

Ultra low background HPGe detector OBELIX



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**collaboration project between
JINR (Dubna), LSM (Modane),
IEAP CTU (Prague).**

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Measurements of double beta decay

➤ **HPGe detector OBELIX:**

1. Detector description
2. Background measurements
3. ^{100}Mo measurement
4. ^{106}Cd measurement
5. ^{58}Ni measurement

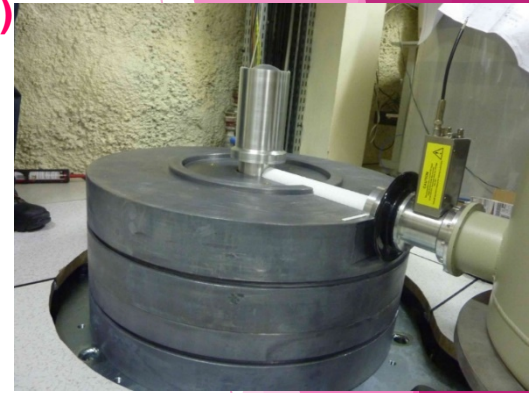
➤ **Summary**

Detector “Obelix” (JINR/IEAP CTU/LSM)



P type coaxial HPGe detector Canberra in U-type ultra low background cryostat located at LSM, France (4800 m w.e.)

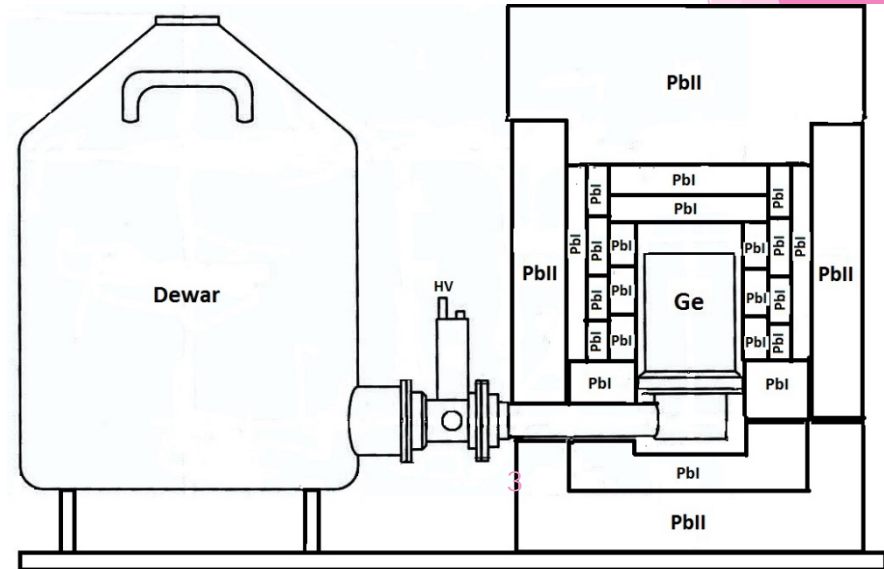
Sensitive volume	600 cm³	Efficiency	162%
Peak / Compton	83		
Energy resolution	~1.2 keV at 122 keV (⁵⁷Co), ~2 keV at 1332 keV (⁶⁰Co)		
Distance from cap	4 mm	Entrance window	Al, 1.6 mm



