IUPAP Report 41a

A Report on Deep Underground Research Facilities Worldwide

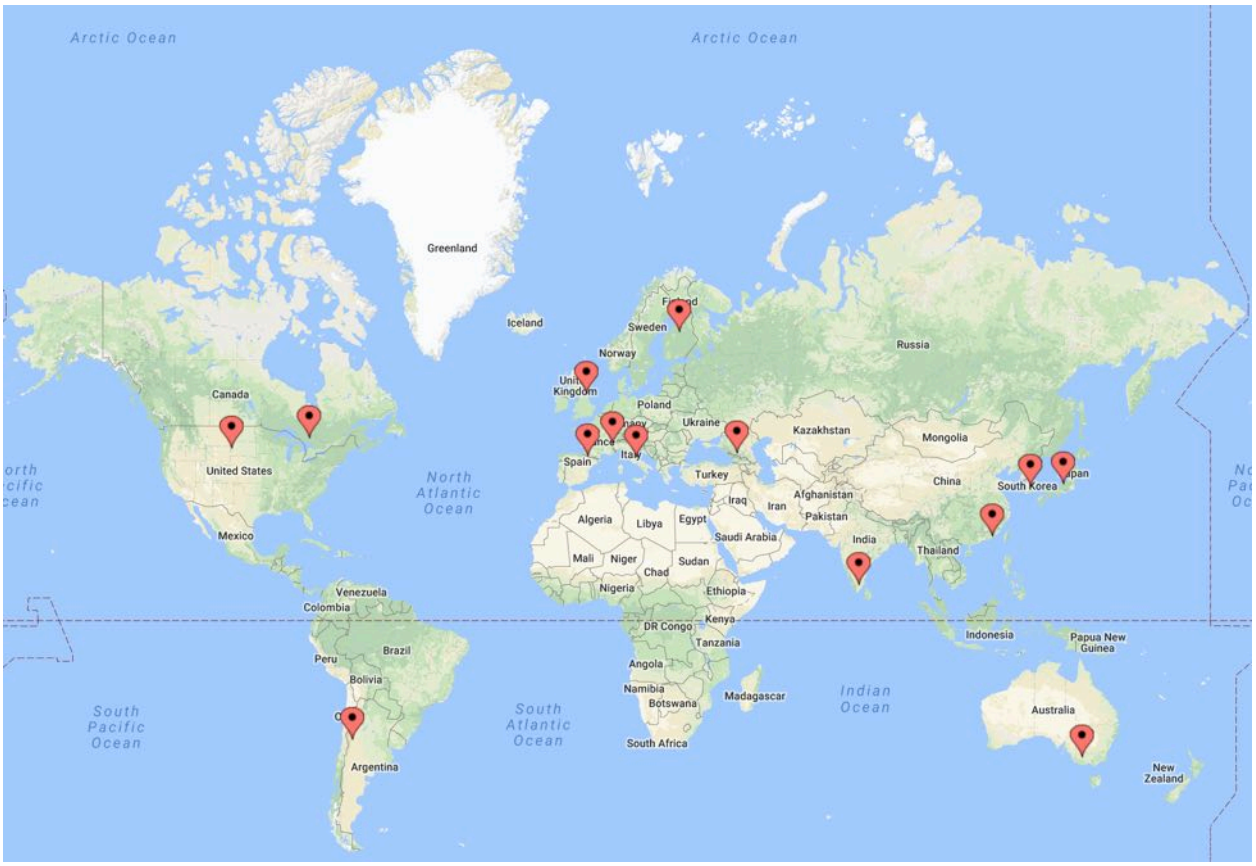
(updated version of August 8, 2018)

Table of Contents

LABORATORY ENTRIES BY GEOGRAPHICAL REGION

Deep Underground Laboratories and their associated infrastructures are indicated on the following map. These laboratories offer low background radiation for sensitive detection systems with an external users group for research in nuclear physics, astroparticle physics, and dark matter.

The individual entries on the Deep Underground Laboratories are primarily the responses obtained through a questionnaire that was circulated. In a few cases, entries were taken from the public information supplied on the lab's website. The information was provided on a voluntary basis and not all laboratories included in this list have completed construction, as a result, there are some unavoidable gaps.



SNOLAB
1039 Regional Road 24, Creighton Mine #9, Lively ON Canada P3Y 1N2

Telephone: 705-692-7000
Facsimile: 705-692-7001
Email: info@snolab.ca

Website: www.snolab.ca

Oversight and governance of the SNOLAB facility and the operational management is through the SNOLAB Institute Board of Directors, whose member institutions are Carleton University, Laurentian University, Queen's University, University of Alberta and the Université de Montréal.

Construction: 2007
Operation: 2011 to present

Head of the Facility:
Prof. Nigel Smith, Executive Director, SNOLAB

Scientific Mission and Research Programs:
SNOLAB has established a bold vision: to be an internationally recognized laboratory and partner of choice for deep underground science, delivering world-class research, scientific discovery and benefits to Canada and her global partners, by facilitating national and international access to its unique capabilities, facilities and expertise**.**

This vision is anchored on the following four key strategic goals that underpinned SNOLAB's inaugural strategic plan, and will guide the next five years of SNOLAB's evolution:
- Enable and spearhead world-class underground science
- Develop and maintain world-class facilities and infrastructure
- Educate, inspire and innovate
- Develop quality delivery systems of internationally recognized standard

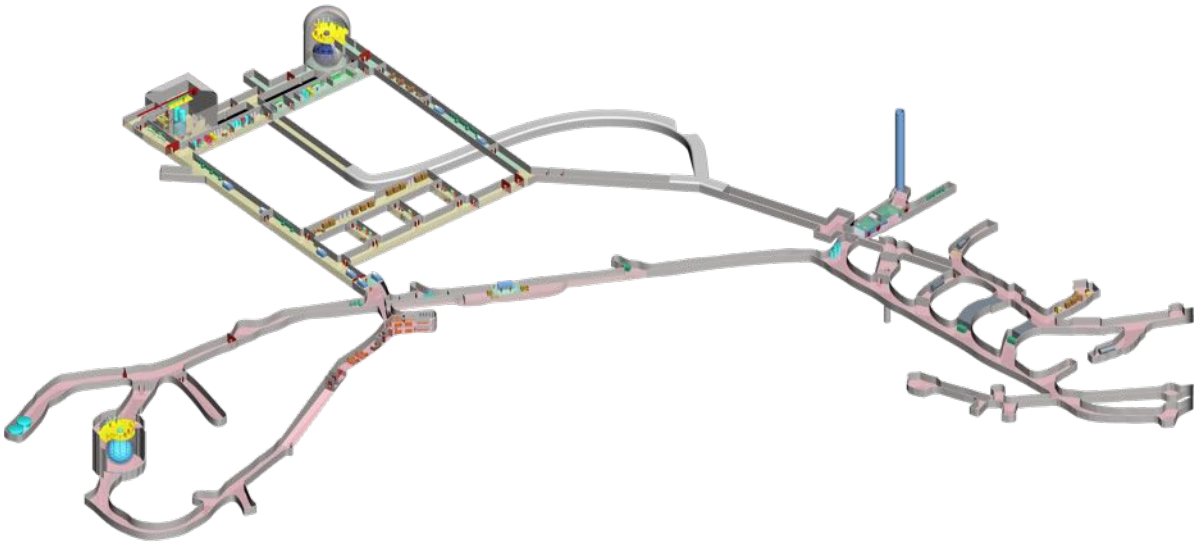
The SNOLAB science programme has expanded significantly over the last five years. Although approximately 95% of SNOLAB's scientific programme is dedicated to the conduct of sub-atomic and particle astrophysics experiments, it also facilitates research and discovery in other

scientific fields such as biology, geo-physics and mining innovation. Overall, the SNOLAB programme now encompasses subatomic and nuclear physics, astrophysics, genomics and mining innovation. Specifically, SNOLAB now has dark matter, neutrinoless double-beta decay, supernova neutrino, low dose radiation, genomics, and mining engineering experiments within its underground laboratory.

Key areas of focus include:
Astro-particle and Particle Physics – Dark Matter Studies;
Astro-particle and Particle Physics – Neutrino Studies;
Mining data analytics – MODCC;
Biology, Engineering and Geology; and
Centre of Excellence for Low Background Studies

Technical Facilities:
The SNOLAB underground laboratory is an expansion of the original SNO facility consisting of a large cavern housing the detector and ancillary spaces in mining tunnels (drifts) for the experiment and personnel infrastructure. The main level of the laboratory is located at the 6800 ft level of the mine with 2070 m of granite rock overburden.

The SNOLAB expansion added an additional 6,300 m^2 of excavations of which 3,700 m^2 is clean room space attached to the existing facility. The clean/dirty boundary was moved for the expanded laboratory and some existing excavations were converted to additional clean space. The SNOLAB underground laboratory has 5,000 m^2 of clean space. Of this, 3,100 $m^2$is experimental laboratory space. There is an additional 2,600 m^2 of excavation outside the clean room used by SNOLAB for the service infrastructure and material transportation and storage.



The SNOLAB underground facilities are located at the 6800 foot level of the Vale Creighton Mine and include the original SNO cavern.

The surface building provides clean room space, change facilities, meeting rooms and office space for the underground experiments.

Facility Parameters:
Depth: 2070m
Access: V
Muon Flux ($m/m^2/s$): 3.1×10^{-6}
Radon: 130 Bq/m3
Cleanliness: 2000 or better
Staff: 103

The underground facility is located at a depth of 2070m and comprises 5000m^2 of clean room facility, at better than Class2000, including three large detector cavities. In addition to the required health and safety systems and user support services, support infrastructure for experiments within the underground laboratory include HVAC, electrical power, ultra-pure water, compressed air, radiological source control, radioassay capability, chemistry lab, I.T. and networking, and materials handling and transportation.

The very specific requirements of developing and operating experiments in an underground laboratory are supported by SNOLAB staff covering business processes, engineering design, construction, installation, technical support and operations.

The SNOLAB scientific research group connects to the experiments and provides expert and local support, as well as undertaking research in its own right as full members of the research collaborations.

The facility includes a surface building which houses offices, conference rooms, IT systems, clean-rooms, electronics labs, warehousing and change rooms.

Program Advisory Committee/experiment proposals:
All experiment LOI's are submitted to SNOLAB to be reviewed by the Experiment Advisory Committee at biannual meetings.

Number of active users and their origin:
Note: Active Users defined as the number of on-site, remote and data users

Argentina – 3
Brazil – 1
Canada – 99
Czech Republic – 3
France – 53
Germany – 22
Greece – 13
India – 73
Mexico – 8
Paraguay – 3
Portugal – 8
Spain – 113
Switzerland – 4
UK – 56
USA – 155
TOTAL – 614

Percentage of users, and percentage of facility use that come from inside the institution:
All users of the SNOLAB facility are external.

Percentage of users and percentage of facility use from national users:
16% of SNOLAB users are Canadian.

Percentage of users and percentage of facility use form outside the country where your facility is located:
84% of the users are from outside of Canada

Fraction of the international users outside of geographical region:
41% of the SNOLAB users are from outside North America.

