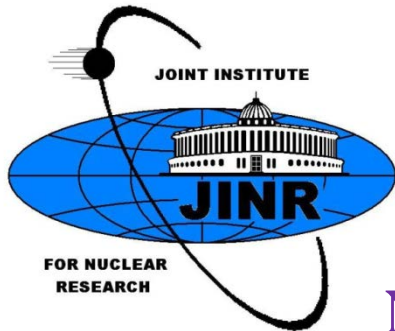


Search for β^+ EC and EC/EC decay of ^{74}Se

**N.I.Rukhadze (JINR, Dubna)
on behalf of Obelix collaboration**



**NRC “Kurchatov Institute - ITEP, Russia
JINR, Dubna, Russia
IEAP, CTU Prague, Czech Republic
LSM, Modane, France**



Medex'19, Prague, May 30st, 2019

SEARCH FOR DOUBLE BETA DECAY

● At present $2\nu 2\beta^-$ decay was detected in **11** nuclei:

^{48}Ca , ^{76}Ge , ^{82}Se , ^{96}Zr , ^{100}Mo , ^{116}Cd , ^{128}Te , ^{130}Te , ^{136}Xe , ^{150}Nd , ^{238}U

and $2\nu\text{EC/EC}$ in ^{130}Ba was detected in geochemical experiment

Double beta decay to excited states of daughter nuclei are accompanied by emission of γ -quanta in de-excitation of excited states. These γ -quanta may be detected by low background HPGe detectors with high efficiency and good energy resolution.

$2\nu 2\beta^-$ decay to excited states was detected in

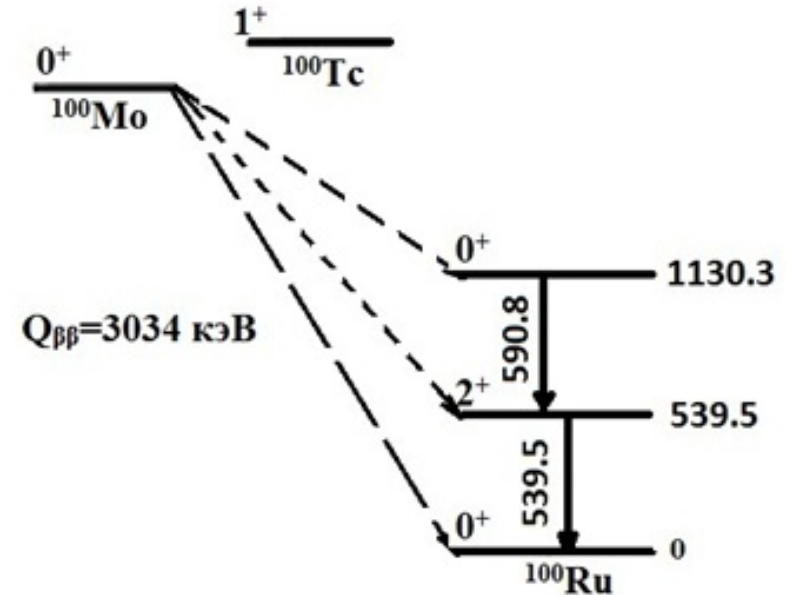
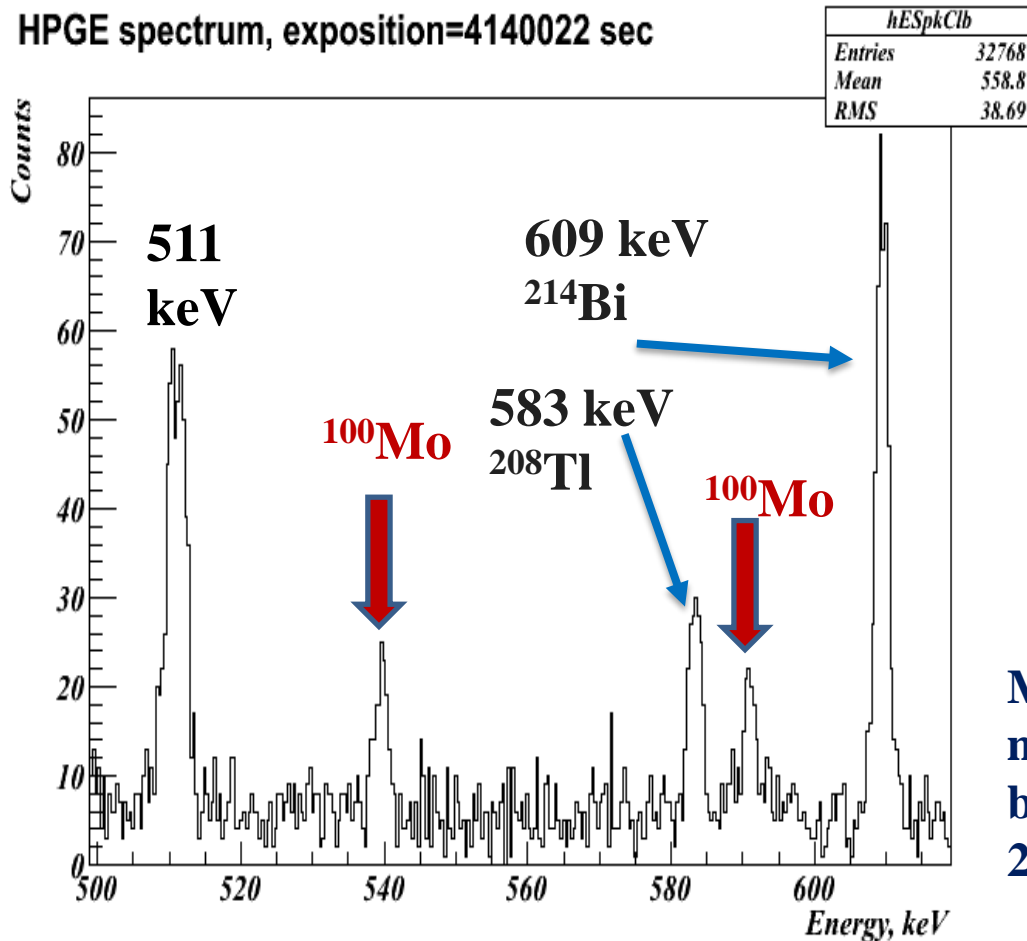
$^{100}\text{Mo} - ^{100}\text{Ru} (0^+_{1}, 1130.3 \text{ keV})$ and $^{150}\text{Nd} - ^{150}\text{Sm} (0^+_{1}, 740.4 \text{ keV})$.

$^{100}\text{Mo} - ^{100}\text{Ru} (0^+_{1}, 1130.3 \text{ keV})$ decay was detected in several experiments, including measurements performed at LSM, Modane with the Obelix HPGe spectrometer

(**R. Arnold et al. Nucl. Phys. A 925 (2014) 25**)

Investigation of $2\nu\beta\beta$ decay of ^{100}Mo - ^{100}Ru to excited states

HPGE spectrum, exposition=4140022 sec



Metallic foil of enriched ^{100}Mo with a total mass of 2 505 g was measured in Marinelli bobbin with the OBELIX spectrometer for 2 288 hours.

