Towards the

Paarl Africa Underground Laboratory (PAUL)

PAUL General Meeting, 30 April 2024

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PAARL AFRICA UNDERGROUND LABORATORY

Photo by RT Newman

Supporting Institutions

Stellenbosch University
iYunivesithi
Universiteit

University of the Western Cape

cnrs
Nucléaire & Particules

LPSC Grenoble | Modane

LSM

INFN LNGS

Sponsors

science & innovation
Department:
Science and Innovation
REPUBLIC OF SOUTH AFRICA

Stellenbosch University
iYunivesithi
Universiteit

PAUL Organization

- Steering Committee
- Project Manager (appointed by Steering Committee)
- International Advisory Board (being established)
- Task teams (e-groups)
- Twiki Home page
- Note: PAUL not yet a legal entity

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PAUL Steering Committee

- Prof. Fairouz Malek (CNRS) - Chair
- Dr Rob Adam (SKA International)
- Dr Xavier Bertou (CNEA)
- Prof. Lerothodi Leeuw (UWC)
- Prof. Robbie Lindsay (UWC)
- Prof. Shaun Wyngaardt (SU)
- Prof. Richard Newman (SU) – Project Manager

PAUL arXiv Concept paper

High Energy Physics – Experiment

[Submitted on 21 Jun 2023]

Paarl Africa Underground Laboratory (PAUL)

Robert Adam (5 and 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 and 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) 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)

PAUL Budget

- R 5M seed-funding grant (Dept. of Science and Innovation)
- R 130k seed-funding grant (Stellenbosch University)
- R 4M earmarked for engineering feasibility study and detailed engineering design

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PAUL Design Study

- Have a concept design
- Basic engineering design guideline document
- Contract with engineering company SMEC to do engineering feasibility study

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Map of the Western Coast of Cape Town and the location of the Huguenot tunnel. Modified image extracted from Google Map.

- Tunnel has South and North bores
- 3.9 km long, longest road tunnel in South Africa
- currently: single-laned highway or single carriageway (one lane in each direction) in Huguenot Tunnel South Bore [no physical barrier between lanes]
- Currently: North Bore is used as service/emergency tunnel

South Bore Tunnel at the Huguenot Tunnel Complex

North Bore Tunnel at the Huguenot Tunnel Complex

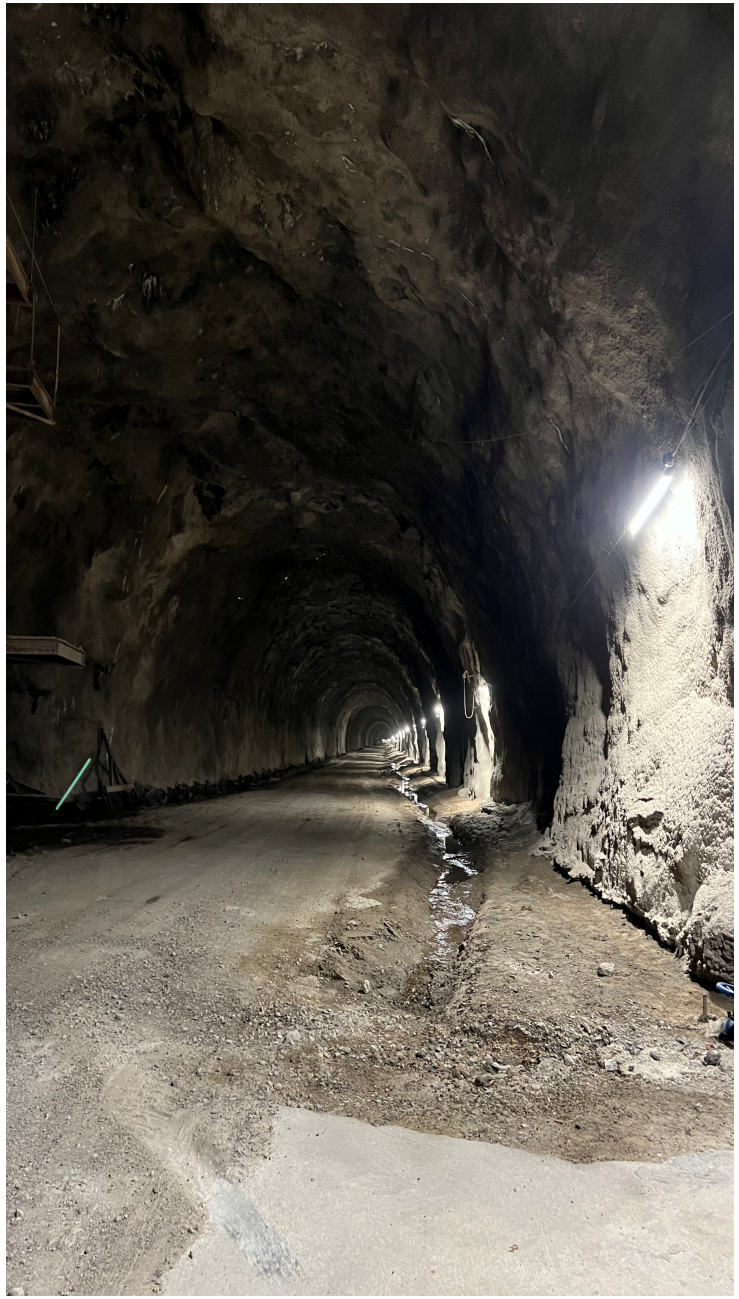


Photo by Stefan Els

- The tunnel is managed by the South African National Roads Agency Limited (SANRAL)
- SANRAL is a parastatal falling under the Ministry of Transport
- A formal **expression of interest** to interest to establish

