Features of using of the hard X-rays (60 – 120 keV) of synchrotron radiation for determination the trace concentrations of rare-earth and heavy elements by the SRXRF method

Outline

BEAMLINE №8 (VEPP - 4M)

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

SRXRF experimental setup at the beamline № 8 (VEPP - 4M)

Experimental results SRXRF obtained on the excitation energy 60, 72, 86, 112 keV

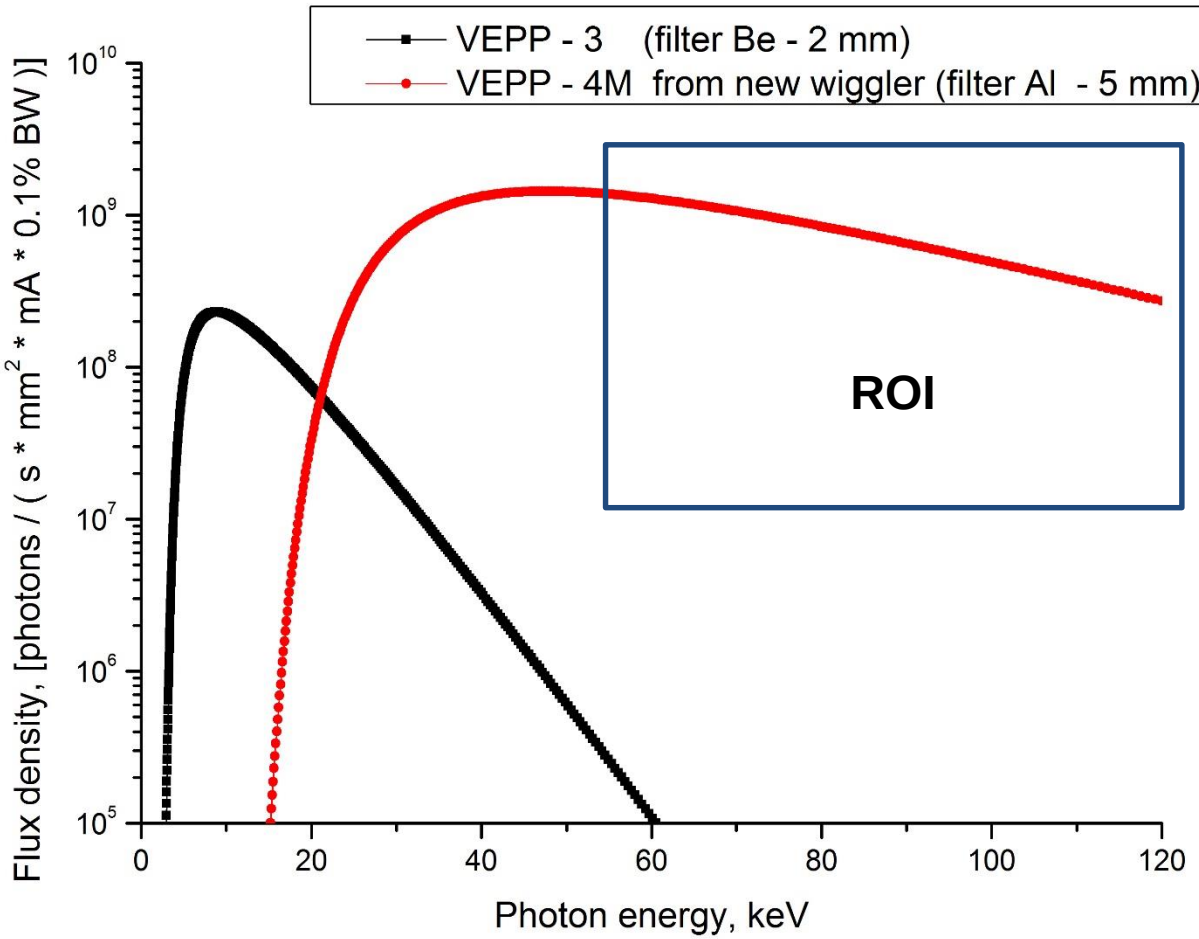
Measurements with compound parabolic crossed polymeric refractive lens at the beamline № 8 (VEPP- 4M)

Conclusion

BEAMLINE №8 (VEPP - 4M)

