Systems for Detecting and Measuring Backgrounds with the SABRE South Experiment

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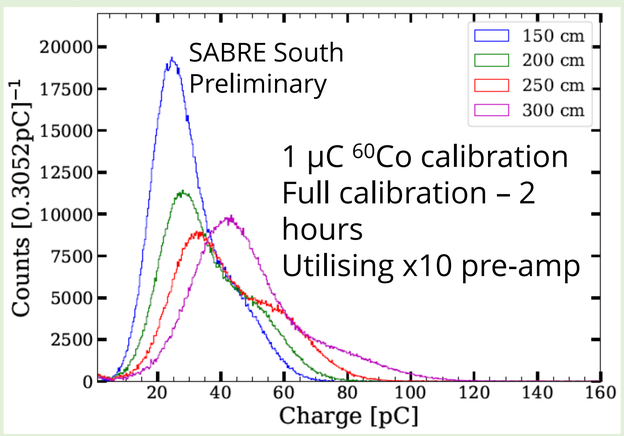
See the other SABRE South posters!

The SABRE South veto system is designed to detect the signals generated by radiation and cosmic rays using a 12kL linear alkyl-benzene based liquid scintillator (LS) detector contained in a steel vessel and instrumented with 18 Hamamatsu R5912 photomultiplier tubes (PMTs), alongside a plane of 8 plastic scintillator modules (instrumented with 2 PMTs) located above the vessel to reliably detect muons from cosmic-rays and perform position reconstruction to a resolution of 5 cm. This poster reports on the calibration procedures of the liquid and plastic scintillator detection systems, as well as capabilities for particle identification and position reconstruction.

Muon Veto Calibration Systems

Linear stage system, with a ^{60}Co source placed on the stage.
Detectors are calibrated with stage placed laterally, at one position each.
Calibration checks stability of PMT gain and timing reconstruction of each paddle.

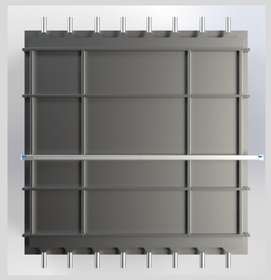


SABRE South Muon Veto

The SABRE South muon veto sits on top of the shielding to tag muon events – **scintillator modules with 9.6 m² coverage.**

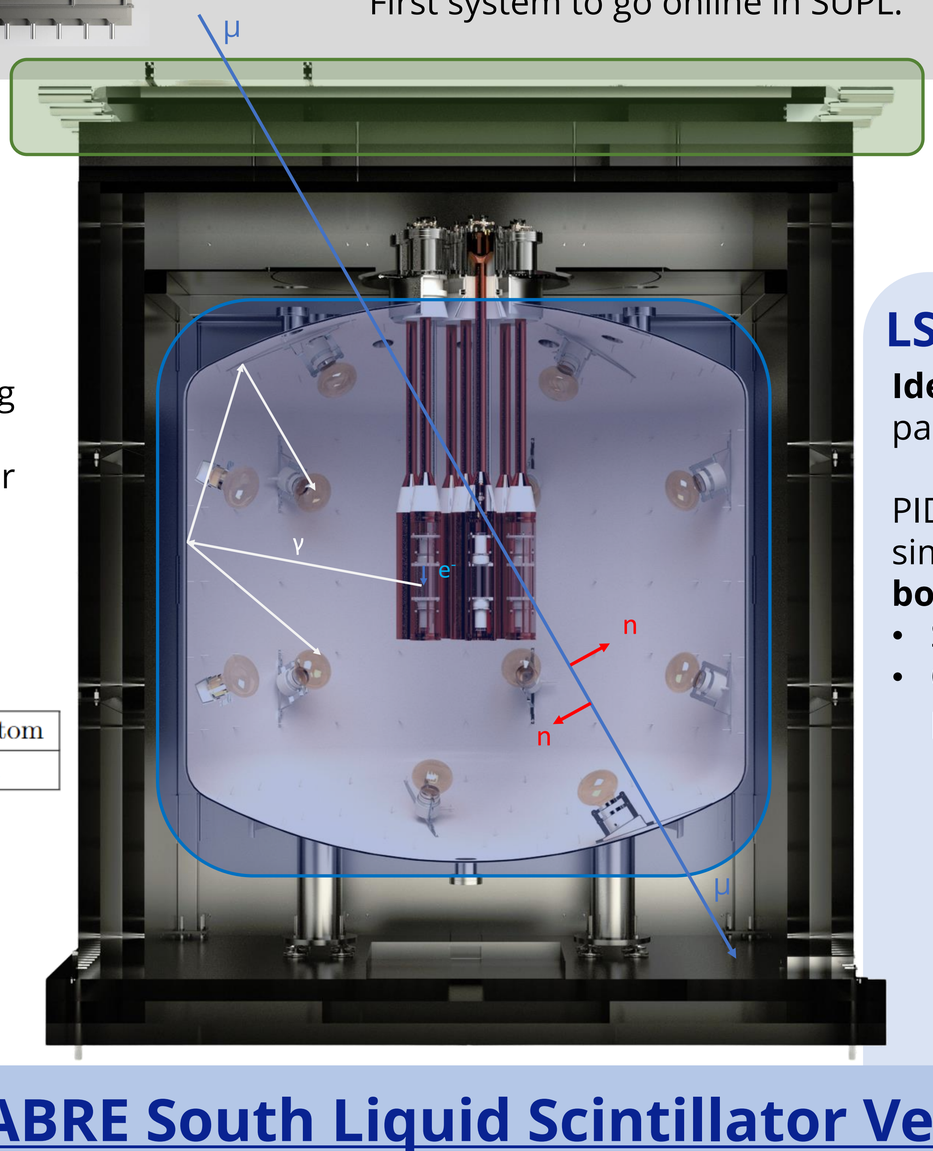
EJ200 plastic scintillator coupled to R13089 PMTs, via acrylic light guide.

