أكاديمية البحث العلمي والتكنولوجيا
Academy of Scientific Research & Technology

JOINT INSTITUTE FOR NUCLEAR RESEARCH

Neutron Activation Analysis for Life Sciences

INTERNATIONAL STUDENTS' PRACTICE 2017, JINR, DUBNA

Frank Laboratory of Neutron Physics

The Sector of Neutron Activation Analysis and Applied Research

Fatma Said
Ain-shams University

Mohamed El-Henawey
Mansoura University

Yasmine Sarhan
Minufiya University

Said Moawad
Egyptian Atomic Energy Authority

Fatma Shafiek
Minufiya University

Moushira Saleh
Assiut University

Reem Mohammed
Ain-shams University

JOINT INSTITUTE
FOR NUCLEAR RESEARCH

Contents

JOINT INSTITUTE
FOR NUCLEAR RESEARCH

1. Introduction

Founder of FLNP

FRANK LABORATORY OF NEUTRON PHYSICS
JOINT INSTITUTE FOR NUCLEAR RESEARCH 1956

- Ilrja Mikhailovich Frank (1908-1990)
- The Nobel Prize winner in Physics
- Stalin prize in 1946 and 1953 and the USSR state prize in 1971.

What is NAA?

JOINT INSTITUTE
FOR NUCLEAR RESEARCH

- Neutron activation analysis is an isotope specific analytical technique for the qualitative and quantitative determination of elemental content.

- NAA was discovered in 1936

G. Hevesy

H. Levi

JOINT INSTITUTE
FOR NUCLEAR RESEARCH

2. Physical concepts

What is Neutron Activation Analysis ??

JOINT INSTITUTE
FOR NUCLEAR RESEARCH

Neutron activation analysis (NAA) : is a non destructive nuclear process used for

1- determining the concentrations of elements in a vast amount of materials.

2- determining the elemental composition of materials

NAA Principle

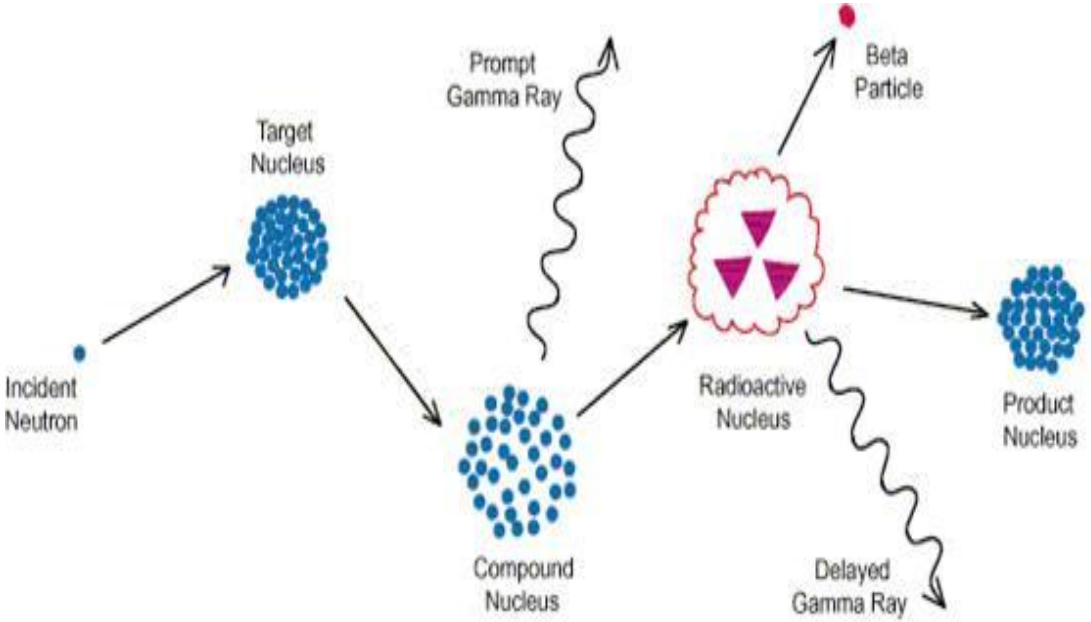
JOINT INSTITUTE
FOR NUCLEAR RESEARCH

NAA relies on irradiation by neutrons so that the treated sample will be excites then it de-excites emitting gamma-rays (prompt). The resulted sample is radioactive so *it emits Negative Beta and Gamma ray to turn into stable isotope*.

The second Gamma ray is our purpose.

It allows the precise identification and quantification of the elements, above all of the trace elements in the sample.

The study spectra of the emissions of the radioactive sample allows the identification of the element. By knowing the Energy of Gamma ray we can determine the element and number of Gamma rays emitted is correlated to the number of elements in the sample.

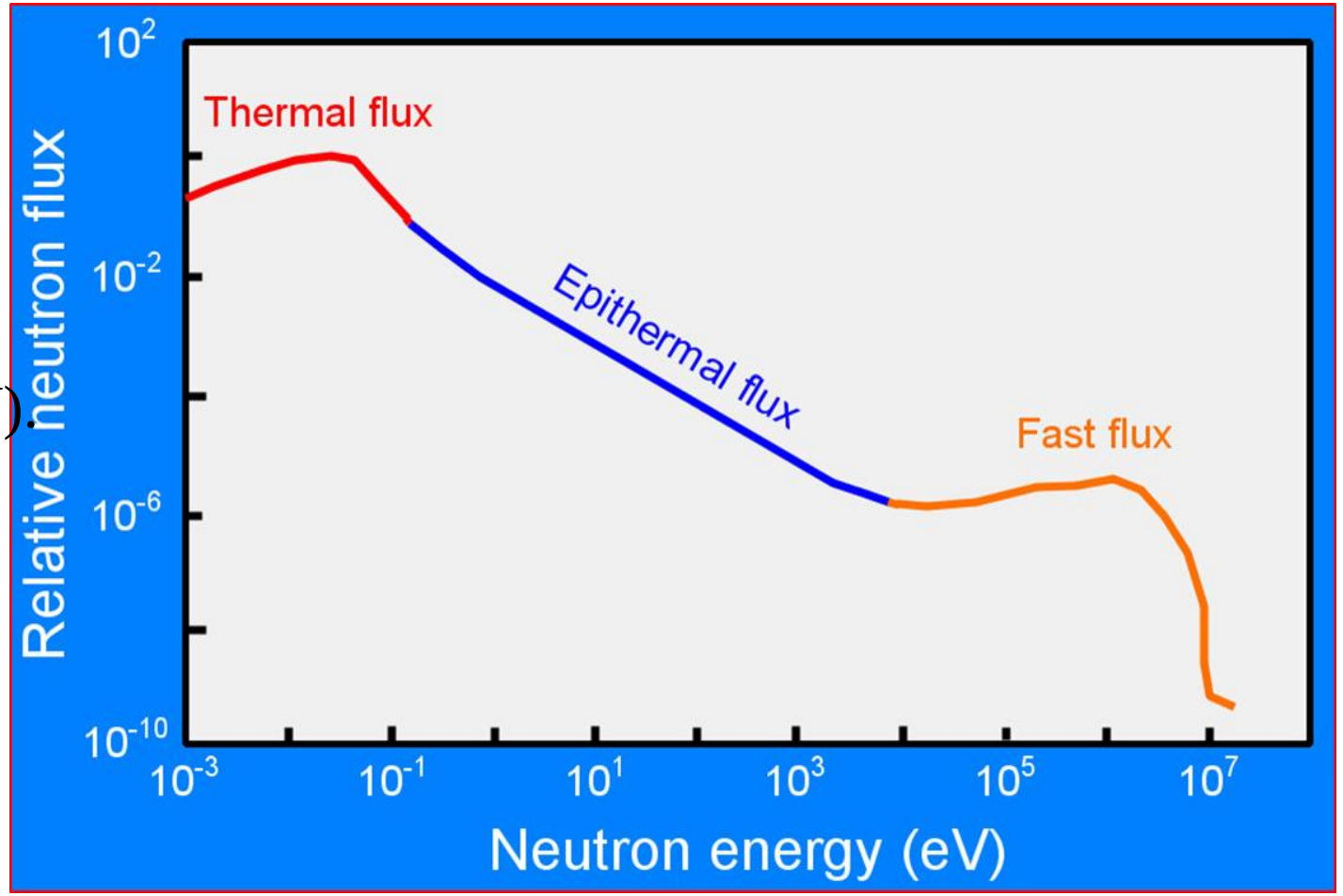


NAA Principle

JOINT INSTITUTE
FOR NUCLEAR RESEARCH

The Neutrons used in irradiation can be thermal or epithermal neutrons

- **Thermal neutrons** (0.025 eV).
- **Epithermal neutrons** (0.025 eV – 0.4 eV).
- **Fast neutrons** (1 MeV – 20 MeV).