Source - wiggler, B = 1.9 T (9-pole), E_{el} = 4.5 GeV, I_{el} = 20 mA

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



Hard X-ray Advantage
REE and Heavy elements analysis

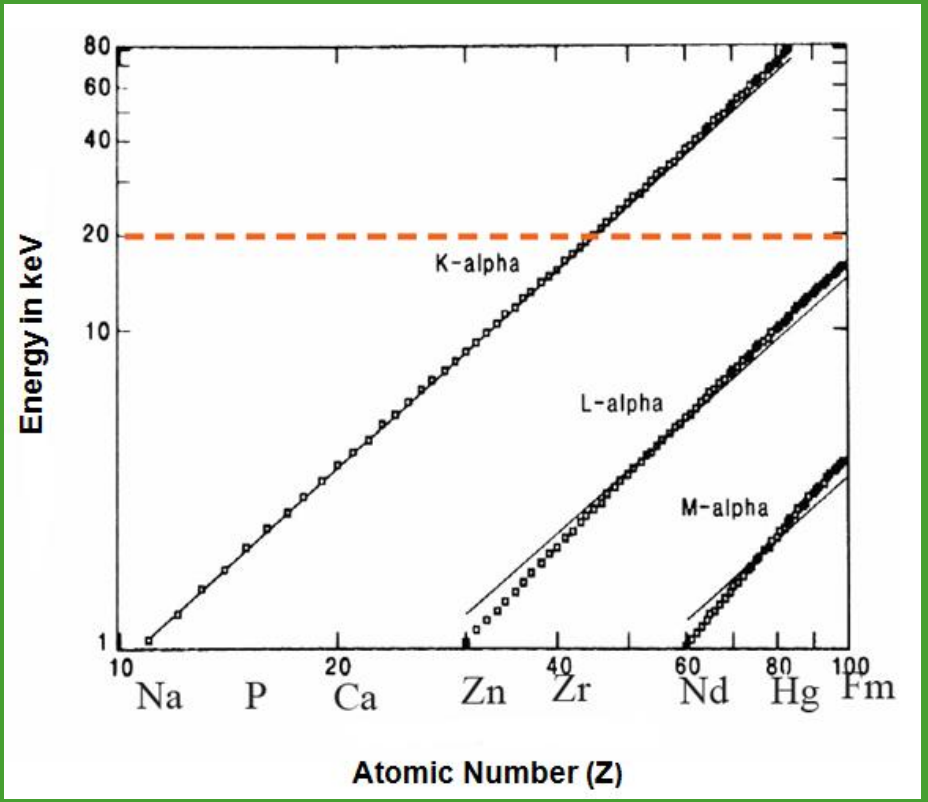
Disadvantage of L series analysis

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

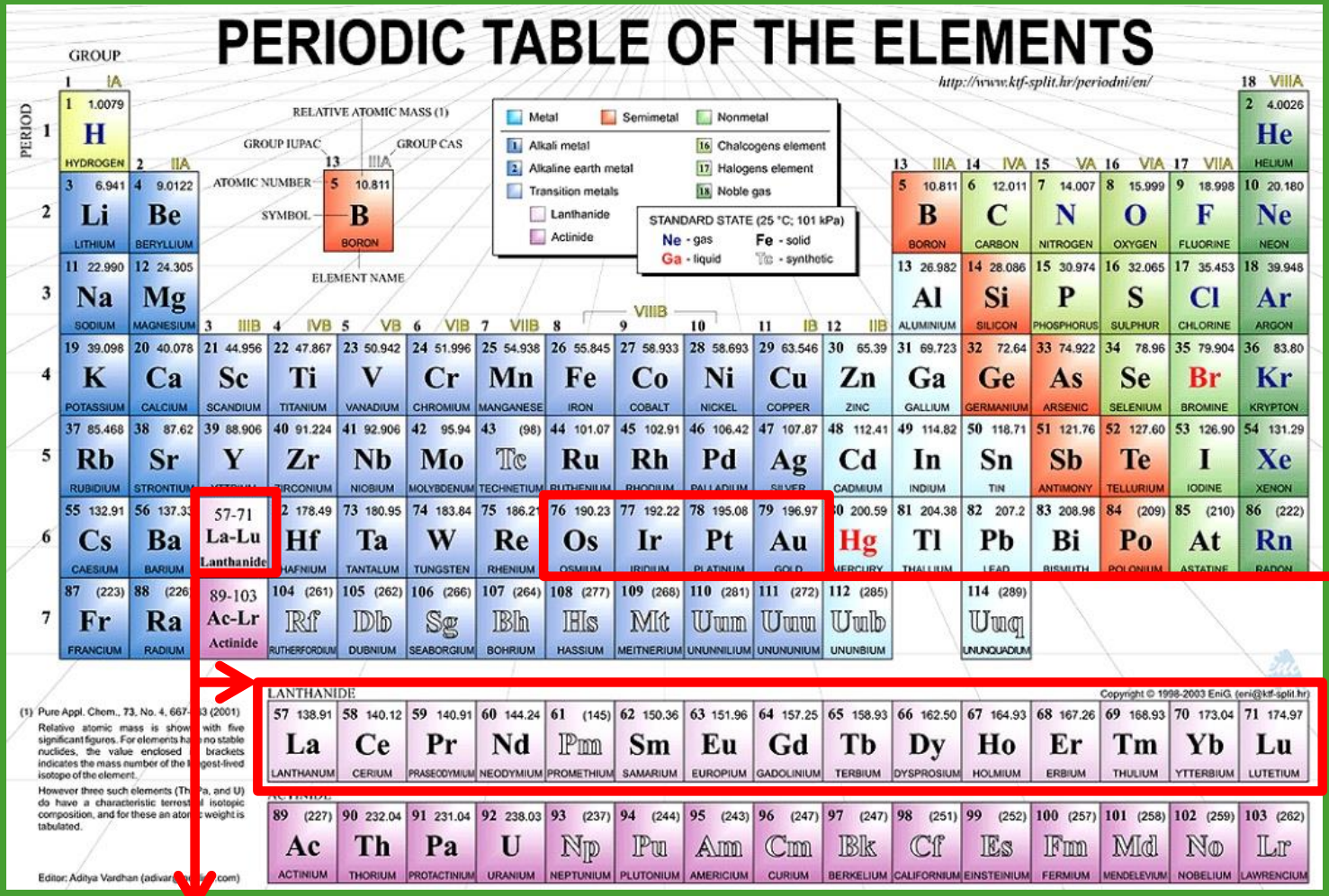
High Energy X-ray Excitation

Advantage of K series analysis

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



REE – Rare Earth Elements and HP - Heavy Platinoids



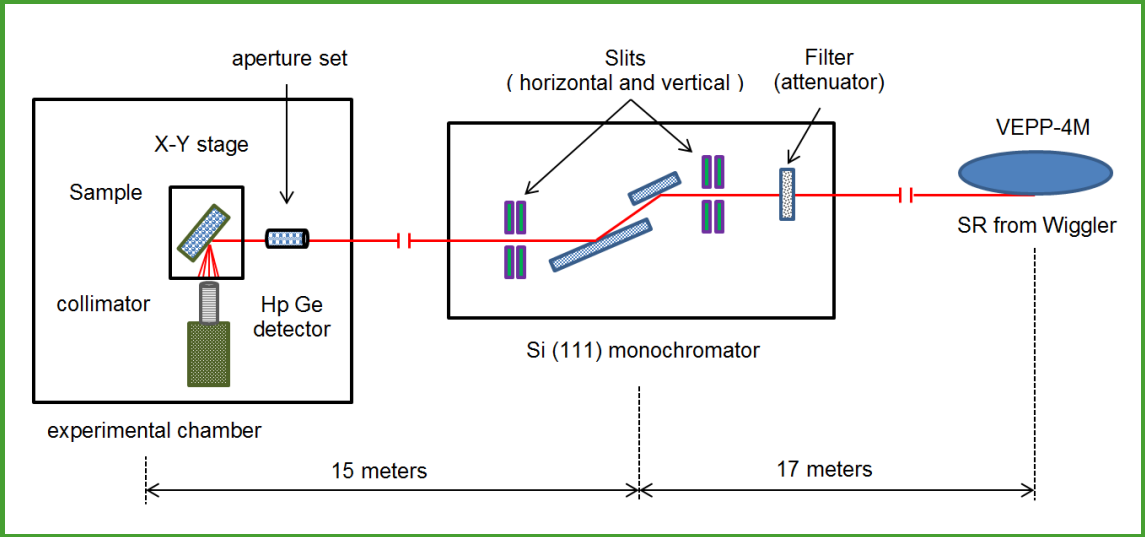
Rare Earth Elements La [Z=57] – Lu [Z=71]

