# Status of the ANAIS Dark Matter Project at the Canfranc Underground Laboratory

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The ANAIS experiment aims at the confirmation of the DAMA/LIBRA signal. A detailed analysis of two NaI(Tl) crystals of 12.5 kg each grown by Alpha Spectra will be shown: effective threshold at 1 keVee is at reach thanks to outstanding light collection and robust PMT noise filtering protocols and the measured background is well understood down to 3 keVee, having quantified K, U and Th content and cosmogenic activation in the crystals. A new detector was installed in Canfranc in March 2015 together with the two previous modules and preliminary characterization results will be presented. Finally, the status and expected sensitivity of the full experiment with 112 kg will be reviewed.

## 1 The ANAIS experiment

The ANAIS (Annual modulation with NaI Scintillators) project is intended to search for dark matter annual modulation with ultrapure NaI(Tl) scintillators at the Canfranc Underground Laboratory (LSC) in Spain, in order to provide a model-independent confirmation of the signal reported by the DAMA/LIBRA collaboration [1] using the same target and technique. Similar performance to DAMA/LIBRA detectors in terms of threshold and background are consequently mandatory. The total active mass will be divided into modules, each consisting of a 12.5 kg NaI(Tl) crystal encapsulated in copper and optically coupled to two photomultipliers (PMTs) working in coincidence. Nine modules in a 3×3 matrix are expected to be set-up at LSC along 2016. The shielding for the experiment consists of 10 cm of archaeological lead, 20 cm of low activity lead, 40 cm of neutron moderator, an anti-radon box, and an active muon veto system made up of plastic scintillators covering the top and sides of the whole set-up. The experiment hut at the hall B of LSC (under 2450 m.w.e.) is already operative and shielding materials, selected Hamamatsu R12669SEL2 PMTs and electronic chain components are ready. The main challenge of the project has been the achievement of the required crystal radiopurity. A 9.6 kg NaI(Tl) crystal made by Saint-Gobain was first operated [2–5] but disregarded due

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| $^{40}$K (mBq/kg) | $^{238}$U (mBq/kg) | $^{210}$Pb (mBq/kg) | $^{232}$Th (mBq/kg) |
|---|---|---|---|
| $1.25 \pm 0.11$ (41 ppb K) | $0.010 \pm 0.002$ | 3.15 | $0.0020 \pm 0.0008$ |

Table 1: Internal activity measured in the ANAIS-25 detectors.

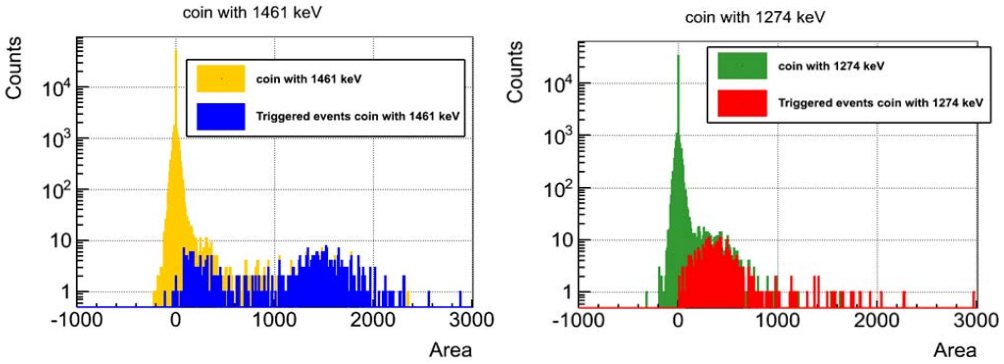


Figure 1: ANAIS-25 D0 coincident events at low energy for $^{40}$K (left) and for $^{22}$Na (right).

to an unacceptable K content. Two prototypes of 12.5 kg mass, made by Alpha Spectra, Inc. Colorado with ultrapure NaI powder, took data at the LSC since December 2012 (ANAIS-25 set-up) and a new module also built by Alpha Spectra using improved protocols for detector production was added in March 2015 (ANAIS-37 set-up).

