The Stawell Underground Physics Laboratory
or
The Hunt for Dark Matter in a Gold Mine

8th CYGNUS Workshop

Sydney, 12th December 2023

Zuzana Slavkovská

Postdoctoral Fellow

Australian National University

STAWELL UNDERGROUND PHYSICS LAB

ARC CENTRE OF EXCELLENCE FOR DARK MATTER PARTICLE PHYSICS

Australian National University

A tiny Australian mining town might hold the key to solving one of the universe's biggest mysteries – and to a local economic boom. What do scientists hope to find in a cave 1km underground?

Deep down and dark: Stawell's genius lair

1 kilometre down an old gold mine...inspection of the area within the Stawell gold mine that was to one day house SUPL. Credit: SUPL

Country Victoria is set to host one of the coolest experiments going, an attempt to solve the mystery of dark matter. Will they succeed?

The Guardian

Laboratory to study dark matter opens 1km under Australian town – with no bananas allowed

The Guardian

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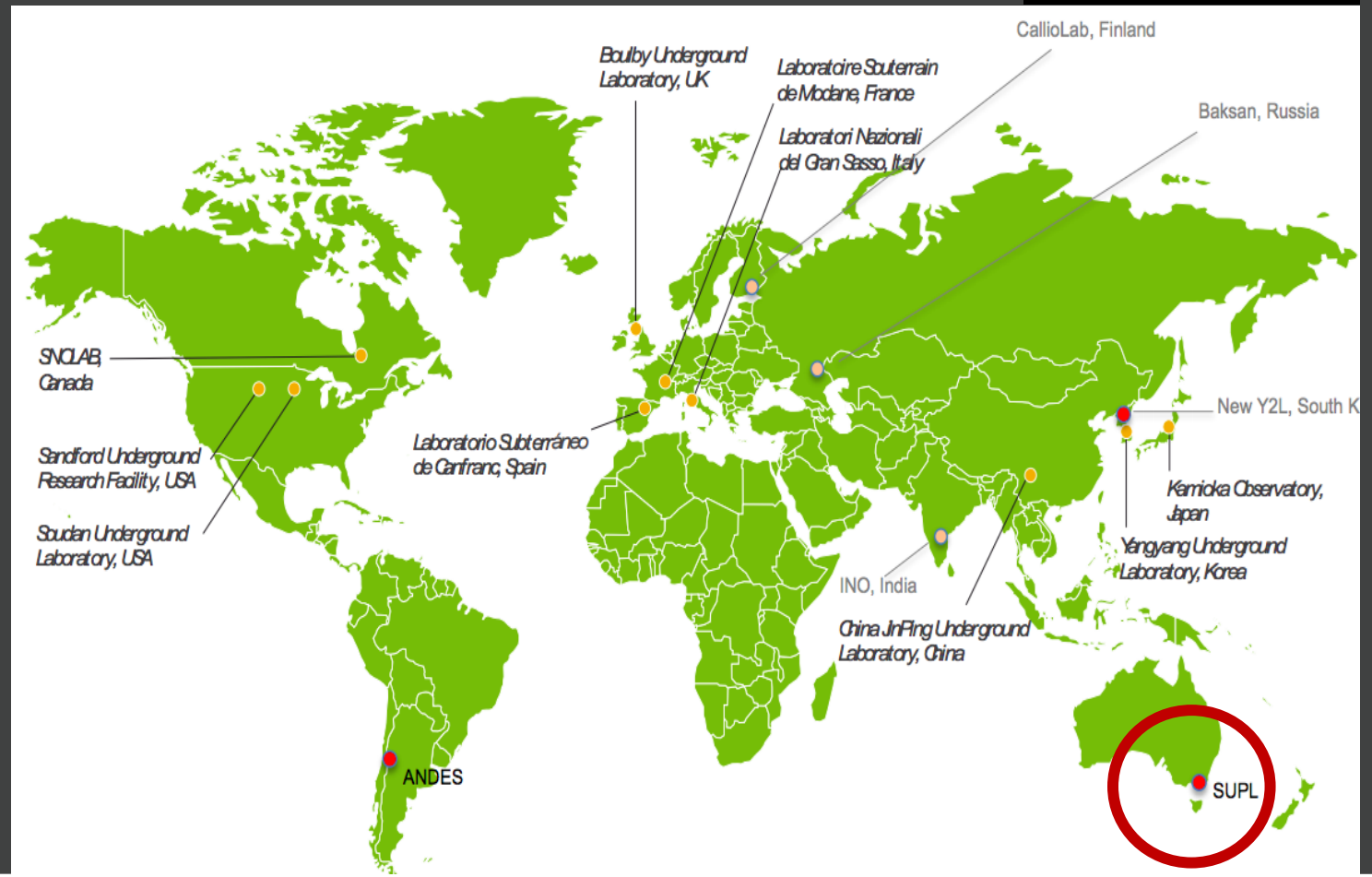
The Stawell Underground Physics Laboratory (SUPL)

- First general-purpose underground laboratory in the Southern Hemisphere

- Built with support from state/federal funding

- Member institutions to manage SUPL:

