Search for long-lived superheavy eka-tungsten (Sg – Seaborgium) with radiopure enriched $^{116}CdWO_4$ crystal scintillators

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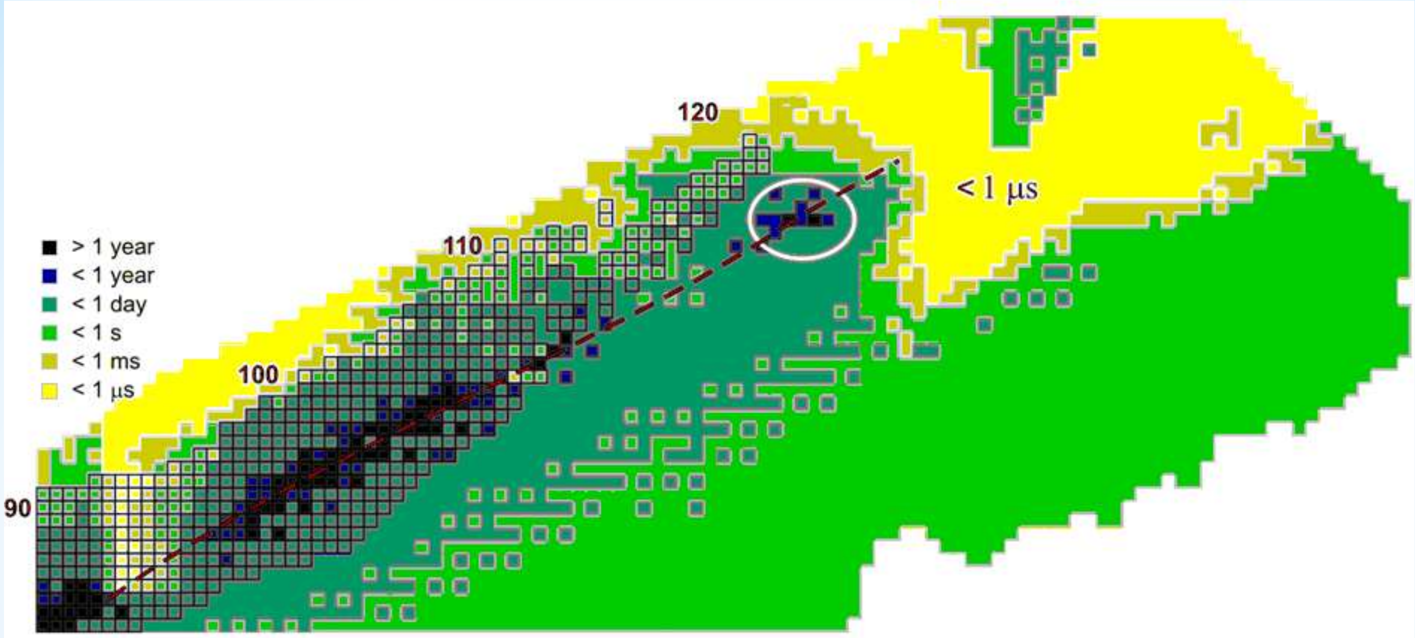
LNGS
July 19, 2019

Island of stability



It is expected that only the edge of the 'island of stability' has been reached to date in laboratory conditions, long-lived SHEs were probably produced in explosive stellar events by a sequence of rapid neutron captures (r-processes, but the question is – if in sufficient amount?) and β decays.

In 2006 scientists from JINR(Russia) led by Oganessian announced first element with a long-lived number 114 which means the experimental confirmation of the existence of the "island of stability".

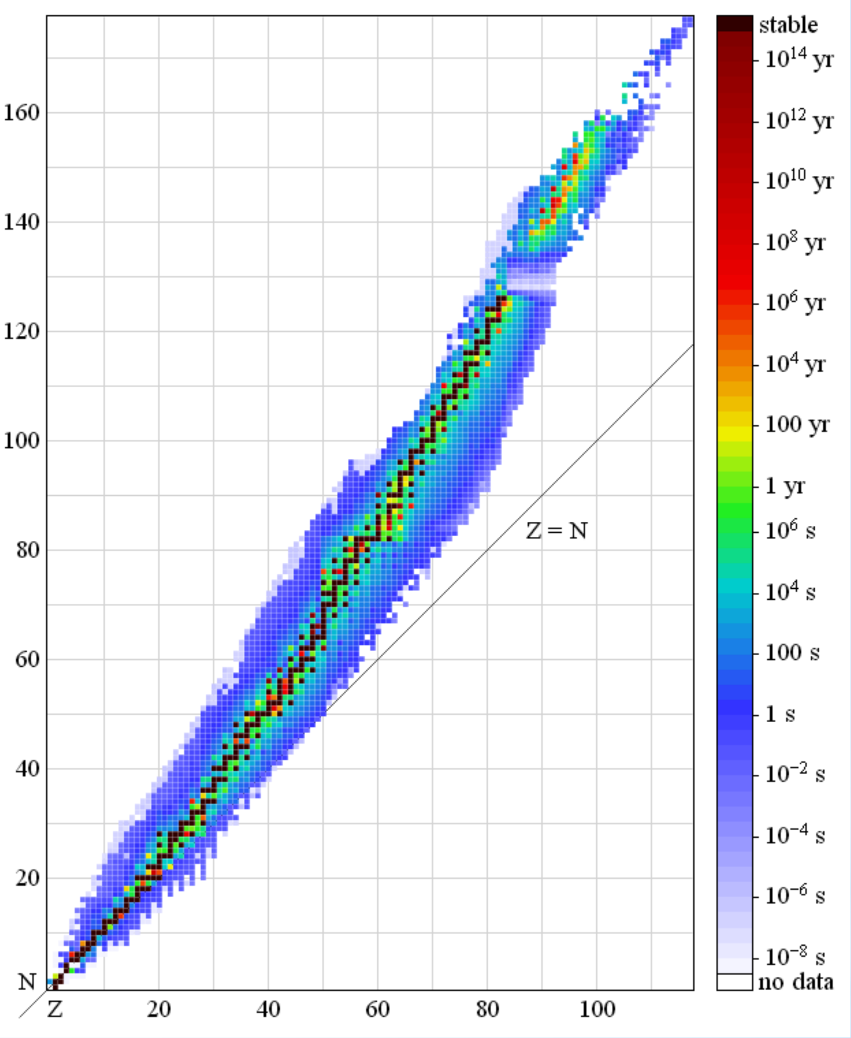
[1] Nature 231(1971)103
[2] Phys. At. Nucl. 72(2009)1026
[3] Eur. Phys. J. A 48(2012)122
[4] Astron. Lett. 39(2013)150
[5] Oganessian et al. Phys. Rev. C. 70(2004)064609

Superheavy elements (SHE) in nature

- $Z \geq 104$ and $A \geq 250$ [1];
- formed in fusion reaction [2] or r-processes;
- $T_{1/2}$ – from μs to hours (with number of neutrons near the magic number 184 are expected to be longer);
- SHE with Z= 102 – 107 lie in the interval 7.8 – 10.6 MeV [3];
- strong increase in the stability of nuclei near the magic numbers Z = 114 and N = 184, which could lead to the existence of stability islands (due to the increased stability provided by shell effects).

Could decay through:

- emission of β^- particles or by EC (or β^+ decay);
- α decays followed by spontaneous fission [4];
- cluster decay [5]



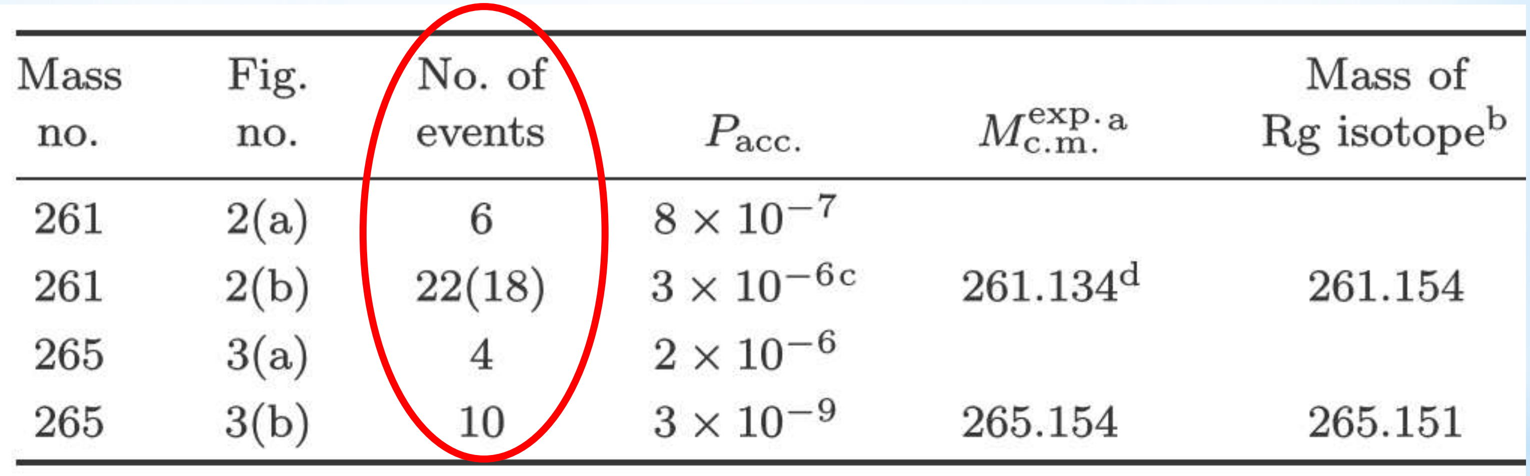
The possibility of the existence of superheavy nuclei is of significant importance for the understand ing of the properties of nuclear matter.

[1] Nucleonics 15 (1957) 122;
[2] Rev. Mod. Phys. 72 (2000) 733; J. Phys. G 34 (2007) R165
[3] At. Data Nucl. Data Tables 98 (2012) 1096
[4] Annu. Rev. Nucl. Part. Sci. 63 (2013) 383
[5] Prog. Part. Nucl. Phys. 58 (2007) 292

Studying of long-lived isotopes of a SHE in natural Au by ISPMS

The closest chemical homologue for Au among SHE is Rg (Roentgenium) with Z = 111 (if exist in nature!).

The accurate mass measurements (using a high resolution inductively coupled plasma- sector field mass spectrometer (ICP-SFMS)) for masses 254 and 259–269 was performed.



Mass no.	Fig. no.	No. of events	$P_{\mathrm{acc.}}$	$M_{\mathrm{c.m.}}^{\mathrm{exp.}}$[a]	Mass of Rg isotope[b]
261	2(a)	6	8×10^{-7}		
261	2(b)	22(18)	3×10^{-6}[c]	261.134[d]	261.154
265	3(a)	4	2×10^{-6}		
265	3(b)	10	3×10^{-9}	265.154	265.151

Evidence for the existence of isotopes with masses that fit the predictions for the masses of ^{261}Rg and ^{265}Rg was obtained. The predicted g.s. half-lives of these Rg isotopes are of the order of 1 μs. This suggests that the observed events are due to long-lived Rg isomers.

Int. J. Mod. Phys. E 18(2009)621

Search for SHE in nature with accelerator mass spectrometry

Problems of the artificial creation in laboratory :

\+ production of isotopes of nuclei near the stability island

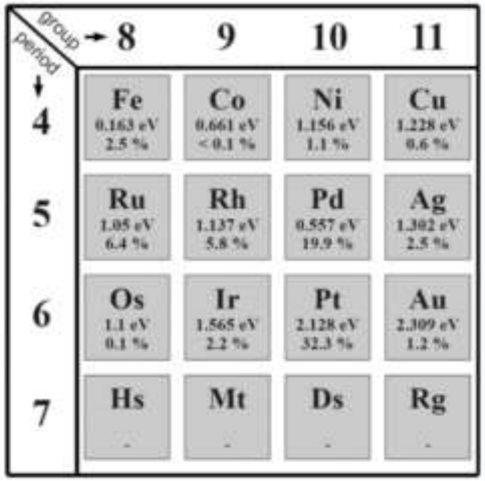
\+ AMS does not have to deal with molecular background, unlike other mass spectrometry methods such as ICPMS

- the extremely small cross sections;
- the lack of stable target-projectile combinations neutron-rich enough to reach the theoretical island of stability;
- half-lives of SHEs could be so short that their abundance in the samples has dropped below detection limits in the time since their synthesis until today;
- should be synthesized in sufficient amounts in the rapid neutron capture process (then could be still present in nature)
- discovery without confirmation: different approach couldn't reach results of each other (for example, SHE with Z = 122 and A = 292 in a sample of natural thorium by using inductively coupled plasma mass spectrometry (ICPMS) could not be confirmed by using accelerator mass spectrometry (AMS) and is thus doubtful);

✓ It is favorable to use a sample material consisting of several possibly chemically homologous elements for a wide-spread search for SHEs in nature.

