ANDES

AGUA NEGRA DEEP EXPERIMENT SITE

Proposal for a Deep Underground Laboratory
in the Southern Hemisphere

Claudio Dib
Universidad T. Federico Santa Maria, Valparaiso, Chile
on behalf of ANDES Coord. Team.

HEP 2018, Valparaíso, Chile

Proposal:

- To build an Underground Lab in the AGUA NEGRA tunnel.

First **deep underground Lab** in the **Southern Hemisphere.**

Content

- The Agua Negra Tunnel
- ANDES Lab proposal
  - Scientific programme (preliminary)
  - Conceptual design
- Organization (CLES)
- Current status

The Agua Negra Tunnel

The Tunnel Proposal

- Why a Road tunnel: - growing trade of Argentina and Brazil with Asia.
- Shipping through Chilean ports → to cross the Andes.
- The mountain Pass suffers severe cuts in winter.

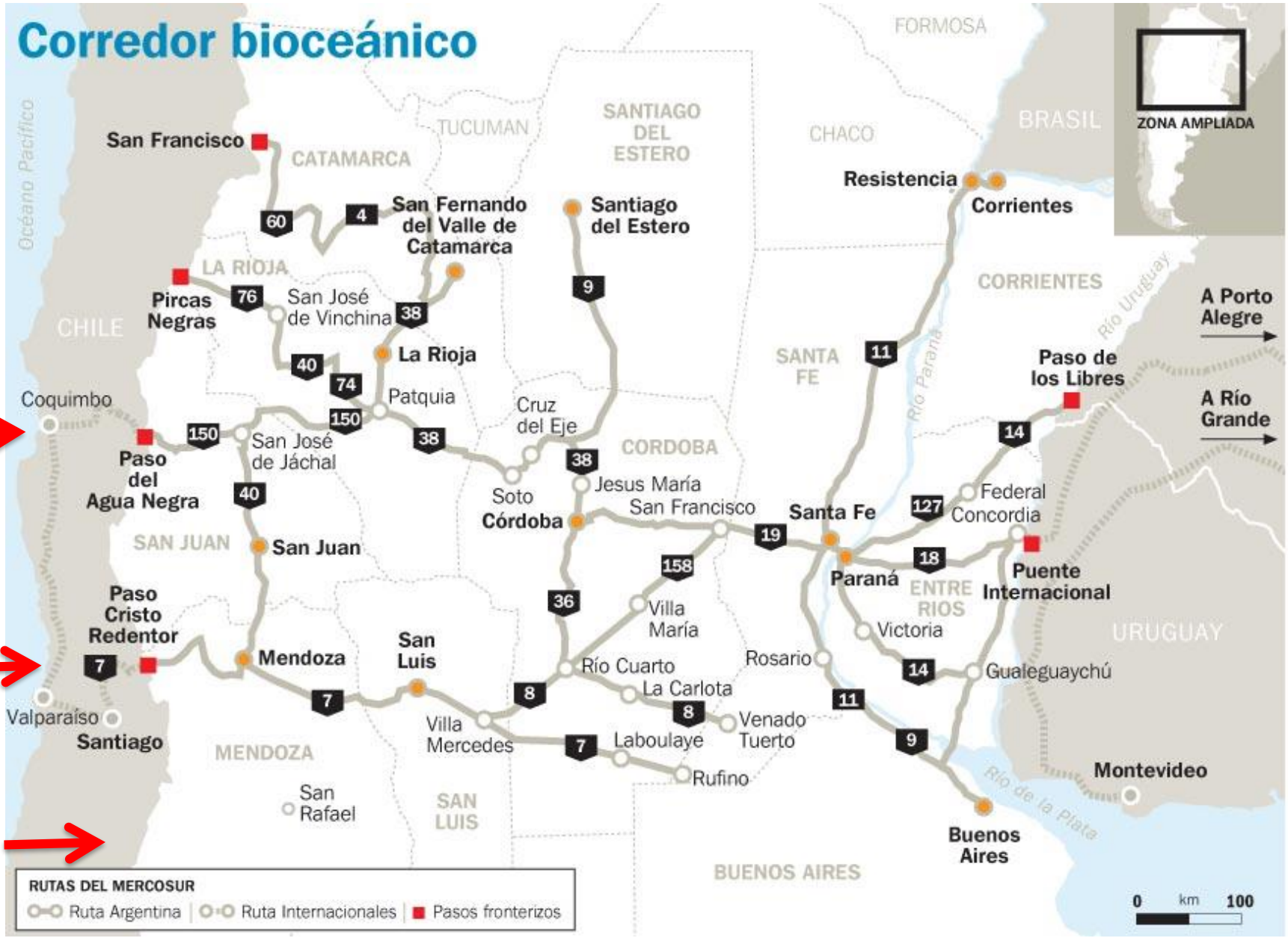
Views of the Agua Negra pass at 4780 m a.s.l.

Tunnel approx. Coordinates: 30.19 South, 69.82 West

La Serena, Chile

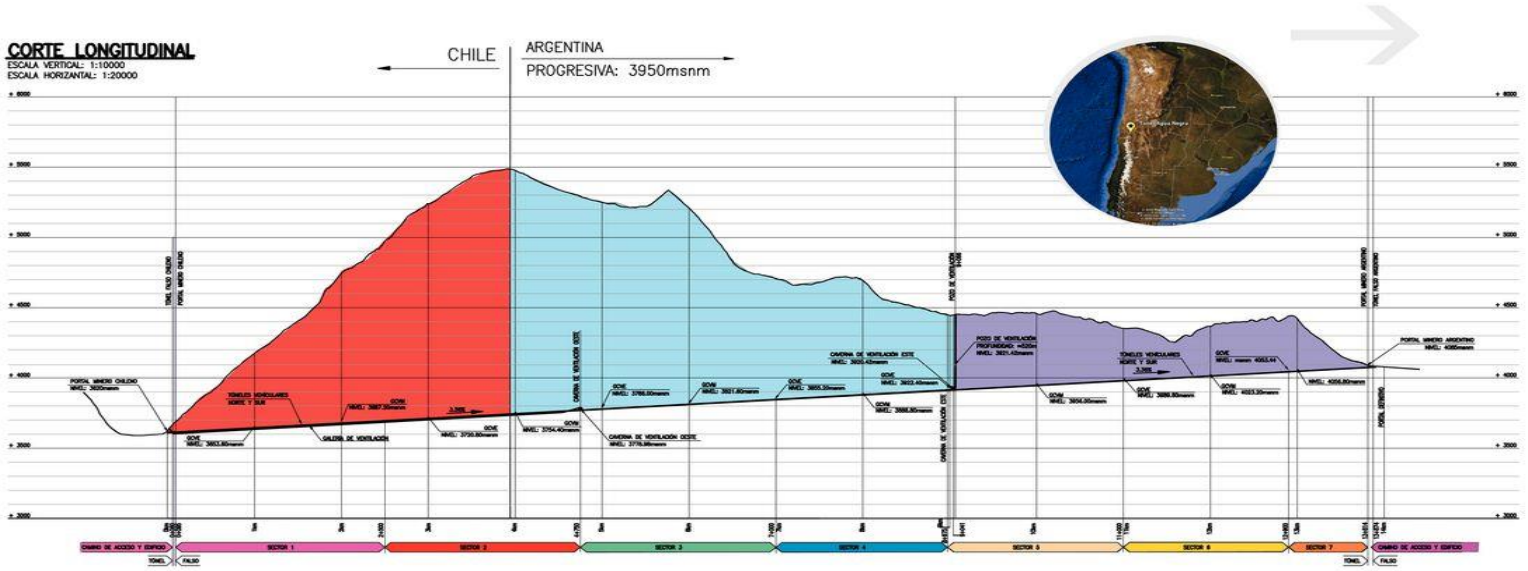
Cerro Tololo
Int. Am. Observatory

San Juan,
Argentina


Corredor bioceánico
Océano Pacífico
CHILE
San Francisco
CATAMARCA
TUCUMAN
SANTIAGO DEL ESTERO
CHACO
FORMOSA
BRASIL
ZONA AMPLIADA
Resistencia
Corrientes
San Fernando del Valle de Catamarca
Santiago del Estero
LA RIOJA
Pircas Negras
San José de Vinchina
La Rioja
CORRIENTES
Río Uruguay
A Porto Alegre
A Río Grande
Río Paraná
SANTA FE
Paso de los Libres
Coquimbo
Patquia
Cruz del Eje
Paso del Agua Negra
San José de Jáchal
CORDOBA
Soto
Córdoba
Jesus María
San Francisco
Santa Fe
Federal
Concordia
SAN JUAN
San Juan
Paraná
ENTRE RIOS
Puente Internacional
Paso Cristo Redentor
Villa María
Victoria
URUGUAY
Mendoza
San Luis
Río Cuarto
Rosario
La Carlota
Gualeguaychú
Valparaíso
Santiago
Villa Mercedes
Laboulaye
Venado Tuerto
MENDOZA
Rufino
Montevideo
San Rafael
SAN LUIS
Río de la Plata
Buenos Aires
BUENOS AIRES
RUTAS DEL MERCOSUR
Ruta Argentina
Ruta Internacionales
Pasos fronterizos
0 km 100

Tunnel features

- Altitude: 3600 m asl (Chile), 4085 m asl (Argentina), slope ~ 3%
- Two parallel tunnels, 14 km long, 60 m separation
- 12 m diameter (two lanes each), connecting galleries every 500 m.
- Deepest point: 1750 m depth.
- Forced ventilation (14.5 MW).



Tunnel proposal updates

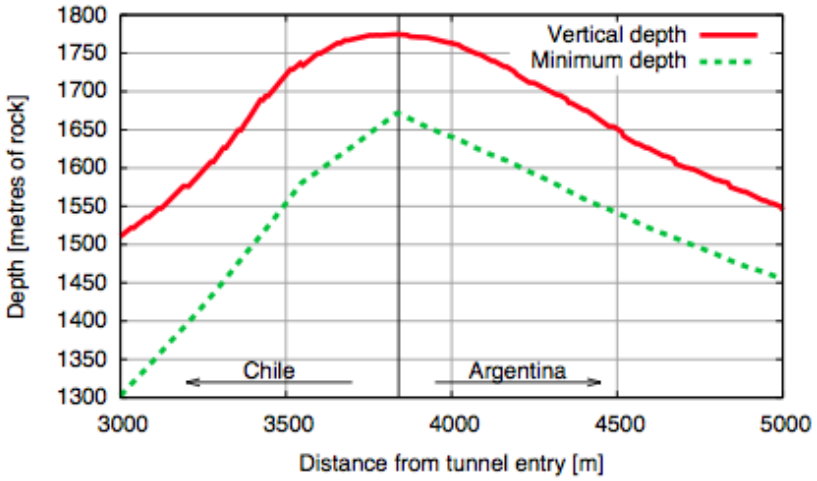
- Pre-feasibility study done in 2005, feasibility in 2008.
- 2009, October: presidents of Argentina and Chile signed a Bi-National Integration Treaty, including San Juan-Coquimbo.
- 2010, August: MERCOCUR Meeting in San Juan: “strong support for Agua Negra Tunnel”, with President of Brazil pushing for tunnel tender.
- 2011, December: Argentina Congress voted a 800 MU$D guarantee fund for the Agua Negra tunnel.
- 2012, March: presidents of Argentina and Chile signed international agreement asking for the tender of the tunnel.
- 2013: New Conceptual Design and budget review.
- 2014: Detailed Engineering Design.
- 2015, June: Chile Congress approval for new budget.
- 2017: Call for tender
- 2018: Start construction (expected)