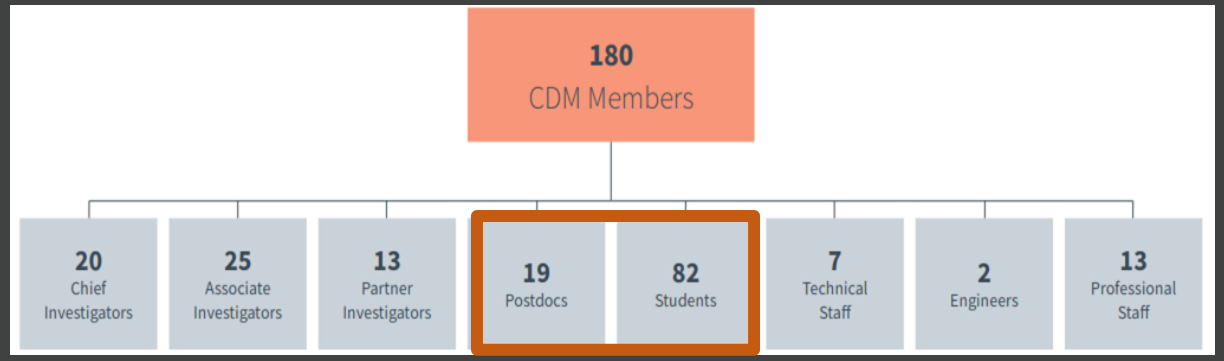


ARC Centre of Excellence

- **ARC Centre of Excellence for Dark Matter (DM) Particle Physics**

- **Significant long-term (7 years) funding -> majority of funds to personnel (ECRs)**

- Main purpose: **"deliver breakthroughs in our understanding of the Universe through the pursuit of the discovery of dark matter particles "** ARC



