Розробка радіоактивно чистих сцинтиляторів $ZnWO_4$ для пошуку подвійного бета-розпаду і темної матерії

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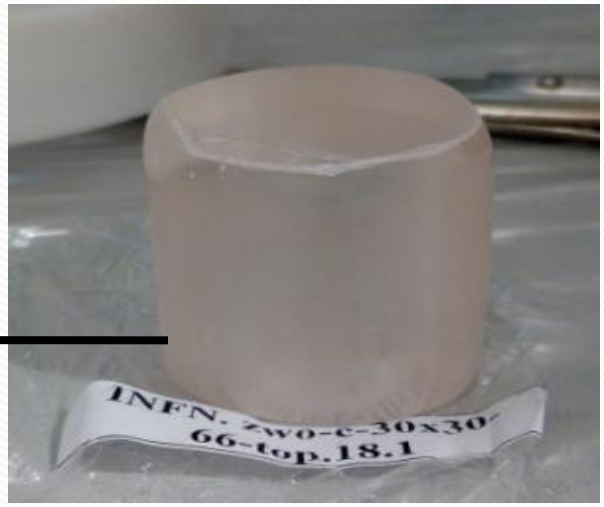
Properties of the $ZnWO_4$ crystal scintillators and the aim of the work

- Non-hygroscopic and chemically resistant
- Anisotropy → to measure the directionality of Dark Matter
- High level of radiopurity → 2β decay of ^{64}Zn, ^{70}Zn, ^{180}W and ^{186}W; α decay and $0\nu2\varepsilon$ of ^{183}Zn
- Luminescence of $ZnWO_4$ down to helium temperature → crystals as scintillating bolometer
- Ability of Pulse Shape Discrimination (PSD)

Investigation of the effect of the re-crystallization on the radioactive contamination of the material

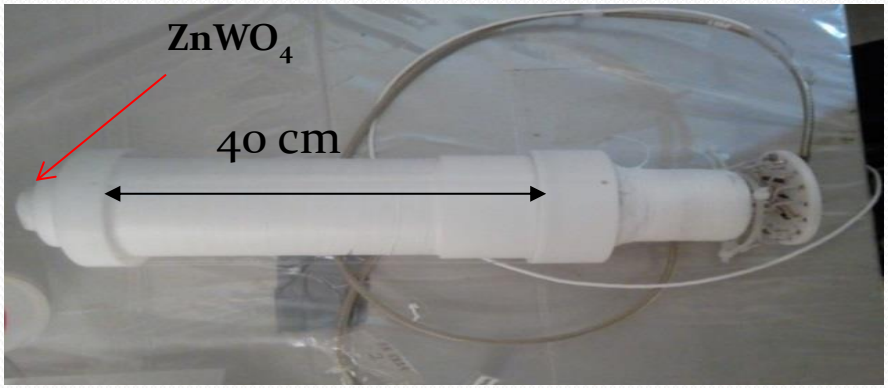
Properties of the $ZnWO_4$ crystal scintillators

Crystal	Size (mm), mass (kg)	Crystallization	FWHM (%), for 662 keV of ^{137}Cs
$ZnWO_4$-16.4 **bottom**	∅50.5×50.4, 0.7	second	28.6
$ZnWO_4$-16.3 **top**	∅50.5×50.4, 0.7	second	23.4
$ZnWO_4$-16.1 **bottom**	∅50×50, 0.68	first	19.2
$ZnWO_4$-16.2 **top**	∅50×50, 0.68	first	17.7
$ZnWO_4$-18.2 **bottom**	∅30×66, 0.15	first + deep WO_4 purification	18.6
$ZnWO_4$-18.1 **top**	∅30×66, 0.15	--//--	13.7



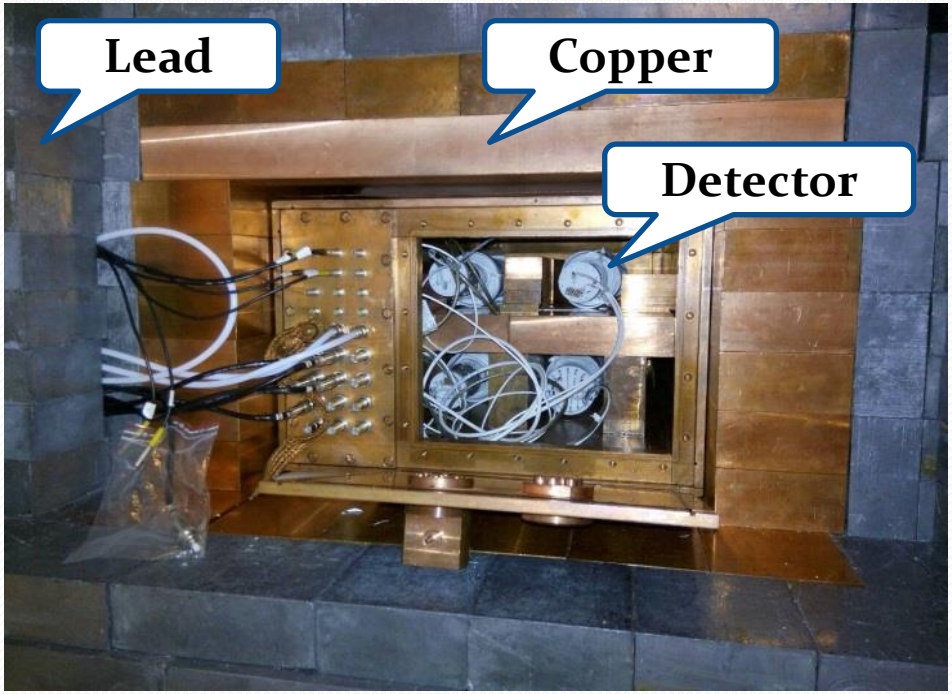
Crystals were produced in the Nikolaev Institute of Inorganic Chemistry (Novosibirsk, Russia) by the low-thermal gradient Czochralski technique in a platinum crucible (two of them (16.3 and 16.4) were additionally recrystallized

