Expected Backgrounds at the ANDES Underground Laboratory

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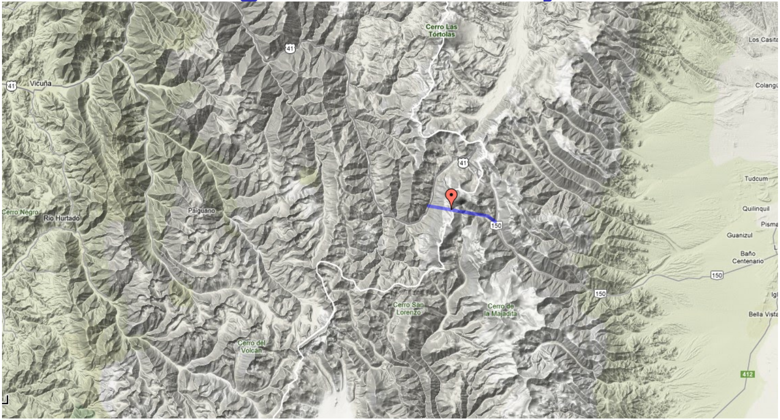
The Andes Underground Laboratory



Location

- 30.23 N 69.88 S, 3700 − 4000 m a.s.l.
- Magnetic field (IGRF'11): $B_N = 20.37\,\mu$T, $B_Z = -11.87\,\mu$T
- Rigidity cut-off 10.8 GV

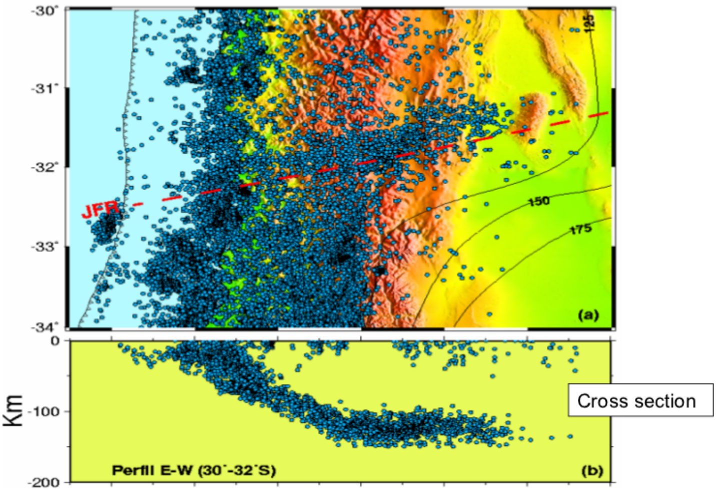
Outline

Some geological aspects
- Seismology
- Location

Background radiation
- Natural radioactivity
- Cosmic rays

Conclusions and future work
- Conclusions
- Future work

A bit of geology



Active seismological region: Subduction and Juan Fernandez Ridge

Source:S. Silvana, Seismological Laboratory in Agua Negra Tunnel, http://bit.ly/zIILBh

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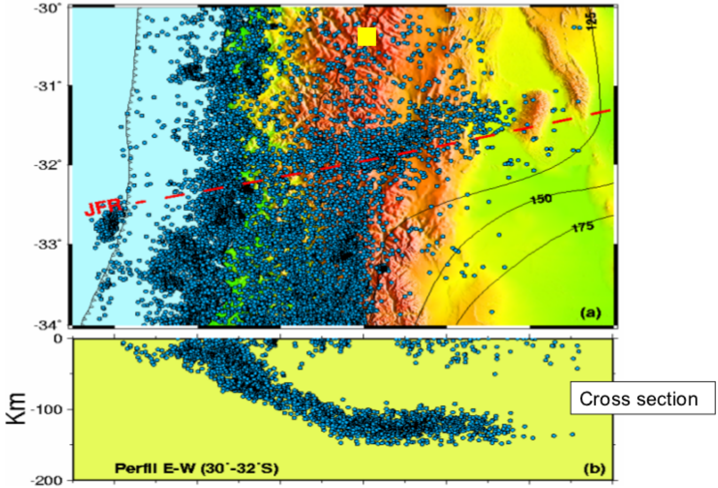
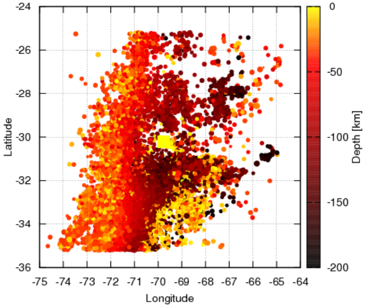


