The ANDES Deep Underground Laboratory in South America: status and prospects



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Cosmic radiation and underground laboratories



Cosmic rays

Primaries

- Protons
- Nuclei (Helium... Oxygen... Iron)
- Neutrons •
- Gammas

Secondaries

- muons ۲
- electrons/positrons ۲
- ۲ gammas
- neutrons
- neutrinos





...

Cosmic rays as noise

In a cubic meter of detector at ground level, one detects every day:

- 10⁸ muons
- 10⁸ gammas/electrons/positrons
- 10⁶ neutrons
- ▷ 10⁻³ neutrinos
- ▷ 10⁻⁷ supernova neutrinos
- > maybe 100s of dark matter particles



Muon flux vs depth

Muon flux at ground level: a few $100 \text{ m}^{-2} \text{ s}^{-1}$



Muon flux at 5000 m.w.e. underground: 1 m⁻² day⁻¹

Dark Matter search

Dark Matter represents 26% of Universe energy, 85% of matter

- different detector techniques used (cryogenics, noble gas/liquids, ...)
- some "exotic" techniques (bubble chambers, CCD, ...)



- direct detection
- indirect search (modulation)



Neutrino underground experiments

Sources

- neutrinos from nuclear reactors
- neutrinos from particle accelerators
- atmospheric neutrinos
- solar neutrinos
- astrophysical neutrinos
- geoneutrinos

Physics

- neutrino oscillation
- neutrinos mass
- neutrino nature
- astrophysics
- geophysics







Multidisciplinary underground experiments

- Geoscience
 - geoneutrinos
 - low frequency seismographs
- Biology
- Low radiation measurements...
 - material selection
 - climatology, environment
 - microelectronics, wine









World map of underground laboratories



Dark Matter(?) modulation from DAMA/LIBRA





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The ANDES laboratory



The Agua Negra tunnel (Coquimbo - San Juan)

- Crossing the Andes is of strategic importance for the region to link productive areas to the Asian market
- 2 tunnels, 12 m \varnothing each, 60 m one from another, \approx 14 km
- Deepest point at \approx 1750 m depth
- International tender started in January 2013, construction 2017-2026



The Agua Negra tunnel recent history

- Pre-feasibility study done in 2005, feasibility in 2008
- Presidents signed a Bi-National Integration treaty, including the San Juan Coquimbo option, in October 2009, voted later on by both countries
- August 2010 MERCOSUR meeting in San Juan with strong support for Agua Negra
- Since 2011 the Argentine congress votes every year a 800 M\$ guarantee fund
- In March 2012, Presidents signed an agreement to start the international tender
- 2013: new conceptual design and budget review
- 2014: detailed engineering design completed and construction protocol agreed upon
- In 2015, the IDB accepted to finance the project
- In December 2016, the first 40M\$ from IDB were received
- Total cost estimated to about 1250 M\$



A scientific opportunity in the south?

- Opportunity for a big AND deep laboratory
- Located in the south
 - opposite weather modulation (dark matter)
 - complementary for supernovae neutrinos
- Geoneutrinos
 - (Low neutrino flux from nuclear power plants)
- Geoactive region
 - ightarrow Underground geophysics laboratory

Manage it from an international consortium

- Opportunity to have not only international experiments but an international laboratory
- The consortium would be the seed of a "CERN" focused on underground science (high energies, geology, biology, technology...)



Original scientific programme for ANDES

- Neutrino
 - host a double beta decay experiment
 - build a large neutrino detector as a flagship experiment
 - similar to KamLAND/Borexino?
 - focused on low energies
 - solar/supernovae/geo-neutrinos
- Dark Matter
 - modulation measurements
 - new technologies

- Geophysics
 - Natural link of seismograph networks
 - "flat slab" study
- Biology
- Low radiation measurements
- Accelerator
 - Nuclear astrophysics
 - o DAR neutrino beam?

Need to start define more precisely parts of the programme later this year



SuperNEMO: double beta decay experiment

- based on NEMO-NEMO3 expertise (LSM)
- 100 200 kg of ⁸²Se
- sensitive to a neutrino mass of $\approx 0.05 0.1 \text{ eV}$
- modular design: $\approx 20 \text{ modules}$
- Status in 2026?



