



Analysis of K-lines X-ray fluorescence of Rare-Earth and High-Z elements on storage ring of the VEPP-4M

Outline

BEAMLINE №8 (VEPP - 4M)

Experiment layout for X-ray fluorescence (monochromator, detector, etc.)

XFA-SR experimental setup on the VEPP - 4M

Results of the MDLs REE (65 - 100 keV)

Results of the MDLs heavy platinoides (Os, Ir, Pt, Au) (100 keV)

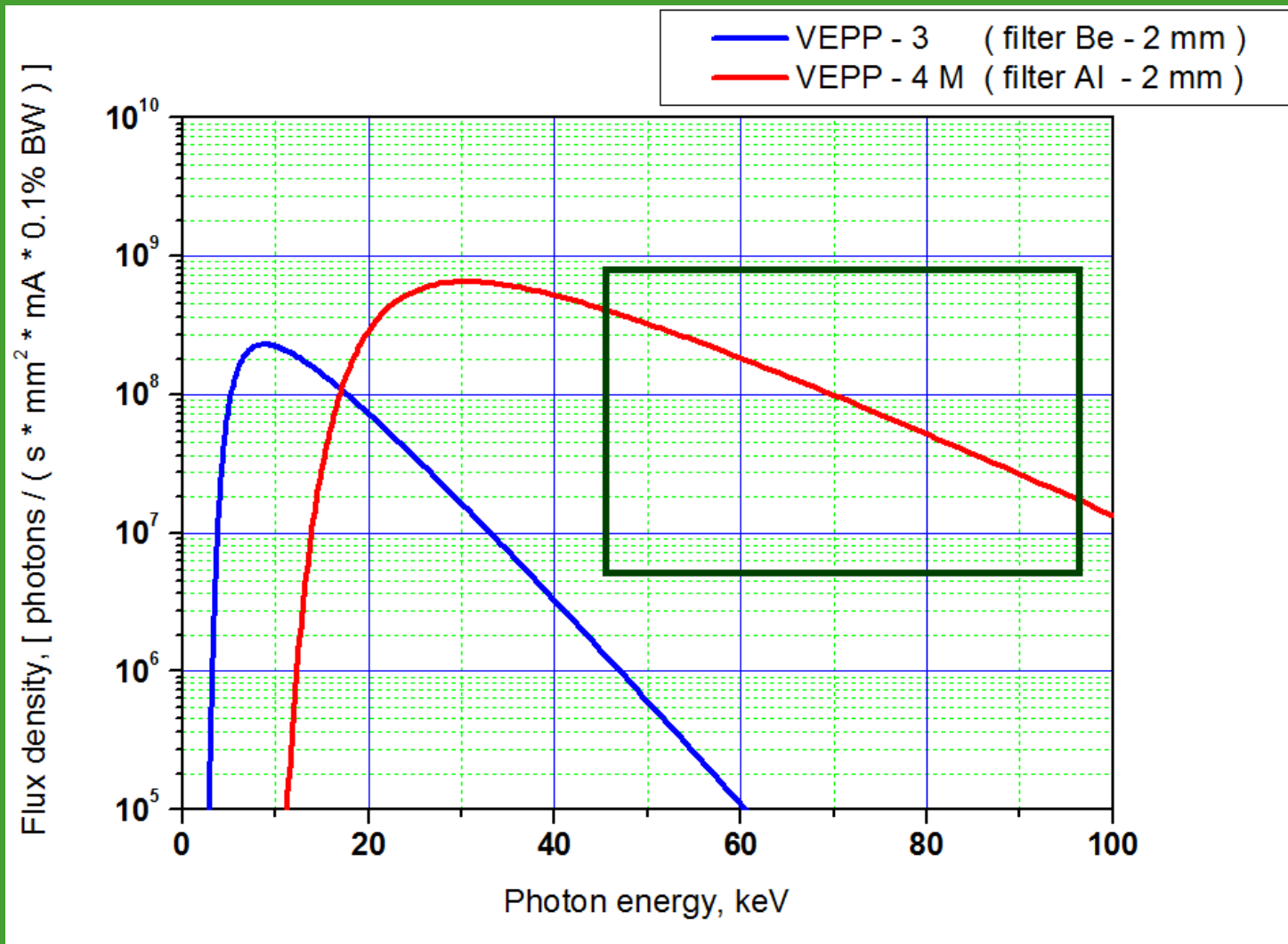
Conclusion

BEAMLINE №8 (VEPP - 4M)



Source - wiggler, $B = 1.2 \text{ T}$ (7-pole), $E_{\text{el}} = 4 \text{ GeV}$, $I_{\text{el}} = 10 \text{ mA}$