Number of theoretical staff employed at the facility: permanent, postdoctoral, students: 0
There are no theoreticians employed at the facility.

Number of non-resident graduate students with thesis work primarily done at the facility: 37
Note: Graduate student defined as 'Masters' level

Involvement of undergraduate students in research (approximate average number at a given time):
55 (as of June 2018)

Special student programs:
High School: SNOLAB hosts 3 summer schools targeted at High School students
Undergraduate: In conjunction with the McDonald Institute, SNOLAB hosts an undergraduate summer school as well as hosting multiple co-op term students.
Graduate: SNOLAB is part of TRISEP and hosts the graduate level summer school every 3 years.
Teachers: Teacher Workshop (20 spots), CAP teacher award host (1 spot/year)
Journal Club: Weekly presentations on new and interesting science.

Future Plans:
Facility upgrades:

- Additional cavities
- LN_2 plant and distribution system (complete August 2018)
- Surface Diesel Generator Plant
- Additional Office space underground
- Chemistry Lab (complete August 2018)
- Low Background Laboratory and Assay Capabilities
- Upgrade to offsite communications' lines

Additional Projects:

- 7 new projects have reached Gateway 0 in the SNOLAB Life Cycle.

Short Descriptions of Pertinent Existing Experiments *(focus on nuclear physics, mainly neutrinos)***:**

Experiment	Focus
SNO+	A tonne-scale double beta decay detector making use of the existing SNO detector and loading liquid scintillator with tellurium. The collaboration extends across 23 institutions.
Super CDMS SNOLAB	A second-generation dark matter detector using cryogenic germanium and silicon crystals supported by 135 researchers from 26 institutions.
HALO	An experiment to detect neutrinos from supernovae that is part of the global network SNEWS using 79 tonnes of lead and 128 tubular He-3 detectors.
DEAP-3600	A second-generation dark matter experiment and collaborative effort with 65 researchers from 10 institutions in Canada, the United Kingdom and Mexico using 3.6 tonnes of liquid argon.
MiniCLEAN	An alternative technology detector with researchers from 7 US institutions using 500kg of liquid argon.
PICO	A second-generation detector using super-heated fluids to search for dark matter across 17 institutions worldwide.

DAMIC	A dark matter experiment using charged couple devices with a worldwide collaboration of scientists.
NEWS-G	A Canada-France collaborative effort in dark matter detection in the low mass range using high pressure gases.
FLAME (Flies in a MinE)	A genetics experiment that takes advantage of the increased pressure to study the impacts of working deep underground using fruit flies as a model organism.
REPAIR	A Canadian bioinformatics experiment that explores cellular mutations in low radiation environments.
CUTE (Cryogenic Underground Test Facility)	A Cryogenic Underground Test Facility (CUTE) to be installed at SNOLAB with the goal to do performance tests, calibrations and background measurements.
Low Background Counting	SNOLAB is developing a low background centre of excellence, which will incorporate the local expertise and capitalises on the low background HPGe detectors currently at SNOLAB while adding additional hardware to this suite.
MODCC (Mining Operations Data Control Centre)	This co-located centre will capitalize on existing data integration and sharing expertise at SNOLAB as well as the significant investments already made in its deep underground facility to look at large date collection, integration and storage.

SANFORD UNDERGROUND RESEARCH FACILIATY (UNITED STATES)

Sanford Underground Research Facility (SURF)
630 East Summit St, Lead, SD 57754

Telephone: (605) 722-8650
Facsimile: (605) 722-4501

Email:
Executive/Laboratory Director: mheadley@sanfordlab.org
Education & Outreach Director: June.Apaza@bhsu.edu
Communications Director: cwalter@sanfordlab.org
Science Director: jaret@sanfordlab.org

Website: http://sanfordlab.org/

Operated and managed by the South Dakota Science & Technology Authority (SDSTA)

Operation since 2007
(also Ray Davis Chlorine Solar Neutrino Experiment legacy dating to the mid-1960s)

Head of the Facility:
Mike Headley, Executive and Laboratory Director

Scientific Mission and Research Programs:
Mission: To advance compelling underground, multidisciplinary research in a safe work environment and to inspire and educate through science, technology, and engineering.
Research Programs: Physics, Geology, Biology, Engineering; currently 23 groups considered active

Technical Facilities:

- Surface Laboratory: 2 cleanrooms, low-Rn (metal construction) cleanroom and commercial (Ateko) Rn-reduction system (~300 m^3/hr)
- 4850L Davis Campus:
    - Key Design Requirements
        - Environmental Conditioning: 21C, 50% RH
            - Working in clean room garb resulted lowering the temperature, leading to higher relative humidity and HV breakdown, corrosion concerns – this illustrates the importance of challenging requirements.
        - Chilling System: Air cooled chilled water system (closed loop)
        - Cleanliness:
            - AHU-1/Davis Cavern Cleanroom: Nominal Class 1000 (5,250 cfm, ~150 air changes per hour); removed during 2018 renovation for LZ

            - AHU-2/Davis Cavern + Common Spaces: Nominal Class 10,000 (8,590 cfm, ~6 air changes per hour)
            - AHU-3/MJD: Nominal Class 2000 (7,250 cfm, ~18 air changes per hour)
        - Power: 1500 kVA, backup for life safety, incl communications, AHUs, exhaust fans, egress lighting
    - Ground Support
        - 1" dia. x 10' long resin-grouted threaded rebar
        - Standard- and low-activity aggregate shotcrete (7.5 cm thick)
    - Monitoring
        - Single- and multi-point extensometers for ground movement
        - Life safety: smoke/heat/low O2, also CO
        - Radon, particle counts
    - Special Considerations
        - Shielding: 6-m high x 8-m diameter water shielding tank (72,000 gallons), iron plates below
        - Water purification system (commercial RO/ultra-filtration)
        - Material transport from shaft station to lab (air bearings), via decline/stairs (electric dolly)
- 4850L Ross Campus
    - Key Design Requirements
        - Environmental Conditioning: 20–25C, 20–50% RH
        - Chilling System: water heat rejection (~40 gpm, not closed loop)
        - Cleanliness:
            - BHUC Counting Cleanroom: Nominal Class 1000 (2,400 cfm, ~30 air changes per hour)
            - BHUC Multi-Use Cleanroom: Nominal Class 10,000 (600 cfm, ~23 air changes per hour)
            - CASPAR: No cleanliness class (1000 cfm, ~1.3 air changes per hour)
        - Power: 300 kVA (CASPAR+BHUC), E-Forming = 75 kVA, emergency = egress lighting (no generator for AHUs, etc)
    - Ground Support
        - 6' - 8' long resin-grouted threaded rebar, 12' long cement-grouted cable bolts
        - Standard-activity aggregate shotcrete
    - Monitoring
        - Life safety: smoke/heat/low O2, also CO
        - Radon, particle counts
        - Radiation (gamma, neutron)
    - Special Considerations
        - Reduce radon emanation from rock walls using special coatings, macropoxy/TSL's
        - Radiation shielding from CASPAR accelerator (doors, utility mazes)

Facility Parameters:
Depth: Of the 29 underground elevations that are currently accessible, six have been identified as key levels for science activities (average level station depths indicated): 300L (130 m), 800L (273 m), 1700L (551 m), 2000L (649 m), 4100L (1283 m), 4850L (1511 m). On the 4850L, different rock overburdens exist for various laboratories, which average to 1490 m corresponding to an average of 4300 m.w.e.

Facility Area/Volume:
- Total property: 223 acres (surface), 7700 acres (underground)
- Total surface structures: 26088 m^2
- Surface Laboratory: 210 m^2 [Science]; 265 m^2 [Total]
- 4850L Davis Campus: 1015 m^2 / 4627 m^3 [Science]; 3017 m^2 / 11354 m^3 [Total space]
- 4850L Ross Campus: 1148 m^2 / 2644 m^3 [Science]; 3510 m^2 / 6849 m^3 [Total space]
- LBNF (Future): 9869 m^2 / 194365 m^3 [Science]

Muon Flux: 4850L Davis Campus: $(5.31 \pm 0.17) \times 10^{-5}$ muons/m^2/s [MJD (Abgrall *et al.*), Astro. Phys. **93** 70-75 (2017)]

Radon Level:
- *Surface: ~15 Bq/m^3*
- *Underground (occasional excursions due to changing ventilation route, fan maintenance, etc.):*
    - *4850L Davis Campus (average ~2000 days): ~300 Bq/m^3*
    - *4850L Ross Campus (average ~2000 days): ~500 Bq/m^3*

Cleanliness Level: Facility air handling, cleaning support + modest protocols achieve Class ~3000 in common laboratory areas; Class ~100 supported in specific facilities with additional effort and protocols

Access Type: Vertical (300L also affords horizontal access), two shafts for redundant access (Yates and Ross), also two shafts for ventilation

***Number of Staff*:** 120 full-time (majority support facility maintenance, 24-hr shaft operations)
- Science Dept = 4 people, incl 1 cleanroom custodian and 3 staff scientists
- Engineering Dept = 11 people, many supported by specific experiments
- Environment, Safety & Health Dept = 10 people, incl training, industrial hygiene, radiation/experiment safety

Program Advisory Committee/experiment proposals: Various Scientific Program Advisory Committees (SPACs) have been in place to evaluate previous DUSEL and Sanford Lab projects. A new SPAC is being constituted to meet current needs.

Number of active users and their origin:
- 81 institutions collaborating on active projects at SURF, of which 65 are national (US), 8 regional (South Dakota), 16 international (13 Europe, 2 Asia, 1 non-US North America)

- 503 members of active collaborations at SURF, of which 416 based in North America, 415 national (US), 85 regional (South Dakota), 88 international (83 Europe, 4 Asia, 1 non-US North America) [these data are used for subsequent demographic calculations]
- Since 2017, a total of 437 individuals have been onsite at SURF in support of experiments (including contractors engaged by LZ and LBNF). Of that number, an estimated 185 researchers are considered regular/active users.

