Neutron activation analysis (NAA) for life sciences

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General Info about Practice

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  Wael Badawy – Senior scientist, Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research
- Laboratory:

  Frank Laboratory of Neutron Physics


NIKE
KENYA
2017


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МЭД
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STAR WARS


ЛАБОРАТОРИЯ
НЕЙТРОННОЙ
ФИЗИКИ
ФЕДОР ЛЬВОВИЧ
ШАПИРО

Contents of Presentation

- Physical concepts – Introduction to NAA
- Sampling and sample preparation
- Data processing and analyzing
- General outcomes

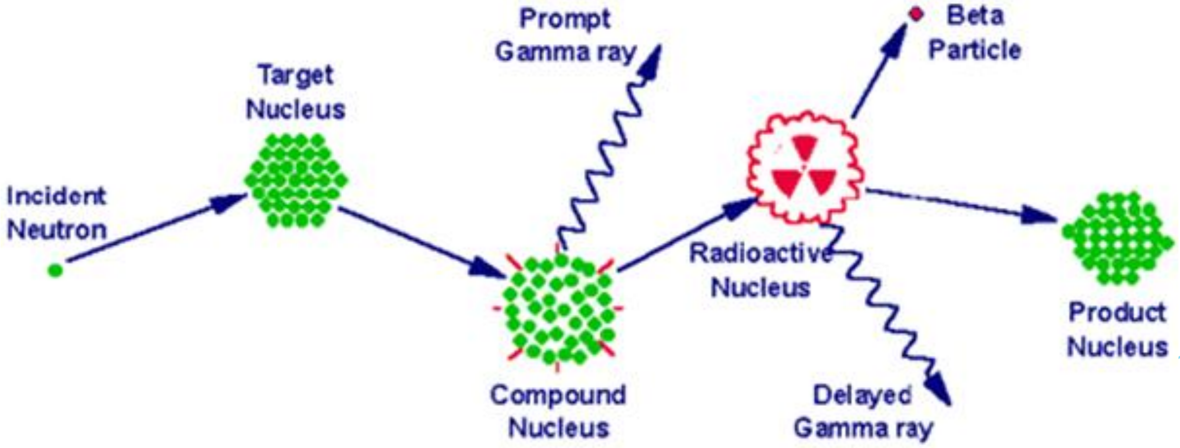
Neutron Activation Analysis

Historical review of NAA

- Most powerful multi-element analytical technique used in geosciences, life sciences and material sciences
- NAA was discovered in 1936 when Hevesy and Levi found that samples containing certain rare earth elements became highly radioactive after exposure to a source of neutrons
- Application of NAA to investigate archaeological problems began in the mid-1950s, when scientists at Brookhaven National Laboratory recognized its potential for relating artifacts to source materials through their chemical signatures
- The basic essentials required to carry out an analysis of samples by NAA are a source of neutrons, instrumentation suitable for detecting gamma rays, and a detailed knowledge of the reactions that occur when neutrons interact with target nuclei

Neutron Activation Analysis

- Neutron activation analysis is an isotope specific analytical technique for the qualitative and quantitative determination of elemental content
- The method is based upon the conversion of stable atomic nuclei into radioactive nuclei by irradiation with neutrons and the subsequent detection of the gamma radiation emitted during the decay of these radioactive nuclei.
- Activation by neutrons may result in radionuclides from all elements (that have radioactive daughter products) present in the sample



Elements obtained by NAA

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac**											Rf	Db	Sg	Bh	Hs
	*	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu		
	**	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lw		

- NAA ~ 55 elements

Characteristics of NAA

- The method is based upon processes in the atomic nucleus.
- The chemical form and physical state of the elements do not influence the activation and decay process.
- The method is suitable for determination of masses in the order of 10^{-6}–10^{-9} *g* and less, depending on the element to be determined.

Types of NAA

- Instrumental (Nondestructive) – the resulting radioactive sample is kept intact

- Radiochemical (Destructive) – the resulting radioactive sample is chemically decomposed and the elements are chemically separated

- Prompt or delayed gamma-ray neutron activation analysis

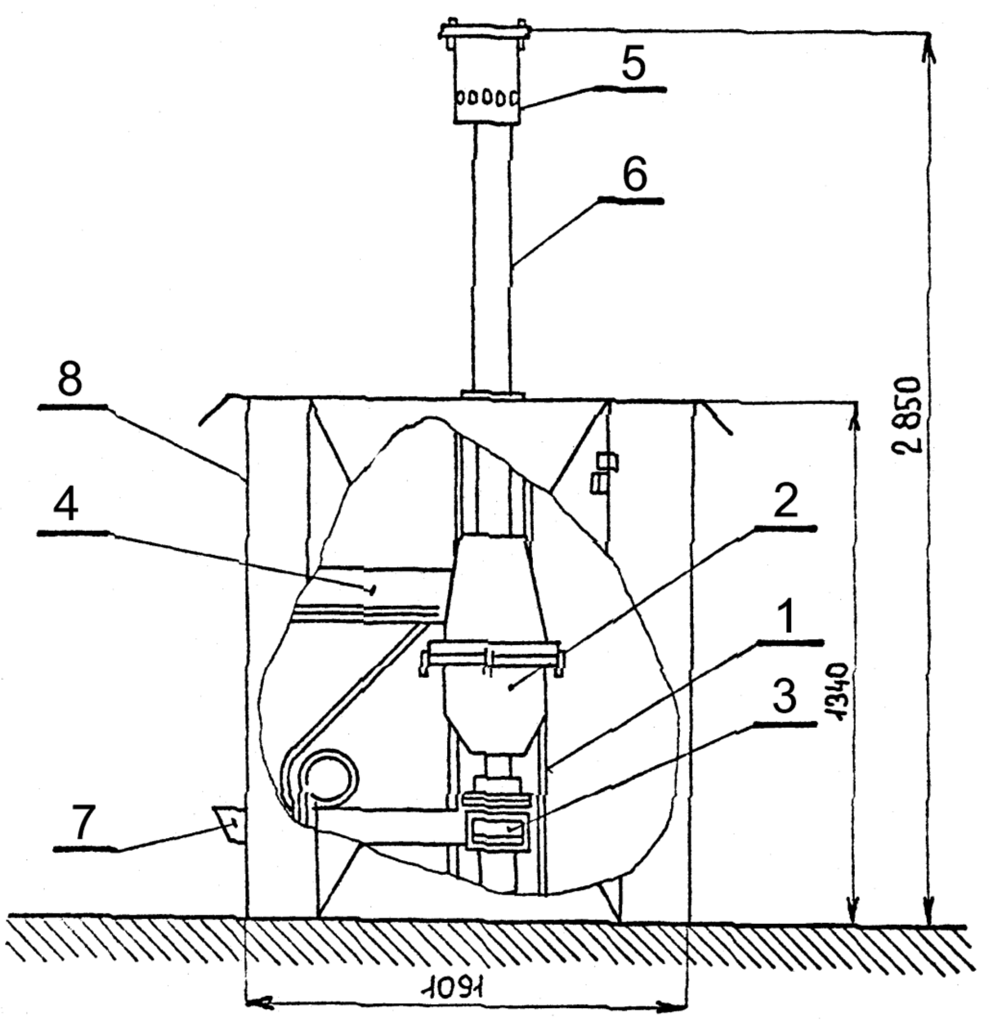
Applications of NAA at IBR-2

- Life sciences
  - Biomonitoring of air pollution (using mosses)
  - Monitoring using different components of terrestrial ecosystem i.e. soil, plants…etc.
  - Control of quality of foodstuffs

- Material sciences
  - Bio-nanotechnologies
  - Analysis of historical objects
  - Synthesis of diamonds and boron nitride

Air Sampling

- nitro-cellulose membrane filters
  - diameter of hole 0.8 mm
  - collection efficiency ~ 100 %
- sampling period
  - one – two weeks
- volume of sampled air
  - 3000 – 7000 m^3



Soil Sampling

Moss sampling

Collection of moss ...

