ANDES

Agua Negra Deep Experiment Site

AN UNDERGROUND LABORATORY IN THE AGUA NEGRA TUNNEL

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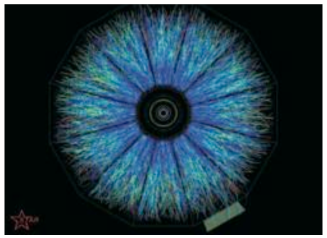
AGUA NEGRA DEEP EXPERIMENT SITE

THE ANDES UNDERGROUND LABORATORY

AND THE LATIN AMERICAN CONSORSIUM

FOR UNDERGROUND EXPERIMENTS

(CLES)






THE ANDES UNDERGROUND LABORATORY

The Earth is permanently bombarded by cosmic rays coming from many astrophysical objects (the Sun, supernovae, supermassive black holes in the center of far away galaxies). At ground level, about fifteen million particles impact every square meter every day. In order to study the most evasive phenomena of the Universe, the scientific community is building underground laboratories to protect their experiments from this radiation.

1700m underground, only a few particles per day have enough energy to reach through the mountain an underground experiment, allowing scientists to study weak interacting particles that could cross millions of kilometers of rock without interacting (such as the neutrino), or study dark matter, which seems to be omnipresent in the Universe. 10 underground laboratories are in operation worldwide, in the USA, Canada, Europe and Japan.

The underground science is rapidly expanding and new installations are required, and while India and China are advancing on their first laboratories, USA and Europe and both planning for a next generation large laboratory.

The construction of the Agua Negra tunnel is a unique opportunity to plan the construction of the ANDES underground laboratory. It would be the only such laboratory in the southern hemisphere.

The deep regional integration provided by tha Agua Negra tunnel in connecting the MERCOSUR countries of Argentina, Brazil and Chile, can also manifest itself in a scientific integration of these countries with other Latin American countries such as Mexico with the creation of the Latin American Consortium for Underground Experiments (CLES for its initials in spanish: Consorcio Latinoamericano de Experimentos Subterráneos). These countries have already demonstrated their capability to build major scientific projects such as the Pierre Auger Observatory in Argentina, the European Southern Observatory (ESO) in Chile, the Synchrotron Light National Laboratory (LNLS) in Brasil and the HAWC gamma ray Observatory in Mexico.

One of the 1600 decteors of the Pierre Auger Observatory in Argentina, the biggest cosmic ray observatory in the world.

The Very Large Telescope (VLT) of the European Southern Observatory (ESO) at Cerro Paranal in Chile (© ESO/Y. Beletsky).

HAWC (High Altitude Water Cherenkov), a unique observatory able to monitor distant gamma ray astrophysical sources, on the slopes of Sierra Negra volcano, Mexico.

The accelerator of the Synchrotron Light National Laboratory (LNLS) in Brasil, unique in Latin America, used by more than 1000 scientist every year (© LNLS).

DESCRIPTION OF ANDES

The chosen location for the construction of the underground laboratory in the Augua Negra tunnel is between km 3.5 and 5 out of the 14 km of the tunnel, close to the Argentina-Chile borderline. This location ensures a maximum over burden of more than 1700m of rock to provide a better shielding to the cosmic radiation, reducing it by a factor one million.

The ANDES laboratory will host various experiments in a main hall, a secondary hall cut in 4 floors, and a third cilindrical pit, for a total of 2500m^2 of undergound surface. Its planification will be integrated to the one of the tunnel to minimize construction and operation costs.

The cost of the excavation and terminations will be below ten million dollars, taking advantage of all the infrastructure available from the tunnel civil work (which has an approximate cost of 850 million dollars). Together with the underground laboratory, two support laboratories will be built, one in Argentina and one in Chile. These external facilities will have permanent staff (scientists, tecnicians and administrative) to ensure the proper operation of the experiments installed underground, for a total of 10 to 15 people.

The scientific experiments that ANDES will host will allow the exploration of currently unknown phenomena - related to neutrinos and dark matter - with fundamental impact on the understanding of the Universe, its evolution and origin.

