Update on the ANAIS experiment. ANAIS-0 prototype results at the new Canfranc Underground Laboratory.

OUTLINE

1. ANAIS EXPERIMENT
   Introduction and present status.

2. ANAIS-0 MODULE
   Description and experimental results: background analysis, events selection.

3. BACKGROUND SIMULATION
   Description of the simulated set-ups, components of the background model, simulation inputs, results for different configurations (present and future).

4. CONCLUSIONS
ANAIS is a project aiming to set up, at the new facilities of the Canfranc Underground Laboratory (SPAIN), a large scale NaI(Tl) experiment to look for dark matter.

**Motivation**
Study of the annual modulation DAMA/LIBRA positive signal. CoGeNT results as another hint.

**Experimental goals:**
- Energy threshold < 2 keV.
- Background at low energy as low as possible.
- Very stable operation conditions.

**Detector mass:**
100 kg funding guaranteed, possible enlargement up to 250 kg.
ANAIS STATUS

• **Ultrapure NaI(Tl) crystals** are being developed:
  – NaI powder is being purified in order to reduce K-40 bulk content.
    First 1 kg of purified NaI powder (below 100 ppb K by AAS) is being screened by HP Ge spectrometry at LSC.
  – NaI growing that should reduce U and Th bulk content. Terms under discussion.

• **Photomultipliers and light guides.** Two options still under consideration:
  1) Low background PMTs + Light guides.
     Hamamatsu (R6233-100).
     Electron Tubes Limited (9302B).
  2) Ultra low background PMTs without light guides.
     Hamamatsu (R11065SEL).

• **VME acquisition** completed, being tested at the University of Zaragoza.

• **Stability conditions** and environmental parameters are being monitored with ANAIS-0 module at new LSC facilities.
2. ANAIS-0 MODULE

On-going measurements at new facilities of the Canfranc Underground Laboratory to:
• Characterize ANAIS background.
• Optimize events selection.
• Determine the calibration method.
• Test the acquisition code and electronics.

Copper encapsulation allowing different configurations and tests of PMTs.

Configurations with and without light guides.

NaI(Tl) (9.6kg) old crystal made by St Gobain.
254x101.6x101.6mm³
Beta – gamma spectrum of different set-ups (only alpha particles at high energy have been filtered):

**Ultra low background PMTs**
- Ultra low background PMTs + Light guides
- Low background PMTs
- Low background PMTs + Light guides

**HIGH ENERGY**

Results:
- Low background PMTs require light guides.
- Ultra low background PMTs could be used without light guides.
Both options are almost equivalent in the low energy background.
ANAIS-0 EXPERIMENTAL RESULTS. EVENTS SELECTION

ANAIS 0 with ULB Ham PMTs without light guides.
- Live time = 37.4914 days.
- Muon related events are rejected (LT = 37.4897 days).
- NaI(Tl) scintillation events selected through number of photoelectrons (n>4).
- Efficiency checked with calibrations.

![Graphs showing raw and selected scintillation events with counts and channels.]

C. Cuesta
Screening of all materials used with a HP Ge detector at LSC

- Photomultipliers:

<table>
<thead>
<tr>
<th>Material</th>
<th>$^{40}$K (mBq/PMT)</th>
<th>$^{232}$Th (mBq/PMT)</th>
<th>$^{238}$U (mBq/PMT)</th>
<th>$^{60}$Co (mBq/PMT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low background Electron Tubes Limited 9302B</td>
<td>420 ± 50</td>
<td>24 ± 4</td>
<td>220 ± 12</td>
<td>-</td>
</tr>
<tr>
<td>Low background Hamamatsu R6233-100</td>
<td>678 ± 42</td>
<td>67.8 ± 2.8</td>
<td>100 ± 2.8</td>
<td>-</td>
</tr>
<tr>
<td>Ultra low background Hamamatsu R11065SEL</td>
<td>32 ± 9</td>
<td>1.9 ± 0.7</td>
<td>$^{238}$U - 33 ± 7 $^{226}$Ra - 6.7 ± 0.9</td>
<td>3.7 ± 0.5</td>
</tr>
</tbody>
</table>

- Light guides, quartz windows, voltage dividers, reflectant, mylar, optical coupling grease, glue, teflon, roman lead, normal lead, copper have been screened and upper limits for the different contributions obtained.

C. Cuesta
**ANAIS-0 CRYSTAL: \( ^{40}\)K BULK CONTENT**

**Measurement in coincidence**

Coincidence criteria: 3.2 keV in ANAIS-0 and 1460.9 keV in the other.