PAUL sent to SANRAL on 2 Apr 2024

SANRAL
SOUTH AFRICAN NATIONAL ROADS AGENCY SOC LTD
Reg.No.1998/009584/30
BUILDING SOUTH AFRICA THROUGH BETTER ROADS

Cross-section of the Huguenot Tunnel

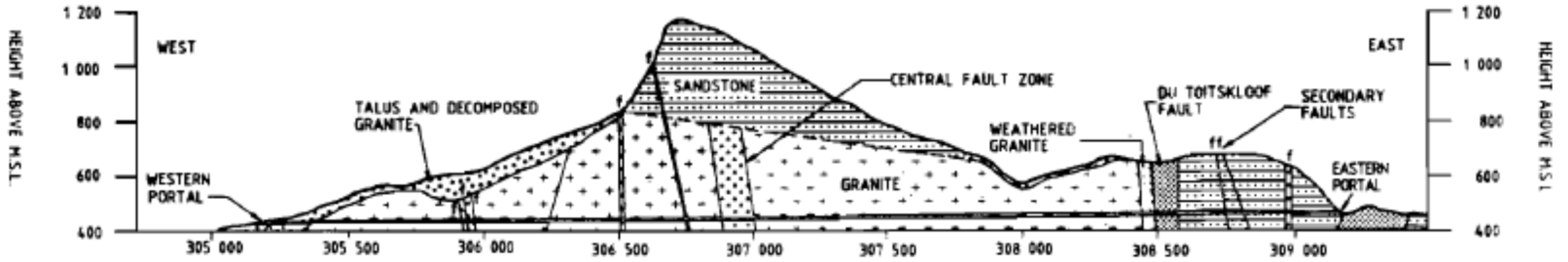
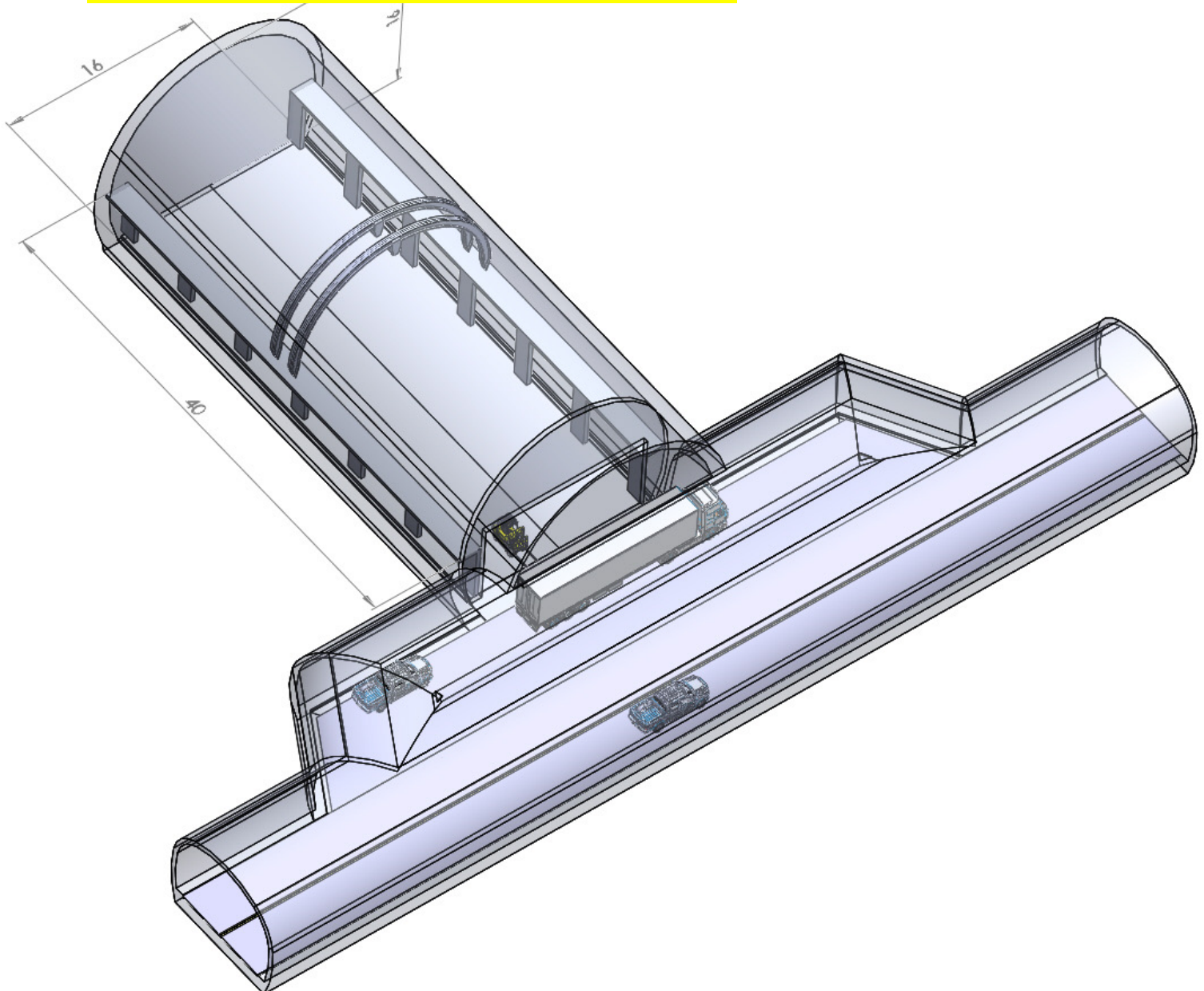


Fig 3: Post-pilot bore geology

PAUL Concept Design



Floor space: 640 m^2

Volume: 10240 m^3

- We propose to locate PAUL off the North-Bore Tunnel adjacent to the Central Fault Zone inside the tunnel.

