The ANDES Underground Laboratory*

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Abstract

ANDES (Agua Negra Deep Experiment Site) is a proposed underground laboratory to be built inside the Agua Negra road tunnel under the Andes Mountains at the border between Argentina and Chile. It will be the 3rd deepest underground lab in the world and the deepest in the Southern Hemisphere. ANDES is expected to host experiments from world level collaborations in Particle and Astroparticle Physics, Seismology, Geology, Geophysics and Biology. Here we present the general features of the laboratory, the expected science program and the current status of the proposal.

INTRODUCTION

ANDES (Agua Negra Deep Underground Site) is a proposed underground laboratory [1–3] to be built inside the Agua Negra road tunnel. The proposal takes advantage of the planned construction of this road tunnel which will connect Argentina and Chile across the Andes mountains between the San Juan Province (Argentina) and the Coquimbo Region (Chile). As of today, ANDES will be one the first two underground laboratories of this kind in the Southern Hemisphere.

ANDES is proposed to be located at the deepest point in the tunnel, 1750 m vertical below the surface, becoming the third deepest underground lab in the world and providing an attenuation of 10^{-7} for the atmospheric muon flux. This level of shielding will provide the sensitivity required for unique experiments in Physics such as Dark matter searches and Neutrino physics, and other sciences as Geophysics, Seismology, Biology, environmental studies, cosmic radiation impact on instrumentation and more.

The lab is planned to host experiments from collaborations worldwide. The selection of experiments will be based on their scientific value and their relevance to the member nations, and shall fulfill aspects of safety and environmental impact. In addition to the underground site, there will be two Support Laboratories on the surface, one near the city of La Serena (Chile) and the other in the town of Rodeo (Argentina).

The laboratory will be managed by a Latin American consortium, CLES (Consorcio Latinoamericano de Estudios Subterráneos), an entity formed among the participating countries. The current participants leading this proposal are Argentina, Brazil, Chile and Mexico. It is expected that further nations will join in. The following sections describe the Agua Negra Tunnel, the Laboratory with its preliminary science program and the description of its conceptual design, preliminaries for the organization, and a summary.

THE AGUA NEGRA TUNNEL

The Agua Negra tunnel across the Andes mountains is part of the new international road that will connect the Province of San Juan, Argentina with the Region of Coquimbo, Chile, at latitude 30.19° S and longitude 69.82° W, providing a year-long access between the countries. The current pass, at 4780 m a.s.l., is closed most of the year due to poor weather conditions. It will be a system of two parallel tunnels 14 km long with two lanes

each, running nearly 100 m apart and connected every 500 m with galleries for pedestrians and every 1500 m for emergency vehicles. The Chilean entrance will be at an altitude of 3600 m a.s.l. and the Argentinian entrance at 4080 m a.s.l., thus providing a 3% slope for natural ventilation and drainage. The total power consumption for the tunnel, including emergency ventilation, is estimated to be near 15 MW. The tunnel has an estimated cost of USD 1.5 billion. Its construction is expected to start in 2016 and will take about eight years until open to the public.

THE LABORATORY

The underground laboratory, If the rock conditions are adequate, will be located at about 4 km from the Chilean entrance, on the south side of the eastbound tunnel where the mountain is higher, providing a vertical coverage near 1750 m of rock and an omnidirectional shield not less than 1670 m (Fig. 1). The exact location will depend mainly on the geomechanical condition of the rock that assures stability, and then on the depth of the site. A 1750 m of vertical rock overburden, 4500 m water equivalent, will place ANDES among the deepest labs in the world, after Jin Ping, China (2400 m) [4] and SNOLAB, Canada (2070 m) [5]. See Fig. 2. The laboratory should be operational at the same time as the tunnel and its estimated cost is around USD 40 million, 2.5 % of the tunnel cost.

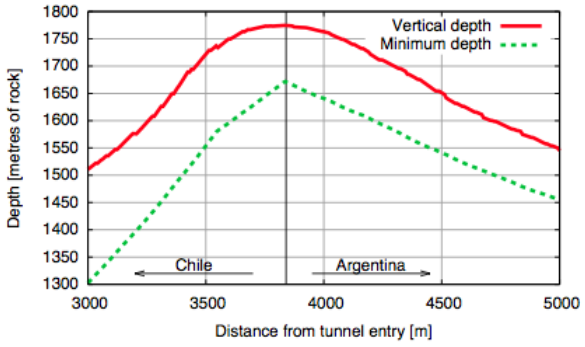

FIG. 1: Vertical and omnidirectional coverage of the rock vs. lab location in meters from the Chilean entrance.

