Neutron Activation Analysis for life sciences

Supervised By:

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(Frank laboratory of Neutron Physics)

The sector of neutron activation analysis and applied research

Neutron Activation analysis NAA

Introduction

Stop, stare and listen!

Innovation

Ideas

Crushing boundaries

Jumping out of the box

Neutron Activation Analysis in a nutshell

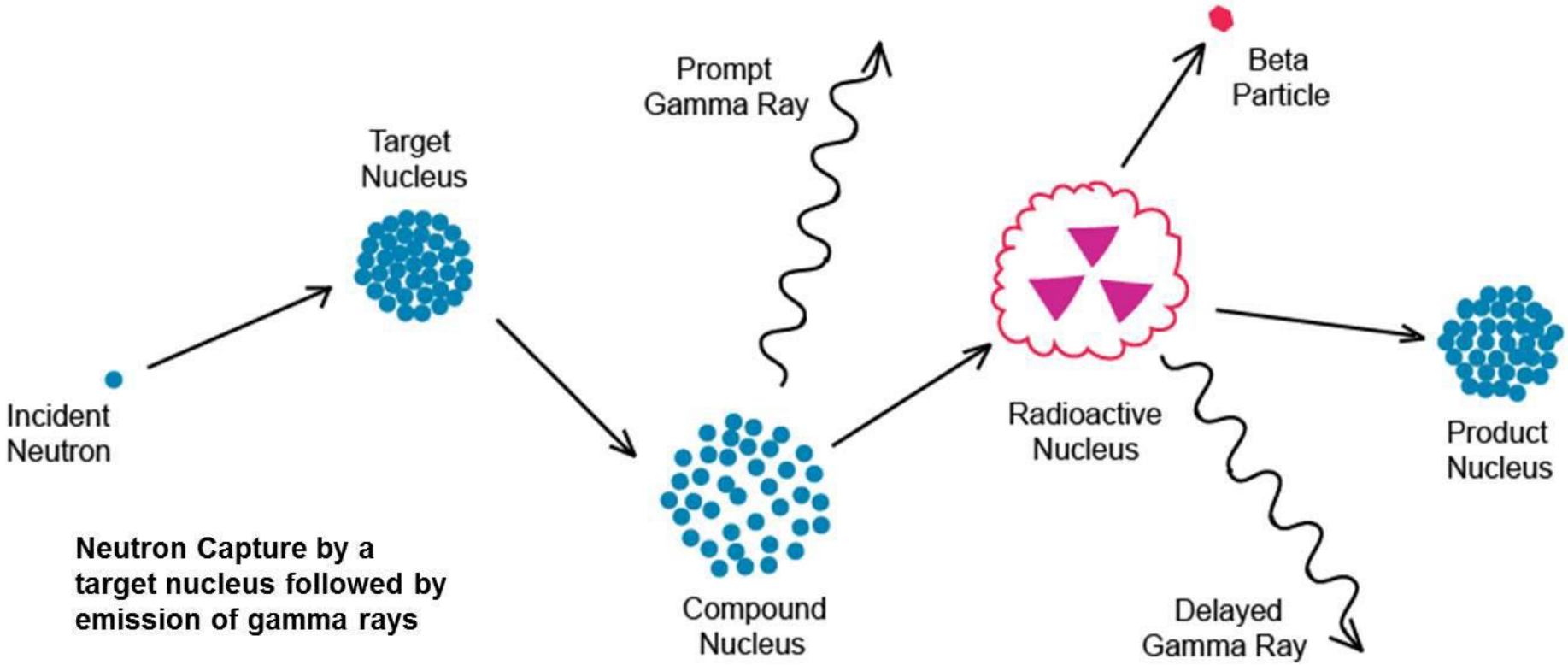
History:

- Discovery of Neutrons - James Chadwick
- Discovery of NAA - George Charles de Hevesy and Hilde Levi

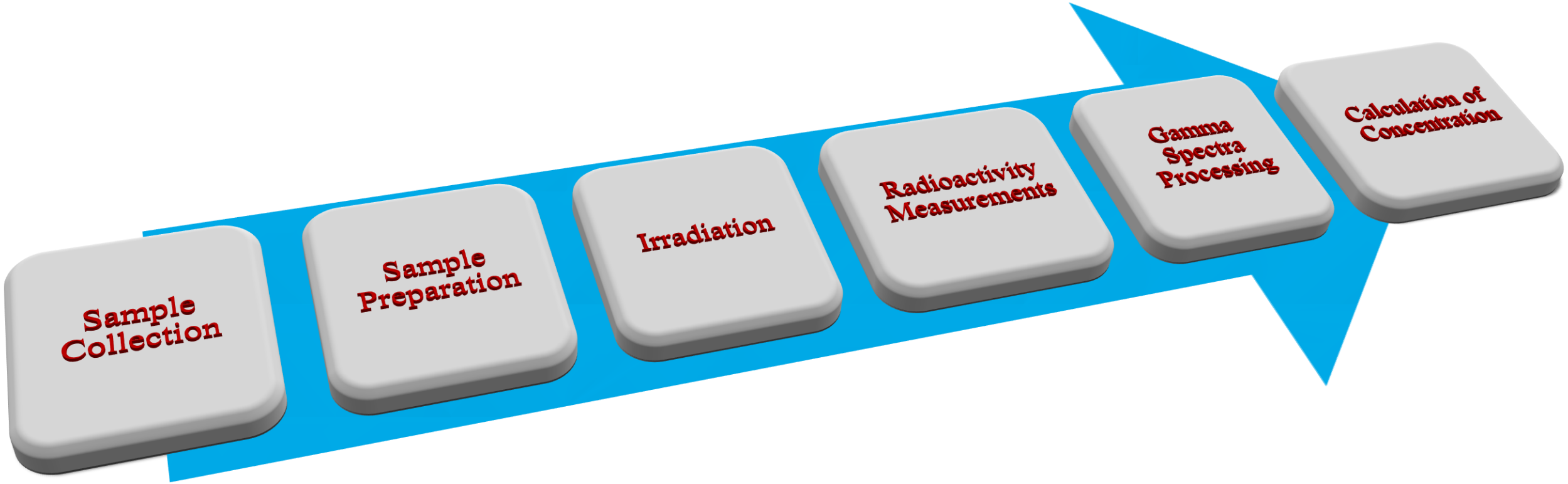
Definition:

The conversion of the stable nuclei to a radioactive one and the release of a measured gamma rays.

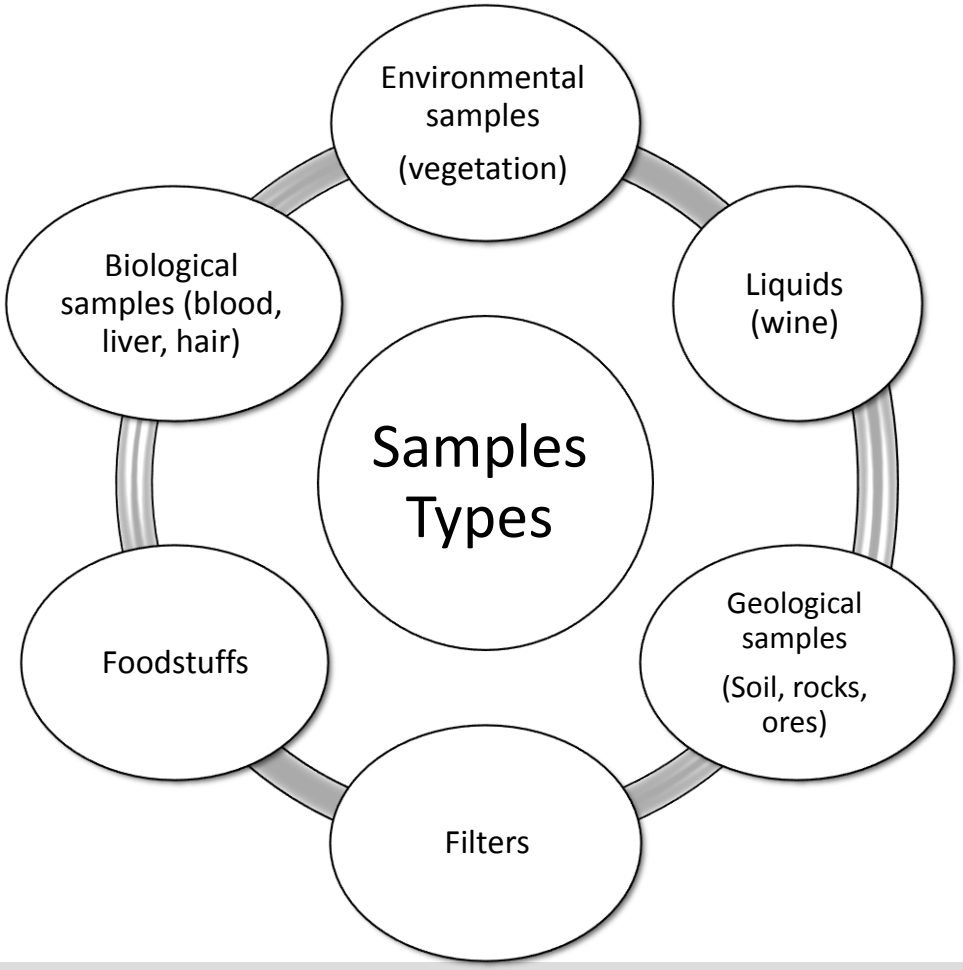
Nuclear Interactions



Neutron Activation Analysis Flow Chart



Sample Collection



A) Moss Sample Collection

- There are two moss species are collected for metal analysis:

