Background radioactivity of construction materials, raw substance and ready-made $CaMoO_4$ crystals

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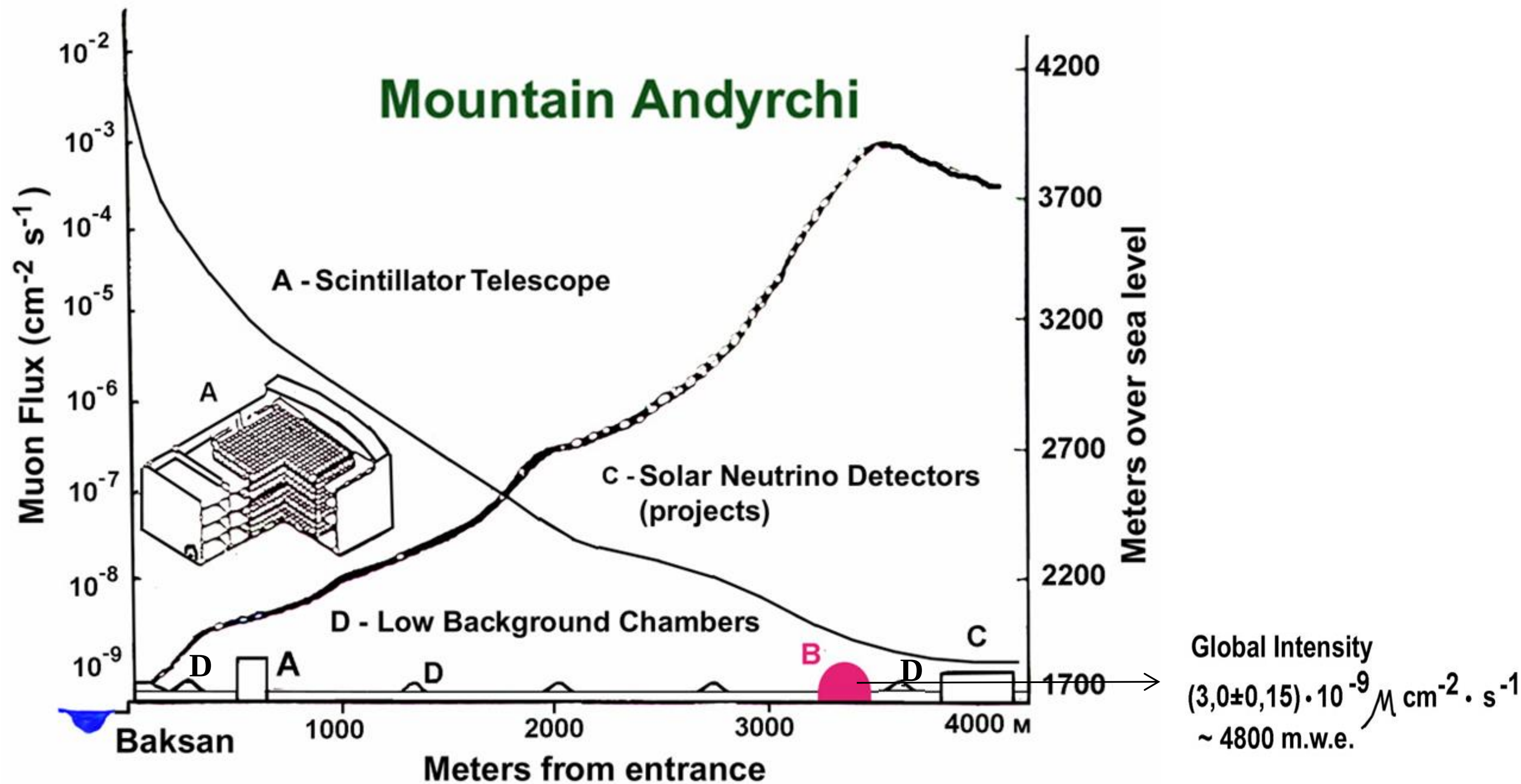
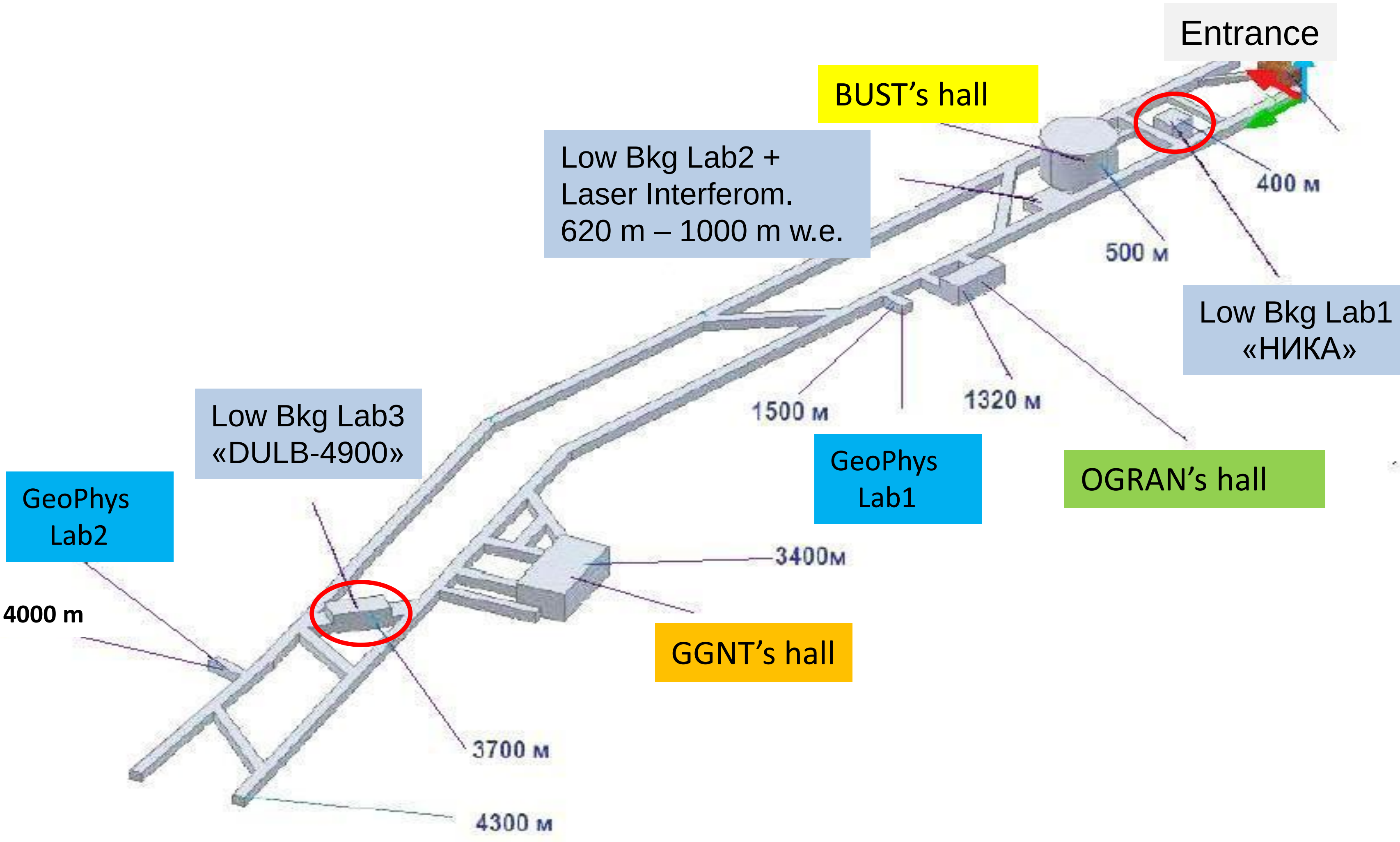
General view of underground objects of BNO