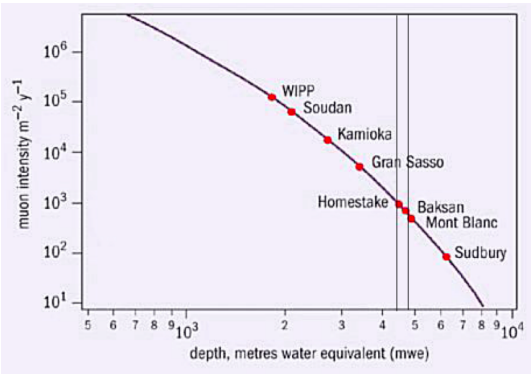

FIG. 2: Muon flux crossing a horizontal section vs. depth, expected at ANDES (vertical band). Muon flux at sea level is near 100 $[1/m^2 s]$.

Nine preliminary rock samples from eight perforations at 600 m deep were analyzed, showing basalt, andesite and rhyolites, with activities that range within 2 - 15 [Bq/kg] for U-238, 0.9 - 5.7 [Bq/kg] for Th-232, and 45 - 60 [Bq/kg] for K-40. These figures can be compared to 4.5 - 30 [Bq/kg] for U-238, 8.5 - 76 [Bq/kg] for Th-232 and 4.5 - 30 [Bq/kg] for K-40 at the Canfranc Laboratory, Spain.

To date all deep underground laboratories are in the Northern Hemisphere. ANDES in South America and SUPL, Stawell, Australia, will be the first in the Southern Hemisphere [6]. A southern location is valuable for several reasons[7], e.g. Dark Matter search at

a southern site may help eliminate possible season-induced backgrounds on the observed yearly modulations in experiments in the north [8, 9]. An additional site in the south will also be valuable to test whether neutrinos from an eventual supernova oscillate as they travel through the inside of the earth.

Other special features of the ANDES site are the low neutrino background from nuclear reactors and its location on the earth's crust near the subduction of the Pacific and Continental tectonic plates, issues that could be relevant for geoneutrino studies [10]. The nearest nuclear reactors are in Argentina: one 2.1 GWth reactor in Embalse, 560 km away, and two other reactors, Atucha I of 1.2 GWth and Atucha II of 2.1 GWth, 1080 km away. The next nearest reactors are in Angra dos Reis, Brazil, about 2660 km away.

SCIENCE AT ANDES

ANDES is expected to host experiments at the frontier in the fields of astro and particle physics in the next decades. It will also host experiments in other sciences, such as Geology, Geophysics and Biology. The southern Andes mountain range is one of the most active seismic regions in the world, and an underground facility like ANDES will provide a valuable site for seismological studies and monitoring. As a low-background facility it will also provide services for high sensitivity measurements in environmental studies and for development in state-of-the art instrumentation and electronics. The preliminary scientific program at ANDES then considers:

Neutrino Physics: these experiments are flagship in many underground laboratories. At ANDES there is a proposal to install a 3 kton liquid scintillator neutrino detector, for studies of geoneutrinos and neutrinos from supernovae, among other sources [11]. This major size detector would be located inside the large pit. In addition, there are proposals for installing neutrinoless double beta nuclear decay experiments, most of which of considerably smaller size, to be located in some of the other caverns.

Dark Matter Searches: the particles that compose the dark matter in the universe is one of the most outstanding questions in Cosmology and Astroparticle Physics. Many experimental techniques exist so far and further techniques are being proposed. Different techniques are sensitive to different ranges of masses of the hypothetical dark matter particles, so this diversity in techniques is still necessary. Some experiments have claimed to see signals that modulate with a year period, possibly due to the variation of the dark matter wind as the earth goes around the sun [8, 9]. To rule out possible backgrounds from seasonal effects, similar detections could be done in a southern site such as ANDES. New Dark Matter detection techniques will also find space at ANDES, as they are expected to fit in the proposed caverns.

Nuclear Astrophysics: the low radiation environment of the ANDES site also allows studies of low energy nuclear physics [12]. These experiments require low energy accelerators in low background environments to study ion collisions of the type that occur in stars.