Elements that may be analyzed via INAA include:

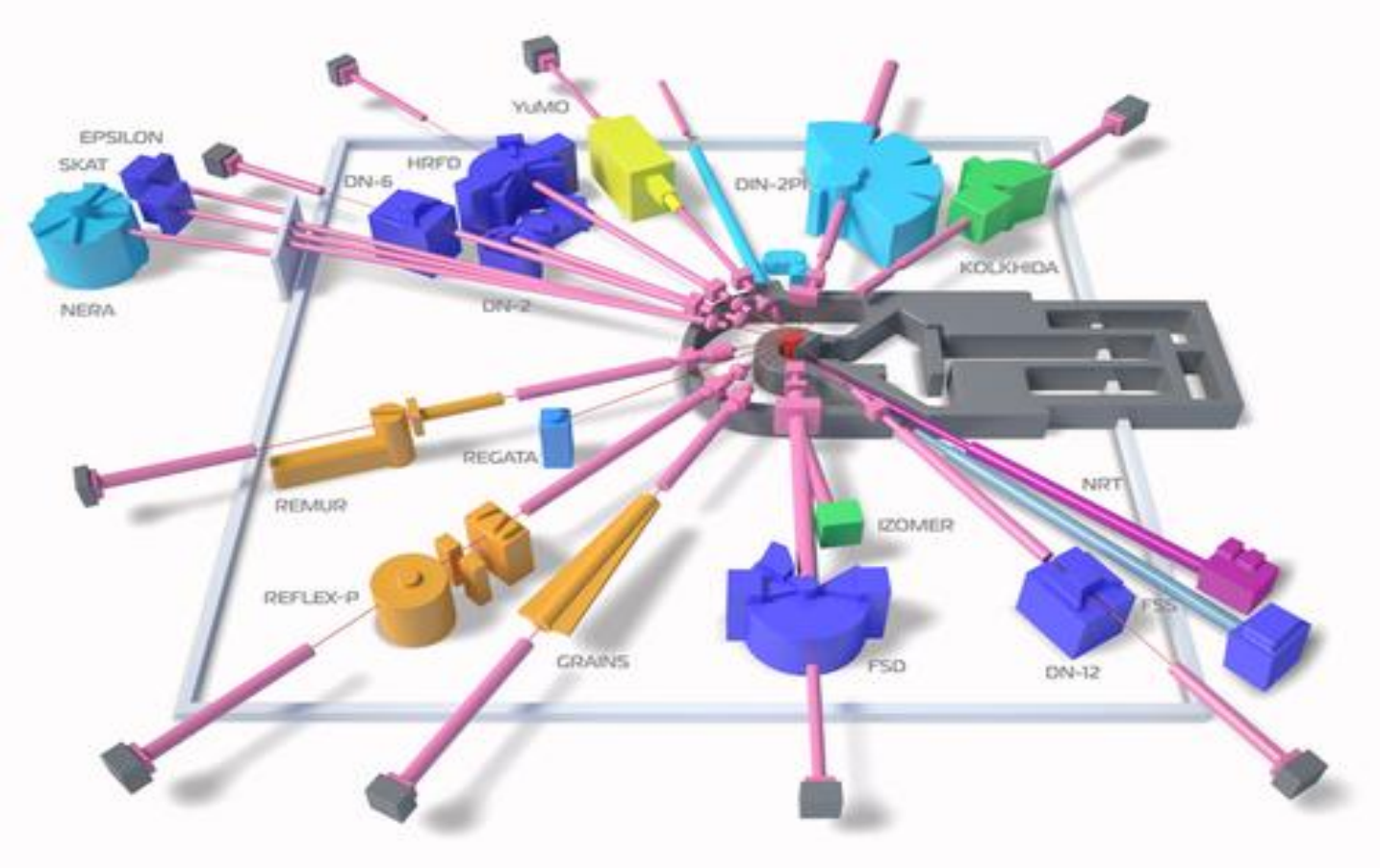
JOINT INSTITUTE
FOR NUCLEAR RESEARCH

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		

The IBR-2 Reactor

JOINT INSTITUTE
FOR NUCLEAR RESEARCH

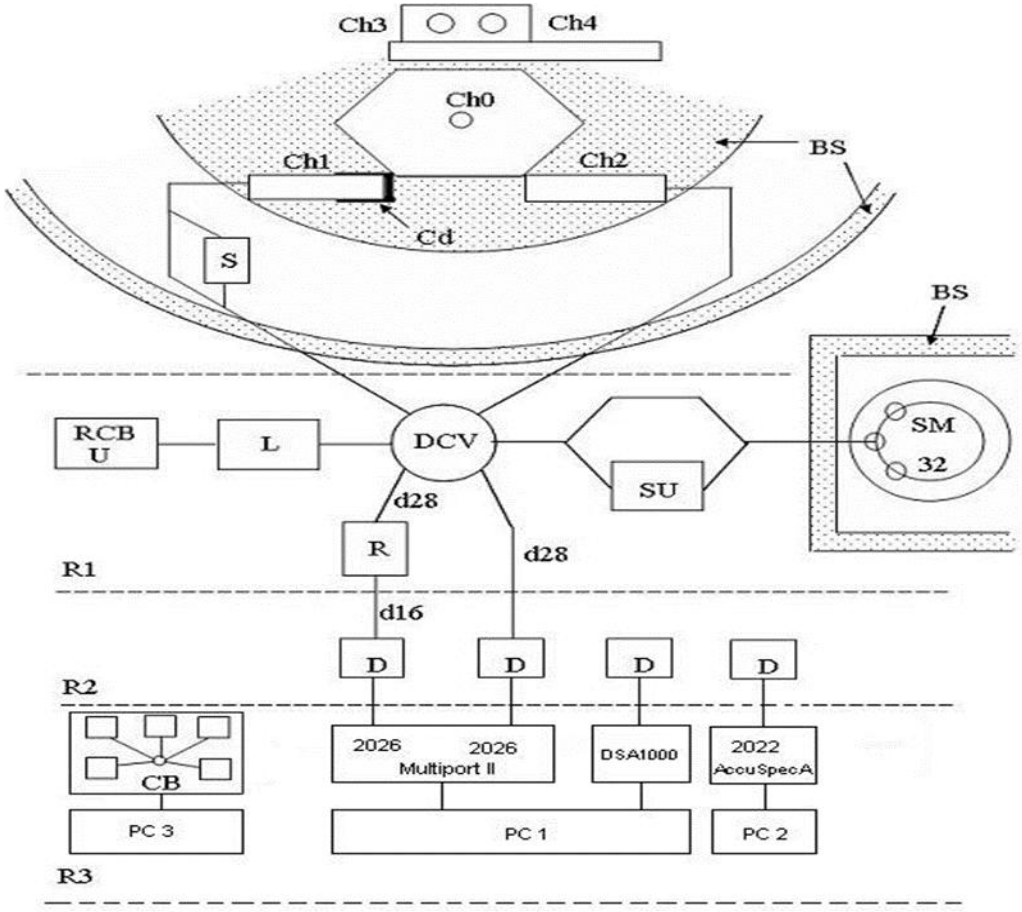
- Average power 2 MW
- PuO_2 fuel
- ^{252}Cf
- Neutron density flux ~ 10^{16} n/cm^2/s
- 9 cycles a year
- Each cycle = 12 days

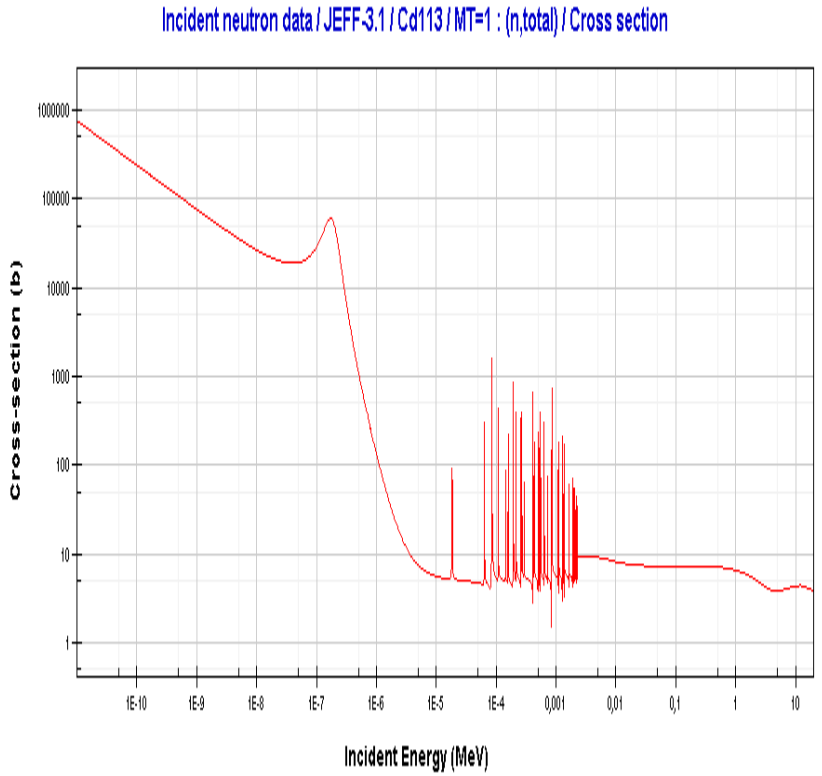


REGATA :

JOINT INSTITUTE
FOR NUCLEAR RESEARCH

Channel 1 and 2 are connected directly to the reactor core.
Ch1 : Cd screening .





