JOINT INSTITUTE FOR NUCLEAR RESEARCH

INSTITUTE OF NUCLEAR PHYSICS

FLNP FRANK LABORATORY OF NEUTRON PHYSICS

Review report on scientific activities and infrastructure of FLNP

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JOINT INSTITUTE FOR NUCLEAR RESEARCH

International Intergovernmental Organization

1956

- established on March 26,1956 by eleven founding States
- registered with the United Nations on February 1,1957

2026

Member States

Armenia, Cuba, Kazakhstan, Slovakia, Azerbaijan, DPRK, Mongolia, Uzbekistan, Belarus, Egypt, Romania, Vietnam, Bulgaria, Georgia, Russia

Associate Members

Germany, Hungary, Italy, The Republic of South Africa, Serbia

Joint Coordinating Committee Expert Working Group

China, Mexico, Brazil

JINR comprises 7 Laboratories, each being comparable with a large institute in the scale and scope of investigations performed

+ university center

~1000 partner research organizations and universities from ~**70** countries


DLNP


BLTP


FLNR


FLNP


MLIT

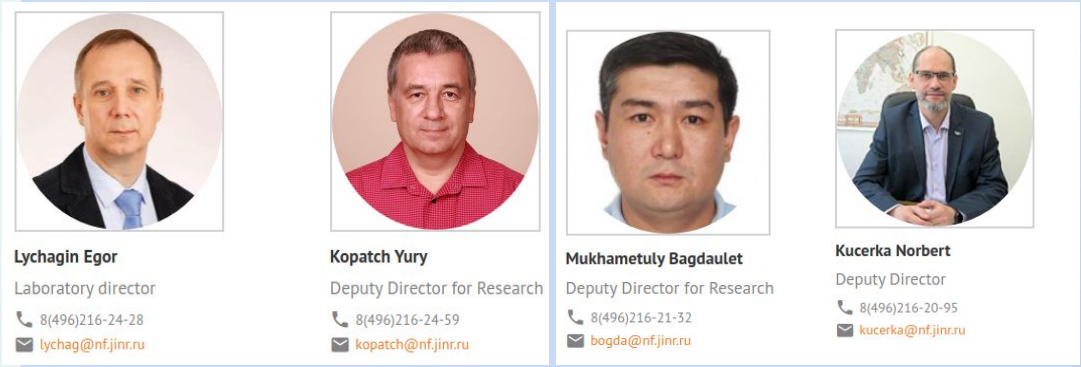

LRB


VBLHEP


UNC

FLNP staff breakdown:

Total	557
Scientists	202
Engineers and specialists	152
Workers	171
Administrative staff	32



Average age – 48.1 years
Women – 27 %
Doctors – 29 persons
PhD – 108 persons
Foreigners – 96 persons

THREE MAIN SCIENTIFIC DEPARTMENTS of FLNP:

- **Department of nuclear physics** (139 persons)
- **Department of Neutron Investigations of Condensed Matter** (99 persons)
- **Department of Spectrometers Complex IBR-2** (51 persons)
- **+ Raman spectroscopy sector** (10 persons)
- **Sector of a new source and complex of moderators** (26 persons)

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FLNP FRANK LABORATORY OF NEUTRON PHYSICS

EG-5 - Van-de-Graaff Electrostatic accelerator
TANGRA - (TAgged Neutrons and Gamma RAys) is devoted to study of neutron-nuclear interactions, using the tagged neutron method
IREN – Intense REsonance Neutron source
CARS - Multimodal platform for Raman and nonlinear optical microscopy and microspectroscopy for condensed matter studies
ENGREN - Project Investigation of Prompt Fission Neutron Emission in Fission
XEUSS 3.0 - new X-ray scattering facility

NPD - Nuclear Physics Division
DNICM - Department of Neutron Investigations of Condensed Matter
DSC - Department of Spectrometers Complex IBR-2
SRS - Sector of Raman Spectroscopy (Centre "Nanobiophotonics")
SNSCM - Sector of the New Source and Complex of Moderators

Diffraction: HRFD, RTD, DN-6, SKAT-EPSILON, FSD, DN-12, FSS
Small-angle scattering: YuMO
Reflectometry: REMUR, REFLEX, GRAINS
Inelastic scattering: NERA
Neutron imaging: NRT
Nuclear Physics: ISOMER
Neutron Activation Analysis: REGATA
Irradiation Facility

The building of the IBR-2 reactor

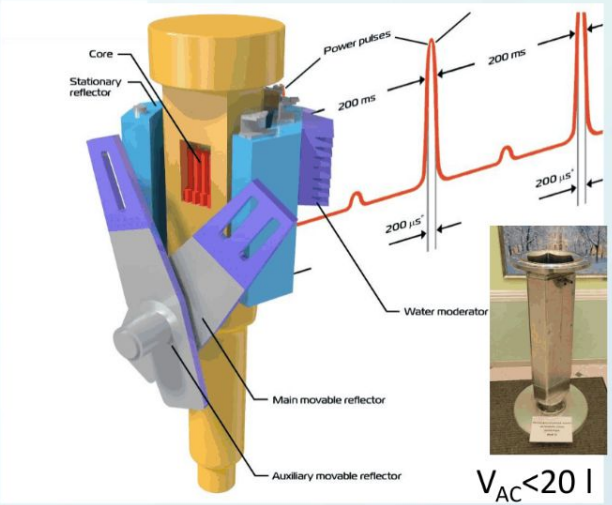
Experimental hall at the IBR-2 reactor

https://flnp.jinr.int/en-us/main/facilities/ibr-2

IBR-2 Pulsed Reactor

Operating since 1984

Deep modernization was carried out in 2006-2011



- October 16, 2021 - February 17, 2025 – reactor **shutdown**
- **Resumption** of operation was done **in March 2025**