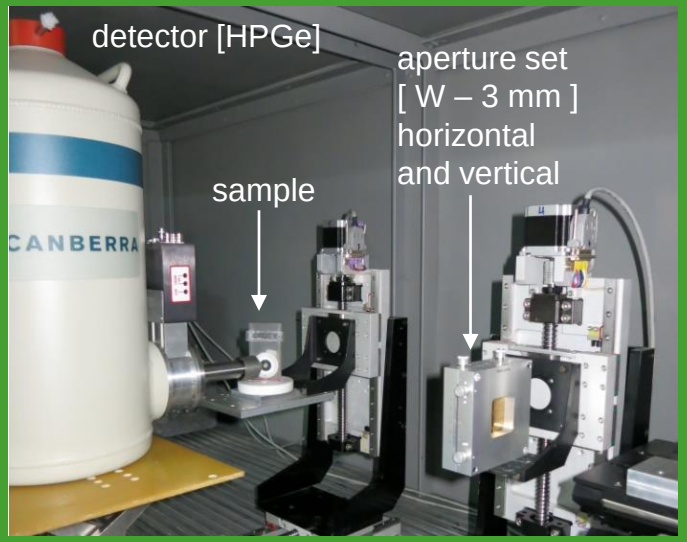
Emission K – lines from 33 keV to 61 keV

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

Emission K – lines from 63 keV to 78 keV

Experiment layout for X-ray fluorescence





monochromator parameters

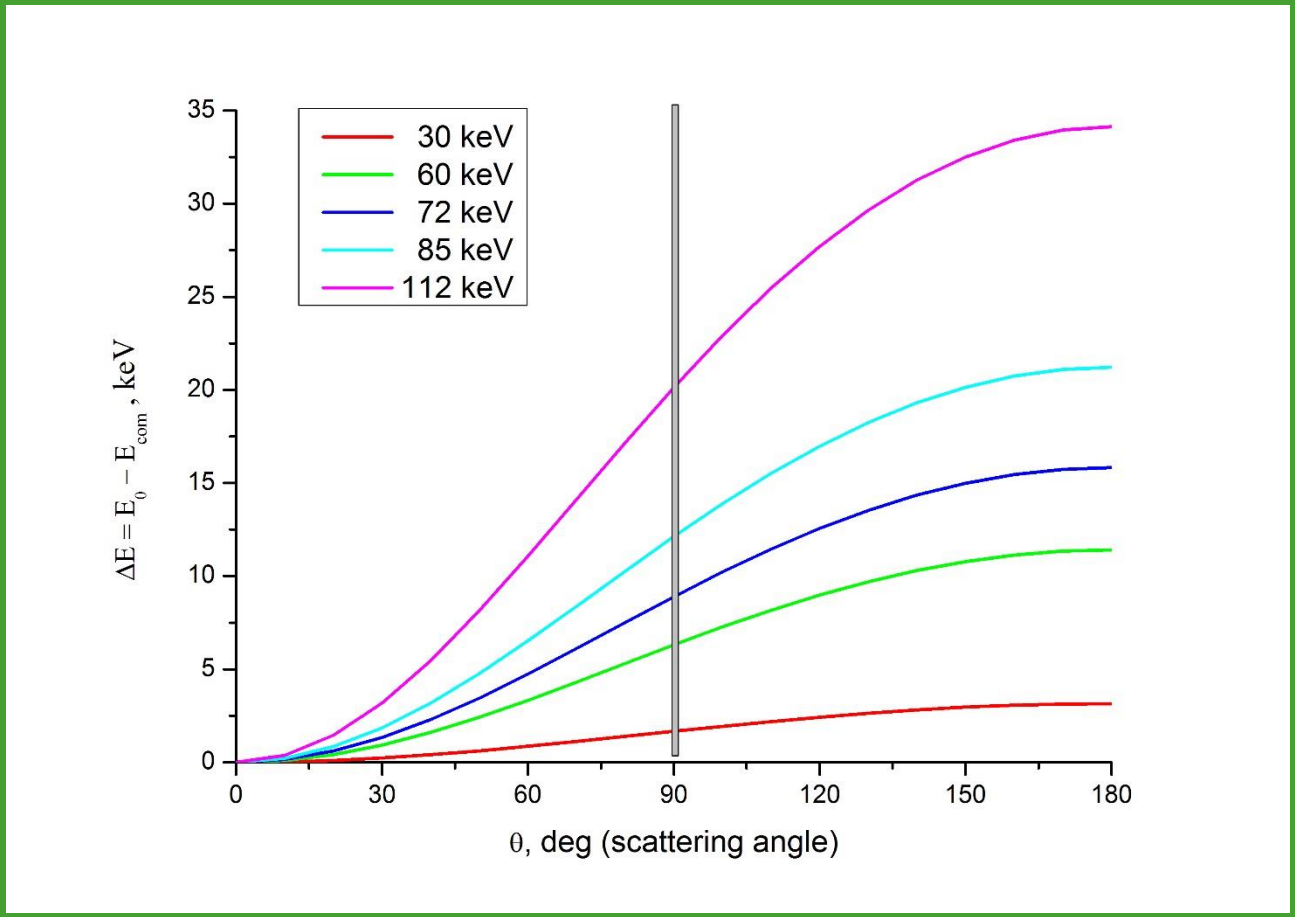
length of the first crystal	40 mm
length of the second crystal	110 mm
distance between crystals	4 mm
period 2d for Si (111)	6.271 A
energy range	120 keV (1.13 ^{0}) 40 keV (2.83 ^{0})
energy resolution	$3 \cdot 10^{-3}$

detector parameters

Active diameter – 13.5 mm
Active area - 100 mm^2
Thickness (Ge) – 10.5 mm
Thickness windows (Be) – 25.4 mkm

