

The SABRE South DAQ system

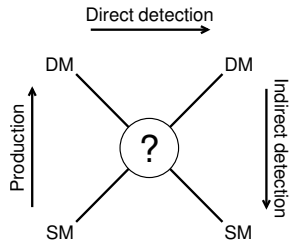
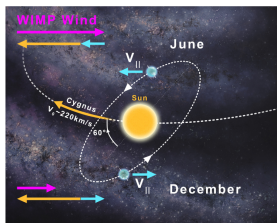
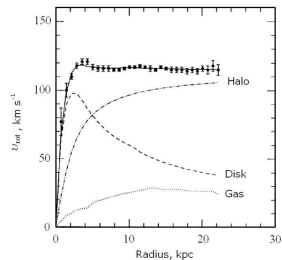
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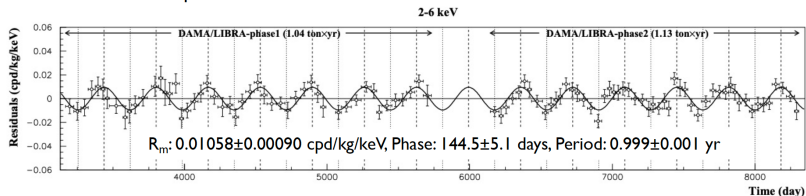
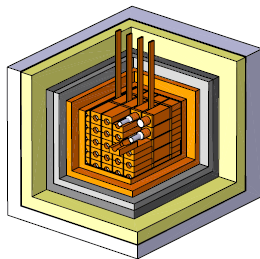
On behalf of the SABRE South Collaboration
University of Melbourne

July 31, 2022

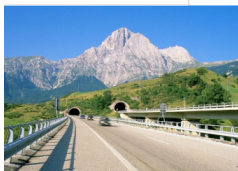
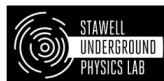
- Cosmological observations suggest the existence of dark matter but there's been no confirmed observation
- Direct-detection rate should modulate annually as the Earth orbits the Sun
 - ▶ Period 1 year
 - ▶ Peak in June
 - ▶ Low energy
 - ▶ Low cross-section

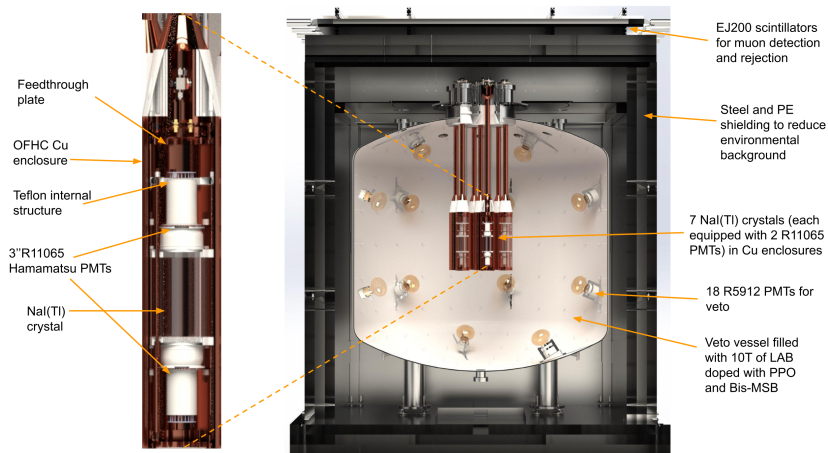


- 250 kg NaI(Tl) dark-matter detector located at LNGS
- ~ 20 -year, annual-modulation signal consistent with dark-matter
- Inconsistent with other null results BUT these comparisons are target/model dependent
- Model-independent tests (i.e. same target) are needed
 - ▶ SABRE (among others)



