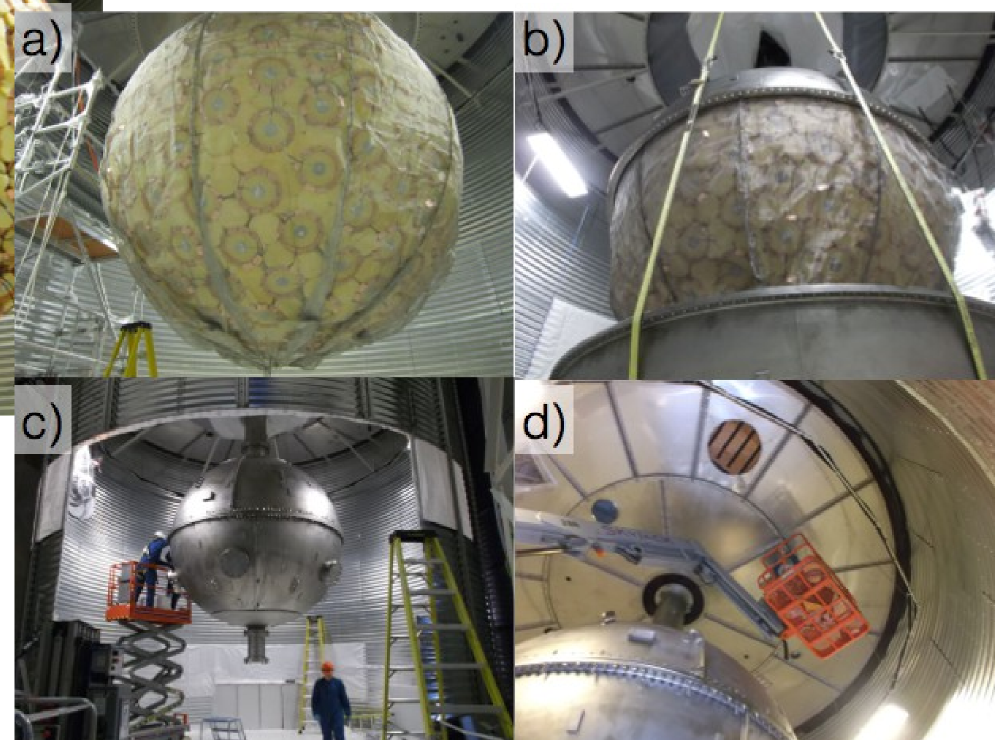
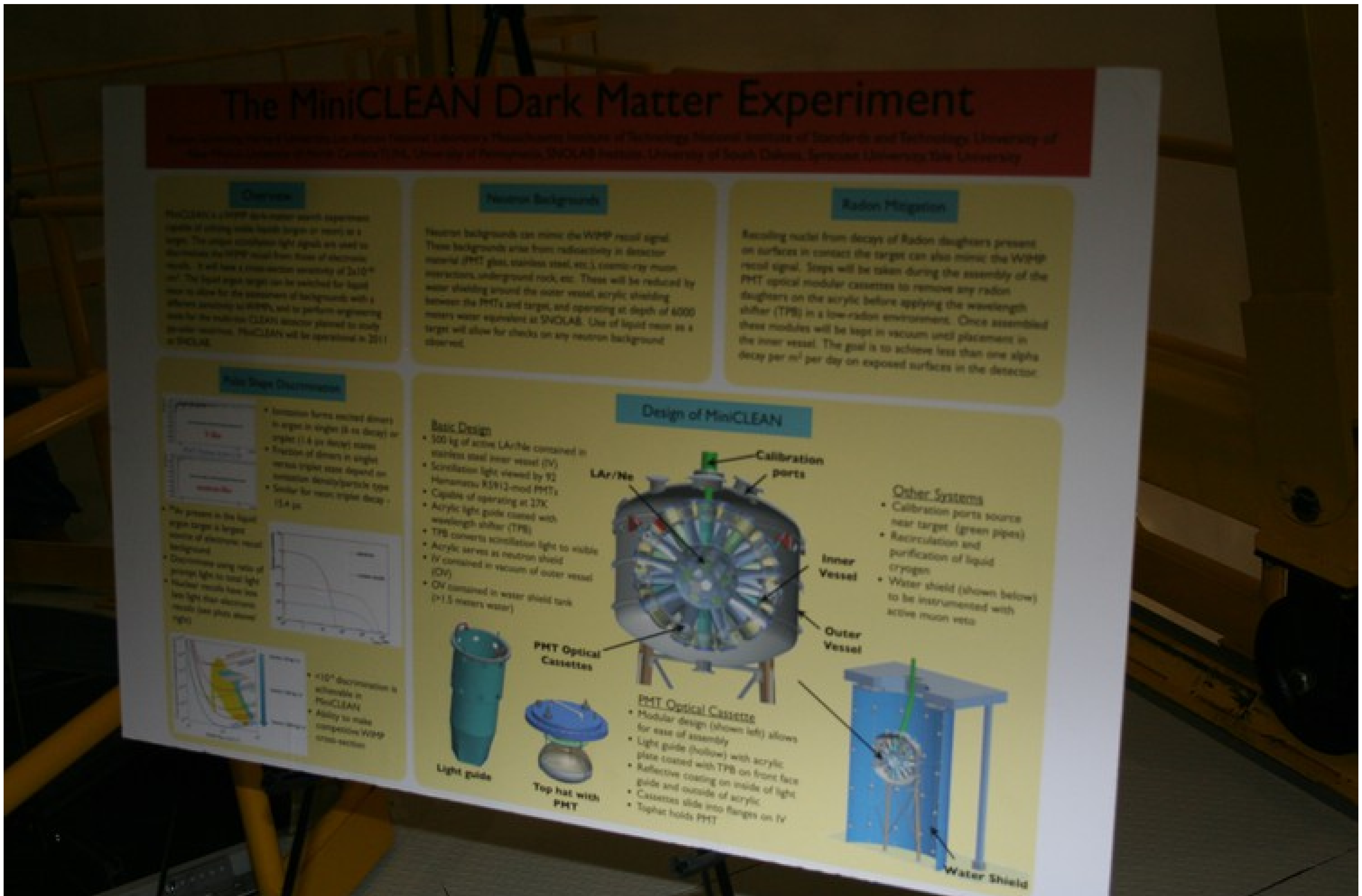