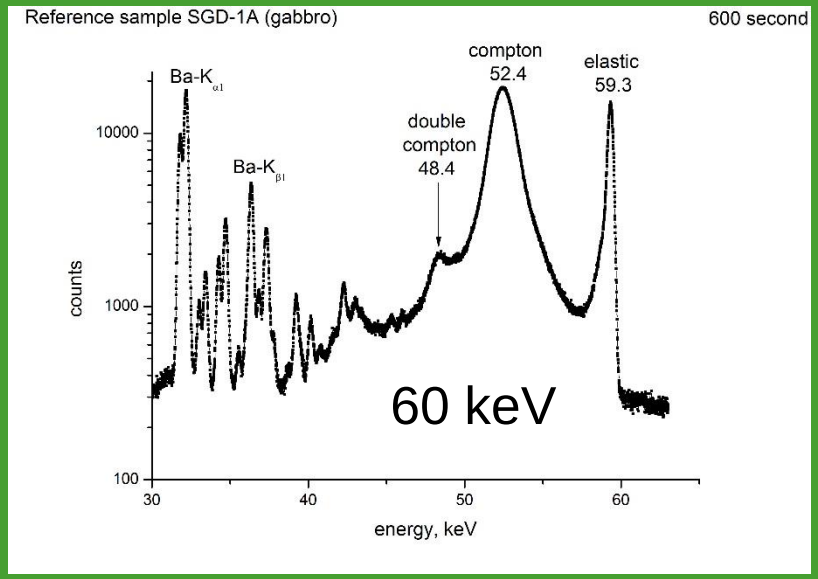
Energy [keV]	5.9	122
Resolution (FWHM) [eV]	125	460

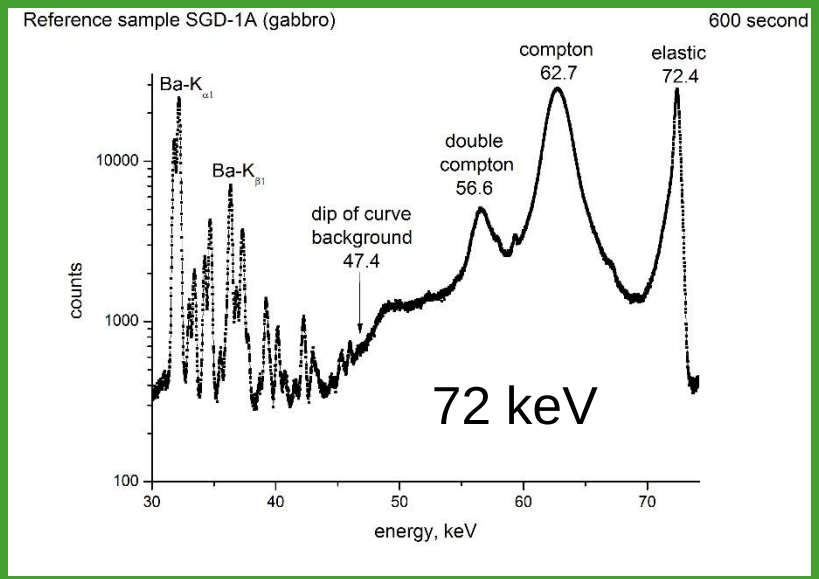
ΔE is shift between the elastic and the Compton peak

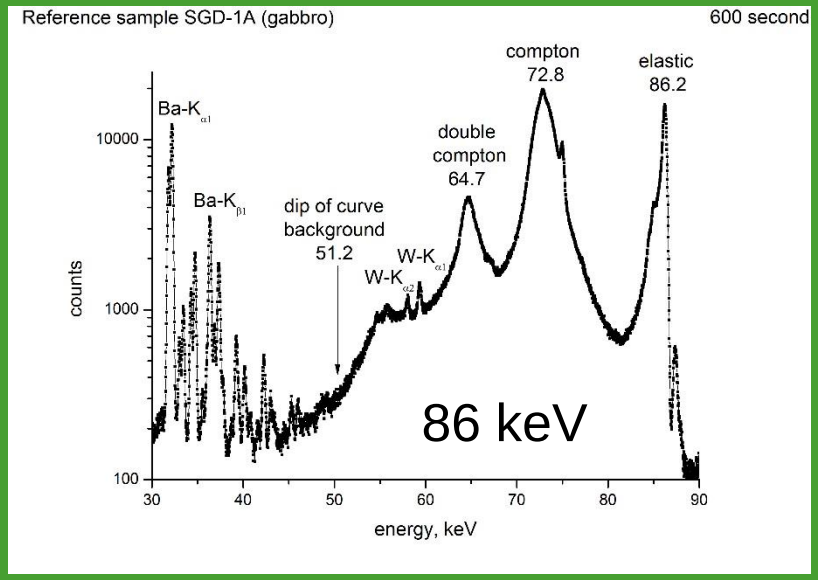


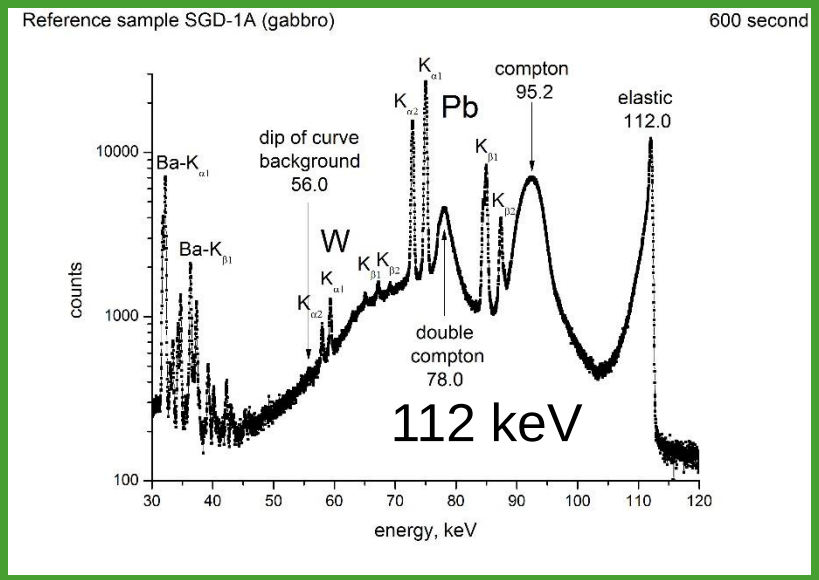
$$\Delta E = E_0 - E_{compton} = \frac{E_0 \cdot E_{compton}}{m_0 \cdot C^2} \cdot [1 - \cos(\theta)]$$