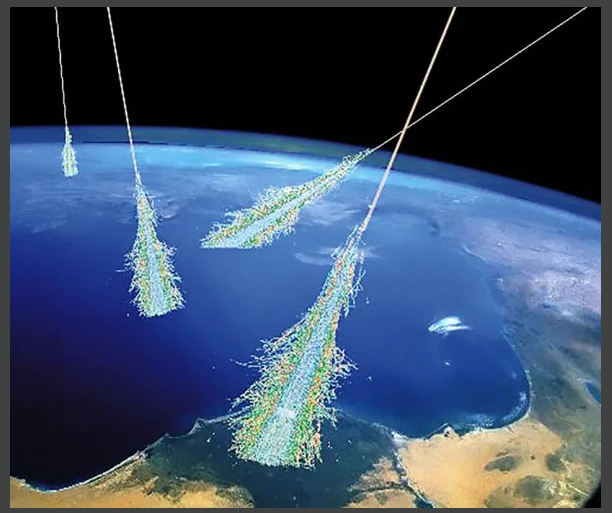
- **Research themes:**

  Direct Detection (WIMP/WISP), Precision Metrology, Theory, and LHC

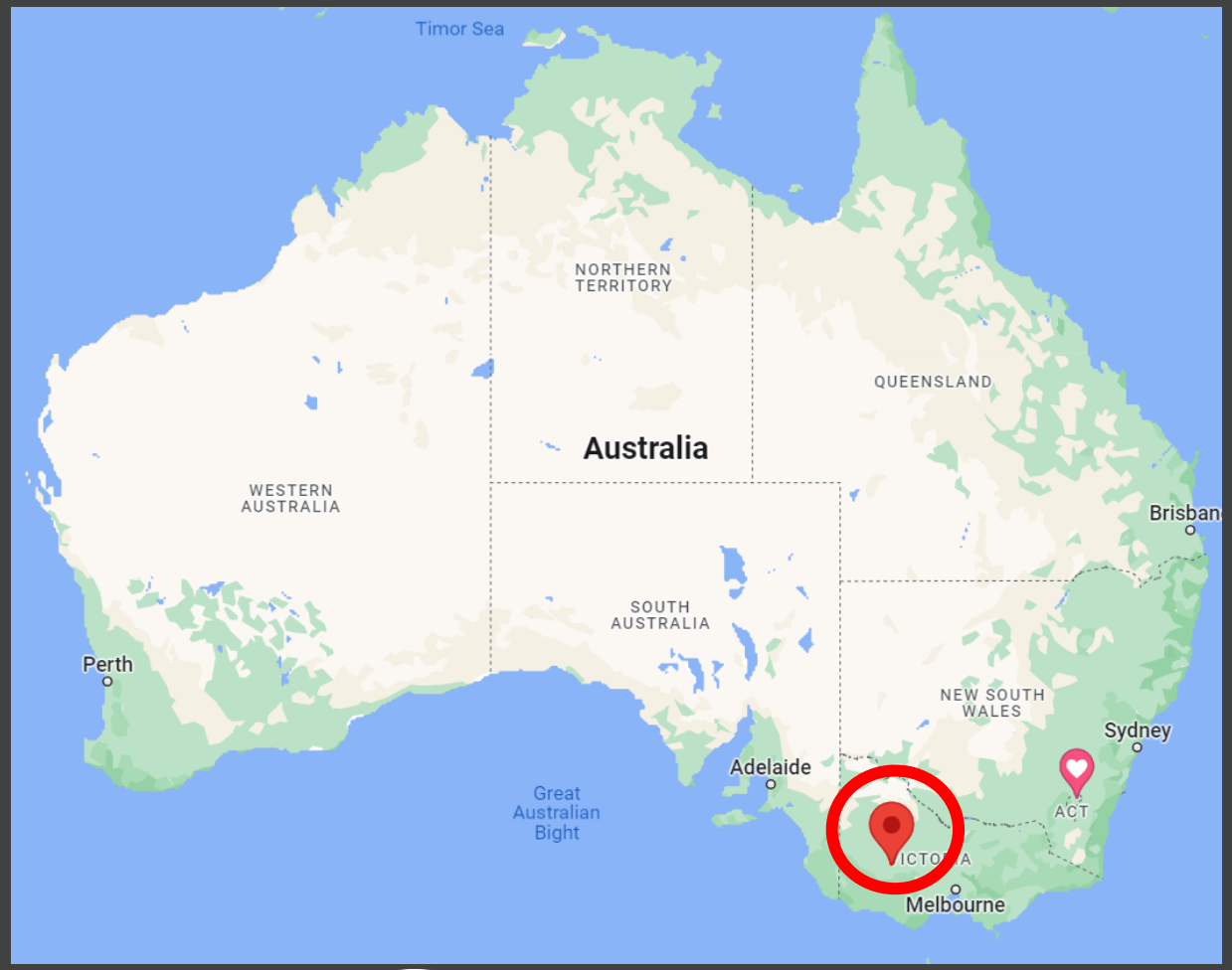
SUPL

- 1025 m deep underground in an **active gold mine** in Stawell, Victoria, Australia

- **Protection from interference from cosmic radiation** by a factor of 10^7



Stawell



Stawell

Grampians NP

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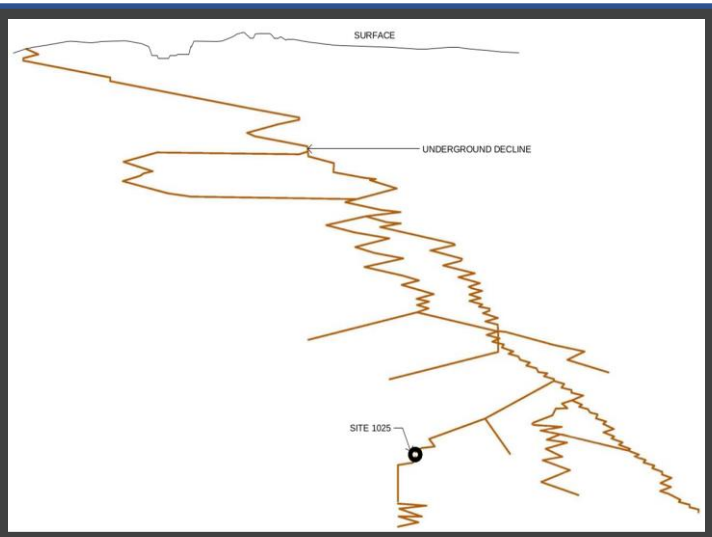
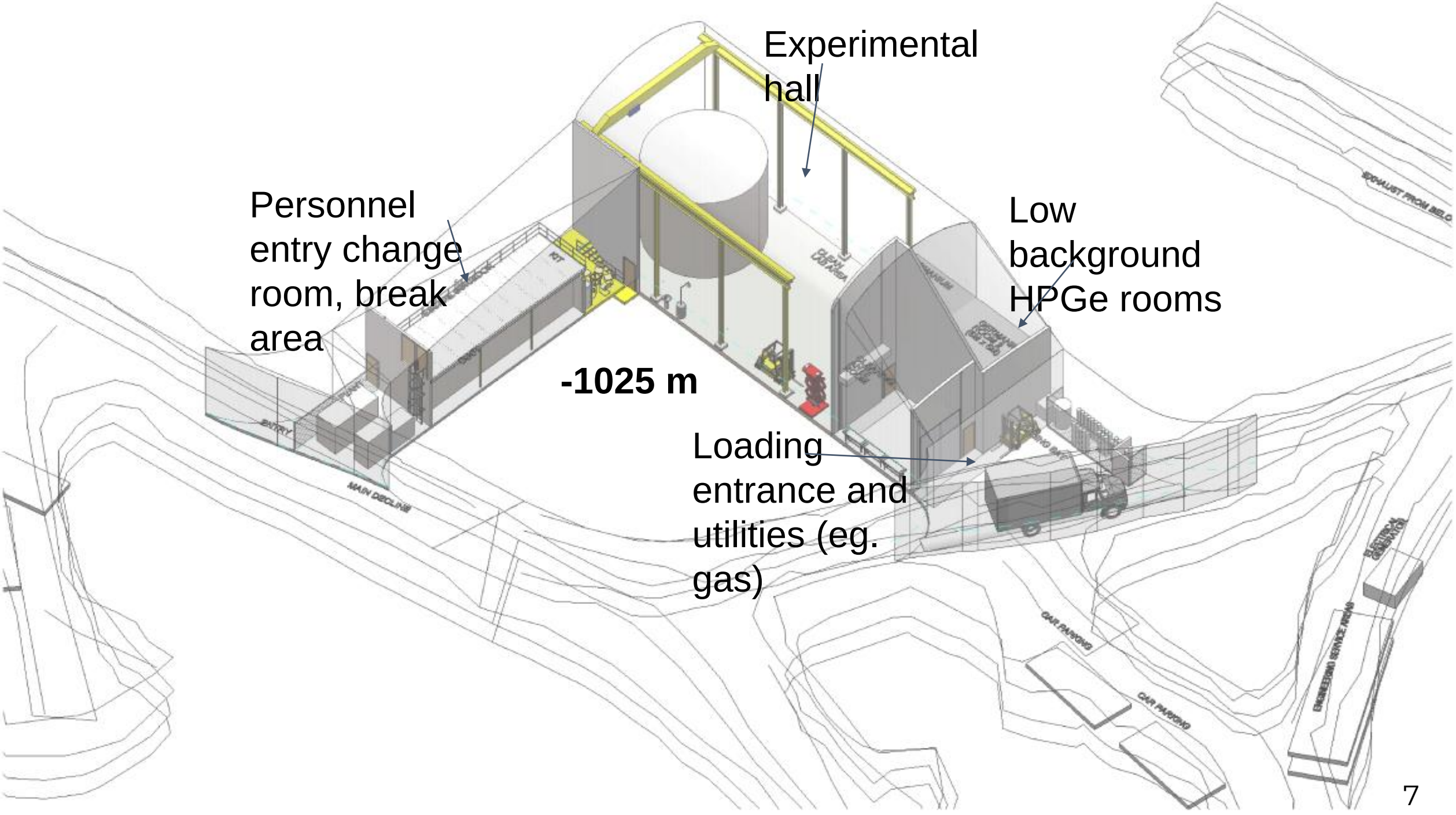
Stawell vs. Sydney

