ANDES

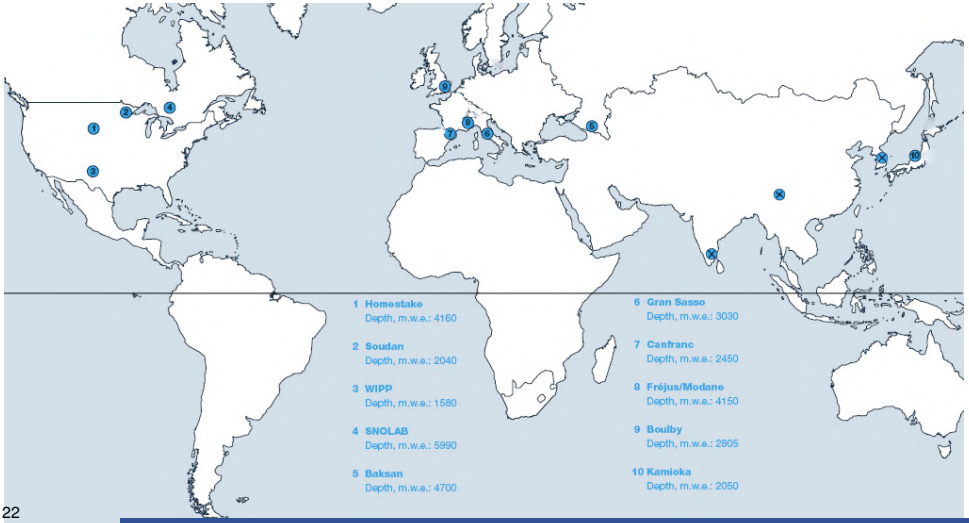
Agua Negra Deep Experiment Site

Xavier Bertou

Centro Atómico Bariloche
CNEA/CONICET

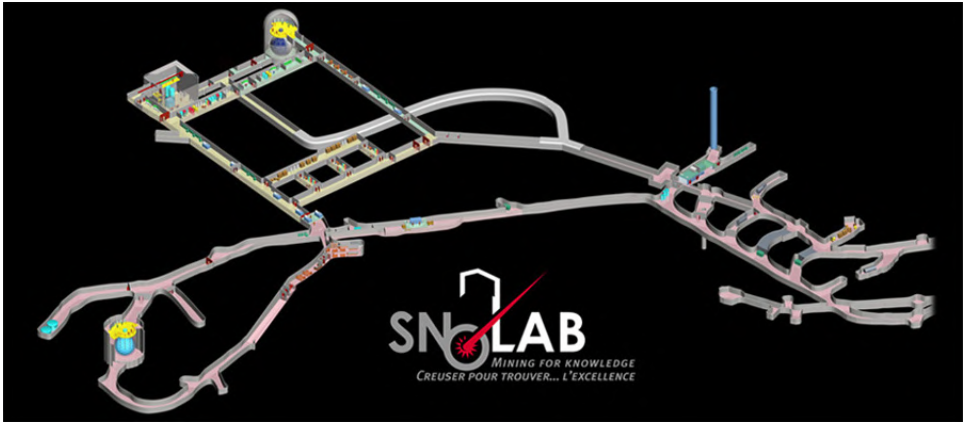
Dark Side of the Universe, Buenos Aires, 18 July 2019

World map of underground laboratories - 2010

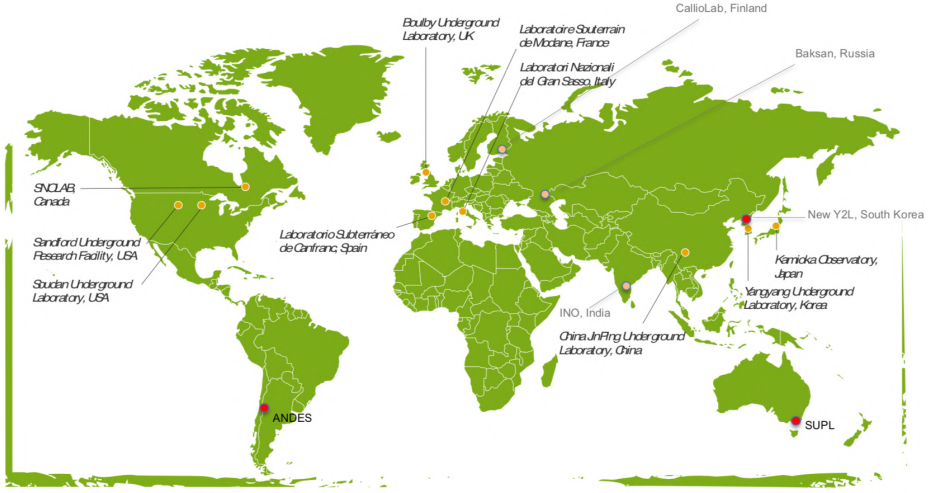


Gran Sasso, Italy

SNOLAB, Canada

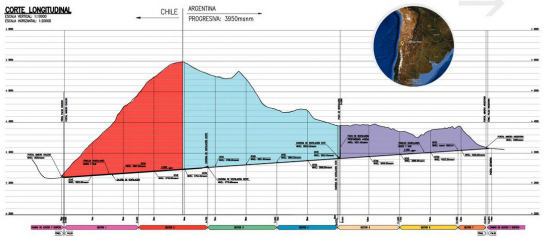


World map of underground laboratories - 2017



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 ⌀ each, 60 m one from another, ≈ 14 km
- Deepest point at ≈ 1750 m depth
- International tender started in January 2013, construction 2020-2028

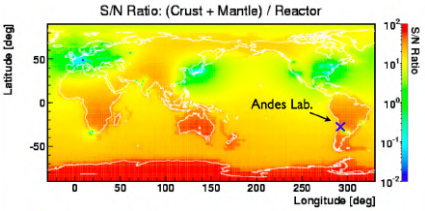


The Agua Negra tunnel recent history

- 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 MU$D guarantee fund
- In March 2012, Presidents signed an agreement to start the international tender
- 2013: new conceptual design and budget review
- 2014: detailed engineering design completed and construction protocol agreed upon
- In 2015, the IDB accepted to finance the project
- In December 2016, the first 40M$ from IDB were received
- In October 2017, 280M$ more from IDB were received
- Total cost estimated to about 1.5 BU$D

A scientific opportunity in the south?

