Nuclear and related analytical techniques in archaeological and ecological studies

Supervisors: Dr. A. Dmitreiv; Dr. Wael Badawy

Group of neutron activation analysis

Frank Laboratory of Neutron Physics

Group members

Fouad Ismail El Agwany

Assistant Lecturer , Physics department, Faculty of Science – Menoufia University

fouaadesmail@yahoo.com

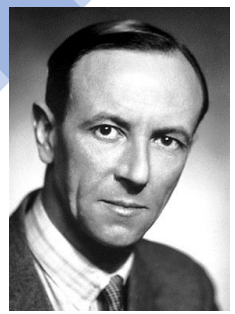
Romisaa Gamal Mahmoud

Assistant Lecturer, Faculty of Engineering and technology, Future University.

romisaa.abdelrhman@fue.edu.eg

Outlines

- History and Discovery of the neutron
- Neutron Activation Analysis (NAA).
- Types of NAA
- Pross and Cons of NAA
- Applications
- NAA Procedures
- Genie 2000
- Case Study
- Outcomes and Capacity building



James Chadwick

(1891-1974)

Neutron Discovery

1932 “Possible Existence of a Neutron”– February

“The Existence of a Neutron”

George Charles de Hevesy

George Charles de Hevesy was a Hungarian radiochemist and Nobel Prize in Chemistry laureate 1943. The discovery of Neutron Activation Analysis in 1936.

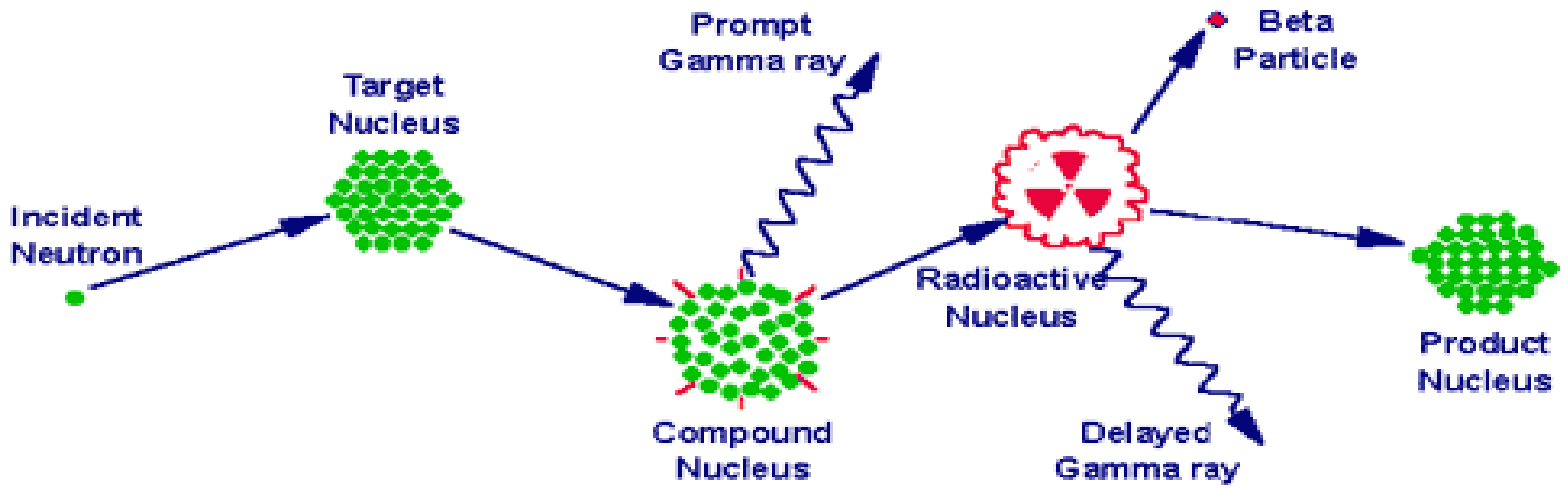
The discovery of Neutron Activation Analysis in 1936.

Hilde Levi was the assistant of George Charles de Hevesy, applying Hevesy's radioactive indicator technique in biology, an application which had recently been made possible by the discovery of artificial radioactivity in 1934.

Hilde Levi

Neutron activation analysis

- It is a sensitive multi-element analytical technique used for both qualitative and quantitative analysis of major, minor, trace and rare elements in samples from almost every field of scientific or technical interest.



