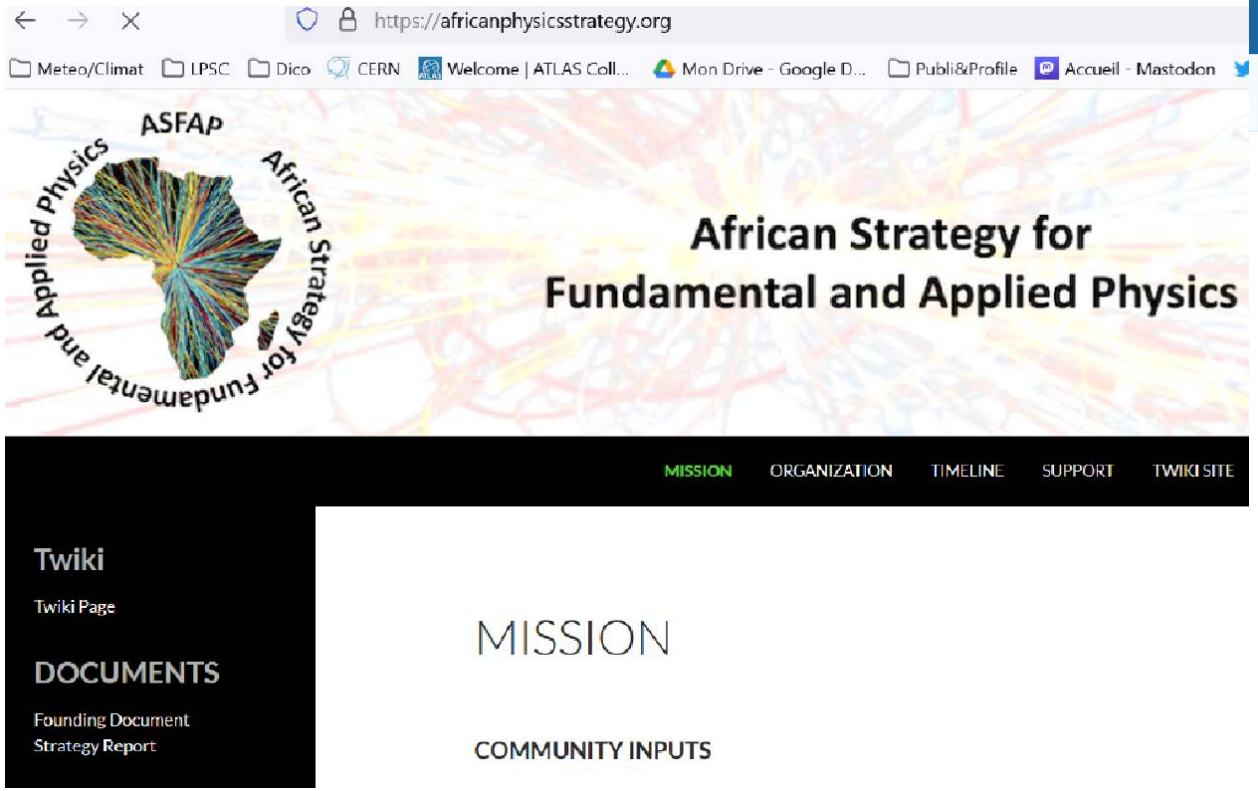
Paarl Africa Underground Laboratory (PAUL)

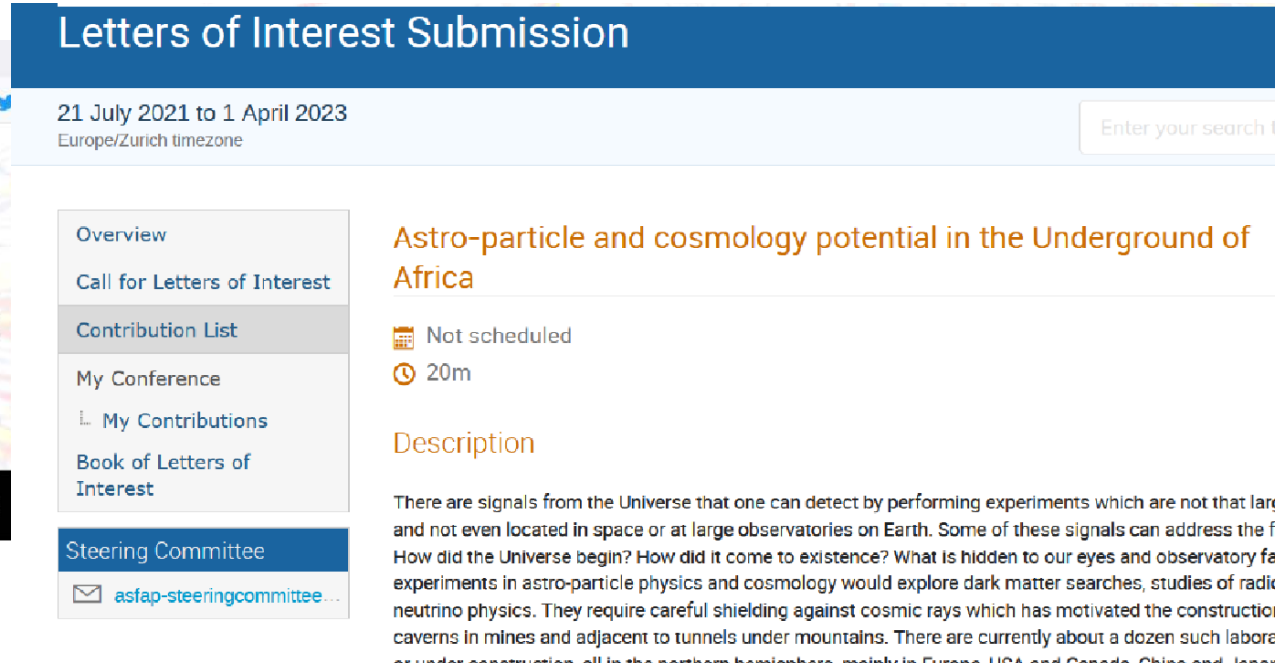
GDR Deep Underground Physics plenary meeting

