# International Student Practice 2017, JINR, Dubna

# Neutron Activation Analysis(NAA) for Life Science

N.M. Dhlalani, H.P. Moabi, V. Gorskaya, R. Titkov

**The Sector of NAA and Applied Research**
**Frank Laboratory of Neutron Physics**

11th to 29th September 2017

# The NAA Participants 2017

**South Africa**

Hendric Moabi

Nomcebo Dhlalani

**Belarus**

Veronica Gorskaya

Ruslan Titkov

# Profile of Participants

Nomcebo M Dhlalani
University of Stellenbosch
BSc Physics
BSc Hons Nuclear Physics

Hendric Moabi
North West University NWU
BSc Physical & Chemical Science
BSc Hons Radiation Science
MSc Radiation Science

Veronica Gorskaya
ISEI BSU
Student

Ruslan Titkov
ISEI BSU
Student

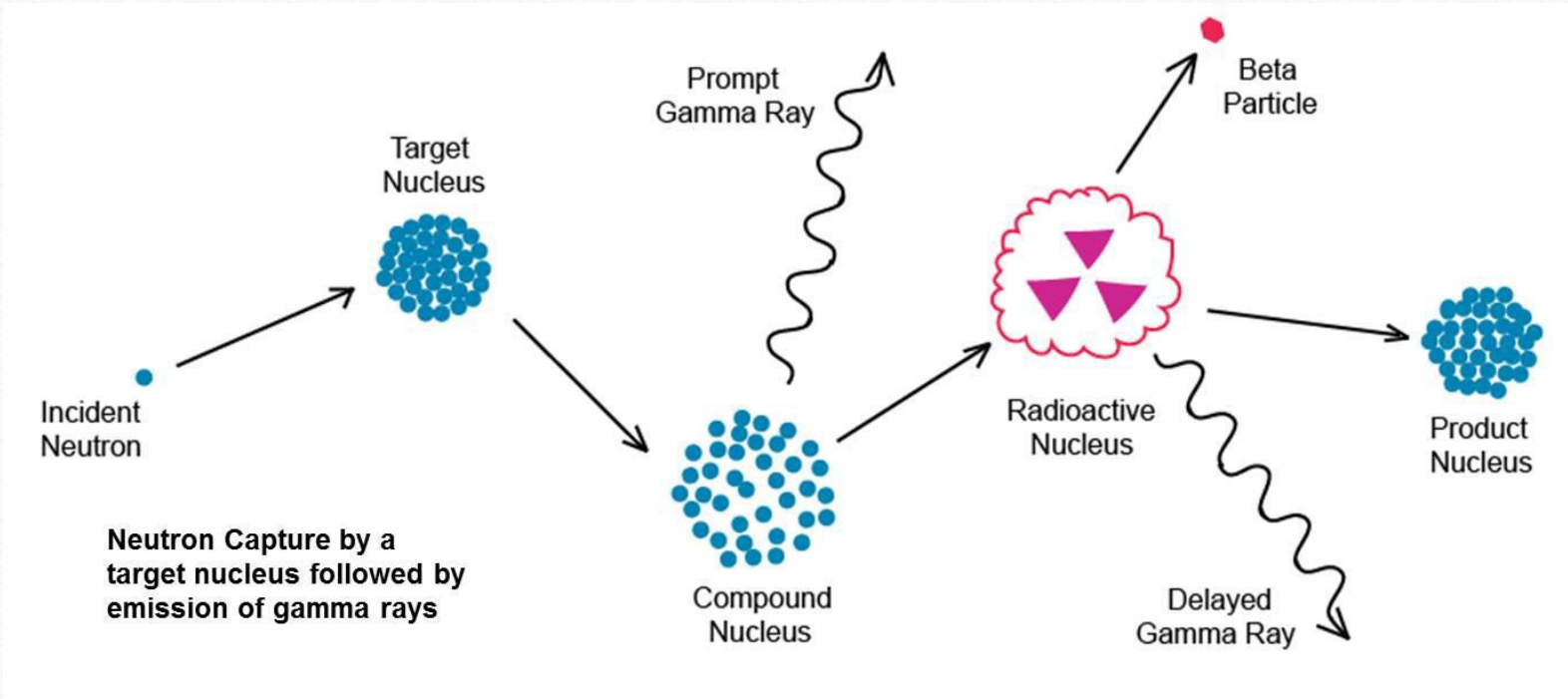
# Content

- Introduction and history of NAA
- Principles of NAA
- Applications of NAA
- Types of NAA
- Environmental sampling and preparation
- Irradiation using IBR-2 reactor
- Analysis of Spectrum
- Advantages and limitations of NAA
- Joint projects with RSA and Belarus
- Outcome
- Acknowledgement

# Introduction and history of NAA

- Neutron Activation Analysis (NAA):is an isotope specific analytical technique for the qualitative and quantitative determination of elemental content.
- In 1936, G. Hevesy (Hungary) and H. Levi (Denmark) discovered NAA when they found that samples containing certain rare earth elements became highly radioactive after exposure to a source of neutrons.