Schematic view of a section of the Andyrchy slope along the adit (write scale) and dependence of underground muon flux on the laboratory location depth (left scale).

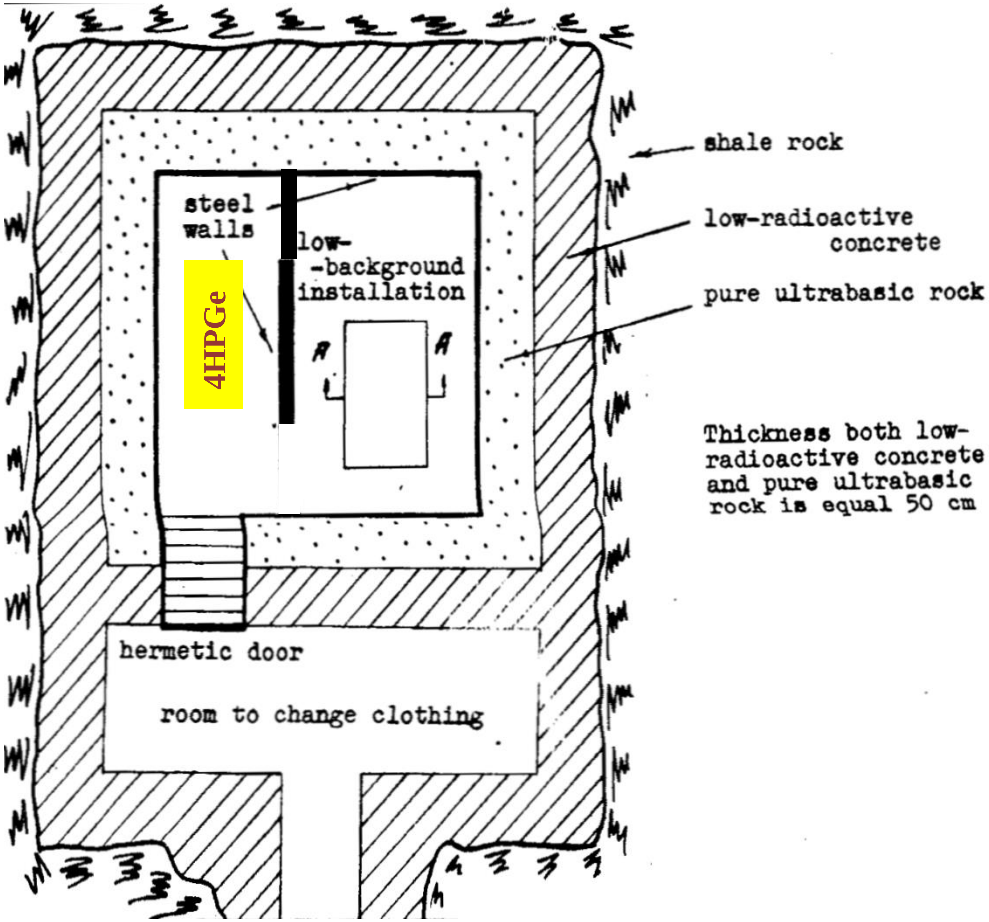
General view of underground objects of BNO

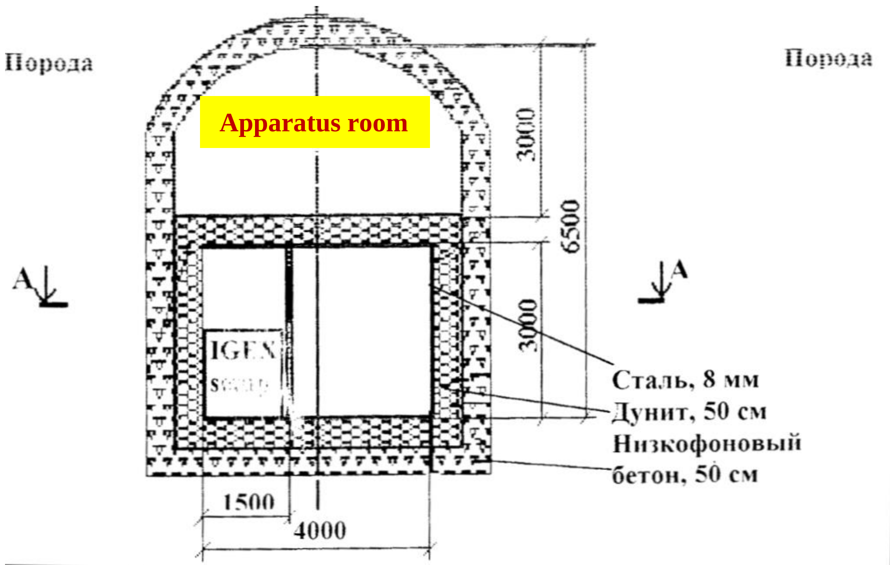


Underground Laboratories of the BNO INR RAS

Characteristics of LBL «НИКА»