Phys. Rev. C 85 (2012) 024315 + Phys. Rev. C 83 (2011) 015801 + Phys. Rev. C 83 (2011) 065806
Int. J. Mod. Phys. E 19(2010) 131

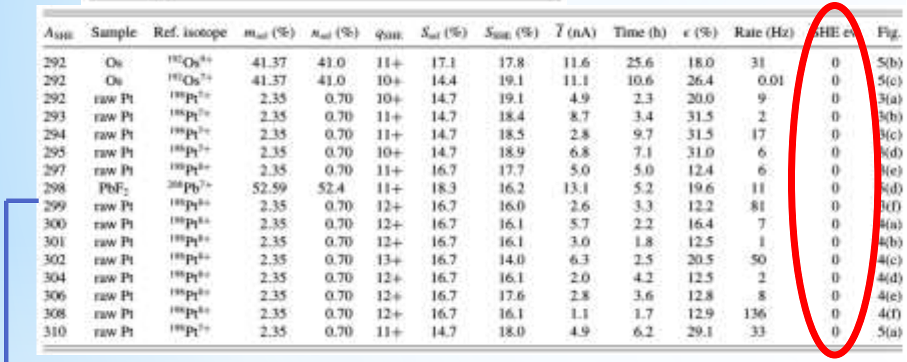
Search for SHE in Pt with accelerator mass spectrometry



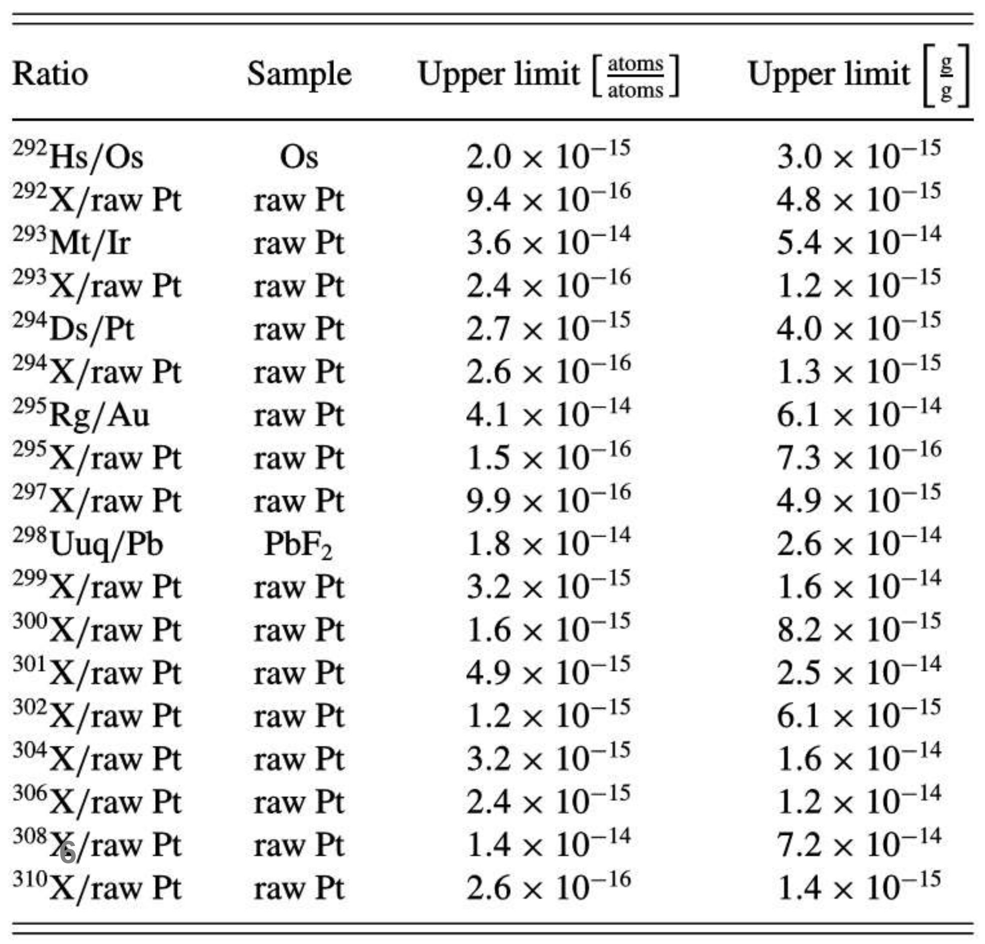
	8	9	10	11
4	**Fe** 0.163 eV 2.5 %	**Co** 0.661 eV < 0.1 %	**Ni** 1.156 eV 1.1 %	**Cu** 1.228 eV 0.6 %
5	**Ru** 1.05 eV 6.4 %	**Rh** 1.137 eV 5.8 %	**Pd** 0.557 eV 19.9 %	**Ag** 1.302 eV 2.5 %
6	**Os** 1.1 eV 0.1 %	**Ir** 1.565 eV 2.2 %	**Pt** 2.128 eV 32.3 %	**Au** 2.309 eV 1.2 %
7	**Hs** -	**Mt** -	**Ds** -	**Rg** -

A total of 14 different masses in the range 292 < A< 310 were scanned with AMS.

The use of raw platinum allowed to scan for several SHEs in one sample material, (it contains different possible chemical homologues to SHEs: **Ru, Rh, Pd, Os, Ir, Pt**).



A_{SHE}	Sample	Ref. isotope	m_{rel} (%)	n_{rel} (%)	q_{SHE}	S_{rel} (%)	S_{SHE} (%)	$\bar{I}$ (nA)	Time (h)	ϵ (%)	Rate (Hz)	SHE ev	Fig.
292	Os	$^{192}Os^{8+}$	41.37	41.0	11+	17.1	17.8	11.6	25.6	18.0	31	0	5(b)
292	Os	$^{192}Os^{7+}$	41.37	41.0	10+	14.4	19.1	11.1	10.6	26.4	0.01	0	5(c)
292	raw Pt	$^{198}Pt^{7+}$	2.35	0.70	10+	14.7	19.1	4.9	2.3	20.0	9	0	3(a)
293	raw Pt	$^{198}Pt^{7+}$	2.35	0.70	11+	14.7	18.4	8.7	3.4	31.5	2	0	3(b)
294	raw Pt	$^{198}Pt^{7+}$	2.35	0.70	11+	14.7	18.5	2.8	9.7	31.5	17	0	3(c)
295	raw Pt	$^{198}Pt^{7+}$	2.35	0.70	10+	14.7	18.9	6.8	7.1	31.0	6	0	3(d)
297	raw Pt	$^{198}Pt^{8+}$	2.35	0.70	11+	16.7	17.7	5.0	5.0	12.4	6	0	3(e)
298	PbF_2	$^{208}Pb^{7+}$	52.59	52.4	11+	18.3	16.2	13.1	5.2	19.6	11	0	5(d)
299	raw Pt	$^{198}Pt^{8+}$	2.35	0.70	12+	16.7	16.0	2.6	3.3	12.2	81	0	3(f)
300	raw Pt	$^{198}Pt^{8+}$	2.35	0.70	12+	16.7	16.1	5.7	2.2	16.4	7	0	4(a)
301	raw Pt	$^{198}Pt^{8+}$	2.35	0.70	12+	16.7	16.1	3.0	1.8	12.5	1	0	4(b)
302	raw Pt	$^{198}Pt^{8+}$	2.35	0.70	13+	16.7	14.0	6.3	2.5	20.5	50	0	4(c)
304	raw Pt	$^{198}Pt^{8+}$	2.35	0.70	12+	16.7	16.1	2.0	4.2	12.5	2	0	4(d)
306	raw Pt	$^{198}Pt^{8+}$	2.35	0.70	12+	16.7	17.6	2.8	3.6	12.8	8	0	4(e)
308	raw Pt	$^{198}Pt^{8+}$	2.35	0.70	12+	16.7	16.1	1.1	1.7	12.9	136	0	4(f)
310	raw Pt	$^{198}Pt^{7+}$	2.35	0.70	11+	14.7	18.0	4.9	6.2	29.1	33	0	5(a)



Ratio	Sample	Upper limit $\left[\frac{\text{atoms}}{\text{atoms}}\right]$	Upper limit $\left[\frac{\text{g}}{\text{g}}\right]$
^{292}Hs/Os	Os	2.0×10^{-15}	3.0×10^{-15}
^{292}X/raw Pt	raw Pt	9.4×10^{-16}	4.8×10^{-15}
^{293}Mt/Ir	raw Pt	3.6×10^{-14}	5.4×10^{-14}
^{293}X/raw Pt	raw Pt	2.4×10^{-16}	1.2×10^{-15}
^{294}Ds/Pt	raw Pt	2.7×10^{-15}	4.0×10^{-15}
^{294}X/raw Pt	raw Pt	2.6×10^{-16}	1.3×10^{-15}
^{295}Rg/Au	raw Pt	4.1×10^{-14}	6.1×10^{-14}
^{295}X/raw Pt	raw Pt	1.5×10^{-16}	7.3×10^{-16}
^{297}X/raw Pt	raw Pt	9.9×10^{-16}	4.9×10^{-15}
^{298}Uuq/Pb	PbF_2	1.8×10^{-14}	2.6×10^{-14}
^{299}X/raw Pt	raw Pt	3.2×10^{-15}	1.6×10^{-14}
^{300}X/raw Pt	raw Pt	1.6×10^{-15}	8.2×10^{-15}
^{301}X/raw Pt	raw Pt	4.9×10^{-15}	2.5×10^{-14}
^{302}X/raw Pt	raw Pt	1.2×10^{-15}	6.1×10^{-15}
^{304}X/raw Pt	raw Pt	3.2×10^{-15}	1.6×10^{-14}
^{306}X/raw Pt	raw Pt	2.4×10^{-15}	1.2×10^{-14}
^{308}X/raw Pt	raw Pt	1.4×10^{-14}	7.2×10^{-14}
^{310}X/raw Pt	raw Pt	2.6×10^{-16}	1.4×10^{-15}

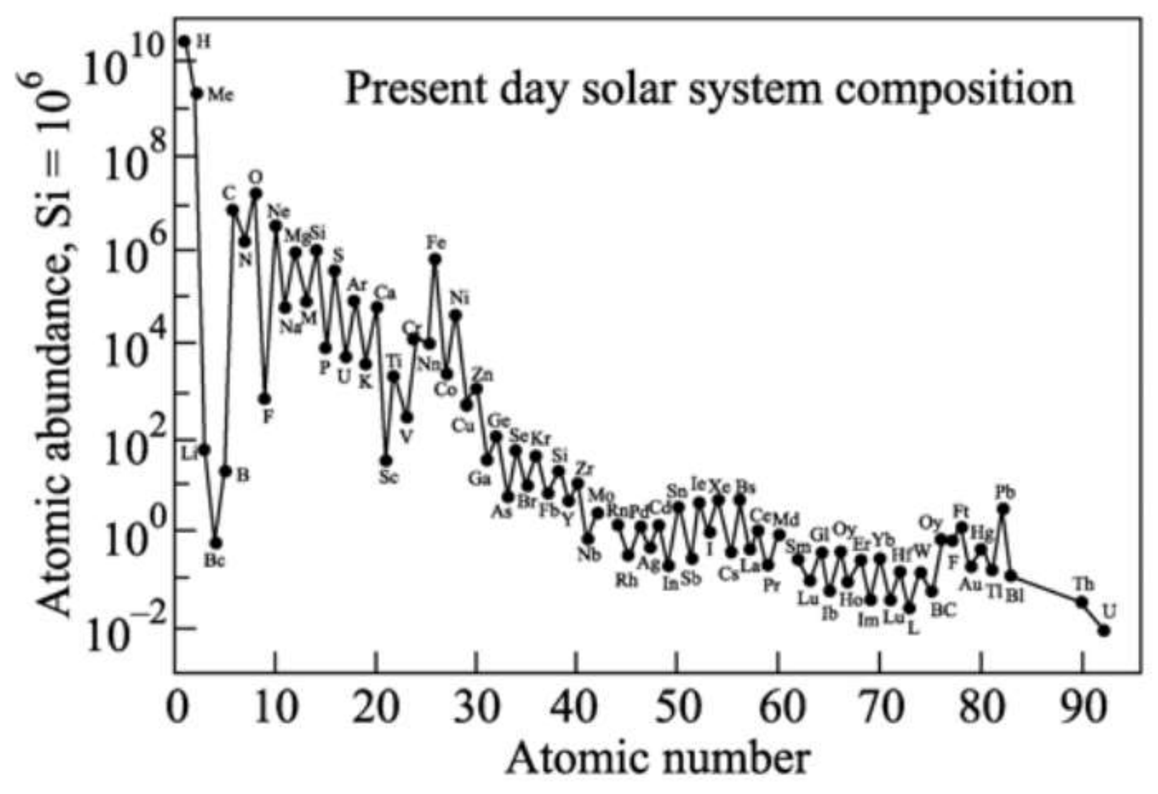
^{298}114 (by Oganessian) was conducted in its possible chem. homologue lead

There were no SHE events recorded for any of the mass settings → upper limits on their abundances in the sample materials are of the order 10^{-14} – 10^{-16}

Search for SHE in Galactic Cosmic Rays

6000 nuclei with Z>55 in galactic cosmic rays has been obtained in the **OLIMPIYA** project.
3 SHE with 105 < Z < 130 have been detected.

Their detection in nature could confirms theoretical predictions and justifies efforts for their synthesis under terrestrial conditions



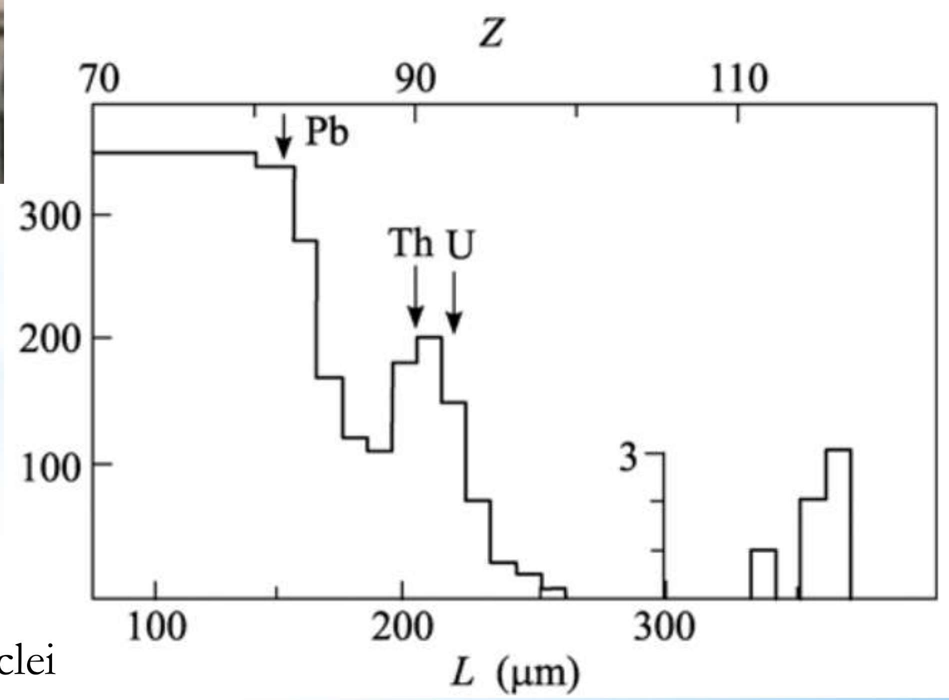
The abundance of elements obtained in studies with aerostats, satellites, and meteorites

JETP Letters, 2013, Vol. 97, No. 12

OLIMPIYA project

Search for the abundance of nuclei (with Z > 86) in cosmic rays is the extremely low flux of these nuclei (1-2 nuclei/m^2/yr) with solid state track detectors, where particles are detected in terms of radiation damage induced by heavy and SHE from CR in olivine crystals from meteorites

Eagle Station meteorite sample used in the OLIMPIYA project



Distribution of the number of the detected and identified superheavy nuclei

Potentiality of scintillators to search for SHE

Searching for high energy α's from the decay of natural SHE (or its daughters), embedded in a detector:

1) $ZnWO_4$ for superheavy eka-W (Z = 106)
2) $CdWO_4$ for superheavy eka-W (Z = 106)
3) $BiGe_3O_{12}$ (BGO) scintillators or scintillating bolometers for superheavy eka-Bi (Z = 115)
4) $PbWO_4$ for superheavy eka-Pb
5) NaI(Tl) for eka-Tl
6) ……

\+ good PSD allows so select alpha events with high energy (> 8 MeV)
\+ possibility to reject Bi-Po events, pile-ups…
– can't distinguish a specific isotope (e.g. eka-W or eka-Bi)

if alternative explanations (of events with shape of scintillation signal typical for α's and high energy) will be absent, this would be an indication on presence of SHE

Decay of superheavy Sg (Z = 106)

Chemical properties of **Sg** are similar to those of **W** [1-3] and one could expect that long-lived Sg follows W in the processes of chemical separation and growth of the crystals, and could be present at some amount in the detectors.

