



SABRE South: Results from Underground Operation of SABRE South at the Stawell Underground Physics Laboratory (SUPL)

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1 · SABRE SOUTH: INTRODUCTION AND MOTIVATION

- DAMA/LIBRA anomaly:** a decades-long annual modulation signal in NaI(Tl) detectors at Gran Sasso, consistent with dark matter but not yet independently confirmed
- SABRE South tests this anomaly using high-purity NaI(Tl) crystals as a target
- Three key subsystems (Figure 1.1):
 - NaI(Tl) crystal array:** 7 × 7 kg crystals, each coupled to two Hamamatsu R11065 PMTs
 - Liquid scintillator veto (LAB):** surrounds the crystal array to tag backgrounds; up to 32 oilproof Hamamatsu R5912 PMTs
 - Muon veto:** tags cosmic muons passing through the detector
- Dual-site with SABRE North (LNGS) (Figure 1.2) to disentangle seasonal effects such as muon flux

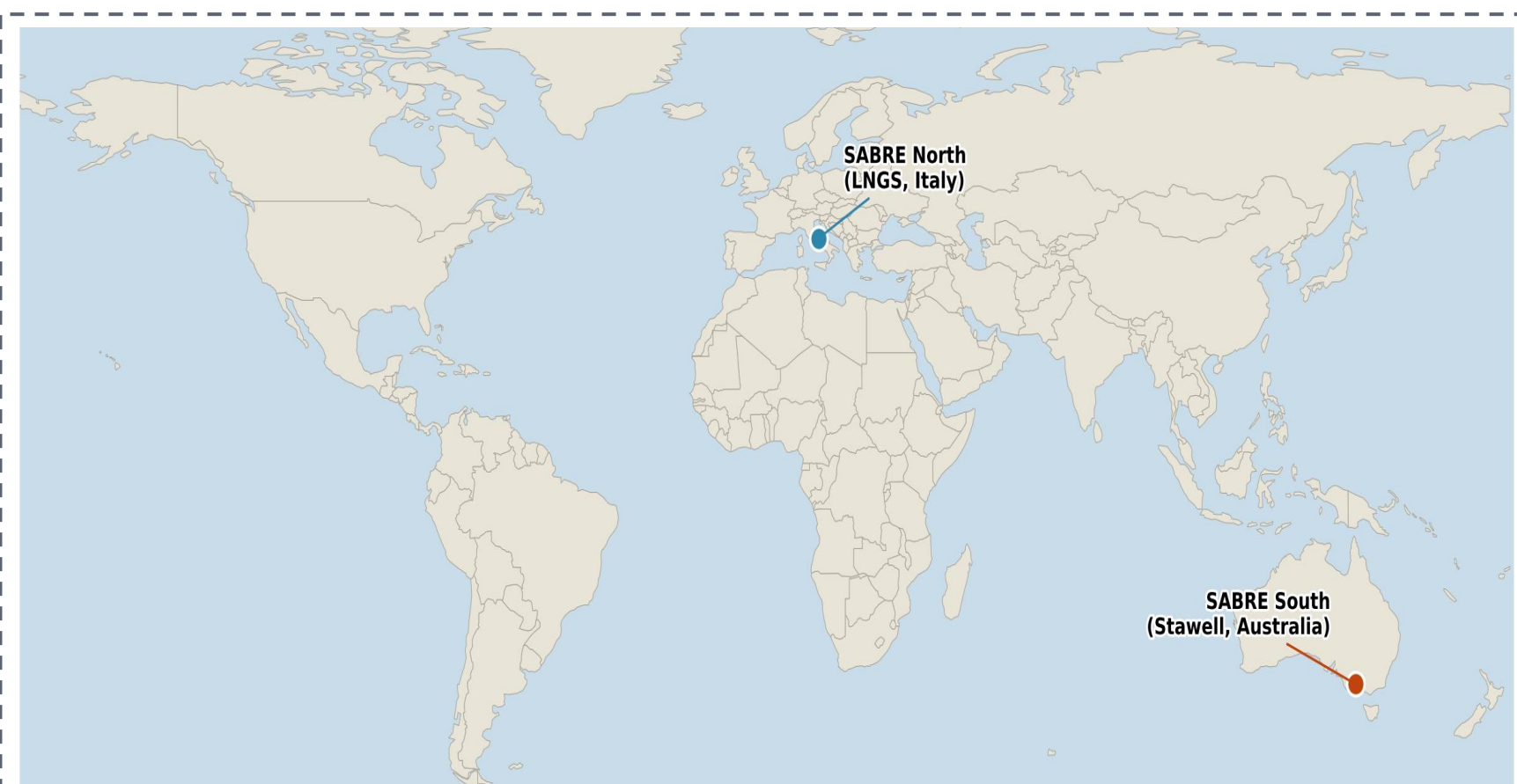


Figure 1.2: Dual-site nature of the SABRE experiment across both hemispheres enables the disentangling of seasonal effects from an annually modulating signal