Types of NAA

Non-destructive

The resulting radioactive sample is kept intact

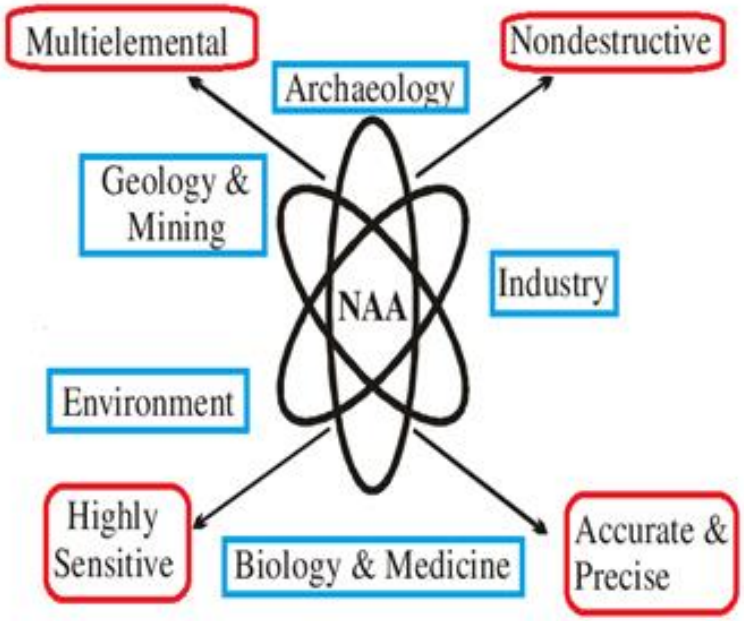
Destructive

The resulting radioactive sample is decomposed

Why NAA?????

Pros

- Industry (synthesis of diamonds).
- Biology (Natural dispersion of elemental content in normal and tumor tissues).
- Medicine (Neutron activation analysis used to study of some indicators of water-salt metabolism).
- Environment (Investigation of element content of natural water by the neutron activation analysis method using the adsorption complexes).
- Archeology (Analysis of archaeological and museum objects from Russia and other countries)

