# Development of Deep Underground Facilities

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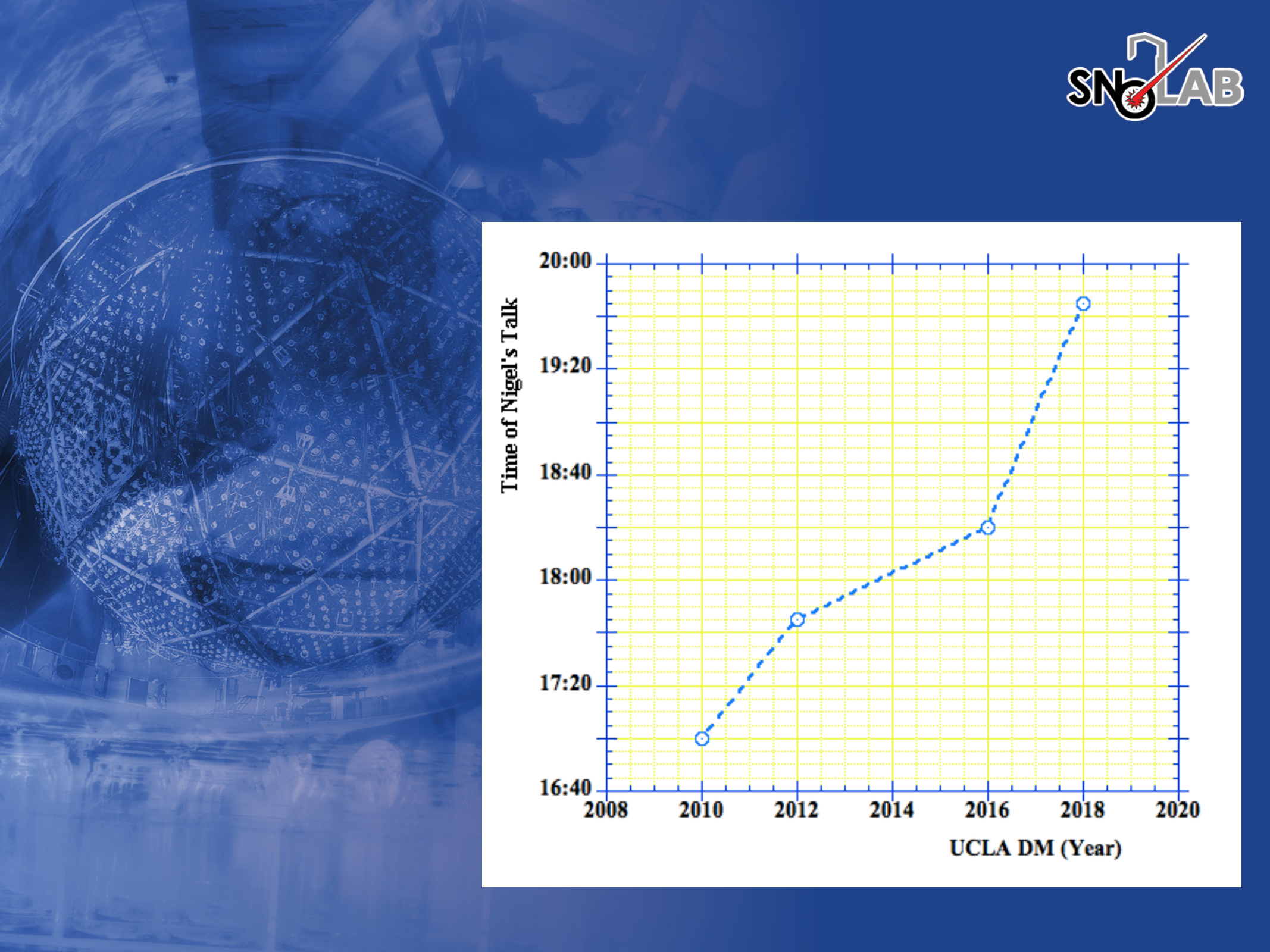
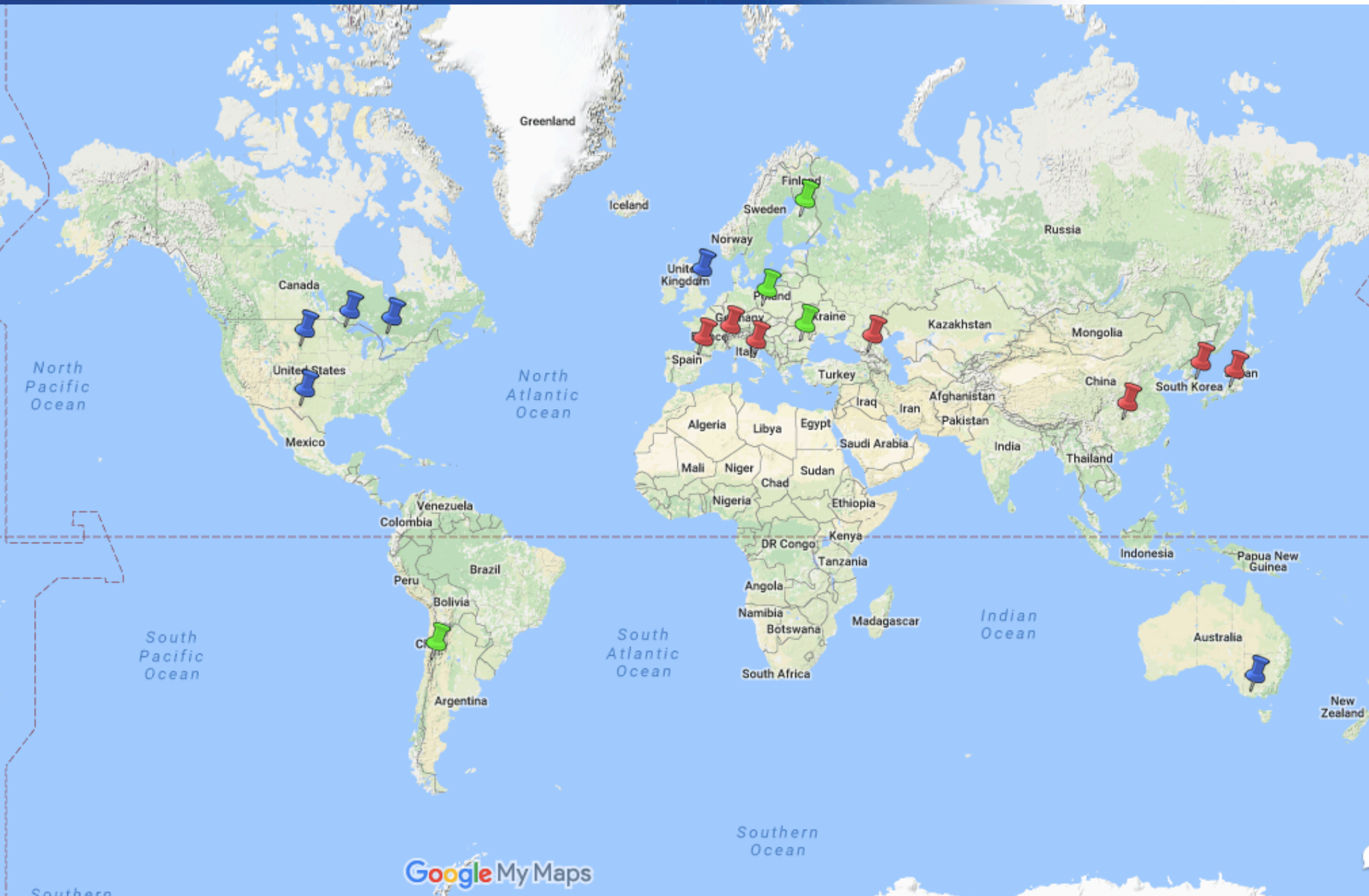