Percentage of users, and percentage of facility use that come from inside the institution: 7+4=11 (SDSTA) / 503 (total) = 2.2%

Percentage of users and percentage of facility use from national users: 415 (US) / 503 (total = 82.5%

Percentage of users and percentage of facility use from outside the country where your facility is located: 1+83+4=88 (non-US) / 503 (total) = 17.5%

Fraction of the ~~international~~ users outside of geographical region: 503-85=418 (non-SD) / 503 (total) = 83.1%

Number of theoretical staff employed at the facility: permanent, postdoctoral, students: 0

Number of non-resident graduate students with thesis work primarily done at the facility: 98-1 (SD) = 97

Involvement of undergraduate students in research (approximate average number at a given time): 28 maximum

Special student programs:
- Davis-Bahcall scholar program since 2008, generally accepting 8 scholars per year http://www.doe.sd.gov/scholarships/DAVIS-BAHCALL.aspx
- Dave Bozied & Chris Bauer summer internship program since 2009, accepting 4-6 students http://www.sanfordlab.org/careers/dave-bozied-and-chris-bauer-internships
- Related programs: BHSU REU http://www.bhsu.edu/research/reu, BHSU QuarkNet http://www.bhsu.edu/Academics/Natural-Sciences/Physics/QuarkNet/About both with research conducted at SURF

Year	Davis-Bahcall Scholarship	Intern Program		
		Dave Bozied	Chris Bauer	Other
2008	2	-	-	
2009	27	7	-	
2010	20	5	-	
2011	10	4	-	
2012	10	4	-	1
2013	9	3	2	
2014	10	4	2	
2015	9	3	2	

2016	8	4	2	
2017	8	4	2	
2018	8	*2-3 (expected)*	*2 (expected)*	

Future Plans:

- SURF is exploring options for an additional experiment hall on the 4850L and engaging with the DOE regarding the possibility. Conceptual designs exist for a number of candidate sites.
- The LZ detector will employ approximately 10 tonnes of liquid xenon (~50x LUX fiducial) with a projected sensitivity 100x better than the final LUX result. The entire xenon inventory is on contract, and the majority has been delivered to SLAC for purification. Necessary SURF surface infrastructure upgrades have been completed and underground modifications are underway (including the installation of an additional radon-mitigation system), with completion projected by mid-2018. Detector assembly at the Surface Laboratory is expected to begin in 2018, with underground installation anticipated in 2019 followed by operation in 2020. The nominal data run is 5 years.
- The Long Baseline Neutrino Facility (LBNF)/Deep Underground Neutrino Experiment (DUNE) is the first internationally conceived, constructed, and operated mega-science project hosted by the Department of Energy in the United States. Led by Fermilab, LBNF will provide facilities at two locations: accelerator facilities at Fermilab to create the neutrino beam as well as facilities at SURF to support the DUNE detectors that will investigate neutrino properties (oscillations, CP violation, mass hierarchy), nucleon decay and supernovae using a total of 70 ktonnes (40 kT fiducial) liquid argon on the 4850L. Geotechnical studies on the 4850L were completed in the spring of 2014, and an initial test-blast program was completed in the spring of 2016. A groundbreaking ceremony for LBNF was held in July 2017, and underground construction will begin mid 2018 with the main excavation to commence in 2019 and last roughly three years. The current design for the underground laboratory envisions four detector chambers, each 20 m wide x 29 m tall x 70 m long and able to accommodate a 10-kT liquid argon detector.
- There is interest from several other groups, including physics, biology and engineering.

Short Descriptions of Pertinent Existing Experiments *(focus on nuclear physics, mainly neutrinos)*:

- The Majorana collaboration is investigating neutrinoless double-beta decay at the 4850L Davis Campus using the MAJORANA DEMONSTRATOR (MJD) detector, which consists of 44 kg of germanium detectors (approximately 30 kg enriched in ^{76}Ge) within two ultrapure copper cryostats protected by a 66-tonne shield comprised of layers of copper, lead and HDPE with an active muon veto. The Majorana group is currently in production operation and plans to continue operations through 2020. Some research and development for the next-generation germanium-based ton-scale LEGEND project may be possible at SURF. The MAJORANA DEMONSTRATOR electroforming facility that operated at the Ross Campus since 2011 was decommissioned in 2017.
- The Compact Accelerator System for Performing Astrophysical Research (CASPAR) collaboration is using a 1-MV Van de Graaff accelerator to study reactions at stellar energies associated with the slow neutron-capture nucleosynthesis process (s-process). The accelerator was relocated from the University of Notre Dame in the summer of 2015

to an underground laboratory at the 4850L Ross Campus. The beamline has been assembled and commissioned, with first beam in May 2017. The group expects to begin taking physics data beginning in February 2018.

Agua Negra Deep Experiment Site (ANDES)

Email: info@andeslab.org
Website: http://andeslab.org/main.php?lang=uk

Head of the Facility:
Dr. Xavier Bertou, Coordinator, ANDES

Scientific Mission and Research Programs:
Operate a first class deep and large underground laboratory in the southern hemisphere. Research will be focused on Beyond the Standard Model physics (Dark Matter and Neutrino), Geoscience, Bioscience, and Multidisciplinary low radiation research.

Technical Facilities:
ANDES (Agua Negra Deep Experiment Site), is still at the proposal stage. It is scheduled to open in 2027. Construction of the tunnel that would host it will start in 2019, and lab construction should start in 2022.

Facility Parameters *(i.e. Depth (m), Facility area/volume (m^2/m^3), Muon flux (/m^2/s), Radon level (Bq/m^3), Cleanliness level, Access type (H or V), Number of staff)*:
Depth: 1750m
Area/Volume: 4000 m2/70000m3
Access type: Horizontal

Program Advisory Committee/experiment proposals:
No data

Number of active users and their origin:
No data

Percentage of users, and percentage of facility use that come from inside the institution:
No data

Percentage of users and percentage of facility use from national users:
No data

Percentage of users and percentage of facility use form outside the country where your facility is located:
No data

Fraction of the international users outside of geographical region:
No data

Number of theoretical staff employed at the facility permanent, postdoctoral, students:
No data

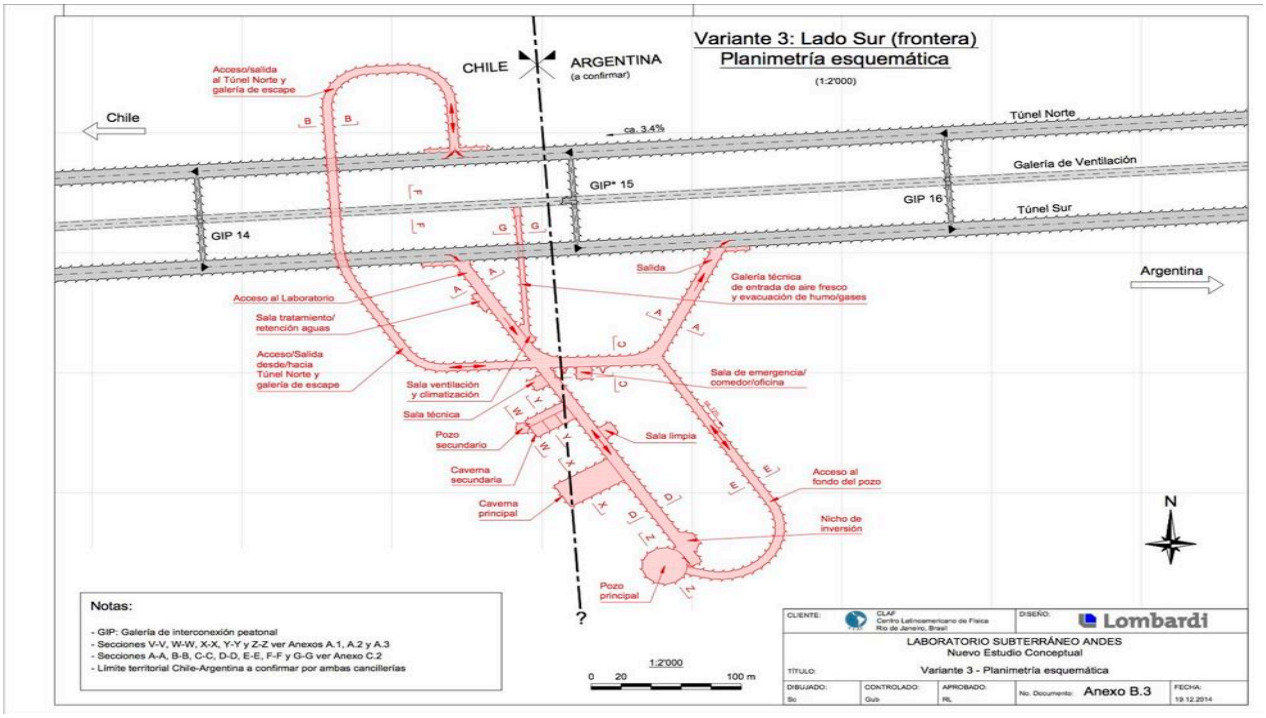
Number of non-resident graduate students with thesis work primarily done at the facility:
No data

Involvement of undergraduate students in research (approximate average number at a given time):
No data

Special student programs:
No data

Future Plans:
No data

Short Descriptions of Pertinent Existing Experiments *(focus on nuclear physics, mainly neutrinos)***:**
No data



A new conceptual design for the ANDES laboratory as part of Agua Negra was requested to Lombardi, the company in charge of the civil work design of the Agua Negra tunnel, at the end of 2014.

BOULBY UNDERGROUND LABORATORY(UNITED KINGDOM)

Boulby Underground Laboratory
Boulby Mine, Saltburn-by-the-sea, Cleveland & Redcar. England. TS13 4UZ

Telephone: +44 (0)1287 646300
Email: Sean.Paling@stfc.ac.uk
Email: Boulby@stfc.ac.uk
Website: https://www.boulby.stfc.ac.uk/Pages/home.aspx

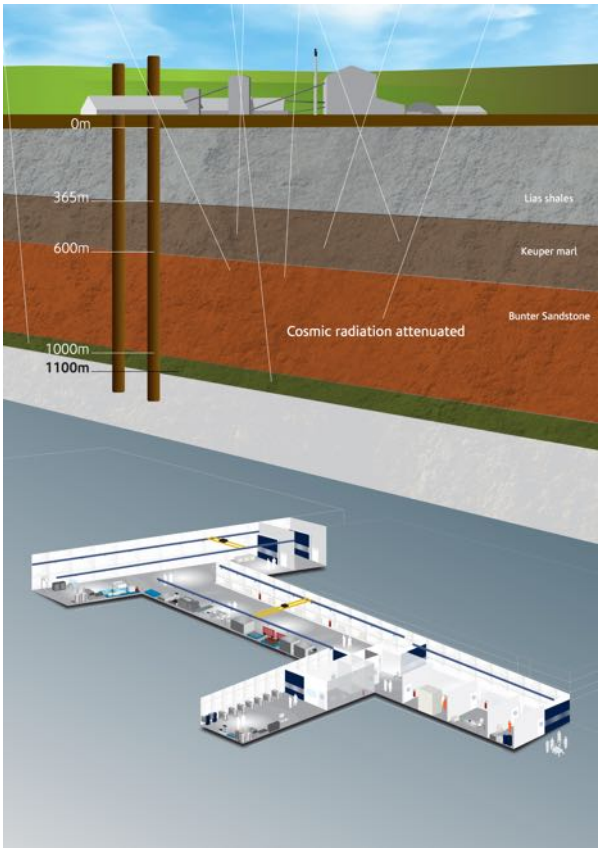
Head of the Facility:
Prof. Sean Paling

Scientific Mission and Research Programs:
Multi-disciplinary Deep Underground science: Dark Matter searches, Ultralow background material screening, studies of geology, geophysics, climate and the environment, astrobiology and life in extreme environments, planetary exploration technology development.

Technical Facilities (Surface Facilities)
We have a 1000m2 surface support facility with:

- Conference room
- Admin facilities
- Changing rooms
- Chemistry Lab
- Machine Shop
- Storage and staging space

Also we operate the BUGS+ Germanium facility Underground with 7 ultra low background Germanium detectors dedicated to material screening.