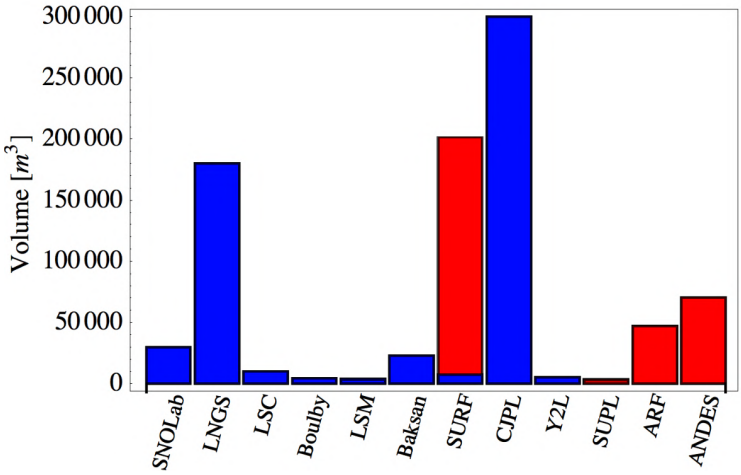
- Opportunity for a big AND deep laboratory
- Located in the south
  - opposite weather modulation (dark matter)
  - complementary for supernovae neutrinos
- Geoneutrinos
  (Low neutrino flux from nuclear power plants)
- Geoactive region
  → Underground geophysics laboratory



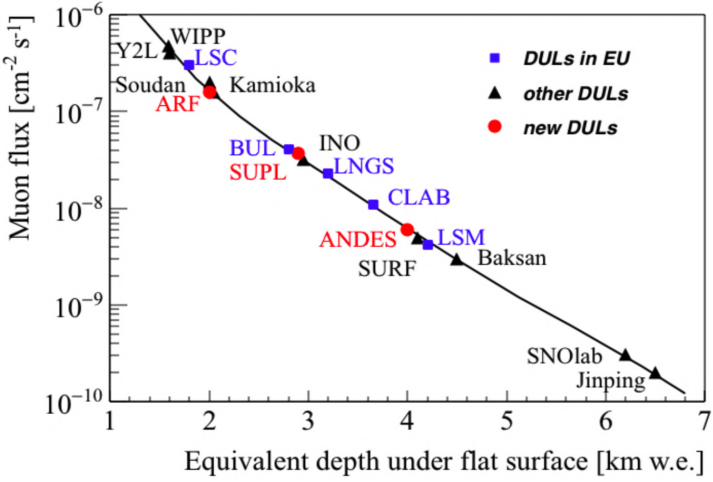
Manage it from an international consortium

- 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...)

ANDES size (Aldo Ianni, TAUP 2017)



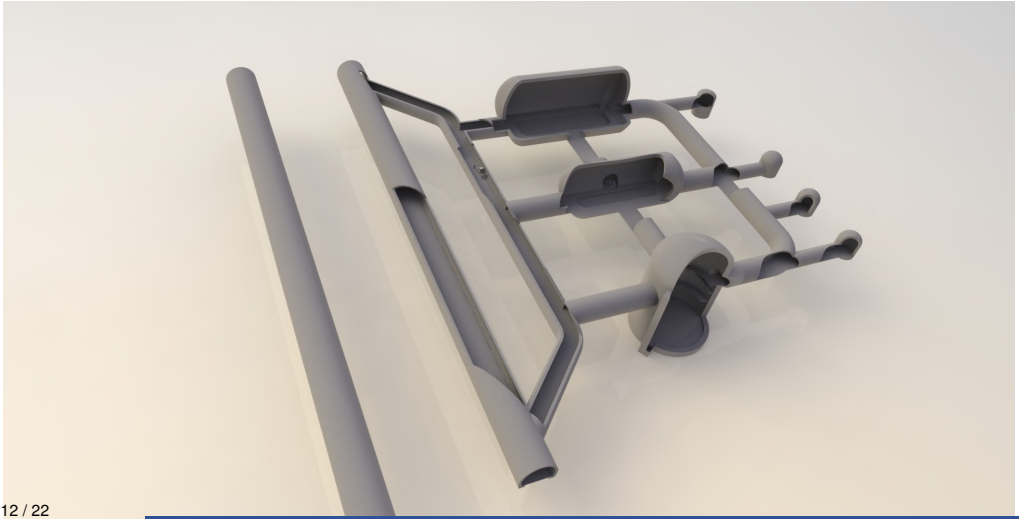
Expected Muon Flux (Aldo Ianni - TAUP 2017)



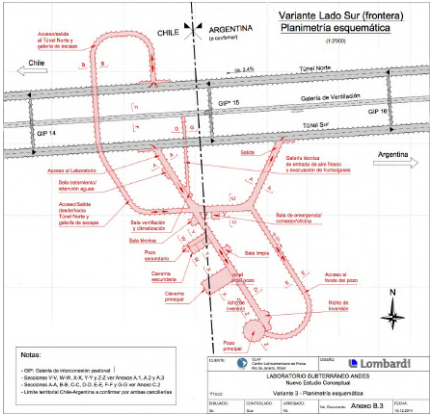
Original scientific programme for ANDES

- 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
  - 4th generation
  - new technologies
- Geophysics
  - Natural link of seismograph networks
  - “flat slab” study
- Biology
- Low radiation measurements
- Accelerator (Nuclear astrophysics)

First proposal for the ANDES laboratory (2011)



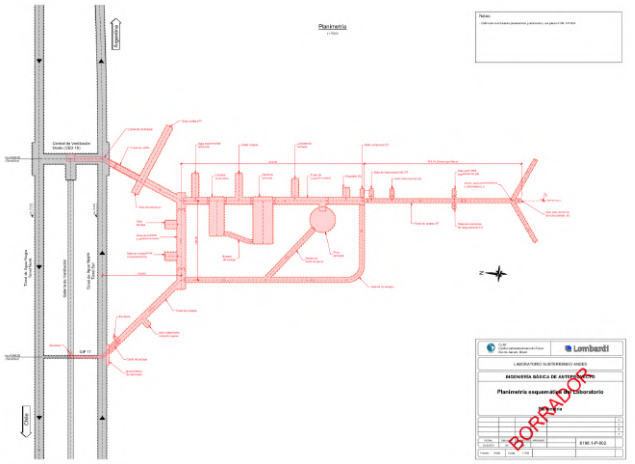
Conceptual design for the ANDES laboratory (2015-2016)



- main hall: $(21 \times 23 \times 50)\,\mathrm{m}^3$
- secondary hall: $(16 \times 14 \times 40)\,\mathrm{m}^3$
- small halls (office, workshop, clean room, ...): total $340\,\mathrm{m}^2$
- ultra-low radiation pit: $\varnothing 9\,\mathrm{m}$, $9\,\mathrm{m}$ depth
- single experiment pit: $\varnothing 30\,\mathrm{m}$, $30\,\mathrm{m}$ depth

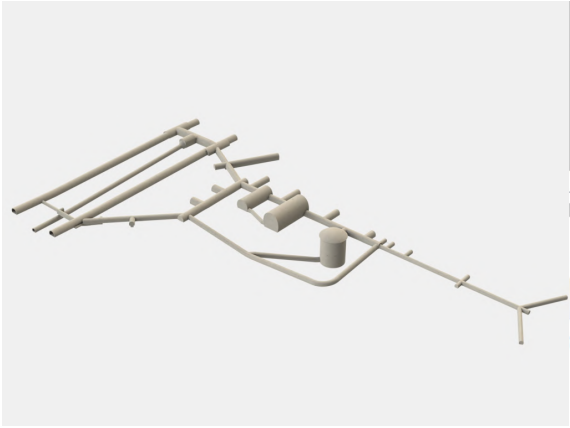
Total civil work cost: 38.1M$
$< 2.5\,\%$ of tunnel cost

