



Strategic plan for the long-term development of JINR

The scientific program of the Laboratory of Radiation Biology for the period up to 2030

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The **main stages** of the implementation of JINR's radiobiological research **strategy**

- *Establishment of an international working group* - 2018.
- *Discussion of the main fields* of the strategic plan "JINR's Radiobiological Research" at a visiting session of the Bureau of the RAS Scientific Council on Radiobiology (Dubna, 30 May 2018).
- *Discussion of the strategy* of JINR's radiobiology and astrobiology research development at the International Conference "Modern Problems of General and Space Radiobiology" (Dubna, 11–12 October 2018).
- *Publication of the International Working Group's scientific report* of JINR's radiobiological research strategy *in the 2nd quarter* of 2019.

THE MAIN FIELDS OF RESEARCH

15 people

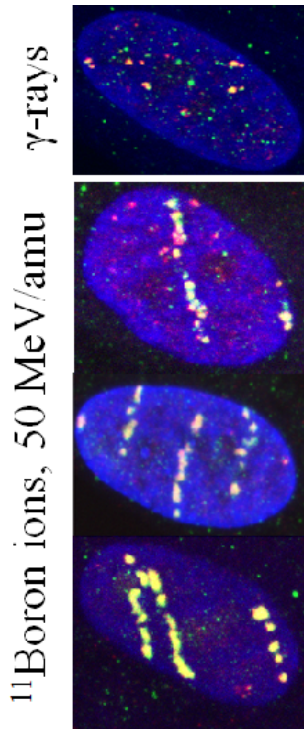
Molecular radiobiology

Induction and repair of DNA double-strand breaks (DSB) by particle beams:

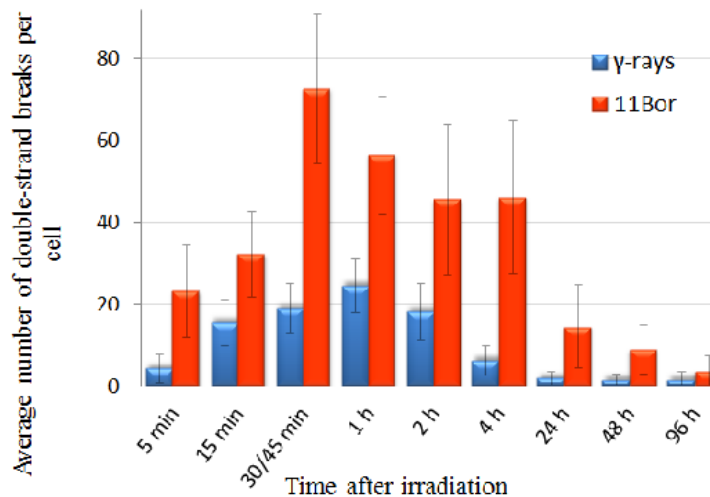
- clustered DNA damage
- normal human cells of different origin

Main future topics:

- Evaluation of DNA damage and repair in:
 - tumor cell lines
 - brain structures *in vivo*
 - different neural cells
- Contribution of different repair pathways in the repair of clustered DNA damage

