Measure of internal contamination from electronic components

Use of a technic from nuclear physics to improve detection limits and to identify alpha emitter
Montain stop most of them
This is the deepest lab in Europe
the 1700 m of the rock overburden reduce
By a million factor
this cosmic ray flux

first goal Protection against cosmic rays

For the rare event experiments this background is too important for the experiment to be settled at the surface
Caracterisation of background

• Neutron background due to self fission from U Th
  – Flux measured in different location in the laboratory.

• Radon in air
  – Radonless air in critical location.
  – Continuous monitoring in the laboratory.
NEMO
neutrino ettore majorana experiment

double bêta decay

Dirac’s Neutrino: $\bar{\nu} \neq \nu$

Majorana’s Neutrino: $\bar{\nu} = \nu$

neutrino mass ???

neutrino = antineutrino ???

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NEMO 3
ββ expt with $^{100}$Mo

- ~ 2000 PM tubes
- 40,000 wires
- X 20 modules
- Plastic scintillator
- Mixture Helium – alcool 30 m³
- Sources = 10 kg $^{100}$Mo, $^{82}$Se, ...
- Surface = 20 m²

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EDELWEISS II

- Goal: Discovering Dark matter
- Anomalous rotation speed
- Germaniums detectors cooled down to 20mK
EDELWEISS II

Electrodes ionisation

Electrons

Energie de recul

heat

NTD (°)

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Natural radioactivity

- There are different kinds of radioactivity. Alpha decay is the only constraint for electronic devices.
- $\alpha$ Particles have an important LET so they can ionise matter enough to perturbate electronic devices.
## Desintegration rate

<table>
<thead>
<tr>
<th>Élément</th>
<th>$T_{1/2}$ (s)</th>
<th>Abundance (%)</th>
<th>Désintégrations/ bilions of d'hours (pour un volume 250 µm x 1 cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{147}$Sm</td>
<td>$3.34 \times 10^{18}$</td>
<td>15</td>
<td>$1.40 \times 10^{14}$</td>
</tr>
<tr>
<td>$^{190}$Pt</td>
<td>$2.05 \times 10^{19}$</td>
<td>0.014</td>
<td>$2.13 \times 10^{10}$</td>
</tr>
<tr>
<td>$^{144}$Nd</td>
<td>$7.23 \times 10^{22}$</td>
<td>23.8</td>
<td>$1.03 \times 10^{10}$</td>
</tr>
<tr>
<td>$^{152}$Gd</td>
<td>$3.41 \times 10^{21}$</td>
<td>0.2</td>
<td>$1.94 \times 10^{9}$</td>
</tr>
<tr>
<td>$^{148}$Sm</td>
<td>$2.21 \times 10^{23}$</td>
<td>11.24</td>
<td>$1.59 \times 10^{9}$</td>
</tr>
<tr>
<td>$^{187}$Re</td>
<td>$1.37 \times 10^{18}$</td>
<td>62.6</td>
<td>$1.43 \times 10^{9}$</td>
</tr>
<tr>
<td>$^{186}$Os</td>
<td>$6.31 \times 10^{22}$</td>
<td>1.59</td>
<td>$7.86 \times 10^{9}$</td>
</tr>
<tr>
<td>$^{174}$Hf</td>
<td>$6.31 \times 10^{22}$</td>
<td>0.16</td>
<td>$7.91 \times 10^{8}$</td>
</tr>
<tr>
<td>$^{238}$U (1ppb)</td>
<td>$1.41 \times 10^{17}$</td>
<td>99.2742</td>
<td>$2.20 \times 10^{7}$</td>
</tr>
<tr>
<td>$^{232}$Th (1ppb)</td>
<td>$4.43 \times 10^{17}$</td>
<td>100</td>
<td>$7.04 \times 10^{6}$</td>
</tr>
</tbody>
</table>

0,6 réaction/jour = $2.50 \times 10^{7}$ /milliard heures
Desintegration rate

• **Material**: desintegration rate are very high because they don’t take into account the mass used in the final application.
  These rates show that to an equal volume there will be more alpha decays than nuclear reaction induced by neutrons.

