International Student Practice 2017, JINR, Dubna

NEUTRON ACTIVATION ANALYSIS FOR LIFE SCIENCES

By

MacDonald, R. T; Zimri, M. N; Mukaba, JL; Tsewu, A. and Uche, C.C.

Supervised by: Prof. M.V. Frontasyeva and Dr W. Badawy

Frank Laboratory of Neutron Physics
The Sector of Neutron Activation Analysis and Applied Research

29th May – 16th June 2017

GROUP MEMBERS

Riccarda Thelma MacDonald
University of the Western Cape
BSc (Hons) Chemical Sciences
MSc Nanoscience

Monushia Natasha Zimri
University of the Western Cape
BSc (Hons) Biotechnology
MSc Nanoscience

Ayabulela Tsewu
University of Fort Hare
BSc Physical Sciences
BSc (Hons) Nuclear Physics

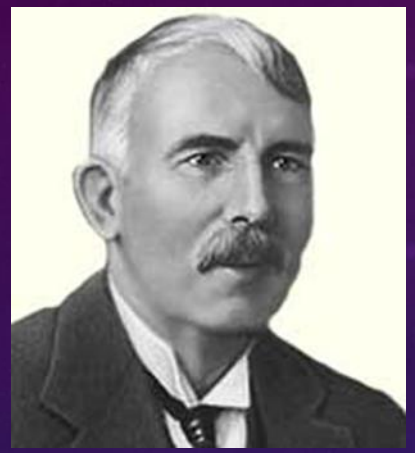
Muvumbu Jean-Luc Mukaba
University of the Western Cape
MSc Chemistry
PhD

Cosmas Chinedu Uche
University of the Western Cape
MSc Pollution Control
PhD (In view)

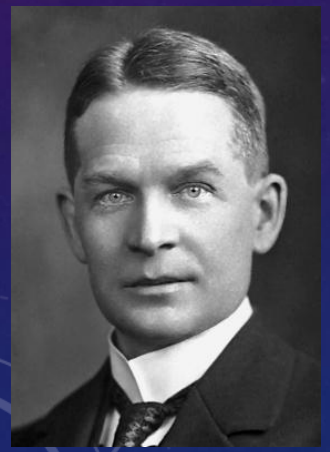
Presentation content

- Introduction
- Sample Collection and Preparation
- Sample Analysis and Data Processing
- Programs for Data Interpretation
- Conclusions
- Acknowledgements
- References

Neutron Discovery



Ernest Rutherford



Frederick Soddy

1909: scattering of α- particles

1911: nuclear model of the atom

1919: $^{14}N + \alpha \rightarrow {}^{17}O + p$

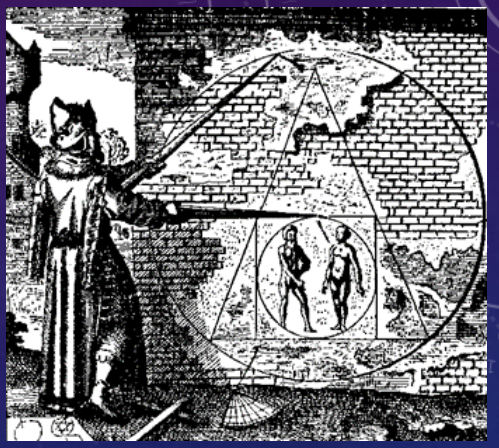
p-e model of the atom

1920: n = p + e

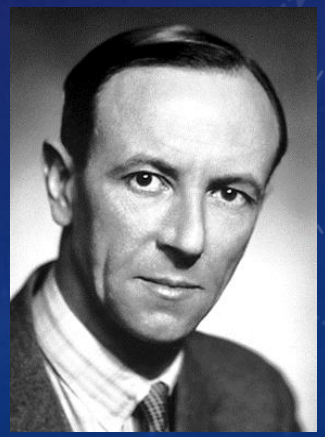
1932: "Possible Existence of a Neutron" – February

"The Existence of a Neutron" – May

1934: Establishment of newly discovered neutron as fundamental particle



The Philosopher's Stone



James Chadwick

Neutron Activation Analysis

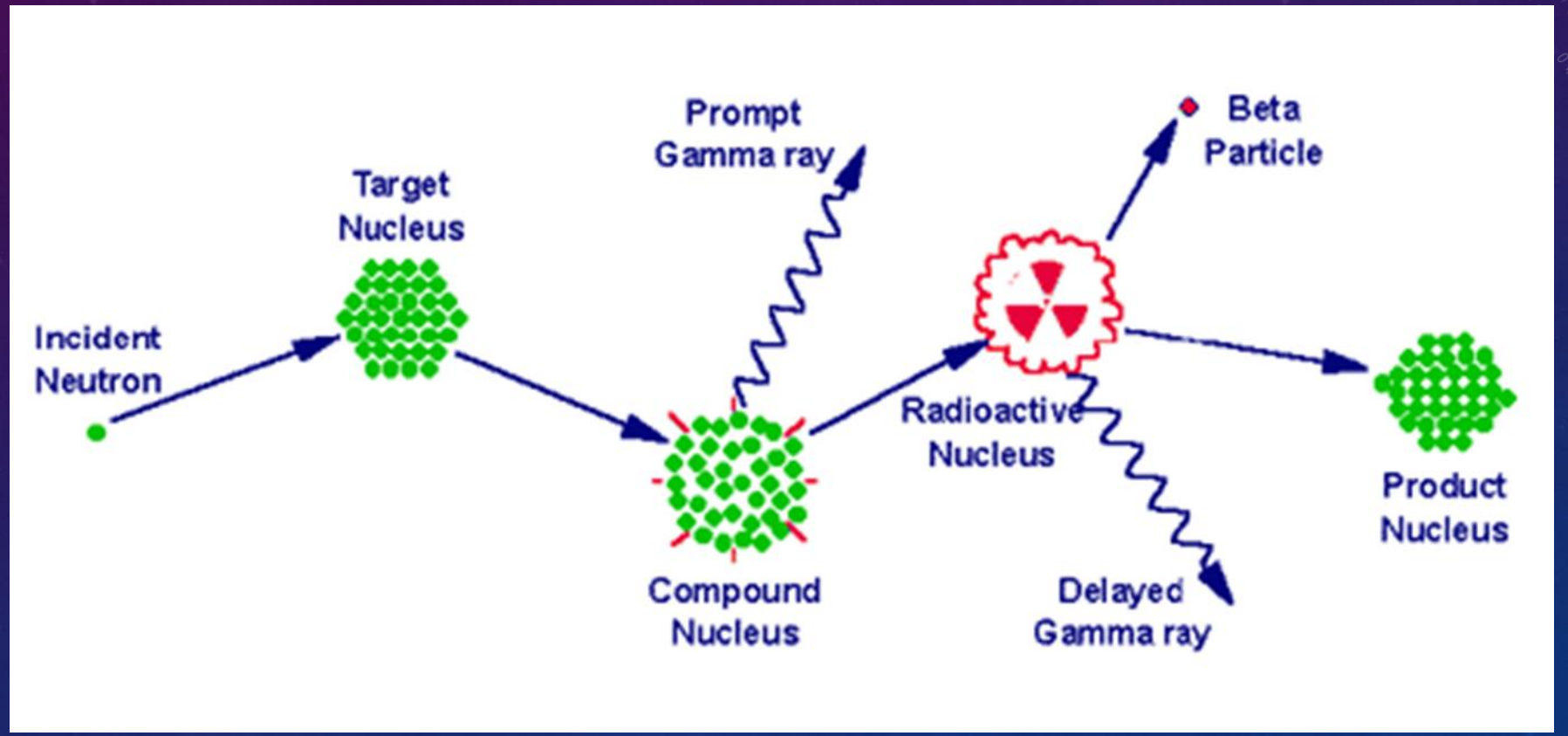
- Is an isotope specific analytical technique for the qualitative and quantitative determination of elemental content
- Discovered in 1936

P. Bode, J.J.M. de Goeij, '*Activation Analysis*', Encyclopedia of Environmental Analysis and Remediation, J. Wiley & Sons, New York, 1998, ISBN 0-471-11708-0, pp 68-84