Facility Parameters *(i.e. Depth (m), Facility area/volume (m^2/m^3), Muon flux (/m^2/s), Radon level (Bq/m^3), Cleanliness level, Access type (H or V), Number of staff)***:**

Depth: 1.1km, 2805 mwe
Facility Area / Volume: 800m2/4000m3
Muon Flux: $3.75 \pm 0.09 \times 10^{-8}$ $cm^{-2}. s^{-1}$

Radon: ~3Bq/m3
Cleanliness level: Class 10,000 and Class 1,000 spaces
Access Type: Vertical
Number of Staff: 8

Program Advisory Committee/experiment proposals:
Yes - Boulby Science Advisory Group

Number of active users and their origin:
~70 – UK & international

Percentage of users, and percentage of facility use that come from inside the institution:
10%

Percentage of users and percentage of facility use from national users:
45%

Percentage of users and percentage of facility use form outside the country where your facility is located:
45%

Fraction of the international users outside of geographical region:
50%

Number of theoretical staff employed at the facility: permanent, postdoctoral, students:
None

Number of non-resident graduate students with thesis work primarily done at the facility:
5

Special student programs:
Misc local schools programmes

Future Plans:
We have recently completed our new underground laboratory and Outside Experimentation area at Boulby. Our plans are to continue and expand current our science programme in all areas, and adding neutrino studies.

Short Descriptions of Pertinent Existing Experiments *(focus on nuclear physics, mainly neutrinos)***:**

DRIFT Directional Dark Matter Search
BUGS: Boulby Germanium Suite – Ultralow background Material Screening
SELLR: Studies of Life in low background environments
BISAL: Astrobiology and studies of life in extreme environments
MINAR: Planetary Exploration Technology Development

LABORATOIRE SOUTERRAIN DE MODANE (FRANCE)

Laboratoire Souterrain de Modane (LSM)
(Modane Underground Laboratory)
Carre Science
1125 route de bardonneche
F-73500 Modane

Telephone: +33 (0)4 79 05 22 57
Facsimile: +33 (0) 4 79 05 24 74
Email: contact@lsm.fr
Website: http://www-lsm.in2p3.fr/

CNRS/IN2P3 and Grenoble-Alpes University

Construction: 1979 - 1981
Operation: Since 1981

Head of the Facility:
Dr. Fabrice Piquemal

Scientific Mission and Research Programs:
To host experiments requiring low radioactive conditions and to develop low radioactive techniques

Technical Facilities: Radon free air facility, clean room class 100 without radon, 17 gamma-ray spectrometer, alpha counter

Facility Parameters *(i.e. Depth (m), Facility area/volume (m^2/m^3), Muon flux (/m^2/s), Radon level (Bq/m^3), Cleanliness level, Access type (H or V), Number of staff)***:**
Depth: 1700 m
Area: 400 m^2
Volume: 3500 m^3
Muons flux: 4,6 10^{-5} /m^2/s
Air cleanless: ISO8
Access type: Horizontal
Number of staff: 12

Program Advisory Committee/experiment proposals: The scientific council advise for the selection of proposal. Small and/or temporary experiments can be accepted by the director of the laboratory after agreement of the operators.

Number of active users and their origin: about 200 users

Percentage of users, and percentage of facility use that come from inside the institution:

95 users from particles and nuclear physics, 90 % of the use of the facility. 5% of users from interdisciplinary, using 10% of the facility

Percentage of users and percentage of facility use from national users:
25% of national users, they use almost 100% of the facility through the large experiement and the interdisciplinary experiments

Percentage of users and percentage of facility use form outside the country where your facility is located:
75 % of users from abroad and 90% of the use of the facility

Fraction of the international users outside of geographical region:
5%

Number of theoretical staff employed at the facility: permanent, postdoctoral, students:
0

Number of non-resident graduate students with thesis work primarily done at the facility:
30

Involvement of undergraduate students in research (approximate average number at a given time):
No data

Special student programs:
No data

Future Plans:
No data

Short Descriptions of Pertinent Existing Experiments *(focus on nuclear physics, mainly neutrinos)***:**
SuperNEMO looking for Neutrinoless double beta decay
EDELWEISS and SEDINE for dark matter detection
TGV looking for Double electrons capture

LABORATORIO SUBTERRÁNEO DE CANFRANC (SPAIN)

Laboratorio Subterraneo de Canfranc (LSC)
Paseo de los Ayerbe, s/n Canfranc Estación, Spain

Telephone: +34 974 37 34 74
Facsimile: +34 974 37 35 04
Email: ylabarta@lsc-canfranc.es
Website: http://www.lsc-canfranc.es/en/

Head of the Facility:
Carlos Peña Garay, Director

Scientific Mission and Research Programs:
Neutrino physics, dark matter and rare processes in physics. Geophysics. Biology in exteme environments.

Technical Facilities:
Material radio-purity measurements (radio-purity screening) with very low background HPGe detectors and ICP-MS (Ultra-Low Background Service, ULBS)

Radio-pure copper parts manufacturing service using the electro-forming technique (Copper Electro-forming Service, CES).

Underground clean room class ISO 6 and class ISO 7 (Clean Room Service, CRS).

Facility Parameters:
Depth: 850 m rock overburden (about 2500 m.w.e.)
Muon flux: $3x10^{-3}$ m^{-2} s^{-1}
Underground surface: 1600 m^2
Underground volume: 10,000 m^3
Radon level: 80 – 100 Bq/m^3
Access type: horizontal
Cleanliness level: weekly cleaning of floor in underground; ISO6 and ISO7 clean room in underground
Number of staff: 13

Program Advisory Committee/experiment proposals:

International Advisory Committee

David Sinclair (Chair) - Carleton University (Canada)

Frank T. Avignone - University of South Carolina (USA)

Antonio Bueno Villar- Universidad de Granada, Granada (Spain)

Cristiano Galbiati - Princeton University, New Jersey (USA)

Andrea Giuliani - CSNSM, Orsay Campus (France)

Berta Rubio Barroso - CSIC, Instituto de Física Crepuscular, Valencia (Spain)

Mark Chen - Queen's University, Ontario (Canada)

Eligio Lisi - INFN, Bari (Italy)

Paola Tropea - CERN, Geneva (Switzerland)

Jens Kallmeyer, GFZ-Postdam (Germany): external member on biology

Number of active users and their origin:
279, from 20 different countries (mainly from Spain, France, Italy, Switzerland, UK and USA)

Percentage of users, and percentage of facility use that come from inside the institution:
Facilities at LSC are maintained for external users. Internal users might carry out R&D and outreach activities and for this they can use LSC facilities.

Percentage of users and percentage of facility use from national users:
38% national users

Percentage of users and percentage of facility use form outside the country where your facility is located:
62% foreign users

Fraction of the international users outside of geographical region:

Number of theoretical staff employed at the facility: permanent, postdoctoral, students:
zero

Number of non-resident graduate students with thesis work primarily done at the facility:
13

Involvement of undergraduate students in research (approximate average number at a given time):
15

Special student programs:
Graduate student grant supported by local Government

Future Plans:
Research activities based on 4-year strategic plan approved by Governing Council

Short Descriptions of Pertinent Existing Experiments *(focus on nuclear physics, mainly neutrinos)***:**

Neutrinos:
BiPo: Collaboration between the Laboratoire de l'accelérateur linéaire (LAL), Laboratoire de Physique Corpusculaire (LPC), IFIC, University of Osaka and UNIZAR.
General facility intended for the measurement of the radio-purity of large surfaces dedicated to underground experiments.

This facility has been built for the SuperNEMO experiment to determine the surface contamination in uranium and thorium in enriched selenium foils.

NEXT: Collaboration between the Institut de Física d'Altes Energies (IFAE), Lawrence Berkeley National Laboratory, Joint Instutute for Nuclear Research in Russia, University of Coimbra, CINEMAT, CEA, IRFU, University de Santiago de Compostela, IFIC, Instituto ITACA, Universidad Politécnica de Valencia and Universidad de Zaragoza (UNIZAR).
World leading project studying the nature of the neutrinos by means of neutrinoless double beta decay. The detector consists of a high pressure TPC with enriched xenon gas. The detector is characterized by a 0.5% FWHM energy resolution at $Q_{\beta\beta}$ and tracking possibility to reject background events.

SuperKGd: Collaboration between the Institute for Cosmic Ray Research, Tokyo (ICRR), Institute for the Physics and Mathematics of the Universe, University of Tokyo (IPMU), University California Irvine (UCI) and the Universidad Autonoma de Madrid.
Very low background measurements for Super-Kamiokande with gadolinium. This project makes use of the low background facility at LSC to carry out screening of gadolinium salt.

CROSS: This project is based on an ERC Advanced grant awarded to Andrea Giuliani from the French National Center for Scientific Research. The detector consists of a bolometer based on tellurium and/or molybdenum with the possibility to reject surface alpha and beta background to search for neutrinoless double beta decay.

Dark Matter:

ANAIS: Formed by a group from the University of Zaragoza (UNIZAR)
Dark matter detection by looking at the annual modulation of the expected interaction rates in a target of sodium iodide.

ArDM: Collaboration between the ETH Zurich, Zurich University, University of Granada, CIEMAT, and CERN.
Particle physics experiment based on a ton scale liquid argon detector to search for signals from WIMPs (Weakly Interacting Massive Particles), which are candidates for the Dark Matter in the universe. The detector consists of a two-phase TPC.

TREX-DM: The TREX-DM experiment at the LSC, led by the University of Zaragoza, aims for the detection of WIMPs with very particular characteristics, with a very low mass (below 10 GeV), which could have passed unnoticed in previous experiments. The detector consists of a high pressure TPC filled either with argon depleted in ^{39}Ar or neon. The detector read the charge released by particle interactions.

LABORATORI NAZIONALE DEL GRAN SASSO (ITALY)

Laboratori Nazionali del Gran Sasso (LNGS)
(Gran Sasso National Laboratory)
Via G. Acitelli, 22
67100 Assergi (L'Aquila)

Telephone : +39 0862 4371
Facsimile : +39 0862 410795
Email: info@lngs.infn.it
Website : http://www.lngs.infn.it

Head of the Facility:
Dr. Stefano Ragazzi, Director, LNGS

Scientific Mission and Research Programs:
LNGS research activities range from neutrino physics to dark matter search, to nuclear astrophysics, and also to earth physics, biology and fundamental physics.

Technical Facilities:
INFN Gran Sasso National Laboratory (LNGS) is the largest underground laboratory in the world devoted to neutrino and astroparticle physics, a worldwide research facility for scientists working in this field of research, where particle physics, cosmology and astrophysics meet. It is unequalled anywhere else, as it offers the most advanced underground infrastructures in terms of dimensions, complexity and completeness.

LNGS is funded by the National Institute for Nuclear Physics (INFN), the Italian Institution in charge to coordinate and support research in elementary particles physics, nuclear and sub nuclear physics

Access to experimental halls is horizontal and it is made easier by the highway tunnel. Halls are equipped with all technical and safety equipment and plants necessary for the experimental activities and to ensure proper working conditions for people involved.