1) **Sg could decay through**
- β^- channel (→ Z = 107)
- EC/β+ (→ Z = 105)
- α decay (→ Z = 104) with "low-energy" α's (4 – 6 MeV ≅ α's from U/Th chains)

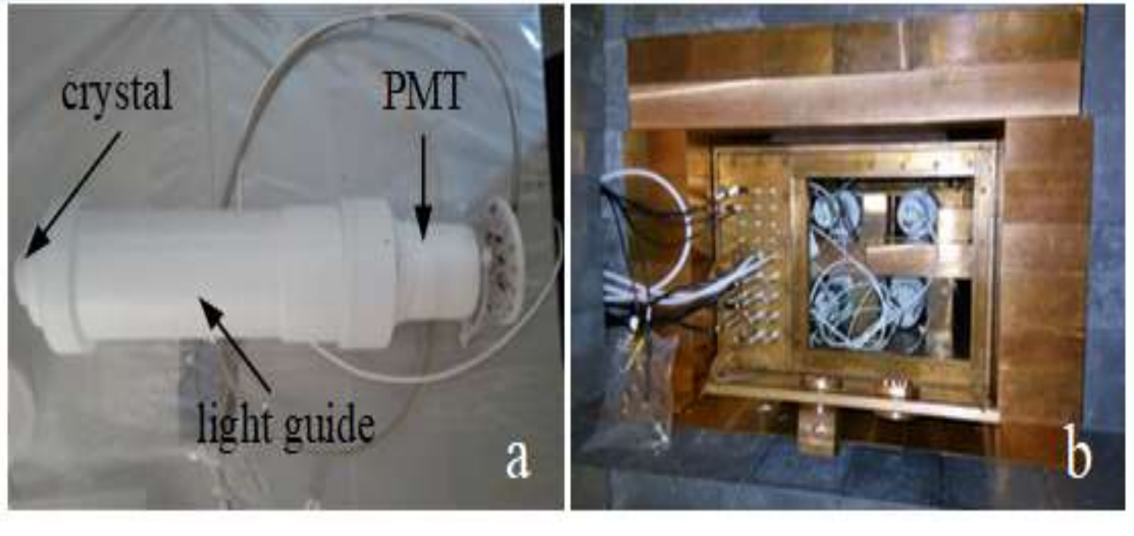
2) The created nucleus (or one of its daughters) decays with emission of high energy **α** particle (**Q > 8 MeV**)

3) If these α's live long enough (seconds or larger), they could to be registered outside by data acquisition system. The theoretical predictions [4–6] also confirm this assumption.

[1] Nature 388 (1997) 55
[2] J. Chem. Phys. 138 (2013) 174301
[3] Science 345 (2014) 1491
[4] At. Data Nucl. Data Tables 94 (2008) 781
[5] Phys. Rev. C 81 (2010) 034613
[6] Phys. Rev. C 86 (2012) 014322

SHE with $ZnWO_4$

Laboratori Nazionali del Gran Sasso (INFN, Italy)



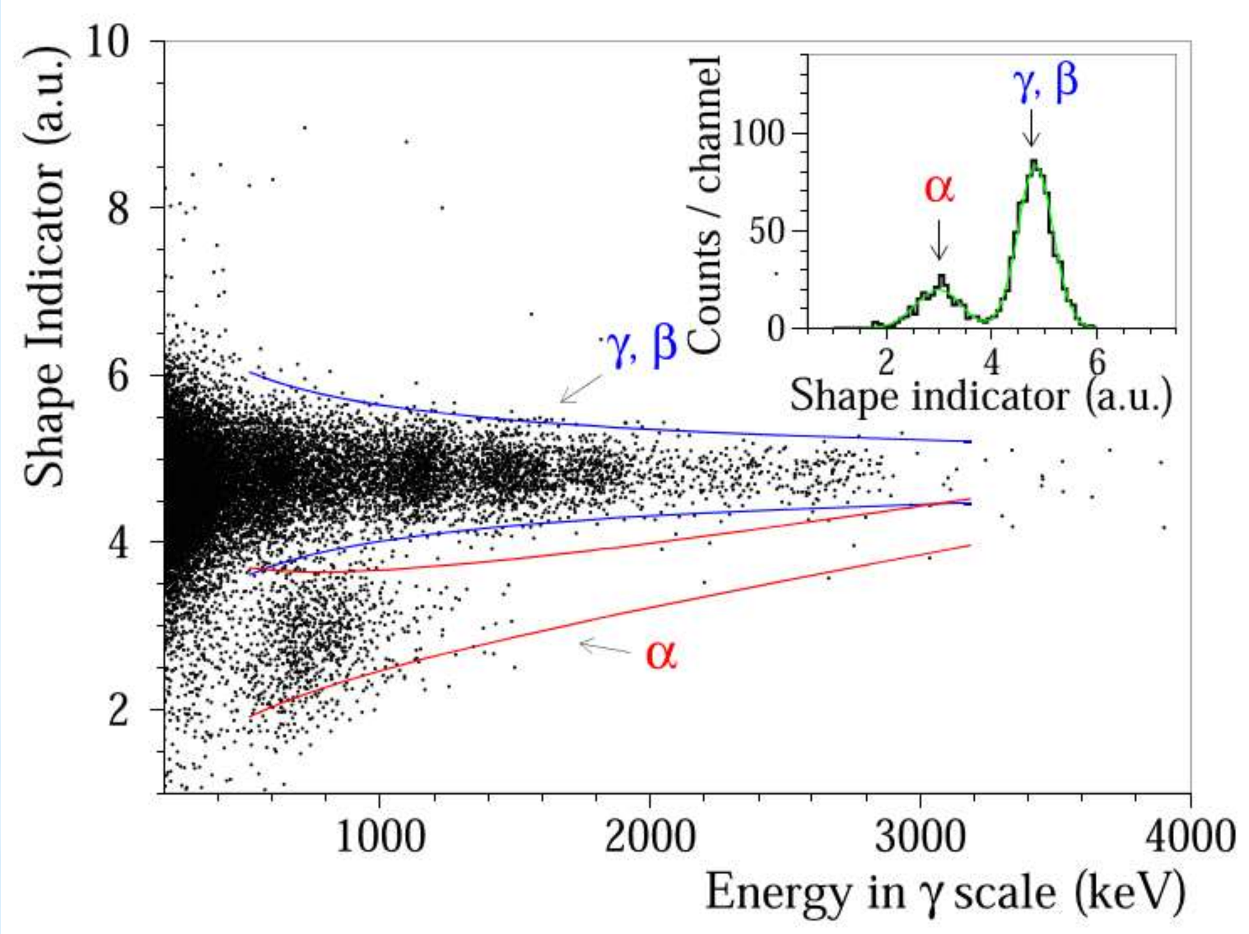
$ZnWO_4$ (699 g) was produced in the Institute for Scintillation Materials (ISMA, Kharkiv, Ukraine) from crystal ingots grown in platinum crucibles by the Czochralski method.

It was investigated in low background measurements during 2130 h at LNGS

We looked for high energy α particles ($Q > 8$ MeV)

Pulse-shape discrimination

The optimal filter method proposed by E. Gatti and F. De Martini [1] was applied



Shape indicator (SI):

$$SI = \frac{\sum f(t_k) \times P(t_k)}{\sum f(t_k)}$$

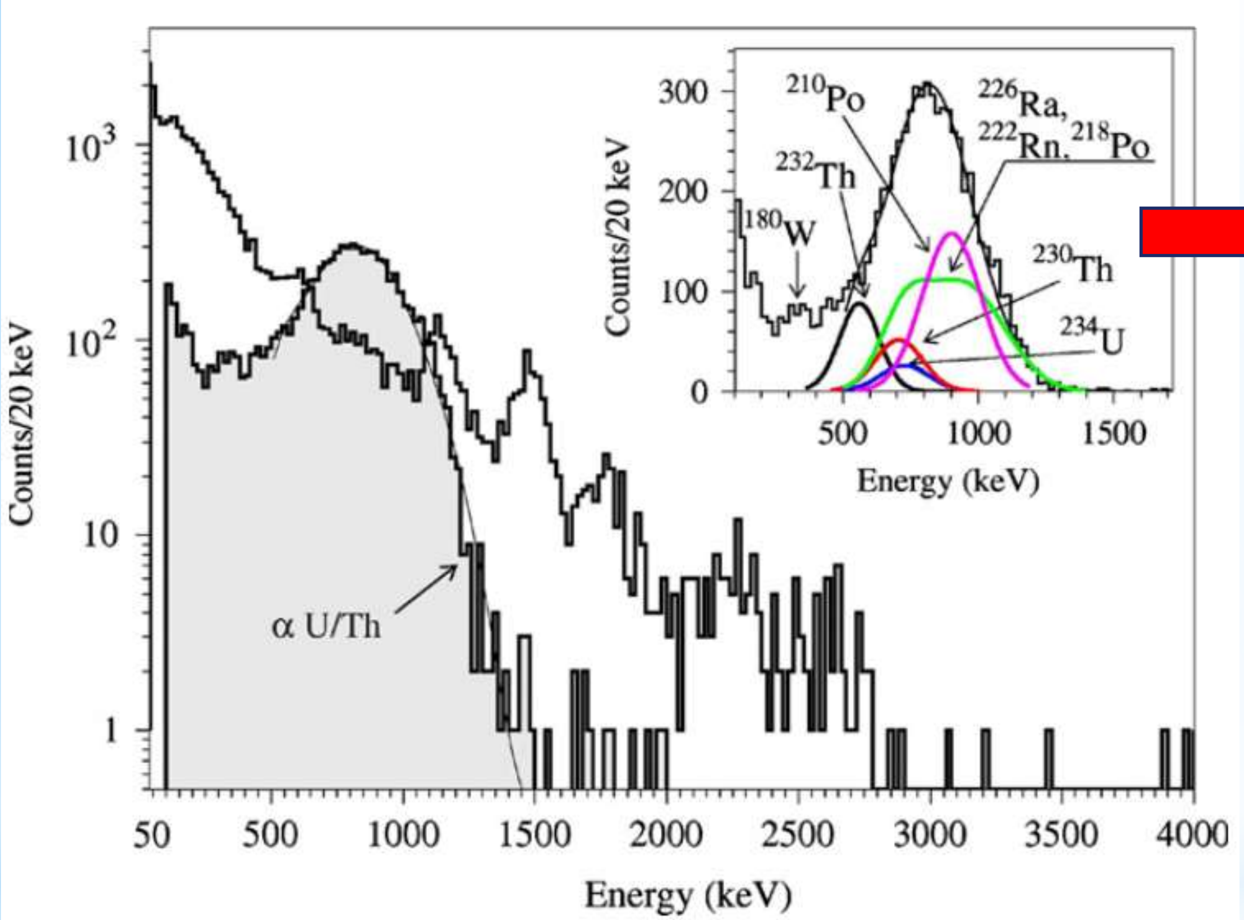
$f(t_k)$ is a digital amplitude of a signal at the time channel t_k; $P(t_k)$ is a weight function

$$P(t_k) = \frac{|f_\alpha(t) - f_\gamma(t)|}{f_\alpha(t) + f_\gamma(t)}$$

$f_\alpha(t)$ and $f_\gamma(t)$ are digital amplitudes of reference α and γ/β signals, respectively

[1] Proceedings of the Conference on Nuclear Electronics Vol. II (International Atomic Energy Agency, Vienna, 1962), p. 265.

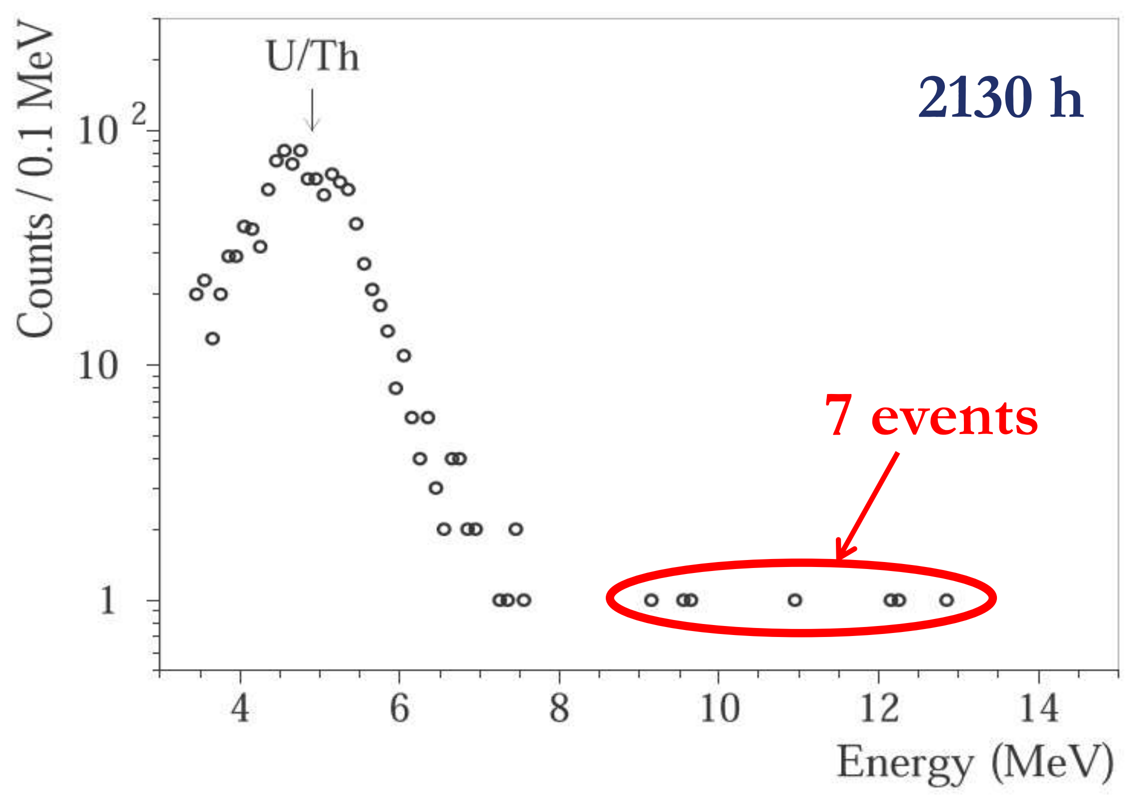
Energy spectra of events selected by PSD



α/γ ratio

The energy distributions of the β particles (γ quanta) and α particles selected by applying the PSD. In the inset, the a spectrum is depicted together with the model, which includes a decays from ^{238}U and ^{232}Th families.