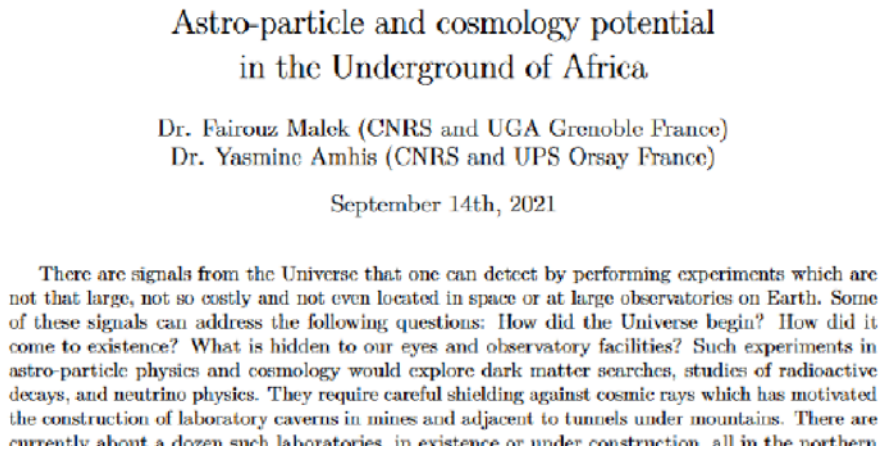
Aussois –June 23, 2023

Dr Fairouz Malek (Grenoble LPSC)

How did it start ?







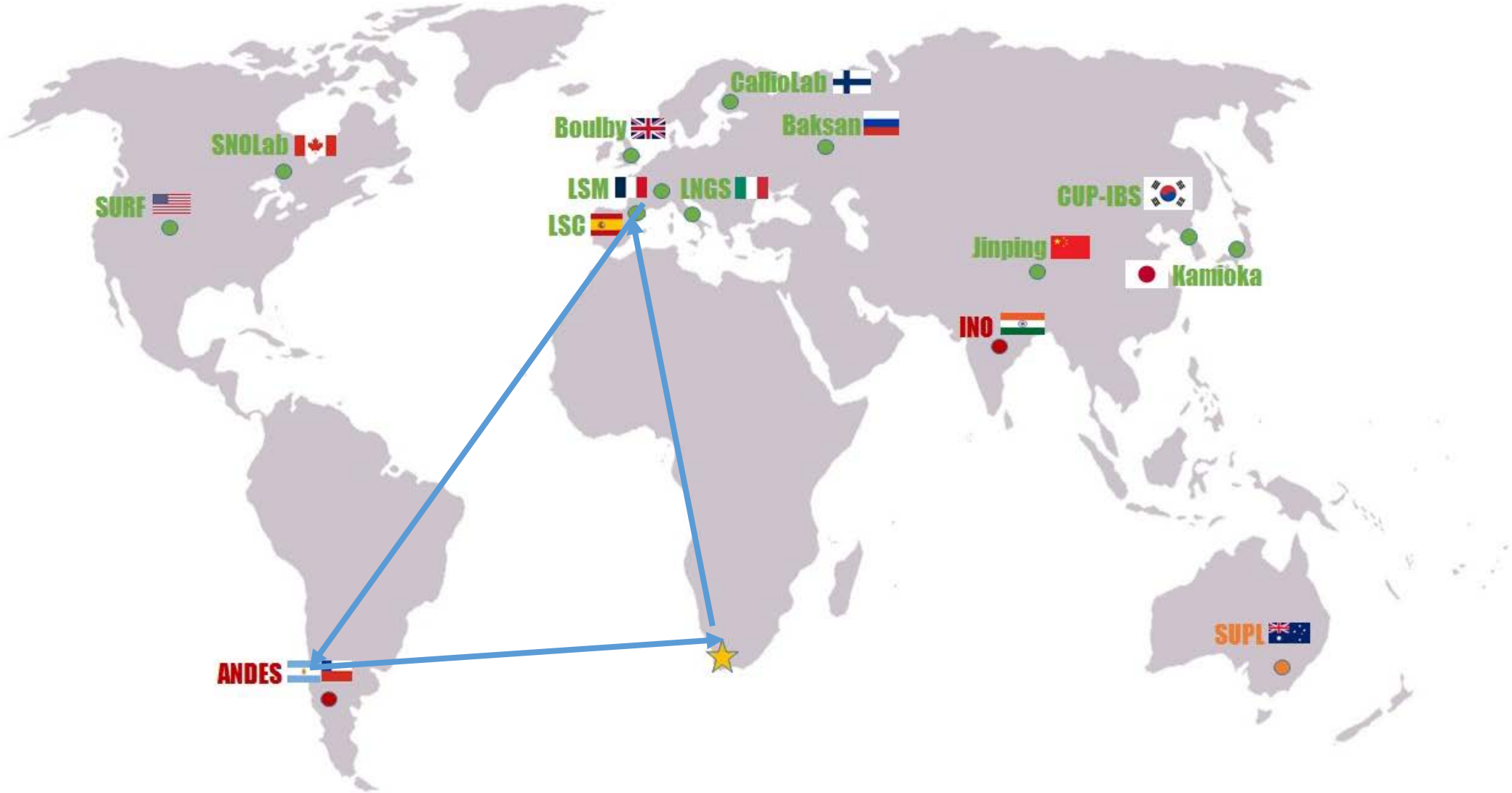
Astro-particle and cosmology potential
in the Underground of Africa

Dr. Fairouz Malek (CNRS and UGA Grenoble France)
Dr. Yasmine Amhis (CNRS and UPS Orsay France)

September 14th, 2021

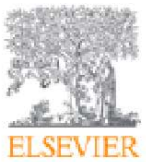
There are signals from the Universe that one can detect by performing experiments which are not that large, not so costly and not even located in space or at large observatories on Earth. Some of these signals can address the following questions: How did the Universe begin? How did it come to existence? What is hidden to our eyes and observatory facilities? Such experiments in astro-particle physics and cosmology would explore dark matter searches, studies of radioactive decays, and neutrino physics. They require careful shielding against cosmic rays which has motivated the construction of laboratory caverns in mines and adjacent to tunnels under mountains. There are currently about a dozen such laboratories, in existence or under construction, all in the northern

How has it been kicked off ?