**~12 cm
arch. Pb**

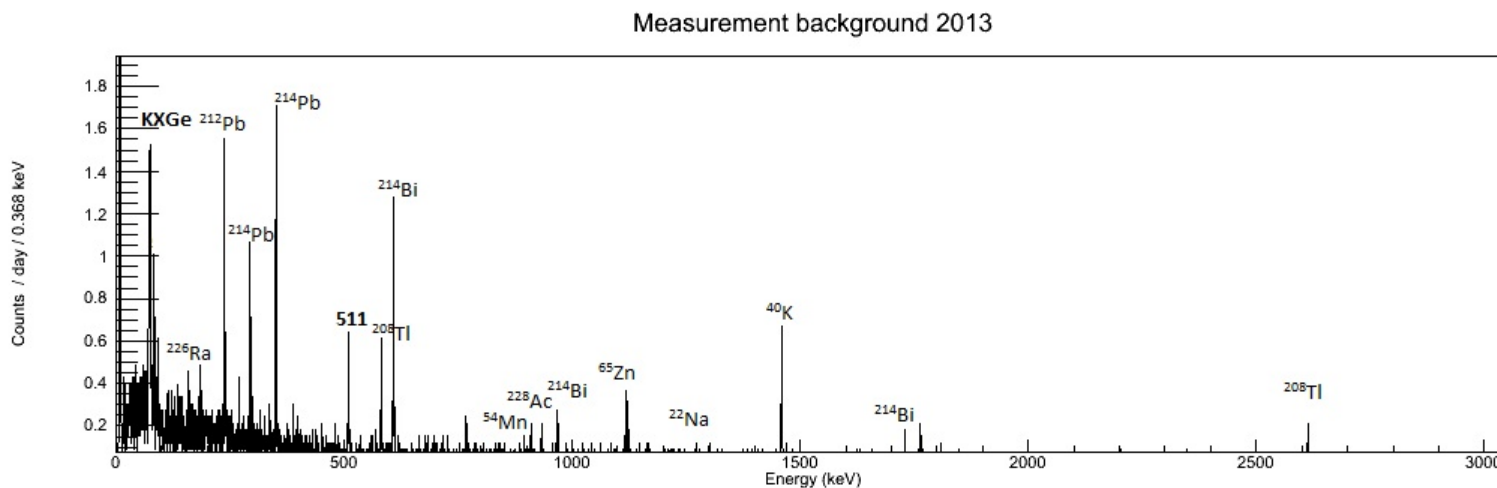
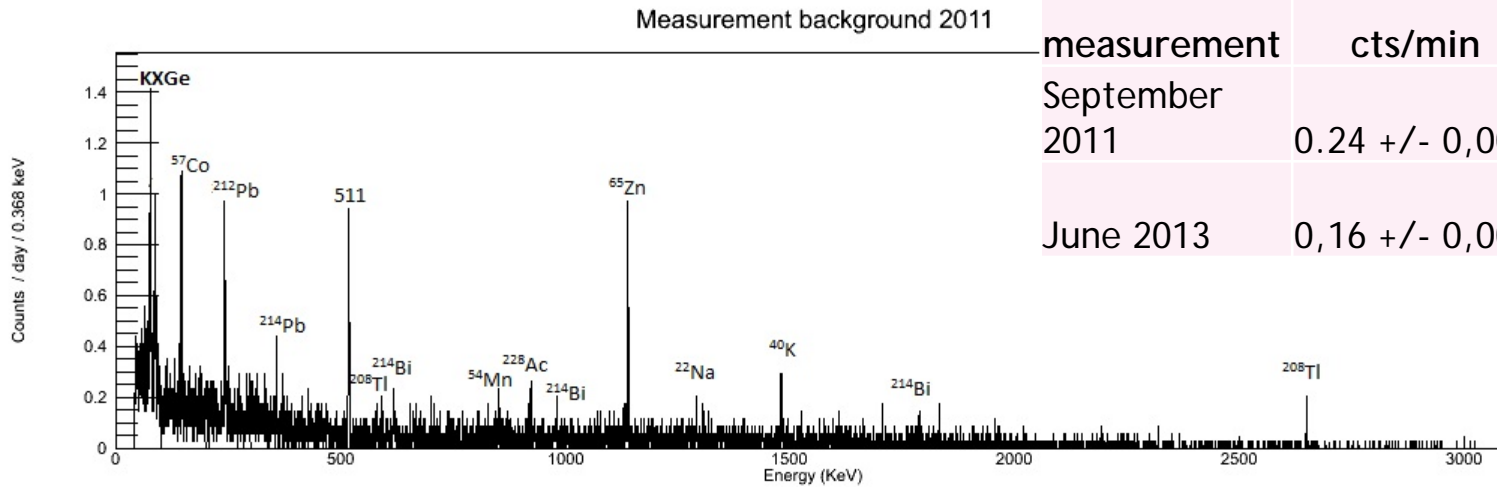
**~20 cm
low
active Pb**