The 1400 metre-rock thickness above the Laboratory represents a natural coverage that provides a cosmic ray flux reduction by one million times; moreover, the flux of neutrons in the underground halls is about thousand times less than on the surface due to the very small amount of uranium and thorium of the Dolomite calcareous rock of the mountain.

The permeability of cosmic radiation provided by the rock coverage together with the huge dimensions and the impressive basic infrastructure, make the Laboratory unmatched in the detection of weak or rare signals, which are relevant for astroparticle, sub nuclear and nuclear physics.

Outside, immersed in a National Park of exceptional environmental and naturalistic interest on the slopes of the Gran Sasso mountain chain, an area of more than 23 acres hosts laboratories and workshops, the Computing Centre, the Directorate and several other Offices.

Facility Parameters *(i.e. Depth (m), Facility area/volume (m^2/m^3), Muon flux (/m^2/s), Radon level (Bq/m^3), Cleanliness level, Access type (H or V), Number of staff)***:**
Located between L'Aquila and Teramo, at about 120 kilometres from Rome, the underground structures are on one side of the 10-kilometre long highway tunnel which crosses the Gran Sasso massif (towards Rome); the underground complex consists of three huge experimental halls (each 100-metre long, 20-metre large and 18-metre high) and bypass tunnels, for a total volume of about 180.000 m3.

Program Advisory Committee/experiment proposals:
No data

Number of active users and their origin:
Currently 1100 scientists from 29 different Countries are taking part in the experimental activities of LNGS.

Percentage of users, and percentage of facility use that come from inside the institution:
No data

Percentage of users and percentage of facility use from national users:
No data

Percentage of users and percentage of facility use form outside the country where your facility is located:
No data

Fraction of the international users outside of geographical region:
No data

Number of theoretical staff employed at the facility: permanent, postdoctoral, students:
No data

Number of non-resident graduate students with thesis work primarily done at the facility:
No data

Involvement of undergraduate students in research (approximate average number at a given time):
No data

Special student programs:
No data

Future Plans:
Enlargement of the low background levels laboratory

Short Descriptions of Pertinent Existing Experiments *(focus on nuclear physics, mainly neutrinos)***:**
No data

Callio Lab
Ollintie 26
FI-86800 Pyhäsalmi
Finland

Telephone: +358 40 180 9511
Email: info@calliolab.com
Email: jari.joutsenvaara@calliolab.com
Website: calliolab.com
Website: callio.info

Kerttu Saalasti Institute, University of Oulu
University of Jyväskylä

Existing underground mine
Scientific activities since 1997

Head of the Facility:
The Callio Lab is governed by the Callio steering group consisting of representatives from University of Oulu and Jyväskylä, Finland, the Town of Pyhäjärvi and Pyhäsalmi Mine.

Scientific Mission and Research Programs:
Callio Lab is a world-class underground center, which offers proven optimal premises and conditions for scientific research, as well as versatile opportunities for commercial use. Readymade and expandable facilities with easy access are located at the Pyhäsalmi Mine, Pyhäjärvi, Finland. The Mine is owned by the First Quantum Minerals Ltd.

Technical Facilities:
The large underground areas transformed from mining supporting areas to science supporting areas enables variety of possibilities for scientists and researchers alike. The operations are supported by mechanical and electrical workshops at site in cooperative use with the mining company, and the IT-company is together with mine electricians assisting users with connectivity related issues.

Facility Parameters
Callio Lab is located in the Pyhäsalmi Mine, Pyhäjärvi, Finland. The depth of the mine (bottom of the elevator shaft) is 1 444m (~4 000 m.w.e). The mine is divided in to section the old mine (from surface down to 990 m) and the new mine (from 1 000m down to 1420 meters below the surface). The access (vertical) to the new mine is via incline (it takes roughly half an hour to drive) or with the elevator (3 min) from the surface. The surface of the mine is flat.

The general rock type is volcanogenic massive sulfide ore with pyrite and zinc ore. The average density of the rock is 2.8 kg/dm3. Muon flux has been measured at different levels with three different experimental setups: MUD, MUG and EMMA.

Depth meters in rock	Muon flux [$m^{-2}s^{-1}$]
0	180±20
90	1.3
210	2.3·10-1
400	$(2.1\pm0.2)\cdot10^{-2}$
660	$(3\pm0.3.2)\cdot10^{-3}$
990	$(6.2\pm0.6)\cdot10^{-4}$
1390	$(1.1\pm0.1)\cdot10^{-4}$

The Callio Lab has now four experimental sites from which two LAB 1 and LAB 2 are currently used for physics experiments. LAB 3 is used as a test site for growing mushrooms in mine environment and LAB 4 has dedicated hydroponic greenhouses operated by Finnish Centre for Natural Resources (abb. LUKE in Finnish).

LAB 1, which consists of total 11 detector stations at depths of 45 (130 m.w.e.) and 75 (210 m.w.e.) meters, hosts EMMA - Experiment with MultiMuon Array measuring the composition of cosmic rays at the so called knee region. This is a joint experiment with Universities of Oulu and Jyväskylä, Finland, the Institute of Nuclear Research of Russian Academy of Sciences (INR RAS), University of Aarhus, Denmark.
The experiment occupies roughly 150 meters of caverns (5 meters wide) at those two levels. The average relative humidity in the caverns is 100 % and temperature around 11 degrees Celsius. The detector stations separate the experiment from the hostile environment by providing steady temperature around 20 degrees with RH 60-70%. Radon level in the cavern varies but is usually above 400 Bq/m^3. The LAB 1 is well connected (1 GB LAN, two-way radio).

LAB 2 is located at the depth of 1 430 meters (~4 000 m.w.e.). This old ore exploration tunnel was converted into a measuring hall for low background measurements. The LAB 2 consists of entrance hall (120 m2, height 6 m) and actual experimental hall (120m2, height 8-10 m, sloping wall). The halls are separated by blast doors from mining activities and therefore the actual measuring hall is behind two sequential blast doors. The radon level inside the cavern is on average kept around 70 Bq/m3 but with no ventilations the radon levels can reach up to 600 Bq/m2. The temperature is 26-28 degrees Celsius. RH is 65%. The halls are equipped with analog radio to access the mine radio network (to prevent EM-emissions from the two-way radio network) and with 1 GB LAN.
The LAB 2 hosts currently C14-experiment in which liquid scintillator samples from e.g. JUNO, SNO+, and BOREXINO are being measured for their abundance of C14 nuclei within the samples. This is a joint experiment with Universities of Oulu and Jyväskylä, Finland, and the Institute of Nuclear Research of Russian Academy of Sciences (INR RAS). This research is part of research activities of JUNO.

LAB 3 is located at the depth of 990 meters in an old underground dining hall. The hall is approx. 40 m2 in total with height of 5-6 meters. The hall is currently used as a test site for growing mushrooms. Radon level is around 200 Bq/m3.

LAB 4 is located at the depth of 660 meters. The greenhouses had been built at this level due to the optimal geothermal temperature of 16-18 degree for plant growth. The greenhouses are equipped with environmental automation control to keep the conditions optimal of each type of a plant and the facilities can be remotely monitored.

Program Advisory Committee/experiment proposals:
Steering group of Callio is in charge of evaluating incoming program proposals. Open call procedure has been first launched in 2015 and has been running until 2017 to gather proposals from potential users. The next Open call launch is in 2018.

Number of active users and their origin:
There are two active physics collaborations operating in the Callio Lab.
EMMA experiment is a joint experiment with Universities of Oulu and Jyväskylä, and INR RAS. Collaboration size is 15-20 people.
C14 experiment is a part of research activities of JUNO. The C14 experiment is conducted at the depth of 4 000 m.w.e. inside the LAB2. The C14 collaboration has partners from Universities of Oulu and Jyväskylä, and INR RAS. Collaboration size is 15-20 people.

Percentage of users and percentage of facility use that come from inside the institution:
On average around 50 % of the users are from the governing institutions.

Percentage of users and percentage of facility use from national users:
On average around 50 % of the users are from the governing institutions.

Percentage of users and percentage of facility use form outside the country where your facility is located:
On average 50% of collaboration members come from outside Finland

Fraction of the international users outside of geographical region:
In current research activities there are 15 Russians, five Germans, and two Danes in research collaboration.

Number of theoretical staff employed at the facility: permanent, postdoctoral, students:
We collaborate both with national and international physicists on theoretical matters. Our international collaborators come from Russia, German and Poland, and our national collaborators from Universities of Oulu, Jyväskylä and Helsinki.

Number of non-resident graduate students with thesis work primarily done at the facility:
On average there is one non-resident graduate student per collaborating institution doing their research related to experiments operated in Callio Lab. See appendix 1. for a list of PhD and Master thesis works conducted at Callio Lab.

Involvement of undergraduate students in research (approximate average number at a given time):
On average there is one undergraduate student per participating institution. Currently there are three undergraduate students involved in research. Addition to these there have been up to five internationals trainees through ERASMUS program working on various projects.

Special student programs:

TRAINEESHIP: Traineeship program for undergraduate students to help them to enter the world of research and encourage them pursue for a career in science.

OUTREACH: Outreach program for high school students to encourage students to learn more about nature and science. Activity is aimed at regional and rural schools far away from University centers.

MINETRAIN: The teaching in university classrooms and university laboratories is not enough. In a conventional research laboratory, it is impossible to do a test considering all important factors such as real in situ stresses and real sizes of tunnels in a deep mine. Pyhäsalmi mine is about 1400 m deep which makes it as a perfect experimental mine for high education and research.
The main target group of the training is students in bachelor, technical, post-graduate students, professionals and operators who have to put hands-on the real in mining engineering, geology, geophysics and mineral processing. The training package consists of courses covering the whole life of the mining cycle.

Future Plans:
As the unique underground environment in stable bedrock, the already existing LAB –facilities and possibility to excavate new underground facilities make Callio Lab a unique site for future large-scale (several kilotons) experiments. The open call procedure is open for new ideas and project proposals. The existing experiments continue to operate to full fill their scientific tasks and ideas for using the existing experimental infrastructures will be develop.

Short Descriptions of Pertinent Existing Experiments *(focus on nuclear physics, mainly neutrinos)***:**

EMMA-experiment: The Experiment with MultiMuon Array (EMMA) is an underground EAS array designed to study cosmic-ray composition around the knee region (1 to 10 PeV) by measuring the high-energy muon component ($E\mu > 50$ GeV). It consists of eleven muon tracking detectors at the depths of 75 meters (210 m.w.e.) and 45 meters (130 m.w.e.) in the Callio Lab in Pyhäsalmi Mine, Finland).

C14- experiment: The radioactive purity of liquid scintillator samples are studied in the C14 Experiment, and in specially the activity of 14C isotope in liquid scintillator. Liquid scintillator is an oil- or gas-based hydrocarbon compound. Various liquid scintillator samples, based on oil, gas and coal derivatives, will be measured in the C14 Experiment to possibly find out samples

having 14C concentration close to or below 10^{-20}. Measurements take place in two underground laboratories: in the Baksan Neutrino Observatory, Russia, and in the Callio Lab in the Pyhäsalmi mine, Finland.