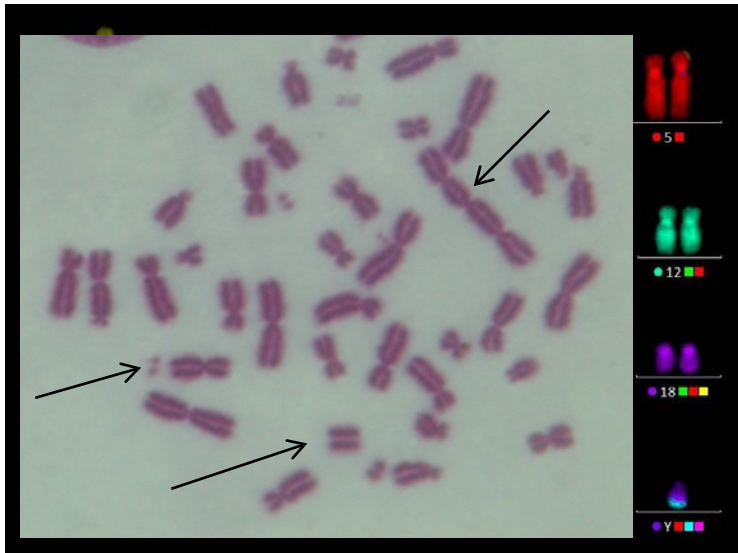


Comparison of DNA double-strand breaks:
γ-rays and ¹¹B

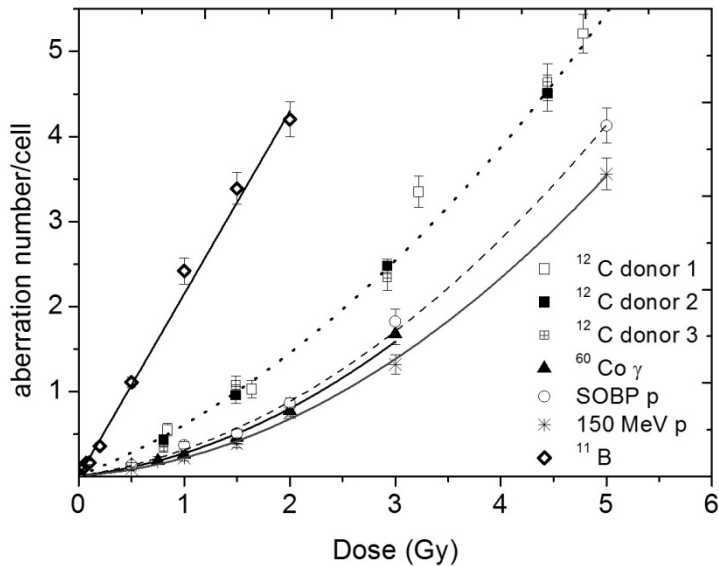
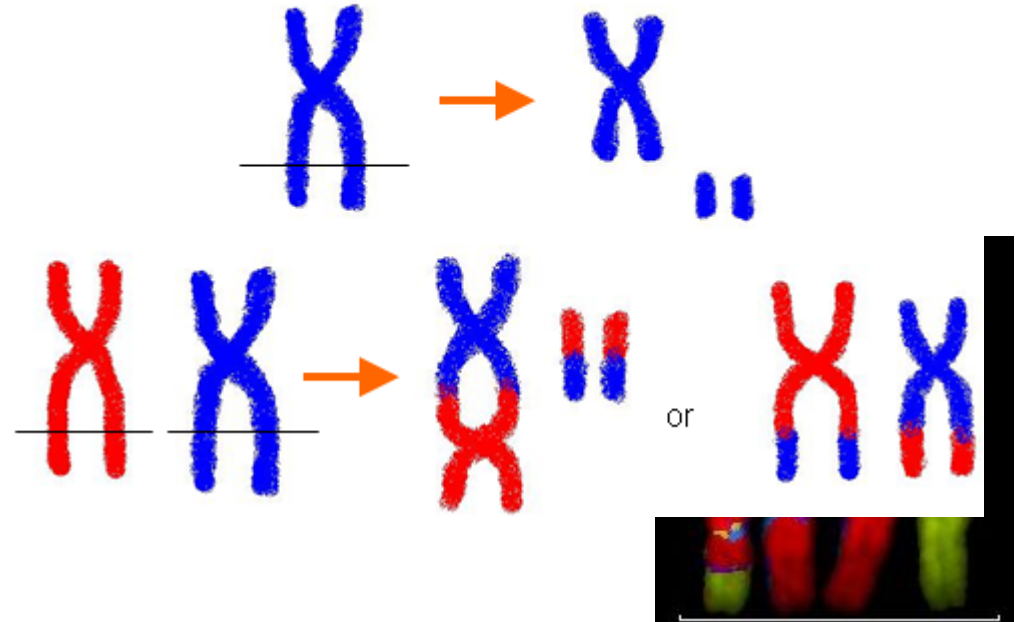