Time of Nigel's Talk
20:00
19:20
18:40
18:00
17:20
16:40
2008
2010
2012
2014
2016
2018
2020
UCLA DM (Year)

# Considerations for a facility

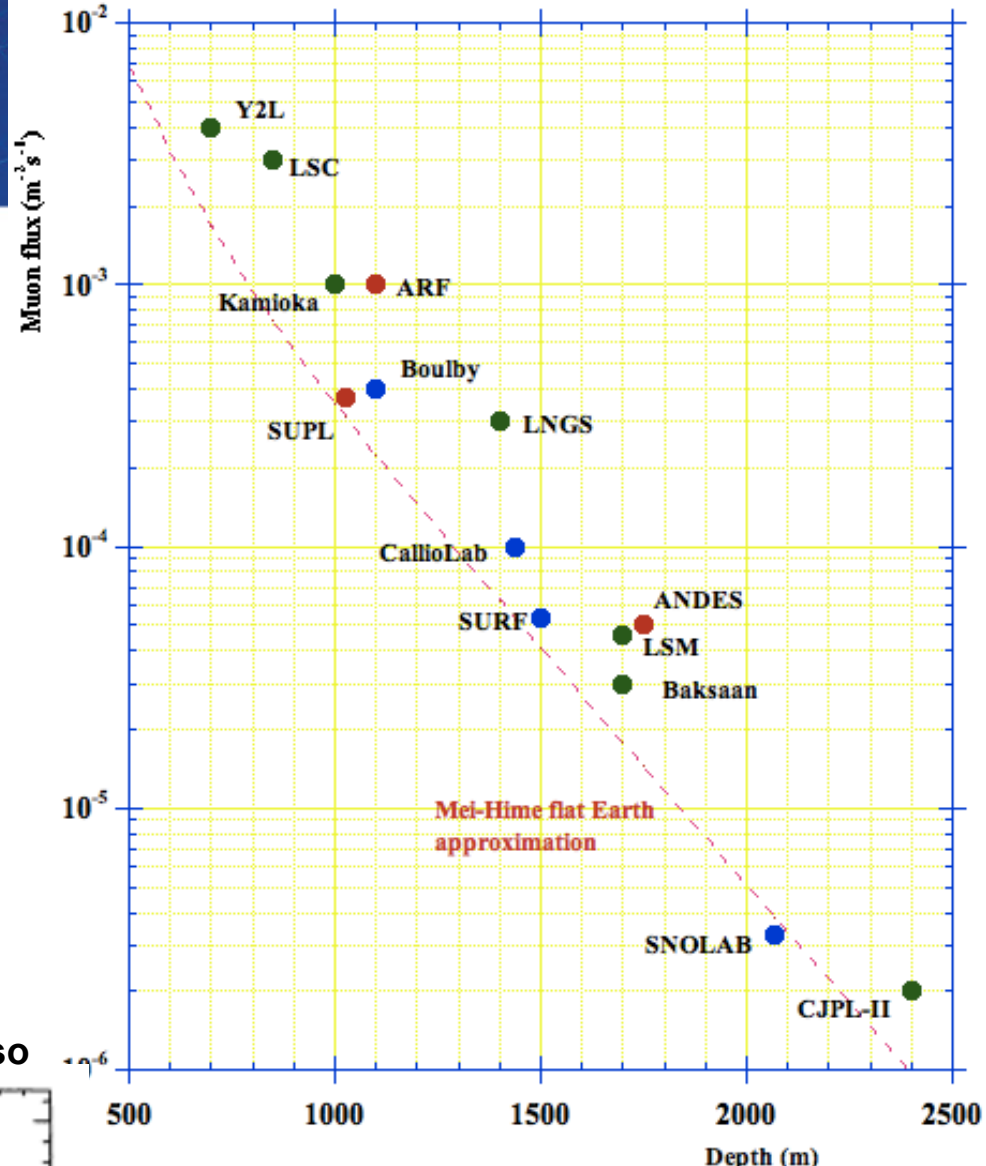
- Facilities provide:
  - Surface support and facilities
  - Scientific support and personnel: design, construction, operation/analysis
  - Ancillary science support: low background assay
  - Infrastructure support and personnel: workshops, chem labs, I.T.
  - Access (vertical or horizontal); Space (monolithic or distributed; scale)
  - Utilities: power, ventilation, heat management, water, gases/liquids
- Other characteristics
  - Location (neutrino flux from beam, reactor, Earth, access to facility)
  - Depth - limits muons, cosmogenics
  - Backgrounds - muon, spallation, local environment
  - Cleanliness and radiological interference
  - “Quality of life” for researchers: breadth of programme, access policies
- Health/Safety and security protocols
- Funding and stability: multi-year budgets, host nation support, host organisation stability and engagement

# Underground Facilities

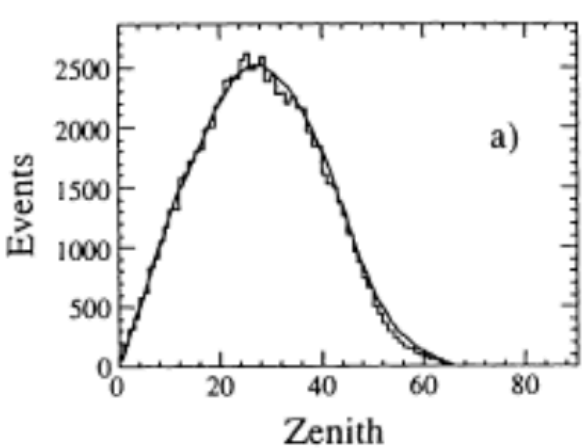


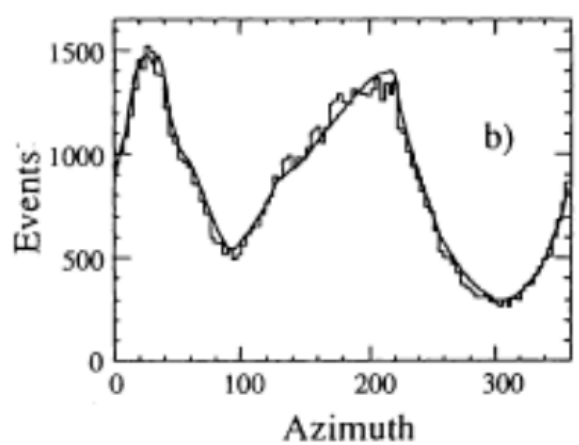
# Effect of over-burden

- Deep underground facilities provide significant rock overburden and commensurate reduction in c.r. flux, and c.r.-spallation induced products
- Muons can be veto'd in anti-coincidence shield; secondary products may be an issue
- Cosmogenics may require underground material production or purification
  - May also contribute to b/grounds (e.g. $^{11}C$)
- Muon flux depends on
  - overburden
  - overburden profile
  - seasonal effects