Baksan Neutrino Observatory (BNO) of the Institute for Nuclear Research (INR) of the Russian Academy of Sciences (RAS).
361609, poselok Neutrino, El'brusskij rajon
KBR, Russian Federation

Telephone:
+7(86638)75149 – Director
+7(86638)75205 - Secretary
+7(86638)75206 - Scientific Secretary
Facsimile:
+7(86638)75103
Email:
bnoinr@yandex.ru
bno_vvk@mail.ru – Director
vvk1982@mail.ru - Scientific Secretary
Website: http://www.inr.troitsk.ru/eng/ebno.html

University Institute

Construction: From 1968 to 2013
Operation: From 1973

Head of the Facility:
Dr. Valery V. Kuzminov, Director, BNO

Scientific Mission:
Fundamental research activities in the field of nuclear physics, elementary particle physics, cosmic-ray physics, and neutrino astrophysics.
Developing and creation of neutrino telescopes in low-background underground laboratories for studying natural neutrino fluxes and other elementary particles.

Research Programs:
1) studies of the internal structure and evolution of the Sun, stars, Galaxy nucleus and other objects of the Universe by detecting their neutrino emission;
2) studies of neutrino properties with artificial neutrino sources;
3) a search for new particles and super-rare processes predicted by various modern theoretical models at a sensitivity level inaccessible to other methods;
4)investigation of high-energy cosmic rays, gamma-astronomy, a search for gravitational waves;
5)studies of the influence of cosmic factors on the processes in the atmosphere and on the surface of the Earth.

Technical Facilities:

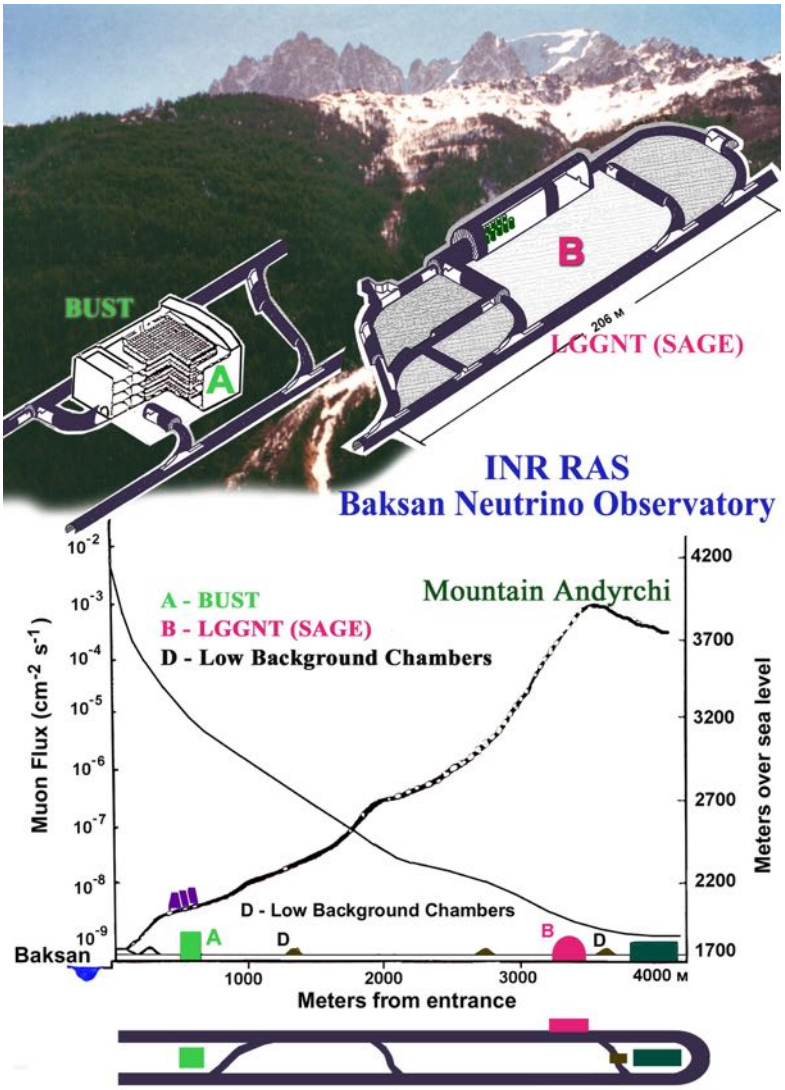
1) The Baksan Underground Scintillation Telescope (BUST) - installation for a wide range of research in the field of cosmic ray physics and astrophysics

2) The highland setup Andyrchy for detecting wide atmospheric showers of cosmic rays;

3) The ground-based facility Carpet comprising a Large Muon Detector, Scintillation Telescope and Neutron Monitor for studying a hard component of cosmic rays and wide atmospheric showers;

4) The Gallium-Germanium Neutrino Telescope for research of neutrinos from the Sun and neutrino properties.

5) Low-background laboratories located at a depth of 100, 600 and 4800 m w.e.



BNO INR RAS underground facilities location.

Facility Parameters *(i.e. Depth (m), Facility area/volume (m^2/m^3), Muon flux (/m^2/s), Radon level (Bq/m^3), Cleanliness level, Access type (H or V), Number of staff)***:**

1. BUST is situated in the underground hall of ~ 12000 m^3 at a distance of 550 m from the entrance to the underground horizontal tunnel. The effective thickness of the ground above BUST is 850 g/cm^2. The telescope is a rectangular building of 11.1 m height and 280 m^2 base. The blocks of the building are made of low-radioactive concrete. Its four horizontal and four vertical planes are covered with standard scintillation detectors (3180 in total). The total mass of the telescope is 2500 t, that of the scintillator is 330 t.

A view of the BUST top horizontal plane (left), vertical side surfaces (right)

2) The highland setup Andyrchy for detecting wide atmospheric showers, which is located directly above the BUST (vertical distance 350 m). It consists of 37 detectors (1m^2 each, plastic scintillator) evenly spread over the area of 45000 m^2 on the slope of the Andyrchy mountain with a maximum gradient of altitude of 150 m and at a distance of 40m from each other.

One of the detectors of the Andyrchy array

3) EAS array "Carpet" for the study of cosmic rays and gamma-astronomy, which includes 400 scintillation detectors of 200 square meters with six remote points with a total area of 54 square meters, muon detector - area of 410 square meters and neutron supermonitor;

Muon detector of installation “Carpet-2”

4) The underground complex of Gallium-Germanium Neutrino Telescope (GGNT) laboratories is situated at a distance of 3.5 km from the entrance to the tunnel, at a depth of 4700 m w.e. where the muon flux is reduced by 10^7 times due to the mountain rock shielding, and is $(3.03\pm0.10)\cdot10^{-9}$ cm^{-2} s^{-1}. The main hall of this complex is of 60m×10m×12m dimensions. To reduce the background caused by neutrons and gamma-rays coming from the surrounding natural rocks the hall is encased in low-radioactivity concrete and steel sheets of 600 mm and 6 mm thickness, respectively. The flux of neutrons with energies of 1.0–11 MeV in the laboratory is $\leq 2.3 \cdot 10^{-7}$ cm^{-2} s^{-1}. The underground complex of the GGNT laboratories includes rooms for:

analytical chemistry, ^{71}Ge decay registration system, low-background semiconductor Ge detector and a number of other auxiliary subdivisions. About 50 t of metallic gallium in a melted state is placed into seven chemical reactors.

A view of the GGNT(left) and 2 zone installation BEST(right)

5) There are three underground laboratories, situated at a different depth, where low-background researches are carried out: 1) a low-background chamber at a depth of 660 m w.e, 385 m from the entrance to the tunnel, a useful area of 100m^2; 2) a chamber for precise measurements at 1000m w.e. of depth, at 620m of distance from the entrance, a useful area of 20 m^2; 3) a deep underground low-background laboratory (DULB-4900) at 4900m w.e. of depth, 3670m from the entrance, a useful area of 200 m^2. The cosmic-ray flux in these three chambers is reduced by $2\cdot10^3$, $8\cdot10^3$, and 10^7, respectively.

A view of DULB-4900

Program Advisory Committee/experiment proposals:
Yes

Number of active users and their origin:
6 per year

Percentage of users, and percentage of facility use that come from inside the institution:
80% (estimate)

Percentage of users and percentage of facility use from national users:
95%

Percentage of users and percentage of facility use form outside the country where your facility is located:
5%

Fraction of the international users outside of geographical region:
5%

Number of theoretical staff employed at the facility: permanent, postdoctoral, students:
27

Number of non-resident graduate students with thesis work primarily done at the facility:
0

Involvement of undergraduate students in research (approximate average number at a given time):
3

Special student programs:
Yes

Future Plans:
Search for astrophysical neutrino sources at the Baksan Underground Scintillation Telescope using data of gamma and gravitational-wave observatories

Carpet-3 – a new experiment for UHE gamma-astronomy and to study primary composition around the knee. The Carpet-3 EAS array is the further development of the Carpet-2 EAS array (1700 m a.s.l., Baksan Valley) and it is supposed to be a multi-component and multi-purpose array detecting, in the EASs with E > 10 TeV, electrons, gammas, muons (with a threshold energy of 1 GeV), hadrons (with energies more than 30 GeV), and thermal neutrons as well.

The BEST experiment for Very Short Baseline $\nu_e \rightarrow \nu_x$ oscillation search on dual metallic Ga target with artificial 3MCi ^{51}Cr neutrino source. (Baksan Experiment on Sterile Transitions).

Short Descriptions of Pertinent Existing Experiments *(focus on nuclear physics, mainly neutrinos)***:**
At the Baksan Underground Scintillation Telescope:
search for neutrino bursts from supernovae in the Galaxy ;
search for astrophysical sources of muon neutrino with energy ≥ 1 GeV ;

Search for isotropic diffuse gamma-ray flux between 100 TeV and 1 PeV at the Carpet-2 EAS array.

Monitoring of solar neutrinos and search for sterile neutrinos from beta decay artificial neutrinos sources of high intensity on the GGNT.

Numerous experiments are being carried out in the low background laboratory (LBL), thanks to a new experimental hall located 3.67 km from the tunnel entrance (providing shielding equivalent of 4900 m of water). Some of them:
1) search for solar axions via their resonant reconversion on ^{83}Kr, and this experiment has already resulted in the world's best constraint on certain couplings of the hadronic axion;
2) search for 2K-capture of ^{124}Xe (^{78}Kr) by large volume proportional counters with the case made from pure oxygen-free copper.
In addition, LBL group have two setups based on HPGe detectors intended for material screening. These setups are located at a depth of 600 and 4900 m w.e, respectively.

India based Neutrino Observatory (INO)

Tel: 91-22-22782715
Fax: 91-22-2280-4610 / 4611
Email: vivek.datar@tifr.res.in
Website: http://www.ino.tifr.res.in/ino/

Tata Institute of Fundamental Research

Head of the Facility: Prof. V.M. Datar (Project Director, INO)

Scientific Mission and Research Programs: To carry out research that benefits from low cosmic ray background environment, mainly in the areas of atmospheric neutrinos, neutrinoless double beta decay, search for dark matter and possibly measuring nuclear reactions of astrophysical interest using a low energy accelerator.