Measurements

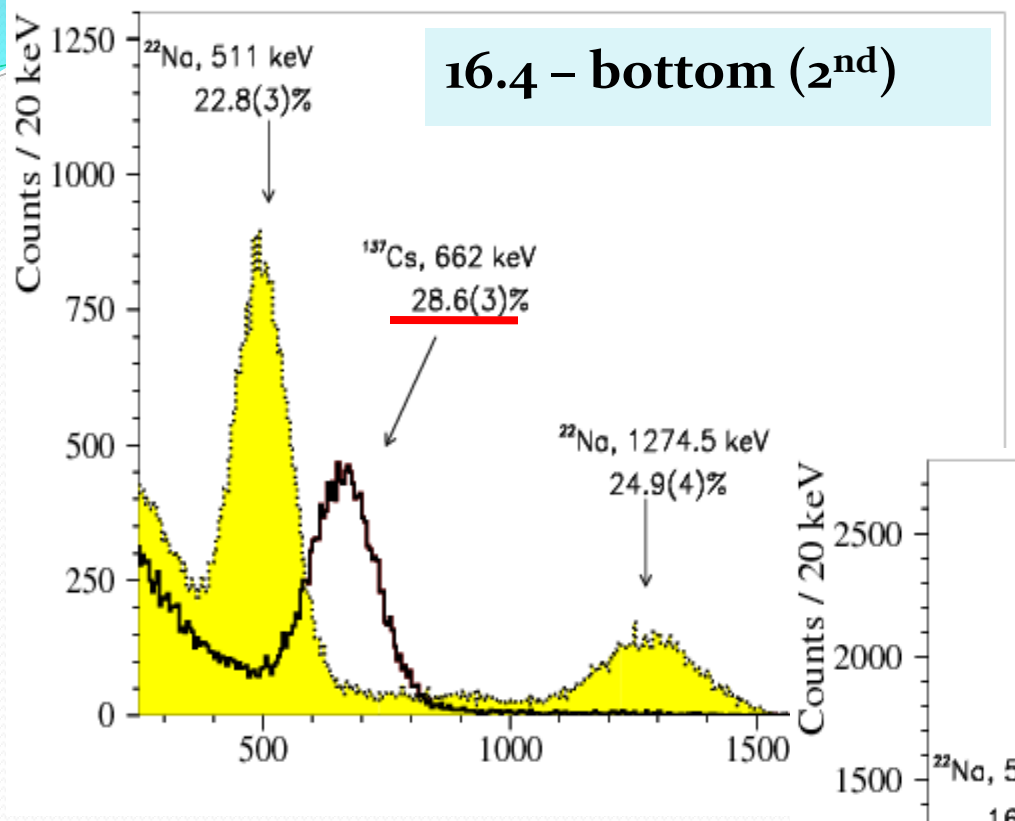


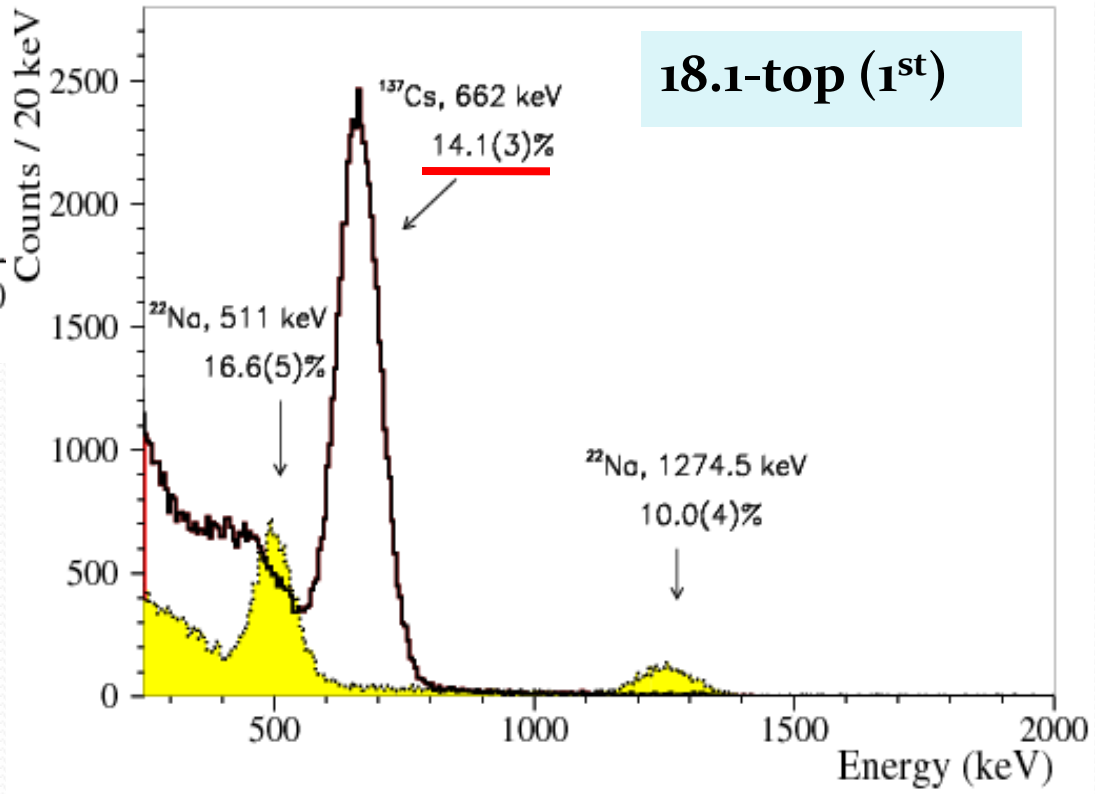
6 crystals of $ZnWO_4$, in DAMA/R&D

2 stages of the experiment started in June 2017

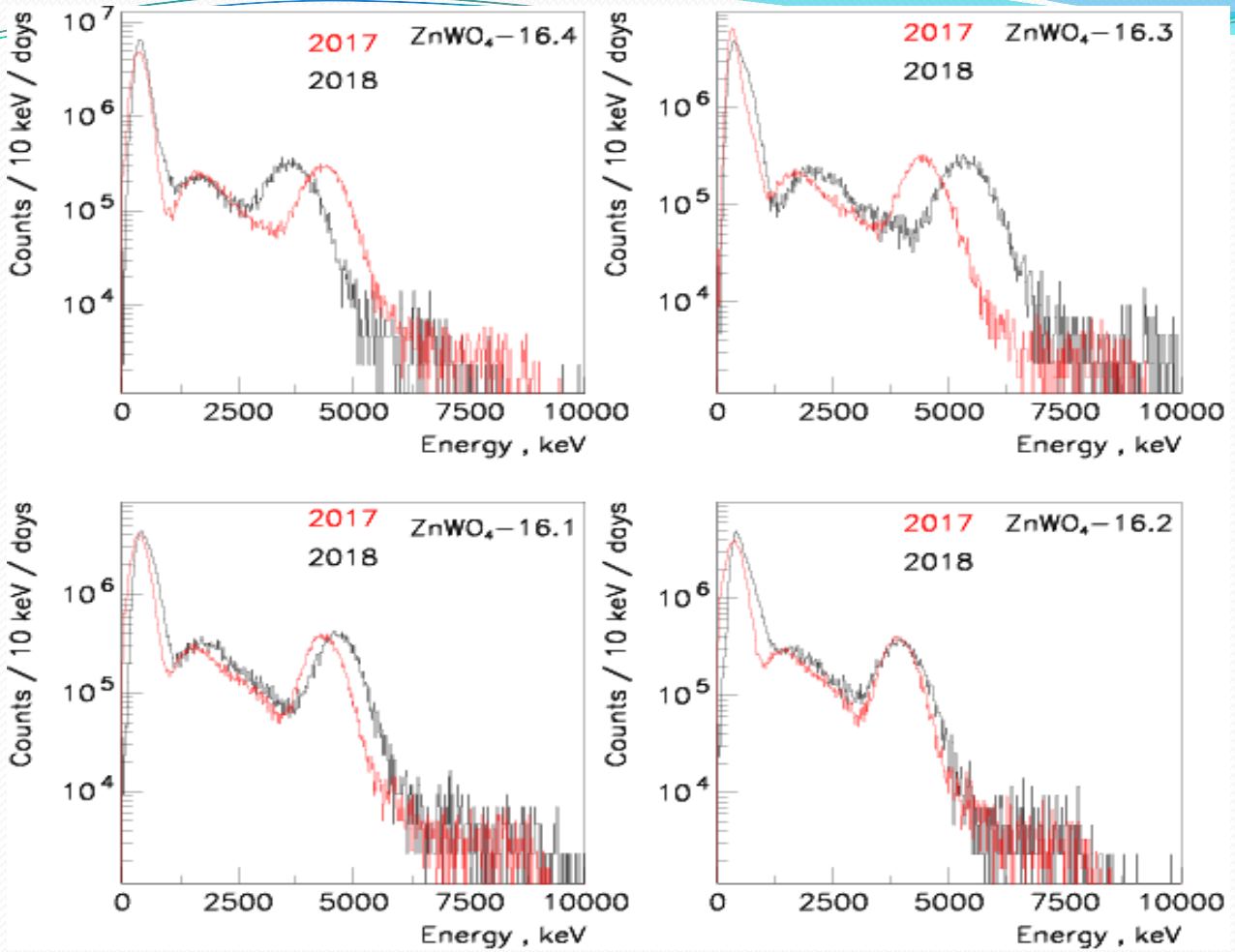


Energy resolution of $ZnWO_4$ crystals



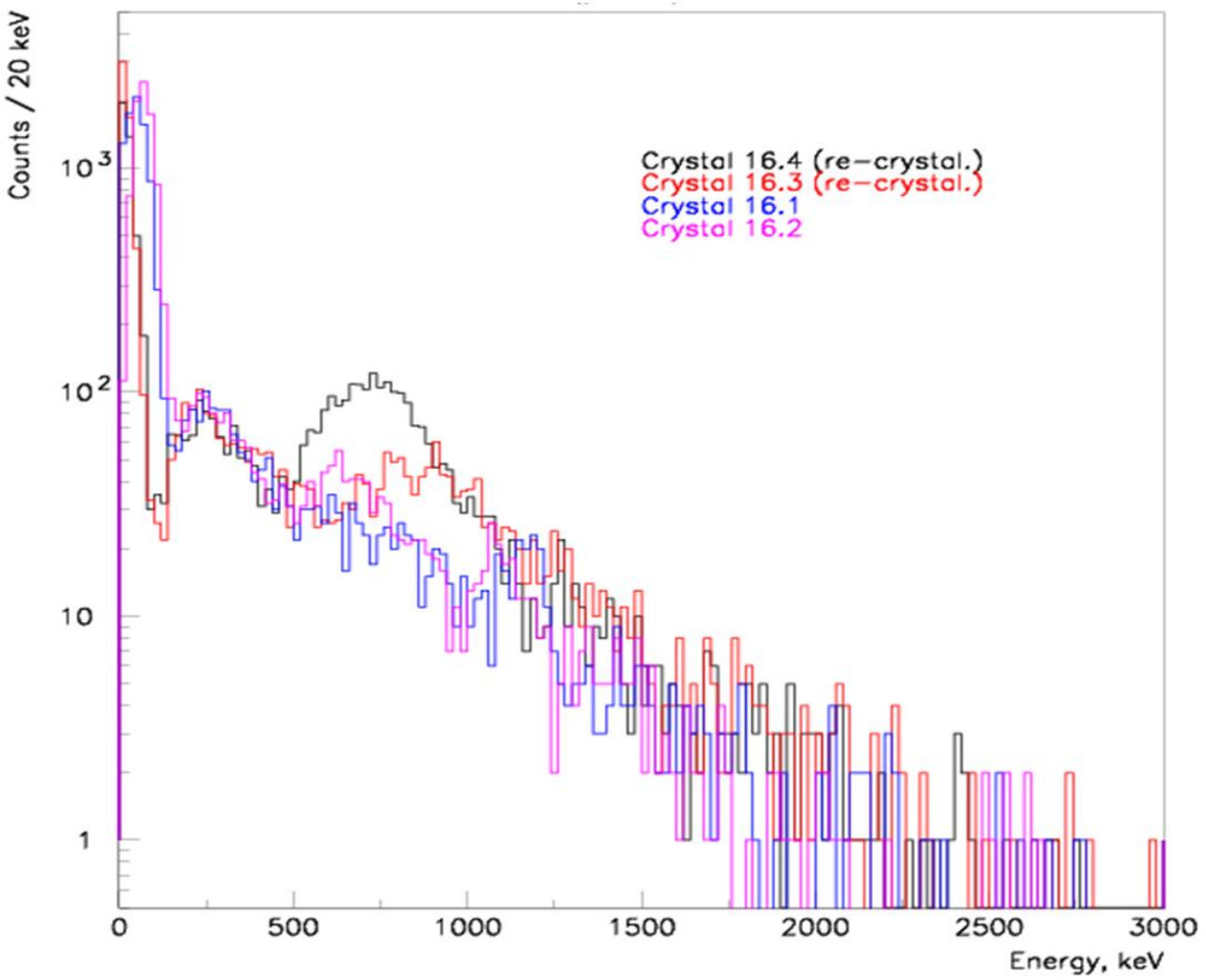


Energy shift



