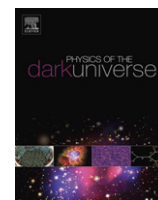




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New underground laboratories: Europe, Asia and the Americas



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ABSTRACT

Deep underground laboratories provide the low radioactive background environment necessary to explore the highest energy scales that cannot be reached with accelerators, by searching for extremely rare phenomena. In addition, these laboratories provide unique opportunities to sectors of other fields: geodynamics, rock mechanics, hydrology and the study of life under extreme conditions.

Underground laboratories of different size and depth exist in all the regions. This article is focussed on future perspectives, reviewing the newer facilities, those still under project and the space becoming available at the older laboratories. We shall not discuss the existing or proposed facilities dedicated to detectors of long base line experiment with reactor or accelerator beams.

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1. A bit of history

The first experiments underground date back to the 1960s. They were performed very deeply in mines. In 1965 the first “natural” neutrinos, produced by cosmic rays interactions in the atmosphere were discovered, almost at the same time, by two groups working in the Kolar Gold Mine in South India [1] at a depth of 2700 m and in the East Rand Property Gold Mine in South-Africa [2] at a depth of 3200 m. A cavity in the Homestake Mine in S. Dakota in the USA was the site of the fundamental experiment by R. Davis [3], who first detected in 1968 neutrinos from the Sun. The observed rate resulted about three times smaller than that calculated by J. Bahcall [4]. As we have gradually learned, with other experiments underground since then, this was the first evidence for physics beyond the Standard Model.

A hall in a mine is not however a laboratory. The first full-fledged underground laboratory is the Baksan Neutrino Observatory (BNO). In 1966, under the action of M. Markov, the Academy of Sciences of the USSR obtained a Decree of the Soviet Government for the construction of the underground and surface facilities. Scientific activity started under the leadership of G. Zatsepin and A. Chudakov. The underground laboratory, including a horizontal access tunnel, was excavated and built under the mount Andyrchi in the Caucasus.

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In 1979 a double tunnel was under construction for a freeway under the Gran Sasso Mountain in central Italy. A. Zichichi, then President of the INFN, saw the unique opportunity of building a world-class underground laboratory (LNGS) with a broad spectrum of potential scientific programme, including a future neutrino beam from CERN. In 1982 the Parliament approved and funded the construction, which was completed in 1987, at a very low cost.

In 1983 M. Koshiya established the Kamioka Underground Observatory, in a modern working mine with horizontal access, to host the KamiokaNDE water Cherenkov detector. Later on its bigger successor was built, SuperKamiokande, which in 1998 [5] discovered neutrino oscillations in the muon-neutrinos from the atmosphere, complementing the Davis and Bahcall discovery. Several other facilities were built after those, of different sizes and at different depths.

I have been requested to limit this review to the recently built facilities and to those under project, and to the underground space available in the older ones. For a more complete review I refer to a set of articles I have co-ordinated [6] in 2012 on: BNO [7], Canfranc (LSC) [8], Kamioka [9], Modane (LSM) [10], LNGS [11], SNOLab [12], SURF [13], and the Indian INO [14], Chinese CJPL [15] and South-American ANDES [16] projects. The introductory article [6] includes also brief descriptions of the smaller laboratories: CUPP in Finland, SUL in Ukraine, Y2L in Korea, Oto Cosmo in Japan, Sudan and WIPP in the USA.

2. Characteristics

The deep underground laboratories (DULs) differ from many points of view.

Depth is an important parameter, because the μ flux and the fluence of the μ -induced spallation neutrons decrease with increasing depth. However, these are only two of the background components and do not contribute substantially to the background budget below about 1500 m of rock overburden in the majority of the cases. On the other hand muons are also useful for calibration purposes.

In the design of a laboratory, halls of different sizes may be foreseen. 15–20 m diameters *and* heights are needed for water shields (e.g. in dark matter and double beta searches) and for large liquid scintillator detectors, as those necessary for solar and geo-neutrinos. Large heights require, in particular, thick enough layers of good quality rock.