**Radon
free
air**



Background measurements in September 2011 and September 2013

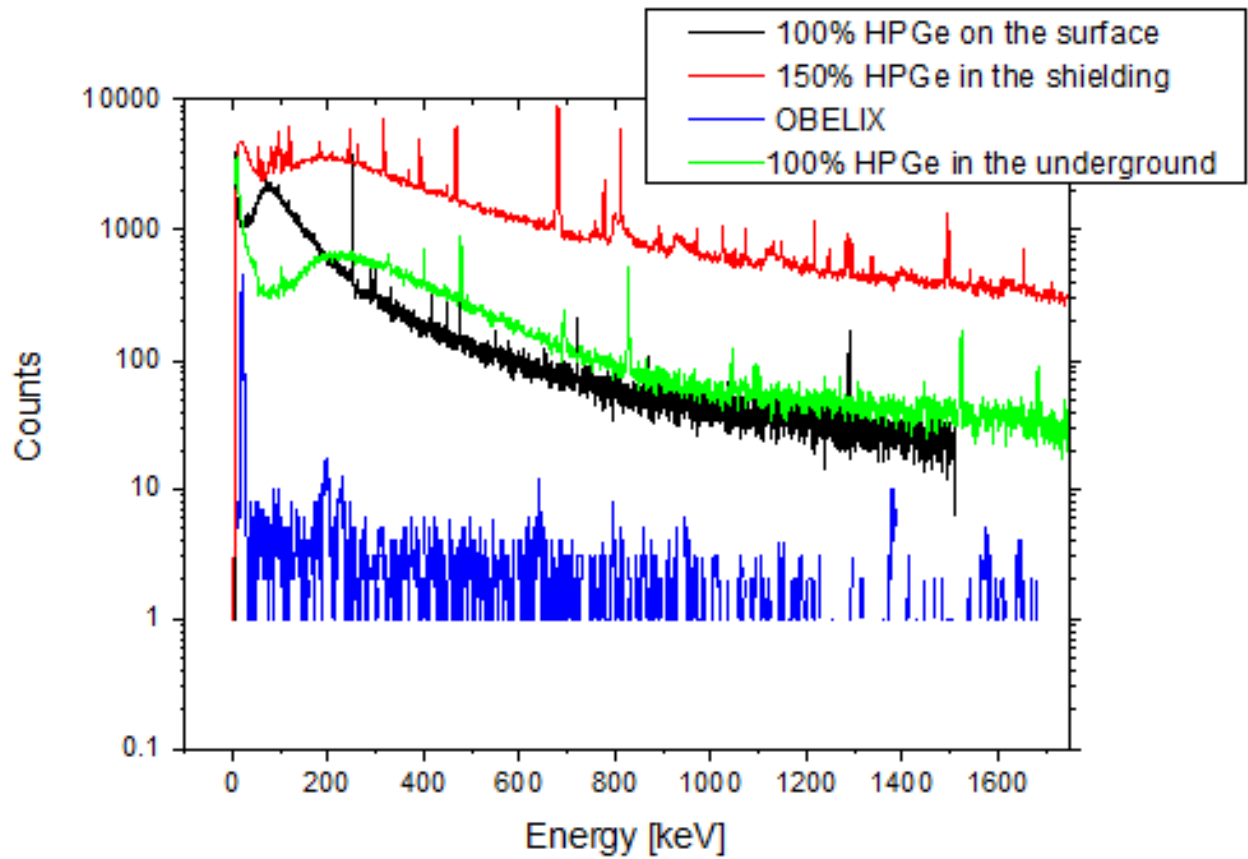
Period of measurement	Total [40-3000 keV] cts/min	Total time of measurement
September 2011	0.24 +/- 0,002	40 days
June 2013	0,16 +/- 0,003	35 days



Comparison of background spectra (IEAP CTU/ NRPI):

3 HPGe detectors (150%, 100%, OBELIX)

5 different measurements – 150% HPGe det. without and with Pb shielding; 100% HPGe det. in improved shielding; 100% HPGe det. in Modane; OBELIX)