## 2 The ANAIS-25 and ANAIS-37 set-ups

The main goals for the ANAIS-25 set-up [6] were to measure the crystal contamination, evaluate light collection, fine-tune the data acquisition and test the filtering and analysis protocols. The two modules (named D0 and D1) are cylindrical, 4.75" in diameter and 11.75" in length, with quartz windows for PMTs coupling. A Mylar window in the lateral face allows for low energy calibration. After testing other PMT models, Hamamatsu R12669SEL2 units were used for both detectors. The modules were shielded by 10 cm of archaeological plus 20 cm of low activity lead at LSC. An impressive light collection at the level of ∼15 phe/keV has been measured for these detectors [7]. Background contributions have been thoroughly analyzed and Table 1 shows the results of the activities determined for the main crystal contaminations: $^{40}$K content has been measured performing coincidence analysis between 1461 keV and 3.2 keV energy depositions in different detectors [4] and the activities from $^{210}$Pb and $^{232}$Th and $^{238}$U chains have been deduced by quantifying Bi/Po sequences and the total alpha rate determined through pulse shape analysis. The content of $^{40}$K, above the initial goal of ANAIS (20 ppb of K), is acceptable, $^{232}$Th and $^{238}$U activities are low enough but an out-of-equilibrium activity of $^{210}$Pb at the mBq/kg level was observed, precluding the background goals of the experiment. Cosmogenic radionuclide production in NaI(Tl) was also quantified [8] and $^{22}$Na and $^{3}$H were found to be very relevant in the region of interest. A complete background model of ANAIS-25 data has been developed [9] and the measured background is well understood down to 3 keVee.

The low energy events populations from internal $^{40}$K and $^{22}$Na have been studied. The K-shell electron binding energy following electron capture in $^{40}$K (3.2 keV) and $^{22}$Na (0.9 keV) can be tagged by the coincidence with a high energy $\gamma$-ray in a second detector (1461 keV

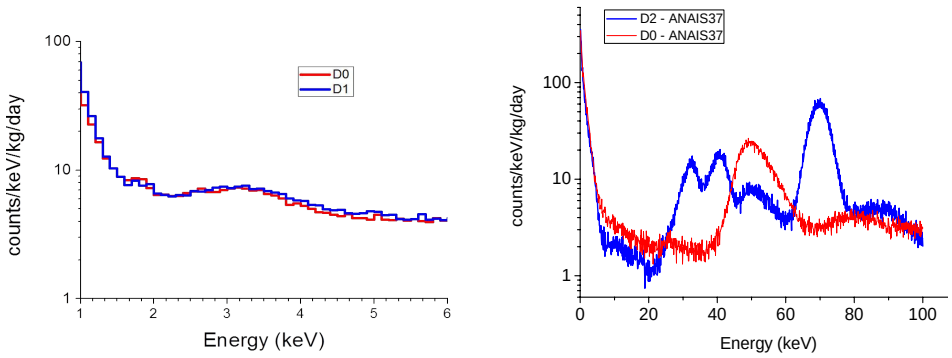


Figure 2: Left: Preliminary filtered background spectra corrected by triggering and filtering efficiencies for ANAIS-25 detectors D0 and D1 (filtering procedures still being optimized). Right: Raw background spectra of D0 and D2 detectors measured at the ANAIS-37 set-up.

and 1274 keV respectively). In Figure 1 both populations are shown, together with the events effectively triggering our acquisition. It can be concluded that triggering at 1 keVee is clearly achieved in ANAIS-25 and therefore an energy threshold of the order of 1 keVee is at reach. To remove the PMT origin events, dominating the background below 10 keVee, and then reach the 1 keVee threshold, specific filtering protocols for ANAIS-25 detectors have been designed following [2]. A preliminary spectrum, after filtering and correcting for the efficiencies of the cuts, determined with low energy events from a $^{109}$Cd calibration, is shown in Fig. 2 (left).