The comparison of radiation from the VEPP-3 and VEPP-4M



Hard X-ray Advantage

REE and Heavy elements analysis

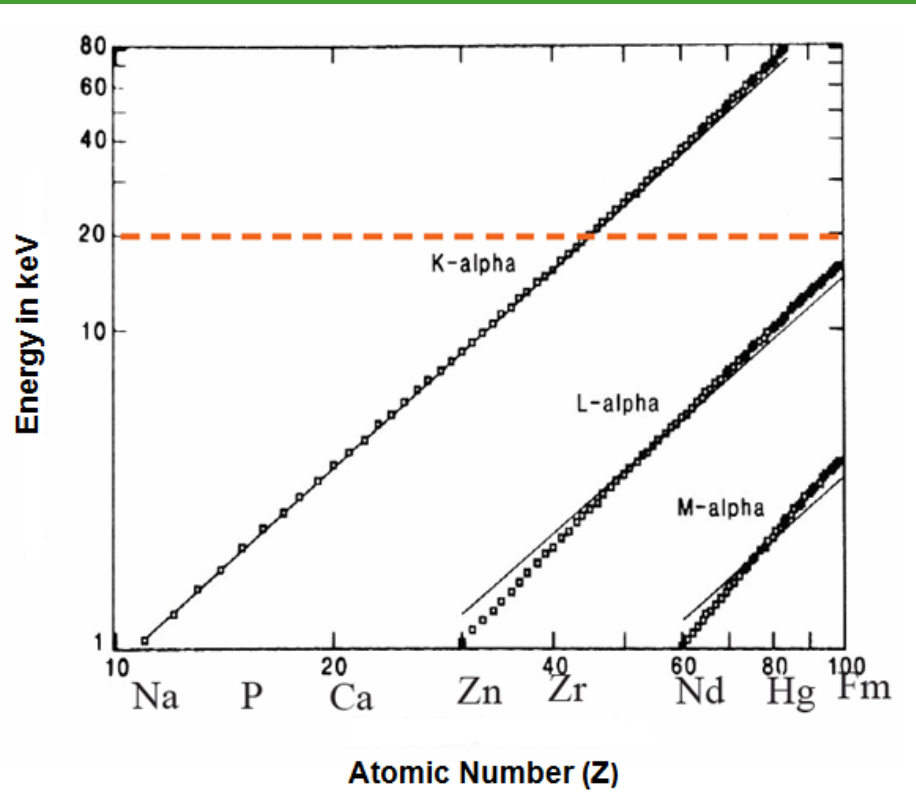
Disadvantage of L series analysis

- *Complicated lines L (α , β , γ , I , s)*
- *Peak overlapping between L and K series lines*

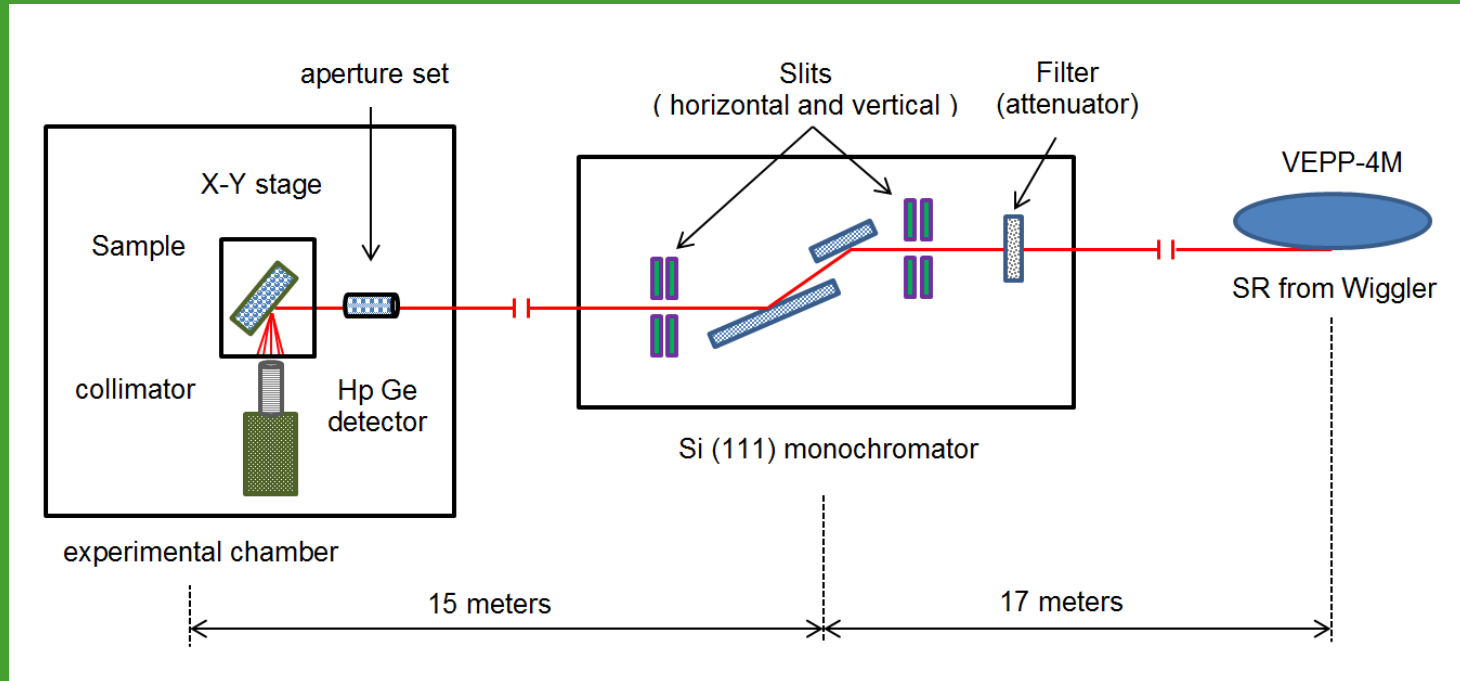
High Energy X-ray Excitation

Advantage of K series analysis

- *Simple line Structure K (α , β)*
- *High sensitivity*
- *Low absorption (bulk analysis)*