# Principles of NAA

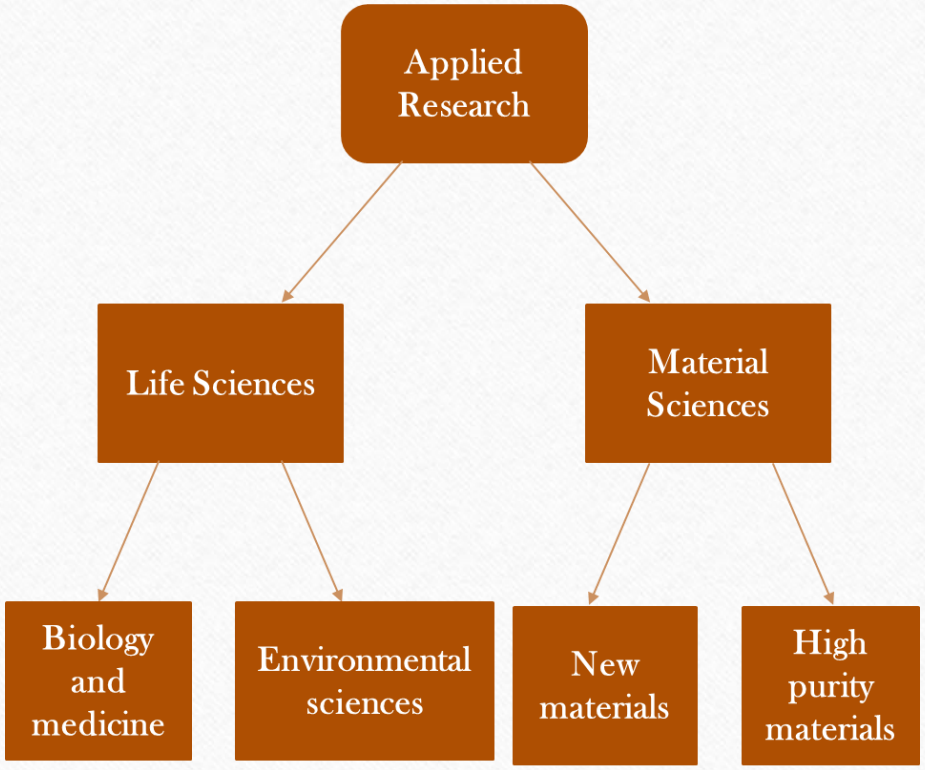


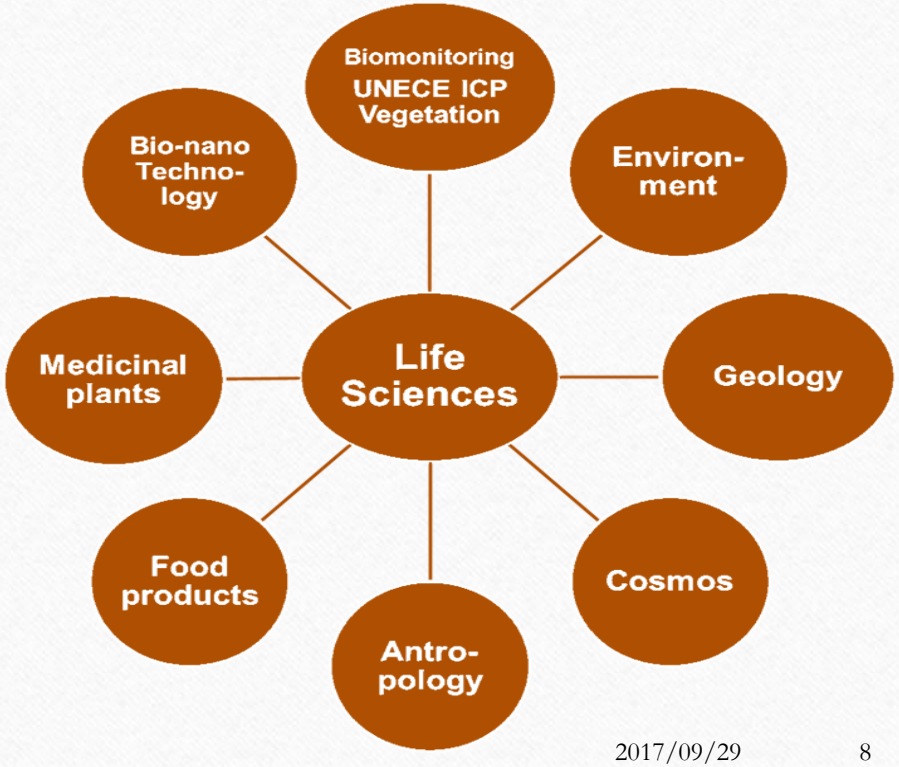
# Types of NAA

- Destructive (radiochemical) RNAA – the resulting radioactive sample is chemically decomposed, and the elements are chemically separated

- Nondestructive (instrumental) INAA – the resulting radioactive sample is kept intact

# Applications of NAA



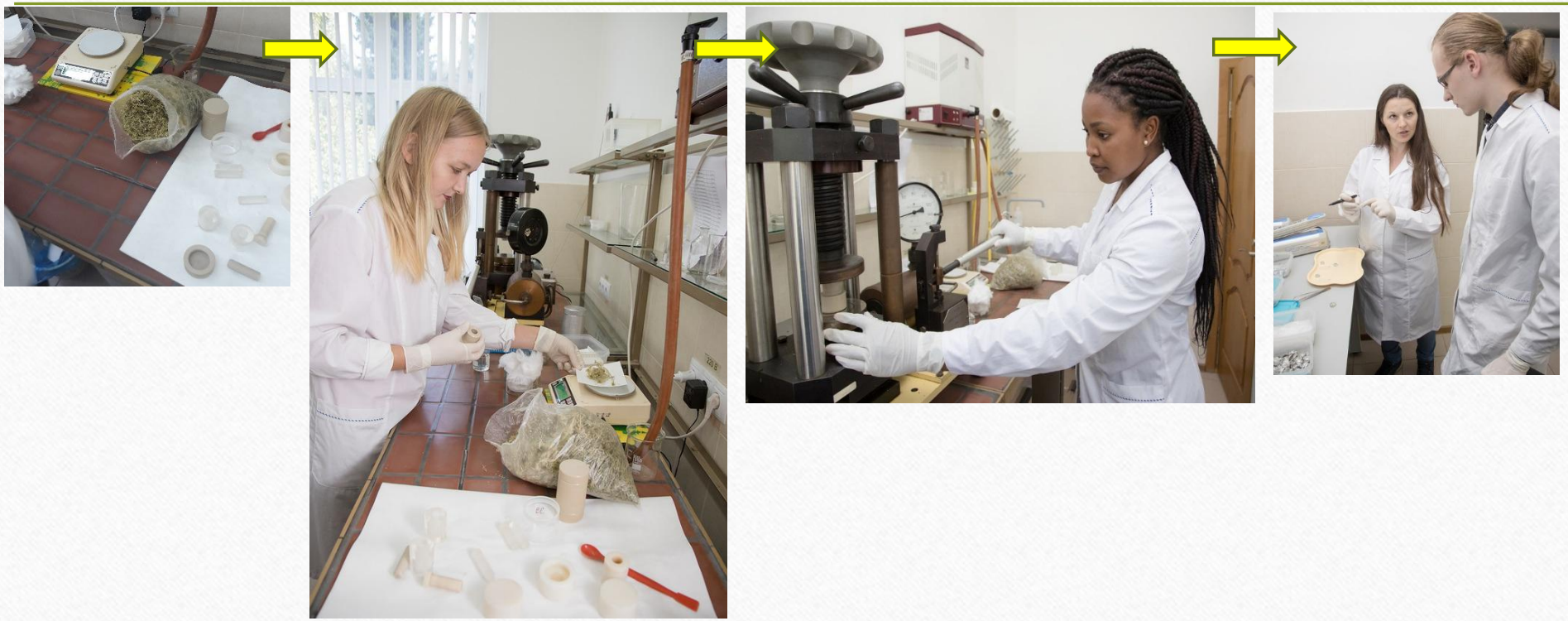



# Environmental sampling and preparation

# 1.Types of Samples

- Environmental samples
- Geological samples
- Biological samples
- Liquids
- Filters
- Foodstuffs

# 2. Sample preparation



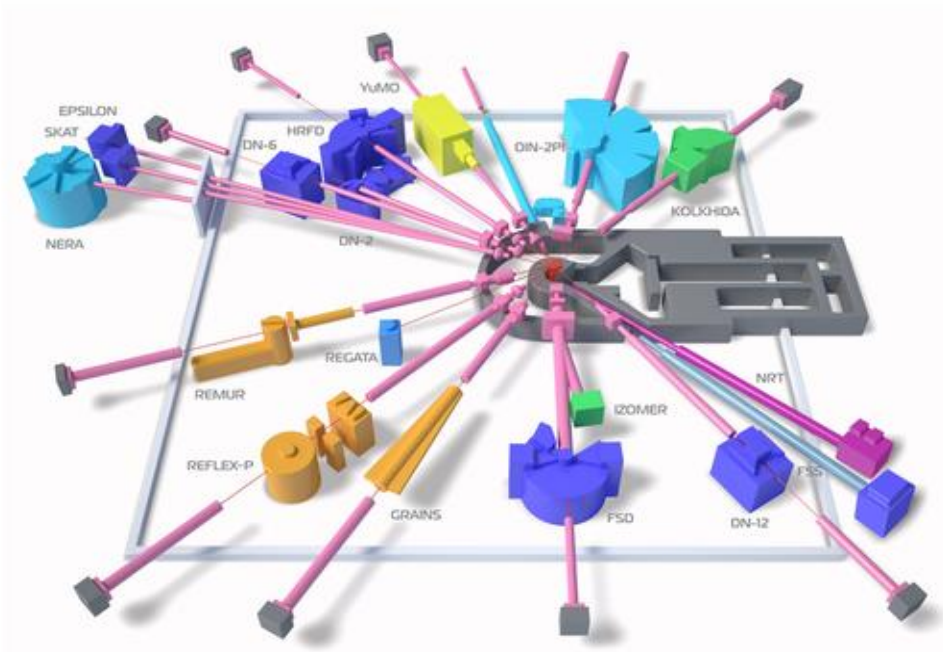
# 3. Sample Packing

- Moss samples wrapped in polyethylene bag and aluminium pan for short- and long-lived irradiations respectively.
- Samples placed in transport capsules
- Short-lived isotopes - samples irradiated for 60 seconds
- Long-lived isotopes – samples irradiated for 4 days

