

# The Stawell Underground Physics Laboratory

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### The Stawell Underground Physics Laboratory (SUPL)

First general-purpose Southern Hemisphere underground laboratory

Laboratory construction recently completed!

-1025 m in a working gold mine at Stawell, Vic

**Operations**: SUPL Co. **Member institutions**:

**SWINBURNE** 

UNIVERSITY OF

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THE UNIVERSITY OF

MELBOURNE

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Baulby Underground

Laboratory, UK

Laboratoire Souterrain

de Modane, France

Laboratori Nazionali del Gran Sasso, Italiv



Baksan, Russia

CallioLab, Finland

#### Underground Science in the Southern Hemisphere

Scientific benefits from a Southern location:

 Annual modulation (eg. SABRE South)



- May be advantageous for Certain dark matter models
  - Dissipative mirror DM
    Foot and Vagnozzi, Phys Lett B, 748:61-66 (2015)
  - Luminous DM Eby et al., J High En Phys 2019, 115 (2019)
  - Boosted DM from the galactic

#### centre

Baracchini et al., Phys. Rev. D 102:075036 (2020) Dent et al., Phys. Rev. D 101:116007 (2020)



#### Centre of Excellence for Dark Matter Particle Physics

"Centres of Excellence are prestigious focal points of expertise [to]... maintain and develop Australia's international standing in research areas of national priority." - ARC

**Significant long-term (7 year) funding**  $\Rightarrow$  Majority of funds to personnel (ECRs).

Research themes

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



Equity, Diversity, and Inclusion ⇒ 3 tenure-track female-only continuing positions.





#### Stawell



Population 6000 (2016)

- Home to first nations, Djab Wurrung speakers.
- Settled by europeans during the Victorian gold rush.
- Mining and tourism.



### **Stawell Gold Mine**

COSCO

Gold ore (basalt) mine and processing plant. 850 kT/year ore capacity.

Decline mine (single portal), flat overburden. 30 minute drive to laboratory.

~  $40^{\circ}$  C (104 F), relative humidity ~99 %





### SUPL

10 m x 16.4 m x 12 m experimental hall.

Two smaller gamma spectroscopy rooms.

Future general-purpose clean area

- \* 10 T overhead crane
- \* Plumbed cylinder gas
- \* Bunded spill pit
- \* Clean electrical ground
- \* Fibre connection to surface
- \* Air conditioned



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

#### Shotcrete screening:

Screening: ICP-MS of sand, cement, and aggregate. Batch QA: 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) <sup>*</sup>	1.4	1.9



#### Measurements taken at the SUPL site before the construction of the laboratory

#### Gamma ray flux

Nal:TI detector measurements:

	E>100 keV	E>600 keV	<sup>40</sup> K (1461 keV)	<sup>208</sup> TI (2614 keV)
Flux (cm <sup>-2</sup> s <sup>-1</sup> )	0.23	0.089	1.3 x 10 <sup>-2</sup>	2.1 x 10 <sup>-3</sup>

LNGS flux (> 7 keV) is 0.25 cm<sup>-2</sup>s<sup>-1</sup> [1]

#### Neutron flux

BF<sub>3</sub> long counter measurements:

	Thermal	Fast
Flux (cm <sup>-2</sup> s <sup>-1</sup> )	1 x 10 <sup>-4</sup>	2 x 10 <sup>-5</sup>

#### LNGS measurements: $(1.7 - 3.8) \times 10^{-6}$ total flux [2]

[1] Malczewski et al., J Radioanal Nucl Chem, 295(1):749–754 (2013) [2] H. Wulandari et al., Astropart Phys 22:313–322 (2004)



- Muon background (3.7  $\pm$  0.4) x 10<sup>-8</sup> cm<sup>-2</sup>s<sup>-1</sup>
- Plastic (PVT) scintillator paddles 60x30x5 cm<sup>3</sup>, coupled to 2" PMTs



Guo et al, Chin Phys. C 45 025001 (2021)





Radon measured using AlphaGuard instrument

470 ± 75 Bq m<sup>-3</sup>

This is high compared to other underground laboratories. Tekflex coating, future upgrade: radon suppression (Ateko)







### **SUPL** Construction

Construction commenced 2019. Initial plan for 2020 completion.

COVID-19...

Longest lockdown in the world!

#### The Lost Months of the **Coronavirus Pandemic**

Areas with the longest cumulative pandemic lockdowns (in days)\*

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\* Shutdowns of parts of the economy due to anti-pandemic measures, e.g. closing of schools and kindergartens or curfews. Data as of Oct 21, 2021. Source: Statista research







### SUPL Construction





#### SUPL Construction

#### Laboratory handover 10 June!









### SUPL Media

Dozens of media articles Television and radio appearances Visit from federal and state ministers Featured in Veritasium (YouTube) > 4 million views!



## SABRE South

First major experiment at SUPL.

50 kg Ultrapure Nal:Tl

10 T liquid scintillator veto (linear alkylbenzene) Muon veto (9.6 m<sup>2</sup>) and 26 cm HDPE/steel shield.

Rule in/out DAMA based on modulation signal.

-0.015 -0.01 -0.005 0 0.005 0.01 0.015 Annual modulation amplitude in 1-6 keV region (cpd/kg/keV)



### SABRE South: shielding

8 cm Steel, 8 cm HDPE, 8 cm steel sandwich.

Steel

**HDPE** 

Steel

~ 120 tonnes, samples screened for radioactivity. Reusable.

Inner space flushed with low Rn air.





### SABRE South: liquid scintillator

17 kL of purified linear alkylbenzene under N<sub>2</sub> blanket Nanjing chemicals – JUNO specifications

Challenging transport down decline: ISO tank requires skid, but LAB is too heavy. Likely solution: decant to lined IBCs

Fluorophores 3.5 g/L PPO and 15 mg/L bis-MSB Recirculation mixing of concentrated master solution.





#### SABRE South: muon veto

EJ-200 plastic scintillator, 3 m x 0.4 m x 5 cm panels.

Resolvable position using PMT relative time.

3 m positional source calibration system. System going underground shortly!



## SABRE South construction

Subset of other activities...





#### SABRE South

Background estimate: 0.66 cpd kg<sup>-1</sup> keV<sup>-1</sup>

Major contribution to background from <sup>210</sup>Pb (intrinsic) and <sup>3</sup>H (cosmogenic).

Discover (exclude) DAMA modulation at ~5 (3)  $\sigma$  in 2 years

Data in 2023!



10-38

SABRE South

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### What's Next?

R&D and prototypes for future major experiments while SABRE is operational

#### Superfluid He for Low mass WIMPs

- \* Microwave resonance modes.
- \* Optomechanical cavity modes.

#### CYGNUS

- \* Directional detection with micropatterned gas TPC.
- Gamma ray spectroscopy for applications and detector R&D



#### Summary

New underground facility for rare event physics and applications.

Major research investment in Dark Matter physics

SABRE and low background gamma spectroscopy. R&D for future experiments.

Twitter: <u>@ARC\_CDMPP</u>