The background territory – Domkini Bay of Ivan’kovo Reservoir - 140 km North of Moscow

Sample preparation

Preparation of moss bags (10×10 cm)
for exposure, nylon net is if with 1mm mesh

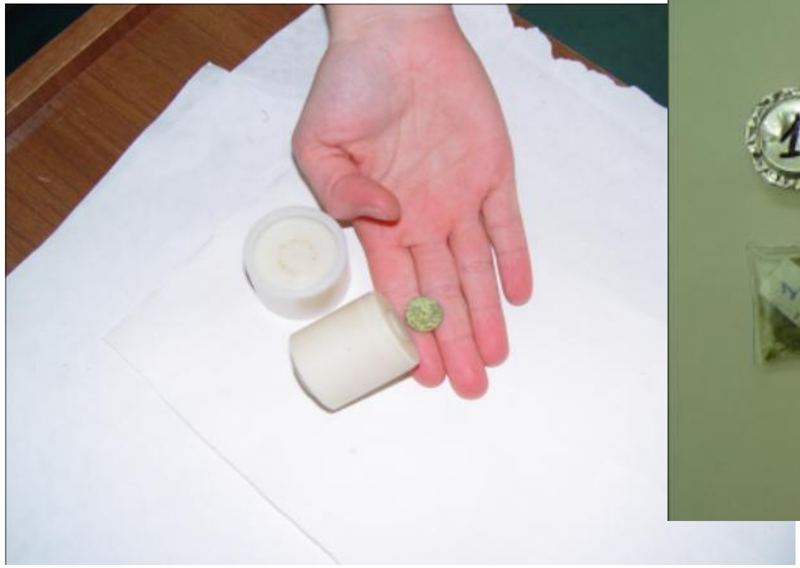
Con't

Chemical laboratory at the sector of NAA and Applied Research

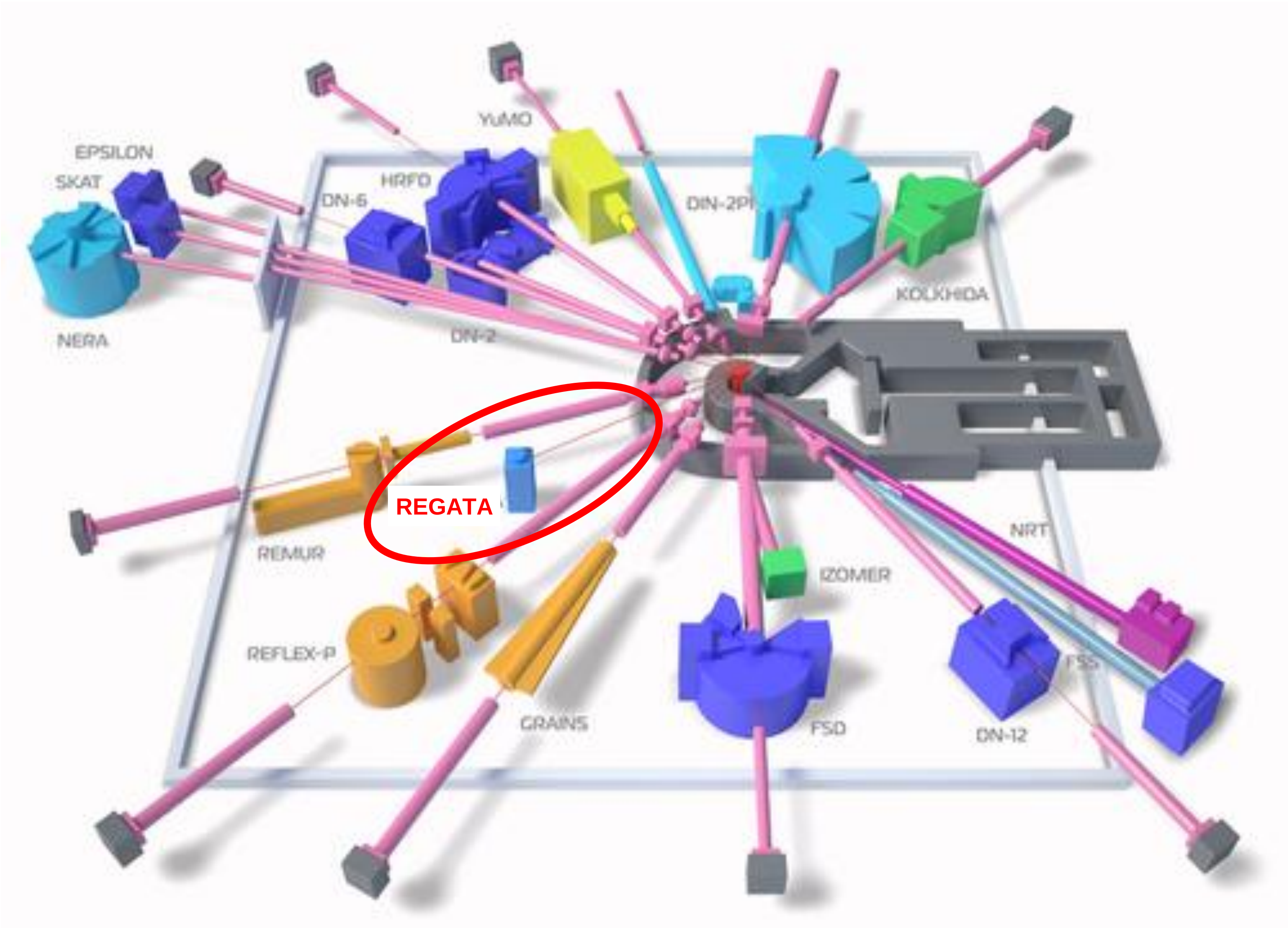
Con’t

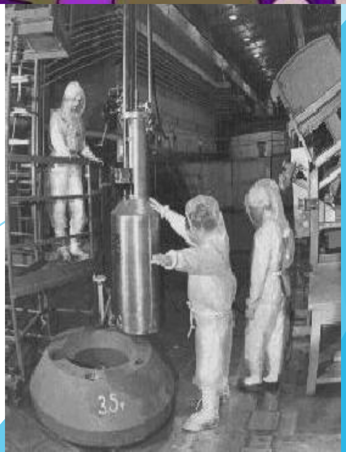
Dr. Inga Zinicovscaia

Con’t



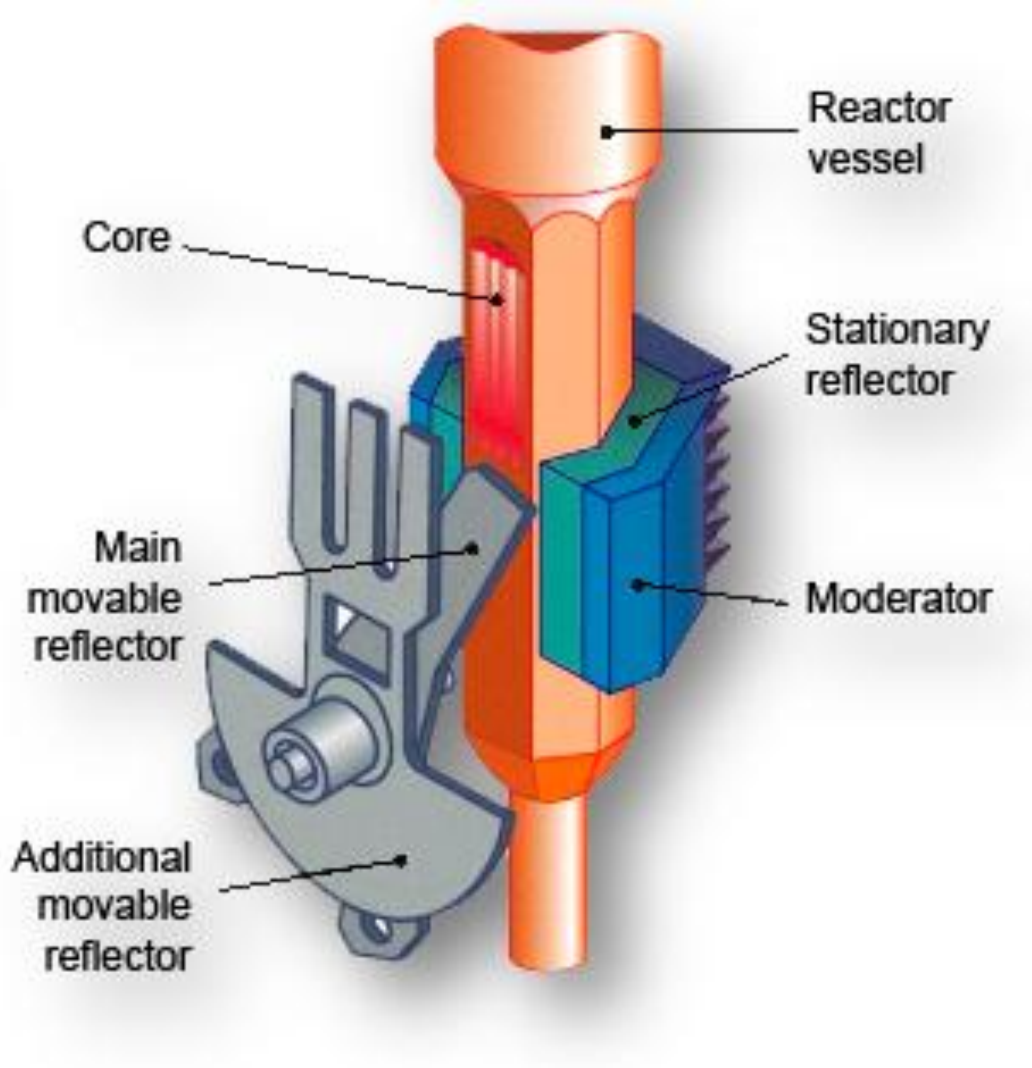
IBR-2 Pulsed Fast Reactor and Radioanalytical complex REGATA





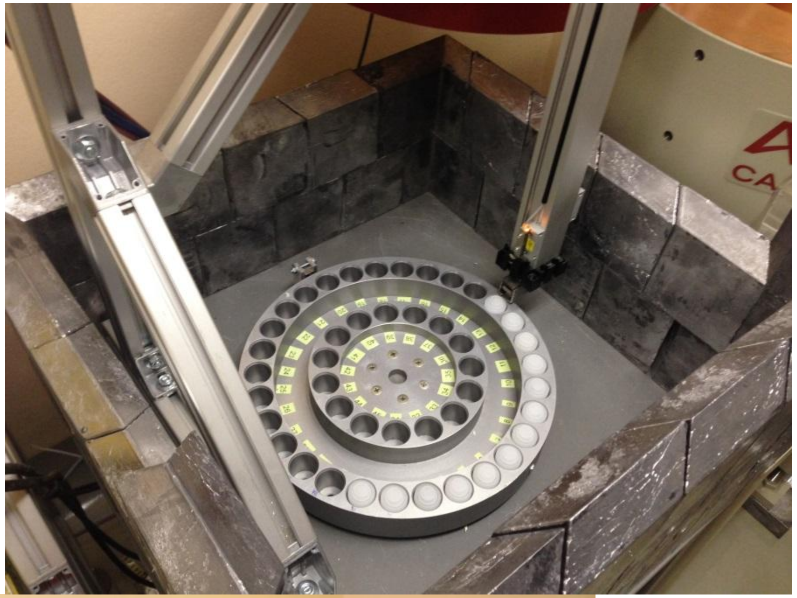
IBR-2 Pulsed Reactor at FLNP in JINR