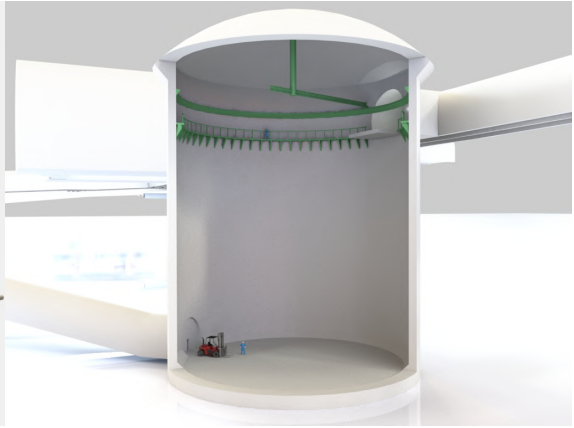
Detailed engineering under way (2018-)



- Add GEO portion (inspired by BFO, Germany)
- Add BIO independent laboratory
- Reorder small rooms
- Add Accelerator room
- Keep cost below 5% of tunnel cost while adding multidisciplinarity platforms

Current design for the ANDES laboratory



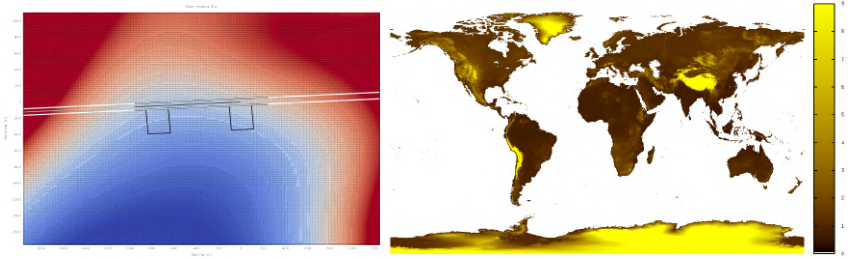


Background studies for ANDES

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

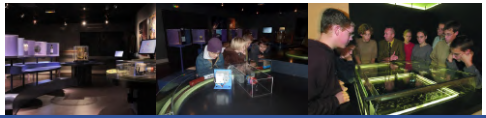
(Bq/kg)	Basalt	Andesite	Rhyolite 1	Rhyolite 2	Canfranc
^{238}U	2.6 ± 0.5	9.2 ± 0.9	14.7 ± 2.0	11.5 ± 1.3	$4.5 - 30$
^{232}Th	0.94 ± 0.09	5.2 ± 0.5	4.5 ± 0.4	4.8 ± 0.5	$8.5 - 76$
^{40}K	50 ± 3	47 ± 3	57 ± 3	52 ± 3	$37 - 880$

- Depth, muon flux and neutron activation calculations



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 and agreed on including it in the Agua Negra tunnel project in its XXXVth meeting
- Support and interest by latin american institutions:
  - CONICET, Argentina
  - MinCyT, Argentina
  - Universidad de La Plata, Argentina
  - Universidad de San Juan, Argentina
  - ANDES Unit in CLAF
  - Universidad La Serena, Chile
  - Gobierno de la provincia de San Juan, Argentina
  - CONICYT, Chile
  - Gobierno de la provincia de Elqui, Chile
  - Gobierno de la región de Coquimbo, Chile
  - CCHEN, Chile
  - MinRel, 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
  - 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
  - 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 3 ANDES workshops in Buenos Aires, Argentina, April 2011, Rio de Janeiro, Brazil, June 2011, 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
- Fifth ANDES workshop in Buenos Aires, Argentina, June 2017
- ANDES proposed for the TAN civil work by EBITAN, July 2017
- Sixth ANDES workshop in São Paulo, Brasil, August 2018

- ▷ Detailed engineering (0.5 M$) started in August 2018
- ▷ Construction together with tunnel 2020-2028 (2024-2030)

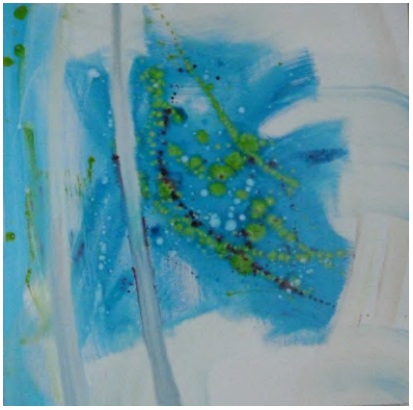
Conclusion

Underground Laboratory science is at the frontier.

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

http://andeslab.org/

Thank you!



Neutrino search
(Kay Quattrocchi, 2012)

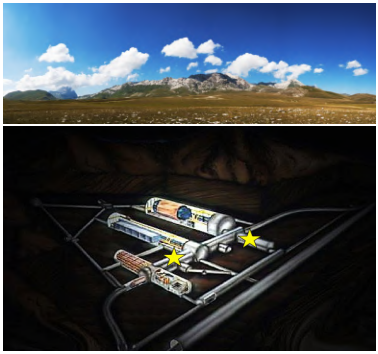
Dark Matter Day: 31 October 2019

http://andeslab.org/darkmatterday2019/
twitter: @andeslab

Backup

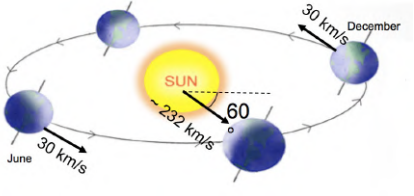
Signal in DAMA/LIBRA at Gran Sasso?

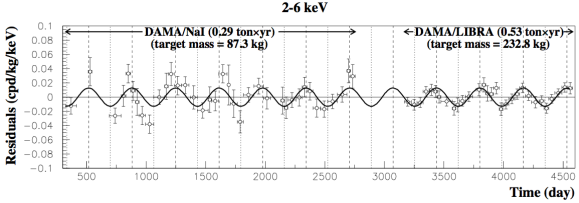
DAMA/LIBRA:
250 kg crystals of ultra-pure sodium iodide
(Thallium doped)