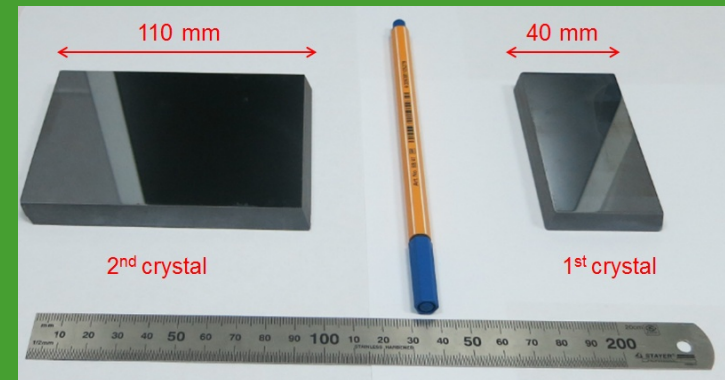


Experiment layout for X-ray fluorescence

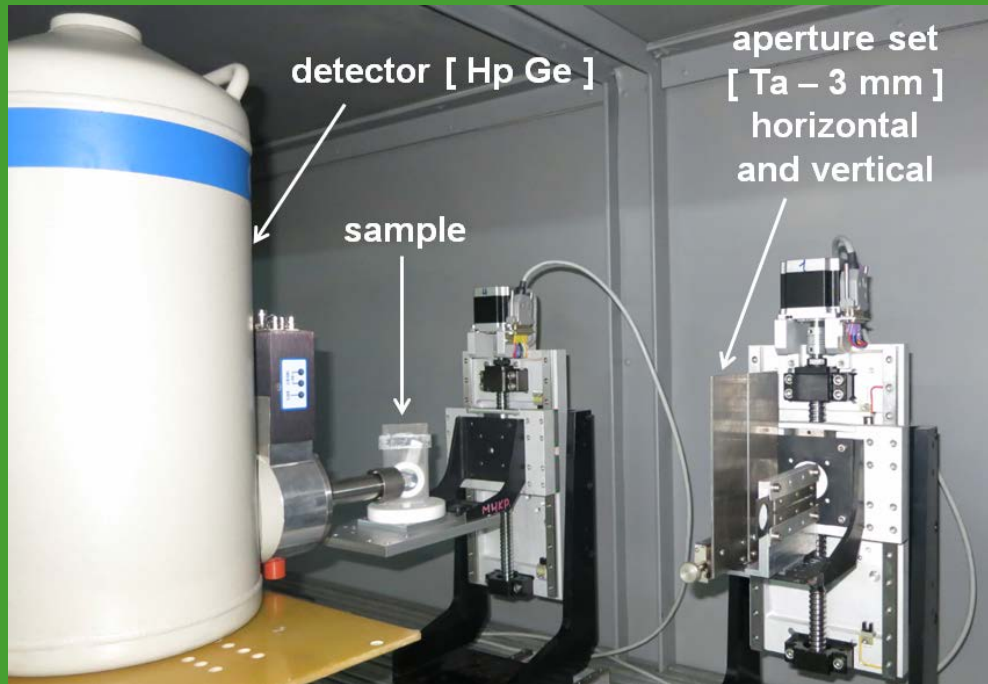


monochromator parameters

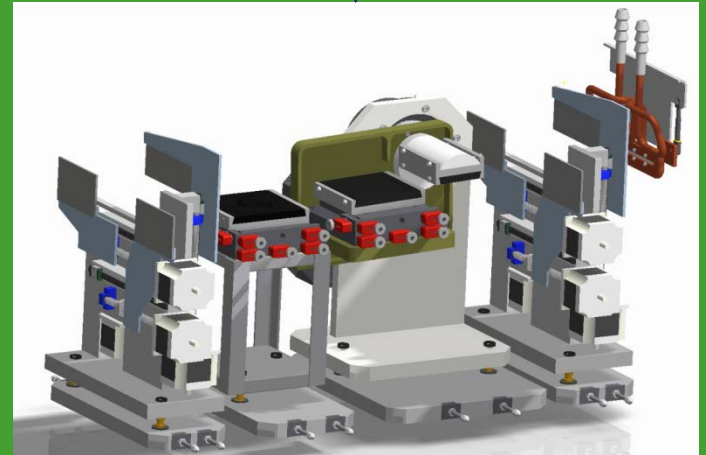
length of the first crystal	40 mm
length of the second crystal	110 mm
distance between crystals	4 mm
period of crystal (2d) for Si (111)	6.271 Å
energy range	100 keV (1.13°) 40 keV (2.83°)
energy resolution	$3 \cdot 10^{-3}$



