



---

Activity Report of WP3.3

12 | 2021

---

# **Scheme of Callio Lab devoted to natural background radiation (NBR) characterization - supplement to the scheme prepared in the BSUIN project**

**Author: Katarzyna Szkliniarz, Jan Kisiel  
University of Silesia, Poland**

## Contents

1. General information.....	5
2. Laboratory analyses of the water samples.....	6
<i>a. Uranium concentration in water samples .....</i>	<i>7</i>
3. Laboratory analyses of the rock samples .....	10
<i>a. Radium and potassium concentration in rock samples .....</i>	<i>10</i>
<i>b. Uranium concentration in rock samples.....</i>	<i>12</i>

## Figures

<b>Fig. 1 Water samples from Lab 3 and Lab 4.....</b>	<b>6</b>
<b>Fig. 2 (a) the spectrometer 7401VR (Canberra, USA), (b) the alpha spectrometer Alpha Analyst™ (Mirion Technologies (Canberra), Inc., USA).....</b>	<b>7</b>
<b>Fig. 3 The alpha spectrum of a water sample from Lab 3.....</b>	<b>8</b>
<b>Fig. 4 The alpha spectrum of a water sample from Lab 4.....</b>	<b>9</b>
<b>Fig. 5 (a) Lab 4, (b) rock sample from Lab 4.....</b>	<b>10</b>
<b>Fig. 6 (a) HPGe detector with shielding, (b) crushed rock sample, (c) rock sample in Marinelli containers. ....</b>	<b>11</b>
<b>Fig. 7 Gamma-ray spectrum of a rock sample from Lab 4. ....</b>	<b>12</b>
<b>Fig. 8 (a) The alpha spectrometer 7401VR (Canberra, USA), (b) the alpha spectrometer Alpha Analyst™ (Mirion Technologies (Canberra), Inc., USA).....</b>	<b>13</b>
<b>Fig. 9 The alpha spectrum of a rock sample from Lab 4. ....</b>	<b>14</b>

## Tables

<b>Tab. 1 Description of the sites where water samples were collected.....</b>	<b>6</b>
<b>Tab. 2 Results of uranium radioisotopes concentration in water samples from Lab 3 and Lab 4 (Callio Lab). ....</b>	<b>8</b>
<b>Tab. 3 Description of the site where the rock sample were collected. ....</b>	<b>10</b>
<b>Tab. 4 Results of radium and potassium concentration in a rock sample from Lab 4 (Callio Lab).....</b>	<b>11</b>
<b>Tab. 5 Results of uranium radioisotopes concentration in a rock sample from Lab 4 (Callio Lab).....</b>	<b>13</b>

## 1. General information

Name of Underground Laboratory:

**Callio Lab**

([www.calliolab.com](http://www.calliolab.com)) located in Pyhäsalmi Mine

Localization (country/city):

**Pyhäsalmi/Finland**

Coordinates to the facility:

63°39'31" North

26°02'28" East

The altitude of the facility:

143 m



Name of the responsible scientist/measurer:

University of Silesia, Poland:

Agata Walencik-Łata

Katarzyna Szkliniarz

Place where the data is stored (e.g., file in a drawer X, internal data cloud, etc.):

Pendrive, external memory,

## 2. Laboratory analyses of the water samples

Measurements of the concentration of radium and uranium radioisotopes in water samples were carried out in an external laboratory - "Low-level Activity Research Laboratory", Institute of Physics, the University of Silesia in Katowice, Poland.

Description of the sites where water samples were taken:

**Tab. 1 Description of the sites where water samples were collected.**

Hall ID	Depth below surface [m w.e.]	Sites (wall, water gulleys, water reservoir, other.....)	Method of the sampling
Lab 3	2752	large puddles formed by water dripping from the rock ceiling and walls	Sampling for polyethylene bottles
Lab 4	1835	leaking water from the rock ceiling	

The samples were acidified immediately after collection to avoid precipitation of radionuclides and adsorption on the walls of the containers.



