Background studies for NaI(Tl) detectors in the ANAIS dark matter project

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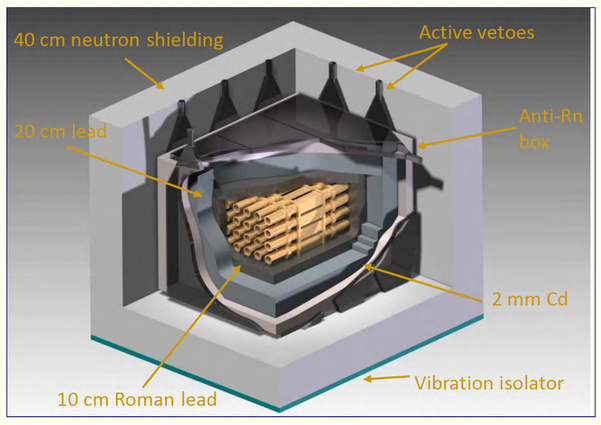
ANAIS project: Annual modulation with NaI Scintillators

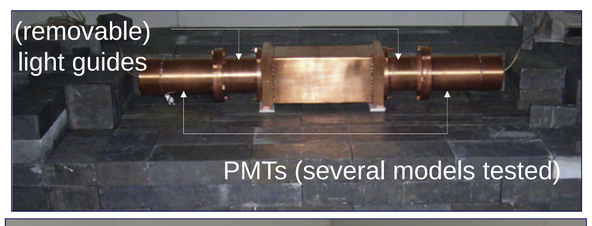


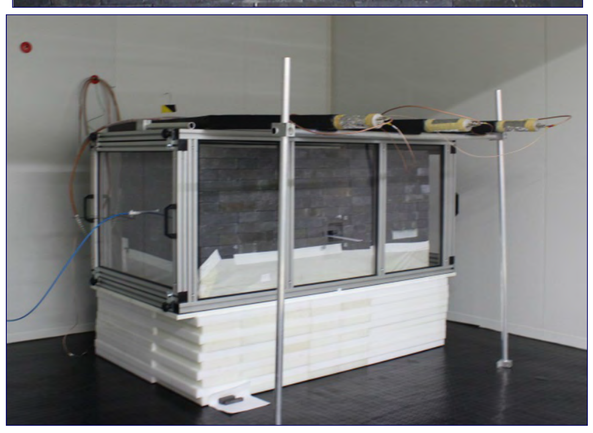
- Search for dark matter annual modulation with 250 kg of ultrapure NaI(Tl) scintillators
- To be installed in the Canfranc Underground Laboratory (LSC), Spain
- Same target and technique than DAMA/LIBRA
- Hut, shielding, electronic chain and readout ready
- **Main challenge:** development of crystals having K content <20 ppb

ANAIS-0 prototype: Background model [1,2]

Set-up

- A 9.6 kg NaI(Tl) crystal (4''x4''x10'') produced by Saint-Gobain and encapsulated using ETP copper at University of Zaragoza
- Operated at hall B in LSC from February 2011 to December 2012

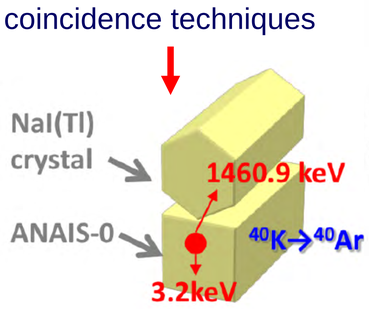


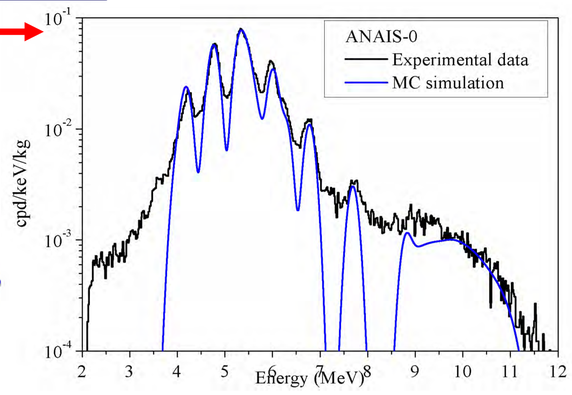


Internal contaminants

- ^{232}Th and ^{238}U chains quantified by PSA discrimination (α vs. β/γ)
- ^{40}K measured in a dedicated set-up by coincidence techniques