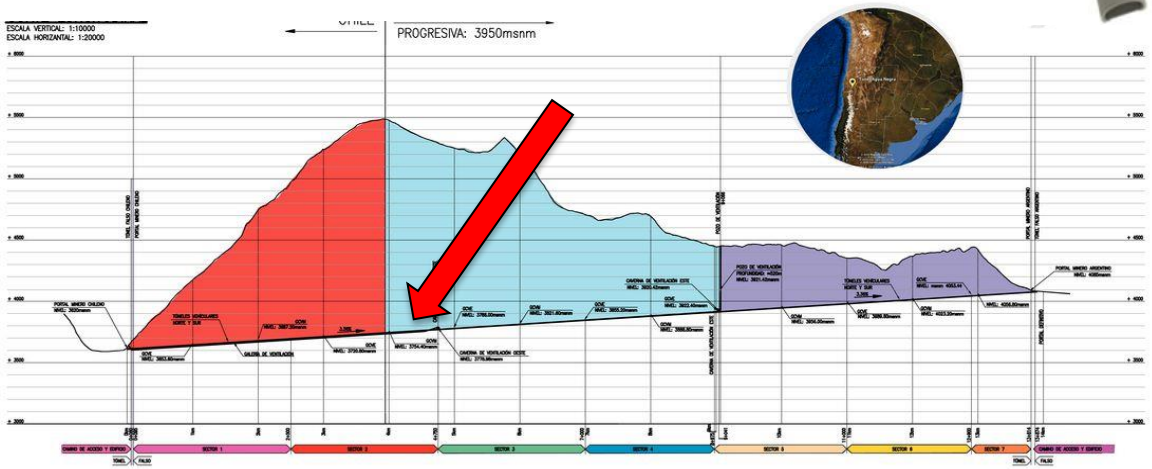
The ANDES Laboratory proposal

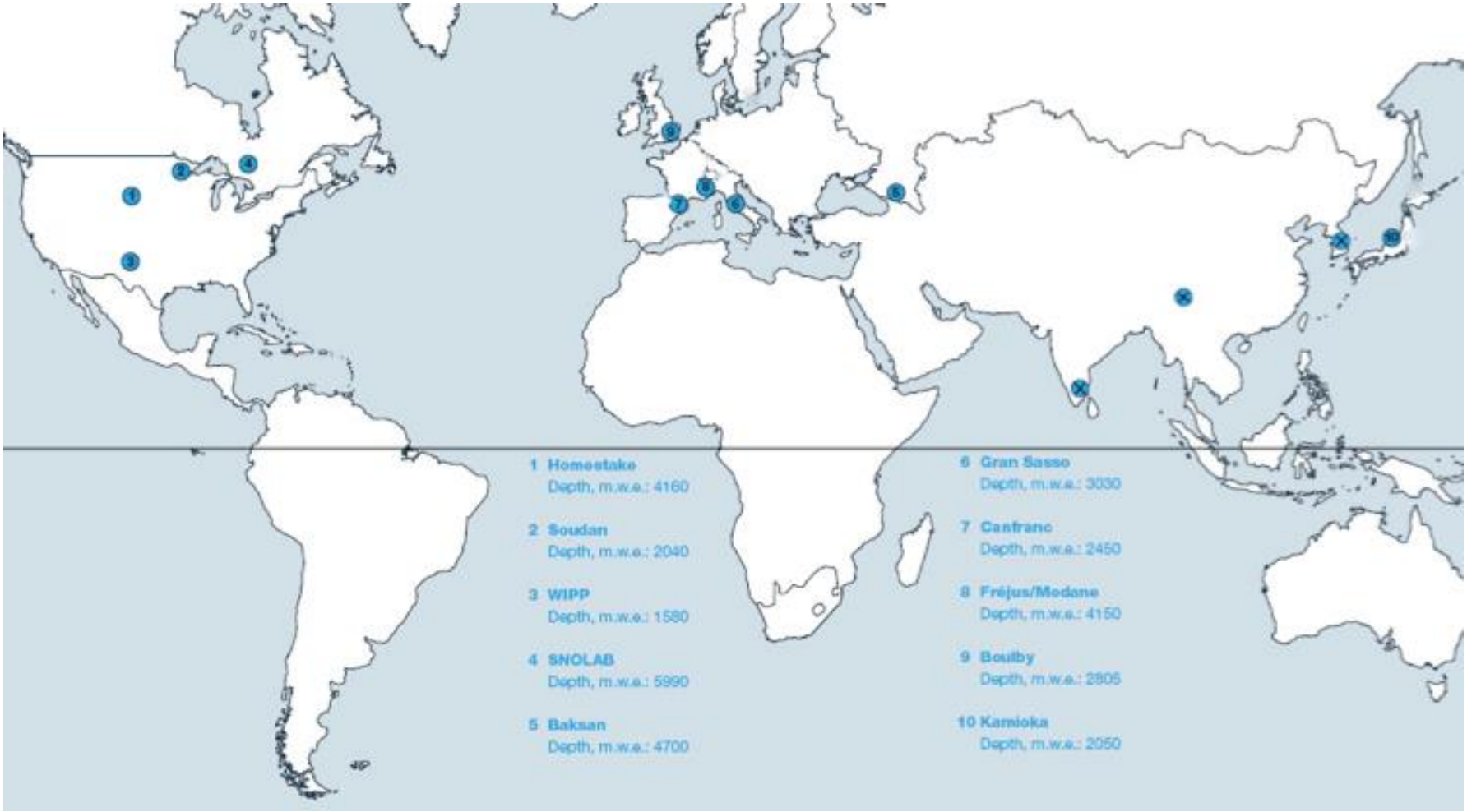
ANDES: **A**gua **N**egra **D**eep **E**xperiment **S**ite

The ANDES Lab proposal

- Deepest point in tunnel (~ 1750 m deep)
  ≈ 3.5 km to Chile entrance, 10 km to Argentina exit

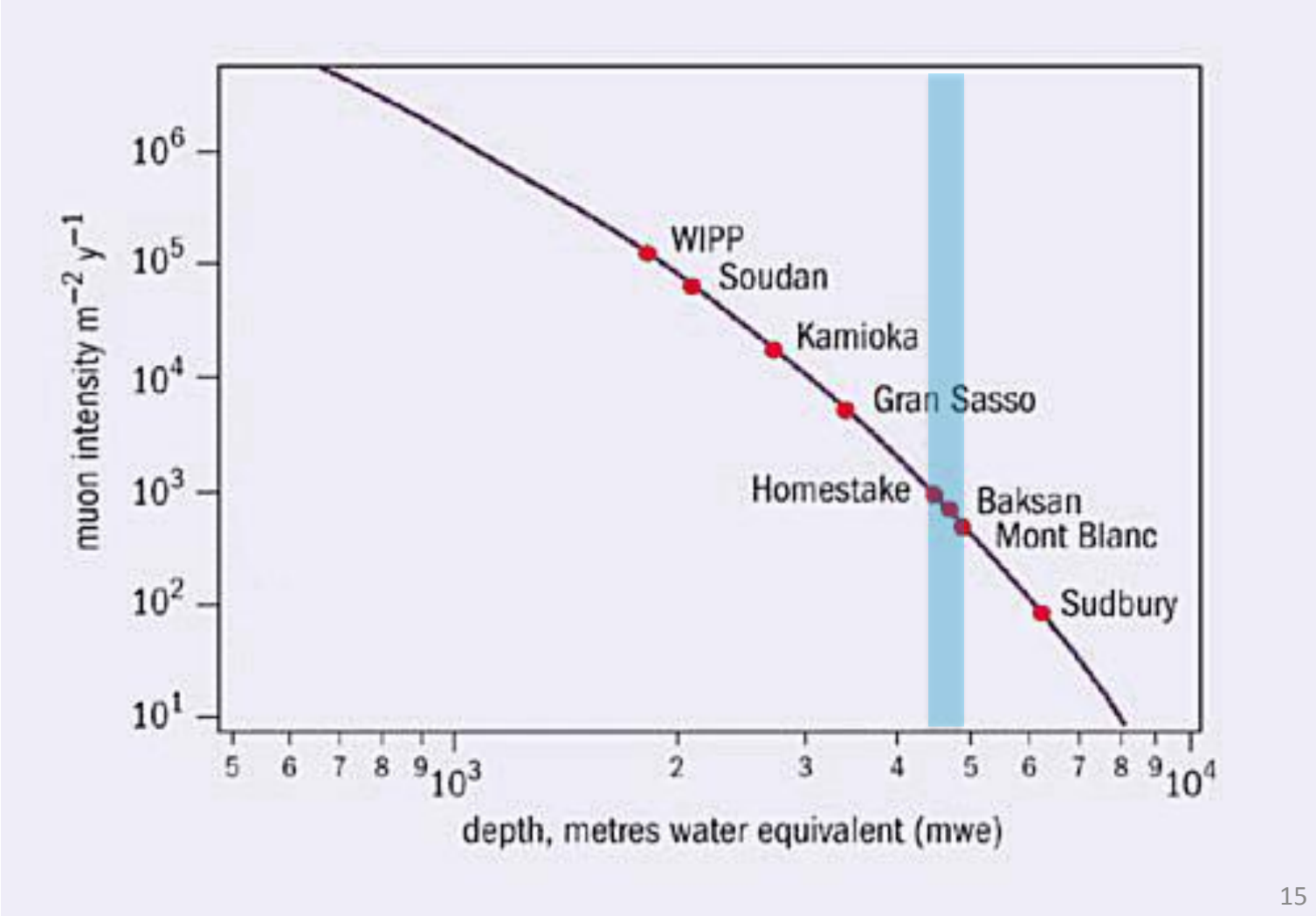






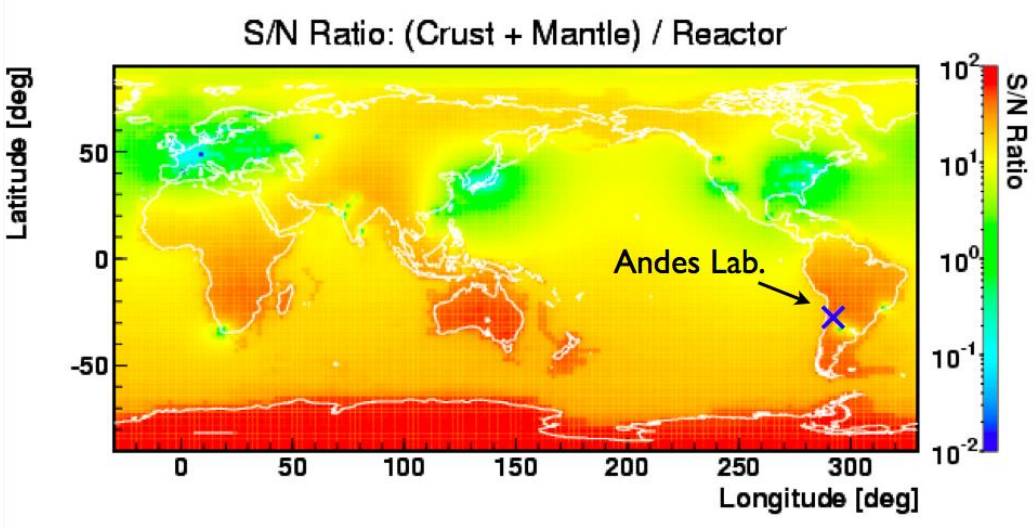
So far, all deep U. Labs are in the Northern Hemisphere.

Flux at sea level ~ 100 /m^2 s ANDES: ~ 4500 mwe; atn: 10^{-7}



What makes ANDES special?

- Third deepest Lab in the world.
- First in the southern hemisphere
  - Opposite weather-induced modulations
- Low reactor neutrino bkg
  - Embalse: 2.1 GWth, 560 km
  - Atucha: 1.2 GWth, 1080 km
  - Atucha II: 2.1 GWth
- Geoactive Region
  - Geophysics experiments
- Very long baselines...?
  - CERN: 9920 km.
  - Fermilab: 7640 km.
  - KEK: 12400 km (1500 km from earth center)



ANDES scientific programme
(tentative)

ANDES initial Scientific Programme

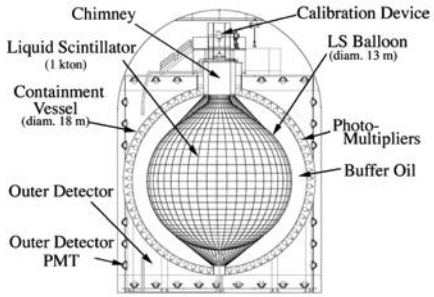
- Neutrino physics:
  - host double beta decay experiments
  - large neutrino detector (similar to KamLAND / Borexino)
    - focused on low energies (solar / SN / geoneutrinos)

- Dark Matter
  - modulation measurements
  - new technologies

- Geophysics
  - link Chile-Argentina seismograph networks
- Biology
- Low radiation measurements
- Nuclear Astrophysics (low energy beams)

Proposed **Large Latinamerican Neutrino Detector**

- 3 – 10 kton of liq. Scintillator
- arXiv:1027.5454
- Main topic for next ANDES workshop.



