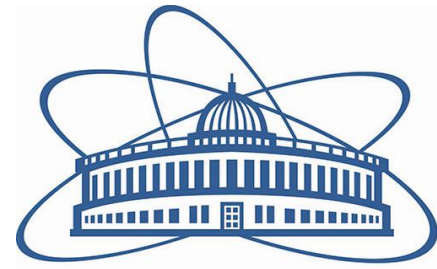




أكاديمية البحث  
العلمي والتكنولوجيا  
Academy of Scientific  
Research & Technology



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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**

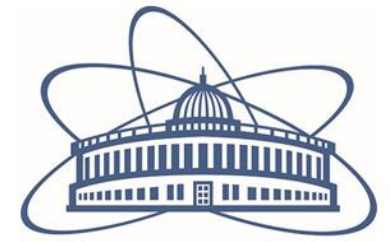
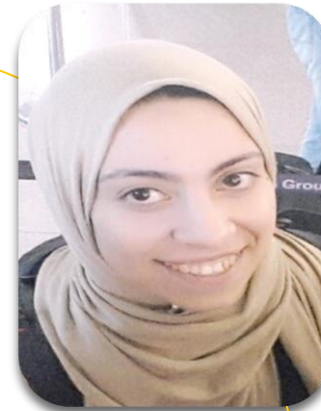
**Mohamed El-Henawey**  
**Mansoura University**



**Fatma Said**  
**Ain-shams University**



**Yasmine Sarhan**  
**Minufiya University**



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**Said Moawad**  
**Egyptian Atomic  
Energy Authority**



**Fatma Shafiek**  
**Minufiya University**



**Moushira Saleh**  
**Assiut University**

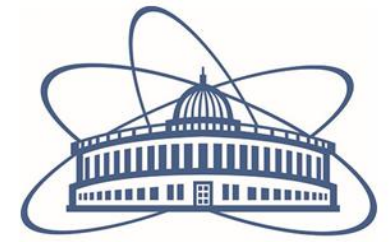


**Reem Mohammed**  
**Ain-shams University**



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- b. Different types of NAA

## 3- Sampling and sample preparation

- a. Sample collection
- b. Sample preparations
- c. Irradiation process (REGATA)

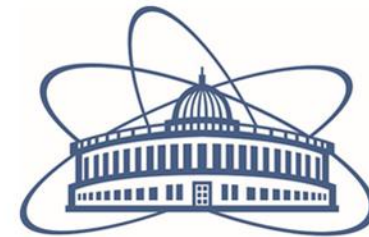
## 4- Data processing and analyzing

- a. Genie2000
- b. Concentration program
- c. Data plotting

## 5- Advantages and limitations of NAA

## 6- General outcomes

- a. Joint projects with Egypt
- b. Outcomes



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# 1. Introduction

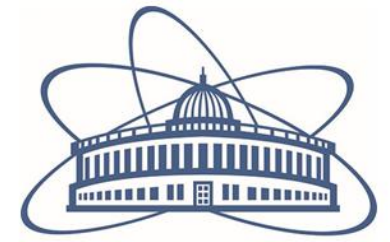
# Founder of FLNP

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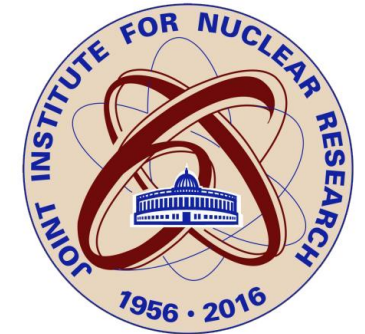
**FRANK LABORATORY OF NEUTRON PHYSICS**  
JOINT INSTITUTE FOR NUCLEAR RESEARCH 1956



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

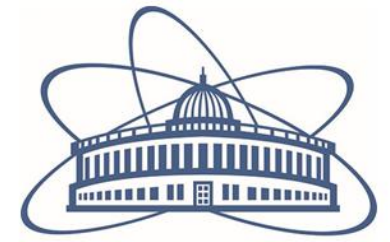


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# What is NAA?

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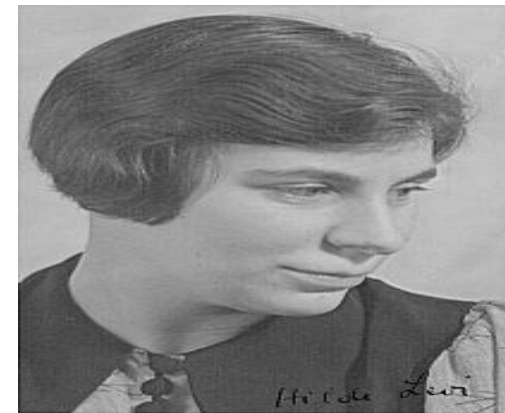
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➤ Neutron activation analysis is an isotope specific analytical technique for the qualitative and quantitative determination of elemental content.

➤ NAA was discovered in 1936



**G. Hevesy**



**H. Levi**

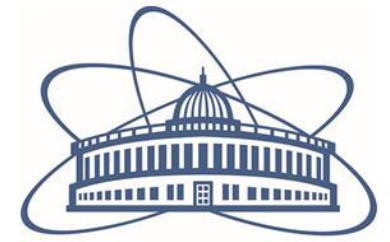


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## 2. Physical concepts

# What is Neutron Activation Analysis ??

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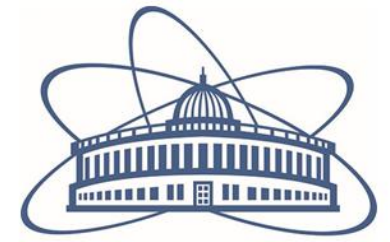
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**Neutron activation analysis (NAA)** : is a non destructive nuclear process used for

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



# NAA Principle



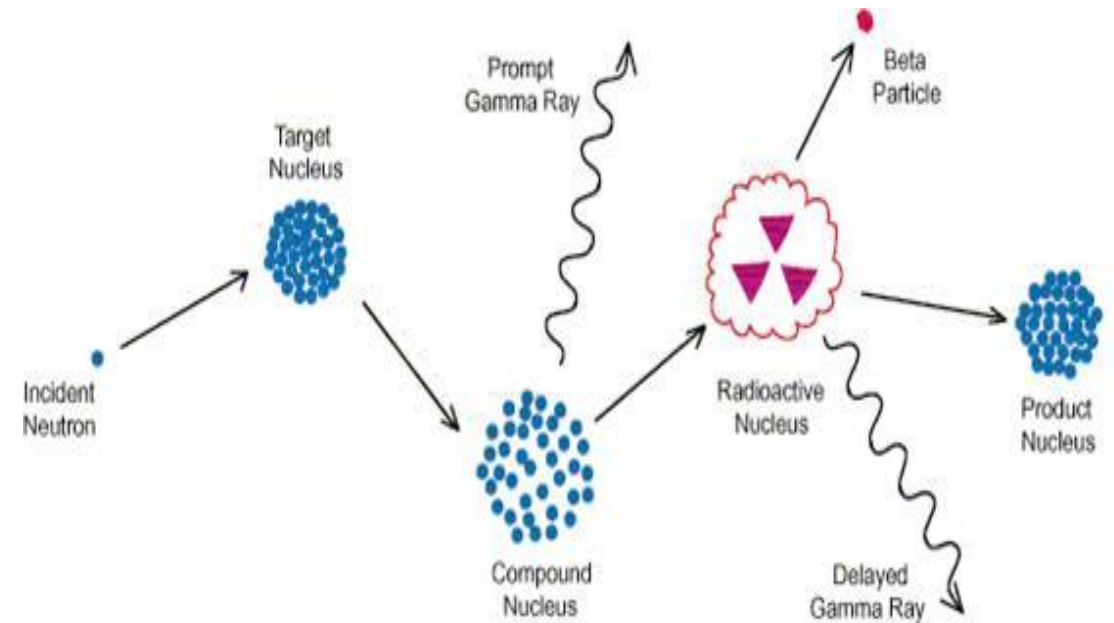
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**NAA** relies on irradiation by neutrons so that the treated sample will be excited then it de-excites emitting gamma-rays (prompt). The resulted sample is radioactive so *it emits Negative Beta and Gamma ray to turn into stable isotope.*

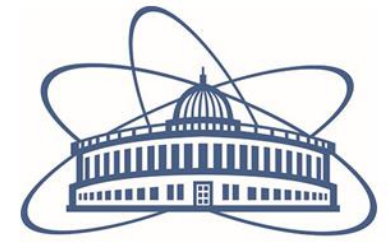
**The second Gamma ray is our purpose.**

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.