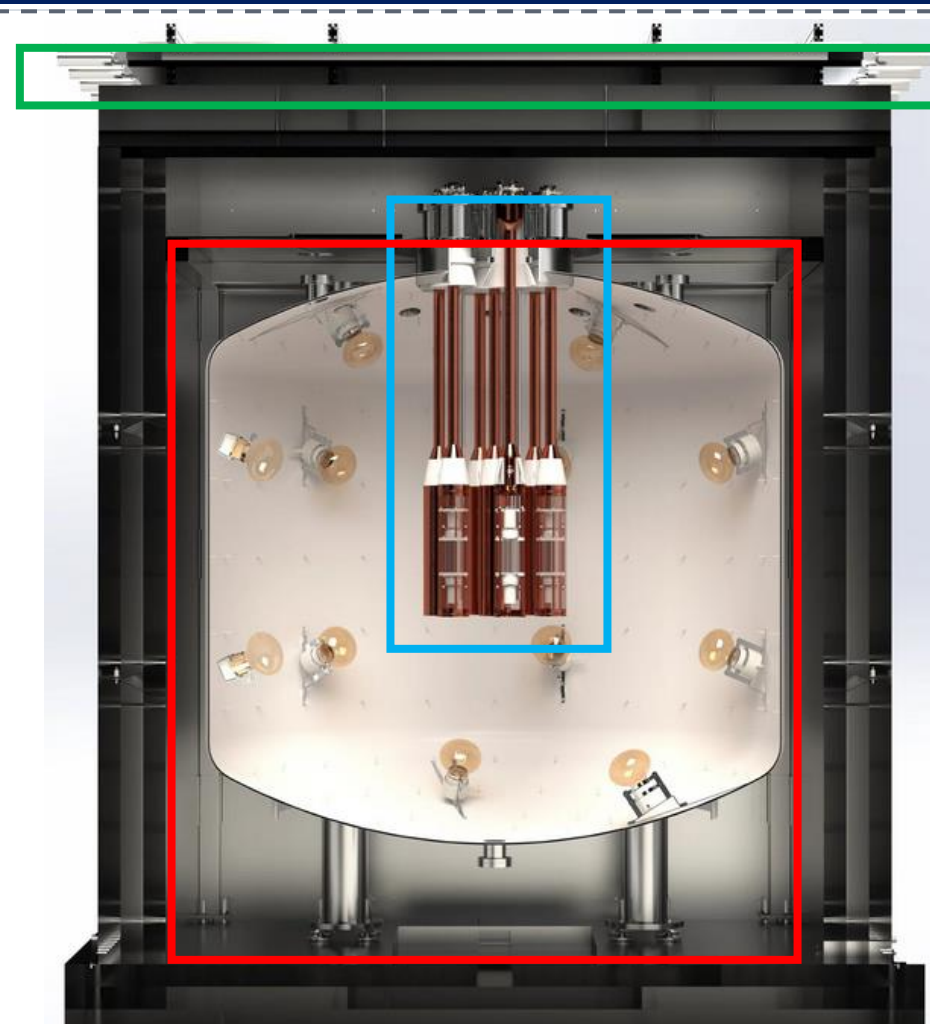


Figure 1.1: Schematic diagram of the SABRE South detector system illustrating the NaI(Tl) crystal array, liquid scintillator veto and muon veto system. Barberio et al. (2024)

Expected WIMP Dark Matter Interaction Rate with Target Nucleus:

$$R(t) = \underbrace{R_0}_{\text{Interaction rate}} + \underbrace{R_m}_{\text{Non-modulating rate}} \cos(\omega(t - t_0))$$

