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Natural radioactivity in the salt cavern of Polkowice-Sieroszowice copper mine

Kinga Polaczek-Grelik, Jan Kisiel
University of Silesia, Katowice, Poland

Jerzy Wojciech Mietelski, Paweł Janowski, Małgorzata Harańczyk
Institute of Nuclear Physics Polish Accademy of Science, Kraków, Poland

Outline

- Polkowice – Sieroszowice copper mine
  - Location
  - Activity
- The salt board
  - Geological localisation
  - Experimental site
- Measurement of natural radioactivity
  - The goal
  - Equipment
  - Results
  - Analysis
- Conclusions

Location

Polkowice – Sieroszowice copper mine

South – West of Poland

~90 km North – West from Wrocław

Belongs to KGHM Polska Miedź S.A. holding

Activity

Polkowice – Sieroszowice copper mine

Copper – in the top ten of the world's exploitation ranking

Silver – at 3rd place

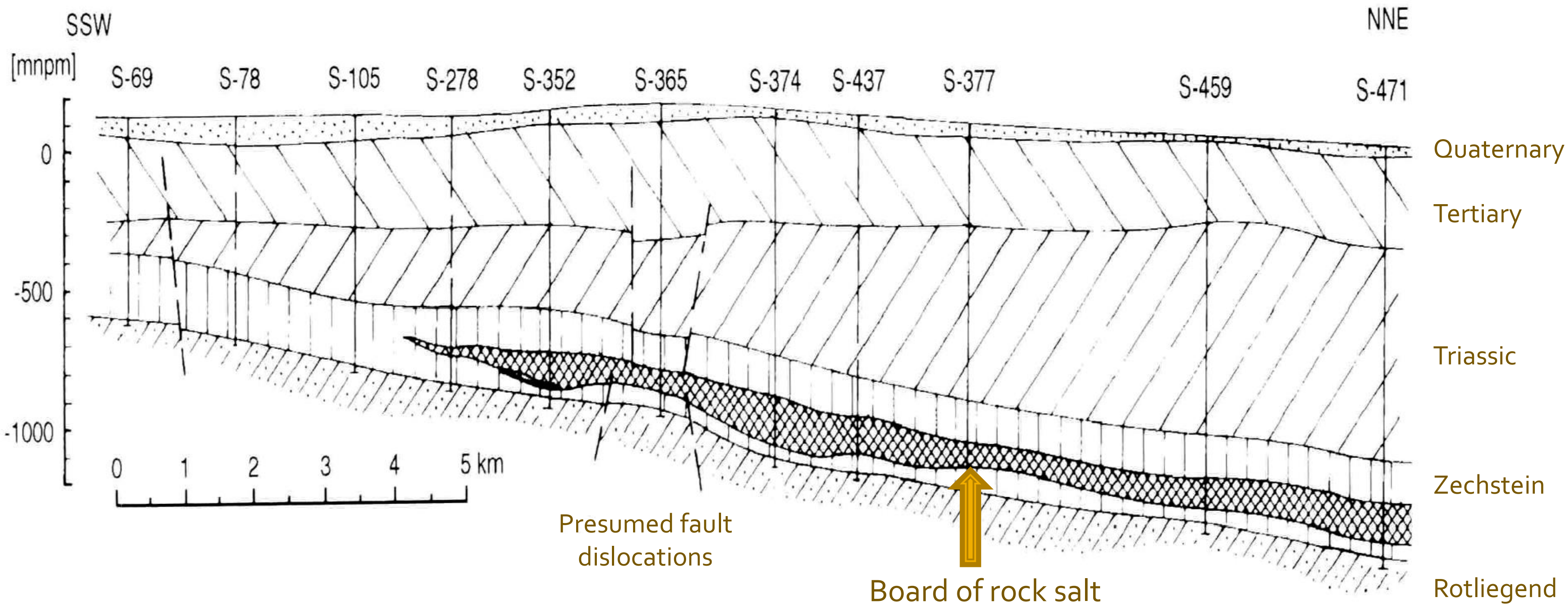
Rock salt for winter maintenance of roads and pavements

Products:
- Copper – cathodes, wire rod, Cu-OFE wire, Cu-Ag wire, round billets, granulates
- Precious metals – silver, gold
- Rhenium – pellets of metalic rhenium, ammonium perrhenate
- Other products – refined lead, sulphuric acid, copper sulphate, nickel sulphate, technical selenium

Salt board

Polkowice – Sieroszowice copper mine

- The salt board in the Lower Silesia region is located from about 500 to 1000 m beneth the ground.
- Exploitation of rock salt at a depth of about 950 m.