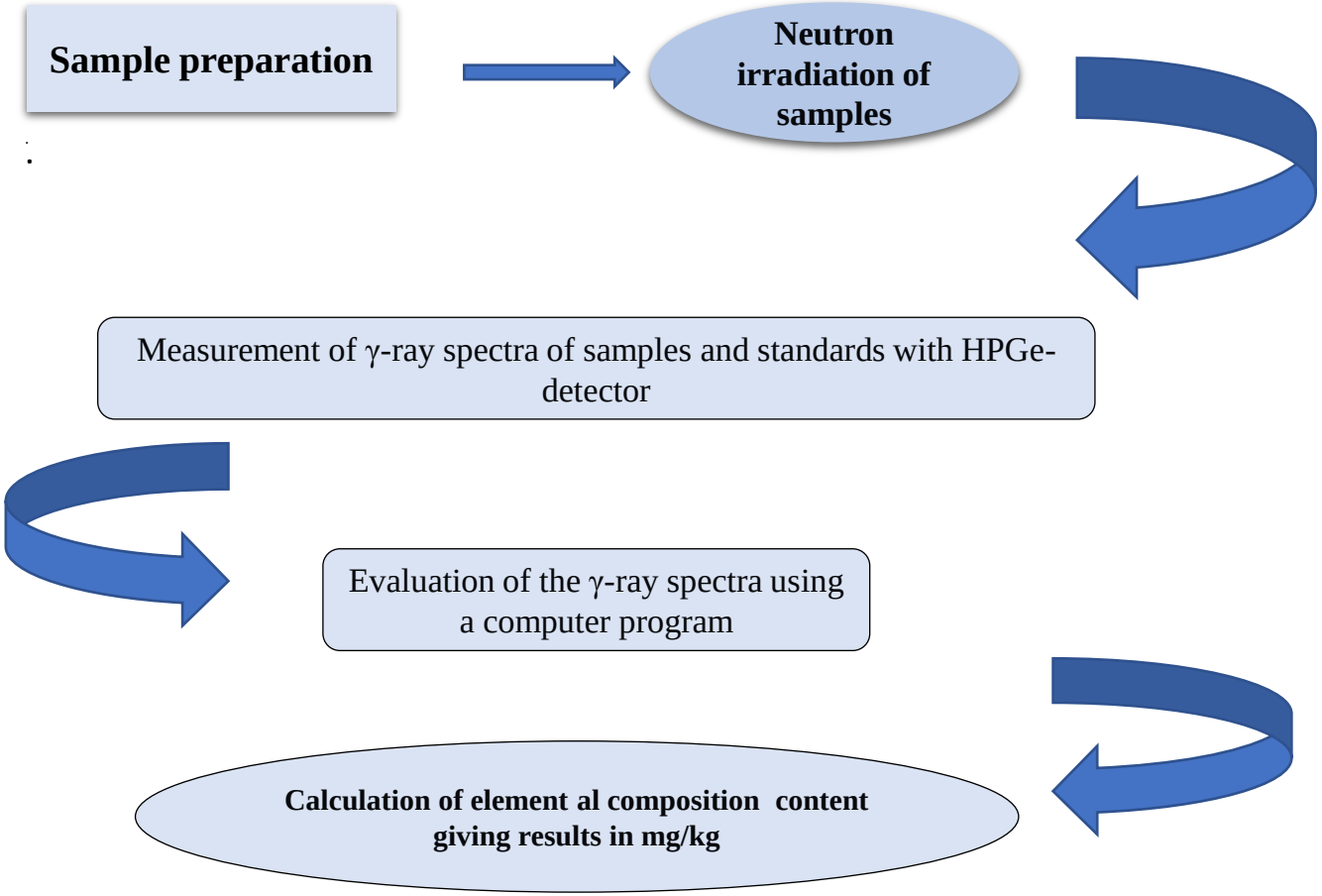


H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac**											Rf	Db	Sg	Bh	Hs
	*	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb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

Cons

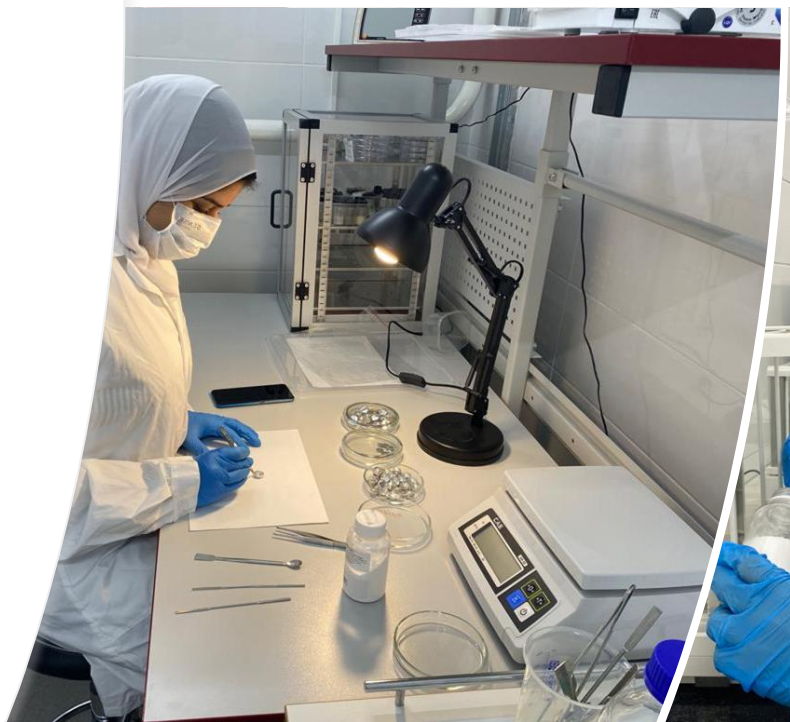
- **Need for neutron source**
- **Work with radioactive materials**
- **Time of analysis.**

NAA Procedure



Sample Preparation

- **Samples are washed and air-dried**
- **Samples are homogenized by an agate ball mill machine**
- **samples are weighed and capsulated**