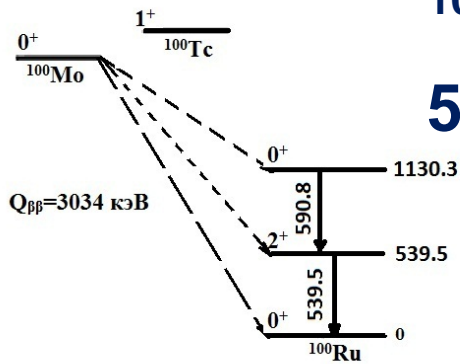


Minimal Detectable Activities (in Bq/unit, 600 000s, 3 l Marinelli):

En. keV	46.5	186	352	511	609	1173
100% in LSM	6,2e-2	2,4e-2	2,9e-2	2,2e-2	2,5e-2	1,5e-2
OBELIX 8,1e-3	4,9e-4	5,6e-4	4,5e-4	4,5e-4	4,7e-4	2,5e-4

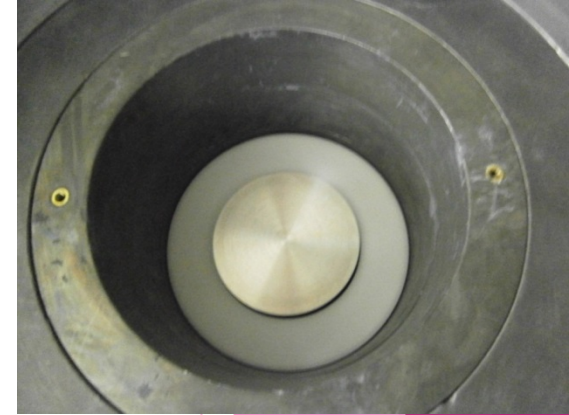
$^{100}\text{Mo} \rightarrow 0^+, 1130 \text{ keV } ^{100}\text{Ru}$