1. Big Red Stem Moss **(*Pleurozium schreberi*)**

2. Stair-steps Moss **(*Hylocomium splendens*)**

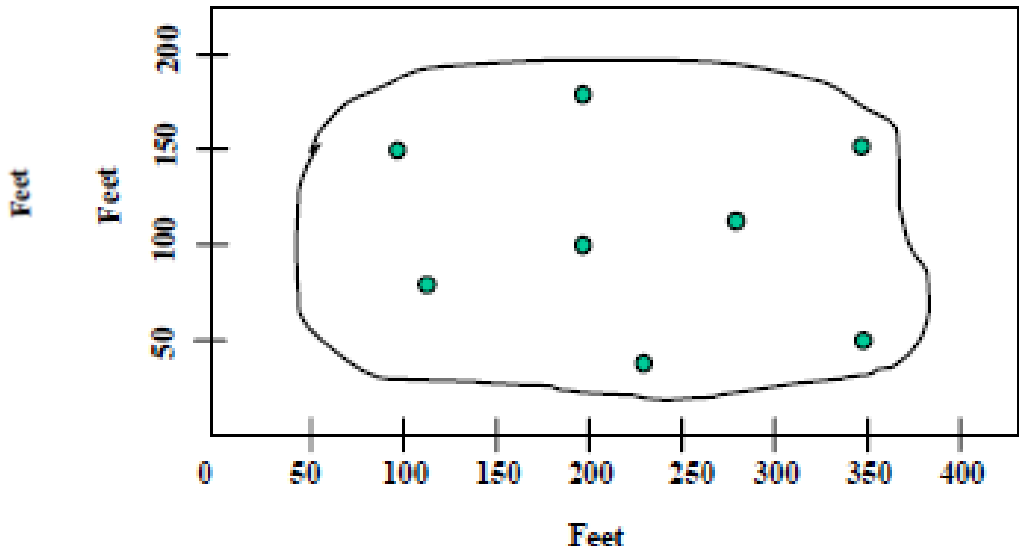
B) Soil Sample Collection

-The longitude and latitude of the sample **location** should be recorded

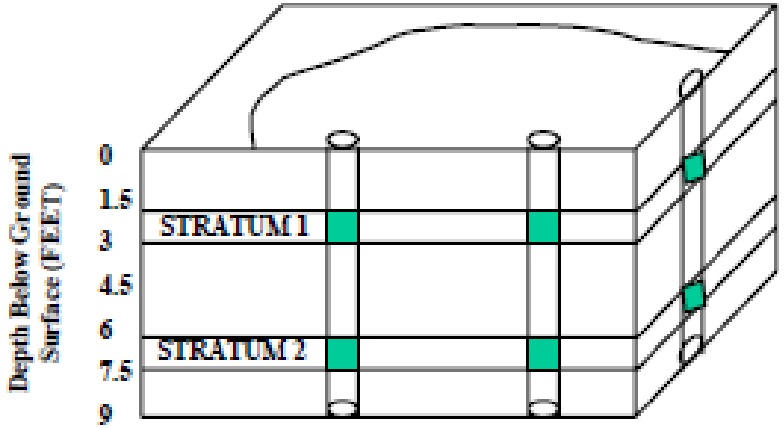
-Samples need to be **Separated** from other impurities

-**Packed** in zip-bags and the numbers need to be written on the bag.

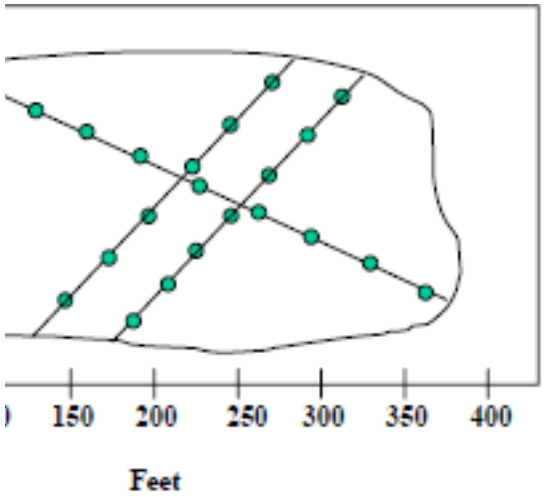
-The sample after collection are sent to the lab



a) Random Sampling



b) Stratified Random Sampling



ansect Sampling

- Random
- Systematic
- Search

Sample Preparation

A) Devices and equipment:

AA spectrometer
(iCE™ 3000 Series)

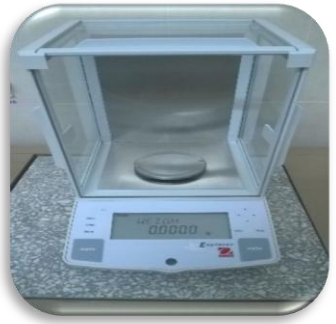
Microwave
digestion system

Ball mill
homogenizer

Hydraulic compressor

Freeze dryer

Electrical oven (30-300)^{0}C

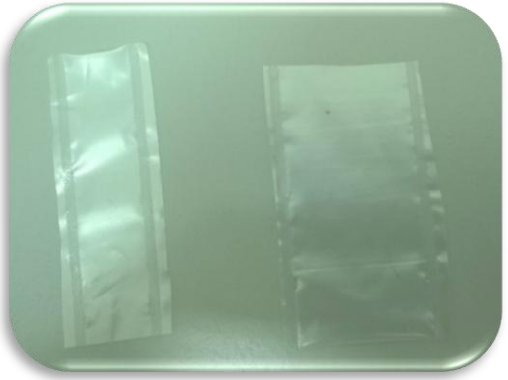


Balance

Sample Preparation

B) Materials:

Sealing machine



Poly ethylene plastic bags

Aluminum covers

Pelletizer

Sample Preparation

C) Preparation steps for NAA: "For Moss and Soil Samples"

I. • **Drying**

II. • **Pelletizing**

III. • **Weighing & Recording**

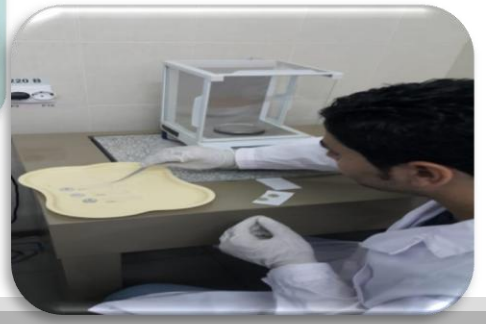
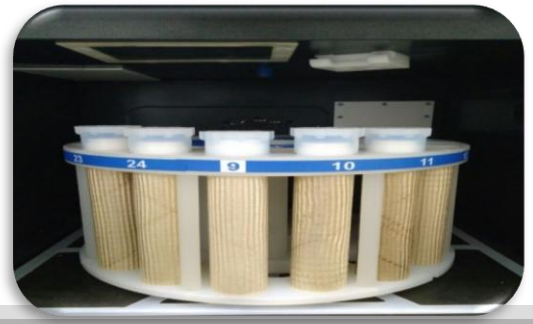
IV. • **Packing**

Sample Preparation

D) Preparation steps for AAS: "For Moss and Soil Samples"

- **Drying**
  - Air- dried then in the oven
- **Homogenization**
  - (soil, lichens)
  - Using ball mill
- **Weighing and Recording**
  - Using the lab program
- **Sample digestion**
  - Using microwave system
- **Sample dilution**
  - To specified volume



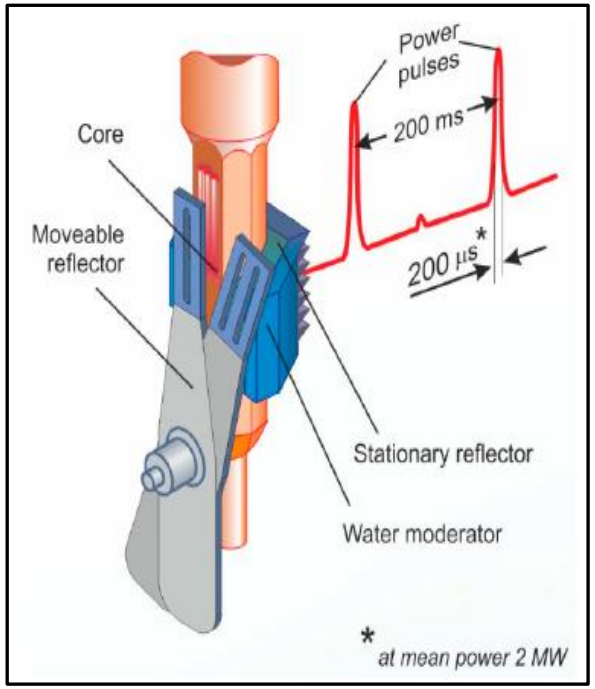



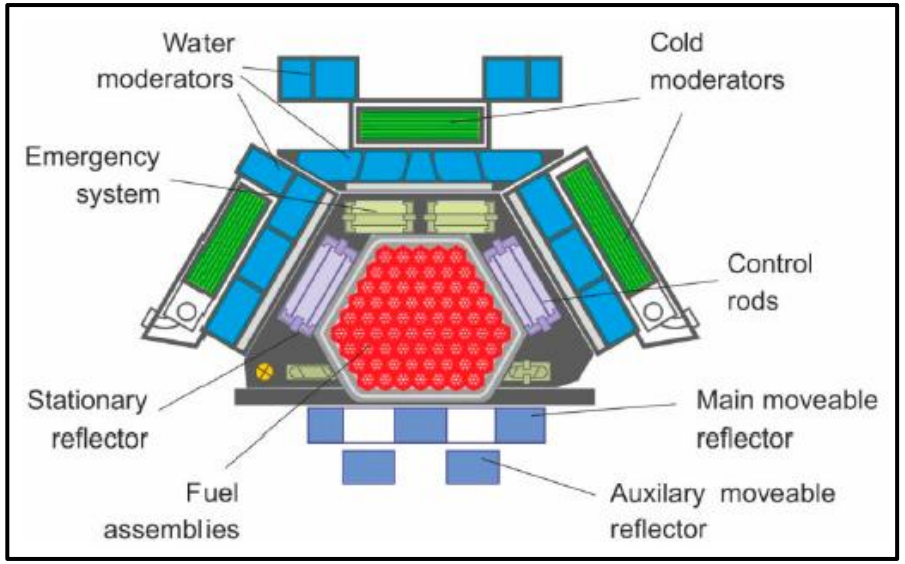

Sample Preparation

E) Handling precautions During preparation of the sample:

- To **remove impurities** from the sample
- To be sure that the **samples well dried**
- To **write down the numbers** on the bags clearly
- To use the **plastic zip-bags for the short live** radiation and **the aluminum one for long live** radiation
- To use **the metallic tweezers in packing the samples** and **the plastic one for weighting**