XFA-SR experimental setup on VEPP-4M



Monochromator components



monochromator
chamber

experimental
chamber

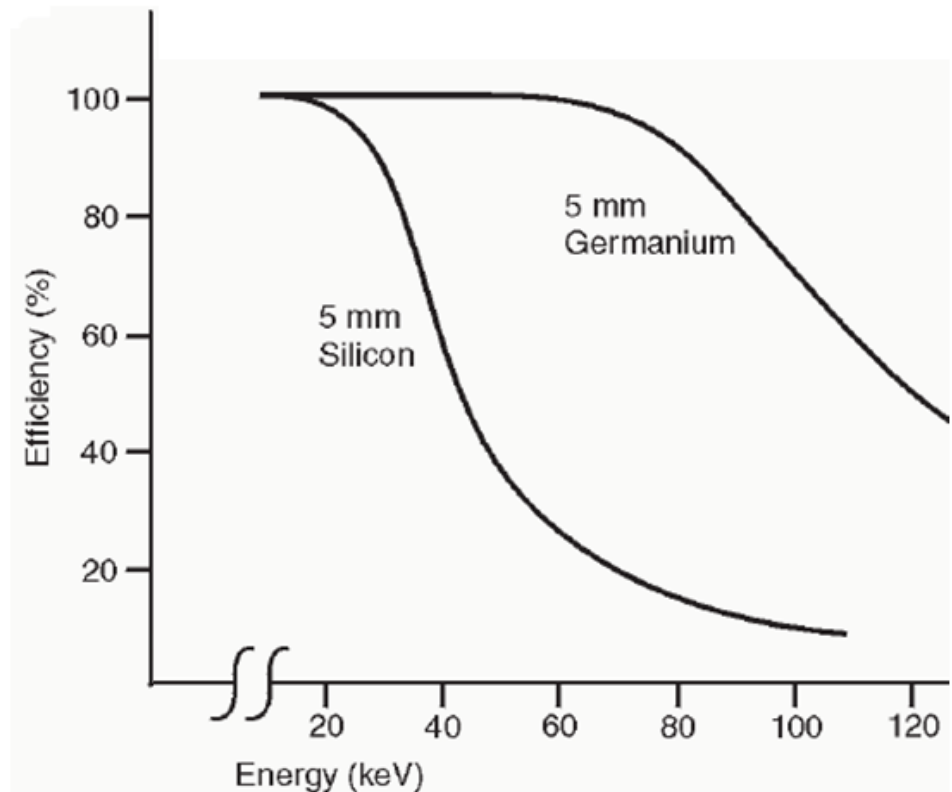


Physical Characteristics

Germanium Detector «CANBERRA»

Active diameter – 3.6 mm
Active area - 10 mm²
Thickness (Ge) – 5 mm
Thickness windows (Be) – 0.025 mm

Energy [keV]	5.9	122
Resolution (FWHM) [eV]	150	460



REE – Rare Earth Elements and HP - Heavy Platinoids

PERIODIC TABLE OF THE ELEMENTS

<http://www.ktf-split.hr/periodni/en/>

Legend:

- Metal
- Semimetal
- Nonmetal
- Alkali metal
- Chalcogens element
- Alkaline earth metal
- Halogens element
- Transition metals
- Noble gas
- Lanthanide
- Actinide

Standard State (25 °C; 101 kPa):

- Ne - gas
- Fe - solid
- Ga - liquid
- Tc - synthetic

LANTHANIDE

57 138.91	58 140.12	59 140.91	60 144.24	61 (145)	62 150.36	63 151.96	64 157.25	65 158.93	66 162.50	67 164.93	68 167.26	69 168.93	70 173.04	71 174.97
La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
LANTHANUM	CERUM	PRASEODYMIUM	NEODYMIUM	PROMETHIUM	SAMARIUM	EUROPIUM	GADOLINIUM	TERBIUM	DYSPROSIUM	HOLMIUM	ERBIUM	THULIUM	YTTERIUM	LUTETIUM

ACTINIDE

89 (227)	90 232.04	91 231.04	92 238.03	93 (237)	94 (244)	95 (243)	96 (247)	97 (247)	98 (251)	99 (252)	100 (257)	101 (258)	102 (259)	103 (262)
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
ACTINIUM	THORIUM	PROTACTINIUM	URANIUM	NEPTUNIUM	PLUTONIUM	AMERICIUM	CURIUM	BERKELIUM	CALIFORNIUM	EINSTEINIUM	FERMIUM	MENDELEVIUM	NOBELIUM	LAWRENCIUM

(1) Pure Appl. Chem., 73, No. 4, 667-683 (2001)
Relative atomic mass is shown with five significant figures. For elements having no stable nuclides, the value enclosed in brackets indicates the mass number of the longest-lived isotope of the element.
However three such elements (Th, Pa, and U) do have a characteristic terrestrial isotopic composition, and for these an atomic weight is tabulated.