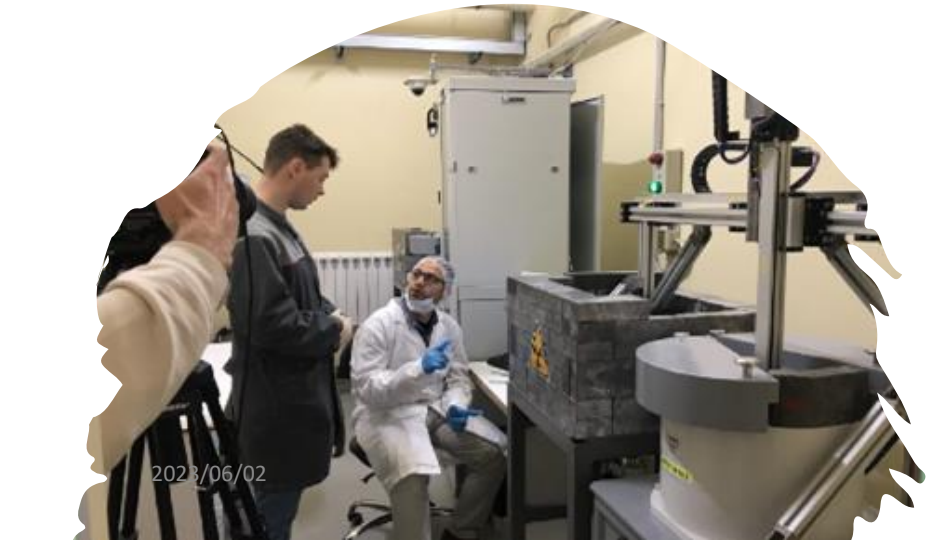
Sample Packing for irradiation

Samples wrapped in polyethylene bags and aluminium container for short- and long-lived irradiations, respectively.

Samples placed in transport capsules

Short-lived isotopes

Long-lived isotopes



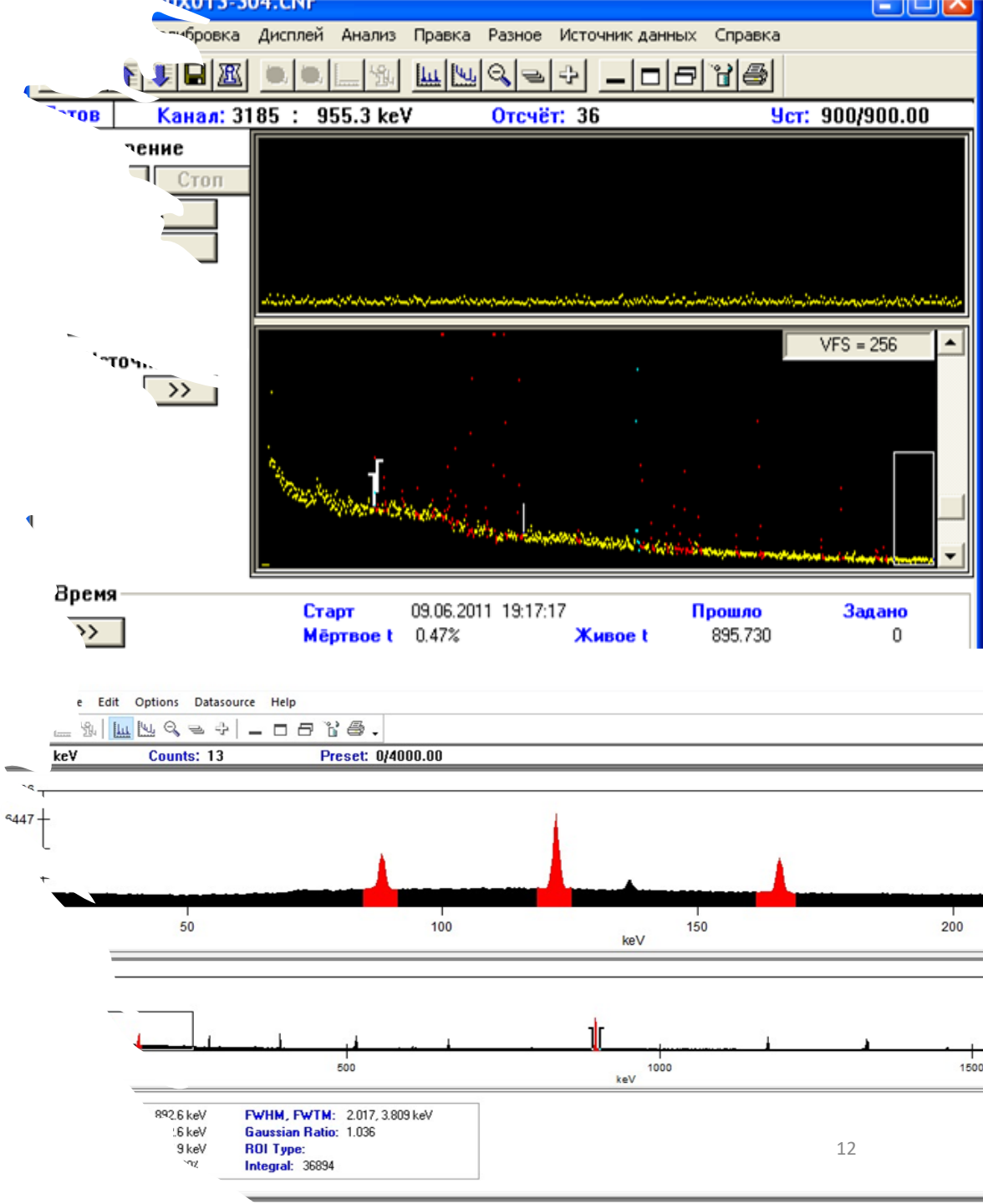
Pneumatic transport system at the IREN Facility is designed for sample irradiation

- Pneumatic transport system at the IREN Facility is designed for sample irradiation,
- the samples are delivered through the pneumatic system
- the channel is chosen, the time of irradiation is set,
- after that the samples transported for irradiation,
- after that the sample are delivered back after the irradiation after that we can detect gamma rays by using High Purity Germanium Detector.