First Underground Flux Measurement



See G. Fu P20, for more detail

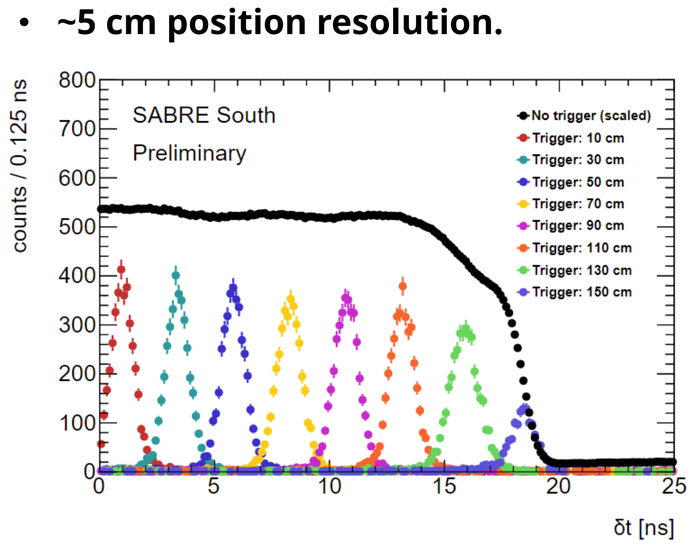
Detectors to go into SUPL in coming months **(August-October).**
Configured for **flux and angular measurements** (North-South, East-West).
First system to go online in SUPL.



Muon Veto Reconstruction Capabilities

Position reconstruction along the length of panel:

- $\sigma(\Delta t = t_L - t_R) \sim 400$ ps,
- **~5 cm position resolution.**



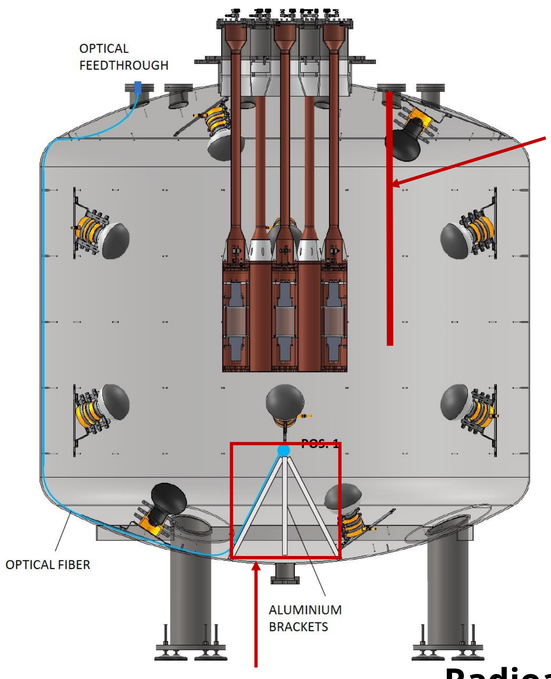
LS Veto Calibration Systems

1. Radioactive calibration system monitoring energy reconstruction/scale and PMT gain.
2. Light injection calibration system to monitor PMT performance/stability – timing and gain.

PMTs fully pre-calibrated – see O. Stanley P18.

Optical calibration system

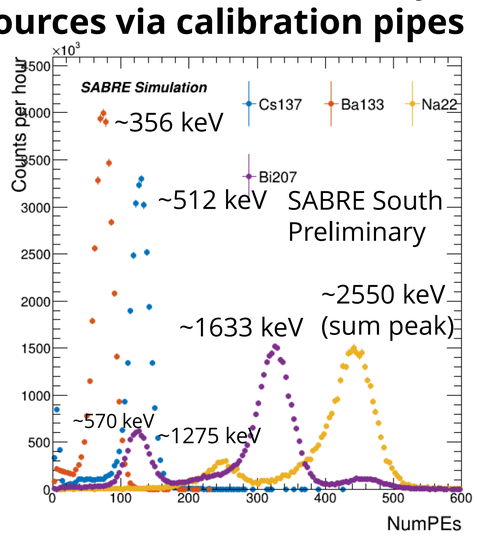
PMT Position	Top	Upper barrel	Lower barrel	Bottom
% Detected photons	2.45	5.31	4.40	2.01



Calibration tubes.