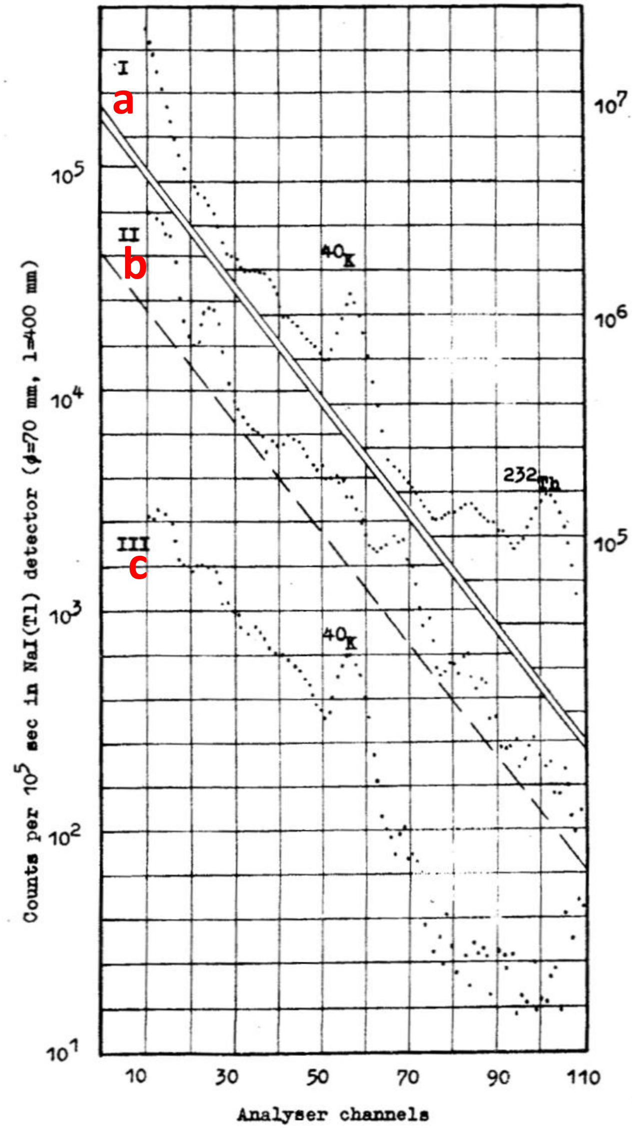
Low-background laboratory at a depth of 660 m w.e, 385 m from the entrance to the tunnel, useful area of 100m^2, put into operation in 1974





E.L.Kovalchuk, V.V.Kuzminov, A.A.Pomansky, G.T.Zatsepin. "Deep underground laboratory for low-radioactivity measurements". Proc. of the Int. Conf. on Low-Radioactivity Measurements and Applications, The High Tatras, Czechoslovakia, October 6-10, 1975. Comenius University, Bratislava, Slovenske Pedagogicke Nakladatel'ctvo, 1977, 23-27.

Characteristics of LBL «НИКА»



Background γ-spectra of NaI(Tl) crystal (d=70 mm, h=400 mm, m=5.645 kg) at different conditions.

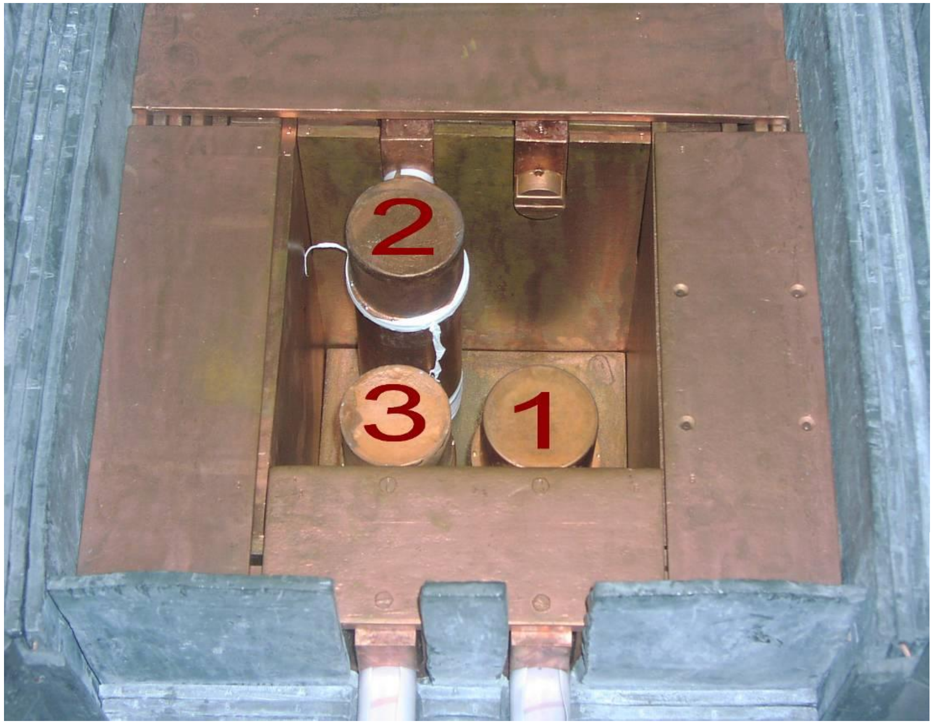
a. Cavern excavated in the rock.
count rate [0.2-3.0 MeV] – 252 [1/(s·kg)]