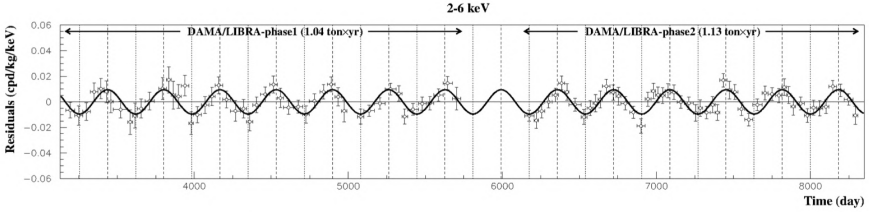


Gran Sasso Laboratory:
The largest underground laboratory
in the world

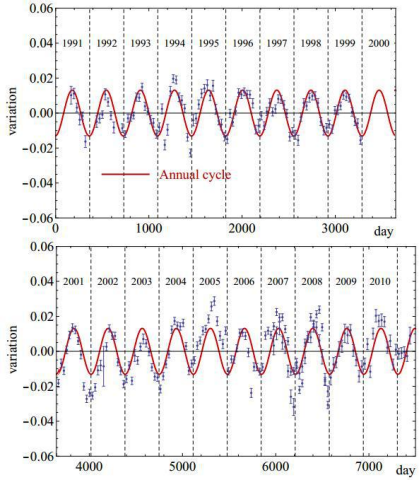
Modulation results from DAMA/LIBRA

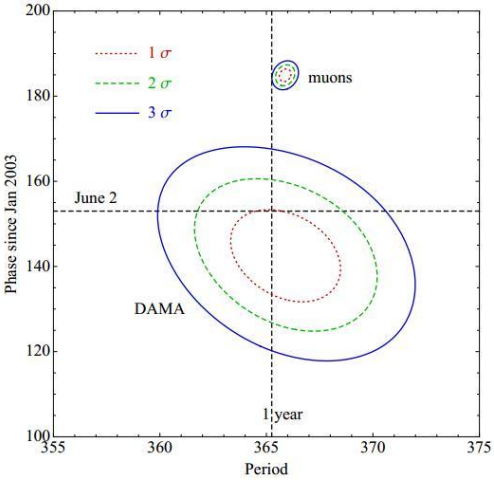






Modulation from DAMA/LIBRA and atmospheric effects



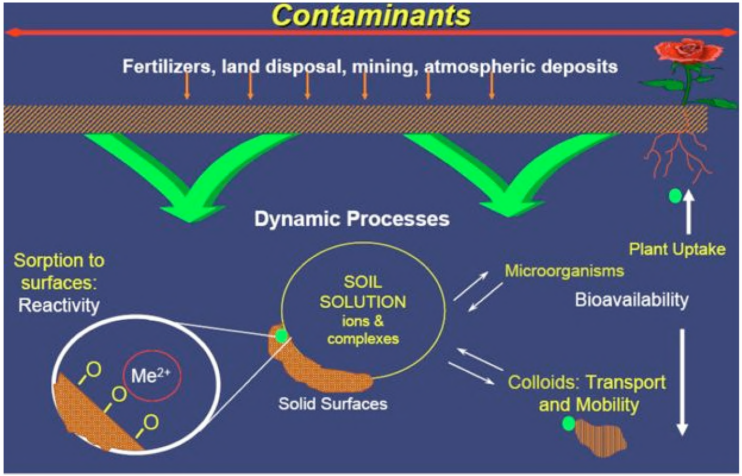


Cosmic radiation impact on cells

”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))

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.

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
  - → Expand the data set by low radiation measurements

Lead contamination in alpine lakes

- Can be traced by ^{210}Pb
- Usually resolution of tens of years
  - → Can be measured on a yearly timescale in an underground laboratory
  - → Look at leadless gasoline impact

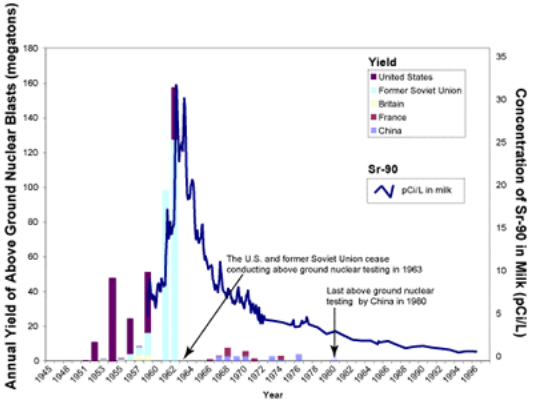
Microelectronics and wine

IBM test of microchips

- Study bit error rate

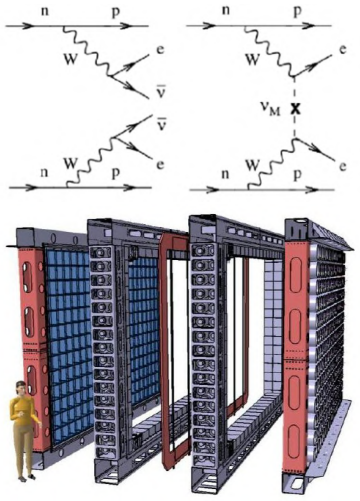
Wine datation for fraud

- Check century old bottles with Cs



SuperNEMO: double beta decay experiment

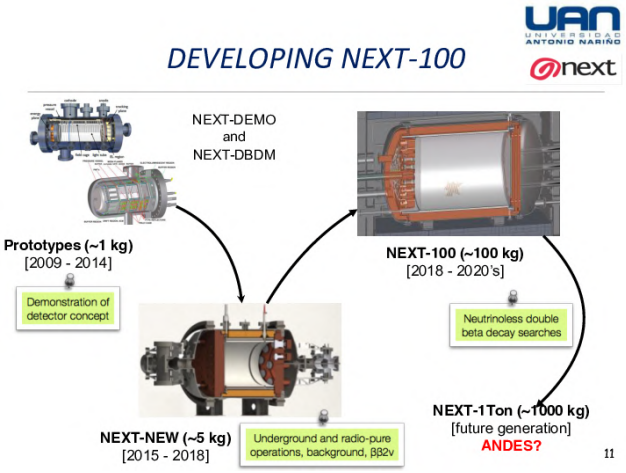
- based on NEMO-NEMO3 expertise (LSM)
- $100 - 200$ kg of ^{82}Se
- sensitive to a neutrino mass of
  $\approx 0.05 - 0.1$ eV
- modular design:
  $\approx$ 20 modules
- Status in 2027?



NEXT: double beta decay Xenon TPC

- NEXT at Canfranc
- Xenon TPC
- Background rejection by looking at blobs at both ends on trace

- Timescale ANDES compatible
- Discussed at 5th ANDES Workshop (June 2017)

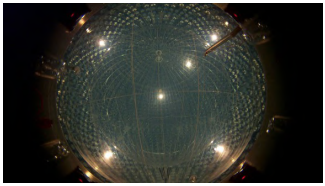


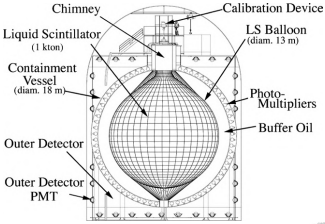
Large Neutrino Detector

- design similar to Borexino and KamLAND?
  - $3 - 10$ kton of scintillator

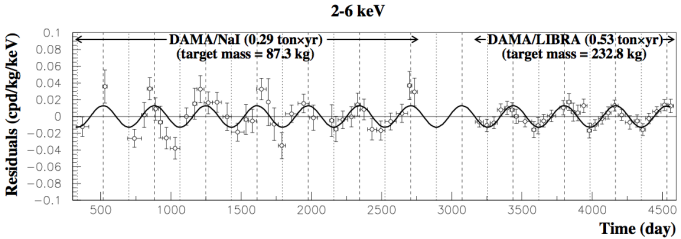
- interesting site for geoneutrinos
- complementary for supernovae neutrino measurements: arXiv:1027.5454

$\rightarrow$ Have a large pit foreseen for the detector



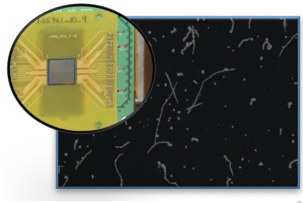


Dark Matter in ANDES



- host a copy of an experiment observing a modulation
- host a 4th generation experiment

- work on new technologies (actively evolving area)
  - ex: DAMIC (Dark Matter In CCD)



Dark Side: Argon TPC

- Argon community joined on Dark Side
- Timescale ANDES compatible
- Discussed at 5th ANDES Workshop (June 2017)

(New) Argon Collaboration

planning to collaborate on future program:

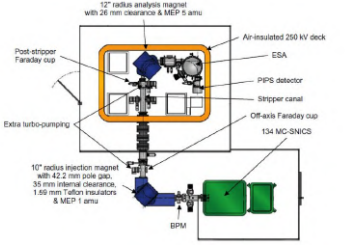
- Completion of current science and R&D programs by each collaboration (DS-50, DEAP-3600, MiniCLEAN, ArDM)
- Joint collaboration on DS-20K at LNGS, including Low Radioactivity Argon (operation starting 2021) and SiPM photodetectors
- Joint collaboration on future multi-hundred-tonne LAr detector, site TBD (mid-2020's)

Mark Boulay 3/23/2017

Nuclear astrophysics

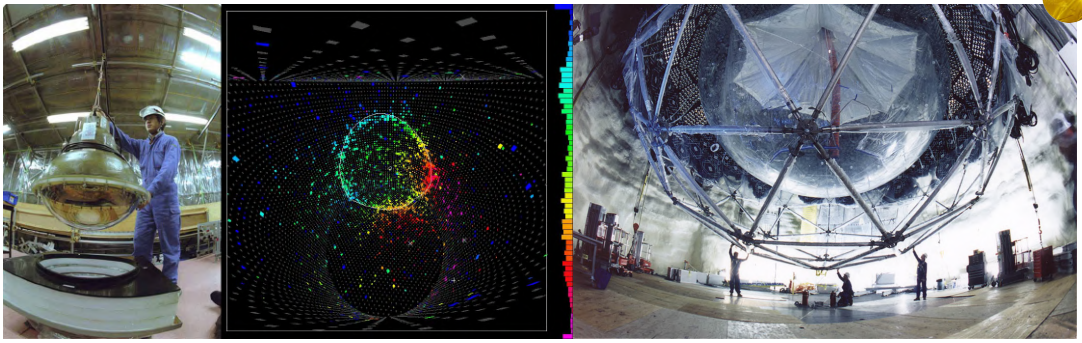
LUNA: Laboratory for Underground Nuclear Astrophysics

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



Proposal for a 300 kV high intensity platform for ANDES

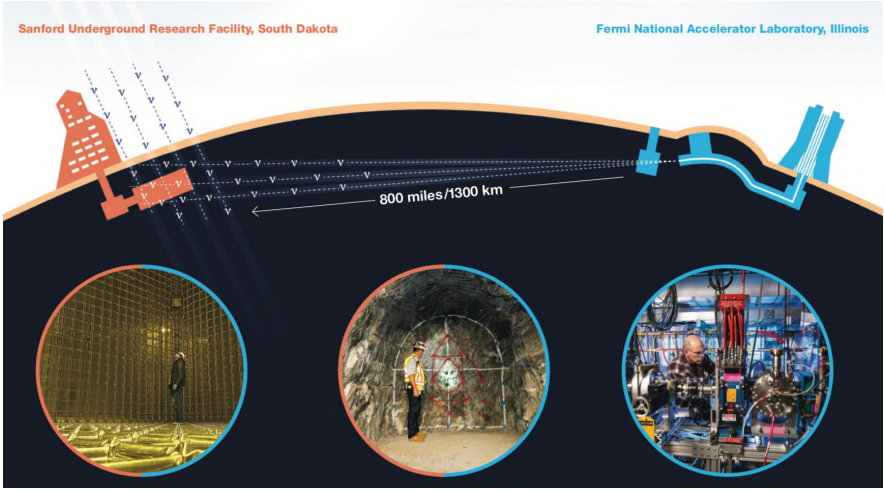
Main recent result in neutrino from Underground Labs



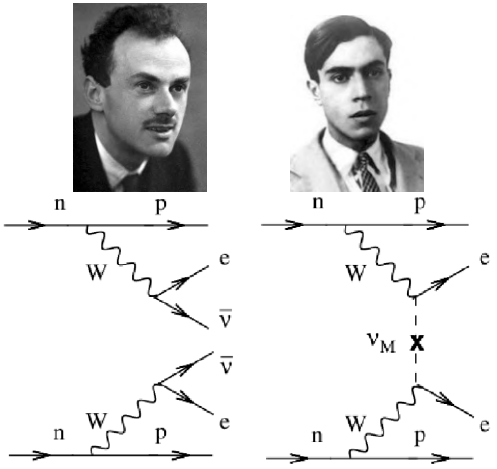
2015 Nobel Prize: Kajita (SuperKamiokande) and McDonald (SNO)

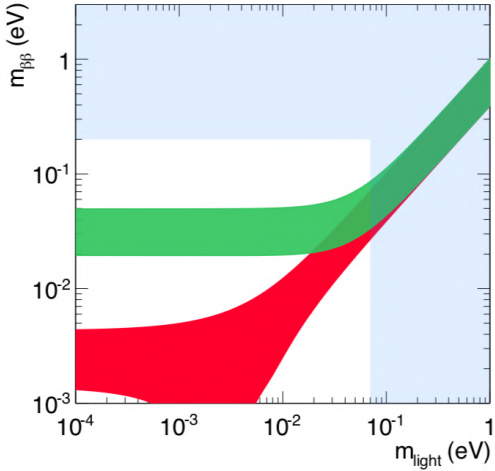
- Neutrino oscillations
- K2K, MINOS, OPERA, T2K

Future major experiment: DUNE

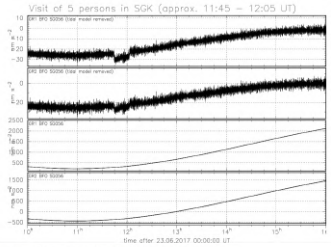


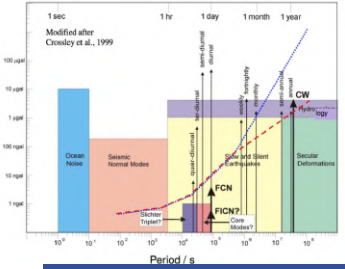
Neutrino nature via neutrinoless double beta decay

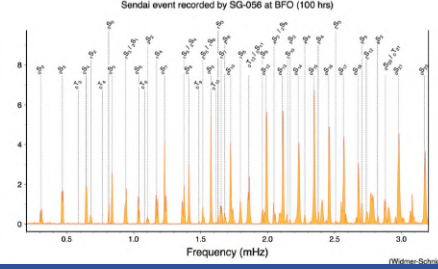




Geo science in Underground sites







(Widmer-Schnidrig, 2011)