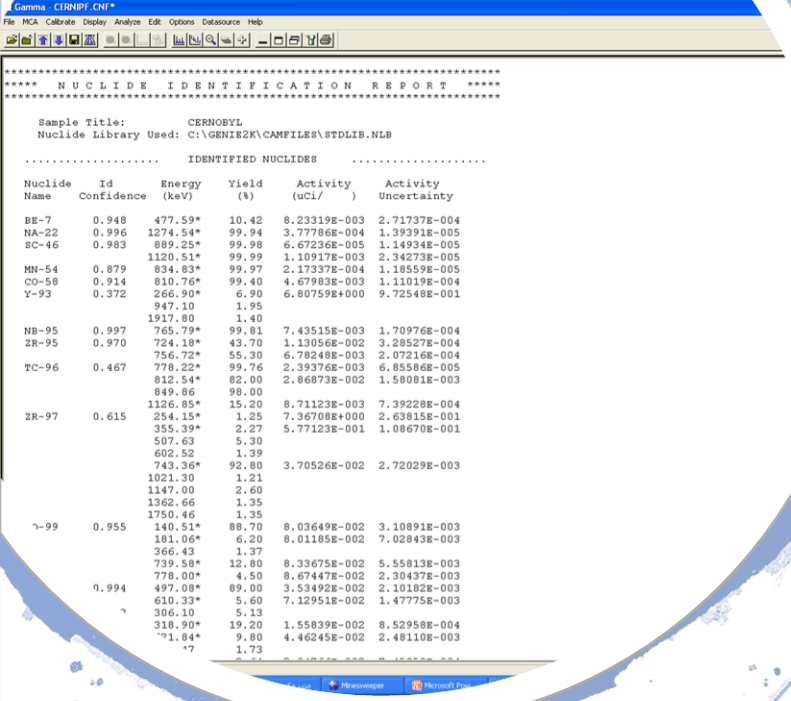
Spectra processing using Genie2000

The program allows minimizing human involvement in routine long-term

➢Software systems: **Genie 2000™ (Canberra)**



Spectra processing and reporting the results


Gamma - CERNIPF.CNF*

File MCA Calibrate Display Analyze Edit Options Datasource Help

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**********************************************************************
*****   N U C L I D E   I D E N T I F I C A T I O N   R E P O R T   *****
**********************************************************************

    Sample Title:          CERNOBYL
    Nuclide Library Used: C:\GENIE2K\CAMFILES\STDLIB.NLB

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

  Nuclide     Id       Energy     Yield      Activity      Activity
  Name     Confidence   (keV)       (%)      (uCi/    )   Uncertainty