445 nm laser light injected via diffusion bulb.

Radioactive calibration system, sources via calibration pipes



Sum of detected (25% QE) photoelectrons in all PMTs, matched to energy deposit.

SABRE South Liquid Scintillator Veto

Liquid scintillator veto serves three key purposes:

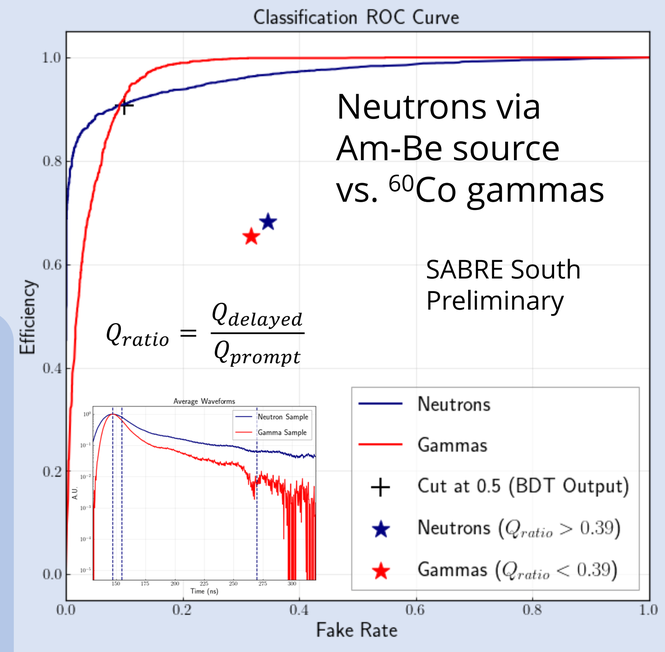
- Rejection and tagging of background >50 keV$_{ee}$, especially peaking ^{40}**K background, reduced from 0.1 to 0.013 cpd/kg/keV$_{ee}$ (~x10 reduction),**
- Reconstruction of event/background mechanisms – potential mimics of the DAMA/LIBRA signal,
- Passive shielding for crystal array.

LS Veto Particle ID (PID) Capabilities

Identifying/discriminating neutrons from other particles (i.e. gammas) in veto is a requirement.

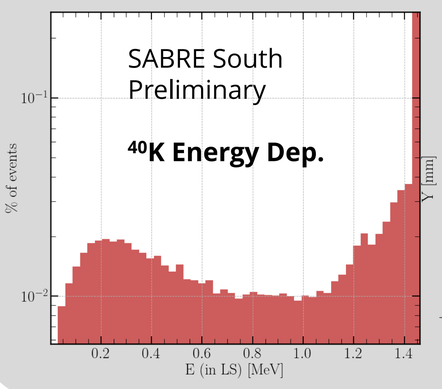
PID studies with **small LS test vessel** (1 PMT, similar LS), and **4 pulse shape variables in boosted decision tree** for multivariate analysis:

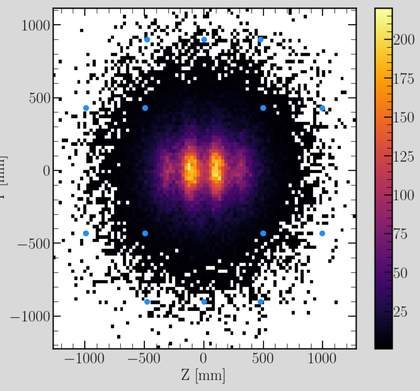
- Skew & Kurtosis,
- Charge ratio – ratio delayed/prompt charge in pulse tail, & Amplitude-weighted mean time.

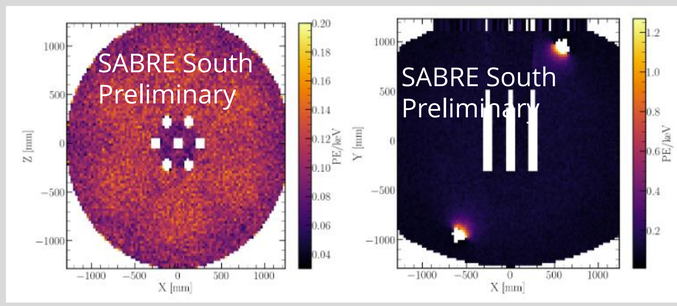


LS Veto Performance Studies

- ^{40}K events and energy deposits in LS are localised around crystals.
- **~85% can be vetoed.**
- Photo-electron detection prob. In vessel.
- **~0.20 PE/keV/PMT.**







Summary

The SABRE South experiment will employ the capabilities of two systems for background characterisation and detection – a 12 kL liquid scintillator (LS) veto, and a 9.6 m² muon veto. Both systems will uniquely leverage in-situ calibration systems and background reconstruction, including:

- In-situ radioactive calibration systems for each subdetector, and in in-situ optical calibration system for the LS veto
- 5 cm position resolution for the muon veto
- Particle ID capabilities for the veto have been demonstrated by a small- scale test detector

Assembly to begin late 2023/24