$^{100}\text{Mo} \rightarrow 0^+, 1130 \text{ keV } ^{100}\text{Ru}^* \text{ observable } \gamma 590.8 + \gamma 539.5 \text{ keV}$

$^{100}\text{Mo} \rightarrow 2^+, 540 \text{ keV } ^{100}\text{Ru} \text{ observable } \gamma 539.5 \text{ keV}$

$T_{1/2} (0^+_1, 1130.3 \text{ keV}) = [7.5 \pm 0.6(\text{stat.}) \pm 0.6(\text{sys.})] \times 10^{20} \text{ yr (90 \% CL)}$



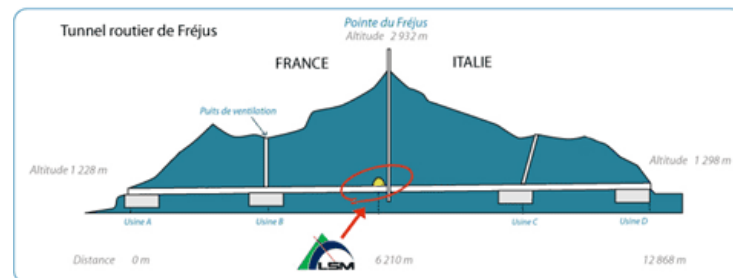
Laboratoire Souterrain de Modane

Fréjus Tunnel at the French-Italian border

Depth - 1800 m of rock (4800 mwe)

Muons flux - 4 muons / m² x day⁻¹
(2x10⁶ reduction factor)

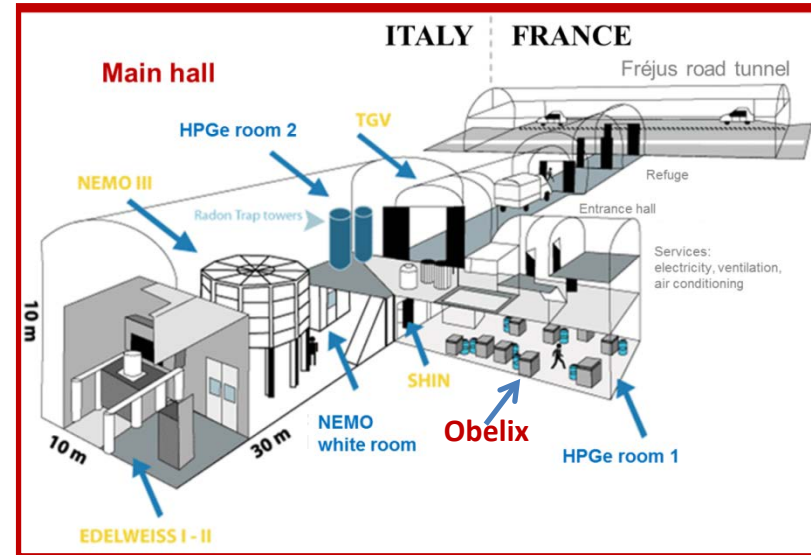
Neutrons flux - 3000 fast neutrons (>1MeV) per m² and per day
(1000 reduction factor)



Detector Obelix*

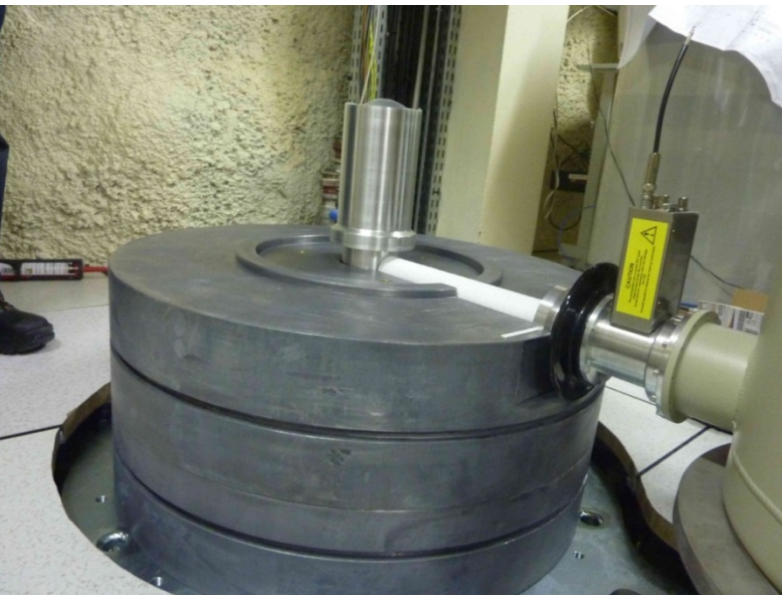
P type coaxial HPGe detector Canberra
in U-type ultra low background cryostat
located at LSM, France (4800 m w.e.)

Sensitive volume 600 cm³
Efficiency ~160%
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