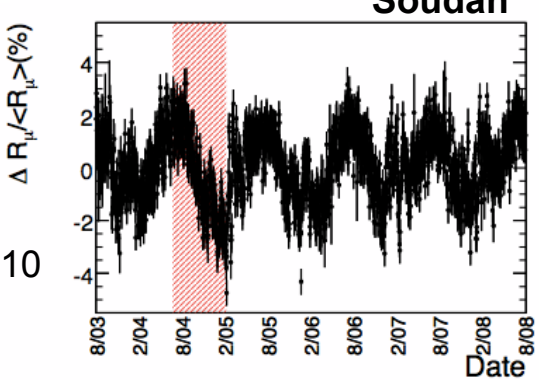

Gran Sasso




Bellotti 1990

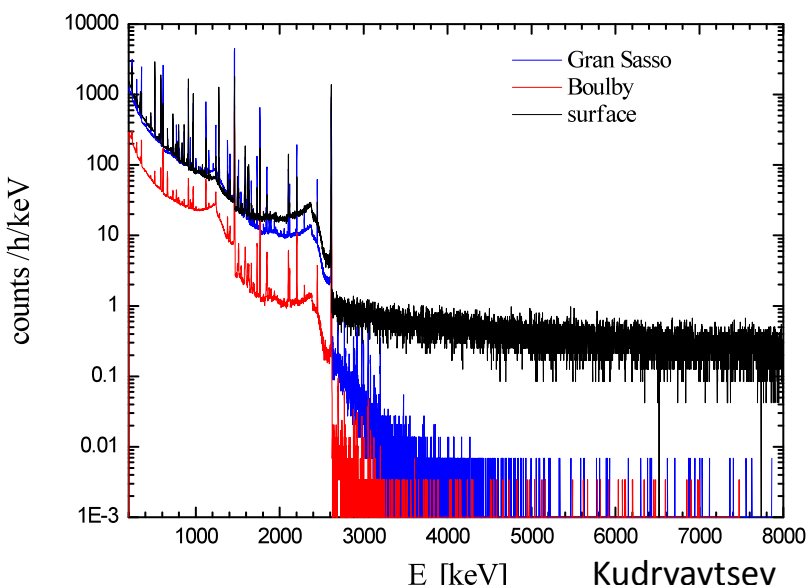
Soudan



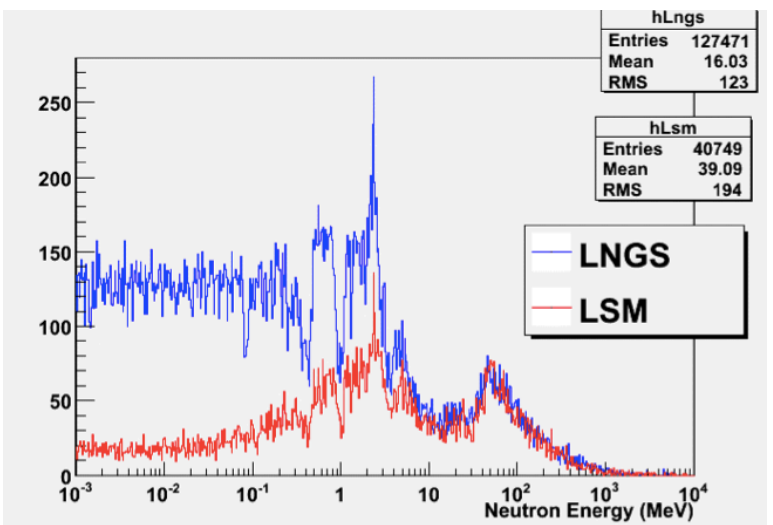

Adamson 2010

# Radiogenic Backgrounds

- Deep underground facilities provide significant rock overburden and commensurate reduction in c.r. flux, and c.r.-spallation induced products (neutrons)
- Cosmogenics may require underground material production or purification
  - May also contribute to b/grounds (e.g. $^{11}C$)




- Reduction in $\gamma$-ray background at higher energies from c.r. and neutron reduction
- Below 3.5MeV dependent on local geology and rock material




Persiani / Selvi

- Neutron production from c.r. muon spallation, U/Th fission, ($\alpha$, n) reactions, radon reactions
- Spectrum in laboratory depends on local geology (rock composition)