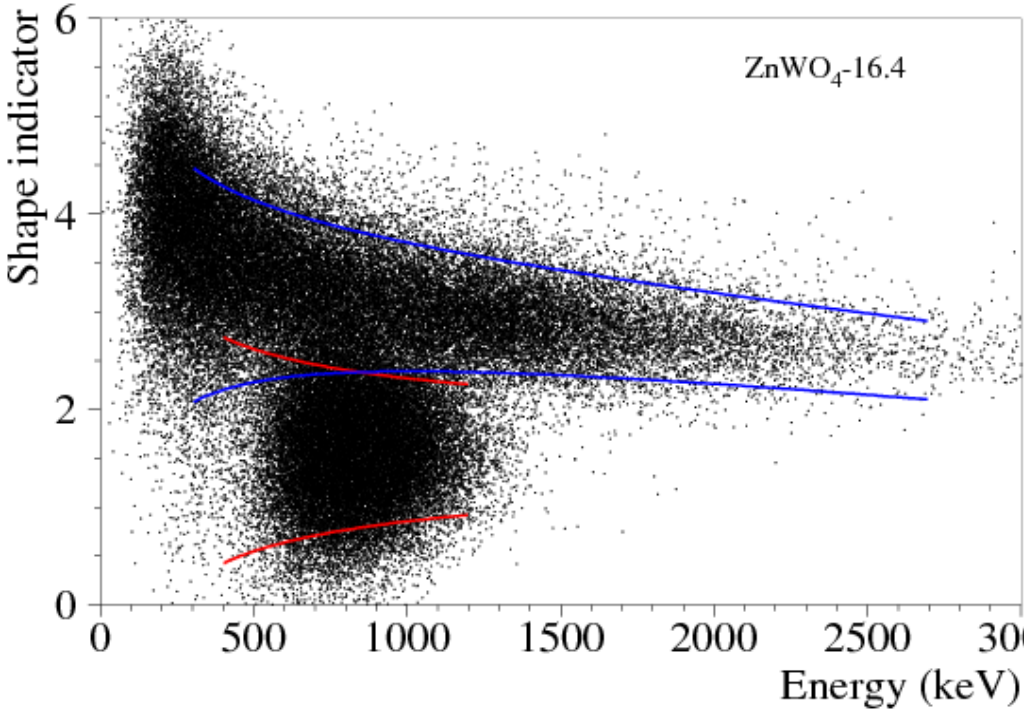
- the energy resolutions were decreased
- no problems with optical contact were noticed (the optical grease didn't change its color and transparency)
- all 4 crystals didn't significantly change their properties (at least it was not possible to see by eyes)

Summary spectra of four crystals (8097 h)