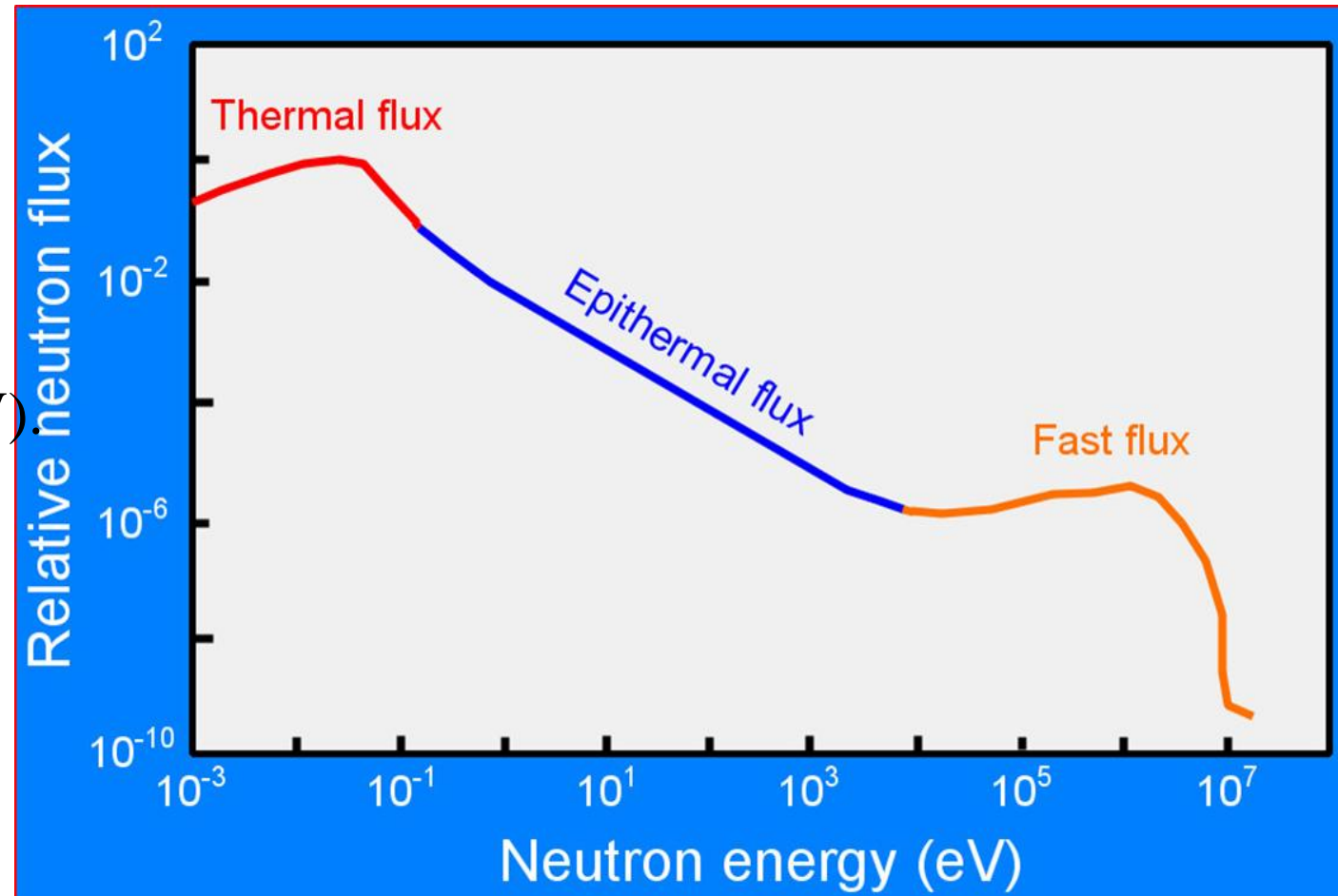
# NAA Principle



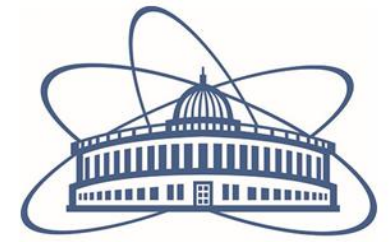
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The Neutrons used in irradiation can be thermal or epithermal neutrons

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



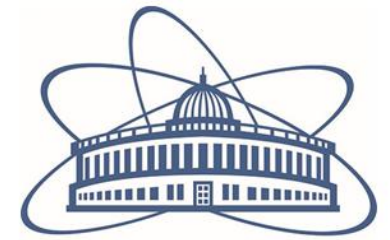
# Elements that may be analyzed via INAA include:



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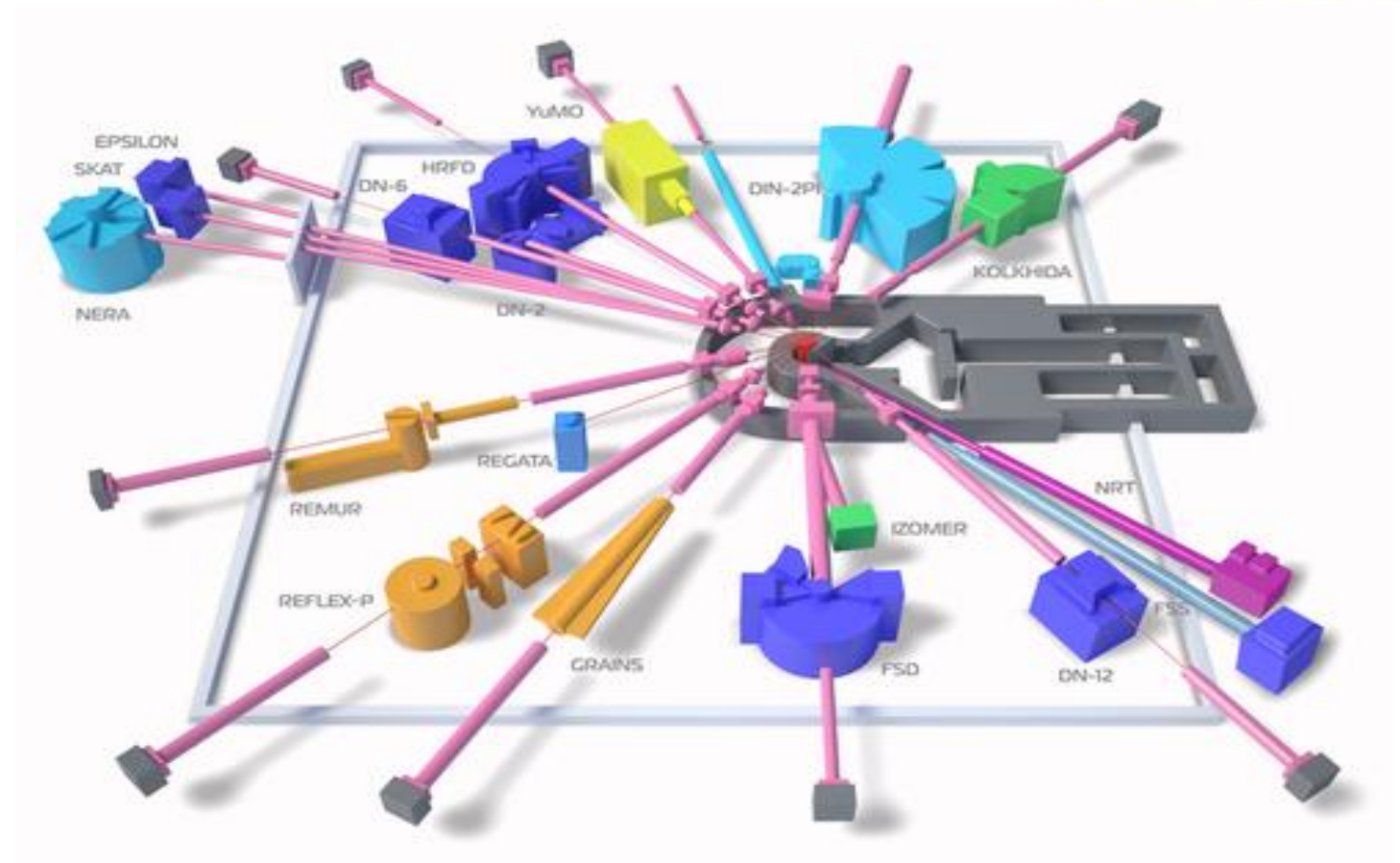
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac**											Rf	Db	Sg	Bh	Hs
	*	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb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

# The IBR-2 Reactor

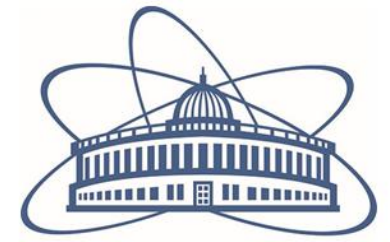


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- ❖ Average power 2 MW
- ❖ PuO<sub>2</sub> fuel
- ❖ <sup>252</sup>Cf
- ❖ Neutron density flux  $\sim 10^{16}$  n/cm<sup>2</sup>/s
- ❖ 9 cycles a year
- ❖ Each cycle = 12 days

