ANAIS DARK MATTER EXPERIMENT
XXXIX IMFP
CANFRANC 10-FEB-2011

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On behalf of ANAIS coll.
DM expected signal and DM direct detection
The ANAIS experiment
  - Description
  - Prototypes
  - Background and Threshold improvements
  - Slow Control
  - New electronics and acquisition
  - Analysis
  - G4 simulations
Summary
Dark Matter Interaction Rates

Isothermal spherical halo

\[ \sigma_{SI} = 7.2 \times 10^{-6} \text{ pb} \]

Detector physics

- $F^2$ form factor
- $m_n$ target nucleus mass
- $N_T$ number of target nuclei
- $E_R$ recoil energy
- $Q$ REF minor uncertainties

Astrophysics

- $n_0 = \rho_0 / m_w$ local halo density
- $f(v)$ WIMP velocity distr.
- $v_{max}$ escape velocity
- estimates

Particle physics

- $m_w$ WIMP mass
- $\sigma_0$ WIMP elastic scattering cross section
- unknown
Direct Detection of WIMPs

A nuclear recoil is usually expected
Direct Detection with NaI(Tl)

- High light yield
- Low light levels
- 230ns scintillation
- Large masses
- Annual modulation
- Higroscopic
- Internal contaminations
- Quenching factors
- Possible channeling effects
Positive result but difficult comparison among experiments

Annual modulation in the dark matter signal

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

- sinusoidal behaviour
- annual periodicity
- Maximum at around 1 June
- Small effect (<7%)
- Only relevant at very low energy (for NaI, E<6 keVee)
ANAIS Project

With 500 kg.years data, DAMA result could be reproduced if threshold $\sim 2$ keVee and bkg $< 2$ evt/keV/kg/day

- Goal 250 kg NaI
- Several annual cycles
- To be installed at the new LSC facilities
- In ApPEC Roadmap
- MultiDark and CPAN support
ANAIS experiment: antecedents

14 NaI(Tl), used in previous experiments, underground since 1988

PMT EMI9765
quartz window
stainless steel vessel
0.5 mm

Two PMTs needed for threshold improvement
High radiopurity materials selection for background reduction
Re-encapsulation required

10.7 kg
Bare crystal + Teflon diffusor + Light guide+ 2 low bkg PMTs inside a tight Cu box

Tested at LSC old facilities
ANAIS prototypes

OFHC Copper tightly sealed vessel with a calibration window
3” quartz optical windows
ANAIS prototypes

- 9.6 kg NaI(Tl) similar to DAMA crystals bought to Saint Gobain (low K)
- Kept in dry atmosphere (HR<1% glove box for manipulation)
- We measured all materials with our HPGe spectrometer at Canfranc
- We designed the new encapsulation in ETP Copper
- ANAIS-0 module
ANAIS prototypes
Relevant results

Mylar window to allow calibration below 100 keV.

Linear behaviour down to 3 keV
Supporting that our threshold is at 2 keVee
LE lines from $^{55}\text{Fe}$ (5.9keV) and $^{57}\text{Co}$ (6.4keV) affected by surface effects
$^{40}\text{K}$ Crystal characterization

- Dedicated set-ups at old LSC to estimate internal K40 background
- Coincidence measurement: x-ray+ auger-e (3.2keV) with 1460keV
- Estimation of K40 internal contamination and calibration in energy and efficiency

G4DecayTable: K40[0.0]
0: BR: 0.8928  [Phase Space] : e- Ca40[0.0] anti_nu_e
1: BR: 0.00325729 [Phase Space] : nu_e Ar40[1460.9]
2: BR: 0.02206024 [Phase Space] : nu_e Ar40[1460.9]
3: BR: 0.0028845003 [Phase Space] : nu_e Ar40[1460.9]
4: BR: 0.000774271 [Phase Space] : nu_e Ar40[0.0]
5: BR: 0.00017397588 [Phase Space] : nu_e Ar40[0.0]
6: BR: 2.5499654e-05 [Phase Space] : nu_e Ar40[0.0]
7: BR: 9.87e-06 [Phase Space] : e+ Ar40[0.0] nu_e
**$^{40}$K Crystal characterization**