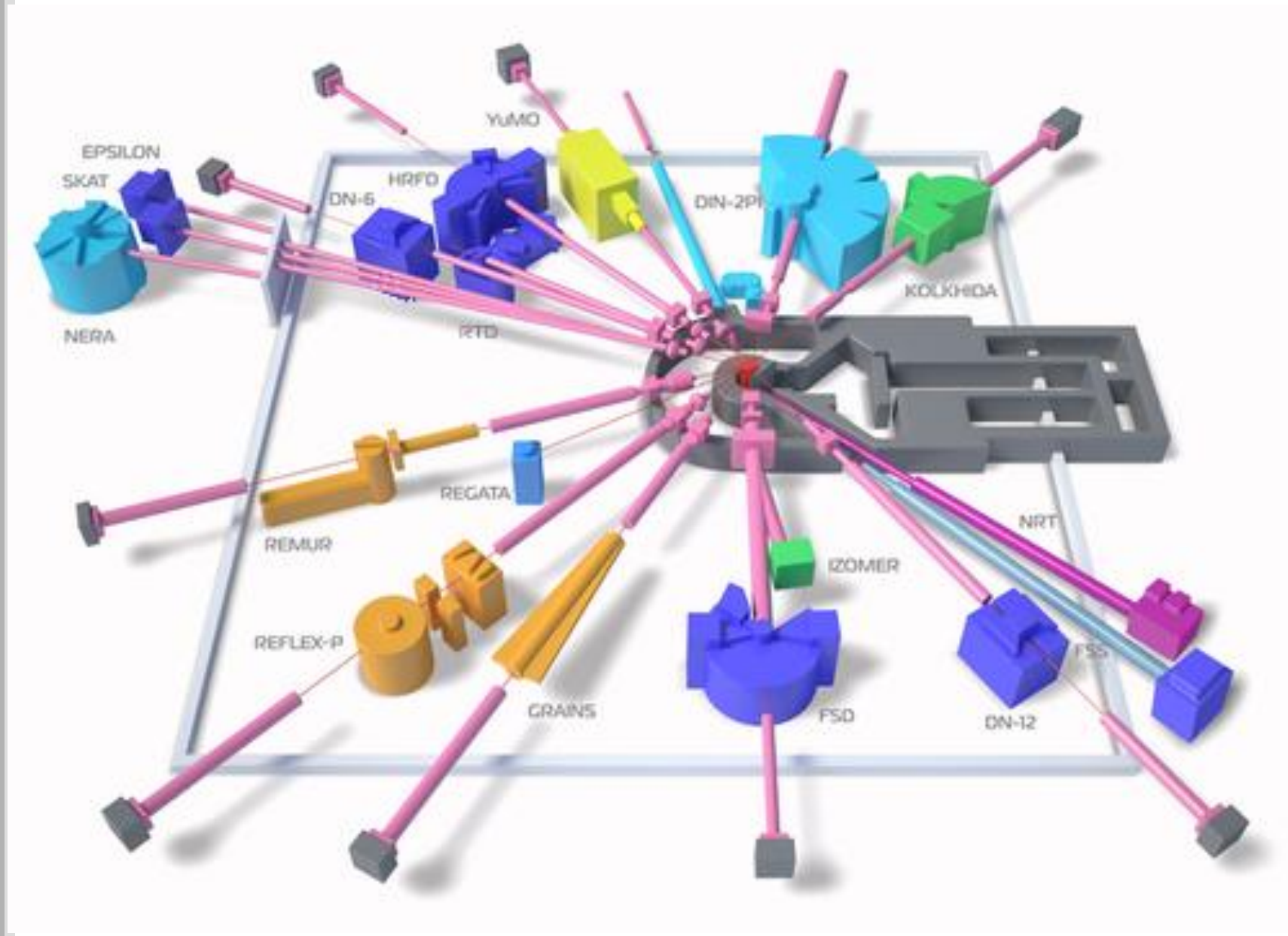
IBR-2M Pulsed Fast Rea

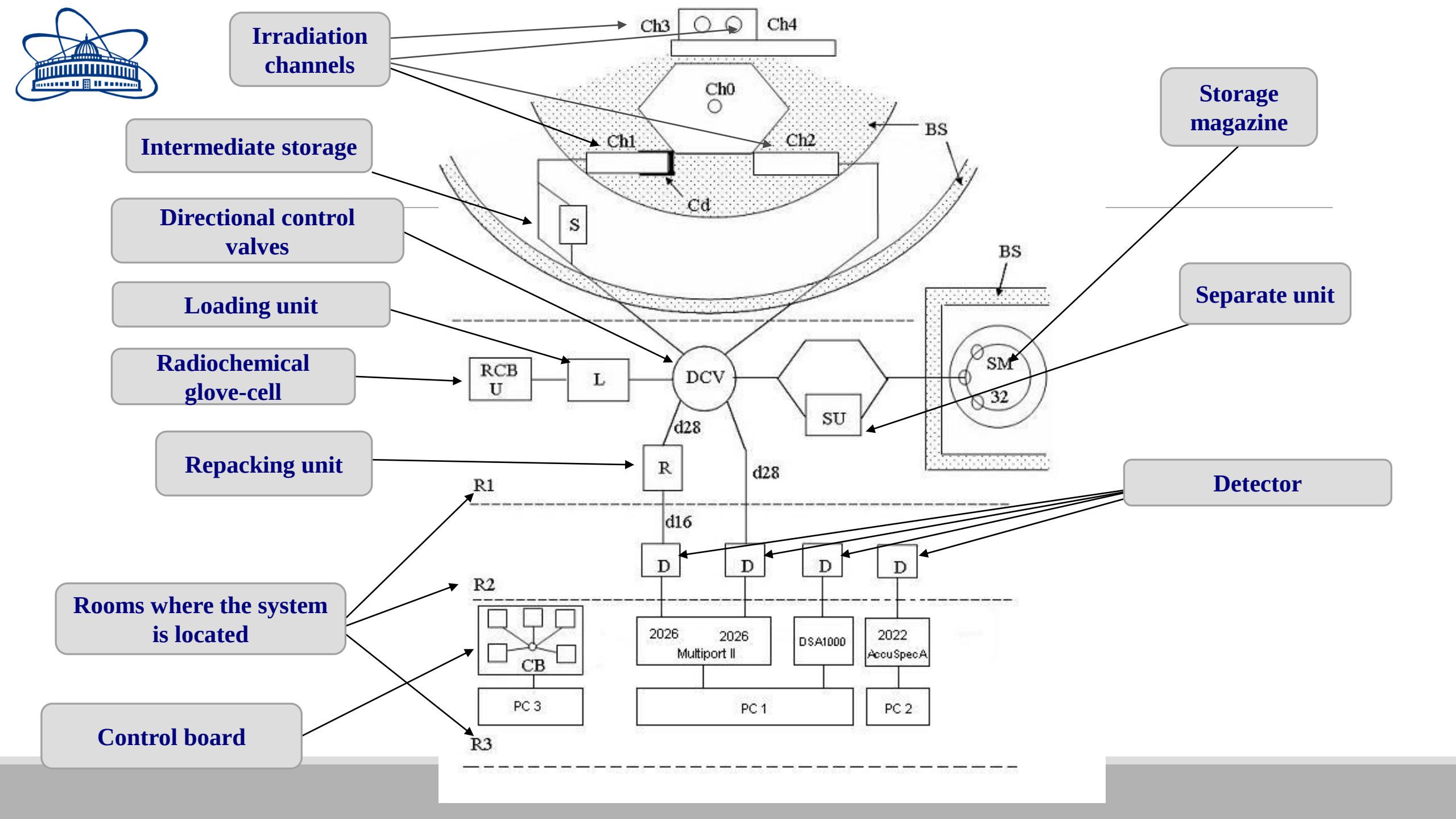




Parameter	Value
Average power (MW)	2
Fuel	PuO_2
Number of fuel assemblies	69
Maximum burnup(%)	9
Pulse Repetition rate (Hz)	5.10
Pulse Half width, μs: • Fast neutron • Thermal neutron	 245 340
Rotation rate (rev/min): • Main reflector • Auxiliary reflector	 600 300
Coolant	Sodium
Thermal neutron flux density from moderator surface ($n.cm^{-1}.s$): • Time average • Burst maximum	 ~10^{13} ~10^{16}

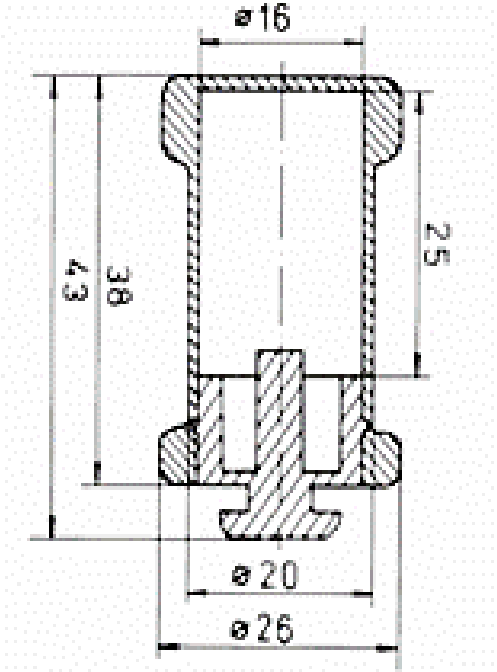
Experimental facility REGATA at IBR-2 reactor



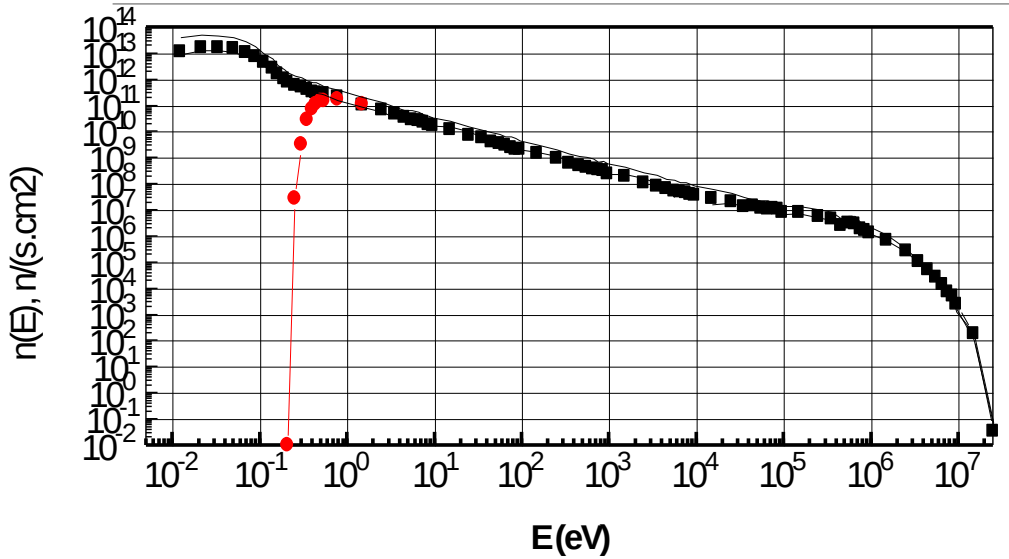

Irradiation channels
Intermediate storage
Directional control valves
Loading unit
Radiochemical glove-cell
Repacking unit
Rooms where the system is located
Control board
Storage magazine
Separate unit
Detector
Ch3
Ch4
Ch0
Ch1
Ch2
BS
Cd
S
BS
SM
32
SU
RCB U
L
DCV
d28
R
d28
R1
d16
D
D
D
D
R2
CB
2026
2026
Multiport II
DSA1000
2022
AccuSpecA
PC 3
PC 1
PC 2
R3

