Status of the ANAIS experiment.

1. ANAIS EXPERIMENT
   Introduction and present status of ultrapure NaI(Tl) crystals.

2. ANAIS-0 MODULE
   Description and experimental results.

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

C. Cuesta
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:**
250 kg potassium-purified NaI(Tl) crystal. Complementary funding of Multidark and LSC.
ULTRAPURE NaI(Tl) POWDER

- Goal: 20 ppb of potassium.
- Radioactivity of several NaI samples from different suppliers have been measured. AAS and HP Ge spectrometry techniques have been used.
- Finally, 1 kg of NaI powder with < 100 ppb K has been screened by HP Ge spectrometry at LSC. Improving the limit requires other approach. Due to the sensitivity level of the detector no more precision is possible.
ULTRAPURE NaI(Tl) CRYSTALS

• **2 Ultrapure NaI(Tl) detectors** are being built:
  – 2 NaI(Tl) crystals have been grown with this ultrapure NaI powder.
  – At the moment, they are being encapsulated.

  ![Diagram of NaI(Tl) crystals]

  • Cylindrical shape (4.75" x 11.75") of 12.5 kg each.
  • OFHC copper encapsulated.
  • Mylar window allowing low energy calibrations.
  • Demountable in order to test them with our PMTs (already tested).

  – They will be ready along May, and shipped to the Canfranc Underground Laboratory.
  – $^{40}\text{K}$ coincidence measurement will be immediately carried out to quantify potassium contamination at the required level.
  – Next steps depend on this result.

C. Cuesta
2. ANAIS-0 MODULE

On-going measurements at new facilities of the Canfranc Underground Laboratory to:

- Characterize ANAIS background.
- Optimize events selection.
- Design the calibration method.
- Test the acquisition code and electronics.
- Determine the optimum configuration of photomultipliers and light guides.

Copper encapsulation allowing different configurations and tests of PMTs.

<table>
<thead>
<tr>
<th>Set-up</th>
<th>PTM</th>
<th>Light guides</th>
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<tbody>
<tr>
<td>1</td>
<td>ET LB</td>
<td>No</td>
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<td>Ham LB</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>Ham ULB</td>
<td>Yes</td>
</tr>
<tr>
<td>4</td>
<td>Ham ULB</td>
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</table>

Nal(Tl) (9.6kg) old crystal made by St Gobain.
254x101.6x101.6mm³
ANAIS-0 MODULE

• **Shielding:**
  - 10 cm roman lead + 20 cm lead.
  - 3 active vetoes anti-muons.
  - New anti-radon box, adaptable to the complete ANAIS experiment.

• **Photomultipliers:** Two options have been considered:
  1) Low background PMTs + Light guides.
     Hamamatsu (R6233-100). Ham LB
     Electron Tubes Limited (9302B). ET LB
  2) Ultra low background PMTs without light guides.
     Hamamatsu (R11065SEL). Ham ULB
     Recently, other option under study:
     Hamamatsu (R6956MOD).

• **VME electronics** and final acquisition are being tested.
ANAIOS-0 EXPERIMENTAL RESULTS. RAW BACKGROUND.

- **HIGH ENERGY**

Only filtered high energy alpha particles.

- **LOW ENERGY**

Cosmogenic lines (CL).

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**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 with ULB Ham PMTs without light guides.

- Live time = 123.25 days.
- Muon related events are rejected.
- NaI(Tl) scintillation events selected through number of photoelectrons ($n > 4$) and p1 parameter.
- Efficiency checked with calibrations.
MATERIAL SCREENING FOR ANAIS BKG UNDERSTANDING

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

- Photomultipliers:

<table>
<thead>
<tr>
<th>Material/Manufacturer</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>68 ± 3</td>
<td>100 ± 3</td>
<td>-</td>
</tr>
<tr>
<td>Ultra low background Hamamatsu R11065SEL</td>
<td>12 ± 7</td>
<td>3.6 ± 1.2</td>
<td>$^{238}$U - 47 ± 28</td>
<td>$^{226}$Ra – 8.0 ± 1.2</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.

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**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.