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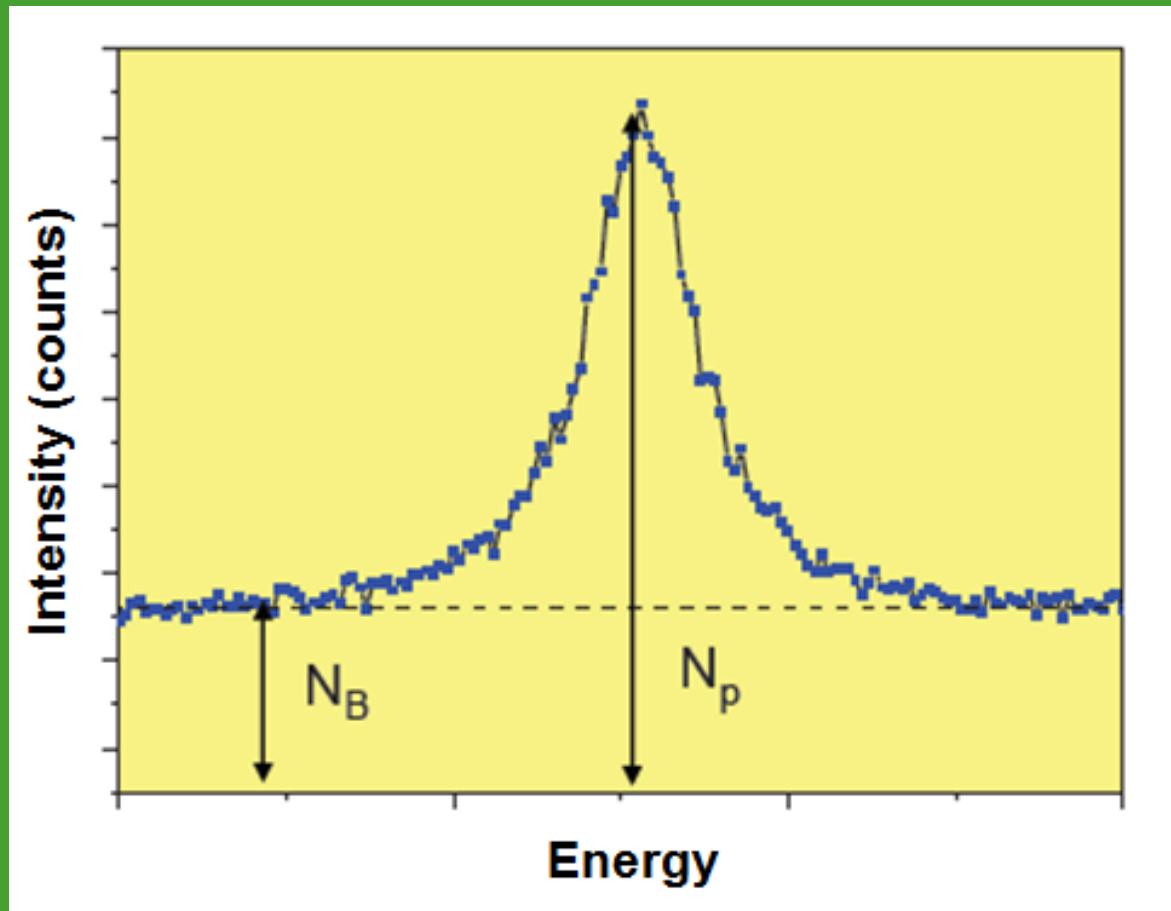
Rare Earth Elements La [Z=57] – Lu [Z=71]

Emission K – lines from 33 keV to 61 keV

Heavy platinoides Os [Z=76] – Au [Z=79]