Horizontal access has many advantages over the vertical one, which typical in some mines. It allows drive-in to the experiments, the installation of large pieces of apparatus built on the surface and reduced operation costs. In one case, BNO, the access tunnel was built on purpose, in other (LNGS, LSC, LSM and ANDES) is (or will be) provided by a road tunnel. Notice however, that in this case a unique window of opportunity exists, during the construction of the tunnel itself, before it is opened to the traffic. The Kamioka observatory is in a mine, with horizontal access. Hydroelectric power stations offer similar opportunities (CJPL, INO, CUNPA). SNOLab and SURF have vertical access, in mines, operational for the former, dismissed for the latter. The operation costs are higher for vertical access. However, in the case of SNOLab the mine contributes in-kind in sectors like safety, security, access.

The support facilities on the surface differ widely between the DULs, both in the laboratories and workshop and in the quantity and skills of personnel.

Underground space is the main mission of all the DULs. The corresponding allocation policies differ. Some laboratories do that on the advice of a fully international Scientific Advisory Committee, other are substantially controlled by the host Nation or Institution. Two different approaches are exemplified by LNGS, which has three large general purpose halls and allocates space, in general, for a defined period of time, and Kamioka that builds new halls “on demand” of new experiments.

Other differences are in the degree of internationality of the community, in the presence or not of other science (biology, geology, engineering, etc.), in the structure of the management, in the funding regulations, in the safety, security, environmental, technology transfer and accountability policies.

The capital investment necessary to build the laboratory infrastructures is obviously an important issue and needs to be accurately evaluated in the design phase. A number of test drills is necessary for a complete knowledge of the geology of the site. Notice that not all the rock types are suitable for excavation of stable cavities. All the costs of the project must be evaluated as accurately as possible and a proper risk analysis performed before submitting the project to the Funding Agencies. Missing to do so in a few cases in the past lead to loss of credibility.

It may be useful to have an order of magnitude idea, analysing the costs of the existing infrastructures. Site dependent factors can be sizeable, but, in general, the costs of excavation, once the starting ones are covered, are proportional to the volume and those for the rocks stabilization to the area of the surfaces. I give a few examples. The cost of the service equipped LNGS, which an excavated volume of 190,000 m³, extrapolated to 2011 is of 57 M€, or 300 €/m³. The project of an independent access tunnel, 6 m diameter, 5 km length, made in 1999 to be excavated with a tunnel boring machine (TBM) lead to a cost evaluation, which extrapolated to 2011 is of 55 M€, or 220 €/m³. The DOMUS project of LSM takes the opportunity of the excavation of a second road tunnel, for building a new experimental hall of about 14,000 m³ plus access corridors, with a cost of 7 M€ evaluated on the basis of

a unitary cost of 300 €/m³. The cryopit at SNOLab has a volume of 40,000 m³ and an area of 3500 m². Its cost was 15 M\$Can, corresponding, once more, to about 300 €/m³. The unitary cost is substantially lower for larger cavities as those of the LAGUNA study.

Only a fraction of the total volume is directly available to experiments. Corridors connecting the experimental halls may reach a substantial fraction of the total. Consequently, compact structures are cheaper, but require the availability of a large enough volume of good rock. For newly built infrastructures this can be searched for in the project phase, while may require substantial tunnelling to be reached in an existing mine (which are excavated for other purposes). Notice on purpose that refurbishing an existing mine tunnel is substantially more expensive than drilling a new one. Very high and difficult to evaluate in advance are the costs to rehabilitate an old infrastructure in an abandoned mine, corresponding to an increased project risk.

3. Monitoring

Progress in the underground experiments is strictly linked to the progress in background reduction. The background budget contains intrinsic components in the detector itself and its shields and external components due to the environment. The latter are different in different laboratories and must be known by the scientific users to be able to design their shields. The environmental background fields are the following.

Atmospheric muons. Their flux decreases almost exponentially with increasing depth from a few 10⁻³ m⁻² s⁻¹ at Kamioka and LSC (at about 2 km water equivalent) to a few 10⁻⁶ m⁻² s⁻¹ at SNOLab and CJPL. They induce background both directly, interacting in or near the detectors, and indirectly producing neutrons by spallation. The former can be suppressed by anti-coincidence. Muon flux varies during the year with a periodic modulation of a few per cent, with maximum in summer and minimum in winter, due to the variation of the atmospheric temperature and density. Muon flux can have substantial direction dependence that must be measured.

Neutrons. Neutrons come mainly from (α , n) reactions and fission of U and Th in the rocks and in the concrete used for stabilization. Their energy spectrum, which must be measured, decreases almost exponentially, but with several peaks, with increasing energy up to about 8 MeV. The fluence does not depend on the depth (if larger than 100 m or so), but depends on the local geology and on the concrete used for lining (and that consequently must be accurately selected). The flux ranges from a few to many 10⁻² m⁻² s⁻¹. Very low radioactivity concrete has been used at BNO to reduce the neutron flux down to 0.2310⁻² m⁻² s⁻¹. These neutrons can be shielded.