The positions of alpha peaks for the different detectors are slightly shifted (in gamma scale). It can be caused by different origin of alpha contaminations (internal or surface contamination that could appear during polishing of crystals by diamond sandpaper).

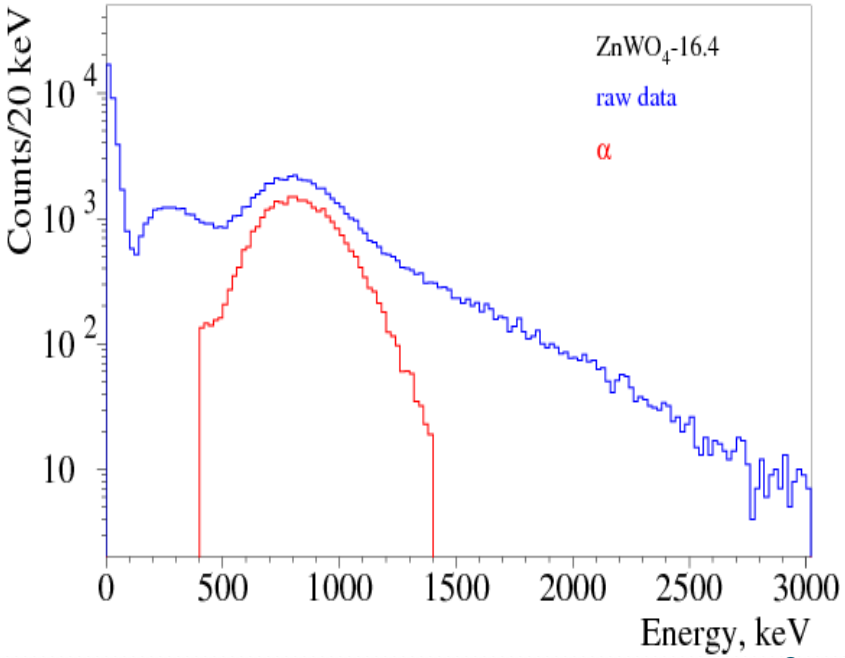
Pulse shape discrimination (8097 h, crys.16.4)



