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ANAIS: Status and prospects

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Abstract

ANAIS (Annual modulation with NAI Scintillators) experiment aims to look for dark matter annual modulation with 250 kg of ultra-pure NaI(Tl) scintillators at the Canfranc Underground Laboratory (LSC), in order to confirm the DAMA/LIBRA positive signal in a model-independent way. The detector will consists in an array of close-packed single modules, each of them coupled to two high efficiency Hamamatsu photomultipliers. Two 12.5 kg each NaI(Tl) crystals provided by Alpha Spectra are currently taking data at the LSC. These modules have shown an outstanding light collection efficiency (12-16 phe/keV), about the double of that from DAMA/LIBRA phase 1 detectors, which could enable reducing the energy threshold down to 1 keVee. ANAIS crystal radiopurity goals are fulfilled for ^{232}Th and ^{238}U chains, assuming equilibrium, and in the case of ^{40}K, present crystals activity (although not at the required 20 ppb level) could be acceptable. However, a ^{210}Pb contamination out-of-equilibrium has been identified and its origin traced back, so we expect it will be avoided in next prototypes. Finally, current status and prospects of the experiment considering several exposure and background scenarios are presented.

Keywords: dark matter, annual modulation, NaI(Tl) scintillators

1. Introduction

The ANAIS experiment [1, 2] aims to look for dark matter (DM) annual modulation at the Canfranc Underground Laboratory (LSC) in order to confirm the DAMA/LIBRA positive DM signal [3] in a model independent way (using the same target and technique). The design goal is to set up 250 kg of ultrapure NaI(Tl) scintillators with an energy threshold ≤2 keVee (electron equivalent units) and radioactive background near threshold below 2 c/keVee/kg/day. In this paper we briefly report on the performances of two ANAIS prototypes that are currently taking data at LSC (Sec. 2), the ongoing activities (Sec. 3) and the prospects of the experiment in several exposure/background scenarios (Sec. 4).

2. ANAIS-25 experimental set-up

The ANAIS-25 set-up, installed at LSC in December 2012 [4], consist in two 12.5 kg cylindrical (4.75” ϕ × 11.75” length) NaI(Tl) crystals made by Alpha Spectra (AS), enclosed in a 30 cm lead shielding plus anti-radon box and active vetoes. Each module was coupled to two Hamamatsu photomultipliers (PMTs) through quartz windows, without light guides to improve light collection. The aim was to perform a comprehensive assessment of detector performances (*i.e.*, light collection, energy resolution and threshold and crystals radiopurity, in particular potassium content). On the other hand this set-up is being used for testing and fine-tuning the ANAIS data acquisition (DAQ) and analysis tools.

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2.1. Light collection, resolution and energy threshold

We can report an excellent light collection efficiency: 16.13±0.66 phe/keV for the module with high quantum efficiency PMTs (Model R12669SEL2) and 12.58±0.13 phe/keV for the prototype with R11065SEL PMTs. The outstanding light collection achieved translates in a clear improvement in energy resolution and threshold with respect to previous ANAIS prototypes. FWHM resolutions as good as 11.3 (2.8) keV @ 122.1 (5.9) keV have been obtained. As regards the energy threshold, Fig. 1 shows a scatter plot of coincidence events in both detectors during a background measurement, where the two low energy lines at 3.2 and 0.9 keV following EC in ^{40}K (internal contamination) and ^{22}Na (cosmogenic origin) are clearly visible in one detector when the corresponding γ line from the daughter nucleus de-excitation (1460.8 and 1274.5 keV respectively) is detected in the other module. We are still working in the evaluation of the efficiency at the 0.9 keV line, but in any case a threshold of the order of 1 keVee seems achievable with high efficiency in the AS crystals.