Higher energy neutrons, up to several GeV, are induced by the muons by spallation reactions in the environment, in the shields and in the experiment itself. Their flux depends on the depth and is typically two or three orders of magnitude smaller than for the low energy neutrons. However, only the externally produced component can be shielded and requires thick shields. The fast internal component can be reduced by anti-coincidence of the muon. This is done to four orders of magnitudes in BOREXINO. Metastable nuclei are more difficult; they can reduced increasing depth. The background is experiment dependent, being more severe if high-Z materials are used, in particular in the shield.

The gamma background field is due to nuclear decays in the environment, mainly in the rocks and in the atmosphere due to ²²²Rn and daughters. Flux and energy spectrum must be measured. The flux is a function of the local geology and does not depend directly on the depth. Typical values are a few 10⁴ m⁻² s⁻¹.

Radon. ^{222}Rn in the air is a source of background both direct and through the long life daughters it brings to the experimental surfaces. Its activity in the air strongly depends on the local conditions and on the ventilation and must be constantly monitored in a few locations in the laboratory. In the DULs its average ranges from tens to hundreds of Bq/m^3 , with periodic and non periodic variations. Strong seasonal dependence has been observed, for example, in the Amran tunnel. The 120 m long structure was originally excavated to host a gravitational antenna in the Negev desert in Israel and is now used as an underground geophysics observatory. Rn activity is minimum in winter and an order of magnitude larger in summer ($40 \text{ kBq}/\text{m}^3$) in phase with the external temperature [17]. An annual modulation of about 20% amplitude with maximum in summer is observed also at LSC, strongly correlated, in opposite phase, with humidity [18].

Rn can be reduced by orders of magnitude in limited regions by fluxing pure N_2 or “Rn free” air produced by dedicated structures. Three of them, reducing Rn by three orders of magnitudes, are installed at LSM and at LNGS for the CUORE and DarkSide experiments.

Temperature and humidity. The temperature underground tends to be constant and is controlled, at least in the main laboratories, by air conditioning. On the contrary, the humidity in the input air varies with a strong seasonal component. For example at LSC the variation is between 50% in winter and 80%–90% in summer. Depending on the air conditioning system, part of the modulation may survive after treatment.

Other environmental parameters may need monitoring. This is done for example at LSC for the convergence in several locations by means of a monitoring system based on optical fibres that measures the distance between their extremes on a number of sections with micrometric accuracy.

4. Space available in “old” laboratories

4.1. LNGS [11]. <http://www.lngs.infn.it/>

The conclusion of the CNCS programme and the termination of the WARP experiment will make available, after their decommissioning in the next few years, Hall B, which is 100 m long, with the exception of the space taken by XENON 1 t, and 33 m length in Hall C. The “third generation” scientific programme is being defined on the basis of the experimental proposals, including a next generation nuclear astrophysics facility.

4.2. LSM [10]. <http://www-lsm.in2p3.fr/>

The DOMUS project consists of a new hall of $40\text{--}50 \times 18.2 \times 15.6 \text{ H m}^3$ that will be built near the old laboratory between the existing road tunnel and a new parallel one under construction, with a TBM. The latter entered from the French side and is already beyond the LSM location.

The scientific programme is under definition. Proposals and expression of interest include dark matter search (EURECA with bolometers, DARWIN with noble liquids, MIMAC with TPC), double beta decay (SuperNEMO tracking calorimeter, and COBRA), Double EC (TGVIII pixel detector and Ge), Supernova neutrinos (TPC sphere) and R&D activities, geology and environmental studies.

4.3. CUPP. Centre for Underground Physics in Pyhäsalmi (Finland). <http://www.cupp.fi>

The Centre is hosted in a working mine, which is expected to close around 2019. Several cavities, dismissed by the mine, are available at different depths down to 980 m, for a total area of more than 1000 m^2 . Presently, the mine works at between 1000 and

1440 m depth. Access is both via a shaft and an inclined tunnel. The EMMA experiment on atmospheric muons has been installed. CUPP has been proposed by the LAGUNA-LBNO project as the site of the far detector of a neutrino beam from CERN. A site Investigation Project for very large caverns, has been funded for 1.5 M€ by Finland.