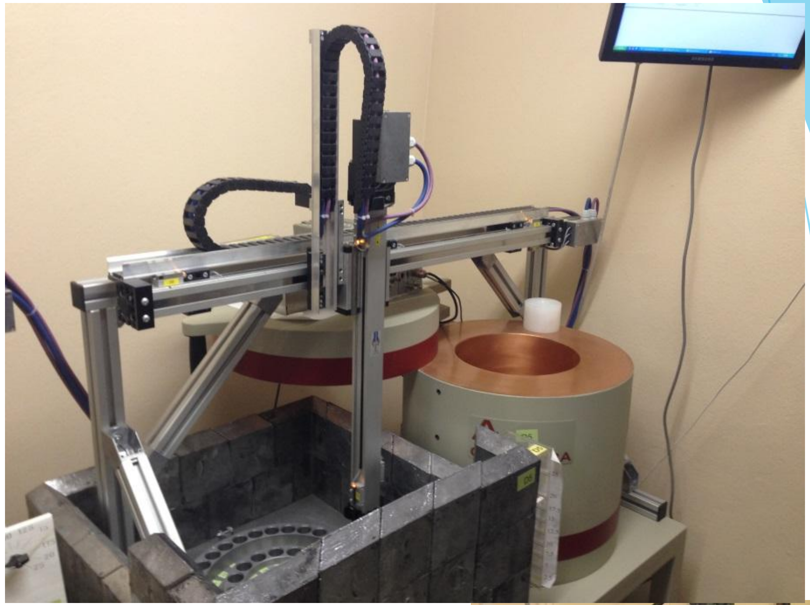
- Unique experimental reactor
- Most intense pulse neutron flux
- Power of 2 MW
- Neutron density flux $10^{16}\ n{\cdot}m^{-2}{\cdot}s^{-1}$
- Periodical changes due to rotating reflectors
- Water as a moderator, sodium as a coolant



Loading of containers with samples for irradiation

Pneumatic system using air pressure





- Three sample changers were installed
- Each sample changer consists of:
  - two axes liner movement device M202A
  - Rotated disk with 40 cells for samples
  - Three axes Xemo Motion controller with software and cables