Energy spectrum of α particles registered by $ZnWO_4$ detector



$T_{1/2} = 10^9$ yr [1,2]

$S = 7$ events (with 0 background, very conservatively) → lim $S < 11.77$ at 90% C.L.

lim $S = \ln 2 \cdot \varepsilon \cdot N \cdot t \,/\, T_{1/2}$ → N(Sb)

N(Sg)/N(W) < 5.5×10^{-14} atoms/atom at 90% C.L.

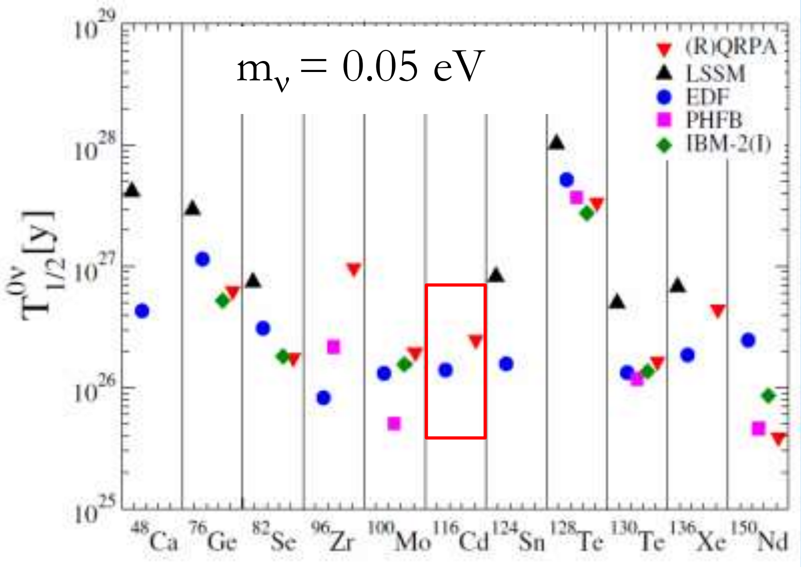
This value is comparable with the sensitivity reached in the searches for eka-Os in the SHIN experiment $< 10^{-14}$ g/g [2]

[1] Rep. Prog. Phys. 47 (1983) 817

[2] AIP Conf. Proc. 1175 (2009) 297

CdWO$_4$ crystals

- good scintillation properties
- “source = detector approach” (~100% efficiency)
- low levels of internal contamination
- particle discrimination ability (↓ background)
- possibility to search SHE



J.D. Vergados et al., RPP 75(2012)106301

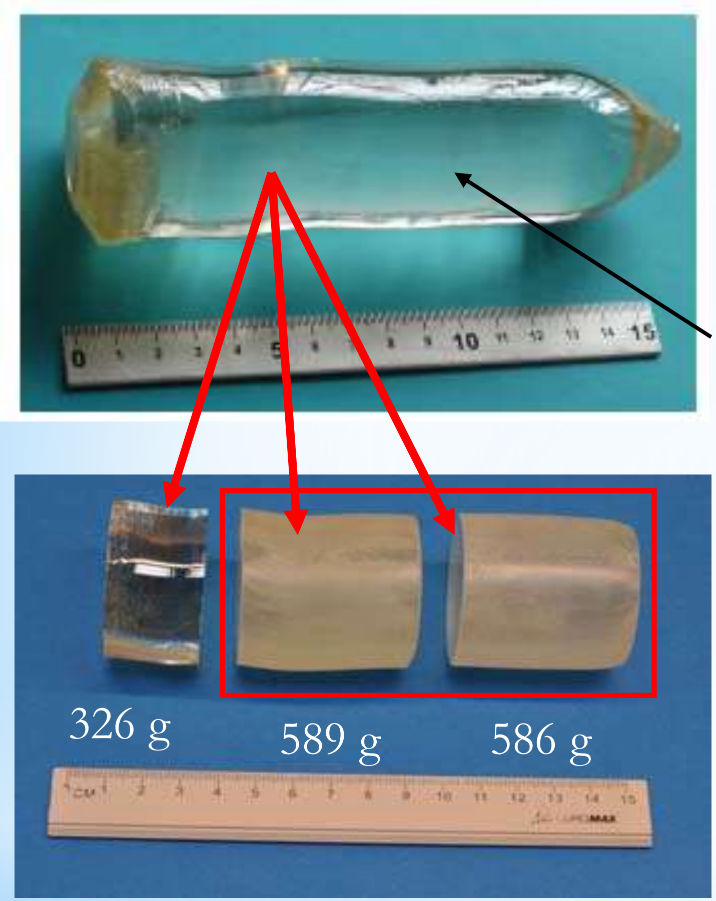
CdWO$_4$ were successfully used in low-background experiments on search for 2β decay of Cd and W [1], as well as for the study of rare α [2] and β [3] decays

^{116}Cd - One of the most promising isotopes to search for 0ν2β decay

- $Q_{2\beta}$ = 2813.44(13) keV
- δ = 7.5%
- promising theoretical calculation
- possible isotopic enrichment in large amount

[1] ZPA 355(1996)433, EPJA 36(2008)167, PRC 93(2016)045502;
[2] PRC 67(2003)014310;
[3] PAN 59(1996)1, PRC 76(2007)064603

$^{116}CdWO_4$ crystal scintillator



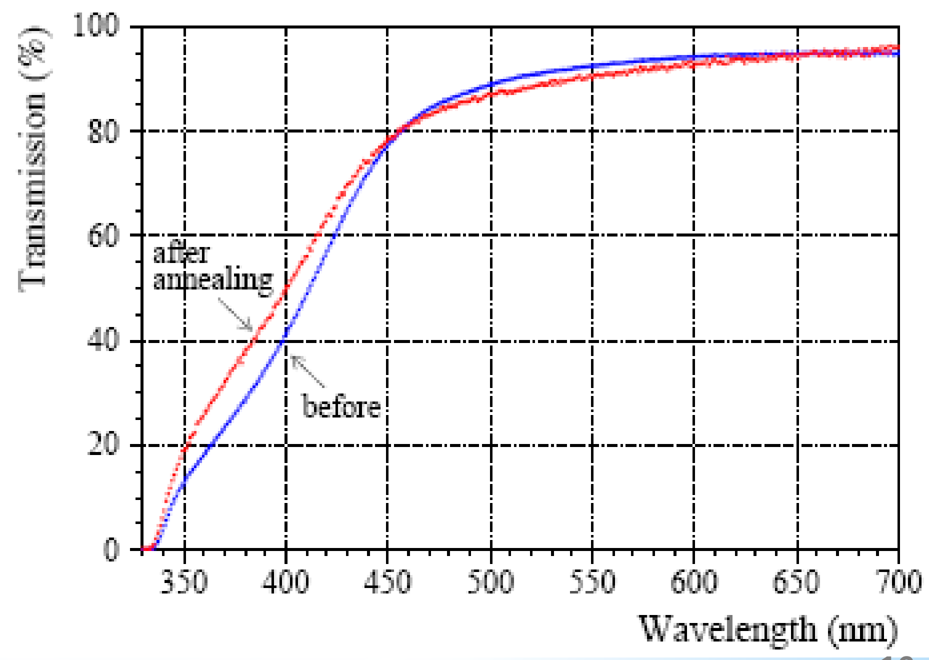
Good optical and scintillation properties of the crystal were obtained thanks to the deep purification of ^{116}Cd and W, and the advantage of the low-thermal-gradient Czochralski technique to grow the crystal [1]

Boule of enriched $^{116}CdWO_4$ crystal (82% of ^{116}Cd). The conic part of the boule is the beginning of the crystal growth.