Radiation cytogenetics

10 people

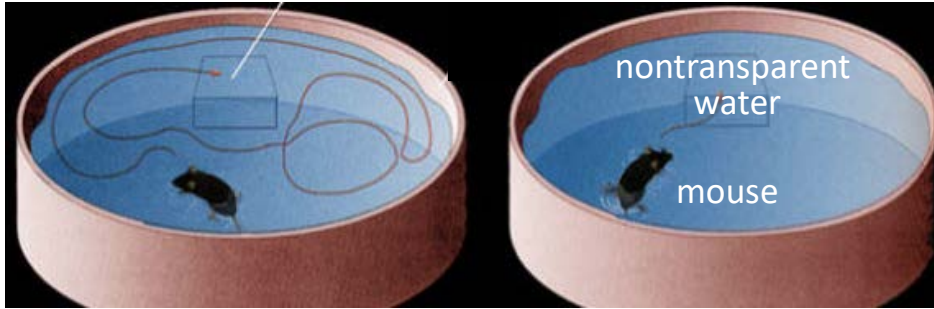


chromosome aberrations – biomarker of radiation exposure



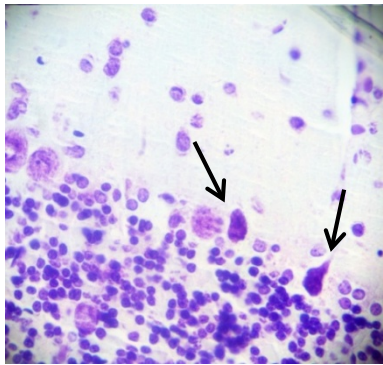
Main future topics:

- *complex aberrations induction by particle beams* → revision of previously obtained RBE values
- *long-term consequences of radiation exposure in human and mammals*

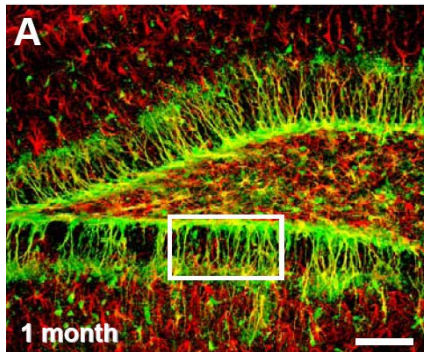


Main future topics:

➤ Large-scale animal *in vivo* experiments to evaluate radiation-induced damage to Central Nervous System (CNS)

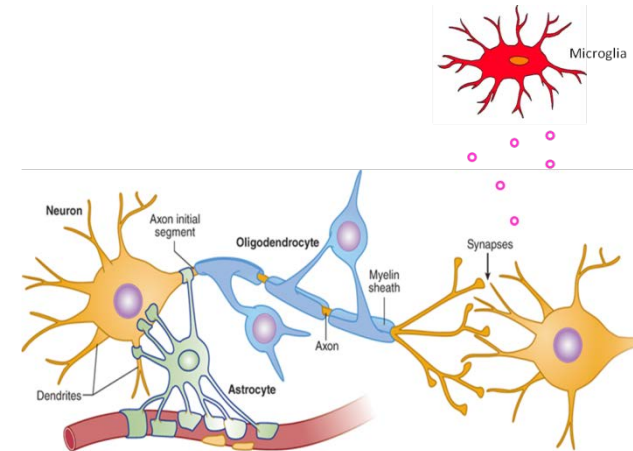


- *pathomorphological changes in CNS structures*
- *behavioral and cognitive disorders*
- *radioprotectors and modification of induced damage*



➤ Mechanisms of CNS radiation damage:

- *Neurogenesis*
- *The role of glial cells:*
 - Neuroinflammation*
 - Demyelination*



Source: Bertram G. Katzung, Anthony J. Trevor: Basic & Clinical Pharmacology, 13th Ed.

Radiation Physiological studies on primates

top priority research!