Measurement site

Polkowice – Sieroszowice copper mine

Salt cavern at a depth of ~930 m (2200 m w.e.)

Cavern dimensions:
- 15 m wide
- 20 m high
- 100 m long

Salt layer thickness ~70m

Surrounded by anhydrite

Temperature ~36°C

Goal

Measurement of natural radioactivity

ISOTTA (Isotope Trace Analysis) – advanced techniques for the production, purification and radio-purity analysis of isotopically enriched sources for double beta decay

The ISOTTA project of Polish group partly aimed at a construction of low-background HPGe spectrometer

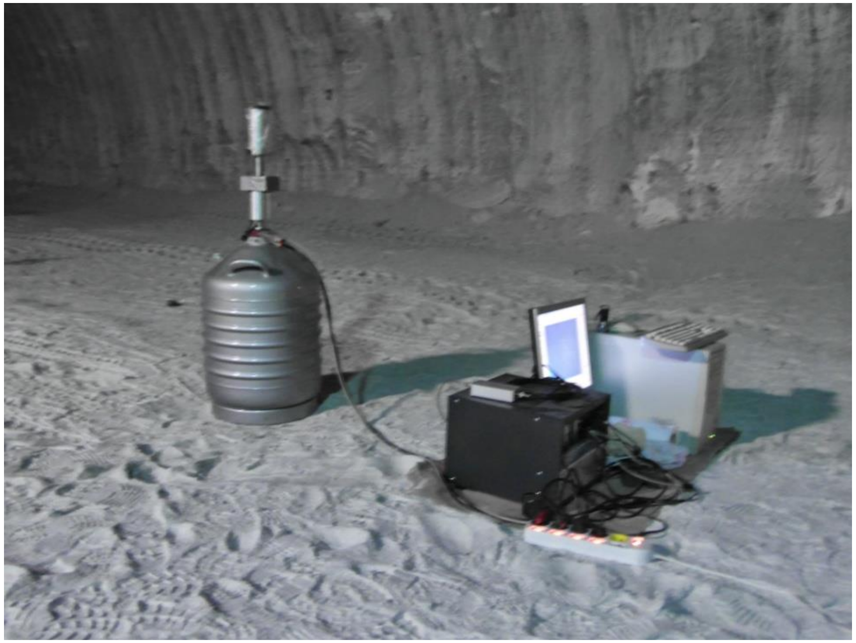
Ultimately, the detector is to operate surrounded by Pb shielding in underground laboratory

The location of such laboratory is not established yet, but Polkowice-Sieroszowice mine is probable

- Check the environmental radioactivity in a potential location of underground laboratory
- Test the newly constructed low-background HPGe spectrometer
- Estimate the efficiency of Pb shielding additionally designed for detector operation

Equipment 1

Measurement of natural radioactivity



HPGe low-background detector

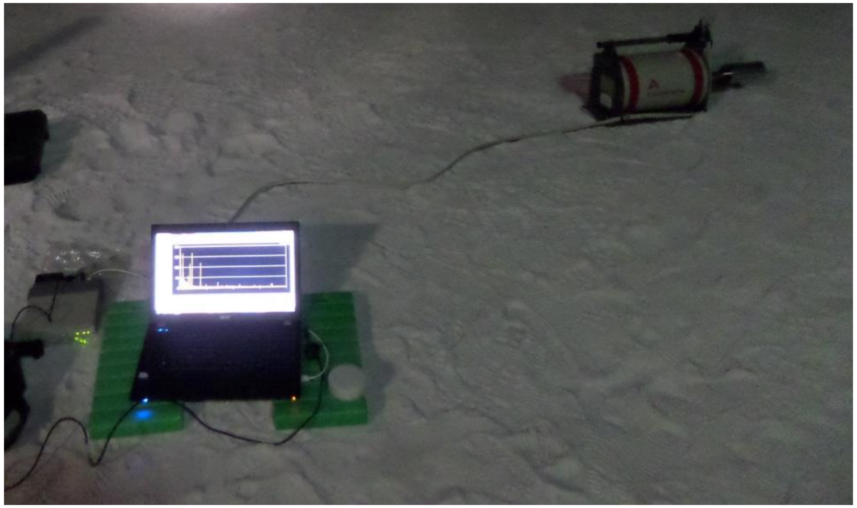
- n-type coaxial
- manufactured at IFJ PAN from Umicore germanium monocrystal (about 600 g)
- vertical cryostat produced by Baltic Scientific Instruments (Riga, Latvia)
- standard Canberra NIM modules: HV supply and amplifier, and Polish MCA Tukan 8K USB (NCNR, Świerk, Poland)
- total U and Th concentration :
  - in copper elements of cryostat – below **0.1 ppb**
  - in aluminium alloys of detector holder or endcap – below **1 ppb**
- endcap (Ø 83 mm) equipped with carbon fibre composite window (8 mm thick, Ø 50 mm)
- cold finger and preamplifier housings – made of stainless steel.

