TESTING DAMA/LIBRA RESULT WITH ANAIS-112 EXPERIMENT


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**ANAIS**

Dark Matter 2018

Coming to UCLA February 21-23, 2018
• ANAIS scientific case
• ANAIS status
  • Detectors performance
  • ANAIS-112 set-up accomplishment
• ANAIS sensitivity prospects
• Summary and outlook
• Confirmation of DAMA-LIBRA modulation signal -> same target and technique / different experimental approach / different environmental conditions affecting systematics

• At Canfranc Underground Laboratory @ SPAIN (under 2450 m.w.e.)

• 3x3 matrix of 12.5 kg cylindrical modules = 112.5 kg of active mass
Annual modulation in the DM detection rate is produced by the change on the relative velocity WIMP-detector along the year.

\[ \eta(t) = v_\odot(t)/v_0 = \eta_0 + \Delta \eta \cos \omega(t - t_0) \]

\[ S_k(t) = S_{0,k} + S_{m,k} \cos \omega(t - t_0) \]

Small effect (<7% of \( S_0 \))

Inverse modulation at very low energies

DAMA/LIBRA modulation result is highly significant, but difficult to reconcile with other experiments. We need model independent confirmation or refutation.
**BICRON**

9.6 kg
Saint-Gobain

12.5 kg
Alpha Spectra Inc.

107 kg
BICRON

**DM-32**

**ANAIS-25**

**ANAIS-37**

**ANAIS-112**

**Experimental Approach**
• 12.5 kg cylindrical NaI(Tl) detectors built @ Alpha Spectra, Co (US) from NaI selected powder & developing specific radiopurity protocols with them
• Housed in OFE copper @ AS
• Mylar windows allow for LE calibration
• HQE PMTs Ham12669SEL2 coupled at LSC clean room
• Electroformed copper PMT housing prepared at LSC electroforming facility

Last three modules received at LSC in March 2017
### Excellent light collection

A factor of 2 larger than the published light collection for DAMA/LIBRA detectors

<table>
<thead>
<tr>
<th>Detector</th>
<th>PMT/set-up</th>
<th>Total Light Collection (phe/keV)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>D0</strong></td>
<td>Ham R12669 / ANAIS25</td>
<td>15.6 ± 0.2</td>
</tr>
<tr>
<td></td>
<td>Ham R12669 / ANAIS37</td>
<td>15.3 ± 0.1</td>
</tr>
<tr>
<td></td>
<td>Ham R12669 / A37D3</td>
<td>15.1 ± 0.1</td>
</tr>
<tr>
<td></td>
<td>Ham R12669 / ANAIS112</td>
<td>14.6 ± 0.1</td>
</tr>
<tr>
<td><strong>D1</strong></td>
<td>Ham R11065 / ANAIS25</td>
<td>12.6 ± 0.1</td>
</tr>
<tr>
<td></td>
<td>Ham R12669 / ANAIS25-III</td>
<td>15.2 ± 0.1</td>
</tr>
<tr>
<td></td>
<td>Ham R12669 / ANAIS37</td>
<td>14.4 ± 0.1</td>
</tr>
<tr>
<td></td>
<td>Ham R12669 / ANAIS112</td>
<td>14.7 ± 0.1</td>
</tr>
<tr>
<td><strong>D2</strong></td>
<td>Ham R12669 / ANAIS37</td>
<td>154 ± 0.1</td>
</tr>
<tr>
<td></td>
<td>Ham R12669 / ANAIS112</td>
<td>14.6 ± 0.1</td>
</tr>
<tr>
<td><strong>D3</strong></td>
<td>Ham R12669 / A37D3</td>
<td>15.2 ± 0.5</td>
</tr>
<tr>
<td></td>
<td>Ham R12669 / ANAIS112</td>
<td>14.6 ± 0.1</td>
</tr>
<tr>
<td><strong>D4</strong></td>
<td>Ham R12669 / A37D5</td>
<td>14 ± 1</td>
</tr>
<tr>
<td></td>
<td>Ham R12669 / ANAIS112</td>
<td>14.5 ± 0.1</td>
</tr>
<tr>
<td><strong>D5</strong></td>
<td>Ham R12669 / A37D5</td>
<td>15 ± 1</td>
</tr>
<tr>
<td></td>
<td>Ham R12669 / ANAIS112</td>
<td>14.3 ± 0.1</td>
</tr>
<tr>
<td><strong>D6</strong></td>
<td>Ham R12669 / ANAIS112</td>
<td>12.7 ± 0.1</td>
</tr>
<tr>
<td><strong>D7</strong></td>
<td>Ham R12669 / ANAIS112</td>
<td>14.9 ± 0.1</td>
</tr>
<tr>
<td><strong>D8</strong></td>
<td>Ham R12669 / ANAIS112</td>
<td>16.0 ± 0.1</td>
</tr>
</tbody>
</table>
ANAIS-112 consists of a matrix of 3x3 modules and was installed in March 2017.