Result for $^{40}$K bulk activity of the ANAIS-0 crystal:

$$12.7 \pm 0.5 \text{ mBq/kg}$$

(i.e. $0.42 \pm 0.02 \text{ ppm K}$)
1) Alpha events can be discriminated from beta-gamma by PSA.
2) Alpha-Alpa 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.

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<tr>
<th>Parent Isotope</th>
<th>Activity (mBq/kg)</th>
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<tr>
<td>$^{232}$Th</td>
<td>0.013 ± 0.005</td>
</tr>
<tr>
<td>$^{228}$Th</td>
<td>0.035 ± 0.003</td>
</tr>
<tr>
<td>$^{238}$U / $^{234}$U</td>
<td>0.075 ± 0.005</td>
</tr>
<tr>
<td>$^{230}$Th</td>
<td>0.023 ± 0.007</td>
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<tr>
<td>$^{226}$Ra</td>
<td>0.098 ± 0.004</td>
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<tr>
<td>$^{210}$Pb</td>
<td>0.188 ± 0.005</td>
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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**

![Diagram of ANAIS-0 geometry](image)

Bulk contaminations in NaI(Tl) crystal of: $^{40}$K → Coincidence measurement $^{232}$Th, $^{228}$Th, $^{238}$U, $^{234}$U, $^{226}$Ra and $^{210}$Pb → PSA $^{129}$I → 9.01 mBq/crystal, *NIM A 592 (2008) 297*

Photomultipliers contaminations.
Upper limits for contamination in quartz windows, light guides, OFHC copper, roman lead. Radon content in the air filling the inner volume of the shielding.

Shielding:
- 10 cm roman lead
- 20 cm lead
BACKGROUND SIMULATION: ALPHA SPECTRUM

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

- NaI crystal **bulk background** contributions.

![Graph showing alpha energy spectrum with isotopes labeled](image)

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Nal crystal bulk background contributions.
BACKGROUND SIMULATION: BETA-GAMMA SPECTRUM

Contributions from the **rest of components** (many of them upper limits...).
**BACKGROUND SIMULATION: BETA-GAMMA SPECTRUM**

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

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**Graph:**

- **x-axis:** Energy (keV)
- **y-axis:** cpd/keV/kg

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**BACKGROUND SIMULATION: BETA-GAMMA SPECTRUM**

Comparison of simulated and experimental spectra at set-up 4.

- **HIGH ENERGY**

![High Energy Spectrum](image)

- **LOW ENERGY**

![Low Energy Spectrum](image)

C. Cuesta
At low energy we find some non-explained components. We have considered some hypotheses to explain those events:

- $^{210}$Pb at NaI(Tl) surface (1.7 mBq in 1µm).
- $^{210}$Pb at copper encapsulation surface (75 mBq in 1µm).
- $^{210}$Pb at roman lead shielding (1Bq/kg).
- Bulk $^{3}$H at NaI(Tl) (90 µBq/kg).
- $^{129}$I incremented in 4.5 mBq/crystal.

Some upper limits have been reduced.

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PROSPECTS FOR ANAIS

Using the same background model described but:

- **20 ppb K** (level of new ultrapure crystals).

Remarks:

- $^{232}$Th & $^{238}$U will be reduced.
- Working to minimize external background components.
- Unexplained components should be kept under control (added in green line).

Expected background fulfill ANAIS requirements.

However, unexplained components should be well understood.
CONCLUSIONS

• **ANAIS status.**

  2 ultrapure NaI crystals for ANAIS have been grown with potassium below 100 ppb (at the limit of the analytical techniques available).

  They will be tested in the next future at the LSC to verify potassium level at or below 20ppb.

  Next months are crucial to start the growing of the 250kg if potassium level is finally achieved.

• **ANAIS-0 results.**

  ANAIS-0 (old NaI crystal) taking data at the LSC to test new PMTs, optimize electronic chain and acquisition protocols.

  Two configurations tested: Ultra low background PMTs or low background PMTs and light guides equivalent in background. Other PMTs are being tested now.

• **ANAIS-0 background simulation.**

  Background above 500 keV seems to be nicely explained by the considered contributions.

  At low energy we find some non-explained components that are under study.

C. Cuesta