• **Impureties**: rates are higher because there is a whole chain the main challenge is to measure the breaks in the secular equilibrium.
Radioactives Chains

Famille de $^{238}$U

- $^{238}$U
- $^{234}$Th ($\alpha$ 4.3 MeV, $\beta$ 1.98 MeV)
- $^{234}$Pa ($\beta$ 2.3 MeV, $\alpha$ 4.7 MeV
- $^{234}$U ($\beta$ 4.3 MeV)
- $^{234}$Th ($\alpha$ 4.7 MeV, $\alpha$ 4.8 MeV, $\alpha$ 5.5 MeV, $\alpha$ 6.0 MeV, $\beta$ 1.02 MeV, γ 295 keV, 352 keV)
- $^{214}$Bi ($\beta$ 3.27 MeV, γ 609 keV, 1120 keV, 1765 keV)
- $^{214}$Po ($\beta$ 61 keV, 15 keV, γ 46.5 keV)
- $^{214}$Pb ($\beta$ 1.16 MeV, $\alpha$ 5.3 MeV)

Famille de $^{232}$Th

- $^{232}$Th ($\beta$ 4.0 MeV, $\alpha$ 4.0 MeV)
- $^{228}$Ra ($\beta$ 39 keV, $\beta$ 2.13 MeV)
- $^{228}$Ac ($\beta$ 5.4 MeV, $\alpha$ 5.7 MeV, $\alpha$ 6.3 MeV, $\alpha$ 6.8 MeV, $\beta$ 540 keV, γ 238.6 keV, 64%, $\beta$ 2.2 MeV)
- $^{212}$Po ($\alpha$ 6.0 MeV, 36%, $\beta$ 5.0 MeV, γ 583 keV, 2614 keV, $\alpha$ 8.8 MeV, $\beta$ 8.8 MeV, Stable)
Radioactivities Chains

- Radioactivity is measured in Becquerels
- 1Bq = one decay per second
- For an alpha emitter 1 alpha per second
- Secular equilibrium break means that U/Th activity is different from its daughter
Equilibrium breaks

• Secular equilibrium is broken by chemical operation which depends on properties of elements
• It is reached after 10 half lives of the daughter
• At the timescale of a component it could be broken for these nuclides
Equilibrium breaks

Famille de $^{238}\text{U}$

$^{238}\text{U}$

$^{234}\text{Th}$

$^{234}\text{Pa}$

$^{234}\text{U}$

$^{230}\text{Th}$

$^{230}\text{Ra}$

$^{226}\text{Rn}$

$^{218}\text{Po}$

$^{214}\text{Bi}$

$^{212}\text{Pb}$

$^{208}\text{TI}$

Famille de $^{232}\text{Th}$

$^{232}\text{Th}$

$^{228}\text{Ra}$

$^{228}\text{Ac}$

$^{226}\text{Th}$

$^{226}\text{Rn}$

$^{216}\text{Po}$

$^{212}\text{Bi}$

$^{208}\text{Th}$

$^{208}\text{Pb}$ Stable
Equilibrium breaks

- Measuring U/Th $\Rightarrow$ measuring radioactive contamination
- Measure radioactivity in becquerel
  - Conversion mass-becquerel
  - 1 ppb $^{238}$U = 12 mBq/kg
  - 1 ppb $^{232}$Th = $10^{-6}$ g/kg = 3.1 mBq/kg
  - 1 Bq/kg $^{226}$Ra = $2.7 \times 10^{-11}$ g/kg = 27 pps
  - 1 Bq/kg $^{210}$Pb = $3.7 \times 10^{-13}$ g/kg

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Equilibrium breaks

• Examples: measure Al/Mg/Si 98/1/1 Goodfellow 5N
• 1Bq / kg of Uranium but no daughters
• High purity products
• Low radioactives products
Equilibrium breaks