Equipment 2

Measurement of natural radioactivity

HPGe in situ gamma spectrometer

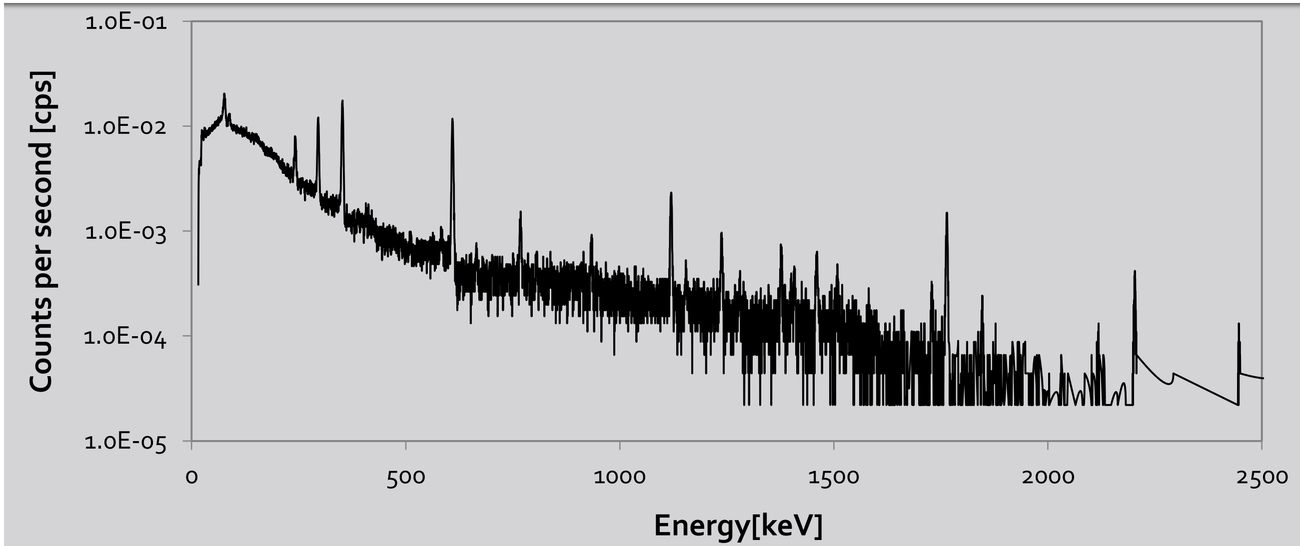
- reverse-electrode type (REGe)
- GR4020, Canberra Industries, Inc.
- crystal: Ø61 mm, 63 mm long
- portable spectroscopy workstation InSpector 2000 DSP
- resolution: 1.12 keV (at 122 keV), 2.08 keV (at 1.33 MeV)
- (P/C) ratio: 57/1
- carbon composite entrance window: 0.6 mm thick
- energy range: 10 keV – 3.2 MeV.
- Genie 2000 v.3.2.1 software package.
- additional shielding: 2.5 cm Pb (ISOXSHLD, Canberra)