Modulating rate

2 · SABRE SOUTH: CONSTRUCTION AND COMMISSIONING STATUS

- Based at the **Stawell Underground Physics Laboratory (SUPL)**:
 - Located 240 km north-west of Melbourne
 - 1025 m deep with flat overburden (2900 m w.e)
- First deep underground lab in the Southern Hemisphere (completed 2023)**
- SABRE South is the **flagship experiment of SUPL**, and is **currently in the commissioning and construction phase**
- Crystal and veto PMTs characterised, with energy thresholds of:
 - Crystal: 1 keV
 - Veto: 30–50 keV
- Crystal enclosure assembly tests completed with a commercial encapsulated crystal (Figure 2.1)
- Shielding and veto vessel test-assembled above ground (Figure 2.2)
- First physics result from SUPL: **cosmic muon flux** measured with the SABRE South muon veto system (Section 3)
- Crystal **prototyping and production in progress** (Section 4)

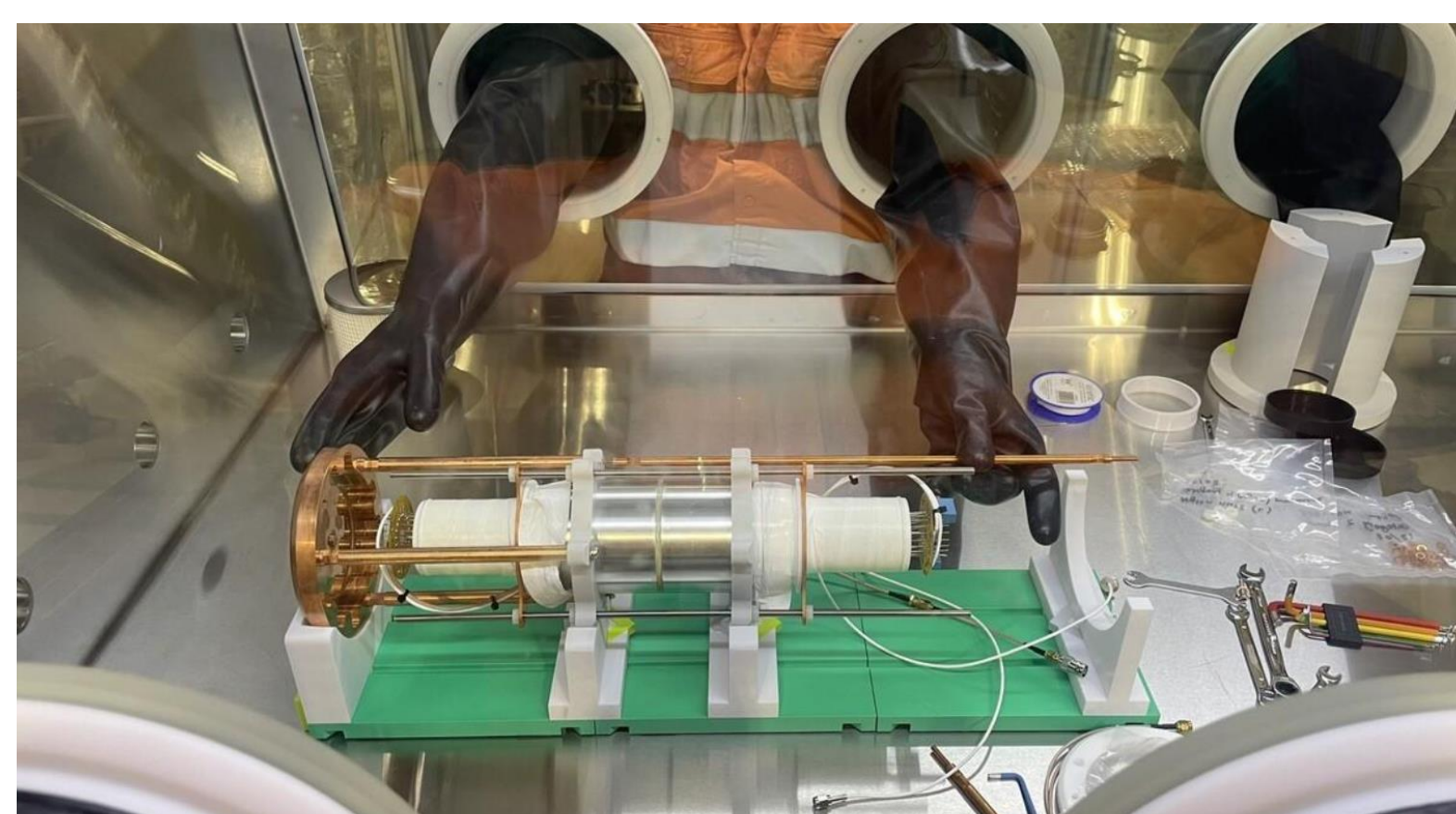


Figure 2.1: Crystal enclosure assembly completed using a 6.68 kg commercial encapsulated crystal



Figure 2.2: Test assembly of the shielding and veto vessel completed above ground.

