



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

International students practice in JINR (Dubna, 08.09.2018)



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:

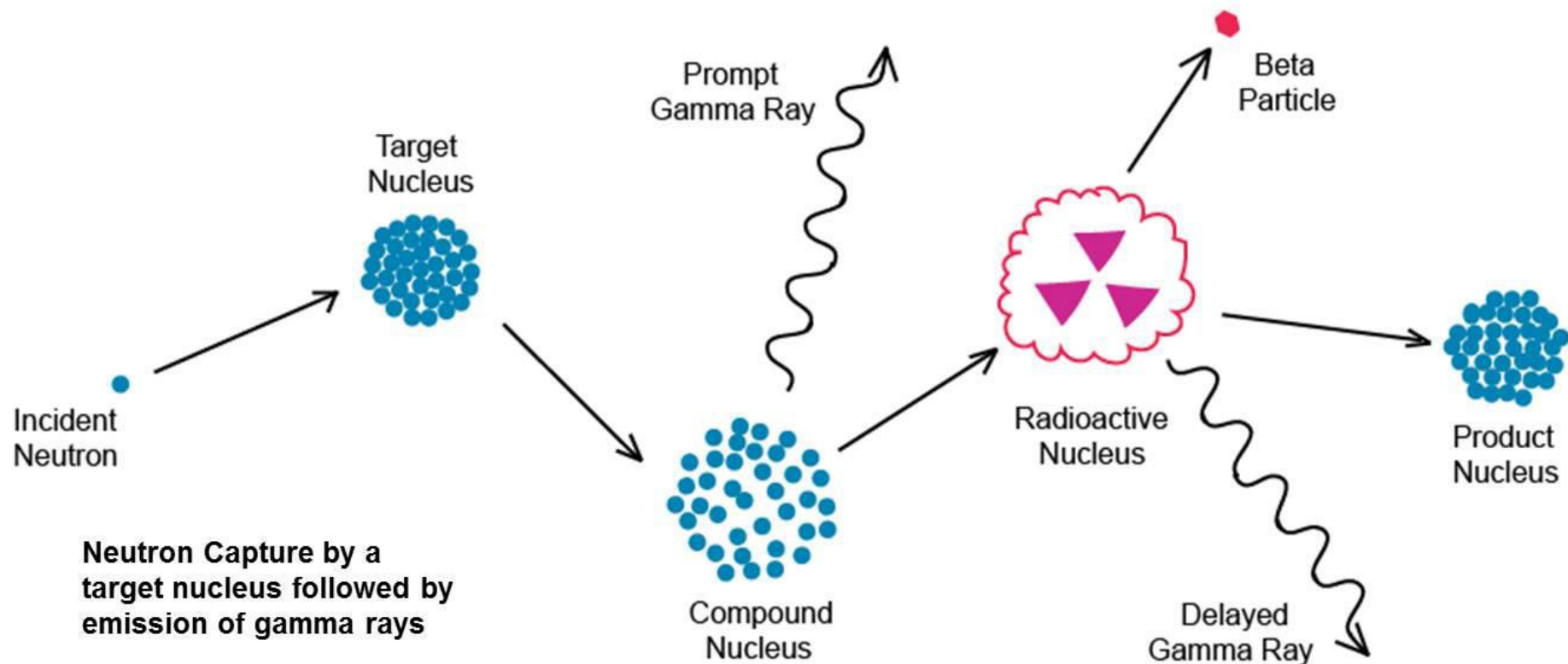
- Discovery of Neutrons - James Chadwick
- Discovery of NAA - George Charles de Hevesy and Hilde Levi

Definition:

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

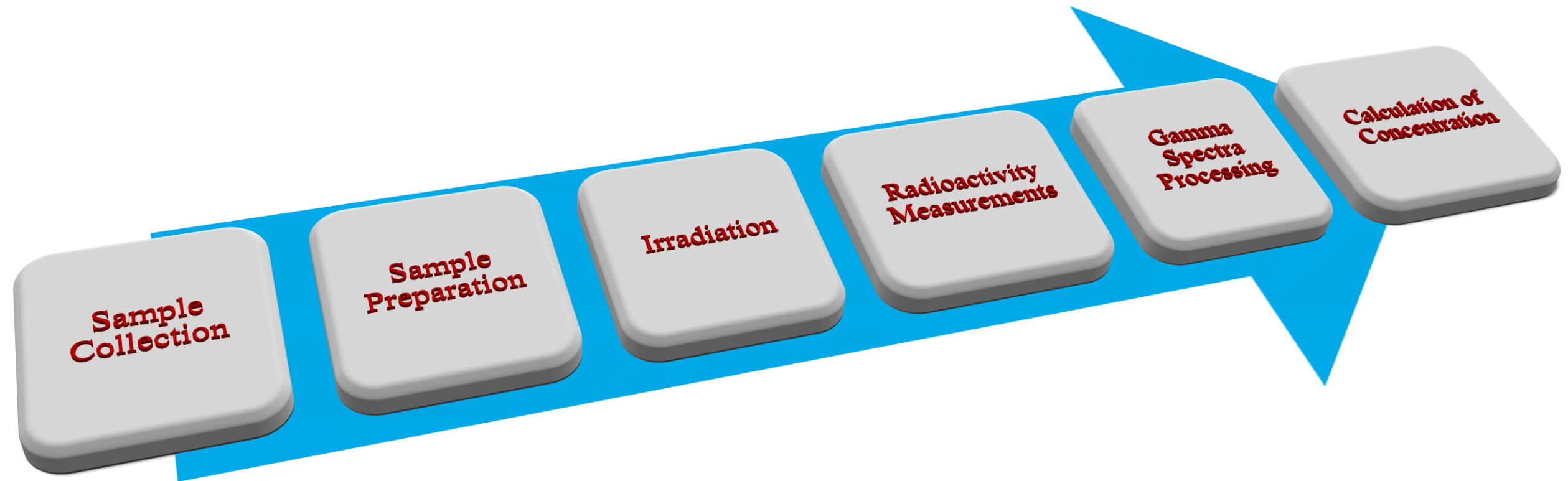


Nuclear Interactions



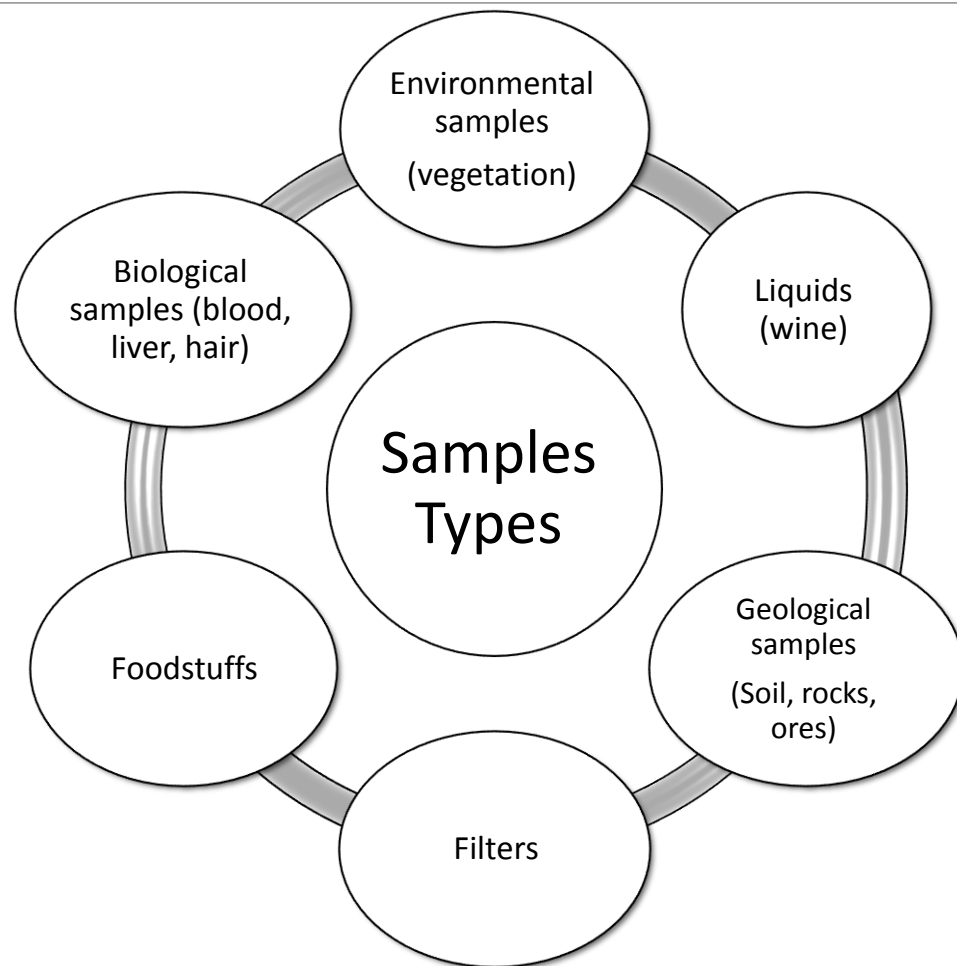


Neutron Activation Analysis Flow Chart





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*)