Yield of the crystal boule is 87% of the initial powder

Losses (the total production cycle) < 3%

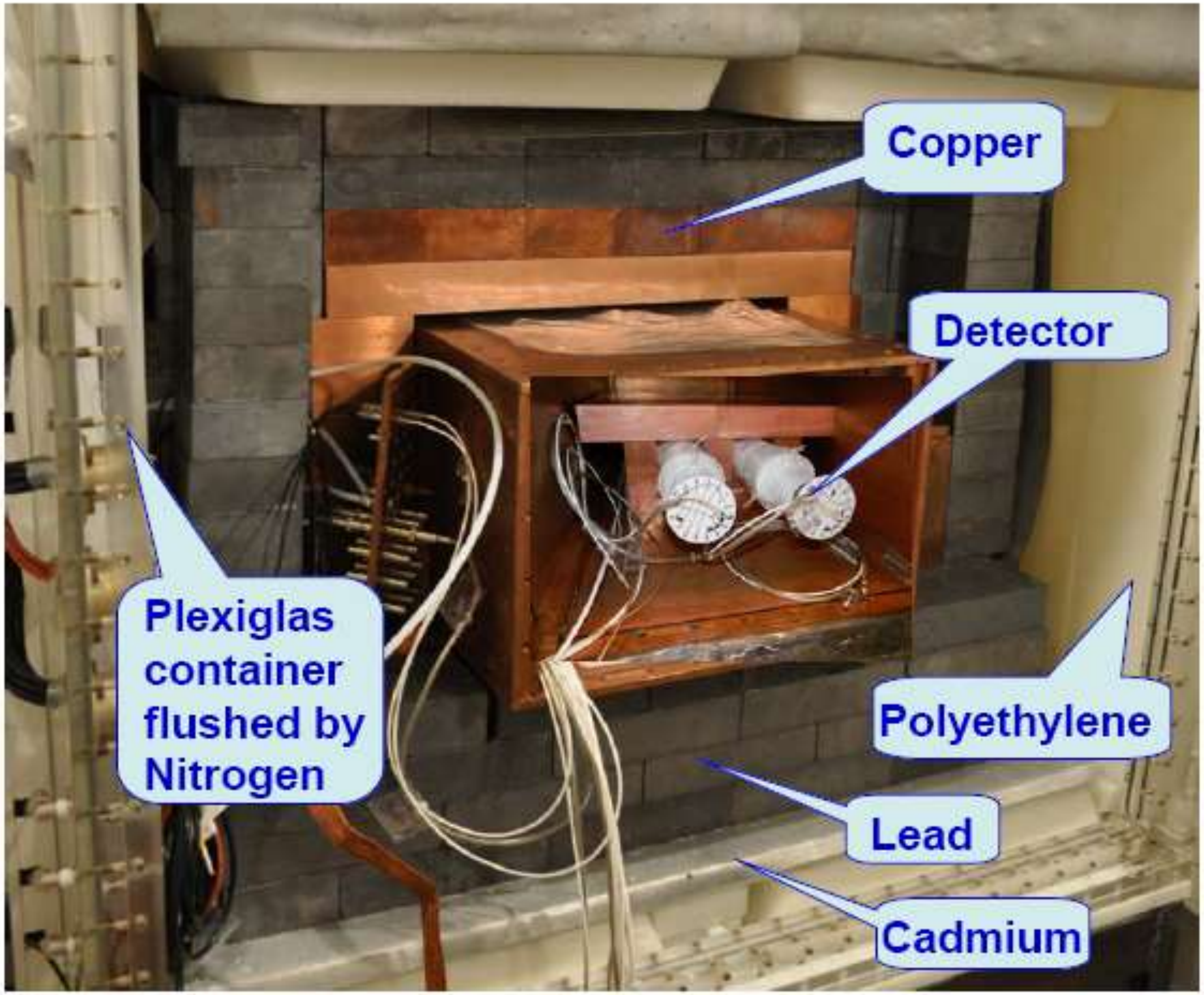
[1] JINST 6(2011)P08011



The optical transmission curve of $^{116}CdWO_4$ before and after annealing

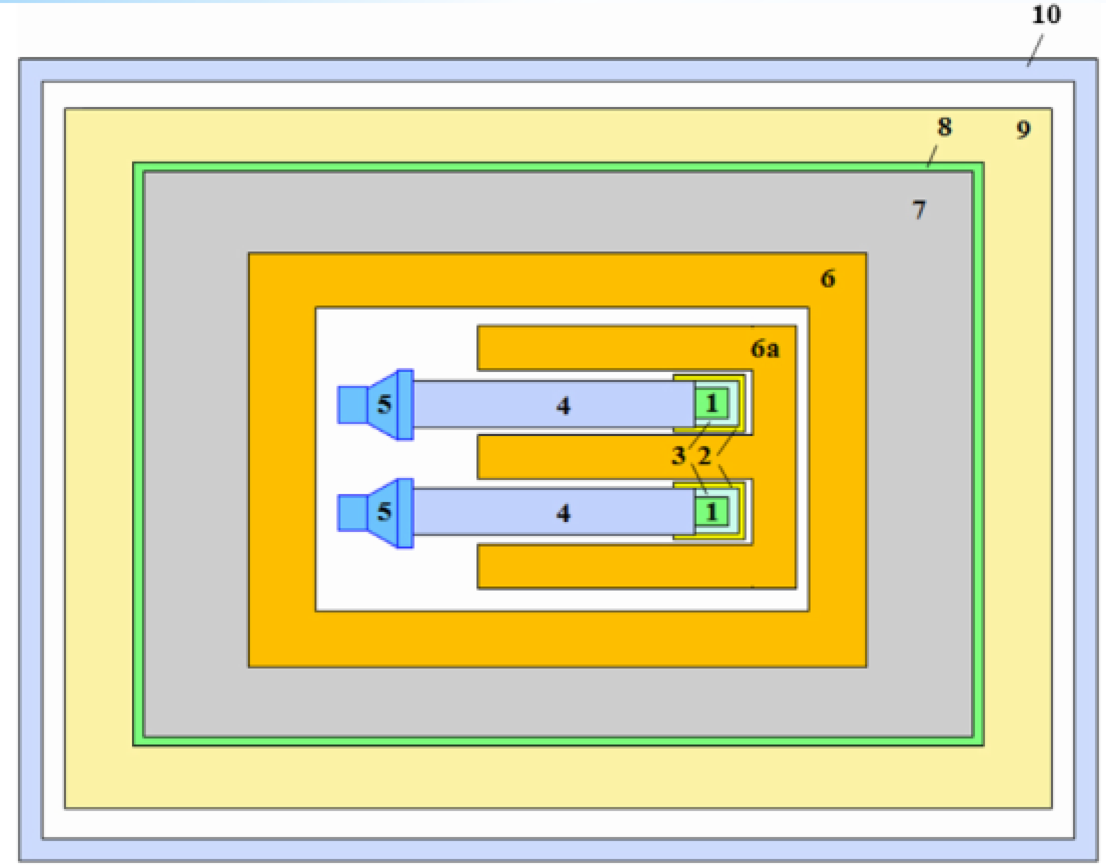
Attenuation length is 60 cm

Experimental set-up with $^{116}CdWO_4$

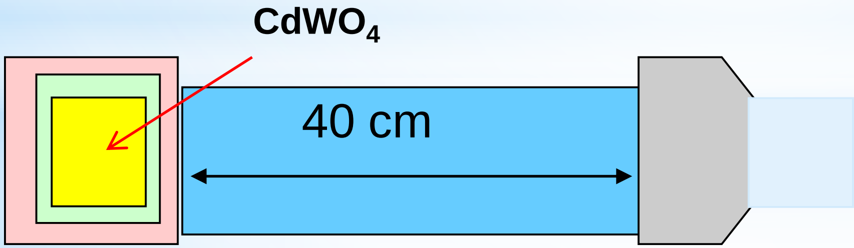


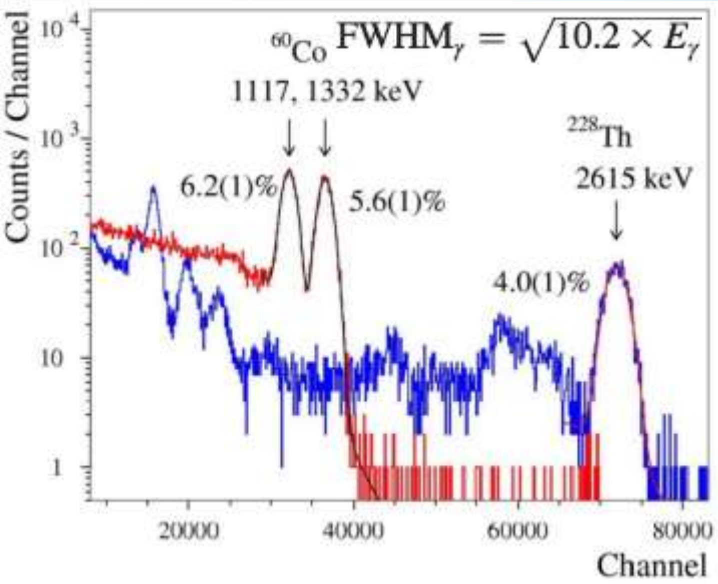

Laboratori Nazionali del Gran Sasso, Italy (3600 m w.e)

Experimental set-up with $^{116}CdWO_4$



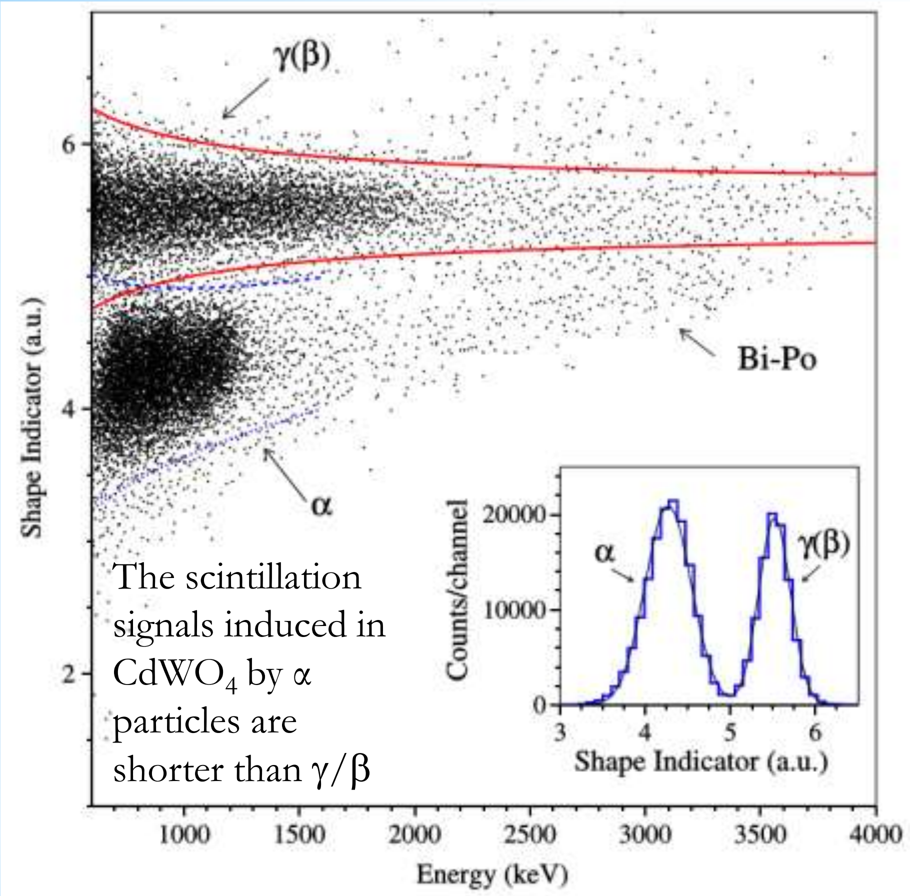
1) $^{116}CdWO_4$ crystal scintillators
2) teflon containers
3) liquid scintillator
4) quartz light guides (∅7×40 cm)
5) photomultipliers (3” Hamamatsu R6233MOD)
6) high-purity copper (10 cm)
7) low radioactive lead (15 cm)
8) cadmium (1.5 mm)
9) polyethylene/paraffin (4 to 10 cm)
10) plexiglas box (flushed by HP N_2)





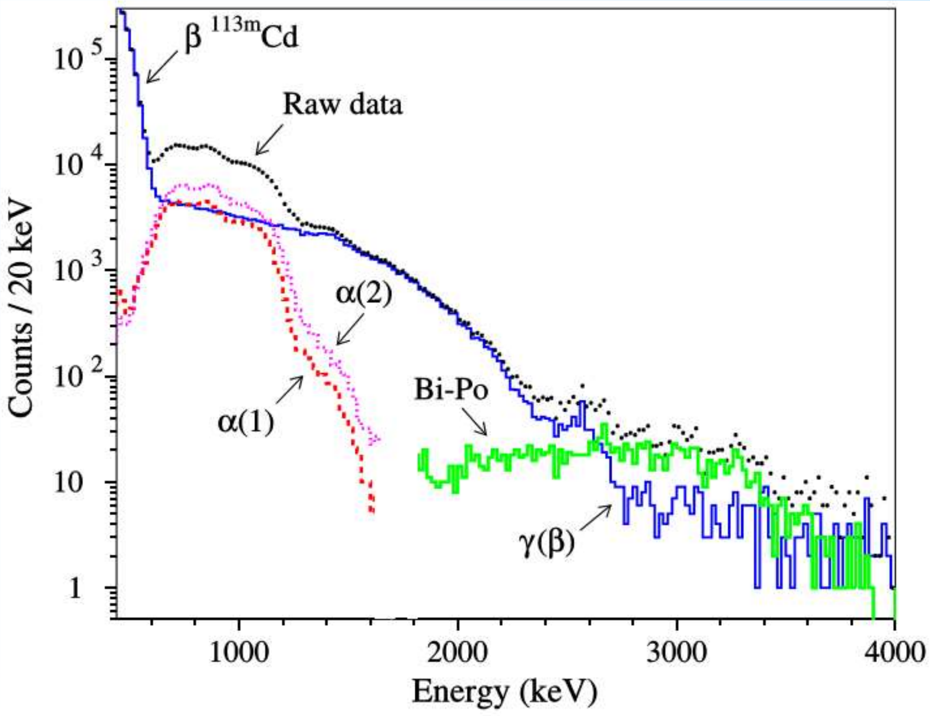
DAQ:
- arrival time
- amplitude
- pulse shape (50 μs with 20 ns bin)

Pulse shape discrimination (PSD), 26831 h



The scintillation signals induced in $CdWO_4$ by α particles are shorter than γ/β

Shape indicator (SI) versus energy for the background exposure (26831 h × 1.162 kg)



$$SI = \sum f(t_k) \times P(t_k) / \sum f(t_k)$$

$f(t_k)$ – amplitude at time t_k

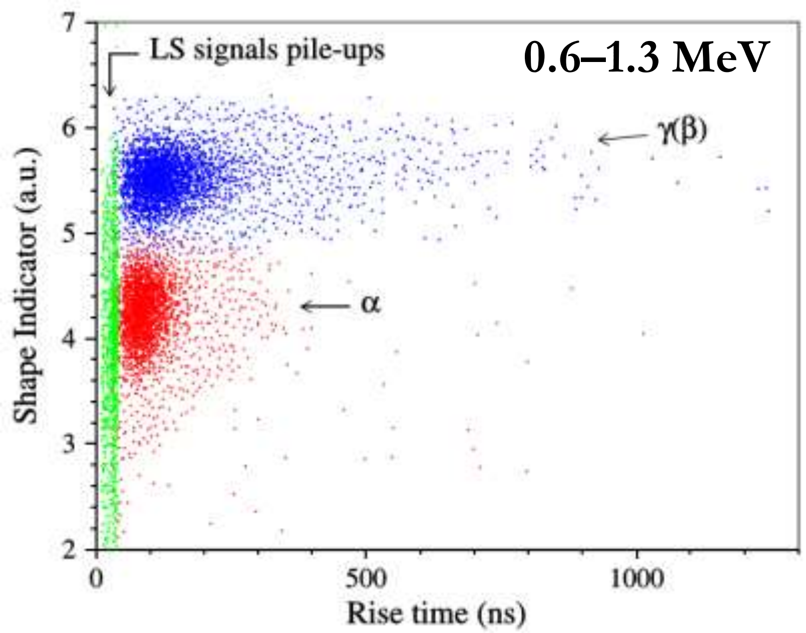
$$P(t) = [\, f_\alpha(t) - f_\gamma(t)] / [\, f_\alpha(t) + f_\gamma(t)],$$

$f_\alpha(t), f_\gamma(t)$ – shapes of the signals

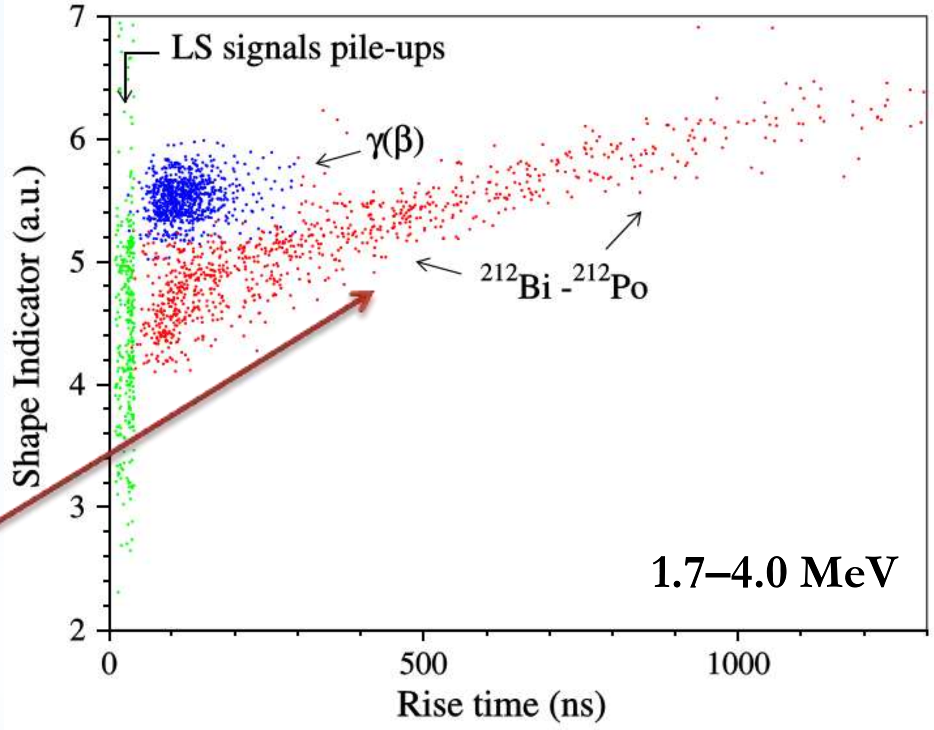
The optimal filter method proposed by E. Gatti and F. De Martini, developed for CdWO scintillation detectors [1 and ref.]