George Charles de Hevesy

Hilde Levi

Fundamentals of NAA

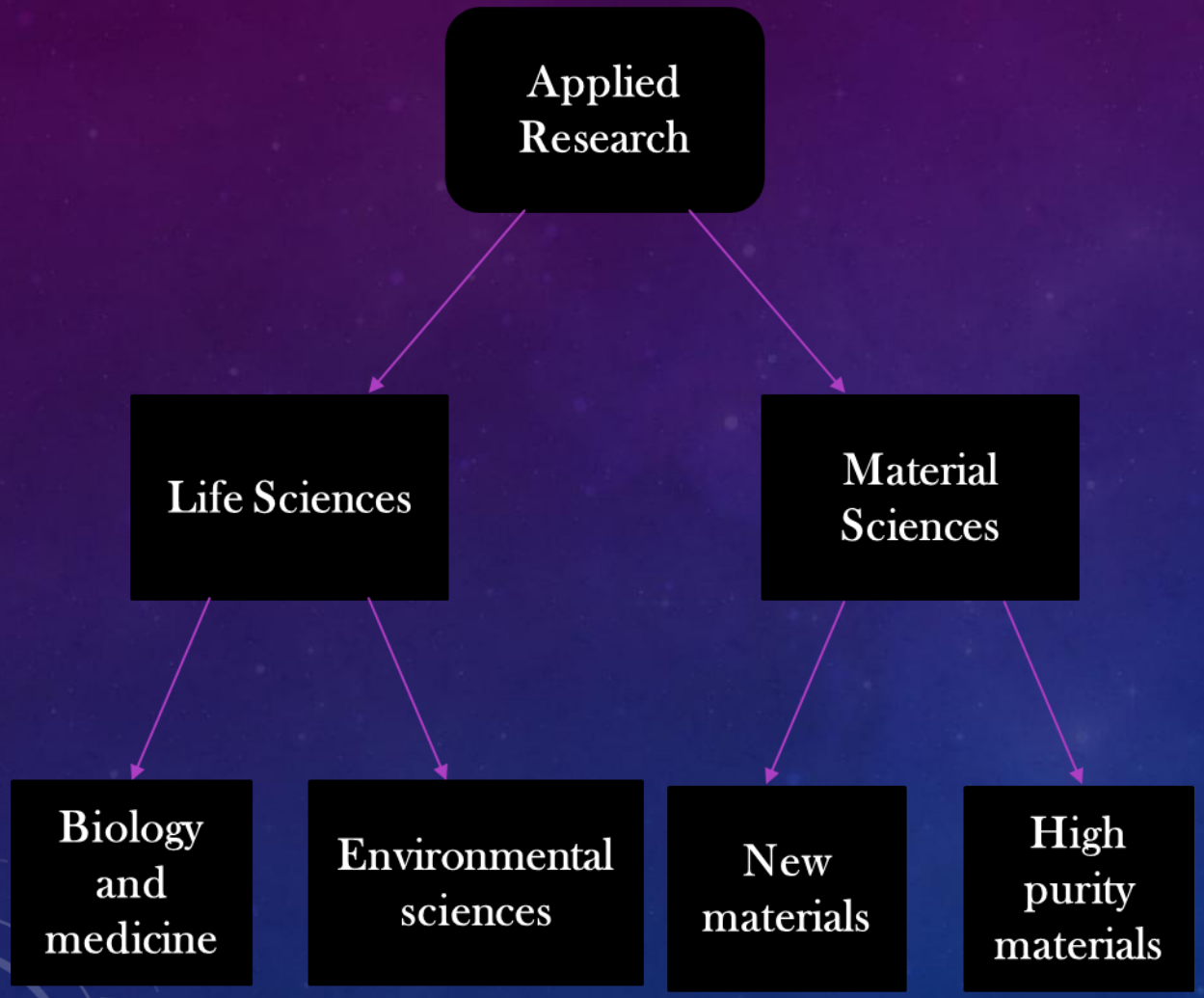


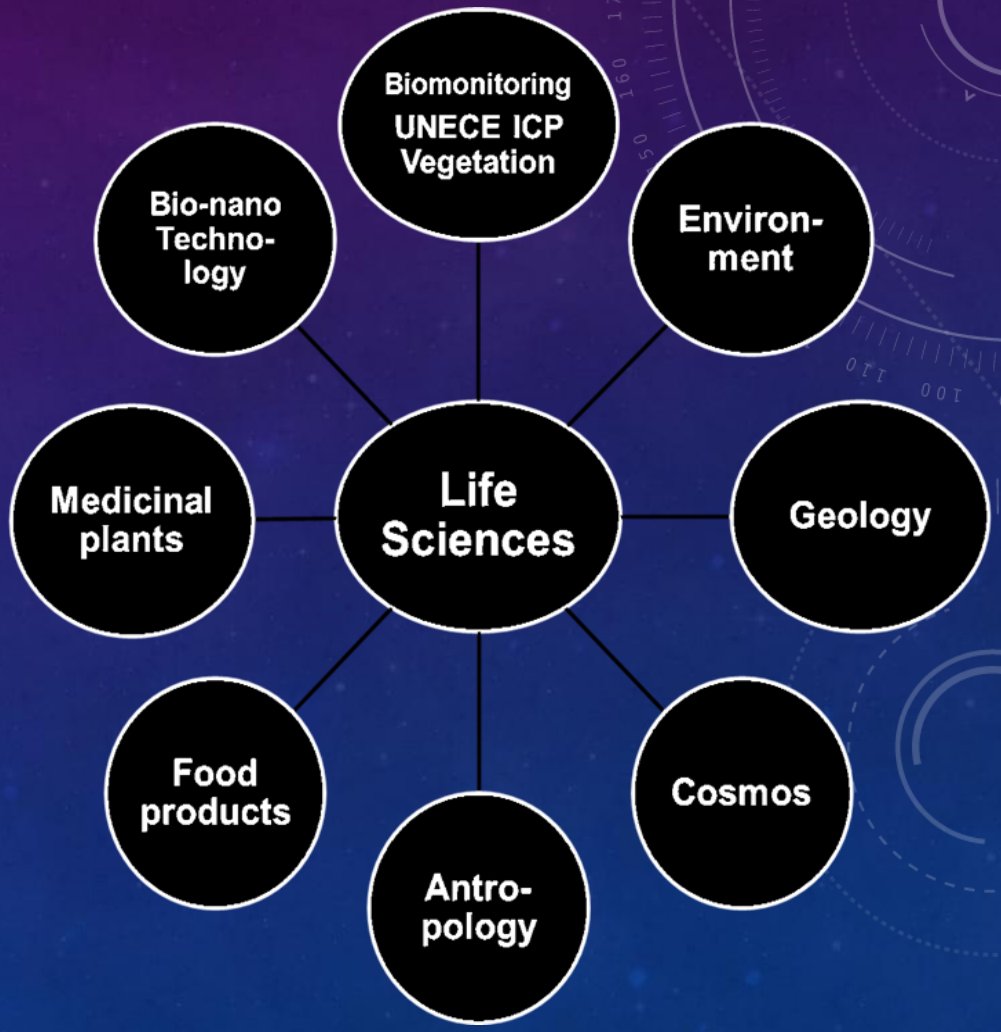
Types of NAA

Destructive (radiochemical)
the resulting radioactive sample is chemically decomposed and the elements are chemically separated

Non-destructive (instrumental)
the resulting radioactive sample is kept intact and the radionuclides are determined, taking advantage of the differences in decay rates via measurements at different decay intervals