590.8+539.5 keV*

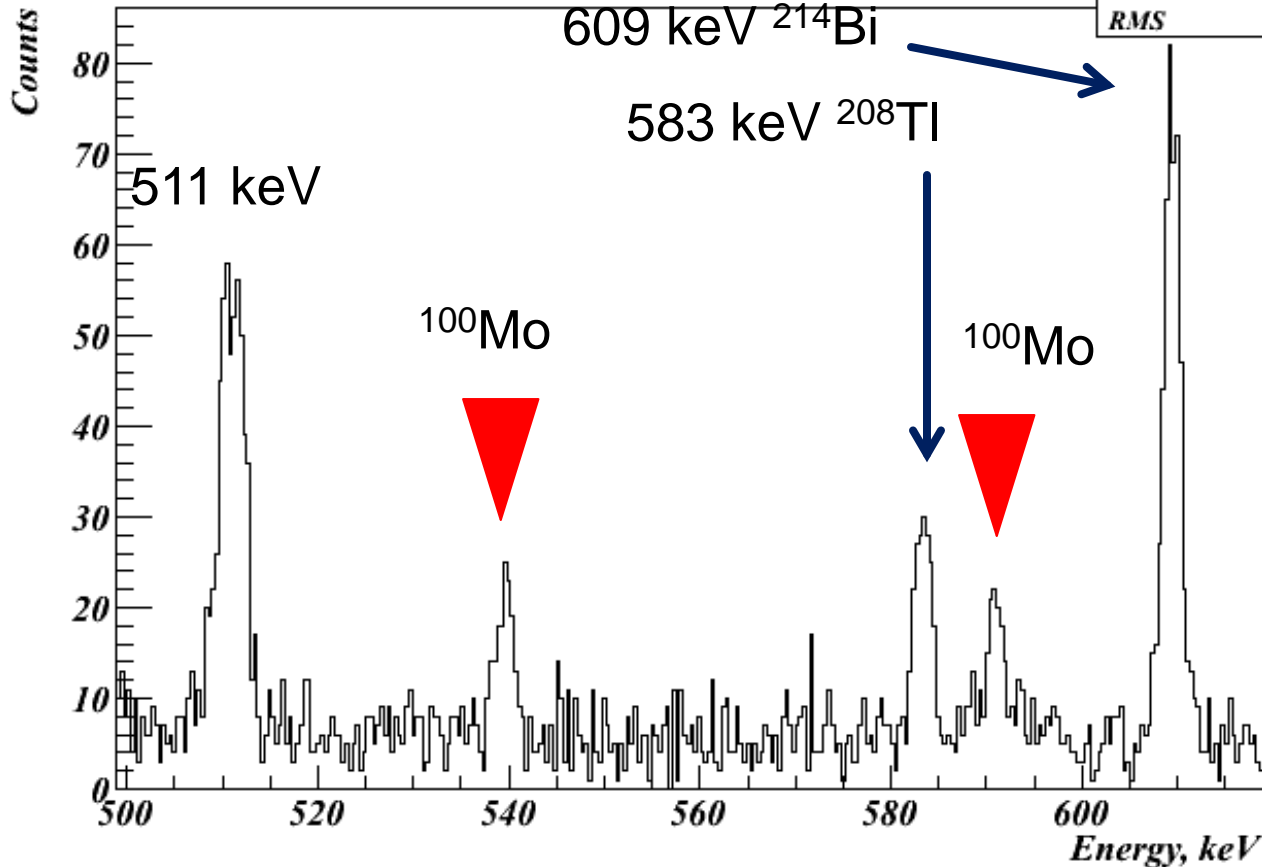


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HPGE spectrum, exposition=4140022 sec



hESpkClb	
Entries	32768
Mean	558.8
RMS	38.69

1st run – 09.11.2011 –

02.12.2012

2nd run – 19.02.2012 –

02.04.2012

- in Marinelli bobbin
- Mass of foils – **2595,02 g**
- Mass of ^{100}Mo – **2517,15 g**
- Total measurement time – **2288 h**

Process	$T_{1/2}$ [years]
$2\nu 2\beta^-$ decay to 0^+_1 [1130 keV]	7.5×10^{20}
$2\nu 2\beta^-$ decay to 2^+_1 [540 keV]	$> 2.5 \times 10^{21}$

Measurement of ^{106}Cd sources with Obelix detector

17 days of measurement

November 2013

stacked in a Teflon box

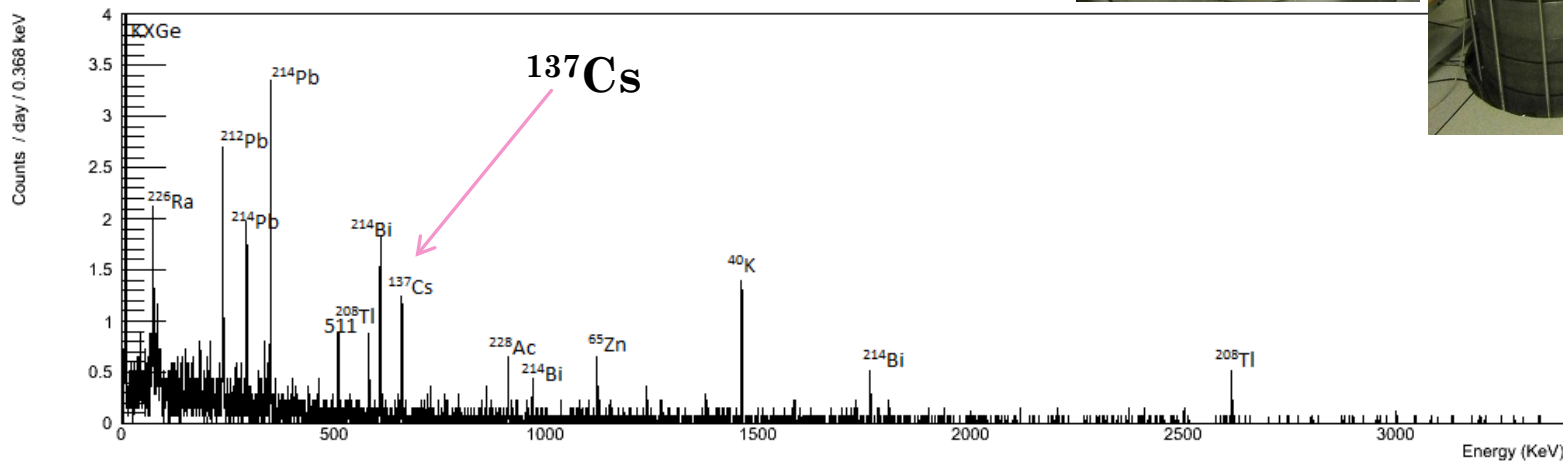
^{137}Cs (661keV):