Lab located in a quite calm zone with no volcanic activity

Source:S. Silvana, Seismological Laboratory in Agua Negra Tunnel, http://bit.ly/zIILBh

Earthquakes



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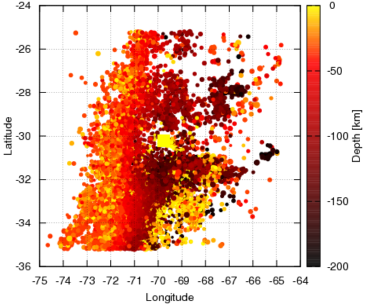

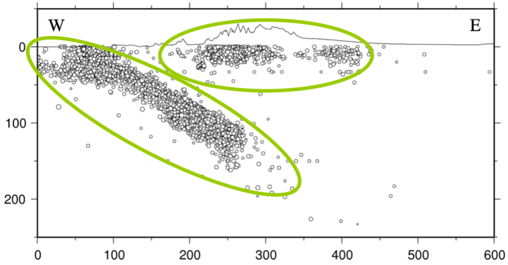

Two populations

- Deeper quakes: subduction
- Surface quakes: crust-ridge

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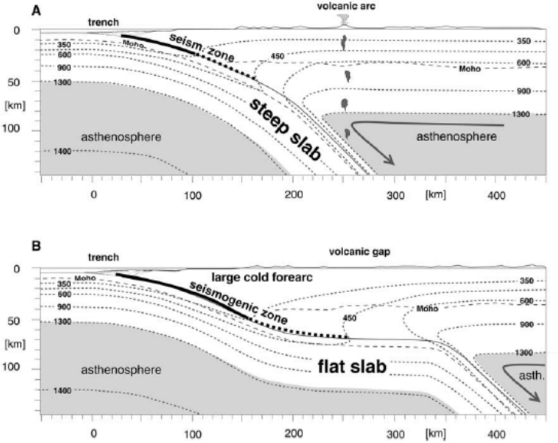
Flat slab



A
volcanic arc
trench
0
seism. zone
Moho
350
600
900
1300
450
Moho
50
[km]
100
steep slab
asthenosphere
asthenosphere
1400
0
100
200
300
[km]
400
B
volcanic gap
trench
Moho
large cold forearc
seismogenic zone
450
Moho
flat slab
asthenosphere
asth.
1400

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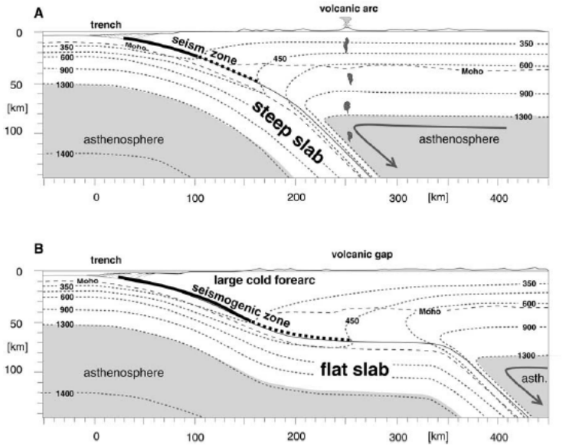

- Mechanical interaction: high seismicity
- Cooler upper plate: No volcanic activity and higher degree of interplate coupling

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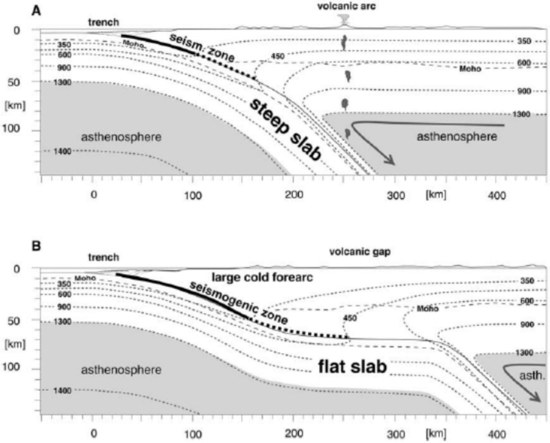

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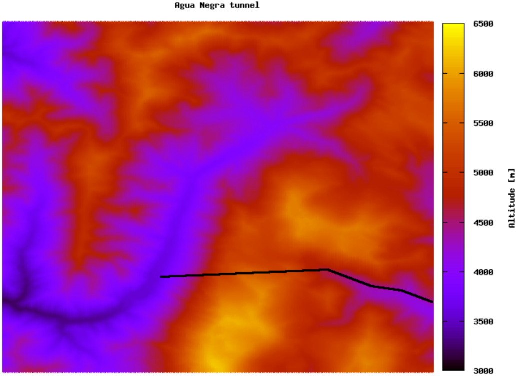
Proposal to install a complete Seismological Lab at ANDES

Where is the best place?