Main goal:

to model the human ability to perform under radiation exposure during deep space flights

Collaboration:

RAS Institute of Biomedical Problems,
RAS Institute of Medical Primatology,
RAS Institute of Higher Nervous Activity
and Neurophysiology,
Moscow State University

Main future topics:

- **cognitive, behavioral and physiological disorders**
- caused by **heavy charged particles** (C, Fe)
- during **deep space flight simulation** (chronic γ - irradiation combined with **periodic ion exposure** and **hypokinesia**);
- **radioprotectors** which can prevent or reduce the radiation-induced central nervous system disorders



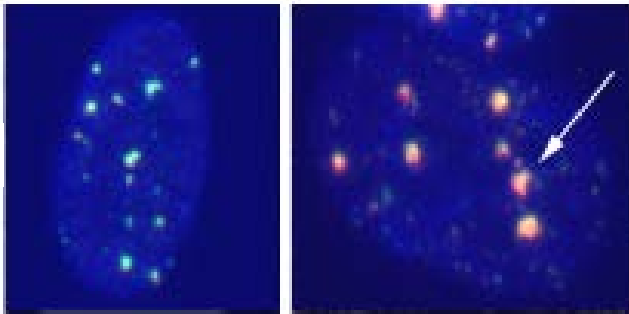
Radiation Medicine



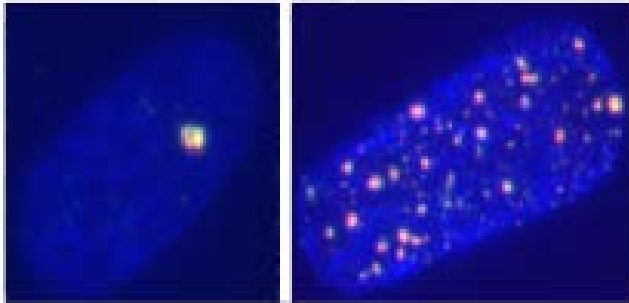
Without RM

With RM

4 h



24 h



The new method for increasing the biological efficiency of ionizing radiation, particularly, proton beams was invented and recently patented in LRB

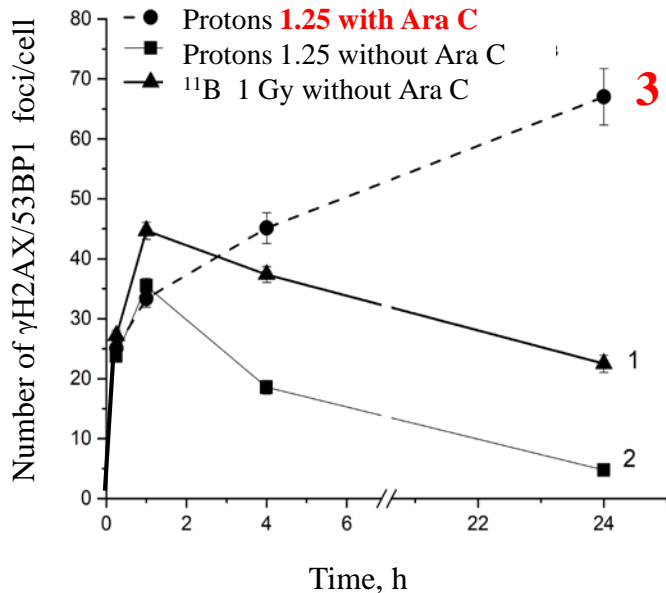
15-fold increase of proton beam efficiency by DNA synthesis inhibitors

Main future topics:

➤ effect of **DNA synthesis inhibitors**

- on survival of **normal and tumor human cell lines (glioblastoma)** after **proton and γ -irradiation**
- on the biological **efficiency of proton and γ -ray exposures *in vivo*.**