The context: Previous publications

2015: Towards the South African Underground Laboratory :



Physics Procedia
Volume 61, 2015, Pages 586-590

Towards the South African Underground Laboratory (SAUL) ☆

S.M. Wyngaardt [a], R.T. Newman [a], R. Lindsay [b], A. Buffler [c], R. de Meijer [b], P. Maleka [d], J. Bezuidenhout [e], R. Nchodu [d], M. van Rooyen [a], Z. Ndlovu [a]

[a] Department of Physics, Stellenbosch University, Private Bag X1, Matieland, Stellenbosch, 7602
[b] Department of Physics, University of the Western Cape, Modderdam Road, Private Bag X17, Bellville, 7530
[c] Department of Physics, University of Cape Town, Rondebosch, 7700, South Africa
[d] iThemba LABS, P.O. Box 722, Somerset West, 7129, South Africa
[e] Military Academy, Private Bag X2, Saldanha, 7395

2019: Latest Updates on Developments of the Underground Neutrino Facility in South Africa

World Scientific
Connecting Great Minds

LABORATOIRE DE PHYSIQUE SUBATOMI

Subject ~ Journals Books Major Reference Works Resources For Partners ~ Open Access About Us ~ Help ~

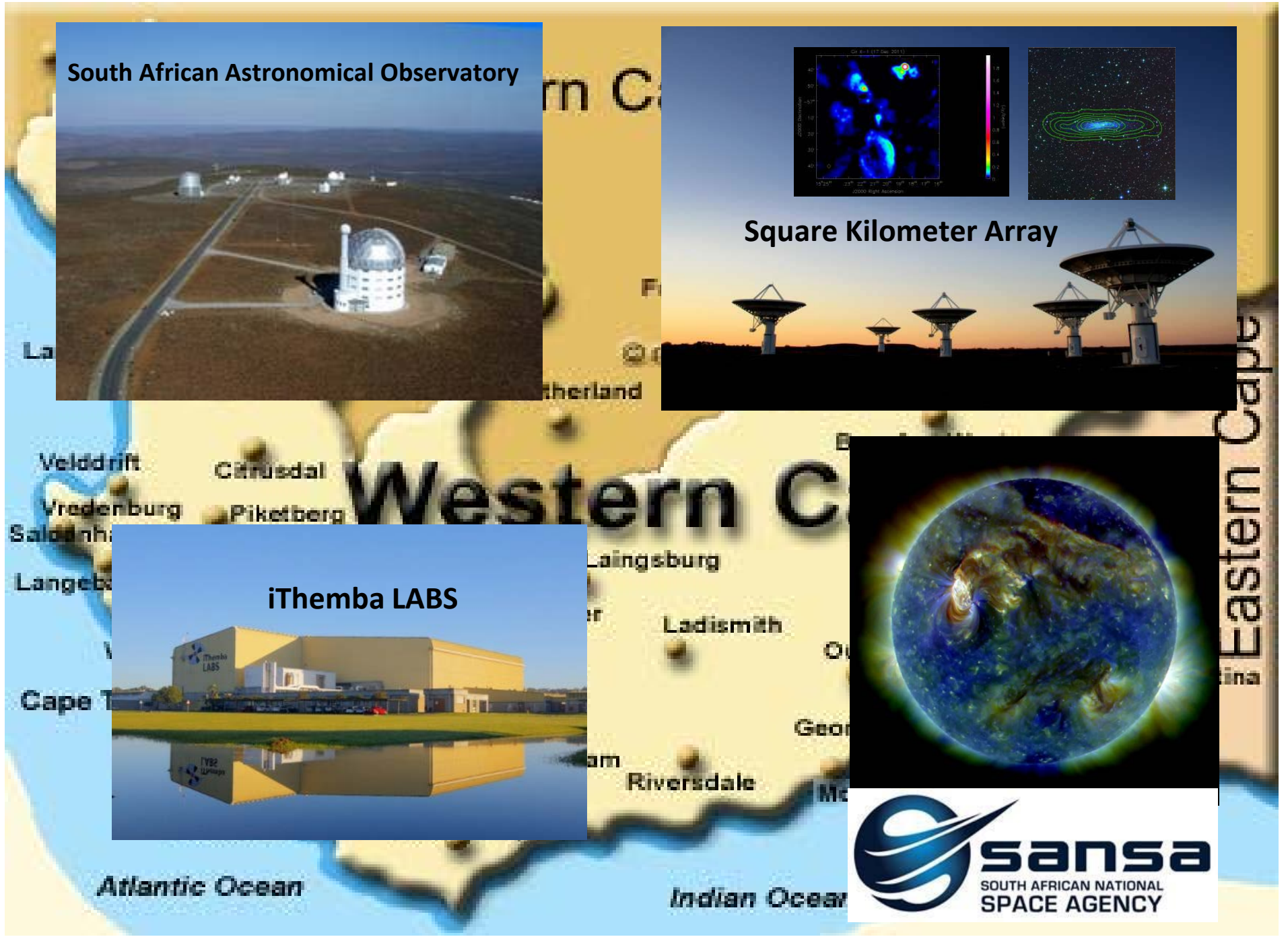
Exotic Nuclei. pp. 478-485 (2019) | CR

No Access

Latest Updates on Developments of the Underground Neutrino Facility in South Africa

Z. Z. Vilakazi, S. M. Wyngaardt, R. T. Newman, R. Lindsay, A. Buffler, R. de Meijer, P. Maleka, J. Bezuidenhout, R. Nchodu, M. van Rooyen and Z. Ndlovu

https://doi.org/10.1142/9789811209451_0069 | **Cited by:** 0


South African Astronomical Observatory
Square Kilometer Array
iThemba LABS
Western Ca
Eastern Cape
Veldrift
Citrusdal
Vredenburg
Piketberg
Laingsburg
Ladismith
Riversdale
Cape T
Atlantic Ocean
Indian Ocean
sansa
SOUTH AFRICAN NATIONAL
SPACE AGENCY