Data processing and analyzing

Genie-2000

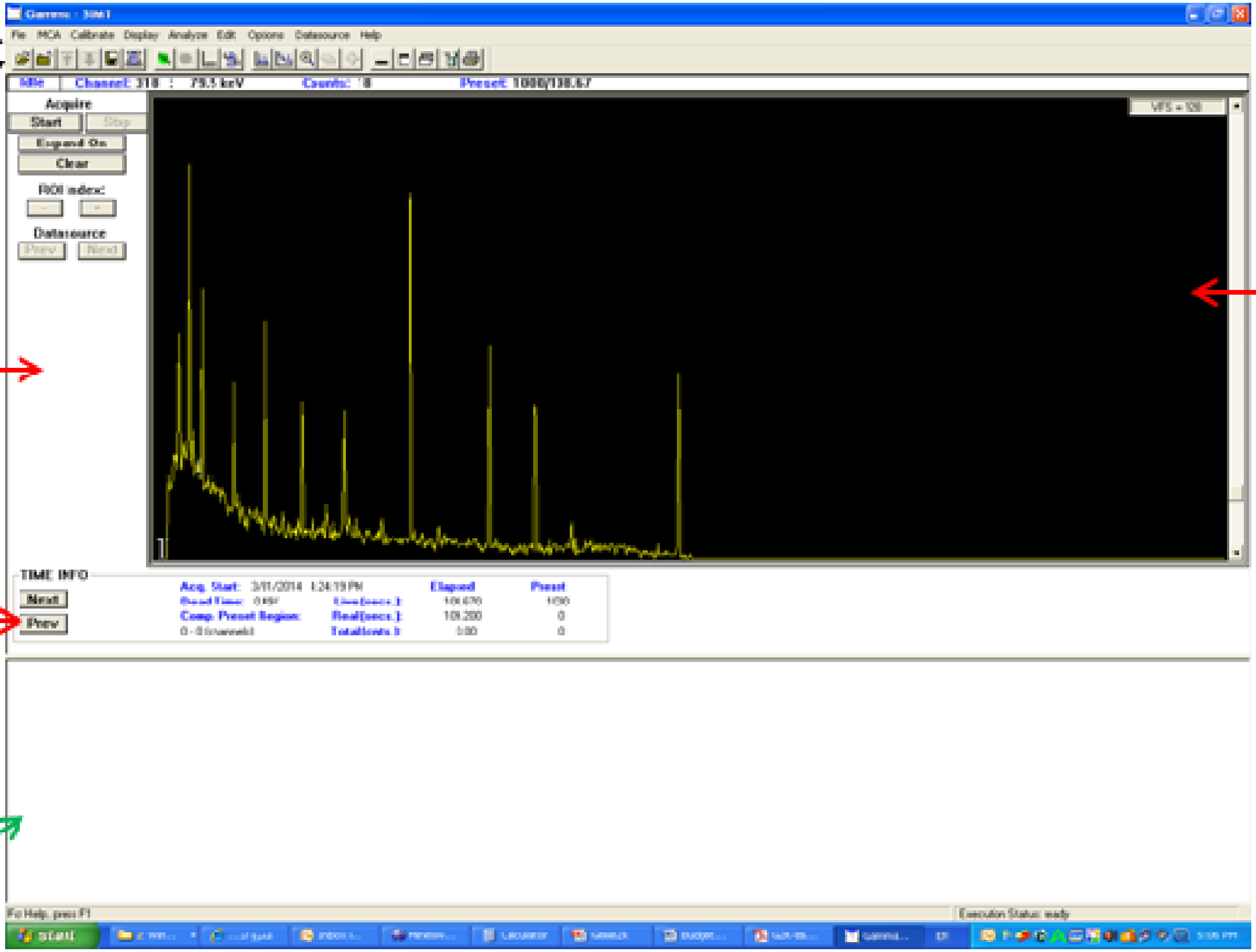
- Wide variety of layered software options available for specialized spectroscopy applications
- Integrated data acquisition and analysis
- Independent support for over 250 detector inputs
- Comprehensive and flexible user programming capability

» Menu bar

» Tool bar

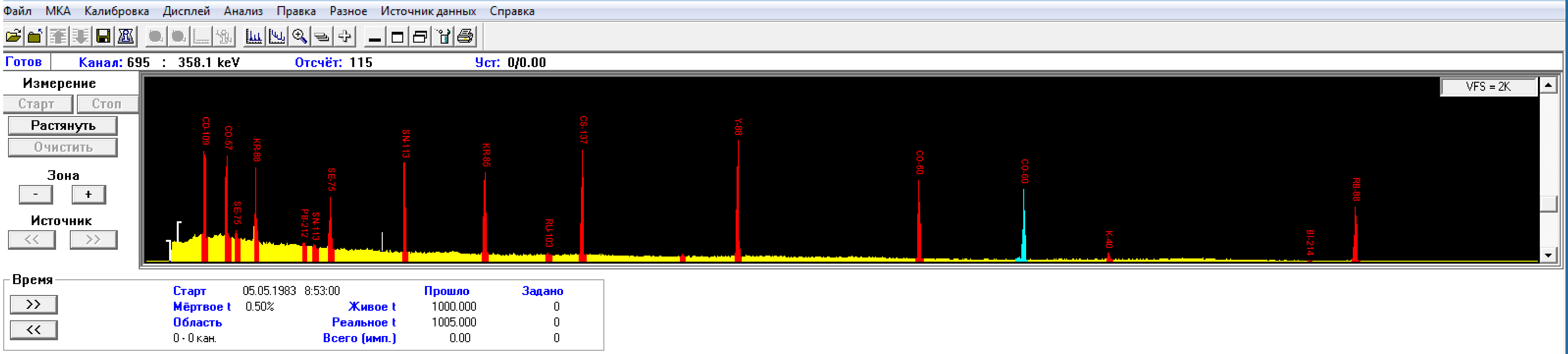
» Control panel

» Status page



» Spectrum Area

» Report Window



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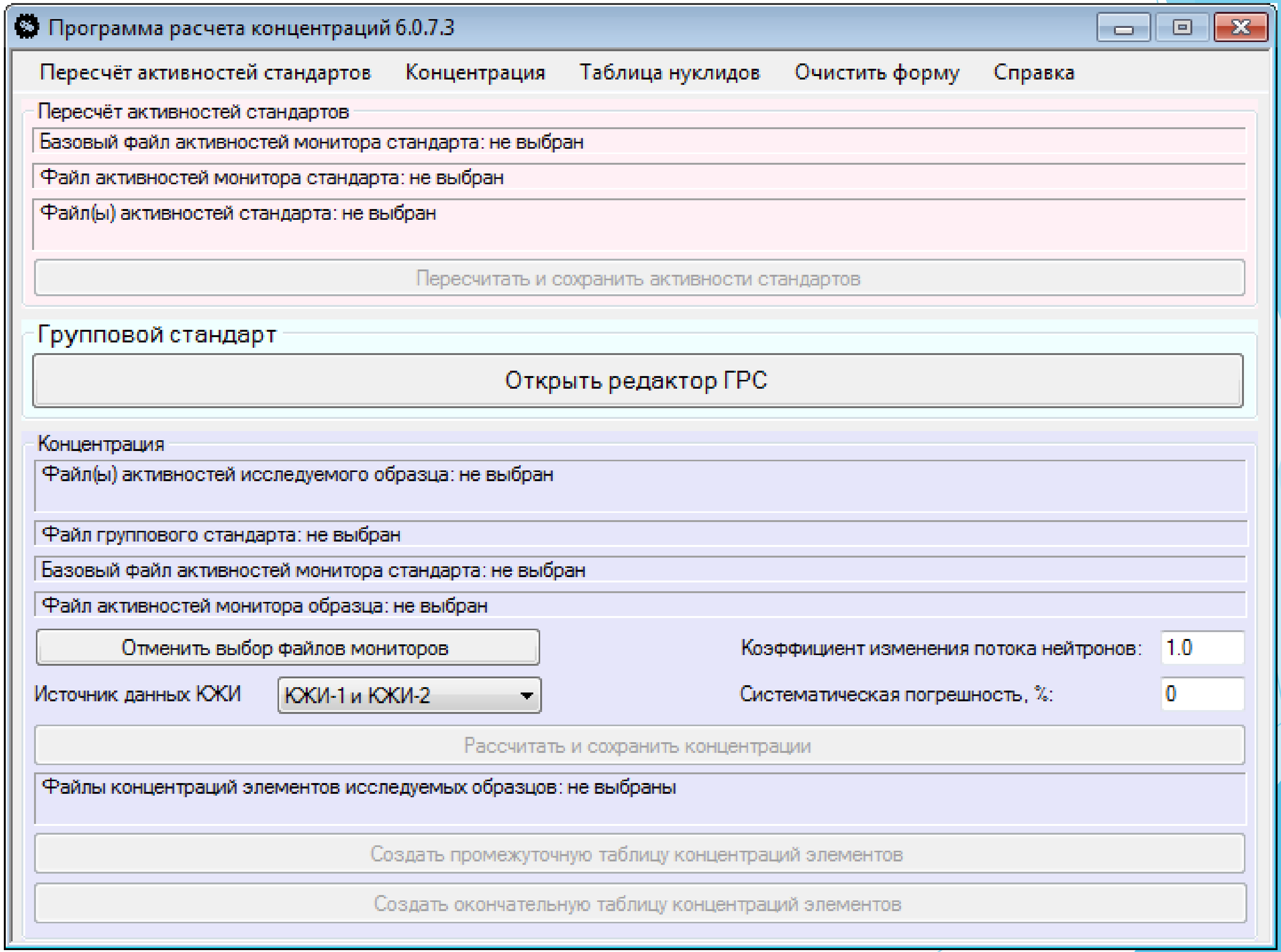
***** ОТЧЁТ О ИДЕНТИФИКАЦИИ НУКЛИДОВ С КОРРЕКЦИЕЙ НА ИНТЕРФЕРЕНЦИЮ *****