The origin of the large $^{210}$Pb contamination found in ANAIS-25 crystals was identified and addressed by Alpha Spectra in the construction of the new module (named D2) integrated in the ANAIS-37 set-up. Very preliminary results corresponding to 50 days of live-time are presented here for D2. A total alpha rate of $0.58 \pm 0.01$ mBq/kg has been obtained, which is a factor 5 lower than in D0 and D1, concluding that effective reduction of Rn entrance in the growing and/or purification at Alpha Spectra has been achieved. A K content of $44 \pm 4$ ppb compatible with that of D0 and D1 (see Table 1) has been measured using the same technique applied to previous prototypes. The measured light collection of D2 is compatible with that of ANAIS-25 detectors too [7] and the measured background of the new module is well described by the expected components [9]. Figure 2 (right) compares the raw background spectra of D0 and D2 in the ANAIS-37 setup; in spite of the presence of cosmogenic activation in D2 (still decaying) there is a very promising reduction of the background level below 20 keVee.

## 3 Sensitivity

Figure 3 (left) shows the design for the full ANAIS experiment considering a $3\times3$ crystal configuration. Prospects of the sensitivity to the annual modulation in the WIMP mass–cross-section parameter space are shown in Fig. 3, right for a 100 kg configuration and 5 years of data taking. The analysis window considered is from 1 to 6 keVee. The background assumed is the one measured in ANAIS-25 (shown in Fig. 2), but with the $^{210}$Pb activity measured in the new module D2, i.e. the contribution of 2.57 mBq/kg of $^{210}$Pb has been subtracted to the background measured at ANAIS-25. Further reduction from anticoincidence measurements, dependent on the detector matrix assumed, is expected. A conservative approach to derive these

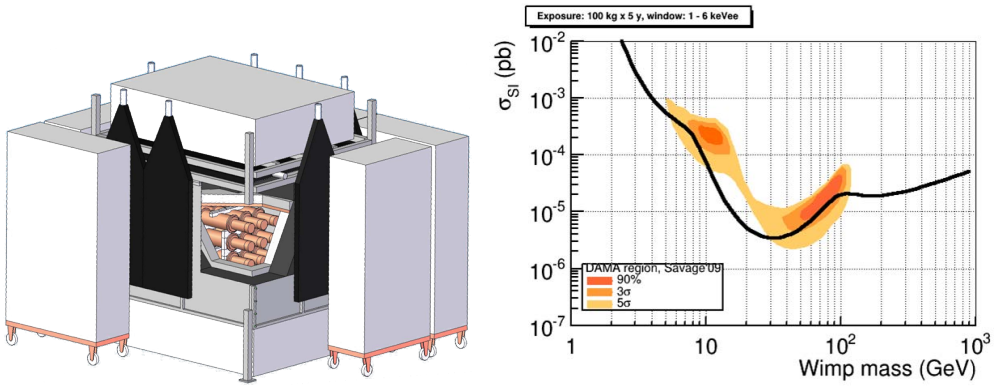


Figure 3: Left: Design of the ANAIS experiment for a 3×3 crystal matrix with a total mass of 112 kg. Right: Prospects of ANAIS annual modulation sensitivity for 100 kg total detection mass, presently achieved background without profiting from anticoincidence rejection, five years of data taking and an energy window from 1 to 6 keVee. These prospects correspond to a detection limit at 90% CL with a critical limit at 90% CL, following [10].

prospects has been followed, but even in this case, there is a considerable discovery potential of dark matter particles as responsible of the DAMA/LIBRA signal.

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## References

[1] R. Bernabei *et al.*, Eur. Phys. J. C **73**, 2648 (2013).

[2] C. Cuesta *et al.*, Eur. Phys. J. C **74**, 3150 (2014).

[3] S. Cebrián *et al.*, Astropart. Phys. **37**, 60 (2012).

[4] C. Cuesta *et al.*, Int. J. of Mod. Phys. A. **29**, 1443010 (2014).

[5] C. Cuesta *et al.*, Opt. Mat. **36**, 316 (2013).

[6] J. Amaré *et al.*, Nucl. Instrum. Meth. A **742**, 197 (2014).

[7] J. Amaré *et al.*, "Light collection in the prototypes of the ANAIS dark matter project", in these proceedings.

[8] J. Amaré *et al.*, JCAP **02**, 046 (2015).

[9] J. Amaré *et al.*, "Background model of NaI(Tl) detectors for the ANAIS dark matter project", in these proceedings.

[10] S. Cebrián *et al.*, Astropart. Phys. **14**, 339350 (2001).