Transport capsules for irradiation

Container material	Irradiation time
Polyethylene	Up to 30 minutes
Aluminum	Longer time irradiation



Irradiation Channels



Neutron energy spectra
in irradiation channels CH1
and CH2 (curve)

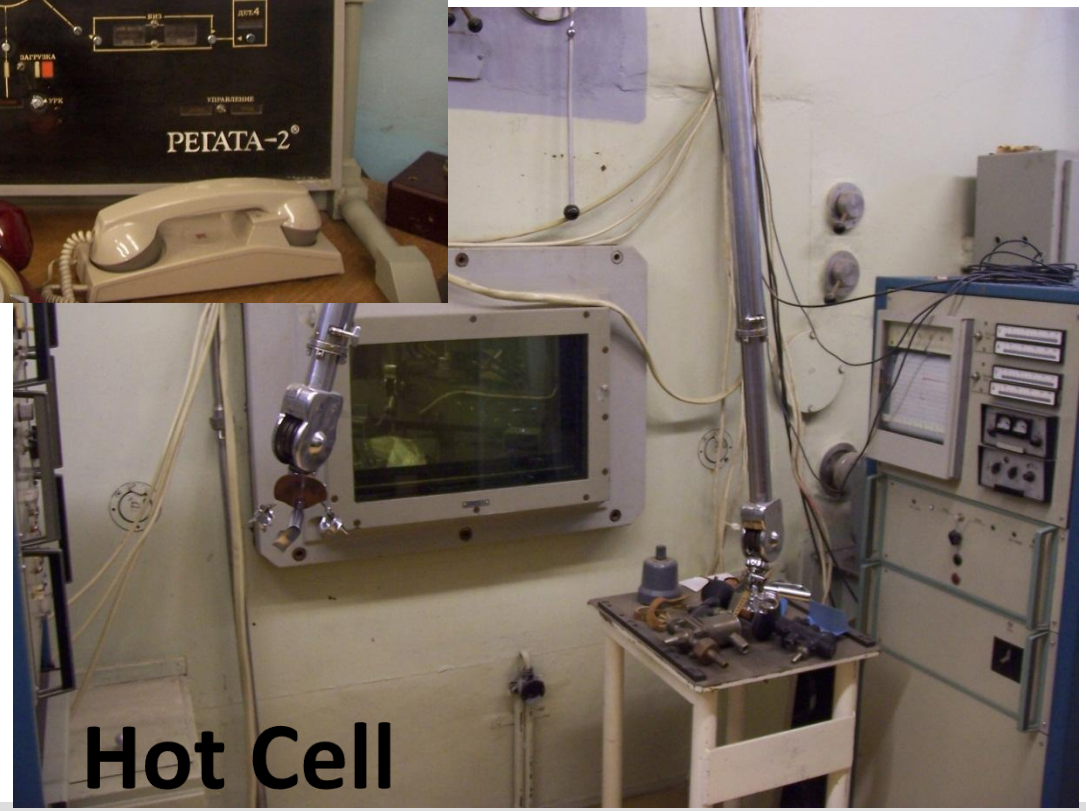
Irradiation site	Neutron flux density (n/cm^2 s) 10^{12}			T ^{0}C	Channel diam., mm	Channel length, mm
	Thermal	Resonance	Fast			
Ch1	Cd-coated	3.31	4.32	70	28	260
Ch2	1.23	2.96	4.1	60	28	260
Ch3	Gd-coated	7.5	7.7	30-40	30	400
Ch4	4.2	7.6	7.7	30-40	30	400

The main characteristics of
the irradiation channels at 1.5 MW

closer look on REGATA


Directional control valves


РЕГАТА-2®

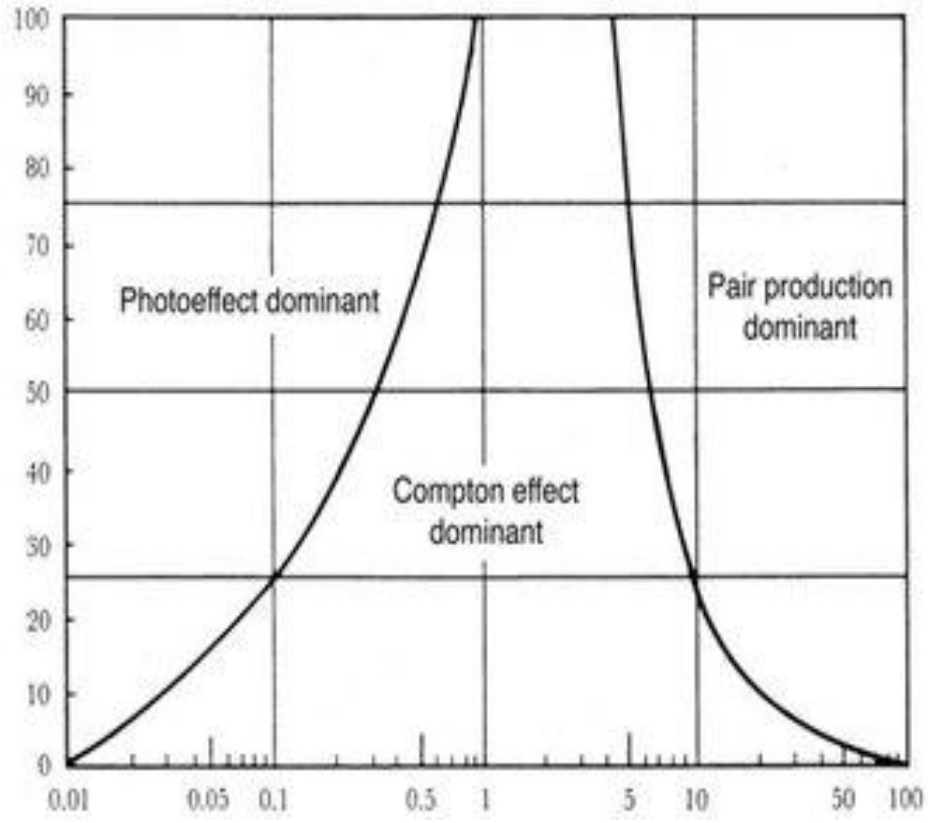

Hot Cell

Radioactivity measurement of the irradiated samples

1. Interaction of Gamma with matter:

There are three modes of interaction (depending on photon energy)

A- Photoelectric effect
B- Compton Effect
C- Pair production



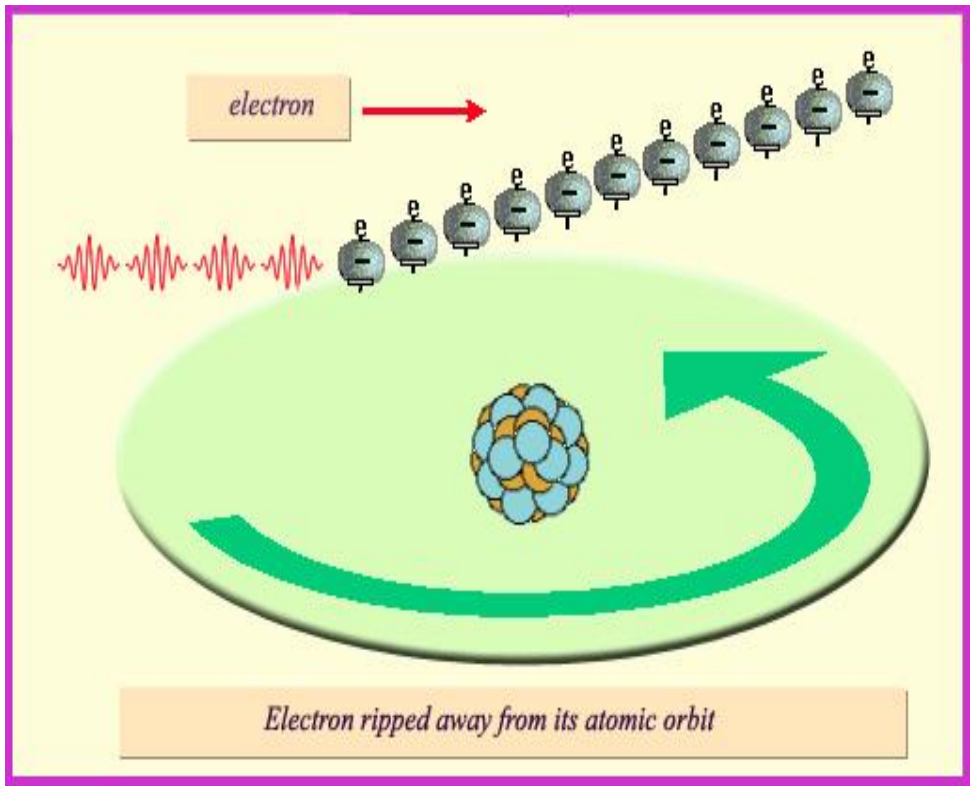
Con’t

A) Photoelectric effect:

-Most important interaction of low-energy photons with matter

-Cross-sections for photoelectric effect increase strongly, especially for high-Z media

-Photoelectric effect totally predominates over the Compton Effect at low photon energies