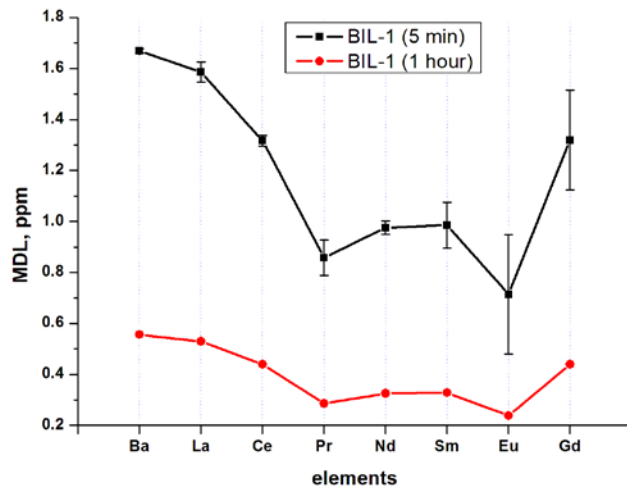
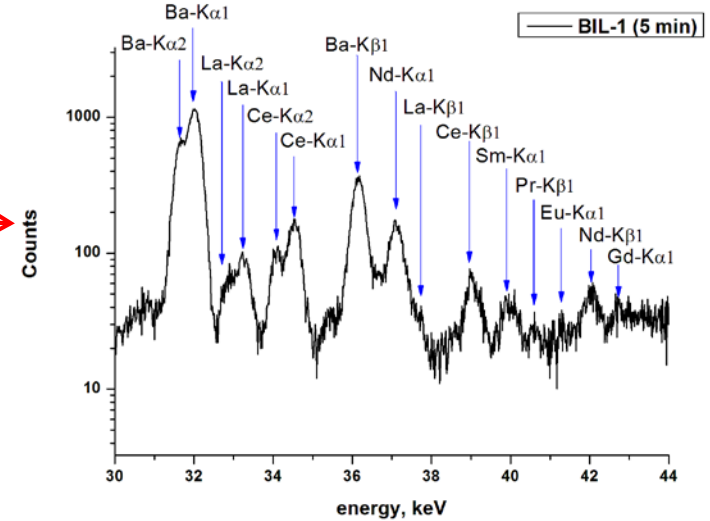
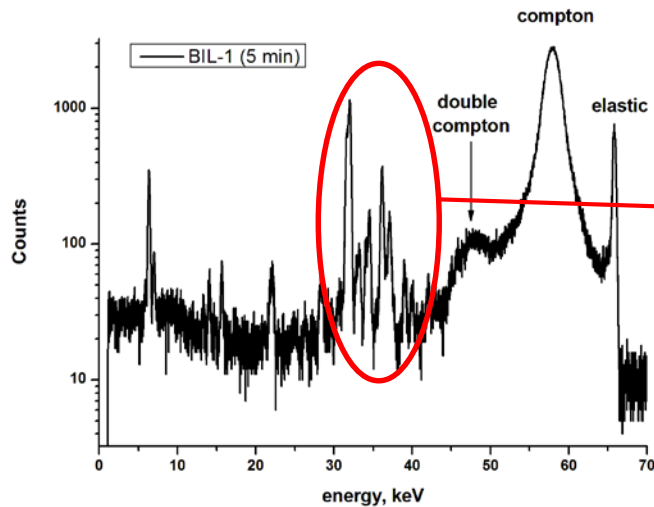
Emission K – lines from 63 keV to 78 keV

MDL (Minimum detection limit)



$$\text{MDL} = \frac{3 \cdot C \cdot \sqrt{N_B}}{N_P - N_B}$$

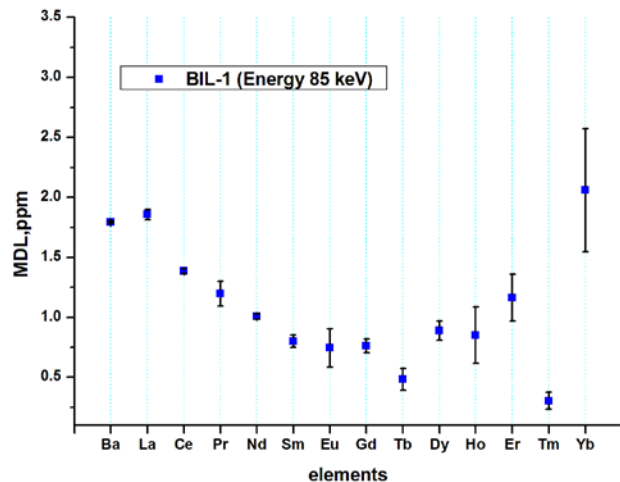
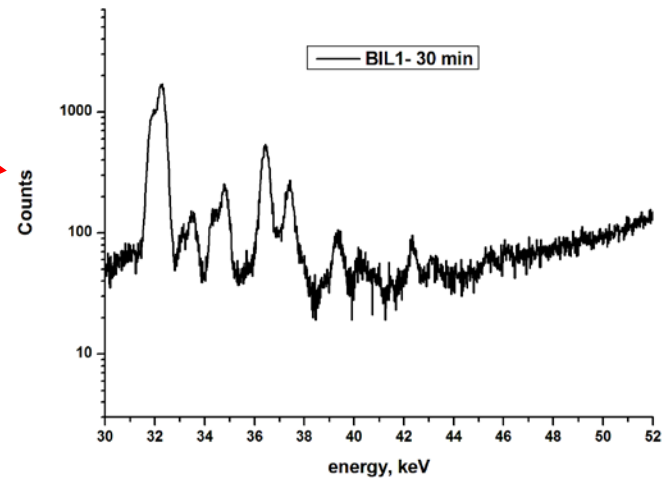
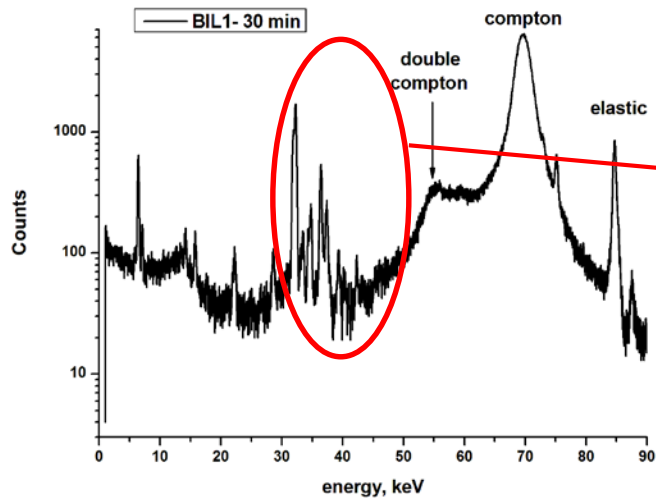
Energy of excitation 65 keV