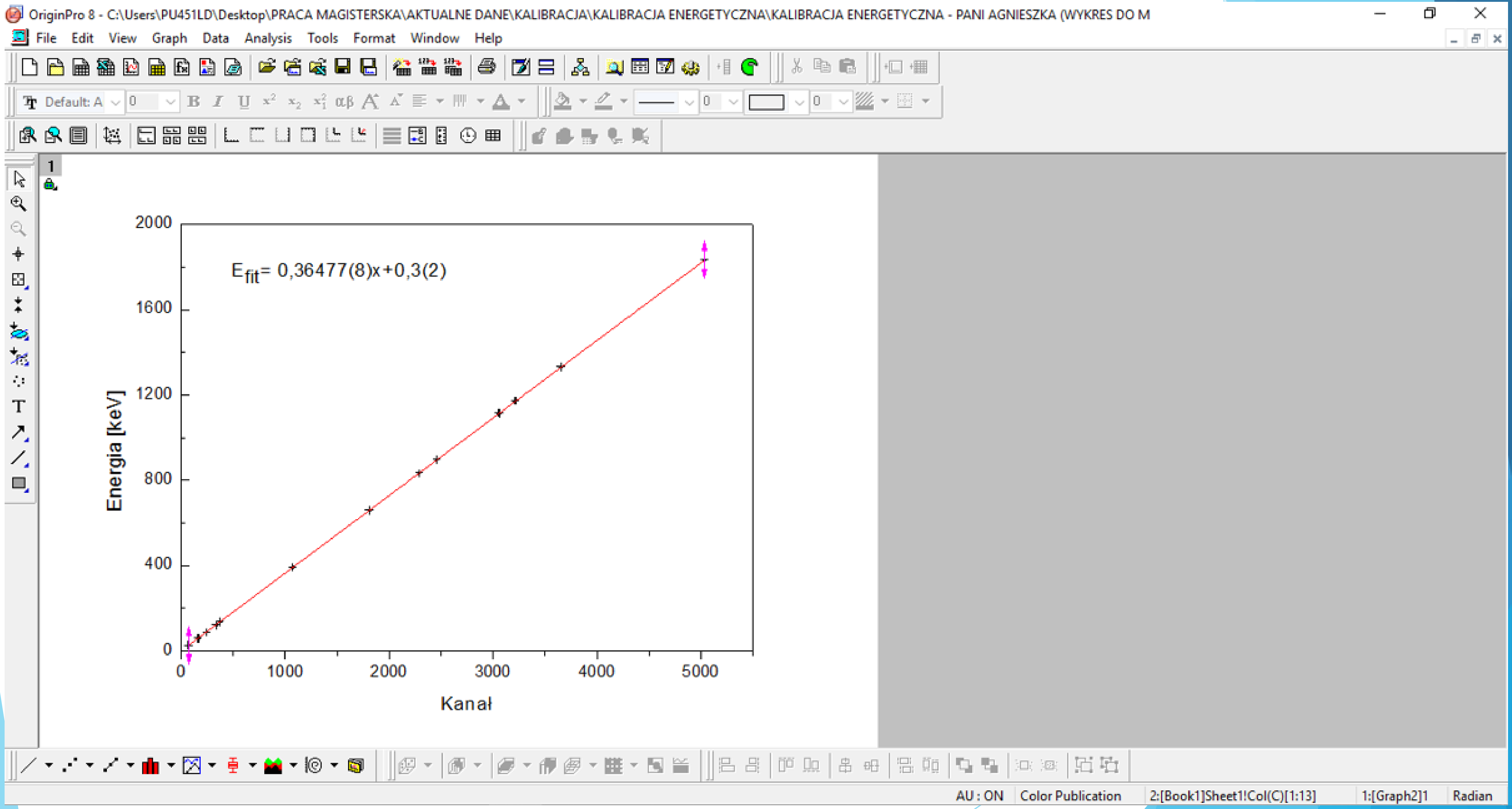
****

	Нуклид	Достоверность идентификации	Средневзвешенная активность, uCi /Unit	Погрешность
	K-40	1.000	8.355436E-002	5.453692E-003
	CO-57	0.999	2.042702E-002	6.674282E-004
	CO-60	1.000	1.001828E-001	1.519389E-003
X	SE-75	0.368		
?	KR-85	1.000	9.932121E+000	3.103463E-001
?	SR-85	0.990	1.144207E-001	3.575751E-003
	Y-88	0.996	1.950978E-001	4.255064E-003
	CD-109	1.000	4.830184E-001	2.265024E-002
	SN-113	0.997	9.289792E-002	4.113244E-003
?	XE-131M	0.637	1.585421E+002	9.367100E+000
	CS-137	1.000	8.264808E-002	2.387381E-003
?	CE-139	0.998	2.662466E-002	1.037309E-003
	HG-203	0.980	7.836262E-002	4.134530E-003
	PB-212	0.359	1.806896E-003	4.405844E-004
	BI-214	0.357	3.195765E-003	5.380830E-004

Concentration program


Программа расчета концентраций 6.0.7.3
Пересчёт активностей стандартов
Концентрация
Таблица нуклидов
Очистить форму
Справка
Пересчёт активностей стандартов
Базовый файл активностей монитора стандарта: не выбран
Файл активностей монитора стандарта: не выбран
Файл(ы) активностей стандарта: не выбран
Пересчитать и сохранить активности стандартов
Групповой стандарт
Открыть редактор ГРС
Концентрация
Файл(ы) активностей исследуемого образца: не выбран
Файл группового стандарта: не выбран
Базовый файл активностей монитора стандарта: не выбран
Файл активностей монитора образца: не выбран
Отменить выбор файлов мониторов
Коэффициент изменения потока нейтронов:
1.0
Источник данных КЖИ
КЖИ-1 и КЖИ-2
Систематическая погрешность, %:
0
Рассчитать и сохранить концентрации
Файлы концентраций элементов исследуемых образцов: не выбраны
Создать промежуточную таблицу концентраций элементов
Создать окончательную таблицу концентраций элементов