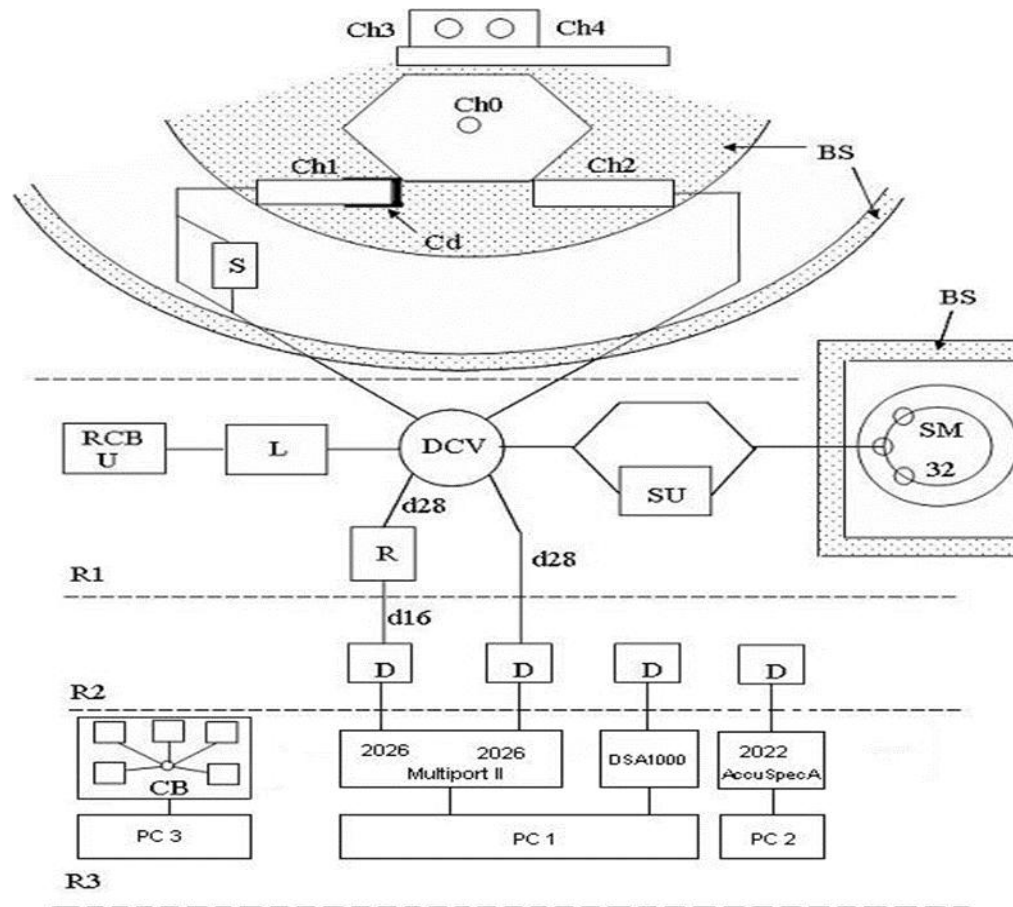


# REGATA :

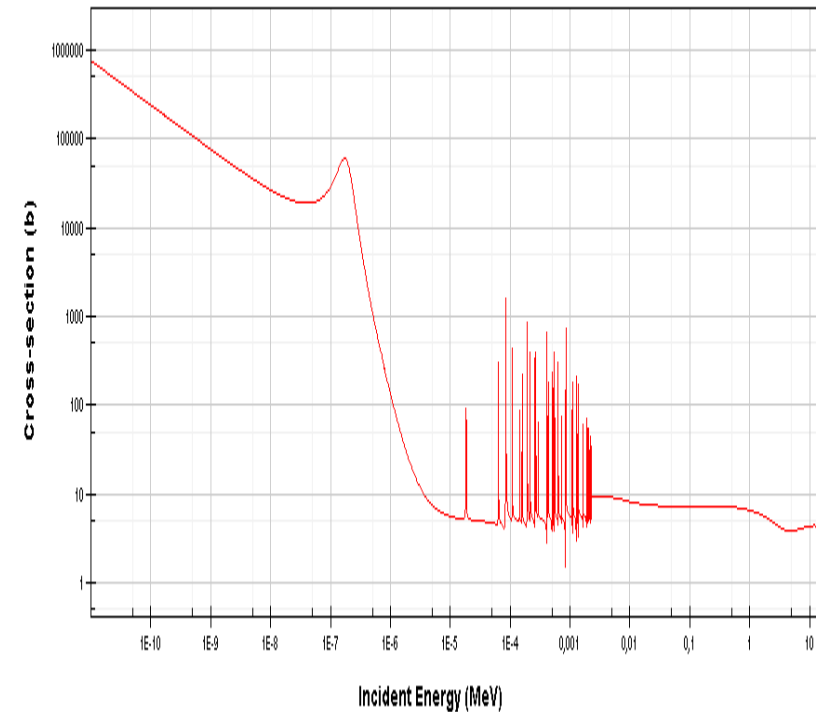


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Channel 1 and 2 are connected directly to the reactor core.  
Ch1 : Cd screening .

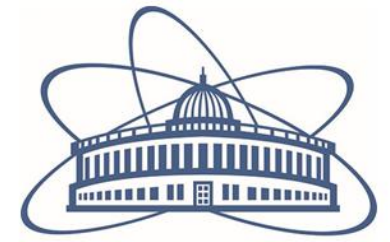


Incident neutron data / JEFF-3.1 / Cd113 / MT=1 : (n,total) / Cross section



# Different Types of NAA

---



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## **Destructive (radiochemical):**

The resulting radioactive sample is chemically decomposed and the elements are chemically separated

## **Non-destructive (instrumental):**

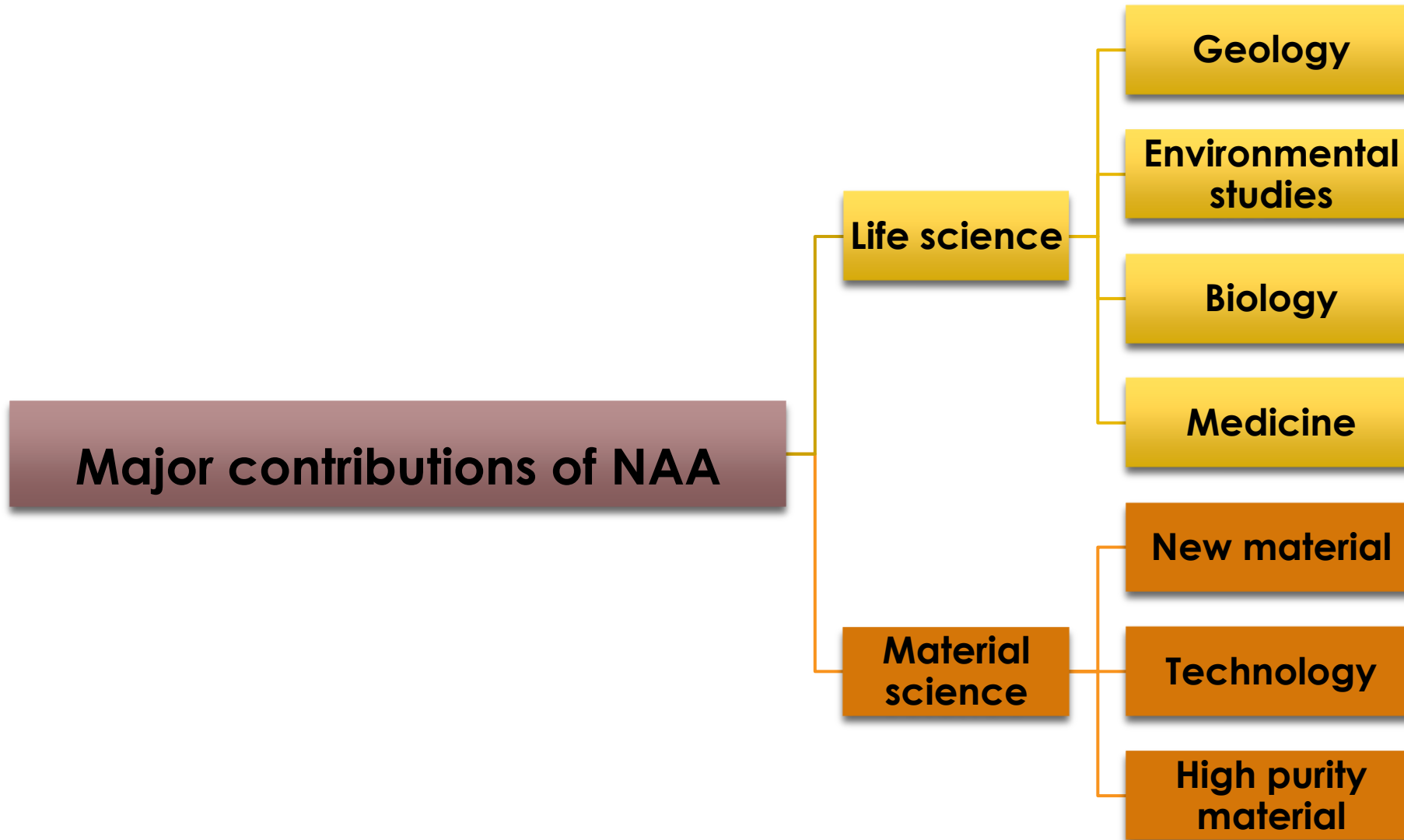
The resulting radioactive sample is kept intact and the radionuclides are determined, taking advantage of the differences in decay rates via measurements at different decay intervals