Isotope	NaI crystal bulk activity (mBq/kg)
^{40}K	12.7 ± 0.5
^{129}I	0.96 ± 0.06
^{238}U/^{234}U	0.075 ± 0.005
^{230}Th	0.023 ± 0.007
^{226}Ra	0.098 ± 0.004
^{210}Pb	0.188 ± 0.005
^{232}Th	0.013 ± 0.005
^{228}Th	0.035 ± 0.003





Monte Carlo simulation

- MC simulations using Geant4 package carried out to evaluate contribution from each measured contaminant
- Some hypotheses added (no fitting of the experimental data to a combination of these contributions has been attempted): some values below upper limits, ^{210}Pb surface emissions on crystal and copper vessel, cosmogenic ^{3}H and ^{129}I in crystal, extra ^{210}Pb in lead

External contaminants

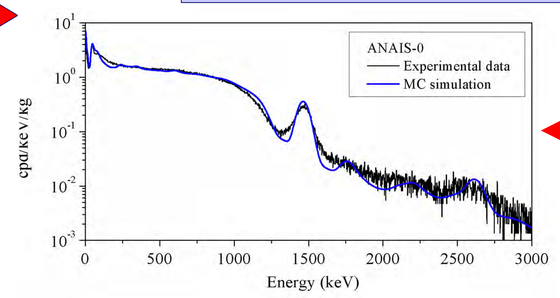
- Radioactive contaminations in external components determined by HPGe spectrometry performed at LSC

Detector component	Isotope	Activity (mBq/PMT)	
ET LB PMT	^{40}K	420 ± 50	
	^{232}Th	24 ± 4	
	^{238}U	220 ± 12	
Ham LB PMT	^{40}K	678 ± 42	647 ± 56
	^{232}Th	68 ± 3	75 ± 4
	^{238}U	100 ± 3	109 ± 5
Ham ULB PMT	^{40}K	12 ± 7	24 ± 9
	^{232}Th	3.6 ± 1.2	1.8 ± 1.0
	^{238}U	47 ± 28	59 ± 28
	^{226}Ra	8.0 ± 1.2	6.1 ± 1.2
	^{60}Co	4.1 ± 0.7	5.1 ± 0.8

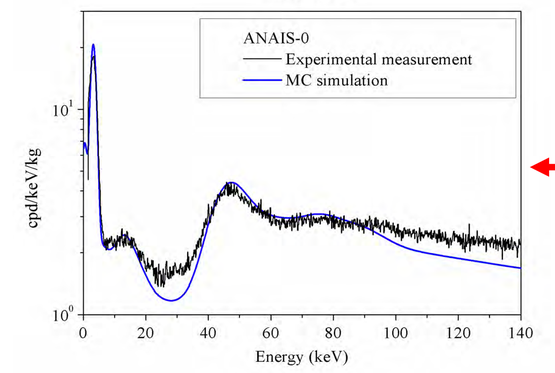
PMT models: ET LB PMT = ET 9302B
Ham LB PMT = Hamamatsu R6233-100 MOD
Ham ULB PMT = Hamamatsu R11065 SEL

Simulated component	Isotope	Activity
Copper encapsulation	^{40}K	< 11 mBq
	^{232}Th	< 4.1 mBq
	^{238}U	< 140 mBq
	^{226}Ra	< 2 mBq
	^{60}Co	< 0.94 mBq
Quartz optical window	^{40}K	< 12 mBq/kg
	^{232}Th	< 2.2 mBq/kg
	^{238}U	< 100 mBq/kg
	^{226}Ra	< 1.9 mBq/kg
Light guides	^{40}K	< 21 mBq/guide
	^{232}Th	< 4.1 mBq/guide
	^{238}U	< 120 mBq/guide
	^{226}Ra	< 4.7 mBq/guide
Optical coupling grease	^{40}K	< 200 mBq/kg
	^{232}Th	< 200 mBq/kg
	^{238}U	< 2000 mBq/kg
	^{226}Ra	< 30 mBq/kg
Archaeological lead	^{210}Pb	< 20 mBq/kg
	^{232}Th	< 0.3 mBq/kg
	^{238}U	< 0.2 mBq/kg
Inner volume air	^{222}Rn	< 0.6 Bq/m^3

Data vs simulated contributions



High energy spectrum: most of the measured background is nicely reproduced

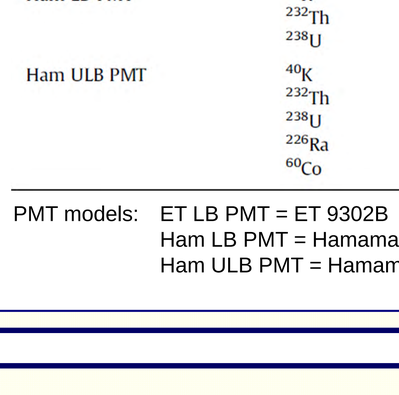


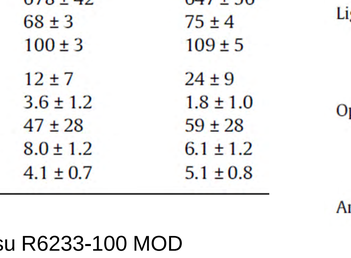
Low energy spectrum: some non-explained components are still present (plausible background sources analyzed)