Shape indicator (SI) versus energy for the background exposure

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

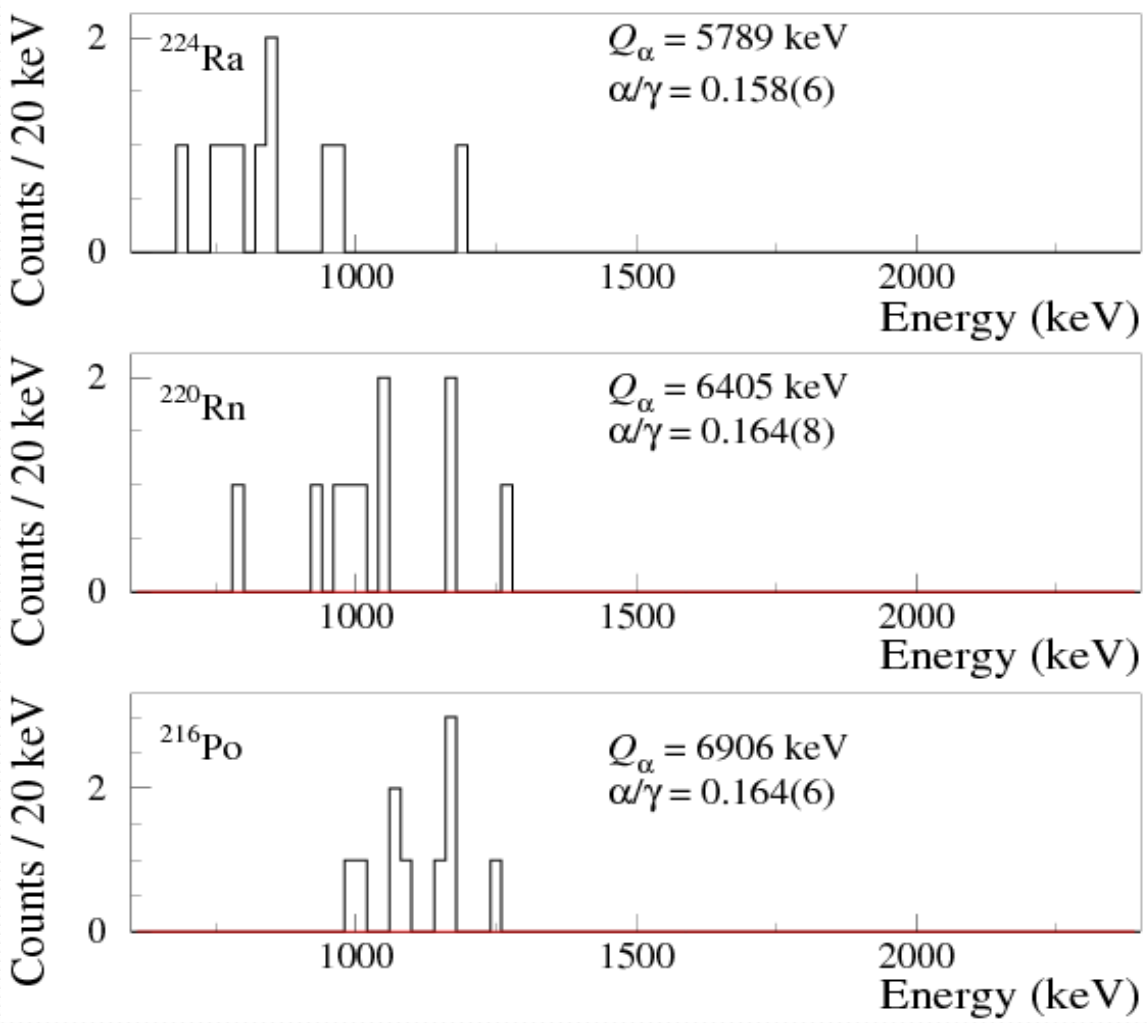
$f(t_k)$ – amplitude at time t_k
$P(t) = [f_\alpha(t) - f_\gamma(t)]/[f_\alpha(t) + f_\gamma(t)]$,
$f\alpha(t)$, $f\gamma(t)$ – shapes of the signals



$$I_\alpha = \frac{N}{t * m * \eta}$$

where t is a time of measurements (8097 h);
N is a number of alpha events;
m is a mass of a certain $ZnWO_4$ crystal;
η is an efficiency of the particle selection by the pulse-shapes analysis

Time-amplitude analysis(8097 h, crys.16.4)



Alpha peaks of ^{224}Ra, ^{220}Rn and ^{216}Po selected by the time-amplitude analysis from the data accumulated over 8097 h with the $ZnWO_4$ detector No.16.4.