Experimental results obtained on the excitation energy 60, 72, 86, 112 keV

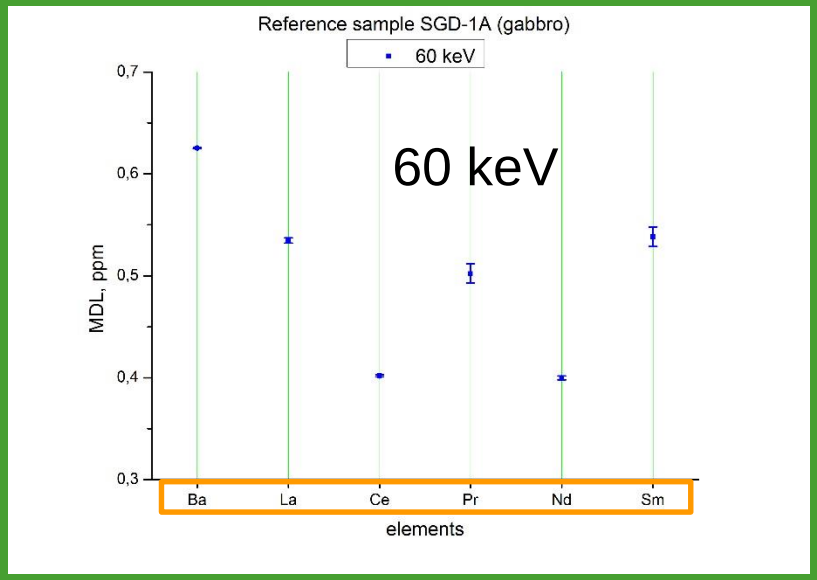


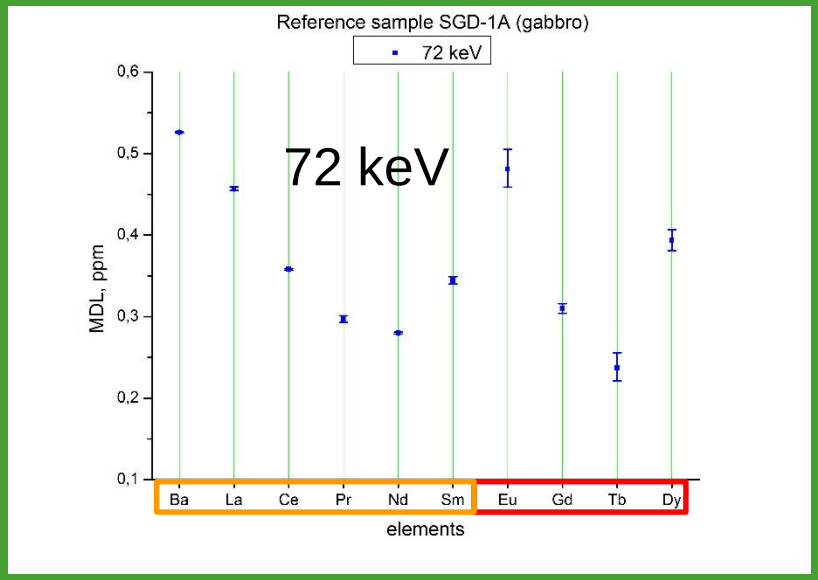


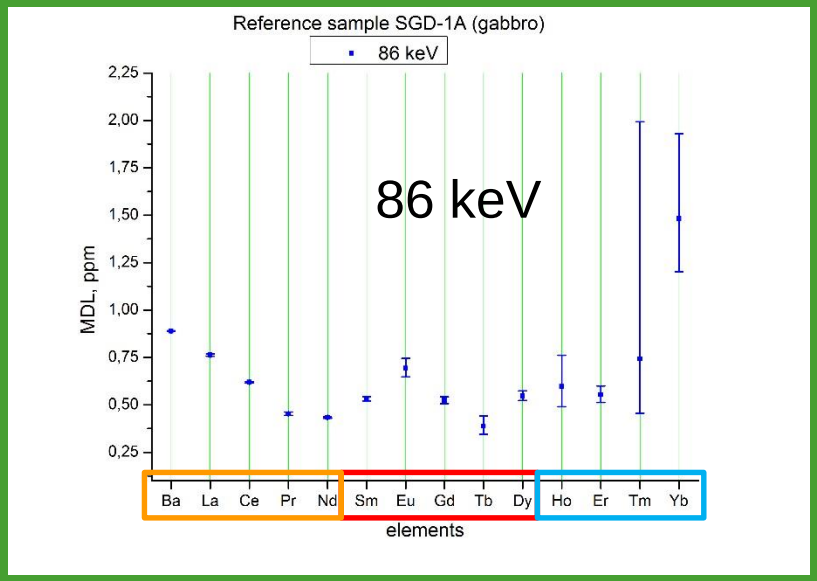


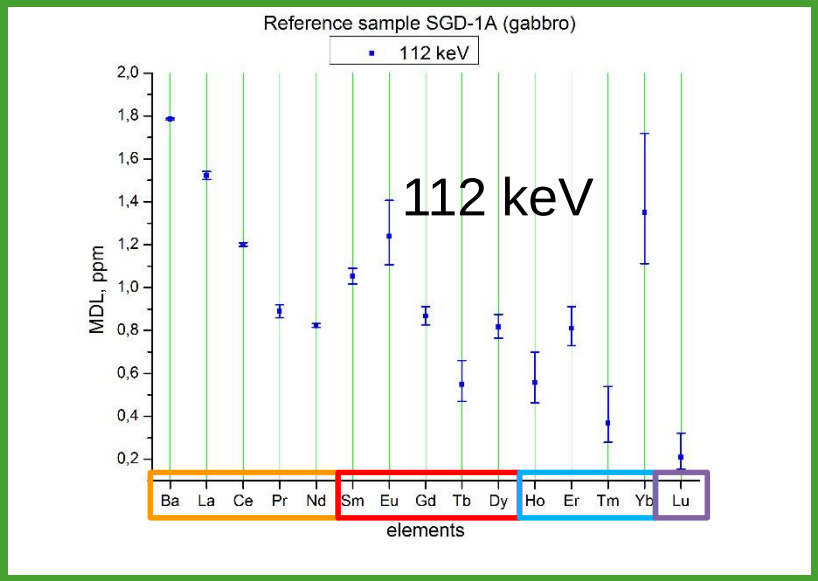


Minimum detection limits (MDL) obtained at the excitation energy of 60, 72, 86, 112 keV