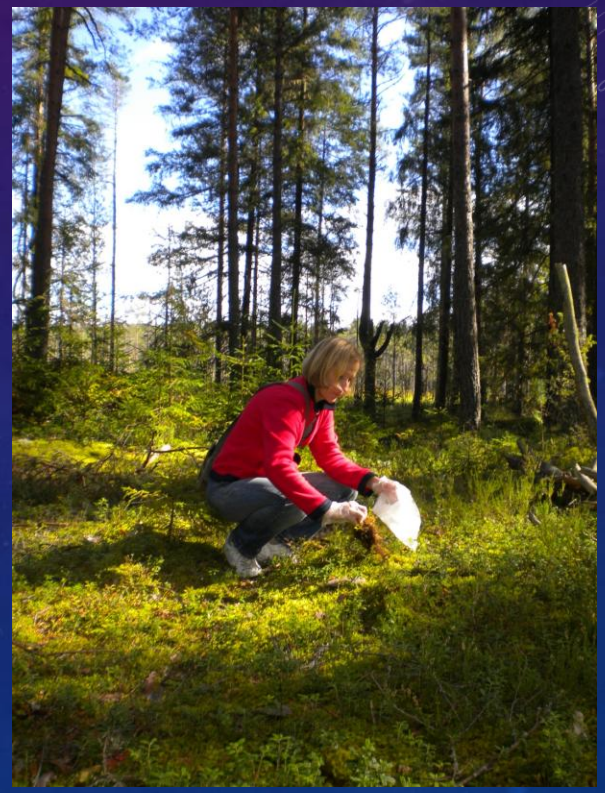
Applications





Sample Collection

- ***Hylocomium splendens* and *Pleurozium Schreberi***



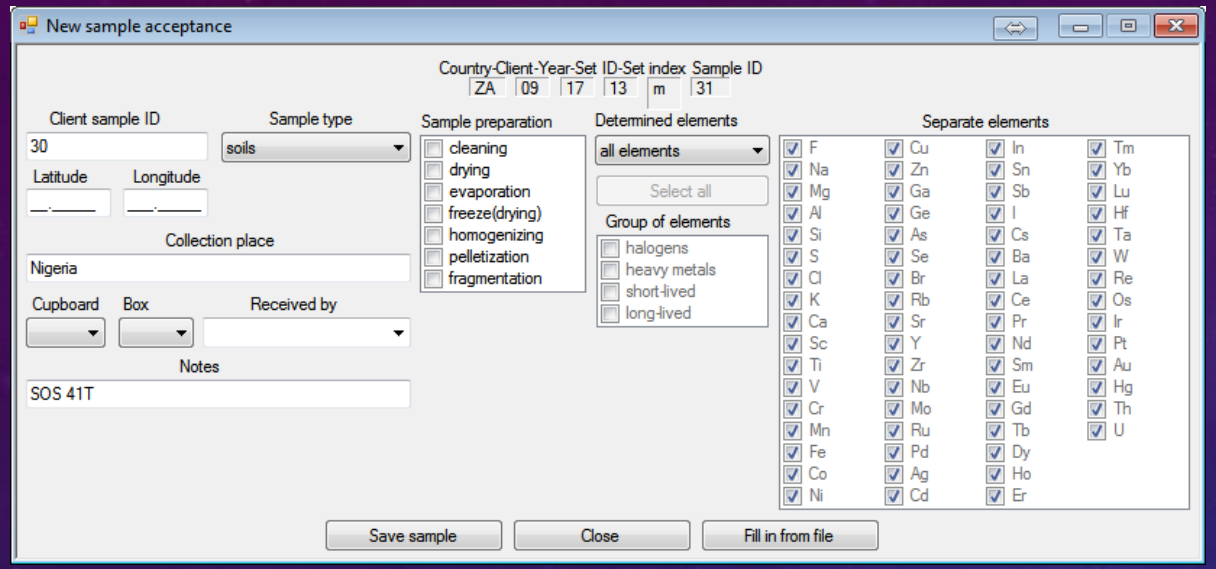
Sample Preparation

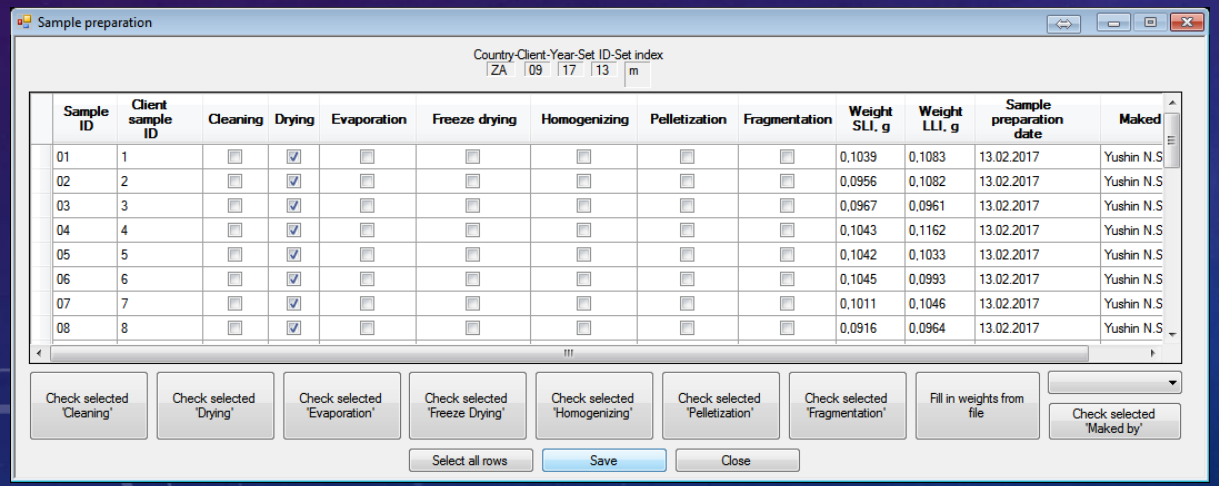
- Samples air-dried and cleaned from roots of plants and wastes
- Sample weighed and homogenized by an agate ball mill

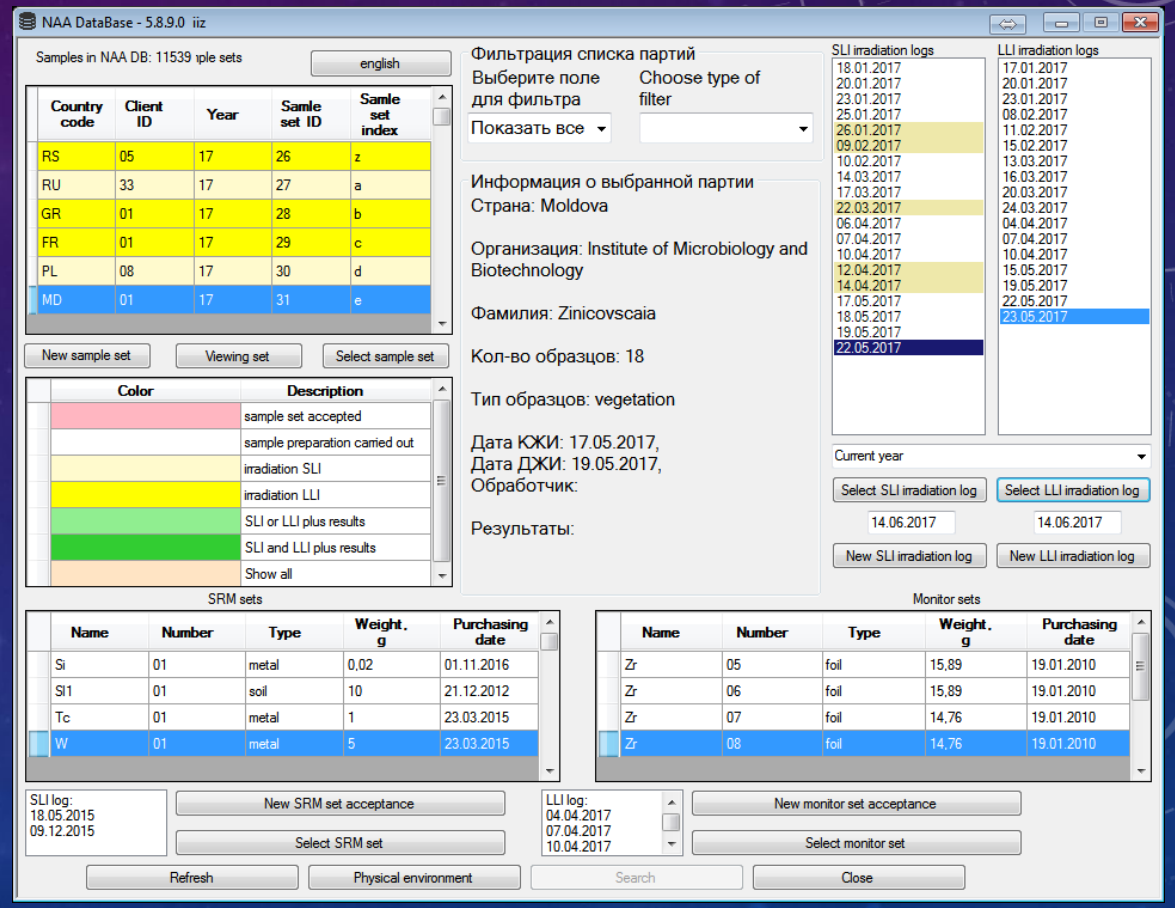
Sample Packing

- Moss samples wrapped in polyethylene bag and aluminium pan for short- and long-lived irradiations respectively.
- Samples placed in transport capsules
- Short-lived isotopes - samples irradiated for 60 seconds
- Long-lived isotopes – samples irradiated for 4 days