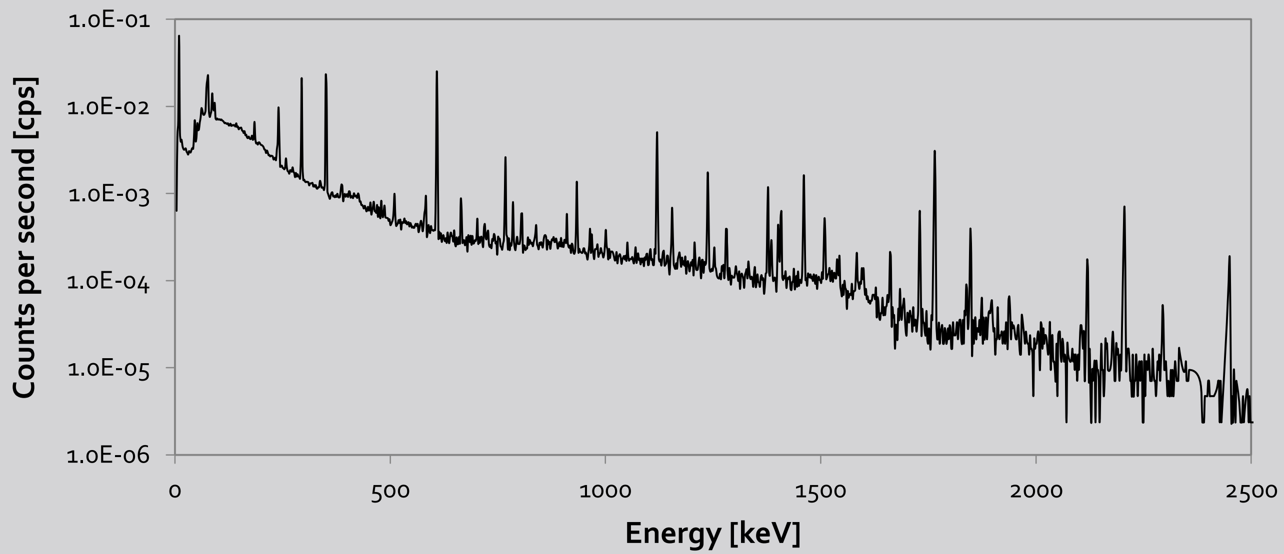
Results 1

Measurement of natural radioactivity

Low-background HPGe
24-h spectrum registration



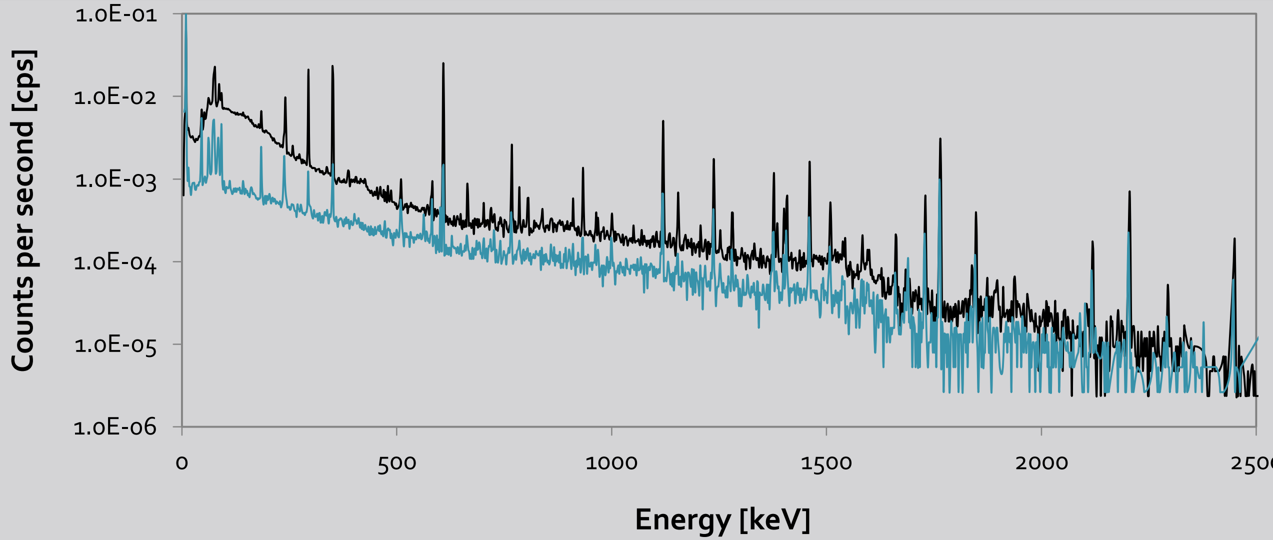
***In-situ* REGe**
23-h spectrum for bare detector
~10 cm above the salt ground