World Class Universities

Stellenbosch University

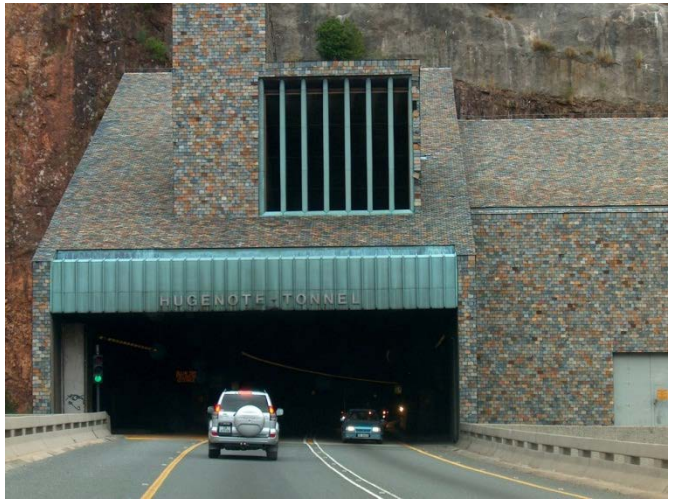
University of Cape Town

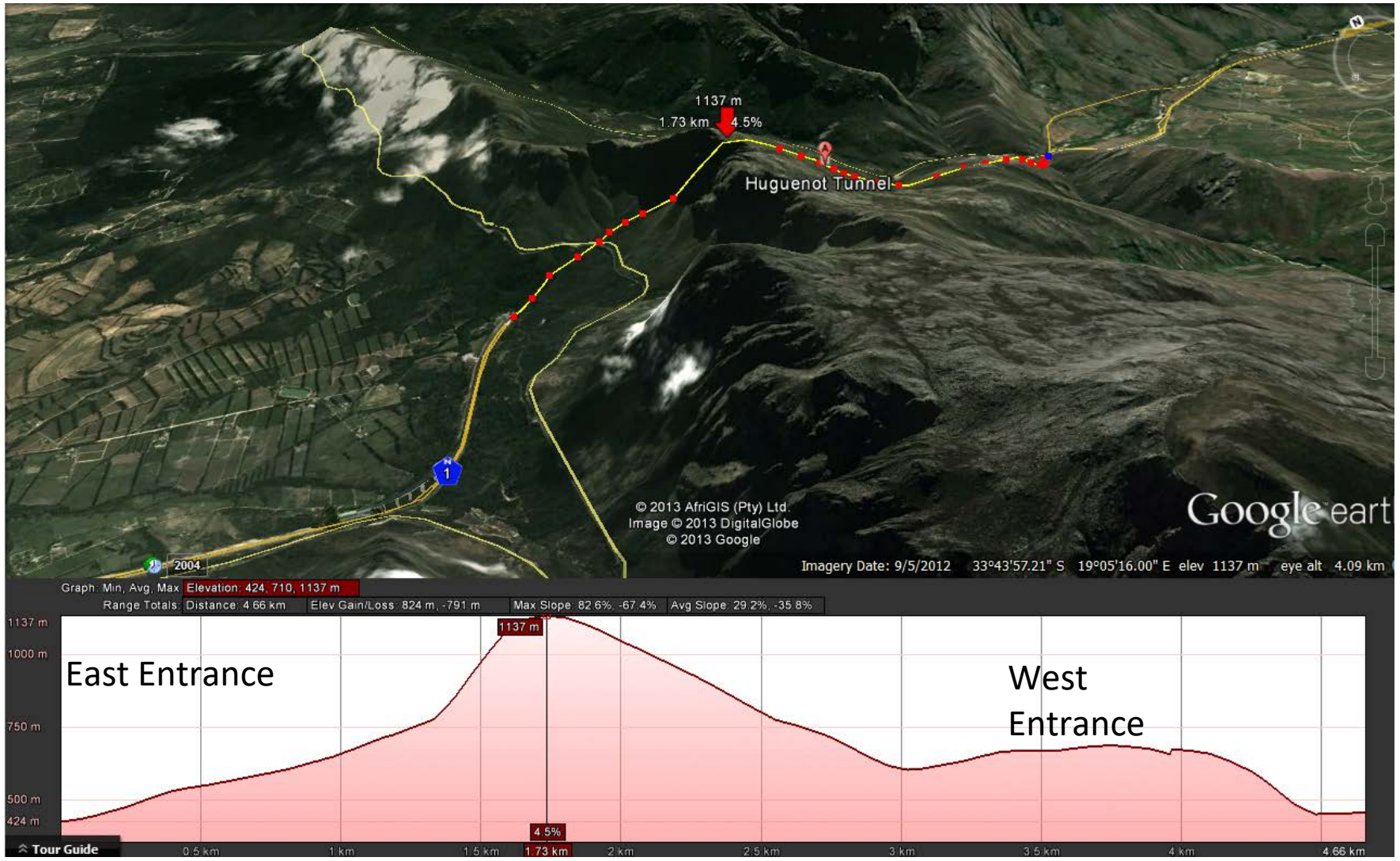
University of the Western Cape


Koeberg Nuclear Power plant
Wellington
Huguenot Tunnel
60 km
20 km
Cape Town
Cape Town
Bellville
Stellenbosch
Mitchells Plain
Somerset West
Fish Hoek
Grabouw
© 2013 Google
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2013 AfriGIS (Pty) Ltd.
Google earth
Imagery Date: 4/10/2013 34°00'12.74" S 18°36'19.67" E elev 37 m eye alt 99.10 km


Huguenot Tunnel
Paarl
Stellenbosch
iThemba LABS
Cape Town
Robben Island
Philadelphia
Windmeul
Wellington
Bain`s Kloof Pass
Slanghoek
Worcester
Nuy
Aan de Doorns
Brandvlei
Alfalfa
Area
Klapmuts
Winelands Lifestyle Estate
Haweqwa Nature Reserve
Hou Moed
Wemmershoek
Franschhoek
Mount Eland Twp
Jonkershoek Nature Reserve
Villiersdorp
Riviersonderend Nature Reserve
Dennehof
Greyton
Vyeboom
Helderstroom
Klipkraal
Groenlandberg Nature Reserve
Sir Lowry's Pass
Grabouw
Hottentots-Holland Mountain Catchment Area
False Bay
Table Mountain National Park
Bot River
Caledon
Oudekraal
Rooi-Els
Oude Bosch
Arabella Country Estate
Kleinmond
Pringle Bay
Betty's Bay
Bovenplaats
Tesselaarsdal
Hawston
Onrus
Hermanus
R300

The Huguenot tunnel





1300m Du Toitskloof mountain with ~800 m of rock overburden for the Huguenot tunnel