MiniCLEAN- Détecteur de matière noire



MiniCLEAN- Détecteur de matière noire

The MiniCLEAN Dark Matter Experiment

Boston University, University of California, Berkeley, Los Alamos National Laboratory, Massachusetts Institute of Technology, National Institute of Standards and Technology, University of New Mexico, University of North Carolina/TUNL, University of Pennsylvania, Royal Holloway University London, SNOLAB Institute, University of South Dakota, Syracuse University, Yale University

Overview

MiniCLEAN is a WIMP dark-matter search experiment capable of utilizing noble liquids (argon or neon) as a target. The unique scintillation light signals are used to discriminate the WIMP recoil from those of electronic recoils. It will have a cross-section sensitivity of 2×10^{-45} cm^2. The liquid argon target can be switched for liquid neon to allow for the assessment of backgrounds with a different sensitivity to WIMPs, and to perform engineering tests for the multi-ton CLEAN detector planned to study pp-solar neutrinos. MiniCLEAN will be operational in 2013 at SNOLAB.

Neutron Backgrounds

Neutron backgrounds can mimic the WIMP recoil signal. These backgrounds arise from: radioactivity in detector material (PMT glass, stainless steel, etc.), cosmic-ray muon interactions, underground rock, etc. These will be reduced by water shielding around the outer vessel, acrylic shielding between the PMTs and target, and operating at depth of 6000 meters water equivalent at SNOLAB. Use of liquid neon as a target will allow for checks on any neutron background observed.

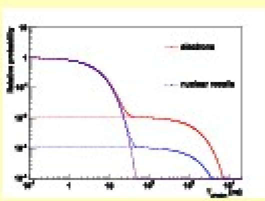
Radon Mitigation

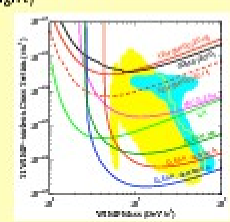
Recoiling nuclei from decays of Radon daughters present on surfaces in contact the target can also mimic the WIMP recoil signal. Steps will be taken during the assembly of the PMT optical modular cassettes to remove any radon daughters on the acrylic before applying the wavelength shifter (TPB) in a low-radon environment. Once assembled these modules will be kept in a low radon environment until placement in the inner vessel. The goal is to achieve less than one alpha decay per m^2 per day on exposed surfaces in the detector.

Pulse Shape Discrimination

- Ionization forms excited dimers in argon in singlet (6 ns decay) or triplet (1.6 μs decay) states
- Fraction of dimers in singlet versus triplet state depend on ionization density/particle type
- Similar for neon: triplet decay - 15.4 μs

- ^{39}Ar present in the liquid argon target is largest source of electronic recoil background
- Discriminate using ratio of prompt light to total light
- Nuclear recoils have less late light than electronic recoils (see plots above/right)



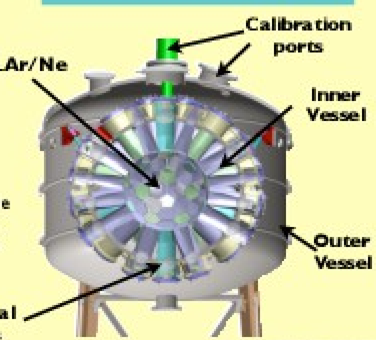


- $<10^{-9}$ discrimination is achievable in MiniCLEAN
- Ability to make competitive WIMP cross-section

Design of MiniCLEAN

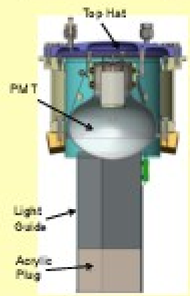
Basic Design

- 500 kg of active LAr/Ne contained in stainless steel inner vessel (IV)
- Scintillation light viewed by 92 Hamamatsu R5912-mod PMTs
- Capable of operating at 27K
- Acrylic light guide coated with wavelength shifter (TPB)
- TPB converts scintillation light to visible
- Acrylic serves as neutron shield
- IV contained in vacuum of outer vessel (OV)
- OV contained in water shield tank (>1.5 meters water)



Other Systems

- Calibration ports source near target (green pipes at left)
- Recirculation and purification of liquid cryogen
- Water shield to be instrumented with active muon veto



PMT Optical Cassette

- Modular design (shown left) allows for ease of assembly
- Light guide (hollow) with acrylic plate coated with TPB on front face
- Reflector inside of light guide and outside of acrylic
- Cassettes slide into flanges on IV
- Tophat holds PMT

Status of MiniCLEAN

- Outer vessel (left) is complete
- Inner Vessel (above after welding) will be delivered in Fall 2012
- MiniCLEAN will be assembled starting Fall 2012 and be filled with liquid argon by Summer 2013

Références

http://www.snolab.ca/
http://www.sno.phy.queensu.ca/

Merci de votre attention

ociété
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entre
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