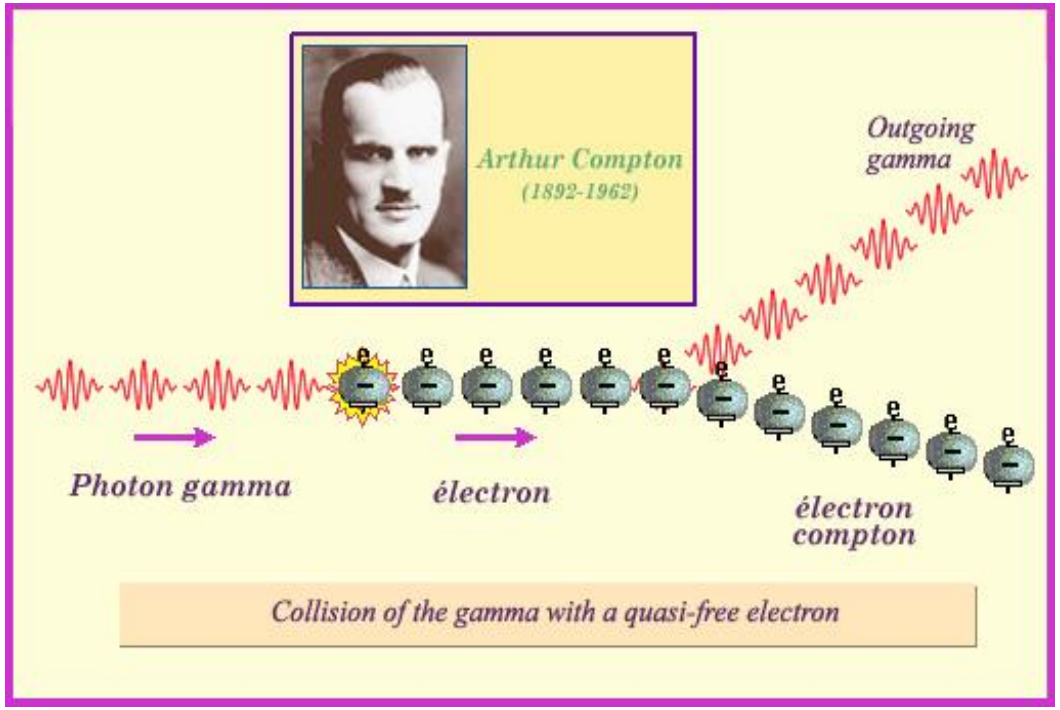
Con’t

B) Compton scattering:

-Only part of the incident energy is absorbed to eject an electron (Compton electron)

-During interaction:

The photon disappears, a secondary photon is created with reduced energy – propagating in a changed direction.



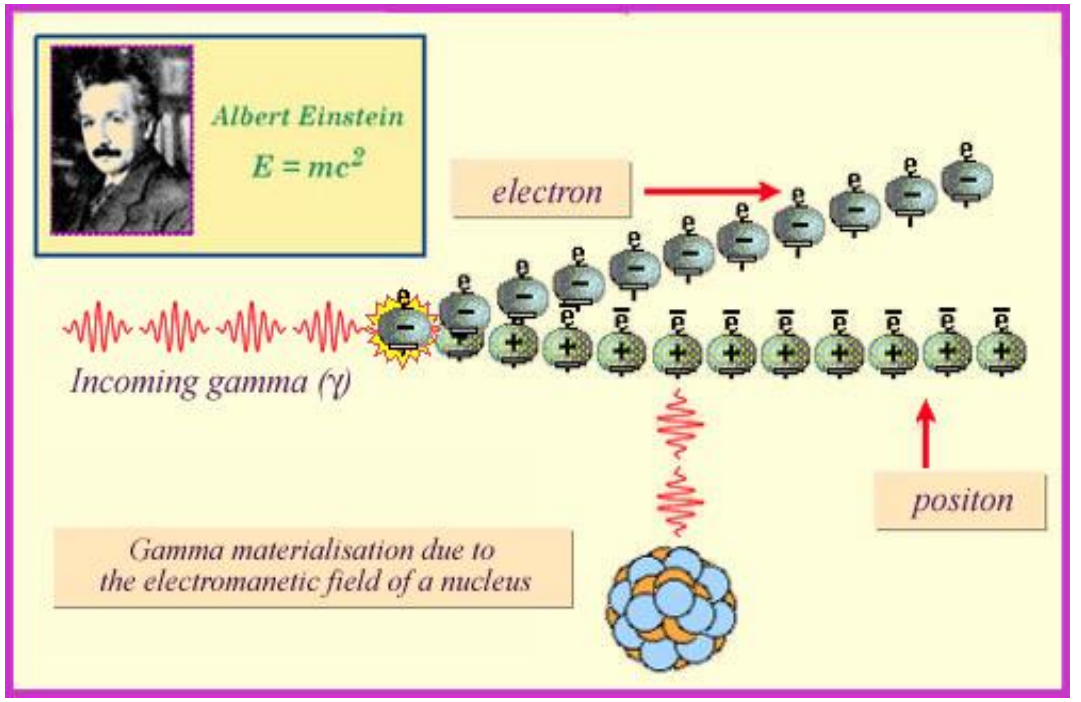
Con’t

C) Pair production:

-For photoelectric and Compton effects the interaction of photon is with electrons of atom

-Pair production involves interaction of photons with the nucleus of the atom

-The photon disappears and a positron and an electron appear



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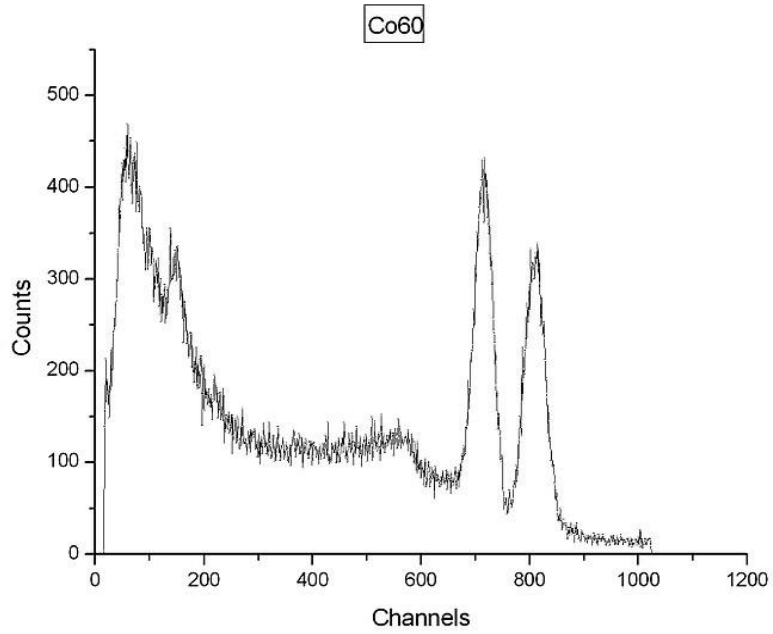
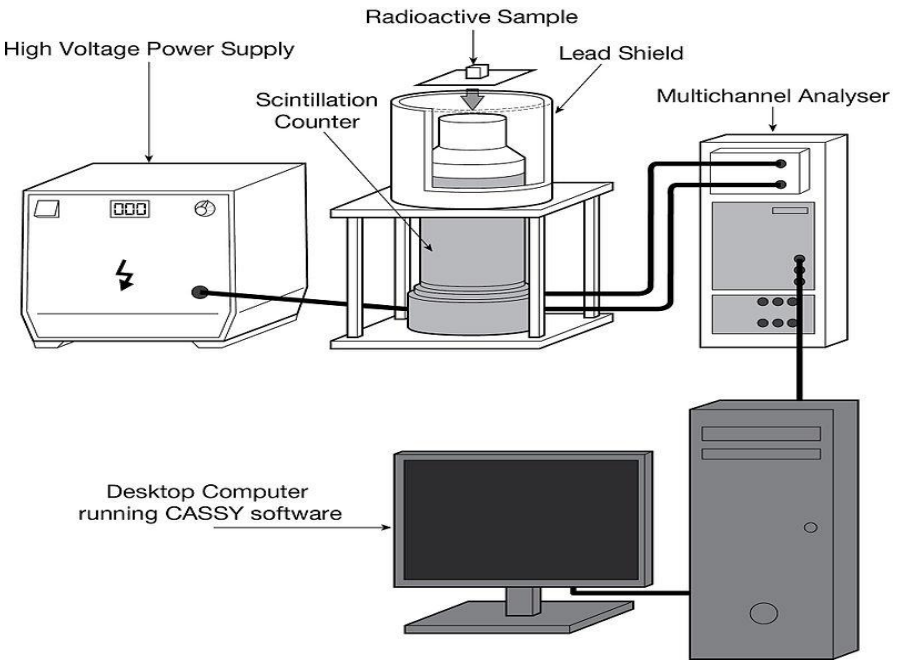
2. Gamma spectrometer

A gamma-ray spectrometer (GRS) is an instrument for measuring the distribution of the intensity of gamma radiation versus the energy of each photon.

Gamma-ray spectroscopy is laboratory equipment for determination of γ-radiation spectrum with a scintillation counter.