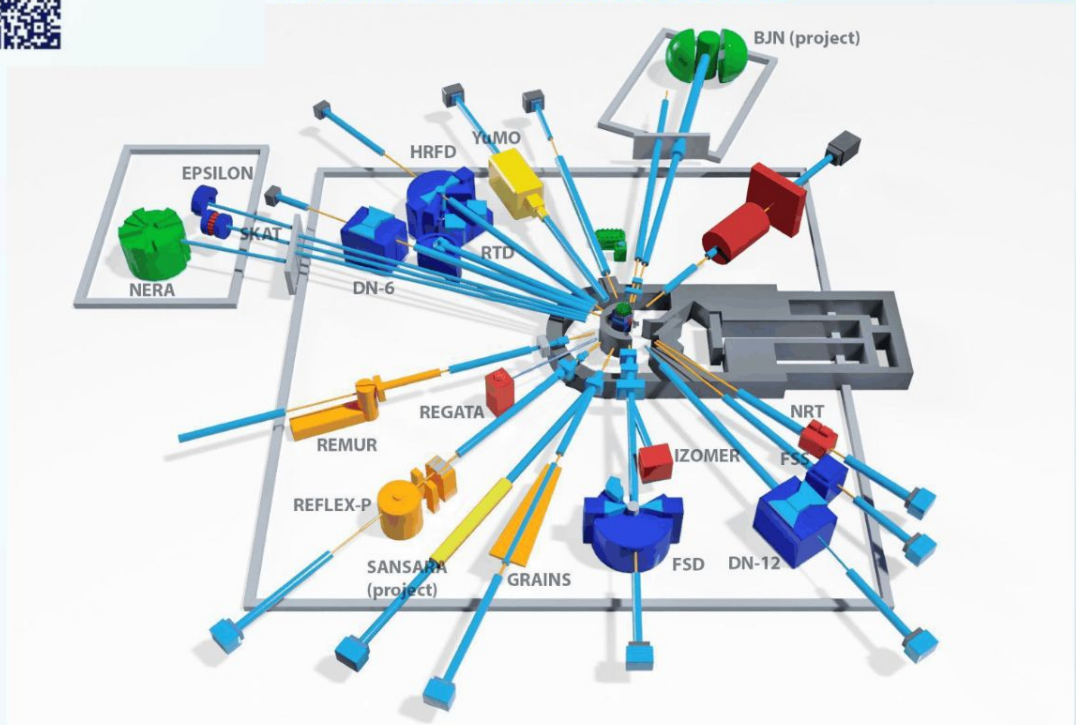
Average power, MW	**2**
Fuel	PuO_2
Pulse repetition rate, Hz	**5**
Pulse half-width, μs: fast neutrons thermal neutrons	 200* **340**
Rotation rate, rev/min • Main reflector • Auxiliary reflector	 600 300
Background, %	**7.5**
Thermal neutron flux density from the surface of the moderator • Time average • Burst maximum	 **~10^{13} n/cm^2 s** **~10^{16} n/cm^2 s**

* at reactor power of 2MW

prepared by Dr. D. Chudoba

https://ibr-2.jinr.int

Neutron Instruments



- Length of neutron guides – up to ~30 m in the experimental halls and up to ~100 m in two pavilions.
- Typical neutron flux density on the sample – ~10^6 $cm^{-2}s^1$ (up to 4 x 10^7 $cm^{-2}s^1$)

14 INSTRUMENTS INCLUDED IN USER PROGRAM

Diffraction:
HRFD
RTD
DN-6
EPSILON
SKAT
DN-12
FSD

Small-Angle
YuMo

Reflectometry:
GRAINS
REMUR
REFLEX

Inelastic scattering:
NERA

NAA:
REGATA

Under construction:
- **SANSARA** – small angle + imaging (2026)
- **BJN** – inelastic scattering (2027)

NRT (neutron imaging) was included in the User Program in the second half of **2025**

The Instruments parameters could be found at https://flnp.jinr.int/en-us/main/facilities/ibr-2

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FLNP User Program

https://ibr-2.jinr.int

Who can apply for beam time?

- Scientists from **any country of the world** can apply for beam time.
- Scientists from member states of JINR get additional financial support.

https://ibr-2.jinr.int

I. Regular access applications

	First round	Second round
Period for proposal submission	September 1 - October 15	March 1 – April 15
Experiments time	1 half-year	2 half-year

Distribution of the beam time

In the FLNP JINR the neutron beam time at the high flux pulsed IBR-2 reactor is distributed between **internal users** (FLNP) and **general science community** (GSC) in the ratio of

- **35%** (internal proposals)
- **55%** (external regular proposals)
- **10%** (external urgent beam time requests)

II. Fast access applications

- NO DEADLINE
- Submission – via FLNP scientific secretary

https://ibr-2.jinr.int

FLNP User Program

The proposals are evaluated by **Experts Committees** (**technical and scientific**) and beam time for experiments is granted upon possibility of technical implementation and scientific merit of the proposal.