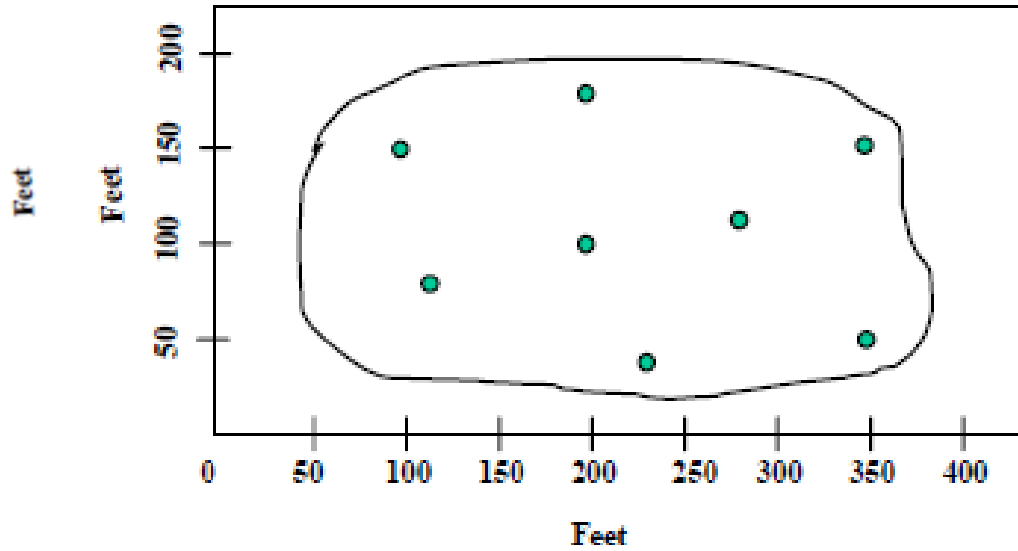




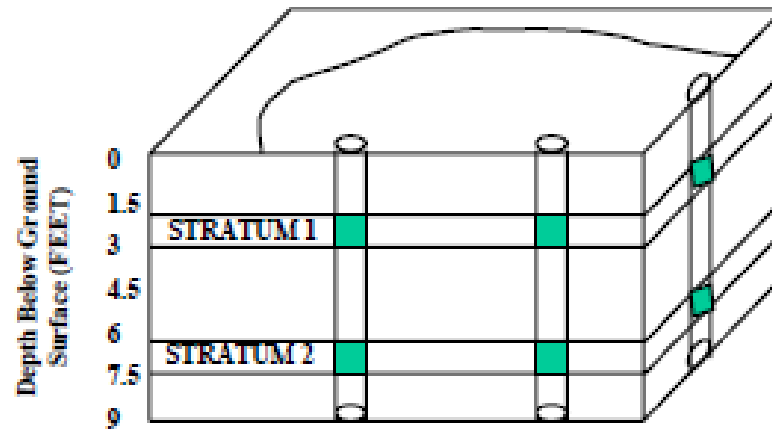
B) Soil Sample Collection



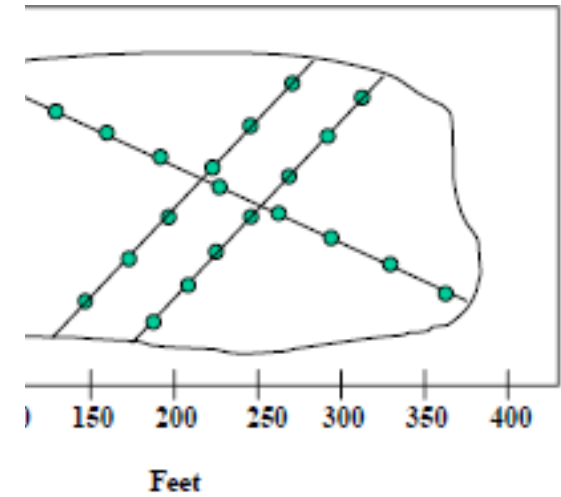
- The longitude and latitude of the sample **location** should be recorded
- Samples need to be **Separated** from **other impurities**
- Packed** in zip-bags and the numbers need to be written on the bag.
- The sample after collection are sent to the lab



a) Random Sampling



b) Stratified Random Sampling



c) Transect 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)°C



Balance

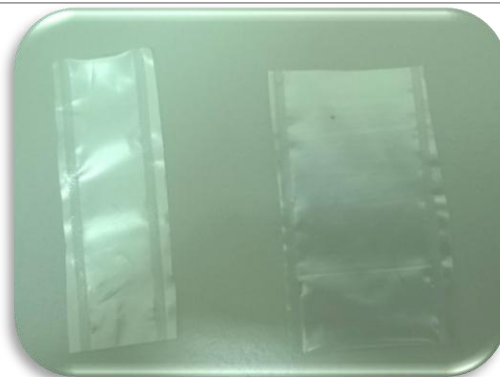


Sample Preparation

B) Materials:



Sealing machine



Poly ethylene plastic bags



Aluminum covers



Pelletizer



Sample Preparation

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

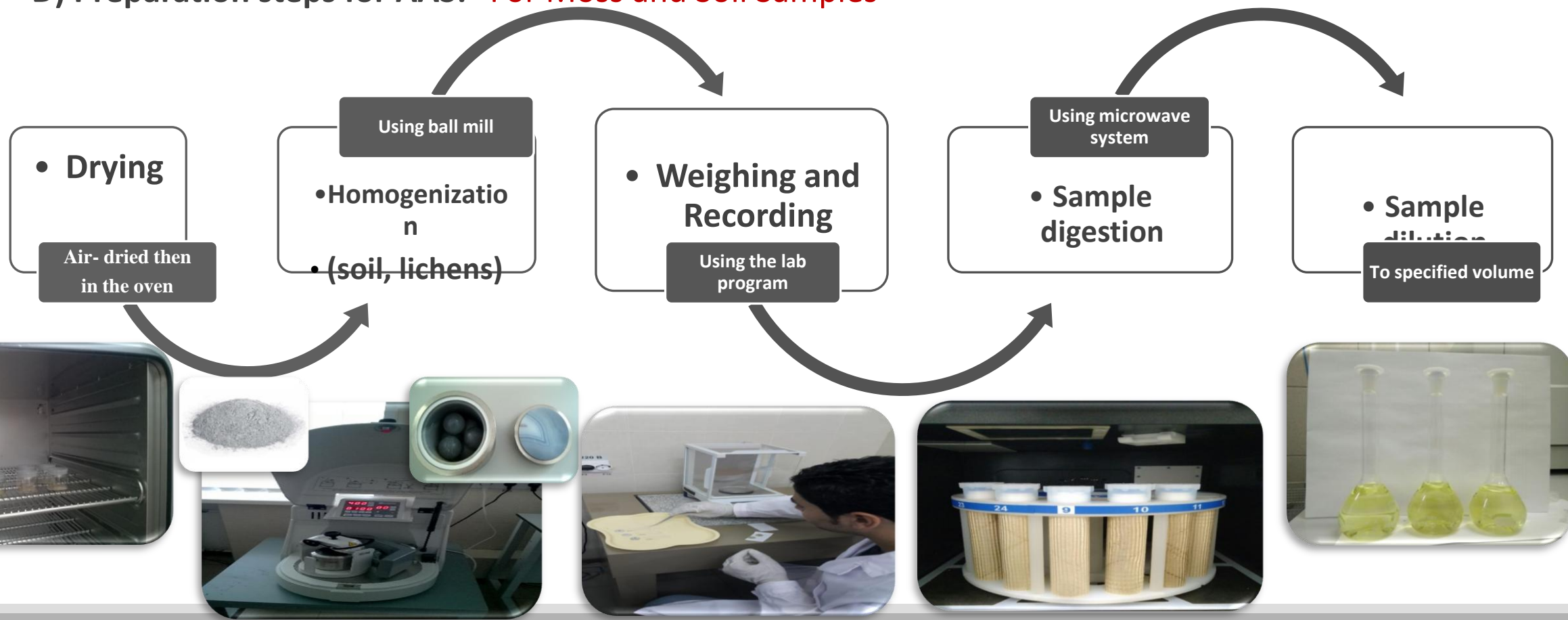
- I.
 - Drying
- II.
 - Pelletizing
- III.
 - Weighing & Recording
- IV.
 - Packing





Sample Preparation

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





Sample Preparation

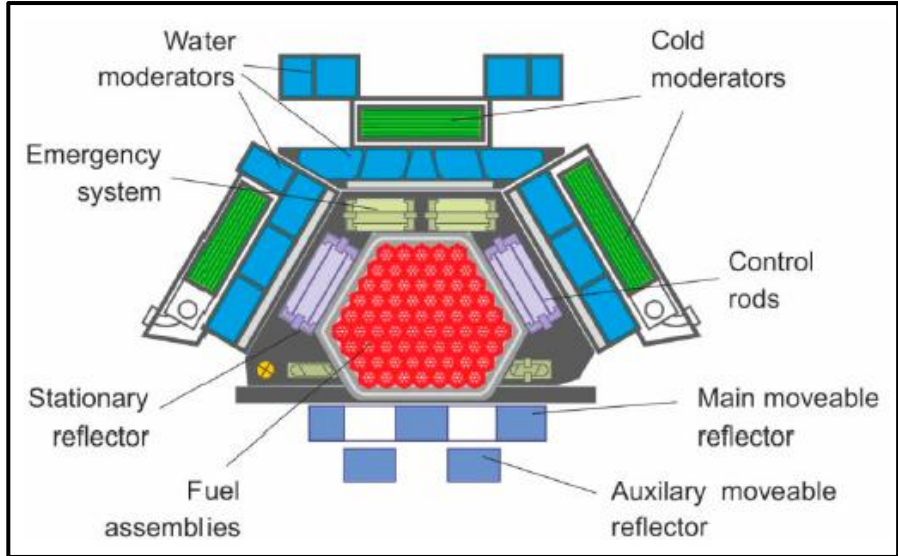
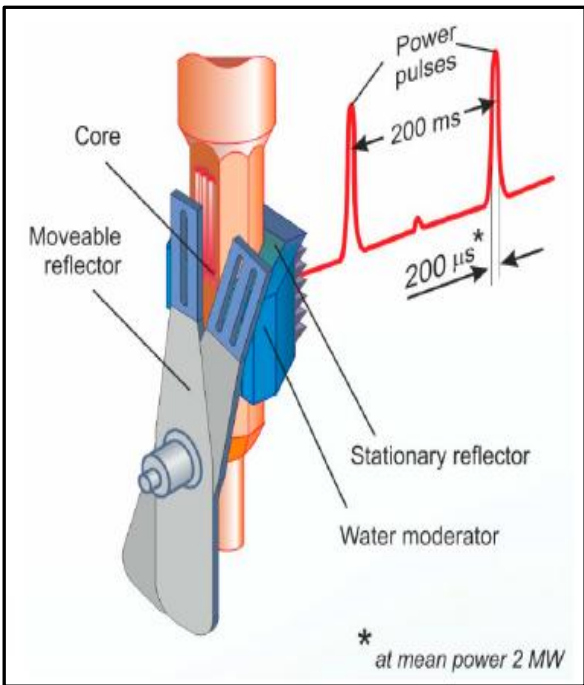