# Characteristics

| | SNOLab | LNGS | LSC | Boulby | LSM | Callio Lab | Baksan | SURF | CJPL-I/II | Kamioka | Y2L |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date of creation | 2003 (1991) | 1987 | 2010 | 1989 | 1982 | 1995 | 1967 | 2007 (1967) | 2009/ 2014 | 1983 | 2003 A6 2014 A5 |
| **Personnel** | 100 | 106 | 12 | 6 | 12 | 13 | 227 | 125 | 20 | 94 | 4 |
| Surface U/S [$m^2$] | 5350/ 3100 | 17000/ 95000 | 1600/ 2550 | 1700/ 400 | 400 | 220 | 1600/ 10000 | 1900/ 190 | 8000 | 15000/ 3000 | 300/ 60 |
| **Volume [$m^3$]** | 30000 | **180000** | 10000 | 7200 | 3500 | 1000* | 23000 | 7160 | 4000/ **300000** | 150000 | 5000 |
| Depth [m] | 2070 | 1400 | 850 | 1100 | 1700 | 1440 | 1700 | 1500 | 2400 | 1000 | 700 |
| **Access [V or H]** | V | H | H | V | H | V / drive in | H | H | H | H | Drive in |
| Makeup Air [$m^3/h$] | 12000 | 35000-60000 | 20000 | 300 | 5500 | 3600 | 1440 | 510000 | _ | 6000 | 3300 |
| Air change/day | 10 | 5-8 | 48 | 24 | 38 | 7 | _ | 144 (LUX) | _ | 6 | 15 |
| Muon flux [$m/m^2/s$] | $3.1\ 10^{-6}$ | $3\ 10^{-4}$ | $3\ 10^{-3}$ | $4\ 10^{-4}$ | $4.6\ 10^{-5}$ | $1\ 10^{-4}$ | $3\ 10^{-5}$ | $5.3\ 10^{-5}$ | $2\ 10^{-6}$ | $10^{-3}$ | $4\ 10^{-3}$ |
| Radon [$Bq/m^3$] | 130 | 80 | 100 | **<3** | 15 | 70 | 40 | 300 | 40 | 80 | 40 |
| **Cleanliness** | 2000 or better | Only in sector | Only in sector | 10000 | ISO9 | Only in sector | Only in sectors | 3000 | Only in sectors | Only in sectors | Only in sectors |

Ianni - TAUP2017

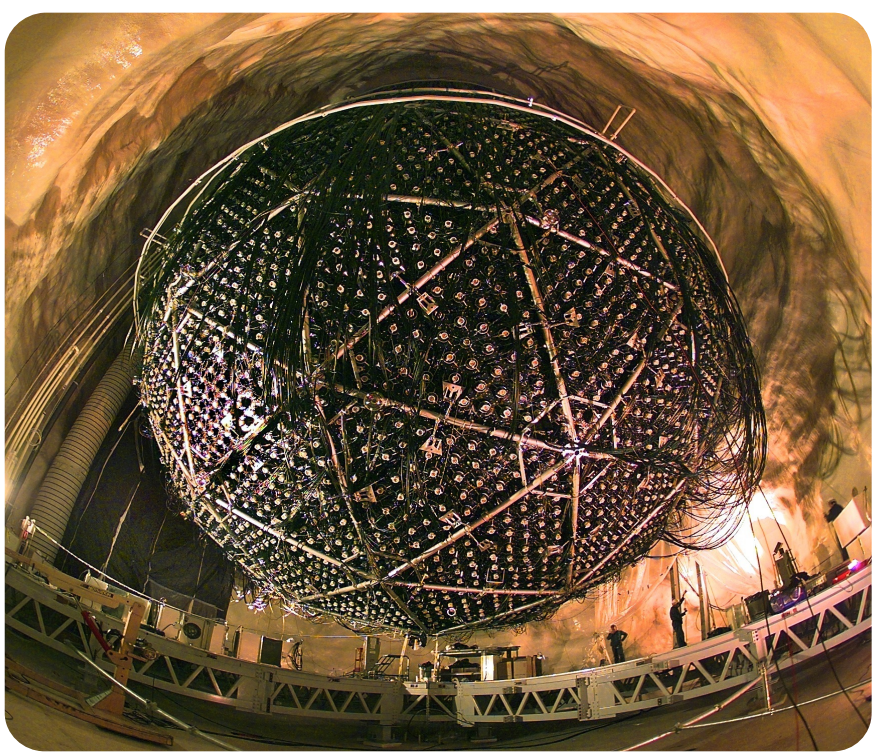
# Upcoming facilities

| | SUPL | ARF | ANDES |
|---|---|---|---|
| **Expected to be in operation** | end of 2018 | mid-end of 2019 | 2027 |
| Personnel | 3 | 20 | – |
| Access | Drive in | V / drive in | H |
| Volume [$m^3$] | 3025 | 47000 | 70000 |
| Surface [$m^2$] | 350 | 2000 | 2800 |
| Outside surface [$m^2$] | 100 | 1000 | Foreseen building |
| Depth [m] | 1025 | 1100 | 1750 |
| Muon Flux [$\mu/m^2/s$] | $3.7\ 10^{-4}$ | $\sim 10^{-3}$ | $\sim 5\ 10^{-5}$ |
| Makeup air [$m^3/h$] | From the mine through Rn purification | 7840 | - |
| Air change/day | 96 | 6 | - |
| Cleanliness requirement | Yes (SNOLab style) | Only in sectors | – |

