PROCEEDINGS OF SCIENCE

The SABRE South experiment at the Stawell Underground Physics Laboratory

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The SABRE (Sodium iodide with Active Background REjection) experiment aims to provide a model independent test of the signal observed by DAMA/LIBRA by detecting an annual modulation from dark matter interactions in ultra-high purity NaI(Tl) crystals. SABRE consists of two detectors: SABRE North, located at the Laboratori Nazionali del Gran Sasso (LNGS), and SABRE South, located at the newly completed Stawell Underground Physics Laboratory (SUPL) in Stawell, Australia - the first deep underground laboratory in the Southern Hemisphere. Here we present the status of both the SABRE South experiment and SUPL.

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1. Introduction

Particle dark matter, particularly WIMP dark matter, remains one of the strongest candidate models for a number of discrepant astrophysical observations, with evidence mounting in the last century on all cosmological scales [1]. Direct detection experiments aim to measure the scattering of WIMPs off standard model particles as they pass through the Earth, observed as a recoil in a target material. To date, only one direct detection experiment has observed a positive signal compatible with the WIMP hypothesis - DAMA (and later DAMA/LIBRA) have reported a 13.7 σ annual modulation signal consistent with WIMP-like dark matter [2]. Although almost every other experiment has reported a null-signal in this region of parameter space, none have done so using the same NaI target with sufficient precision. The SABRE experiments will attempt to provide a model-independent test of the DAMA/LIBRA signal. SABRE will operate in two separate hemispheres: SABRE North, operating at the Laboratori Nazionali del Gran Sasso (LNGS) in Italy, and SABRE South, at the Stawell Underground Physics Laboratory (SUPL) in Australia [3][4]. Both SABRE North and South will attempt to detect the annual-modulation signal predicted by the relative motion of the Earth's solar orbit. The experiment will use high purity thallium-doped sodium iodide crystals as a target for the dark-matter nuclear-recoil signals. SABRE South will also submerge the target crystals in 12 kt linear alkylbenzene (LAB) as an active veto to suppress background processes.

2. The SABRE South experiment at SUPL

The SABRE South experiment will operate at the newly constructed Stawell Underground Physics Laboratory, 240 km north-west of Melbourne, Australia. Built in an active gold-mine, SUPL is 1025 m underground with a flat, basalt rock-overburden providing 2870 m water-equivalent shielding yielding a 10^6 reduction in the muon flux. The laboratory has been sealed with low-radioactivity shotcrete walls and Tekflex to supress radon intrusion. Construction of the laboratory has been completed, and construction and calibration of the veto systems will commence in the first quarter of 2023, with assembly of the main detector components and commencement of data-taking scheduled for late 2023.

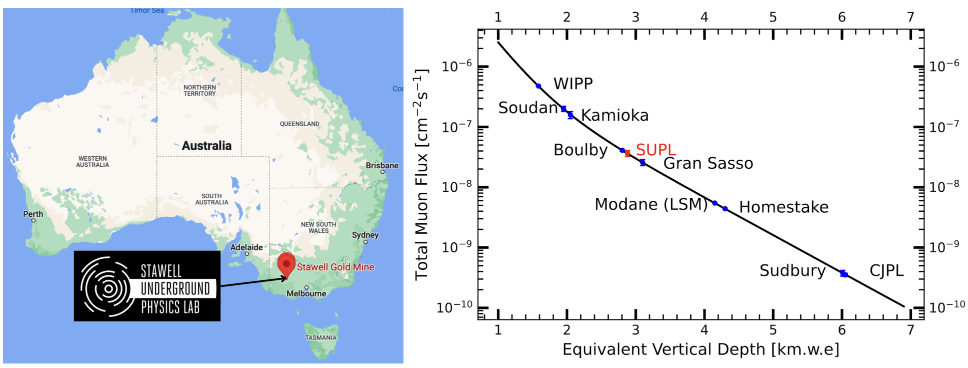

Figure 1: Left: Location of SUPL. **Right:** Muon flux at a number of underground laboratories including SUPL's estimated flux.

The SABRE South detector is comprised of three main sub-detectors: the dark matter target - an array of seven NaI(Tl) crystals, each coupled to two Hamamatsu R11065 PMTs; the active liquid veto system - 12 kL of linear alkylbenzene (LAB); and a muon veto layer - eight plastic scintillator panels. The primary purpose of the active veto liquid scintillator system is to tag and reject intrinsic background processes in the NaI(Tl) crystals, and extrinsic decays from the surrounding material and rock. The LAB is doped with fluourphores and wavelength shifters PPO, and Bis-MSB, and is instrumented with eighteen 204 mm Hamamatsu R5912 PMTs on the inner surface of the veto tank. Both the target crystal and veto PMTs are readout at 500 MS/s using five CAEN1730 digitisers. The muon veto system consists of eight $3 \times 0.4 \times 0.05$ m^3 panels, each with two Hamamatsu R13089 PMTs for dual readout. With a timing resolution of 400 ps, the muon veto is capable of not only veto incoming cosmic rays, but resolve their position in the longest dimension of each detector panel to 3.5 cm. This position resolution will allow for the background processes in SABRE South to be characterised and identified using the time-of-flight between energy depositions in the muon detectors above, and the liquid veto below.