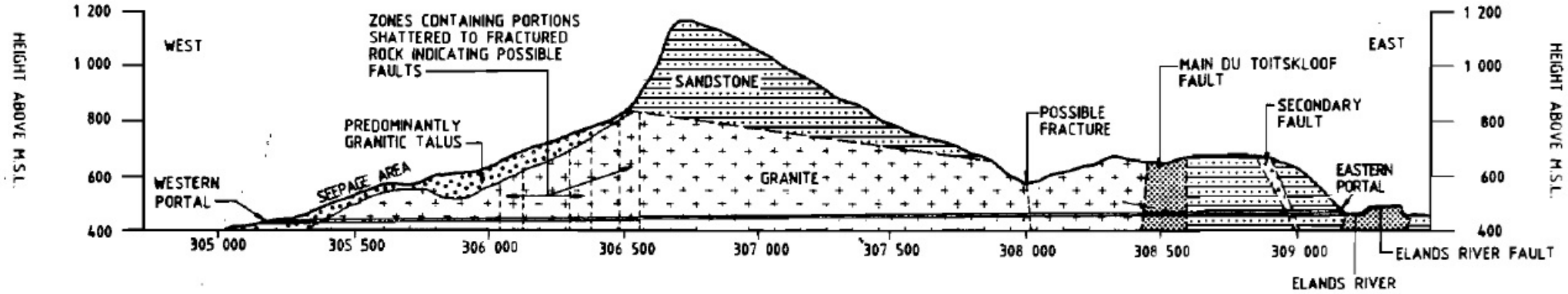
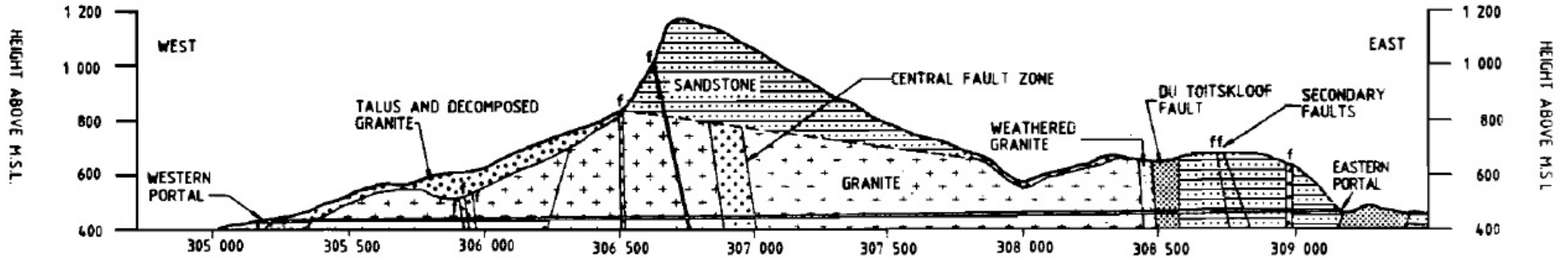


Fig 2: Pre-pilot bore geology

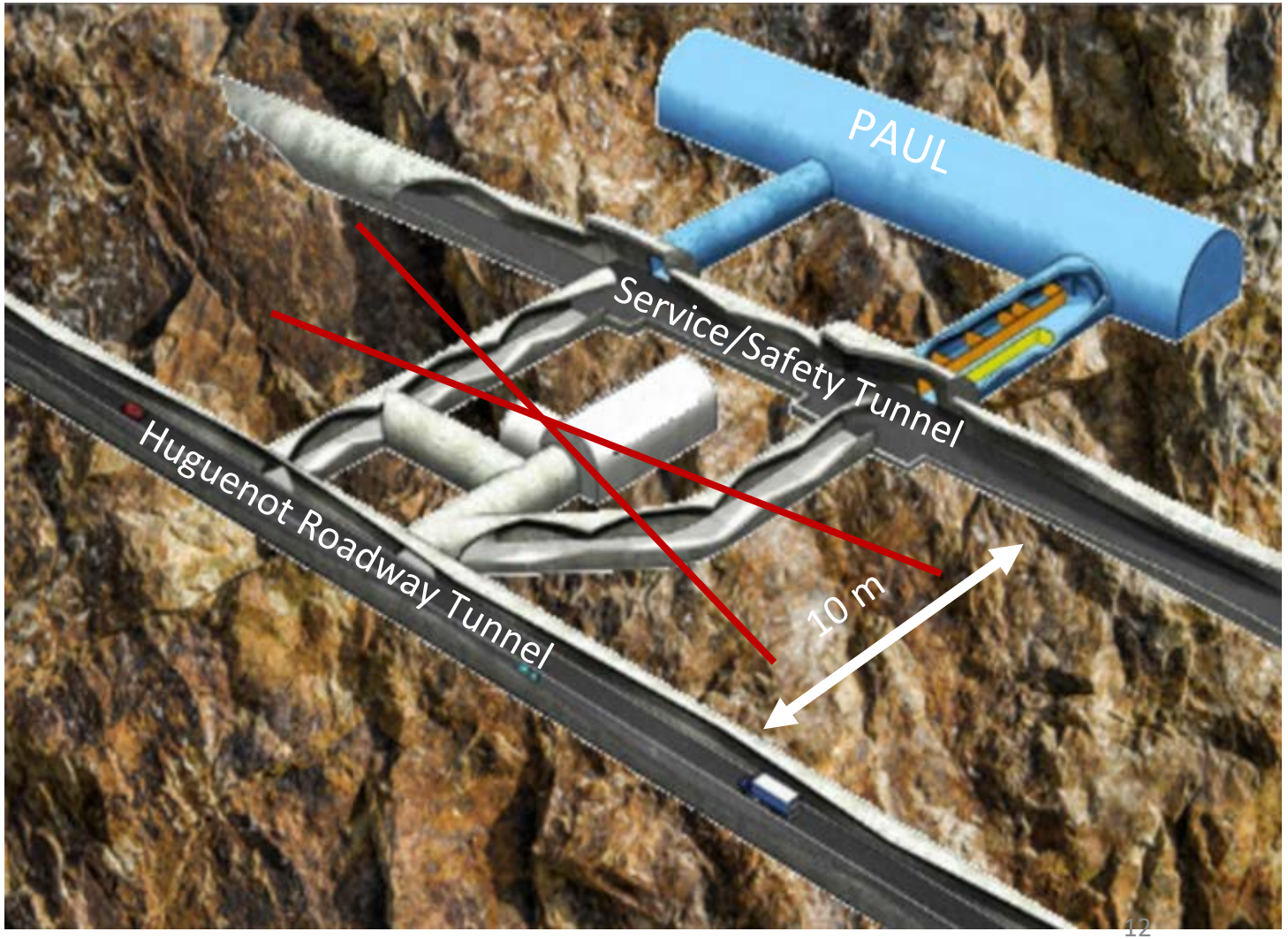


The range mostly consists of Table Mountain sandstone, an erosion-resistant quatzitic sandstone