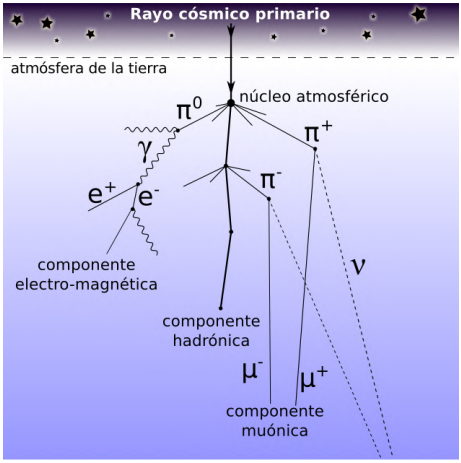
Cosmic rays

Primaries

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

Secondaries

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

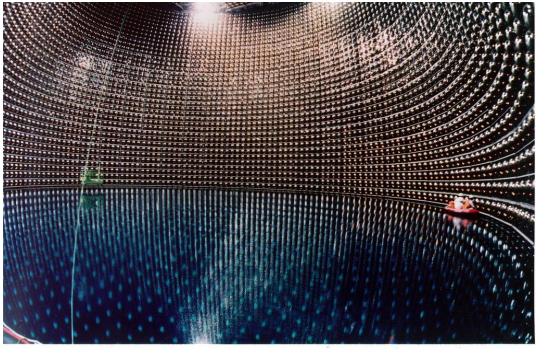


Cosmic rays as noise

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

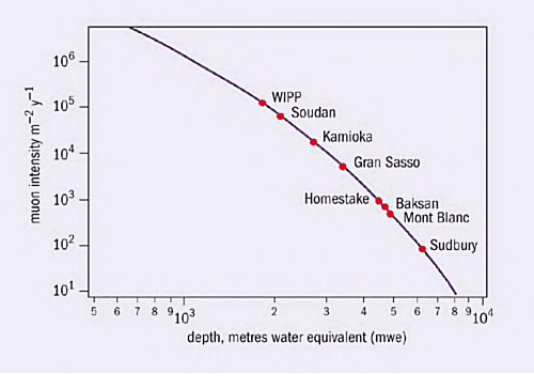
- 10^8 muons
- 10^8 gammas/electrons/positrons
- 10^6 neutrons
  - ▷ 10^{-3} neutrinos
  - ▷ 10^{-7} supernova neutrinos
  - ▷ maybe 100s of dark matter particles

Weakly interacting



Muon flux vs depth

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



Muon flux at 5000 m.w.e. underground: 1 $m^{-2}\,day^{-1}$

The Majorana low background low noise front-end electronics. Analytic approach to three-neutrino oscillations in the Earth. The ICARUS Experiment; latest results. The Micro
and ArgoNeuT Experiments. Uncovering Multiple Mechanisms of bb0nu Decay. Investigation of double beta decay of 100Mo to excited final states of 100Ru. Kinetic Indu
Detectors as light detectors for neutrino and dark matter searches.. Final results of a Dark Matter Search with the Silicon Detectors of the CDMS II Experiment and future resu
SuperCDMS Soudan. The SNO+ Experiment. Latest Results of the NEMO-3 Experiment and Status of SuperNEMO. DEAP-3600 Dark Matter Search with Argon. Halo-indep
ests relevant for inelastic dark matter scattering. Radon-Related Backgrounds in the LUX Dark Matter Search. Searching for Dark Matter with XENON100 and XENON
LAGUNA-LBNO Project. Solar Neutrino Results and Future Opportunities with Borexino. Observation of the Dependence of Scintillation from Nuclear Recoils in Liquid Ar
Drift Field. The new wide-band solar neutrino trigger for Super-Kamiokande. Dark matter anisotropic distribution functions and impact on WIMP direct detection. Develop
SiPMs for ultra low background LAr and LXe detectors. Neutrino(Antineutrino) Cross Sections in some Nuclear Targets at Supernova Neutrino Energies. DAMIC at SNOLAB:
DAMIC100. Future Geo-Neutrino Experiments. Search for the light WIMP captured in the Sun using contained events in Super-Kamiokande. The Status of the Search
Mass WIMPs: 2013. Search for an annual modulation in 3.4 years of CoGeNT data. Coherent Inverse Primakoff-Bragg Conversion of Solar Axions in Single Crystal Bolo
Recent results from EXO-200. Updates from the DMTPC directional dark matter experiment. Recent Results from the KamLAND-Zen Experiment. Halo Independent Com
of Direct Dark Matter Detection Data. Non-Standard Mechanisms for Double Beta Decay. ANDES: an underground laboratory in South America. Recent results from the C
experiment. Geo-neutrinos and Earth Models. The EDELWEISS Dark Matter search. The status of the MARE experiment with 187Re and 163Ho isotpes. KamLAND-PIC
Matter Search Project. Atmospheric neutrino calculations. The Electron Capture 163Ho experiment ECHo. First results from subkeV energy threshold spherical gazeous dete
light Dark Matter identification. The LUX Experiment. A Dark Matter Search with The MAJORANA Low-Background Broad Energy Germanium Detector. The Majorana Demo
Calibration System. Dark Matter search with CUORE-0 and CUORE. The Majorana Demonstrator for 0vBB: Current Status and Future Plans. A CDMS low ionization th
experiment and SuperCDMS SNOLAB. CUORE and beyond: bolometry techniques to explore inverted neutrino mass hierarchy. Model-Independent Analyses of Dark Matter
interactions. Physics beyond neutrinoless double-beta decay with a tonnescale germanium experiment. Status of NEXT-100. New Limits on Sterile Neutrino Mixing with Atmo
Neutrinos. The Precision Tracker of the OPERA Detector. Design of low energy calibration sources for liquid xenon dark matter detectors.. Neutron detection and distinguishi
energy Anti-neutrinos in Super-Kamiokande. Searching for Dark Matter with PICASSO. The unbearable lightness of being: CDMS versus XENON. The latest results from
the neutrino oscillation. SNO+ experiment. Recent progress in KIMS experiment. The AMoRE project to search for neutrinoless double decay of 100Mo using cryogenic C
detectors. Sterile neutrino oscillations: the global picture. Production of 51Cr neutrino and 144Ce antineutrino sources for SOXand CeLAND experiments (presented by
Cribier). Analysis of 3+ years of CoGeNT Data. GADZOOKS!. The Sanford Underground Research Facility (SURF). Limits on spin-independent couplings of WIMP dark
with a p-type point- contact germanium detector. Progress and results from COUPP60. Neutrino flavor sensitivity of large scintillator detectors. Reaching higher sensitiv
neutrinoless doube beta decay with GERDA phase II. The LUX Experiment: Background Modeling and Sensitivity Projections. DarkSide-50 experiment status. Testing th
Exclusion Principle for Electrons at LNGS. Development of Germanium Detectors with n/g Discrimination at 77 K for Dark Matter Experiments. DarkSide-50: a two-phas
TPC for a direct WIMP search. Improving Dark Matter Searches by Measuring the Nucleon Axial Form Factor: perspectives from MicroBooNE. The DRIFT Directional Dark
Detector. NEST, the Noble Element Simulation Technique. Status of XMASS experiment. GLACIER for LBNO: Physics motivation and R and D results. Future of Super-Kami
and Hyper-Kamiokande. NEWAGE. PICOlite: A bubble chamber to search for light WIMPs. A maximum-likelihood-method search for low-mass WIMPs using the CDMS II expe
Ton-scale Xenon Gas TPC Concept for Simultaneous Searches for WIMP Dark Matter with Directional Sensitivity and Neutrino-less Double Beta Decay. Solar Neutrino Pr
with the SNO+ Experiment. Atmospheric neutrino oscillation and mass hierarchy determination in Super-Kamiokande. First experimental results in High Pressure Xe + TMA n
owards supra-intrinsic energy resolution and sensing of Dark Matter directionality. Trigger and analysis tools for Dark Matter Search in CUORE-0. Activites at Modane Under
Laboratory. Characterization of Nuclear Recoils in High-Pressure Xenon Gas: Towards a Simultaneous Search for WIMP Dark Matter and Neutrinoless Double Beta Decay.
Solar Neutrino Results From Super-Kamiokande. Update on the MiniCLEAN Dark Matter Experiment. DIANA - An Underground Accelerator Facility for Nuclear Astro
Status Report. The Origin of Neutrino Masses and Neutrinoless Double Beta Decay. Measurements of low-energy nuclear recoils in liquid argon. PRELIMINARY RESUL
ANAIS-25 AT THE CANFRANC UNDERGROUND LABORATORY. Results from the GERDA experiment. SABRE: A new NaI(Tl) dark matter direct detection experiment. P
resent experiments of geoneutrinos. The Nuclear Matrix Elements for 0nbb-Decay: Current Status. The SNOLAB Science Programme. SOX: Short distance neutrino Osc
with BoreXino. Systematics of Low Threshold Modulation Searches in CDMS-II. Light WIMPs And Equivalent Neutrinos. LUMINEU: a pilote scintillating bolometer exp