PAUL Engineering Design Guidelines

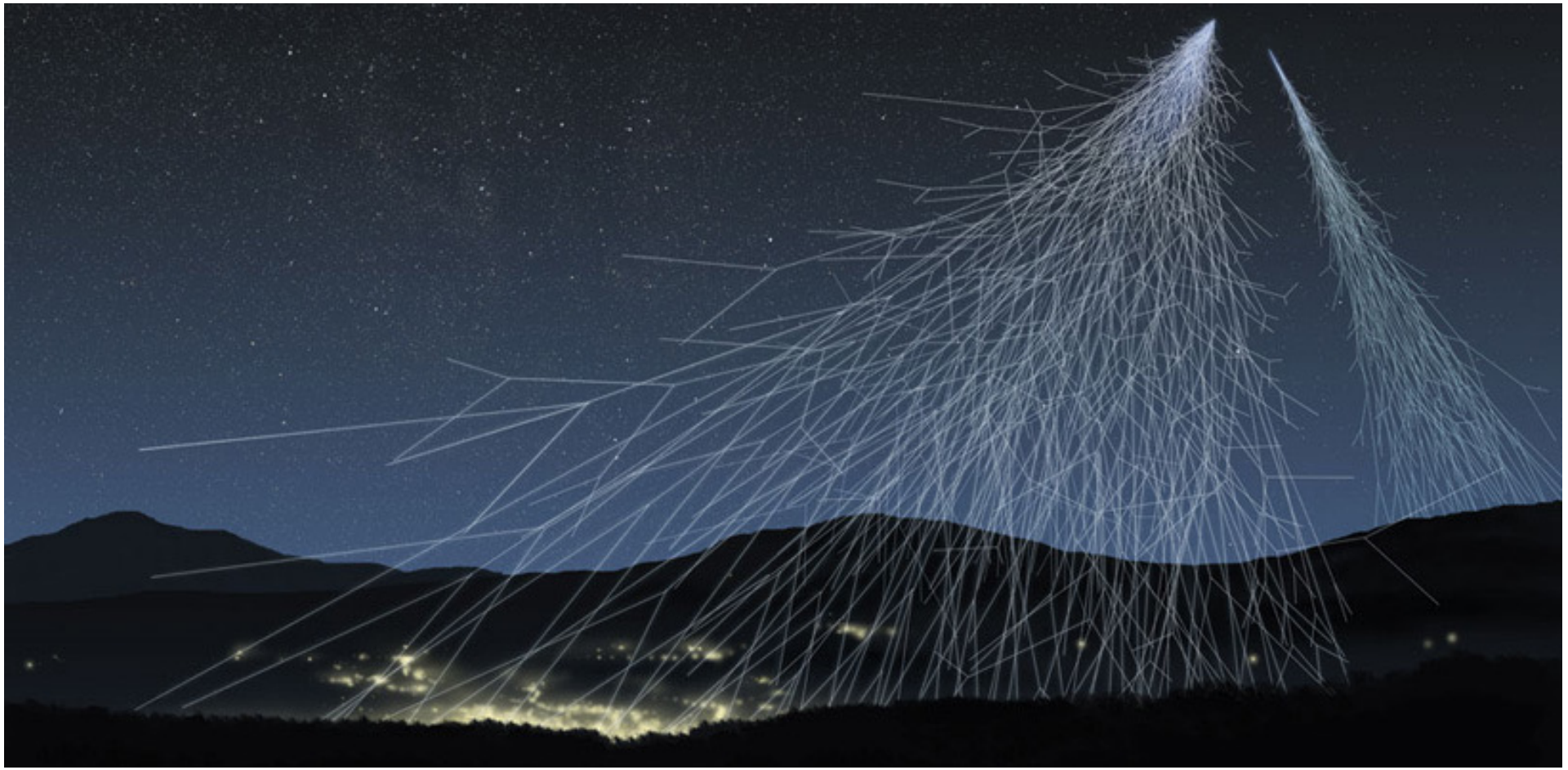
- location: close to largest mountain overburden
- layout: one large cavern or multiple smaller ones, connected
- preferred layout: one cavern (16 m width, height 16 m, length 40 m)
- ventilation: 1 air exchange per hour
- radon levels: < 15 Bq/m^3 (ideal), < 150 Bq/m^3 (minimum)
- maximum electrical power: 400 kW
- clean room (at least part of lab)
- air lock
- alarms: smoke, oxygen, carbon monoxide, movement
- external PAUL Support Building
- fibre internet/copper cable connection to Paarl side

- **Engineering feasibility study** by SMEC Engineering – first meeting held on 15 Feb 24

- Study expected to last 3 months, completion July 2024.