Origin 8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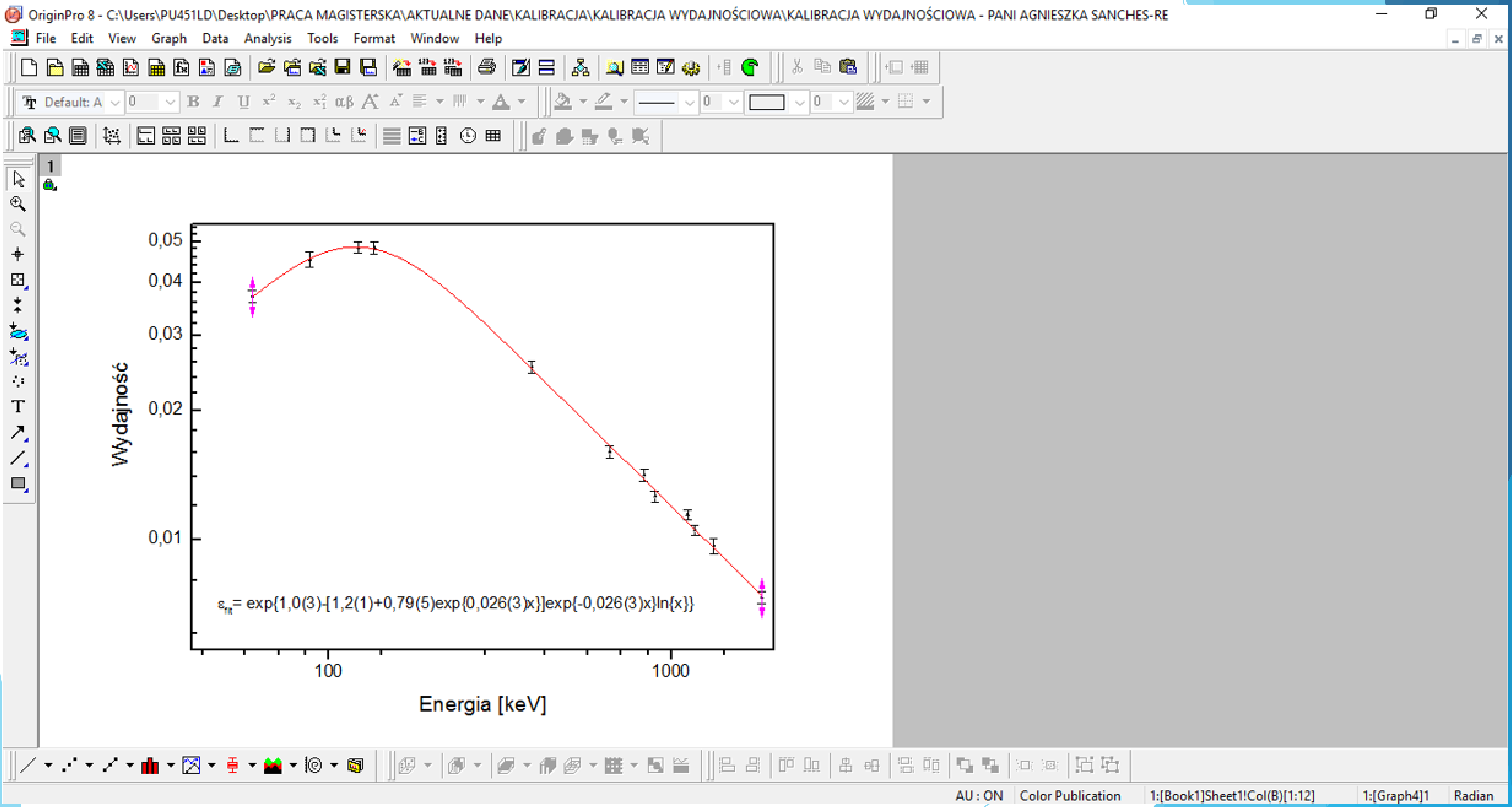
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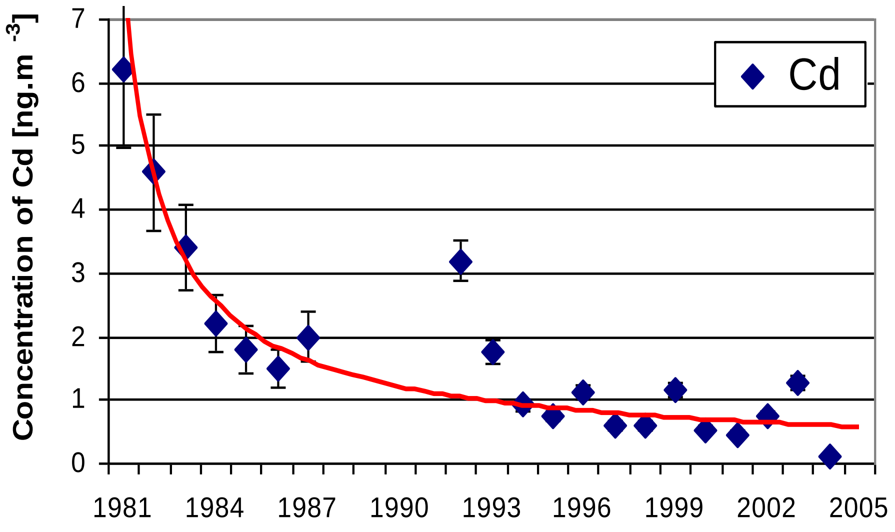
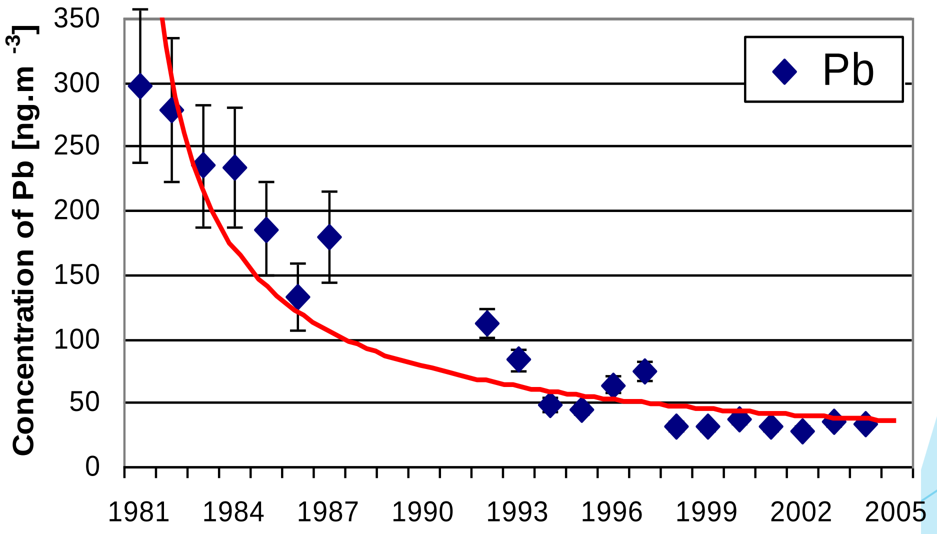
Joint Project - Slovakia

- Atmospheric deposition of 46 elements were determined using the moss monitoring technique
- Heavy metals were determined in mosses sampling taking from localities near oil plant SLOVNAFT (Bratislava - capital)

