Gamma Spectrometric techniques
for Ultra Low Activity Measurements

Underground Facilities

Anti Cosmic and Anti Compton Radiation Shield Systems

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Why Low Activity Measurements are needed ???

• 40-50 years after the introduction of anthropogenic radionuclides into the environment their concentrations have decreased considerably

• Highly accurate and precise data are required for environmental and climate change studies

• Sample size for radiometrics analyses should be comparable to mass spectrometry requirements
Developments in radiometrics techniques:

- **The operation of high efficiency HPGe detectors often placed underground**
  
  - Low activity $\Rightarrow$ High efficiency detector
  - High efficiency detector $\Rightarrow$ Higher sensitivity to background and cosmic rays
  - Sensitivity to the background $\Rightarrow$ Ultra low Background Lead Shield
  - Sensitivity to the cosmic rays $\Rightarrow$ Deep Underground Lab

- **Anti-cosmic and anti-Compton shielding of detectors**
  
  - Not deep enough U-Lab $\Rightarrow$ Anti Cosmic shield
  - Background coming from sample $\Rightarrow$ Anti-Compton system

- **Coincidence gamma-ray spectrometry**
  
  - $(\gamma-\gamma, \beta-\gamma, \beta-\gamma-\gamma, \text{etc.})$
  
  - Background still too high $\Rightarrow$ $\gamma-\gamma$ coincidences
  - Background still too high $\Rightarrow$ $B-\gamma$, $B-\gamma-\gamma$, coincidences etc ...
Cosmic radiations attenuation depending on the rock thickness

<table>
<thead>
<tr>
<th>Depth</th>
<th>Attenuation</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 m</td>
<td>100</td>
</tr>
<tr>
<td>10 m</td>
<td>100 000</td>
</tr>
<tr>
<td>50 m</td>
<td>10 000 000</td>
</tr>
<tr>
<td>100 m</td>
<td>100 000 000</td>
</tr>
<tr>
<td>1000 m</td>
<td>1 000 000 000</td>
</tr>
</tbody>
</table>
UNDERGROUND LABORATORY
Fresh Air, Air Conditioning, Electricity

Fresh Air
(+3 m Altitude from the ground floor)

Filter

Fresh Air 120 m³/h
(Overpressure in this room)

Air Conditioning Modules
(Cold only)

Dehumidification System

Air Extraction 100 m³/h

Public Corridor

SAS

Counting Room

UPS 5 kVA (Supplied by an Electric Generator in case of electricity breakdown)
MEL Underground Laboratory

- Anti-Compton Spectrometer
- 4 Anti-Cosmic Spectrometers
- BE-Ge Spectrometer
- 70 %Well Type Spectrometer
- ULB Liquid scintillation Spectrometer
- Radon Spectrometer
Anti-cosmic Spectrometers
Anti-cosmic spectrometers
Principle

The system operates in anti-coincidence mode
View of the lead shield with anti-cosmic plastic scintillation shielding
Anti-Cosmic Spectrometers
Anti-cosmic Spectrometers
Anti-Cosmic Spectrometers
Anti-cosmic Spectrometers
Annihilation peak 512 keV.

Counting rate = $5.2 \times 10^6$ c/d
Attenuation: 5

Background without lead shield and without electronic anti-cosmic system.

Annihilation peak 512 keV.

Counting rate = $1.728 \times 10^4$ c/d
Attenuation: 307

Background with lead shield and without electronic anti-cosmic system.

Counting rate = $1.728 \times 10^3$ c/d
Attenuation: 10

Background with lead shield and with electronic anti-cosmic system.
Anti-cosmic Spectrometers

BACKGROUND GE-SPECTRA WITH ANTICOSMIC SHIELDING

Counts (day$^{-1}$ kg$^{-1}$ Ge)

Counts (day$^{-1}$ kg$^{-1}$ Ge)

Counts (day$^{-1}$ kg$^{-1}$ Ge)

Counts (day$^{-1}$ kg$^{-1}$ Ge)

keV

keV

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Anti-cosmic Spectrometers

1. Photomultiplicateurs et comptateurs plastiques
2. Summing preamplifier
3. Fast Amplifier
4. Constant Fraction discriminator
5. Calibrated Delay
6. Time Amplitude Converter
7. Delay and Shape
8. Gate Input Multi Channel Analyser

International Atomic Energy Agency
Dept. of Nuclear Sciences and Applications
# Anti-cosmic Spectrometers

## Comparison with other U-Lab

Low-background gamma spectroscopy for environmental spectroscopy T.M. Semkow and all. Applied Radiation and Isotopes 57, 213-223 2002