3 · UNDERGROUND MUON FLUX MEASUREMENT AT SUPL

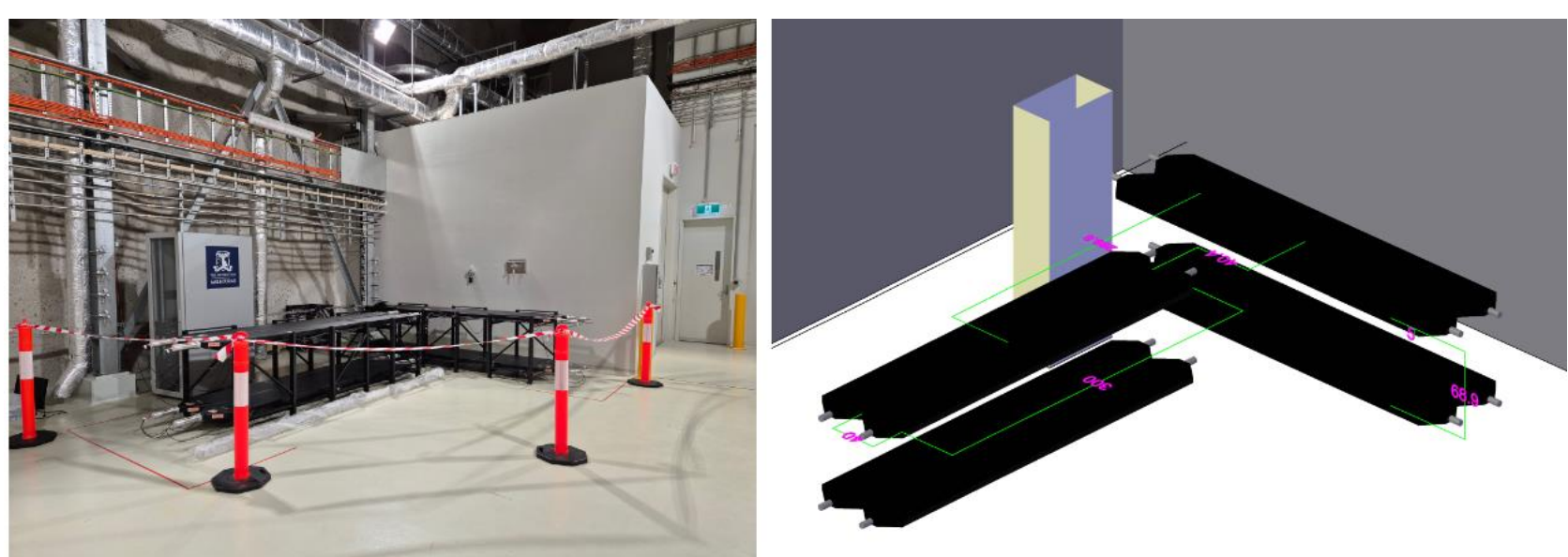


Figure 3.1: (a) Muon detector configuration at SUPL for the muon flux measurements. Eight muon detector panels are employed in two layers and in two orientations. (b) A diagram of the layout of the muon telescope configuration at SUPL for the flux measurement. Fu et al. (2026)