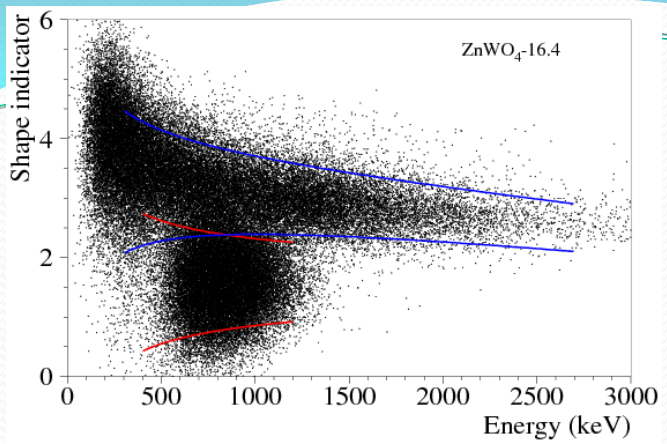
The activity of ^{228}Th have been estimated as **0.7(2)μBq/kg**

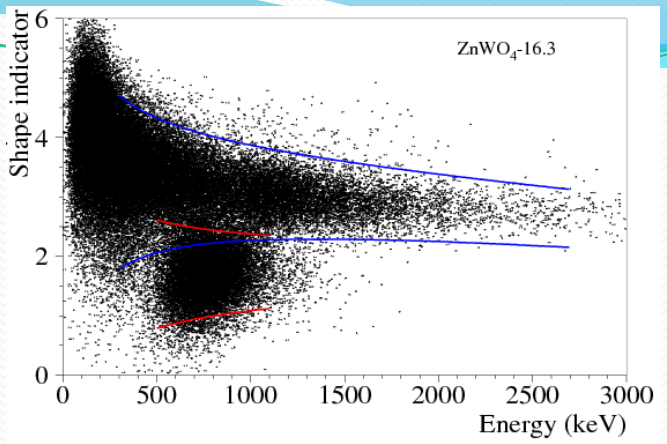
Results of the measurements

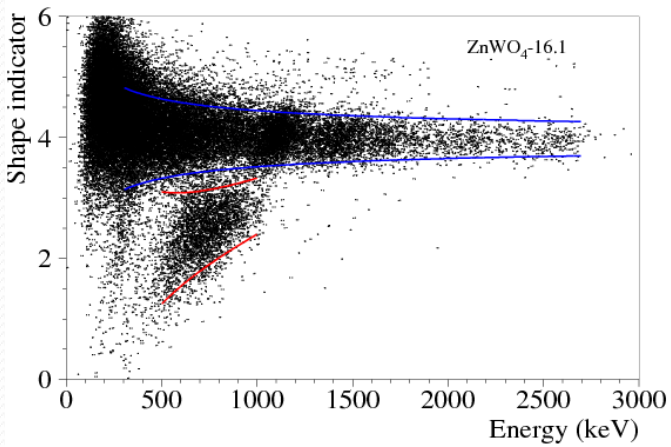
Crystal	Time, h	**FWHM (%), for 662 keV of ^{137}Cs**	**Total alpha activity, mBq/kg**	Activity of ^{228}Th, μBq/kg (90% C.L.)
$ZnWO_4$-16.4 bottom	8097	28.6	**1.50(1)**	0.7(2)
$ZnWO_4$-16.3 top	8097	23.4	**0.62(7)**	<0.3
$ZnWO_4$-16.1 bottom	8097	19.2	**0.38(1)**	<0.2
$ZnWO_4$-16.2 top	8097	17.7	**0.15(3)**	<0.2
$ZnWO_4$-18.2 bottom	705	18.6	**0.39(2)**	<10
$ZnWO_4$-18.1 top	705	14.1	**0.19(4)**	<10

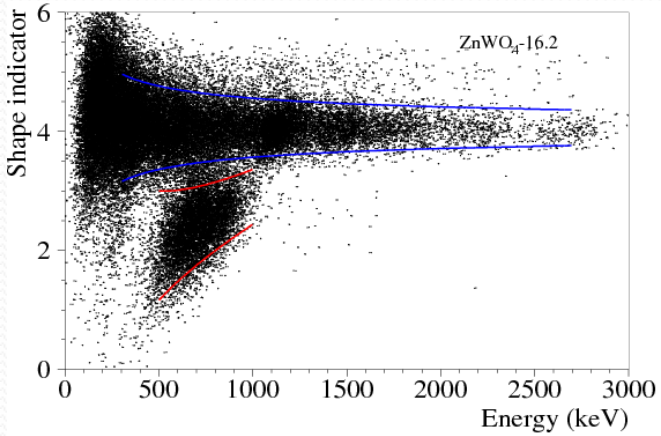
Conclusions

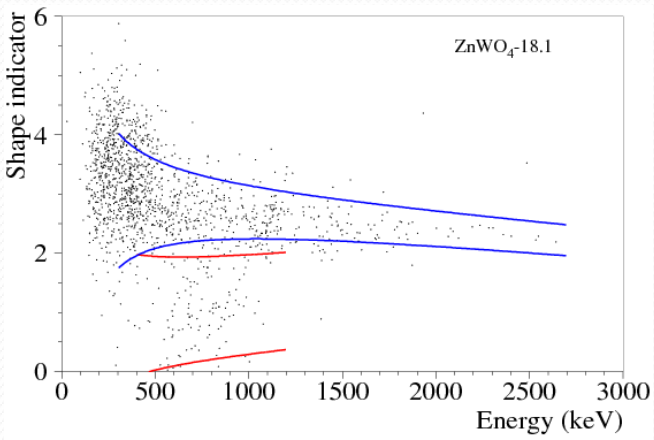
- $ZnWO_4$ crystals are perspective detectors for searching of 2β decay, eka-elements, rare alpha decays and investigation of Dark Matter
- The investigation of six $ZnWO_4$ crystals after first and second crystallization was performed (the measurements with new two crystals $ZnWO_4$ (18.1-2) are in progress).
- Crystals (1^{st} crystallization, before and after deep WO_4 source purification) have the same total alpha activity.
- Crystals after 2^{nd} crystallization have worse energy resolution and higher α-active contamination.
- The origin of alpha (internal or surface contamination) should be analyzed.