# 4.Other Sampling Methods

# Irradiation using IBR-2 reactor

# 1. Irradiation using IBR-2 reactor




**IBR-2 Spectrometers for submission of applications:**

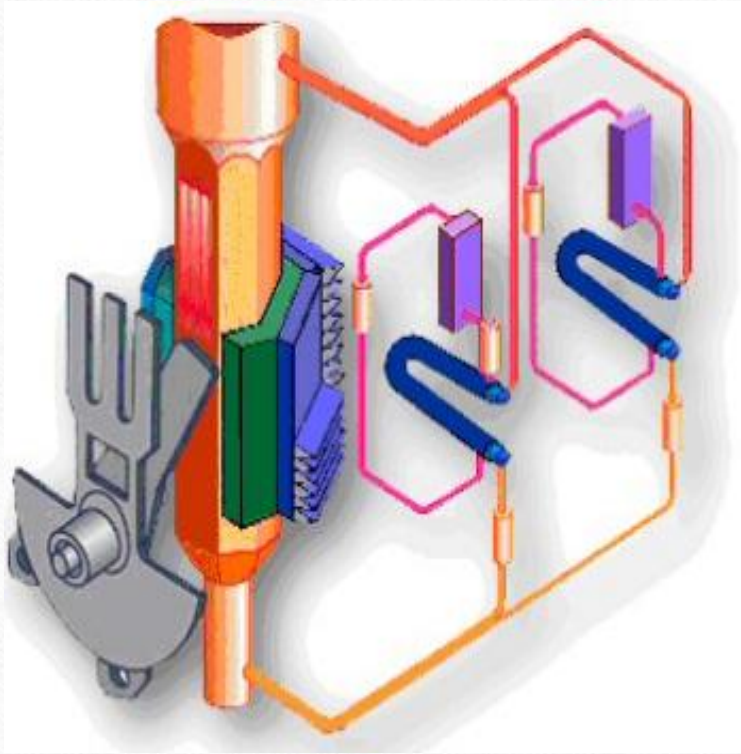
Diffraction:
**HRFD**
**RTD**
**DN-12**
**SKAT-EPSILON**
**FSD**

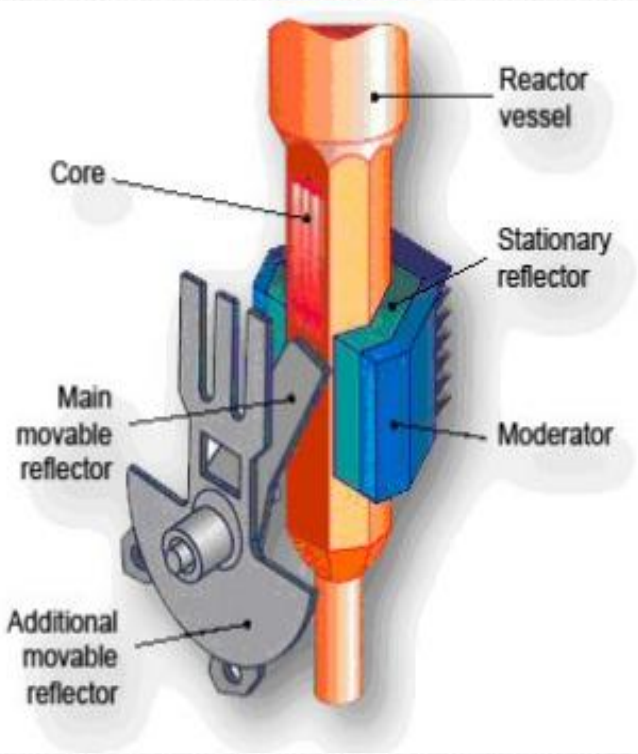
Small-angle scattering:
**YuMO**

Reflectometry:
**REMUR**
**REFLEX**
**GRAINS**

Inelastic scattering:
**DIN-2PI**
**NERA**

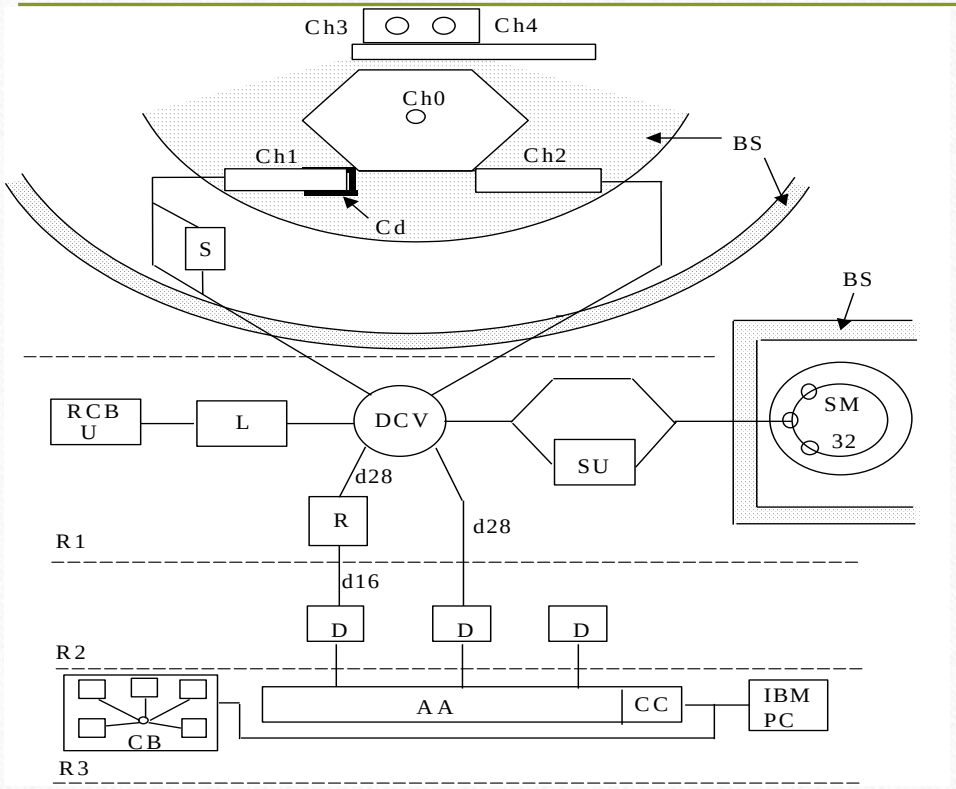
# 2. Principle of functioning






**Parameters of IBR-2:**
**-Average power 2 MW**
**-PuO2 fuel**
**-Rotation rate, rev/min:**
**main reflector 600**
**auxiliary reflector 300**
- **Neutron density flux**
  $10^{16}\ n \cdot m^{-2} \cdot s^{-1}$