Different Types of NAA

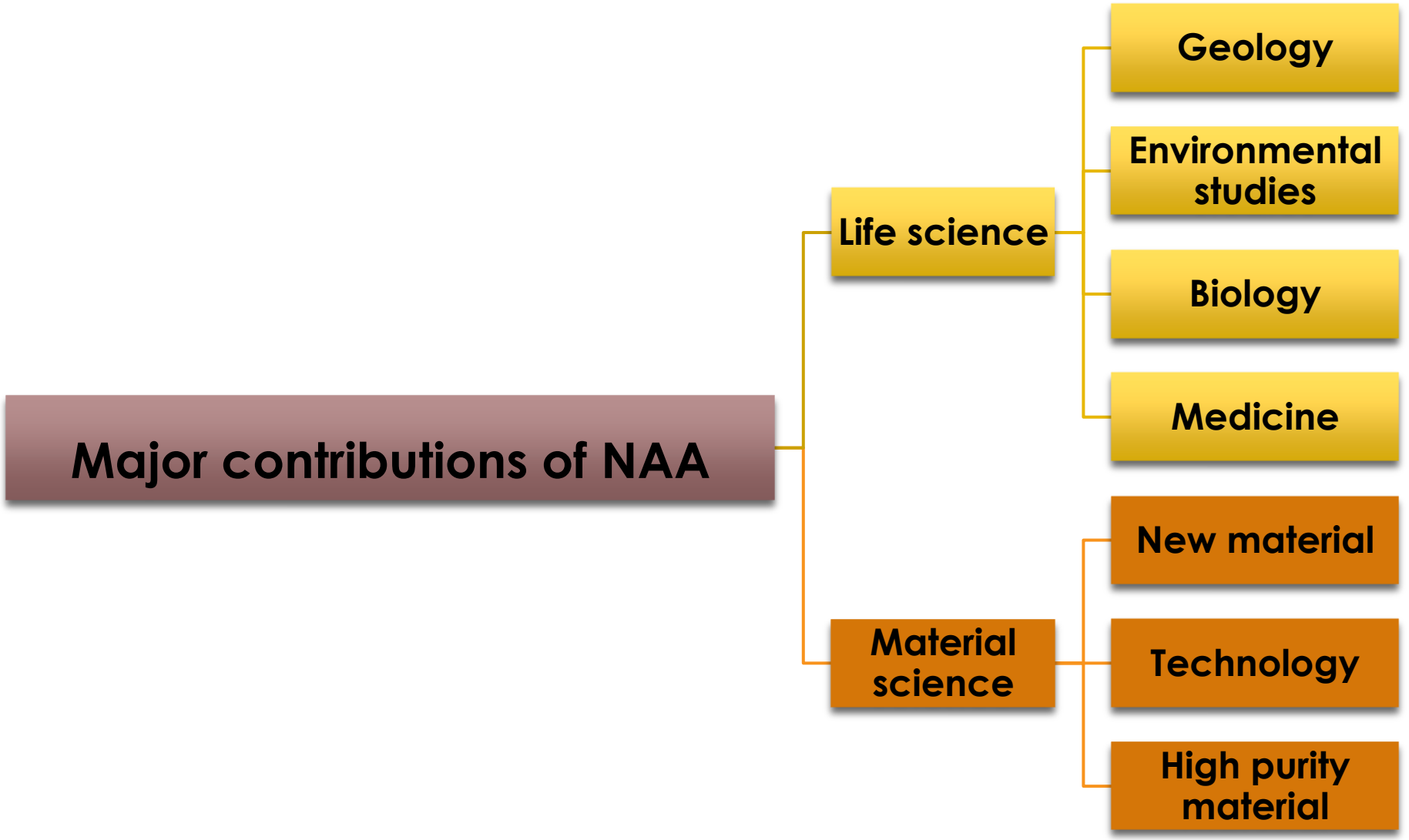
JOINT INSTITUTE
FOR NUCLEAR RESEARCH

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 of NAA

JOINT INSTITUTE
FOR NUCLEAR RESEARCH

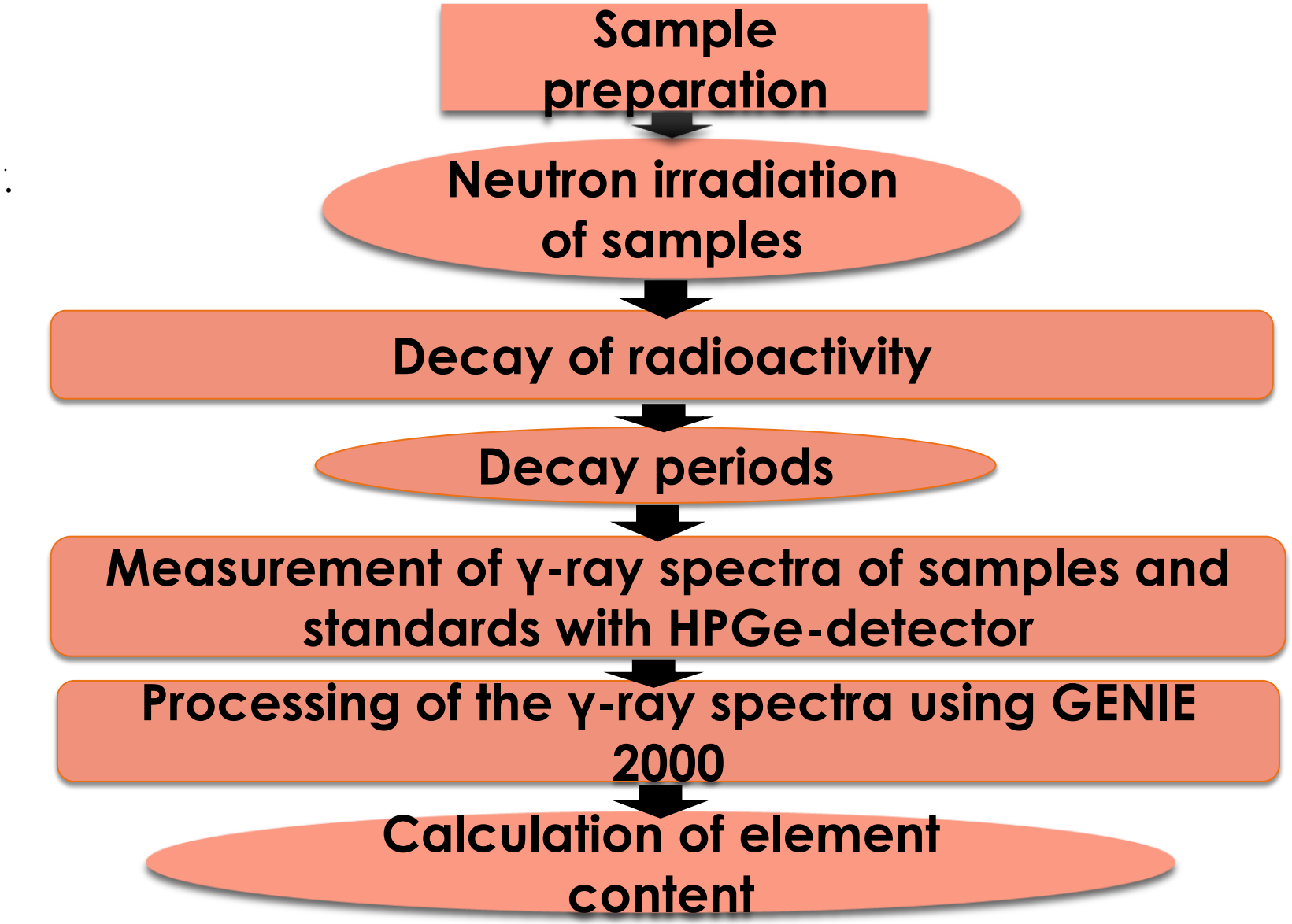


JOINT INSTITUTE
FOR NUCLEAR RESEARCH

3. Sampling and sample preparation

Measurement of content of samples

JOINT INSTITUTE
FOR NUCLEAR RESEARCH



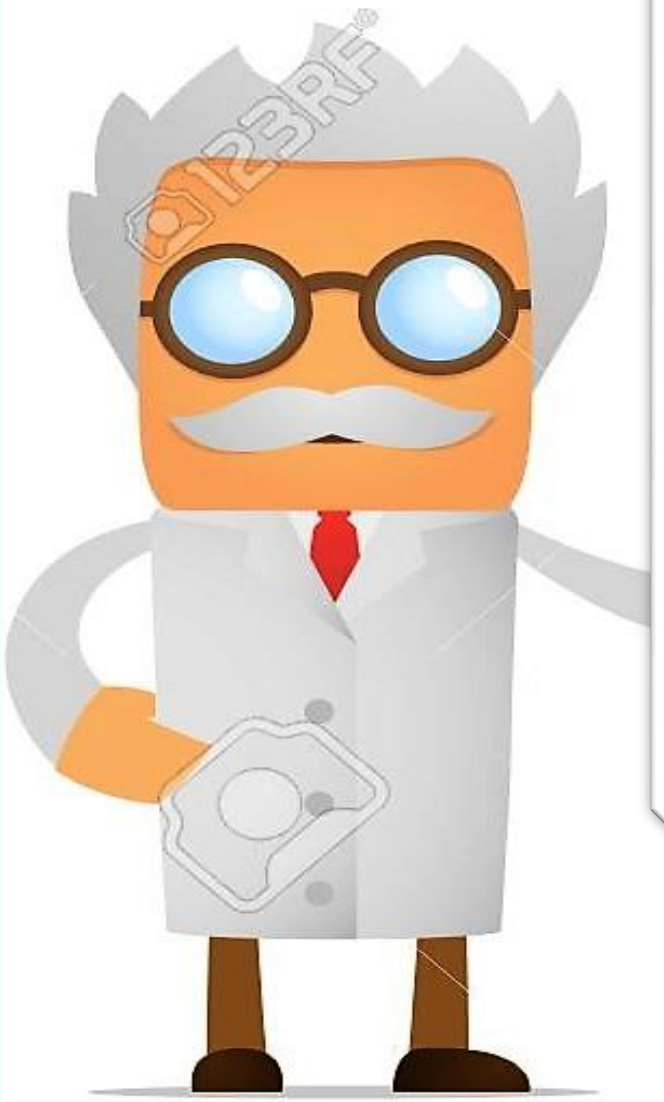
Types of samples and sample Collection

JOINT INSTITUTE
FOR NUCLEAR RESEARCH

- **Enviromental samples**
- **Geological samples**
- **Biological samples**
- **Liquids**
- **Foodstuffs, etc**

Environmental Sampling & Preparation

JOINT INSTITUTE
FOR NUCLEAR RESEARCH



Chemical laboratory of the dept. NAA and Applied Research and some equipment for sample preparation.

Drying

JOINT INSTITUTE
FOR NUCLEAR RESEARCH

- Temperature range 30-300^{0}C;
- Optimal temperature for NAA – 40^{0}C;