E) Handling precautions During preparation of the sample:

- 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**



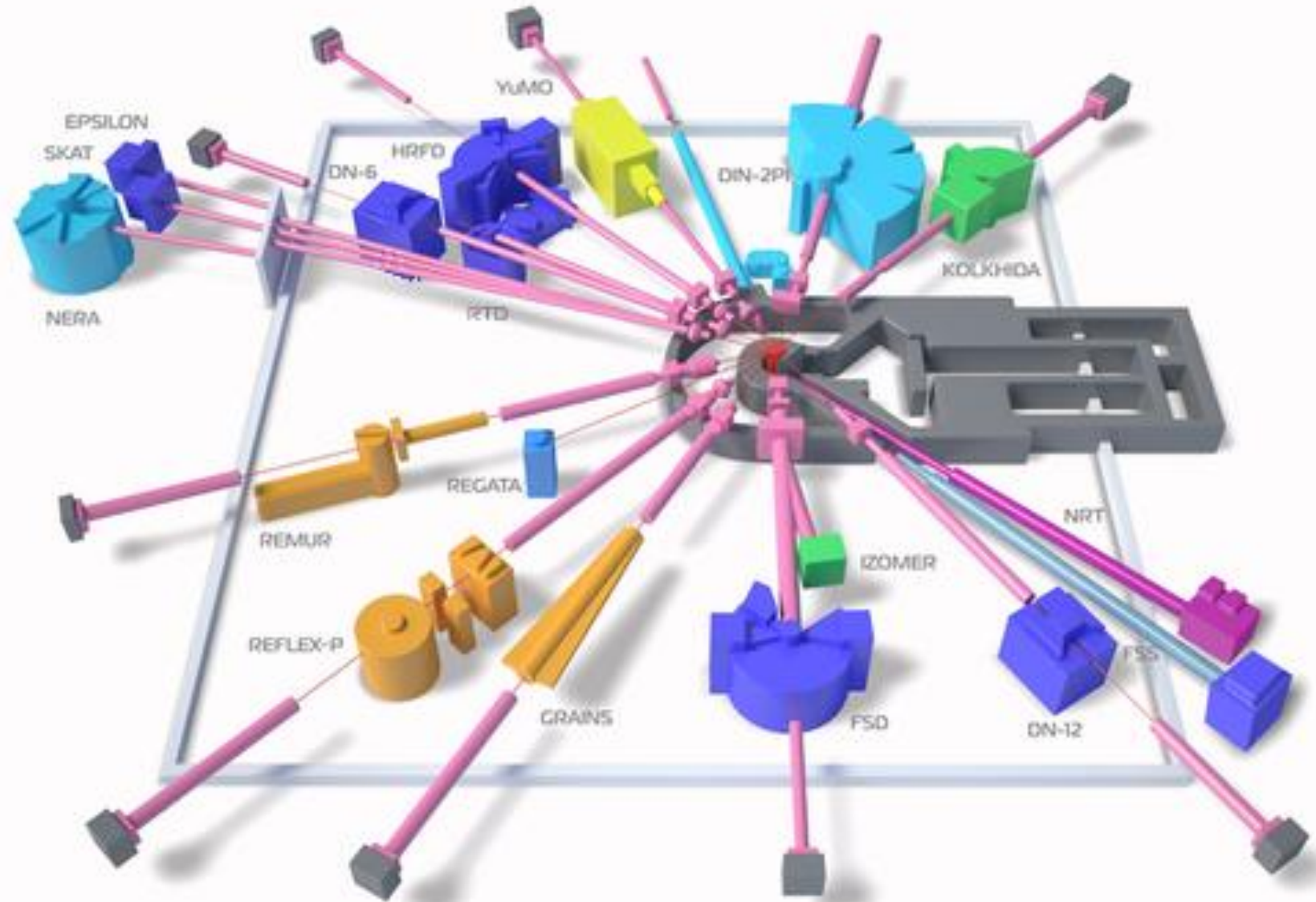
IBR-2M Pulsed Fast Rea



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	245
• Thermal neutron	340
Rotation rate (rev/min):	
• Main reflector	600
• Auxiliary reflector	300
Coolant	Sodium
Thermal neutron flux density from moderator surface (n.cm ⁻¹ .s):	
• Time average	~10 ¹³
• Burst maximum	~10 ¹⁶