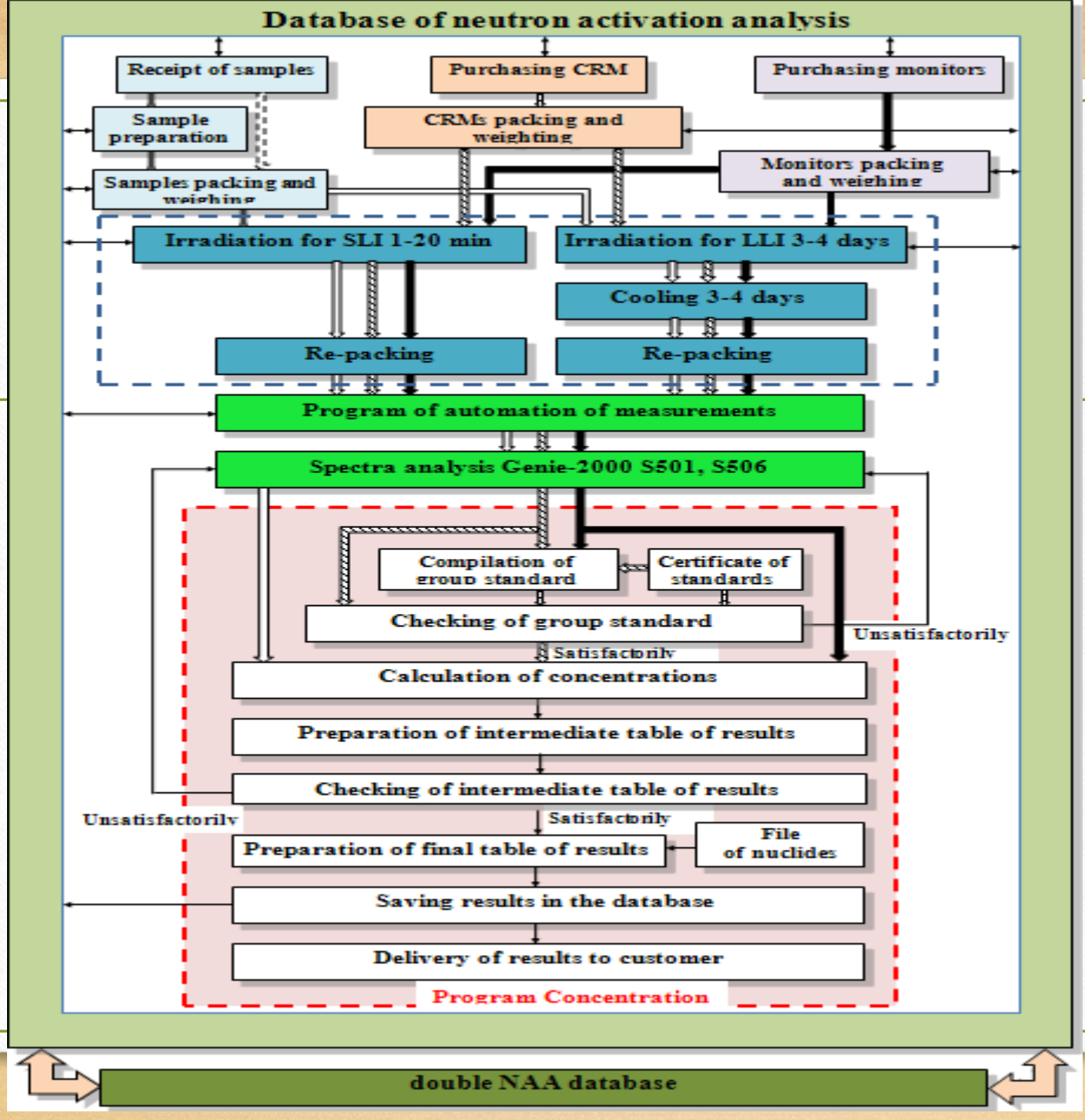
# 3. REGATA




Ch1-Ch4 –irradiation channels, S- intermediate storage, DCV- directional control valves,
L- loading unit, RCB- radiochemical glove-cell, U- unloading unit, SU- separate unit, SM- storage magazine, R- repacking unit, D- Ge(Li) detector, AA- amplitude analyser,
CB- control board, CC- CAMAC controller, R1-R3- the rooms where the system is located.

# 4. The flow chart of NAA at IBR-2 reactor

- All data about of all stages of analysis are stored in the database
- The database allows to use the electronic document circulation, gives a broad opportunities of search, sorting and the analysis of the collected data.
- There is the program and equipment for automation of spectra measurement
- There is the program for automation of concentration calculation and final result receiving
- Several service programs bring additional opportunities to automation of NAA


Database of neutron activation analysis
Receipt of samples
Purchasing CRM
Purchasing monitors
Sample preparation
CRMs packing and weighting
Monitors packing and weighing
Samples packing and weighing
Irradiation for SLI 1-20 min
Irradiation for LLI 3-4 days
Cooling 3-4 days
Re-packing
Re-packing
Program of automation of measurements
Spectra analysis Genie-2000 S501, S506
Compilation of group standard
Certificate of standards
Checking of group standard
Unsatisfactorily
Satisfactorily
Calculation of concentrations
Preparation of intermediate table of results
Checking of intermediate table of results
Unsatisfactorily
Satisfactorily
Preparation of final table of results
File of nuclides
Saving results in the database
Delivery of results to customer
Program Concentration
double NAA database