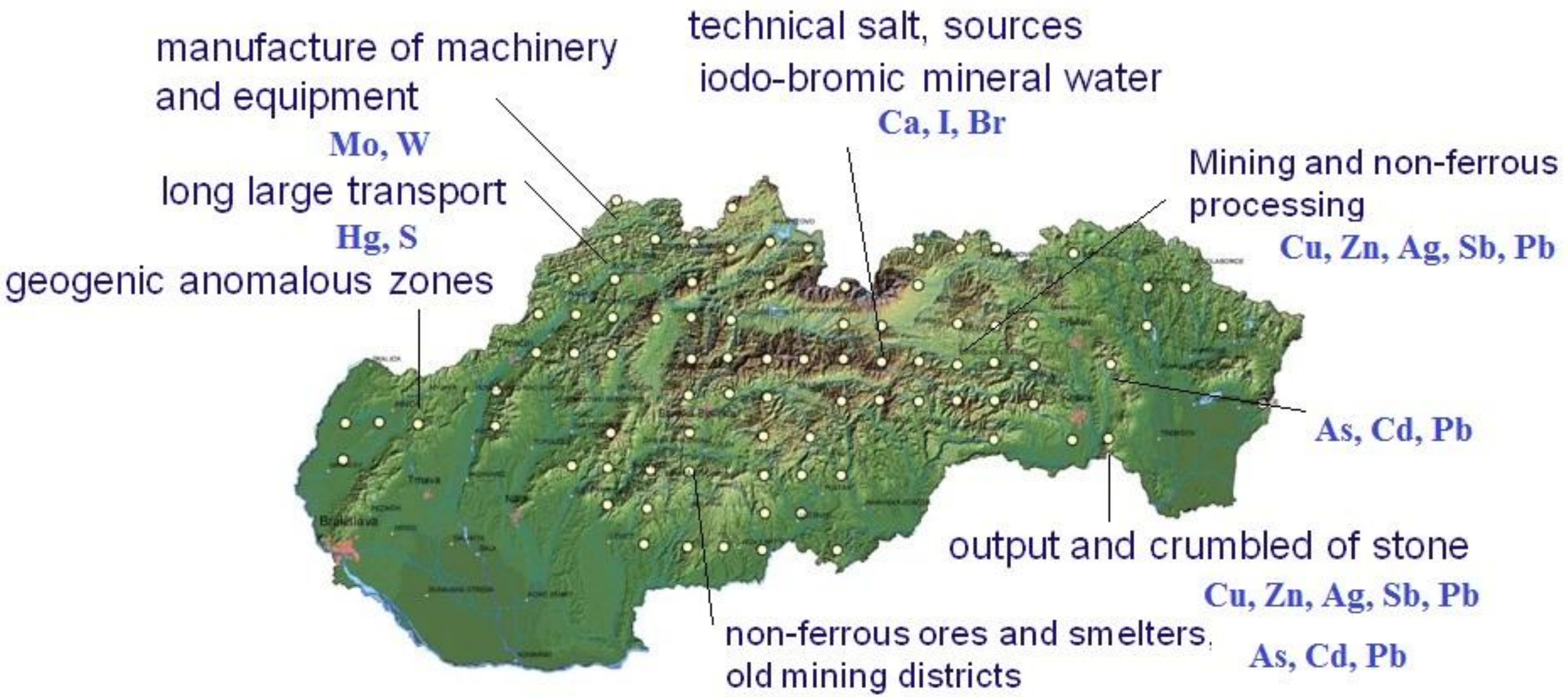




- The decreasing trend of atmospheric pollution by heavy metals in period of last 20 years

Projects - Slovakia

- Distribution of elements over the territory Slovakia



EPC´06, Alexandria, 2006

Projects - Poland

- Biomonitoring of atmospheric pollution in Poland

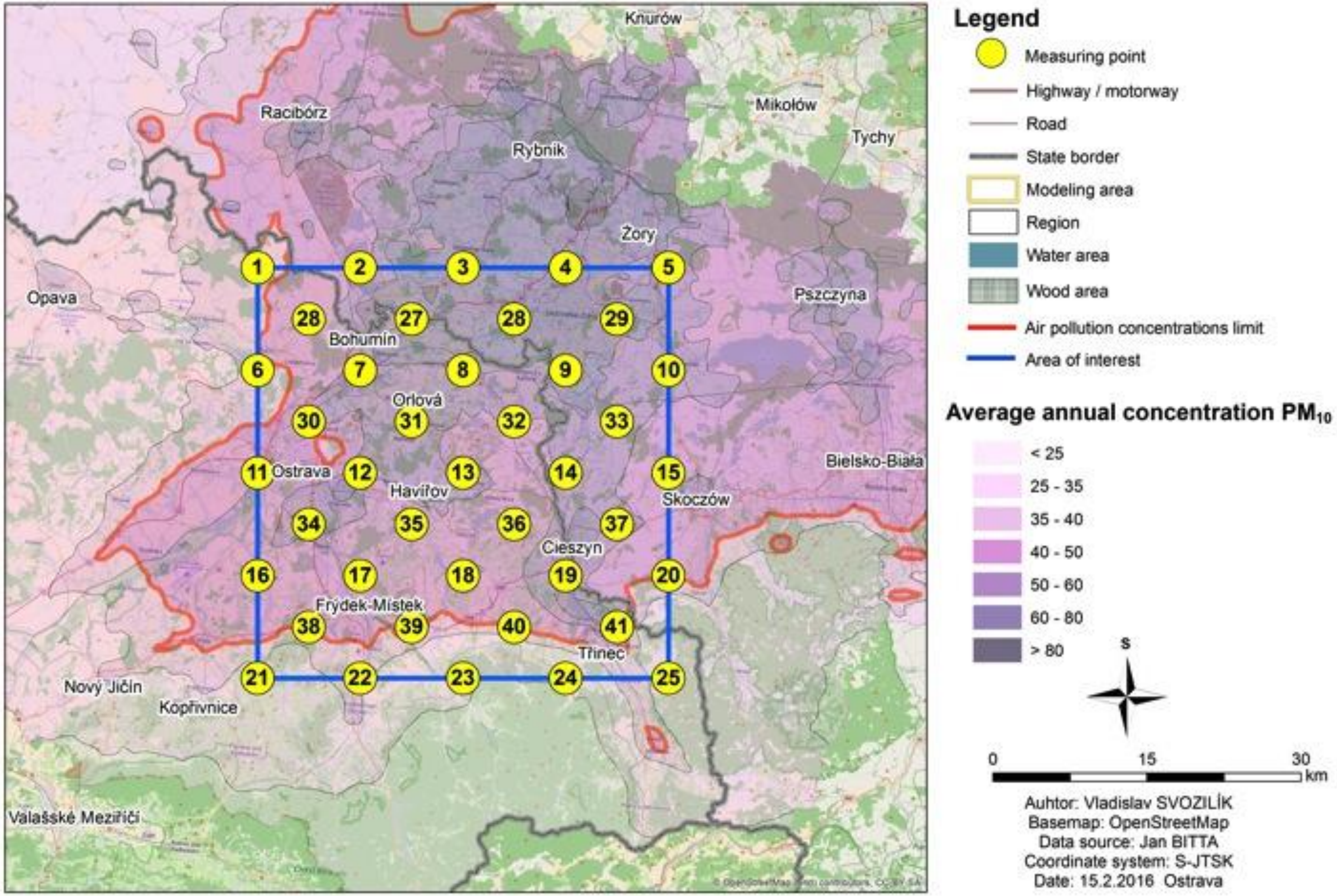
- In 2005 an international project was set up under the 5th framework program of the EU ("Copernicus" program)

- 2005-2006: cooperation of polish NAA scientists "Assessment of negative effects of poisonous substances on aquatic and human ecosystems, studies on the example of Mazurian lakes in Poland and the Rybińsk Reserve in central Russia using methods of nuclear physics."