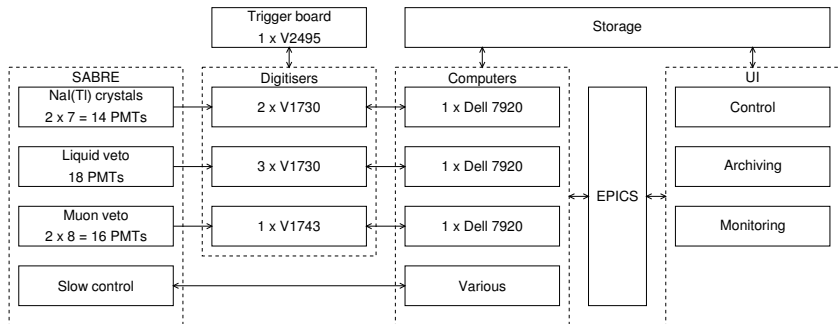
- The SABRE (Sodium-Iodide with **A**ctive **B**ackground **RE**jection) experiment aims to test and improve upon the DAMA result
 - ▶ Ultra high-purity NaI(Tl), active background rejection, dual-hemisphere data
- The program foresees two NaI(Tl) detectors in two underground locations
 - ▶ SABRE North at Laboratori Nazionali del Gran Sasso (LNGS) in Italy
 - ▶ SABRE South at Stawell Underground Physics Laboratory (SUPL) in Australia



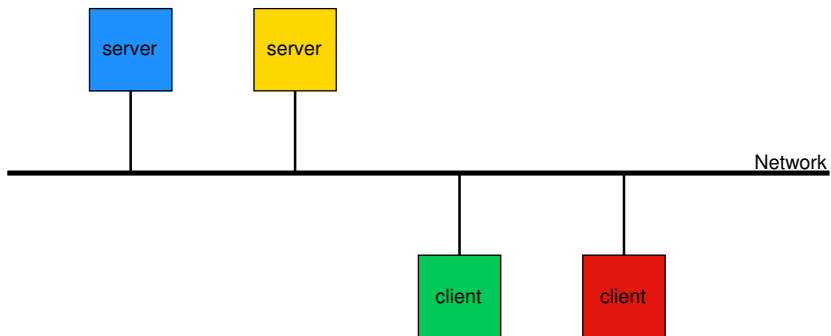


- DAQ needs to acquire raw waveforms for 48 PMTs across 3 sub-detectors
 - ▶ NaI(Tl) crystals – $2 \times 7 = 14$ PMTs
 - ▶ Liquid veto – 18 PMTs
 - ▶ Muon veto – $2 \times 8 = 16$ PMTs

- CAEN hardware
 - ▶ Digitisers – 500 MS/s V1730 (crystal and LAB), 3.2GS/s V1743 (muon)
 - ▶ Trigger board – V2495 (custom firmware)
 - ▶ Fibre optic readout – A3818 (85 MB/s per instance)
- Dell 7920 servers for readout, storage, and UI
- Independent instances for each sub-detector
 - ▶ EPICS-integrated software for common control and monitoring



- **Experimental Physics and Industrial Control System**
 - ▶ <https://epics-controls.org/>
- A set of tools that uses client/server techniques to build distributed control systems
- Adds a layer of abstraction between servers (DAQ, slow control, etc.) and clients (UI, archiving, etc.)



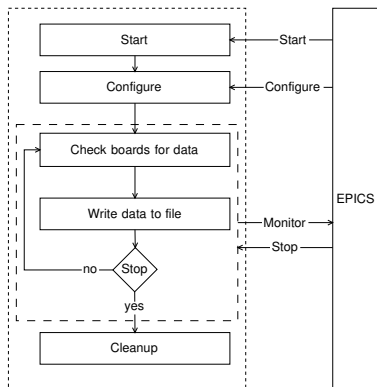
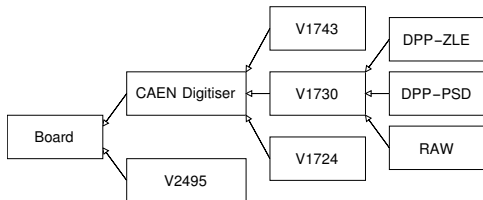
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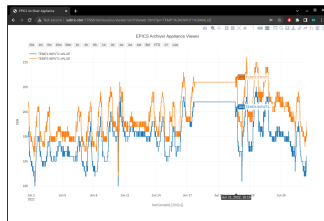
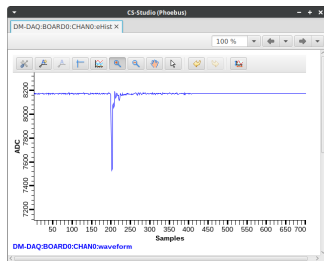
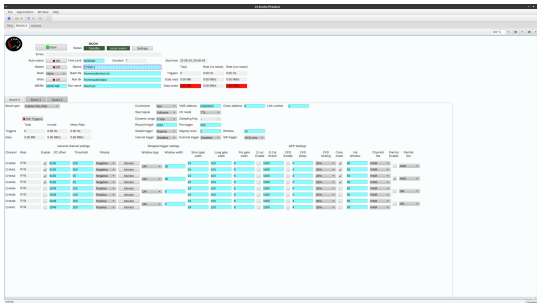
Network