$6,3 \pm 0,1$ counts/day

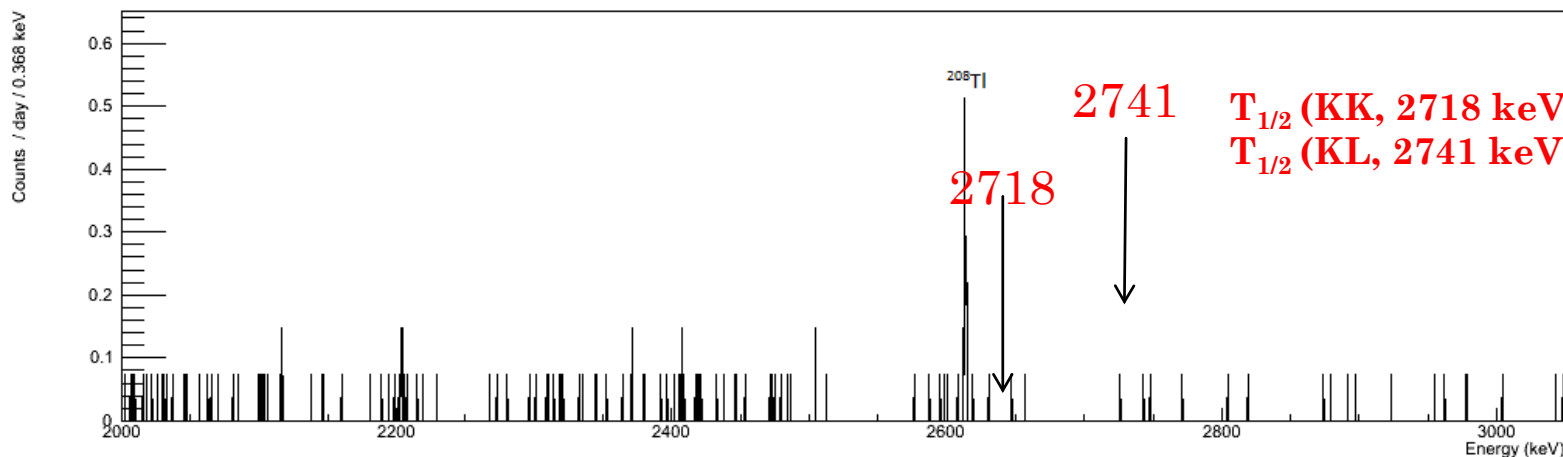
16 samples ($\sim 70 \mu\text{m}$) of ^{106}Cd (enrich. 99.57%)

$\sim 23.2 \text{ g}$ $\sim 1.3 \times 10^{23}$ atoms of ^{106}Cd

Measurement 106Cd 2013



Region of interest 106Cd



Air-filters from Temelin power station (measurement for NRPI)

Sample ETE 2013:

First measurement time-

10.12.13/22.01.14.