  BE-7        0.948     477.59*    10.42   8.23319E-003  2.71737E-004
  NA-22       0.996    1274.54*    99.94   3.77786E-004  1.39391E-005
  SC-46       0.983     889.25*    99.98   6.67236E-005  1.14934E-005
                       1120.51*    99.99   1.10917E-003  2.34273E-005
  MN-54       0.879     834.83*    99.97   2.17337E-004  1.18559E-005
  CO-58       0.914     810.76*    99.40   4.67983E-003  1.11019E-004
  Y-93        0.372     266.90*     6.90   6.80759E+000  9.72548E-001
                        947.10       1.95
                       1917.80       1.40
  NB-95       0.997     765.79*    99.81   7.43515E-003  1.70976E-004
  ZR-95       0.970     724.18*    43.70   1.13056E-002  3.28527E-004
                        756.72*    55.30   6.78248E-003  2.07216E-004
  TC-96       0.467     778.22*    99.76   2.39376E-003  6.85586E-005
                        812.54*    82.00   2.86873E-002  1.58081E-003
                        849.86     98.00
                       1126.85*    15.20   8.71123E-003  7.39228E-004
  ZR-97       0.615     254.15*     1.25   7.36708E+000  2.63815E-001
                        355.39*     2.27   5.77123E-001  1.08670E-001
                        507.63      5.30
                        602.52      1.39
                        743.36*    92.80   3.70526E-002  2.72029E-003
                       1021.30      1.21
                       1147.00      2.60
                       1362.66      1.35
                       1750.46      1.35
  ?-99        0.955     140.51*    88.70   8.03649E-002  3.10891E-003
                        181.06*     6.20   8.01185E-002  7.02843E-003
                        366.43      1.37
                        739.58*    12.80   8.33675E-002  5.55813E-003
                        778.00*     4.50   8.67447E-002  2.30437E-003
              0.994     497.08*    89.00   3.53492E-002  2.10182E-003
                        610.33*     5.60   7.12951E-002  1.47775E-003
                  ?     306.10      5.13
                        318.90*    19.20   1.55839E-002  8.52958E-004
                        ?21.84*     9.80   4.46245E-002  2.48110E-003
                            47      1.73
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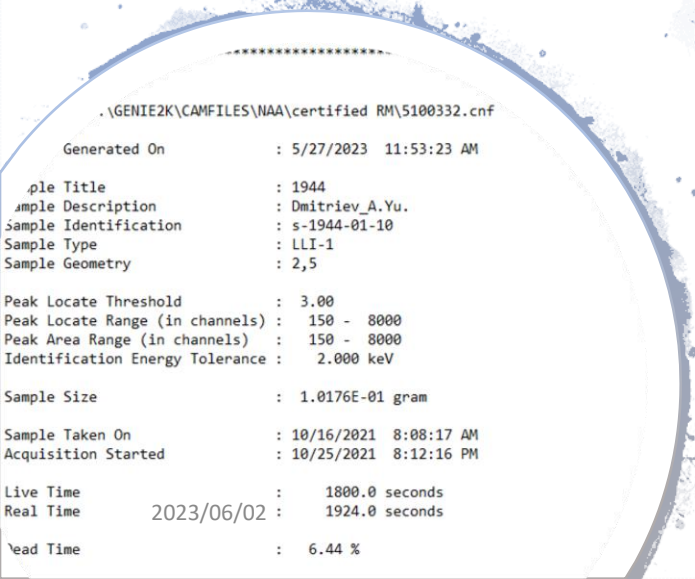
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 mple Description              : Dmitriev_A.Yu.
Sample Identification          : s-1944-01-10
Sample Type                    : LLI-1
Sample Geometry                : 2,5

Peak Locate Threshold          :  3.00
Peak Locate Range (in channels) :   150 -  8000
Peak Area Range (in channels)  :   150 -  8000
Identification Energy Tolerance :    2.000 keV

Sample Size                    :  1.0176E-01 gram

Sample Taken On                : 10/16/2021  8:08:17 AM
Acquisition Started            : 10/25/2021  8:12:16 PM

Live Time                      :     1800.0 seconds
Real Time                      :     1924.0 seconds