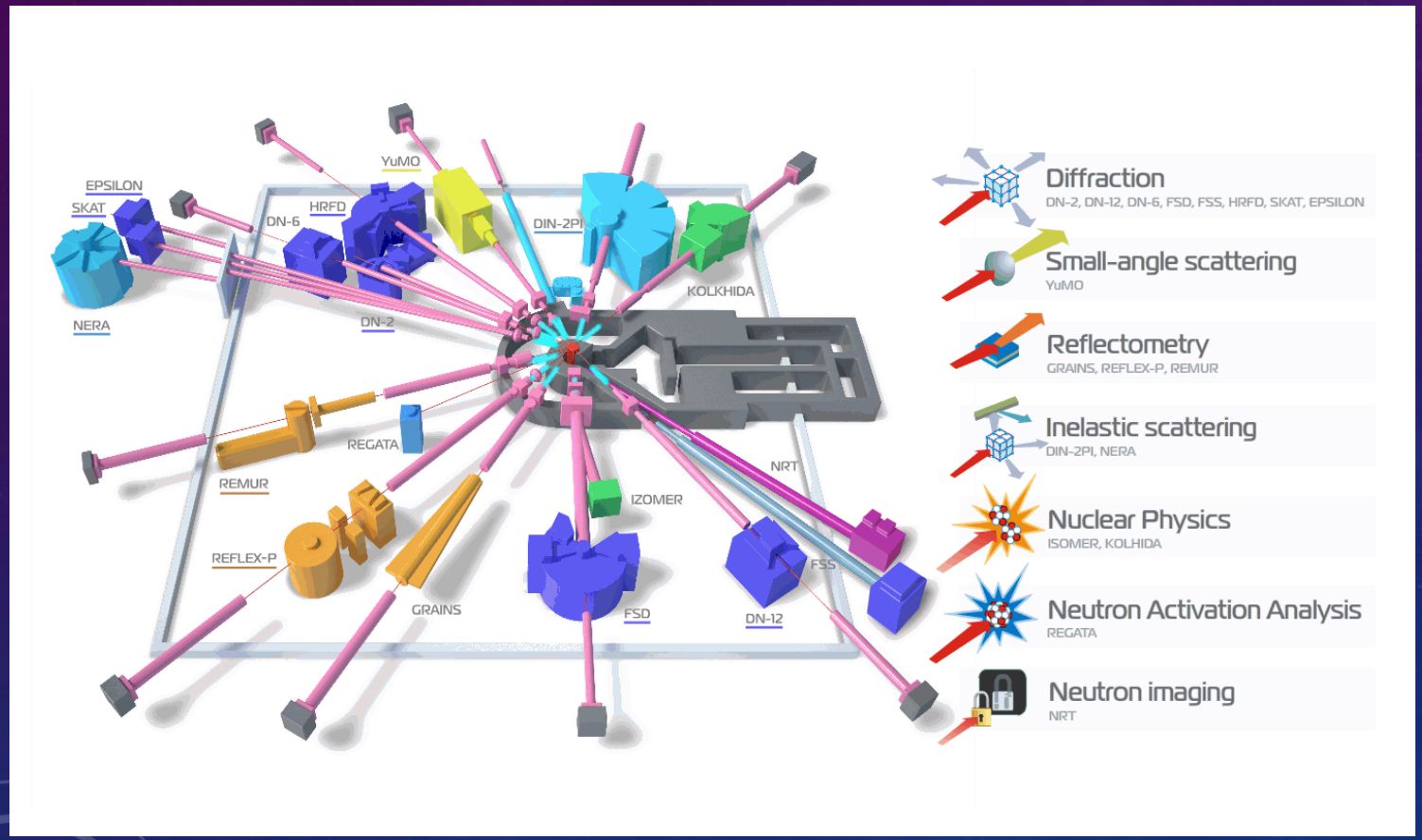
Sample Information Sheets





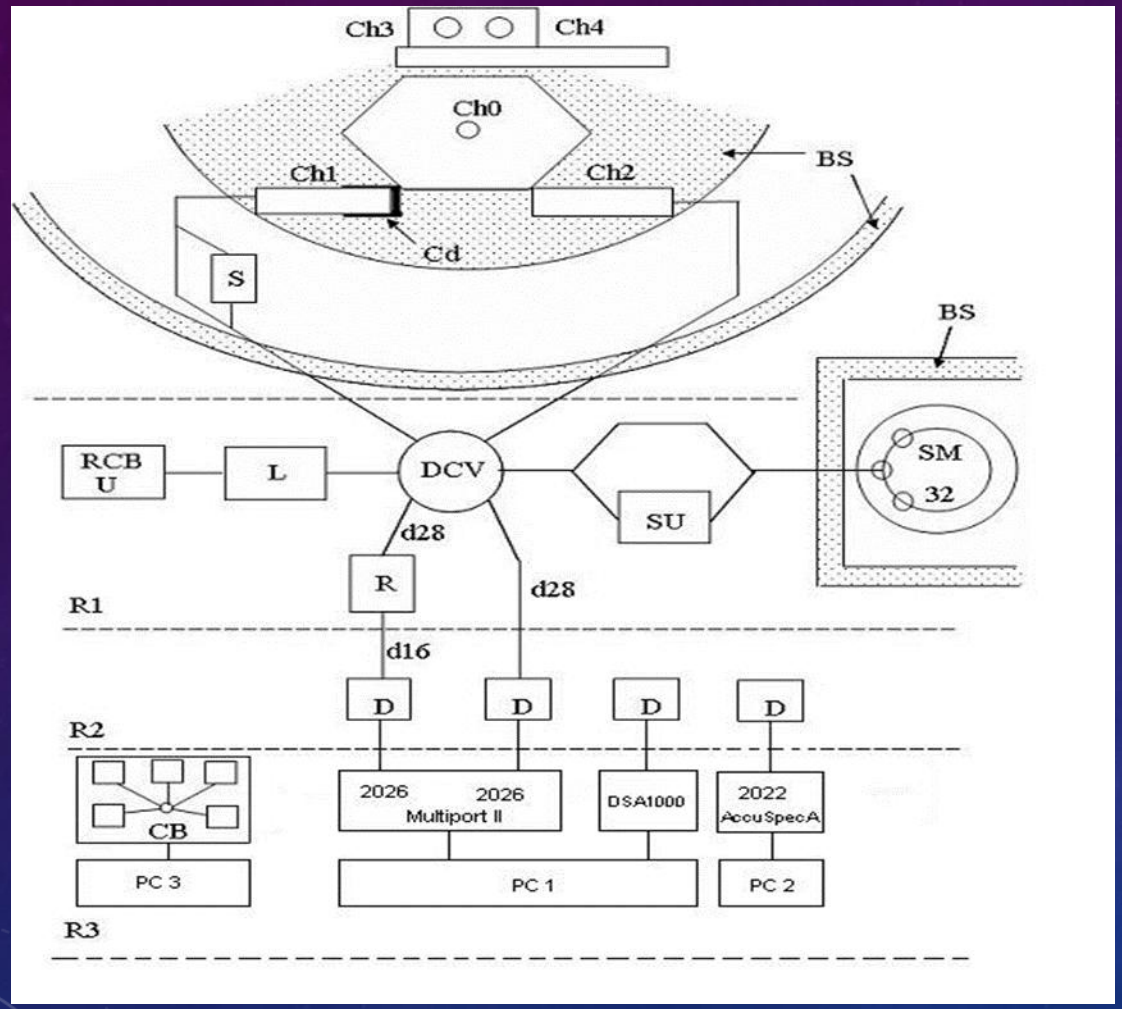


IBR-2 Reactor



- Average power 2 MW
- PuO_2 fuel
- ^{252}Cf
- Neutron density flux:
  ~ 10^{16} n/cm^2/s