- Radon issues
- External source of contaminations
- $^{220}\text{Rn}$ 55s $3\alpha$ low contamination
- $^{222}\text{Rn}$ 3.66j $3\alpha$ and radioactives daughters
- Penetration through plastics
- Daughter implantation
Gamma ray measurement

- Base of the law background experiment
- 20 years of optimisation at LSM
- Various application:
  - Élément de structure des expériences bas bruit (CENBG, LSM, EDELWEISS)
  - Surveillance environnementale (IRSN, DASE)
  - Datation d’objet (LSCE, LSM, CENBG)
  - Identification de provenance (LSCE)
Collaboration with iRoC
benchmark alpha-gamma performed
Global alpha measurement
Gamma ray measurement of the same sample
Gamma ray measurement

- Alpha emission: $2.40 \pm 0.06 \pm 0.05$
- iRoC counting $(2.4 \pm 0.5)$

<table>
<thead>
<tr>
<th>Chain parent</th>
<th>Sub-chain parent</th>
<th>Activity or MDA $(10^5 \text{ Bq/g})$</th>
<th>Alpha emitted $(\alpha/\text{h.cm}^2) 10^{-3}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{232}\text{Th}$</td>
<td>$^{228}\text{Ra}$</td>
<td>$&lt; 12$</td>
<td>$0$</td>
</tr>
<tr>
<td>$^{228}\text{Th}$</td>
<td></td>
<td>$5 \pm 1$</td>
<td>$0.17 \pm 0.01$</td>
</tr>
<tr>
<td>$^{238}\text{U}$</td>
<td>$^{234}\text{Th}$</td>
<td>$14.3 \pm 3.4$</td>
<td>$0.035 \pm 0.008$</td>
</tr>
<tr>
<td></td>
<td>$^{226}\text{Ra}$</td>
<td>$8.9 \pm 2.5$</td>
<td>$0.20 \pm 0.06$</td>
</tr>
<tr>
<td></td>
<td>$^{210}\text{Pb}$</td>
<td>$35.5 \pm 7.6$</td>
<td>$0.16 \pm 0.03$</td>
</tr>
</tbody>
</table>

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• Improving the detection limit
• Main advantage
  – Low background:
    • 6 count per hour in 15-1500keV
    • Energy resolution 900 eV
    • Detection limits about 1 mBq/kg for ten days 50g
    • Testing the volume not the surface
    • Radionuclide identification
    • Simulation more accurate introducing energy emitted
Gamma ray measurement

- disadvantage:
  - Isotopes without gamma rays
    » Possibility to measure mother or daughter and use secular equilibrium
  - Simulation needed for alpha emission measurement
Gamma ray measurement

- Disadvantage
- Underground lab and radonless to reach low level of radioactivity
- Non direct results
- Usefull for volumic samples
• Volumic samples not surface only
• Detection limits about 1 mBq/kg for 10 days for 50g ⇔ 10^-4 α/cm2.h
• Determination around 0.1 ppb for U/Th
Gamma ray measurement

• Simulations nucleus by nucleus
• Simulation changing the sample shape
• No need for flat samples
• Allow to dismantle chip and make benchmark after use
• Need of recognition
• Need chip tests
• Possibility to dismantle
• Measure of different layer
• Simulation of the number of error
• Accelerated test with source
Fukushima

- Fission Product = Bêta emitter
- Transuranien products
- 0,3Bq / kg Pu on vegetables from Sendai market
- France Cs/I/Ba/La/Te
- Nd métal coming from Japan
• **Conclusion**

- Less sensitivity for surface contamination during manipulation
- Reconstruction of the final emission by simulation
- Possibility to use different kind of samples and the
- Hypothesis on secular equilibrium or coupling with radiochemistry and ICP-MS
- Simulation of alpha emitted to have the energy dependance
- Max sample size 196mm

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