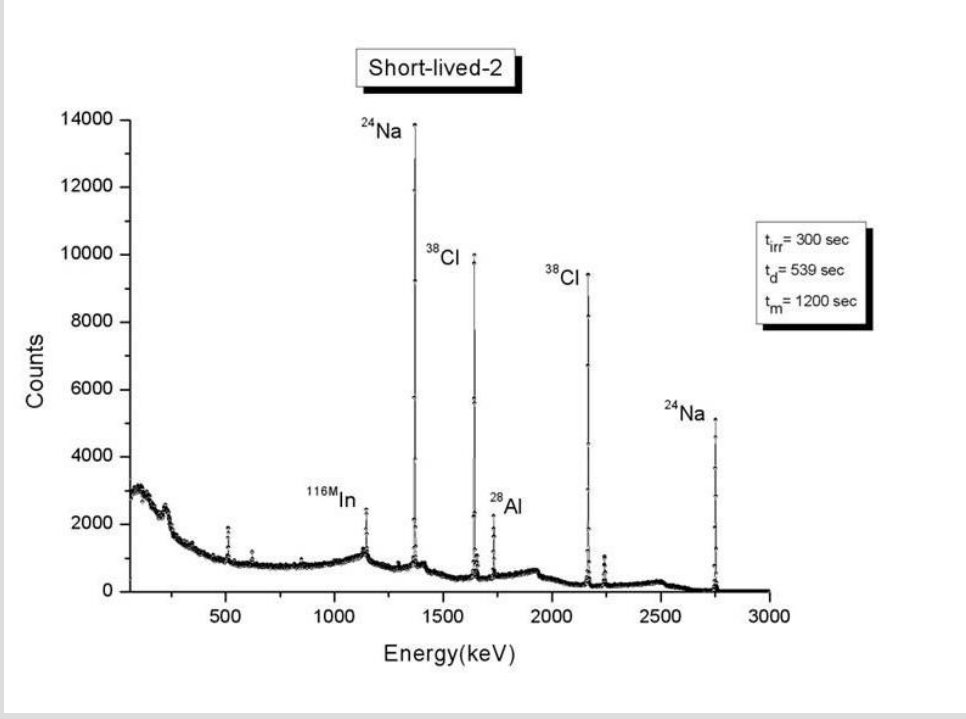


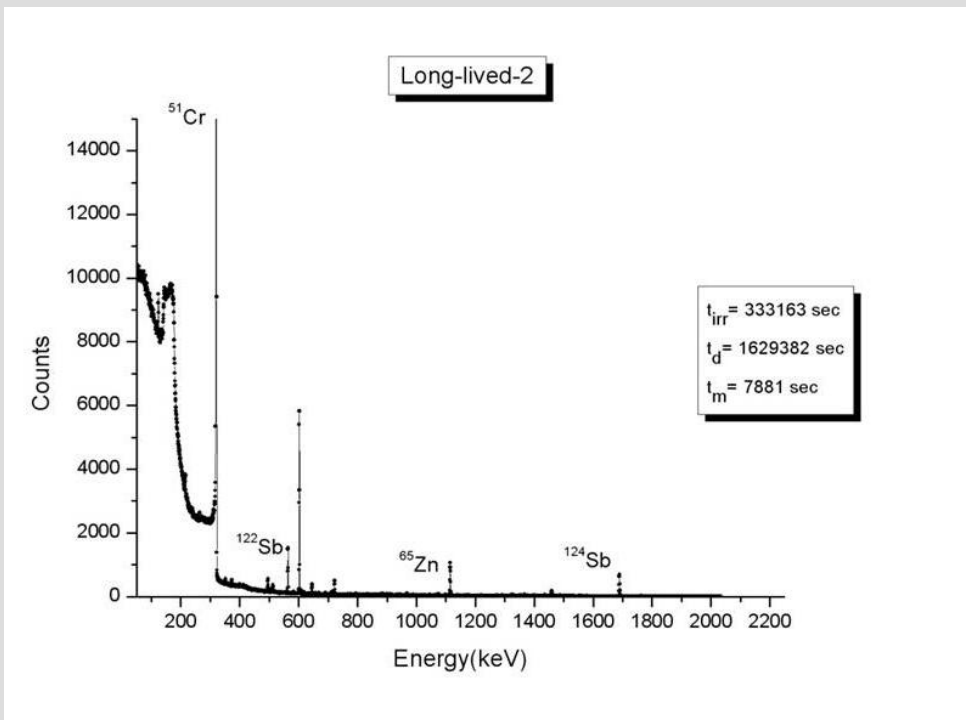
Con’t

3. Measurements

- Long lived isotopes are measured twice after 3-4 days and 20-22 days of decay, measurement time is 30 mins. And 90 mins. respectively

- Short lived isotopes are measured 15 mins. Of decay

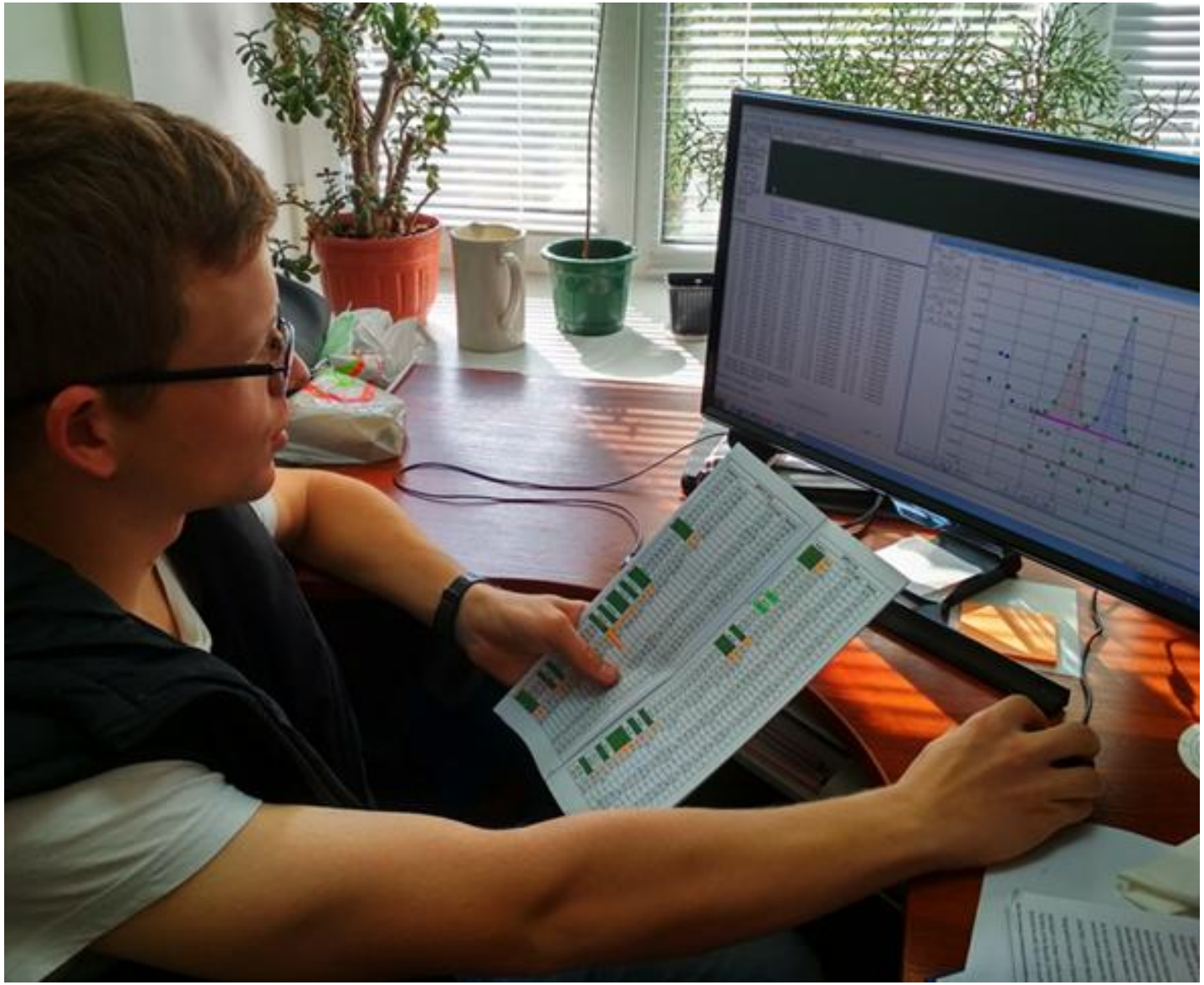


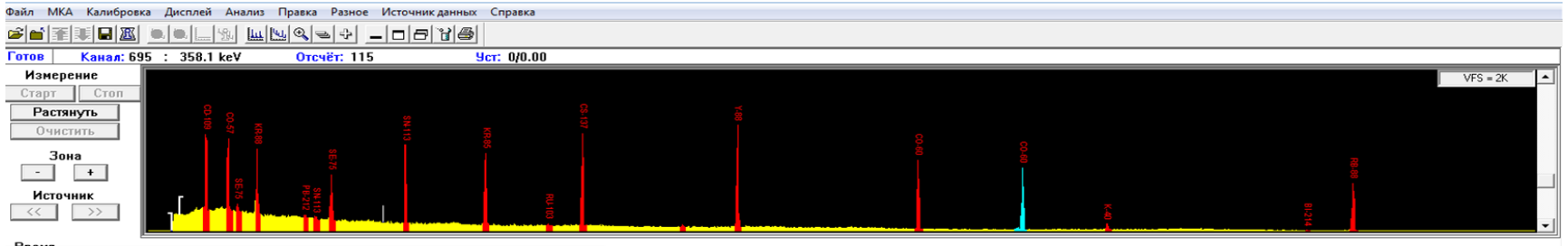


Processing of gamma spectra using G2X

- Software systems (Genie 2000™):

- Provides full energy calibration, peak width and detector efficiency
- Allows you to search the spectrum, search for statistically significant peaks, assign them nuclides and calculate the activity of the sample.



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

        Нуклид Достоверность Средневзвешенная  Погрешность
               идентификации активность,
                             uCi /Unit