Scientific research in Underground Laboratories

These many topics can usually be grouped into:

- Neutrino physics
- Dark Matter search
- Low radiation and multidisciplinary experiments

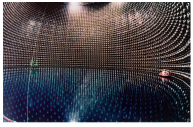
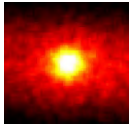
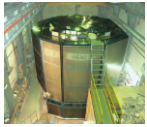
Neutrino underground experiments

Sources

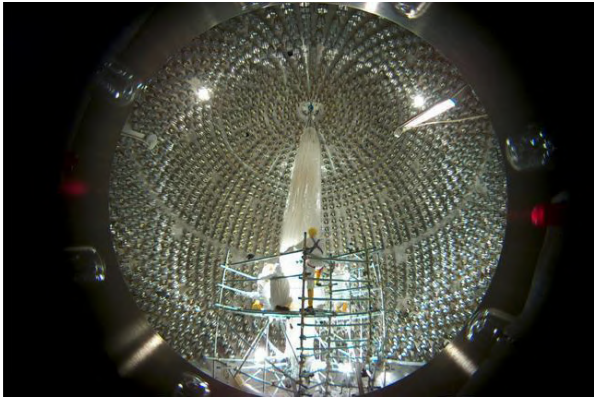
- neutrinos from nuclear reactors
- neutrinos from particle accelerators
- atmospheric neutrinos
- solar neutrinos
- astrophysical neutrinos
- geoneutrinos

Physics

- neutrino oscillation
- neutrino masses
- neutrino nature
- astrophysics
- geophysics

Current state of the art neutrino detector: Borexino



Low energy neutrino detector @ Gran Sasso

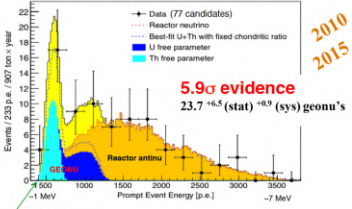
ARTICLE

doi:10.1038/nature13702

Neutrinos from the primary proton–proton fusion process in the Sun

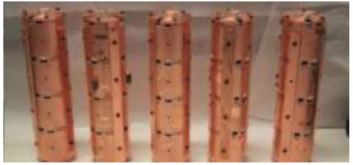
Borexino Collaboration*

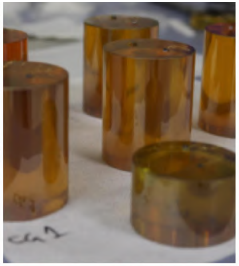
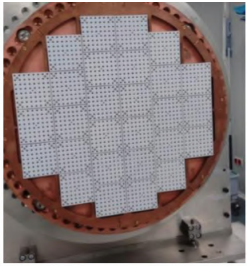
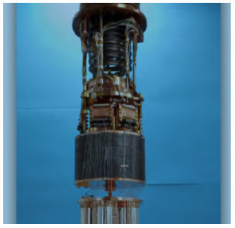
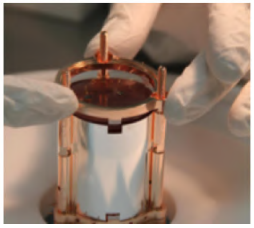
In the core of the Sun, energy is released through sequences of nuclear reactions that convert hydrogen into helium. The primary reaction is thought to be the fusion of two protons with the emission of a low-energy neutrino. These so-called *pp* neutrinos constitute nearly the entirety of the solar neutrino flux, vastly outnumbering those emitted in the reactions that follow. Although solar neutrinos from secondary processes have been observed, proving the nuclear origin of the Sun's energy and contributing to the discovery of neutrino oscillations, those from proton–proton fusion have hitherto eluded direct detection. Here we report spectral observations of *pp* neutrinos, demonstrating that about 99 per cent of the power of the Sun, 3.84×10^{26} ergs per second, is generated by the proton–proton fusion process.



Non antineutrino background is almost invisible!

Neutrinoless double beta decay search

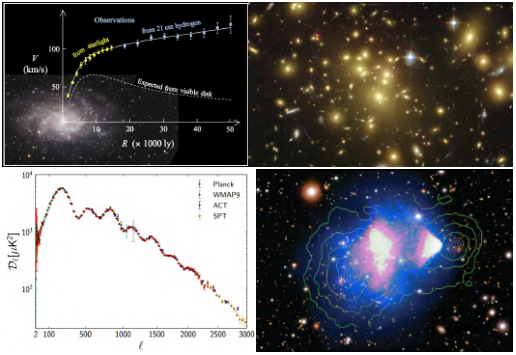






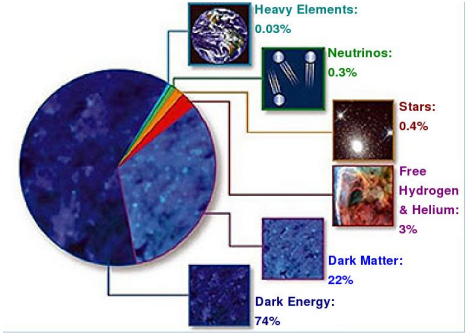
Kamland-Zen
SNO+
CUORE
Majorana
GERDA
CUPID
nEXO
SuperNEMO
NEXT
...

Dark matter in the Universe

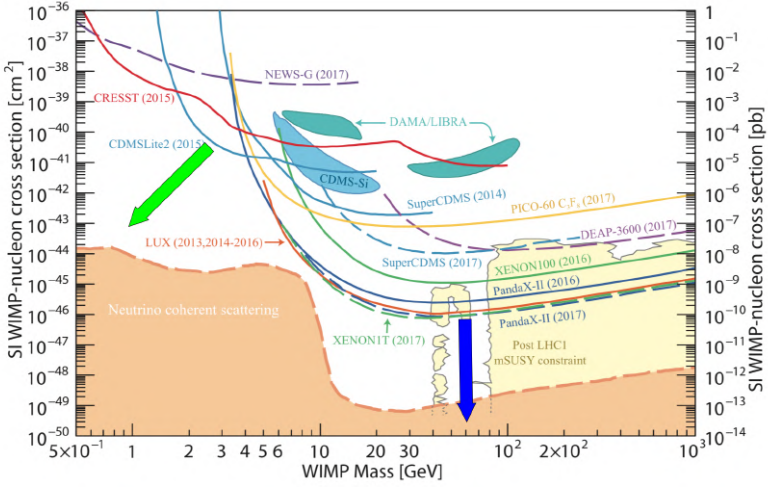
"There are known knowns; there are things we know we know.
We also know there are **known unknowns**; that is to say, we know there are some things we do not know.
But there are also unknown unknowns - the ones we don't know we don't know."