Scientific Experts Committees:

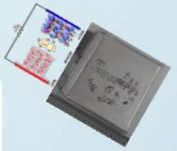
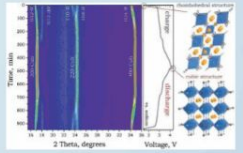
- Nanosystems and Soft Matter (YuMO, GRAINS, REFLEX, REMUR, NRT)
- Atomic and Magnetic Structure

  (RTD, DN-6, DN-12, SKAT, EPSILON, FSD, HRFD)
- Lattice and Molecular Dynamics (NERA)
- Neutron Activation Analysis (REGATA)

Detailed information could be found at:

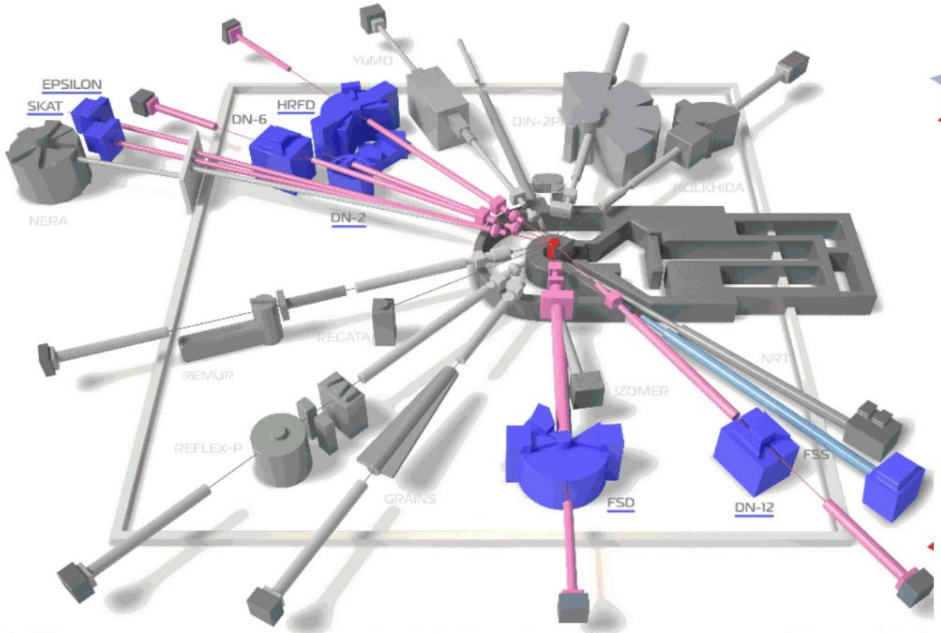
Sidorov N.E., Chudoba D.M., Gorshkova Yu.E., Kochnev P.O., Sadovsky D.A. "User program for the neutron source reactor IBR-2 (FLNP JINR)" Physics of Particles and Nuclei Letters, ISSN 1547-4771, 2024, Vol. 21, No. 3, pp. 553–559.

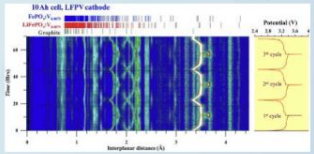
Neutron scattering in condensed matter physics

Diffraction

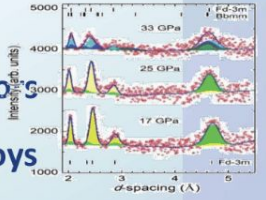
Experimental facilities

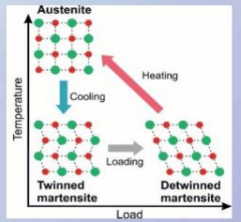




Diffraction
DN-2, DN-12, DN-6, FSD, FSS, HRFD, SKAT, EPSILON

- Crystal and magnetic structure of novel materials under ambient and extreme conditions
- Real-time studies of Li-based accumulators
- Phase transitions of H-based storage alloys
- Crystallographic texture of metals, rocks and biological objects
- Strain measurements in structural materials
- 2D van der Waals magnetic materials



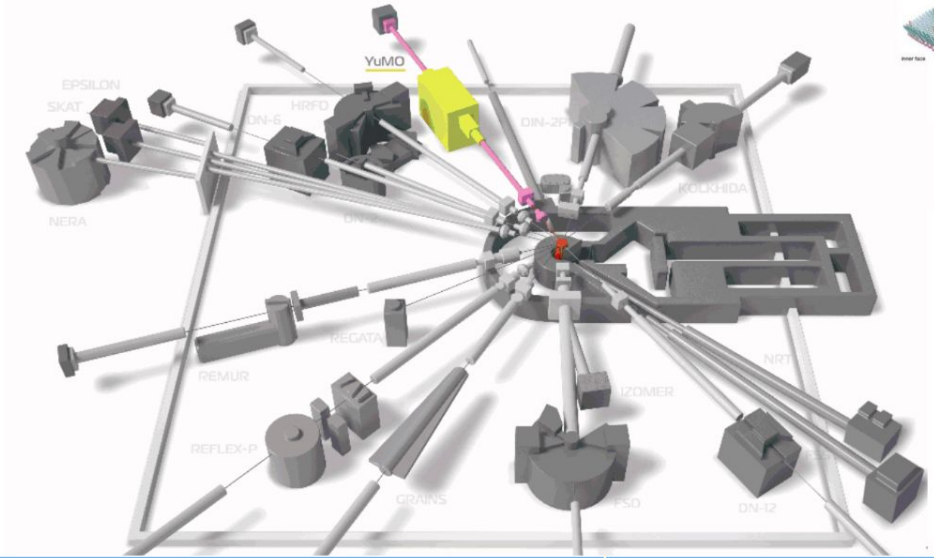


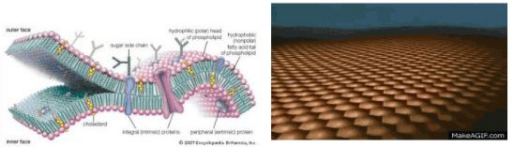
Diffractometers equipped with Fourier choppers to achieve high resolution at short beamlines with long pulse of the reactor