Technical Facilities: A 51 kton Iron Calorimeter (ICAL), Cryogenic bolometer, Low background HPGe detector set up.

Facility Parameters:

Depth (m): > 1000m rock overburden in all directions,
Facility area/volume (m^2/m^3): No data
Muon flux (/m^2/sr/s): estimated to be 10^{-4}
Radon level (Bq/m^3): No data
Cleanliness level: As in any laboratory (for ICAL)
Access type (H or V): H
***Number of staff*:** about 20 when facility is set up

Program Advisory Committee/experiment proposals: Scientific Management Board

Number of active users and their origin: Project construction not yet begun. About 100 members in INO Collaboration.

Percentage of users, and percentage of facility* use that come from inside the institution:
7

Percentage of users and percentage of facility use from national users:
93

Percentage of users and percentage of facility use form outside the country where your facility is located:
0

Fraction of the international users outside of geographical region:
95

Fraction of the international users outside of geographical region:
0

Number of theoretical staff employed at the facility: permanent, postdoctoral, students:
5, 0, 5

Number of non-resident graduate students with thesis work primarily done at the facility:
15

Involvement of undergraduate students in research (approximate average number at a given time):
3

Special student programs: summer programs of University/IIT/NIT students ~ 6

Future Plans: An underground lab for not only neutrino and other physics experiments but also experiments in other areas of science such as geophysics and life sciences.

Short Descriptions of Pertinent ~~Existing~~ Planned Experiments *(focus on nuclear physics, mainly neutrinos)***:**

1. The experiment to measure atmospheric neutrinos using the Iron Calorimeter detector aims to measure neutrino properties such as the mass hierarchy, precision values of the $\sin^2\theta_{23}$ and Δm_{23}^2 as also search for long range forces and sterile neutrinos.
2. The neutrinoless double beta experiments is working on a prototype tin bolometer that will operate at around 10mK and aims to target ^{124}Sn.
3. A dark matter experiment based on a CsI(Tl) detector operated at cryogenic temperature, providing scintillation and phonon signals, is also planned.

*Not yet a facility, it is still a project waiting for Environmental and Pollution clearances

CHINA JINPING UNDERGROUND LABORATORY (CHINA)

China Jinping Underground Laboratory (CJPL)
Jinping tunnel, Sichuan province, China

Telephone: +86 10 62772821
Email: yueq@mail.tsinghua.edu.cn
Website: http://cjpl.tsinghua.edu.cn/

Tsinghua University

Construction: 2009
Operation: 2010 to present

Head of the Facility:
Dr. Yue Qian

Scientific Mission and Research Programs:
Be a world-level ultra-low background platform for rare-event experiments including dark matter direct detection, neutrinoless double beta decay, solar neutrino experiment, astroparticle physics, and so on. CJPL also support to develop the advanced ultra-low background technologies and methods to match the upgraded requirements of the rare-event experiments in the future.

Technical Facilities:
Ultra-low background facilities, neutron background detector, radon monitor, cosmic-ray flux measurement facility and so on.

Facility Parameters
Depth:2400m
Volume: 4000 m3 for CJPL Phase-I; 300000 m3 for CJPL Phase-II
Muon Flux: $2.0*10^{-6}$/m^2/s (0.17/m^2/day)
Radon level : ~50 Bq/m^3
Cleanliness: NONE
Access type: Horizon
Number of Staff: ~30 in 2017

Program Advisory Committee/experiment proposals:
CDEX, PandaX, JUNA, Jinping Neutrino Experiment, and so on

Number of active users and their origin:
50, mainly from the universities and institute of China.

Percentage of users, and percentage of facility use that come from inside the institution:
100%

Percentage of users and percentage of facility use from national users:
90%

Percentage of users and percentage of facility use form outside the country where your facility is located:
10%

Fraction of the international users outside of geographical region:
10%

Fraction of the international users outside of geographical region:
10%

Number of theoretical staff employed at the facility: permanent, postdoctoral, students:
No data

Number of non-resident graduate students with thesis work primarily done at the facility:
No data

Involvement of undergraduate students in research (approximate average number at a given time):
~20

Special student programs:
Training base for graduate students of Tsinghua University and other universities/institutes in China

Future Plans:
CJPL phase-II under construction in the next five years to be the deepest (2400m rock overdburden) and largest (300000m^3 available space) underground laboratory for rare-event experiments

Short Descriptions of Pertinent Existing Experiments *(focus on nuclear physics, mainly neutrinos)*:

CDEX for both dark matter search and neutrinoless double beta decay experiment with germanium detector array
PandaX for both dark matter search and neutrinoless double beta decay experiment with Xenon experiment
JUNA for astroparticle physics
Jinping neutrino experiment for solar neutrino detection and geo-neutrino research

YANGYANG UNDERGROUND LABORATORY (SOUTH KOREA)

Yangyang underground Laboratory (Y2L)
2403, Guryongnyeong-ro, Seo-myeon, Yangyang-gun, Gangwon-do 25039, Republic of Korea

Telephone: +82-33-673-1383
Facsimile: +82-42-878-8509
E-mail: wgkang@ibs.re.kr
Website: https://www.ibs.re.kr/eng/sub02_03_04.do

Center for Underground Physics (CUP), Institute for Basic Science (IBS)

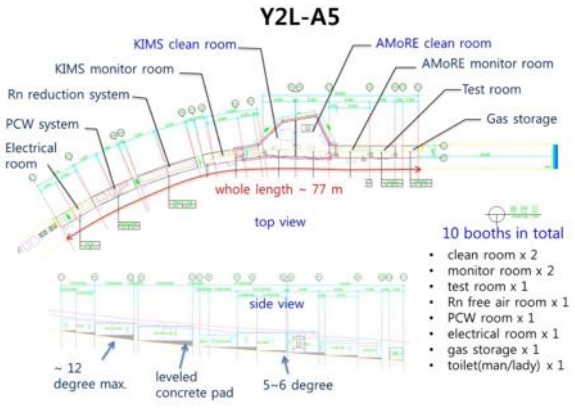
Construction: 2003
Operation: 2004 to present

Head of the Facility:
Dr. Yeongduk Kim

Scientific Mission and Research Programs:

- AMoRE (Pilot & Phase-1): Search for neutrinoless double beta decay with 1-5 kg $^{40}Ca^{100}MoO_4$ scintillation crystals by a cryogenic detection.
- COSINE (Phase-1): Search for Dark Matter WIMPs with 106 kg NaI(Tl) scintillation crystals which was started in September 2015.
- COSINE (Phase-2): Search for Dark Matter WIMPs with 200 kg NaI(Tl) scintillation crystals with ultra-low background crystals (scheduled from 2020).
- Rare decay searches with HPGe systems including a HPGe array made of fourteen 75% HPGe detectors.

Technical Facilities:



- 120 CMH Rn-free air (Radon reduction system)

- 100 m^2 class 10,000 clean room and Rn free area
- 200 kW electric power
- 30 kW cooling water (Chiller)
- 80 KVA & 1 hour UPS
- 3 HPGe detector systems for low background measurements
- A gas ionization alpha counter

Facility Parameters:
- 700 m (1890 m.w.e.) deep underground
- 300 m^2 area
- Measured muon rate at the Y2L-A5 lab: 3.8 x $10^{-3}/m^2/s$

Program Advisory Committee/experiment proposals:
Annual review by SAC (Scientific Advisory Committee)

Number of active users and their origin:
- 84 from CUP IBS and 12 institutes (inside country)
- 61 from 19 institutes from 10 countries (outside country)

Percentage of users, and percentage of facility use that come from inside the institution:
31 % (percentage of facility is the same as the percentage of users)

Percentage of users and percentage of facility use from national users:
59 % (percentage of facility is the same as the percentage of users)

Percentage of users and percentage of facility use form outside the country where your facility is located:
41 % (percentage of facility is the same as the percentage of users)

Fraction of the international users outside of geographical region:
31% (percentage of facility is the same as the percentage of users)

Number of theoretical staff employed at the facility: permanent, postdoctoral, students:
None

Number of non-resident graduate students with thesis work primarily done at the facility:
26

Involvement of undergraduate students in research (approximate average number at a given time):
5

Special student programs: Summer & Winter Intern Program
2

Future Plans:
Plan to operate at least until 2023 when the new facility at Jeongseon would be in a full operation.

Short Descriptions of Pertinent Existing Experiments *(focus on nuclear physics, mainly neutrinos)*:
The KIMS experiment searching for dark matter WIMPs with CsI(Tl) scintillation crystals was running from 2003 to 2015 at this facility. After the selection of the CUP by the IBS from 2014, the facility has expanded the facility from the A6 area to the A5 area in late 2014 and accommodated the two new experiments, COSINE and AMoRE. In addition to the two major experiments, a dual-purpose facility (rare decay search and low background measurements of raw materials) with an array of 14 HPGe detectors has been installed and running.

IBS ASTROPHYSICS RESEARCH FACILITY (SOUTH KOREA)

IBS ARF (Astrophysics Research Facility) in Jeongseon Korea
154, Jodong 1-gil, Sindong-eup, Jeongseon-gun, Gangwon-do 26141, Republic of Korea

Telephone: +82-42-878-8526
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Website: https://www.ibs.re.kr/eng.do

Center for Underground Physics (CUP), Institute for Basic Science (IBS)

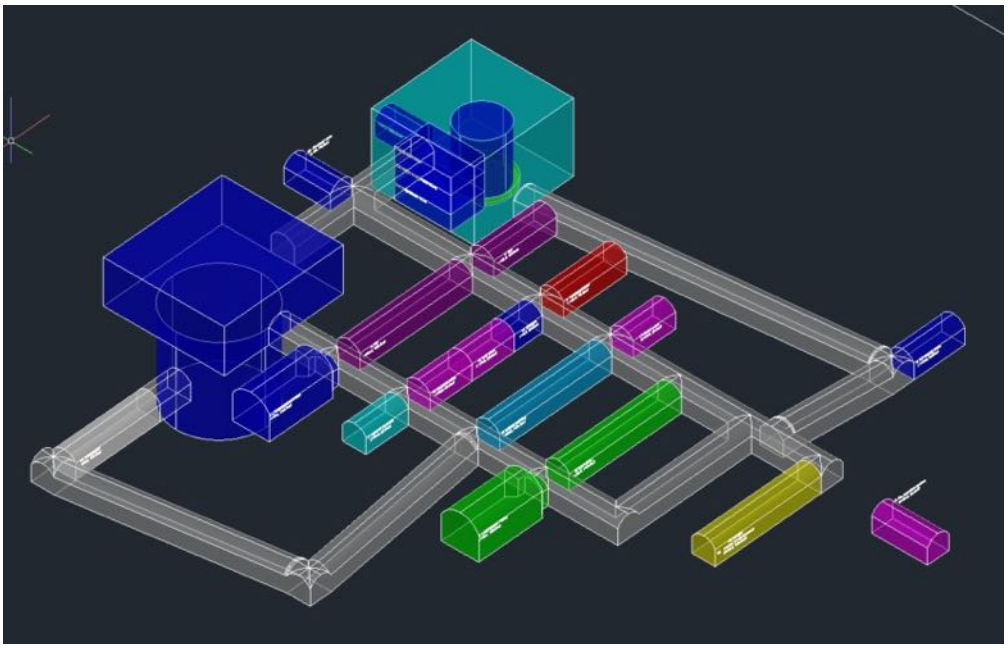
[To be completed by 2019]

Head of the Facility:
Dr. Yeongduk Kim

Scientific Mission and Research Programs:

- AMoRE: Search for neutrinoless double beta decay with 50 - 200 kg molybdate scintillation crystals by using cryogenic detectors.
- COSINE: Search for low mass Dark Matter.
- LSC: Multi-purpose Liquid Scintillation Counter to study neutrinos and dark photons.
- Rare decay searches with HPGe systems.