- Study will also provide a more accurate cost estimate.

https://www.lngs.infn.it/it/raggi-cosmici

Schematic representation of cosmic-ray shower. By locating a laboratory underground (inside a mountain or down a mine) one can shield experiments from unwanted background signal produced by the cosmic-ray showers. Such laboratories are called deep underground laboratories (DULs).



PAUL Muon flux measurements

- Using detector system of Jacques Marteau (CNRS, France)
- Measurements started in Dec. 2023

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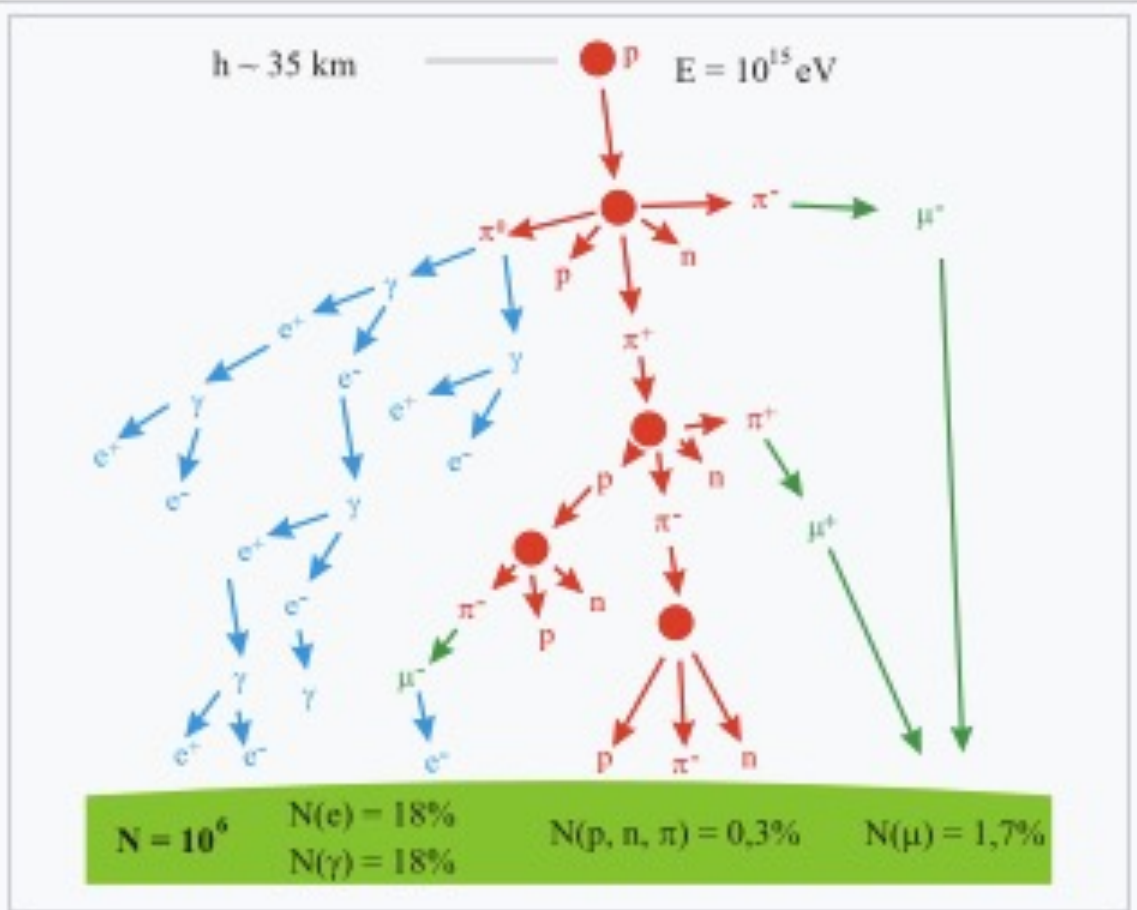
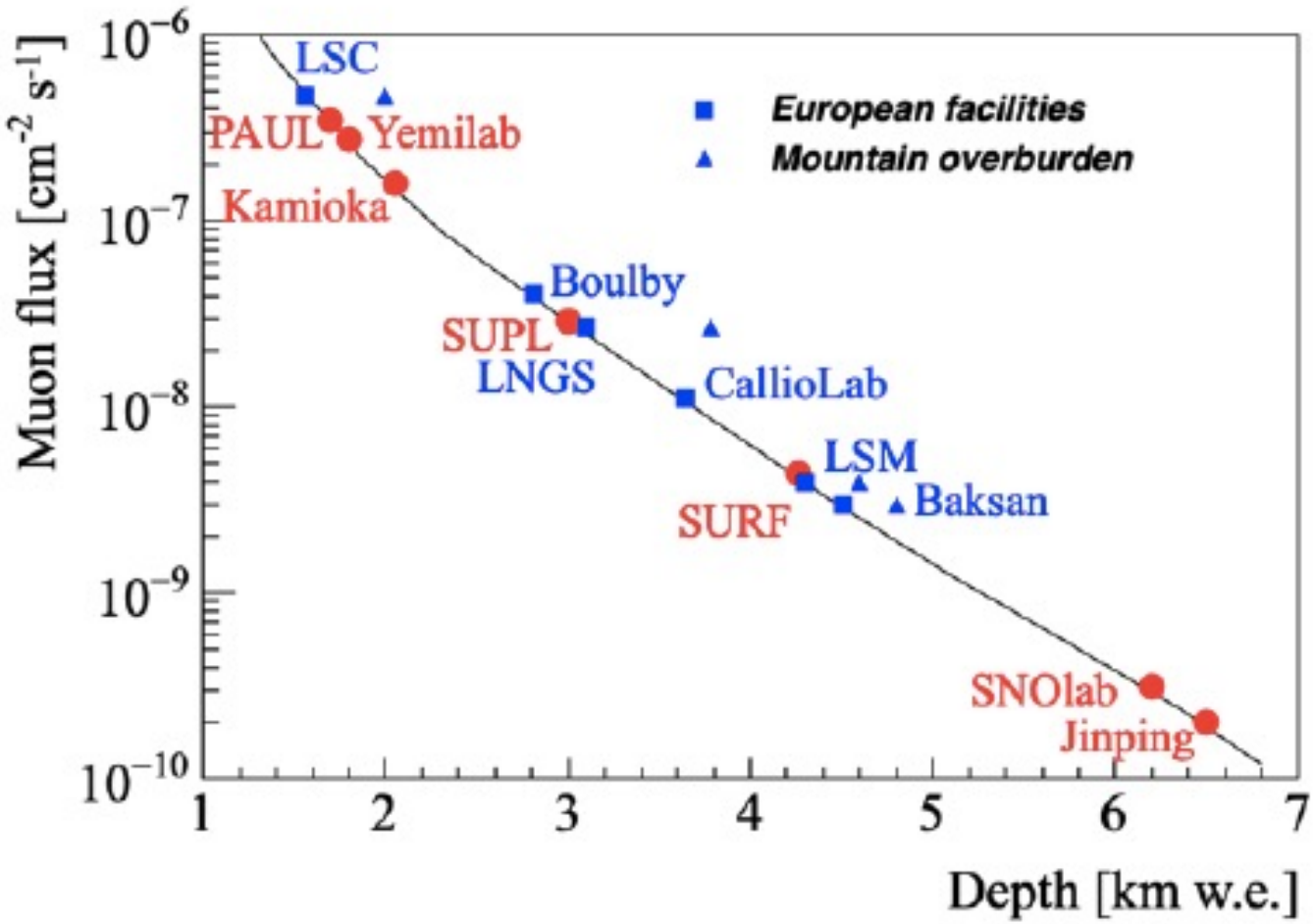
Muon flux attenuation measurements