b. Cavern wall covered by 50 cm low-radioactive concrete + 50 cm pure dunite.
count rate [0.2-3.0 MeV] – 1.17 [1/(s·kg)]

c. "b" + 4.5 cm Pb + 10 cm Cu + 3 cm W.
count rate [0.2-3.0 MeV] – 0.120 [1/(s·kg)]

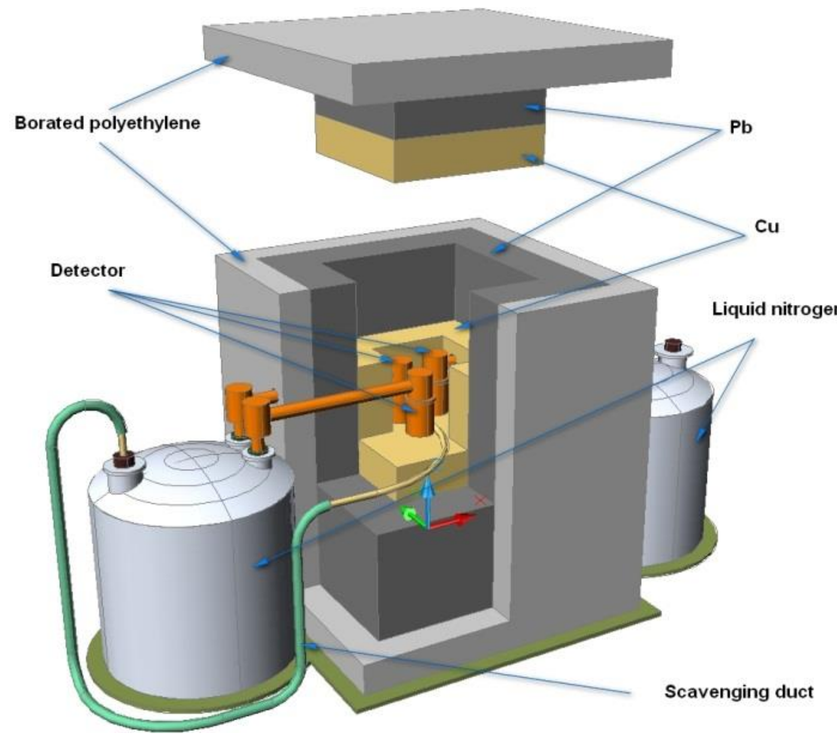
a/b = 215 **a/c = 2092**

Ultra low background germanium gamma-spectrometer



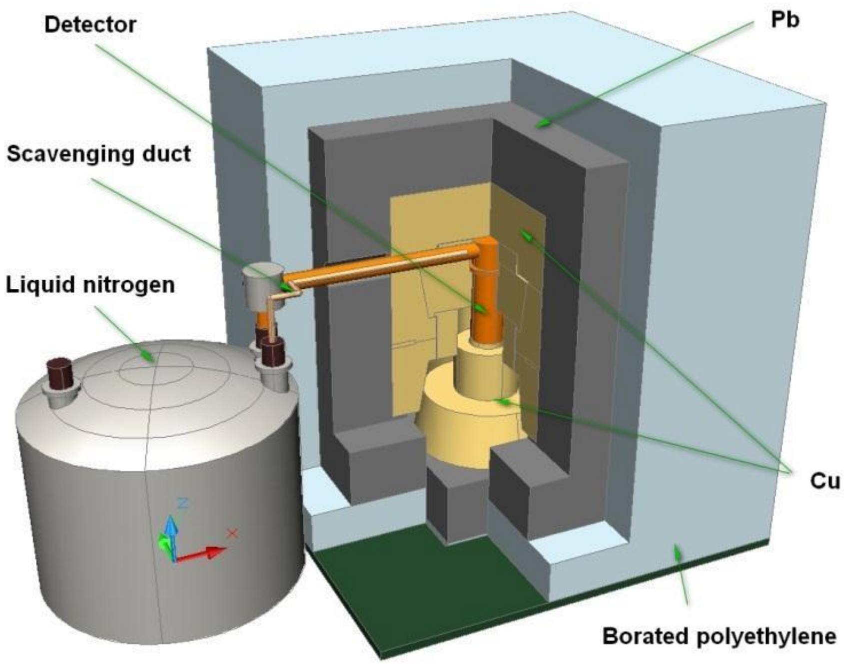
80 mm borated polyethylene
230 mm Pb
120 mm Cu

Detectors "1,2" are made of high-purity germanium, enriched by ^{76}Ge isotope to 87%, detector "3" is made of natural content, high-purity germanium (7,76% of ^{76}Ge). Effective mass of det.№3 is 980 g.