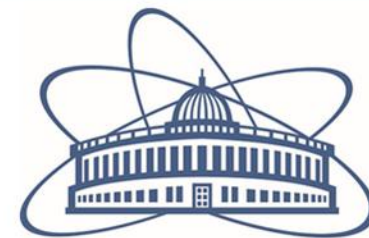
# Applications of NAA

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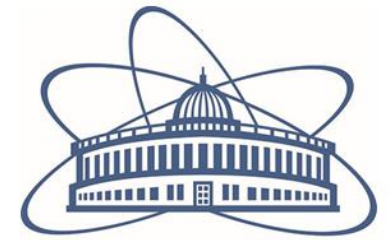


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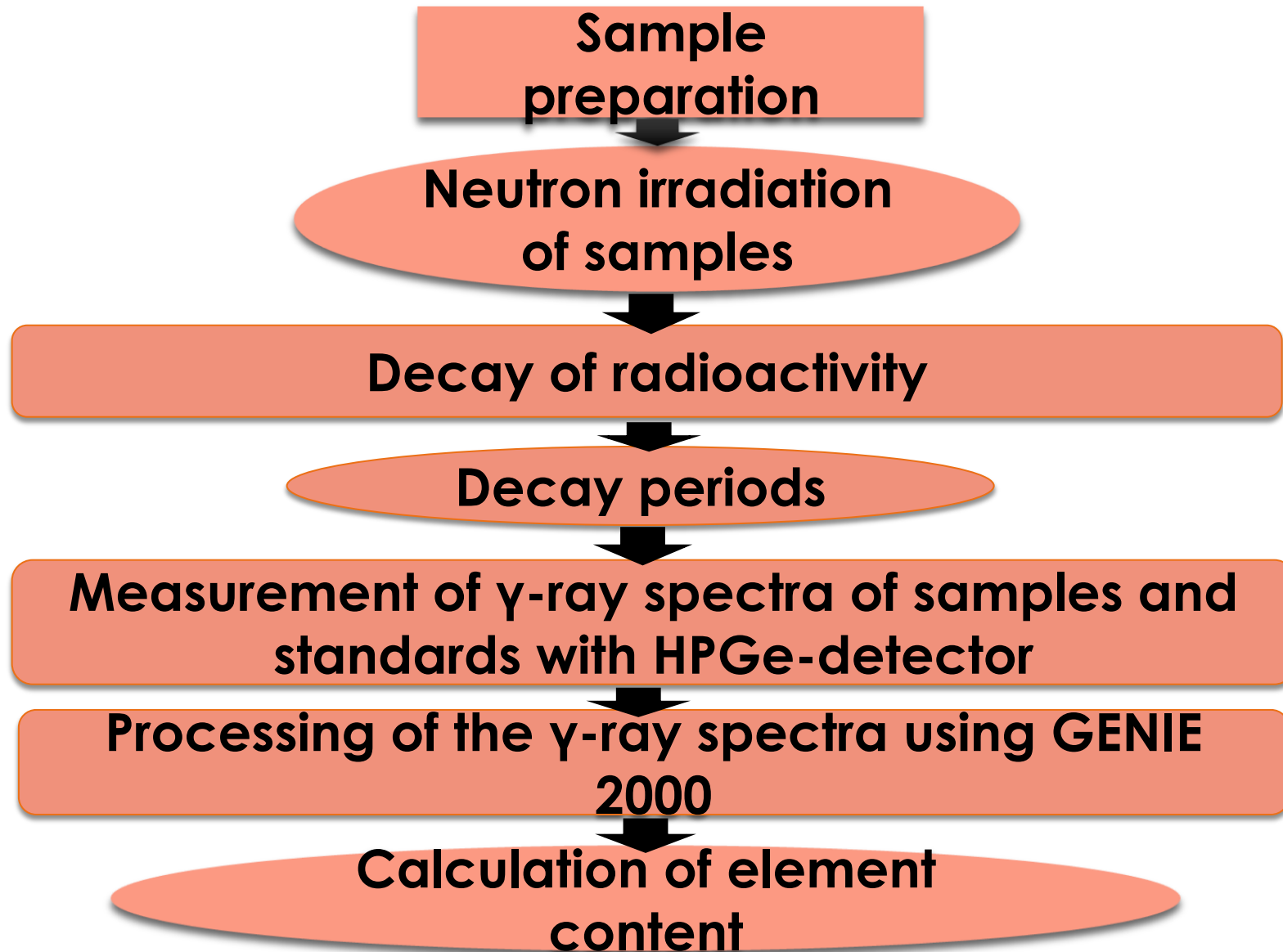
# **3. Sampling and sample preparation**



# Measurement of content of samples



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# Types of samples and sample Collection

---

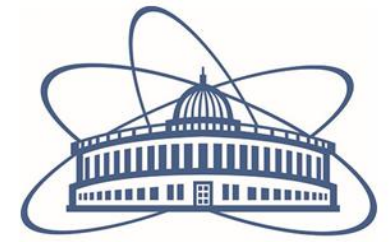


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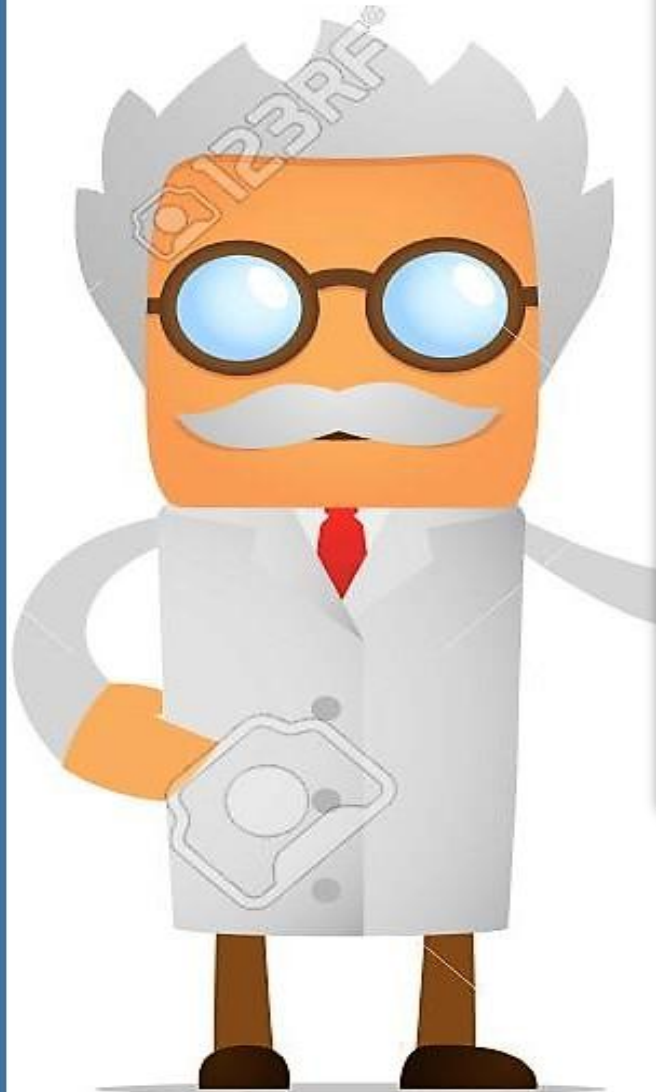
- **Enviromental samples**
- **Geological samples**
- **Biological samples**
- **Liquids**
- **Foodstuffs, etc**



# Environmental Sampling & Preparation



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

# Drying

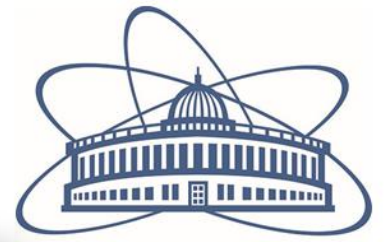


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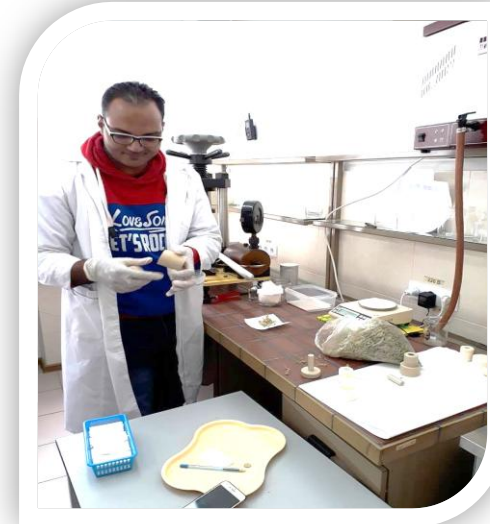


- Temperature range 30-300<sup>0</sup>C;
- Optimal temperature for NAA – 40<sup>0</sup>C;
- Samples are dried till constant weight.