ead Time                       :   6.44 %
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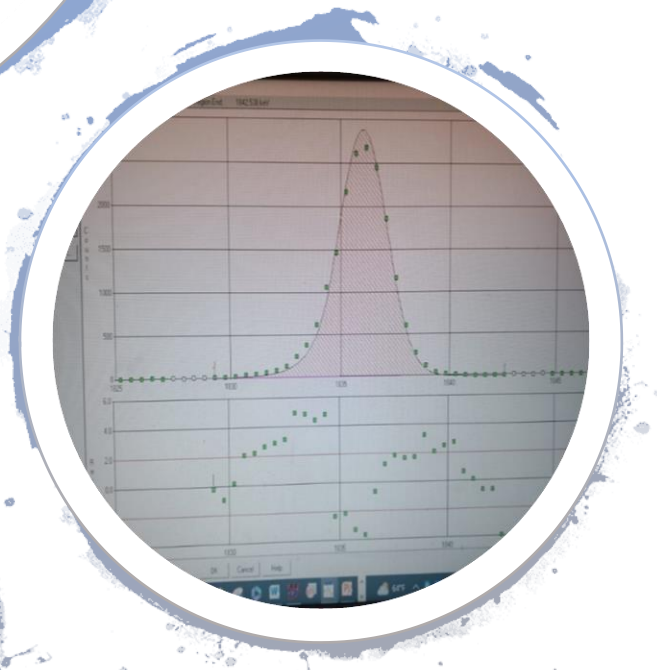
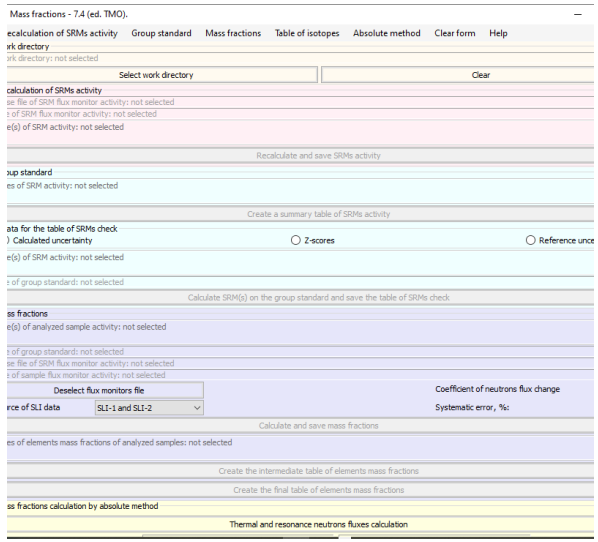
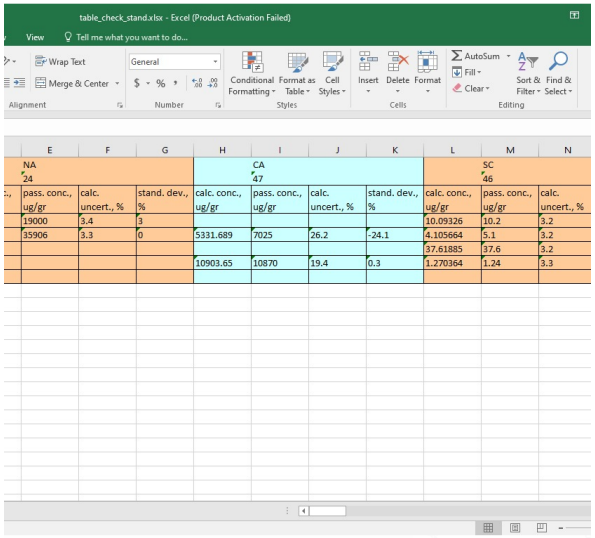
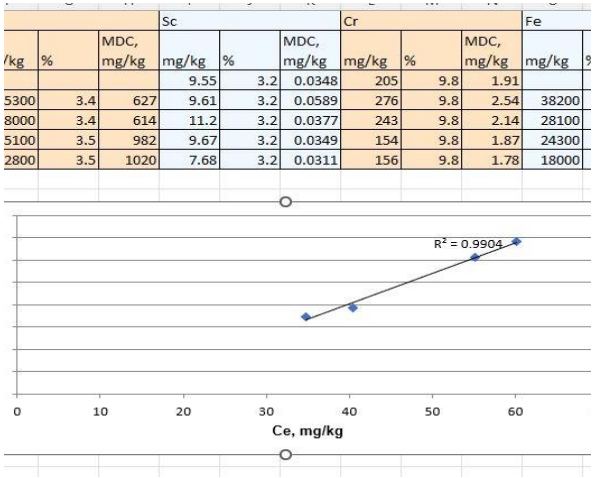