- Samples are dried till constant weight.

pelletizing

JOINT INSTITUTE
FOR NUCLEAR RESEARCH

Weighting and Packing

JOINT INSTITUTE
FOR NUCLEAR RESEARCH

For short irradiation

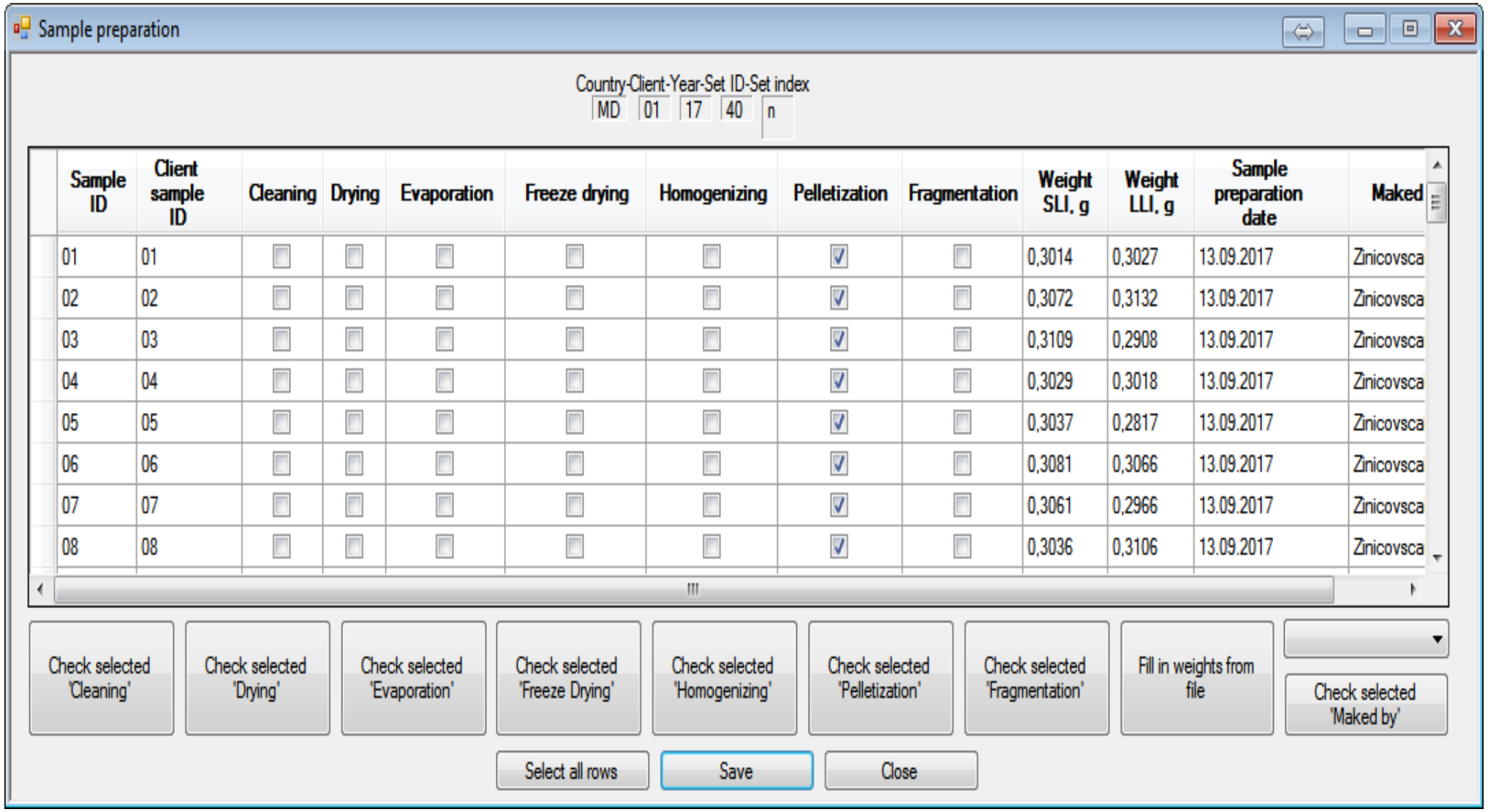
Standards packed
for short irradiation

For long irradiation

Standards packed
for long irradiation

Sample Preparation

JOINT INSTITUTE
FOR NUCLEAR RESEARCH



Irradiation of Samples

JOINT INSTITUTE
FOR NUCLEAR RESEARCH

Types of containers

Boxes for re-packing samples after irradiation

JOINT INSTITUTE
FOR NUCLEAR RESEARCH

4. Data processing and analyzing

Data processing and analyzing

JOINT INSTITUTE FOR NUCLEAR RESEARCH

- The accumulated spectra were analyzed for the isotopes radioactivity (μCi/g) using Genie 2000 by Canberra.

➢In general, a full computer spectrum analysis will consist of three phases:

(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, peak width and efficiency calibration data files.