reference sample BIL-1

element	concentration (ppm)
Ba	710
La	45
Ce	80
Pr	8
Nd	39
Sm	7
Eu	1.4
Gd	5.8

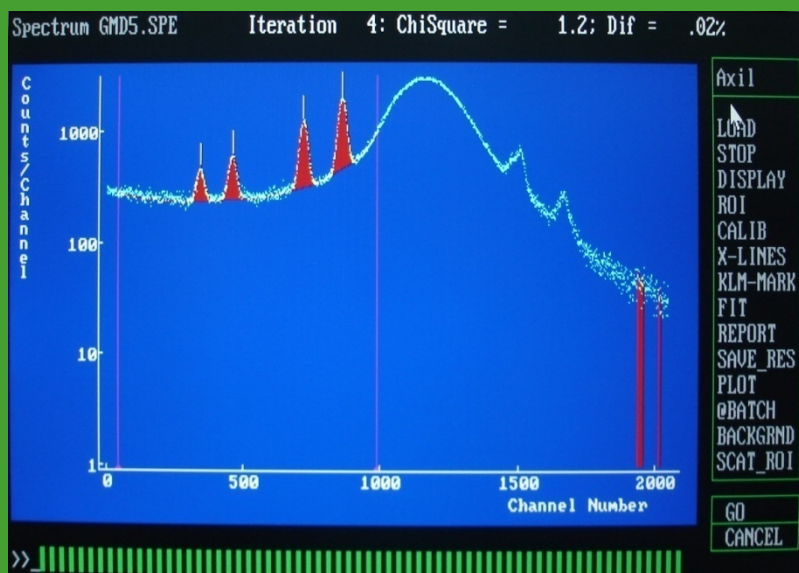
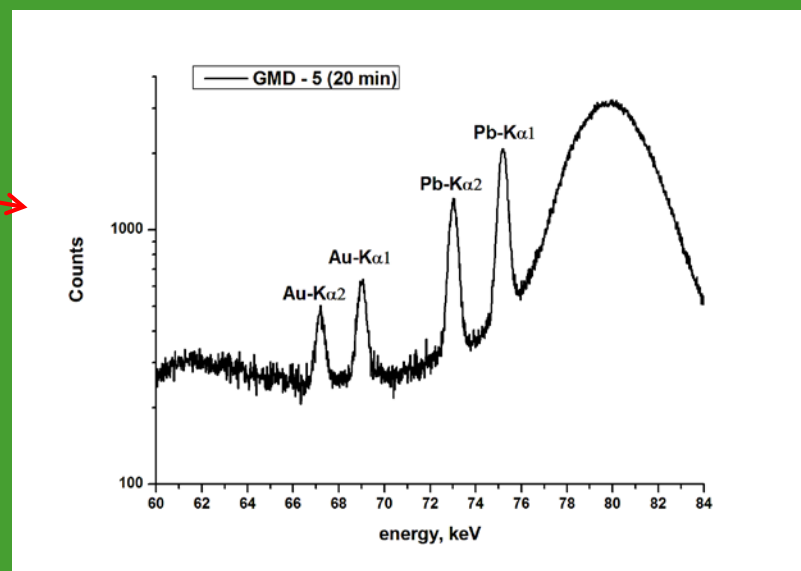
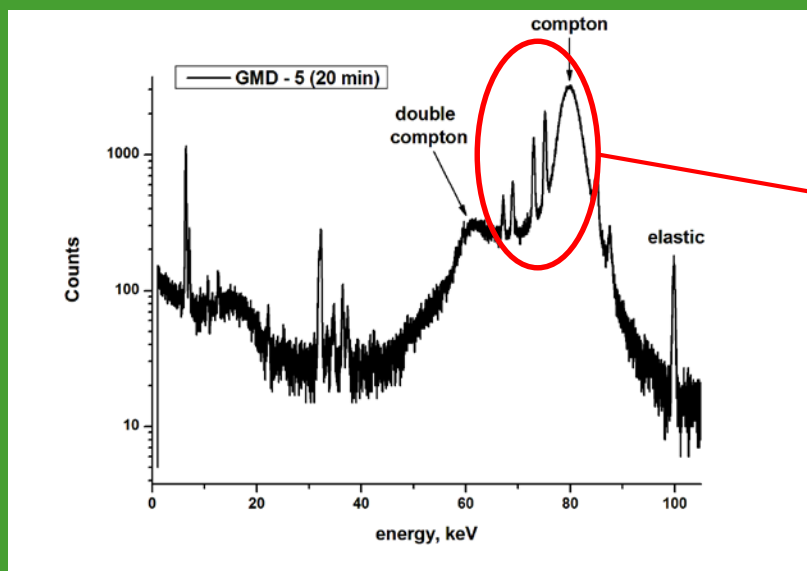
Energy of excitation 85 keV