10 cm archaeological lead + 20 cm low activity lead

ANAIS-112 detectors testing and commissioning run started immediately and was fully operative by June-July 2017 for detector calibration and general assessment.
ANAIS-112 scintillators veto system was installed in May 2017.

ANAIS-112 neutron shielding was installed in July 2017. It consists of water tanks and polyethylene (40 cm) It allows partial periodic opening for calibrations

ANAIS-112 DM run started on August 3, 2017
• DAQ hardware and software designed and tested with previous set-ups
  -> ROBUST & SCALABLE
  • Individual PMT signals digitized * and fully processed
  • Trigger at phe level for each PMT
  • Logical AND coincidence in 200ns window for each module triggering
  • Redundant energy conversion
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  • Preamplifiers designed at UZ
  • Electronics at air-conditioned-room to decouple from Hall B temperature fluctuations

* CAEN V1729A – VME 6U board – MATACQ chip
  14 bits / 2 GS/s

   ![Diagram of the DAQ setup]
Calibrations every 2 weeks at low energy

$^{109}$Cd sources on flexible wires allowing the simultaneous calibration of the 9 modules
Energies 11.9 keV, 22.6 keV and 88.0 keV
Monitoring of environmental parameters

It consists of several windows for monitoring LN2 flux; temperatures at electronics, inner shielding, laboratory, preamplifiers, etc.; radon content in laboratory air; relative humidity; HV supply to every PMT; muon rates; etc. All the data are saved every few minutes and alarms have been set on the most relevant parameters sending an alarm message to ANAIS GLIMOS through Telegram.
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First six and a half months of ANAIS-112DM run, from 03-08-17 until 15-02-18

185.81 days of live time accumulated
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1 hour with rate calculated every second
Periodic $^{109}$Cd calibrations

They allow monitoring (and if necessary correcting) possible gain drifts in the modules.

Evolution of the positions of $^{109}$Cd lines along the six months of measurement.

Most of the modules have been very stable during this period of data taking.
Periodic monitoring of light collection along ANAIS-112 DM run.

Evolution of the light collection estimates per PMT and per module, using the periodic Cd-109 calibration (22.6 keV line) and the photoelectron area distribution derived from background runs.

It is to remark the stability of the total light collection per module along the data taking.
Monitoring of alpha decay rate in D5-D8 in ANAIS-112

Alpha events rate is dominated by $^{210}$Po decay, allowing to characterize the $^{210}$Pb content in all the crystals.
Potassium content in all the AS modules: obtained by using coincidences with all the modules