(3) Analyze sample spectra by referring to those data libraries and calibration files.

Screenshot of Spectrum Analysis by Genie 2000

Gamma - TEST_SPC.CNF*

File MCA Calibrate Display Analyze Edit Options Datasource Help

Sample Title: GENIE-PC Spectrum No. 2
Nuclide Library Used: C:\GENIE2K\CAMFILES\STDLIB.NLB

..... IDENTIFIED NUCLIDES .....

Nuclide Name	Id Confidence	Energy (keV)	Yield (%)	Activity (uCi/Unit)	Activity Uncertainty
K-40	1.000	1460.81*	10.67	2.07669E+011	1.50873E+010
CO-57	0.999	122.06*	85.51	4.62033E+001	4.71397E+000
		136.48*	10.60	3.89136E+001	6.20410E+000
CO-60	1.000	1173.22*	100.00	1.08663E+003	4.61601E+001
		1332.49*	100.00	1.05537E+003	4.50689E+001
KR-85	0.999	513.99*	0.43	3.07903E+005	2.16921E+004
SR-85	0.989	513.99*	99.27	5.87540E+001	4.13949E+000
Y-88	0.995	898.02*	93.40	1.33658E+002	6.94523E+000
		1836.01*	99.38	1.01443E+002	4.36404E+000
CD-109	1.000	88.03*	3.72	1.40574E+003	1.49328E+002
SN-113	0.944	255.12	1.93		
		391.69*	64.90	8.83145E+001	7.28108E+000
CS-137	0.999	661.65*	85.12	6.63019E+003	4.08342E+002
CE-139	0.998	165.85*	80.35	3.50101E+001	3.35897E+000
HG-203	0.980	279.19*	77.30	3.19099E+001	2.68499E+000

* = Energy line found in the spectrum.
@ = Energy line not used for Weighted Mean Activity
Energy Tolerance : 1.000 keV
Nuclide confidence index threshold = 0.30
Errors quoted at 1.000 sigma

Interference Corrected Activity Report 12/22/2011 9:51:52 AM Page 2

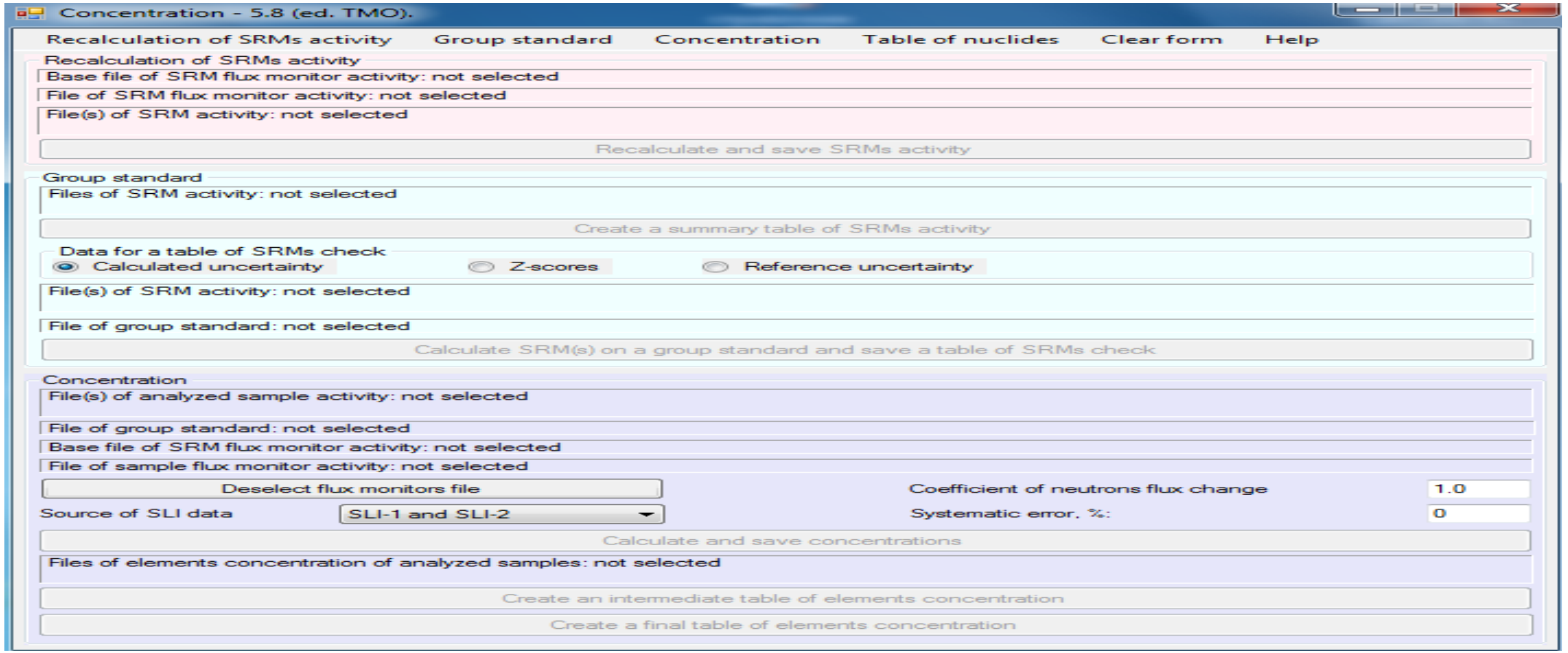
For Help, press F1 Execution Status: ready

EN 9:57 AM 12/22/2011

Screenshot of CalcConc Program

JOINT INSTITUTE FOR NUCLEAR RESEARCH

- A developed software **CalcConc** at the Neutron activation sector was used to calculate the content of the elements in (mg/kg).



Data plotting

JOINT INSTITUTE
FOR NUCLEAR RESEARCH

- **Geographic information system** (**GIS**) is a system designed to capture, store, manipulate, analyze, manage, and present spatial or geographic data.
- Maps in computer.
- Do you use GIS ?