➤ **Preclinical animal study with transplanted tumors**

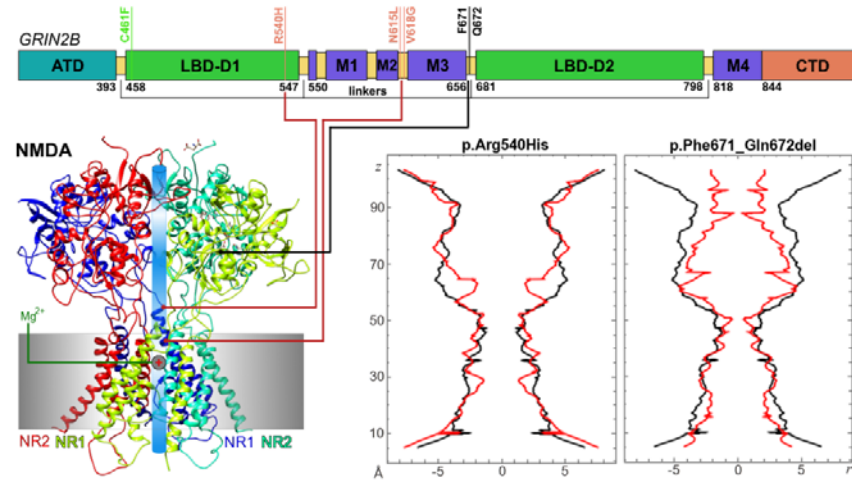
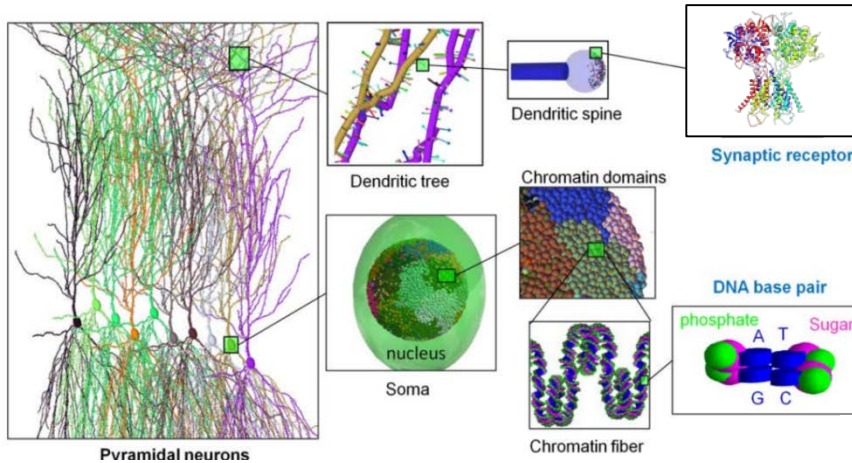


10 people

Mathematical modeling of radiation-induced effects

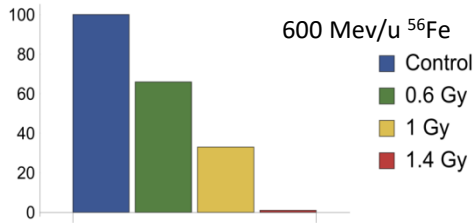
Application of **novel** for traditional theoretical radiation biology methods

Hierarchy of models:



Molecular dynamics Decreased conductance of mutant synaptic receptors

Simulation of molecular damage in neural tissue

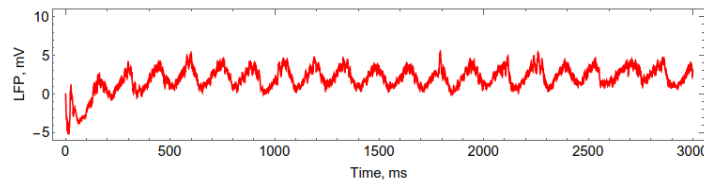
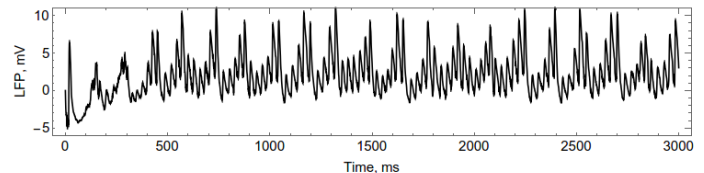