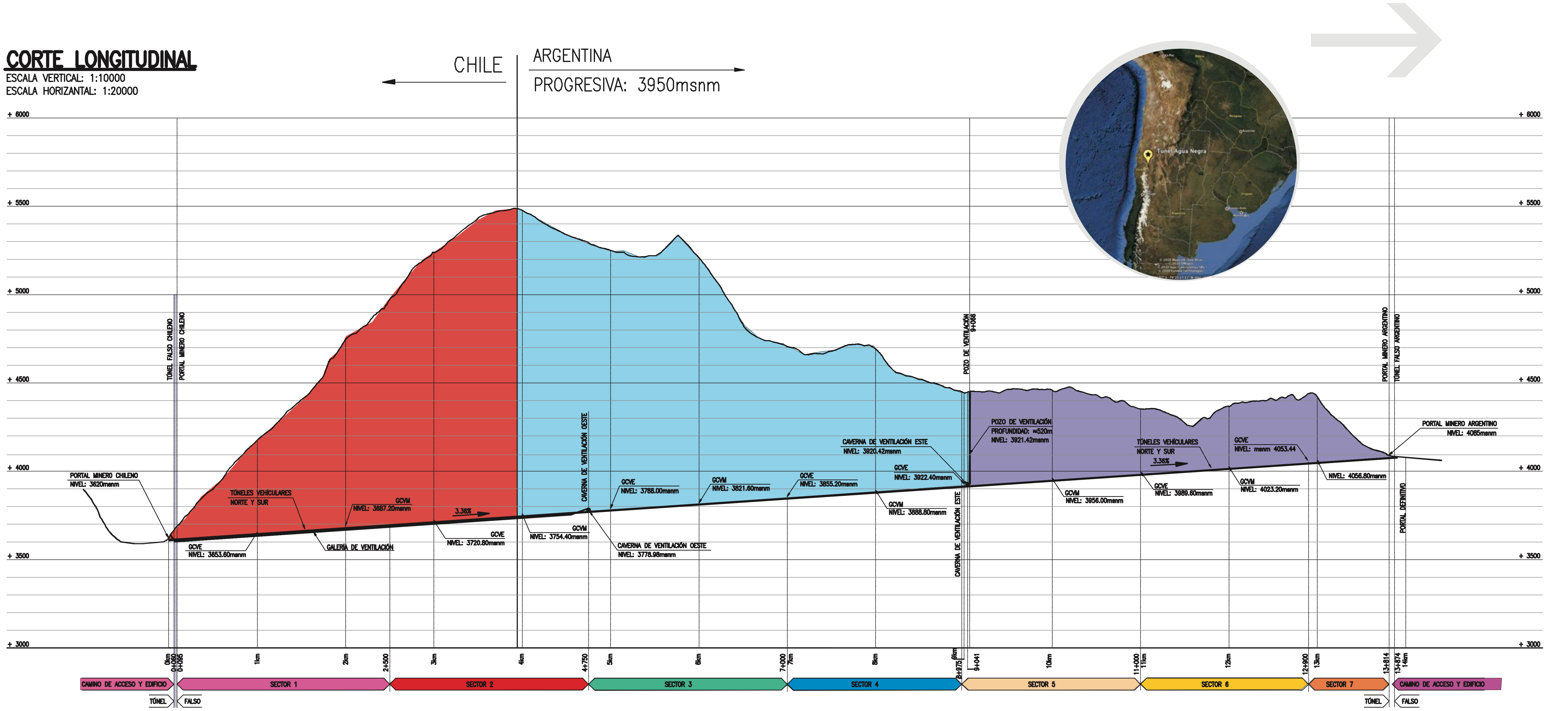
In this unique location, new kinds of multidisciplinary experiments will be able to operate, such as geophysics and geomechanics studies of slow sismic waves and underground propagation, or biological experiments focused on undergound life and the influence of cosmic rays on mutations and cell damage.

The operation of these experiments will not only strenghen the existing scientific communities, but also provide developments in state-of-the-art technologies and for higly trained human ressources in the areas of science, tecnology and engineering.

The creation of the ANDES laboratory could involve new high-tech companies (as it happened around similar laboratories in Europe), together with new postdoctoral courses.

The long lasting impact of a totally new laboratory (offering a unique environment) over a period of 50 years is without comparison with the one of its individual projects (on the 5-10 years time scale), and will surely be at the level of the challenges that represent the building of such an investigation center.