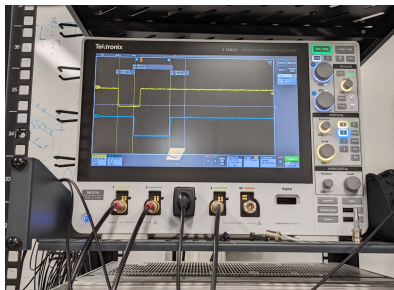
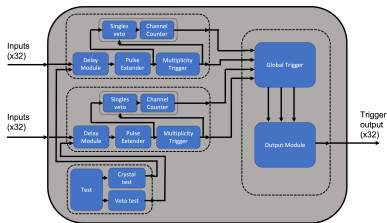
- Custom EPICS server to configure, monitor and readout DAQ
 - ▶ Abstracted control/monitoring works through *any* EPICS system
- Developed in C++ at UniMelb
 - ▶ OO design can support various hardware – currently only CAEN devices



- Utilises existing EPICS clients
- CSS-Phoebus
 - ▶ Custom SABRE UI developed at UniMelb
 - ▶ Common control of multiple DAQ instances
 - ▶ Slow control systems to be integrated
- EPICS Archiver Appliance
 - ▶ Archiving for millions of EPICS variables
 - ▶ Development instance at UniMelb



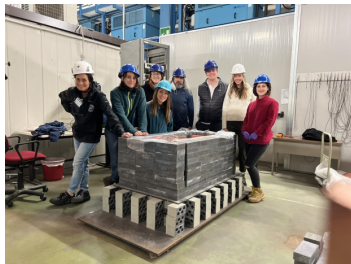
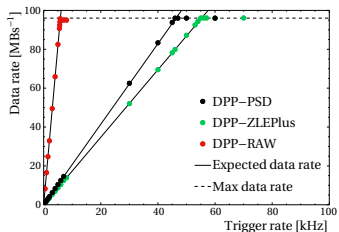
- CAEN V2495 to manage triggering and synchronisation across digitisers
- Custom VHDL firmware in development at the ANU
 - ▶ Gate-delay-generator
 - ▶ Multiplicity trigger
 - ▶ Calibration trigger
 - ▶ Start signal
- Prototype tested June 2022



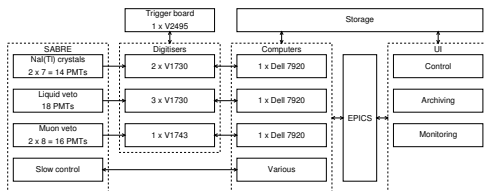
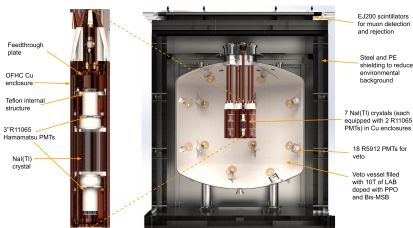
- Hardware – Acquired
 - ▶ 1 × SY5527 High-voltage mainframe
 - ▶ 5 × V1730 500-MS/s digitisers
 - ▶ 1 × V1743 3.2-GS/s digitiser
 - ▶ 1 × V2495 Trigger unit
 - ▶ 3 × A3818 optical links
 - ▶ 3 × DAQ PCs
 - ▶ 1 × Storage/processing PC
 - ▶ 2 × Control/monitoring PCs
 - ▶ 1 × APC SmartUPS system
 - ▶ 1 × Post-doc
- Firmware – In development
 - ▶ Prototype developed and tested
 - ▶ Final trigger design TBD
- Software – Refinement
 - ▶ Bugfixes, QA, etc.