**Fig. 1 Water samples from Lab 3 and Lab 4.**

### *a. Uranium concentration in water samples*

- Description of the performed chemical procedure

The concentration of uranium  $^{234}\text{U}$  and  $^{238}\text{U}$  isotopes in the water samples were determined by semiconductor alpha spectrometry using a 7401VR spectrometer (Canberra, USA) and an Alpha Analyst™ (Mirion Technologies (Canberra), Inc., USA) (Fig. 2). Before measurement, a radiochemical procedure was applied to prepare an alpha spectrometric source. The samples were acidified with  $\text{HNO}_3$  and spiked with a known amount of  $^{232}\text{U}$ . The separation of U is performed using the anion exchange resin Dowex 1×8 ( $\text{Cl}^-$  type, 200-400 mesh) based on a procedure worked out by Suomela (1993). The spectrometric source was prepared by co-precipitation of U with  $\text{NdF}_3$  and deposition on polypropylene disks (0.1  $\mu\text{m}$ ) (Pall Corporation).

#### References:

J. Suomela, Method for determination of U-isotopes in water, Swedish Radiation Institute, Stockholm, SSI-rapport, 0282-4434, 93:14 (1993).

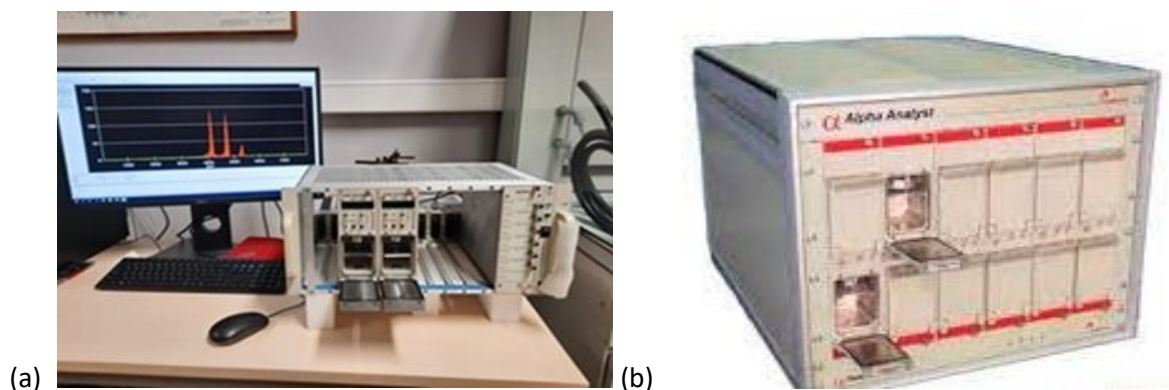


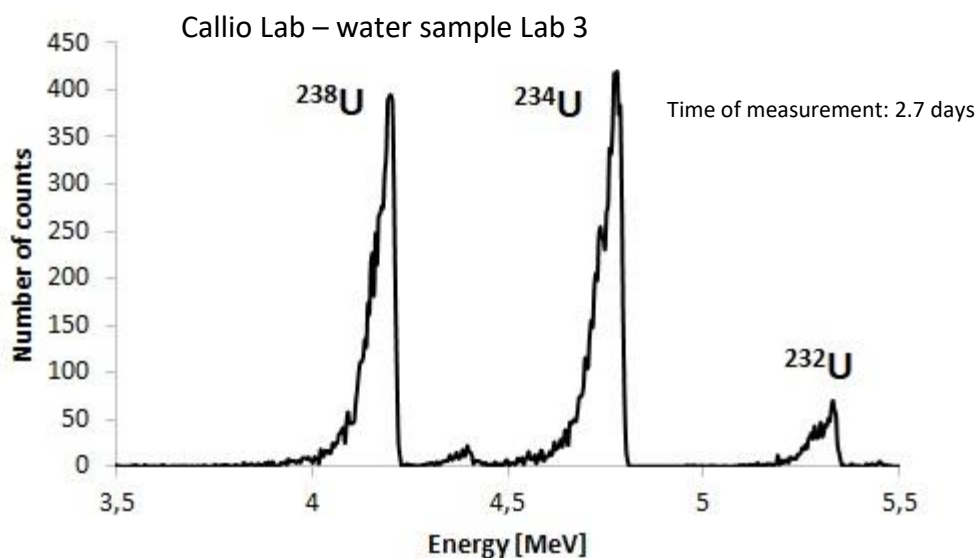
Fig. 2 (a) the spectrometer 7401VR (Canberra, USA), (b) the alpha spectrometer Alpha Analyst™ (Mirion Technologies (Canberra), Inc., USA).

