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The ANDES Underground Laboratory Project

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Abstract

This talk will be devoted to the presentation of the ANDES underground laboratory project. We shall talk about the motivations, prospects and design of this facility, which will be the first of its type in the southern hemisphere. The physics involved, as well as other potential applications to biology, geology and material sciences, are discussed.

Keywords:
neutrino physics, dark matter, underground lab, low-radiation environment,

1. Motivations

The activity generally referred to as experimental underground physics aims at the measurement and detection of events which require extremely low backgrounds. This is the case of the detection of dark-matter particles, double beta decays, supernovae-neutrinos, etc. The existing underground facilities are most of them in the northern hemisphere. The main characteristics and research lines of some of the major underground laboratories are described in the review by A. Bettini [1]. As an example, a list of the current and planed experiments of SNO-lab can be found in [2]. The basic research related to dark-matter and neutrino properties is pointing out to basic questions like the composition and structure of the Universe [3], the nature of the neutrino [4, 5], and the evolution of matter in extreme stellar conditions [6, 7]. From the experimental point of view, the events which may lead to the identification of dark matter particles and rare electroweak decays, like the neutrinoless double beta decay, have extremely low counting rates and/or produce transitions at energies which almost always overlap with transitions which take place in radioactive natural elements of the background. The detection of these rare events is strongly hampered by cosmic radiation. Then the need to shield detectors by going underground. In fact, one can get a reduction of the cosmic radiation effects, by orders of magnitude, by digging labs some kilometers under-the-surface, or by building them under mountain rocks. The ANDES laboratory project aims at the construction of a horizontal facility under the ANDES mountains, in San Juan Province (Argentina). The lab will be located next to a couple of road tunnels (the Agua Negra complex), which run under the mountains leaving some 1800 meters of rocks on top of the planned site of the lab (about 4800 meters of water equivalent). Figure 1 shows a comparison between the shield, in meters of water equivalent, at some of the existing underground laboratories, and that of ANDES.

About the tunnel: the project which has been approved and which is managed by the Bi-Nacional Commission Tunel de Agua Negra (EBITAN), a joint entity created by Argentina and Chile, proposed the construction of two tunnels, each of them of 12 meters of diameter, separated by 60 meters and running across the ANDES some 14 km long from the Argentine entry point at the Quebrada San Lorenzo, 4085 meters above sea level to the Chilean entry point on a ridge, at 3600 meters above sea level. The system will be connected by internal connection galleries every 500 meters. The deepest point under the mountain is 1750 meters below the peak. The tender is expected in 2015 and the construction will begin in 2016 and it will go for four years.

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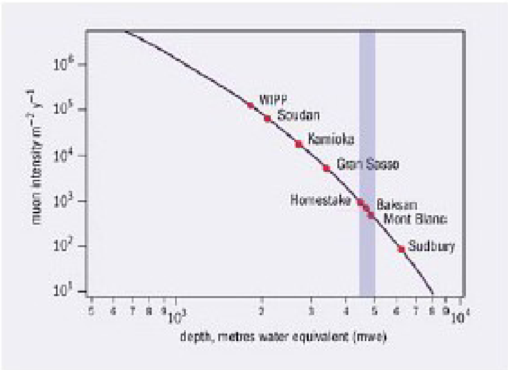

Figure 1: Radiation shielding of some of the largest underground laboratories, measured in meters of water equivalents, and the one expected for ANDES

The construction of the tunnel offers then a unique possibility to built up a scientific complex suitable for the detection of events under ultra-low radiation exposure, as required for dark matter and neutrino studies, as well as for other areas of research. The planned laboratory will have a structure similar to the Gran Sasso and Modane laboratories, and it will be a unique facility in the southern hemisphere, with a large potentiality for regional integration of efforts in several branches of science.

2. The Underground Laboratory ANDES

The ANDES Laboratory Project, which started some four years ago following a proposal made by a group of physicist from Argentina, Brazil, Chile and Mexico, consists of the design and construction of an underground laboratory in a site adjoint to the Agua Negra Tunnel complex in San Juan Province, Argentina. It will be the first underground facility in the southern hemisphere and for its size and location, it will offer a unique possibility to perform ultra-sensitive measurements in physics, geology, biology and material sciences.