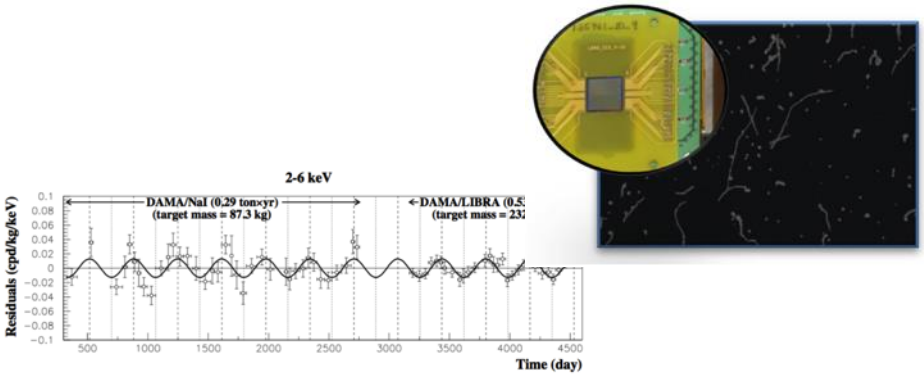
Double Beta experiments:

Manifested interest:

- NEXT
- SuperNEMO modules: ~ 100 kg ^{82}Se

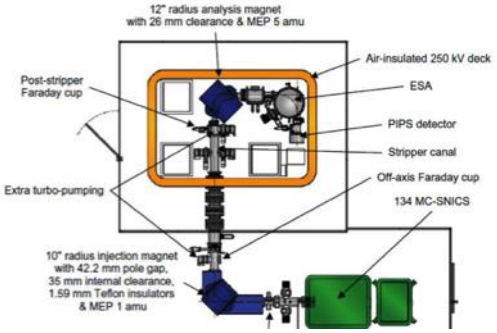
Dark Matter:

- Host a south copy of a DM experiment with modulation signal.
- Host a next gen. DM experiment.



Nuclear Astrophysics:

- proposal for a 300 keV high intensity ion beam (similar to LUNA)
- Study nuclear reactions of stars



ANDES Conceptual Design

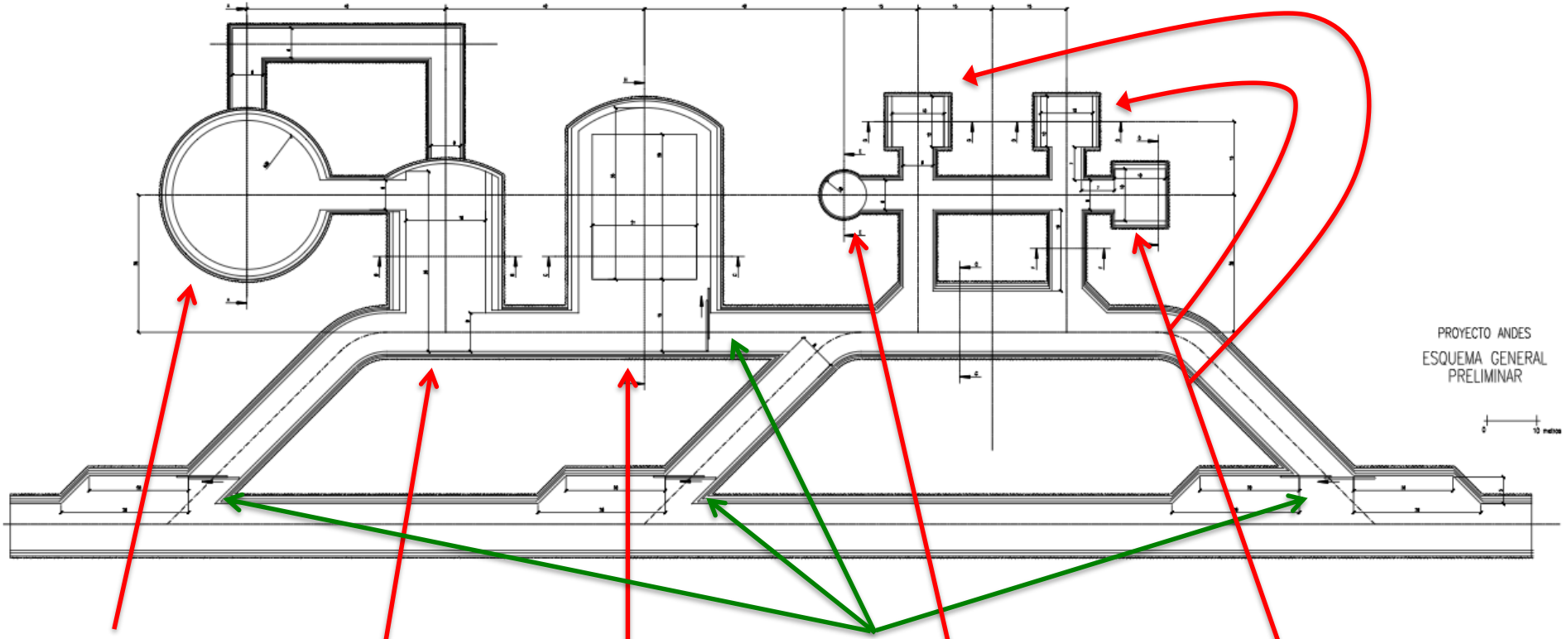
ANDES proposed infrastructure

- **The underground Lab itself:**
  - 2 horizontal caverns, 1 large pit, 1 small pit, service room, access galeries.

- **Support Laboratories:**
  - One in Chile (La Serena), and one in Argentina (Rodeo)
  - To host Laboratories, administration, offices and an Outreach Center.

- **Lodging at the borders (portals).**
  - Office, bedrooms, storage

Proposed schematic layout



Large pit
30 m diam
42 m deep

Access:
at 30 m high
and
at bottom

Service hall
40 m long
16 m wide
15 m high
Oval section

Main hall
50 m long
21 m wide
23 m high
Oval section

Gates

Ultra low radiation pit
9 m diam
15 m deep

Access:
At 10 m high and bottom

3 secondary caverns
10 x 10 x 10 m

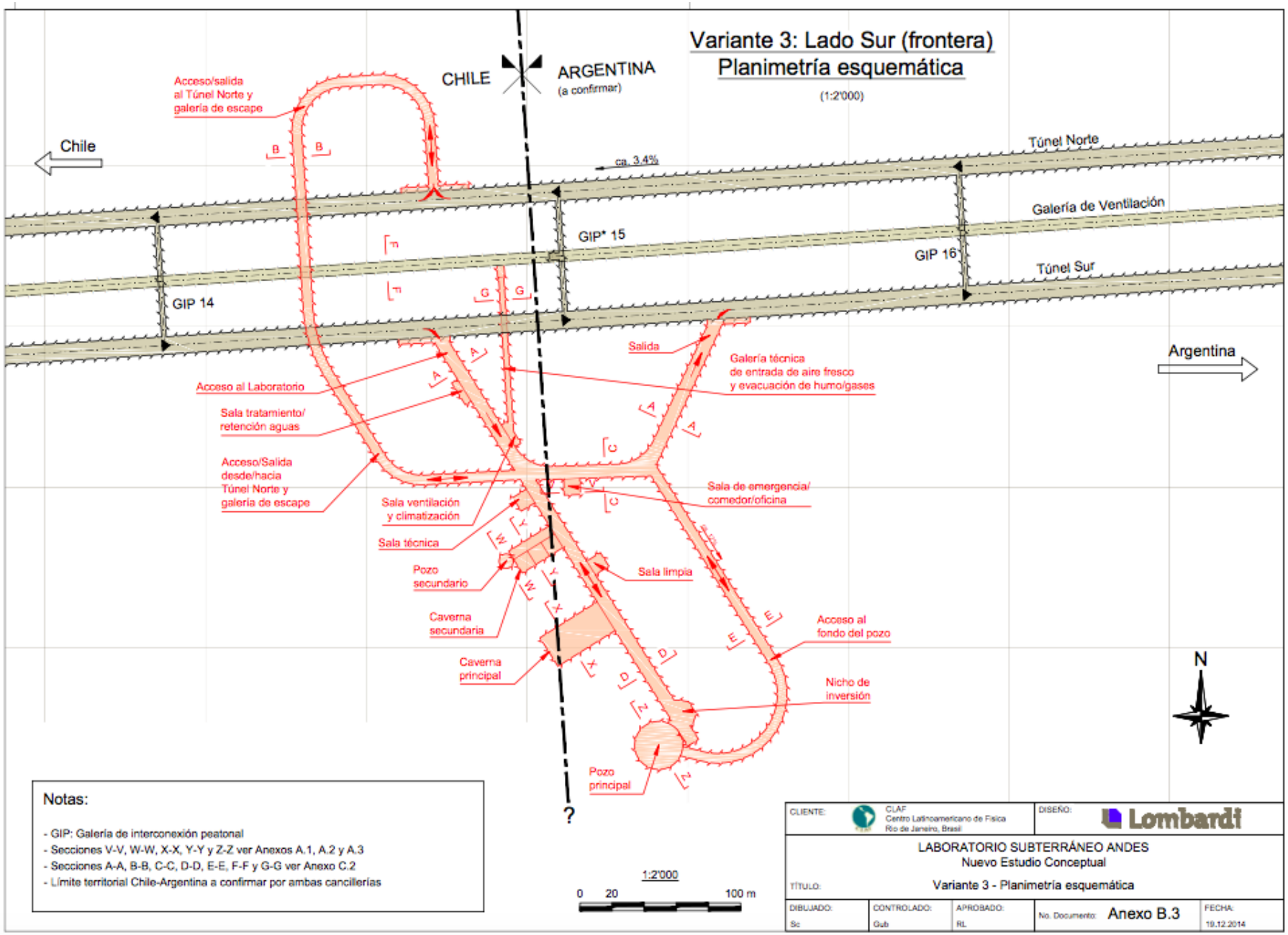
CLAF
Centro Latinoamericano de Física
Rio de Janeiro
Brasil