Agua Negra Pass. International limit between Argentina and Chile


CORTE LONGITUDINAL
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ESCALA HORIZANTAL: 1:20000
CHILE
ARGENTINA
PROGRESIVA: 3950msnm
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+ 5500
+ 5000
+ 4500
+ 4000
+ 3500
+ 3000
TÚNEL FALSO CHILENO
PORTAL MINERO CHILENO
PORTAL MINERO CHILENO
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GCVE
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TÚNELES VEHÍCULARES
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NIVEL: 3754.40msnm
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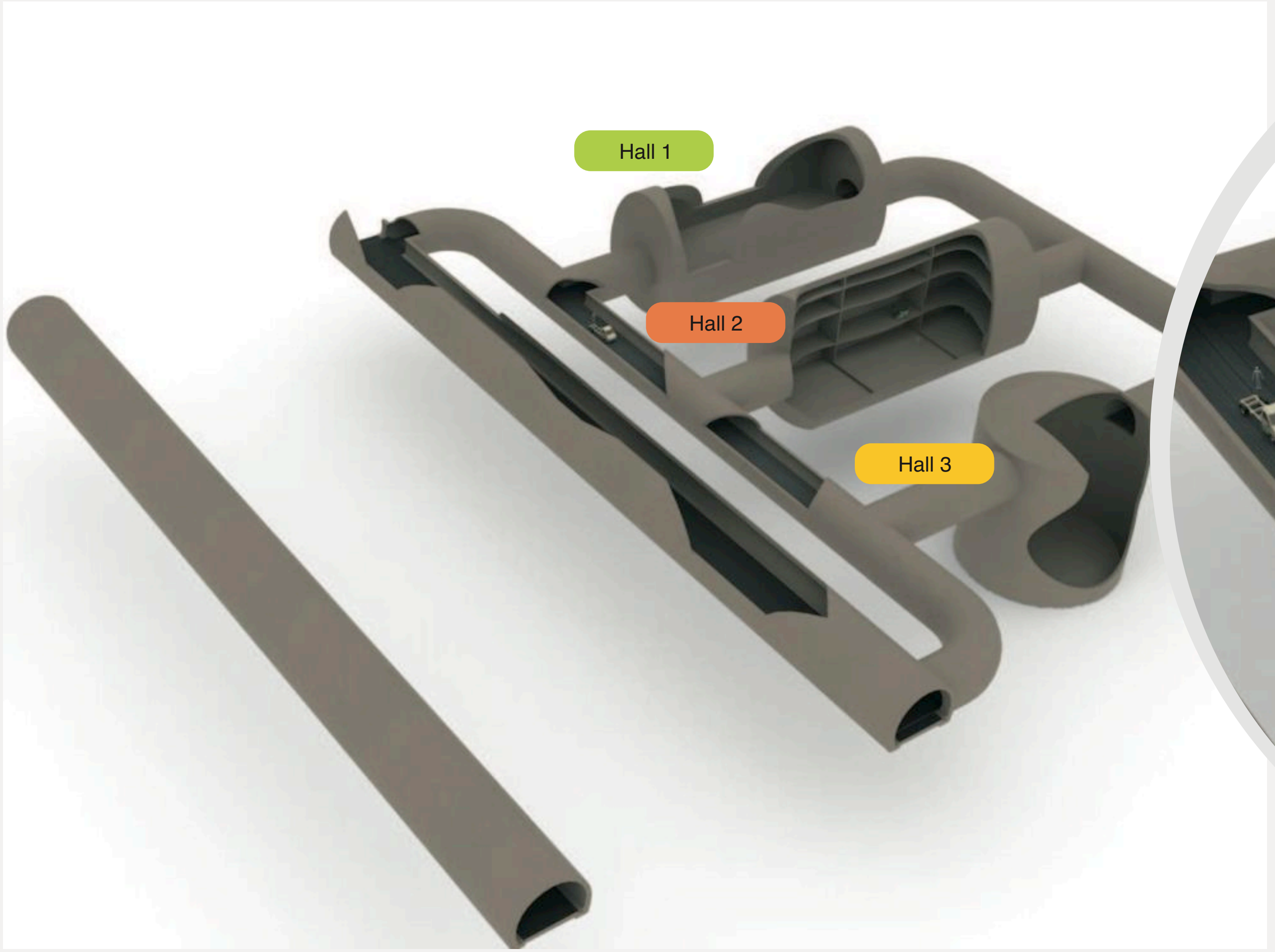
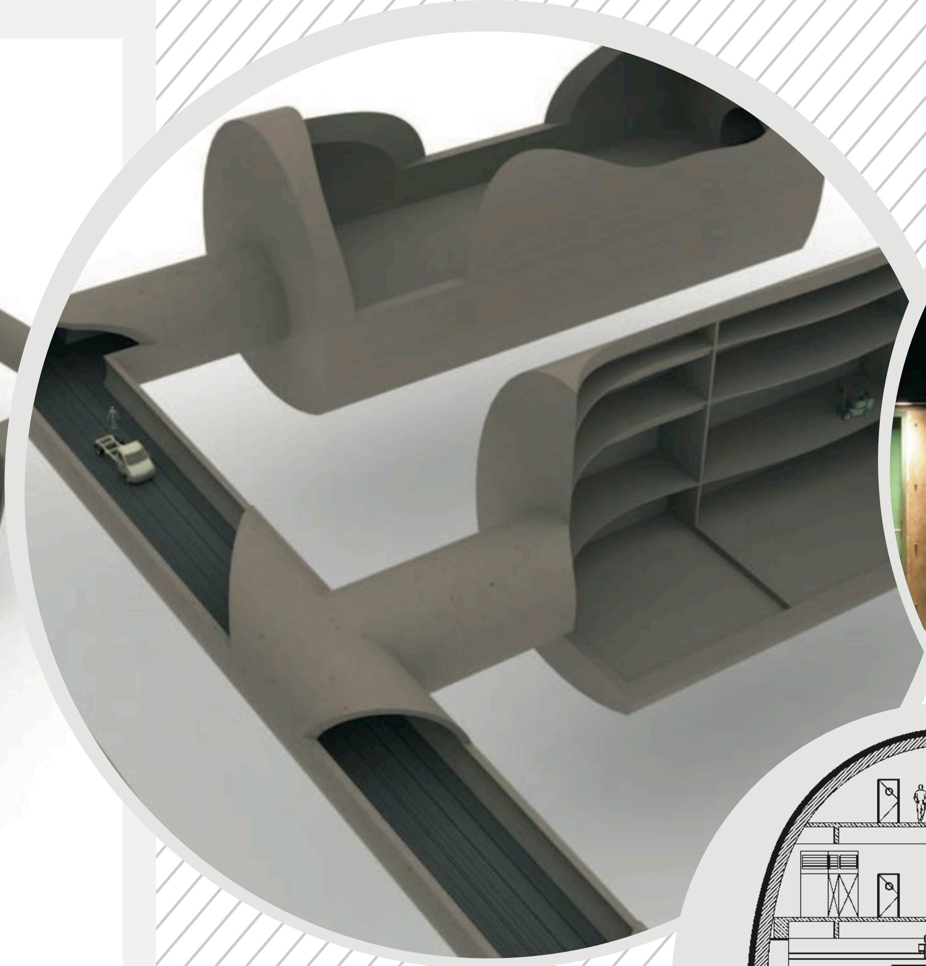
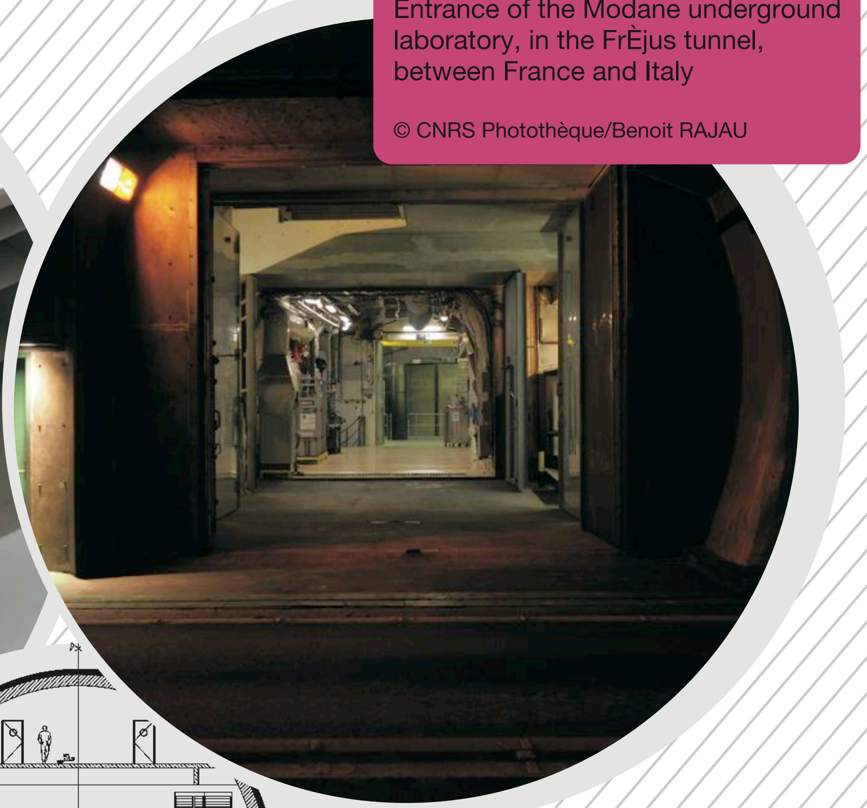
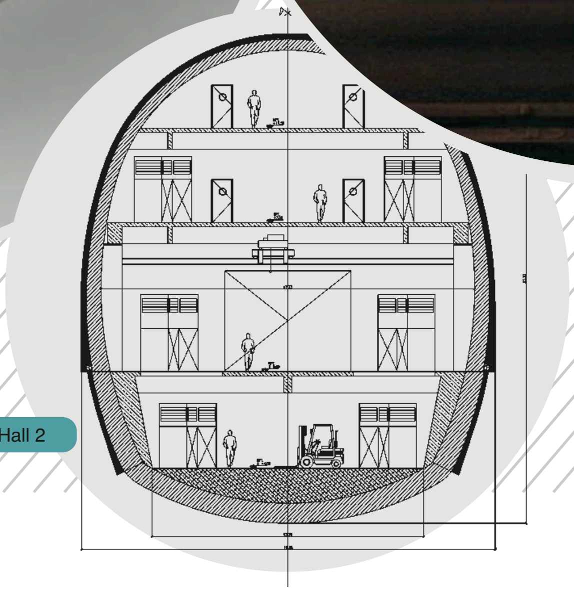
CONCEPT DRAWINGS OF THE ANDES LABORATORY