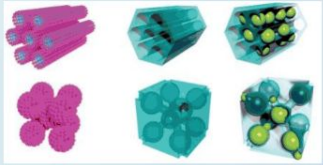
Neutron scattering in condensed matter

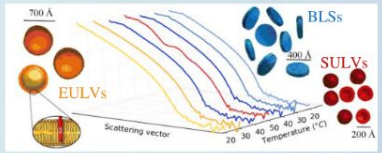
Small Angle Scattering

Experimental facilities









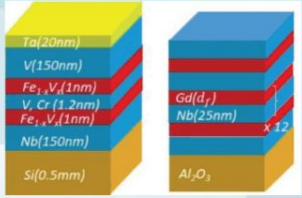
Small-angle scattering
YuMO

- **Structural organization** and **aggregation** of nanoparticles and **composite systems**
- Interactions of **nanoparticles** with **bio-macromolecules**

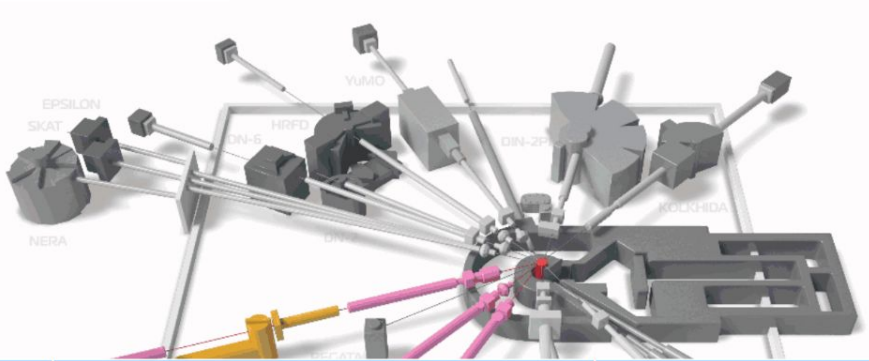
Applications	Basic parameters	Specific features
Determination of sizes, shapes, spatial correlations of particles, agglomerates, pores, as well as fractal dimension in nanomaterials, biological objects, polymers, colloidal solutions	Q-range: 7×10^{-3} - 0.5 $Å^{-1}$ Temperature range: 10-180°C	Characteristic particle size that can be identified: 1-500 nm Minimum sample volume: 500 µl Characteristic sample size is up to 1.4 cm in diameter

Neutron scattering in condensed matter

Reflectometry



Experimental facilities



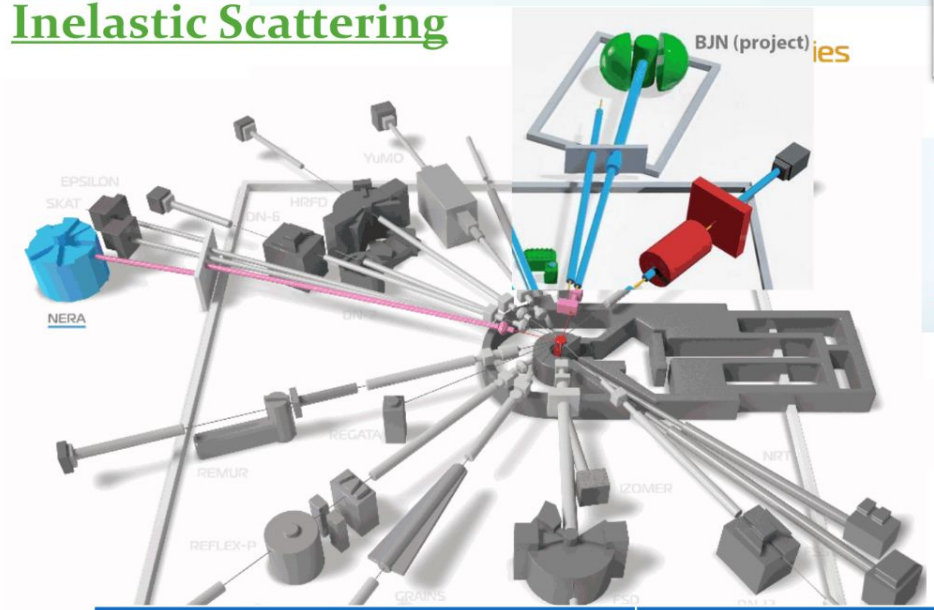
- **Thin films** and surfaces
- **Surface adsorption** of magnetic nanoparticles
- Superconducting and magnetic properties of the **complex layered heterostructures**