5. New laboratories and projects

5.1. LSC [8]. <http://www.lsc-canfranc.es/en/index.html>

The old Canfranc underground laboratory was created under the Pyrenees and operated since 1985 by A. Morales and the Nuclear and High-Energy Physics Department of the Zaragoza University. The new LSC has started operation in 2010. Its maximum rock overburden is 850 m. Including the old facilities, the total area is 1560 m^2 and the volume 10500 m^3 . It is located between two parallel tunnels, one for road traffic and one for safety. The two are connected by by-pass galleries. The access is horizontal on the basis of an agreement with the Tunnel Control Centre, which provides a substantial in-kind contribution to LSC in matter of safety and control of access. Rn activity in the air is variable around $70 \text{ Bq}/\text{m}^3$ (average $60 \text{ Bq}/\text{m}^3$ in November–December, $80 \text{ Bq}/\text{m}^3$ in June–August). Preliminary measurements of the μ flux gave $5 \times 10^{-3} \text{ m}^{-2} \text{ s}^{-1}$. The neutron flux is $3.47 \pm 0.35 \times 10^{-2} \text{ m}^{-2} \text{ s}^{-1}$ and the γ flux $1.23 \pm 0.17 \times 10^4 \text{ m}^{-2} \text{ s}^{-1}$.

The scientific programme is under development. Double beta decay search is performed by NEXT, a high pressure 100 kg enriched ^{136}Xe TPC with electroluminescence read out; dark matter search experiments include ANAIS, looking for annual modulation with NaI crystals, ROSEBUD with scintillating bolometers and ArDM with a two-phase TPC. Two more experiments, BiPo and SKGd, perform R&D for SuperNEMO and for the possible addition of gadolinium to SuperKamiokande respectively.

About one third of the larger hall (Hall A: $14.5 \times 40 \times 10 \text{ H m}^3$) is still available for more experiments.

The GEODYN observatory consists of instruments measuring strain, velocity and acceleration. Geodynamic observatories underground provide complementary information to surface. In addition, the background that on surface is due to natural and anthropogenic phenomena is substantially reduced underground. Correlations between seismic signals and water flow in Aragon valley as well as storms in the bay of Biscay have been observed and are being studied. GEODYN is part of EPOS (European Plate Observing System) and is integrated in the seismic European networks.

LSC and the network of nearby tunnels offers an interesting possibility to study life deep the underground, which are under study.

The proposal for an extension to build a nuclear astrophysics facility with a 3 MV ion accelerator has been submitted.

5.2. SNOLab [12]

In Northern Ontario (Canada) is the third largest and second (after CJPL) deepest of the working laboratories at 2070 m under flat surface, in the working Creighton nickel mine operated by Vale Ltd. It has the unique feature to be all of clean room characteristics. The access is vertical through the Vale maintained shaft and conveyances. The pros are significant operation savings and the integration of the safety procedures with the mine ones, the cons the need to synchronize access with mine works and the limits on the size of the elements introduced from outside to $3.7 \times 1.5 \times 2.6 \text{ m}^3$. Procedures are in place to separate the “dirty” mine environment from the clean one of the laboratory. Rn activity in the air is $130 \text{ Bq}/\text{m}^3$, the muon flux is $3 \times 10^{-6} \text{ m}^{-2} \text{ s}^{-1}$, the neutron flux is $9.3 \times 10^{-2} \text{ m}^{-2} \text{ s}^{-1}$.

A rich programme is ongoing and under development. It includes: dark matter search with DEAP and CLEAN with noble liquids, COUPP with bubble chamber, PICASSO with superheated sphere, SuperCDMS with Ge bolometers; Double beta decay and neutrino physics with SNO+ (^{130}Te in liquid scintillator) and EXOgas R&D; Supernova neutrinos with HALO (ν_e CC interactions in Pb).

Space for more experiments is still available, in particular in the cryopit and in the ladder laboratories.

5.3. SURF [13]. <http://www.sanfordlab.org>

As recalled in Section 1, the Homestake Gold Mine, in Lead, South Dakota, was the historical site where R. Davis discovered the “solar neutrino puzzle”. The experiment was located in a cavity at the mining level 4850 ft (1480 m) below ground and is now referred to as the 4850 L or as Davis Campus.