Entrance of the Modane underground laboratory, in the FrÈjus tunnel, between France and Italy



Inside of Hall 2

POTENTIAL EXPERIMENTS IN THE LABORATORY

DARK MATTER

The expansion of the Universe was proposed and observed by Lemaître and Hubble at the beginning of last century. The observation of the cosmic microwave background, the radiation left over from the Big Bang, confirmed this model as the reference model. The recent discovery of the acceleration of this expansion indicates that the content of the Universe is different from what was expected: only 4.4% of the total mass and energy of the Universe is visible, with the 95.6% missing being dark matter (21%) and dark energy (74%).

The nature of dark matter is totally unknown: its vast majority should be a new kind of matter, different to all the matter found up to now. The main candidates proposed by theories are axions, massive sterile neutrinos and WIMPs (weakly interacting massive particles), including the LSPs (lightest supersymmetric particles), whose natural candidate would be the neutralinos.

Determining the nature of dark matter is one of the main topics of modern cosmology and high energy physics, with huge impact on our understanding of the Universe.

Detecting dark matter is a complex task: it involves huge detection mass, very low detection thresholds, an excellent control of the detector background, and a cosmic background well below one event a day, something only possible in very deep underground laboratories.

The detection techniques used are based on noble gases in liquid state (allowing an excellent discriminating power from signal to noise), or detectors operating at ultra low temperatures (where one detects the effect of the interaction on the cooled material), trying to detect a dark matter particle interaction. The installation of similar detectors in ANDES will furthermore conduce to technology transfers in state-of-the-art technology.

Furthermore, an indirect way to detect dark matter is to find a modulation caused by the movement of the Earth in the halo of dark matter. There has been a strong controversy in the community about this signal, which could be faked by atmospheric effects. By being located in the southern hemisphere, ANDES could unambiguously discriminate the two scenarios.

Building the Edelweiss dark matter detector (© LSM)

NEUTRINOS

The law of conservation of energy is one of the pillars of modern physics. However, some experiments in the 30s seemed to indicate that the energy was not conserved. The evidence was so strong that scientist such as Niels Bohr were considering that maybe in some circumstances the energy could not be conserved.

To solve this issue, Wolfgang Pauli postulated the existence of a new and elusive particle which would explain the missing energy. In 1956, a revolutionnary experiment from Cowan and Reines showed this particle did indeed exist: it was the neutrino.

The observation of neutrinos is hard given its very low interaction rate with matter. However, it was found recently that neutrinos oscillate, which means thay change from one flavor to another. This means neutrinos have mass, something which was not foreseen in the particle physics standard model. Detailled studies of the nature and mass of the neutrinos is a very active field in the high energy physics community, given the huge impact these will have on our understanding of Nature. ANDES will host experiments investigating these lines.

In addition to the participation of the ANDES laboratory in the worldwide campaign on the nature of neutrinos, the location of ANDES as only underground laboratory in the southern hemisphere opens the door to totally new experiments.