The laboratory will be located in the deepest part of the Agua Negra pass, which is composed by two tunnels running 1750 meters below the Andes. From the point of view of insulation to cosmic radiation that deep amount to about 4800 meters of water equivalent. Due to this unique location, the ANDES lab will be able to host sensitive experiments which require ultra-low background radiation, like dark matter detection, neutrino related experiments (geo-neutrinos, neutrino oscillations, double beta decay experiments), low-radiation biology, crystal-growing at low radiation and geology, as well as the development of new materials under ultra-low radiation conditions.

The laboratory will be managed by a board, the Latin-American Consortium for Underground Studies (CLES), composed by representatives from at least four countries (Argentina, Brazil, Chile and Mexico), which will have a structure similar to the CERN in Europe, and to which other countries of the region can access.

ANDES will host international collaborations on experimental areas of great impact in physics, cosmology, geology, biology and material sciences. Among the main planned research lines are dark matter detection, the development of new ultra-sensitive detectors, the use of modular detectors like Majorana and SuperNemo modulus, and the development of a low energy-high intensity source for nuclear astrophysics experiments. The selection of the proposals will be made on the basis of the scientific relevance and regional impact for the CLES participant countries. As in any other large laboratory, the analysis of the proposals will be made by a scientific committee under well defined requirements concerning size, time-scale and financial aspects.

The activities of the laboratory will be accompanied by at least two supporting centers, one in La Serena (Chile) and another one in Rodeo (Argentina). In addition, the University of San Juan and the National Research Council of Argentina (CONICET) will offer academic support to the activities of the laboratory by means of the CONICET regional research center of the San Juan area.

3. Brief report on technical details about the laboratory

In this section we shall describe briefly some of the technical details of the ANDES laboratory. We shall mainly discuss some aspects of the design to give an idea about the size of the project and about its possibilities concerning current and future research and development in matter of detectors for neutrino and dark matter physics.

3.1. Location and geology of the site

The laboratory ANDES will be located at 4.5 km from the western (Chile) entrance to the tunnels, at about 60 meters from the southern tunnel (The Agua Negra complex consists of two parallel tunnels with a total length of about 11 km). At this location the vertical shielding of rocks is of the order of 1750 meters. However, the final location of the laboratory will be determined by the composition of the rocks at the site, its geo-mechanical properties, the amount of cosmic radiation at the place, and the natural radioactivity of the rocks. Preliminary studies have shown that the background radiation (40K, 232 Th and 238 U) calculated on the basis of a simulation of the composition of the rocks at the site, which are Andesita, Rhyolite and Basalt, may be of the order of 60 Bq/kg for each of the rock species.

ANDES is very important, as a prospect, in addition for us of being in Latin America, because being the only deep underground laboratory in southern hemisphere it will display opposite seasonal induced modulations, the region has low reactor-neutrino activity, distances to the reactors are the following: to Embalse (2.1 GWt reactor) 560km, to Atucha (1.2 GWt) 1080km (idem to Atucha II which is a 2.1 GWt reactor). ANDES will be a suitable place to perform geophysical underground measurements. It will be located at almost ideal distances, for long baseline neutrino oscillation experiments, from CERN (9920 km), Fermilab (7640 km), KEK (12425 km) and of course at 1500 km from Earth center (geo-neutrino experiments).

The ANDES initial scientific programme on neutrino physics includes double beta decay experiments, a large Latin-American neutrino detector KamLAND-Borexino-style focus on low energy solar, supernovae and geo-neutrinos, and dark matter modulation measurements. It also aims at new detector-technologies, a seismograph station, and to the construction of an accelerator to measure nuclear astrophysical reactions at low background conditions. The other aspects of the research plan include biology measurements under low radiation and the evaluation of radiation damages in materials.

3.2. Access to the laboratory

The main road in the southern tunnel will be broadened to allow the access to the laboratory of vehicles of large size and containers. The access will also include a loop to access the other tunnel in case of accidents or fire incidents in the southern tunnel. The details of the access to the laboratory from the tunnel are shown in the drawings. It has been designed accordingly to safety reasons, and to allow the circulation of large vehicles. The laboratory compound and the transit tunnels will be isolated to prevent fire from the tunnels to enter the laboratory.

3.3. The principal cavern

The principal cavern is a 50 meters long, 23 meters height and 21 meters broad room, located in the central part of the complex. The entrance to the principal cavern is by the access tunnel, which is protected by a heavy door, in order to isolate it from the transit tunnels, as shown in the pictures. In the upper part of the main cavern it will be placed a crane-bridge of 40Tn. It is there to allow for the access to the carriers of the equipments and to the transport of them to the area of ensemble, which is a 35 meters long and 19 meters wider area. The ensemble area is provided by system of lateral channels which will drain liquids which may accidentally leak during the charge and discharge operations. These liquids, in turn, will be directed to the secondary cavern for processing and cleaning.