Air shower formation in the atmosphere. First proton collides with a particle in the air creating pions, protons and neutrons.

Source: Wikipedia

Muon flux attenuation measurements

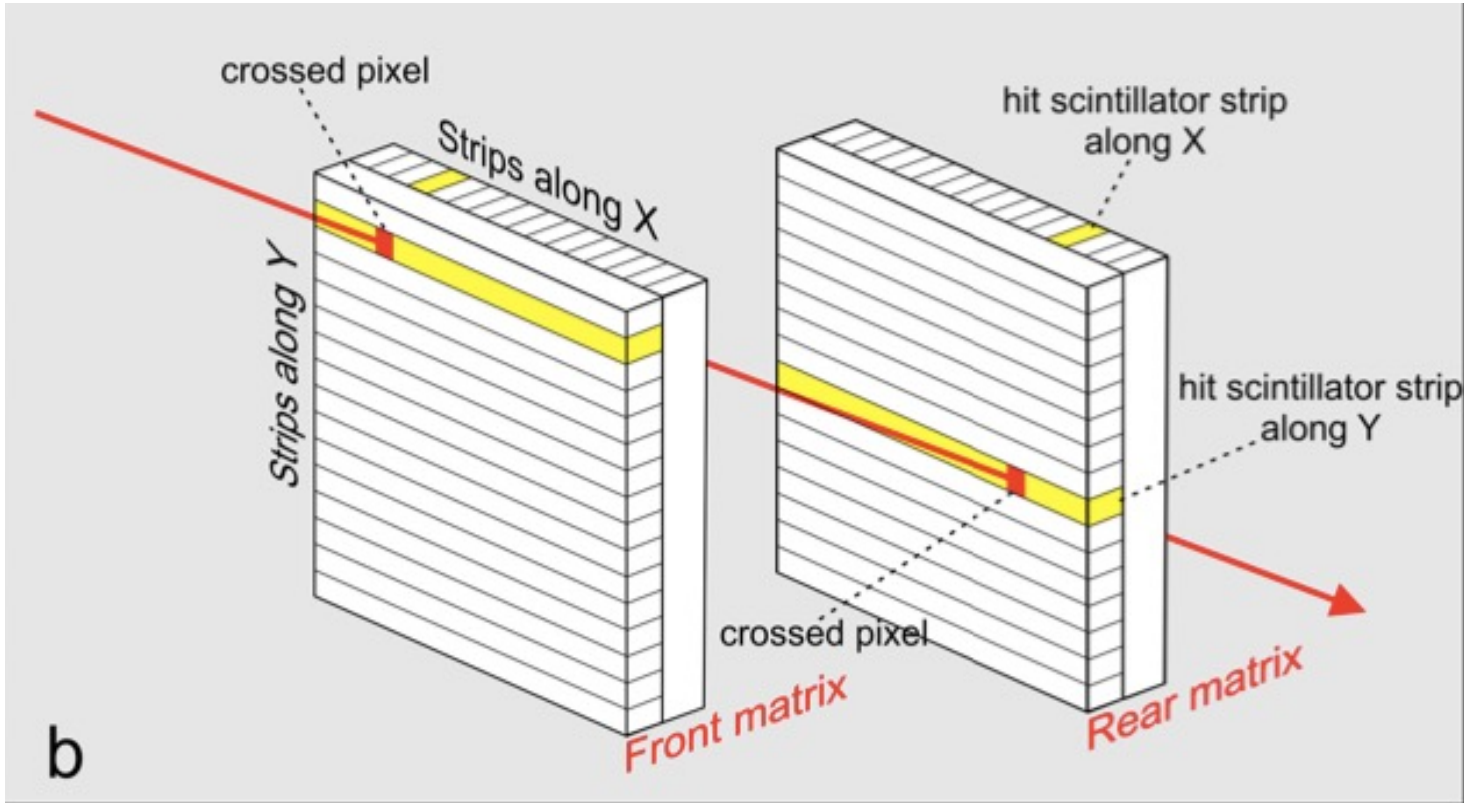


Source: Aldo Ianni, 2023

Fig. 2 Cosmic muons flux in ULs. The solid line shows the flux under a flat surface. The approximate position of PAUL in this line is shown. For ULs under a mountain the maximum overburden is also reported (this will also be the case for PAUL – here not shown).

Muon flux attenuation measurements

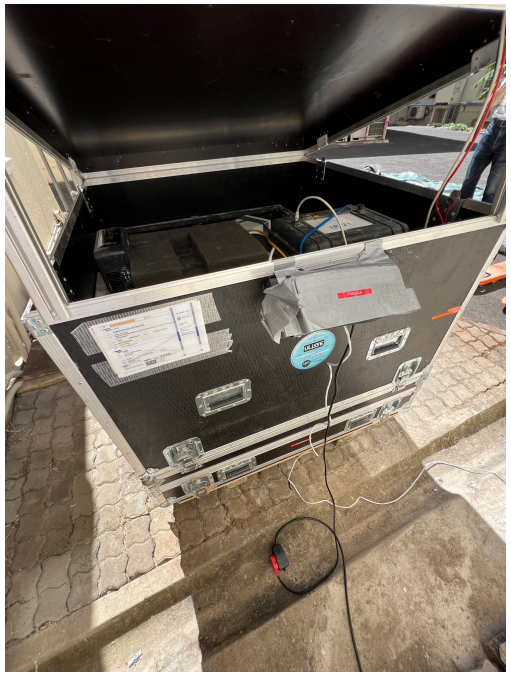
- Detector principle



Source:
Daniele Carbone, Dominique Gibert, Jacques Marteau, Michel Diament, Luciano Zuccarello, Emmanuelle Galichet, An experiment of muon radiography at Mt Etna (Italy), *Geophysical Journal International*, Volume 196, Issue 2, February, 2014, Pages 633–643, https://doi.org/10.1093/gji/ggt403