Nowadays, many experiments detect neutrinos produced by a particle accelerator located at hundreds of kilometers of distance. The distance of ANDES to the main accelerators can be used to its advantage. As an example, the propagation of neutrinos in matter induces specific effects on the oscillations (MSW effect), that at a distance of 7500 km cancel many terms allowing a precision measurement of factors that are very difficult to measure at other distances.

ANDES is located at 7650 km of Fermilab, in Chicago, one of the three main worldwide particle accelerators, allowing such a measurement. Furthemore, the neutrino beam of KEK, in Japan, would have to cross 12500 km to reach ANDES, meaning it would have to go through the core of the Earth, allowing measurements on the MSW effect no other neutrino experiment could produce.

Finally, ANDES could contribute to the new field of geoneutrino detection. Geoneutrinos are neutrinos produced in the Earth in the decays from the planet own radioactive matter. These geoneutrinos seem necessary to understand the thermal equilibrium of the Earth. While very difficult to detect in Europe, Japan or Northern America due to the neutrino background produced by nuclear reactors, they would be clearly visible in ANDES.

Detector Nemo 3 in the Modane undergound laboratory (© LSM).

PLATE TECTONICS

The Andes Laboratory is placed in a region where the tectonic framework is controlled by the Nazca plate flat subduction under the South American plate. Sub-horizontal subduction have been occurring during at least the last 10 Ma, and although its cause is not yet well known becomes clear that it is the responsible of the profuse all magnitudes seismicity, the mountain building and the lack of Cenozoic volcanism. The magnitude 8.2, 3 April 1943, Ovalle earthquake, was the last very large damaging earthquake of the region, which suggest to put some attention to the seismic cycle after almost 70 years of stress accumulation.

The laboratory low background noise (excluding the unavoidable sporadic two narrow band frequencies of oceanic microseism) is ideal to place highly sensitive seismographs able to record seismic frequencies from around 1 Hz, of local earthquakes, to very ultra-long periods of more than 100 sec of the earth normal modes vibrations excited by a large earthquake.

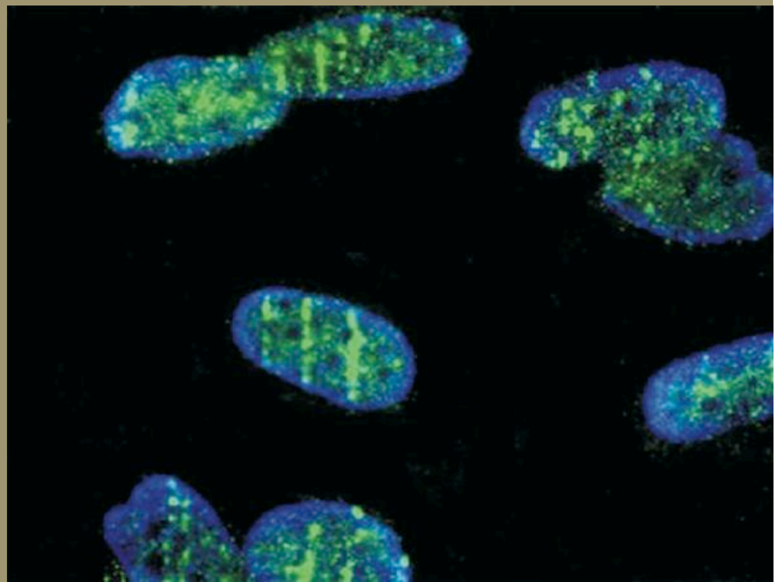
A broadband seismograph installed close to the Argentina-Chile boundary, make a privileged natural nexus between the two countries existent seismic networks. Therefore, useful to study seismic risk, peculiar subduction and mountain building characteristics, and topics related to global seismicity.

BIOLOGY

Cellular redox metabolism and exogenous agent like ionizing radiation are the major source of DNA damage. Double strand break are the principal lesion of DNA that could produce different kind of mutation. These mutations may induce changes or loss of the genetic function of the DNA, leading to the development of numerous pathologies.

Generally, damage and repair cellular processes could be studied by exposing cells to a damage agent, but always control cells show a basal DNA damage due to cellular metabolism. A radiation-free laboratory may allow studying the relevance of the contribution of the cosmic radiation to the basal DNA damage and, in consequence, to the development of pathologies like cancer.