Elevation data

- 3 arc-sec resolution elevation data from SRTM
- Line indicates the axis of the planned tunnel
- Cerro San Lorenzo peaks at South

Source: X. Bertou, Rock overburden for the ANDES deep underground laboratory, TAN-2011-001

Rock overburden

At each point in a grid centred at the tunnel:

- Determine the vertical (Z) distance to the surface
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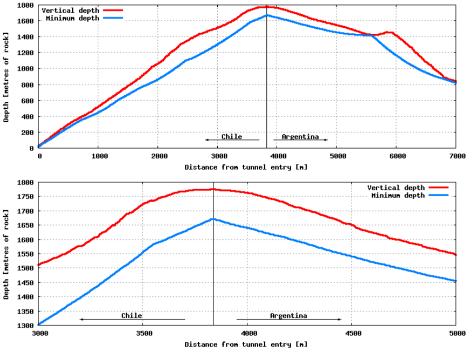

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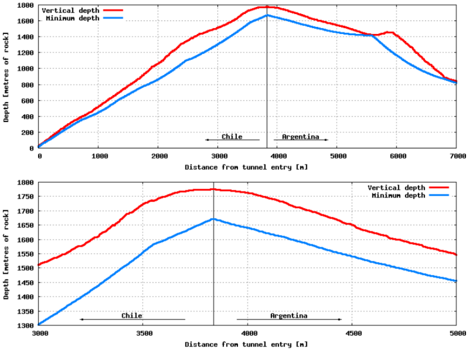

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Overburden rock: 1750 m vertical, 1620 m omnidirectional

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Background

Two main sources for background:

Natural radioactivity

- Nuclear decays in the rocks
- Main sources: Uranium, Thorium and Potassium
- Strategy: **Direct measurements**

High Energy Cosmic Rays

- Atmospheric production of secondary particles
- Main sources: Muons (highly penetrating) and neutrino interactions
- Strategy: **Simulations**

Geological prospections at Agua Negra

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- **Andesite**: Extrusive igneous volcanic rock: 52%-63% of SiO_2
- **Basalt**: Aphanite volcanic rock: 45%-52% of SiO_2
- **Rhyolite**: Felsic igneous volcanic rock: ($> 69\%$ SiO_2), but 5–20 times the Uranium concentration respect other rocks

Measurements with Germanium detectors

- Analysis made at Neutronic Activation Lab at Centro Atómico Bariloche
- Reference sources: Baltic Sea Sediment (IAEA-300); Radionuclides in Solid (IAEA-327); Freshwater lake sediment (NIST-4354)

First results - Direct measurements

Agua Negra rock samples

Channel	**Andesite**	**Basalt**	**Rhyolite 1**	**Rhyolite 2**
^{238}U	(9.2 ± 0.9)	(2.6 ± 0.5)	(14.7 ± 2.0)	(11.5 ± 1.3)
^{232}Th	(5.2 ± 0.5)	(0.94 ± 0.09)	(4.5 ± 0.4)	(4.8 ± 0.5)
^{40}K	(47 ± 3)	(50 ± 3)	(57 ± 3)	(52 ± 3)

Activity in Bq/kg. Reference: Decay of ^{40}K in human body: ~ 65 **Bq/kg**

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Canfranc Underground Lab

Channel	Ranges
^{238}U	(4.5 ± 0.2)–(30 ± 3)
^{232}Th	(8.5 ± 0.3)–(76 ± 2)
^{40}K	(37 ± 1)–(880 ± 36)

Activity in Bq/kg. Source: J. Amar et al. (2006) doi:10.1088/1742-6596/39/1/035

First results - Neutrons from spontaneous fission

Agua Negra rock samples - Neutrons per kg per second

Channel	**Andesite**	**Basalt**	**Rhyolite 1**	**Rhyolite 2**
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Other Labs (spontaneous fission channel)

Laboratory	Ranges
Canfranc	(5.4×10^{-6})–(3.7×10^{-5})
Gran Sasso A	$\sim (1 \times 10^{-4})$
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- Neutrons from (α, n) reactions: calculations are underway (ALPHN code)
- **Similar (and even better) values for ANDES compared to other underground facilities**

Cosmic rays background

Cosmic Rays are one of the main sources of natural radiation

How to estimate the underground background?