Muon flux attenuation measurements: at Stellenbosch University

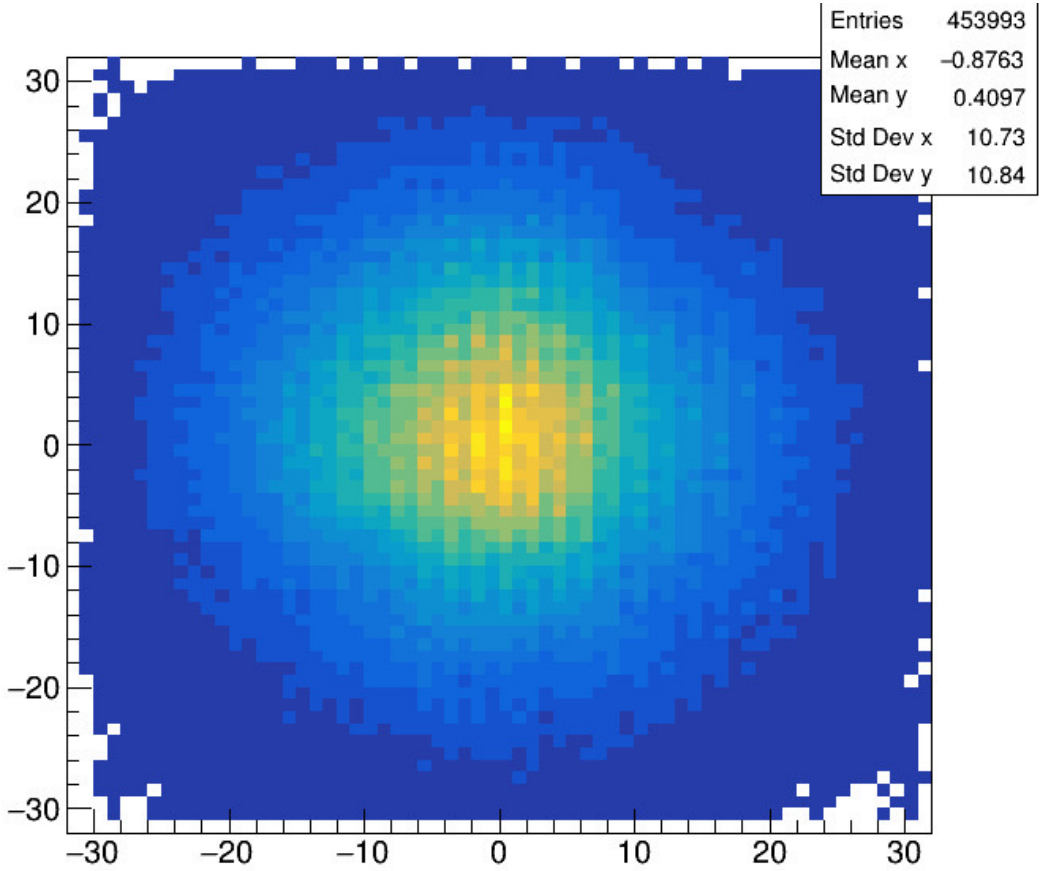
- equipment



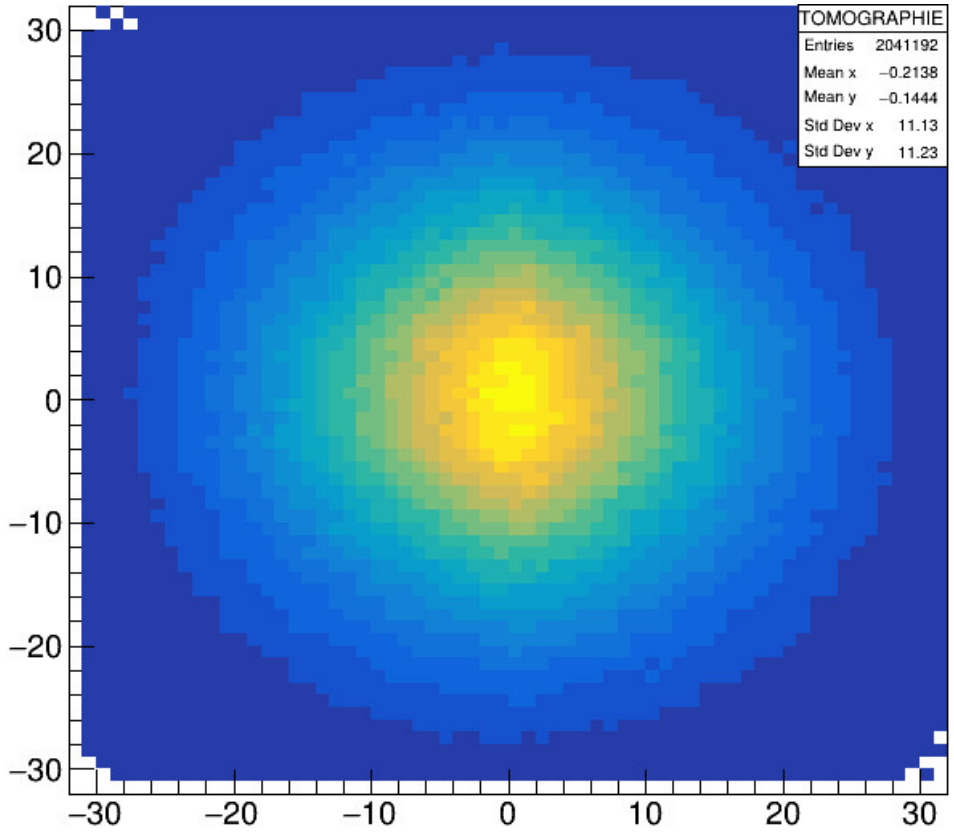
Muon flux attenuation measurements: at University of the Western Cape

Muon flux attenuation measurements

- preliminary data



At Stellenbosch University



At University of the Western Cape

Muon flux attenuation measurements

- first location: Physics Dept., SU
- second location: UWC
- next location: near/inside VCC1 and VCC2 (inside tunnel)
- services needed: electricity, internet access would be ideal
- start/duration: ~ 3 May 24/up to 3 months per location
- data will yield information on mountain geology, allowing for comparisons with current understanding

PAUL Project Timelines

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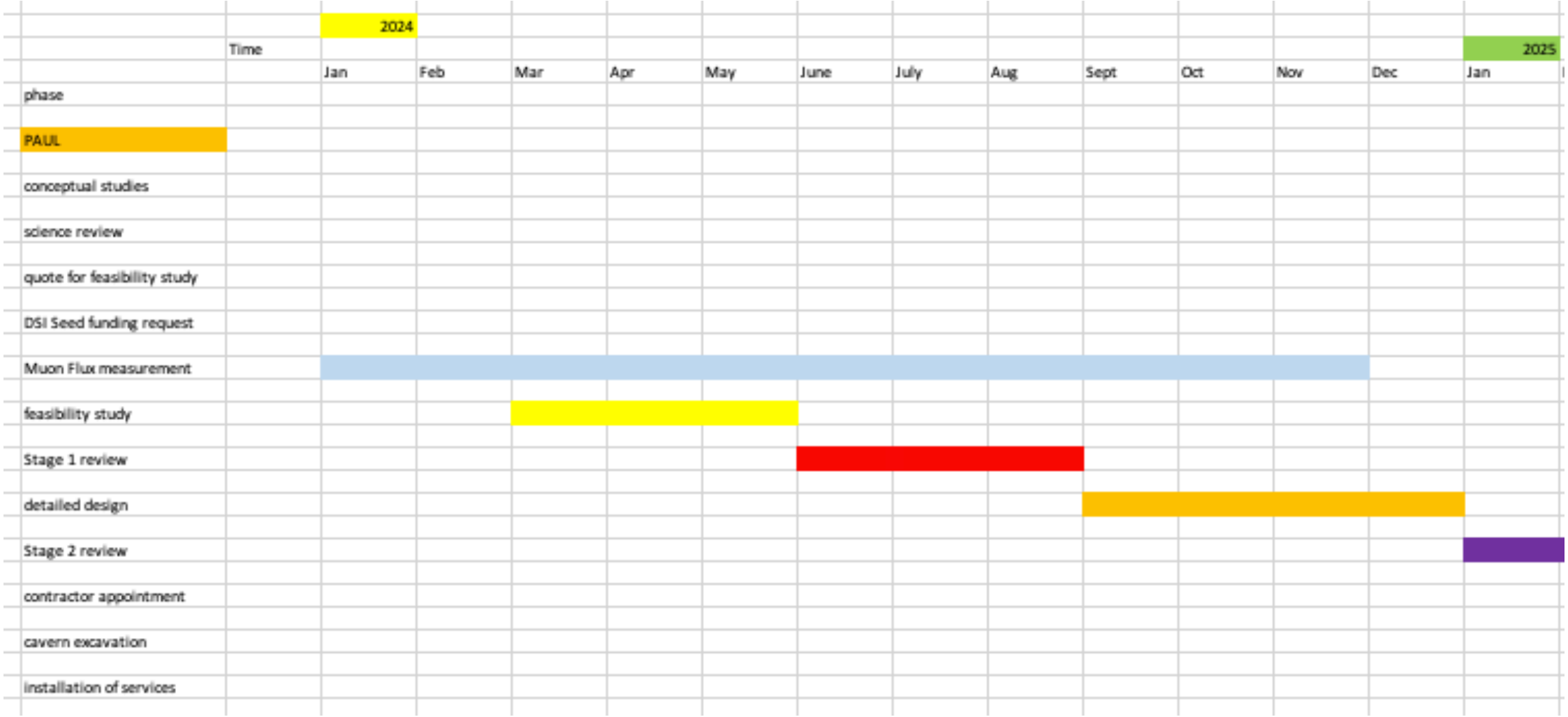
- SANRAL is planning to upgrade the North Bore Tunnel in order for it to lower traffic volumes in the existing South Bore Tunnel.
- current traffic in South Bore: up to 20k vehicles per day
- Will have two-lane highway (one way) in both bores.
- This project is estimated to cost ~ R 4 billion.
- Engineering firm SMEC is contracted to design plans for the North Bore upgrade.
- SANRAL would like upgrade work to start by end of 2024.

- Assume excavation rate (drill and blast):

  30 m^3 per day

- According to current timeline, fully serviced laboratory to be completed by mid 2027.