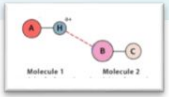
Reflectometry
GRAINS, REFLEX-P, REMUR

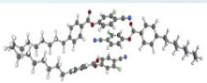
Spectrometer, Instrument	Applications	Basic parameters	Specific features
REMUR	Determination of parameters of magnetic and superconducting heterostructures, nonmetallic thin films	Q-range: 0.001 - 2 nm^{-1}, resolution $\Delta Q/Q \approx 1$ % Temperature range: 1.5 - 300 K Magnetic field on the sample: up to 1.5 T	Minimum surface area of the sample – 5x5 mm^2, thickness of layers accessible for research – **0.5-500 nm**, roughness – ~1 nm
REFLEX	Determination of structural parameters of thin-film nanostructures	Q-range: 0.01 - 1.3 nm^{-1}, resolution $\Delta Q/Q \approx 1$ - 15 % Temperature range: 1.5 - 300 K Magnetic field on the sample: up to 0.5 T	Minimum surface area of the sample – 20x20 mm^2, thickness of layers accessible for research – **2-500 nm**, roughness – ~3 nm
GRAINS	Determination of structural parameters of **interfaces with "soft" and liquid media**	Q-range: 0.05 - 1.0 nm^{-1}, resolution $\Delta Q/Q \approx 5$ %. Temperature range: 10 - 150°C	Minimum surface area of the sample – 5x5 cm, maximum interface thickness – **100 nm**, roughness – up to 5 nm (at a thickness of 100 nm)

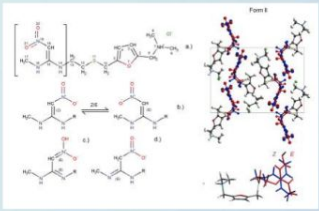
Neutron scattering in condensed matter physics

Inelastic Scattering

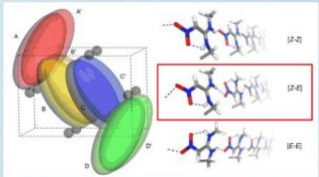


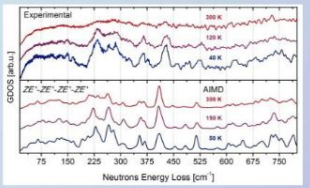


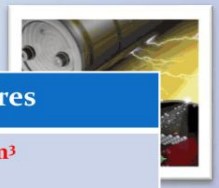




- Molecular structure and **dynamics**
- **Isomeric forms** of drugs
- **Drug delivery systems**

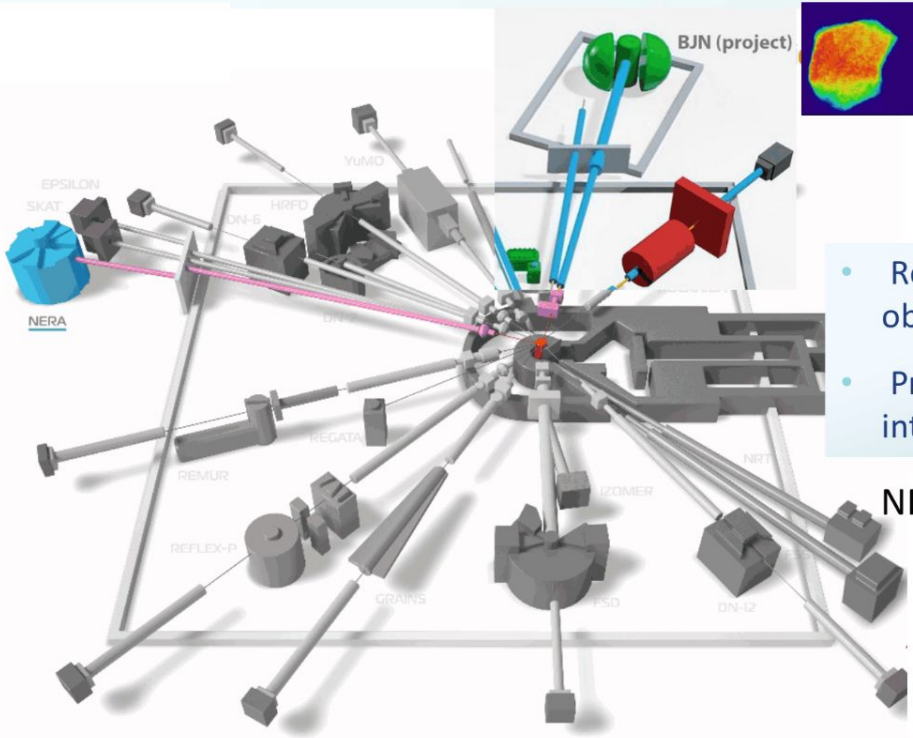


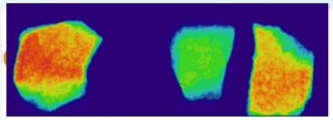




Applications	Basic parameters	Specific features
Investigation of atomic and molecular dynamics of hydrogen-containing compounds, including pharmacological substances, analysis of the effect of phase polymorphism	Energy transfer range: **1 - 160 meV** Resolution $\Delta E/E \approx$ 2- 4% Temperature range: 4 - 300 K	Sample volume is about **4-5 cm³**

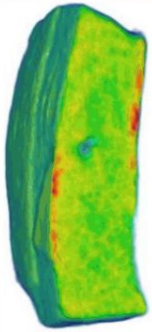
Neutron radiography and tomography station (NRT)

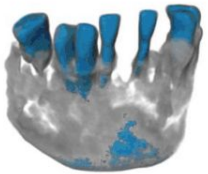




- Research of internal structure of objects
- Processes of water penetration into materials

