Commissioning and prospects of the ANAIS-112 experiment

Patricia Villar on behalf of the ANAIS team

RENATA meeting - VIII CPAN days, 28 – 30 November 2016, Zaragoza, Spain
Outline

- The ANAIS experiment
- Detectors performance
- Background evaluation
- ANAIS-112: Status & prospects
- Summary and conclusions
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P. Villar
The ANAIS experiment

**ANAIIS**

Annual modulation with NaI Scintillators

112.5 kg of ultrapure NaI(Tl) detectors in a 3 x 3 matrix configuration at LSC

Confirming DAMA/LIBRA modulation signal:
- Same target and technique
- Different experimental approach
- Different environmental conditions affecting systematics

Experimental requirements:
- Energy threshold < 2 keVee
- Background near the threshold at or below a few counts/(keV kg day)

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The ANAIS experiment

**ANAIS-37**
3 x 12.5 kg
Alpha Spectra Inc.

**ANAIS-0**
9.6 kg Saint-Gobain

**NaI-32**
10.7 kg BICRON

**ANAIS-25**
2 x 12.5 kg
Alpha Spectra Inc.

**ANAIS-112**
9 x 12.5 kg Alpha Spectra Inc.

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Manufacturer: **Alpha Spectra Inc. CO (USA)** from NaI selected powder

**Characteristics:**

- 4.75” φ x 11.75” length cylindrical shape
- OFHC copper encapsulation + Teflon diffusor
- Mylar window for low energy calibration
- Two optical windows for PMTs coupling
- PMTs: Ham12669SEL2 with high quantum efficiency (>33%) and low dark current

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**NO LIGHT GUIDES** → Increase light collection
ANAIS experimental features

**Monitor environmental parameters:**
(External Rn air content, humidity, temperature (inside/outside/electronics), pressure, N\textsubscript{2} flux, PMT HV, gain, trigger rate and level, coincidence window…)

**Muon-tagging system**

**Radon-free low energy calibration system**

**Individual PMT signals digitized 2GS/s with high resolution (14 bits)**

**Electronics:** Air conditioned room to avoid temperature fluctuations

**Robust algorithm for peak identification at low energy**
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Alpha Spectra Inc. detectors for ANAIS

**D0 / D1 modules:** First AS modules grown with purified NaI powder < 90 ppb (Dec 2012)

**D2 module:** WIMPScent-II powder
Improved protocols to reduce $^{210}\text{Pb}$ (March 2015)

**D3 module:** WIMPScent-III powder
Improved powder purification to reduce Potassium (March 2016)

**D4 / D5 modules:**
- WIMPScent-III powder
- Checking/confirming radiopurity protocols @ AS (just arrived at LSC)

ANAIS-25 set-up

ANAIS-37 set-up
(D0+D3+D2)

ANAIS-37 set-up
(D0+D2+D1)

**ANAIS-37 set-up**

**D3 module**

**D4 / D5 modules**

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Excellent Duty Cycle at different ANAIS set-ups and runs

Very important for annual modulation analysis

ANAIS-25-III

ANAIS-37-B
EXCELLENT LIGHT COLLECTION in Alpha Spectra Inc. detectors in all set-ups

<table>
<thead>
<tr>
<th>Detector</th>
<th>Set-up</th>
<th>Light collected (phe/keV) at 22 keV</th>
</tr>
</thead>
<tbody>
<tr>
<td>D0</td>
<td>ANAIS25</td>
<td>15.6 ± 0.2</td>
</tr>
<tr>
<td></td>
<td>ANAIS37</td>
<td>15.3 ± 0.1</td>
</tr>
<tr>
<td></td>
<td>ANAIS37</td>
<td>15.1 ± 0.1</td>
</tr>
<tr>
<td>D1</td>
<td>ANAIS25 (*)</td>
<td>12.6 ± 0.1</td>
</tr>
<tr>
<td></td>
<td>ANAIS25</td>
<td>15.2 ± 0.1</td>
</tr>
<tr>
<td></td>
<td>ANAIS37</td>
<td>14.4 ± 0.1</td>
</tr>
<tr>
<td>D2</td>
<td>ANAIS37</td>
<td>15.4 ± 0.1</td>
</tr>
<tr>
<td>D3</td>
<td>ANAIS37</td>
<td>15.2 ± 0.5</td>
</tr>
</tbody>
</table>