Large Neutrino Detector

- design similar to Borexino and KamLAND?
 3 10 kton of scintillator
- interesting site for geoneutrinos
- complementary for supernovae neutrino measurements: arXiv:1027.5454
- → Have a large pit foreseen for the detector





Dark Matter in ANDES



- host a copy of an experiment observing a modulation
- host a 3rd generation experiment
- work on new technologies (actively evolving area)
 ex: DAMIC (Dark Matter Identification with CCD)



Nuclear astrophysics

LUNA: Laboratory for Underground Nuclear Astrophysics

- installed at LNGS (Gran Sasso)
- 50 kV accelerator
- 400 kV (LUNA II)
 - study nuclear reactions at low energies, relevant in astrophysics (Gamow peak)
 - ex: ³He(³He,2p)⁴He below 21 keV

Proposal for a 300 kV high intensity platform for ANDES



Current conceptual design for the ANDES laboratory



- main hall: (21×23×50) m^3
- secondary hall: (16×14×40) m³
- small halls (office, workshop, clean room, ...): total 340 m²
- ultra-low radiation pit: Ø9m, 9m depth
- single experiment pit: Ø30 m, 30 m depth

Total civil work cost: 38.1 M\$ < 2.5 % of tunnel cost

Two support laboratories



- At La Serena (Chile) and Rodeo (Argentina)
- Workshops for the underground activities
- Integration with local universities (academic activity)
- Visitor centres



International and institutional support

- Memorandum of Understanding signed during the first ANDES workshop (includes the signaturs of the director of Modane, the emeritus director of Homestake, the spokespersons of SuperNEMO and Edelweiss II).
- EBITAN (Entidad Binacional Túnel Agua Negra), supported the ANDES laboratory in its Xth meeting
- Support and interest by latin american institutions:
 - CONICET, Argentina
 - Comisión Asesora Grandes Instrumentos, MinCyT, Argentina
 - Universidad de La Plata, Argentina
 - O Universidad de San Juan, Argentina
 - ANDES Unit in CLAF
 - Universidad La Serena, Chile
 - O Gobierno de la provincia de San Juan, Argentina
 - CONICYT, Chile
 - Gobierno de la provincia de Elqui, Chile
 - Gobierno de la región de Coquimbo, Chile

- Support and interest by representatives of latin american scientists and institutions:
 - Claudio Dib, representing groups from 4 Chilean universities
 - Juan Carlos D'Olivo, High Energy Physics Network, Mexico
 - Ronald Shellard, CBPF and SBF vice director, Brazil
 - Eduardo Charreau, ANCEFN president, Argentina
 - Francisco Tamarit, AFA president, Argentina
- Support from scientists and international experiments:
 - Stephen Adler, Princeton
 - M. Miller, A. Garcia, University of Washington
 - Bob Svoboda, LNBE Spokesperson
 - Nigel Smith, SNOLAB Director
 - Kunio Inoue, KamLAND Spokesperson
 - Hiro Ejiri, Former RCNP Director
 - Yoichiro Suzuki, Kamioka Director, Super Kamiokande Spokesperson
 - Takaaki Kajita, ICRR Director
 - P. Brink et al., DM modulation
 - O D.A. Harris, K. McFarland, MINERvA Spokespersons
 - A.B. McDonald, Nobel Physics Laureate

Manifested interest in contributing to ANDES

- interest for collaboration and instrument installation in ANDES:
 - Jennifer Thomas, SuperNEMO CB Chair
 - Daniel Santos, MIMAC Spokesperson
 - Kai Zuber, COBRA Spokesperson
 - J. Conrad, M. Shaevitz, DAEDALUS Spokespersons
 - A. Galindo-Uribarri et al., ORNL

Interest in collaborating to the construction and operantion of the ANDES laboratory by latin american groups:

- Argentina:
 - IFLP, UNLP
 - Neutrones y Reactores, CAB
 - Partículas y Campos, CAB
 - Bajas Temperaturas, CAB
 - Instituto Geofísico Sismológico Volponi, San Juan
 - ITeDA, CNEA-CAC
 - I&D PNGRR, CNEA-CAC
 - Física Experimental Altas Energías, UBA
 - Instituto de Matemática Aplicada, San Luis
 - Empresa SOLYDES