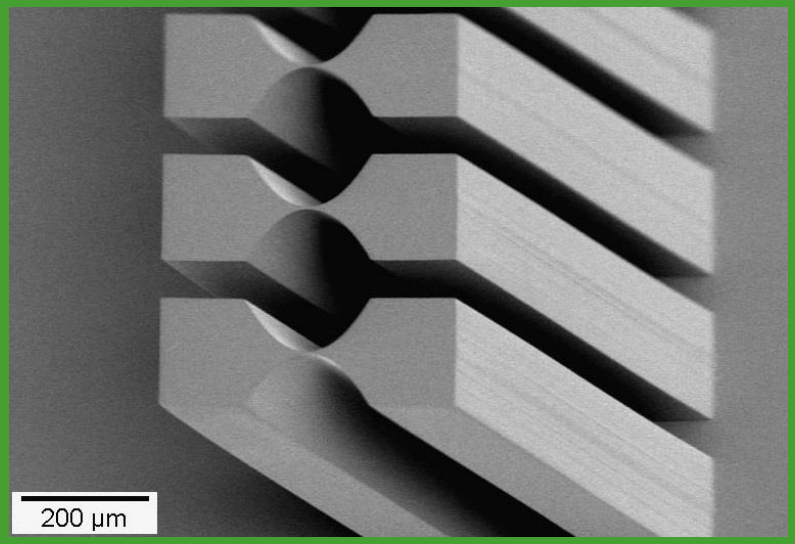


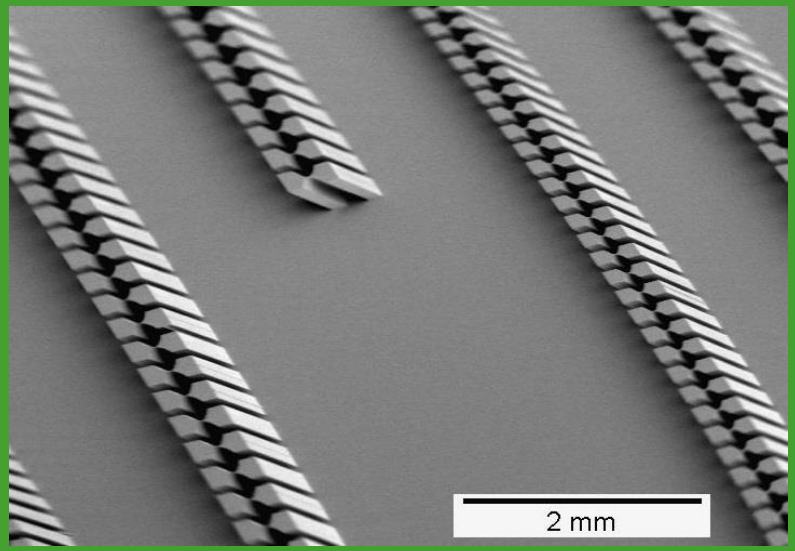






Measurements with compound parabolic crossed polymeric refractive lens at the beamline № 8 (VEPP- 4M)





$$n = 1 - \delta + i\beta$$

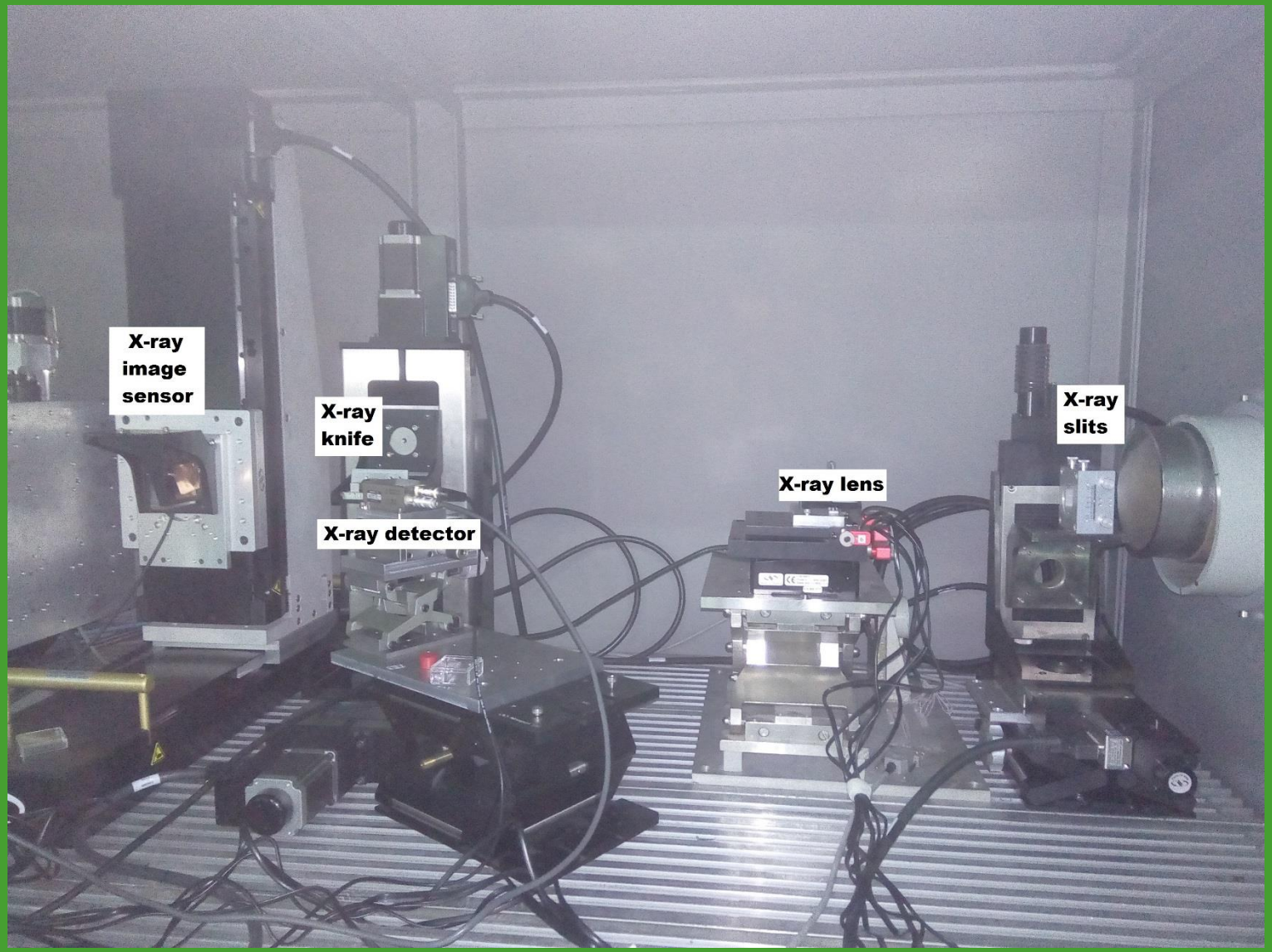
$$F = \frac{R}{2 \cdot \delta \cdot N}$$