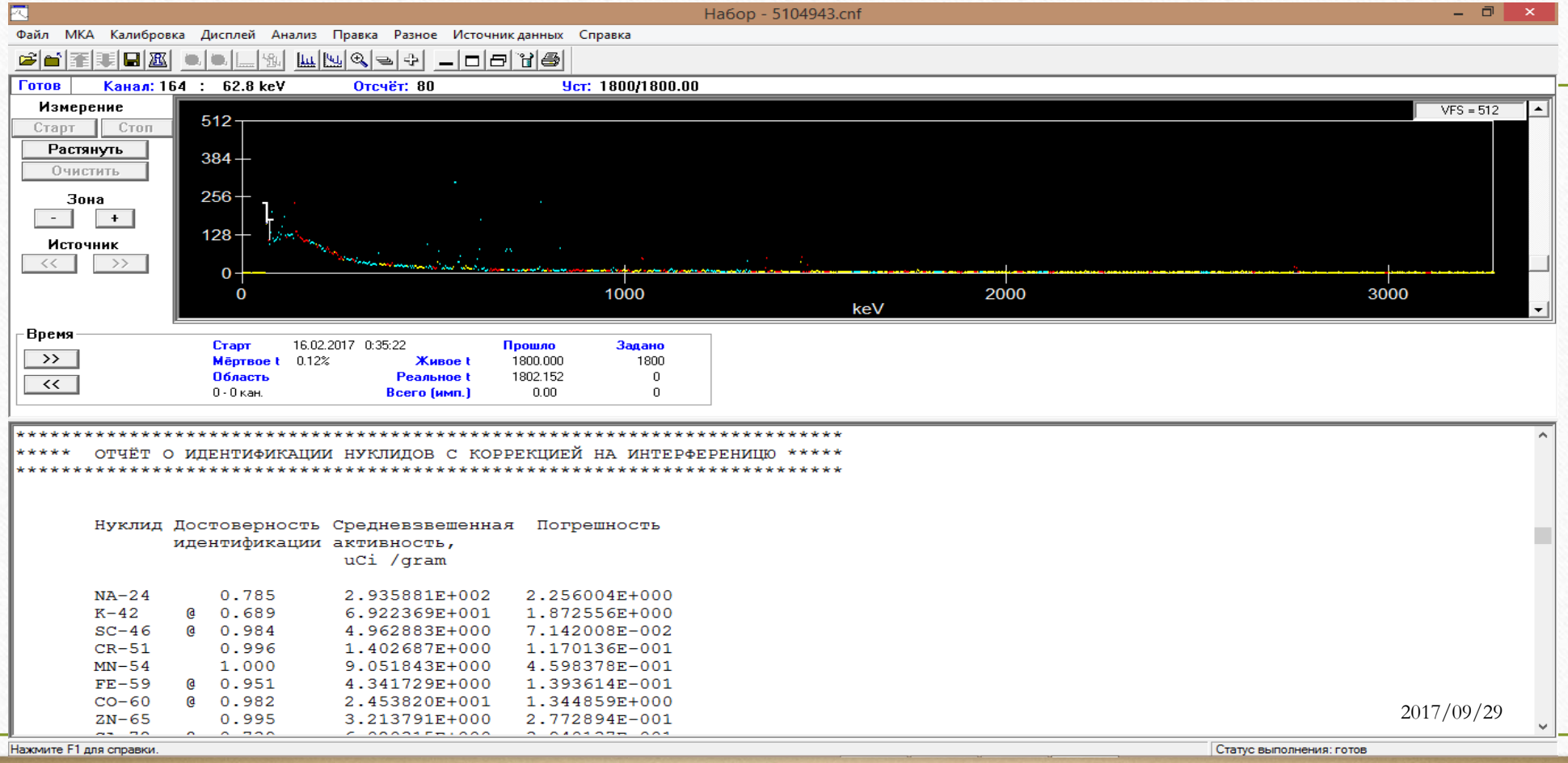
# Analysis of Spectrum

# 1. Processing of Gamma-Ray Spectra

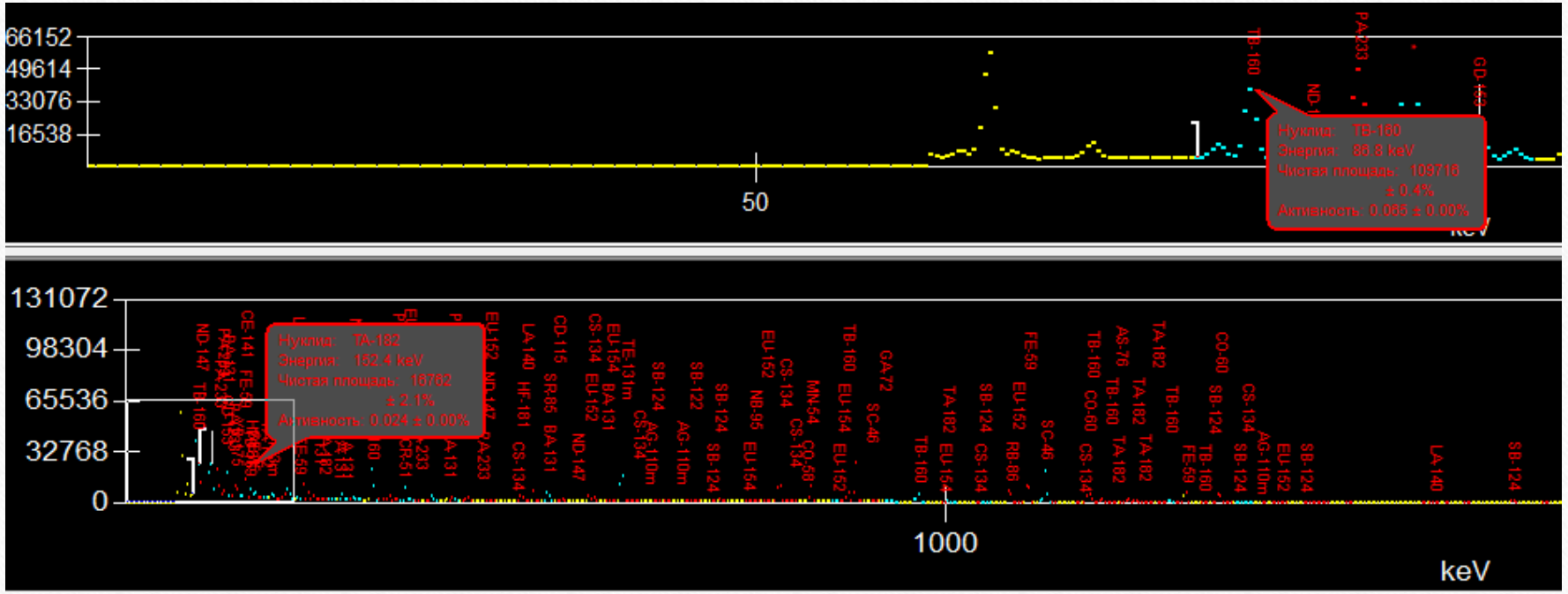
The minimum requirements:

- Determine the position of peaks in the spectrum
- Estimate the areas of the peaks (together with uncertainties)
- Calculate the energy of the gamma-ray each peak represents
- Correct for counting losses due to dead time and random summing
- Make corrections for decay from a reference time

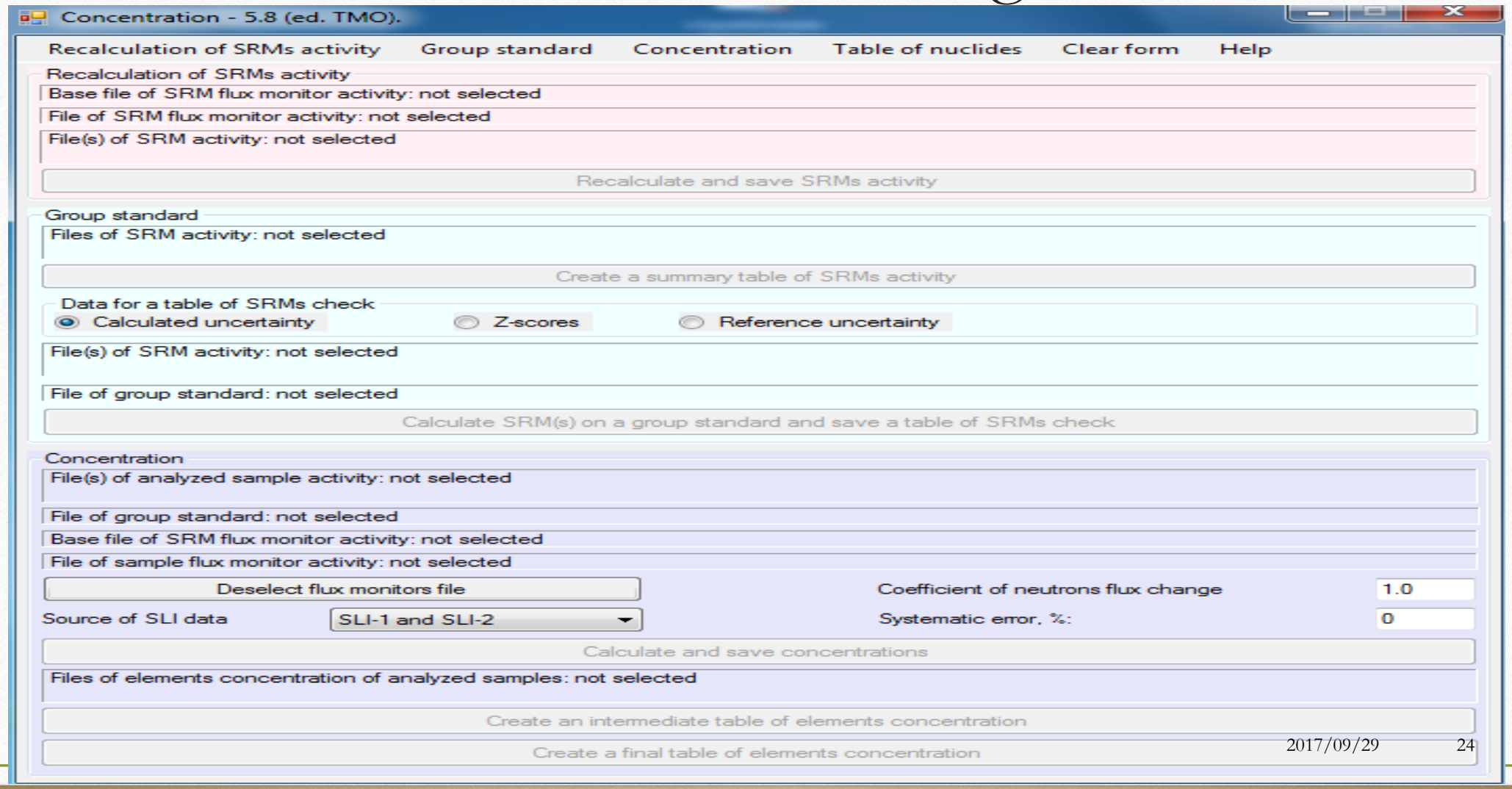
# 2. Genie-2000


Набор - 5104943.cnf
Файл МКА Калибровка Дисплей Анализ Правка Разное Источник данных Справка
Готов
Канал: 164 : 62.8 keV
Отсчёт: 80
Уст: 1800/1800.00
Измерение
Старт
Стоп
Растянуть
Очистить
Зона
Источник
VFS = 512
512
384
256
128
0
0
1000
2000
3000
keV
Время
Старт 16.02.2017 0:35:22
Мёртвое t 0.12%
Область
0 - 0 кан.
Живое t
Реальное t
Всего (имп.)
Прошло
1800.000
1802.152
0.00
Задано
1800
0
0
**********
***** ОТЧЁТ О ИДЕНТИФИКАЦИИ НУКЛИДОВ С КОРРЕКЦИЕЙ НА ИНТЕРФЕРЕНЦИЮ *****
**********
Нуклид Достоверность идентификации
Средневзвешенная активность, uCi /gram
Погрешность
NA-24 0.785 2.935881E+002 2.256004E+000
K-42 @ 0.689 6.922369E+001 1.872556E+000
SC-46 @ 0.984 4.962883E+000 7.142008E-002
CR-51 0.996 1.402687E+000 1.170136E-001
MN-54 1.000 9.051843E+000 4.598378E-001
FE-59 @ 0.951 4.341729E+000 1.393614E-001
CO-60 @ 0.982 2.453820E+001 1.344859E+000
ZN-65 0.995 3.213791E+000 2.772894E-001
Нажмите F1 для справки.
Статус выполнения: готов