reference
sample
BIL-1

element	concentration (ppm)
Ba	710
La	45
Ce	80
Pr	8
Nd	39
Sm	7
Eu	1.4
Gd	5.8
Tb	0.9
Dy	4.6
Ho	1
Er	2.6
Tm	0.4
Yb	2.9

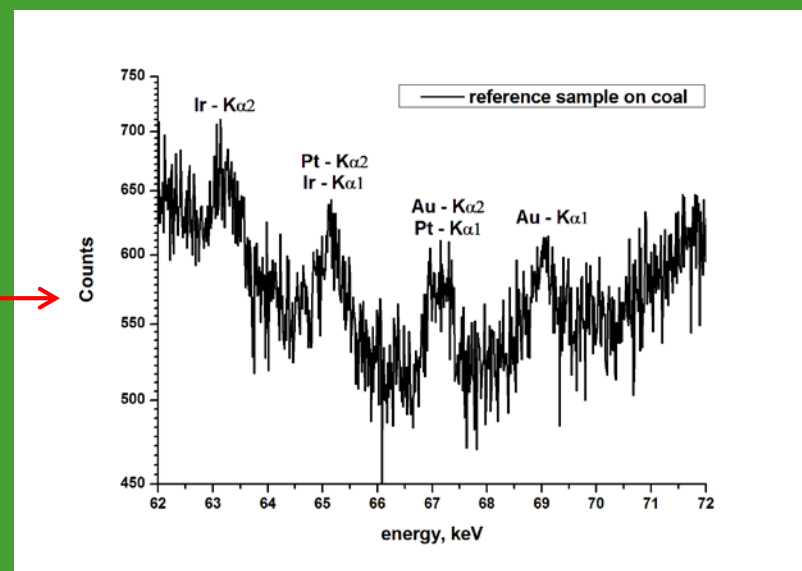
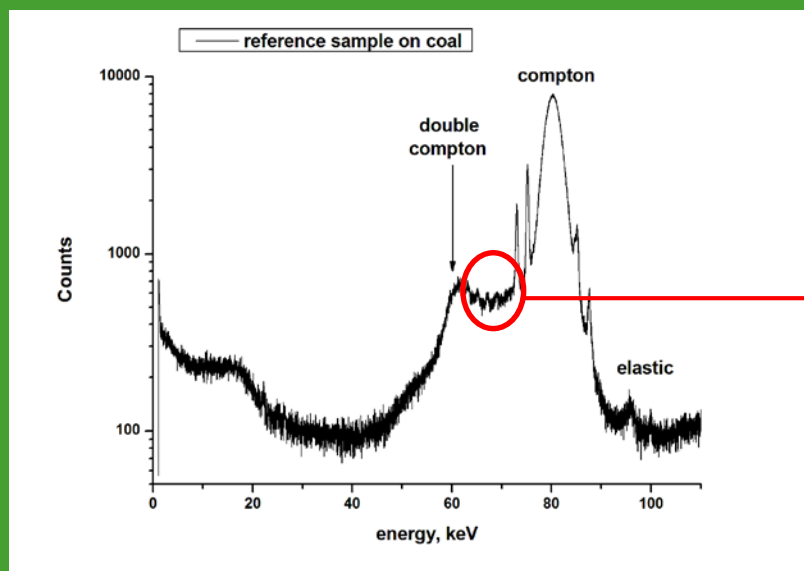
Energy of excitation 100 keV



**reference sample GMD-5
(concentration Au – 44 ppm)**

element	MDL (ppm)
Au – K α 1	0.75
Au – K α 2	1.24

Energy of excitation 100 keV



coal reference sample (concentration Ir, Pt, and Au = 10 ppm)

element	lines energy [keV]	peaks overlap [eV]	MDL (ppm)
Ir - K α 2	63.28	no	1.1
Ir - K α 1	64.89	220	-----
Pt - K α 2	65.11		0.8
Pt - K α 1	66.82	160	-----
Au - K α 2	66.98		-----
Au - K α 1	68.79	no	1.0

Conclusion

- The powerful measurement technique has been developed at the new XFA-SR station of VEPP-4M storage ring for the analysis of geological, archaeological and geochemical samples containing heavy and rare earth elements
- The experimental values for minimum detection limits of rare earth elements from La to Lu are in the range from 0.2 to 1 ppm
- The experimental values for minimum detection limits of heavy platinoids (Os, Ir, Pt, Au) are in the range below 1 ppm
- We invite all the interested users to carry out the scientific experiments at our new XFA-SR station of VEPP-4M storage ring

Thank you for your attention