PAUL in the Huguenot Tunnel

The design of LSM-Modane was used for the purpose of the illustration

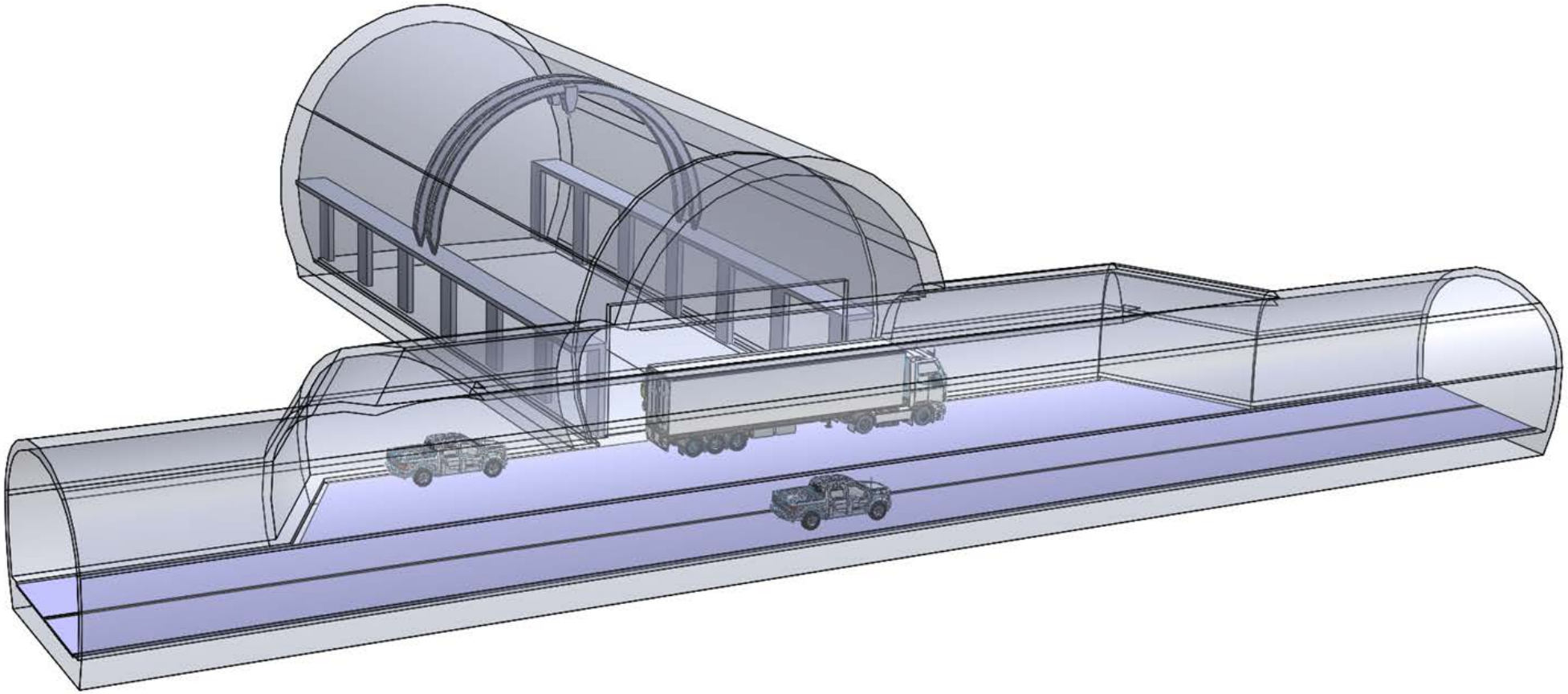
The future underground laboratory is currently being designed; It directly involves the company operating the Huguenot tunnel (SANRAL) since earthworks and infrastructure construction are planned over the next five to ten years.



Gamma-ray mapping in the Huguenot tunnel, 2013
Phys. Proc. 61 (2015) 586-590

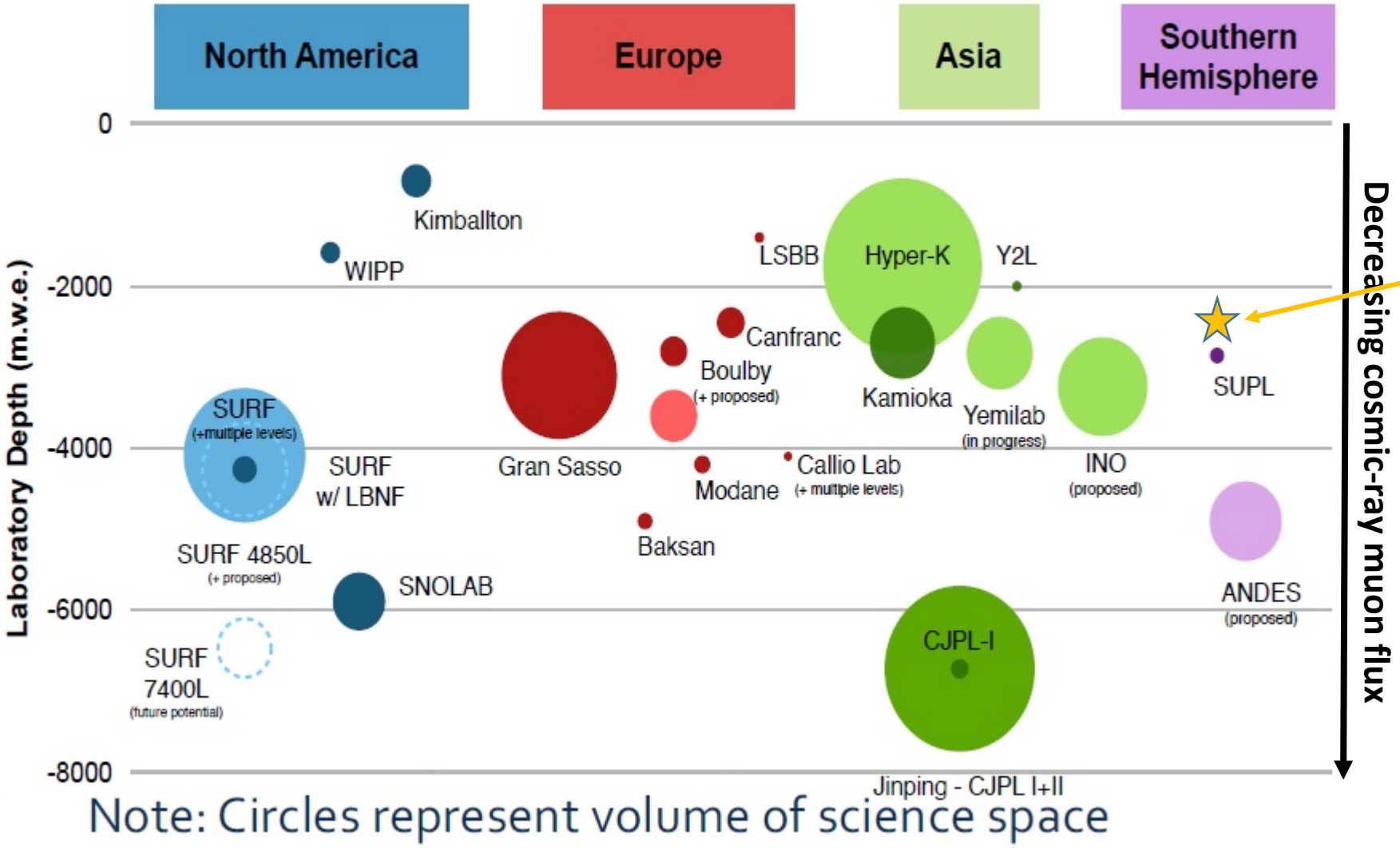
The concentrations measured at three sites confirm that the level of radon is well below any degree of consideration, with a mean level of radon no more than ~50 Bqm^{-3}