A view of DULB-4800

Ultra low background germanium gamma-spectrometer “СНЕГ”



80 mm borated polyethylene
1 mm Cd
150 mm Pb
180 mm Cu

Measurements for AMoRE collaboration

Activity of radioactive isotopes in the samples (Bq/kg) (95% C.L.)

Sample, material	Isotopes			
	^{40}K	^{228}Ac=(^{232}Th)	^{208}Tl [(^{232}Th)]	^{214}Bi=(^{238}U)
	Activity of radioactive isotopes			
Charge A1 ~$CaMoO_4$ Sintered material of cylindrical shape d=70 mm, h=30mm Mass=414 g, Measurement time=115 h	$(2.7\pm0.5)\cdot10^{-1}$	$(5.3\pm1.9)\cdot10^{-2}$	$(1.3\pm0.3)\cdot10^{-2}$ [$(3.6\pm0.8)\cdot10^{-2}$]	3.07 ± 0.05
Charge A2 ~$CaMoO_4$ Sintered material of cylindrical shape d=72mm, h=27mm Mass=420 g, Measurement time=209 h	$(4.7\pm0.5)\cdot10^{-1}$	$(2.6\pm1.4)\cdot10^{-2}$	$(1.9\pm0.3)\cdot10^{-2}$ [$(5.3\pm0.8)\cdot10^{-2}$]	3.51 ± 0.04
Charge B ~$CaMoO_4$ Sintered material of cylindrical shape d=80mm, h=29mm Mass=523 g, Measurement time=143 h	$(3.6\pm0.4)\cdot10^{-2}$	$\leq7.1\cdot10^{-3}$	$(2.8\pm1.5)\cdot10^{-3}$ [$(7.8\pm4.2)\cdot10^{-3}$]	$(7.8\pm1.1)\cdot10^{-2}$
Monocrystal $CaMoO_4$ from B Elliptical the cylinder with a convex top d_1=50mm, d_2=44mm, h≈40mm Mass=348,5 g, Measurement time=498 h	$(2.0\pm0.8)\cdot10^{-2}$	$\leq5.6\cdot10^{-3}$	$\leq1.4\cdot10^{-3}$ [$\leq3.9\cdot10^{-3}$]	$\leq2.2\cdot10^{-3}$
Calcium formate $Ca(HCOO)_2$ Powder in two plastic bags ~130mm×90mm×13mm Mass=400 g, Measurement time=333 h	$\leq7.0\cdot10^{-3}$	$\leq3.0\cdot10^{-3}$	$\leq8.9\cdot10^{-4}$ [$\leq2.5\cdot10^{-3}$]	$\leq1.7\cdot10^{-3}$

Activity of radioactive isotopes in the samples (Bq/kg) (95% C.L.)