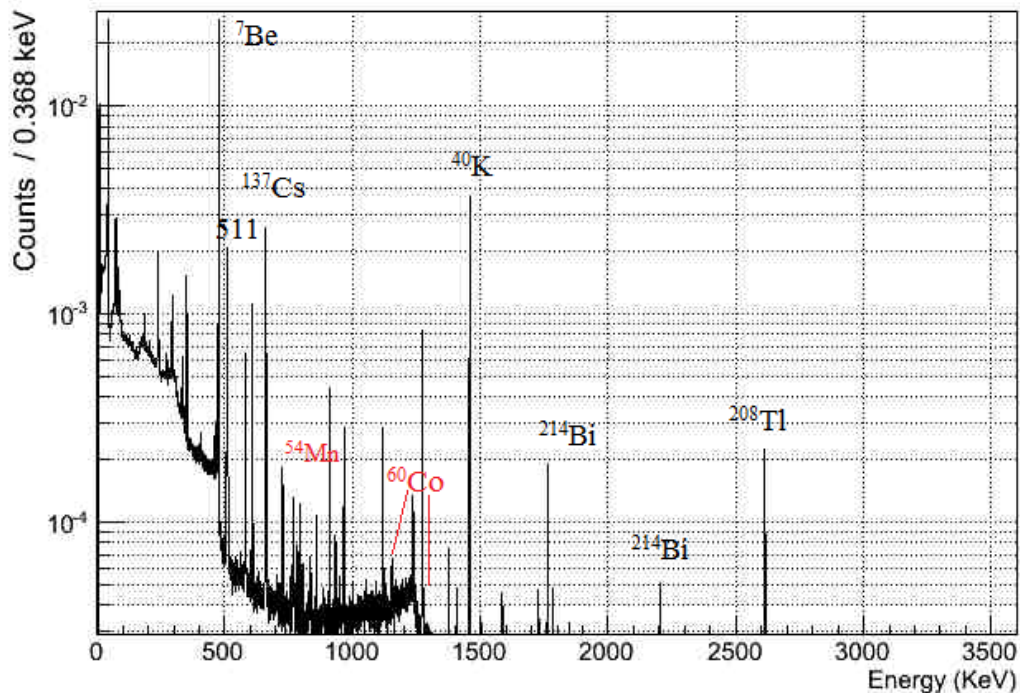
Second period- 1.6.2014/10.7.2014.

Total measurement time - 56 days

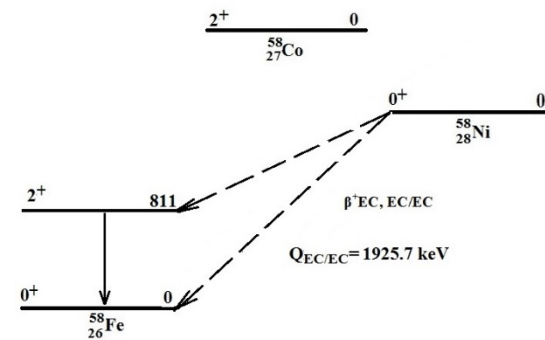
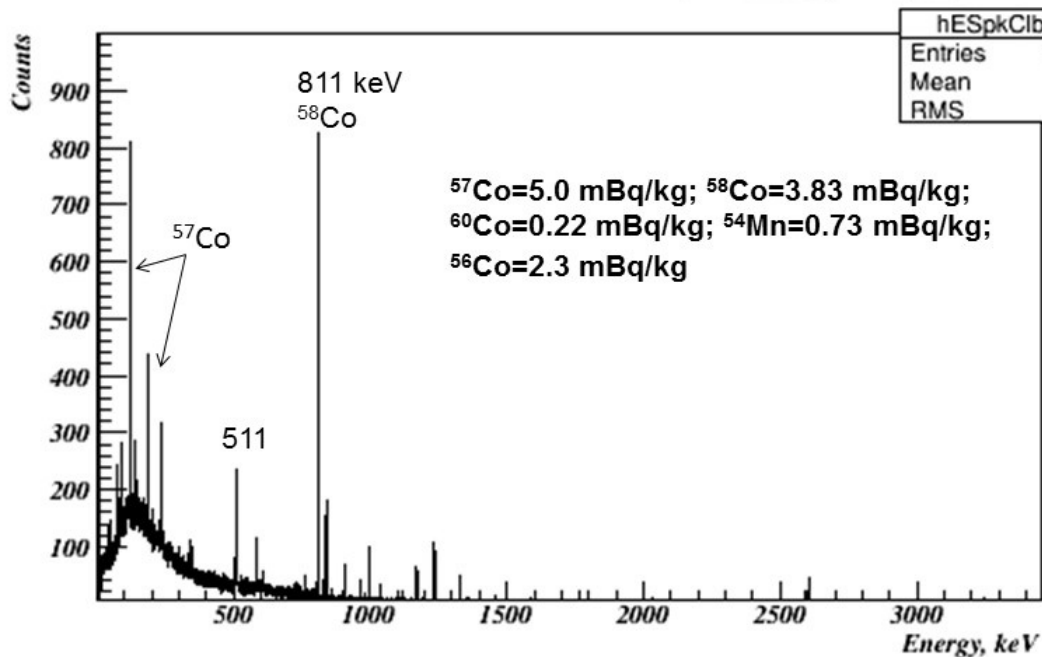
**⁵⁴Mn and ⁶⁰Co were first time seen
in the spectrum**

