Heavy Radiation Backgrounds in the LSBB

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ABSTRACT

We briefly describe studies of the existing neutron and alpha radiation fields in the GESA site of the LSBB common to such experimental environments, the impact of various shieldings in their suppression, and the results of their measurement using SIMPLE detectors.

INTRODUCTION

The SIMPLE dark matter search [1] is sited in the GESA facility of the LSBB [2]. The SIMPLE detectors are based on superheated liquids [3]: their operating temperature (9ºC) and pressure (2 bar) have been adjusted to be insensitive to backgrounds from electrons, γ's and minimum ionizing radiations common to other dark matter experiments, but sensitive to neutron and α radiations. Underground siting is *a priori* to all such rare event searches, in order to reduce backgrounds associated with cosmic rays.

At 500 m depth, the estimated muon flux, capable of producing cosmogenic neutrons, is 1 x 10^{-2} $m^{-2}s^{-1}$ [4]. Although this decreases exponentially with increasing depth, the background neutron field becomes essentially constant owing to U/Th contaminants in the rock itself, with a neutron flux of ~ 3.5 x 10^{-1} $m^{-2}s^{-1}$ [5]. Shieldings introduced to reduce these backgrounds also contribute to the background as a result of their own U/Th impurities. The α-decay of radon diffused into the detectors from the atmosphere may also contribute, the level of which varies seasonally between 20-1000 Bq/m^3 as a result of groundwater circulation in the mountain.

The background signal expected from the ambient neutron- and α-fields have been estimated based on radio-assays of the surrounding rock, concrete and shielding materials. We here compare experimental results from a run of 15 SIMPLE detectors with these estimates.

SITE DESCRIPTION

GESA is a 60 m^3 cavern with 505 m calcite rock overburden. The cavern itself is shielded from the rock by a 30-100 cm thickness of low grade concrete, internally sheathed by 1 cm of steel to form a Faraday cage. The detectors themselves are immersed in a 700 liter waterpool for temperature control, which also serves as a neutron moderator with a reduction factor of ~ 5 per 10 cm of water thickness. Additional neutron shielding below the waterpool is provided by a 20 cm wood platform, with about half the moderating power of an equal water thickness.

Without the concrete, 7.2 x 10^5 neutron events per kg of detector per day (evt/kgd) would be expected in the detector area. Radio-assays of the GESA concrete and steel yield levels of 1.90 ± 0.05 ppm ^{232}Th and 0.850 ± 0.081ppm ^{238}U (concrete); 3.20 ± 0.25 ppb ^{232}Th and 2.9 ± 0.2 ppb ^{238}U (steel), respectively. Variation of the concrete thickness suggest no significant differences for thicknesses > 20 cm. MCNP simulations of the on-detector neutron field, which account for spontaneous fission (sf) plus decay-induced (*α*,n) reactions, yields 3.0 x 10^3 evt/kgd.

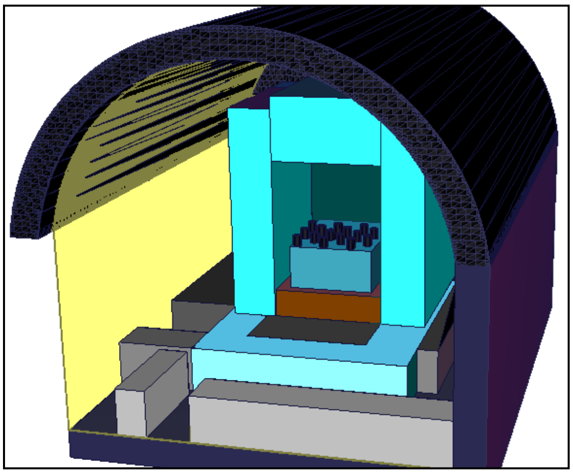

Fig. 1: schematic of the SIMPLE SDDS in the GESA site. The dark areas represent wall concrete, the light areas, the floor concrete and water shield surrounding the centrally located detectors.

To further reduce this neutron background, a water shield of 50-75 cm thickness surrounding the detectors was installed, yielding an expected rate of 1.09 ± 0.02 (stat) ± 0.07 (syst) evt/kgd. Table I displays the various contribution estimates, discriminated with respect to shielding.