[1] Nucl. Instrum. Methods Phys. A 410 (1998) 213 (1998)

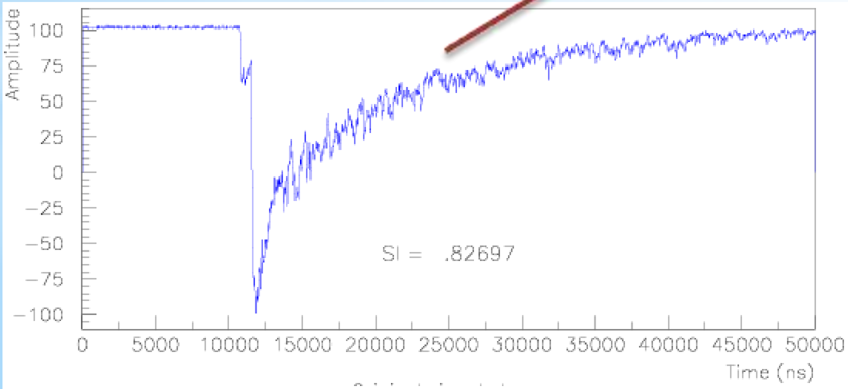
Selection of ^{212}Bi-^{212}Po events by front-edge analysis



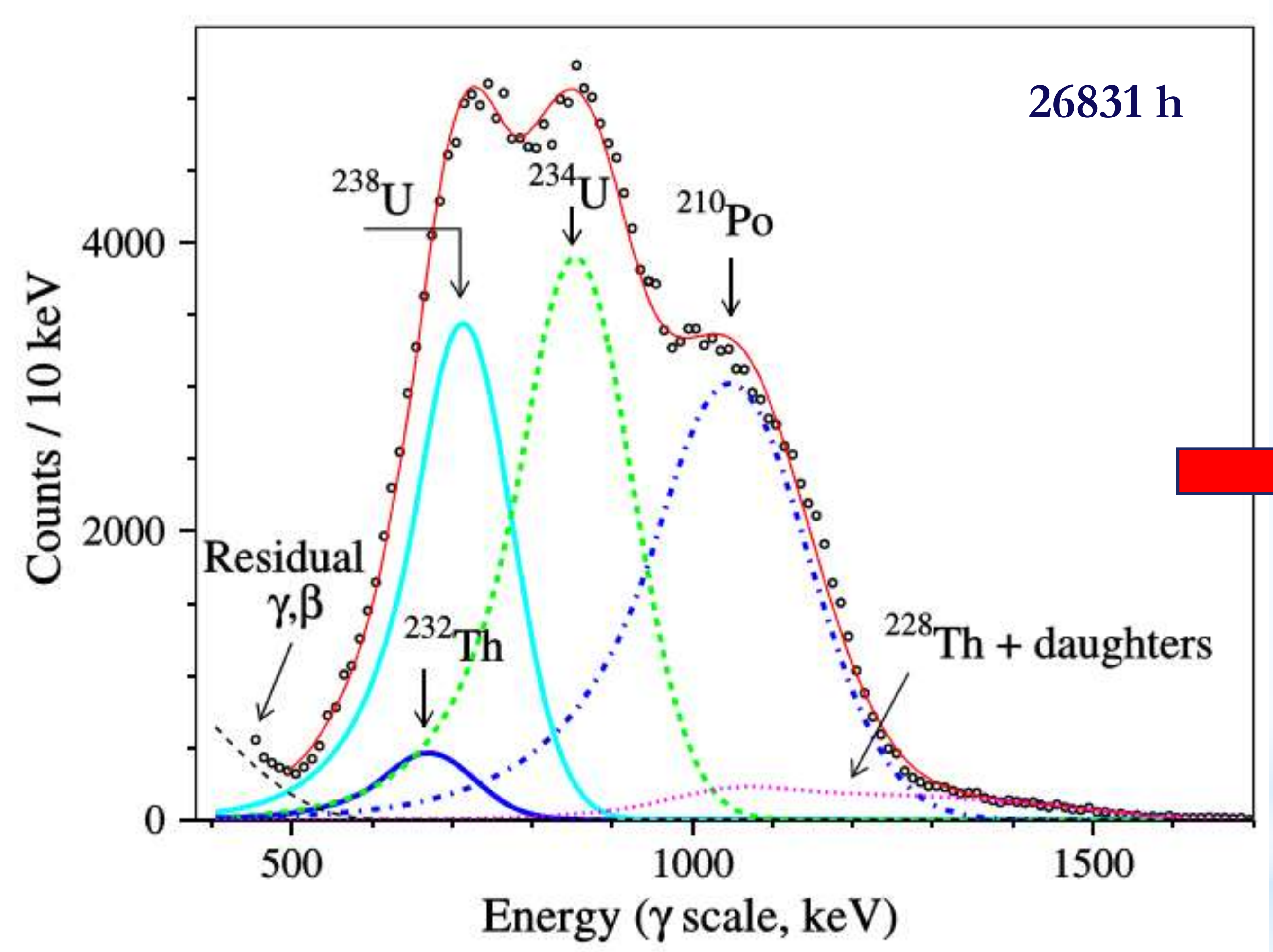
2D histogram: SI versus front edge for the background measurements



21470 h



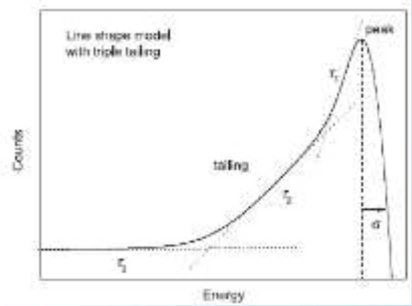
Sum energy spectrum of α events selected by PSD



→ α/γ ratio

The fit of the data by the model built from α decays of U and Th with daughters, and residual γ, β background

Time-amplitude analysis



M.J. Koskelo et al.,
Radioact. Radiochem. 7(1996)18

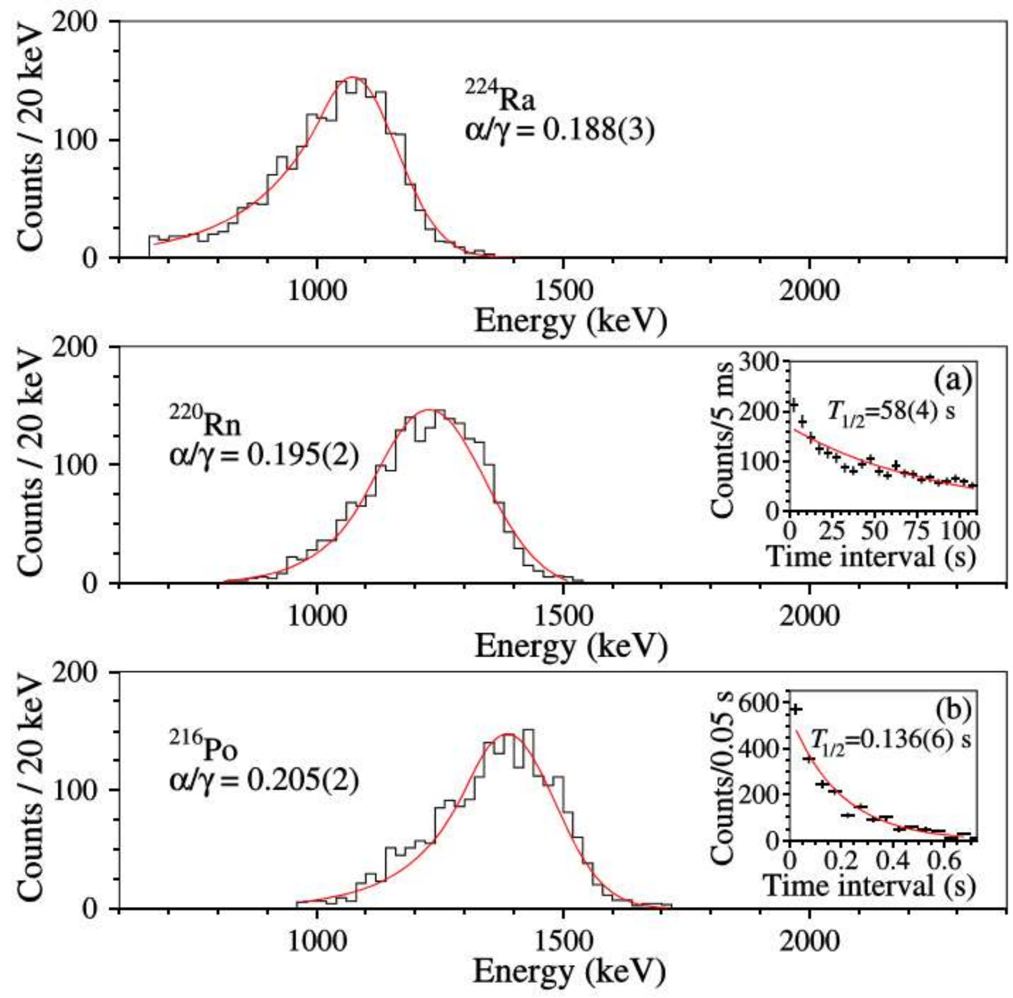
$$f(u) = \begin{cases} A \exp\left[-\dfrac{(u-\mu)^2}{2\sigma^2}\right], & \text{if } u \geq \mu - T \\ A \exp\left[\dfrac{T(2u-2\mu+T)}{2\sigma^2}\right], & \text{if } u < \mu - T \end{cases},$$

A – amplitude of Gauss

μ – center of Gauss

σ – standard deviation

T determines both the characteristics of the tailing and its joining point with the Gaussian



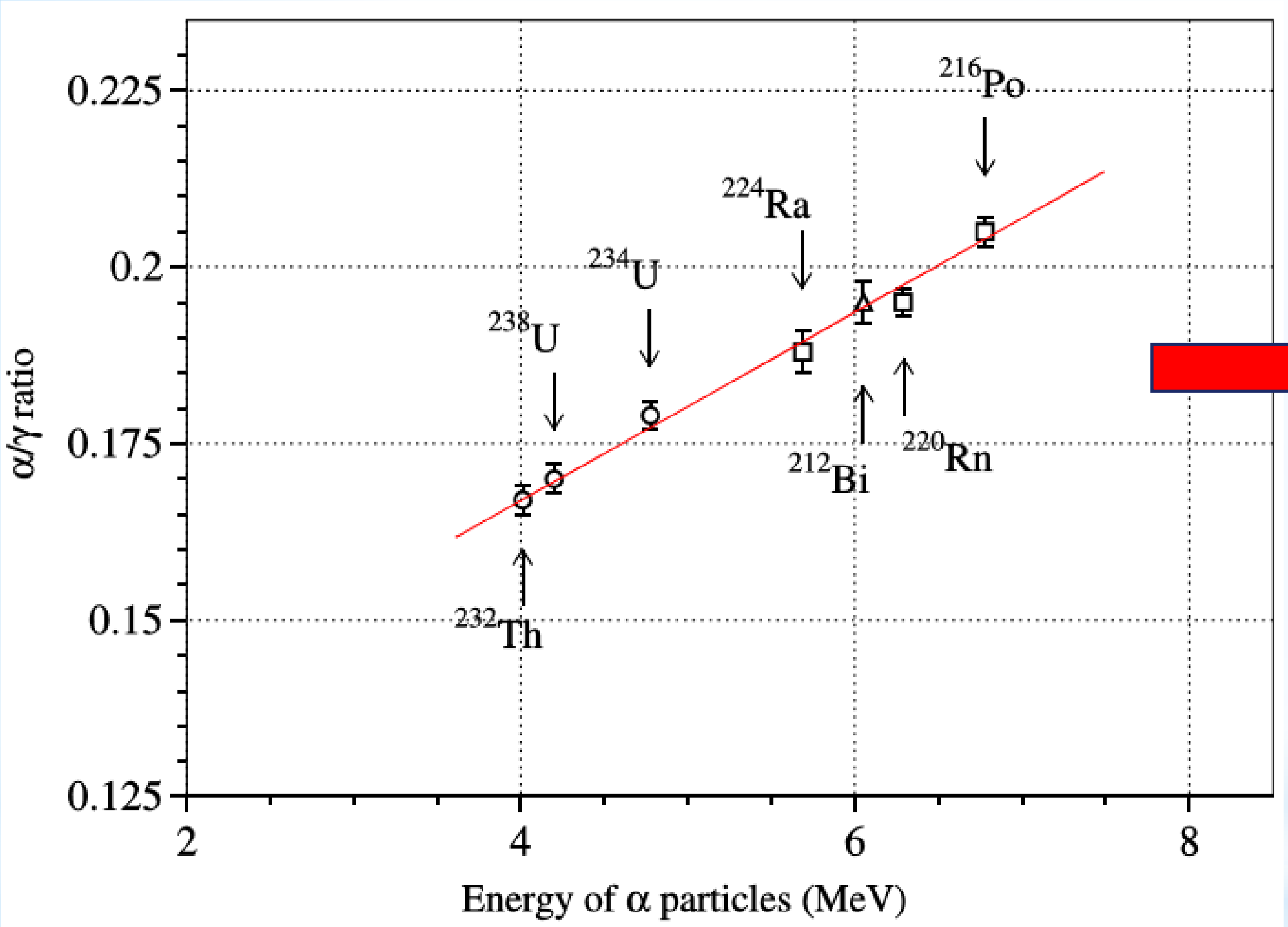
Alpha peaks of ^{224}Ra, ^{220}Rn and ^{216}Po selected by the time-amplitude analysis from the data accumulated during 26831 h with the ^{116}CdWO$_4$ detector No. 1. The obtained half-lives of **^{220}Rn (58 ± 4 s)** and **^{216}Po (0.136 ± 0.006 s)** are in agreement with the table values (**55.6 ± 0.1 s** and **0.145 ± 0.002 s**, respectively [TOI]).