- Information about measurement and results

**Tab. 2 Results of uranium radioisotopes concentration in water samples from Lab 3 and Lab 4 (Callio Lab).**

Hall ID (name of the sample)	Measurement method	Equipment type	Collection period	Limit of detection	Average results [mBq/l]		ratio $^{234}\text{U}/^{238}\text{U}$	U [ $\mu\text{g/l}$ ]
					$^{234}\text{U}$	$^{238}\text{U}$		
water sample Lab 3	Alpha spectroscopy	spectrometer 7401VR (Canberra)	2.7 days	0.5 mBq/l for $^{234,238}\text{U}$ , 0.5 l initial sample volume	678.2 $\pm$ 23.1	611.8 $\pm$ 20.9	1.11 $\pm$ 0.05	49.54 $\pm$ 1.71
water sample Lab 4		and Alpha Analyst (Mirion Technologies (Canberra))	4.1 days		17.3 $\pm$ 1.0	2.6 $\pm$ 0.4	6.64 $\pm$ 1.01	0.21 $\pm$ 0.03

Alpha spectra:



**Fig. 3 The alpha spectrum of a water sample from Lab 3.**

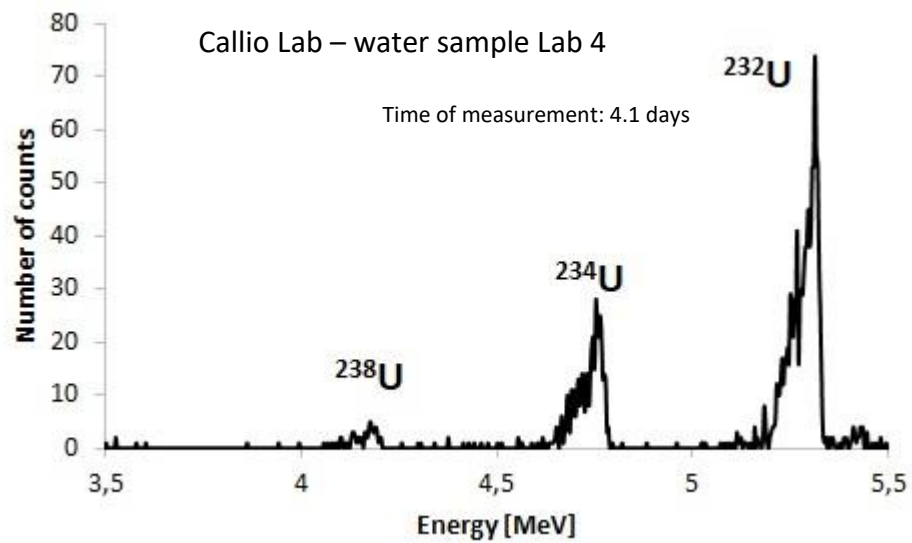


Fig. 4 The alpha spectrum of a water sample from Lab 4.

### 3. Laboratory analyses of the rock samples

Measurements of the concentration of uranium, radium, and potassium radioisotopes in the rock sample (**Fig. 5**) were performed in an external laboratory -"Low-level Activity Research Laboratory", Institute of Physics, the University of Silesia in Katowice, Poland.

Description of the sites where rock samples were taken:

**Tab. 3** Description of the site where the rock sample were collected.

Hall ID	Depth below surface [m w.e.]	Sites (wall, floor, brick, concrete, other)	Method of the sampling	Name of the sample
Lab 4	1835	Wall (rock from around Lab 4)	newly chipped rock samples from walls	rock sample Lab 4

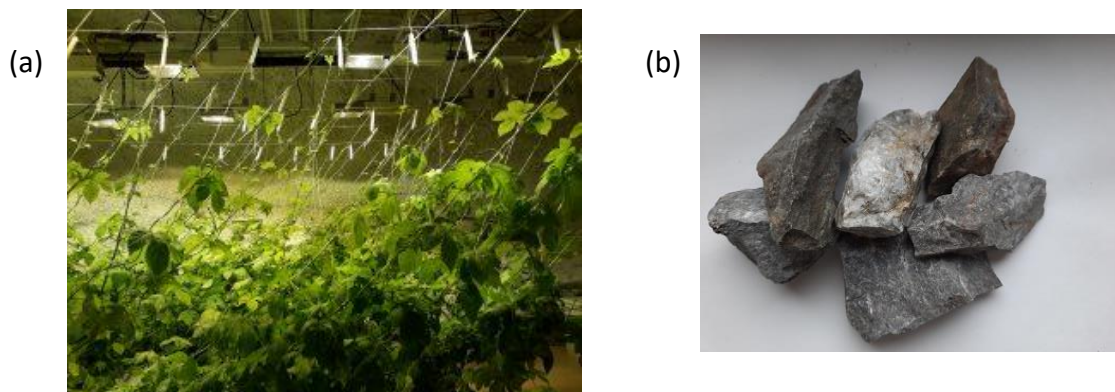


Fig. 5 (a) Lab 4, (b) rock sample from Lab 4.