Ianni - TAUP2017

# The SNOLAB Facility

- Hosted in the Creighton nickel mine, near Sudbury, Ontario, hosted by Vale Ltd.
- Underground campus at 6800' level, 0.27μ/m2/day
- Developed from the original SNO detector to develop Canadian facilities for international engagement
- Operational funding through CFI, MRI/MEDI (Province of Ontario)
  - Operated under 'free-at-point-of-access' model ubiquitous in nuclear and particle physics
- Managed as a joint venture between five Canadian Universities (Alberta, Carleton, Queen's, Laurentian, Montréal)

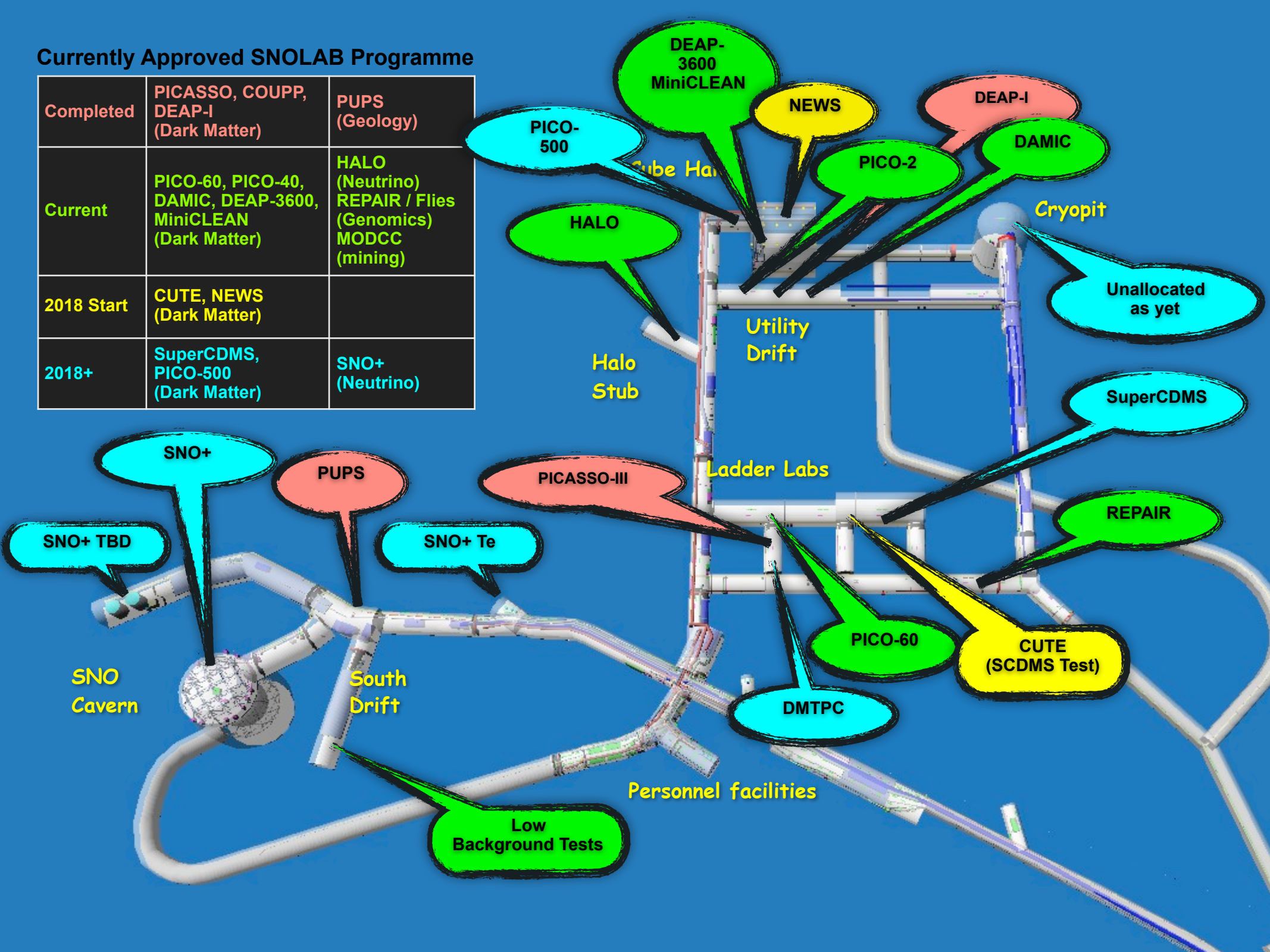


# SNOLAB Science Programme

| Experiment | Neutrino | Dark Matter | Other | Space allocated | Status |
|---|---|---|---|---|---|
| COUPP-4 | | √ | | "J"-Drift | Completed |
| CUTE | | √ | Test Facility | Ladder Labs | In Preparation |
| DAMIC | | √ | | "J"-Drift | Operational |
| DEAP-1 | | √ | | "J"-Drift | Completed |
| DEAP-3600 | | √ | | Cube Hall | Operational |
| DEAP-50T/CLEAN | | √ | | Cube Hall | Letter of Intent |
| DMTPC | | √ | | Ladder Labs | Concept Phase |
| DUST | | | Test Facility | Ladder Labs | Letter of Intent |
| FLAME | | | Genomics | External Drifts | Operational |
| Ge-1T | √ | | | Cryopit | Letter of Intent |
| nEXO | √ | | | Cryopit | Concept Phase |
| nEXO Shield | √ | | | Cryopit | Concept Phase |
| HALO | √ | | | Halo Stub | Operational |
| MiniCLEAN | | √ | | Cube Hall | Commissioning |
| MODCC | | | Mining Data Centre | Surface Facility | Operational |
| NEWS | | √ | | Cube Hall | In Preparation |
| PICASSO-III | | √ | | Ladders Labs | Completed |
| PICO-2L | | √ | | "J"-Drift | Operational |
| PICO-60 | | √ | | Ladder Labs | Operational |
| PICO-500 | | √ | | Ladder Labs | Letter of Intent |
| PUPS | | | Seismicity | Various | Completed |
| REPAIR | | | Genomics | Chem Labs | Operational |
| SuperCDMS | | √ | | Ladder Labs | In Preparation |
| SNO+ | √ | | | SNO Cavern | Commissioning |