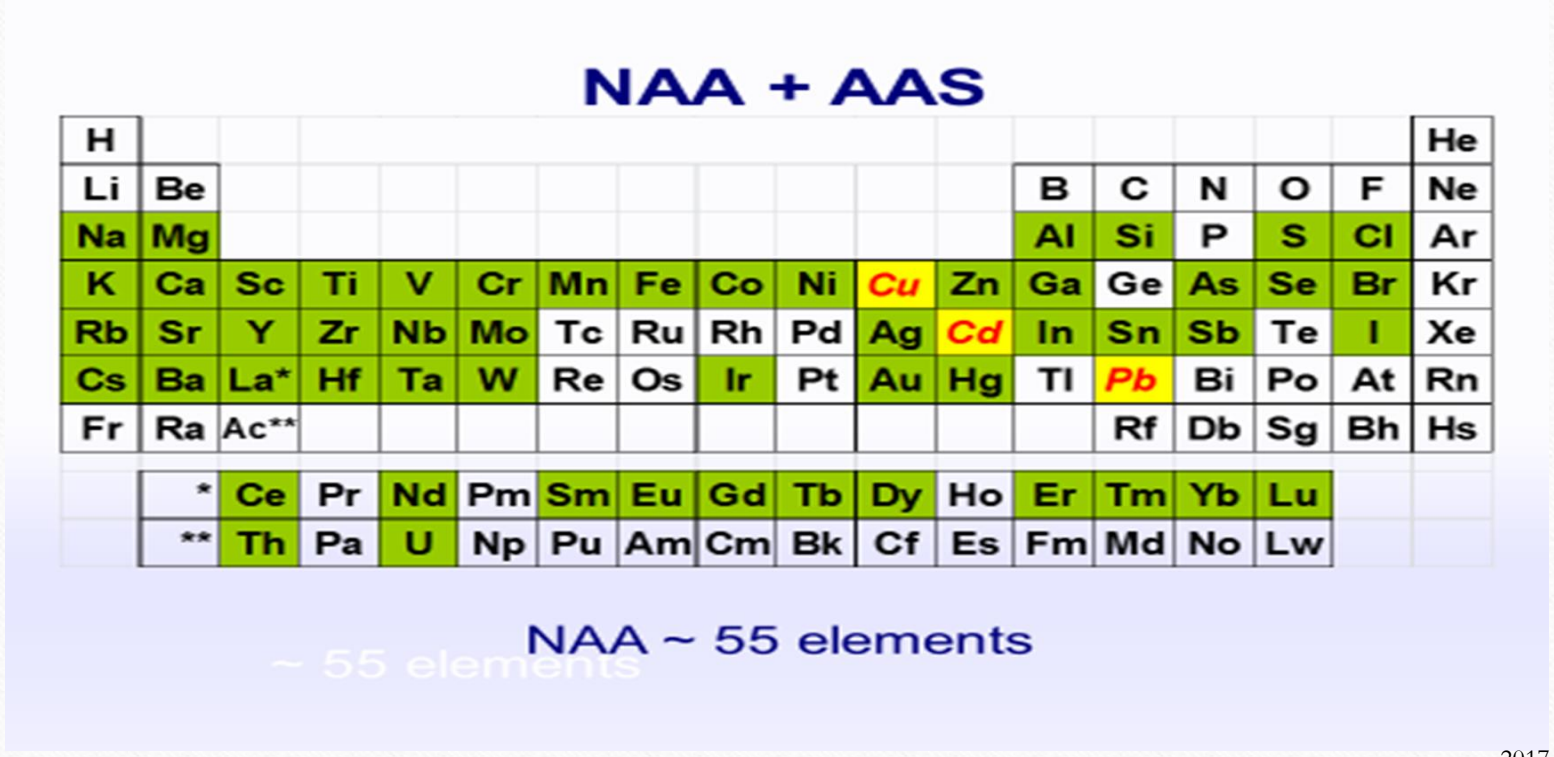
# Genie 2000


66152
49614
33076
16538
50
TB-160
Нуклид TB-160
Энергия 86.8 keV
Чистая площадь 109716
± 0.4%
Активность 0.065 ± 0.00%
131072
98304
65536
32768
0
Нуклид TA-182
Энергия 152.4 keV
Чистая площадь 16762
± 2.1%
Активность 0.024 ± 0.00%
1000
keV