- NAA's technical cooperation with the Technical University of Opole (2008-2010) "Forest pollution in the south-western region of Poland with radioactive nuclides and heavy metals"

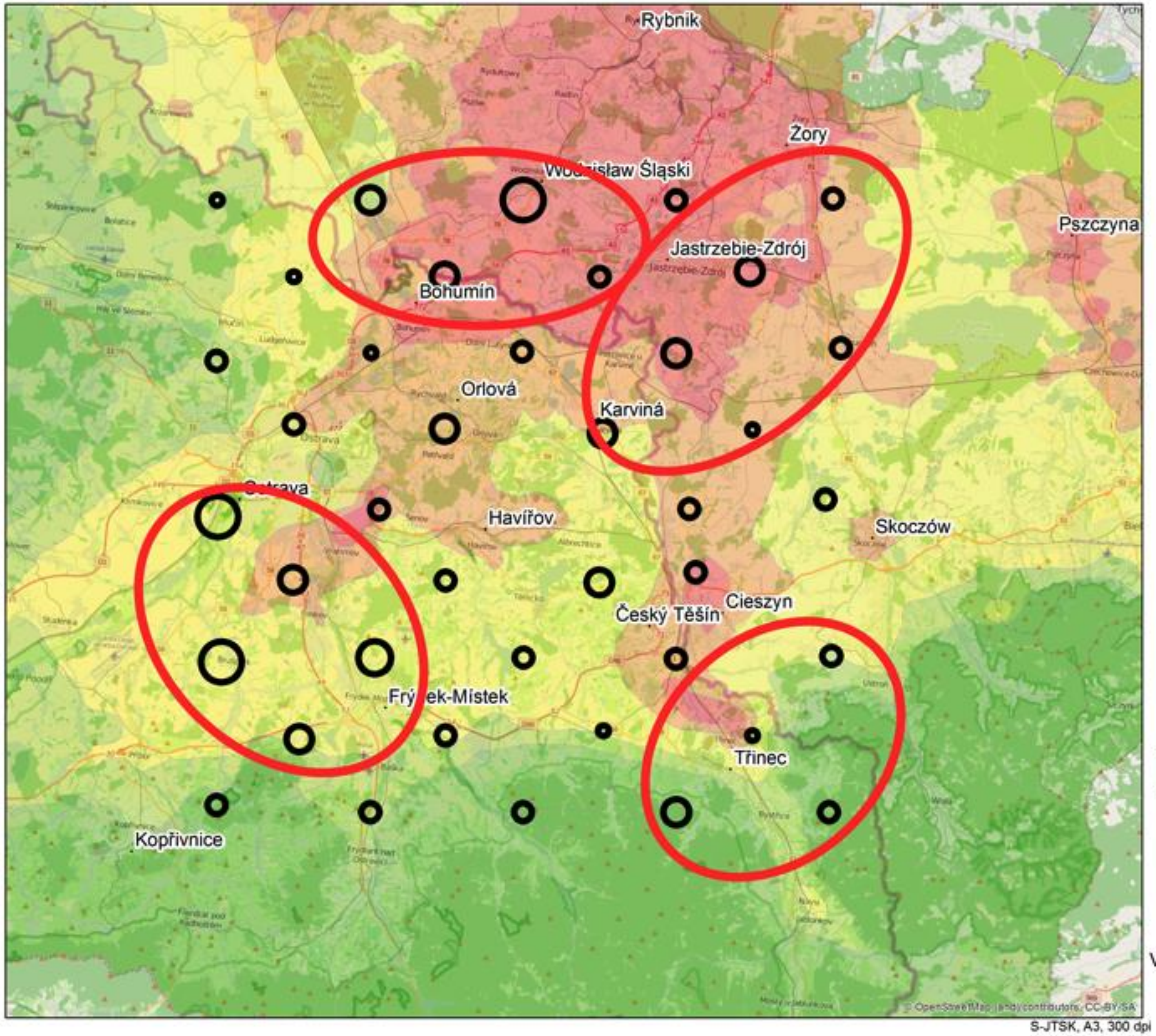
SAMPLING SITES FOR MOSS MONITORING IN MORAVIAN-SILESIAN REGION

Year 2015



ELEMENTS IDENTIFIED BY NEUTRON ACTIVATION ANALYSIS IN SILESIAN REGION

YEAR 2015



Technical content: Doc. Ing. Petr Jančík, Ph.D.
Author: Ing. Vladislav Svozilík

Vysoká škola báňská - Technická univerzita Ostrava, 2016

Advantages

- Primary analytical technique
- Ease of sample preparation
- High sensitivity and precision
- Simultaneous measurement of multiple elements
- Outstanding replicability
- Wide possibilities of applications

Limitations

- Need for nuclear reactor
- Work with radioactive materials
- Time of analysis
- Sample preference

General outcomes

- NAA is a useful method for the simultaneous determination of elemental composition of geological, environmental and biological samples
- Data analysis yields concenztrations of major, minor, trace and rare earth elemets
- Enriched our knowledge in this important field, learned sample preparaion for NAA
- Met new people, made new friends and gained experiences
- Found an inspiration on our future master/PhD. thesis
- Visited amazing places, cities, etc.

Capacity building

- The aim of this practice is to expose students to scientific research and facilities of world class standard manned by JINR

- The practice provides us, who will transfer the nuclear technology, to suppert the development of our countries

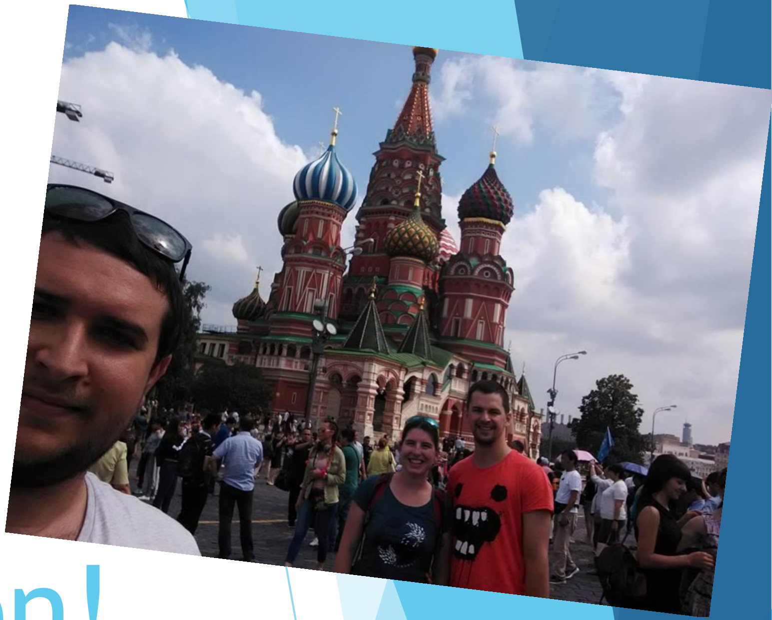
Acknowledgements

- Prof. Marina V. Frontasyeva

- Dr. Wael Badawy

- All staff of the Neutron Activation Analysis and Applied Research Unit, Frank Laboratory of Neutron Physics





Thank you for your attention!