Stawell Gold Mine



- Opened in 1982
- Gold ore (basalt) mine and processing plant
- 850 kT/year ore capacity
- Decline mine with a single portal
- 30 minute drive to the laboratory
- 40ºC (104 F)
- Relative humidity ~99%

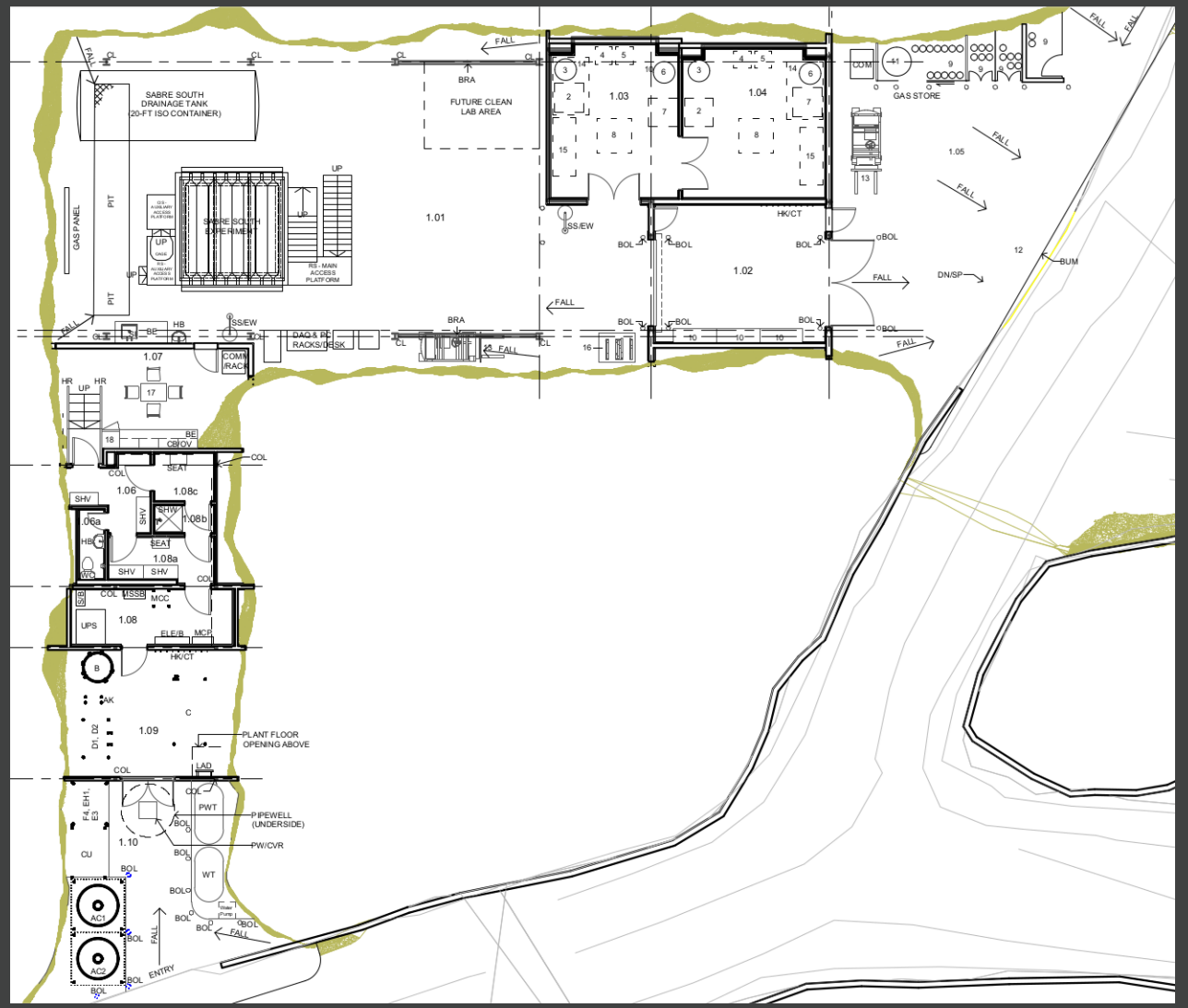

Experimental hall
Personnel entry change room, break area
Low background HPGe rooms
-1025 m
Loading entrance and utilities (eg. gas)
MAIN DECLINE
CAR PARKING
CAR PARKING