(*) PMT: Ham R11065

Good energy resolution and threshold
Triggering below 1 keV with high efficiency

Determined by coincidences between high energy gammas and low energy events in due to $^{22}$Na and $^{40}$K decays in the bulk of adjacent modules.

Physical events

But difficult to disentangle from PMT-origin events.
Linear calibration **down to 0.9 keV using** internal emissions (from $^{40}$K and $^{22}$Na in the bulk) and external sources at low energy ($^{109}$Cd).
MULTIPARAMETRIC CUTS required for data selection down to 1 keVee:

- Number of peaks in the pulse (>2 per PMT)
- Temporal parameters of the total light pulse
- Asymmetry in the light sharing
- Coincidence with a signal in the muon veto
- Time difference with previous event
- Quality cut on baseline calculation
- Coincidence among modules

Acceptance efficiency estimate

Live Time Estimate

Robust acceptance efficiency Estimate (during $^{109}$Cd/$^{57}$Co calibrations)
The ANAIS experiment
Detectors performance
**Background evaluation**
ANAIS-112: Status & prospects
Summary and conclusions
## Internal contaminations

<table>
<thead>
<tr>
<th></th>
<th>$^{40}$K</th>
<th>$^{238}$U</th>
<th>$^{210}$Pb</th>
<th>$^{232}$Th</th>
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<tr>
<td>D0</td>
<td>1.4 mBq/kg (45 ppb K)</td>
<td>9 μBq/kg</td>
<td>3.15 mBq/kg</td>
<td>5 μBq/kg ($^{220}$Rn-$^{216}$Po) 3 μBq/kg ($^{212}$Bi-Po)</td>
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<tr>
<td>D1</td>
<td>1.1 mBq/kg (34 ppb K)</td>
<td>9 μBq/kg</td>
<td>3.15 mBq/kg</td>
<td>4 μBq/kg ($^{220}$Rn-$^{216}$Po)</td>
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<tr>
<td>D2</td>
<td>1.1 mBq/kg (34 ppb K)</td>
<td>2.7 μBq/kg</td>
<td>0.70 mBq/kg</td>
<td>$\approx$1 μBq/kg ($^{220}$Rn-$^{216}$Po) $\approx$1 μBq/kg ($^{212}$Bi-Po)</td>
</tr>
<tr>
<td>D3</td>
<td>0.6 mBq/kg (19 ppb K)</td>
<td>$\sim$4 μBq/kg</td>
<td>$\sim$1.8 mBq/kg</td>
<td>$\approx$0.6 μBq/kg ($^{220}$Rn-$^{216}$Po) $\approx$0.6 μBq/kg ($^{212}$Bi-Po)</td>
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- **Very good levels of $^{238}$U & $^{232}$Th**
- **Acceptable levels of $^{40}$K (improved in last module to the DAMA upper limit)**
- **$^{210}$Pb out-of-equilibrium contamination, improved in D2, but increased again in D3**
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- Very good levels of $^{238}$U & $^{232}$Th
- Acceptable levels of $^{40}$K (improved in last module to the DAMA upper limit)
- $^{210}$Pb out-of-equilibrium contamination, improved in D2, but increased again in D3
The $^{210}\text{Pb}$ problem

$^{210}\text{Pb}$ contamination is a problem at low energy

Origin of the $^{210}\text{Pb}$ contamination is under study in collaboration with Alpha Spectra

→ 1 kg crystals tests at LSC

Two of the samples measured by now are below 0.7 mBq/kg (D2 level)
Background in the RoI

Background at low energy is dominated by $^{210}\text{Pb}$ (continuum) and $^{40}\text{K}$ (peak) contaminations in the crystal.