In July 2007, concluding a long competitive process, the US National Science Foundation (NSF) selected the Homestake mine as the site for the Deep Underground Science and Engineering Laboratory (DUSEL). By then, mining activity had already ceased since several years, after over 125 years of mining, and water had filled the lower parts of the mine at the rate of 1.2 Mt/yr. In 2003 Barrick Gold Corporation had donated the site to the State of South Dakota. Then, the South Dakota philanthropist, T. Denny Sanford had gifted 70 M\$ to build a research laboratory and develop a science education facility. More funds were provided by the State of SD and by NSF. After the decision of the National Science Board, in December 2010, to discontinue further funding, NSF DUSEL activities were zeroed in fiscal year 2012. Consideration of the activities of the Sanford Laboratory, or SURF, as had been named in the meantime, was shifted to the DoE with continuing support of the State of South Dakota.

With these funds, accumulated underground water has been pumped out, the two vertical accesses to 4840L were rehabilitated and improved. The Davis Cavity was enlarged ($18 \times 11 \times 13 \text{ m}^3$) and brought to laboratory standards. A new laboratory has been excavated nearby ($43 \times 16 \times 5 \text{ m}^3$). These two labs host respectively the LUX experiment, a liquid Xe TPC for dark matter search, and the MAJORANA Demonstrator, on neutrino-less double beta decay with Ge detectors. Geophysics, geology and detector development activities are also part of the programme.

As it is often the case in a mine, the (two) experimental laboratories and the services are connected to the (two are needed for safety) access shafts by pretty long tunnels. Of the total area of 2730 m^2 , 930 m^2 are directly used for science. On the other hand, long existing galleries, similarly to SNOLab and Kamioka Observatories, allow excavation of new halls, with reduced interference in the ongoing activities, if needed.

The site has been proposed as the host of the far detector for next generation long base line neutrino project (LBNE) from Fermilab.

5.4. INO [14]. <http://www.ino.tifr.res.in/ino/>

The India-based Observatory is foreseen to be built 115 km west of Mandurai (that has an international airport) in Tamil Nadu, near the border with Kerala, under 1200 m rock overburden with a 1.9 km long horizontal access.

The forest and environmental clearances have been obtained and civil construction can start soon. The Tamil Nadu government has handed over 66 acres of land for the construction of INO facilities at site. Additional 33 acres of land acquired at Madurai for the INO centre. Graduate training programme with emphasis on hands for detector development running since 5 yr. The project is waiting for the final approval of the Federal Government.

The planned underground structures include a large hall $132 \times 26 \times \text{H } 30 \text{ m}^3$, smaller halls of $55 \times 12.5 \text{ m}^2$ and $40 \times 20 \text{ m}^2$ and connecting tunnels.

The larger hall can host a 100 kt mass ICAL detector dedicated to neutrino physics. It is a magnetized iron tracking calorimeter (MONOLITH technique). 50 kt will be initially built. With the now known “large” value of θ_{13} the mass order can be determined at 3σ with 600 kg yr exposure. Notice that the result is substantially guaranteed, provided the design muon momentum resolution is obtained. A large collaboration has been developed with more than 20 Indian Universities and Institutions. International collaboration is welcome.

5.5. CJPL [15]. China JinPing underground laboratory

The Yalong river in China makes a large U-turn while descending from the 4000 m high JinPing mountain. A hydroelectric power stations system consisting of five parallel, 17 km long tunnels is under construction. Service tunnels run parallel to the water ducts at about 1500 m elevation. The site for the new CJPL is in the middle of a service tunnel, under an overburden of 2400 m, the deepest world wide. The μ flux is only $2 \times 10^{-6} \text{ m}^{-2} \text{ s}^{-1}$. A hall of $40 \times 6 \times 6 \text{ m}^2$ has been completed in 2011. The phase two, with a larger expansion, is under study. The laboratory is open to international collaboration.

The present research programme appears to be rapidly developing. It presently includes dark matter searches with CDEX (China Dark Matter Experiment) based on hyper-pure Ge detectors and with PANDA-X a liquid Xe TPC, with modules of 25 kg in phase 1200 kg in phase 2.