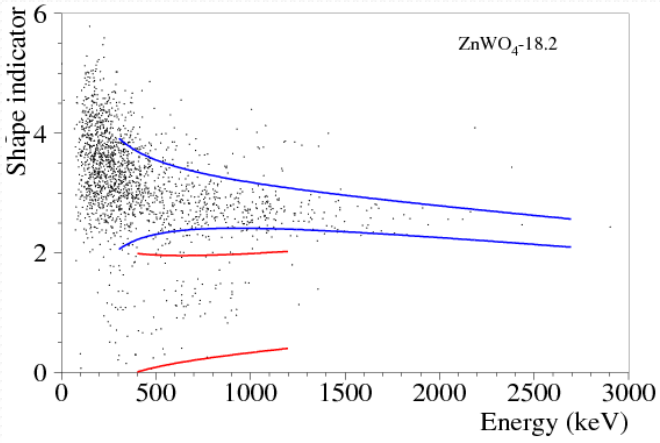

ZnWO4-16.4
Shape indicator
Energy (keV)

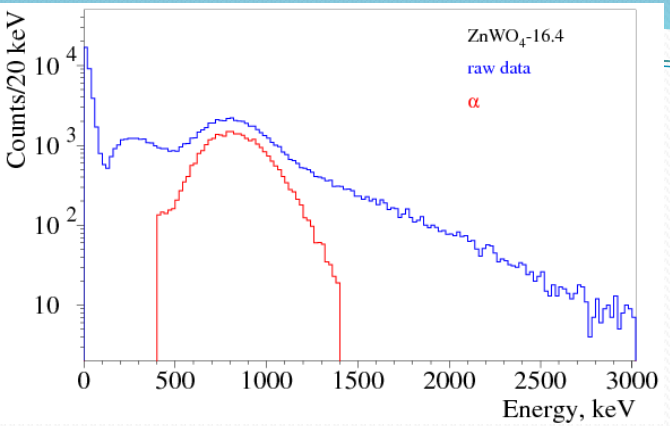

ZnWO4-16.3
Shape indicator
Energy (keV)

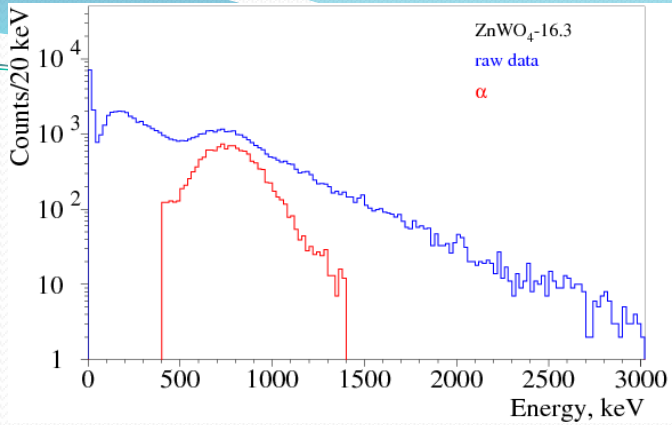

ZnWO4-16.1
Shape indicator
Energy (keV)

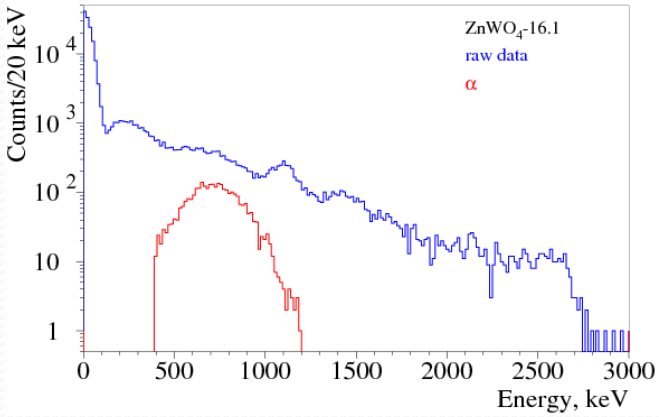

ZnWO4-16.2
Shape indicator
Energy (keV)

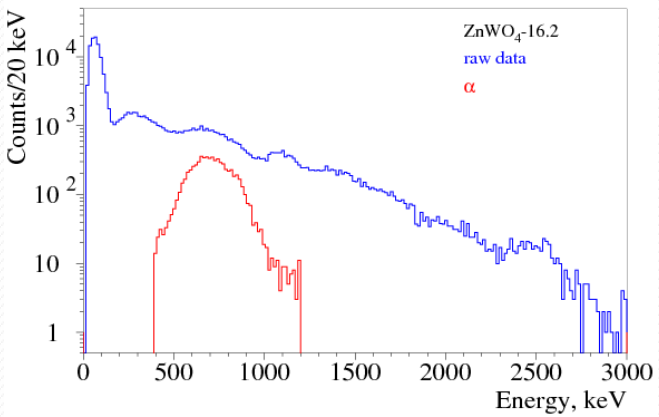

ZnWO4-18.1
Shape indicator
Energy (keV)

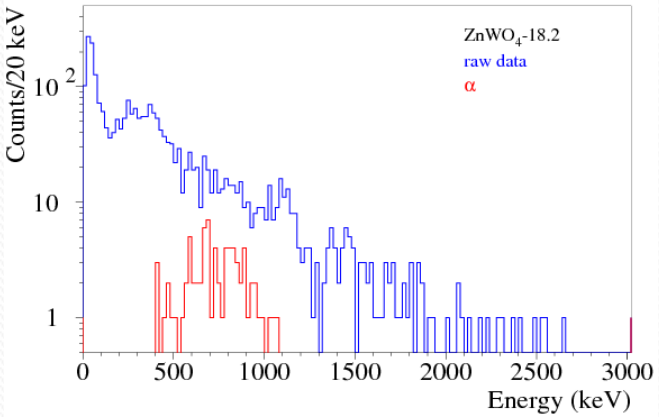

ZnWO4-18.2
Shape indicator
Energy (keV)