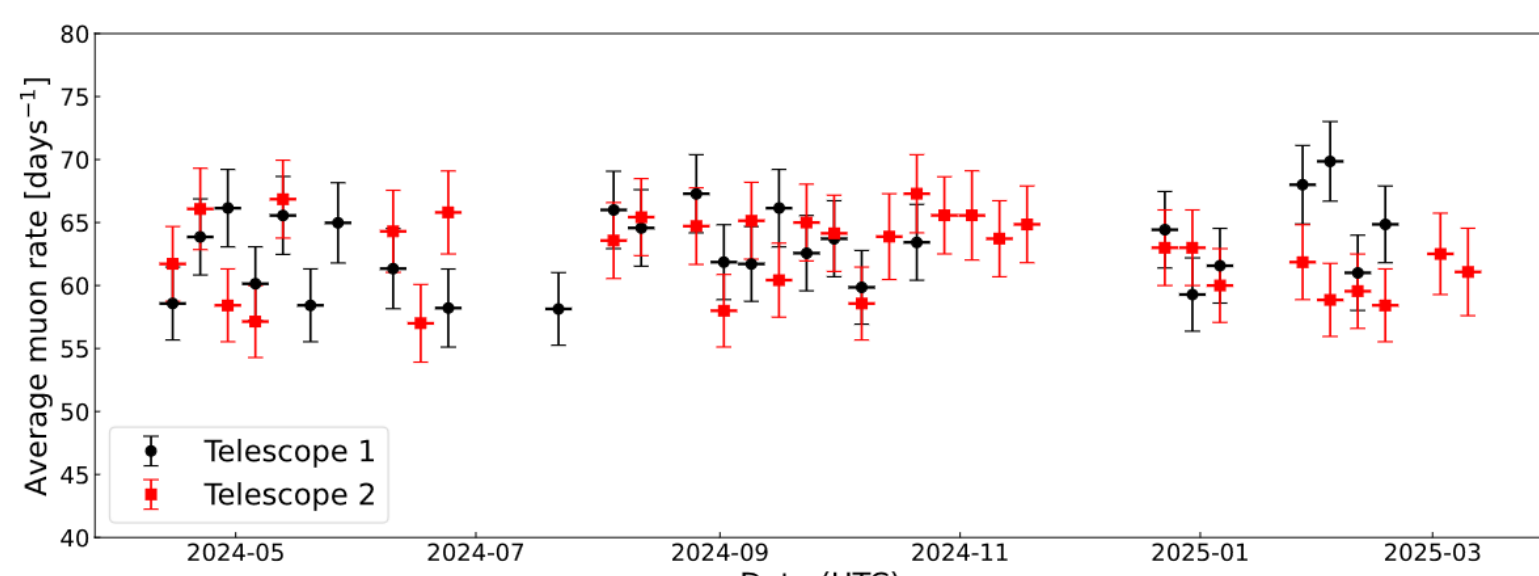


Figure 3.2: Muon rate measured at the Stawell Underground Physics Laboratory as a function of time. The daily rate is averaged over the course of a week. Fu et al. (2026)

- Low cosmic ray and radioactivity environment** in SUPL is **essential to SABRE South's physics goals**
- Muon flux measured using the SABRE South muon veto system in a telescopic configuration (Figure 3.1): **8 Eljen EJ-200 panels (3 m x 0.4 m x 5 cm), 236 days of data (2024-2025)**
- Observed muon rate shown in Figure 3.2

Measured muon flux at the Stawell Underground Physics Laboratory:
 $f = (6.33 \pm 0.04_{\text{stat}} \pm 0.35_{\text{sys}}) \times 10^{-8} [\text{s}^{-1} \text{cm}^{-2}]$