Experimental facility REGATA at IBR-2 reactor





Irradiation channels

Intermediate storage

Directional control valves

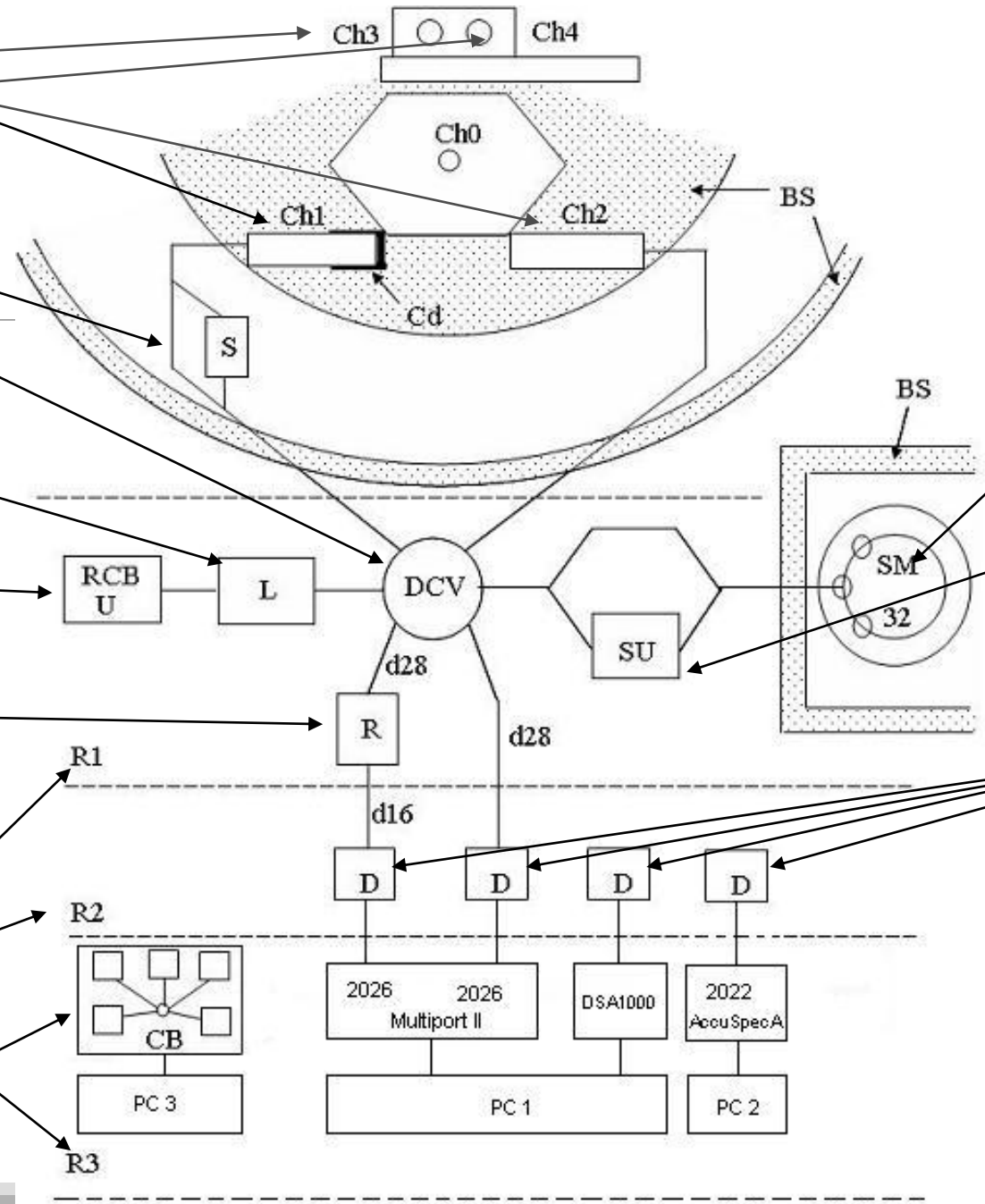
Loading unit

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

DCV

SU

RCB U

L

R

R1

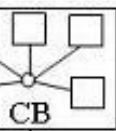
D

D

D

D

R2



PC 3

2026 Multiport II

PC 1

DSA1000

PC 2

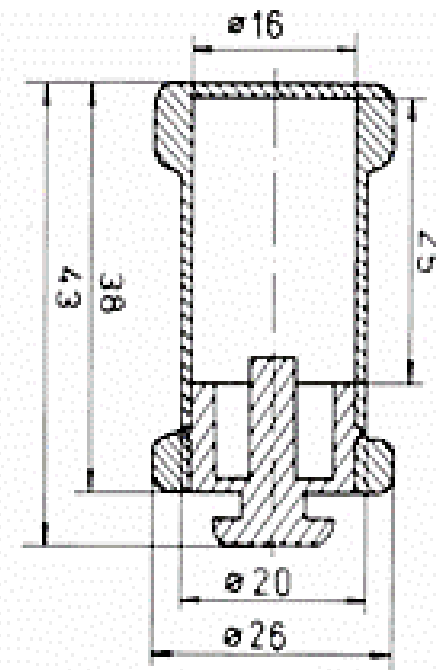
2022 AccuSpecA

R3



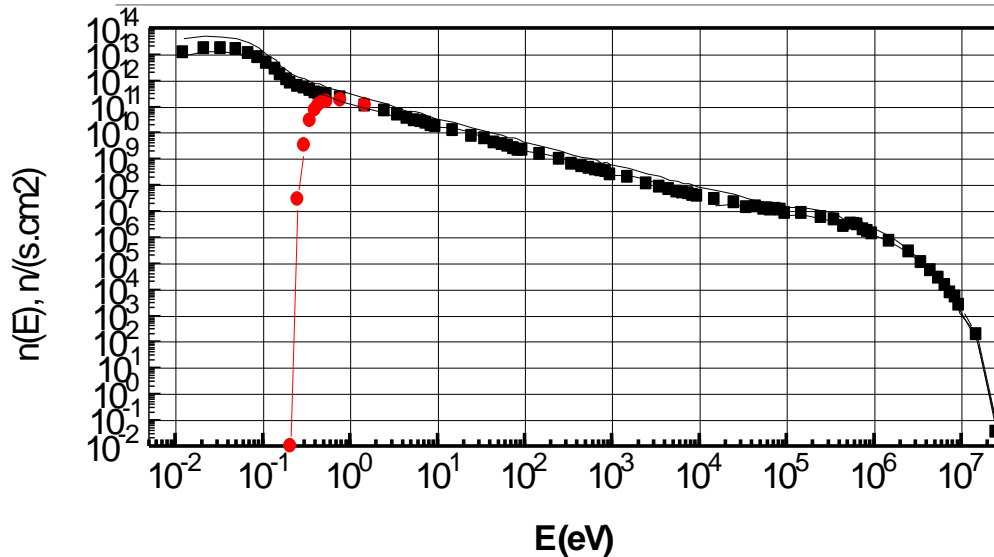
Transport capsules for irradiation

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}			$T^{\circ}C$	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

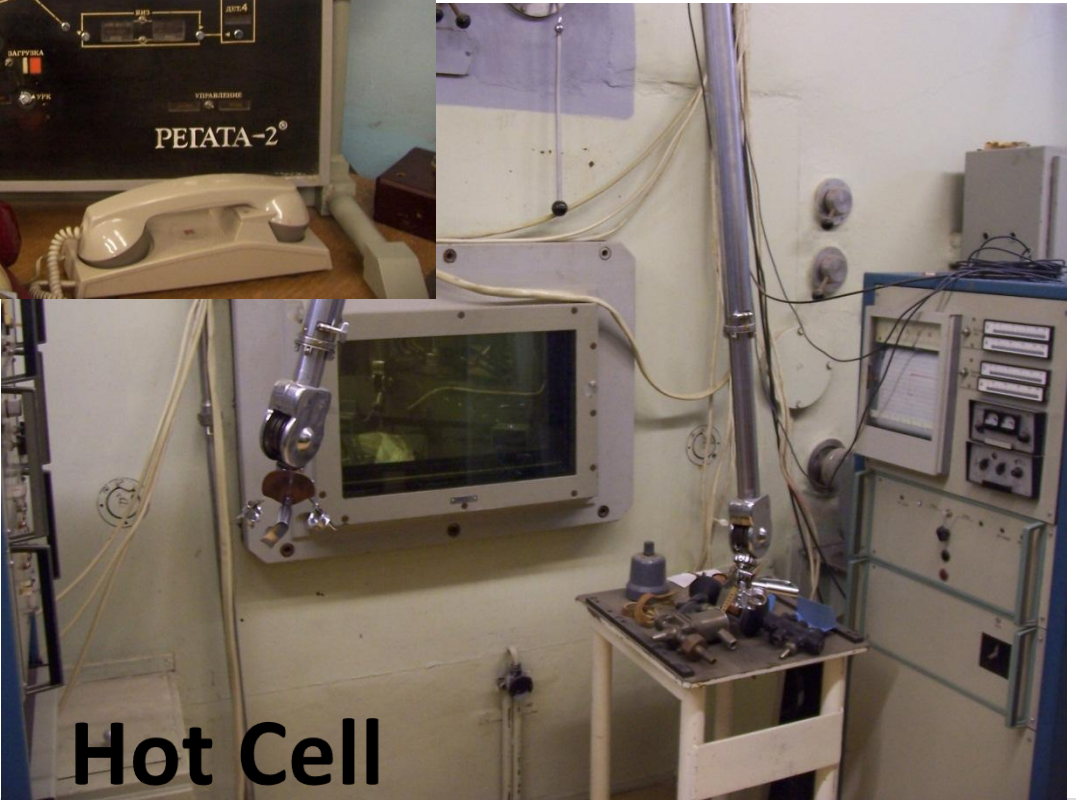
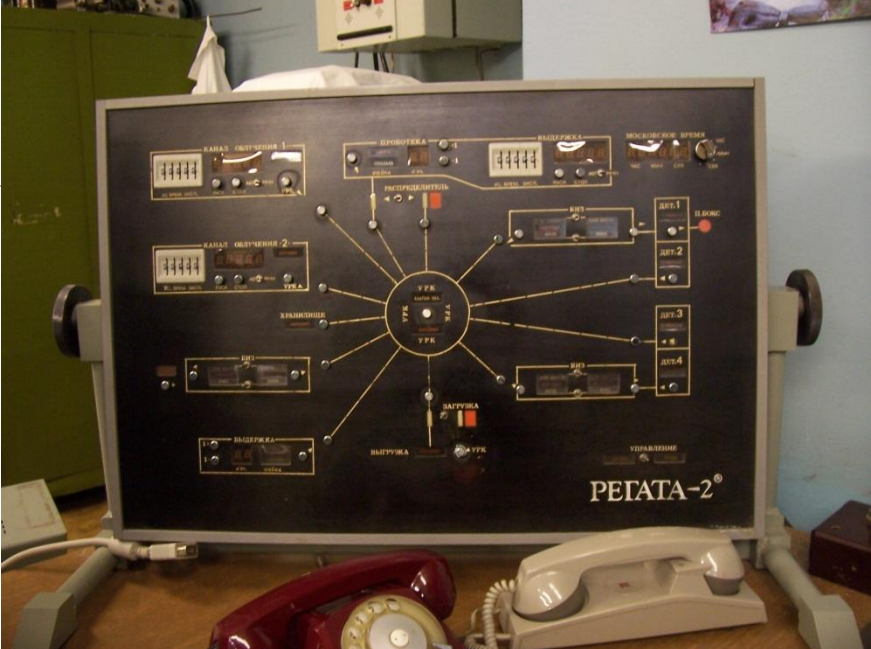