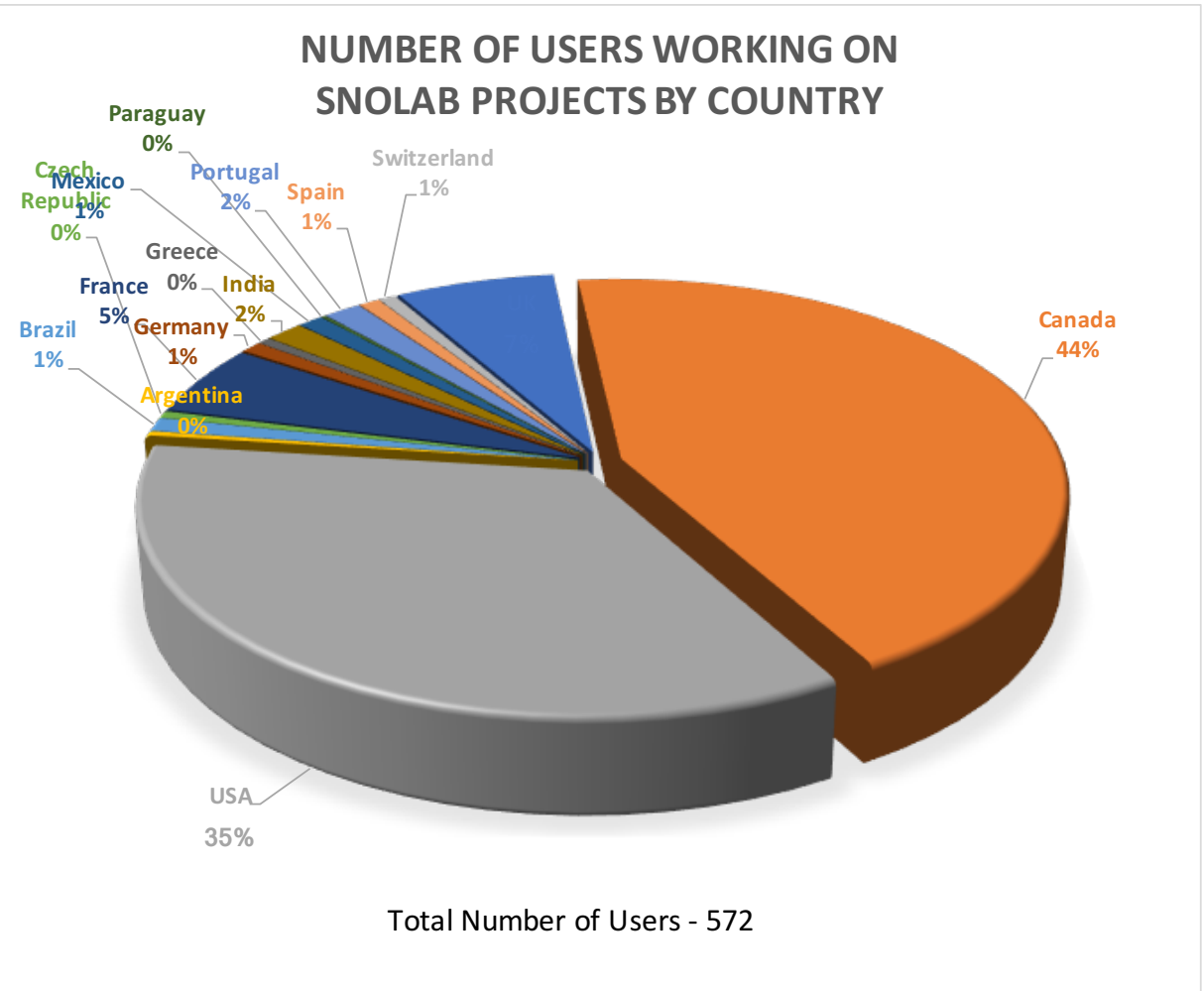
## Currently Approved SNOLAB Programme

| | | |
|---|---|---|
| Completed | PICASSO, COUPP, DEAP-I (Dark Matter) | PUPS (Geology) |
| Current | PICO-60, PICO-40, DAMIC, DEAP-3600, MiniCLEAN (Dark Matter) | HALO (Neutrino) REPAIR / Flies (Genomics) MODCC (mining) |
| 2018 Start | CUTE, NEWS (Dark Matter) | |
| 2018+ | SuperCDMS, PICO-500 (Dark Matter) | SNO+ (Neutrino) |



# Global connections

| Country | N_Institutes | Total | Academics |
|---|---|---|---|
| Canada | 17 | 249 | 54 |
| USA | 37 | 201 | 74 |
| Argentina | 1 | 2 | 1 |
| Brazil | 1 | 6 | 1 |
| Czech Republic | 1 | 3 | 1 |
| France | 7 | 31 | 8 |
| Germany | 3 | 5 | 3 |
| Greece | 1 | 3 | 2 |
| India | 2 | 9 | 5 |
| Mexico | 2 | 6 | 3 |
| Paraguay | 1 | 1 | 1 |
| Portugal | 1 | 9 | 4 |
| Spain | 3 | 5 | 3 |
| Switzerland | 1 | 4 | 1 |
| UK | 11 | 38 | 18 |
| TOTAL | 89 | 572 | 179 |



# Lab Co-ordination efforts

- Co-ordination efforts between deep underground facilities are strengthening
  - LNGS/SNOLAB initiated G7 GRO GRI proposal
    - https://www.bmbf.de/files/151109_G7_Broschere.pdf
  - DULIA: attempt for EU coordination (funding) between LNGS, LSC, Boulby, LSM, CallioLab
  - Coordination and links on outreach and comms
    - LNGS/LSC deploying muon counters available to public
  - Sharing of best practice
    - Developing in operational matters, EH&S, expt. management, expt. reviews, governance
    - low background counting/assay (LRT series), shared databases
  - Sharing of work loads
    - 'blitzes' on low background counting
  - Can this extend to science projects?
    - e.g. Cygnus distributed array of detectors for DM
- IUPAP WG9 Neutrino Panel and inclusion of $0\nu\beta\beta$
  - Forms a major part of the drivers for deep underground facilities as **infrastructure** for the delivery of this science field
  - Connecting to ApPIC working group

# Global Argon Collaboration

- An example of the deep underground laboratories coordinating together to support a major community global initiative