Technical Facilities:



Facility Parameters:

- 1000 m (2700 m.w.e.) deep underground
- Expected muon reduction factor from the surface: 8×10^{-6}
- About 3,700 m^2 area and 35,000 m^3 volume except the entrance tunnel

Program Advisory Committee/experiment proposals:

- Construction design review committee is currently formed.
- Experiment proposals are going to be accepted as soon as the facility is ready.

Future Plans:

Multi-purpose liquid scintillation counter (LSC) is going to be constructed.

Short Descriptions of Pertinent Existing Experiments *(focus on nuclear physics, mainly neutrinos)*:

In the new underground facility, the AMoRE phase-II and other future experiments are going to be located.

Kamioka Observatory
456 Higashi-Mozumi, Kamioka-cho, Hida-shi,
Gifu-ken, Japan, 506-1205

Telephone: +81- 578-85-9620
Facsimile: +81- 578-85-2121
E-mail: nakahata@suketto.icrr.u-tokyo.ac.jp
Website: http://www-sk.icrr.u-tokyo.ac.jp/index-e.html

Construction and Operation – Institute for Cosmic Ray Research, The University of Tokyo

Dr. M. Nakahata, Director, Kamioka Observatory

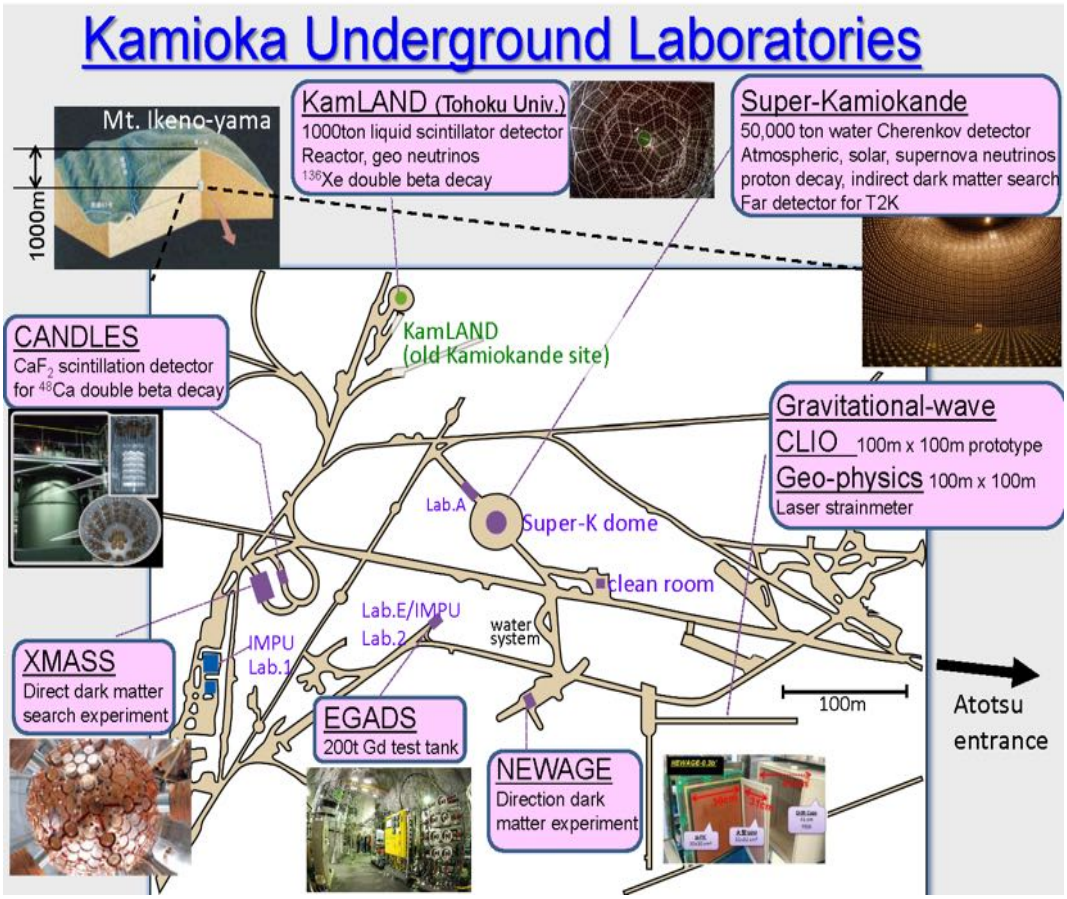
Head of the facility:
Dr. M. Nakahata, Director, Kamioka Observatory

Scientific Mission and Research Programs:

There are four operating bodies for the underground site in Kamioka: 1) Kamioka Observatory, Institute for Cosmic Ray Research (ICRR), the University of Tokyo; 2) KAGRA Observatory, ICRR, the University of Tokyo; 3) Kamioka Satellite, Kavli Institute for the Physics and Mathematics of the Universe (Kavli IPMU), the University of Tokyo; 4) and Tohoku University Research Center for Neutrino Science. They are cooperating each other in many aspects such as safety issues.

Kamioka Observatory was established in 1995, initially to house and operate the Super-Kamiokande detector which is a 50,000 tons imaging water Cherenkov detector, mainly to measure neutrinos from the sun, atmosphere and supernova, and to look for proton decay and so on. Kamioka Observatory has expanded its role and now it operates XMASS, the direct dark matter search experiment, and also accepts experiments to use underground spaces by external research institutions.

Technical facilities:



The underground facilities are located at 1000 m underground of the Kamioka Mine, Gifu prefecture, about 200 km west of Tokyo.

The surface building (left) provides a computer system for offline analyses, meeting rooms and office space for the underground experiments. In addition, a dormitory (right) provides bedrooms and a dining hall for visiting researchers.

Facility parameters:
The main facility is the Super-Kamikande detector, 50,000 ton water Cherenkov detector with 42 m in hight and 39 m in diameter, at 1000 meter (2700 meter water equivalent) underground of the Kamioka Mine. In addition, several laboratories to accommodate the XMASS, CANDLES, NEWAGE, EGADS expeiments and etc.

Program Advisory Committee/experiment proposals:
Yes

Number of active users and their origin:
The Super-Kamiokande collaboration consists of about 160 physicists. They are from institutes in Japan, US, Poland, Korea, China, Spain, Canada, UK, Italy, and France. The Super-Kamiokande detector is used as the far detector of the T2K (Tokai to Kamioka) experiment which consists of about 460 physicists. In addition, about 80 physicists mostly from Japanese institutes use underground facilities for other experiments.

Percentage of users, and percentage of facility use that come from inside the institution:
Almost 20% of users are from inside Kamioka Observatory

Percentage of users and percentage of facility use from national users:
About 50% of the users are from Japan

Percentage of users and percentage of facility use from outside the country where your facility is located:
About 50% of the users are from outside Japan

Fraction of the international users outside of geographical region:
About 45% of users are from outside of East Asia region

Number of theoretical staff employed at the facility: permanent; postdoctoral, students:
There are no theoreticians employed at the facility.

Number of non-resident graduate students with thesis work primarily done at the facility:
~30

Involvement of undergraduate students in research (approximate average number at a given time):
~2 as internship students only in summer time

STAWELL UNDERGROUND PHYSICS LABORATORY (AUSTRALIA)

Stawell Underground Physics Laboratory (SUPL)

Head of the Facility:
Prof. Elisabetta Barberio

Scientific Mission and Research Programs:
The Stawell Underground Physics Laboratory (SUPL) is a laboratory under construction 1 km deep in the Stawell Goldmine, located in Stawell, Victoria, Australia. Of the two underground particle physics laboratories being proposed in the Southern Hemisphere, it is by far the most advanced. It has close collaboration with the Gran Sasso Laboratory in Italy, the largest such underground laboratory, and shall conduct research into dark matter.

Its Southern Hemisphere location has bearing on the possible differential detection of the putative WIMP-wind. Northern Hemisphere instruments are showing hints of a June "bump" of possible dark matter hits,[9] which is expected given the galaxy's rotation, but it is hard to be sure that it is not a false signal due to some subtle seasonal environmental effect. A Southern Hemisphere location, with opposite seasons, would be valuable confirmation. Secondly, the sundry particles (apparently from the constellation Cygnus) would have travelled through the Earth itself before reaching SUPL's instruments. Finally, its Southern Hemisphere location also makes it potentially very sensitive to daily variation effects which would be a smoking-gun for self-interacting dark matter or dark matter with a significant stopping rate.

Neutrino experiments do not benefit in the same way from a Southern Hemisphere location, and what need there is for neutrino astronomy in the Southern Hemisphere is satisfied by IceCube, so it is unlikely that any neutrino detectors will be housed at SUPL.

Technical Facilities:
No data

Facility Parameters *(i.e. Depth (m), Facility area/volume (m^2/m^3), Muon flux (/m^2/s), Radon level (Bq/m^3), Cleanliness level, Access type (H or V), Number of staff)*:

Depth (m): 1025m, providing approximately 2900 meter water equivalent shielding against cosmic rays
Muon flux (/cm^2/s): (3.6 ± 0.4) E-08 *(Note the change of units)*
Radon level (Bq/m^3): <30 after filtration
Cleanliness level: TBD
Access type (H or V): H
Number of staff: TBD

Program Advisory Committee/experiment proposals:
Program Advisory Committee/experiment proposals SABRE-South

Number of active users and their origin:

TBD

Percentage of users, and percentage of facility use that come from inside the institution:
No data

Percentage of users and percentage of facility use from national users:
No data

Percentage of users and percentage of facility use form outside the country where your facility is located:
No data

Fraction of the international users outside of geographical region:
No data

Number of theoretical staff employed at the facility: permanent, postdoctoral, students:
No data

Number of non-resident graduate students with thesis work primarily done at the facility:
No data

Involvement of undergraduate students in research (approximate average number at a given time):
No data

Special student programs:
TBD

Future Plans:
The Stawell Underground Physics Laboratory is scheduled to open in 2019. The first experiment planned for SUPL is SABRE (Sodium-iodide with Active Background REjection), based on 50 kg of thallium-doped sodium iodide. An improved version of the DAMA/LIBRA detector already operating at LNGS, two copies will be built: one at LNGS and one at SUPL. Consistent results between the two will be very strong evidence.

Short Descriptions of Pertinent Existing Experiments *(focus on nuclear physics, mainly neutrinos)***:**
No data