closer look on REGATA





**Directional control
valves**



Hot Cell

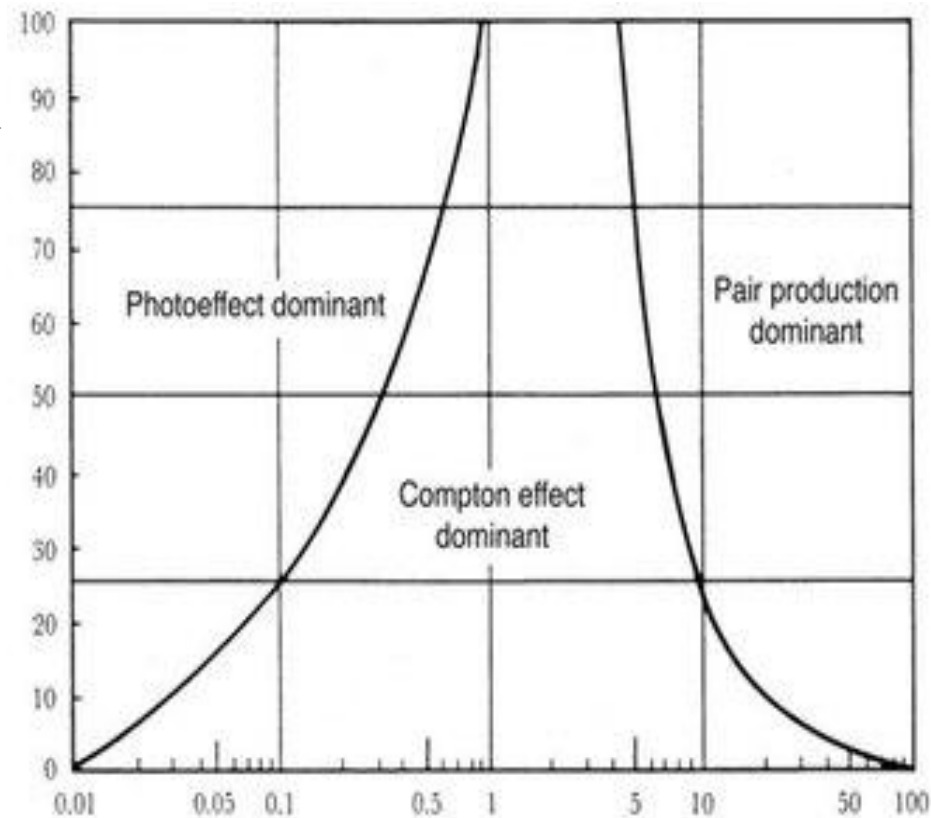


Radioactivity measurement of the irradiated samples

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





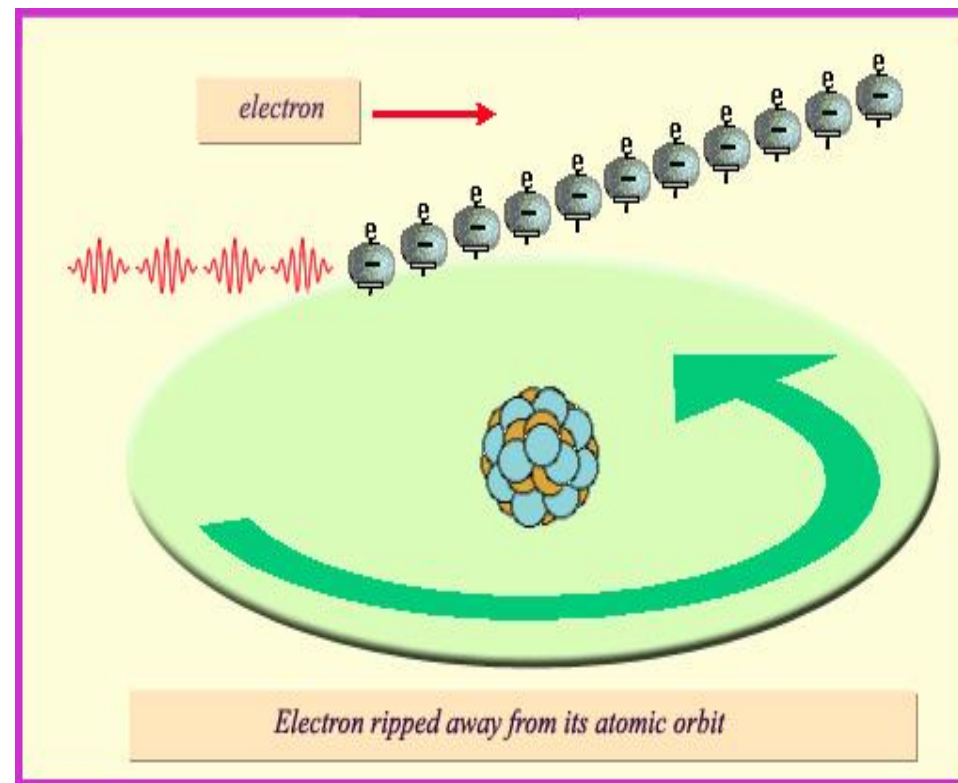
Con't

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





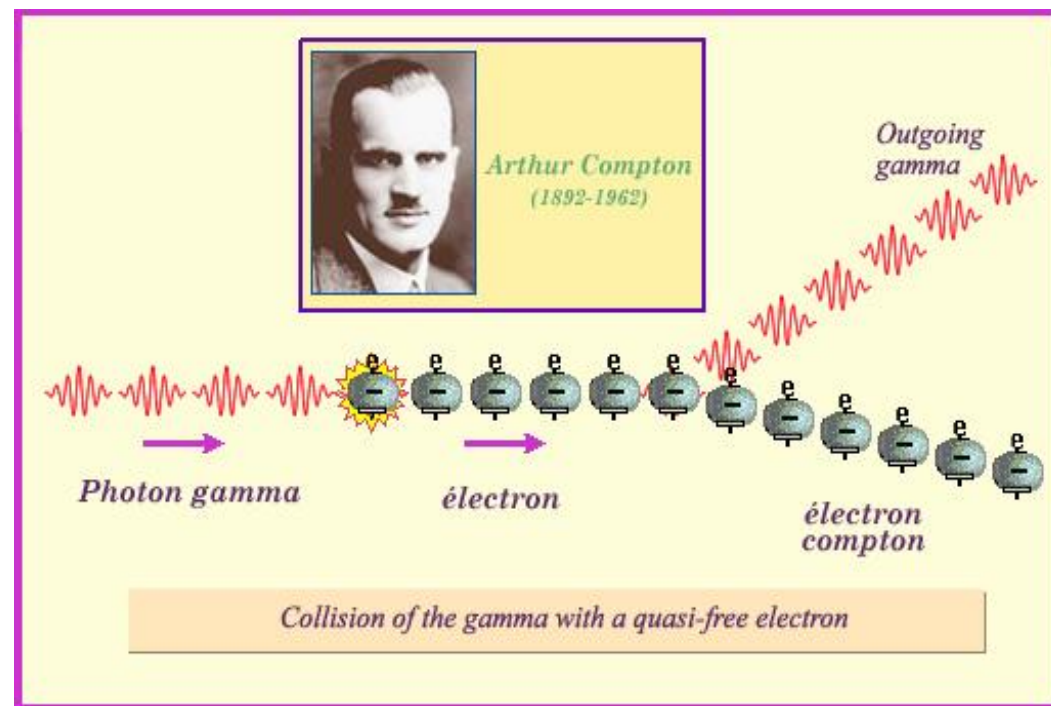
Con't

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.





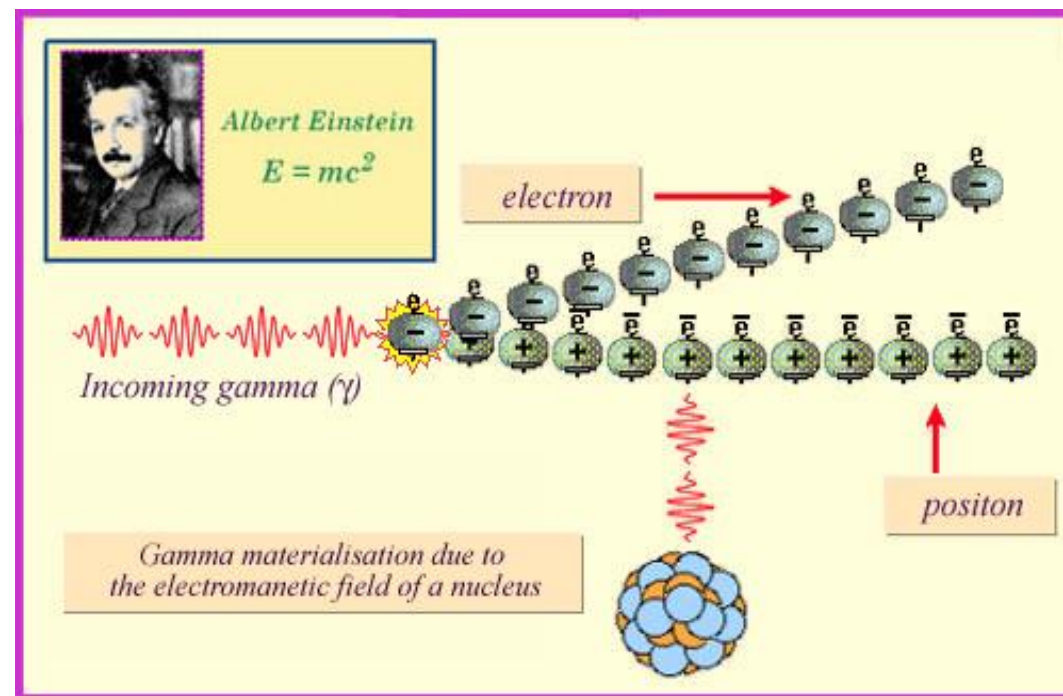
Con't

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



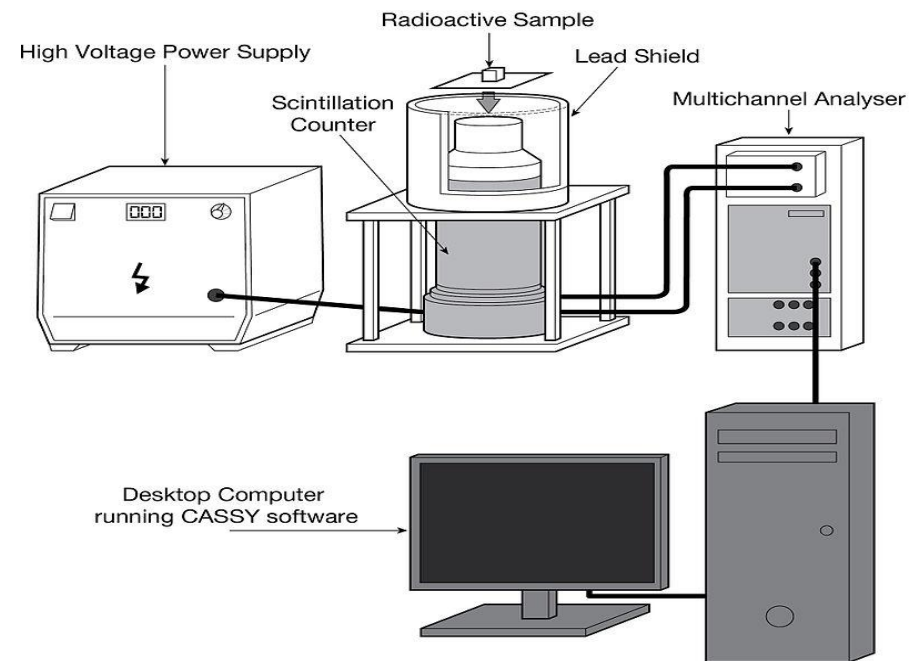
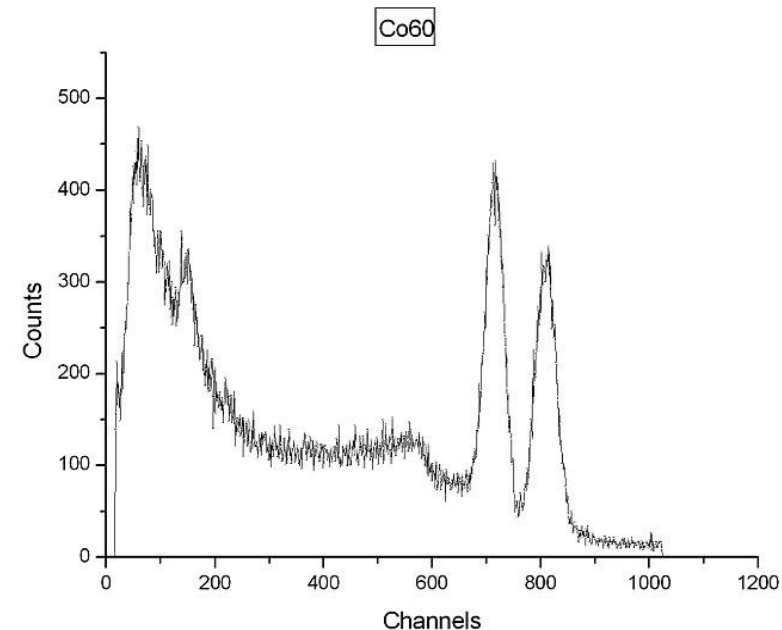


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2. Gamma spectrometer

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.