        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
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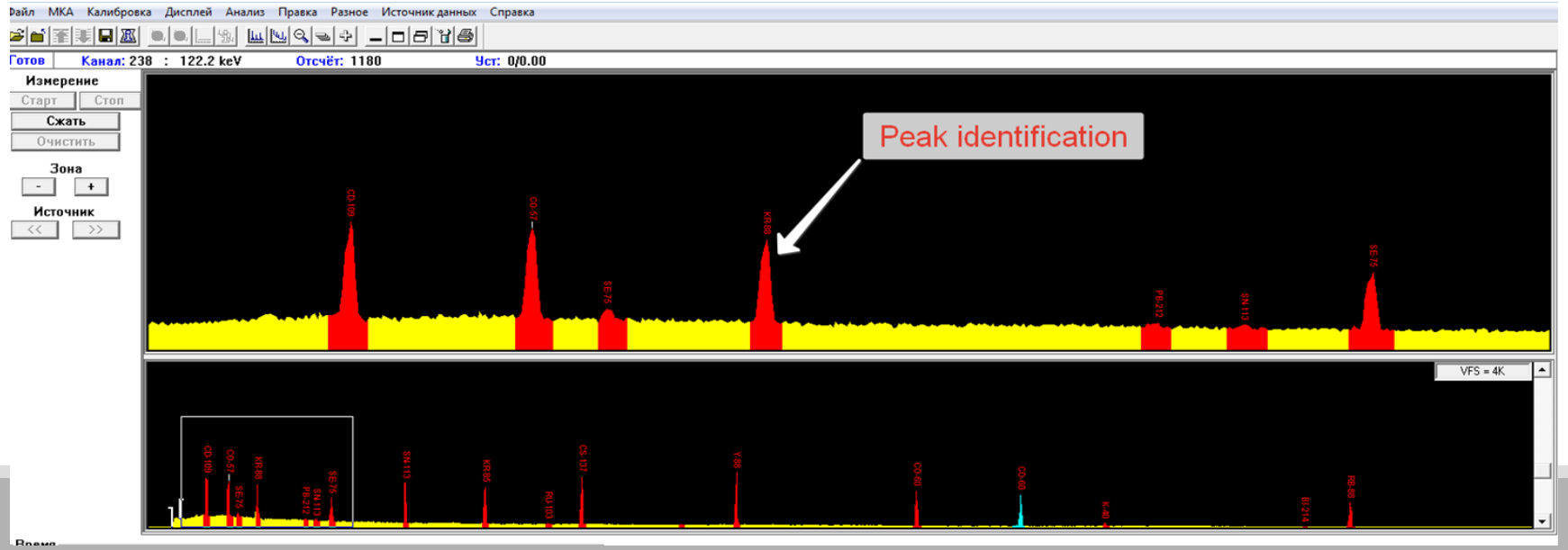
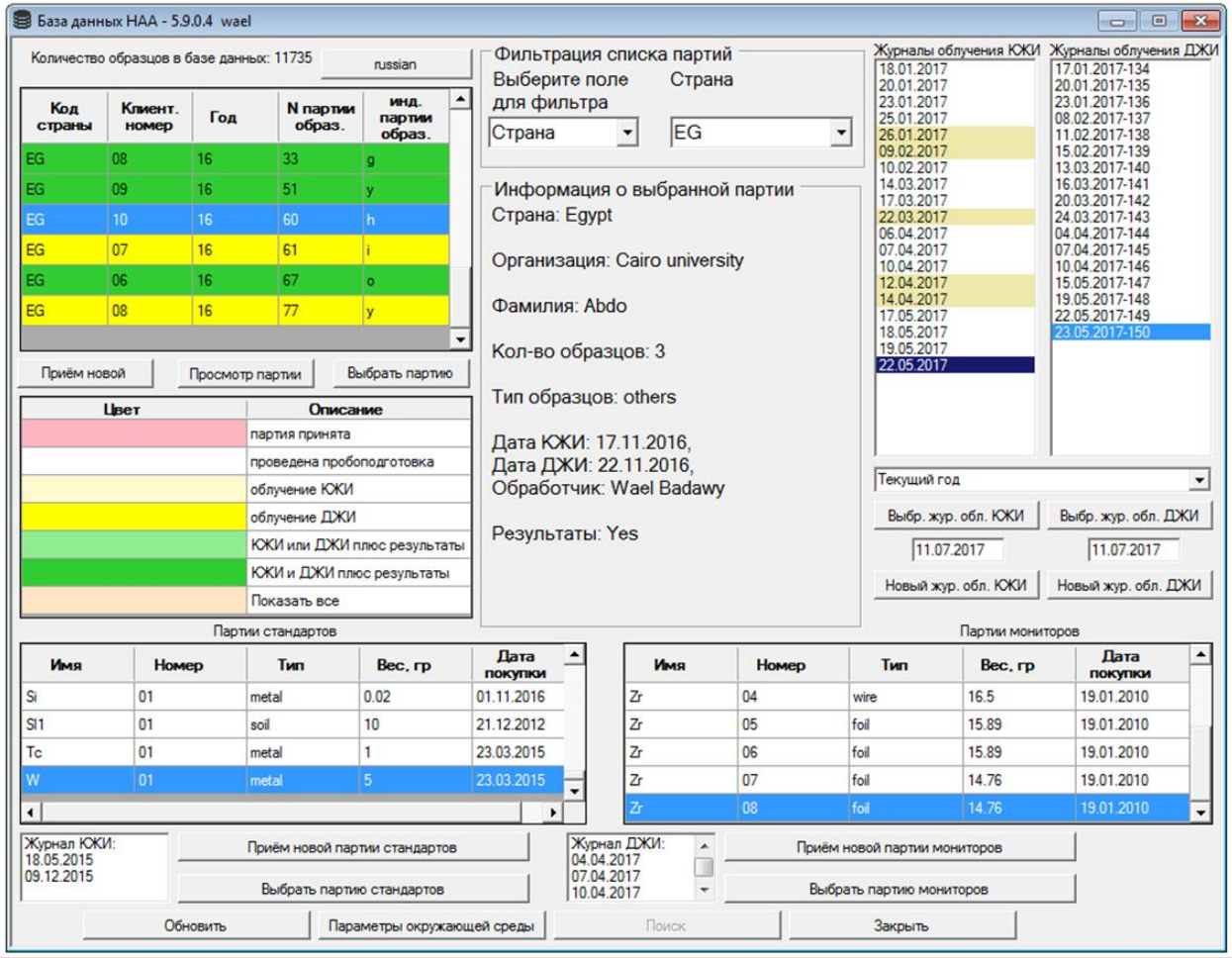
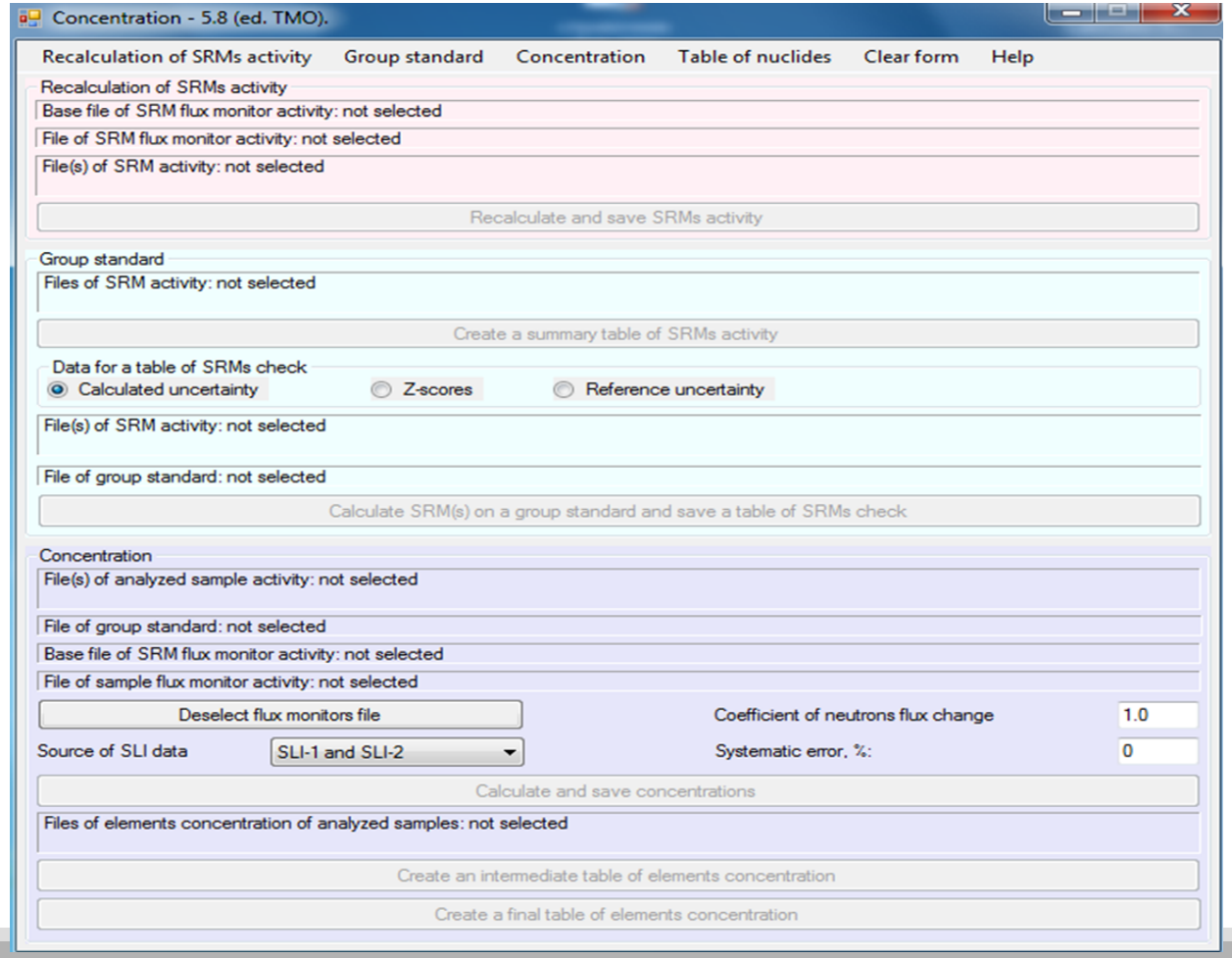