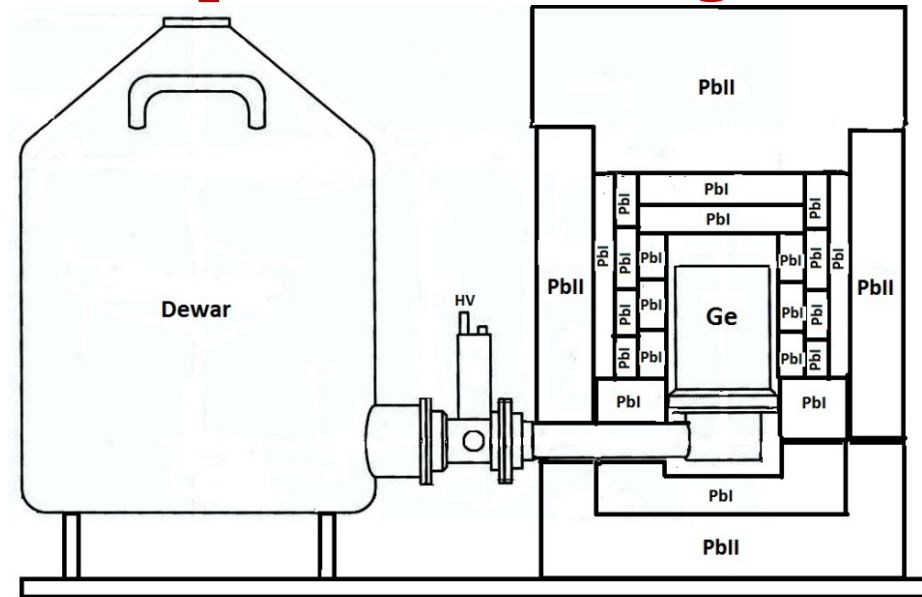
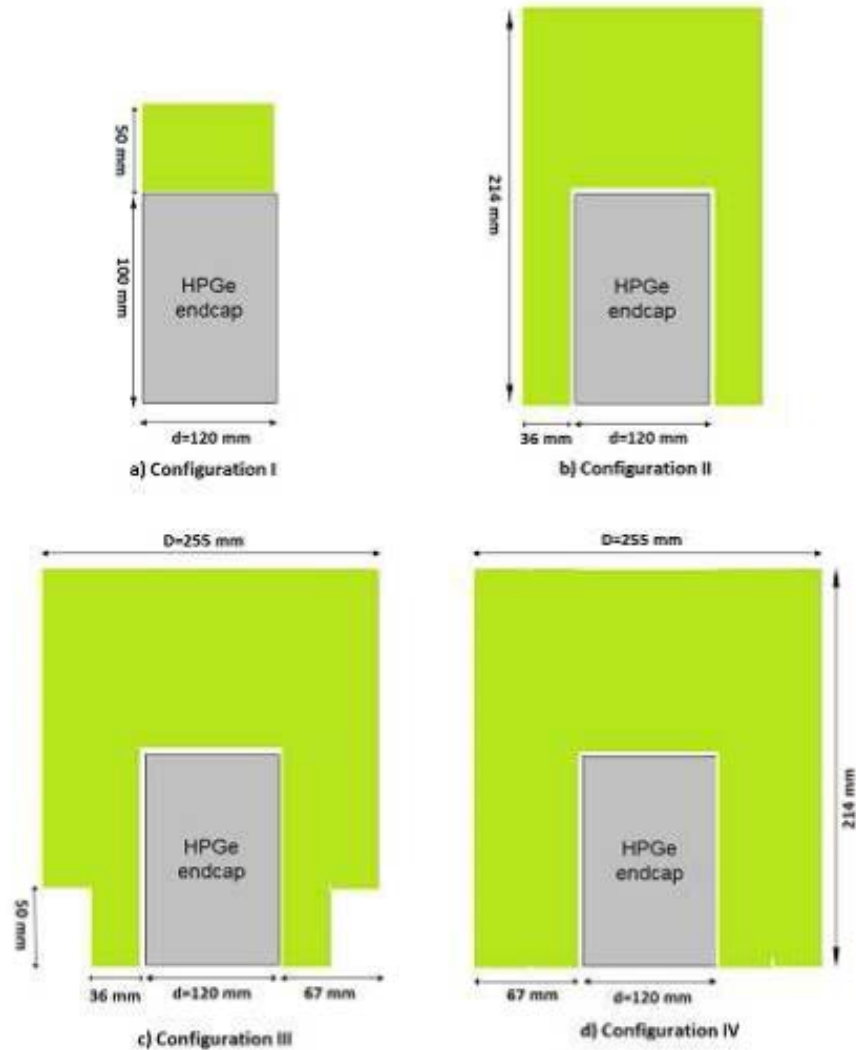


* JINST 12 (2017) P02004.

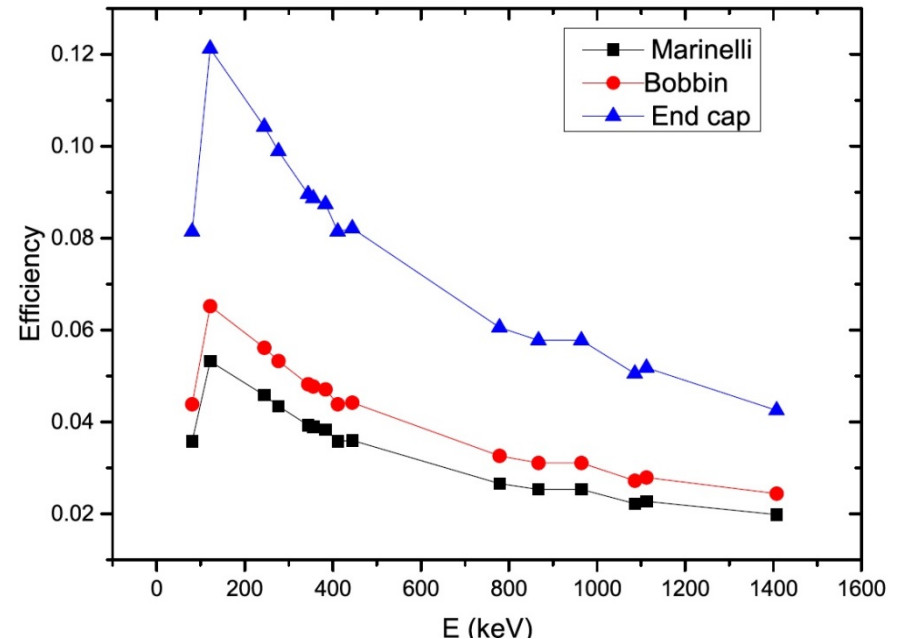
Passive Shielding
 ~12 cm arch. Pb
 ~20 cm low active Pb,
 Radon free air