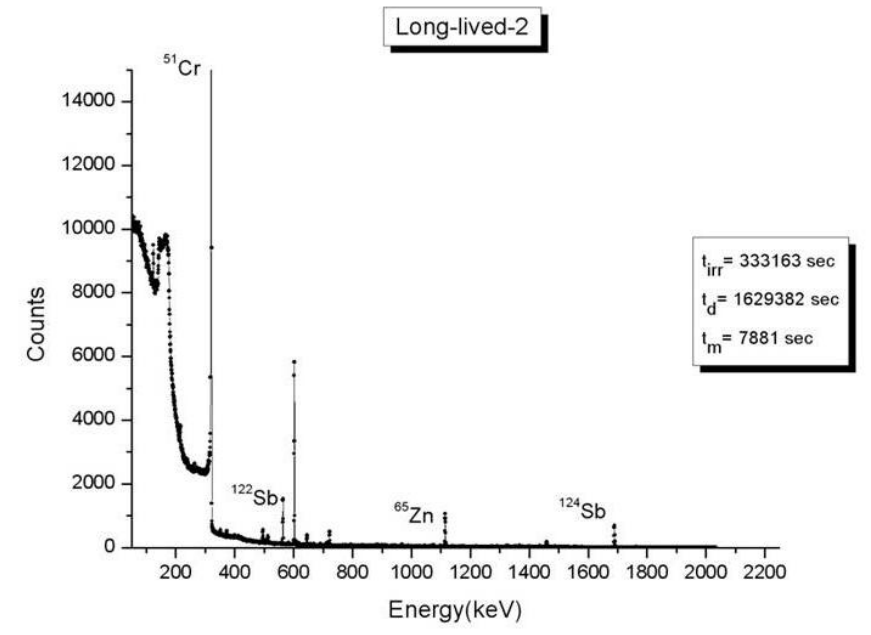
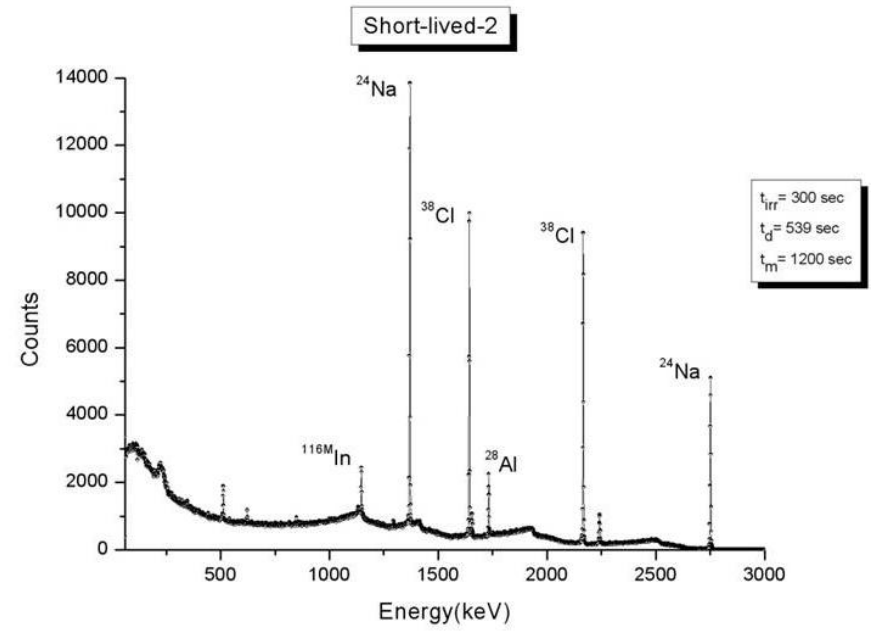




Con't

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

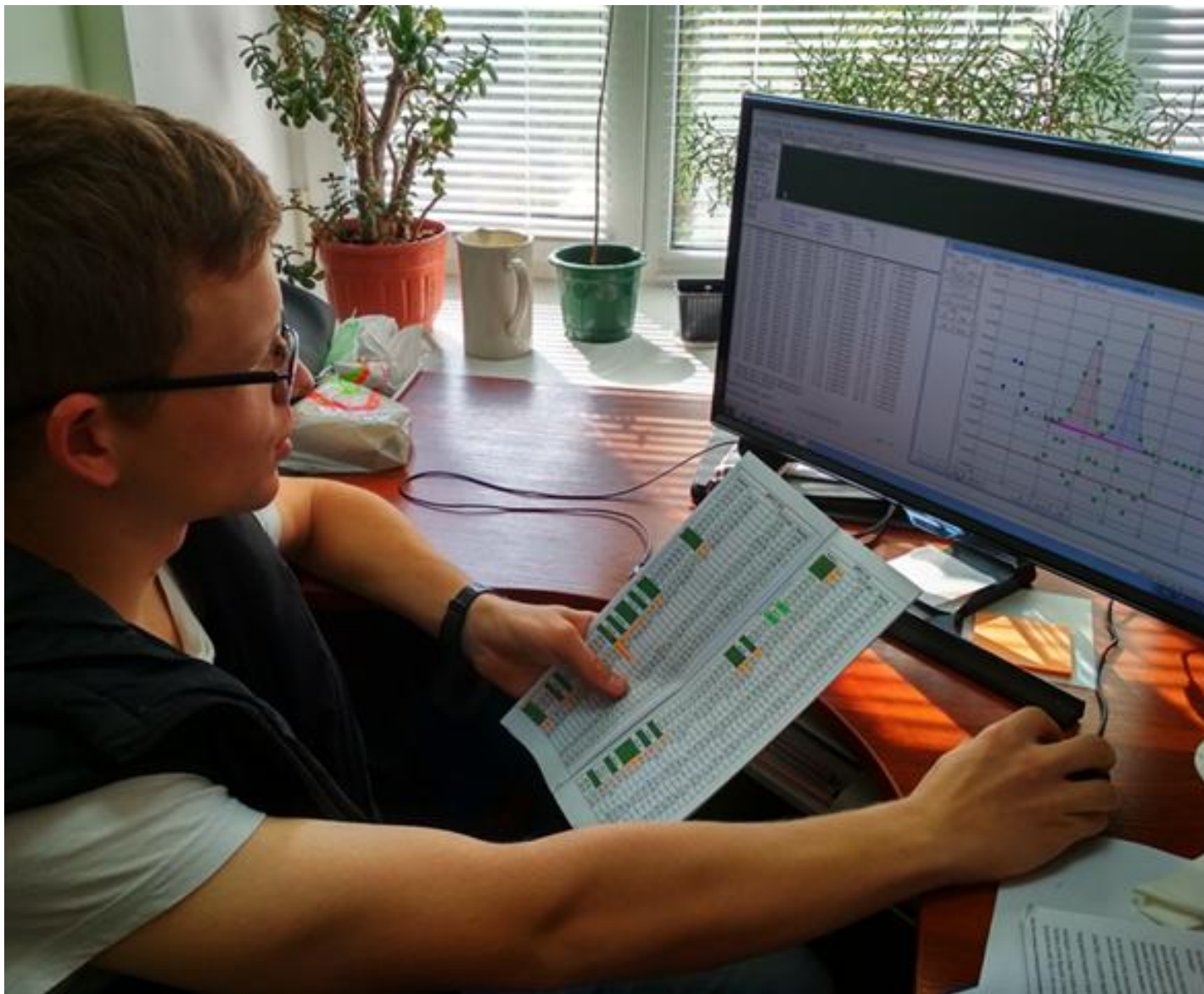


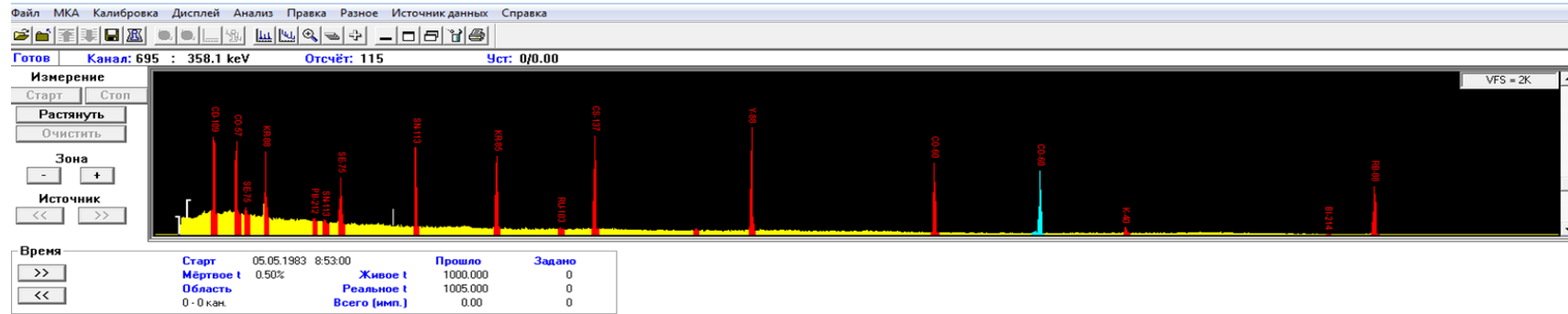


Processing of gamma spectra using G2X

- Software systems (Genie 2000™):