5.6. CUNPA. Centre for Underground Nuclear & Particle Astrophysics in Korea. <https://www.ibs.re.kr/en/research/astrophysics/astrophysics.jsp>

The existing Y2L laboratory utilizes a cavity of the host YangYang Pumped Storage Power Plant. Access is horizontal by car. The rock overburden is 700 m with a μ flux of $2.7 \times 10^{-3} \text{ m}^{-2} \text{ s}^{-1}$. The neutron flux is $8 \times 10^{-3} \text{ m}^{-2} \text{ s}^{-1}$ for $1.5 \text{ MeV} < E_n < 6.0 \text{ MeV}$. The radon activity is 40–80 Bq/m³. The underground space is mostly occupied by the Korea Invisible Mass Search (KIMS) experiment, currently taking data for a WIMP search with 100 kg CsI(Tl) crystal detectors. Other activities include R&D for $0\nu 2\beta$ decay and background measurements with a HPGe counter.

The new Institute for Basic Science (IBS) was established in Korea in 2011. In 2012 IBS launched a first call for research centres and for corresponding director appointments. The proposal for the CUNPA research centre was approved by IBS in May 2013 and funded with 10 M\$/yr, for infrastructures and experiments, starting in the same year.

Three different alternatives are under study: 1. An experimental hall of 1000 m^2 area and 7 m height at the Y2L site, with an estimated cost of about 5 M\$; 2. A hall of the same dimensions, but 1050 m deep, with an access tunnel of $1600 \times 4.5 \times 4.5 \text{ m}^3$ and an estimated cost of about 10–15 M\$; 3. Another location near an operational mine. The experimental programme under study includes proposals for dark matter search (KIMS+), double beta decay (AMoRE), Nuclear astrophysics and low temperature detectors R&D.

5.7. ANDES [16]. Agua Negra Deep Experiments Site

A large freeway infrastructure joining Pacific and Atlantic Oceans between Chile and Argentina, connected to Brazil and Paraguay has been recently approved in South America. Two parallel tunnels, one for each direction, 13.9 km in length, will cross the Andes. The Argentine entrance will be on altitude of 4085 m, the

Chilean one of 3620 m. The deepest point will have a rock overburden of about 1750 m. The call for expressions of interest was published in July 2013. The completion of the tunnel is expected for 2021.

The construction of the Agua Negra tunnel offers a unique opportunity to build an international facility for multidisciplinary underground science in the southern hemisphere. The CLES Latin American Consortium for Underground Experiments has been created (Argentina, Brazil, Chile and Mexico). It is open to international partners.

The first design of the laboratory is expected to be completed by October 2013, to be submitted for approval. Civil works will be part of the tender for the tunnel. The lab volume and cost are around 2% of those of the tunnels.

The present design foresees a main hall $21 \times 23 \times 50 \text{ m}^3$ a secondary hall of $16 \times 14 \times 40 \text{ m}^3$ and a large pit 30 m diameter 30 m H and a few smaller halls. Two surface laboratories at lower altitudes are foreseen, at Rodeo in Argentina and Vicuña in Chile.

The scientific programme under development includes neutrino physics, astrophysics and geology. A large neutrino detector with the BOREXINO technology is under study, taking into account the opportunities for geo-neutrinos at the location. Supernova neutrinos detection will allow triangulation with Northern detectors. Double beta decay can be part of the programme, as well as dark matter exploiting modulation (different environmental phases) and developing new technologies. Other chapters will be on geophysics (the site is on the Nazca plate), biology underground, low background measurements and nuclear astrophysics.

6. Conclusions

Underground laboratories have discovered physics beyond the Standard Model, almost contemporarily to its creation, in the Homestake mine. Since then the field is progressing steadily.

Much underground space is already available in several laboratories and more will be ready in the next decennium. Underground space will not be a limiting factor.

The cost for next generation – ton scale – double beta decay and – multi-ton scale – dark matter experiments will be comparable

with that of the laboratory hosting them. An enormous effort will be needed to reduce the background index as much as needed for so large exposures. We do not know what will come next.

The chapter of atmospheric neutrinos is far to be closed, importantly enough, it can give us the sign of the mass hierarchy, provided the international effort is sufficient.

Supernova neutrinos, especially electron neutrinos, need more consideration.

Geology, as exemplified by GIGS at LNGS and GEODYN at LSC, may become an important, even if limited, element of the programme, provided professional geophysicists are involved. A global network for geo-neutrinos might give important contributions. Study of how life develops in the massif hosting the laboratory can give interesting results.

The moderate costs of an underground facility, compared to other scientific laboratories, tends to induce decisions in different countries, which appear to be sensitive to geo-political arguments. We, the scientific community, should pay attention mainly to the scientific relevance.

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