PAUL Project Timeline part A (11 Mar 24)



PAUL Project Timeline part B (11 Mar 24)

PAUL students and post-docs

- Dr Lumkile Msebi, UWC, 2024 – 2025, muon measurements
- Stephan Jonker, Stellenbosch University, Master of Science, 2024 - 2025, muon measurements and simulations
- Motlatsi Vincent Mahanyapane (Stellenbosch University), PhD, 2024 – 2026, neutron and gamma background in Huguenot Tunnel

PAUL Collaborations

- muon flux measurements (Marteau et al.) - ongoing
- neutron flux measurements (Fard et al.) – proposed
- biological science (JINR) - proposed
- low-level gamma-spec (JINR) - proposed

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PAUL outlook

- Busy appointing a PAUL International Advisory Board
- Richard Newman and Fairouz Malek to visit LSM (Modane) and LSC (Canfranc) labs 26 May – 9 June.
- RTN to present on PAUL science at South African Institute of Physics conference 2024 (1-5 Jul 2024)
- Dr JJ Van Zyl (SU) to visit Czech Republic (Prof. I. Stekl) and Poland (Prof. P. Moskal) – exploring new muon detector development

Thank you !

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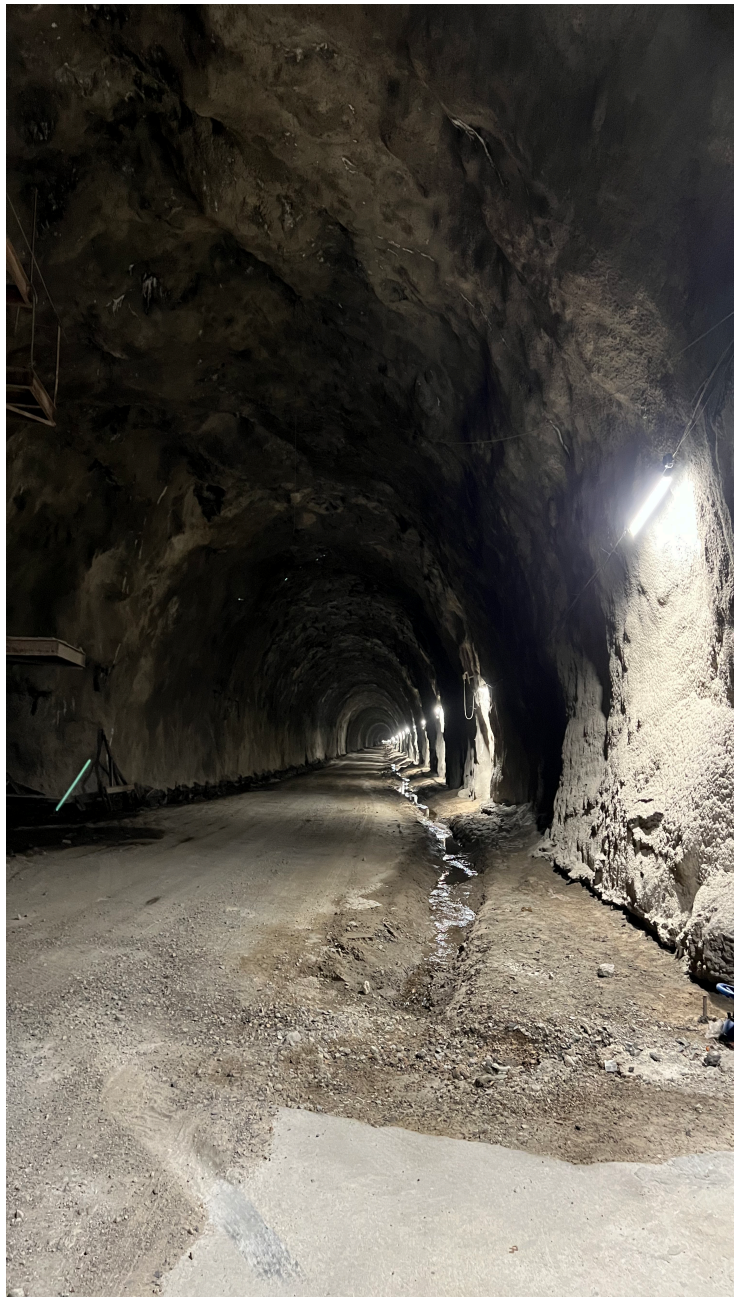
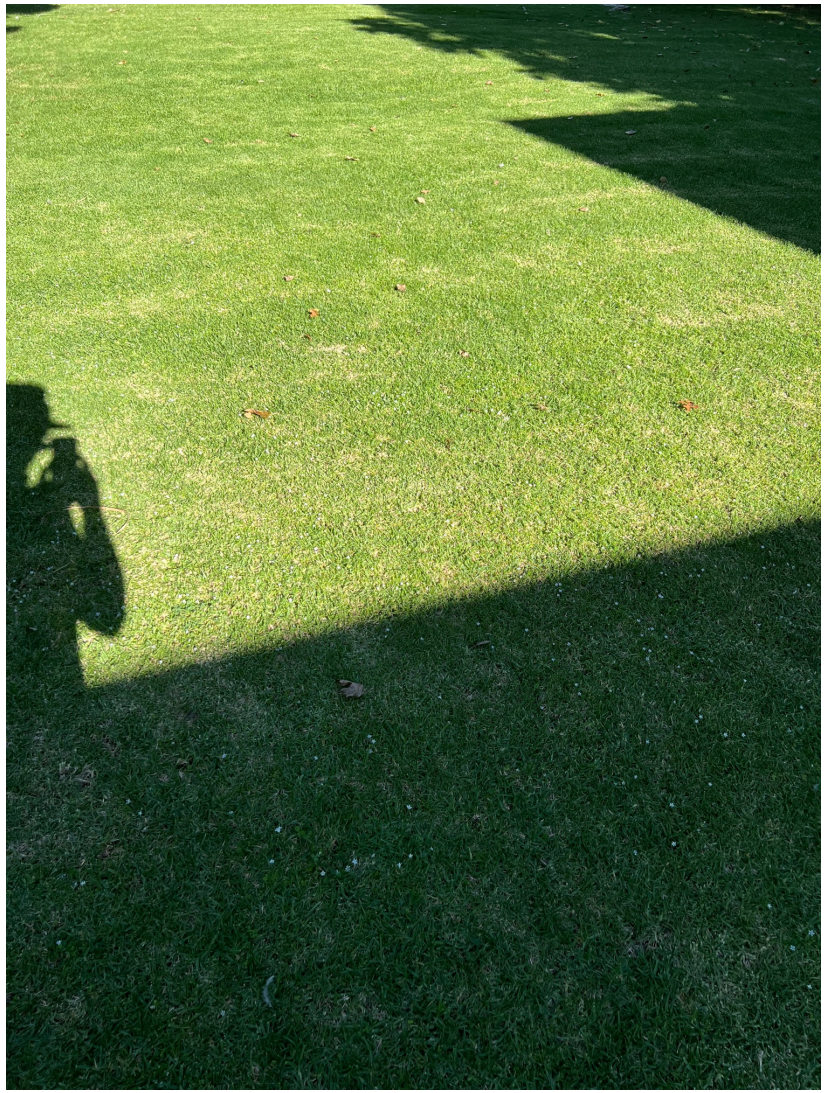


Photo by Stefan Els

Seeking the daisy .....