Radioanalytical complex REGATA



Ch1-Ch4: Irradiation channels

S: storage (intermediate)

DCV: Directional Control Valves

L: Loading unit

RCB: Radiochemical glove-cell

U: Unloading unit

SU: Separate unit

SM: Storage Magazine

R: Repacking unit

D: Detector

CB: Control Board

R1-R3: Rooms location of the system

Analysis of Samples

Sample Irradiation

↓

Decay Time

↓

Measurements (HP Ge detector)

↓

Gamma-Ray spectra processing (Genie2000)

↓

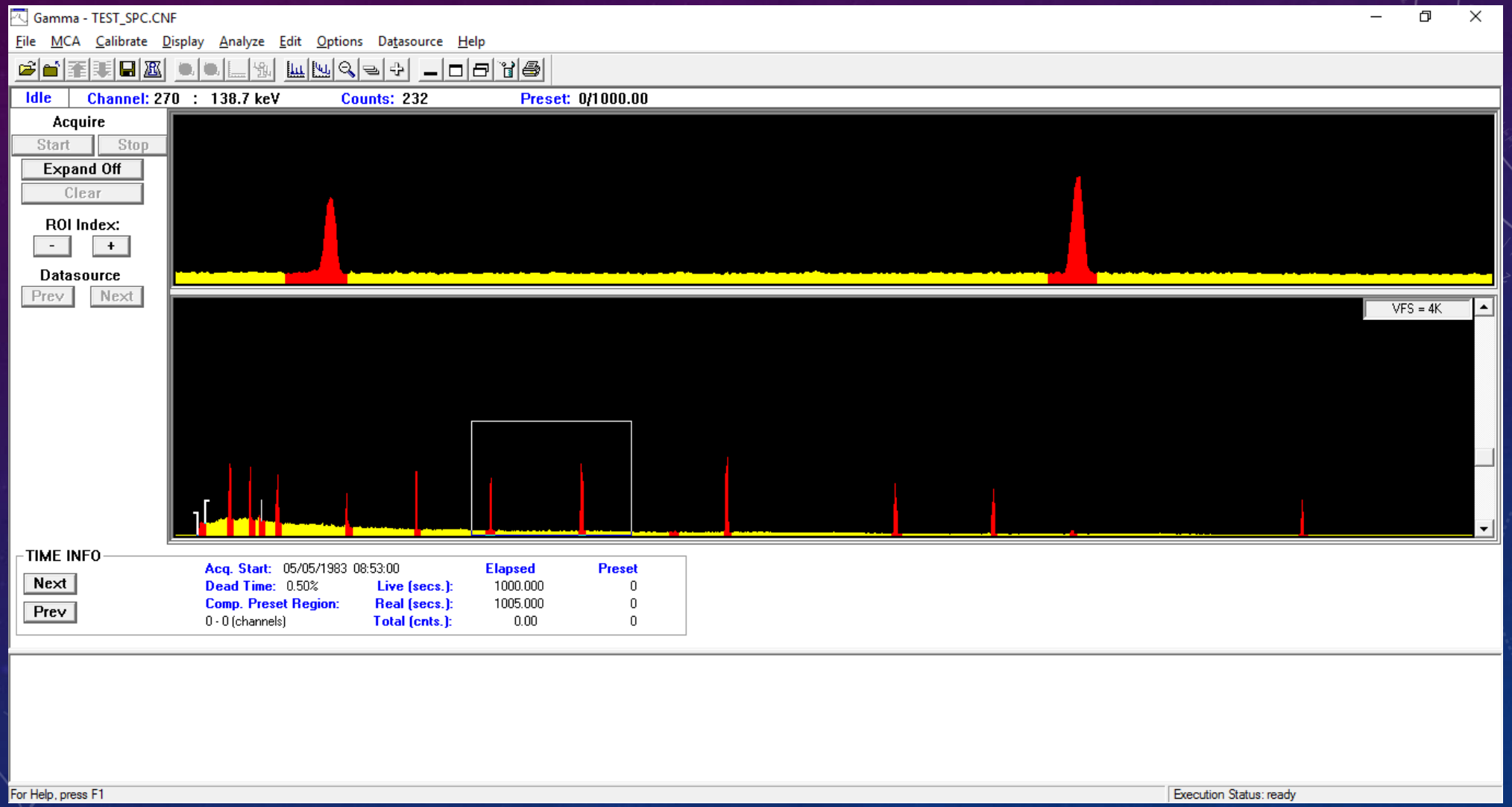
Determination of Elemental Content

Processing of Gamma-Ray Spectra

A full computer spectrum analysis includes 3 steps

1. **Set up data libraries for energy, peak width and efficiency calibration and for sample analysis.**
2. **Use spectra of reference sources to generate energy, width and efficiency calibration data files**
3. **Analyze sample spectra by referring to those data libraries and calibration files.**