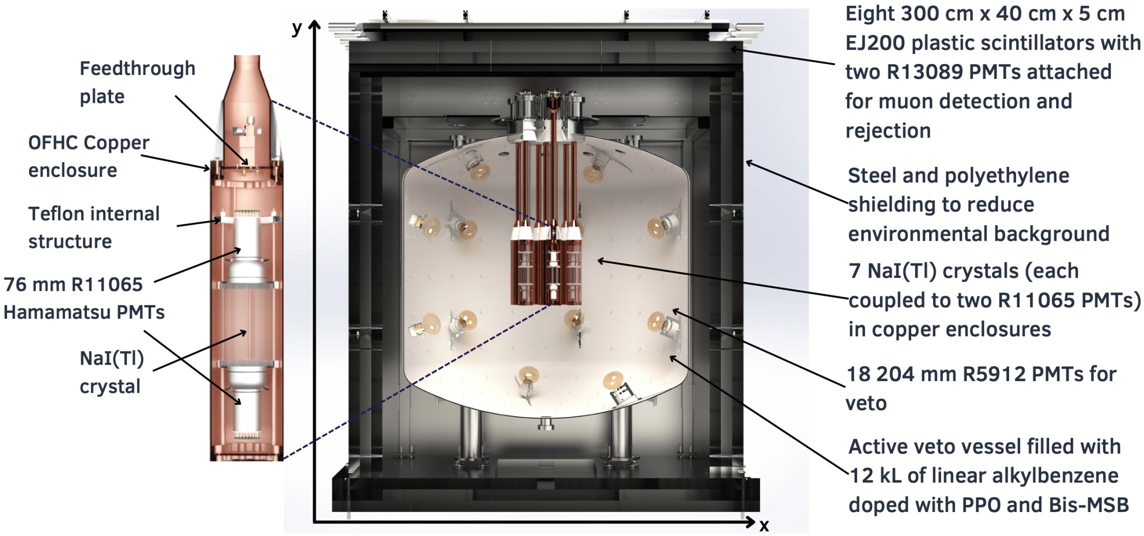

Figure 2: Cutaway render of the SABRE experiment annotated with the main components. Enlarged on the left is a cutaway of one of the seven target crystal modules.

3. Background Simulation

A simulation of the SABRE South vessel was produced in Geant4 and used to model the expected background radiation [4]. The majority of the contributions (over 90%) to the background is expected to come from radioactive contamination in the NaI(Tl) crystals, predominantly from ^{210}Pb (0.28 cpd/kg/keV$_{ee}$). Cosmogenic activation of the crystals during transit from the production facility to SUPL is the next largest source of background, contributing a further 0.032 cpd/kg/keV$_{ee}$ (however this background will decrease over time). ^{40}K is the next most relevant background for SABRE, peaking in the 1-6 keV$_{ee}$ region of interest. The active liquid veto can suppress a significant fraction of the background events that have both escaped the crystal enclosures, and have sufficiently high energy. With the veto detector, events that deposit more than 50 keV$_{ee}$ in the in the liquid scintillator can be rejected. The result of which can be see in Figure 3: the number of candidate events from ^{40}K is reduced from 0.1 to 0.013 cpd/kg/keV$_{ee}$. Overall, the veto is expected to suppress 27% of the total background giving a background rate less than 0.72 cpd/kg/keV$_{ee}$ in the 1-6 keV$_{ee}$ signal region. Using these results, the sensitivity of SABRE South to a typical WIMP has been computed. Assuming the Standard Halo Model, SABRE South is expected to reject the DAMA/LIBRA modulation at 3σ or confirm it at 5σ within 2.5 years of live data taking.

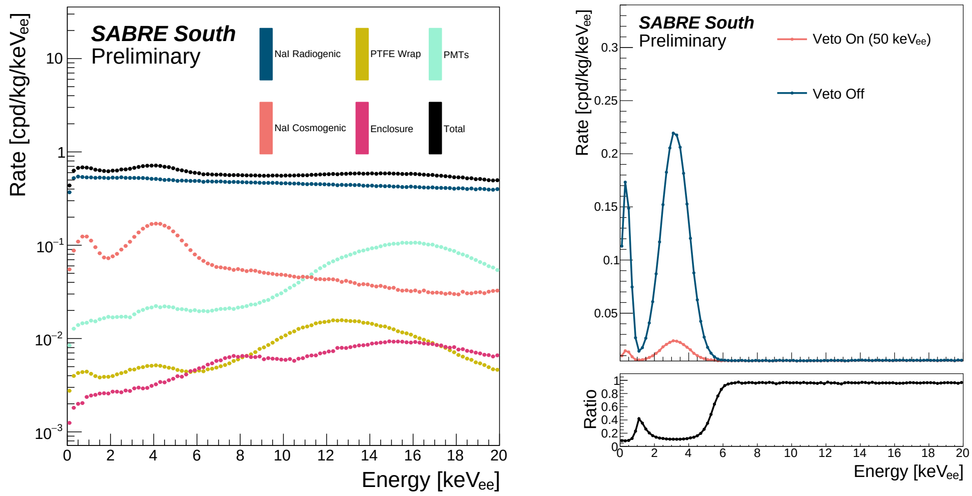

Figure 3: Crystal energy distributions in the range of 0-20 keV$_{ee}$. **Left:** Background processes originating in the SABRE South detector components that pass the veto requirement. **Right:** Background due to ^{40}K decays in the crystal with the veto off (blue) and on (orange).

4. Acknowledgements

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