Mock up of PAUL facility



A possible 600m^2 laboratory (40x16x16 m^3) in the Huguenot tunnel.
Courtesy: Joaquin Venturino (CNEA), April 2023.

Lab Depth (mwe) vs Decreasing cosmic-ray muon flux



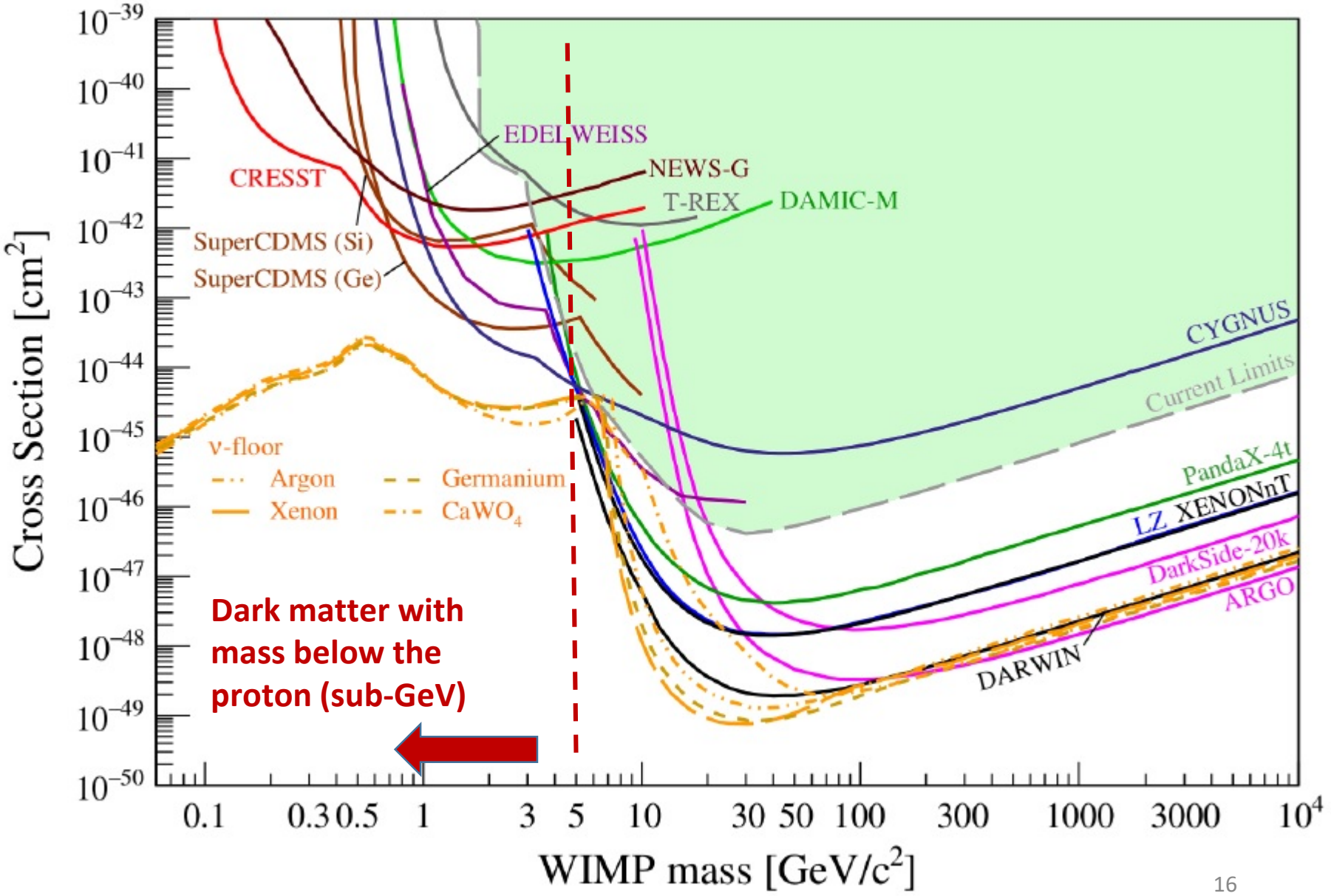
For PAUL, it is only an estimate as the cosmic-ray muon flux is not yet well measured, nor the real rock overburden known exactly (~800 m, ~2000 mwe)

Potential of Astroparticle research

The challenge is to develop detectors with very low energy thresholds and excellent control over detector backgrounds.