Configurations of the Obelix passive shielding

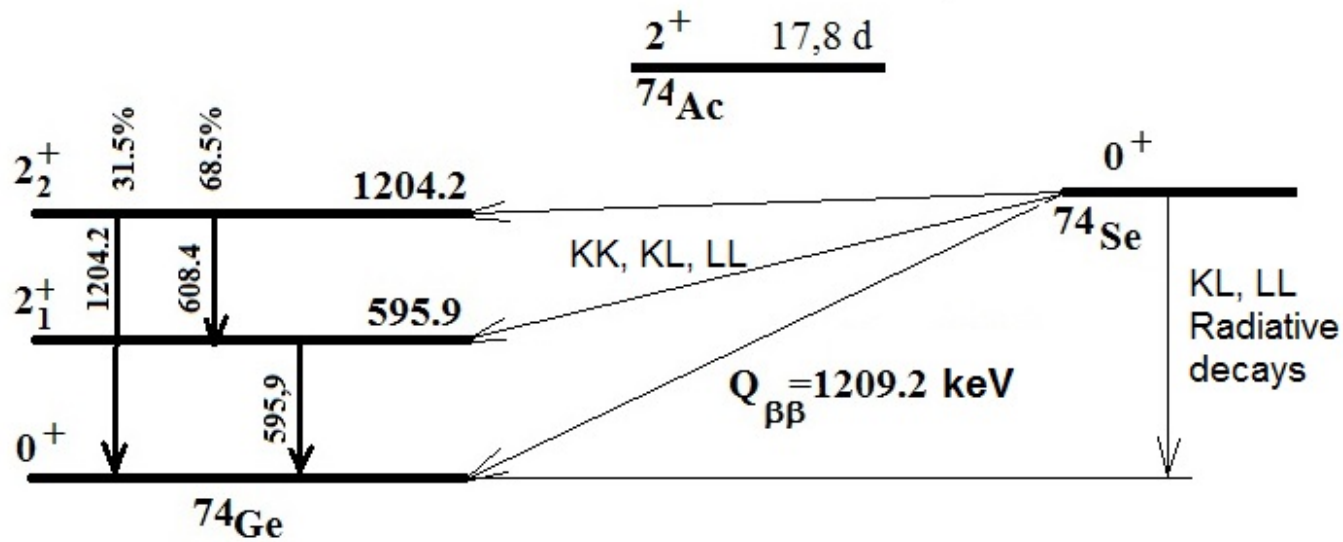


Efficiencies of the Obelix for some geometries

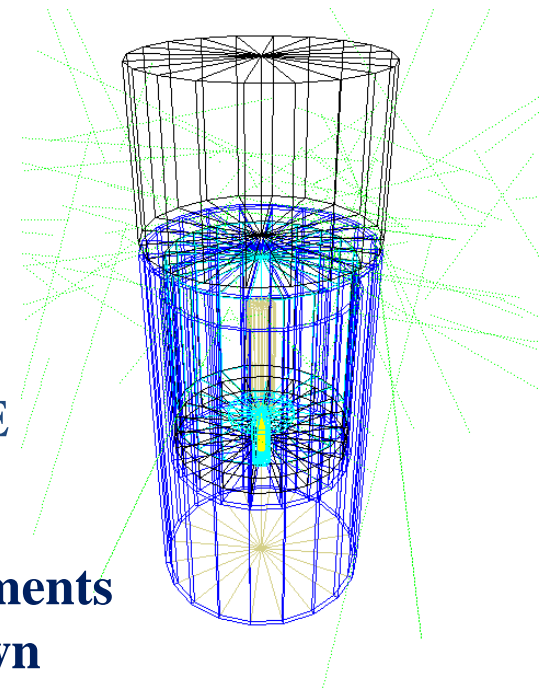


PbI ~ 12 cm of archeological lead (activity of < 60 mBq/kg) (~7 cm can be removed)
PbII ~ 20 cm of low-active lead (activity of 5 - 20 Bq/kg)

Double beta decay of ^{74}Se



Simulated geometry of measurements

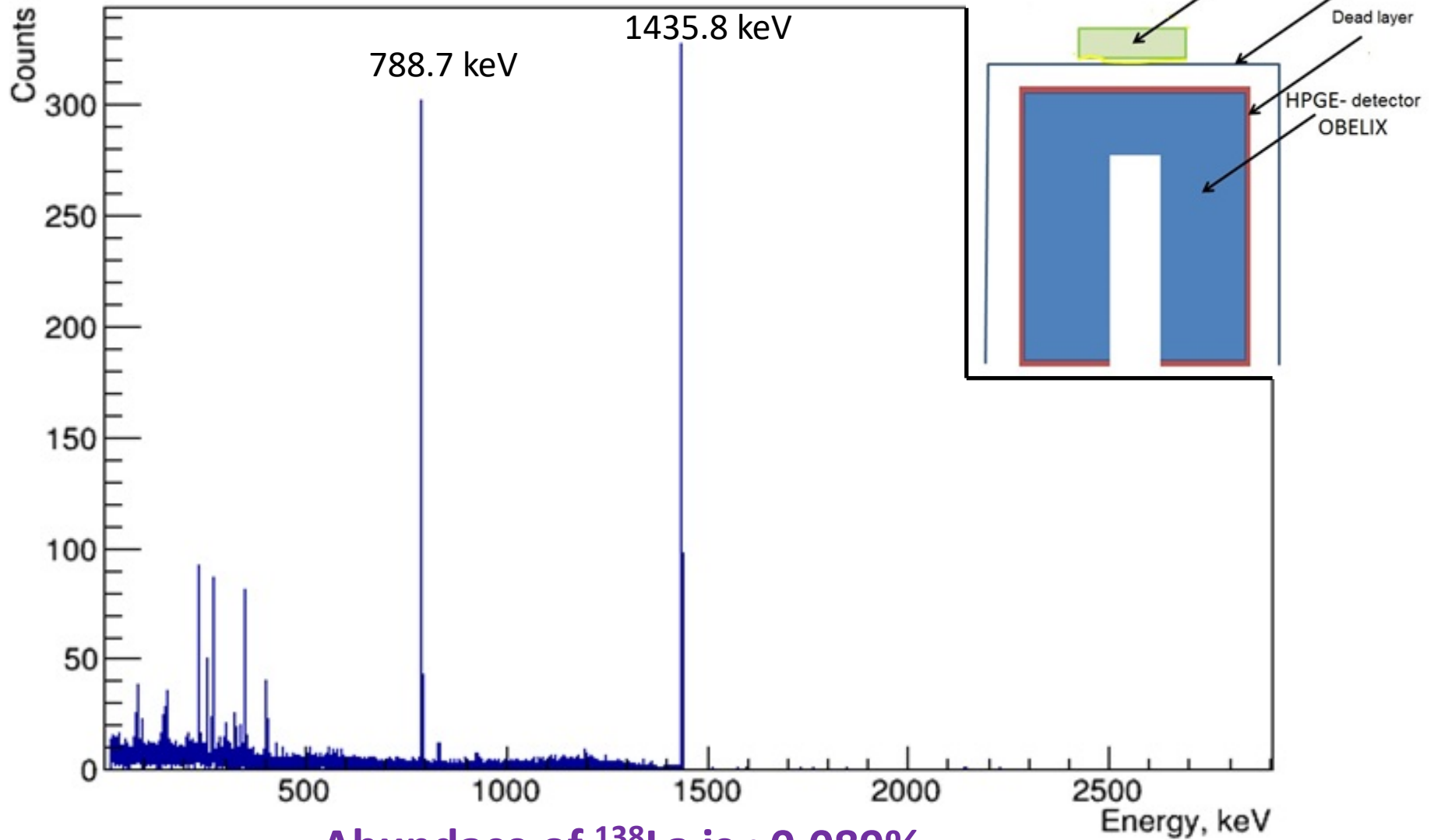


In present investigation we used powder of natural Se with a mass of $m=1.6$ kg, containing $\approx 0.89\%$ of ^{74}Se (14.24 g). Natural Se was placed into a Teflon box with a diameter of $d=115$ mm, a height of $h=80$ mm, and thickness of walls 3 mm. Sample with natural Se was placed on the end cap of the Obelix detector and measured during 135 days.

Simulation was performed using ROOT-VMC-GEANT4 DPGE package in the energy region of 0.05- 5 MeV.

To test the detector efficiency for low background measurements we used low-active samples prepared from La_2O_3 with known mass and activity. (JINST 12 (2017) P02004)