<table>
<thead>
<tr>
<th>Localization Meters Water Equivalent (mwe)</th>
<th>Active Shield</th>
<th>Volume of Ge (Cm³)</th>
<th>Energy Range (keV)</th>
<th>Background (c/s/100cm³)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Level Plastic Scintillator 4 faces</td>
<td>131</td>
<td>40-3000</td>
<td></td>
<td>2,1 x 10¹</td>
<td>Shizuma (1992)</td>
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<td>180</td>
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<td>Laurec (1996)</td>
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<td>El-Daoushi (1995)</td>
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<tr>
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<td>487</td>
<td>30-2700</td>
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<td>100-2000</td>
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<td>4,1 x 10⁻²</td>
<td>Miley (1992)</td>
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<td>50-2680</td>
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<td>Heusser (1991)</td>
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<td>Beda (2000)</td>
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<tr>
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<td>20-2700</td>
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<td>Mouchel (1996)</td>
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<tr>
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<td>207</td>
<td>20-2000</td>
<td></td>
<td>8,2 x 10⁻³</td>
<td>Bourlat (1994)</td>
</tr>
<tr>
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<td>30-2700</td>
<td></td>
<td>5,8 x 10⁻³</td>
<td>MEL Ulab</td>
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<tr>
<td>500 mwe None</td>
<td>234</td>
<td>40-2700</td>
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<td>Hult (2000)</td>
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<td>50-2750</td>
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<td>200</td>
<td>100-2000</td>
<td></td>
<td>1,3 x 10⁻⁴</td>
<td>Miley (1992)</td>
</tr>
</tbody>
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Anti-cosmic Spectrometers

Comparison with other U-Lab

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Anti-cosmic Spectrometers
Comparison with other U-Lab
The Anti-Compton Spectrometer
Anti-Compton Spectrometer and Marine Samples

Compton Effect
(continuous distribution)

Pair Production
(512 keV)

Photoelectric Effect
(Pic $^{40}$K (1460 keV))

Marine Salt Gamma Spectrum
The Anti-Compton Spectrometer

Scintillator (NaI (Tl))

ULB Lead

Sample
(Seawater, sediments, …)

HpGe Detector

YES
(Count accepted)

NO
(Compton detected by NaI detector)

Count not accepted,
The Anti-Compton Spectrometer
The Anti-Compton Spectrometer
The Anti-Compton Spectrometer

H.T. : High Voltage  
P.A. : Preamplifier  
T.A.C. : Time Amplitude Converter

A.R. : Fast Amplifier  
L.A. : Linear Amplifier  
D. : Delay

S.C.A. : Single Channel Analyzer  
M.C.A. : Multi Channel Analyzer  
T.P. : Time Pickoff

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The Anti-Compton Spectrometer

chronograms
The Anti-Compton Spectrometer
Results

$^{60}\text{Co}: A = 2.8$

Direct mode

Anti-Compton mode

P/C=57

P/C=160

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The Anti-Compton Spectrometer Results

$^{137}\text{Cs}: A = 4.7$

P/C = 91

Direct mode

Anti-Compton mode

P/C = 427
The Anti-Compton Spectrometer Results

85 Sr: A = ??

65 Zn: A = 11.5

P/C = 86

P/C = 960
The Anti-Compton Spectrometer and $\gamma-\gamma$ Coincidences
The Anti-Compton Spectrometer and $\gamma-\gamma$ Coincidences

Electronics

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Monaco
\( \gamma-\gamma \) Coïncidence + Anti-Compton Spectrometer: Results

**Direct Spectrum \(^{60}\text{Co} + ^{137}\text{Cs}**

- \(661.61 \text{ keV}^{137}\text{Cs} \)
- \(1173.23 \text{ keV}^{60}\text{Co} \)
- \(1332.51 \text{ keV}^{60}\text{Co} \)

Pic/Compton ratio: 56

**Anti-Compton Spectrum \(^{60}\text{Co} + ^{137}\text{Cs}**

- \(661.61 \text{ keV}^{137}\text{Cs} \)
- \(1173.23 \text{ keV}^{60}\text{Co} \)
- \(1332.51 \text{ keV}^{60}\text{Co} \)

Pic/Compton ratio: 144

**\( \gamma-\gamma \) coincidence + Anti-Compton \(^{60}\text{Co} + ^{137}\text{Cs}**

- \(661.61 \text{ keV}^{137}\text{Cs} \)
- \(1173.23 \text{ keV}^{60}\text{Co} \)
- \(1332.51 \text{ keV}^{60}\text{Co} \)

Pic/Compton ratio: 244
The new techniques have opened doors for investigations

- which previously required too large samples
- were not possible because of lack of sensitivity
- were not possible because of lack of precision
Conclusion

GOALS : ACHIEVED !

✓ - To decrease the background and to increase the sensitivity of the gamma spectrometers: **0.02 cps between 20 et 2500 keV using 100% to 200% efficiency HPGe detector**

✓ - To decrease the size of the Marine Samples: **factor of 10**

✓ - To decrease the measurement duration: **factor of 5**

  More than 2000 samples has been measured since 2003