Hippocampal neural network pattern encoding and retrieval success, %

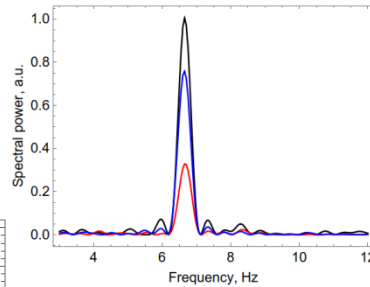
Neural network modeling

Main future topics:

- Monte Carlo modeling of energy deposition in charged particle tracks, molecular damage
- DNA damage repair, formation of mutations and chromosome aberrations
- Structure and functions of mutant forms of proteins
- Intracellular signaling processes, oxidative stress
- Neurogenesis and gliogenesis
- Functional electrophysiological activity of brain neural networks



Normal and postirradiation brain EEG



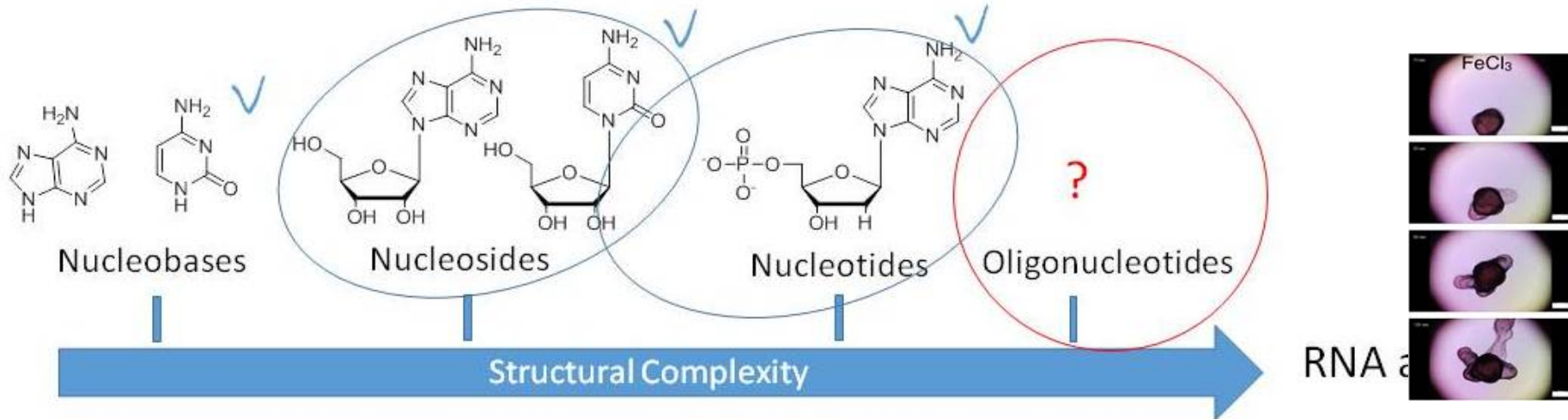
— control
 — 5 Gy 170 Mev proton
 — 1.5 Gy 600 Mev/u ⁵⁶Fe

5 people

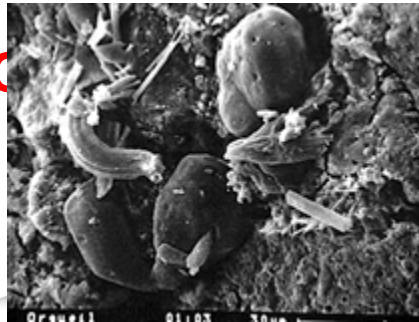
Astrobiology

OPEN Proton irradiation: a key to the challenge of N-glycosidic bond formation in a prebiotic context