Geophysics/Geology/Seismology: the Andes mountain range is an active tectonic site in the planet, with plenty of seismic activity. This constitutes a challenge for the design of the experimental equipment. On the other hand it is an opportunity to do underground research

and monitoring of the seismic activity. ANDES should at least be part of a seismograph network within Chile and Argentina. Moreover, taking advantage of the high sensitivity instrumentation at ANDES, several studies of correlation between seismic activity or rock burst and other signals such as radon release can be performed.

Biology: underground sites provide special environments for studies of biological systems in extreme media, in low radiation conditions and the like. ANDES expects to host experiments in these sciences as well.

Low radiation measurements: low background instrumentation in underground sites have been finding new applications and services for the industry and for measurements of traces of indicators and contaminants applied to environmental studies. ANDES will be a unique site in South America for these new types of measurements.

THE UNDERGROUND CAVERNS

Here we describe the caverns in its current status, according to the New Conceptual Design done by Lombardi S.A.[13]. This new design considers longer access tunnels from previous designs to improve rock stability. It includes four full size alternatives depending on the quality of the rock found on site, and two reduced size options as well. The preferred option is the deepest point, located at the frontier between the countries, on the south side of the eastbound Agua Negra tunnel, near km 4 from the Chilean entrance. See Fig. 3.

The access to and exit from the lab will be through detention bays in the tunnel, including traffic lights for flow control. The main access gallery be about 100 long, 3.5 m wide by 4.5 m high, able to fit up to 40 ft container trucks. In the central transit area the gallery will have two lanes for vehicles to cross or park. The emergency room/cafeteria will be located in this sector. There will also be a 470 m long, 3 m wide and 3.5 m high, emergency gallery for light vehicles connecting to the opposite tunnel.

A main gate will be kept closed to limit access to the complex, and further along a second barrier will be closed when the main gate is open.

The laboratory spaces (technical room, secondary cavern and pit, main cavern and main pit, in that order) will be located along a gallery 200 m long, 3.5 x 4.5 m cross section, with enough space for all cables, supply and ventilation ducts required for the lab. For the purpose of rock stability, the minimal spacing between the caverns is estimated to be 40-60 m. The bottom of the main pit will be accessed through another gallery, 250 m long 3.5 m wide, 4.0 m high, with a 12% slope. We now describe the caverns according to Fig. 3.

Service rooms

In the new conceptual design the services are separated in different rooms, for practical purposes. The following rooms are located outside the experimental area:

- The ventilation and air filtering room will be located by the access gallery, connecting to the ventilation gallery; the ventilation equipment will be able to renew the full volume of the lab air every hour and to filter the existing radon in the air. A slight