Sample, material	Isotopes			
	^{40}K	^{228}Ac=(^{232}Th)	^{208}Tl [(^{232}Th)]	^{214}Bi=(^{238}U)
	Activity of radioactive isotopes			
Molybdenum oxide $^{100}MoO_3$ Powder in plastic bag ~115mm×100mm×10mm Mass=223 g, Measurement time=840 h	(5.3±0,8)·10^{-2}	≤3.8·10^{-3}	≤1.0·10^{-3} [≤2.8·10^{-3}]	≤2.3·10^{-3}
$^{40}CaCo_3$ White powder in a cylindrical plastic capsule d=52mm, h=27mm Mass=60,25 g, Measurement time=557 h	(7.3±3.1)·10^{-2}	(1.6±0.2)·10^{-1}	(4.4±3.6)·10^{-3} [(1.2±1.0)·10^{-2}]	(2.6±0.2)·10^{-1}
Monocrystal $CaMoO_4$ The elliptical cylinder with a convex top d_1=49mm, d_2=42mm, h≈71mm Mass=553,5 g, Measurement time=795 h	≤8.2·10^{-3}	≤3.1·10^{-3}	≤6.6·10^{-4} [≤1.8·10^{-3}]	≤3.2·10^{-3}
$^{40}CaCo_3$ White powder in plastic bags (4 bags) ~100mm×100mm×15mm Mass=525,04 g, Measurement time=542 h	≤1.24·10^{-2}	(5.9±0.5)·10^{-2}	(1.1±0.1)·10^{-2} [(3.03±0.27)·10^{-2}]	(1.72±0.05)·10^{-1}
Monocrystal $CaMoO_4$ Elliptical the cylinder with a convex top d_1=48mm, d_2=45mm, h≈95mm Mass=494,87 g, Measurement time=893 h	(1.2±0.6)·10^{-2}	≤3.28·10^{-3}	≤7,80·10^{-4} [≤2.15·10^{-3}]	(1.6±0.2)·10^{-2}
$^{40}CaCo_3$ White powder in plastic bags (4 bags) ~60mm×60mm×15mm Mass=540 g, Measurement time=277 h	(1.4±0.5)·10^{-2}	≤3.2·10^{-3}	≤9.0·10^{-4} [≤2.48·10^{-3}]	(5.7±0.3)·10^{-2}

Activity of radioactive isotopes in the samples (Bq/kg) (95% C.L.)

Sample, material	Isotopes			
	^{40}K	$^{228}Ac=(^{232}Th)$	$^{208}Tl\ [(^{232}Th)]$	$^{214}Bi=(^{238}U)$
	Activity of radioactive isotopes			
ZnO White powder in plastic bag ~220mm×150mm×30mm Mass=1018 g, Measurement time=709 h	$(3,8 \pm 3,3)^* \ 10^{-3}$	$(2,7 \pm 0,8)^* \ 10^{-3}$	$(3,2 \pm 1,6)^* \ 10^{-4}$	$(1,4 \pm 0,8)^* \ 10^{-3}$
ZrO_2 Ceramic ring R=137mm,r=87mm,h=25mm Mass=720 g, Measurement time=1 h	≤ 13	47 ± 4	15 ± 1	435 ± 6
Monocrystal $CaMoO_4$ Boule d=45,2mm, h=7mm Mass=494,87 g, Measurement time=515 h	$\leq 1,2 \cdot 10^{-2}$	$\leq 2,4 \cdot 10^{-3}$	$(9,4 \pm 5,4)^* \ 10^{-4}$	$(9,5 \pm 2,2)^* \ 10^{-3}$
Niobium pentoxid Nb_2O_5 White powder in plastic bags d=32,5 mm, h=45mm Mass=60,78 g, Measurement time=638 h	$\leq 3,6 \cdot 10^{-2}$	$\leq 6,8 \cdot 10^{-3}$	$\leq 5,4 \cdot 10^{-3}$	$\leq 5,8 \cdot 10^{-3}$
Monocrystal $CaMoO_4$ Boule (blue color) d_1=52/47mm, d_2=52/46mm, h≈100/60mm Mass=657,83 g, Measurement time=323 h	$\leq 1,4 \cdot 10^{-2}$	$(2,3 \pm 1,9) \cdot 10^{-4}$	$(9,5 \pm 6,4) \cdot 10^{-4}$	$(1,0 \pm 0,3) \cdot 10^{-2}$
Monocrystal $CaMoO_4$ Boule (white color) d_1=52/47mm, d_2=52/46mm, h≈105/56mm Mass=661,28 g, Measurement time=482 h	$\leq 1,2 \cdot 10^{-2}$	$\leq 3,1 \cdot 10^{-3}$	$(1,0 \pm 0,5) \cdot 10^{-3}$	$(1,0 \pm 0,3) \cdot 10^{-2}$

Activity of radioactive isotopes in the samples (Bq/kg) (95% C.L.)