- Small scale – ongoing
 - ▶ Performance tests
 - ▶ Detector characterisation at UniMelb
 - ★ PMTs, Liquid veto, Muon detectors
 - ▶ Crystal characterisation at LNGS
 - ★ NaI-35 – First SABRE-South crystal
 - ★ NaI-37 – Next SABRE-North crystal
- Large scale – upcoming
 - ▶ SABRE South assembly starts Sep 2022
 - ▶ Commissioning mid/late 2023



- SABRE is a dual-site experiment to test the DAMA annual modulation result
 - ▶ SABRE North at LNGS in Italy
 - ▶ SABRE South at SUPL in Australia
- An EPICS based DAQ system is under development
 - ▶ Hardware acquired
 - ▶ Trigger firmware under development
 - ▶ Software largely finalised
 - ▶ Testing and deployment ongoing



SABRE North



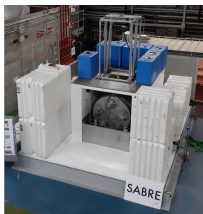
SABRE South



SABRE: A dual site experiment

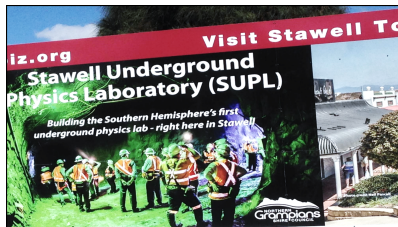
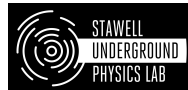
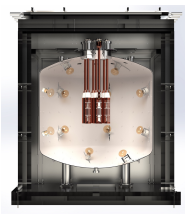
SABRE North

Laboratori Nazionali del Gran Sasso (LNGS), Italy

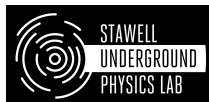


SABRE South

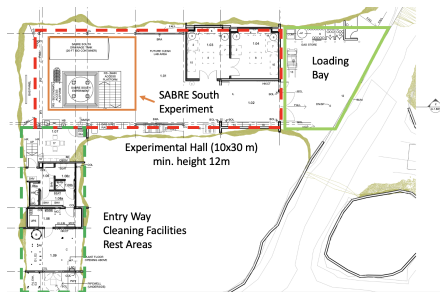
Stawell Underground Physics Laboratory (SUPL), Australia



- First deep underground laboratory in the Southern Hemisphere
 - ▶ 1025 m deep (2900 m water equivalent) with flat over burden
- Located in Stawell Gold Mine, 240-km west of Melbourne, Victoria, Australia
 - ▶ Helical drive access
- Construction complete and operations will start in August/September 2022



<https://www.supl.org.au>

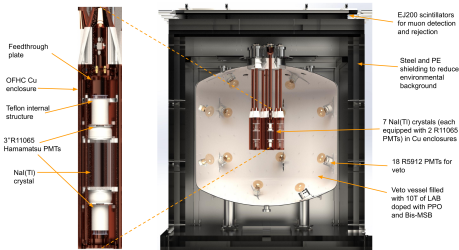


SABRE North and South detectors have **common core features**:

- Same detector module concept (Ultra-pure crystals and HPK R11065 PMTs)
- Common simulation, DAQ and software frameworks
- Exchange of engineering know-how with official collaboration agreements between the ARC Centre of Excellence for Dark Matter and the INFN

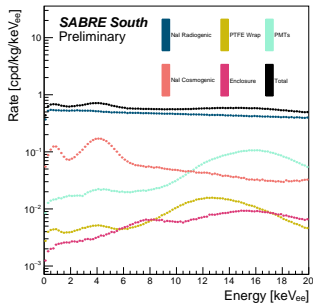
SABRE North and South detectors have **different shielding designs**:

- SABRE North has opted for a fully passive shielding due to the phase out of organic scintillators at LNGS. Direct counting and simulations demonstrate that this is compliant with the background goal of SABRE North at LNGS
- SABRE South will be the first experiment in SUPL, the liquid scintillator will be used for in-situ evaluation and validation of the background in addition of background rejection and particle identification



- Highest purity crystals and largest active veto: 0.73 cpd/kg/keV
- Crystal procurement is on-going
- One low background NaI(Tl) crystal in testing phase at LNGS

- Assembly in SUPL will start September 2022 with commissioning in mid/late 2023
- Vessel, LAB, PMTs, muon detectors, DAQ, slow control, crystal insertion system all ready



<http://arxiv.org/abs/2205.13849>

- PMT HV
 - ▶ CAEN SY5527 built in EPICS server
- Muon calibration system
 - ▶ Festo stage – EPICS modbus support
- Veto calibration system – TBD
- Environment sensors and fluid handling
 - ▶ NI-cRIO based prototype developed at Swinburne
 - ▶ EPICS + Ethercat system under development at ANU