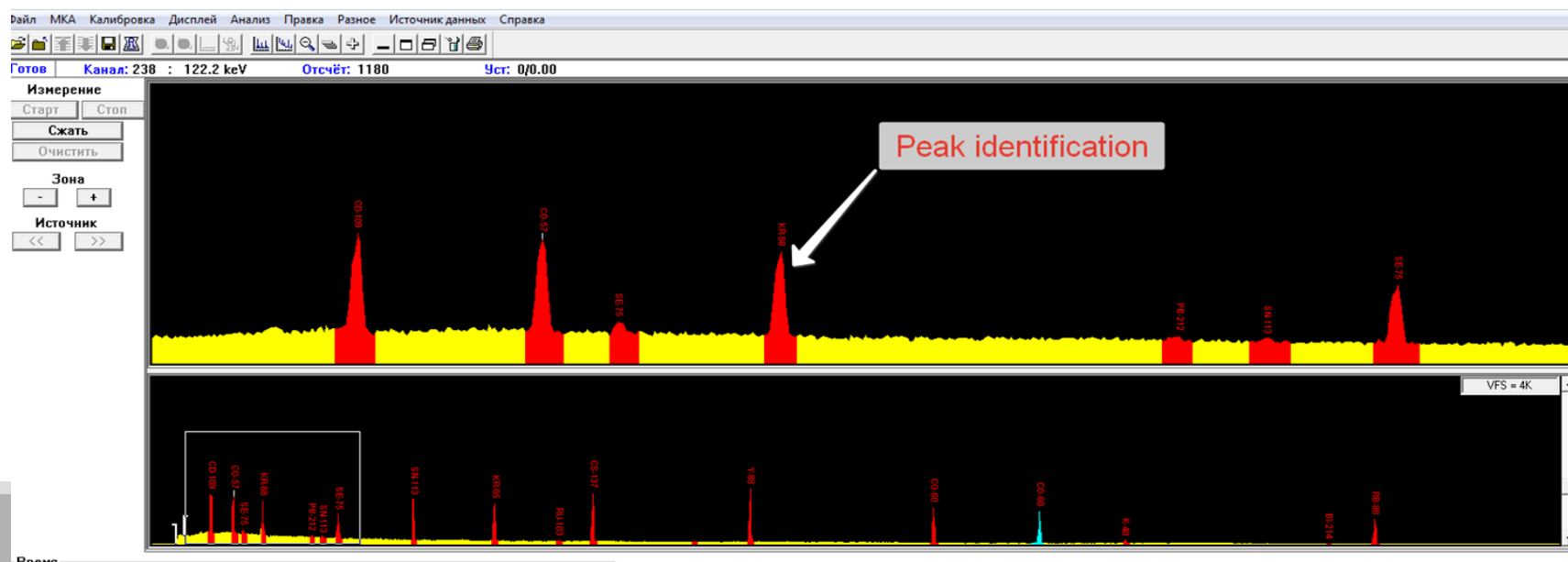
- Provides full energy calibration, peak width and detector efficiency
- Allows you to search the spectrum, search for statistically significant peaks, assign them nuclides and calculate the activity of the sample.





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

Нуклид	Достоверность идентификации	Средневзвешенная активность, uCi /Unit	Погрешность
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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База данных НАА - 5.9.0.4 wael

Количество образцов в базе данных: 11735 russian

Код страны	Клиент. номер	Год	N партии образ.	инд. партии образ.
EG	08	16	33	g
EG	09	16	51	y
EG	10	16	60	h
EG	07	16	61	i
EG	06	16	67	o
EG	08	16	77	y

Приём новой Просмотр партии Выбрать партию

Цвет	Описание
Розовый	партия принята
Белый	проведена пробоподготовка
Желтый	облучение ЮКИ
Зеленый	облучение ДЖИ
Светло-зеленый	ЮКИ или ДЖИ плюс результаты
Темно-зеленый	ЮКИ и ДЖИ плюс результаты
Оранжевый	Показать все

Партии стандартов

Имя	Номер	Тип	Вес. гр	Дата покупки
Si	01	metal	0.02	01.11.2016
Si1	01	soil	10	21.12.2012
Tc	01	metal	1	23.03.2015
W	01	metal	5	23.03.2015

Партии мониторов

Имя	Номер	Тип	Вес. гр	Дата покупки
Zr	04	wire	16.5	19.01.2010
Zr	05	foil	15.89	19.01.2010
Zr	06	foil	15.89	19.01.2010
Zr	07	foil	14.76	19.01.2010
Zr	08	foil	14.76	19.01.2010

Журнал ЮКИ: 18.05.2015, 09.12.2015

Журнал ДЖИ: 04.04.2017, 07.04.2017, 10.04.2017

Фильтрация списка партий
Выберите поле Страна для фильтра
Страна: EG

Информация о выбранной партии
Страна: Египт
Организация: Cairo university
Фамилия: Abdo
Кол-во образцов: 3
Тип образцов: others
Дата ЮКИ: 17.11.2016,
Дата ДЖИ: 22.11.2016,
Обработчик: Wael Badawy
Результаты: Yes

Журналы облучения ЮКИ
18.01.2017
20.01.2017
23.01.2017
25.01.2017
26.01.2017
09.02.2017
10.02.2017
14.03.2017
17.03.2017
22.03.2017
06.04.2017
07.04.2017
10.04.2017
12.04.2017
14.04.2017
17.05.2017
18.05.2017
19.05.2017
22.05.2017

Журналы облучения ДЖИ
17.01.2017-134
20.01.2017-135
23.01.2017-136
08.02.2017-137
11.02.2017-138
15.02.2017-139
13.03.2017-140
16.03.2017-141
20.03.2017-142
24.03.2017-143
04.04.2017-144
07.04.2017-145
10.04.2017-146
15.05.2017-147
19.05.2017-148
22.05.2017-149
23.05.2017-150

Текущий год

Выбр. жур. обл. ЮКИ Выбр. жур. обл. ДЖИ
11.07.2017 11.07.2017

Новый жур. обл. ЮКИ Новый жур. обл. ДЖИ

Приём новой партии стандартов Приём новой партии мониторов
Выбрать партию стандартов Выбрать партию мониторов

Обновить Параметры окружающей среды Поиск Закрыть

Database



Con't

Concentration - 5.8 (ed. TMO)

Recalculation of SRMs activity Group standard Concentration Table of nuclides Clear form Help

Recalculation of SRMs activity

Base file of SRM flux monitor activity: not selected

File of SRM flux monitor activity: not selected

File(s) of SRM activity: not selected

Recalculate and save SRMs activity

Group standard

Files of SRM activity: not selected

Create a summary table of SRMs activity

Data for a table of SRMs check

Calculated uncertainty Z-scores Reference uncertainty

File(s) of SRM activity: not selected

File of group standard: not selected

Calculate SRM(s) on a group standard and save a table of SRMs check

Concentration

File(s) of analyzed sample activity: not selected

File of group standard: not selected

Base file of SRM flux monitor activity: not selected

File of sample flux monitor activity: not selected

Deselect flux monitors file

Coefficient of neutrons flux change 1.0

Source of SLI data SLI-1 and SLI-2

Systematic error, %: 0

Calculate and save concentrations

Files of elements concentration of analyzed samples: not selected

Create an intermediate table of elements concentration

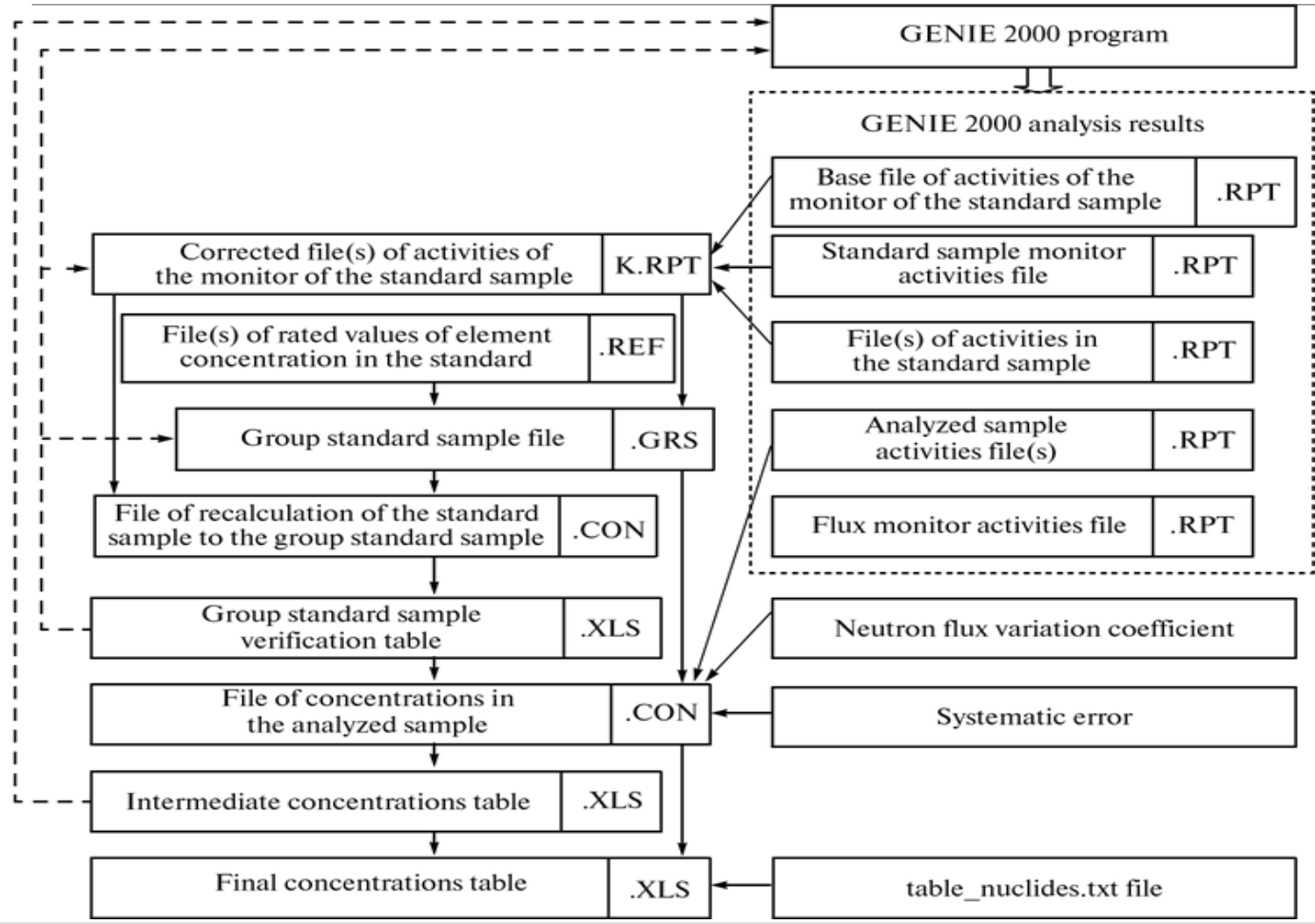
Create a final table of elements concentration