QGIS

JOINT INSTITUTE
FOR NUCLEAR RESEARCH

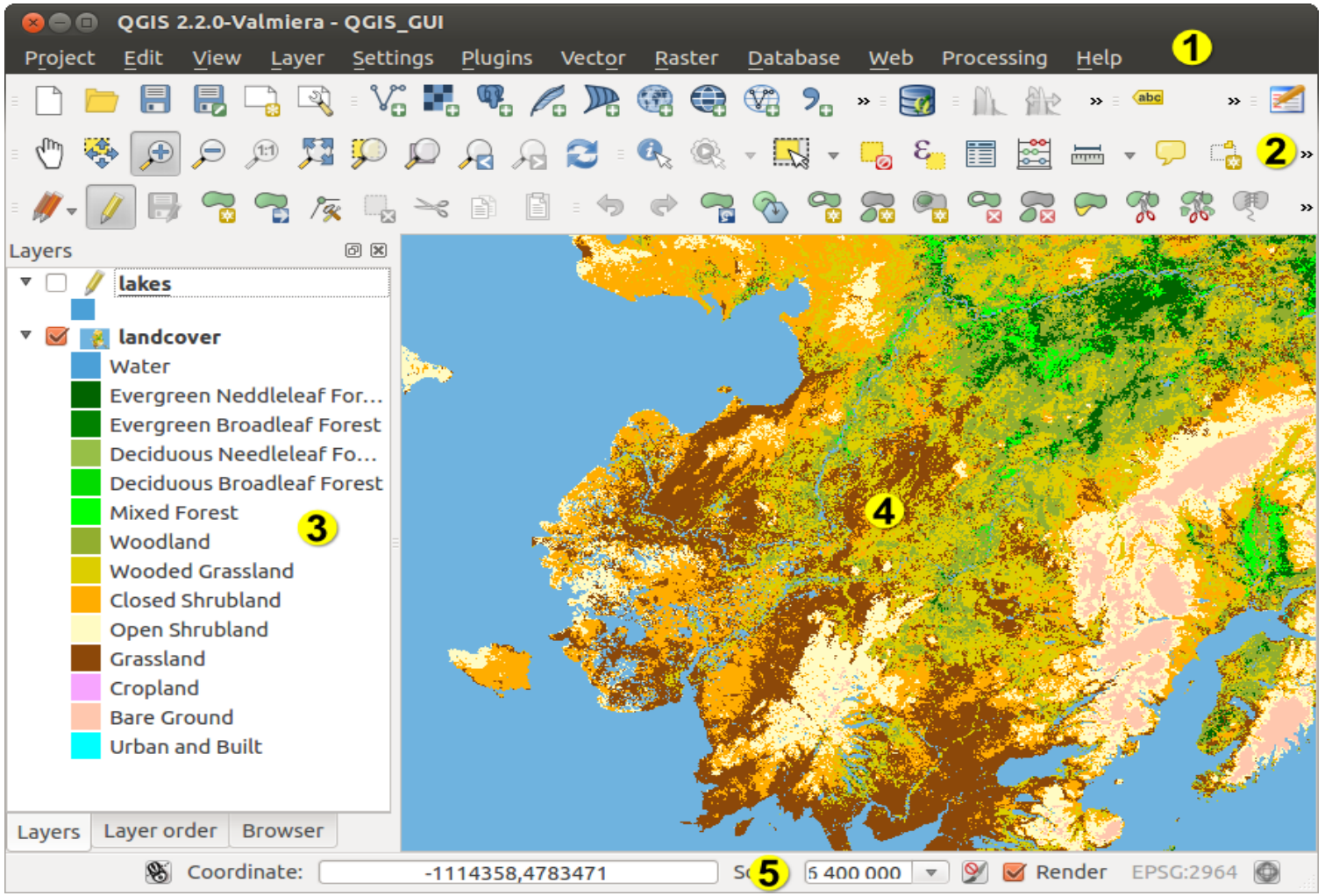
❖**Spatial distribution maps**

- **Advantage**

Big user base for free open-source

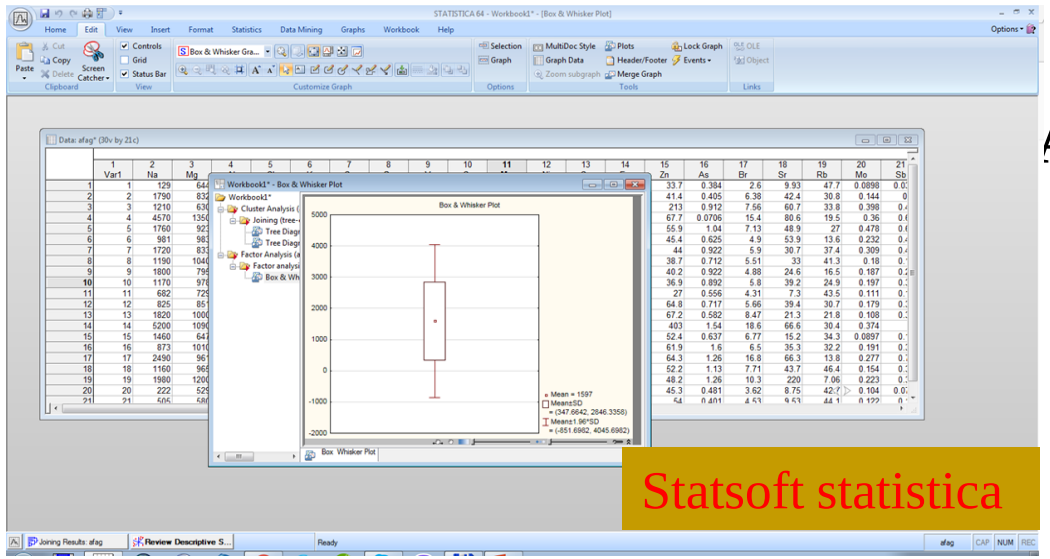
- **Limitation**

No 3D



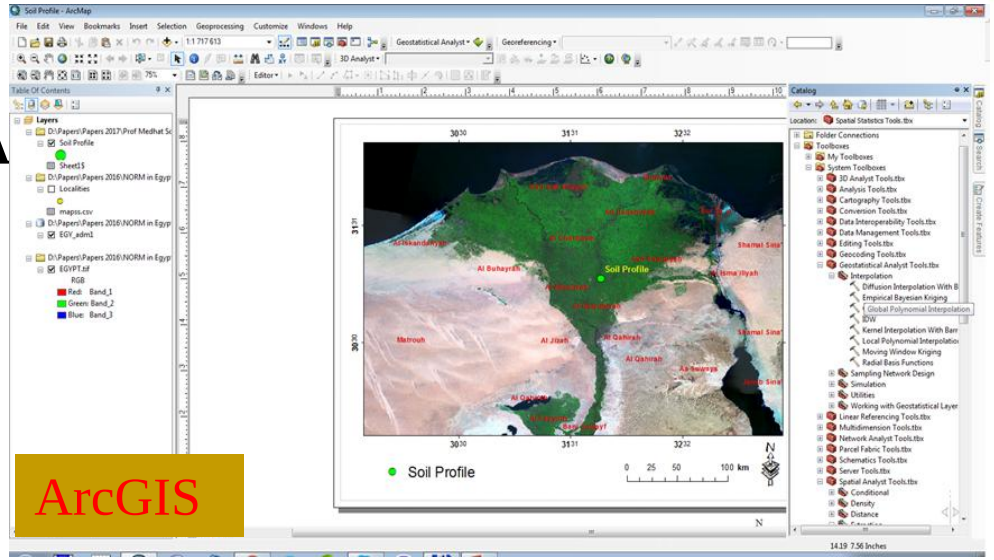
Used Software Packages in Analysis

JOINT INSTITUTE
FOR NUCLEAR RESEARCH

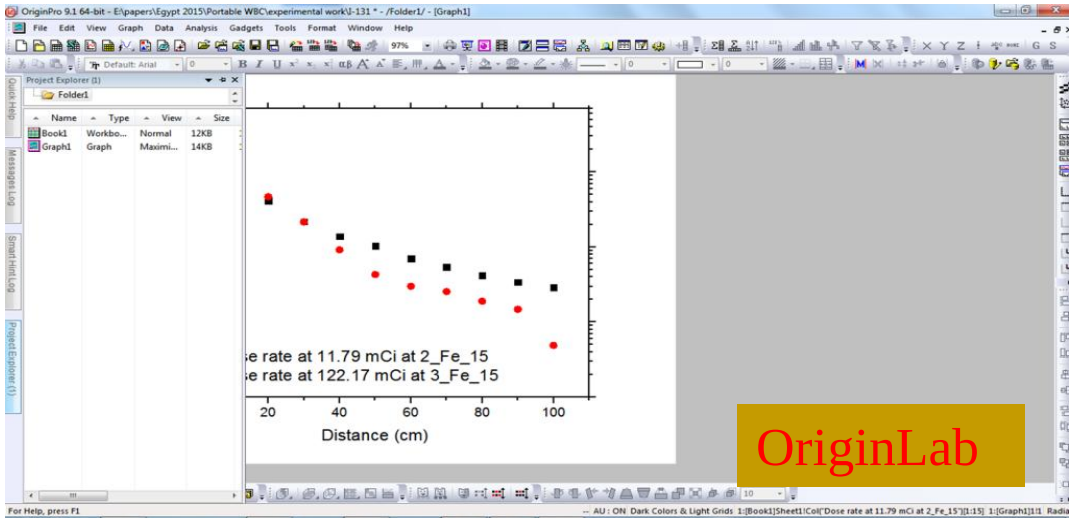


Statsoft statistica

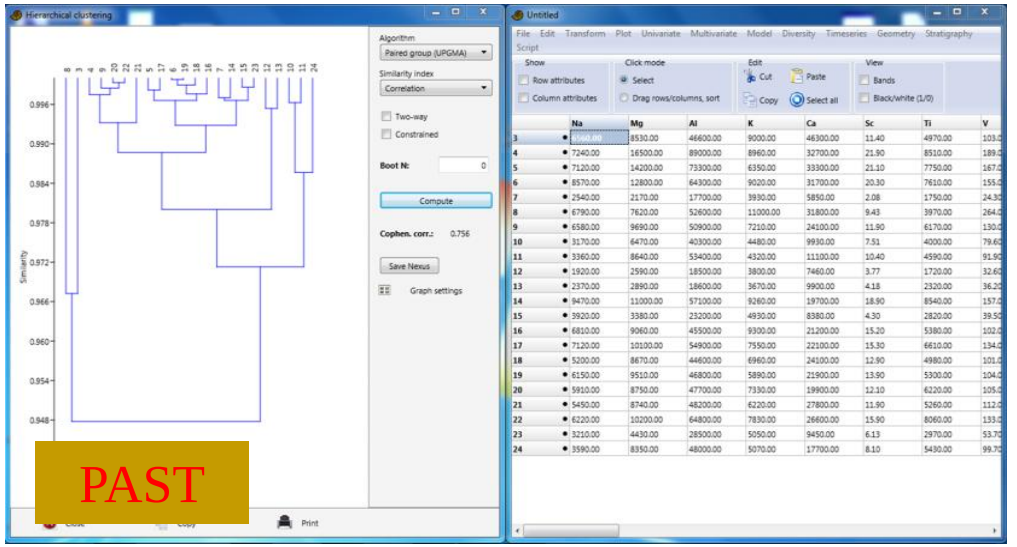
A



ArcGIS



OriginLab

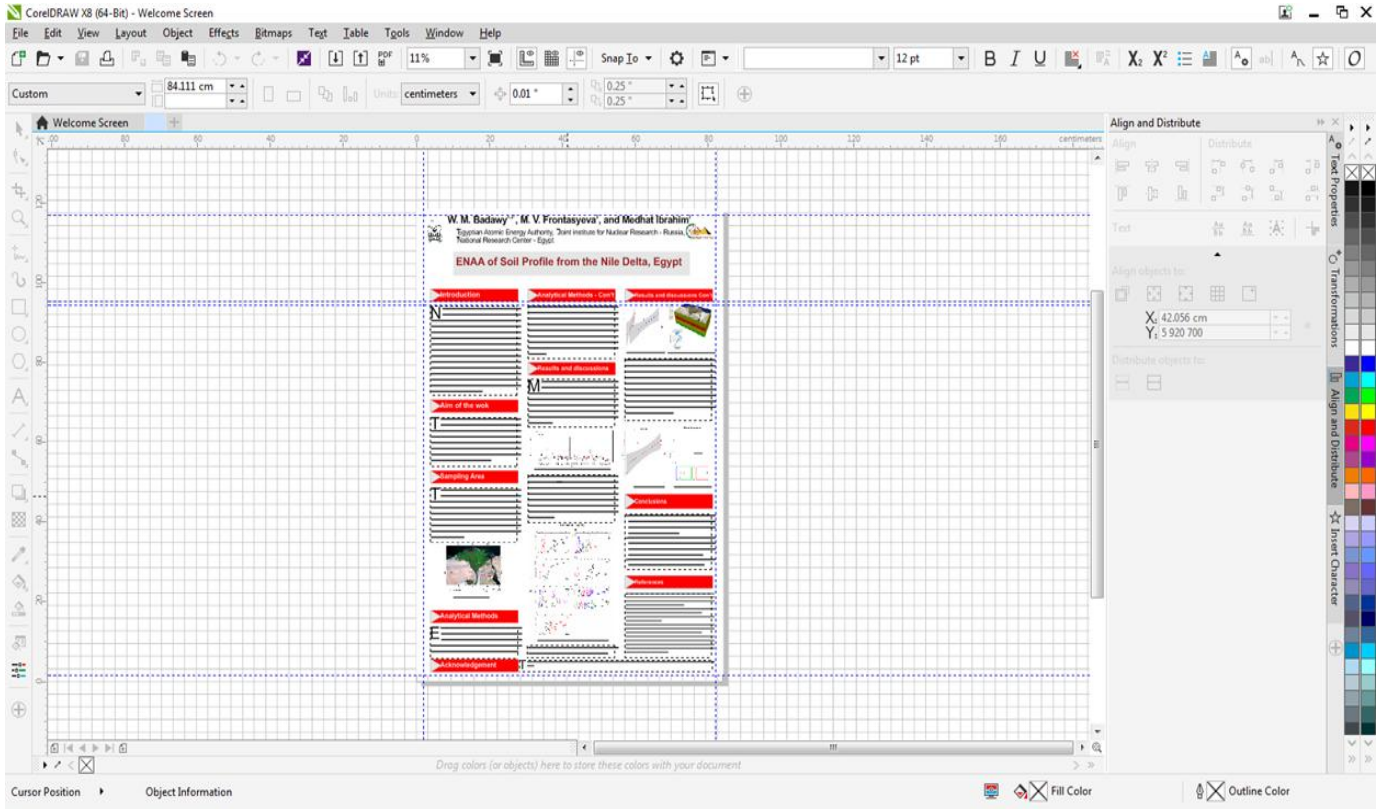


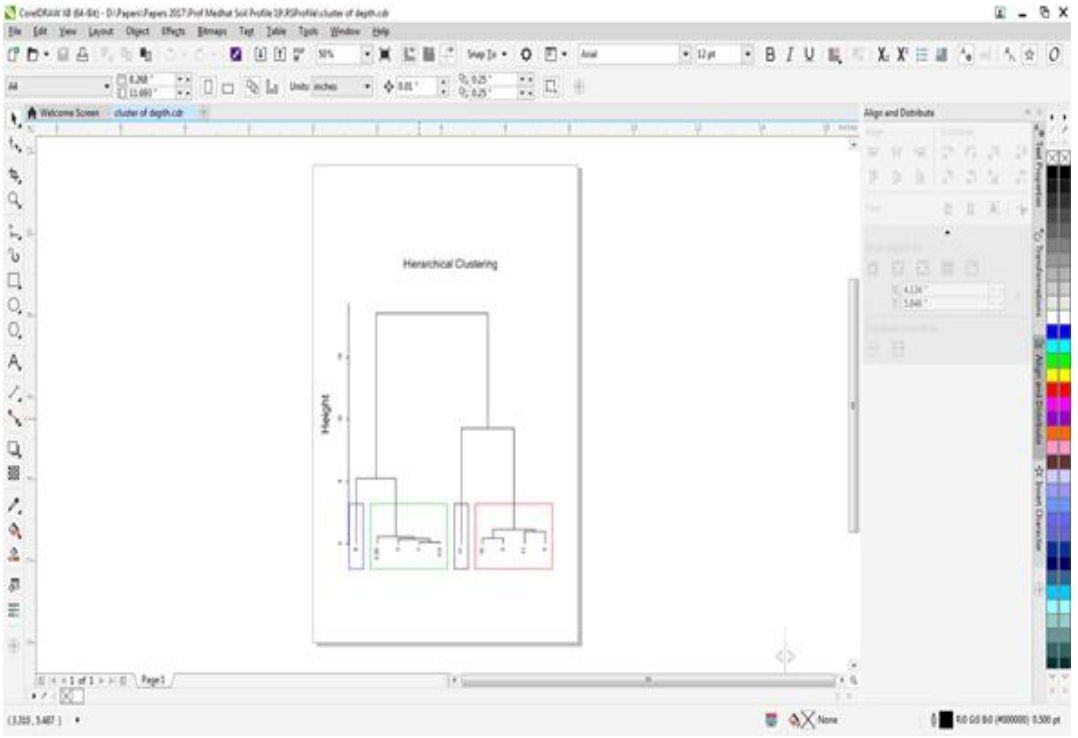
PAST

CorelDraw

JOINT INSTITUTE
FOR NUCLEAR RESEARCH

- **Graphic management and posters**





JOINT INSTITUTE
FOR NUCLEAR RESEARCH

5. Advantages and limitations

Advantages of using INAA for trace element analysis:

JOINT INSTITUTE
FOR NUCLEAR RESEARCH

- It is a multi-element technique capable of determining approximately 65 elements in many types of materials.

- It is non-destructive and therefore, does not suffer from the errors associated with yield determinations.

- It has very high sensitivities for most of the elements that can be determined by INAA – most detection limits range from ~0.05 to ~50 ppm (≤ 1 ppb for some high-purity materials).

- It is highly precise and accurate.

Limitations of using INAA for trace element analysis:

JOINT INSTITUTE
FOR NUCLEAR RESEARCH

- Irradiated samples by NAA will remain radioactive for a period of time.
- Radioactive samples require special handle and disposal protocols .
- The need for neutron source as reactor or neutron generator .