- NaI(Tl) crystal
- ANAIS-0

**$^{40}$K $\rightarrow^{40}$Ar**

- 1460.9 keV
- 3.2 keV

**1460 keV coincidence window**

**Higher E coincidence window**
### $^{40}$K Crystal Characterization

<table>
<thead>
<tr>
<th>Detector</th>
<th>$^{40}$K Activity (mBq/kg)</th>
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</thead>
<tbody>
<tr>
<td>EL603</td>
<td>14.5±0.2</td>
</tr>
<tr>
<td>EP508</td>
<td>16.2±0.3</td>
</tr>
<tr>
<td>EP509</td>
<td>16.6±0.2</td>
</tr>
<tr>
<td>EP055</td>
<td>15.2±0.1</td>
</tr>
<tr>
<td>EP056</td>
<td>18.8±0.2</td>
</tr>
<tr>
<td>EL214</td>
<td>17.9±0.4</td>
</tr>
<tr>
<td>EP057</td>
<td>20.9±0.4</td>
</tr>
<tr>
<td>EM301</td>
<td>21.2±0.4</td>
</tr>
<tr>
<td>EP604</td>
<td>16.5±0.3</td>
</tr>
<tr>
<td>EP054</td>
<td>13.7±0.3</td>
</tr>
<tr>
<td>PIII</td>
<td>15.7±0.5</td>
</tr>
<tr>
<td>ANAIS-0</td>
<td>12.7±0.5</td>
</tr>
</tbody>
</table>

#### Results

These activities mean about 50 events/kg/day at 3.2 keV.

Anticoincidence between crystals improves the background, but more radiopure crystals are required.
Search for more radiopure NaI(Tl) crystals

Comercial agreement DAMA-St Gobain prevents buying clean NaI crystals
New Development needed

3-Phase project with ElectroChemical Systems Inc. Goal <0.1 ppm in Knat

- 1. purification method selection. Completed
- 2. proof of concept. Almost completed
- 3. mass production of 200kg clean NaI powder. Yet to start

In parallel contacts with growing companies

In the process the group has gain experience in the measurement of extremely low contamination levels through AAS in contact with MARTE group (UZ). Results compared with HPGe measurements in order to check the full process
Photomultipliers (PMTs)

Several PMT tested for:
- radiopurity
- QE and SER
- Resolution
## PMTs contamination levels

<table>
<thead>
<tr>
<th></th>
<th>ET 9302B</th>
<th>HAM High QE R6233-100</th>
<th>HAM LB ZE5331</th>
<th>HAM ULB ZK5171</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>40K</strong></td>
<td>(420 ± 50) mBq/PMT</td>
<td>(184.5 ± 0.9) Bq/PMT</td>
<td>678± 42 mBq/PMT</td>
<td>32±9 mBq/PMT</td>
</tr>
<tr>
<td><strong>232Th</strong></td>
<td>(24 ± 4) mBq/PMT</td>
<td>(0.42 ± 0.04) Bq/PMT</td>
<td>678± 2.8 mBq/PMT</td>
<td>1.9±0.7 mBq/PMT</td>
</tr>
<tr>
<td><strong>238U</strong></td>
<td>(220 ± 12) mBq/PMT</td>
<td>(0.513 ± 0.03) Bq/PMT</td>
<td>100±2.8 mBq/PMT</td>
<td>238U 33±7 226Ra 6.7±0.9 mBq/PMT</td>
</tr>
</tbody>
</table>

- HQE Hamamatsu better resolution and response, but extremely high contaminations
- ULB Hamamatsu 1 order of magnitude better background but expensive
- Two ULB-selected Ham PMTs have been bought and are being tested at Zaragoza and Canfranc
Slow Control

- Slow Control program developed in LabView
- Rate and Gain have been observed to vary with T at old LSC
- Control of stability essential for ANAIS
Slow Control

Rate may vary due to DC changes in electronics
But also indirectly due to Rn
New Electronics and Acquisition system

- Migration from CAMAC to VME
- Full C++ environment developed
- Store as much information as possible
- Modular and configurable
- Direct link with analysis
- Drivers, modules testing, etc. done at Zaragoza
Analysis

- ROOT framework for analysis
- Ntuples obtained from digitized pulses plus hardware info (QDCs, etc)
- Noise rejection parameters, new developments at LE
- Low level implementation and parallelization for speed gain 10-100 factor
Analysis
Simulations

- Geant4 tool used to simulate whole set-up
- Important to understand our background (Contribution from various components, internal contaminations, etc)
- G4 developed for HE physics
- Important failures at LE encountered
- The code has to be verified
Summary

- ANAIS may reproduce DAMA signal, can be crucial in the DM puzzle
- Various prototypes developed along the past decade
- Improvements in background and threshold ensure good potential for final experiment
- K40 contamination of existing crystals have force the search and development of new methods to get more radiopure detectors
- Mass production should start end 2011
- Rest of components under control (copper electroforming, material selection and HPGe screening, Low bkg PMTs, ...)
- New acquisition ready to store all relevant information, analysis to get the maximum from it and stability control to guarantee best performances
- Anais-0 already being tested at old LSC and ready to be installed in the new LSC facilities