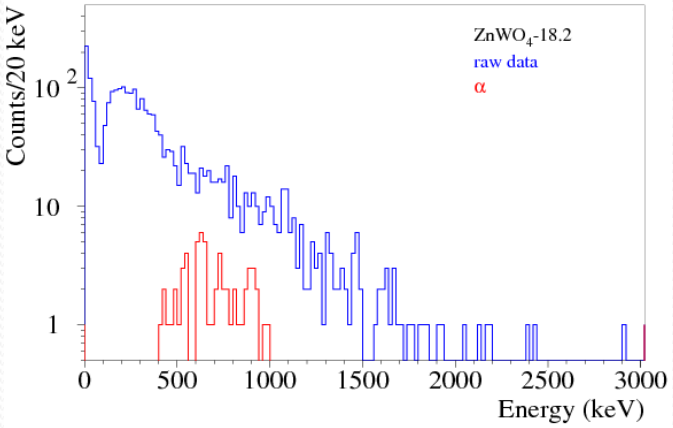

ZnWO4-16.4
raw data
α
Counts/20 keV
Energy, keV

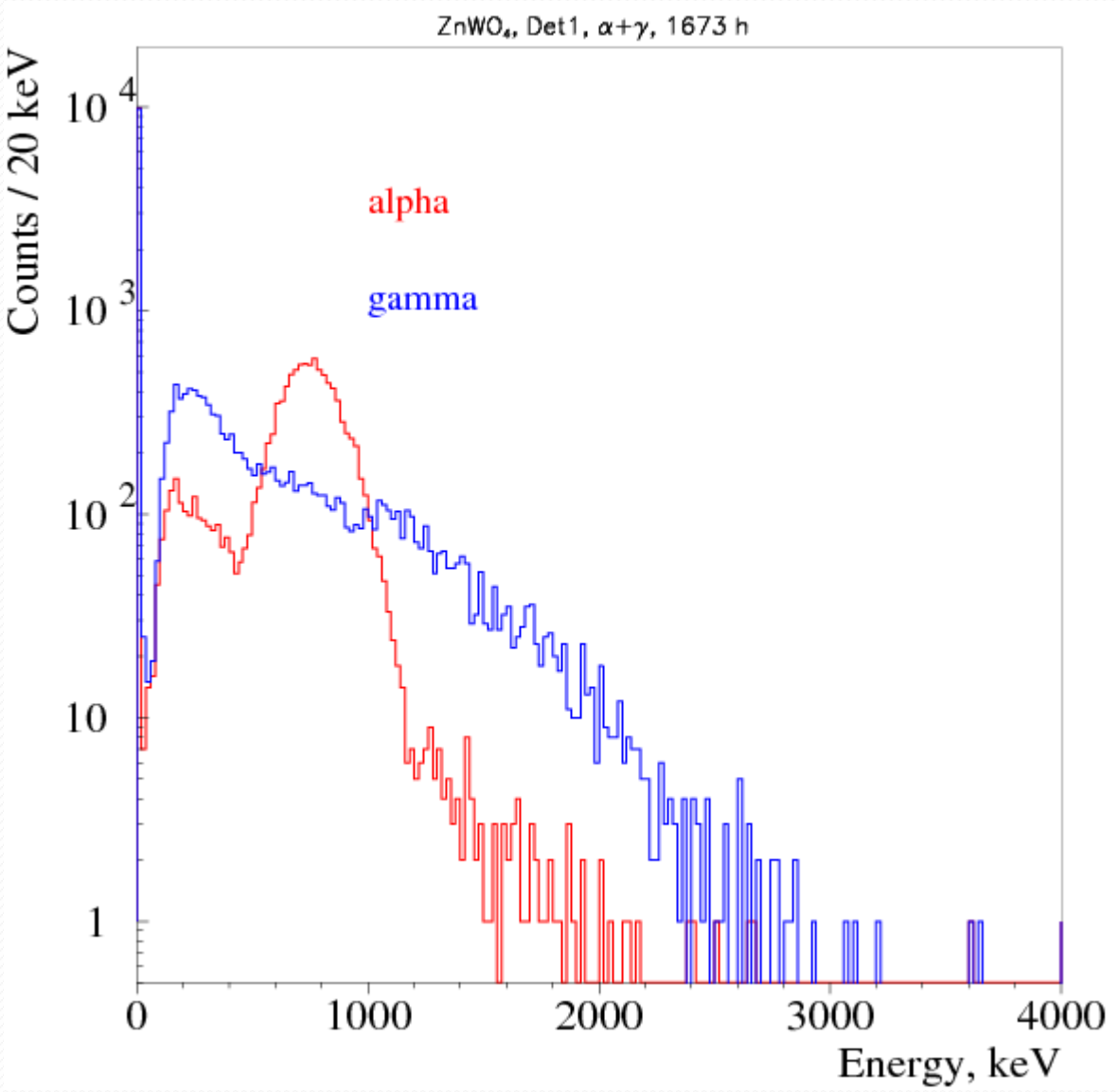

ZnWO4-16.3
raw data
α
Counts/20 keV
Energy, keV


ZnWO4-16.1
raw data
α
Counts/20 keV
Energy, keV


ZnWO4-16.2
raw data
α
Counts/20 keV
Energy, keV


ZnWO4-18.2
raw data
α
Counts/20 keV
Energy (keV)


ZnWO4-18.2
raw data
α
Counts/20 keV
Energy (keV)


ZnWO4, Det1, α+γ, 1673 h
Counts / 20 keV
10 4
10 3
10 2
10
1
alpha
gamma
0
1000
2000
3000
4000
Energy, keV