#### a. Radium and potassium concentration in rock samples

- Information about measurement

The concentration of radium and potassium isotopes in the rock sample was determined by gamma spectroscopy with the HPGe detector in a lead shield (**Fig. 6a**). The activity of  $^{40}\text{K}$  was calculated directly from a single 1460.8 keV line. The activity of  $^{226}\text{Ra}$  was calculated as the weighted mean of the values obtained from the  $^{214}\text{Pb}$  (295.2, 351.9 keV) and  $^{214}\text{Bi}$  (609.3, 1120.3 keV) isotopes, while  $^{228}\text{Ra}$  activity was calculated from the gamma lines 338.3 keV and 911.1 keV

originating from  $^{228}\text{Ac}$  decay. The total duration of a single measurement depended on the sample activity.

Description of the procedure performed before measurements and conditions during measurements (e.g., use of a Marinelli beaker; shielding of the detector; drying, crushing, grinding, mixing of rock; other relevant information): **Before the measurements, the rock sample was dried, crushed, ground, mixed and placed in a Marinelli container (Fig. 6b,c), which was then sealed and left for one month to achieve secular equilibrium in the thorium and uranium series. The grains diameter after crushing the rock sample was less than 1 mm. Measurements were made in a shielded cover made of lead and copper.**

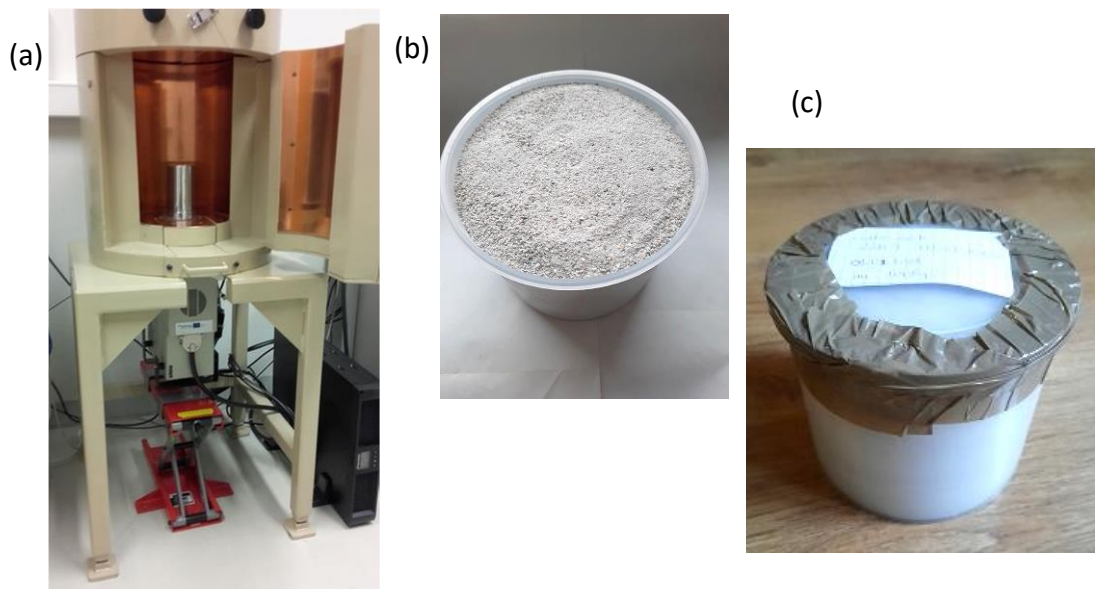


Fig. 6 (a) HPGe detector with shielding, (b) crushed rock sample, (c) rock sample in Marinelli containers.

Tab. 4 Results of radium and potassium concentration in a rock sample from Lab 4 (Callio Lab).