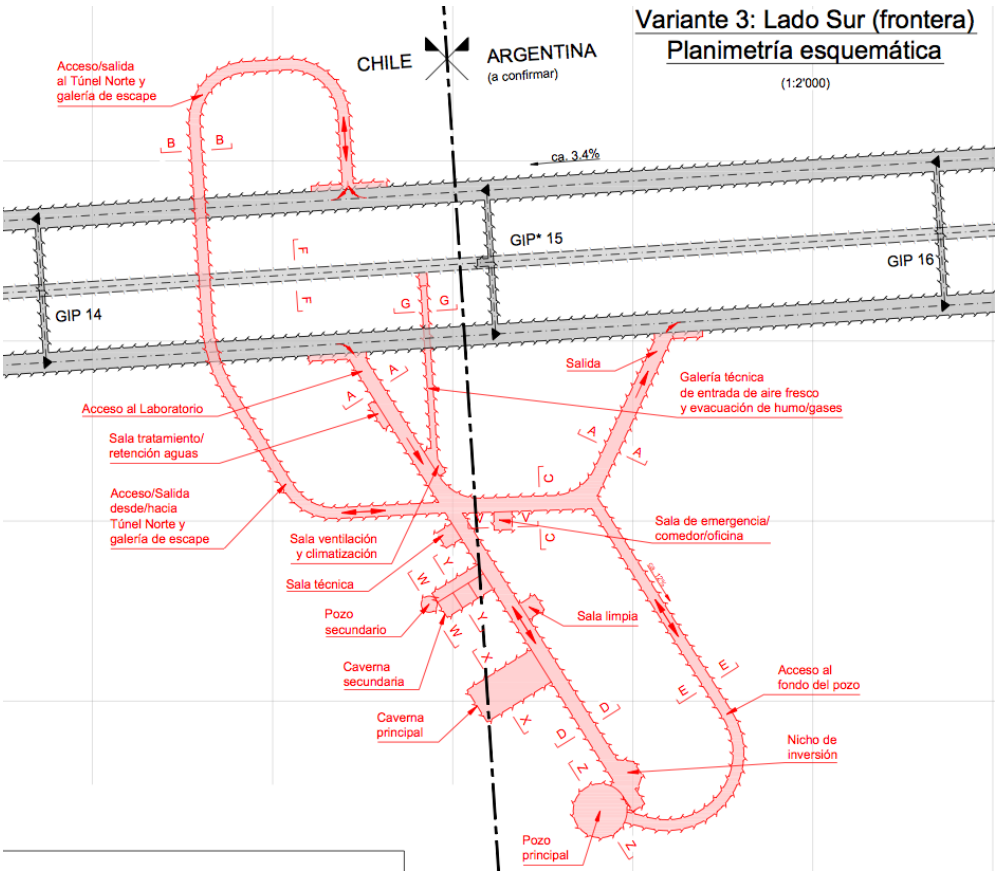

FIG. 3: Top view (not to scale) of the proposed laboratory according to the New Conceptual Study (Lombardi S.A).

overpressure inside the lab area must be maintained. Air conditioning will keep the lab at 21°C even at the 2 MW peak consumption, and will also control the relative humidity to guarantee operation of the equipment and human hygrothermal comfort.

- The water treatment room will be by the entrance gallery; it shall also include a 50 m^3 water reserve tank.

- The emergency room, combined with dining, resting and meeting room will be by the central transit area near the exit gallery. A medical kit for care in case of accidents and in case of altitude sickness will be included. This cavern will include an office with the computer data acquisition and communications systems. The computer center must have a fibre optic connection to both Argentina and Chile: redundant single-mode fibres for internet and one additional fibre for high-precision GPS-calibrated time signals. Two copper lines will be added for emergency communications in the event of fibre failure.

The following two rooms will be inside the experimental area:

- A technical room, located near the entrance, will have the power equipment and generators, compressed air, water and other supplies, including a battery bank for

protection against potential critical outages. The maximum total power required for the laboratory is 2 MW. In emergencies only a small fraction is needed, since most primary systems switch off. Half of the power is required for ventilation and air conditioning and the other half will be available to the experiments. This cavern will include an equipped workshop. It will also include fire control systems, monitoring and safety systems tightly integrated to the Agua Negra tunnel safety system.

- A clean room with controlled environment parameters for experimental work will be located in the central part of the experimental area.

The Secondary Cavern

The originally proposed three secondary caverns are merged into a single excavation 14 m long, 16 m wide, 14 m high, which may be subdivided by concrete walls if several independent spaces are necessary. This area will host smaller size experiments, offices, laboratories, and services for the lab personnel and visitors.

The Secondary Pit

Located at the end of the secondary cavern. It is 9 m diameter by 15 m total depth, dedicated to ultra low background measurements. It is accessed by a central corridor at 10 m above the bottom. It will have a suitable vessel for low radiation measurements, properly supported to prevent flotation in the case the pit is flooded with water for further shielding. A sealed system for power lines, data, and monitoring will reach the interior of the vessel.

The Main Cavern

It shall be 50 m long, 21 m wide and 23 m high, with oval profile for structural stability. A 40 ton bridge crane on the ceiling will slide longitudinally on rails, reaching the loading area. The total use of space is achieved by making the main beams of the bridge crane having the curvature of the roof of the cavern. Lateral displacement of the load must be done by a zipper mechanism. The area for experimental equipment shall be rectangular 35 m by 19 m. The equipment area shall have a drainage system that channels fluid leaks into lateral gutters, and a pumping system according to the drain thereof. Collected fluid will be directed to the service cavern. Conveniently distributed panels for power supply, low power lines, communication networks, compressed air, water and services shall be included.

The Main Pit

It will be 30 m in diameter and 38 m deep (instead of the 42 m originally proposed). Located at the end of the lab gallery, accessed at a point 30 m above the bottom. An additional access with a 12% slope will reach the bottom. The pit will host a single large

size neutrino experiment of high sensitivity. As a shield from ambient radiation, the pit could be filled with water to a height of 30 m from the bottom, after the experiment is installed. A pump system for the filling and emptying of the well is therefore required. The pump system may also connect to the fire safety network, so that the pit can be used as an additional water reservoir for fire fighting. A 20 ton bridge crane will be installed in the ceiling in order to move equipment inside the pit.