PAUL Science

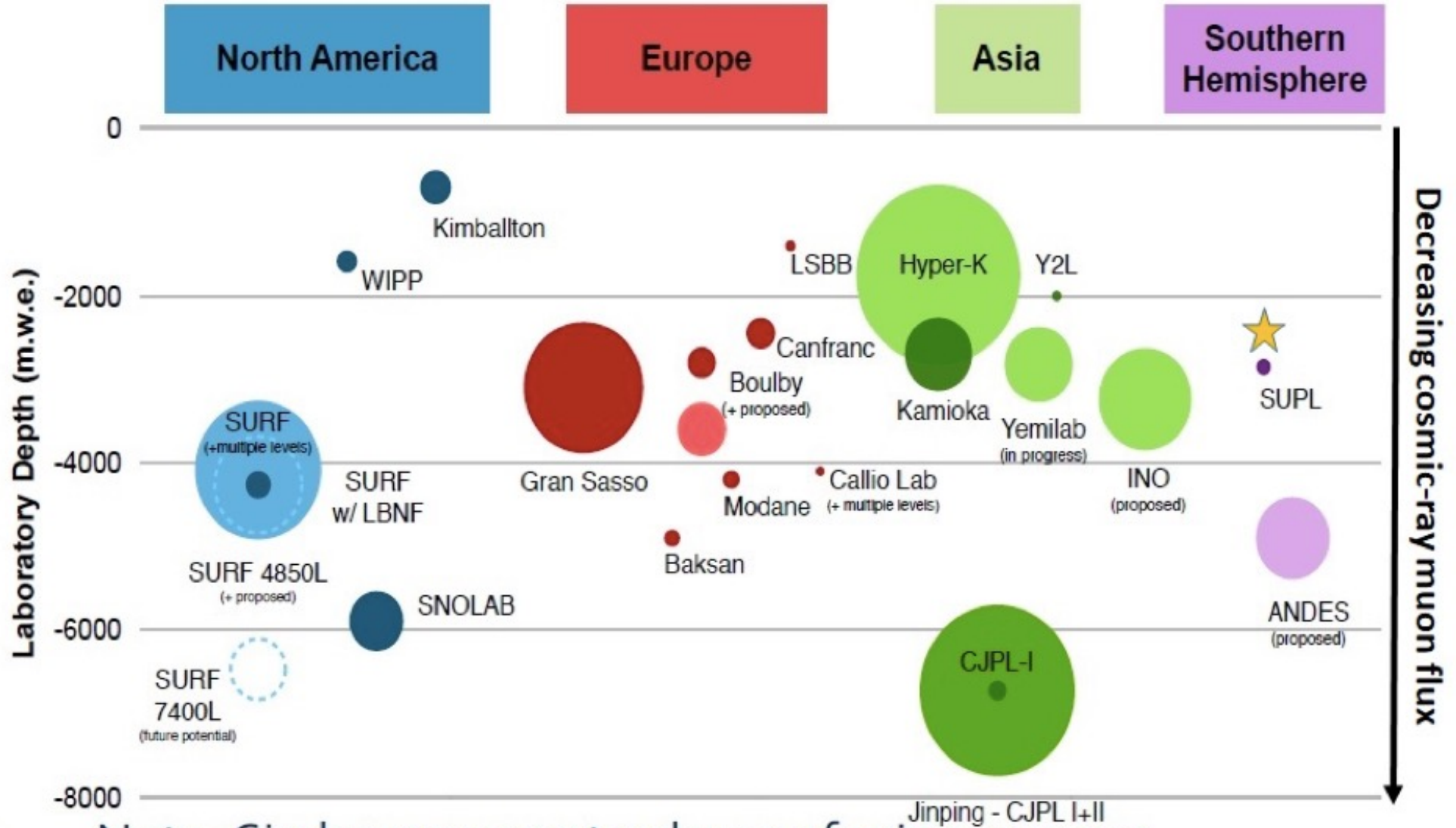
- Geoscience – muon tomography of mountains
- Ultra-low level radioactivity measurements

(related to climate science amongst others)

- Dark Matter search
- Biological science (effect of cosmic radiation on cells and reference organisms – radiation biology)
- possibly anti-neutrino monitoring (radiated from Koeberg Nuclear Power Station) (neutrino physics)

Why PAUL ?

- To allow comparison of results, especially related to attempts to detect Dark Matter, from other DULs in the Northern Hemisphere and the only other one in the Southern Hemisphere (Stawell Underground Physics Laboratory in Australia).
- To complement indirect searches for Dark Matter (via e.g. SKA)
- The planned upgrade of the North Bore tunnel at the Huguenot Tunnel complex presents a unique geographic, time-sensitive opportunity to build a DUL in South Africa and first in Africa.



Note: Circles represent volume of science space

Inside view of LSC laboratory (Spain, France border)

- Assume excavation cost (drill and blast):

  100 US$ per m^3

- Assume a contingency of 20 %.
- Includes estimated cost (R 5 million) to build a PAUL Support Facility outside tunnel on Paarl side.

- Current estimate to construct PAUL:

  - R 130 million (~ US$ 6.5 million)

											01-Aug-23
item	total volume	cost per m^3	US$/R	total floor area	cost per m^2	assumed cost per m^2	cost	cost			Ask from SA gov
	m^3	US$			US$	US$	US$	Rands			
excavation	10240	100	20		(from ChatGBT)		1024000	20480000	1,00E+07		2,20E+07
structural reinforcement				600	1000 - 3000	2000	1200000	24000000			2,40E+07
foundation work				600	500 - 1500	1000	600000	12000000			1,20E+07
utilities				600	500 - 2000	1200	720000	14400000			1,44E+07
interior finishes				600	1000-5000	2500	1500000	30000000			3,00E+07
Ultra-low background facility								8000000			
Dark Matter Facility							400000	8000000			
Biological Science Facility								5000000			
above ground offices/workshops								5000000			5,00E+06
						Grand Total		126880000	105880000		1,07E+08
											1,29E+08
										Rands	1,30E+08
										US$	6,50E+06

- Edict of Fountainebleau (1685), by King Louis XIV overturning Edict of Nantes (1598) by King Henry IV.
- Huguenots = Calvinist Protestants in France
- Revoked rights of Huguenots to practice their religion
- Fled France, some to South Africa