Table I: background neutron contributions to the measurement with various shieldings.

	sf	(α,n)^{238}U	(α,n)^{232}Th
	(evt/kgd)	(evt/kgd)	(evt/kgd)
concrete	1203	972	816
+wood	371	310	263
+ water	2.51	2.11	1.78
+wood,water	0.362	0.306	0.306

ANALYSIS & DISCUSSION

Data was taken from a run of a 0.208 kg, 15 detector array over 67 days of measurement. Analysis of the measurement signals, involving the pulse shapes, frequency distributions, and signal timing constants, is capable of discriminating all acoustic from particle-induced events [6]. The resulting particle events (1.3% of the recorded 4588 events) are shown in Fig. 2.

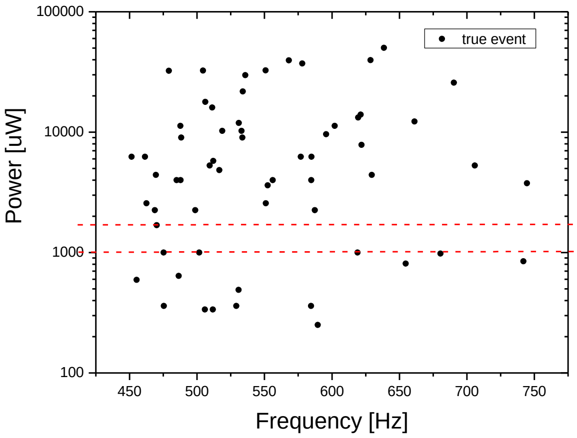

FIG. 2: scatter plot of power and primary frequency of the 61 true events, with the gap around 10^3 μW demarcating the high (α) from the low (neutron) amplitude populations.

The low amplitude region of Fig. 2 contains a total of 15 events corresponding to a rate of 1±0.28(stat) ±0.22(syst) evt/kgd, consistent with the above estimate of the neutron field. The remaining 46 true events are associated with the α-field, consistent with larger signal amplitudes as a result of the larger associated energy depositions in the detector droplets [7]. This contribution is 3.4 ±0.51(stat) ±0.12(syst) evts/kgd.

Background α's are extremely short-range: they must be essentially inside the detectors in order to produce a signal. All detector construction materials have been radio-assayed, yielding U/Th concentrations below 10^{-6} Bq/g and an α-contribution < 0.5 evt/kgd.

By far, the least known and shielded, and therefore most serious contribution is the α's from the ambient radon field. Ventilation of the GESA site reduced this to a level of ~70 Bq/m^3.

Diffusion of environmental radon into a detector is limited by the surrounding waterpool, which covers the detectors to just above their glycerin levels. Radon solubility in water is 230 cm^3/kg at 20^{o}C [8] and increases with temperature decrease; with a diffusion length of 2.2 cm, the equilibrium radon concentration is reduced by a factor 60 at 9 cm below the water surface, and a factor 300 further because of the short (< 0.7 mm) radon diffusion lengths of the SDD construction materials (glass, plastic, metal). The pool water is however top-input circulated at 25 liter/min, preventing the upper layer from reaching equilibrium radon saturation. The research grade N2 overpressuring of the device inhibits the advective influx of Rn-bearing water through the detector cappings, as well as diffusion of Rn from the walls of the glass container into the gel (via stiffening of the gel). The glycerin layer covering the gel further inhibits radon diffusion into the gel matrix via the cap and teflon pressure line. Combined, this would suggest an in-detector rate of 4x10^{-3} Bq/m^3, consistent with the measured concentration above the waterpool.

SUMMARY

Measurement of the heavy radiation fields in GESA yields a neutron event rate consistent to within experimental uncertainties with MCNP estimates of the shielded environment, and an α-field consistent with its origin in the radon-bearing atmosphere in the detector vicinity but reduced by a factor ~5 as a result of water circulation which prevents attainment of equilibrium conditions. Thus, the unshielded fields reasonably represent the general radiation fields extant in the LSBB.

From these results, it is possible to draw several conclusions:

- without shielding, the neutron field derives from the U/Th content of the concrete; at ~3000 evt/kgd, it is below levels of concern for "normal" experimental activity (but above those of rare event searches),

- with shielding, the neutron field is reduced to ~1 evt/kgd, and the most significant contribution is from the ambient radon background; this can be reduced to ~2.8 evt/kgd by ventilation and water circulation.

The last, apart from prejudicing rare events searches, has impact on the health aspects of research activity in the LSBB in general.

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