Sample	ETE2013 (II measurement)	ETE2013 (I measurement)
Time of measurement	33,3 days	22.3 days
Nuclide (Kev)	MDA (Bq/m3)	MDA (Bq/m3)
Mn-54 (834)	3.39E-009	8.79E-009
Co-60 (1173)	3.85E-009	1.5E-008
Co-60 (1332)	2.94E-009	9.9E-009
Ag-110M (884)	7.61E-009	2.01E-008

Air-filters ETE2013



Measurement of ^{58}Ni



Preliminary experimental limits obtained with the OBELIX spectrometer (after 47 days of measurement):

$$T_{1/2}(\beta^+\text{EC}, 0^+ \rightarrow 0^+) > 3.8 \times 10^{21} \text{ y (90\%CL)}$$

$$T_{1/2}(\beta^+\text{EC}, 0^+ \rightarrow 2^+) > 2.6 \times 10^{21} \text{ y (90\%CL)}$$

$$T_{1/2}(\text{EC/EC}, 0^+ \rightarrow 2^+) > 1.2 \times 10^{21} \text{ y (90\%CL)}$$

Total mass: 21.7 kg

Sample: natural Ni (~68% of Ni58)

Estimated time of measurement: 1 year

The investigations of double beta decay ($\beta^+\text{EC}$, EC/EC)

Region of interest: 511 KeV and 811 keV

Theoretical prediction:

$$T_{1/2}(2\nu\beta^+\text{EC}, 0^+ \rightarrow 0^+) = 8.6 \times 10^{25} \text{ y}$$

$$T_{1/2}(2\nu\text{EC/EC}) \geq 6.1 \times 10^{24} \text{ y}$$

Existing experimental limits:

$$T_{1/2}(\beta^+\text{EC}, 0^+ \rightarrow 0^+) > 7.0 \times 10^{20} \text{ y (68\%CL)}$$

$$T_{1/2}(\beta^+\text{EC}, 0^+ \rightarrow 2^+) > 4.0 \times 10^{20} \text{ y (68\%CL)}$$

$$T_{1/2}(\text{EC/EC}, 0^+ \rightarrow 2^+) > 4.0 \times 10^{19} \text{ y (90\%CL)}$$

Summary and plans

- ▶ OBELIX detector is very sensitive setup suitable for the investigation of rare nuclear processes such as resonant neutrino-less double electron capture ($0\nu EC/EC$) and double beta decay ($2\nu 2\beta^-$) to the excited states of daughter nuclei
- ▶ Using the OBELIX spectrometer $2\nu\beta^-\beta^-$ decay of ^{100}Mo to the $0_1^+(1130 \text{ keV})$ excited state of ^{100}Ru was detected with high statistics and good S/B ratio
- ▶ **New results** for half-lives of $2\nu 2\beta^-$ decay of ^{100}Mo to the $0^+(1130 \text{ keV}) - T_{1/2} = [7.5 \pm 0.6(\text{stat}) \pm 0.6(\text{syst})] \times 10^{20} \text{ y}$ and $2^+ (540 \text{ keV})$ excited states of $^{100}\text{Ru} - T_{1/2} > 2.5 \times 10^{21} \text{ y}$ were obtained using the OBELIX detector.
- ▶ Preliminary result for half-life of two-neutrino double electron capture decay of ^{58}Ni to the 811 keV excited state of $^{58}\text{Fe} - T_{1/2} > 1.2 \times 10^{21} \text{ y}$ (90%Cl) was obtained
- ▶ The investigations of $\beta\beta$ decay with the OBELIX spectrometer will be continued with ^{82}Se and ^{58}Ni (1 year of measurement more), ^{96}Zr .
- ▶ Selection of construction materials for underground experiments

Thank you for attention!
Děkuji za pozornost!