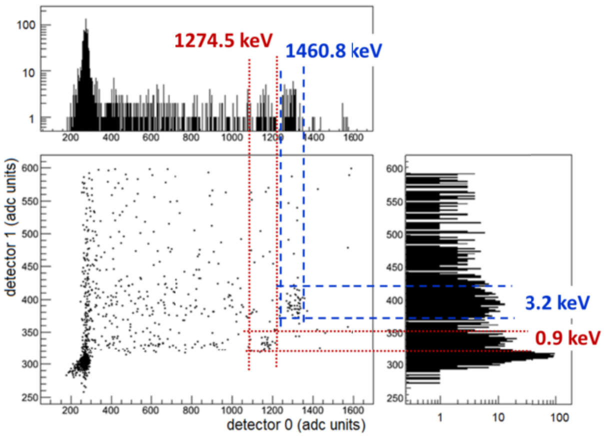

Figure 1: Coincidence plot between both ANAIS-25 detectors. The 0.9-1274.5 keV (internal ^{22}Na) and 3.2-1460.8 keV (internal ^{40}K) coincident events are highlighted with dotted and dashed lines, respectively.

2.2. Background

Fig. 2 compares the background measured in ANAIS-25 in the month immediately following the mounting underground with that measured 15 months after. We can see how the lines having a short-lived cosmogenic origin are strongly reduced, while the non-decaying line at around 50 keV is presumably coming from internal ^{210}Pb, as was confirmed by α spectroscopy. The main crystal contaminations, found by coincidence analysis in the case of ^{40}K [5], and α spectroscopy plus Bi-Po sequences analysis for the radioactive chains, are given in Tab. 1. ^{40}K content is above ANAIS goal (20 ppb K), but MC simulations have shown that, for the measured contamination, the 3.2 keV peak can be reduced below 2 /c/keVee/kg/day by rejecting multiple hit events thanks to the closed-packed ANAIS configuration, obtaining an escaping probability of 25% for the 1460.8 keV γ. Radiopurity goals are fulfilled for ^{232}Th and ^{238}U chains and are sufficient for ^{40}K, but a ^{210}Pb out-of-equilibrium contamination is present at an unacceptable level, being responsible of the increase in background below 20 keV. The origin of this contamination has been identified and has been solved at AS. New material by AS could be ready very soon to be checked at LSC for radiopurity.

^{40}K mBq/kg	^{238}U mBq/kg	^{210}Pb mBq/kg	^{232}Th mBq/kg
1.25±0.11 (41 ppb K)	0.010±0.002	~3.15	0.002±0.001

Table 1: Internal contaminations measured in ANAIS-25 prototypes.

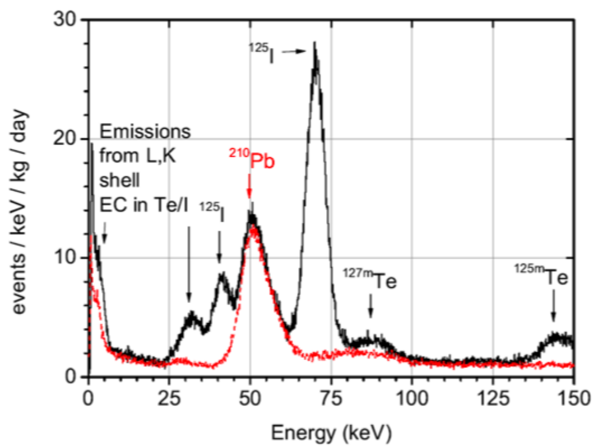

Figure 2: Background measured in ANAIS-25 after the first month underground (black line) and 15 months after (red line). Peaks with cosmogenic origin are labeled.

3. ANAIS Status

Commissioning of the experimental set-up at LSC is undergoing while radiopure enough detectors are built. All the archaeological and low activity lead required for the whole ANAIS shielding plus mechanical isolation, polyethylene and anti-radon box are ready for the mounting at the LSC. The active vetoes that will fully cover the ANAIS set-up and the low energy calibration system are being tested at ANAIS-25. Calibration at very low energy is achieved thanks to a Mylar window in the lateral face of the detector's copper encapsulation. Two radioactive sources (^{57}Co and ^{109}Cd) are mounted along flexible wires that are introduced into the shielding through a closed Rn-free tube and positioned in front of the Mylar windows.