Results 2

Measurement of natural radioactivity

***In-situ* REGe**
23-h spectrum for bare detector
21-h spectrum with 2.5 Pb shield



Estimated gamma-ray flux in the centre of P1 salt cavern:
0.124(4) γ/cm²s

A difference of activity between particular decay chains

Decay series	Count rate [s^{-1}]	
	Unshielded	with 2.5 cm Pb shield
Uranium	0.602 (120)	0.122(7)
Actinum	0.016(2)	0.019(1)
Thorium	0.023(2)	0.016(2)

Concentration of Radon (^{222}Rn) activity during the measurements of gamma radiation spectra:
15.4(11) Bq/m^3

Results 2

Measurement of natural radioactivity

2.5 cm Pb shielding reduces majority of lines' intensities

Low-energy lines are practically unaffected by the Pb shield, i.e. in this energy region detector is counting its own impurities

Uranium series nuclides are built-in the (comercially available) detector

The decrease in ^{40}K line intensity is fully describe by the shielding efficiency (potassium is the content of salt)

Thorium and Actinum series nuclides are absent in the environment of salt cavern

Decay chain	Isotope	Energy [keV]	Count rate [s^{-1}]		
			Portable HPGe		Low-background HPGe
			Unshielded	with 2.5 cm Pb shield	
Uranium	^{210}Pb	46.54	0.0219(12)	0.0270(8)	<0.02
Uranium	^{234}Th	63.29	0.0159(17)	0.0160(9)	–
Uranium	^{234}Pa	73.92	–	0.0153(6)	–
Uranium	^{234}Th	92.59	0.0238(10)	0.0192(10)	–
Actinum	^{235}U	185.71	0.0158(15)	0.0108(6)	–
Thorium	^{212}Pb	238.63	0.0121(6)	0.0092(4)	–
Uranium	^{214}Pb	295.21	0.1082(14)	0.0043(6)	0.0577(12)
Uranium	^{214}Pb	351.92	0.1820(17)	0.0075(6)	0.0957(13)
Thorium	^{208}Tl	510.77	0.0038(6)	0.0028(4)	–
Thorium	^{208}Tl	583.19	0.0033(4)	0.0021(3)	–
Uranium	^{214}Bi	609.31	0.1549(14)	0.0125(4)	0.0687(10)
Uranium	^{214}Bi	665.45	0.0042(5)	0.0002(2)	0.0014(3)
Thorium	^{212}Bi	727.33	0.0012(2)	0.0005(2)	–
Uranium	^{214}Bi	768.36	0.0142(6)	0.0023(3)	0.0059(4)
Thorium	^{228}Ac	964.77	0.0013(2)	0.0003(2)	–
Uranium	^{234}Pa	1001.03	0.0014(4)	0.0008(2)	–
Uranium	^{214}Bi	1120.29	0.0328(7)	0.0055(4)	0.0129(5)
Uranium	^{214}Bi	1238.11	0.0121(5)	0.0024(2)	0.0045(3)
—	^{40}K	1460.83	0.0107(4)	0.0023(2)	0.0036(3)
Uranium	^{214}Bi	1764.50	0.0246(6)	0.0068(3)	0.0090(4)
Uranium	^{214}Bi	2204.21	0.0060(3)	0.0017(2)	0.0024(2)
Thorium	^{208}Tl	2614.53	0.0015(1)	0.0012(1)	0.00033(6)