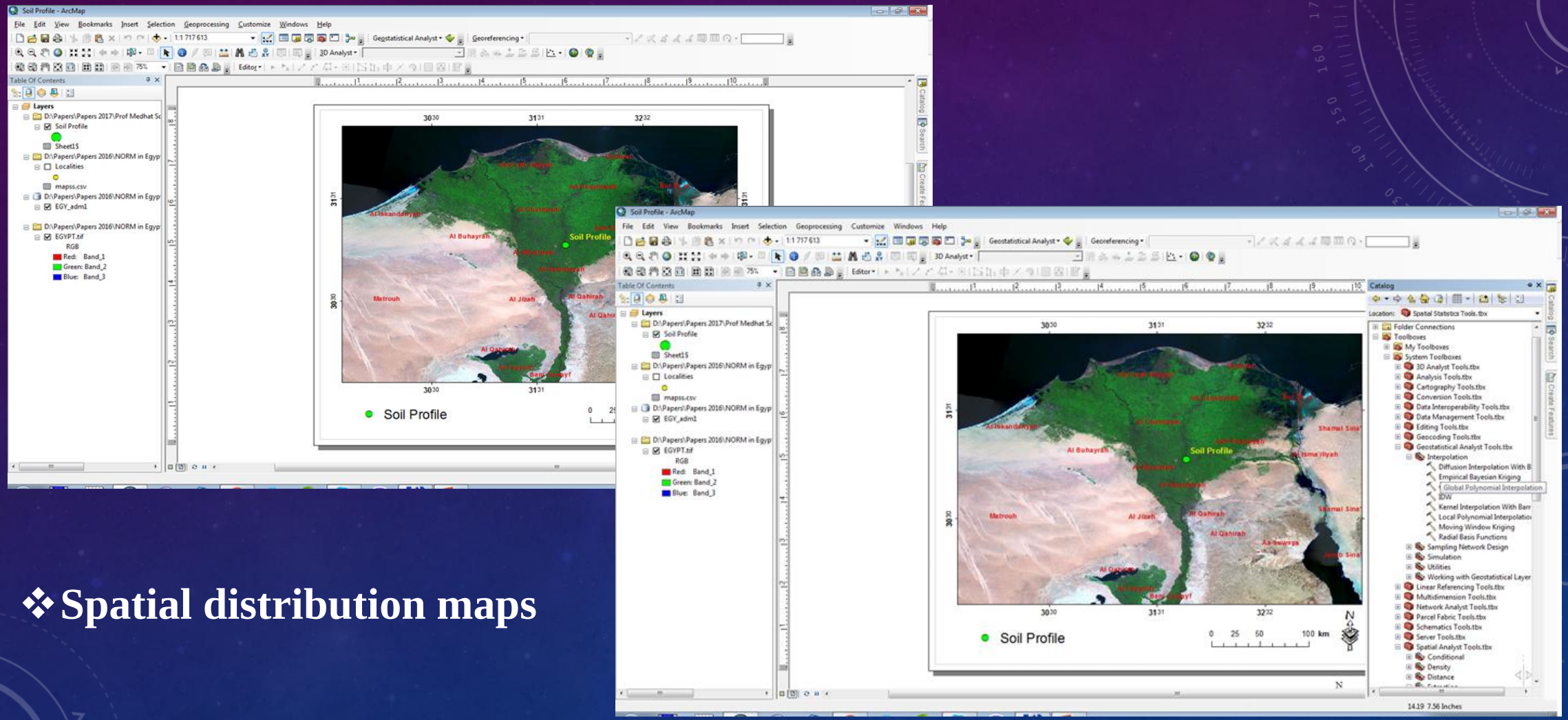
Genie2000


Gamma - TEST_SPC.CNF
File MCA Calibrate Display Analyze Edit Options Datasource Help
Idle
Channel: 270 : 138.7 keV
Counts: 232
Preset: 0/1000.00
Acquire
Start
Stop
Expand Off
Clear
ROI Index:
-
+
Datasource
Prev
Next
VFS = 4K
TIME INFO
Next
Prev
Acq. Start: 05/05/1983 08:53:00
Dead Time: 0.50%
Comp. Preset Region:
0 - 0 (channels)
Live (secs.):
Real (secs.):
Total (cnts.):
Elapsed
Preset
1000.000
0
1005.000
0
0.00
0
For Help, press F1
Execution Status: ready

Most Common Programmes Used For Data Interpretation

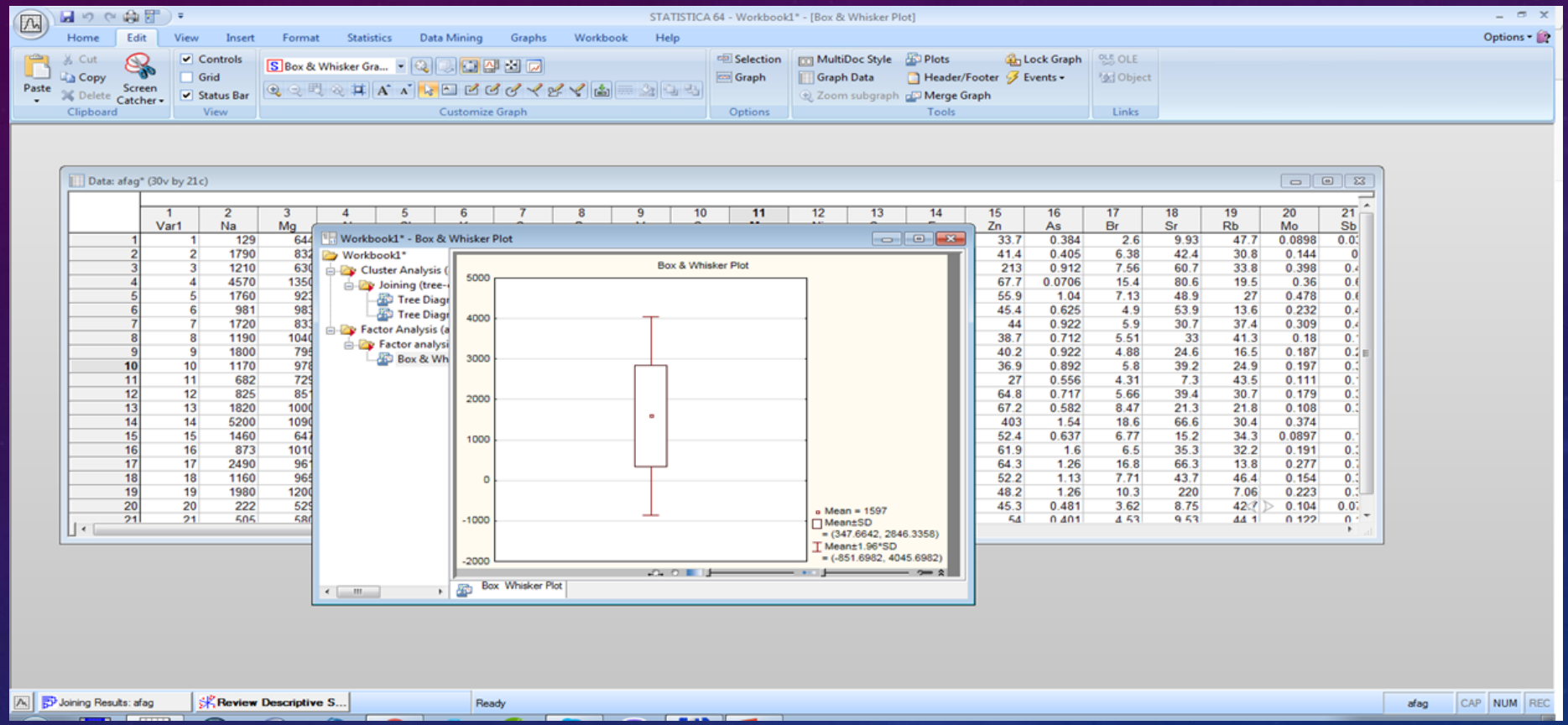
- ArcGIS
- Statistica
- Origin-Lab
- CorelDraw