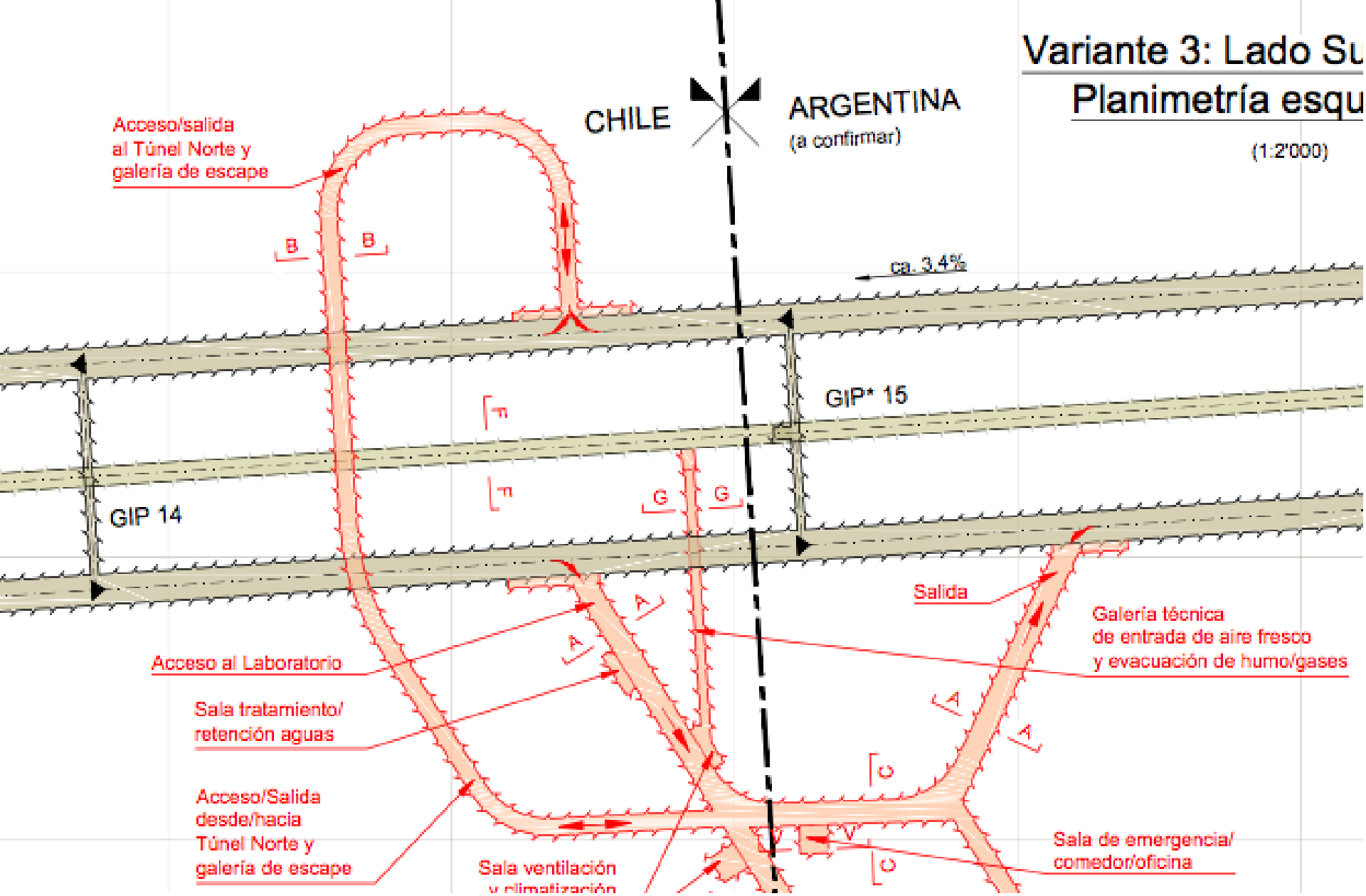
LABORATORIO SUBTERRÁNEO ANDES

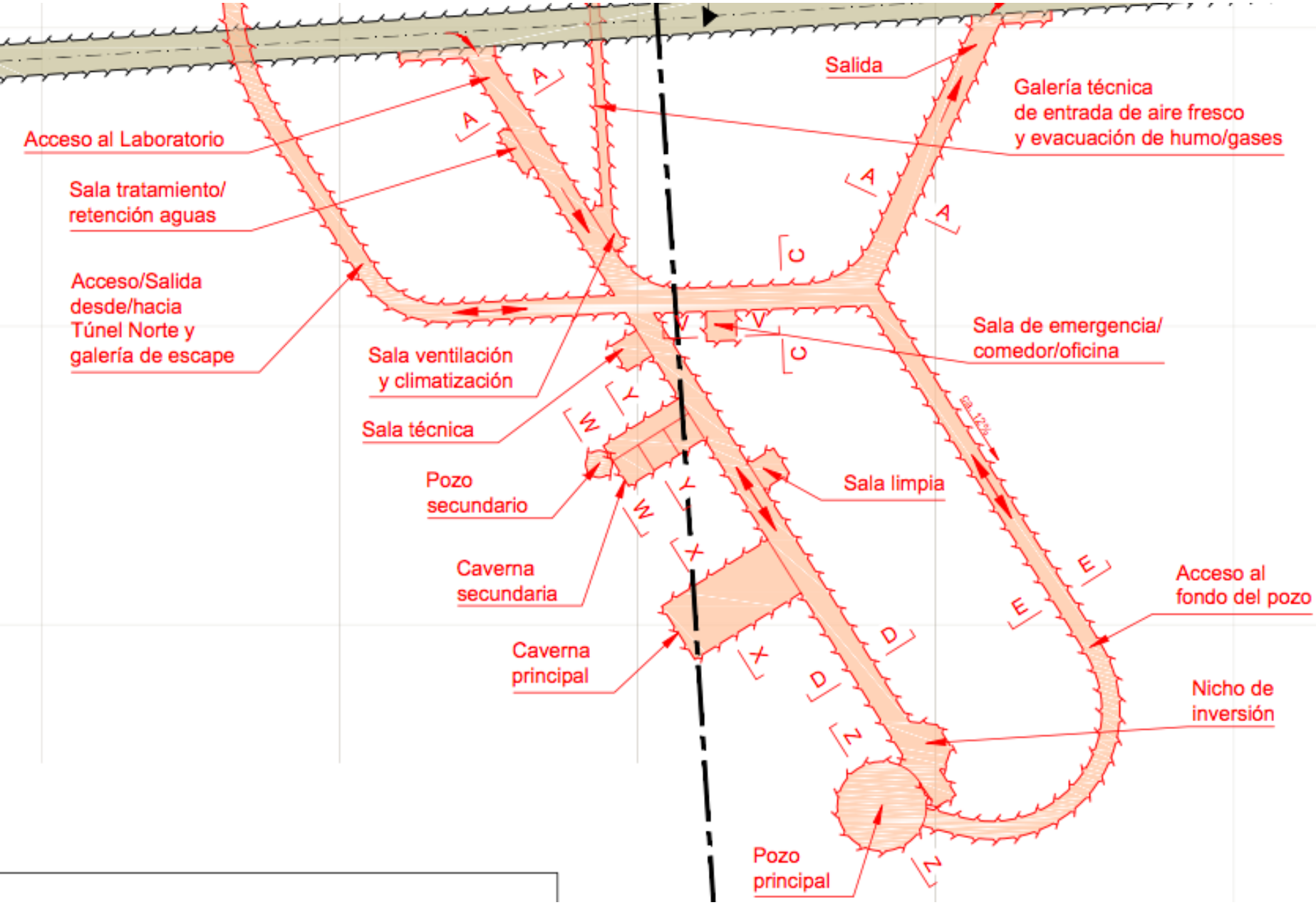
Nuevo Estudio Conceptual

Informe Técnico

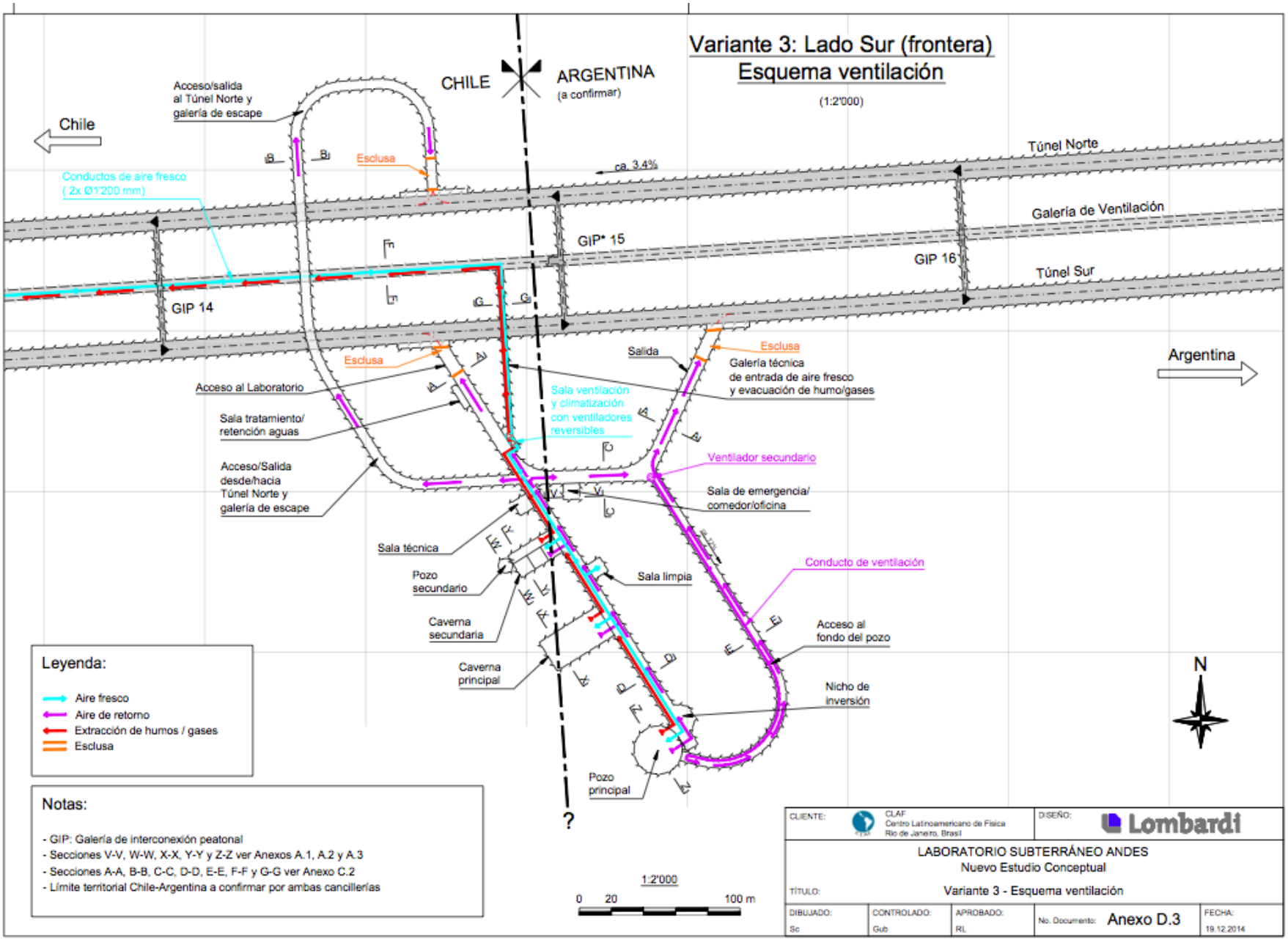
Conceptual Design (by Lombardi): Layout

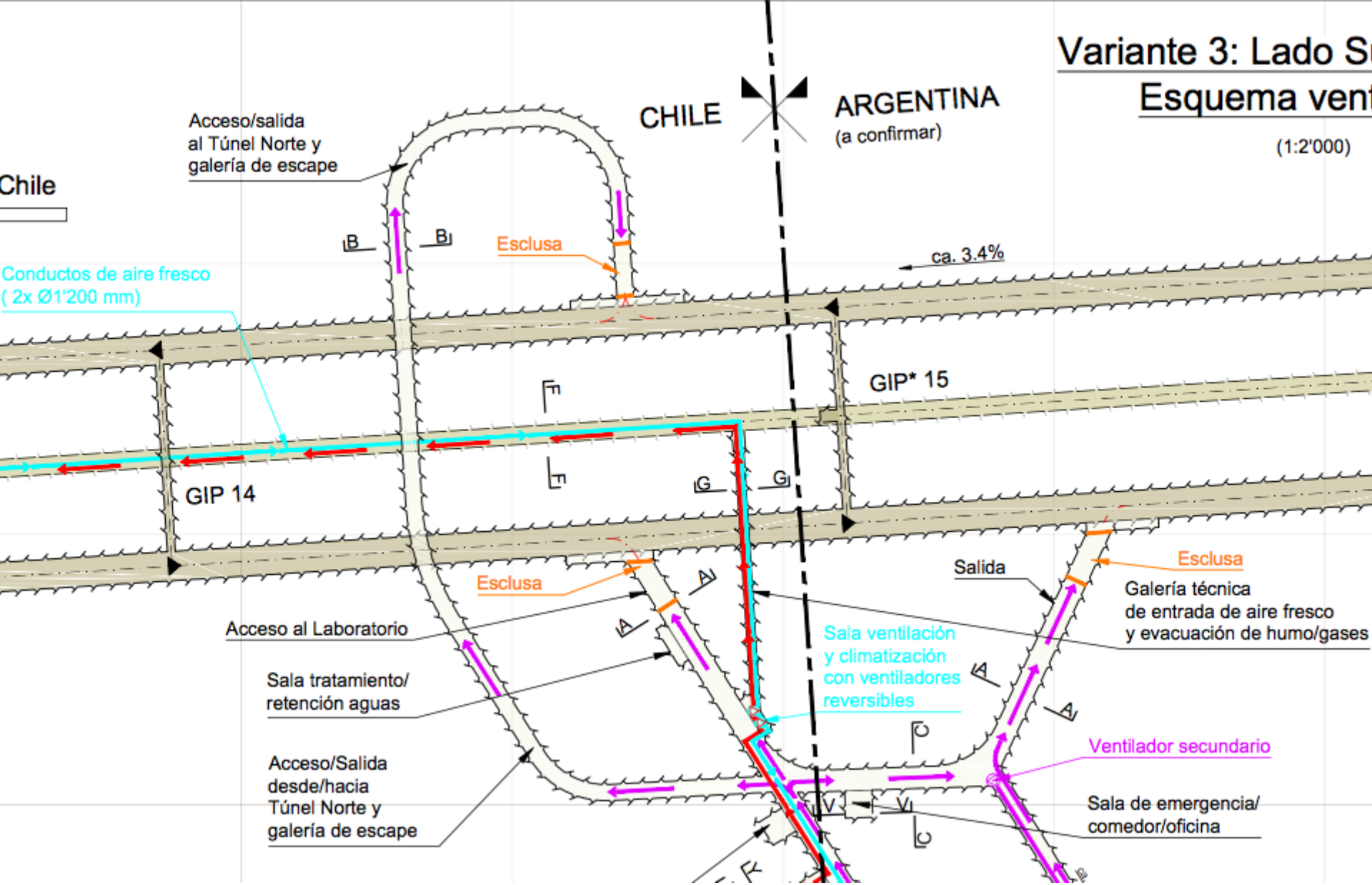


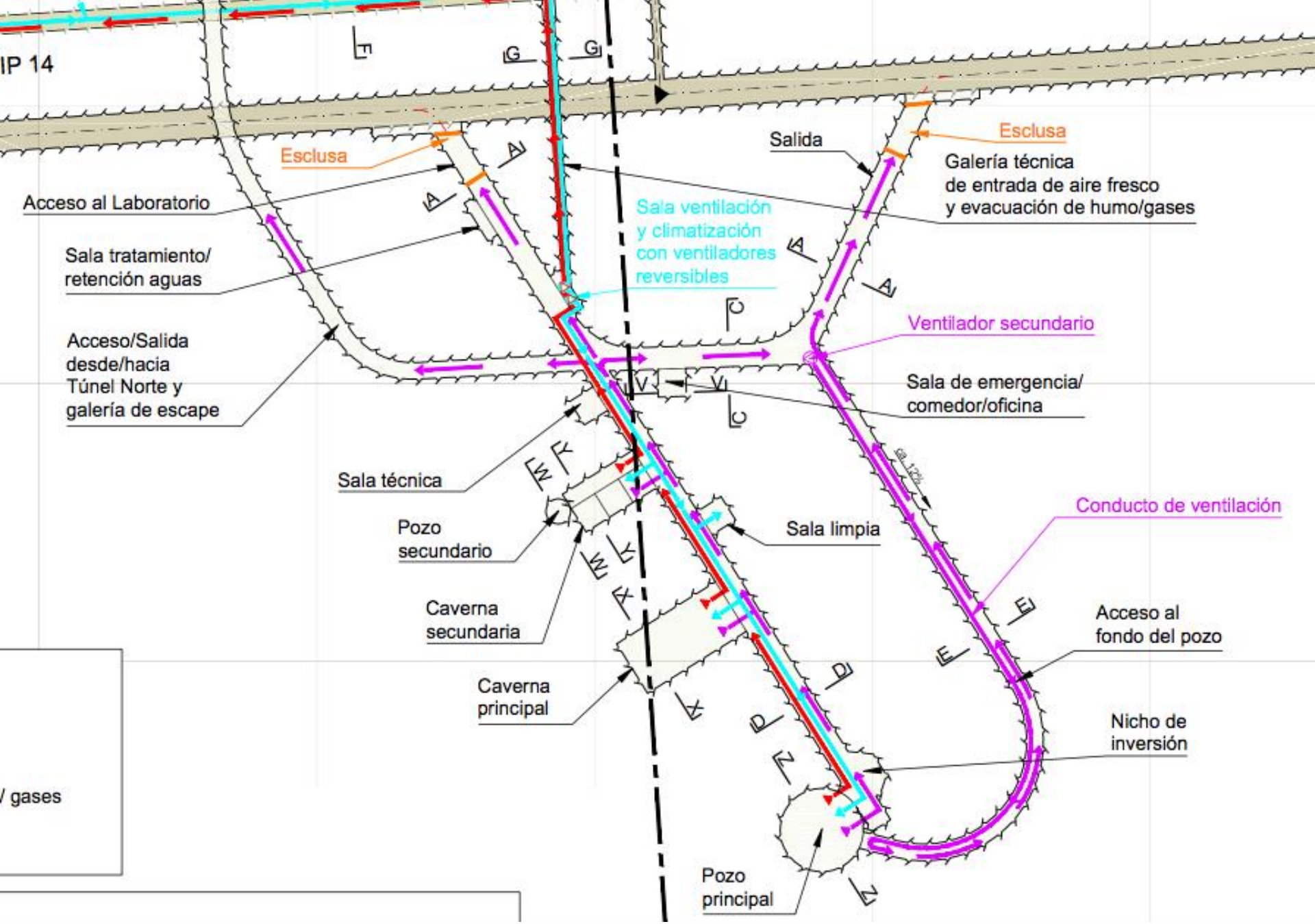

Variante 3: Lado Su
Planimetría esqu
(1:2'000)
CHILE
ARGENTINA
(a confirmar)
Acceso/salida
al Túnel Norte y
galería de escape
B
B
ca. 3.4%
GIP* 15
GIP 14
G
G
Salida
Galería técnica
de entrada de aire fresco
y evacuación de humo/gases
A
A
Acceso al Laboratorio
Sala tratamiento/
retención aguas
A
A
Acceso/Salida
desde/hacia
Túnel Norte y
galería de escape
Sala ventilación
Sala de emergencia/
comedor/oficina


Salida
Galería técnica
de entrada de aire fresco
y evacuación de humo/gases
Acceso al Laboratorio
Sala tratamiento/
retención aguas
Acceso/Salida
desde/hacia
Túnel Norte y