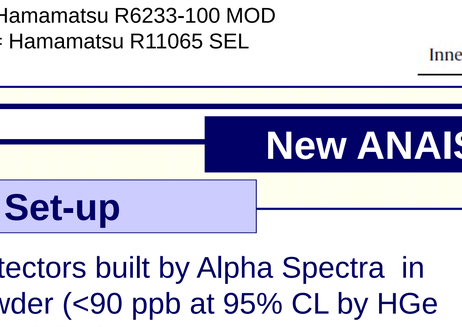
New ANAIS crystals (ANAIS-25): Preliminary background analysis [2]

Set-up

- Two 12.5 kg NaI(Tl) detectors built by Alpha Spectra in USA using screened powder (<90 ppb at 95% CL by HGe spectrometry at LSC) and OFHC copper
- Arrived at Canfranc in December 2012 and coupled to Ham ULB and Hamamatsu R12669 SEL2 PMTs







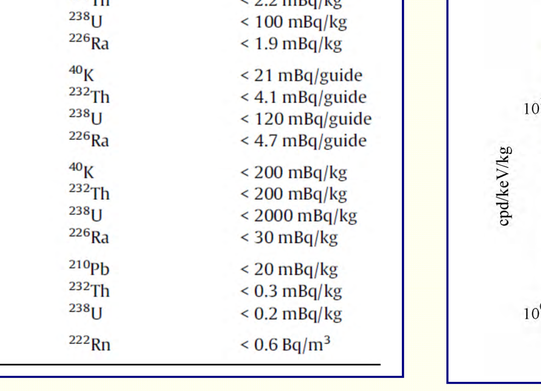
Very good **optical responses:**
(16.13 ± 0.66) phe/keV
(12.58 ± 0.13) phe/keV

Cosmogenic activation

- Emissions from several cosmogenic isotopes identified and decay observed

Difference between first data underground and data taken 75 days later

Emissions from L,K shell EC in Te/I



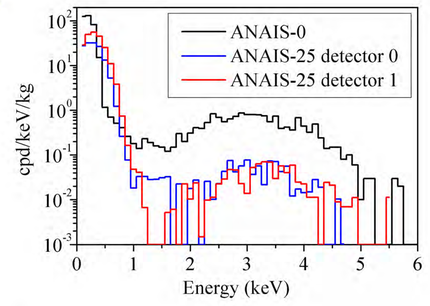
- Preliminary production rates (kg^{-1} d^{-1}) derived

	$T_{1/2}$ (d)	Data	Calculation MENDL2N+YIELDX
^{125}I	59.4	615.5 ± 7.3	600
^{125m}Te	57.4	82.2 ± 2.1	79

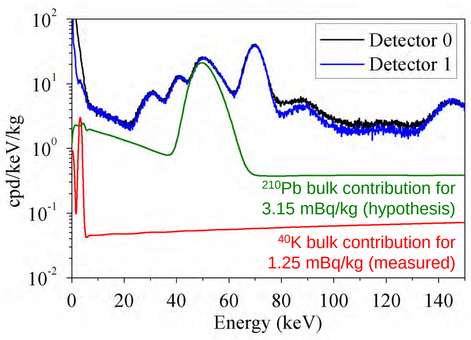
Low energy background

- Preliminary assesment of **^{40}K activity** in crystals using the same coincidence technique

(41.7 ± 3.7) ppb K
(1.25 ± 0.11) mBq/kg ^{40}K



- Although cosmogenic activation is still decaying, complete understanding of background is underway to further reduce it



SUMMARY:

✓ A complete background model was developed for a 9.6 kg detector (ANAIS-0 prototype) after months of data taking in Canfranc based on radiopurity input data and MC simulation, indicating that the NaI(Tl) crystal was the main contributor to the measured background.

✓ First background data of two new 12.5 kg detectors have been analyzed, showing an excellent light collection and a much lower ^{40}K content.

REFERENCES: **[1]** Background model for a NaI(Tl) detector devoted to dark matter searches, Astropart. Phys. 37 (2012) 60-69.
[2] ANAIS-0: Feasibility study for a 250 kg NaI(Tl) dark matter search experiment at the Canfranc Underground Laboratory, C. Cuesta, PhD thesis, March 2013.

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