ArcGIS



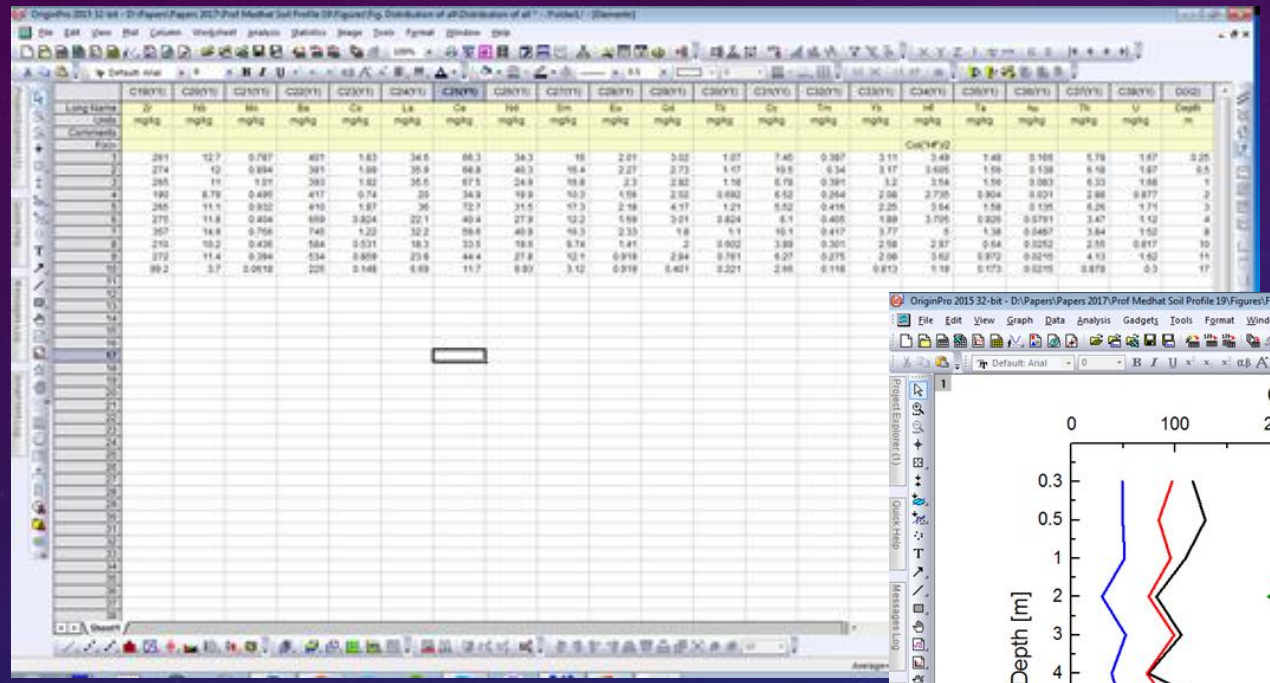
❖Spatial distribution maps

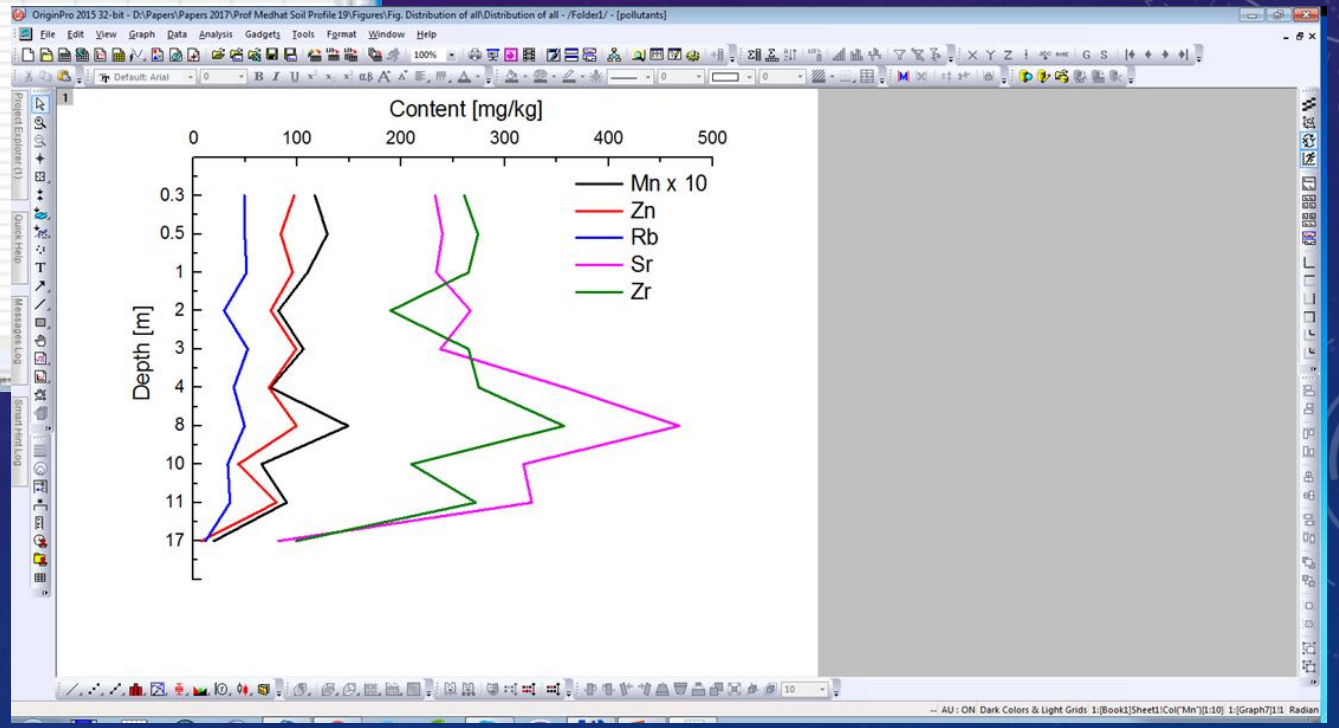
Statistica



- ❖ **Principal component analysis (PCA)**
- ❖ **Graphing**

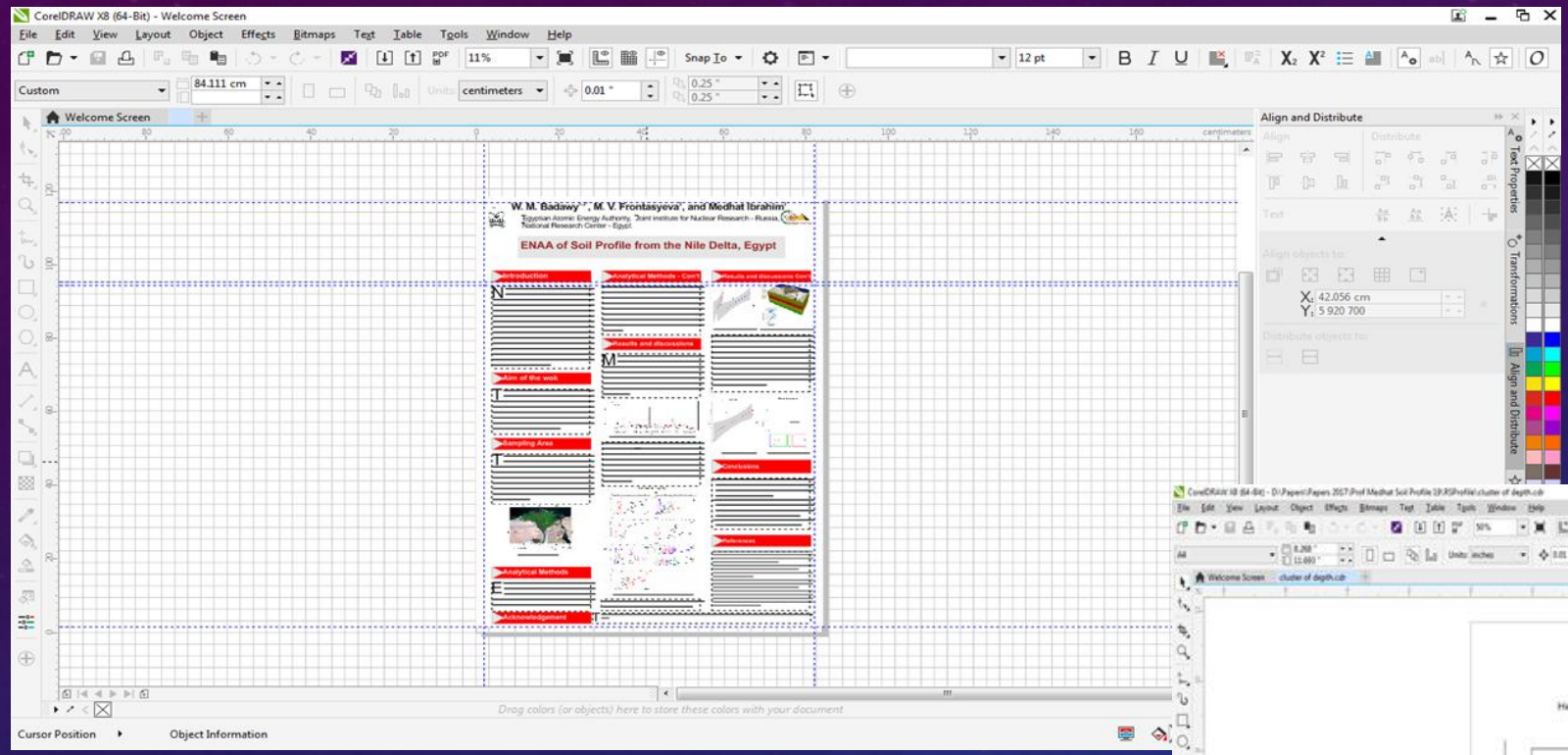
Origin-Lab

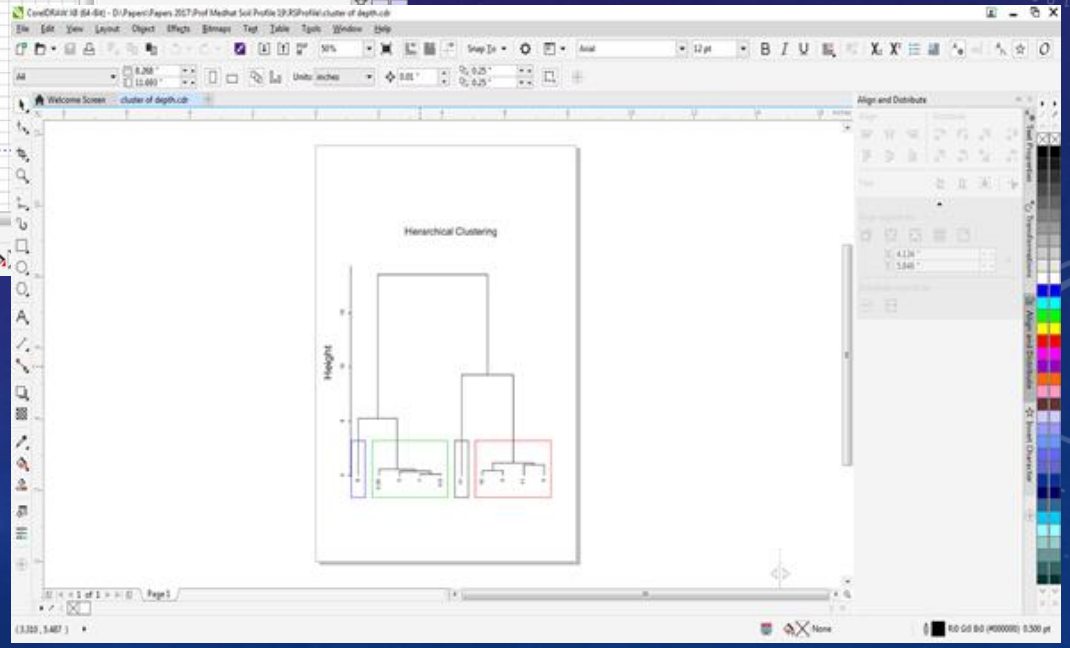




❖Plotting and fitting

CorelDraw





❖Graphic management and posters

NAA + AAS

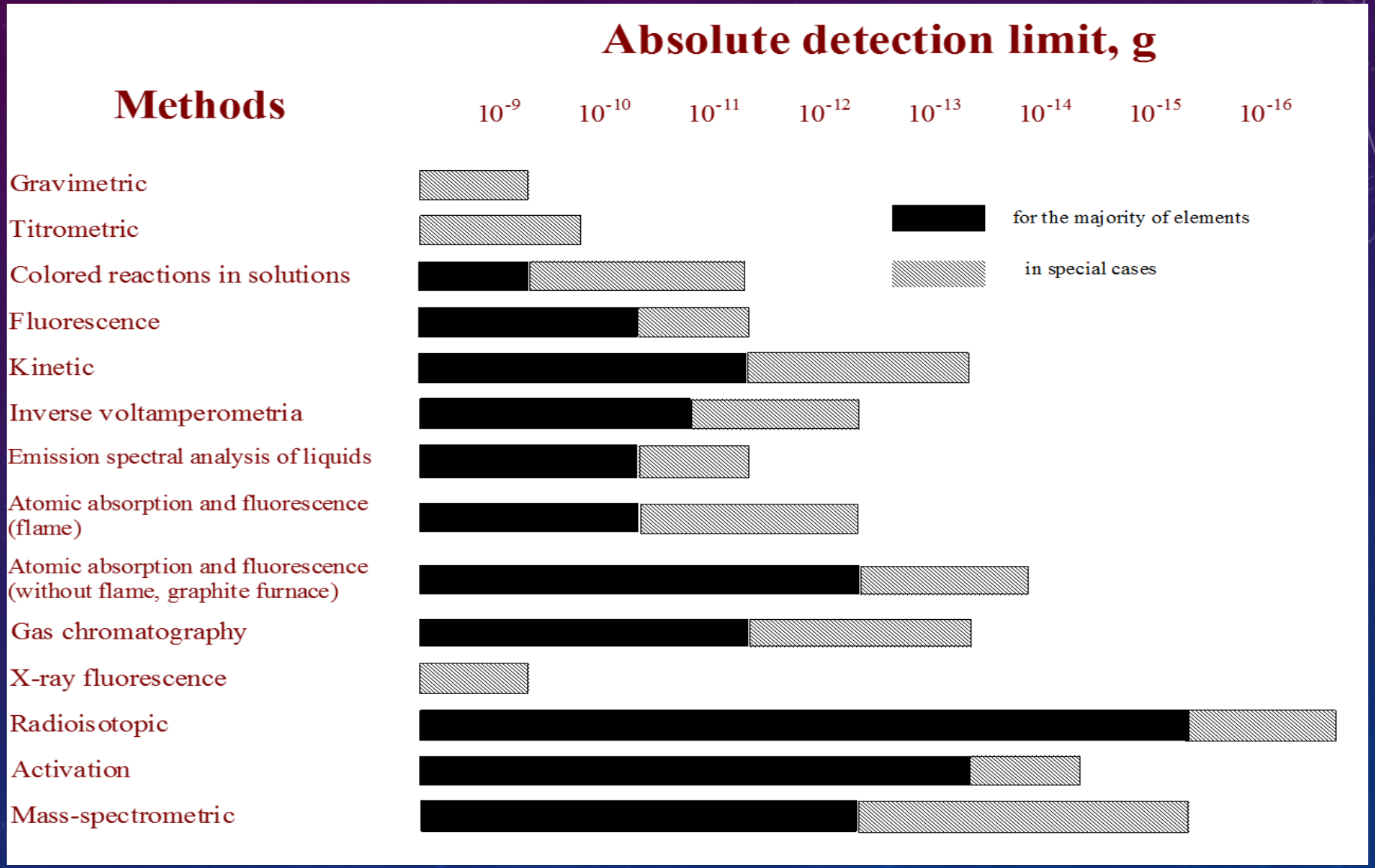
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	*Cu*	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	*Cd*	In	Sn	Sb	Te	I	Xe
Cs	Ba	La*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	*Pb*	Bi	Po	At	Rn
Fr	Ra	Ac**											Rf	Db	Sg	Bh	Hs

*	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

~ 55 elements

How Powerful is this Analytical Technique?



Advantages

- Primary Analytical Technique
- Wide possibilities of applications
- Non-destructive Analysis
- Multi-element Analysis
- High Sensitivity and Precision
- Limited sample handling
- Simultaneous identification of elements
- Low temperature operation (30-70°C)
- The Chemical form and Physical State of the Elements do not Influence the Activation and decay Process

ANALYTICAL INVESTIGATIONS AT IBR-2 REACTOR

Life Sciences

- Biomonitoring of atmospheric deposition of heavy metals and other elements (Project REGATA)
- Assessment of different ecosystems and their impact on human health
- Analysis of extraterrestrial materials

Material Science

- NAA for technological process of synthesis of diamonds.
- Bio-nano-technologies: synthesis of nanoparticles (Ag, Au, Se, Ti, etc.).
- Materials of high purity.
- Analysis of archaeological and museum objects from Russia and other countries

OUTCOMES