- Brasil:
 - Rede Nacional de Física de Altas Energias
 - ICE, UFRJ
 - IFRW, UNICAMP
 - ICRA, CBPF
 - Neutrino Physics group, UFABC
 - HEP, PUC Rio
 - Instituto de Física, USP
- Chile:
 - CCTVAL, UTFSM
 - Pontificia Universidad Católica de Chile
 - Universidad de Santiago de Chile
 - O Dpto Ciencias de la Tierra, Universidad de Concepción
 - ICFM, Universidad Austral
- Mexico:
 - Instituto de Biotecnología, UNAM
 - Instituto de Ciencias Nucleares, UNAM
 - Grupo Astropartículas, UMSNH
 - FCFM, BUAP

ANDES timeline

- Project started in July 2010
- First ANDES workshop in Buenos Aires, Argentina, April 2011
- Second in Rio de Janeiro, Brazil, June 2011
- Third in Valparaíso, Chile, January 2012
- approved by the Argentine MinCyT (CAGICyT) and EBITAN, March 2012
- Fourth workshop in Mexico City, Mexico, January 2014
- ANDES Unit in CLAF created, January 2014
- Laboratory New Conceptual Design ready, January 2016
- Detailed engineering study about to start
- Laboratory to be included in tunnel tender by end of 2017
- > Construction together with tunnel 2018-2026 (2020-2024)



This is a unique opportunity to build a world class deep underground laboratory, one of a kind in the southern hemisphere, operated by an international consortium



Thank you!





Neutrino search (Kay Quattrocchi, 2012)







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Background studies for ANDES

• 600 m deep rock samples measured for natural radioactivity (LAAN, M. Arribere)

(Bq/kg)	Basalt	Andesite	Rhyolite 1	Rhyolite 2	Canfranc
²³⁸ U	$\textbf{2.6} \pm \textbf{0.5}$	$\textbf{9.2}\pm\textbf{0.9}$	14.7 ± 2.0	11.5 ± 1.3	4.5 - 30
²³² Th	0.94 ± 0.09	$\textbf{5.2}\pm\textbf{0.5}$	4.5 ± 0.4	$\textbf{4.8} \pm \textbf{0.5}$	8.5 – 76
⁴⁰ K	50 ± 3	47 ± 3	57 ± 3	52 ± 3	37 – 880

Depth, muon flux and neutron activation calculations



The bullet cluster





Direct searches (spin independent current limits)



CDMS II



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DAMA/LIBRA at Gran Sasso



DAMA/LIBRA: 250 kg crystals of ultra-pure sodium iodide (Thallium doped)



Gran Sasso Laboratory: The largest underground laboratory in the world

Modulation results from DAMA/LIBRA







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Modulation from DAMA/LIBRA and atmospheric effects





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Heavy metals in plants



Some plants uptake heavy metals and process them. Real time analysis of the process would be possible in an underground laboratory. *(from LSMM proposal)*



Cosmic radiation impact on cells

"Underground laboratories provide a novel environment in which to conduct biological experiments, by offering a setting where the cosmic radiation flux is vastly reduced. Growing organisms inside this environment allows the contribution of the normal sea-level background dose received by cells to be suppressed, providing a means of exploring the impact of the natural radiative background on biological systems. Surprisingly, experiments led thus far in underground labs show that a reduction in background radiation has a stressful impact on cells, reducing the growth rate of bacteria when cells were grown in the Waste Isolation Pilot Plant in New Mexico, and reducing the ability of yeast cells grown in the Gran Sasso underground laboratory to withstand exposure to DNA damaging chemicals. [...] Low background experiments in Gran Sasso have been extended to study the impact of radiation on V79 Chinese hamster cells, and human lymphoblastoid TK6 cells. Across the vast range of organisms considered, these experiments in underground laboratories all support the hypothesis that background radiation acts as a conditioning agent for the cellular response to DNA damage."

(Introduction of EPJ Web of Conferences 124, 00006 (2016))

Sardine in Peru and lead contamination in alpine lakes

Sardine vs anchovy evolution in Peruvian coasts

- Populations of sardines and anchovy are anti-correlated in peruvian coasts
- Data only available for last tens of years
 - $\rightarrow~$ Expand the data set by low radiation measurements

Lead contamination in alpine lakes

- Can be traced by ²¹⁰Pb
- Usually resolution of tens of years
 - ightarrow Can be measured on a yearly timescale in an underground laboratory
 - \rightarrow Look at leadless gasoline impact



Microelectronics and wine



IBM test of microchips

Study bit error rate

Wine datation for fraud

Check century old bottles with Cs