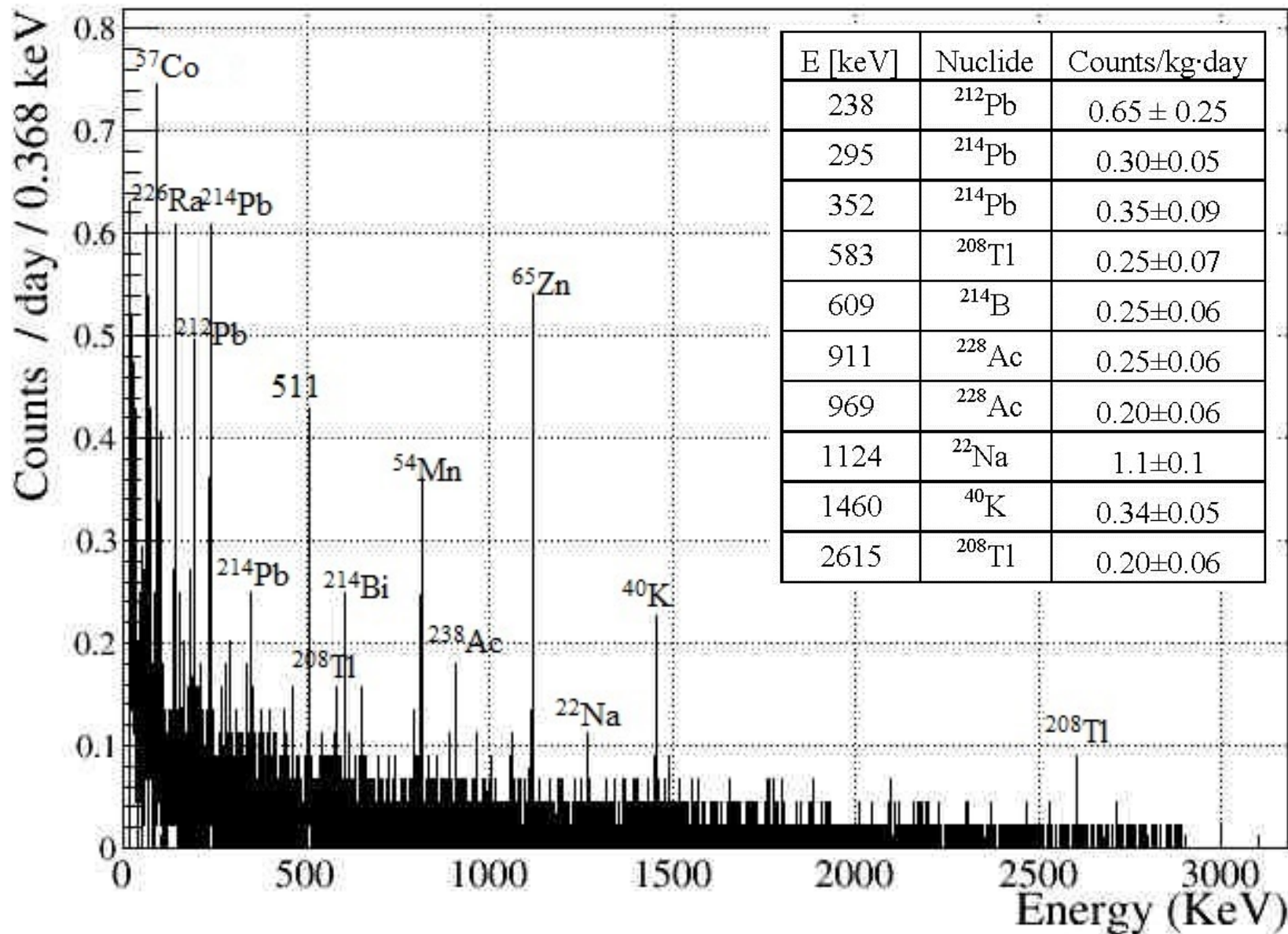
La_2O_3 (87.2 g), $T=2300$ s



Abundance of ^{138}La is $\approx 0.089\%$,
half-life of ^{138}La - $T_{1/2} \approx 1.02 \times 10^{11}$ y,
activity of sample $A \approx 61.8$ Bq

Background measurement with Obelix in 2017

T=44d

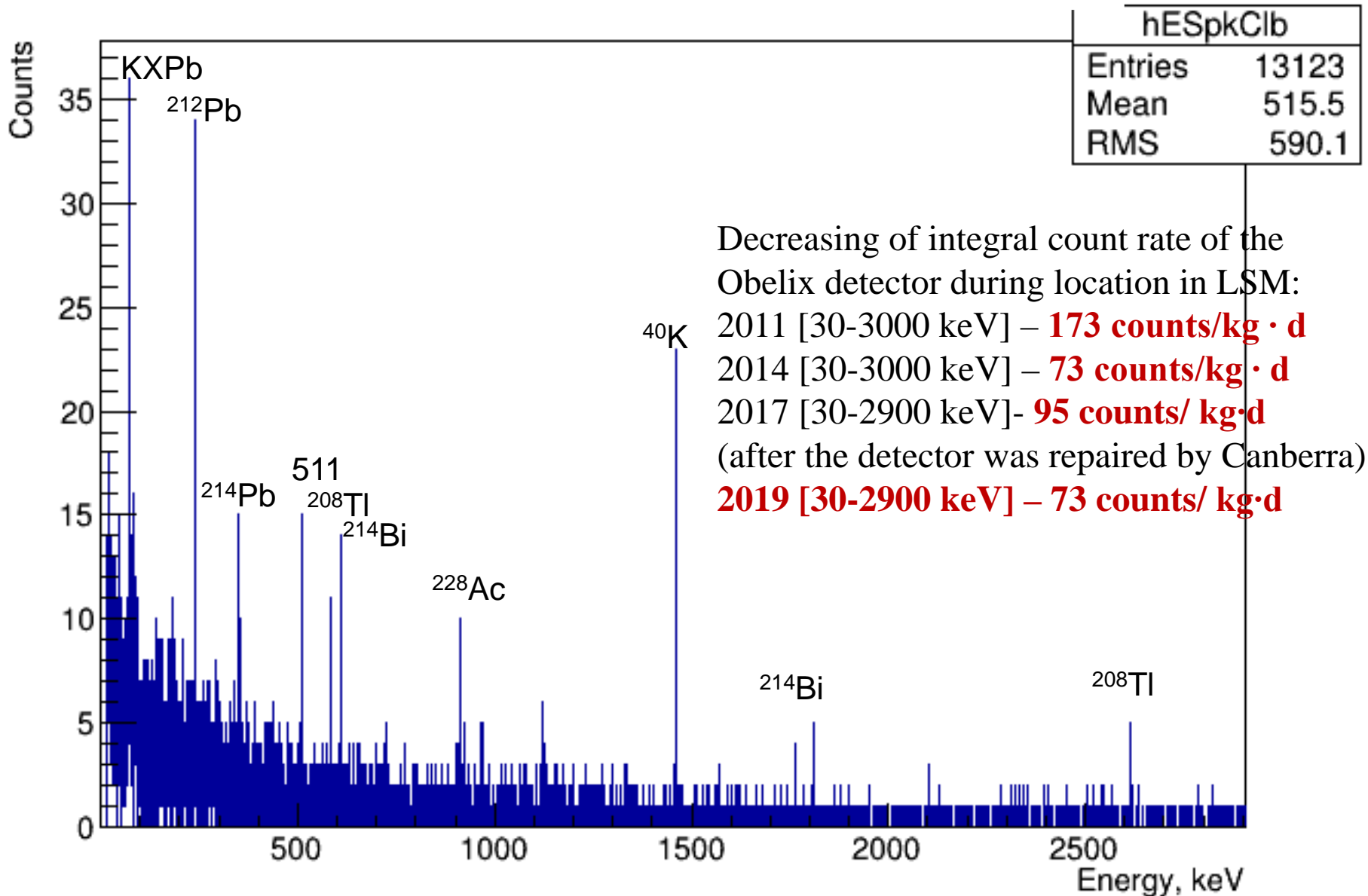


Counting rate [30 – 2900 keV]