Determine the time of exposure	**Fluctuations**
Calculate the integrated flux of primaries at the top of the atmosphere	**Measured spectra**
Propagate primaries through the atmosphere and obtain distribution of secondaries at 4000 m a.s.l.	**Corsika**
Propagate secondaries across 1750 m of rock	**Geant4**

1. Exposure time

Flux of primaries: $j(E) = j_0 \times E^{-\gamma}$ $\quad \gamma : 2.5 \to 2.8$

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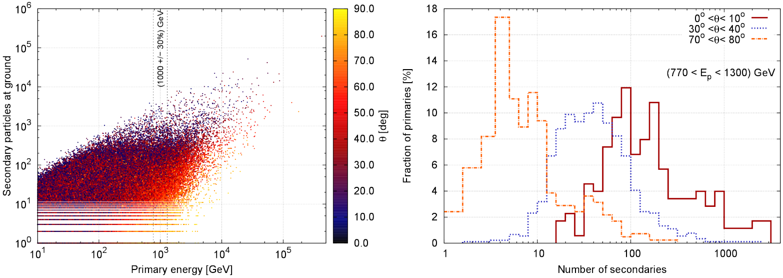

- Higher energy: Low flux but large number of secondaries
- Lower energy: Small number of secondaries compensated by a much larger flux

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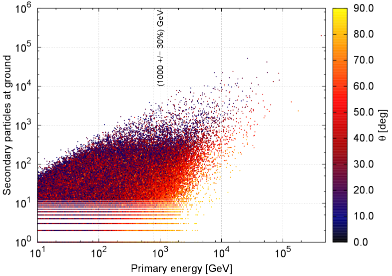

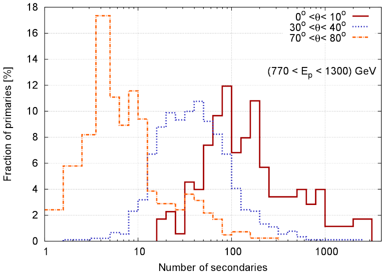

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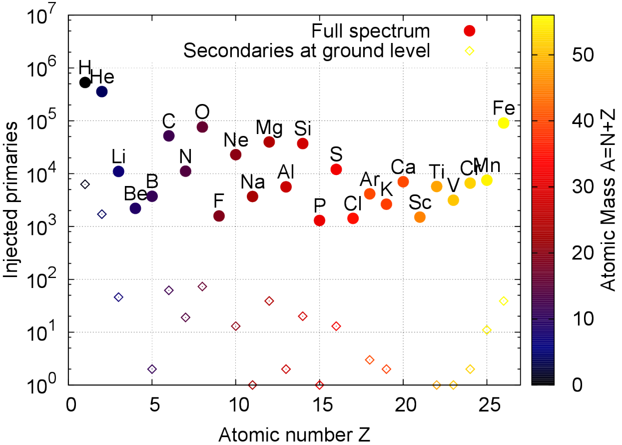
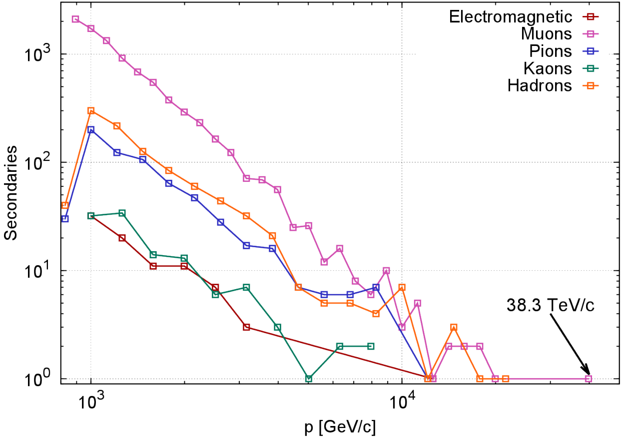
Simulate one month of full spectrum at the top of the atmosphere