<table>
<thead>
<tr>
<th>Module</th>
<th>Potassium content</th>
</tr>
</thead>
<tbody>
<tr>
<td>D0</td>
<td>43 ppb</td>
</tr>
<tr>
<td>D1</td>
<td>35 ppb</td>
</tr>
<tr>
<td>D2</td>
<td>39 ppb</td>
</tr>
<tr>
<td>D3</td>
<td>21 ppb</td>
</tr>
<tr>
<td>D4</td>
<td>18 ppb</td>
</tr>
<tr>
<td>D5</td>
<td>30 ppb</td>
</tr>
<tr>
<td>D6</td>
<td>28 ppb</td>
</tr>
<tr>
<td>D7</td>
<td>31 ppb</td>
</tr>
<tr>
<td>D8</td>
<td>22 ppb</td>
</tr>
</tbody>
</table>
Spectra at low energy in coincidence with a high-energy gamma at 1460.5 keV (1274.5 keV) in another module for all the modules in the ANAIS-112 set-up. These spectra have been used for the determination of the potassium contents, but also for calibrating down to the threshold our experiment.

We are triggering down to 1 keVee

1460.9 keV
3.2 keV

1274.5 keV

40K → 40Ar

22Na → 22Ne

0.9 keV

40K

22Na
PMT events filtering (no electronic noise):

Multiparametric cuts on:
- Number of peaks in the pulse (n>2 in each PMT)
- Temporal parameters of the pulse
- Time after muon veto trigger (Asymmetry in light sharing)

Analysis threshold is limited by efficiency of this filtering

Acceptance efficiency curves from external calibration data
Calibration in energy in two steps—EXTERNAL $^{109}$Cd sources allow to calibrate every two weeks below 100 keV and to correct for possible gain drifts.
Final calibration will use both external sources at LE ($^{109}\text{Cd}$) and internal emissions (from $^{40}\text{K}$ and $^{22}\text{Na}$ in the bulk) in the range 0.9 to 22 keV.
Background model considering the measured crystal activities and the ANAIS-112 configuration, point to equivalent relevant background sources in the very low energy region:

$^{40}$K and $^{22}$Na peaks and $^{210}$Pb (bulk+surface) and $^3$H continua are the most significant contributions in the very low energy region.

- Background model well understood in all the modules


J. Amaré et al. JCAP02 (2015) 046


Detection limit at 90% C.L. for a critical limit at 90% C.L. for ANAIS-112

- Estimated average background from D0-D5 measured levels (corrected for cut efficiency)
- 2-6 keV$_{ee}$ region
- 5 years

ANAIS-112 can detect the annual modulation in the 3σ region compatible with the DAMA/LIBRA result.

90% probability of detecting an annual modulation signal at 90% C.L.
Detection limit at 90% C.L. for a critical limit at 90% C.L. for ANAIS-112

- Estimated average background from D0-D5 measured levels (corrected for cut efficiency)
- 2-6 keV$_{ee}$ region
- 5 years

**ANAIS-112** has a detection limit for annual modulation lower than the measured amplitude by DAMA/LIBRA: $0.0112 \pm 0.0012$ cpd/kg/keV$_{ee}$
ANAIS-112 has been installed successfully at LSC:
- 112.5 kg (3x3 crystals matrix) of NaI(Tl) built at AS
  - outstanding light collection
  - good background understanding
Electronics/Acquisition has been fine-tuned
Dark matter run started data taking by August, 3rd, 2017
Data taking expected to go on in these conditions during the next two years (first phase):
  - Control populations in preparation
  - Blind annual modulation analysis foreseen
Good sensitivity prospects for exploring the DAMA/LIBRA signal:
5 years data taking needed for a 3 sigma significant result
Scintillation Quenching Factor measurement for nuclear recoils @ TUNL laboratories is in preparation

Combining data with COSINE-100 experiment is under discussion

Installation of a blank module before the summer -> control population is under consideration

For the second phase of measurement (last 2 years) we are considering possible experiment upgrades:
  - Application of Si PMs to the light readout of NaI(Tl) LSV System
  - Making ANAIS data public after use to allow for independent analysis
Thank you for your attention