3.4. Secondary cavern

The secondary cavern will be a 40 meters long, 16 meters broad and 14 meters high room of ovoid shape. It will be equipped with a crane-bridge of 20Tn working-weight. The secondary cavern will host, mainly, the central ventilation system (the total volume of air of the complex should be renovated , at least, every hour). The ventilation system will include the radom-filter. Also the cavern will host the air-conditioning system, since the laboratory must be kept at an average temperature of 21 degrees Celcius. Both the ventilation and air-conditioning, must be designed to work even when the laboratory is demanding the peak power of 2MW. The other equipments to be placed in the secondary cavern are the electric power generators, the low-power batteries needed to protect the experimental equipment in case of electrical power-failures, the tanks for the treatment of water, the computers and data-acquisition systems, the communication network, and other auxiliary systems (like medical first-aid facilities, internet nodes, fire-control systems, etc). The total power supply required is of the order of 2MW, half of it will be needed to operate the ventilation system and air-conditioning, and the other half will be available for the experiments.

The rooms will work under a low excess of pressure. It will result from the circulation of air which will enter the lab from the exterior by a stainless steal (or a similar material) pipe to avoid the contamination with the radom.

The flux of water needed for consume, to either human and measurement equipments, will be of some liters per second. In the interior of the cavern will be placed a water-tank and a system to treat disposed liquids, accordingly to standard regulations concerning rules of safety for potential environmental damages.

The computer center of the laboratory will be connected to the supporting centers located at both sides of the tunnel, in Argentina and Chile. The connections will be made of mono-mode optical fibers (for the internet), and one additional channel will propagate a high-precision time-signal calibrated by GPS. Two other additional lines, of copper, will be added to allow for communications in case of failures of the optical fibers.

3.5. Principal pit

The main pit of the laboratory will be a large one, 42 meters deep and 30 meters of diameter. A secondary tunnel will allow the access to the pit, at some 30 meters from the bottom. The pit will host a large size experiment (e.g. a high sensitivity neutrino oscillation detector). To minimize the effect of external radiation, the pit will be flooded with water up to the secondary tunnel. For this, the pit will be dotted with a water-pumping system, which also may work as a backup water-reservoir connected to the fire-preventing main system of the entire facility. An auxiliary access to the pit, at the bottom of it, will be constructed to install measuring equipments and detectors. The access will be closed, once the pit is filled in with water, and it will be designed to resist the pressure of the water at the bottom.

In the upper part of the pit a large crane of at least 20 Tn of working weight will allow to move the equipment to and from the pit and to bring support to the stairs and pipes needed to access the experiments. An isolated system will provided the power, fresh air, and data acquisition lines to the area of the experiments.

3.6. Secondary pit

A secondary pit, 15 meters deep and 9 meters of diameter, will be devoted to measurements in conditions of very low radioactivity. To access the pit an alley located at 10 meters from the bottom of the pit will be constructed. In the interior of the alley will be located a water insulated room, with the measurement devices and to protect them from the water (the pit may eventually be flooded to increase the shielding if the experiments to be performed require such a condition). A system of isolated pipes will provide the power lines, ventilation, data acquisition lines and remote control lines to the control room inside the alley.

3.7. Auxiliary caverns

The complex will include at least three auxiliary caverns of 10m x 10m x 10m, which will host auxiliary installations (like offices for the laboratory staff, technicians, and visitors) and experiments which require small areas.

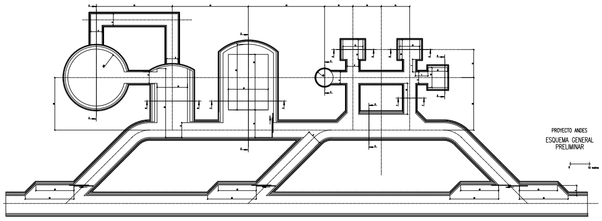

Figure 2: Road-southern tunnel (bottom), the three auxiliary connecting tunnels, and the service tunnel (middle). At the top, from left to right, are shown the main pit, the secondary and main caverns, the secondary pit and the service-caverns and small pits

3.8. Composition of the walls and electrical installations

The walls of the caverns will be covered with concrete of low-radioactivity, following the measurements and control of the samples of the concrete, even in the auxiliary areas. The electricity-control-panels, and the supply cables, will be made of non-toxic materials, to prevent accidental fire. All systems will be supplemented by backup units.