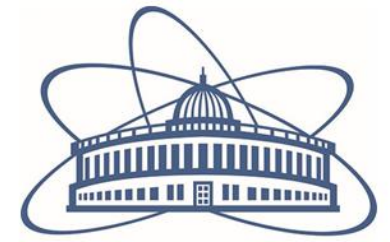
# pelletizing



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# Weighting and Packing

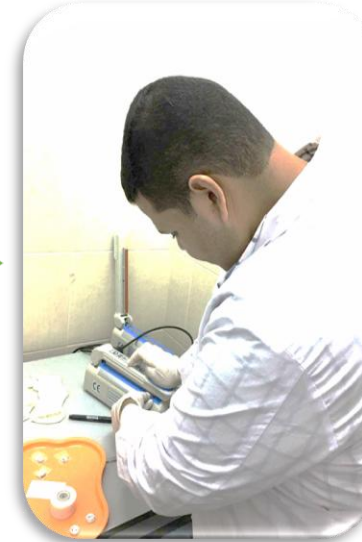


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For short irradiation



For long irradiation

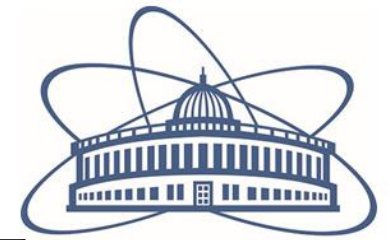


Standards packed  
for short irradiation



Standards packed  
for long irradiation

# Sample Preparation



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Sample preparation

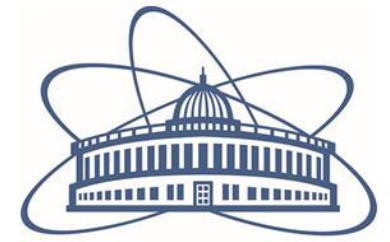
Country-Client-Year-Set ID-Set index  
MD 01 17 40 n

Sample ID	Client sample ID	Cleaning	Drying	Evaporation	Freeze drying	Homogenizing	Pelletization	Fragmentation	Weight SLI, g	Weight LLI, g	Sample preparation date	Maked
01	01	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	0,3014	0,3027	13.09.2017	Znicovsca
02	02	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	0,3072	0,3132	13.09.2017	Znicovsca
03	03	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	0,3109	0,2908	13.09.2017	Znicovsca
04	04	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	0,3029	0,3018	13.09.2017	Znicovsca
05	05	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	0,3037	0,2817	13.09.2017	Znicovsca
06	06	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	0,3081	0,3066	13.09.2017	Znicovsca
07	07	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	0,3061	0,2966	13.09.2017	Znicovsca
08	08	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	0,3036	0,3106	13.09.2017	Znicovsca

Check selected 'Cleaning'    Check selected 'Drying'    Check selected 'Evaporation'    Check selected 'Freeze Drying'    Check selected 'Homogenizing'    Check selected 'Pelletization'    Check selected 'Fragmentation'    Fill in weights from file    Check selected 'Maked by'

Select all rows    Save    Close

# Irradiation of Samples



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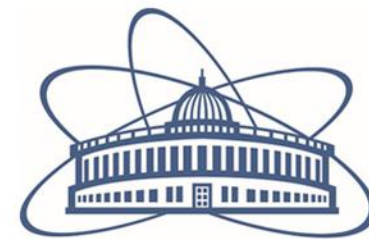


**Types of containers**



**Boxes for re-packing samples after irradiation**



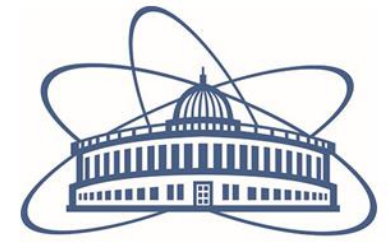


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# 4. Data processing and analyzing

# Data processing and analyzing

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❖ The accumulated spectra were analyzed for the isotopes radioactivity ( $\mu\text{Ci/g}$ ) using **Genie 2000** by Canberra.

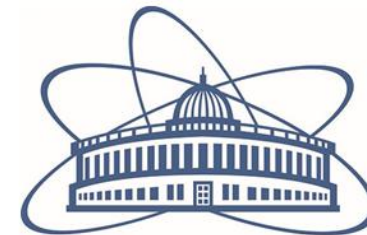
➤ In general, a full computer spectrum analysis will consist of three phases:

(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 - 5002180.CNF  
 File MCA Calibrate Display Analyze Edit Options Datasource Help  
 Idle Channel: 1958 : 782.6 keV Counts: 263 Preset: 900/900.00  
 Acquire Start Stop Expand On Clear

---

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

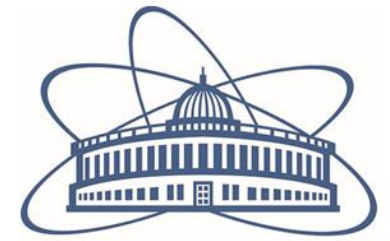
\* = Energy line found in the spectrum.  
 @ = Energy line not used for Weighted Mean Activity  
 Energy Tolerance : 1.000 keV  
 Nuclide confidence index threshold = 0.30  
 Errors quoted at 1.000 sigma

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

\*\*\*\*\*  
 \*\*\*\*\*  
 For Help, press F1 Execution Status: ready

9:57 AM 12/22/2011

# Screenshot of CalcConc Program



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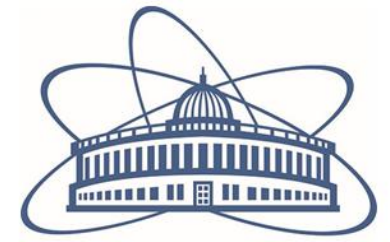
- ▶ A developed software **CalcConc** at the Neutron activation sector was used to calculate the content of the elements in (mg/kg).

The screenshot displays the 'Concentration - 5.8 (ed. TMO)' software window. The interface is organized into several sections:

- Recalculation of SRMs activity:** Includes fields for 'Base file of SRM flux monitor activity: not selected', 'File of SRM flux monitor activity: not selected', and 'File(s) of SRM activity: not selected'. A button 'Recalculate and save SRMs activity' is located below.
- Group standard:** Includes a field for 'Files of SRM activity: not selected' and a button 'Create a summary table of SRMs activity'.
- Data for a table of SRMs check:** Features three radio buttons: 'Calculated uncertainty' (selected), 'Z-scores', and 'Reference uncertainty'. Below are fields for 'File(s) of SRM activity: not selected' and 'File of group standard: not selected', with a button 'Calculate SRM(s) on a group standard and save a table of SRMs check'.
- Concentration:** Includes fields for 'File(s) of analyzed sample activity: not selected', 'File of group standard: not selected', 'Base file of SRM flux monitor activity: not selected', and 'File of sample flux monitor activity: not selected'. It also has a 'Deselect flux monitors file' button, a 'Source of SLI data' dropdown menu set to 'SLI-1 and SLI-2', and input fields for 'Coefficient of neutrons flux change' (value: 1.0) and 'Systematic error, %:' (value: 0). A button 'Calculate and save concentrations' is present.
- Final Output:** Includes a field for 'Files of elements concentration of analyzed samples: not selected' and two buttons: 'Create an intermediate table of elements concentration' and 'Create a final table of elements concentration'.

# Data plotting

---

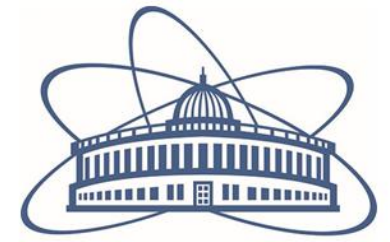


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- **Geographic information system (GIS)** is a system designed to capture, store, manipulate, analyze, manage, and present spatial or geographic data.
- Maps in computer.
- Do you use GIS ?