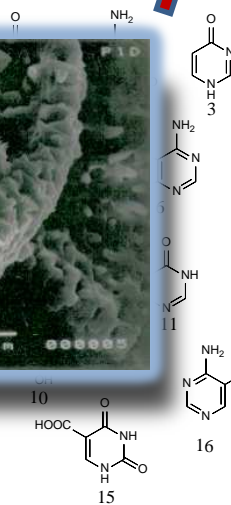
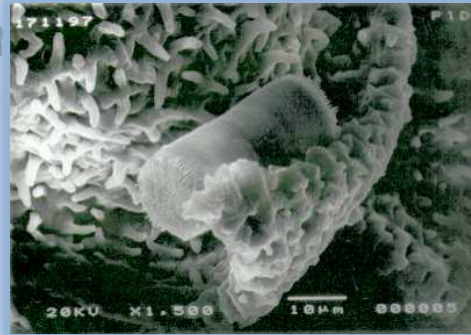
synthesis of prebiotic compounds



P 170MeV



Quest for life:
Study of biofossils in meteorites

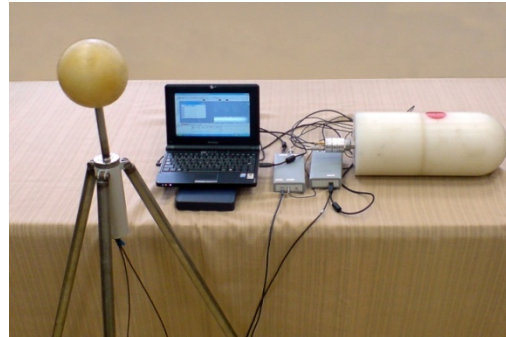
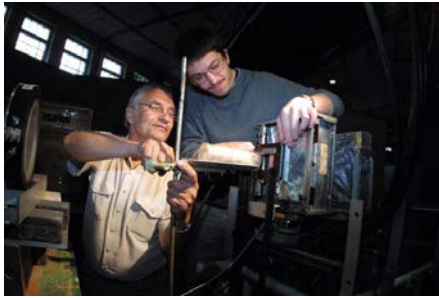


Radiation research

Radiation Protection

- Design of radiation protection management and shielding at new nuclear facilities
- Neutron spectrometry in wide energy range
- Astronaut's risk assessment during long-term interplanetary flights

NICA



Portable multisphere
neutron spectrometer

Nuclear Planetology

- Nuclear planetary science instruments for space in collaboration with FLNP, Roskosmos, NASA and ESA
- Our home-designed neutron and gamma-ray spectrometers onboard of ISS, Lunar, Martian, Mercury missions
- LRB radiation facility for testing nuclear planetology instruments in collaboration with SRI



LRB model of planetary ground
at the testing facility

Infrastructure development

Purchasing of new modern equipment:

- **Flow cytometer sorter FACS AriaIII (~ 0.7 mln. \$)**
- **System for scanning, processing and analysis of cytogenetic images (~ 0.2 mln. \$)**
- **Station for automated cultivation and analysis of cell cultures IM-Q (~ 0.09 mln \$)**
- **Real-time amplifier with the ability to set a temperature gradient (~ 0.03 mln \$)**
- **Gel and chemodocumenting system with transilluminator (~ 0.015 mln \$)**
- **Solid-state thermostat and reagents for genetic engineering (~ 0.013 mln \$)**
- **Fluorescent tomography in vivo imaging system and hemoanalyser (~ 0.37 mln \$)**
- **Upgrade of computing infrastructure (~ 0.54 mln \$)**

Total: ~2 mln \$

Sources of ionizing radiation

- **FLNR: U400M accelerator: light ions with an energy of up to 50 MeV / nucleon;**
- **VLHEP: Nuclotron accelerator: Carbon ions beams (E=500 MeV/nucleon), krypton ions (E=2.57 GeV / nucleon)**
- **DLNP: Medical technical complex: proton beams 170 MeV ans SOBP**
- **In future: Nuclotron (NICA): iron and other ions with an energy of ~ 500 MeV/nucleon.**

Education

For more than 20 years, the Department of Biophysics at the Dubna State University has been preparing undergraduate and graduate students.

- *the preparation of bachelors* in the field of Nuclear Physics and Technology (the Radiation Safety of Man and the Environment profile);
- *preparation of masters* in the field of "Physics" (master's program "Radiation Biophysics and Astrobiology");
- training of highly qualified personnel - *in the postgraduate course "Radiobiology"*.



Thank you for attention!