SUPL

- 10 m x 16.4 m x 12 m experimental hall

- Two small **gamma spectroscopy** rooms

- **General-purpose area:**
  10 T overhead crane
  Air conditioning
  Fibre connection to surface
  Bunded spill pit
  Clean electrical ground



SUPL

Entrance

SUPL Background

Rock assay: (ICP-MS)
Comparable activities to other laboratories

Shotcrete screening:
Screening: ICP-MS of sand, cement, and aggregate
Underground gamma spectrometry

	Th-232 (ppm)	U-238 (ppm)
SUPL (rock)	0.31	3.42
SUPL(shotcrete)	0.84	0.51
LNGS (Hall C)*	0.07	0.66
LNGS (concrete)*	0.66	1.05
LSM (rock)*	2.45	0.84
LSM (concrete)*	1.4	1.9

*Miramonti, AIP Conf Proc 785, 3 (2005)

SUPL Background

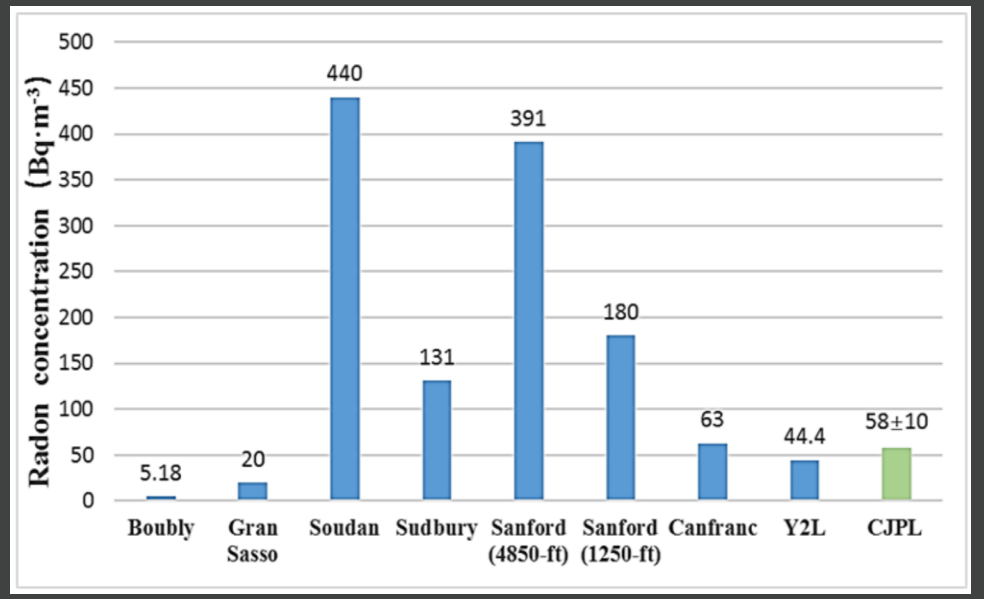
- Radon measured: 470 ± 75 Bq m^{-3}

-High compared to other underground labs

Solutions:
-> Tekflex sealant rock coating on walls

Recent measurement: 415 ± 5 Bq m^{-3}

➔ Potentially: Radon suppression system



Near future plans:

Gamma-ray measurements (previous measurement with a 3” x 3” NaI(Tl): 2.5 cm^{-2} s^{-1})
Neutron measurements (Kyle Leaver, University of Adelaide)