95 counts/day·kg

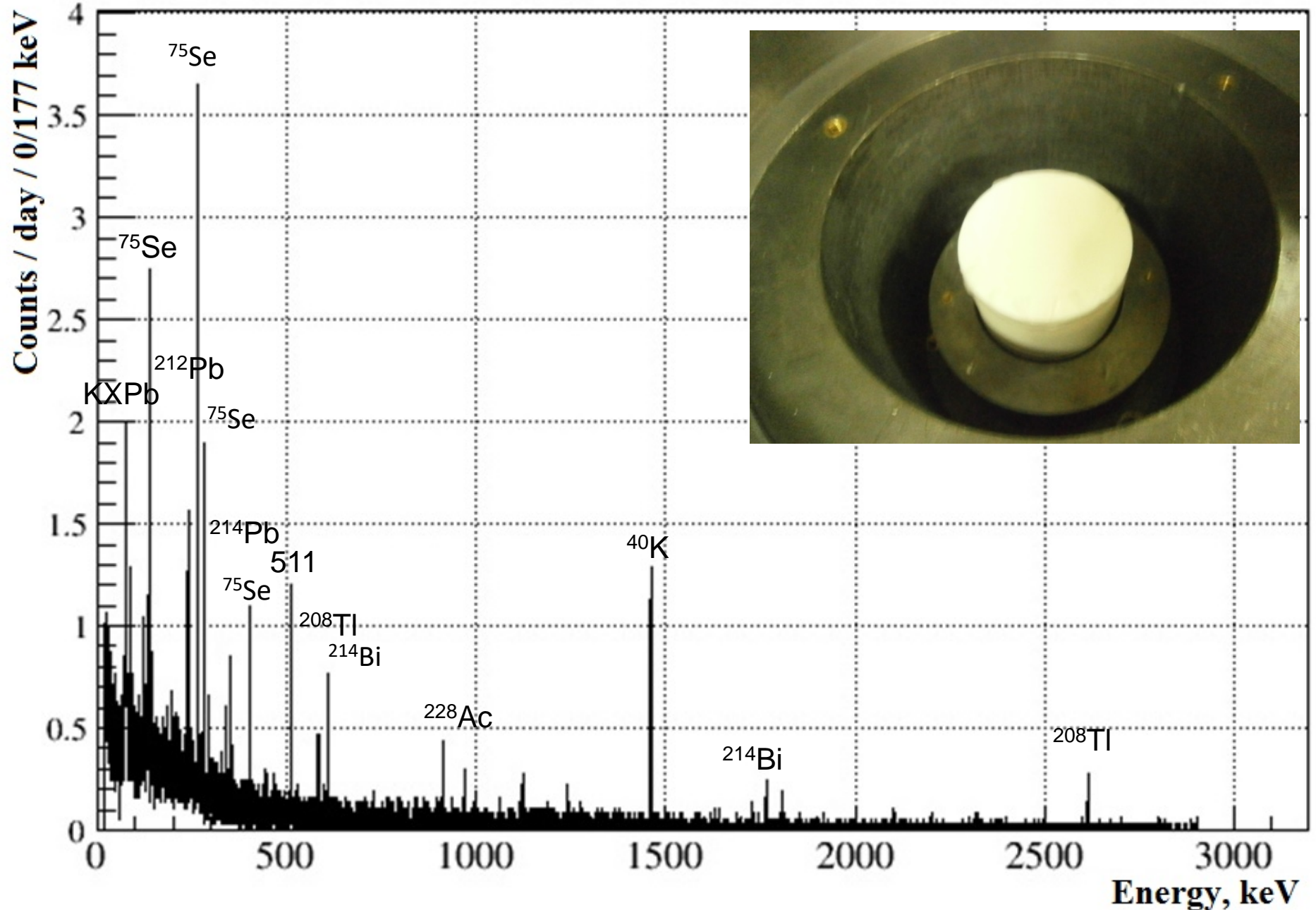
Background of Obelix in 2019, $T_{\text{meas}}=1278\text{h}$