2. Integrated flux at the top of the atmosphere

- Set of (CORSIKA+QGSJET-II+GHEISHA) simulations
- Measured spectra for all nuclei $1 \leq Z_p \leq 26$ (p $\rightarrow$ Fe)
- Energy range: $1 < (E_p/\mathrm{TeV}) < 10^4$,
- Arrival directions: Isotropic flux, $0^\mathrm{o} < \theta < 88^\mathrm{o}$
- 30 days of the flux of primaries: $\sim 1.3 \times 10^6$ nuclei m^{-2}



3. Secondaries at 4000 m a.s.l.



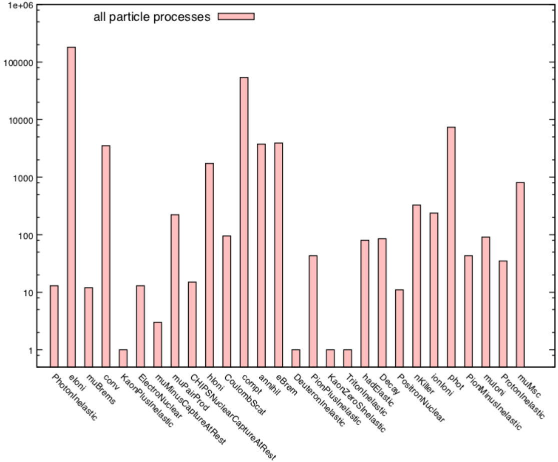
- High energy cut-off for secondaries: $E_c = 800\,\mathrm{MeV}$
- 11290 secondary particles with $E_s \geq E_c$
- 56 photons; 32 electrons; 9395 muons; 1807 hadrons

3. Integrated flux at 4000 m a.s.l. for $E_s > 800$ MeV

Particle	Expected number	Flux [counts m^{-2} s^{-1}]
γ	56	(2.1×10^{-5})
$e^{\pm}$	32	(1.2×10^{-5})
$\mu^{\pm}$	9395	(3.6×10^{-3})
$\pi^{\pm}$	692	(2.7×10^{-4})
K_L^0	49	(1.9×10^{-5})
$K^{\pm}$	71	(2.7×10^{-5})
$n + \bar{n}$	444	(1.7×10^{-4})
$p + \bar{p}$	549	(2.1×10^{-4})
Λ	2	(7.7×10^{-8})
Total flux	**11290**	$(\mathbf{4.4 \times 10^{-3}})$

4. Flux of particles 1750 m deep underground

- Geant4 simulation
- Propagation of particles through 1750 m of Andesite (average composition, $\rho = 2.8\,\mathrm{g\,cm^{-3}}$)
- Space grid resolution: $1\,\mathrm{m} \times 1\,\mathrm{m}$



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Particle	Expected number	Flux [counts $m^{-2}\,s^{-1}$]
μ^+	15	(5.79×10^{-6})
μ^-	13	(5.01×10^{-6})
ν_e	6901	(2.66×10^{-4})
$\bar{\nu}_e$	2042	(7.88×10^{-4})
ν_μ	71125	(2.74×10^{-2})
$\bar{\nu}_\mu$	71256	(2.75×10^{-2})

Muon underground flux

- Total flux: (1.08×10^{-5}) muons $m^{-2}\,s^{-2}$
- Energy range: $5.4 \leq E_\mu/\mathrm{GeV} \leq 1470$, flat spectrum
- Three muons with $E_\mu > 1$ TeV (one of them with $E_\mu = 10.5$ TeV)

Conclusions

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- **I'm not a geologist**

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- Flat slab: potential interest for geologists
- 1750 m ($\sim$ 4900 mwe) of vertical deep and 1620 m omnidirectional overburden rock
- The natural radioactivity and the neutron production from fission reactor was measured:
  Compatible (or even better) values for ANDES compared to similar underground facilities
- The muon underground flux was simulated:
  $(1.08 \times 10^{-5})\,\mathrm{muons\,m^{-2}\,s^{-2}} \approx 1$ event per day per m^2

Future work

- Increase the accuracy of radioactivity measurements with a new calibration procedure (underway)
- Determine neutron production from (α, n) reactions (underway)
- Increase the total time of the simulated flux up to one year
- Include some extra neutrino interactions in Geant4 simulations (underway)
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