# QGIS



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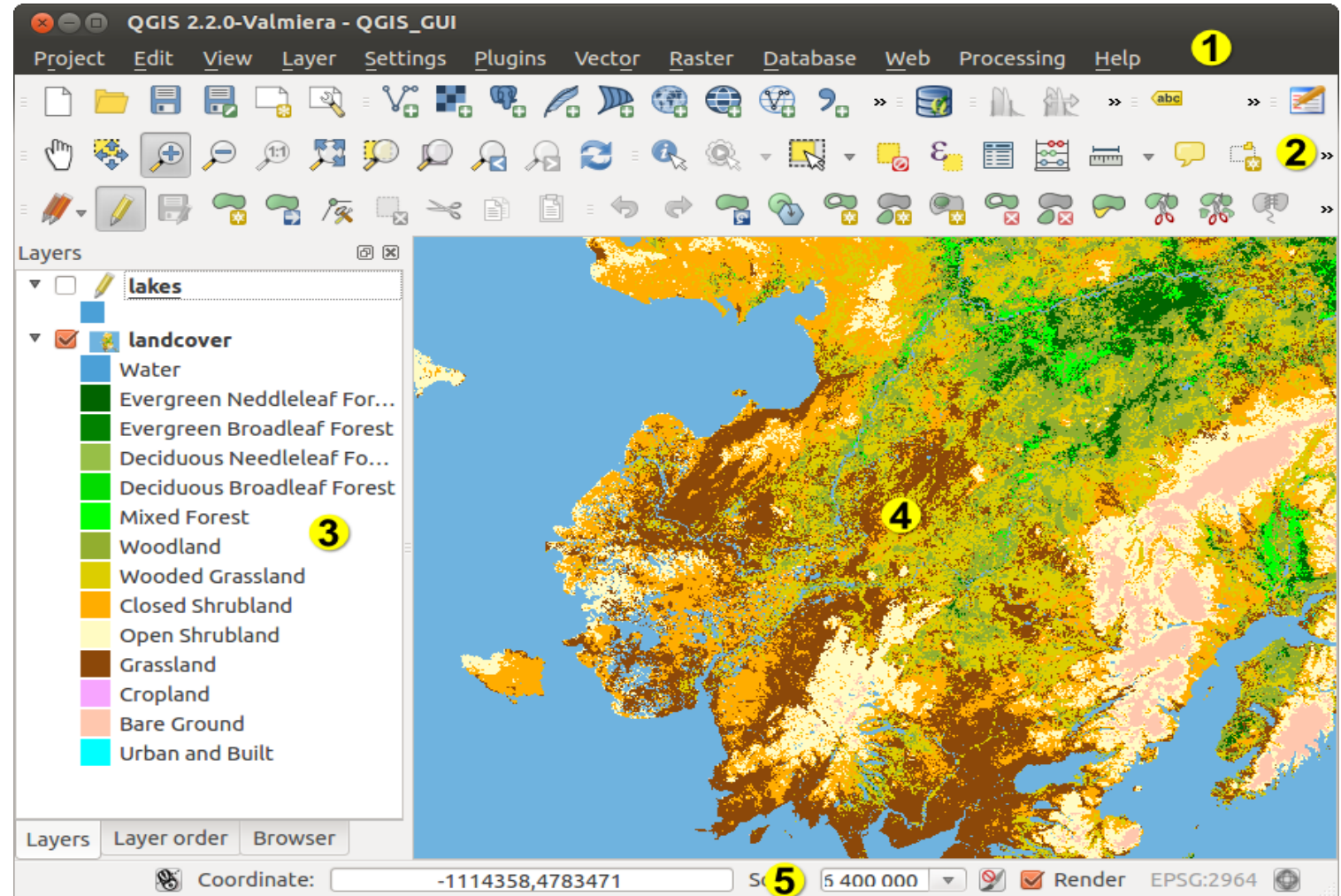
## ❖ Spatial distribution maps

- **Advantage**

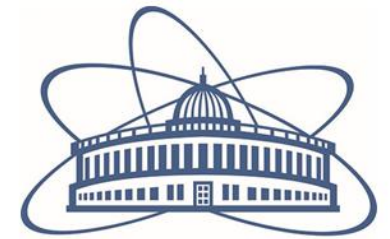
Big user base for free  
open-source

- **Limitation**

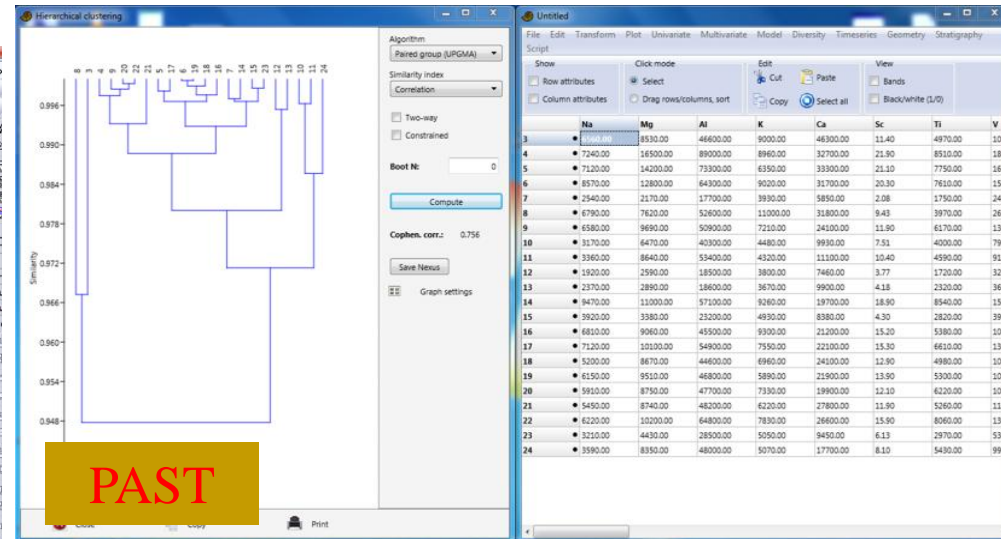
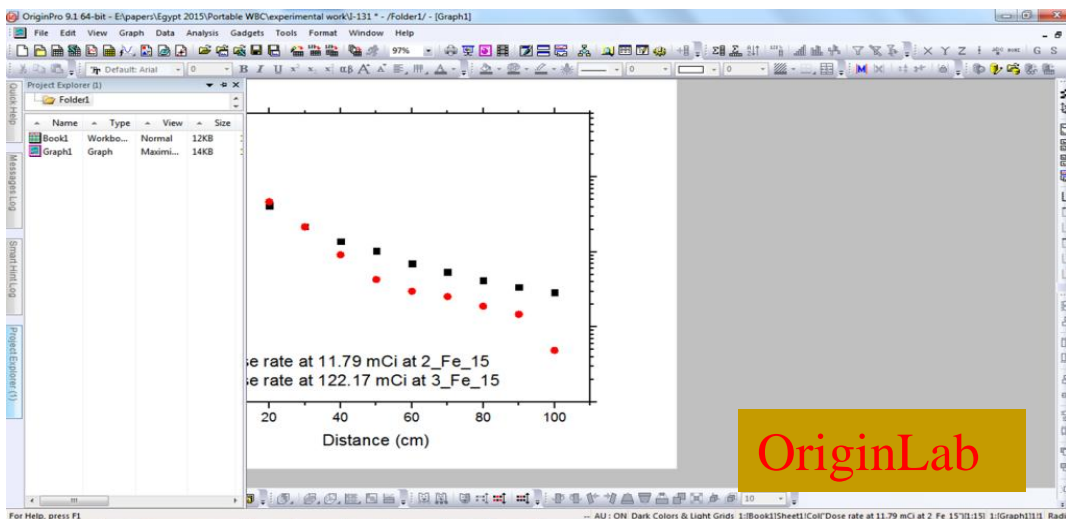
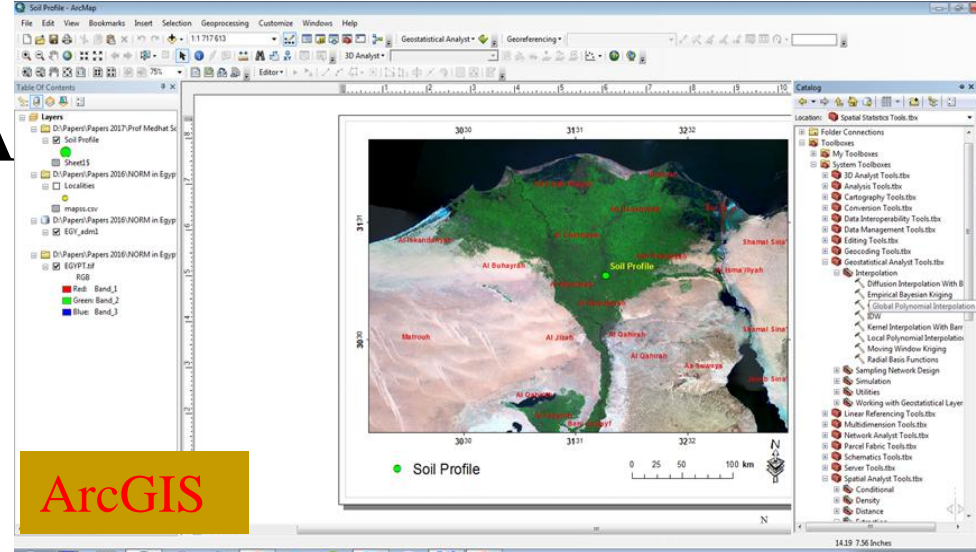
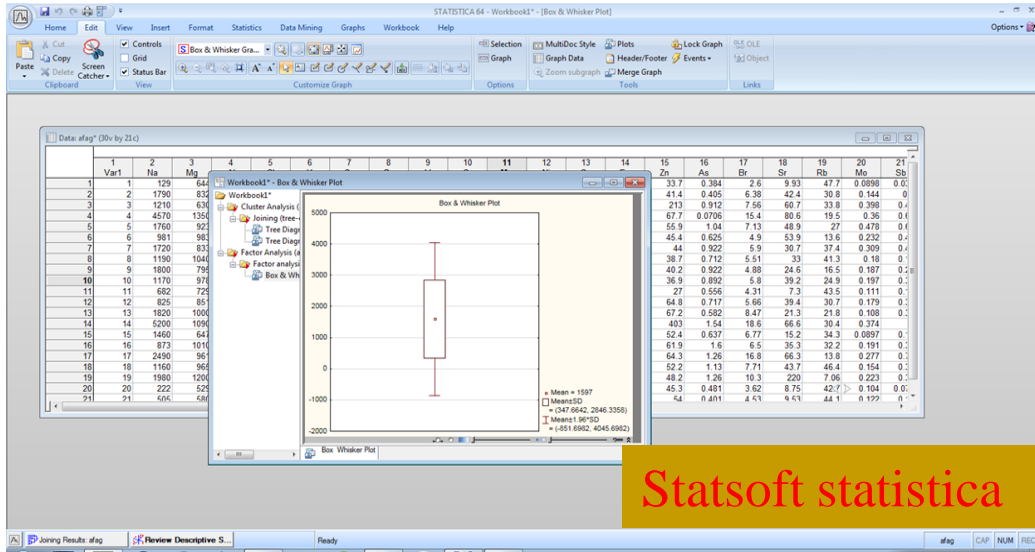
No 3D