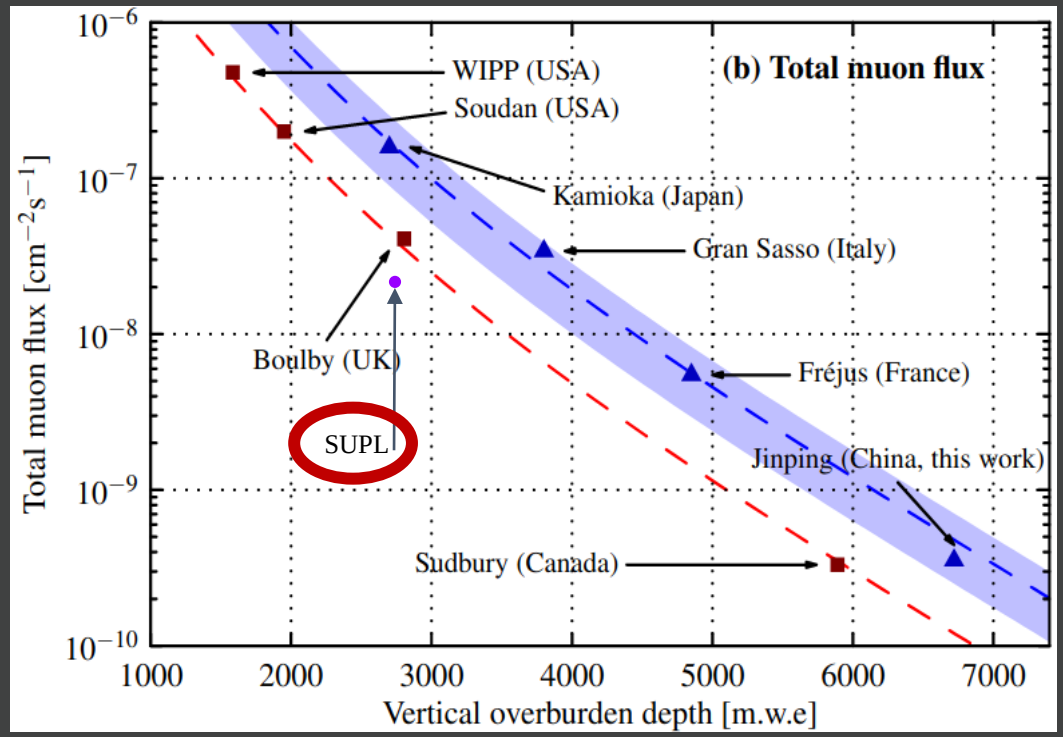
SUPL Background

- **Muon background:**

  in October 2023: **(2.9 ± 0.4) x 10^{-8} cm^{-2} s^{-1}**

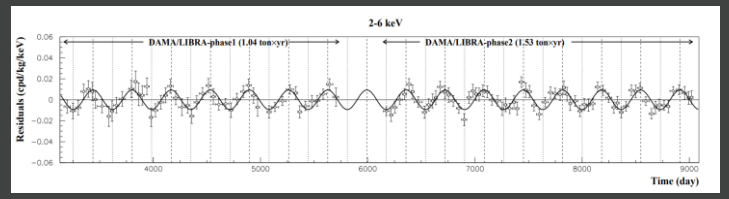
- Predicted total muons at SUPL**: ~245 per day**

- Plastic (PVT) scintillator paddles
- 60 x 30 x 5 cm^3, coupled to 2” PMTs



SABRE South Collaboration

- First major experiment at SUPL: **SABRE South**
- Aiming for **50 kg ultrapure NaI:Tl crystals**
- 10 T liquid scintillator veto (linear alkylbenzene)
- Muon veto (9.6 m^2) + PE and double-steel shielding
- **Rule in/out DAMA** based on modulation signal



Bernabei et al. 2021

Background in SABRE

- **Focus on radioactive isotopes** -> in detector materials

-> around the detector material

(+ environment)

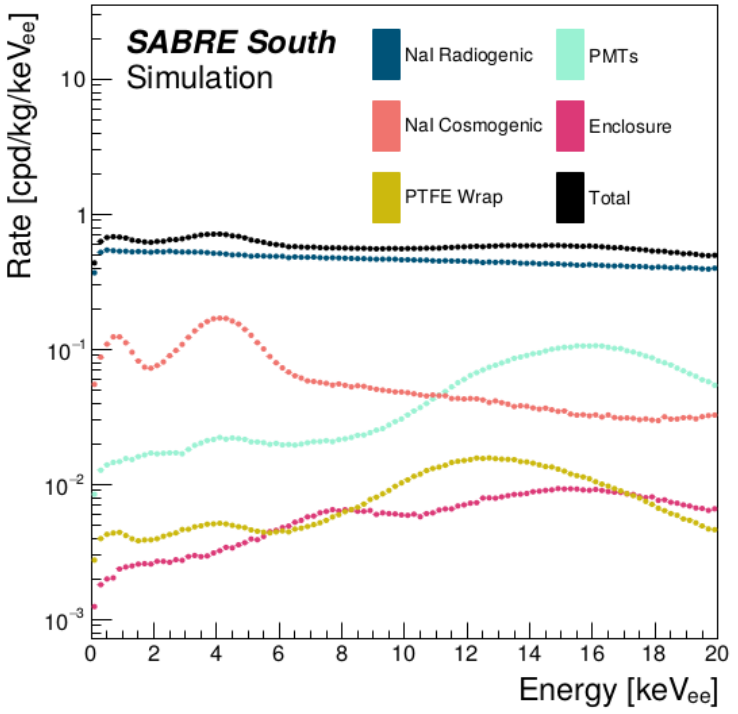
^{40}K, ^{129}I, ^{210}Pb, ^{232}Th, ^{238}U

- In particular Radon (radioactive chains from Th and U,

decays in ^{210}Pb)

<10% from outside the crystal

	Rate [cpd/kg/keV]	Veto Efficiency [%]
Crystal radiogenic	$5.2 \cdot 10^{-1}$	13
Crystal cosmogenic	$1.6 \cdot 10^{-1}$	40
Crystal PMTs	$3.8 \cdot 10^{-2}$	60
PTFE wrap	$4.5 \cdot 10^{-3}$	13
Enclosures	$3.2 \cdot 10^{-3}$	85
Conduits	$1.9 \cdot 10^{-5}$	96
Liquid scintillator	$4.9 \cdot 10^{-8}$	> 99
Steel vessel	$1.4 \cdot 10^{-5}$	> 99
Veto PMTs	$1.9 \cdot 10^{-5}$	> 99
Shielding	$3.9 \cdot 10^{-6}$	> 99
External	$O(10^{-4})$	> 99
Total	$7.2 \cdot 10^{-1}$	27