Results 3

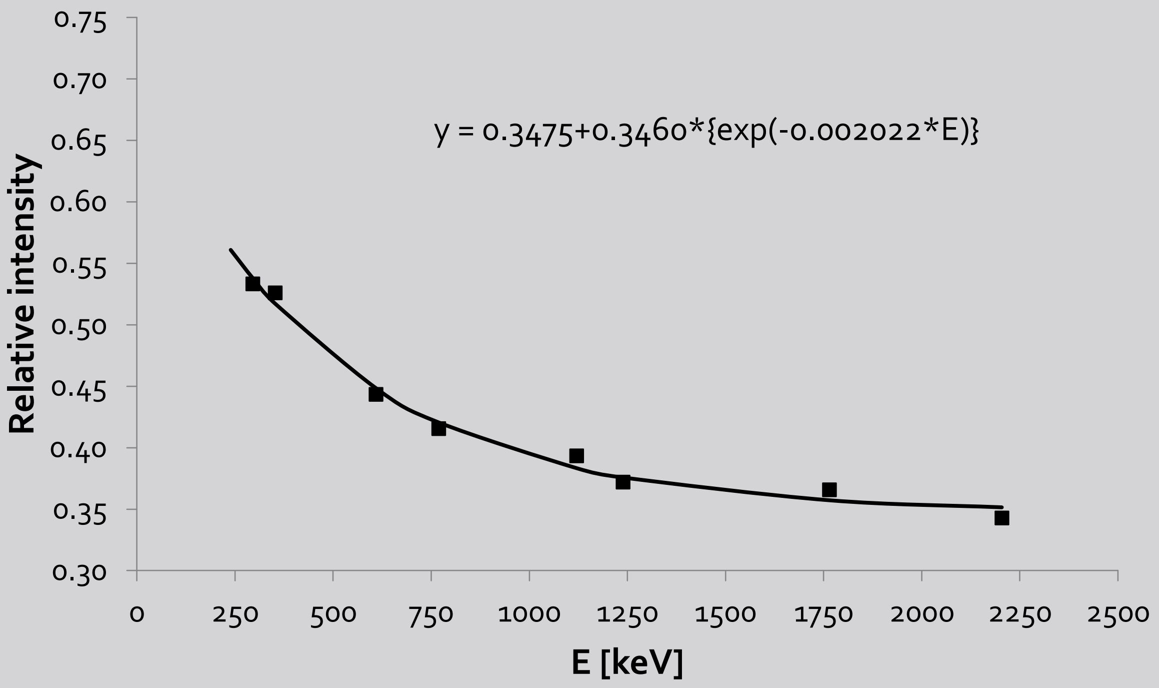
Measurement of natural radioactivity

Cps ratio between low-background and portable detectors for main uranium series gamma lines:

295.21 keV ^{214}Pb
351.92 keV ^{214}Pb
609.31 keV ^{214}Bi
768.38 keV ^{214}Bi
1120.29 keV ^{214}Bi
1238.11 keV ^{214}Bi
1764.50 keV ^{214}Bi
2204.21 keV ^{214}Bi

Values from 0.55 to 0.35

A significant reduction of internal background



Analysis

Measurement of natural radioactivity

48-day measurement on the ground level – well characterised

Pb shielding (10 cm thick) built for low-background spectrometer

The efficiency of the final Pb shield for low-background detector

Energy [keV]	Origin	Ground level shielded [cps]	Unshielded, P1 cavern	Prediction for shielded in P1 salt cavern
242.0	^{214}Pb	0.001248(94)		0.0012
295.2	^{214}Pb	0.002114(82)	0.0587	0.0021
351.1	^{214}Pb	0.003709(74)	0.0957	0.0037
510.8	e^+e^-	0.007602(74)		<0.0001
609.3	^{214}Bi	0.002902(52)	0.0687	0.0029
768.4	^{214}Bi	0.000288(35)	0.0059	0.00027
911.2	^{228}Ac	0.000142(38)		0.00013
1120.3	^{214}Bi	0.000682(35)	0.0129	0.00060
1238.1	^{214}Bi	0.000293(32)	0.045	0.00022
1460.8	^{40}K	0.001222(32)	0.0036	0.0012
1764.5	^{214}Bi	0.000572(25)	0.0090	0.00036
2614.3	^{208}Tl	0.000625(21)	0.00033	0.00010

Conclusions

- The salt deposit in Polkowice-Sieroszowice region has very low potassium content.
- The differences between natural radioactive series are clearly visible.
- Attention must be paid for low-background materials.
- It is possible to achieve as low count rate as 10^{-3} cps in studied localisation by applying a proper Pb shielding.
- Natural radioactivity is one the order of magnitude lower than in other underground laboratories (measured within ILIAS project).