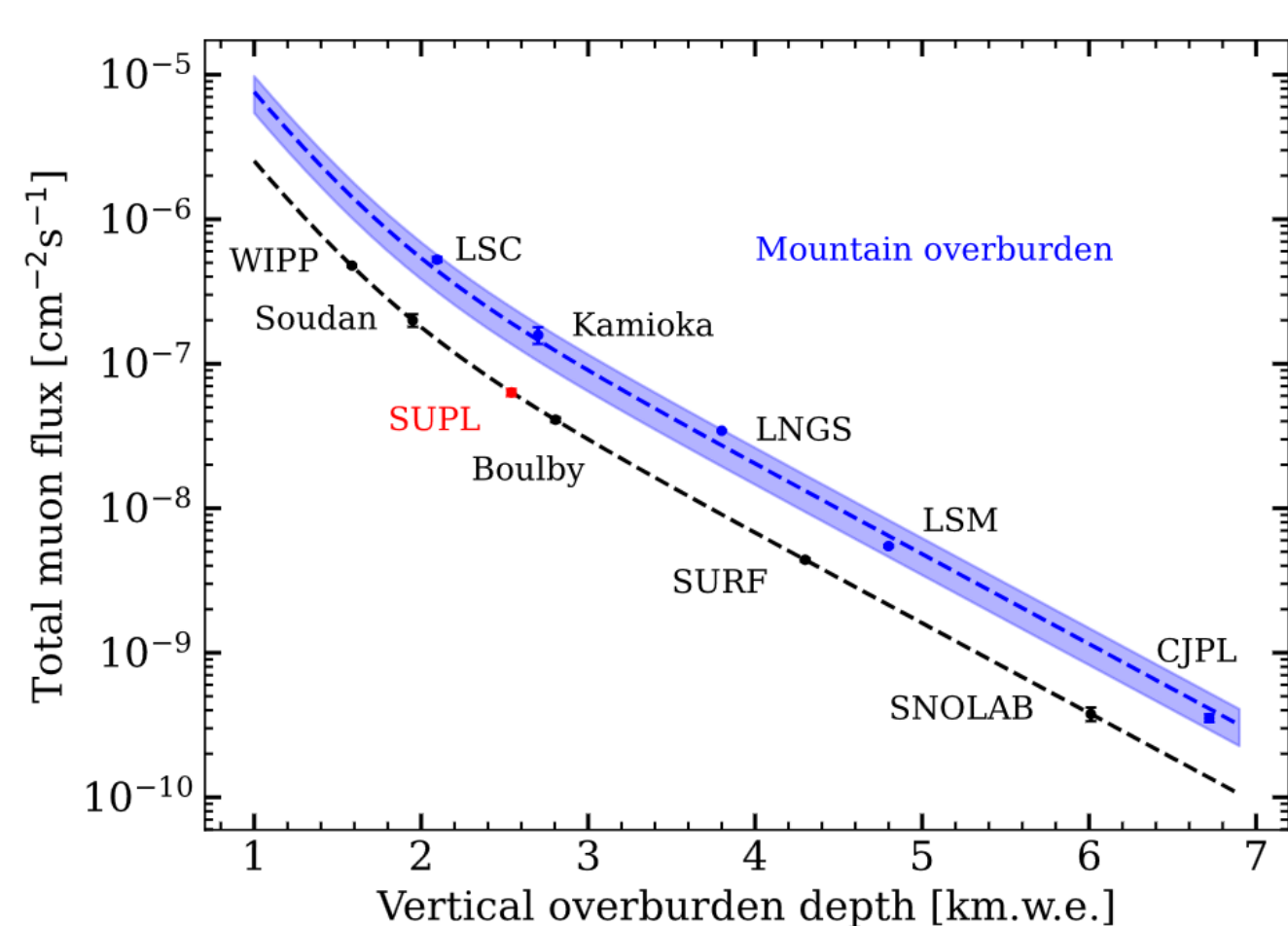
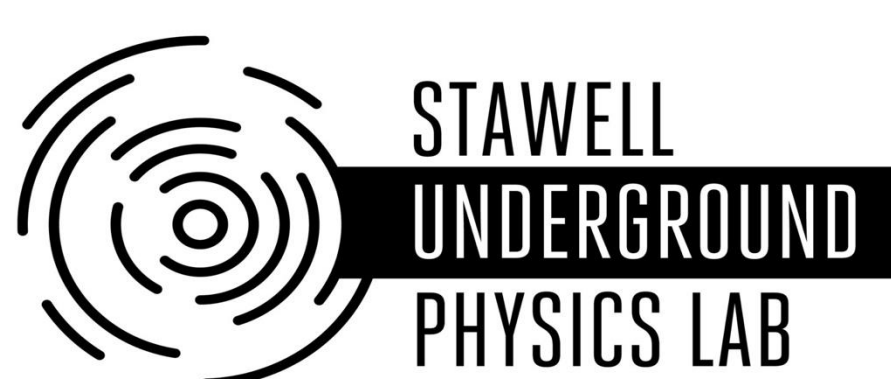


Figure 3.3: Measured muon flux vs. vertical overburden depth, compared to other underground laboratories (flat vs. mountain overburden). SUPL's result is consistent with the flat-overburden model curve

- SUPL's measured flux agrees with the flat-overburden model. **Consistent with other underground labs (Figure 3.3)**
- First **complete test of the underground DAQ infrastructure, control, monitoring and analysis framework**