Activity ^{228}Th, μBq/kg

	PSD	T-A
Crystal 1	**17(2)**	**17(1)**
Crystal 2	**26(2)**	**27(1)**

+ α/γ ratio

Dependence of α/γ ratio on energy of the α particles



real
energies
for α
particles

$$\alpha/\gamma \text{ ratio} = 0.114(7) + 0.0133(12)E_\alpha$$

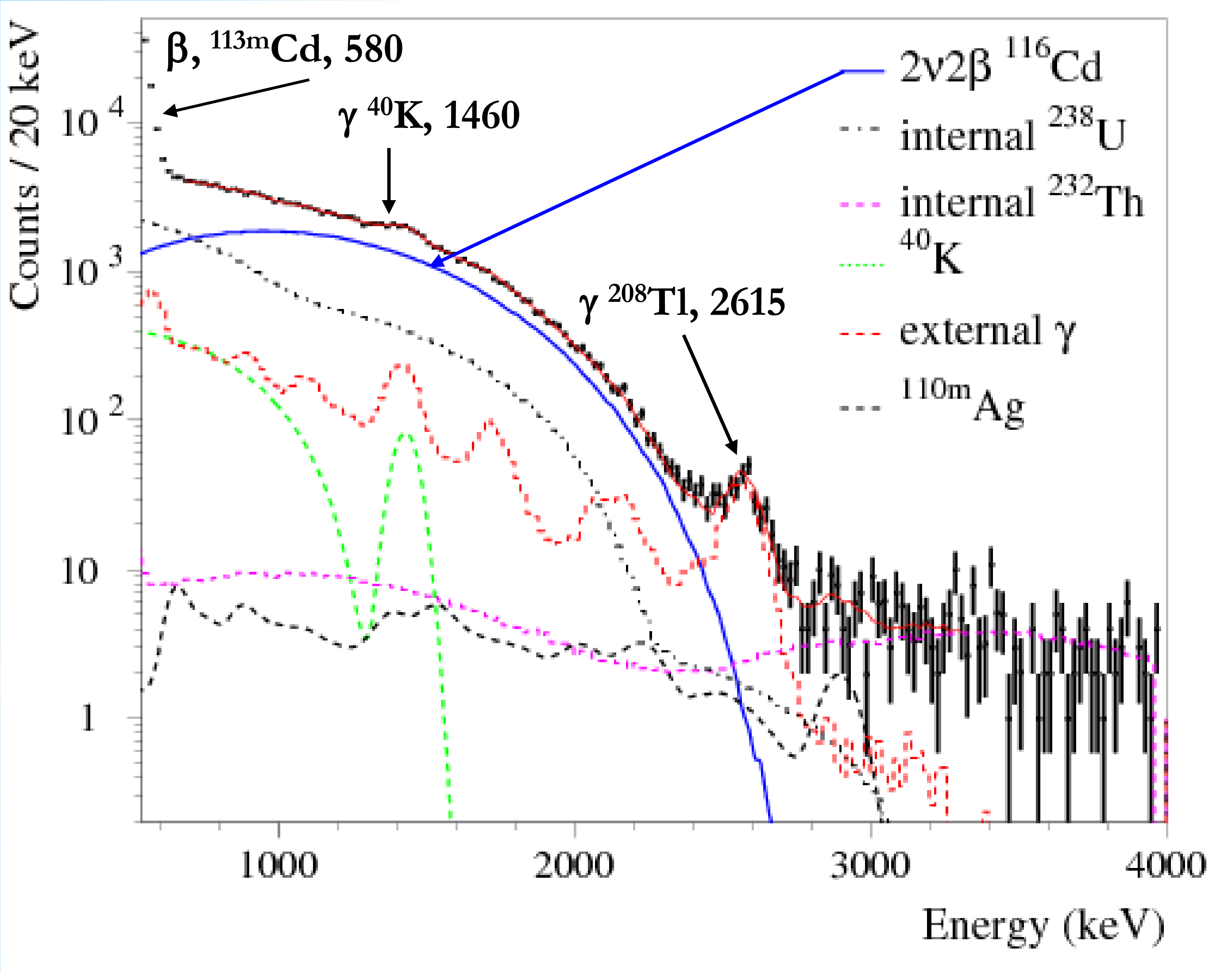
Radioactive contaminations of $^{116}CdWO_4$ crystal scintillators (and elements of the set-up)

Chain	Nuclide	Activity, mBq/kg
^{232}Th	^{232}Th	0.07(2)
	^{228}Th	0.020(1)
^{238}U	^{238}U	0.58(4)
	^{234}U	0.6(1)
	^{230}Th	≤ 0.13
	^{226}Ra	≤ 0.006
	^{210}Pb	0.70(4)
	^{116}Cd	1.138(5)
	^{40}K	0.22(9)
	^{110m}Ag	<0.007

	Nuclide	Activity, mBq/kg
PMT	^{226}Ra	$<0.9\times10^3$
	^{228}Ra	$0.12(5)\times10^3$
	^{228}Th	$0.83(2)\times10^2$
	^{40}K	$<13\times10^3$
Copper	U	0.11(2)
	Th	0.06(1)
	^{40}K	0.27(6)
Light guides	U	0.20(2)
	Th	0.10(1)
	^{40}K	1.3(3)

Total α activity of two crystals = 2.14(2) mBq/kg

Two neutrino double beta decay of ^{116}Cd (25037 h)



Signal to bg ratio:

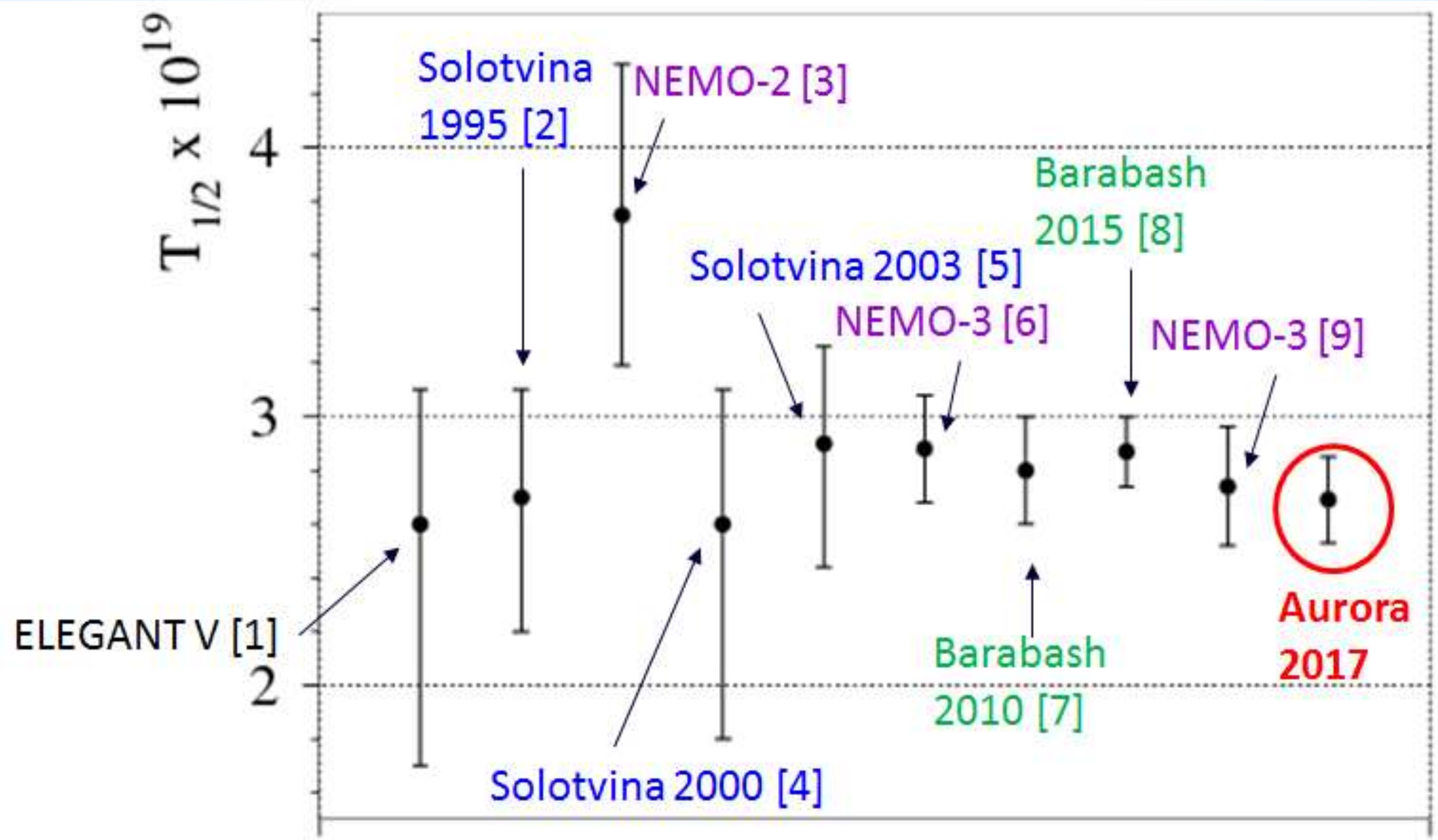
2.6 in [1.1–2.8] MeV

Index of Bg:

0.12 in [2.7-2.9] MeV

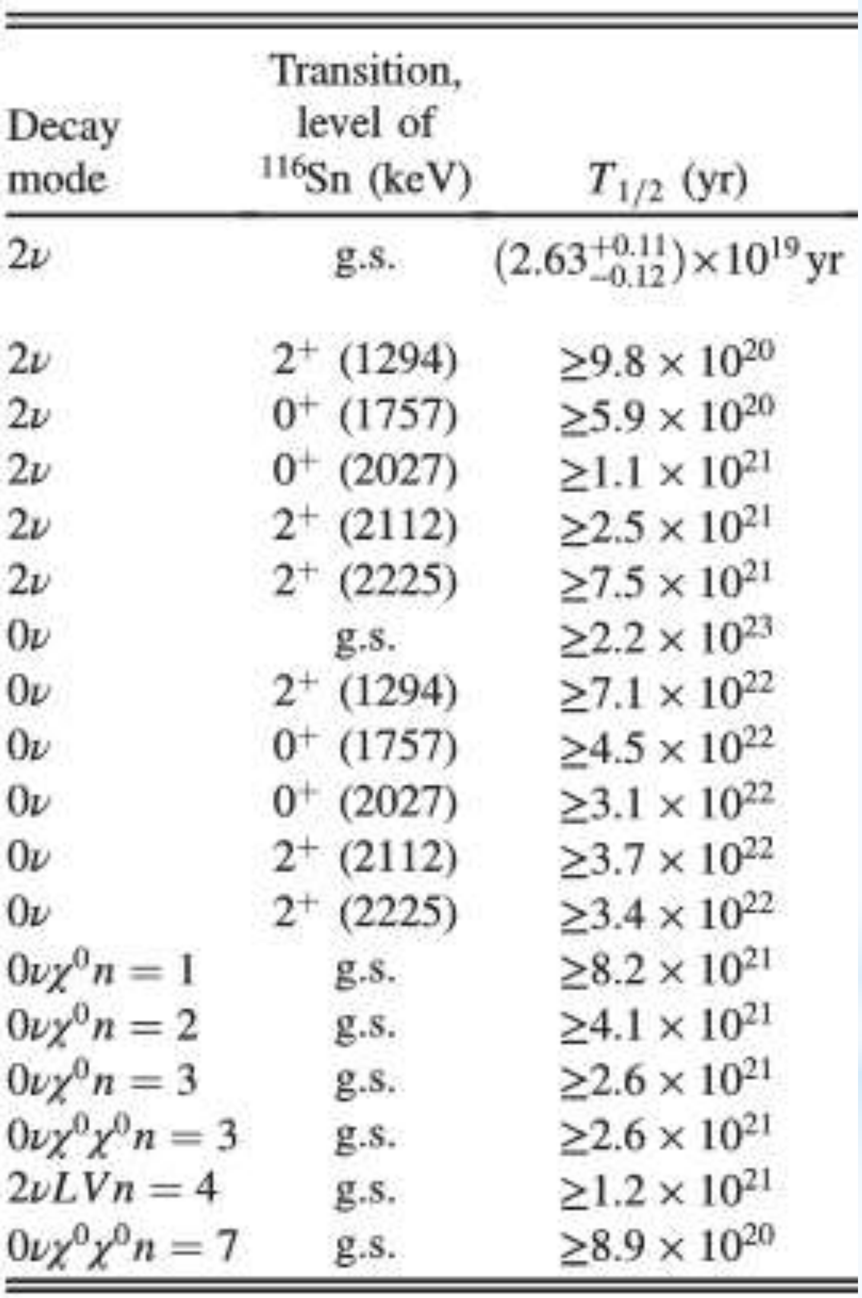
$T_{1/2}$ = [2.69 ± 0.02(stat.) ± 0.14(syst.)] × 10^{19} yr

Summary of the $T_{1/2}(2\nu2\beta)$ results ^{116}Cd



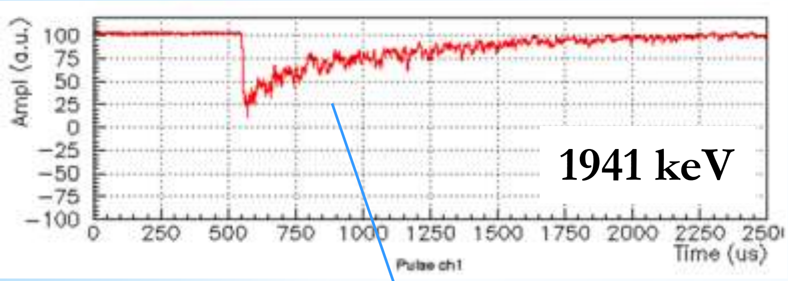
[1] J. Phys. Soc. Japan 64(1995)339; [2] Phys. Lett. B 344(1995)72;
[3] Z. Phys. C 72(1996)239; [4] PRC 62(2000)045501;
[5] PRC 68(2003)035501; [6] AIP Conf. Proc. 1572(2013)110;
[7] PRC 81(2010)035501; [8] NPA 935(2015)52;
[9] PRD 95(2017)012007.