Hall ID (name of sample)	Meas- urement method	Equipment type	Detection relative efficiency [%]	Collection period	Average results [Bq/kg]		
					$^{226}\text{Ra}$	$^{228}\text{Ra}$	$^{40}\text{K}$
rock sample Lab 4	Gamma spectro- metry	HPGe detector	20	2.1 days	44.9±1.6	15.0±0.3	464.6±6.9

Gamma-ray spectrum:

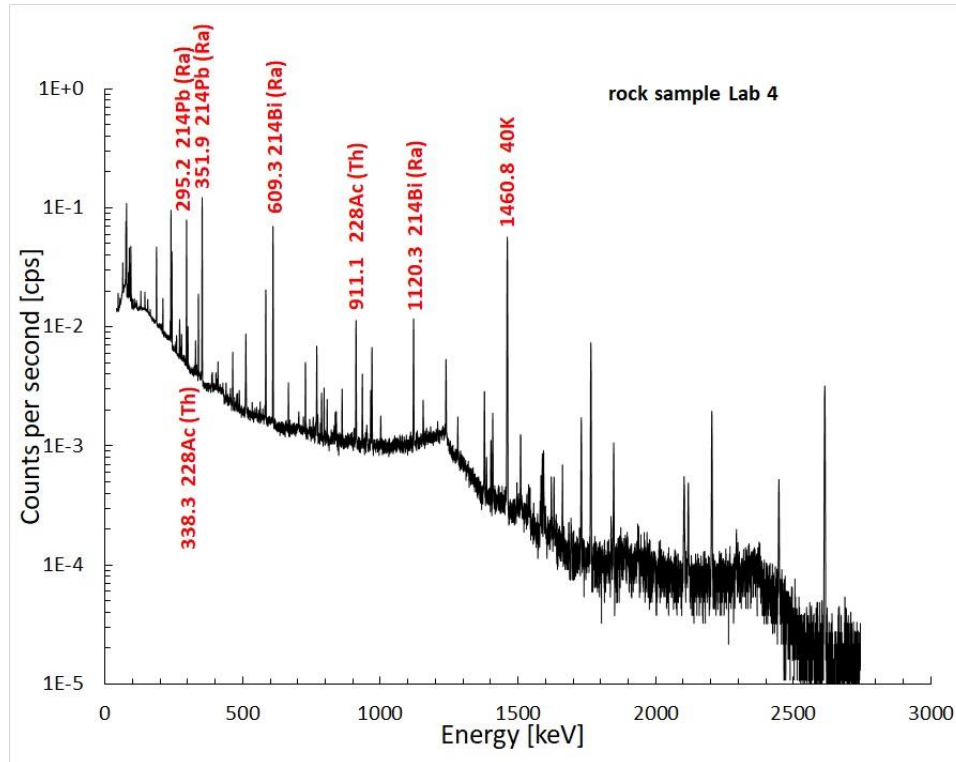


Fig. 7 Gamma-ray spectrum of a rock sample from Lab 4.

### *b. Uranium concentration in rock samples*

- Description of the performed chemical procedure

The concentration of uranium  $^{234}\text{U}$  and  $^{238}\text{U}$  isotopes in the rock sample was determined by semiconductor alpha spectrometry and 7401VR (Canberra, USA) and Alpha Analyst™ (Mirion Technologies (Canberra), Inc., USA) spectrometers (Fig. 8a,b). A radiochemical procedure was applied to prepare an alpha spectrometric source before measurement. For this purpose, wet mineralization of the rock sample was performed using hot acids: HF, HNO<sub>3</sub>, HCl with H<sub>3</sub>BO<sub>3</sub>. Uranium was pre-concentrated with iron and co-precipitated at pH 9. The separation of U was performed using the anion exchange resin Dowex 1×8 (Cl<sup>-</sup> type, 200-400 mesh) based on a procedure worked out by Suomela (1993). The spectrometric source was prepared by co-precipitation of U with NdF<sub>3</sub> and deposition on polypropylene disks (0.1 μm) (Pall Corporation).

References:

J. Suomela, Method for determination of U-isotopes in water, Swedish Radiation Institute, Stockholm, SSI-rapport, 0282-4434, 93:14 (1993).