Cygnus-Oz

- Following presentations from

- Lindsey Bignell
- Ferdos Dastgiri
- Lachlan McKie

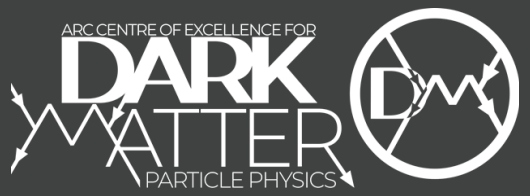
Summary

- SUPL = Stawell Underground Physics Laboratory = first underground laboratory in Southern Hemisphere - operational

- Devoted to dark matter research

- SABRE South starting in 2024

- Followed by the CYGNUS experiment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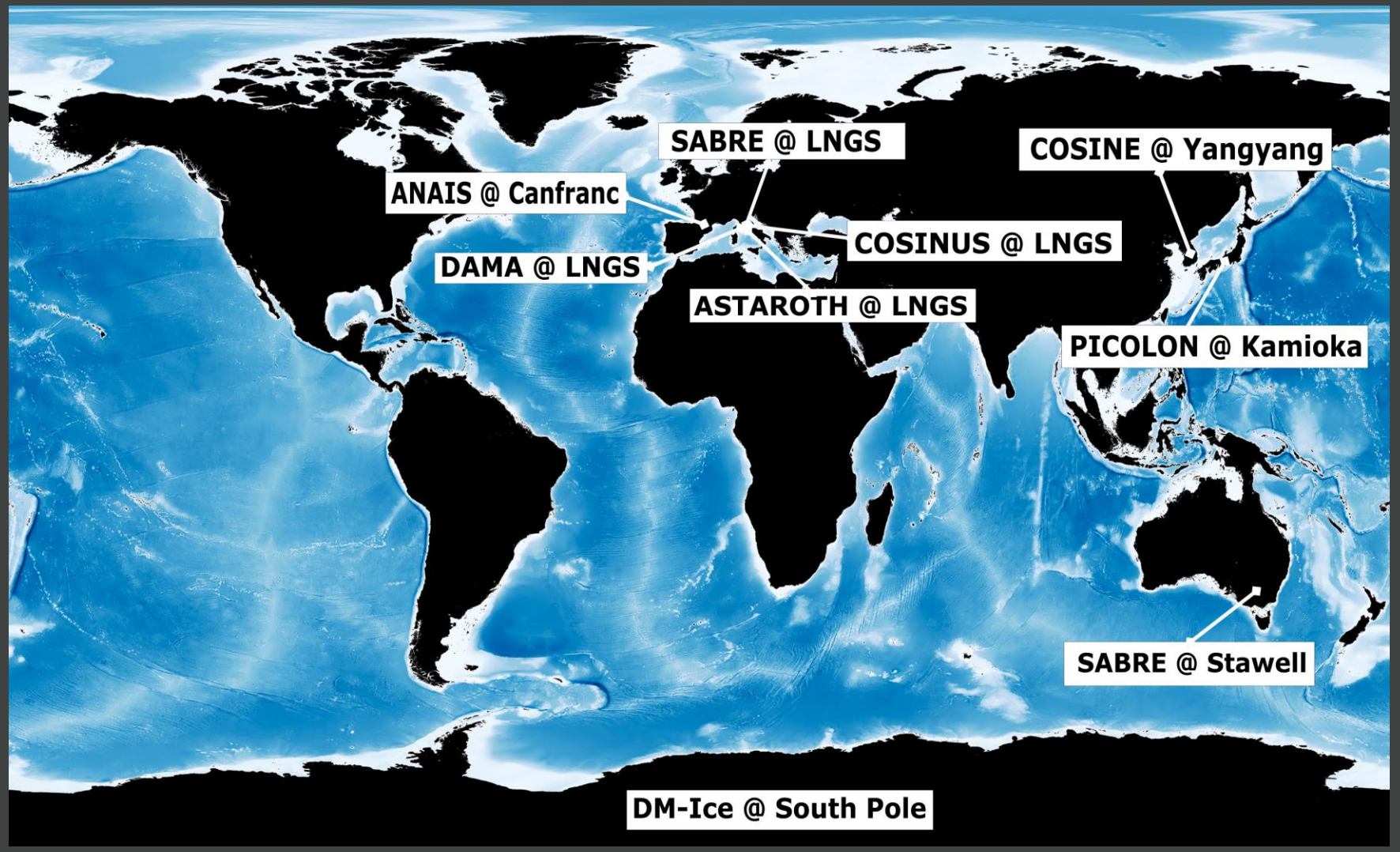
Dark Matter search in the world