galería de escape
Sala ventilación
y climatización
Sala técnica
Sala de emergencia/
comedor/oficina
Pozo
secundario
Sala limpia
Caverna
secundaria
Acceso al
fondo del pozo
Caverna
principal
Nicho de
inversión
Pozo
principal
A
C
V
Y
W
X
D
E
Z

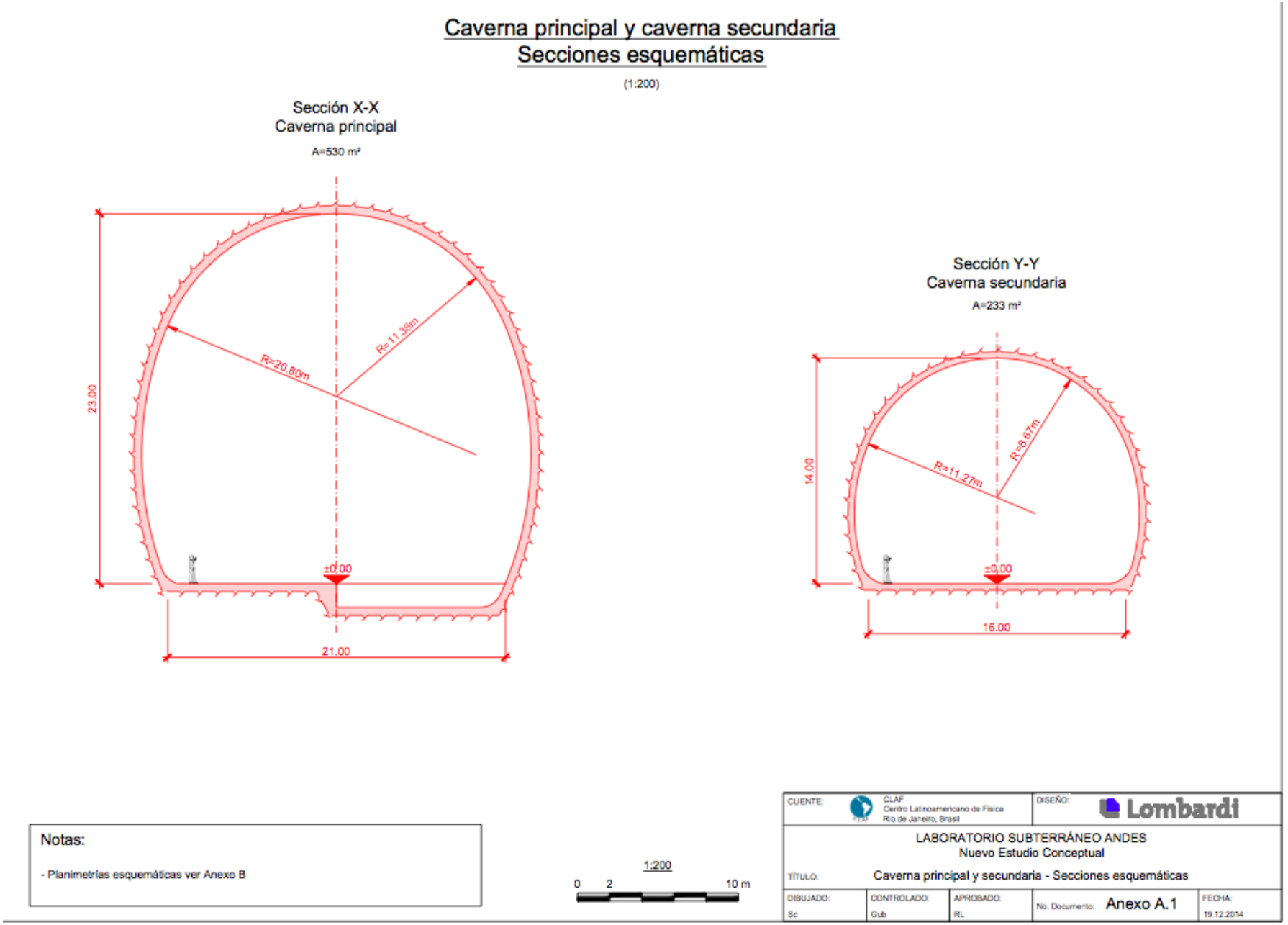
Conceptual Design (by Lombardi): Ventilation



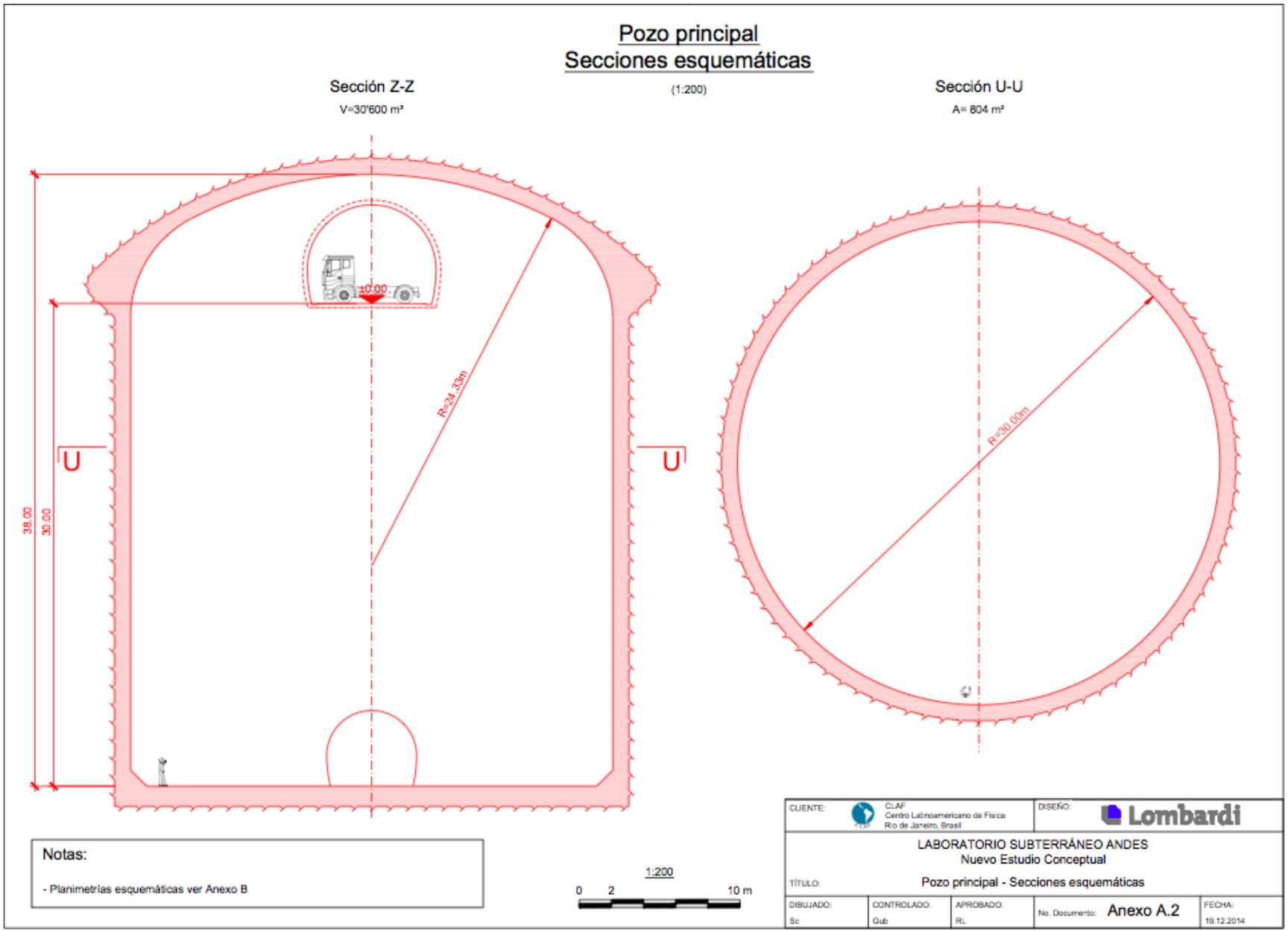

Variante 3: Lado S
Esquema vent
(1:2'000)
CHILE
ARGENTINA
(a confirmar)
Chile
Acceso/salida
al Túnel Norte y
galería de escape
Esclusa
ca. 3.4%
Conductos de aire fresco
(2x Ø1'200 mm)
GIP* 15
GIP 14
Esclusa
Salida
Esclusa
Galería técnica
de entrada de aire fresco
y evacuación de humo/gases
Acceso al Laboratorio
Sala ventilación
y climatización
con ventiladores
reversibles
Sala tratamiento/
retención aguas
Ventilador secundario
Acceso/Salida
desde/hacia
Túnel Norte y
galería de escape
Sala de emergencia/
comedor/oficina