HPGE spectrum

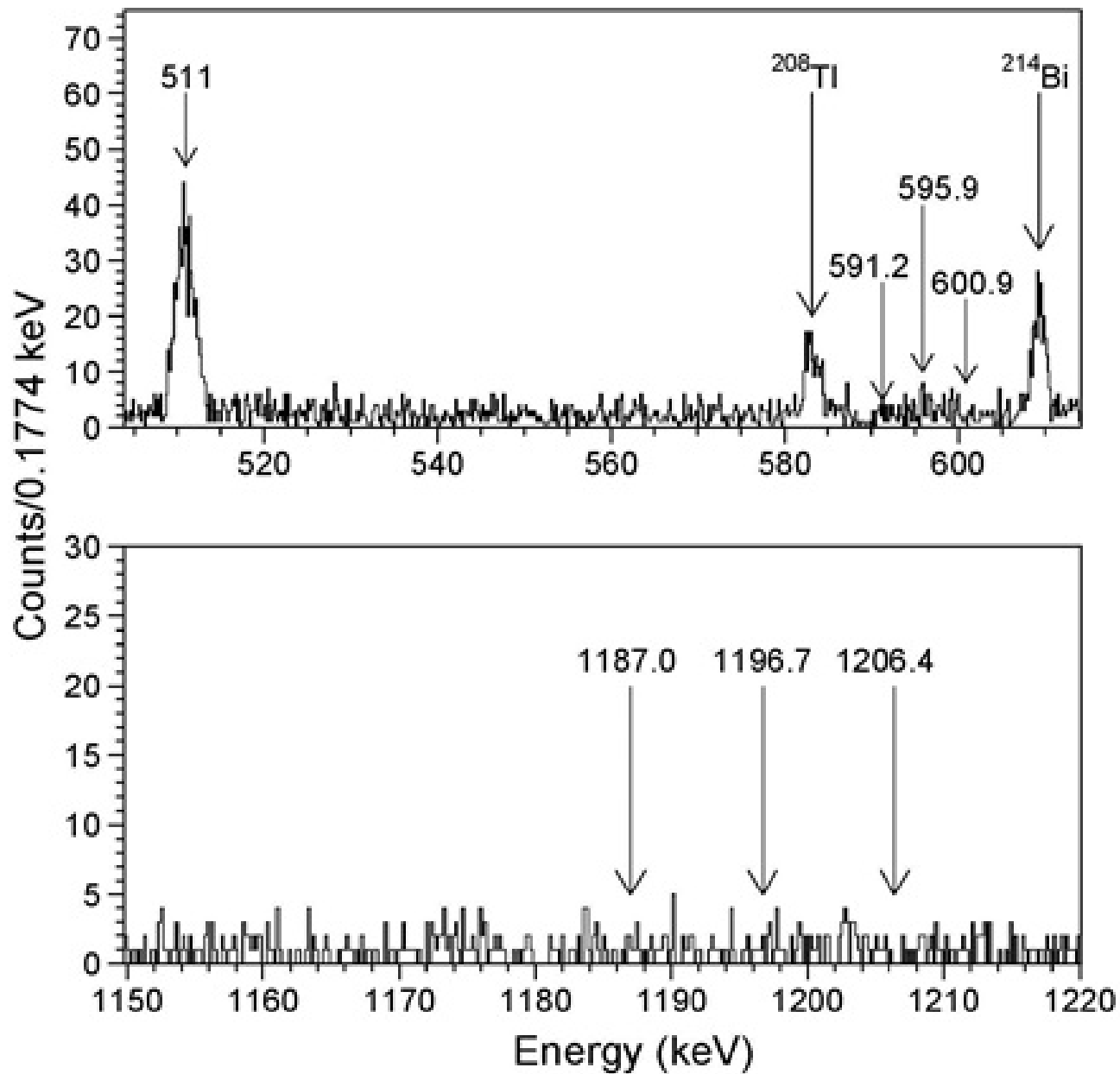


Measurement of Se sample

$T_{\text{meas}}=135\text{d}$

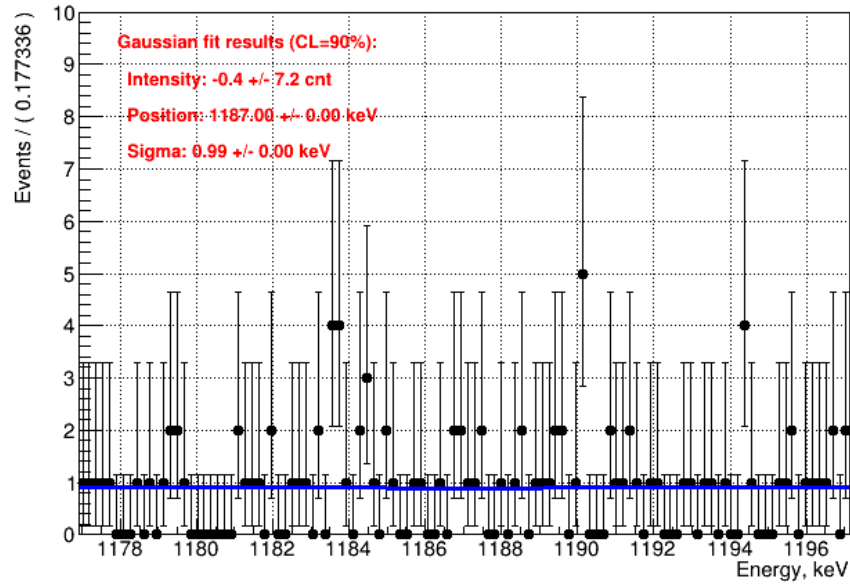


ROI of the spectrum of Se-nat

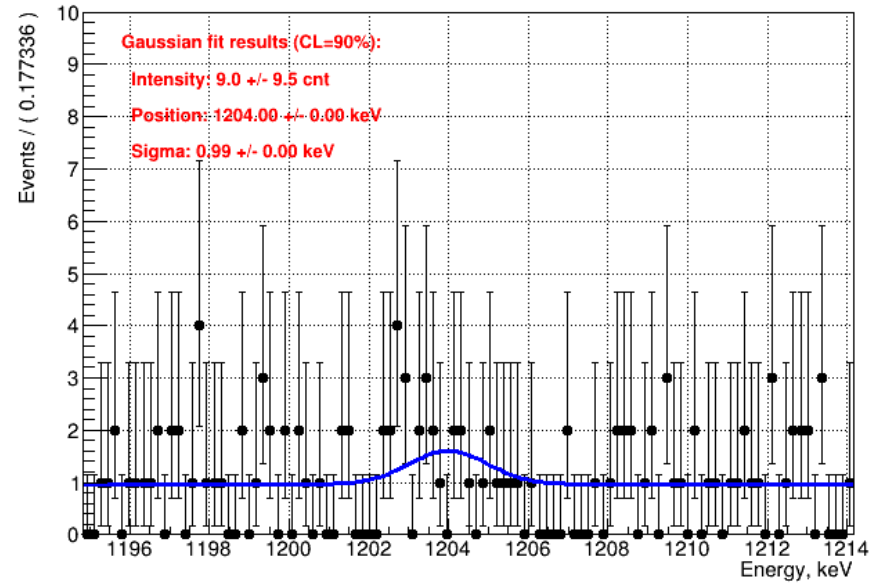


Fit of some ROI of the spectrum of Se-nat

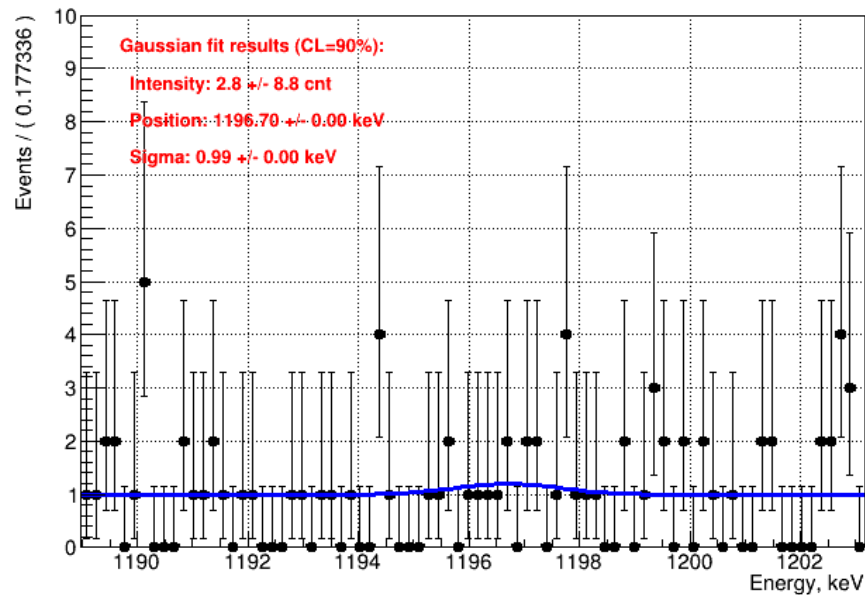
1187.0 keV



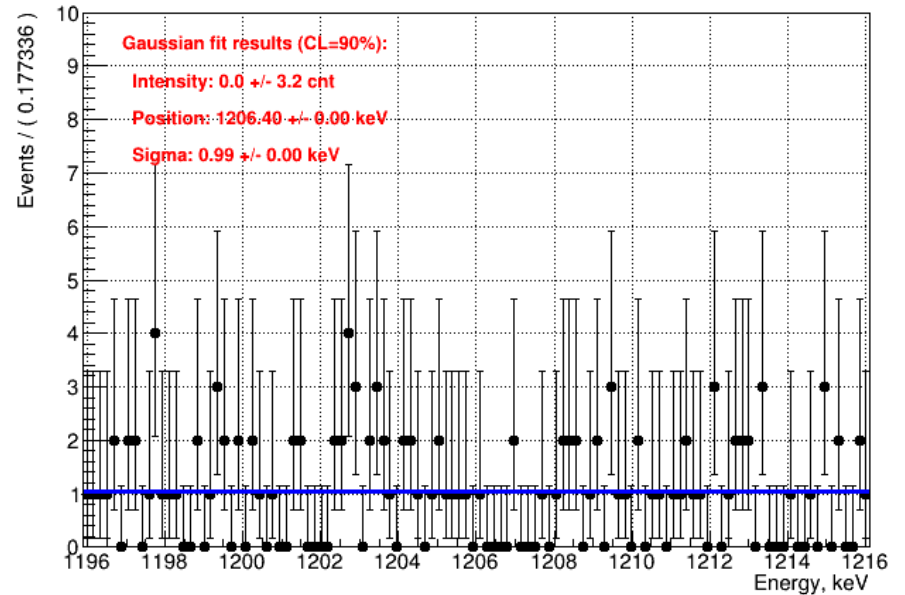
1204.2 keV



1196.7 keV



1206.4 keV



Preliminary results for double beta decay of ^{74}Se

Decay transition	γ -rays, keV	Efficien- cy, %	N_{excl}	$T_{1/2}$, 10^{19}y CL=90%, this work	$T_{1/2}$, 10^{19}y CL=90% [1]	$T_{1/2}$, 10^{19}y CL=90% [2]
$0\nu\text{LL} \rightarrow 2^+_{2,1204.2}$	595.9 + 1204.2	1.23 0.57	31.3 18.5	1.10	0.55	0.70
$0\nu\text{LL} \rightarrow 2^+_{1,595.9}$	595.9	1.82	31.3	1.58	1.30	0.82
$0\nu\text{LL} \rightarrow \text{g.s.}$	1206.4	1.67	7.0	6.47	0.41	0.58
$0\nu\text{KL} \rightarrow 2^+_{1,595.9}$	600.9 595.9	1.81 1.81	11.3 31.3	4.37 1.57	1.12	0.82
$0\nu\text{KL} \rightarrow \text{g.s.}$	1196.7	1.67	13.1	3.48	0.64	0.96