$$\delta \div 10^{-5} \div 10^{-8}$$

$$\delta \div \lambda^2 \cdot \rho \div \frac{\rho}{E^2}$$

$$F \div \frac{R \cdot E^2}{\rho \cdot N}$$

Experimental setup for the measurement of the focus of polymeric refractive lens at the beamline № 8 (VEPP- 4M)

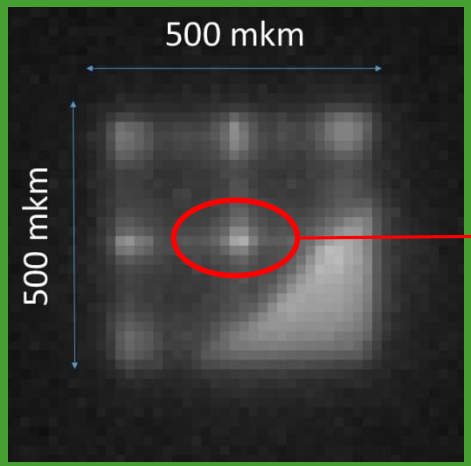


CMOS area image sensors for X-ray imaging

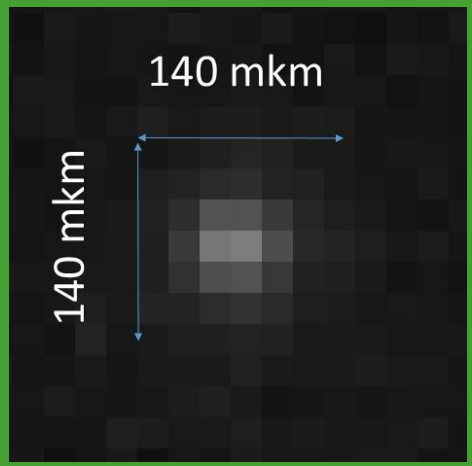
HAMAMATSU
PHOTON IS OUR BUSINESS

Parameter

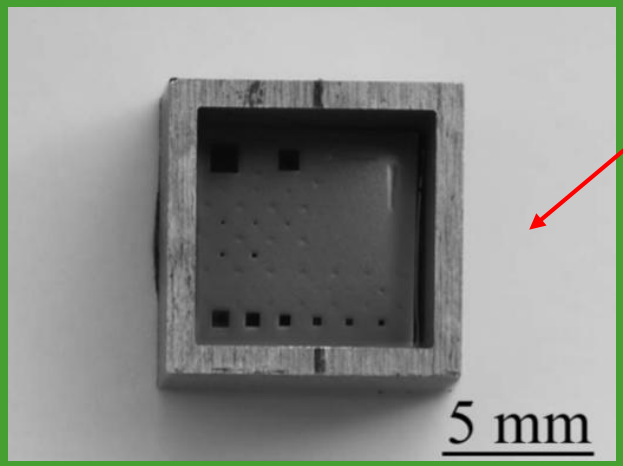
Image size (H x V)	26 x 34 mm
Pixel size	20 x 20 mkm
Number of pixels (H x V)	1300 x 1700
Scintillator type	CsI (Tl)
Interface	USB 2.0



Focus



X-ray knife



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TECHNICAL PAPER

LIGA micro-openings for coherence characterization of X-rays

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F. Marschall · J. Mohr · H. Vogt · R. Simon

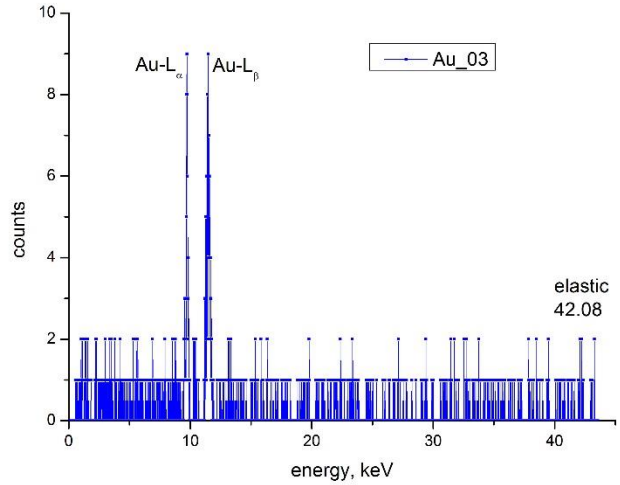
X-ray detector

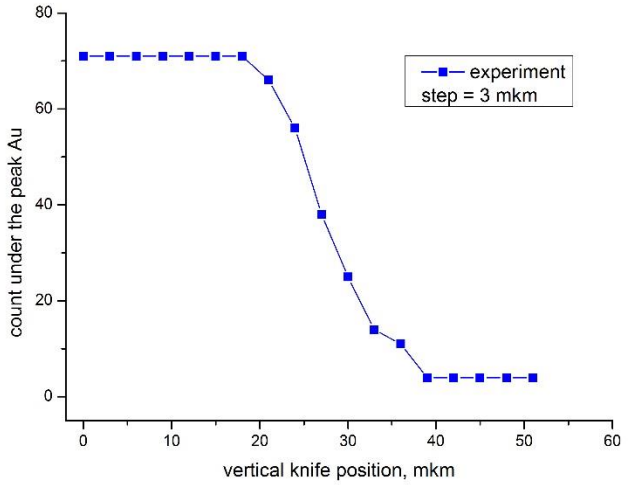
Active diameter – 5 mm
Active area - 20 mm^2
Thickness (Si) – 0.5 mm
Thickness windows (Be) – 25.4 mkm