NRT

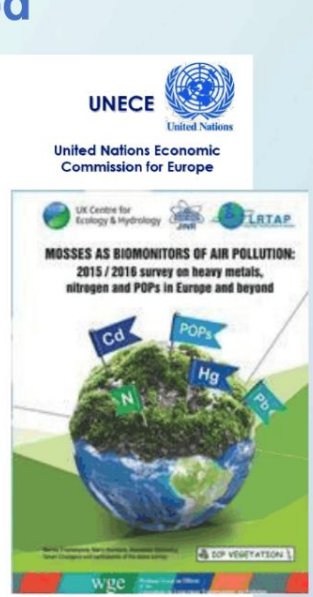


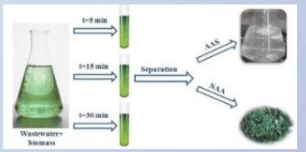


Nuclear analytical method

Neutron Activation Analysis

Experimental facilities

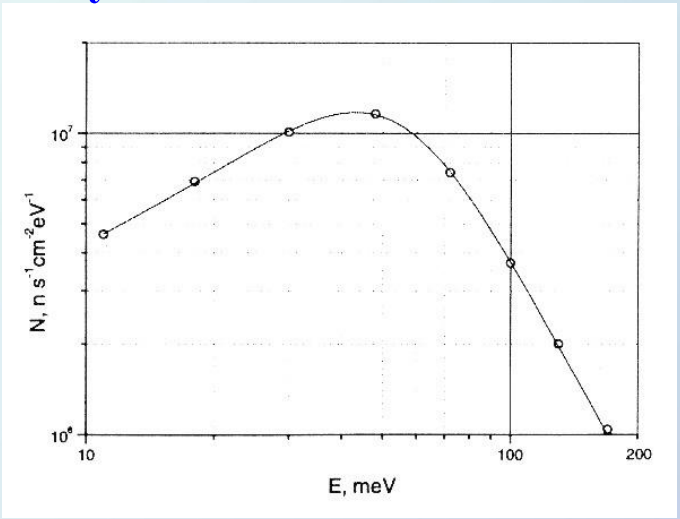




Neutron Activation Analysis
REGATA

- **Elemental composition analysis** of air, water, and soil or objects of cultural heritage

Nuclear Physics



Interactions of polarized neutrons with nuclei

Parameters of polarized neutron beam

Angle θ, (deg)	19	12	6	4	3
Wavelength λ, $(\AA)$	1.15	0.74	0.37	0.25	0.19
Energy E_n, (eV)	0.062	0.15	0.6	1.3	2.3
The detector count rate after polarizer n_1, (sec^{-1}),	800	270	65	33	22
Polarized beam intensity I_1, (n/cm^2sec)	430	200	80	60	50
The detector count rate after analysis n_2, (sec^{-1})	70	23	3.1	0.6	0.2

FLNP offers a large suite of equipment for comprehensive study of samples by complementary techniques

It includes:

- Xeuss 3.0 X-ray scattering station;
- X-ray Diffractometer EMPYREAN (PANalytical);
- Coherent Anti-Stokes Raman Spectrometer
- Raman spectrometers;
- IR and UV spectrometers;
- RFA;
- ICP-MS
- Chromatography System NGC Quest™ 10 Plus
- AFMs
- …etc.

https://flnp.jinr.int/images/box-slider/Laboratory_Equipment_DNICM_FLNP_JINR_2021.pdf

Source of resonance neutrons IREN based at lineal electron accelerator

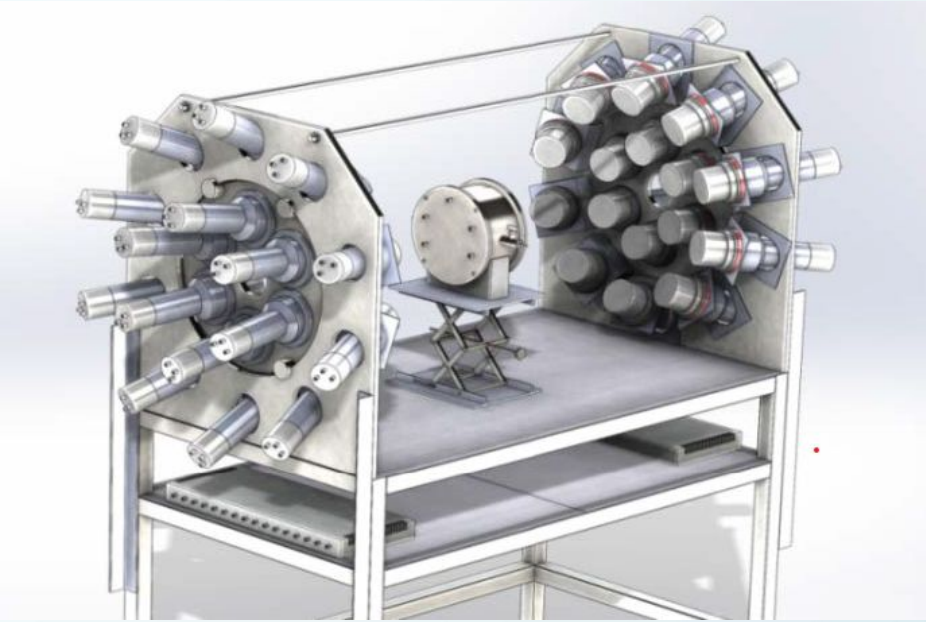
https://flnp.jinr.int/en-us/main/facilities/iren

The linear electron accelerator LUE-200 used as a driver for the intense resonance neutron source IREN. The accelerator is positioned vertically. It consists of a pulsed electron gun, an accelerating system, microwave power sources based on 10-cm klystrons with modulators, a focusing-beam transport system, a diagnostics system with a broadband magnetic spectrometer and a vacuum system.