Support Laboratories

In addition to the underground site, ANDES, as most underground laboratories, requires infrastructure at surface level as well in order to provide all the services related to administration, reception of equipment, preparation of experiments, office and meeting space, data processing and connectivity, and outreach to the public.

Since the underground site lies at high altitude (near 3800 m a.s.l.) in a relative isolated place, two support labs are proposed. The current proposed sites are one in La Serena, a city of 230,000 inhabitants and port at the Pacific coast in Chile, 200 km from the tunnel, and one in Rodeo, a town of 2,400 inhabitants in Argentina, 90 km from the tunnel. La Serena is a city with universities and a technical infrastructure that supports major astronomy observatories in the region, so that this support laboratory is envisioned as hosting most of the administrative and long term equipment construction and assembly. The support laboratory at Rodeo, which is closer to the tunnel, shall be used for more frequent installation and operations of the experiments.

An important activity of the support laboratories will be the outreach to the public. The support laboratories shall consider 100 to 200 m^2 for office space, 200 to 400 m^2 for equipment and laboratory space, and 100 to 200 m^2 for an adequate visitor center.

ORGANIZATION

Since ANDES will be the first international laboratory of its kind in Latin America, groundbreaking steps at the highest political levels of the participating nations will be required. Notwithstanding the foreseen efforts, the proposal has received widespread support.

The current proposal is that ANDES will be managed by an international institution called *Consorcio Latinoamericano de Estudios Subterráneos* or CLES (Latinamerican Consortium for Underground Studies). The organization of CLES is still under discussion, but it must: (i) conduct, through the concurrence of the interested parts, the administrative organization of ANDES and its integration to the scientific communities of the region; (ii) define and coordinate the areas of scientific interest; (iii) coordinate the division of the different sciences; (iv) form the external scientific advisory boards, and the internal committees that oversee the operation of the experiments; (v) establish the rules and protocols for the selection and setup of the experimental proposals; (vi) coordinate the academic integration with other institutions, including the participation of researchers and students; (vii) identify the regular sources of financing for ANDES, establish the financing mechanisms, define the

budgets and the rules for support and overheads of the experiments; (viii) organise scientific events, such as conferences and workshops; (ix) promote the outreach of the laboratory activities; (x) establish the long term plans for the ANDES laboratory, including expansion and upgrades.

The ANDES initiative can be thought of as the experimental branch of a broader scientific organization, aimed at strengthening the links between the laboratory and academic communities in Latin America. CLES can be envisioned as an institution analogous to CERN in Europe, in its role as coordinator of scientific endeavours. As such, the existence of CLES will enable not only the definition of the management and organizational structures for ANDES, but also as an instrument for the creation of the appropriate environment for regional integration in science and culture.

The participating nations in the initial proposal at the scientific level are Argentina, Brazil, Chile and Mexico. Further Latin American countries are expected to join. In particular, Colombia has already expressed interest in being part of the ANDES proposal.

SUMMARY

ANDES (Agua Negra Deep Experiment Site) is a proposed underground laboratory to be built inside the Agua Negra tunnel, the latter a tunnel which is part of an international road that will connect Argentina and Chile, between the province of San Juan (Argentina) and the region of Coquimbo (Chile). The laboratory will be set at the deepest point, 1750 m vertical under the rock, at an altitude of approximately 3,800 m a.s.l. It will include a large cylindrical pit 38 m deep and 30 m diameter to host a large neutrino experiment, a main cavern 50 m long, 21 m wide and 23 m high for other large experiments, a secondary cavern of smaller size, an ultra low background pit, and several smaller service caverns, including an emergency room. Due to its location, it will be third deepest underground lab in the world and one of the first two to be built in the Southern Hemisphere. Construction of the tunnel should start in 2016 and will take eight years to complete, together with the laboratory.

The scientific programme of the laboratory will include experiments in particle and astroparticle physics, in particular Neutrino and Dark Matter experiments, and other experiments in Nuclear Physics, Biology, Geophysics, Geology and Seismology. It will also provide services of ultra low background measurements and applications to instrumentation development and industry.

The underground site will be accompanied by two support laboratories at surface level at the most convenient places. One of them could be set in the city of La Serena, Chile and the other in the town of Rodeo, Argentina.

The laboratory will be managed by an international Consortium formed by scientists and representatives of the participating Latinamerican nations, called CLES (Consorcio Latinoamericano de Estudios Subterraneos). This consortium, besides managing the ANDES laboratory, shall constitute a seed for further integration of the sciences and culture in the continent.

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