JOINT INSTITUTE
FOR NUCLEAR RESEARCH

6. General outcomes

Joint projects with Egypt

JOINT INSTITUTE
FOR NUCLEAR RESEARCH

- **The current joint projects with Egypt represented in:**

1. Assessment of the environmental situation in the basin of the **Nile River** using nuclear and related analytical techniques
2. Environmental studies in Egypt using neutron activation analysis and other analytical techniques

Joint projects with Egypt

JOINT INSTITUTE
FOR NUCLEAR RESEARCH

- **The Nile River was key to the development of the Egyptian civilization and still represent the most important source for the life on Egypt land.**

- **Recently, Civilization progress has led to the pollution of the Nile River and hence the Delta land.**

The goals of joint projects with Egypt

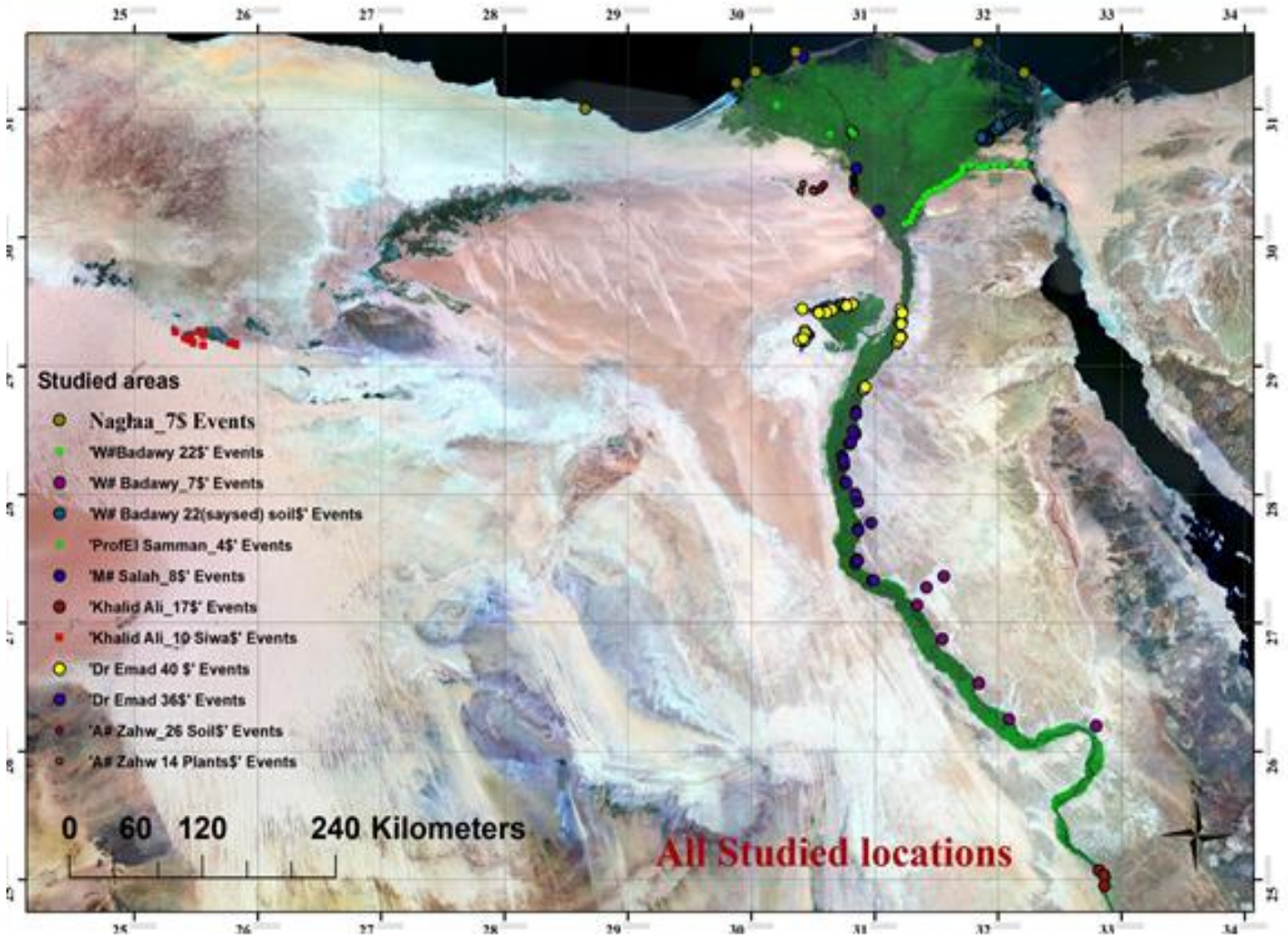
JOINT INSTITUTE
FOR NUCLEAR RESEARCH

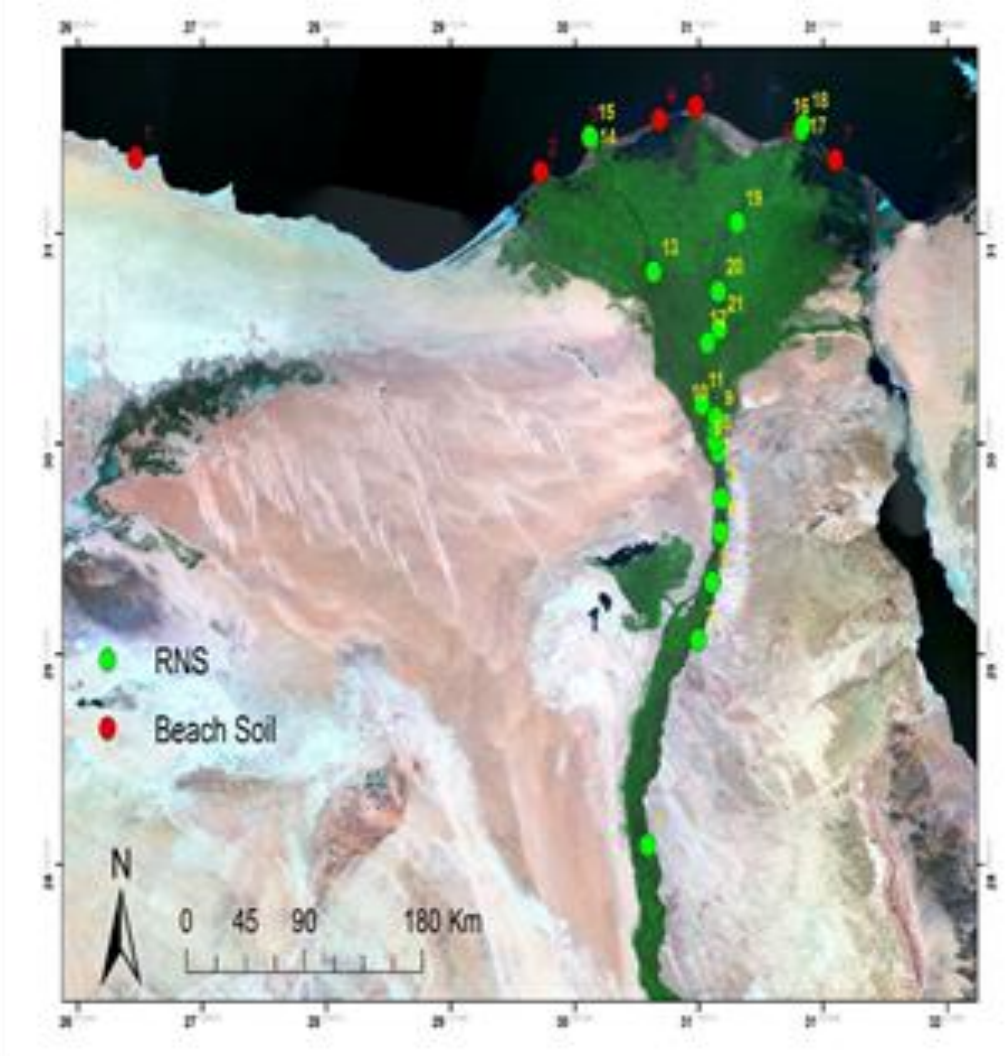
- **Joint projects with Egypt aim to:**

1. Determination of pollution sources in the basin of Nile river and its Delta.
2. Determination of the content in mg/kg the minor, major and trace elements in soil and sediment as a monitor of pollution.
3. Base-line information for constructing an ecological map of Egypt.
4. Predictions and actions.

Study locations

JOINT INSTITUTE
FOR NUCLEAR RESEARCH





General outcomes

JOINT INSTITUTE
FOR NUCLEAR RESEARCH

1. Biomonitoring of atmospheric deposition of heavy metals and other elements.
2. Controlling the quality and safety of foodstuffs.
3. Assessment of different ecosystems and their impact on human health.

Cont.,

JOINT INSTITUTE
FOR NUCLEAR RESEARCH

- **So, the team members have recognized the Steps to perform these operations which include:**

1. Sample collection
2. Sample preparations
3. Irradiation process (REGATA)
4. Data processing and analyzing

Capacity building

JOINT INSTITUTE
FOR NUCLEAR RESEARCH

Now, after this practice, the students have become able to transfer this technology to Egypt to serve scientific, medical and environmental sectors, which, in turn, are working to establish a bright future.

Acknowledgement

- **Prof. Marina Frontasyeva.**
- **Assoc. Prof. Wael M. Badawy.**
- **Inga Zinicovscaia.**
- **All the members in the sector of NAA- FLNP – JINR.**
- **Julia Rybachuk & Elizabeth Budennaya**

JOINT INSTITUTE
FOR NUCLEAR RESEARCH

ANY QUESTIONS?