4 · CRYSTAL PRODUCTION & SICCAS ASSAY STATUS

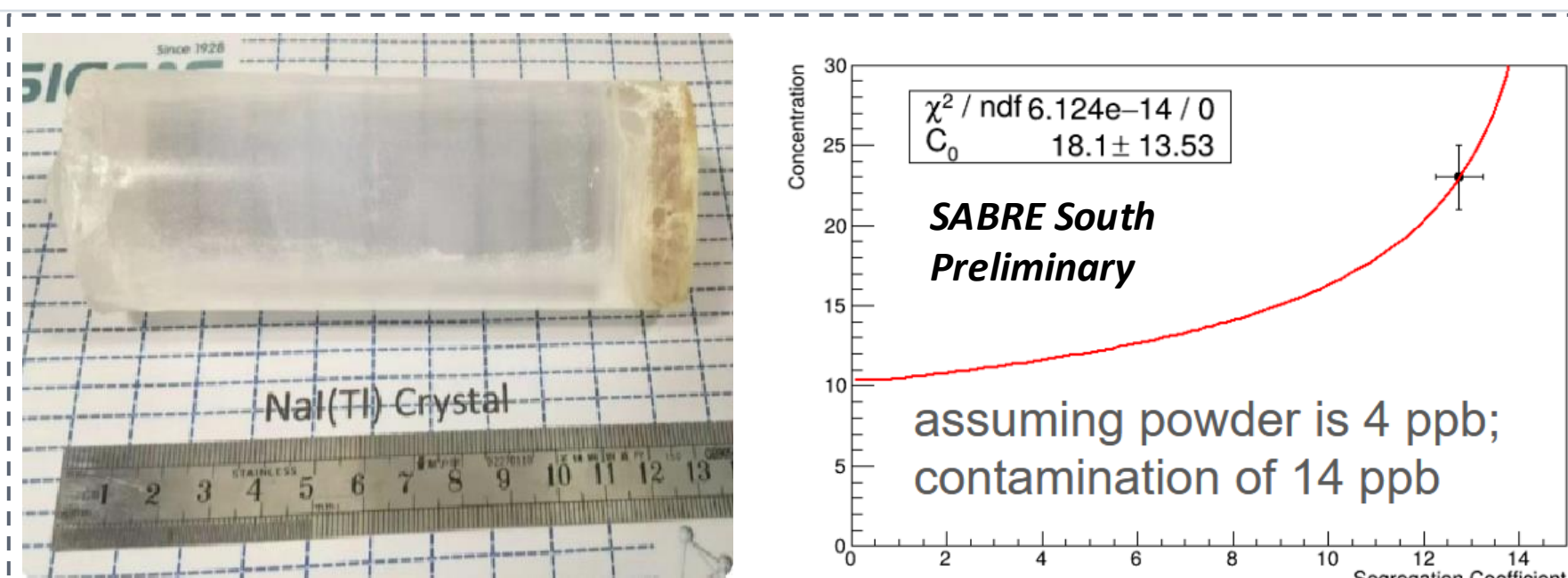


Figure 4.1: (a) One of two 0.5 kg SICCAS NaI(Tl) test crystals grown with Astrograde powder. (b) ICP-MS measurement of K-39 in the tail (23 ppb; blank 3–5 ppb); assuming 4 ppb powder purity, this implies ~14 ppb of contamination from growth and a final crystal concentration of ~12 ppb.

- Crystal qualification: **two 0.5 kg test crystals** grown by Shanghai Institute of Ceramics, Chinese Academy of Sciences (SICCAS) with Astrograde powder (Figure 4.1 (a))
- A **commercial encapsulated NaI(Tl) crystal** of mass 6.68 kg currently being used for **enclosure assembly tests in SUPL** (see Section 2)
- SICCAS test crystals will undergo **chemical or mechanical polishing** respectively to investigate **impact of Pb-210 surface contamination**

Preliminary ICP-MS measurements of K-39 contamination in test crystals performed at Shanghai Jiaotong University (SJTU) (Figure 4.1 (b)): **23 ppb of K-39 (blank ~3-5 ppb) → 12 ppb final crystal**



Figure 4.2: First successfully grown production-level NaI(Tl) crystal, grown from 10 kg of powder, weighing approximately 7 kg

First production crystal growth successful (Figure 4.2): 10 kg of Astrograde powder yields ~7 kg crystal

- Production level crystal (Figure 4.2) to be shipped to Melbourne after cutting and polishing to minimise activation



Scan this QR code or visit <https://bit.ly/4hhdV1x> for the most recent SICCAS crystal assay results from the SABRE South Experiment