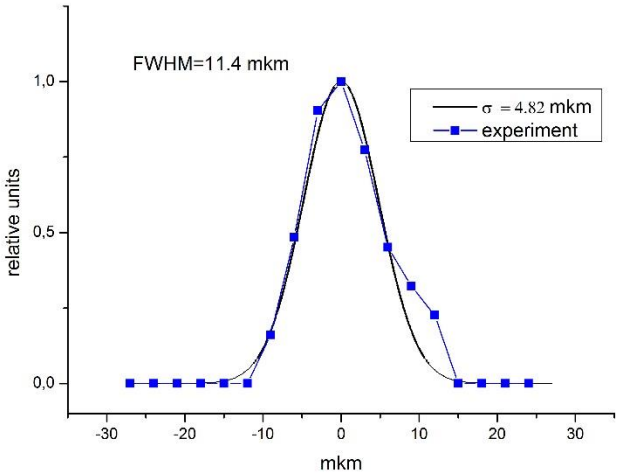
X-ray refractive lens parameters, «produced by KIT»

Lens number	Structure number	Aperture, μm	Curvature radius, μm	Structure length, μm
1	216	40.85	4.6	127
2	157	60	6.6	164
3	129	84.6	9.8	213
4	88	128.3	15.9	312
5	75	156.2	19.4	367
6	57	214.9	27.4	484
7	45	278.6	35.4	611
8	35	369	47.6	778

Experimental results







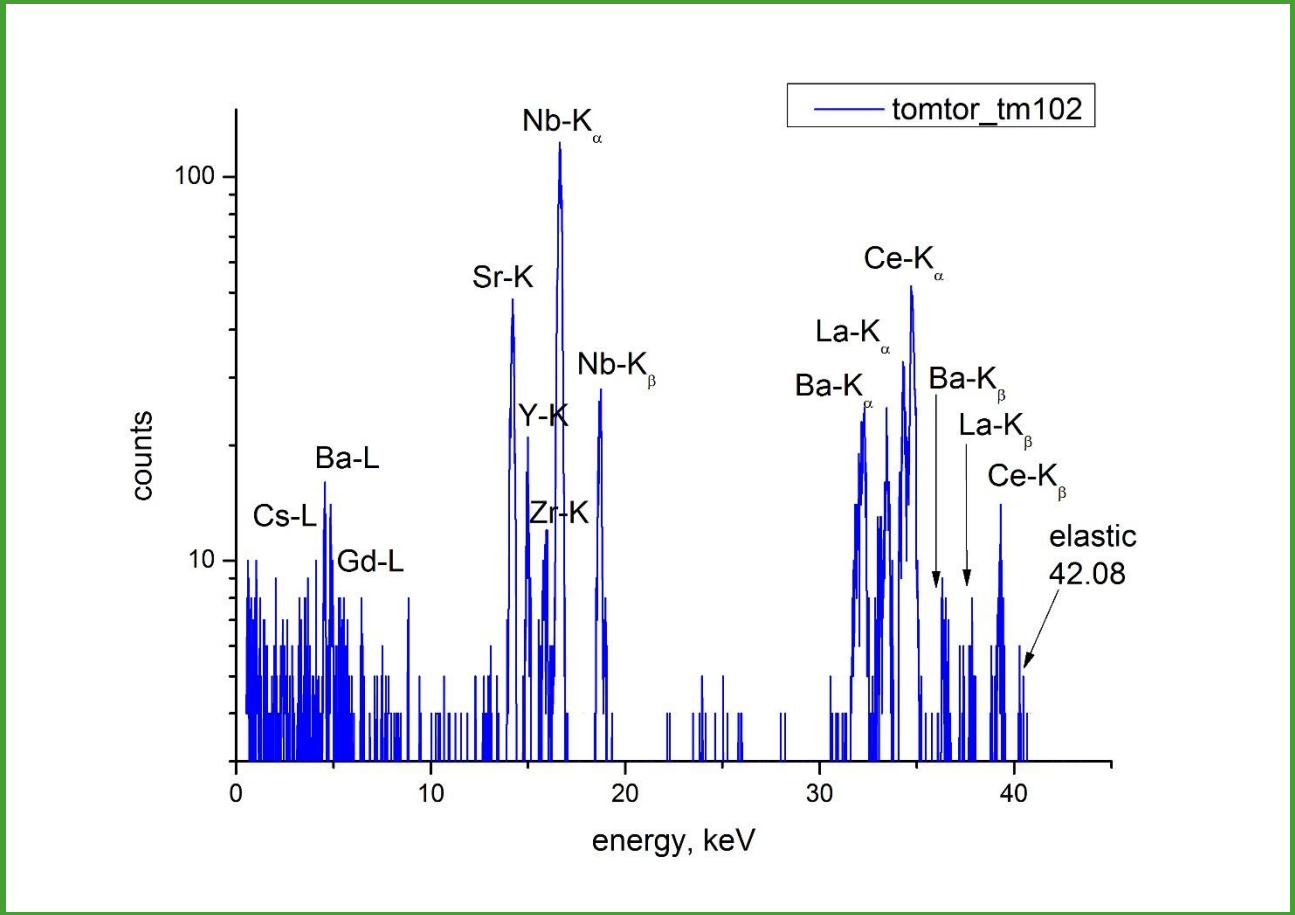
$$E_0 = 42\ keV$$

$$F = 590\ mm$$

$$\sigma_{(vertical)} = 4.8\ mkm$$

$$FWHM_{(vertical)} = 11\ mkm$$

SRXRF spectrum with focused x-ray beam of 42 keV at VEPP-4M



X-ray fluorescence spectrum from the voxel behind the 11 μm x-ray focal spot. Vertical gain factor ≈ 10.

Conclusion

- **The SRXRF method for of the panoramic determination of the concentration of rare earth elements in geological samples on the VEPP - 4M storage ring has been developed**
- **The experimental values for minimum detection limits of rare earth elements from La to Lu are in the range from 100 ppb to 1 ppm**
- **The first experiments on focusing hard x-ray radiation on the VEPP-4M storage ring were carry out**
- **A focus size of 11 μm on vertical was achieved for a photon energy of 42 keV, and the use of a focused beam helps to reduce the intensity background**

Thank you for your attention