As concerns the DAQ system, the electronic chain is fully commissioned for 40 channels (20 detectors x 2 PMTs), and a slow control system to monitorize environmental parameters (temperature at Hut/electronics/LSC Hall B, N_2 flux, HV supply, baseline noise, radon concentration at LSC Hall B, muon rate...) is almost completed. The successive ANAIS prototypes have allowed to test the hardware as well as optimize the first level analysis and events selection protocols [6].

4. Sensitivity prospects

Finally, we present the projected sensitivity of ANAIS to DM annual modulation. If the ^{210}Pb level is reduced in the new crystals, the main background contribution at low energy will come from internal ^{40}K and PMTs contamination (specially ^{226}Ra). We have considered the current K concentration (40 ppb) in the new crystals. This background model (ANAIS-250) is our baseline, but we have considered also two more conservative scenarios in case the ^{210}Pb suppression is not achieved: the background level measured in ANAIS-25 and a background model for ANAIS-25 considering PMTs, copper encapsulation, optical windows, lead shielding, radon in the inner volume air and NaI bulk contaminations, based on the work presented in [7]. Based on the results of ANAIS-25 reported in Sec. 2.1, we have supposed an energy threshold of 1 keVee and two possible total masses (100 and 250 kg) for the experiment in a 5 years data taking period.

Fig. 3 shows the projected ANAIS spin independent sensitivity to annual modulation supposing the three background models describe above. In the calculation, we have considered Helm form factors, a standard halo model (isothermal sphere) with $\rho_W = 0.3$ GeV/cm^3, $v_0 = 220$ km/s and $v_{esc} = 650$ km/s, quenching factors 0.3 for Na and 0.1 for I, and the energy window to look for the modulated signal is [1-3] keVee. We can see how, thanks to the low energy threshold, even in the more conservative scenarios, a good sensitivity in the

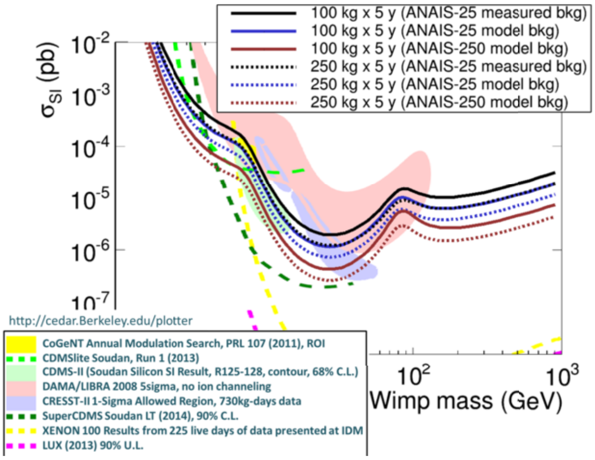

Figure 3: Spin independent ANAIS projected sensitivity in 6 different scenarios (see text). Comparison with DAMA-LIBRA positive result on annual modulation is model independent.

parameters region of the DAMA/LIBRA positive signal is obtained.

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References

[1] J. Amaré *et al.* J. Phys. Conf. Ser. 375 (2012) 012026
[2] J. Amaré *et al.* arXiv:1404.3564, to appear in Physics Procedia
[3] R. Bernabei *et al.* Eur. Phys. J. C. 73 (2013) 2648
[4] J. Amaré *et al.* Nucl. Instr. Meth. A 742 (2014) 187
[5] C. Cuesta *et al.* Int. J. of Mod. Phys. A. 29 (2014) 1443010
[6] C. Cuesta *et al.* arXiv:1407.5125, submitted to Eur. Phys. J. C.
[7] S. Cebrián *et al.* Astrop. Phys. 37 (2012) 60