Thank you for your attention

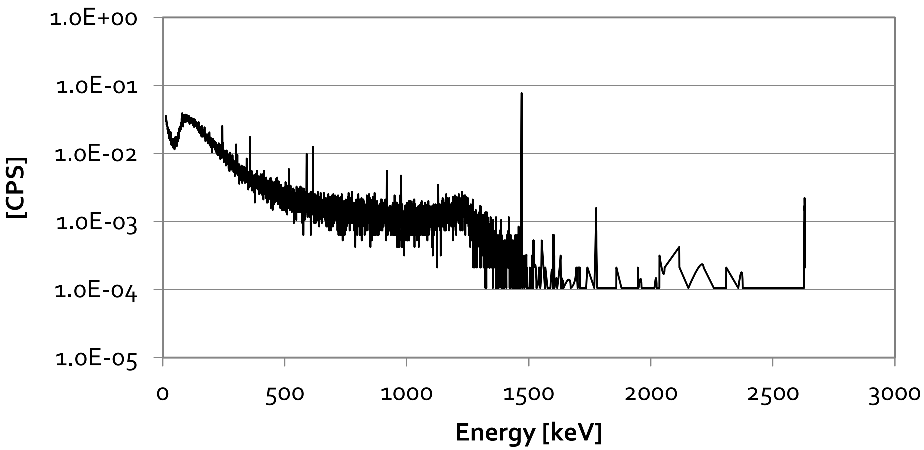
jan.kisiel@us.edu.pl

jerzy.mietelski@ifj.edu.pl

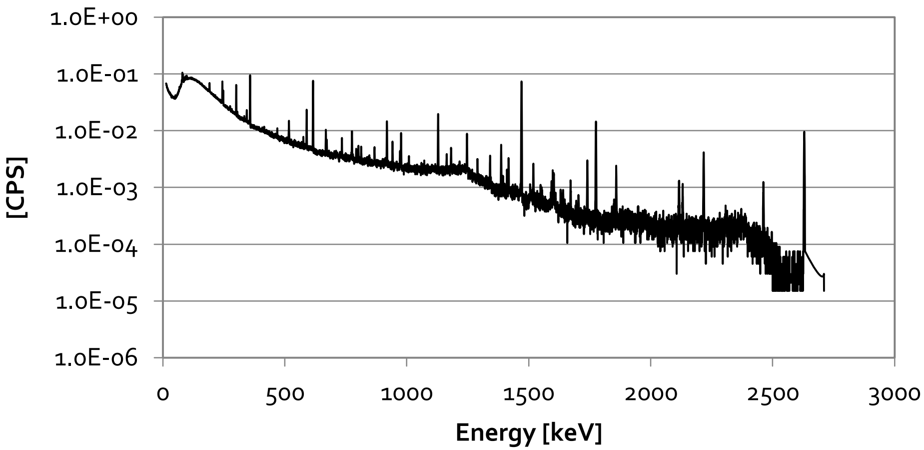
kinga.polaczek-grelik@us.edu.pl

Comparison with underground laboratories (ILIAS Project)

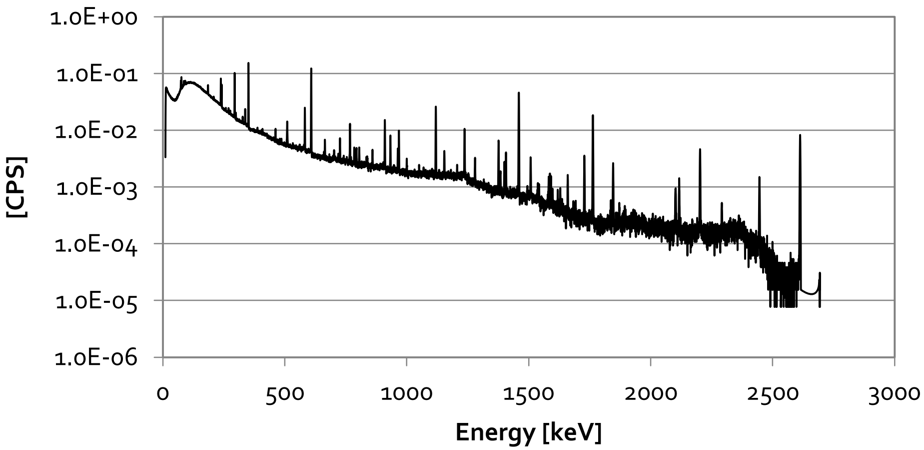
Boulby 2004



Modane 2004



Gran Sasso 2004



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