Donald Rumsfeld

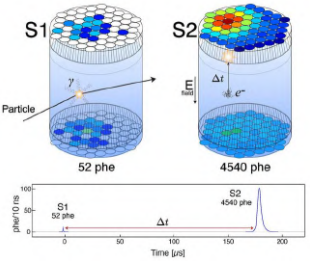




Direct searches (spin independent current limits - PDG2018)

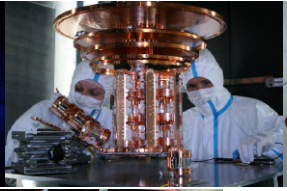
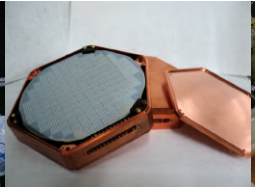


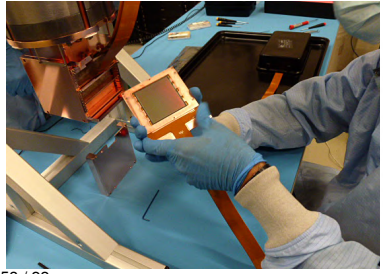
Going down: Xenon/Argon dual phase TPC

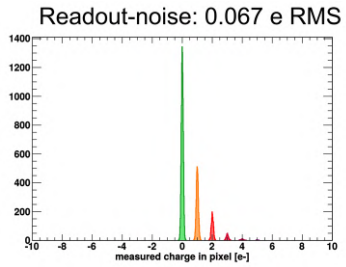


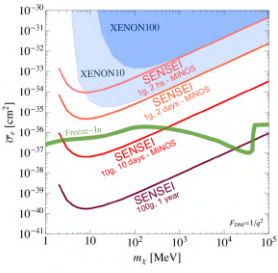
Going left: Low threshold detectors

CRESST, SuperCDMS, DAMIC, SENSEI (NEWS-G...)

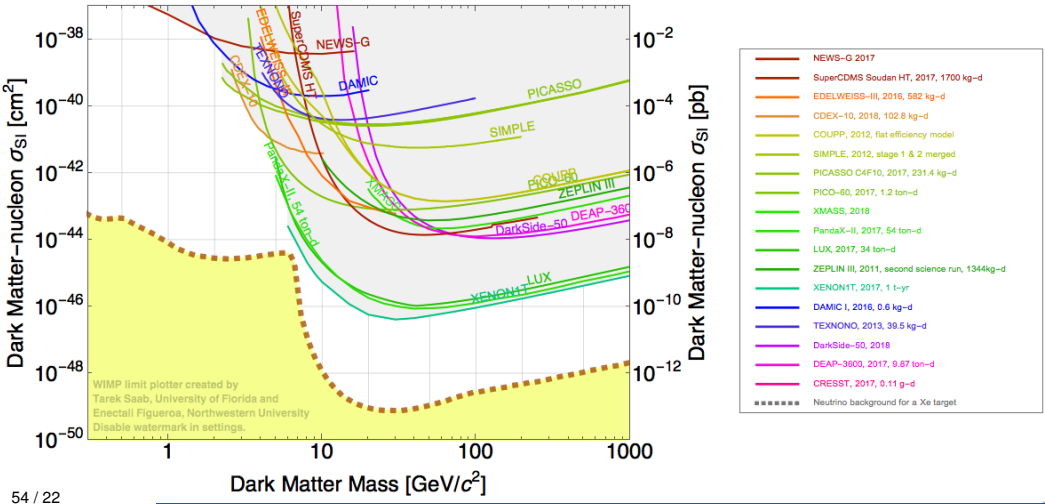










Many experiments and new ideas



Multidisciplinary underground experiments

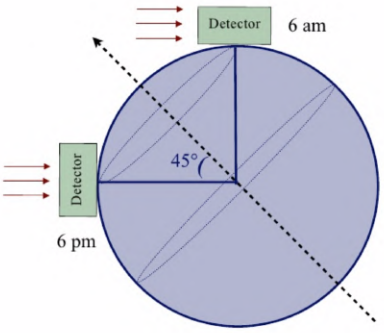
- Geoscience
- Radiation impact on Biology
- Low radiation measurements...
  - material selection
  - climatology, environment
  - microelectronics, wine

Introducing Sierra Grande

- Underground Laboratory operated in the 1990s
- Experiment from F. Avignone et al.
  Sideral day dark matter signal modulation
- located 400 m deep, 1000 m.w.e.
- See for example:
  - Astroparticle Physics 6, 63 (1996)
  - arXiv:astro-ph/9809018
  - arXiv:astro-ph/9712308
  - arXiv:astro-ph/9708008
  - arXiv:astro-ph/9311049

Directional Detection

Motivation



Daily Modulation

Wind direction changes every 12 hrs

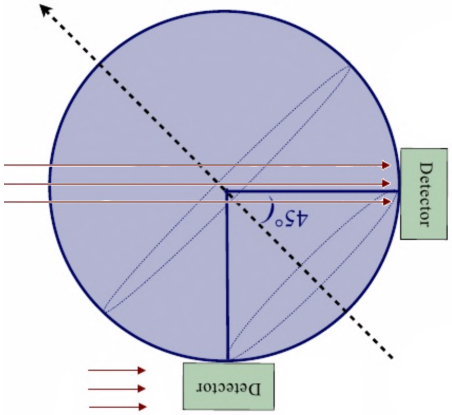
Large Amplitude

Daily modulation amplitude ~ 100%
Annual modulation amplitude ~ 5%

Smaller Backgrounds

Spergel, *Phys. Rev D* **37**, 1353 (1988)

Sideral day modulation in the South

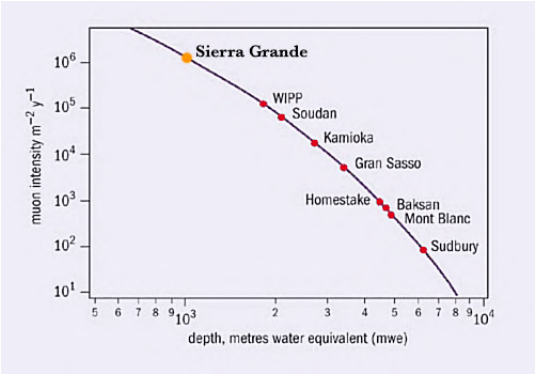


- WIMP wind coming from $\approx$ 40 deg North (Cygnus)
- Maximum modulation if WIMP flux modified by in Earth interactions (strong energy loss, self-interaction...)
- Sideral modulation: can be seen in one day, checked after a few (6?) months

Sierra Grande, we were there

Muon flux vs depth

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



Muon flux at Sierra Grande: $\approx 2\,\mathrm{m^{-2}\,min^{-1}}$

Sierra Grande, schedule

- First trip and contact — July 19, 2018
- Signed interest letter from MCC Sierra Grande president — Aug 15, 2018
- Signed agreement between CNEA and MCC — Sept 2019(?)
- First measurements: muon flux, radon — Sept 2019(?)
- First experiment: CCD daily modulation experiment — End 2019(?)

- Site available for 5 years
- After that may need to move 100 m up for permanent site
- Develop new skills underground (copper electroforming?)
- Start multidisciplinary underground activities?
  - Need agreement from MCC for extra activities