Sample, material	Isotopes			
	^{40}K	^{228}Ac=(^{232}Th)	^{208}Tl [(^{232}Th)]	^{214}Bi=(^{238}U)
	Activity of radioactive isotopes			
Calcium formate *$Ca(HCOO)_2$ (purified)* *White powder in plastic bag* *~110mm×110mm×40mm* *Mass=503 g,* *Measurement time=437 h*	$\leq 8,6 \cdot 10^{-3}$	$(1,3 \pm 1,1) \cdot 10^{-3}$	$\leq 1,3 \cdot 10^{-3}$	$(1,4 \pm 0,9) \cdot 10^{-3}$
Charge $CaMoO_4$ *White powder in plastic bag* *~110mm×110mm×40mm* *Mass=500 g,* *Measurement time=380 h*	$\leq 9,4 \cdot 10^{-3}$	$(1,9 \pm 1,3) \cdot 10^{-3}$	$\leq 1,1 \cdot 10^{-3}$	$\leq 1,6 \cdot 10^{-3}$
Monocrystal $CaMoO_4$ *cut from one side* *Boule (white color)* *d_1=52/47mm, d_2=52mm, h≈100/60mm* *Mass=473,9 g,* *Measurement time=527 h*	$\leq 1,3 \cdot 10^{-2}$	$\leq 3,4 \cdot 10^{-3}$	$(5,0 \pm 4,9) \cdot 10^{-4}$	$\leq 5,3 \cdot 10^{-3}$
Calcium formate *$Ca(HCOO)_2$ (unpurified)* *White powder in plastic bag* *~110mm×80mm×40mm* *Mass=500 g,* *Measurement time=543 h*	$\leq 3,4 \cdot 10^{-2}$	$\leq 9,1 \cdot 10^{-3}$	$\leq 8,3 \cdot 10^{-3}$	$(5,9 \pm 3,8) \cdot 10^{-3}$

Constructional materials

Sample, material	Isotopes					
	^{40}K	^{232}Th	^{238}U (^{214}Bi)	^{54}Mn	^{56}Co	^{58}Co
	Radioactive isotopes activity, (Bq / kg)					
Copper M00k	$(2,0\pm0,5)\cdot10^{-3}$	$\leq2,1\cdot10^{-4}$	$\leq7,8\cdot10^{-4}$	$(1,2\pm0,5)\cdot10^{-4}$	$(1,4\pm0,5)\cdot10^{-4}$	$(4,7\pm0,7)\cdot10^{-4}$
Copper M0k	$\leq1,1\cdot10^{-3}$	$\leq2,5\cdot10^{-4}$	$\leq1,1\cdot10^{-3}$	$\leq1,1\cdot10^{-4}$	$\leq1,2\cdot10^{-4}$	$(3,0\pm0,7)\cdot10^{-4}$
Copper M1B	$(2,3\pm1,2)\cdot10^{-3}$	$\leq4,1\cdot10^{-4}$	$\leq1,5\cdot10^{-3}$	-	-	-
Copper M0B	$(3,2\pm1,1)\cdot10^{-4}$	$\leq7,0\cdot10^{-5}$	$\leq6,1\cdot10^{-4}$	-	-	-
Copper M(?)	$(3,7\pm1,0)\cdot10^{-3}$	$\leq3,6\cdot10^{-4}$	$\leq1,2\cdot10^{-3}$	-	-	-
Lead C1C	$\leq5,2\cdot10^{-3}$	$\leq1,4\cdot10^{-3}$	$(1,2\pm0,2)\cdot10^{-2}$	-	-	-

Sample, material	Isotopes					
	^{40}K	^{232}Th	^{238}U	^{54}Mn	^{56}Co	^{58}Co
	Radioactive isotopes activity, (Bq / kg)					
H.V. connectors SUHNER SHV	80,8±0,9	0,44±0,04	1,06±0,09	-	-	-
L.V. connectors 50-SUHNER	11,2±0,3	$(4{,}7\pm1{,}7)\cdot10^{-2}$	$(5{,}6\pm2{,}6)\cdot10^{-2}$	-	-	-
Lavsan	$\le6{,}8\cdot10^{-3}$	$\le1{,}4\cdot10^{-3}$	$\le5{,}7\cdot10^{-3}$	-	-	-
IGLIDUR	$(4{,}1\pm0{,}7)\cdot10^{-2}$	$\le1{,}5\cdot10^{-3}$	$\le2{,}4\cdot10^{-3}$			
Quartz State Standard 15130-86	$\le7{,}2\cdot10^{-3}$	$\le3{,}6\cdot10^{-3}$	$\le6{,}0\cdot10^{-3}$	-	-	-
Developed plates of nuclear photographic emulsion emulsion	6,0±0,1	$(1.1\pm0{,}3)\cdot10^{-2}$	$\le4{,}9\cdot10^{-3}$	-	-	-
Nuclear photographic emulsion	9,2±0,2	$\le7{,}8\cdot10^{-3}$	$(9{,}7\pm7{,}8)\cdot\cdot10^{-3}$	^{108m}Ag - $(4{,}7\pm0{,}6)\cdot10^{-2}$		

Thank you very much for your attention!