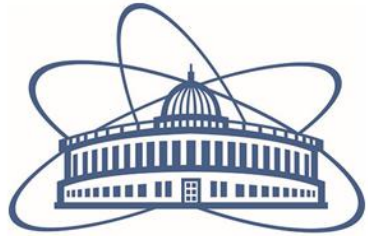
# Used Software Packages in Analysis



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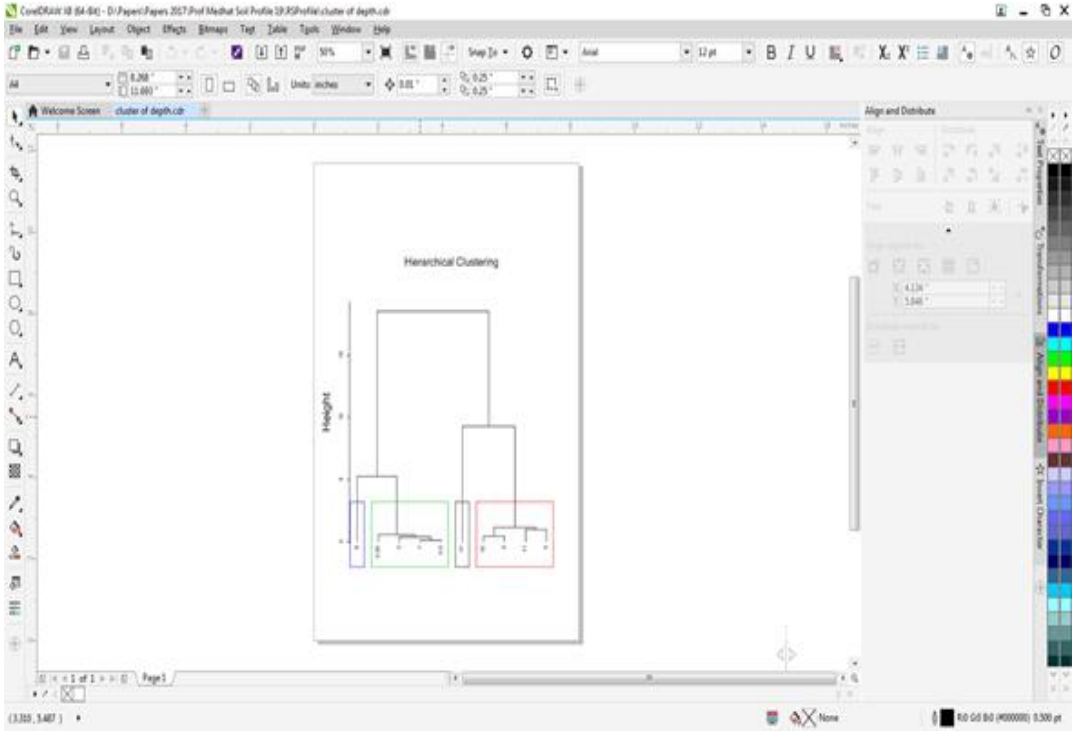
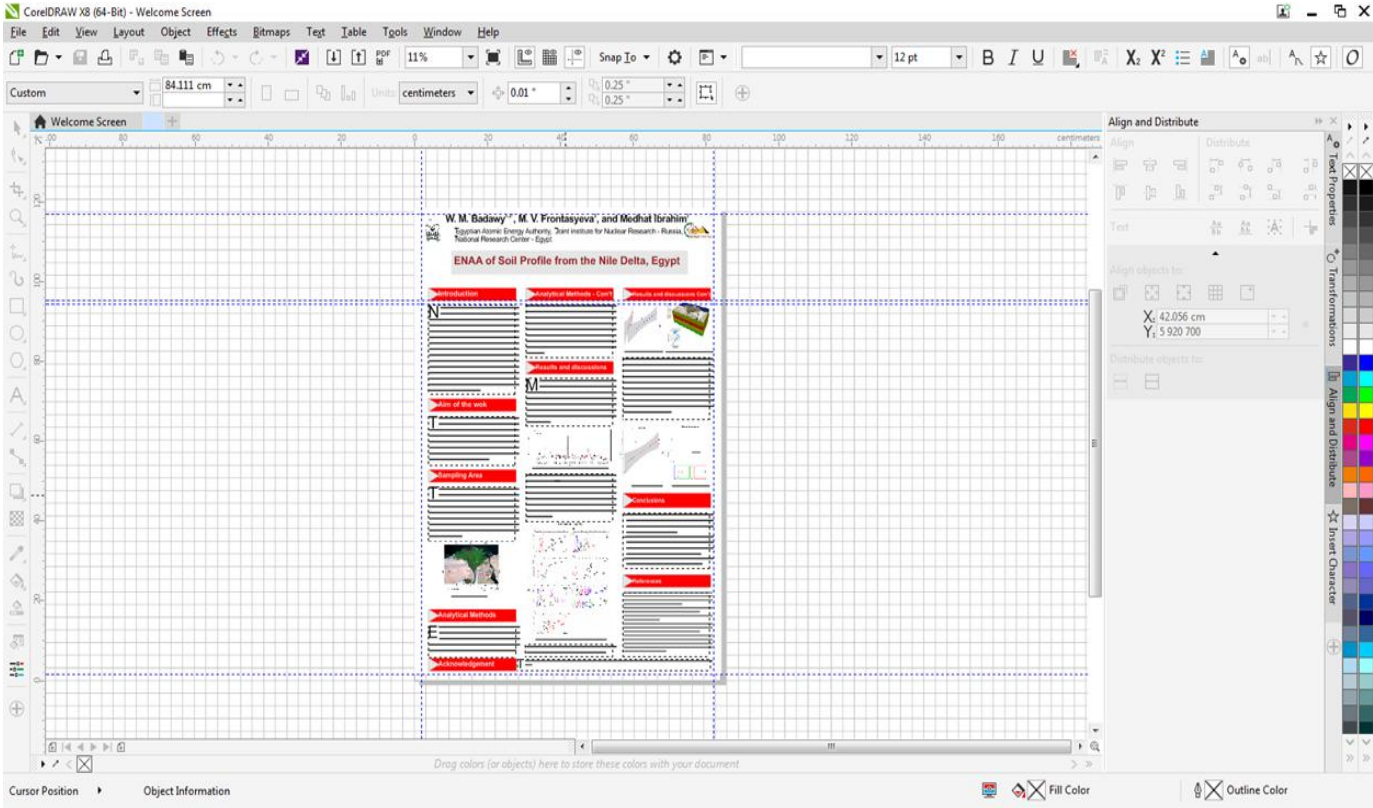


# CorelDraw



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## ❖ Graphic management and posters





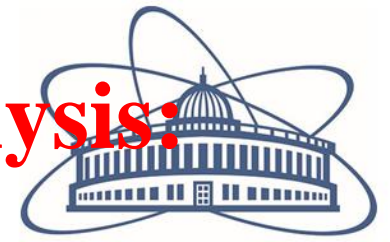


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# **5. Advantages and limitations**

# Advantages of using INAA for trace element analysis:

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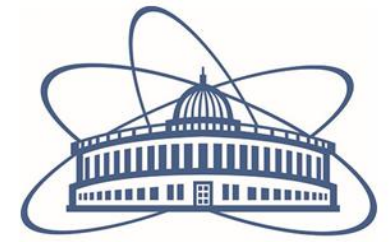


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- ❖ It is a multi-element technique capable of determining approximately 65 elements in many types of materials.
- ❖ It is non-destructive and therefore, does not suffer from the errors associated with yield determinations.
- ❖ It has very high sensitivities for most of the elements that can be determined by INAA – most detection limits range from ~0.05 to ~50 ppm ( $\leq 1$  ppb for some high-purity materials).
- ❖ It is highly precise and accurate.

# Limitations of using INAA for trace element analysis:

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- ❖ 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 .