Concentration Program

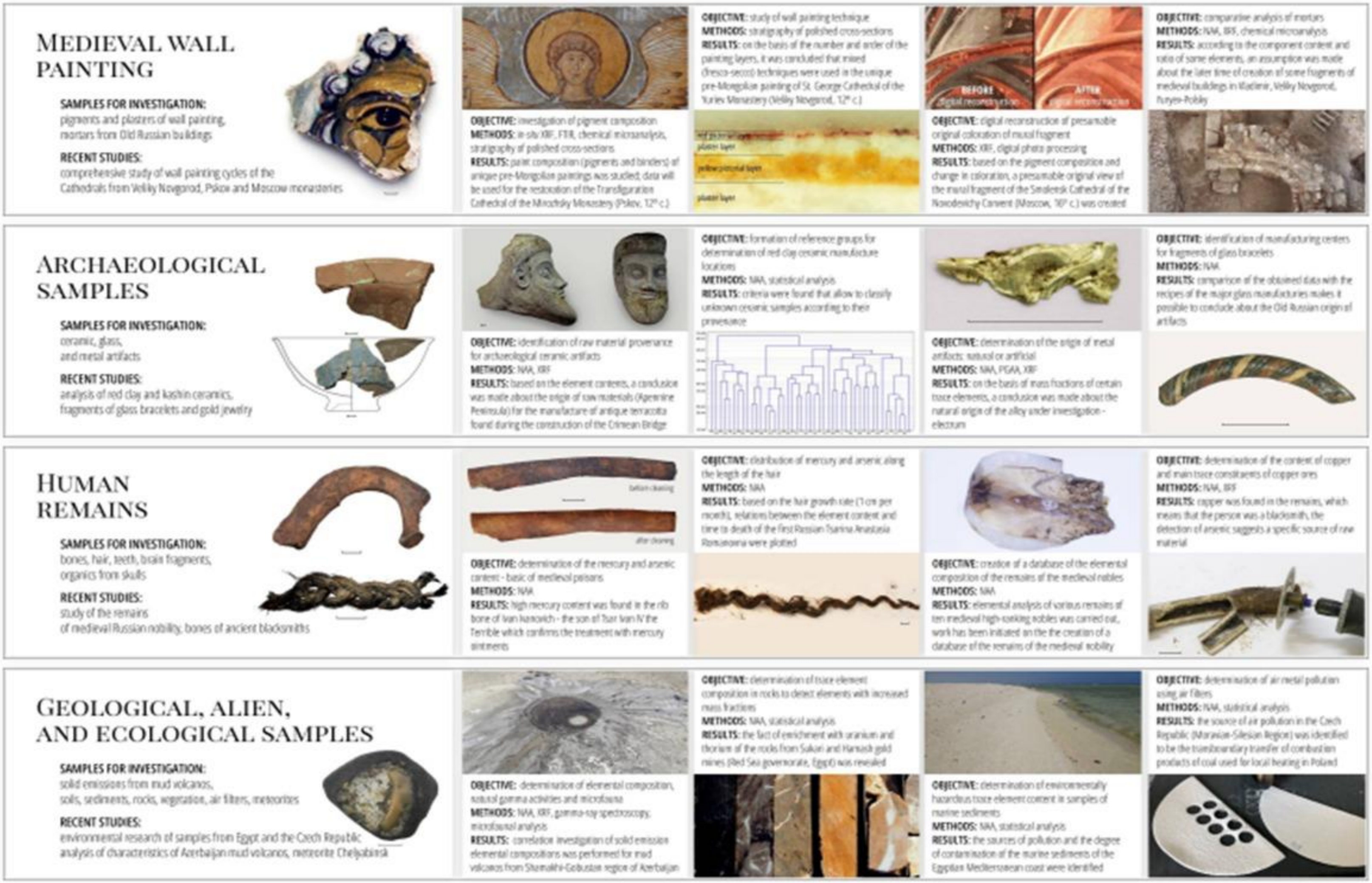






Most Common Programmes Used For Data Interpretation

- ArcGIS
- Statistica
- Origin-Lab
- CorelDraw



http://flnph.jinr.ru/en/

Joint projects – Egypt

1st Phase	• Assessment of the environmental situation in the basin of the River Nile using nuclear and related analytical techniques (2011-2014).
2nd Phase	• Environmental studies in Egypt using neutron activation analysis and other analytical techniques (2015-2018).
3rd Phase	• Assessment of the environmental situation in the marine ecosystems in Egypt using neutron activation analysis and other analytical techniques (2018-2019).
4th , 5th Phase	• Assessment of ecological situation of different ecosystems by using neutron activation and related analytical techniques: an approach of baseline concentrations, pollution indicators, and health hazard (2020-till now)
	• Application of Nuclear and related analytical techniques to investigate the Egyptian archaeological materials.

The international student practice at JINR offered us several outcomes

- **Enhanced Knowledge and Skills**
- **Research Collaboration**
- **Cultural Exchange**
- **Professional Development**
- **Future Opportunities**

Acknowledgment

- We are deeply grateful to ASRT and JINR for the invaluable opportunity to participate in the international student practice. Our time at JINR has been enriching, with special thanks to the University Centre team and the Group of Neutron Activation Analysis – Frank Laboratory of Neutron Physics for their warm welcome, collaboration, and expertise sharing. We appreciate the stimulating scientific discussions and access to cutting-edge research equipment.
- Dr. Andrey Dmitriev and Dr. Wael Badawy, our supervisors at JINR, for their guidance, mentorship, and expertise. Their knowledge and encouragement have been instrumental in shaping our understanding of neutron activation analysis.
- Thank you all for making our international student practice at JINR a remarkable and unforgettable journey.

References

- P. Bode, J. J. M. de Goeij, Activation Analysis, Encyclopedia of Environmental Analysis and Remediation
- P. Bode, Instrumental and organizational aspects of a neutron activation analysis laboratory.

Born to be explorers!

Thank you for your attention!