  - LNGS, LSC, SNOLAB supporting assay programme
  - Coordinated approach for UAr extraction, assay and storage
  - Coordinating with collaboration on engaging funding agencies

**Deep underground laboratory support for global collaboration towards discovery of dark matter utilising liquid argon detectors.**

To whom it may concern;

As hosts of the existing operational liquid argon direct dark matter detectors, and as proponents and supporters of the Underground-GRI initiative, the LNGS, SNOLAB and LSC deep underground research facilities are pleased to recognize the collaborative developments within the global liquid argon dark matter community. The DarkSide project at LNGS, the DEAP project at SNOLAB and the ArDM project at LSC are all developing new technologies and capabilities to search for WIMP dark matter, and are beginning to coalesce into one collaboration to develop future, larger generations of liquid argon direct dark matter detectors. We encourage and support the development of this global community, with a focus on the development of DarkSide-20k at LNGS in the first instance, and a larger detector at a location to be determined from scientific requirements, in the future. Using available assay and research infrastructure, the three deep underground research facilities will support the activities and development of the various generations of liquid argon detectors.

Stefano Ragazzi
Director, LNGS

Aldo Ianni
Director, LSC

Nigel J.T. Smith
Director, SNOLAB

# Summary

- Deep underground research facilities provide the ultra-quiet radioactive background environments for rare or low energy interactions studies
- Coordination between the deep underground facilities is growing, with dialogue about areas where we can improve support to the community
  - Low background assay and material production
  - Dissemination of best practice in technical support
  - Dissemination of best practice in management support
  - Coordination of work loads
  - Strategic engagement with community groups
  - Strategic engagement with funding and support groups