5 · PYRATE SOFTWARE ANALYSIS FRAMEWORK

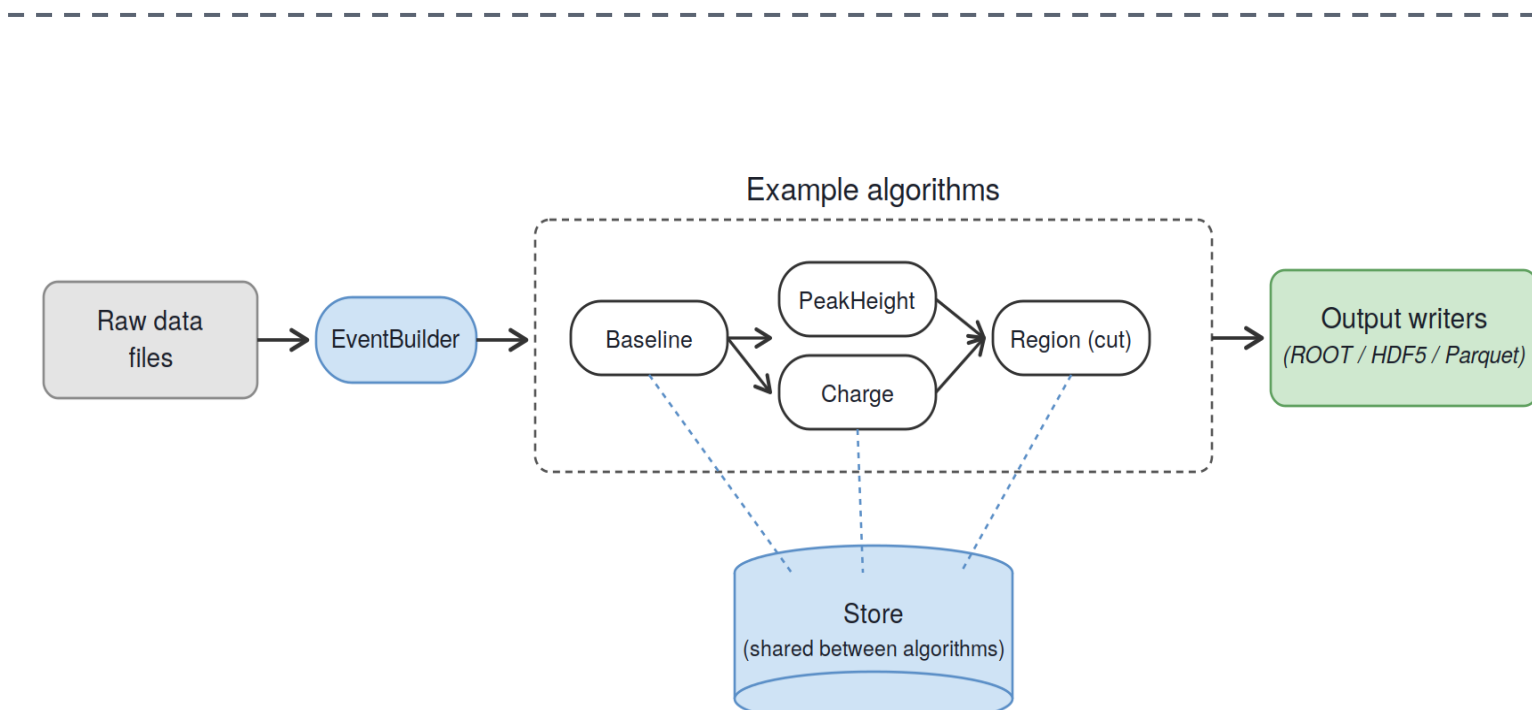


Figure 5.1: Pyrate data flow: raw data is built into events, then passed through reconstruction algorithms that share data via a common Store.

What it is:

- Python-based framework** for data transformation, event reconstruction, and analysis
- Originally developed for and used by SABRE South
- Modular;** steps share data through a common store, so components can be swapped or extended without rewriting the whole pipeline (Figure 5.1)

Why it matters:

- No C++ build step:** physicists can read, extend, and debug it using standard scientific Python tools
- Actively used for real detector calibration and reconstruction
- Tagged, versioned releases** aim to keep results reproducible over SABRE South's multi-year run

Portability:

- Same core framework reused for Hyper-Kamiokande PMT pre-calibration: different hardware, different data format, same pipeline

Performance:

- Able to run **over 6× faster** using 8 CPU cores
- Automatically **skips unnecessary computation** for events that fail early selection cuts

6 · CONCLUSION

- SABRE South is progressing towards an independent test of the DAMA/LIBRA annual modulation anomaly using high-purity NaI(Tl) crystals**
- First physics result from SUPL:** measured cosmic muon flux agrees with the flat-overburden model, consistent with other underground labs
- Crystal production and Pyrate analysis pipeline** both in active development, on track to support SABRE South's physics program

ACKNOWLEDGEMENTS AND PARTICIPATING INSTITUTIONS

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*Pyrate arXiv preprint forthcoming
SABRE South Collaboration: Prepared for the Low Radioactivity Techniques (LRT) Conference in York, UK (September 21–24 2026)