IP 14
Esclusa
Acceso al Laboratorio
Sala tratamiento/
retención aguas
Acceso/Salida
desde/hacia
Túnel Norte y
galería de escape
Esclusa
Salida
Galería técnica
de entrada de aire fresco
y evacuación de humo/gases
Sala ventilación
y climatización
con ventiladores
reversibles
Ventilador secundario
Sala de emergencia/
comedor/oficina
Sala técnica
Pozo
secundario
Caverna
secundaria
Caverna
principal
Sala limpia
Conducto de ventilación
Acceso al
fondo del pozo
Nicho de
inversión
Pozo
principal
/ gases

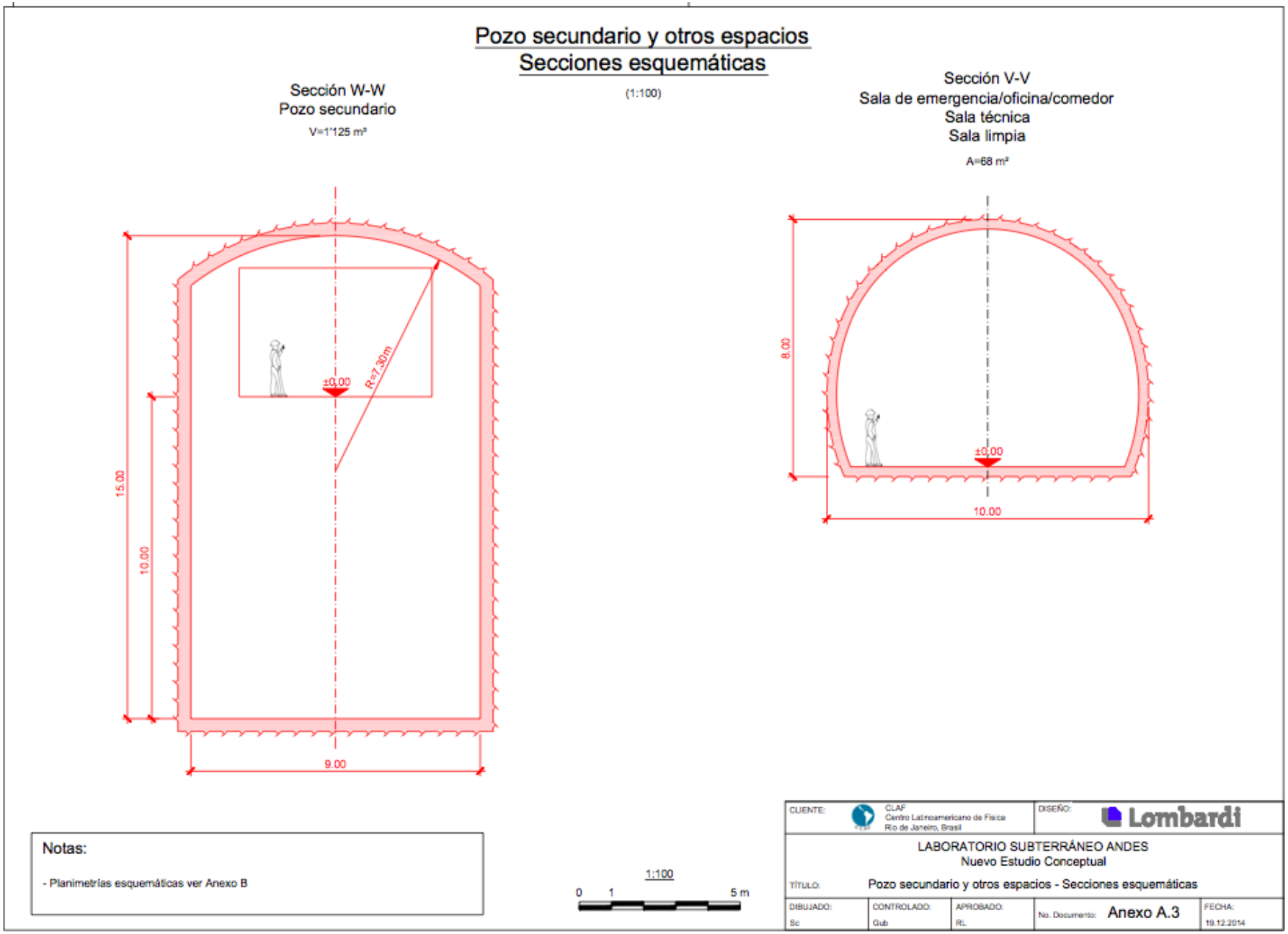
Conceptual Design (by Lombardi): Cavern sections



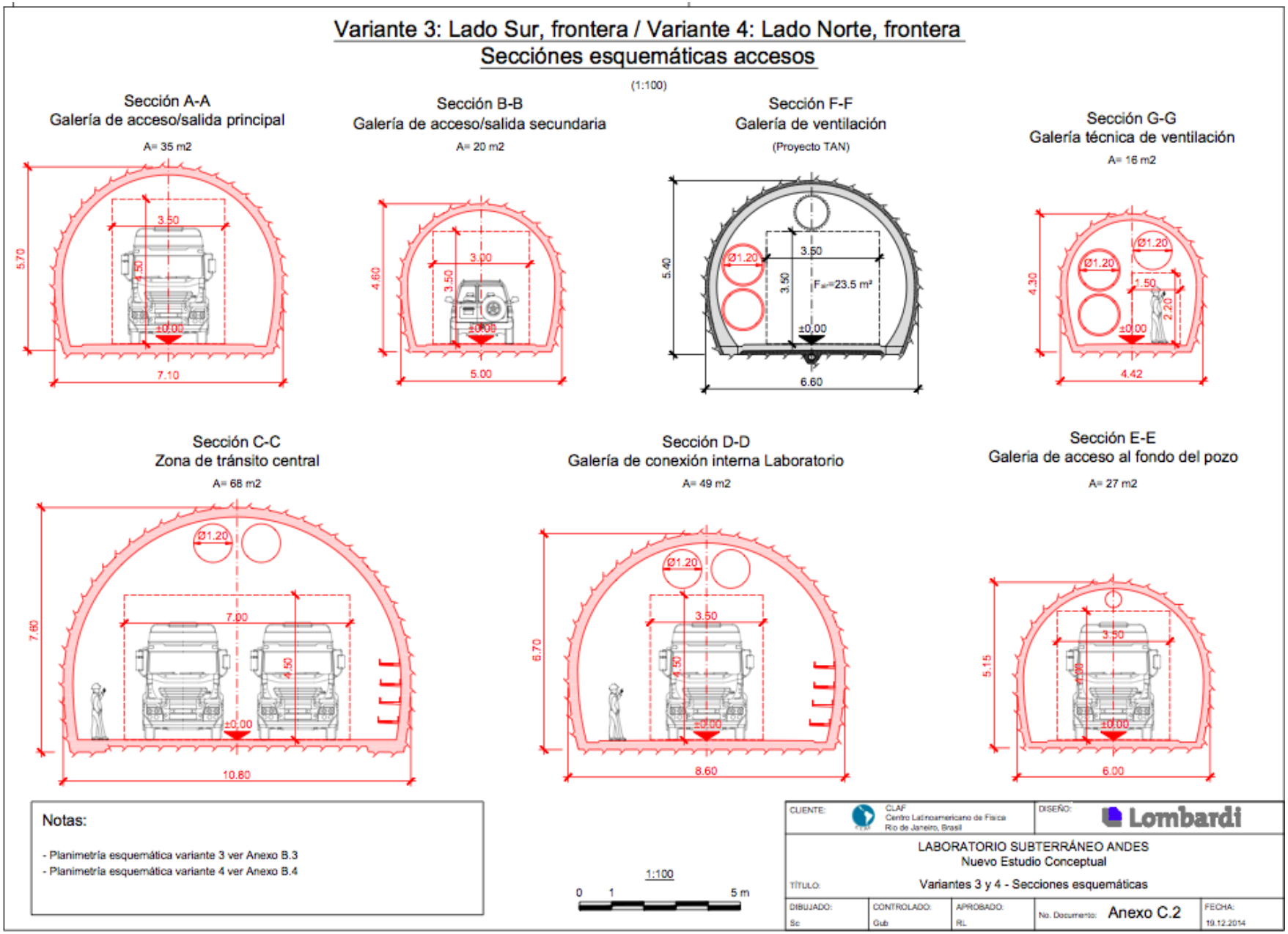
Conceptual Design (by Lombardi): Main pit sections



Conceptual Design (by Lombardi): Secondary pit sections



Conceptual Design (by Lombardi): Access sections

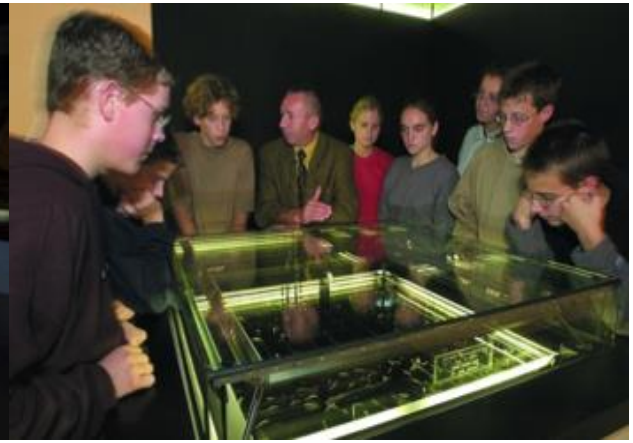


Conceptual Design (by Lombardi): Dimensions

Objeto	Longitud [m]	Area sección [m2]	Volumen [m3]
Espacios Laboratorio			
Caverna principal	50	530	26'500
Pozo principal	-	-	30'600
Caverna secundaria	40	233	9'320
Pozo secundario	-	-	1'125
Otros espacios			
Sala emergencia, comedor, oficina	10	68	680
Sala limpia	10	68	680
Sala técnica	10	68	680
Sala tratamiento aguas	5	68	340
Sala ventilación	5	68	340
Accesos y tránsito interno			
Entrada principal	100	35	3'500
Salida principal	100	35	3'500
Zona central	80	68	5'440
Acceso/salida túnel opuesto/galería de escape	460	20	9'200
Acceso al fondo del pozo	250	27	6'750
Túnel de conexión laboratorio	195	49	9'555
Otros objetos			
Bahía salida principal	-	-	600
Bahía acceso principal	-	-	1'200
Bahía acceso/salida Túnel Norte/Sur	-	-	1'200
Galería técnica ventilación	100	16	1'600
TOTAL parcial obra civil			112'810

Support Labs

- **Two Support Labs** (one on each side):
  - Tentative sites: La Serena (Chile) , Rodeo (Argentina)
  - Integration with local Universities
  - Host a visitor center



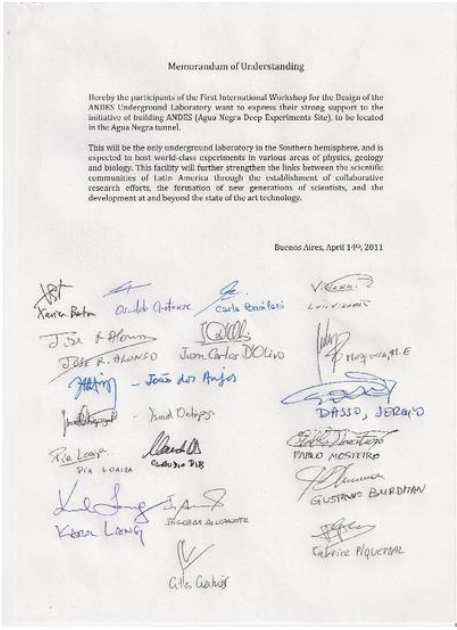
Organization

Proposal for Organization: **CLES**

"**C**onsorcio **L**atinoamericano de **E**studios **S**ubterráneos"
(Latin American Consortium for Underground Studies).