![Graph showing background at low energy](image)

- Cosmogenics still decaying in D3
- Working to improve filtering protocols below 2 keV
D0 & D2: Continuum excess at low energy can be explained by including $^3$H and $^{210}$Pb at a surface depth from 10 - 100 $\mu$m
Background in the RoI

**D0 Detector**

**D2 Detector**

**D3 Detector**

**D0 & D2**: Continuum excess at low energy can be explained by including $^3$H and $^{210}$Pb at a surface depth from 10 - 100 $\mu$m

**D3**: Under construction

D0 & D2 model preliminarily extended to D3

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Background in the RoI

D0 Detector & D2 Detector: Continuum excess at low energy can be explained by including $^{3}$H and $^{210}$Pb at a surface depth from 10 - 100 $\mu$m.

D3 Detector

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ANAIS-112 status

**D4 & D5 arrived at LSC!**

- D4 → same ingot as D3
- D5 → same ingot as AS2K2/3

**SCHEDULE:**

- Nov 14th: Start data-taking for background assessment

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**The ANAIS Diary**

- D6, D7, D8 (AS2K2/3 ingot)
  - purchasing immediately after confirming $^{210}\text{Pb}$ content
    - production: 6/8 weeks
    - transport: 4 weeks

**February:**

- Mounting ANAIS-112
- End February /
beginning March:

**START DATA-TAKING!!**
ANAIS-112 sensitivity

- 1-6 keVee region
- D2 background level
- 5 years data taking
- Detection limit at 90% C.L. for a critical limit at 90% C.L.

According to S. Cebrián et al., Astroparticle Physics 14, 2001, 339
A Liquid Scintillator Veto (LSV) could be incorporated to ANAIS-112 in a second phase of the experiment.

**LSVc**
3.8 t LAB scintillator

**LSVb**
1.7 t LAB scintillator (fits in present experimental setup)

<table>
<thead>
<tr>
<th>Configuration</th>
<th>R.F. (% $^{40}\text{K}$ from crystals)</th>
<th>R.F. (% $^{22}\text{Na}$ from crystals)</th>
<th>R.F. (% PMTs)</th>
<th>R.F. (% All)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3x3 modules</td>
<td>69.0</td>
<td>62.4</td>
<td>62.3</td>
<td>83.7</td>
</tr>
<tr>
<td>3x3 modules + LSVb (500 keV threshold)</td>
<td>20.5</td>
<td>11.0</td>
<td>31.1</td>
<td>61.3</td>
</tr>
<tr>
<td>3x3 modules + LSVb</td>
<td>14.5</td>
<td>3.7</td>
<td>7.3</td>
<td>56.6</td>
</tr>
<tr>
<td>3x3 modules + LSVc (500 keV threshold)</td>
<td>15.5</td>
<td>5.7</td>
<td>29.3</td>
<td>59.1</td>
</tr>
<tr>
<td>3x3 modules + LSVc</td>
<td>11.9</td>
<td>1.2</td>
<td>7.3</td>
<td>55.6</td>
</tr>
</tbody>
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ANAIS experimental proposal:

• **112.5 kg (3x3 crystals matrix) of NaI(Tl) at LSC:**
  - 6 modules available at LSC (75 kg) / waiting for 3 more with improved radiopurity
  - Blind Analysis Strategy

• **Good quality NaI(Tl) detectors from Alpha Spectra:**
  - Outstanding light collection
  - Triggering at 1 keVee
  - Potassium content at 20ppb level
  - $^{210}\text{Pb}$ required level to be confirmed with D5

• Shielding, DAQ system and software ready at LSC – Hall B
• Expected to start data-taking by the beginning of March 2017
• Neutron calibrations and REF measurements pending

Good sensitivity prospects for exploring the DAMA/LIBRA signal in a model independent way:

DISCOVERY POTENTIAL
Thank you