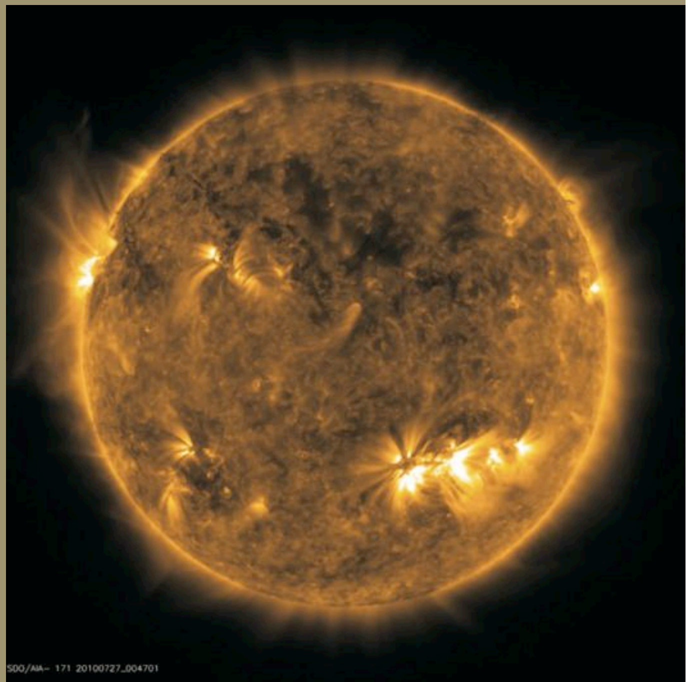
In addition, it will be also possible to study the influence of cosmic radiation over the modulation of antioxidant enzyme system since the ionizing radiation produces reactive oxygen species. Ageing processes are also associated with free radical generation and in this context it would be interesting to evaluate the influence of the cosmic radiation in senescence. The possibility of working in a radiation-free condition would be a great opportunity to study these effects in numerous biological processes.



Damage in neurons exposed to an ionizing beam

NUCLEAR ASTROPHYSICS AND FUSION

The study of nuclear reactions occurring in stars during the various stages of their lives allows explaining both the energy they generate and the formation and abundance of the chemical elements and their isotopes. A precise measurement of these phenomena is an experimental challenge that can be met by operating a particle accelerator in a deep underground laboratory. The low radiation background of ANDES will allow such direct measurement experiment without interfering background signals. The knowledge acquired will furthermore play a special role in the development of the next generation of nuclear reactors: the fusion reactors. These are based on the fusion of light elements in a similar way to what happens in stars, and could be a clean source of energy in the future.



Solar Dynamic Observatory (SDO/NASA).

UV picture of our Sun, showing an increasing activity while we come closer to 2013.

LOW RADIOACTIVITY MEASUREMENTS: CLIMATE, ENVIRONMENT AND INDUSTRIAL APPLICATIONS

The need for very low radioactive material for dark matter and neutrino underground experiments gave birth to the study of new detectors able to measure extremely low radiation levels. These very sensitive detectors, able to detect levels of radiation of a millionth of the natural radiation of the human body, have to be located deep under ground to be shielded from cosmic ray radiation. The industry has shown interest in these techniques to select pure materials with almost no radioactive content.

The ANDES laboratory can also provide a new insight on environmental topics.

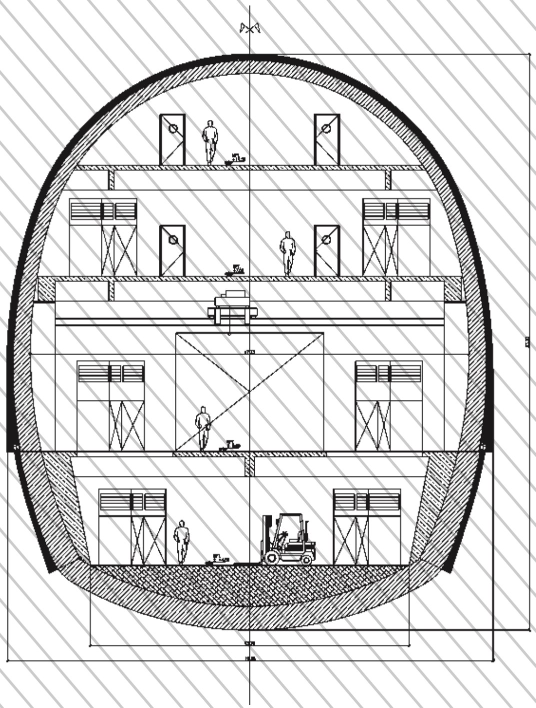
In glaciology, the study of ice samples from the Artic, Antartic, the Alps or the Andes allows to map the evolution of climatic parameters and contamination both in space and over time for the last centuries. The measurement of ^{137}Cs and ^{241}Am is the only way to get a precise dating of ice samples and has to be done in underground laboratories.