# 3. Concentration Program



# 4. Elements measured using NAA



# 5. The most commonly used programs

- ArcGIS
- Statistica
- Origin-Lab
- CorelDraw

# ArcGIS

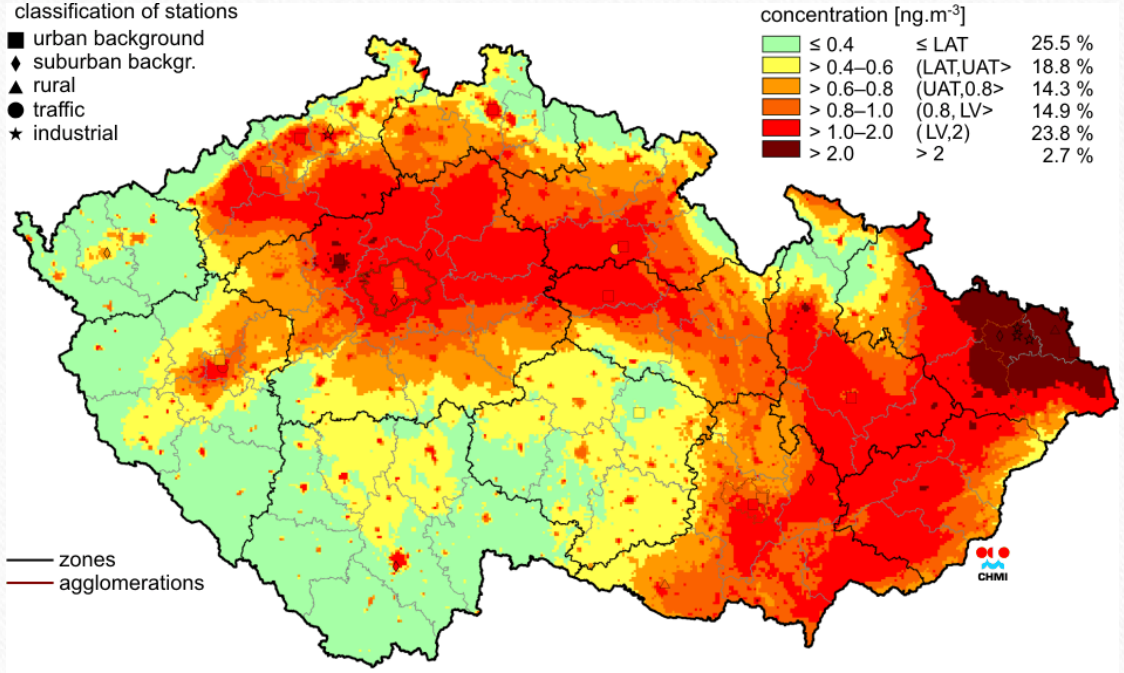
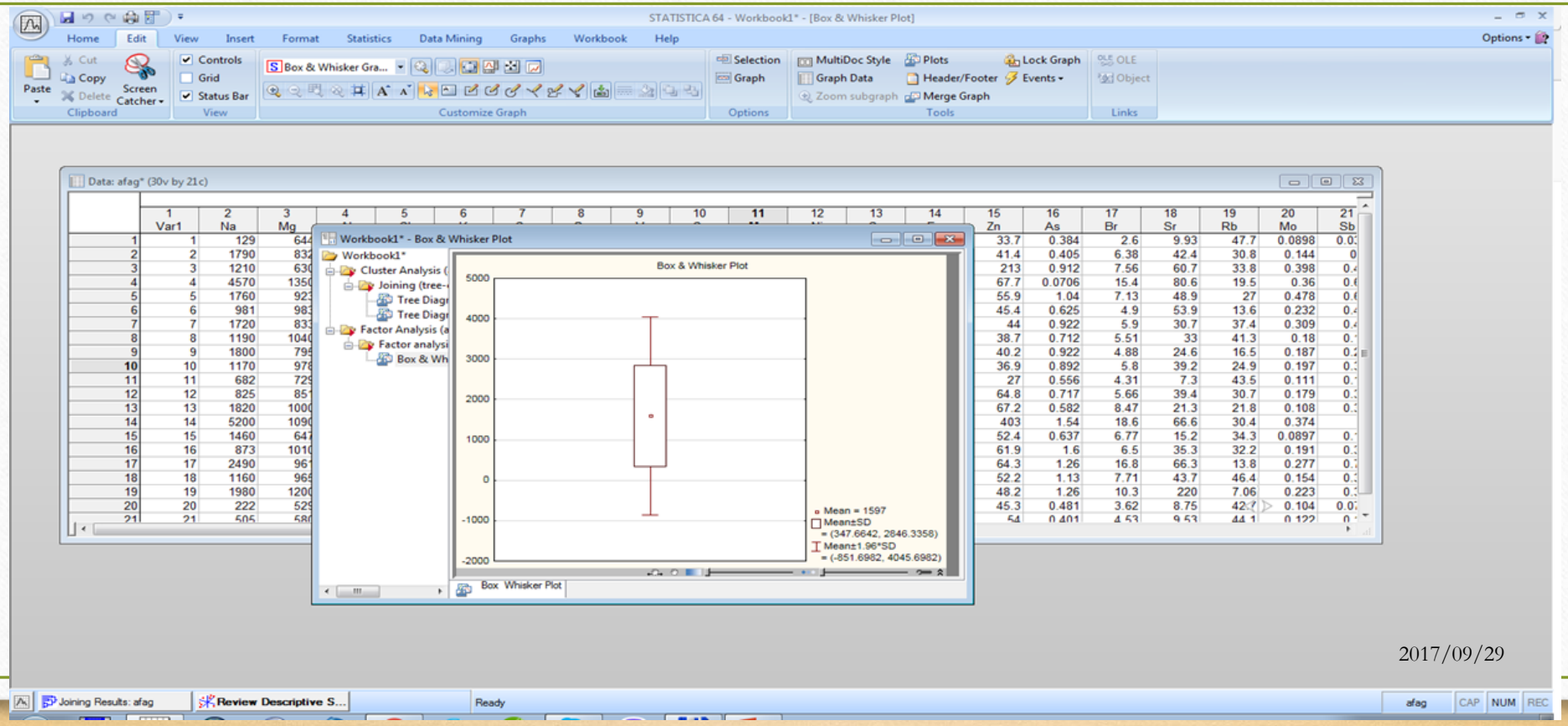
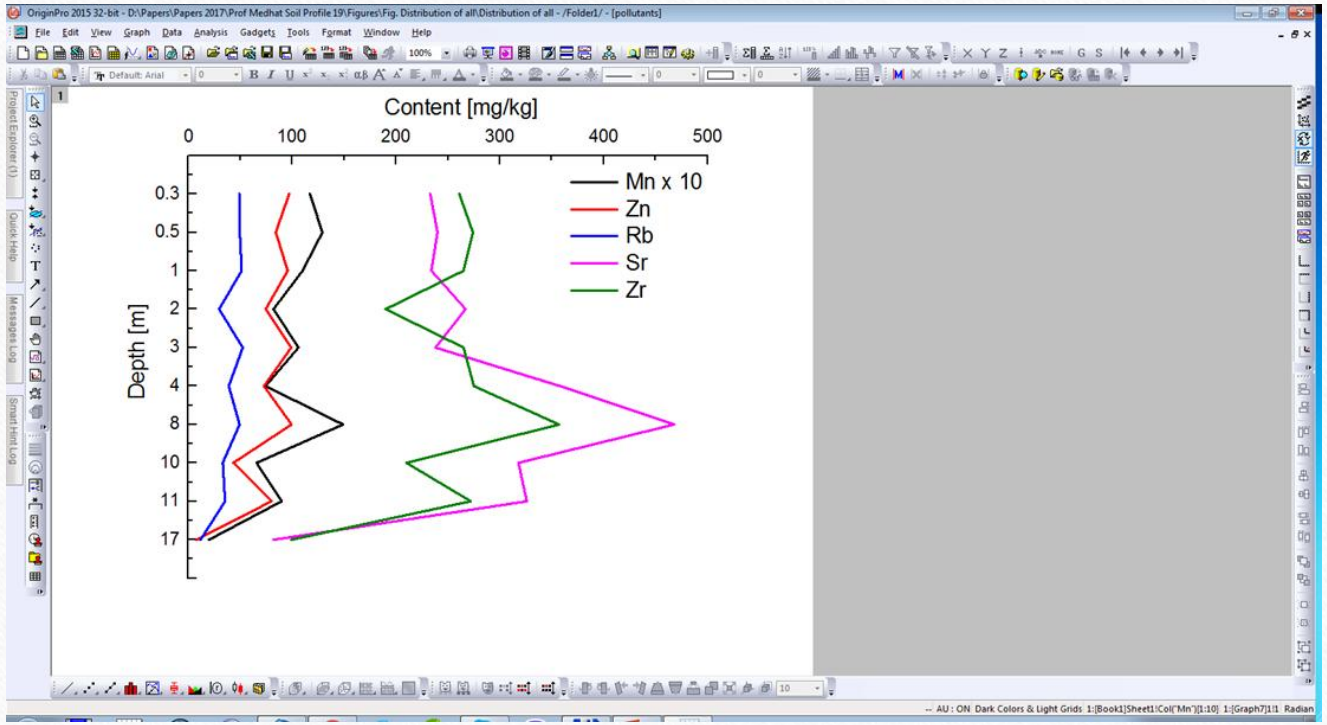