- CLES will manage the ANDES Laboratory
  - With support from external international scientific advisory board.
- Initial participanting countries: Argentina Brazil, Chile and Mexico. Recent interest from Colombia.
- CLES could be the seed for a small CERN-like organization with focus on all underground science (Physics, Biology, etc…)

Current status



Memorandum of Understanding

Hereby the participants of the First International Workshop for the Design of the ANDES Underground Laboratory want to express their strong support to the initiative of building ANDES (Agua Negra Deep Experiments Site), to be located in the Agua Negra tunnel.

This will be the only underground laboratory in the Southern hemisphere, and is expected to host world-class experiments in various areas of physics, geology and biology. This facility will further strengthen the links between the scientific communities of Latin America through the establishment of collaborative research efforts, the formation of new generations of scientists, and the development at and beyond the state of the art technology.

Buenos Aires, April 1st, 2011

- > 20 support letters from International community

  (underground lab directors, intl. exp spokespersons, natl. physics associations and academies,…)
- Regional interest: 26 letters from latin american groups.
- Official support from MinCyT (Argentina) and EBITAN (Entidad Binacional Túnel Agua Negra).

- 4 workshops for the Lab design (Argentina, Brazil, Chile, Mexico).
- CLAF (Centro Latinoamericano de Fisica) creates ANDES unit.
- Conceptual Design
  (done by Lombardi S.A., paid 50/50 by Chile and Argentina)

- In Chile: proposal well received in all government instances, waiting for oficial approval.

e.g. Letter from T. Kajita in 2011 (Nobel laureate in Physics 2015)

Sep. 18, 2011

Dear Professor Bertou,

I write this letter in order to support your proposal of the ANDES Underground Laboratory.

From our experience in Japan, I can say that underground laboratories are going to be the one of the most important infrastructures for the basic science in the next decades to come. Let me explain the case of Japanese underground lab. In the early 1980's, Prof. Koshiba started the Kamiokande experiment in a mine in Kamioka, Gifu prefecture, Japan. It was a 3000 ton water Cherenkov detector, and was located in 1000 meters deep underground. Due to the depth, the cosmic ray background was reduced to about 1/100,000, and it was possible to observe rare events such as neutrinos. In fact, the observation of a burst of neutrinos produced by a supernova explosion in 1987 (SN1987A) opened the new field of neutrino astronomy. This achievement was recognized as the Novel prize in physics in 2002 with Ray Davis Jr, who led a solar neutrinos experiment at a deep underground lab., in Homestake, USA. The Japanese government understood the importance of underground experiments, and approved the 50,000 ton water Cherenkov detector Super-Kamiokande, and 1000 ton liquid scintillator detector KamLAND, both in Kamioka underground. Both of them contributed to our present understanding of the neutrino masses, which are evidences for the physics beyond the standard model of elementary particle physics. The underground lab in Kamioka, Japan is still growing with more experiments in the areas of dark matter search, double beta decay, gravitational wave detection, etc.

From the Japanese experience, I recommend strongly to build a new underground lab in South America. I am sure that this lab will contribute to various field in science in the coming decades. Especially I would like to stress the importance of an underground lab in the Southern Hemisphere. There are several underground labs in the world. However, all of them are located in the Northern Hemisphere. It will be extremely important to have an underground lab in the Southern Hemisphere. I mention two examples: The DAMA experiment in Europe observed the annual modulation of signals which could be interpreted as evidence for dark matter. However, in order to demonstrate that the signal is really due to dark matter, one has to make independent observation in the Southern Hemisphere; the signal should keep the same annual modulation phase, while the possible background should change the phase due to the different annual temperature variation etc. Another example could be the neutrino detection from a supernova. Neutrinos may change their flavor (type) while propagating the Earth. Therefore the Supernova neutrinos should be observed in several locations all over the world so that some detectors would see such an oscillation effect (induced by the Earth matter) but some others would not, making it possible to compare the spectra of neutrinos with and without oscillation, which could provide us some useful information to understand further the neutrino properties. In this sense, it is essentially important to have a detector in the Southern Hemisphere.

In summary, from the experiences and reasons mentioned above, I strongly support the proposal of the ANDES Underground Lab. if you want to hear more, please do not hesitate to ask me. I am very happy to write more.

Sincerely yours,

T. Kajita

Takaaki Kajita,
Director, Institute for Cosmic Ray Research,
University of Tokyo
Email: kajita@icrr.u-tokyo.ac.jp

Extracts from Kajita's letter (2011):

"…underground laboratories will be one of the most important infrastructures for basic science in the next decades…."

"…The underground lab in Kamioka, Japan, is still growing with more experiments in the areas of dark matter search, double beta decay, gravitational wave detection, etc."

"There are several underground labs in the world, however they are all in the northern hemisphere. It will be extremely important to have an underground lab in the southern hemisphere. I mention two examples: … "

"…from the experience and reasons mentioned above, I strongly support the proposal of the ANDES Underground lab. If you want to hear more, please do not hesitate to ask me. I am very happy to write more."

..and the letter from **Art McDonald**, 2015 Nobel Laureate, to the Minister of Education, cc. Minister of Finance and Minister of Public Work; Chile

Queen's University

DEPARTMENT OF PHYSICS
ENGINEERING PHYSICS, ASTRONOMY
STIRLING HALL,
QUEEN'S UNIVERSITY
KINGSTON, ONTARIO,
CANADA K7L 3N6

Professor Emeritus A. B. McDonald
2015 Nobel Physics Laureate

August 13, 2016

Sra. Adriana Delpiano Puelma
Ministra de Educacion
Ministerio de Educación de Chile
Alameda 1371, Santiago
CHILE

Dear Sra. Ministra,

I am writing to urge you to approve the ANDES underground laboratory to enable Chile to become a world leader in many areas of research. Having a laboratory with ultra-low radioactivity levels provides the opportunity for unique scientific measurements, as we have proven with SNOLAB in Canada where we performed neutrino measurements leading to the 2015 Nobel Prize in Physics. The ANDES laboratory will be so deep at 1750 meters that it will be among the world leaders in reducing cosmic radiation, an essential part of achieving low-radioactivity levels in the laboratory. This depth is close to the depth of other world leading laboratories such as SNOLAB in Canada and JinPing in China and will undoubtedly lead to the siting of many world-class experiments at ANDES such as measurements of Dark Matter particles and of new neutrino properties.

The world-wide interest in experiments performed in an environment such as will be achieved at ANDES is increasing at a high rate. As we have observed with SNOLAB, this provides major opportunities for our Canadian university faculty and students to work with the best scientists in the world on research that is of Nobel Prize quality. The fundamental physics measurements that will be performed in future at ANDES will address some of the most important questions in science and attract international interest to Chile. As Ministra de Educacion, I urge you to approve this laboratory as a major educational opportunity for Chile that will develop new generations of students working side by side with the best scientists in the world and developing skills that will be of substantial value to Chile in the longer term. There are very few underground sites in the world with the high quality of the ANDES location and I urge you not to miss this remarkable opportunity for your country, particularly with only a small percentage of the total cost of the tunnel required to make it happen. The world demand for space in ultra-low radioactivity laboratories will be greater than can be accommodated with presently available facilities and Chile will be a location of considerable interest in future.

The development and ongoing operation of SNOLAB has also resulted in substantial economic opportunities for Canada. The major experiments that choose to be sited in these underground laboratories are typically $30 million to $100 million in total cost. Much of this is funded by other international countries and results in substantial local economic impact as local companies construct the experiments and develop new skills at the leading edge of many technologies. The

visits of international scientists to work on the experiments also provides additional economic benefits. I predict that similar benefits will accrue for Chile.

Besides the exciting future program in particle astrophysics that I have outlined above, the ANDES laboratory will enable new research at the frontiers of Seismology, Geophysics, Biology, environmental studies and radiation effects on instruments. This research will enable measurements in these fields that cannot be done without the unique environment that will be provided in the ANDES laboratory.

The organizational structure for the ANDES laboratory is well advanced, with strong cooperation between Chile, Argentina, Brazil and Mexico. The Chilean coordinator is Dr. Claudio Dib, Universidad F. Santa Maria, who is well known internationally in this field. There are international advisors who have been providing expert reviews of the plans for this laboratory, including my colleague Professor A. J. Noble from Queen's University, former Director of SNOLAB, who has spoken very favorably to me about the prospects and organization for this project following his reviews.

I urge you to provide approval for this laboratory. The international scientific community is eagerly awaiting Chile to become a leader of this important developing field.

Sincerely,
Professor Emeritus A. B. McDonald,
2015 Nobel Laureate in Physics

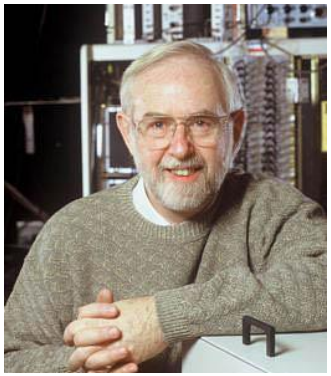
Cc

Sr. Alberto Undurraga V.
Ministro de Obras Publicas
Ministerio de Obras Publicas de Chile
Morande 59, Santiago
CHILE

Sr. Rodrigo Valdes P.
Ministro de Hacienda
Ministerio de Hacienda de Chile
Teatinos 120, Santiago
CHILE

Dr. Claudio Dib, Universidad F. Santa Maria
Professor A. J. Noble, Queen's University

Extracts from the letter (August 2016)



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ANDES Coordination Team

- **General coordinator:**
  Xavier Bertou (Centro Atómico de Bariloche, Argentina)
- **Country coordinators:**
  - **Argentina:** Osvaldo Civitarese (IFLP, U. Nac. La Plata)
  - **Chile:** Claudio Dib (UTFSM, Valparaiso)
  - **Brasil:** Joao dos Anjos (CBPF)
  - **Mexico:** Juan Carlos D'Olivo (UNAM)

- Web site http://andeslab.org

Summary

- ANDES is a unique opportunity for a deep and large underground lab in Southern Hemisphere:
  - To educate new scientists within Latinamerica.
  - To establish international collaboration in many sciences.
  - To integrate Latin American nations around science objectives.
- International support, interest from world exp. collaborations.
- CLES: Opportunity for a Latin American Science integration.
- Expected Construction: 2018 -- finished in ~ 10 years
- More info at http://andeslab.org

Thank you

Backup slides

Rock studies

Main rock: - Andesite
variations: - rhyolite
- basalt
- dacite
- trachyte

9 samples from 8 perforations up to 600 m deep

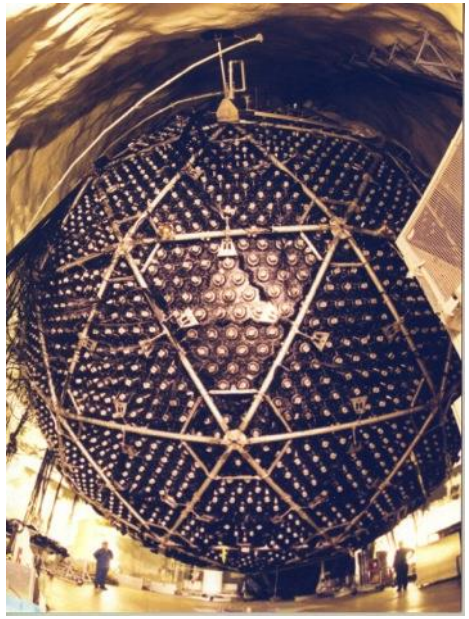
(Bq/kg):	Andesite	Basalt	Rhyolite 1	Rhyolite 2	Canfranc
U-238	9.2 ± 0.9	2.6 ± 0.5	14.7 ± 2.0	11.5 ± 1.3	4.5 -- 30
Th-232	5.2 ± 0.5	0.94 ± 0.09	4.5 ± 0.4	4.8 ± 0.5	8.5 -- 76
K-40	47 ± 3	50 ± 3	57 ± 3	52 ± 3	37 -- 880