$0\nu\text{KK} \rightarrow 2^+_{1,595.9}$	591.2 595.9	1.81 1.81	11.2 31.3	4.39 1.57	1.57	1.43
$0\nu\text{KK} \rightarrow \text{g.s.*}$	1187.0	1.67	9.4	4.83	0.62	–
$2\nu\text{ECEC} \rightarrow 2^+_{2,1204.2}$	595.9 + 1204.2	1.23 0.57	31.3 18.5	1.10	0.55	0.70
$2\nu\text{ECEC} \rightarrow 2^+_{1,595.9}$	595.9	2.11	31.3	1.83	0.77	0.92
$(0\nu+2\nu)\beta^+\text{EC} \rightarrow \text{g.s.}$	511	4.32	511.8	0.23	0.19	–

[1] A.S.Barabash et al., Nuclear Physics A 785(2007)371

[2] B.Lehnert et al.. J.Phys.G. Nucl. Part. Phys. 43 (2016) 085201

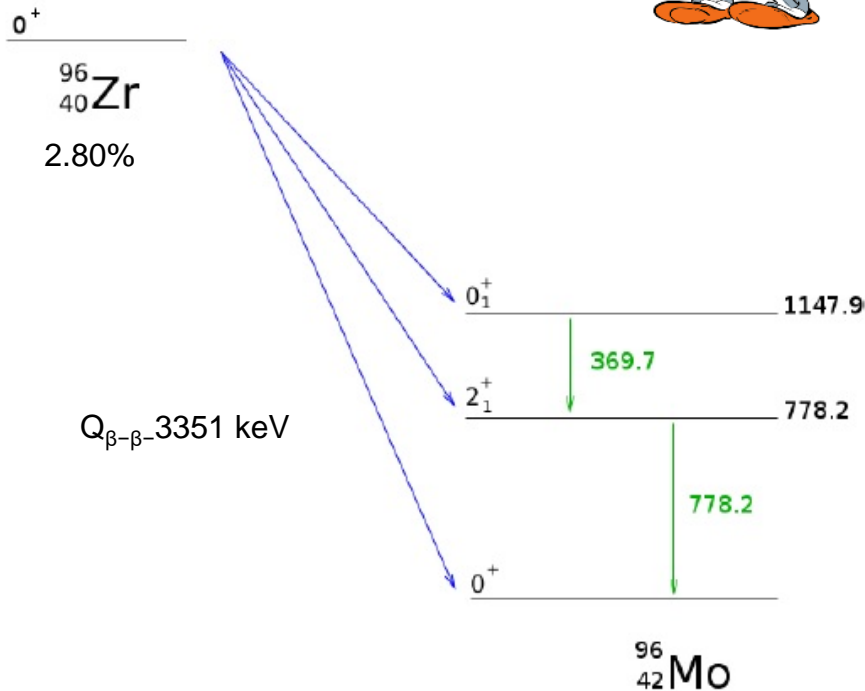
Future plans of measurements

The investigation of double beta decay of ^{96}Zr and ^{150}Nd to excited states of daughter nuclei will be performed with detectors Obelix and Idefix (new P type coaxial ultra low-background HPGe detector similar to Obelix). Idefix was produced by company of Mirion (Canberra) and installed in LSM in 2017.

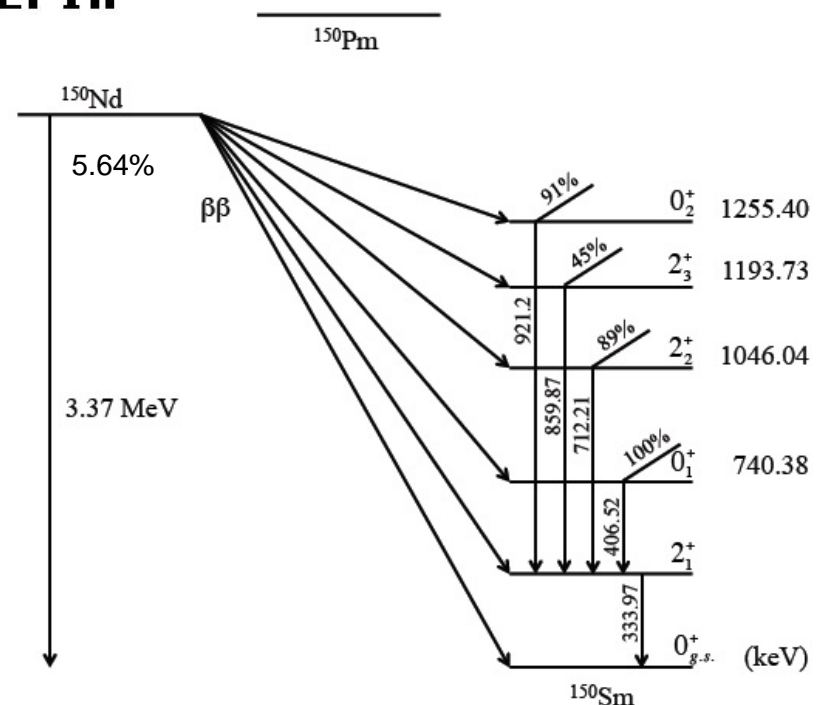


IDEFIX

^{96}Zr decay scheme



^{150}Nd decay scheme



Thank you for your attention