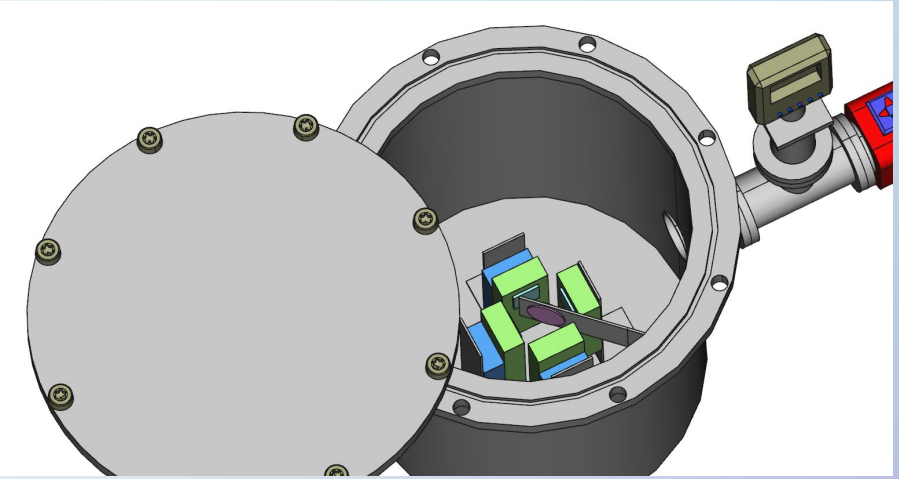
Peak current (A)	3
Repetition rate (Hz)	50
Electron pulse duration (ns)	100
Electron energy (MeV)	110
Beam power (kW)	1.5
Multiplication	1
Neutron intensity (n/s)	~3×10^{11}

1200 hours/year

Nuclear Physics research



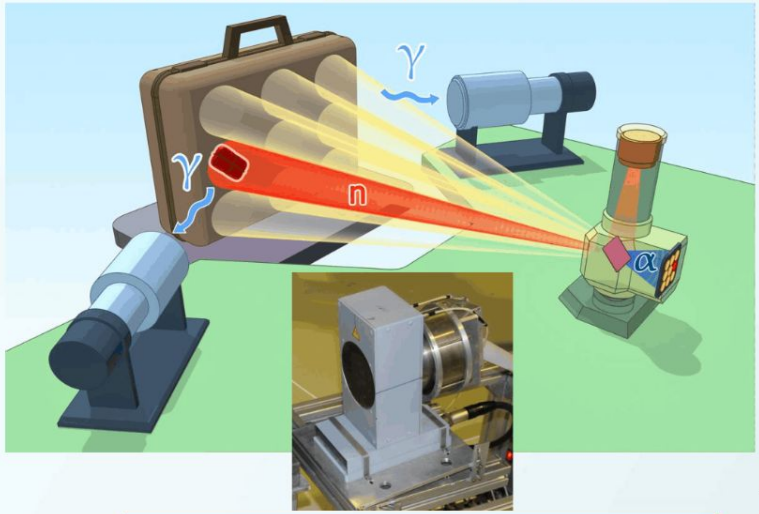
ENGREN project



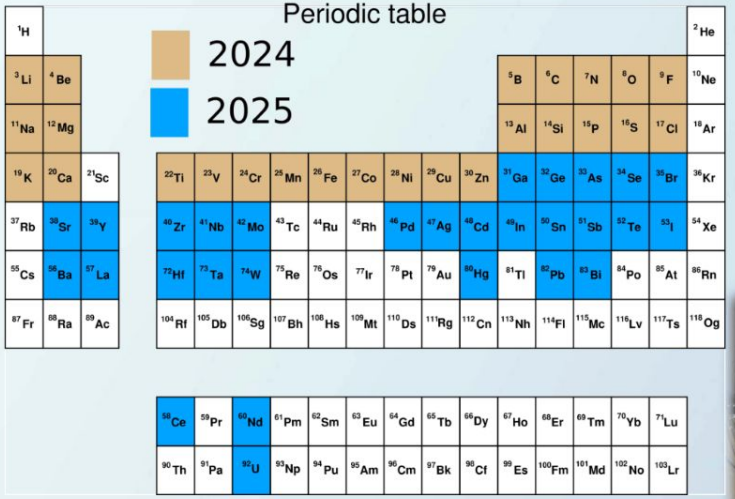
Studying of rare modes nuclear fission

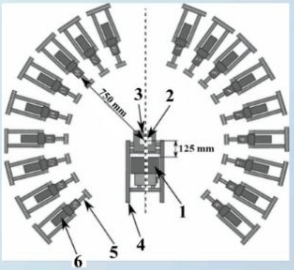
D-T generator for tagged neutron technique (TANGRA Project)

https://flnp.jinr.int/en-us/main/facilities/tangra-project-en



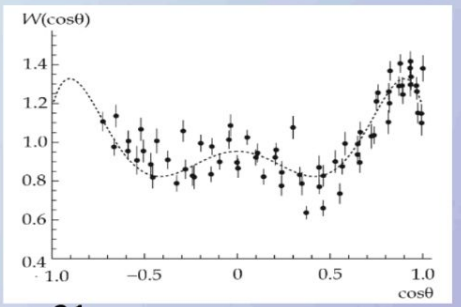
yield up to 10^8 c^{-1}
Set of NaI(Tl) detectors
Set of BGO detectors
Set of LaBr detectors
Set of detectors based on different plastics
HPGe detector