**Fig. II.4.2.42 Field of annual average concentration of benzo(a)pyrene in the ambient air in 2012**

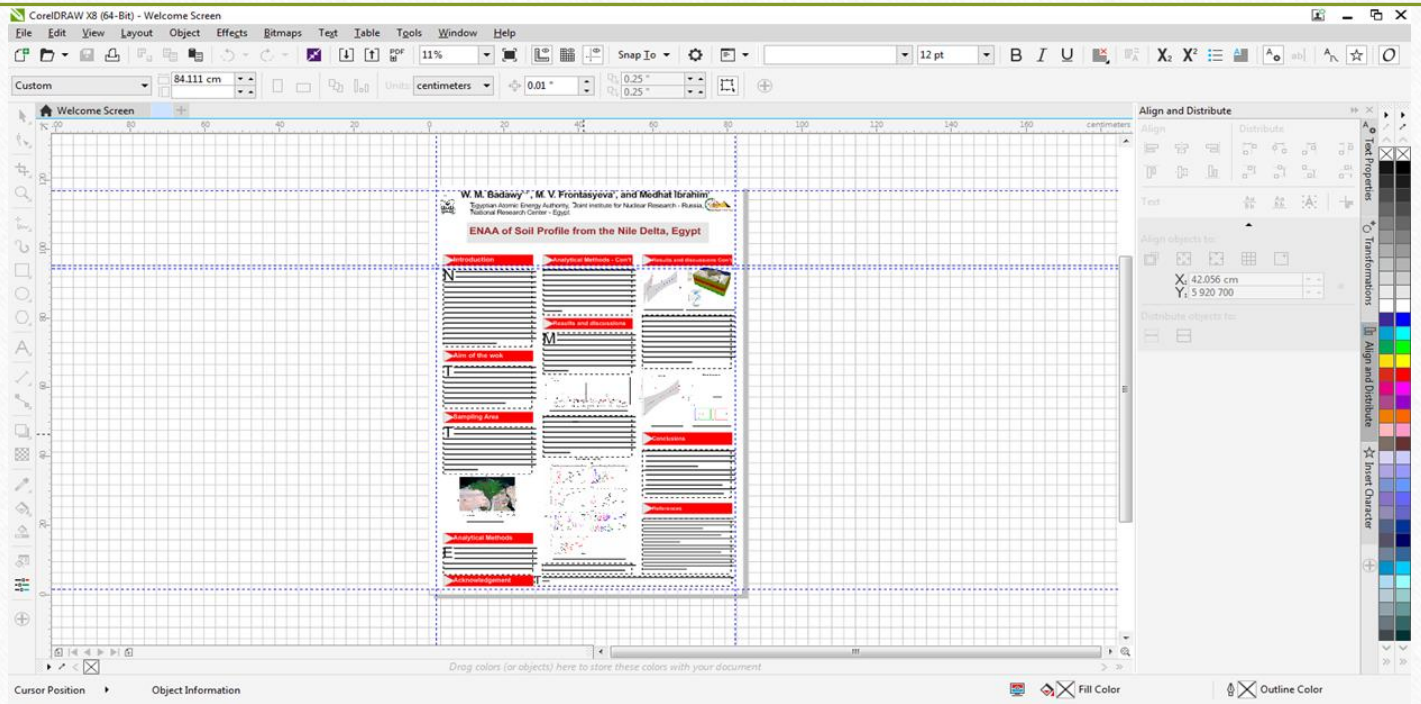
# Statistica


STATISTICA 64 - Workbook1* - [Box & Whisker Plot]
Home
Edit
View
Insert
Format
Statistics
Data Mining
Graphs
Workbook
Help
Options
Paste
Cut
Copy
Delete
Screen Catcher
Clipboard
Controls
Grid
Status Bar
View
Box & Whisker Gra...
Customize Graph
Selection
Graph
Options
MultiDoc Style
Graph Data
Zoom subgraph
Plots
Header/Footer
Merge Graph
Lock Graph
Events
Tools
OLE
Object
Links
Data: afag* (30v by 21c)
Workbook1* - Box & Whisker Plot
Workbook1*
Cluster Analysis
Joining (tree-
Tree Diagr
Tree Diagr
Factor Analysis (a
Factor analysi
Box & Wh
Box & Whisker Plot
5000
4000
3000
2000
1000
0
-1000
-2000
Mean = 1597
Mean±SD
= (347.6642, 2846.3358)
Mean±1.96*SD
= (-851.6982, 4045.6982)
Box Whisker Plot
Joining Results: afag
Review Descriptive S...
Ready
afag
CAP
NUM
REC

# Origin-Lab


Content [mg/kg]
0
100
200
300
400
500
Depth [m]
0.3
0.5
1
2
3
4
8
10
11
17
Mn x 10
Zn
Rb
Sr
Zr

# CorelDraw


CorelDRAW X8 (64-Bit) - Welcome Screen
File Edit View Layout Object Effects Bitmaps Text Table Tools Window Help
Welcome Screen
ENAA of Soil Profile from the Nile Delta, Egypt
Align and Distribute
Cursor Position
Object Information
Fill Color
Outline Color

# Advantages and limitations of NAA

# Advantages

- **Primary Analytical Technique**
- **Wide possibilities of applications**
- **Non-destructive Analysis**
- **Multi-element Analysis**
- **High Sensitivity and Precision**
- **Limited sample handling**
- **Simultaneous identification of elements**
- **Low temperature operation (30-70°C)**
- **The Chemical form and Physical State of the Elements do not Influence the Activation and decay Process**

# Limitations

- Samples irradiated in NAA will remain radioactive for a period of time
- Radioactive samples require special handling and disposal protocols
- The need for neutron source as reactor or neutron generator

# Joint projects with Republic of South Africa(RSA)

- Atmospheric Deposition of Trace Elements in the Western Cape, South Africa, Studied with the Biomonitoring Technique, NAA, ICP-MS and GIS Technology
- Study on Levels of Priority Aquatic Pollutants in South African Cultivated Bivalve Mollusks ("The South African Mussel Watch")
- Use of INAA to Determine Rare Earth Element Contents in Different Fresh and Weathered South African Fly Ash
- Elemental Composition of Fly Ash: A Comparative Study Using Nuclear and Related Analytical Techniques

# Joint projects with Belarus

- Investigation of the crystallization processes and characteristics of the diamonds obtained in the C-Mn-Ni-Fe system
- Study of the phase formation processes and physical characteristics of compounds in the Cu-Fe-S system under the influence of high pressures and temperatures
- Study of the phase formation processes and physical characteristics of composite materials in the system of B-N-Al-Ti obtained under the influence of high pressures and temperatures
- Investigation of the crystallization processes of cubic boron nitride in the $Li_3N$-BN system in high-pressure devices of the "toroid" type

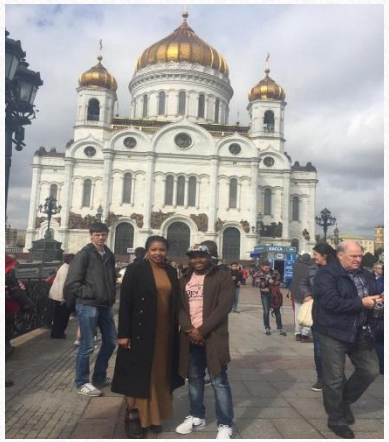
# Outcome

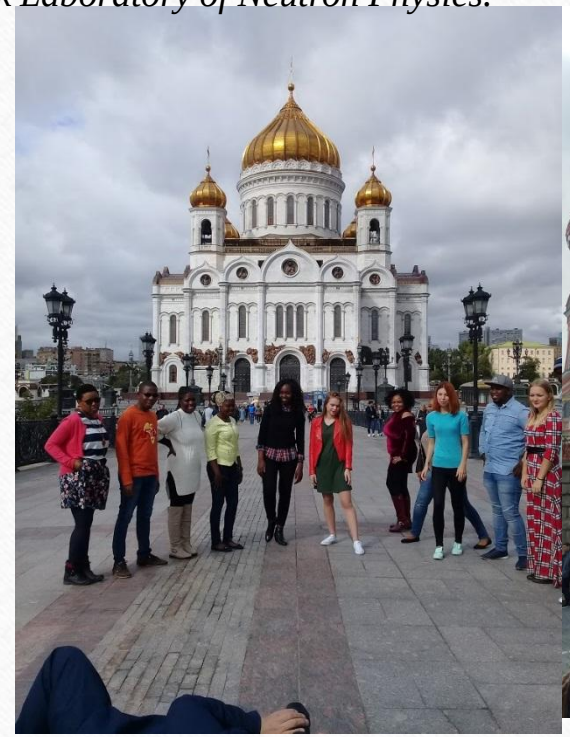
- The aim of this practice is to expose students from member state countries to scientific research and facilities of world class standard, managed by JINR.

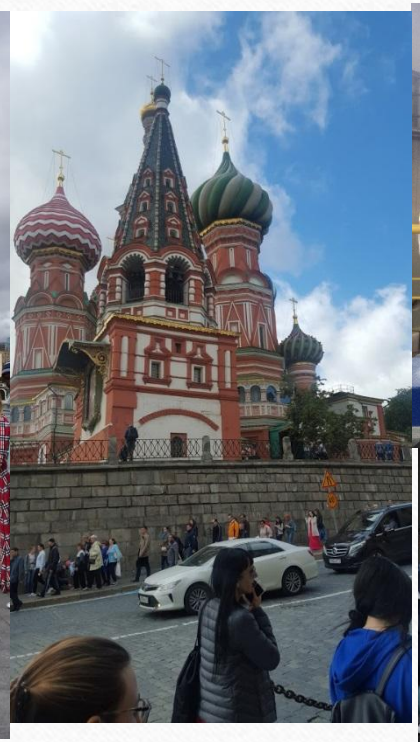
- The practice provides students with knowledge that will improve their respective country's nuclear technology, to support the development of the entire country.

# Acknowledgement

*Prof. Marina V. Frontasyeva. Assoc Prof. Wael Badawy. Also special thanks to all staff of the Neutron Activation Analysis and Applied Research Unit, Frank Laboratory of Neutron Physics.*







# Thank you for your time

We hope for no questions