ANDES could also be a test bed for microelectronics. The race towards miniaturization of electronics allows huge increase in computing power but renders the chips sensitive to ionizing particles, producing bit errors through their interaction. By getting rid of the cosmic component of this radiation, one could study in ANDES the impact of natural radioactivity on everyday life technology.

Measuring low radioactivity samples.
(© CNRS Photothèque/Benoit RAJAU).

Perito Moreno glacier in Argentina. The study of ice samples in underground laboratories such as ANDES allow to study contamination on time scales from years to centuries.

CPU chips tested in the Modane undergound laboratory (© LSM).



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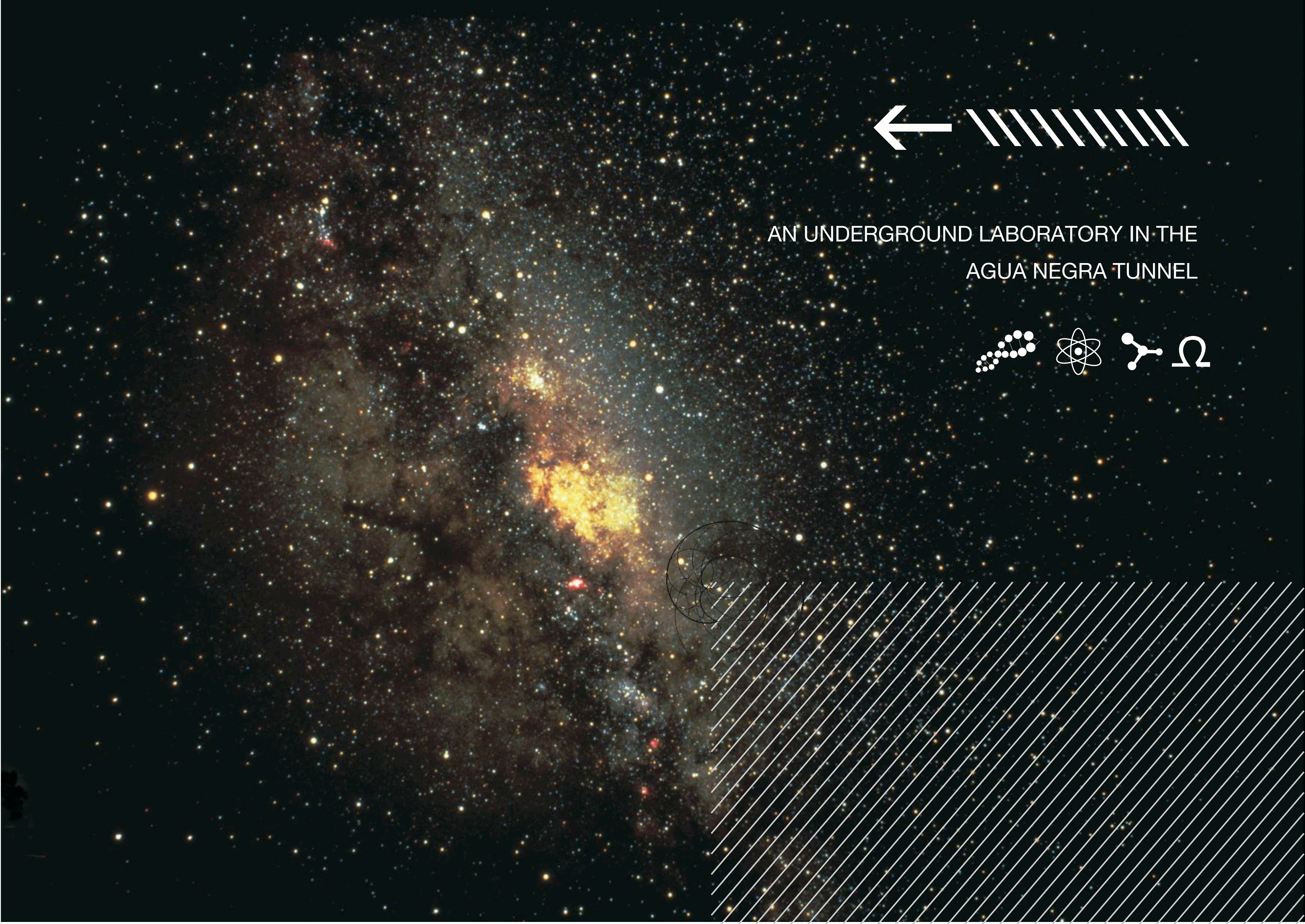
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