Technology

- ✓ Charge Coupled Devices (CCDs), Skipper-CCD (SENSEI, DAMIC, OSCURA)
- ✓ Solid-state cryogenic detectors (Ge, Si, ..), operating at T<15 mK, (Edelweiss)
- ✓ Noble Liquid target (Xe, Ar)



Other Research Purposes of great interest in ZA

- Measurement of **extremely low radiation levels**. These very sensitive detectors, able to detect levels of radiation a millionth of the natural radiation of the human body. Researchers involved in this work can contribute to many needs in South Africa for accurate measurements, such as the detection of the radioactive gas radon that has been identified as a major radiation hazard in South African underground mines.

- The research of **endolithic bacteria** and technologies for bio-leaching

- **Astrobiology** , examining the impact of radiation (or the lack of it) to evolutionary processes or formation of bio-aerosols.

- In glaciology, the study of **ice samples from the Arctic, Antarctic** etc. allows mapping of the **evolution of climatic parameters** and contamination both in space and over time for the last centuries. The measurement of 137Cs and 241Am is the only way to get a precise dating of ice.

- The Cape Supergroup (in Natal and the Northern Transkei), where the lab would sit, has been identified as a region of interest for **geothermal research** .

→ see Lucas Terray talk

Conclusion on PAUL

PAUL is foreseen as an open **international laboratory**, a unique opportunity for Africa devoted to the development of a competitive science in the region. It has the advantage that the location**, the Huguenot tunnel, exists** already and the geology and the environment of the site is appropriate for an experimental facility.

Perform an experiment of direct dark matter detection in an underground laboratory located in the Southern Hemisphere is **to compare the eventual systematic errors or modulation with respect to the same detector in the Northern Hemisphere**. Any systematic error or annual modulation correlated to a seasonal variation will have an opposed phase, giving the opportunity to discriminate them with respect to a dark matter signal. It also opens different regions of parameter space when searching for daily modulations

The other advantage to build an UL facility in South Africa is to **combine the direct detection with indirect dark matter detection from radio astronomy** surveys that South Africa is leading (SKA, MeerKAT, etc.). Therefore, the strong synergy between the astrophysical (indirect) probes and Paarl Africa Underground Laboratory (direct probe) can jointly measure and constrain dark matter effect, which may shed lights on new physics.

Publications and communications in 2023

June 21st: arXiv:2306.12083 [hep-ex]

Paarl Africa Underground Laboratory

Robert Adam[5,1], Claire Antel[14], Munirat Bashir[23], Driss Benchekroun[18], Xavier Bertou[20], Markus Böttcher[8], Andy Buffler[7], Andrew Chen[4], Rouven Essig[22], Jules Gascon[12], Mohamed Gouighri[19], Trevor Hass[1], Gregory Hillhouse[6], Abdeslam Hoummada[18], Anslyn John[1], Pete Jones[3], Youssef Khoulaki[18], Luca Lavina[13], Lerothodi Leeuw[2], Mantile Lekala[9], Robert Lindsay[2], Roy Maartens[2], Yin-Zhe Ma[1], Fairouz Malek[11,*], Peane Maleka[3], Jacques Marteau[12], Rachid Mazini[21], Thebe Medupe[8], Bruce Mellado Garcia[4], Marcello Messina[15], Lumkile Msebi[2], Chilufya Mwewa[26], Zina Ndabeni[3,7], Richard Newman[1], George O'Neill[16], Fabrice Piquemal[10], Lydia Roos[13], Daniel Santos[11], Silvia Scorza[11], Fedor Simkovic[24], Ivan Stekl[25], Yahya Tayalati[17], Smarajit Triambak[2], Zeblon Vilakazi[4], Shaun Wyngaardt[1], JJ van Zyl[1]

[1]Stellenbosch University-South Africa;
[2]University of the Western Cape-South Africa;
[3]iThemba LABS-South Africa;
[4]School of Physics, University of the Witwatersrand Johannesburg-South Africa;
[5]Square Kilometre Array Observatory-South Africa;
[6]Botswana International University of Science and Technology-Botswana;
[7]University of Cape Town-South Africa;
[8]North West University Potchefstroom-South Africa;
[9]The University of South Africa;
[10]LP2I, CNRS-IN2P3, Université Bordeaux-France;
[11]LPSC, CNRS-IN2P3, Université Grenoble Alpes-France;
[12]IP2I, CNRS-IN2P3, Université Claude Bernard Lyon-France;
[13]LPNHE, CNRS-IN2P3, Sorbonne Université Paris-France;
[14] Université de Genève-Switzerland;
[15] LNGS, Gran-Sasso-Italy;
[16]European Spallation Source ERIC, Lund,-Sweden;
[17]Mohammed V university of Rabat-Morocco;
[18]Hassan II university of Casablanca-Morocco;
[19]Ibn Tofail University of Kenitra-Morocco;
[20]Centro Atómico Bariloche, CNEA/CONICET-Argentina;
[21]Institute of Physics, Academia Sinica, Taipei-Taiwan;
[22]Stony Brook University, USA;
[23]Ibrahim Badamasi Babangida University-Nigeria;
[24]Comenius University Bratislava-Slovakia;
[25]IEAP CTU Prague-Czechia;
[26]Brookhaven National Laboratory, USA.

*Contact editor:fmalek@in2p3.fr

Workshop, congress and conferences

1)- Underground Labs Workshop at Aussois: June 21-23

2)- French Physics Society General Congress, Paris, 3-7 July

3)- EAS Crakow, July 10-14

4) High Energy Astrophysics in Southern Africa (HEASA) July 31st

5) TAUP 2023, August 28 – September 1, 2023

6) African Nuclear Physics Conference, 29 Nov – 3 Dec in Kruger National Park.

International Networking time line

- **September 2022**: local ZA academic reactivation
- **Jan 2023**: 1st contact with French colleagues working at underground labs: LPSC, LPNHE, IP2I and LP2I
- **April 2023**: Political ZA reactivation (DSI)
- Inform IN2P3 and LNGS
- contacts with the Huguenot tunnel company/SANRAL
- **May 2023**: 2 year bilateral project, seed budget to start networking: PHC Protea (FR-ZA) application (results in August 2023)
- **June 19th**: IN2P3 support building an IRN

- **Next plan**:

Open call: December 6th: Strengthen the bilateral cooperation on research infrastructures with :HORIZON-INFRA-2024-DEV-01