- Neutron Activation Analysis (NAA) is a useful method for the simultaneous determination of elemental composition of geological, environmental and biological samples in mg/kg range. It is a powerful analytical tool for monitoring and sustainability studies.

- Data analysis yields concentrations of major, minor, trace and rare earth elements.

- Multi-disciplinary applications (Physics, Chemistry, Biology, Ecology, Soil Science, Material Science, etc.)

- We have learned sample preparation for NAA in the Chemistry Lab. and have enriched our knowledge in this all-important field.

CAPACITY BUILDING

Is this Programme Achieving its Purpose?

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

- The practice provides South African students, who will transfer the nuclear technology, to support the development of the entire country.

SA-JINR COLLABORATION FLNP PROJECTS SO FAR

- **Atmospheric Deposition of Trace Elements in the Western Cape, South Africa, Studied with the Biomonitoring Technique, NAA, ICP-MS and GIS Technology**

- **Study on Levels of Priority Aquatic Pollutants in South African Cultivated Bivalve Mollusks ("The South African Mussel Watch")**

- **Use of INAA to Determine Rare Earth Element Contents in Different Fresh and Weathered South African Fly Ash**

- **Elemental Composition of Fly Ash: A Comparative Study Using Nuclear and Related Analytical Techniques**

Chucks P. Eze, Olanrenwaju FATOBA, Godfrey MADZIVIRE, Tatyna OSTROVNAYA, Leslie F. PETRIK, Marina FRONTASYEVA and Alexander NECHAEV (2013)

Acknowledgements

- Prof. Marina V. Frontasyeva
- Dr. Wael Badawy

Also special thanks to all staff of the Neutron Activation Analysis and Applied Research Unit, Frank Laboratory of Neutron Physics.

WE LOVE YOU ALL!!!

THANK YOU FOR YOUR ATTENTION!

Questions?