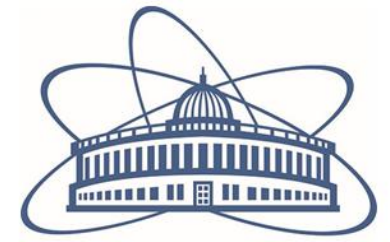


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# 6. General outcomes

# Joint projects with Egypt

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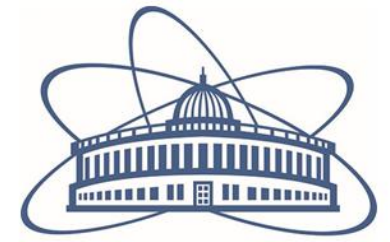


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- **The current joint projects with Egypt represented in:**
  1. Assessment of the environmental situation in the basin of the **Nile River** using nuclear and related analytical techniques
  2. Environmental studies in Egypt using neutron activation analysis and other analytical techniques

# Joint projects with Egypt

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- **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

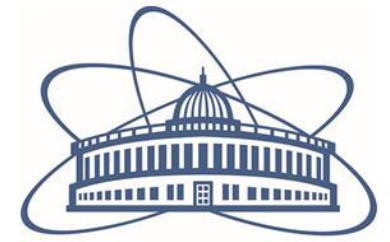
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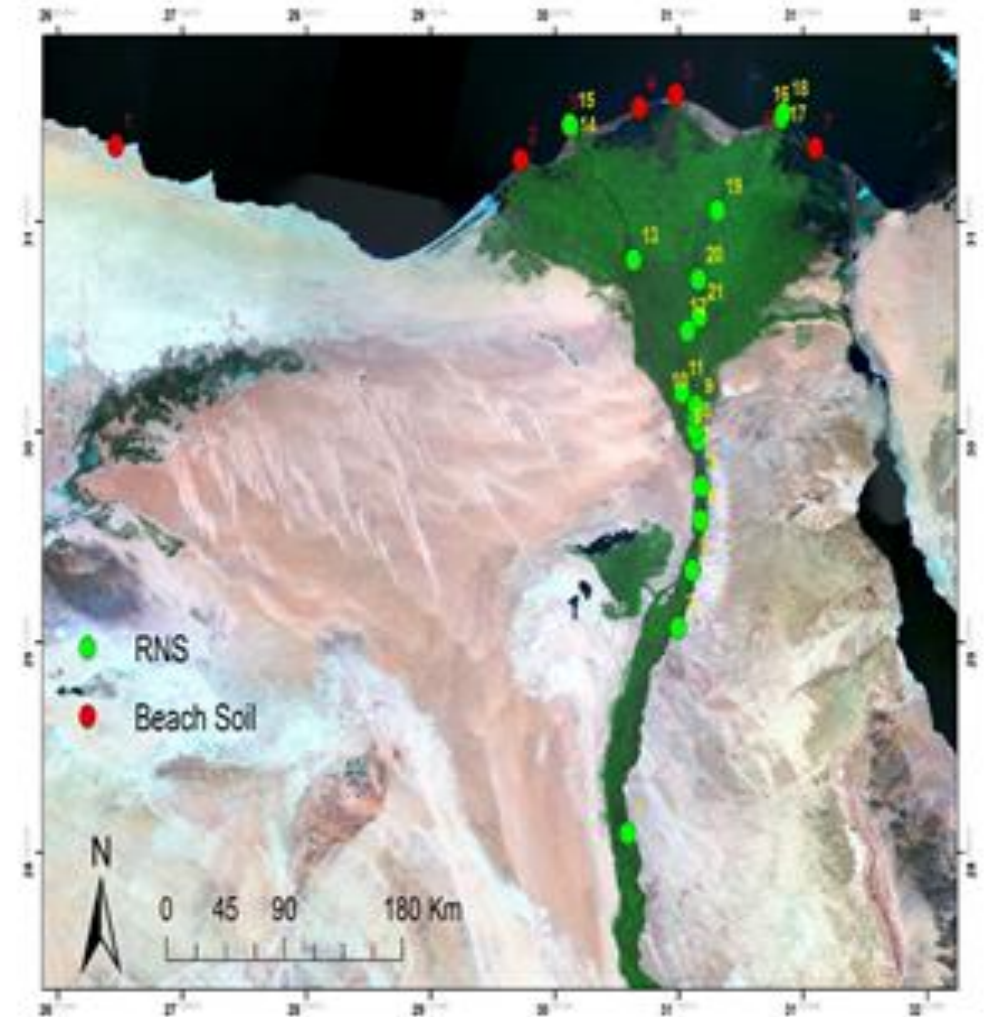
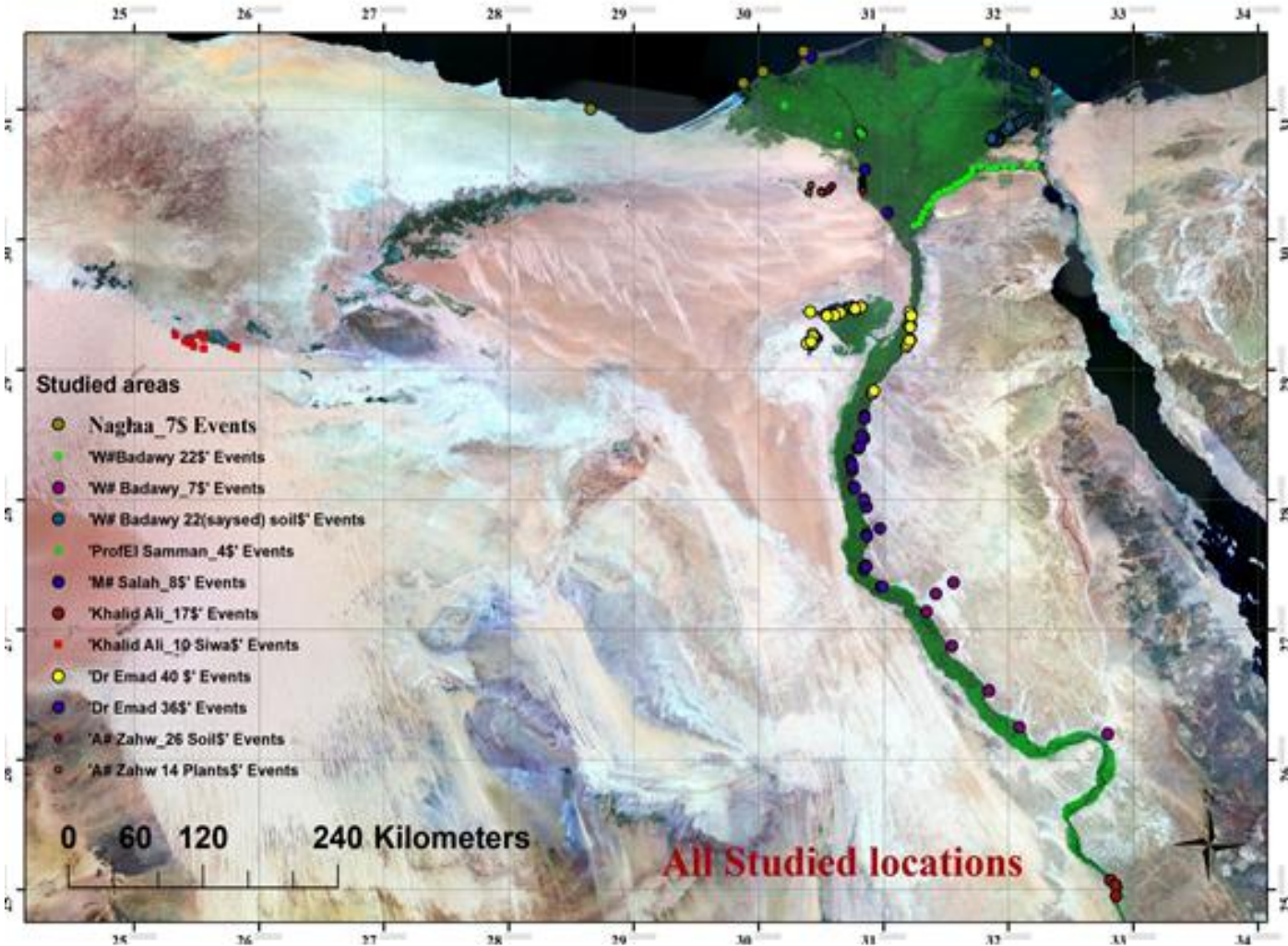
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- **Joint projects with Egypt aim to:**
  1. Determination of pollution sources in the basin of Nile river and its Delta.
  2. Determination of the content in mg/kg the minor, major and trace elements in soil and sediment as a monitor of pollution.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

# Study locations



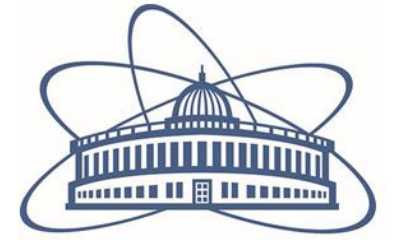
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# General outcomes

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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.,

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- **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

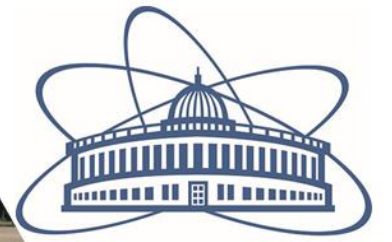
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Now, after this practice, the students have become able to transfer this technology to Egypt to serve scientific, medical and environmental sectors, which, in turn, are working to establish a bright future.

# Acknowledgement



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





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Thanks



**ANY  
QUESTIONS?**