Efficiency of the coincidence determined by MC.

\[ ^{40}\text{K} \quad (T_{1/2} = 1.277 \times 10^9 \text{ years}) \]

- E.C. (10.72\%) \( Q = 1504.8 \text{ keV} \)
- \( \beta^- \) (89.28\%) \( Q = 1312.1 \text{ keV} \)

\( ^{40}\text{Ar} \)

\( ^{40}\text{Ca} \)

\( ^{40}\text{K} \rightarrow ^{40}\text{Ar} \)

\( \gamma \) 1460.9 keV (10.62\%)

\( \beta^- \) (89.28\%) \( (Q_{\beta} = 1312.1 \text{ keV}) \)

\( 10.67\% \)

\( 0.05\% \)

\( 3.2 \text{ keV} \)

\( LT = 5412391 \text{ s (63 days)} \)

Result for \( ^{40}\text{K} \) bulk activity of the ANAIS-0 crystal:

\[ 12.7 \pm 0.6 \text{ mBq/kg} \]

(i.e. 0.42 \pm 0.02 ppm K)
1) Alpha events can be discriminated from beta-gamma by PSA.
2) Alpha-Alpaha events from Bi-Po sequences have been identified and used for calibration of the spectrum.
3) Alpha spectrum has been fitted allowing broken equilibrium in natural chains.

<table>
<thead>
<tr>
<th>Parent Isotope</th>
<th>Activity (mBq/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{232}$Th</td>
<td>$0.013 \pm 0.005$</td>
</tr>
<tr>
<td>$^{228}$Th</td>
<td>$0.035 \pm 0.003$</td>
</tr>
<tr>
<td>$^{238}$U / $^{234}$U</td>
<td>$0.075 \pm 0.005$</td>
</tr>
<tr>
<td>$^{230}$Th</td>
<td>$0.023 \pm 0.007$</td>
</tr>
<tr>
<td>$^{226}$Ra</td>
<td>$0.098 \pm 0.004$</td>
</tr>
<tr>
<td>$^{210}$Pb</td>
<td>$0.188 \pm 0.005$</td>
</tr>
</tbody>
</table>
3. BACKGROUND SIMULATION

• **Geant4.9.4.p01**
  
  Energy conservation in the decays has been checked.
  
  Some improvements in the code with respect to previous versions.

• **ANAIS-0 geometry**

  Shielding:
  
  10 cm roman lead
  
  20 cm lead

  Bulk contaminations of:

  - $^{40}$K $\rightarrow$ Coincidence measurement
  - $^{232}$Th, $^{228}$Th, $^{238}$U, $^{234}$U, $^{226}$Ra and $^{210}$Pb $\rightarrow$ PSA-alfa analysis
  - $^{129}$I $\rightarrow$ 9.01 mBq/kg, *NIM A 592 (2008) 297*

  PMTs and other materials contaminations (upper limits).
BACKGROUND SIMULATION: ALPHA SPECTRUM

ANAIS-0 background with LB Ham PMTs and light guides.

- NaI crystal **bulk background** contributions.

![Graph showing the alpha spectrum with various isotopes and their contributions.](image)
BACKGROUND SIMULATION: BETA-GAMMA SPECTRUM

ANAIS-0 background with ULB Ham PMTs without light guides.

- NaI crystal **bulk background** contributions.

![Graph showing beta-gamma spectrum with various contributions and energy levels.](image-url)
BACKGROUND SIMULATION: BETA-GAMMA SPECTRUM

ANAIS 0 background with ULB Ham PMTs without light guides.

- Adding **contributions from the rest of components** (many of them upper limits...).

Above 500 keV the background seems to be completely explained by the considered contributions.
At low energy we find some non-explained components.

Contributions under study:
- $^{210}\text{Pb}$ at NaI(Tl) surface.
- $^{210}\text{Pb}$ at copper encapsulation surface.
- Bulk $^3\text{H}$ at NaI(Tl).
- Scintillation in other materials.
- Fast neutrons.
BACKGROUND SIMULATION: DIFFERENT CONFIGURATIONS

- High energy

- Low energy

Raw spectra. Cosmogenic lines (CL) have not been simulated.

C. Cuesta
PROSPECTS FOR ANAIS

- 20 ppb K
- $^{232}\text{Th}$ & $^{238}\text{U}$ not reduced

Expected background fulfill ANAIS requirements. However, unexplained components should be well understood.
CONCLUSIONS

• **ANAIS status.**
  On-going NaI purification.
  Crystal growing terms under discussion (production along 2012).
  ANAIS-0 (old NaI crystal) taking data at the LSC.

• **ANAIS-0 results.**
  Two configurations tested: Ultra low background PMTs or low background PMTs and light guides equivalent in background.

• **ANAIS-0 background simulation.**
  Background above 500 keV seems to be completely explained by the considered contributions.
  At low energy we find some non-explained components that are under study.
  New crystals (20 ppb K) could reach the required background level.

C. Cuesta