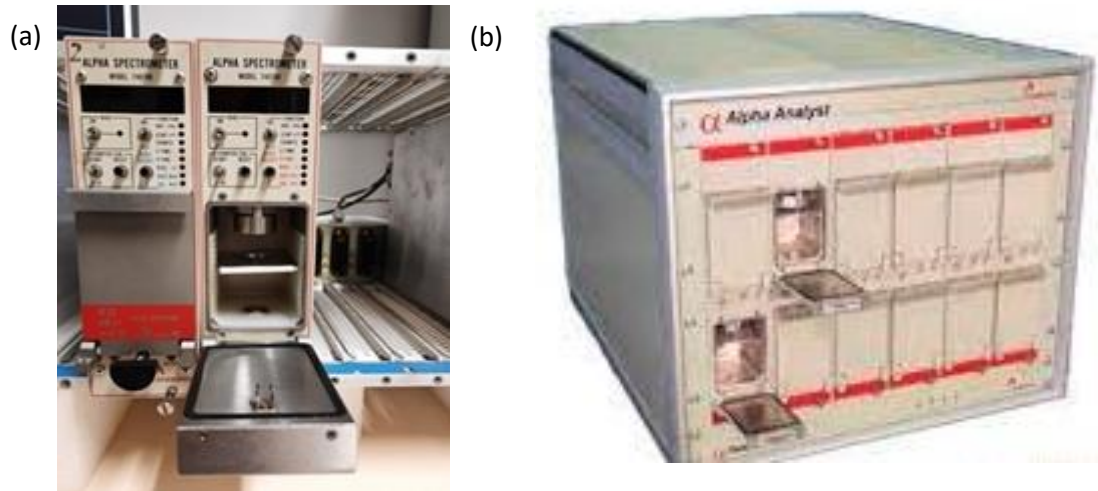


Fig. 8 (a) The alpha spectrometer 7401VR (Canberra, USA), (b) the alpha spectrometer Alpha Analyst™ (Mirion Technologies (Canberra), Inc., USA).

- Information about measurement and results

Tab. 5 Results of uranium radioisotopes concentration in a rock sample from Lab 4 (Callio Lab).

Hall ID (name of the sample)	Measu- rement method	Equipment type	Collection period	Limit of detection	Average results [Bq/kg]		ratio $^{234}\text{U}/^{238}\text{U}$	U [ppm]
					$^{234}\text{U}$	$^{238}\text{U}$		
rock sample Lab 4	Alpha spectro- scopy	spectrometers 7401VR (Canberra– Packard) and Alpha Analyst™ (Mirion Technologies (Canberra), Inc., USA)	3 days	0.5 mBq/l for both $^{234,238}\text{U}$ isotopes and 0.5 l initial sample volume	31.98±1.43	32.46±1.45	0.99±0.06	2.63±0.12

Alpha spectrum:

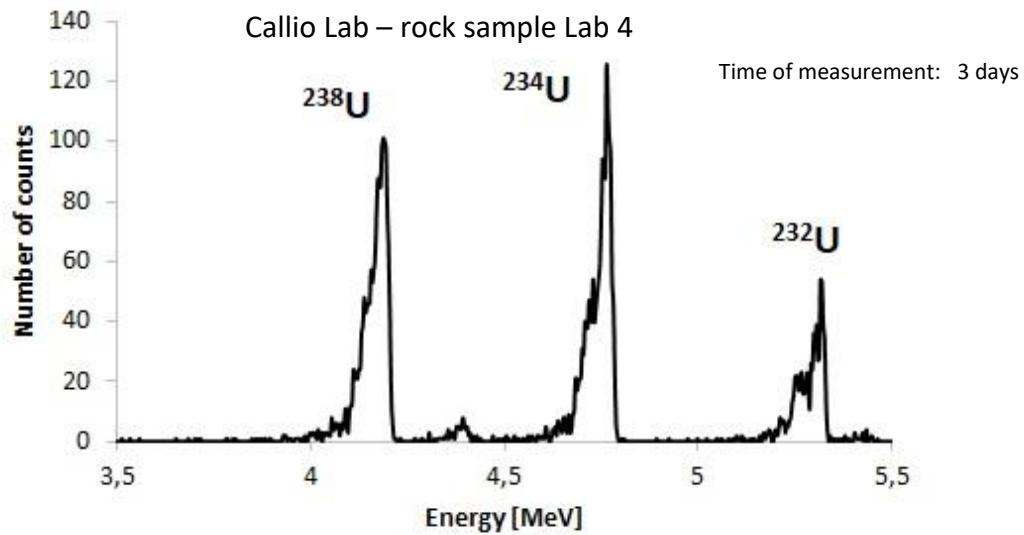


Fig. 9 The alpha spectrum of a rock sample from Lab 4.