Con’t



Database

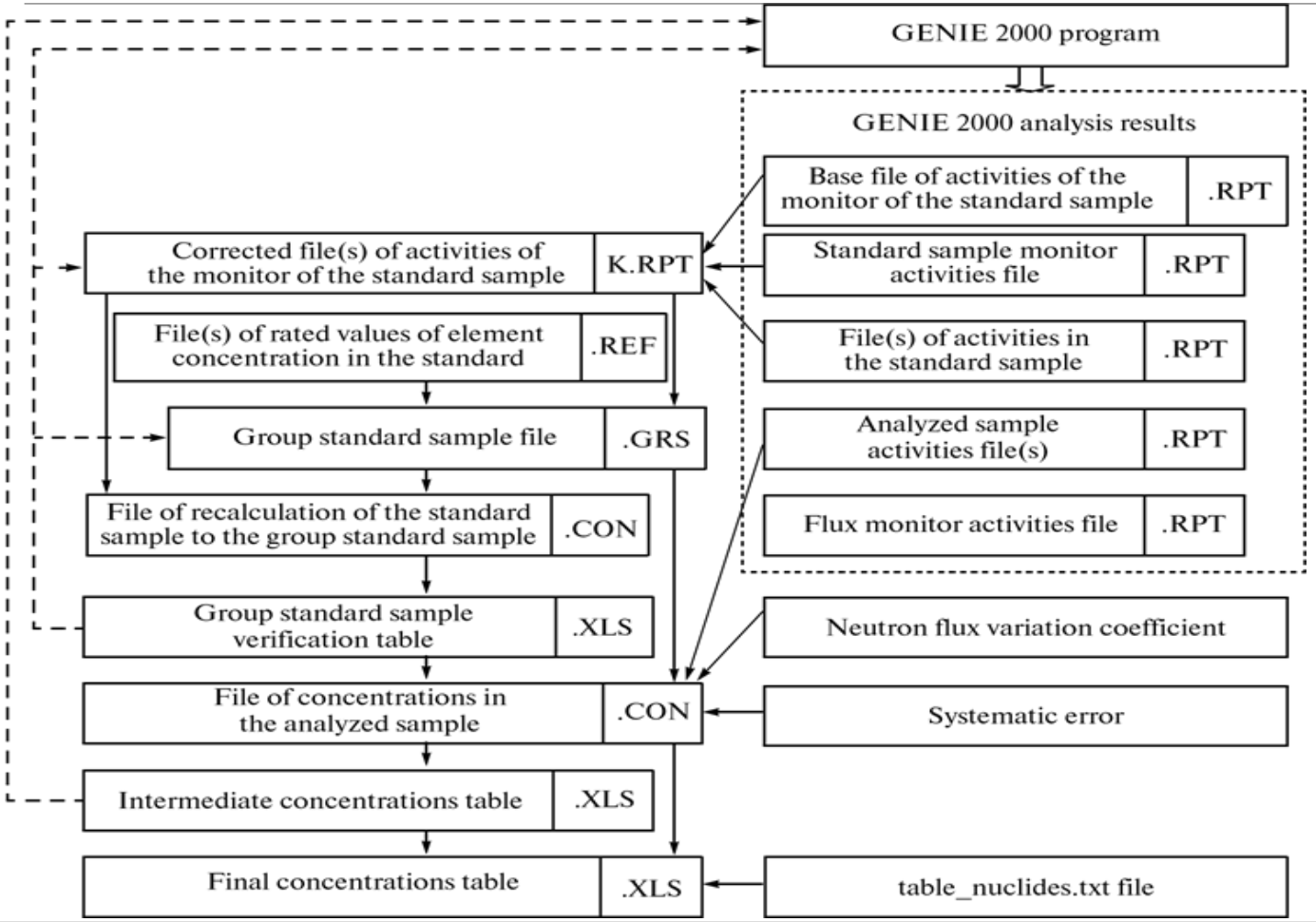
Con’t



Calculation of Concentration

“Main window of the conc. program”

Con’t



Functional scheme of the Concentration program

Advantages and limitations of NAA

Advantages

Multi-element analysis

Simultaneously detect all elements in the sample

Customizable analysis

Wide possibilities of applications

Non destructive analysis

Time-efficient for analyzing many samples

Limitations

Need for nuclear reactor

Work with radioactive materials

Time of analysis

Sample preference

Not all elements are detectable

The main applications of NAA

Bio-nanotechnology

Nutritiology

Archeology

Environment

Biomonitoring

Forensics

Toxicology

Cosmos

Geology

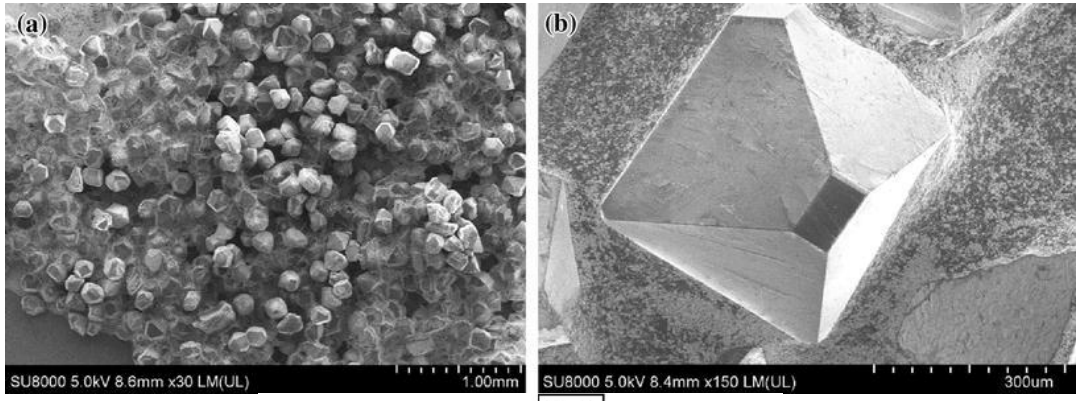
Semiconductor industry

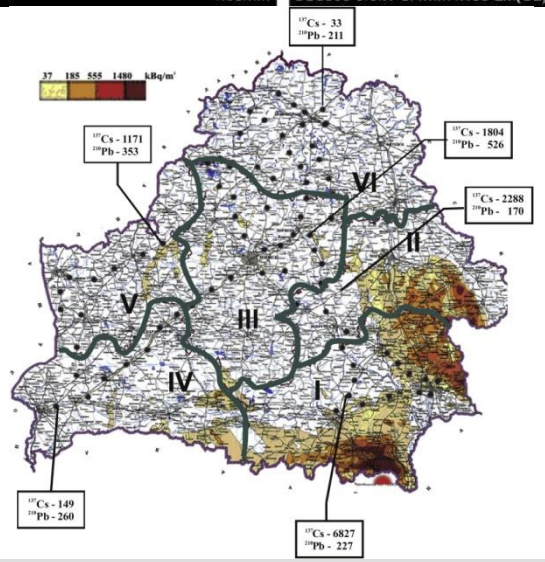
Joint projects (Belarus - Egypt)

A) Belarus:

1. Neutron activation analysis and electron microscopy in investigation of processes of crystallization and characteristics of diamonds in the systems C-Mn-Ni-Fe (Yulia Aleksiayenak , S.V. Leonchik, O.V. Ignatenko, V.A. Komar, A.V. Konovalova, M.V. Frontasyeva);

2. 137 Cs in moss samples from Belarus collected 2006-2007 (Yu. Aleksiayenak)



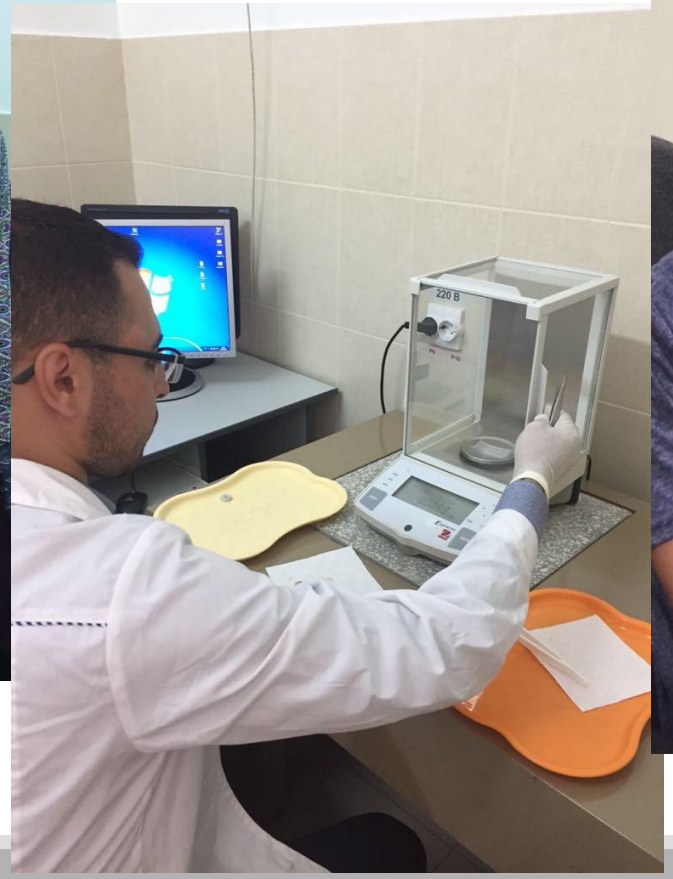


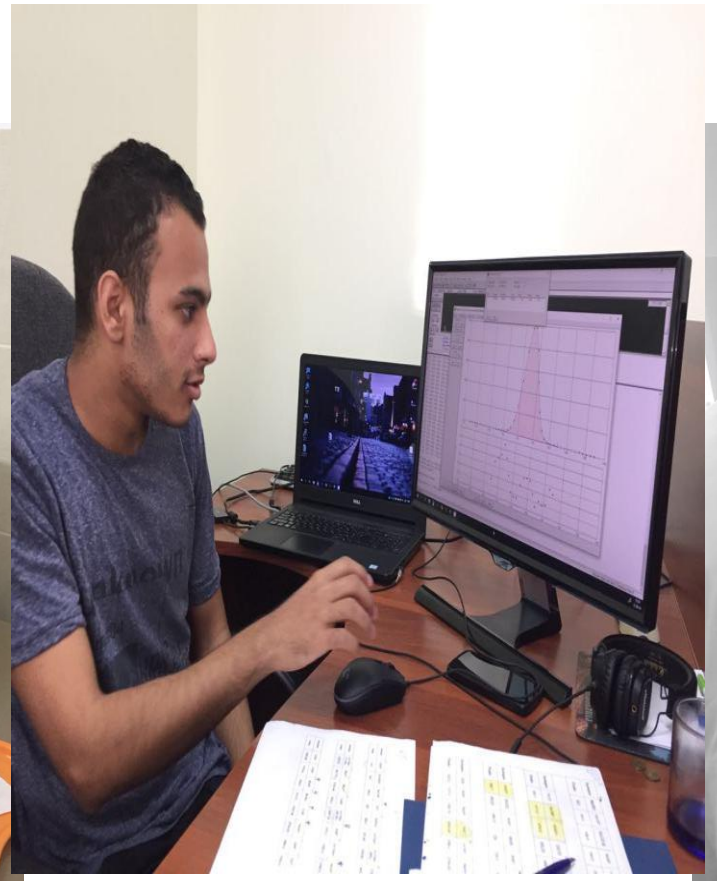
Con’t

B) 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:**
  - Environmental Assessment of the marine environment in Egypt (Mediterranean sea and Red sea)

Our Journey was EXTRAORDINARY!





Our Journey was INSIGHTFUL!

This is our three-week story!

Thank you.