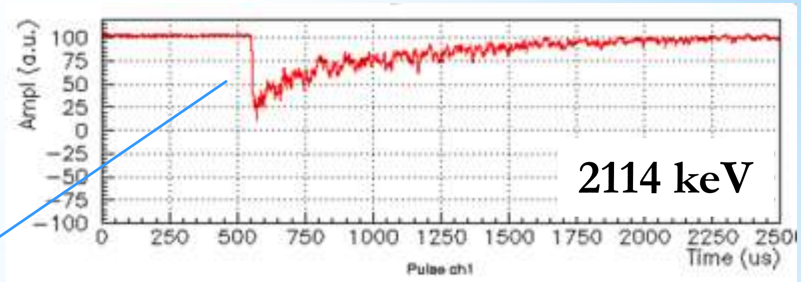
Results

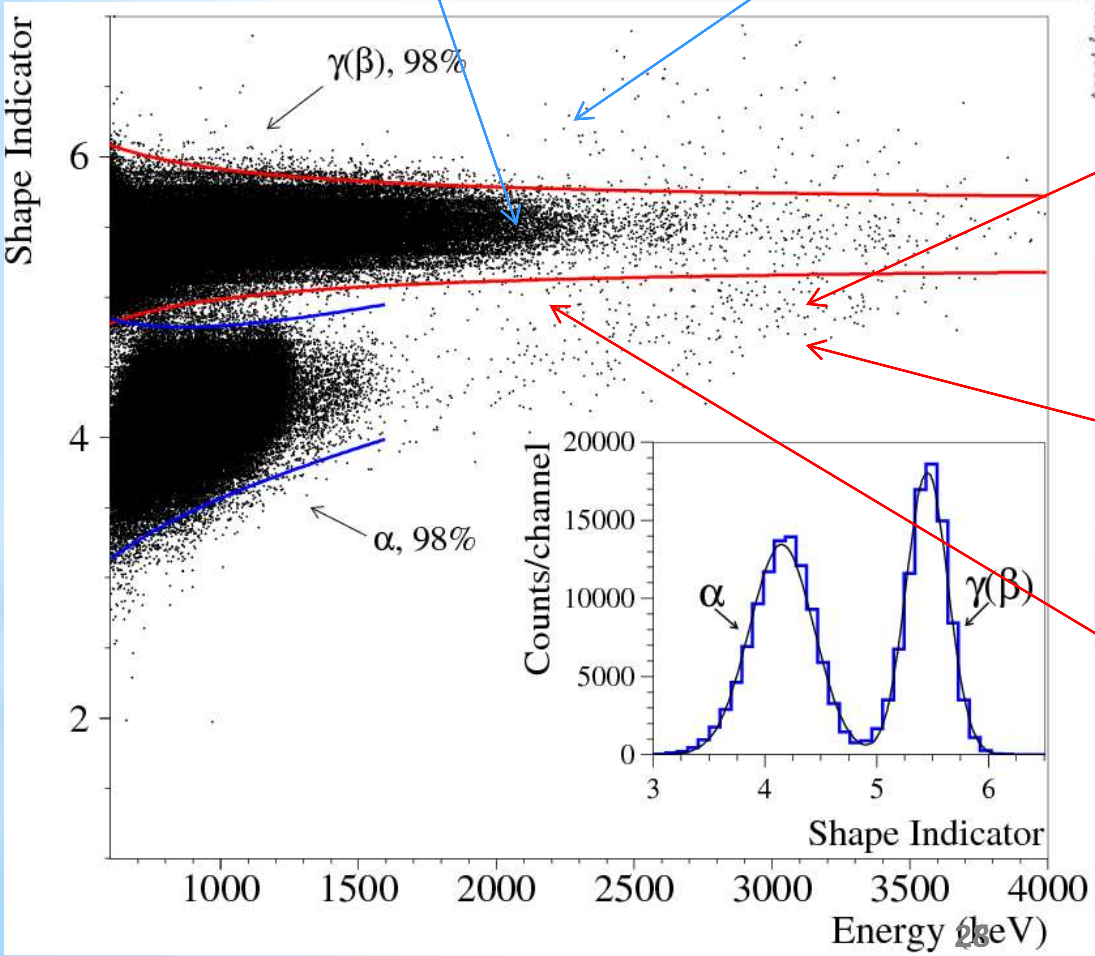


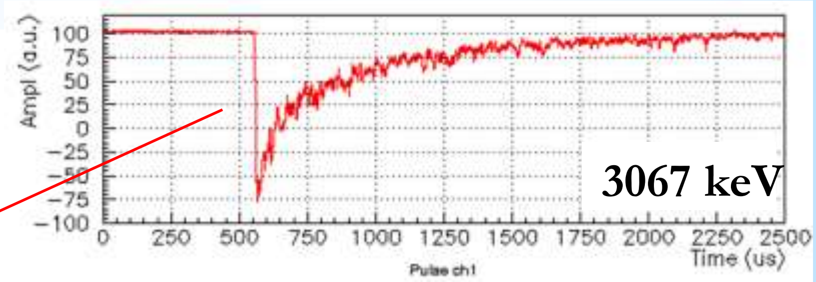
Decay mode	Transition, level of ^{116}Sn (keV)	$T_{1/2}$ (yr)
2ν	g.s.	$(2.63^{+0.11}_{-0.12})\times10^{19}$ yr
2ν	2^+ (1294)	$\geq 9.8\times10^{20}$
2ν	0^+ (1757)	$\geq 5.9\times10^{20}$
2ν	0^+ (2027)	$\geq 1.1\times10^{21}$
2ν	2^+ (2112)	$\geq 2.5\times10^{21}$
2ν	2^+ (2225)	$\geq 7.5\times10^{21}$
0ν	g.s.	$\geq 2.2\times10^{23}$
0ν	2^+ (1294)	$\geq 7.1\times10^{22}$
0ν	0^+ (1757)	$\geq 4.5\times10^{22}$
0ν	0^+ (2027)	$\geq 3.1\times10^{22}$
0ν	2^+ (2112)	$\geq 3.7\times10^{22}$
0ν	2^+ (2225)	$\geq 3.4\times10^{22}$
$0\nu\chi^0 n=1$	g.s.	$\geq 8.2\times10^{21}$
$0\nu\chi^0 n=2$	g.s.	$\geq 4.1\times10^{21}$
$0\nu\chi^0 n=3$	g.s.	$\geq 2.6\times10^{21}$
$0\nu\chi^0\chi^0 n=3$	g.s.	$\geq 2.6\times10^{21}$
$2\nu LV n=4$	g.s.	$\geq 1.2\times10^{21}$
$0\nu\chi^0\chi^0 n=7$	g.s.	$\geq 8.9\times10^{20}$

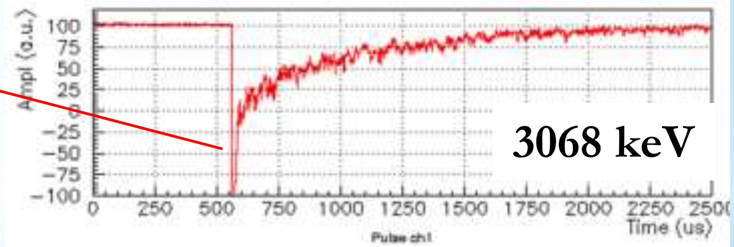
[1] PRC 68(2003)035501 **[2]** Phys.Lett.B 249(1990)186 *68% C.L. **[3]** NPA 577(1994)493

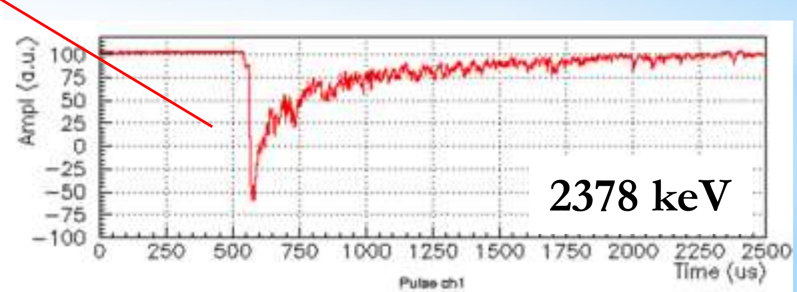

Ampl (a.u.)
100
75
50
25
0
−25
−50
−75
−100
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
Time (us)
Pulse ch1
1941 keV


Ampl (a.u.)
100
75
50
25
0
−25
−50
−75
−100
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
Time (us)
Pulse ch1
2114 keV


Shape Indicator
6
4
2
γ(β), 98%
α, 98%
1000
1500
2000
2500
3000
3500
4000
Energy (keV)
Counts/channel
20000
15000
10000
5000
0
3
4
5
6
α
γ(β)
Shape Indicator


Ampl (a.u.)
100
75
50
25
0
−25
−50
−75
−100
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
Time (us)
Pulse ch1
3067 keV


Ampl (a.u.)
100
75
50
25
0
−25
−50
−75
−100
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
Time (us)
Pulse ch1
3068 keV

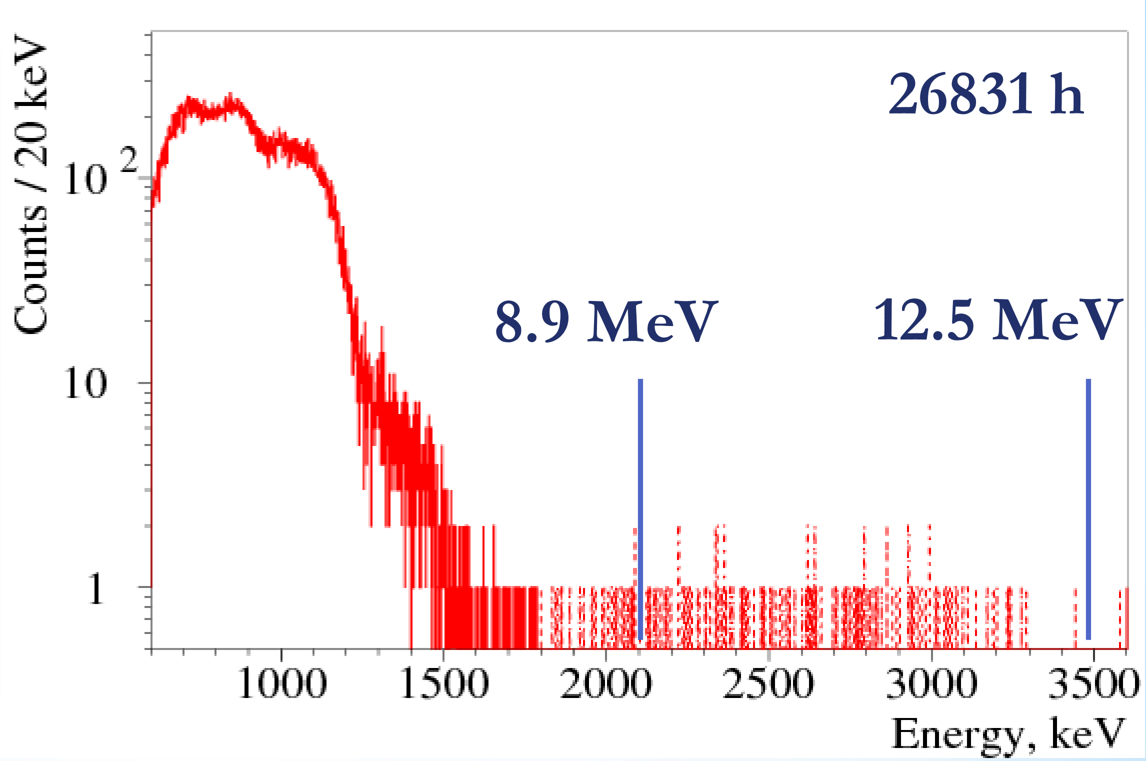

Ampl (a.u.)
100
75
50
25
0
−25
−50
−75
−100
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
Time (us)
Pulse ch1
2378 keV

First results

m(det1) = 579.8 g → $N_1(W)$ = 9.67×10^{23} nuclei
m(det2) = 582.4 g → $N_2(W)$ = 9.71×10^{23} nuclei

$T_{1/2}$ (Sg) = 10^9 yr [1,2] – standard assumption in the SHE search in nature.

$\lim S_1 < 193$
$\lim S_2 < 199$

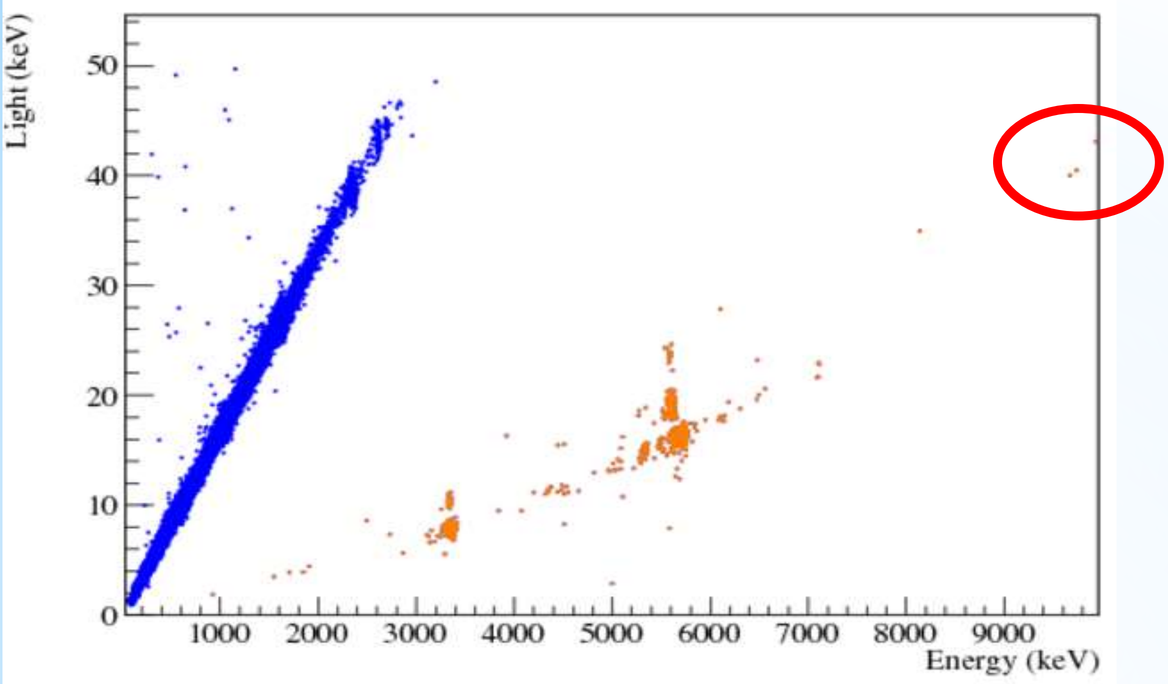


$$N(\mathrm{Sg})_1 / N(\mathrm{W}) < 9.8 \times 10^{-14} \text{ atoms/atom at 90\% C.L.}$$
$$N(\mathrm{Sg})_2 / N(\mathrm{W}) < 1.0 \times 10^{-13} \text{ atoms/atom at 90\% C.L.}$$

[1] Rep. Prog. Phys. 47 (1983) 817
[2] AIP Conf. Proc. 1175 (2009) 297

This values are comparable with the sensitivity reached in the searches for eka-W with $ZnWO_4$ < 5.5×10^{-14} g/g [2]

Search for eka-B [Cardani et al., JINST 7(2012)P10022]



LNGS, BGO scintillating bolometer (891 g), t = 455 h
3 α events in the energy interval 9.5–10 MeV (while one could expect no events after the energy of the most energetic in the U/Th chains α particles from Po with Q = 8.954 MeV).
If they are not pile-ups of two α signals or BiPo event, then →

If S < 6.68 at 90% C.L.,
$T_{1/2}$(Sb) = 10^9 yr for eka-Bi
N(eka-Bi) =1.9 × 10^{11}.
N(Bi) =1.7 × 10^{24}

N(eka-Bi)/N(Bi) <1.1*10^{-13} atoms/atom

This is better than the limits obtained in recent searches with the accelerator mass spectrometry δ<(5-30)×10^{-13} atoms/atom (for A= 293−300) demonstrating the good potentiality of the approach considered here to search for SHE

Thank you for attention!