3.9. Design

In the attached figures we show a possible distribution of places in the laboratory. The size of each compartment and the arrangement shown in the drawings are preliminary, since they are depending on the structural properties of the site, as determined by the excavations. The technical adjustments will preserve the inner size of each of the caverns, to optimize the available space. The actual size of the laboratory has been designed to accommodate the state of the art experiments in each of the scientific areas described before, particularly concerning those which require a large space, like the neutrino oscillation experiments.

Figure 1 shows the distribution of sectors in the lab. From the road tunnel (bottom of the figure) the three auxiliary tunnels connect it with the access tunnel (service tunnel) of the lab (middle of the figure) and from it one can reach the main and secondary caverns as well as the main and secondary pits and service areas of the laboratory. The actual dimensions are given in meters.

Figure 2 shows the section of the main pit, which will be devoted to a large size neutrino experiment, like a neutrino-oscillation detector. The sources will then be supernovae, the sun and the earth (geo-neutrinos).

Next figures 3 and 4 show the size of the service and access galleries and the main hall of the laboratory, as compared with the size of the road-tunnels.

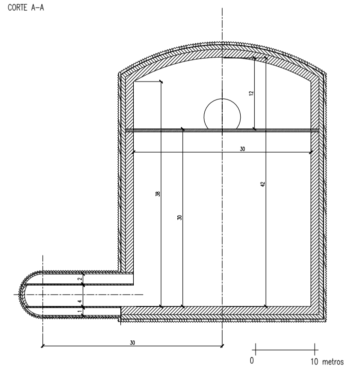

Figure 3: View of the principal pit, with the service alley at the bottom, the curvature of the top is designed for structural reasons

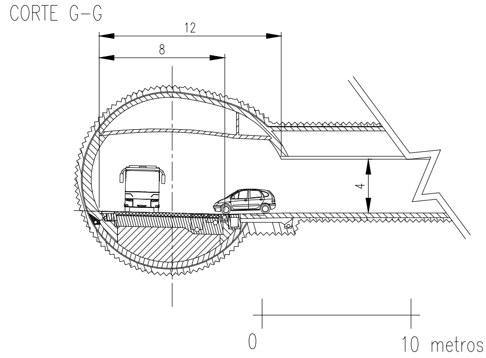

Figure 4: Access gallery from the road tunnel. The vehicles are shown to give an idea about the actual size of the complex

4. Conclusions and prospects

The ANDES laboratory enterprize will be a unique opportunity for a Latinamerican Consortium devoted to the development of a competitive science in the region. The proposal has already received the support of Argentina, Brazil, Chile and Mexico. Particularly, it went through a detailed evaluation by the Argentine Ministry of Science and Technology and it was approved as a major project. The participation of these countries, and eventually of other countries in the region, to the Scientific Committee of ANDES will allow for a definition, selection and construction of a Latinamerican neutrino flag experiment. It will offer the chance to integrate with other labs/experiments, host third generation double beta decay and dark matter experiments and increase the potential of the region by increasing its academic activities, the formation of new human resources and the development of new basic research and technologies.

To conclude, this is a unique opportunity to build a world class deep underground laboratory, the only one in the southern hemisphere, with a strong impact on the regional integration. In this respect we hope that the long range aim of building a scientific network similar to the CERN, adapted to the regional needs and possibilities of Latin America may indeed materialize, for the benefit of the generations to come.

5. Acknowledgements

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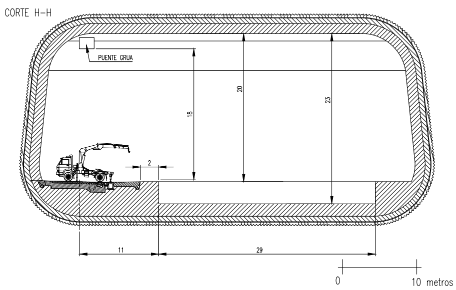

Figure 5: Main service hall of the laboratory. For the sake of illustration about the size of the hall a mobile crane is depicted in the figure

For further details about the laboratory and contacts, please visit the official web page of ANDES,

http://andeslab.org/

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