Test of annual modulation with NaI



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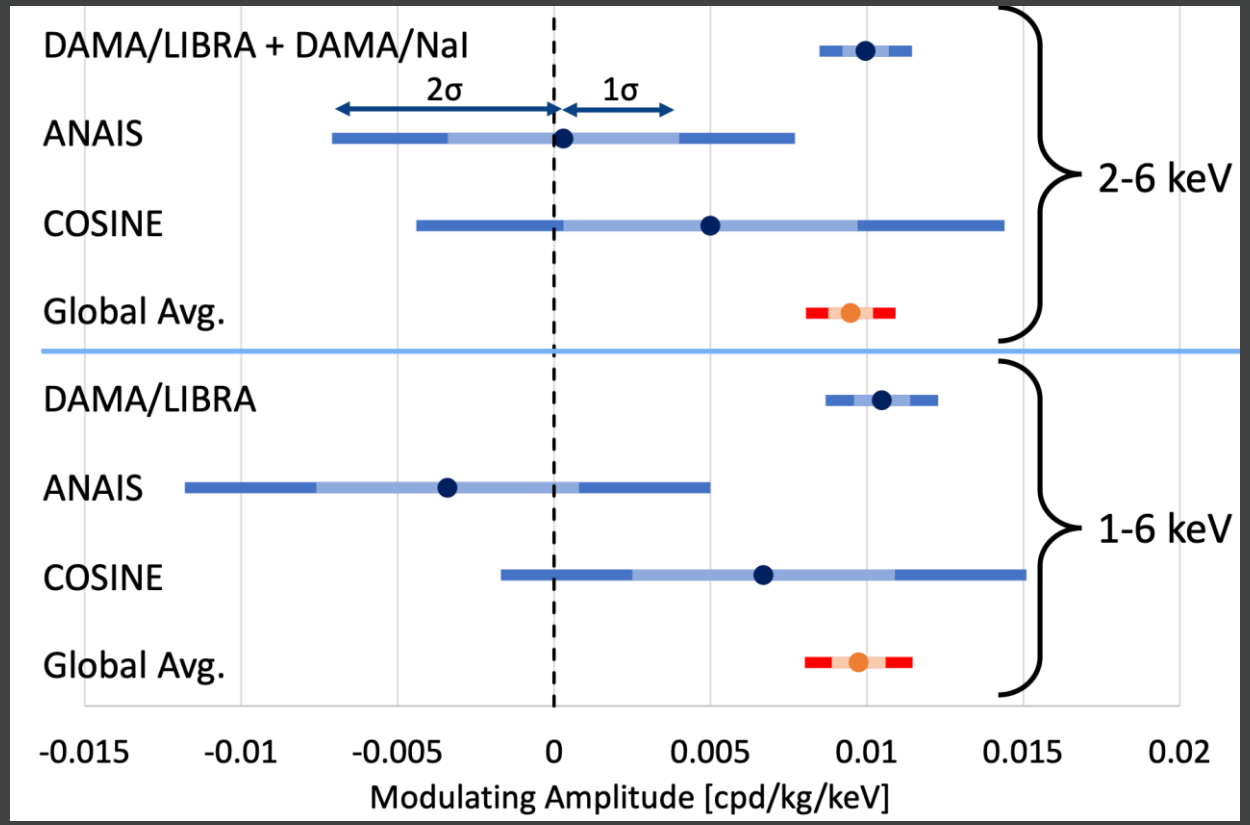
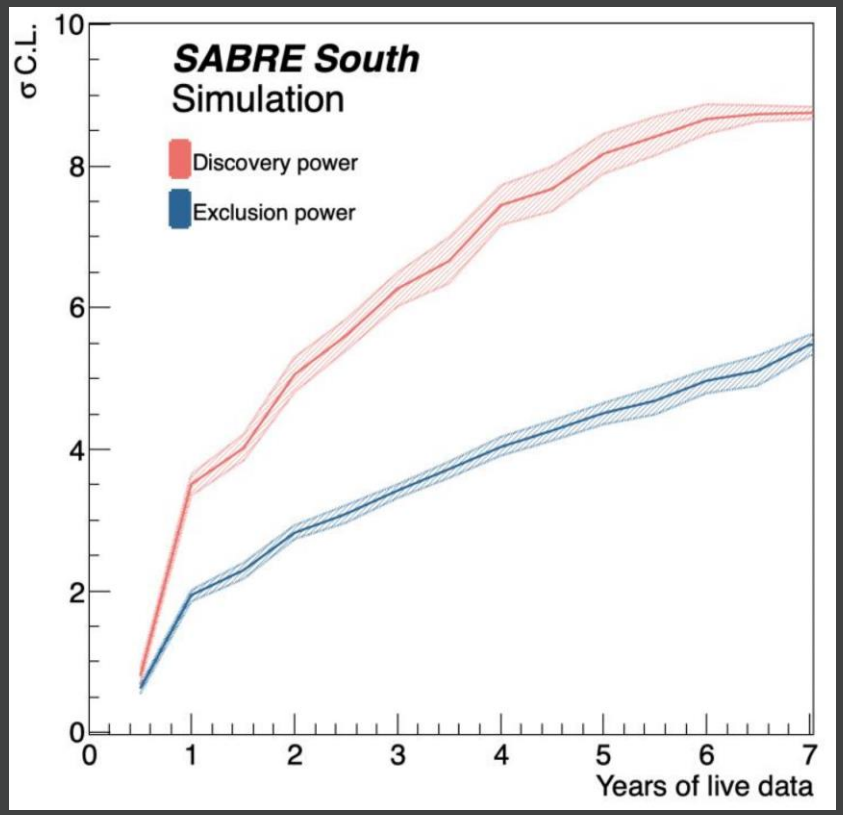
ANAIS, COSINE and SABRE

At present time, DAMA has the smallest uncertainty and best sensitivity





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