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

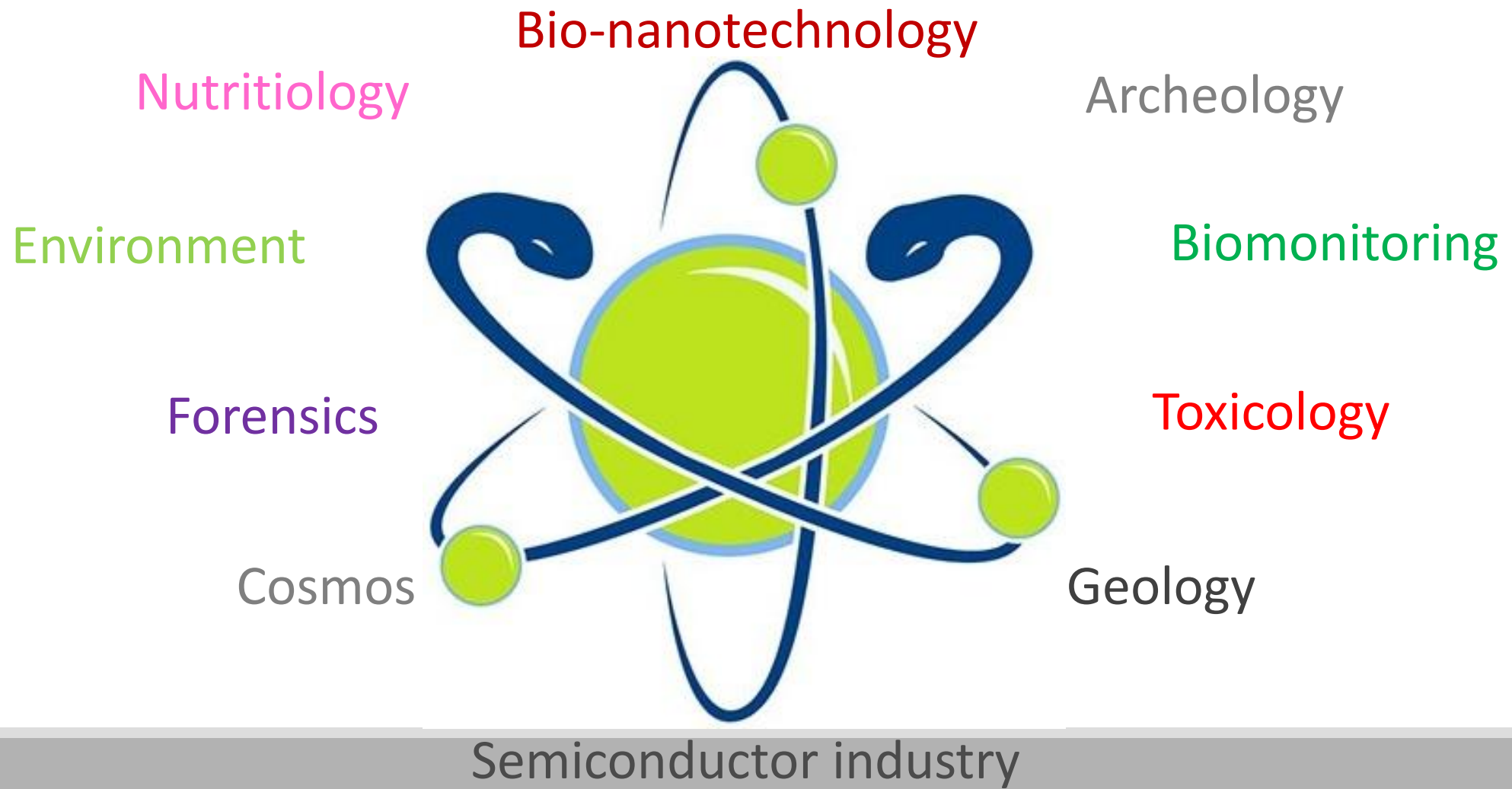
Limitations



- Need for nuclear reactor
- Work with radioactive materials
- Time of analysis
- Sample preference
- Not all elements are detectable



The main applications of NAA

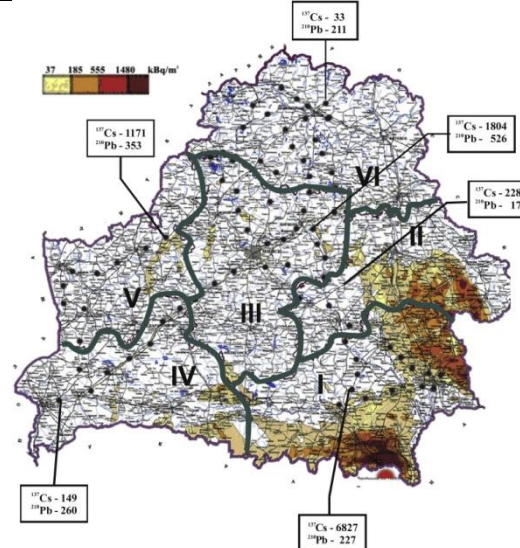
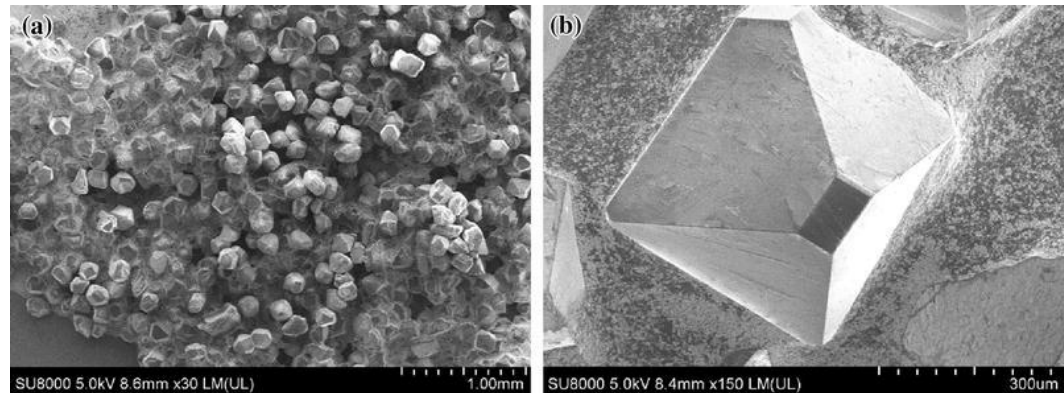




Joint projects (Belarus - Egypt)

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 Aleksiyenak , 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. Aleksiyenak)





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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)

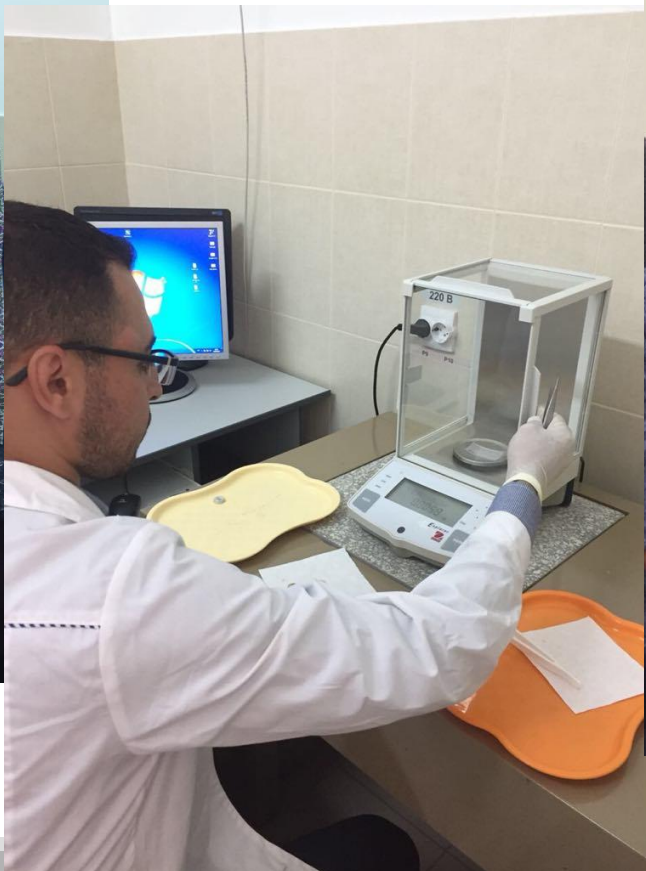
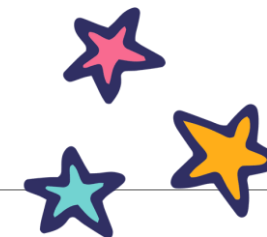
❑ 3rd Phase:

○ 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.