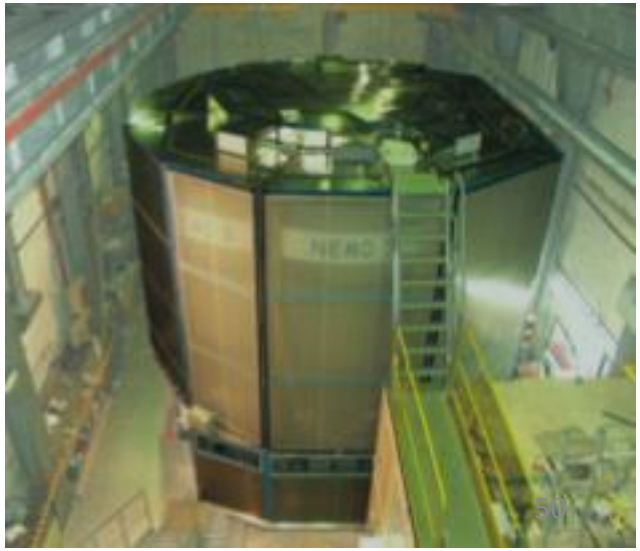
Thanks to Laboratorio de Activación Neutrónica (Bariloche, Argentina)

Experiments in U Labs

Experiments in underground Labs:

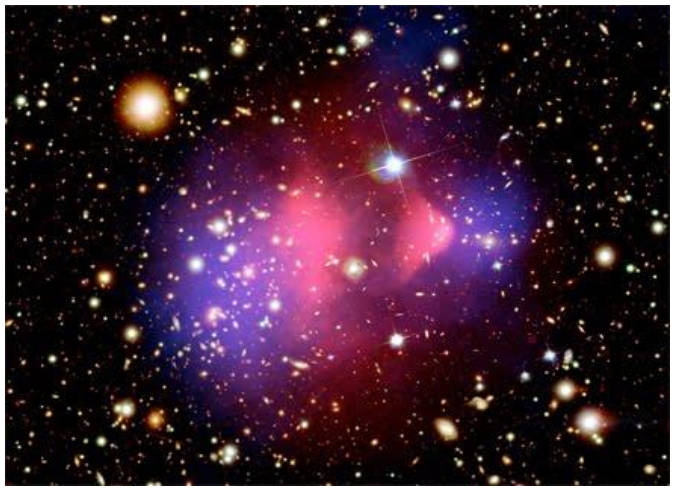
- **Neutrinos:**
  - from nuclear reactors
  - from accelerators
  - from the atmosphere
  - from the Sun
  - cosmic and Supernovae
  - from inside the Earth



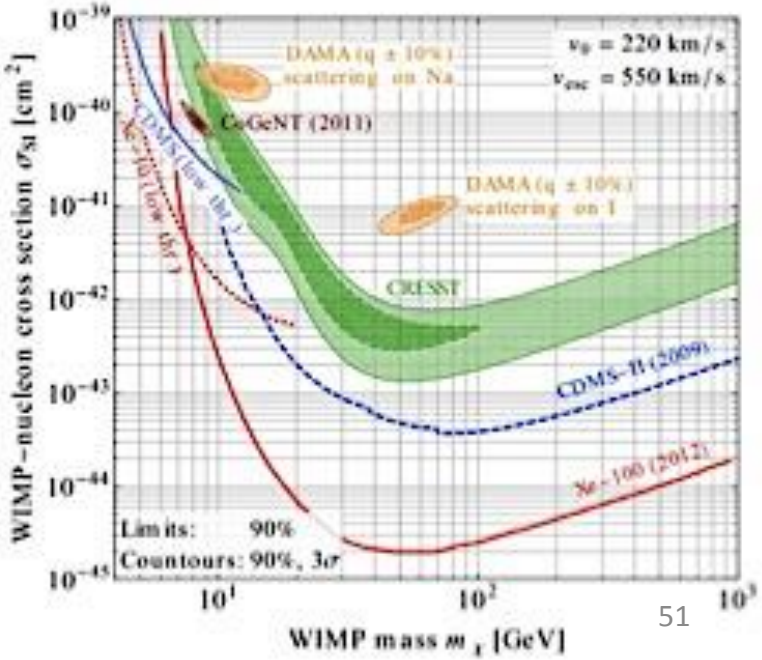


Experiments in underground Labs:

- **Dark Matter search:**
  - Needs different detector techniques (noble gas/liquid, …)
  - New techniques (bubble chambers, CCD, …)

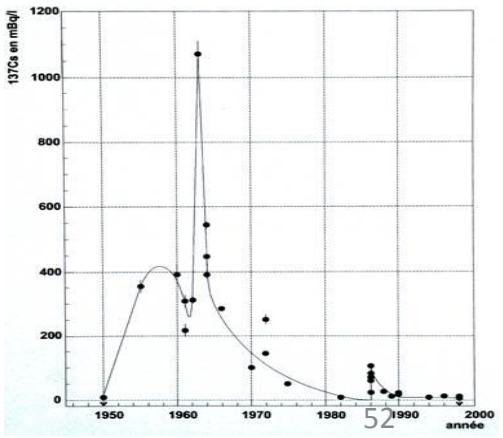


  - Direct Detection
  - Yearly modulation



Experiments in underground Labs:

- **Geoscience**
  - Low frec. Seismographs
  - Radon measurements
  - geoneutrinos
- **Low radiation measurements**
  - Material selection
  - Environment pollution
  - microelectronics
- **Biology**



Preliminary
ANDES Science program

ANDES initial Scientific Programme

- Neutrino physics:
  - host double beta decay experiments
  - large Latin American neutrino detector
    - KamLAND / Borexino style
    - focus on low energy
    - Solar / Supernova / Geo neutrinos
- Dark Matter
  - modulation measurements
  - new technologies
- Geophysics
  - link Chile-Argentina seismograph networks
- Biology
  - life in extreme and low radiation environments
- Low background measurements
- Nuclear Astrophysics (low energy beams)

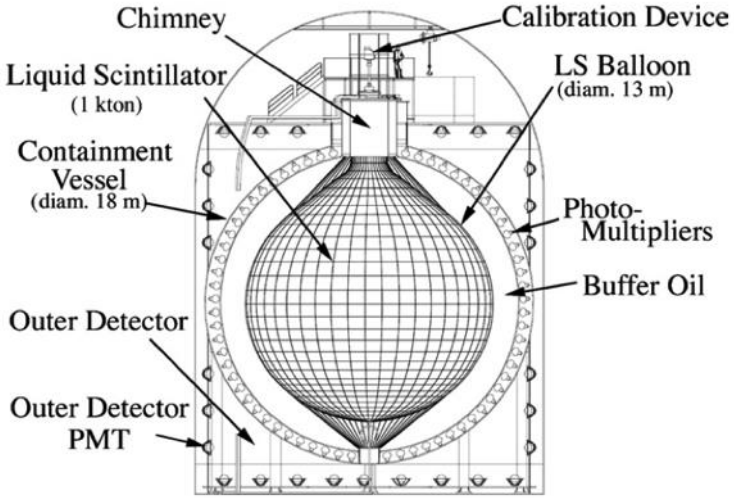
eg. Proposed Neutrino detector

- 3 – 10 kton of liq. Scintillator
- similar to Borexino or KamLAND

- ANDES: unique site for geo nu's

- Can be used for Supernova nu's

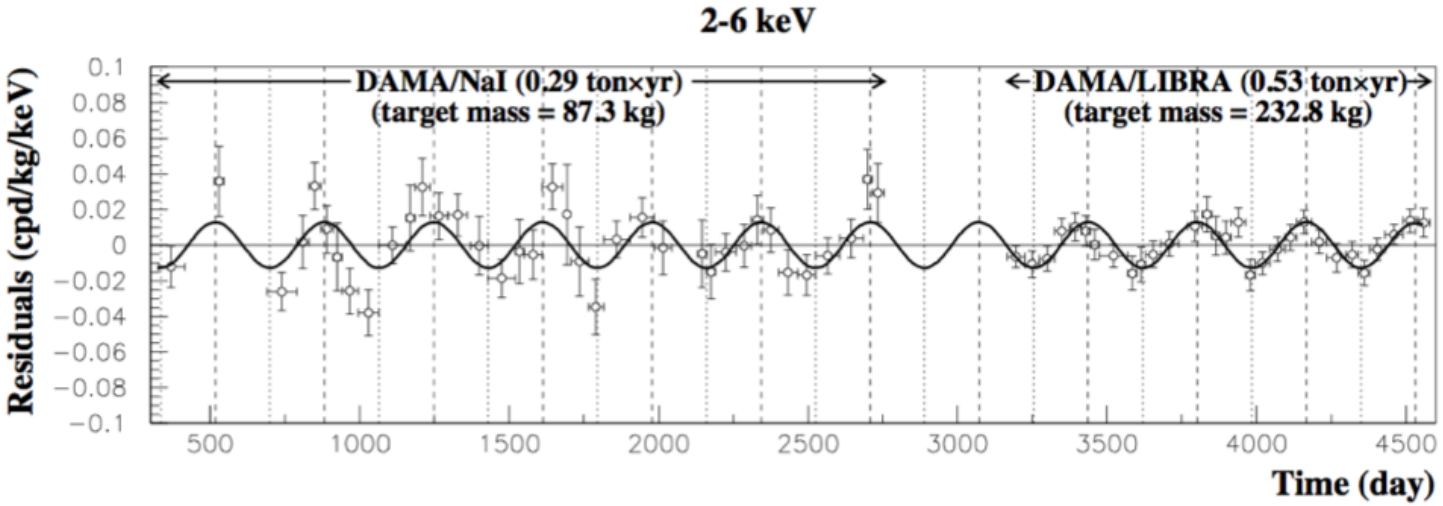
- arXiv:1027.5454



Double beta decay experiments

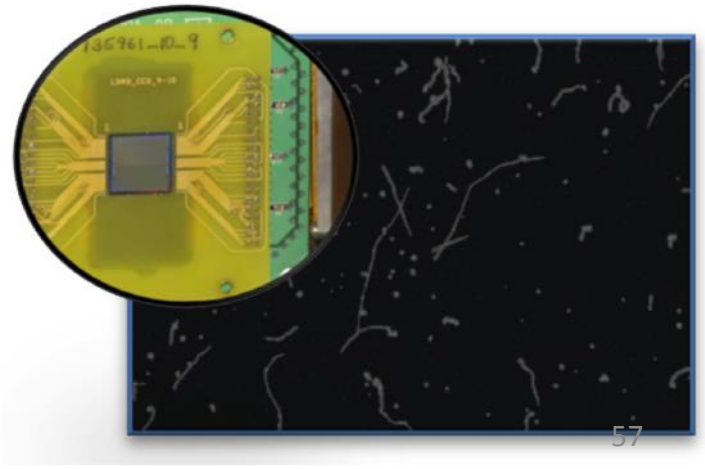
- eg. SuperNEMO:
  - 100 – 200 kg of ^{82}Se
  - Larger experiment,
    based on NEMO, NEMO3 (LSM).
  - Modular design ≈ 20 modules
  - Neutrino mass sensitivity ≈ 0.05 eV
  - Design and schedule fits ANDES
  - strong interest from SuperNEMO
- Also: NEXT.
- others

Dark Matter at ANDES



- To host copy of northern DM modulation exp.
- Host a 3rd generation DM exp.

- Work on new techniques…
  - e.g. CCD's, DNA chains, et c.



Nuclear reactions for Astrophysics

- LUNA (Laboratory for Underground Nuclear Astrophysics).
- installed at Gran Sasso
- 50 kV accelerator

- LUNA II: 400 kV

- Study low energy nuclear reactions in stars (Gamow peak)

- Proposal for a 300 kV, high intensity setup at ANDES