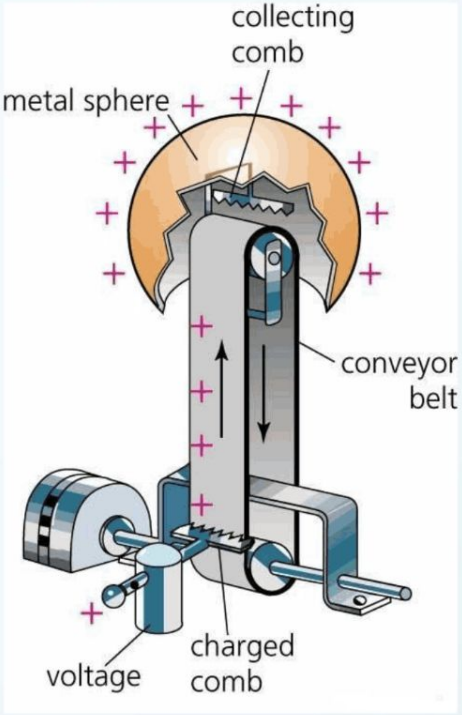
In 2024 γ-ray emission cross sections for light elements was measured: B, C, N, O, F, Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Sn.

Gamma-spectra and angular distributions of gamma ray have been measured in inelastic neutron scattering reactions for 20 nuclei.



EG-5 *https://flnp.jinr.int/en-us/main/facilities/eg-5*

Electrostatic Van de Graaff accelerator, was built in 1965.



The installation remains in demand today.

The characteristics of EG-5 Accelerator:	
Energy region	0.9 – 3.5 MeV
Beam intensity for $H+$	30 μA
Beam intensity for $He+$	10 μA
Energy spread	< 500 eV
Number of beam lines	6

600 hours/year

Plan of modernization 2023-2026:

Before modernization	After modernization
Terminal voltage - 2,5 MV Beam current – 100nA Ion Energy – 2,5 MeV	Terminal voltage - **4,1 MV** Beam current – **50-100mkA** Ion Energy – **4,1 MeV**

EG-5 activities

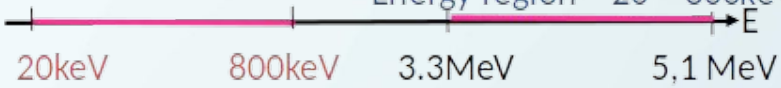
Fast neutron reactions

Gas Target D(d,n)^{3}He

- Neutron flux – 5 10^7 n/s sm^2
- Max. neutrons energy - 5,5 ± 0,1 MeV

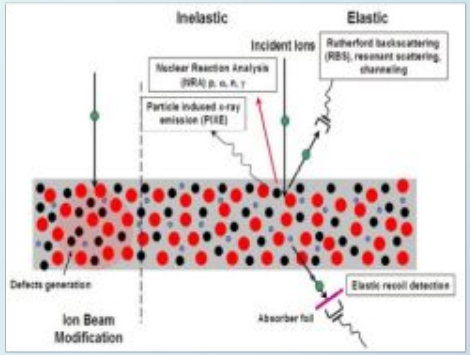
Solid-state target $^1H + {}^7Li - {}^7Be + n$

- Neutrons flux – 5 10^7 pat/s sm^2
- Energy region – 20 – 800keV



- Quasi-monochromatic neutrons in a wide range of energies

Ion Beam Analysis & complementary methods

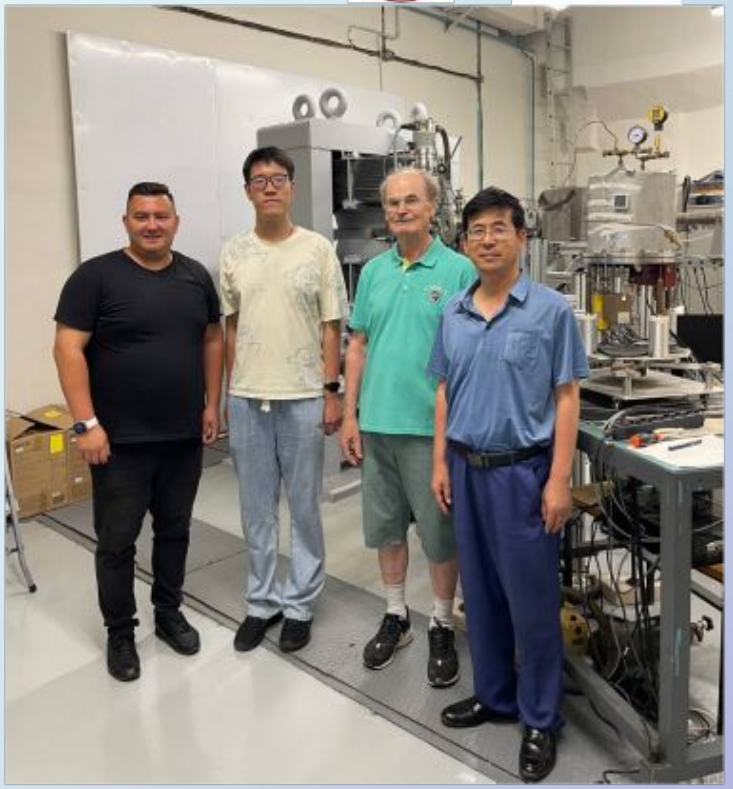


- The elemental composition of multilayer systems, isotopic composition, stoichiometry of films.
- Optical, electronic and electrical properties using complementary methods (ellipsometry voltammetry impedance spectroscopy).

Investigation of neutron-induced reactions with charge particles emission

The cooperation between JINR-LNP, PKU started in 1990 and CIAE started in 2017 and continues today.

Systematic measurements on (n, α) reactions



Thank you for attention and we invite you to joint research